ISOLDE isotope production (LE, post-accel), for physics, material and life sciences (MEDICIS included)

Magdalena Kowalska
CERN-ISOLDE

With input from ISOLDE Technical Teams

Outline

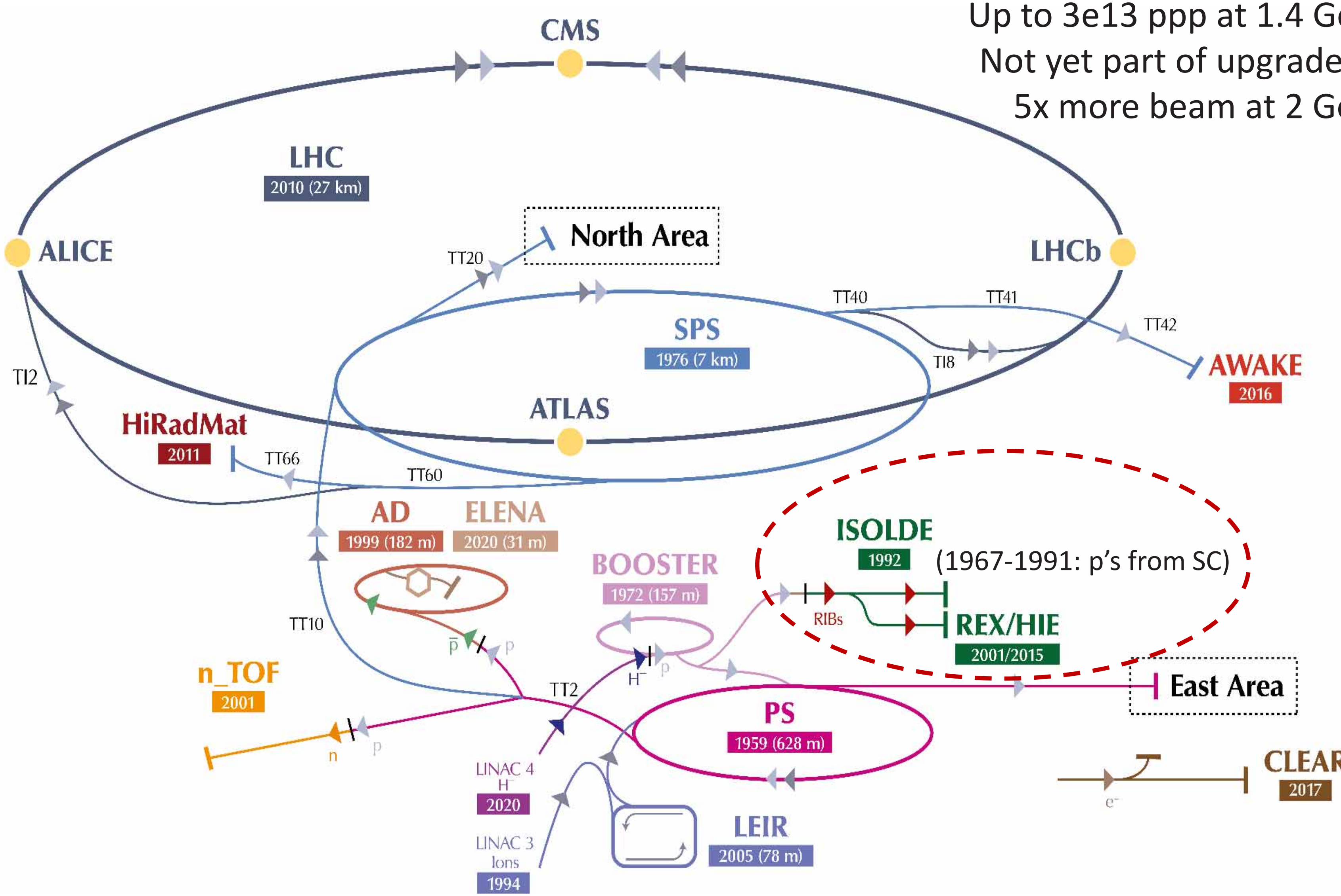
- **ISOLDE in CERN landscape**

- **News from targets, ion sources, and separators**
- **HIE-ISOLDE accelerator**
- **MEDICIS and medical isotopes**
- **11C for hadron therapy**
- **EPIC proposal**

- **Summary**

ISOLDE in CERN landscape

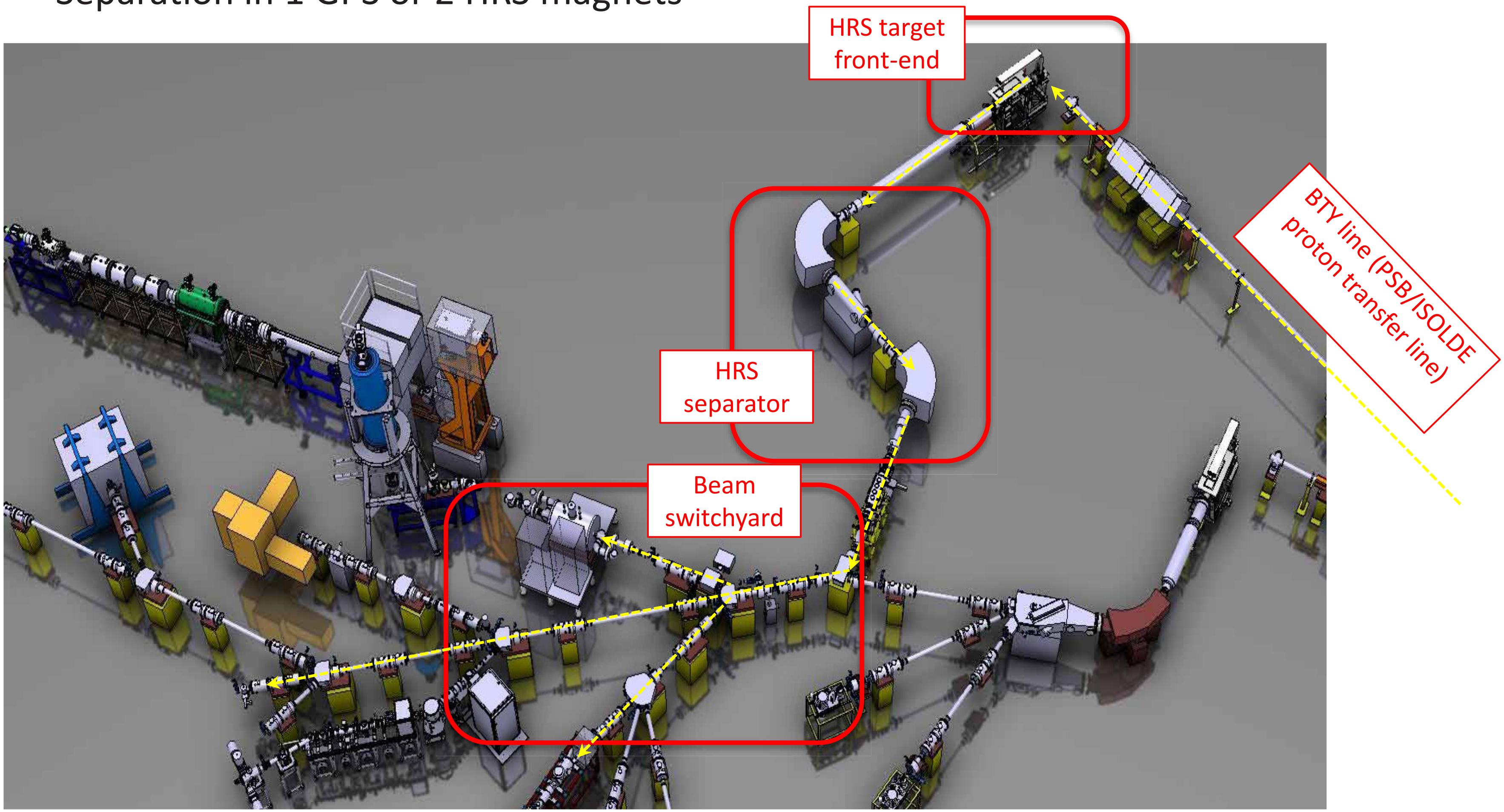
Up to 3e13 ppp at 1.4 GeV
Not yet part of upgrades:
5x more beam at 2 GeV



ISOLDE isotope production and extraction

- Protons from PSB at 1 of 2 target
- Targets heated up to 2000 C
- Ionisation (mostly to 1+ state)
- Extraction at 30-60 keV
- Separation in 1 GPS or 2 HRS magnets

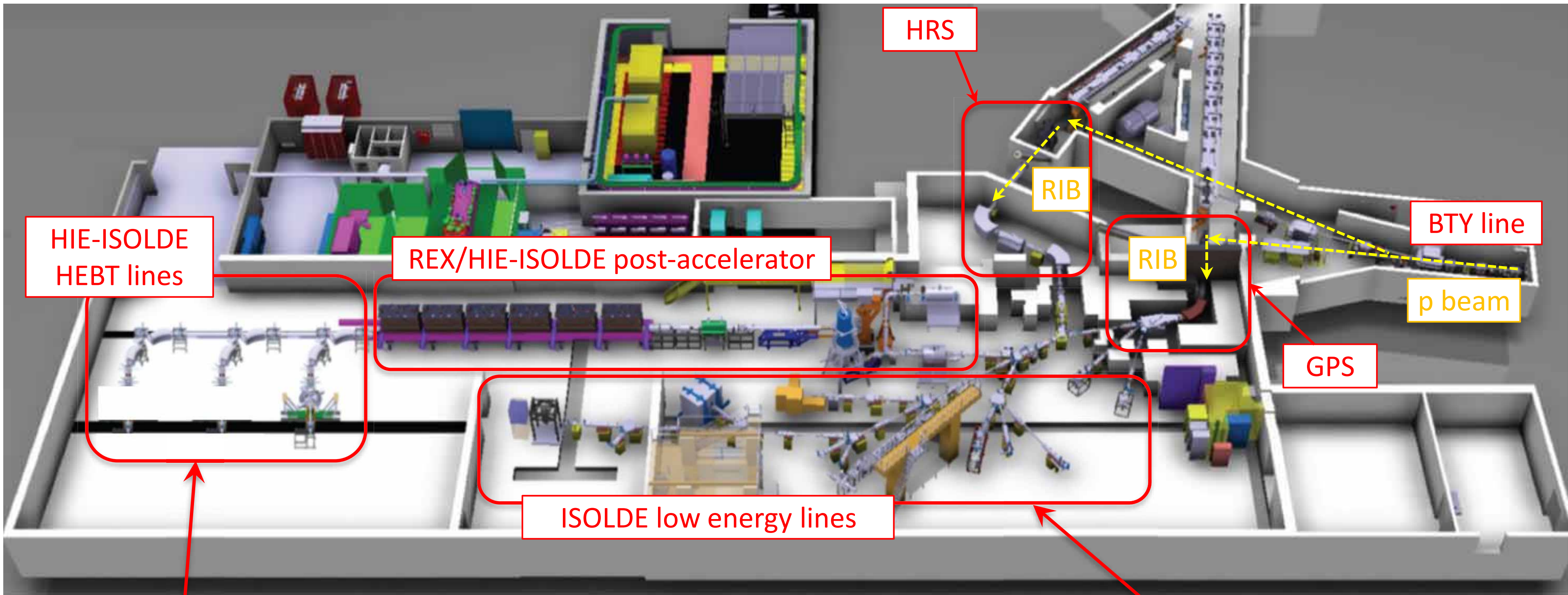
Up to 3e13 p's at 1.4 GeV



ISOLDE hall

- Beam delivery to low energy beamlines
- Or post-acceleration with REX + HIE-ISOLDE and delivery to HIE-ISOLDE beamlines

Nuclear physics
Astrophysics
Fundamental interactions
Material science



High energy experimental stations:

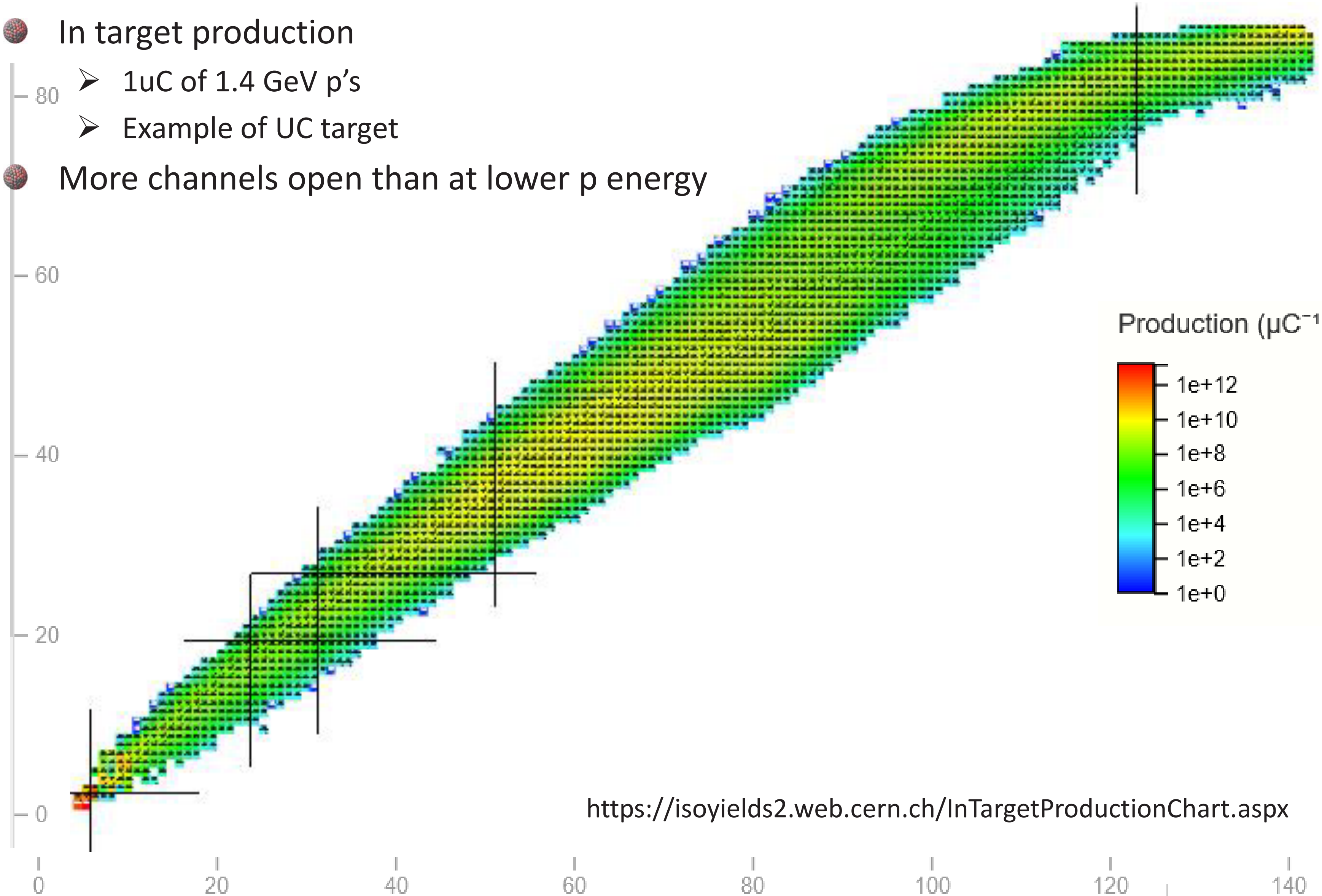
- Miniball
- ISS
- Scattering Chamber

Low energy experimental stations:

- IDS
- ISOLTRAP
- CRIS
- COLLAPS
- SSP stations
- VITO
- NICOLE
- WISARD

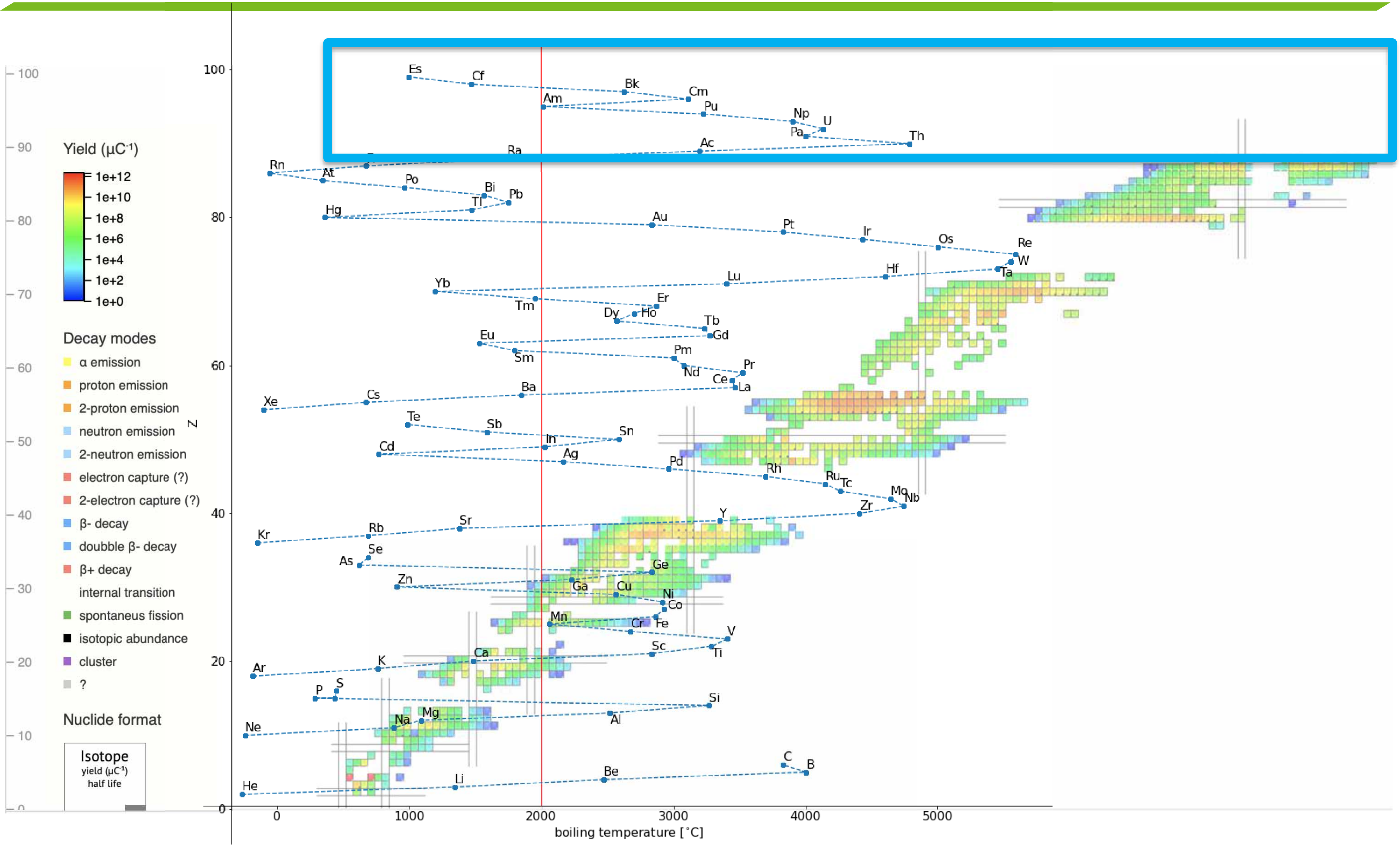
ISOLDE Isotope production cross sections

- In target production
  - ➢ 1uC of 1.4 GeV p's
  - ➢ Example of UC target
- More channels open than at lower p energy



https://isoyields2.web.cern.ch/InTargetProductionChart.aspx

Delivered beams & boiling temperature

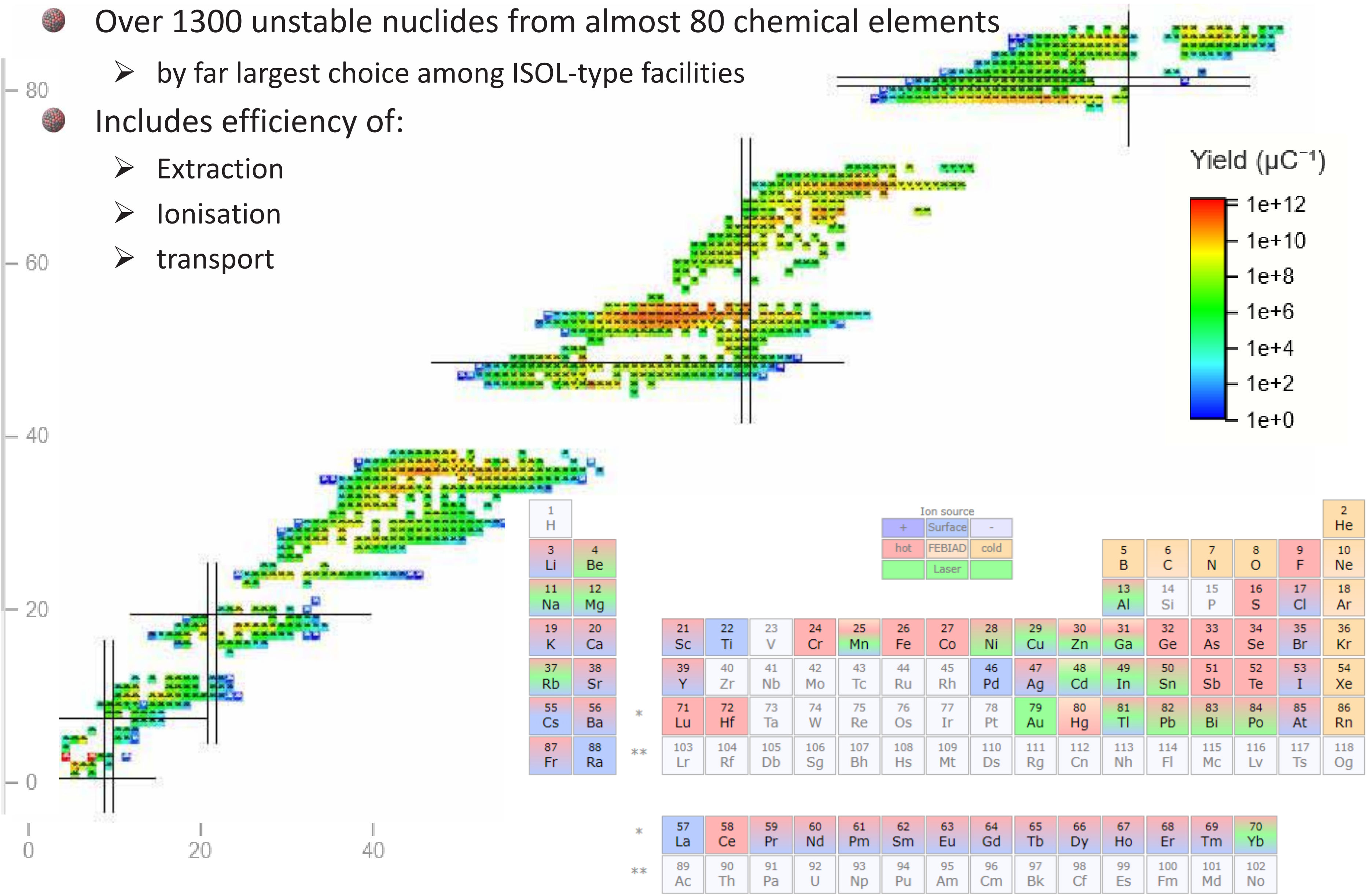


M. Au

cern.ch/isolde-yields

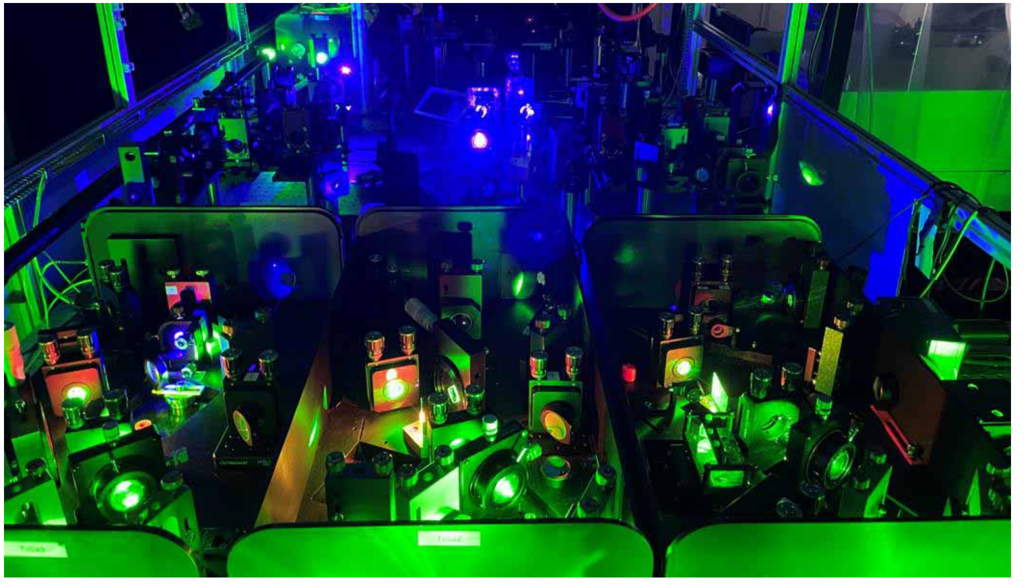
Beams for experiments

- Over 1300 unstable nuclides from almost 80 chemical elements
  - by far largest choice among ISOL-type facilities
- Includes efficiency of:
  - Extraction
  - Ionisation
  - transport

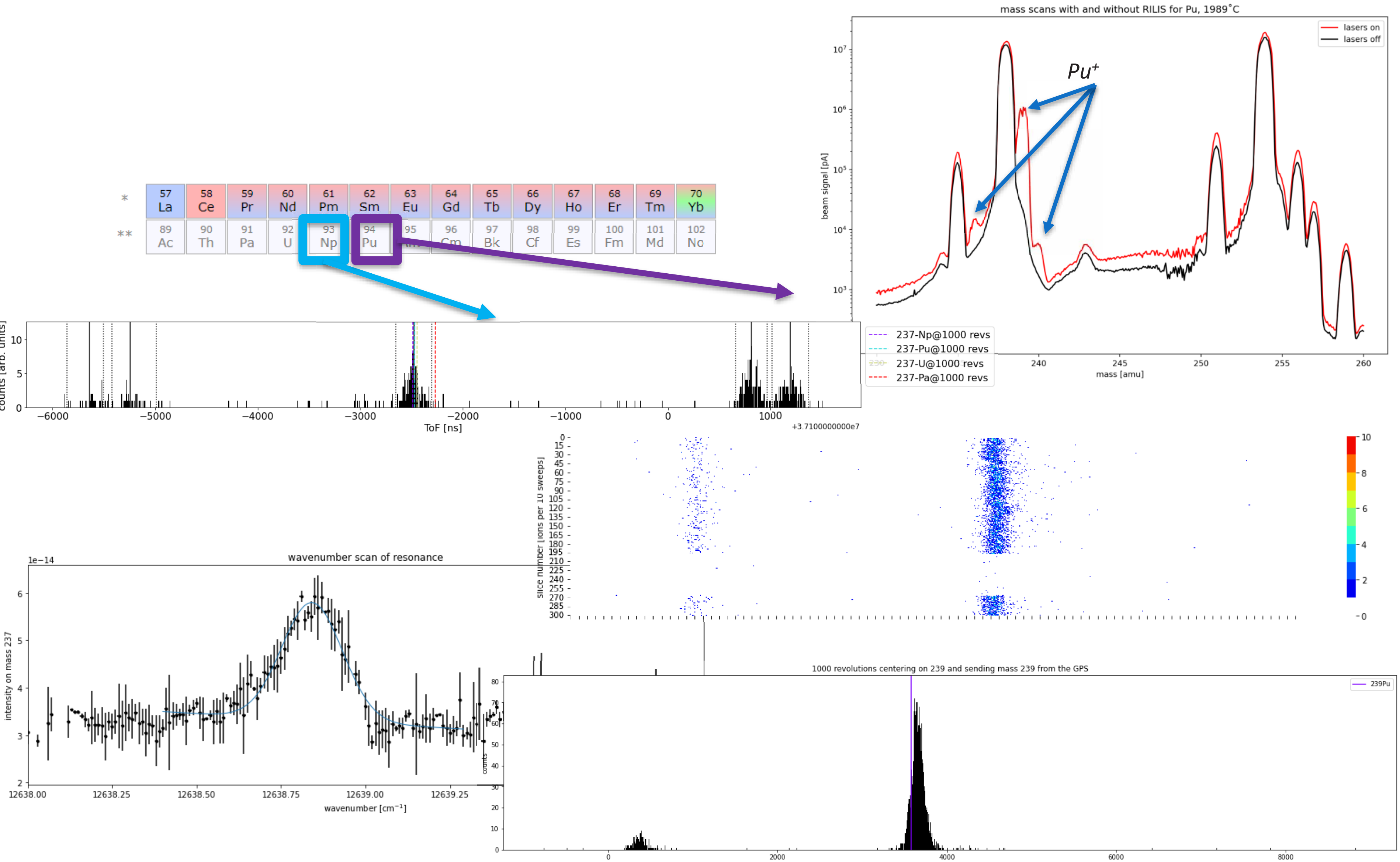


Ionisation

- Surface, plasma, laser ionisation
- Resonant laser ionisation (RILIS)
  - used for 60-80 % of shifts
  - Pioneered at Gatchina and ISOLDE
- Improved ionisation efficiency
  - New RILIS schemes
- Increased beam purity
  - Molecular beams
  - LIST: Laser Ionisation Trap
  - Pi-LIST: perpendicular LIST
  - MR-TOF
  - Negative ions in charge-exchange process



Above-target beams

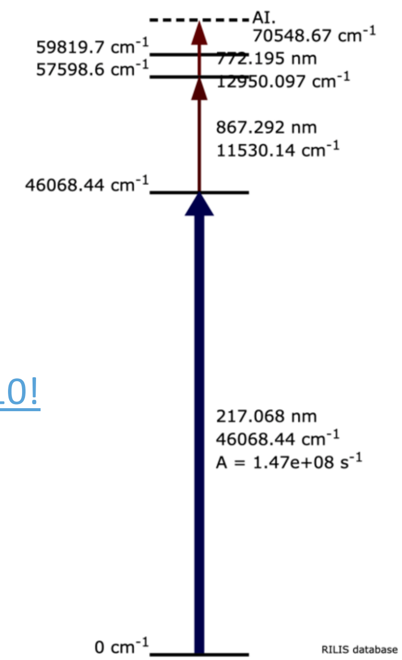


Au, M. et al (2021)
10.5281/zenodo.6519521

RILIS activities and developments

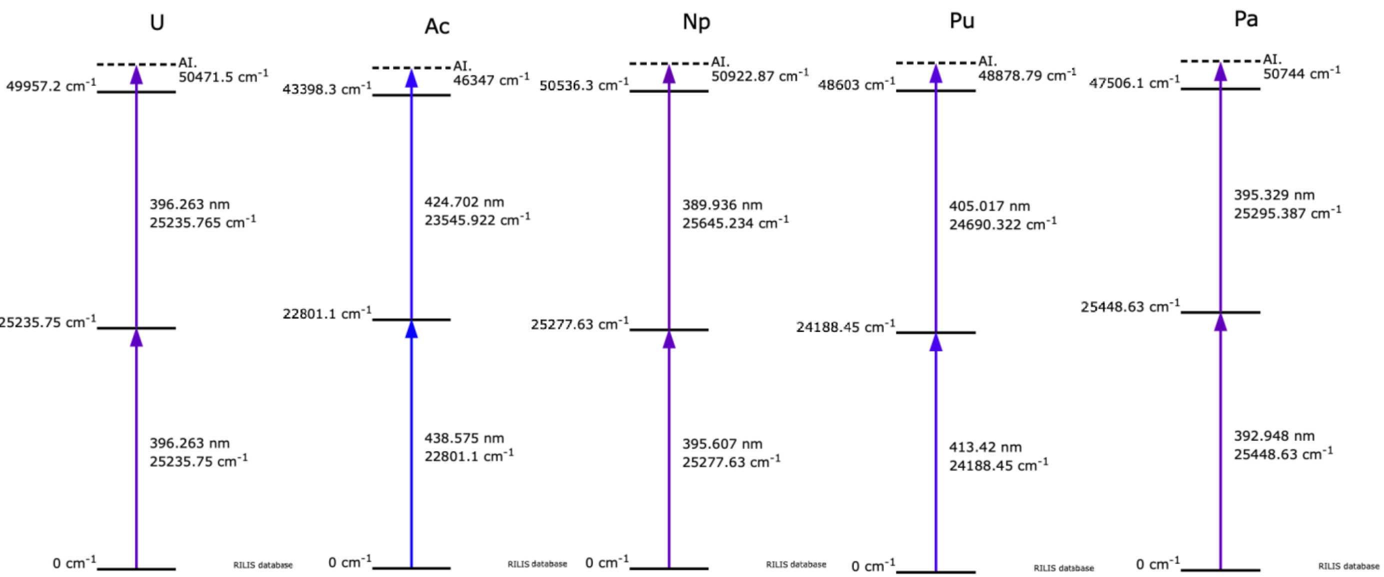
→ 21 weeks out of 23 weeks of ISOLDE operations in 2021

*Pb



Elements: Ag, Mg, Cu, Ca, In, Au, Ac, Zn, Pb*, Sb, Dy, Sc, Be
Physics runs: 17
TISD runs*: 4

- New Pb laser ionization scheme
- Developed Jan 2021)
- First used on-line Sep 2021
- Efficiency enhancement by factor 10!



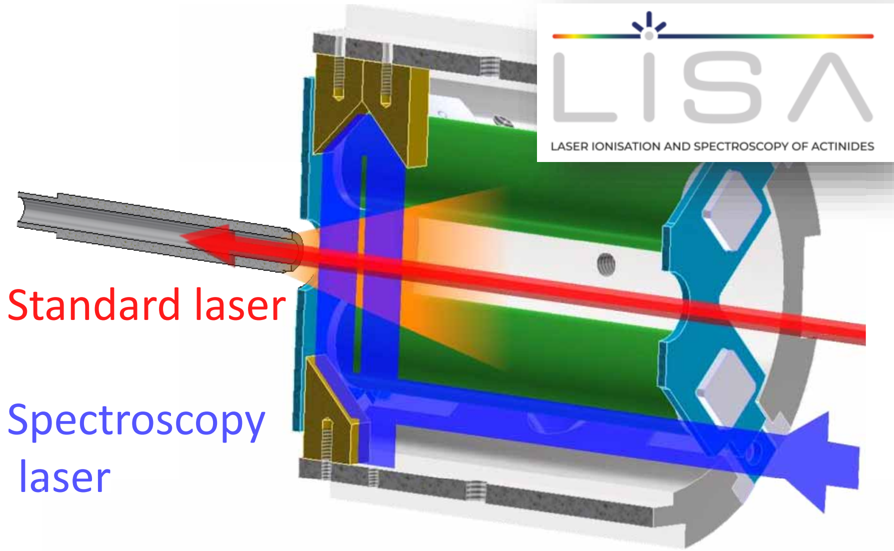
K. Chrysalidis

TISD on Actinde extraction

Many actinide schemes tested on-line
Np, Pu, Ac were seen!
Additionally molecular extraction tested

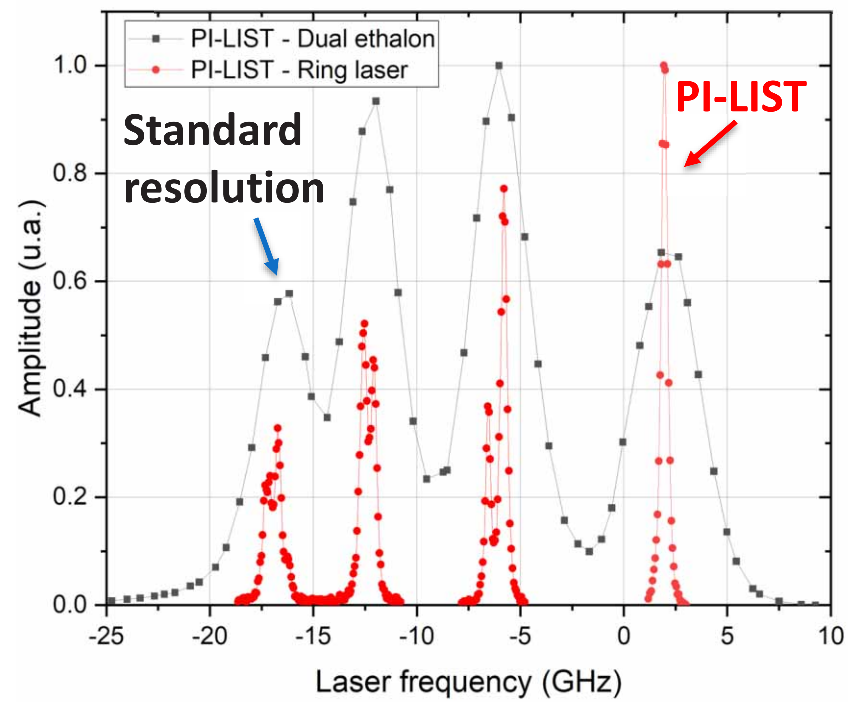
RILIS developments: PI-LIST

- LIST = Laser Ion Source Trap
  - ➢ Deflect ions created without laser (surface)
  - ➢ PI: Ionise wih RILIS perpendicular to extraction
- => extract only laser-ionised species



05/2022: First experiment using PI-LIST at ISOLDE

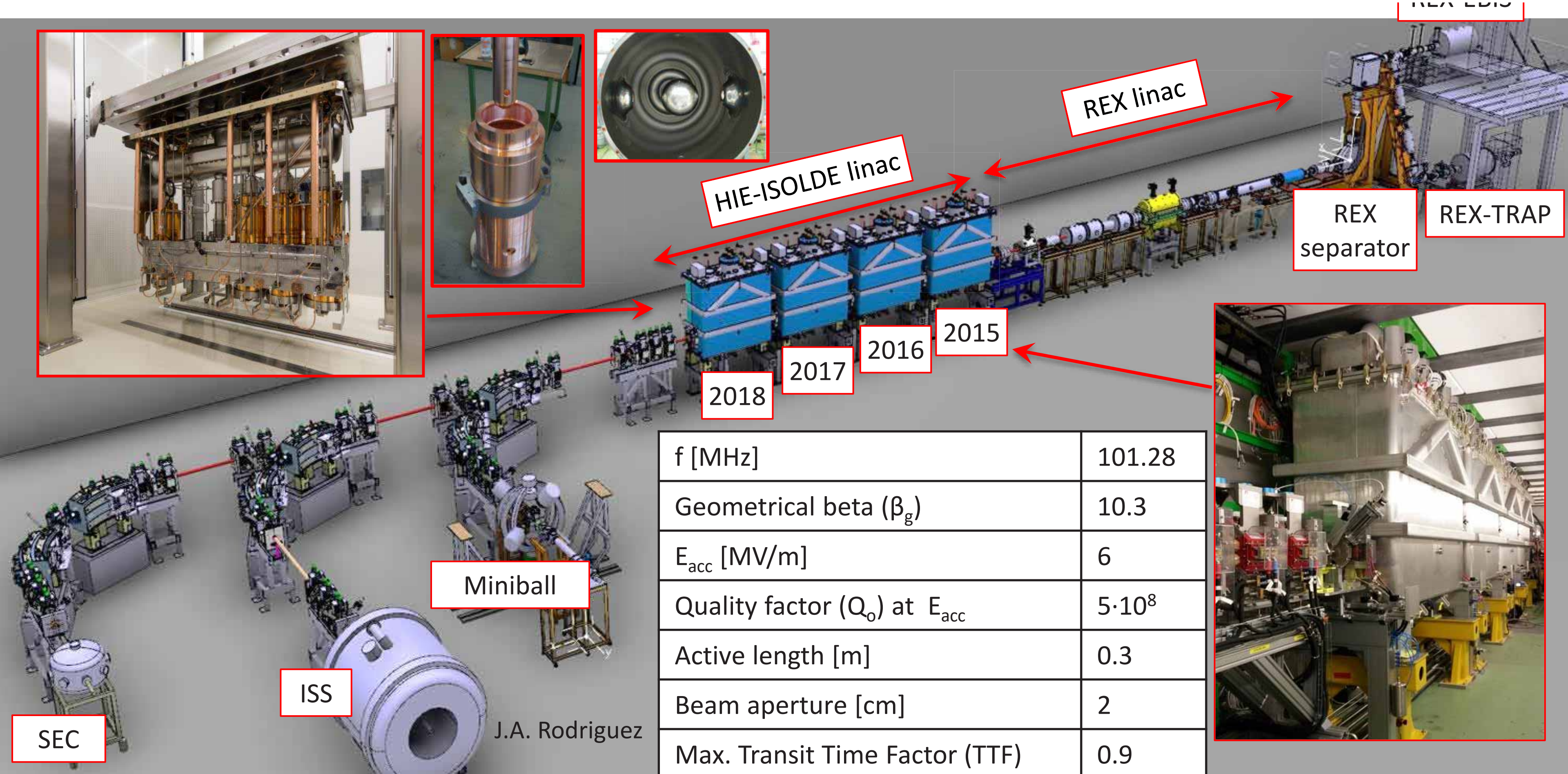
- ○ Additional operation mode of LIST ion source perpendicular laser/atom interaction
- ○ Reducing spectral linewidth from few GHz to ~200MHz (at cost of efficiency loss)
- ○ Application for high resolution spectroscopy and isomer-pure RIB production
- ○ New data on nuclear shapes in Ac isotope chain



R. Heinke, S. Rothe

HIE-ISOLDE SC linac (post)-accelerator

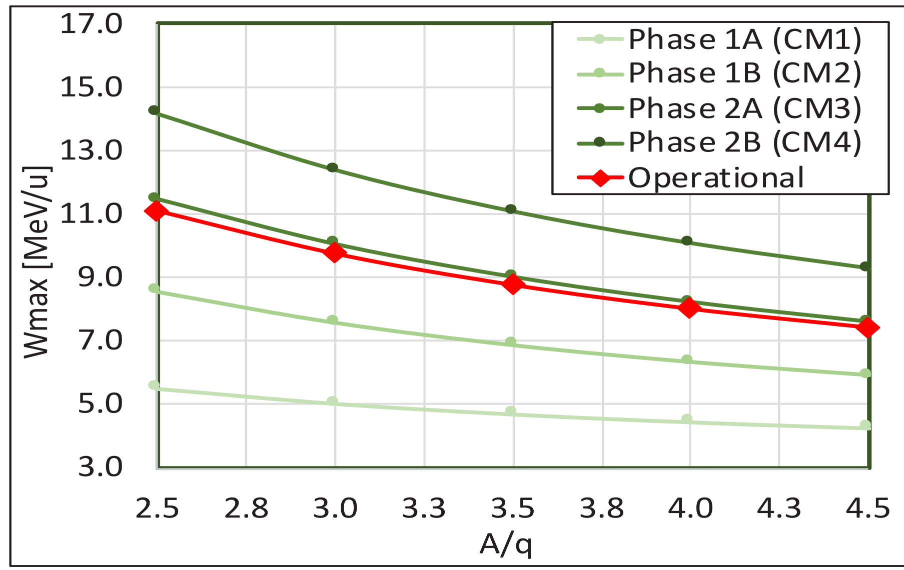
- Cavities: Quarter Wave Resonators (QWR) made of Nb-sputtered Cu substrate
- Cryomodule: 5 QWR + 1 SC solenoid, common insulation and beam vacuum, top plate mounted
- Nominal energy: 9.2 MeV/u for A/q = 4.5, 14.2 MeV/u for A/q = 2.5
- Diagnostics: Scanning slits, collimators and FCs
- Focusing: SC solenoids, quadrupoles 			Steering: Vertical/horizontal very few meters



f [MHz]	101.28
Geometrical beta (β_g)	10.3
E_{acc} [MV/m]	6
Quality factor (Q_o) at E_{acc}	$5 \cdot 10^8$
Active length [m]	0.3
Beam aperture [cm]	2
Max. Transit Time Factor (TTF)	0.9

HIE-ISOLDE post-accelerated beams

Beam(s)	Energies [MeV/u]
$^{74}Zn^{21, 25+}$, $^{76}Zn^{22+}$	2.8, 4.0
$^{108}Sn^{26+}$ $^{110}Sn^{26+}$	4.5
$^{142}Xe^{33+}$	4.5
$^{78}Zn^{20+}$	4.3
$^{132}Sn^{31+}$	5.5
$^{9}Li^{3+\rightarrow 3+}$	6.8; 8
$^{66}Ni^{16+}$	4.5
$^{72}Se^{19+}$	4.4
$^{66}Ge^{17+}$, $^{70}Se^{16+}$	4.4
$^{142}Ba^{33+}$, $^{144}Ba^{33+}$	3.4, 4.2
$^{140}Sm^{34+}$	4.7
$^{15}C^{5+\rightarrow 6+}$	4.4
$^{94}Rb^{23+}$	6.2
$^{142}Sm^{33+}$, $^{140}Nd^{33+}$	4.6
$^{30}Mg^{11+}$	8.5
$^{209}Fr^{53+}$	7.6
$^{206}Hg^{46+}$	4.2; 7.4
$^{59}Cu^{20+}$	3.6, 4, 5, 4.3, 4.7
$^{28}Mg^{9+}$	5.5; 9.5
$^{96}Kr^{23+}$	4.7, 5.3
$^{212}Rn^{50+}$	3.8, 4.4; 7.6
$^{222}Ra^{51+}$, $^{228}Ra^{53+}$	4.3
$^{224, 226}Rn^{52+}$, $^{222}Rn^{51+}$	4.2, 5.1
$^{134, 132}Sn^{31+}$	7.4, 7.2
$^{106}Sn^{26+}$	4.4
$^{8}B^{3+\rightarrow 5+}$	4.9
$^{11}Be^{4+\rightarrow 4+}$	7.5
$^{61}Zn^{16+}$	7.5
$^{7}Be^{2+\rightarrow 4+}$	5.0



