SUMMARY FROM THE FCCIS COLLABORATION MEETING AND STEPS GOING FORWARD

Manuela Boscolo and Mike Sullivan

thanks to Luigi Pellegrino

13 December 2021
MDI meeting #35

Outline

Summary of the MDI related discussions at the FCCSIS workshop with current status of the activity plan for MDI and follow-up topics

Agenda MDI session 3/12

MDI Part 1		
09:00 - 09:20	MDI status and plans	Manuela Boscolo
09:20 - 09:40	Mechanical model	Francesco Fransesini
09:40-10:00	CAD integration	Luigi Pellegrino
break		
10:15 – 10.40	Alignment system in the MDI	Leonard Watrelot
10:40 – 11:00	Vibration tolerance for IP and arc magnets, feedback performance criteria	Katsunobu Oide
11:00 – 11:20	Strategy for vibration suppression	Laurent Brunetti
11:20 – 12:00	MADX simulations of vibration in the MDI	Eva Montbarbon
Lunch		

MDI Part 2		
13:30 – 14:00	Low angle radiative bhabha monitor	Alain Blondel
14:00 – 14:30	CCT magnet design	Mike Koratzinos
break		
15:15	CCT magnet tour	

MDI main tasks

1. Engineering mechanical model with assembly concept
2. Backgrounds, beam loss and radiation
3. Conceptual design of IR elements/systems
4. Alignment tolerances & vibration control
5. Heat load assessment

FCC-ee MDI activity plan

Draft

Task 0. Coordination (INFN, SLAC)

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

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. (CERN, INFN)

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 (MIT, BINP, INFN, NBI, SLAC, CERN)

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 (CERN)

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

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

Task 5. Heat Load Assessment (INFN, SLAC, CERN)

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

1. Engineering mechanical model with integration and assembly concept (INFN)

- Beam pipe design
- Magnets integration
- Cryostat integration
- Shielding design
- IP detectors integration
- Vacuum system integration
- Supporting structures design
- Thermal simulations
- Management of electrical and hydraulic connections/routing
- Mechanical IR assembly, disassembly & repair procedures
- Project Design Management

This activity comprehends *the integration and/or the design* of the systems, as indicated

CAD integration

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Luigi Pellegrino

PBS - detail

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

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**

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.

WBS - detail

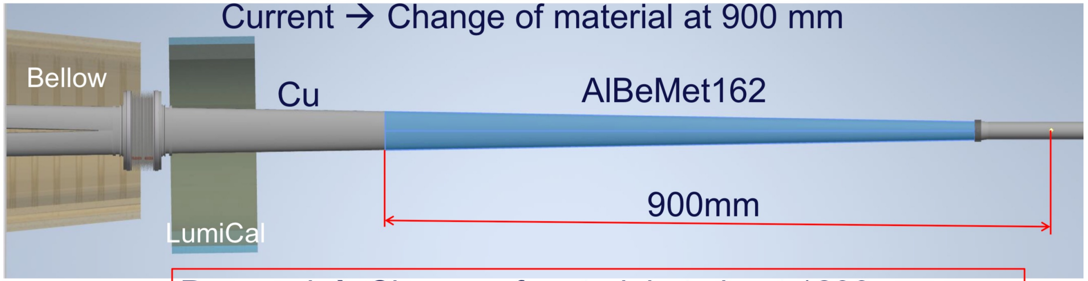
1 1	**Beam pipe design**
1 1 1	IR chamber conceptual design
1 1 2	IP AlBemet chamber design
1 1 3	IP AlBemet chamber cooling system study
	IP AlBemet chamber prototyping
1 1 4	Chambers thermo-structural analysis
1 1 5	AlBemet-copper transitions study
1 1 5 1	AlBemet-copper transitions preliminary design
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

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

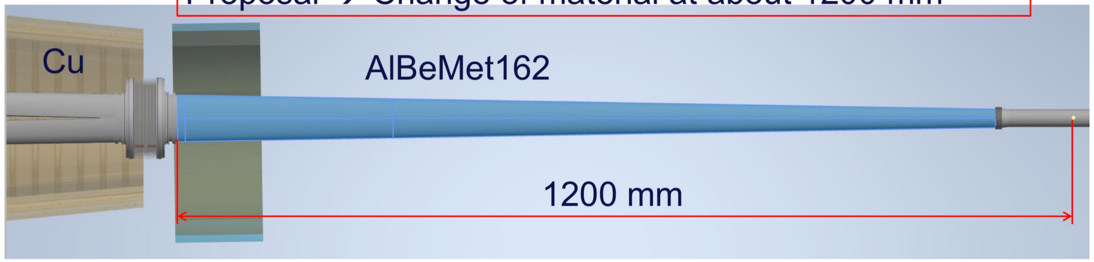
Mechanical Model

Francesco Fransesini

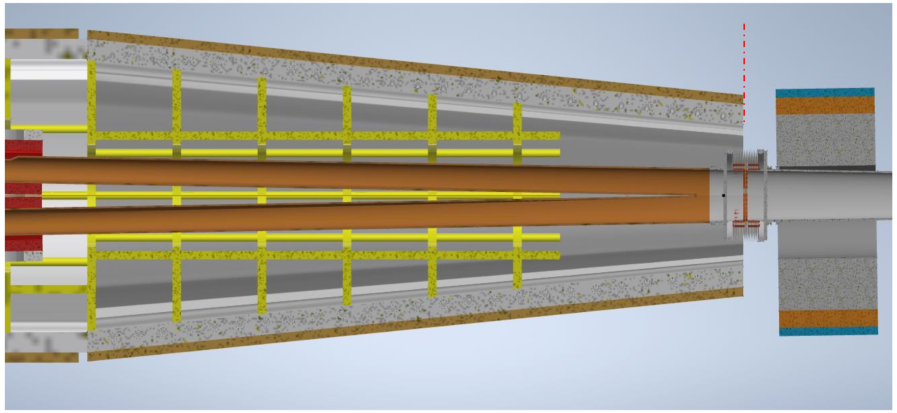
Current → Change of material at 900 mm



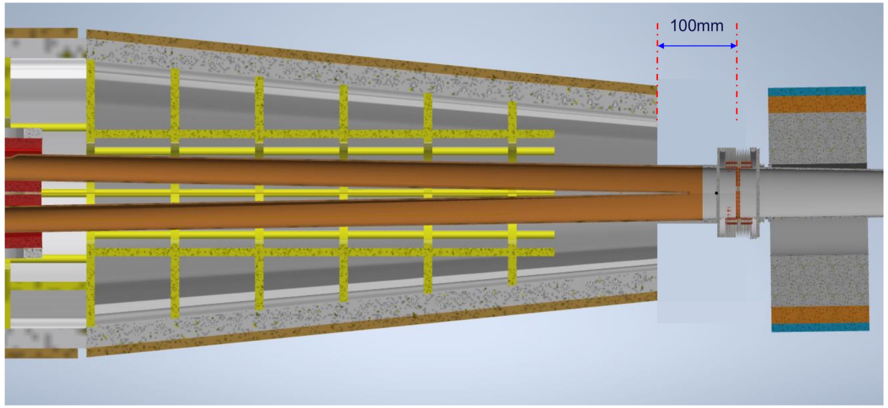
Proposal → Change of material at about 1200 mm



