FCC POLARIMETER

Robert Kieffer, on behalf of the EPOL working group and of the CERN BI group.

Energy calibration and polarisation overview

FCCee physics program and key parameters

The FCCee lepton machine aim to run at 4 energy modes located at dedicated physics resonances.

Parameter	Z	WW	H(ZH)	ttbar	
Circumference C [km]	97.75	97.75	97.75	97.75	97.75
Energy E [GeV]	45.6	80	120	175	182.5
Number of bunches per beam	16640	2000	328	59	48
Bunch population N_p [10^{11}]	1.7	1.5	1.8	2.2	2.3
Beam current I [mA]	1390	147	29	6.4	5.4
SR energy loss per turn [GeV]	0.036	0.34	1.72	7.8	9.21
Bunch length with SR/BS, σ_z [mm]	3.5/12.1	3.0/6.0	3.15/5.3	2.75/3.82	1.97/2.54
Bunch energy spread, SR/BS [%]	0.038/0.132	0.066/0.131	0.099/0.165	0.144/0.196	0.150/0.192
Longitudinal damping time [turns]	1281	235	70	23.1	20
Horizontal emittance ε_x [nm]	0.27	0.84	0.63	1.34	1.46
Vertical emittance ε_y [pm]	1.0	1.7	1.3	2.7	2.9
Luminosity per IP [10^{34} cm^{-2}s^{-1}]	230	28	8.5	1.8	1.55

Polarimetry based energy calibration is only possible (and needed) at low energy Modes

FCCee Energy calibration RDP

Resonant Depolarisation (RDP) method will be used to measure the average ring beam energy. One polarimeter per beam is necessary.

The spin precession tune of the accelerator is closely related to the beam energy. Depolarization happens when the spin precession is coherent with the perturbations from synchro-betatron oscillations.

$$\upsilon_0 = k + k_x Q_x + k_y Q_y + k_s Q_s$$

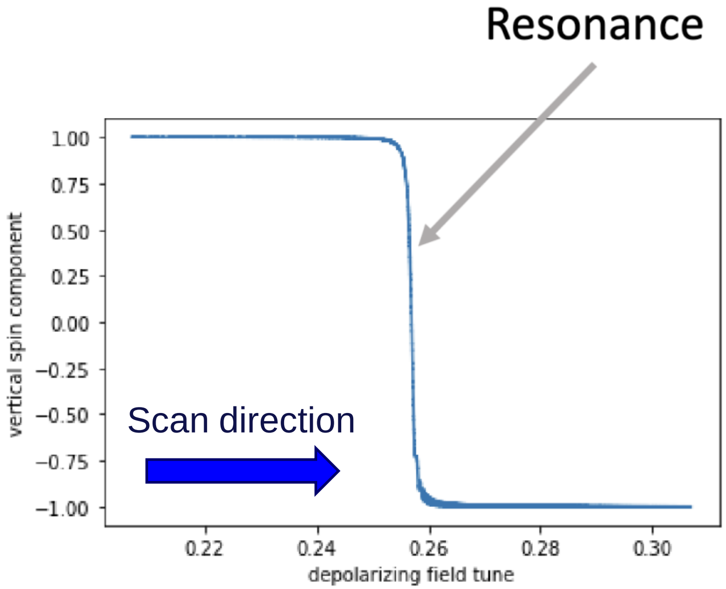
Closed-orbit spin-tune

Gyromagnetic anomaly of the electron

$$\upsilon_0 = a\gamma$$

Lorentz factor (energy)

- 100 pilot bunches are injected, and we wait for the Sokolov-Ternov effect to provide polarization buildup.
- At Z mode a wiggler might be necessary (polarized beams is an option)
- Physics bunches are then injected and start to collide at the IPs.
- Every 15 min a bunch from the polarized pilot train is selected for RDP.
- A dedicated set of kickers, act on the selected bunch.
- The kickers excitation frequency is scanned by small steps (1keV eq.).
- At each frequency step a **polarization measurement is performed** by targeting the selected bunch with a laser pulse.
- The **polarization level** along the scan provide a mean to detect the spin resonance transition. The associated frequency of the spin tune provide the **energy measurement**.



FCCee Polarimeters

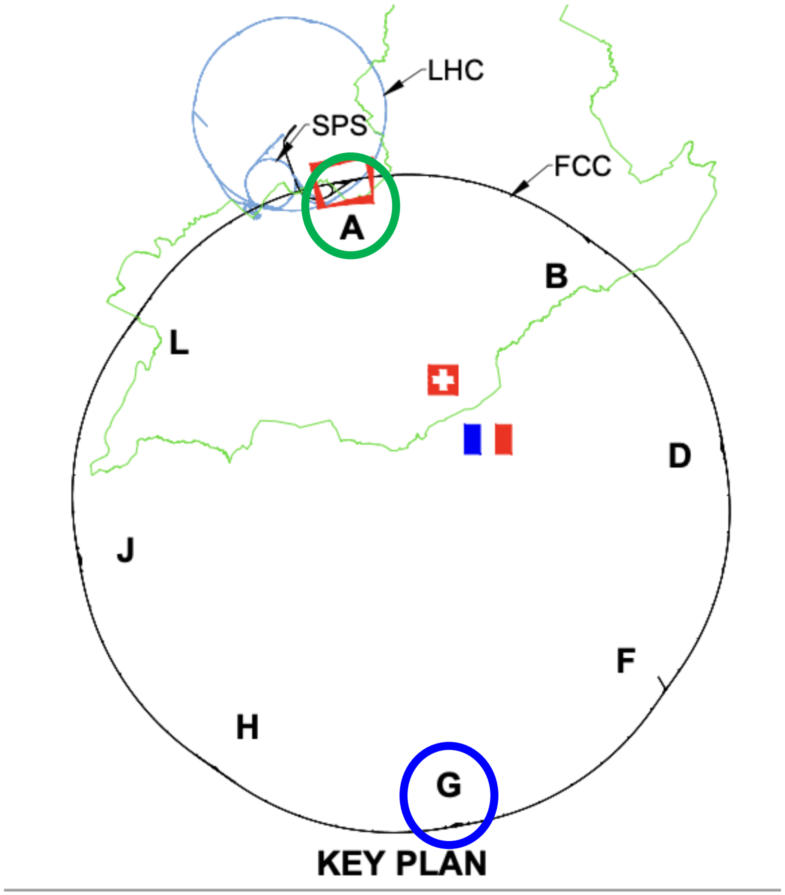
Objective 95% availability

Original proposal: a single polarimeter per beam (2 total)

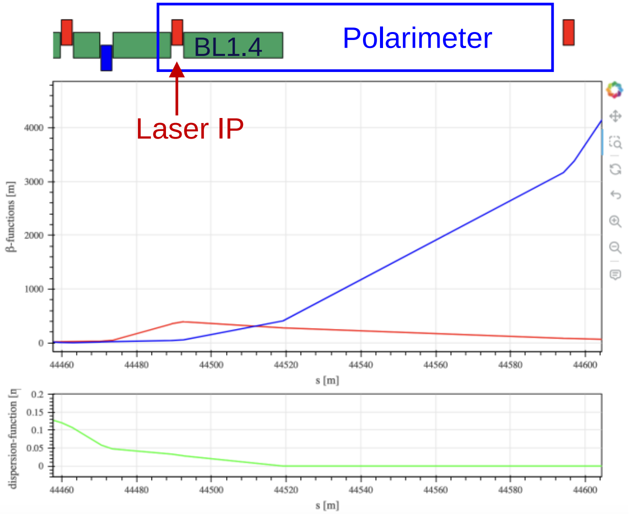
- Instrument location: both ends of **LSS** on experimental **IP A.**
- **Needs dedicated laser hutch and 24h/7d access tunnels.**
- **Duplicate the laser system for redundancy**

Full redundancy option : two polarimeters per beam (4 total)

