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SRF 19 DRESDEN
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

MOFAA4

Outline

- ESS Intro
  - From construction to operation in a (former) ”green-field” organization
- High Level Accelerator Milestones
- SRF Activities at ESS
  - Elliptical test stand preparation
  - Incoming cryomodule reception
  - (Preparation of) testing
- 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

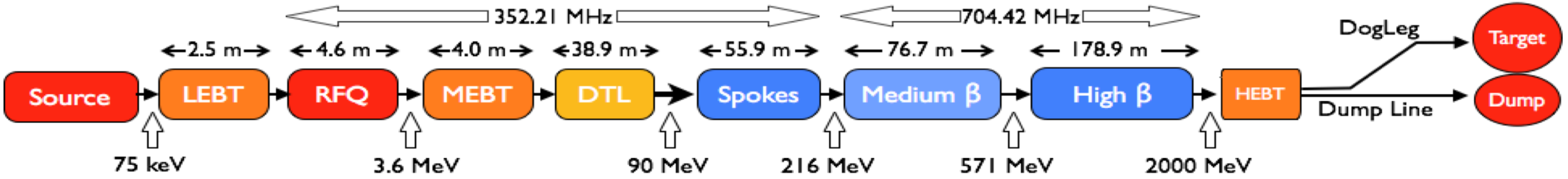
125 MW

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**



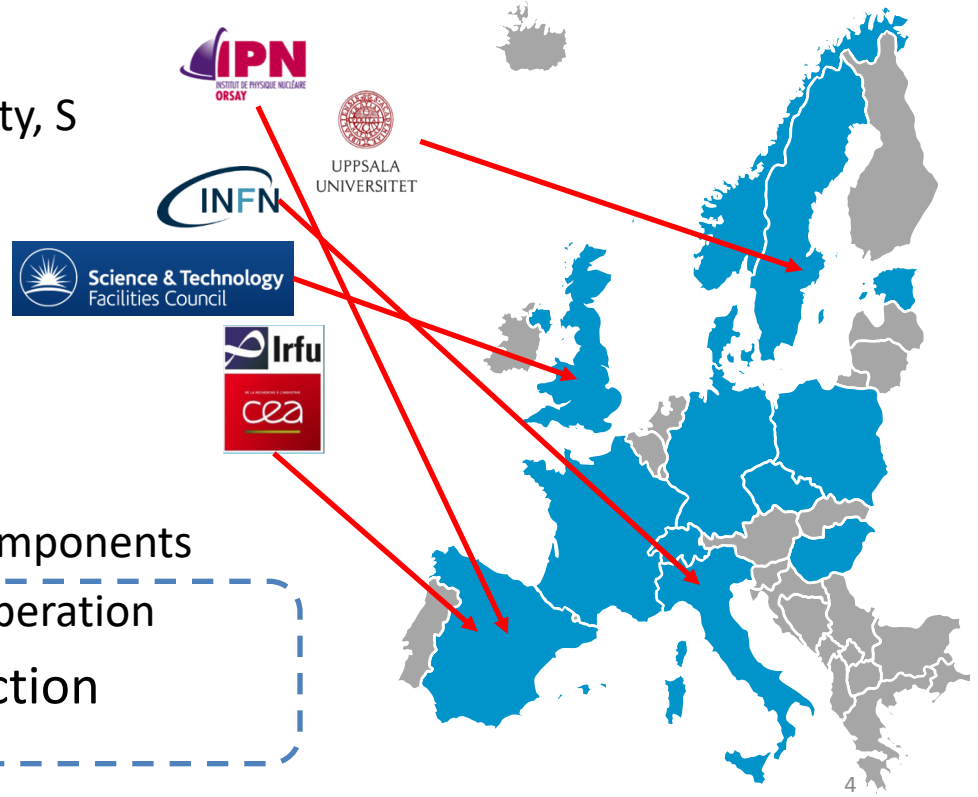
Collaborative: 18 IK partners in 8 countries, 5 collaboration partners

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

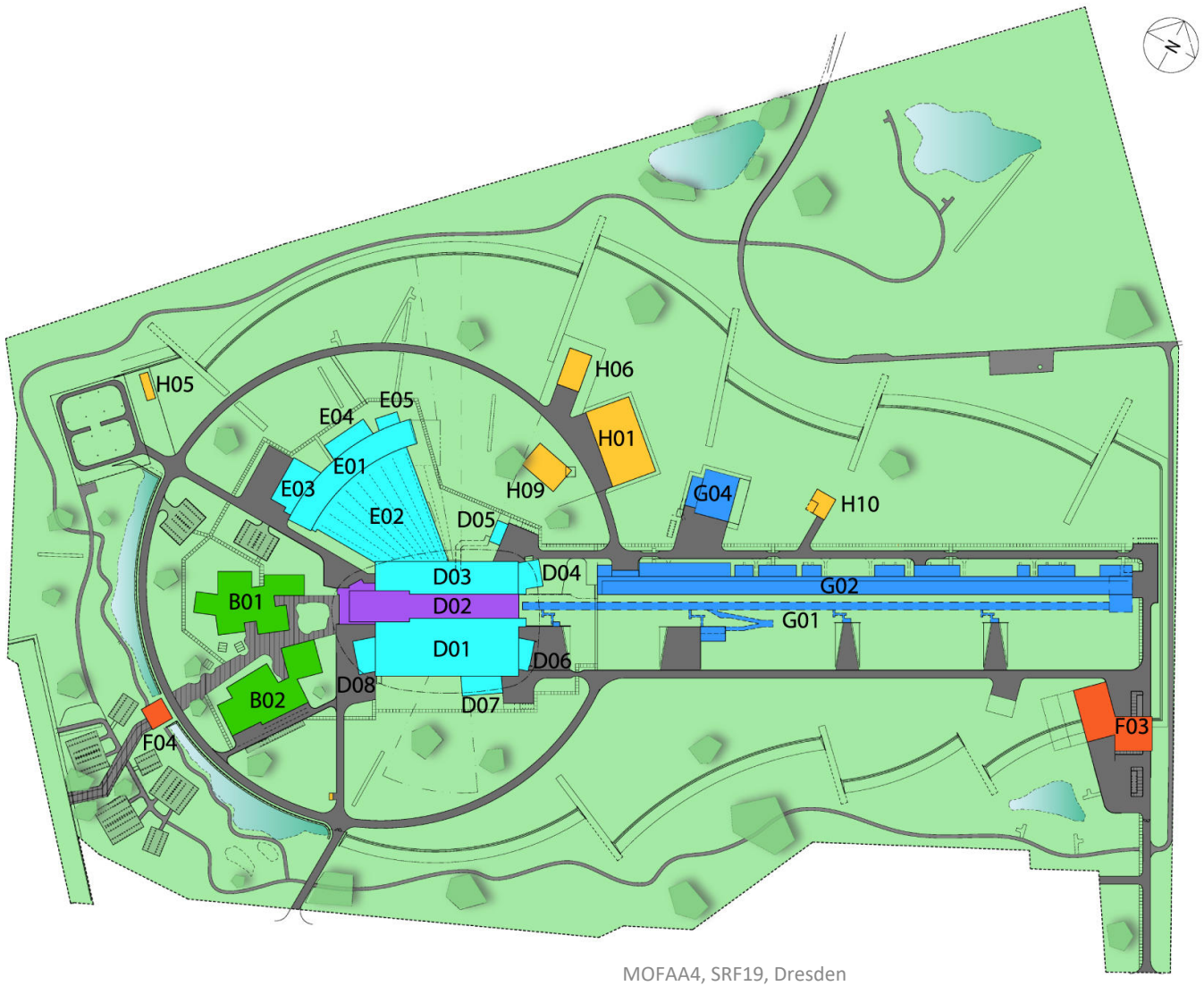
- Almost all **components of the linac are designed and provided as in kind contributions**
- **After handover scope transferred to ESS**
- For the SRF linac, the partners are organized in the **ESS SRF Collaboration** with the workshare:
  - Spoke cavities and cryomodules (including prototype) by IPNO, 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

ESS Site Layout



Accelerator
- G01 Accelerator Tunnel
- G02 Klystron Gallery
- G04 Cryo Compressor Building

Target
- D02 Target Building

Experimental Halls
- D01 Experimental Hall 1
- D03 Experimental Hall 2
- D04 Labs, Hall 2
- D05 Substation
- D06 Substation
- D07 Labs, Hall 2
- D08 Labs, Hall 2

- E01 Experimental Hall 3
- E02 Beam Line Gallery
- E03 Labs, Hall 3
- E04 Labs, Hall 3
- E05 Substation

