Using DAFNE to study the physics of e+/e- beam interaction with vacuum devices

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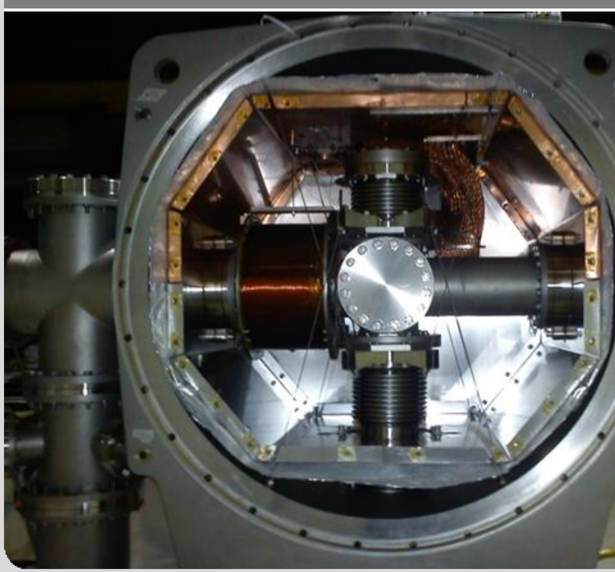

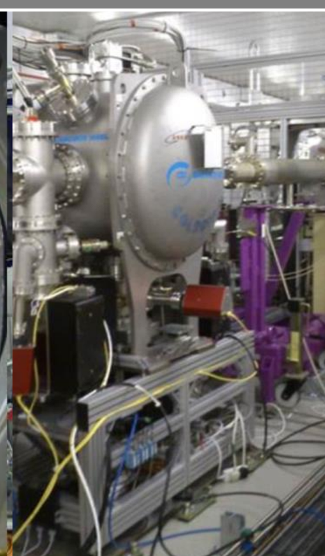

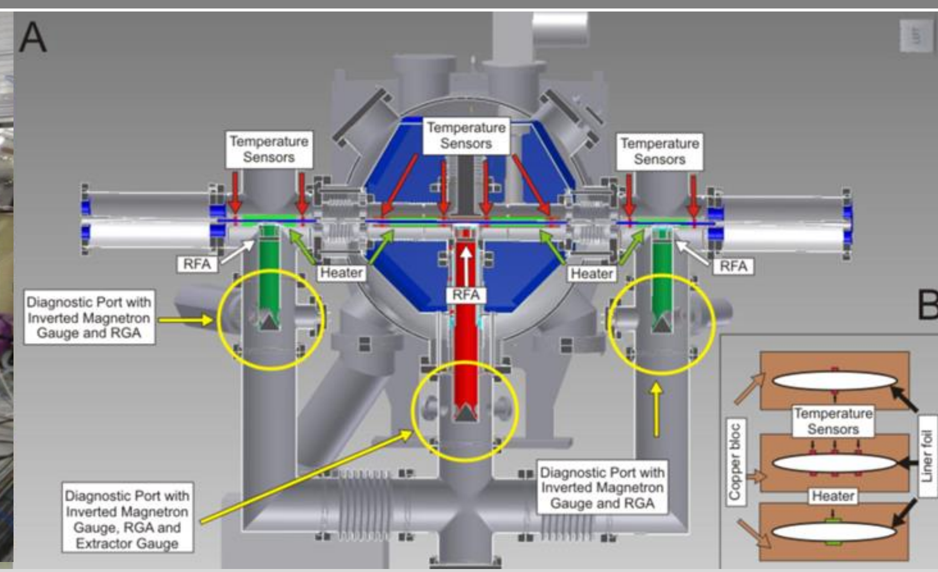

Outline

- Motivation
- Examples of vacuum chambers
- Diagnostics vacuum devices
  - COLDDIAG
  - BESTEX
- Summary

Motivation

- Accelerator vacuum chambers must be designed to minimize the impedance and possible electron cloud formation to avoid instabilities and minimize the beam heat load, of particular concern for cold vacuum chambers used in superconducting magnets

Important to characterize vacuum chambers with specific geometries and materials using e+/e- beams

Goal: Study impedance, synchrotron radiation and electron cloud, on vacuum chambers for future colliders and insertion devices for light sources

Motivation

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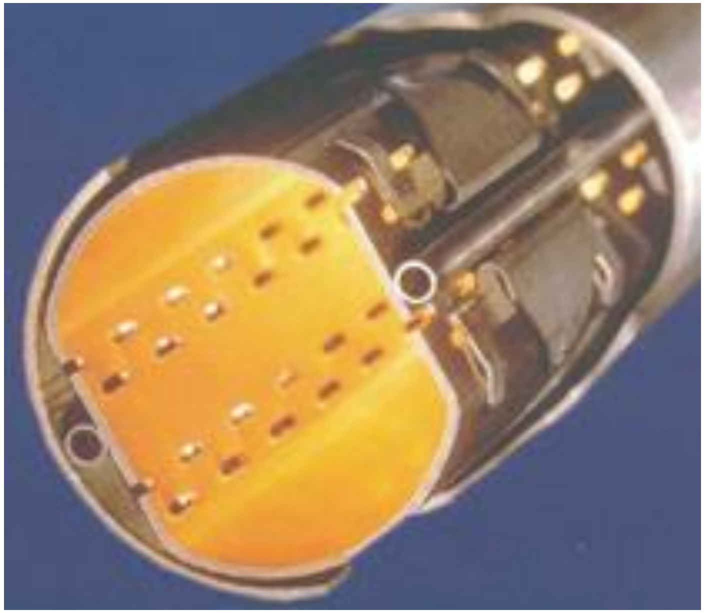
- A beam heat load to superconducting magnets higher than predicted could cause a lower magnetic field seen by the beam up to a complete failure of the machine in case of a quench of a superconducting magnet (zero magnetic field)
- The measurements of the beam heat load on a cold bore are also essential to benchmark: different kind of simulations of beam heat load due to synchrotron radiation, impedance, and electron cloud
- Insight on impedance, and electron cloud, which often causes harmful beam instabilities, can produce relevant improvement in terms of beam currents, and in turn of luminosity for colliders and brilliance in light sources

