FUTURE CIRCULAR COLLIDER
Innovation Study

FEW SELECTED HIGHLIGHTS FROM THE MDI WG

Manuela Boscolo
for the MDI team

Thanks to many people for inputs!

25 July 2024
FCC-ee Accelerator Design meeting, CERN

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

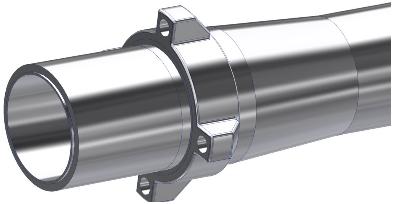
Mechanical model of the IR vacuum chamber

Central chamber

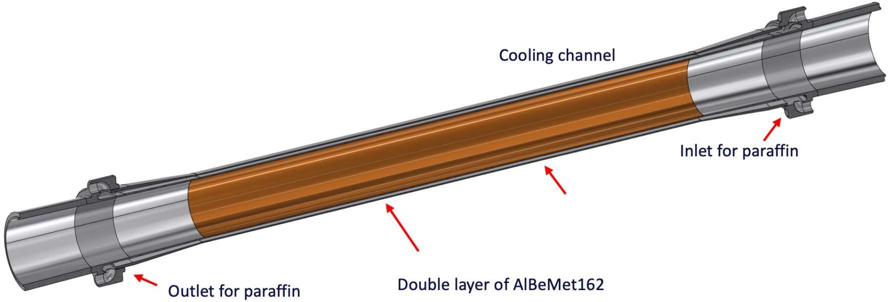
Change of the inlet and outlet material

- Reduction of the material budget in front of the lumical, avoiding any manifold in copper

Inlet/outlet for paraffin cooling (AlBeMet)

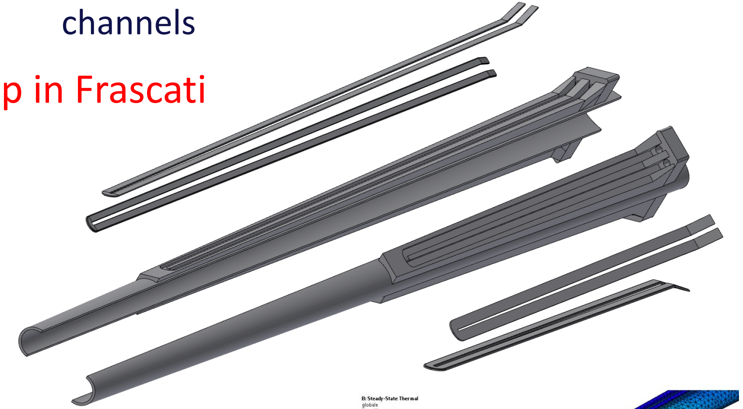


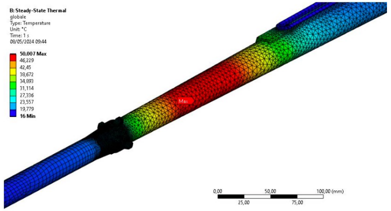
to be fabricated in Al for a mockup in Frascati



Conical chamber all AlBeMet

- Reduction of the material budget in front of the lumical, avoiding any manifold in copper
- Machined cooling system over the chamber, creating 4 channels



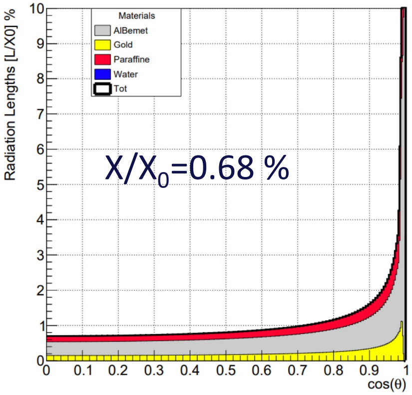


Courtesy plots by F. Fransesini

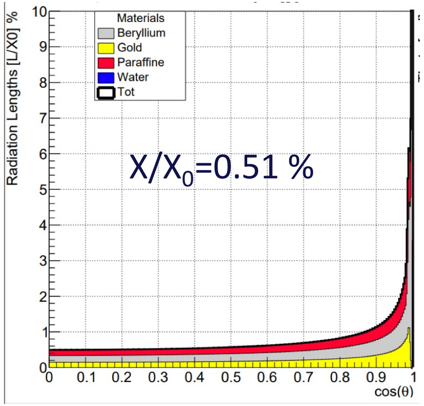
Optimization of the material budget of the central vacuum chamber

