STATUS AND WAY FORWARD FOR THE FCC POLARIMETER

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

FCCee physics program and key parameters

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

Machine Parameters M.Benedikt FCCweek24

Parameter	Z	WW	H (ZH)	ttbar
beam energy [GeV]	45.6	80	120	182.5
beam current [mA]	1270	137	26.7	4.9
number bunches/beam	11200	1780	440	60
bunch intensity [10^{11}]	2.14	1.45	1.15	1.55
SR energy loss / turn [GeV]	0.0394	0.374	1.89	10.4
total RF voltage 400/800 MHz [GV]	0.120/0	1.0/0	2.1/0	2.1/9.4
long. damping time [turns]	1158	215	64	18
horizontal beta* [m]	0.11	0.2	0.24	1.0
vertical beta* [mm]	0.7	1.0	1.0	1.6
horizontal geometric emittance [nm]	0.71	2.17	0.71	1.59
vertical geom. emittance [pm]	1.9	2.2	1.4	1.6
vertical rms IP spot size [nm]	36	47	40	51
beam-beam parameter ξ_x / ξ_y	0.002/0.0973	0.013/0.128	0.010/0.088	0.073/0.134
rms bunch length with SR / BS [mm]	5.6 / 15.5	3.5 / 5.4	3.4 / 4.7	1.8 / 2.2
luminosity per IP [10^{34} cm^{-2}s^{-1}]	140	20	≥5.0	1.25
total integrated luminosity / IP / year [ab^{-1}/yr]	17	2.4	0.6	0.15
beam lifetime rad Bhabha + BS [min]	15	12	12	11

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.

The spin precession tune of the accelerator is 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

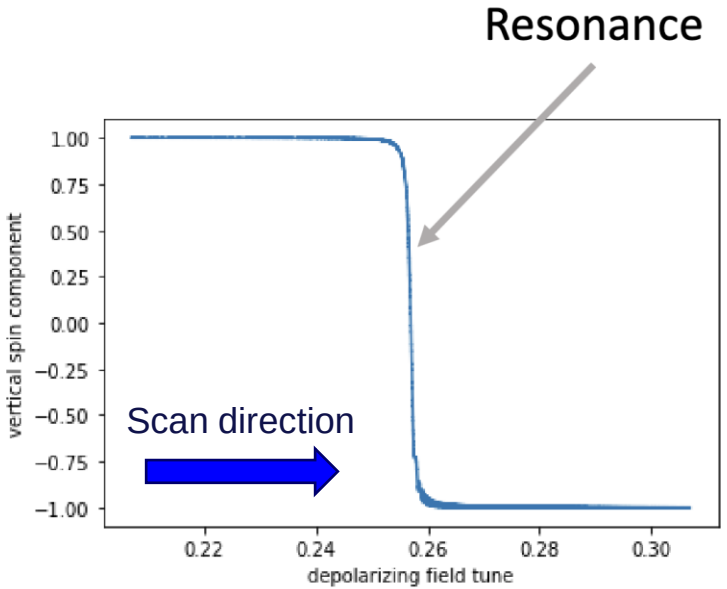
Gyromagnetic anomaly of the electron

$$\upsilon_0 = a\gamma$$

Lorentz factor (energy)

Method for the FCC energy calibration

- 100 pilot bunches are injected, and we wait for the Sokolov-Ternov effect to provide polarization buildup over time.
- 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**.

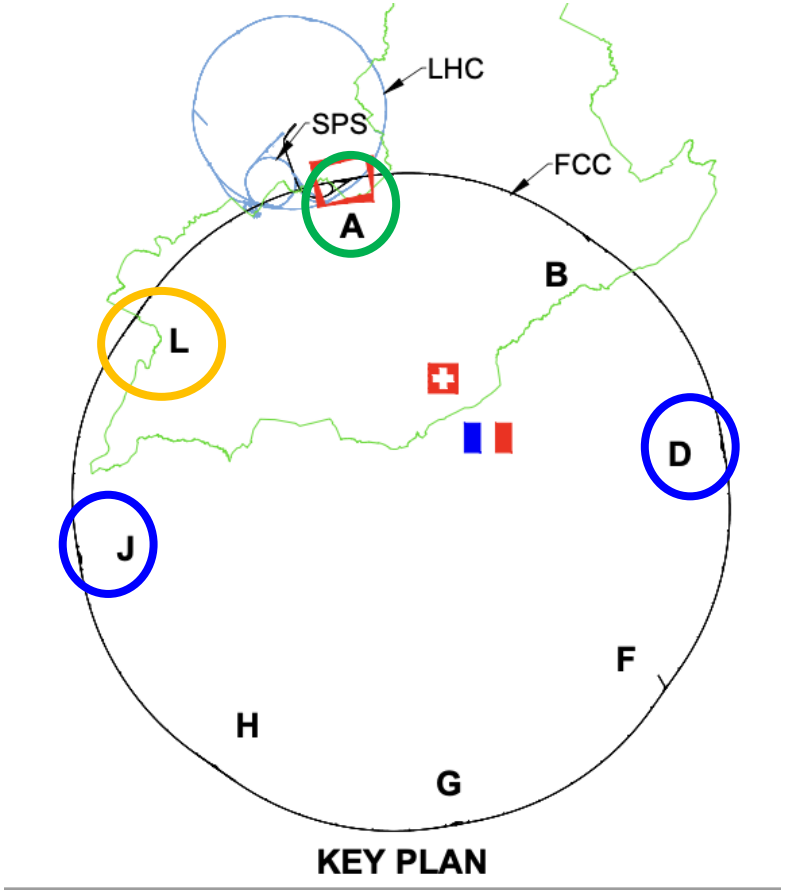


FCCee Polarimeters

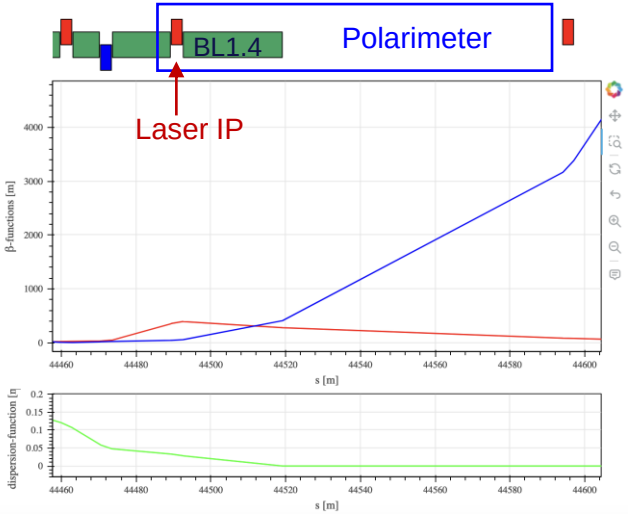
Base line: a single polarimeter per beam (2 total)
- Instrument location: both ends of **LSS** on experimental **IP A.**
- **Needs dedicated laser hutch and 24h/7d access tunnels.**
- **Duplicate the laser system for redundancy**

RF Option : a single polarimeter per beam (2 total)
- Instrument location in **point L booster RF**
- **Optics need to be changed to fit polarimeter requirements**
- **Difficult** to fit the Polarimeter chamber (transverse size 1-2m).
- Noise and **background from RF** could be a showstopper.
- Laser hutch in Klystron galleries.
- **Duplicate the laser system for redundancy**

