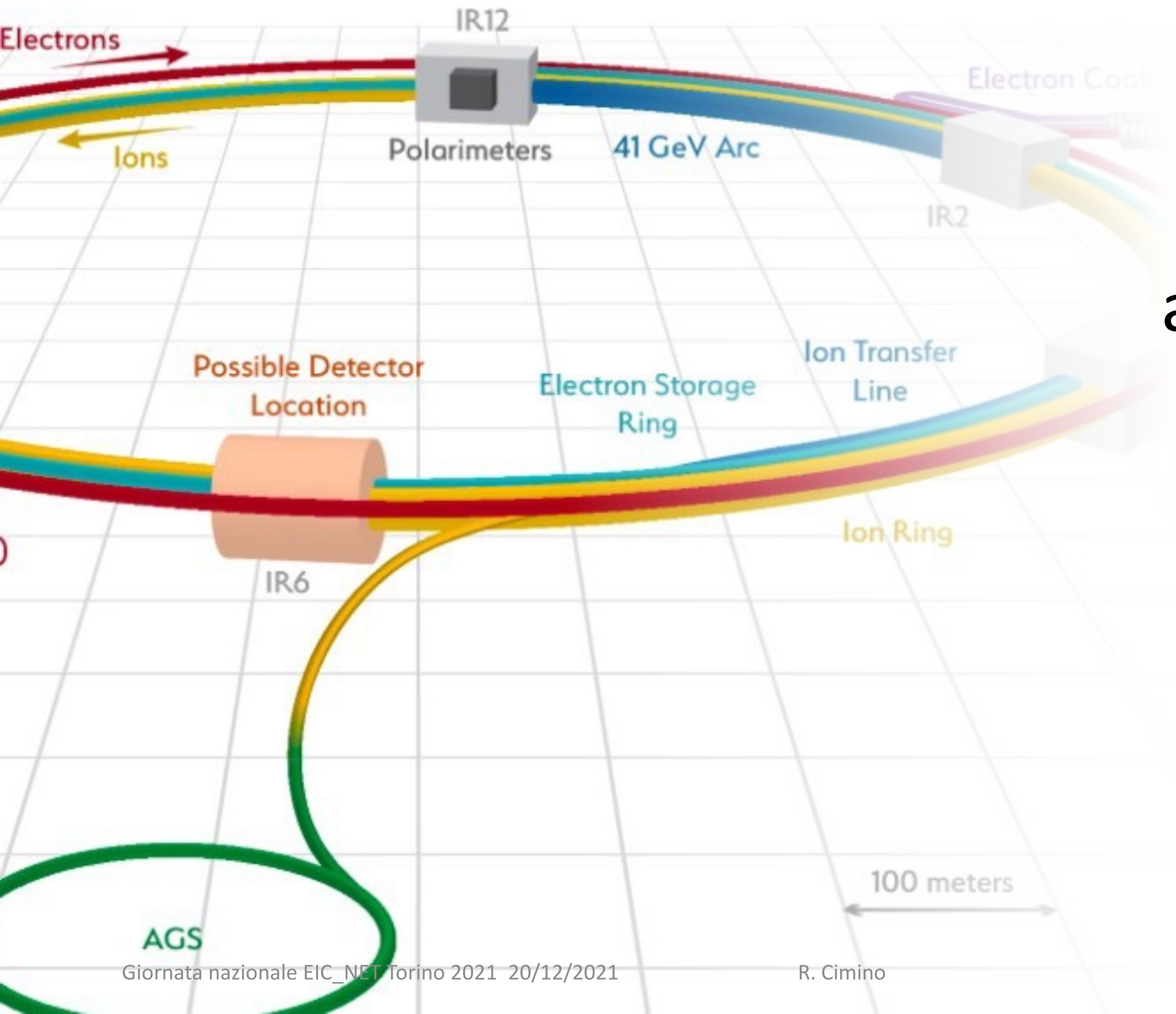

EIC and INFN accelerator experts: update on possible perspectives

Giornata nazionale EIC_NET Torino
20/12/2021

Roberto Cimino

INFN LNF
Istituto Nazionale di Fisica Nucleare

TRIUMF 2021 EIC Accelerator Partnership Workshop

26 Oct 2021, 07:00 → 29 Oct 2021, 12:30 US/Pacific

Andrei Seryi (Jefferson Lab) , Oliver Kester (TRIUMF)

Description

EIC2021, October 26-29, 2021 On-line Format

The EIC Accelerator Partnership Workshop 2021 – Promoting Collaboration on the Electron-Ion Collider – will be hosted by TRIUMF Laboratory, Canada. The virtual meeting will take place from October 26 to October 28, 2021, and will include a half-day satellite meeting on October 29. Similar to the first partnership workshop hosted by the Cockcroft Institute last year, the 2021 workshop will include sessions spread around different time zones.

With EIC project having received the CD1 approval in June 2021, and with the EIC project aiming at CD2 in about one and a half years, the EIC project team is aiming to advance the progress on defining the areas of collaboration and possible contribution from potential partners well before CD2. Therefore, unlike the 2020 workshop which included broad overview of EIC and related accelerator technology topics, the planned 2021 Accelerator Partnership Workshop will focus primarily on the areas where there are advanced technical discussions between the EIC Project and potential partners regarding collaboration and technical scope of work. We encourage all accelerator groups interested in EIC to participate in the workshop, while also encouraging the interested groups to contact the EIC project directly in parallel.

