ATDC
FCC POLARIMETER UPDATE

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
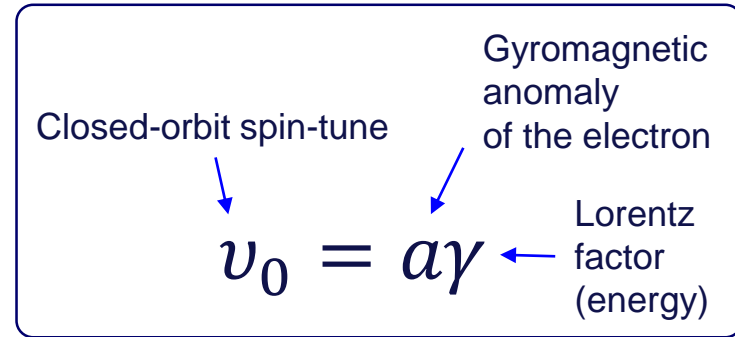
FCCee Energy calibration RDP

Resonant Depolarisation (RDP) method will be used to measure the average ring beam energy. One polarimeter per beam is necessary.
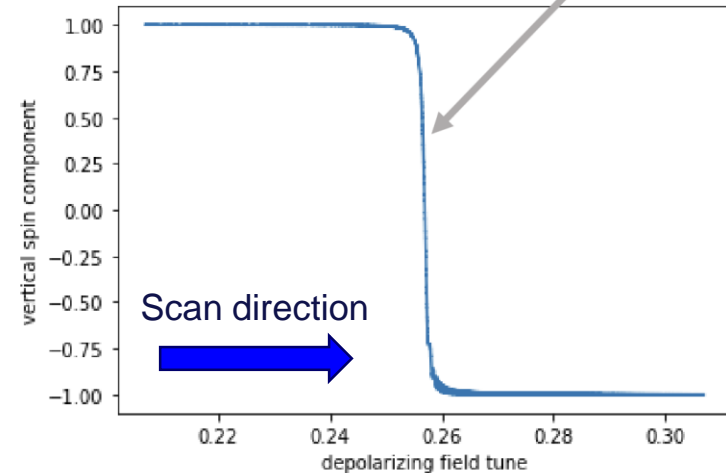
The spin precession tune of the accelerator is closely related to the beam energy. Depolarization happens when the spin precession is coherent with the perturbations from synchro-betatron oscillations.

$$v_0 = k + k_x Q_x + k_y Q_y + k_s Q_s$$

- 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**.

Closed-orbit spin-tune   Gyromagnetic anomaly of the electron

$$v_0 = a\gamma$$

Lorentz factor (energy)

Resonance

Scan direction

FCCee Polarimeters

**Base line: 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.**
- **Possible scenario, in the first alcove of the arc.**
- **Duplicate the laser system for redundancy**

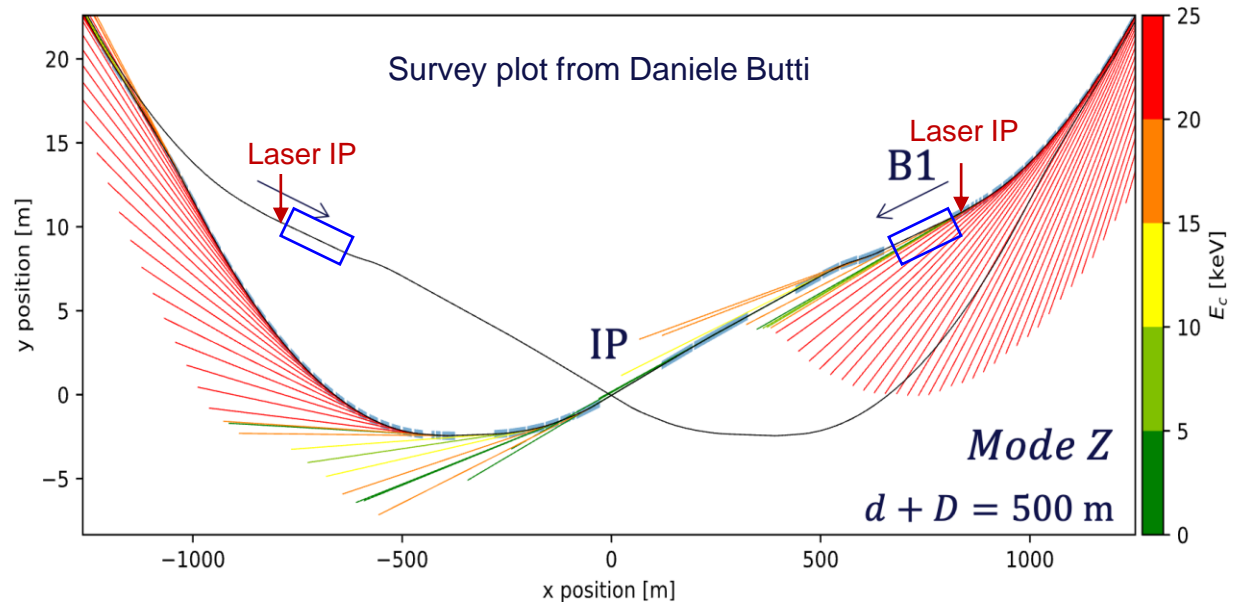**Full redundancy option : two polarimeters per beam (4 total)**
- Instrument location: both ends of LSS on each experimental IP **points G (or D or J)**
- Each exp. IP would need **dedicated laser hutches.**
- **Possible scenario, in the first alcove of the arc.**
- **Full System level redundancy**.

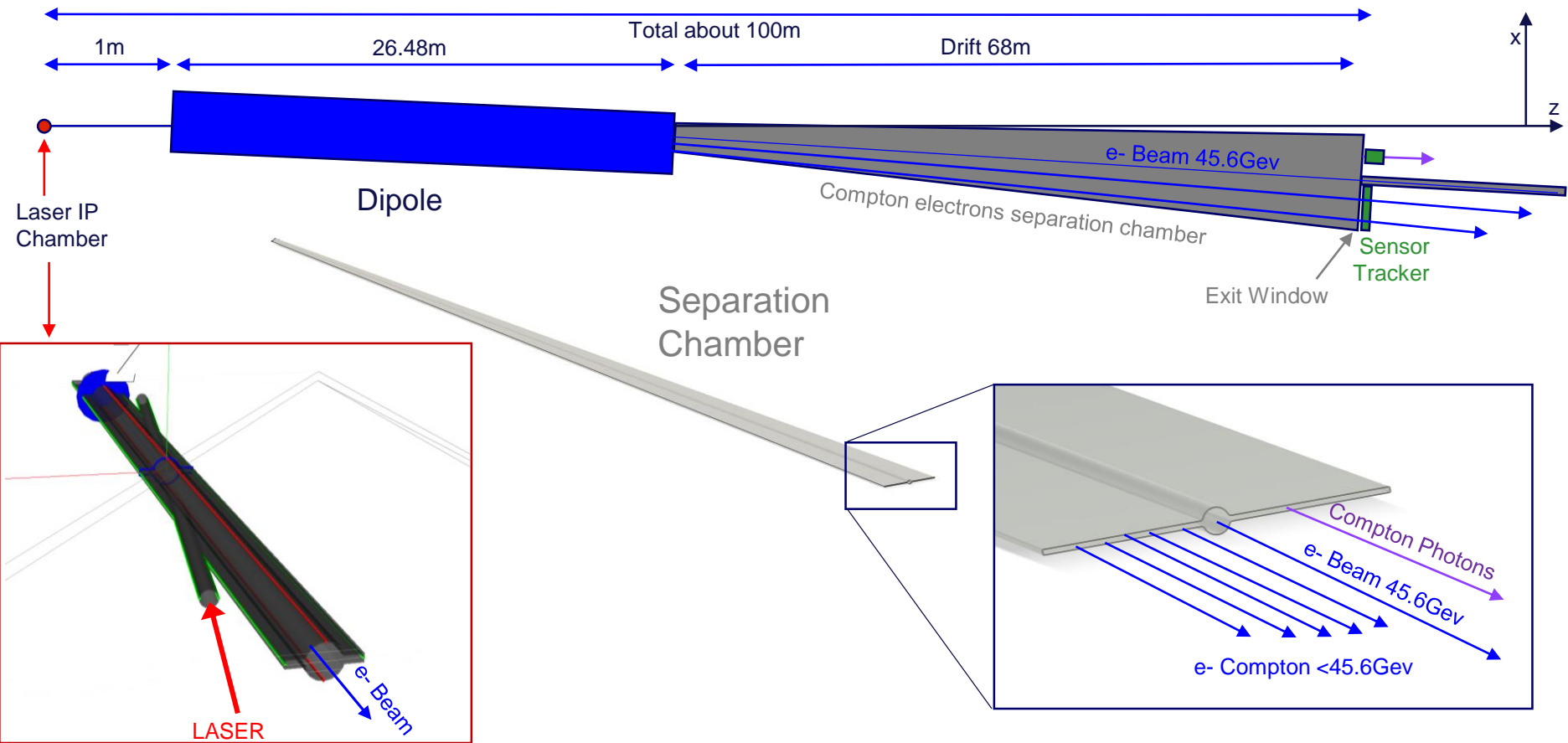KEY PLAN
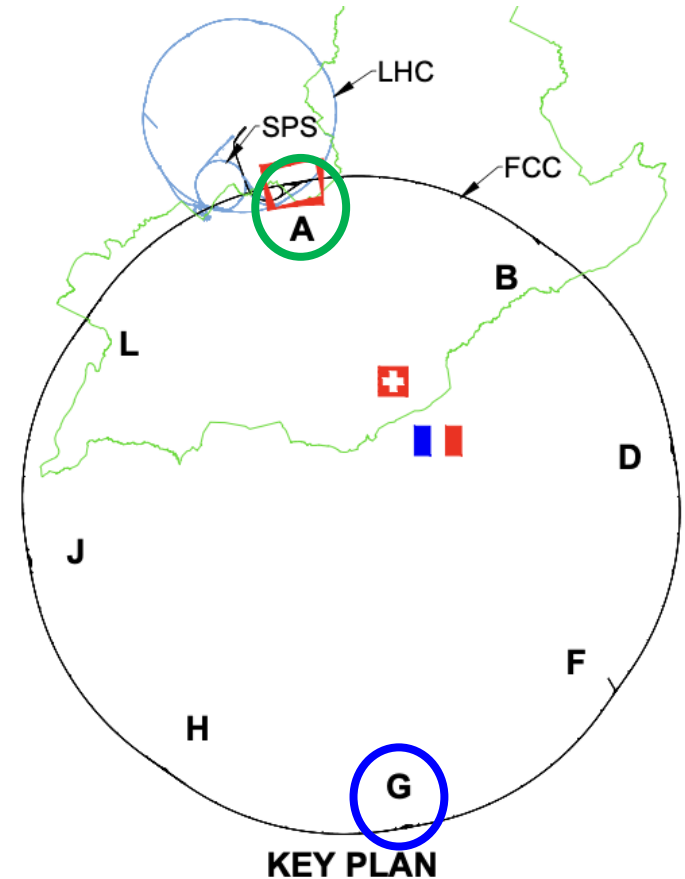
FCCee Polarimeters baseline in Experimental IP A