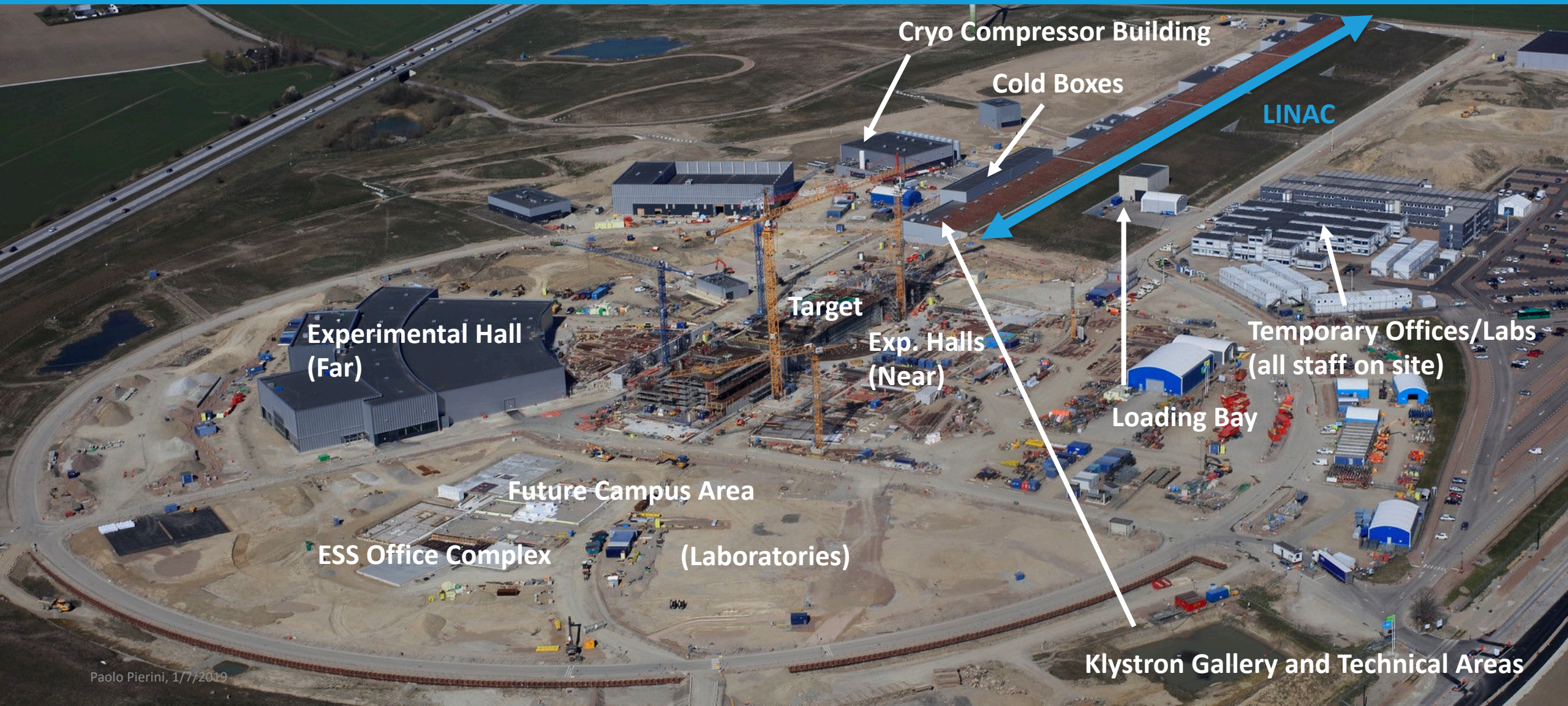
Utilities
- H01 Central Utility Building
- H05 Substation
- H06 Substation
- H09 Waste Building
- H10 Sprinkler Building

Service
- F03 Logistic Center
- F04 Entrance Building

Campus
- B01 Office Building
- B02 Lab/Workshop Building

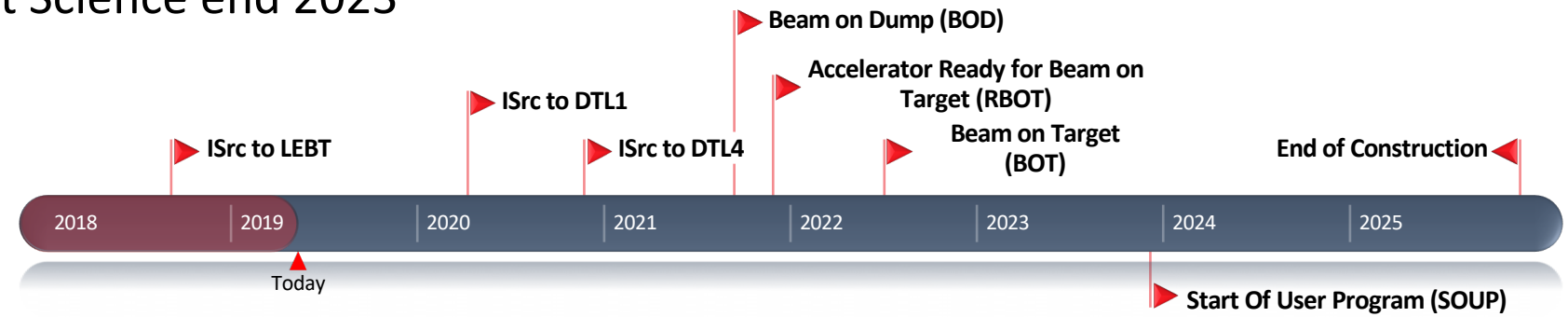
The ESS site in April 2019

Target area more advanced now, Tunnel and Gallery transferred to ESS



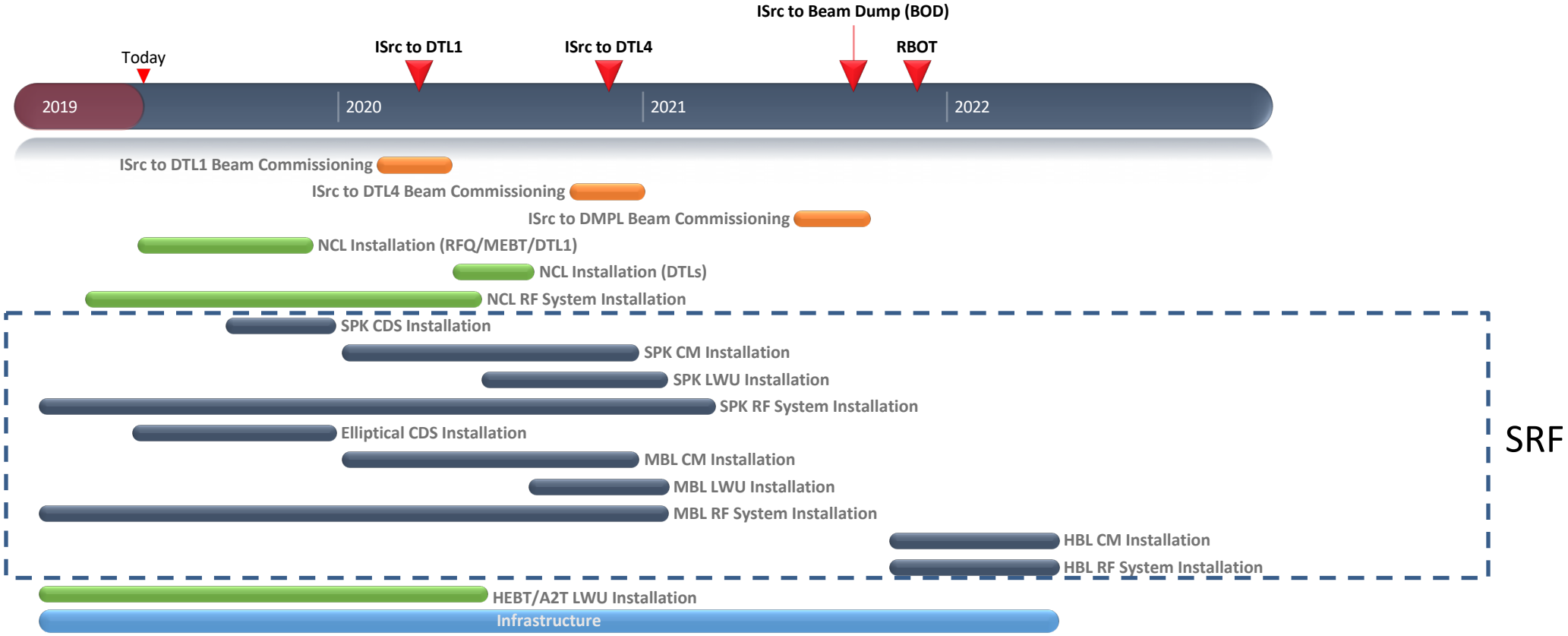
Major Accelerator milestones

- Source 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 activities

- 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 receival

- 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

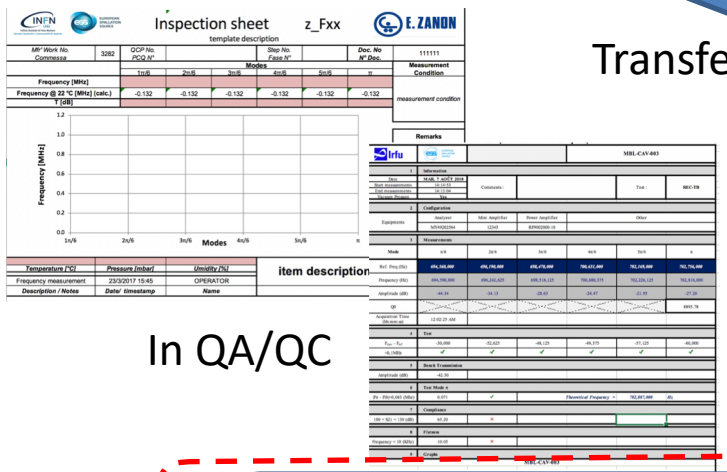
- **Prototype cryomodule** transported to ESS in February 2019
  - Beam vacuum preserved
  - Few loose screws on isovac flanges and tuner components

