



19th International Conference on RF Superconductivity

June 30th – July 5th 2019



EUROPEAN
SPALLATION
SOURCE

European Spallation Source SRF Systems, Overview and Status

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European Spallation Source ERIC

July 1st 2019

- **ESS Intro**
 - From construction to operation in a (former) "green-field" organization
- **High Level Accelerator Milestones**
- **SRF Activities at ESS**
 - Incoming cryomodule reception
 - (Preparation of) testing
 - Elliptical test stand preparation
- **Status of SRF infrastructure**
 - Tunnel installations
 - Power RF installation activities in the service gallery
 - Cryoplants status

Not covering component design and status of activities at IK partners!

- Talk by G. Devanz, WETEA1
ESS Technology Development at IPNO and CEA Paris-Saclay
- INFN: MOP056, MOP058, THP093
- IPNO: TUP019
- CEA: WETEA1, MOP086, THP096, THP097
- UU: THP057, THP058
- STFC: TUP040, THP027

The ESS Accelerator

Scope, Parameters, Technical Performances

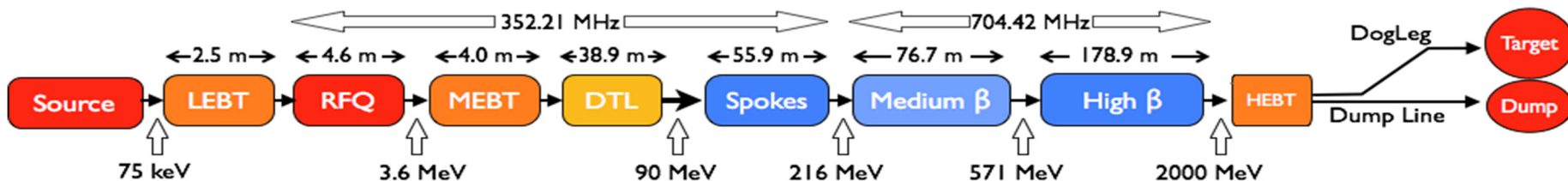
Design Drivers:

- High Average Beam Power
5 MW (Initially 2 MW)
- High Peak Beam Power
125 MW
- High Availability (User Facility)
95%



Key parameters & Design criteria:

- **Pulse length:** 2.86 ms pulses
- **Max Energy:** 2 GeV
- **Pulse peak current:** 62.5 mA
- **Pulse Repetition rate:** 14 Hz
- **Particles:** Protons (H⁺)
- **Low losses**
- **Minimize energy use**
- **Flexible design for risk mitigation and future upgrades**



Collaborative:

18 IK partners in 8 countries,
5 collaboration partners

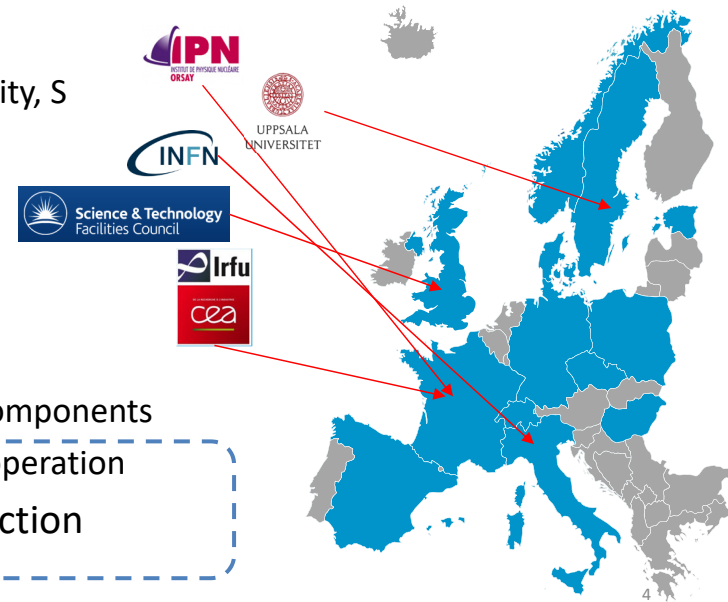
Staged:

1.3 GeV capacity with 2 MW on target for 2025
remaining RF sources (40) installed after 2026

ESS, **large** in kind scope

Technical SRF work so far at IK, shift to ESS for test/install/commissioning

- **Almost all** components of the linac are designed and provided as in kind contributions
- **After handover scope transferred to ESS**
- For the SRF linac, the partners are organized in the **ESS SRF Collaboration** with the workshare:
 - Spoke cavities and cryomodules (including prototype) by IPNO, F
 - **Testing** of spokes modules by FREIA laboratory of Uppsala University, S
 - Medium beta cavity production, by INFN, I
 - High beta cavity production, by STFC, UK
 - Cryomodule assembly and prototyping, CEA, F
 - **Testing** of elliptical module at TS2@**ESS**
- Construction project:
 - External WP4 (IPNO) WP5 (CEA) for preparation and delivery of components
 - Internal WP19 for testing, installation, commissioning and initial operation
- ESS Organization: Accelerator Division/Linac Group/SRF Section



