FAIR:
Challenges Overcome… and still to be met !

Horst Stöcker

GSI Helmholtz Zentrum für Schwerionenforschung
&
FIAS Frankfurt Institute for Advanced Studies

FAIR Launched 7.11.2007

German Minister Ms. Schavan on November 7, 2007

Partners signing communiqué:
Austria, Germany, Spain, Finland, France, Poland, Romania, Russia, Sweden, Great Britain

Communiqué
on the Official Launch of the
Facility for Antiproton and Ion Research (FAIR)

Darmstadt, 07 November 2007

Representatives of the FAIR partner countries have met in Darmstadt today, 07 November 2007, to jointly announce the beginning of the realization of the FAIR project in Darmstadt. The FAIR partner countries have issued statements on their intended contributions to funding FAIR. Furthermore, the signatory representatives declare the following:

Dr. A. Stoklaska
Federal Ministry of Science and Research
Austria

Dr. A. Schavan
Federal Minister of Education and Research
Germany

J. Doncel
Ministry of Education and Science
Spain

M. Arajärvi
Ministry of Education
Finland

Dr. G. Bloch
Director-General
Ministry of Higher Education and Research
France

Dr. O. Gajl
Ministry of Science and Higher Education
Poland

Prof. Dr. A. Anton
President of the National Authority for Scientific Research
Romania

V.I. Rachkov
Federal Agency for Atomic Energy
Russian Federation

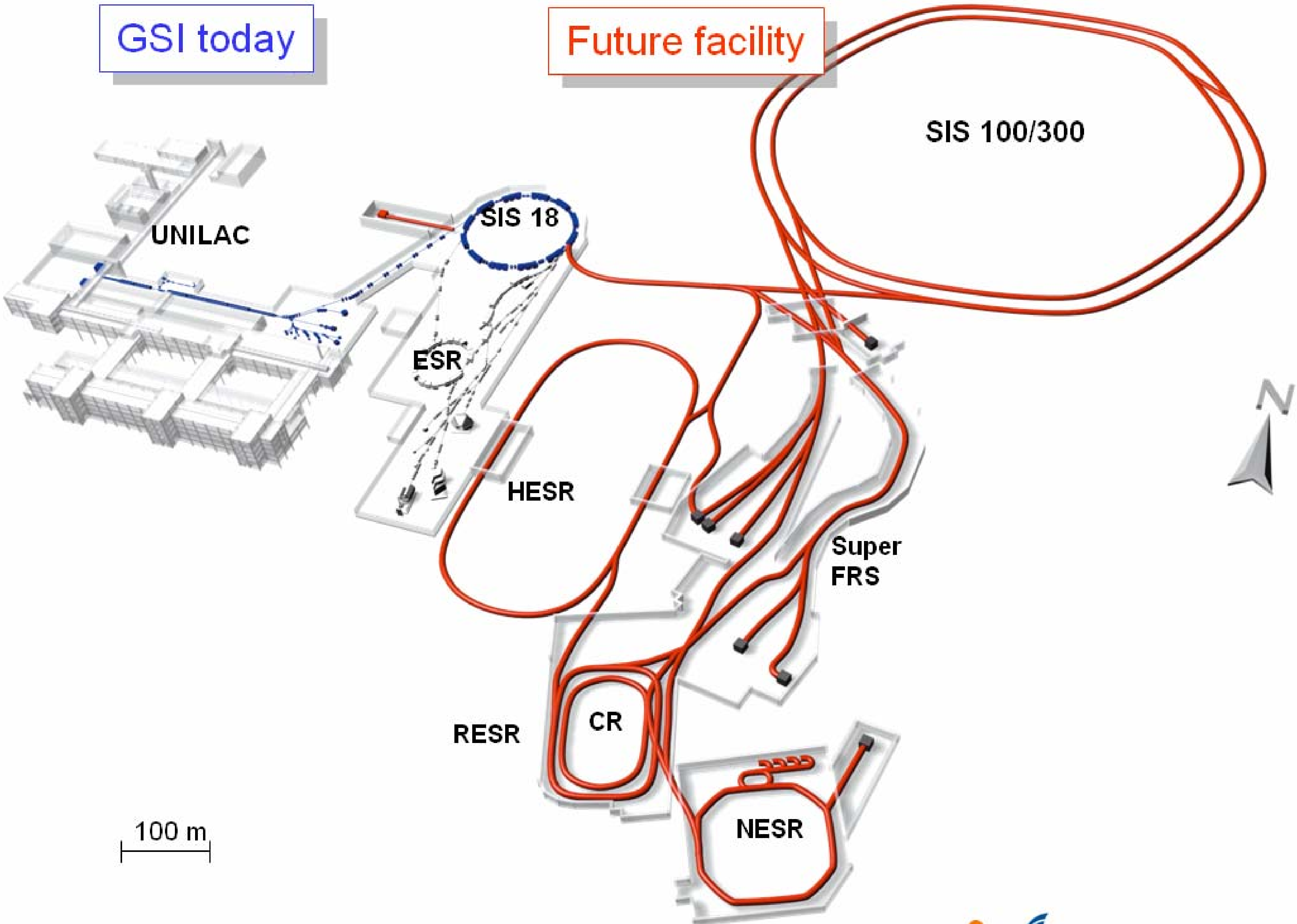
M. Johnsson
Ministry of Education, Research and Culture
Sweden

Prof. Dr. J. Womersley
Science and Technology Facilities Council
United Kingdom

FAIR Start Event - 7.11.2007

- 1400 international participants
- 500 international scientists attended the symposium on the Physics of FAIR

The Big Challenge ...



The Big Challenge ...

Gain Factors

- Beam intensities by factors of 100 - 10000
- Beam energies by a factor 20
- Production of antimatter beams
- Factor 10000 in beam brilliance via cooling
- Efficient parallel operation of programs

Construction Period, Cost, Users

- Construction in three phases until 2016
- Total cost 1.2 B€
- Scientific users: 2500 - 3000 per year

Financing

- 65 % Federal Government of Germany
- 10 % State of Hessen
- 25 % Partner Countries

→ FAIR GmbH with International Shareholders

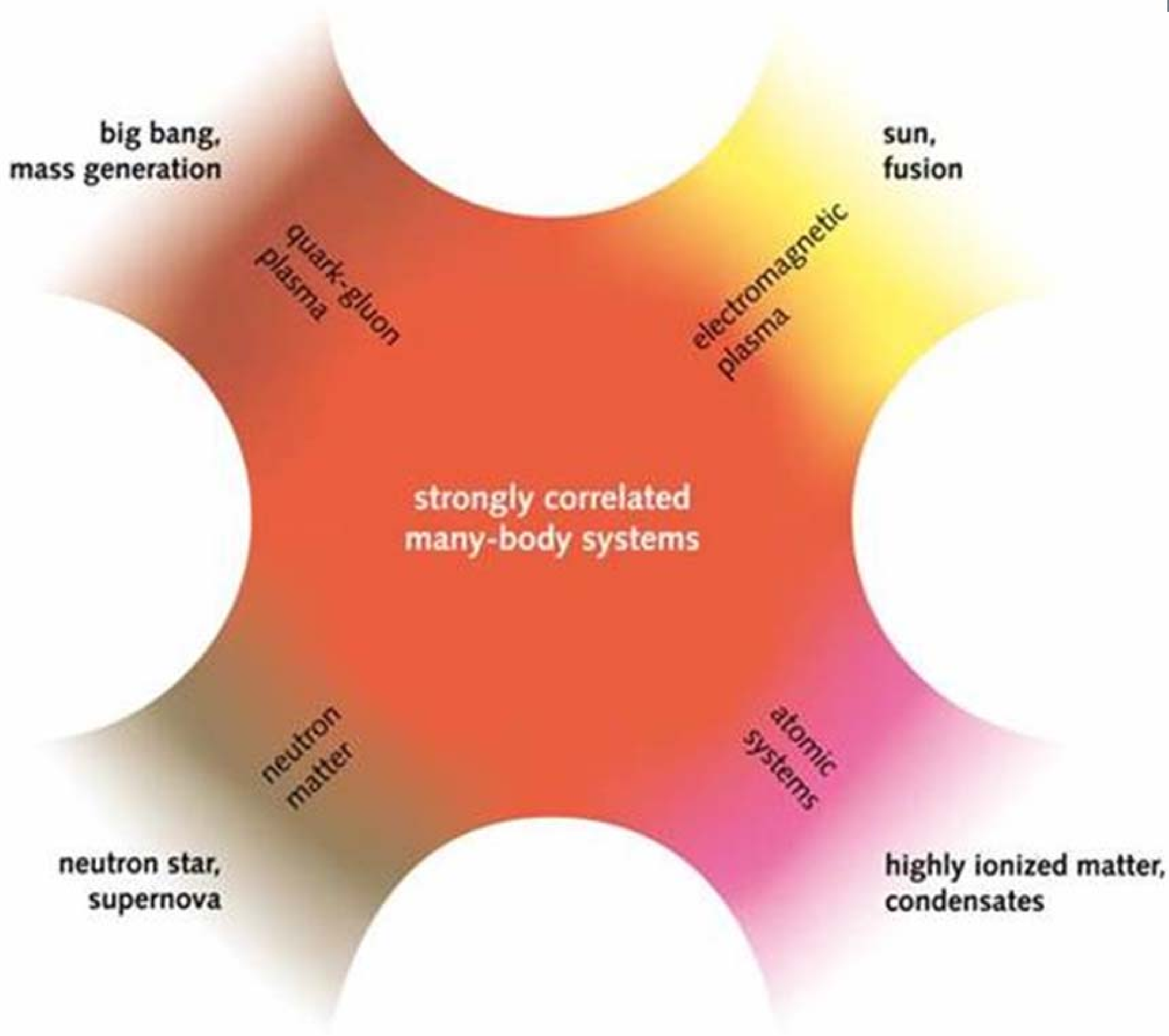
Largest fundamental science research project in Europe for the next decade!

National and International Cooperation

50 German Universities
& Research Centres

..in total more than 150 research institutions
from over 35 countries

FAIR Research Topics and Inter-links



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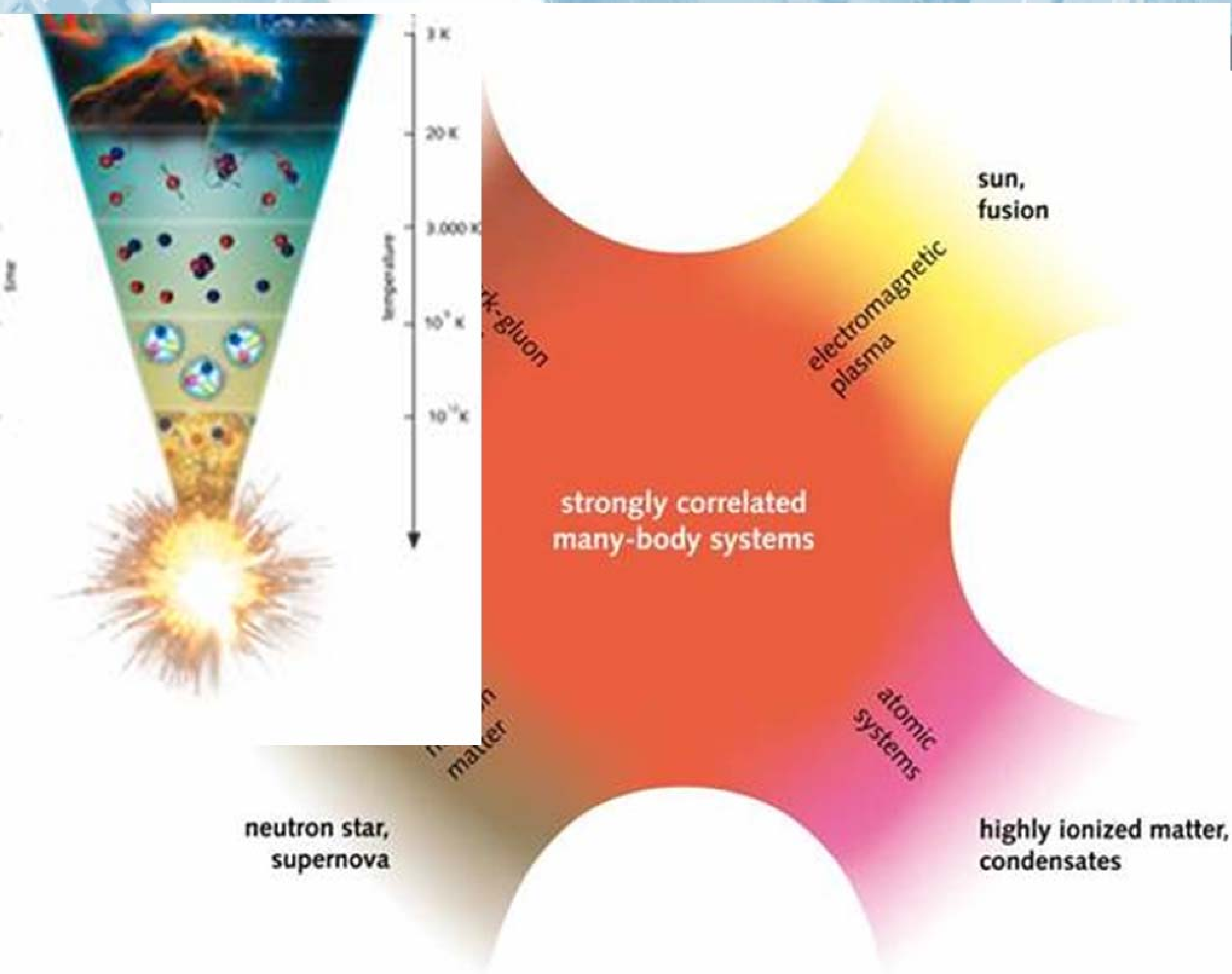

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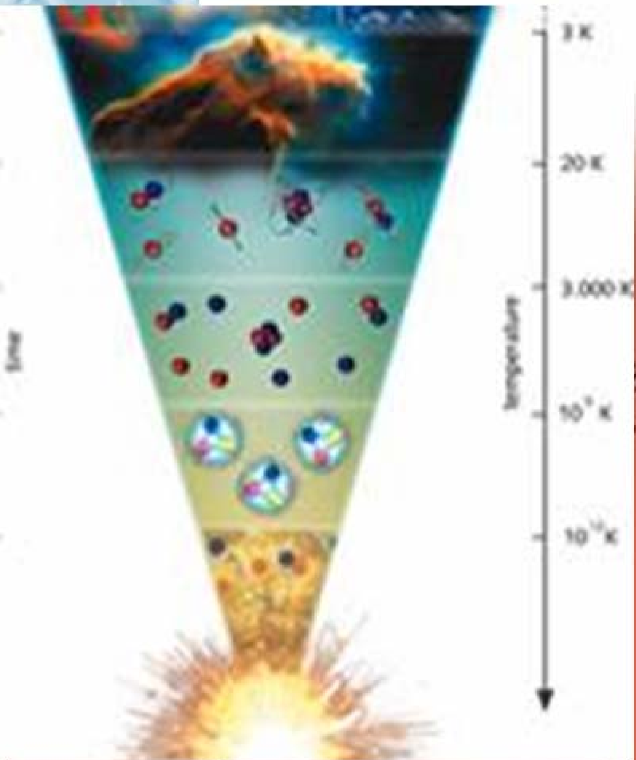

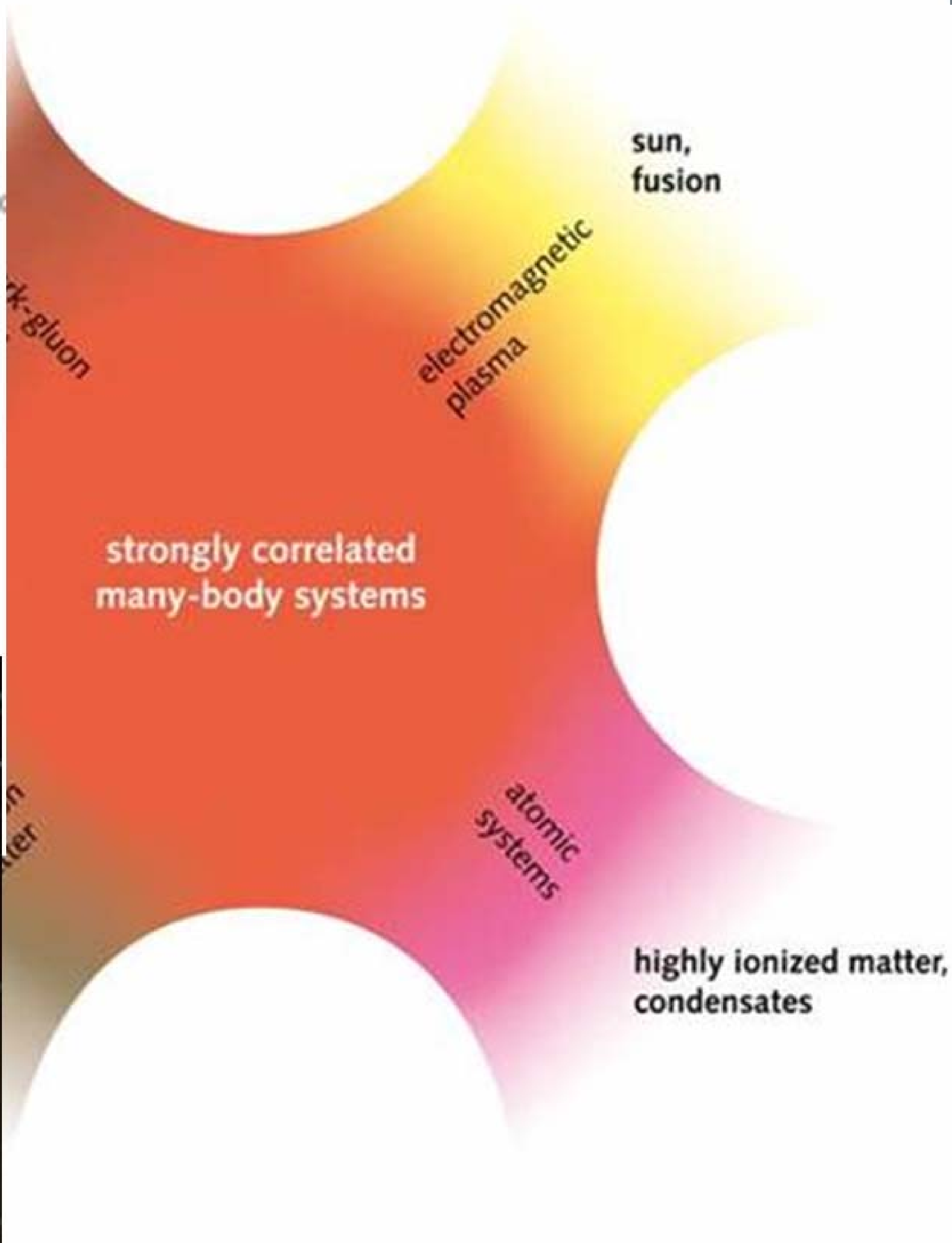

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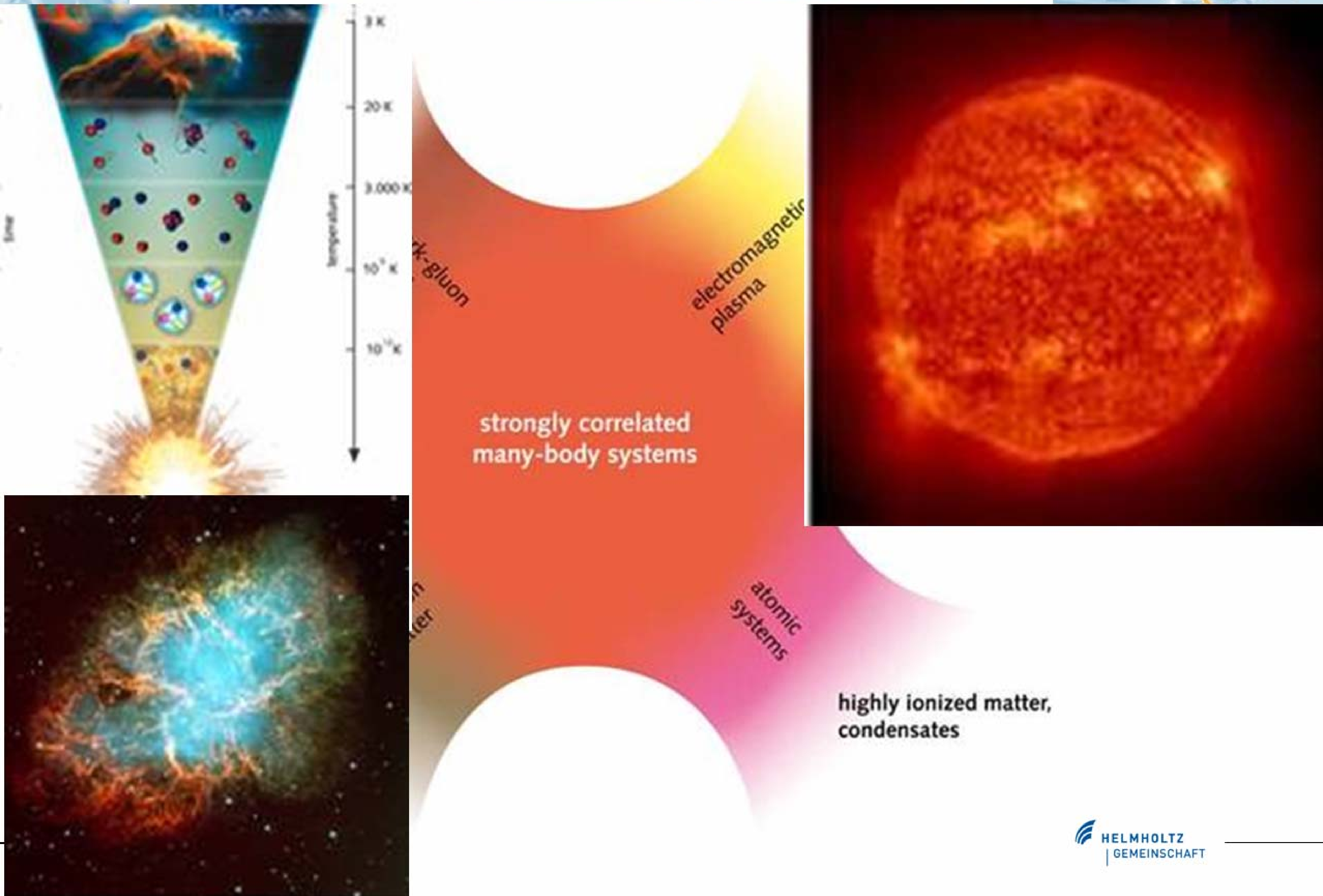

