The X-band and High-Gradient Landscape

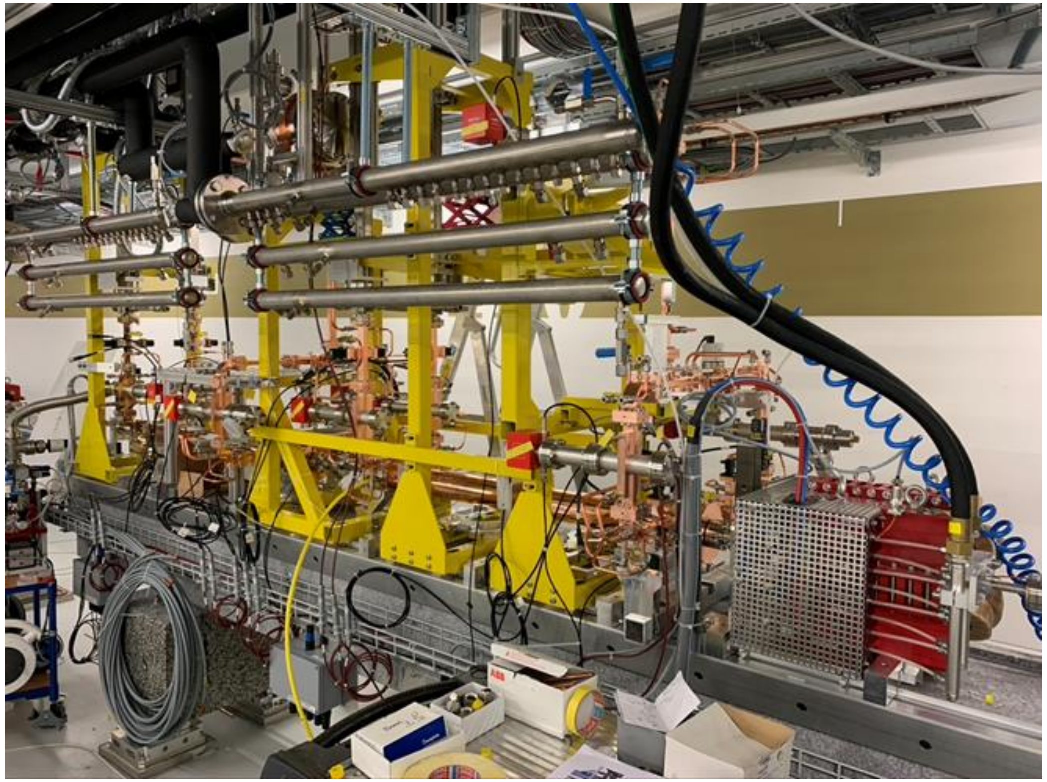
Objective

The objective of this presentation is to give you a feeling for the numerous X-band and high-gradient projects currently underway – all in one go.
I will go fast. With some selected images from various presentations given over the past year.

Please let me know if there are projects I have missed!

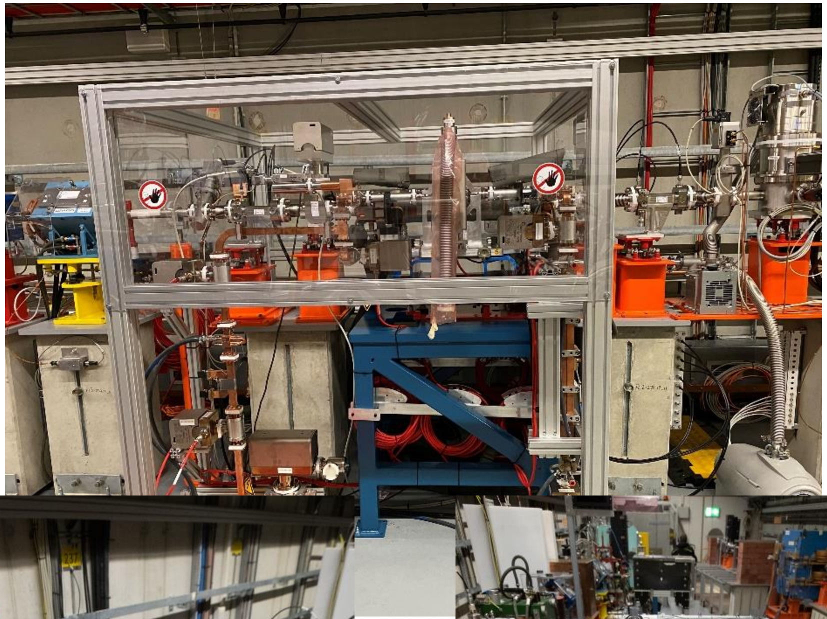
Beam facilities: Operational and Commissioning

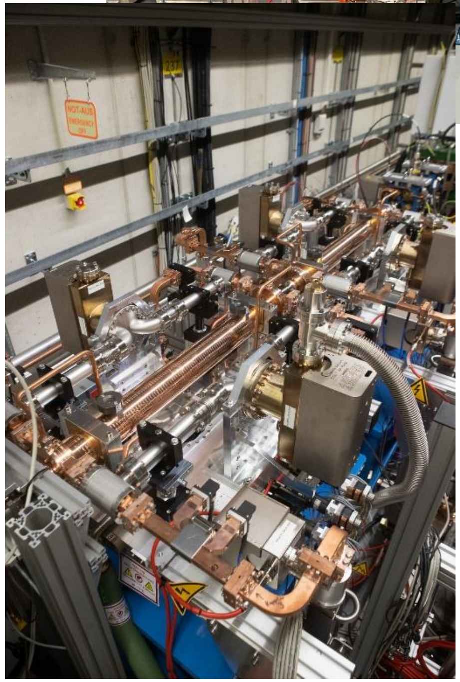
- Trieste, FERMI: Linearizer
- SwissFEL: Linearizer and PolariX deflector
- SARI: Linearizer, deflectors
- CERN: XBox-1 with CLEAR, accelerator
- DESY: FLASHForward and FLASH2, PolariX deflectors
- SLAC: NLCTA, XTA
- Argonne: AWA

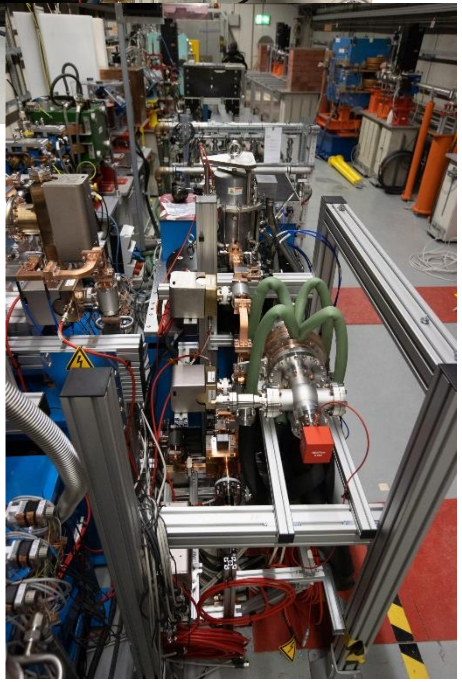


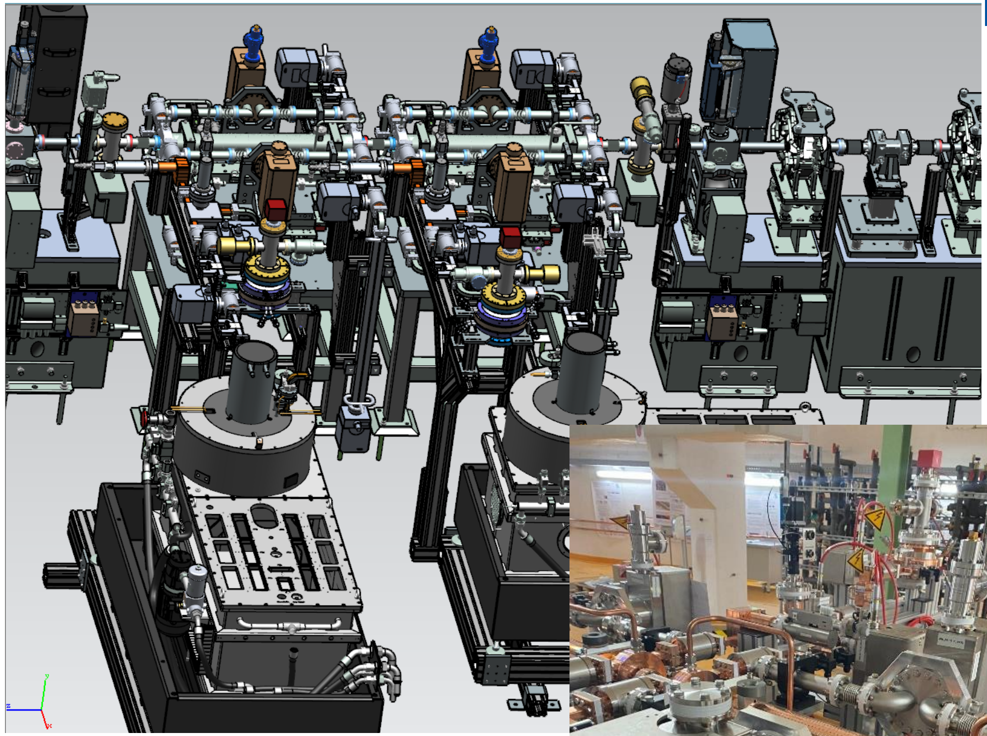
Post-undulator PolariX TDS for ATHOS beamline (SwissFEL)

