

RADIATION ENVIRONMENT IN THE FCC-EE ARCS

B. Humann, A. Lechner

Thanks to F. Valchkova Georgieva, M. Morrone, C. Garion, J. Bauche, L. van Freeden, A. Romero Francia, M. Calviani

Outline

- **Synchrotron radiation in FCC-ee**
 - Relevant physical properties
- **Geometry layout and simulation setup**
 - Design development
- **Radiation load in the FCC-ee arcs**
 - Power dissipation
 - Annual ionizing dose levels
 - Radiation levels in the electronics bunker
- **Summary and outlook**

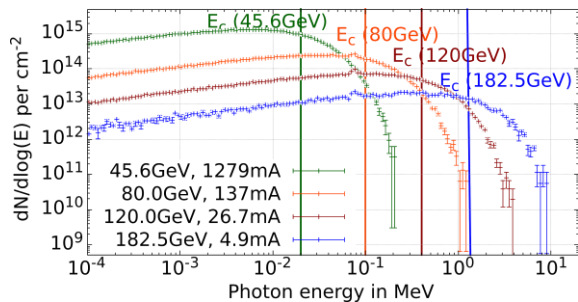
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Synchrotron radiation (SR) in FCC-ee

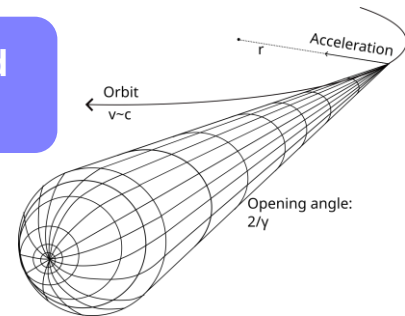
γ of various energy

e^-, e^+
(45.6 GeV-182.5 GeV)



Electromagnetic radiation emitted by charged particles following a curved trajectory

$\rho = 10.021\text{km}$



$E_c \propto E^3$ is a measure for how protruding the SR photons are. It splits the spectrum in two parts of equal power.

$P_{SR} = 50\text{MW}/\text{beam}$ for all operation modes

This presentation provides the results for the *ttbar* operation mode

Radiation load challenges



Instantaneous effect: dissipated power

- Heat deposition in the accelerator components and tunnel



Cumulative effect: ionizing dose

- Cables, optical fibres (for BI)
- Organic insulation material in the magnet coils

In this presentation the ionizing dose is normalized to **1 year of operation** ($1.2 \times 10^7 \text{s}$)

Radiated equipment in LEP



<https://cds.cern.ch/record/1112575/files/cer-002765351.pdf>



R2E

Radiation to electronics (R2E)

Cumulative effects:

- Total ionizing dose
- Si-1MeV neutron equivalent fluence

Single event effects:

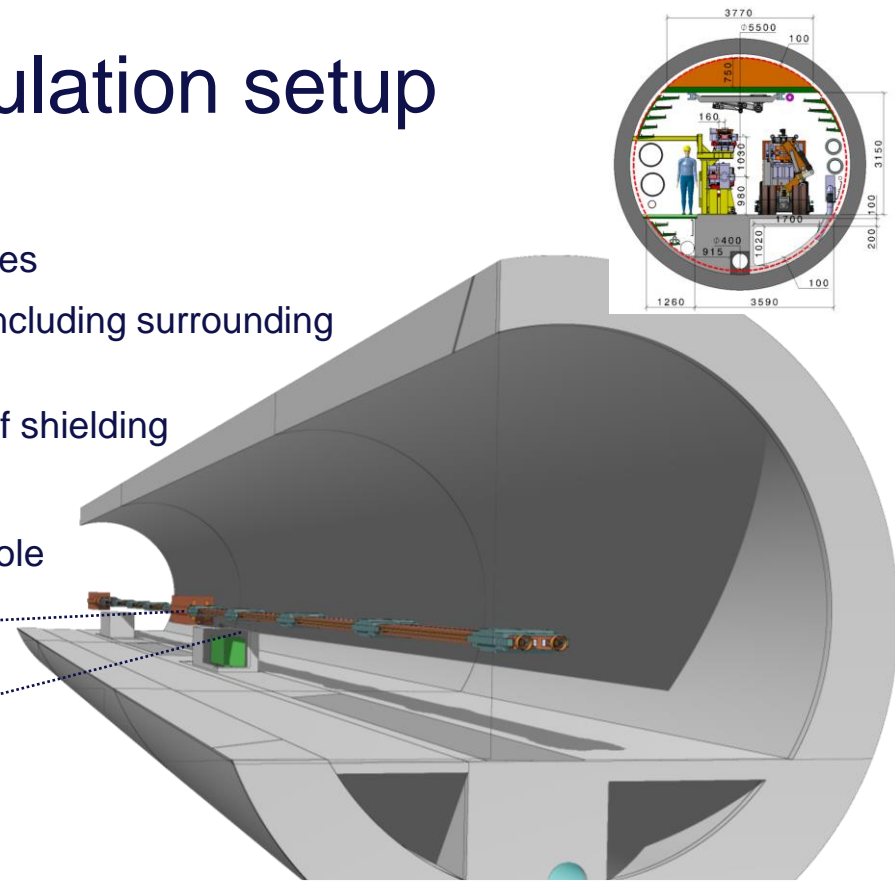
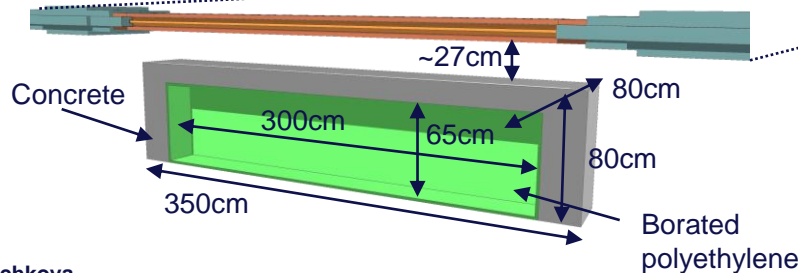
- High energy hadron equiv. fluence
- Thermal neutron equiv. fluence

