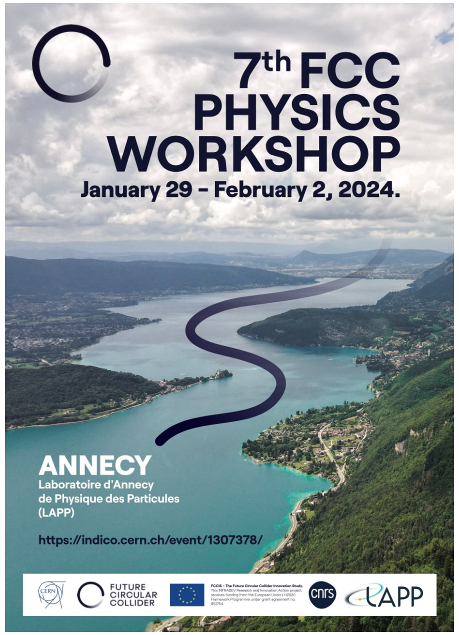
FCCIS – The Future Circular Collider Innovation Study. This INFRADEV Research and Innovation Action project receives funding from the European Union’s H2020 Framework Programme under grant agreement no. 951754.

FUTURE CIRCULAR COLLIDER
Innovation Study



PROGRESS AND PROSPECTS ON THE MDI STUDY

Manuela Boscolo (INFN-LNF)

on behalf of the MDI group

7th FCC Physics Workshop
29 January – 2 February 2024
Laboratoire d'Annecy de physique des particules, Annecy, France

Istituto Nazionale di Fisica Nucleare

Outline

- IR mechanical model
- Interaction Region layout
- Backgrounds simulations
- Outlook

FCC-ee MDI & IR Mock-up Workshop

16-17 November 2023 Frascati

https://agenda.infn.it/event/37720/

MDI monthly meetings: https://indico.cern.ch/category/5665/

Agenda MDI sessions

Tuesday 30/1 9H00-10H30 Joint Session: Detector & MDI	
Fabrizio Palla (INFN-Pisa)	Vertex Detector
C. Turrioni (INFN-Perugia)	Progress on air cooling of the vertex detector
Armin Ilg (Univ. Zurich)	Vertex detector and silicon wrapper simulation and material budget
Andrea Gaddi (CERN)	First studies on detector integration in the beamline

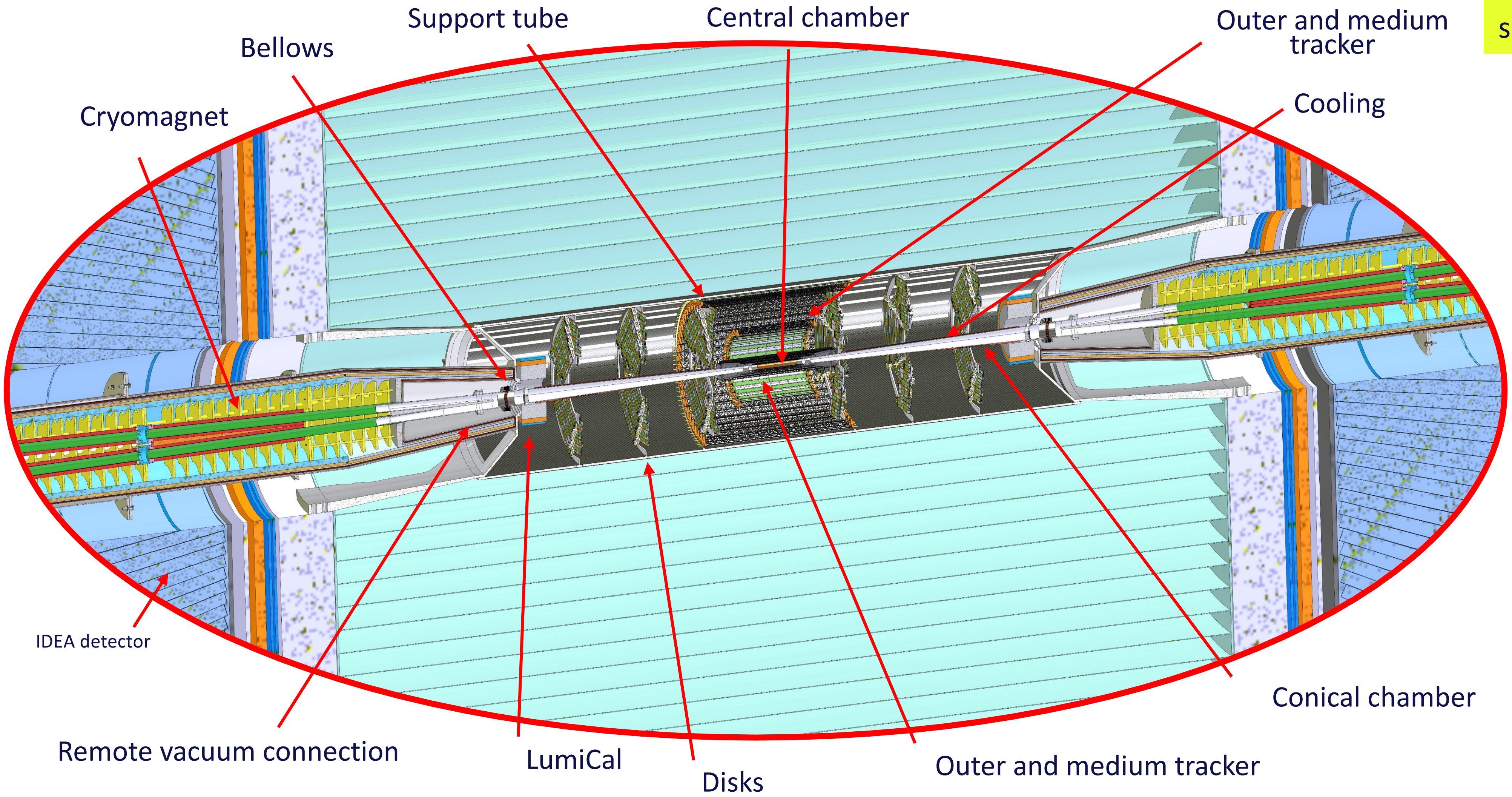
Wedn. 31/1 9H00-10H30 MDI I	
F. Fransesini (INFN)	Progress on the MDI mechanical design
J. Seeman (SLAC)	Status of the IR magnet system design
A. Ciarma (INFN)	Solenoid Coupling compensation scheme

Wedn. 31/1 11H00-12H30 MDI II	
R. Kersevan (CERN)	Vacuum system and requirements in the IR
K. Andre (CERN)	Synchrotron Radiation Background
A. Abramov (CERN)	IR Beam losses and collimation system
A. Frasca (CERN)	Results and prospects of radiation level studies in the FCC Interaction Region

Wedn. 31/1 17H45-18H45 MDI III	
P. Raimondi (FERMILAB)	LCCO Final Focus beam dynamics studies
Peter Kicsiny (EPFL)	Status of the beam-beam studies
E. Montbarbon (LAPP)	An FCC-ee vibrations study for its MDI

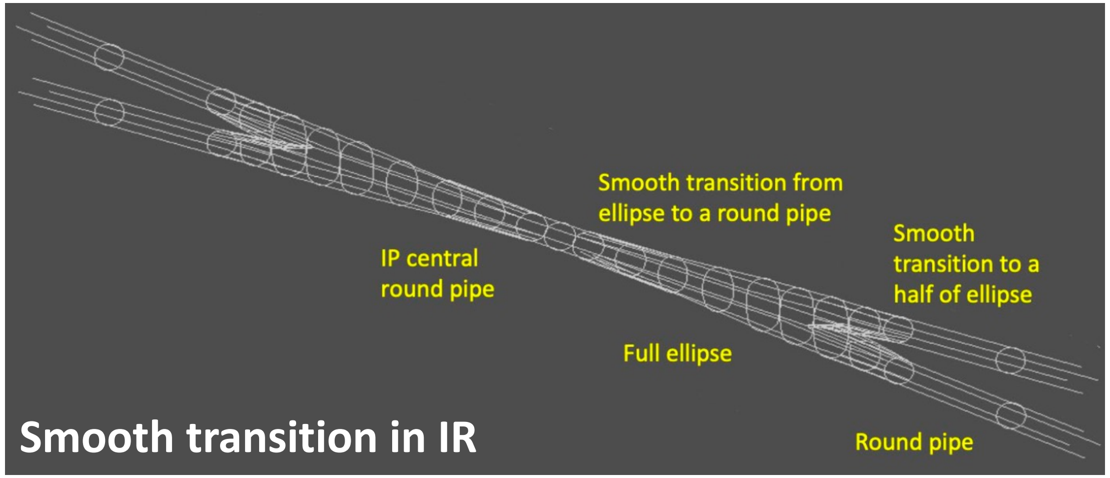
FCC-ee engineered Central Interaction Region

see talk by F. Fransesini



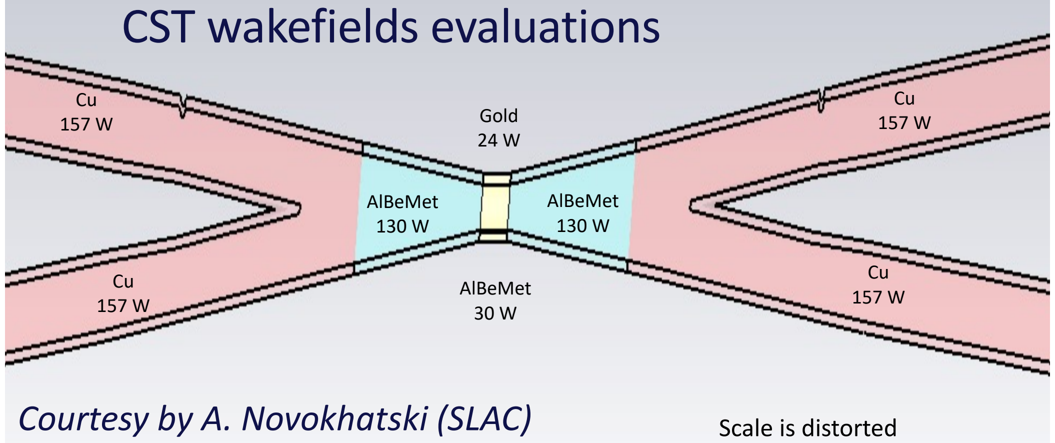
Ref: M. Boscolo, F. Palla, et al., *Mechanical model for the FCC-ee MDI*, EPJ+ Techn. and Instr., https://doi.org/10.1140/epjti/s40485-023-00103-7

Low-impedance vacuum chamber and its cooling system



Smooth transition in IR

- warm and cooled vacuum chamber
  Beam heat load evaluated, cooling system made of paraffin in the central chamber and water elsewhere
- **Integration and assembly of the luminosity calorimeter**: the crotch slightly shifted from IP,
  - allowing the integration of the lumical as a single object,
  - and a BPM next to lumical



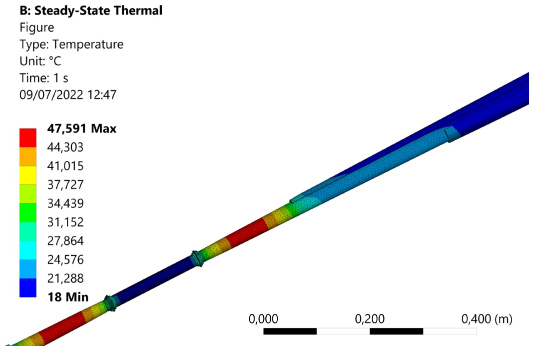
CST wakefields evaluations

Courtesy by A. Novokhatski (SLAC)

Scale is distorted

parameter	value
beam energy [GeV]	45
beam current [mA]	1280
number bunches/beam	1000
rms bunch length with SR / BS [mm]	4.38 / 14.5
bunch spacing [ns]	32

	trapezoidal chamber	central chamber
T_{max}	48°C	33°C
$T_{coolant}$	20.5 °C (paraffin)	20 °C (water)



AlBeMet central vacuum chamber

180 mm

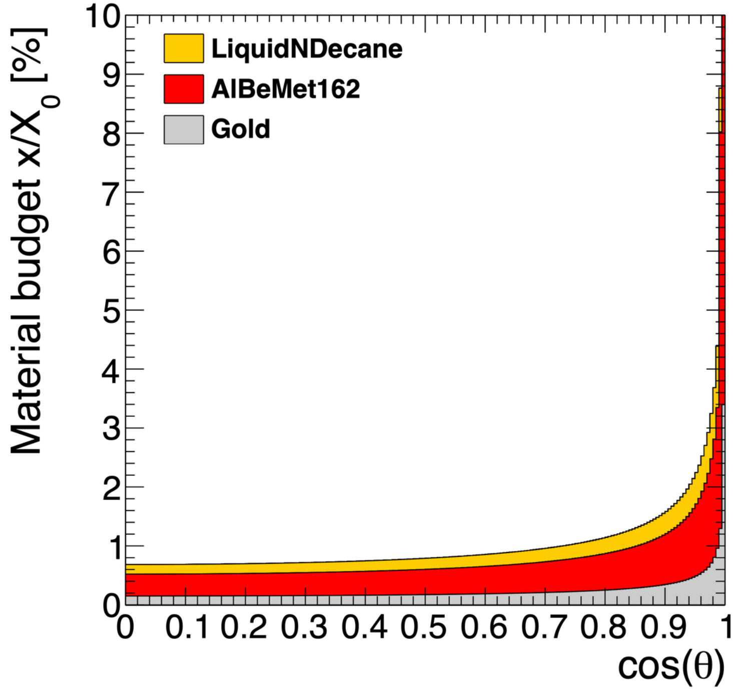
Inlet/outlet for paraffin cooling
all AlBemet

Inner / Outer radius 10/ 11.7 mm

Material	thickness
AlBeMet162(*)	0.35 mm
Paraffin (coolant)	1 mm
AlBeMet162	0.35 mm
Au	5 µm