Beam facilities: Operational and Commissioning 2







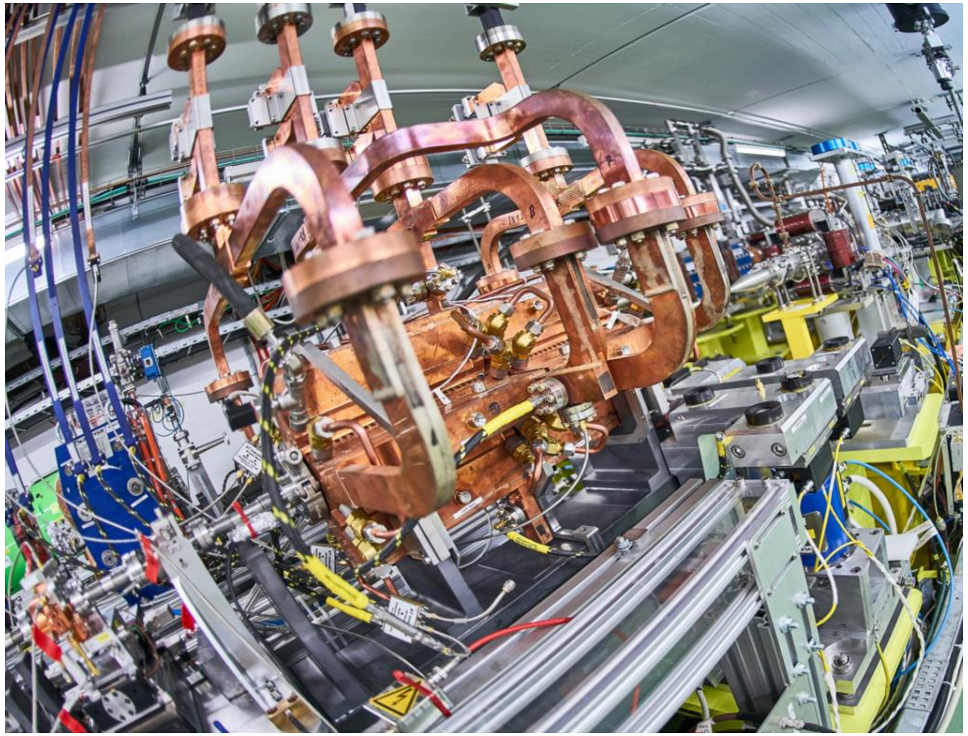


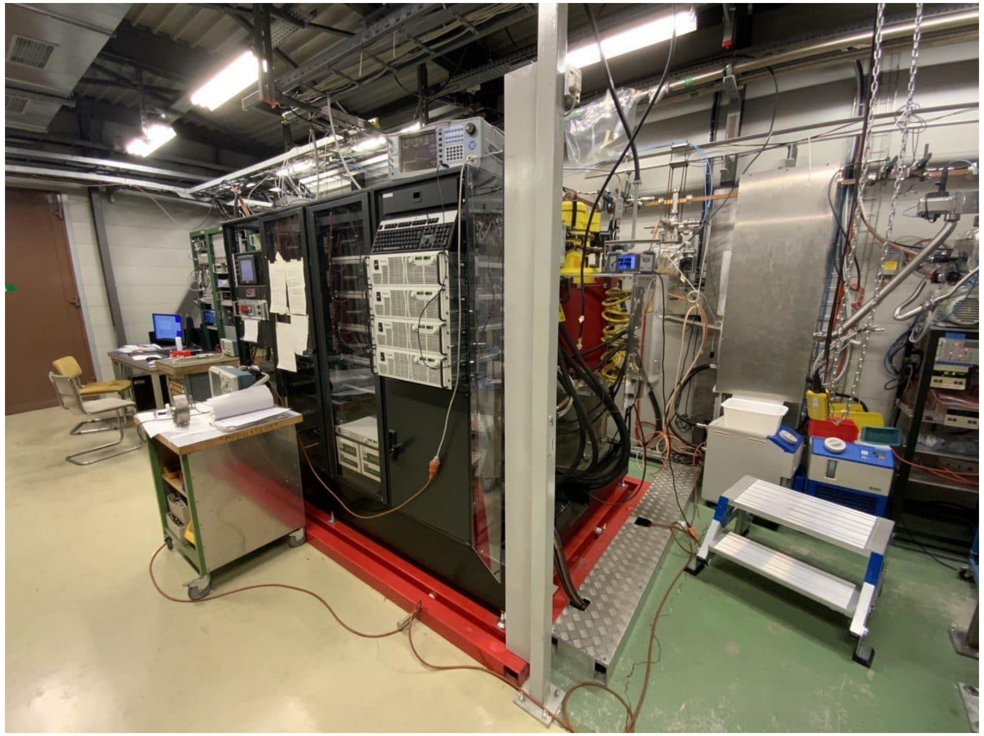
SINBAD/ARES

FLASHForward

FLASH2

Beam facilities: Operational and Commissioning 3

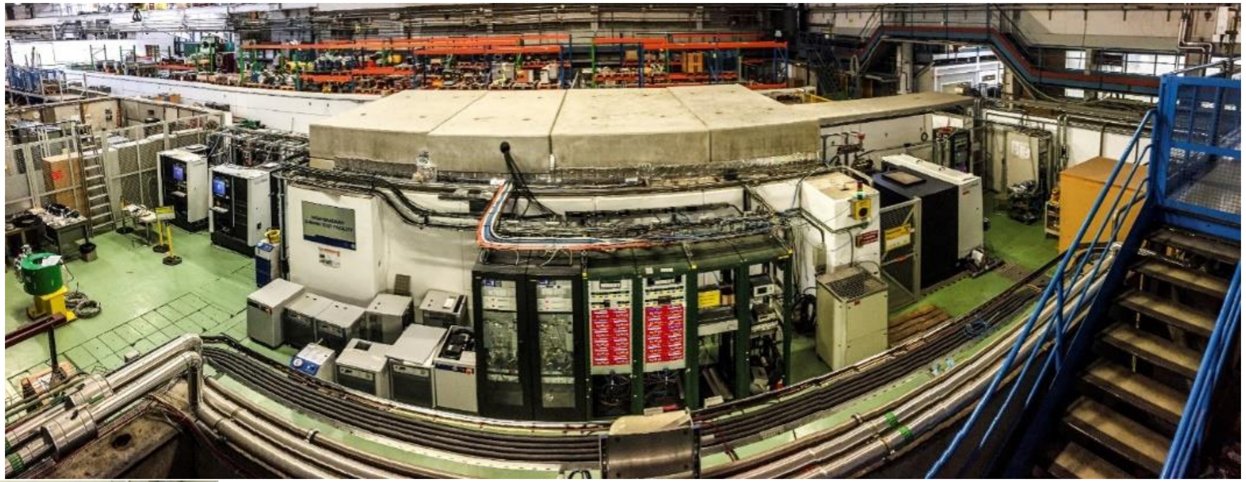


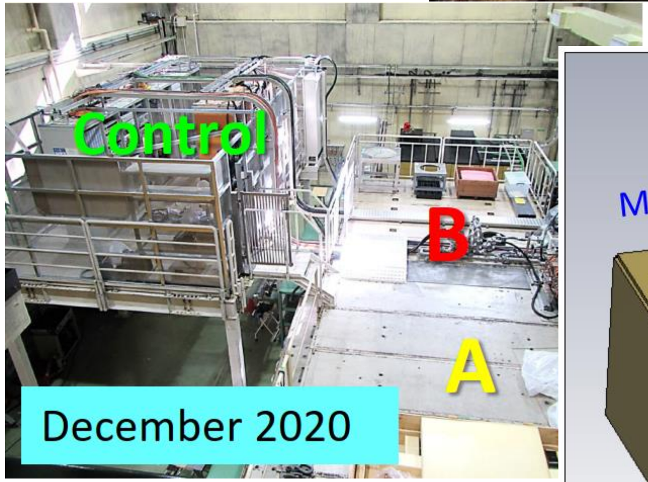


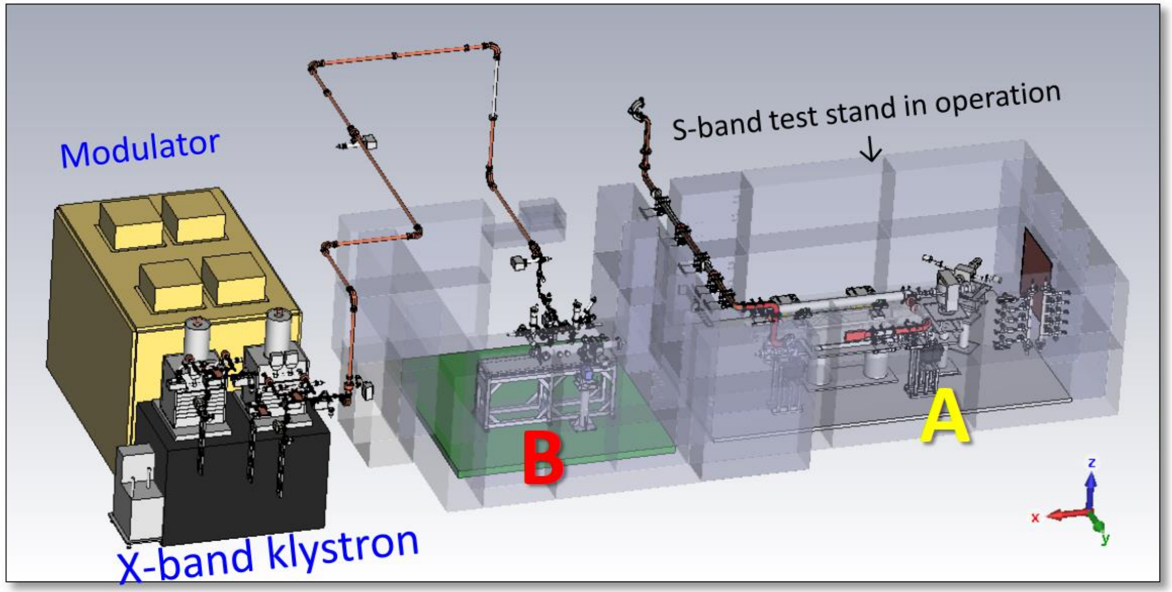
CLEAR

RF facilities: Operational and Commissioning (and construction)

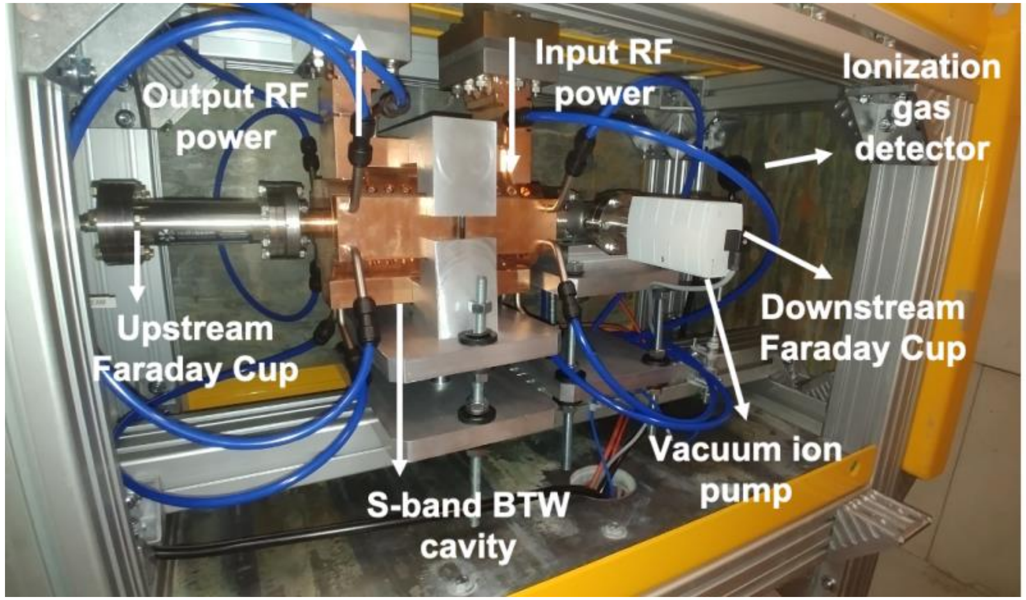
- KEK: NEXTEF
- CERN: XBox-2,3 and SBox
- Tsinghua: TPot
- Valencia: IFIC VBox
- Trieste: FRMI S-Band
- SLAC: Cryo-systems
- LANL: CERF-NM
- INFN Frascati: TEX
- Melbourne: AusBox