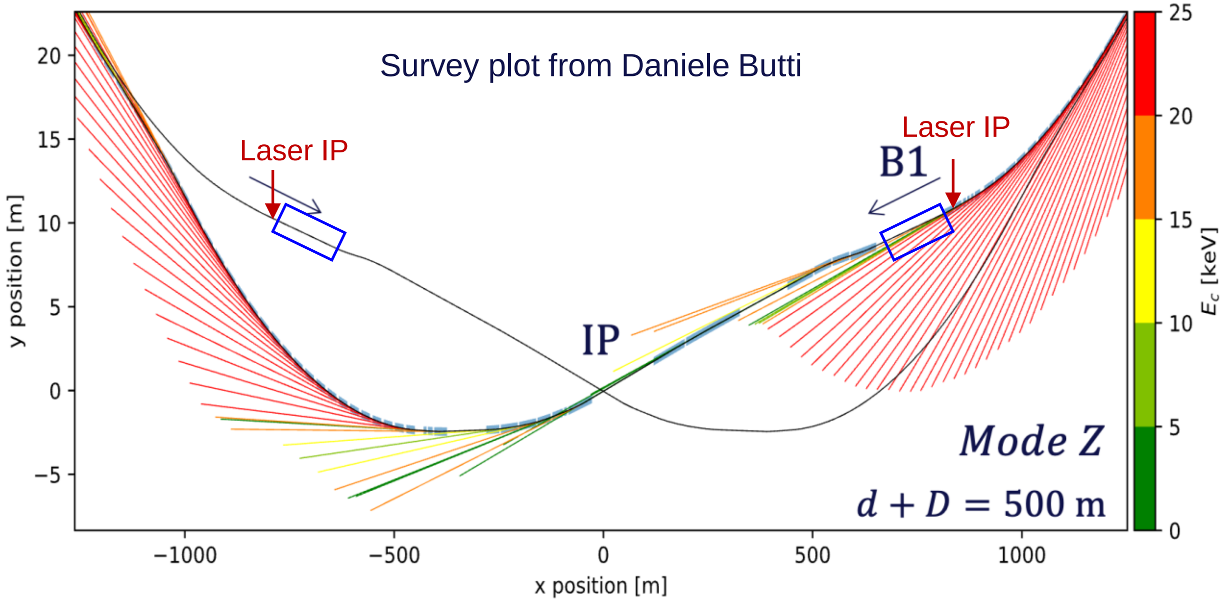
- Instrument location: both ends of LSS on each experimental IP **points G (or D or J)**
- Each exp. IP would need **dedicated laser hutches.**
- **Full System level redundancy**.



FCCee Polarimeters baseline in Experimental IP A



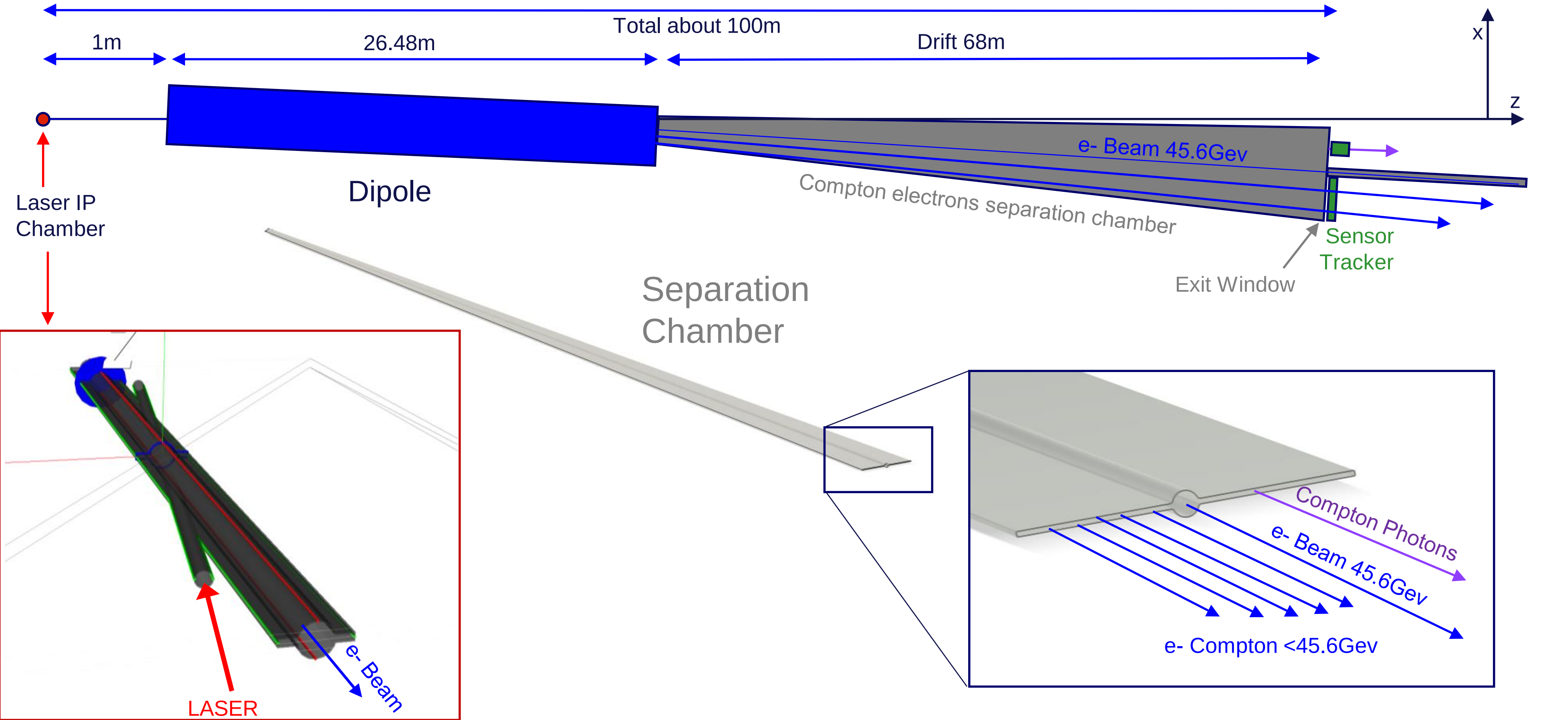
GHC optics is used. The polarimeter is not yet tested in the LCC optics.



Synchrotron Radiation fan shows a potentially strong contamination from SR in the compton gammas extraction line.

Polarimeter Instrument development

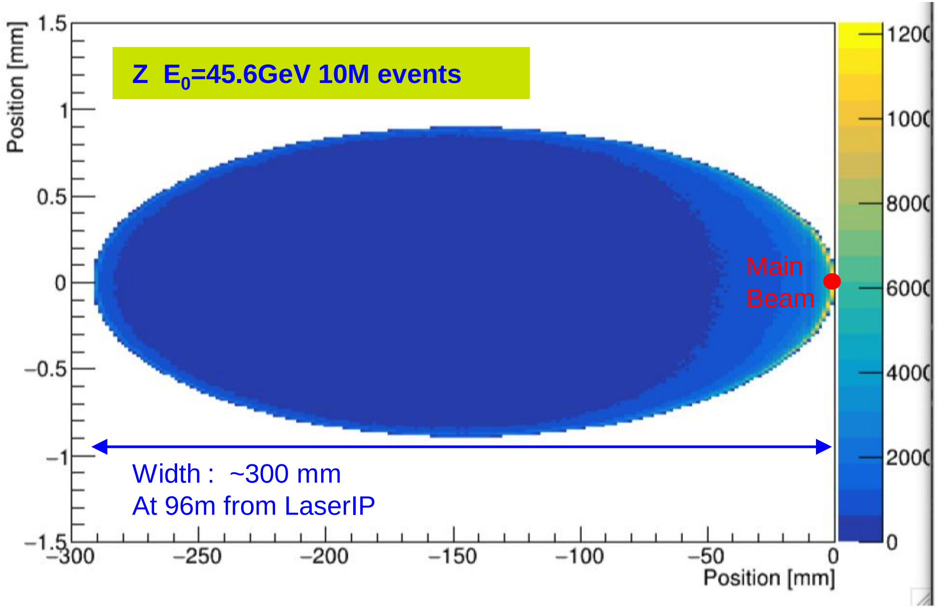
BDSIM Model description of Compton electrons separation



Compton pattern at Z mode energy scale Exiting the Separation Chamber (96m from LIP)

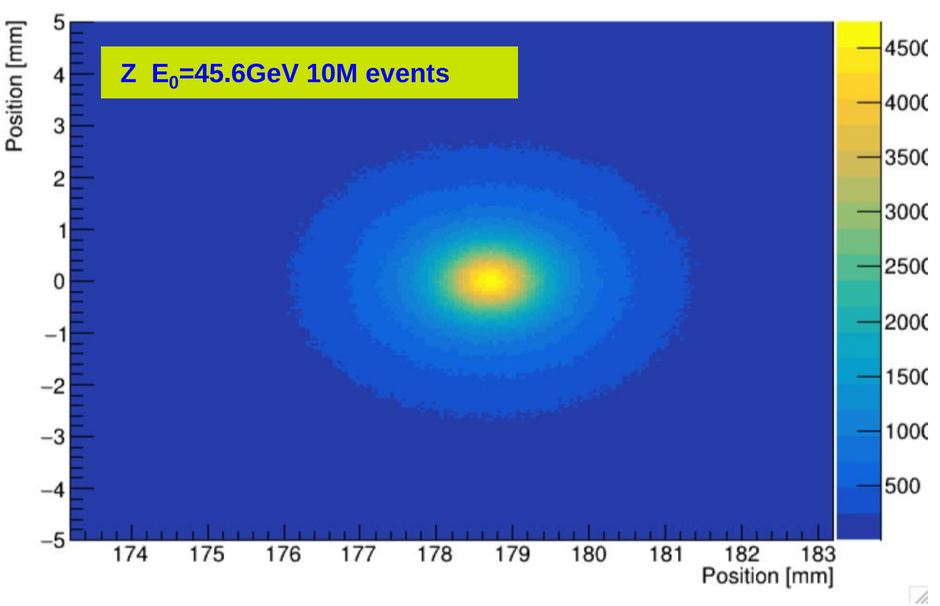
Source: BDSIM Compton simulation of Laser-Beam interaction