AlBeMet 162
62% Be and 38% Al alloy

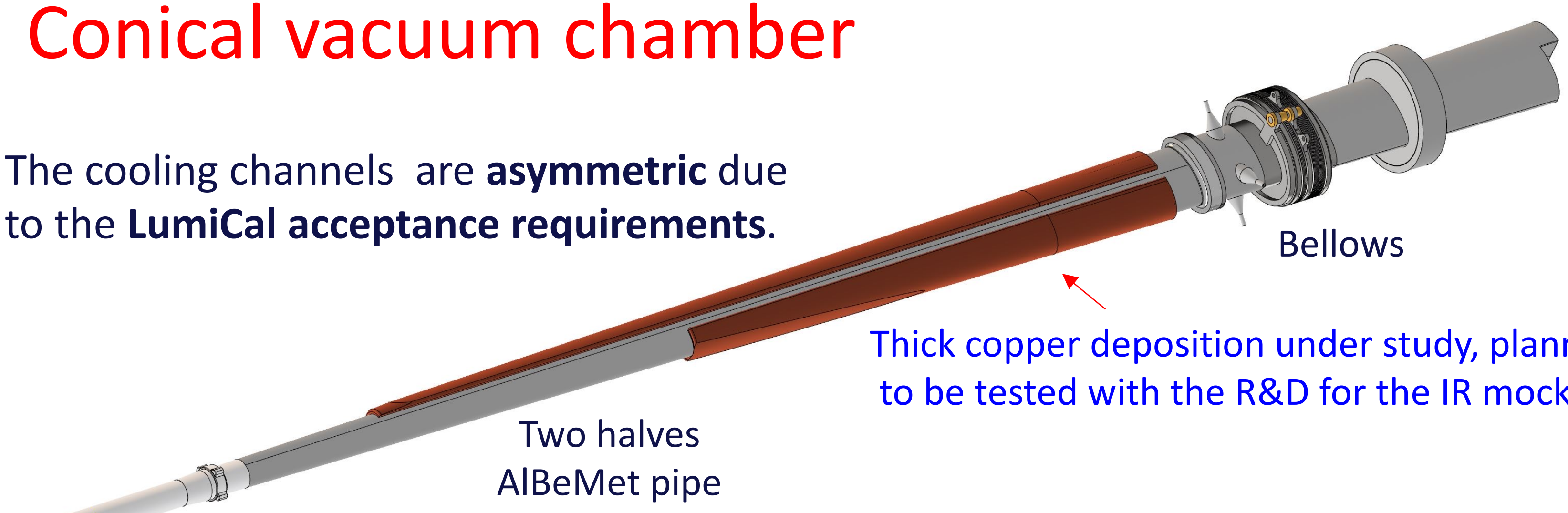
Central beam pipe material budget



R&D started for a prototype as part of the IR mockup at LNF, with paraffin cooling test and welding process study

Conical vacuum chamber

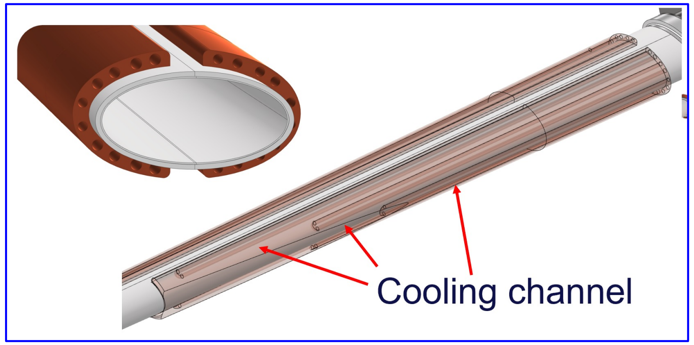
The cooling channels are **asymmetric** due to the **LumiCal acceptance requirements**.



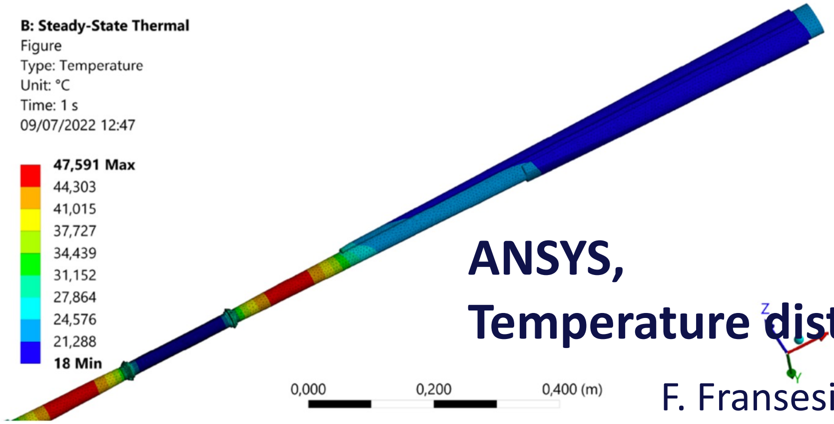
Bellows

Thick copper deposition under study, planned to be tested with the R&D for the IR mockup

Two halves AlBeMet pipe



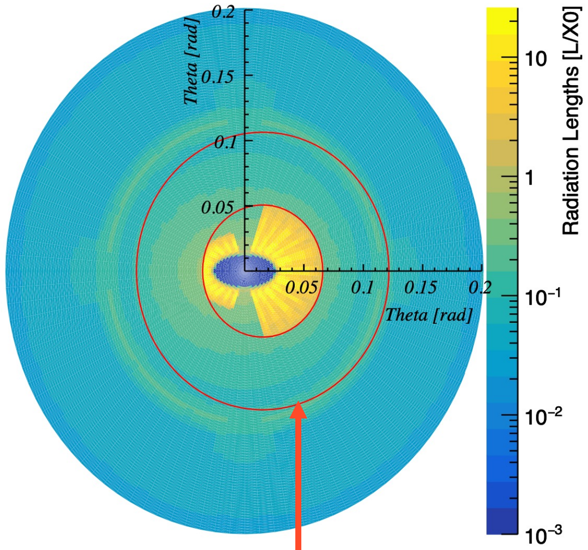
Cooling channel



ANSYS, Temperature distribution

F. Fransesini

Beam pipe material budget as seen from lumical



Lumical Acceptance

Geant4, A. Ciarma

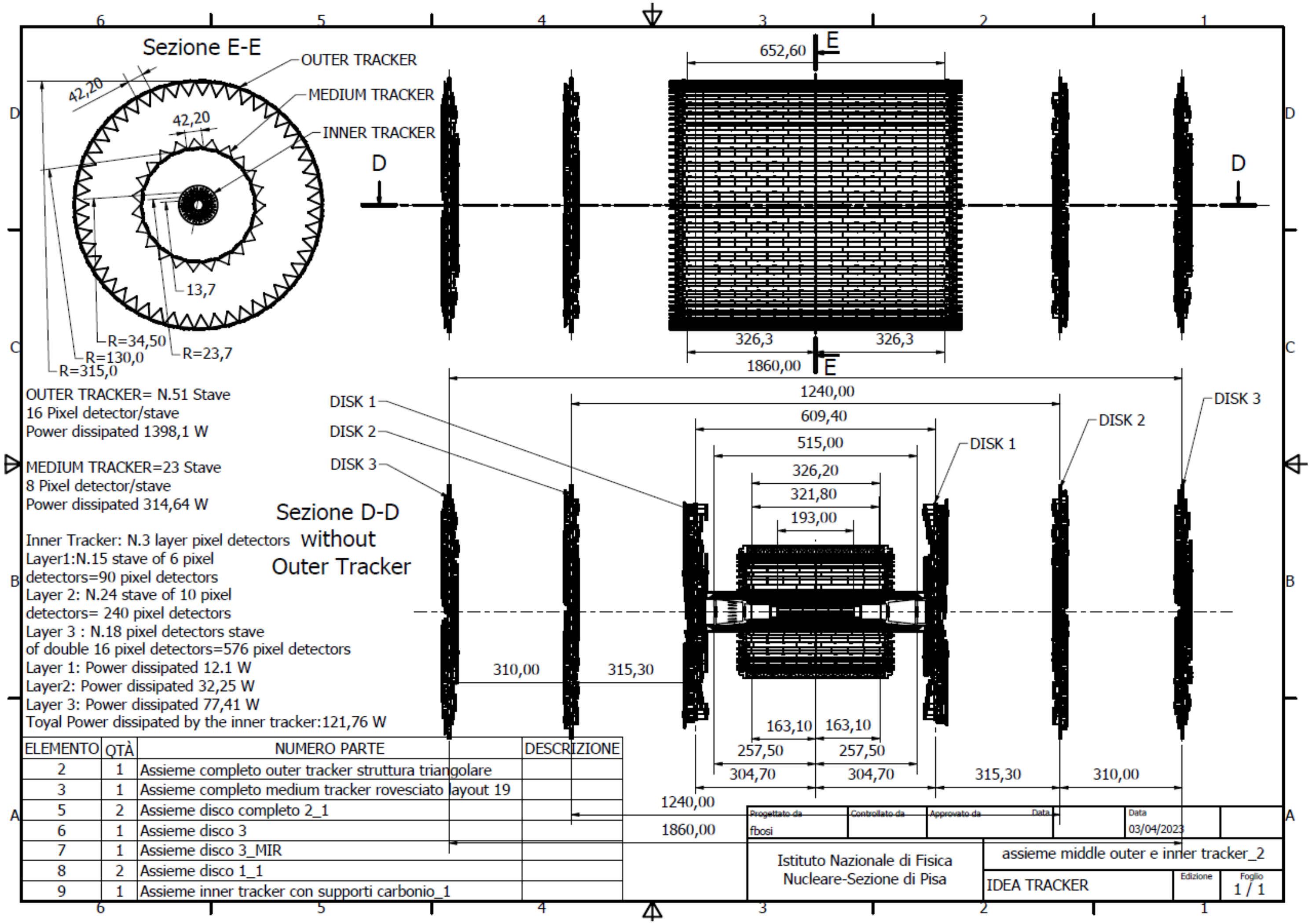
Effect of the lumiCal to be verified with simulation (talk by M. Dam and J. Jallberg, Luminosity measurements session)

CAD model of this chamber imported in Key4hep

Midterm review vertex detector layout and dimensions

Vertex detector engineered

see talk by F. Palla



OUTER TRACKER= N.51 Stave
16 Pixel detector/stave
Power dissipated 1398,1 W

MEDIUM TRACKER=23 Stave
8 Pixel detector/stave
Power dissipated 314,64 W

Inner Tracker: N.3 layer pixel detectors
Layer1:N.15 stave of 6 pixel detectors=90 pixel detectors
Layer 2: N.24 stave of 10 pixel detectors= 240 pixel detectors
Layer 3 : N.18 pixel detectors stave of double 16 pixel detectors=576 pixel detectors
Layer 1: Power dissipated 12.1 W
Layer2: Power dissipated 32,25 W
Layer 3: Power dissipated 77,41 W
Toyal Power dissipated by the inner tracker:121,76 W

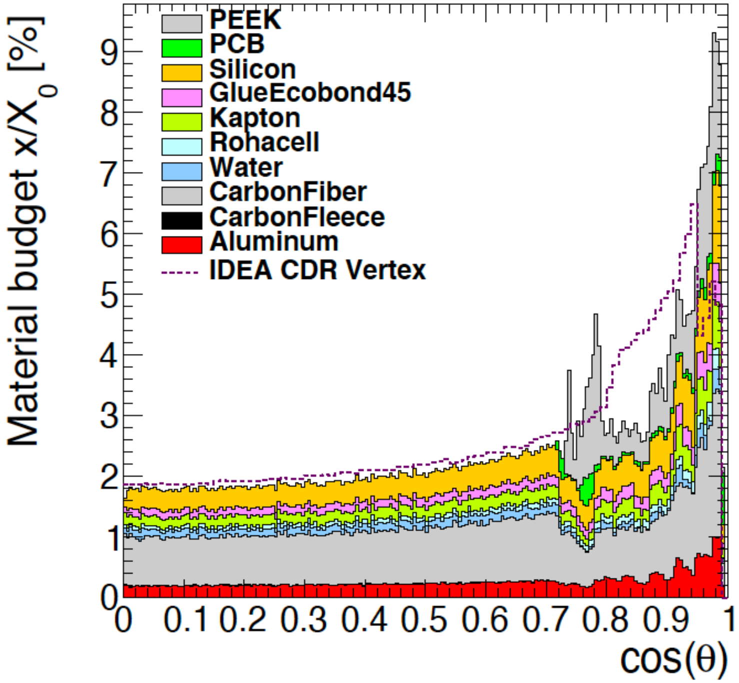
ELEMENTO	QTÀ	NUMERO PARTE	DESCRIZIONE
2	1	Assieme completo outer tracker struttura triangolare	
3	1	Assieme completo medium tracker rovesciato layout 19	
5	2	Assieme disco completo 2_1	
6	1	Assieme disco 3	
7	1	Assieme disco 3_MIR	
8	2	Assieme disco 1_1	
9	1	Assieme inner tracker con supporti carbonio_1	

Progettato da	Controllato da	Approvato da	Data	Data
fbosi				03/04/2023

Istituto Nazionale di Fisica Nucleare-Sezione di Pisa
assieme middle outer e inner tracker_2
IDEA TRACKER
Edizione
Foglio 1 / 1

see talk by A. Ilg

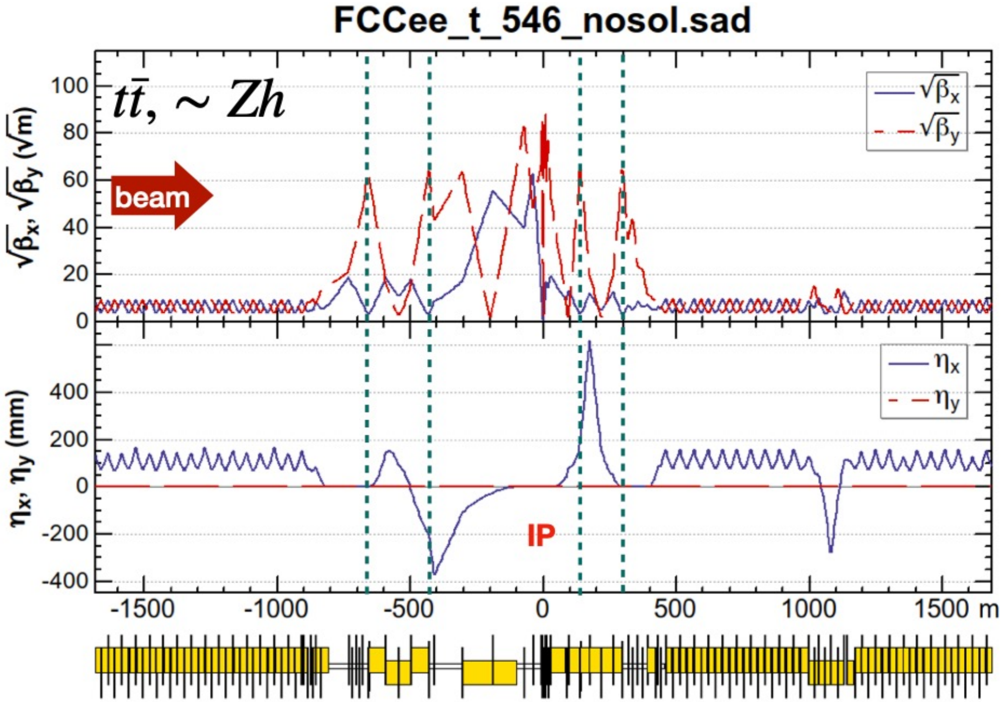
Simulated material budget



- In agreement with CAD estimates
- Smaller X/X_0 wrt IDEA CDR estimates even including power and readout cables in the sensitive region
- Silicon only ~15% of the total