  - **Not cold tested yet!**

Preparation for tests

Know what to expect… Estabilished **ESS Cavity Database (THP099)**

MEASUREMENTS @ IKC
- After fabrication
- Intermediate handover
- Outgoing



In QA/QC

Transfer

ESS Scope

Measurement&Calibration DB
(ownCloud service)

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

Live Staging Area
(typ. text files)

Script

Normalized Data
(HDF files, metadata)

ESS Asset
Management
ID Installation
Structure

Tagging (in metadata)

https://gitlab.esss.lu.se/SRF_Section

APPLICATIONS
- Browse
- Compare
- Assess

Script

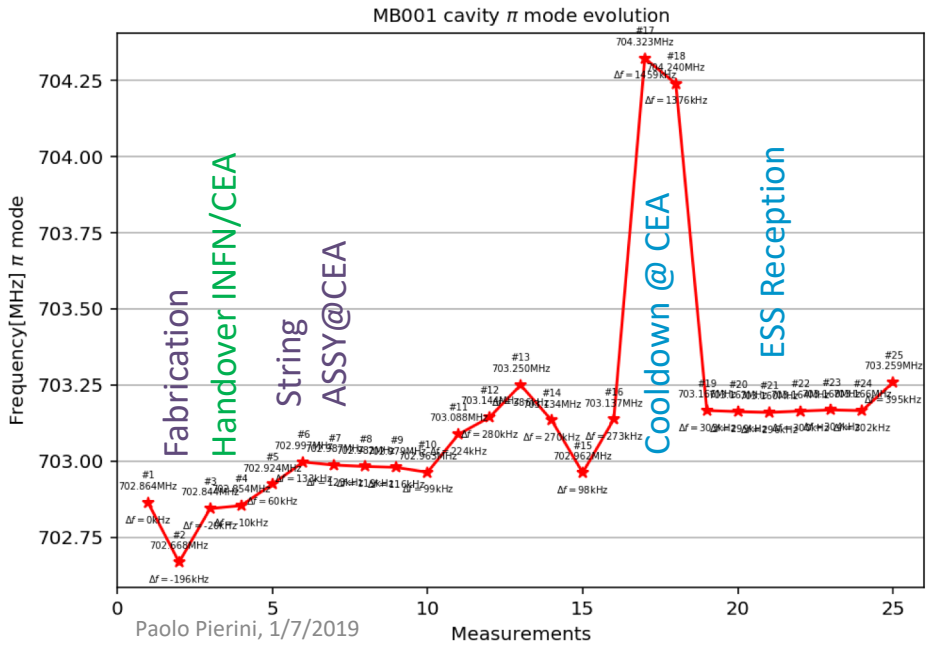
Save

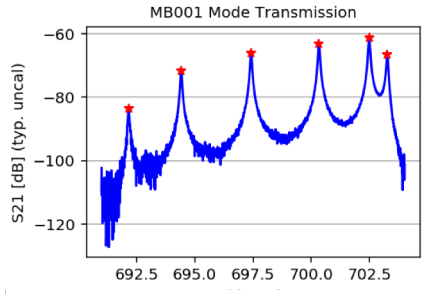
MEASUREMENTS @ ESS
- Incoming
- Preparation TS2/Linac

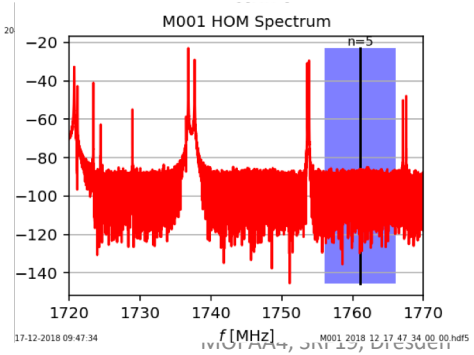
Preparation activities: We need to know our cavities!

