INTERACTION REGION AND MACHINE DETECTOR INTERFACE DESIGN FOR THE FCC FEASIBILITY STUDY

Manuela Boscolo

15 December 2021
RD_FCC meeting

Outline

Summary of the MDI related discussions at the FCC workshop (29/11 – 10/12)

with current status of the activity plan for MDI and follow-up topics

with some general slides on FCC FS

FUTURE
CIRCULAR
COLLIDER
Innovation Study

FUTURE
CIRCULAR
COLLIDER

FCC IS WP2 “Working Weeks” with integrated “FCC Accelerators & Beam Physics Day”

29 November – 10 December 2021

Frank Zimmermann,

with input from Michael Hofer, Manuela Boscolo et al.

thanks to Julie Hadre and Suzanne Chibli

https://indico.cern.ch/event/1085318

ESPP Update 2020 “High-priority future initiatives”

- An **electron-positron Higgs factory is the highest-priority next collider**. For the longer term, the European particle physics community has the ambition to operate a **proton-proton collider at the highest achievable energy**.

- “Europe, together with its international partners, should investigate the **technical and financial feasibility of a future hadron collider at CERN with a centre-of-mass energy of at least 100 TeV** and with an **electron-positron Higgs and electroweak factory as a possible first stage**.
- Such a **feasibility study of the colliders and related infrastructure** should be established as a global endeavour and be **completed on the timescale of the next Strategy update**..”

→ launch of Future Circular Collider Feasibility Study in summer 2021

FCC-ee figures of merit – cost & sustainability

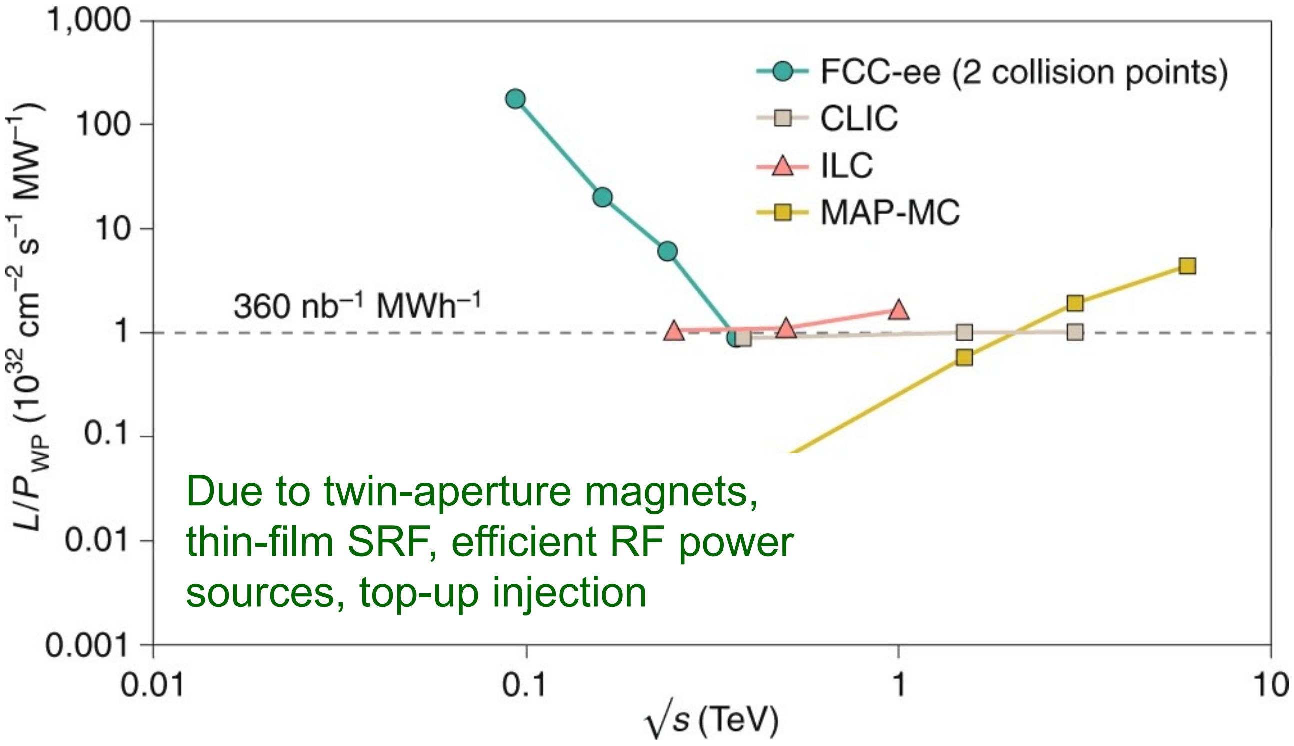
Luminosity vs. capital cost

- for the H running, **with 5 ab^{-1} accumulated over 3 years and 10^6 H produced**, the total investment cost (~10 BCHF) corresponds to
  → **10 kCHF per produced Higgs boson**
- for the Z running with **150 ab^{-1} accumulated over 4 years and 5×10^{12} Z produced,** the total investment cost corresponds to
  → **10 kCHF per 5×10^6 Z bosons**

This is the number of Z bosons collected by each experiment during the entire LEP programme !

Capital cost per luminosity dramatically decreased compared with LEP !

Luminosity vs. electricity consumption



Due to twin-aperture magnets, thin-film SRF, efficient RF power sources, top-up injection

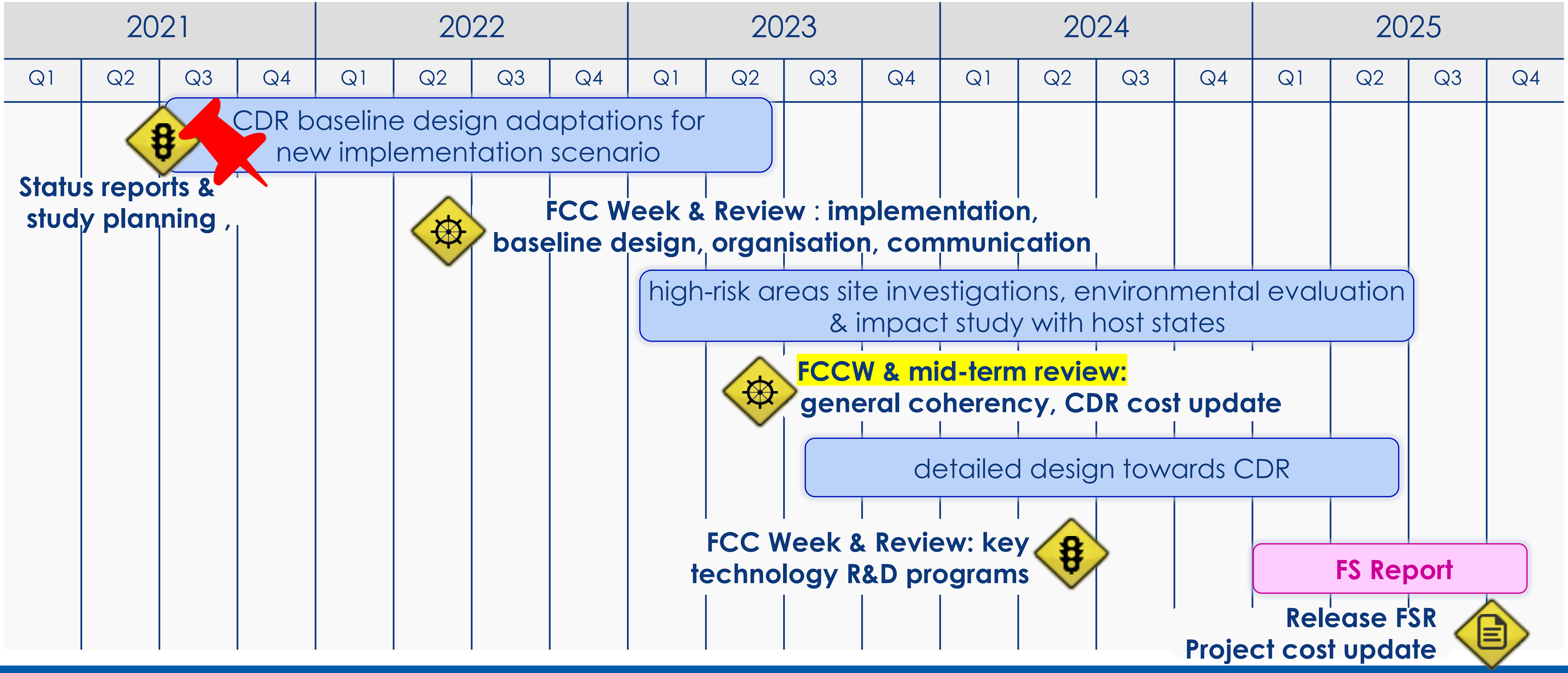
Highest lumi/power of all proposals
Electricity cost ~200 CHF per Higgs boson

M. Benedikt, A. Blondel, P. Janot, et al., **Nature Physics 16**, 402-407 (2020), and **European Strategy** for Particle Physics Preparatory Group, *Physics Briefing Book* (CERN, 2019)

FUTURE
CIRCULAR
COLLIDER

Feasibility Study Timeline

M. Benedikt



CDR baseline design adaptations for new implementation scenario

Status reports & study planning ,

FCC Week & Review : implementation, baseline design, organisation, communication

high-risk areas site investigations, environmental evaluation & impact study with host states

FCCW & mid-term review:
general coherency, CDR cost update

detailed design towards CDR

FCC Week & Review: key technology R&D programs

FS Report

Release FSR
Project cost update

FCC Feasibility Study – coordination team and contact persons

EU Projects
NN

Collaboration building
Emmanuel Tsesmelis

Communications
Panagiotis Charitos, James Gillies

Study Support and Coordination
Study Leader: Michael Benedikt
Deputy Study Leader: Frank Zimmermann

Study Support Unit
IT: Sylvain Girod
Procurement: Adam Horridge
Quality control: NN
Resources: Sylvie Prodon
Scheduling, quality mangement: NN
Secretariat: Julie Hadre

Physics, Experiments and Detectors
Patrick Janot
Gavin Salam

- **Physics programme** – Matthew McCullough, Frank Simon
- **Detector concept** – Mogens Dam
- **Physics performance** – Patrizia Azzi, Emmanuel Perez
- **Software and computing** – Gerardo Ganis, Clément Helsens

Accelerators
Tor Raubenheimer
Frank Zimmermann

- **FCC-ee collider design** – Katsunobu Oide
- **FCC-hh design** – Massimo Giovannozzi
- **Technology R&D** – Roberto Losito
- **FCC-ee booster design** – Antoine Chancé
- **FCC-ee injector** – Paolo Craievich, Alexej Grudiev
- **FCC-ee energy calibration polarization** – Alain Blondel, Jorg Wenninger
- **FCC-ee MDI** – Manuela Boscolo, Mike Sullivan

Technical Infrastructures
Klaus Hanke

- **Integration** – Jean-Pierre Corso
- **Geodesy & survey** – Hélène Mainaud Durand
- **Electricity and energy management** – Jean-Paul Burnet
- **Cooling and ventilation** – Guillermo Peon
- **Cryogenics systems** – Laurent Delprat
- **Computing and controls infrastructure, communication and network** – Dirk Duellmann
- **Safety** – Thomas Otto
- **Operation, maintenance, availability, reliability** – Jesper Nielsen
- **Transport, installation concepts** – Cristiana Colloca

Host State processes and civil engineering
Timothy Watson

- **Administrative processes** – Friedemann Eder
- **Placement studies** – Johannes Gutleber, Volker Mertens
- **Environmental evaluation** – Johannes Gutleber
- **Tunnel, subsurface design** – John Osborne
- **Surface sites layout, access and building design**

Organisation and financing models
Paul Collier (interim)

- **Project organisation model**
- **Financing model** – Florian Sonnemann
- **Procurement strategy and rules**
- **In-kind contributions**
- **Operation model** – Paul Collier, Jorg Wenninger

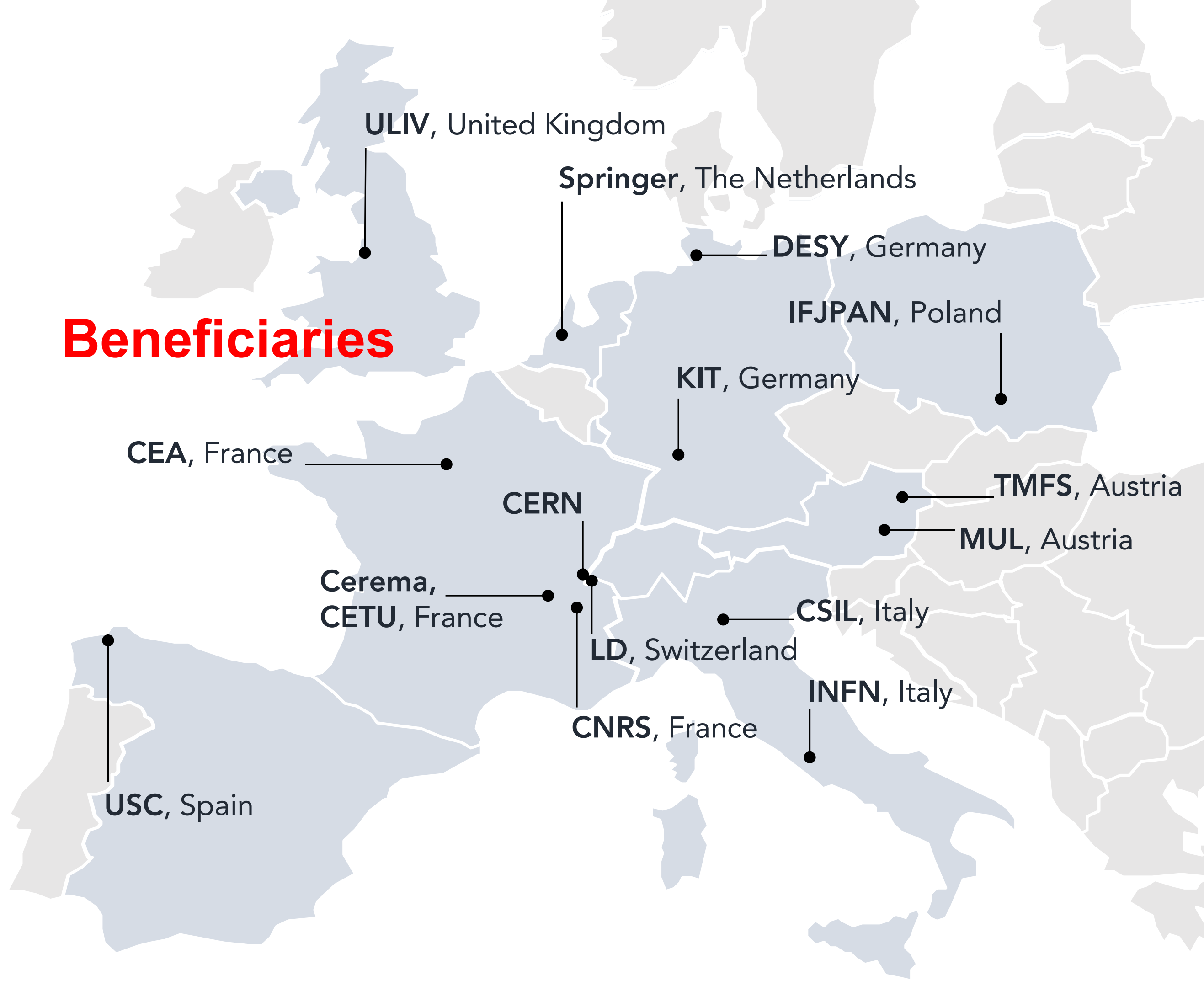
FCC Status and Outlook

- Following the European Strategy Update, the **organization structure and major milestones and deliverables for the FCC Feasibility Study were approved by the CERN Council in June 2021.**
- Main activities concern the **development and confirmation of a concrete implementation scenario** in collaboration **with host state authorities**, accompanied by **machine optimization, physics studies and technology R&D**, performed **via global collaboration** and supported by the **EC H2020 Design Study FCCIS, with the goal to demonstrate feasibility by 2025/26.**
- Long term goal: **world-leading HEP infrastructure for 21st century** to push the particle-physics **precision and energy frontiers** far beyond present limits.

