PLAN AND VISION
MDI WORK PACKAGE

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and
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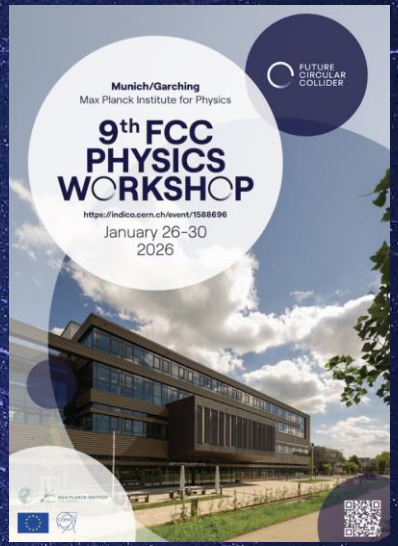
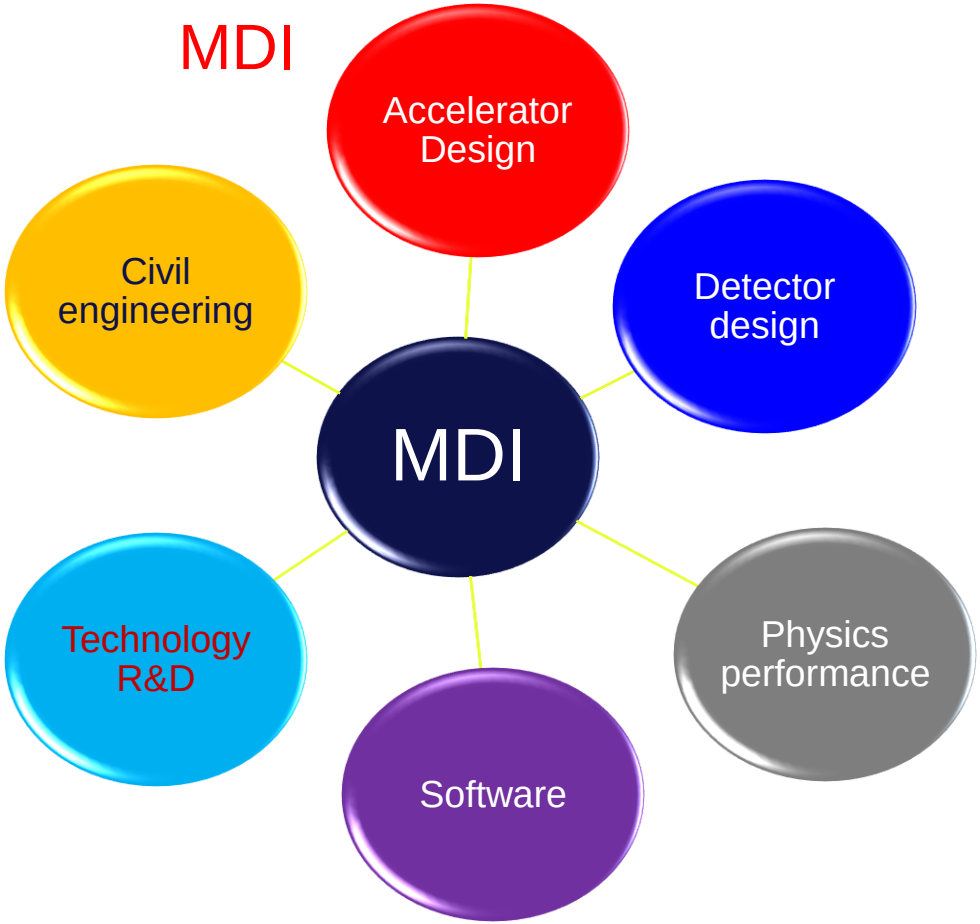
[3] INFN-Pisa