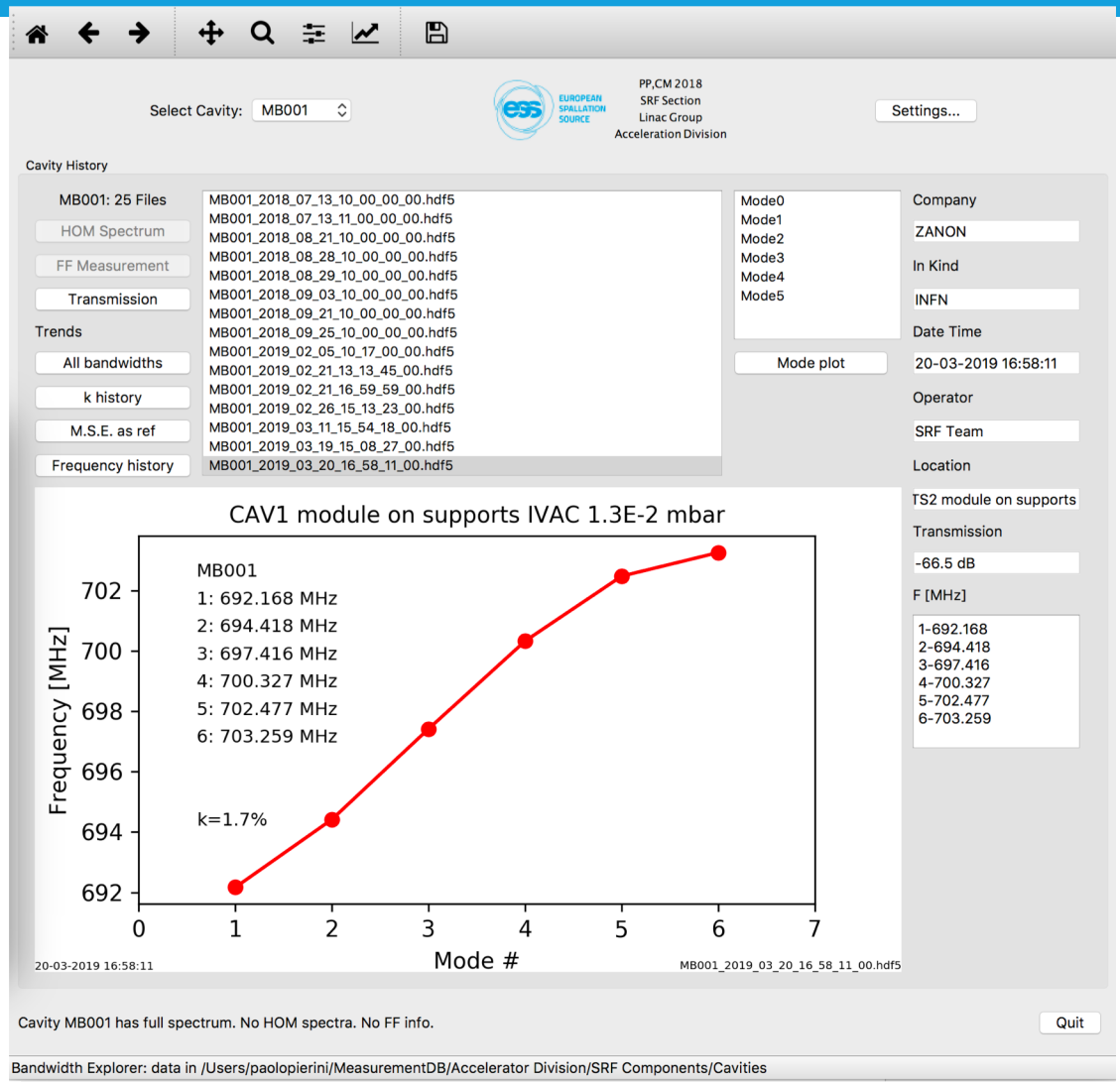
ESS Cavity DB

- 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





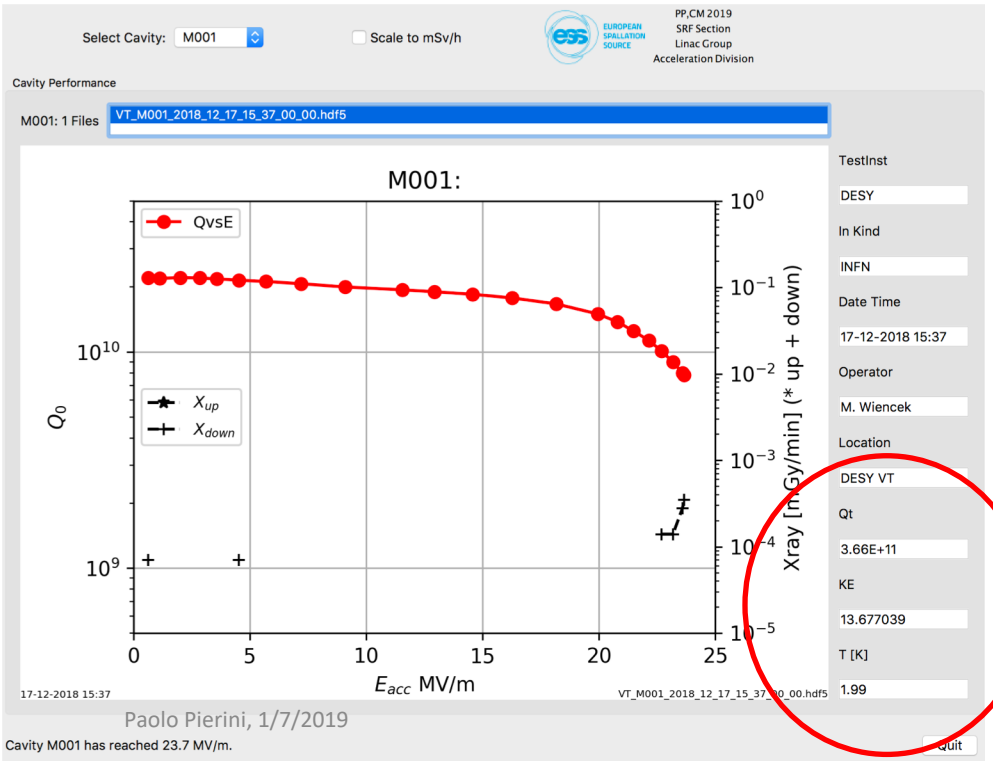




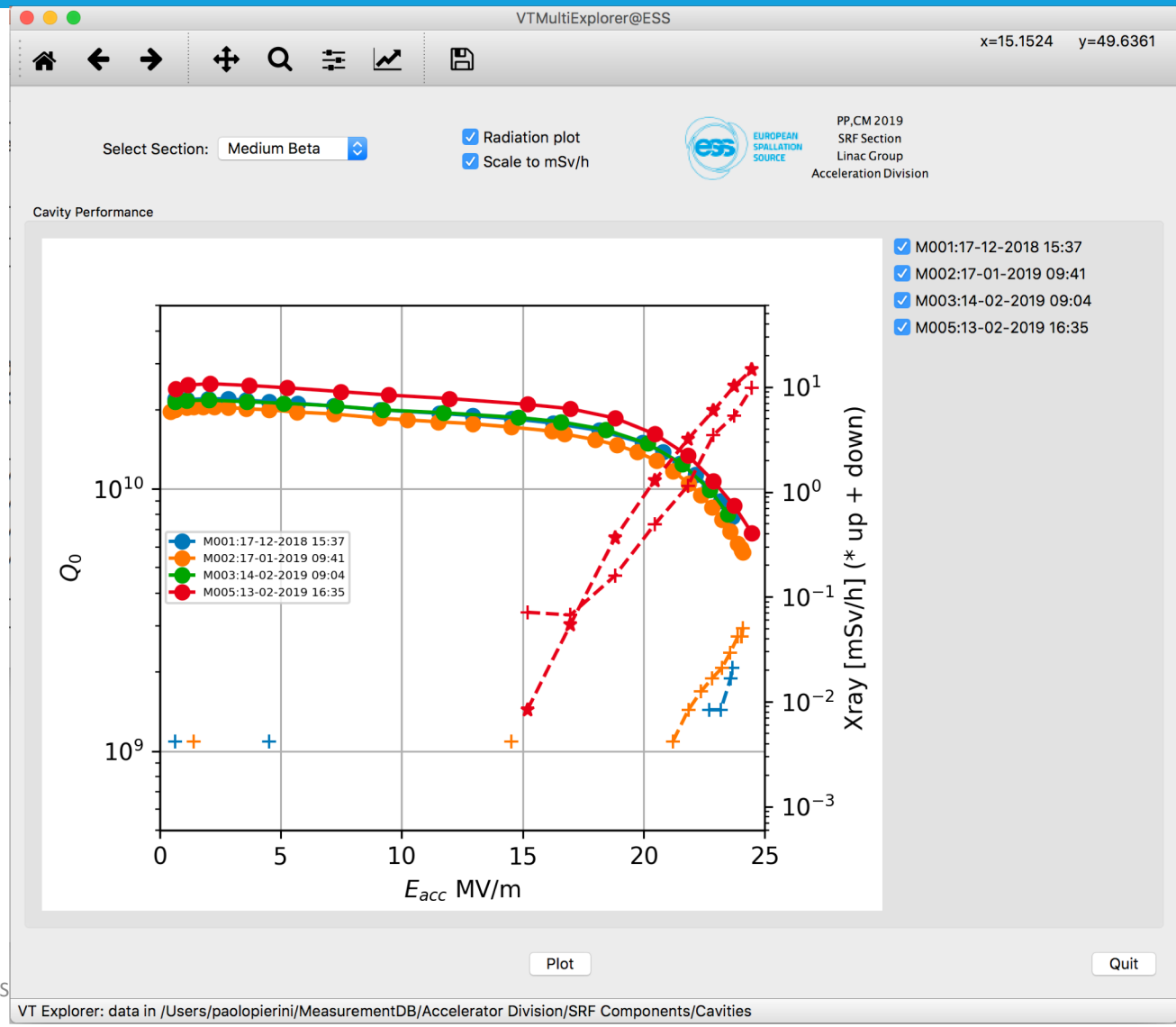
Preparation activities: Cavity performance data

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 (Eacc, radiation levels)
  - Calibration data for TS2



e.g. PU calibration data from DESY VT



Sensitivity analysis

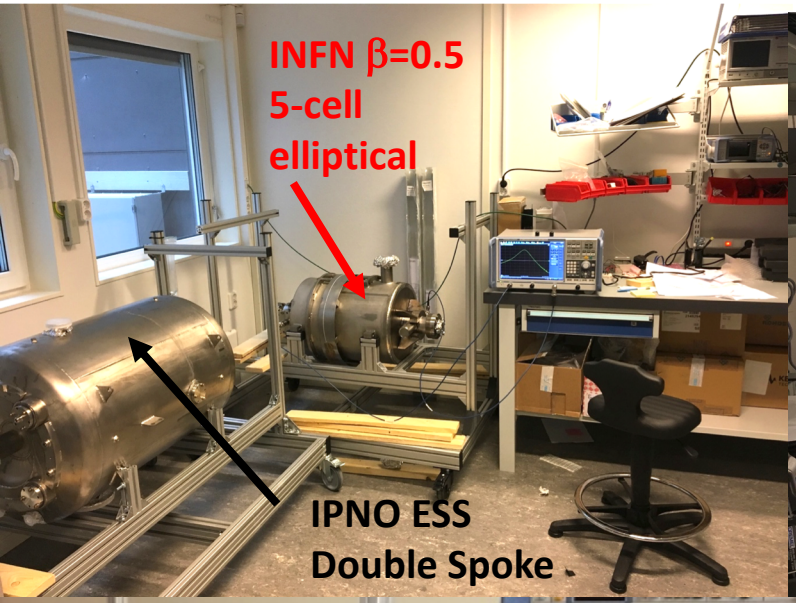
From demonstrator retrieved data of **expected behavior** of series in TS2

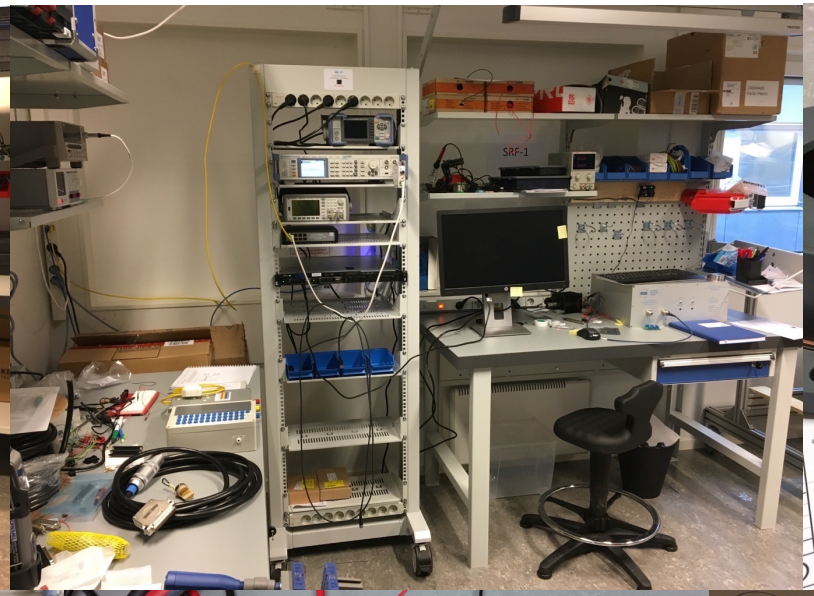
Parameter, all data kHz	CAV1 M001	CAV2 MP04	CAV3 MP01	CAV4 MP02	<AVE> SPREAD
From string in vacuum, RT, VV&tank PA, to 4.2 K	1186	1181	1169	1150	1172±18
From string in vacuum, RF, VV&tank PA, to 2K	1103	1107	1091	1080	1095±14
4.2K to 2K, cold, (Pressure sensitivity 1 bar to 30 mbar)	-83	-74	-78	-70	-76±7
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

