FUTURE CIRCULAR COLLIDER
Innovation Study

MDI SUMMARY

Manuela Boscolo (INFN-LNF)

FCC WEEK Conference 2024
10 - 14 June 2024
San Francisco, USA

FCC WEEK 2024 – MDI sessions

2 sessions

Wed 12

Thu 13

90 min. each

Excellent talks and great progress!

MDI-1

MDI-2

Version: 0.15 Date: 29.05.2024

Day	Sunday	Monday		Tuesday					Wednesday					Thursday						Friday	Day
Time SFO	Front desk	Plenary	Board Room	Parallel 1	Parallel 2	Parallel 3	Parallel 4	Board Room	Plenary	Parallel 1	Parallel 2	Parallel 3	Board Room	Plenary	Parallel 1	Parallel 2	Parallel 3	Parallel 4	Board Room	Plenary	Time SFO
Room		Colonial	Yorkshire	Elizabethan A	Elizabethan B	Elizabethan C	Elizabethan D	Yorkshire	Colonial	Elizabethan A	Elizabethan B	Elizabethan C	Yorkshire	Colonial	Elizabethan A	Elizabethan B	Elizabethan C	Elizabethan D	Yorkshire	Colonial	Room
08:00-08:30		Welcome coffee (Italian)		Welcome coffee (California East & West)					Welcome coffee (California East & West)					Welcome coffee (California East & West)						Welcome coffee	
08:30-09:00		1) Welcome remarks 2) CERN plans 3) A view from CERN Council 4+5) NSF and DOE Opening Remarks		Physics Case & Th. Calculations (i)	FCC-ee baseline design & optics, top-up	Safety				Detector Requirements (i)	Collective Effects	Sustainability and impact generation			Detector Requirements (ii)	FCC-ee code development and other themes		RF and Cryo	Governance meeting	Plenary session: summaries	08:30-09:00
09:00-09:30																					09:00-09:30
09:30-10:00																					09:30-10:00
10:00-10:30		Coffee break (Italian)		Coffee Break (California East & West)					Coffee Break (California East & West)					Coffee Break (California East & West)							10:00-10:30
10:30-11:00		1) Key Note 2) FCC FS status 3) FCC Collaboration status		Physics Case & Th. Calculations (ii)	Optics alternatives & lessons	Transport, logistic and Survey	Synergies and innovation			Software	FCC-ee optics correction & tuning	Sustainability and impact generation			Machine Detector Interface (ii)	FCC-hh design	Injection & instrumentation	Utilities		Coffee break	10:30-11:00
11:00-11:30																				Plenary session: summaries	11:00-11:30
11:30-12:00																					11:30-12:00
12:00-12:30				Lunch break (California East & West)				Governance meeting	Lunch break (California East & West)					Lunch break (California East & West)							12:00-12:30
12:30-13:00		Lunch break (Grand Ballroom/ Italian)																			12:30-13:00
13:00-13:30																					13:00-13:30
13:30-14:00				Detector Concepts (i)	FCC-ee injector incl. booster (i)	Civil Engineering	Directions for R&D	Governance meeting		Machine Detector Interface (i)	SRF Technology (ii)	Magnets			EPOL (i)	high-field magnets for FCC-hh 1	Vacuum	mini workshop	Governance meeting		13:30-14:00
14:00-14:30		1) Implementation scenario 2) Civil Engineering 3) Accelerator status 4) Technologies & TI																			14:00-14:30
14:30-15:00																					14:30-15:00
15:00-15:30	Registration + as from 07:30am on Monday			Coffee Break (California East & West)					Coffee Break (California East & West)					Coffee Break (California East & West)							15:00-15:30
15:30-16:00		Coffee break (Italian room)		Detector Concepts (ii)	FCC-ee injector incl. booster (ii)	Layout optimisation and services	SRF Technology (i)		Plenary: US Session						EPOL (ii)	high-field magnets for FCC-hh 2	Beam Intercepting devices	mini workshop			15:30-16:00
16:00-16:30		1) Super KEKB status and plans 2) The Physics at FCC 3) Detectors requirements and benchmarks 4) Planning for upcoming workshops 5+6) US Plans FCC-PED, FCC-ACC	Governance meeting																		16:00-16:30
16:30-17:00																					16:30-17:00
17:00-17:30												Early Career Researchers	Governance meeting		PED 9						17:00-17:30
17:30-18:00				Detector Concepts (iii)	FCC-ee injector incl. booster (iii)	Governance meeting															17:30-18:00
18:00-18:30																					18:00-18:30
18:30-19:00														Poster session + cocktail (Grand Ballroom/ Italian)							18:30-19:00
19:00-19:30		Welcome reception (Westin, St. Francis Heights)		Public event (Exploratorium) https://fccweek2024.web.cern.ch/PublicEvent.html																	19:00-19:30
19:30-20:00																					19:30-20:00
20:00-20:30									Conference dinner (Julia Morgan Ballroom, 465 California St, San Francisco https://juliamorganballroom.com/)												20:00-20:30
20:30-21:00																					20:30-21:00
21:00-21:30																					21:00-21:30
21:30 -22:30																					21:30 -22:30

