FCC

BEAMSTRAHLUNG RADIATION PROPERTIES

Other Science Opportunities at the FCC-ee

29/11/2024

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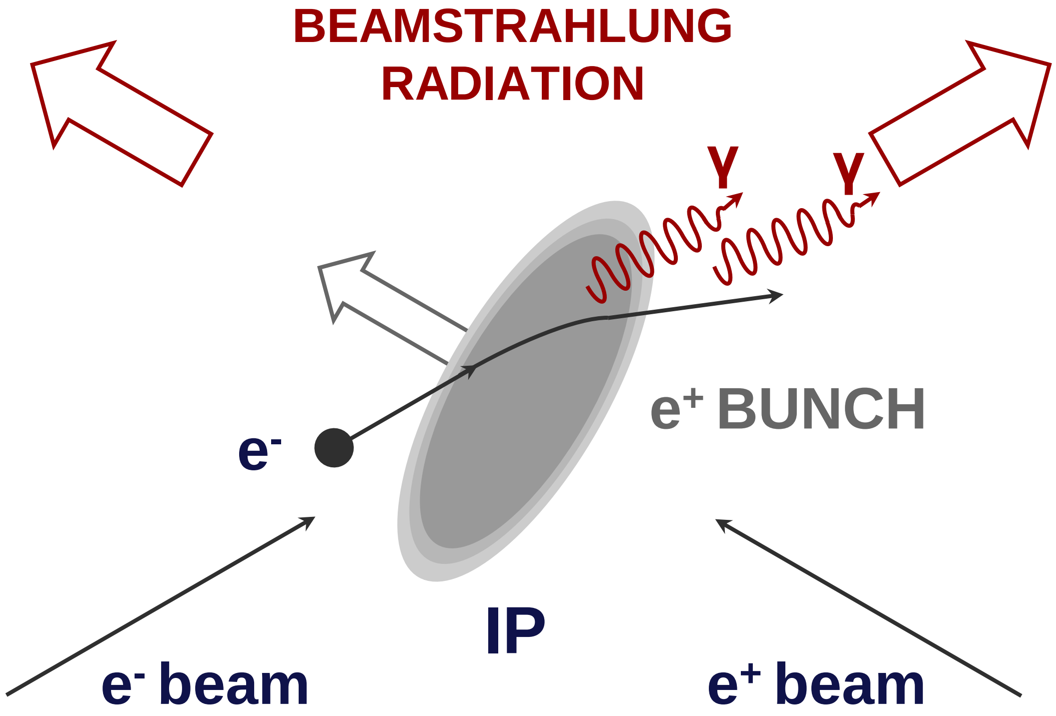
What is beamstrahlung radiation?

- at the IP of particle colliders
- particle trajectories bent by the EM of the opposing bunch
- emission of synchrotron radiation→beamstrahlung radiation
- same is true for the other beam



Why beamstrahlung at FCC-ee?

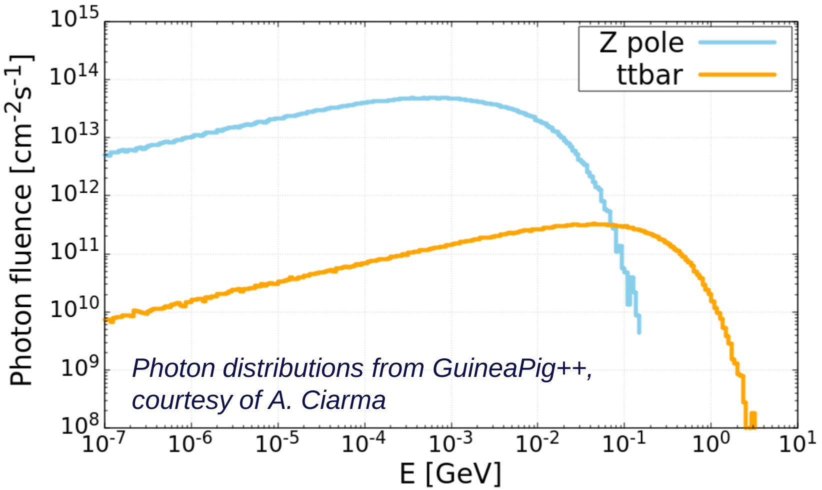
$$\Upsilon_{avg} = \frac{5}{6}\frac{r_e^2\gamma N_e}{\alpha\sigma_z(\sigma_x+\sigma_y)}$$

at FCC-ee **Υ**<<1:

- **$\langle E_\gamma \rangle$** ~ E x 0.462**Υ**
- **$\langle n_\gamma \rangle$** ~ 2.54 **Υ** $\frac{\alpha^2\sigma_z}{r_e\gamma}\frac{1}{[1+\Upsilon^{2/3}]^{1/2}}$

A. Ciarma et al., "Machine Induced Backgrounds in the FCC-ee MDI Region and Beamstrahlung Radiation", JACoW eeFACT2022 (2023)

v22	**Z pole**	**ttbar**
beam energy [GeV]	45.6	182.5
# bunches/beam	10000	36
bunch population [10^{11}]	2.43	2.64
horizontal rms IP spot size [um]	8	21
vertical rms IP spot size [nm]	34	66



	Z pole	**ttbar**
total power per beam [kW]	**370**	**77**
mean photon energy [MeV]	1.7	62.3

extremely intense beamstrahlung radiation!

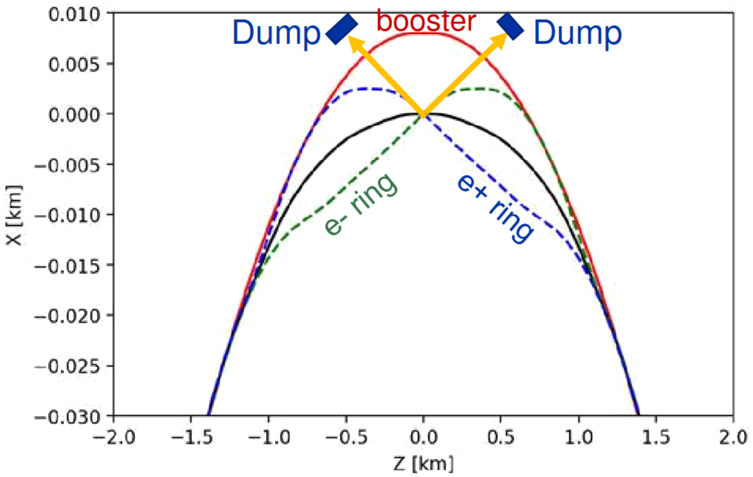
Beamstrahlung dumps

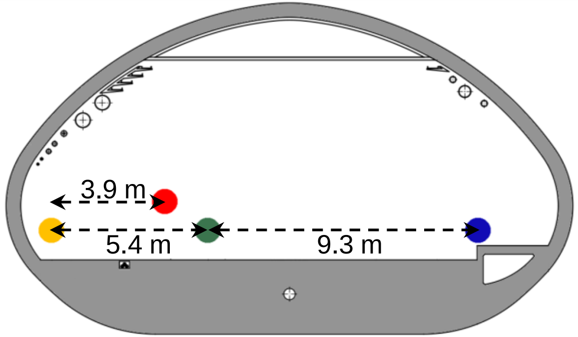
Two dedicated external dumps per IP

- **core** to dispose of this power
  - must withstand high power densities and temperatures
- **shielding** to contain the radiation showers
- located **500 m** downstream
  - largest separation from booster and collider rings
  - far from the IP
  - larger photon beam spot size

