CEPC-SPPC radiation protection and dumps

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2019-8-16

Outline

1. Concerning factors from radiation protection of view
2. Synchrotron radiation shielding
3. Beam dump
4. Research on neutron detectors
5. Radiological impact to environmental

Concerning factors from radiation protection of view

- **Protection of personnel operation, maintenance and installations**
  - Shielding design for prompt and residual radiation
    - Synchrotron radiation, beam dumps
    - Hot pots: collimators, injector/extract sections
  - Dose monitoring and warning system
    - Now conducting research on a new model of neutron detector
- **Potential radiological environmental impact**
- **Radiation to electronics or materials**
  - **Some work is conducting by detector staff**
- **Access control system**
  - **Now in charged by 李俊刚**

Regulation in the law

- Basic Rules of Radiation Protection
  - Justification, Limitation, Optimization
- Annual dose limit adopted by different owners

Owners	**Public**	**radiation workers**	
		B	**A**
Eu-Directive	<1mSv	<6mSv	<20mSv
France	<1mSv	<6mSv	<20mSv
Switzerland	<1mSv	<20mSv	
CERN from 2004	<0.3mSv	<6mSv	<20mSv
CERN until 2004	<0.3mSv	<20mSv	
China	<1mSv	<20mSv	
IHEP	<0.1mSv	<5mSv	

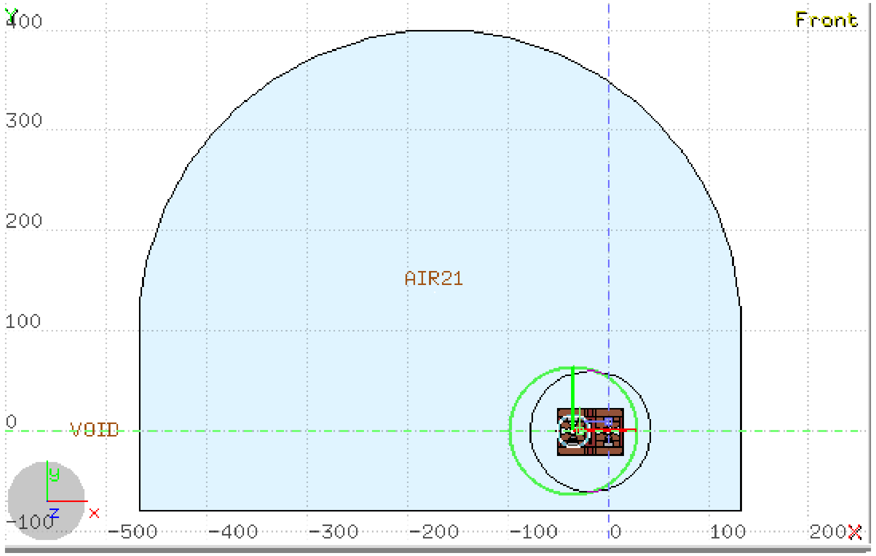
Synchrotron radiation

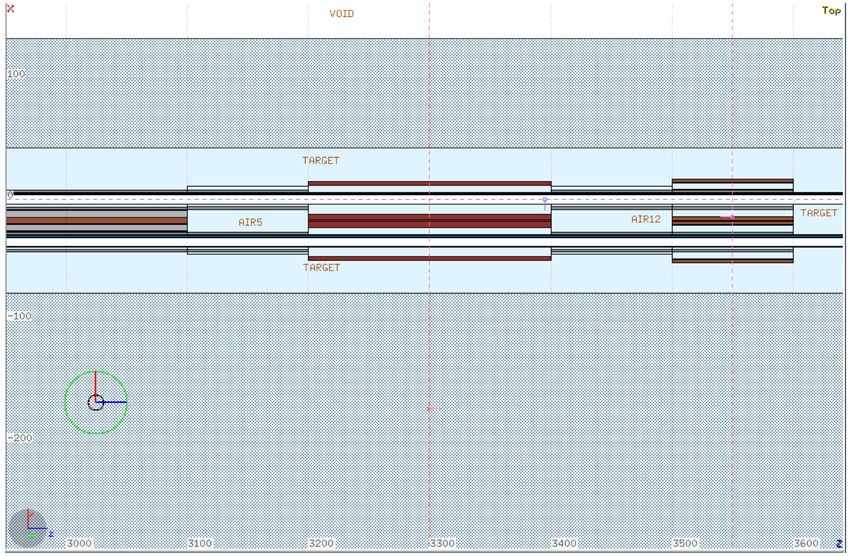
- First designed by Haoyu Shi and Yadong Ding, for 10 years machine operation in condition of 30MW&120GeV
- Now, the operation schedule is 10 years running @ 50MW&120GeV and 3 years running @ 50MW&175GeV
- The person in charge of this issue is transferred to Guangyi Tang

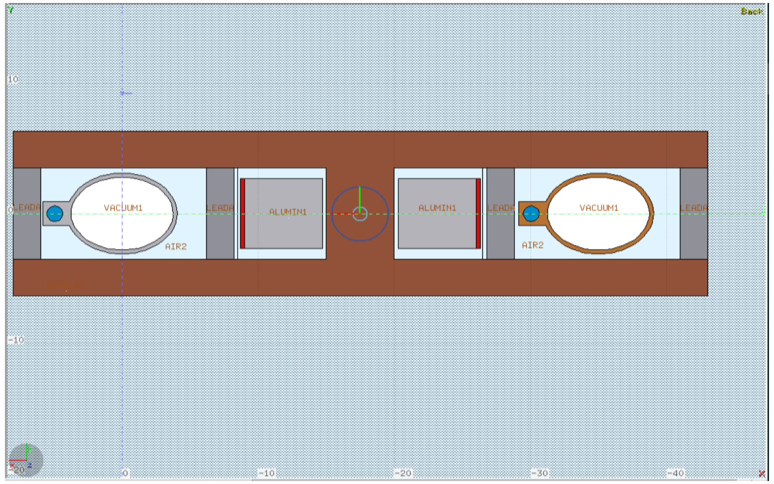
Table 4.3.4.4: Lifetime for magnets coils

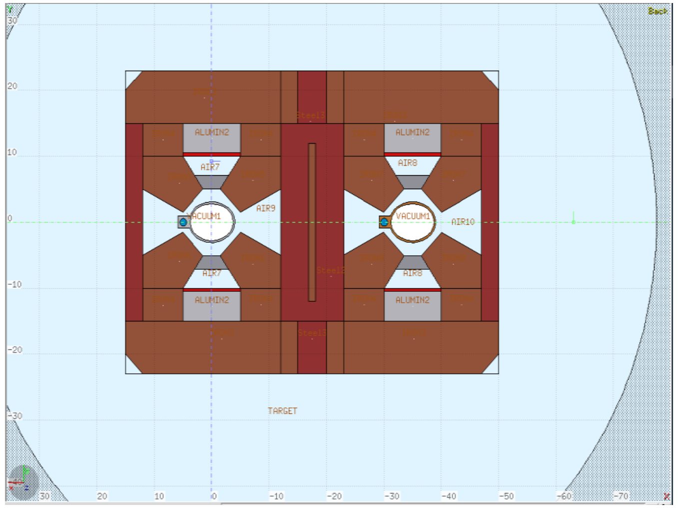
Materials	Upper dose limit in Gy	Radiation dose in Gy/Ah	Time in h
Fiberglass	10^8	1.89×10^4	2.99×10^5
Semi-organic coating	10^8	1.89×10^4	2.99×10^5
Epoxy resin	2×10^7	1.89×10^4	5.98×10^4

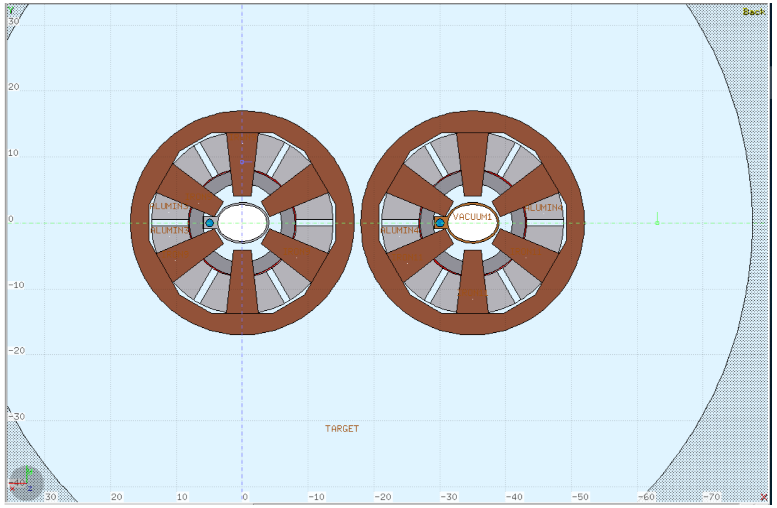
SR re-simulation-model











NUMBER OF SR PHOTON

	SR loss/GeV	Radius/m	N_bunch	Frequency/Hz	population
Pre-CDR 120GeV	3.11	6094	50	5475.46	3.785*10^11
CDR 120GeV	1.73	10700	242	3000	1.5*10^11
175GeV	7.61	10900	34	3000	2.4*10^11