Baseline IR optics

K. Oide



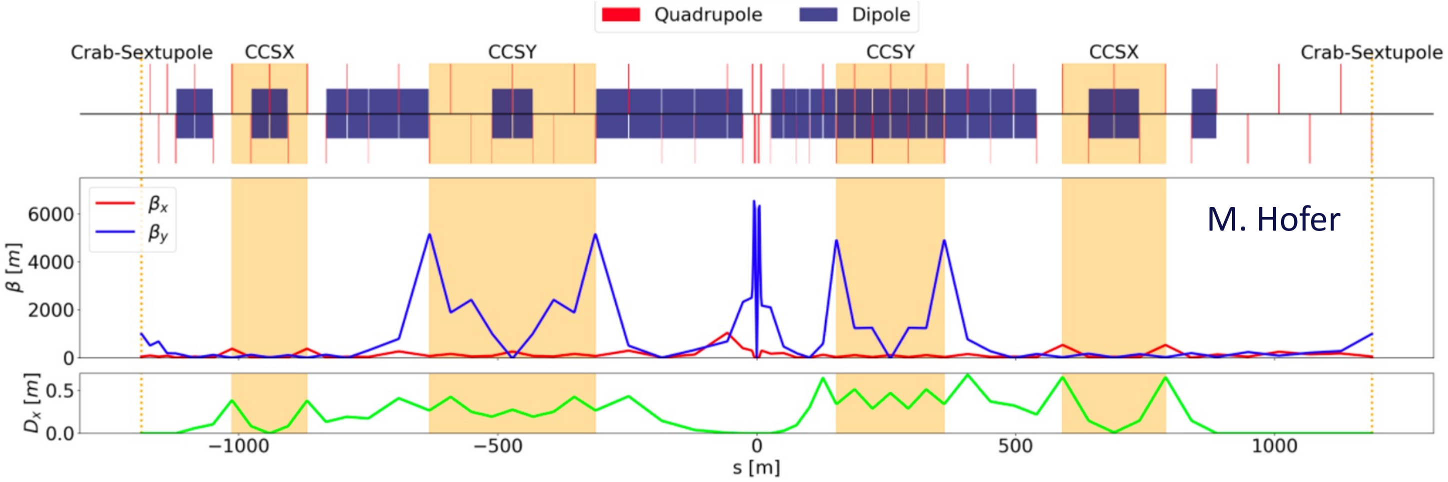
- Crab waist/vertical chromaticity correction sextupoles are located at the dashed lines, they are superconducting.

LCCO (or HFD) Optics

P. Raimondi

see talk by S. Liuzzo and P. Raimondi

ttbar



LCCO: Local Chromatic Correction Optics
HFD: Hybrid FODO

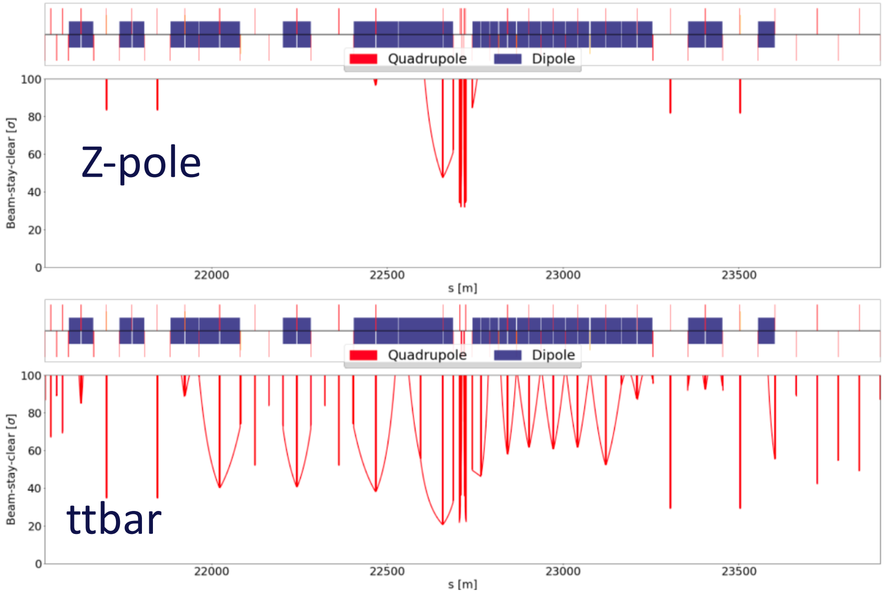
- The crab sextupole is placed at the beginning of the FF to minimize its impact on Momentum Acceptance (MA)
- Weak chromatic correction sextupoles allow to be normal conducting.

The beam optics are asymmetric between upstream/downstream due to crossing angle & suppression of the SR upstream to the IP

LCCO Final Focus - Impact to IR design

- The Final Focus is optimized to have the **largest possible beam stay clear (BSC) and minimum losses** in the final focus system and all the way through the IR

Beam Stay Clear

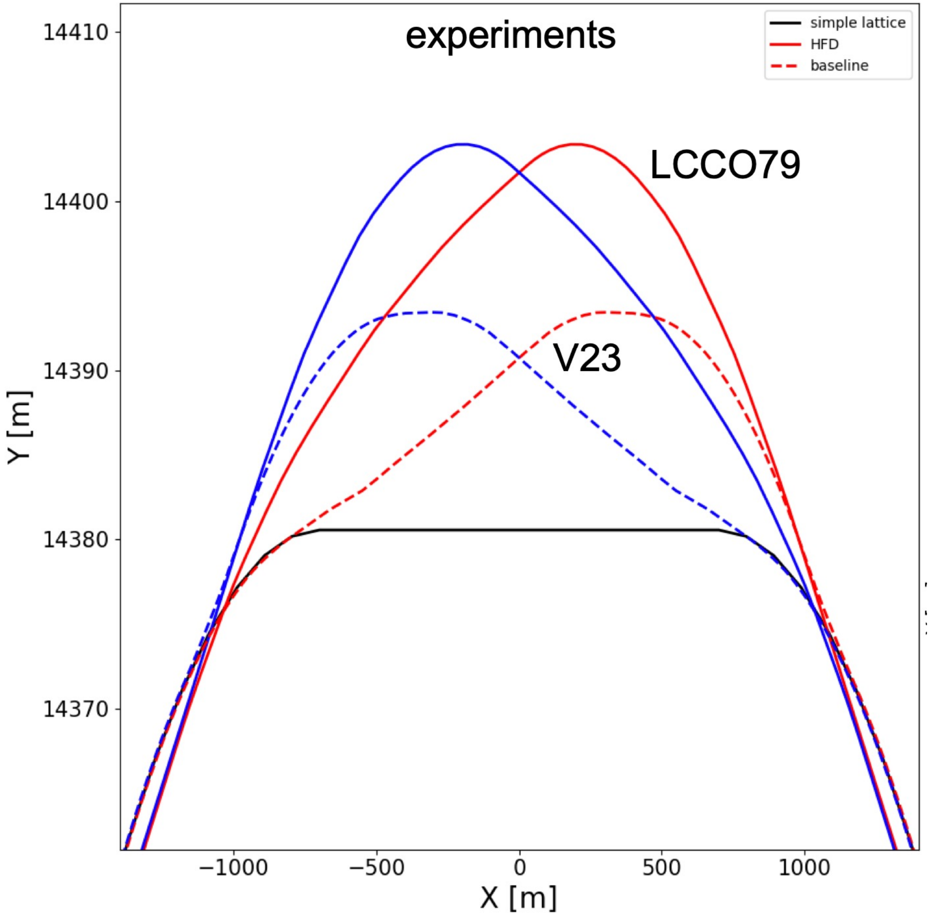


Preliminary aperture model same as baseline,
r=35 mm everywhere, but: r=15 mm at QC1; r=20 mm at QC2
Bottlenecks:

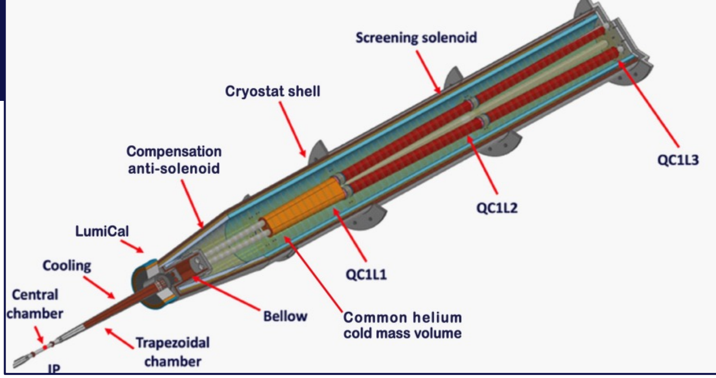
- **baseline Z: 14.5 σ_x / tt_{bar}: 14.4 σ_x**
- **LCCO Z: 31 σ_x / tt_{bar}: 20 σ_x**

M. Hofer, link
173rd Optics meeting

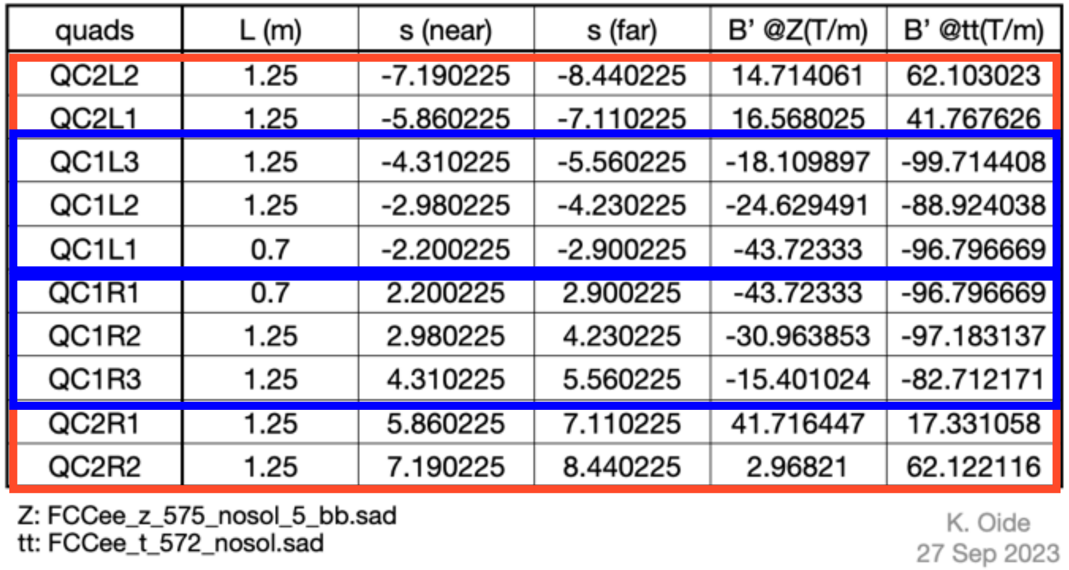
Survey Layout



Final Focus quadrupoles layout



Baseline (K. Oide)

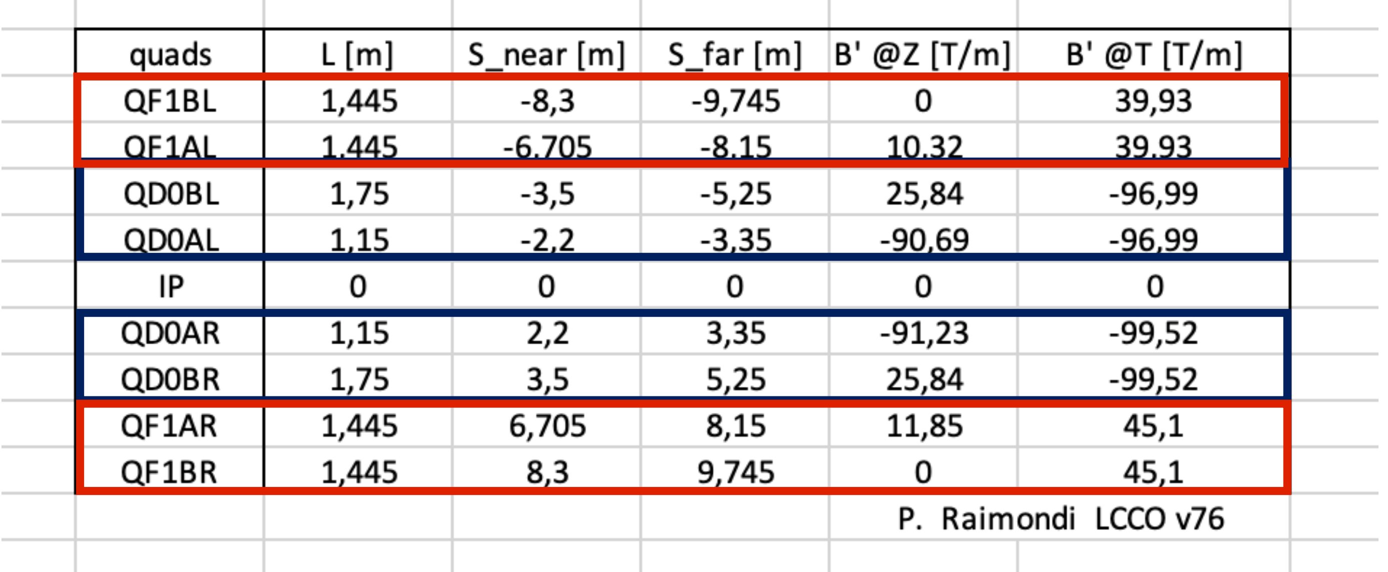


quads	L (m)	s (near)	s (far)	B' @Z(T/m)	B' @tt(T/m)
QC2L2	1.25	-7.190225	-8.440225	14.714061	62.103023
QC2L1	1.25	-5.860225	-7.110225	16.568025	41.767626
QC1L3	1.25	-4.310225	-5.560225	-18.109897	-99.714408
QC1L2	1.25	-2.980225	-4.230225	-24.629491	-88.924038
QC1L1	0.7	-2.200225	-2.900225	-43.72333	-96.796669
QC1R1	0.7	2.200225	2.900225	-43.72333	-96.796669
QC1R2	1.25	2.980225	4.230225	-30.963853	-97.183137
QC1R3	1.25	4.310225	5.560225	-15.401024	-82.712171
QC2R1	1.25	5.860225	7.110225	41.716447	17.331058
QC2R2	1.25	7.190225	8.440225	2.96821	62.122116

