FCC

BEAMSTRAHLUNG DUMP AND RADIATION LEVELS IN THE EXPERIMENT IRS

Alessandro Frasca, Giuseppe Lerner, Anton Lechner (CERN SY-STI-BMI), Marco Calviani, Antonio Perillo Marcone (CERN SY-STI-TCD), Andrea Ciarma (CERN BE-ABP-LAF), Manuela Boscolo (INFN-LNF)

FCC week 2023, 6th June 2023, contact: alessandro.frasca@cern.ch

Introduction

In the FCC-ee interaction regions different processes generate an intense photon flux collinear to each outgoing beam, i.e., two photon beams exiting the IP

- synchrotron photon production in the EM field of the counter-rotating beam (**beamstrahlung**) – **369 kW** for Z-pole operation
- synchrotron photon production in the fringe field of the solenoid and anti-solenoid – **77 kW** for Z-pole operation
- other synchrotron radiation sources to be considered as well

→ **two high-power beam dumps per IP needed to safely dispose of these photons**

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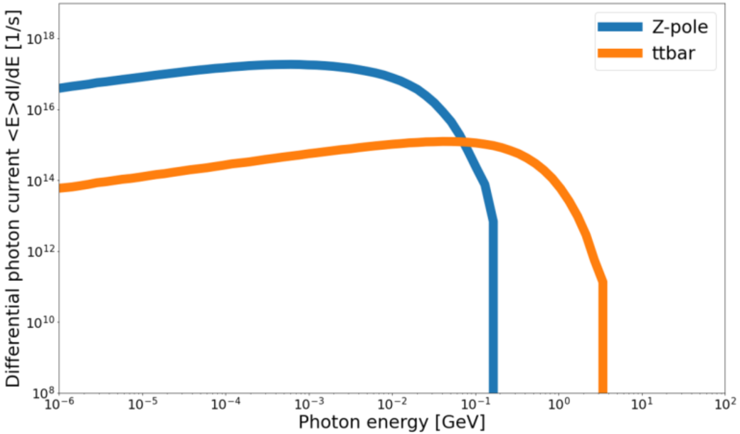
this study presents some preliminary estimates with
FLUKA for the design of the **beam dump**,
taking into account only the **beamstrahlung source**
@Z-pole, ttbar

Beamstrahlung radiation in the FCC-ee IRs

Beamstrahlung photon spectra for Z and ttbar operation, simulated with Guinea-Pig by A. Ciarma

	Z	ttbar
beam energy [GeV]	45	182.5
# of bunches/beam	10000	36
bunch intensity [10^{11}]	2.43	2.64
beam current [mA]	1280	5

→



power radiated by each beam

- Z-pole: 369 kW
- ttbar: 76 kW

Challenging beam dump design

High-power beam dumps

Requirements

- absorb the energy carried by the beam

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DUMP CORE

it must withstand high power densities

→ **graphite**: low density, high service temperature, easier design (common choice for dumps)

→ **liquid lead**: compactness, better heat dissipation, no concern for DPA, high boiling temperature, high Z and density

- limit radiation-induced effects and damage to other equipment
- limit induced radioactivity to protect personnel
- avoid induced background in the detector

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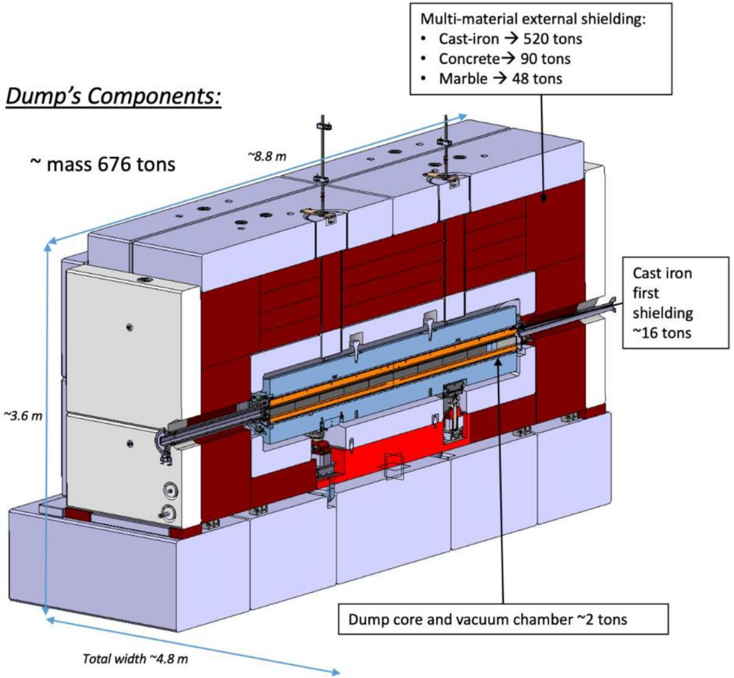
SURROUNDING SHIELDING

it must contain most of the electromagnetic and particle showers induced by the impacting beam