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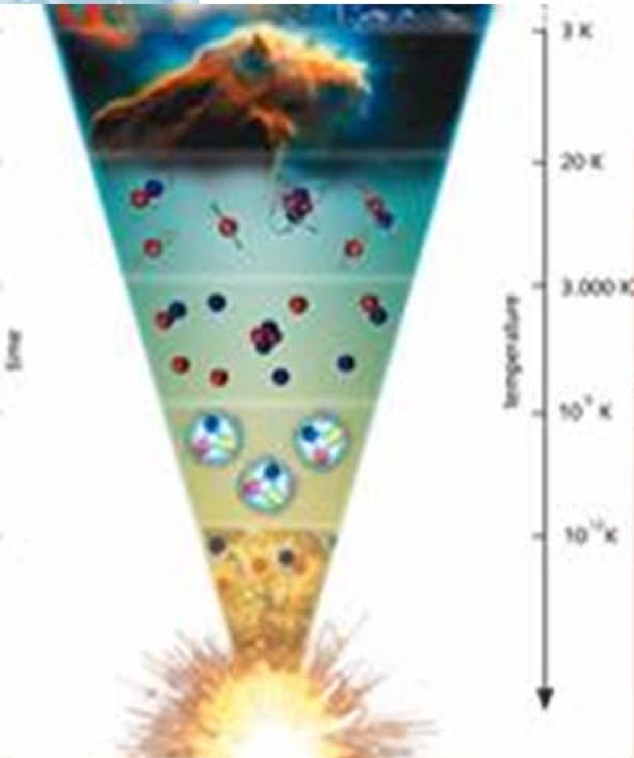
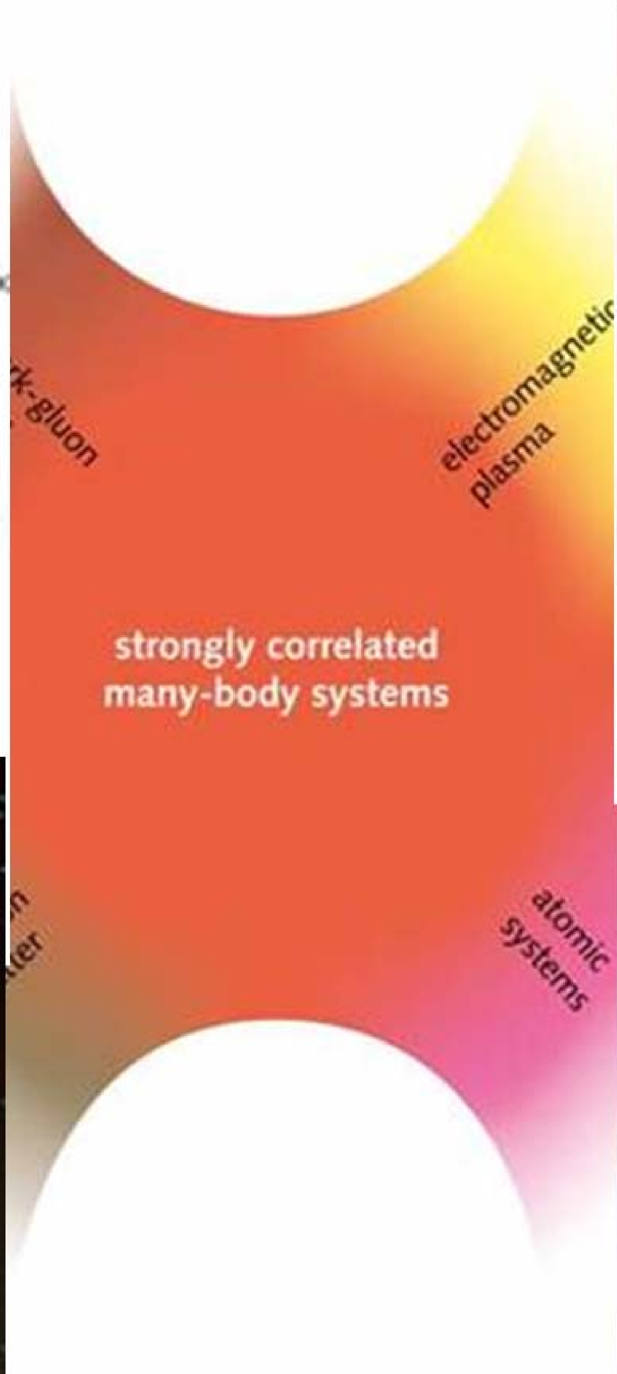
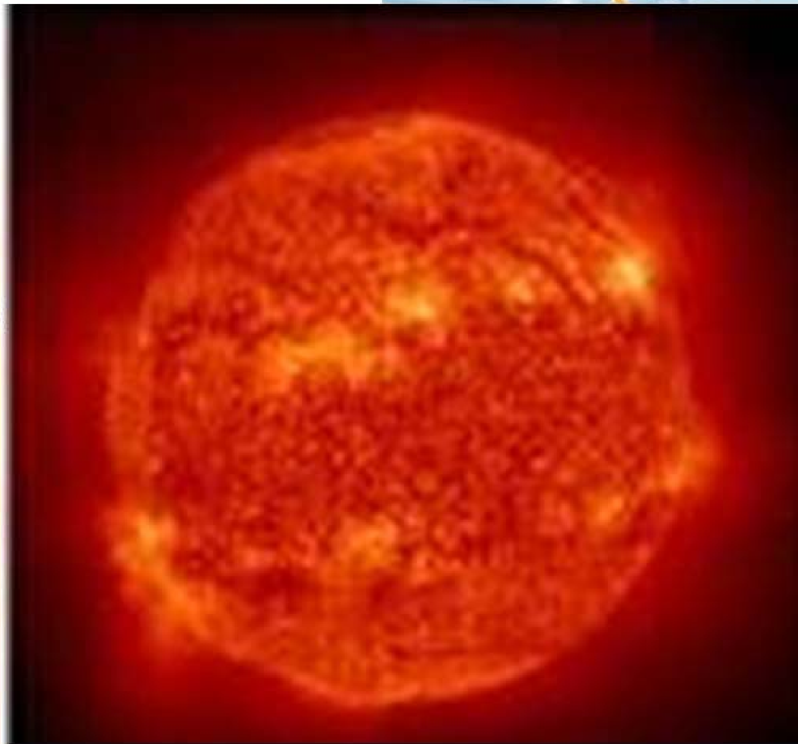
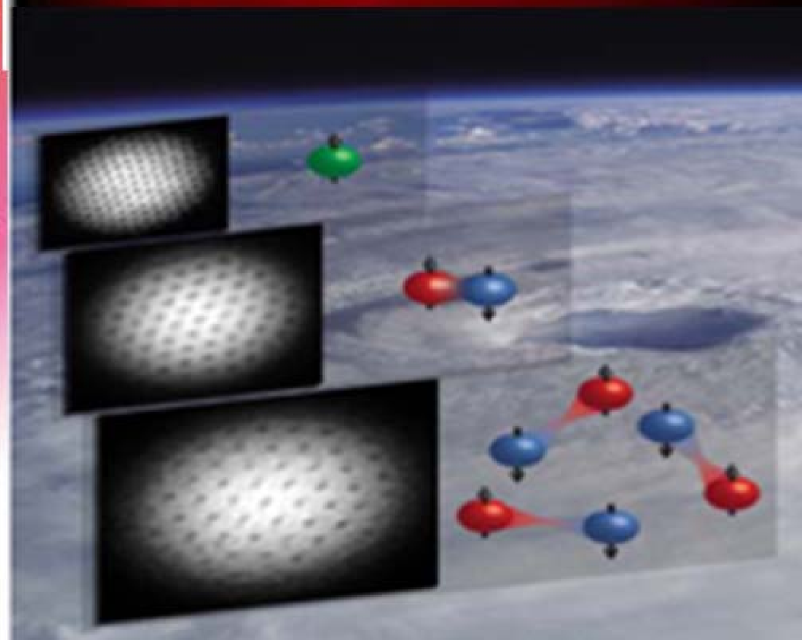


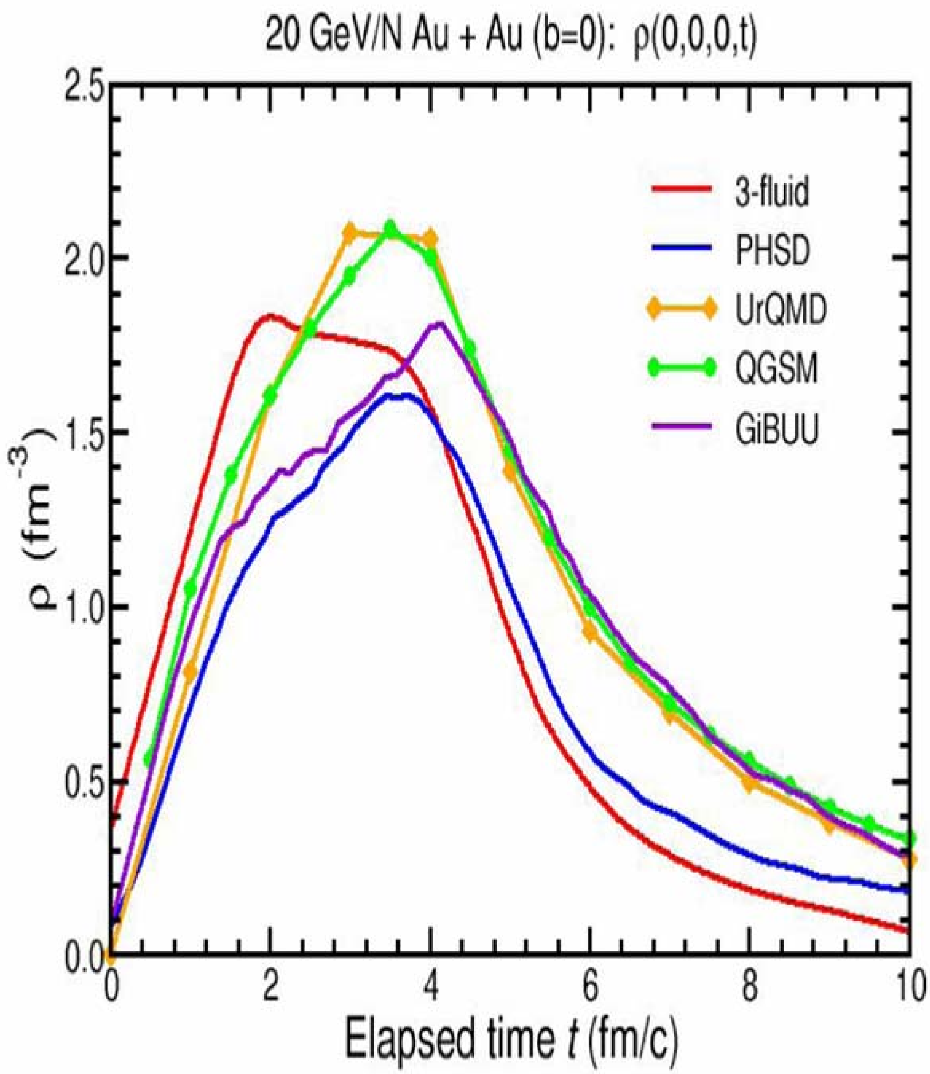


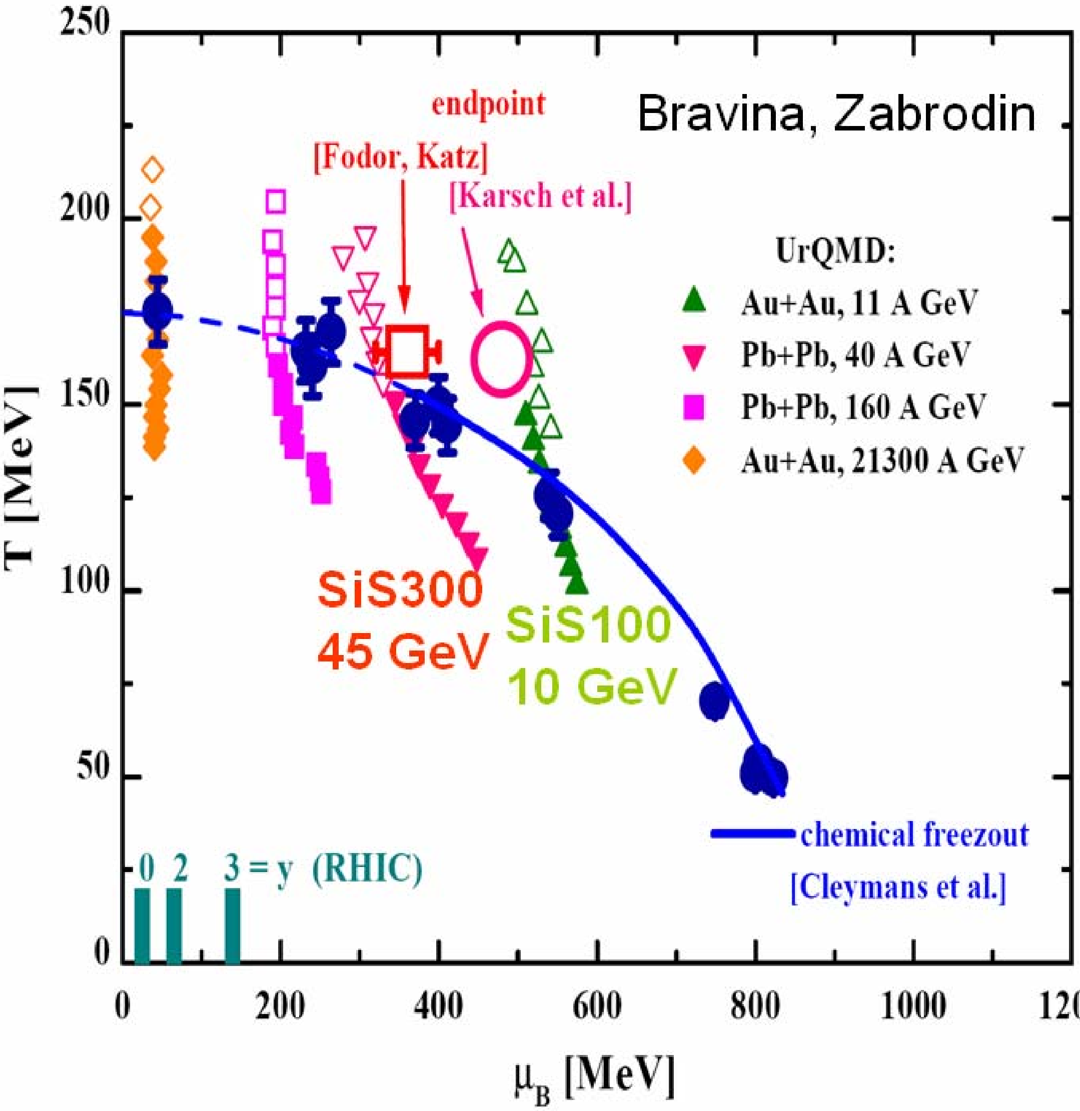




CBM @ FAIR:
QCD phases at High Density ρ_B

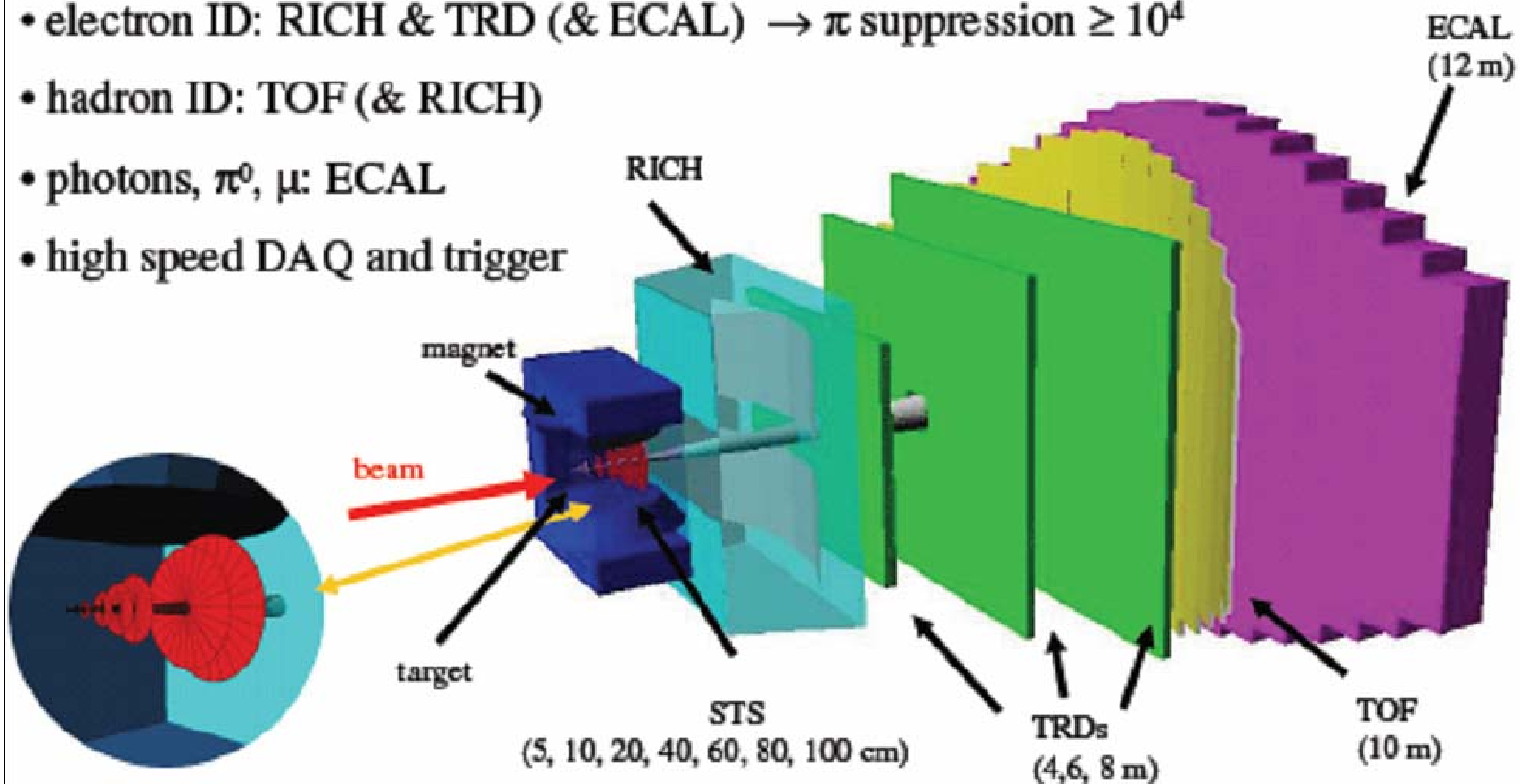
Tenfold Compression! Crossing that 1. Order Transition!





The CBM experiment

- tracking, momentum determination, vertex reconstruction: radiation hard silicon pixel/strip detectors (STS) in a magnetic dipole field
- electron ID: RICH & TRD (& ECAL) $\rightarrow \pi$ suppression $\geq 10^4$
- hadron ID: TOF (& RICH)
- photons, π^0, μ: ECAL
- high speed DAQ and trigger

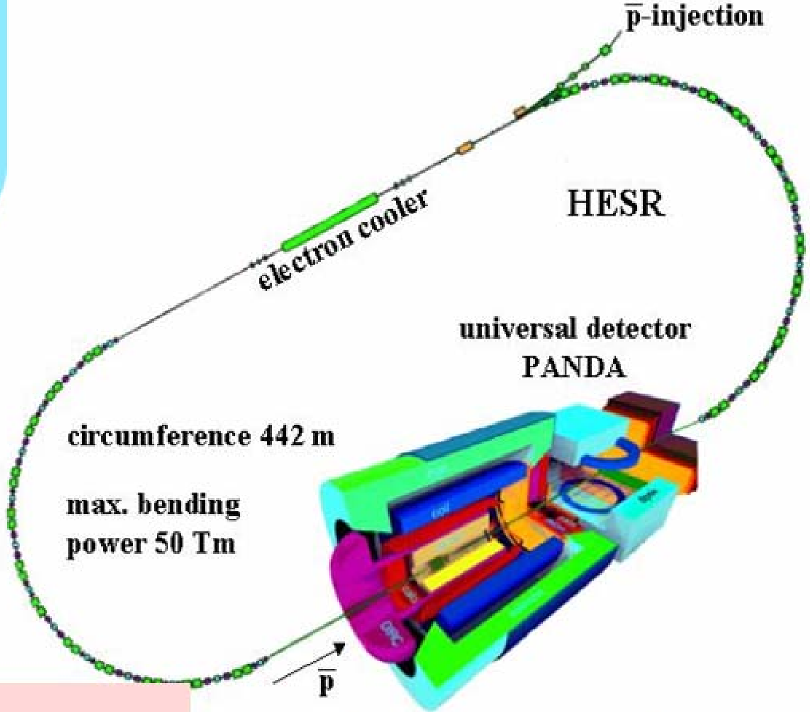


FAIR QCD-Physics Program with Antiprotons

strange and charmed (anti-) baryons in nuclear field

hidden and open charm in nuclei

glueballs (ggg) hybrids ($c\bar{c}g$)



J/ψ spectroscopy confinement, in-medium effects

fundamental symmetries: $\bar{p}$ in traps

FLAIR

HESR Consortium
Jülich / Uppsala / Stockholm / GSI

PANDA

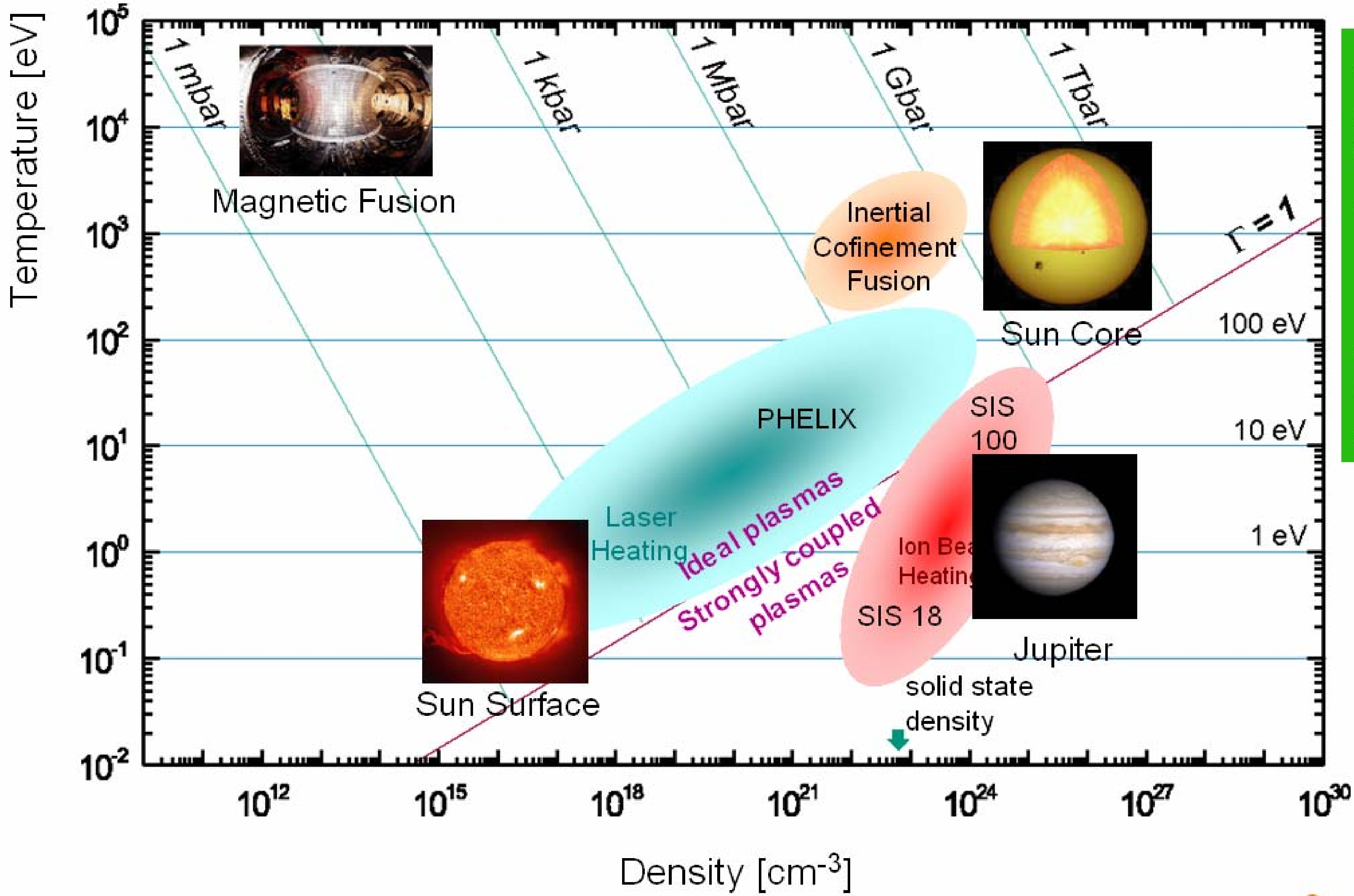
CP-violation (D/Λ - sector)

inverted deeply virtual Compton scattering

spin structure of the proton: polarized antiprotons in PAX

Plasma physics with intense ion bunches and Petawatt Laser pulses

Matter at high energy densities

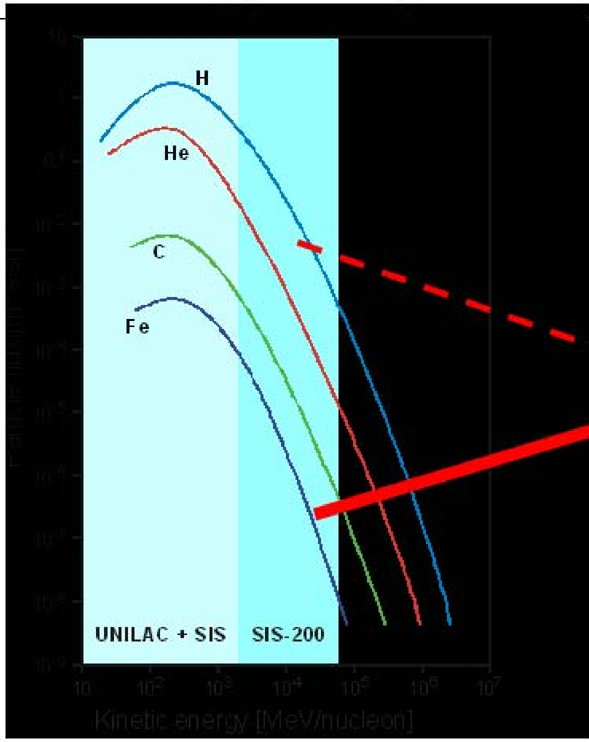


Physics of Fast Ignition (another way to clean energy production)

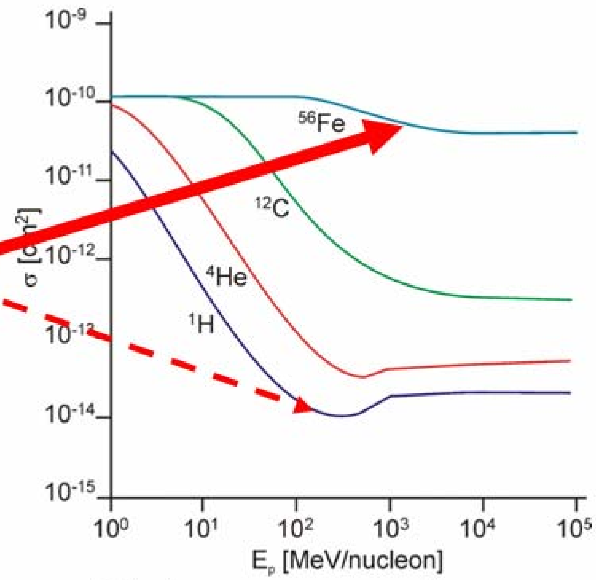
Equation of state of planetary and stellar matter

Applied Research

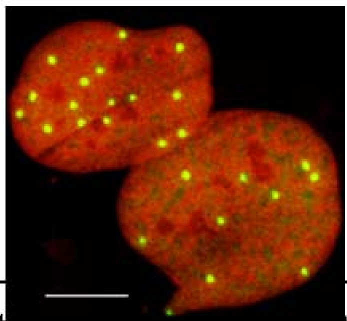
Radiobiology for space research and carbon ion tumor therapy