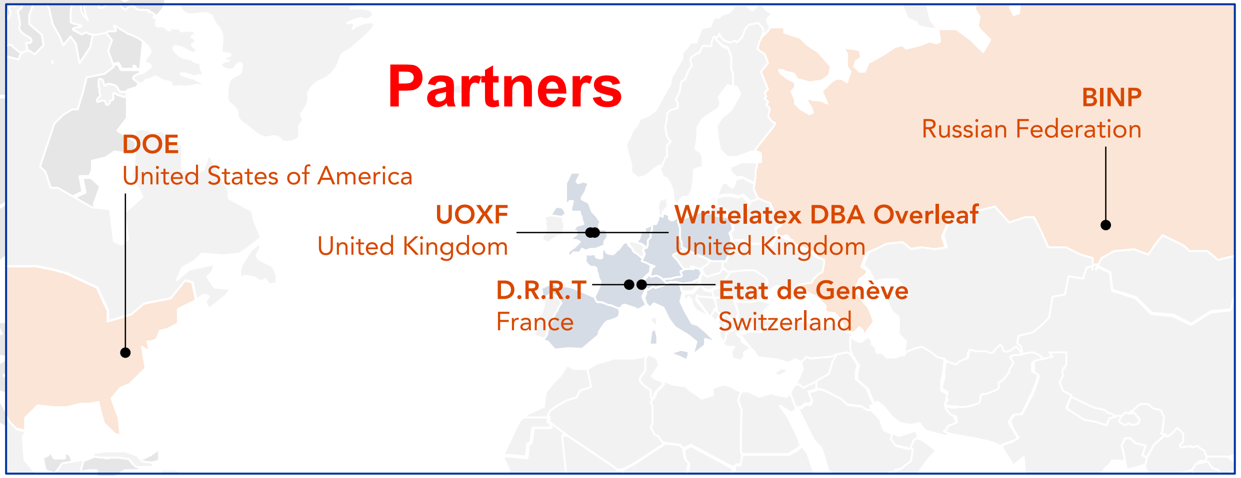
H2020 DS FCC Innovation Study 2020-24

Grant Agreement	FCCIS 951754
Duration	48 months
From-to	2 Nov 2020 – 1 Nov 2024
Project cost	7 435 865 €
EU contribution	2 999 850 €
Beneficiaries	16
Partners	6

Beneficiaries



Partners



FCCIS Work Packages

WP1: study management (CERN)

WP2: collider design (DESY)

Deliver a performance optimised machine design, integrated with the territorial requirements and constraints, considering cost, long-term sustainability, operational efficiency and design for socio-economic impact generation.

WP3: integrate Europe (CERN)

Develop a feasible project scenario compatible with local – territorial constraints while guaranteeing the required physic performance.

WP4: impact & sustainability (CSIL)

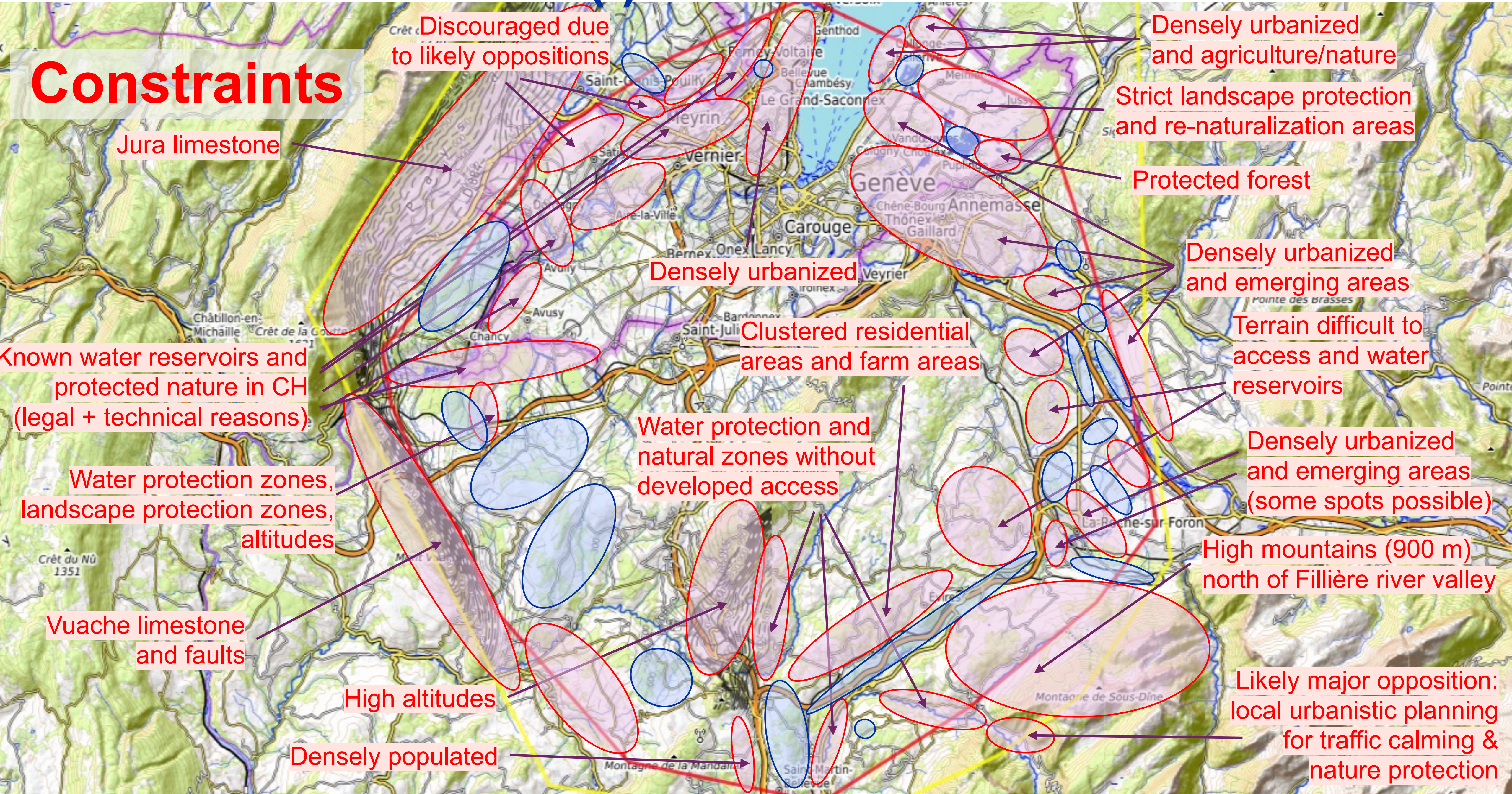
Develop the financial roadmap of the infrastructure project, including the analysis of socio-economic impacts.

WP5: leverage & engage (IFJ PAN)

Engage stakeholders in the preparation of a new research infrastructure. Communicate the project rationale, objectives and progress. Create lasting impact by building theoretical and experimental physics communities, creating awareness of the technical feasibility and financial sustainability, forging a project preparation plan with the host states (France, Switzerland).

Placements studies (i)

J. Gutleber, V. Mertens



Constraints

Discouraged due to likely oppositions

Jura limestone

Known water reservoirs and protected nature in CH (legal + technical reasons)

Water protection zones, landscape protection zones, altitudes

Vuache limestone and faults

High altitudes

Densely populated

Densely urbanized

Clustered residential areas and farm areas

Water protection and natural zones without developed access

Densely urbanized and agriculture/nature

Strict landscape protection and re-naturalization areas

Protected forest

Densely urbanized and emerging areas

Terrain difficult to access and water reservoirs

Densely urbanized and emerging areas (some spots possible)

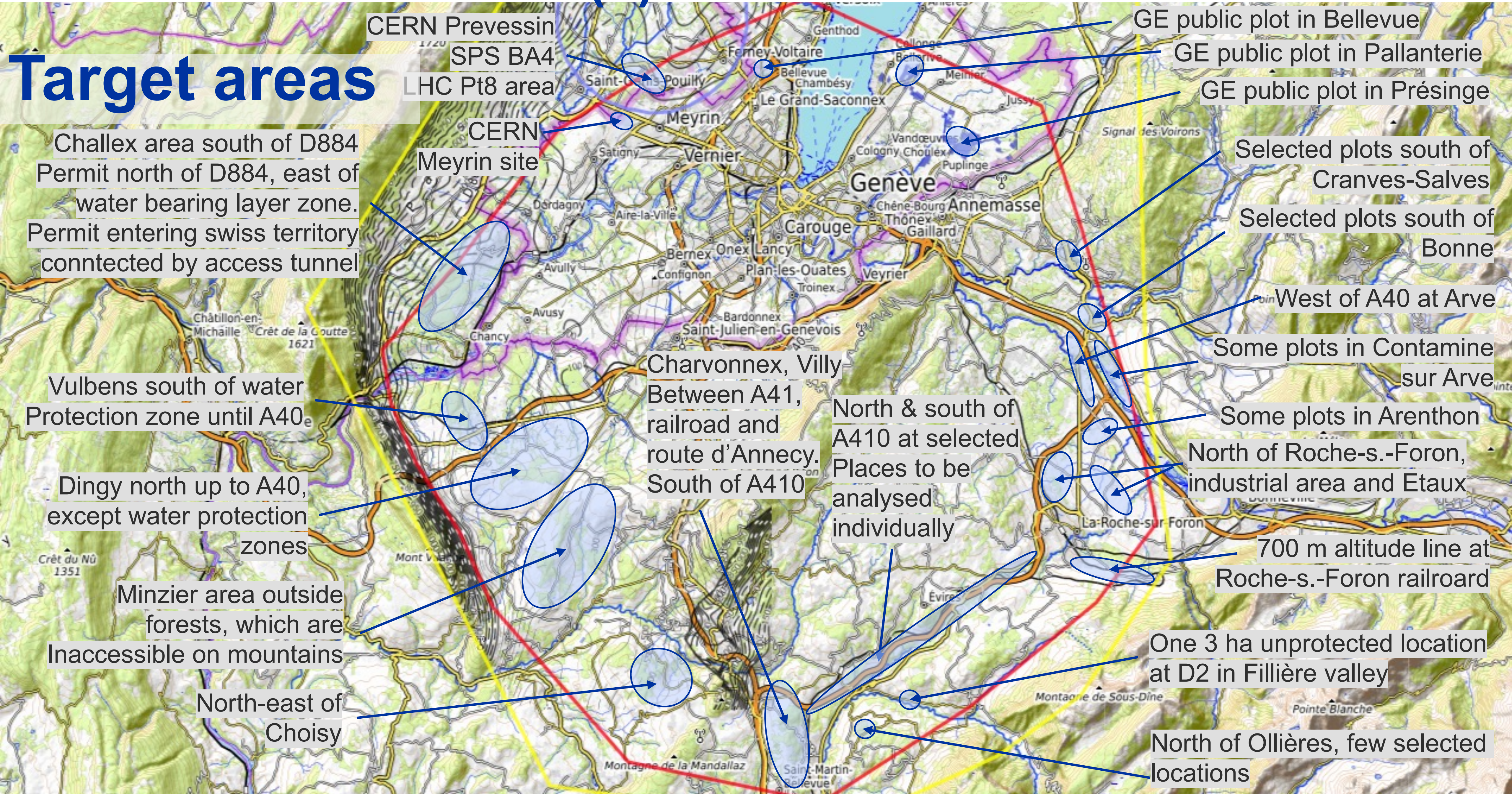
High mountains (900 m) north of Fillière river valley

Likely major opposition: local urbanistic planning for traffic calming & nature protection

Placements studies (ii)

J. Gutleber, V. Mertens

Target areas



CERN Prevessin

SPS BA4

LHC Pt8 area

CERN

Meyrin site

Challex area south of D884
Permit north of D884, east of
water bearing layer zone.
Permit entering swiss territory
conntected by access tunnel