30 January 2026
9th FCC Physics Workshop
Munich/Garching
Germany



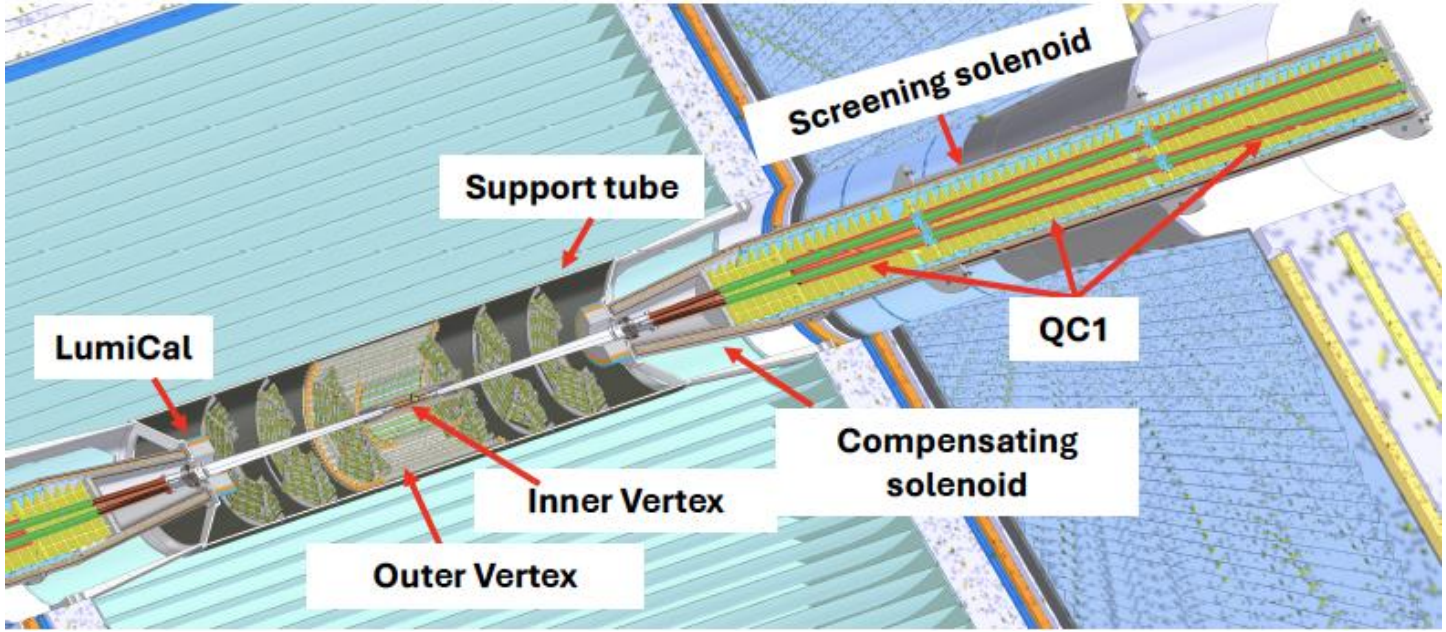
The Machine Detector Interface (MDI) coordinates the integration of the detector and the accelerator, thus determining the ‘interaction’ between the two systems, through the respective constraints and requirements.

Organisation-wise, a good integration with Detector Concepts, Physics Performance and SW WGs has been achieved, and it is important to strengthen in the future.

MDI WP: Main Topics

- IR magnets
- MDI vacuum-related elements/systems
- General integration
- MDI instrumentation
- Alignment tolerances and vibration control
- Beam-induced Backgrounds, beam loss, and radiation
- Final Focus optics and collision optimisation
- Heat load assessment
- IR mockup
- HTS QC1 prototype
- MDI alignment mockup

MDI elements in Feasibility Status Report (31 March 2025)



https://doi.org/10.1140/epjti/s40485-025-00117-3

Status at FSR (31 March 2025)

Topics	
IR Mechanical layout and integration (including services)	Advanced design of beam-pipes and bellows, with cooling systems ; Integration with Vertex and LumiCal; conceptual assembly and maintenance sequence. Alignment studies started. Detector opening scenarios evaluated. FFQ segmentation assessed (2 cryostats needed). Alignment system proposal.
IR magnets configuration	Local and non-local compensation schemes studied; initial studies of effects of fringing fields. Correction optics study started.
Thermal power budget and radiation	Wake field heat load evaluation on the beam pipes and bellows at the Z pole. FFQ heat load from SR, RB, BG. Fluences and TID for FFQ, vertex and LumiCal.
Beam induced backgrounds, beam loss and radiation	Advanced studies on main backgrounds (IPC, Synchrotron radiation, radiative Bhabha's, beam-gas, halo beam) on FFQ and initial studies on detectors. Developed and defined a simulation flow, from accelerator to detectors. Defined SR masks and collimators. Fluences and TID for FFQ, vertex and LumiCal.
Prototypes	IR mechanical mockup started. Aligment mockup started. A first version of QC1 prototype produced

Work ahead for 2026-2027 – I

IR Mechanical layout and integration

- **Beam pipes and IR mechanics**
  - New L*(2.4 m) needs re-assessment of geometry
  - Physics requirements on lowering material budget – is cooling optimal?
  - Integration of “new” elements and their services: Remote Vacuum Connection (RVC) , Beam Position Monitors (BPM)
  - Heat loads:
    - wakefields, synchrotron radiation, radiative Bhabha’s, from subdetectors