Cosmic particle spectrum



Risk cross sections



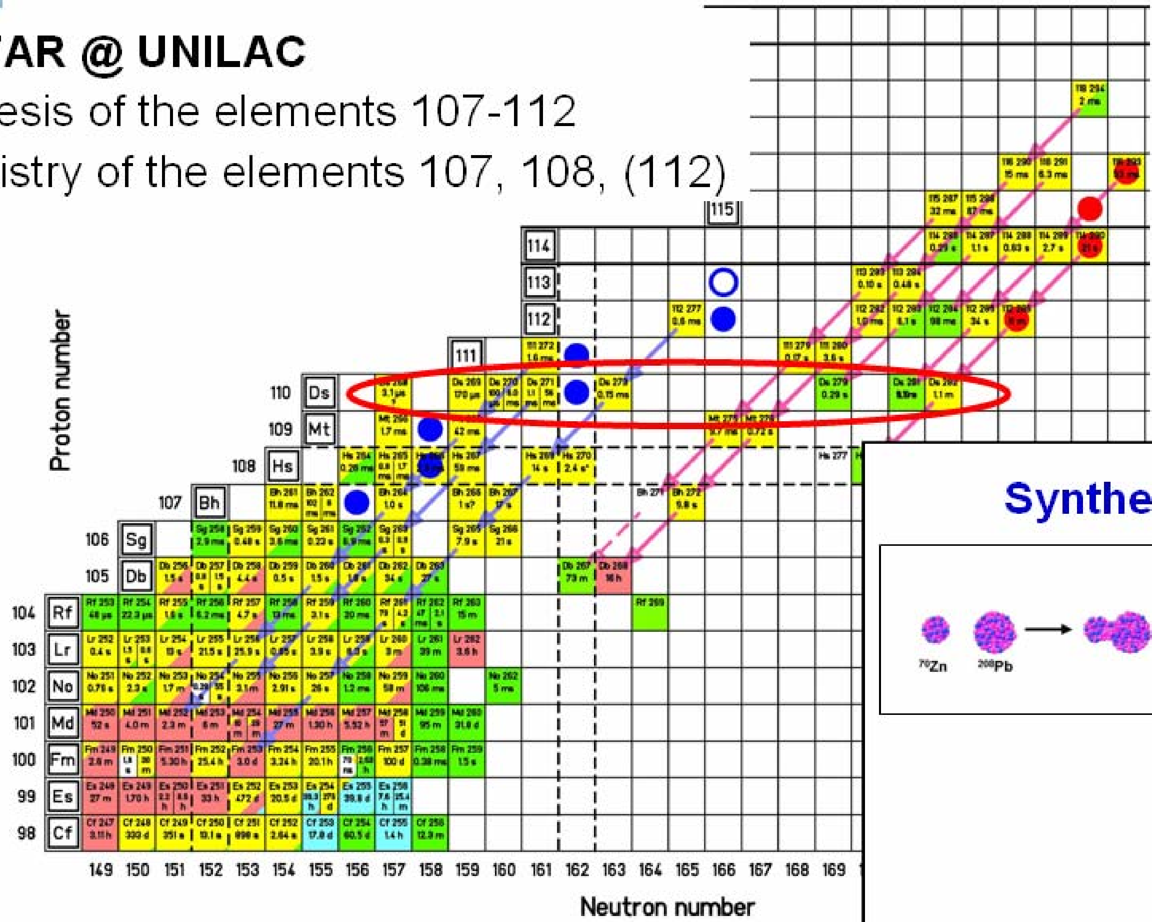
Approaches for risk estimates:
- **Cytogenetics**
- **Cell transformation**
- **Tissue effects**
- **Modelling**

Synthesis and study of the heaviest elements

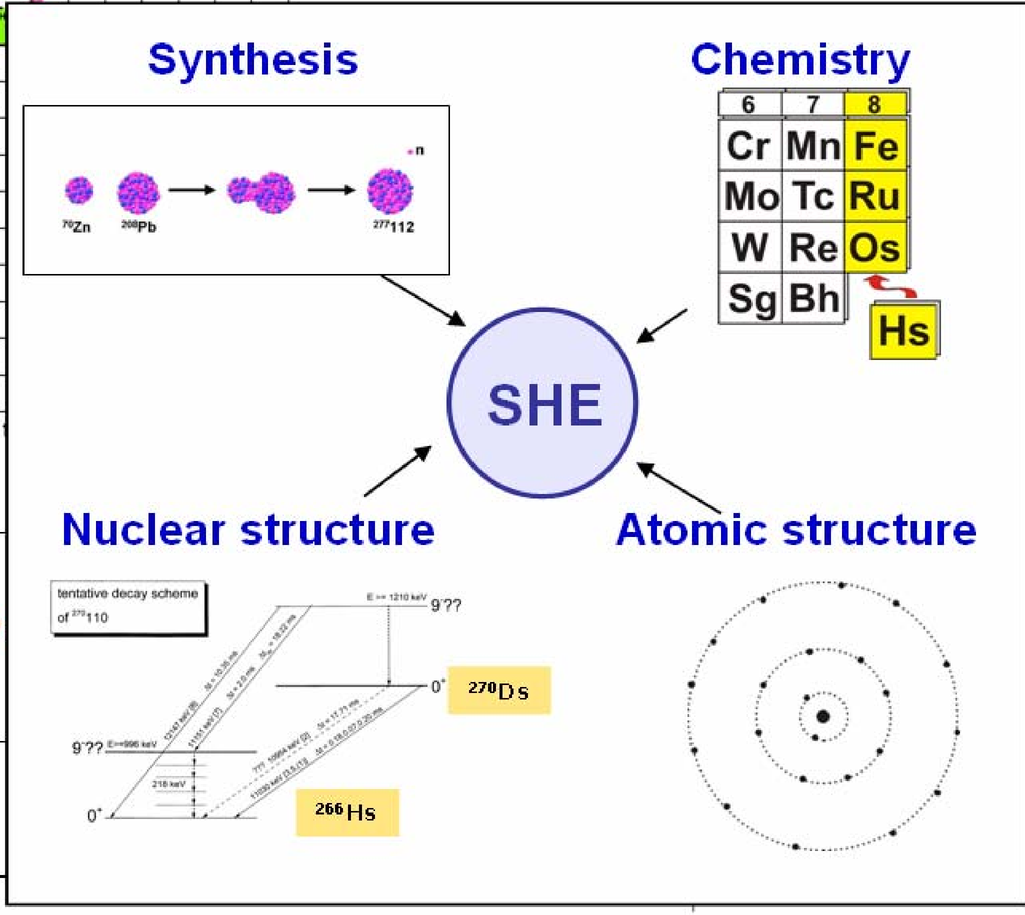
NUSTAR @ UNILAC

Synthesis of the elements 107-112

Chemistry of the elements 107, 108, (112)



SHIP and TASCA

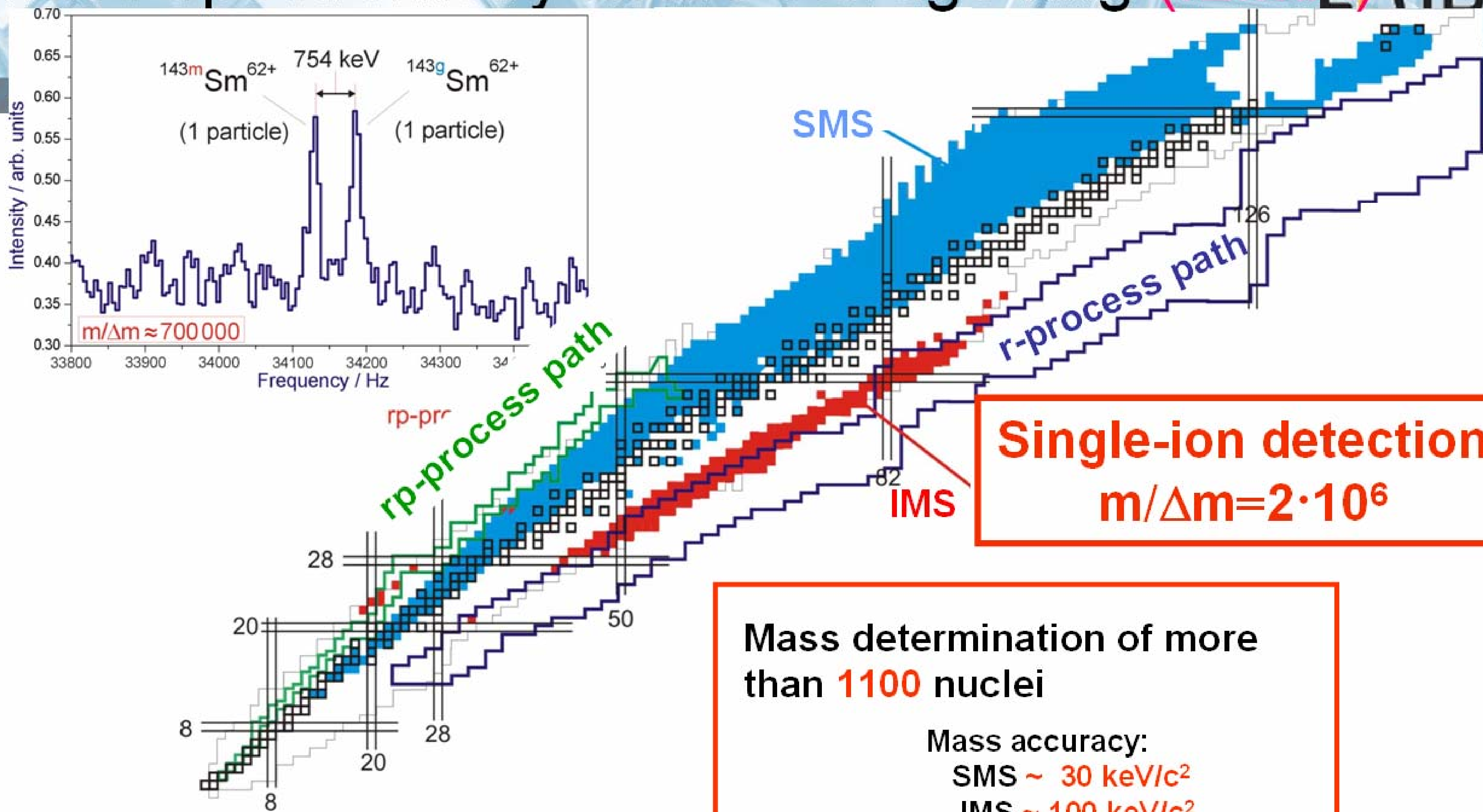


IUPAC:

Element 110 is named "Darmstadtium"

Chemical symbol is "Ds"

Mass spectrometry at the storage ring (ILIMA)



Single-ion detection
$m/\Delta m = 2 \cdot 10^6$

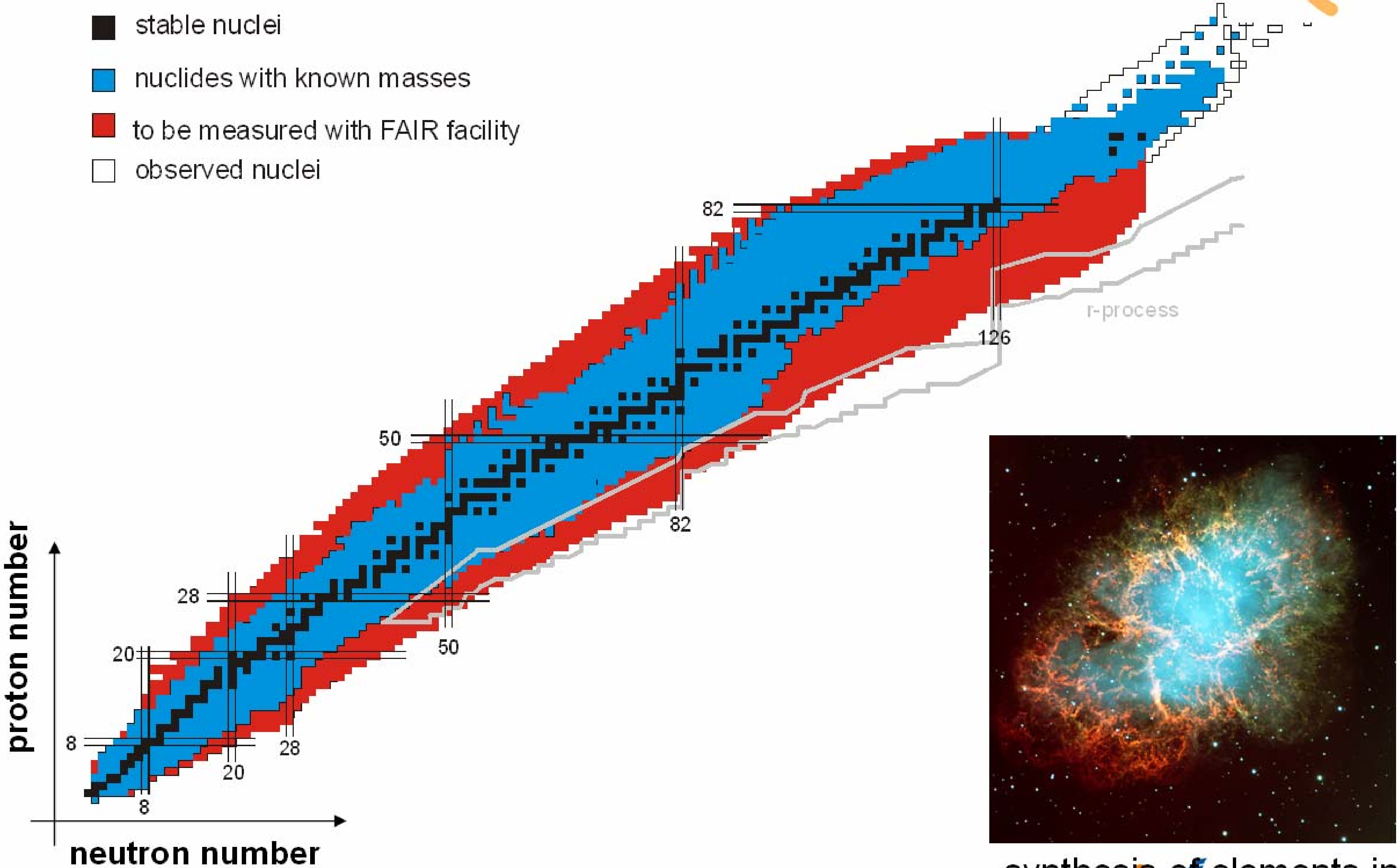
Mass determination of more than 1100 nuclei

Mass accuracy:
SMS ~ 30 keV/c²
IMS ~ 100 keV/c²

Results:

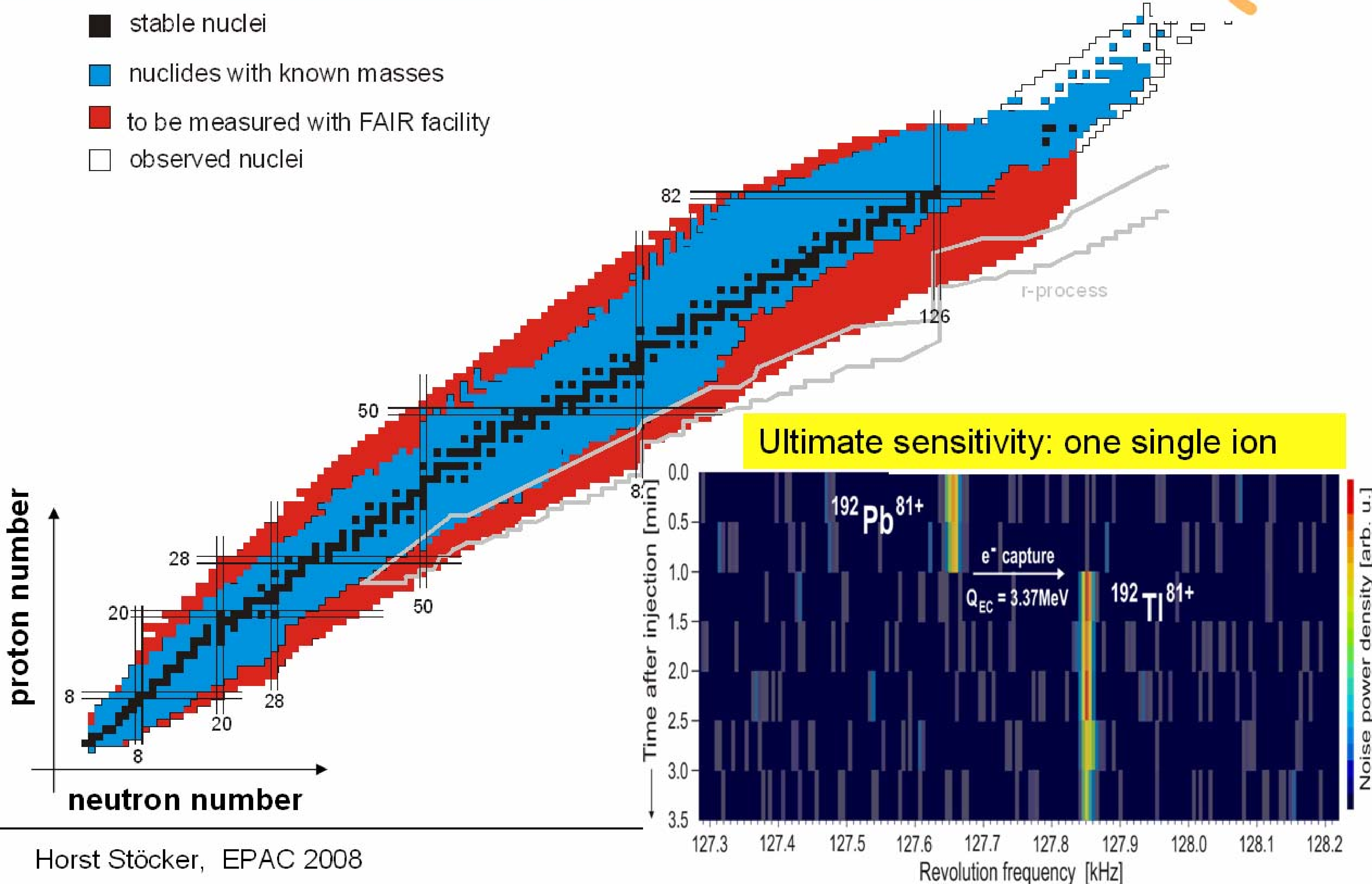
~ 350 new mass values
~ 300 improved mass values

R-Process Nuclei - to be measured at FAIR

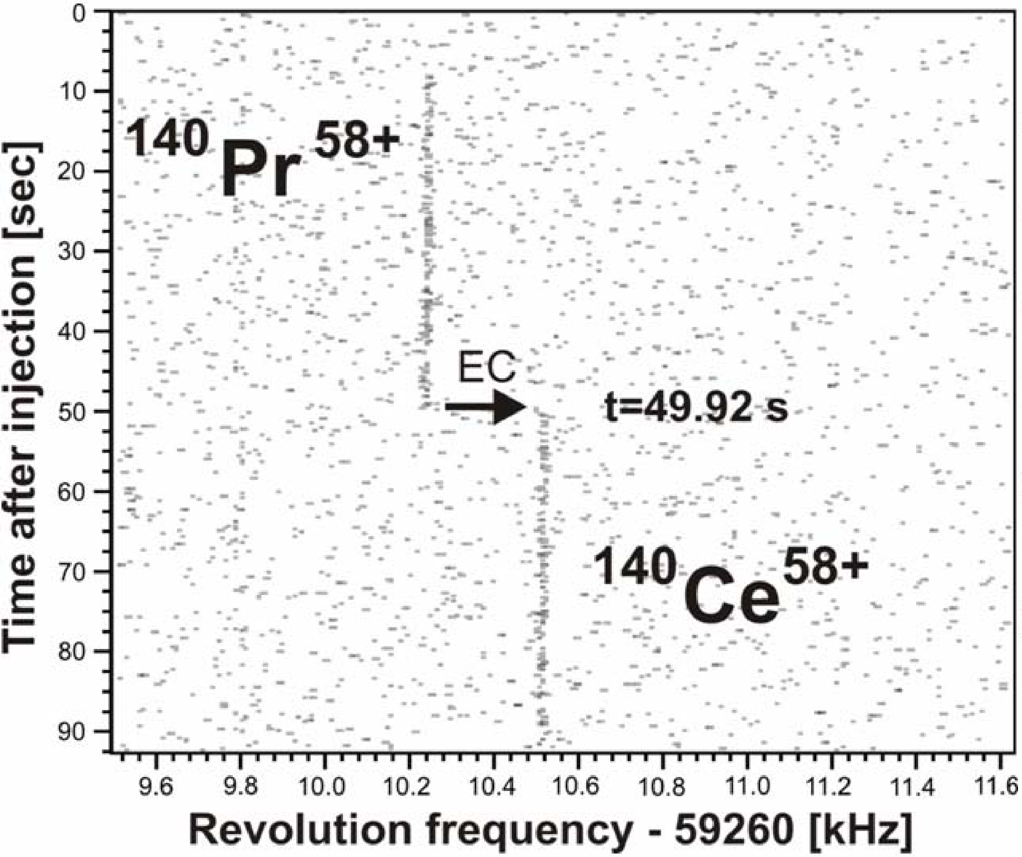


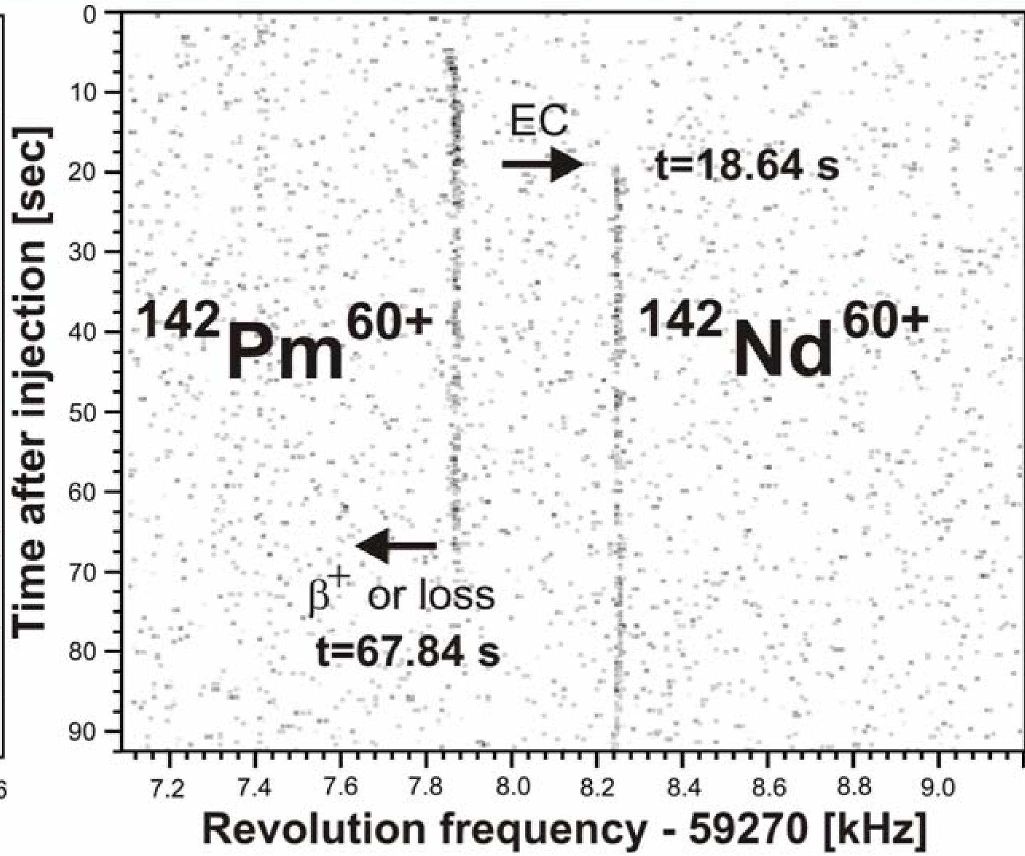
synthesis of elements in supernova explosions

R-Process Nuclei - to be measured at FAIR



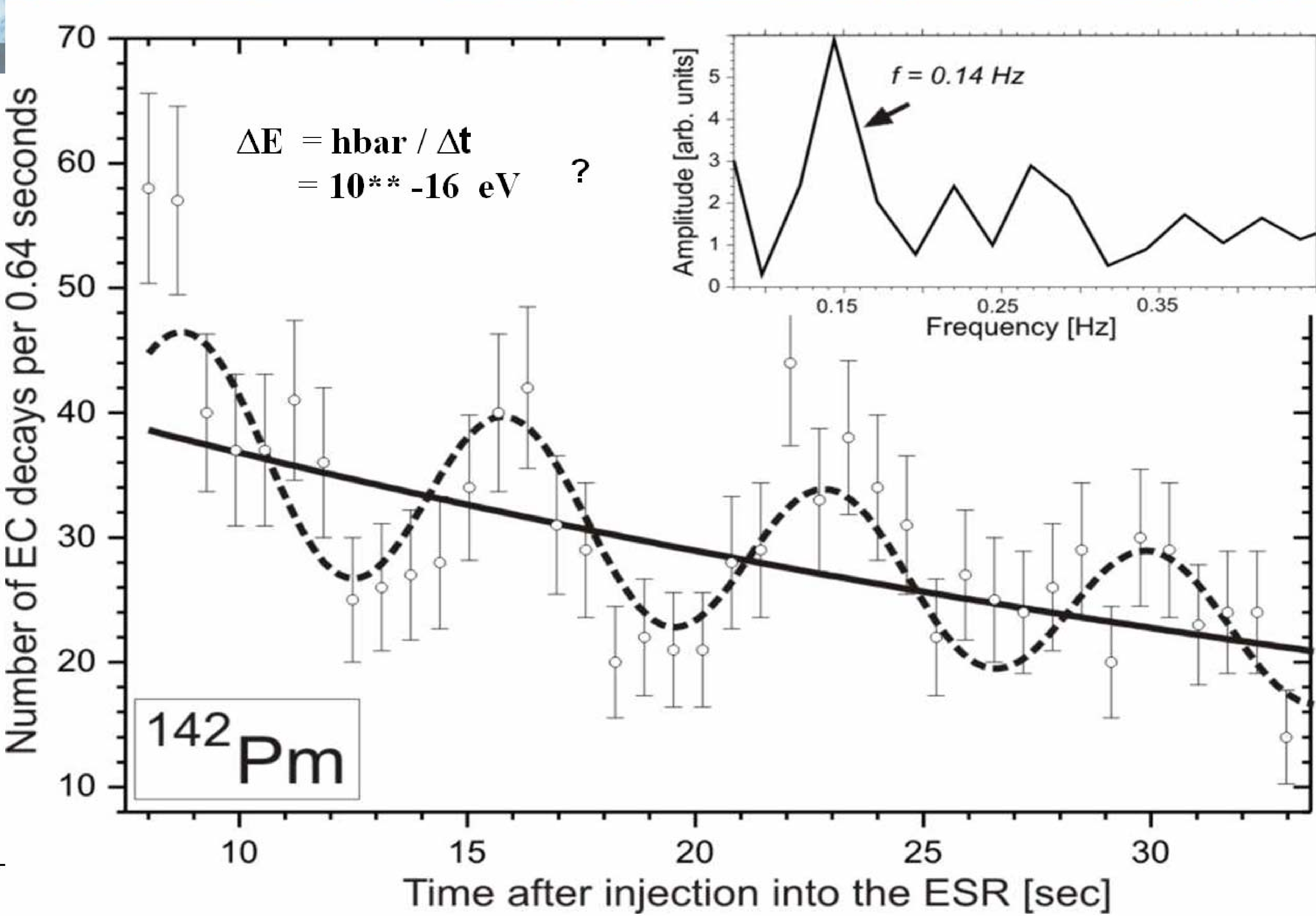
Horst Stöcker, EPAC 2008





1. Continuous observation
2. Parent/daughter correlation
3. Detection of all EC decays
4. Delay between decay and "appearance" due to cooling