Vulbens south of water
Protection zone until A40

Dingy north up to A40,
except water protection
zones

Minzier area outside
forests, which are
Inaccessible on mountains

North-east of
Choisy

Charvonnex, Villy
Between A41,
railroad and
route d'Annecy.
South of A410

North & south of
A410 at selected
Places to be
analysed
individually

GE public plot in Bellevue

GE public plot in Pallanterie

GE public plot in Présinge

Selected plots south of
Cranves-Salves

Selected plots south of
Bonne

West of A40 at Arve

Some plots in Contamine
sur Arve

Some plots in Arenthon

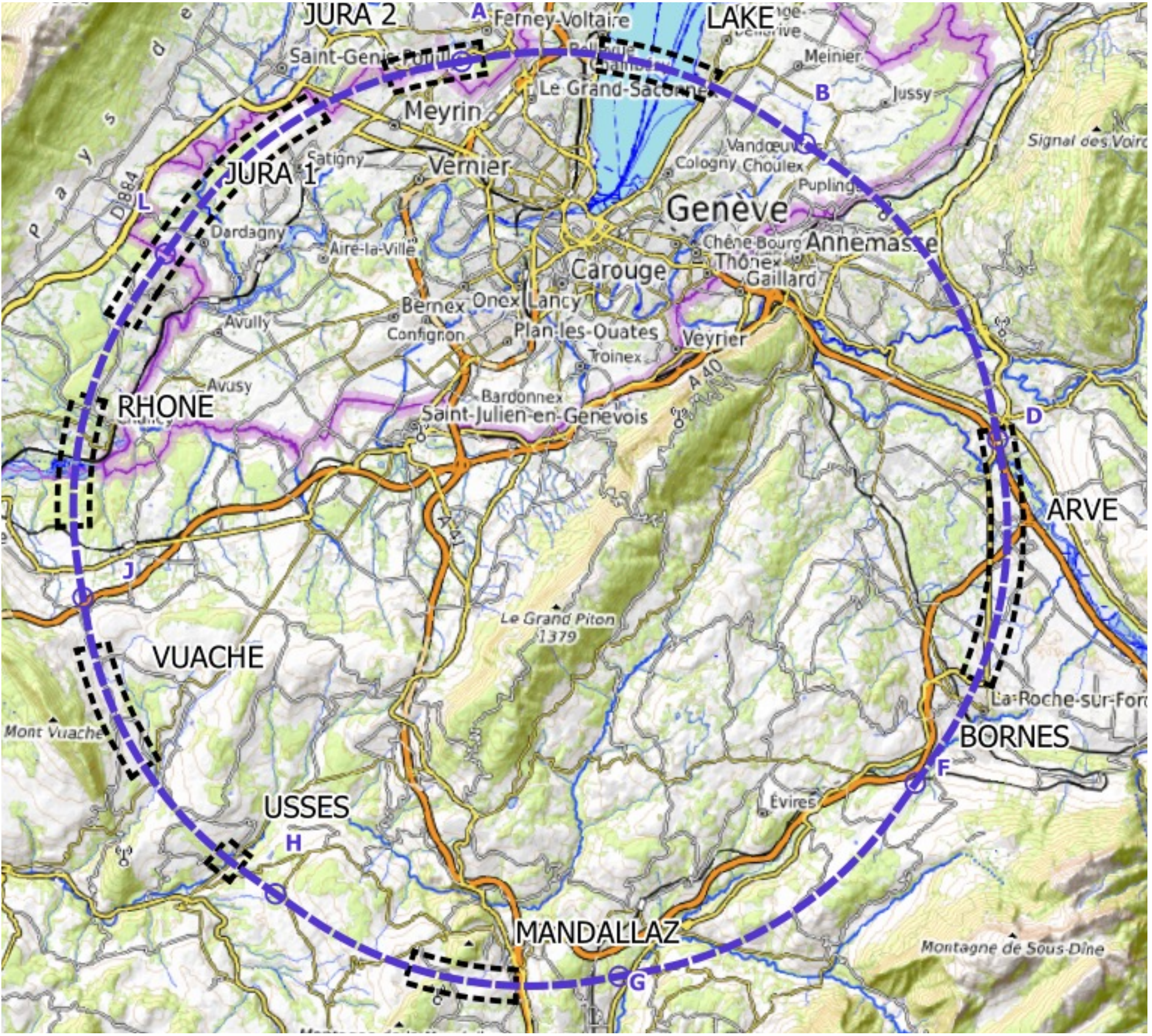
North of Roche-s.-Foron,
industrial area and Etaux

700 m altitude line at
Roche-s.-Foron railroard

One 3 ha unprotected location
at D2 in Fillière valley

North of Ollières, few selected
locations

Plans for high-risk area site investigations



JURA, VUACHE (3 AREAS)

Top of limestone

Karstification and filling-in at the tunnel depth

Water pressure

LAKE, RHÔNE, ARVE AND USSES VALLEY (4 AREAS)

Top of the molasse

Quaternary soft grounds, water bearing layers

MANDALLAZ (1 AREAS)

Water pressure at the tunnel level

Karstification

BORNES (1 AREA)

High overburden molasse properties

Thrust zones

Site investigations planned for mid 2023 – mid 2025: ~40-50 drillings, 100 km of seismic lines

MDI design criteria

double ring e^+e^- collider ~100 km

follows footprint of FCC-hh, except around IPs

crab-waist optics [ArXiv.070233]

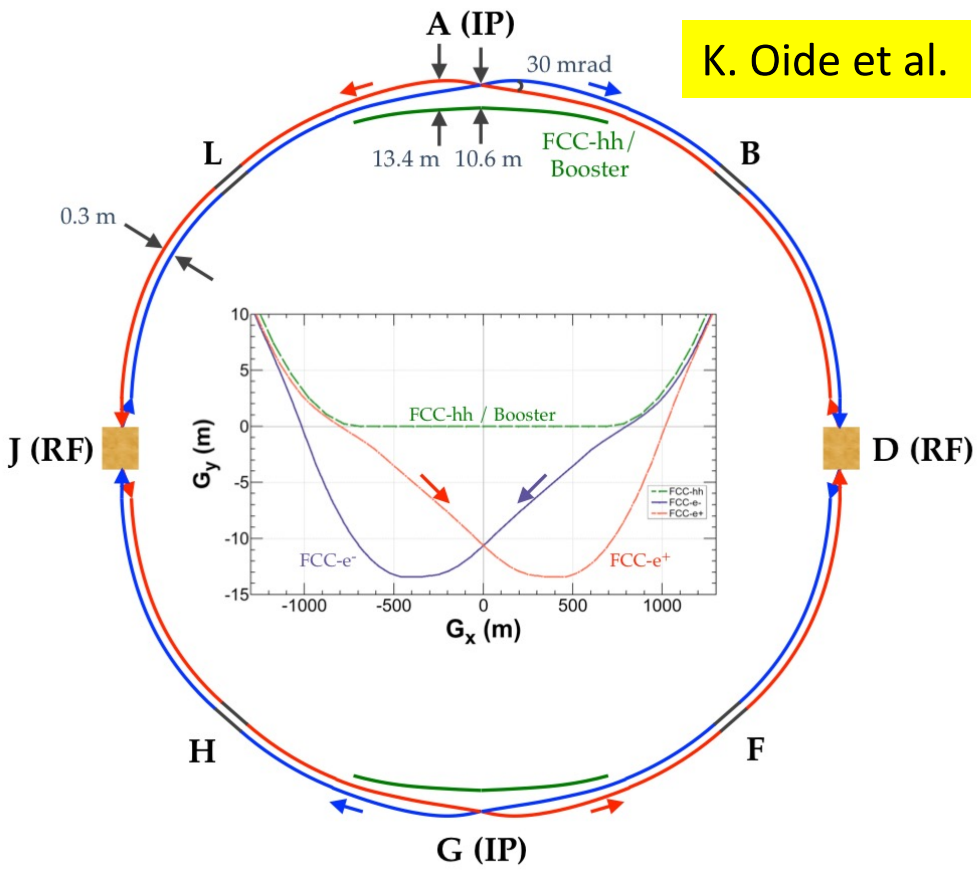
large horizontal crossing angle **30 mrad**

asymmetric IR optics to limit synchrotron radiation towards the detector

SR is one of the main drivers of the MDI design:

requirement $E_{critical}$ < 100 keV for incoming beam from 500 m to IP (based on LEP experience)

Different countermeasures to cope with its impact in the MDI area



K. Oide et al.

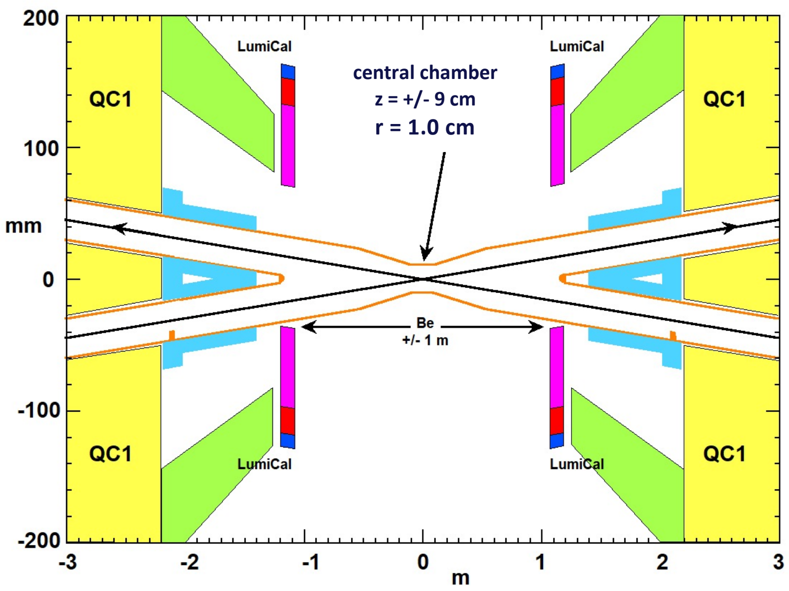
Refs.

- *FCC-ee: The Lepton Collider*, **Eur. Phys. J. Spec. Top. 228**, 261–623 (2019)
- K. Oide et al., **Phys. Rev. Accel. Beams 19**, 111005 (2016)
- M. Boscolo et al., IPAC 2021 e-print: 2105.09698
- M. Boscolo, H. Burkhardt, K. Oide and M. Sullivan, EPJ+ (2021) 136:1068 link
- M. Boscolo, H. Burkhardt, G. Ganis, C. Helsens, EPJ+ (2021) (Essay in Part IV) 2111.09870

FCC-ee Interaction Region

L*=2.2 m
B=2 T

- **Flexible** design, one IR for all energies
- **Compact** design: QC1 and compensation solenoids inside detector
- **Squeezed beams at IP**, tens of nm in σ_y*
  challenges in several aspects, from magnets to vibrations mitigation, alignment and monitoring system, feedback for beam orbit and luminosity
- **High intensity and high energy beam**

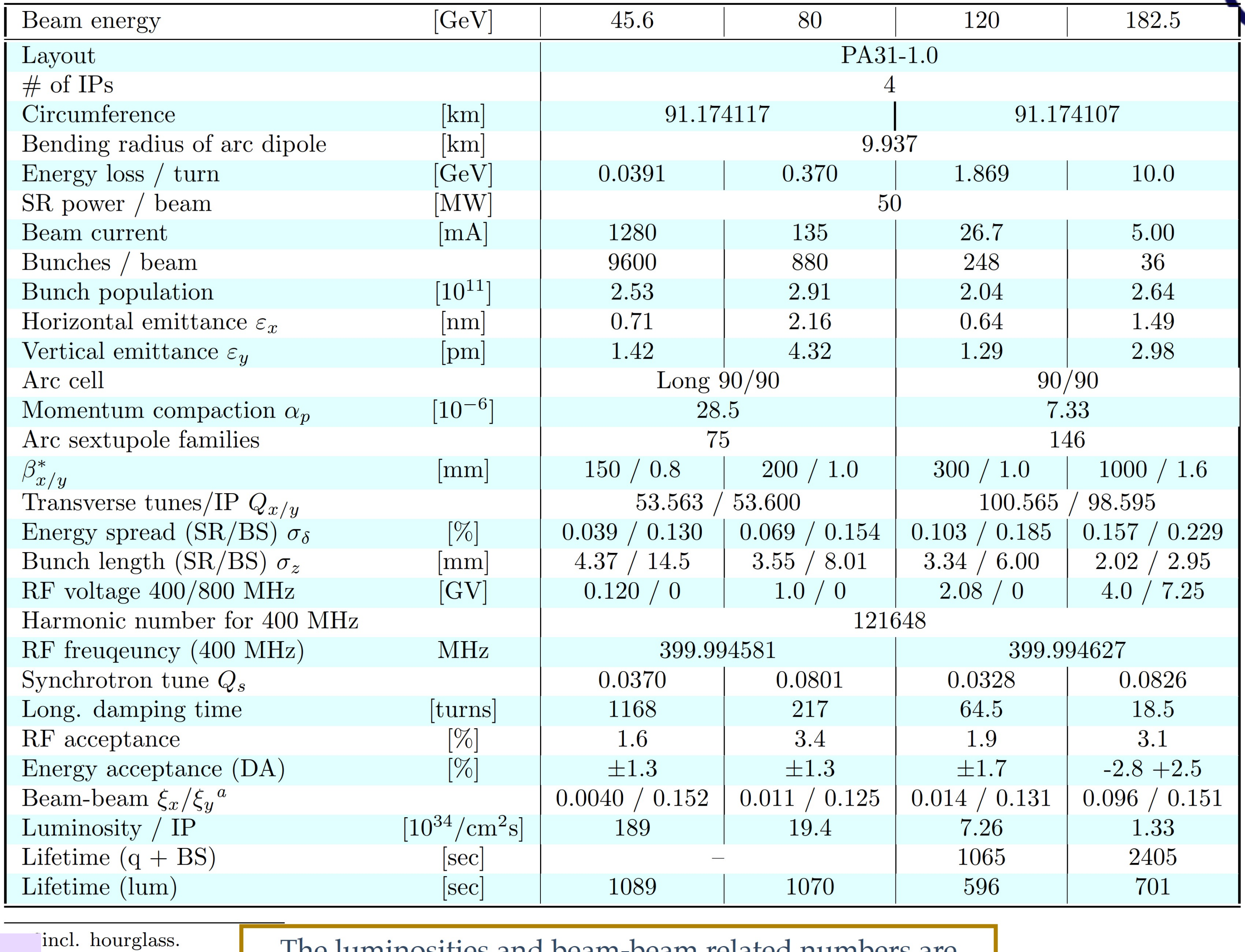


- **Synchrotron radiation:** detector sustainability top priority

- **Solenoid compensation scheme** preserves $\varepsilon_y \approx$ pm
- **Luminosity detector** @Z: absolute meas. to 10^{-4}
- **Robustness against machine bkgs, occupancy**
- **Optimization of the central beam pipe design, material, thickness**
- Keep **low material budget**: minimise mass of electronics, cables, cooling

IR parameters		Z	W^+W^-	ZH	ttbar
β_x^*	m	0.15	0.2	0.3	1.0
β_y^*	mm	0.8	1.0	1.0	1.6
σ_x^*	µm	6.4	13	13.7	38.2
σ_y^*	nm	28	41	36	68
σ_z	mm	12.1	6	5.3	2.54
z^*_{int}	mm	0.42	0.85	0.9	1.8