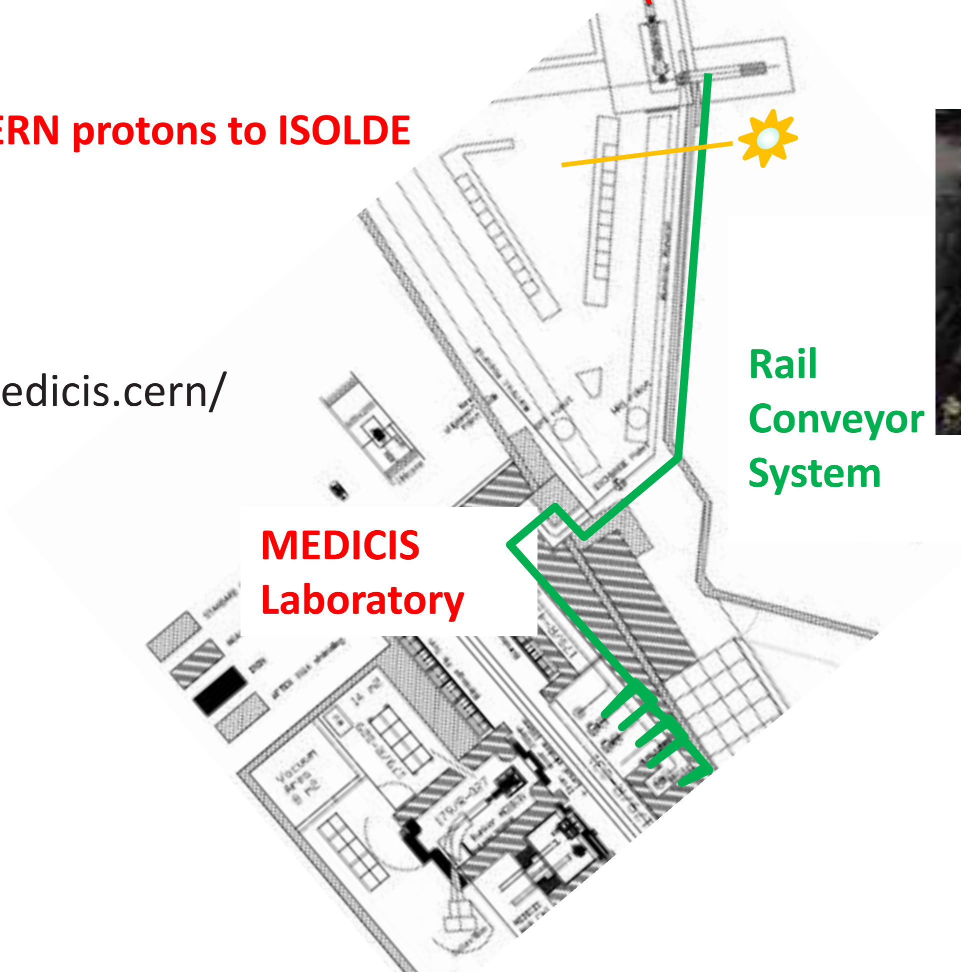
J.A. Rodriguez

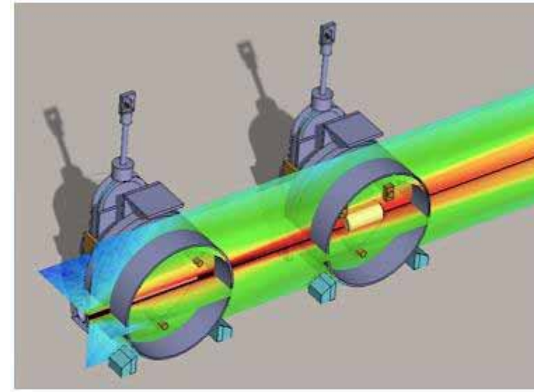
MEDICIS facility for medical isotopes

Non-conventional radioisotopes for medical research

Online production
And/or offline separation

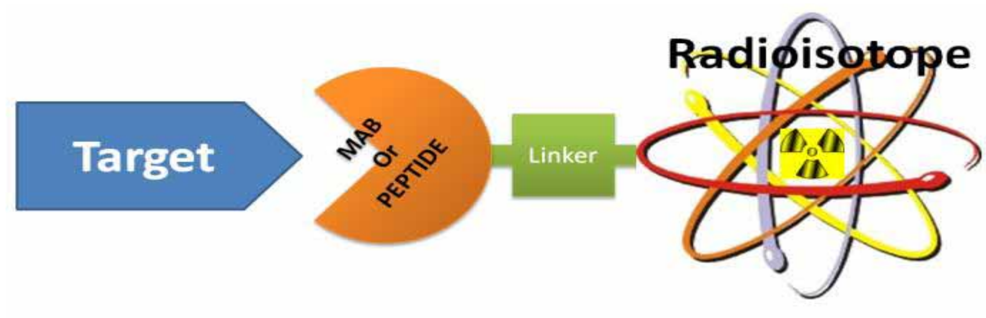
https://medicis.cern/





Th. Stora

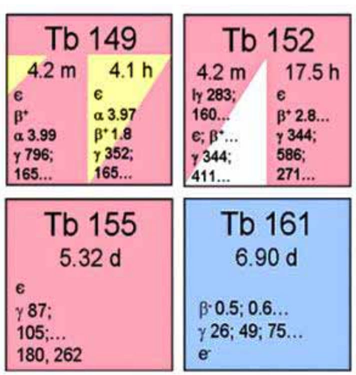
MEDICIS facility for medical isotopes



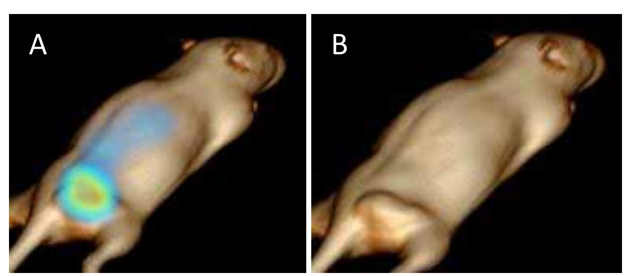
^{153}Sm ^{149}Tb ^{152}Tb ^{155}Tb ^{169}Er

^{175}Yb ^{225}Ac

Theranostics = therapy + diagnostics at the same time



imaging with ^{152}Tb



Coordinator of European project: access to new medical isotopes from different European sources

27 EU PRISMAP Medical Radionuclides

https://www.prismap.eu/

Th. Stora

11C for hadron therapy

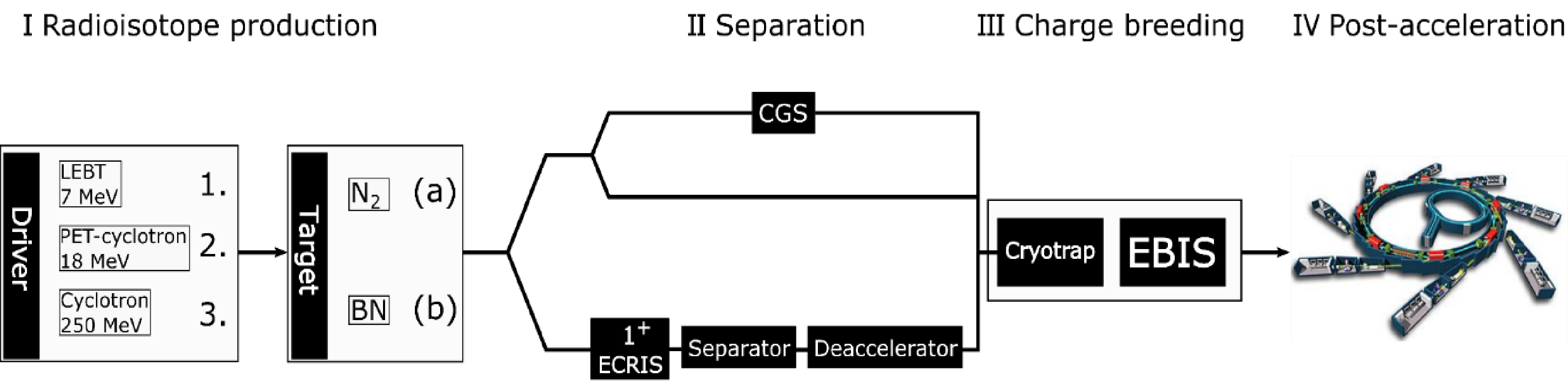
- **Idea:** hadron therapy and PET monitoring with unstable ^{11}C ($t_{1/2}$=20min)
  - E.g. ERC AdG at GSI, M. Durante

Required

- Pure radioactive ion beam (RIB)
- Monoenergetic
- Appropriate beam characteristics (emittance, momentum spread,…)
- Intense: $4 \cdot 10^8\ {}^{11}C^{4^+,6^+}$ per spill
- Implementable into existing treatment facilities

- Work performed by PhD students (MEDICIS-PROMED ITN):
- Simon Stegemann (CERN, KU Leuven): production
- Johanna Pitters (CERN): post-acceleration
- Kyong-Don (CNAO, Pavia): clinical part

- And beyond, e.g. with CERN Medical Applications funds



S. Stegemann

L. Penescu et al., Technical Design Report for a Carbon-11 Treatment Facility, Front. Med., 25 (2022) https://doi.org/10.3389/fmed.2021.697235

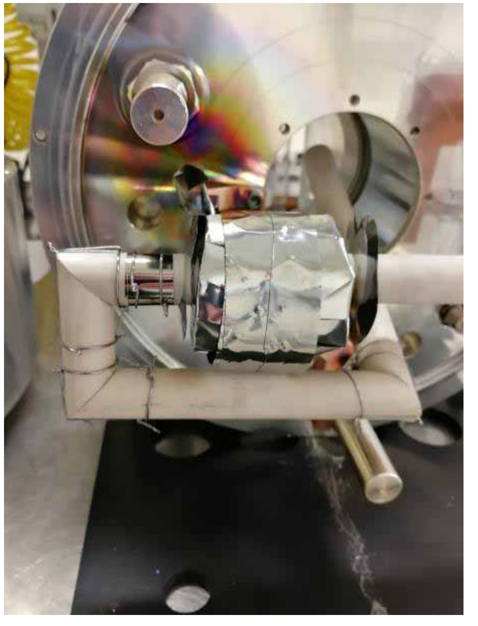
11C production

Carbon → Tailored target-ion source system

- Refractory
- Low vapor pressure ($2 \cdot 10^{-7}$ mbar @ 1800 °C)

➢ Molecular isotope extraction (CO)
➢ Controlled target microstructure
➢ Fast diffusion and effusion

Target material: spark plasma-scintered boron nitride to create ^{11}CO molecules
rigid powder, compact with small grain sizes and high porosity
Ceramic heating unit
Bottleneck: release (limited by diffusion) of only 10%



Yield: $3 \cdot 10^{9}\ s^{-1}$

=> Enough for charge breeding and acceleration

S. Stegemann

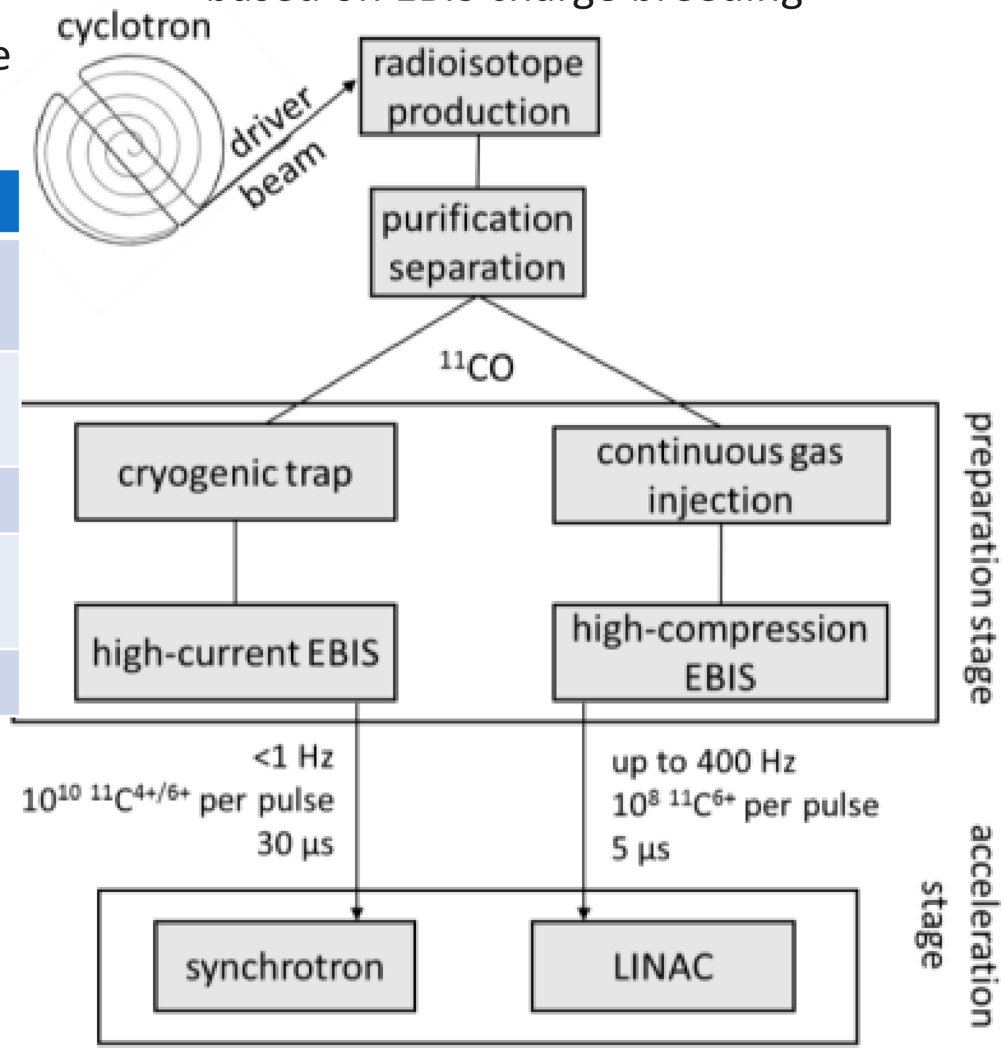
11C charge breeding

- Injection into a medical synchrotron requires a few 10 µs pulses of 10^{10} C ions
- Additional challenge – efficiently introduce and store ^{11}C ions for ~ 1 s

Charge breeding:	ECRIS	EBIS
Space charge capacity	High, no problem	At the limit
$t_{extraction}$	~ ms (afterglow)	down to 5 us
Contaminants out	High levels	UHV
Contaminants in	No restrictions	<100% of C^{11}
Charge state out	Peak at 4+	50% in 6+

* Tests at REX-ISOLDE ruled out Penning trap + EBIS & continuous 1+ ion injection from separator into EBIS

Possible routes for 11C treatment based on EBIS charge breeding



From CERN-ACC-NOTE-2018-0078

Technical Design Report for a Carbon-11 Treatment Facility, doi: 10.3389/fmed.2021.697235

F. Wenander

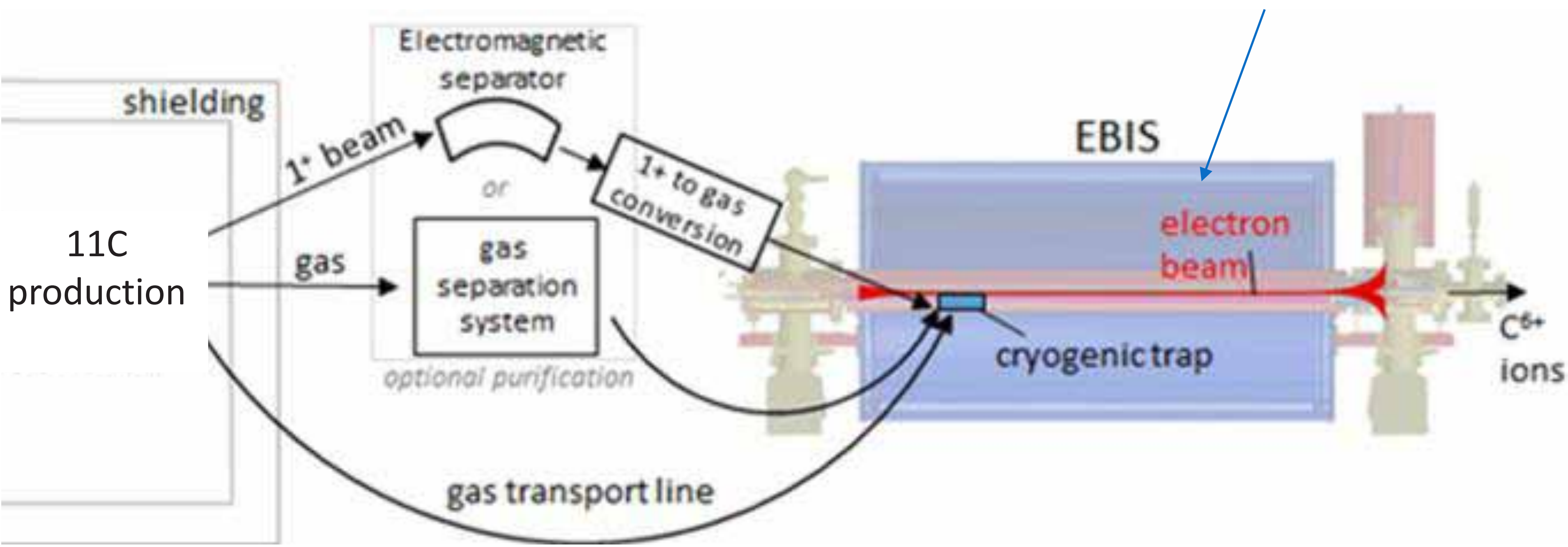
11C Synchrotron-based treatment facilities

* Heat up cryogenic trap ~40 ms before pulse ejection
(avoids ion heating from electron beam during the full synchrotron cycle)

* Charge breed ~50% of ^{11}C to 6+ and eject

* Cryogenic release inside EBIS successfully demonstrated at Dubna

High-capacity BNL-type EBIS



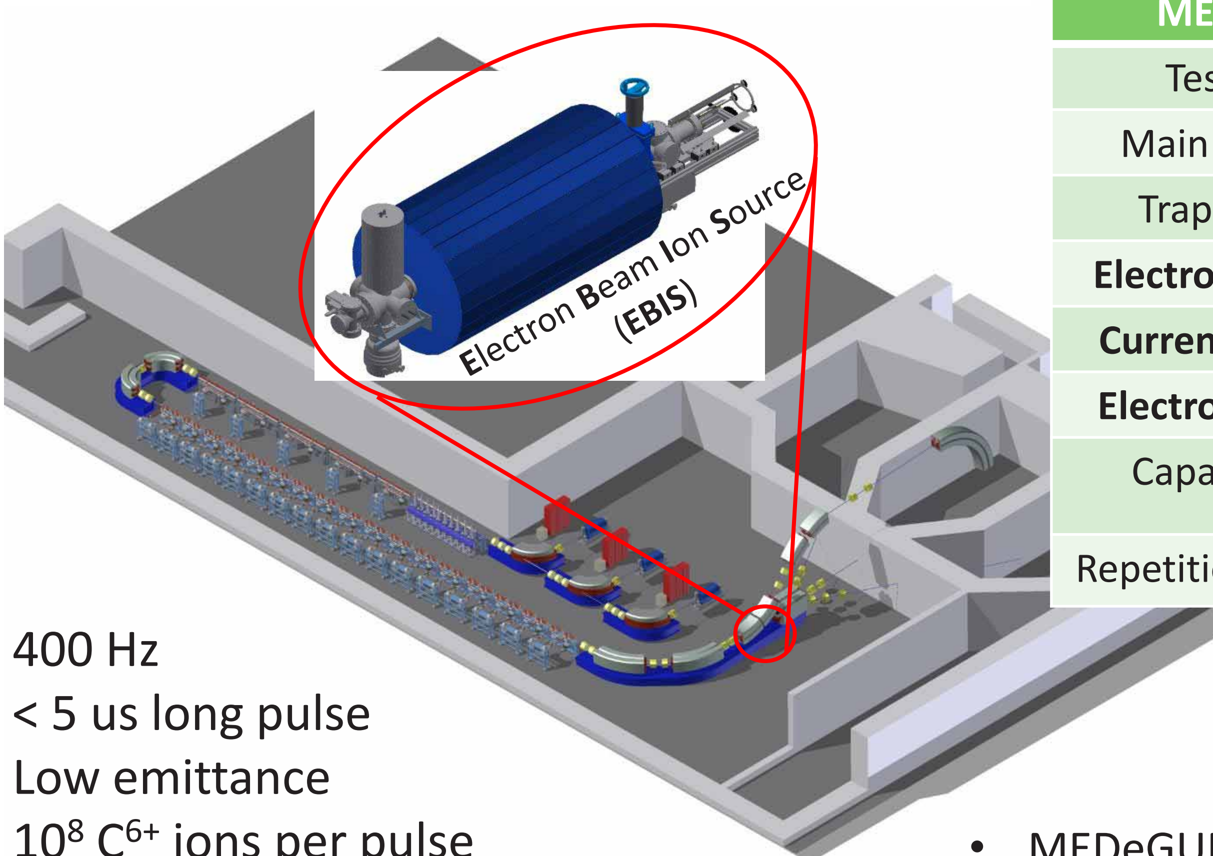
F. Wenander

From https://doi.org/10.3389/fmed.2021.697235

11C Linac-based treatment facilities

Motivation: reduced footprint and higher accuracy of dose delivery

e.g. CABOTO: **CA**rbon **BO**oster for **T**herapy in **O**ncology



MEDeGUN design parameters	
Test site	TwinEBIS, CERN
Main magnet	2 T
Trap length	0.25 m
Electron current	1 A
Current density	1.5 kA/cm^2
Electron energy	7.5 - 10 keV
Capacity C^{6+}	$1 \cdot 10^8$ ions/pulse
Repetition rate C^{6+}	180 Hz

- 400 Hz
- < 5 us long pulse
- Low emittance
- 10^8 C^{6+} ions per pulse

Equipped with:

- MEDeGUN: high compression **Brillouin e- gun** (cathode sees no B-field)
- Low-e- beam energy, **optimized for C^{6+}**
- Achievable vacuum **1*10^{-10} mbar**

S. Verdu-Andres et al., Journal of Radiation Research 54 (2013) il55
S. Benedetti 2016 (talk) Update on TULIP and CABOTO projects

Isolde Upgrades and Expansion

Mid-term goal (2025-2026)

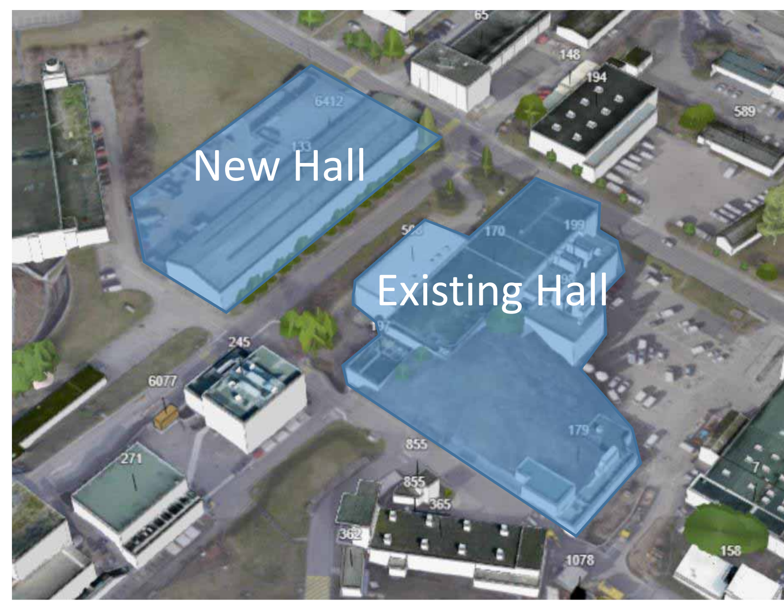
- New beam dumps for 2 existing target stations, allowing to receive higher energy proton beam at double intensity
- Upgrade of transfer line from PBS to ISOLDE to allow sending 2 GeV (+ 1.4 GeV) protons
- Parallel RIB operation

➔ **Increase RIB beam intensity up to 40x (isotope depedent)**

Long-term goals (> 2025): EPIC proposal

- New ISOLDE building + target stations
- Dedicated space and facilities for new (and existing) low-energy experiments
- Improved beam purity (mass resolution) and quality (time structure)
- Parallel operation with exisiting (HIE-ISOLDE) facility
- Space for new re-accelerated RIB experiments, including a new compact storage ring

ISOLDE-EPIC Workshops 2019 and 2020



G. Neyens, S. Freeman

Summary

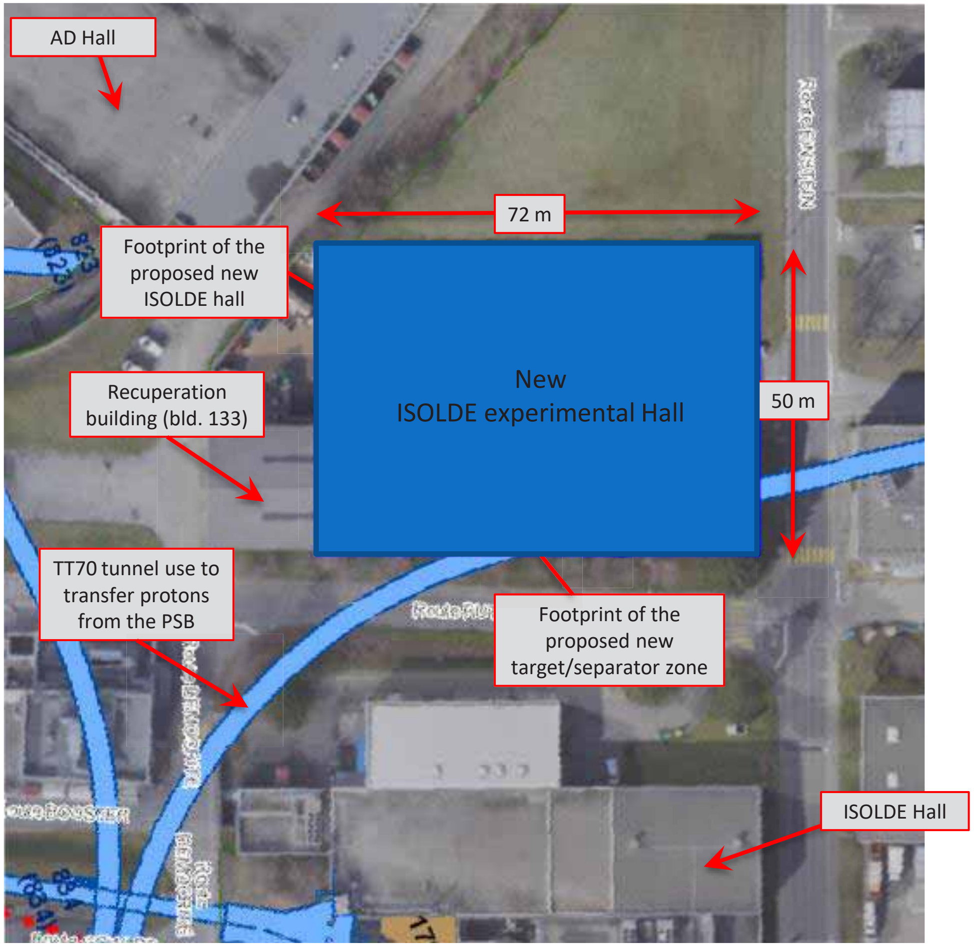
- ISOLDE at CERN: longest running ISOL-type radioactive ion beam facility

- Ongoing developments to keep it at the forefront of research:
  - More beams
  - Purer beams
  - Post-acceleration
  - Medical isotopes
  - 11C for hadron therapy
  - Future: upgrades and EPIC proposal

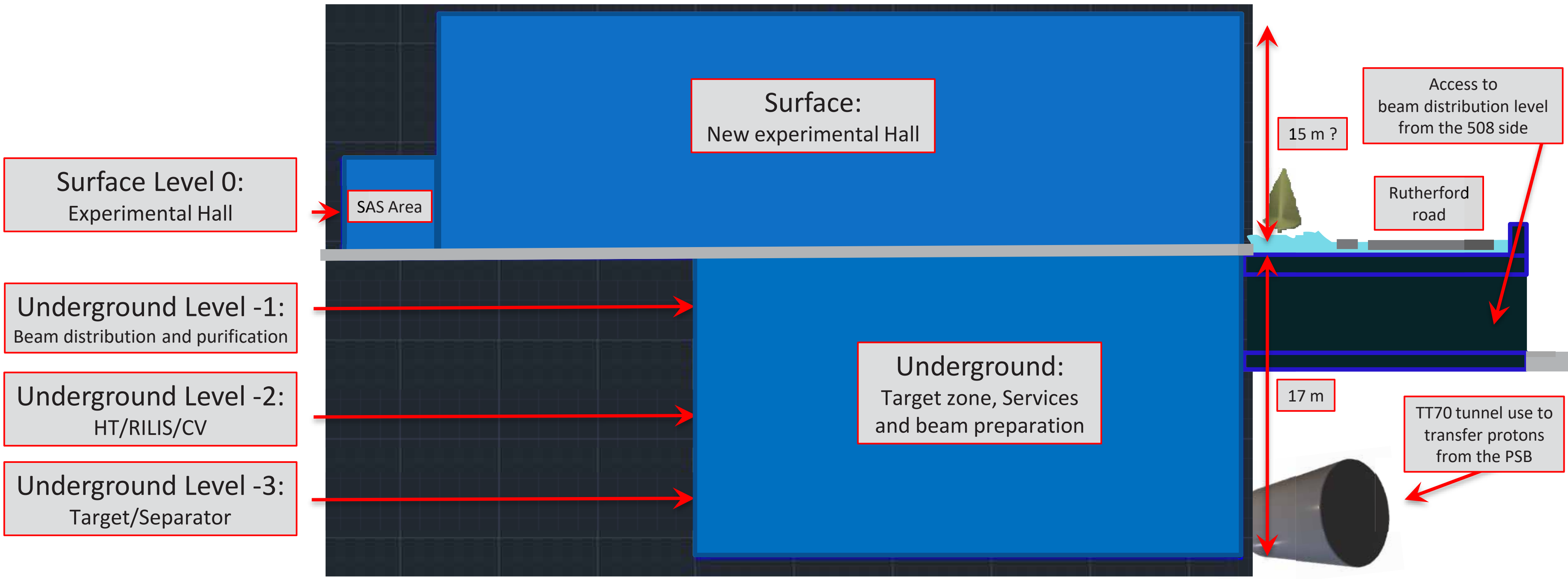
Backup slides

- Proposed layout of the new ISOLDE experimental hall proposed within the ISOLDE-EPIC proposal:
- https://indico.cern.ch/event/928894/timetable/#20201125.detailed
- Talks by E. Siesling and J A Rodriguez

Footprint of the Proposed New Hall and Underground Area:



Cross-section of the Proposed Hall and Underground Area:



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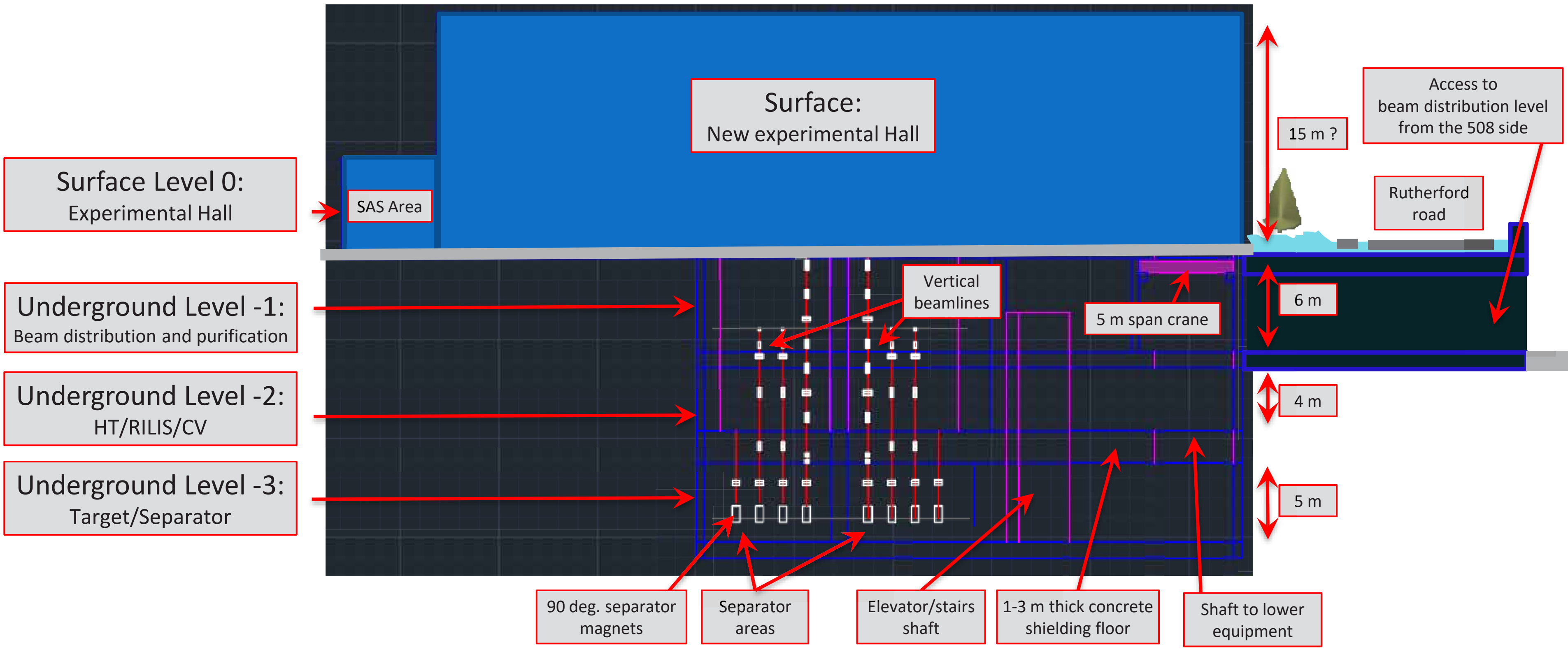

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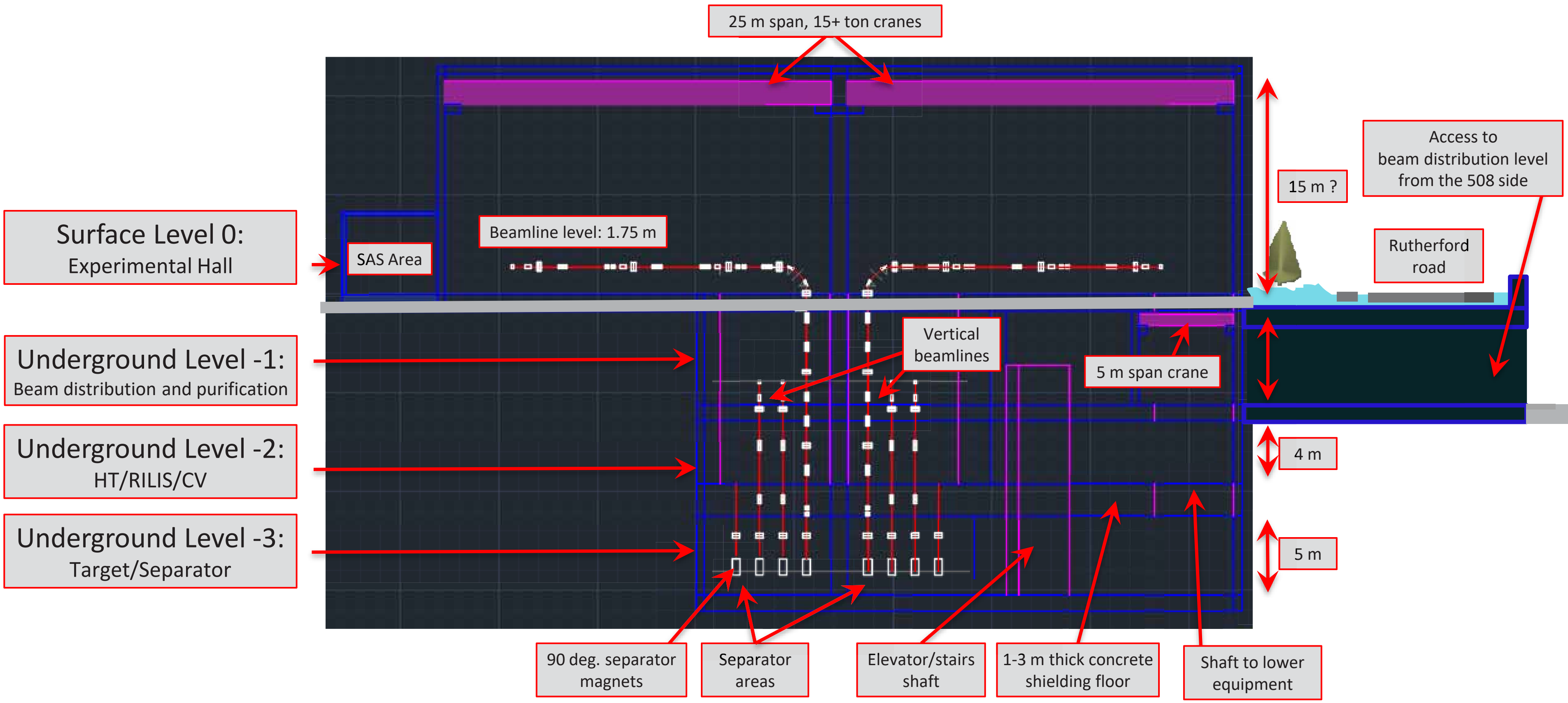

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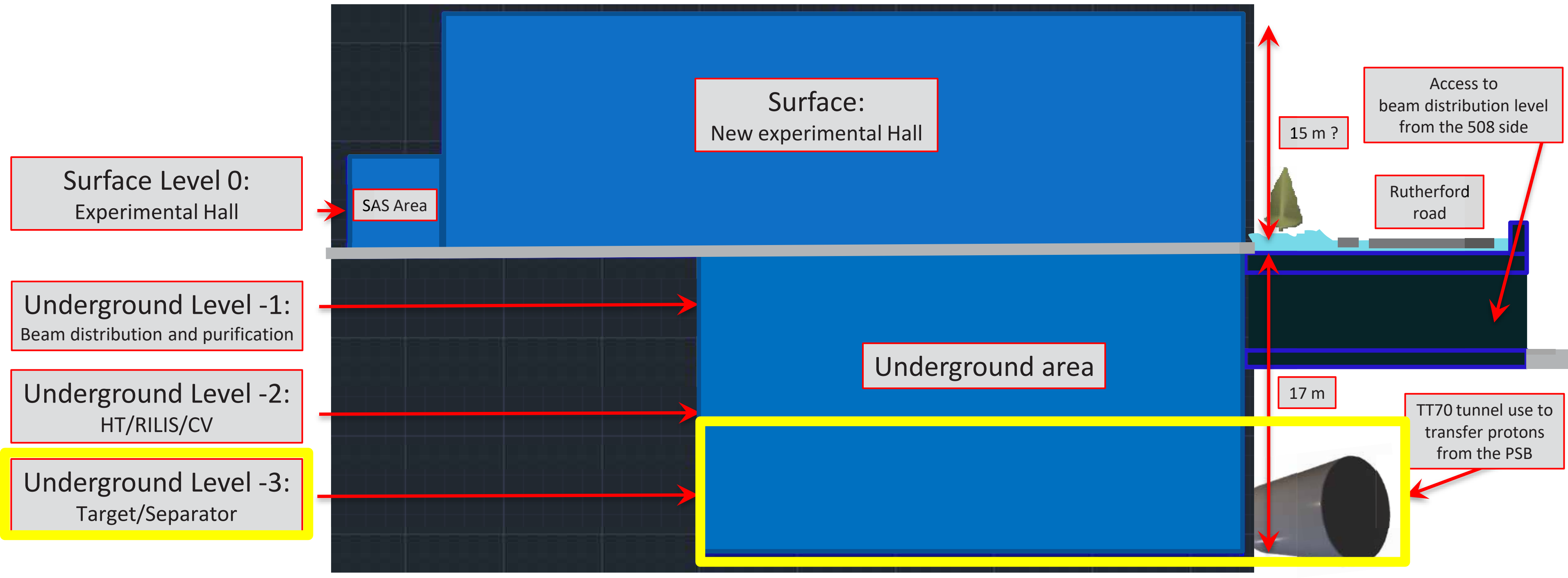
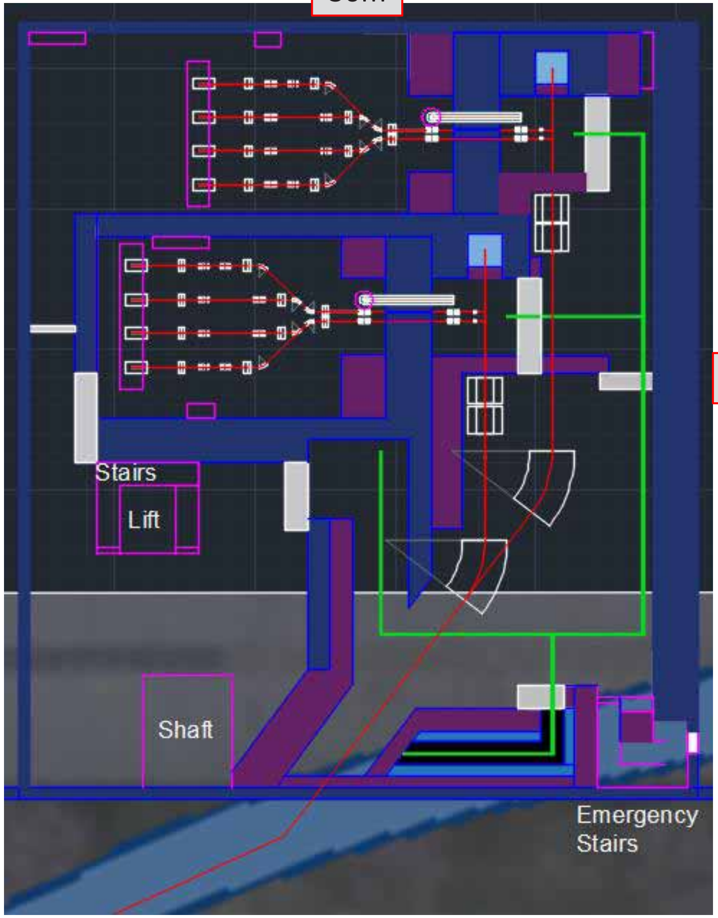


Layout of Underground Level -3: Target/Separator Zones:

30m

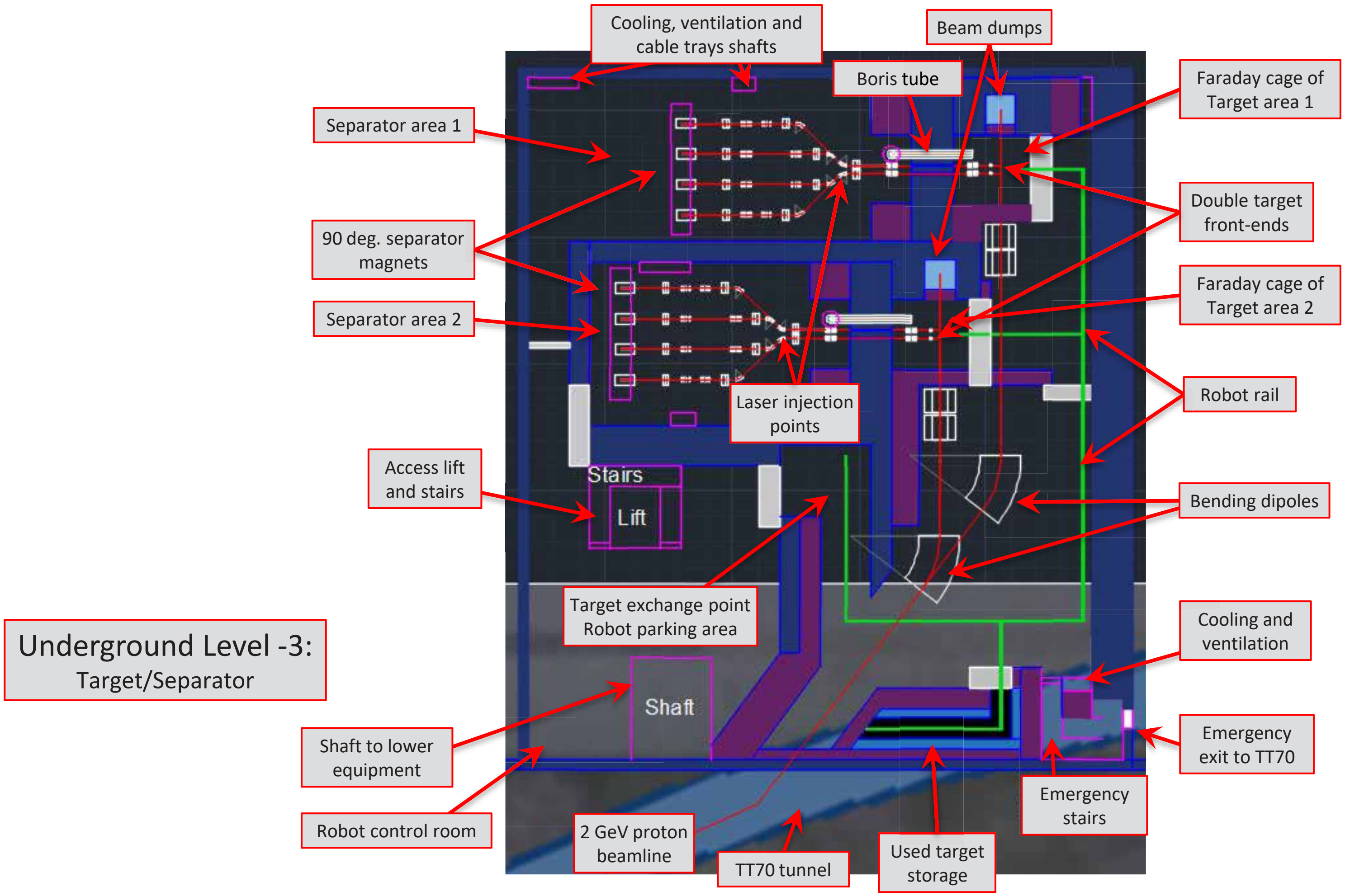


34m

Underground Level -3:
Target/Separator

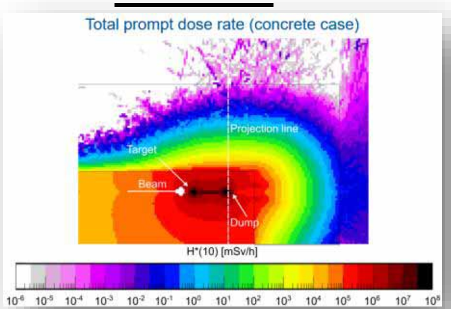
Surface: 1020m^2

Layout of Underground Level -3: Target/Separator Zones:

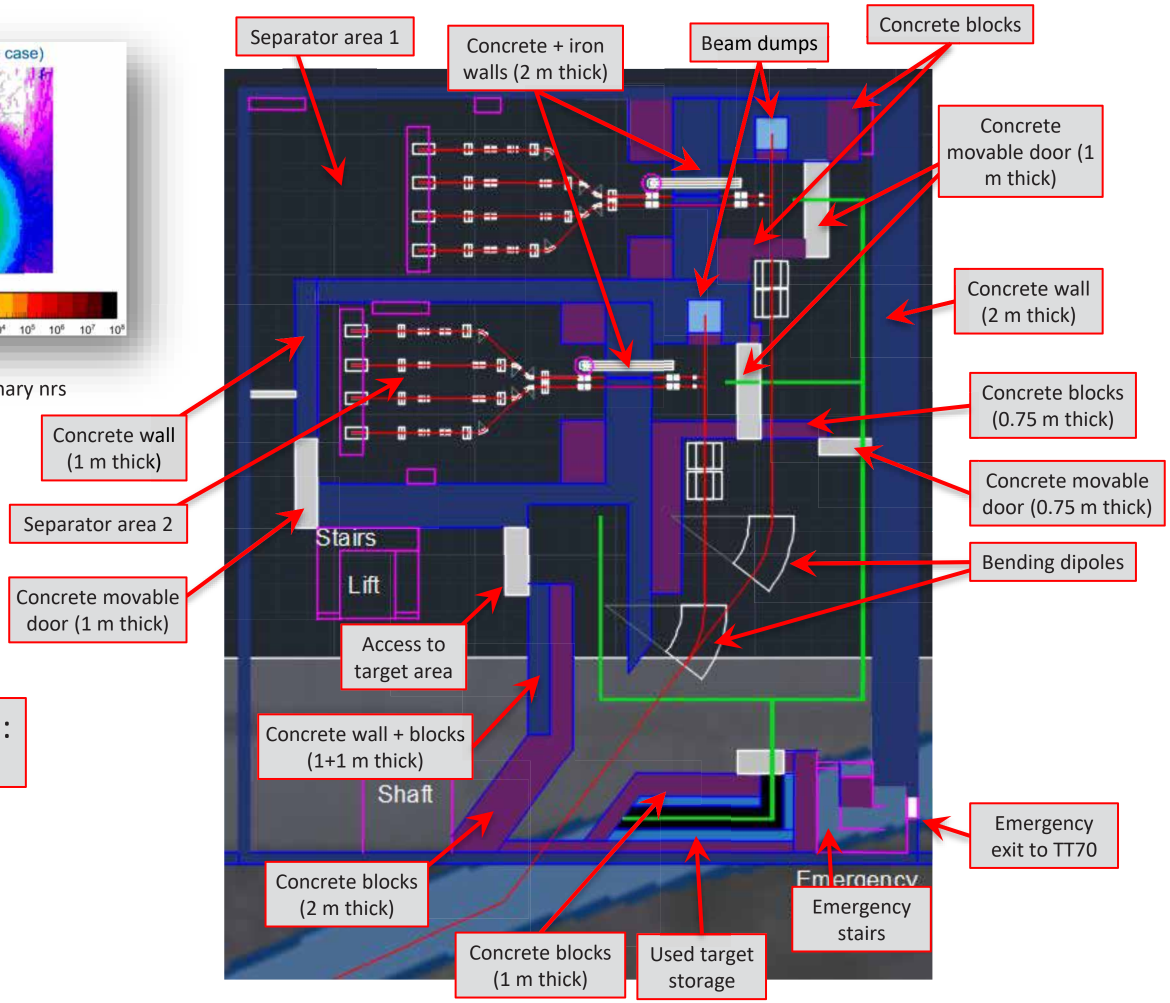


E. Siesling, J.A. Rodriguez - 2020 EPIC Workshop

Radiation shielding of Underground Level -3: Target/Separator Zones:



Courtesy F. Pozzi
ISOLDE beam dump study preliminary nrs

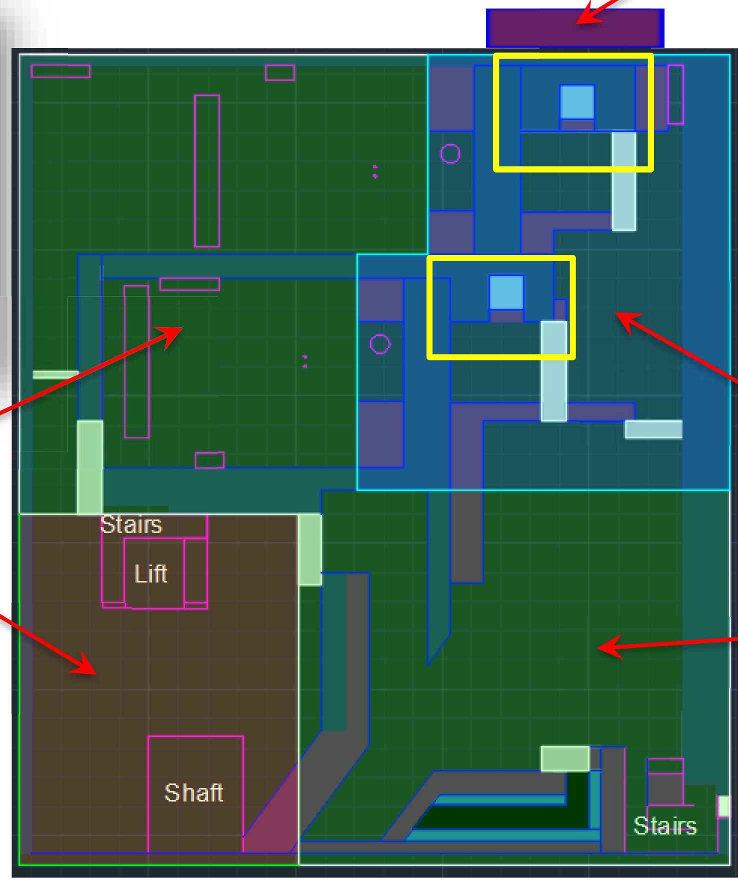


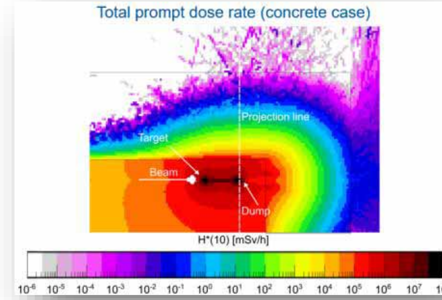
Underground Level -3: Target/Separator

E. Siesling, J.A. Rodriguez - 2020 EPIC Workshop

Target/Separator Ceiling Thickness:

Radiation Area	Area	Dose limit [year]	Ambient dose equivalent rate: permanent	Ambient dose equivalent rate: low occupancy	Sign
	Non-designated	1 mSv	0.5 µSv/h	2.5 µSv/h	
	Supervised	6 mSv	3 µSv/h	15 µSv/h	
Controlled Area	Simple	20 mSv	10 µSv/h	50 µSv/h	
Controlled Area	Limited Stay	20 mSv		2 mSv/h	LIMITED STAY SÉJOUR LIMITÉ
Controlled Area	High Radiation	20 mSv		100 mSv/h	HIGH RADIATION HAUTE RADIATION
Controlled Area	Prohibited	20 mSv		> 100 mSv/h	PROHIBITED AREA ZONE INTERDITE

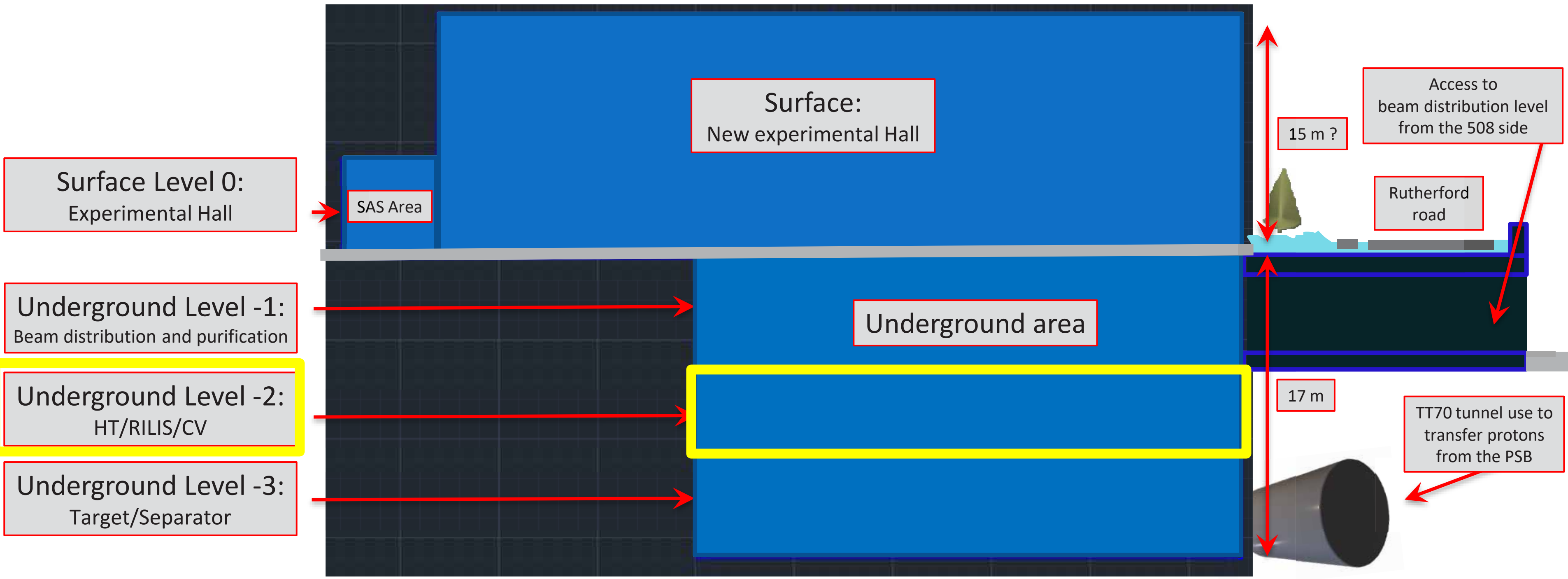




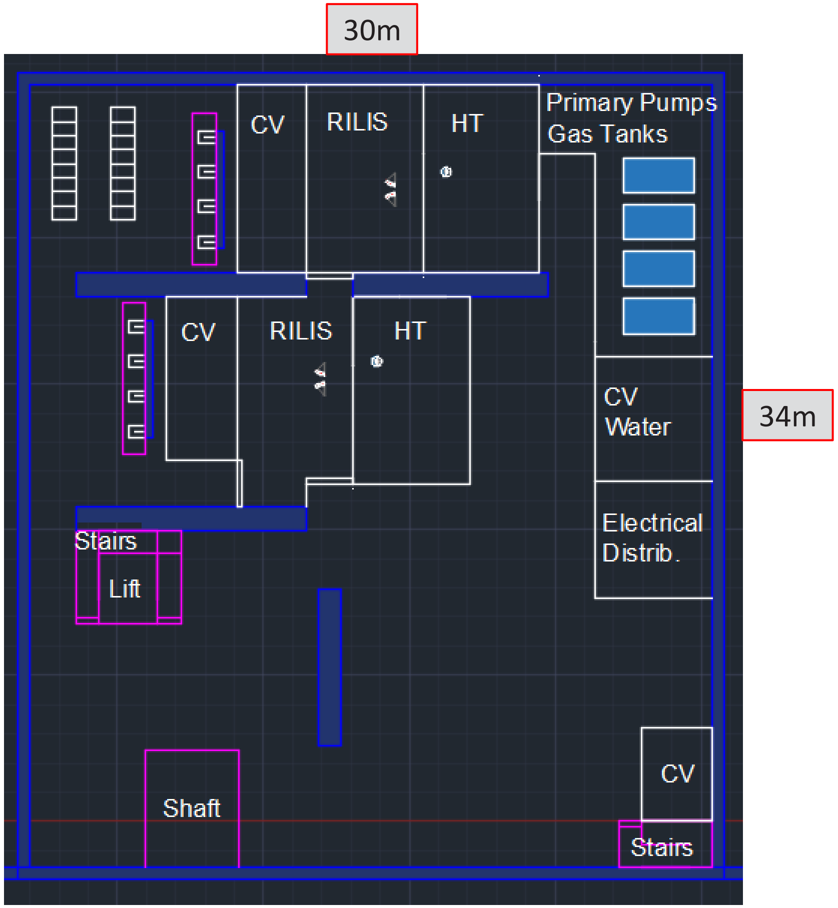
Courtesy F. Pozzi
ISOLDE beam dump study preliminary nrs

Underground Level -3: Target/Separator

Cross-section of the Proposed Hall and Underground Area:



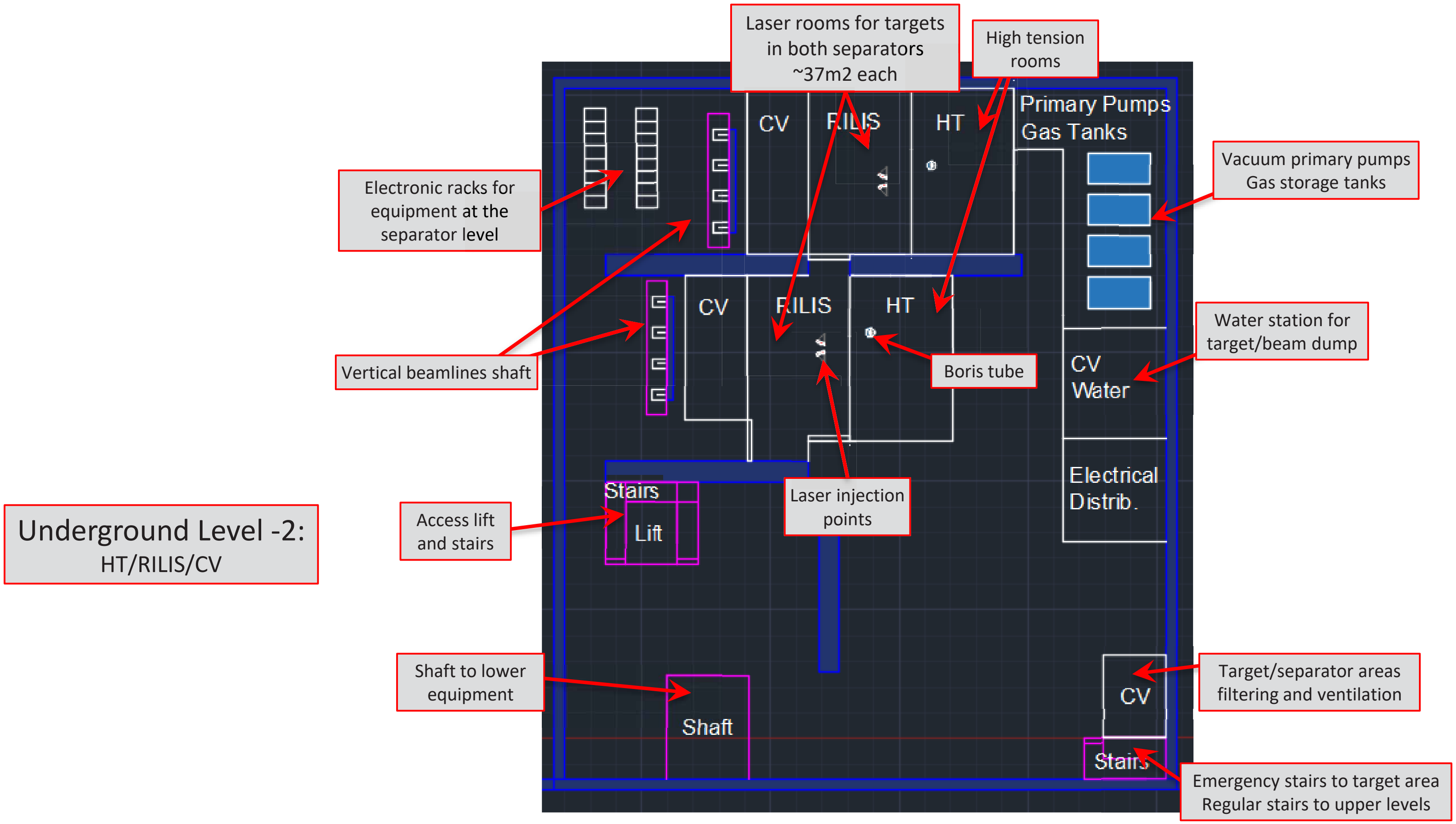
Layout of Underground Level -2: HT/RILIS/CV Zones:



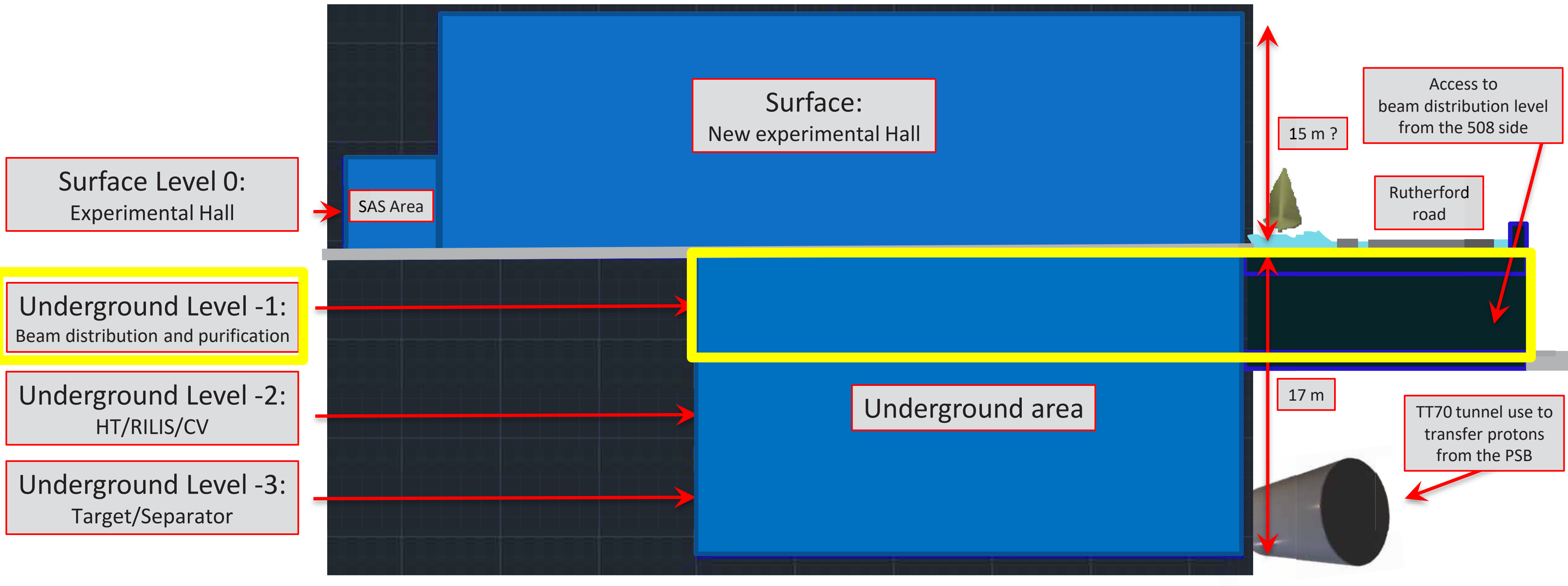
Underground Level -2:
HT/RILIS/CV

Surface: 1020m²

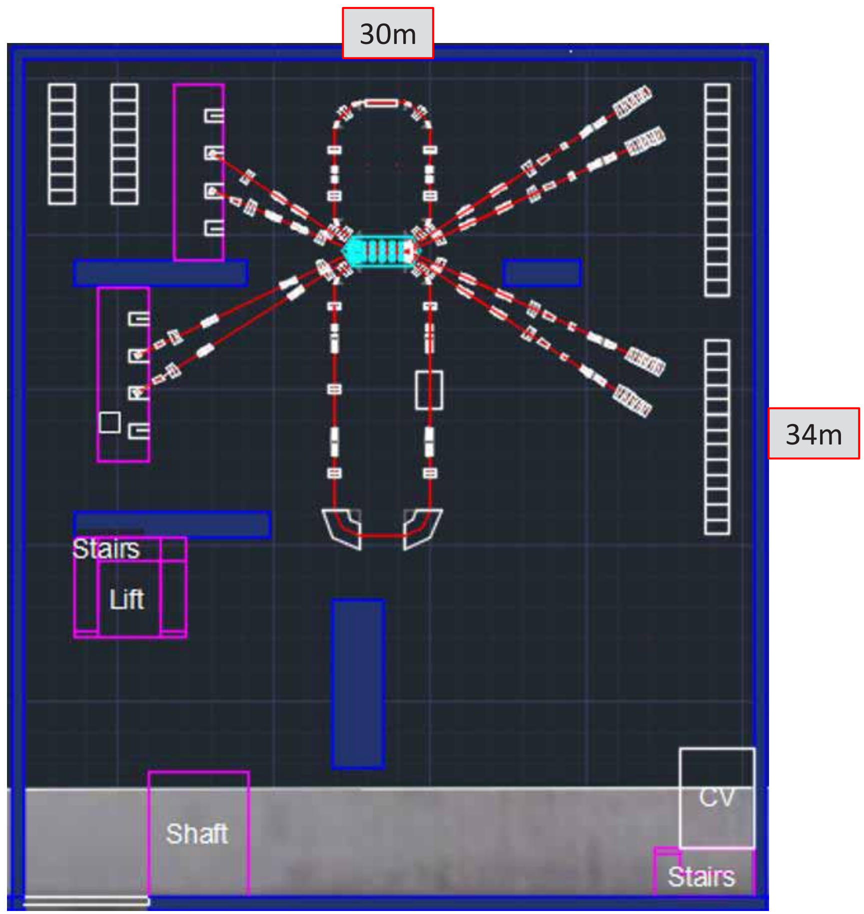
Layout of Underground Level -2: HT/RILIS/CV Zones:



Cross-section of the Proposed Hall and Underground Area:



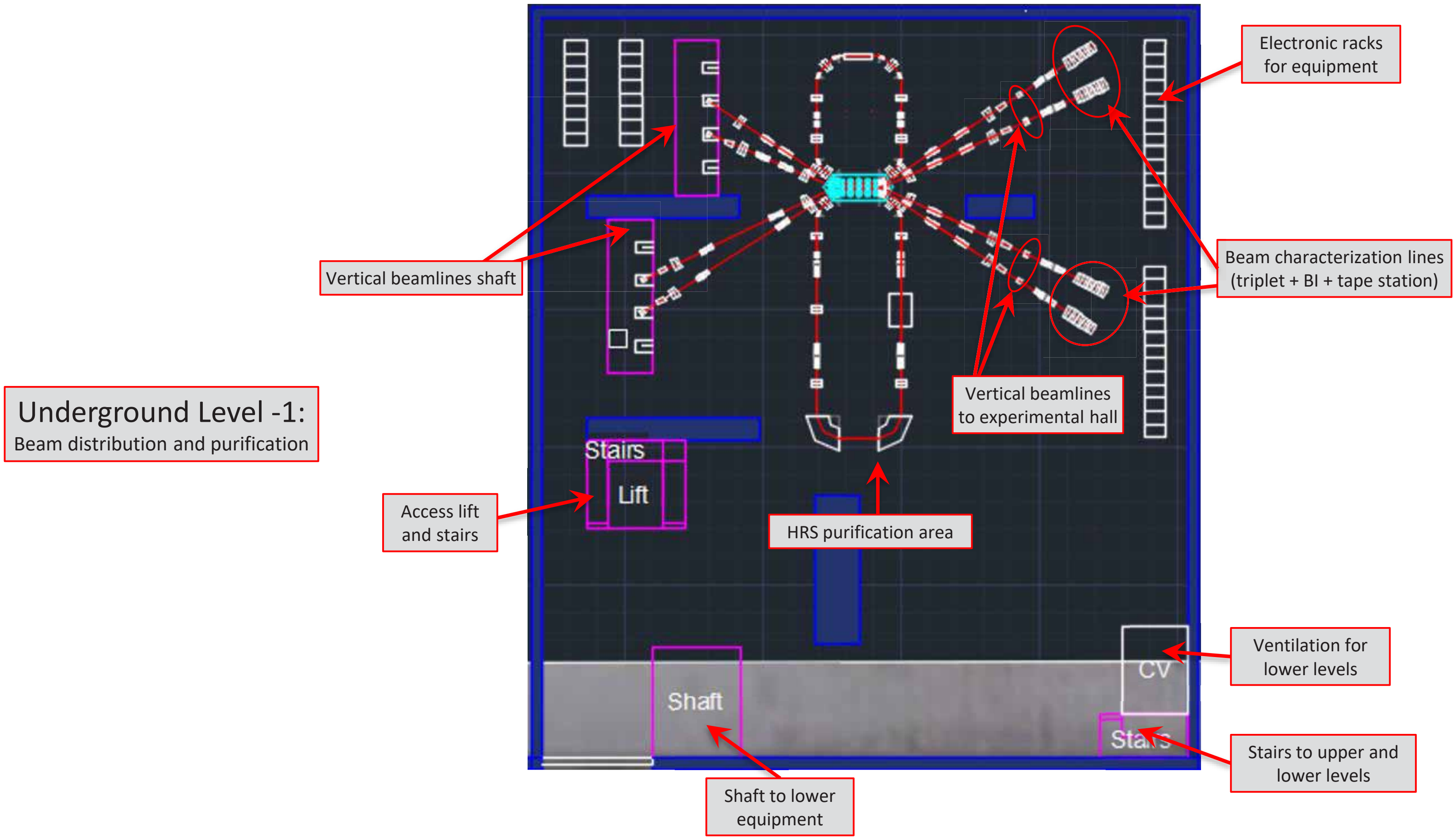
Layout of Underground Level -1: Beam Distribution and Purification:



Underground Level -1:
Beam distribution and purification

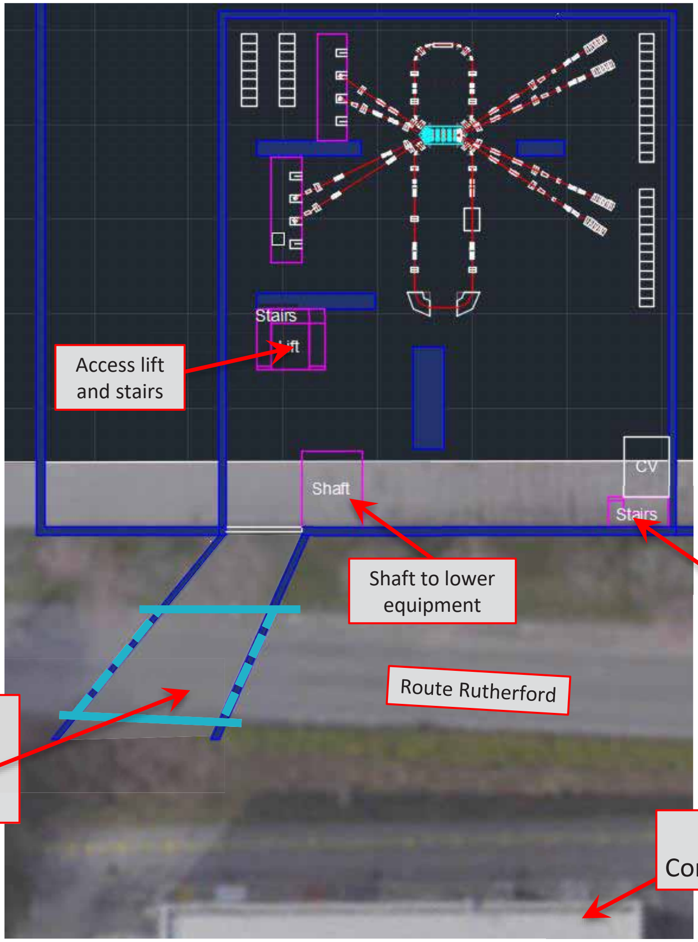
Surface: 1020m²

Layout of Underground Level -1: Beam Distribution and Purification:



Layout of Underground Level -1: Beam Distribution and Purification:

Underground Level -1:
Beam distribution and purification



Access lift and stairs

Shaft to lower equipment

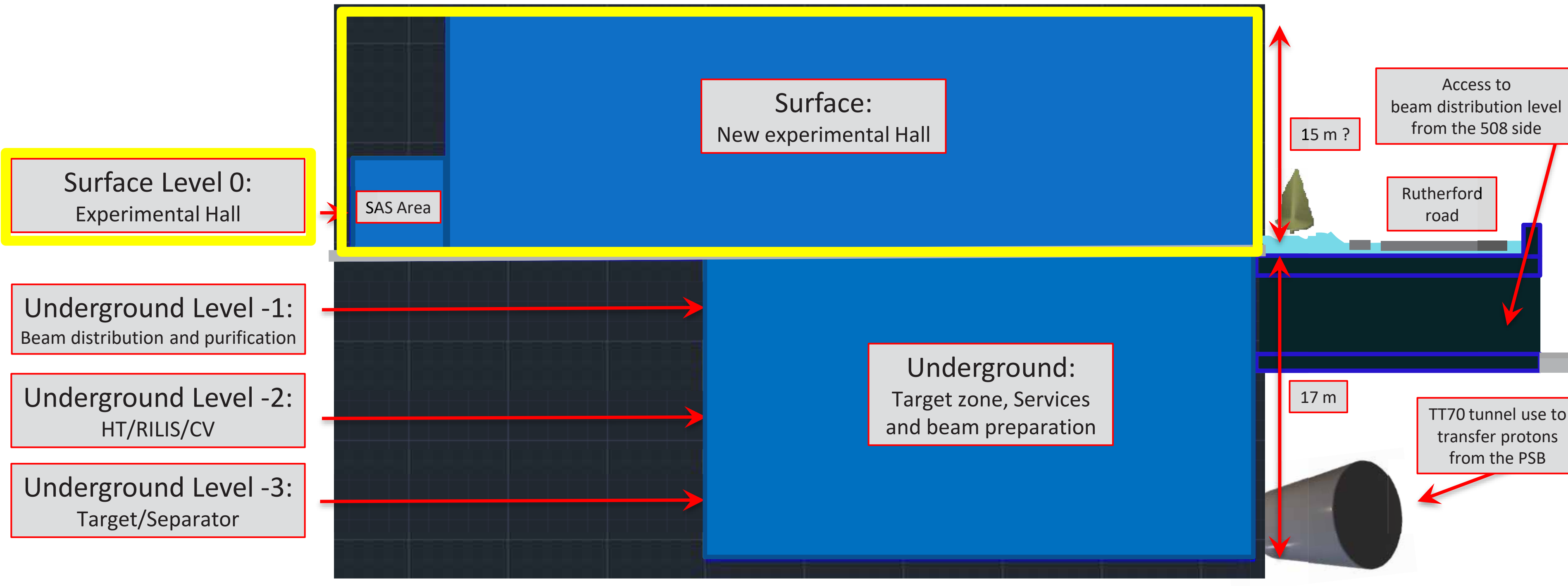
Stairs to upper and lower levels

Route Rutherford

Side access to beam distribution level (under Route Rutherford)

Building 508
Control room and user building

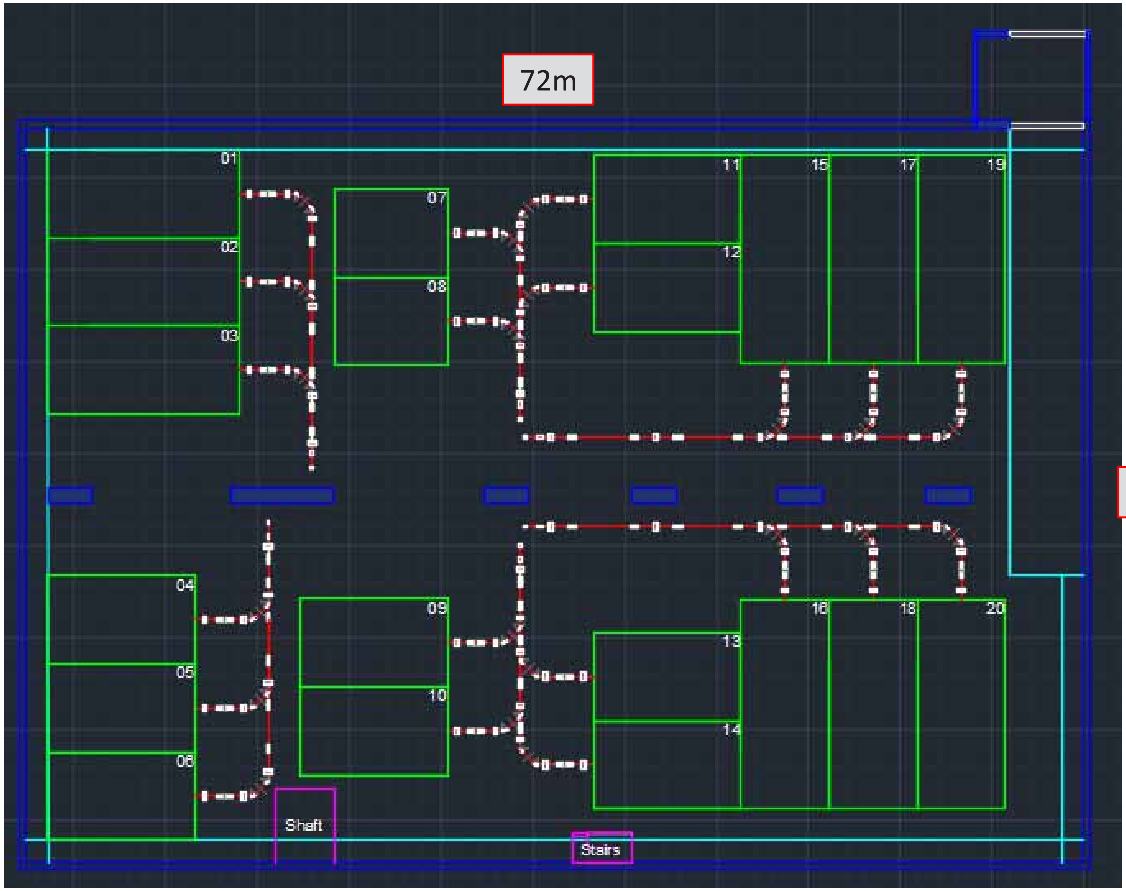
Cross-section of the Proposed Hall and Underground Area:



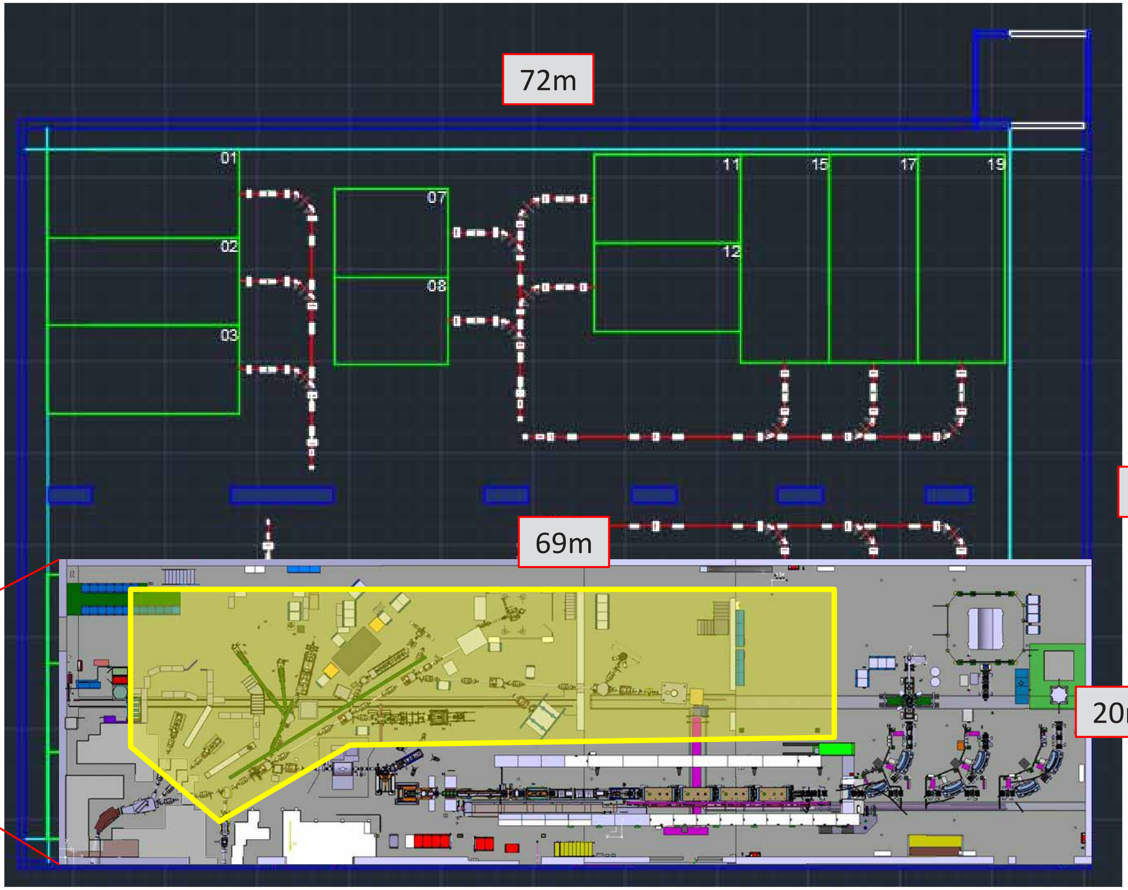
Layout of the experimental hall:

Surface Level 0:
Experimental Hall

Surface: 3600m^2
Low E dedicated



Layout of the experimental hall:



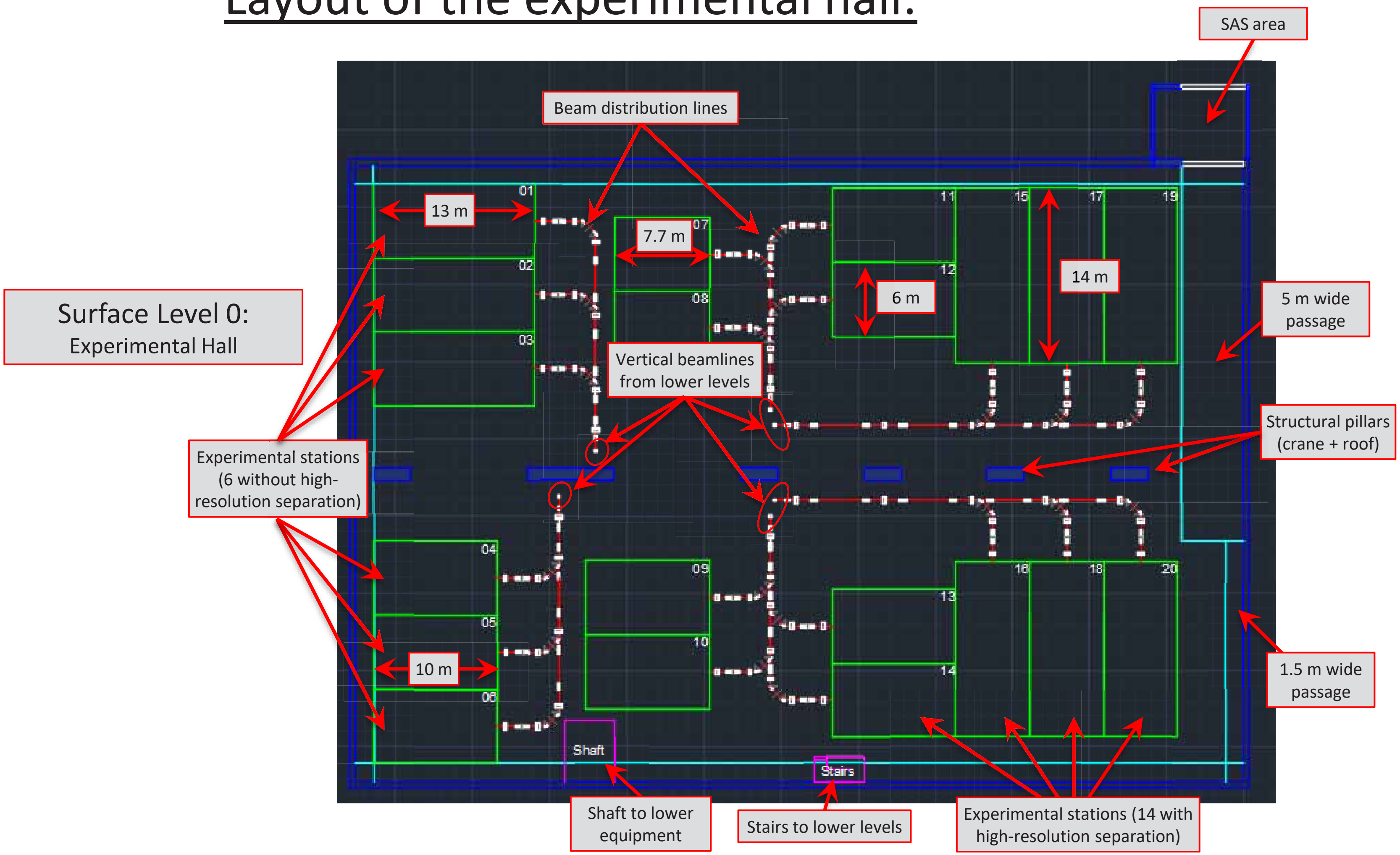
Surface Level 0:
Experimental Hall

Surface: 3600m²
Low E dedicated

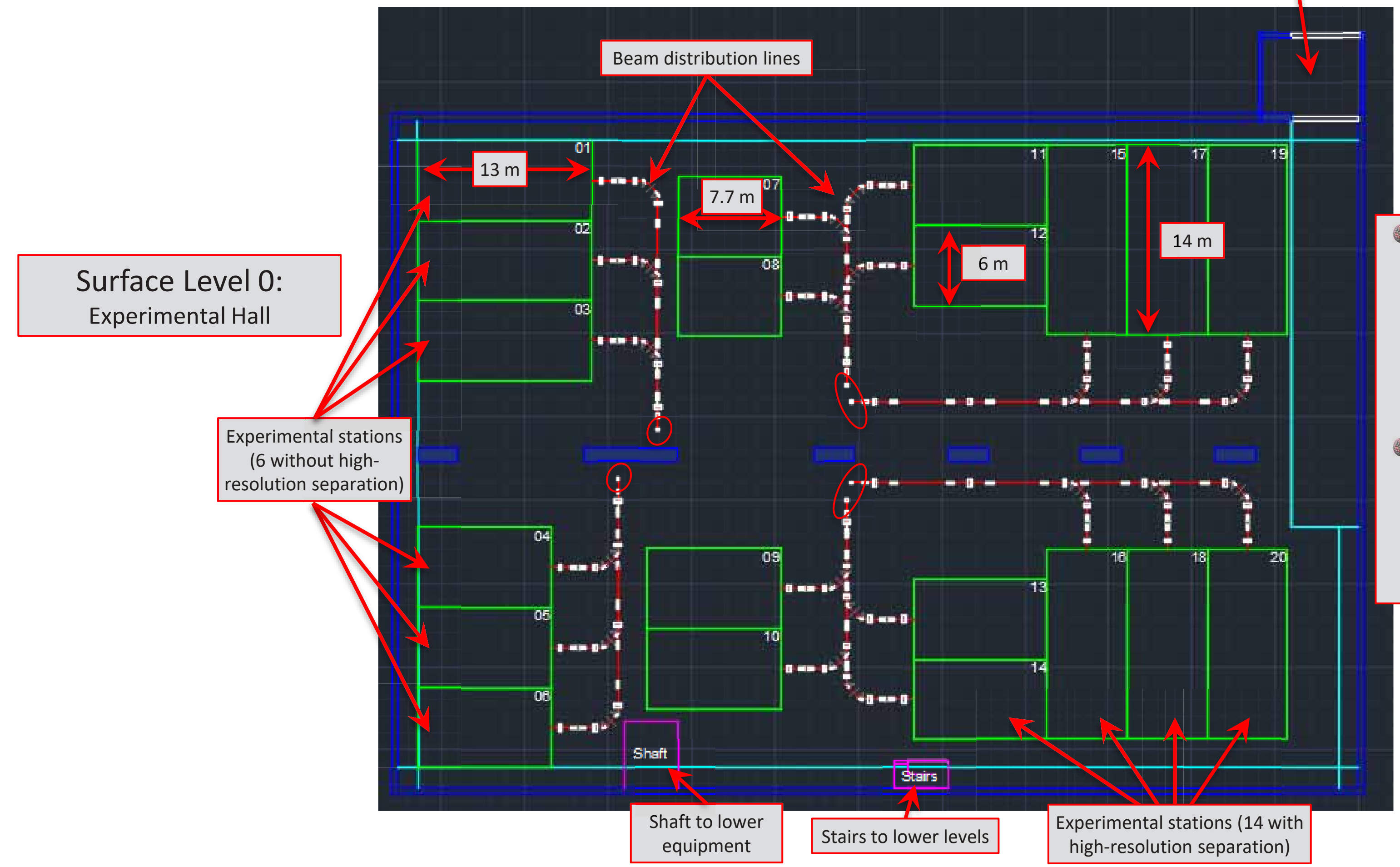
Surface existing hall: 1380m²
Of which half is occupied by the GPS separator zone, the REX/HIE ISOLDE post-accelerator and HEBT lines

E. Siesling, J.A. Rodriguez - 2020 EPIC Workshop

Layout of the experimental hall:



Layout of the experimental hall:

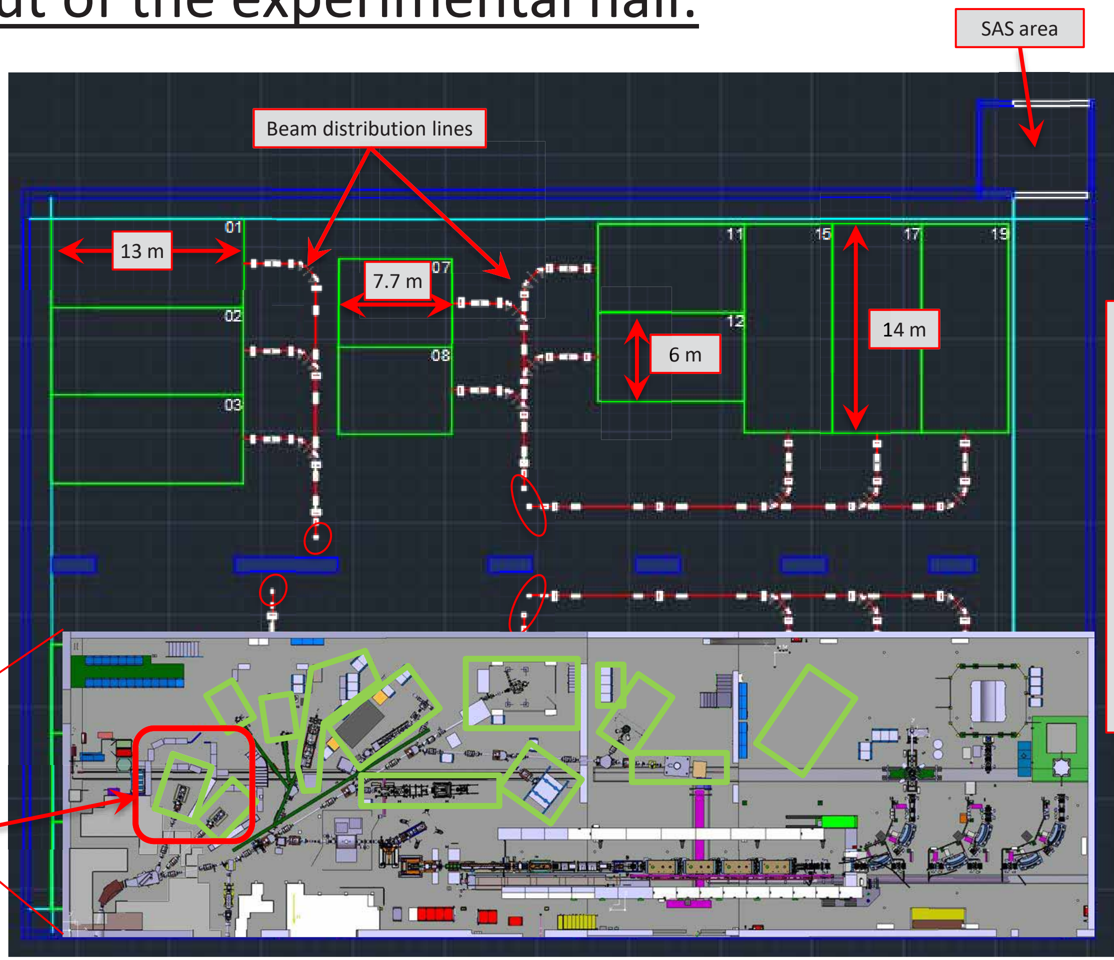


- Experimental areas:
  9: 6x10m (each 60m^2)
  6: 6x14m (each 84m^2)
  3: 6x13m (each 78m^2)
  2: 6x7.7m (each 46m^2)

  20 stations with a total surface: 1370m^2
- Comfortability large areas for housing setup + possible laser setup barrack and exp. infrastructure

Layout of the experimental hall:

Surface Level 0:
Experimental Hall



11+ Low E experimental stations in the existing hall:
To compare: The new GLM/GHM zone is 57m2

- Experimental areas:
  9: 6x10m (each $60m^2$)
  6: 6x14m (each $84m^2$)
  3: 6x13m (each $78m^2$)
  2: 6x7.7m (each $46m^2$)

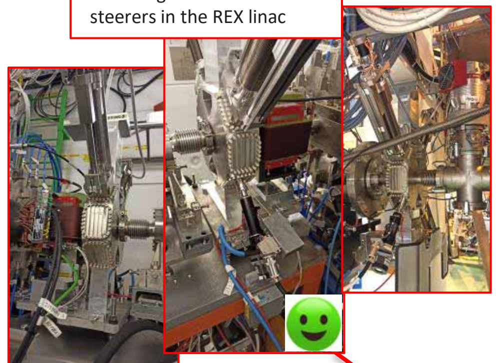
  20 stations with a total surface: $1370m^2$
- Comfortability large areas for housing setup + possible laser setup barrack and exp. Infrastructure