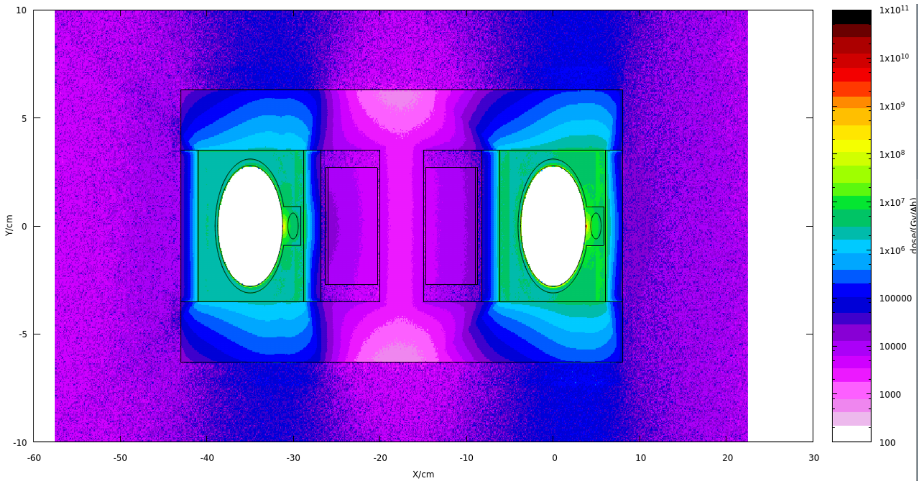
Parameters used to calculate SR photons

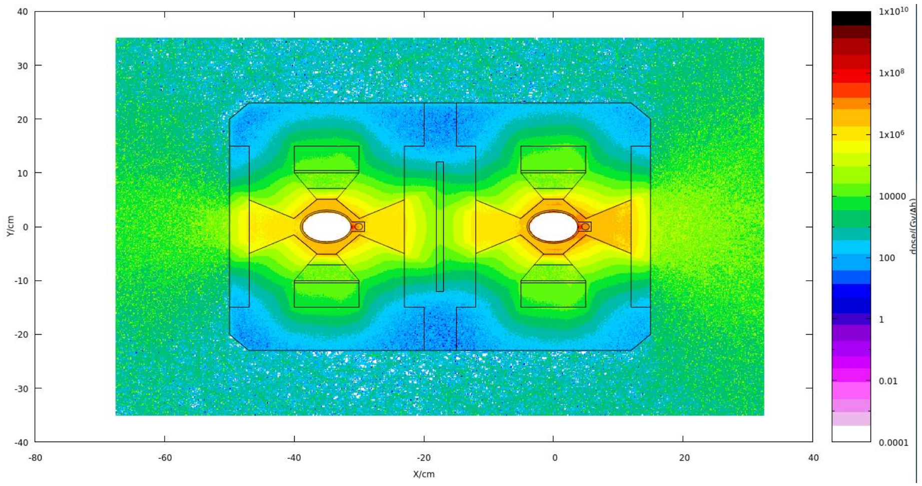
	Number of SR photon/s	Number of SR photon/(m.s)
Pre-CDR 120GeV	1.66×10^{21}	3.33×10^{16}
CDR 120GeV	1.71×10^{21}	1.71×10^{16}
175GeV	5.55×10^{20}	5.55×10^{15}

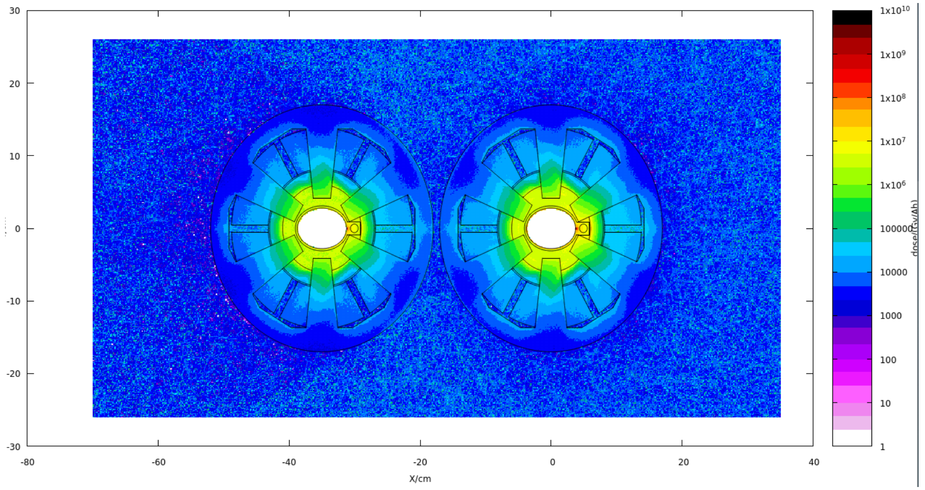
SR Numbers

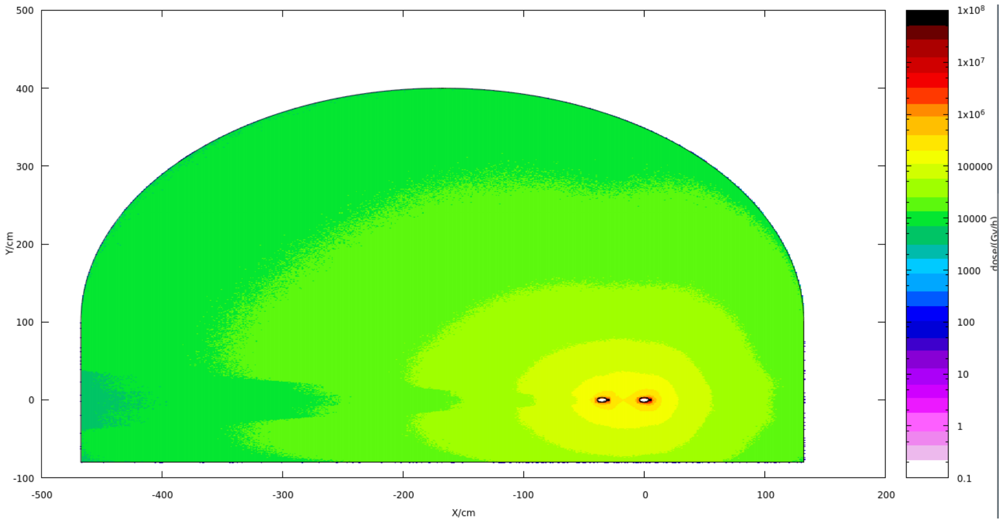
Formula used is on P63-P65 of CEPC CDR

DOSE IN TUNNEL@120GEV









DOSE OF COIL

- GeV/g →Gy/Ah:
  - 120GeV: 1.7*10^16 * 1.6*10^-7 /0.017 * 3600 * 31 ~ 2.25E16
  - photon num gev/g->gy current 1h dipole length
  - 175GeV: 5.6*10^15 * 1.6*10^-7 /0.004 * 3600 * 31 ~ 2.50E16
- Dose of insulators of coil: Ethylene Oxide (Oxirane)

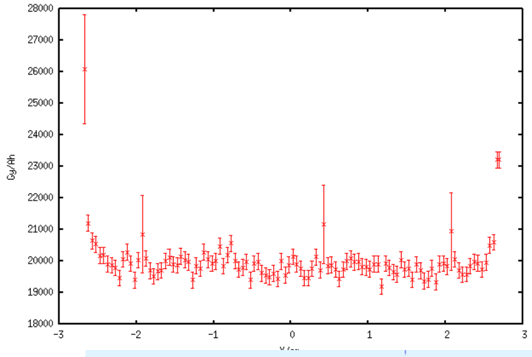
	Dose/(Gy/Ah)			
	120GeV		175GeV	
	average	maximum	average	maximum
Dipole	$(2.6 \pm 0.2) \times 10^4$	$(3.5 \pm 0.2) \times 10^4$	$(2.7 \pm 0.1) \times 10^4$	$(4.0 \pm 0.2) \times 10^4$
Quadpole	$(4.0 \pm 0.5) \times 10^4$	$(10 \pm 5) \times 10^4$	$(2.6 \pm 0.5) \times 10^4$	$(9 \pm 5) \times 10^4$
Sextopole	$(9.0 \pm 1.6) \times 10^4$	$(13 \pm 1) \times 10^4$	$(12 \pm 3) \times 10^4$	$(23 \pm 13) \times 10^4$