Parameters



Beam energy	[GeV]	45.6	80	120	182.5
Layout		PA31-1.0			
# of IPs		4			
Circumference	[km]	91.174117		91.174107	
Bending radius of arc dipole	[km]	9.937			
Energy loss / turn	[GeV]	0.0391	0.370	1.869	10.0
SR power / beam	[MW]	50			
Beam current	[mA]	1280	135	26.7	5.00
Bunches / beam		9600	880	248	36
Bunch population	[10^{11}]	2.53	2.91	2.04	2.64
Horizontal emittance ε_x	[nm]	0.71	2.16	0.64	1.49
Vertical emittance ε_y	[pm]	1.42	4.32	1.29	2.98
Arc cell		Long 90/90		90/90	
Momentum compaction α_p	[10^{-6}]	28.5		7.33	
Arc sextupole families		75		146	
$\beta^*_{x/y}$	[mm]	150 / 0.8	200 / 1.0	300 / 1.0	1000 / 1.6
Transverse tunes/IP $Q_{x/y}$		53.563 / 53.600		100.565 / 98.595	
Energy spread (SR/BS) σ_δ	[%]	0.039 / 0.130	0.069 / 0.154	0.103 / 0.185	0.157 / 0.229
Bunch length (SR/BS) σ_z	[mm]	4.37 / 14.5	3.55 / 8.01	3.34 / 6.00	2.02 / 2.95
RF voltage 400/800 MHz	[GV]	0.120 / 0	1.0 / 0	2.08 / 0	4.0 / 7.25
Harmonic number for 400 MHz		121648			
RF freuqeuncy (400 MHz)	MHz	399.994581		399.994627	
Synchrotron tune Q_s		0.0370	0.0801	0.0328	0.0826
Long. damping time	[turns]	1168	217	64.5	18.5
RF acceptance	[%]	1.6	3.4	1.9	3.1
Energy acceptance (DA)	[%]	±1.3	±1.3	±1.7	-2.8 +2.5
Beam-beam ξ_x/ξ_y[a]		0.0040 / 0.152	0.011 / 0.125	0.014 / 0.131	0.096 / 0.151
Luminosity / IP	[10^{34}/cm^{2}s]	189	19.4	7.26	1.33
Lifetime (q + BS)	[sec]	–		1065	2405
Lifetime (lum)	[sec]	1089	1070	596	701

---

[a] incl. hourglass.

Katsunobu Oide

The luminosities and beam-beam related numbers are based on a simple model w/o beam-beam simulations.

FCC-ee MDI activity plan

Draft

Task 0. Coordination

Task 1. 3D engineering design of IR and MDI mechanical layout with integration

1.1 Beam pipe design –
1.2 Magnet integration incl. el.-magn. forces
1.3 Cryostat integration
1.4 Shielding against hard synchrotron radiation & collision debris
1.5 IP detectors integration, i.e. luminosity calorimeter, Vertex detector (support & alignment) –
1.6 Vacuum sys. integration –
1.7 Supporting structures
1.8 Thermal simulations
1.9 Management of electrical and hydraulic connections/routing
1.10 Mechanical IR assembly, disassembly & repair procedures

Key deliverables: 3D CAD model of whole IR ; Preliminary structure design ; Thermal and mechanical simulations; Civil engineering requirements; Prototypes (IR vacuum chamber, alignment devices)

Task 2. BG, beam loss & rad.

2.1 Top-up injection background incl. beam-beam and dedicated collimation, masking and shielding; comparing background situation for different injection schemes
2.2 SR backgrounds with masking & shielding optim.
2.3 Other single-beam BG (res. gas, Touschek, thermal γ)
2.4 Beam losses from collisions processes: beamstrahlung, luminosity, including spent beam tracking and shielding optimization
2.5 Software tool development in collaboration, link common software –framework FCCSW and MDI codes-
2.6 Effect of backgrounds in detectors
2.7 Tail collimation & machine protection strategy
2.8 Collimation scheme and strategy incl. IR collimators, in collaboration w collimation team
2.9 Neutron radiation in IR area
2.10 Shielding of IR magnets against collision debris
2.11 Handling of incident beamstrahlung (diagnostics?)
2.12 Beam abort system: requirements, abort gaps, signal processing, etc.
2.13 Protection against rare devastating events e.g. dust
2.14 Mask + collimation hardware design

Key deliverables:

Masking, shielding, collimation systems ; Injection scheme(s), Background sustainability by detectors ; Machine protection strategy

Task 3. Conceptual design of IR elements/systems

3.1 IR Magnets design w. field map (solenoid compensation), supports, spatial tolerance, el.-magn. forces, OP conditions
3.2 Cryostat design, dimensioning cooling systems
3.3 Luminosity calorimeter
3.4 Vertex detector & possibly other IP detectors
3.5 Remote vacuum connection
3.6 HOM absorbers
3.7 IR beam diagnostic devices

Key deliverables:

Prototypes (FF magnets, remote vacuum connection)

Task 4. Alignment tolerances & vibration control

4.1 Alignment specifications
4.2 Alignment /survey strategy & requirements –
4.3 Vibration study, stabilization strategy, etc. –
4.4 Feedback systems for beam collision adjustment ; feedback to maintain luminosity with top-up injection-

Key deliverables: Alignment/survey strategy; Stabilization strategy; IP Feedback design

Task 5. Heat Load Assessment

5.1 Resistive wall
5.2 Geometric impedance, HOM heat load, HOM absorbers
5.3 Heat load from SR, Beamstrahlung, radiative Bhabhas
5.4 Electron clouds

Key deliverable: Thermal power budget

CAD integration

Luigi Pellegrino

PBS - detail

1 1	**Vacuum chamber**
1 1 1	IP AlBeMet chamber
1 1 2	IP AlBeMet chamber cooling system
1 1 3	AlBeMet-copper transitions
1 1 4	Y chamber
1 1 5	Y chamber cooling system
1 1 5	Bellows
1 1 6	BPMs
1 1 7	Vacuum equipment (pumps, gauges)
1 1 8	Vacuum chamber supports
1 1 9	Remote vacuum connection
1 1 10	Chamber alignment system

1 2	**Magnets**
1 2 1	Compensating solenoid left
1 2 2	Compensating solenoid right
1 2 3	Screening solenoid left
1 2 4	Screening solenoid right
1 2 5	Quadrupole 1.1, left
1 2 6	Quadrupole 1.2, left
1 2 7	Quadrupole 1.3, left
1 2 8	Quadrupole 1.1, right
1 2 9	Quadrupole 1.2, right
1 2 10	Quadrupole 1.3, right
1 2 11	Magnets power supply Cables
1 2 12	Magnets I/O Cables
1 2 13	Magnets alignment system
1 2 14	Magnets supports

1 3	**Cryostat**
1 3 1	Cryostat, left
1 3 2	Cryostat, right
1 3 3	Cryostat Cables/piping
1 3 4	Cryostat supports
1 4	**Shielding**
1 4 1	Solenoid shielding
1 4 2	Tungsten shielding
1 5	**IP detectors**
1 5 1	luminosity calorimeter
1 5 2	Vertex detector
1 5 3	Supports
1 5 4	Cables
1 6	**Supporting structures (Main)**
1 7	**Electrical and hydraulic connections main routes**
1 8	**Mechanical IR assembly tools**

Follow-up for the integration of the MDI PBS with the general FCC PBS

WBS - detail

1 1	**Beam pipe design**
1 1 1	IR chamber conceptual design
1 1 2	IP AlBemet chamber design
1 1 3	IP AlBemet chamber cooling system study
	IP AlBemet chamber prototyping
1 1 4	Chambers thermo-structural analysis
1 1 5	AlBemet-copper transitions study
1 1 5 1	AlBemet-copper transitions preliminary design
1 1 5 2	AlBemet-copper transitions fabrication prototyping (?)
1 1 6	Y chamber design
1 1 7	Y chamber cooling system design
	Y chamber prototyping
1 1 8	Bellows design
1 1 8 1	Bellows preliminary study
1 1 8 2	Bellows fabrication prototyping
1 1 9	BPM integration
1 1 10	Vacuum equipment integration
1 1 10 1	Vacuum pumps
1 1 10 2	Vacuum gauges
1 1 11	Vacuum chamber supports design
1 1 12	Remote vacuum connection inclusion
	Remote vacuum connection prototyping

1 2	**Magnets integration**
1 2 1	Conceptual CAD model inclusion
1 2 2	Engineered CAD model inclusion
1 2 3	Cables routing
1 2 4	EM forces data inclusion
1 2 5	Magnets supports design
1 3	**Cryostat integration**
1 3 1	Conceptual CAD model inclusion
1 3 2	Engineered CAD model inclusion
1 3 3	Cables/piping routing
1 3 4	Cryostat supports design
1 3 5	Mounting strategy definition
1 4	**Shielding**
1 4 1	Conceptual CAD model inclusion
1 4 2	Engineered CAD model inclusion
1 4 3	Supports design
1 5	**IP detectors integration**
1 5 1	luminosity calorimeter
1 5 1 1	Conceptual CAD model inclusion
1 5 1 2	Engineered CAD model inclusion
1 5 1 3	Supports design
1 5 1 4	Cables routing
1 5 2	Vertex detector
1 5 2 1	Conceptual CAD model inclusion
1 5 2 2	Engineered CAD model inclusion
1 5 2 3	Supports design
1 5 2 4	Cables routing

1 6	**Vacuum system Integration**
1 6 1	(sub-task re-distributed: see above sub-tasks)
1 7	**Supporting structures**
1 7 1	(sub-task re-distributed: see above sub-tasks)
1 7 2	Integration of Task 4 (Alignment &vibration) inputs
1 8	**Thermal simulations**
1 8 1	Thermal management of the whole IR
1 8 2	(sub-task re-distributed: see above sub-tasks)
1 9	**Management of electrical and hydraulic connections/routing**
1 9 1	(sub-task re-distributed: see above sub-tasks)
1 10	**Mechanical IR assembly, disassembly & repair procedures**
1 10 1	Study of mounting strategy
1 11	**Project Design Management**
1 11 1	PDM tool definition
1 11 2	PDM tool settings
1 11 3	PDM tool maintenance

CAD & PDM @ Frascati Mechanical Engineering Group (Accelerator Division)

- Autodesk INVENTOR Pro 2020 (INFN National License)
- Autodesk VAULT Pro 2020
  - 9 Mech Eng Group users
  - 3 external users from other Frascati Groups
- Autodesk Sharedviews
  - Any number of external non-CAD users via WEB (access via web-link – you can manipulate the 3D model, take measurements, make sections, take and share notes, save images…)

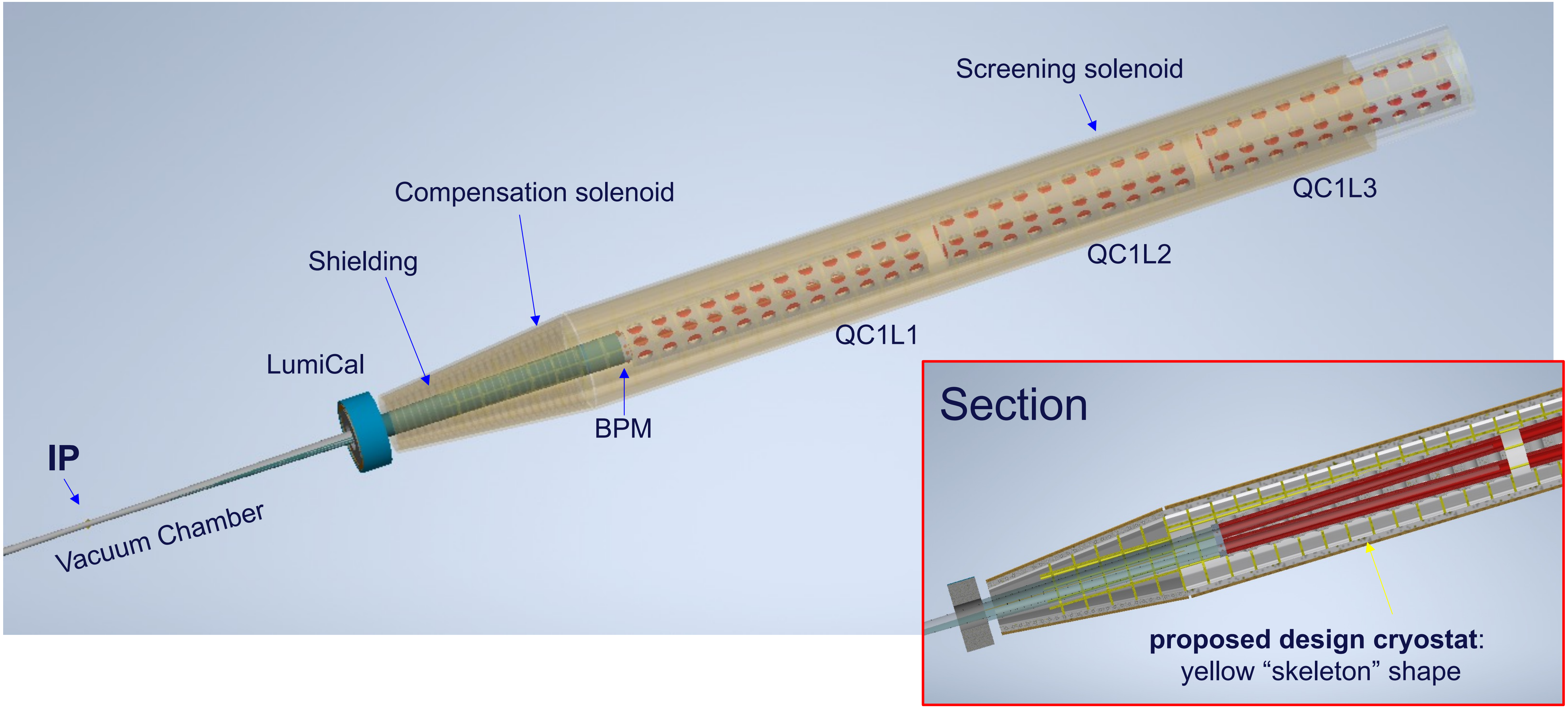
We should start using a collaborative tool for CAD at a broader level (i.e. outside the Frascati Group)

- First Option: use the CERN standard tools (should we switch to CATIA?)
- Backup provisionary choice: extend the Frascati Autodesk Vault Pro license to other CAD users (about 500€/user) to collaborate in designing components and/or import neutral format CAD files in our system.