- **Mechanical integration of vertex and luminosity detectors (and their services)**
  - Finalise integration of already implemented VDET and integration of new VDET concepts
  - Integrate Lumical (variants)
  - Shielding against backgrounds

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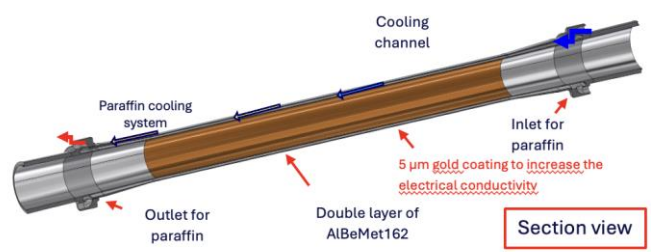
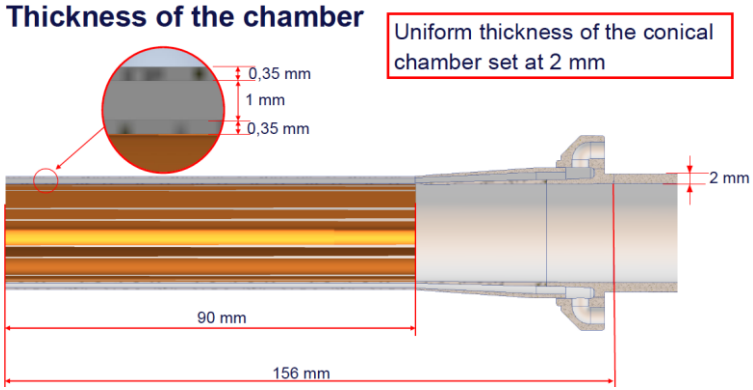
IR Beam pipes



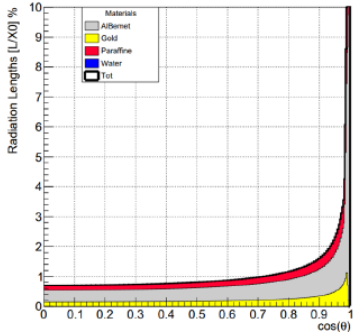
Mechanics

- How to improve the current baseline in lowering material budget?
- Gold layer coating: thickness and extension to the lateral one
- Study RVC (e.g. magic flange)
- Consolidate IR bellows design with integrated HOM absorbers
- NEG pump necessity? (and if so, where?)
- Design and integration of cooling of SR masks, bellows
- Consolidate FFQ vacuum chambers design and cooling



Heat Loads

- Consolidate resistive wall studies (including crotch, masks, bellows)
- Geometric impedance, HOM heat load, HOM absorbers
- Heat load from synchrotron radiation, beamstrahlung, radiative Bhabha
- Electron cloud
- Cooling of detector elements



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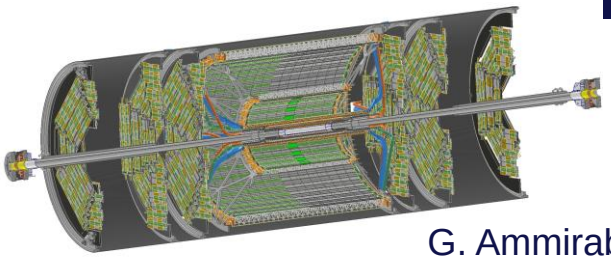
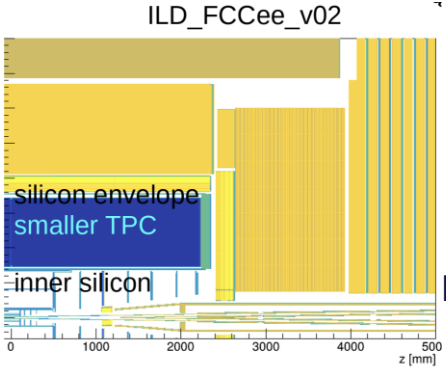
FCC-ee IR: vertex detector integration