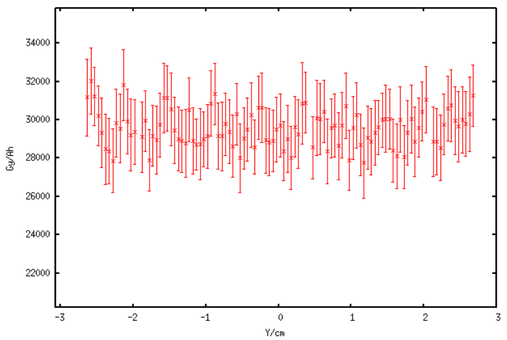
DOSE OF COIL

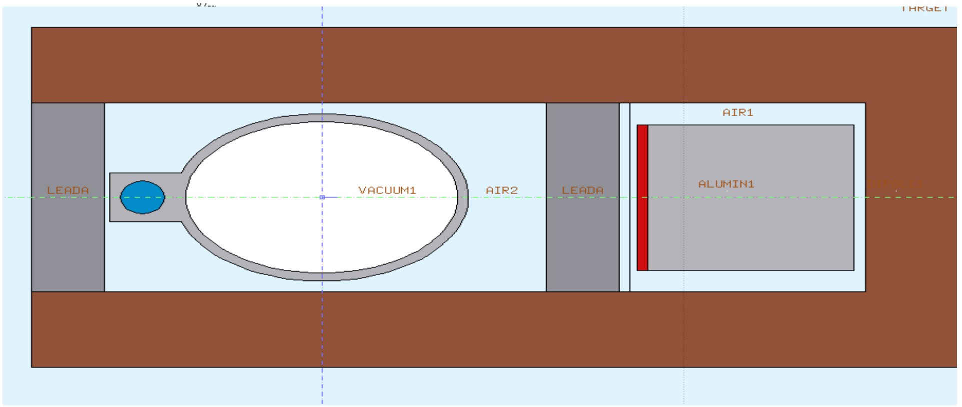
- Running @120GeV for 44000h

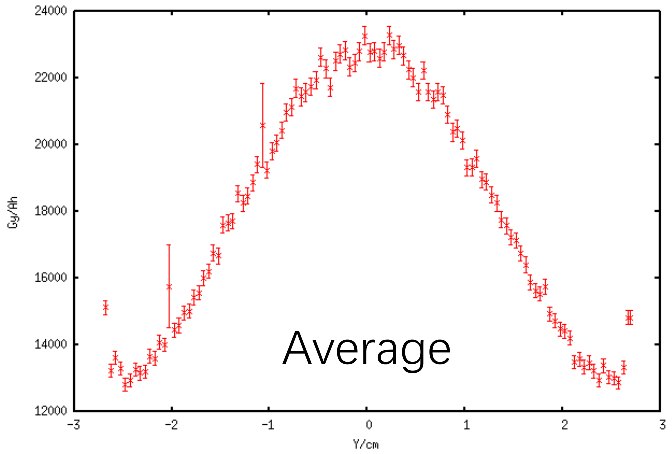
& @175GeV for 13200h

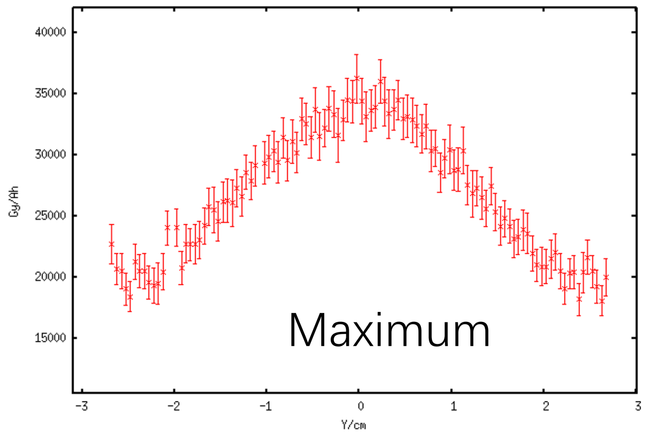
	Dose/Gy	
	120GeV	
	30MW	50MW
Dipole	$(2.0 \pm 0.2) \times 10^7$	$(3.3 \pm 0.3) \times 10^7$
Quadpole	$(3.1 \pm 0.4) \times 10^7$	$(5.1 \pm 0.7) \times 10^7$
Sextopole	$(6.9 \pm 1.2) \times 10^7$	$(12 \pm 2) \times 10^7$