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Geometry layout and simulation setup

- FODO cell
 - 2 dipoles (19m, 22m), 2 quadrupoles, 2 sextupoles
 - 10 photon stoppers (30cm, **CuCrZr**) per dipole including surrounding shielding (130cm, **Pb96Sb4**)
 - Photon stoppers located upstream w.r.t. center of shielding
- Conceptual design
 - Electronics bunker below dipole next to quadrupole with space for 3 racks (15cm, 25cm walls)

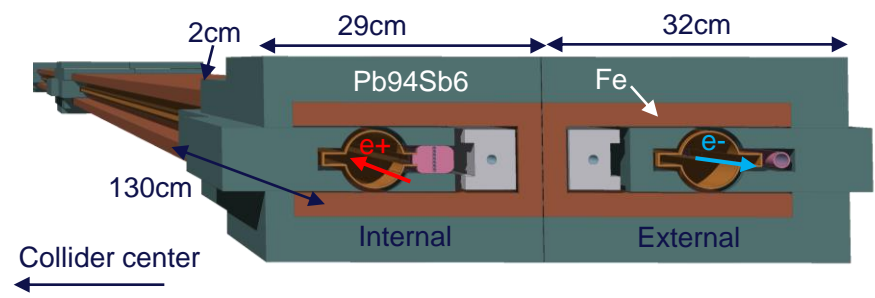


For more information on the shielding strategy, see **A. Lechner's** talk this afternoon

Design development

Feasibility Study Report (FSR):

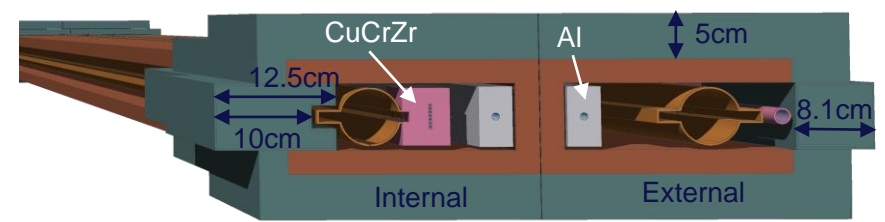
- Shielding enclosing the VC with 5mm gap for bakeout but in contact with photon stopper ($\Delta y = 3\text{cm}$)
- 👎 Complex shape around VC
- 👍 Efficient shielding due to close location of shielding
- **Weight:** ~400kg/shielding
(Total weight: ~10kt for the full machine)



For more information on the technical implementation, see A. Romero Francia presentation this afternoon

Current conceptual design:

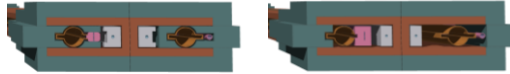
- Enlargement of photon stoppers ($\Delta y = 6.3\text{cm}$)
- 👍 Removal of shielding next to busbars
- Updated busbar dimensions
- Volume of plates on top and bottom as well as lateral extension identical
- **Weight:** ~340kg/shielding