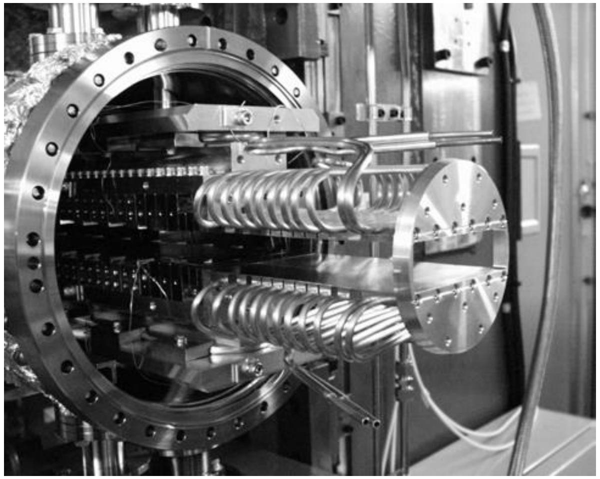
Examples of vacuum chambers

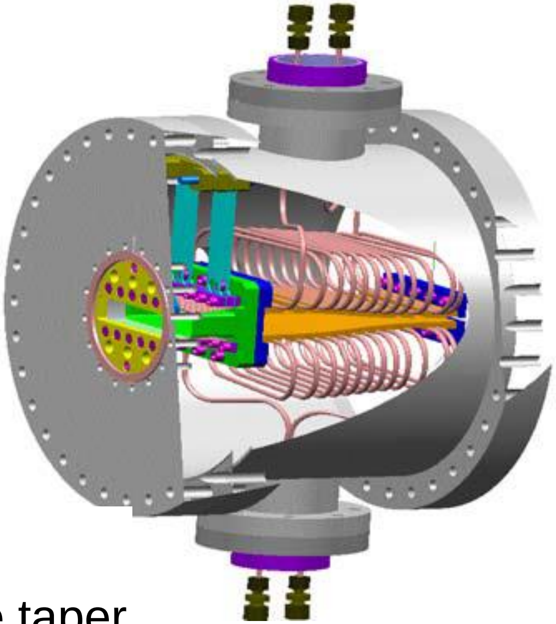
- Beam screens for the LHC and FCC hh



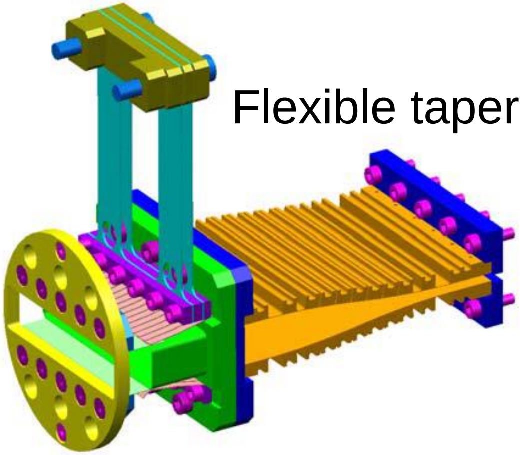
Examples of vacuum chambers

- of in vacuum undulators at room temperature and at cryogenic temperature for light sources





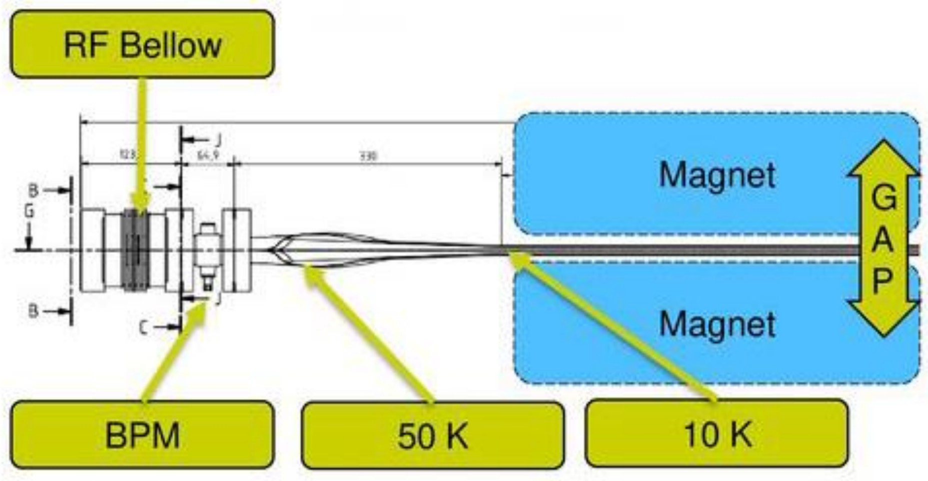
Flexible taper



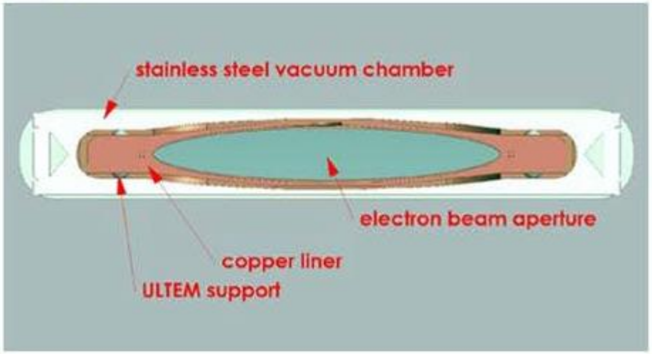
R. Reiser et al., MEDSI02 2002, Argonne, IL, USA

Examples of vacuum chambers

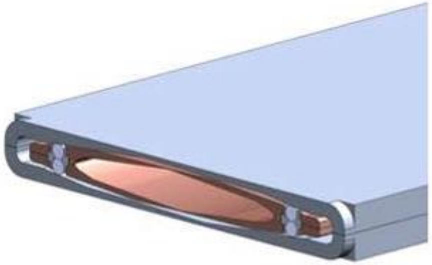
- of superconducting wigglers and undulators for light sources