RF facilities: Operational and Commissioning (and construction) 2



- ❑ **Pulse length:** 200/500/800 ns
- ❑ **Repetition rate**: 50 Hz - 300 Hz
  - ❑ New operation mode in which all pulses are sent to the structure under test allowing to go up to 300 Hz.

Max. power reached ~12.3 MW

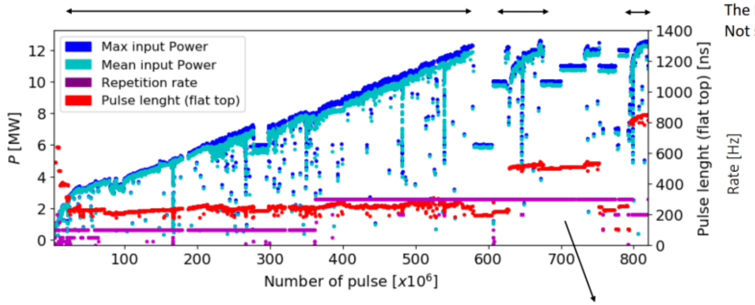
Reached max. power with 200 ns in ~570M pulses

200 ns

500 ns

800 ns

Limit due to The RF system Not structure



Less than month and a half

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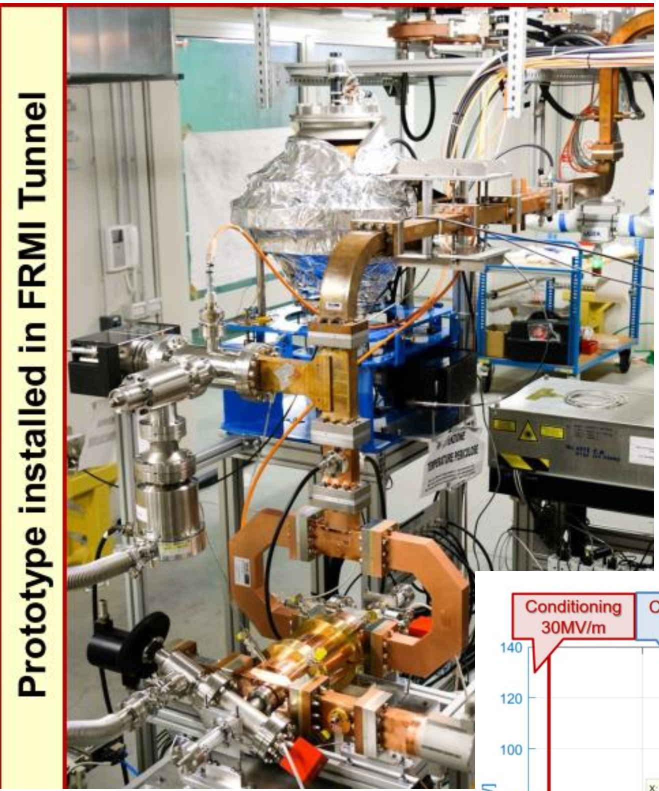
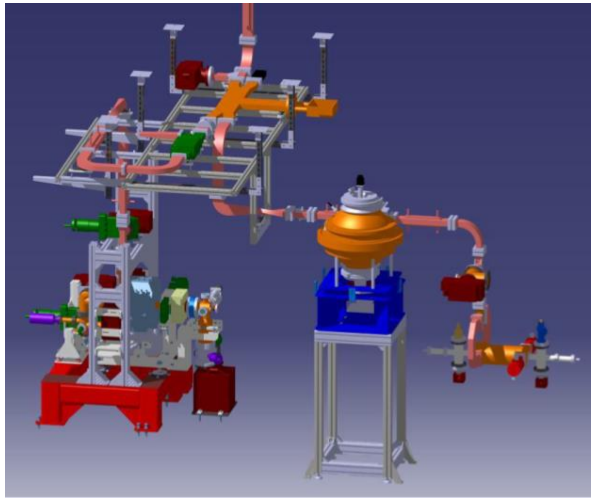
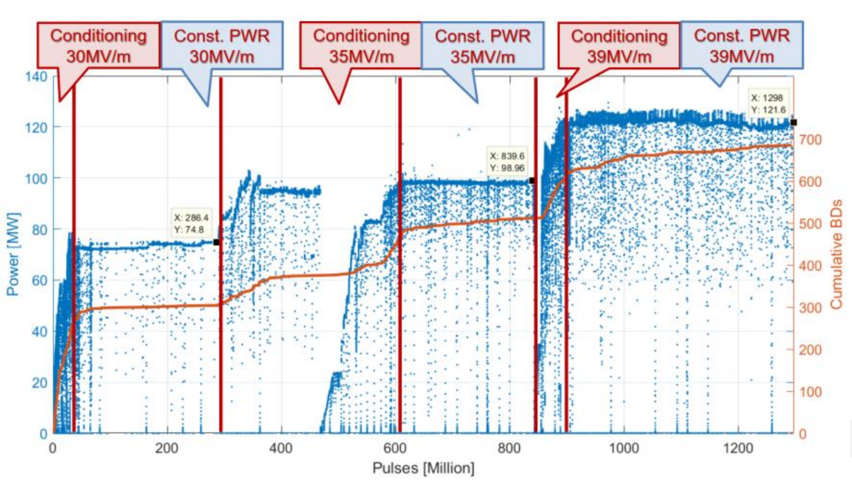
VBox