High-power beam dumps - example

<u>SPS beam dump</u>, designed for 300 kW deposition in the most demanding scenario



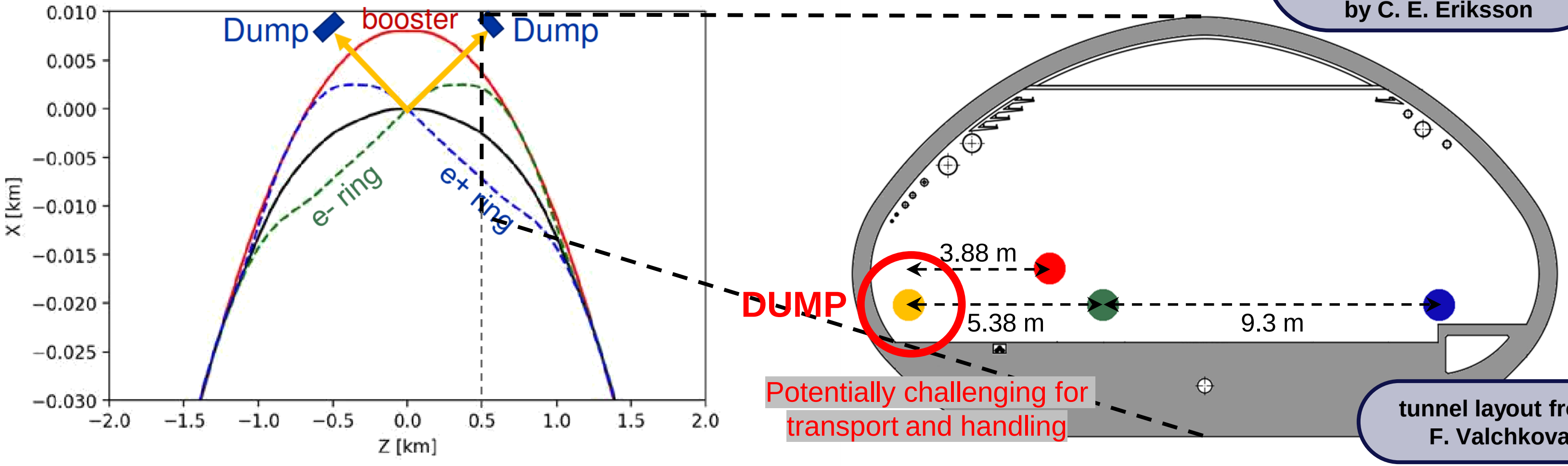
Beamstrahlung dumps

Dump placement:

- **external** to the beamline
- **500 m** downstream of the IP

→ **enough space for shielding between dump and booster, e^- and e^+ rings, but 500 m long photon extraction line needed**

talk on magnet design for beamstrahlung photons extraction line by C. E. Eriksson



