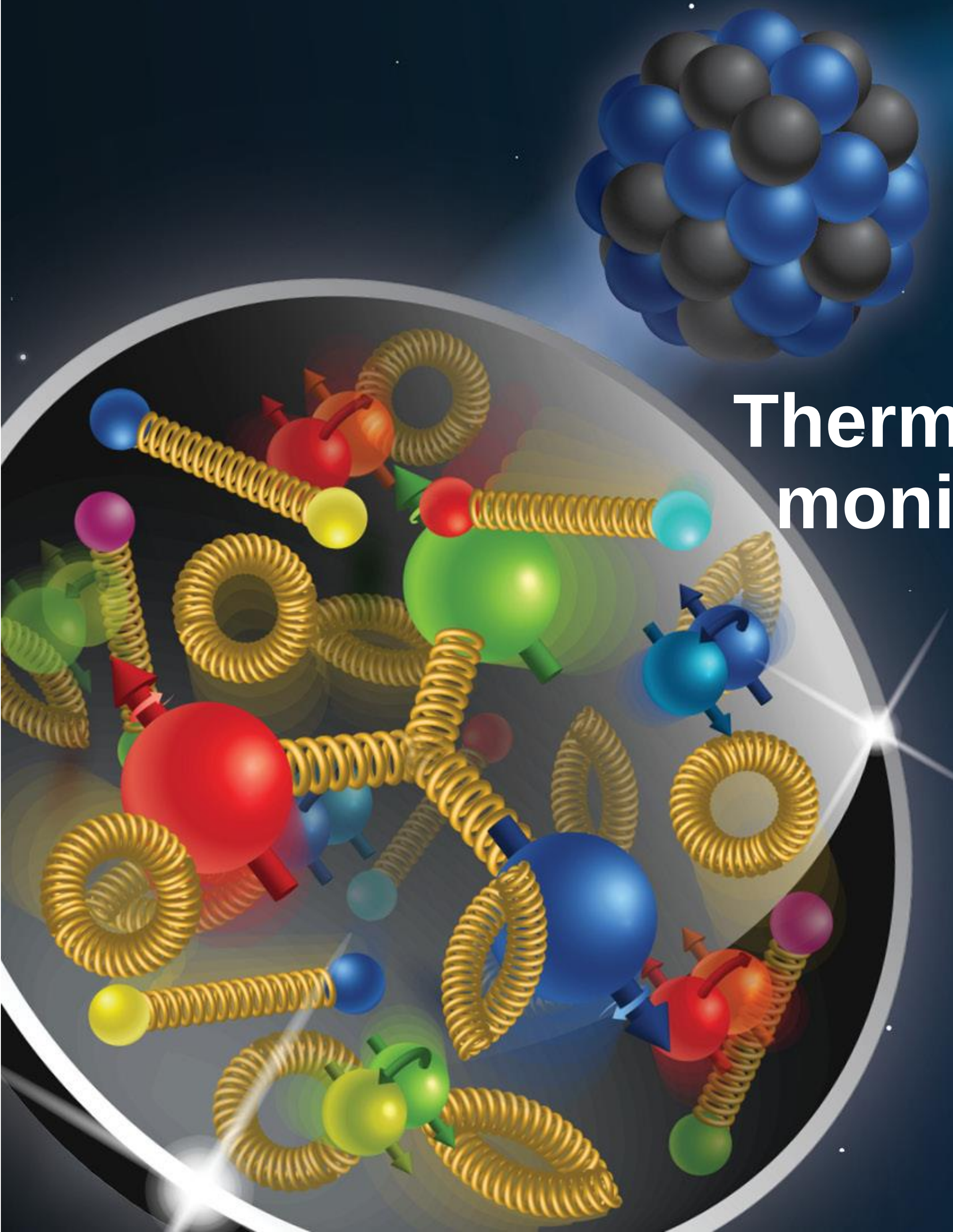


Thermal engineering of the beam position monitors for the EIC hadron storage ring

F. Micolon, J. Bellon, D. Gassner, C. Hetzel, R. Hulsart, D. Holmes, C. Liu, V. Ptitsyn, M. Sangroula, S. Verdu-Andres and others

7/10/2023 - CEC/ICMC 2023

Electron-Ion Collider

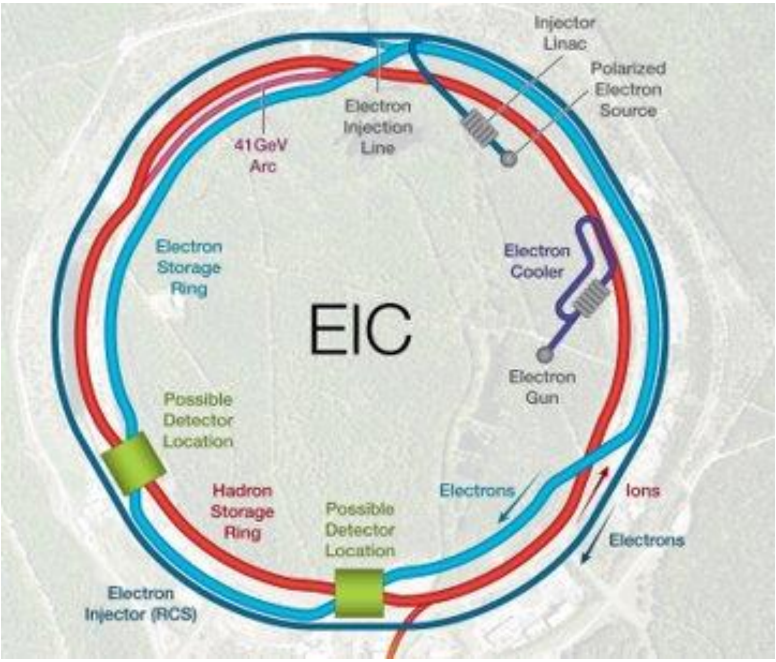
BROOKHAVEN NATIONAL LABORATORY · Jefferson Lab · U.S. DEPARTMENT OF ENERGY | Office of Science

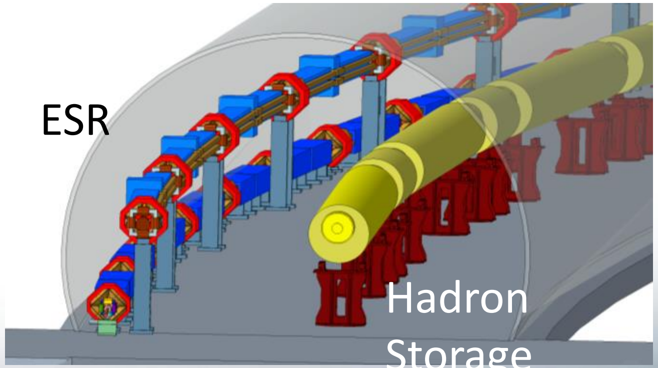
Outline

- The EIC project
- Need for this study
- System integration
- Heating sources
- Analysis results
- Conclusion

The EIC project

- The **Electron-Ion Collider (EIC)** is a project of collider using electrons to probe the hadrons nucleus
- Design based on **existing RHIC Complex in BNL** (NY, USA)
- **Hadron Storage Ring (HSR) 40-275 GeV**
  - Superconducting magnets and cryogenic infrastructure reused
  - 1160 bunches, 1A beam current (3x RHIC)
  - strong hadron cooling
- Two electron - accelerating and storage - rings will be added to the RHIC tunnel