C. Boffo et al., Beam diagnostucs meets vacuum workshop (2017), Karlsruhe, Germany



Cross section of cold vacuum chamber with copper liner inside (bath cryostat version)



Copper liner assembled with vacuum chamber

N. Mezentsev et al., Superconducting undulators workshop (2014), Didcot, UK

Diagnostic vacuum devices

- COLDEX

An experimental test vacuum sector that mimics the cold bore and beam screen cryogenic vacuum system adopted in the LHC cryomagnets

Used to validate LHC vacuum system

Now in SPS to validate of the performance of amorphous carbon coating at cryogenic temperatures, possible solution to reduce the beam heat load in the triplets for the LHC High luminosity upgrade

It is equipped to measure the beam heat load with temperature sensors, the pressure with pressure gauges, the gas content with mass spectrometers and the electron cloud activity by means of electrodes

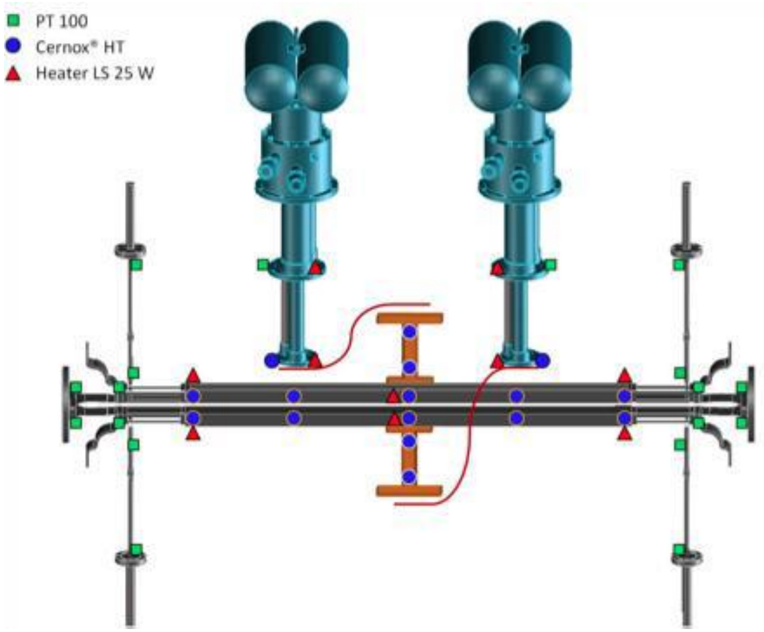
R. Salemme et al., IPAC2015, Richmond, VA, USA

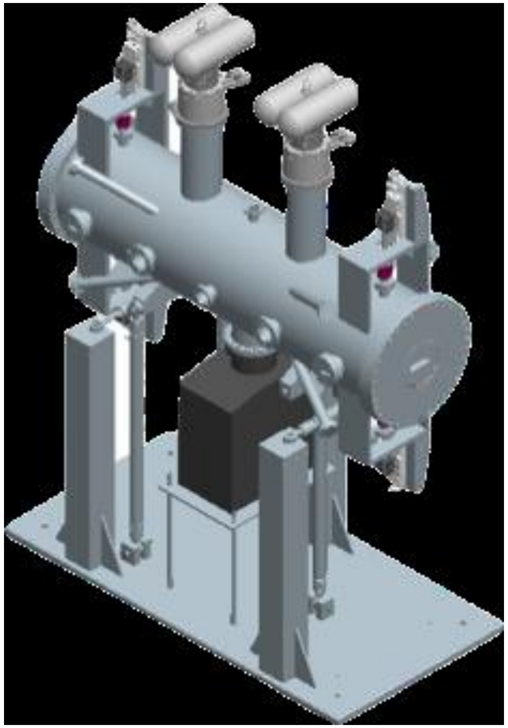
Diagnostic vacuum devices

- SINAP/LBNL calorimeter to measure the beam heat load to a cold bore for superconducting insertion devices, used in synchrotron light sources to improve the brilliance and flux of the photon beam.

Beam heat load measurements

at different vacuum vertical gaps





S. Prestemon, Talk FEL2011

Diagnostic vacuum devices

- COLDDIAG

Cold vacuum chamber for diagnostics to **measure the beam heat load** to a cold bore in different synchrotron light sources

The beam heat load is needed to specify the cooling power for the cryodesign of superconducting insertion devices