Organizing Committee

Oliver Kester (TRIUMF, Canada) Co-Chair – Local Organizing Committee (LOC)
Andrei Seryi (JLab, USA) Co-Chair, Local Organizing Committee (LOC)
Bob Laxdal (TRIUMF, Canada) - LOC
Silke Bergelt-Bruckner (TRIUMF, Canada) – LOC
Ferdinand Willeke (BNL, USA) – LOC
Graeme Burt (Cockcroft Institute, UK)
Peter Williams (Cockcroft Institute, UK)
Pierre Vedrine (CEA Saclay, France)
Walid Kaabi (IJCLab, France)
Roberto Cimino (INFN, Italy)
Roberto Losito (CERN, Switzerland)
Makoto Tobiyama (KEK, Japan)
In Soo Ko (PAL, S. Korea)
Bernd Surrow (EIC UG)
The Organizing Committee can be contacted via eic2021@triumf.ca

~ 240 Participants
~ 10 INFN
4 INFN contributed talks
(on Magnets and Collective effects/Vacuum)

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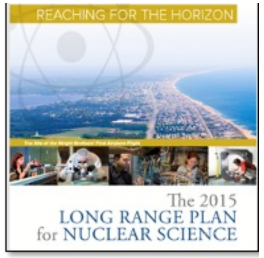
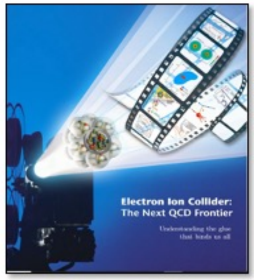
From the opening talk by
A. Seryi & F. Wilke

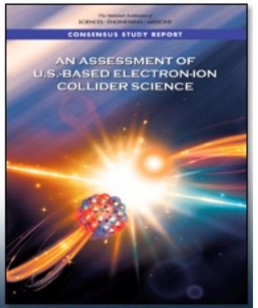
From the opening talk by A. Seryi & F. Wilke

Requirements

- **EIC Design Goals**
  - High luminosity: L=(0.1-1)x10^{34} cm^{-2} s^{-1} → 10-100 fb^{-1}
  - Collisions of highly polarized +/-70% e, p and light ion beams with flexible spin patterns
  - Large range of center of mass energies: E_{cm}=(20-140) GeV
  - Large range of ion species: protons–Uranium
  - Ensure accommodation of a second IR
  - Large detector acceptance
  - Good background conditions
- **Goals match or exceed requirements** of Long-Range Plan & EIC White Paper, endorsed by US National Academy of Science
- **EIC design meets or exceeds these goals**





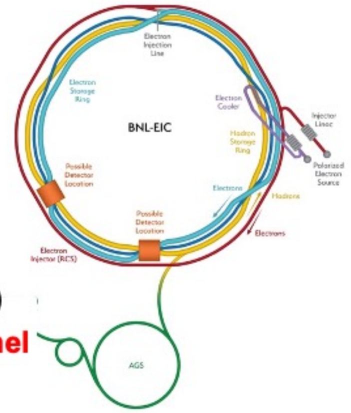


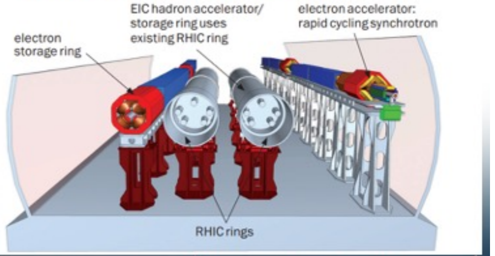
3 Electron-Ion Collider

EIC Overview

Design based on **existing RHIC Complex**
RHIC is well-maintained, operating at its peak

- **Hadron storage ring 40-275 GeV**
  based on existing RHIC
  - 1160 bunches, 1A beam current (3 x RHIC)
  - Bright vertical beam emittance 1.5 nm
  - Strong hadron cooling (coherent electron cooling)
- **Electron storage ring 2.5–18 GeV new ring in RHIC tunnel**
  - 1160 bunches
  - Large beam current, 2.5 A → 9 MW S.R. power
  - SRF cavities
- **Electron rapid cycling synchrotron 0.4- 18 GeV new ring in RHIC tunnel**
  - 2 x 28 nC bunches, 1 Hz cycle time
  - Use spin transparency for high polarization
- **High luminosity interaction region(s) new**
  - L = 10^{34} $cm^{-2}s^{-1}$, Superconducting magnets
  - 25 mrad crossing angle with crab cavities
  - Spin rotators (longitudinal electron spin)
  - Forward hadron instrumentation for tagging





4 Electron-Ion Collider

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From the opening talk by
A. Seryi & F. Wilke

Opportunities for Collaboration

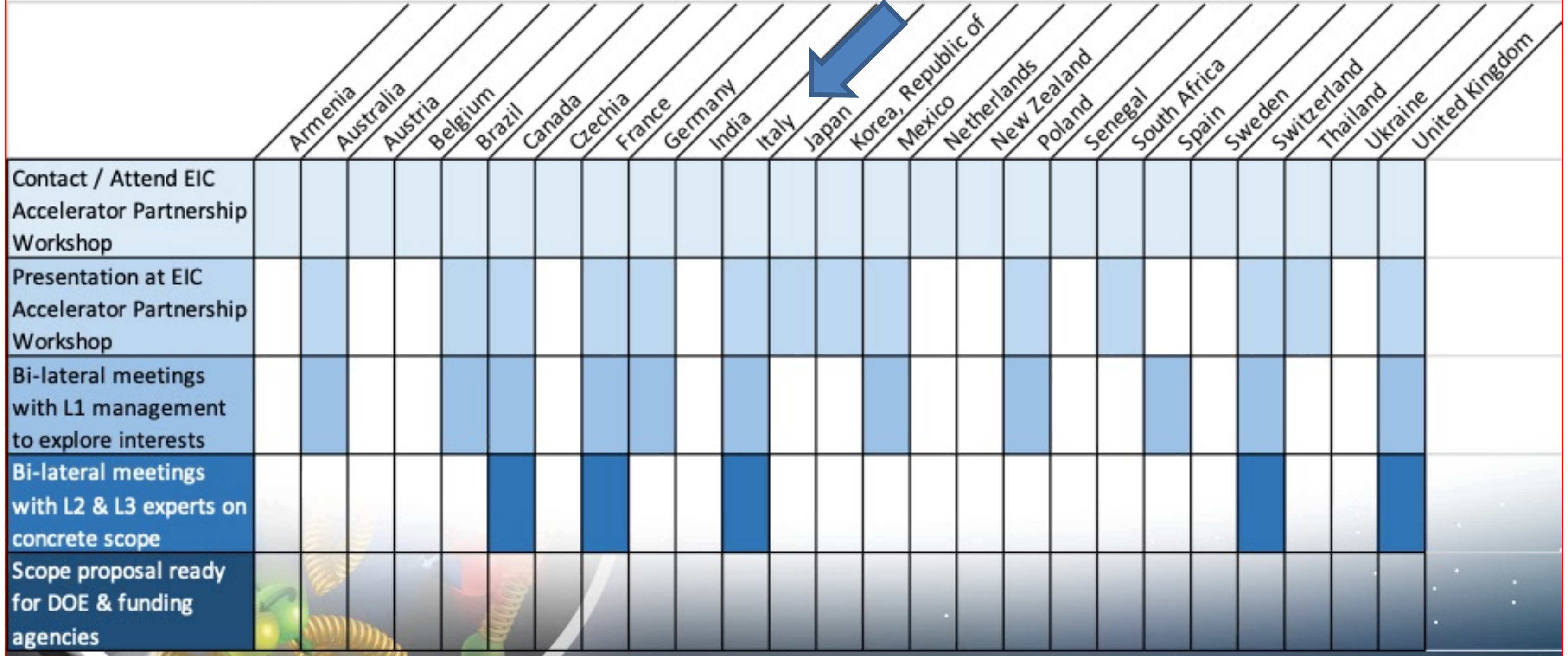
- The EIC teams welcomes any **intellectual contribution** to the EIC accelerator science: Beam-beam interactions, single particle stability, collective effects, physics of strong hadron cooling, physics of ERL and the intricate accelerator design — LNF - Na – RM1
- The EIC requires ~3500 normal conduction magnets ~3000 of storage ring quality
- EIC develops a novel IR design based on superconducting magnets using the traditional collared NbTi magnet design, direct wind methods (NbTi) and for a 2nd IR, Nb_3Sn magnets are envisioned. — (Ge – LASA – Sa)
- The EIC needs ~13 km of new vacuum system,~8 km of Cu systems and ~4km of Cu and aC coated liners. There are a large number of shielded bellows and other vacuum components, that are interesting and challenging especially for the ESR. — LNF - Na
- The EIC requires a large number of new superconducting cavities and cryo-modules: 591MHz single cell for the ESR, 5 Cell cavities for the RCS, the Hadron ring and the ERL and the 197 MHZ and 394 MHz crab - cavities for electrons and Hadrons in the interaction region. They are envisioned to be powered by state-of-the-art solid state RF amplifiers and controlled by the latest generation of digital controls.
- In additions there are collimators, beam diagnostics, ultra-fast pulsed magnets and power supplies.
- Any **contribution to the EIC hardware** leveraging existing expertise and experience will be very beneficial and welcome.
- Any in-kind contribution will be helpful in building out this exciting machine in a timely fashion so it can perform at the highest performance level to the benefit of the Nuclear Physics community.