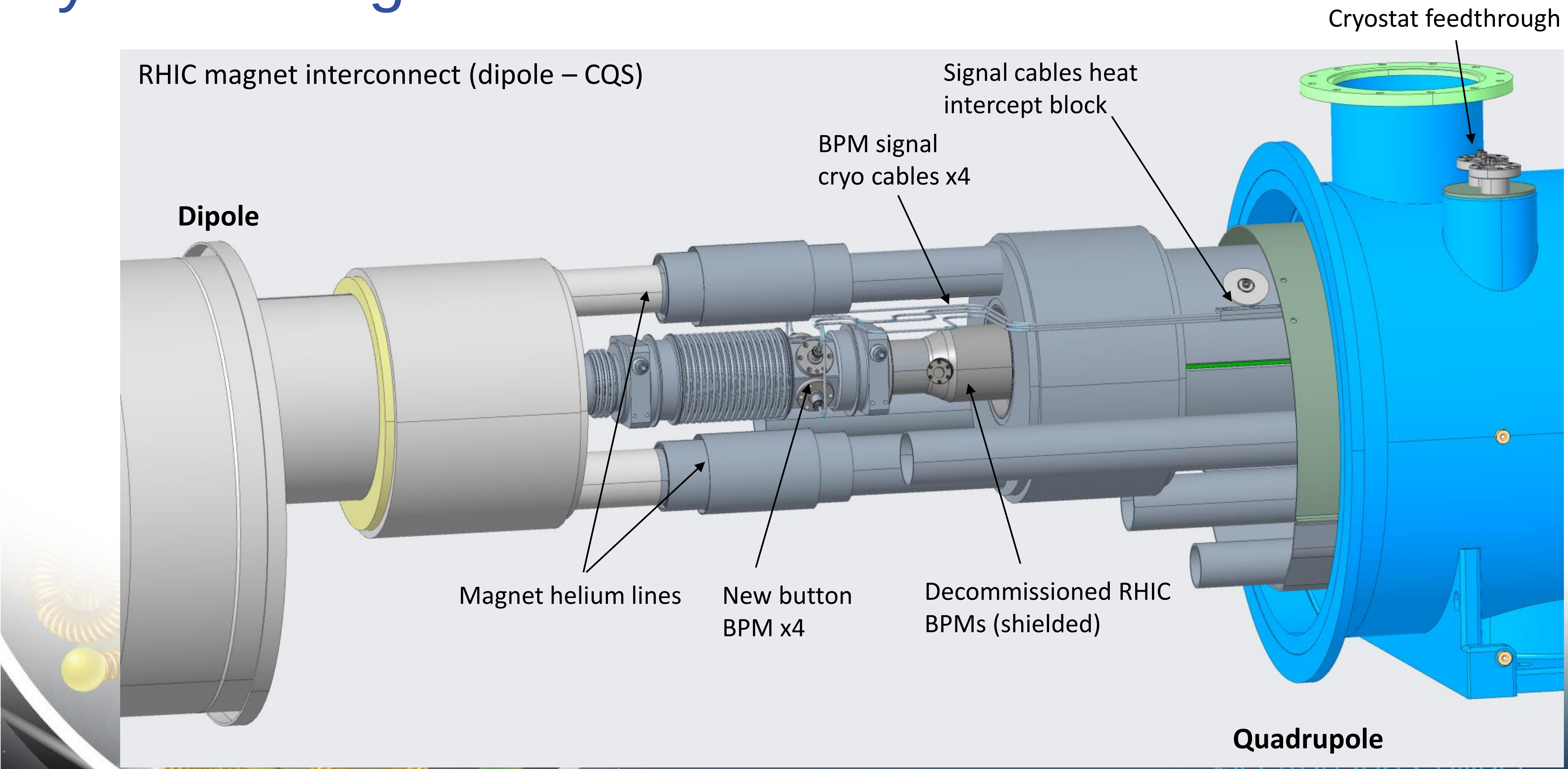
Need for this study

A thermal analysis of the HSR BPM design was made with the following aims :

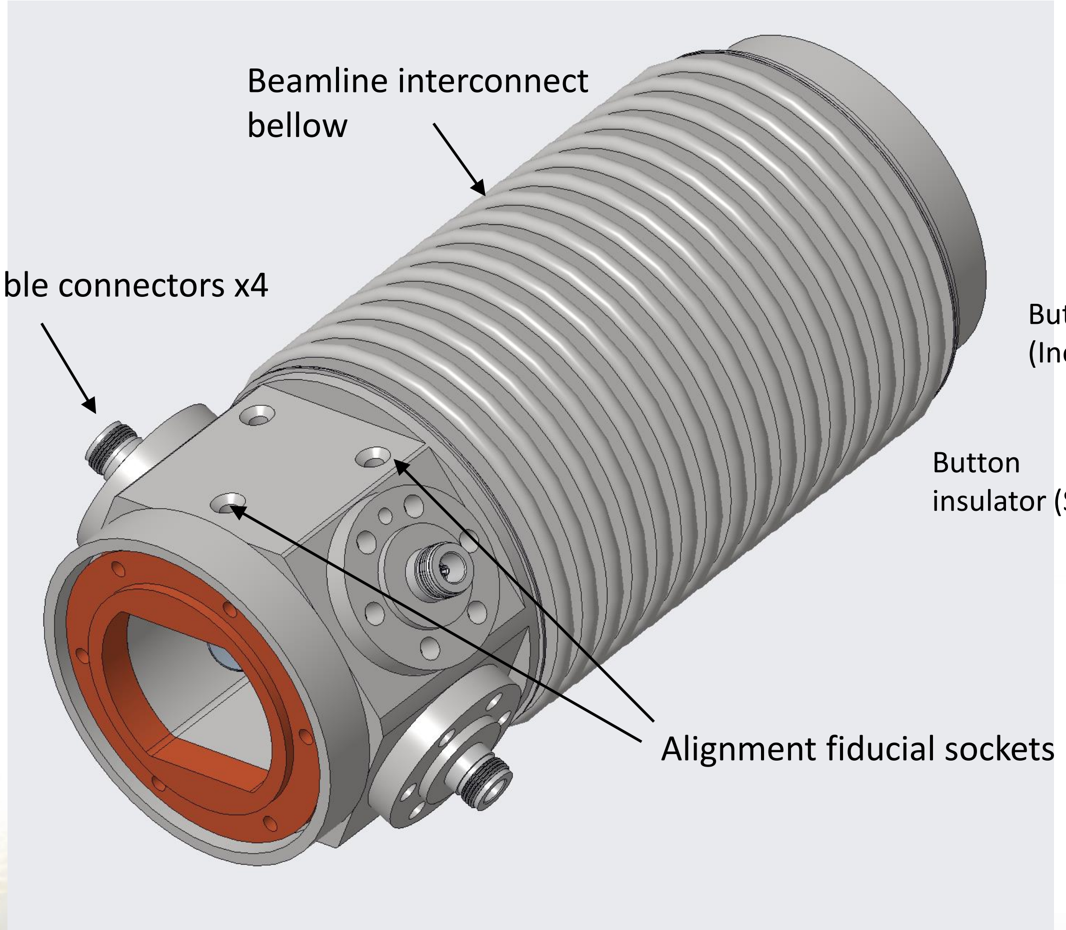
- Making sure the BPMs cable will not overheat and be a limitation to the operation of EIC (it was considered an - unexpected - bunch intensity limit for RHIC)
- Making sure the temperature reached by the button will be compatible with operation
- Making sure the added heat to the cryogenic systems would be within budget

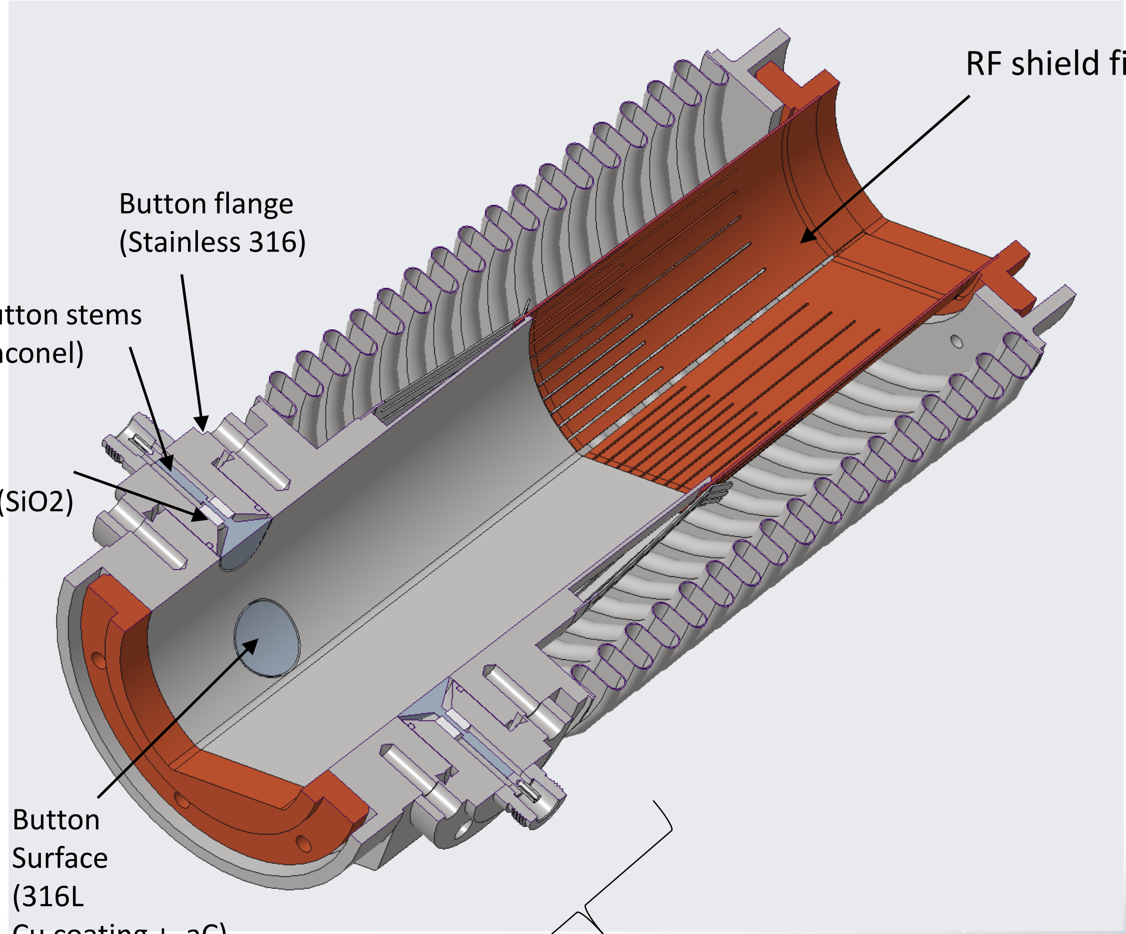
System Integration

System Integration



System Integration





New HSR interconnect module planned for EIC

Sources of Heat

BPM Heating

Thermal conduction through signal cables

The cryostat feedthroughs are kept ~293 K by tunnel air convection

The cryostat heat shield is kept at 50 – 80 K by circulation of supercritical helium