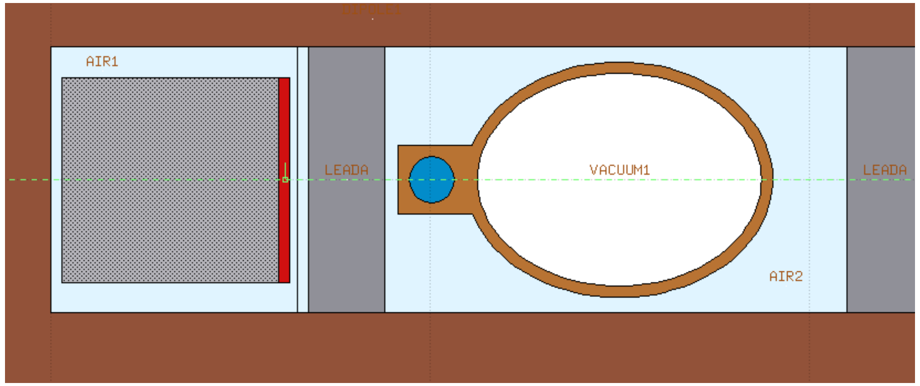












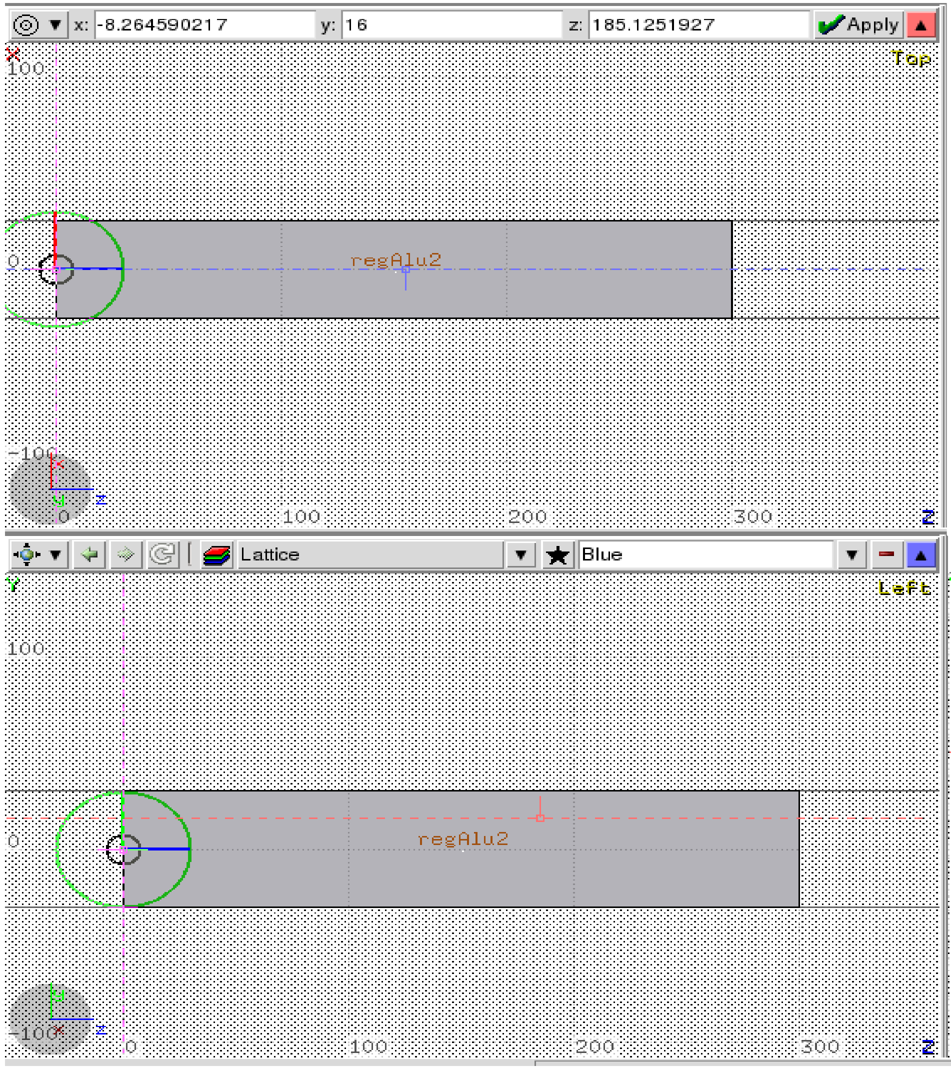
Beam dump design

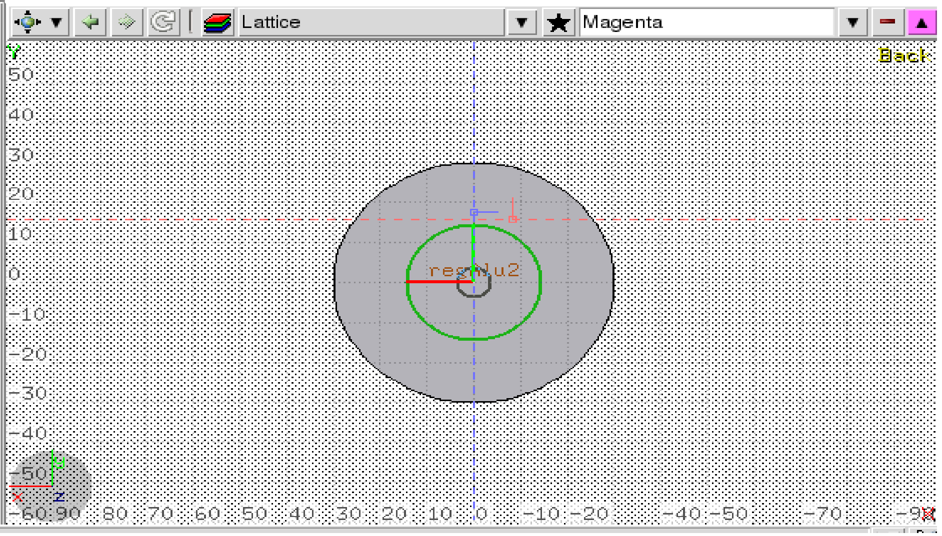
- Parameters used for dump design

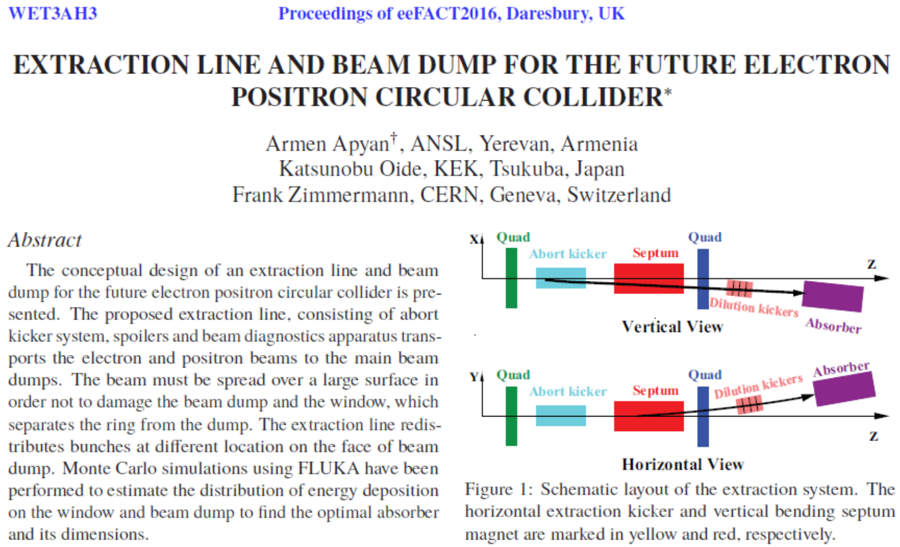
运行模式	能量/ GeV	束团数	单束团电荷量 /nC	束流截面尺寸X/Y	束流收集时间		总电荷量/nC	环中流强 mA	环中电子数	环中存储能量 MJ	打靶功率 MW
						s	电荷量*束团数	束团数*单束团电荷量/转一圈的时间	束团数*单数团电荷量/每电子电荷量	每电子能量*环中电子数	按照一圈时间引出，不考虑束团之间还有间隔时间（会导致有束流的时间内，功率更高）。
Higgs	120	242	24	0.5mm/ 0.02mm	一圈		5808	17.42	3.63E+13	0.4356	1.31E+03
W	80	1524	19.2	0.33mm/ 0.02mm	一圈	3.33E-04	29260.8	87.78	1.829E+14	1.46304	4.39E+03
Z	45.5	12000	12.8	0.19 mm/0.02mm	一圈		153600	460.80	9.6E+14	4.368	1.31E+04

MATERIALS AND GEOMETRY

- Graphite, aluminum, iron, copper, nickel and tungsten are considered.
- Cylinder as basic design.






WET3AH3 Proceedings of eeFACT2016, Daresbury, UK

EXTRACTION LINE AND BEAM DUMP FOR THE FUTURE ELECTRON POSITRON CIRCULAR COLLIDER*

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Frank Zimmermann, CERN, Geneva, Switzerland

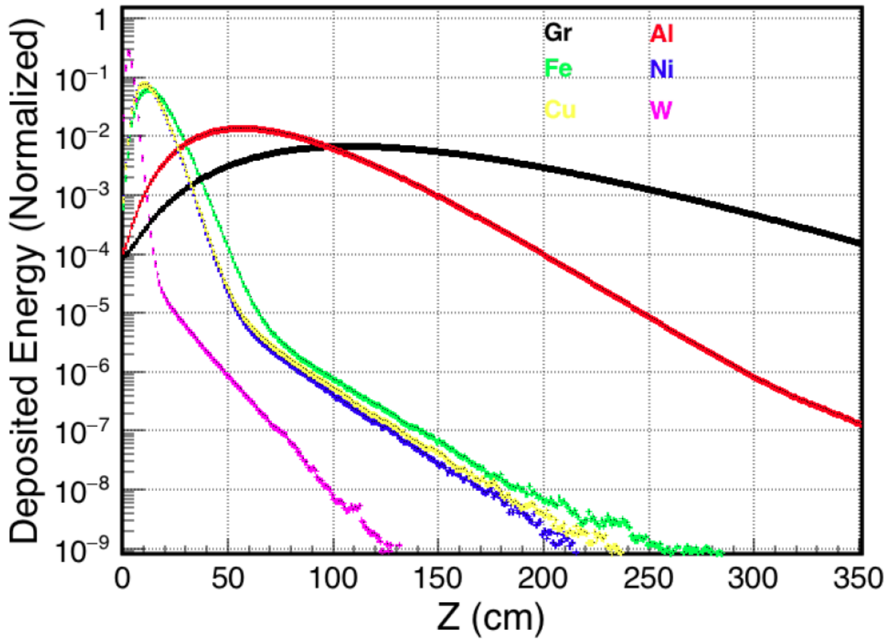
Abstract

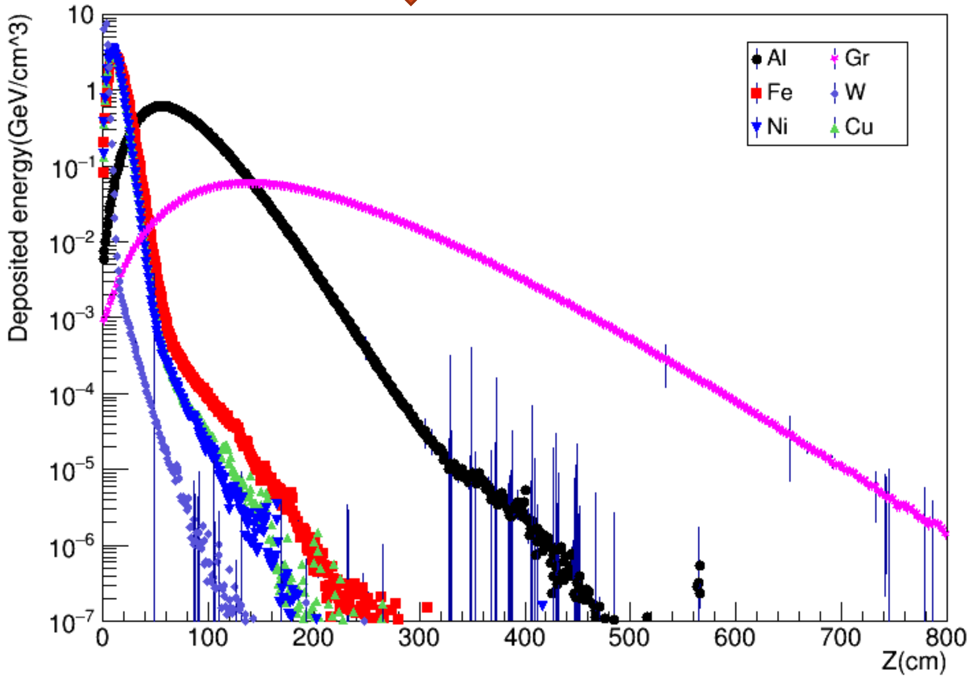
The conceptual design of an extraction line and beam dump for the future electron positron circular collider is presented. The proposed extraction line, consisting of abort kicker system, spoilers and beam diagnostics apparatus transports the electron and positron beams to the main beam dumps. The beam must be spread over a large surface in order not to damage the beam dump and the window, which separates the ring from the dump. The extraction line redistributes bunches at different location on the face of beam dump. Monte Carlo simulations using FLUKA have been performed to estimate the distribution of energy deposition on the window and beam dump to find the optimal absorber and its dimensions.