Follow-up for the integration in the CERN PDM for FCC (management of the design activities)

Preliminary assembly of the MDI

[F. Fransesini]



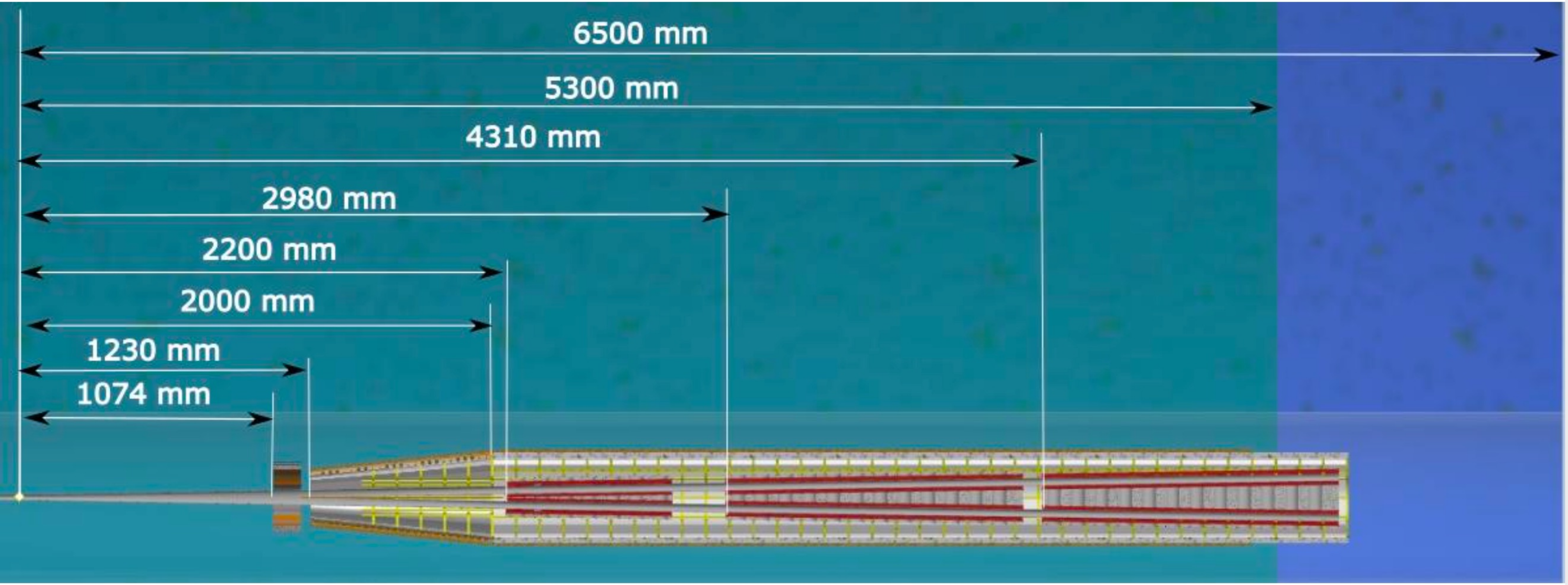
proposed design cryostat:
yellow “skeleton” shape

Preliminary assembly of the MDI

Coordinates for the assembly elements (optics v241):

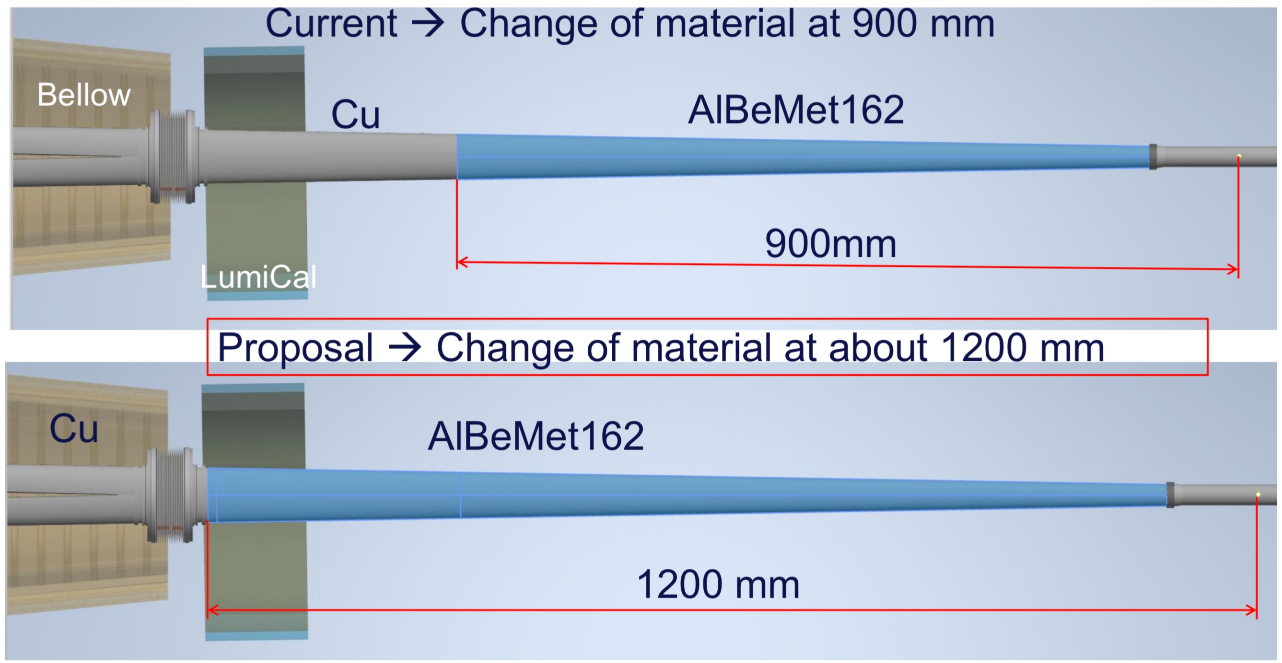
CLD

IDEA



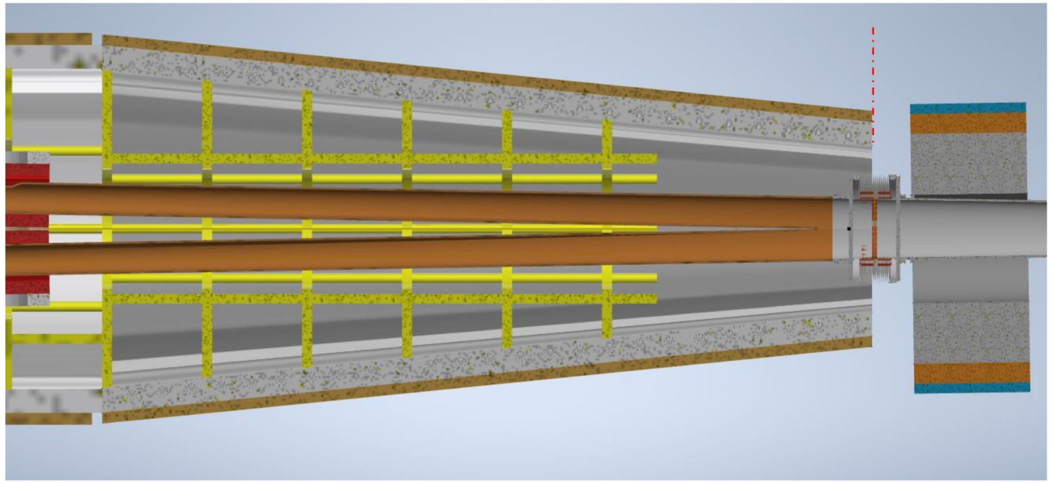
Mechanical Model

Francesco Fransesini

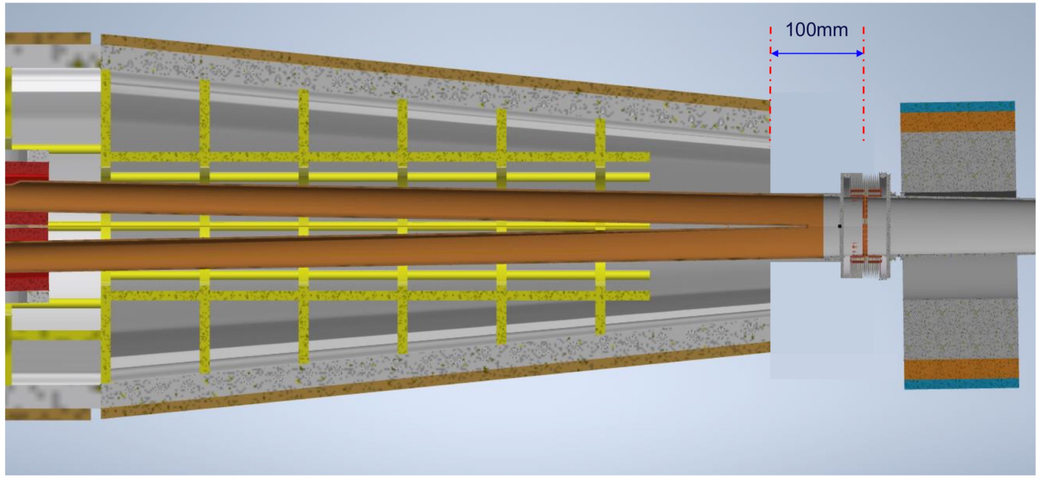

Current → Change of material at 900 mm

Proposal → Change of material at about 1200 mm

Current



Proposal



Proposal for prototypes

Some prototyping is necessary to check the feasibility of the chosen technological solutions:

- **Central IP chamber**: to set and test the paraffin cooling system and to verify the assembly procedure from a vacuum point of view.
- **AlBeMet162-Cu transition**
- **Bellow**: we are studying an upgrade of the bellow used in DAΦNE at INFN (Frascati)

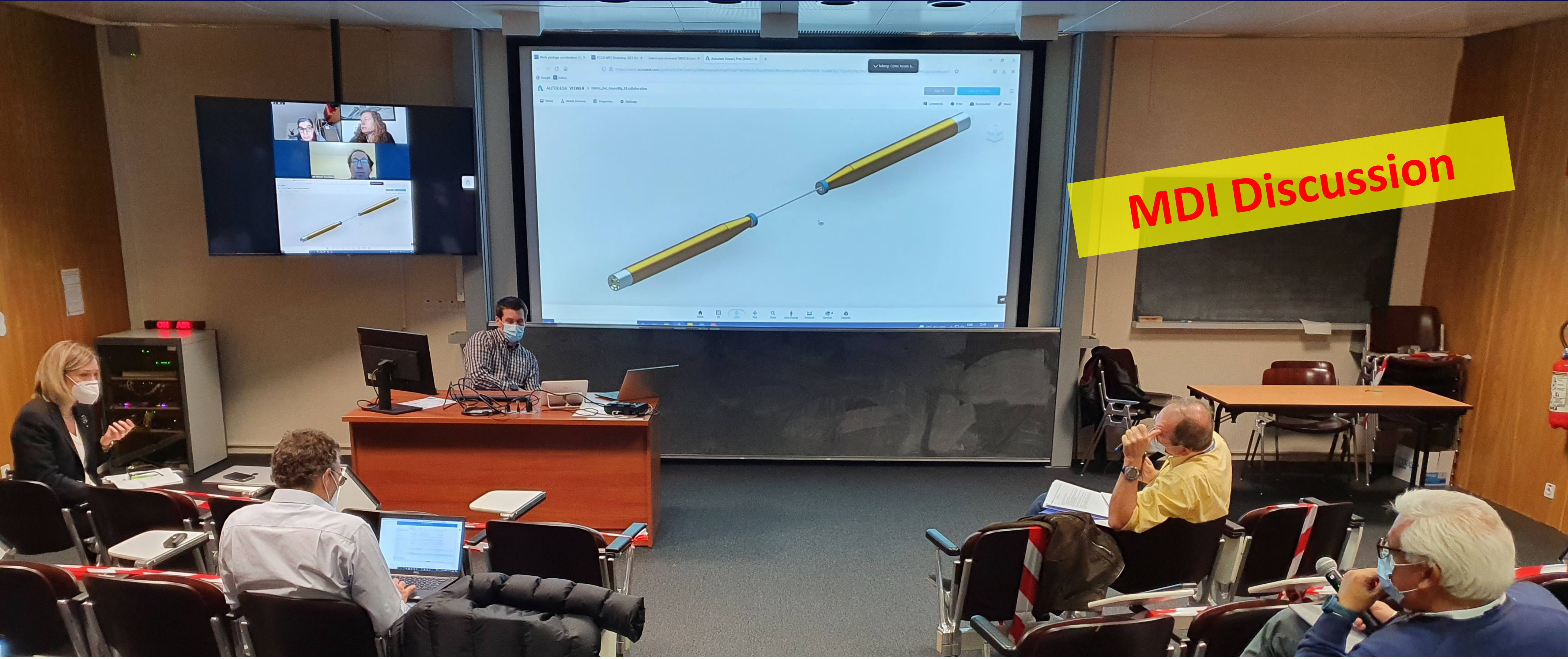
WORK IN PROGRESS -2

- Collect components design, have and give feedbacks on them
- Design (CAD & thermo-mech simulation) of:
  - Paraffin cooled AlBeMet central chamber and Y chamber
  - Bellows and transitions
  - Layout and space management
  - Supports
- Prototyping proposal (*). Cost estimate 100’000 €
  - Central IP chamber
  - AlBeMet162-Cu transition with integrated bellow

(*) see Fransesini presentation

Here you can find the current CAD of the IR: https://autode.sk/2ZMssyr

MDI Discussion



Some comments from the discussion

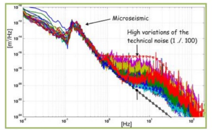
Current design of SC QC1 and solenoids seem too tight to fit into the 100 mrad cone required by the detector group. We need to advance with the engineering design of the magnets, switching to a SC magnet design. In addition, let’s keep in mind that IR magnets design should include its mounting and alignment strategy, and maintenance aspects.

For the MDI integration it is important to define dimensions of detector and hall. Need to define in advance the maintenance procedure with a retractable design, define if we go for a cantilever configuration.