The magnets will be kept at 4.5 K by circulation of supercritical helium

RF signal propagation along BPM cables

The propagation of the RF signal along the BPM cable will produce some resistive and dielectric heating

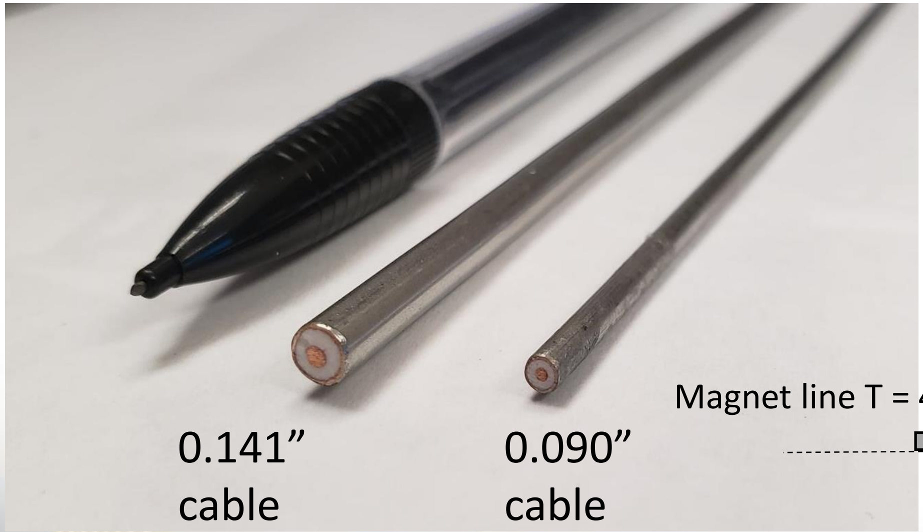
$$\underbrace{\frac{dx.\sqrt{f.\rho_{i,e}(T)}}{r_{i,e}}.\int i^2.dt}_{\text{Resistive heating}} + \underbrace{P_{RF}.\left(1-10^{\frac{-\alpha.dx}{10}}\right)}_{\text{Dielectric heating}} \underbrace{- k(T).S_{i,e}.\frac{dT}{dx}}_{\text{Conduction}} = 0$$

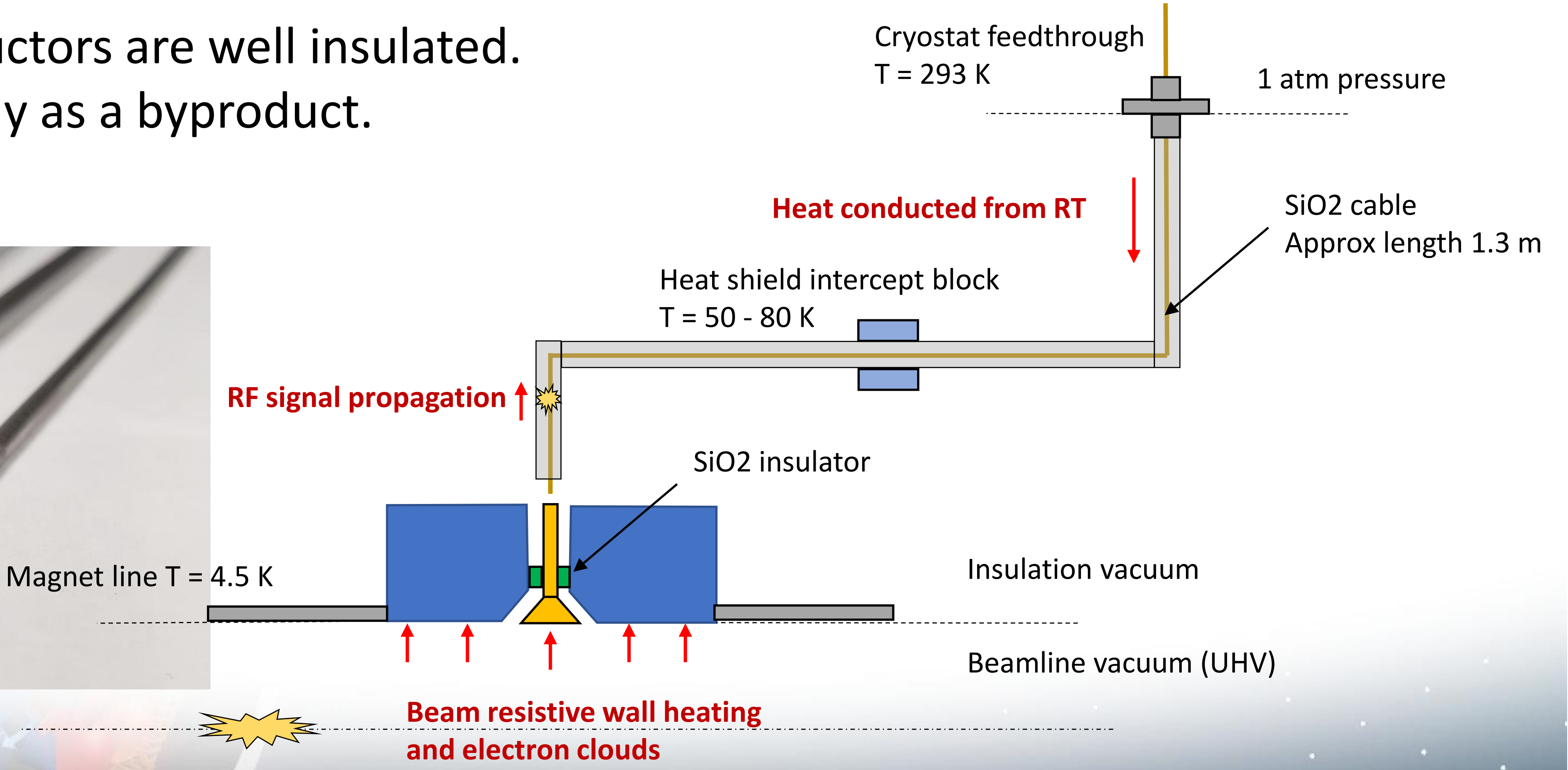
Beam resistive wall heating and electron clouds

The propagation of the beam wall image current on the beam chamber walls and beam-induced electron clouds will produce some heating on the pickup.

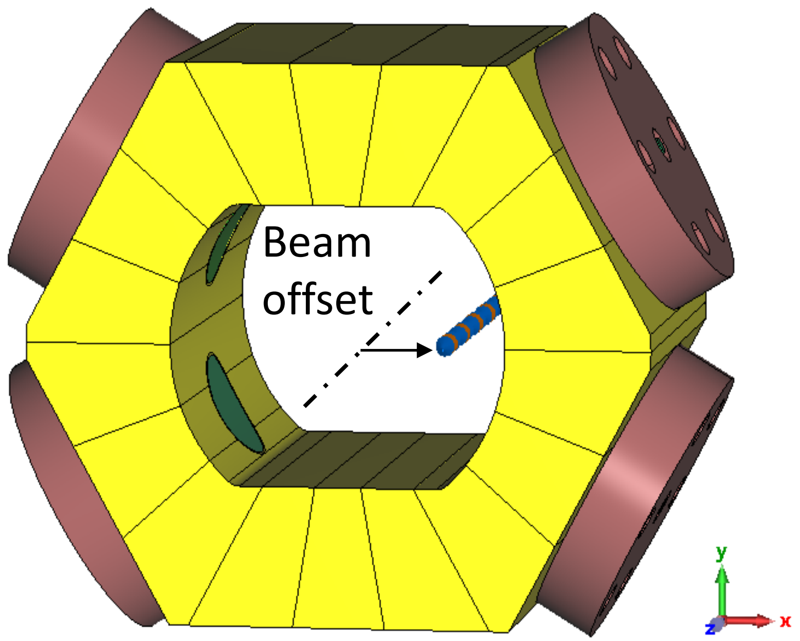
BPM Heating Source – Sketch of Principle