From Construction to installation and operation

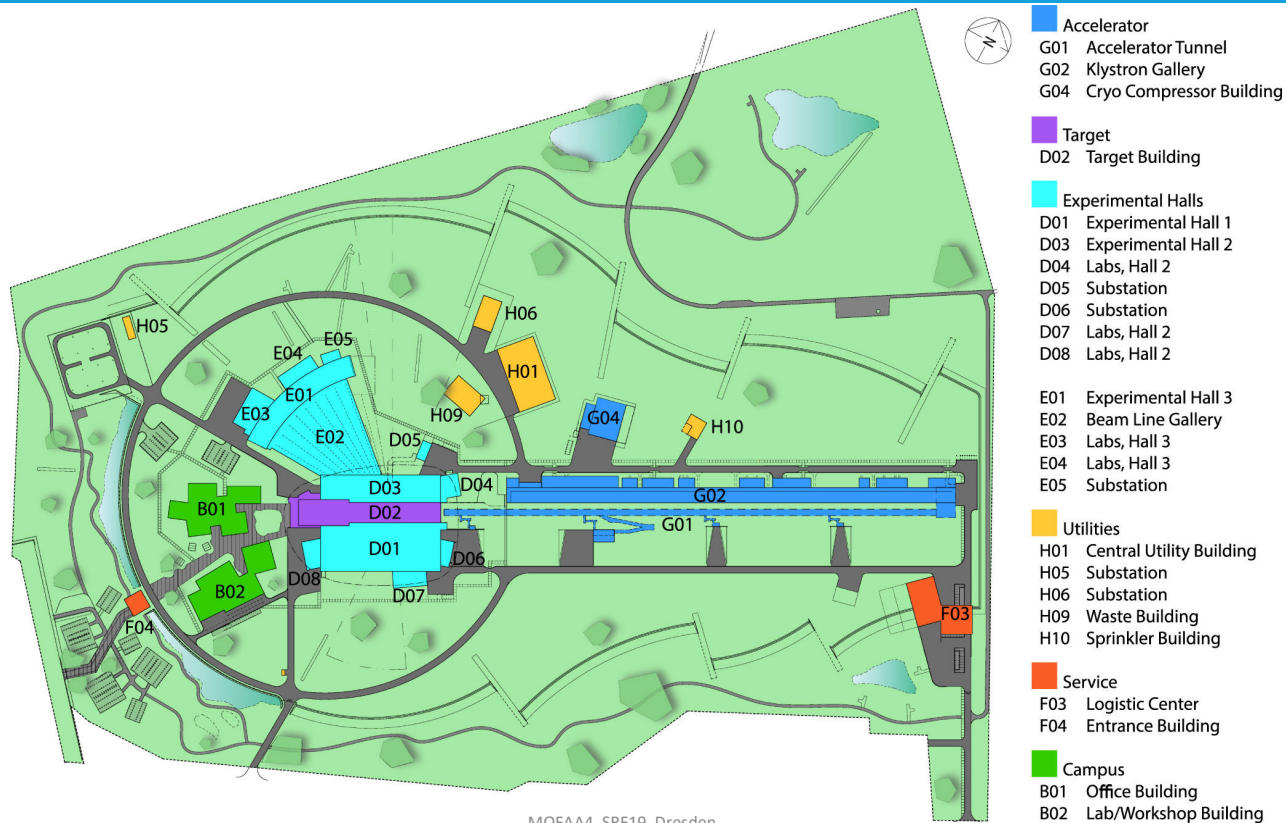
(from IK to ESS)

- **In Construction Phase (Past)**
 - Most of the SRF activities during the Construction Phase so far has been performed by the **In-Kind partners** at the home institutions (CEA, IPNO, INFN and STFC)
 - **Design, construction and prototyping of cavities and modules**
 - ESS in charge of the **CM “interface”** agreements towards neighboring WPs
- **Testing & Installation is getting very close (Now)**
 - **Delivery of prototypes** at test stand happened and **first series components** in **Fall 2019**
 - Start of the **Test Stand 2 operation** for the Elliptical CM testing (summer)
 - Start of the **FREIA Test Stand operation** at UU for Spoke CM testing (UU running!)
- **Getting ready for testing and commissioning (Now & Future)**
 - **Transfer know-how** from IK, capture design intent, get ownership of SRF components
 - Ramp up of **local “hands-on” SRF activities** at ESS