Polarimeter

BL1.4

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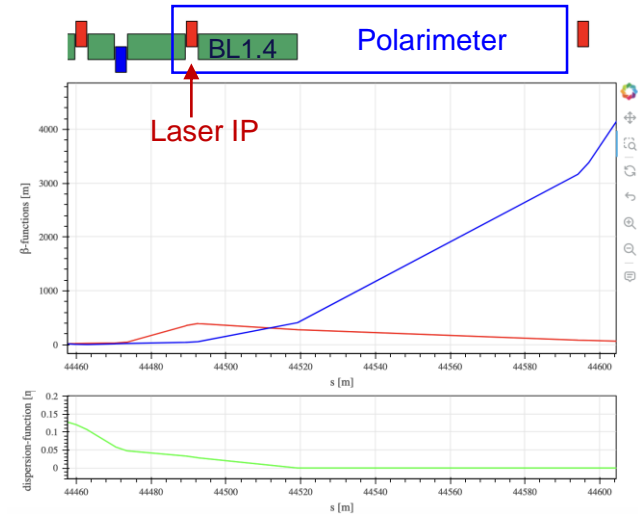
GHC optics is used. The polarimeter is not yet tested in the LCC optics.

Survey plot from Daniele Butti

Laser IP

Laser IP

B1

IP

Mode Z

$d + D = 500$ m

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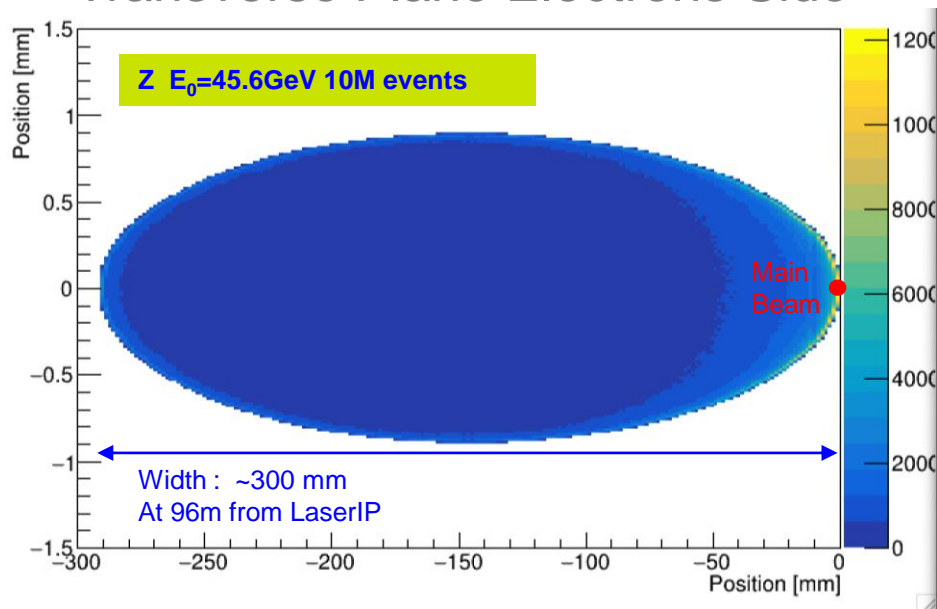
Polarimeter Instrument development