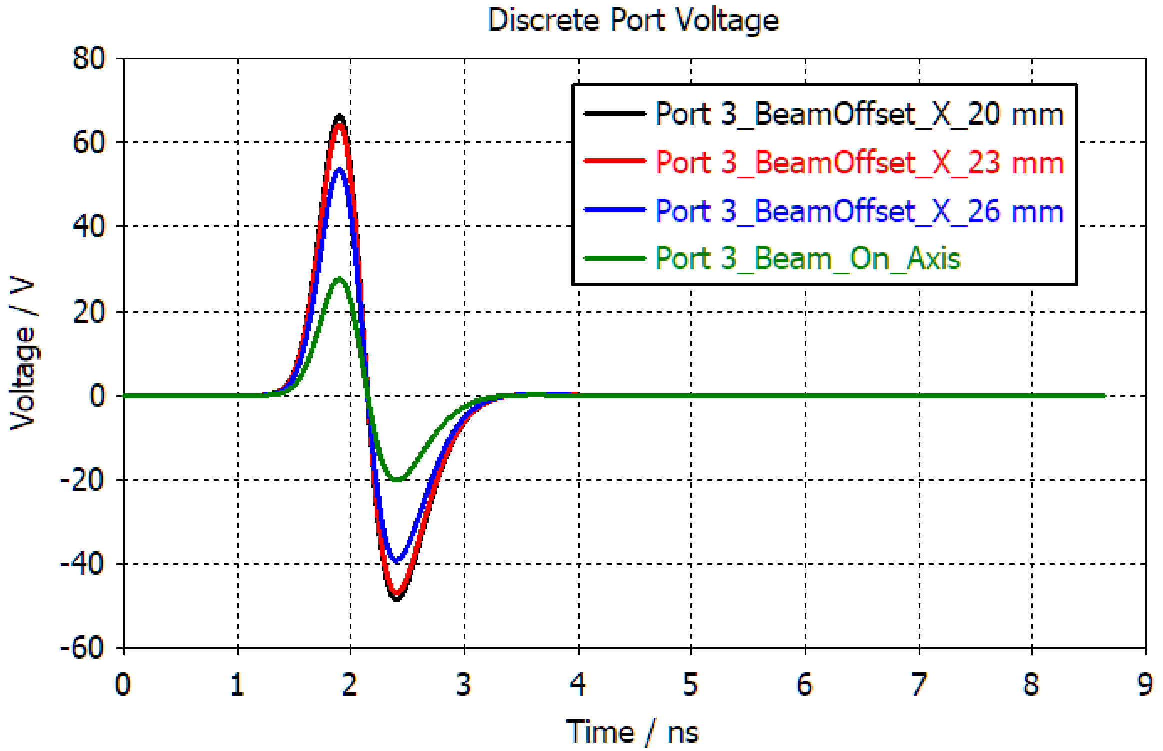
Buttons and inner conductors are well insulated.
Electrically, and thermally as a byproduct.





BPM signal





EIC will operate with a radial offset of the hadron beam.
This will bring a asymmetrical heating of the BPM buttons and cables.

Analysis results

What is the maximum allowable temperature ?

The beamline UHV needs to be preserved.

The pickups have a aC coating to avoid e- clouds, this acts as an adsorber for residual gases.

From the amorphous carbon TDS, H_2 desorption will start past 40 K.

→ **We will strive to stay below 40 K of beam wall temperature.**

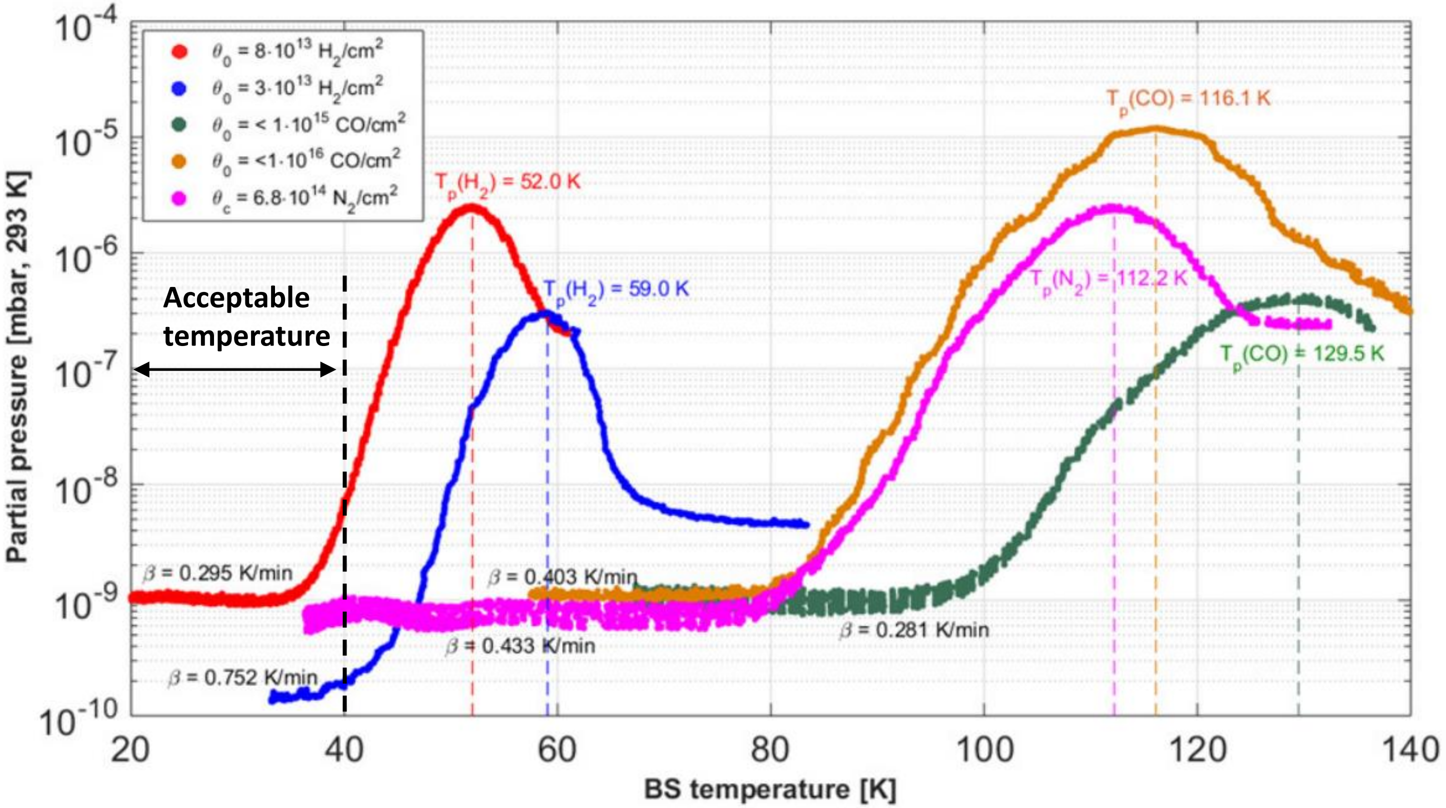
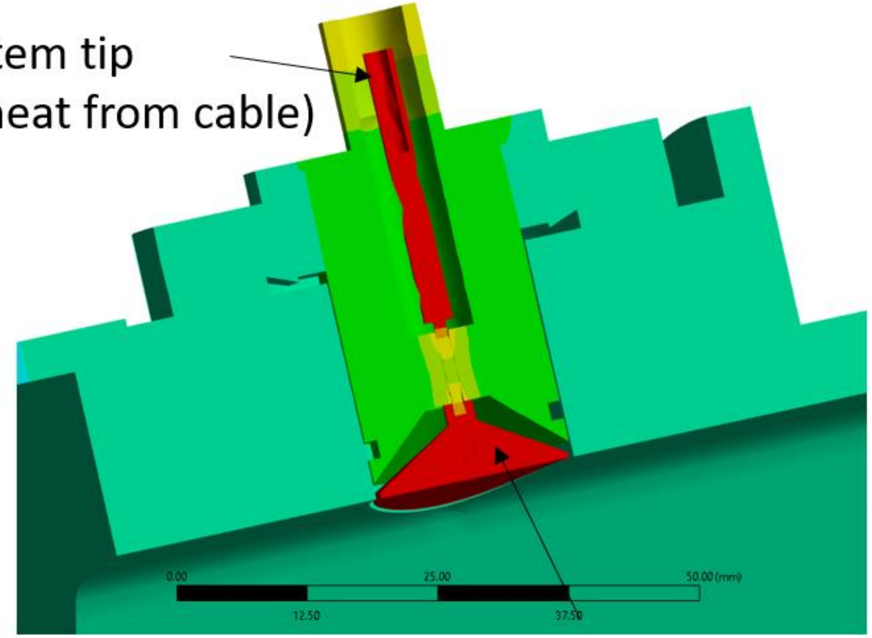
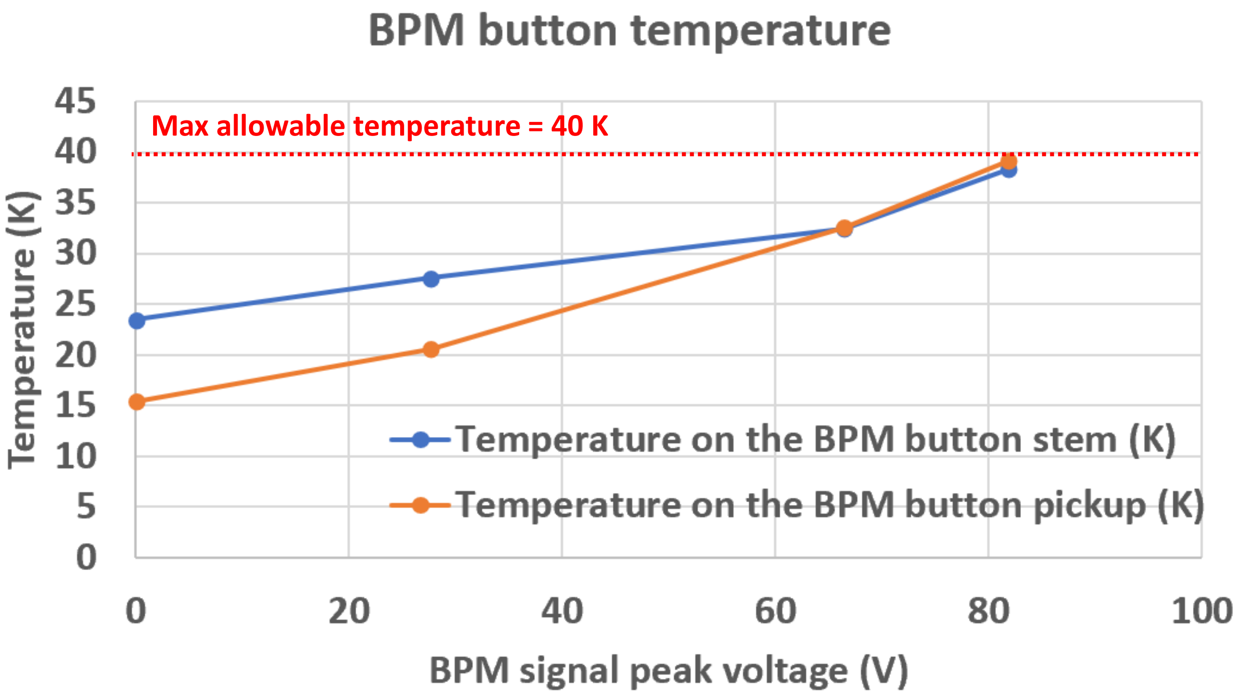