⇩

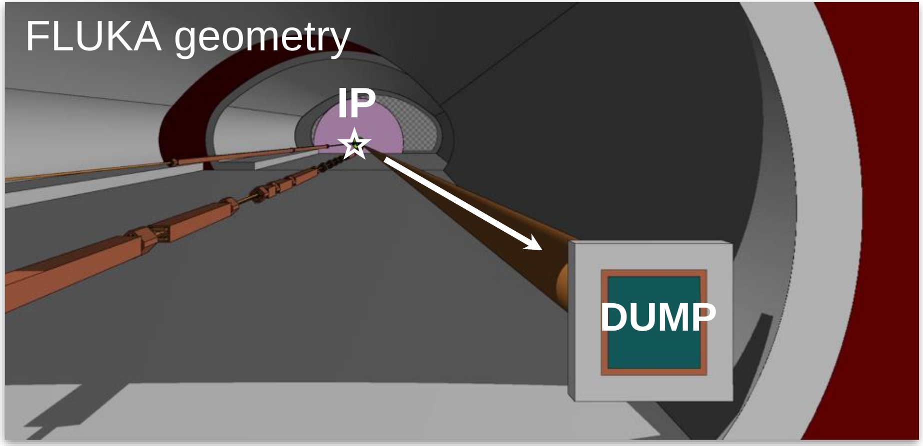
500 m long extraction line to integrate

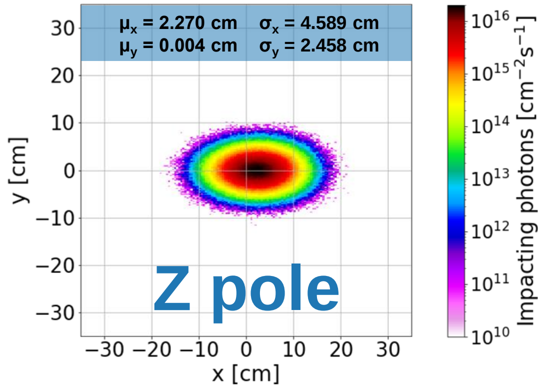


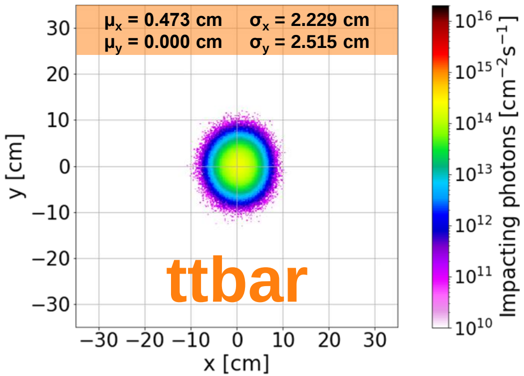


FLUKA model for beamstrahlung dump studies

- guide the thermomechanical design of the dump
- full tunnel geometry with beamlines and soil around
- dump with 70 cm ⌀ to contain $8\sigma_x$ at Z pole
- tested two dummy dump models
  - 3-m long **graphite**
  - 20-cm long **liquid lead**