BDSIM Model description of Compton electrons separation

Total about 100m

1m   26.48m   Drift 68m

x

z

Dipole

Laser IP Chamber

Compton electrons separation chamber

e- Beam 45.6Gev

Sensor Tracker

Exit Window

Separation Chamber

LASER

e- Beam

Compton Photons

e- Beam 45.6Gev

e- Compton <45.6Gev

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

Transverse Plane Photons side

Z E_0=45.6GeV 10M events

Main Beam

Width : ~300 mm
At 96m from LaserIP

Z E_0=45.6GeV 10M events

Beam Polarisation create an asymmetry in the pattern that we can fit.
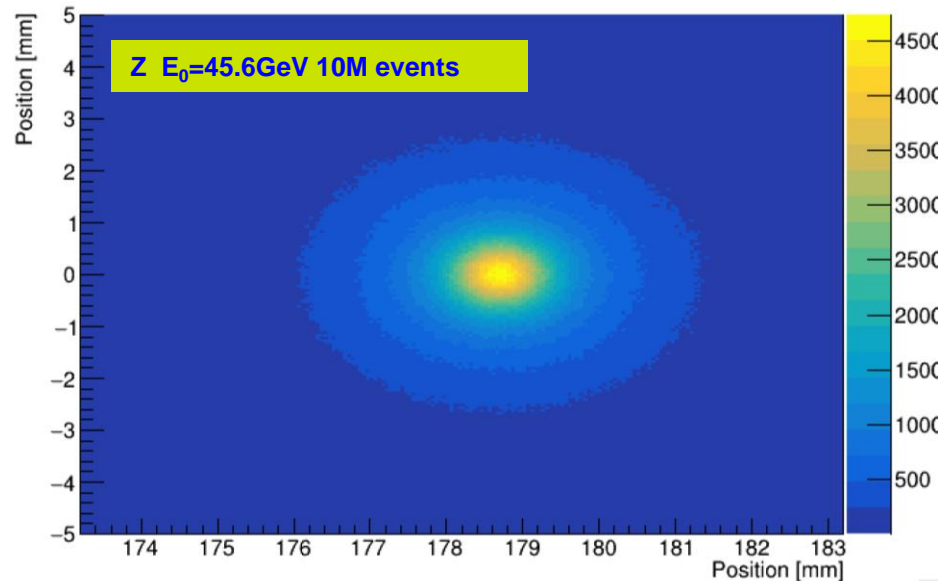
Compton photons pattern extracted at 178.6mm from beam axis
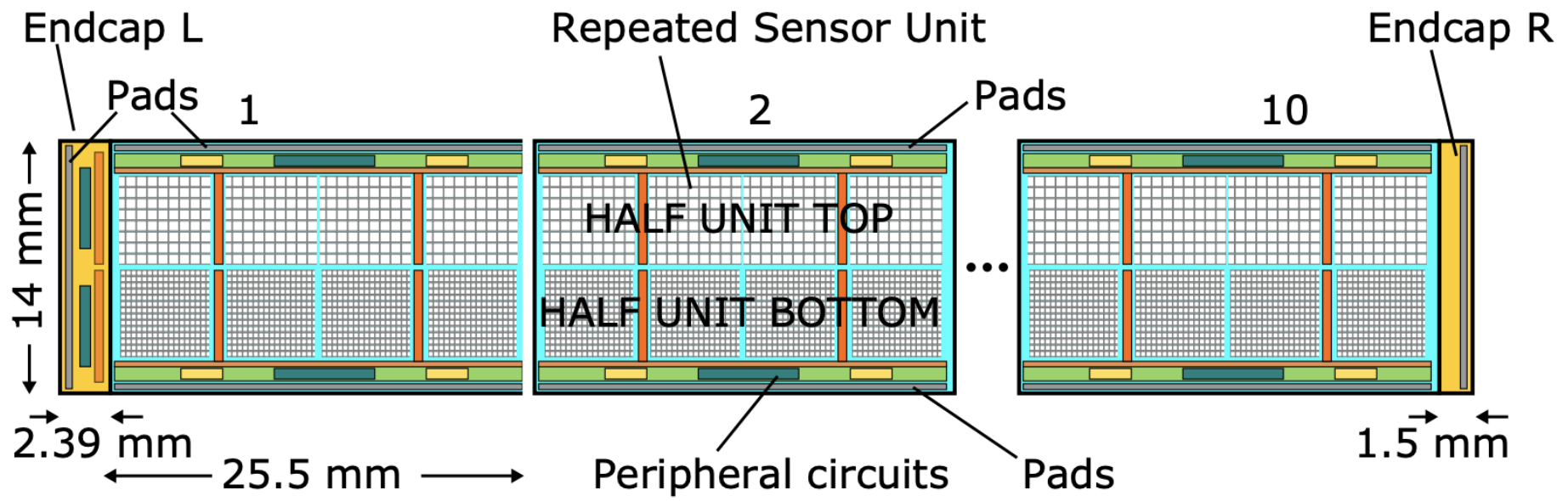
STEP 2 Simulation model in BDSIM
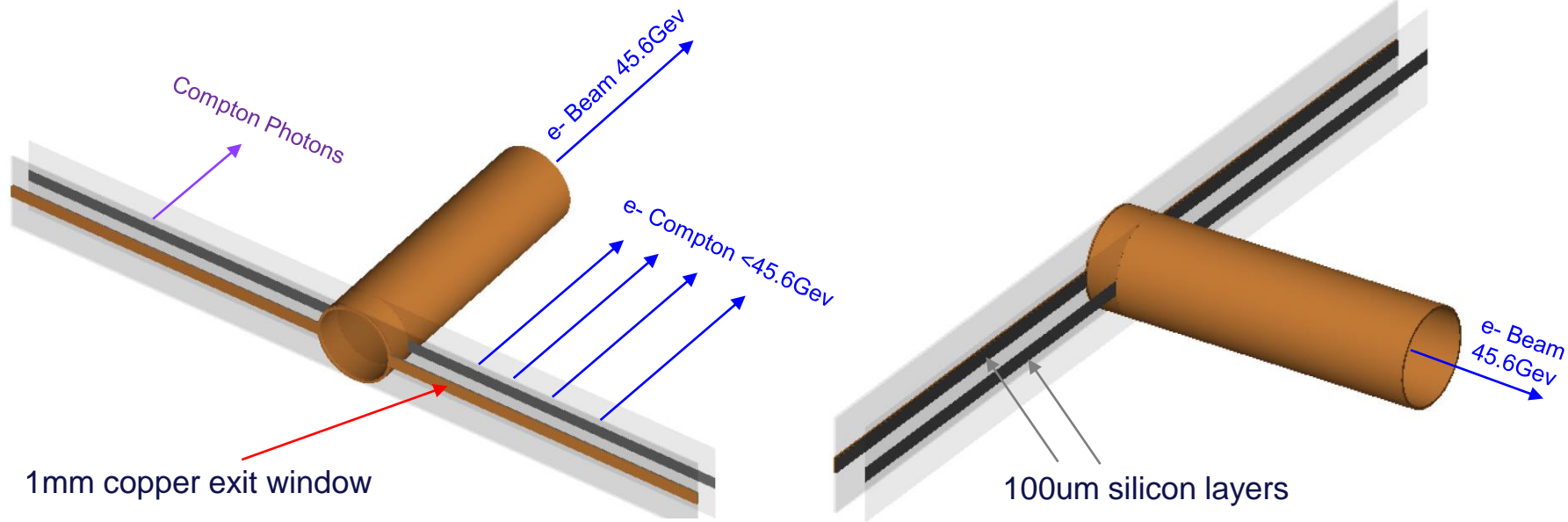
The compton products are transported through the copper exit window.
It is followed by two layers of 100um of silicon, in wich we study the energy deposition.

MOSS the Alice ITS3 Monolithic Active Pixel Sensor MAPS
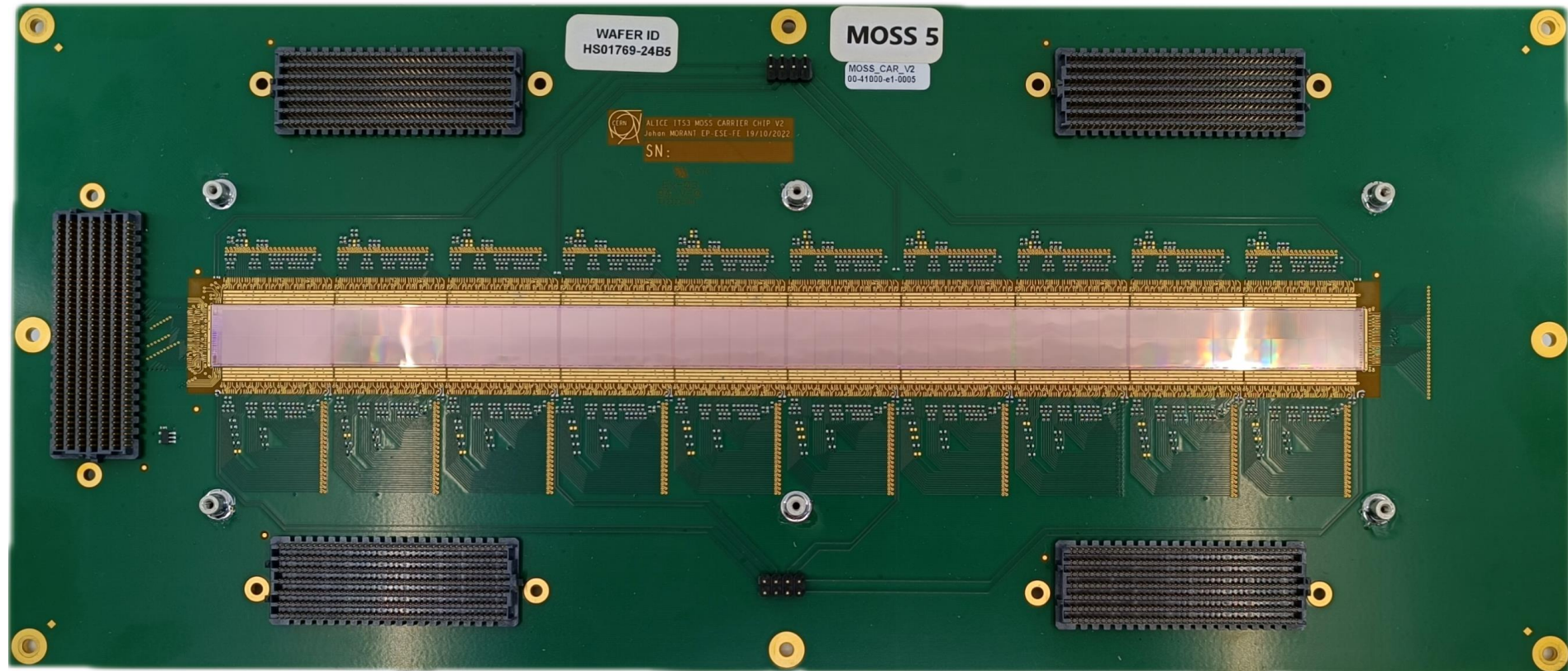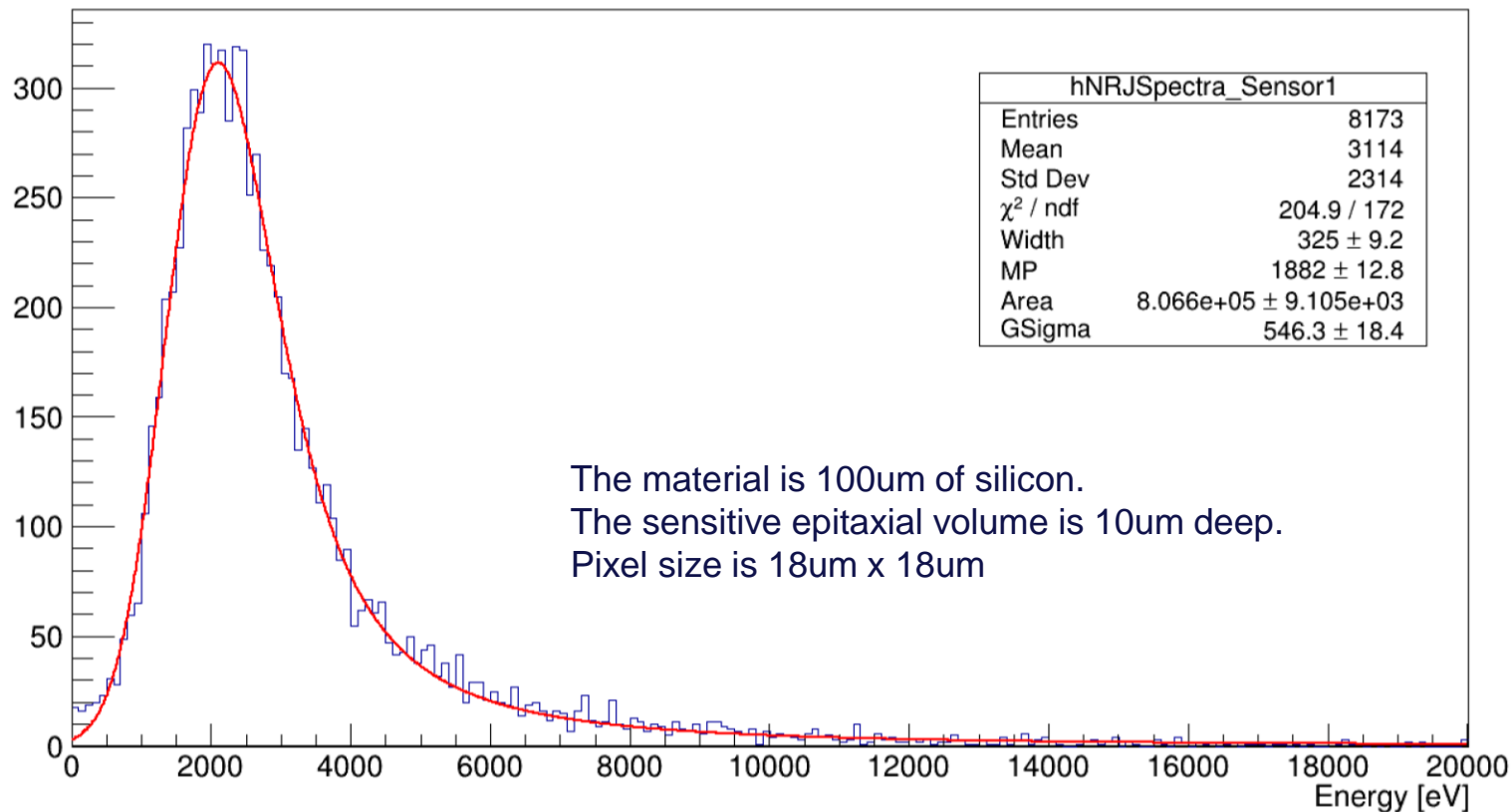
MOSS chip sensor configuration