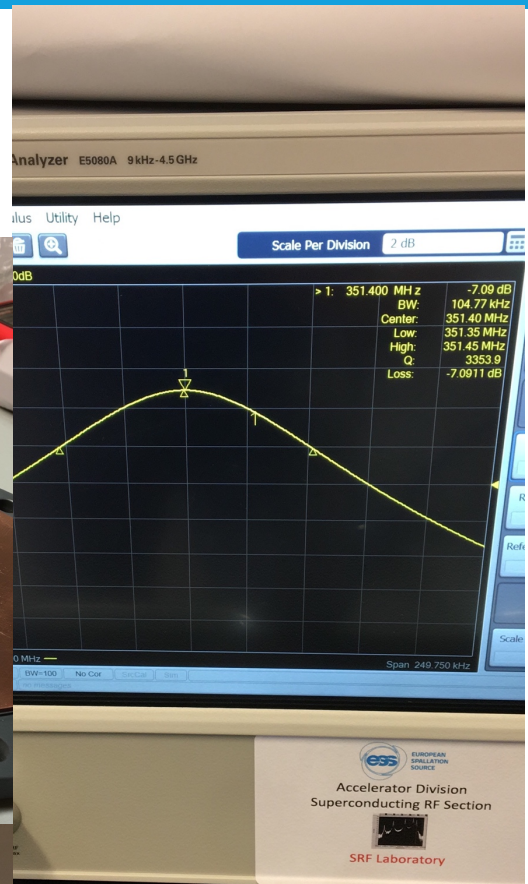
- **Data** to be **used during TS2/Tunnel preparation phases and incoming checks**
  - Account for change in environmental conditions

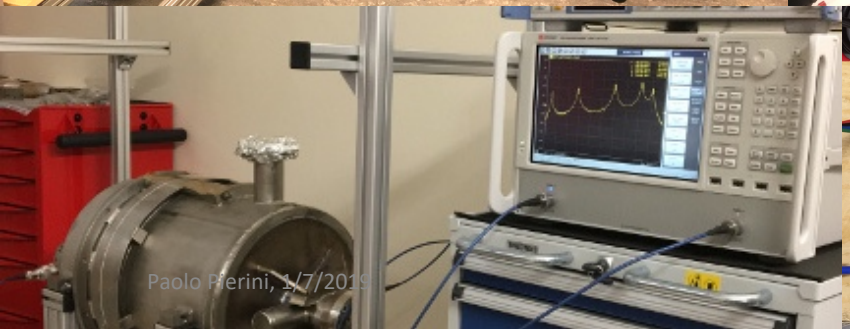
Preparation activities: SRF
Estabilished local laboratories

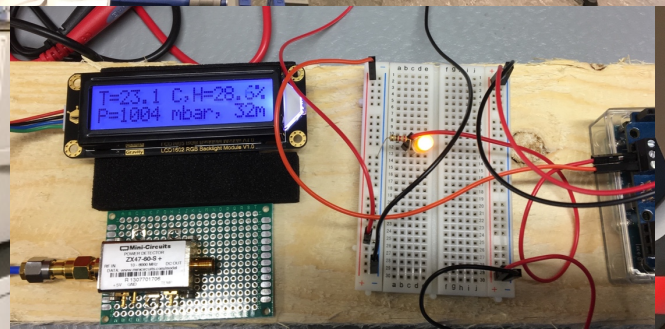
- **All the prior development phase at IK, “hands-on” capabilities at ESS**
  - Setup of SRF Laboratory for the preparation of all incoming reception measurements
  - Permanent laboratories in B02 building when available









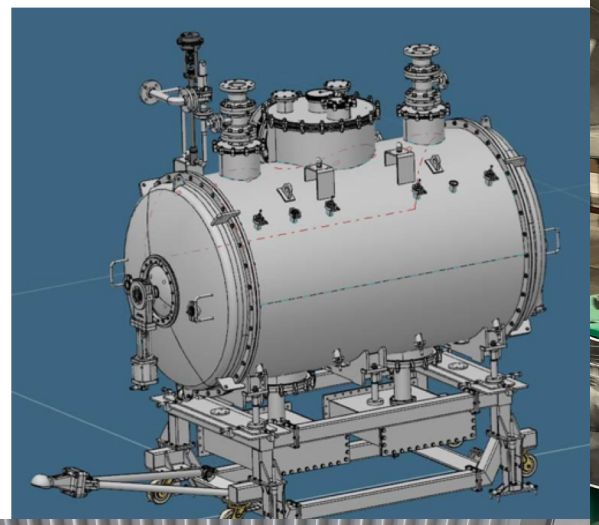


Preparation activities: Mechanical

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

On site transport cart



Spoke cart/support

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 instruments

Test Stand 2 Readiness

Radiation authority permit and internal Safety Readiness Review **in August**

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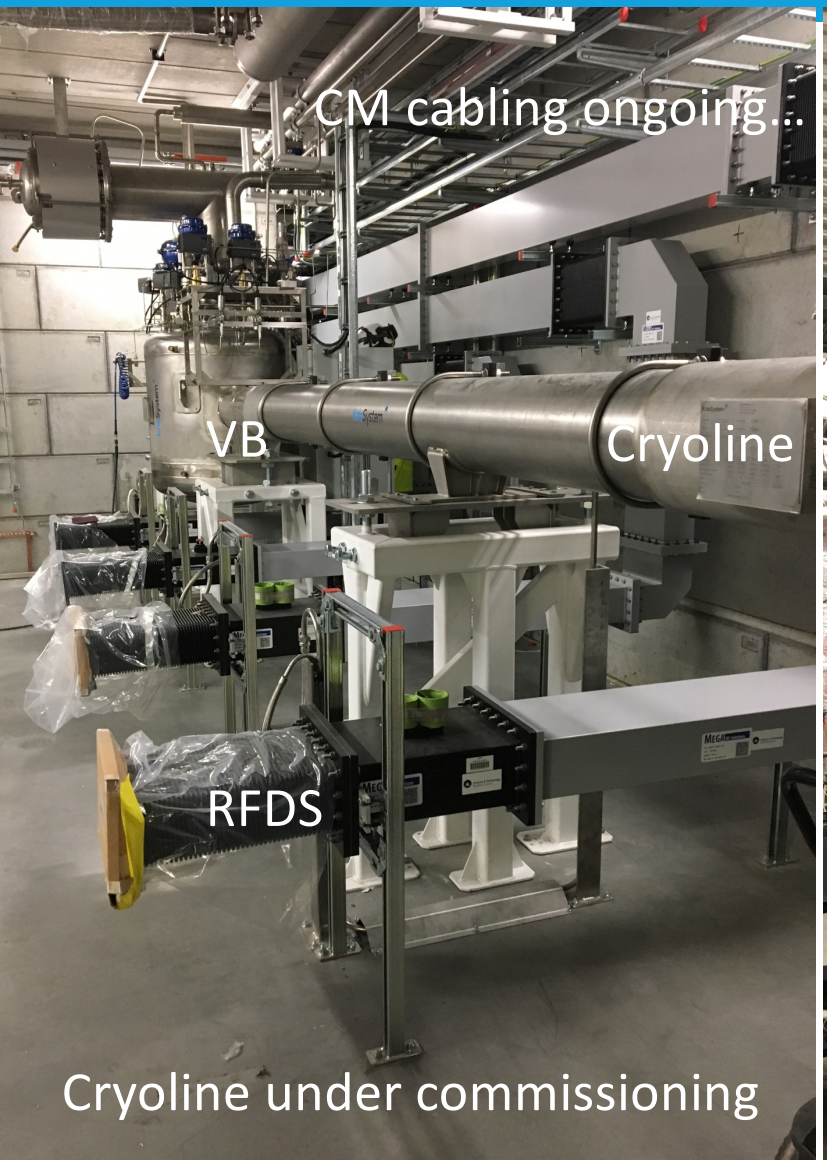
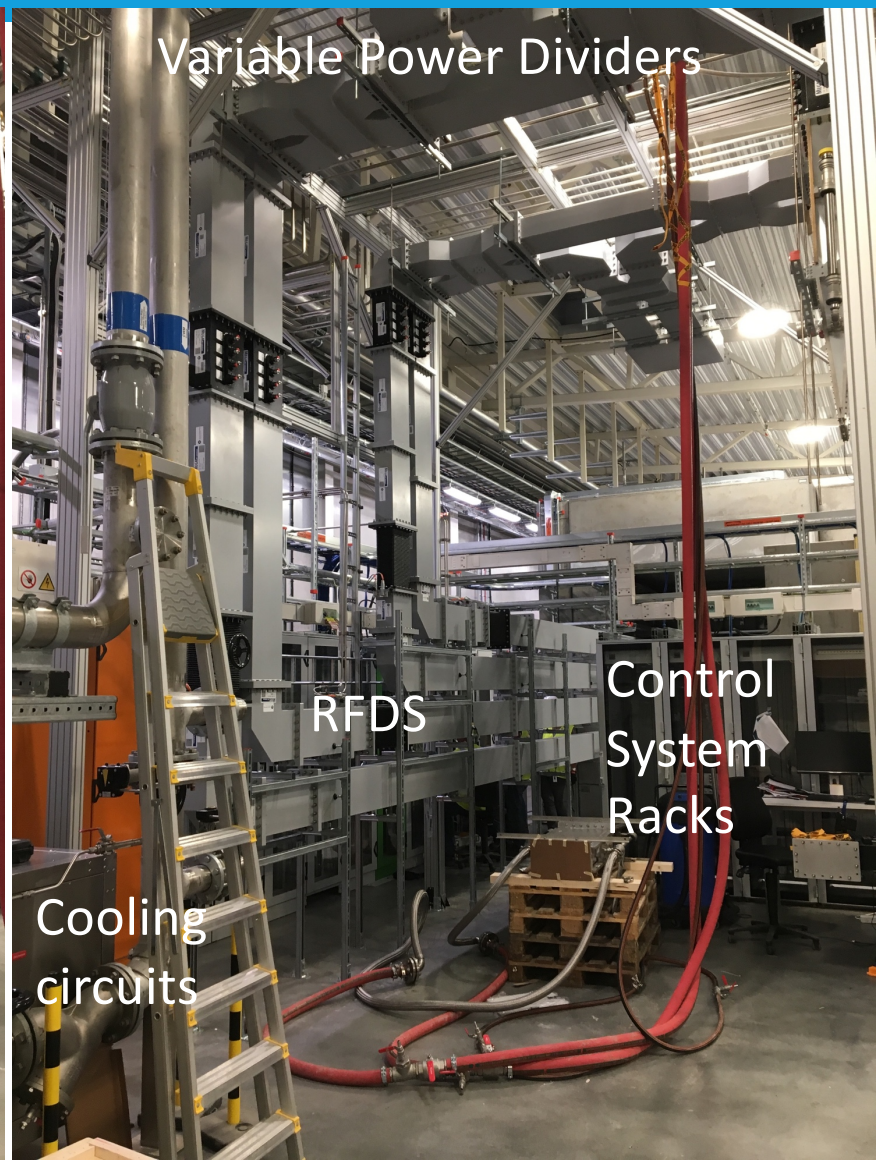