P. Fabbricatore did present INFN capability (on behalf of INFN-Acc.) on magnets.
Non feedback from EIC nor from our Management.
The common feeling is that our laboratories, although capable, do not have resources to contribute to EIC magnets development/construction unless strongly motivated.

From the opening talk by
A. Seryi & F. Wilke

Accelerator outreach – summary

- Approach: bi-lateral meetings & partnership workshops
- Cockcroft, UK - Acc partnership workshop in Oct 2020; TRIUMF, Canada – Oct 2021
- Sample WBS scope as seed for discussion of possible in-kinds for 5-10% identified
- Bi-lateral meetings now expand from EIC L1 management to L2 & L3 EIC experts for detailed technical discussion of possible in-kind scope
  - Examples: Crab Cavity system information exchange meeting with UK and Canada, meetings with INFN-Accelerator collaboration on HSR vac. system, with CERN on ESR vac. sys., etc.



Electron-Ion Collider

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From the closing talk by A. Seryi

Collaboration – path forward

- EIC 2020 Accelerator Partnership Workshop – broad program, broad scope of discussion
- The 2020 workshop and bi-lateral meetings after EIC2020 revealed several areas of mutual interests
- EIC 2021 Accelerator Partnership Workshop – focused on key technical areas of potential collaboration
- Next steps: intensify focused bi-lateral technical meetings
  - include other technical areas and all domestic and international partners who are interested to collaborate
- Next accelerator partnership workshop in about a year

Collaboration in EIC design, construction and scientific exploration is welcome!

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Electron-Ion Collider

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From the closing talk by
A. Seryi

Accelerator Partnership Workshop 2021 - focused

- 2021 Accelerator Partnership Workshop indeed focused on areas where there are advanced technical discussions between EIC and potential partners
- Workshop sessions are targeted to areas of possible collaboration & on 2nd IR

Acc workshop sessions & conveners

- **Crab Cavities**
  - G. Burt (CI), R. Laxdal (TRIUMF), J. Preble (EIC/JLAB)
- **IR SC magnets and spin rotators**
  - P. Vedrine (CEA Saclay), H. Witte (EIC/BNL)
- **HSR vacuum system**
  - R. Cimino (INFN), S. Verdu Andres (EIC/BNL)
- **ESR vacuum system**
  - R. Losito (CERN), C. Hetzel (EIC/BNL)
- **ESR high current elements**
  - R. Losito (CERN), A. Blednykh (EIC/BNL)
- **ESR SRF and CM**
  - R. Losito (CERN), J. Guo (EIC/JLAB)
- **Lessons from SuperKEKB**
  - M. Tobiyama (KEK), M. Blaskiewicz (EIC/BNL)
- **MDI, First and Second IR**
  - In Soo Ko (PAL), A. Drees (EIC/BNL), W. Wittmer (EIC/JLAB)
- **Second IR based on Nb3Sn option**
  - P. Vedrine (CEA Saclay), A. Seryi (EIC/JLAB)
- **ERL Satellite meeting**
  - W. Kaabi (IJCLab), P.Williams (CI), S. Benson (EIC/JLAB)
  - Satellite meeting by invitation only

https://meetings.triumf.ca/event/254/

- **Next steps, after 2021 Accelerator Partnership Workshop, should include detailed bi-lateral meeting for concretization of collaboration scope, in parallel with DOE-agencies level work to prepare for agreements**