E. Siesling, J.A. Rodriguez - 2020 EPIC Workshop

Hardware changes during LS2: REX/HIE-ISOLDE

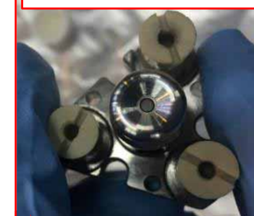
CM4 during installation
after repair in SM18

New diagnostic boxes and
steerers in the REX linac

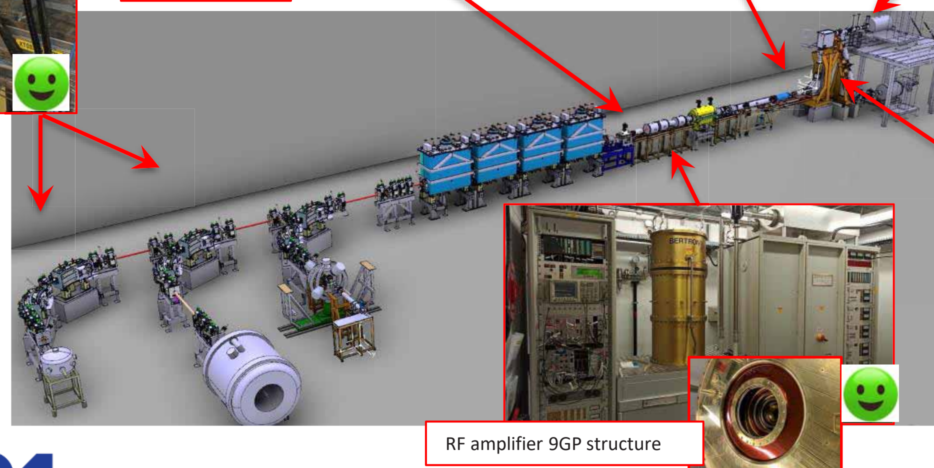


New power converters for
steerers and A/q separator

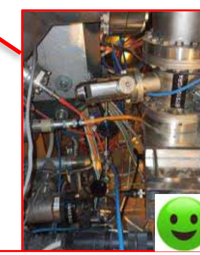
REX-EBIS new electron gun



- New REX-EBIS electron gun
- Power converter REX A/q dipole, steerers
- New gas injection in BTS line
- Repair of CM4
- Refurbishment of REX RF amplifiers
- Consolidation REX beam instrumentation
- Silicon detectors in HEBT (2 units)



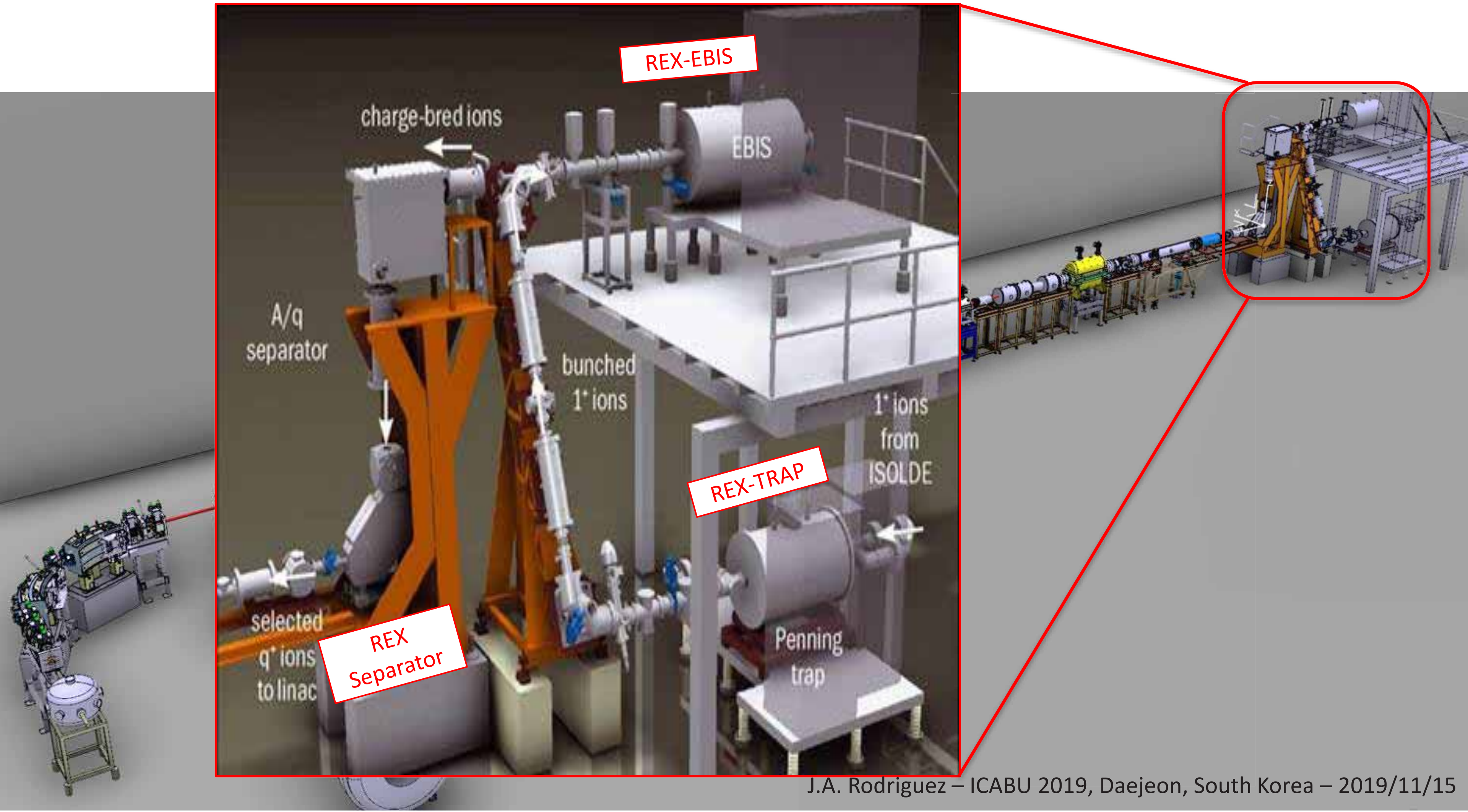
RF amplifier 9GP structure



Needle valve of the new REX-EBIS
external gas injection system

Introduction to ISOLDE:

- Ions are accumulated and transversely cooled in the REX-TRAP and charge bred in the REX-EBIS
- The charge state of interest is selected in the REX separator before injection into the REX/HIE-ISOLDE linac for acceleration and delivery to one of the experimental stations



REX/HIE-ISOLDE beam energy:

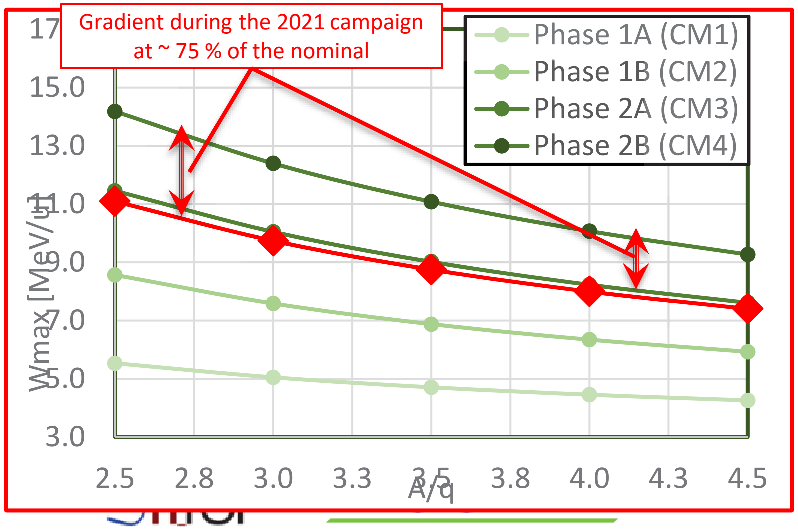
- Coupler of cavity SRF19 successfully repaired during LS2. Very big effort since they cryomodule had to be transported to SM18 and the cavity repair in the clean room. Big thanks to all groups involved!
- Available electric field during operations: ~ 75% of nominal
- Difficult problem to solve (i.e. effort to repair/replacement of SRF cavities, degradation of performance over time, warm-up / cool-down cycles every year, clustering of instabilities…) Not easy path to reach the nominal gradient

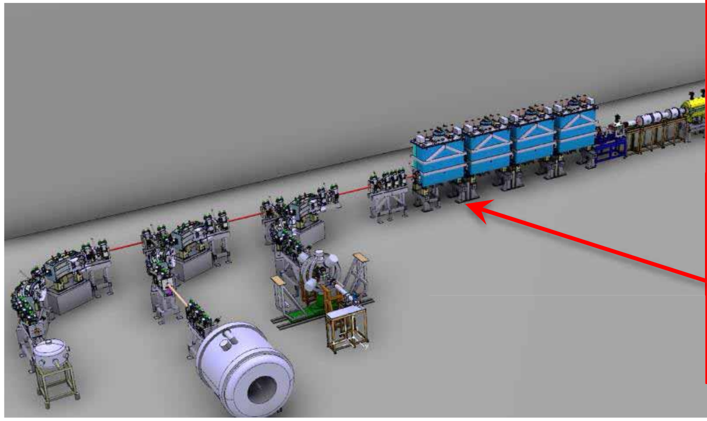
Consequence:

- Physics results limited for several experiments due to the lower beam energy

Possible actions:

- Conditioning of the cavities, improve stability of the cryoplant, adding a fifth cryomodule…?





CM4 during installation after repair in SM18

Jointly expanding (narrow-band) laser capabilities

RILIS + CRIS + COLLAPS + LISA network:

Joint development of **high-resolution versatile laser systems**

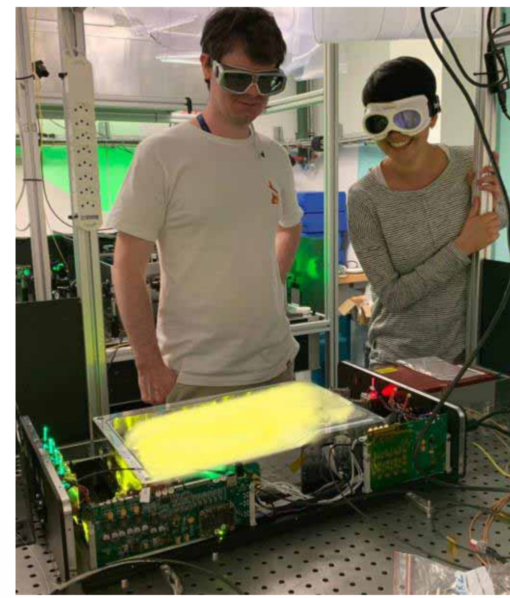
CRIS experiment requiring 328nm narrow-bandwidth (NB) laser light

Several options investigated and used in actual experiment:

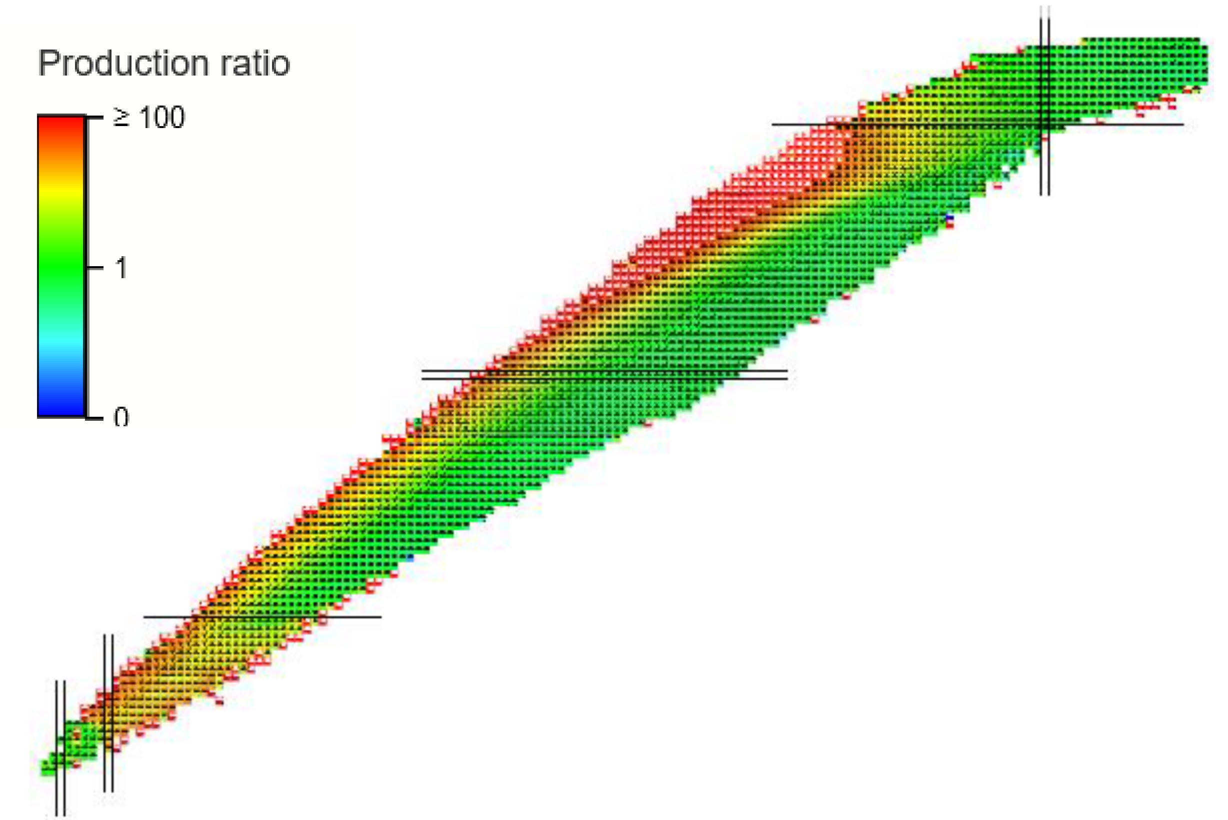
- Pulsed dye amplifier pumped by new RILIS NB pump laser, using COLLAPS NB seed laser or LISA NB OPO laser
- Frequency mixing of CRIS NB laser and RILIS NB pump laser

➔ Combinations of commercial and custom-built systems

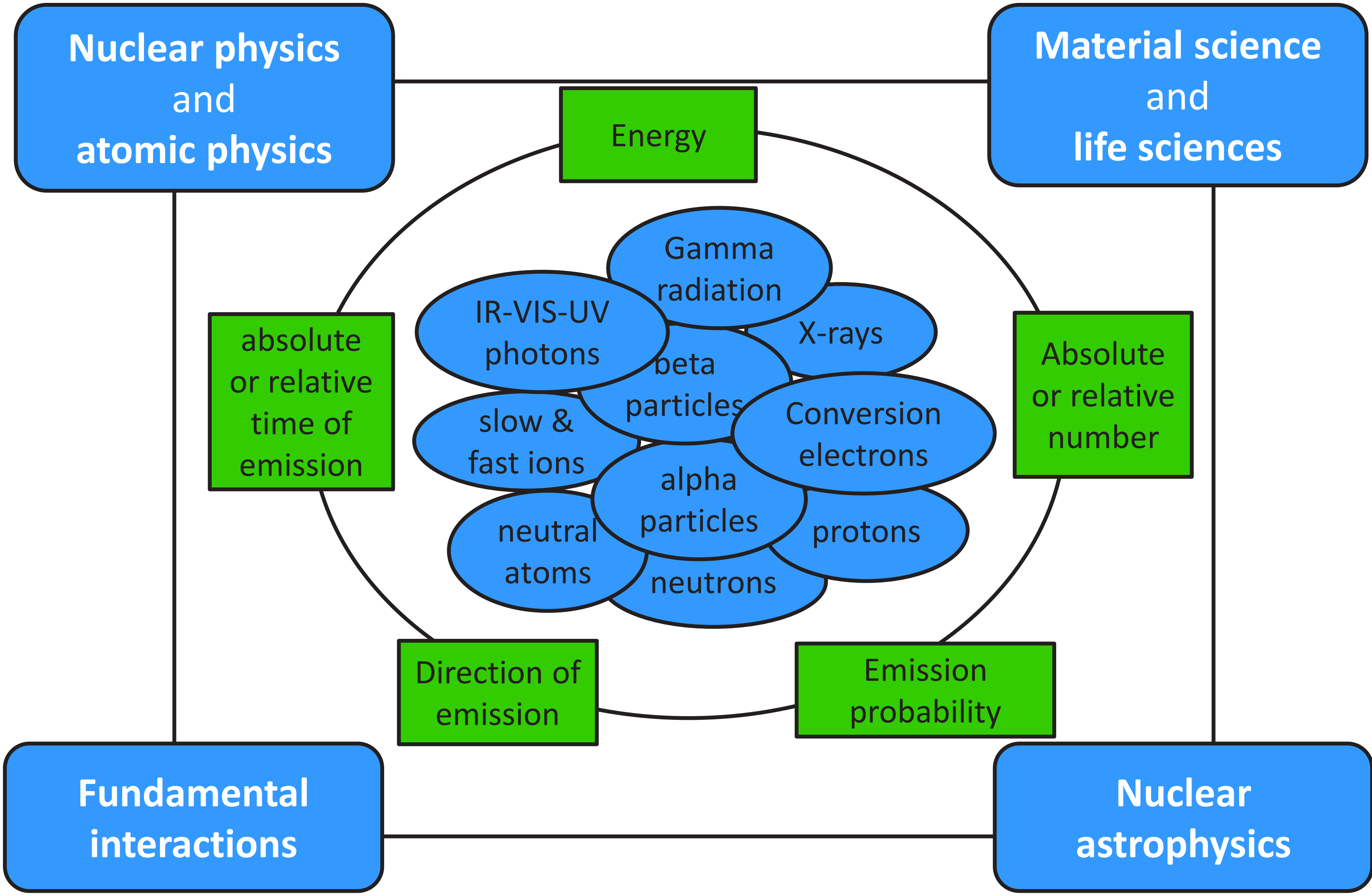
➔ Profit for laser spectroscopy groups at ISOLDE and elsewhere



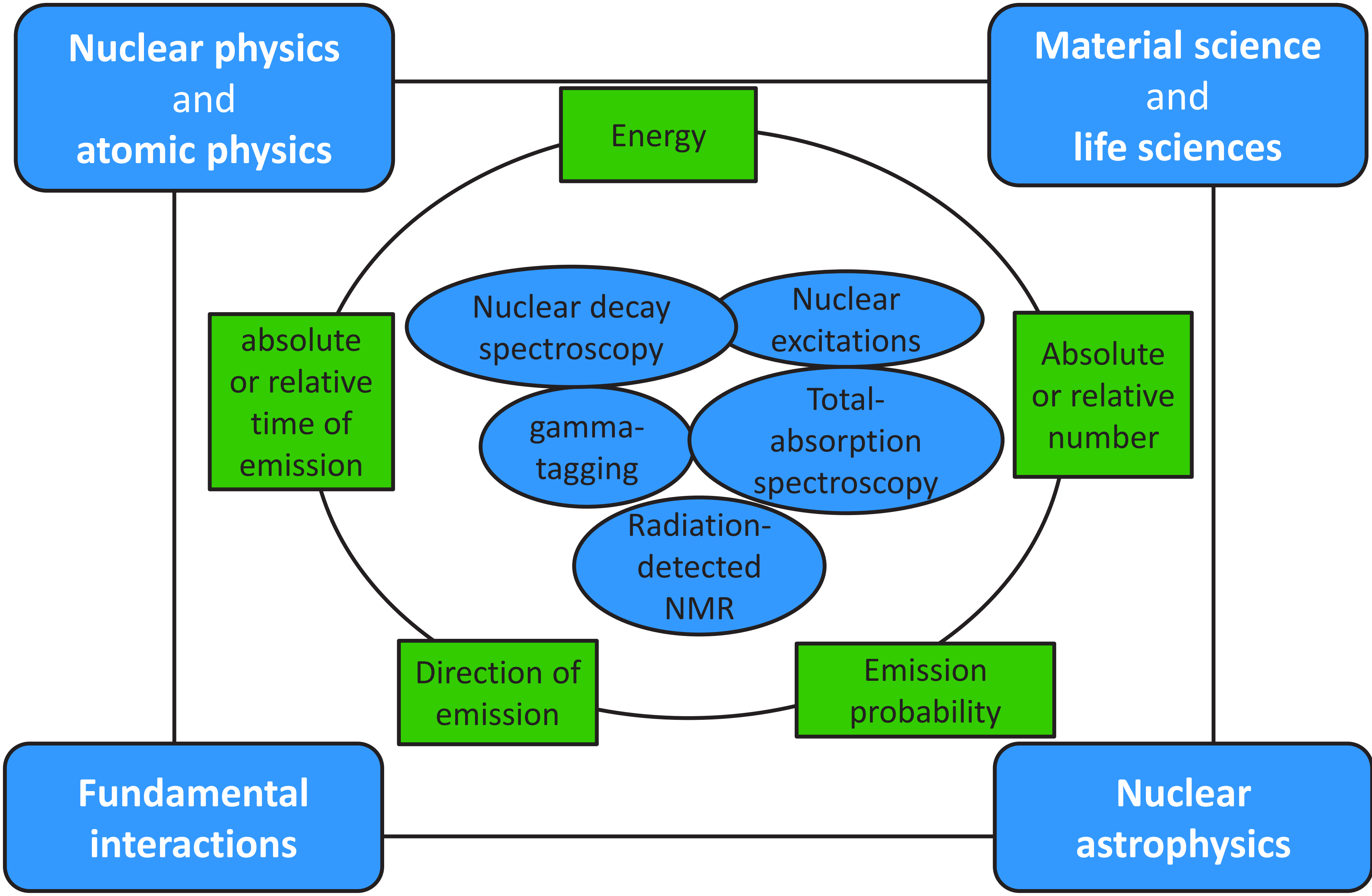
1.4/0.6 GeV p's on UC



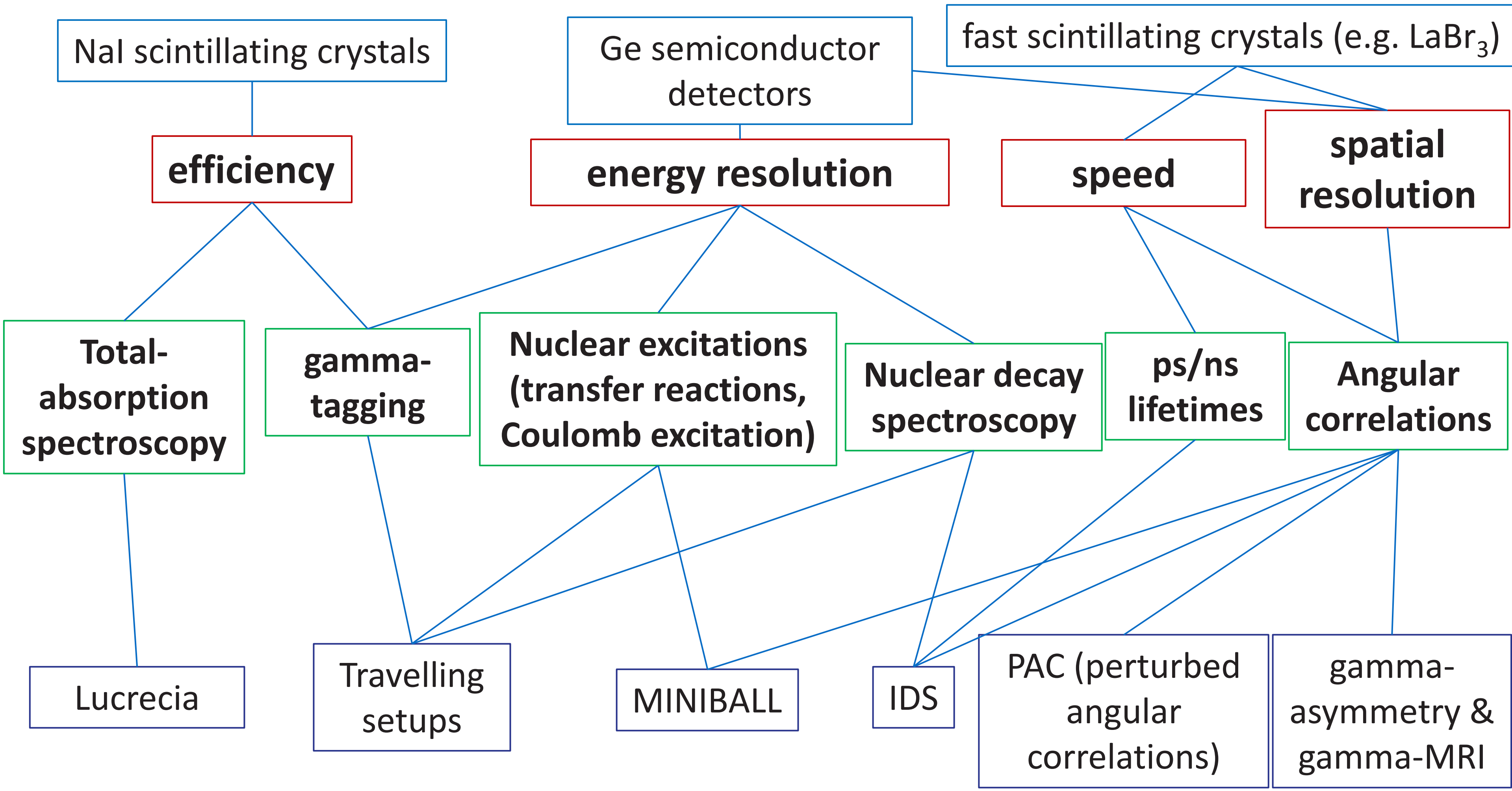
ISOLDE detectors and research topics



Gamma-ray detectors at ISOLDE



ISOLDE gamma-ray detectors



ISOLDE particle detectors

- **To detect particles emitted in decays or reactions of unstable nuclei:**
- Alphas
- Betas
- Protons
- Neutrons
- Other emitted (light particles), e.g. deuterons

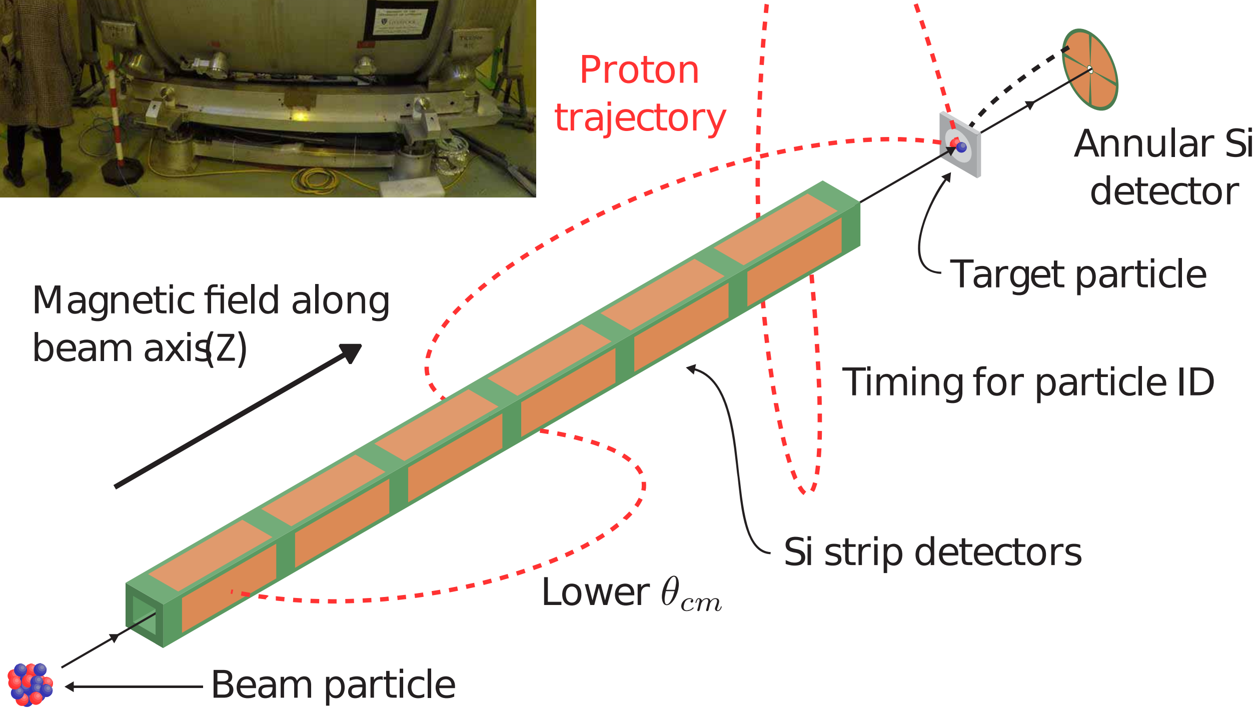
- **What is required:**
- Energy
- Time of emission
- Emission direction

- **Used and tested types of detectors:**
- Si strip detector
- Time projection chamber
- TIMEPIX

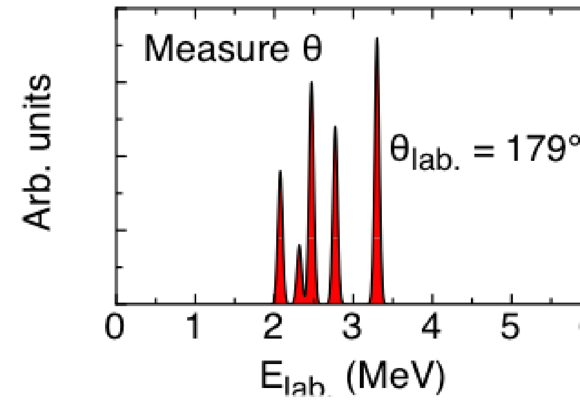
ISS: charged particle detection

ISOLDE Solenoidal Spectrometer

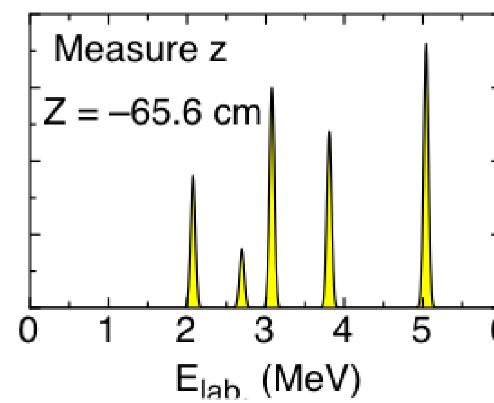
direct reactions at HIE-ISOLDE



Fixed angle



Solenoid



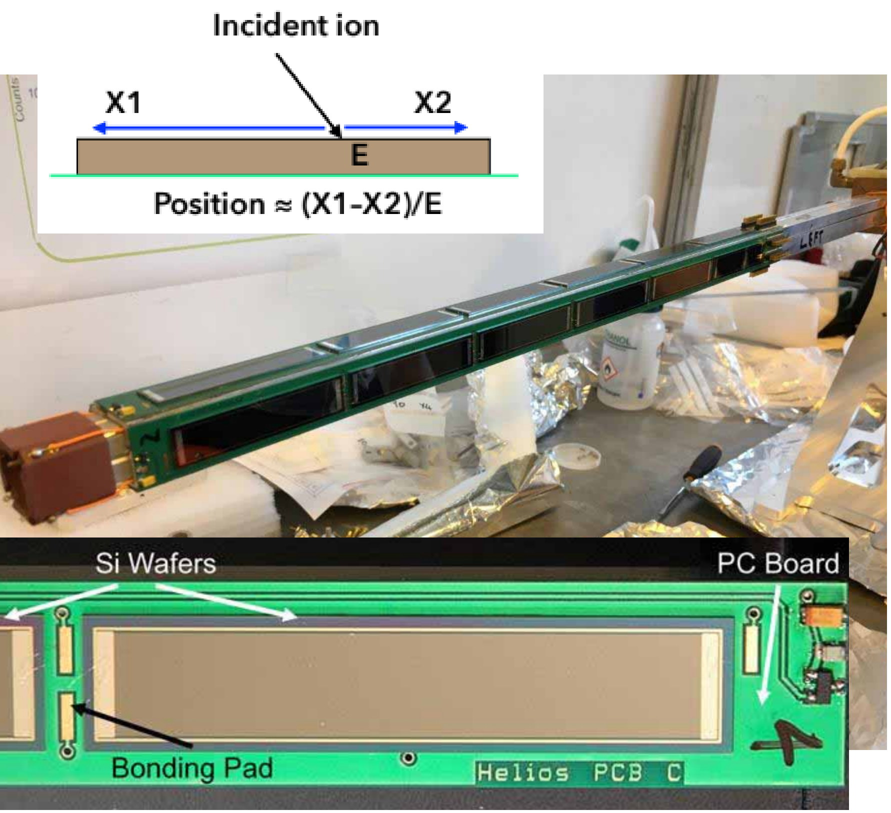
MEASURED: position z where light ejectile returns to axis, cyclotron period T_{cyc}, lab particle energy E_p

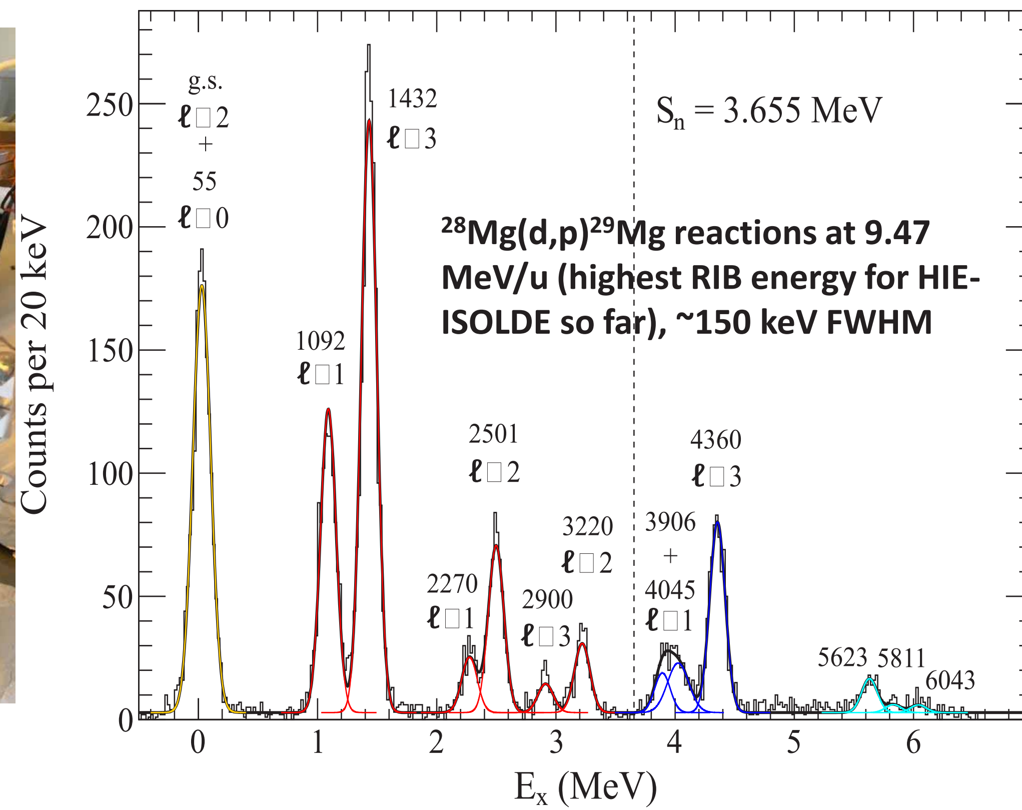
<u>no kinematic compression</u> of energy spectrum (unlike at fixed angles)

Linear relationship between E_{cm} and $E_{lab.}$

1st ISS detectors in 2018

- Used HELIOS solenoid (Argonne) 24 resistive strip detectors (PSD) + electronics and DAQ
- Position determined though comparison of signals from each side of detectors



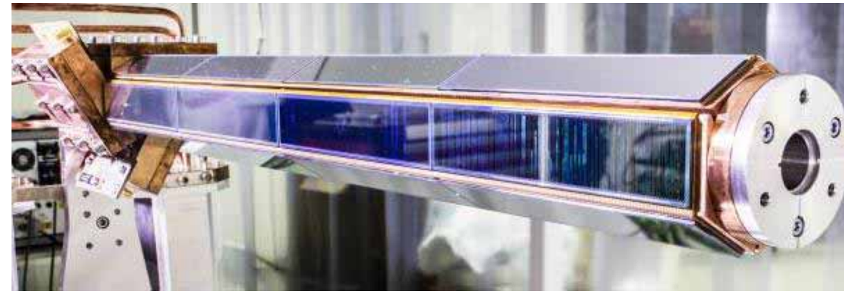


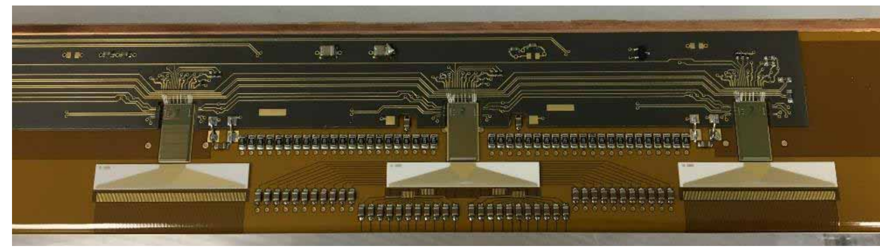
Contact: D. Sharp, U Manchester; L. Gaffney, U Liverpool, et al.

T.L. Tang et al., Phys. Rev. Lett. 124, 062502 (2020)

ISS detectors in 2021

6-sided Si array: 4 double-sided silicon-strip (DSSS) detectors + ASICs readout on each side





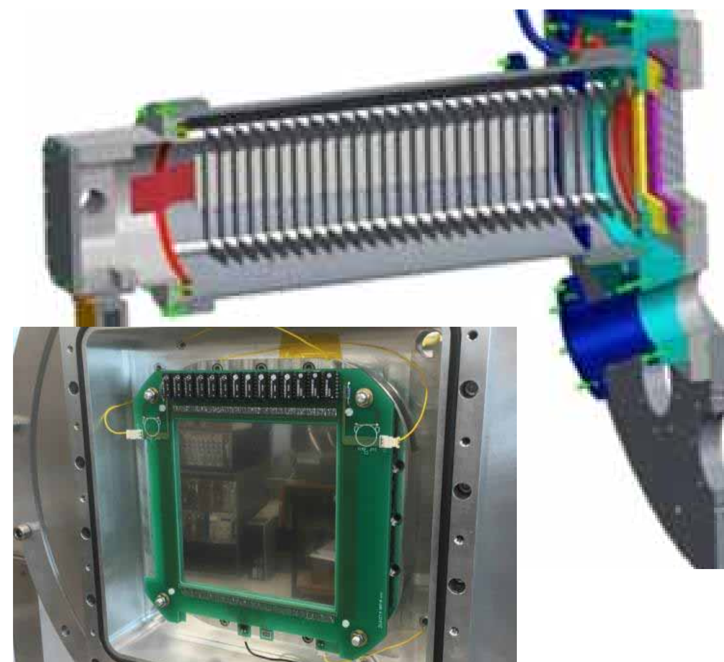
Each detector:

- 128 x 0.95mm strips along detector length
- 11 x 2mm along width
- 3336 channels

Total Si length: 510.4mm (486.4mm active)

- ~70% coverage in azimuthal angle
- Total coverage ~66% (2018: HELIOS PSD ~42%)

New gas-filled recoil detector for recoil identification:



- Position-sensitive multi-wire proportional counter
- Followed by segmented gas-filled ion chamber
- Digitized signals – sample full dE/dx.
- Count rate up to 100kHz

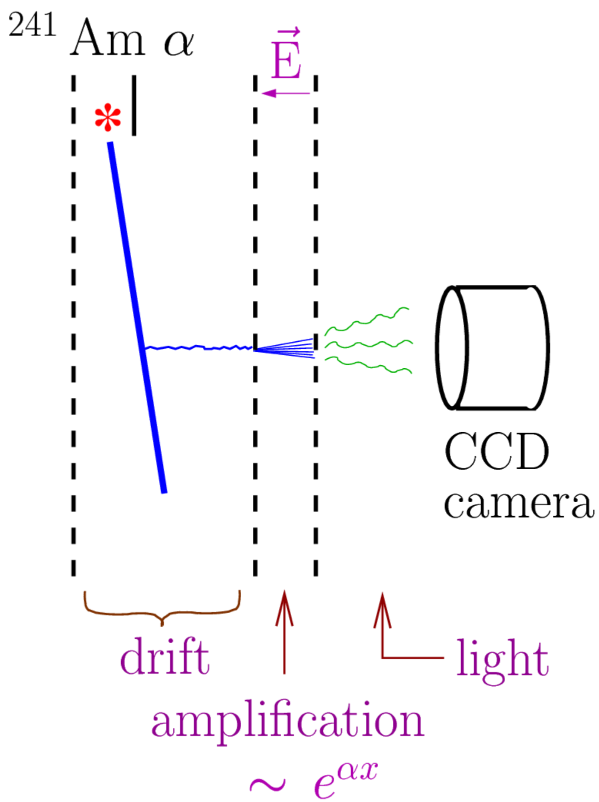
Contact: D. Sharp, U Manchester; L. Gaffney, U Liverpool

Optical TPC: charged-particle imaging

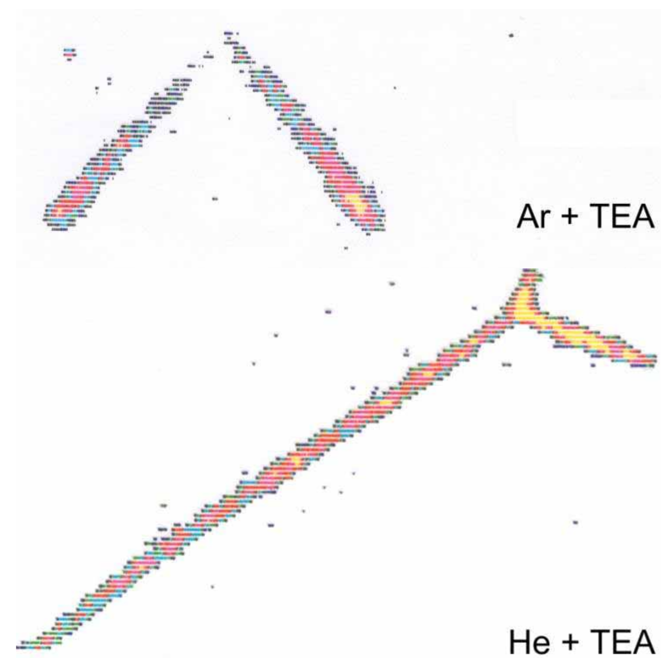
G. Charpak, W. Dominik, J. P. Farbe, J. Gaudaen, F. Sauli, and M. Suzuki,

"Studies of light emission by continuously sensitive avalanche chambers,"

NIM A269 (1988) 142



Example images of α-particle tracks



TEA = Tri-ethyl-amine $N(C_2H_5)_3$

Contact: M. Pfutzner, Warsaw University

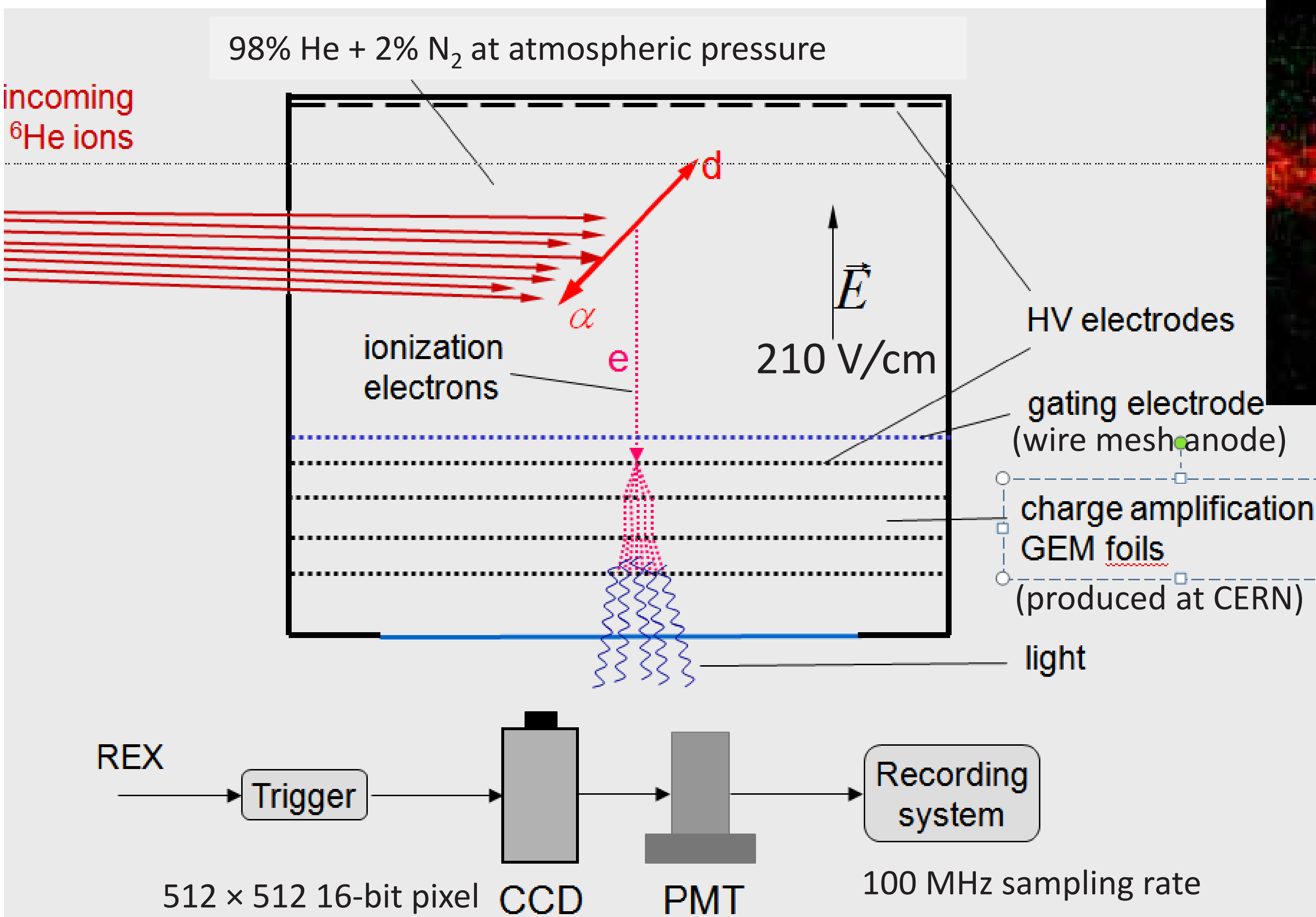
Warsaw OTPC at ISOLDE

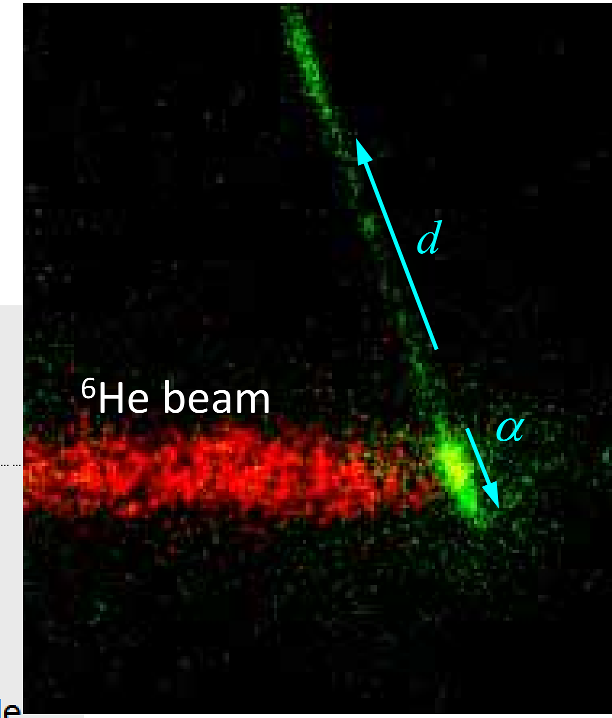
Studying rare decays with particle emission