Cryoline under commissioning

Klystron commissioning on loads



Testing at TS2

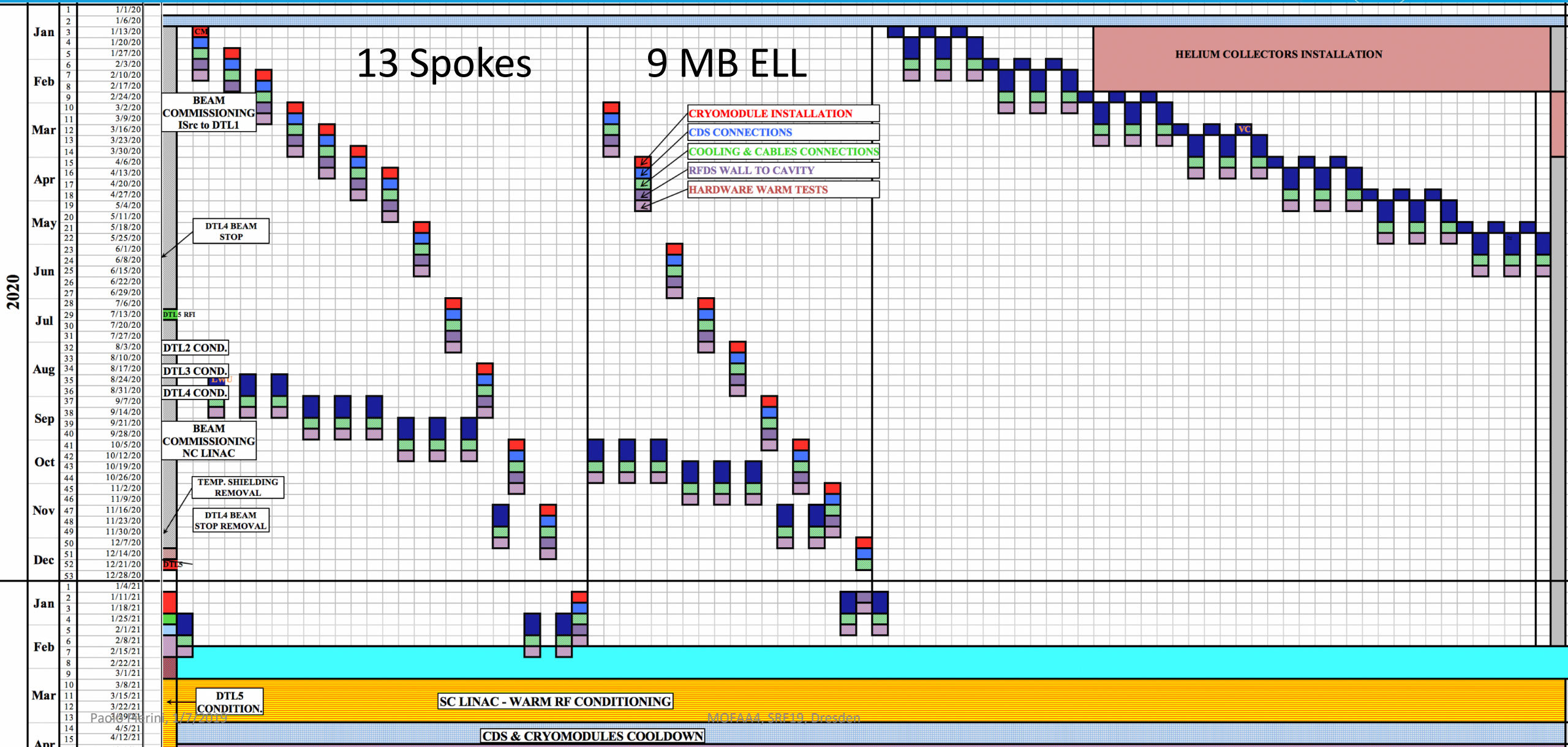
Steady state test cycle: one CM/month

- **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



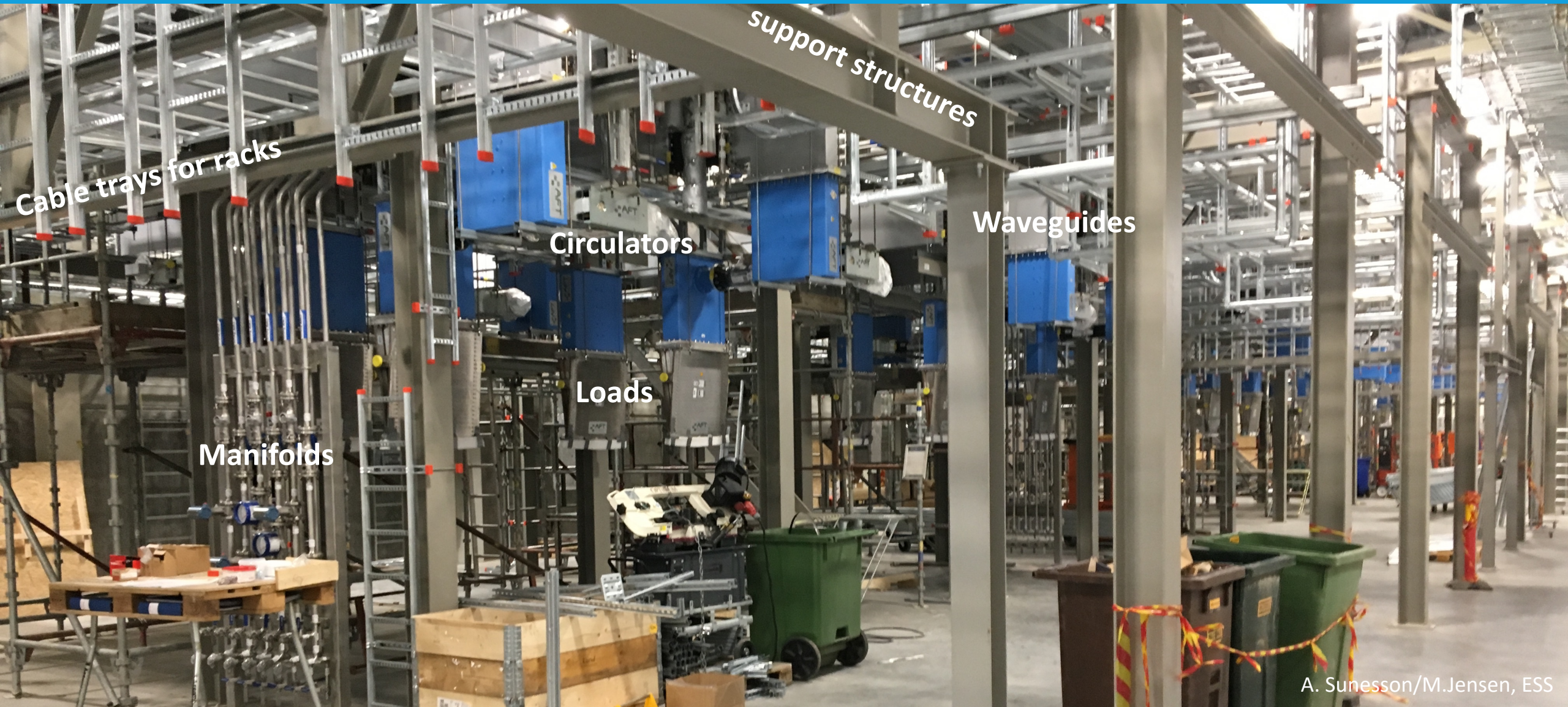
RF infrastructure in Gallery, stubs and tunnel