COLDDIAG at DIAMOND LIGHT SOURCE

S. Gerstl et al., PRSTAB, 17, 103201 (2014)
R. Voutta et al., PRSTAB, 19, 053201 (2016)

COLDDIAG

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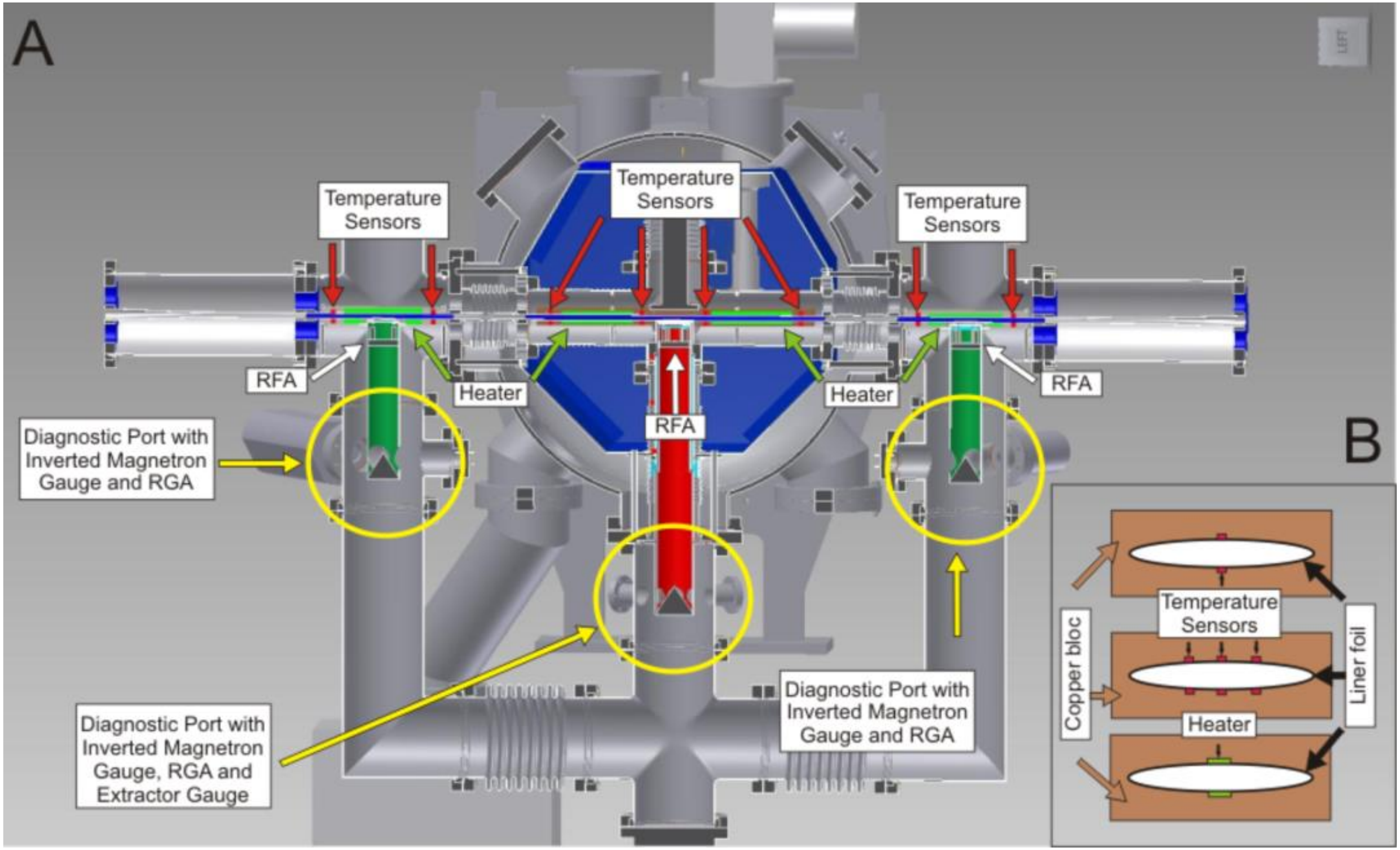
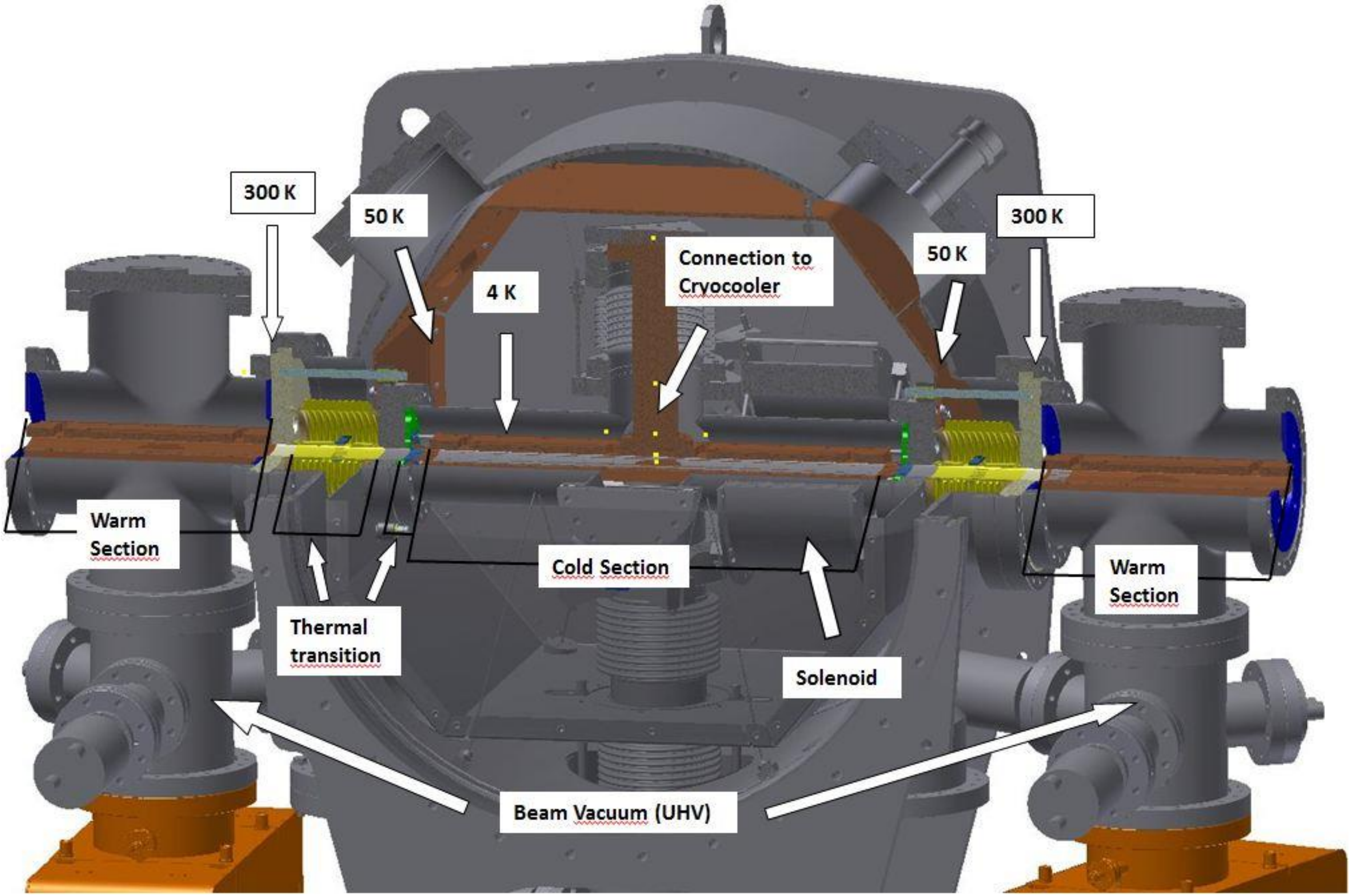
- Two warm section to observe influence of synchrotron radiation and effect of cryosorbed gas layer
- Liner exchangable. Liner at DLS: Solid copper with elliptical cross section 60mmx10mm and 50 μm plated pure copper
- Thermal transition 4-50K: minimize heat intake to 4K => unavoidable steps due to mechanical tolerances
- Thermal transition 50-300K: bellows with RF fingers to compensate for thermal shrinkage
- Diagnostic ports to extract gas and electrons for measurements of pressure, gas content and charged particles