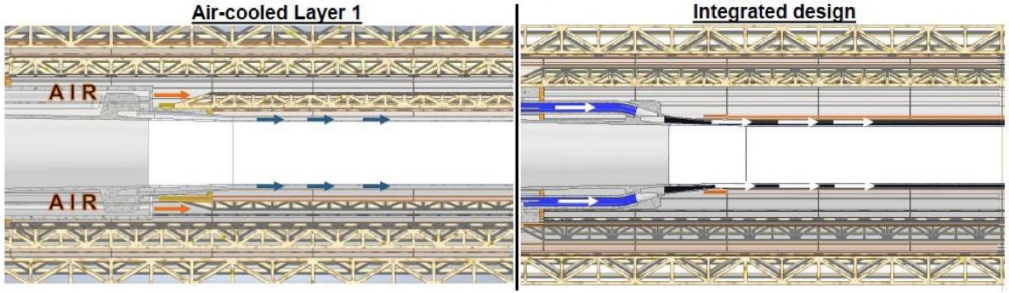


G. Ammirabile

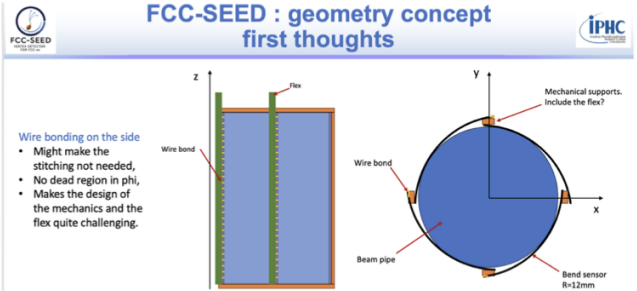
- At least two vertex detector concepts being studied (with additional variants)
  - flat – IDEA vertex integrated. CLD integration not yet studied
  - curved (2 variants) – need to be studied
- Support tube studied only for Silicon+Gas tracking in IDEA
  - needs to be studied for other configurations and all-silicon layouts



D. Jeans

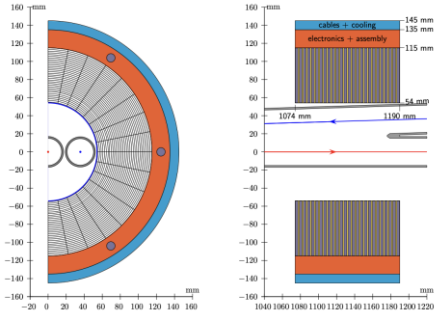


G. Ammirabile

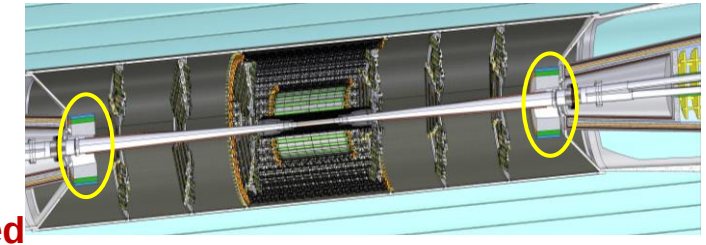


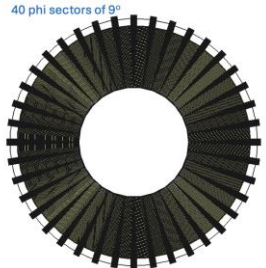
J. Andrea

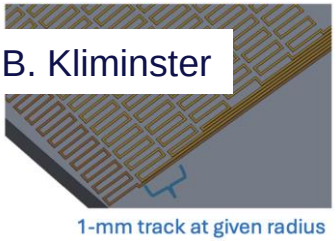
FCC-ee Luminosity Calorimeter integration

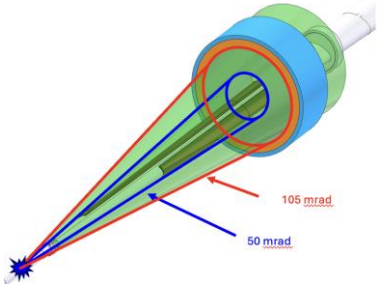


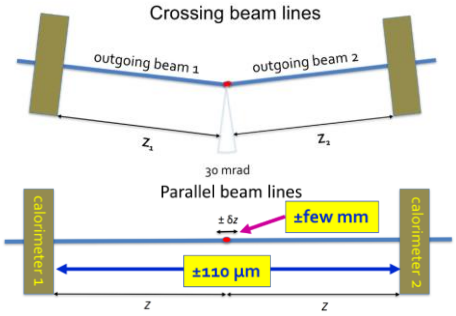
- **Asymmetrical cooling system** in conical pipe to provide angular acceptance to lumical
- **LumiCal held by the endcaps of the support tube**
  - **work needed to fully integrate calorimeter and its services**
  - **extremely tight tolerances**
    - **110 µm longitudinal**
    - **1.5 µm radial**
  - **up to 3 additional different variants of LumiCal expected (4 IP)**
    - **work needs to be repeated**