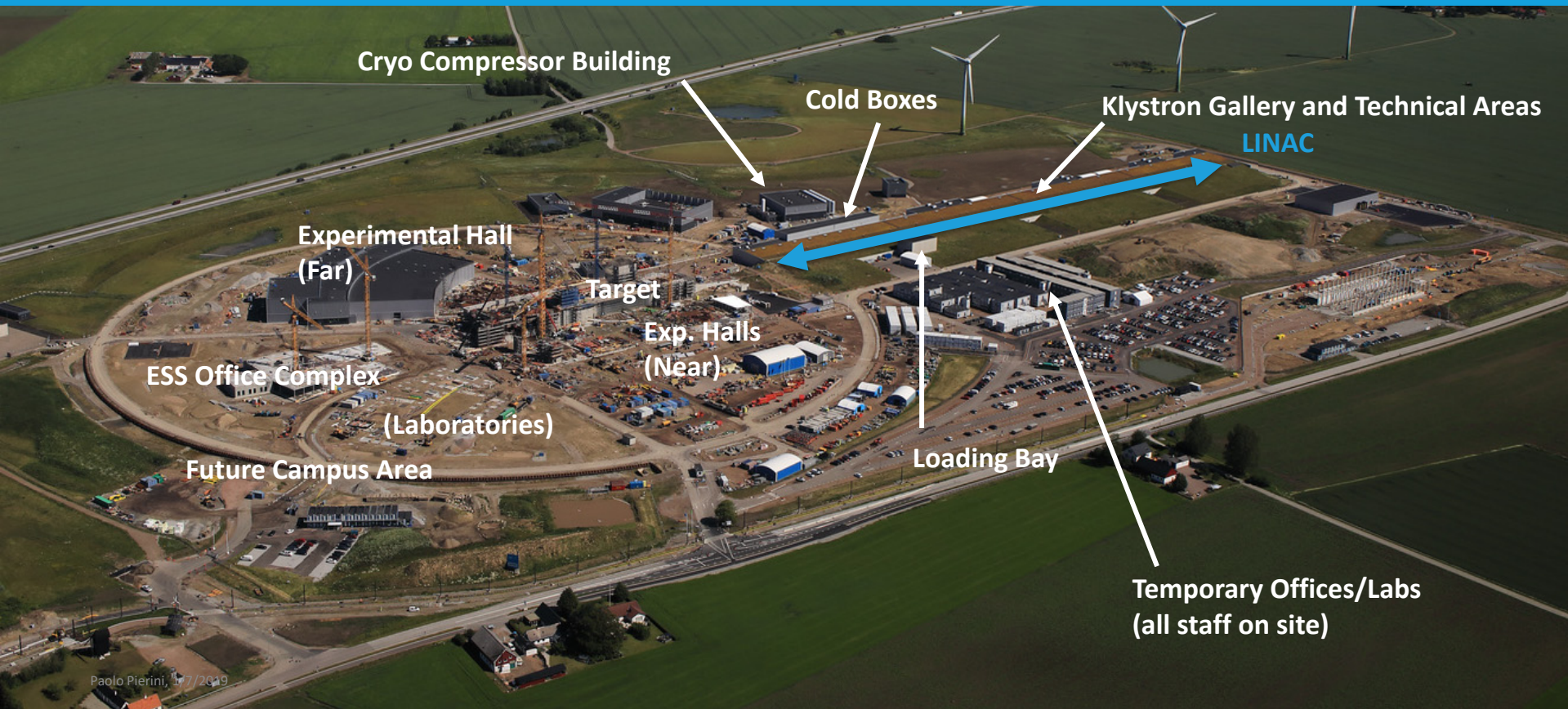
Construction to Test and Operation

ESS Site Layout



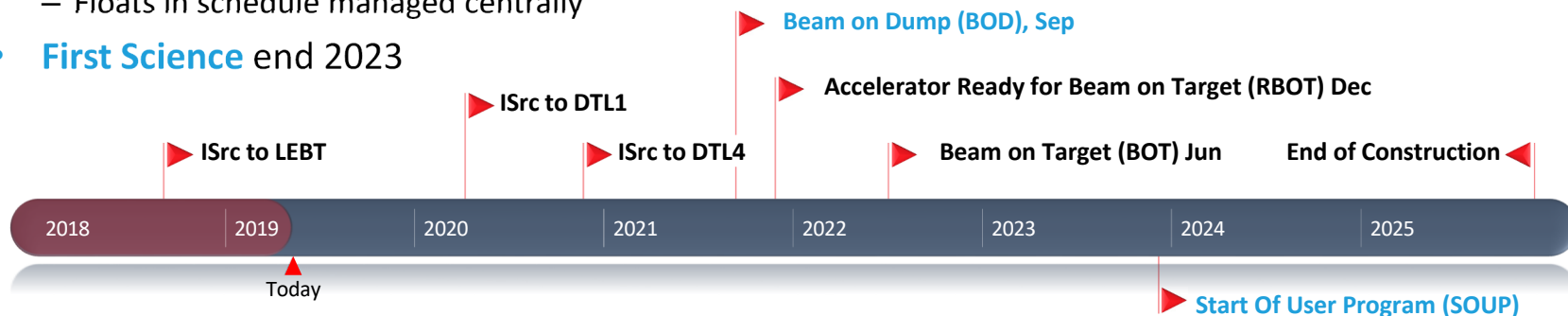
The ESS site, June 20, 2019

Tunnel and Gallery transferred to ESS



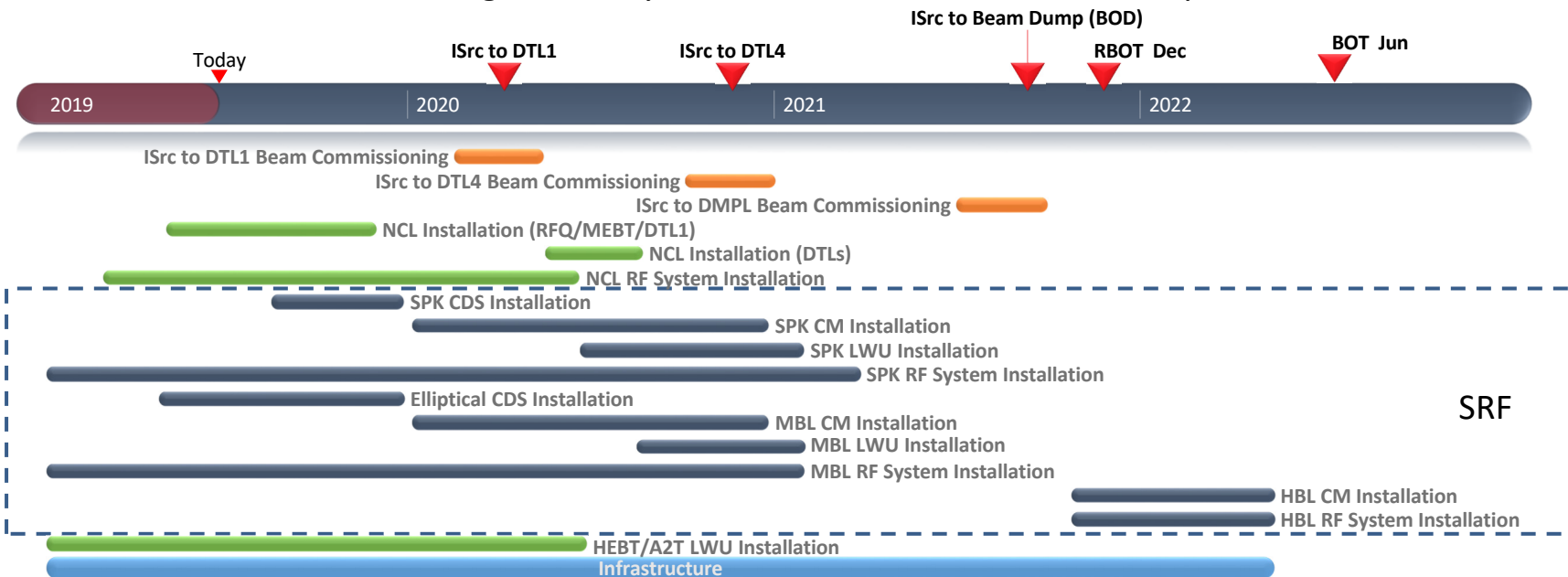
Major Accelerator milestones

- Source & LEBT installed and commissioned, MEBT under installation
- RFQ and DTL sections delivered in 2019
- Staged NC Linac beam commissioning in 2020
 - First to DTL1, then to DTL4
 - Shielding wall in tunnel will allow concurrent installation of SPK and MB CM
- **Beam on Dump (BOD)** commissioning with Linac up to MB Linac
 - Floats in schedule managed centrally
- **First Science** end 2023



Installation and Commissioning schedule

- BOD with Linac up to MBL
- HB CM installation until Target is ready for Beam, Not all HB modules RF powered for BOT



Preparation for elliptical module installation and test

Transport tests and prototype receiveal

- ESS in charge of development and procurement of
 - Transport container (with vibration dampers) at ESS
 - Installation tools and tunnel supports
- Transportation tests performed in 2018 with a bare vessel, to validate design and procedures



Preparation for elliptical module installation and test

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- ESS in charge of development and procurement of
 - Transport container (with vibration dampers) at ESS
 - Installation tools and tunnel supports
- Transportation tests performed in 2018 with a bare vessel, to validate design and procedures
- **Prototype cryomodule** transported to ESS in February 2019
 - Beam vacuum preserved
 - Few loose screws on isovac flanges and tuner components
 - **Not cold tested yet!**
 - Test Stand waiting RP licence and Safety Readiness Review



MEASUREMENTS @ IKC

- After fabrication
- Intermediate handover
- Outgoing

[illegible]

In QA/QC

MEASUREMENTS @ ESS

- Incoming
- Preparation TS2/Linac

Transfer

Measurement&Calibration DB
(ownCloud service)

<https://meas01.esss.lu.se/owncloud/index.php/login>

Live Staging Area
(typ. text files)

Script

Save

Normalized Data
(HDF files, metadata)

Script

ESS Scope

ESS Asset Management ID Installation Structure

Tagging (in metadata)