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

Follow-up to detail the prototype proposal

3. WBS Conceptual design of IR elements/systems

ID CODE			
3			**Task 3. Conceptual design of IR elements/systems**
3	**1**		**IR magnets design**
3	1	1	Quadrupole
3	1	2	Compensating solenoid
3	1	3	Screening solenoid
3	**2**		**Cryostat design**
3	**3**		**Luminosity calorimeter design**
3	**4**		**Vertex detector design**
3	**5**		**Remote vacuum connection**
3	**6**		**HOM absorbers design**
3	7		**IR beam diagnostic devices design**
3	**7**	**1**	BPM design
3	7	2	Beamstrahlung monitor design

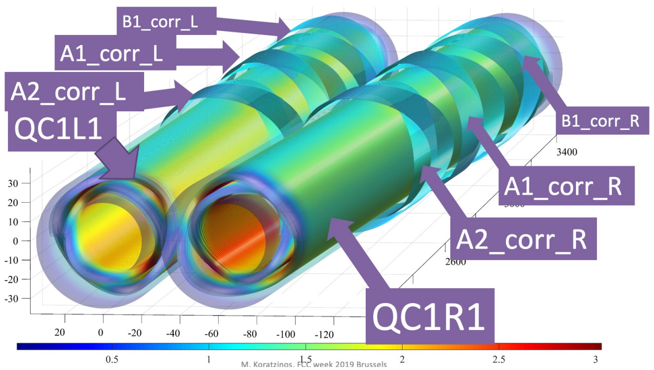
Final Focus quadrupole canted cos-theta design
NEXT STEPS, M. Koratzinos

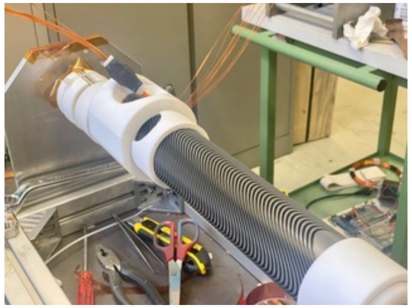
Testing the magnet at cold not foreseen at the moment

- Without impregnation – there is not enough data on impregnation-free magnet performance
- With impregnation (wax or beeswax) – better mechanical characteristics at cryogenic temperatures (cracking) and possible to remove and dismantle

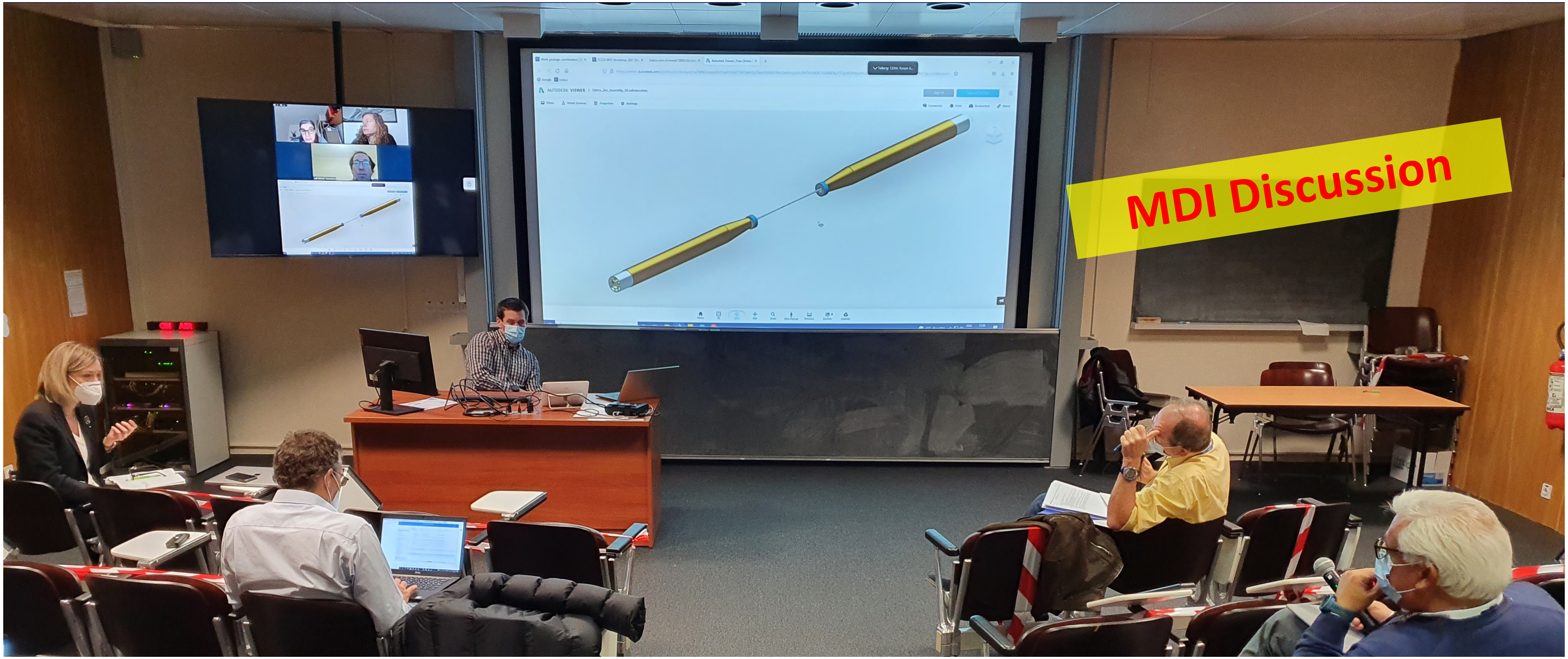
Development of a double aperture prototype

- We can check the full crosstalk compensation
- Design the support mechanics
- Can perform vibration studies





prototype
during construction



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.