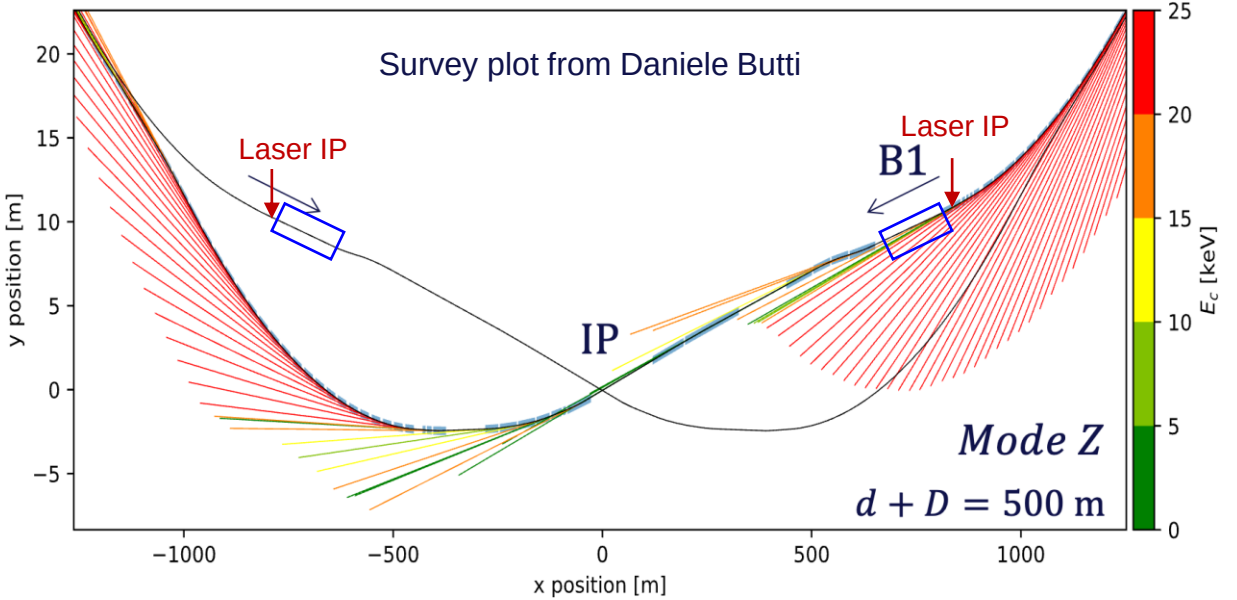
Full redundancy option : two polarimeters per beam (4 total)
- Instrument location: both ends of LSS on each experimental IP **points J (or D or G)**
- Each exp. IP would need **dedicated laser hutches.**
- **Possible scenario, in the first alcove of the arc.**
- **Full System level redundancy**, we could drop 24h/7d access.



FCCee Polarimeters baseline in Experimental IP A

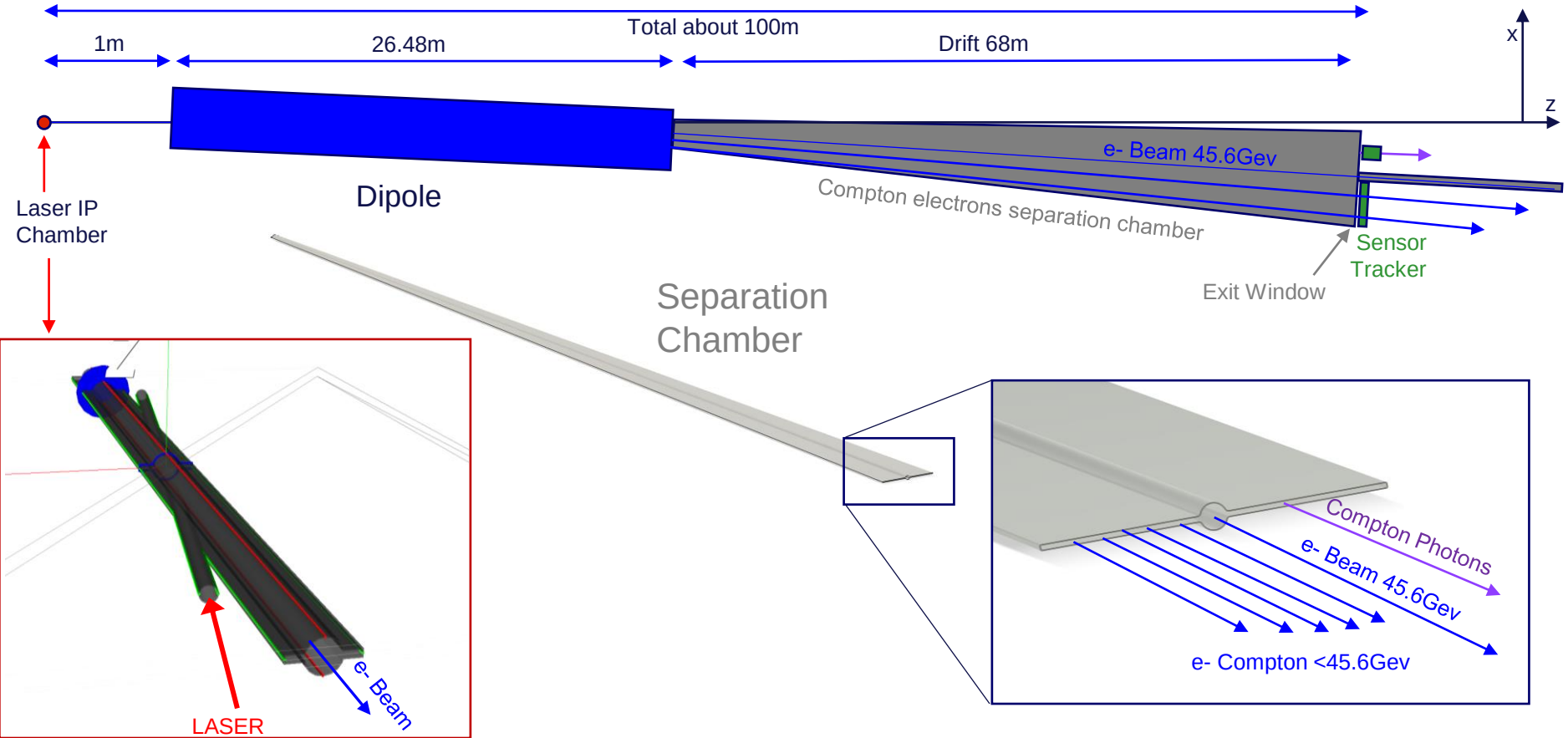


GHC optics is used. The polarimeter is not yet tested in the LCC optics.



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

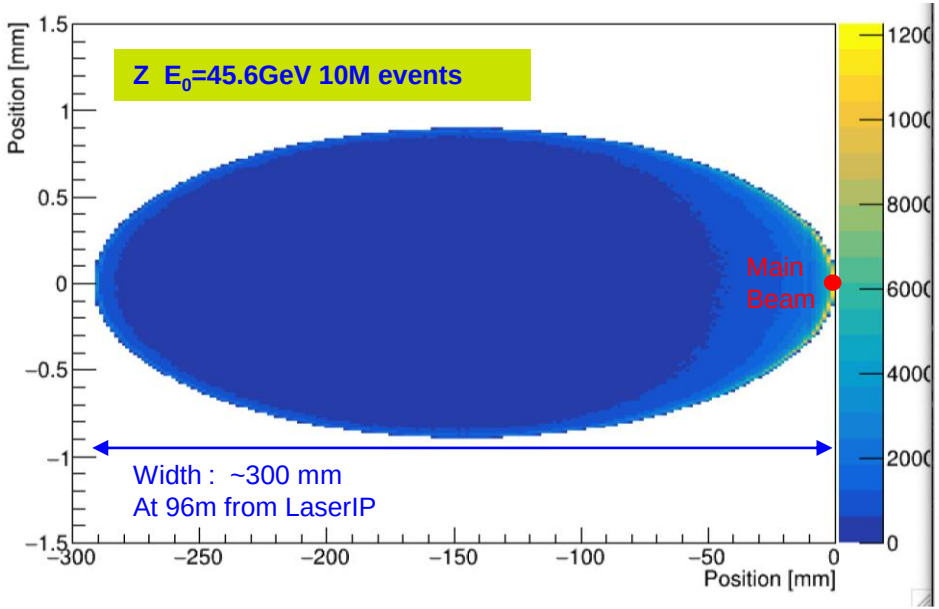
BDSIM Model description of Compton electrons separation



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

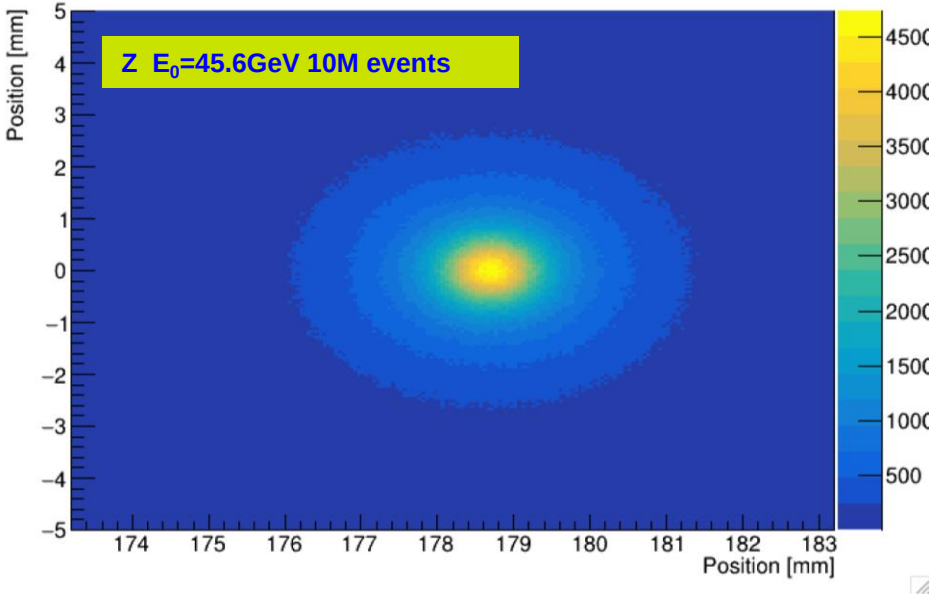
Source: BDSIM Compton simulation of Laser-Beam interaction