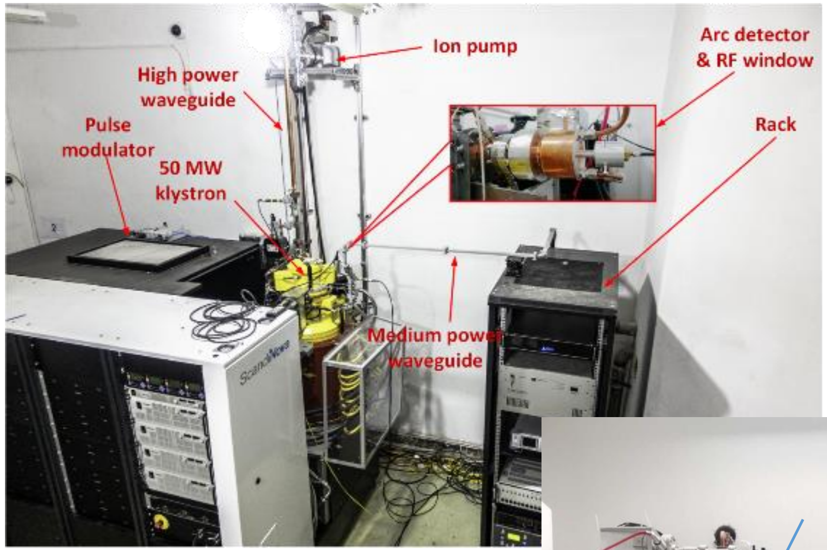
RF facilities: Operational and Commissioning (and construction) 3