Figure 1: TDS for H_2, N2 and CO measured for a-C coating as a function of θ_0 and β.

Source : R. Salemme et al . "Vacuum performance of Amorphous Carbon Coating at Cryogenic Temperature with Presence of Proton Beams" Proc. IPAC16 - DOI : 10.18429/JACoW-IPAC2016-THPMY007

FE Model Results





The button temperature is below 40 K in all cases.

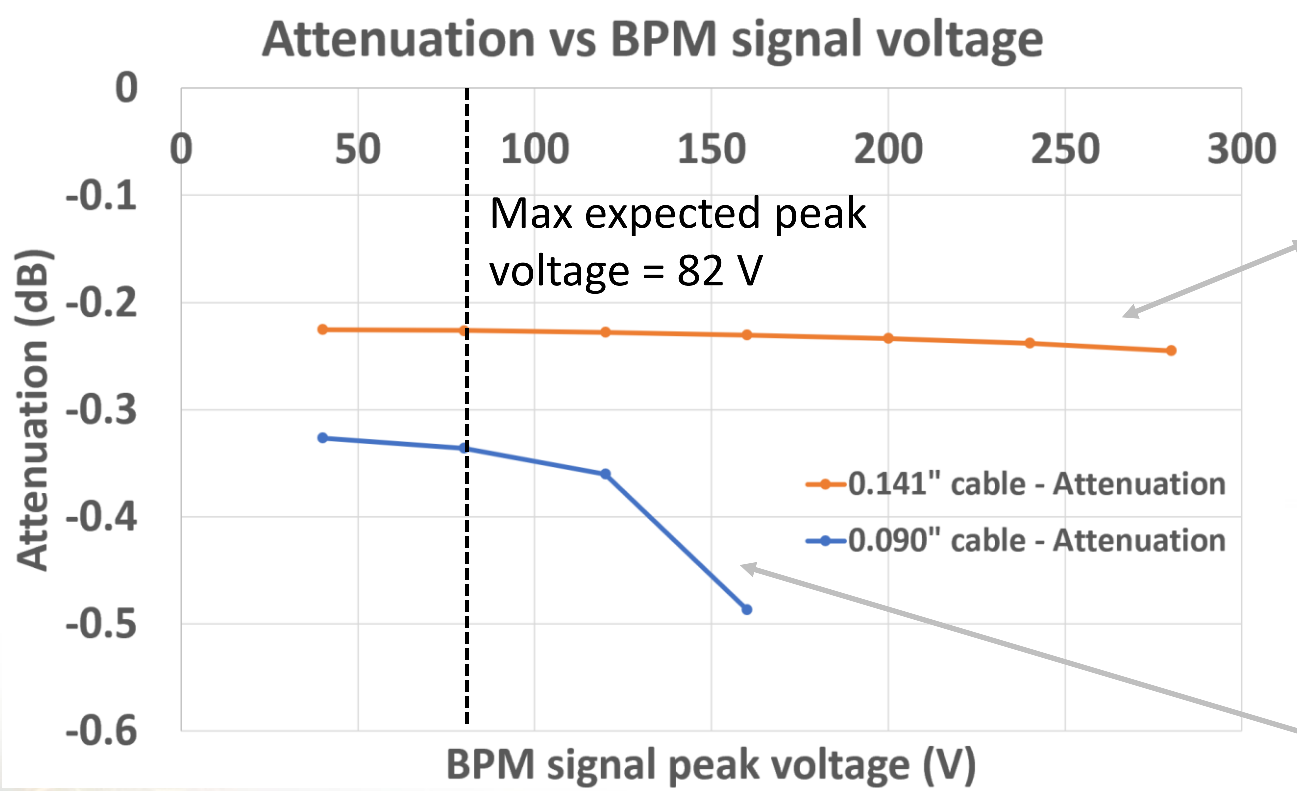
This will be low enough to avoid significant H_2 desorption.