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Power dissipation in one FODO cell



	FSR	Conceptual
Photon stoppers	68.1%	80.7%
Radiation shielding	20.4%	3.7%
Vacuum chambers	7.9%	5.2%
Dipole yokes	3.4%	9.6%
Dipoles busbars	0.1%	0.5%
Environment	<0.03%	<0.05%

- Photon stoppers:** increase of volume vertically
- Maximum total power per photon stopper:
 - FSR: ~3.4kW
 - Conceptual: ~4kW

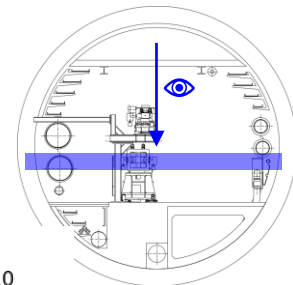
Radiation shielding: removal of material, particularly close to the vacuum chamber

Dipoles: lack of shielding between VC and busbars increases power load

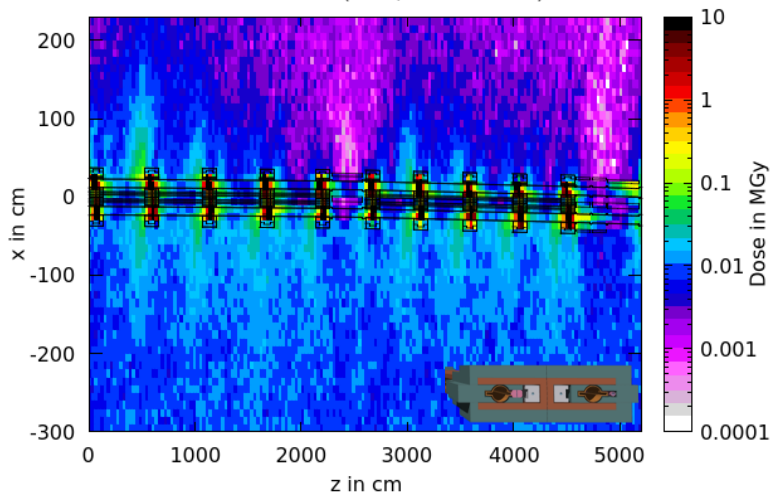
Slight increase in power load in the **tunnel environment** (= everything that is not accelerator)

Dose levels in the tunnel

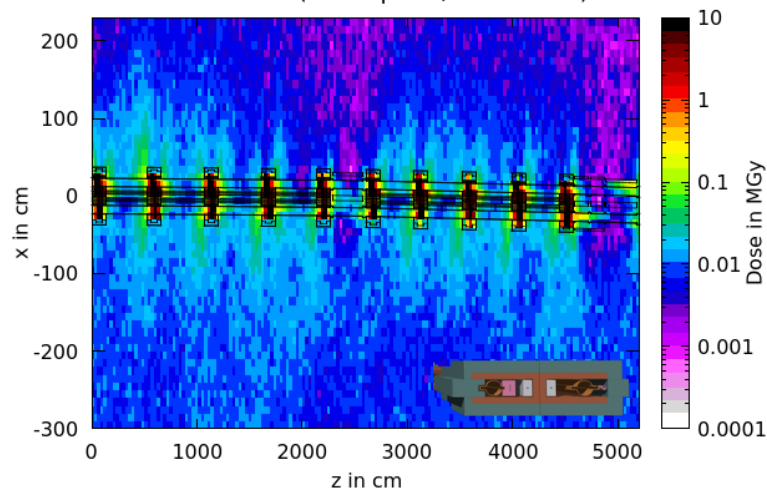
Annual ionizing dose levels at the beam level.



Annual dose (FSR, 182.5 GeV)