Work ahead for 2026-2027 – II

IR Mechanical layout and integration

- **Final focus magnets and magnetic elements**
  - Decide compensation scheme and provide magnetic field map
    - Local vs non-local
  - Cryostat design and its support structure
    - dimensions, cooling technology, vibrations, loads and anchoring
  - Anti-solenoids design
  - IR Correctors design, and direct winding correctors

- **Detector assembly, maintenance and opening scenarios**
  - Detector accessibility requirements and impact on accelerator elements (notably FFQ)
  - FFQ re-alignment precision, reproducibility and timing
    - (do we recover full lumi after an opening?)
  - Cavern dimensions

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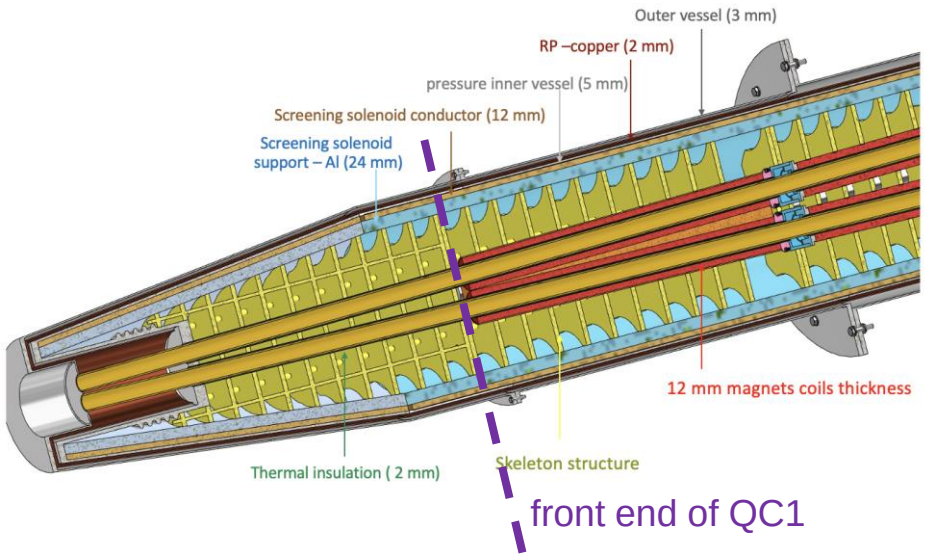
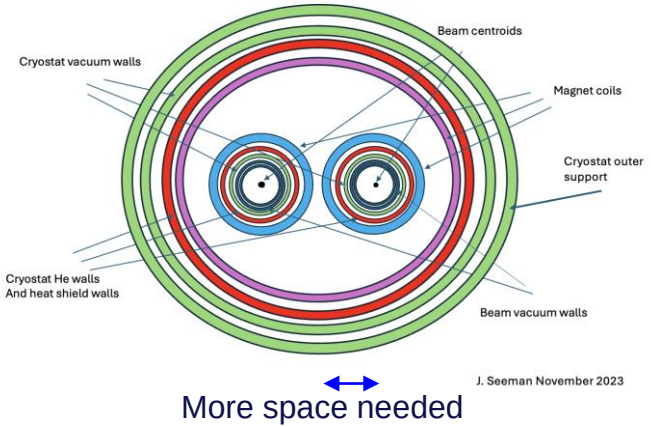
FFQ dimensioning

Solve problems with cryostat design (currently ~10 mm radially missing at QC1a, at 2.4 m from IP)



IR Magnet Cross Section View (front and end of each magnet)
Showing separated heat shield and vacuum vessel.