Figure 1: Schematic layout of the extraction system. The horizontal extraction kicker and vertical bending septum magnet are marked in yellow and red, respectively.

COMPARE WITH REF. 1

	Maximum temperature rise per bunch	
	Ref. 1	ours (statistical uncertainty only)
Graphite	0.5˚C	0.1±0.00003˚C
Iron	2.0˚C	1.8±0.0006˚C
Tungsten	13.0˚C	14.±0.007˚C





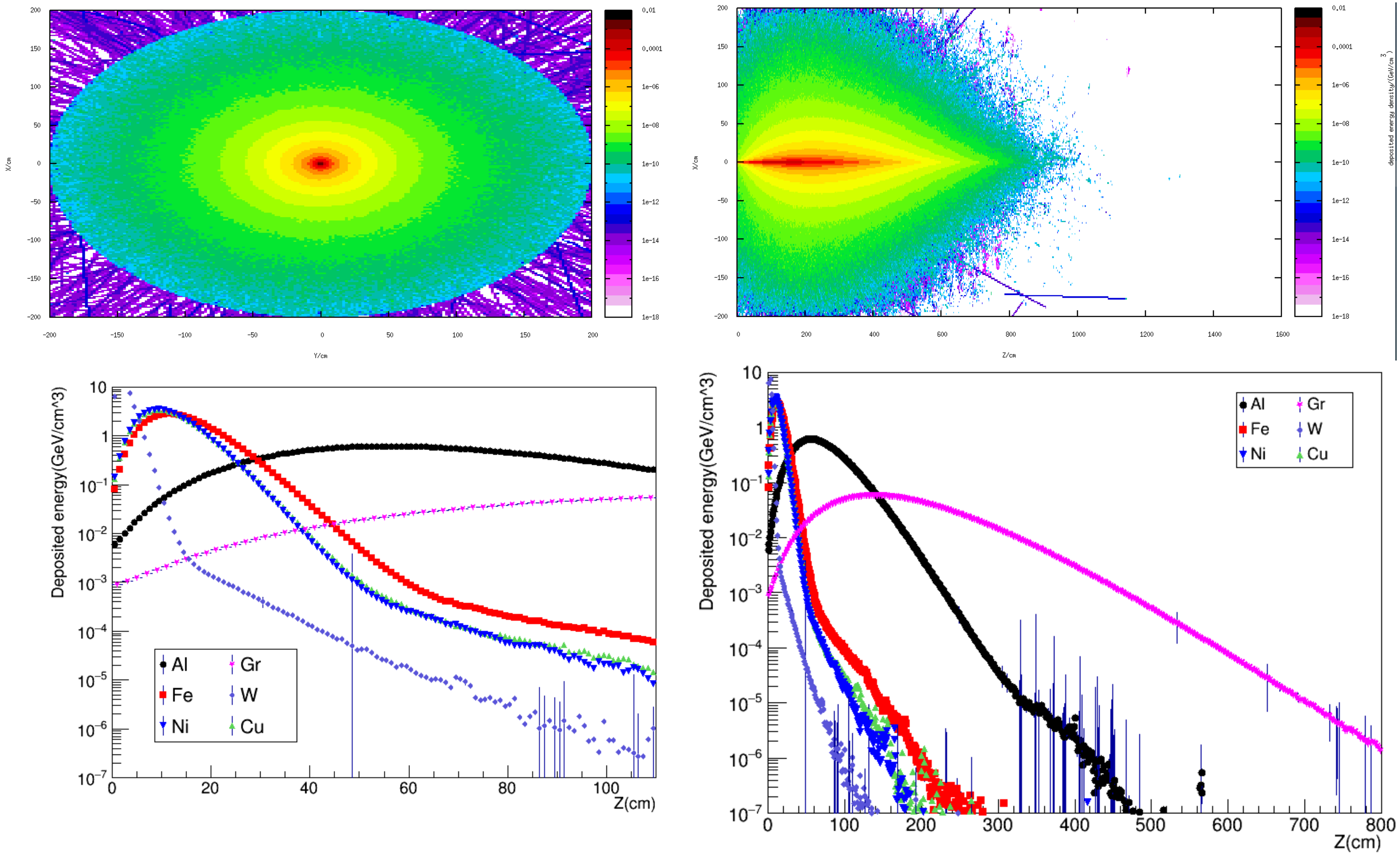
BEAM DUMP@45GEV

- Bunch population: 8*10^10;
- Number of bunches: 12000;
- Volume of grid in simulation: 1cm^3
- Temperature rise (per bunch) = $\frac{E_{depo}/GeV*8*10^{10}*1.602*10^{-10}}{density*specific\ heat}$

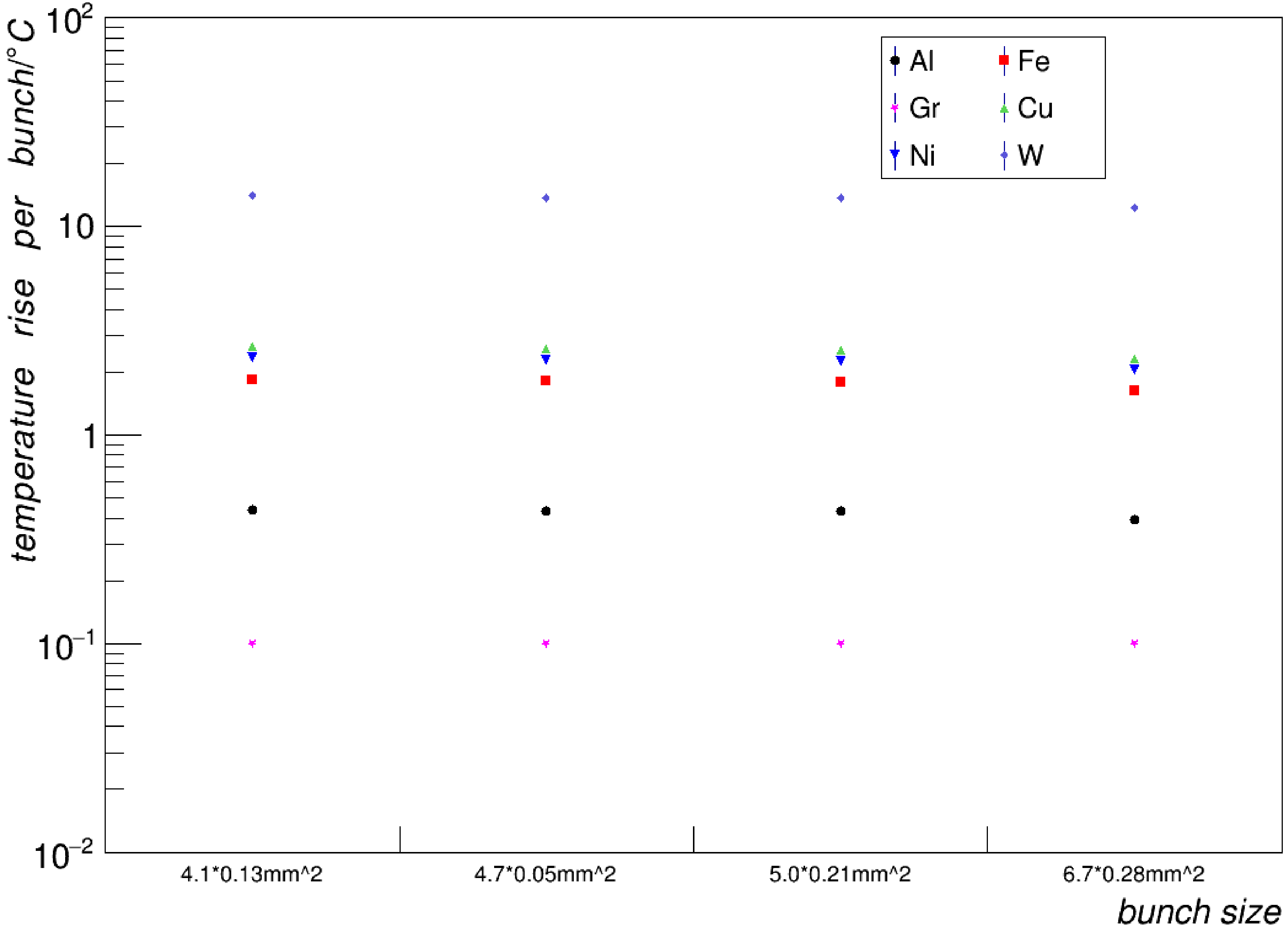
	Aluminum	Graphite	Iron	Nickel	Copper	Tungsten
Density(g/cm^3)	2.7	2.15	7.87	8.91	8.96	19.3
Specific heat(J/g/K)	0.905	0.71	0.503	0.44	0.38	0.13