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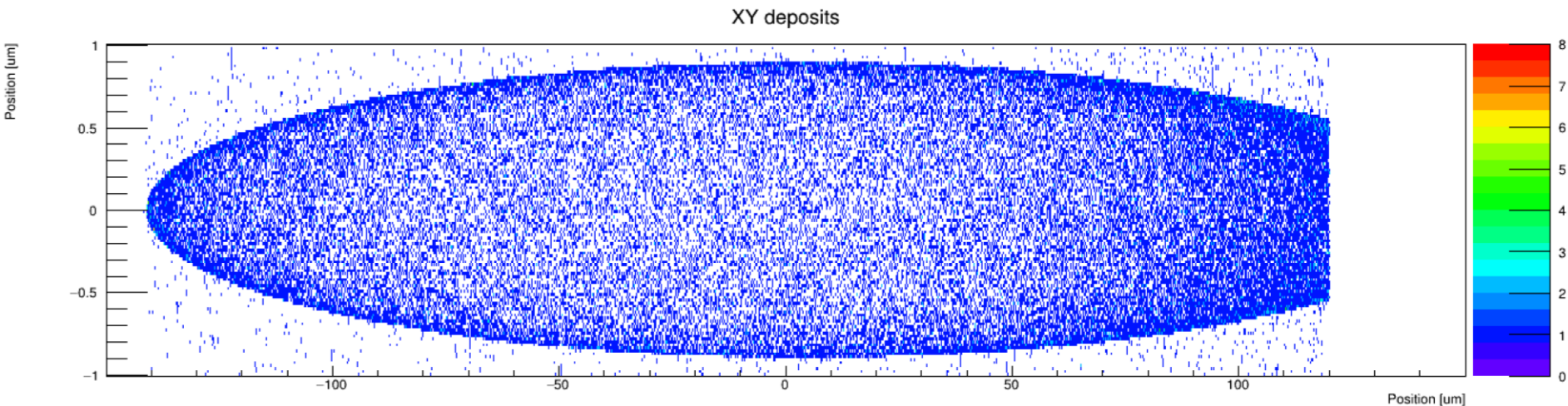
The sensitive epitaxial volume is 10um deep.
Pixel size is 18um x 18um
100k events simulated for this plots 8h of computing time on lxplus

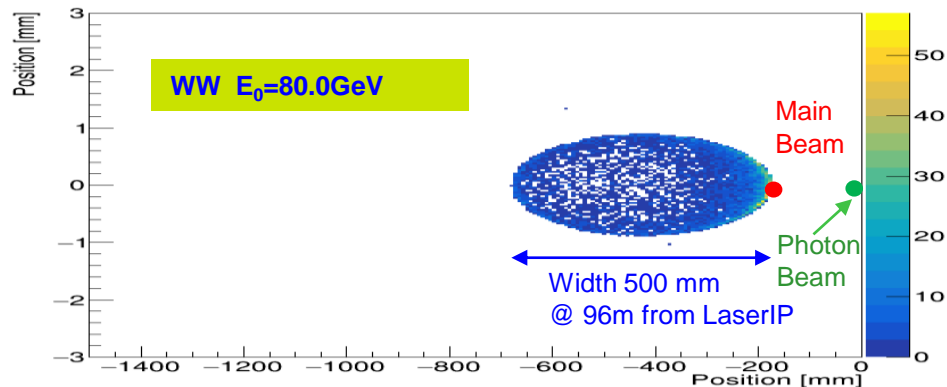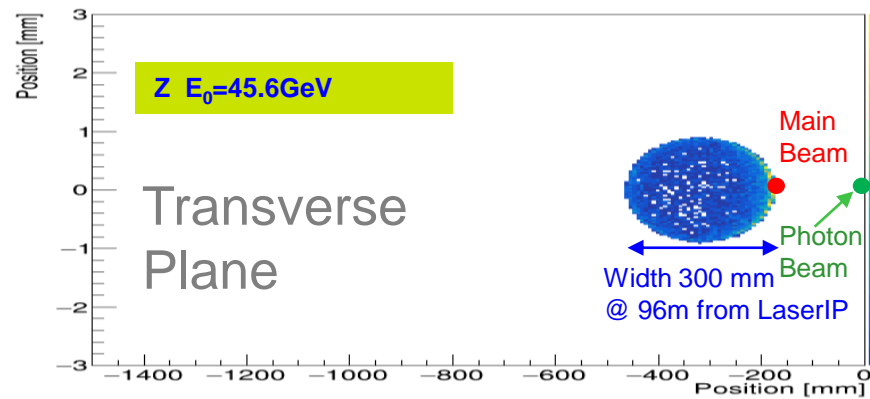# Compton pattern at Z mode energy scale
Recorded by a real silicon sensor (dead zones)