<https://gitlab.esss.lu.se/SRF> Section

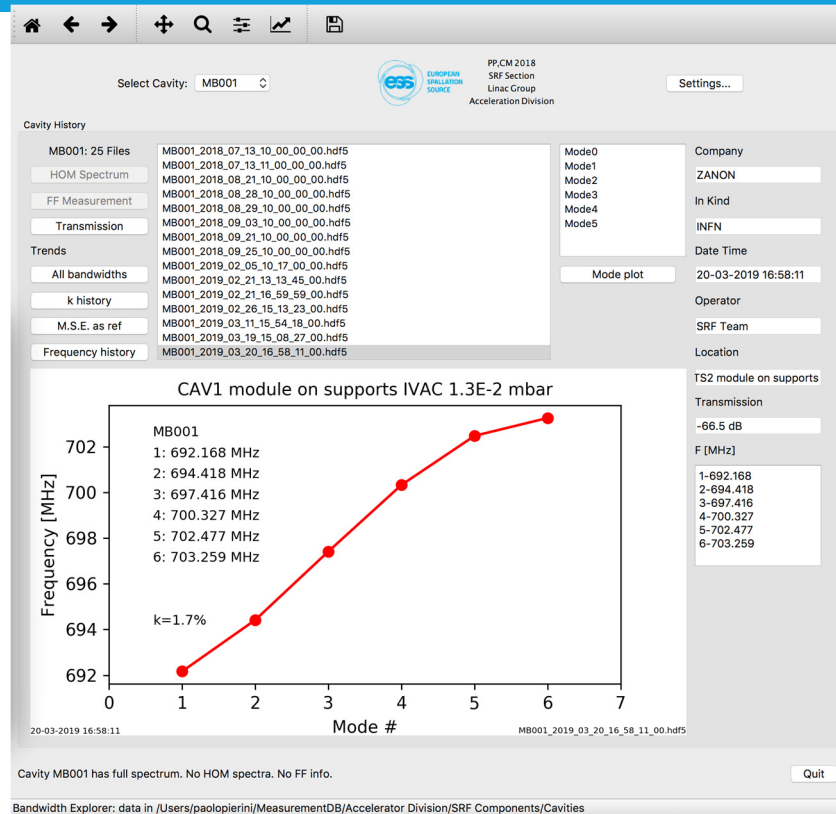
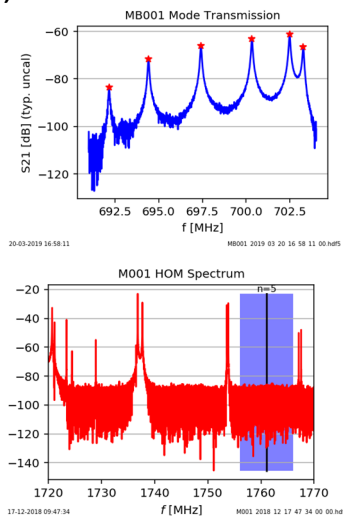
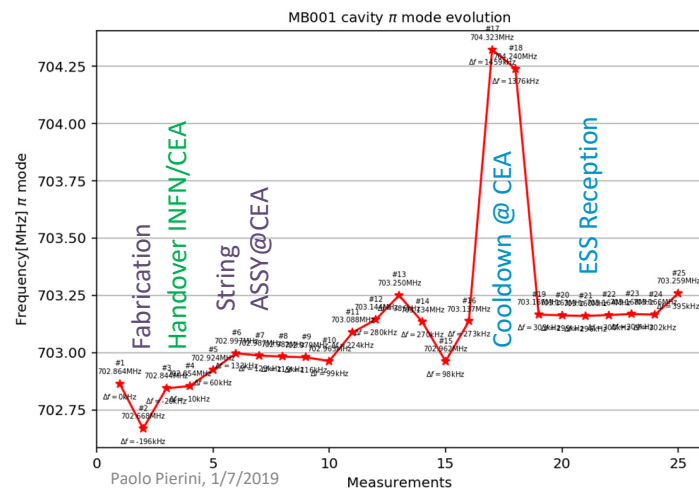
APPLICATIONS

- Browse
- Compare
- Assess

Preparation activities: We need to know **our** cavities!

ESS Cavity DB

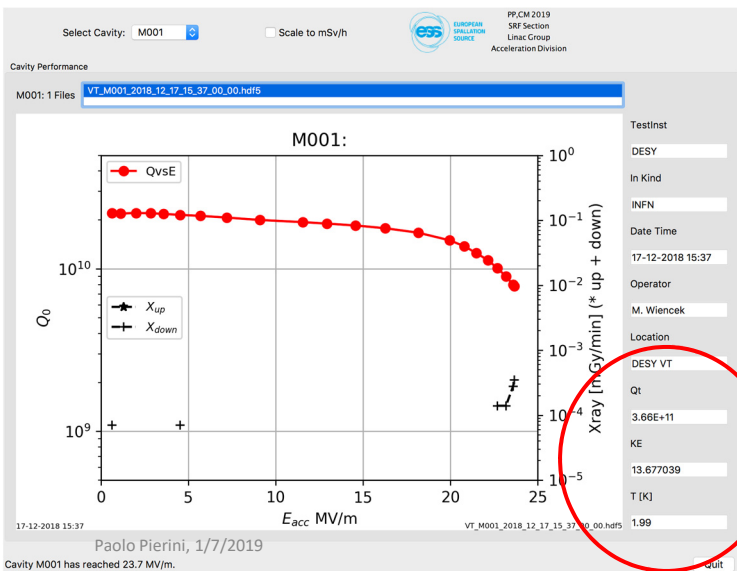
- Measurement at IK are transferred into DB, to allow reception and evaluation
 - Part of handover process IK-CEA-ESS
- Data at ESS then adds to DB
- Historical trends and visualization, for assessments



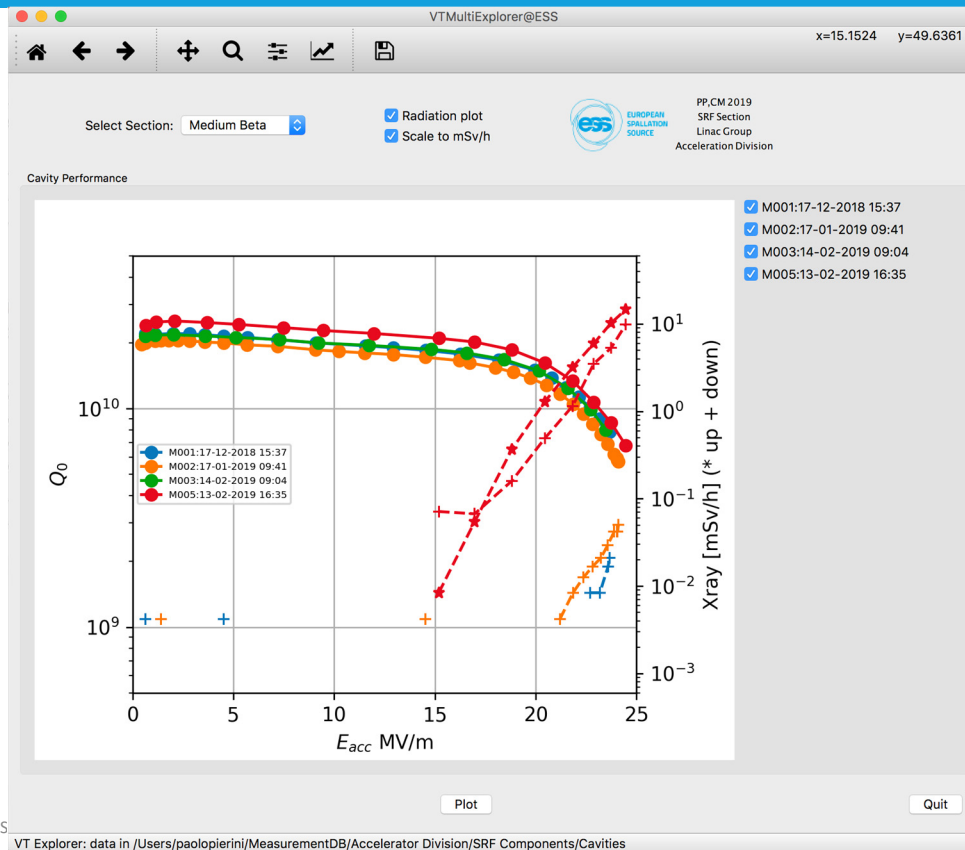
Preparation activities: Cavity performance data