Potentially challenging for transport and handling

tunnel layout from F. Valchkova

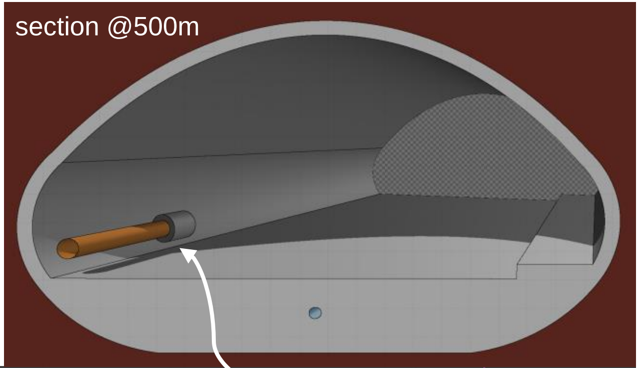
FLUKA simulation model

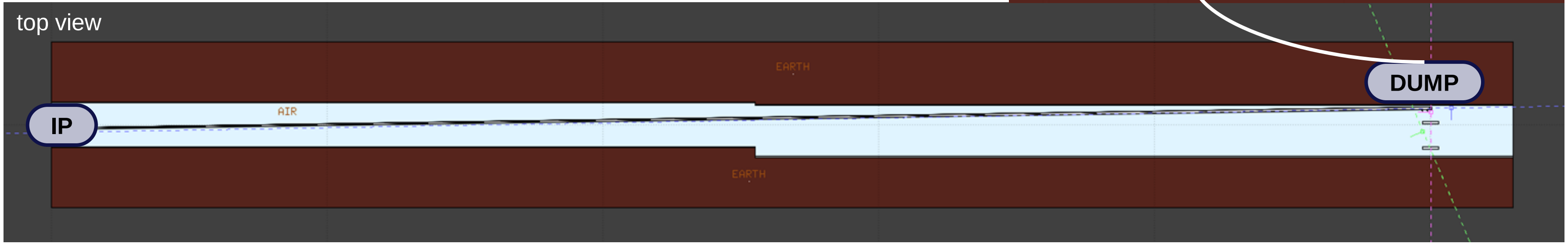
- **Extraction line**
  - 500 m long
  - straight and directed as the outgoing beam (15 mrad)

- **Concrete tunnel surrounded by soil**

- **Two options for the dump core**
  - **graphite** (1.8 g/cm^3), cylindrical (**3 m** long, **35 cm** radius)
  - **liquid lead** (10.678 g/cm^3), cylindrical (**0.2 m** long, **35 cm** radius)

still no beamlines or other equipment included in the FLUKA geometry





Dump analysis

Distributions on the face of the dump @500m

Photon beam spot on the dump:

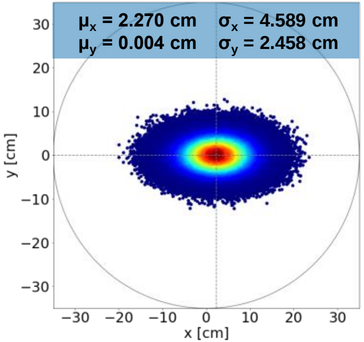
- horizontal shift due to non-zero angle of emission of beamstrahlung photons with respect to the outgoing electron beam axis

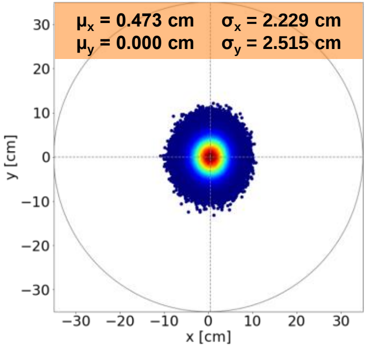
Energy impacting on the dump:

- further horizontal shift due to the correlation between the energy and the angle of emission of beamstrahlung photons