MDI-related posters

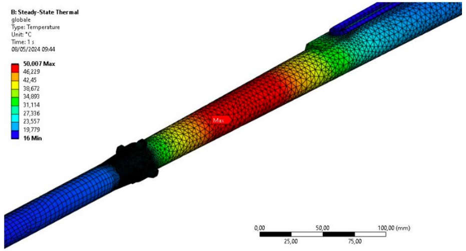
- The air-cooling system for the IDEA Vertex Detector at FCC-ee: thermal performance and vibrational effects, *G. Baldinelli*
- Alternative solenoid compensation scheme, *A. Ciarma*
- Structural Optimization of Future Circular Collider Interaction Region Support Structure, *F. Fransesini*
- Luminosity tuning and optimization, *Vaibhavi Gawas*
- Material Budget of the FCC-ee IR, *G. Nigrelli*

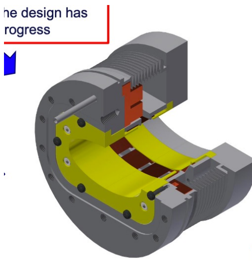
+ Coffee-breaks & lunch discussions

Francesco Fransesini (INFN-LNF)

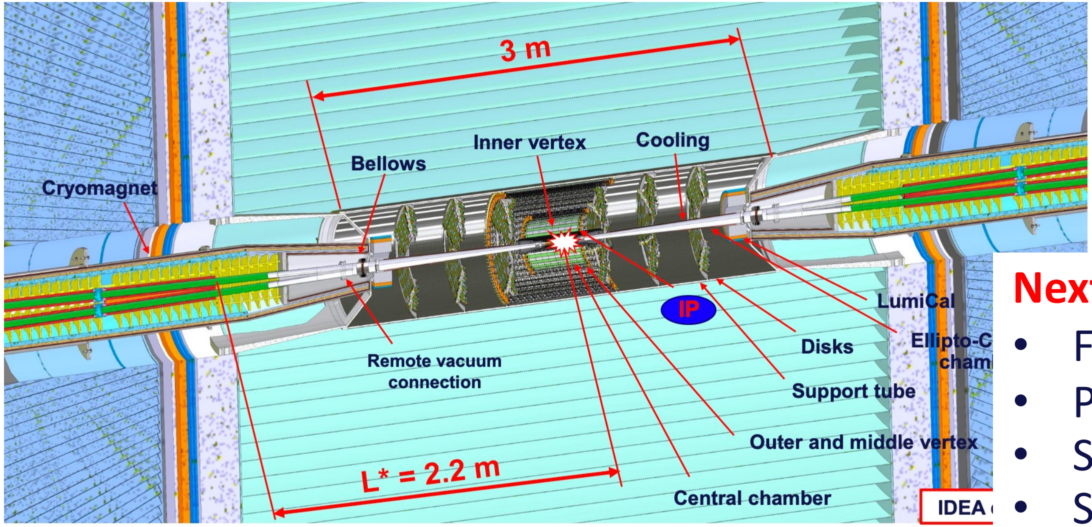
Mechanical model of the MDI

- Progress on the central and conical chamber design
- Vacuum chambers material budget optimization
  - removal of copper manifolds
  - pure Beryllium vs AlBeMet: gain up to a factor 2
  - check paraffin safety → water?