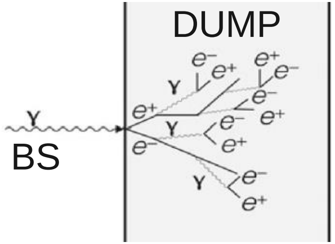




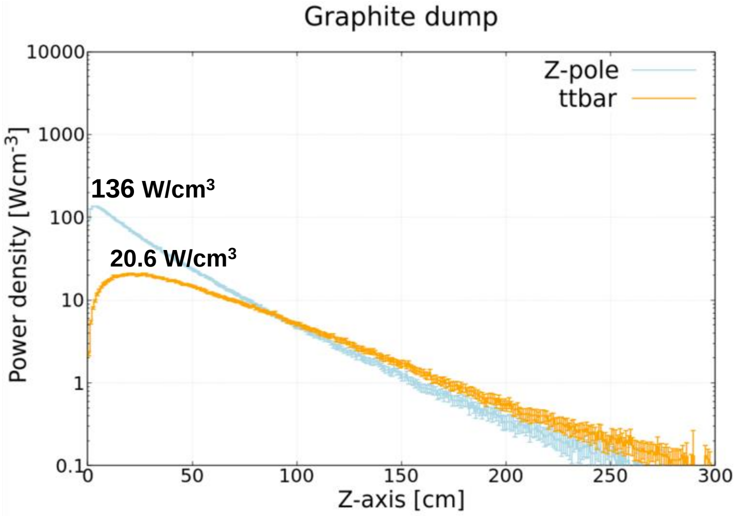
Peak power deposition inside the dump

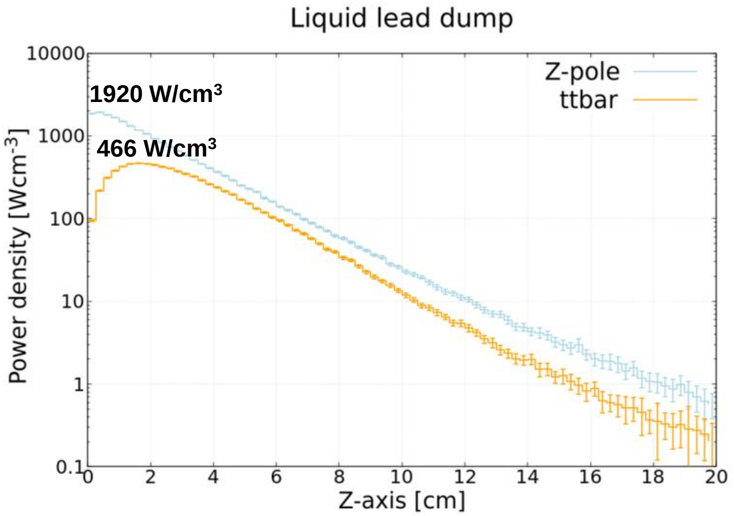
Photons interacting in the dump

- generate EM showers
- induce photonuclear reactions



Power absorbed in dummy models
98% at Z pole
99% at ttbar





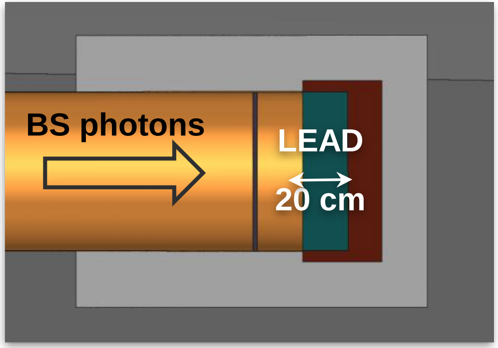
Radiation environment

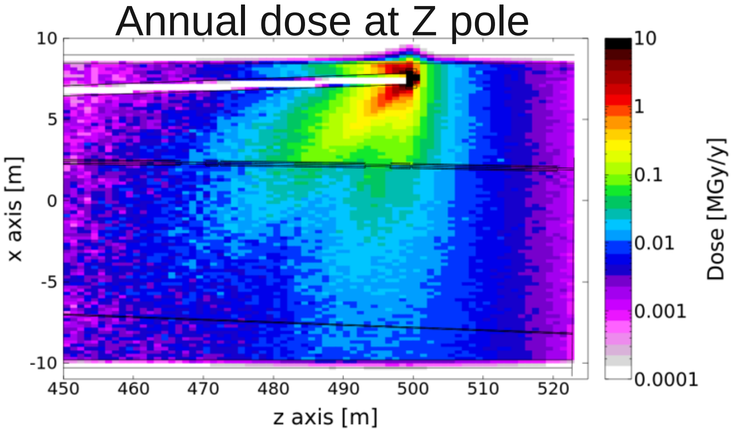
Radiation environment dominated by EM showers with the additional contribution of MeV-scale neutrons from photonuclear reactions

- proper shielding and experiment positioning to isolate neutron field
- dumps must be shielded
  - limit radiation-induced effects to other equipment
  - limit activation in the surroundings to protect personnel

→conceptual two-layer shielding
- 5-cm thick iron
- 20-cm thick concrete

RP requirements need a much thicker shielding ~1m of concrete



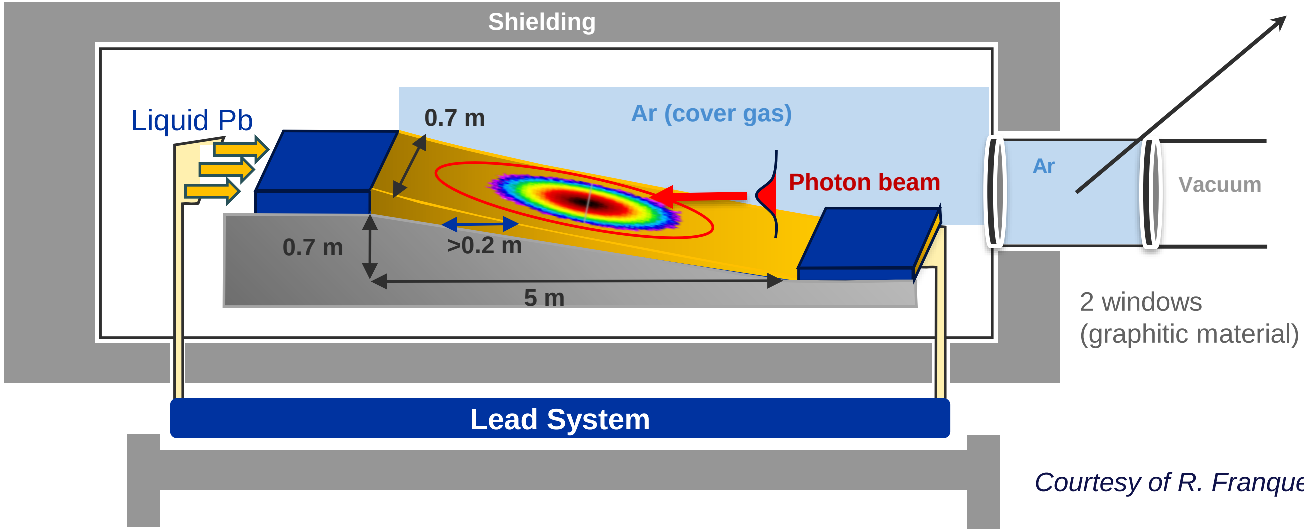


A. Frasca et al., "*Energy deposition and radiation level studies for the FCC-ee experimental insertions*", *IPAC'24*

Implementation of a liquid Pb system

Pure Pb 'slide flow' system under design

- thermomechanical studies showed graphite limitations
- better heat dissipation
- required dimensions with reasonable mass flow rate
- design accompanied by FLUKA studies