^{142}Promethium: zoom on the first 33 s after injection



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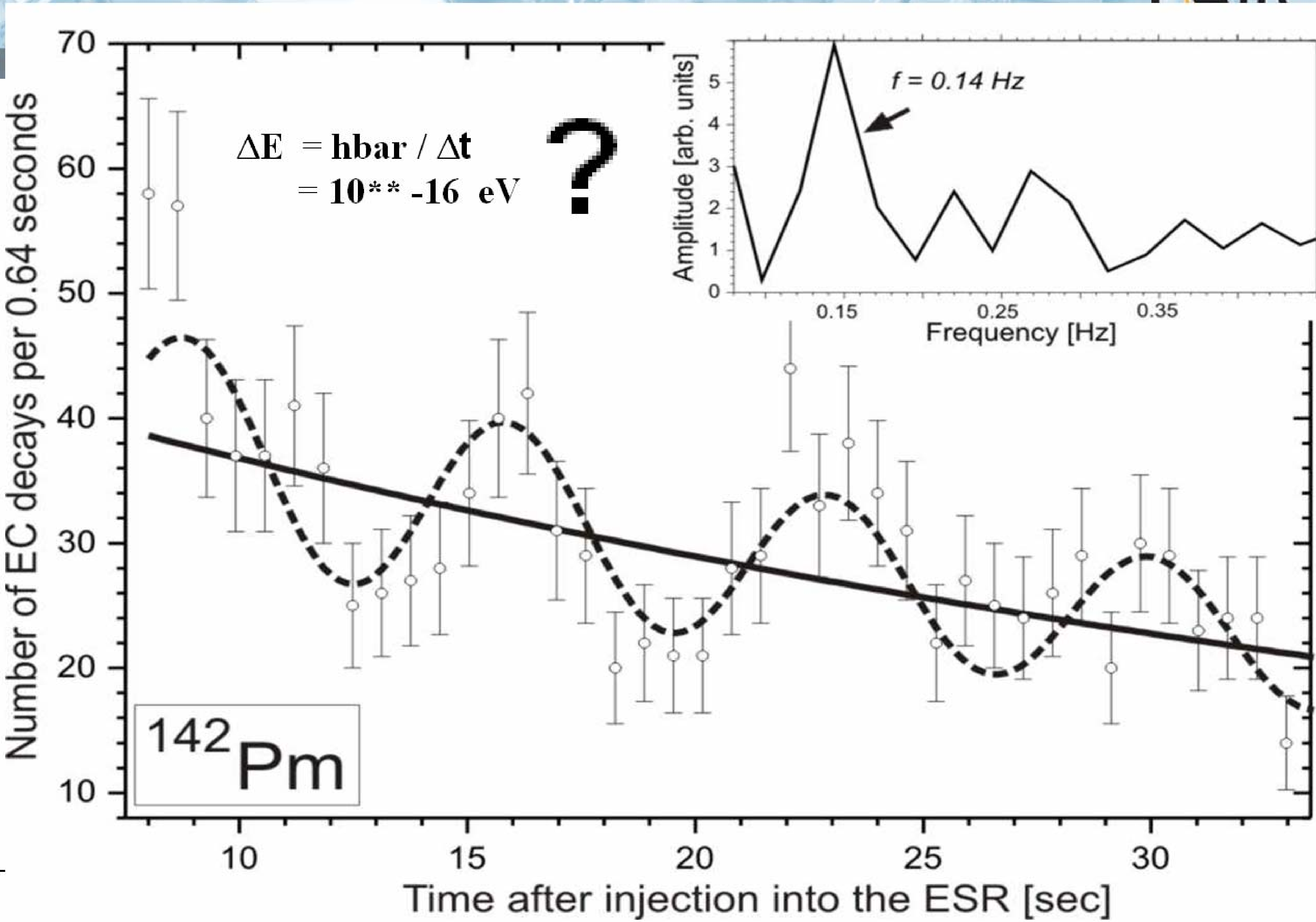


Scattering stored beams off hadronic probes (EXL)

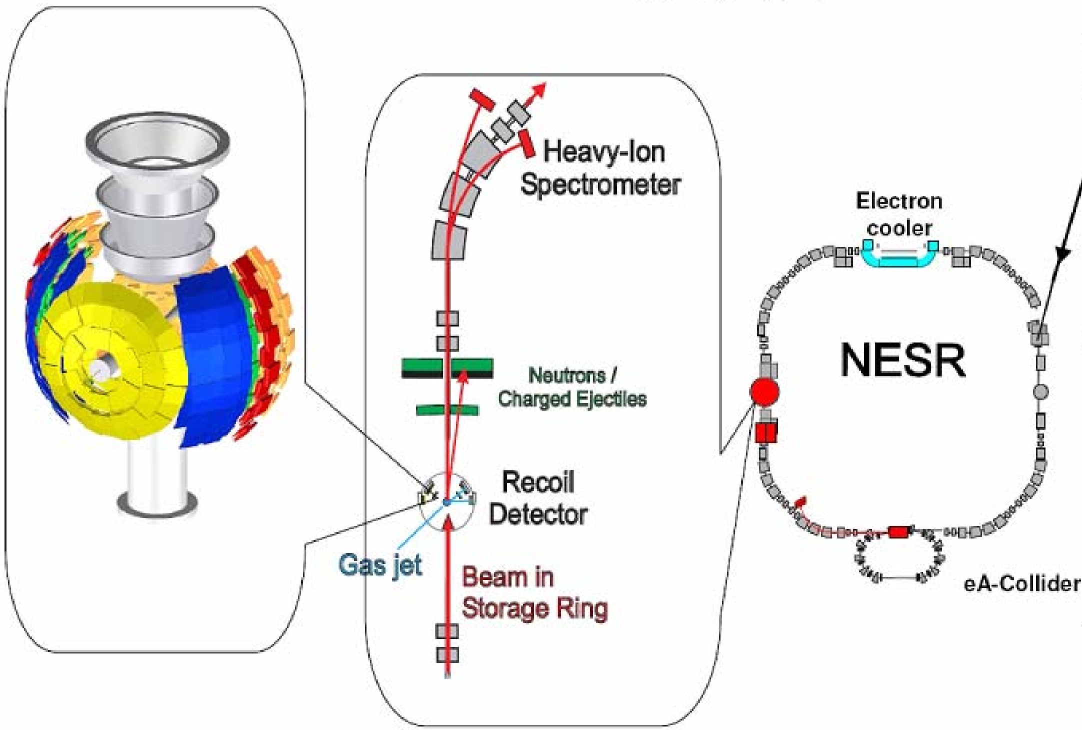
- Inverse kinematics
- Thin gas target (~$10^{15}/cm^2$)
- Kinematically complete measurement
  - Elastic scattering (p,p) …

) …

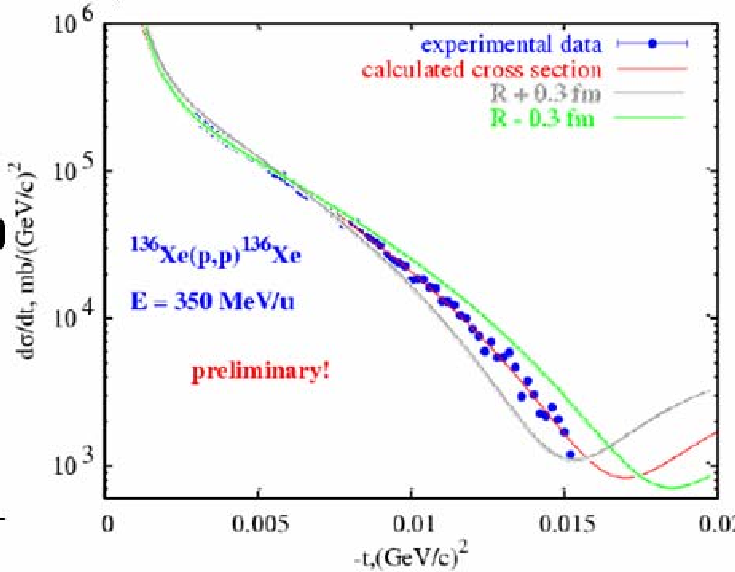
,n),

,2p

→ Excitation energy and form factors via recoil ions at small energy / small momentum transfer



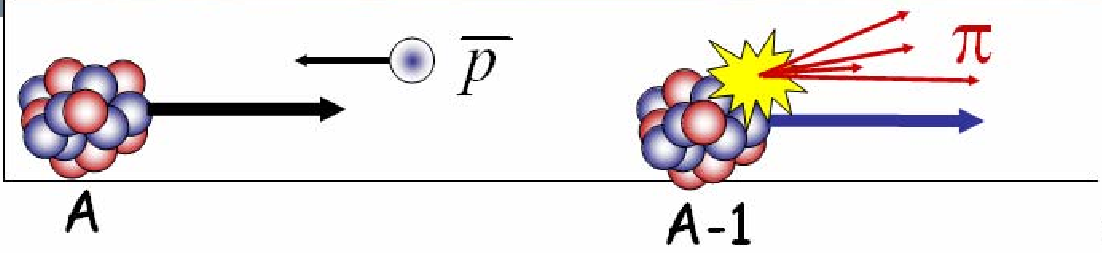
Feasibility study (p,p) with 350 MeV/u ^{136}Xe-ions at ESR

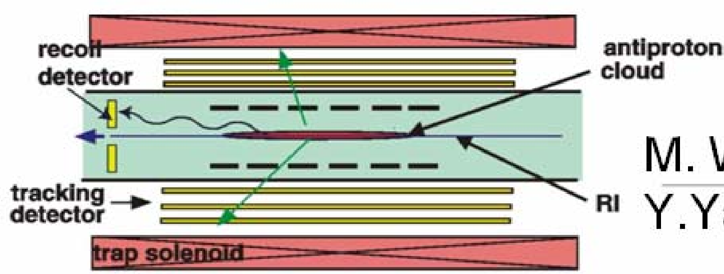


Nuclear matter radius: R_m = 4.89 (10) fm

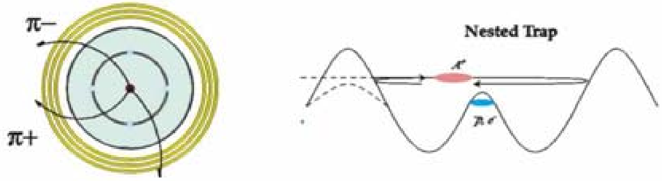
S. Ilieva et al., Eur. Phys. J. Special Topics 150, 357–358 (2007)

Antiprotonic reactions AIC + exotic Atoms exo





M. Wada, Y.Yamazaki



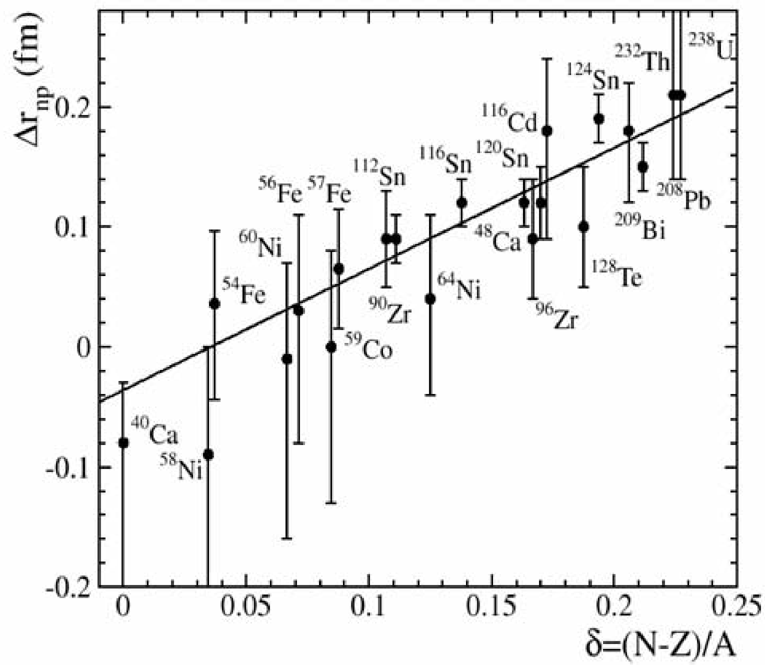
AIC:

at high energy the annihilation cross-section becomes proportional to the mean square radius

exo+pbar:

antiprotonic X rays and pions provide information on the nuclear periphery

➔ Matter and neutron-proton distribution at the nuclear surface

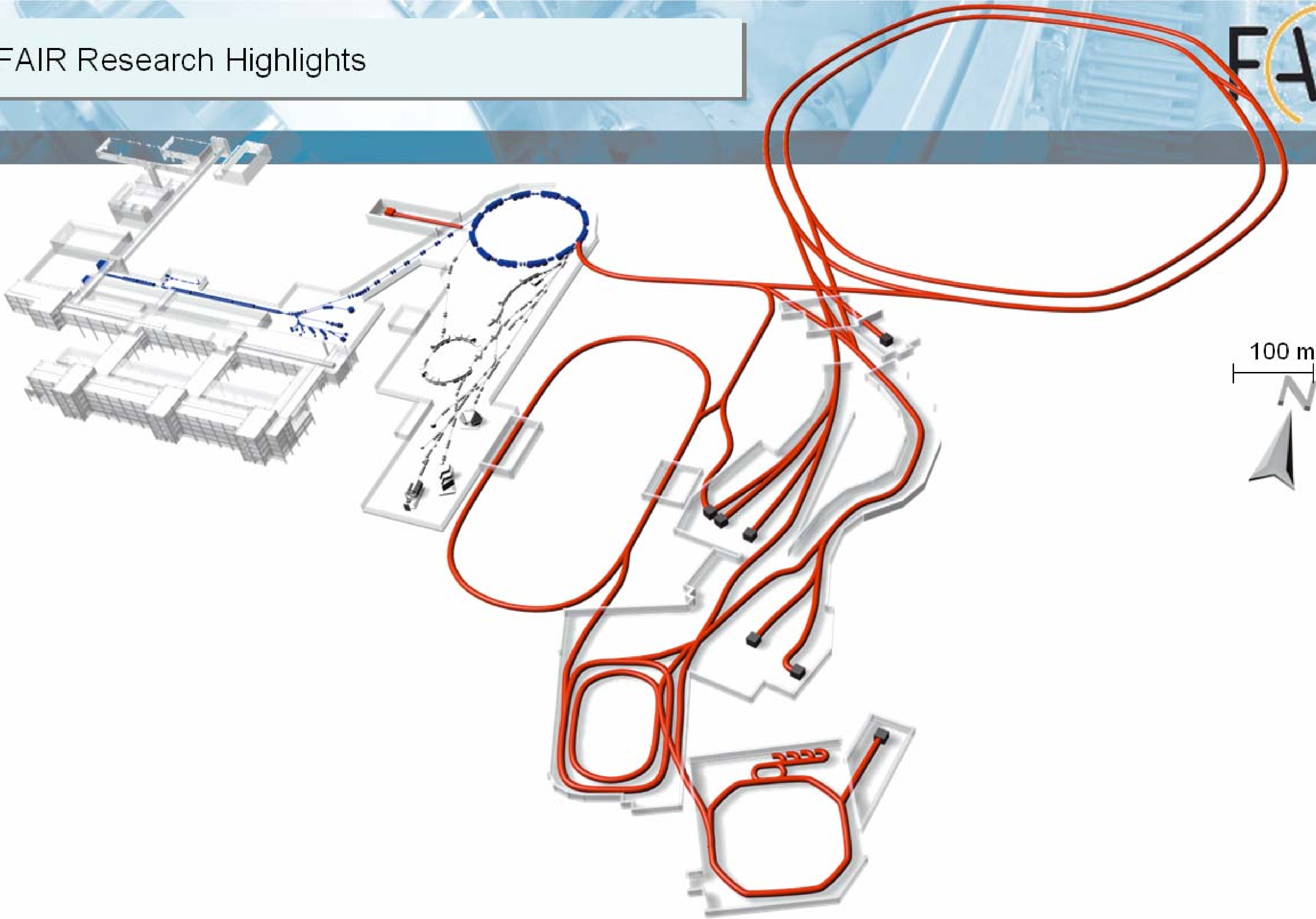


H. Lenske, P. Kienle, PL **B 647** (2007) 82

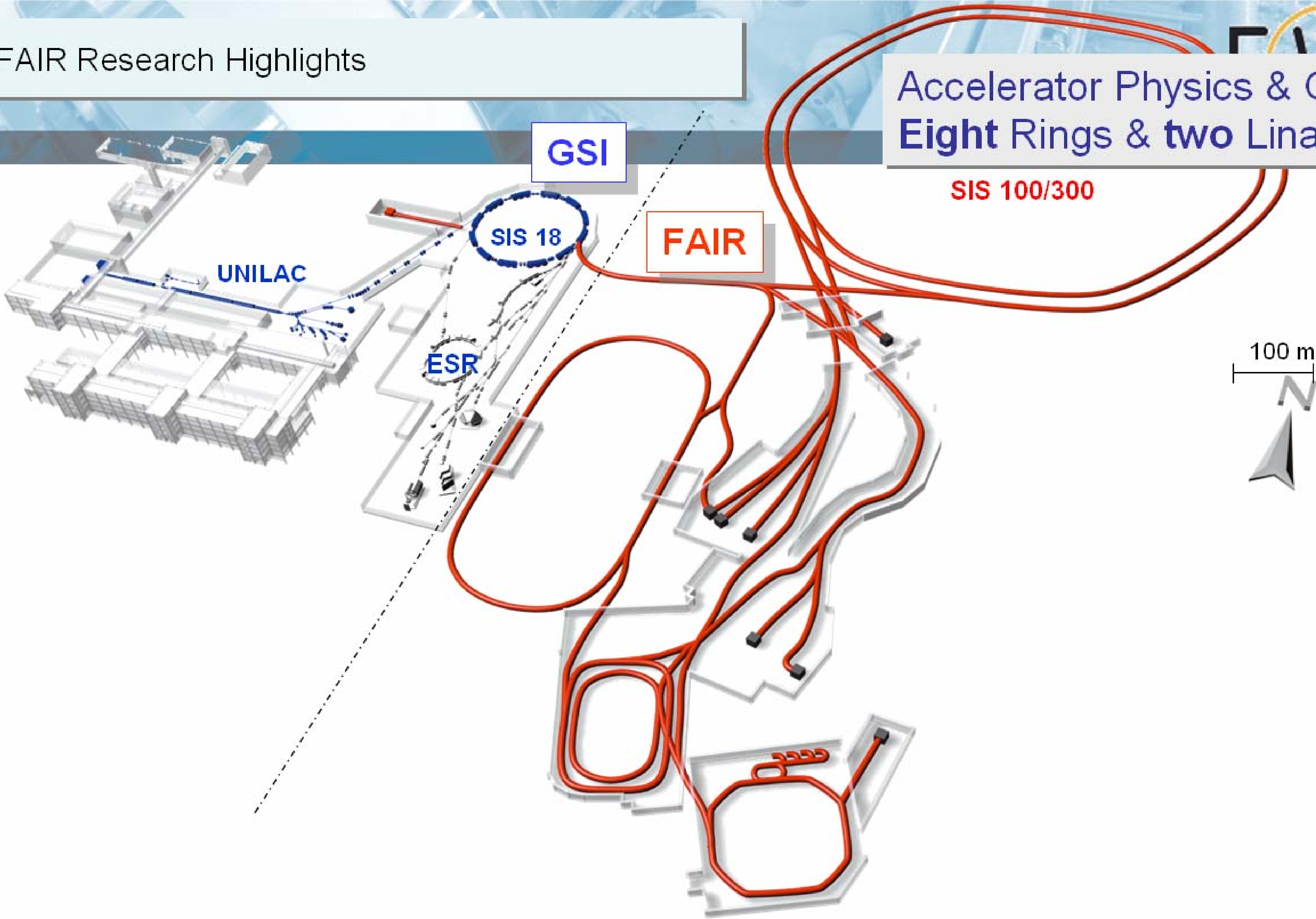
P. Kienle, NIM **B 214** (2004) 193

A. Trzcinska et al., PRL **87** (2001)

FAIR Research Highlights



Accelerator Physics & Gym: **Eight** Rings & **two** Linacs



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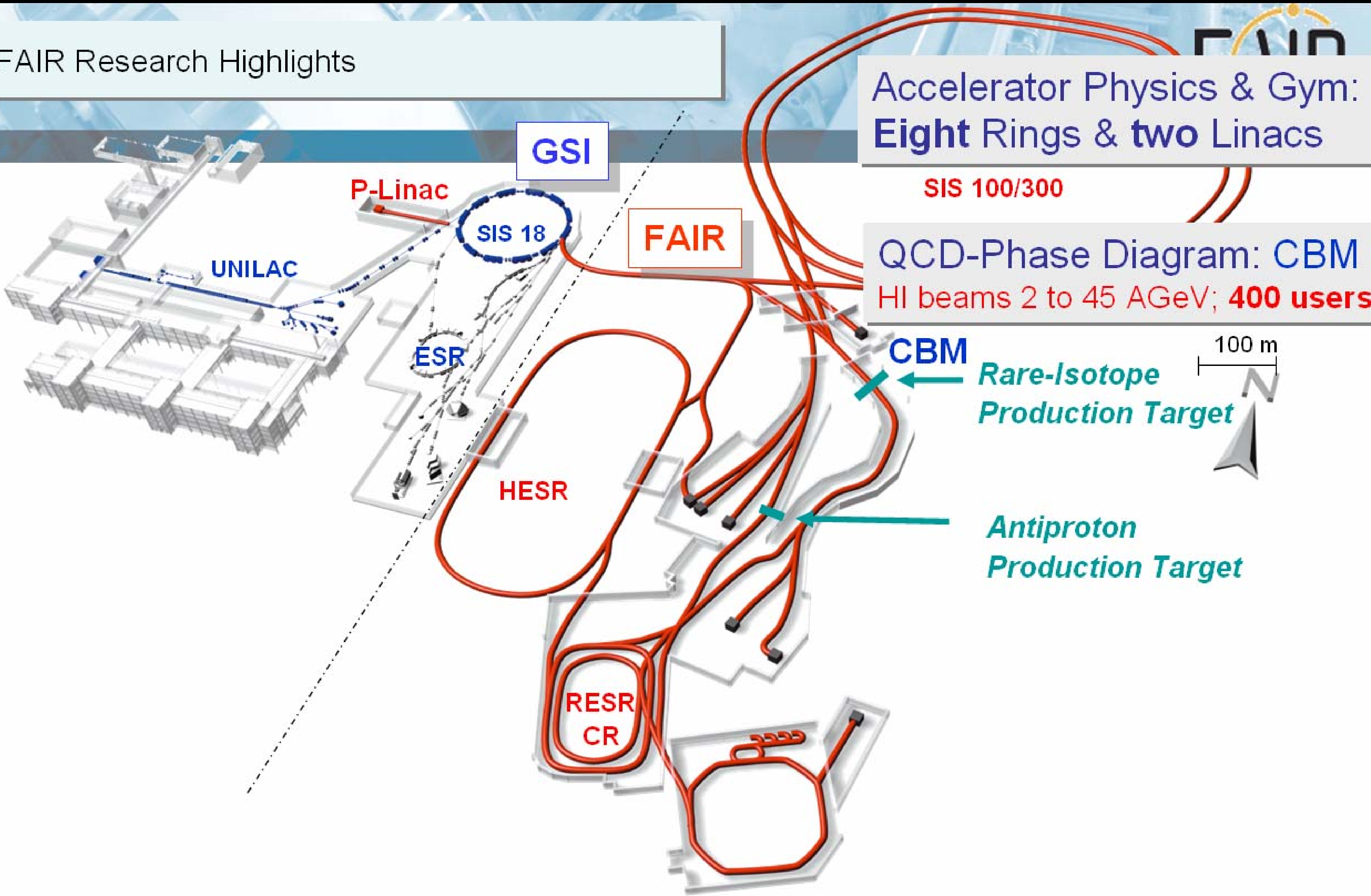
QCD-Phase Diagram: CBM
HI beams 2 to 45 AGeV; **400 users**