Z-pole | **ttbar**

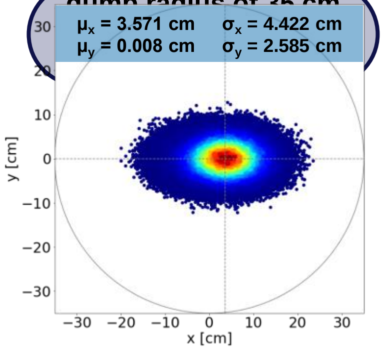
photons on dump

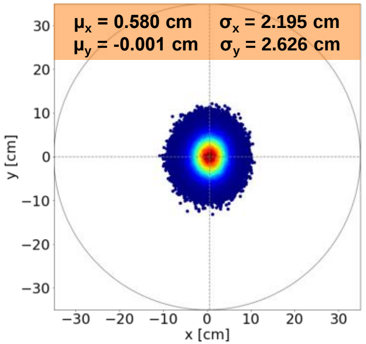




energy on dump

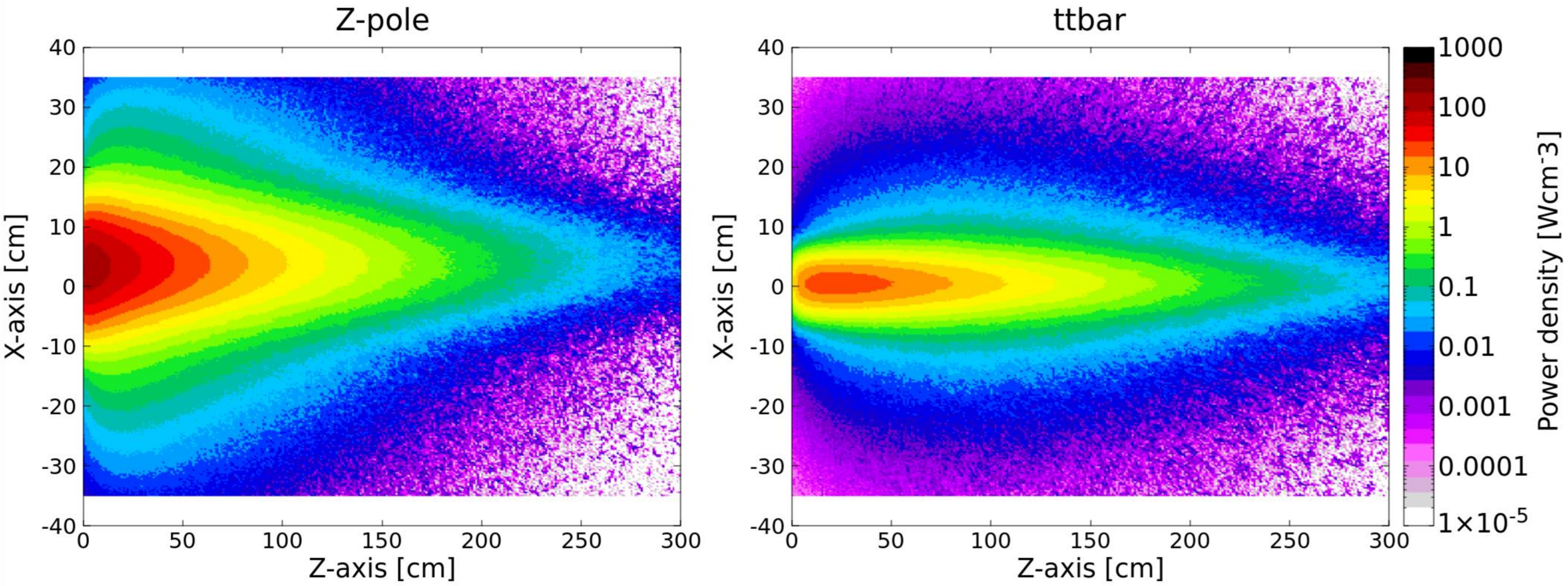
dump radius of 35 cm



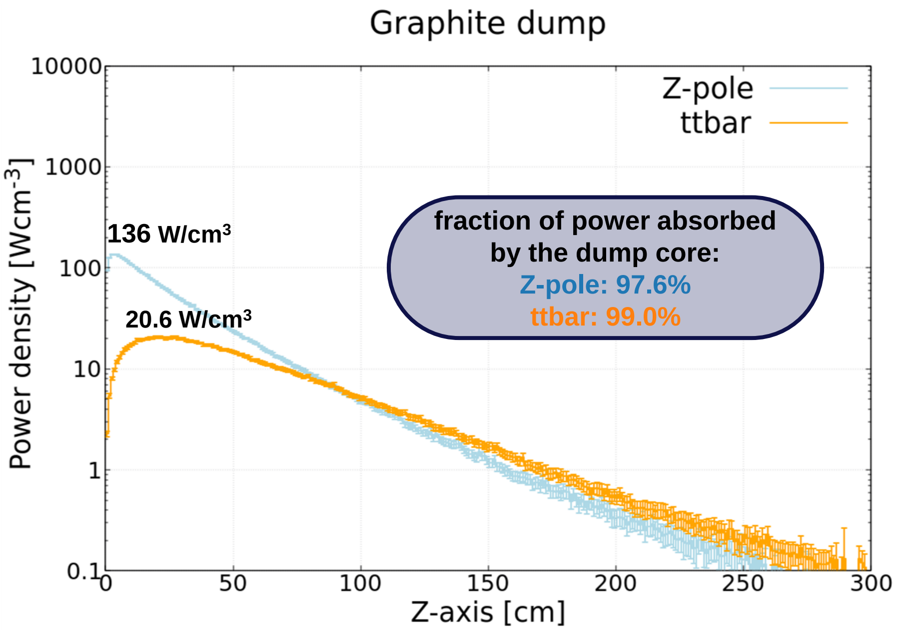


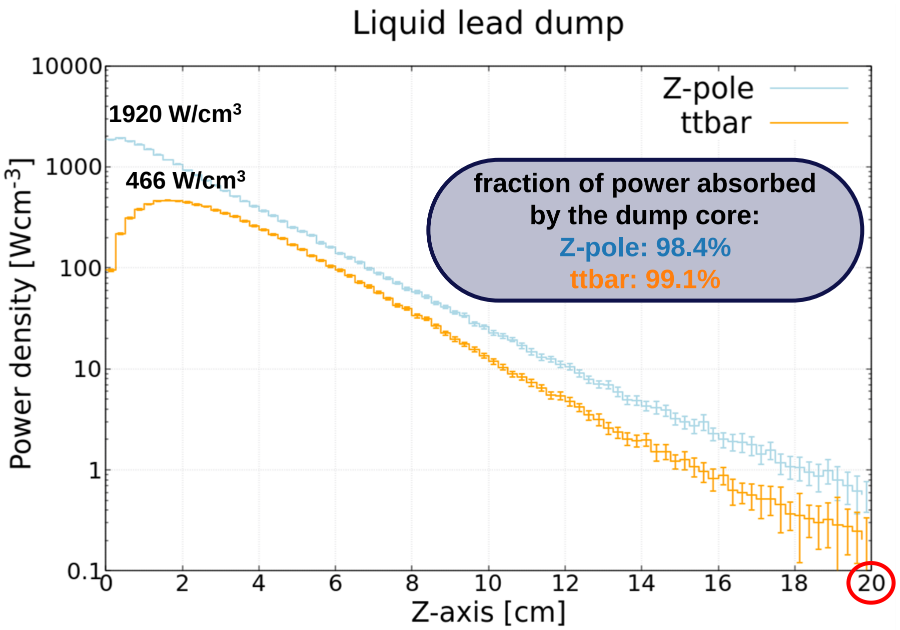