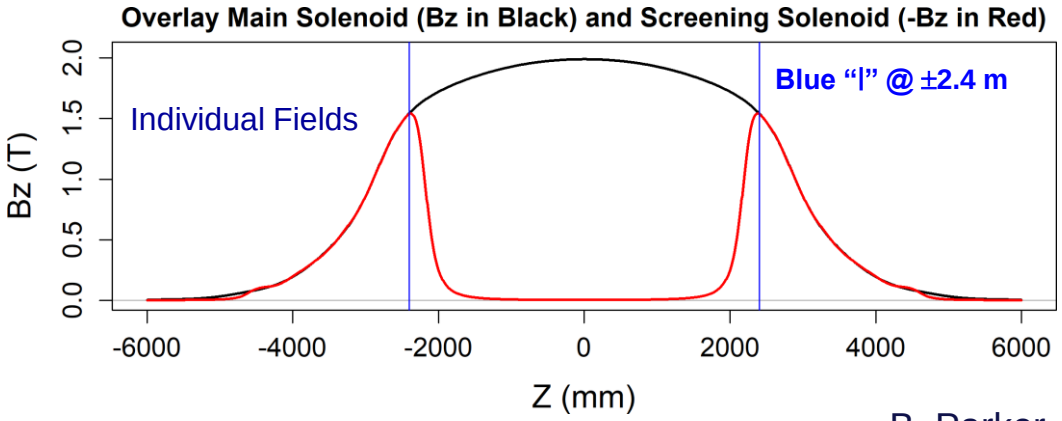
More space needed

J. Seeman

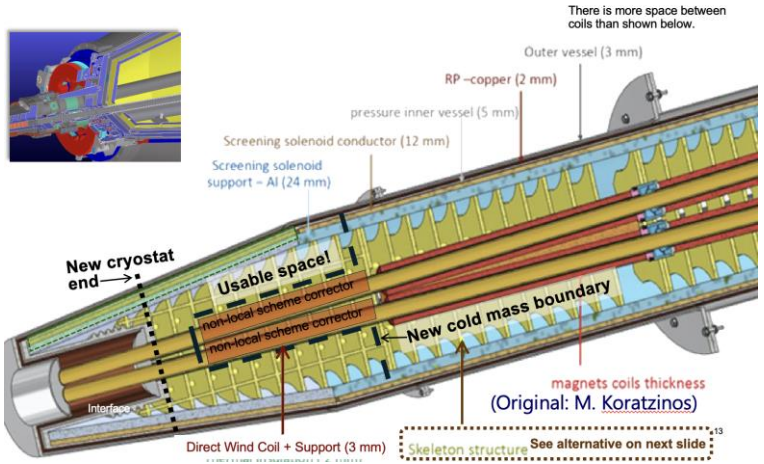
IR magnets

Local vs non-local solenoid compensation needs to be decided

- Beam dynamics and optics considerations, e.g. vertical emittance increase, depolarisation
- Mechanical feasibility and its impact on the detector



B. Parker



Correctors and anti-solenoids design

Detector assembly, maintenance and opening scenarios

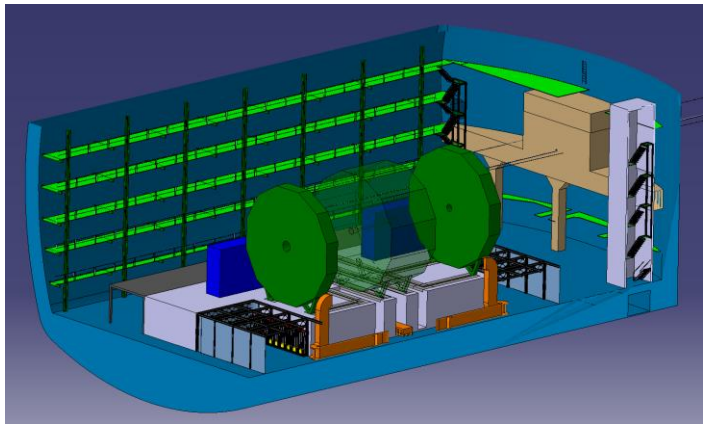
Impact, needs, requirements, cavern dimension need to be studied

Trade off between access needs and re-aligment of quadrupoles – possibly to be quantified in terms of performance/time/risks space

Detector End-Cap Access	Detect End-Cap Move	Warm up cryostat, Vent Vacuum	Remove Accel cryostat	Move detector off-axis	Realign Accel after reinstall	Duration for End-Cap access
Vertical Split	Transverse	No	No	No	No	1
Long in Place	Longitudinal	Yes	Yes	No	Yes	~60-90
Long Off-Axis	Longitudinal	Yes	Yes	Yes	Yes	~120-150