DONE

TO DO

8

Electron-Ion Collider

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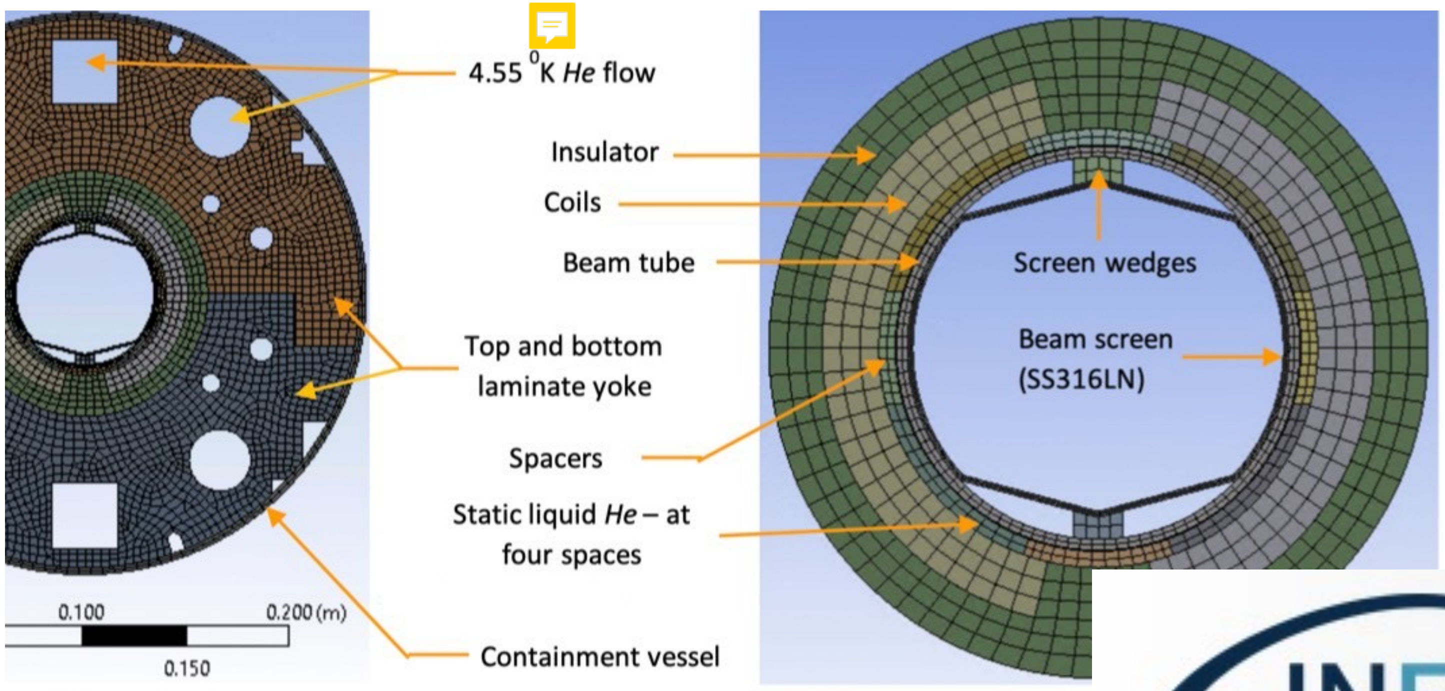
EIC Beam Screen design to be compliant with all the constraints

- Low impedance to limit dynamic heat load to the cryogenic system and to avoid impedance-driven instabilities.
- Adequate vacuum level and stability, which also involves the control of e-clouds.

CERN LHC screen



(a)

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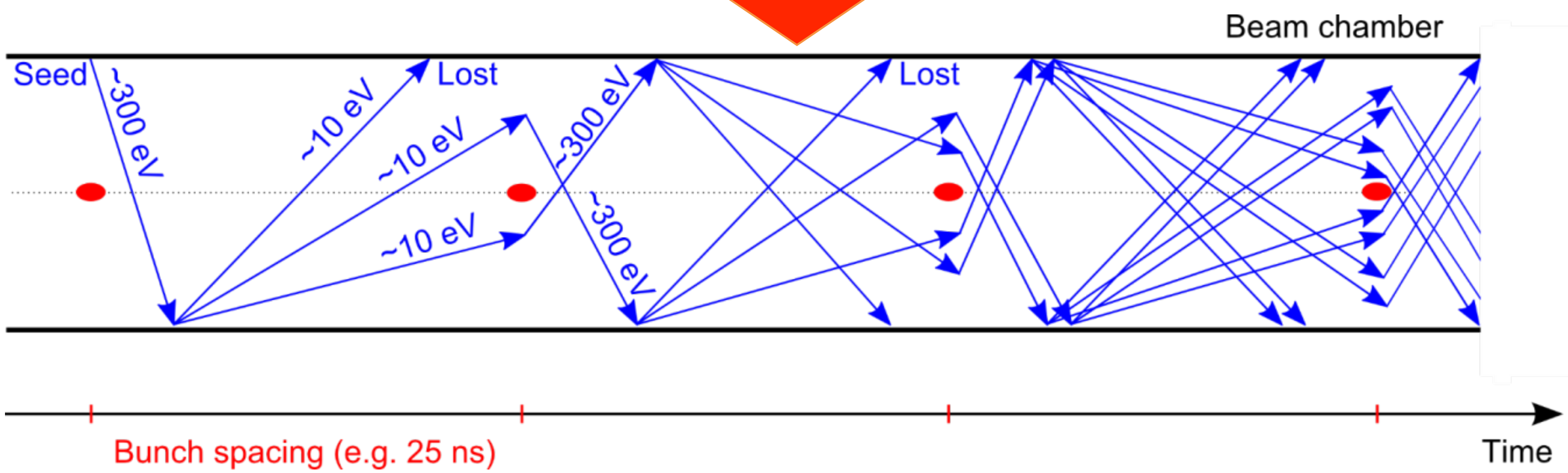
e^- cloud formation

Generation of electrons inside the vacuum chamber
(primary, or seed, electrons)

R. Cimino and T. Demma "Electron cloud in Accelerators" Int. J. Mod. Phys. A 29 (2014) 1430023.

- **Acceleration of primary electrons in the beam field**
- **Secondary electron production when hitting the wall**
- **Avalanche electron multiplication**



e^-cloud, SEY studies and electron induced desorption

The performance reach of accelerators crucially depends on the **vacuum system**

1. The beam interacts with **the rest gas in the vacuum chamber** causing:

   reduced beam lifetime - and/or **emittance growth** - trigger **avalanche** multiplication processes

2. The **vacuum system** plays an important role for beam stability:

   Its material(s) conductivity, shape, coating mainly determine **resistive wall impedance** of a machine

   Transitions between pipes, bellows, etc. significantly contribute to the **global machine impedance**

   Total impedance needs to be kept below a certain **budget** to allow operation at the desired intensity.