- removal of copper manifolds
- pure Beryllium vs AlBeMet: gain up to a factor 2 on the material budget contribution
- check paraffin safety → water (requires 40% thinner cooling channel to give the same material budget contribution)

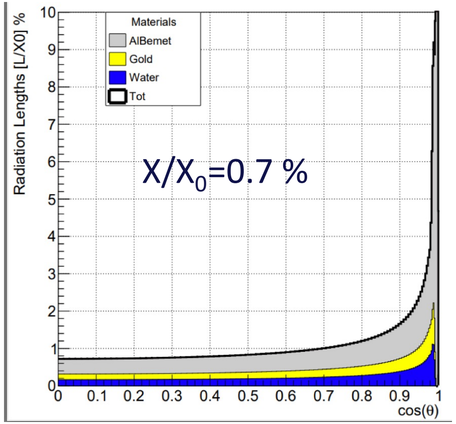
Courtesy plots by G. Nigrelli, link



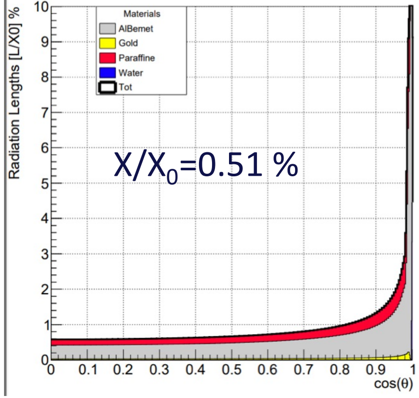
(0.35+0.35) μm AlBemet
1 mm paraffine
5 μm gold



(0.35+0.35) Beryllium
1mm paraffine
5 μm gold



(0.35+0.35) Albemet
600 μm water
5 μm gold



(0.35+0.35) Albemet
600 μm water
1 μm gold

X/X_0=0.39 %
(0.35+0.35) Be/ 600 μm water/ 1 μm gold

A.Novokhatski suggests to add gold layer in the non-cooled conical chamber and 2μm gold layer link