IN PROGRESS



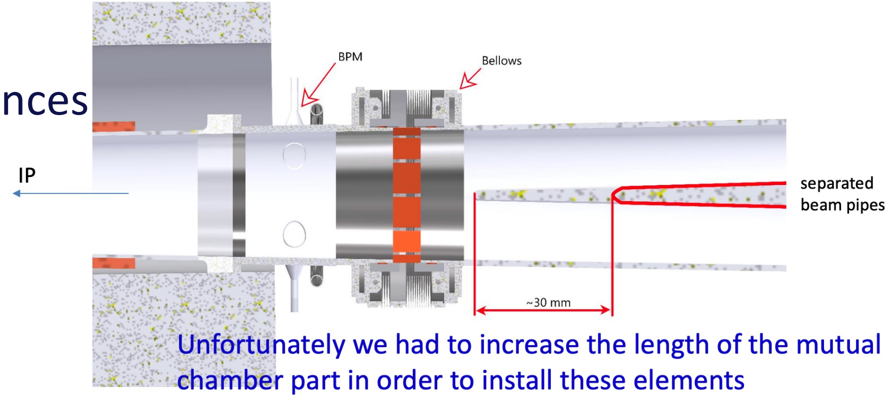
Next steps

- Finalize IR bellows design
- Progress remote vacuum connection
- Services
- Supports

Alexander Novokhatski (SLAC)

Optimization of the FCC-ee IR beam pipe elements

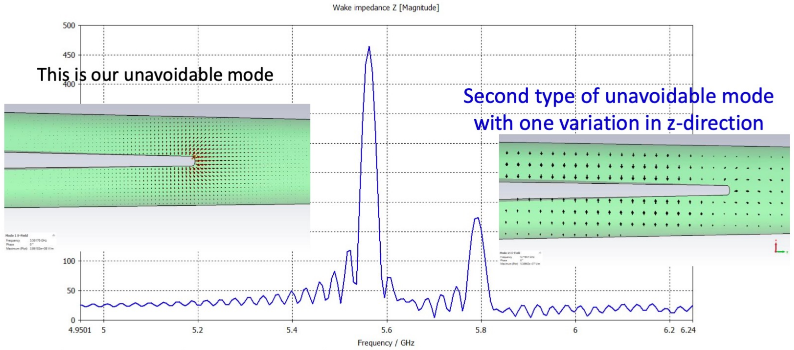
- Goal is to minimize IR heat-load due to impedances
- Low impedance vacuum chamber designed
- New evaluations of trapped modes for
  - different shape of SR masks
  - elliptical shaped BPM



Unfortunately we had to increase the length of the mutual chamber part in order to install these elements

Next steps

- Optimize gold thickness on the internal vacuum chamber
- Finalize IR bellow design
- Evaluate impedance for the global IR model (chambers, bellows, BPM, masks)



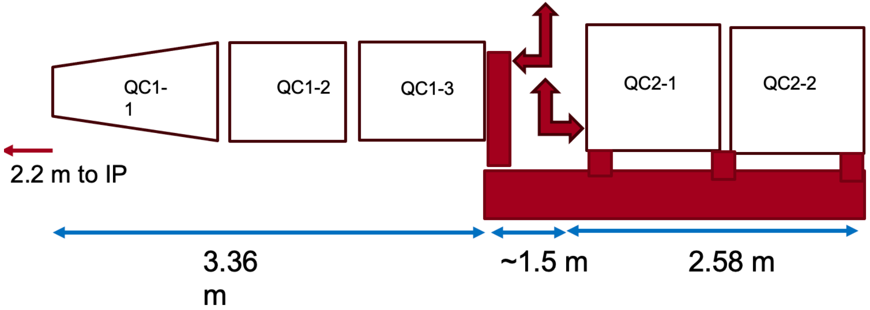
Lengthening the mutual pipe brings more trapped modes