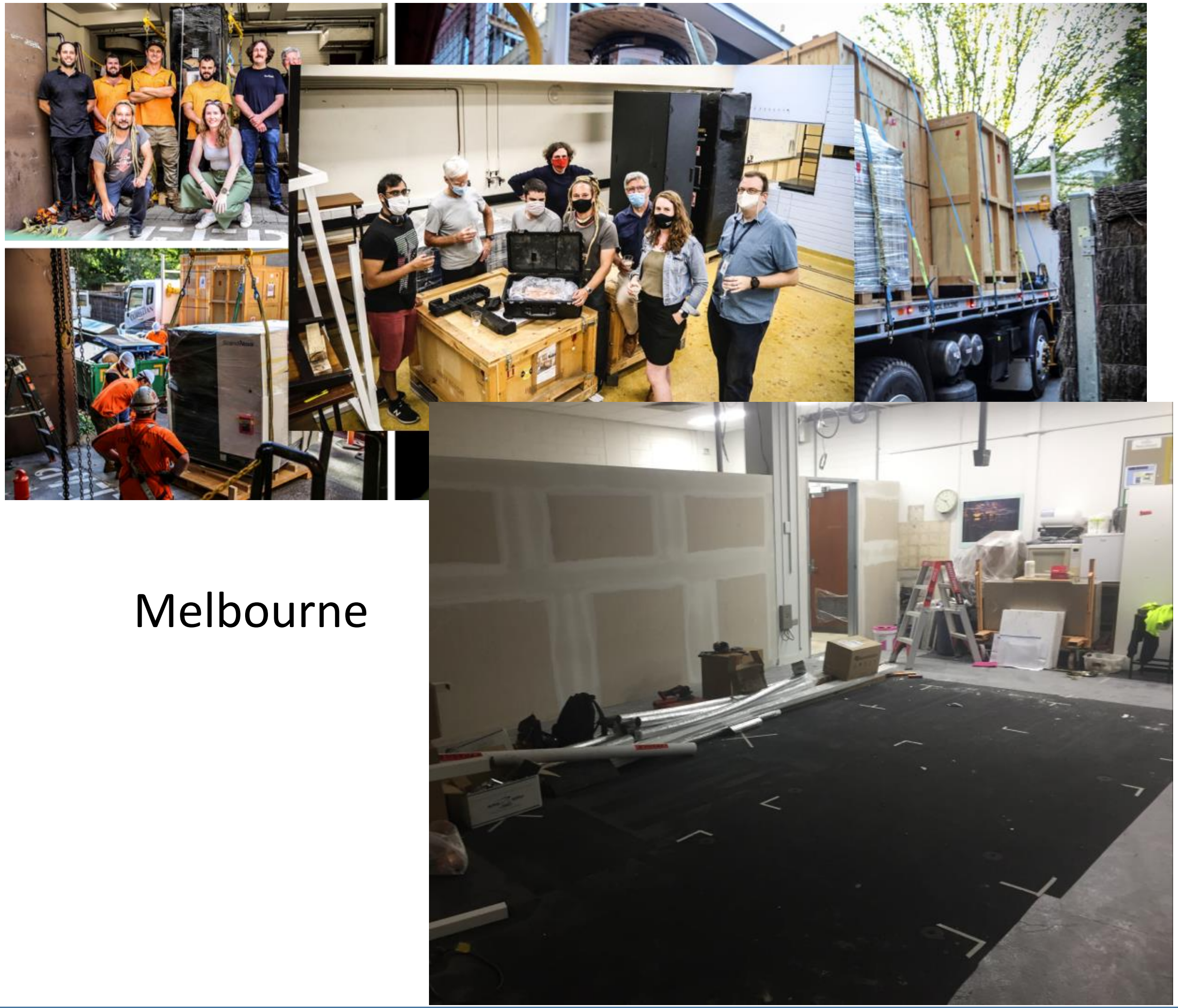


FERMI

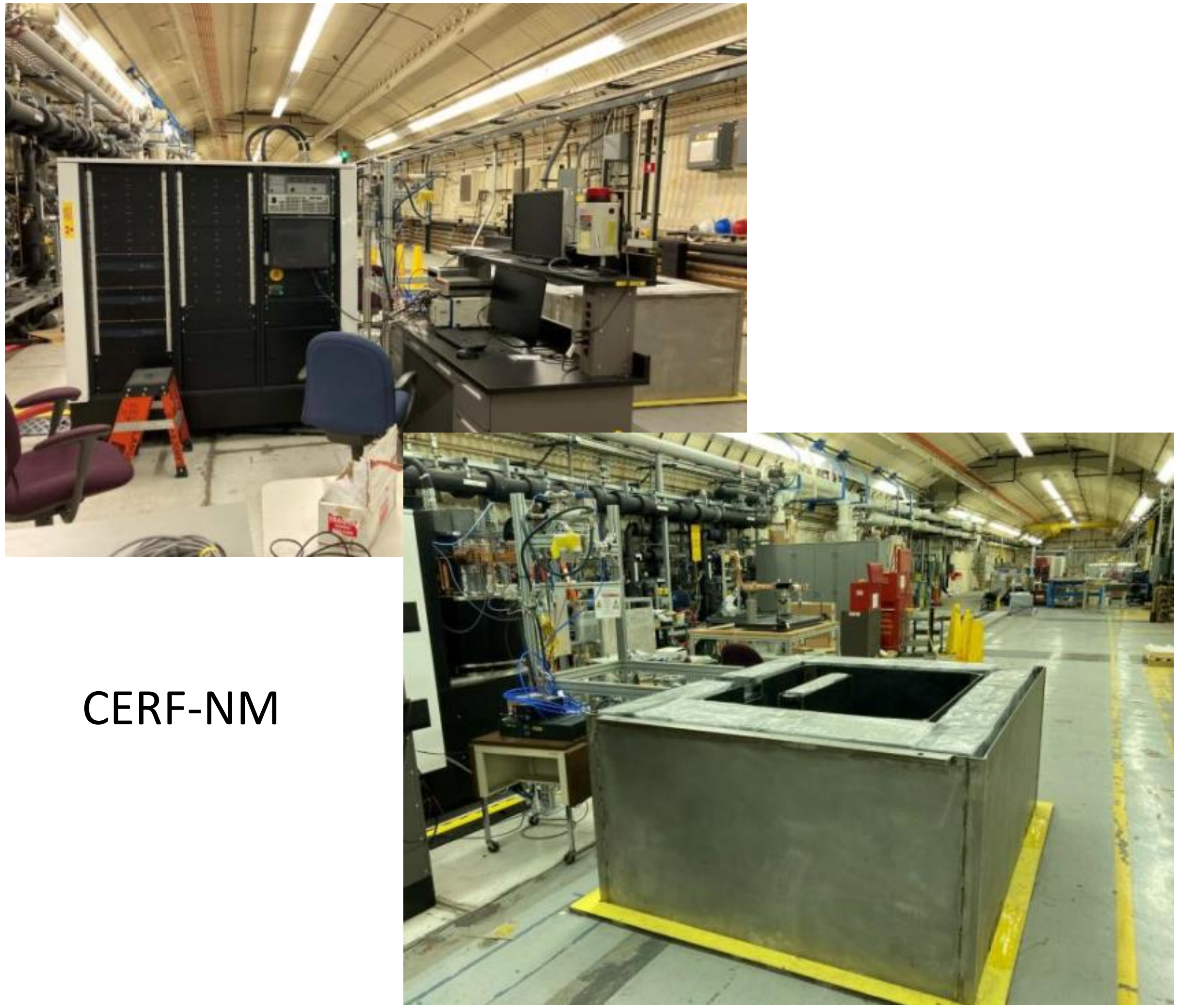


TPOT

RF facilities: Operational and Commissioning (and construction) 4



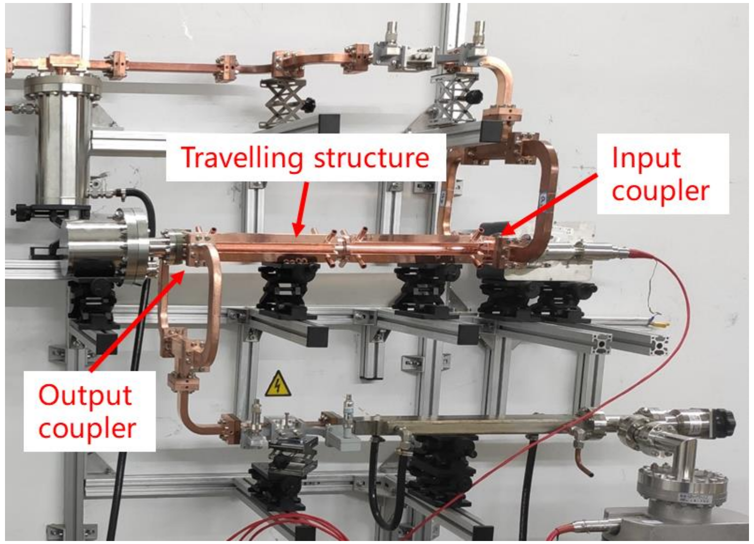
Melbourne



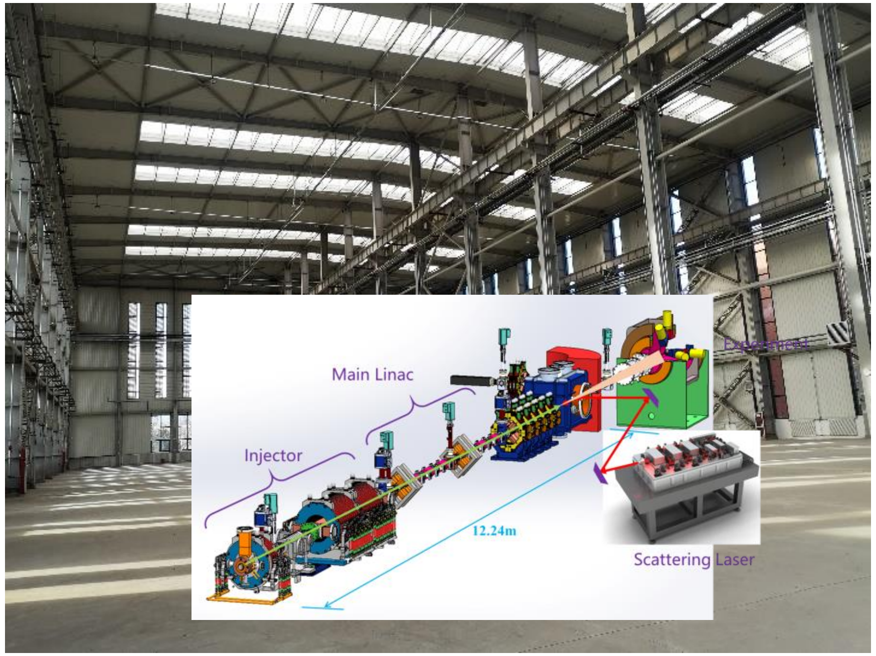
CERF-NM

Beam facilities: Preparation

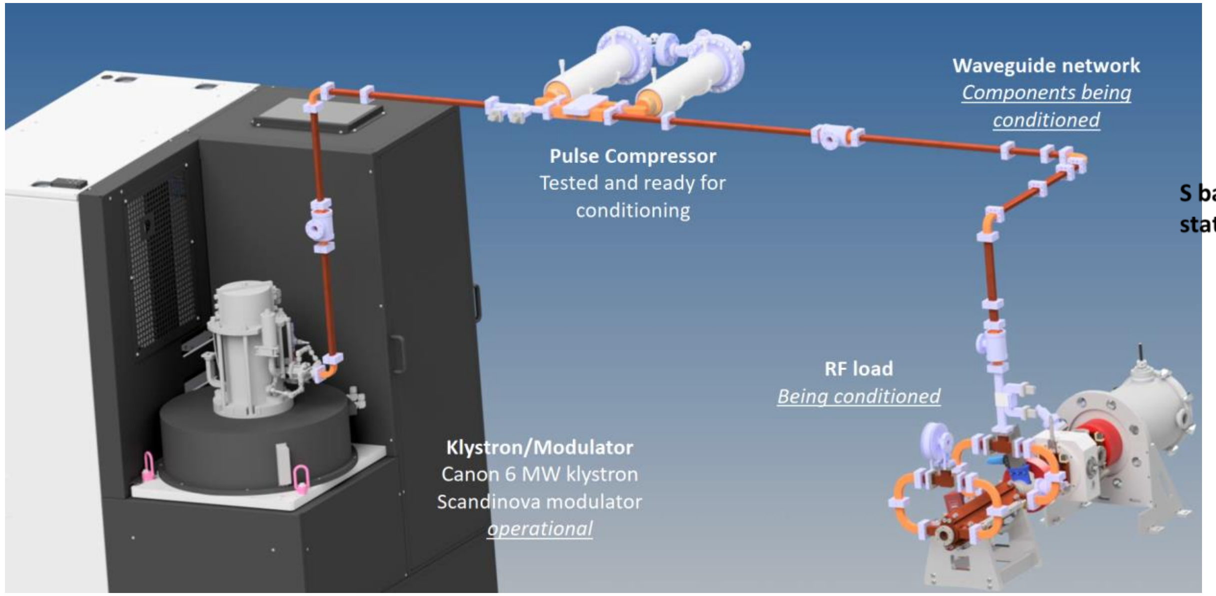
- TU Eindhoven: SMART*LIGHT, ICS
- Tsinghua: VIGAS, ICS
- CERN: AWAKE electron injector
- INFN Frascati: EuPRAXIA@SPARC_LAB, accelerator
- DESY: SINBAD/ARES, deflector
- CHUV/CERN: DEFT, medical accelerator
- Daresbury: CLARA, linearizer
- Trieste: FERMI energy upgrade