COLDDIAG

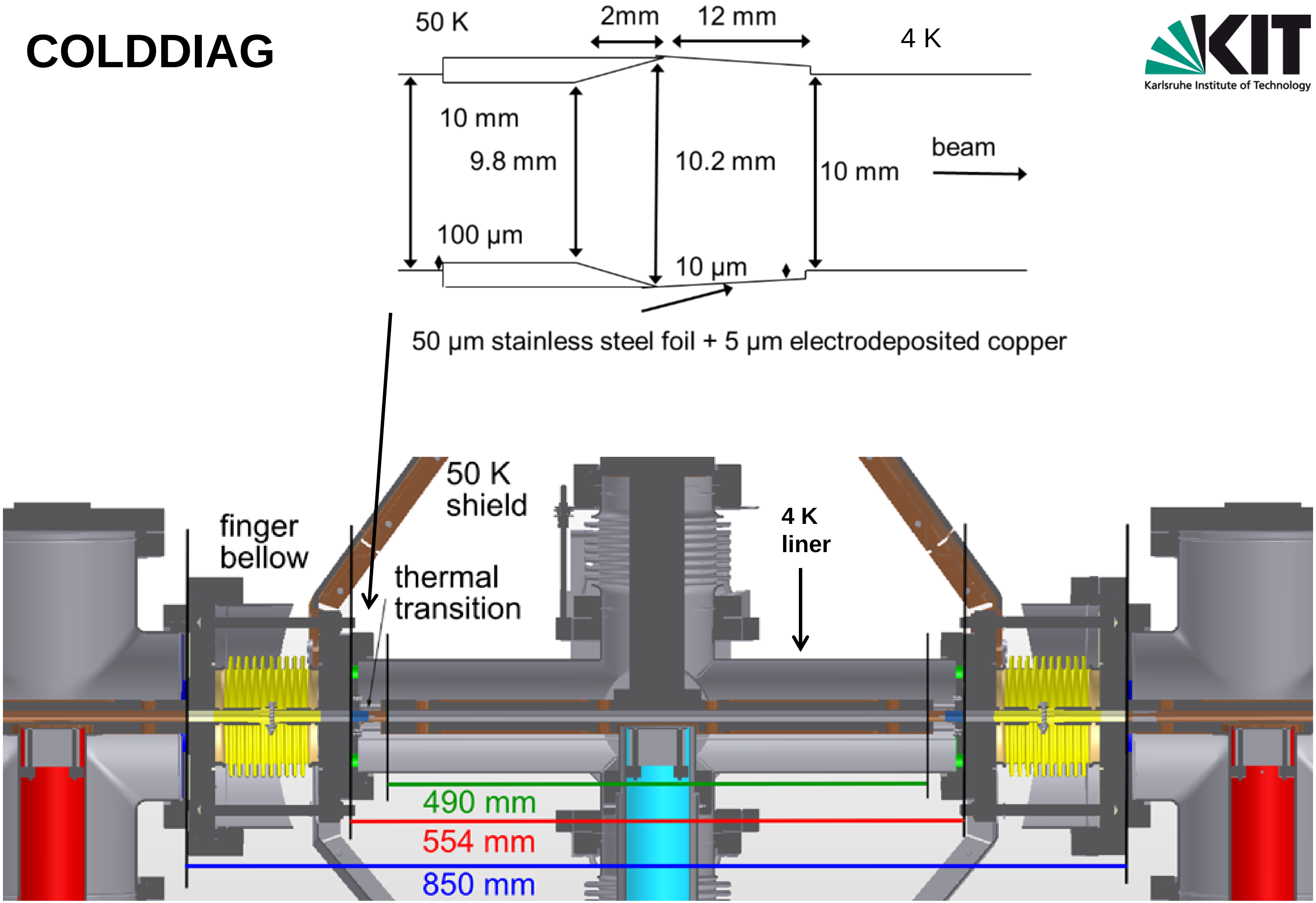


A
Temperature Sensors
Temperature Sensors
Temperature Sensors
RFA
Heater
Heater
RFA
RFA
Diagnostic Port with Inverted Magnetron Gauge and RGA
B
Temperature Sensors
Copper bloc
Liner foil
Heater
Diagnostic Port with Inverted Magnetron Gauge and RGA
Diagnostic Port with Inverted Magnetron Gauge, RGA and Extractor Gauge

COLDDIAG


300 K
50 K
4 K
Connection to Cryocooler
50 K
300 K
Warm Section
Thermal transition
Cold Section
Solenoid
Warm Section
Beam Vacuum (UHV)

COLDDIAG


50 K
2mm
12 mm
4 K
10 mm
9.8 mm
10.2 mm
10 mm
beam
100 µm
10 µm
50 µm stainless steel foil + 5 µm electrodeposited copper
50 K
shield
finger
bellow
thermal
transition
4 K
liner
490 mm
554 mm
850 mm