RM1
NA

3. The **vacuum chamber** also affects beam stability and lifetime otherwise

   Its inner wall surface properties in particular **desorption and electron yields**, are critical

   High desorption yields can lead to **pressure runaway**

   High electron yields can lead to **electron cloud formation**

   Distributed pumping from surface/design (e.g. NEG coating, pumping holes)

   Shape optimization for photon absorption (antechambers, slits)

LNF
NA

Correlated Vacuum Issues

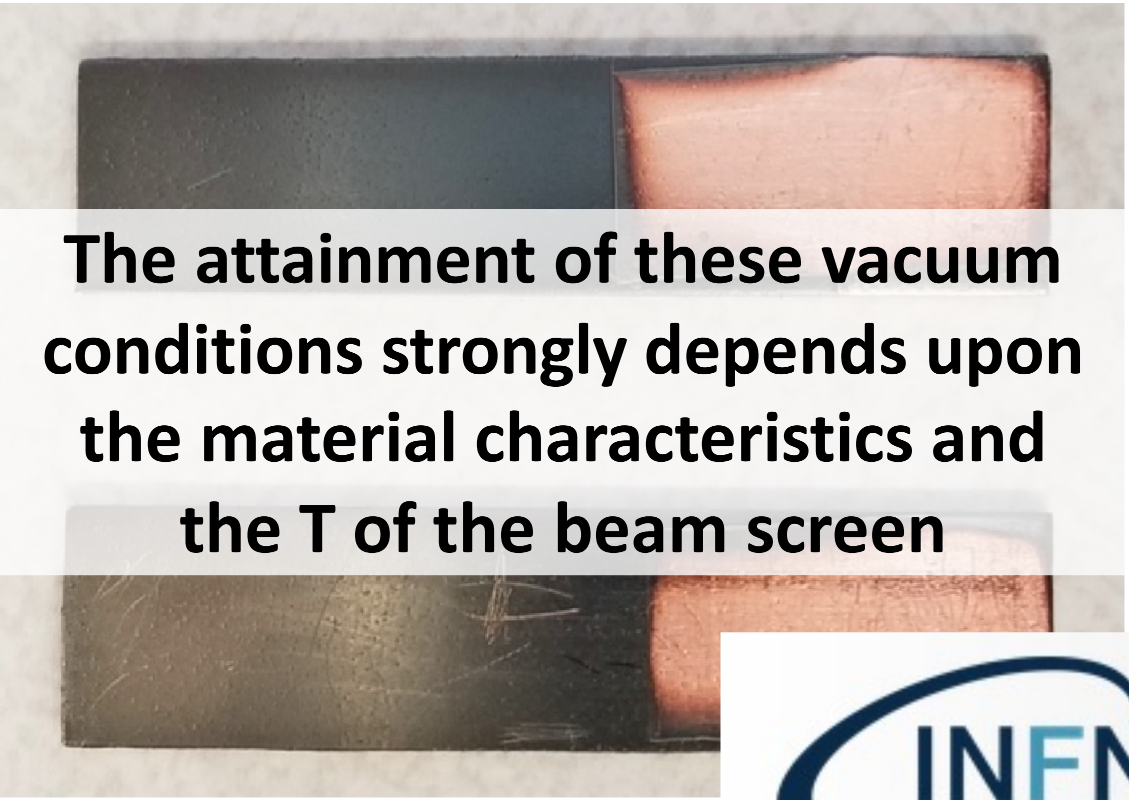
Vacuum level and stability in the Hadron Storage Ring

To preserve the beam lifetime and contain emittance growth, a <u>low vacuum level</u> and <u>stable beam vacuum wall surface</u> in the EIC hadron beamlines is very important.

10^{-11} Torr (2×10^{7} molecules/cm^{3}) comprising exclusively H_2 and He

↓

Beam lifetime ~240 hours



The attainment of these vacuum conditions strongly depends upon the material characteristics and the T of the beam screen