4. Alignment tolerances & vibration control

- Alignment specifications
- Alignment /survey strategy, space requirements
- Vibration study, stabilization strategy, space requirements
- Feedback systems for beams collision adjustment; ; feedback to maintain luminosity with top-up injection

CERN

LAPP

5. Heat load assessment

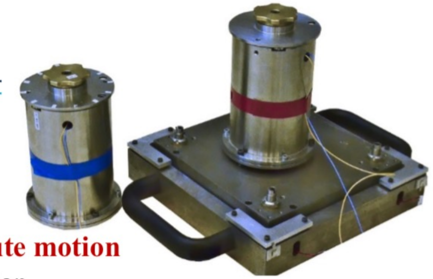
- Resistive wall
- Geometric impedance, HOM heat load, HOM absorbers
- Heat load from synchrotron radiation, Beamstrahlung, radiative Bhabhas
- Electron clouds
- Cooling of detector elements

Vibration Mitigation Strategies

Laurent Brunetti

LAPP

FCC ee mitigation

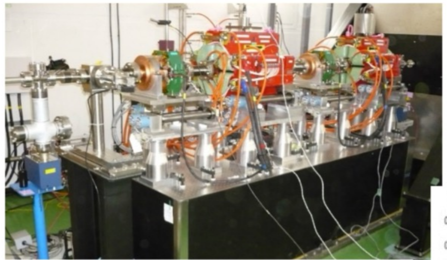


- **Vibrations mitigation strategy – illustrations with LAPP developments**

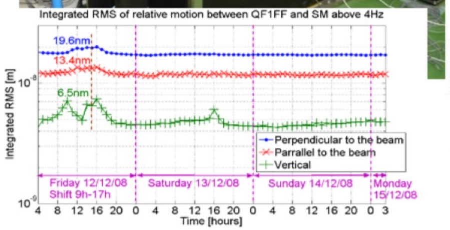
Option "low cost"

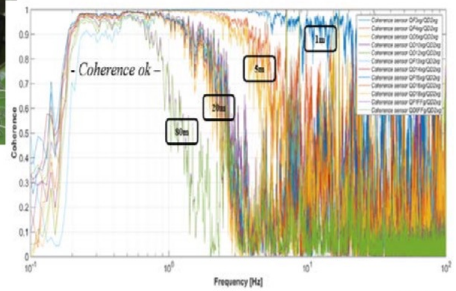
- **Based on the coherence motion, reducing the relative motions between the elements : strategy of the main experiments**

Example of ATF2 (jp) : relative motion between shintake monitor and final doublets of [4 – 6] nm RMS @ 0,1 Hz (vertical axis):



Very stiff in z direction (first eigenfrequency at 70Hz induced by the final doblets supports) - beeswax





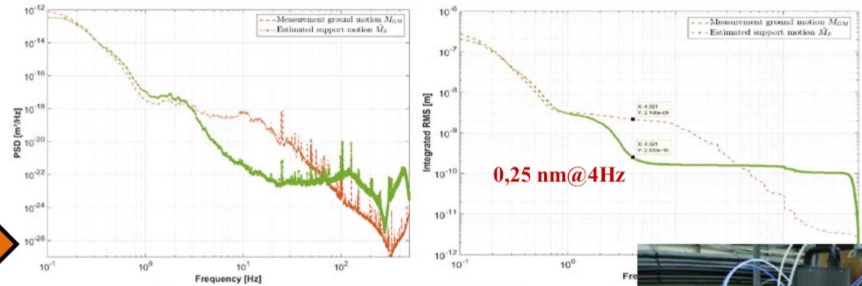
Coherence

Option "high cost"

- **Active control: reducing the absolute motion**

Example of CLIC : feasibility demonstration of an absolute displacement of 0,25nm RMS@4Hz with specific actuators and developed sensors

*- **LAPP** active foot + **LAPP** sensors (one on ground used to monitor ground motion and 1 on top used in feedback) -*



*- Displacement **without control** / **with control** **at LAPP** -*

CLIC Main Linac stabilization
CERN

Active control

Strategy for FCC-ee?

Δd=0 — Criticality of the vibration issues → *d=0*

Not very critical | **Has to be defined** | **Extremely critical**

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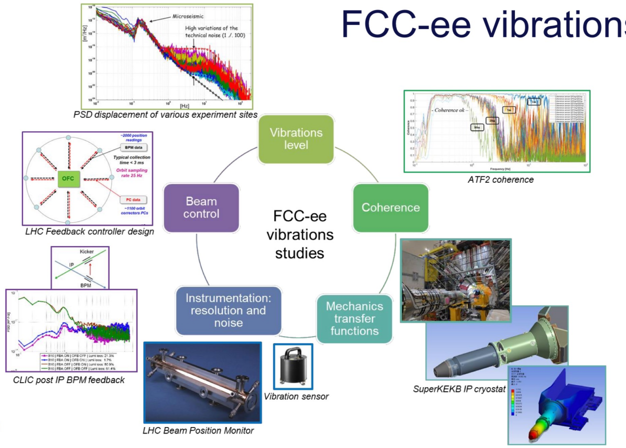
Madx simulations of MDI Vibrations

Eva Montbaron

FCC-ee vibrations studies



PSD displacement of various experiment sites

ATF2 coherence

LHC Feedback controller design

CLIC post IP BPM feedback

LHC Beam Position Monitor

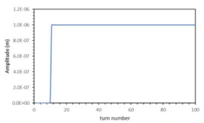
Vibration sensor

SuperKEKB IP cryostat

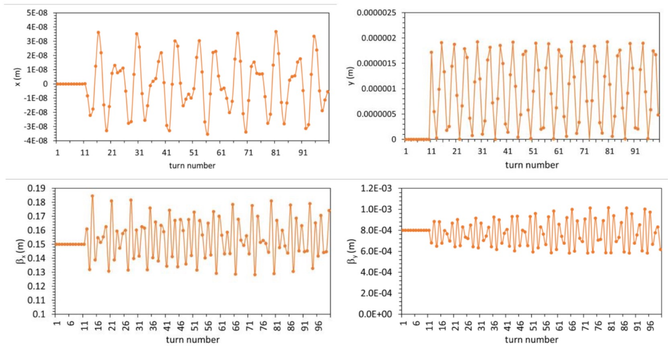
First works with MAD-X

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)

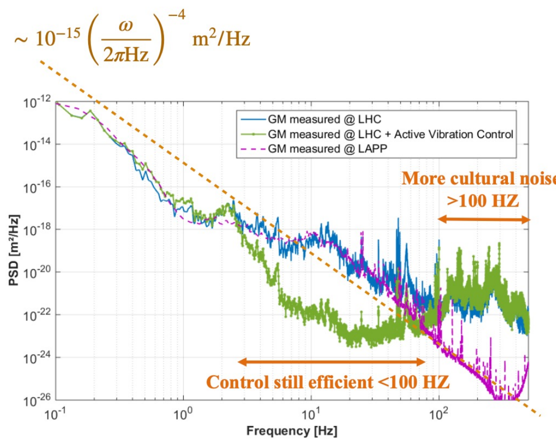
Vibration tolerance for IP and arc magnets, feedback performance criteria

Summary

FUTURE CIRCULAR COLLIDER

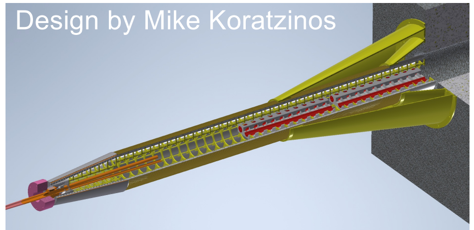
Tolerances for the vibration of quadrupoles are evaluated for three cases:

- 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.