Transverse Plane Electrons Side



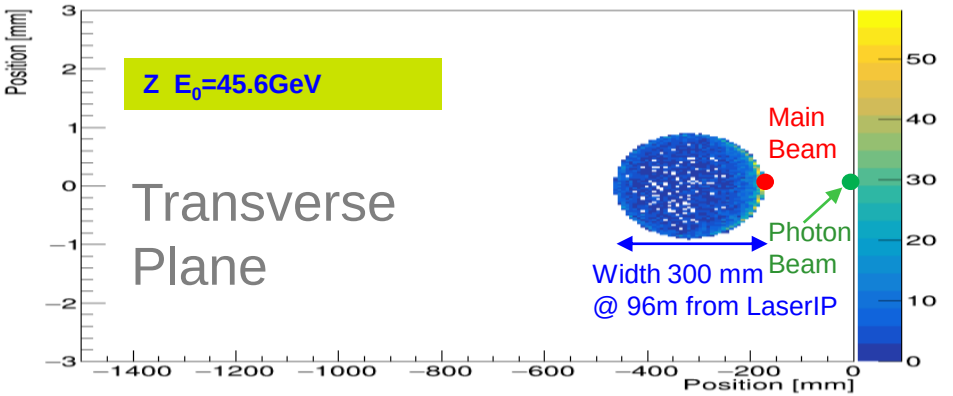
Beam Polarisation create an asymmetry in the pattern that we can fit.

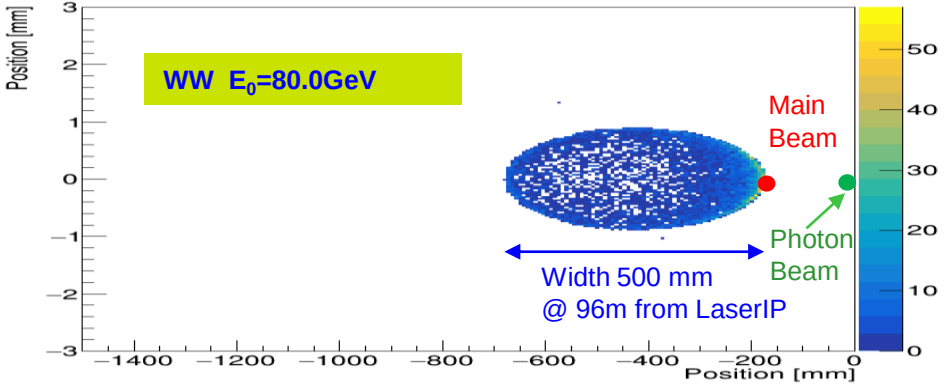
Transverse Plane Photons side

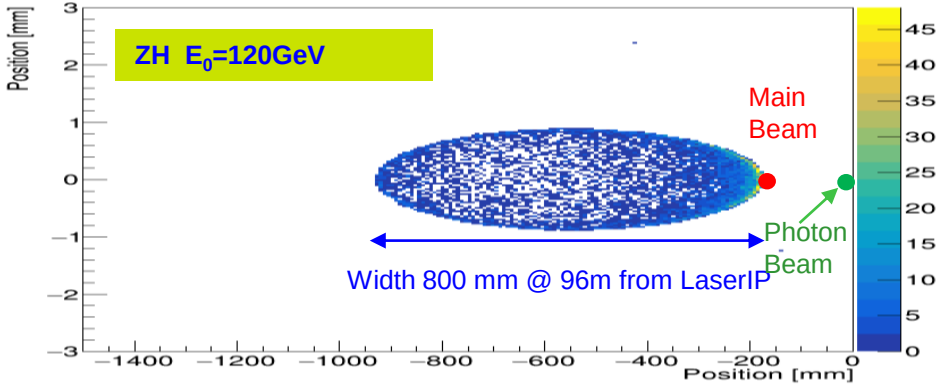


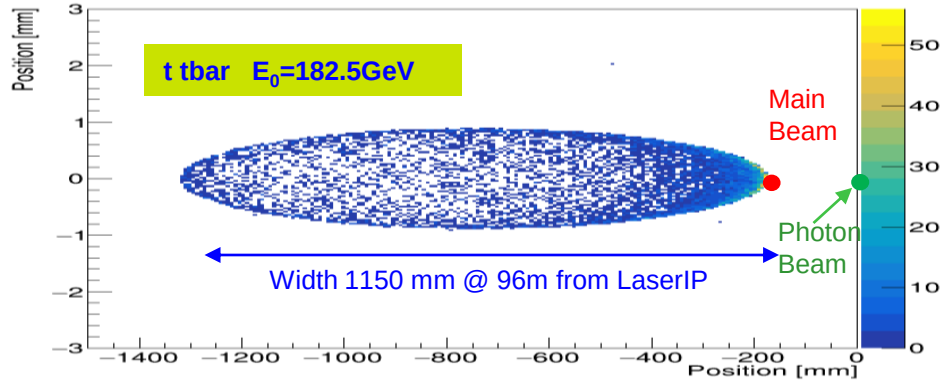
Compton photons pattern extracted at 178.6mm from beam axis

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









Polarimeter availability

- **Baseline plan**, was a single polarimeter in experimental point A for each beam, with full time laser room 24h/7d access tunnels.
- **Reviewed plan** due to budget limitations: No 24h/7d access tunnels in the Feasibility Report, overcoming redundancy by duplicating the full polarimeter system in two experimental IPs.
- Yet very difficult to infer real availability of the instrument with such recent cuts in the design. The aim is to provide the RDP energy calibration 70-90% of the physics running periods.

Civil engineering status

- Bi-weekly Technical Integration meeting and Civil engineering meetings for the follow up.
- Most critical point the laser hutch integration and the potential access tunnel to it.
- The polarimeter location is dictated by the collider optics (different between LCC/GHC)

Ongoing simulation activities

- Simulation and Fit with the ToyMC model from Nikolai (still useful as reference)
- Simulation of SR background in BDSIM (well started)
- Simulation of Compton in BDSIM, adding the polarization to it (on going with RHUL).
- CST impedance validation (green light for the polarimeter)

Future plans

- Detector modeling : New steps toward detector digitization have been started. Simulation of the energy deposition in a detector equivalent silicon layer by the Compton products.
- Simulation of others potential backgrounds: Bremsstrahlung, thermal photons.
- Mixing backgrounds and Compton data to evaluate signal to noise performances.
- Laser mockup system to develop the fully remote laser system (STI).
- Detector R&D will start once the optimal sensors would be identified from simulations.

Thank you for your attention.