- Ref. 1: Proceedings of eeFACT2016
- Ref. 2: slide: Advanced Beam dump for Fcc-ee

ENERGY DISTRIBUTION PER BUNCH

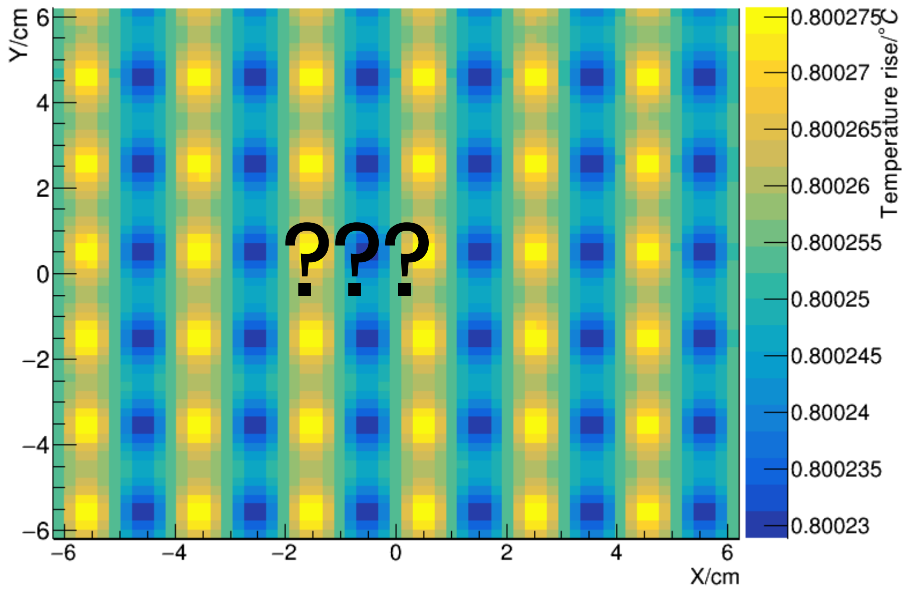


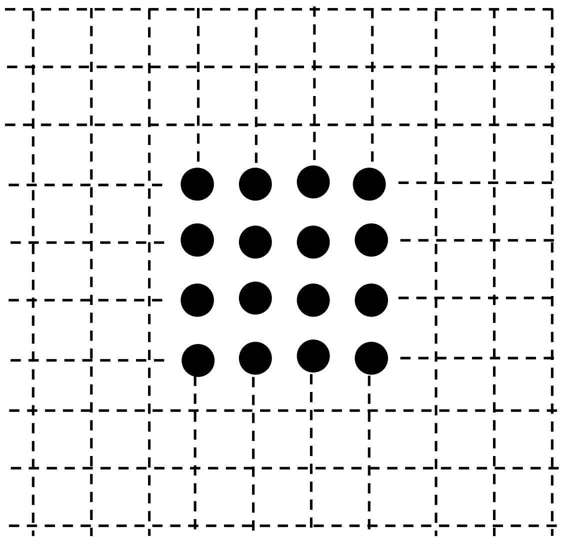
TEMPERATURE RISE PER BUNCH

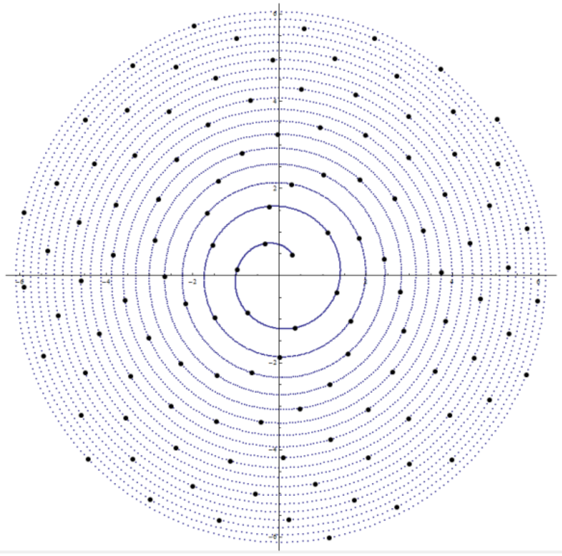


ARRANGE 12000 BUNCHES

Materials	Temperature rise/°C			
	2cm	1cm	0.5cm	0.1cm
Aluminum	0.8	3.2	12.8	296
Graphite	0.6	2.5	10.0	220
Iron	2.3	9.1	36.5	899
Nickel	2.8	11.2	44.9	1111
Copper	3.2	12.7	51.0	1259
Tungsten	14.7	59.0	235.9	5892

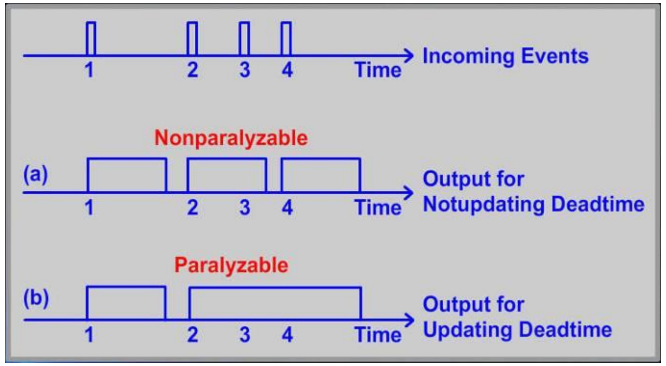


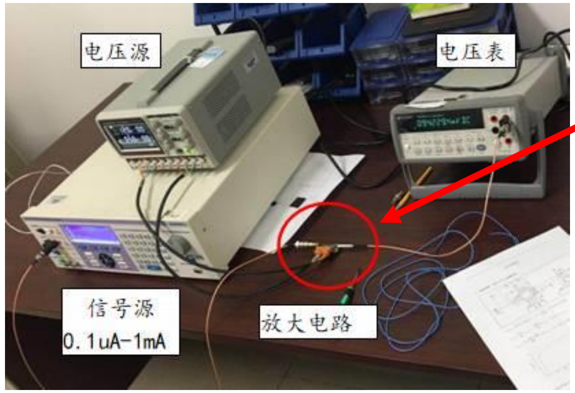


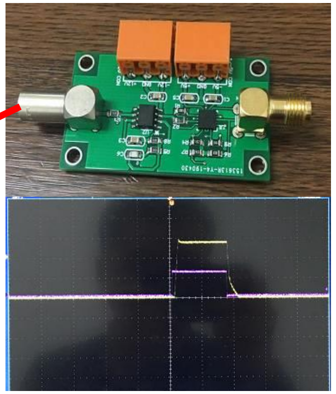


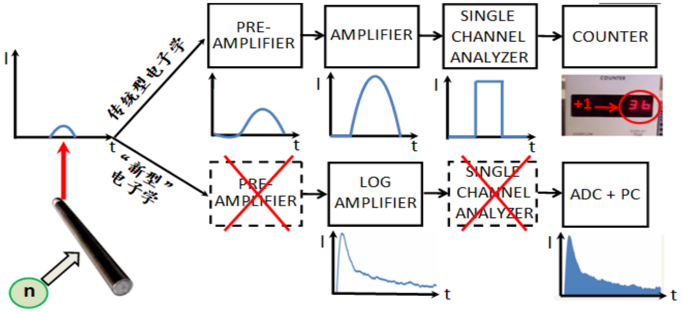
Neutron detector research based on integrated amplified circuits

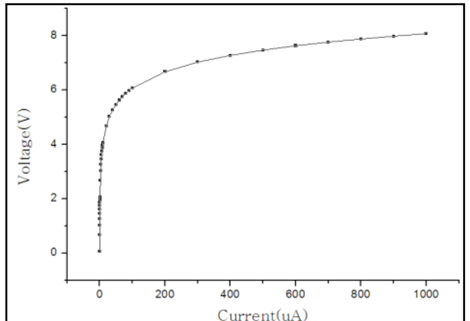
- Project cycle: January 2019 - December 2020
- Innovation: solve the problem of saturation for neutron measurement at high instantaneous dose rate.

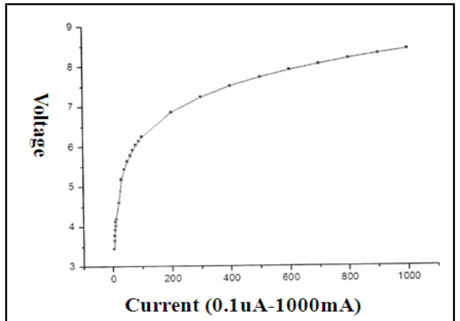












Radiological impact to environmental

- Potential sources for environmental radiological impact:
  - Dose from stray radiation emitted during machine running
  - Dose from radiation emitted by radioactive materials and waste
  - Dose from release of activated water and air
- All these factors are the same for different accelerators, in general, the potential radiological impact of lepton collider is about two orders of magnitude lower than hadron collider.