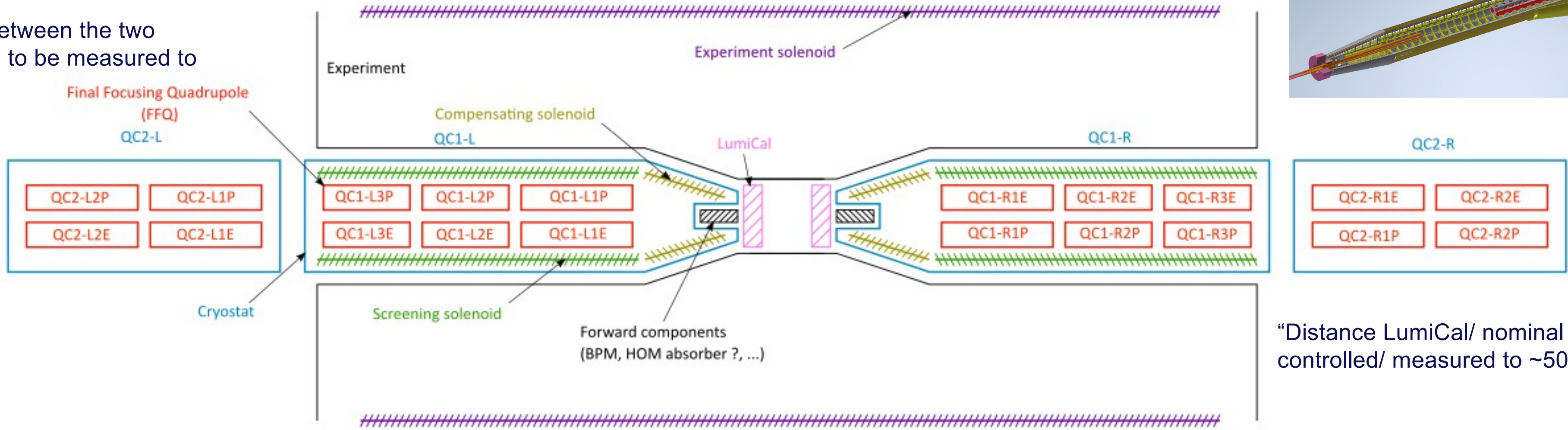


M. Serluca, et al.

FCC-ee MDI requirements so far



" 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)."

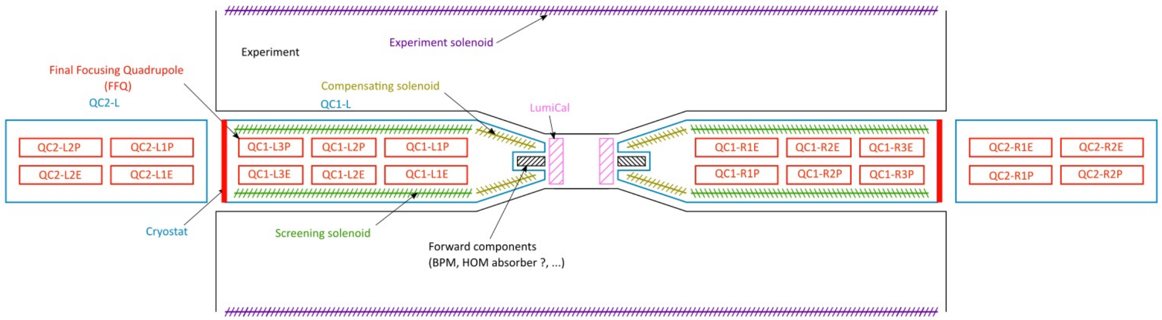
"For a 1mrad tilt of the detector solenoid (wrt the rest of the system – beam, screening and compensation solenoid) the corresponding uncorrected distortion is unacceptably large."

"Alignment accuracy of SC magnets = 100µm"

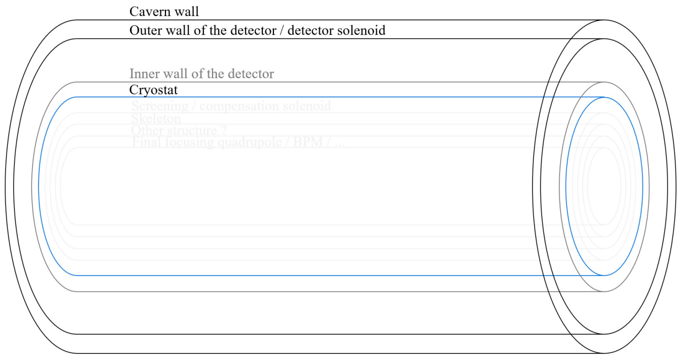
References at the end of the presentation

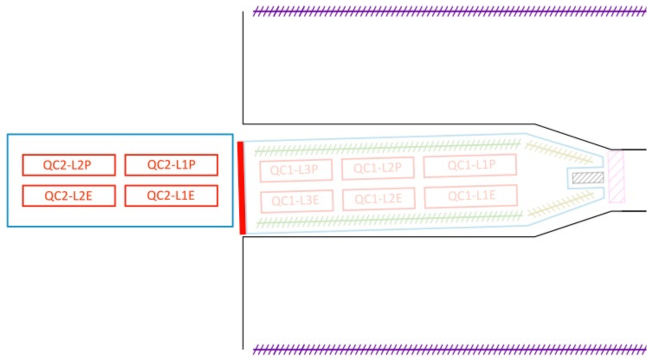
Strategy for a new system

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

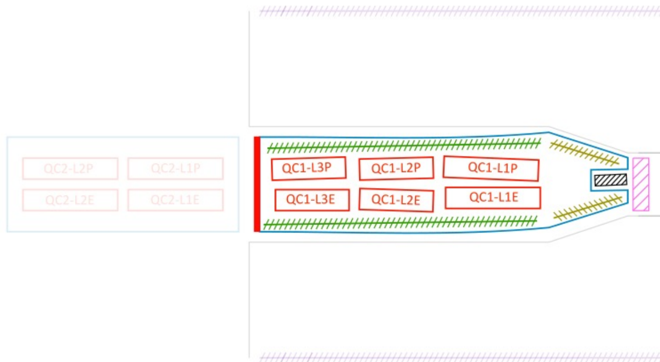


The interface will be monitored from the outside of the experiment. The network will determine the translations and rotations (and scale factor if required) of the interface. Doing that will allow the alignment of the interfaces of the two sides of the detector.