First four cavities of M1 string, real time transfer

- In the handover we also receive from the IK the summary data of the vertical tests
 - Performance data (E_{acc} , radiation levels)
 - Calibration data for TS2



e.g. PU
calibration
data from
DESY VT



Sensitivity analysis

From demonstrator retrieved data of **expected behavior** of series in TS2

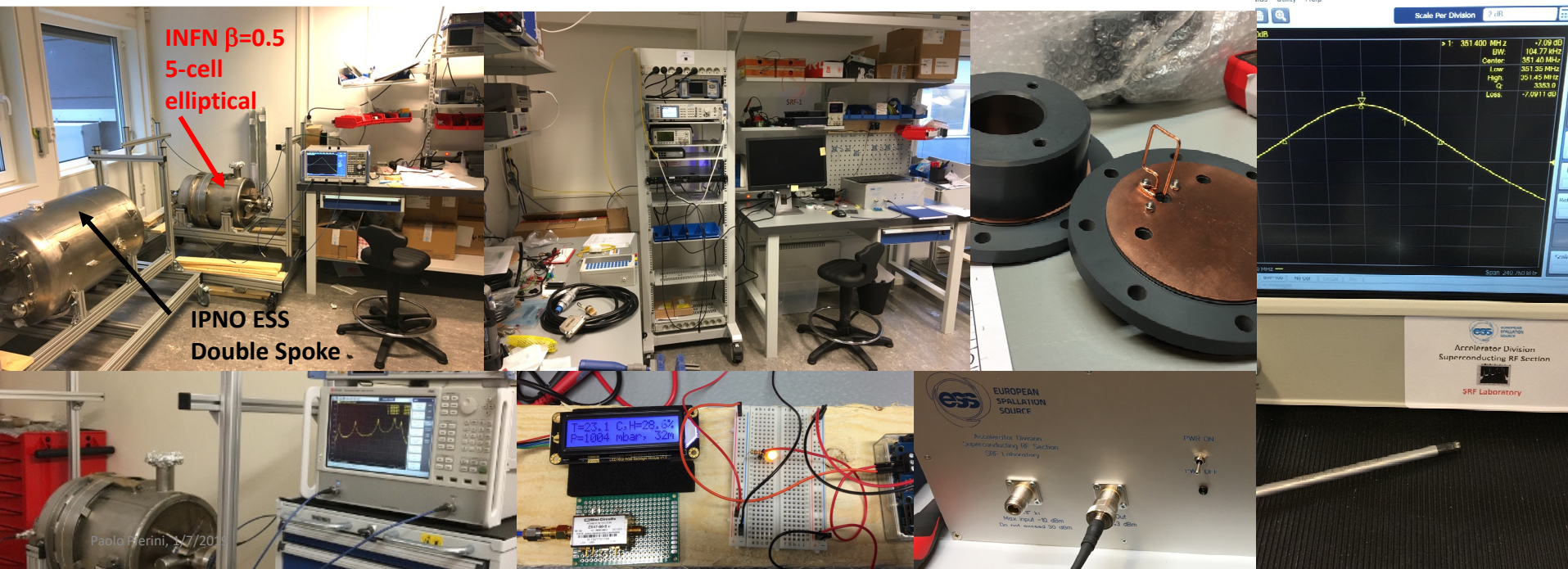
Parameter, all data kHz	CAV1 M001	CAV2 MP04	CAV3 MP01	CAV4 MP02	<AVE> SPREAD
From string in vacuum, RT, VV&tank PA, to 4.2 K	1186	1181	1169	1150	1172±18
From string in vacuum, RF, VV&tank PA, to 2K	1103	1107	1091	1080	1095±14
4.2K to 2K, cold, (Pressure sensitivity 1 bar to 30 mbar)	-83	-74	-78	-70	-76±7
String from air to vacuum (tuner, tank & VV air, RT)	174	177	190	195	184±11
Vessel from air to vacuum (tuner, string vacuum, tank air, RT)	111	105	107	75	99±18

- **Data to be used during TS2/Tunnel preparation phases and incoming checks**
 - Account for change in environmental conditions

Preparation activities: SRF

Established local laboratories and work areas

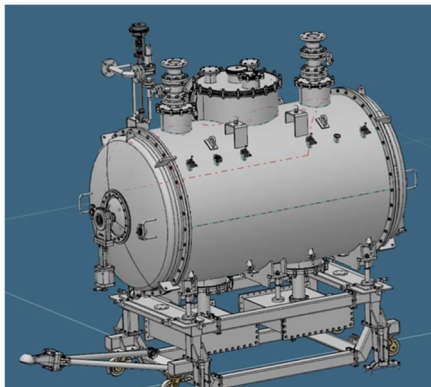
- All the prior development phase at IK, “hands-on” capabilities at ESS
 - Setup of **SRF Laboratory** for the preparation of all incoming reception measurements
 - Permanent laboratories in B02 building when available



Preparation activities: Mechanical

Development of installation tools

- ESS responsibility for **transport tools** (IK, internal) and supports
 - In close contact with ESS Engineering Division (Rigging, Design, Manuf.)
- Customization of CEA **assembly tools** to adapt to the TS2/Tunnel
 - e.g. Doorknob Installation Tool
- Design at ESS, discussed with IK
 - **Part of know-how transfer process**, support from EIS



DK installation tool (ESS)

