FCC POLARIMETER

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

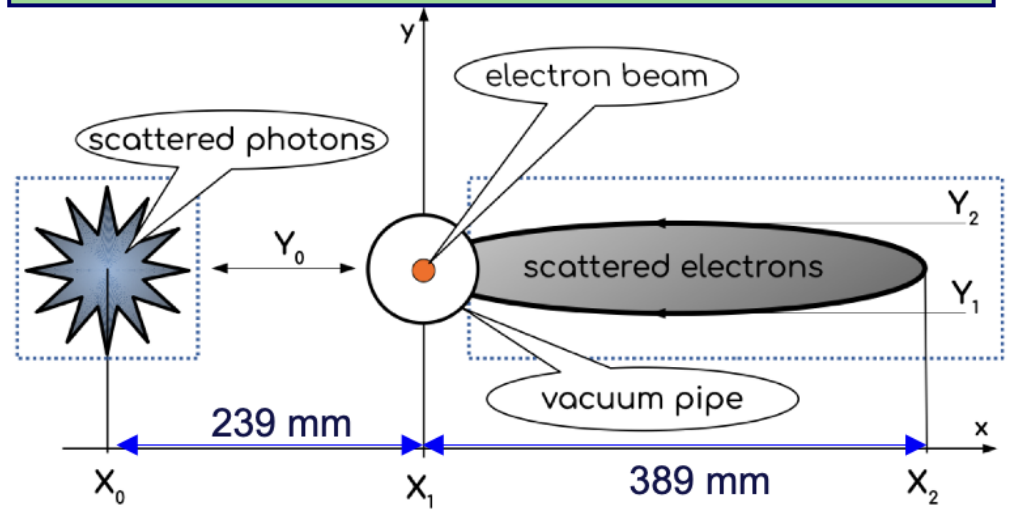
The FCC Compton polarimeter

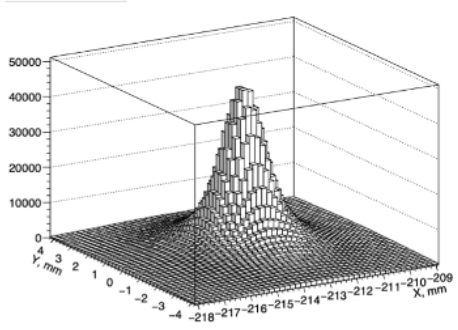
- **Centre of mass energy calibration** is obtained from the resonant depolarization scans (RDP) on pilots.
- **Direct energy measurement** by pattern position
- Precise **longitudinal polarization measurement** on physics bunches (expected to be zero at 10^{-5}).
- **Free spin precession** (looks challenging).

Implementation needs

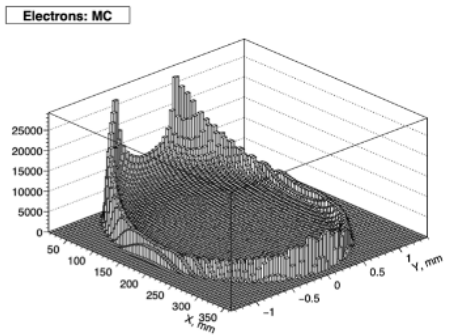
- Dedicated powerful laser and adapted hutch
- Laser Compton interaction chamber LIP
- Spectrometer magnet stuffed with Hall sensors
- Compton electron/photon extraction line chamber
- Particle sensors (silicon pixels detectors)
- Polarizing wigglers to speedup polarization buildup.
- RF kickers to apply resonant depolarization.

Profiles At 96 m from Laser IP





8 x 10 mm²



350 x 2 mm²

From N.Muchnoi

Polarimeter, Who's doing what ?