Rare decay (branching ≈10^{-6}): $^{6}He \rightarrow \alpha$ + *deuteron*

-3 MeV/u bunches of about 10^4 ^{6}He ions

- Implantation into OTCP, 650 ms exposure => decays visible



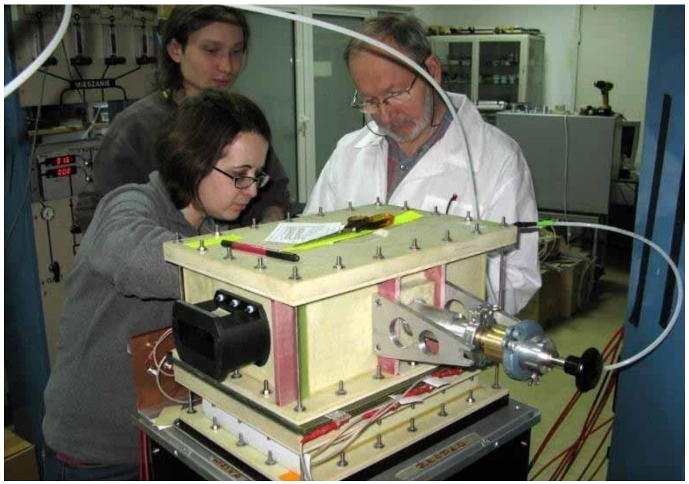


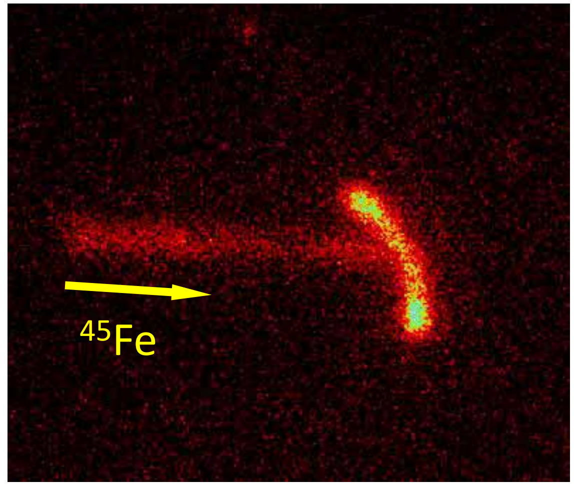
M.Pfutzner et al., Phys. Rev. C 92, 014316 (2015)

Warsaw OTPC at other facilities

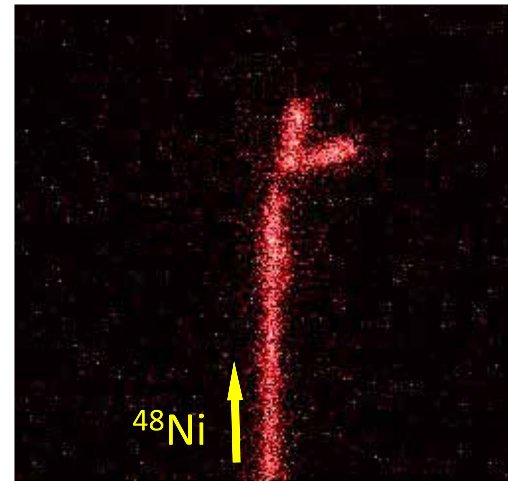
Evidence of 2-proton radioactivity

NSCL, USA: ^{58}Ni @ 161 MeV/u + Ni → ^{45}Fe, ^{48}Ni





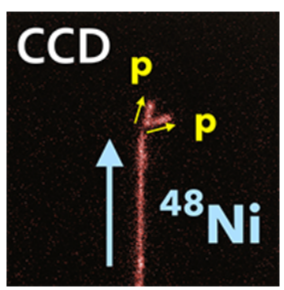
Miernik et al., Phys. Rev. Lett. 99 (2007) 192501



Pomorski et al., Phys. Rev. C 83 (2011) 061303(R)

Physical Review C 50th Anniversary Milestones

50 YEARS PHYSICAL REVIEW C



First observation of two-proton radioactivity in ^{48}Ni

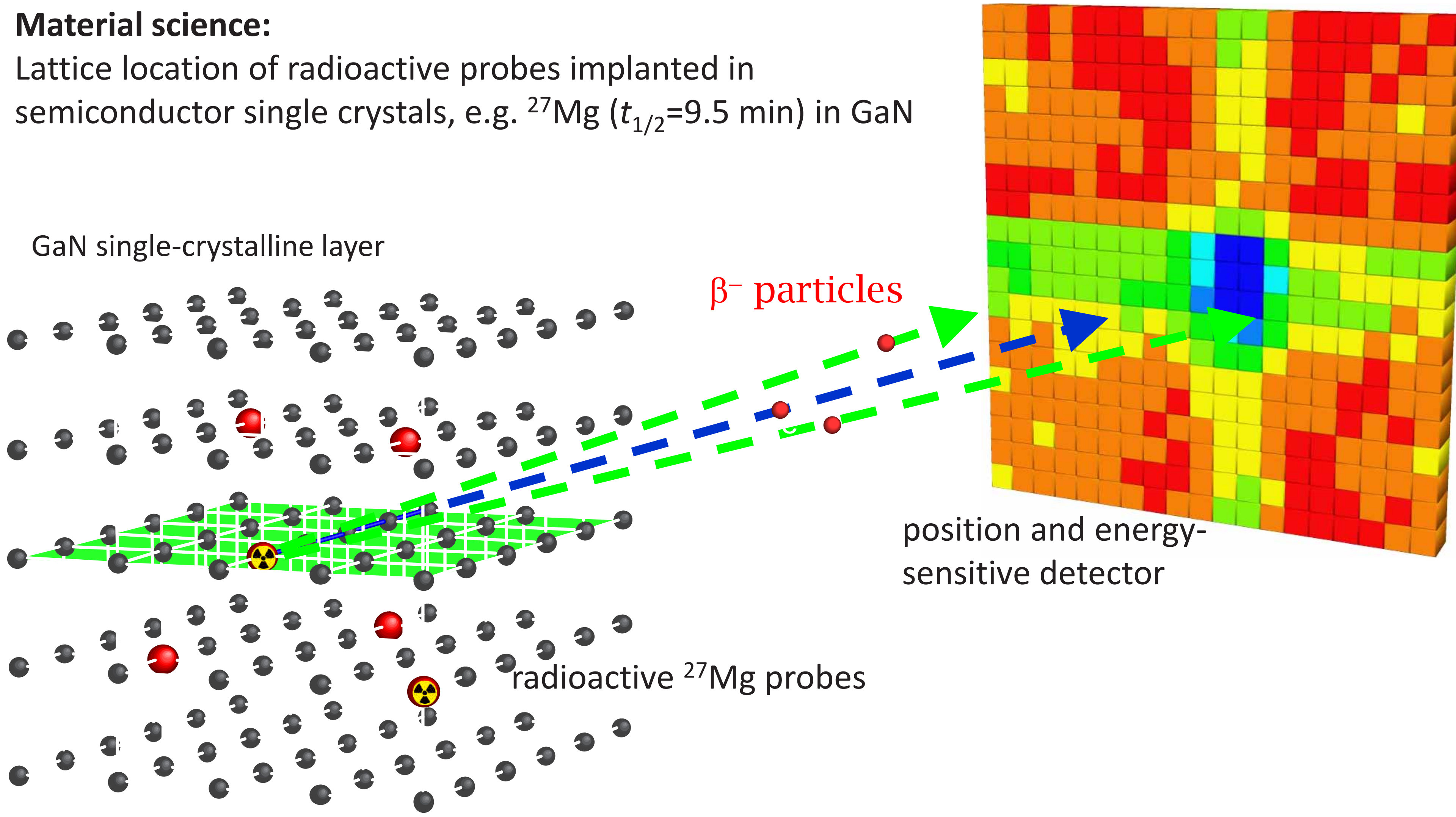
A rare form of radioactivity, in which a proton-laden nucleus decays toward stability via the simultaneous emission of two protons, was observed for ^{48}Ni. Using an optical time-projection chamber, the two-proton emission of four ^{48}Ni nuclei produced at the National Superconducting Cyclotron Laboratory was captured for the first time on CCD camera, marking a new era of optical detection of sub-atomic charged-particle processes in nuclear physics.

First observation of two-proton radioactivity in ^{48}Ni

M. Pomorski, M. Pfützner, W. Dominik, R. Grzywacz, T. Baumann, J. S. Berryman, H. Czyrkowski, R. Dąbrowski, T. Ginter, J. Johnson, G. Kamiński, A. Kuźniak, N. Larson, S. N. Liddick, M. Madurga, C. Mazzocchi, S. Mianowski, K. Miernik, D. Miller, S. Paulauskas, J. Pereira, K. P. Rykaczewski, A. Stolz, and S. Suchyta

EC-SLI: (beta) emission channeling

Material science:
Lattice location of radioactive probes implanted in semiconductor single crystals, e.g. ^{27}Mg ($t_{1/2}$=9.5 min) in GaN

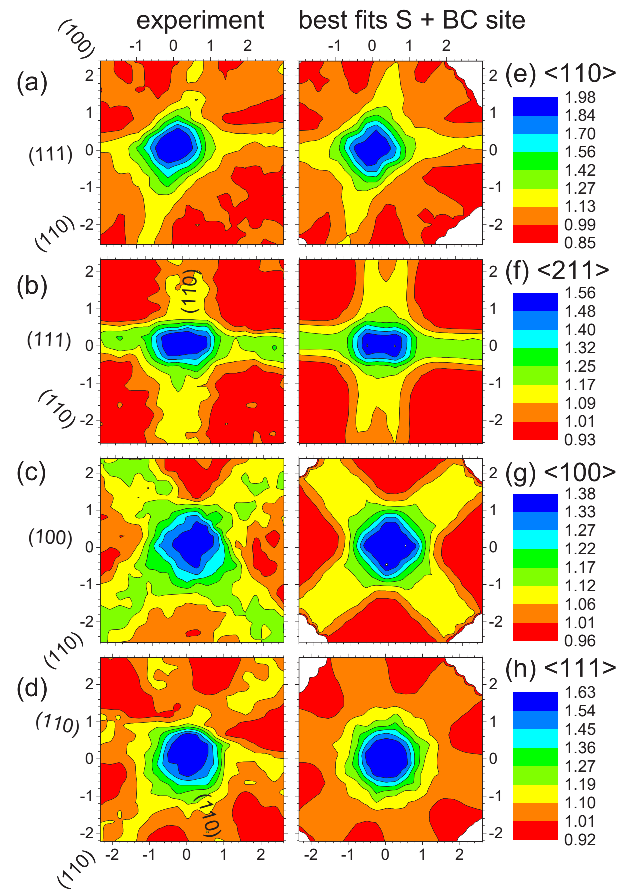


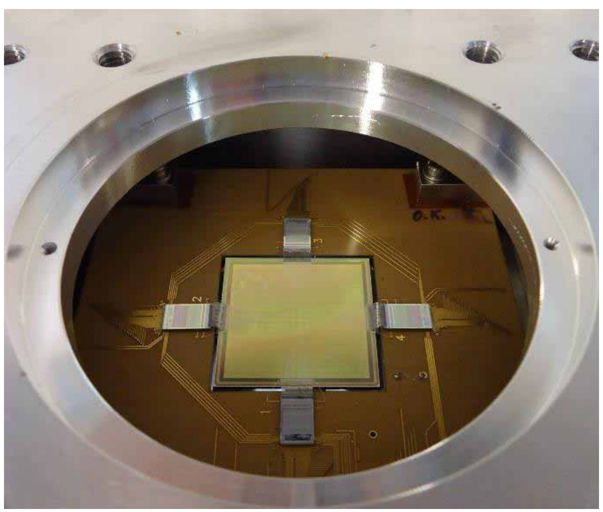
Depending on lattice site of probe atoms =>
emitted β⁻ particles are channeled or blocked on their way out of crystal

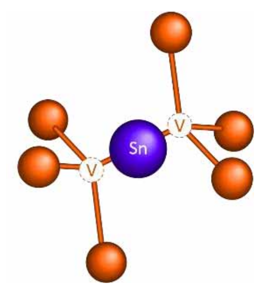
EC-SLI with Si pad detectors

- 3x3 cm^2, 22x22 pixel (1.3x1.3 mm^2) detectors developed at CERN (Peter Weilhammer *et al*) in 1990s as X-ray detectors for PET demonstrators
- Self-triggered readout (VATA-GP3 chips): count rate 3.5 kHz with negligible dead time, saturation at 5 kHz, for on-line measurements
- EC-SLI “Workhorse” detectors since 20 years: a successful spin-off case of CERN detector development

experiment simulation







^{121}Sn (27 h)
in diamond

Contact: U. Wahl, Lisbon

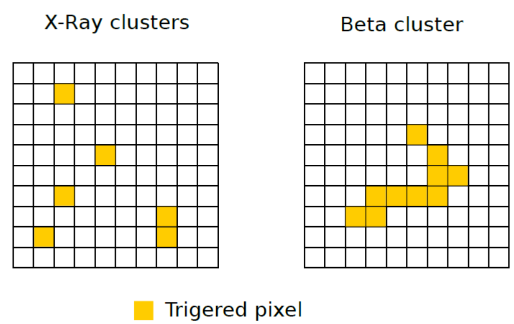
U. Wahl *et al.*, NIMA 524 (2004) 245

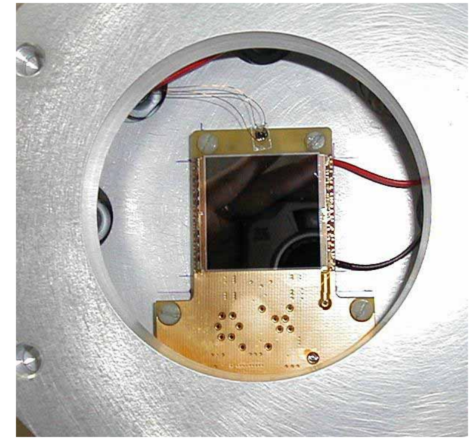
U. Wahl *et al.*, PRL 125 (2020) 045301

EC-SLI with Si Timepix quad detectors

- 3x3 cm2, 512x512 pixel (55´55 mm2) detectors developed by Medipix@CERN collaboration (Michael Campbell et al)
- Needs clustering algorithm

to identify β- tracks

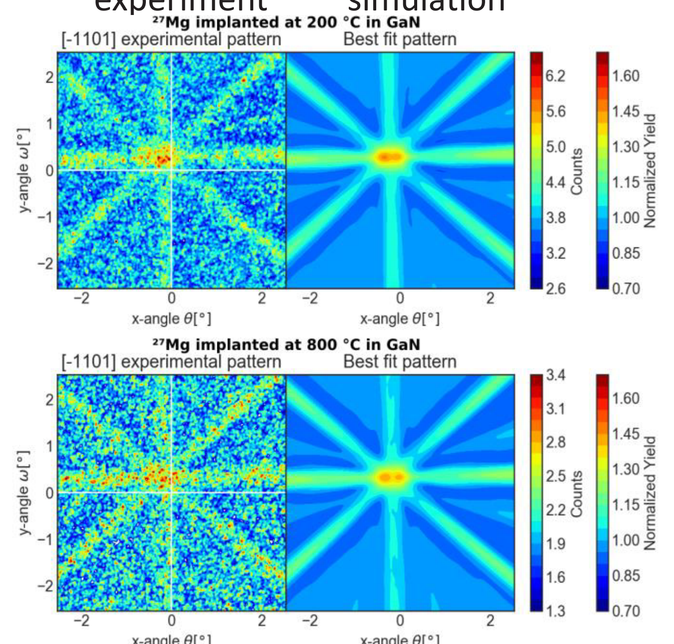




- Tests successful, but frame-based readout of Timepix 2 (e.g. 4 kHz count rate requires 10 frames/s => 50% dead time) proved too slow for EC-SLI routine applications
- Timepix 3 detectors (with faster, data-driven readout in the Mcounts/s range) envisaged to replace the aging pad detectors in the near future

^{27}Mg (9.5 min) *p*-type dopant in GaN (material used in white LEDs)

experiment simulation

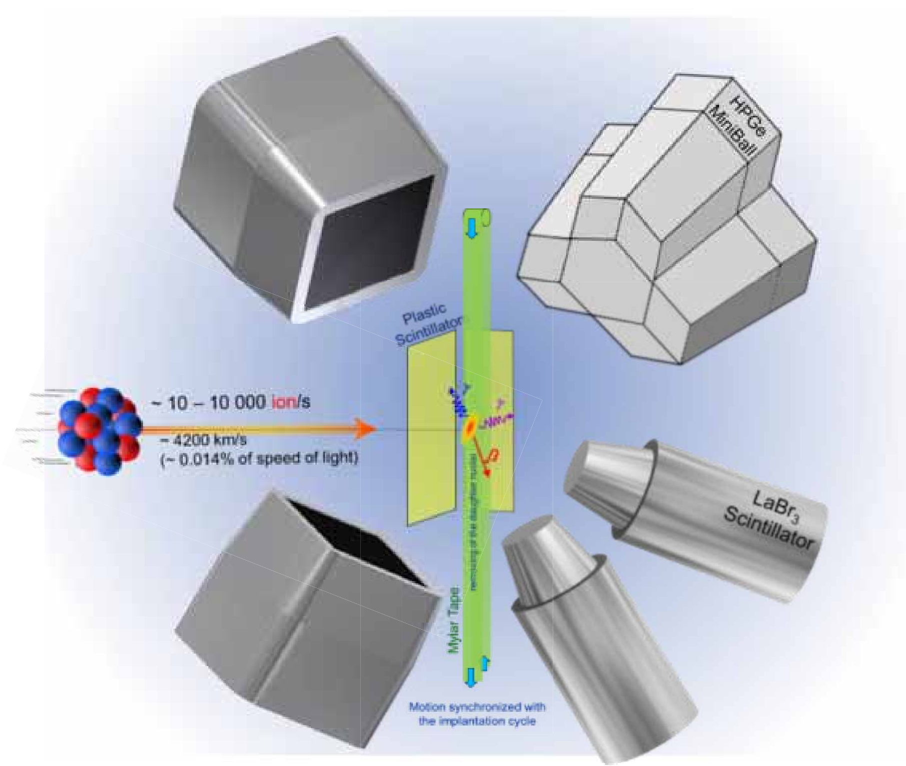


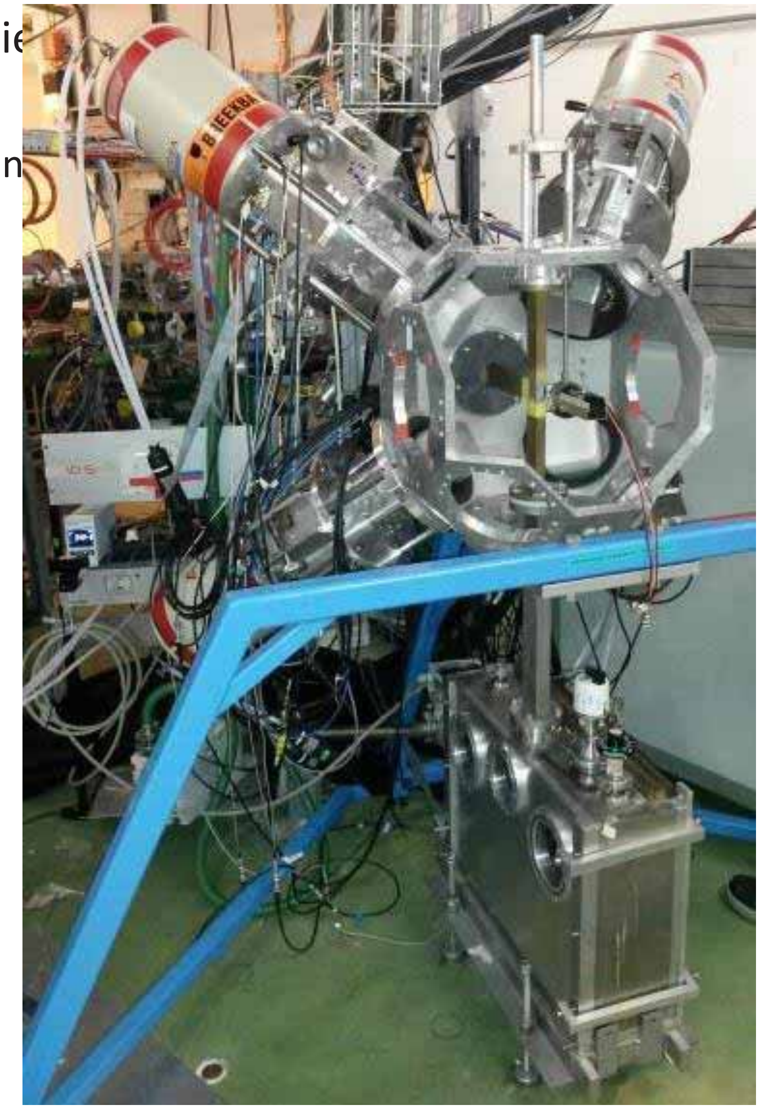
E. Bosne, Emission Channeling Lattice Location Studies in Semiconductors using Highly Pixellated Timepix Detectors, CERN Thesis 2020-239

IDS

ISOLDE Decay Station

- Flexible approach (for several decay types and studie
  - ➢ HPGe detectors (4 permanent Clovers + extra)
  - ➢ Ancillary detectors (LaBr3, plastic scintillator, silicon, n
  - ➢ Tape station
  - ➢ In-Source Laser Spectroscopy Studies

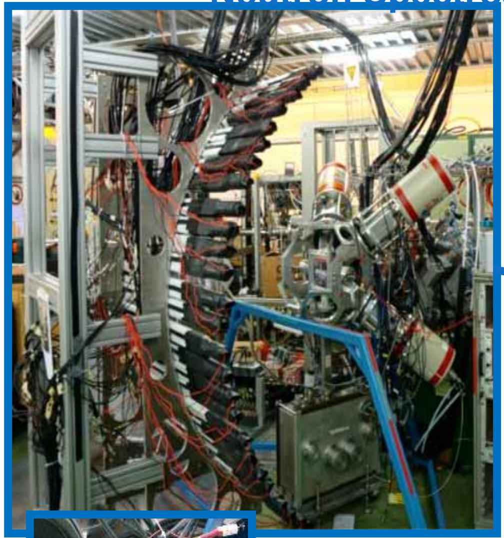


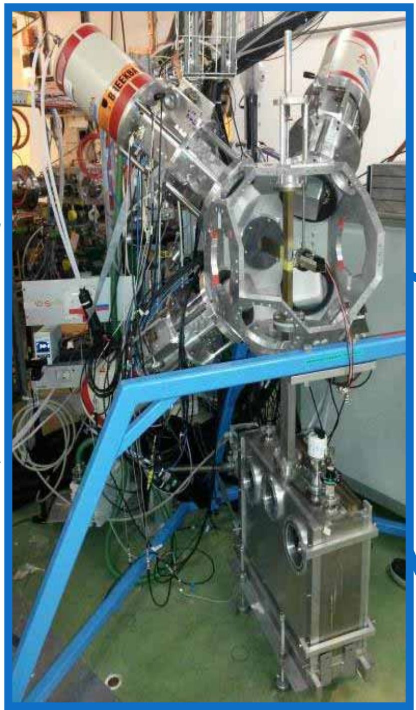


Contact: Razvan LICA, *IFIN-HH, Romania*

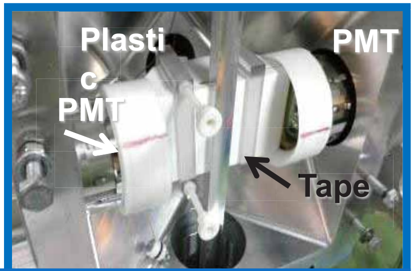
IDS

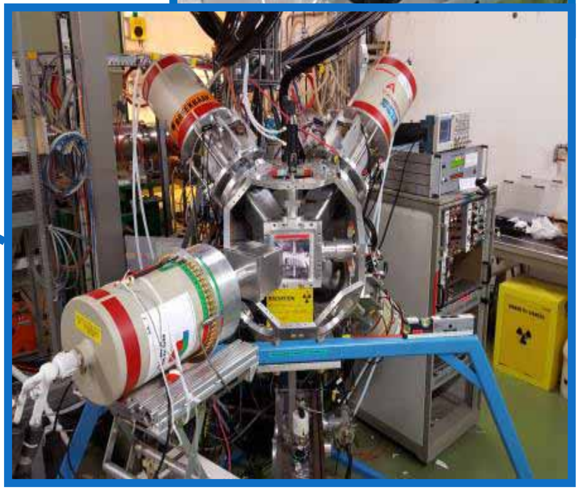
Neutron Spectroscopy

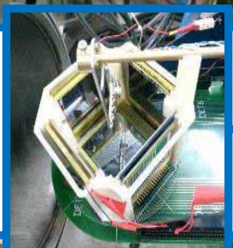




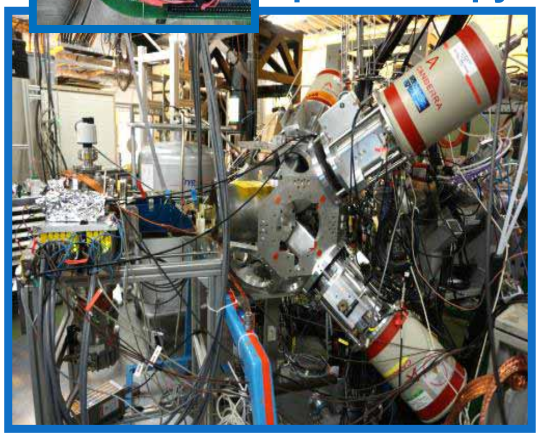
High beta-gamma efficiency



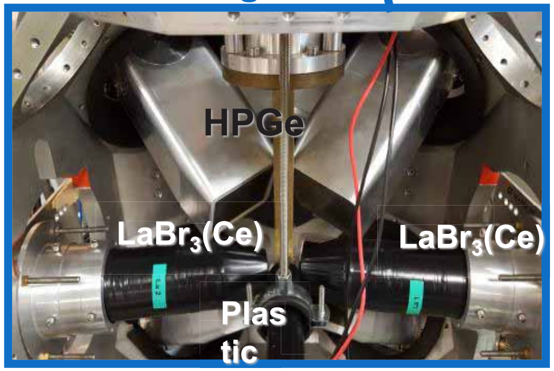




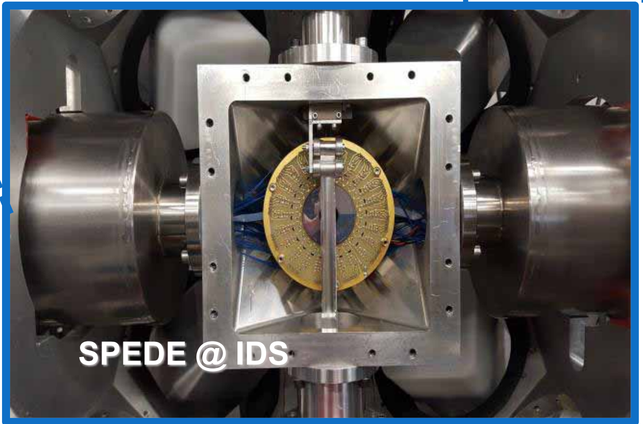
Particle Spectroscopy



Fast-timing studies

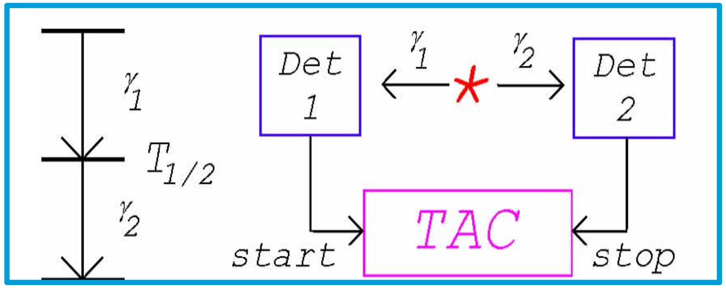


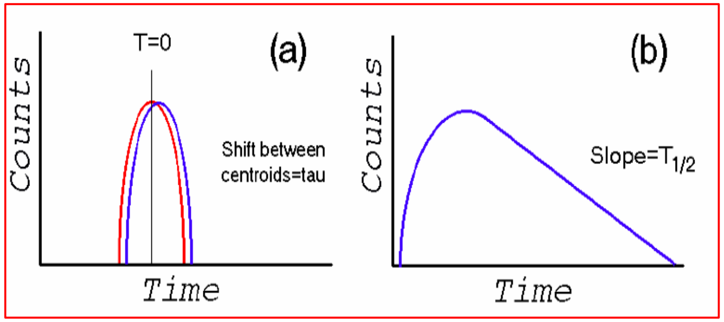
Conversion Electron Spectroscopy

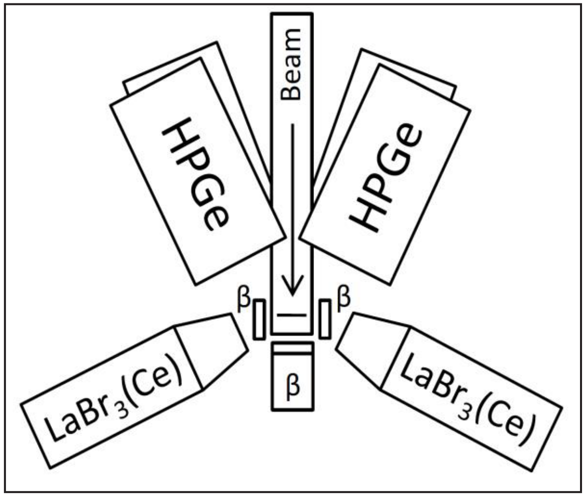


IDS + fast timing

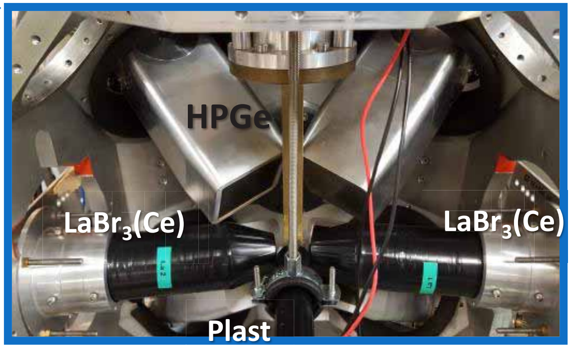
- Well established technique at IDS since 2014
- Detection system:
  - 4 Clover HPGe - 7% abs. eff. at 500keV
  - 2 $LaBr_3(Ce)$ - 3% abs. eff. at 500keV
  - 1 Plastic Scintillator - 20% abs. eff.







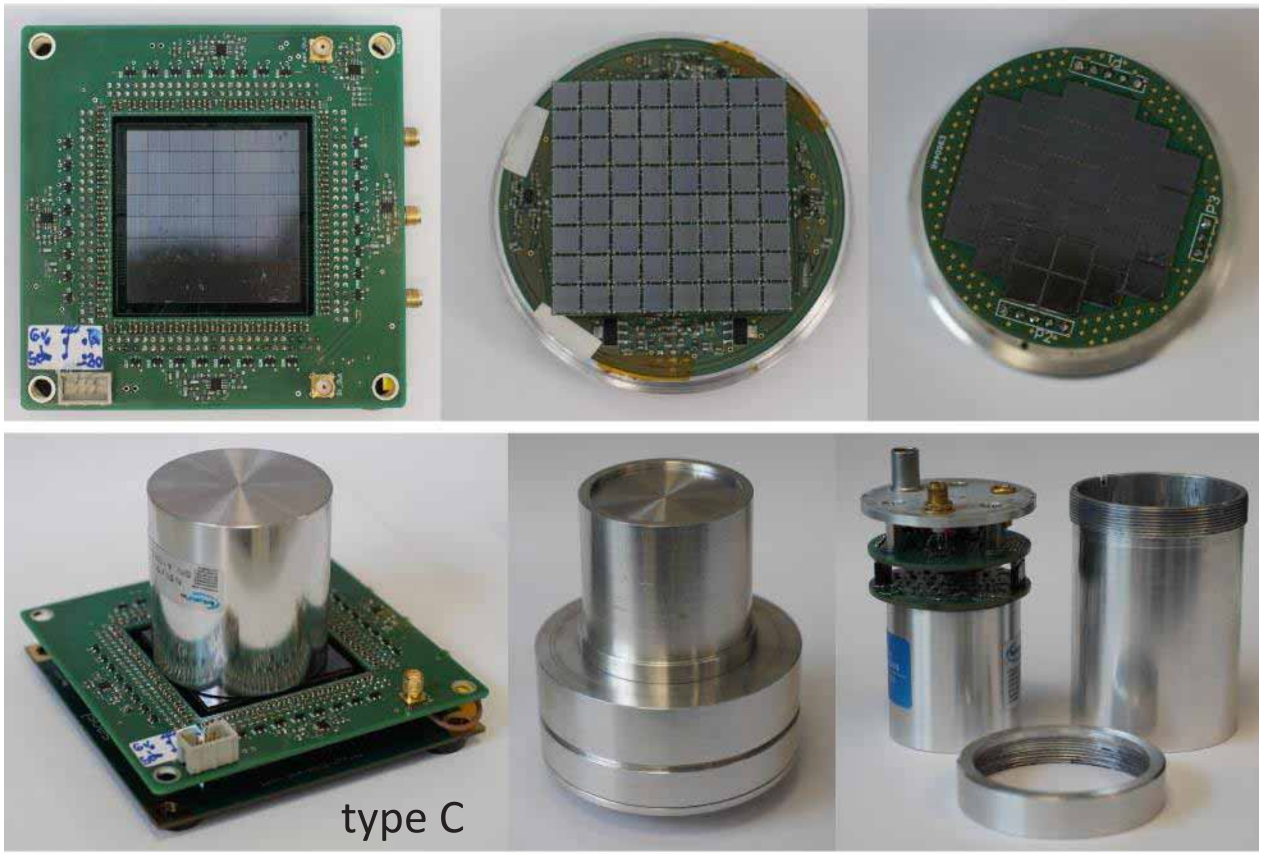
Ranges:
Centroid shift method: - **10 ps - 100 ps**
Slope method - **50 ps - 50 ns** (or longer)
[H. Mach et al. NIM A 280, 49 (1989)]



R. Lica et al., Phys. Rev. C 93, 044303 (2016).
R. Lica et al., J. Phys. G 44, 054002 (2017).
L.M. Fraile, J. Phys. G 44, 094004 (2017).
R. Lica et al., Phys. Rev. C 97, 024305 (2018).

IDS + fast timing

SiPMs developed in-house at IFIN-HH coupled to LaBr3(Ce)



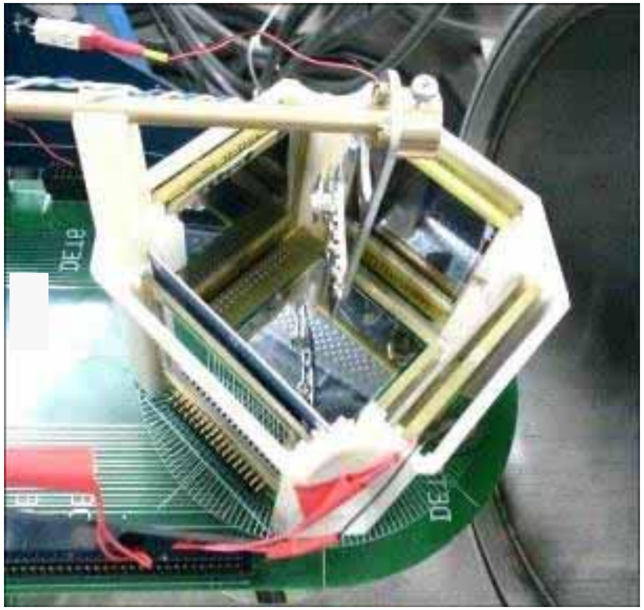
3” crystals with SiPM

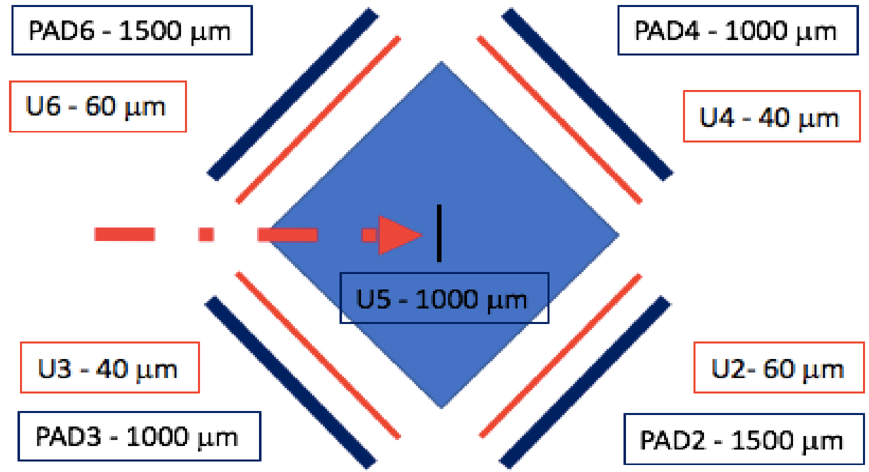
New plastic scintillators

Contact: R. Lica, IFIN-HH, Romania, L. Fraile, Madrid

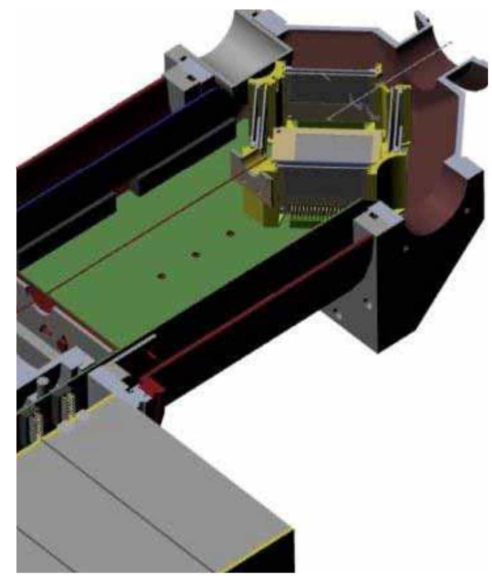
IDS particle detection

MAGISOL





- 4 HPGe Clover-shape detectors at forward angles
  + Si box: 5 Double-Sided Si Strip Detectors (DSSSD), 4 Pads
- **DAQ: ISOLDE MBS** and IDS Nutaq use in parallel (synchronized)
- Beam implanted on ^{12}C foil or tape



MAGISOL detectors, electronics and DAQ:

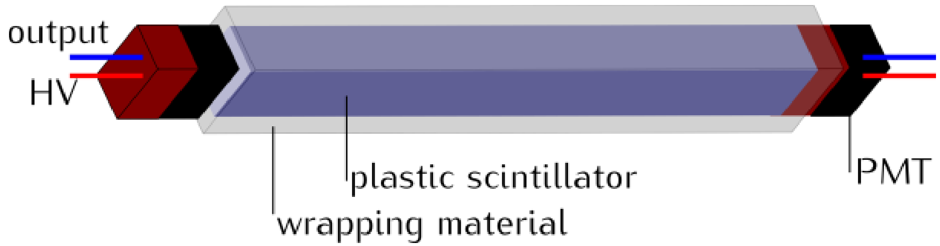
- 165 ch: **Mesytec** preamplifiers (2xMPR64, 2xMPR32)
- Mesytec STM16+ shapers

Contact: H. Fynbo, K. Riisager, U Copenhagen

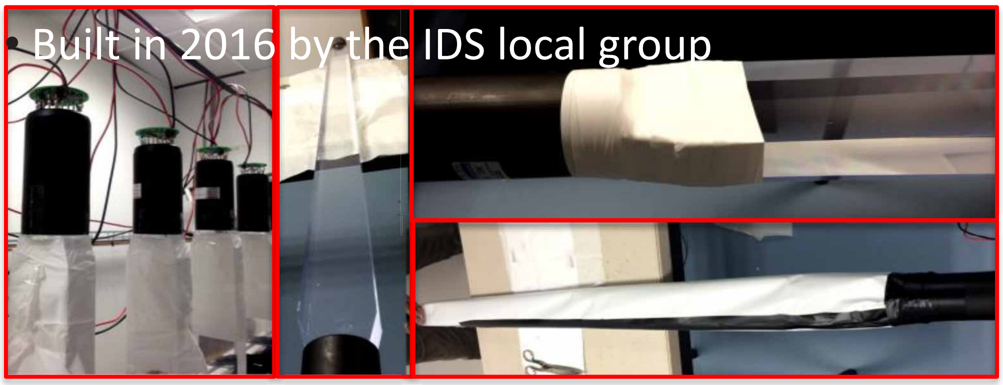
H. Fynbo, O. Tengblad, O. Kirsebom, J. Phys. G 44 (2017), 044005
O. Kisebom et al., Phys. Rev. Lett. 121, 142701 (2018)

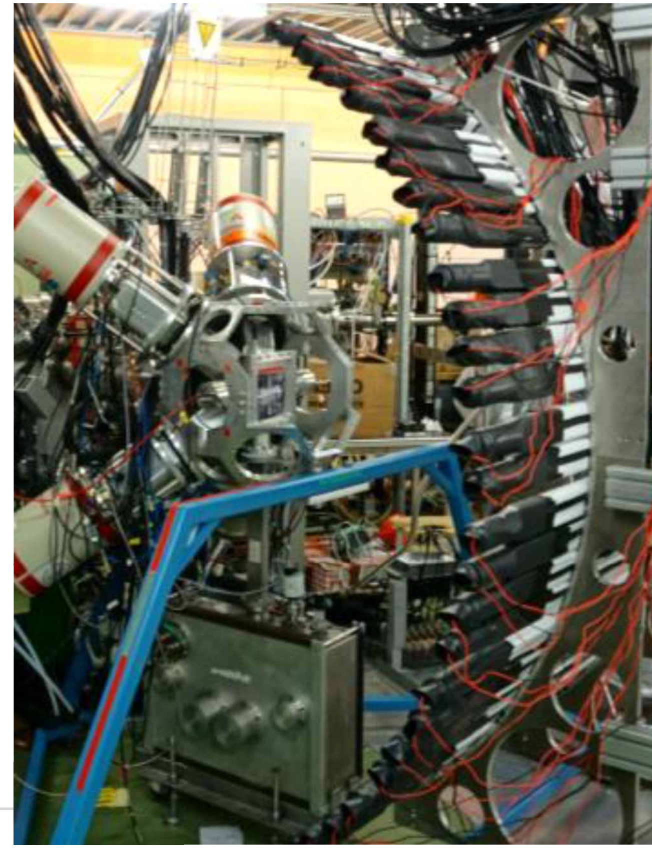
Neutron spectroscopy (INDiE)

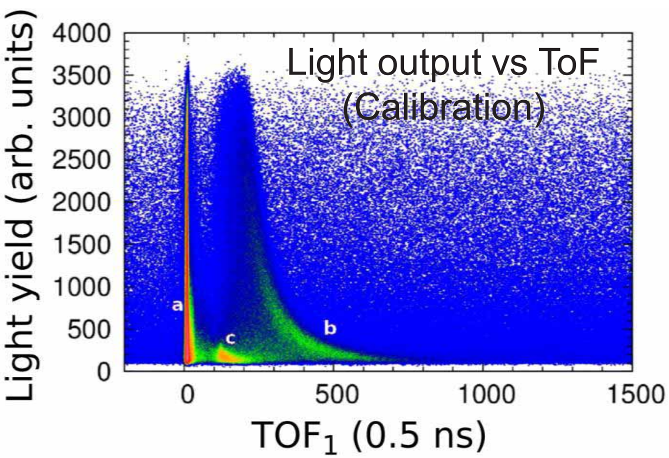
- TOF detector, inspired by VANDLE detector (UTK, USA)

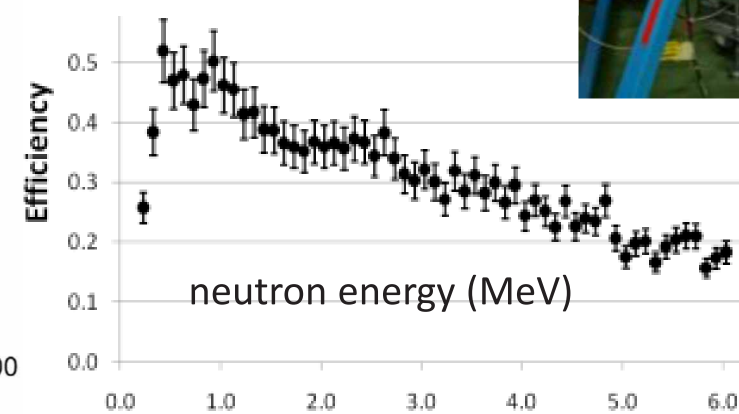


- Built in 2016 by the IDS local group









neutrons @ 1 MeV:
- 45% efficiency/bar
- 80 keV resolution
- Ω = 21.7% of 4π
- 90% β-trigger efficiency
  → 9 % total efficiency

Contact: M. Madurga, U Tennessee - Knoxville

IDS high beta-gamma efficiency

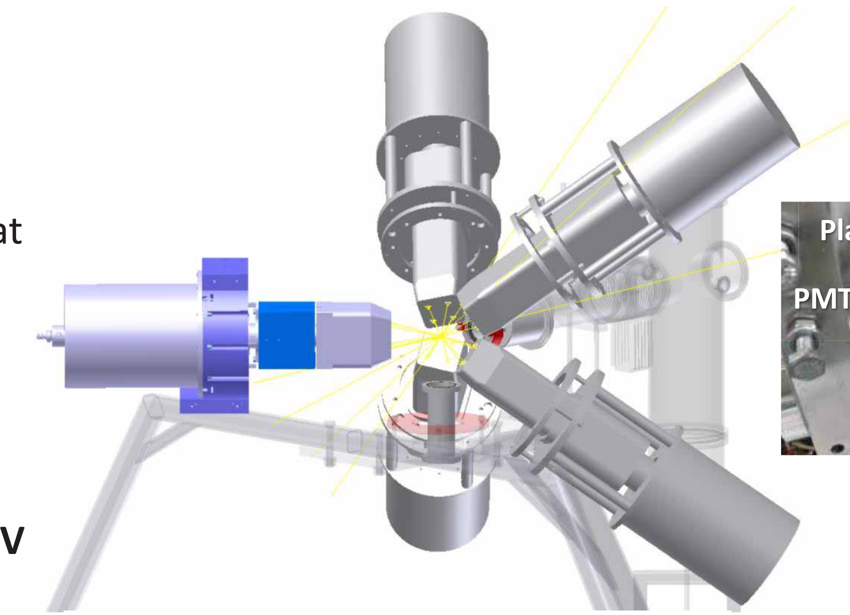
Detection setup

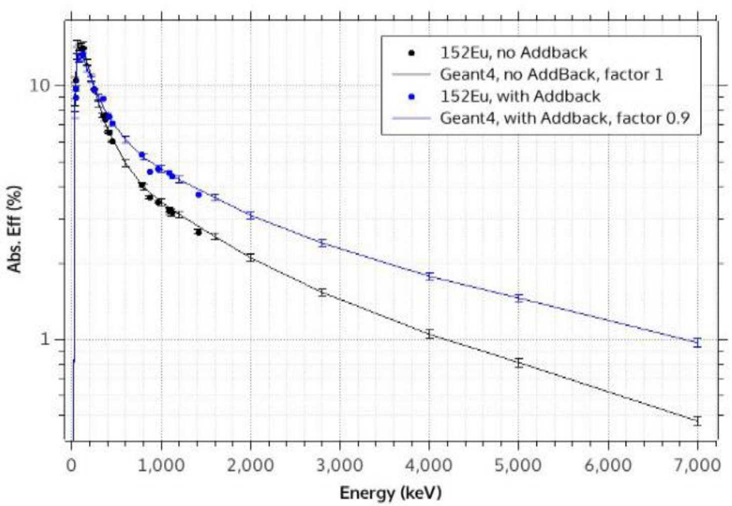
- 5 Clover-shape Ge detectors
- 4π plastic scintillator around implantation point
- 5th Clover detector can be placed at a specific angle to perform **angular correlation studies**.