IR magnet system

Preferred option for the IR cryostat

IR QC1 and QC2 in different cryostats but one integrated raft (not to scale)

Need to make space for cryogens, leads, and cantilever supports.



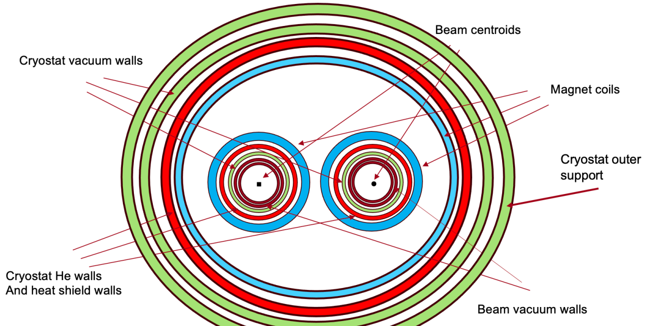
Suggested focus topics for FCCee MDI and IR magnets for 2024-2025

SLAC

1) Add inner background shielding: W, Ta, or Cu inside magnets in cryostat (Δr?)
2) Resolve new IR lattice vs present: QC1,QC2 placement and anti-solenoids
3) Make initial cryostat design (4 or 7 m) by cryogenic/mechanical engineer(s)
4) Answer if IR magnets need higher-order trim coils
5) Confirm 100 mrad detector-accelerator cone angle
6) IR BPMs and other diagnostics

IR Magnet Cross Section View (front and end of each magnet)

Showing separated heat shield and vacuum vessel.



QC1R1

For magnets where there is no room for magnetic yoke material between the coils, the only practical solution is to use flexibility of CCT (double helical) to make local compensation of the magnetic cross talk between side-by-side quadrupole apertures.

J. Seeman November 2023

Radial distance from detector solenoid axis to beam axis: conservative/less conservative approach

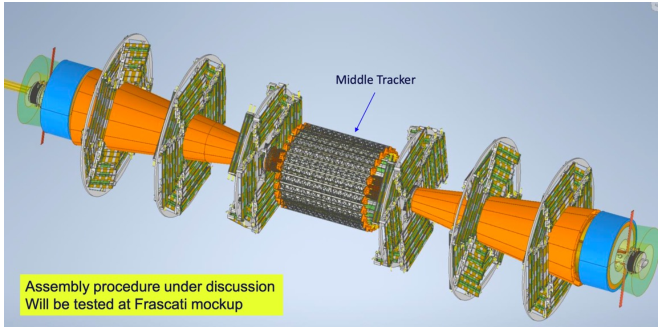
Alternative solenoid compensation scheme

https://doi.org/10.18429/JACoW-IPAC2024-TUPC68

7) Full list of magnet, vacuum, and cryogenic specifications
8) Converge on background mask geometry
9) Make initial layout of magnet/cryogenic splice box
10) Construct a left and right CCT magnet pair for QC1 and test
11) Carry out warm test of CCT quadrupole for reduced left-right field cross-talk
12) Design remote vacuum flanges (need 6 flanges with 2 designs)
13) Radial differential movements during cool down

Fabrizio Palla (INFN-Pisa)