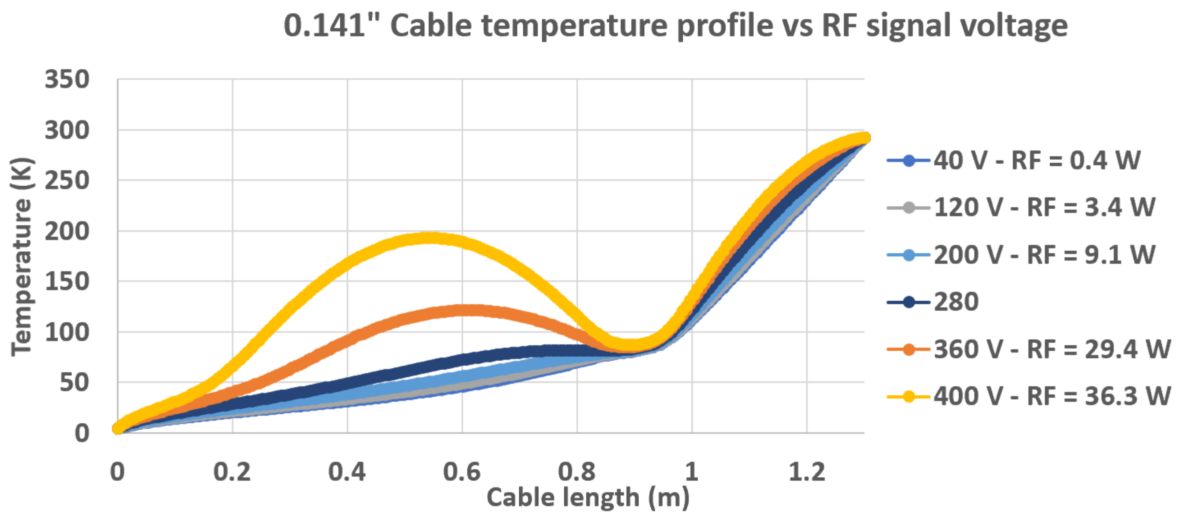
Conclusion

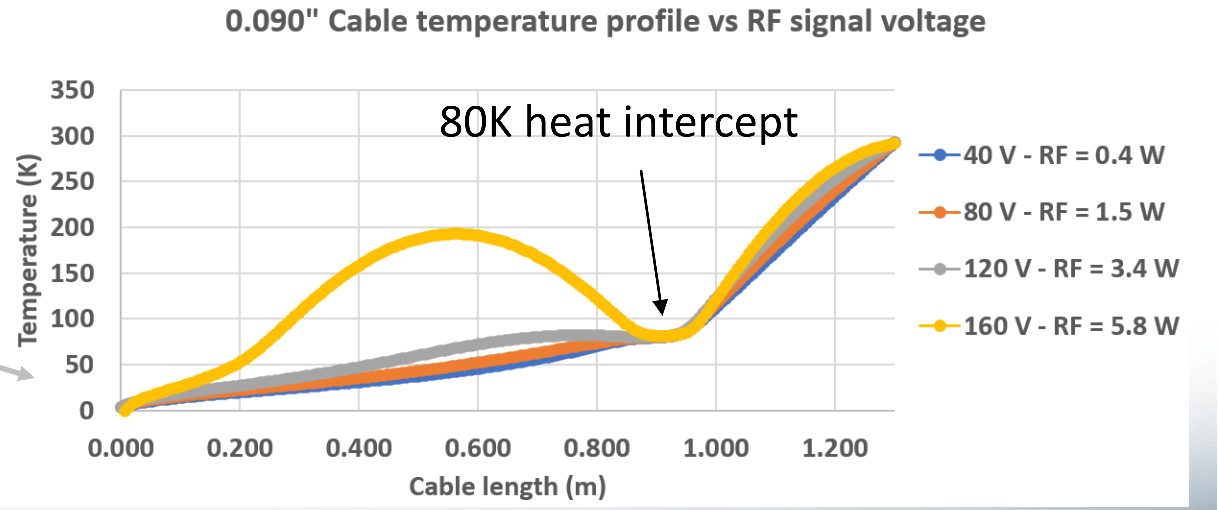
- Engineering analysis of the new HSR button BPM has been carried out in 2023
- Although close to the limit in button temperature and cable attenuation the design is found satisfactory.
- Dedicated tests will be done to validate the thermal conduction and RF heating of the cable.

Happy to take questions !

Cable temperature

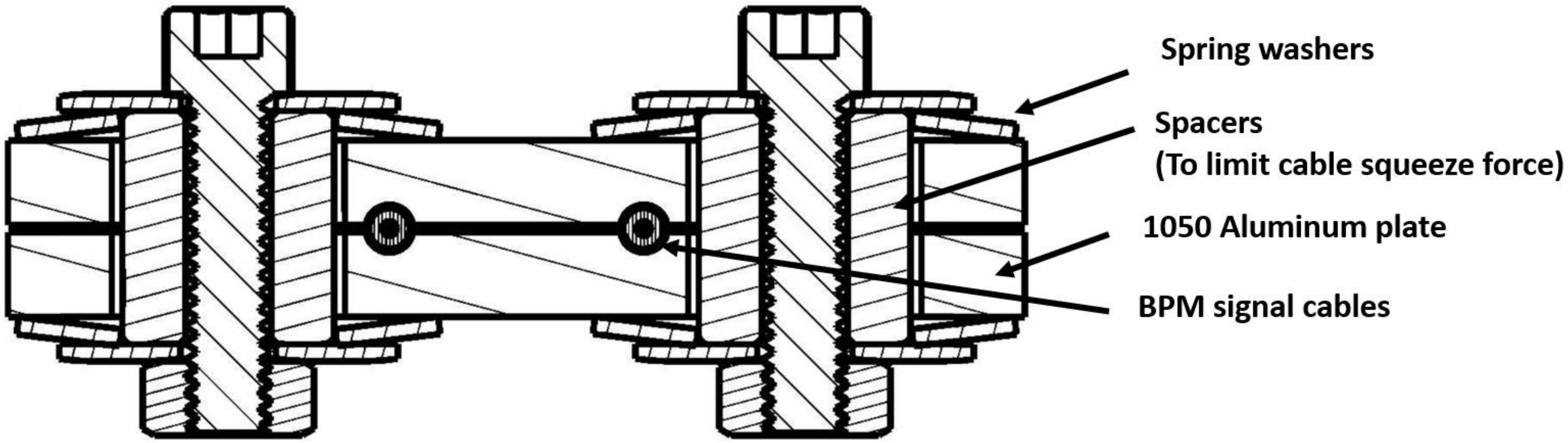






The 0.090" is more susceptible to attenuation variations.
However, in the voltage range expected, the attenuation is still stable for both cables.

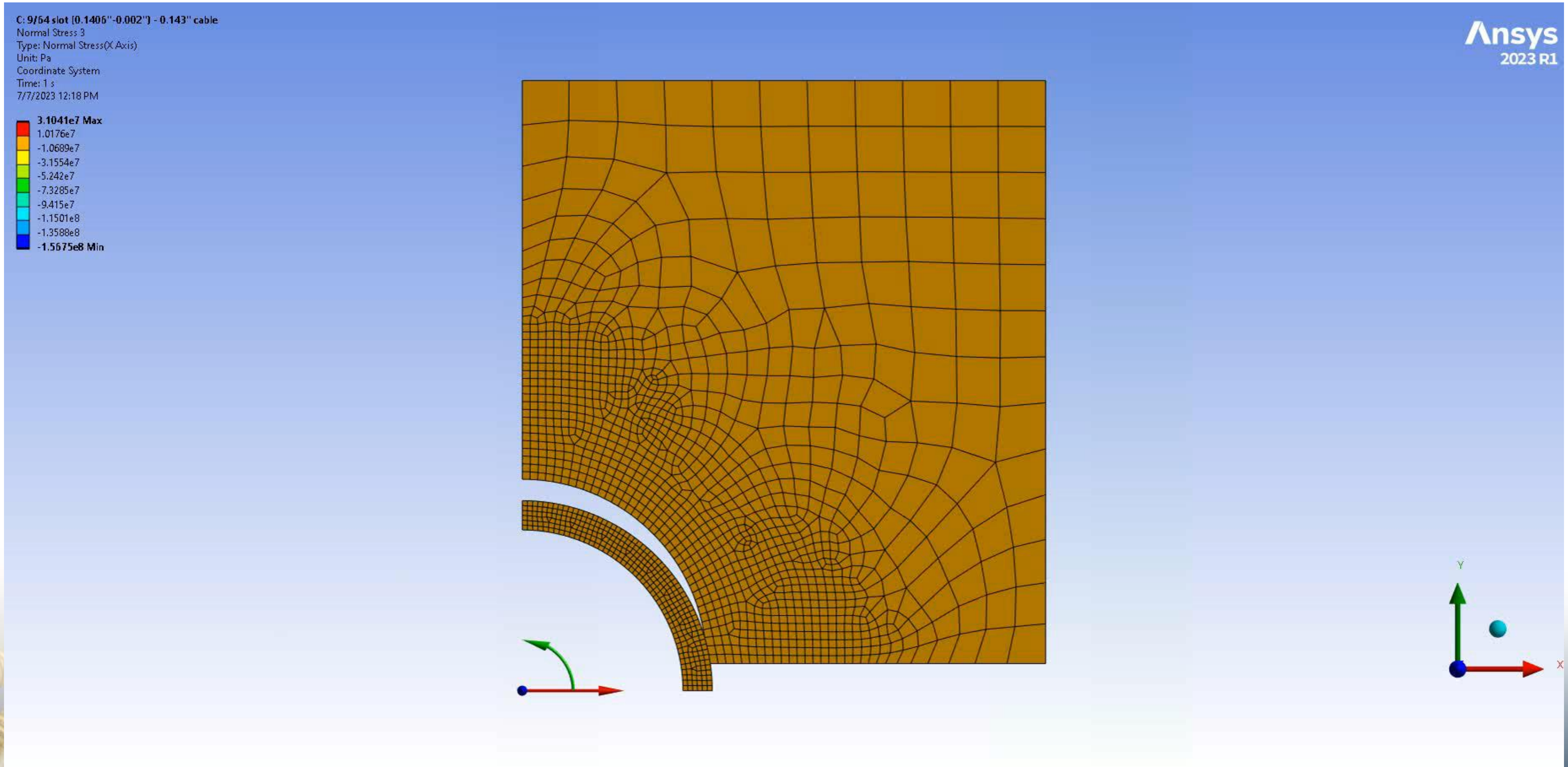
Heat intercept design



Distortion by squeezing the cable will bring unwanted signal reflections
→ We have designed a heat block assembly to limit the maximum squeezing force