Transverse Plane Electrons Side



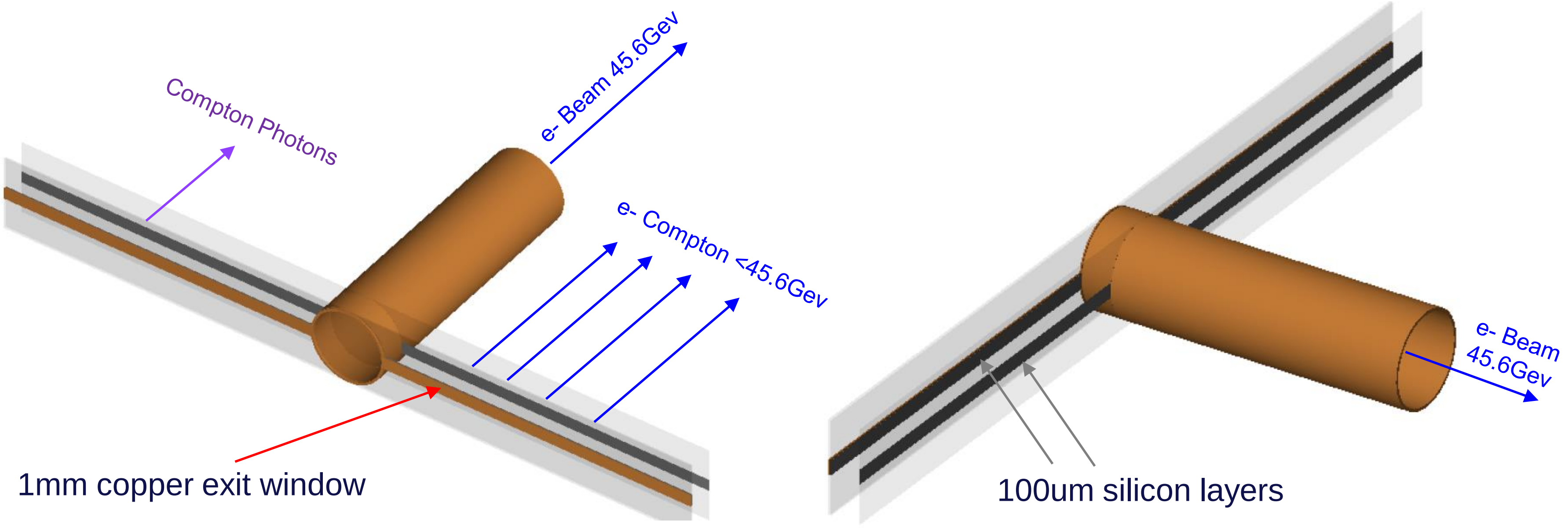
Beam Polarisation create an asymmetry in the pattern that we can fit.

Transverse Plane Photons side



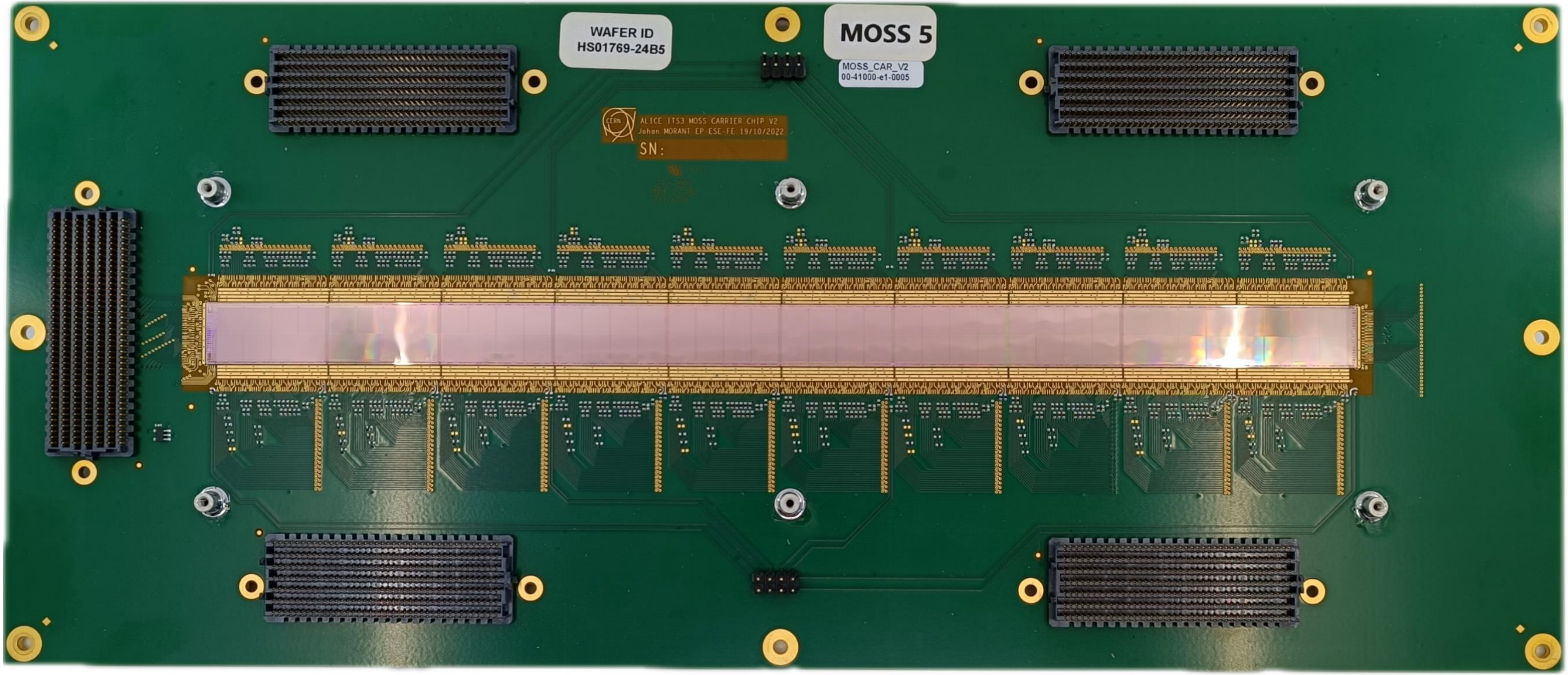
Compton photons pattern extracted at 178.6mm from beam axis

Simulation of interaction with sensor material in BDSIM

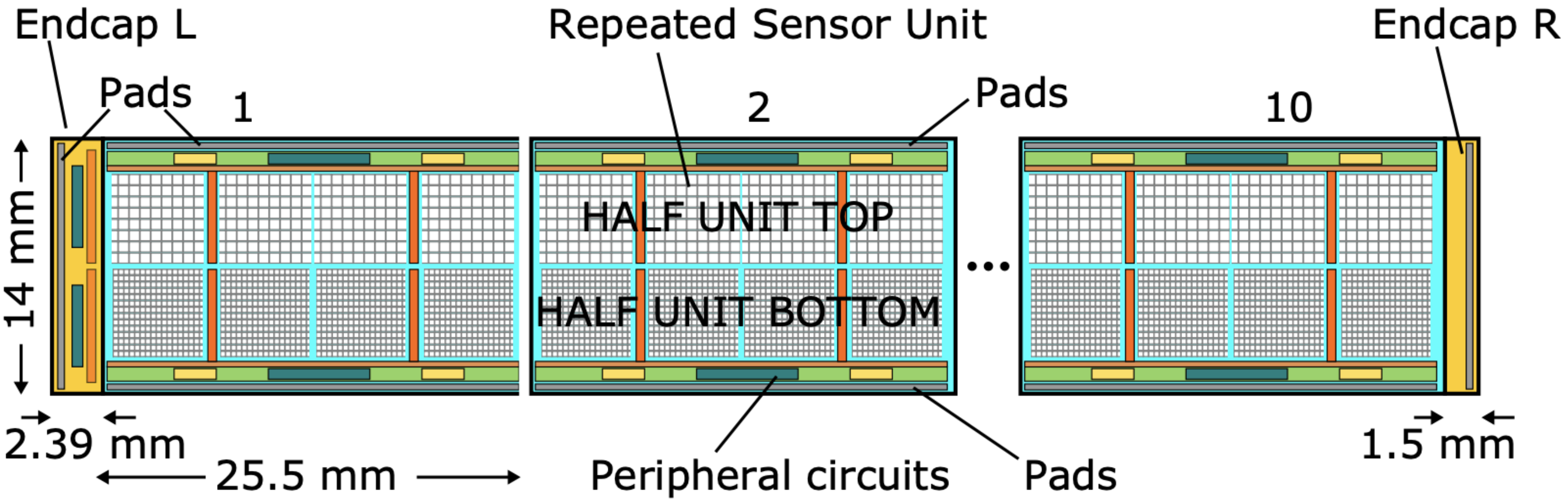


The compton products are transported through the copper exit window.
It is followed by two layers of 100um of silicon, in which we study the energy deposition.