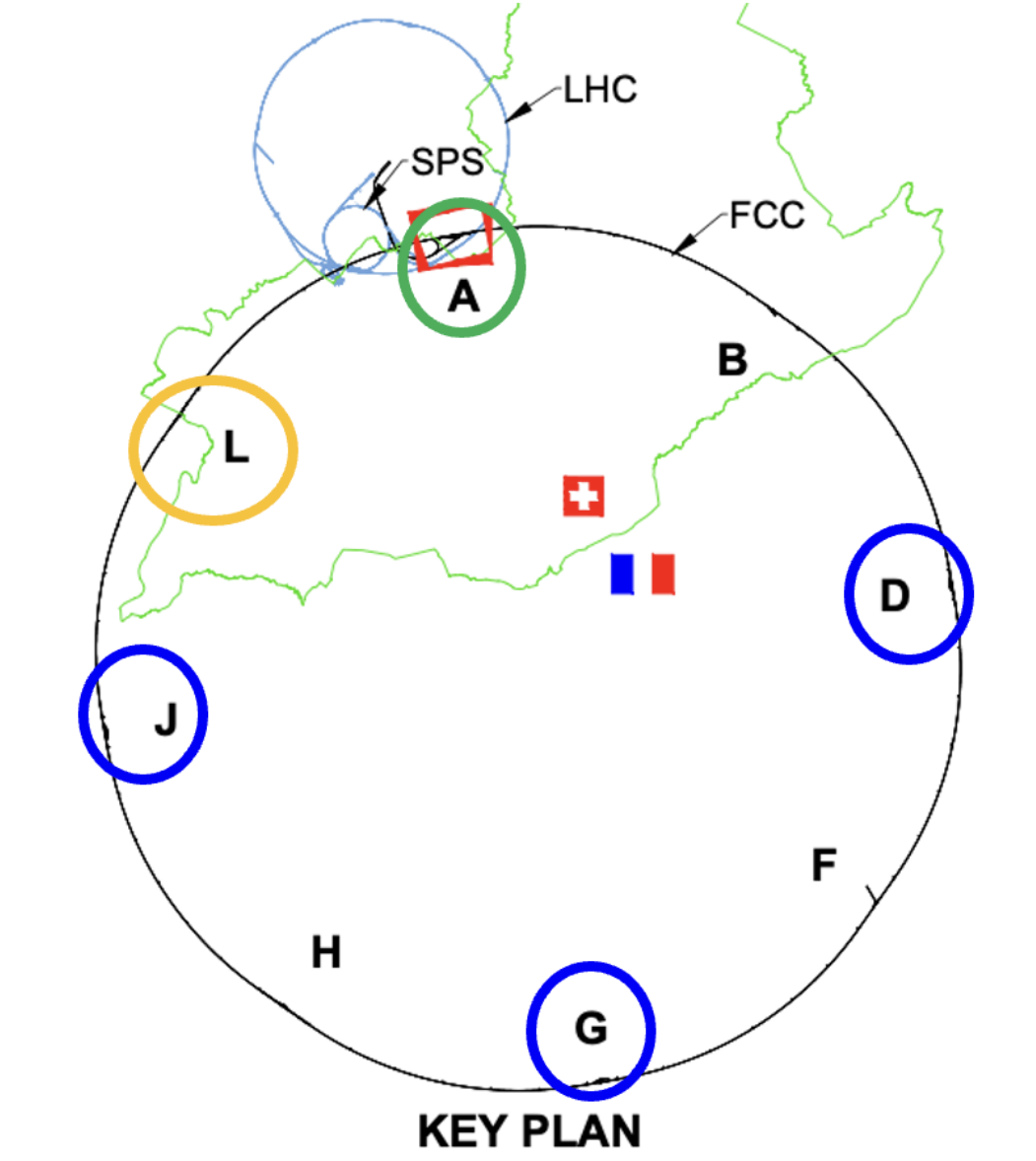
- Specifications of the instrument comes from the EPOL group.
- Baseline design, and toy Monte-Carlo tool (N. Muchnoi).
- Optics and instrument locations (R. Kieffer, G. Roy, K. Oide, P. Raimondi).
- Laser IP (chamber R. Kieffer, laser spec. A. Martens, laser transport line E. Granados)
- Wigglers (no responsible identified yet), LEP design as baseline.
- Kicker design (W. Höfle, discussions started on the topic).
- Wake field studies (M. Migliorati, C. Zannini, D. Gibellieri)
- Separation dipole magnet design (no responsible identified yet)
- Detectors development and simulation (R. Kieffer, N. Riaz, A. Martens)
- Civil engeneering and integration follow up (R. Kieffer, S. Mazzoni)