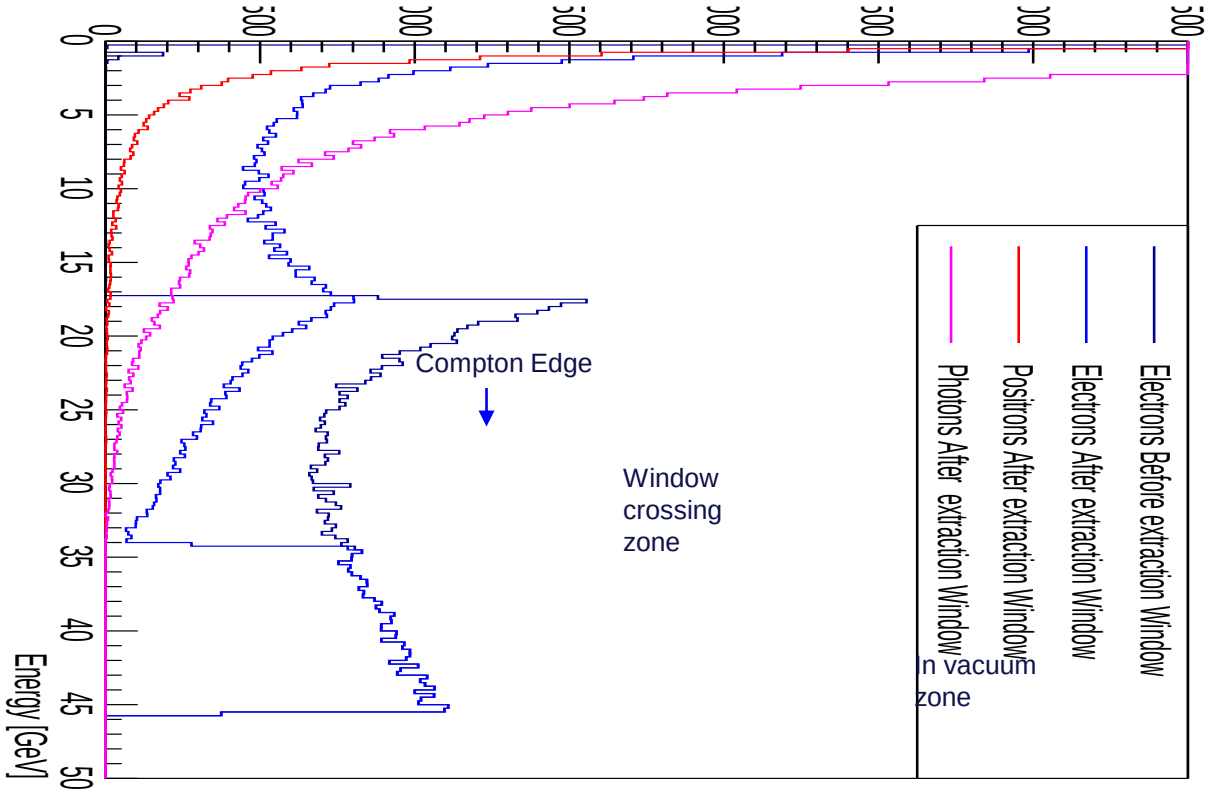
Potential Polarimeter workpackages structure

- Beam optics and energy calibration polarimeter specification needs
- Integration and Civil engineering
- Spectrometer magnet, and field quality
- Polarized Laser source design
- Laser transport
- Detectors hardware development at the extraction window
- Performances simulation and fit. Reconstruction
- Kicker development and spin resonance scan excitation scenario
- Wiggler for beam polarization speed-up
- Potential polarized beam at injection study
- Vacuum chambers design and Impedance studies
  - LIP (laser IP chamber)
  - Separation/Extraction chambers

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.

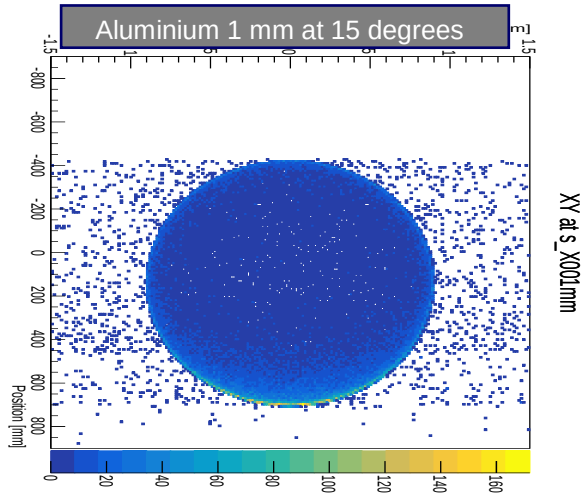


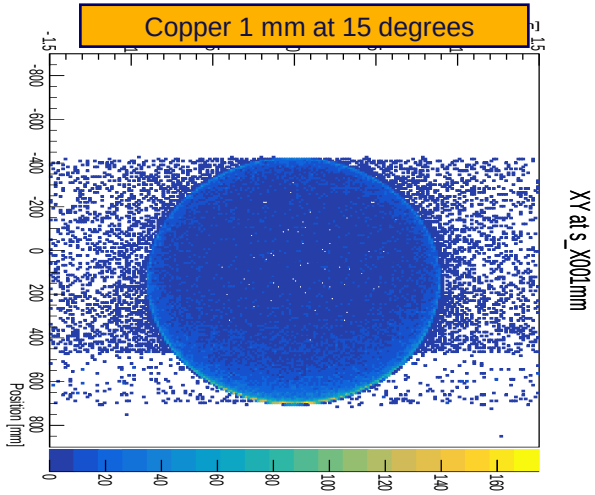
Extraction window material/thickness

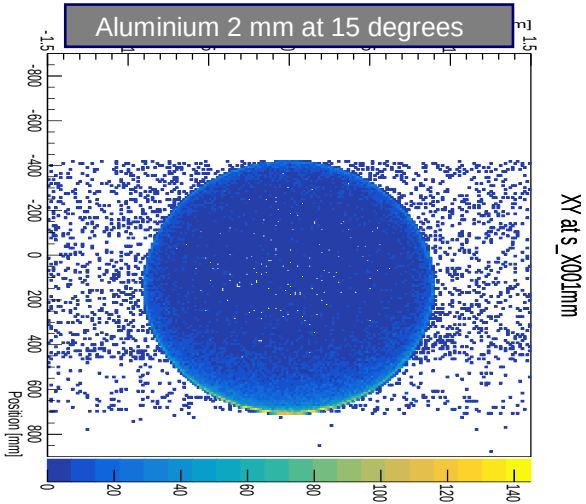
Study at Z pole sampling plane is 1mm after the extraction window.

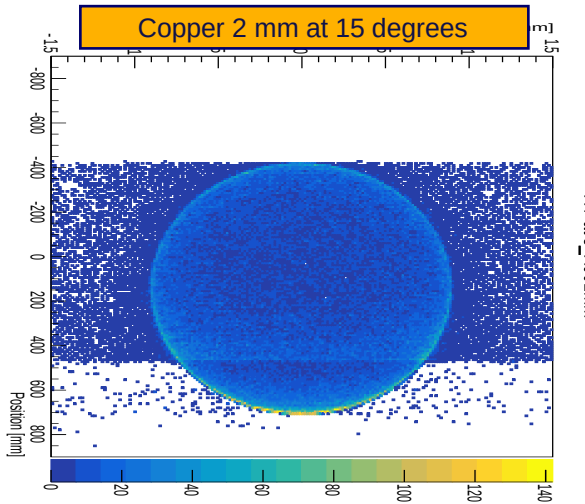
Aluminium and Copper
Two ticknesses 1-2 mm

1 mm Aluminium is the most transparent solution.