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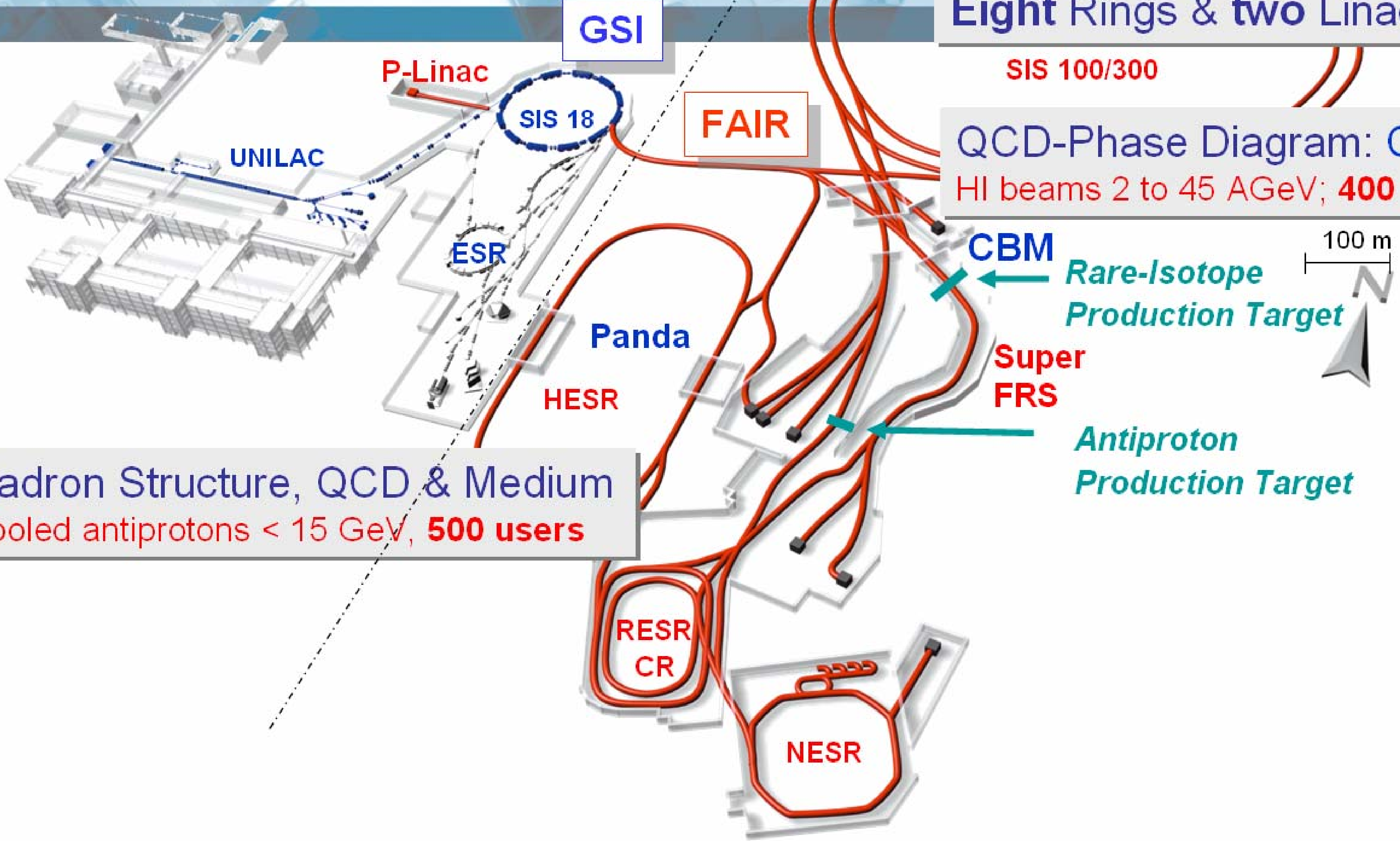

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Hadron Structure, QCD & Medium
Cooled antiprotons < 15 GeV, **500 users**

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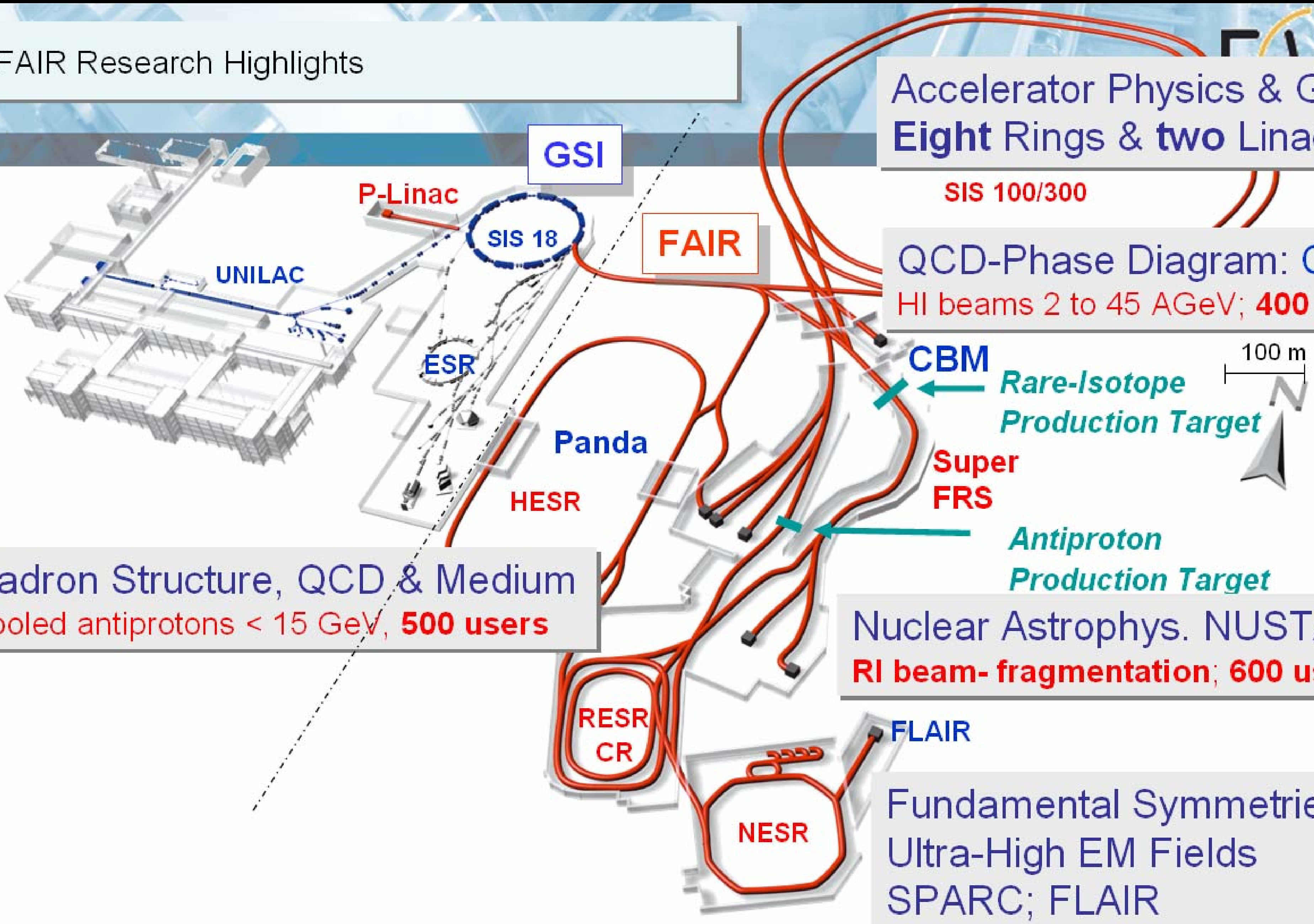

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Nuclear Astrophys. NUSTAR
RI beam- fragmentation; **600 users**

Fundamental Symmetries
Ultra-High EM Fields
SPARC; FLAIR
Antiprotons, Hi-Z ions; **250 users**

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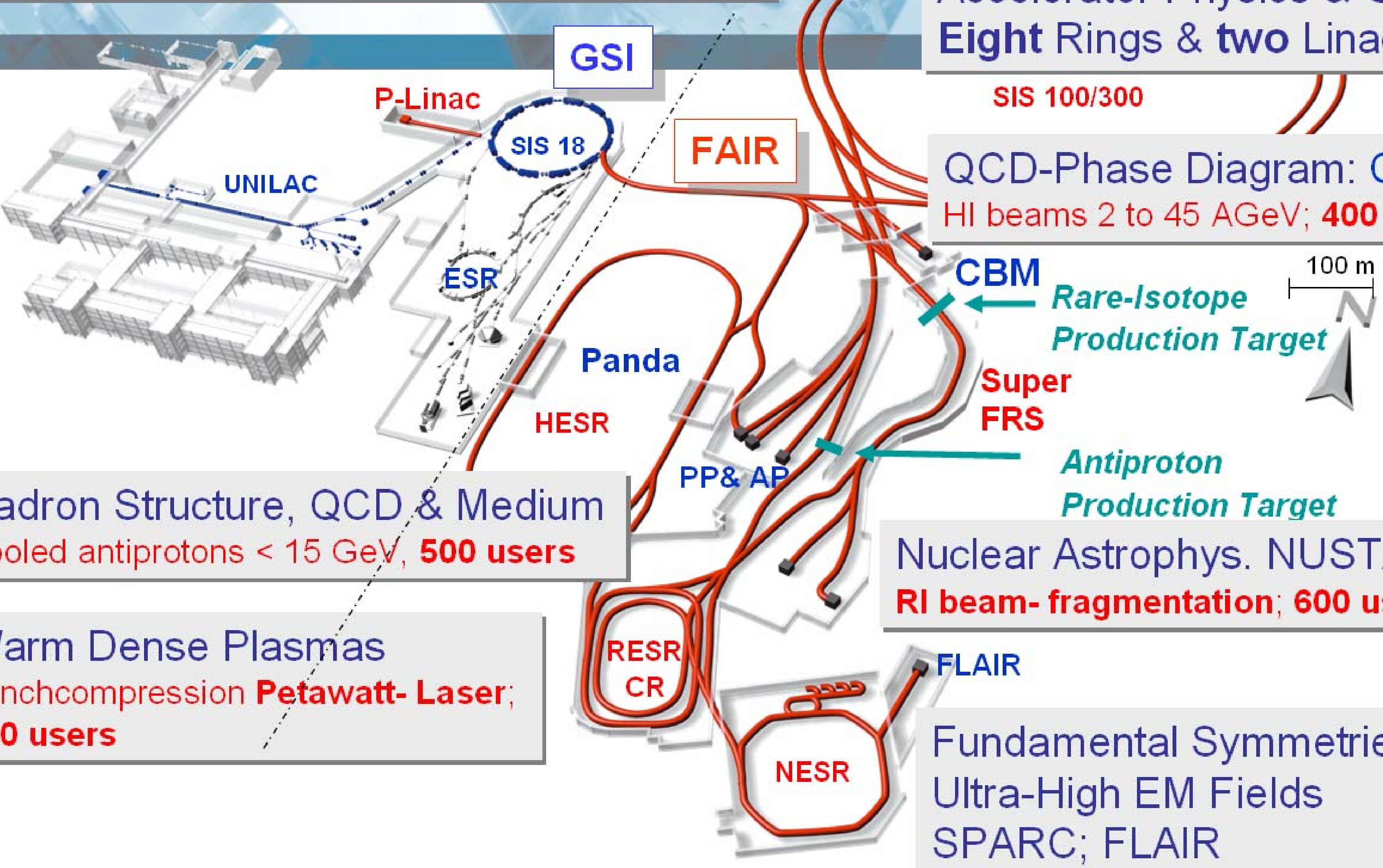

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Warm Dense Plasmas
bunchcompression **Petawatt- Laser**;
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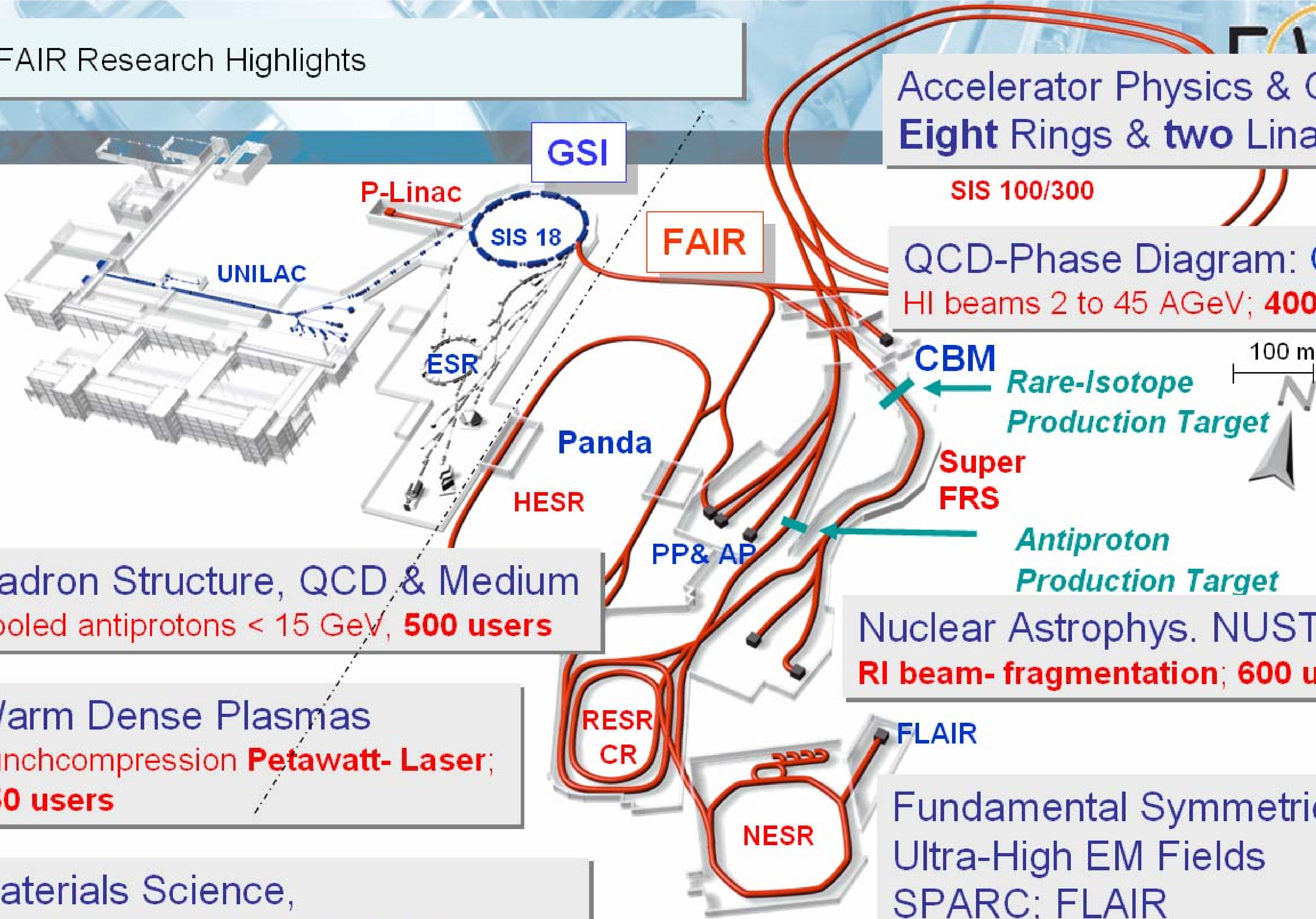

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SPARC; FLAIR
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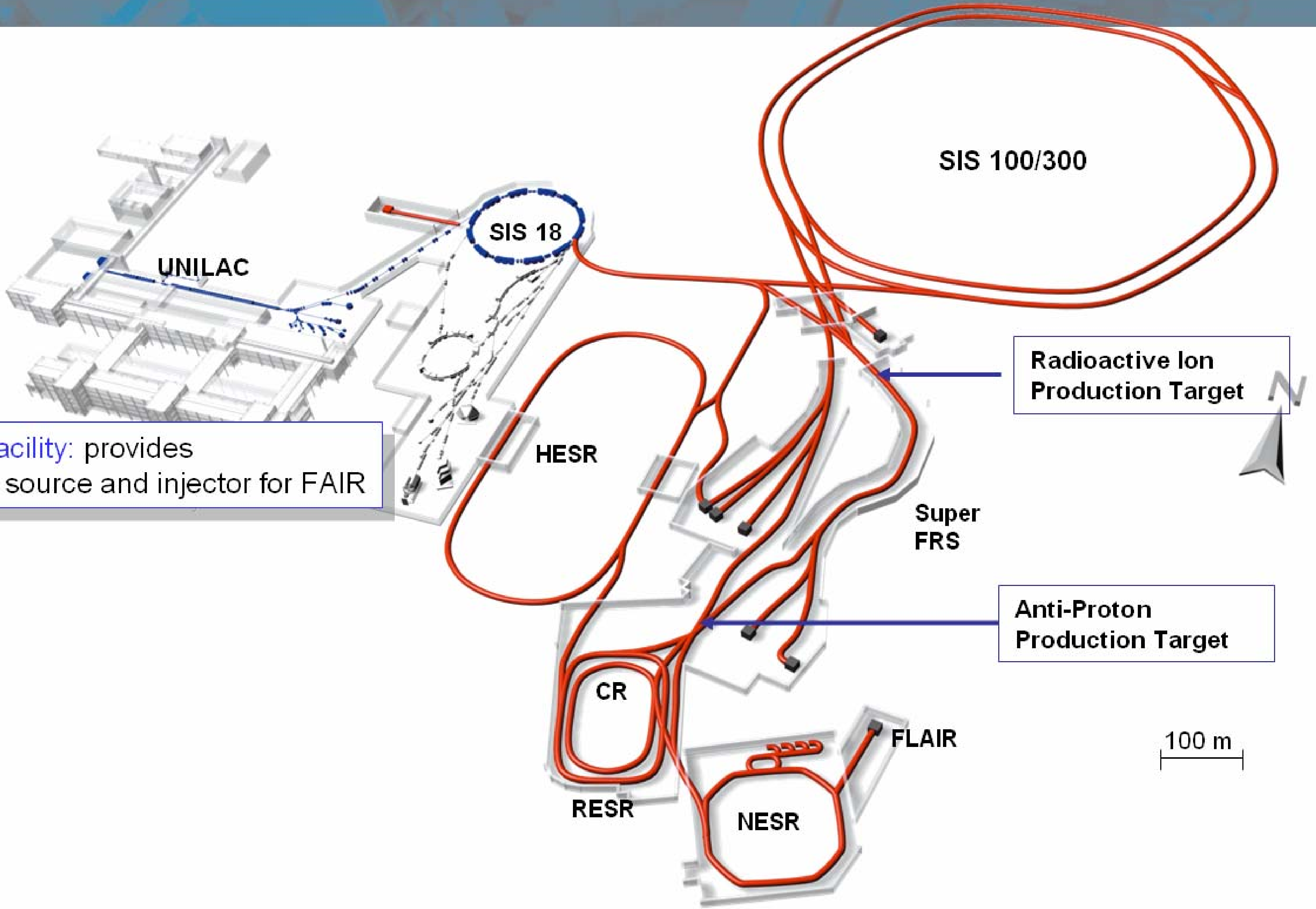
Materials Science,
Space- and Radiation Biology
(Ion- & antiproton- beams; **350 users**

Experiment Requirements (exemplarily)

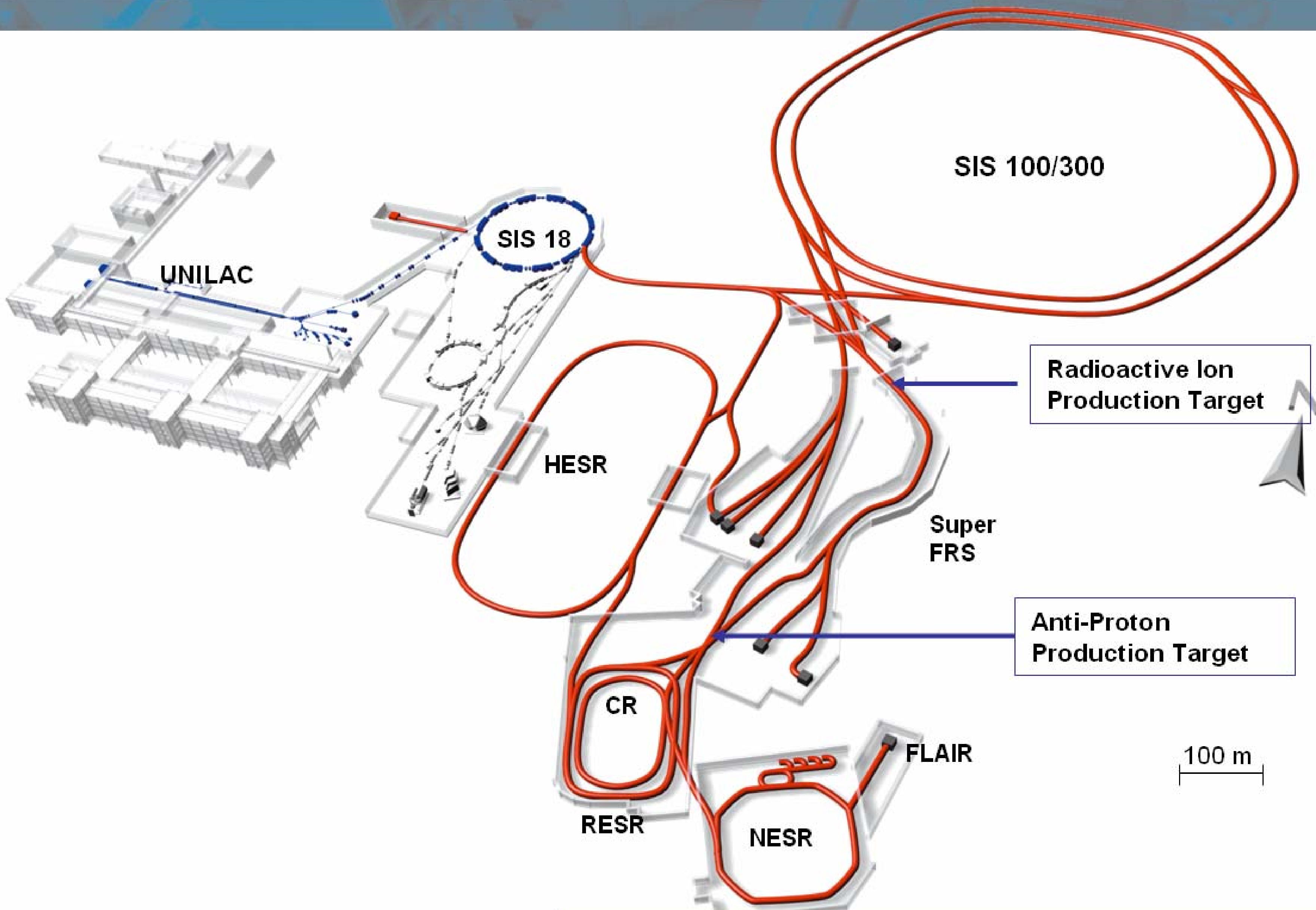
- **NUSTAR**: 2 x 10^{11}/pulse U^{28+} @ 200 MeV/u
  bunch compression to 70 ns
  highest gain factors for exotic nuclear beams
- **CBM**: Heavy-ion beam intensities of 10^{10} particles/s
  @ 34 GeV/u for U^{73+}
- **PANDA**: pbar in wide momentum range (1.5 - 15 GeV/c)
  High luminosity and high momentum resolution
- **FLAIR**: Cooled antiprotons in the 20 keV range
- **SPARC**: Cooled and high brilliance beams of rare isotopes
- **Plasma Physics**:
  High intensity beams
  bunch compression to 70 ns

Ultimate Realization of FAIR



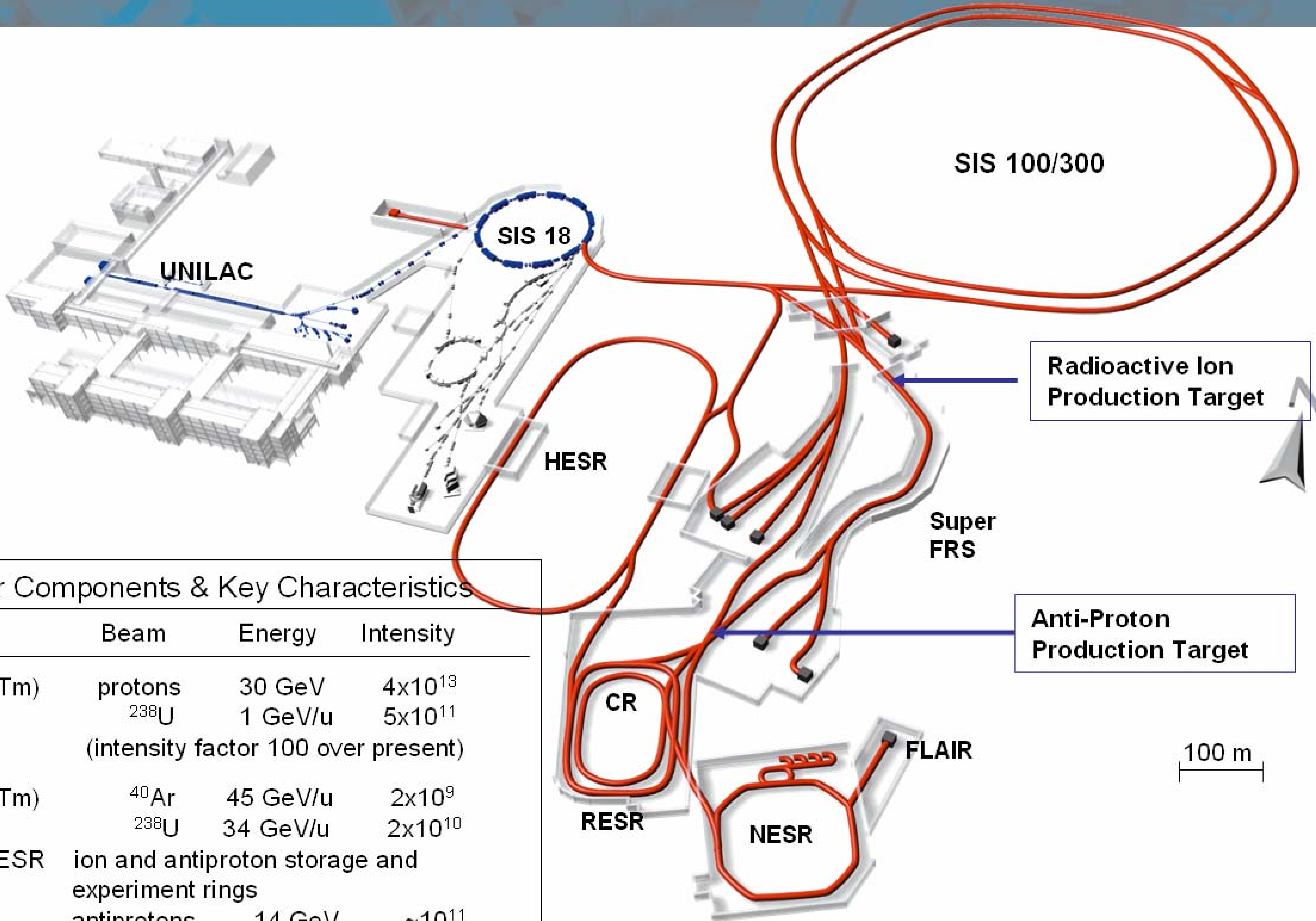
Existing facility: provides ion-beam source and injector for FAIR