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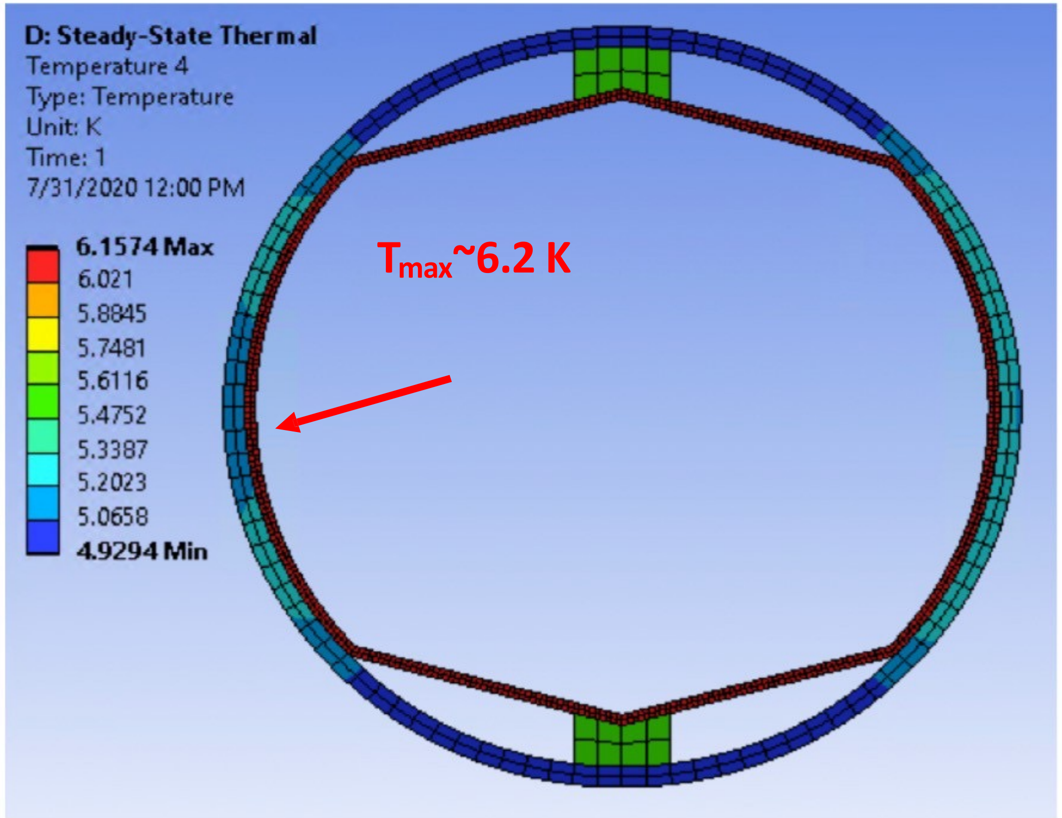
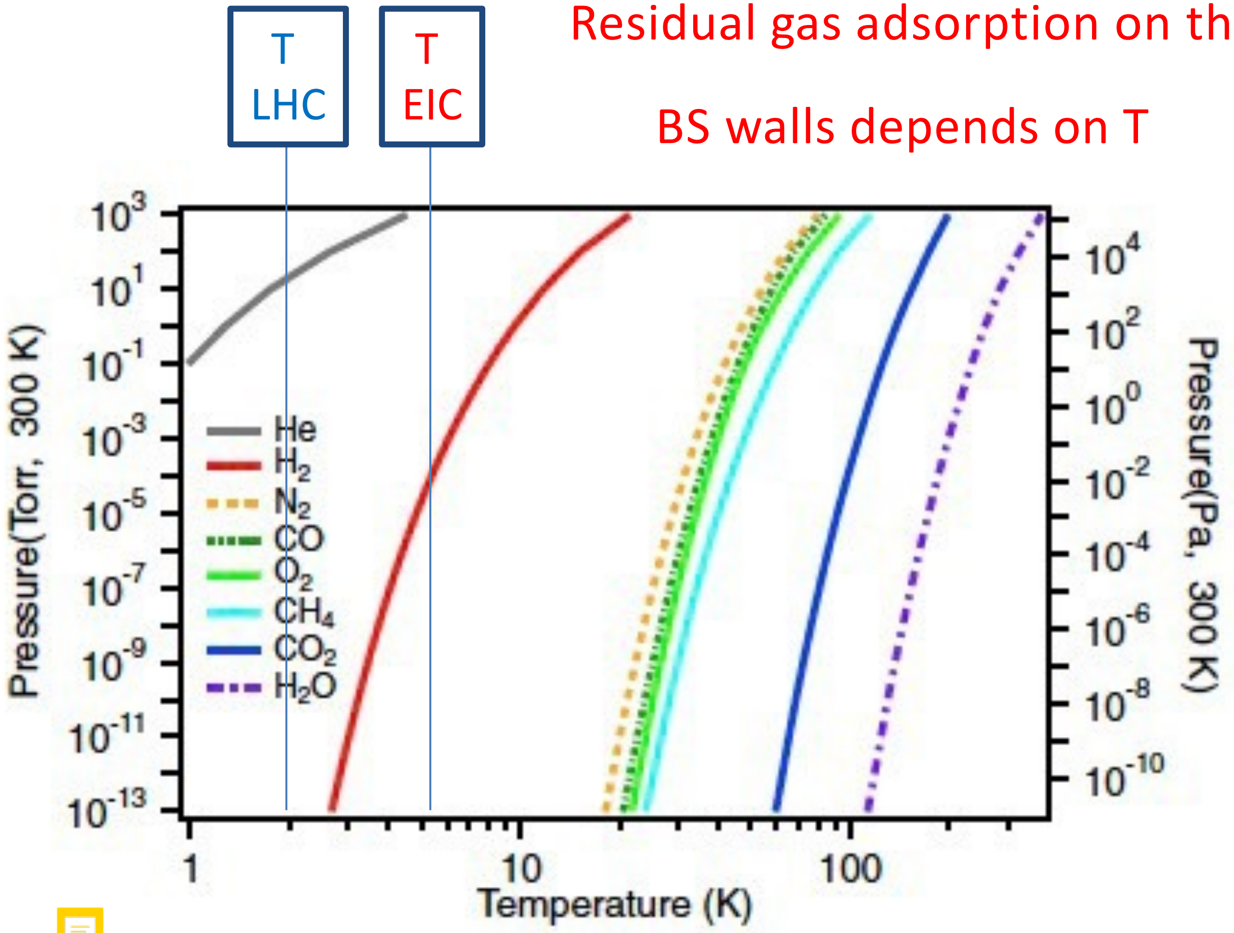
Correlated Vacuum Issues

At cryogenic temperature



Thermal simulation for the beam screen in the Hadron Storage Ring of EIC considering a RW heat load of 0.5 W/m after including magneto-resistance, beam offset, a-C film, and screen geometry effects. (From EIC CDR 2021)

Residual gas adsorption on the BS walls depends on T



Saturated vapour pressure curves from R. E. Honig and H. O. Hook, RCA Rev. 21, 360 (1960)

What will pump H_2???

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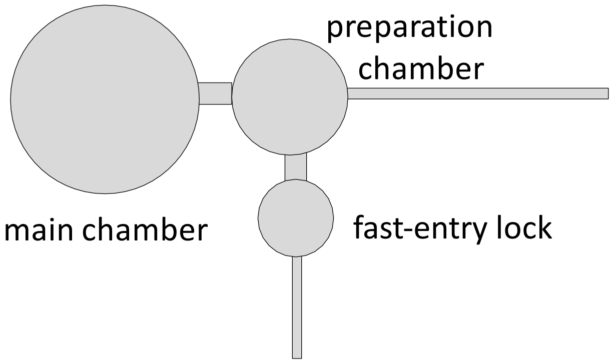
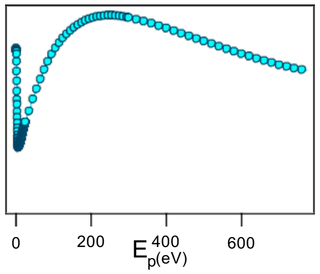
Experimental set-up at LNF: ideal to study those issues (Beneficial experience in studying LHC and FCC-hh Beam Screen)

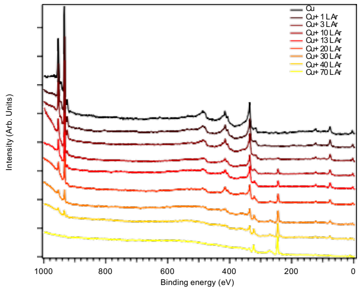
Ultra high vacuum systems



- LNF-cryogenic manipulator
- Sample at 15-300 K

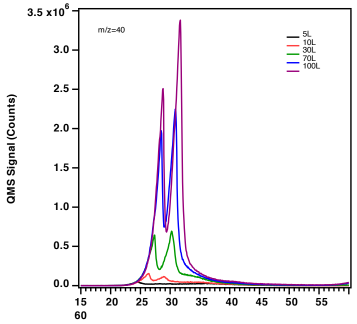
Secondary Electron Yield (SEY) measurements
Equipment : Electron gun, Faraday cup