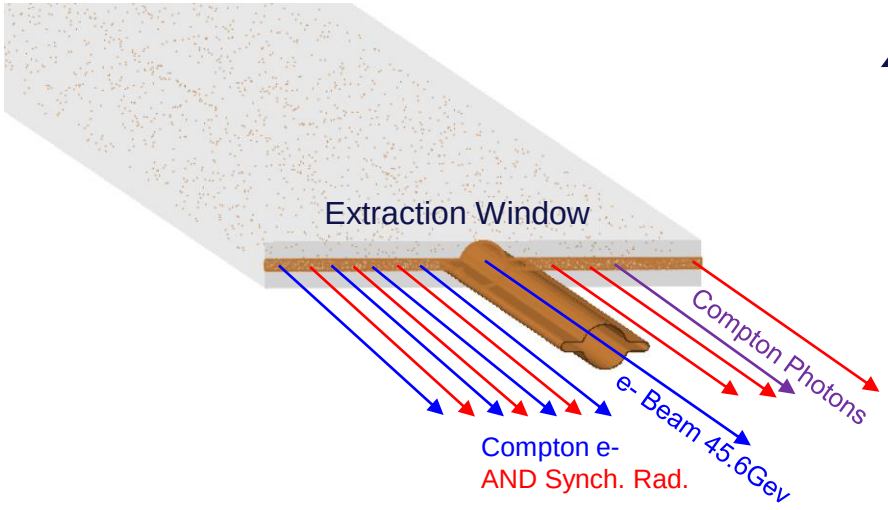


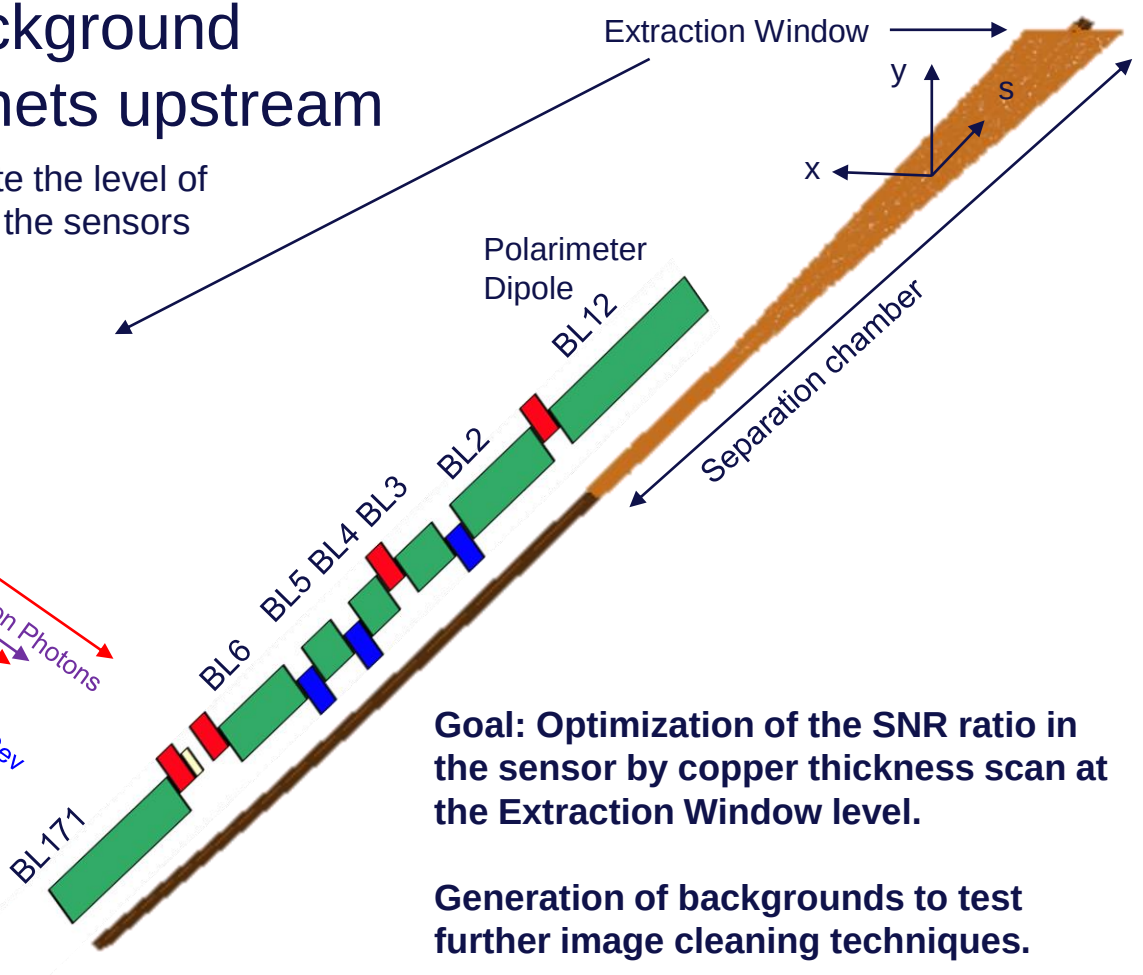




Synchrotron Radiation background BDSIM model with 6 magnets upstream

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

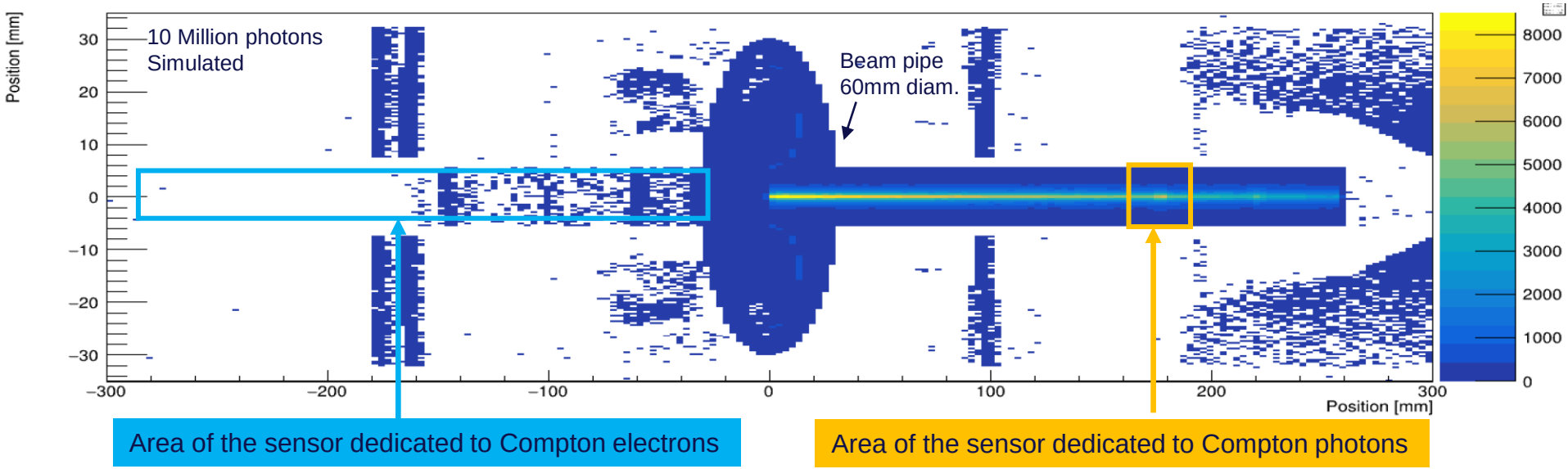




Goal: Optimization of the SNR ratio in the sensor by copper thickness scan at the Extraction Window level.

Generation of backgrounds to test further image cleaning techniques.

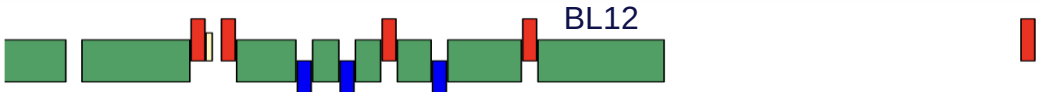
SR background reaching the exit window internal face.



- 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).

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

BEAMLINE FOR THE STUDY

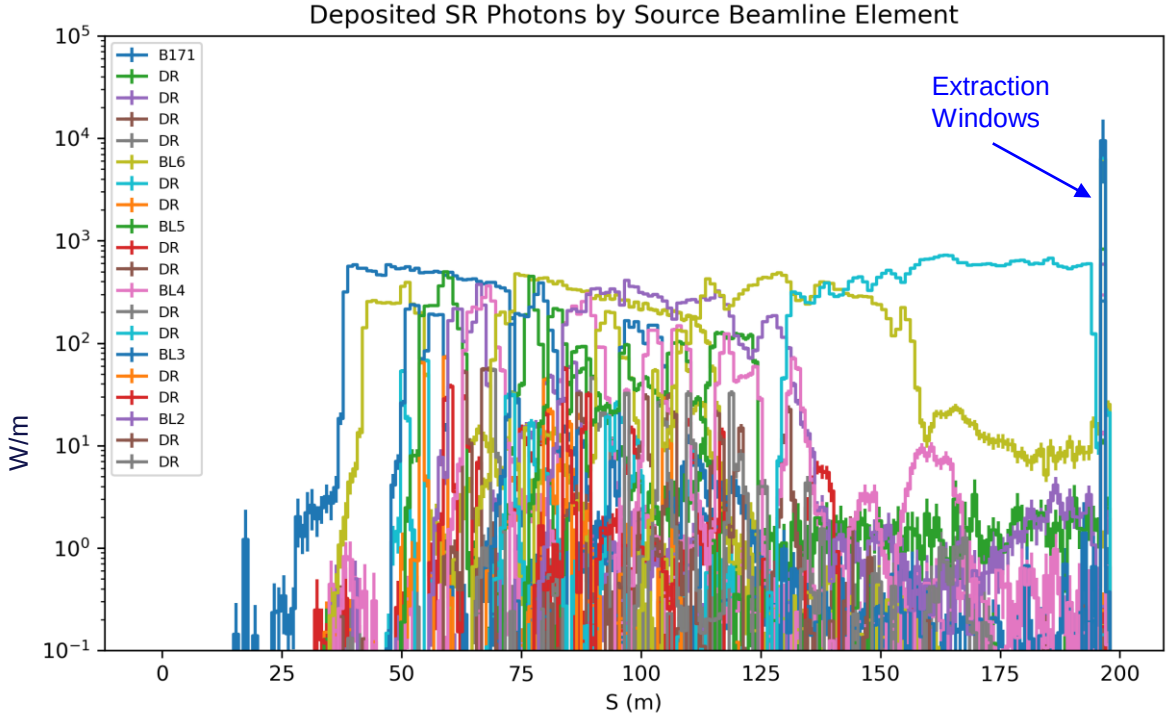


Thanks to the toolkit of Kevin Andre, I was able to simulate SR generation at the polarimeter location including reflections in the beam pipe from upstream magnets.