MOSS the Alice ITS3 Monolithic Active Pixel Sensor MAPS

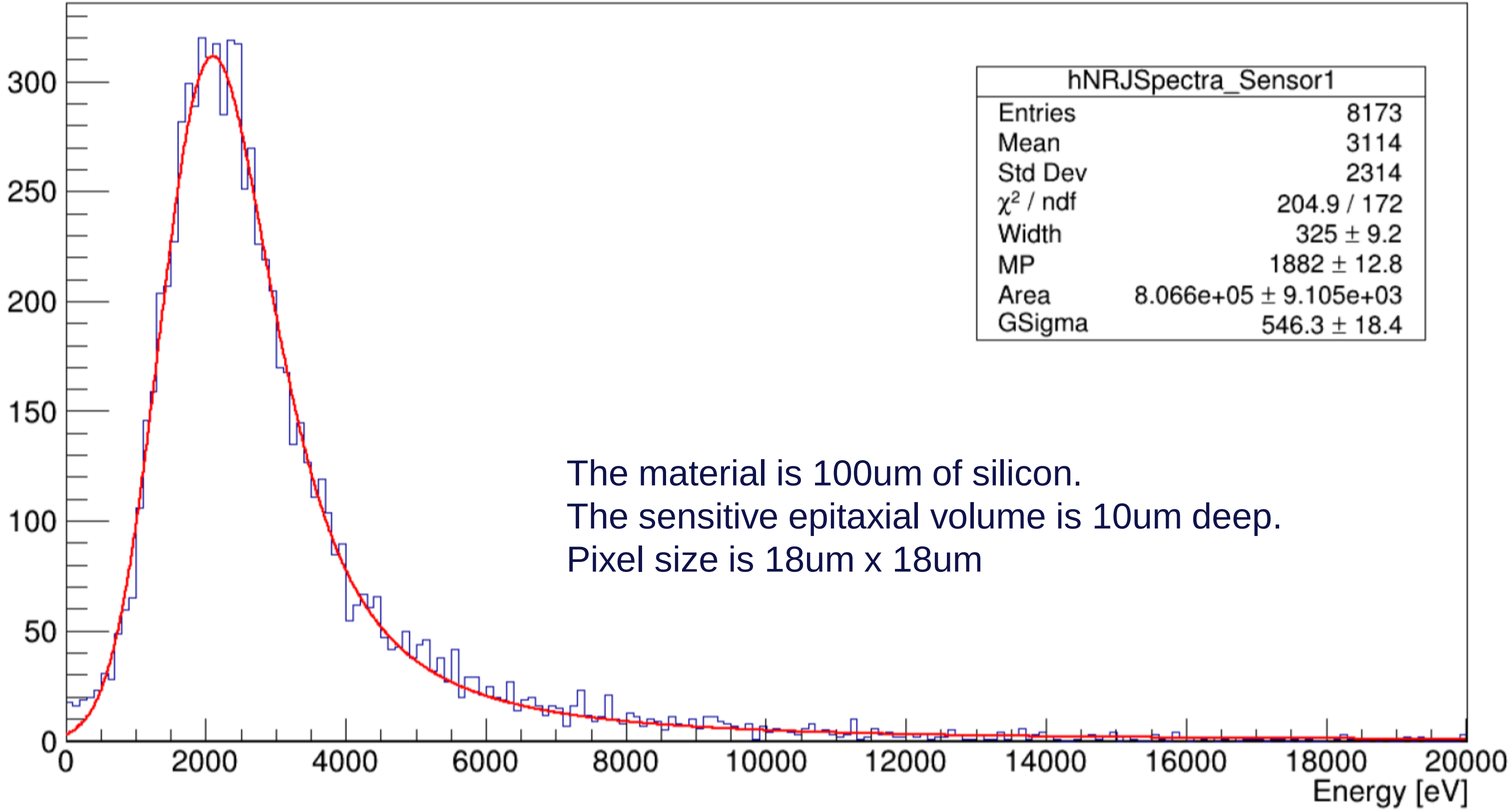


MOSS chip sensor configuration



Bottom: Each matrix is 320x320 pixel (pixel pitch 18um)
Between matrixes we do have a dead zone.
It corresponds to 34 pixel of 18um that need to be removed.

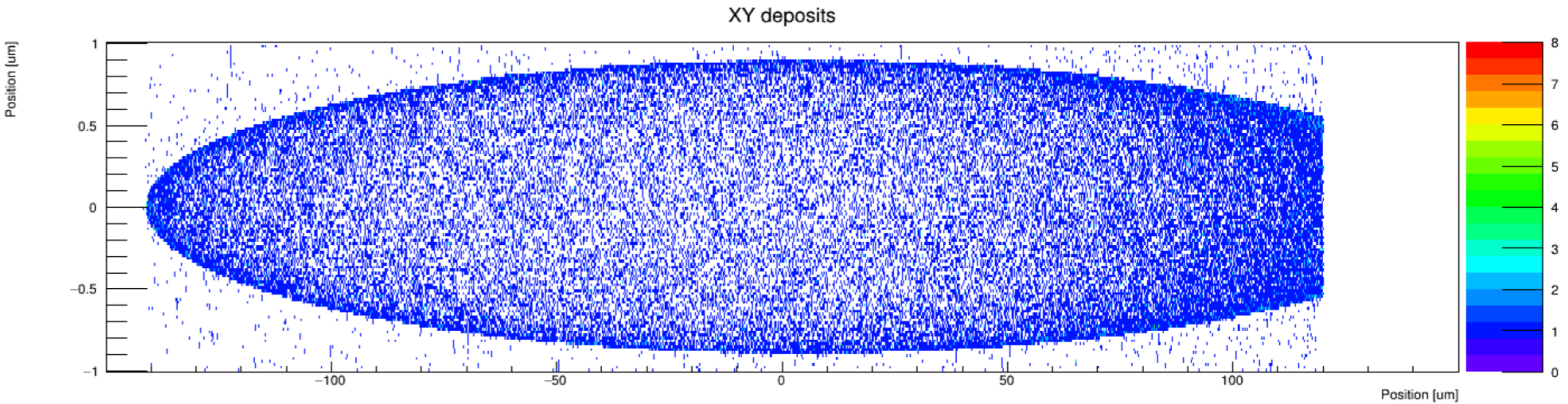
Energy deposition in silicon sensor by Compton Electrons



The material is 100um of silicon.
The sensitive epitaxial volume is 10um deep.
Pixel size is 18um x 18um

Compton pattern at Z mode energy scale Seen by an ideal silicon sensor

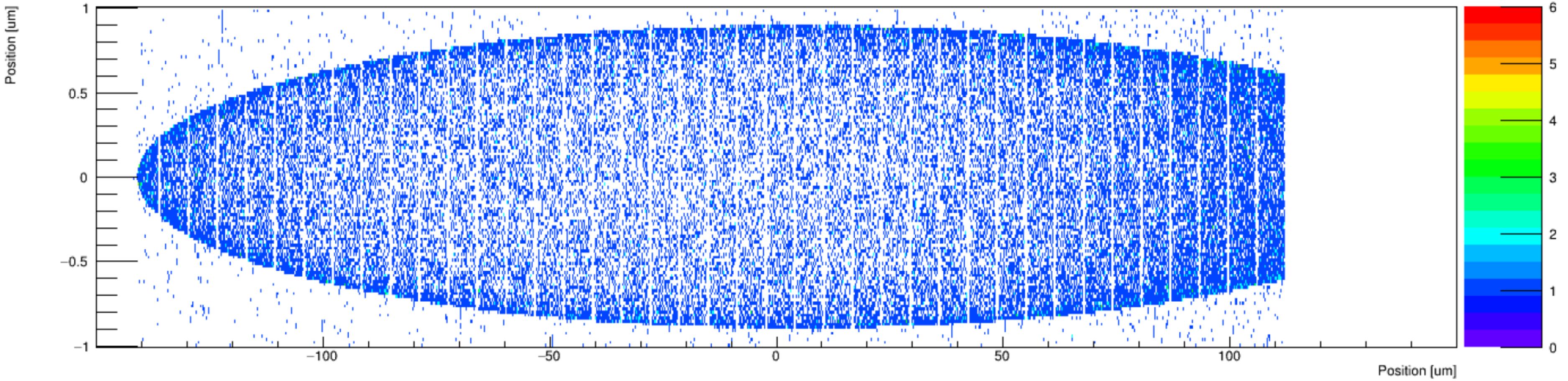
Transverse Plane Electrons Side



The sensitive epitaxial volume is 10um deep.
Pixel size is 18um x 18um
100k events simulated for this plots 8h of computing time on lxplus