Heat block intercept design

Animation of the normal radial stress at the interface cable/heat block

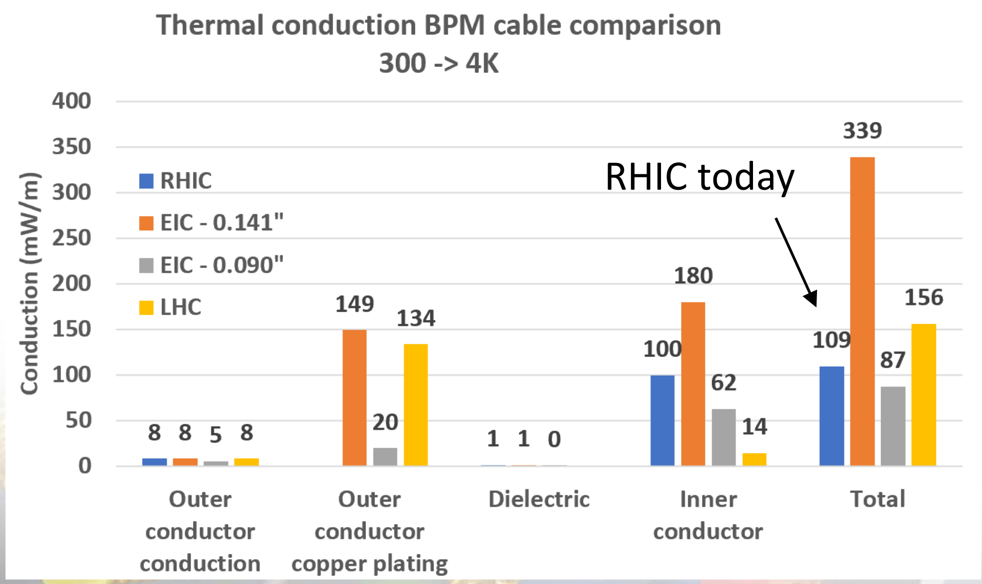


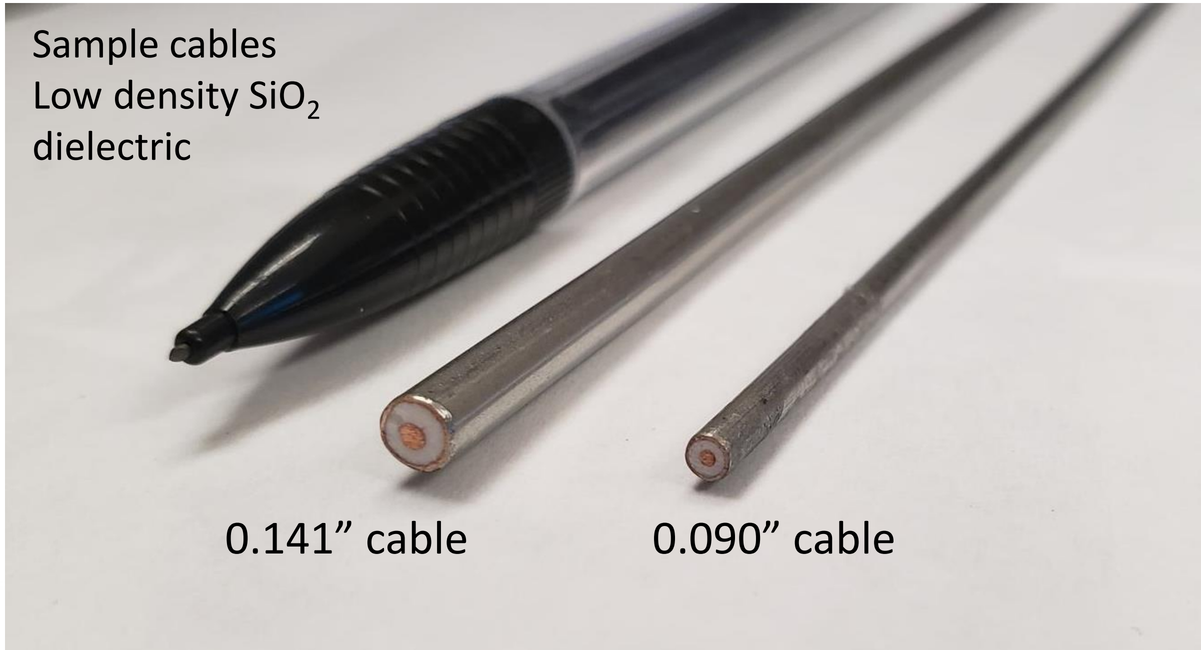
Electron-Ion Collider

Possible Coax Cryo-Cable Options

The plan is to use rigid coaxial cables with a low density SiO_2 dielectric material.

The inner conductor will be bulk copper. The outer conductor will be a stainless-steel jacket with an inner copper coating.





Compared to the current RHIC BPM cables :

~3x bigger thermal conductivity for the 0.141” cable

~lower thermal conductivity for the 0.090” cable

However the RF attenuation is expected ~1.5x higher with the 0.090” cable.

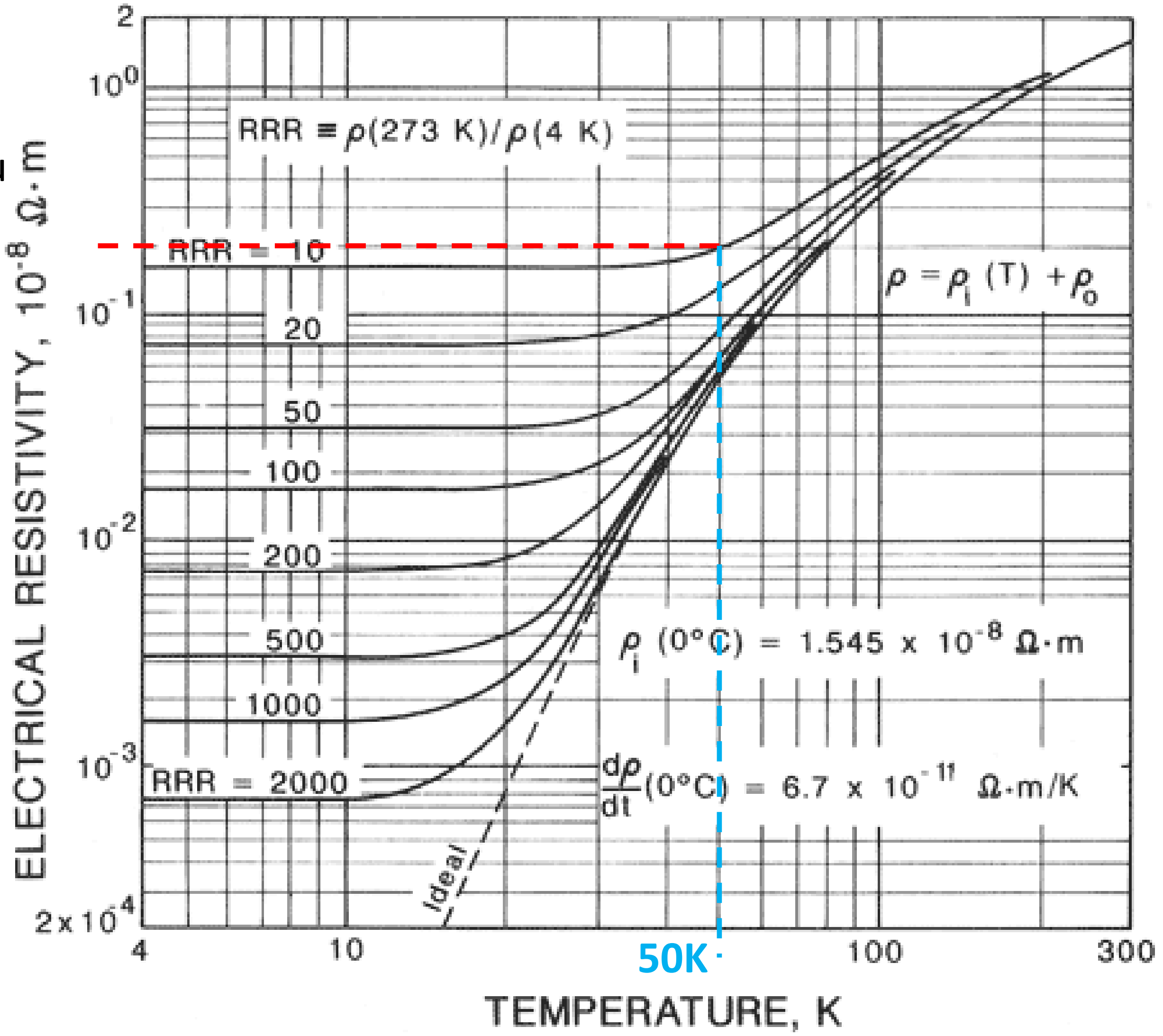
Tech Note Link

- More details on the simulation and results can be found in the BNL technical note published earlier this year :