J. Seeman

Opening scenario



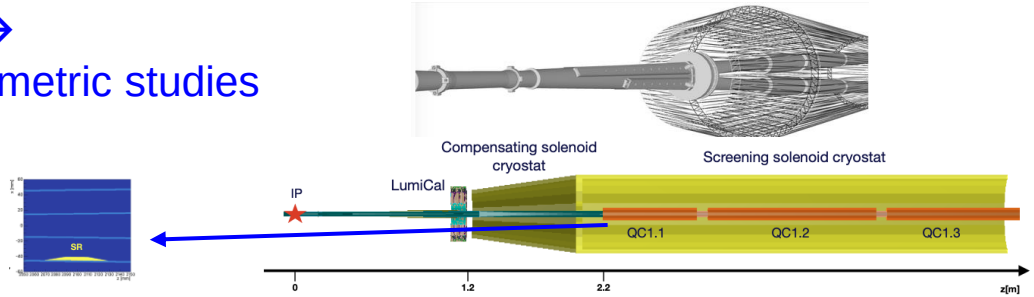
G. Gilmore Kerr

Work ahead for 2026-2027 – III

Beam induced backgrounds, beam loss and radiation

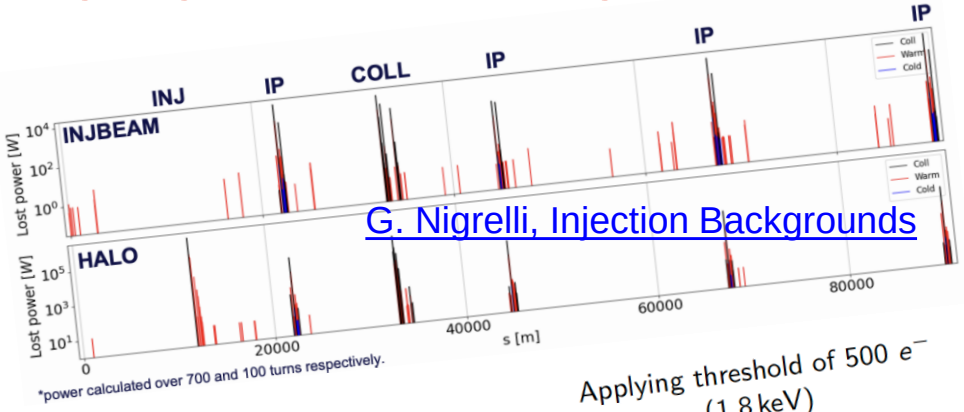
- **Consolidate background simulation flow with improved MDI model**

  Shape-based model vs CAD model →
  Improve shape-based model for parametric studies

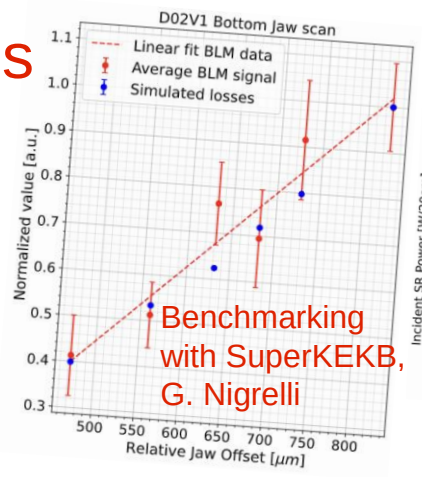


- **Backgrounds optimisations iterating with detectors**
  - Synchrotron radiation
  - New BIB samples will come after optics selection Link to MDI BIB EOS space
  - Other sources not yet implemented (Thermal photons, Touschek …)
  - Beam-gas to be updated with new pressure profiles
  - Fluences and TID to be updated with improved model and new optics
  - Collimation scheme, shielding, masking