FCCee Polarimeters

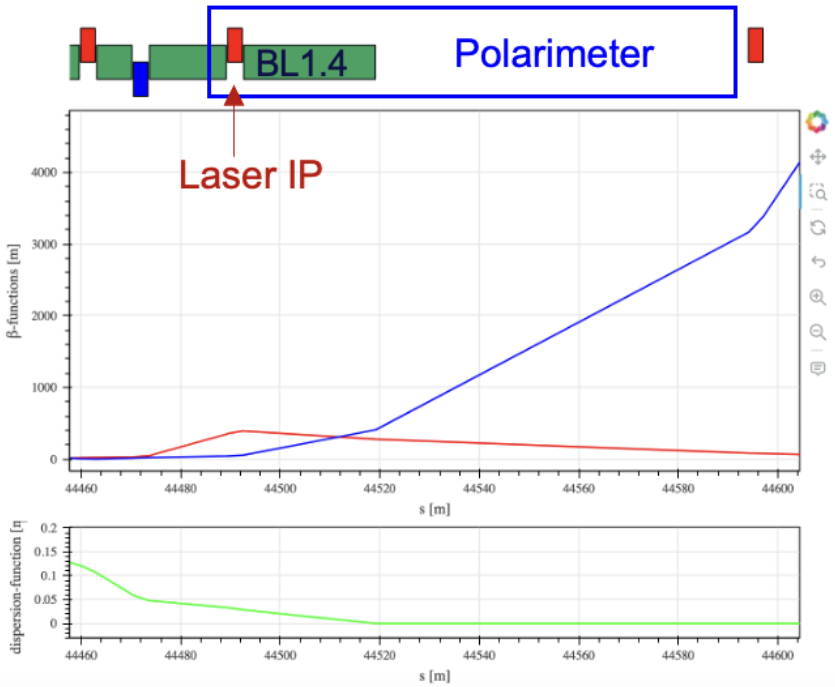
Base line: a single polarimeter per beam (2 total)
- Instrument location: both ends of LSS on each experimental **IP A.**
- Laser room should have a **24/7 access to insure availability**.
- **Needs dedicated laser hutch and access tunnels.**
- Energy at IPs is inferred from one measurement point.
- Energy loss (Tapering), along the ring **induce systematic errors** on the energy inferred at each IP.

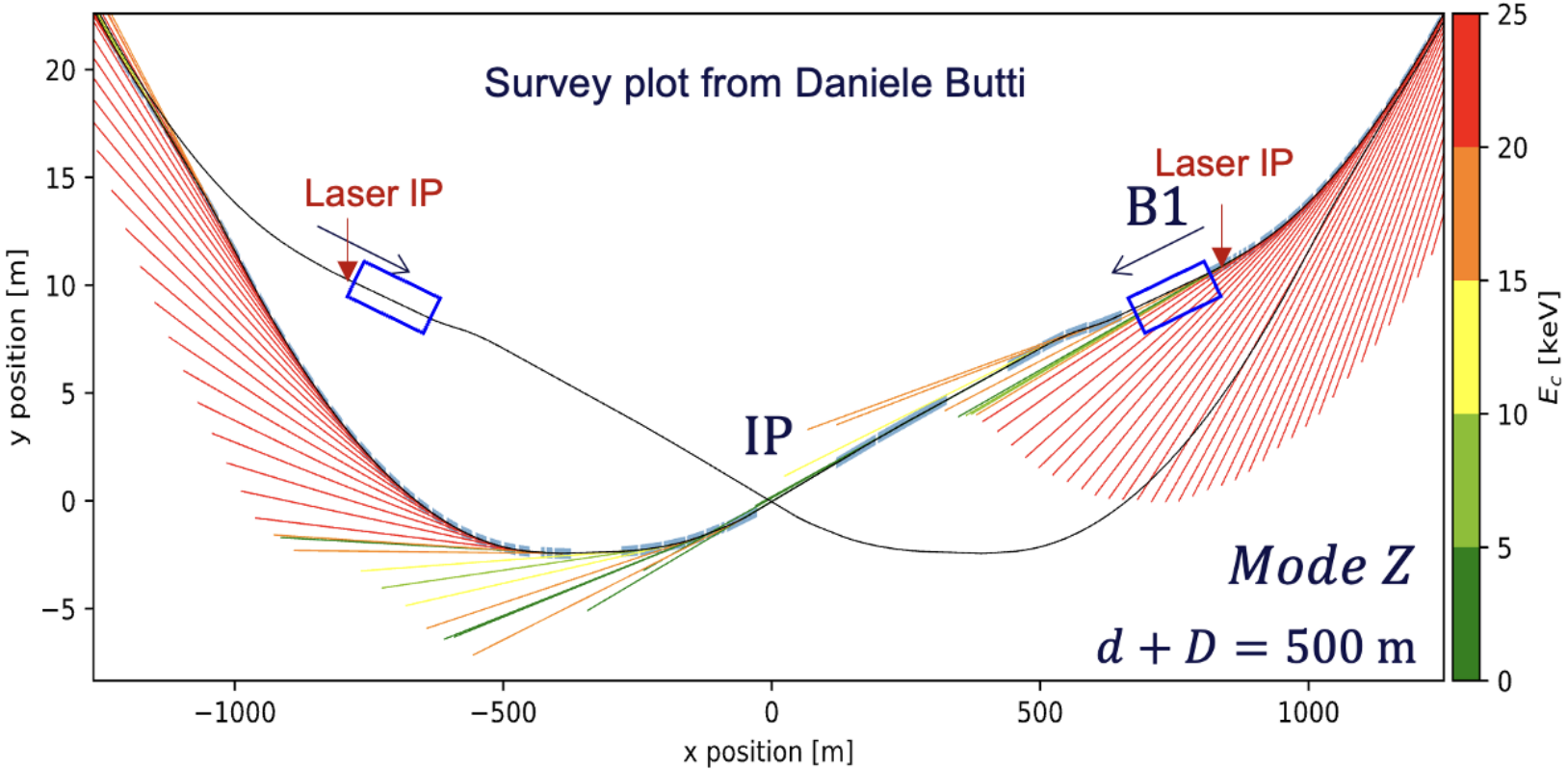
Redundancy option : four polarimeters per beam (8 total)
- Instrument location: both ends of LSS on each experimental IP **points A D G J**
- Each exp. IP would need **dedicated laser hutch.**
- Energy calibration done at each IP, **reduced systematic errors**.