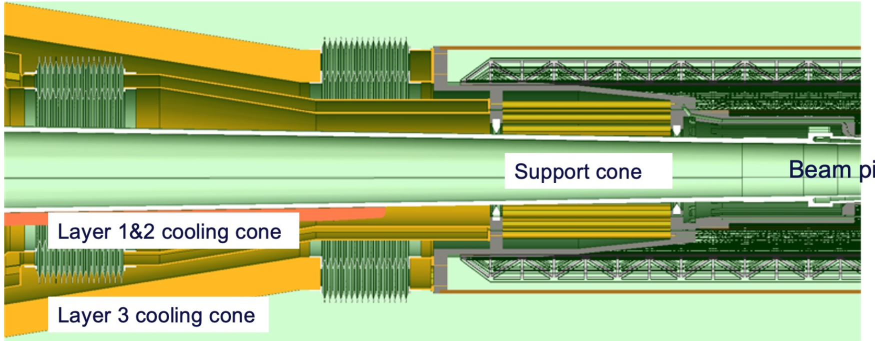
Vertex detector design and integration

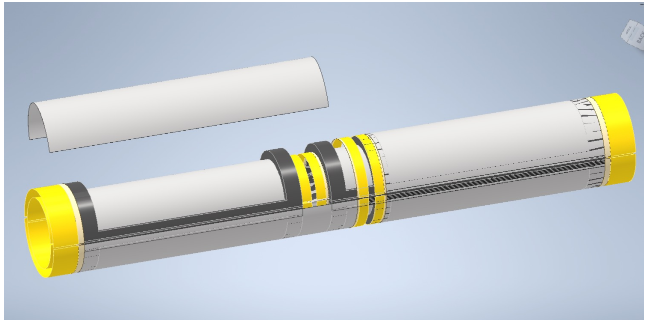


Integration with the machine elements being developed
Services integration and cooling being finalised:

$$\Delta T < 10^{\circ}C \; - 1.5\mu m \; RMS \; displacement$$

A mini-workshop on vertex detector technologies (including system integration and mechanical aspects) will be held at CERN on July 1 and 2: https://indico.cern.ch/event/1417976/





Lightweight layout using an ALICE ITS3 inspired design

A lighter concept with curved and stitched MAPS is being engineered
First layout done
Engineering drawings started, having in mind construction sequence
Cooling (air) and flex circuits routing will be addressed shortly

Excellent progress on Beam Backgrounds

First studies due to luminosity backgrounds (IPC) on detector hit occupancies have been evaluated.

Synchrotron radiation in the IR simulated in detail up to the internal beam pipe.
First evaluation of beam-gas losses up to the internal beam pipe.

Next steps necessitates to track those particles

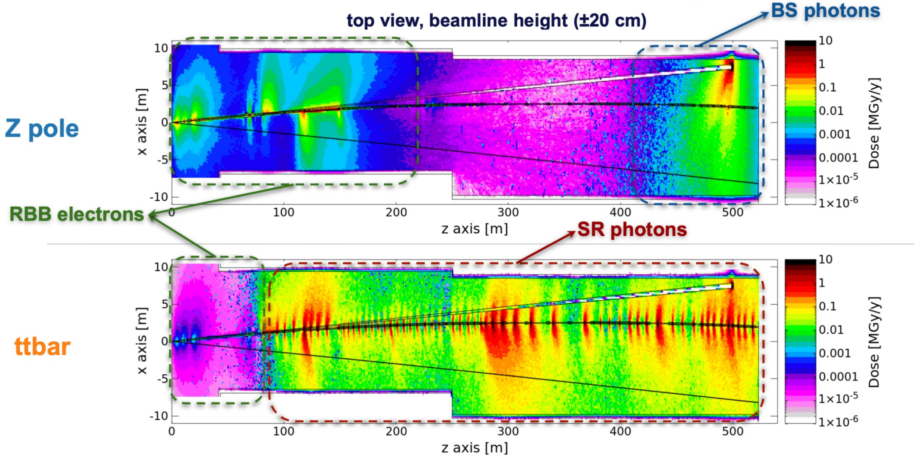
- up to suitable surface before the detector to allow detector hit occupancies
- evaluate energy deposits in the machine components

Alessandro Frasca (CERN & Uni Liv.)