Highlights from background studies

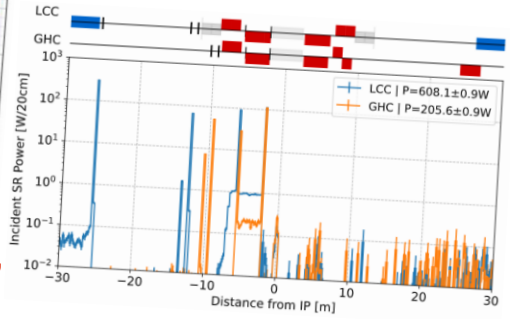


G. Nigrelli, Injection Backgrounds

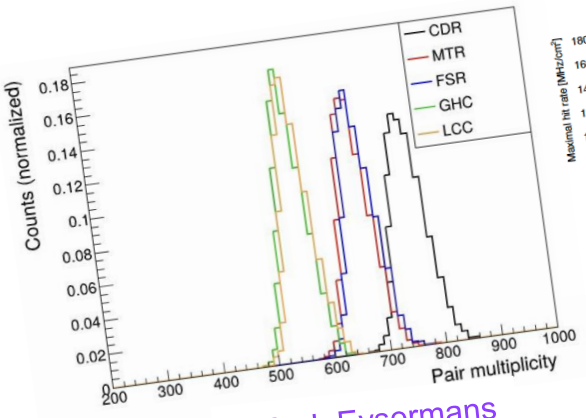


Benchmarking with SuperKEKB, G. Nigrelli

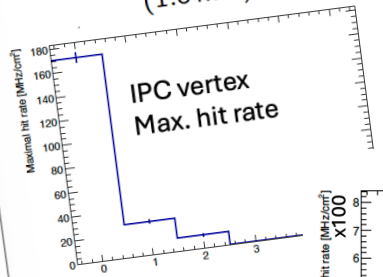
SR, G. Nigrelli



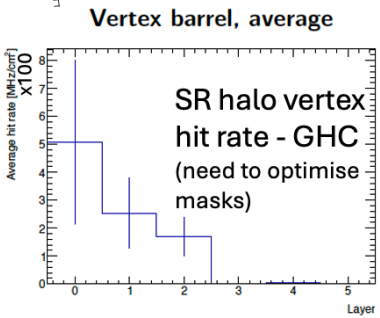
Applying threshold of 500 e^- (1.8 keV)



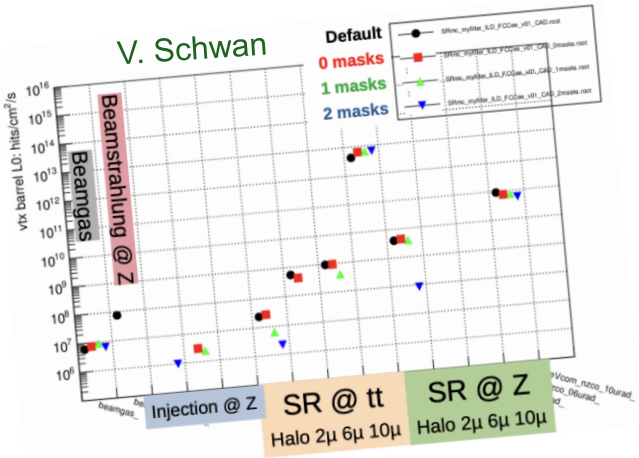
IPC, J. Eysermans



A. Ilg

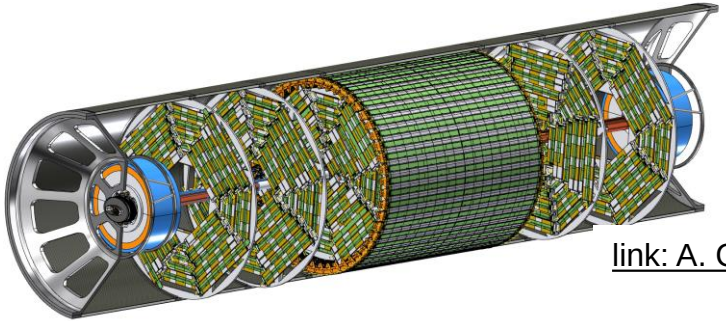


V. Schwan



Work ahead for 2026-2027 -IV

Prototypes



link: A. Ciarma

- Phase 1 of IR mockup at Frascati to be completed
  - cooling validation, structural and assembly tests
- Alignment mock-up at CERN
  - Alignment and deformation monitoring
- HTS QC1 R&D at LAPP

Prototype implementing the fiber measurement and the FSI measurement on reflector

Link: L. Watrelot

Link: M. Le Garrec

- Other mockups welcome!

Objectives and deliverables for MDI pre-TDR

	Objectives
A.	**Finalisation of the IR mechanical layout and integration with the detector**
B.	**Study all backgrounds and evaluate effects on the detectors**

	Deliverables
A.a	**Beam pipe material, geometry, cooling technique, bellows, beam monitors, and remote vacuum connections per each energy**
A.b	**Optimise cavern dimensions wrt detector and accelerator openings for maintenance per each experiment.**
A.c	**Define final configuration of SC IR cryostat technology, design IR cryo-magnets and their supporting structures, IR correction tuning, and optics geometrical parameters (L*, crossing angle)**
B.a	Optimisation of collimators, masks, and shielding for both the accelerator elements and detectors with the chosen optics and operation margins.
B.b	Sub-detector data rates, fluences, and total ionisation doses (TID)

Outlook

- Significant progress achieved in the MDI Feasibility Study.
- Goal of the pre-TDR phase is to converge on a robust and feasible design, addressing and clarifying the critical issues.
- As detector concepts and accelerator design continue to evolve, the MDI will need to adapt.
- The MDI feasibility for the four beam energies will be further developed.
- **An exciting phase lies ahead to refine and consolidate the MDI design. Join us!**