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

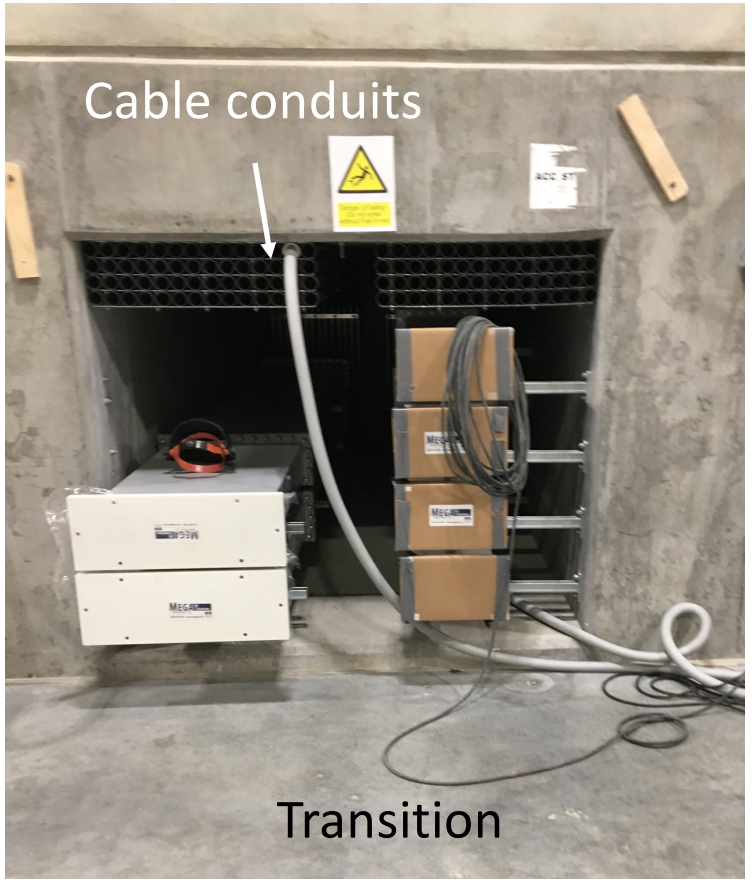
Half of production stored in gallery

A. Sunesson/M.Jensen, ESS

Stubs, gallery side

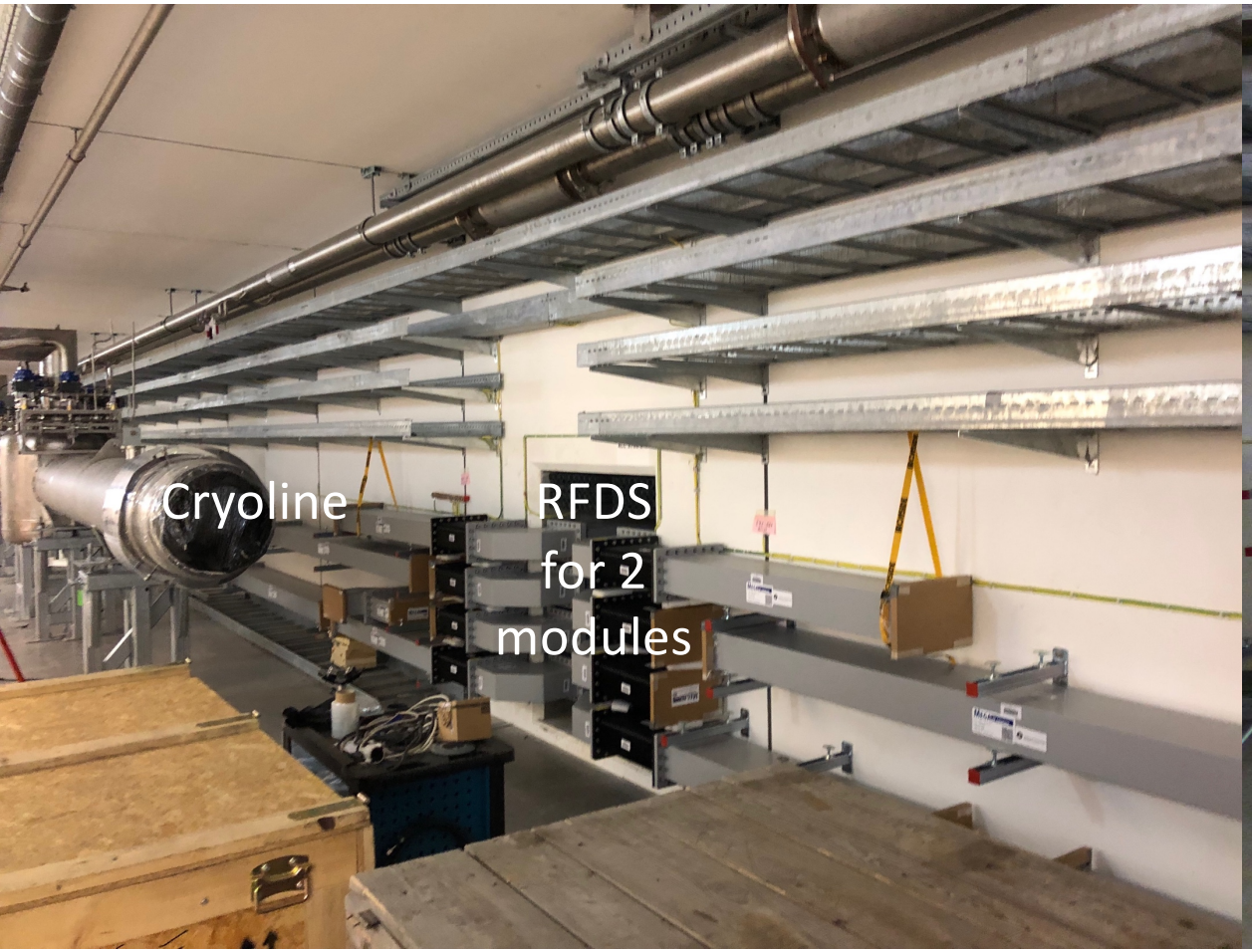
- Close to completion, for the start of the cable pulling operations

A. Sunesson/M.Jensen, ESS



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)