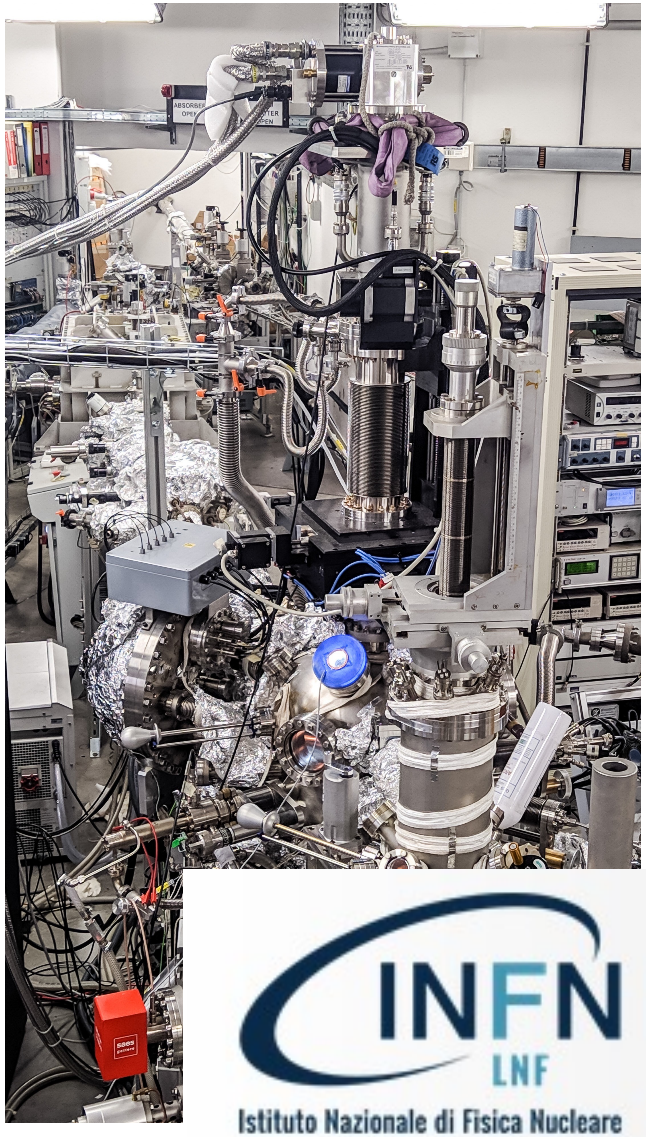




X-Ray Photoelectric Spectroscopy (XPS)
Equipment : Omicron EAC125 electron analyzer, Mg Kα source (hν = 1253.6eV)

Temperature Programmed Desorption (TPD) and Residual Gas Analysis (RGA) measurements Equipment : QMS (Hiden HAL 101 Pic)





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Collective effects in FCC-ee and EIC

(M. Migliorati et al., univ. La Sapienza and INFN-RM1)

Parameter list	FCC-ee Z pole (W)	EIC
Circumference (m)	97756	3834
Beam energy (GeV)	45.6	10 (18)
Beam current (A)	1.39	2.5 (0.27)
Bunch population [10^{11}]	1.7	1.7
Bunch length [mm](SR/BS)	3.5/12.1	20
Energy spread(SR/BS) [10^{-3}]	0.38/1.32	0.58
Synchrotron tune	0.025	0.0815
Bunches/beam	16640	1174
Mom compaction [10^{-6}]	14.8	1450
Energy loss/turn (MeV)	36	9.1
RF Voltage (MV)	100	41

Effects of:

- *Resistive wall*
- *Impedance (vacuum chamber, BPMs, …)*
- *Turbulent Mode Coupling*
- *Transverse Coupled Bunch*

under evaluation for FCC-ee can be extended to EIC using same approach and tools

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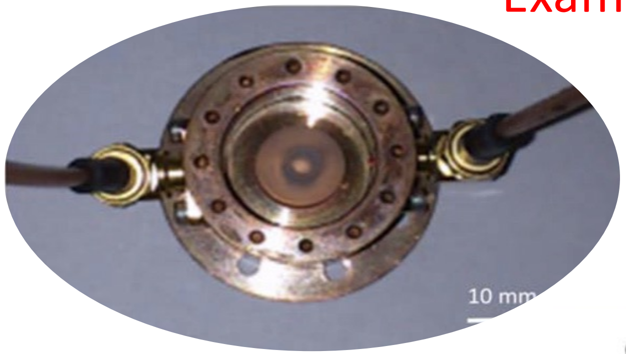
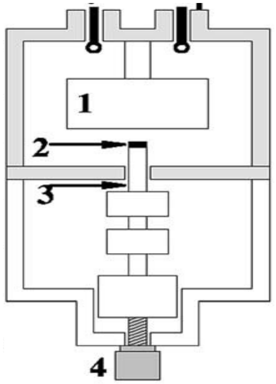
Electromagnetic characterization of coated surfaces for broadband impedance evaluation

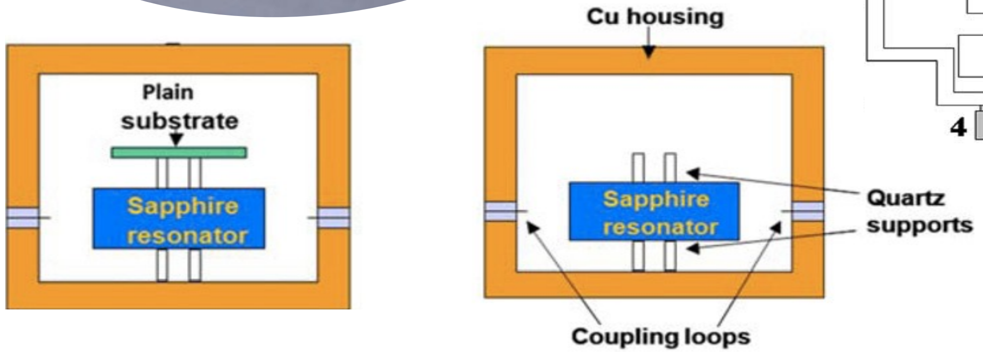
(M.R. Masullo et al., INFN Naples)