Z: FCCee_z_575_nosol_5_bb.sad
tt: FCCee_t_572_nosol.sad

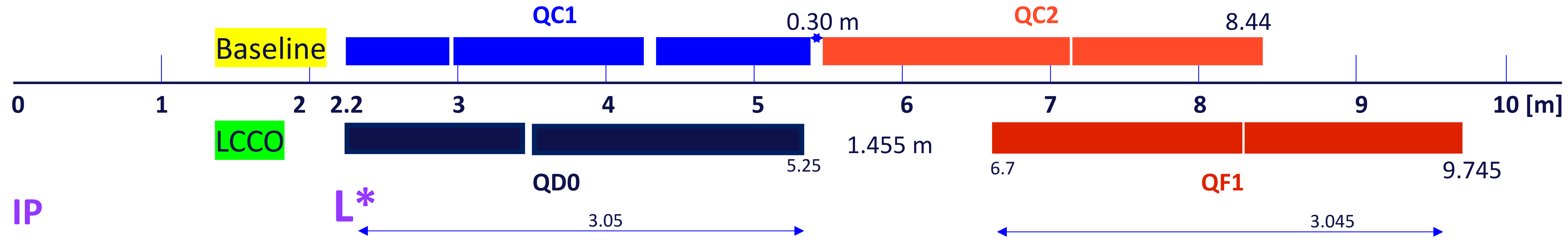
K. Oide
27 Sep 2023

LCCO (P. Raimondi)

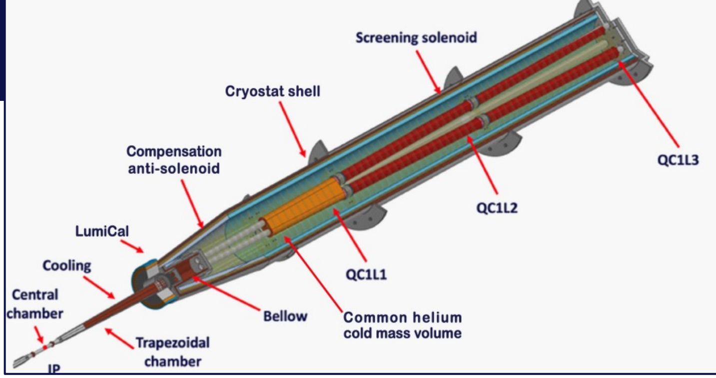


quads	L [m]	S_near [m]	S_far [m]	B' @Z [T/m]	B' @T [T/m]
QF1BL	1,445	-8,3	-9,745	0	39,93
QF1AL	1.445	-6.705	-8.15	10.32	39.93
QD0BL	1,75	-3,5	-5,25	25,84	-96,99
QD0AL	1,15	-2,2	-3,35	-90,69	-96,99
IP	0	0	0	0	0
QD0AR	1,15	2,2	3,35	-91,23	-99,52
QD0BR	1,75	3,5	5,25	25,84	-99,52
QF1AR	1,445	6,705	8,15	11,85	45,1
QF1BR	1,445	8,3	9,745	0	45,1

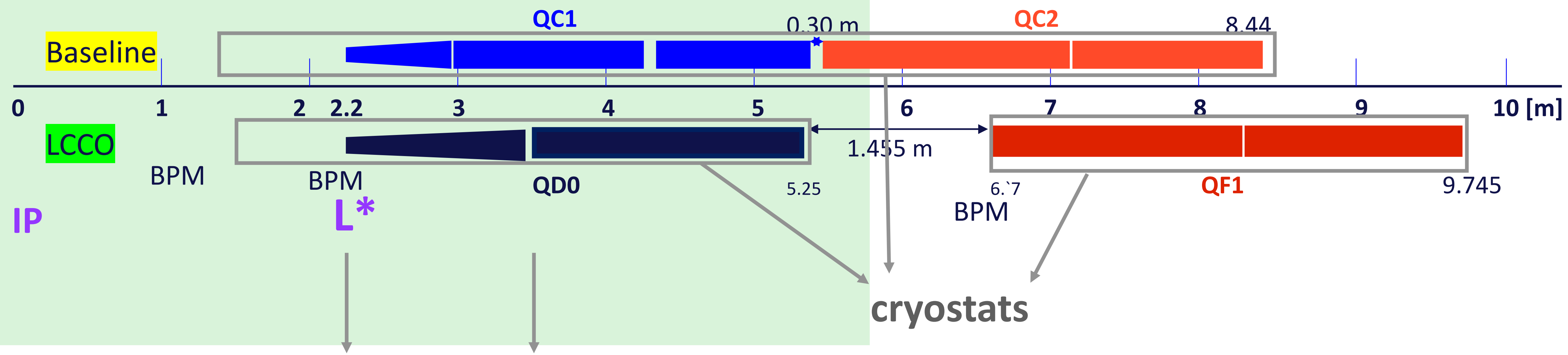
P. Raimondi LCCO v76



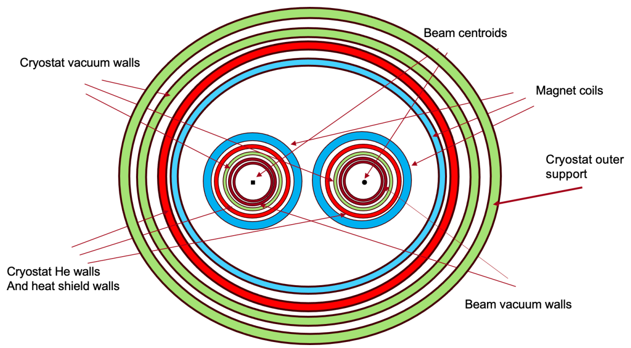
Final Focus quadrupoles layout



(IDEA) Detector half-length



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



J. Seeman Nov 4, 2023

J. Seeman

Option (Leading Candidate): IR QC1 and QC2 in different cryostats but one integrated raft

Design by cryogenic/mechanical engineer(s)

P. Tavares Borges de Sousa (CERN) link,
MDI Workshop, Frascati 16-17 Nov. '23 https://agenda.infn.it/event/37720/

Cryogenic approaches for superconducting magnets in the FCC-ee IR

- A preliminary assessment of **local heat extraction** options for the IR magnet QC1 has been carried out, for present **level of heat load O(100 W)** there are **no showstoppers at either 1.9 K, 4.5-5 K or 10-20 K**
- Aside from local heat extraction, the choice of operating temperature will have a **profound impact on the overall MDI/IR zone** → if unavoidable, operation at **1.9 K needs to be justified**
  - **1.9 K** operation is **4x more power consuming than at 4.5 K**, 20x more than at 10-20 K
  - **Cryo distribution line in the tunnel is larger for 1.9 K** operation due to pumping line
  - **Underground cavern space** for cold compressors is a necessity for **1.9 K**
- **Integration** in the MDI/IR is challenging, would be facilitated by having common temperature levels between different magnets and using cold BPMs
- **Static heat loads** can add up to a significant percentage of the radiation-induced load, once design has matured an estimation should be planned
- We need clear **functional specifications** for both the IR magnets and detector, input is required for cryogenic infrastructure design → impact on costing, availability, integration

Main MDI components being implemented – integrated

- **IR magnet system & cryostat** design and interfaces
- **Remote Vacuum Connection** – Magic Flange
- **IR BPMs** (in front of QC1, QC2, LumiCal)
- **IR bellows** (special-HOM absorber & with cooling)
- **NEG pump** (hard to present tight space constraints)
- **Services (**cooling for vertex and for vacuum chambers) and cables
- **SR Masks – in progress Optimal Shape** & **Longitudinal position** (efficiency vs impedance)
- **Survey & alignment system**

- Beamstrahlung photon dump

- **IR mockup** at LNF

list of components with
different level of complexity and maturity.
The goal of our present study phase is
to prove that the MDI design is feasible,
with no showstoppers

see talk by A. Ciarma

“Standard” Solenoid compensation (P. Raimondi)

Coupling compensation

The best compromise between performances and feasibility seems to be:

- **no compensating solenoid**
- **zero the Bs (solenoid) field with starting from 2mt** from the IP until the end of the detector solenoid
- **zero the Sum(Bs*l) with antisolenoids (2 per beam) outside the IR quads.**
- corrects residual coupling with weak **skew quads** wrapped around the IR quads.
- correct orbit with weak **correctors** in several locations around the IR
- correct dispersion with standard tuning knobs

Courtesy H. Burkhardt

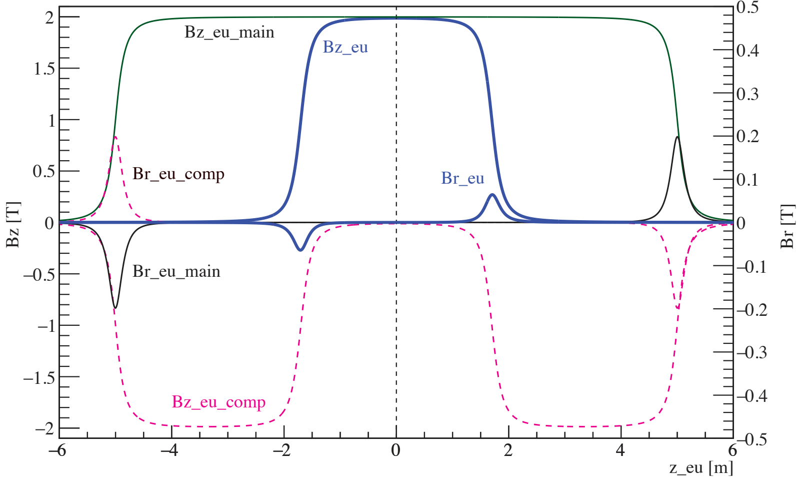


Figure 123: Analytical B_z and radial B_r solenoid fields as seen on a straight line with 15 mrad horizontal angle in detector (eu) coordinates.

Correctors and skews are no matter what needed for orbit and coupling correction (tuning knobs)

This solution is “optics independent”, could be applied to the baseline or the LCCO optic

Screening solenoid wishes/possibilities

- It could have a smaller outer radius
- It could be tapered to minimize the detector end-field effects (probably different for each detector)
- *Could it be generated by QD0A?*

Beam induced Backgrounds

Luminosity induced backgrounds

Radiative Bhabha
Beamstrahlung: photons and spent beam
    Incoherent/ Coherent e^+e^- Pair Creation
    $\gamma\gamma$ to hadrons

Synchronous with the interaction, can be discriminated at trigger level

Single Beam effects

Synchrotron Radiation
Beam-gas
Thermal photons
Touschek

Injection backgrounds

Mostly can be mitigated with collimators & shieldings, except for those produced just in the IR

For the feasibility study the single beam effects was tackled starting from developing a new code for particle tracking and study the **halo beam**, with an LHC-like approach.
A collimation region was implemented for halo beam.

IP backgrounds

Mostly unavoidable and proportional to the luminosity, only the multiturn losses can be mitigated with collimators

Radiative Bhabha *BBBrem/GuineaPig & SAD/MADX*

- multiturn tracking of spent beam
- characterization of photons produced at IP

First studied with SAD (CDR), ongoing effort to implement it in Xsuite.

Partial results also with baseline lattice

Beamstrahlung *GuineaPig /BBWS & SAD/MADX*

see talks by
P. Kicsiny & A. Abramov

Ongoing effort to implement it in Xsuite

Studied with baseline lattice

- multiturn tracking of spent beam
- characterization of photons
  - collinear with the core beam→ BS photon dump
  - **e^+e^- pairs** *GuineaPig, G4 into detector (CDR & baseline lattice)*
    - **Coherent** Pairs Creation: **Negligible**
      Photon interaction with the collective field of the opposite bunch, strongly focused on the forward direction
    - **Incoherent** Pairs Creation**: Dominant** (real or virtual photon scattering)
  - **γγ to hadrons** combination of *GuineaPig and Phythia, G4*
    Small effect (Direct production of hadrons, or indirect, where one or both photons interact hadronically)

Study performed
for the CDR
&
with baseline lattice

Being synchronous with the interaction, can be discriminated at trigger level

Wed. MDI session II 11H00-12H30

Single Beam particles effects

see talk A. Abramov

see talk K. Andre

- Synchrotron Radiation
  - main driver of the IR design, studied with various tools, approaches, for all the optics
  - SR collimators and masks implemented, effect of non-Gaussian tails on the mask tip & effect during top-up injection studied
- Inelastic/ Elastic beam-gas scattering
  - Only first studies done for the CDR.
  - Pressure maps (all ring and MDI region) now available for the baseline lattice.
  - Ongoing effort to implement it in Xsuite for multiturn tracking and loss maps, and eventually determine collimators in the upstream MDI regions.
  - Beam-gas background produced in the IR and its impact to detector: planned with Fluka, now working on the MDI model

see talk R. Kersevan

see talk A. Frasca

- Thermal photons
  - Only first studies done for the CDR
  - Ongoing effort to implement it in Xsuite for multiturn tracking and loss maps, and determine collimators in the upstream MDI regions.
- Touschek
  - Expected not to be relevant due to high beam energy, but to be studied, especially at the Z-pole, due to the dense beam (high bunch current and low emittance)

Conclusion -- Progress & plans on key aspects of the MDI design

❑ IR magnet system & Cryostats
- FF Quads & Correctors
- Solenoid comp. scheme & anti-solenoid design

❑ IR Mechanical model, including vertex and lumical integration, and assembly concept
- Services (i.e. air & water cooling for vertex and vacuum chambers) and cables
- Anchoring to the detector
- Accessibility & Maintenance
- Vacuum connection
- IR BPMs
- Integrate in the design an alignment system

❑ Beam induced backgrounds
- The MDI region is now improved as more realistic, and software model developed.
- Single beam effects being implemented in Xsuite, and additional collimators might be needed. Halo beam collimators have been added.
- SR backgrounds studied in different conditions and beasline/LCCO optics compare
- Study of IR radiation level & fluences started (Fluka)
- Optimization of shielding will follow
- Beamstrahlung dump with radiation levels

❑ Heat Loads from wakefields in IR region
- In progress

And thanks to many people for inputs!