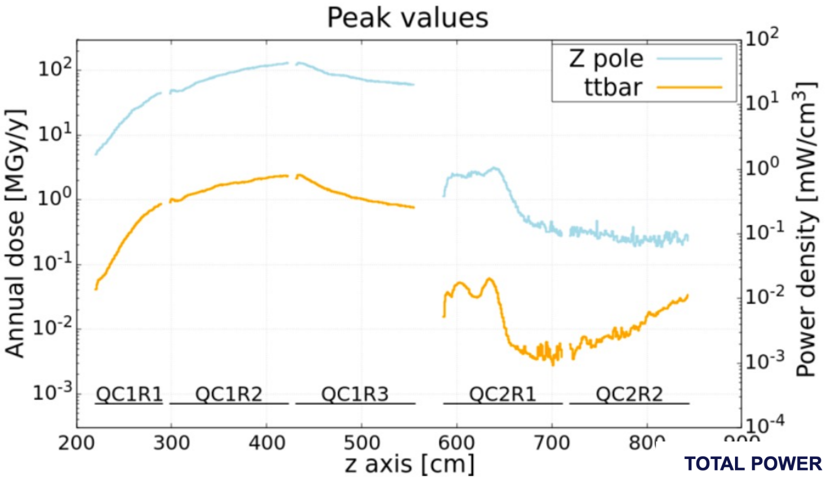
Radiation dose from Fluka simulation in the MDI area

Beamstrahlung dump

Annual TID in the tunnel from BS, SR, and RBB



Power deposition in FFQs SC coils from radiative Bhabhas



TOTAL POWER DEPOSITED

	Z pole	ttbar
QC1R1	0.30 W	3.4 mW
QC1R2	1.54 W	20.4 mW
QC1R3	2.00 W	29.7 mW
QC2R1	0.20 W	1.9 mW
QC2R2	0.04 W	1.8 mW

5 mm of tungsten ensures

- peak dose: 3 MGy/y
- peak power density deposition: 1 mW/cm³

Detector Background Studies

First occupancy calculations from Incoherent pairs in

- IDEA Vertex detector (A. Ilg)
- IDEA drift chamber (B. Francois)
- Allegro ECAL (A. Ciarma)

Next:

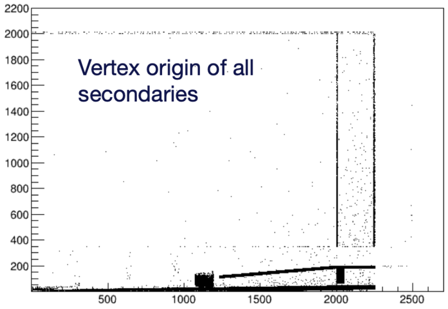
- Add more subdetectors
- Evaluate more background sources

IDEA-VTX

	ARCADIA	ALICE ITS3
Occupancy	$\sim 20\times10^{-6}$	$\sim 30\times10^{-6}$
Hit rate	$170\ MHz/cm^2$	$250\ MHz/cm^2$

data rates of O(10 Gb/s) per module.

IDEA-DCH



SIM hit occupancy of ~15% over **800ns**

ALLEGRO ECAL

Average occupancy per BX (over 1000 BXs):

	NO CUTS	20% MIP CUT	30% MIP CUT
Endcaps	0.1% ~ 0.6%	0.02% ~ 0.2%	0.01% ~ 0.15%
Barrel	< 0.45%	< 0.03%	< 0.01%

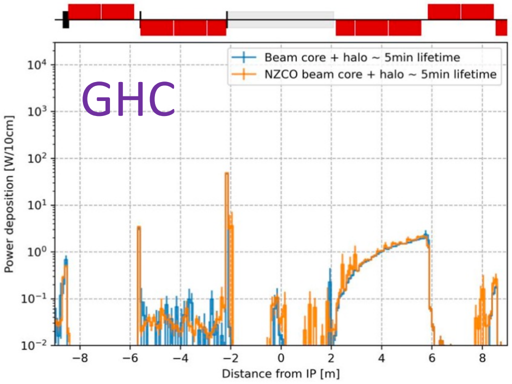
occupancy per layer **up to ~0.5%/BX**

Kevin Andrè (CERN)