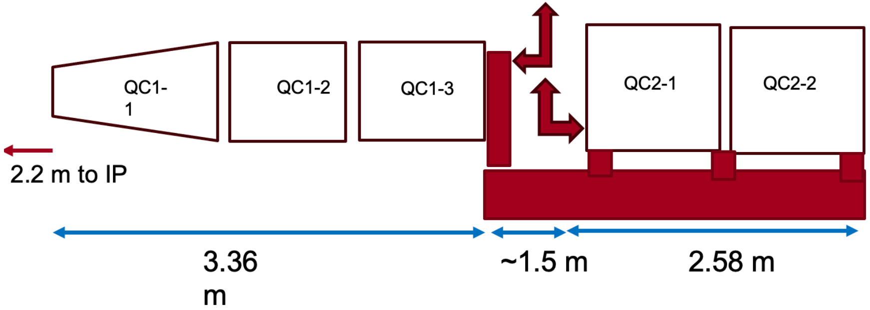
J. Seeman (SLAC), FCC WEEK 24

IR magnet system

Preferred option for the IR cryostat

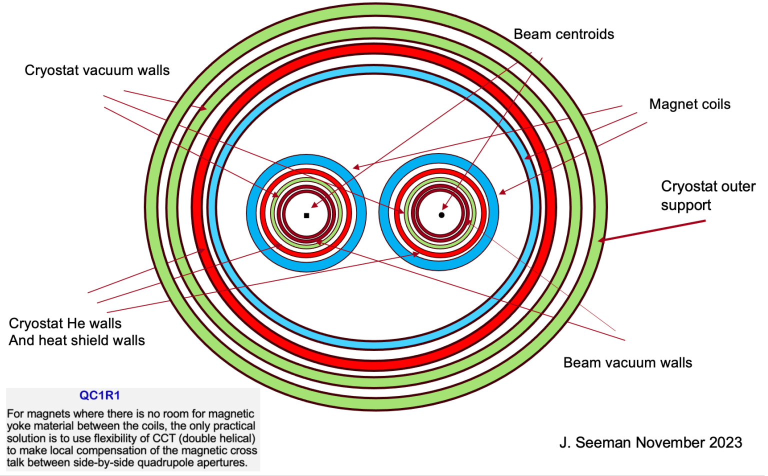
IR QC1 and QC2 in different cryostats but one integrated raft (not to scale)

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



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

Showing separated heat shield and vacuum vessel.



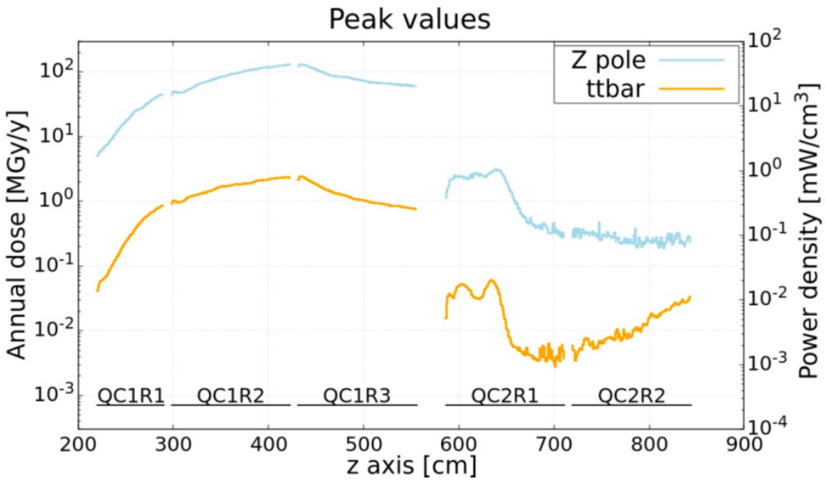
Radial distance from detector solenoid axis to beam axis:
conservative vs less conservative approach

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
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

Radiation dose from Fluka simulation in the MDI area



5 mm of tungsten ensures
- peak dose: 3 MGy/y
- peak power density deposition: 1 mW/cm^3