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

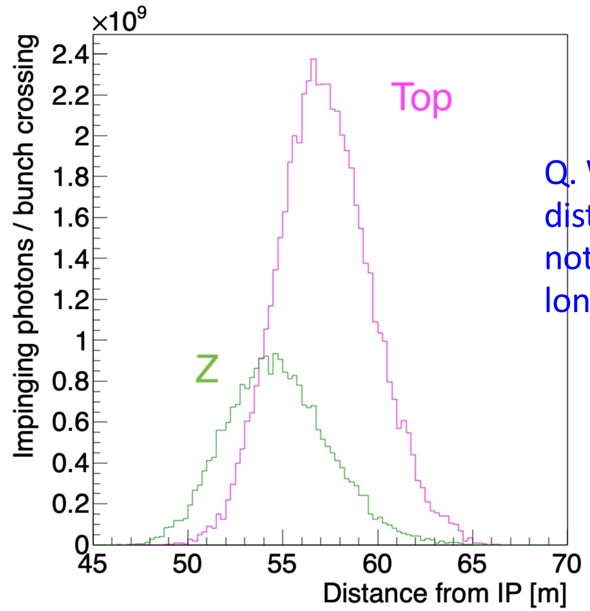


IPAC21: 2105.09698

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.



Q. Why the two distributions are not centered longitudinally on z?

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

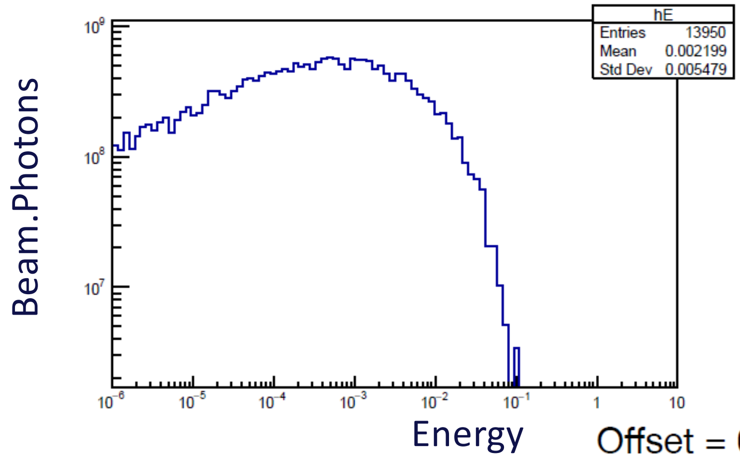
At full luminosity, a vernier scan is a tricky operation and beam beam blow up effects might affect the result

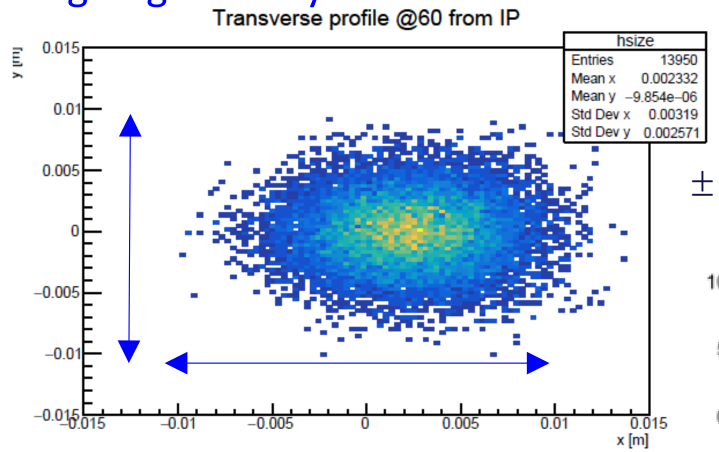
Therefore a beamstrahlung or radiative bhabha monitor seeems highly worthwhile as it give information on the direction of the interacting particles.
it detects
the hard photons emmitted in either e+e- → e+e- γ
or
the hard beamstrahlung photons

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

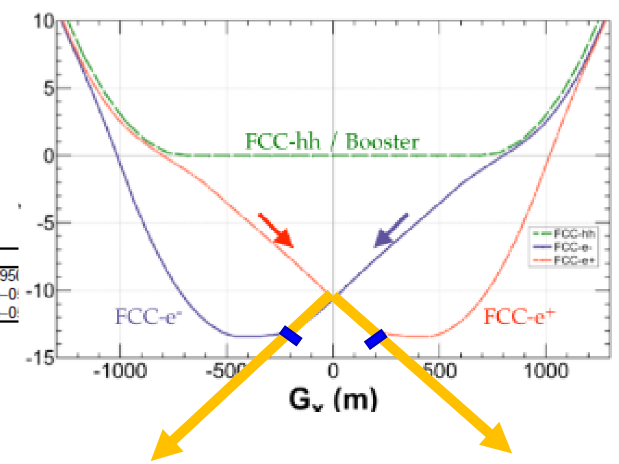


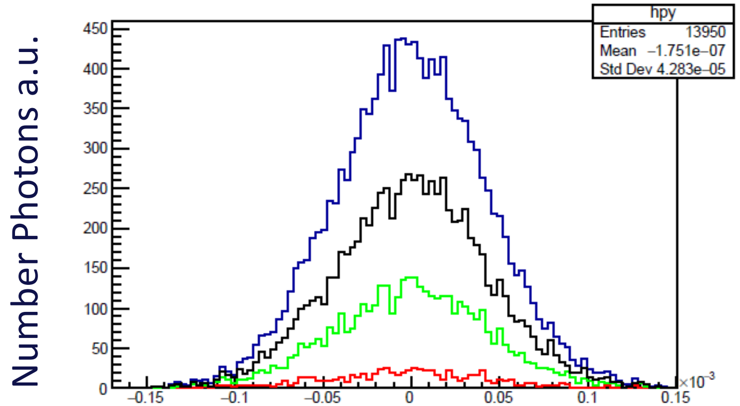


Offset = 0.0 sigma_y

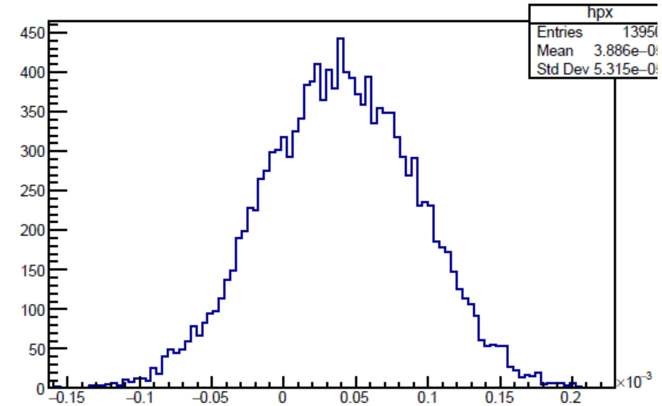
Beamstrahlung, to be understood if radiative bhabhas are masked by beas.