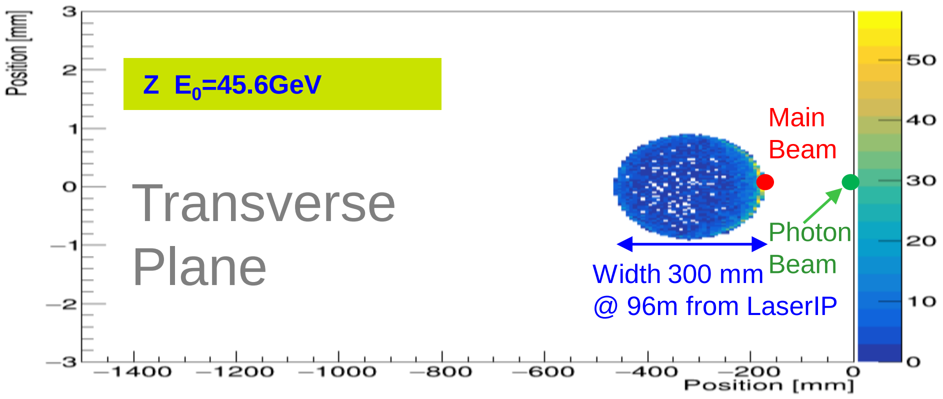
Compton pattern at Z mode energy scale Recorded by a real silicon sensor (dead zones)

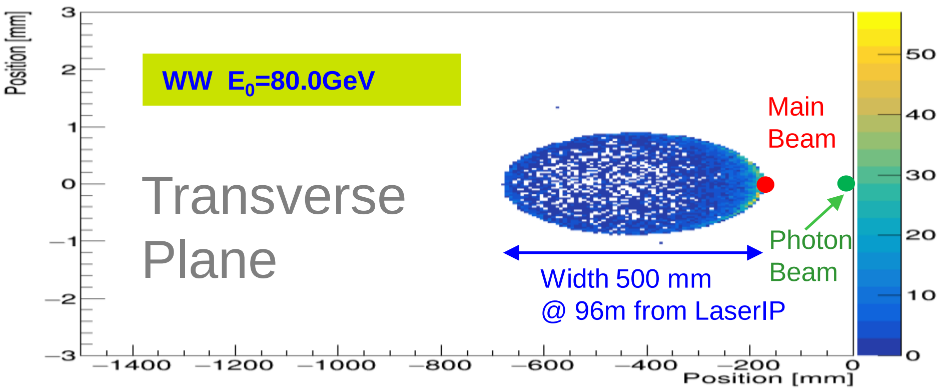
Transverse Plane Electrons Side



Including the dead zones from the MOSS sensor (40 matrixes of 320x320 pixel) separated by dead zone of 34 pixels
100kevts simulated here.

Compton electron pattern at different run energies Exiting the Separation Chamber (96m from LIP)



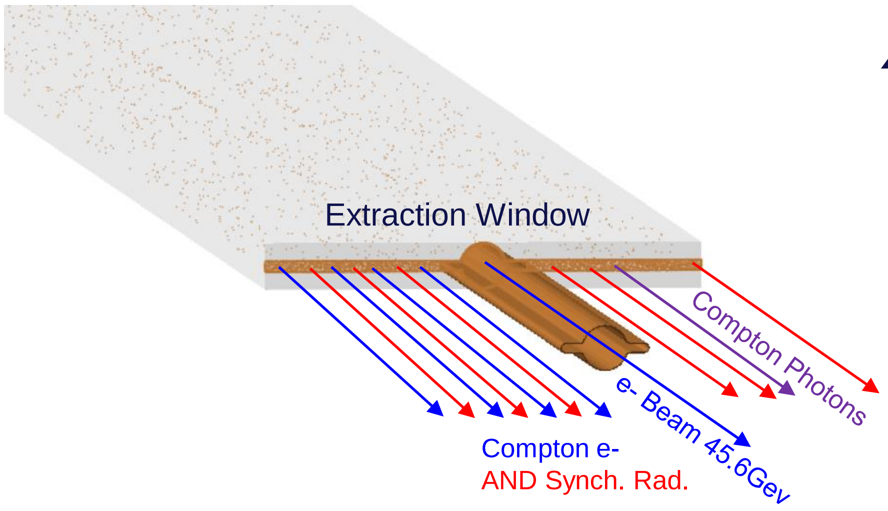


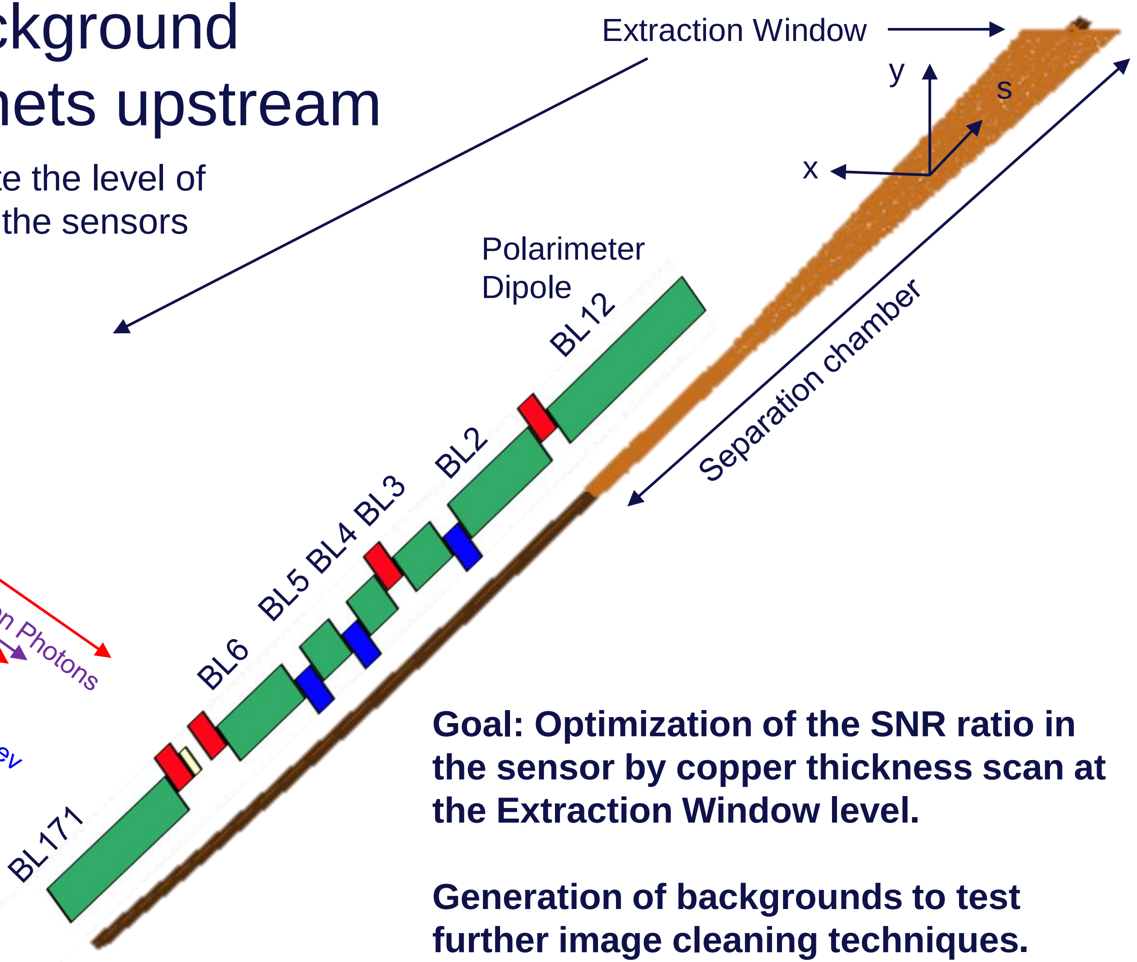
To allow running the polarimeter for both Z and WW modes without hardware changes, the Compton electron sensor transverse acceptance need to reach about 500mm

SR Background impacting the Polarimeter

Synchrotron Radiation background BDSIM model with 6 magnets upstream

Study of the SR background pattern, to evaluate the level of contamination of Compton Images recorded in the sensors