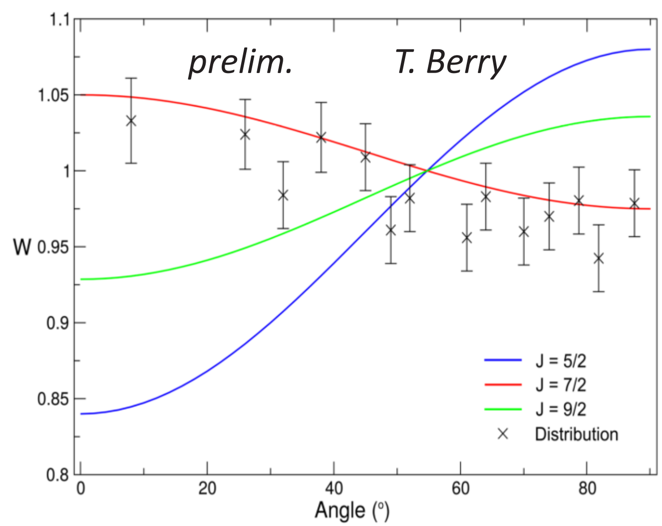
- **Absolute β efficiency - 90(5) %** (single/beta gated ratios)

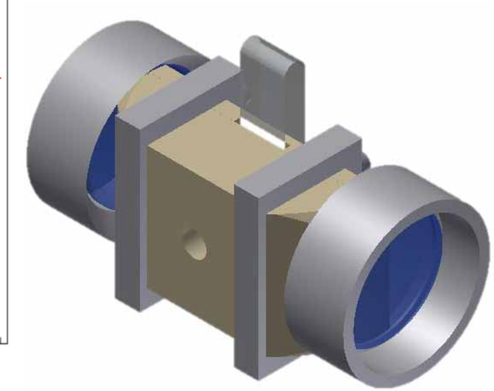
- **Absolute γ efficiency - 4% @1MeV**

Using GEANT4 to extrapolate





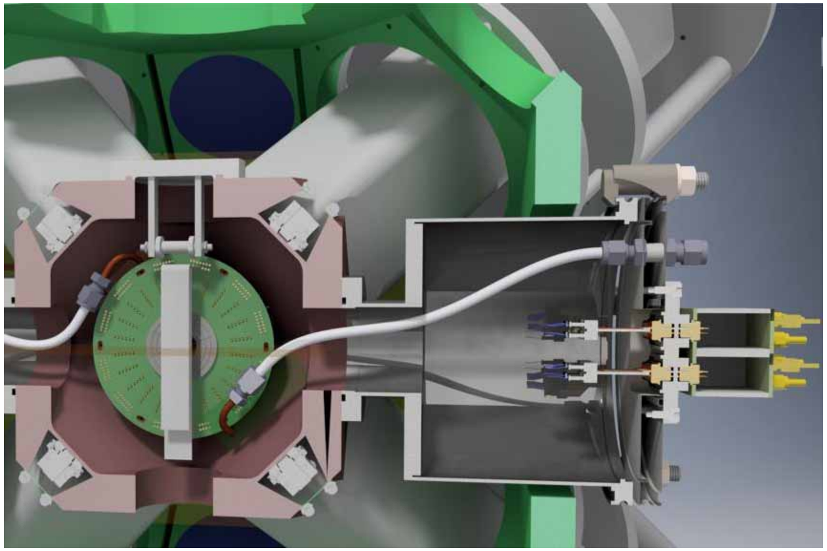


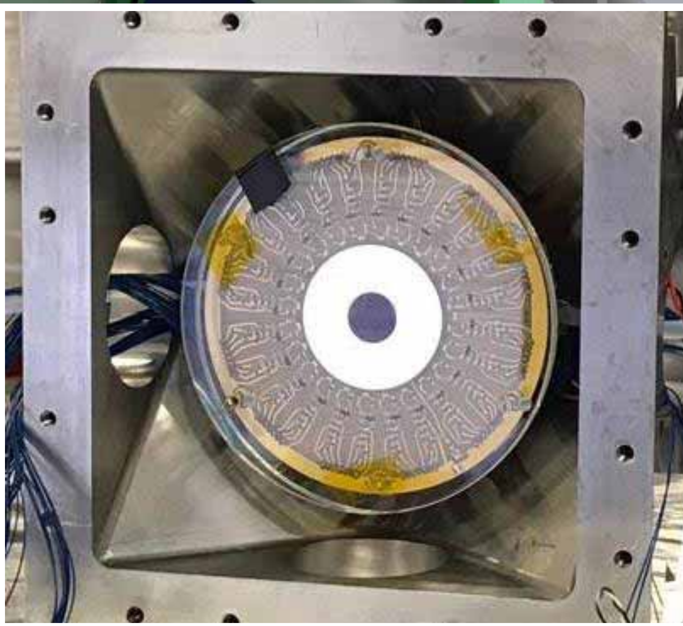


Contact: R. Lica

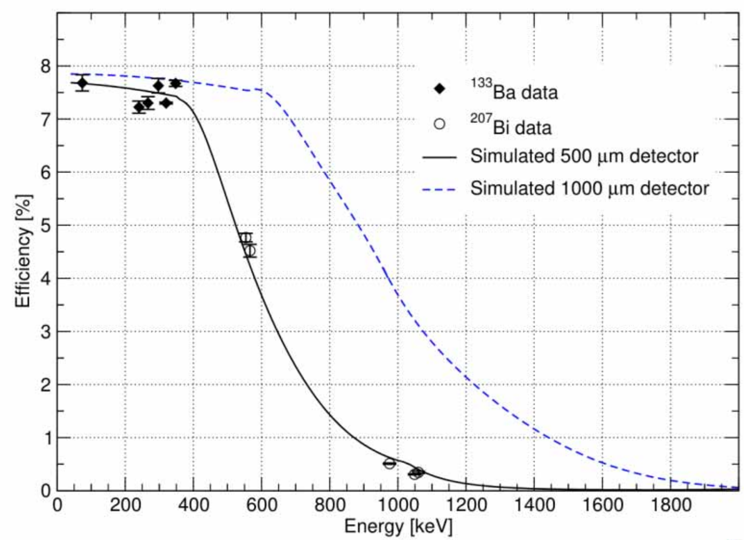
R. Lica et al., Phys. Rev. C 100, 034306 (2019)

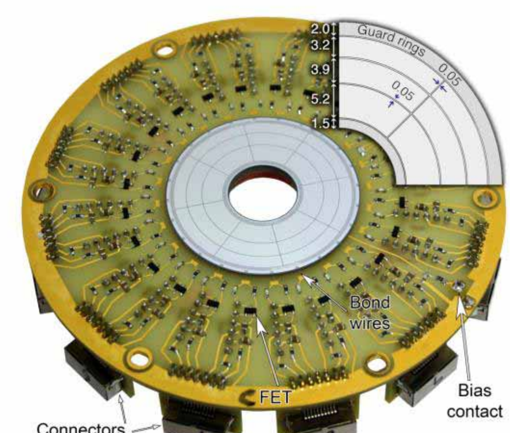
Conversion electron spectroscopy

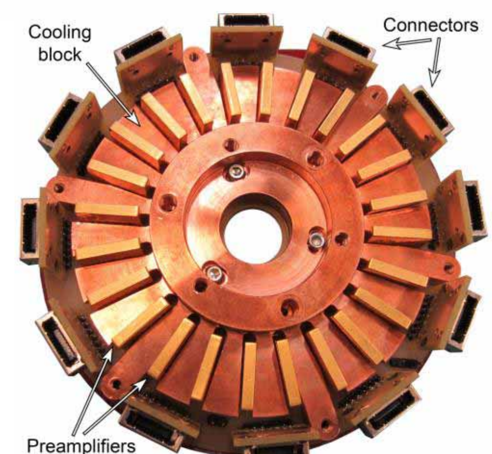




- Annular Si detector with 24 segments
- Ethanol cooled to -20°C
- FWHM at 320 keV around 6-8 keV energy







Contact: J. Pakarinen, Jyvaskyla

P. Papadakis et al., Eur. Phys. J. A. 54:42, 2018

IDS DAQ

Digital DAQ able to run all the different configurations

IDS Configuration	Detectors	Total Channels	OLD DAQ
Particle spectroscopy	4 Clovers + 5 DSSSDs (5 x 32 ch) + 4 PAD (4 x 2 ch) + Logic (6 ch)	**190**	NUTAQ + MBS
Neutron Spectr. (INDiE)	4 Clovers + 26 bars (26 x 2 ch, **traces**) + Beta (2 ch, **traces**) + Logic	**76**	PIXIE
Conversion Electron Spectroscopy	5 Clovers + SPEDE (24 ch) + Beta (1 ch) + Logic	**51**	NUTAQ
High beta-gamma efficiency	5-6 Clovers + Beta (2 ch) + Logic	**32**	NUTAQ
Fast-timing	4 Clovers (4 x 4 ch) + 2 LaBr + Beta (1 ch) + 3 TAC + Logic	**28**	NUTAQ

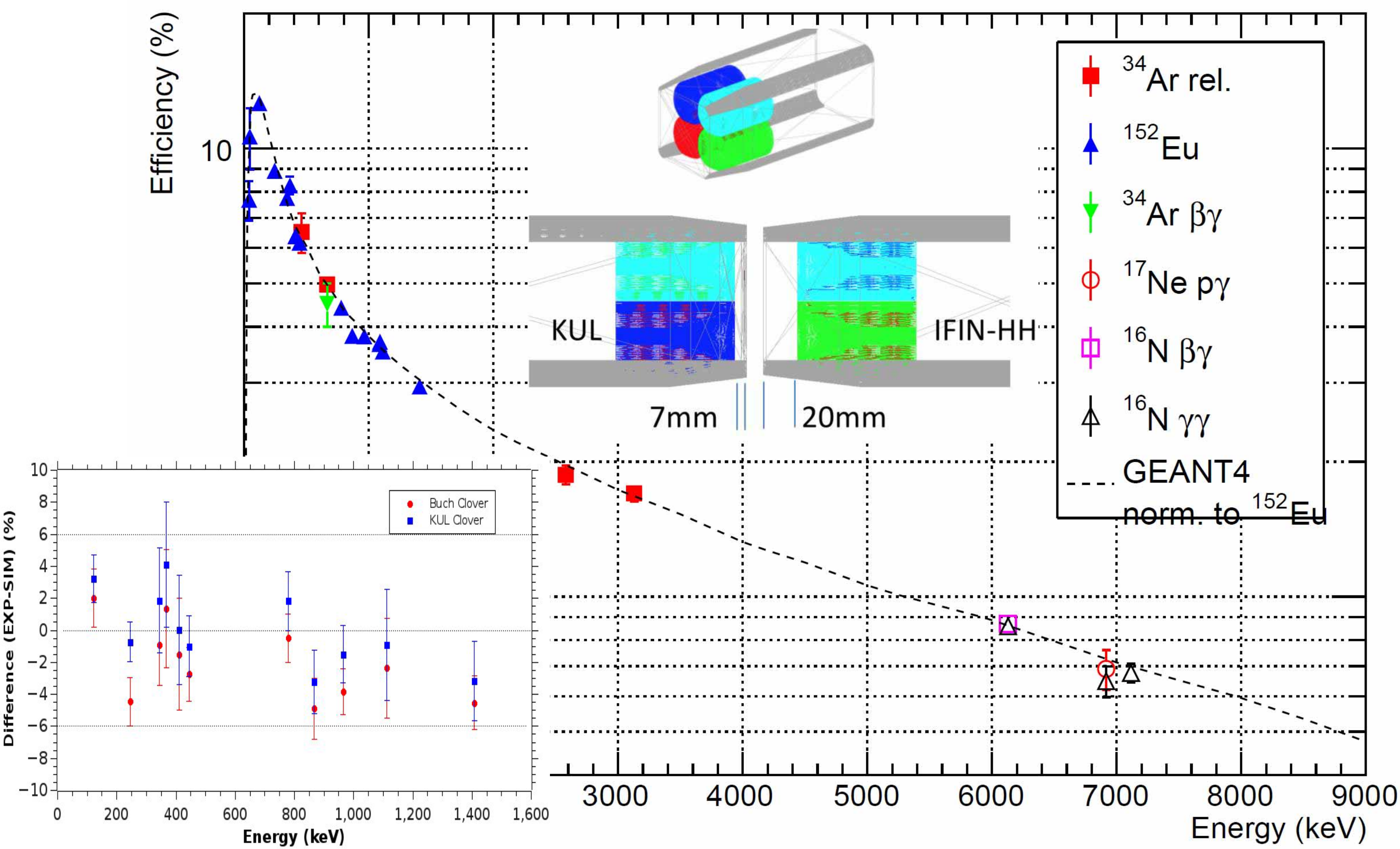
NUTAQ: 100 MHz, 14 bit ADC, **max. 80 ch (5 x 16)**

PIXIE: 250 MHz, 16 bit ADC, **max. 208 ch (13 x 16 / crate) ->** tested and installed in 2020

FEBEX: 100 MHz, 14 bit ADC, 16 ch / module. (v4)

High-purity germanium gamma detectors

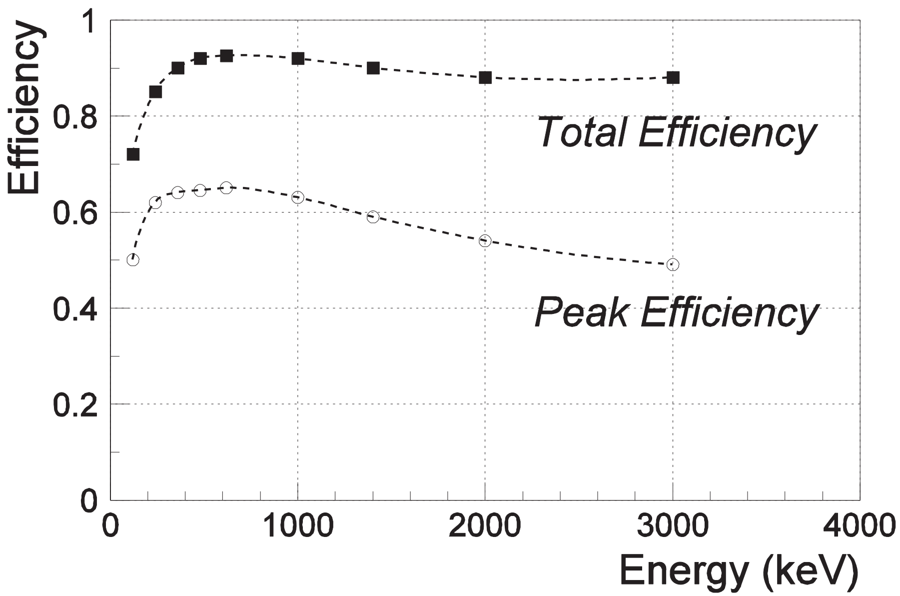
- IDS: GEANT4 simulations

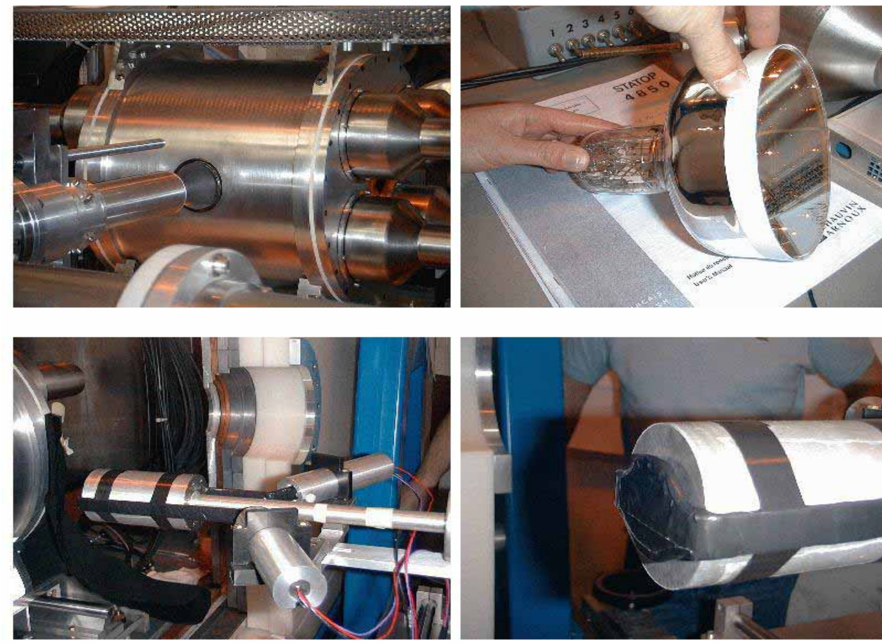


Absolute γ-ray peak detection efficiency (with addback)

LUCRECIA

- Permanent TAS setup at “Lucrecia”





- Main crystal: NaI(Tl) cilinder of big dimensions (∅38 cm x 38 cm);

- Ancillary detectors:
  - plastic scintillator
  - Ge telescope (planar/coaxial)

Summary and oulook

- Number and versatility of ISOLDE detectors matches that of the unstable nuclei it produces

- This talk: examples of detectors for gamma-rays, charged particles, neutrons

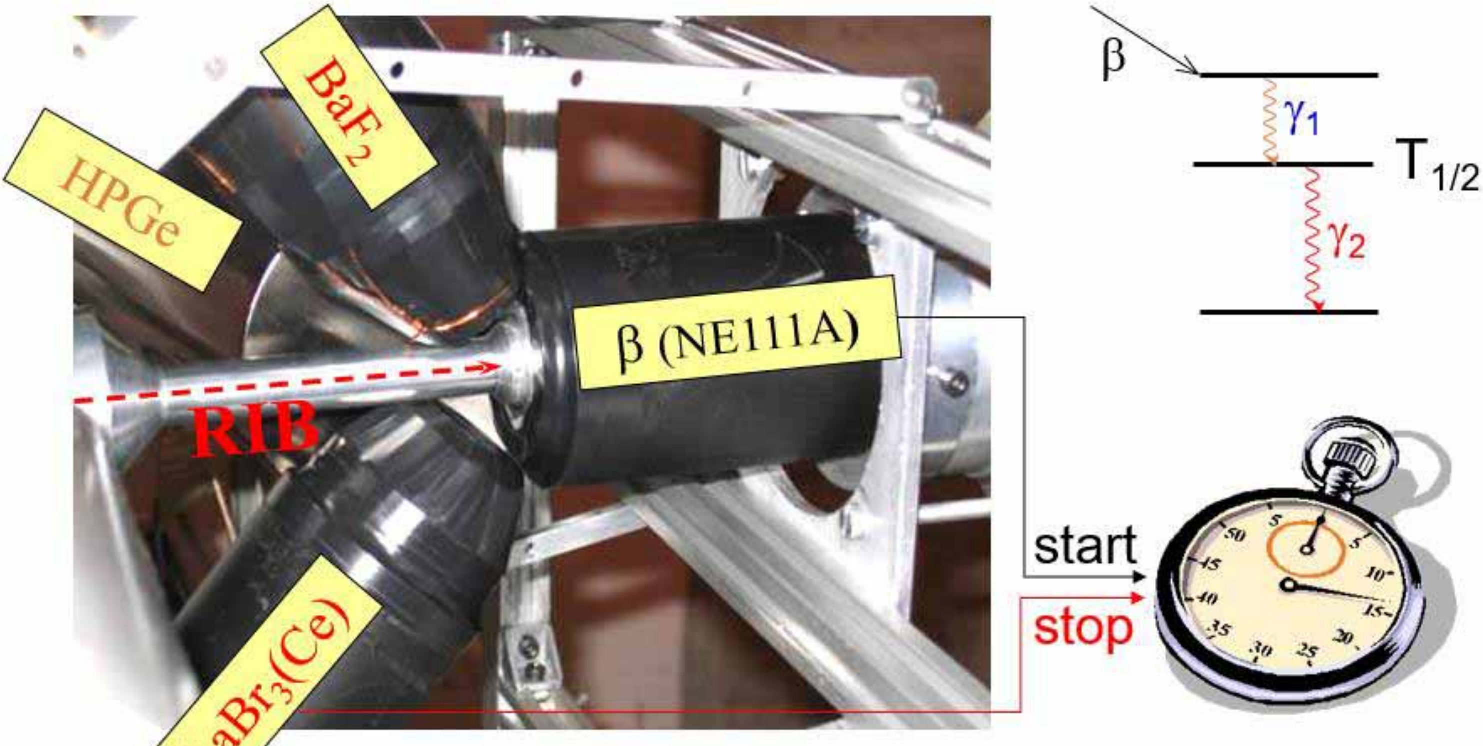
- Not covered in this talk: ion and atom detectors

- Aim: give an overview of ISOLDE detectors and trigger discussions, collaborations with the respective groups

Fast timing

Contact: L. Fraile, UCM, Madrid

The Advanced Time-Delayed ßγγ(t) method



Time difference

[H. Mach et al., NPA 523 (1991) 197]

HPGe: BRANCH SELECTION
High energy resolution
Poor time response

Plastic β scintillator: TIMING
Fast response
Efficient start detector

$LaBr_3(Ce)/BaF_2$: TIMING
Fast response γ-detectors
Stop detectors

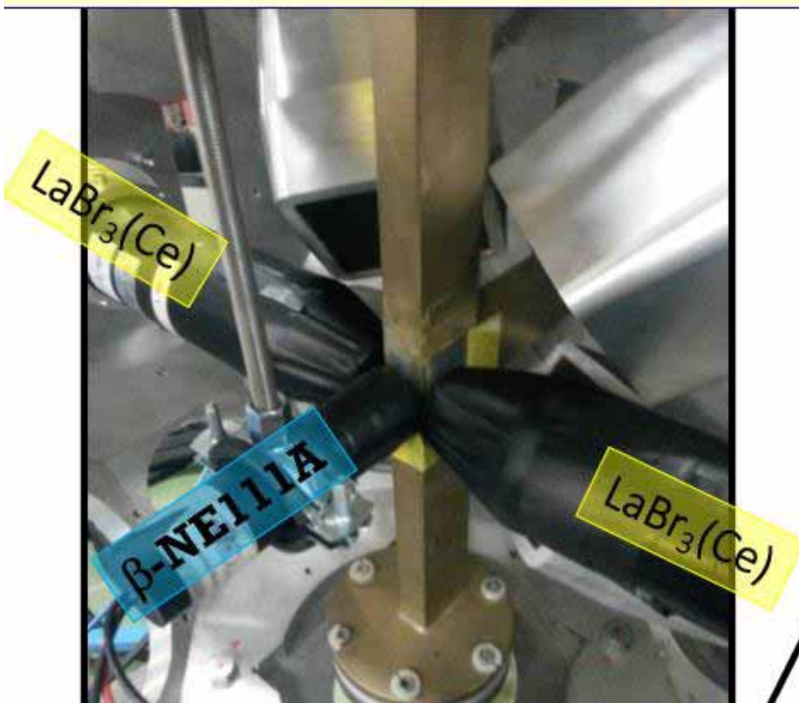
→ **Double coincidences: βγ: beta-Ge and beta-$LaBr_3$**

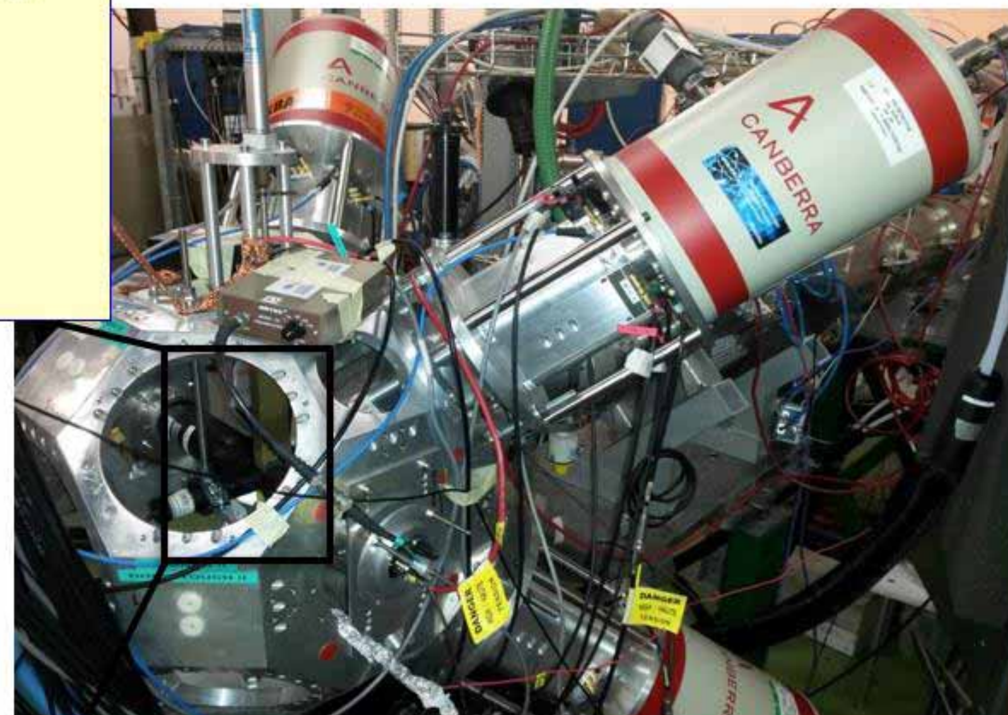
→ **Triple coincidences βγγ: beta-Ge-Ge and beta-Ge-$LaBr_3$**

ISOLDE Decay Station

Fast-timing, GFN-UCM

- 4 Clover HPGe ~ 3.7% **eff**. @600keV
- 2 $LaBr_3$(Ce) ~ 4% (2% each) @600keV (or up to 6 detectors)
- 1 Plastic Scintillator ~ 20% eff.
- DAQ – Digital system
- Analog TACs

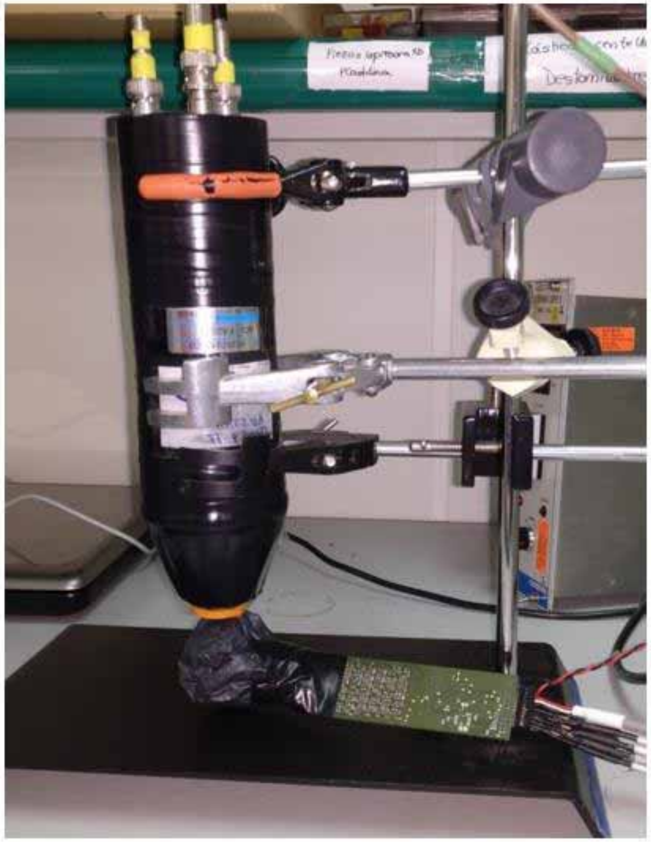




- Analog timing processing: ORTEC CFD and 3 TAC for fast-timing
- Digital DAQ **Nutaq / XIA Pixie**

- Movable tape system to remove activity

Detectors



$LaBr_3(Ce)$

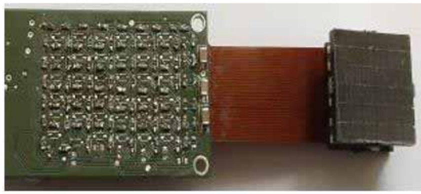
Tipo	Estructura	Cantidad
Alcalinos	$LaBr_3(Ce)$	1
	NaI(Tl)	3
	CsI(Tl)	2
	KI(Tl)	1
No Alcalinos	BaF_2	1
	GSO	1
	LYSO	1
	BGO	1
	LFS	2
	MLS	64

CLYC Pr:LuAG SrI_2

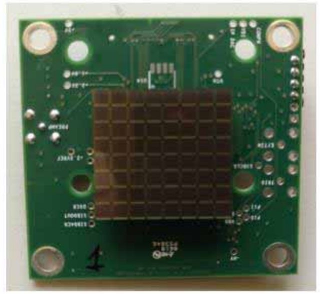
Instituto de Física de Partículas y del Cosmos

Si PMs and boards

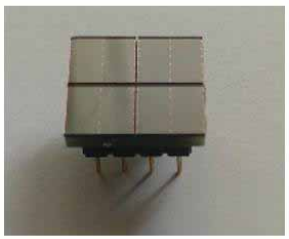
Grupo de Física Nuclear



Array 6x6 MicroFJ-30035 (SensL)

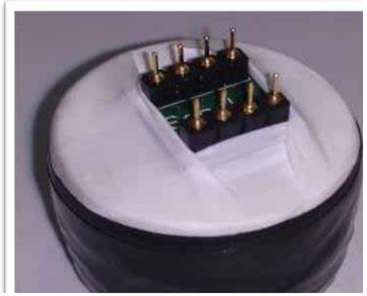


Array 8x8
PA3325-WB
(Ketek)

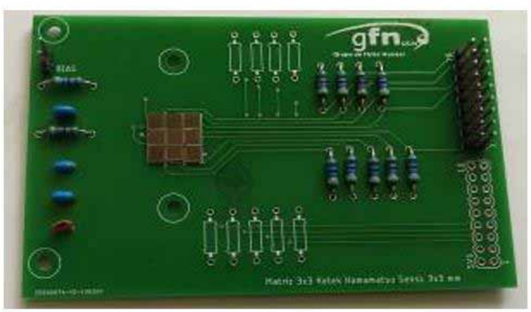


Array 2x2 MicroFJ-60035 (SensL)

Lanthanum bromide 2x2 cm + Array 2x2 SiPM 3x3 mm



Grupo de Física Nuclear



Array 3x3 PM3325-WB (Ketek)
Array 3x3 MicroFJ-30035 (SensL)

Cross Array 2x2 MicroFJ-60035 (SensL)

LaBr3

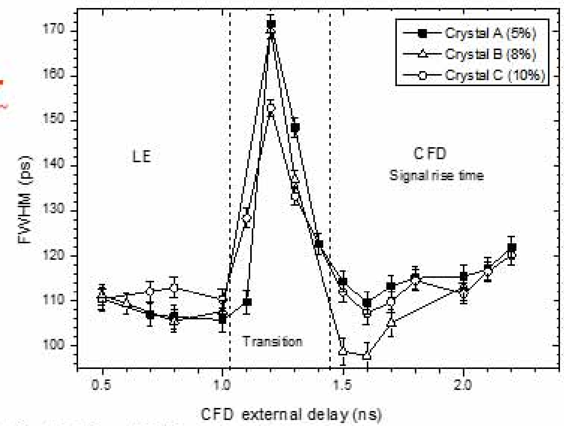
1-inch cylindrical $LaBr_3$(Ce) crystal

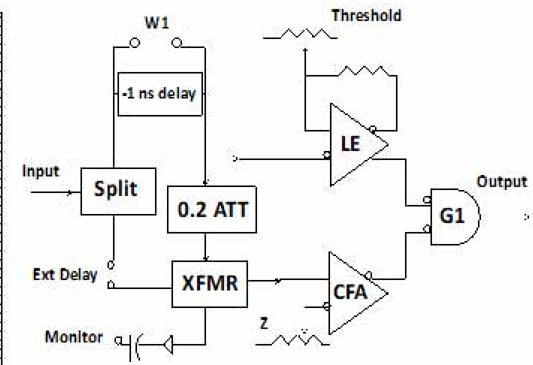
✓ Optimization procedure: PARAMETERS

→ HV applied to PMT

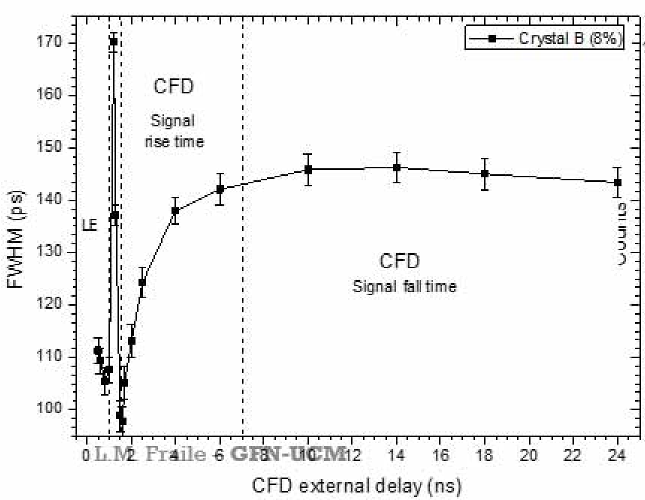
→"External CFD delay

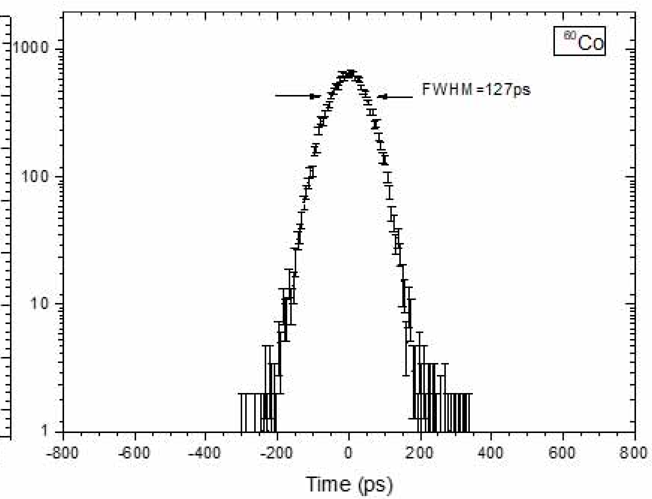
→ Zero crossing





V. Vedia et al.,
Nucl. Instrum. Methods A 795 (2015) 144–150





$LaBr_3$(Ce) detector FWHM time resolution:

148(2) ps ^{22}Na 511 keV
98(2) ps ^{60}Co source.

LaBr3


Nuclear Instruments and Methods in Physics Research A 867 (2017) 98–102

Contents lists available at ScienceDirect

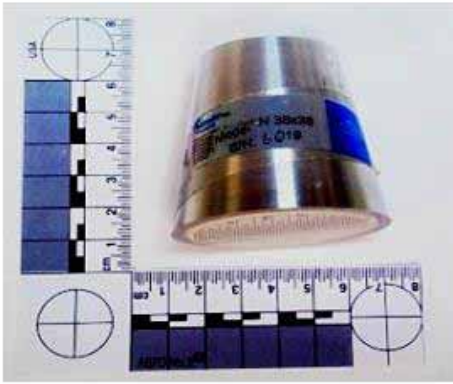
Nuclear Instruments and Methods in Physics Research A

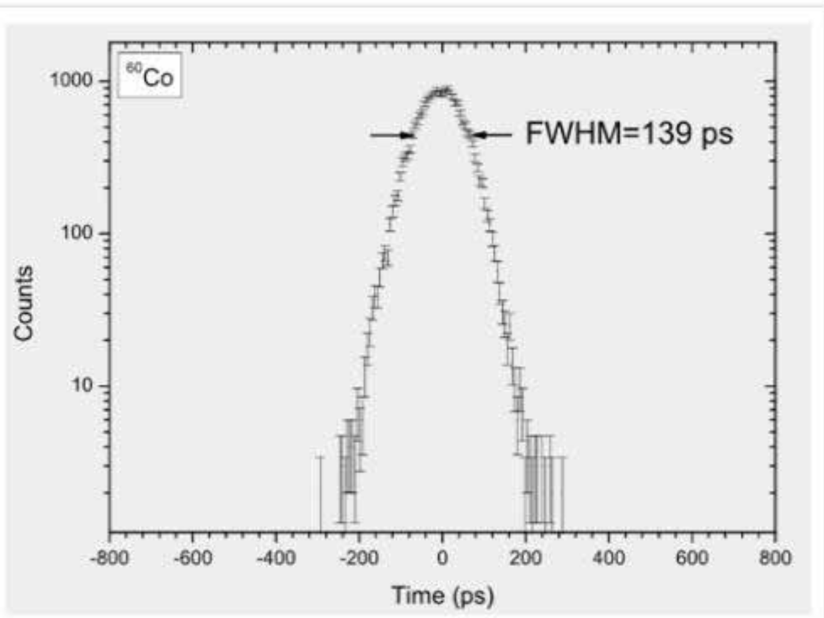
journal homepage: www.elsevier.com/locate/nima

Performance evaluation of novel $LaBr_3(Ce)$ scintillator geometries for fast-timing applications

V. Vedia[a,*], M. Carmona-Gallardo[a], L.M. Fraile[a], H. Mach[a,b,1], J.M. Udías[a]

[a] Grupo de Física Nuclear, Facultad de CC. Físicas, Universidad Complutense, CEI Moncloa, 28040 Madrid, Spain
[b] National Centre for Nuclear Research, Division for Nuclear Physics, BP1, Warsaw, Poland





- Design of scintillator shapes and geometries for fast timing applications
- Optimization of parameters of readout using fast PMTs and analog electronics
- Best time resolution to-date obatined

> FWHM time resolution:
> 110 ± 3 ps @ ^{60}Co
> 158 ± 3 ps @ ^{22}Na 511 keV

- Fully-digital readout for time and energy
- Coupling to SiPM and readout

CeBr3

Alternative:

Price

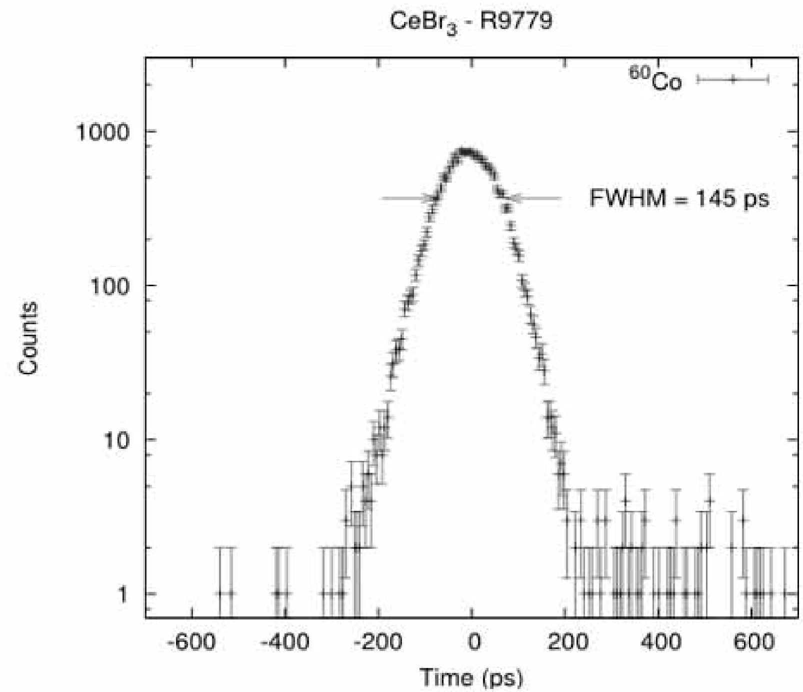
E resolution

Timing

Geometries…

FWHM

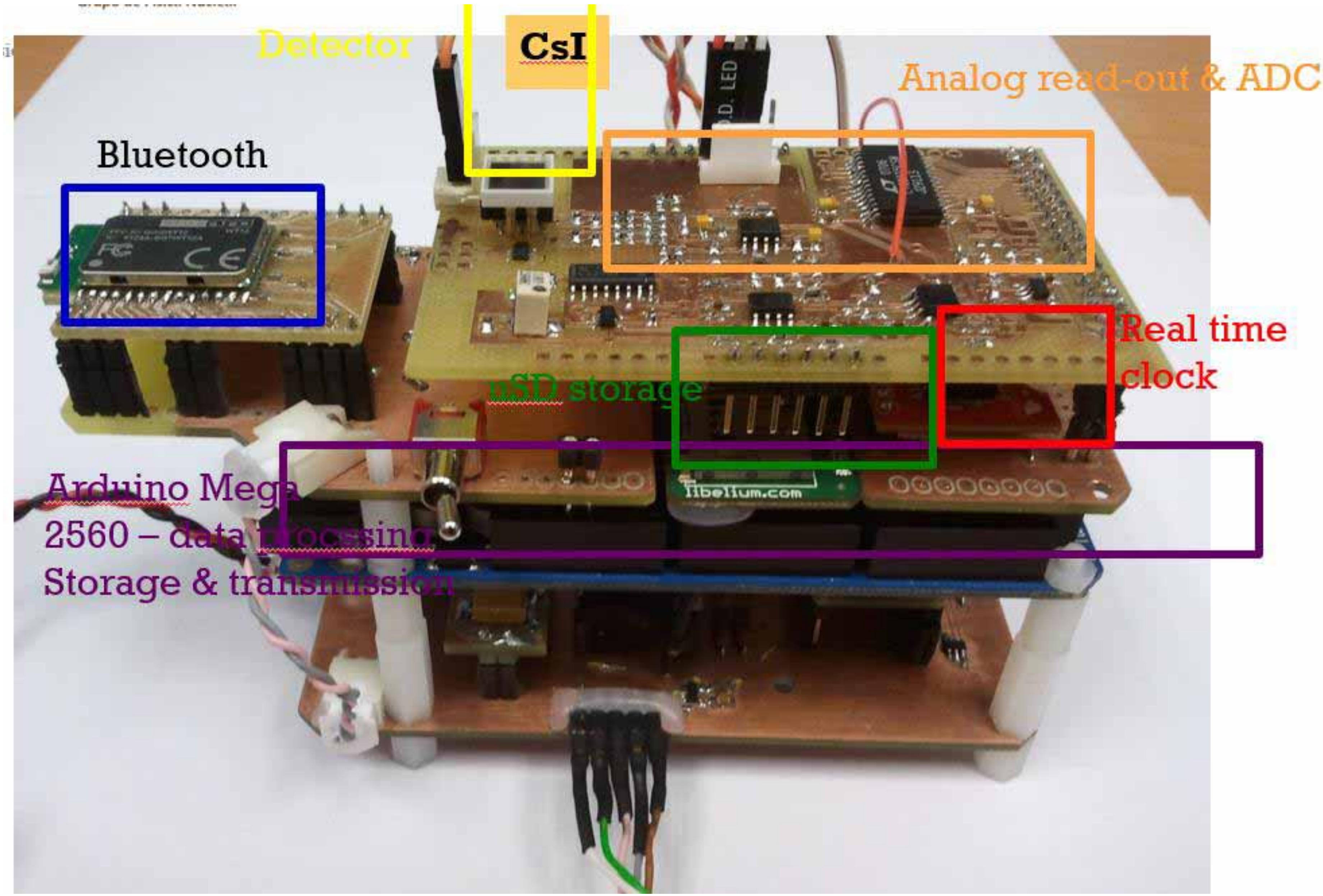
119 ± 2 ps at ^{60}Co



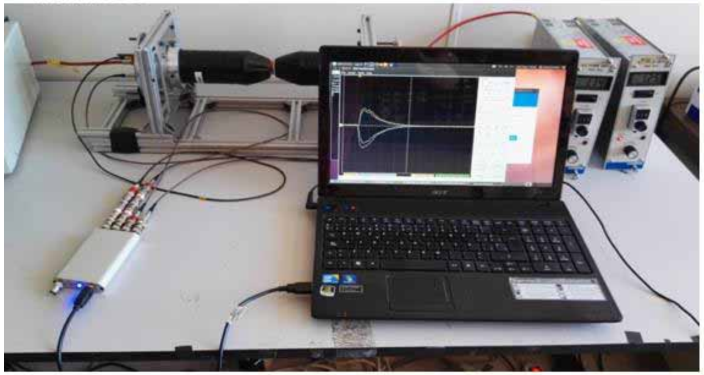
NIM A701 (2013) 235

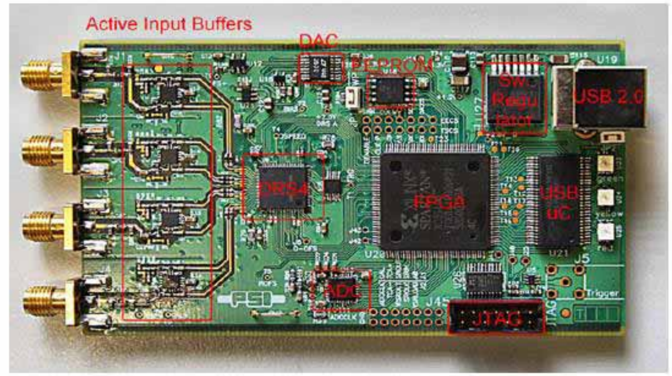
Time resolution FWHM (ps) per detector					
PMT	^{60}Co	^{22}Na	Delay (ns)	HV (V)	Z (mV)
XP20D0	145 ±2	210 ± 2	6.0	1200	-2.2
R9779	119 ±2	164 ±2	1.5	1330	2.0

Integrated system



DAQs





- 4 channels, 1024 samples per channel in a pulse
- 1 to 5 GS/s
- 12 bit
- USB power
- 500 pulses / s in the PC, full 4 channels, 12 bits at 5 GS/s

DRS4 @ PSI
http://drs.web.psi.ch
S. Ritt

- Series 2000
- 1 GS (Maximum) Sampling speed
- 50 MHz bandwidth
- Vertical resolution 8 bits

VME-based data acquisition
XIA digital data acquistion system + …

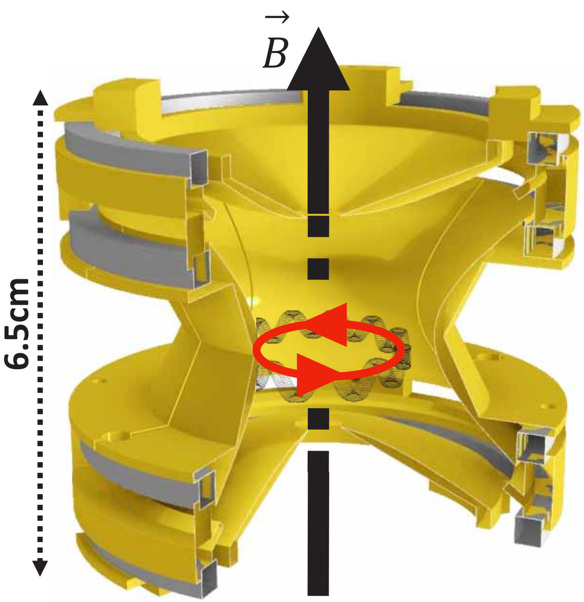
- Continuous digitizing capabilities not really required
- Simple: the same board can acquire and digitize data for energy and time coincidences. Preserve pulse properties
- Flexibe. Any kind of processing and filter is possible, median filter, recursive filters, FFT and frequency based filters.
- Stable and noiseless