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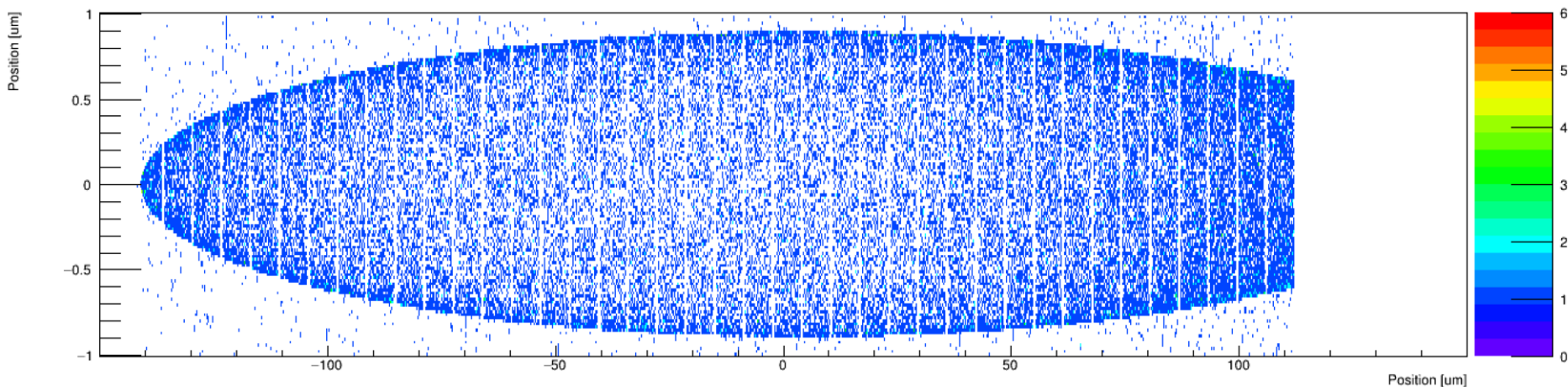
Including the dead zones from the MOSS sensor (40 matrixes of 320x320 pixel)
separated by dead zone of 34 pixels
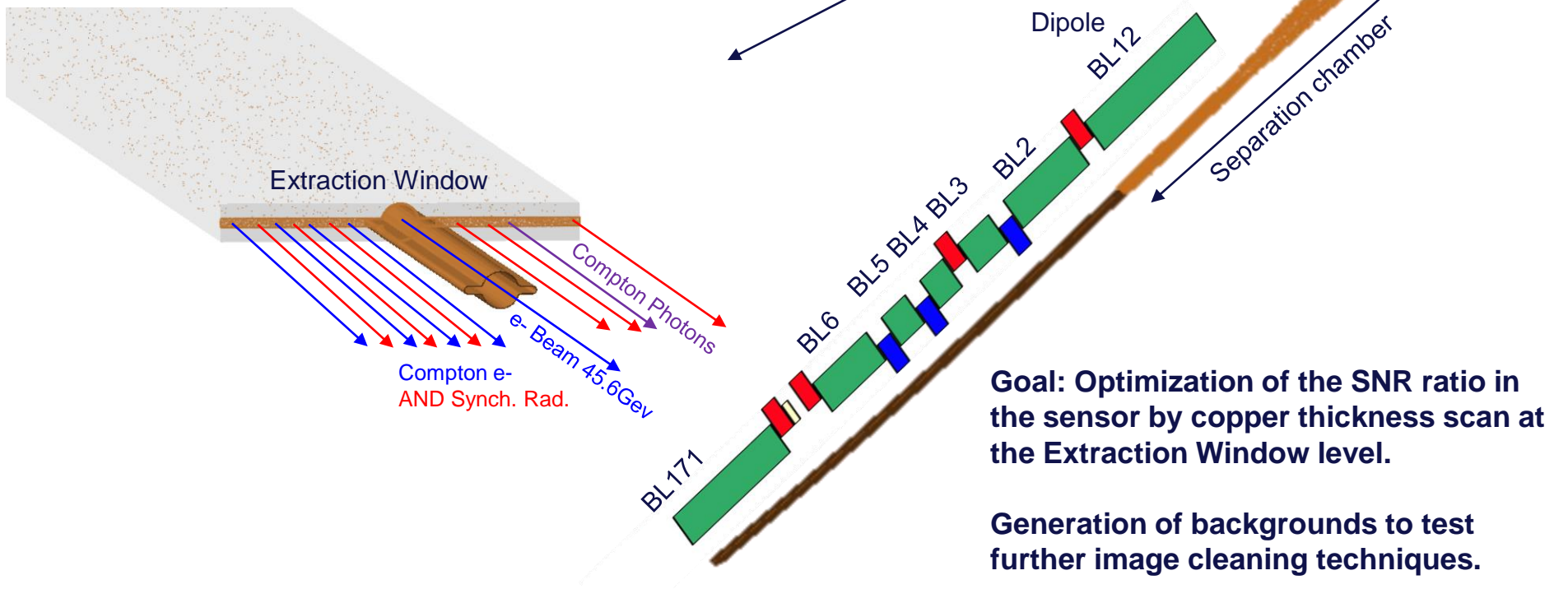100kevts simulated here.

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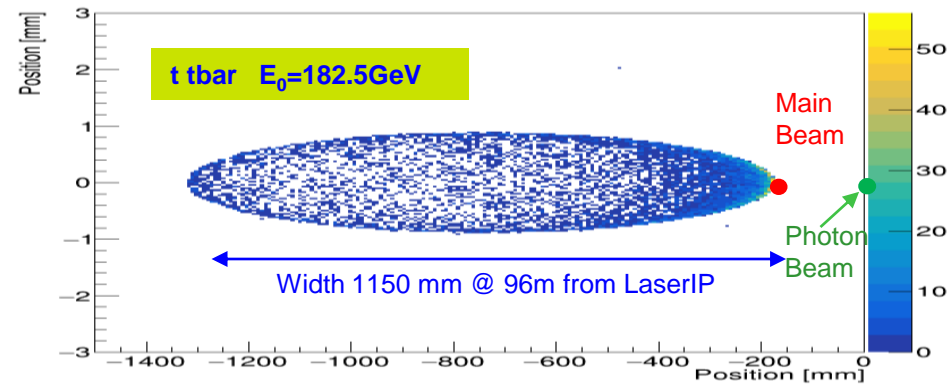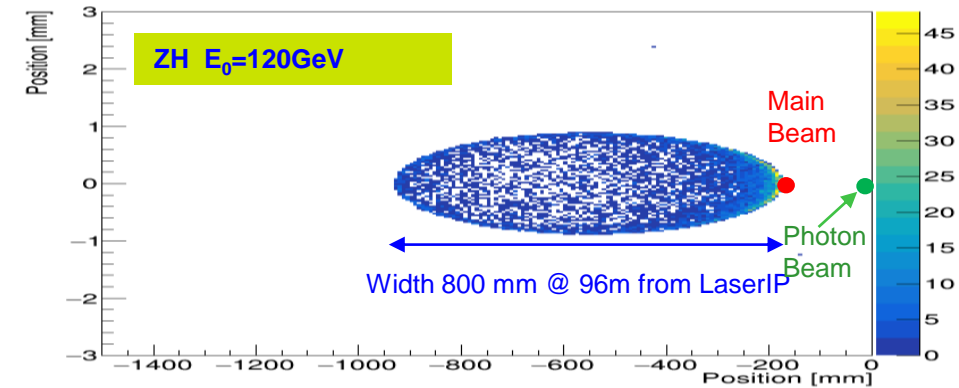
SR Background impacting the Polarimeter

# 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

Extraction Window

y

s

x

Polarimeter Dipole

BL 12

Separation chamber

Extraction Window

Compton Photons

e- Beam 45.6Gev

Compton e- AND Synch. Rad.

BL 6   BL 5 BL 4 BL 3   BL 2

BL 171

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.

Area of the sensor dedicated to Compton electrons

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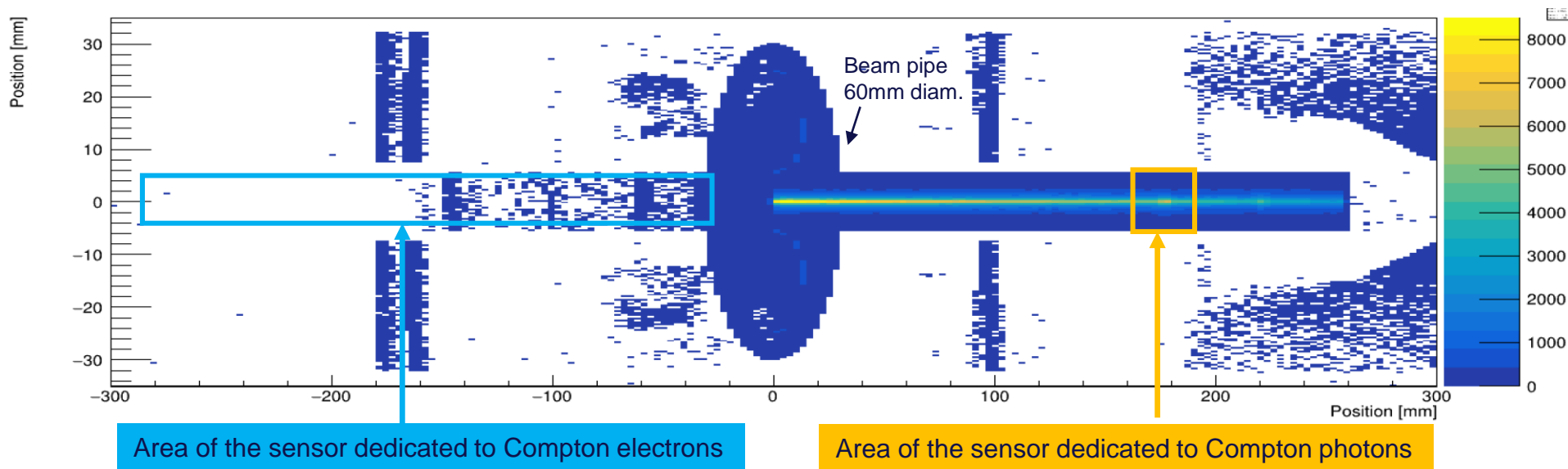
- SR Radiation generated by 6 dipoles upstream the laser IP, plus the main polarimeter spectrometer dipole.
- Internal photons reflection in beam pipe, with surface roughness parameter set to 100nm.
- SR Absorber from R.Kesevan not yet implemented in the simulation (could reduce a bit the photon dose).