Ultimate Realization of FAIR



New future facility: provides ion and anti-matter beams of highest intensities and up to high energies

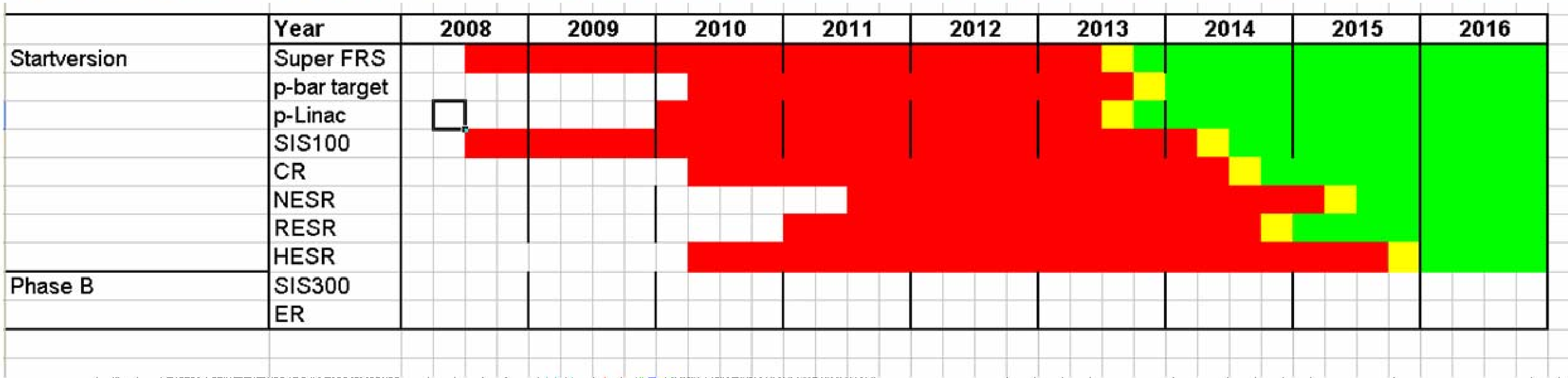
Ultimate Realization of FAIR

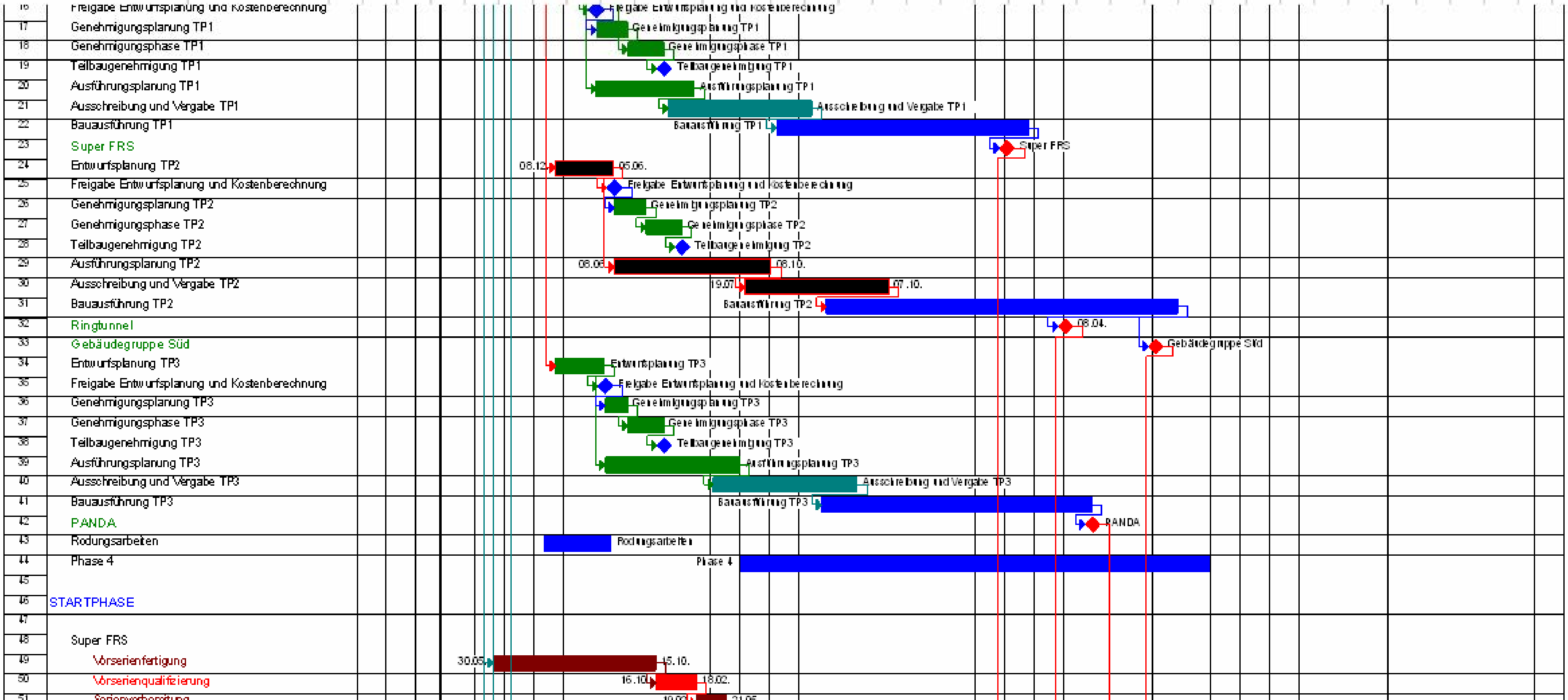


Accelerator Components & Key Characteristics

Ring/Device	Beam	Energy	Intensity
SIS100 (100Tm)	protons	30 GeV	4×10^{13}
	^{238}U	1 GeV/u	5×10^{11}
	(intensity factor 100 over present)		
SIS300 (300Tm)	^{40}Ar	45 GeV/u	2×10^{9}
	^{238}U	34 GeV/u	2×10^{10}
CR/RESR/NESR	ion and antiproton storage and experiment rings		
HESR	antiprotons	14 GeV	$\sim10^{11}$
Super-FRS	rare isotope beams	1 GeV/u	$<10^{9}$

Schedule - Accelerators





FAIR Accelerator Challenges

FAIR

1. Beam Intensity Frontier:

Highest intensities for energetic heavy ion beams

⇒ 100-1000 times higher primary beam intensities than presently

2. Beam Brightness Frontier:

Highest phase space densities

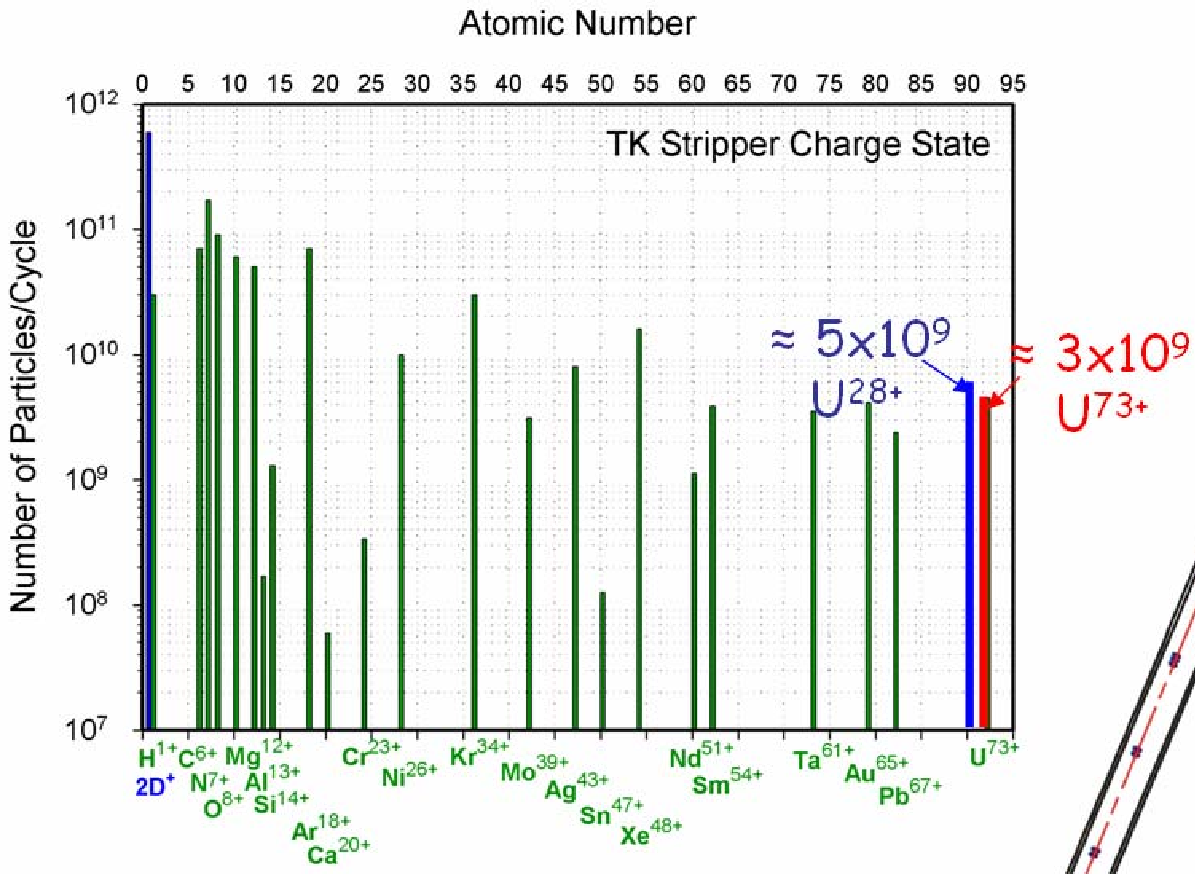
⇒ Compressed and intense primary beams

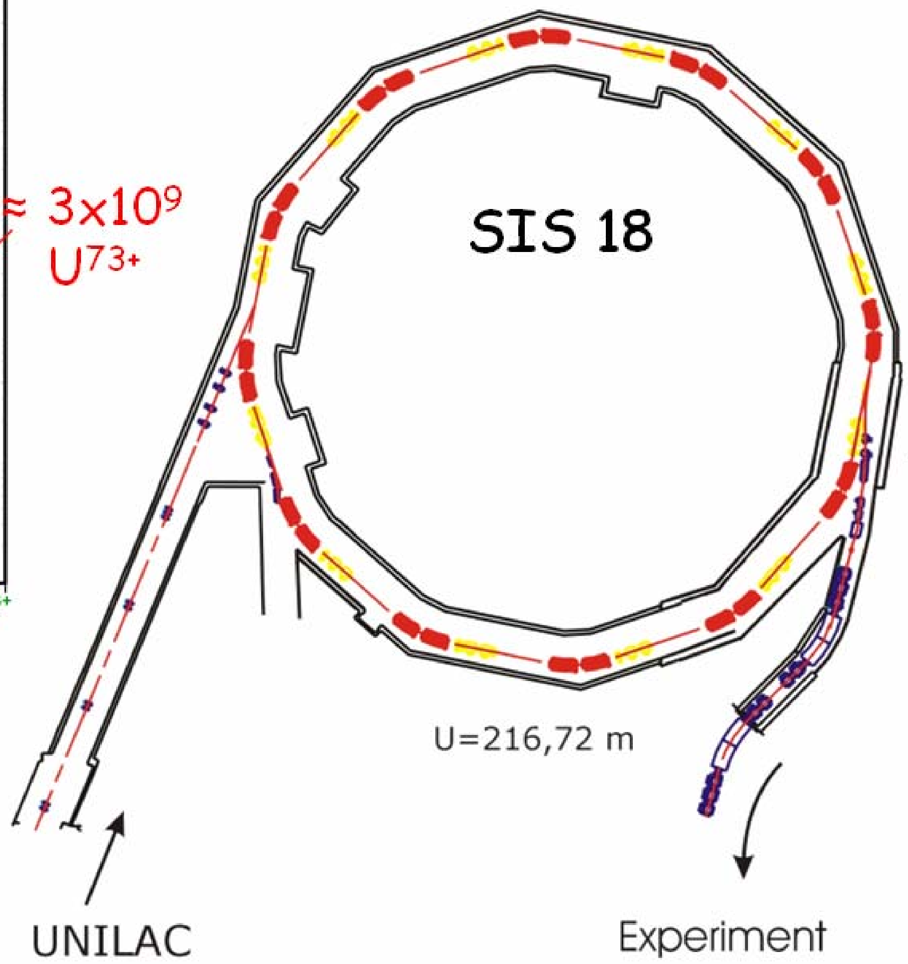
⇒ Cooled radioactive ions and antiprotons

Related Technical Challenges:

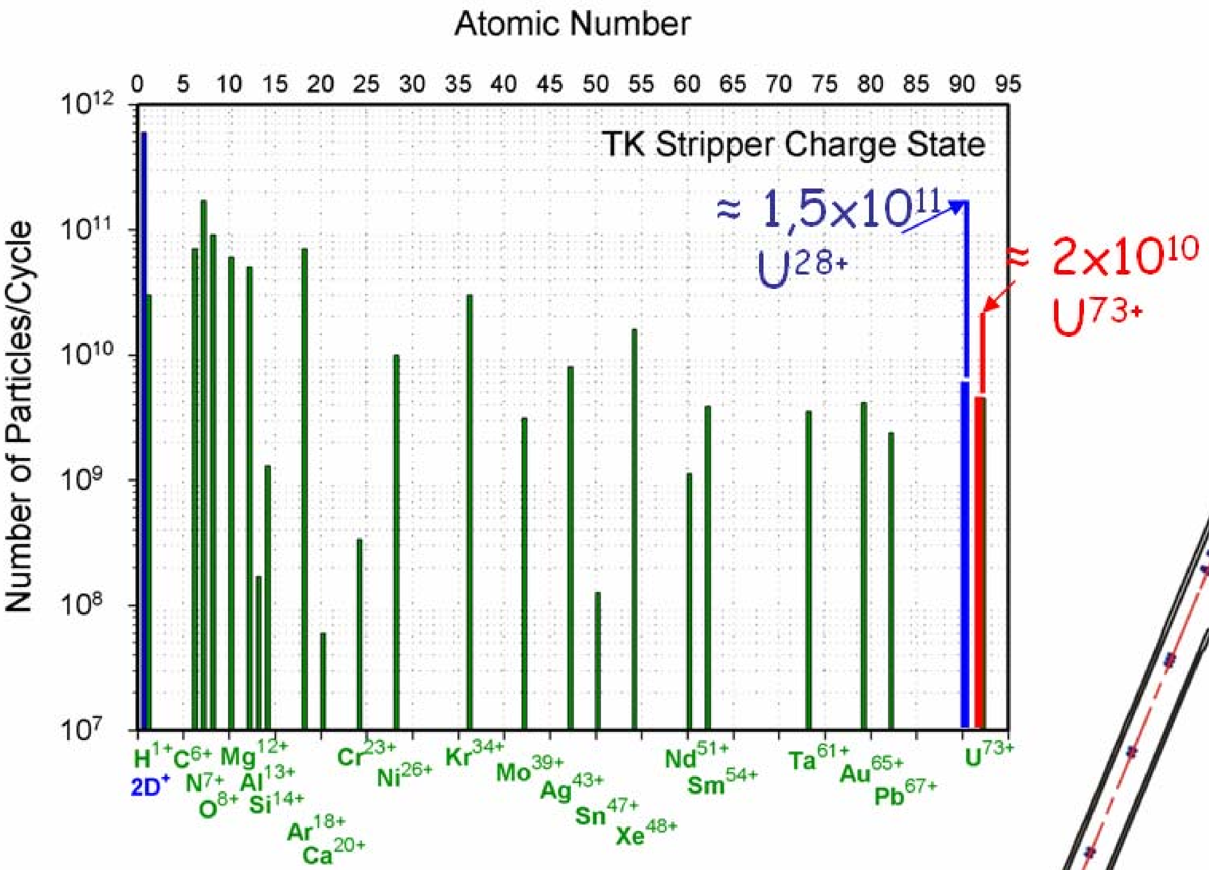
- control of intense, medium charge state heavy ion beams:
  - dynamic vacuum, space charge effects, collective instabilities
- beam cooling at high energies: electron and stochastic cooling
- fast ramping superconducting magnets
- compact rf cavities

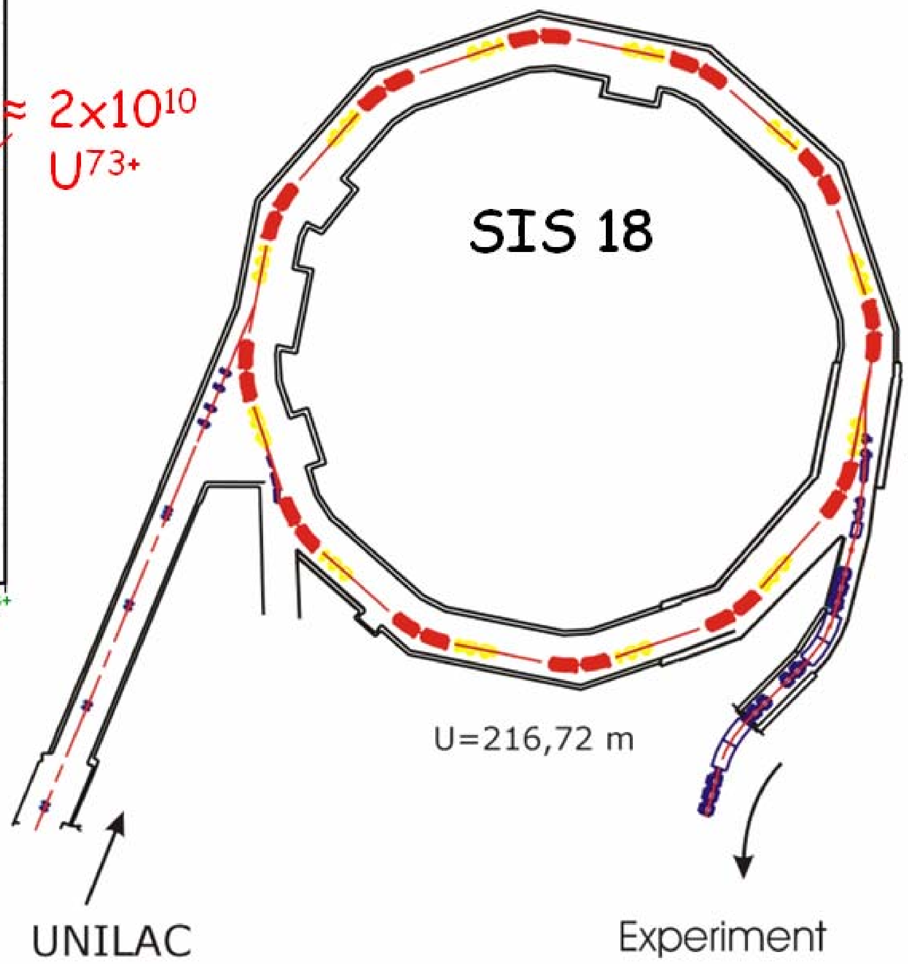
Present SIS 18 Performance





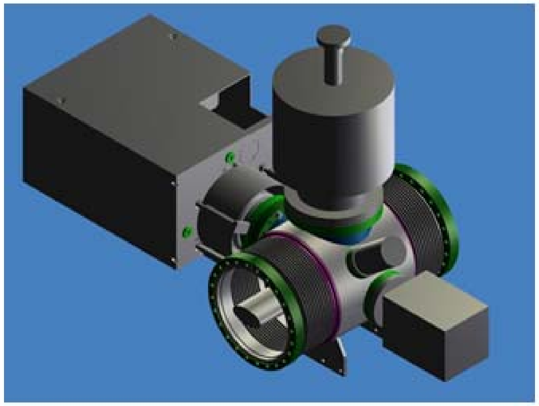
Required SIS 18 Performance





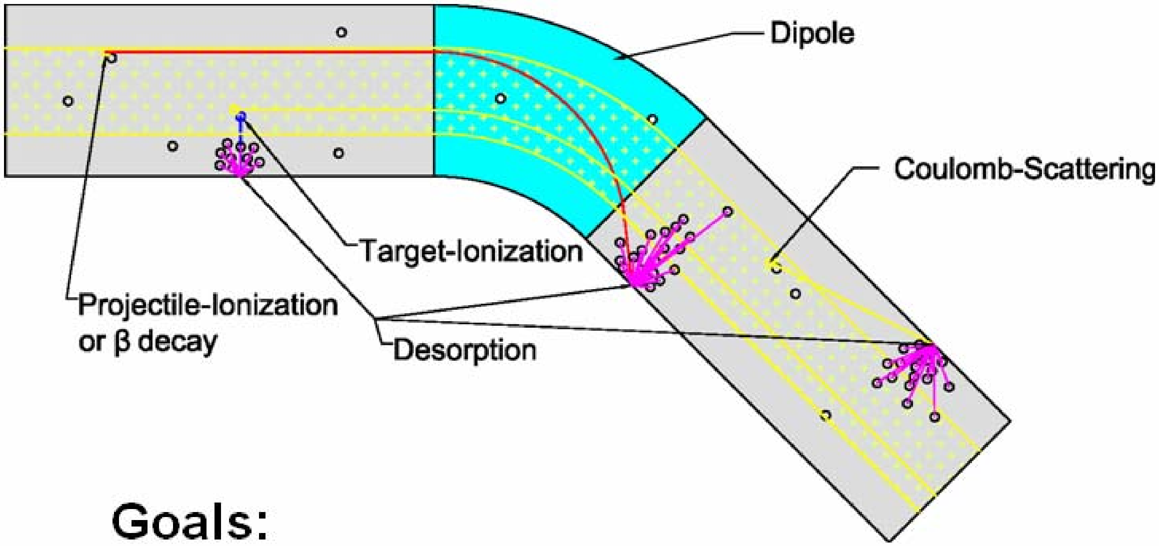
SIS 18 Upgrade Project
Control of the Dynamic Vacuum Pressure

Combined pumping/collimation ports behind every dipole group



NEG coated vacuum chambers

Beam loss mechanisms:
U^{28+} -> U^{29+} (stripping)
U^{73+} -> U^{72+} (capture)



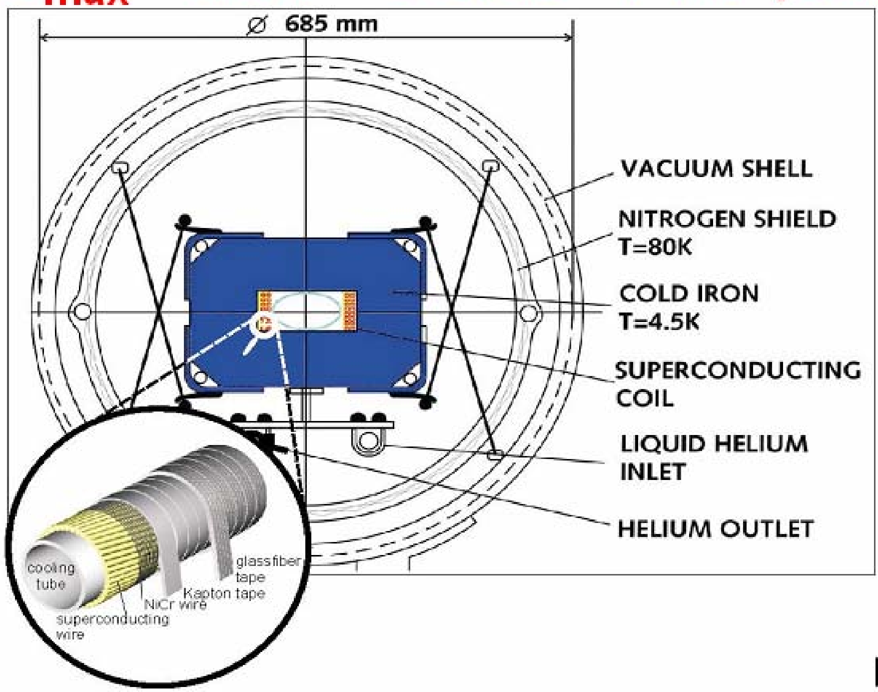
Goals:
- increase pumping speed
- localize beam loss
- minimize desorption