Experience from CERN

- FCC-ee CDR_2019
  - Depending on the operating phase, the beam energy of FCC-ee is between 0.45 and 1.75 times that of LEP, but the luminosities are signicantly higher.
  - Safeguards will be included in the design of the accelerator infrastructure to control the impact on the environment.
  - Dedicated monitoring systems and procedures will ensure continuous parameter recording and auditing throughout the entire operational phase of the facility and will facilitate the control of the impact.

Experience from CERN

- LEP2 Design Report_1996
  - Induced radioactivity is a minor problem in electron accelerators;
  - While the energy spectrum of SR extends well into MeV region, some formation of radioactivity will induce formation of gases and aerosols problems;
  - Activation of the demineralized cooling water is a closed-loop circuits.
  - Radioactivity in the air and water will be analyzed in low-level laboratory.

Experience from CERN

- LHC Design Report
  - Three methods exist for the calculation of the specific activity induced by hadronic interactions in beam line, shielding components and in the environment (air, rock, water, etc.).
  - The environmental monitoring program is to prove that the facility complies with the regulatory limits in force and to provide early warning if violation of these limits is imminent.

Dose from release of activated water and air

- Calculation procedure:
  - beam loss assumption (two parts)
  - Secondary particle production
  - Radioactivity in the outflow (ground water, tunnel air)
  - Impact to the environment
    - Waste liquid: collected and monitored
    - Ventilation air: further evaluated according to diffusion model
- Also will establish a environment monitoring system
  - Refer to Chapter 7.3 in CDR

Many thanks !

Back up

2.8.2 Extraction and beam dump

The extraction system is designed to remove the electron and positron beams from the main ring and transport them to the external beam dump. The system of extraction kickers and a Lambertson septum deflects the beam downwards by 12 mrad. In order not to melt the dump absorber material, the beam is spread over the front surface of the dump in a spiral pattern by means of horizontal and vertical dilution kicker magnets. The energy density deposited in the graphite in the horizontal-longitudinal ($x-z$) plane is shown in Figure 2.42.

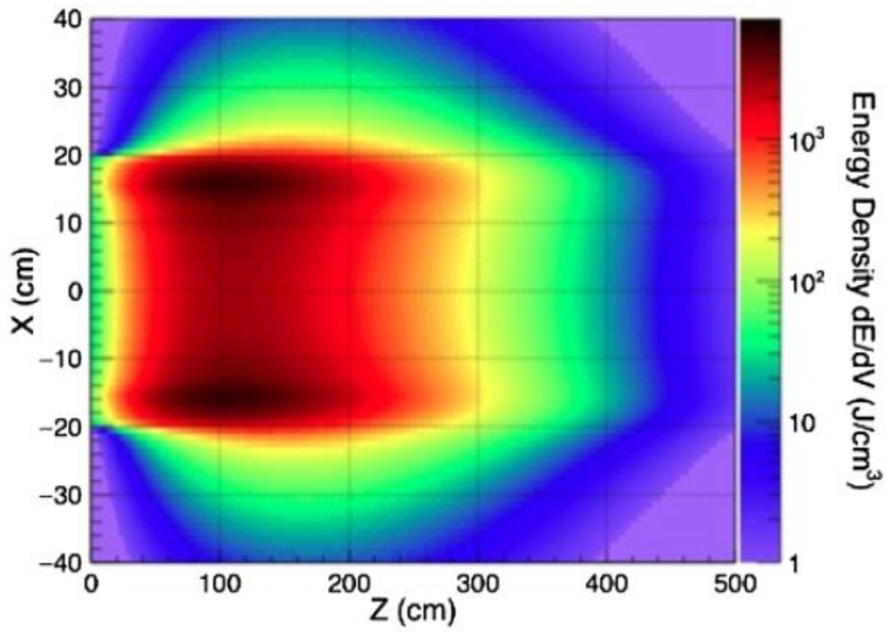
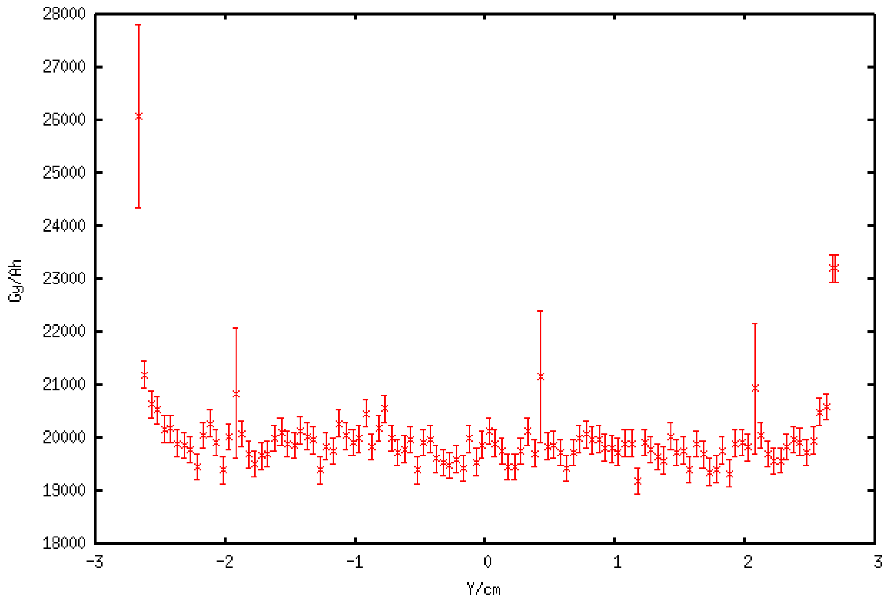


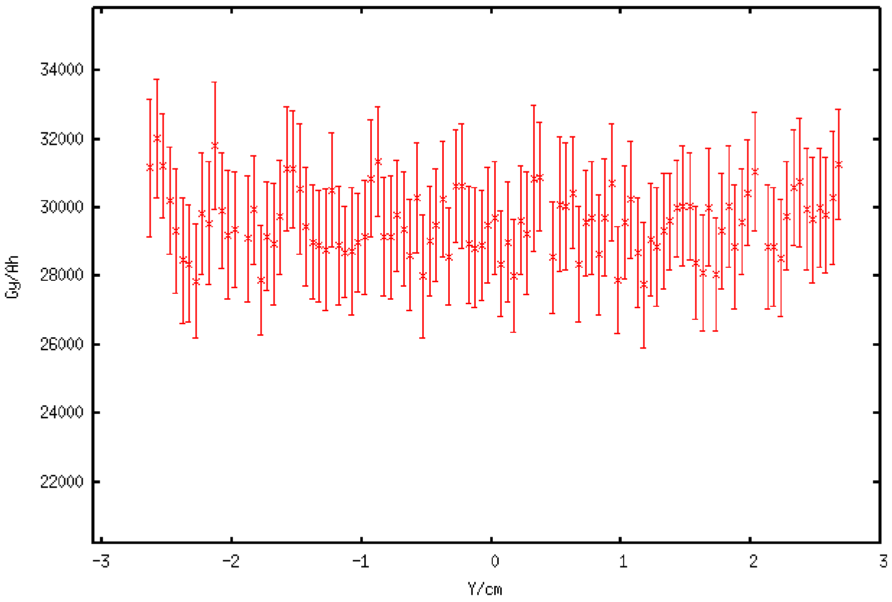
Fig. 2.42. The energy deposition on the beam dump for FCC-ee.