https://www.osti.gov/servlets/purl/1969913

Copper Electrical Resistivity

Assumption for Cu conductivity =5E+8



Impact on Vacuum

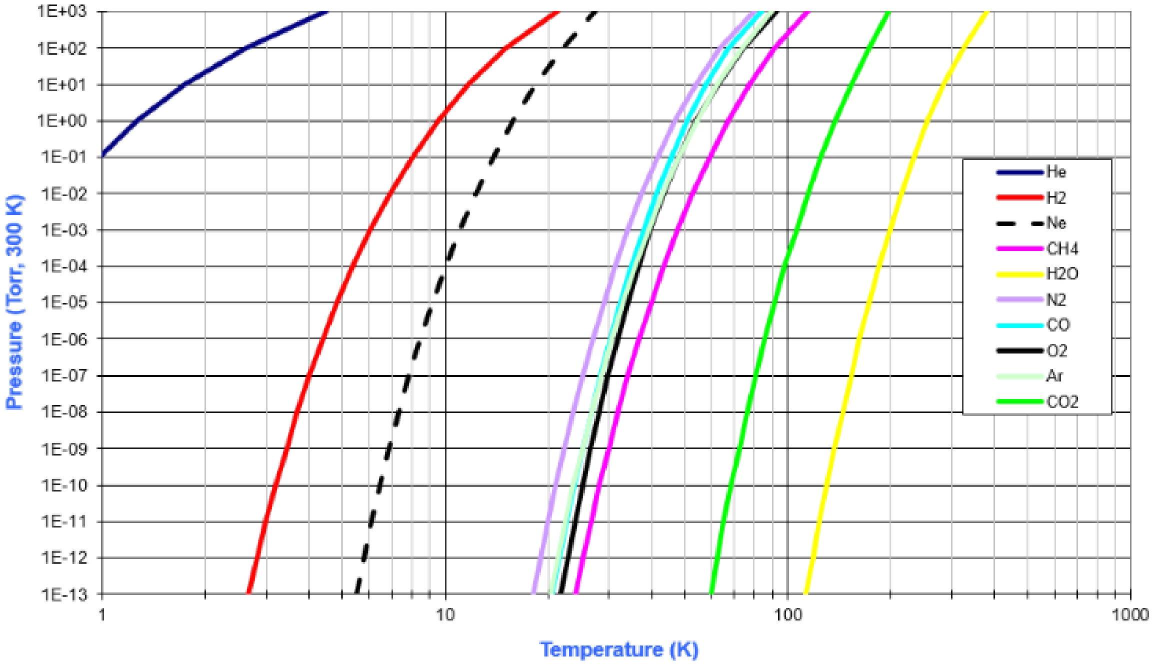


Fig. 7: Saturated vapour pressure curves as a function of the temperature [13, 40, 41].

From V.Baglin [lecture on cryopumping]

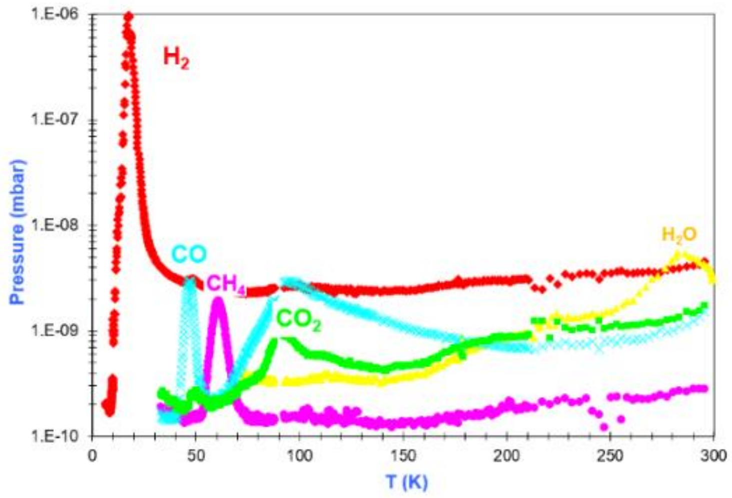


Fig. 2: Molecular species desorbed during a natural warm-up from 10 K to room temperature.

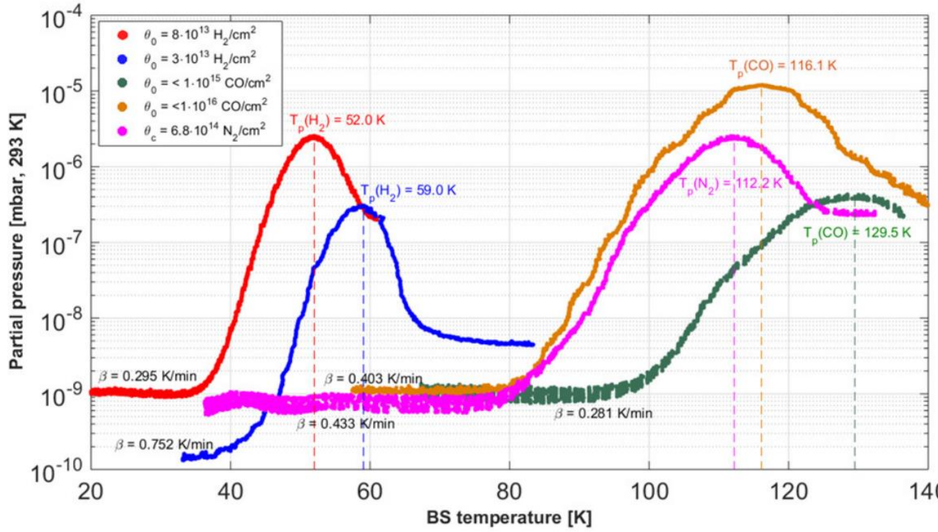
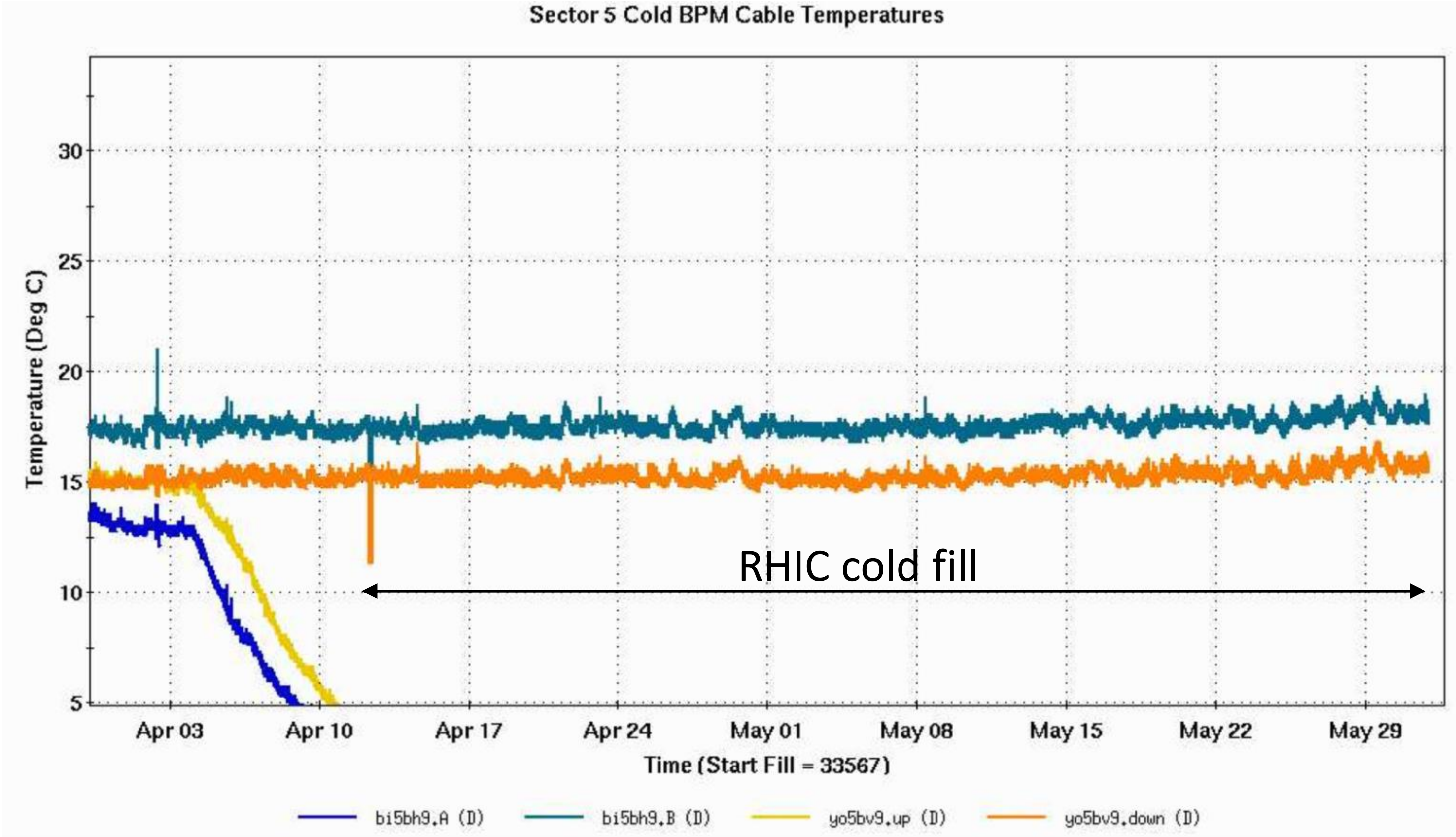


Figure 1: TDS for H_2, N2 and CO measured for a-C coating as a function of θ_0 and β.

Desorption of gas from an aC coated surface vs temperature - Source : R. Salemme et al . [Link]

BPM Feedthrough Temperature



A measurement campaign with thermocouples on the BPM feedthrough has started this year to validate the temperature of the warm end.

During the cold fill the feedthrough temperature has not evolved.