± 1 cm spot of beamstrahlung photons





photon y angular distribution (rad)



photon x angular distribution (rad)

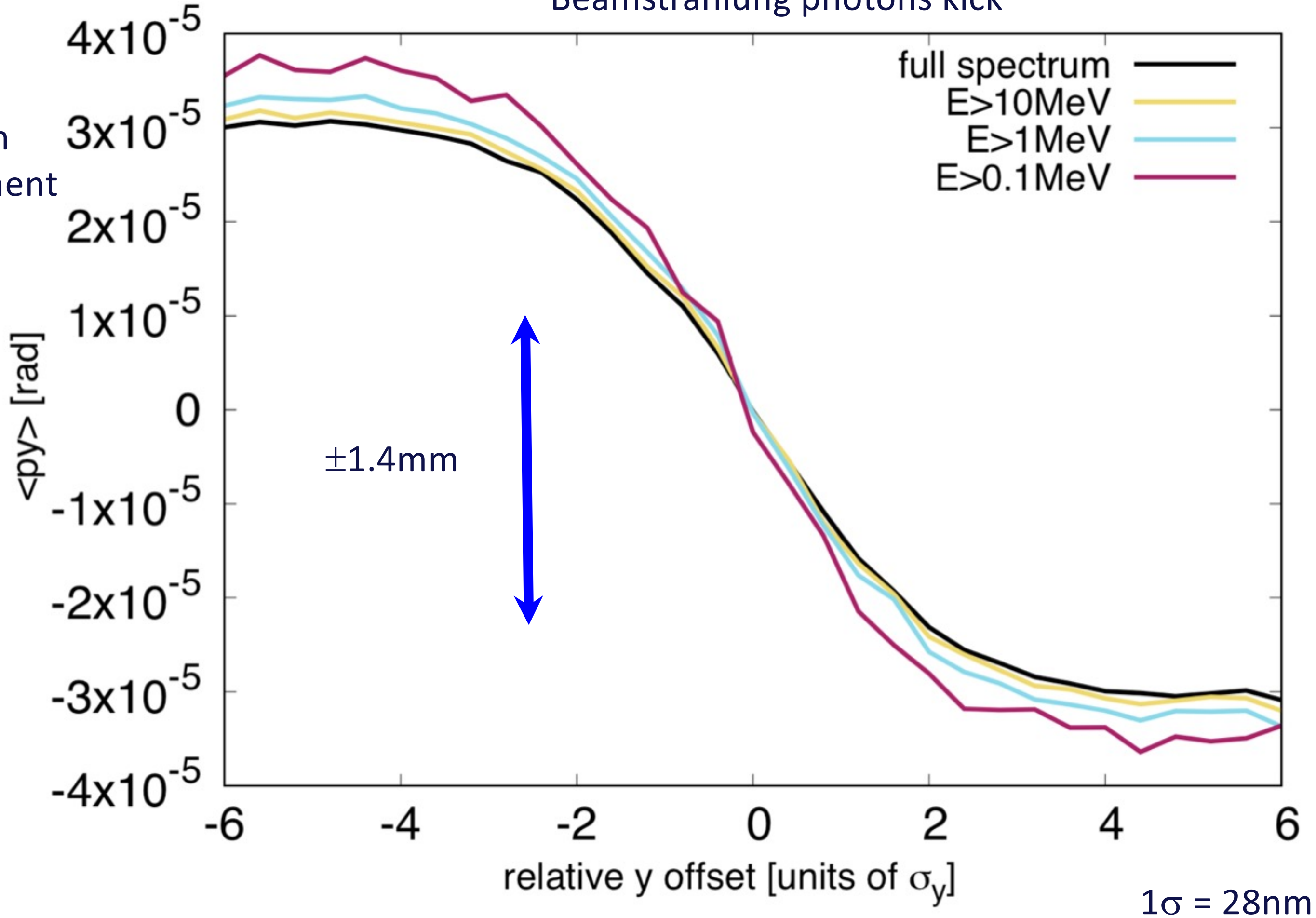
detect photons at exit from bending magnet in a deteector system that is all to be designed!

This offers a continuous monitoring of the beam-beam offset with a linear measurement

Large amplification!

effect should be well measurable IFF we can build a device that
1. can take the radiation
2. take 1 bunch at a time
3. has appropriate resolution (100micron pads should be enough)