Backup

P. Borges de Sousa link,
MDI Workshop, Frascati 16-17 Nov. ’23
https://agenda.infn.it/event/37720/

Comparison of cooling options

1.9 K in He II

- ✓ Stable *T* environment with extremely low vibration levels
- ✓ Allows for highest *T* margin
- ✓ Extremely high heat extraction capability
- ✗ Requires large free x-section for He II in cold mass, not flexible if heat load increases
- ✗ Creates need for He II cryoplant, cold compressors underground
- ✗ Higher cost
- ✗ Higher underground cavern footprint

NB: COP^{-1} at refrigerator I/F ≈ 960 W_{el}/W_{cool}

4.5-5 K in sc or LHe

- ✓ Pool boiling provides stable *T* but difficult to ensure filling; requires exhaust
- ✓ Forced He flow at 3-4 bara can be implemented in small annular space around coils/pipes embedded in former
- ✓ Same *T* level as usually required by detectors, can share same cryoplant if appropriately sized
- ✓ Smaller distribution line required
- ✗ Temperature gradient O(0.5-1 K) along length of cold mass
- ✗ Turbulent flow in annular space or pipes may cause small vibrations

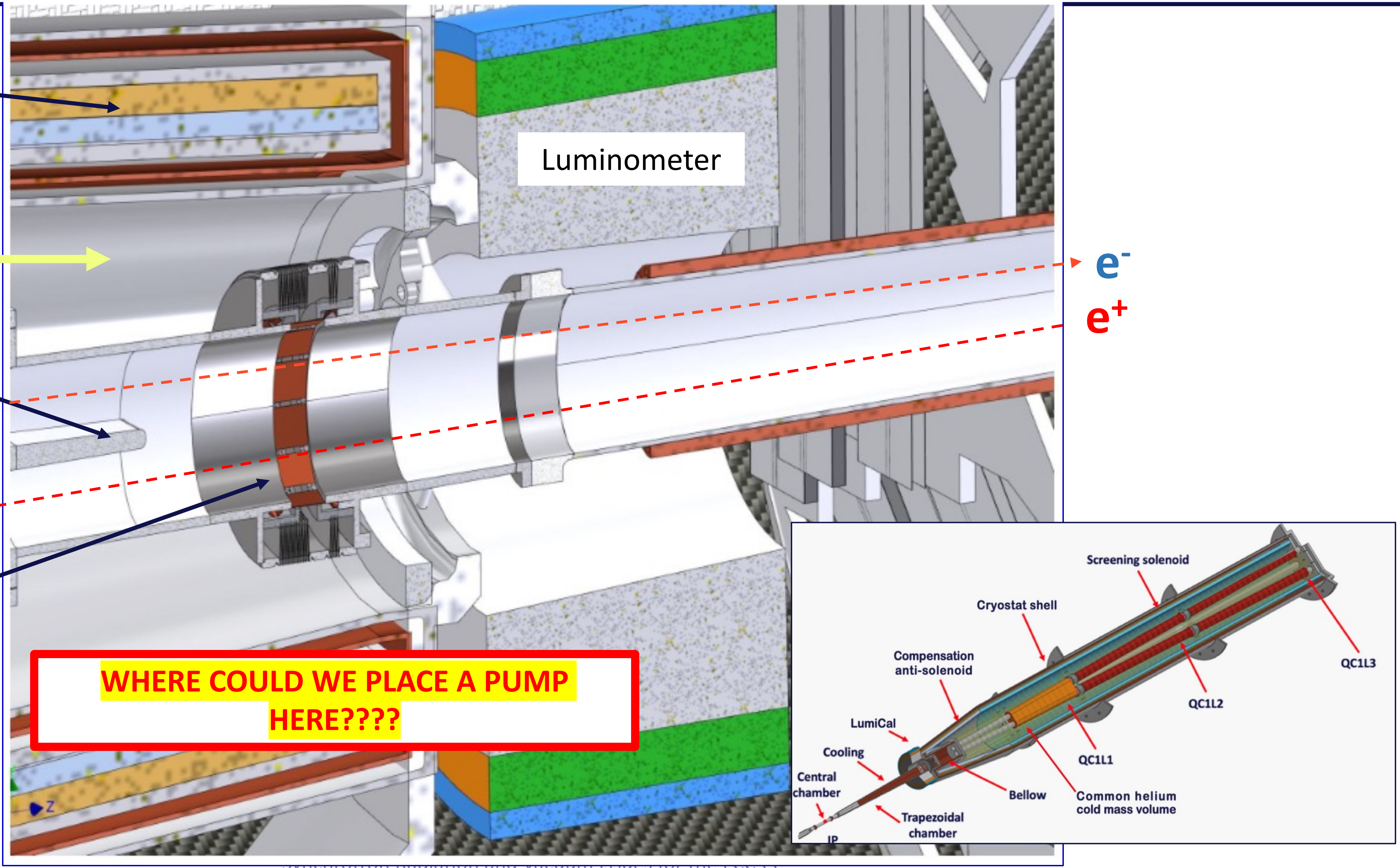
NB: COP^{-1} at refrigerator I/F ≈ 240 W_{el}/W_{cool}

10-20 K He gas

- ✓ Forced He flow at 3-20 bara can be implemented in small annular space around coils/pipes embedded in former
- ✓ Higher *T* means lower overall power consumption for cryo
- ✓ Smaller distribution line required
- ✗ Temperature gradient O(5-10 K) along length of cold mass
- ✗ Turbulent flow in annular space or pipes may cause small vibrations

NB: COP^{-1} at refrigerator I/F ≈ 50 W_{el}/W_{cool}

Extremely tight fabrication and alignment tolerances: accurate ray-tracing is a must



Cryostat with integrated anti-solenoid coils

SPACE RESERVATION FOR **REMOTE FLANGE CONNECTION** (SMA)

Crotch (2 beams→1)

Alignment bellow (ESRF-design)

WHERE COULD WE PLACE A PUMP HERE????

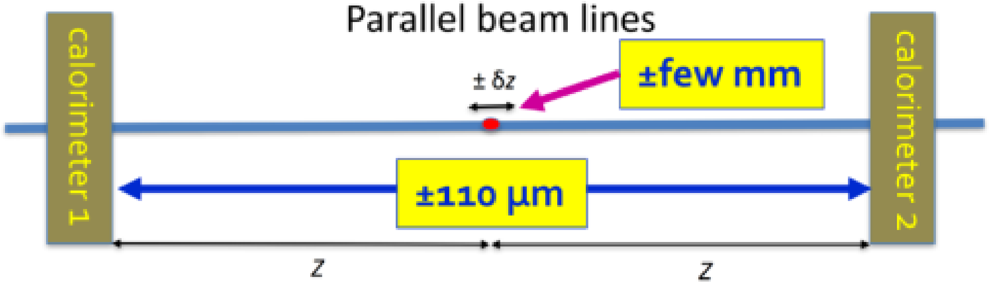
LumiCal constraints & requirements

see talk by M. Dam

Goal: absolute luminosity measurement 10^{-4} at the Z

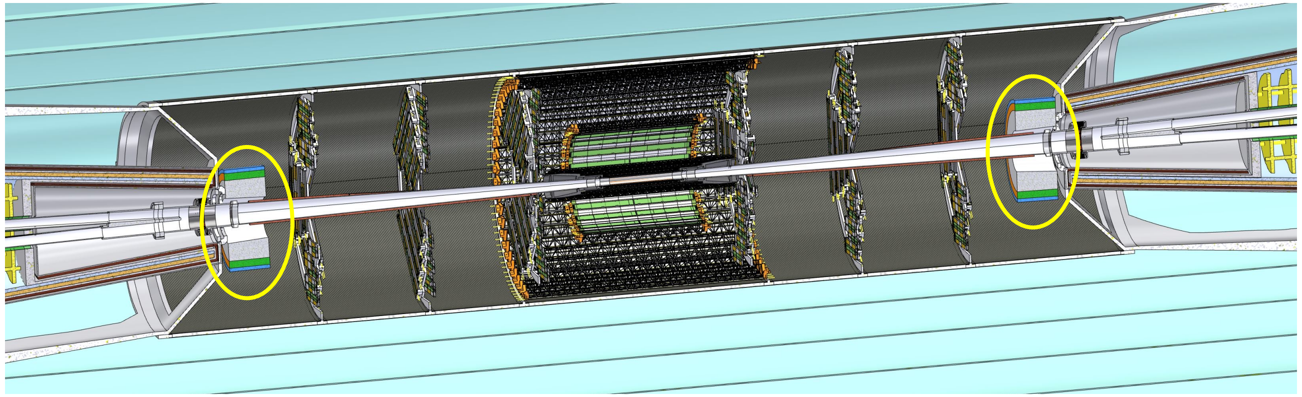
Standard process Bhabha scattering

- Bhabha cross section 12 nb at Z-pole with acceptance **62-88 mrad**
- Requires **50-120 mrad clearance to avoid spoiling the measurement**
- Requirements for alignment
  few hundred μm in radial direction
  few mm in longitudinal direction



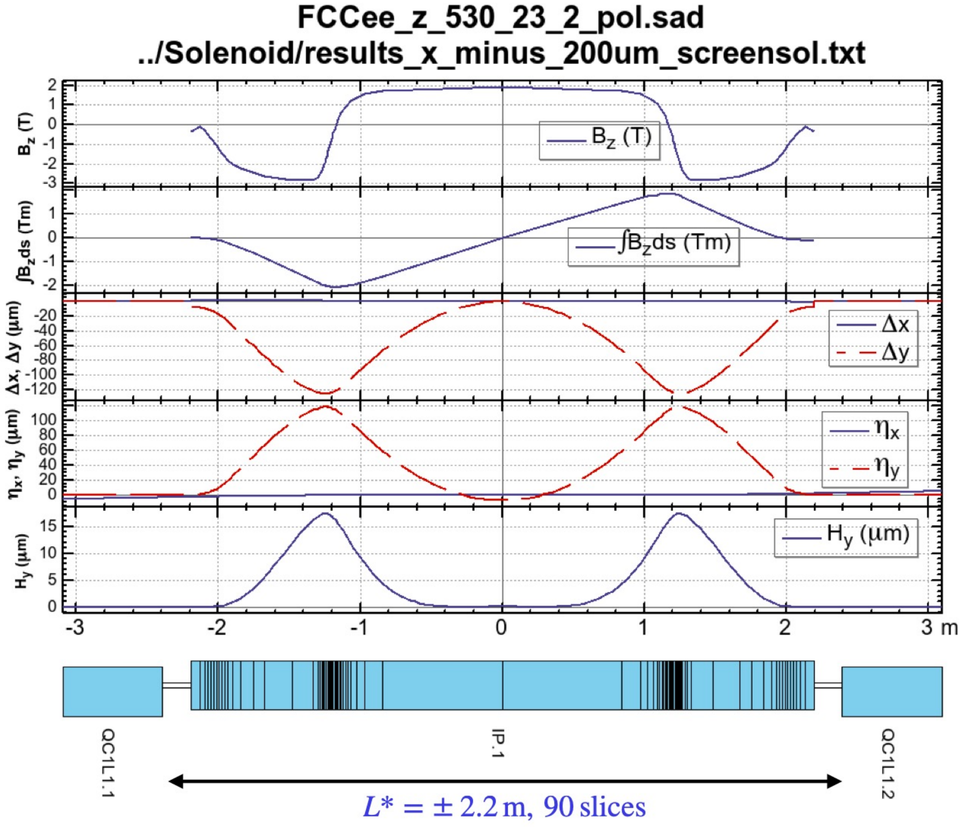
Lumical integration:

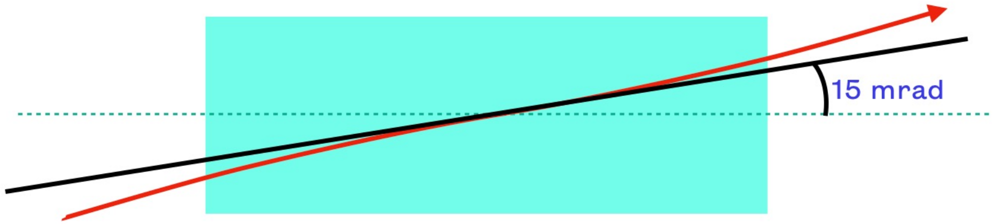
- **Asymmetrical cooling system** in conical pipe to provide angular acceptance to lumical
- **LumiCal held by a mechanical support structure**



Optics including a realistic solenoid (M. Koratzinos)

- A realistic solenoid + multipole field given by M. Koratzinos has been included into the latest 4 IP lattice.
  - Both MAD-X and SAD can include the same solenoid field map, *independently* (H. Burkhardt, L.V. Riesen-Haupt).
- In this SAD model, the L* region (IP±2.2 m) is divided into 90 slices with *unequal thicknesses* ≧5 mm, *along the tilted straight line (±15 mrad),* not along the solenoid axis.
- No leak of vertical dispersion and x-y coupling to the outside region.
  - $\alpha, \beta,$ and hor. dispersion leak outside.
  - The leaked optics and hor. dispersion are adjusted to the no-solenoid case by tweaking several outer quads.
- The associated vertical emittance is 0.43 pm at Z.
- The highest contribution to the vertical emittance comes from the middle transition ($s \sim \pm 1.2$ m) of B_z.





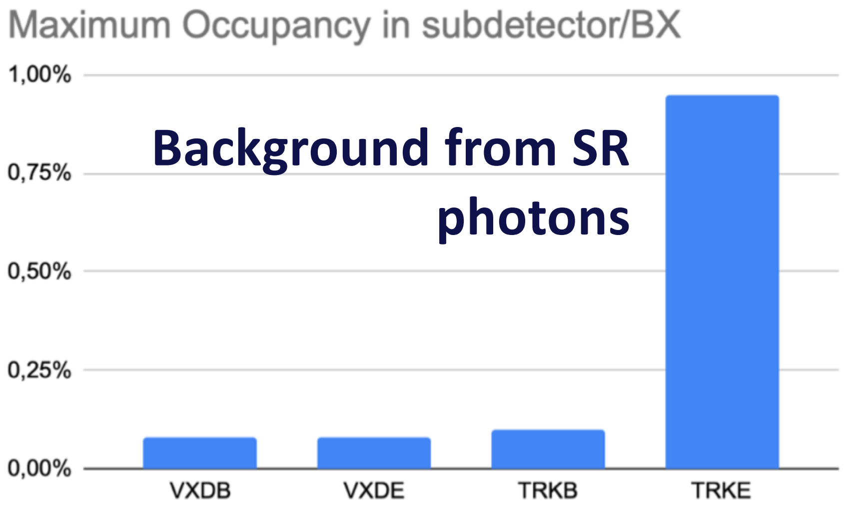
The beam optics shown here and later are not the latest ones in details.