In between windows protected area from high temperature and UHV

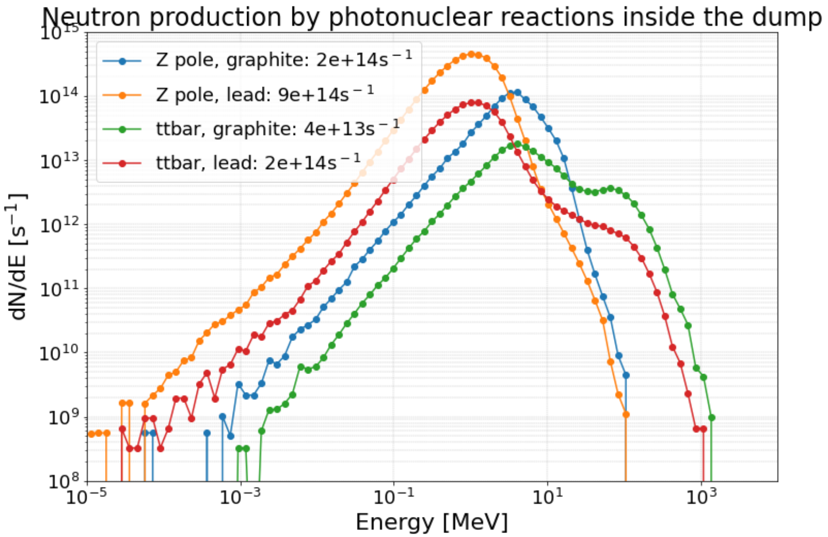
potential experiment placement

Courtesy of R. Franqueira XImenes

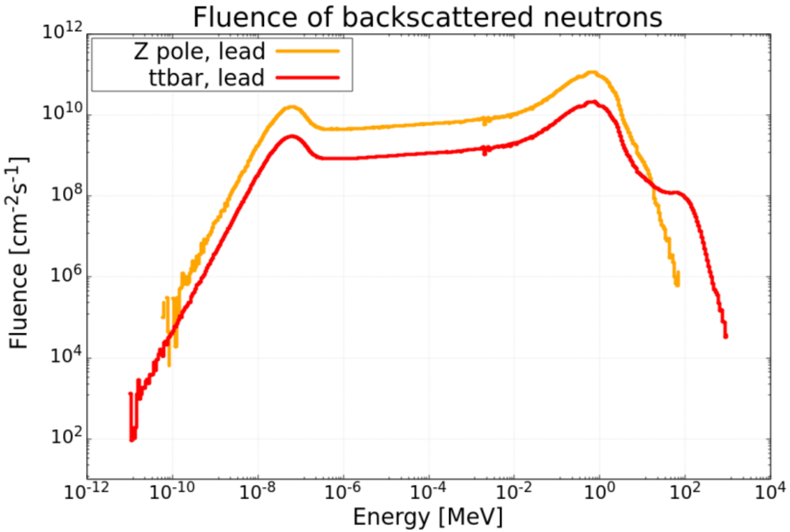
Neutron production

Neutron production from photonuclear reactions in the dump

- different production spectra from different materials and operation modes



These are not the neutrons available for experiments



Neutrons found at the window level, but other radiation backgrounds present

Summary

Intense photon beams ‘for free’ from beamstrahlung

- 370 kW (Z pole) to 77 kW (ttbar) to be safely dumped
- spectra up to ~100 MeV (Z pole) and ~2 GeV (ttbar)
  - photon energies allowing radionuclide production through photonuclear reactions
- peak of 10^{16} $cm^{-2}s^{-1}$ photon flux on the dump at Z pole
  ? possible complementary physics experiments with respect to CBS

Neutron production inside the dump

- photonuclear reactions producing significant neutron fields in every scenario
  ? possible contribution to radionuclide production
  ? exploitable neutron source

To be considered

- assessment of neutron flux in realistic experiment position
- integration constraints
- background from EM showers

Thank you for your attention.