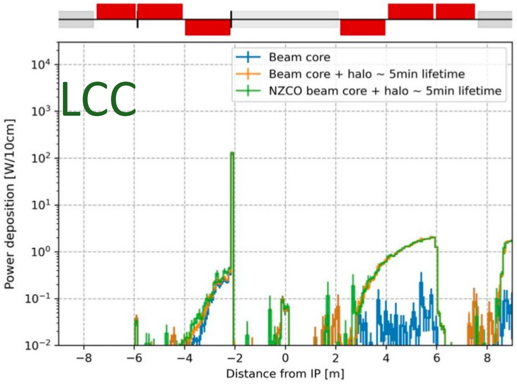
Synchrotron Radiation background

BDSIM (Geant4 based) simulation with comparison of **GHC and LCC optics at Z and ttbar:** **similar power deposited** near the IP was founded.

Results at **Z energy**



GHC - SR power deposition summary
1% of the particles in the tails, with beam lifetime equivalent to 5 min, and 100 um X&Y and 6 urad PX&PY applied to the NZCO beam core.



LCC - SR power deposition summary
1% of the particles in the tails, with beam lifetime equivalent to 5 min, and 100 um X&Y and 6 urad PX&PY applied to the NZCO beam core.

Power deposition ± 8 m from IP

Power deposition on the vacuum chamber from SR evaluated for

- tilted beams
- beam tails
- injected beams
- various optics versions

SR collimators and masks defined

Next steps

- Include X-ray in the simulation
- SR with top-up injection
- Track these photons in subdetectors

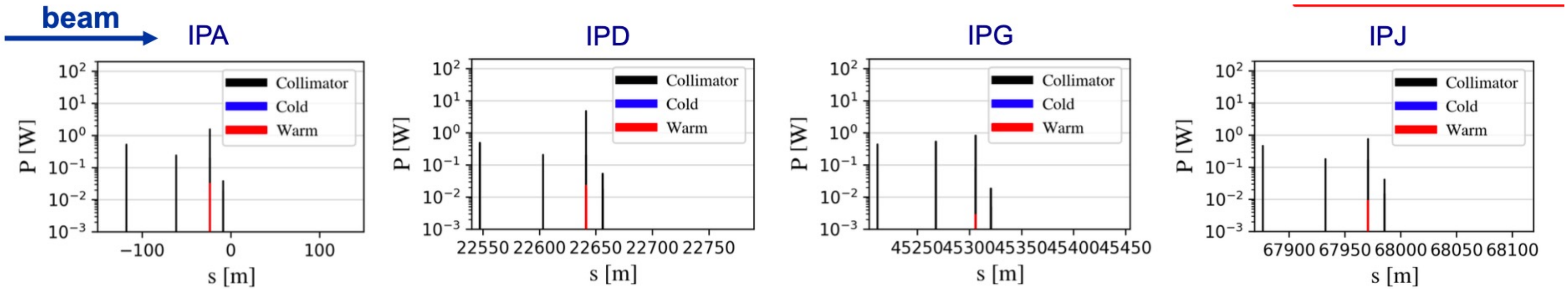
Giacomo Broggi (CERN, INFN-LNF, Uni. Sapienza)

Beam-gas beam losses and MDI collimators

Beam-residual gas interactions implemented in the **Xsuite-BDSIM** simulation tool

First estimated beam-gas lifetime (dominated by bremsstrahlung):

$\tau_{eBrem} \sim 3h\ 20min$



- SR collimators intercept the vast majority of beam-gas beam losses in the IRs

Next steps

- Consolidate results
- Other beam operation modes
- Impact on detector backgrounds