Power density in the graphite dump

Horizontal plane: average for y in [-1,1] cm around the impact centre



Distribution of max longitudinal power density



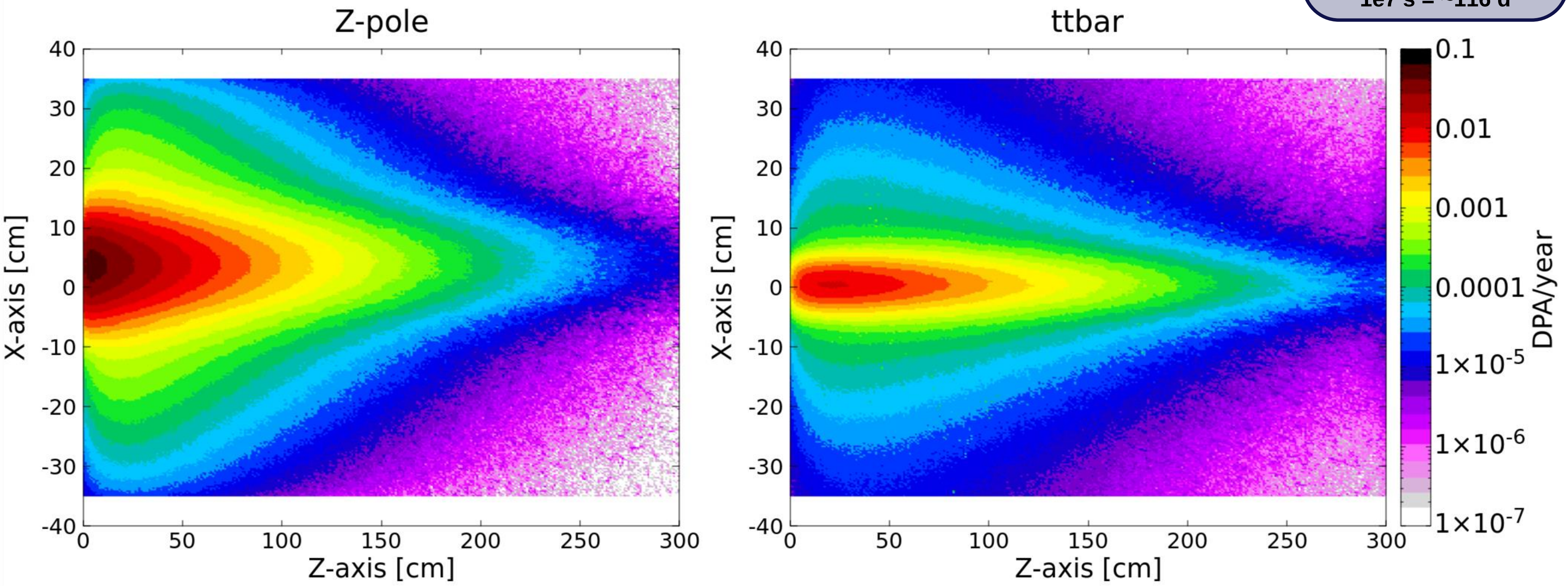


- compatibility of these peak powers with these materials to be studied in thermomechanical studies