Other option under study: one polarimeter per beam (2 total)
- Instrument location: at the center of the RF section in **point L**
- **Only possible for Z and W**, since the beam path is changed for H and ttbar, and the cryomodule will probably take all the available space. => Not the preferred option
- Laser hutch in Klystron galleries.



FCCee Polarimeters baseline in Experimental IP A

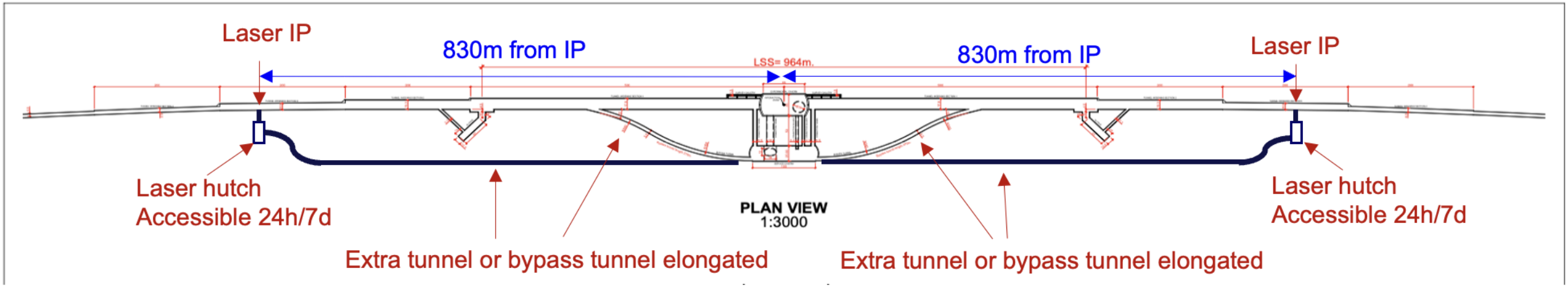




GHC optics is used. The polarimeter is not yet tested in the LCC optics.

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

FCCee Polarimeters baseline in Experimental IP A



The base line is to use the magnet BL1.4 as spectrometer on each beam, followed by 75m of free beam propagation to separate the compton photons and compton electrons from the main beam.

In order to insure full time availlabilty of the RDP energy calibration the **Laser hutch need to be accessible 24h/7days while close to the Laser IP (50m max)**. As few mirror folds and view ports as possible to maintain a good **laser circular polarisation**.