Mass spectrometry with ISOLTRAP

Contact: M. Mougeout, K. Blaum, D. Lunney, L. Schweikhard

Penning-trap mass spectrometry at ISOLTRAP

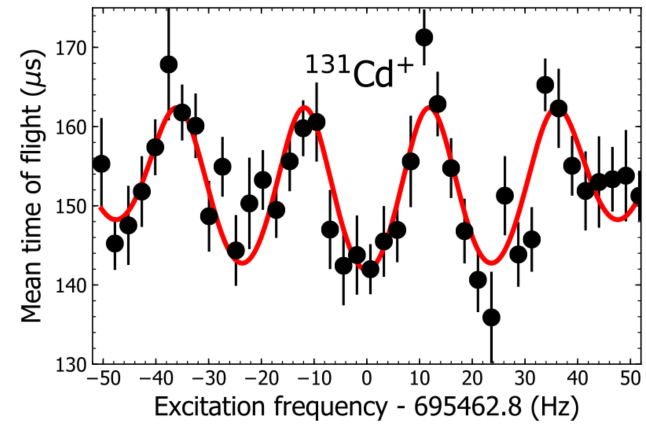
- The Penning trap :



High precision determination of :

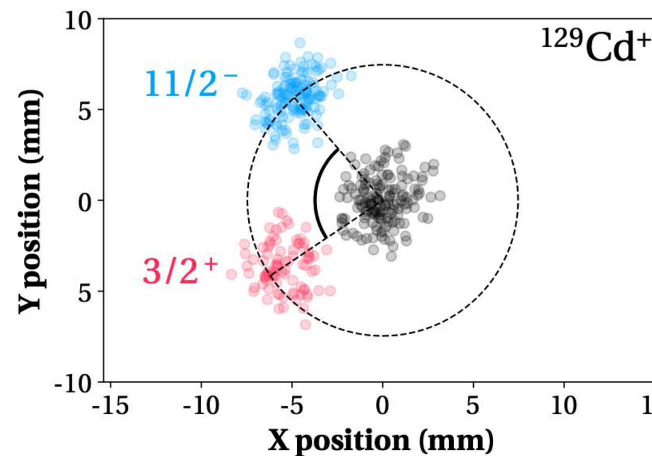
$$\nu_c = \frac{qB}{2\pi m_{ion}}$$

- ToF-ICR:
  - Scanning
  - t_{meas} ~ 50 - 2000 ms
  - $\delta m/m$ ~ 10^{-7} - 10^{-9}
  - $m/\Delta m$ ~ 10^{4} - 10^{6}



- PI-ICR :
  - **Non**-scanning
  - t_{meas} ~ 50 - 2000 ms
  - $\delta m/m$ ~ 10^{-7} - < 10^{-9}
  - $m/\Delta m$ ~ 10^{6} - > 10^{7}

$$\nu = \frac{\phi + 2\pi n}{2\pi t_{meas}}$$

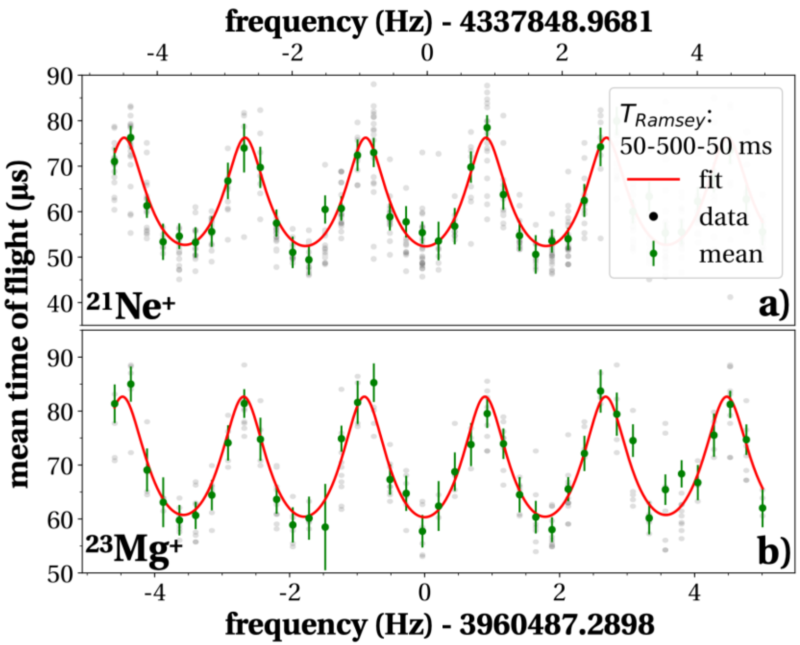


V. Manea, J. Karthein *et al.*, Phys. Rev. Lett. 124, 092502 (2020)

High-precision Q_{EC}-values of mirror nuclei

- ^{21}Na —> ^{21}Ne and ^{23}Mg —> ^{23}Na:

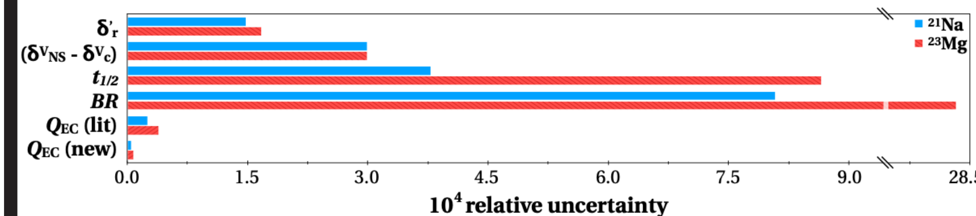
$$Q_{EC} = (M_p - M_d)c^2$$



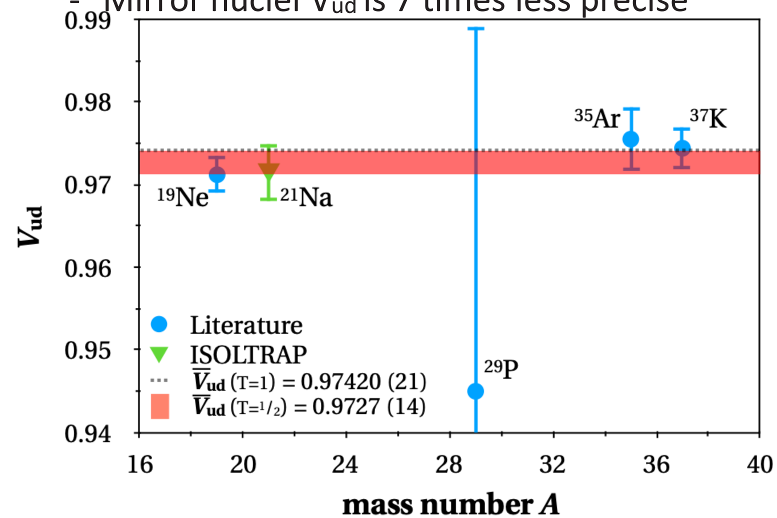
- 30 spectra of ^{21}Na, ^{21}Ne and 18 of ^{23}Mg, ^{23}Na
- ^{21}Na —> ^{21}Ne: $\delta m/m = 9*10^{-10}$
- ^{23}Mg —> ^{23}Na: $\delta m/m = 1.5*10^{-9}$
- Both Q_{EC}-values uncertainty improved by a factor of 5

J. Karthein *et al.*, Phys. Rev. C 100, 015502 (2019)

- V_{ud} element extracted from mirror nuclei:
  - Q_{EC}-values have the smallest contribution to the error budget



  - Cannot extract V_{ud} for ^{23}Mg (missing $\beta\nu$ correlation coefficient)
  - Mirror nuclei V_{ud} value agrees well with the one extracted from super allowed decays
  - Mirror nuclei V_{ud} is 7 times less precise



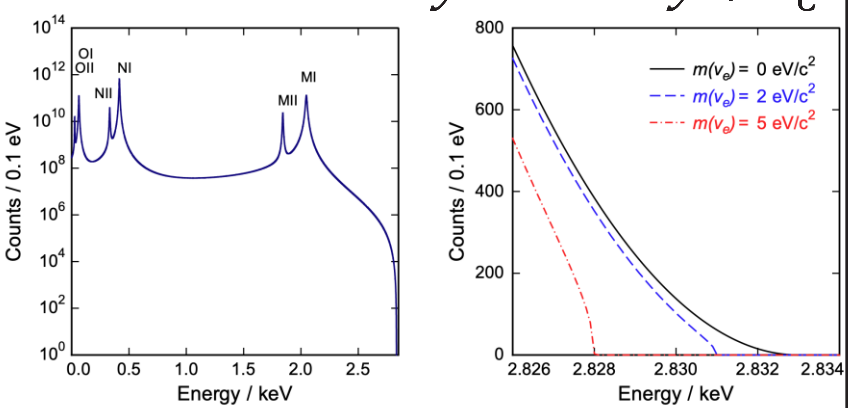
High-precision Q_{EC}-values for neutrino physics

- Primary goal:
  - Contribute to direct determination of neutrino mass
  - Precise knowledge of the QEC-value of EC required by micro-calorimeters

$$Q_{EC} = (M_p - M_d)c^2$$

- Ex: $^{163}Ho + e^- \rightarrow ^{163}Dy^* + \nu_e$

$$^{163}Dy^* \rightarrow ^{163}Dy + E_C$$

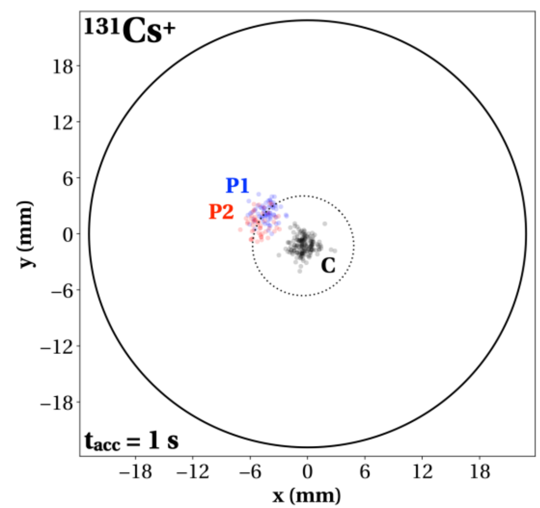


- But also:
  - Test functioning of microcalorimeters
  - Test theoretical description of EC-spectrum
  - Search for new candidate EC-transitions

L. Gastaldo *et al.*, Eur. Phys. J. Special Topics 226, 1623–1694 (2017)

- The ^{131}Cs —> ^{131}Xe candidate pair:
  - Improve Q_{EC} uncertainty by a factor of 25
  - Precludes 131 CS as possible candidate for the ν_e-mass determination
  - Successful PI-ICR online test (1st ISOLTRAP publication on PI-ICR)

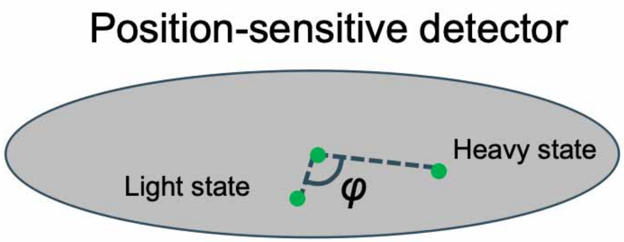
Mother	$T_{1/2}$	Daugh.	Q_{ge} / keV	δQ_{ge} / keV	Decay
^{131}Cs	9.7 d	^{131}Xe	-15 -11	5 5	EC_L EC_M
^{131}Cs	9.7 d	^{131}Xe	-11.5 -7.2	0.2 0.2	EC_L EC_M



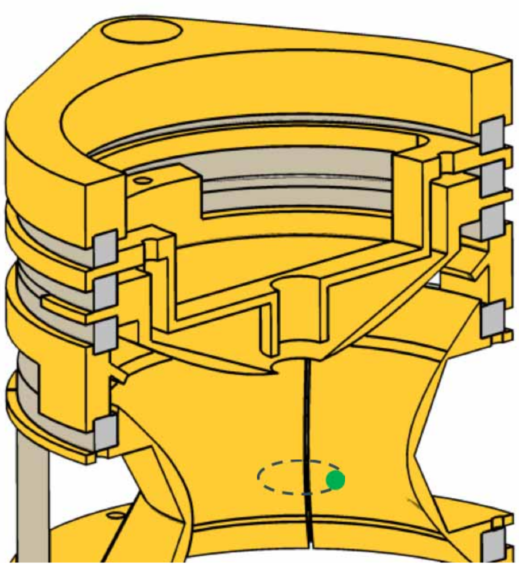
J. Karthein *et al.*, Hyperfine Interact (2019) 240:61

Phase-Imaging Ion Cyclotron Resonance

- The technique:

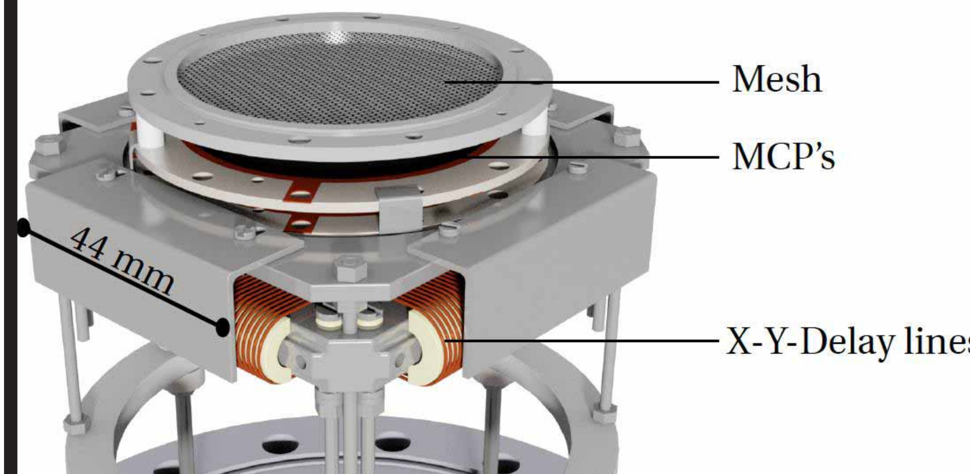


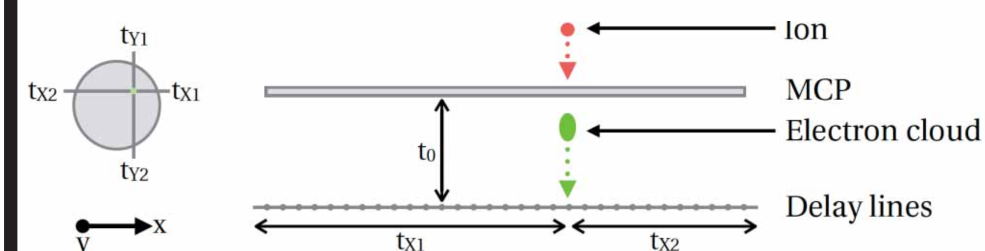
$$\nu = \frac{\phi + 2\pi n}{2\pi t_{meas}}$$



- The delay-line detector:

- Single pitch propagation time (1mm) ~ 0.75ns
- X = t_{x1}-t_{x2} (same for Y)
- Single ion sensitivity :)
- Poor dynamic range (~3ions/bunch) :(



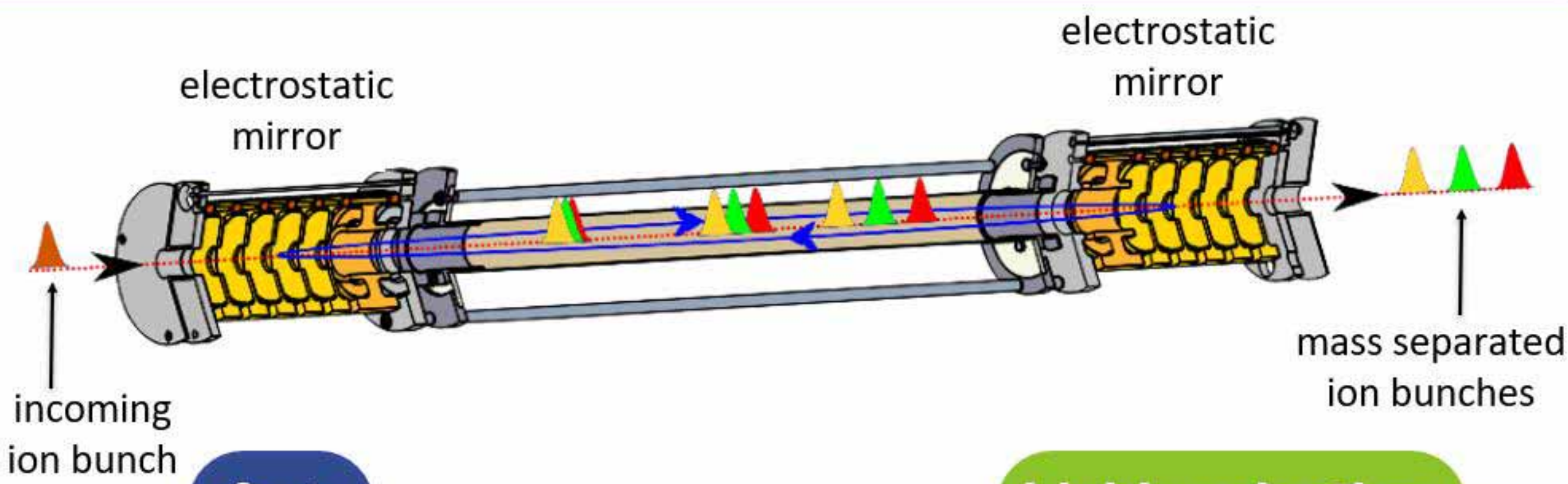


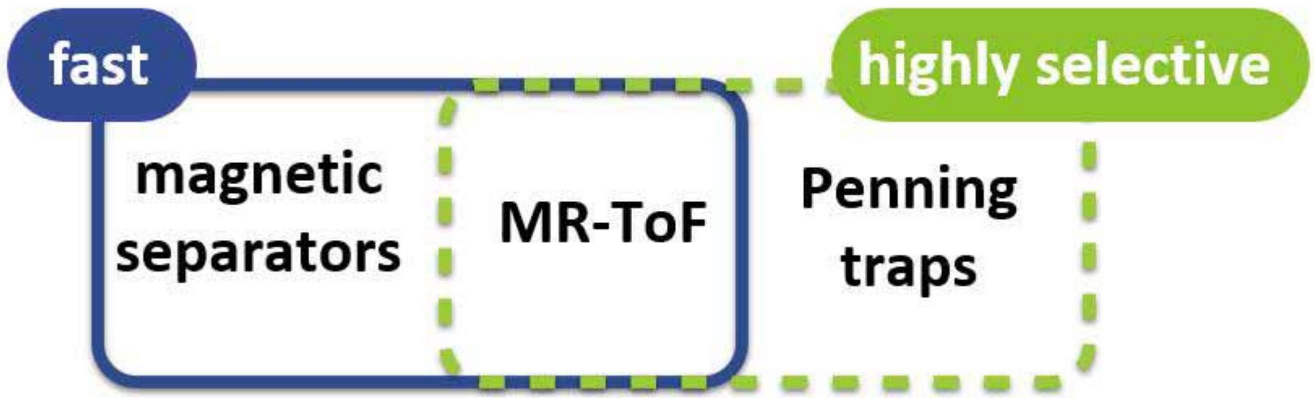
J. Karthein, Master Thesis *CERN-THESIS-2017-281*

MIRACLS: MR-TOF, Multi-Reflection-Time of Flight spectrometer

Contact: S. Malbrunot, CERN

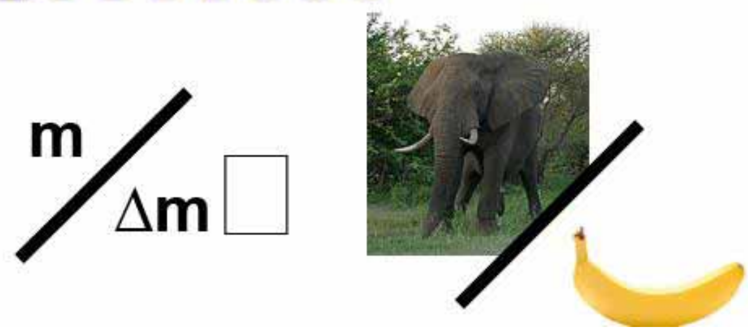
MR-TOF devices



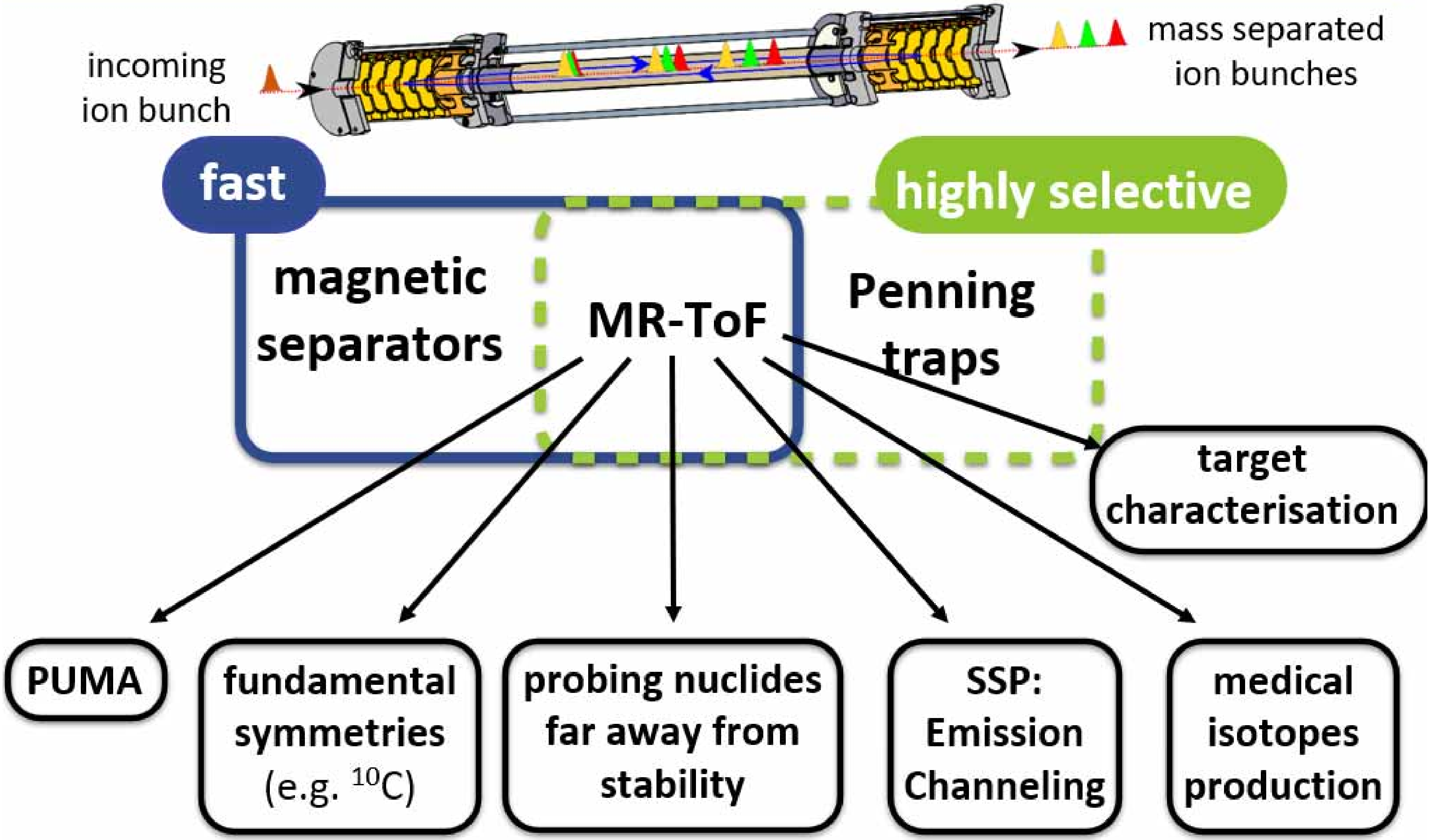


Characteristics:

- $m/\Delta m > 10^5$ achieved in a few milliseconds
- ion capacity to $\approx 10^6$ ions/s (limitation due to space-charge effects limit)

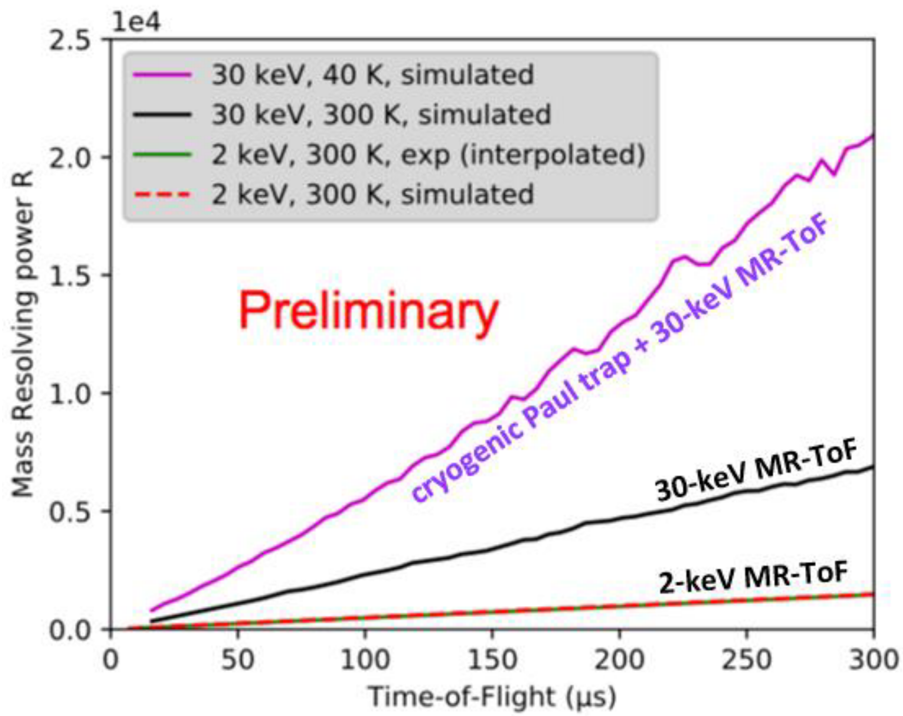


applications for high-flux MR-ToF



⇒highly beneficial for entire ISOLDE community

30-keV MR-ToF: new opportunities for purified ISOLDE beams



faster isobaric separation in MR-ToF while keeping high mass resolving power

➡ higher ion flux through MR-ToF device ('bypass' space-charge limits)

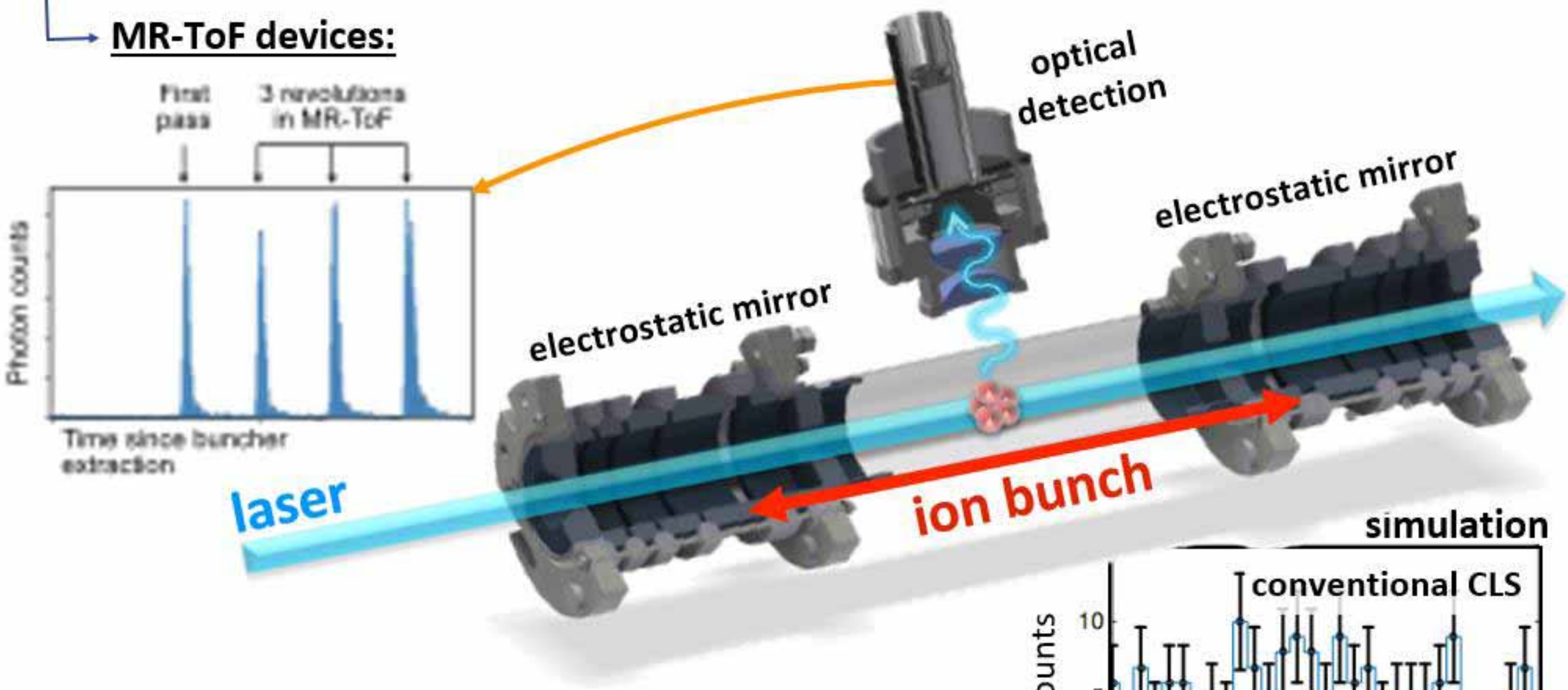
➡ initial goal: a few pA (ultimate goal: >100 pA)

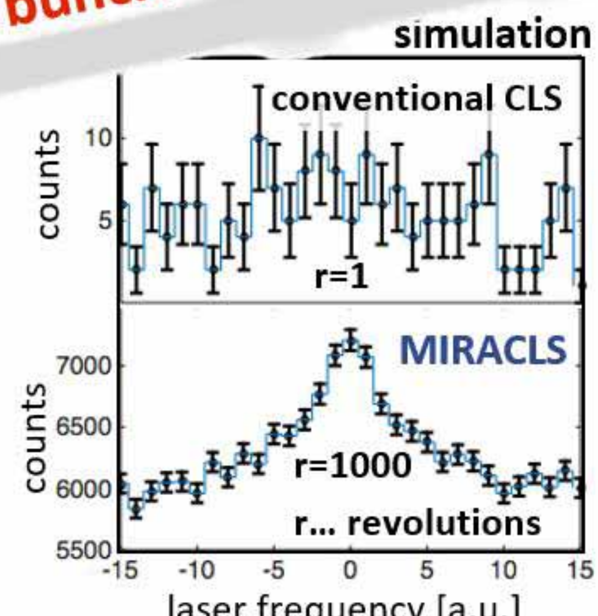
MIRACLS erc ISOLDE

the Multi Ion Reflection Apparatus for Collinear Laser Spectroscopy

trap ⇒ long observation time ⇒ higher sensitivity ⇒ more exotic nuclides accessible

MR-ToF devices:





novel approach for collinear laser spectroscopy:

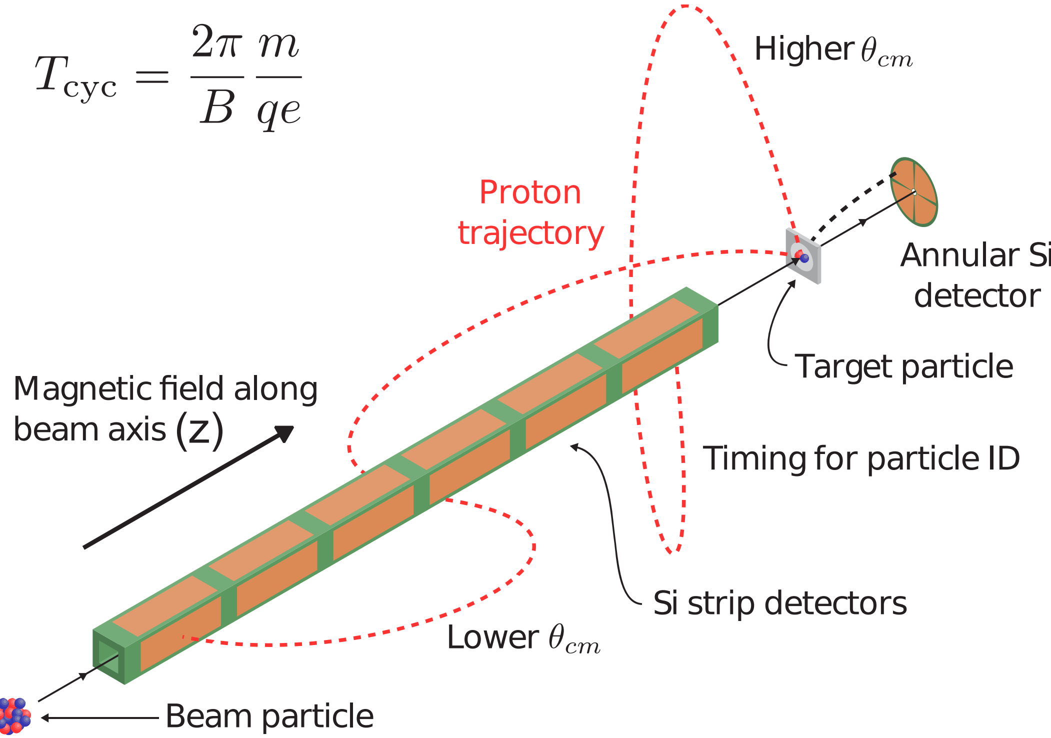
- ion trap ⇒ long observation time
- 30 keV beam ⇒ high resolution

ISS

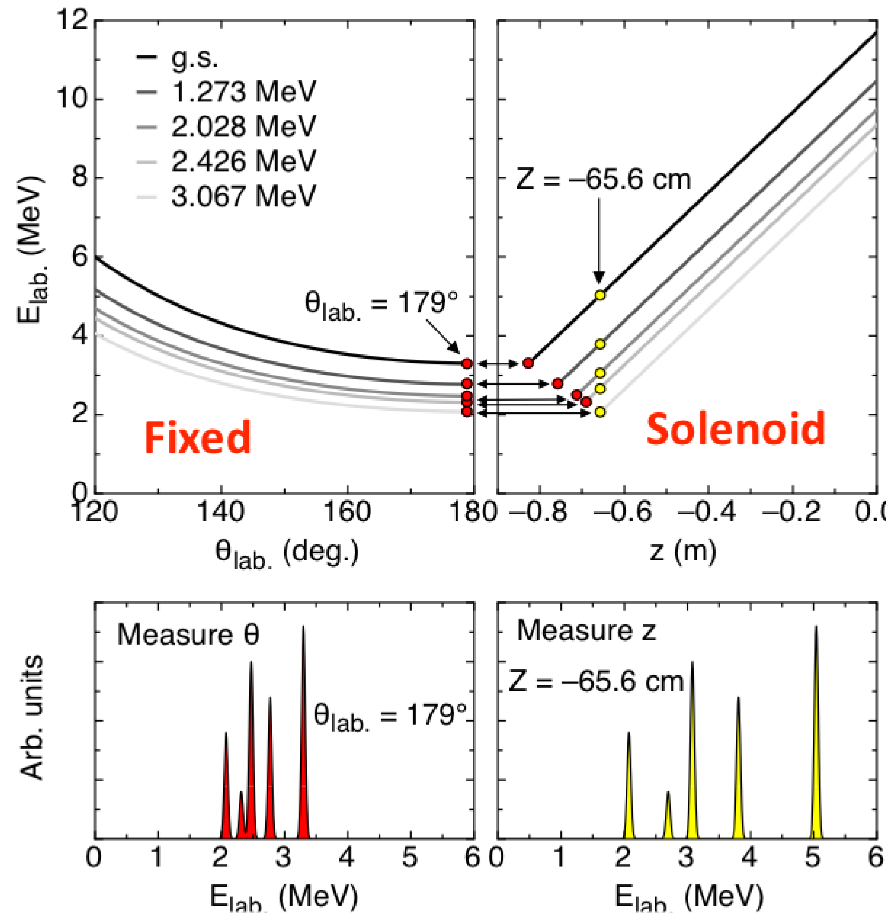
ISS: direct reactions

ISOLDE Solenoidal Spectrometer

$$T_{\text{cyc}} = \frac{2\pi}{B}\frac{m}{qe}$$



$$E_{\text{cm}} = E_{\text{lab}} + \frac{mV_{\text{cm}}^2}{2} - \frac{mzV_{\text{cm}}}{T_{\text{cyc}}}$$



MEASURED: position z that light ejectile returns to axis, cyclotron period T_{cyc} and lab particle energy $E_{p.}$

<u>no kinematic compression</u> of Q-value spectrum (unlike measurements at fixed angles)

Linear relationship between E_{cm} and $E_{lab.}$

Upgraded recoil dete

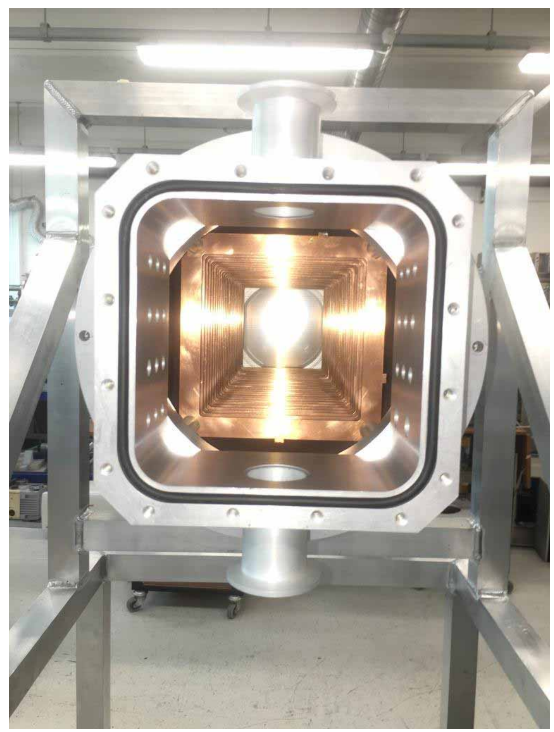
MANCHESTE
1824
The University of Manch

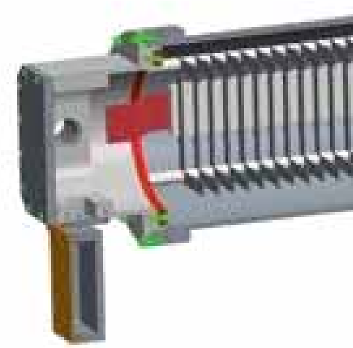
New gas-filled recoil detector for recoil identification

Position-sensitive (delay lines) multi-wire proportional counter. Followed by segmented gas-filled ion chamber.

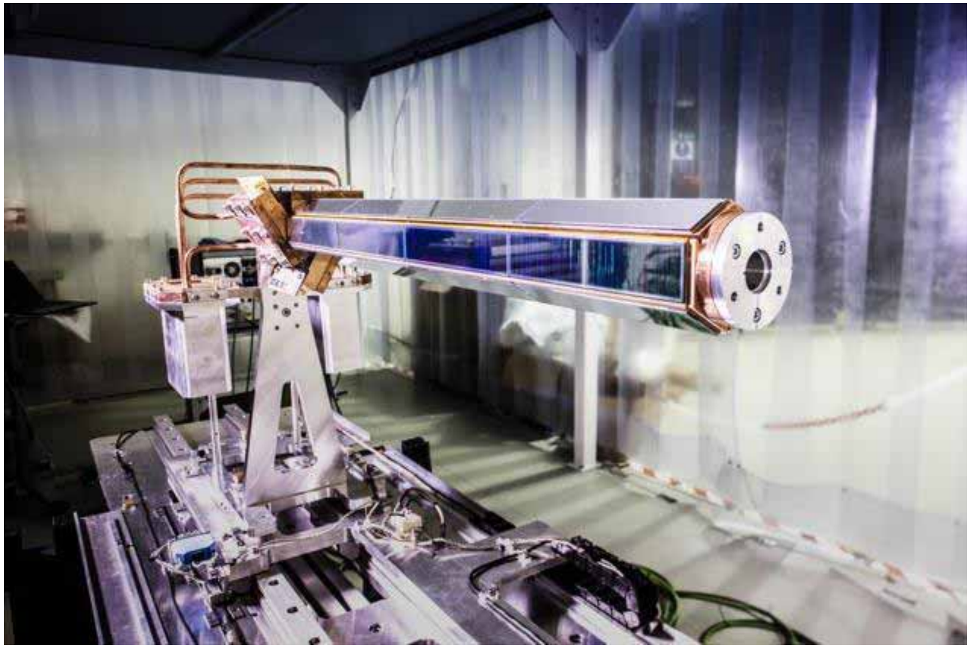
Digitized signals – sample full dE/dx.

Count rate up to 100kHz.





Completed detector of 3 modules

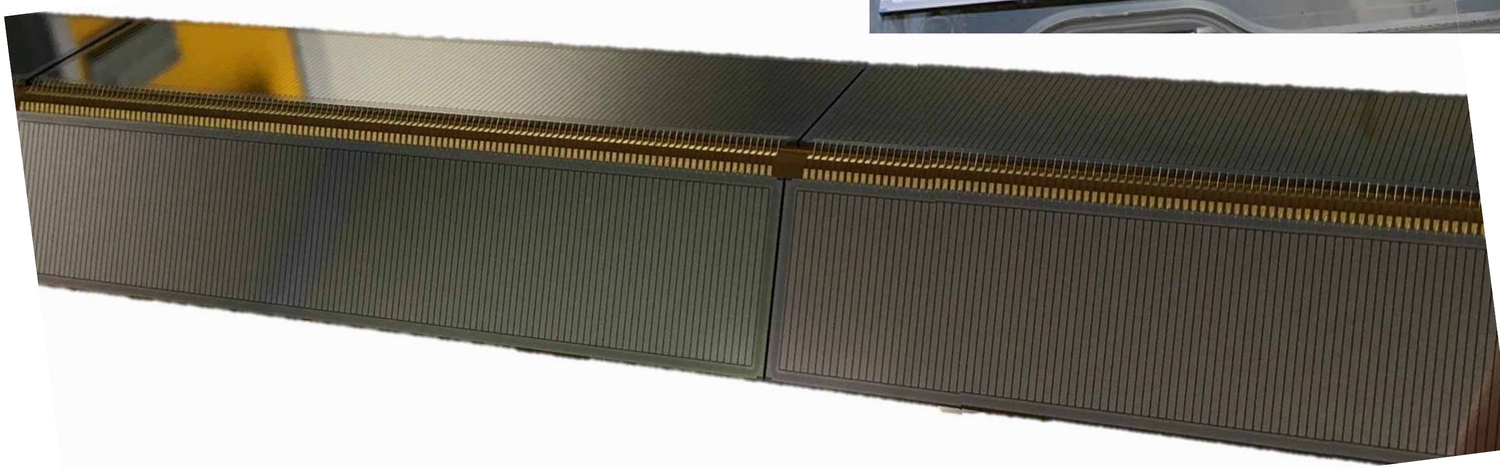


1 module with 2 sides
4xDSSSD wafers per side

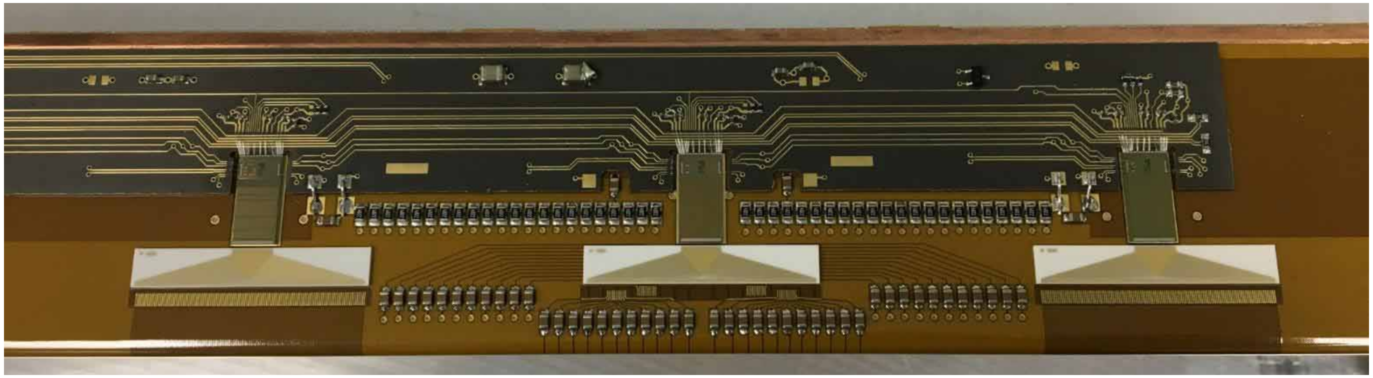
DSSSD wafers

Ohmic (n)
[glue bonded]
back

Junction (p)
[wire bonded]
front



Completed module
3 → Array (CERN)
1 → Spare (CERN)



6 ASICs per module
3 forward end
3 rear end

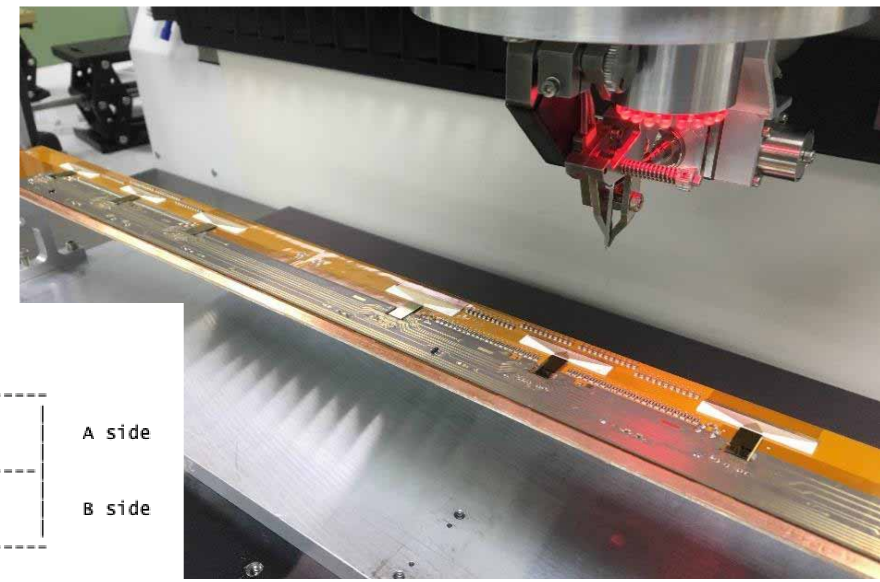
ASIC 0, 2, 3, 5 - p-side strips

- 128 channels per ASIC.
- Strips "paired" by wire bonding from A side to B side

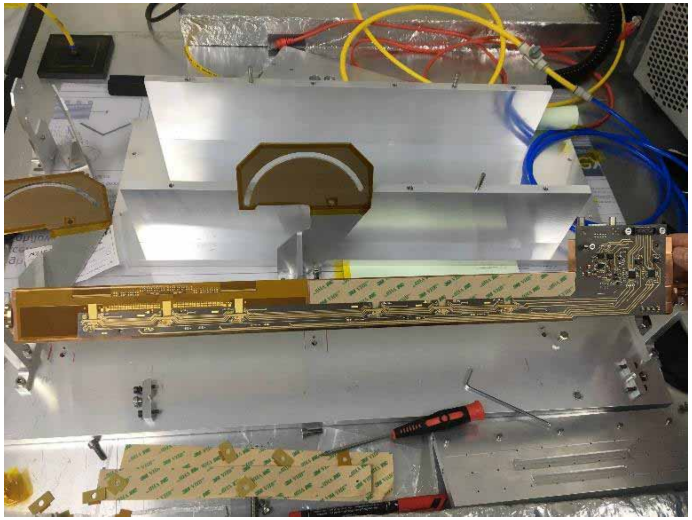
ASIC 1, 4 - n-side

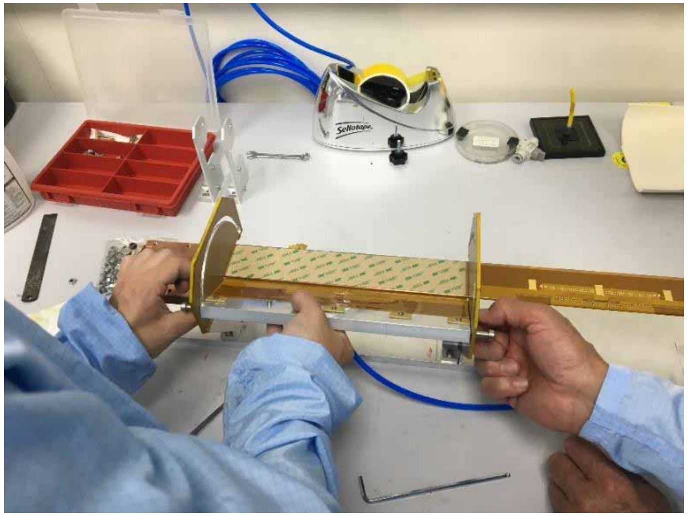
- 44 channels per ASIC.
- Every strip mapped to a single channel.