Linac Warm Units here

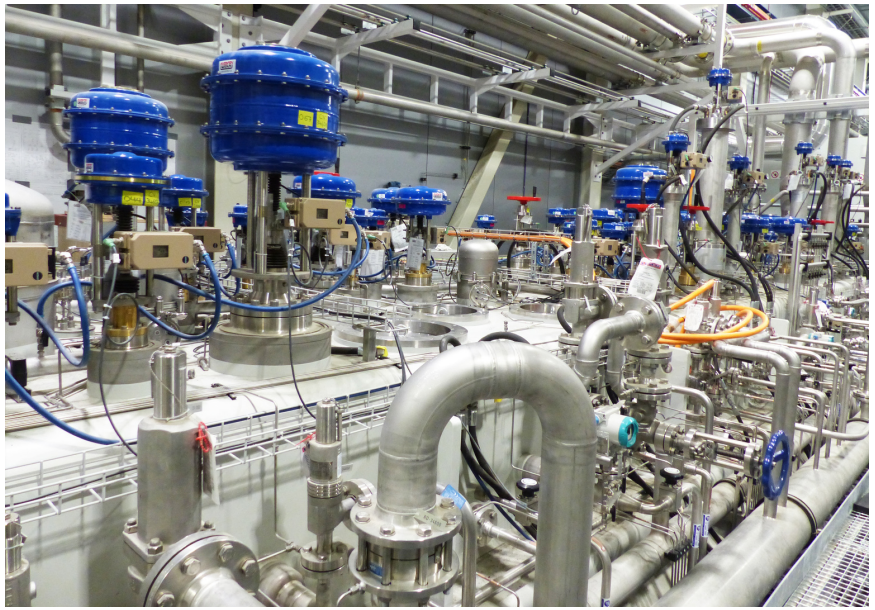
Same flange to flange length of CM

M. Juni Ferreira/ESS

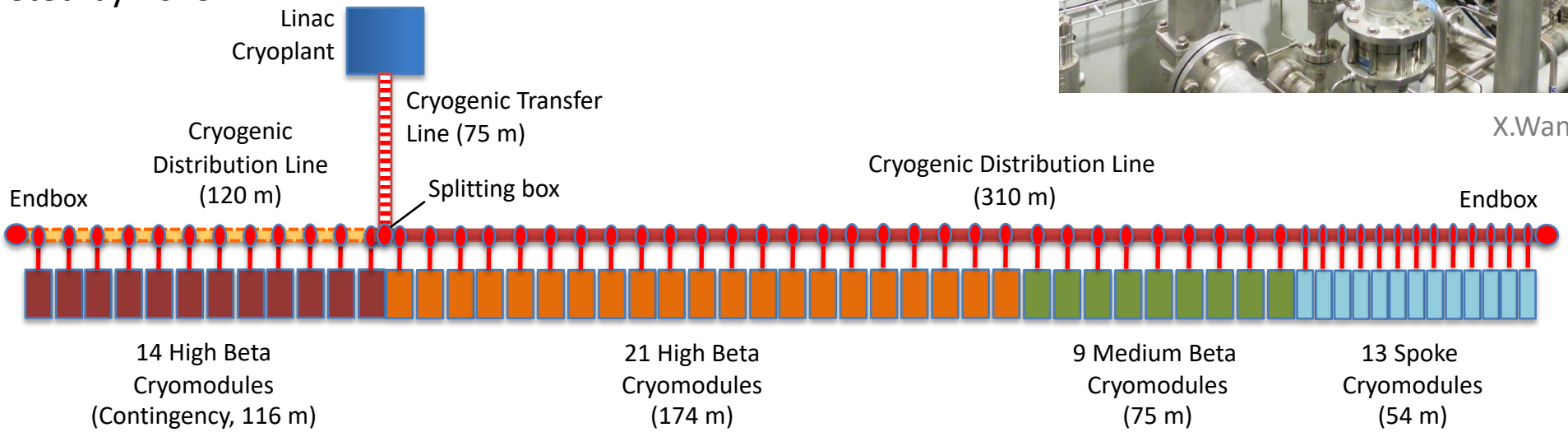
Cryogenics for the Linac

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 end 2019-beginning 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 LH_2 cooling of the Target Moderator: 30 kW @ 15-20K
  - Currently under commissioning

Courtesy P. Arnold, ESS

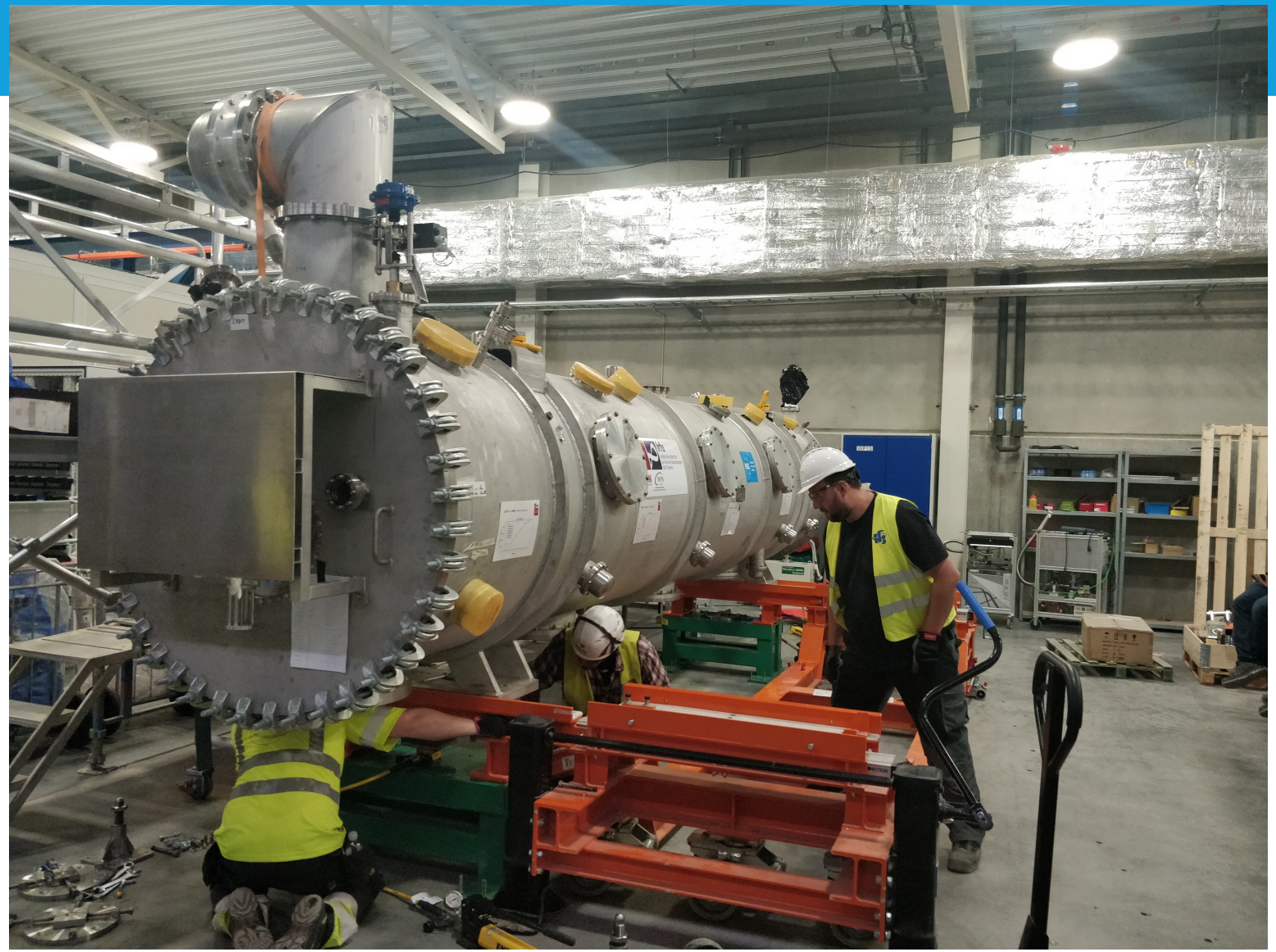
Summary
Intense workload across all SRF machine section

- Installation/Testing goals for 2019
  - Completion of 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 and elliptical modules
- 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)

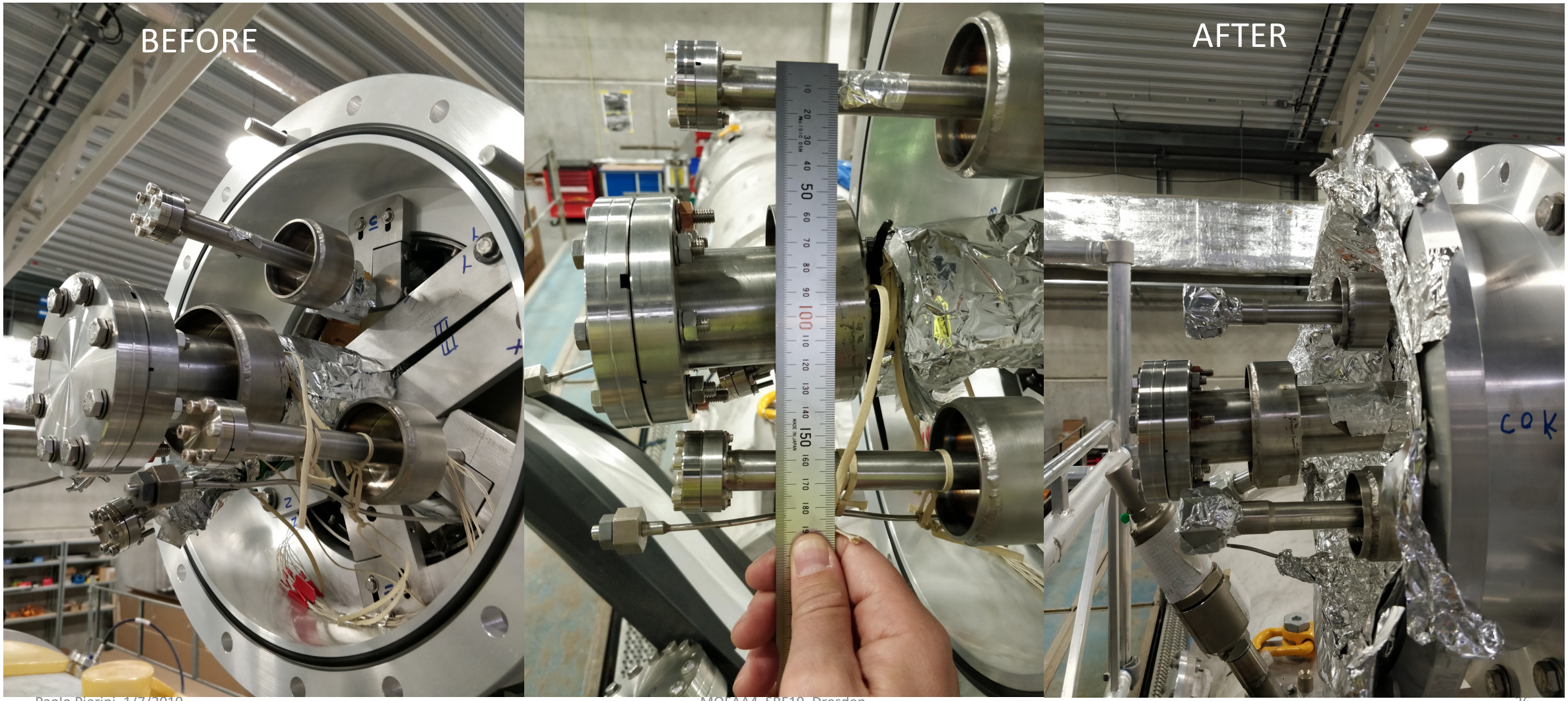
Thank you for the attention!

New Girder & Cart modifications

On and off supports with cart



Modifications of M-ECCTD Jumper



Nothing was set on fire…