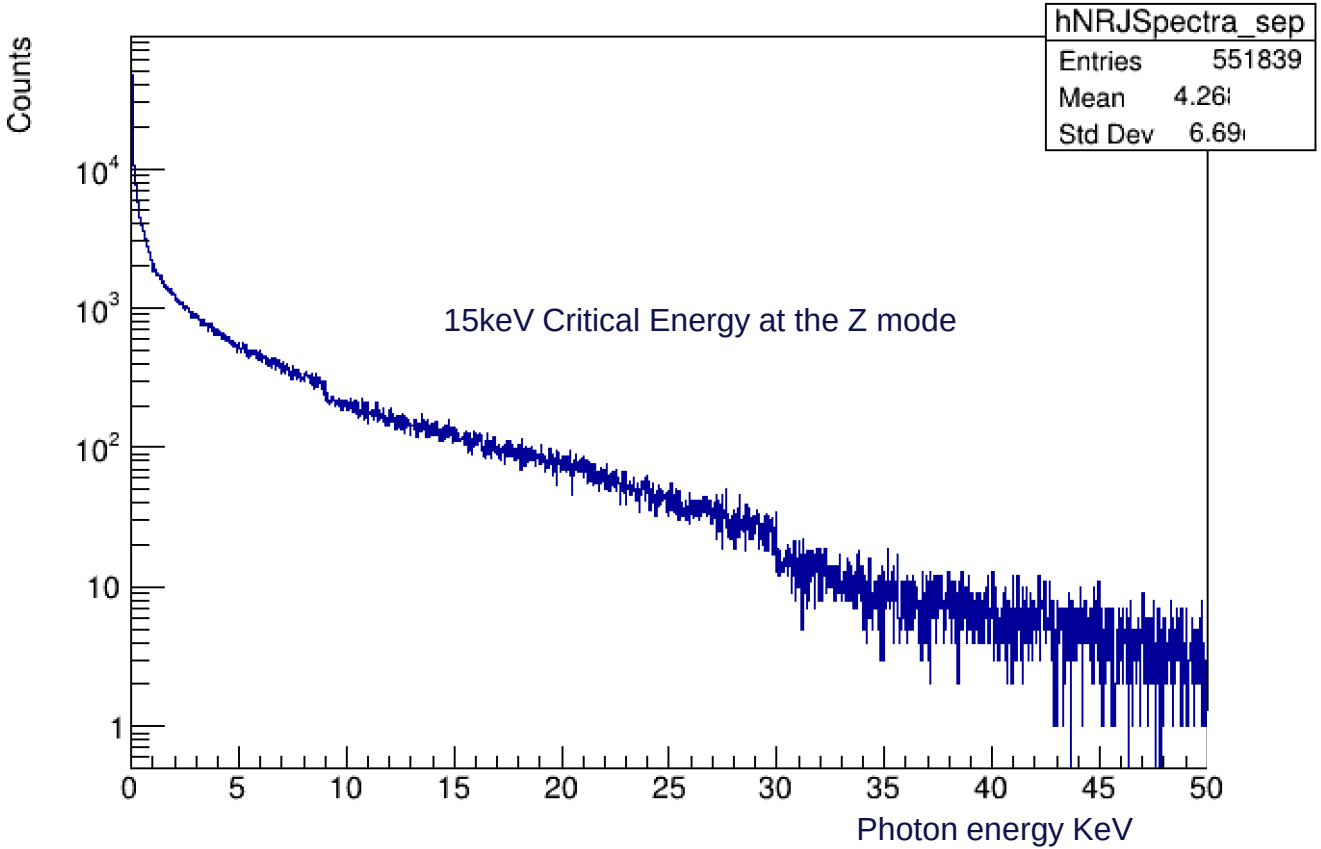
In average a power dissipation of 1kW/m is expected.

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

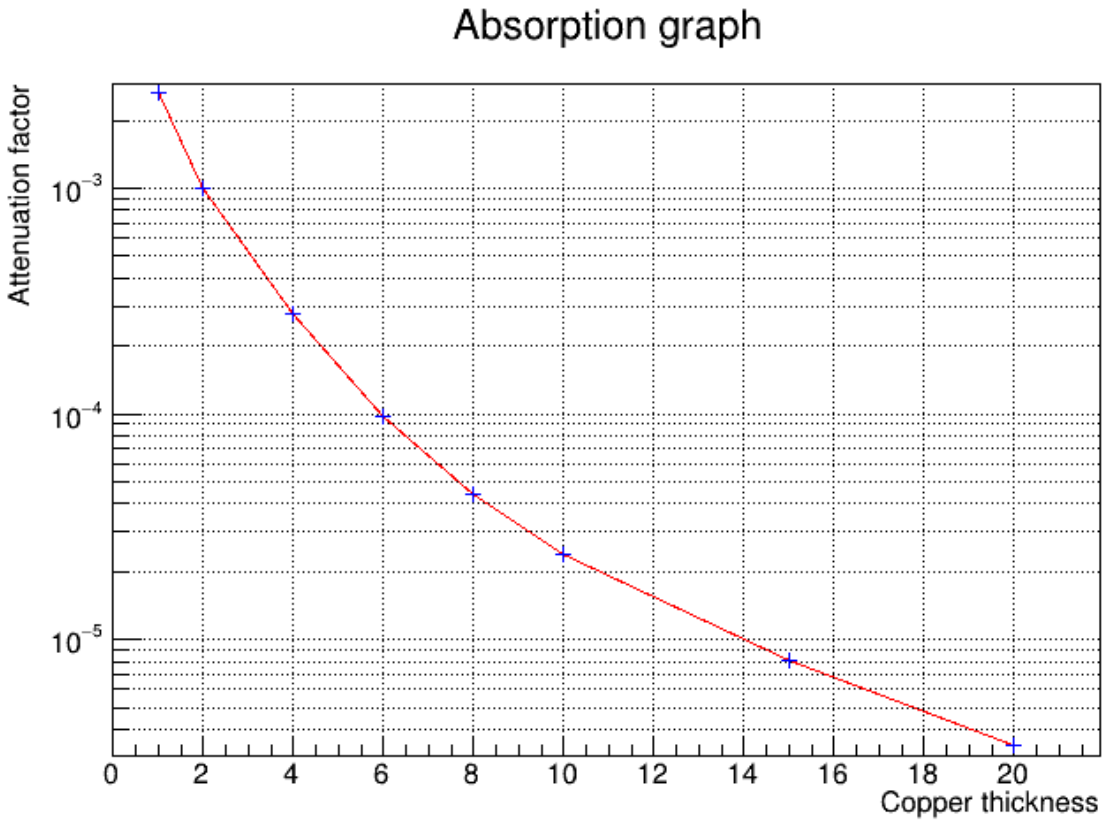
Special cooling of the exit window would eventually be needed.



SR photon spectra impacting the exit window



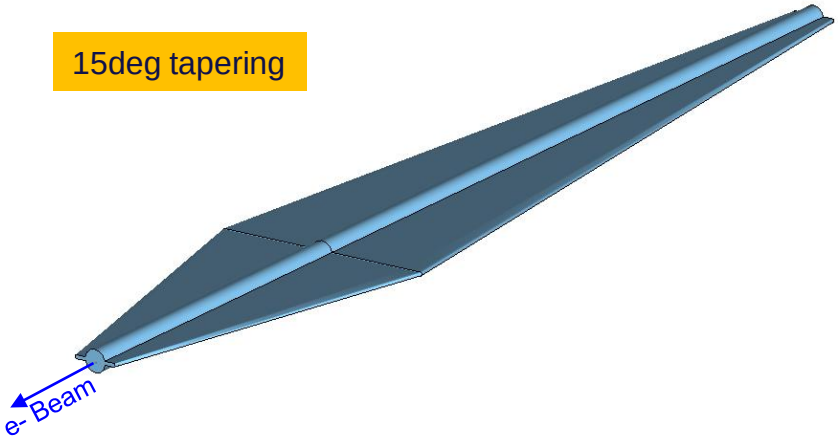
Extinction Ratio With respect to the copper thickness



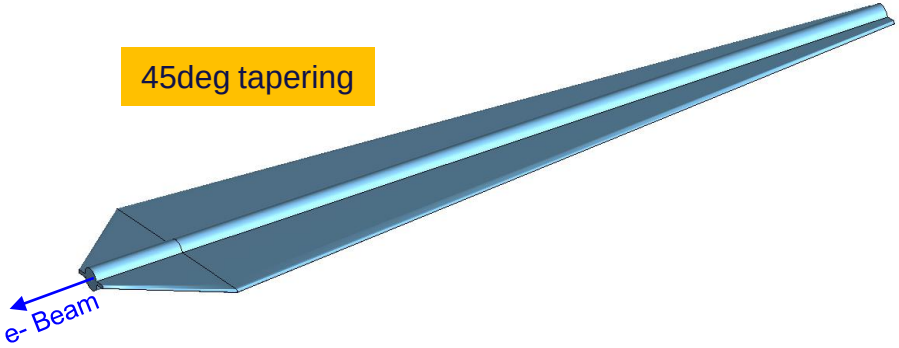
First CST Models of the Polarimeter chamber tested.