Preparation activities: Incoming inspections at TS2

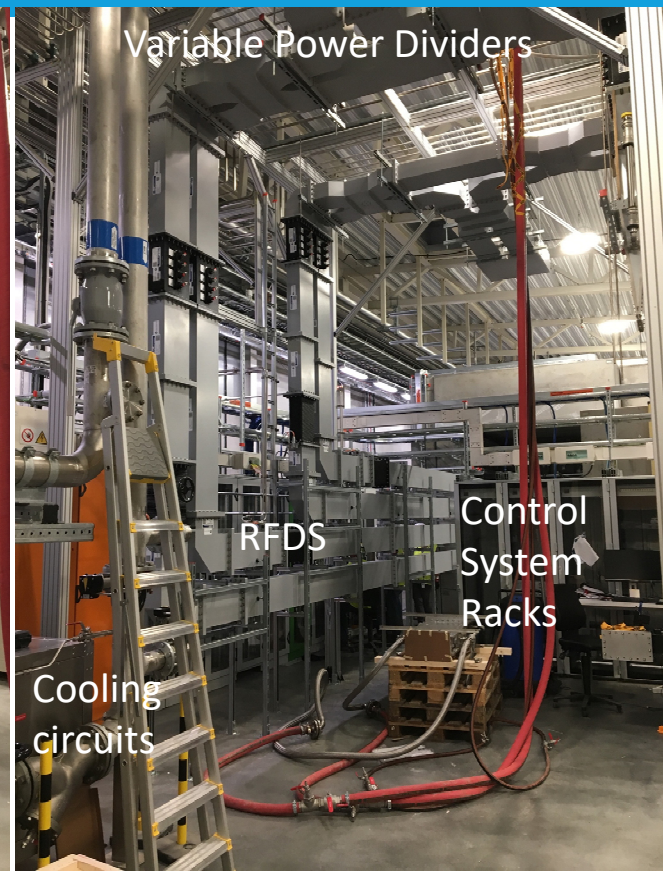
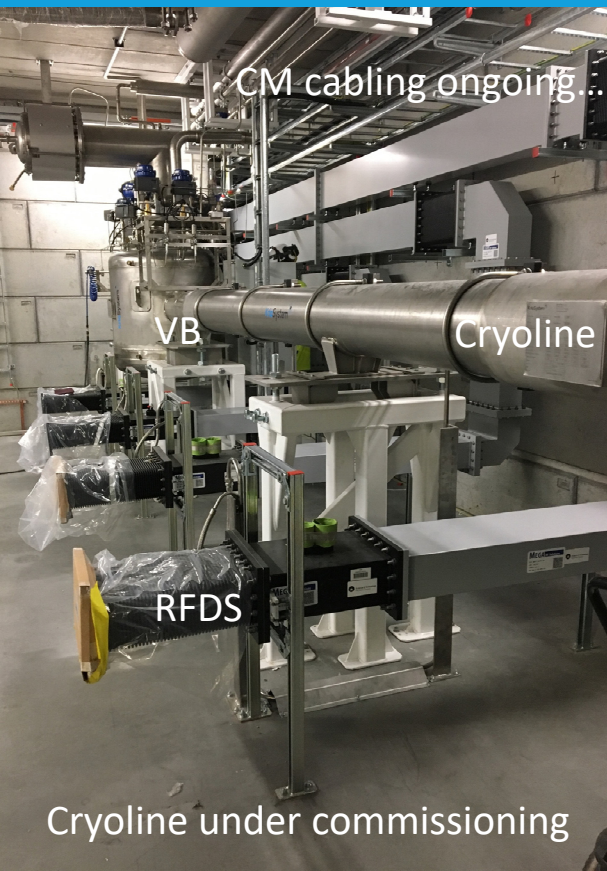
Setup of Module reception area with M-ECCTD

- Preparation of areas for
 - **Storage** of components/instrumentations/tools
 - **Workstations** for mechanical, electrical and RF incoming inspections
 - **Workstations** for activities needed for the TS2 test/tunnel
 - E.g. dismount/remount of transport fixations on thermal shields and string
 - Local instrumentation racks
 - **Training** teams!
 - Main mechanical reception operations on M-ECCTD
 - iso-vacuum procedures
 - RF incoming measurements
 - Electrical measurements on inner instrumentation (sensor, heaters, ...)