Different range of frequencies and material thickness require different approaches

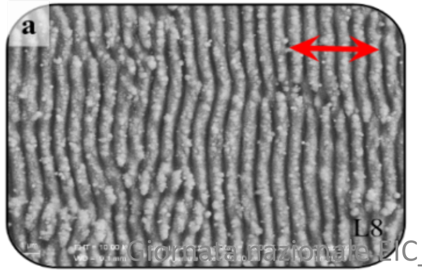
Example of dielectric resonator





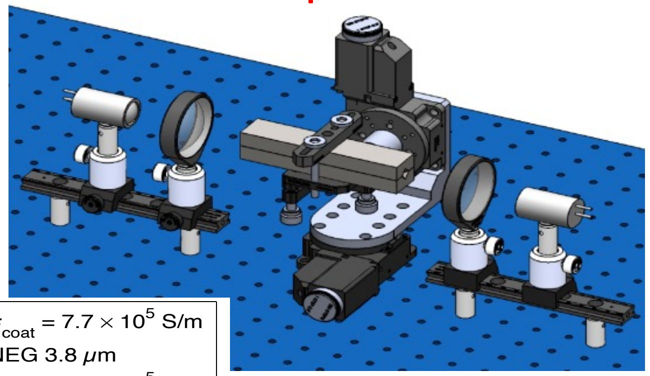


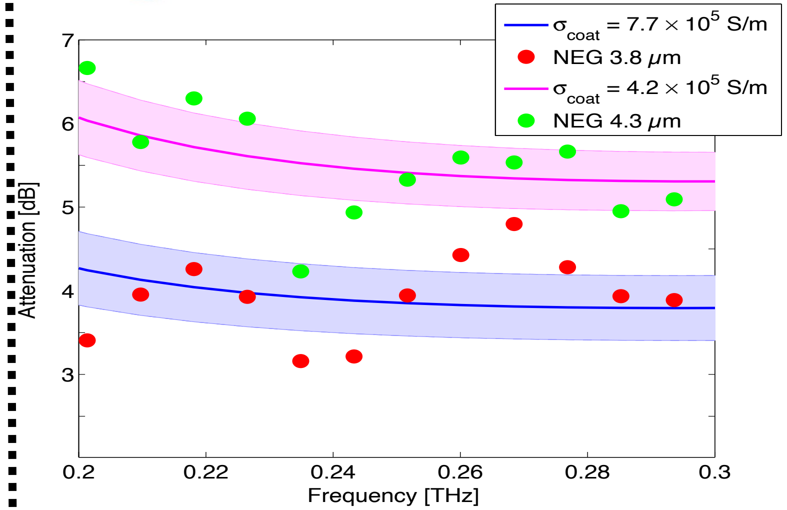
Laser ablated structure



A new waveguide methodology

THz Time domain spectrometer

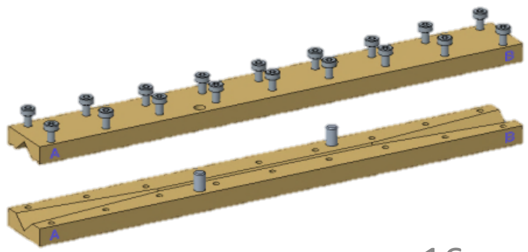




NEG

f [GHz] 5 20 100 300

λ [mm] 60 15 3 1



EIC@INFN: WP on Beam Physics

24 January 2020

Units: INFN-LNF; INFN-Roma1; INFN Napoli.

We individuate deliverables with different level of commitment

Roma1	Deliverables	Human resources	Additional resources /y
D.1	Form and supervise a postdoc on impedance, wakefields and collective effects.	35 k€/y for two years (postdoc salary)	Travel: 5 k€
D.2	Contribution to the evaluation of impedance budget and collective effects for EIC and FCC-ee		Travel: 5 k€

NA	Deliverables	Human/lab res. /y	Additional resources /y
D.1	Consulting	0.5 m/y ~ 20 k€	Travel: 5 k€ Consumable: 15 k€
D.2	Exchange short/long periods visit	0.5 m/y ~ 20 k€	Travel: 5 k€
D.3	Design, EM characterization and test of proposed solutions	1 m/y ~ 40 k€	Travel: 10 k€ Consumable: 50 k€ Cont. to Fellow: 30 k€
D.4	Fellows supervision		Postdoc: 35 k€/y Travel: 5 k€

LNF	Deliverables	Human/lab res. /y	Additional resources /y
D.1	coordinate studies and act as consultant for material, surface, vacuum science related issues.	0.5 m/y ~ 25 k€	Travel: 5 k€ Consumable: 15 k€
D.2	Exchange short/long periods visit	1 m/y ~ 50 k€	Travel: 8 k€ Consumable: 30 k€
D.3	Qualify proposed solutions by measuring some representative small samples	1.5 m/y ~ 75 k€	Travel: 12 k€ Consumable: 45 k€ Cont. to Fellow: 30 k€
D.4	Follow industrial production of sensitive vacuum components	2 m/y ~ 100 k€	Travel: 15 k€ Consumable: 50 k€ Cont. to Fellow: 40 k€

EIC Acc. Group very favourable but waiting for DOE inputs

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Personal comments

- EIC accelerator construction tends to be based on existing technologies and no much space is given to internal R&D (at least on site).
- Much of the technology (especially for the Hadron Ring) can be derived by the LHC experience. For vacuum and instabilities issues it is essential to consider the difference between the Beam Screen ("active" for LHC and "passive" for EIC) and the Cold Bore temperature (1.9 K at LHC and 4.2 K at EIC). Solutions cannot be directly copied from LHC design.
- At EIC, they are certainly looking for experienced people helping with R&D.
  - Ideally from CERN, but now very busy with HL-LHC and unclear if available.
- They have directly contributed to LNF-INFN activities with an outsourcing -conto terzi- contract.
- For the time being, they are waiting that DOE & INFN management finalize (any type) of agreement. In case of negative answer they could consider again ousourcing.

What next

This collaboration should be finalized in a way or an other.... At the moment is slowly dying and INFN people are getting active on other issues.

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