Thanks to Mauro Migliorati, Dora Gibellieri, Carlo Zannini

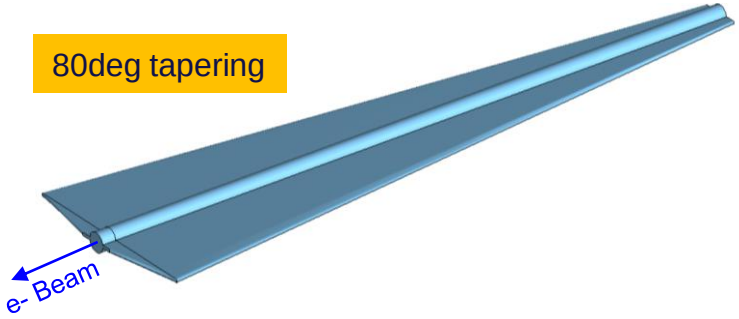
15deg tapering



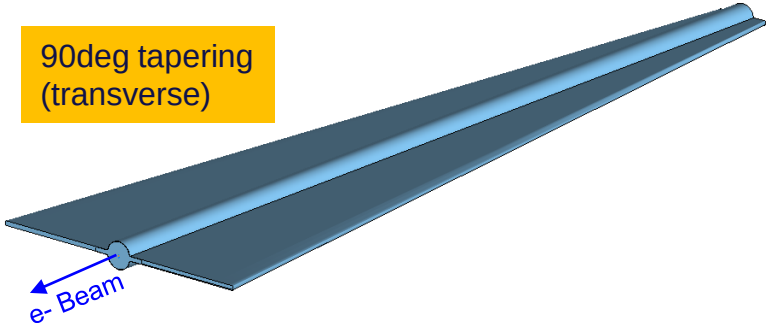
45deg tapering



80deg tapering

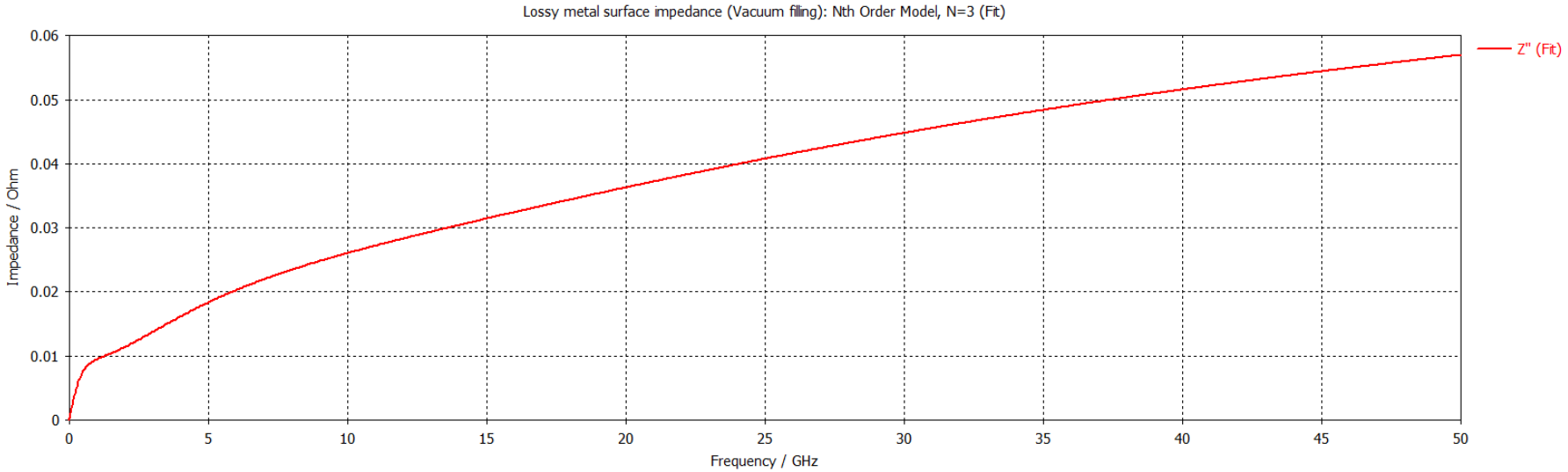


90deg tapering (transverse)



First CST Models of the Polarimeter chamber tested.

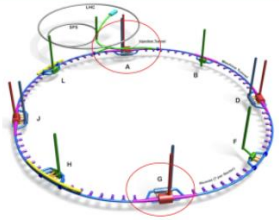
Thanks to Mauro Migliorati, Dora Gibellieri, Carlo Zannini

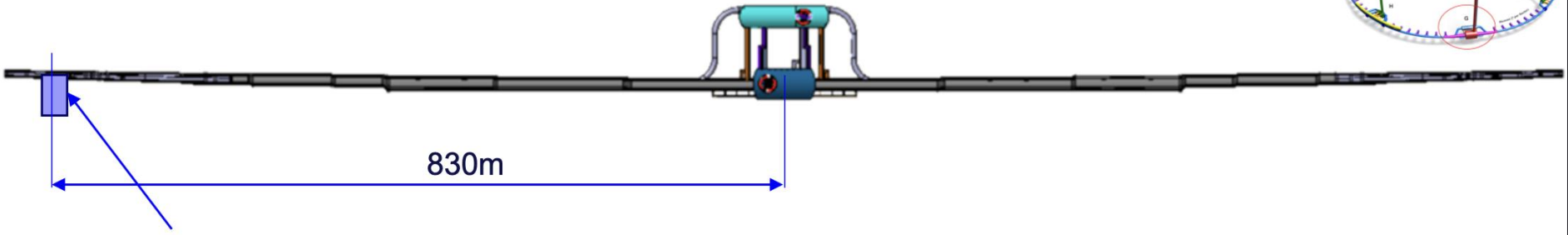


- The CST models that we provided to the FCC **impedance simulation** team have been tested. The study consisted in a scan of different extraction windows angle. From transverse (90deg), to (15deg) tapering.
- All models have successfully passed the impedance evaluation. They fall well bellow the 0.01%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

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

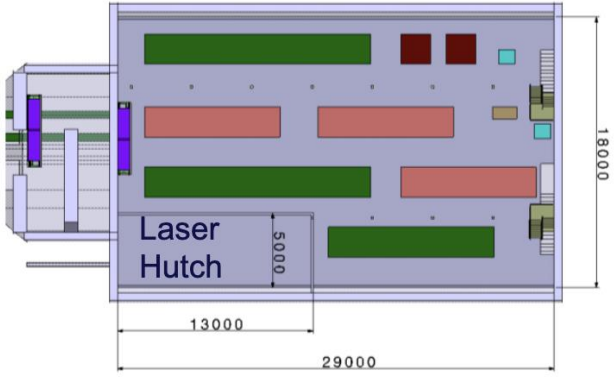
Proposal Slide from Fanny
https://indico.cern.ch/event/1429623/