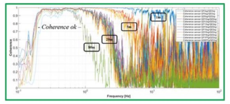
Madx simulations of MDI Vibrations

Eva Montbaron

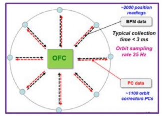
FCC-ee vibrations studies



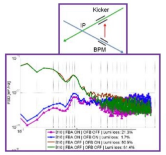
PSD displacement of various experiment sites



ATF2 coherence



LHC Feedback controller design



CLIC post IP BPM feedback

Vibrations level

Coherence

Mechanics transfer functions

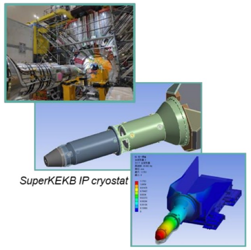
Instrumentation: resolution and noise

Beam control

FCC-ee vibrations studies

LHC Beam Position Monitor

Vibration sensor

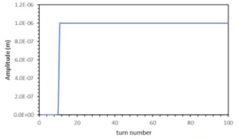


SuperKEKB IP cryostat

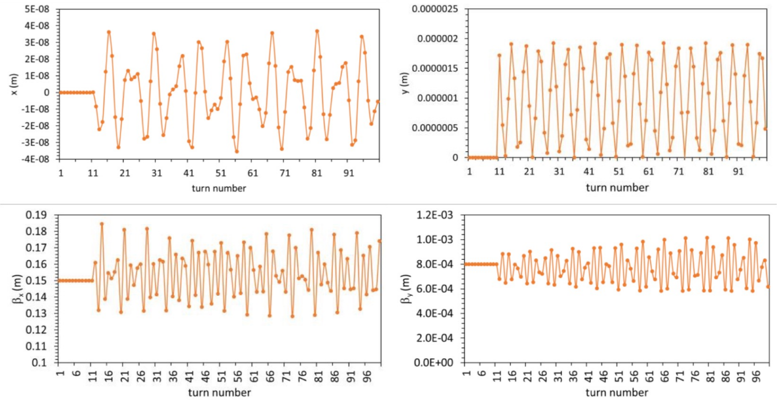
First works with MAD-X

Introduce static misalignments and perform iterative simulations:

- TWISS module used
- 100 turns
- No global correction considered
- Observables @ IP2: β_x, β_y and x, y offsets
- “Old” Z lattice, 2 IPs



Vertical misalignment of QC1



Summary and perspectives

Conclusions:

- Ongoing work to define properly vibrations in MAD-X (PSD)
- Integration of mechanical design in optics simulations
- Complementary study to misalignments results
- Parallel made with SuperKEKB vibrations studies
- Gradually complexify vibrations simulations in MAD-X for MDI studies with the add of mechanical specifications ⇒ check criticality of vibrations in FCC-ee

Lots of things to do before getting and presenting numerical results…

Long-term perspectives:

- Integrate mechanical transfer functions in the definitions of beam elements misalignments
- Consider RF and Radiation (6D problem)
- Test global and local corrections
- Inclusion of previous misalignments and correction
- Consideration of both e^+ and e^- beams (2 different beam pipes)

Vibration tolerance for IP and arc magnets, feedback performance criteria

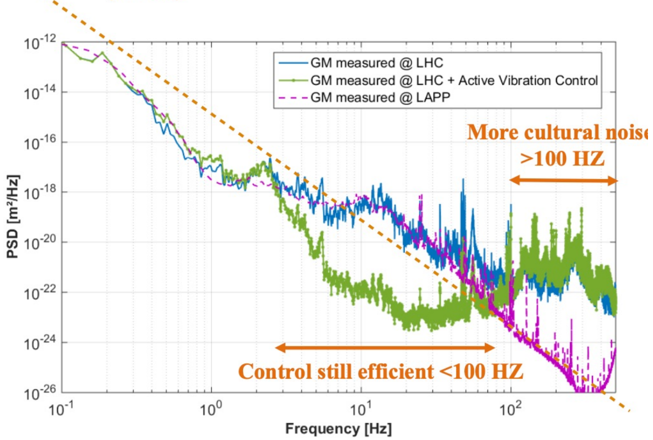
Summary

FUTURE CIRCULAR COLLIDER

Tolerances for the vibration of quadrupoles are evaluated for three cases:

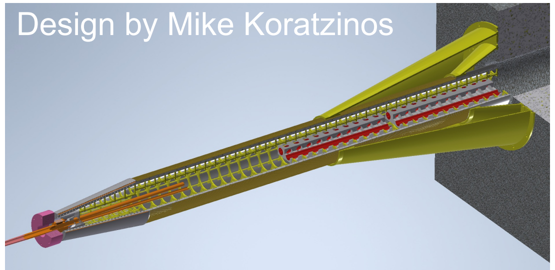
- A seismic wave has smaller effects than random motion of each quadrupole for an equal amplitude.
- Resonance with the betatron frequency: weak, as the betatron frequency is in the range of kHz.
- Non-resonant, incoherent vibration of each quad produces 30 nm vertical motion at the IP for ≧1 Hz.
  - Mostly by the final quads QC1.
  - Assuming each quad follows the ground motion measured at LHC & LAPP.
  - No amplification of the mechanical motion of the girders has been assumed.
  - Below a frequency $\lesssim 10$ Hz, a vertical orbit feedback is required.
- IP vertical offset can be detected by the beam-beam deflection.
  - For horizontal except for tt, dithering method can be user to maximize the luminosity.
- A simple vertical bump orbit can correct the IP offset easily.
  - Frequency response can be an issue.

$$\sim 10^{-15}\left(\frac{\omega}{2\pi\mathrm{Hz}}\right)^{-4}\ \mathrm{m^2/Hz}$$

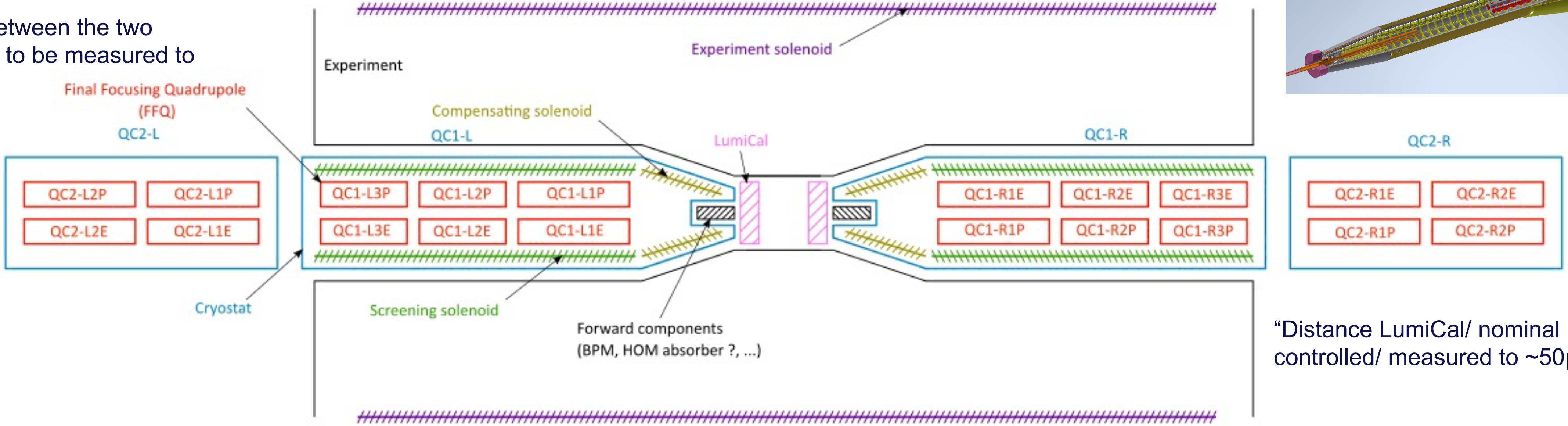


M. Serluca, et al.

FCC-ee MDI requirements so far


Design by Mike Koratzinos

“ The distance between the two calorimeters has to be measured to 110 µm”



“Distance LumiCal/ nominal IP to be controlled/ measured to ~50µm level”

“Final Focusing quads misalignment (QC1_1-QC1_3 and QC2_1-QC2_2) (if not respected, beams do not collide):

- Geodesy : transverse shift of FF quads with sigma xy= 25µm
- vibrations : transverse shift of FF quads with sigma xy= 0.1µm

IR BPM misalignment (if not respected, beams do not collide) :

- geodesy : transverse shift of BPM with sigma xy= 25µm
- vibrations : errors of BPM reading with sigma xy= 0.1µm”

“Internal misalignment should be better than 30µm”

“Measurement of the component's position inside the detector is needed”

“IR quadrupoles and sextupoles (75µm in radial and longitudinal, 100µrad roll), BPM (40µm in radial and 100µrad for the roll relative to quadrupole placement).”

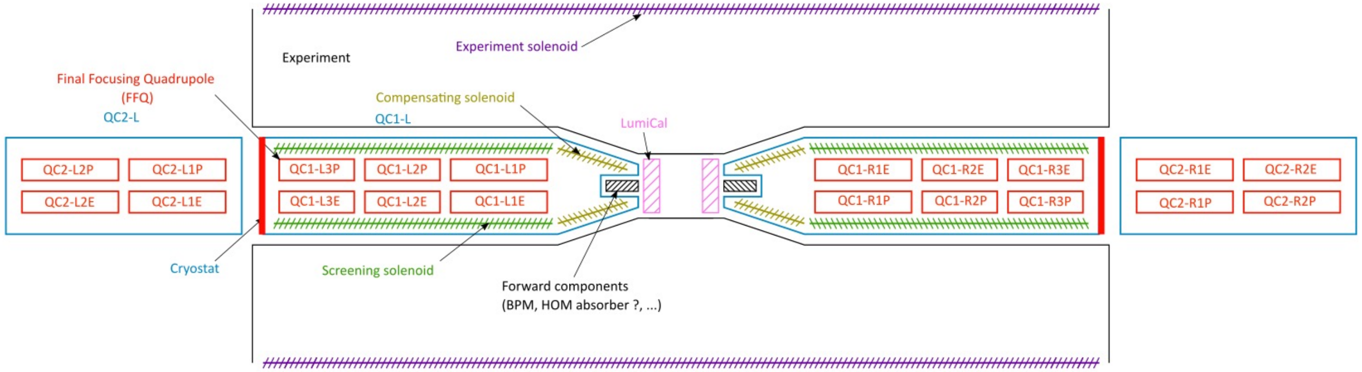
“For a 1mrad tilt of the detector solenoid (wrt the rest of the system – beam, screening and compensation solenoid) the corresponding uncorrected distortion is unacceptably large.”

“Alignment accuracy of SC magnets = 100µm”

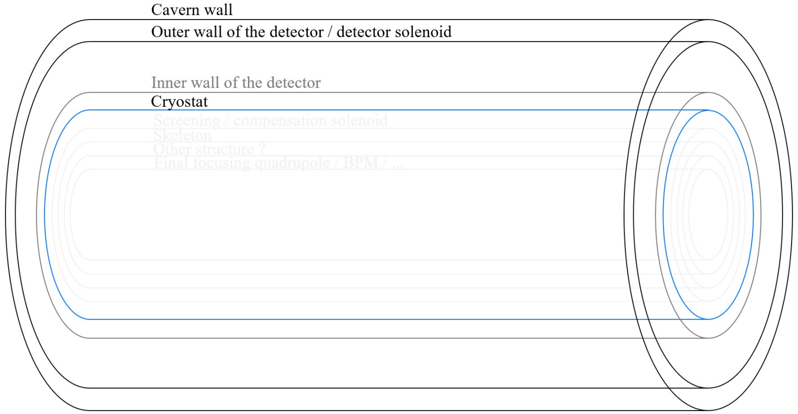
References at the end of the presentation

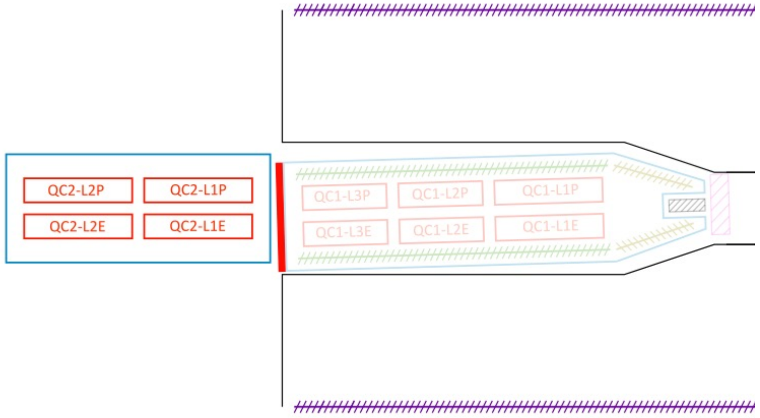
Strategy for a new system

Two systems to monitor the MDI:
- external monitoring system
- Internal monitoring system

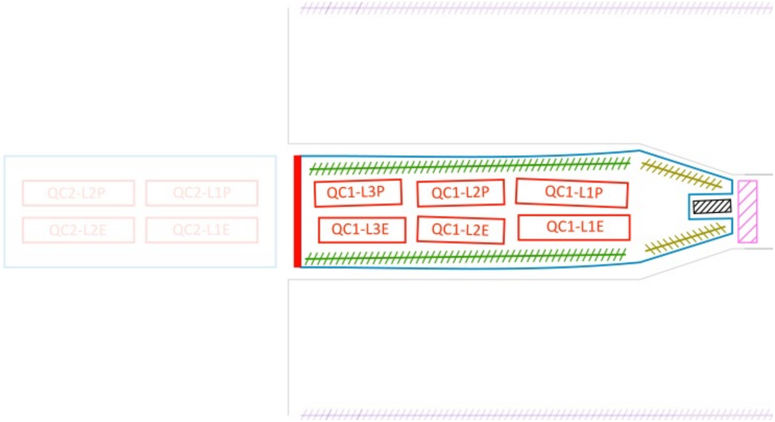


The interface will be monitored from the outside of the experiment. The network will determine the translations and rotations (and scale factor if required) of the interface. Doing that will allow the alignment of the interfaces of the two sides of the detector.





The interface will serve as an origin to compute the deformations of the cryostat and/or skeleton and the position of the inner elements.