COLDDIAG

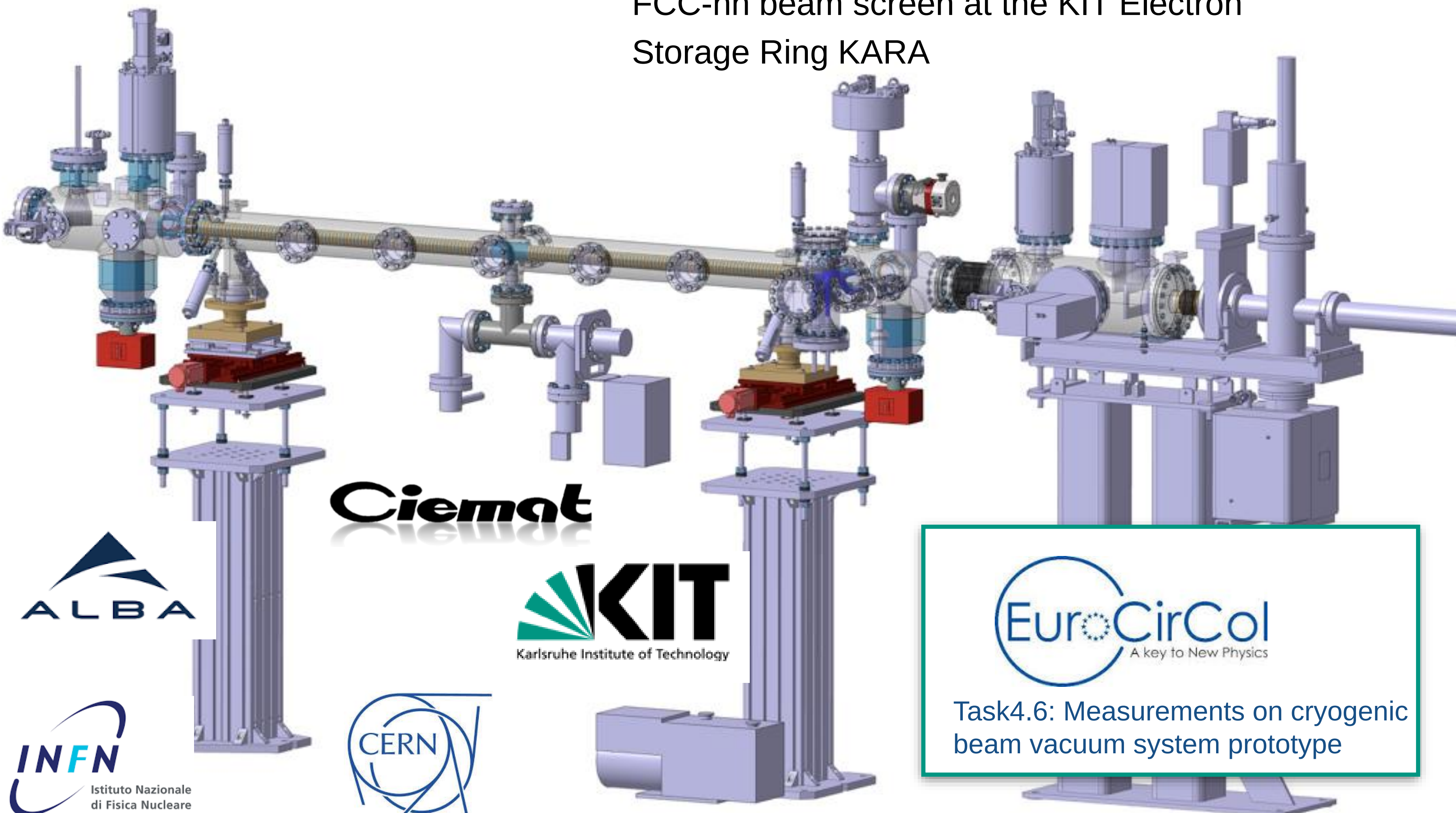
Karlsruhe Institute of Technology

- COLDDIAG can be used in DAFNE for beam heat load, impedance and electron cloud studies
- Thermal transitions 4- 50 K need to be refurbished
- To study different surface treatments it is possible to coat the existing copper liner
- Possible to study a different geometry changing the existing copper liner

BESTEX

BEam Screen Test bench EXperiment

- Photo desorption studies on the FCC-hh beam screen at the KIT Electron Storage Ring KARA

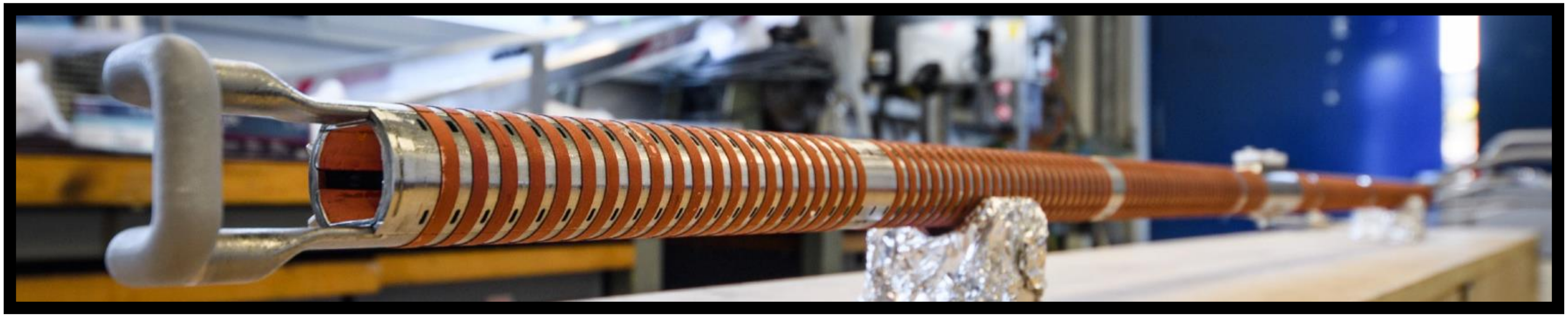


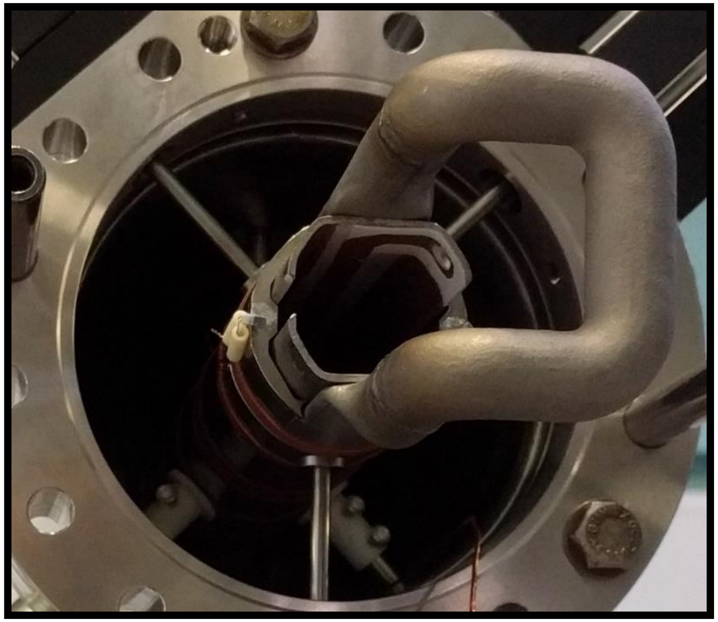
Task4.6: Measurements on cryogenic beam vacuum system prototype