Beamstrahlung photons kick



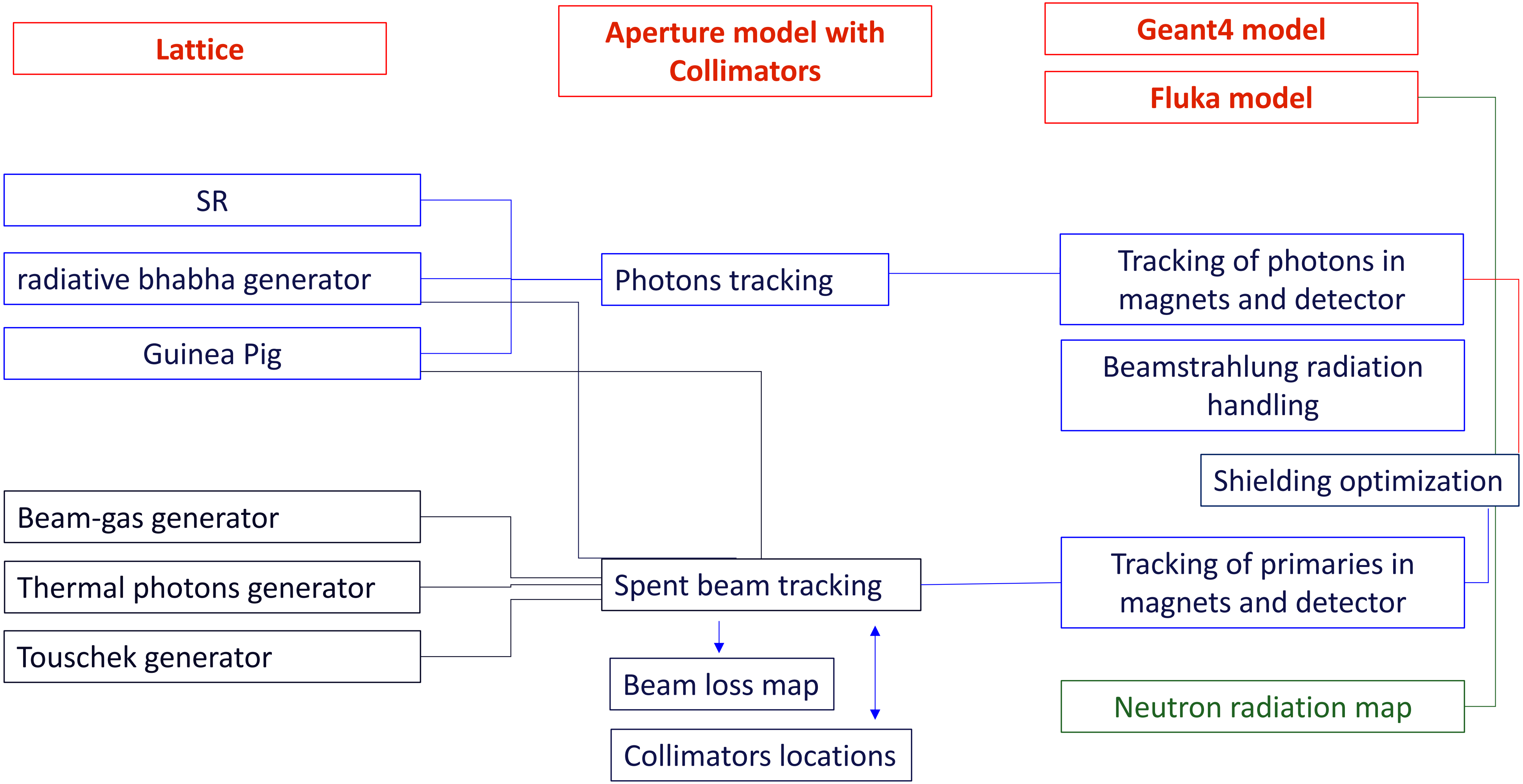
1σ = 28nm

A nice study on-going!

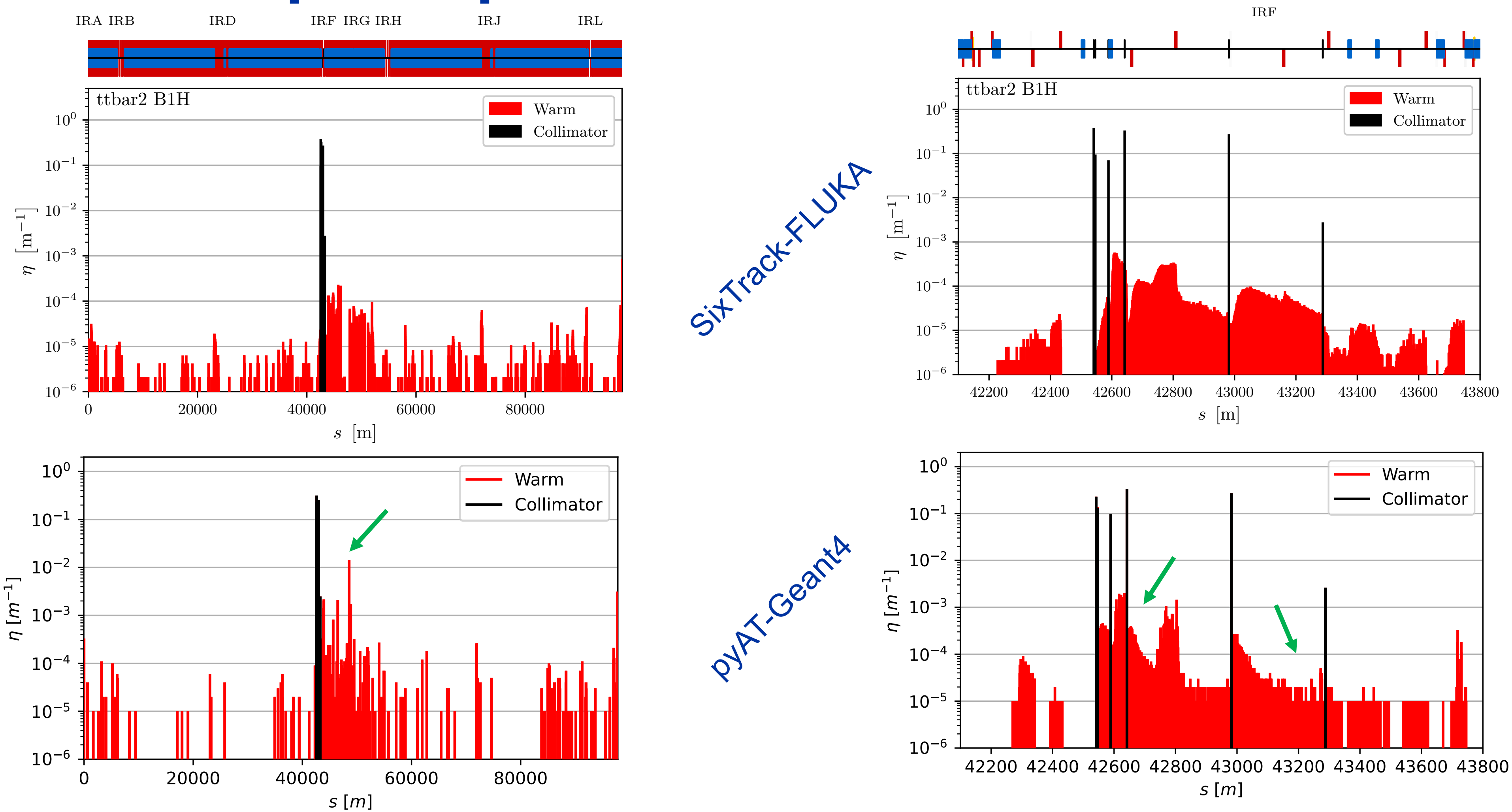
next time : where are the radiative Bhabhas?

Follow-up: radiative Bhabhas with beam-beam (BBBrem input for GuineaPig++)

Task 2. Backgrounds, beam losses and radiation (CERN, in collaboration with various groups)



Loss map comparison



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.

Parameters

FUTURE CIRCULAR COLLIDER

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	$[10^{34}/\text{cm}^2\text{s}]$	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.