Nov. 16, 2023, K. Oide

Detector background simulations

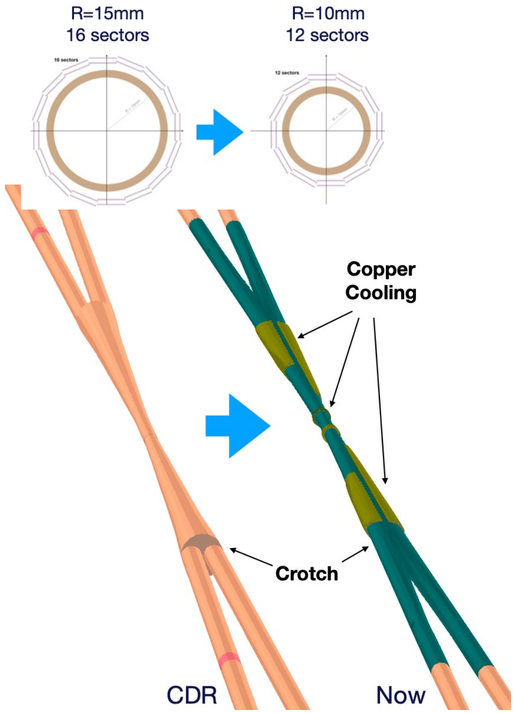
More realistic MDI software model implemented in key4hep:
- CAD beam pipe
- lumical
- IR magnet and cryostat hollow shell
- CLD VXD adapted to the smaller 10mm radius beam pipe

from beam tails hitting SR mask tips

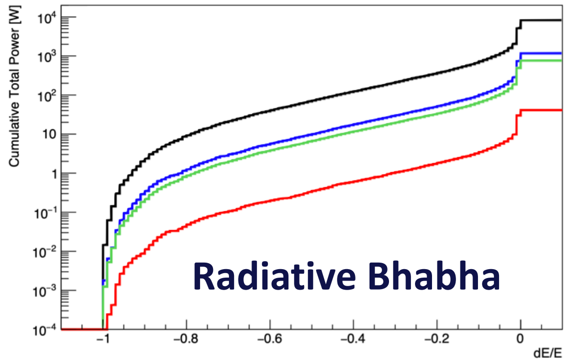


Background from SR photons

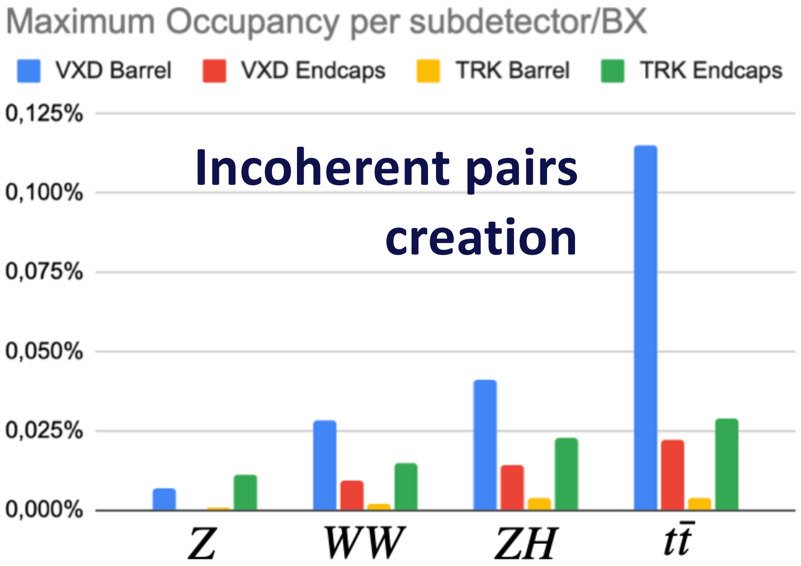
($t\bar{t}$ threshold - CDR beam parameters CLD detector - NO shieldings)



Energy Radiated [dE/E]		>2%	>10%	>50%
Power Carried by spent beam [W]	Z	1500	650	70
	WW	200	100	10
	ZH	150	60	6
	tt	8	3	0.3



Radiative Bhabha

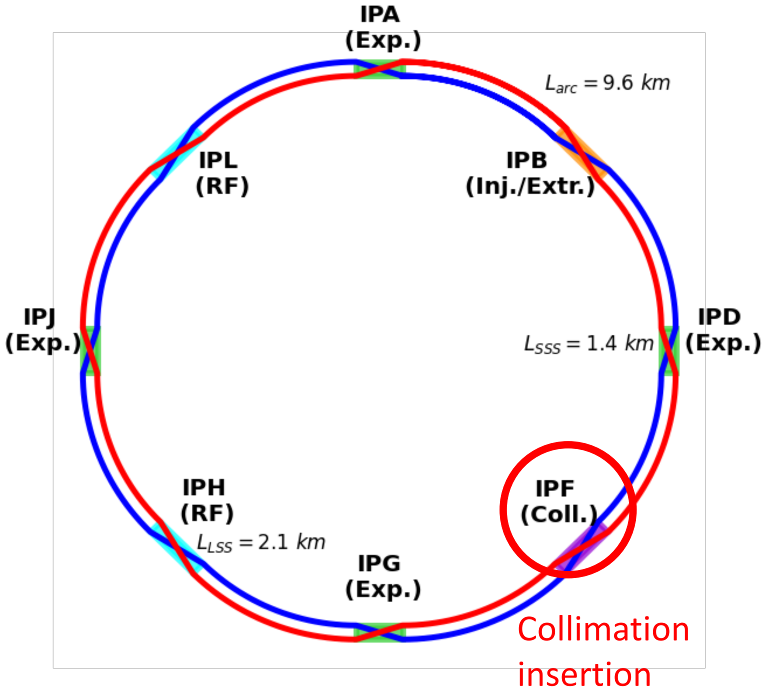


Incoherent pairs creation

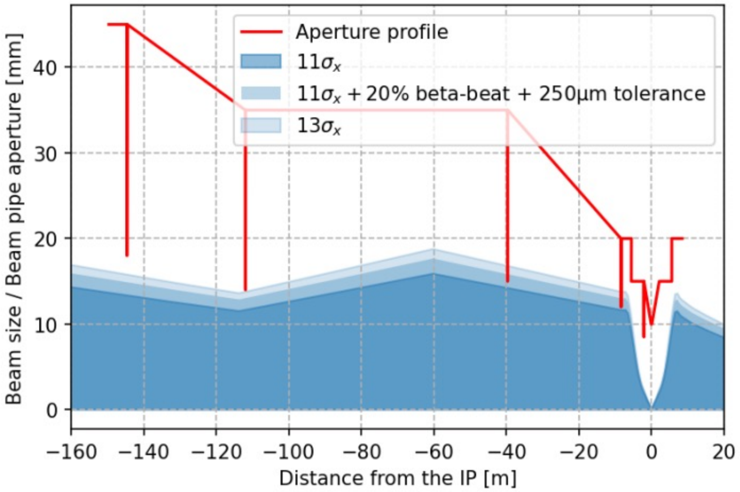
G. Broggi, FCCIS workshop

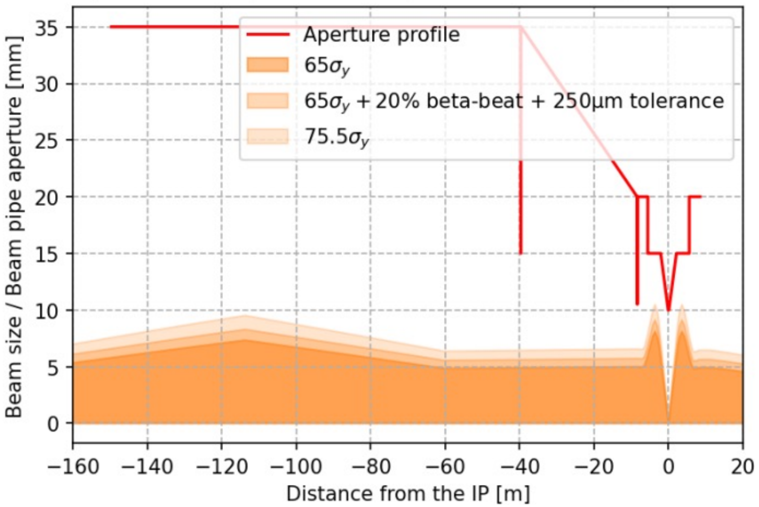
Main Ring Collimation

- **Dedicated halo collimation system in point PF**
  - Two-stage betatron and off-momentum collimation in PF
  - Defines the global aperture bottleneck
  - First collimator design
- **Synchrotron radiation collimators around the IPs**
  - 6 collimators and 2 masks upstream of the IPs
  - Designed to reduce detector backgrounds and power loads in the inner beam pipe due to photon losses



Collimation insertion





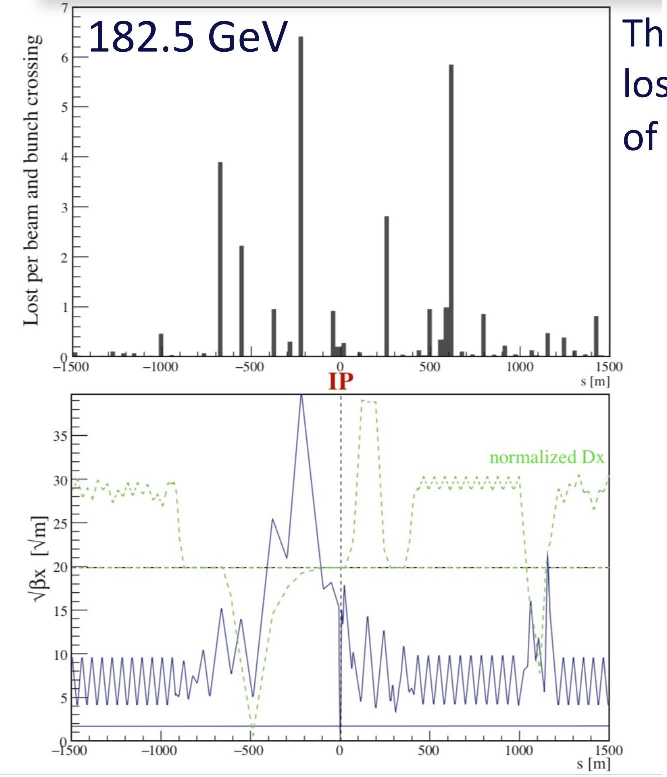
H. Burkhardt, CDR

Thermal photon scattering

First described in <u>1987 by V. Telnov</u> , main single <u>beam lifetime limitation in LEP</u>, <u>well measured</u> and simulated using the algorithm described in <u>SL/Note 93-73</u>

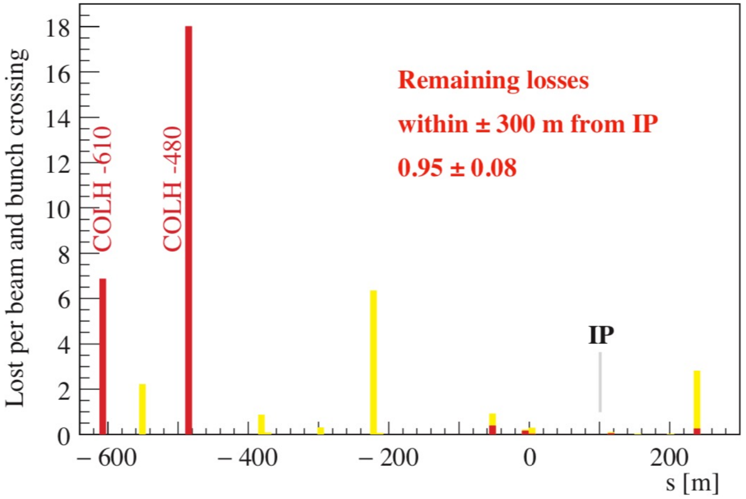
now done using C++ with multithreading, 10^9 events in few min

Normalized loss distribution +/- 1.5 km around IP



Thermal γ 31.2 ± 0.5 |s|<1.5 km from IP lost/beam/crossing
of which 11.1 ± 0.3 |s|< 300 m

Losses now concentrated at these collimators

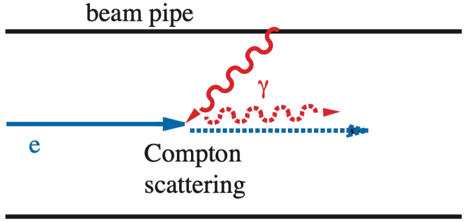


Remaining losses within ± 300 m from IP 0.95 ± 0.08

mitigation by off-momentum collimators

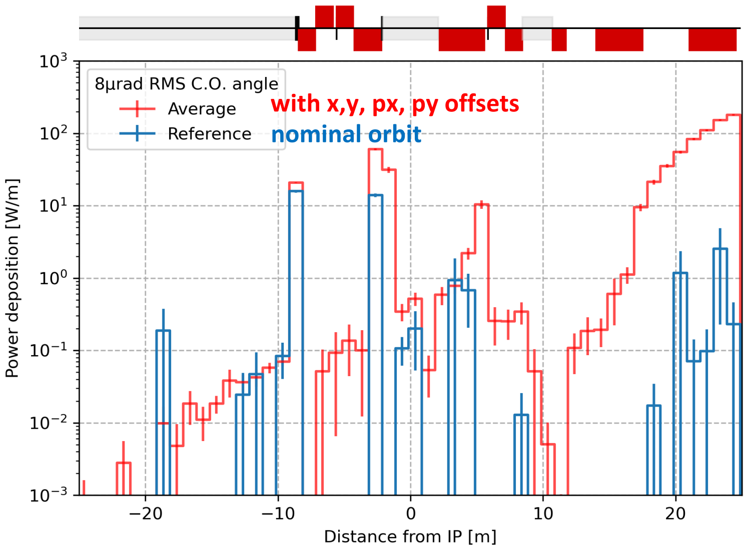
photon density

$\rho_\gamma = 5.3\times10^{14}\ \mathrm{m}^{-3}$



very roughly
0.07 eV thermal photons
boosted by γ^2 to GeV
energy loss from beam

Synchrotron Radiation backgrounds

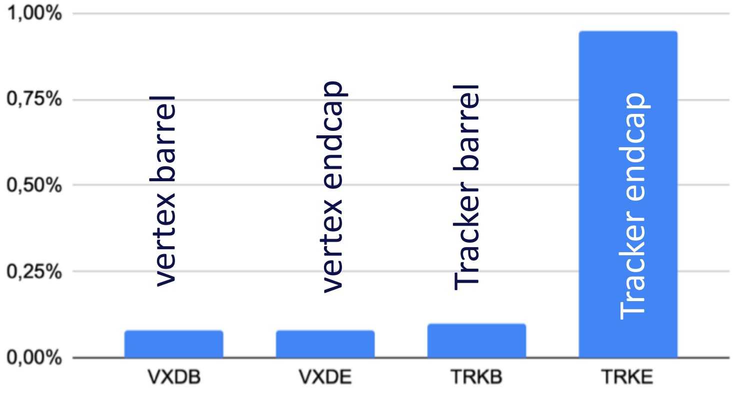


Power deposition from beam core for Z-mode (v22)

Blue is the reference closed orbit

Red is the average with possible offsets due to misalignments

Maximum occupancy in subdetector/BX

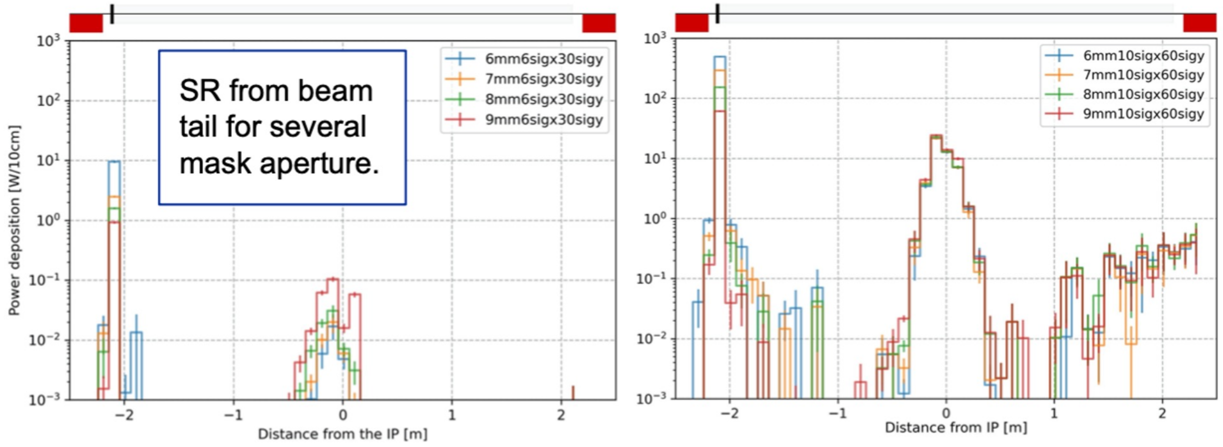


($t\bar{t}$ threshold - CDR beam parameters
CLD detector - NO shieldings)