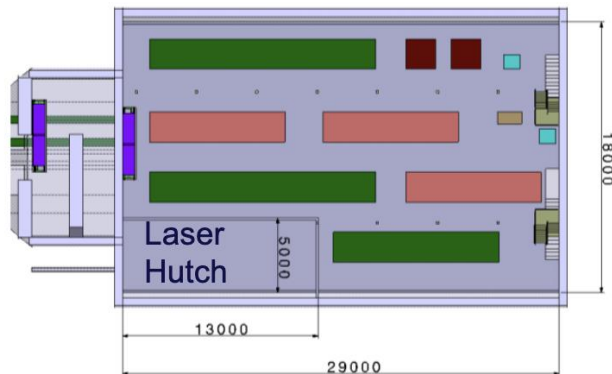# Polarimeter Space resevation
And Integration

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

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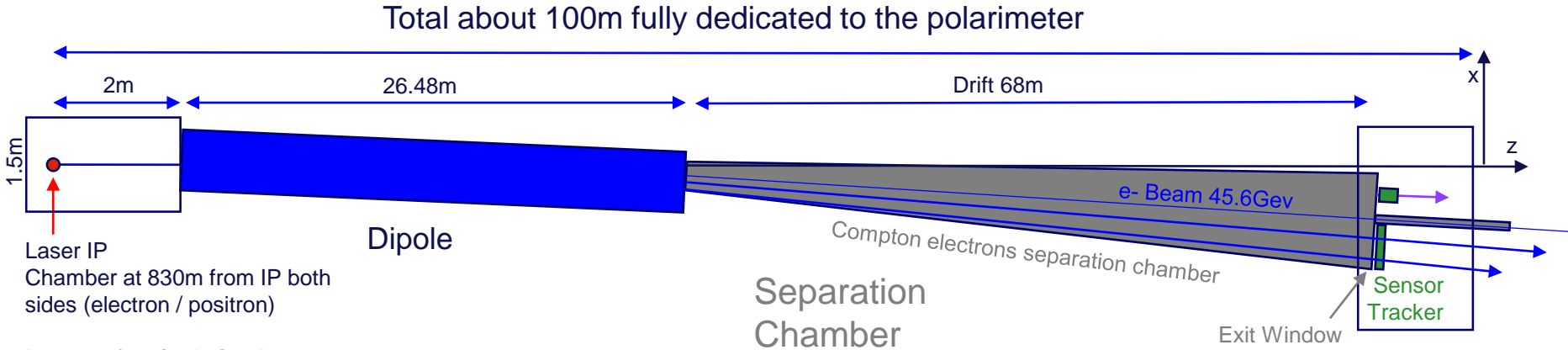

830m
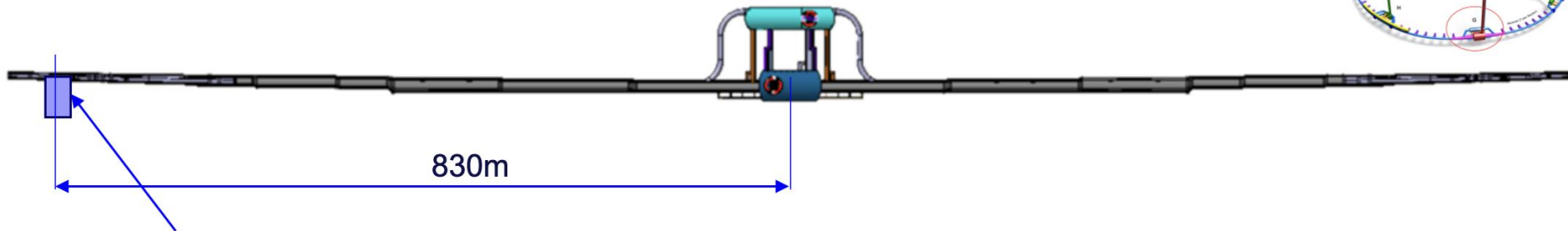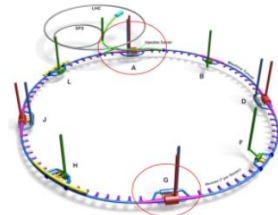
Big Alcove
   Machine level

- Each polarimeter need a dedicated laser Hutch
- Two requirements have been proposed (and refused) for the Feasibility Study
    1. 24h/7d Access tunnel to the laser hutch to ensure maximum availability
    2. Displacement of the first big alcove by 300m to be located at 830m from IP allowing the shorter laser transport distance possible to the laser IP.

For the preTDR phase these items will need to be considered again.

Space reservation volume on the collider tunnel

Total about 100m fully dedicated to the polarimeter

2m   26.48m   Drift 68m

1.5m

Dipole

e- Beam 45.6Gev

Compton electrons separation chamber

Separation
Chamber

x

z

Sensor
Tracker

Exit Window

Laser IP
Chamber at 830m from IP both
sides (electron / positron)

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

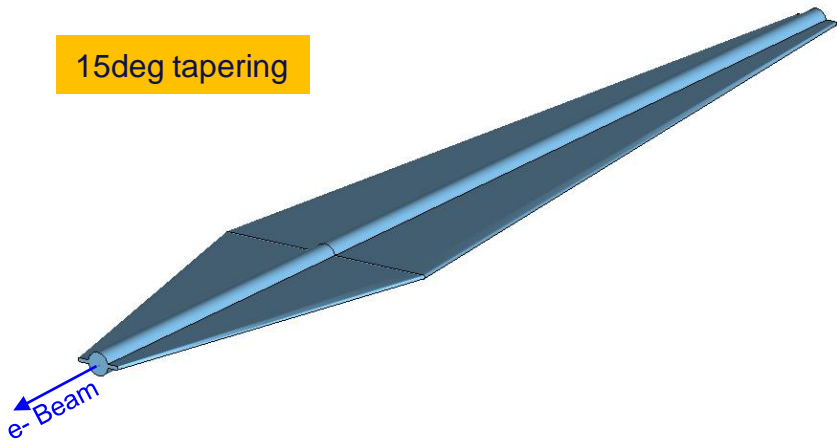**Box containing the instruments**
1.5m large 1.5m long (along beam)
1.8m height

Laser Transport pipes
Needed volume to be defined by STI
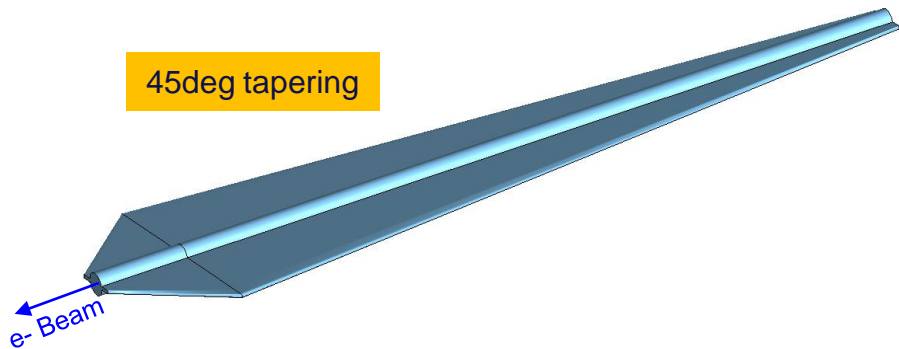
Impedance budget

First CST Models of the Polarimeter chamber tested.