L. Gonzalez et al., IPAC18 (2018), Vancouver, Canada

BESTEX

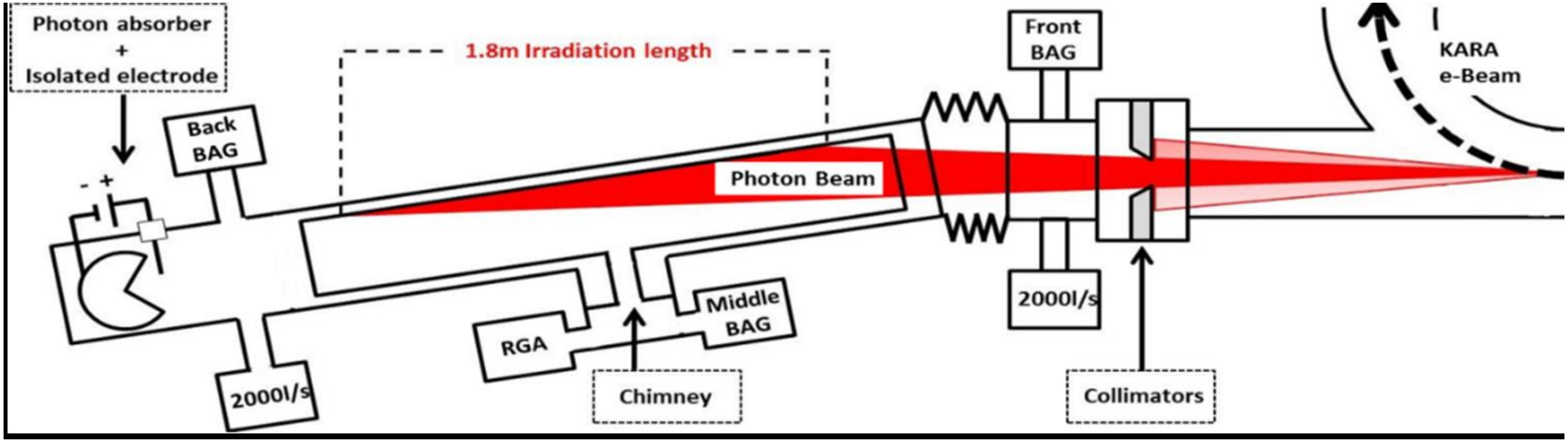
- Exchangable beam screen prototype

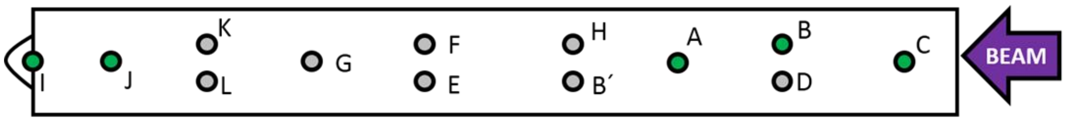




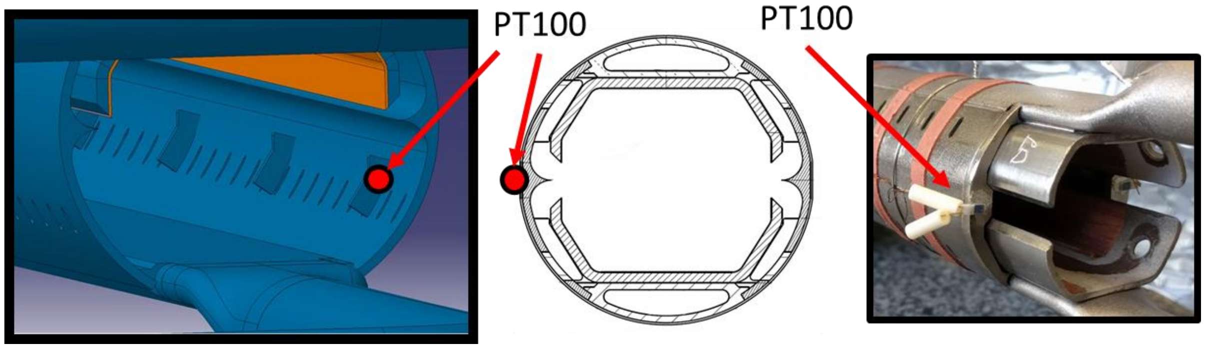
L. Gonzalez et al., IPAC18 (2018), Vancouver, Canada

BESTEX





Temperature sensors



L. Gonzalez et al., IPAC18 (2018), Vancouver, Canada

BESTEX

- Next step at KARA: repeat experiment with LN cooling
- Possible installation at DAFNE of similar system for tests with e+/e- beams

Feasibility study on cryogenic vacuum chamber test set up

Bundesministerium für Bildung und Forschung

Karlsruhe Institute of Technology

- Proposal from KIT has been approved by the German Ministry of Research and Education: 1 Postdoc for 3 years

- Feasibility study of a cryogenic vacuum chamber test set up equipped with different diagnostics to measure the pressure, gas content, low energy electrons formation, as well as the heat load produced by a positively charged beam

- The test set up should be flexible to exchange cold bores with different geometries and surfaces and be adaptable in different accelerator exposed to charged beams as well as to synchrotron radiation

- In this context, such test chamber that could also be tested with electron and, what is more important, with positron beams at DAFNE