Tor Raubenheimer

Accelerator Development Goals and Timeline

- Self-consistent Baseline configuration for Feasibility Study by end of 2025
- Support mid-term and final costing exercises in June 2023 and December 2025
  - Complete beam optics aligned to the present tunnel placement and initial component specification by January 2023 to allow cost development through May 2023 **for mid-term FCC review in June 2023**
    - Optics specifications with correction elements, RF, collimation and injection systems
    - Beam dynamics calculations to include initial studies: tuning and correction; dynamic aperture with errors; beam-beam with errors; collective effects.
    - FCCee Injector and Booster optics and layouts completed with tradeoff studies documented
    - FCChh optics layout in consistent layout
    - Technology R&D specification with milestones
- Iterate to support the Feasibility Study costing exercise from January 2025 through December 2025

Tor Raubenheimer

FCC Accelerator Status

Placement updated with slightly smaller footprint (91 km) and 8 accesses

Updating main ring optics for 4 IPs with new placement for 4 energies

Selected baseline high-level parameters (mostly)

Working on MDI, RF layout, collimation, and injection/extraction

Many outstanding physics and tuning questions

Developing Booster and Injector configurations

Working to ensure compatibility with FCC-hh

Technical R&D program is prioritizing tasks

Energy calibration and polarization studies beginning – critical for Z physics

Tor Raubenheimer

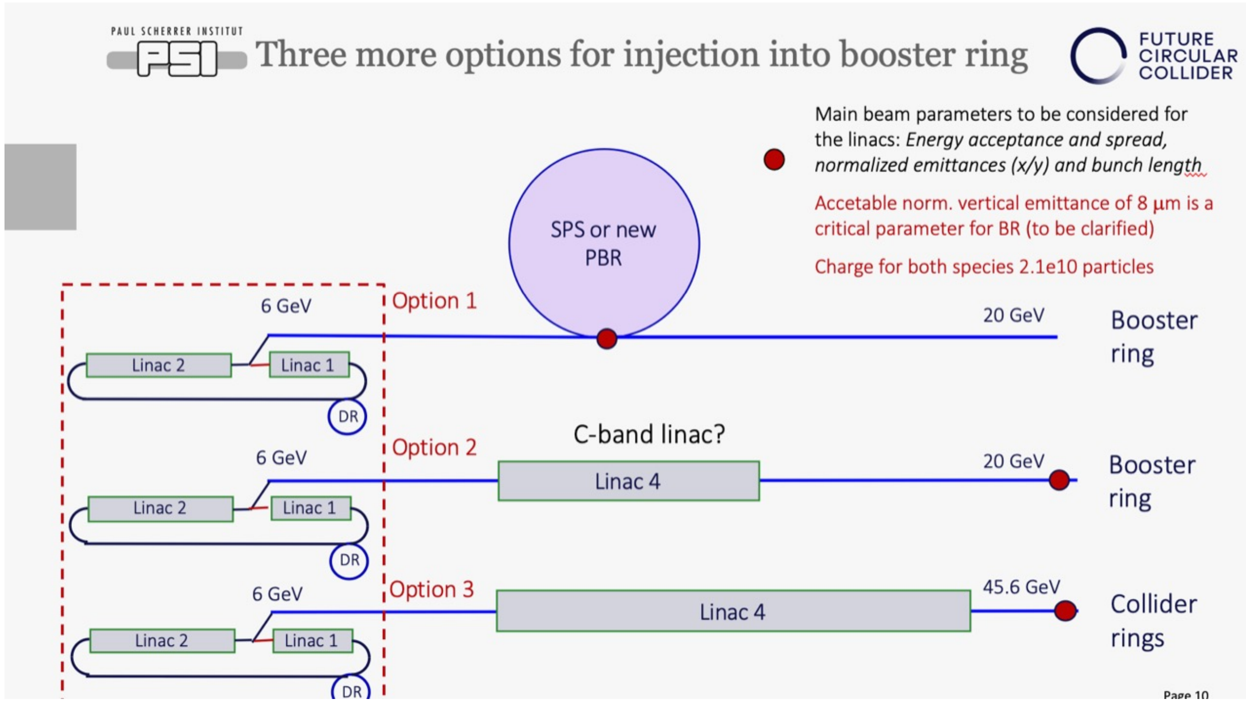
Subsystem Definitions

Along with the main ring placement, major subsystems are being defined and layouts started:

RF, injection/extraction, beam collimation, polarization meas/control, …..

Booster, Injector, Transfer lines

Need iterations on all of these by June 2022 to understand the preliminary civil and infrastructure requirements



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

Conclusion

It has been a great workshop!
Very nice to discuss and meet people in presence, when possible

Activity plan is in progress.
Timelines are established.

We invite the experts that would like to contribute to the MDI activity to contact us and send us a proposal.

Additional slides

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

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**

Comments, Questions, and Conclusions

- The design of some components of the vacuum system of the storge rings is underway, despite limited human resources within the vacuum group mechanical engineering section
- A new fellow will start on Feb 1st, 2022, as responsible person for the BESTEX beamline at KARA/KIT
- We continue our collaboration with the FLUKA team (see next talk) on the design of the chambers and absorbers, and the integration in the tunnel
- **Work should start as soon as possible also on the full-energy booster**: we lack information about the lattice and geometry of the magnets: the only known (to me) parameter is a 50 mm ID (OD?) of a circular vacuum chamber; such a cross-section has a specific conductance of 15.4 *liter*·m/s, i.e 1/3 of that of the storage ring (~46 *liter*·m/s), meaning that if NEG-coating will not be allowed or feasible, reaching a sufficiently low pressure will be rather difficult (for the Z-pole the boostere accelerates a large beam! hence lots of SR-induced desorption). In addition, possibly anti-bend orbits (see B. Dalena's talk), tricky.
- It seems evident that **NEG-coating is mandatory** if we are to reach the nominal beam parameters (full stored current) within the 2-year period envisaged in the experimental program schedule
- **The new concept for the longitudinal absorber implementing a "LHC-type" sawtooth (ST) geometry** is worth investigating from the point of view of its fabrication and thermal behavior as well. If and when a prototype will be ready, we should be able to test it at KARA/KIT, although the SR power density will not be at the same level as in the FCC-ee
- The ST absorber needs also to be characterized by the FLUKA team (although it should follow the case of the no-lumped absorbers case which is already under study)
- Next item we need to study together with FLUKA team is the generation of bremsstrahlung (very high-energy gamma rays, up to the beam energy). **Questions:** is it negligible or is it a limiting factor? What's the highest molecular density and gas composition we can tolerate in terms of bremsstrahlung losses? Highly atomic number Z dependent (~Z^2). **This may be relevant for the MDI region too.**