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

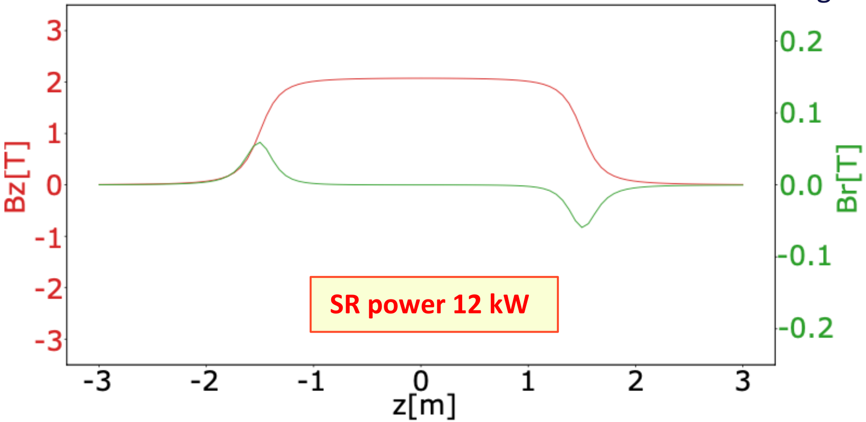
Courtesy by A. Frasca

Solenoid Coupling Compensation Scheme

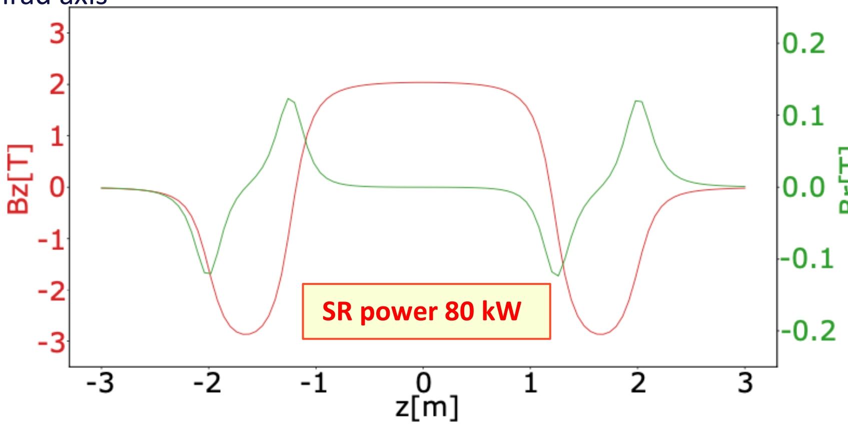
https://doi.org/10.18429/JACoW-IPAC2024-TUPC68

Longitudinal and radial magnetic fields along the 15 mrad axis

Alternative (Non-local) scheme



Baseline (local) scheme



Skew quadrupolar components in the FFQs align the magnet axis to the rotated reference frame of the beam

Correctors right after the beam pipe separation and around the FFQs compensate the orbit distortion generated by the horizontal crossing angle in the detector field

Courtesy plots by A. Ciarma

- Vertical emittance increase is 0.2% of the nominal value of 1 pm.
- Chromatic behavior of the vertical emittance increase small in the range of dE/E = ±4%.

Activity at the optics level to include the non-local solenoid compensation in both the GDH and LCC optics

G. Roi, MDI meeting #55, https://indico.cern.ch/event/1430670/

Solenoid model in MAD-X from field map, translated into

- Thin slices of solenoid kicks interleaved with
  Many correctors to account for orbit perturbations due to crossing angle

Made for the LCC optics of Pantaleo in both the “baseline” or “compact” form and the “standard” or “distributed” form

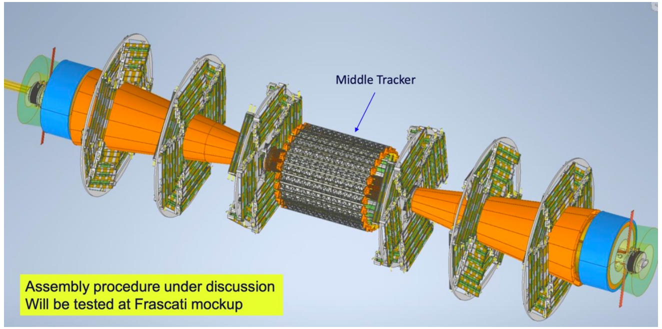
Modifications to the nominal optics file
Several files to be loaded and activated