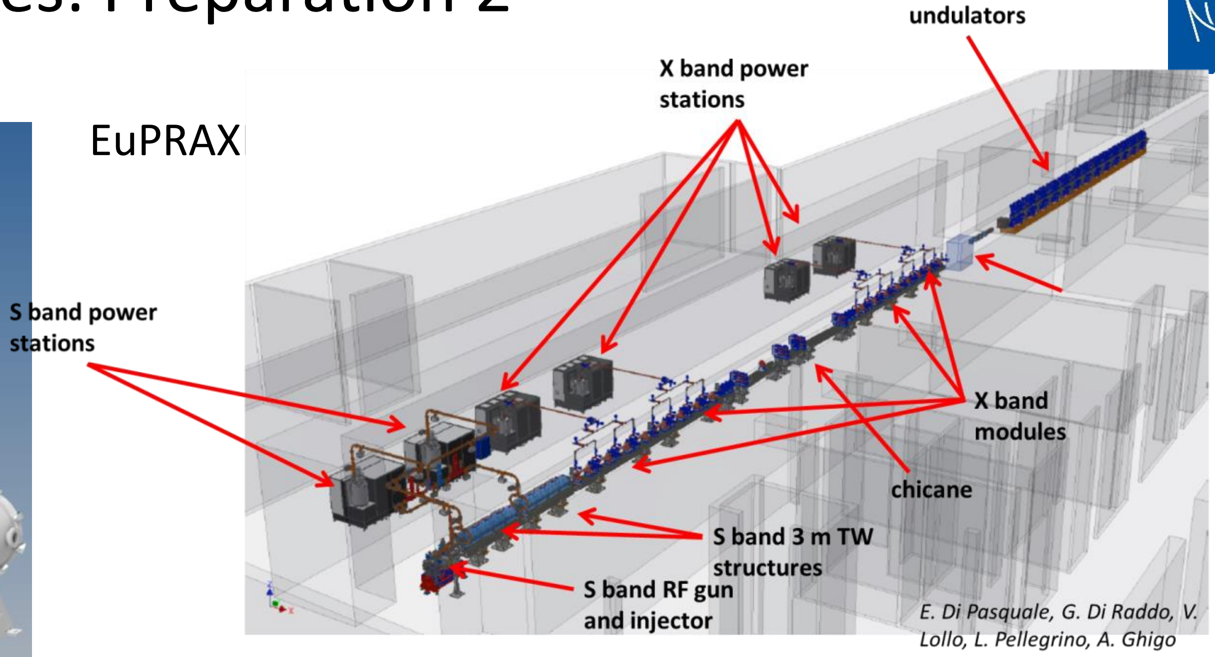
VIGAS



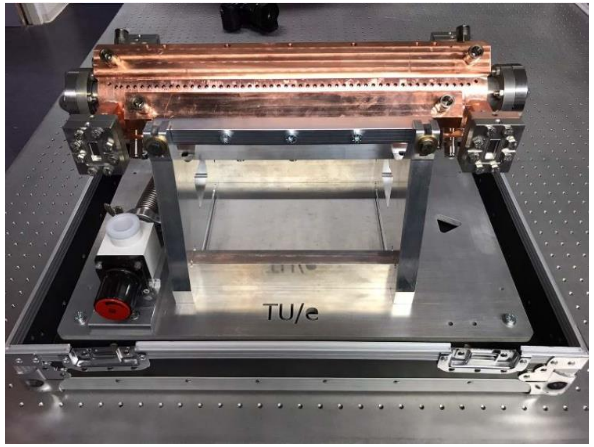
Beam facilities: Preparation 2



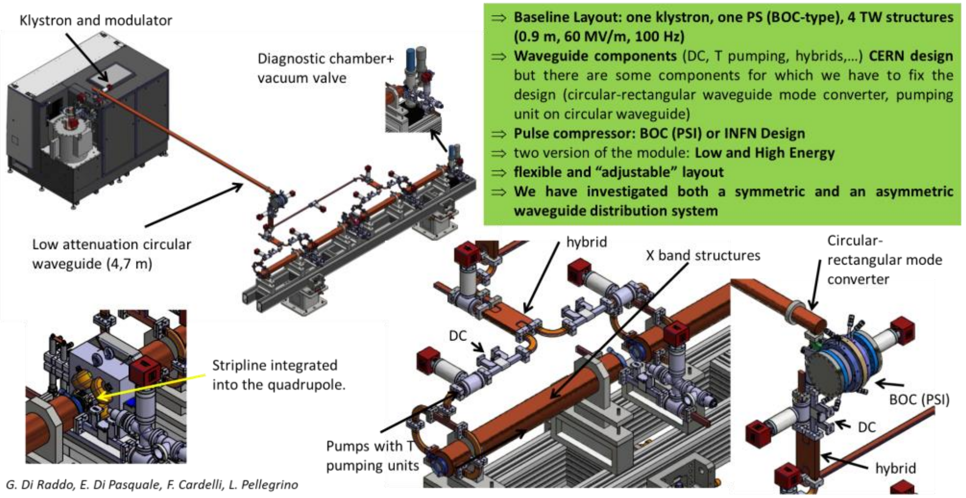
EuPRAX



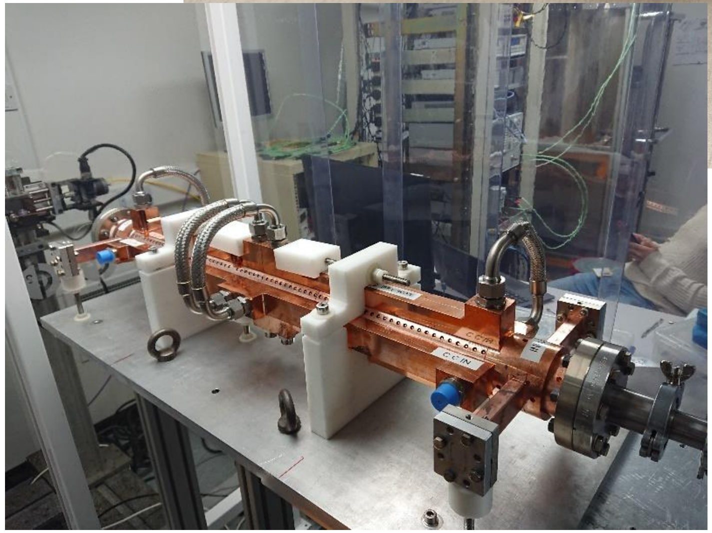
Smart*Light



THE X BAND LINAC: RF MODULE LAYOUT



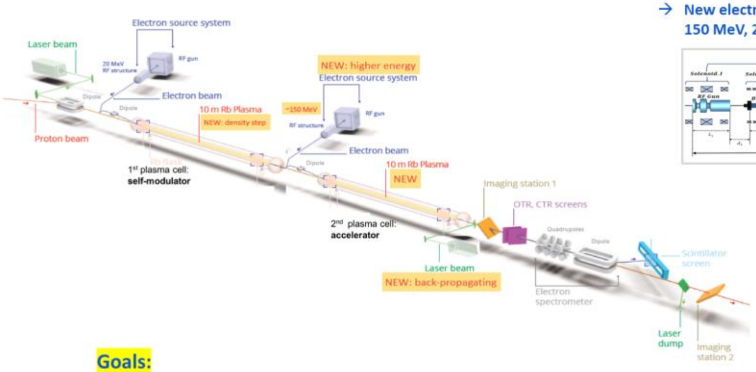
Beam facilities: Preparation 3



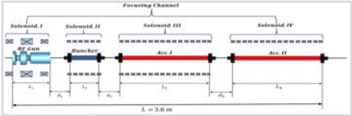
CLARA, plus klystron modulator installation

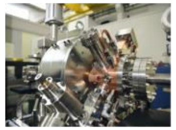
AWAKE Run 2

- Demonstrate possibility to use AWAKE scheme for high energy physics applications in mid-term future!
- Start 2021! Staged program for ~ 10 years



- Need to work in blow-out regime and do beam-loading
- New electron beam based on x-band: 150 MeV, 200 fs, 100 pC, σ = 5.75 μm



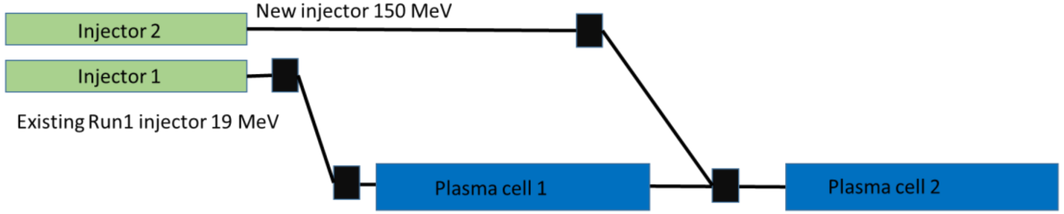


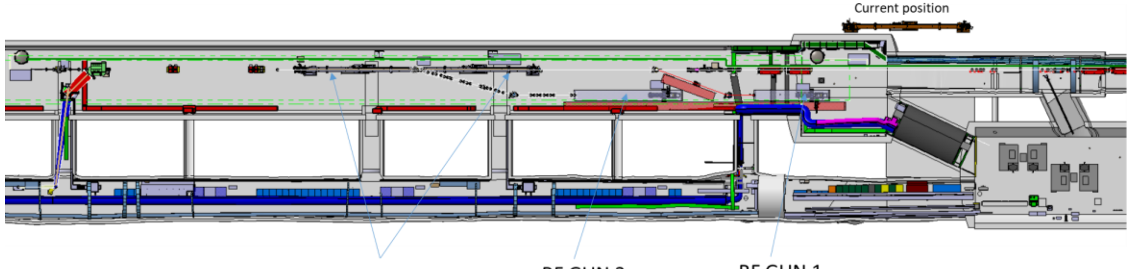
Goals:

Accelerate an electron beam to high energy (gradient of 0.5-1GV/m)
Preserve electron beam quality as well as possible (emittance preservation at 10 mm mrad level)
Demonstrate scalable plasma source technology (e.g. helicon prototype)

3

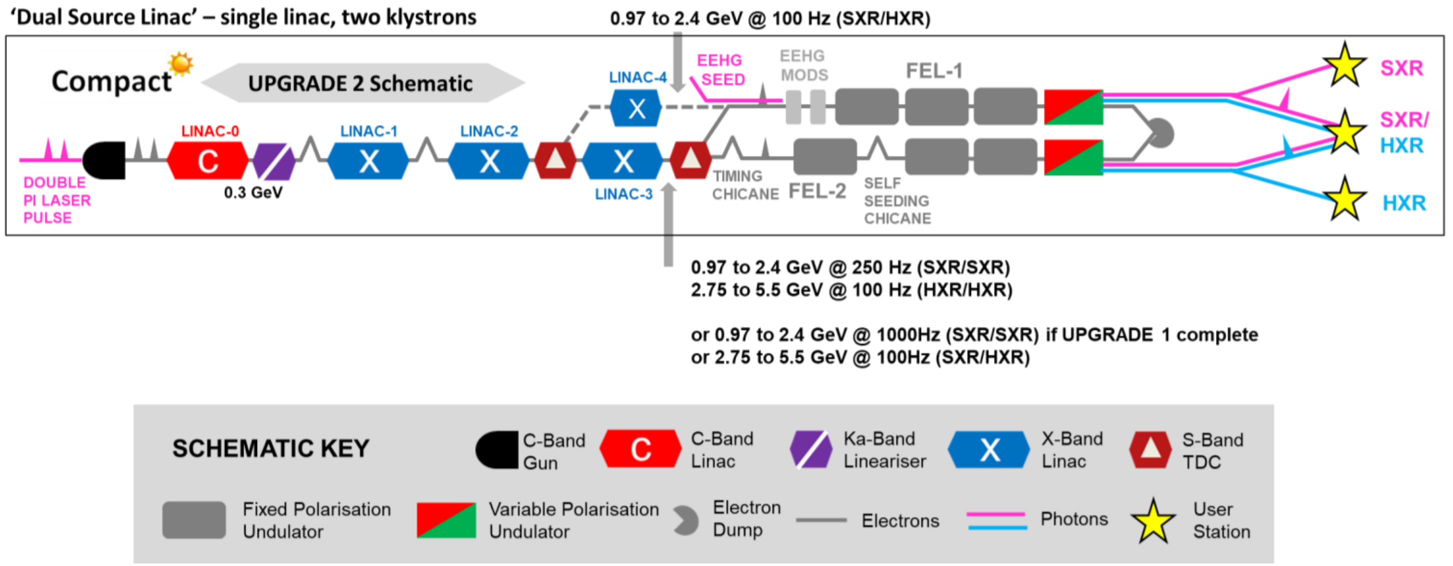
Status of the integration study





Beam facilities: Design studies, initiatives

- CLIC
- CompactLight: EU design study, XFEL
  - Feeds into IFAST, COMPAS accelerating structure fabrication
- CERN: HPCI, ICS
- DESY: Deflector for European XFEL

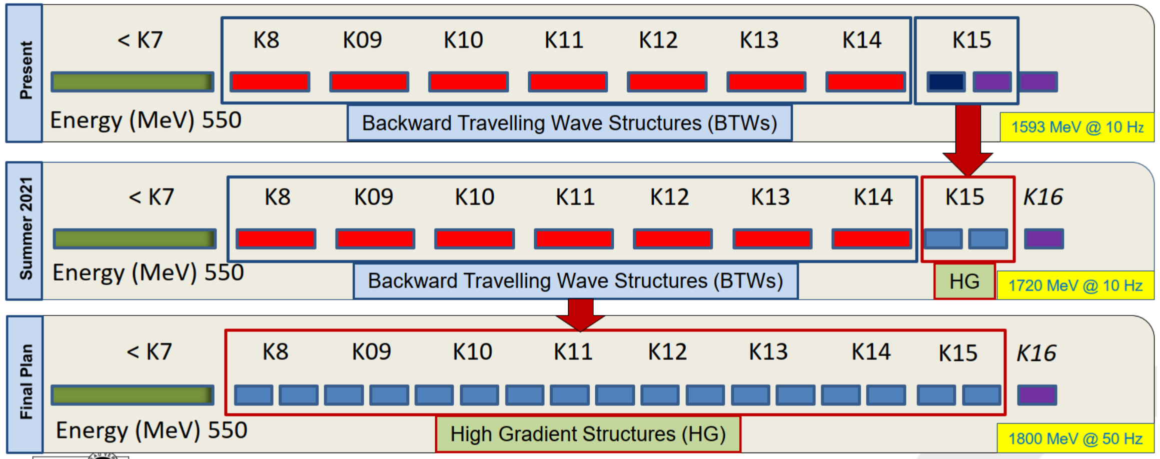


Beam facilities: Design studies, initiatives 2

Elettra Sincrotrone Trieste

THE FERMI FEL UPGRADE PLAN
BEAM ENERGY UPGRADE

- **To reduce pulse duration to the sub-10 fs** range to resolve charge transfer processes, bond dynamics, vibrational dynamics
- **To extend photon energy range to N (410 eV), O (543 eV)** which translates to the extension of operating of FERMI to **~2 nm**.



Nuaman Shafqat, 20/10/2021 6

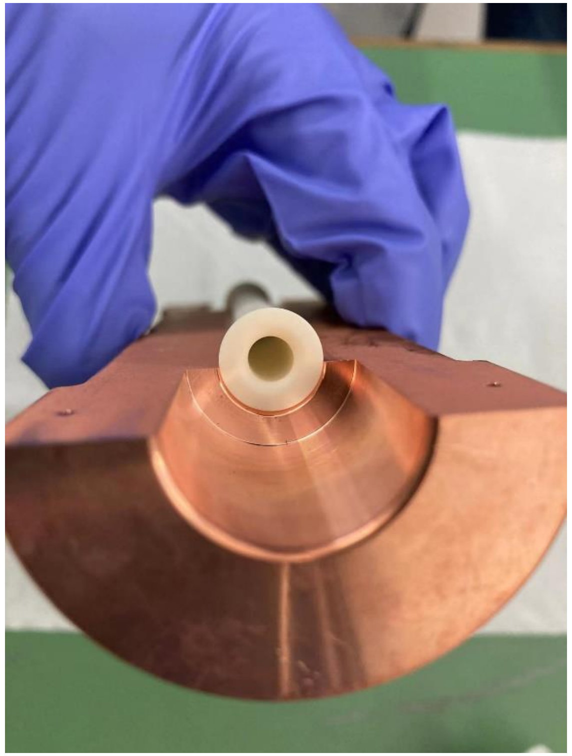
Deflector at EuropeanXFEL?