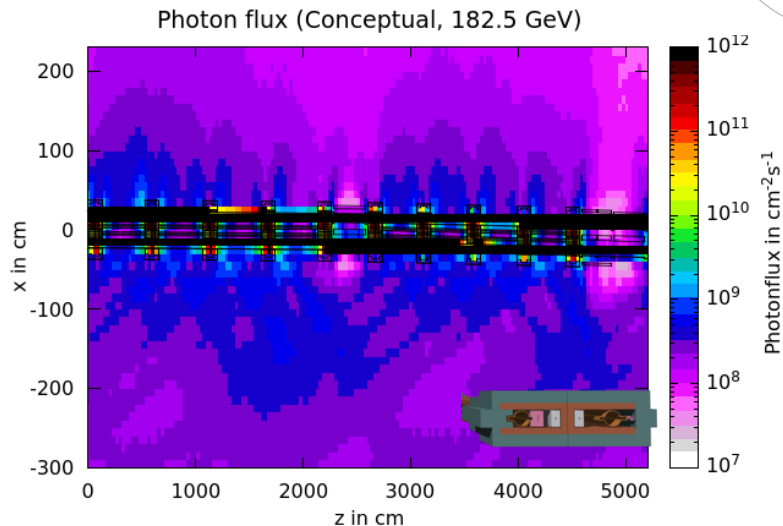
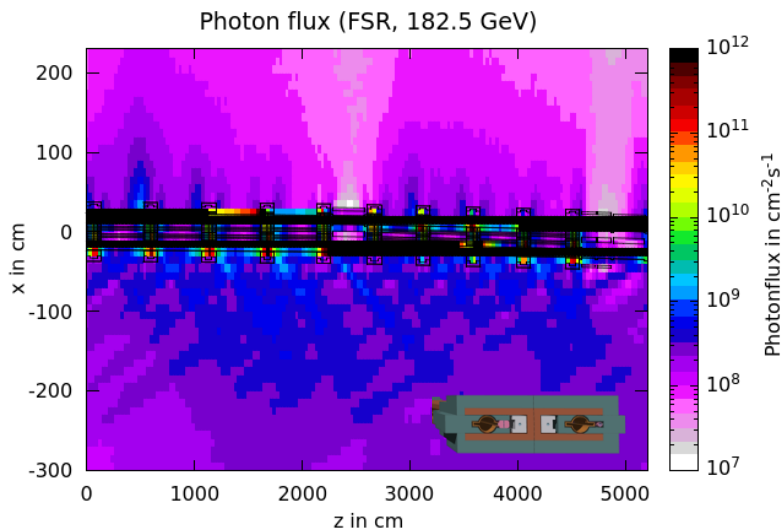
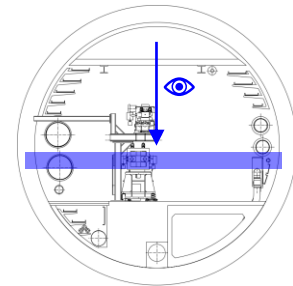
Annual dose (Conceptual, 182.5 GeV)



Externally the dose levels increase from $<10\text{kGy}$ to $\sim 20\text{kGy}$ at the tunnel walls.
Further optimization of the shielding design possible.