Thanks to Mauro Migliorati, Dora Gibellieri, Carlo Zannini

15deg tapering
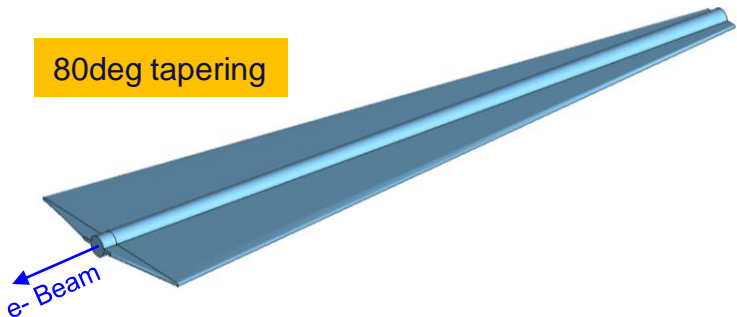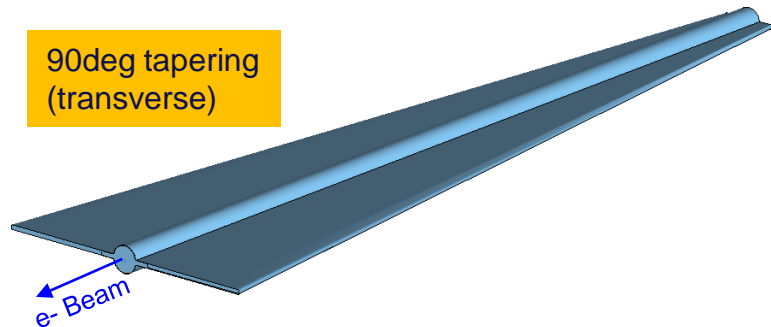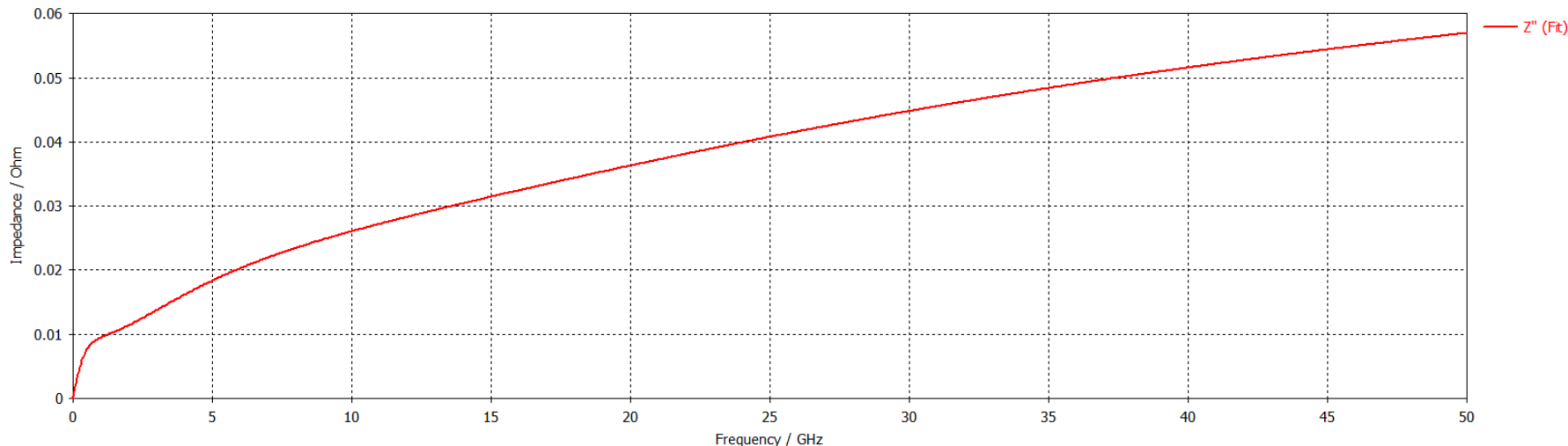
e- Beam

45deg tapering

e- Beam

80deg tapering

e- Beam

90deg tapering
(transverse)

e- Beam

First CST Models of the Polarimeter chamber tested.

Thanks to Mauro Migliorati, Dora Gibellieri, Carlo Zannini

Lossy metal surface impedance (Vacuum filling): Nth Order Model, N=3 (Fit)

- 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.

Other topics on Energy Calibration via RDP

- The design of the depolarizer kicker have been started by the RF goup Wolfgang Hofle and his student, Ivan Koop also participate to the depolarizer simulations.

- Yi Wu (EPFL) the student of Tatiana Pieloni is pursuing a study on Bmad about spin tracking in FCC and mean beam energy measurement through RDP (see [slides](#))

- The Compton Polarimeter has been presented recently to the BI FCC day.

Coming soon

Completion of the Feasibility Study report by end December.

Pre TDR definition of EPOL Work Packages and related manpower
- Spin tracking and energy calibration procedure studies (ABP, EPOL members)
- 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)
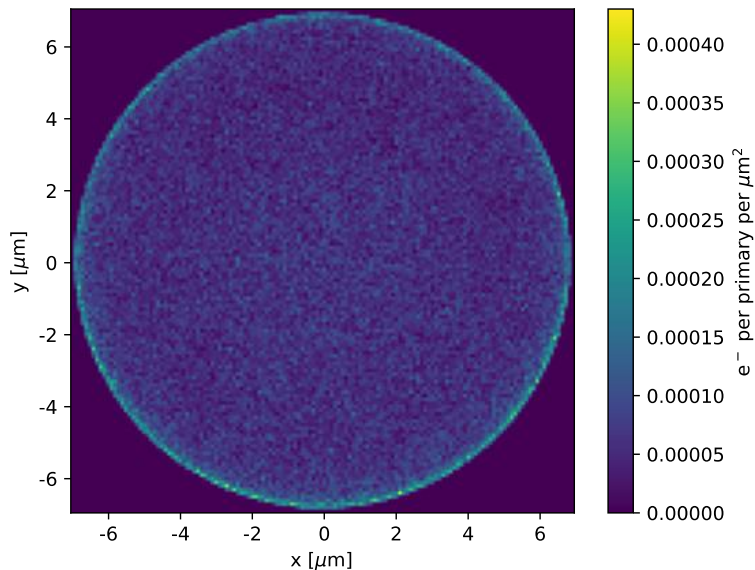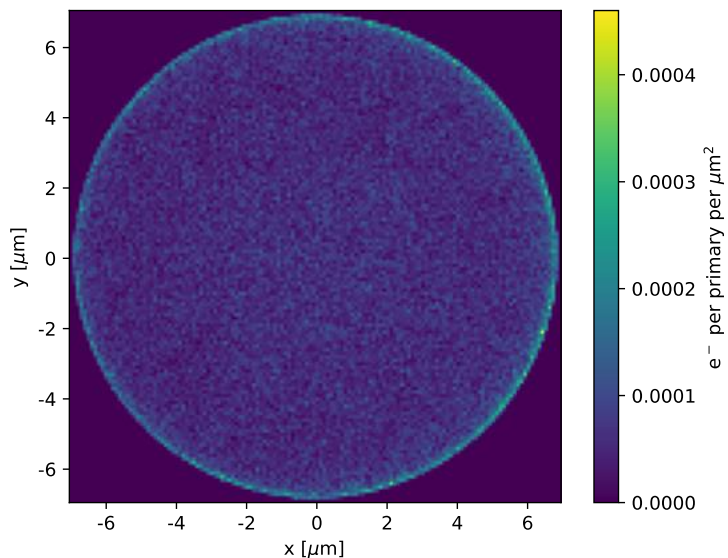- Depolarizing Kickers (RF)
- Impedance evaluation

Follow up on all kind of simulation studies.