Test Stand 2 Readiness

Radiation authority permit and internal Safety Readiness Review in August



Testing at TS2

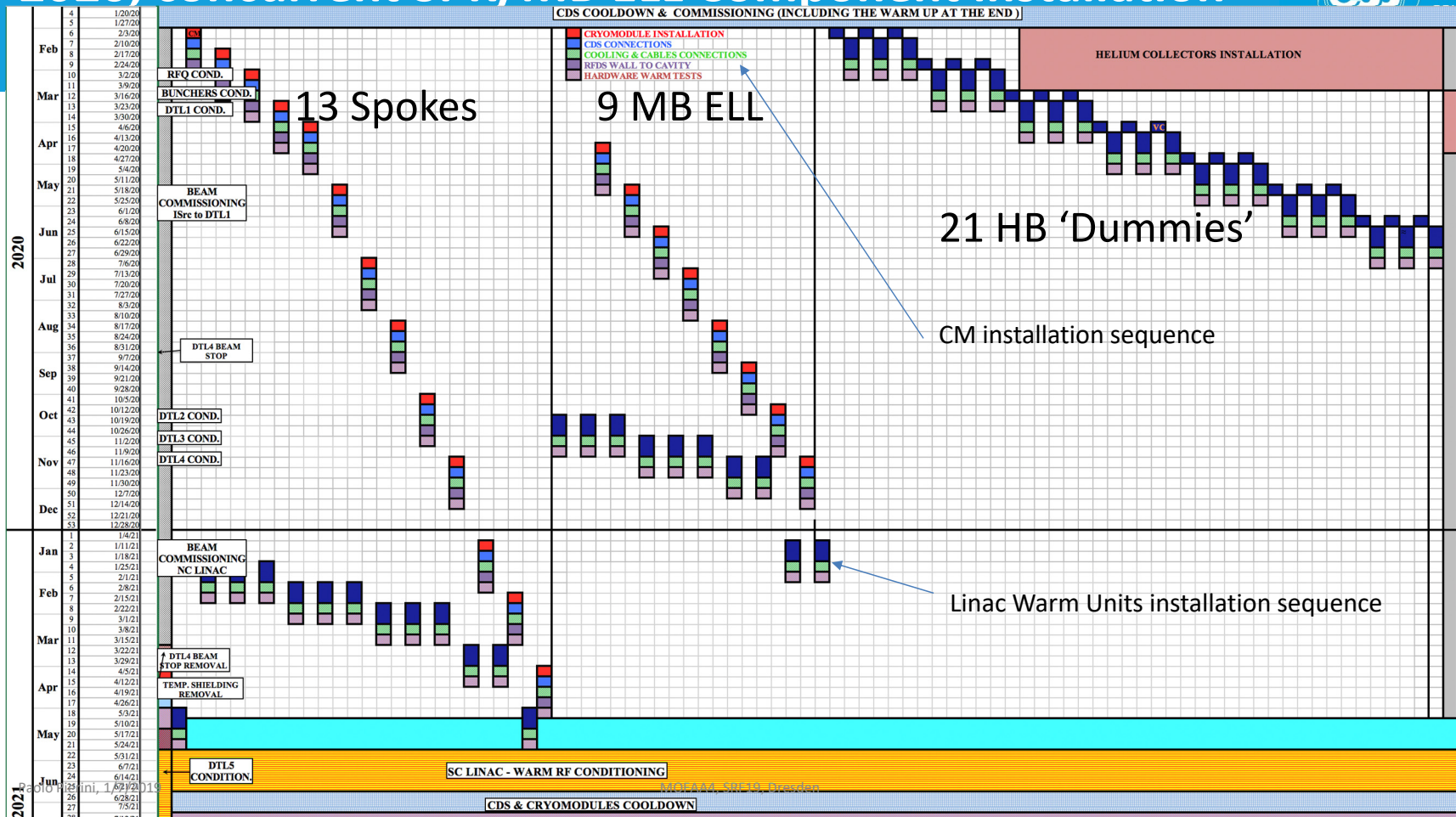
Steady state test cycle: one CM/month

- **Before Cooldown**
 - Warm Cable & Component **Calibration**
 - Warm Input RF Couplers **Conditioning**
- **After cooldown no HP RF**
 - Cold cable **Calibration**
 - 4K/2K passband measurements, before tuning
 - Cavities slow Tuners Test and Cavities Tuning
 - 2K passband measurements, after tuning
- **Stable conditions @2K starting HP RF**
 - Cold coupler **Conditioning** (off-resonance)
 - Open loop operation at low forward power
 - Fine tuning with Pt
 - **Calibration**
 - E_{acc} ramp up (cavities on resonance)
 - Field emission measurements (dose & energy spectrum)

Test goals

- **Performance** assessment (specs fulfilled?)
- **Limiting** mechanisms (quench, FE, Power limitations)
- **Comparison**/correlation wrt VT results (and cryomodule results, where possible)
- **Store** data for future Linac operations (degradation, perf. recovery)

2020, concurrent SPK/MB ELL Component installation



RF infrastructure in Gallery, stubs and tunnel

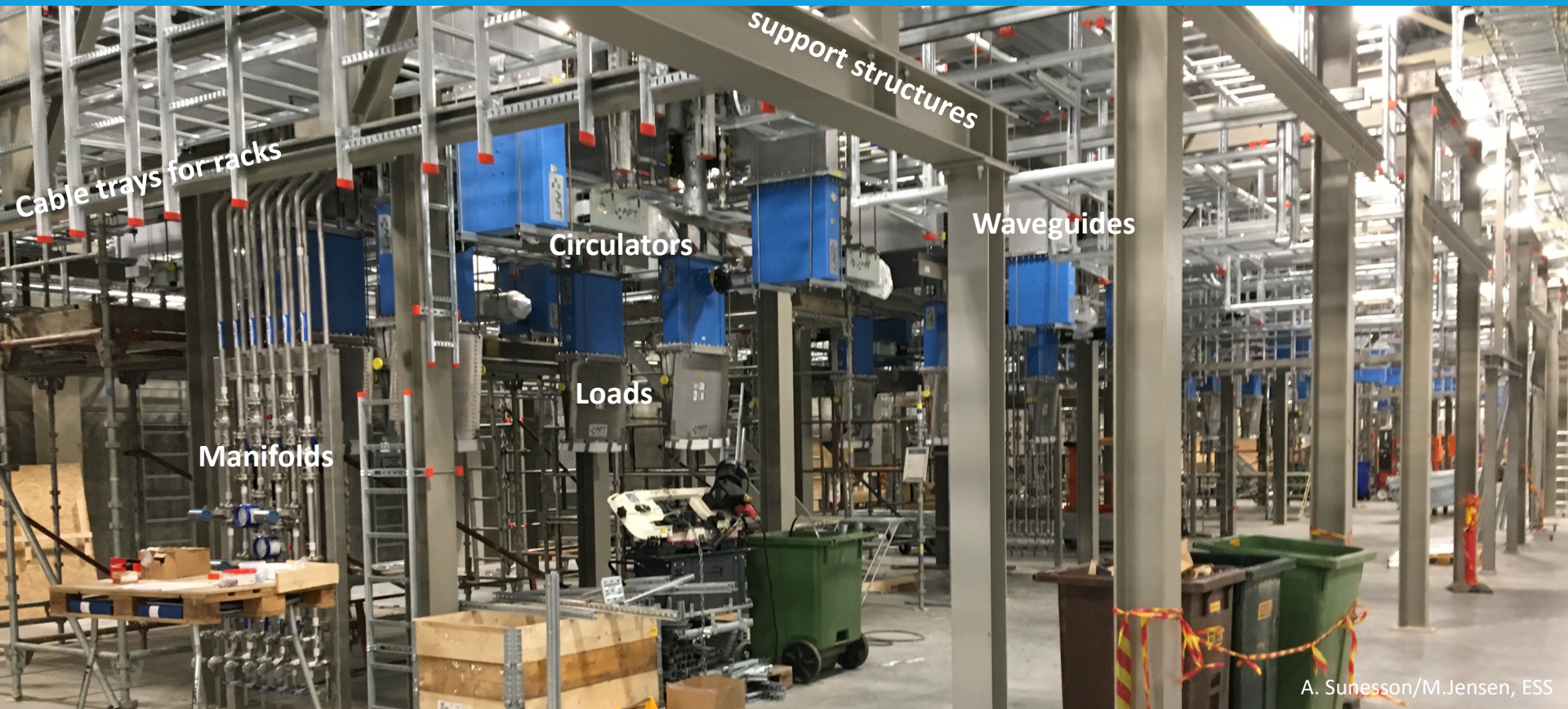
Gallery: RF equipment and electronics. Stubs: route WG/Cables to tunnel



Huge preparation work across all SRF linac in **all** areas.