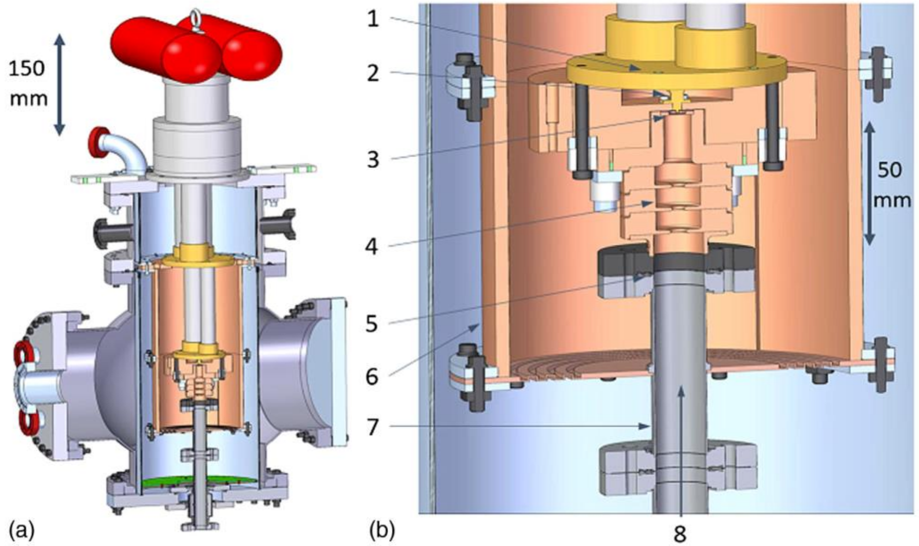
Accelerator X-band power sources

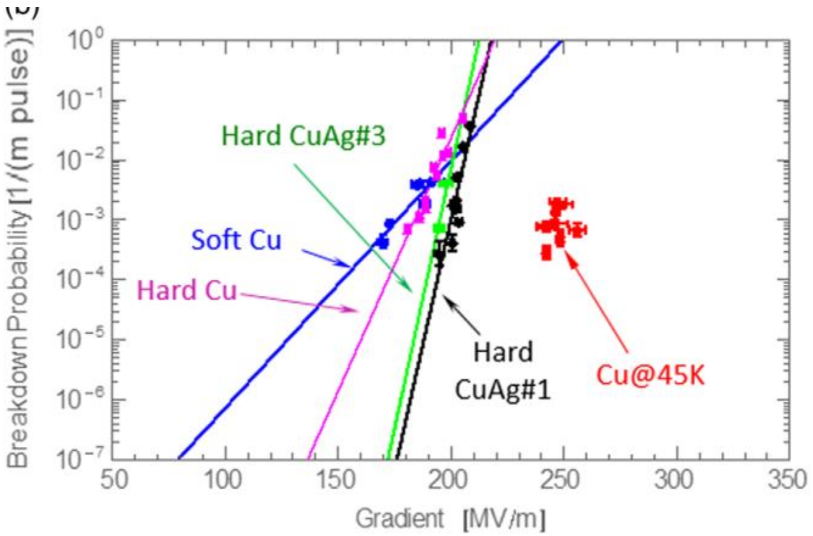
- CPI:
  - 50 MW
  - 59 MW High-efficiency
  - 10 MW
- Canon:
  - 6 MW
  - 8-10 MW High-efficiency
  - 20 MW
- BVERI: 50 MW
- Hitachi: Mg_2B solenoid

New Concepts

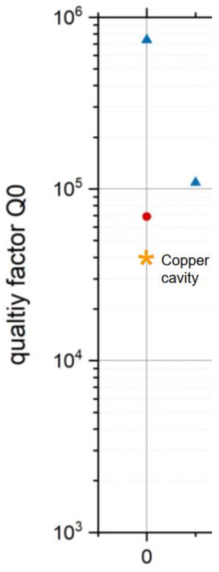
- Cryo-copper
- HTS RF components and cavities
- Dielectric
- Short-pulse

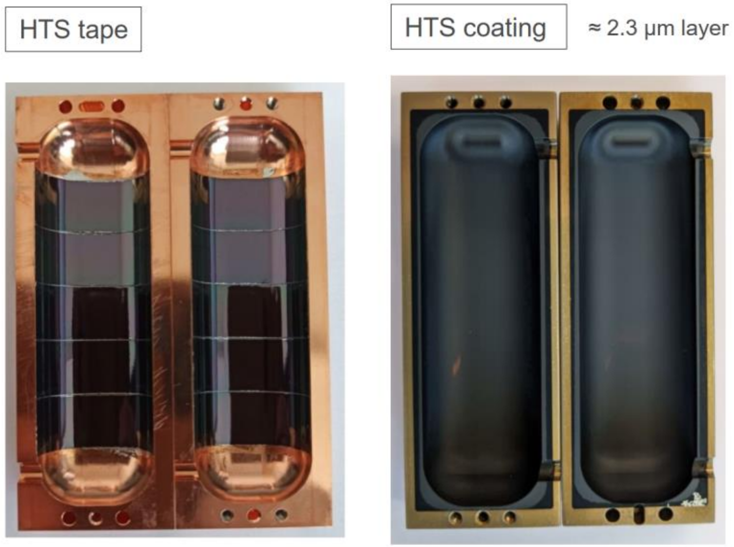






HTS RF cavities





Copper in high electric field region

HTS in high magnetic field region

- copper reference cavity has Q_0 of 40 000* at 4.2 K
- without magnetic field Nb_3Sn cavity has a Q_0 of 700 000 at 4.2 K but degrades a lot in magnetic field
- Q_0 of HTS tape cavity more or less constant in the magnetic field around 70 000 – 80 000
- 60 h of axion search with HTS tape cavity in 11 T dipole short model

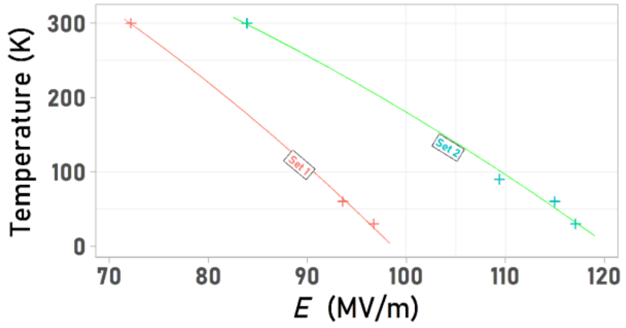
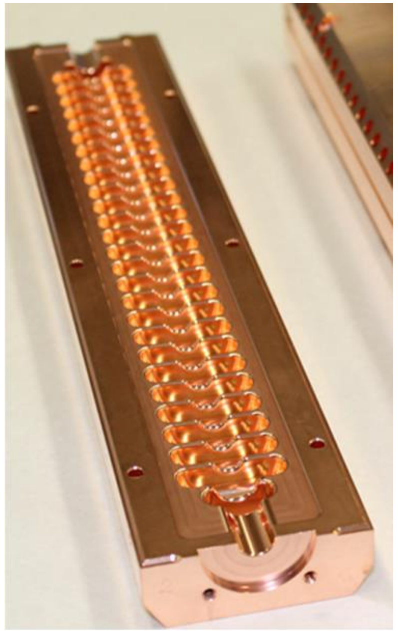
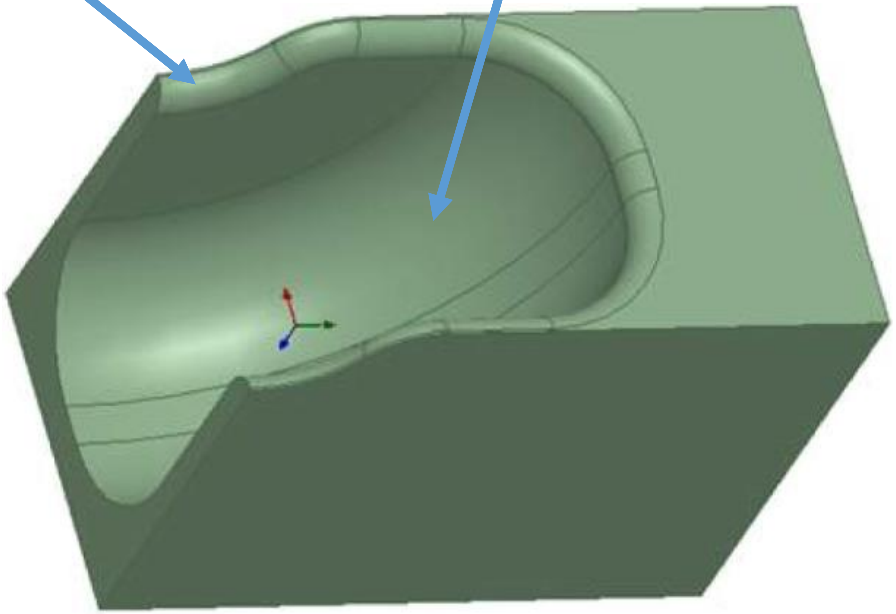


FIG. 2. Measured values of the maximum surface field at different temperatures for both sets of electrodes. The lines are the fits from the crystal defect model [Eq. (2)].





(a) Elliptical Rounding

CHUV/CERN collaboration on FLASH radiation therapy facility.

Promotional animation https://videos.cern.ch/record/2295068

Conclusions

- There is now a diverse and dynamic high-gradient and X-band technology community.
- Facilities are operating, coming on line, and being prepared.
- New ideas are developing.
- Strong theoretical foundation, not spoken about today
- Please help me complete these lists, I try to keep an overview up to date.