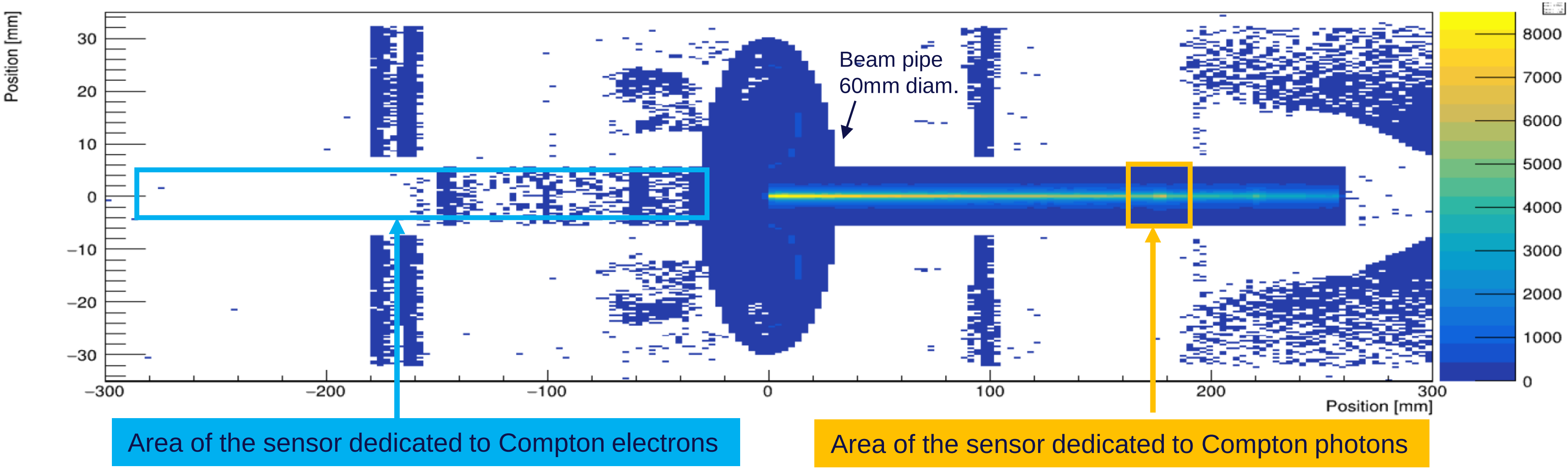




Goal: Optimization of the SNR ratio in the sensor by copper thickness scan at the Extraction Window level.

Generation of backgrounds to test further image cleaning techniques.

SR background reaching the exit window internal face.

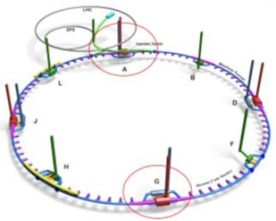


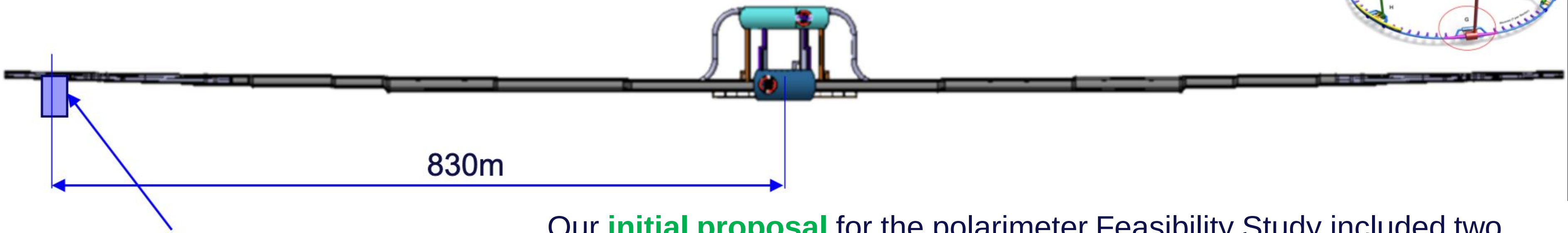
- SR Radiation generated by 6 dipoles upstream the laser IP, plus the main polarimeter spectrometer dipole.
- Internal photons reflection in beam pipe, with surface roughness parameter set to 100nm.
- SR Absorber from R.Kesevan not yet implemented in the simulation (could reduce a bit the photon dose).

Polarimeter Integration

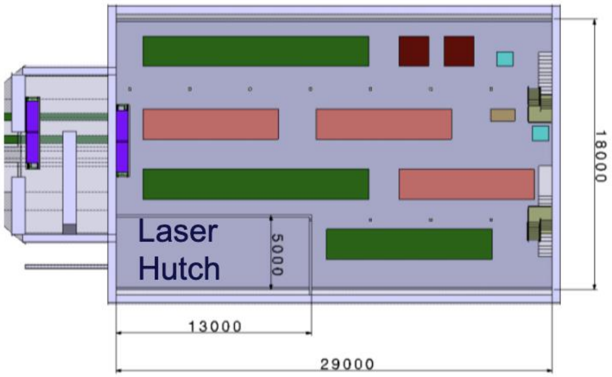
FCC-ee Integration of Big Alcove with Laser Hutch at point A

Proposal Slide from Fanny
https://indico.cern.ch/event/1429623/





Big Alcove
Machine level



Our **initial proposal** for the polarimeter Feasibility Study included two critical integration aspects.

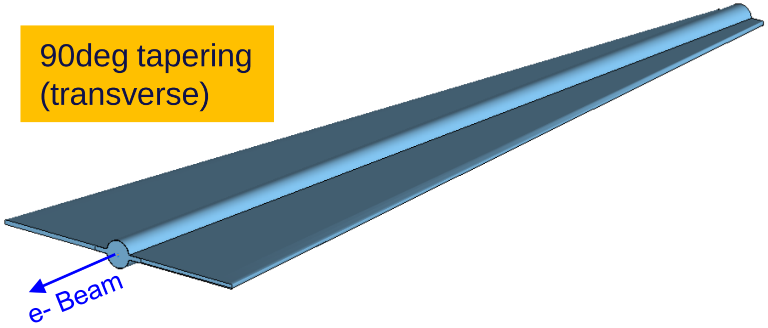
1. 24h/7d Access tunnel to the laser hutch to ensure required polarimeter availability of 95%. (refused at this stage)
2. Laser alcove as close as possible to the laser IP (830m from exp. IP) To reduce costs, proposal of displacement of the first big alcove by 300m to be located at 830m from IP (not confirmed)

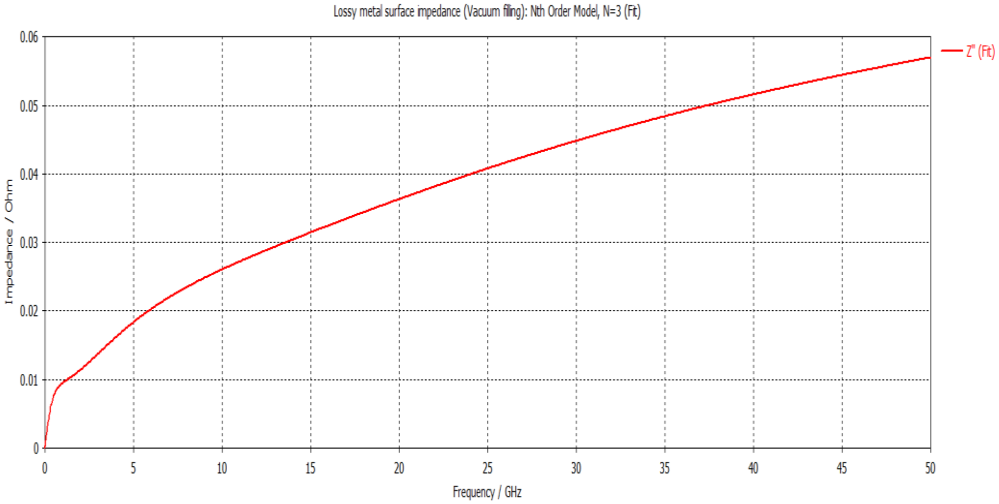
For the preTDR phase these items will need to be considered again with specific studies to evaluate the maximum laser transport distance, and to assess if remote laser control could be considered. This needs dedicated optical test bench to be financed/developed.

Impedance budget

CST Model of the Polarimeter chamber tested.

Thanks to Mauro Migliorati, Dora Gibellieri, Carlo Zannini





- The CST models that we provided to the FCC **impedance simulation** team have been tested. The study consisted in a scan of different extraction windows angle. From transverse (90deg), to (15deg) tapering.
- All models have successfully passed the impedance evaluation. They fall well bellow the 0.01% of the Total Machine budget impedance.
- Based on this result we will use the **transverse (90deg) extraction window geometry** for best performances.

Outlook and plans for the new coming year.

- Completion of the **Feasibility Study** report to be soon published.
- Follow up on all kind of **simulation studies** concerning the polarimeter instrument.