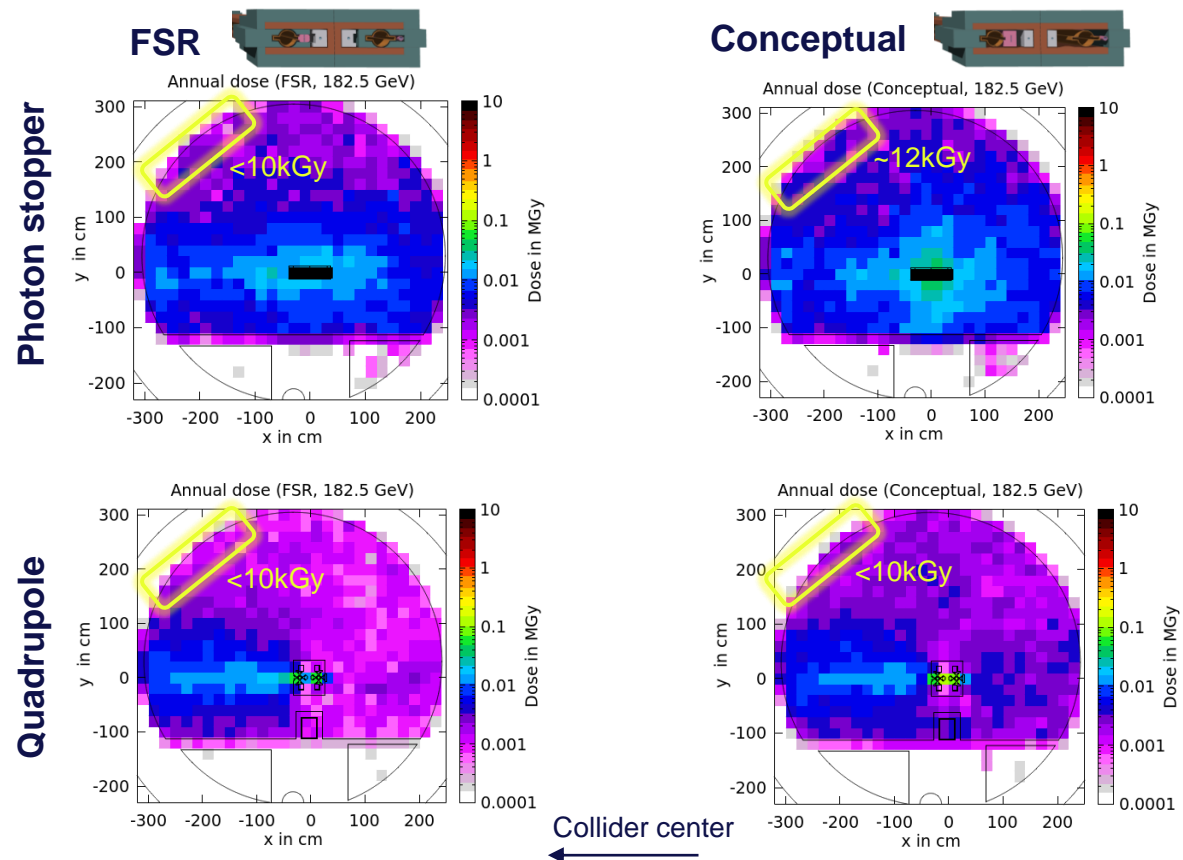
Photon flux in the tunnel

Good indicator helping to understand where the radiation is coming from.



External shielding significantly more effective for the FSR version.
Internally, the C shaped shielding provides good protection with a relatively simple shape.

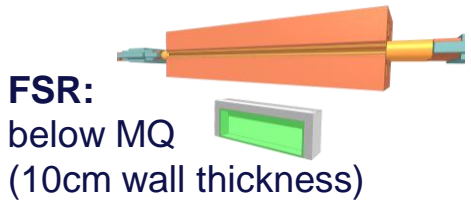
Dose levels in the tunnel – cross section



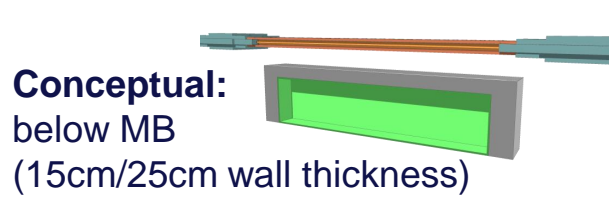
Annual ionizing dose levels at the location of the cable trays.

Slight increase of the dose levels at the cable trays using the conceptual shielding.
Further optimization possible.

R2E related properties in the electronics bunker



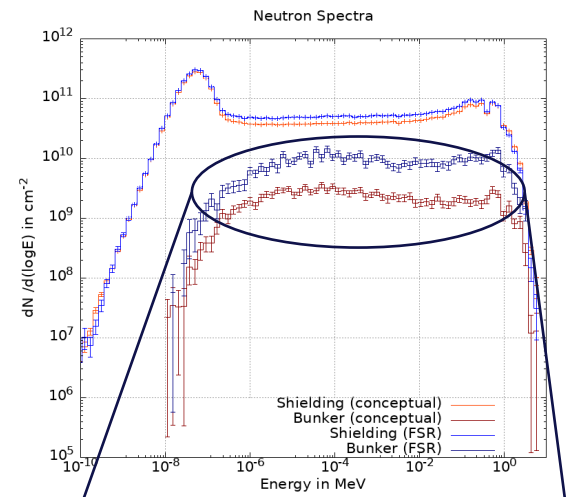
FSR:
below MQ
(10cm wall thickness)



Conceptual:
below MB
(15cm/25cm wall thickness)

	FSR	Conceptual
Total ionizing dose	<10Gy	~3Gy
Si 1 MeV neutron equiv. fluence	$2 \times 10^{10} \text{ cm}^{-2}$	$7 \times 10^9 \text{ cm}^{-2}$
High Energy Hadron equiv. fluence	$2 \times 10^7 \text{ cm}^{-2}$	$1 \times 10^7 \text{ cm}^{-2}$
Thermal Neutron equiv. fluence	$4 \times 10^9 \text{ cm}^{-2}$	$4 \times 10^9 \text{ cm}^{-2}$

Current conceptual bunker design is more efficient due to increase of concrete volume



More efficient shielding results in smaller neutron contribution in the shielded area over all energy ranges

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Summary and Outlook

FSR vs conceptual design

- Simplification of shielding design increases the radiation levels slightly
- Further optimization of shielding design possible

Electronics bunker

- Location below the dipoles is promising
- Assessment of integration still required

What next?

- Implementation of split dipoles and respective photon stopper placement
- Comparison between GHC and LCC lattice



Thank you
for your attention.