To be adapted to the GHC optics of Oide-san

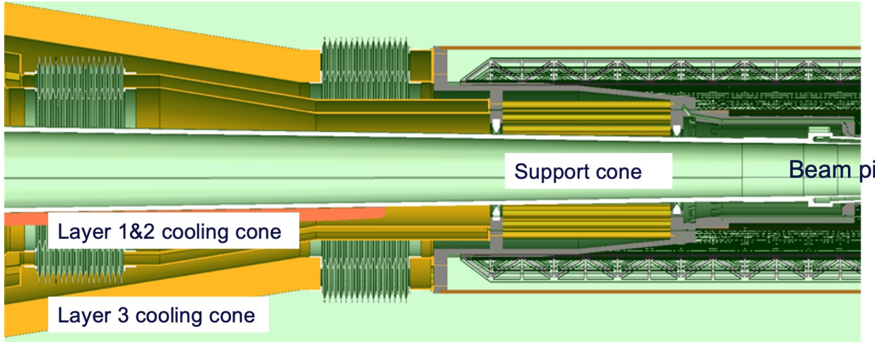
Vertex detector design and integration

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

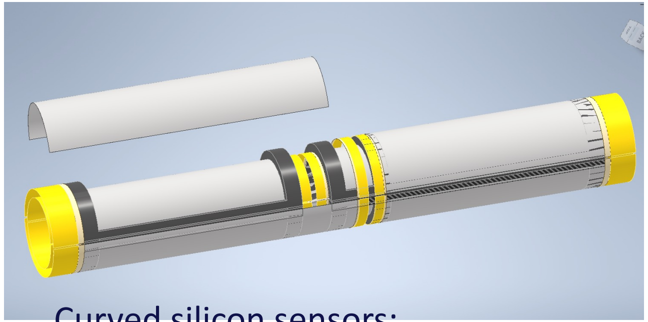
$$\Delta T < 10^{\circ}C \;-\; 1.5\mu m\ RMS\ displacement$$



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



Courtesy plots by F. Palla



Curved silicon sensors:
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

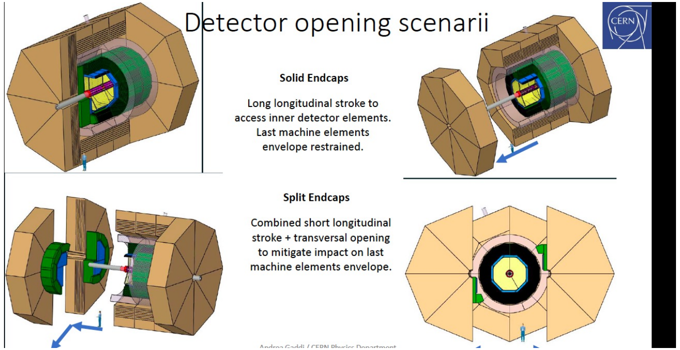
Mini-workshop on vertex detector technologies, July 1 and 2: https://indico.cern.ch/event/1417976/

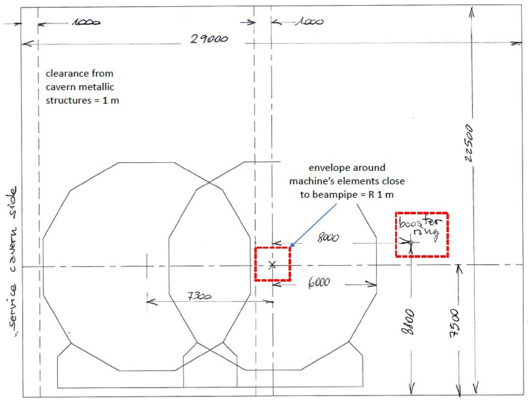
Caverns and detector accessibility

A. Gaddi

Accessibility for maintenance must be considered when designin the vertex detector.

- Large caverns allow opening endcaps aside
- Smaller and lateral space in **“small caverns” can only open endcaps along the beam line**. In addition they require to rise the floor by a O(6-7) meters to allow the centering of the beam, and should move the booster ring aside

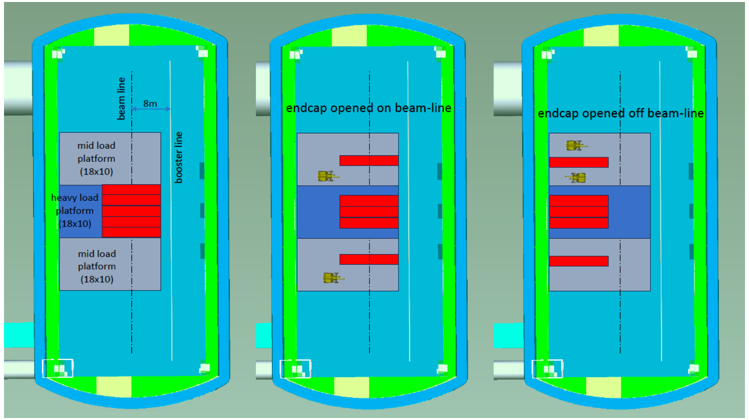




Minimum vital space around the detector

Enough clearance to envisage the scenario to move the detector aside the beamline and get full access to the detector's inner parts