	Spoke Section	Medium Beta Section	High Beta Section
RF Cell support structures	All installed		
Circulator, loads and waveguides	Almost all finished	Installation ongoing	Next
Waveguide in stubs	More than 50%	Completed	Well underway
Cables in stubs	Started cabling for Phase Reference Line		
RF Power systems	Installation in 2020	1/2 production at ESS Installation in 2020	Ordered Installation >2021

Spoke section gallery preparation



Delivery of MB Klystrons

Half of production stored in gallery



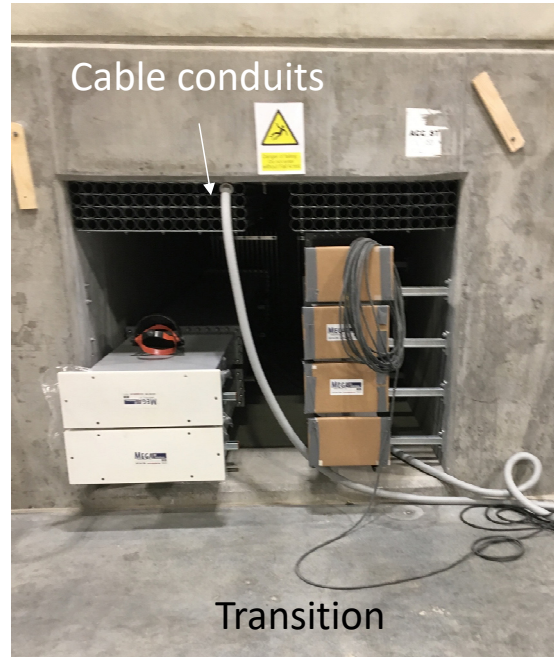
Stubs, gallery side

- Close to completion, for the start of the cable pulling operations

A. Sunesson/M.Jensen, ESS



Paolo Pierini, 1/7/2019



MOFAA4, SRF19, Dresden



Stubs, tunnel side

Installation of tunnel components of RFDS before VB components



A. Sunesson/M.Jensen, ESS

Tunnel: Cryomodule Dummies (and Soon Warm Units)

In the accelerator “contingency” space (reserved for upgrades)



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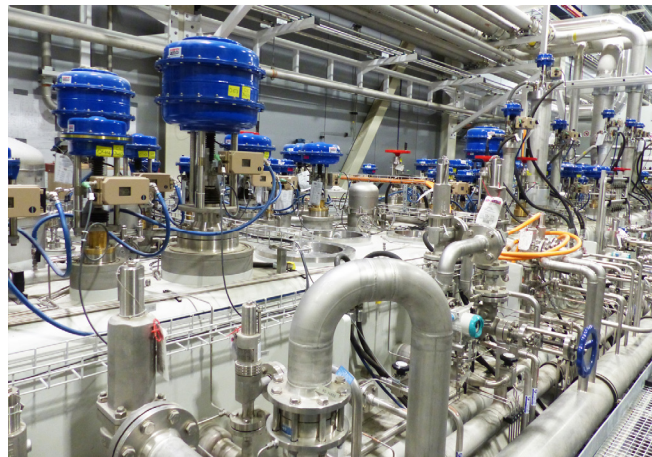
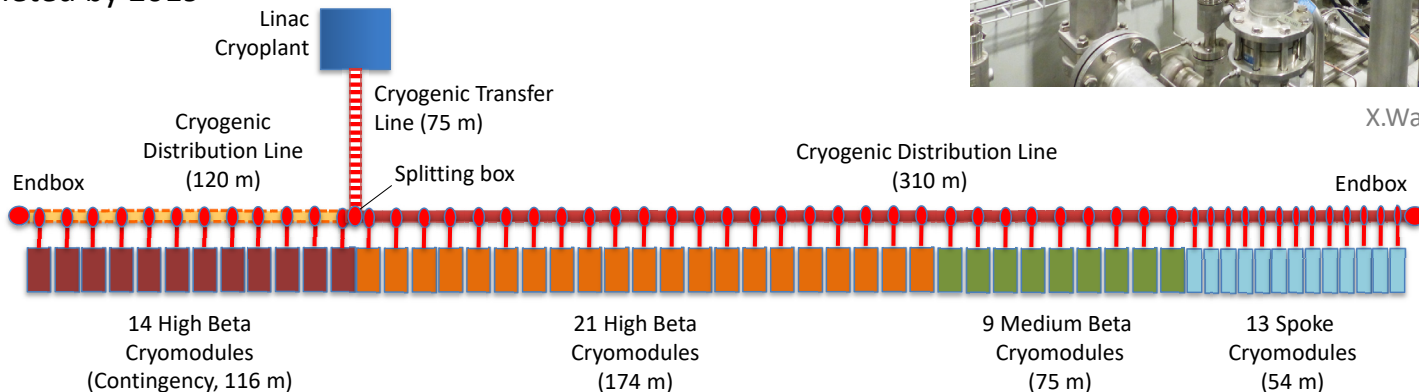
Same flange to flange length of CM

Cryogenics for the Linac

Three cryoplants procured and being commissioned by ESS Cryo Team

- **ACCP (ACcelerator CryoPlant)**

- Main plant for the entire accelerator (96% of energy gain by SRF)
- 3 kW @ 2K, 11.4 kW @ 40-50K, 9 g/s liquefaction @ 4.5K
- Designed to cope with upgrade scenario in the contingency space
- Producing LHe: ready for CDS commissioning in Q1 2020.
- Commissioning (including 2 K operation with cold compressors) completed by 2019



X.Wang/P. Arnold, ESS

Cryogenics for the Linac

Installation of linac Cryogenic Distribution line

- **CDS (Cryogenic Distribution System)**
 - Delivers cryogenics to the Accelerator from ACCP, provided as IK contribution by
 - WUST/PL (CDS-ELL)
 - IPNO/FR (CDS-SPK)
 - 9 CDS-EL Valve boxes installed and connected with Cryolines in tunnel, and other 3 positioned
 - Next: CDS-SPK (VB delays)
- Goal is **CDS cooldown by beginning of 2020**



Cryogenics for the Test Stand and Moderator

Installation of linac Cryogenic Distribution line



- **TICP (Test and Instruments CryoPlant)**
 - Cooling for **CM Test Stand 2**: 76W @ 2K, 420W @ 40K, 6 l/h Liquefaction (137 l/h with purifier on)
 - Liquefaction for **Neutron Instruments / Sample Environments**: 7500 l/month
 - **Commissioned** to specs and currently providing liquid helium to Lund University and MAX IV
 - Warm Pumps for subatmospheric operation
 - Commissioning of transfer line to TS2 currently undergoing, then *cryogenic operation of the TS2 with modules could start in summer*
- **TMCP (Target Moderator CryoPlant)**
 - Non-accelerator related
 - He plant for the LH₂ cooling of the Target Moderator: 30 kW @ 15-20K
 - Currently under commissioning

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Summary

Intense workload across all SRF machine section



- Installation/Testing goals for 2019
 - Completion of cryogenics: CDS-EL and CDS-SPK
 - He recovery line in tunnel (venting events)
 - HEBT LWUs and beam lines
 - Completion of Stubs and waveguides along tunnel walls
 - Installation of Cryomodule support stands
 - Preparation of the infrastructure: cabling, piping and support systems
 - **Start TS2 operation with prototypes**
 - **Start testing of series spokes (UU) and elliptical modules (TS2)**
- Module installation in tunnel will follow in **early 2020**, after the testing of the initial series components now under assembly (see G. Devanz on Wednesday)



A special thank
for the material
here to all our
colleagues in the
Machine
Directorate at
ESS and to the
IFJ-PAN team
stationed in Lund

Thank you for the attention!