Annual DPA graphite dump

Horizontal plane: average for y in [-1,1] cm around the impact centre

1 year of operation
1e7 s = ~116 d



Radiation levels in the tunnel

Radiation effects to electronics and materials

Electronic components and systems exposed to a mixed radiation field experience two main types of radiation effects:

- **cumulative damage** – deterministic
  → evaluated through total ionizing dose (TID) [Gy]

  1 Gy = 1 J/kg of ionizing energy deposition

- **Gy scale**: ok for commercial-based electronics (with qualifications if dose > 1 Gy)
- **>10 kGy**: only rad-hard electronics
- **MGy scale**: material damage

- **single event effects** (SEEs) for active electronics – stochastic
  → probability of occurrence as a function of high-energy hadron equivalent (HEH-eq) fluence [cm^{-2}]

  fluence of hadrons more energetic than 20 MeV
  +
  weighted fluence of neutrons less energetic than 20 MeV

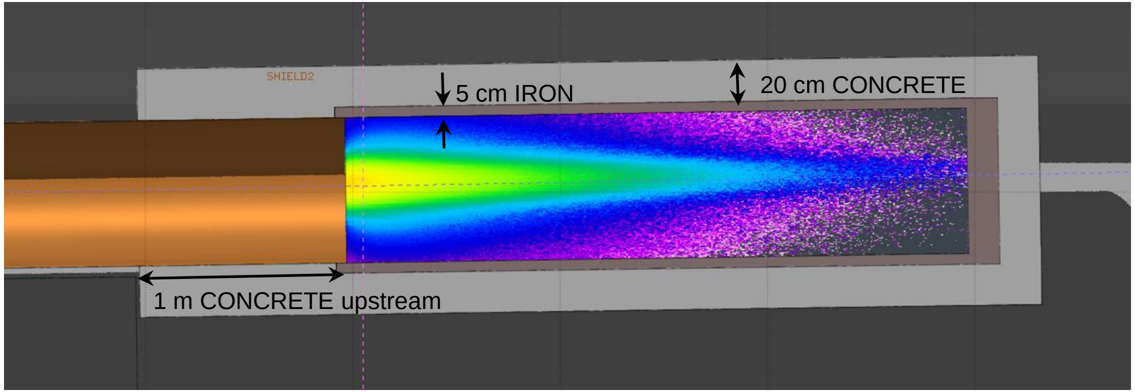
- **earth surface radiation**: HEH ~10^5 cm^{-2}/year
- **LHC tunnel electronics (DS)**: HEH up to >10^{10} cm^{-2}/year

Shielding the dumps

The dumps must be shielded to decrease the radiation levels in the tunnel to values safe for the machine equipment and the personnel

Simple shielding model to evaluate the associated efficiency:

- two-layer cylindrical shield implemented in the simulations of **graphite dump**



First investigation of shielding effectiveness: TID and HEH-eq fluence in the tunnel near the dump with and without the above shielding

Annual TID in the tunnel near graphite dump

- **highest dose @Z-pole without shielding**: up to few MGy around the dump, around 1 MGy at booster and e⁻ ring (x≈0)
- proposed shielding reduces the TID by a factor >>10
- significant **backscattering** for Z-pole, higher TID **beyond** the dump for ttbar