Andrea Gaddi / CERN Physics Department 13



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

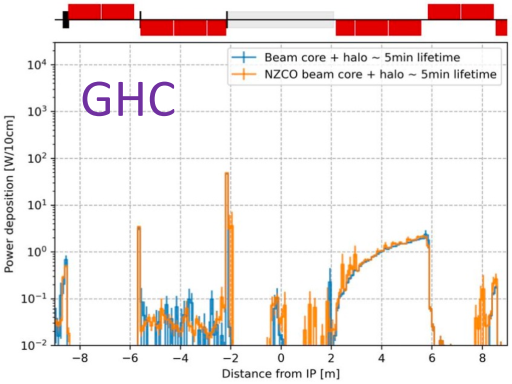
- up to suitable surface before the detector to allow detector hit occupancies
- evaluate energy deposits and radiation levels

Synchrotron Radiation backgrounds

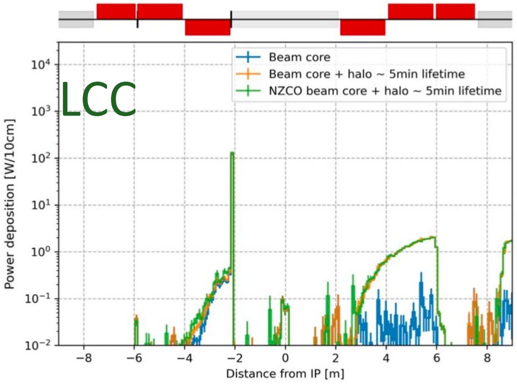
Courtesy plots by Kevin Andrè

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

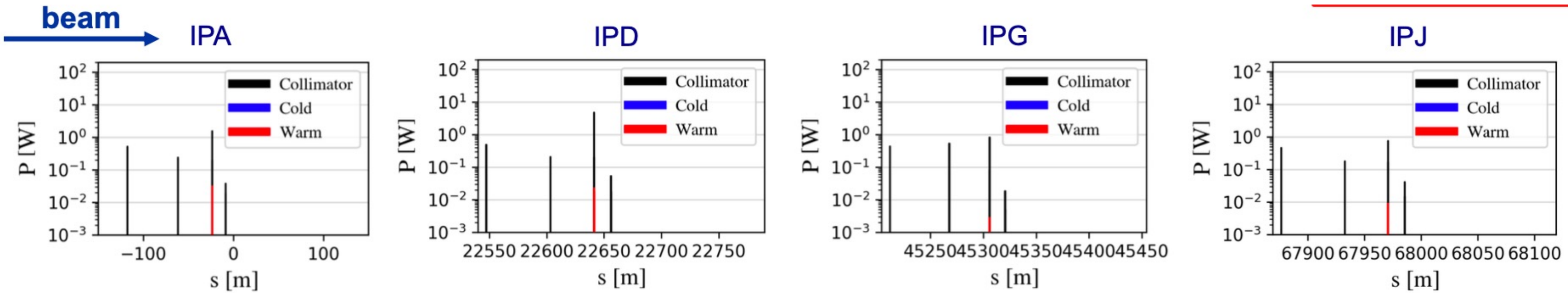
Courtesy plots by Giacomo Broggi

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

Next:
- Add more subdetectors
- Evaluate more background sources

Detector Background Studies

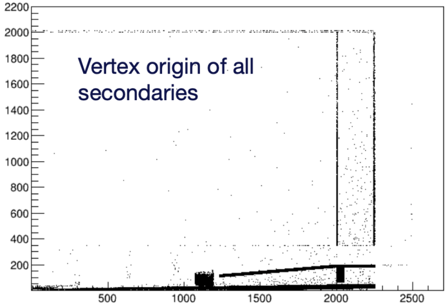
First occupancy calculations from Incoherent pairs in
- IDEA Vertex detector (A. Ilg)
- IDEA drift chamber (B. Francois)
- Allegro ECAL (A. Ciarma)

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 ~7.5% over **400 ns**

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**

Thank you for your attention!