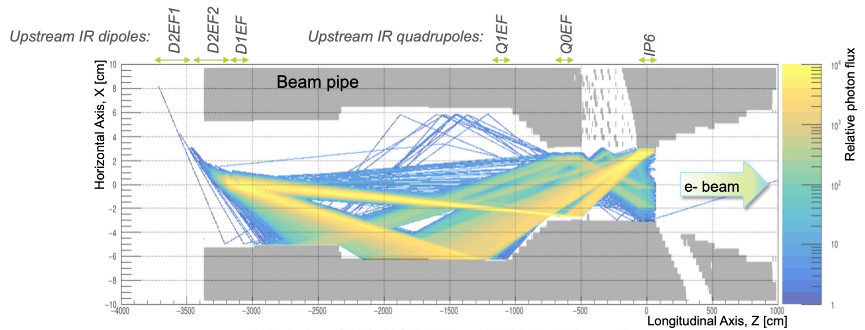
Andrii Natochii (BNL)

A new framework for synchrotron radiation studies in the EIC

Simulation improvement: Geant4-based model for SR simulation + photon reflection physics

SR Background (w/o SR masks)

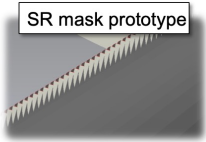
The estimated SR background rate in the innermost vertex detector is **~1 THz** for 0.227 A of the 18 GeV electron beam.

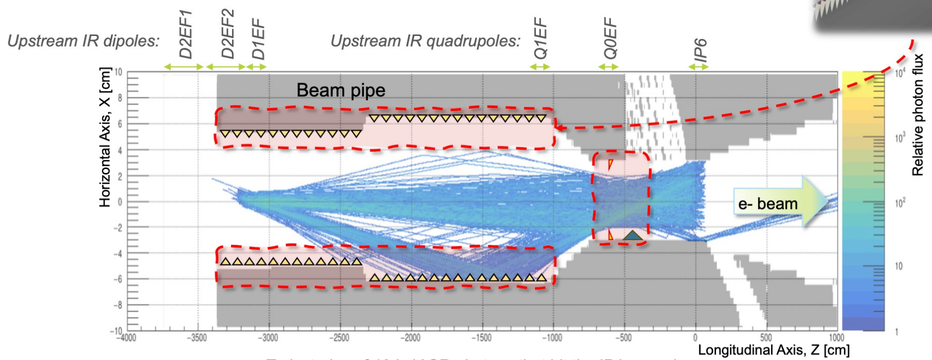


Trajectories of 10 keV SR photons that hit the IP beam pipe

SR Background (w/ SR masks)

The estimated SR background rate in the innermost Vertex detector dropped below **~1 GHz**.





Trajectories of 10 keV SR photons that hit the IP beam pipe

Next steps and in progress

- Beam pipe geometry and cooling
- SR mask
- SR simulations

Main plans on key aspects of the MDI design

❑ IR magnet system & Cryostats

- FF Quads & Correctors
- Solenoid comp. scheme & anti-solenoid design

❑ IR Mechanical model, including vertex and lumical integration, and assembly concept

- Services (i.e. air & water cooling for vertex and vacuum chambers) and cables
- Anchoring to the detector
- Accessibility & Maintenance
- Vacuum connection
- IR BPMs
- Integrate in the design an alignment system

❑ Heat Loads from wakefields in IR region

- In progress

❑ Beam induced backgrounds

- Activity on the software and MDI model level, great effort done, to be continued in the next months.
    - Halo beam collimators implemented.
    - IP backgrounds evaluated.
    - Single beam effects (e.g. beam-gas, thermal photons, Touschek) being implemented in Xsuite.
    - SR backgrounds studied in different conditions and baseline/LCCO optics was compared.
    - Injection backgrounds
    - Study of IR radiation level & fluences started (Fluka)
- Results to be used by the detectors to estimate their backgrounds, and feedbacks to MDI to optimize shieldings, masks and collimators.
- Beamstrahlung dump with radiation levels

Steps towards the FS final report: MDI note written for the midterm report will be updated with the improvements made so far, and it will be expanded with new studies by September 2024.

Thank you
for your attention!