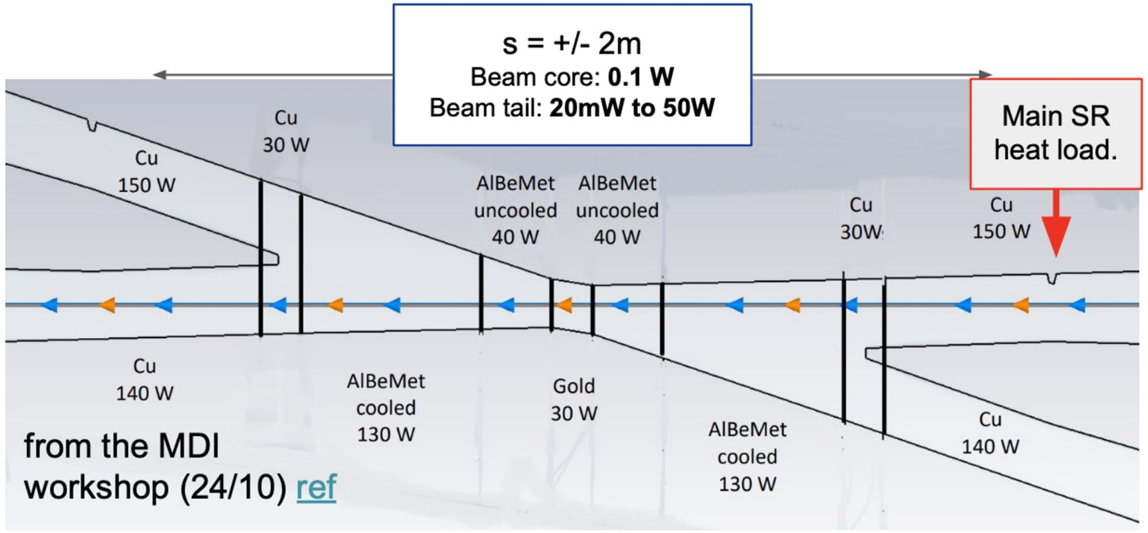
A. Ciarma

from beam tails hitting SR mask tips

Heat load from beam halo synchrotron radiation



SR from beam tail for several mask aperture.



s = +/- 2m
Beam core: **0.1 W**
Beam tail: **20mW to 50W**

Main SR heat load.

from the MDI workshop (24/10) ref

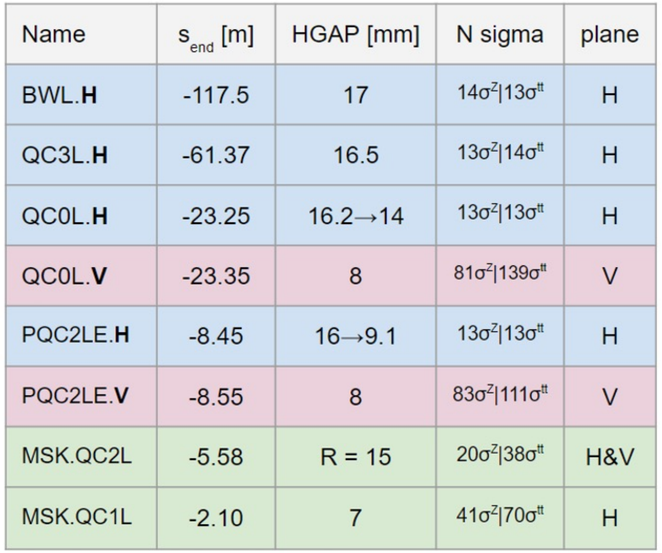
Heat Load from wakefields

SR Studies and Mask Design

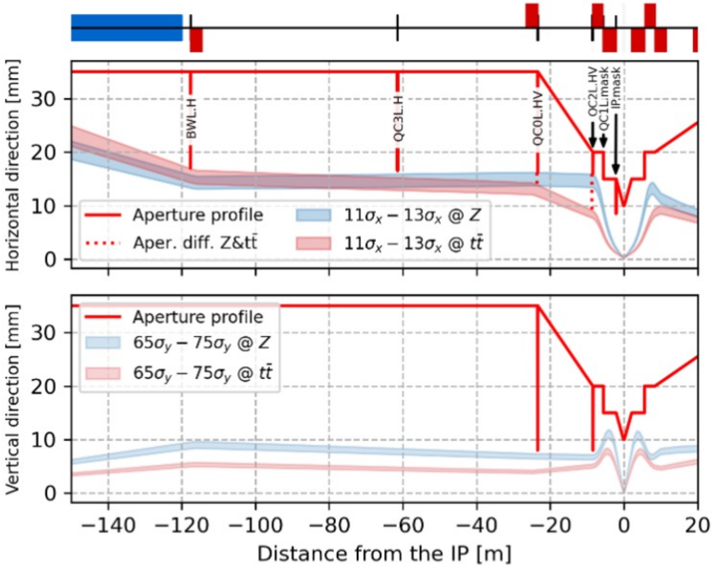
The SR collimation for **Z** and **tt** operation modes including transverse tails and non-zero closed orbit is effective.

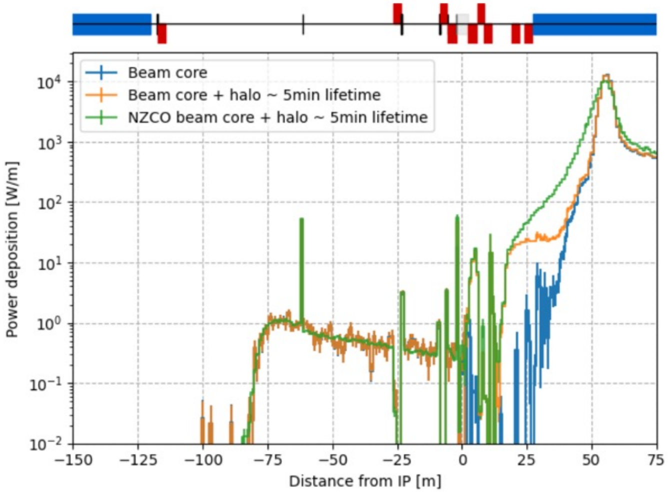
Tens of watts deposited on the mask, cooling ?

The first studies of the V23 lattice and optics designs prove to produce less SR power deposition around the IP.

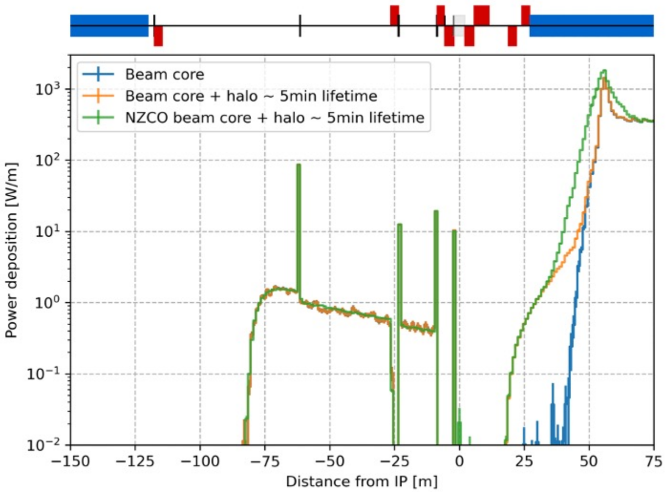


Name	s_{end} [m]	HGAP [mm]	N sigma	plane
BWL.**H**	-117.5	17	$14\sigma^{Z}\|13\sigma^{tt}$	H
QC3L.**H**	-61.37	16.5	$13\sigma^{Z}\|14\sigma^{tt}$	H
QC0L.**H**	-23.25	16.2→14	$13\sigma^{Z}\|13\sigma^{tt}$	H
QC0L.**V**	-23.35	8	$81\sigma^{Z}\|139\sigma^{tt}$	V
PQC2LE.**H**	-8.45	16→9.1	$13\sigma^{Z}\|13\sigma^{tt}$	H
PQC2LE.**V**	-8.55	8	$83\sigma^{Z}\|111\sigma^{tt}$	V
MSK.QC2L	-5.58	R = 15	$20\sigma^{Z}\|38\sigma^{tt}$	H&V
MSK.QC1L	-2.10	7	$41\sigma^{Z}\|70\sigma^{tt}$	H





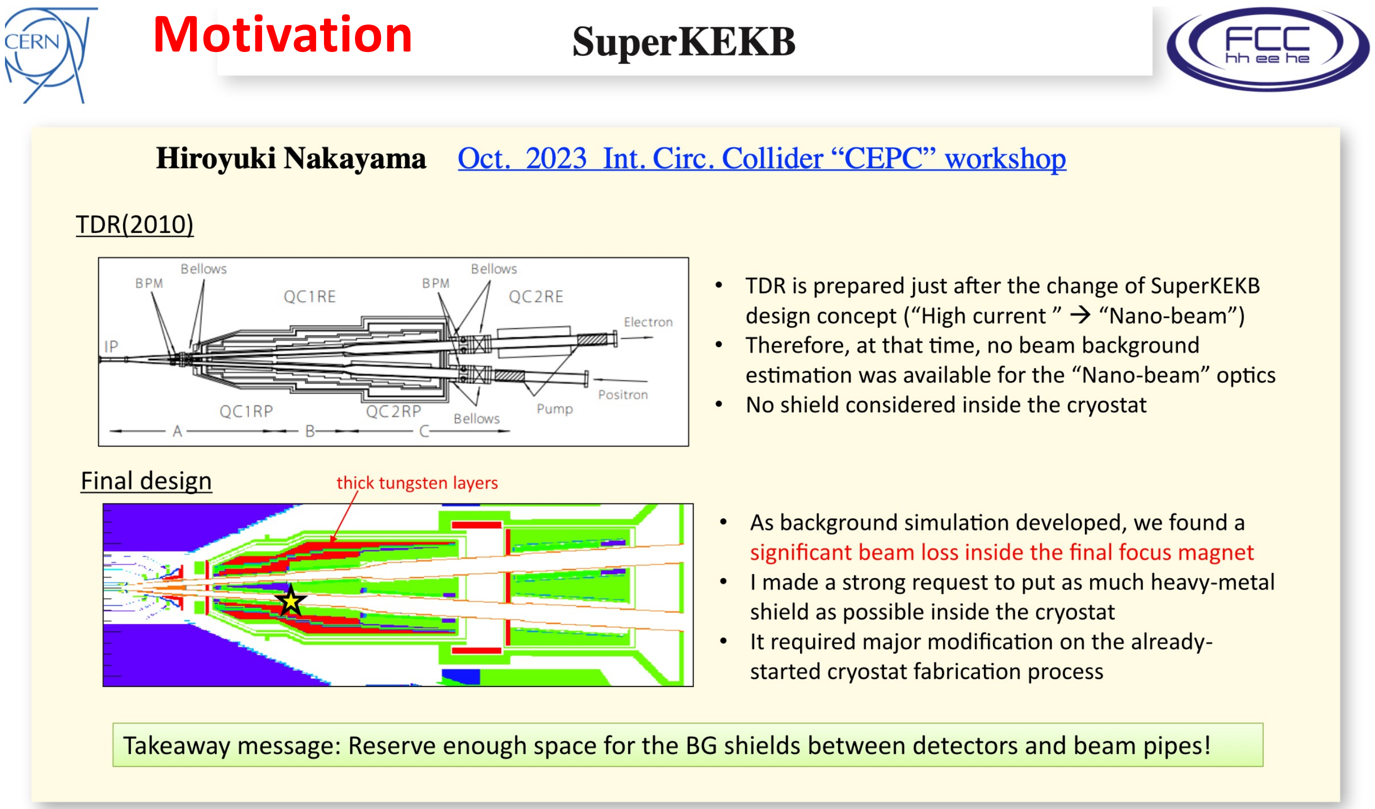
Power deposition from synchrotron radiation at Z



Power deposition from synchrotron radiation at tt

Tungsten Shielding in the MDI and Muon Background

H. Burkhardt



Motivation

SuperKEKB

Hiroyuki Nakayama Oct. 2023 Int. Circ. Collider "CEPC" workshop

TDR(2010)

- TDR is prepared just after the change of SuperKEKB design concept ("High current " → "Nano-beam")
- Therefore, at that time, no beam background estimation was available for the "Nano-beam" optics
- No shield considered inside the cryostat

Final design

- As background simulation developed, we found a significant beam loss inside the final focus magnet
- I made a strong request to put as much heavy-metal shield as possible inside the cryostat
- It required major modification on the already-started cryostat fabrication process

Takeaway message: Reserve enough space for the BG shields between detectors and beam pipes!

Good strategy confirmed by LEP measurements

1) **minimize background at the source**
2) **collimate halo far from IP ; do not reduce lifetime**
3) **off-momentum collimation end of arc each IP**

further beam-gas / thermal photon / collimation & IR modeling studies

SuperKEKB : HER 7 GeV e- LER 4 GeV e+

To which extend do we need that for the FCC-ee IR ?