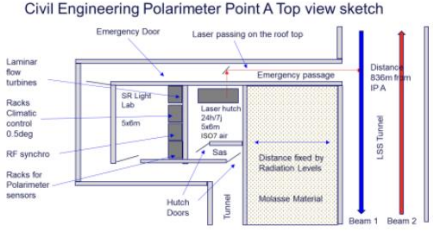




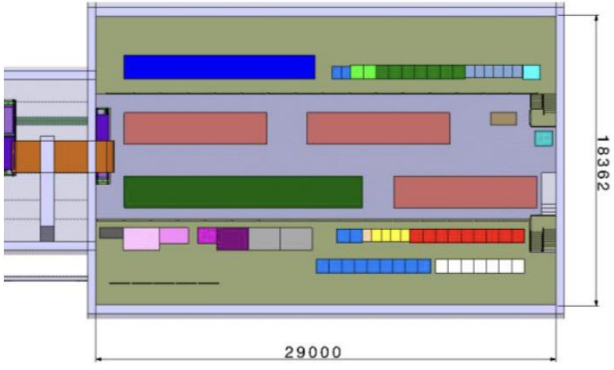
Big Alcove

Machine level



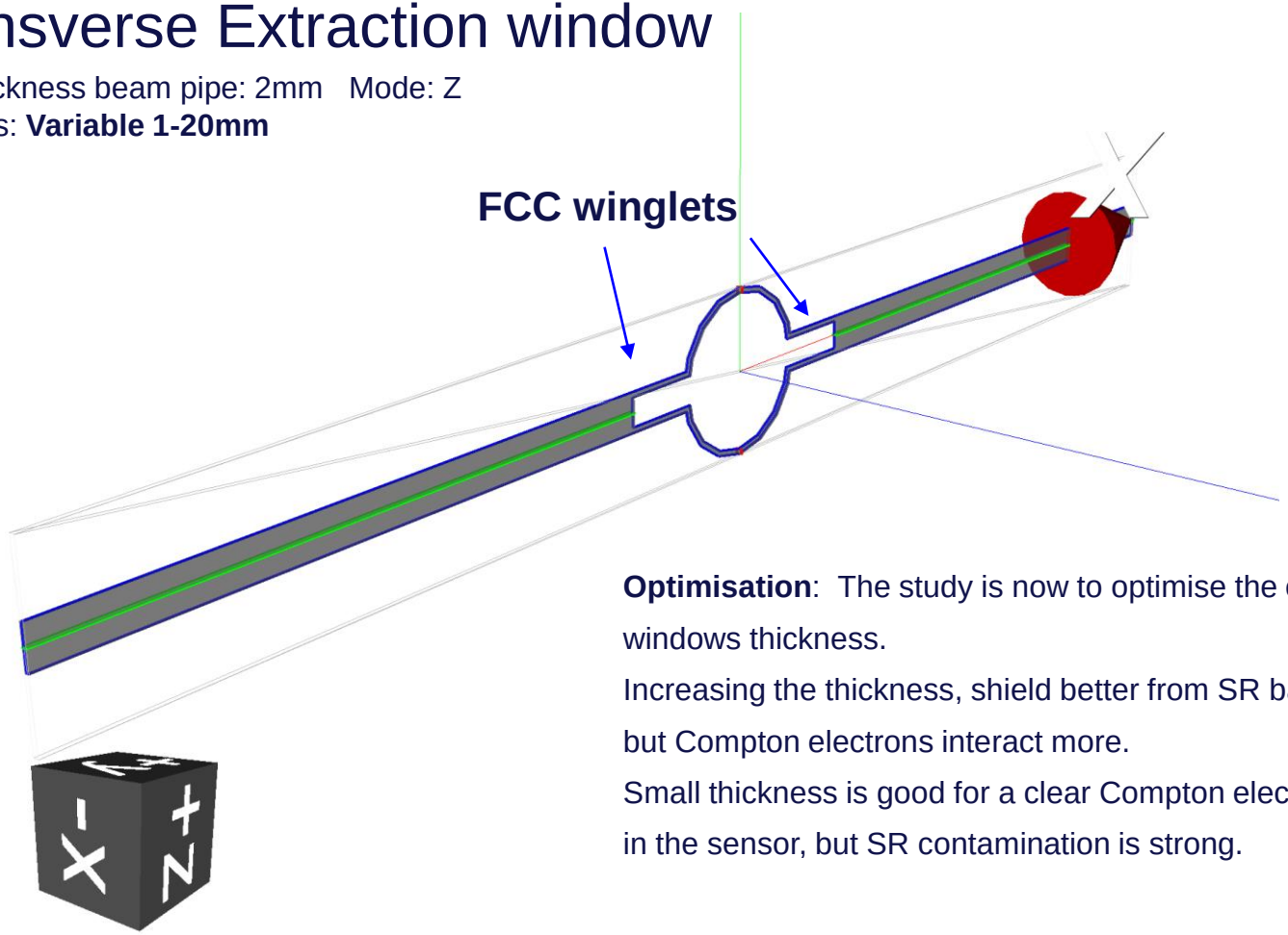


Second level



New Transverse Extraction window

Mat: Copper Thickness beam pipe: 2mm Mode: Z
Copper Thickness: **Variable 1-20mm**

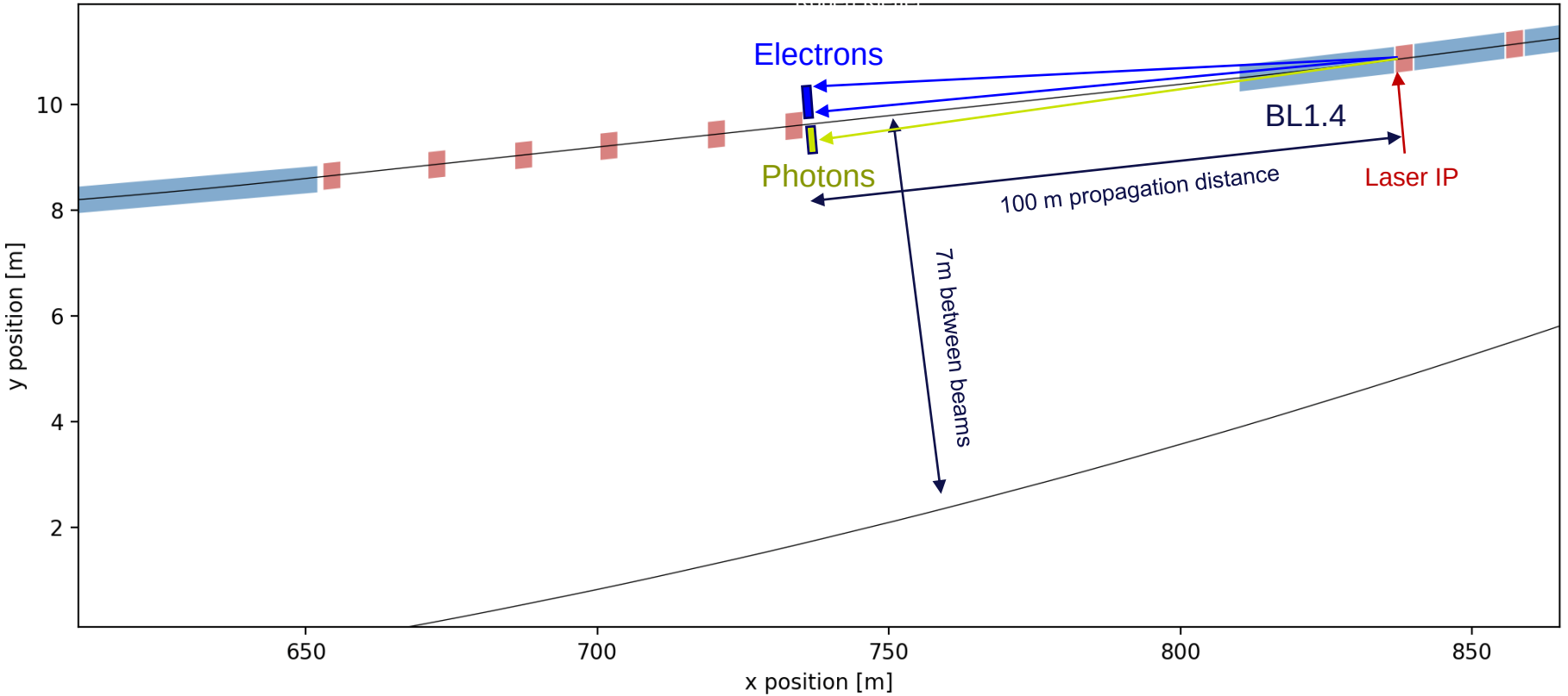


Optimisation: The study is now to optimise the extraction windows thickness.

Increasing the thickness, shield better from SR background, but Compton electrons interact more.

Small thickness is good for a clear Compton electron pattern in the sensor, but SR contamination is strong.

FCCee Polarimeters baseline in Experimental IP A



Optimizing on the separation chamber lenght