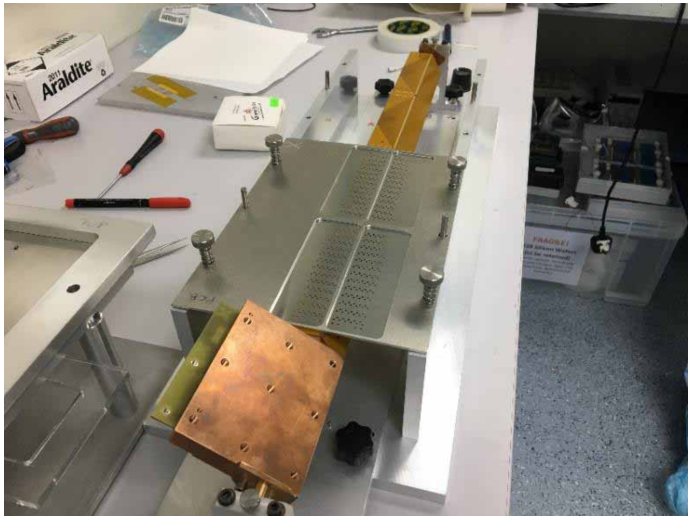
```
----------------------
|                    |
|                    |
|                    ----------------------------------------------------------------
|                    |      0A        |      1A        |      2A        |      3A        |   A side
|                    |-------------ASIC 1-------------------------------ASIC 4------------|
|                    |      0B        |      1B        |      2B        |      3B        |   B side
-----------------------------------------------------------------------------------------
                           Row 0            Row 1            Row 2            Row 3
                          ASIC 0           ASIC 2           ASIC 3           ASIC 5
```

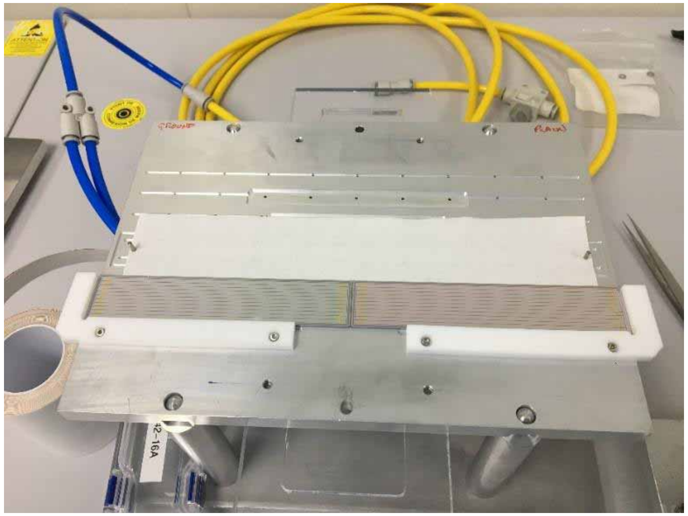


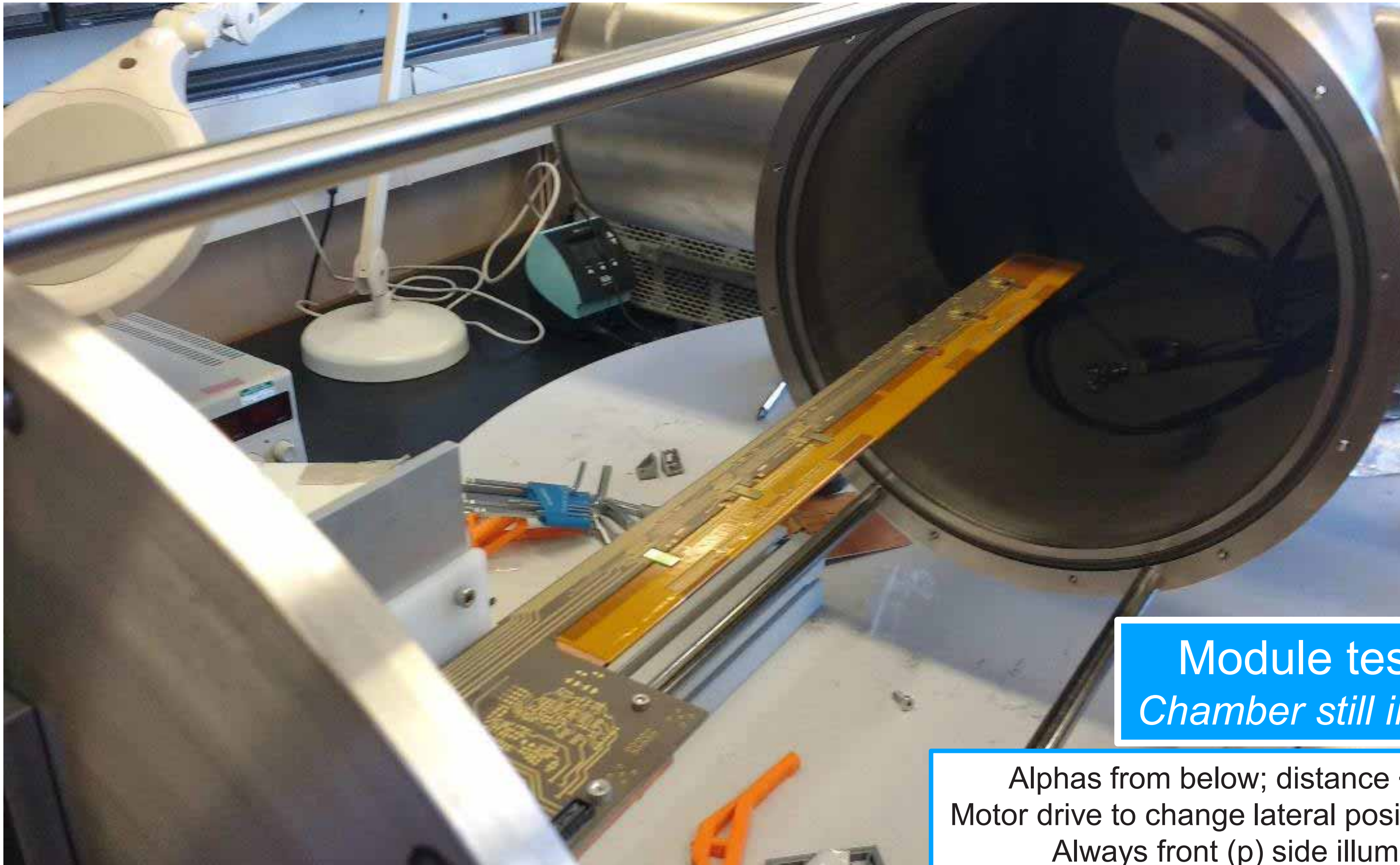
Module Assembly











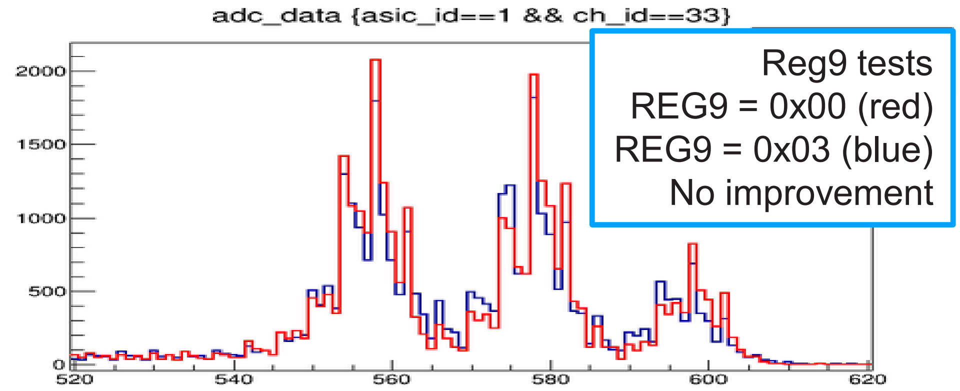
Module test setup

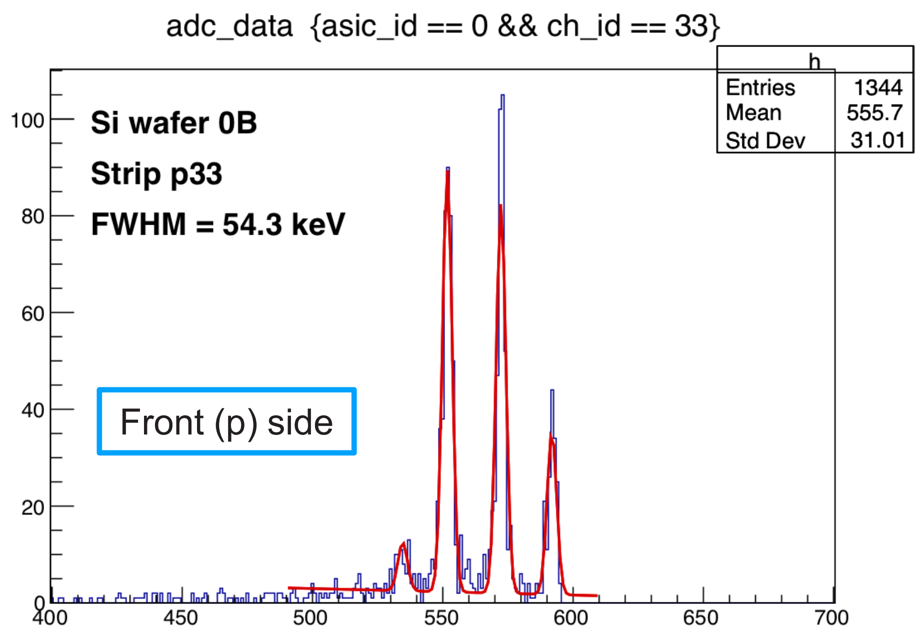
Chamber still in Liverpool

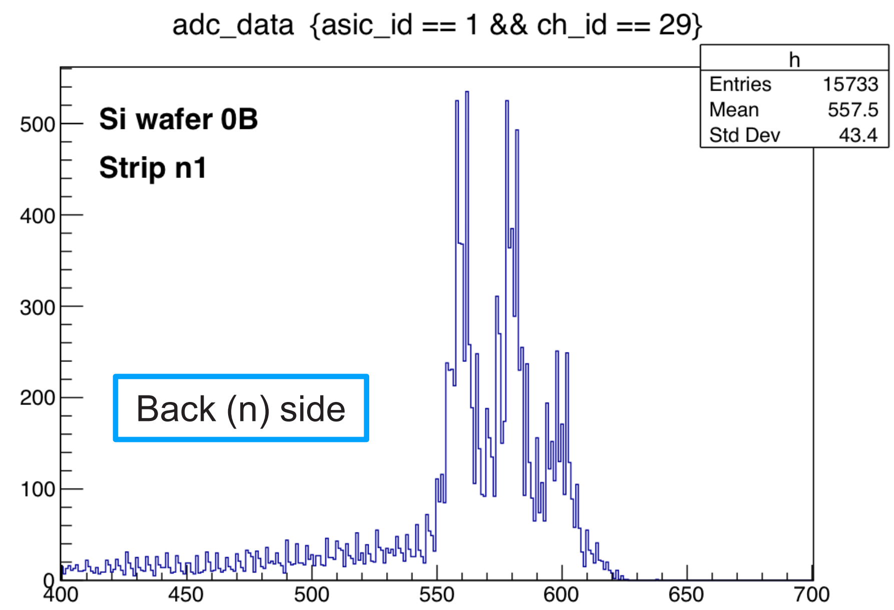
Alphas from below; distance ~250 mm.
Motor drive to change lateral position of source.
Always front (p) side illuminated.

Alpha spectra

- No fine structure included in the fits.
- Edge effects observed (small peak).
- Coincidences not yet tested.







Alpha spectra

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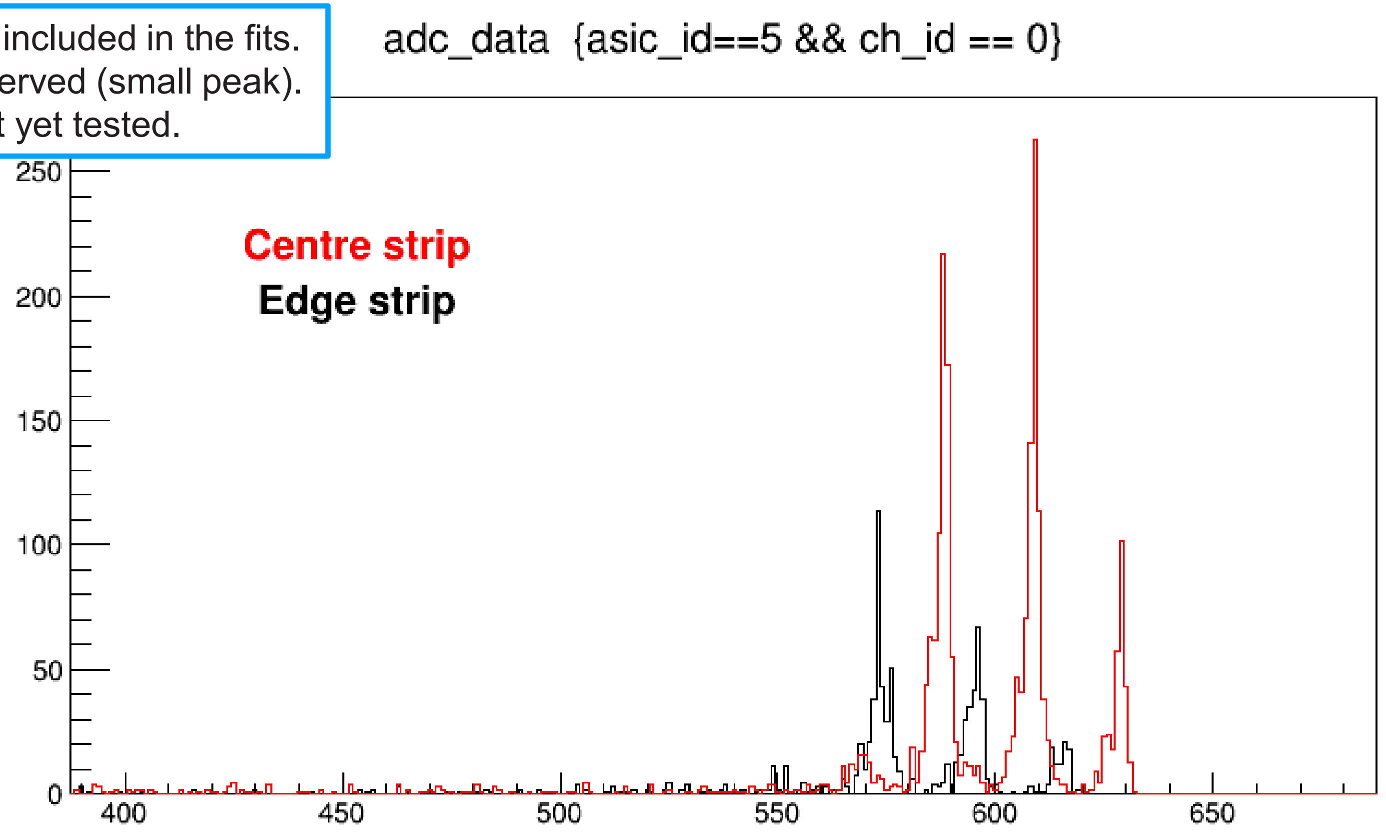


Calibrated Ge detector

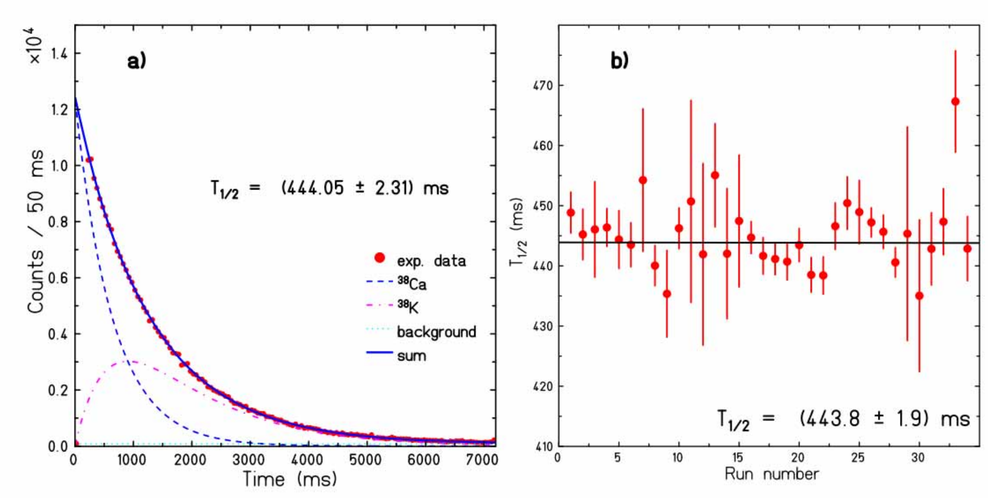
Contact: B. Blank, Bordeaux

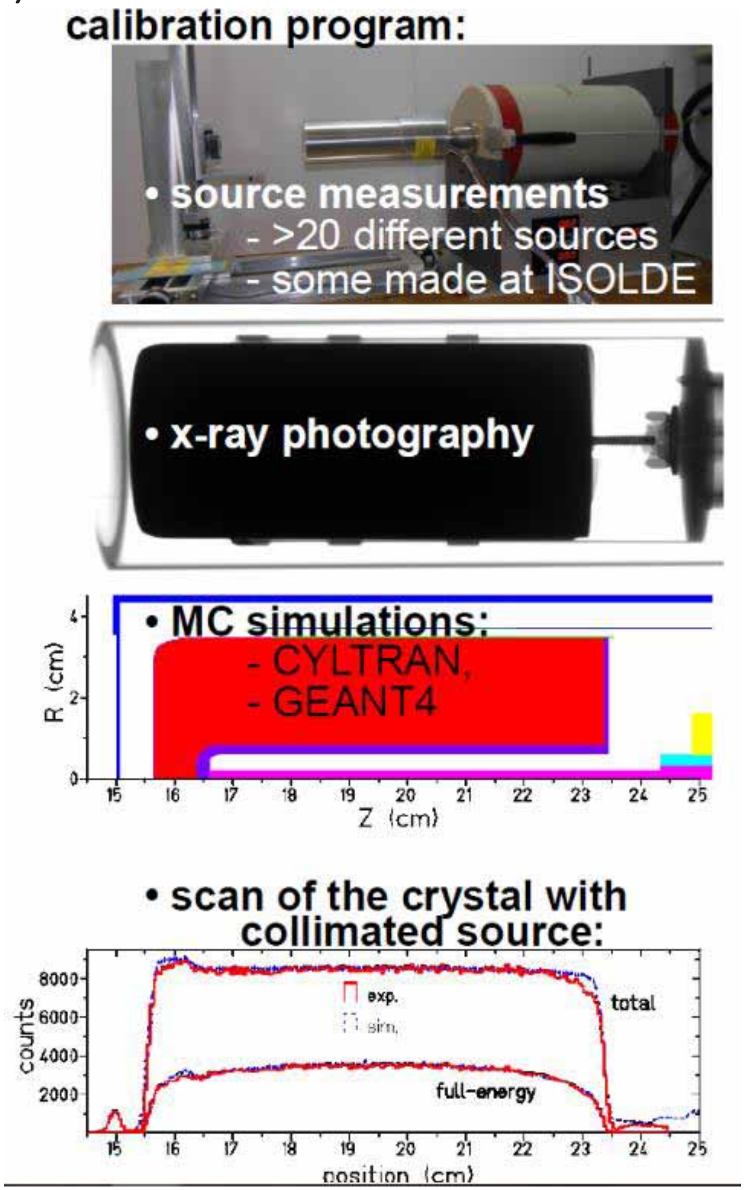
Lifetime t1/2 and branching ratio BR

B. Blank et al., NIM A 776, 34 (2015)

- Decay studies with high-purity Ge detector (Bordeaux)
  - ➢ Very well known efficiency

- Recent examples 38,39Ca, 37K





Contact: B. Blank, Bordeaux

229Th nuclear clock

Contact: P. Van Duppen, KU Leuven

Nuclear clock based on 229mTh

Nucleus is more separated from environment:

- Expected to outperform present-day best clocks
- World-wide effort to created nuclear clock

BUT : Nuclear properties not know with high enough precision!

^{229}Th

β^{-}

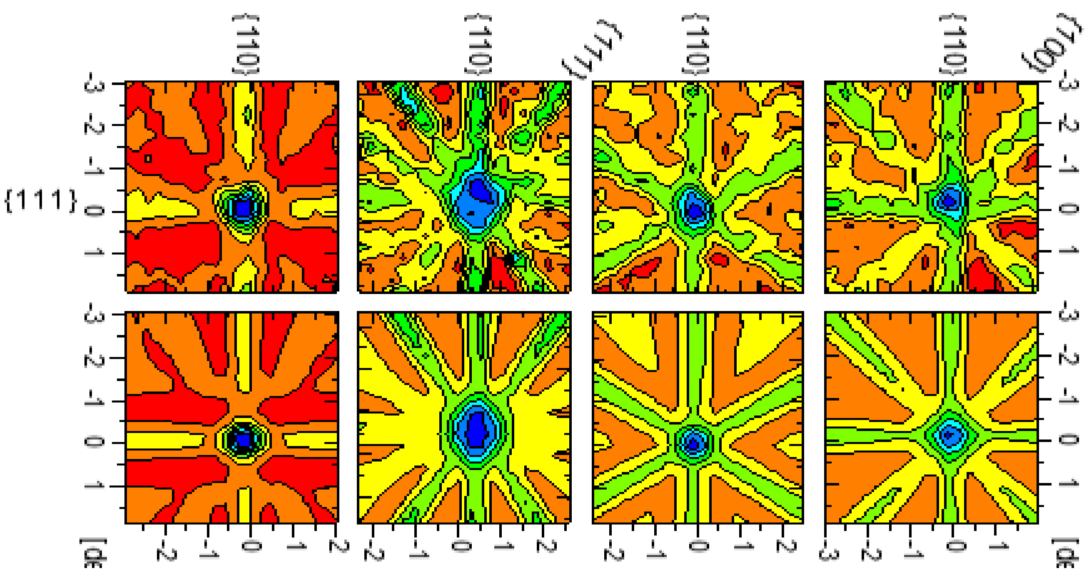
^{229}Ac

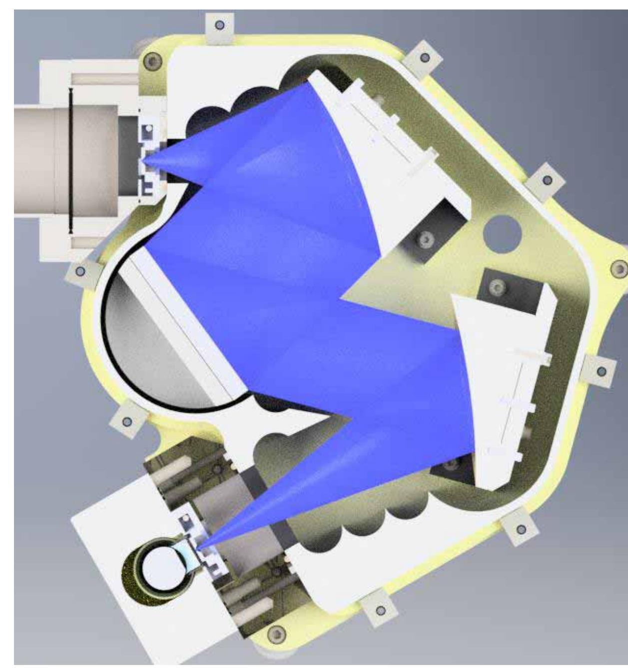
Goal:

- Create ^{229}Ac at ISOLDE, implant it in wide-bandgap CaF crystal at correct site (emission channeling measurement)
- Measure direct photon emission from ^{229m}Th → ^{229}Th with high-resolution VUV photon spectrometer with $\Delta \mathrm{E} < 0.1$ nm
- prerequisite for direct laser excitation

$$\Delta E = 1 \text{ nm} = 0.05\ eV$$

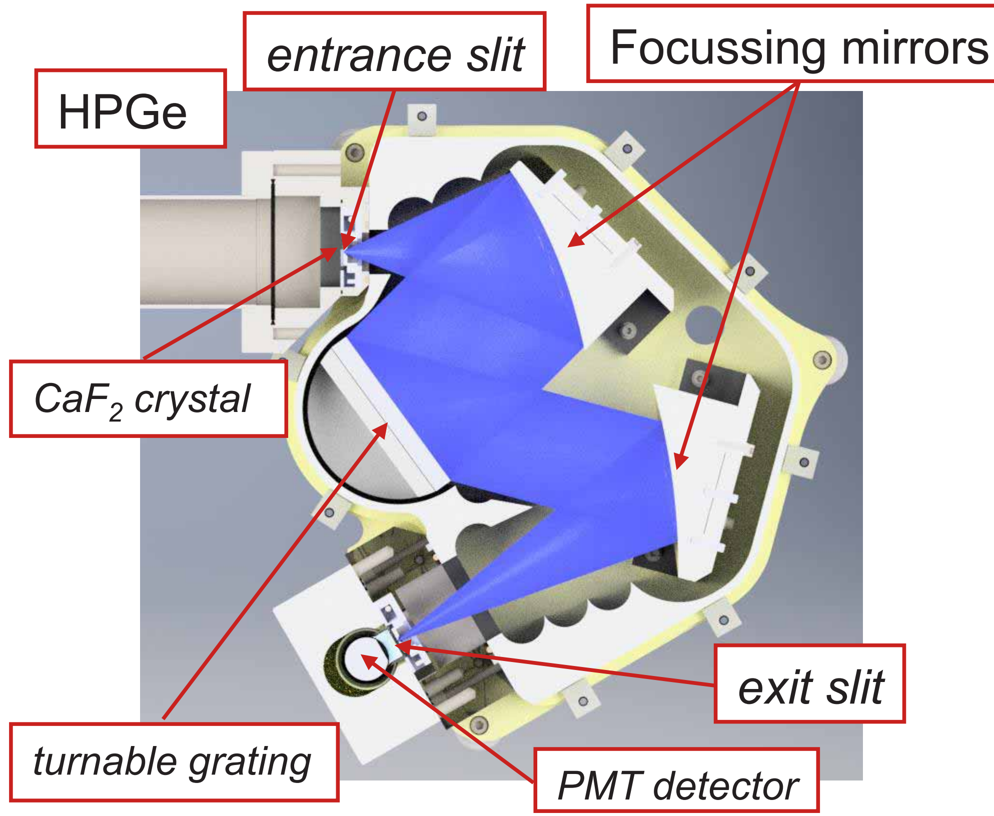
P. Van Duppen, S. Sels, KU Leuven





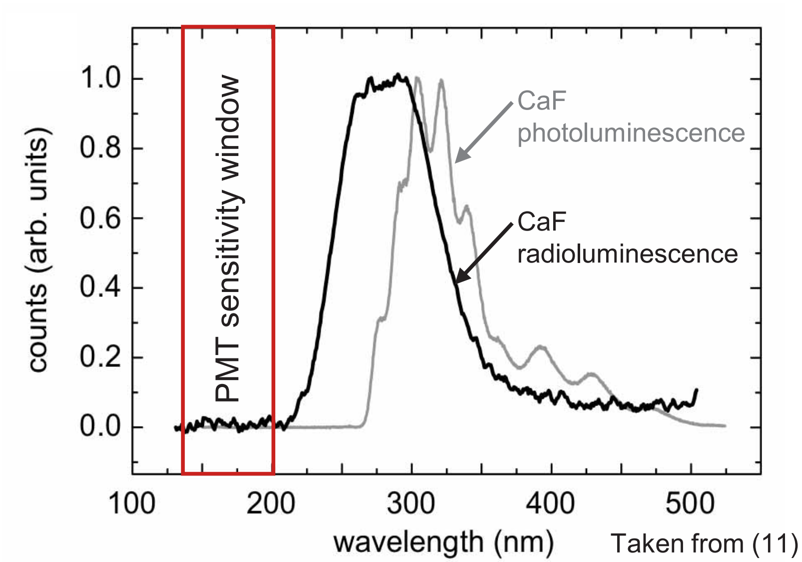
II. Spectroscopy of the Radiative Decay: Methodology

- Implantation into thin (50nm) CaF_2 crystal on Si backing (characterization at KU Leuven)
- Implantation time: 2 half-lives
- Transfer of crystal under vacuum to spectrometer
- Crystal positioned close to entrance slit of VUV spectrometer (design based on Resonance Ltd customized VM180)
- Activity monitoring using a Ge detector
- Simulation of signal strength and worst-case background contributions (see next slide)



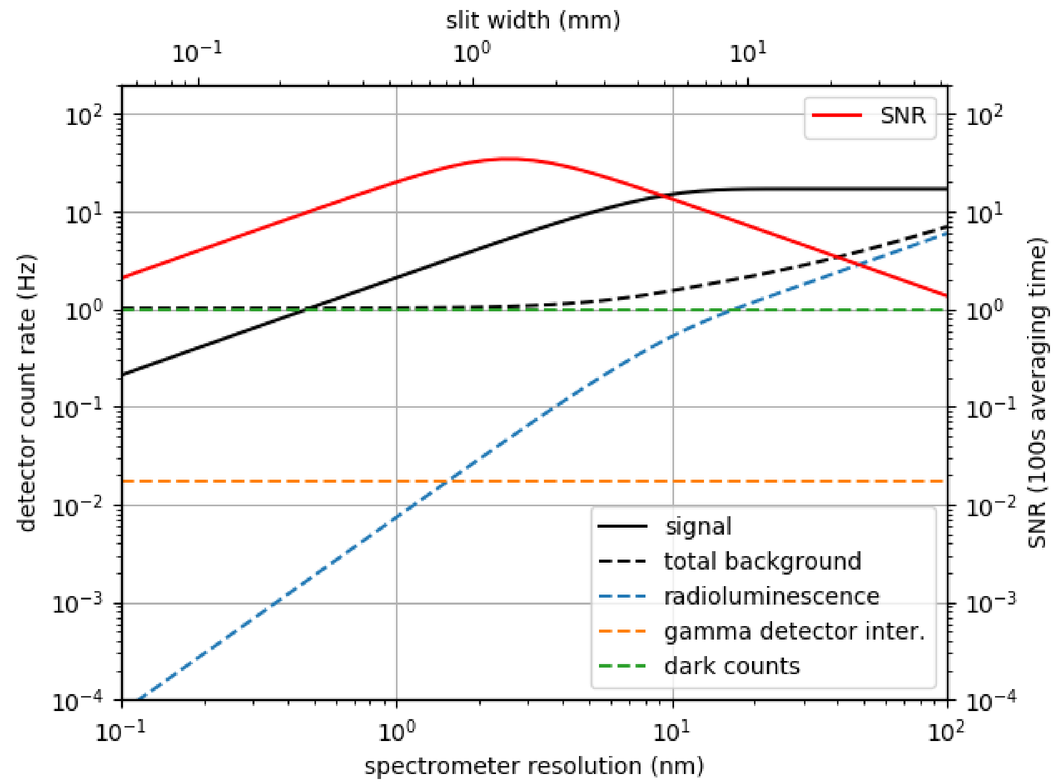
II. Spectroscopy of the Radiative Decay: Background

- Implantation of a 4 mm FWHM ion beam
- Scintillation properties in CaF_2
  α,β: from literature $\sim 1\%$ conversion
  γ: 100% conversion
- PMT sensitivity window
- Conservative estimates of
  - photon coll.+ det. efficiency: $> 0.01\%$
  - substitutional lattice position: 50%
  - isomer feeding: 14%



Taken from (11)

Signal (counts/sec.) and background contributions for $3h$ measurement at $10^6 pps$ implantation (2 h) and $2h$ isomer half-life:



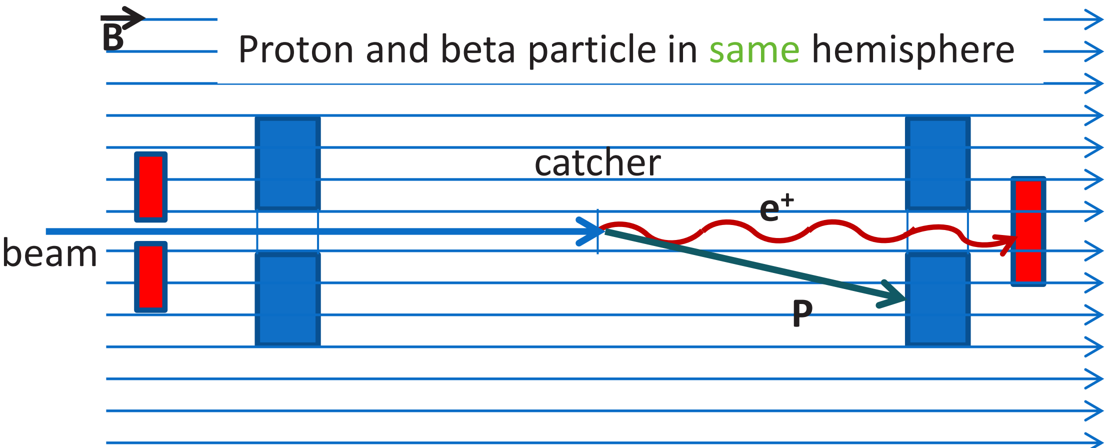
WISARD

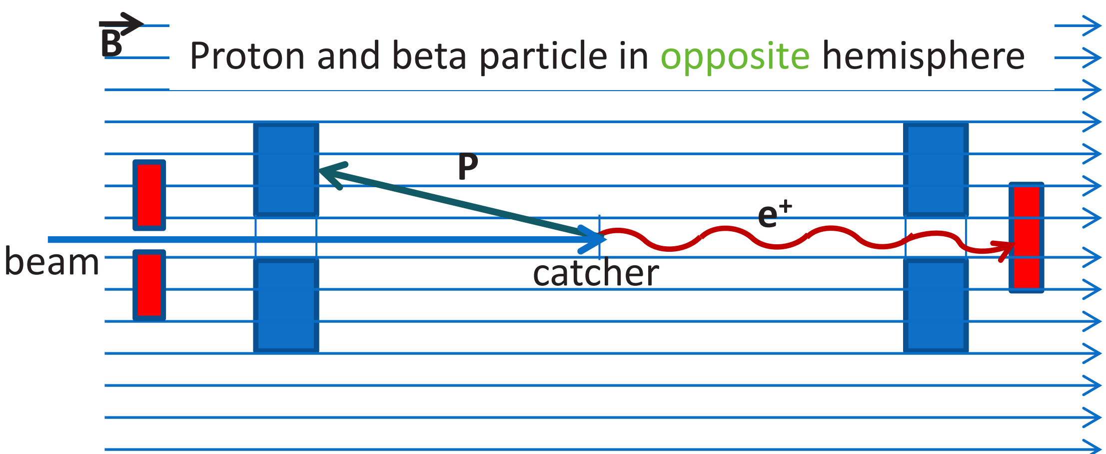
Contact: B. Blank, Bordeaux

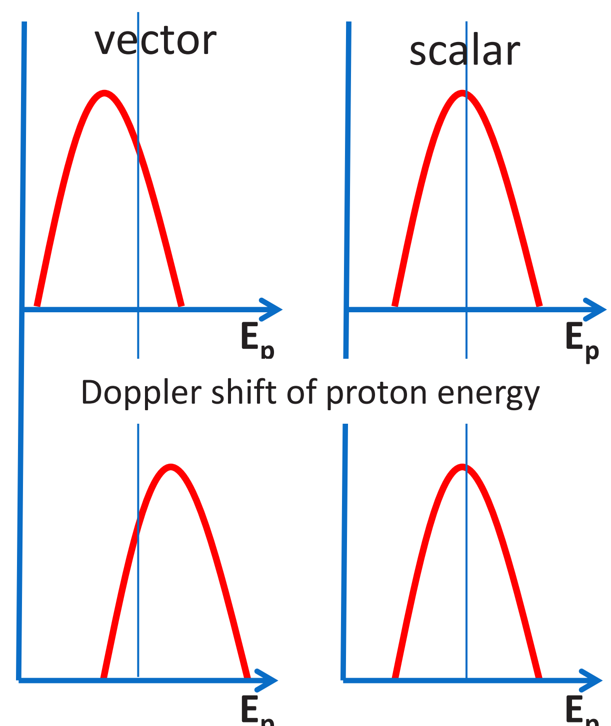
32Ar at WISARD

Weak Interaction Studies with ^{32}AR Decay:

e+-p coincidence in B field







WISARD

Proof of Principle
Detection Setup

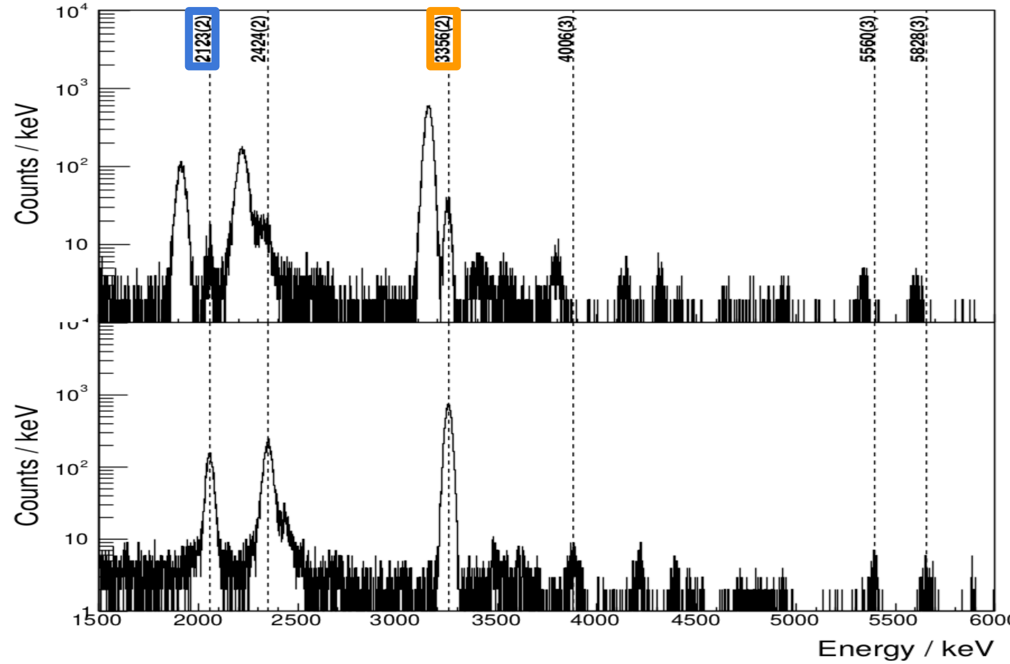
Beta detector*
+
SiPM

proton
detectors
planes**

Catcher***

Upper detectors

- Proton energies shifted due to



Lower detectors

- Energy shifts observed in all detectors due to the dead layer

* Plastic scintillator;
** Silicon surface-barrier (thickness = 300 μm);
*** Aluminized Mylar (thickness = 6.7 μm)

V. Araujo-Escalona et al. Phys. Rev. C101, 055501 (2020)

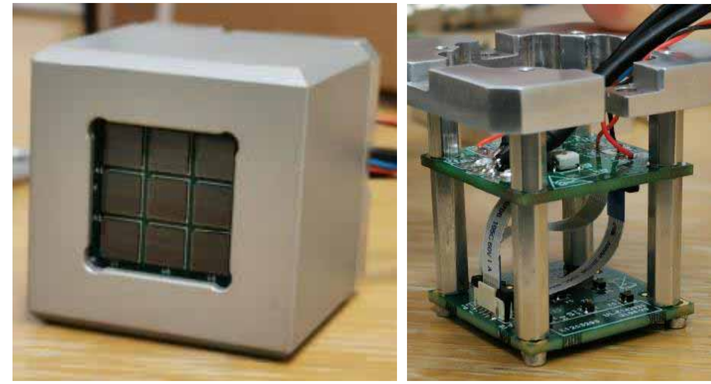
ISOLDE tape station

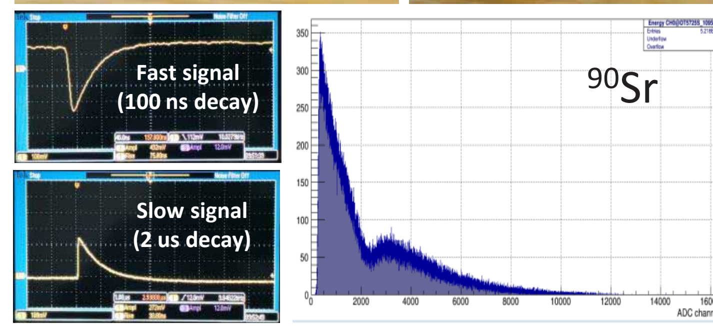
Detectors at ISOLDE tape-station

- **Beam instrumentation and low level control:**
  - Tape control and counter readout tested (on FESA level)
  - Beam scanner to be installed by BE-BI
- **Beta detectors**:
  - 2 prototypes (3x3 SiPM array) tested at CERN, noise at tapestation position is absent, ready for production. Same design can be used for all the positions.
  - Updating drawings and producing new parts, collaboration with SY-STI-TCD.
- **HPGe detector:**
  - Preliminary tests at GSI show a fully recovered resolution, however noise from cooling system was identified and currently addressed.
- **Data acquisition:**
  - CAEN DT5725 purchased, all-in-one solution
- **Top level Controls (GUI)**
  - Basic version by BE-OP (Java)
  - Expert interface via STI-RBS (tbd)
- **Future**
  - Final tests to be performed by March with all detectors in place
  - Once TS1 ready launching TS2 installation

Contact: R. Lica, S. Rothe

IFIN-HH 3x3 SiPM array



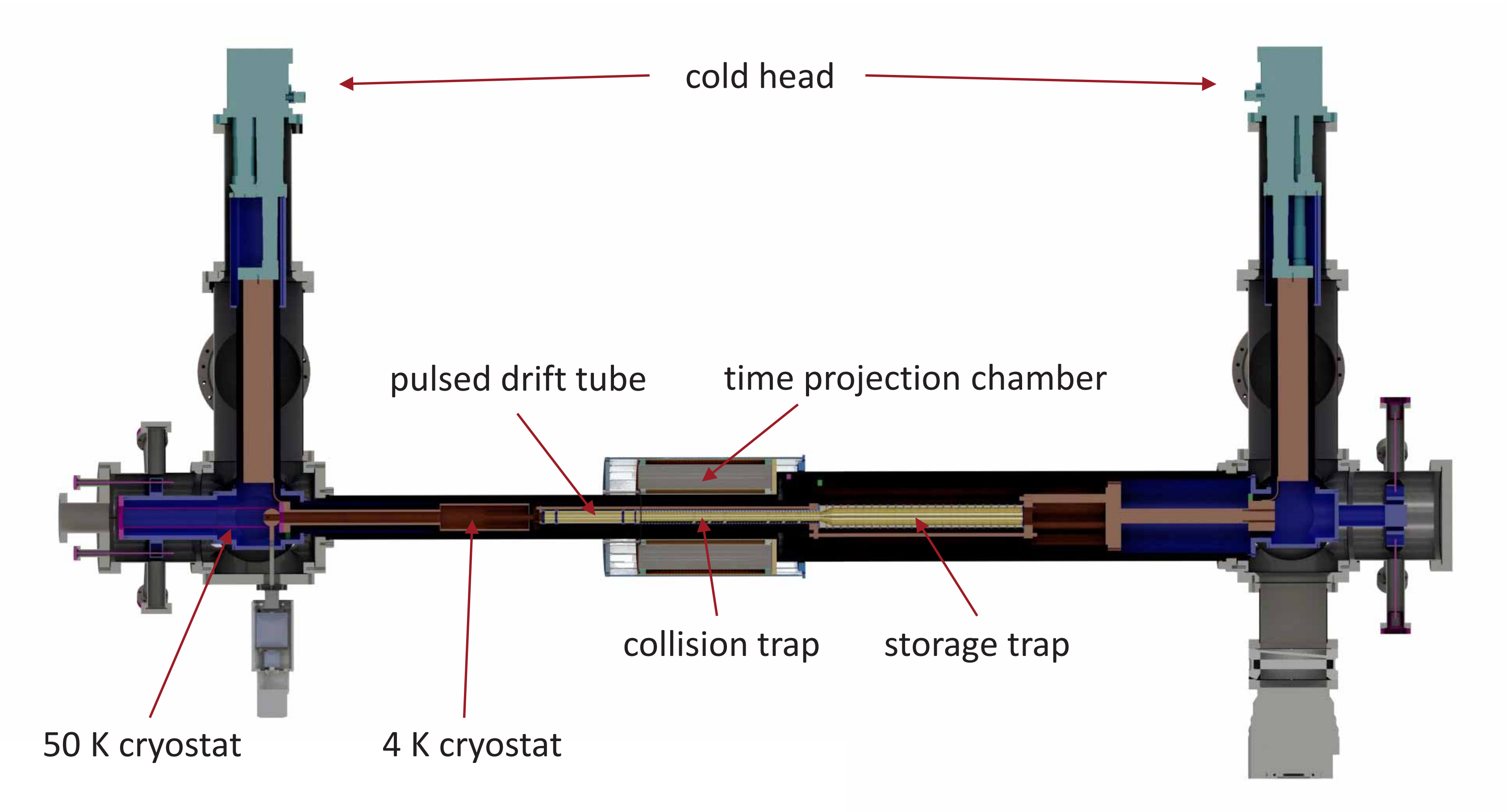


Old Tapestation HPGe detector

PUMA

Contact: A. Obertelli

PUMA cyostat



PUMA traps and detectors