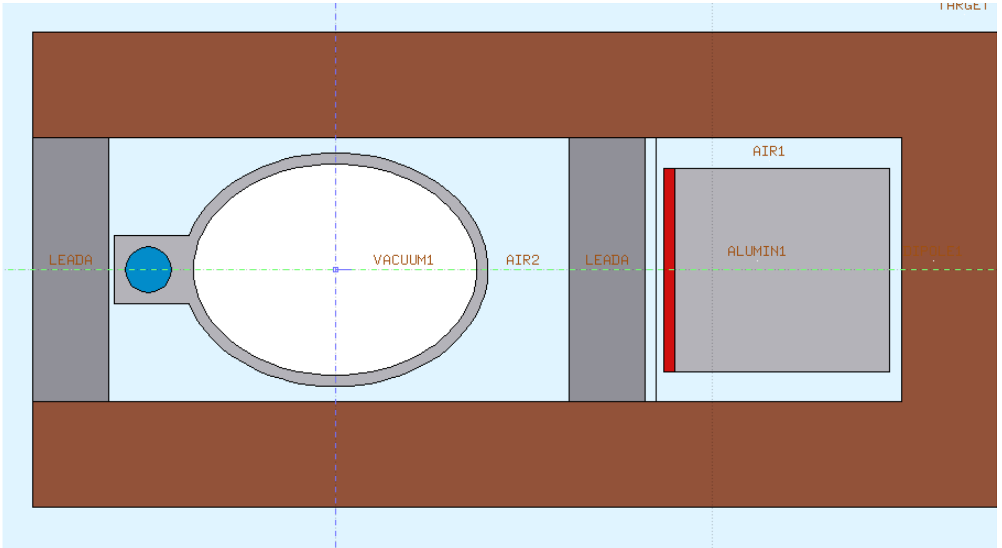
DOSE OF COIL: DIPOLE

- average



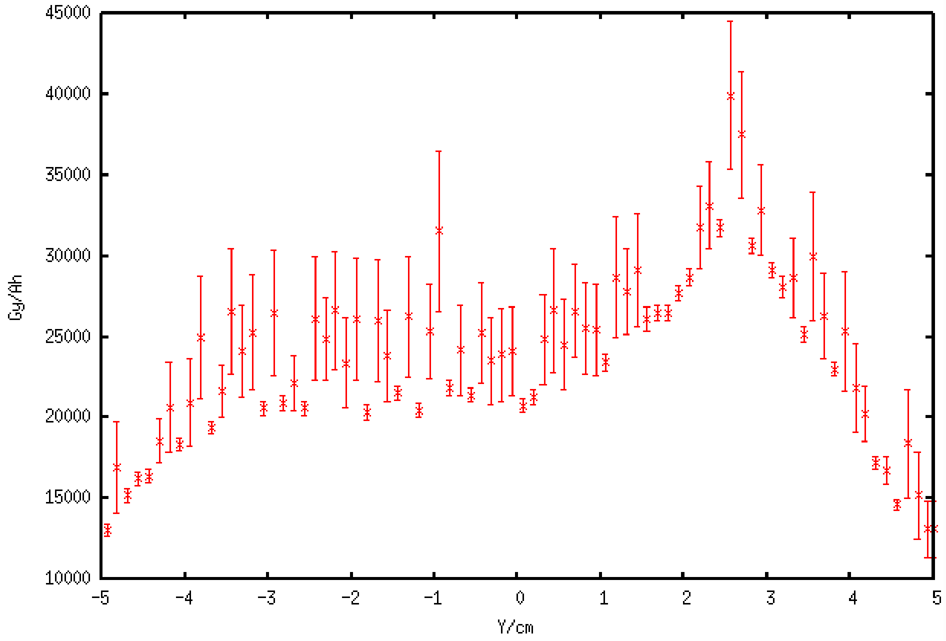
- Maximum



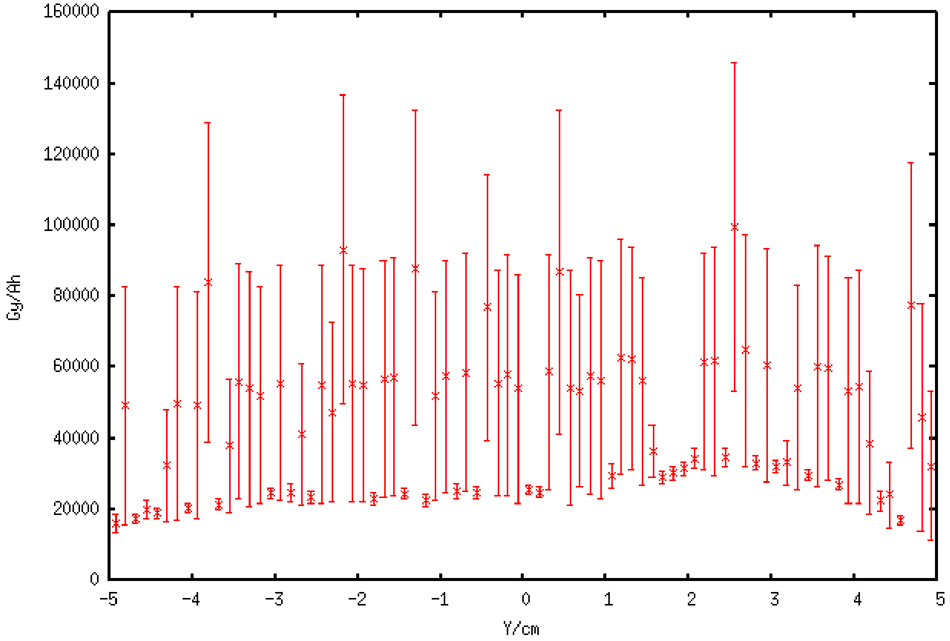


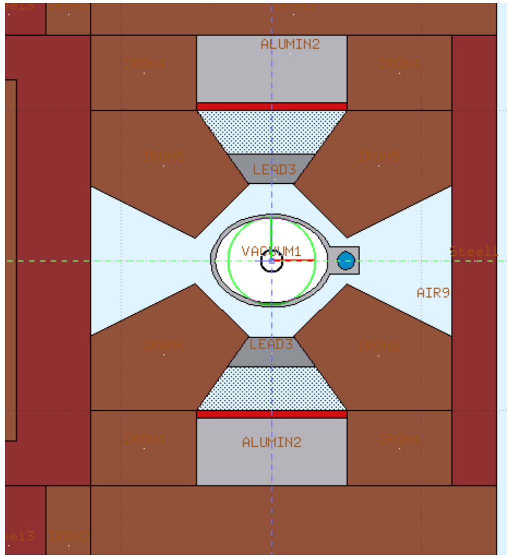
DOSE OF COIL: QUADPOLE

- average



- Maximum





LHC/LEP2 DUMP

	shape	Size	Material
LHC	Cylinder	Length: 7.7m; diameter: 0.7m.	Graphite
LEP2	Cube	2.5*0.4*0.4 m^3	Aluminum, brass

- LHC

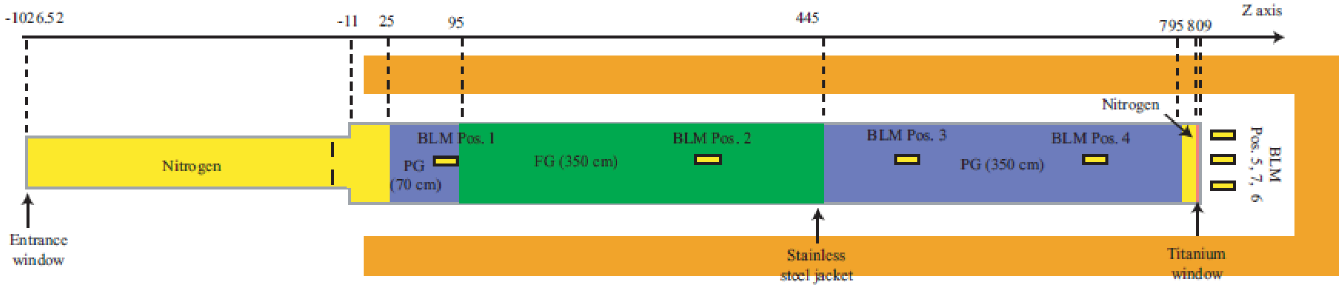


Figure 1: Sketch of the geometry implemented in FLUKA for the calculations of energy deposition and particle spectra at the BLM locations.

- LEP2

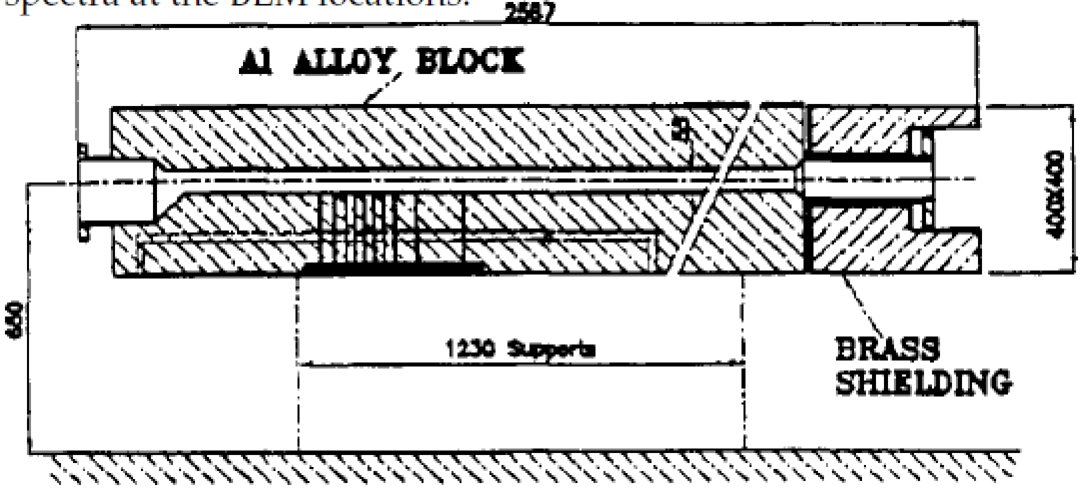


Figure 2: Beam absorber sketch