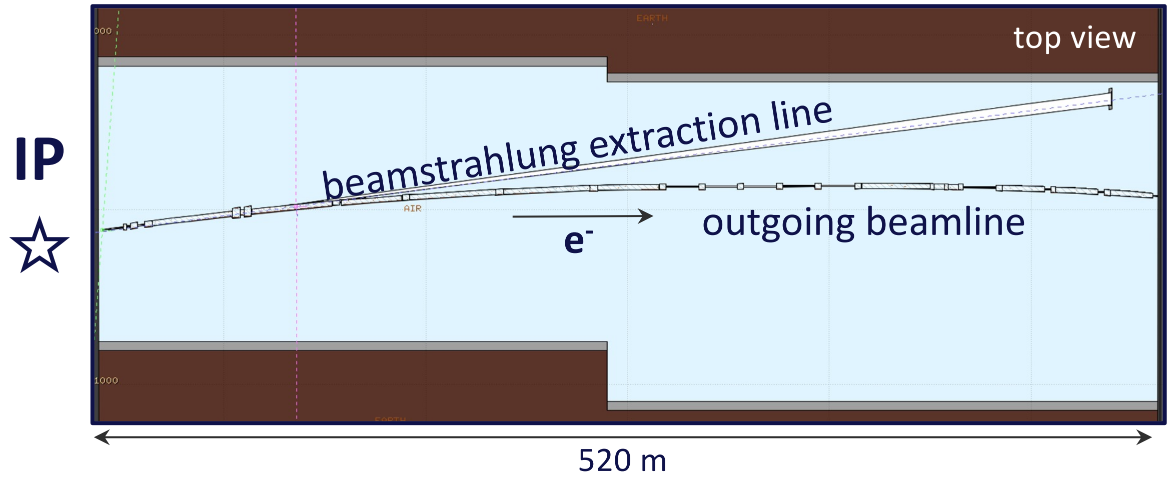
Pay attention to add shielding: it can be a source of background if not properly studied!
Probably additional collimators in the IR need to be added

FLUKA studies of the FCC-ee IR

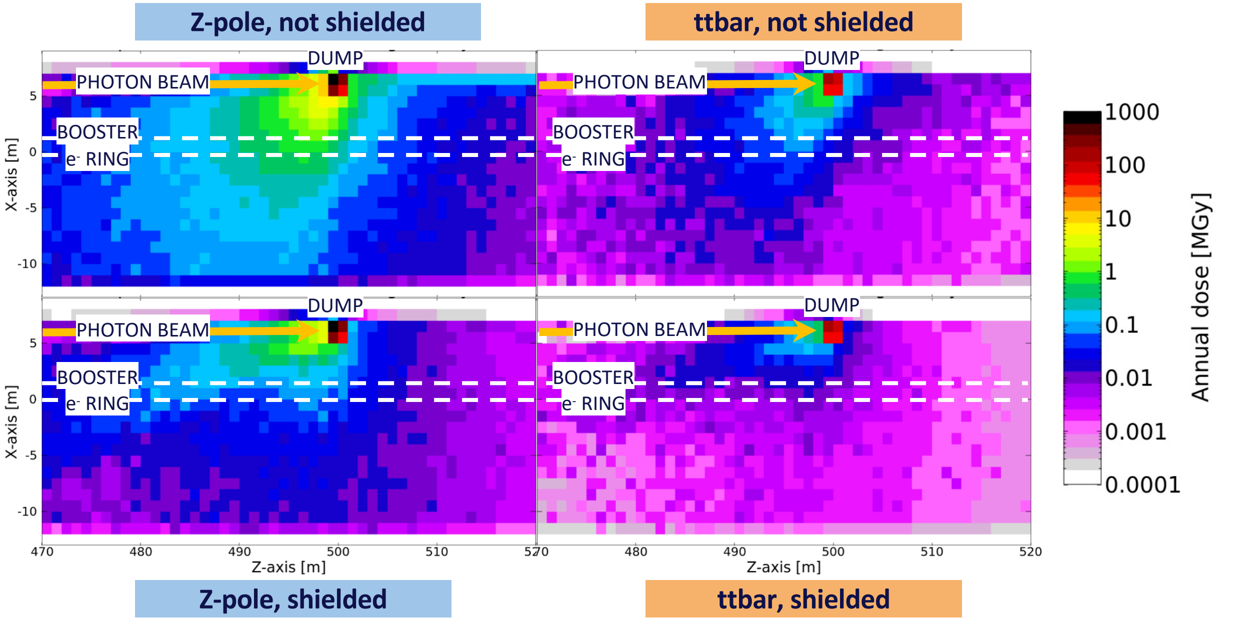
FLUKA model to estimate the radiation levels in the FCC-ee tunnel in the experimental IR

- beamstrahlung dump and synchrotron radiation outgoing from the IP investigated
- no SR absorbers included
- radiation studies for the detector and FFQ to be addressed soon (including beamline incoming to the IP)

FLUKA MODEL

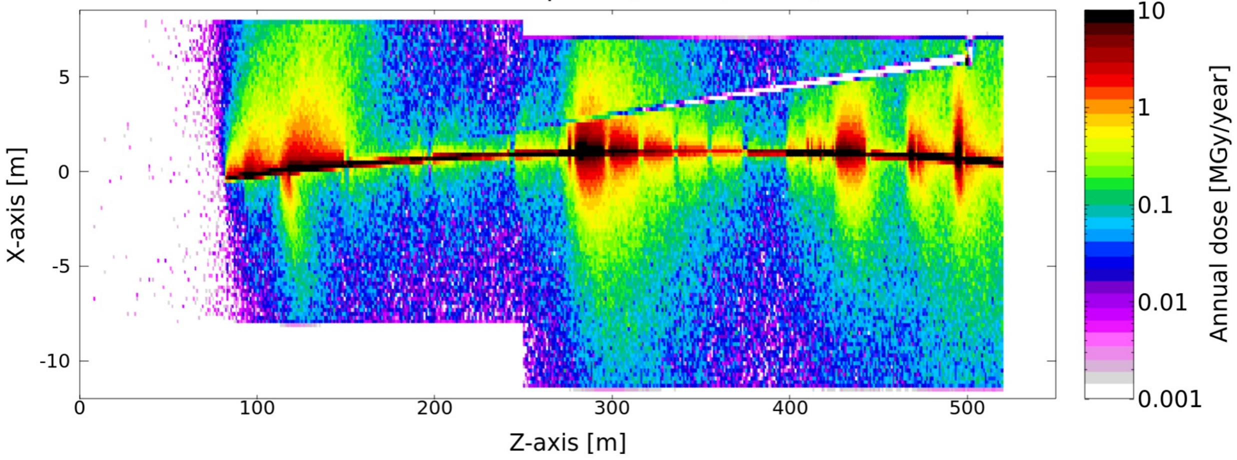


ANNUAL DOSE FROM BEAMSTRAHLUNG DUMP



ANNUAL DOSE FROM SR @ttbar

ttbar - horizontal plane (-20cm, 20cm)

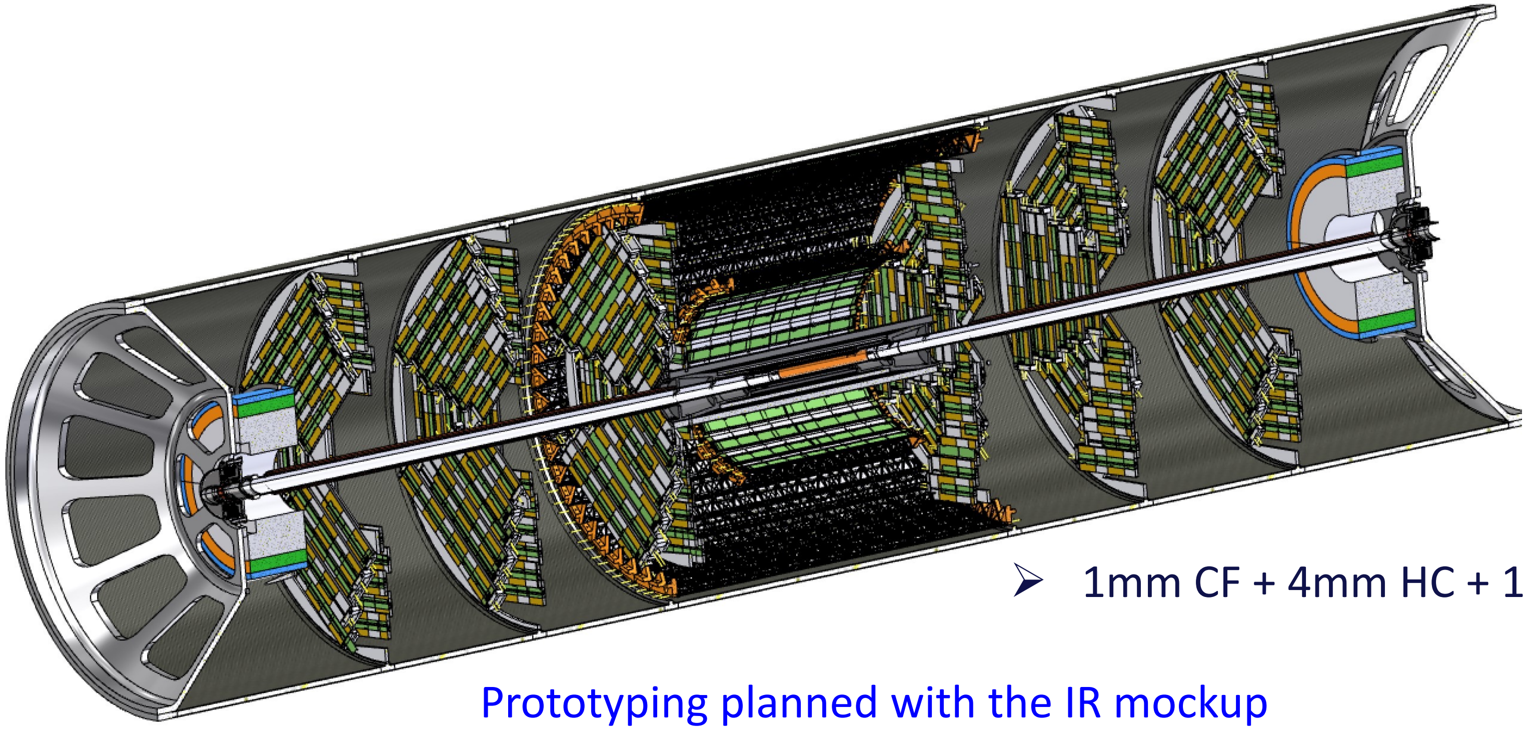


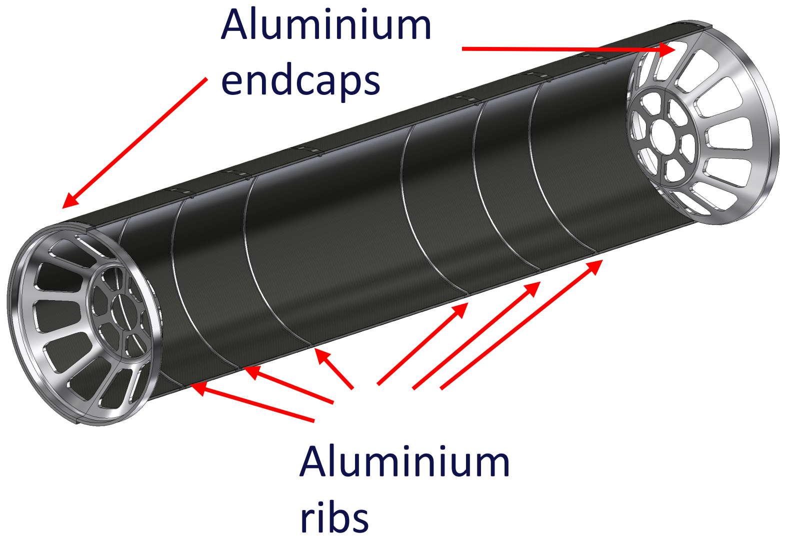
Support cylinder

All elements in the interaction region (Vertex and LumiCal) are mounted rigidly on a support cylinder that guarantees mechanical stability and alignment

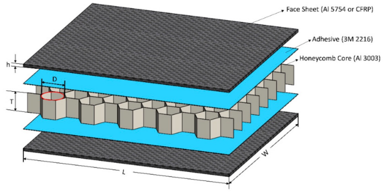
- Provides a cantilevered support for the pipe
- Avoids loads on thin-walled central chamber during assembly or due to its own weight

- Once the structure is assembled it is slided inside the rest of the detector
- Studies on-going where to anchor it (see A. Gaddi, Joint Det.-MDI session)





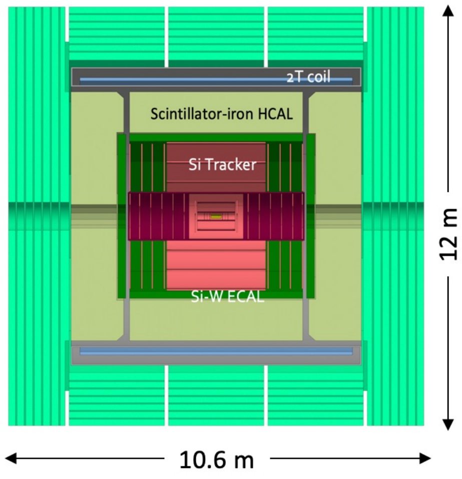
➢ 1mm CF + 4mm HC + 1mm CF



Prototyping planned with the IR mockup

FCC-ee Detector Concepts

CLD

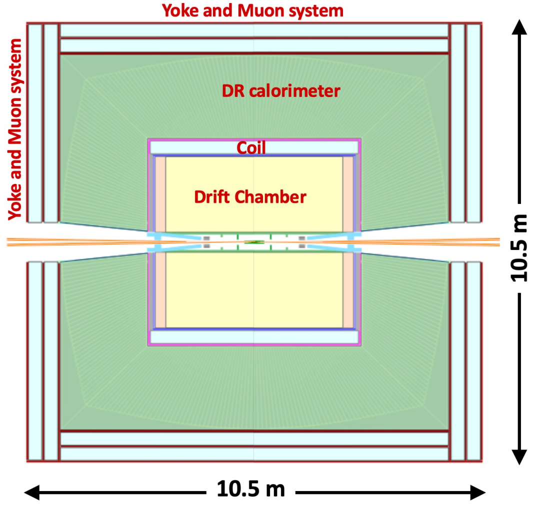


- Full Silicon vertex detector + tracker;
- Very high granularity, CALICE-like calorimetry;
- Muon system
- Large coil outside calorimeter system;

- Possible optimization for
  - Improved momentum and energy resolutions
  - PID capabilities

CDR

IDEA

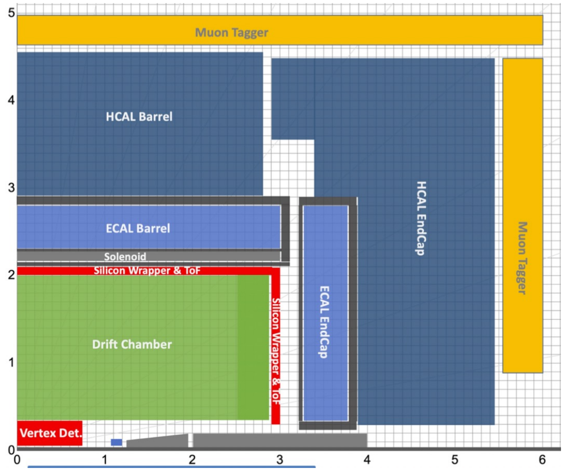


- Si vertex detector;
- Ultra light drift chamber w. powerfull PID;
- Monolitic dual readout calorimeter;
- Muon system;
- Compact, light coil inside calorimeter;

- Possibly augmented by crystal ECAL in front of coil;

ALLEGRO

new



- Noble Liquid ECAL based
- High granularity Noble Liquid ECAL as core;
  - PB+LAr (or denser W+LCr)
- Drift chamber (or Si) tracking;
- CALICE-like HCAL;
- Muon system;
- Coil inside same cryostat as LAr, possibly outside ECAL.