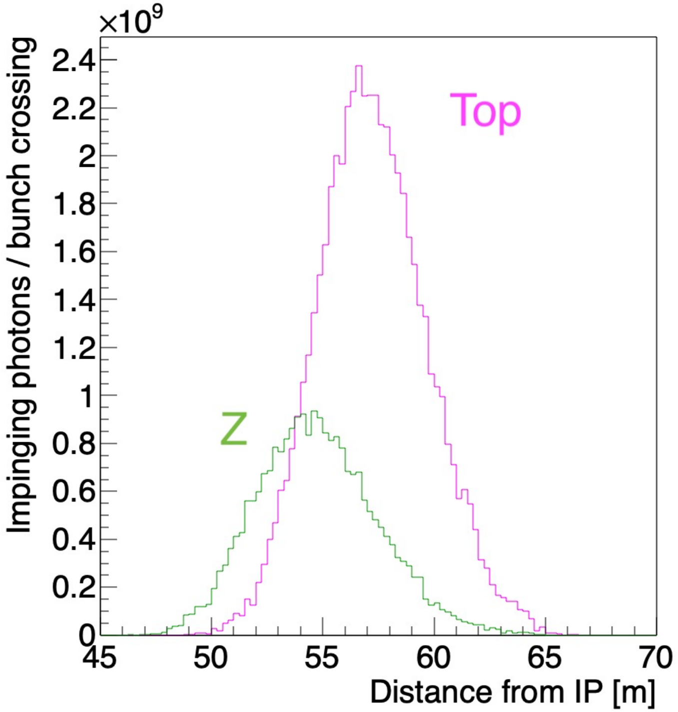


IPAC21: 2105.09698

Beamstrahlung Radiation generated at the IP

[GuineaPig++]

- A significant flux of photons is generated at the IP in the very forward direction by Beamstrahlung, radiative Bhabha, and solenoidal and quadrupolar magnetic fields.
- **Beamstrahlung** interactions produce an **intense source of locally lost beam power**
- The impinging angle of the **Beamstrahlung** photons with the pipe is about 1 mrad for both beam energies.



Andrea Ciarma

Beamstrahlung photons tracked up to their loss points, at about 50-60 m after the IP

Handling of incident beamstrahlung

	Beam energy	**Beamstrahlung Radiation power**
<Eγ> = 2 MeV	45.6 GeV	387 kW
<Eγ>=67 MeV	182.5 GeV	89 kW

Beamstrahlung monitor

Alain Blondel

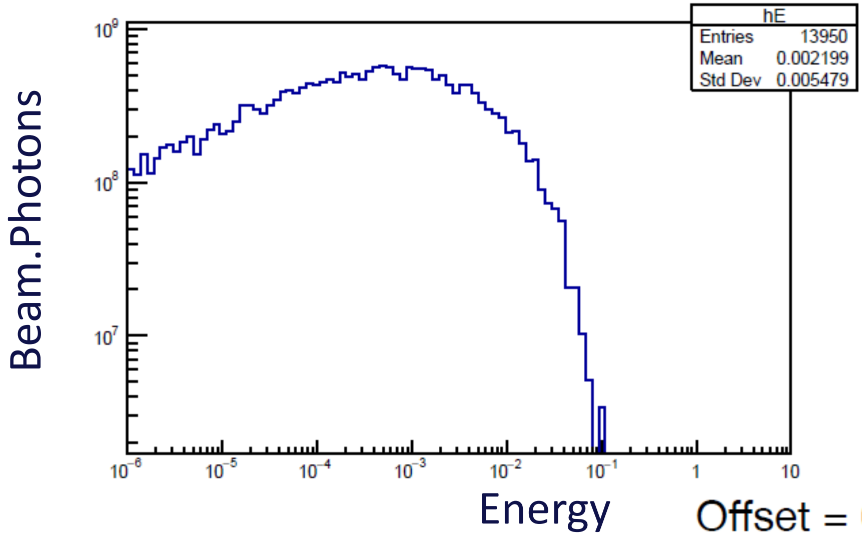
At full luminosity, a vernier scan is a tricky operation and beam beam blow up effects might affect the result

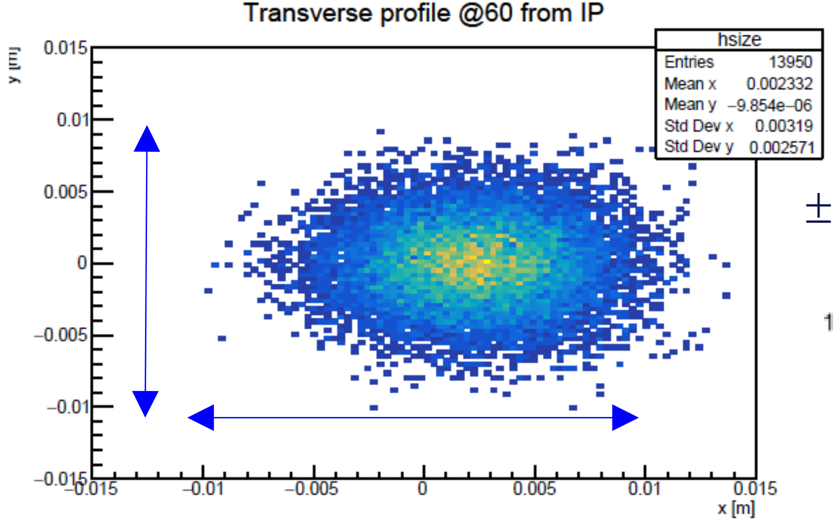
Therefore a beamstrahlung or radiative bhabha monitor seeems highly worthwhile as it give
information on the direction of the interacting particles.
it detects
the hard photons emmitted in either e+e- → e+e- γ
or
the hard beamstrahlung photons

Photons are not affected by the IR magnetic fields.
The beam-beam offset leads to a shift in the beamstrahlung photon beam which is **proportional** to the offset (and to the charge of the opposite beam) for small offsets.
the measurement <u>is passive</u>
the zero position can be operationally established by colliding beams at lower intensity where large vernier scan amplitude is possible.

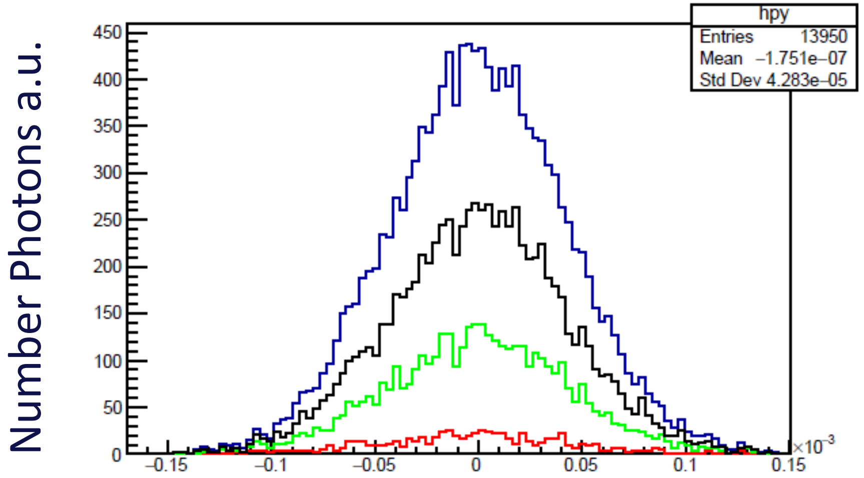
An angular kick of up to 0.18 mrad is expected in the horizontal plane due to EM attraction.

Beamstrahlung/radiative Bhabha monititor: ongoing work by Andrea Ciarma

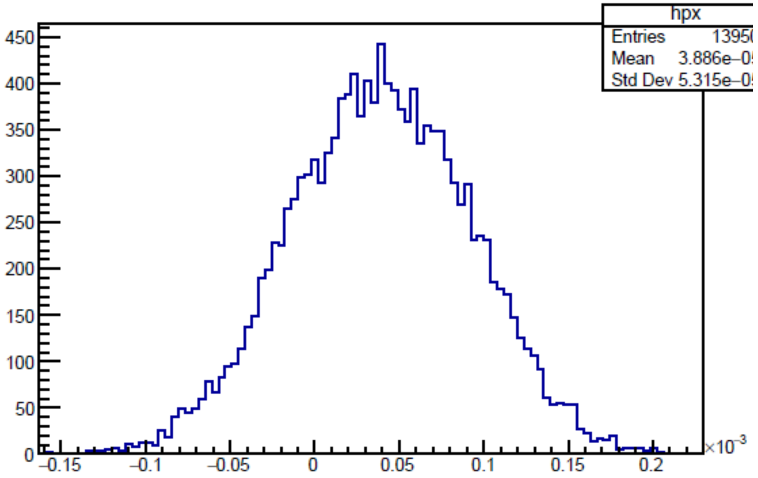




Offset = 0.0 sigma_y



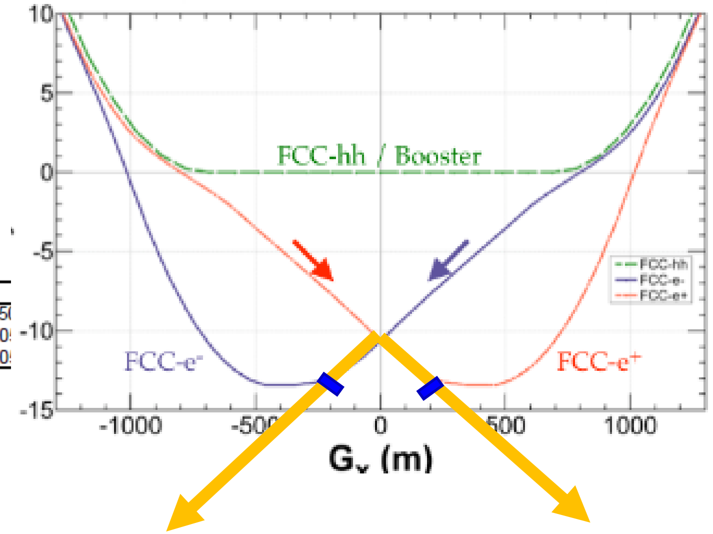
photon y angular distribution (rad)



photon x angular distribution (rad)

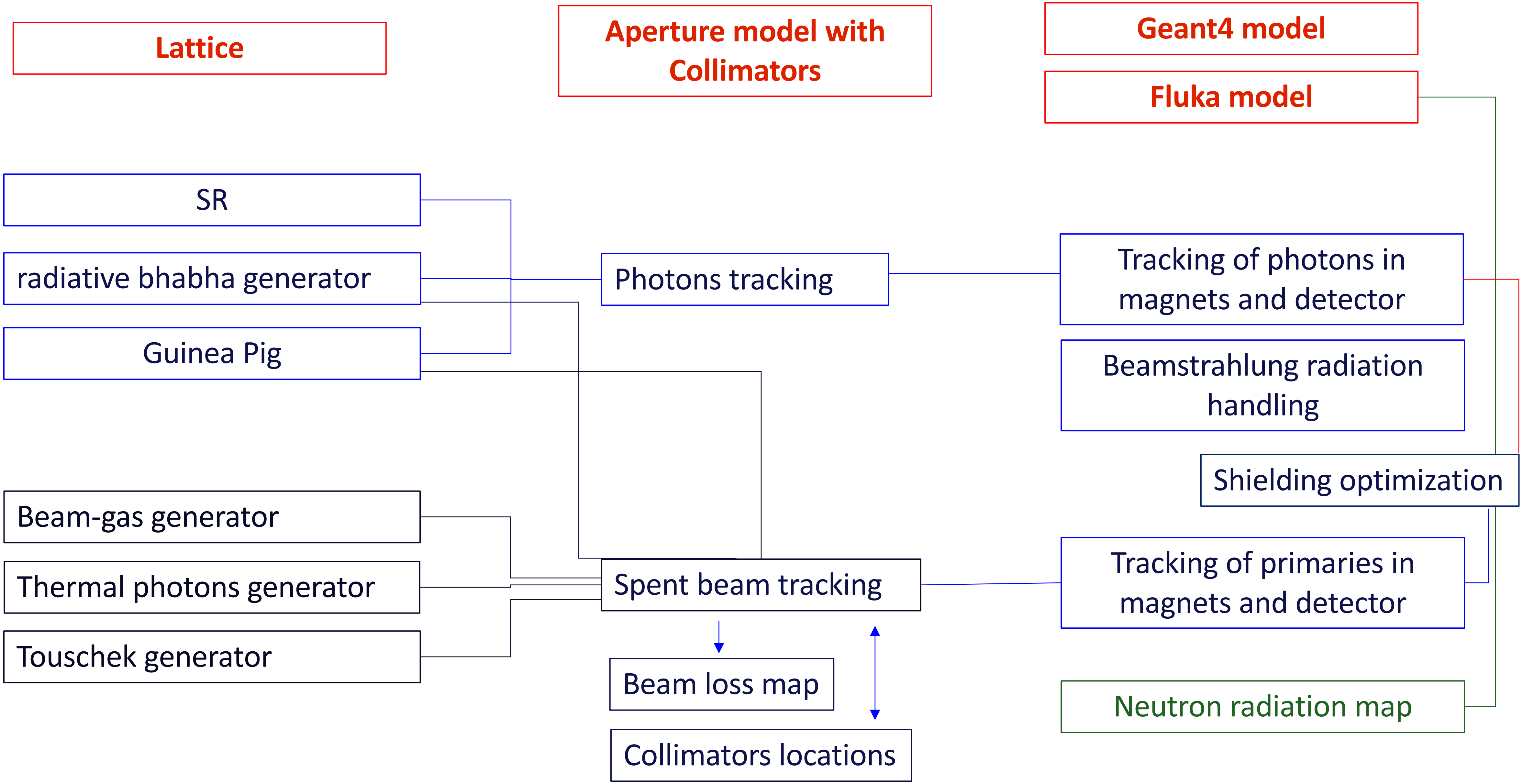
Beamstrahlung, to be understood if radiative bhabhas are masked by beas.

± 1 cm spot of beamstrahlung photons



detect photons at exit from bending magnet in a deteector system that is all to be designed!