SIS 100
High Intensity- and Compressor Stage

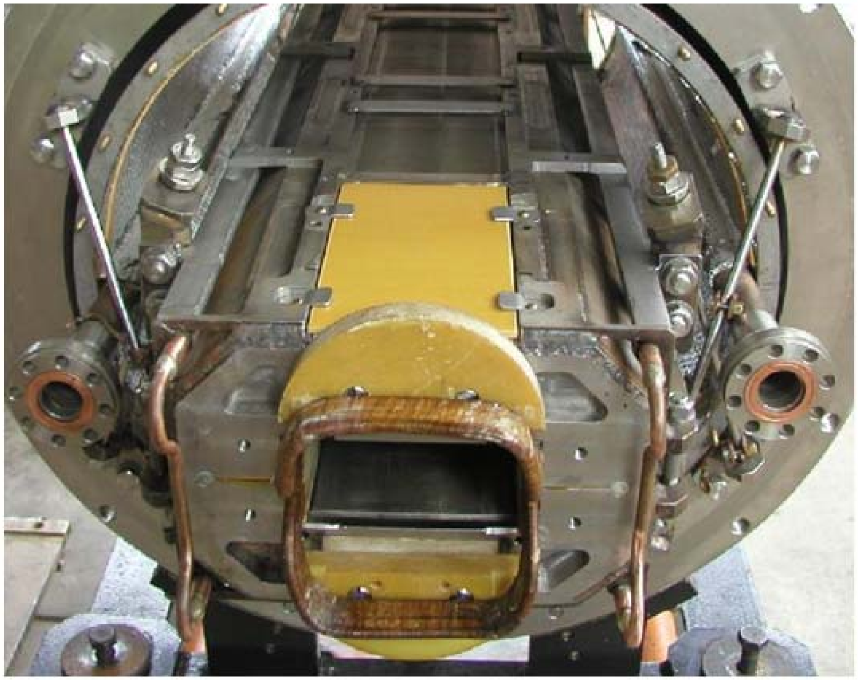
Intermediate charge state ions e.g. U28+-ions up to 2.7 GeV/u
Protons up to 29 GeV

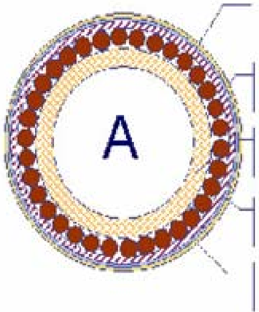
- fast-ramped superconducting magnets and
- strong bunch compression system

Bρ= 100 Tm B_{max}= 1.9 T dB/dt= 4 T/s (curved)

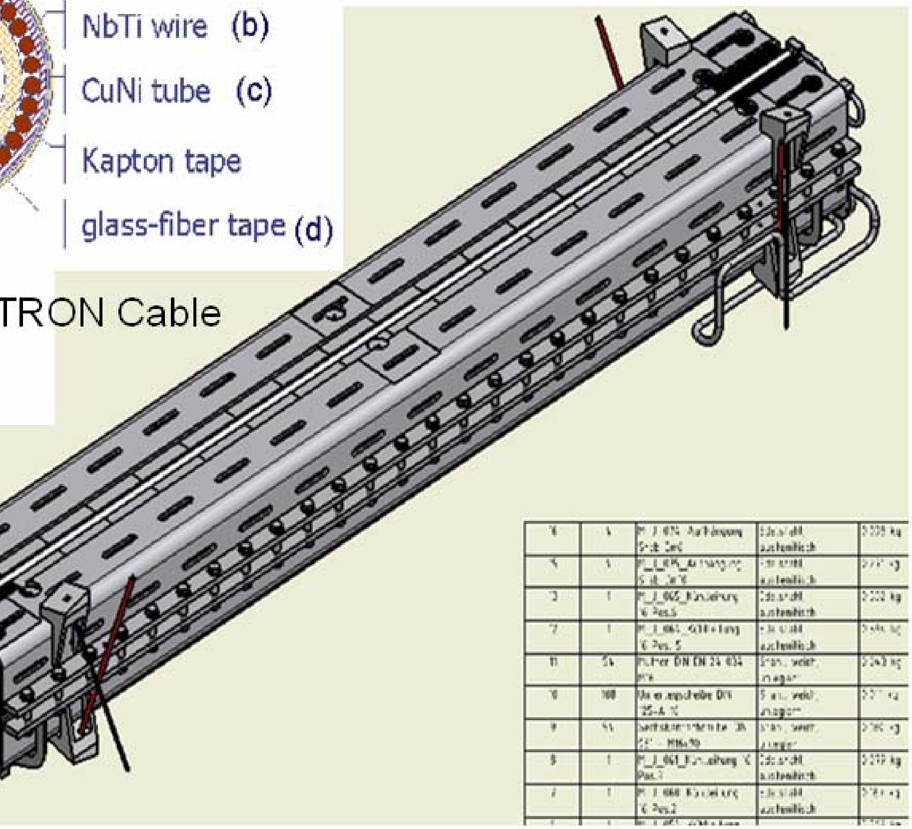


Superconducting Magnet R&D (SIS100)





NUCLOTRON Cable

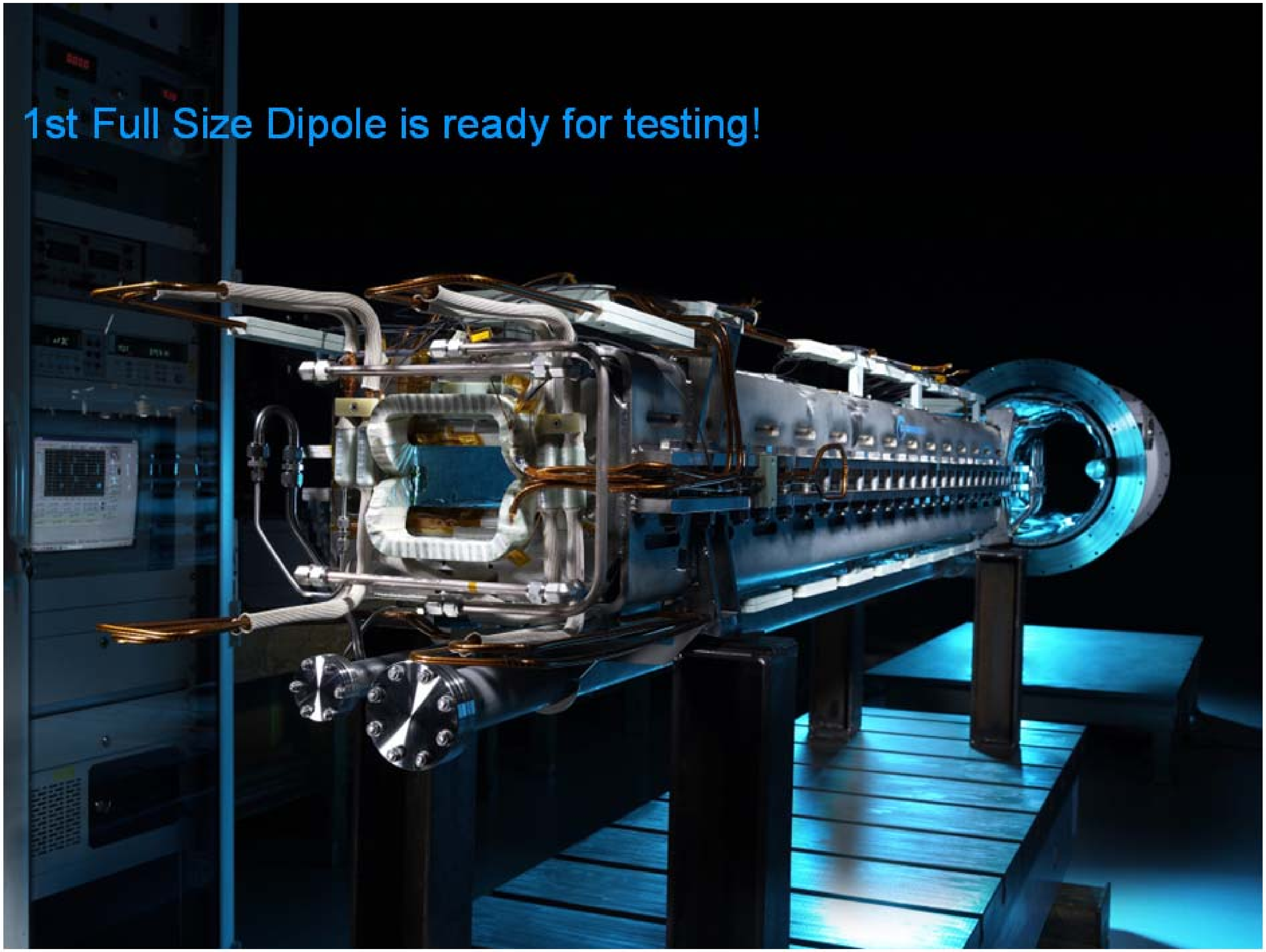


Low loss sc magnet. Losses dominated by eddy currents < 30 W/m. Two-phase LHe cooling (4K).

Prototype production at JINR Dubna, BINP Novosibirsk, and BNG Würzburg

SIS 100 Dipole Magnets

Full Size Model from Babcock Noell GmbH

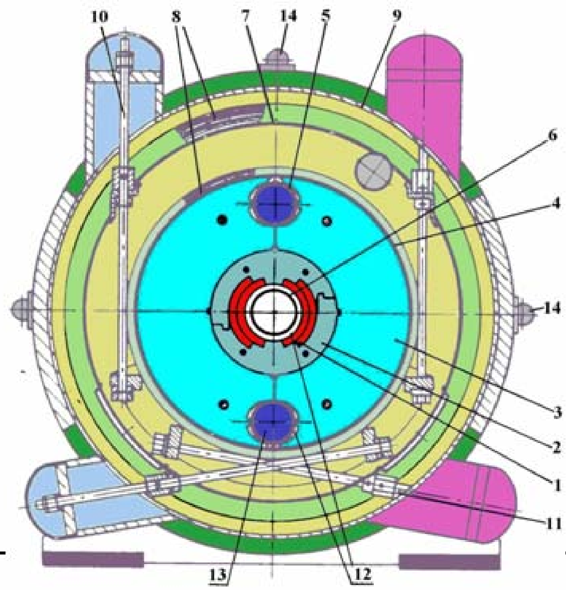


SIS 300 High Energy- and Stretcher Stage

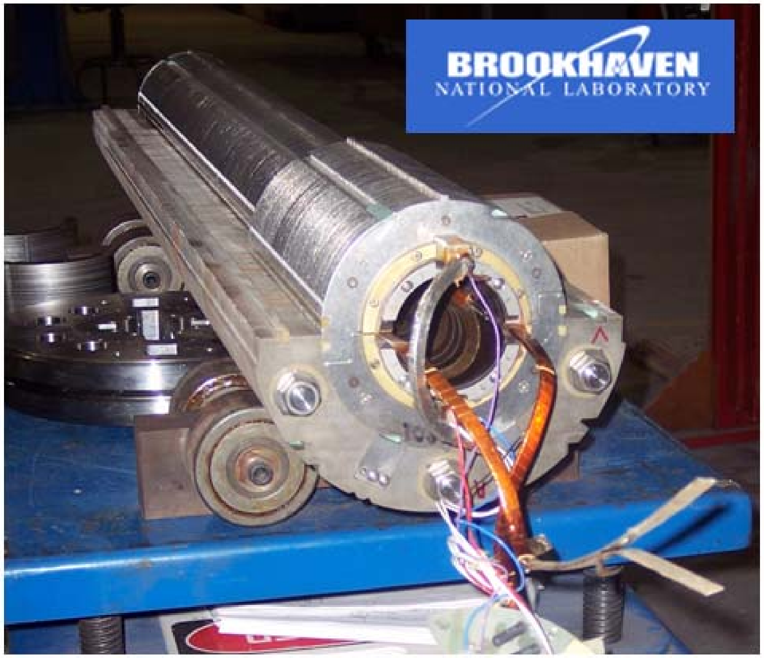
Highly charges ions e.g. U^{92+}-ions up to 34 GeV/u
Intermediate charge state ions U^{28+}- ions at 1.5 to 2.7 GeV/u with 100% duty cycle

- superconducting high-field magnets and
- stretcher function

$B\rho$= 300 Tm B_{max}= 4.5 T dB/dt= 1 T/s (curved)

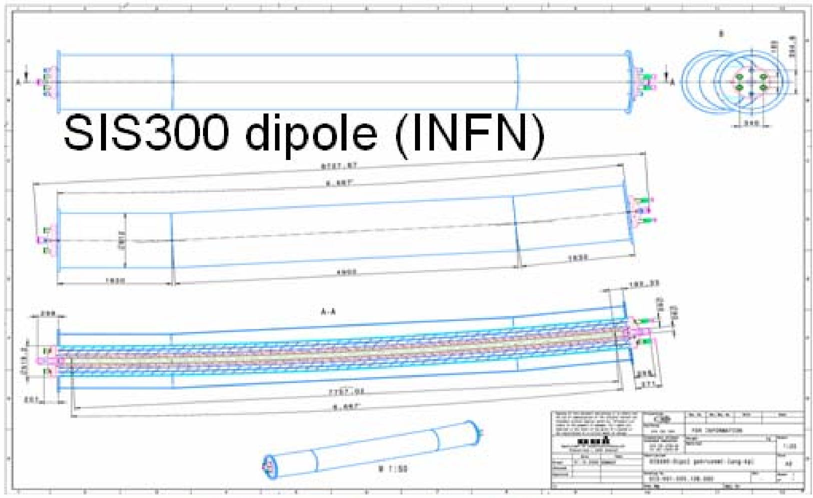


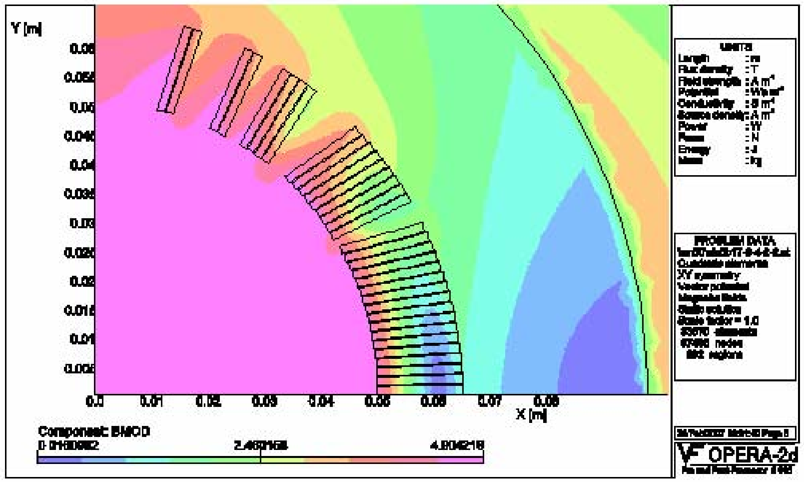
Superconducting Magnet R&D (SIS300)



First cycling sc cosΘ magnet:
GSI001 by BNL (2003)

Model under construction





Ansaldo Superconduttori

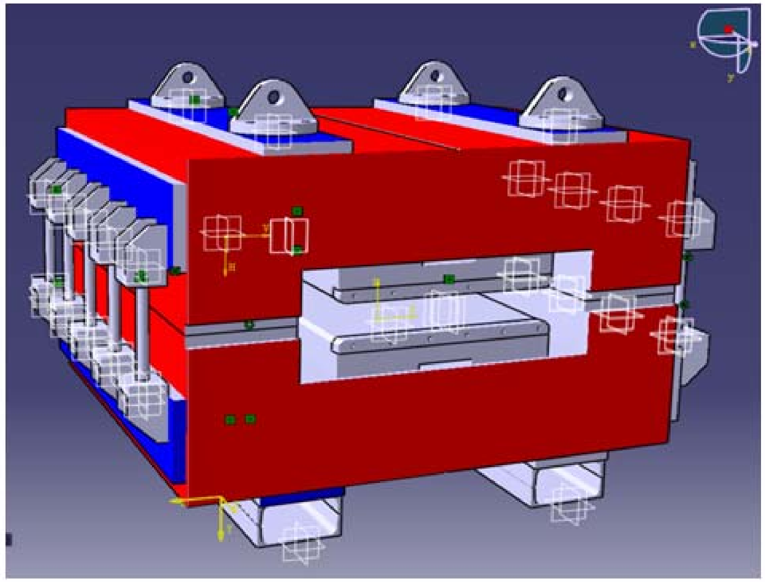
INFN Istituto Nazionale di Fisica Nucleare

Large Aperture Superferric Magnets

Development of large aperture (up to 380 mm) bending magnets (warm iron, sc coil) in China

Chinese Academy of Science

IMP Lanzhou
IPP Hefei
IEE Beijing



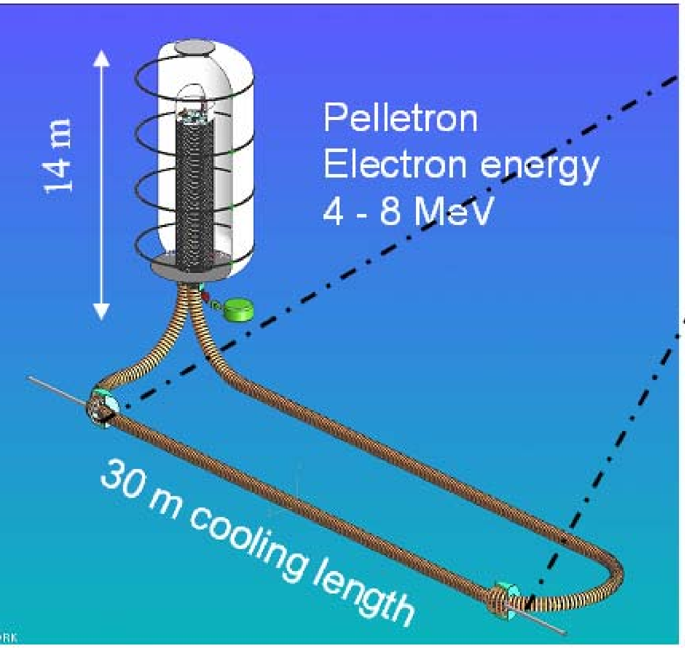
The assembly of die

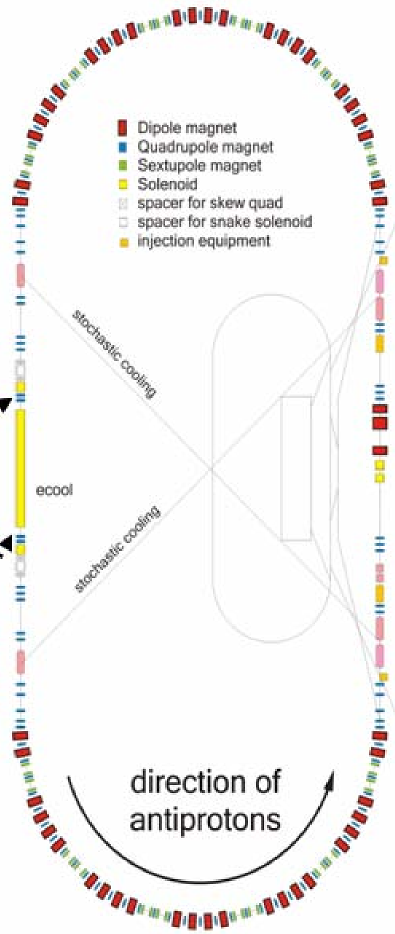
Coil fabrication

Beam Cooling for Precision Beams

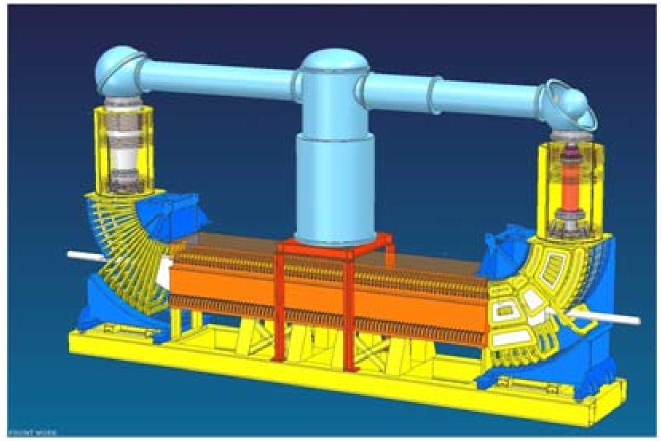
electron cooling at high energies (HESR)

TSL





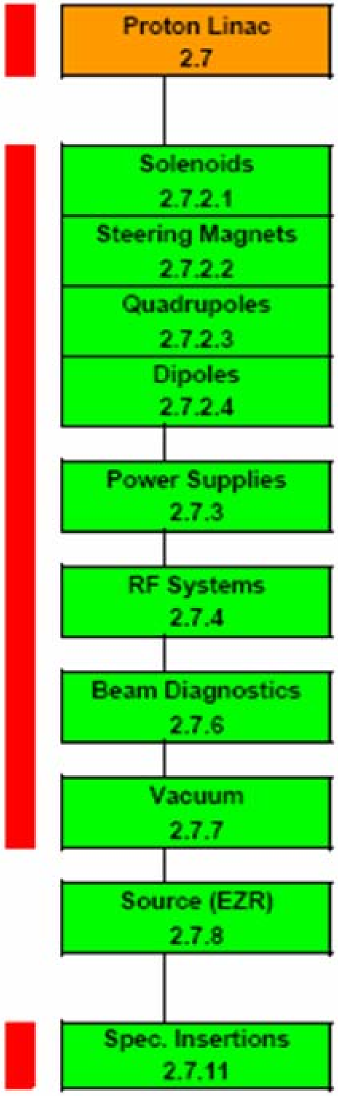
Cooler Parameters (NESR)	
energy	2 - 450 keV
max. current	2 A
beam radius	2.5-14 mm
magnetic field	
gun	up to 0.4 T
cool. sect.	up to 0.2 T
straightness	2×10^{-5}
vacuum	$\leq 10^{-11}$ mbar



Accelerator Work Package Matrix

		WBS 2.3 HEBT	2.4 Supere FRS	2.5 CR	2.6 NESR	2.7 p-lianc	2.8 SIS100	2.9 pbar-target	2.10 RESR	2.11 HESR	2.12 SIS300	2.13 ER	2.14 Com. Sys	3.0 Civ. Const
TS-2	Magnets	Bend	Bend	Bend	Bend	Bend	Bend	Bend	Bend	Bend	Bend	Bend		
		Quad	Quad	Quad	Quad	Quad	Quad	Quad	Quad	Quad	Quad	Quad		
			Sextupoles	Sextupoles	Sextupoles		Sextupoles			Sextupoles	Multipoles	Sextupoles		
		Other	Other	Other	Other		Other		Other	Other	Other	Other		
TS-3	Power Converter	Power Conv	Power Conv	Power Conv	Power Conv	Power Conv	Power Conv	Power Conv	Power Conv	Power Conv	Power Conv	Power Converter		
TS-4	RF-System			RF	RF	RF	RF		RF	RF	RF	RF		
TS-5	Inj/Extraction			Inj/Extr.	Inj/Extr.		Inj/Extr.		Inj/Extr.	Inj/Extr.	Inj/Extr.	Inj/Extr.		
TS-6	Diagnostics	Diagnostics	Diagnostics	Diagnostics	Diagnostics	Diagnostics	Diagnostics	Diagnostics	Diagnostics	Diagnostics	Diagnostics	Diagnostics		
TS-7	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum	Vacuum		
TS-8	Part. Sources					EZR						Linac		
TS-9	ECOOL				ECOOL					ECOOL				
TS-10	St. Cooling			St. Cool					St. Cool	St. Cool				
TS-11	Special inst.	Special	Special			Special	Special	Special						
TS-12	Local Cryo	Local Cryo	Local Cryo	Local Cryo			Local Cryo				Local Cryo		Refrigerator	
TS-14	Common System												Controls/Interfaces	
													Quench Detection	
													Magnet QC	