Thank you
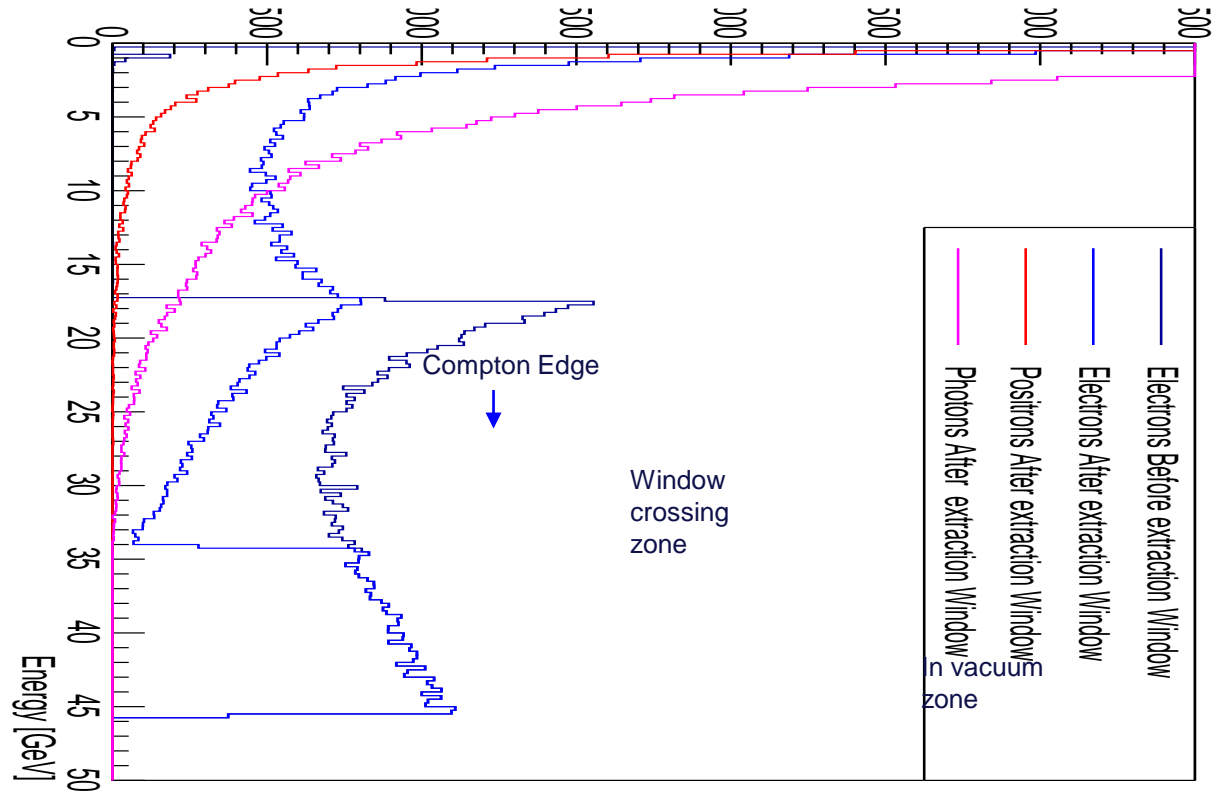# for your attention.

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.

Compton Edge

Window
crossing
zone

In vacuum
zone

Energy [GeV]

Photons After extraction Window
Positrons After extraction Window
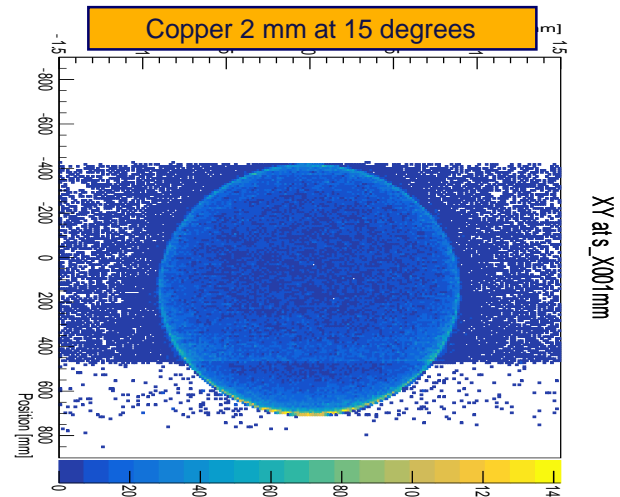Electrons After extraction Window
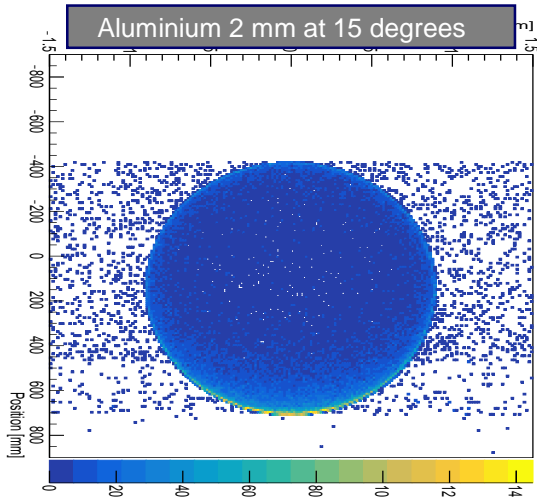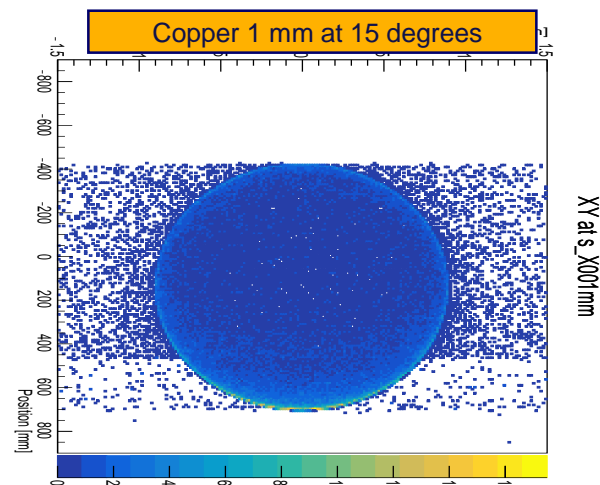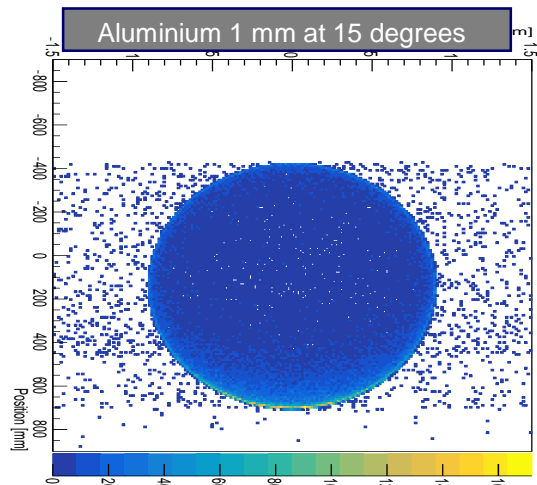Electrons Before extraction Window

Extraction window material/thickness

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

Aluminium and Copper
Two ticknesses 1-2 mm
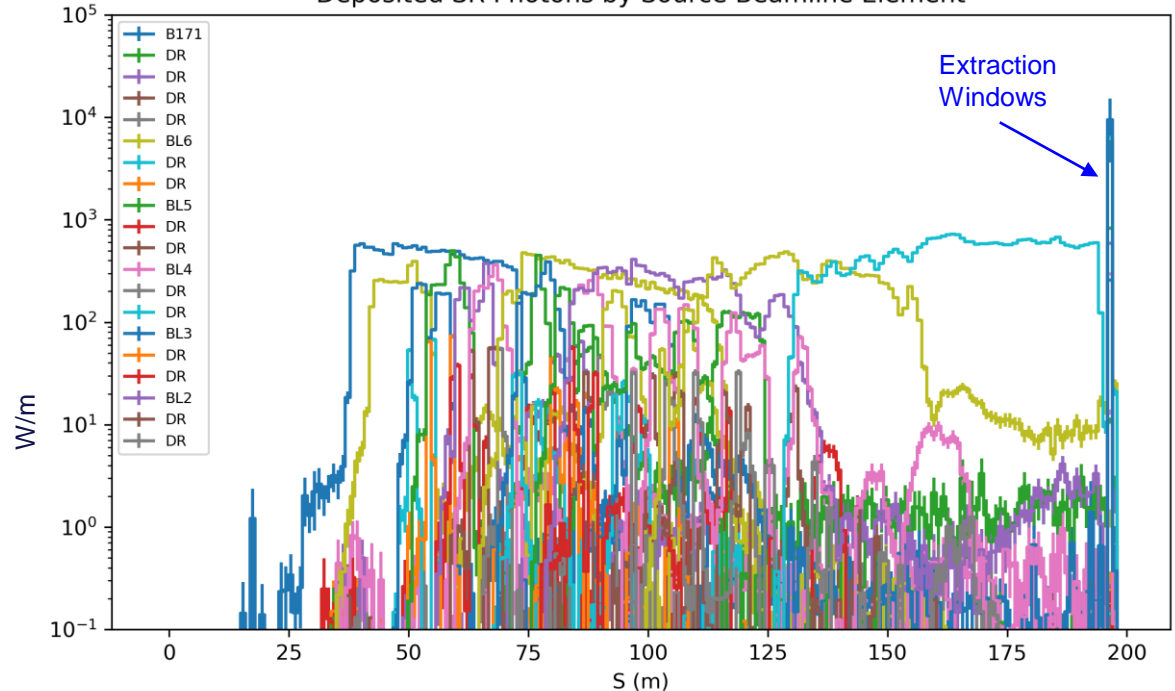
1 mm Aluminium is the most transparent solution.

Aluminium 1 mm at 15 degrees

Copper 1 mm at 15 degrees

Aluminium 2 mm at 15 degrees

Copper 2 mm at 15 degrees

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.

Deposited SR Photons by Source Beamline Element