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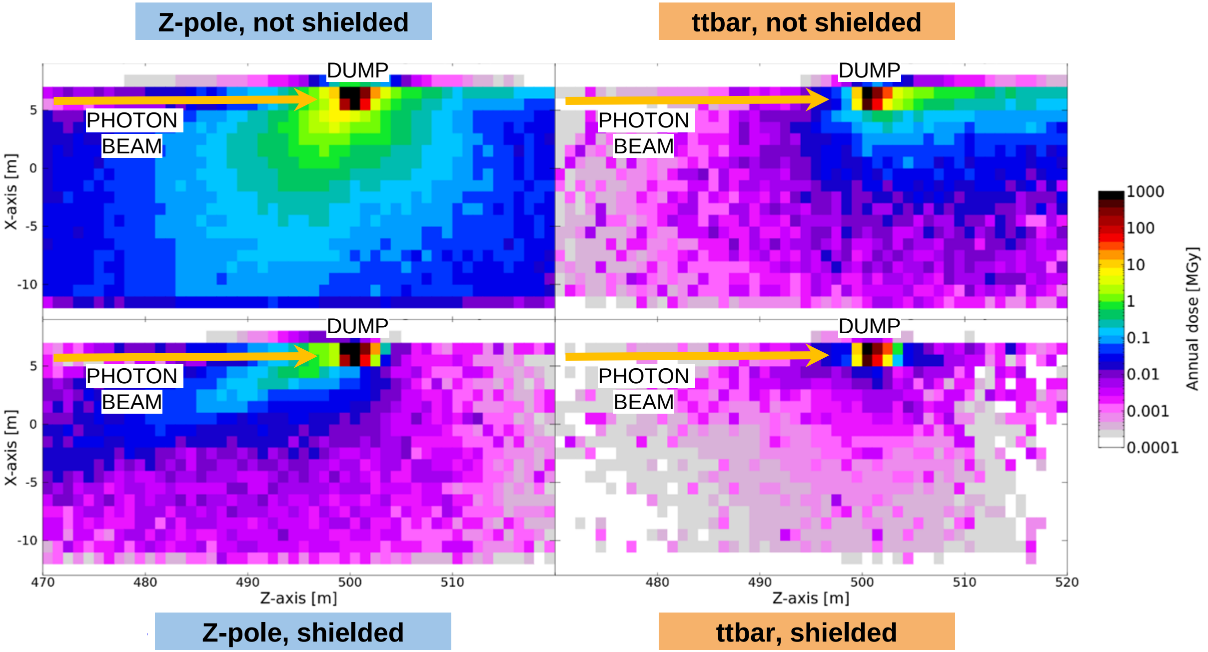
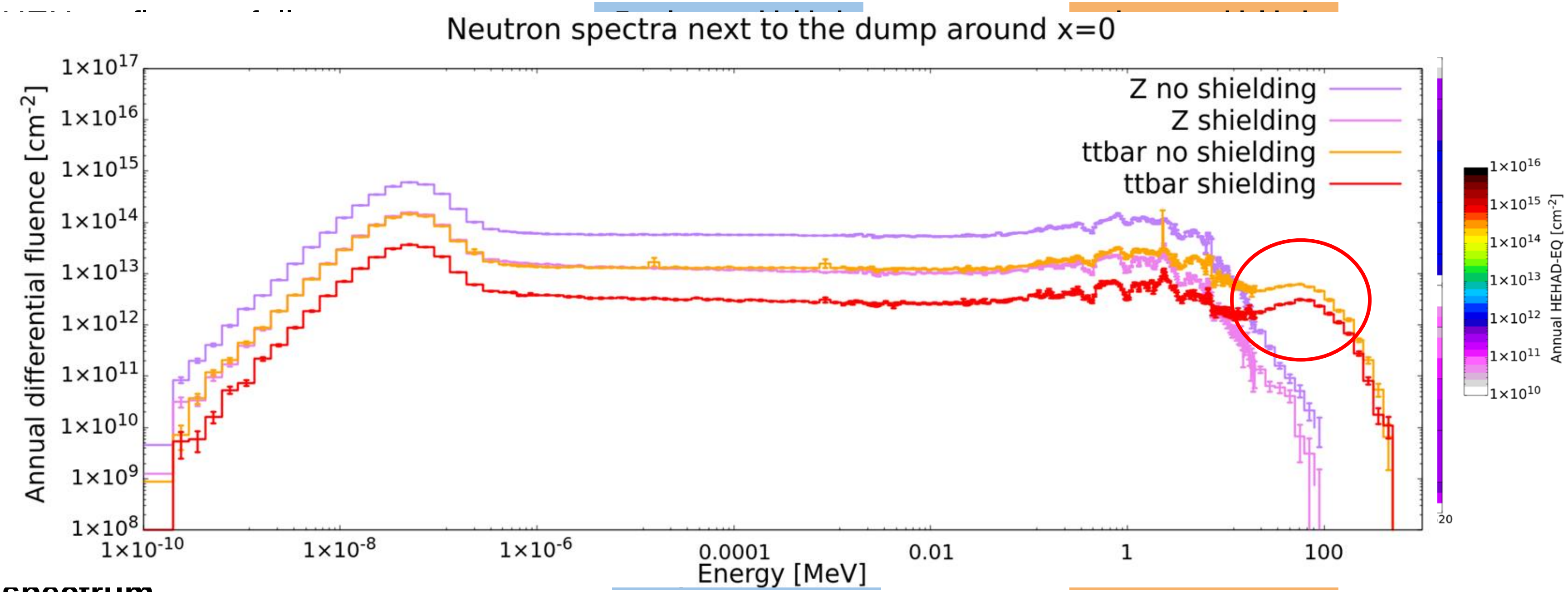
both fixable by further optimizing the shielding, in terms of thickness and length upstream/downstream the dump