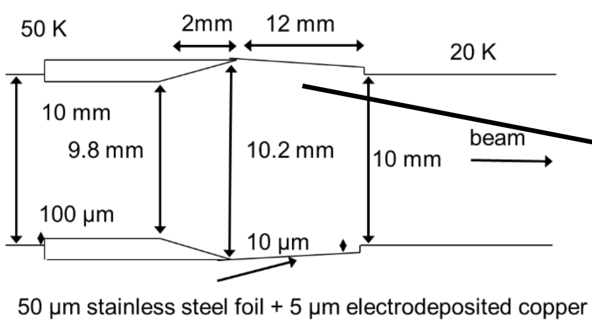
Summary

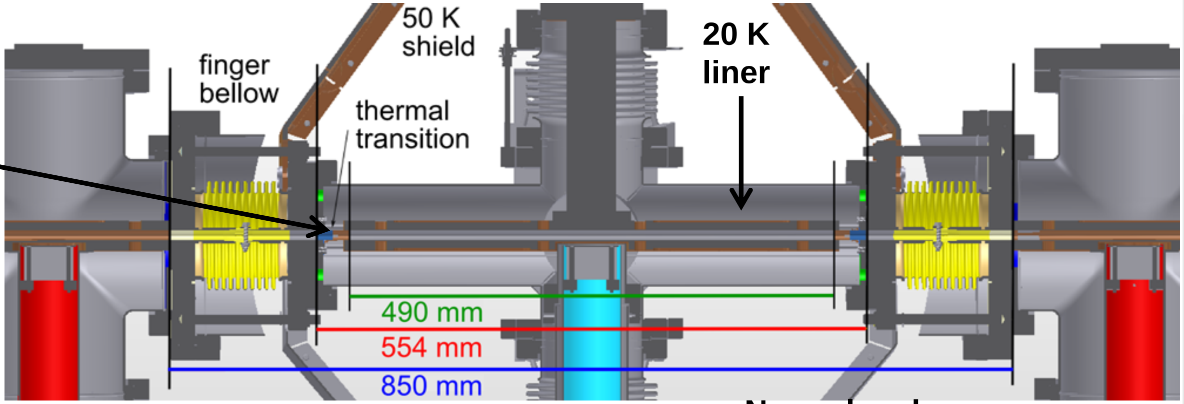
- **Possible vacuum devices to be tested at DAFNE for beam heat load, impedance and electron cloud studies**

  - COLDDIAG with new thermal transitions with existing copper liner or new liner.
  - BESTEX like setup at room temperature and at LN temperature
  - New cryogenic vacuum chamber test set up including lessons learned from COLDEX and COLDDIAG

Backup slides

COLDDIAG

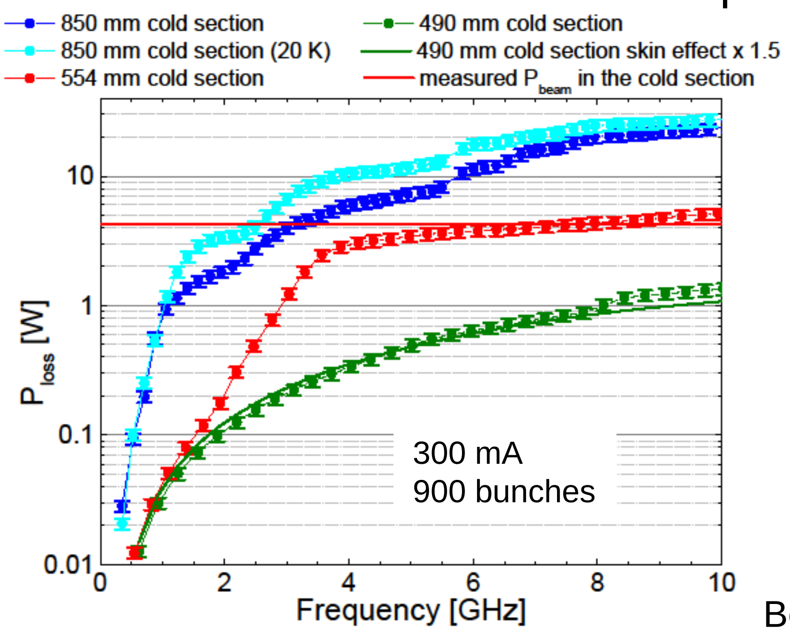




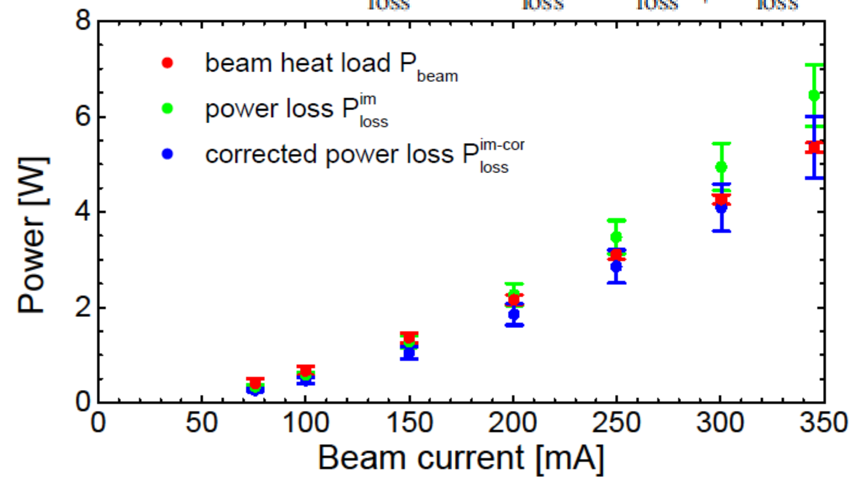
Thermal transitions:
heat from higher temperature regions + imperfections in the geometry.

Impedance bench measurements

Normal and anomalous skin effect



$$P_{\rm loss}^{\rm im\text{-}cor} = P_{\rm loss}^{\rm im} - P_{\rm loss}^{\rm sk} + P_{\rm loss}^{\rm an}$$



R. Voutta et al., PRSTAB, 19, 053201 (2016)

Beam heat load observed understood: due to thermal transitions.
Changes in cross section have to be moved between 50 K and RT.