Expression of Interests



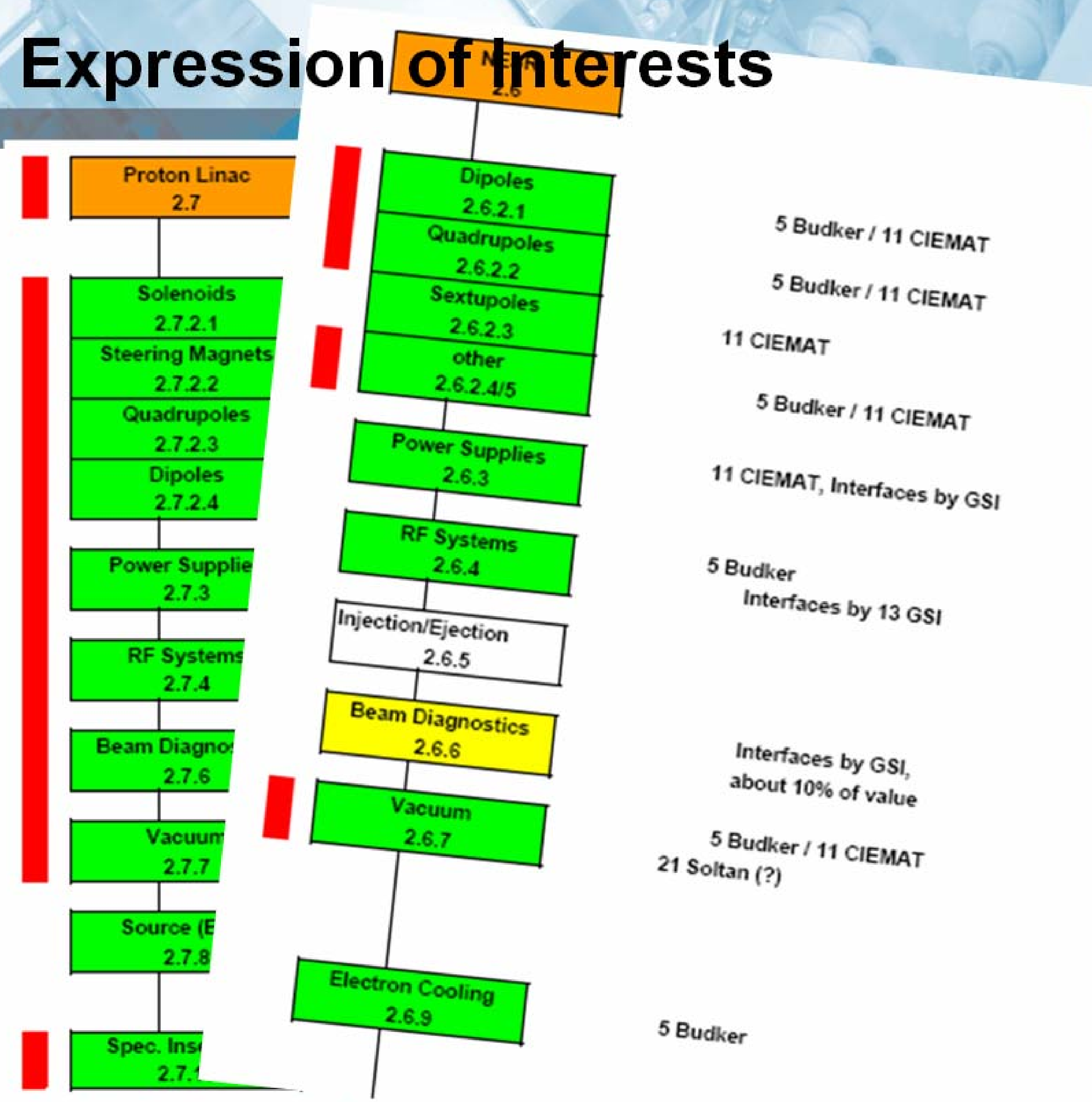
13 GSI (w/o Source)
16 DST India (all)

additionally to 13 / 16:
8 ITEP

not: 13 GSI
orally: France

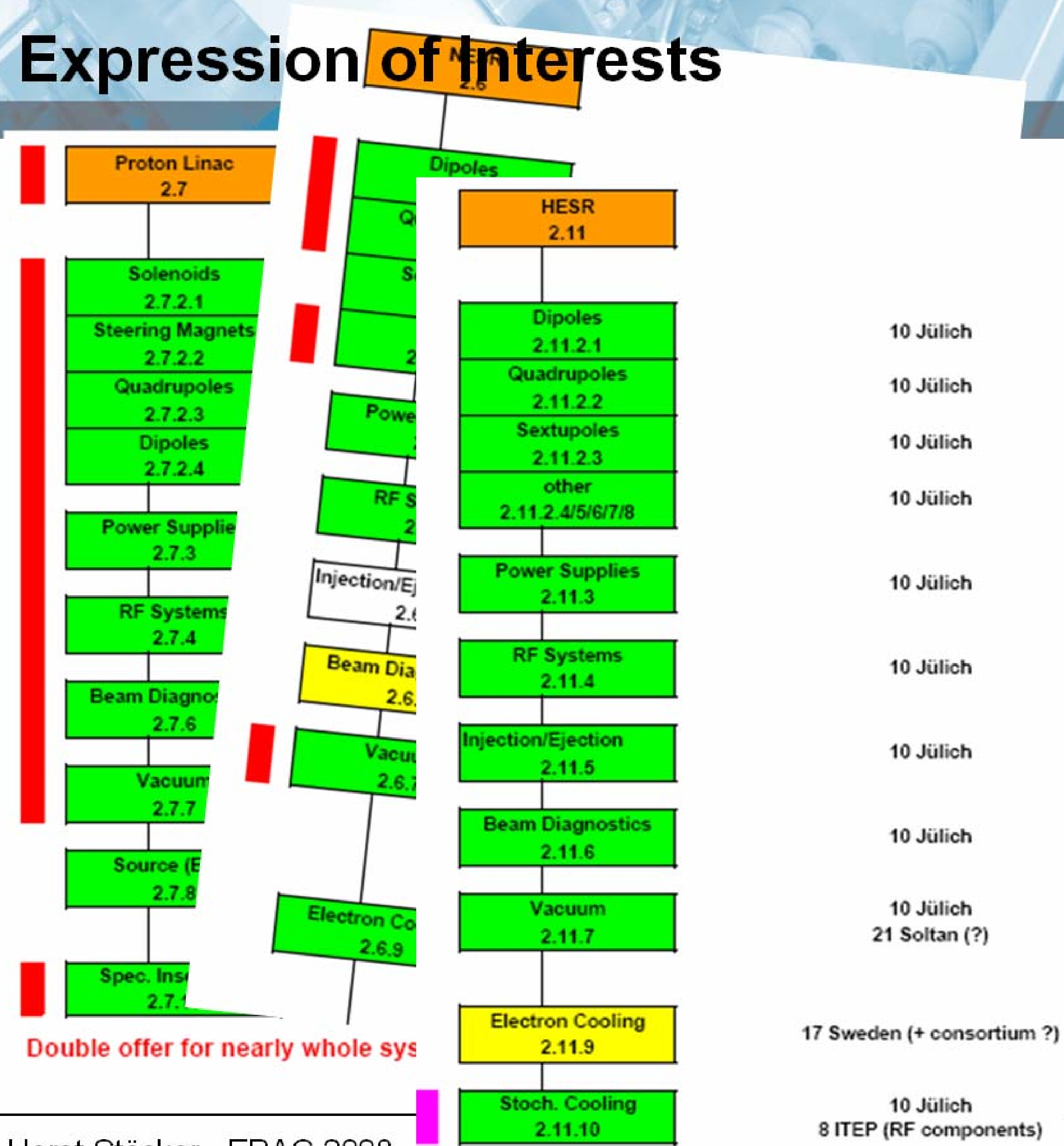
Double offer for nearly whole system

Expression of Interests

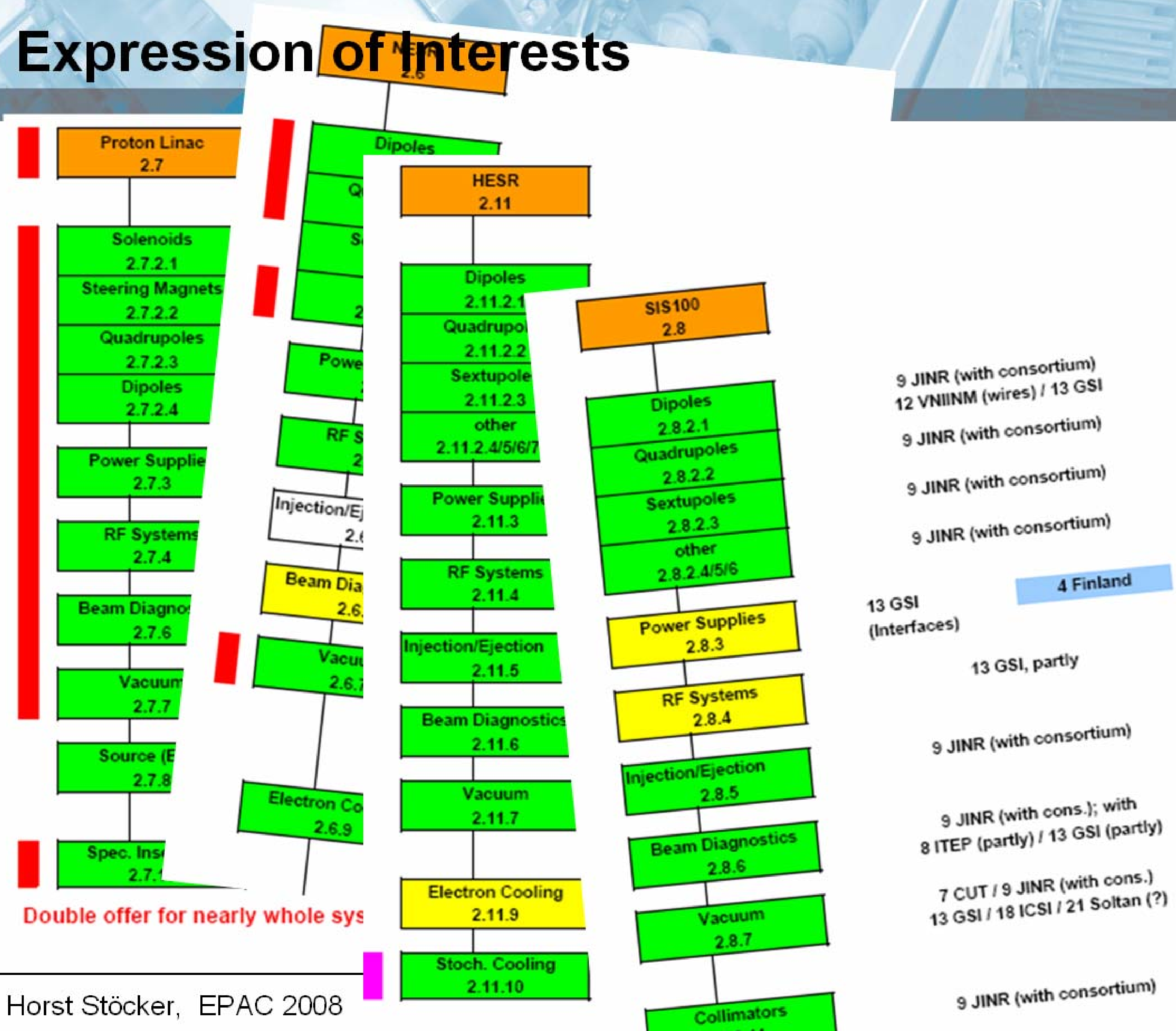


Double offer for nearly whole system

Expression of Interests

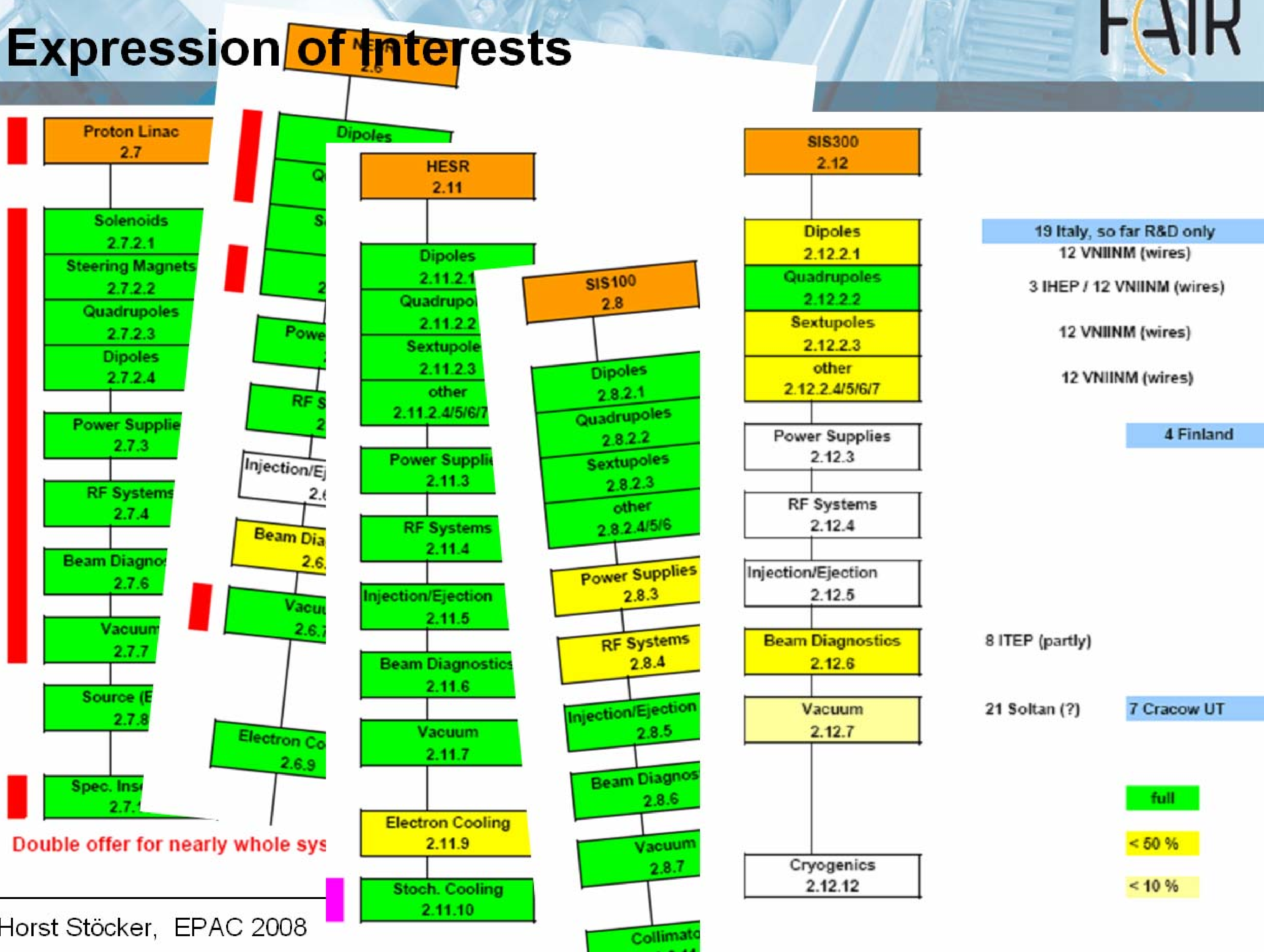


Expression of Interests

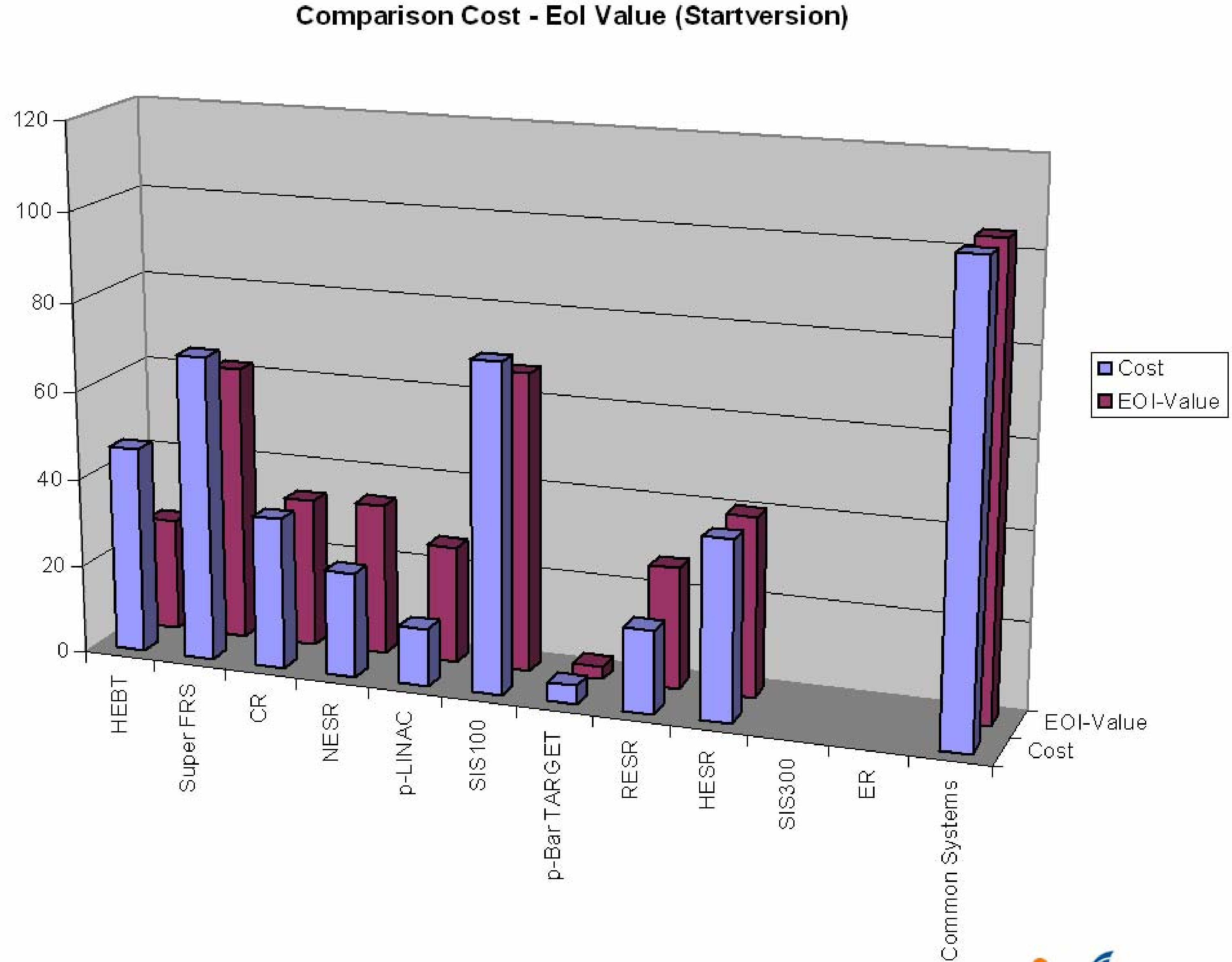


Double offer for nearly whole sys

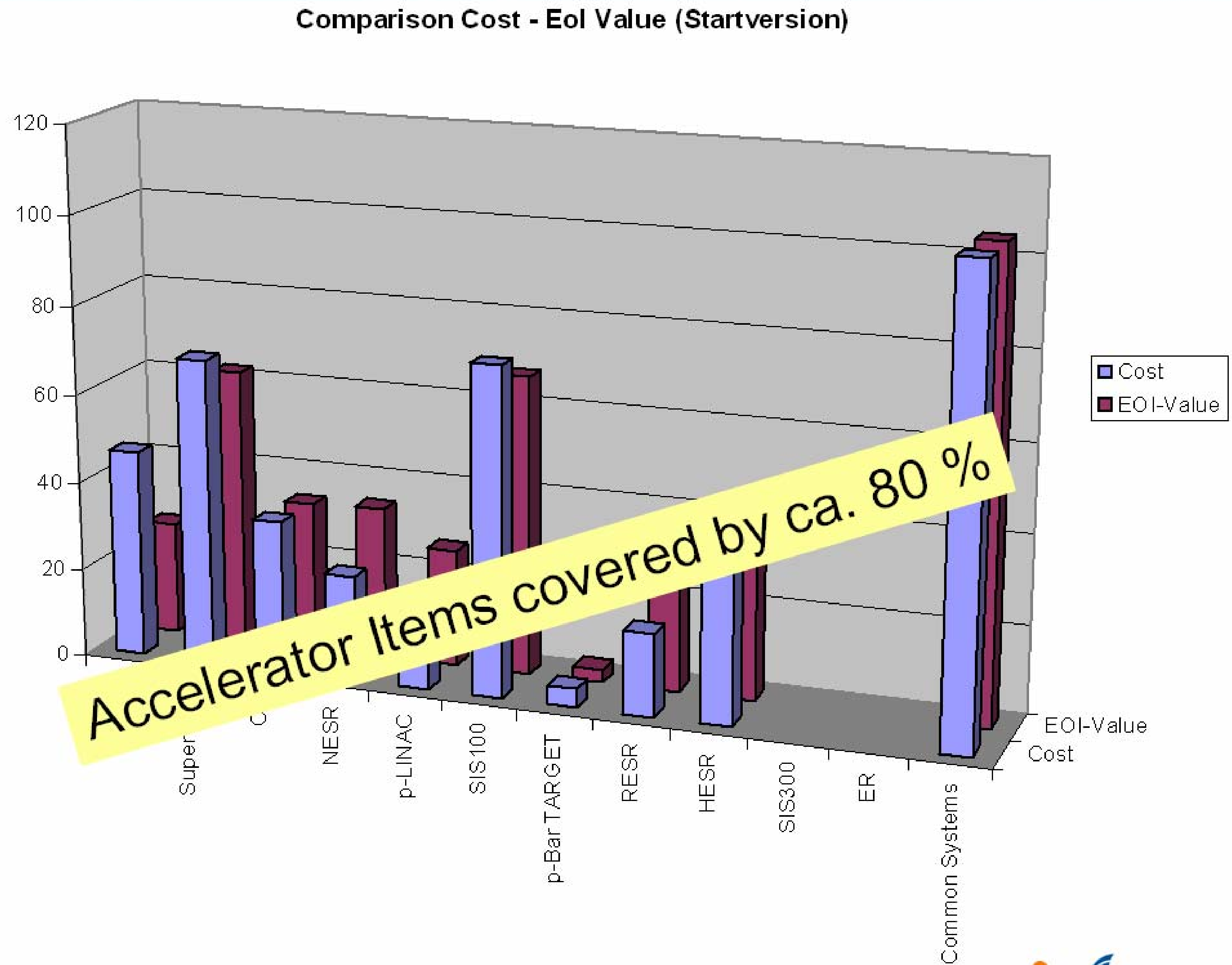
Expression of Interests



Overview on In-Kind Contributions



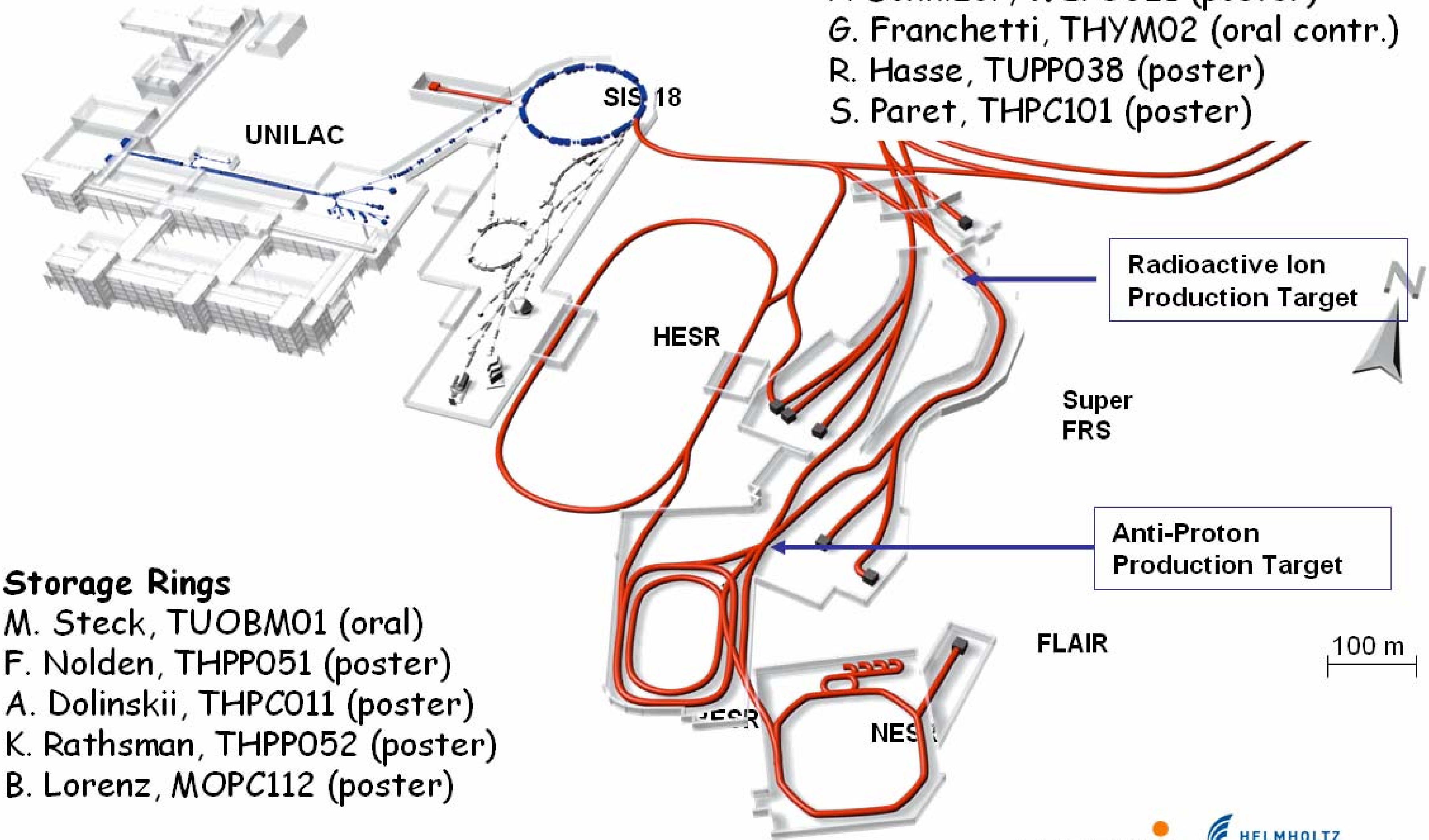
Overview on In-Kind Contributions



FAIR related oral and poster presentations

SIS18
P.Spiller, C. Omet, MOPC099 (poster)

SIS100/300
P. Spiller, MOPC100 (poster)
J. Stadlmann, MOPC124 (poster)
P. Schnizer, WEPD021 (poster)
G. Franchetti, THYM02 (oral contr.)
R. Hasse, TUPP038 (poster)
S. Paret, THPC101 (poster)



Storage Rings
M. Steck, TUOBM01 (oral)
F. Nolden, THPP051 (poster)
A. Dolinskii, THPC011 (poster)
K. Rathsman, THPP052 (poster)
B. Lorenz, MOPC112 (poster)


FAIR in 2016
Observers:
Thank you !
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France
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Greece
India
Italy
Poland
Slovenia
Spain
Sweden
Romania
Russia
UK