Annual HEH-eq fluence



spectrum

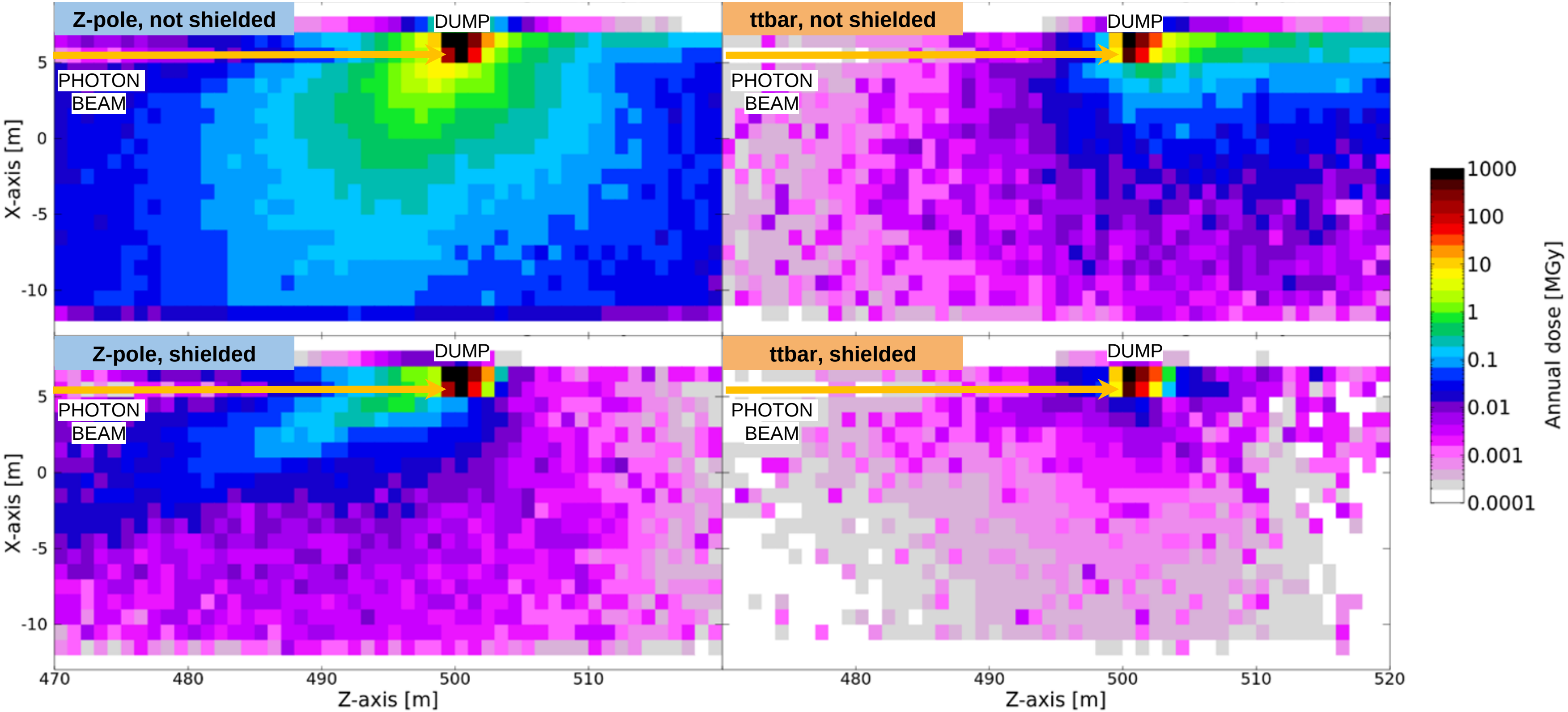
Conclusion

- we presented the challenges and main features of beamstrahlung dumps in terms of power deposition and DPA in the dump core, as well as radiation levels in the tunnel
- implications for the dump core design to be further studied and elaborated in collaboration with the CERN SY-STI-TCD team
  - choice of material still under discussion
- in the vicinity of the dump, high TID and HEH potentially leading to damage to equipment and electronics
  - further optimization for the shield needed
- to be further considered: implications of material activation in the vicinity of the dump for radiation protection (dose to personnel)

SY STI FLUKA

THANK YOU FOR YOUR ATTENTION!

Annual TID near graphite dump



Annual HEH-eq fluence near graphite dump