Task 2. Backgrounds, beam losses and radiation



Lattice

Aperture model with Collimators

Geant4 model

Fluka model

SR

radiative bhabha generator

Guinea Pig

Photons tracking

Tracking of photons in magnets and detector

Beamstrahlung radiation handling

Shielding optimization

Beam-gas generator

Thermal photons generator

Touschek generator

Spent beam tracking

Beam loss map

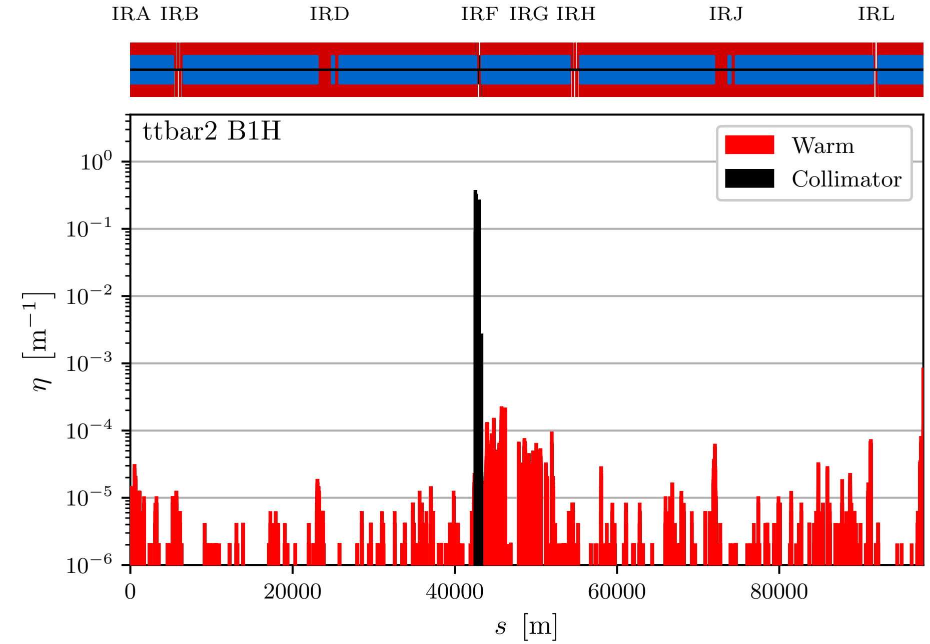
Collimators locations

Tracking of primaries in magnets and detector

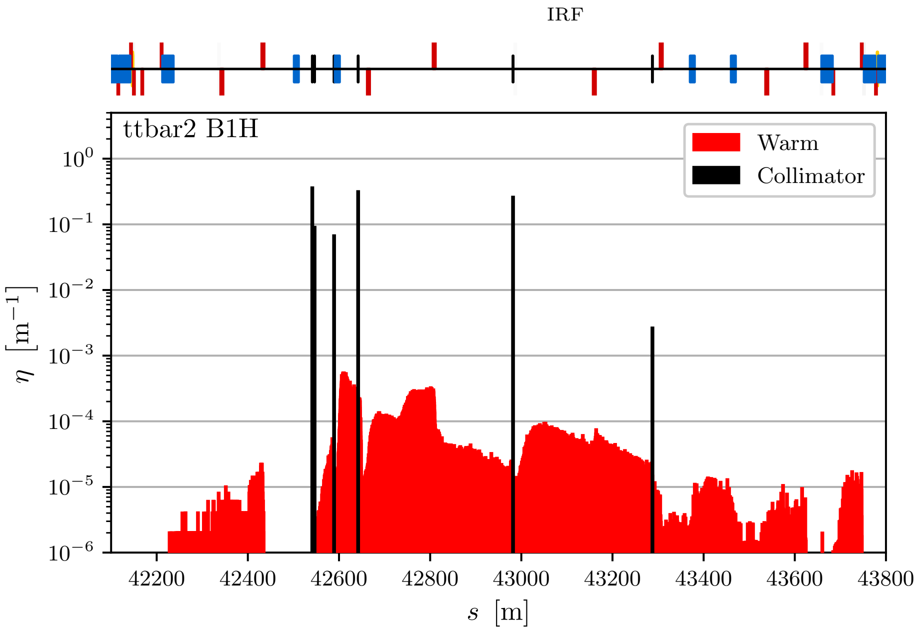
Neutron radiation map

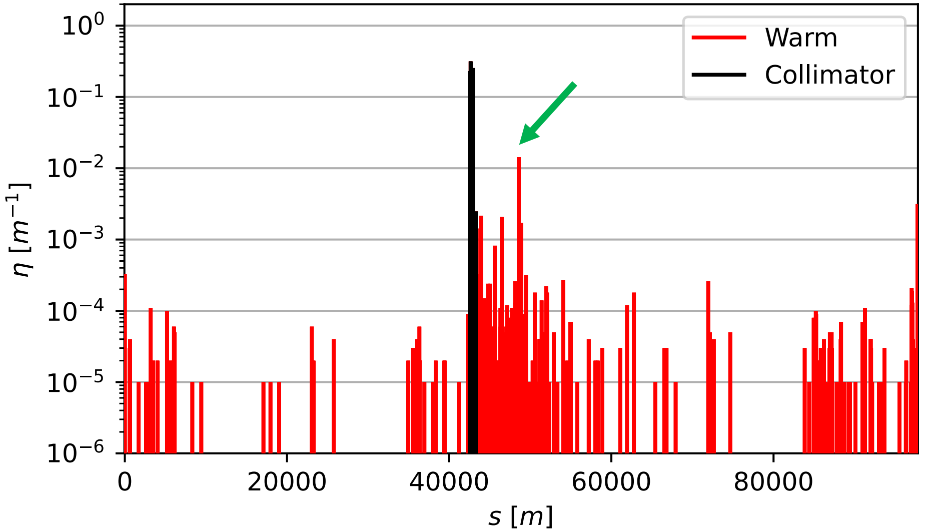
Andrey Abramov

Loss map comparison

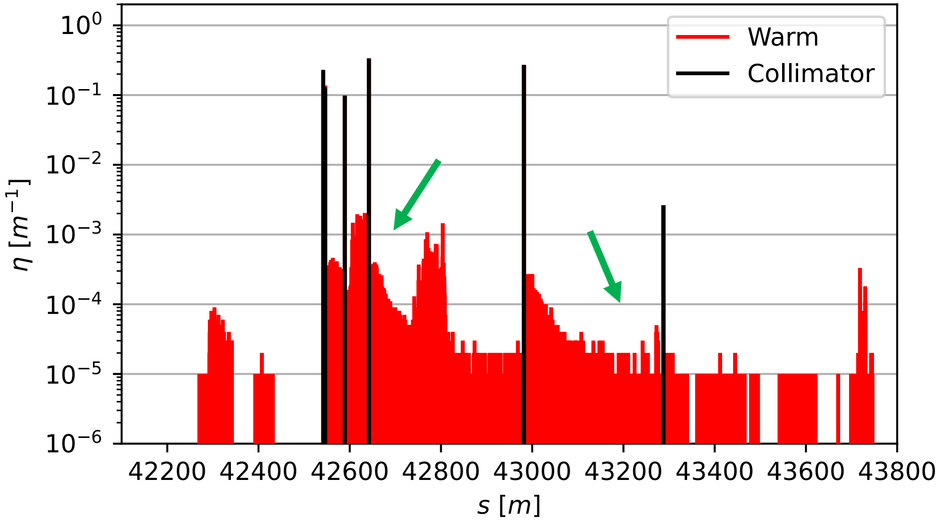


SixTrack-FLUKA





pyAT-Geant4



Some comments on the next steps for collimation and beam backgrounds

We will work together with the collimation team and supply the background events to track.
Work needed to choose the background level for the background sources.

Some next steps on SR backgrounds

- Tolerances in orbit in combination with top-up injection might lead to additional radiation effects.
- Optics changes with potential impact on the SR reaching the IR require new SR simulations. One example is a shift of the last dipole for the insertion of the polarimeter.
- Tail collimation.
- SR collimators in the MDI area, definition of location through the ring.
- SR mask hardware design.
- SR from realistic solenoidal field, using map field.

Some follow-up items

- PDM / CAD to be chosen, compatible with CERN standard
- IR Prototypes
- SC IR magnets design, especially QC1 -> vibration study, alignment
- Integration: detector space and constraints, hall to be taken into account
- Collimation scheme & loss map
- Backgrounds sources and level
- Beamstrahlung monitor & radiative bhabha monitor

Some present hot topics

Flow chart

Prioritization of topics as well as dependencies with other groups in view of the timeline:

- February 2022: 5th Physics workshop, Liverpool
- May/June 2022: FCC WEEK 2022
- June 2023: Mid-term review
- 2025: end of FS

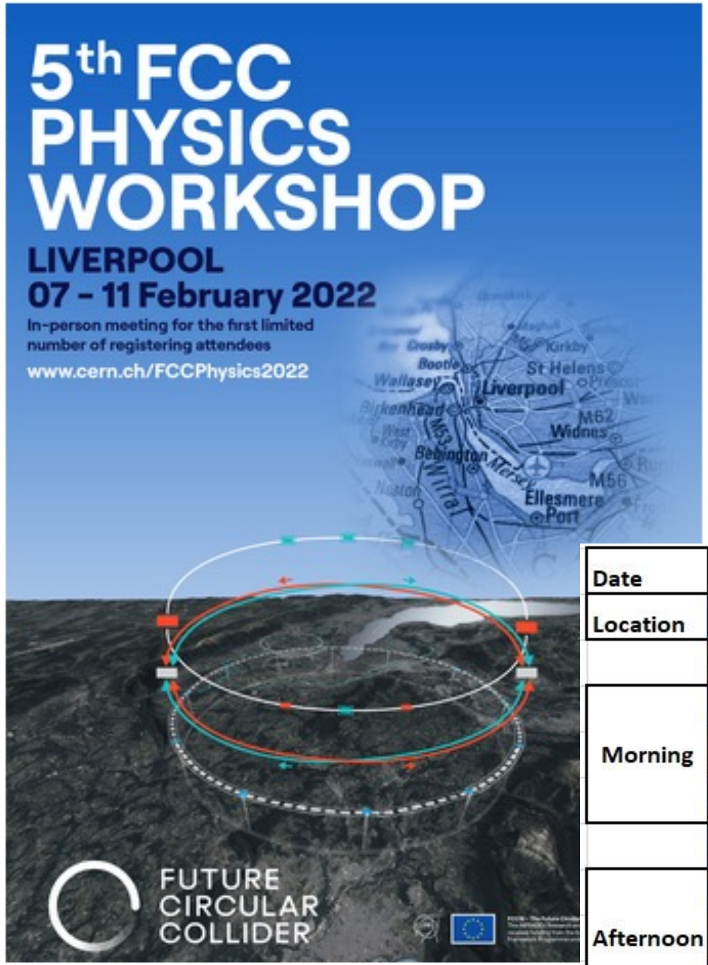
Additional topics to be addressed in this FS

Look at each machine for each energy run individually to optimize layout accordingly.

Follow-up of SuperKEKB problems and progress

FCC Physics Workshop 7-11 February 22

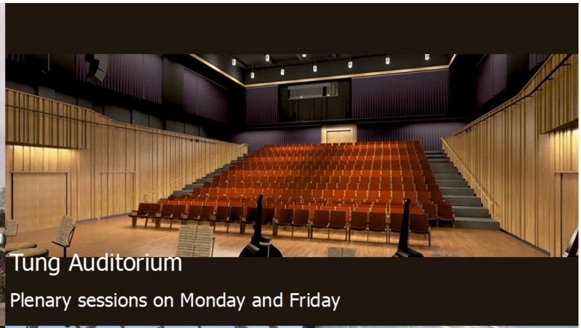
Liverpool, UK



5th FCC
PHYSICS
WORKSHOP
LIVERPOOL
07 - 11 February 2022
In-person meeting for the first limited number of registering attendees
www.cern.ch/FCCPhysics2022

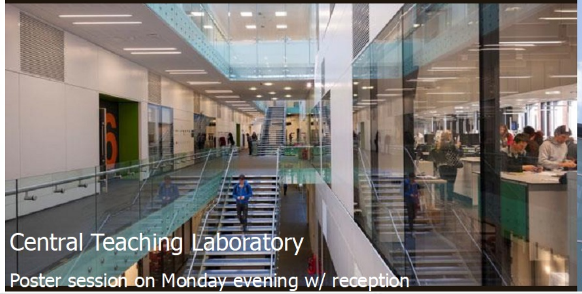
FUTURE
CIRCULAR
COLLIDER

Yoko One Lennon Centre
University of Liverpool

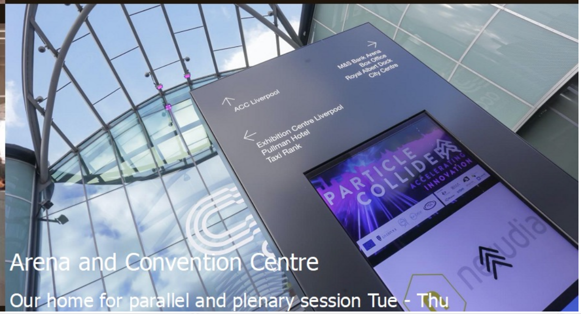


Tung Auditorium
Plenary sessions on Monday and Friday

Royal Liver building
Dinner venue



Central Teaching Laboratory
Poster session on Monday evening w/ reception



Arena and Convention Centre
Our home for parallel and plenary session Tue - Thu

number of in-person participants limited to ~160 (first come -- first served)
- registration fee: 300£
- broadcast on zoom

Date	Monday 7.2.22		Tuesday 8.2.22		Wednesday 9.2.22		Thursday 10.2.22		Friday 11.2.22	
Location	***UoL Campus***		***ACC***		***ACC***		***ACC***		***UoL Campus***	
	Coffee/Tea		*Coffee/Tea*		*Coffee/Tea*		*Coffee/Tea*		*Coffee/Tea*	
Morning	Plenary	Yoko Ono LT	Parallel	Rm 4A, 4B, 14, 12	Parallel	Rm 4A, 4B, 14, 12	Plenary	Rm 11	Plenary	Yoko Ono LT
	Coffee Break		Coffee Break	Rm 12	Coffee Break	Rm 12	Coffee Break	Rm 11	Coffee Break	
	Plenary	Yoko Ono LT	Parallel	Rm 4A, 4B, 14, 12	Parallel	Rm 4A, 4B, 14, 12	Plenary	Rm 11	Plenary	Yoko Ono LT
	Lunch		**Lunch**	Rm 12	**Lunch**	Rm 12	**Lunch**	Rm 11		
Afternoon	Plenary	Yoko Ono LT	Parallel	Rm 4A, 4B, 14, 12	Excursion	Around Liverpool City Centre	Plenary	Rm 11		
	Coffee Break		Coffee Break	Rm 12			Coffee Break	Rm 11		
	Plenary	Yoko Ono LT	Parallel	Rm 4A, 4B, 14, 12			Plenary	Rm 11		
Evening	Drinks and Posters	Atrium CTL	Outreach Event	Anglican Cathedral	Dinner	Liver Building				

FCC Week 2022

In Paris 30 May to 3 June 2022

We are looking forward

to seeing you there !