Some open tasks to be addressed for the Pre TDR phase inside the EPOL

- Spin tracking and energy calibration procedure studies (ABP, EPOL members)
- Polarized pilots beams from the injectors (instead of wigglers)
- Compton polarimeter Instrument development, and integration (BI)
- Vacuum chamber design and cost evaluation (BI with MME)
- Laser system development , laser transport, laser hutch integration (STI, IJClab)
- Depolarizing Kickers (RF)
- Impedance budget evaluation
- Specification of the spectrometer dipole (aperture, instrumentation)

Advertisement for PhD positions

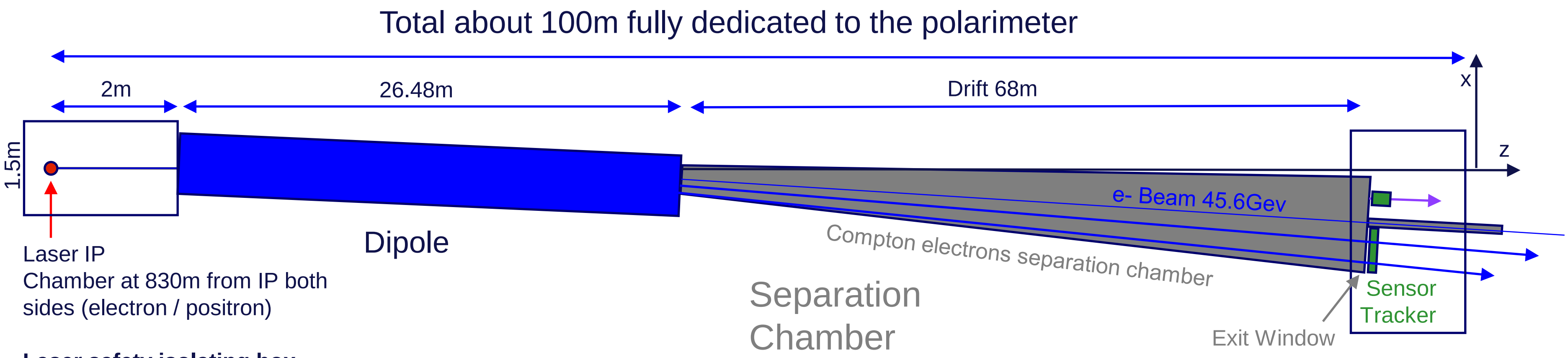
- The BI group is looking for a PhD candidate to work on the polarimeter instrument development. With the main objective: to simulate and develop the Compton Gamma detector.

- We are also looking for a second PhD candidate to work on the Beamsstrahlung monitoring instruments (MDI related).

In case some of you have potential students that could be interested by such position, contact me (Robert.Kieffer@cern.ch).

Thank you
for your attention.

Space reservation volume in the collider tunnel



Laser safety isolating box
1.5m large
2.0m long (as the LIP chamber)
1.8m height

Volume of the chamber
FCC beam pipe shape
Winglets aperture extention
0.5m large exiting the Dipole
1.5m large at the Exit window

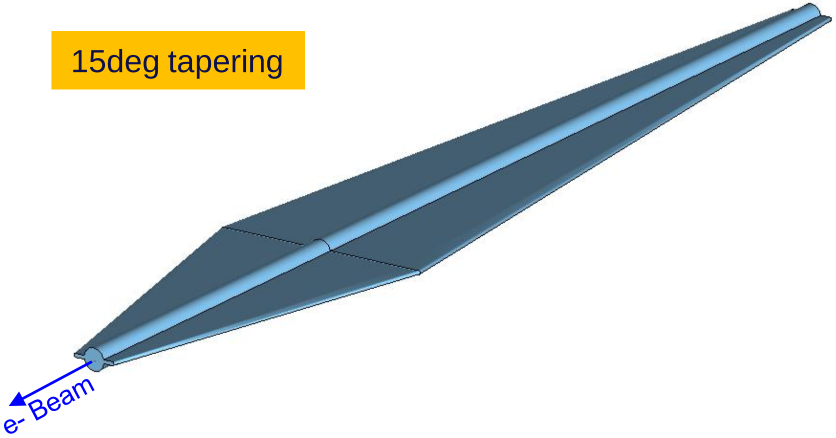
Box containing the instruments
1.5m large 1.5m long (along beam)
1.8m height

Laser Transport pipes
Needed volume to be defined by STI

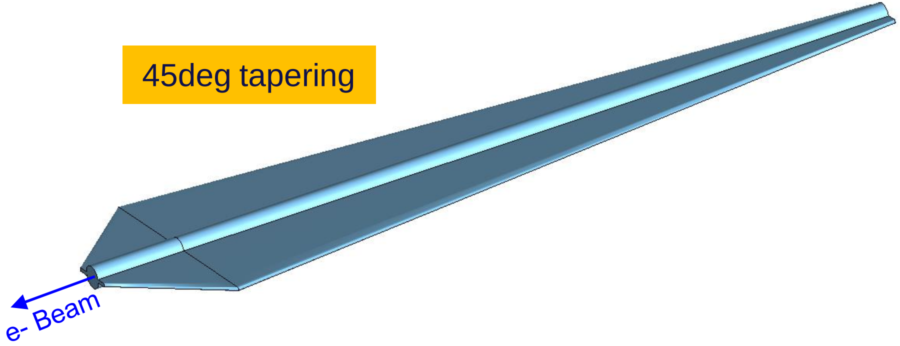
First CST Models of the Polarimeter chamber tested.

Thanks to Mauro Migliorati, Dora Gibellieri, Carlo Zannini

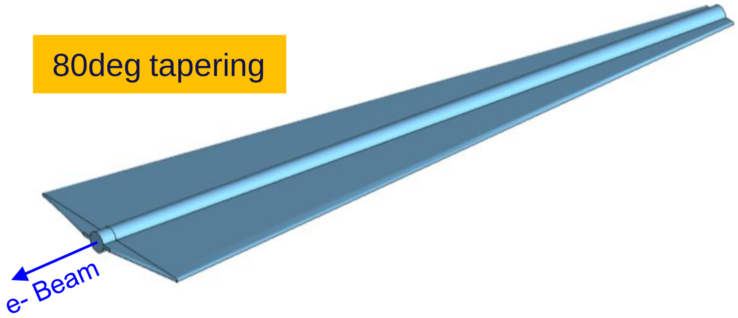
15deg tapering



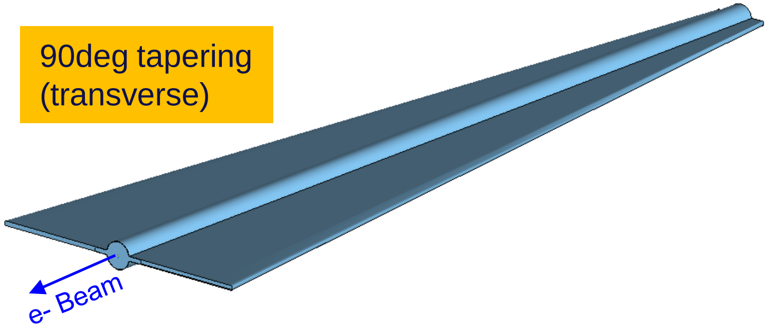
45deg tapering



80deg tapering

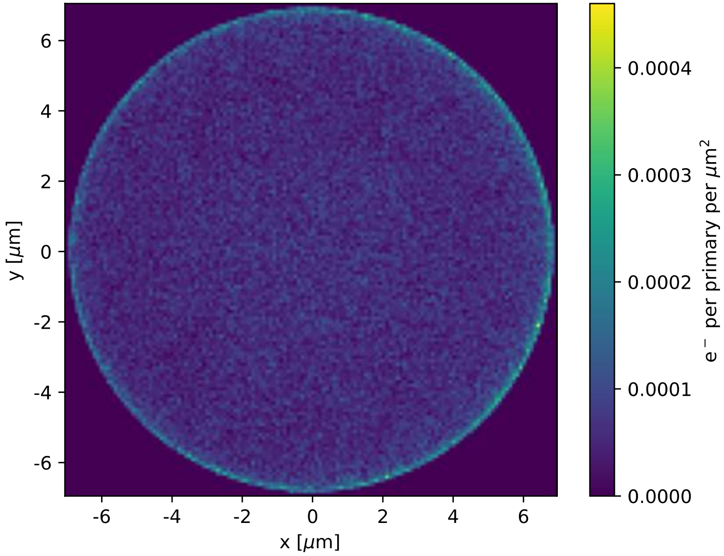


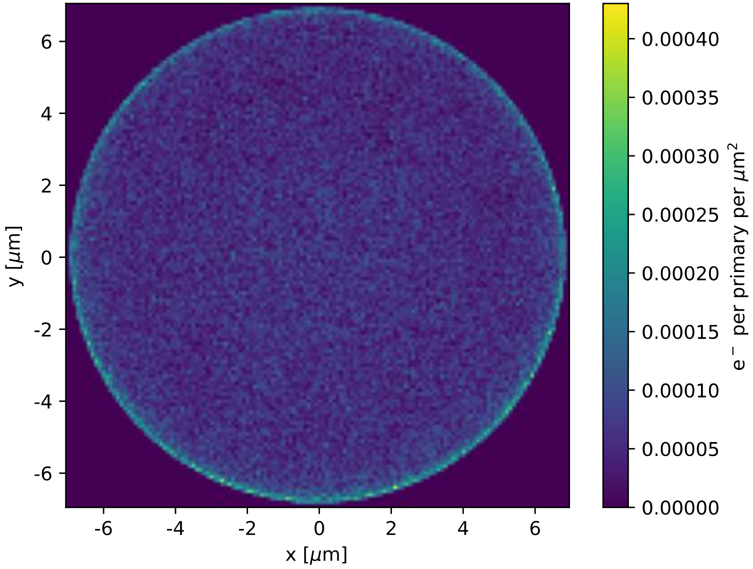
90deg tapering (transverse)



BDSIM Compton

- First benchmark check from polarization in BDSIM looks correct.
- The special version will soon move to git and hopefully will be deployed on CVMFS soon for use with HTCondor (instead of my local laptop version).

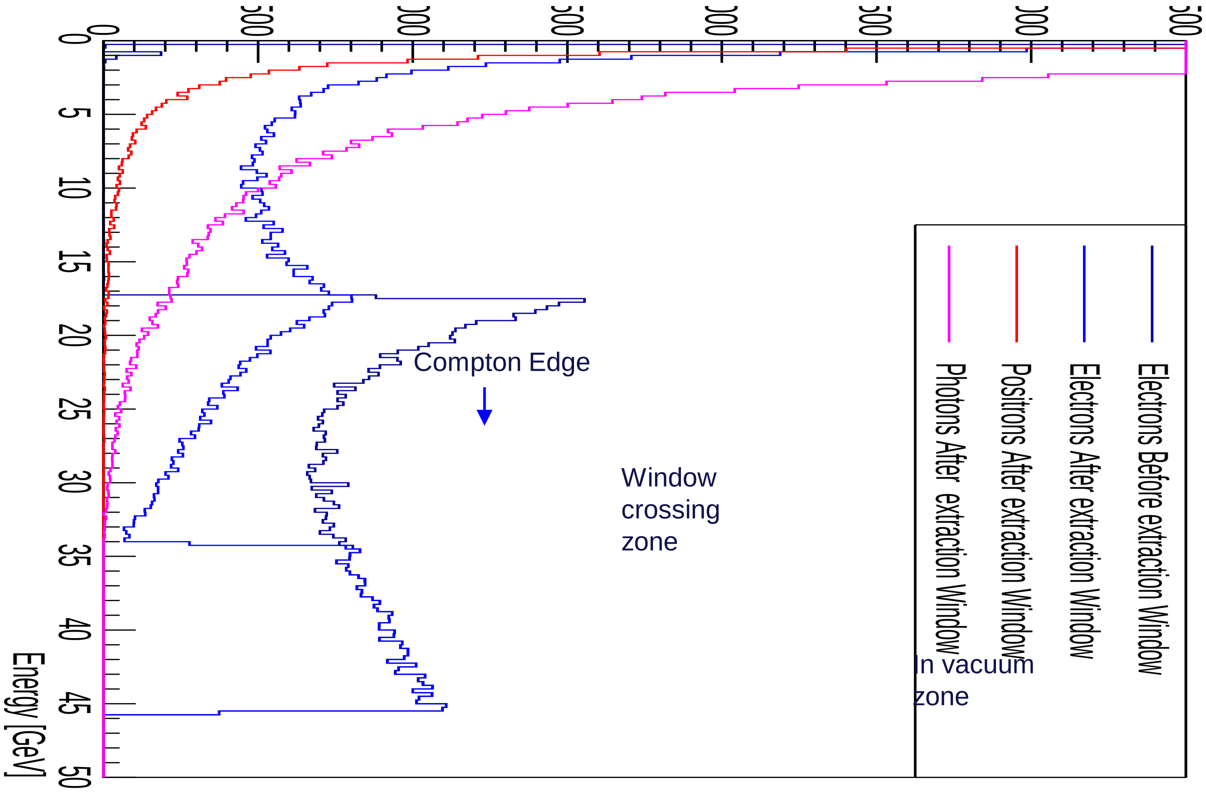




Compton electrons extraction spectra

Z mode 45.6GeV beam energy
Extraction window at 15 deg angle
Window thickness 2mm copper.
Makes a 7.7mm seen by the particles along the track.

We can see that the Compton electrons are undergoing electromagnetic interaction when crossing the exit window.

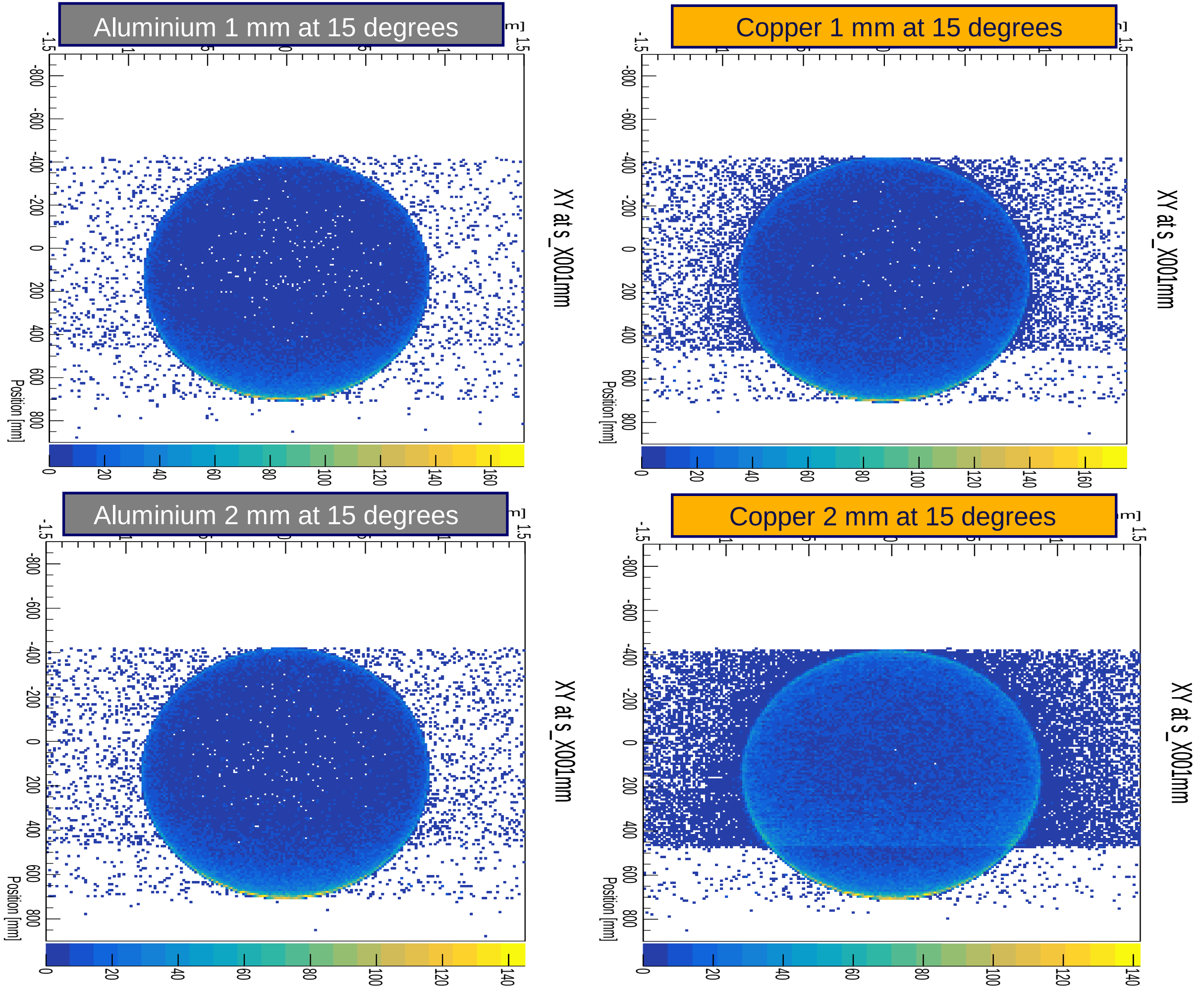


Extraction window material/thickness

Study at Z pole sampling plane is 1mm after the extraction window.

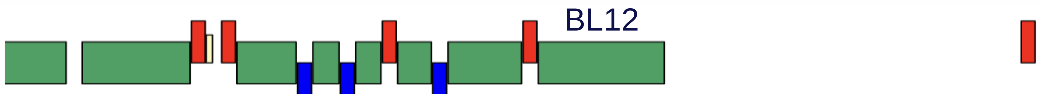
Aluminium and Copper
Two ticknesses 1-2 mm

1 mm Aluminium is the most transparent solution.



Power deposited by All elements (Dipoles, Quads, Drift)

BEAMLINE FOR THE STUDY



Thanks to the toolkit of Kevin Andre, I was able to simulate SR generation at the polarimeter location including reflections in the beam pipe from upstream magnets.

In average a power dissipation of 1kW/m is expected.

We might reach 10kW on the exit window surface (to be confirmed) .

Special cooling of the exit window would eventually be needed.