Simulation toolchain for the polarimeter compton electrons

ToyComptonMC from N.Muchnoi

Generate Compton electrons with polarization and beam parameters at Laser IP

→

BDSIM particle transport

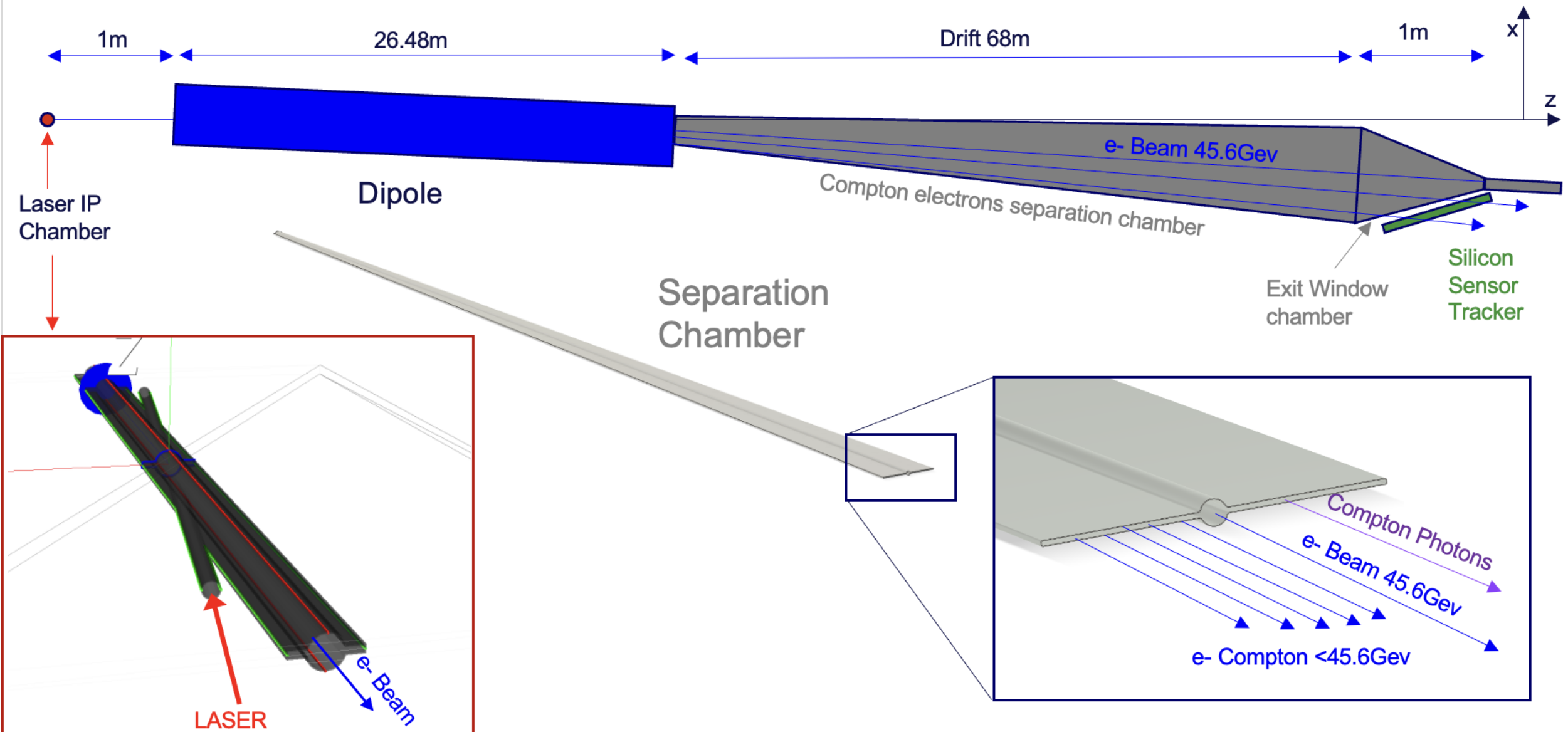
Spectrometer Magnet and extraction window particles interaction

→

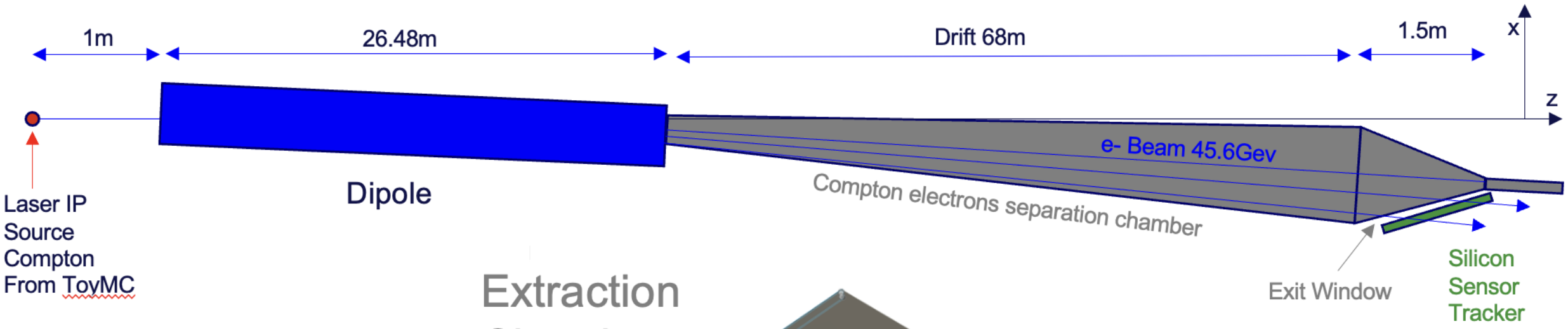
Root plot and fitting

Producing phase space profiles of secondary MC particles

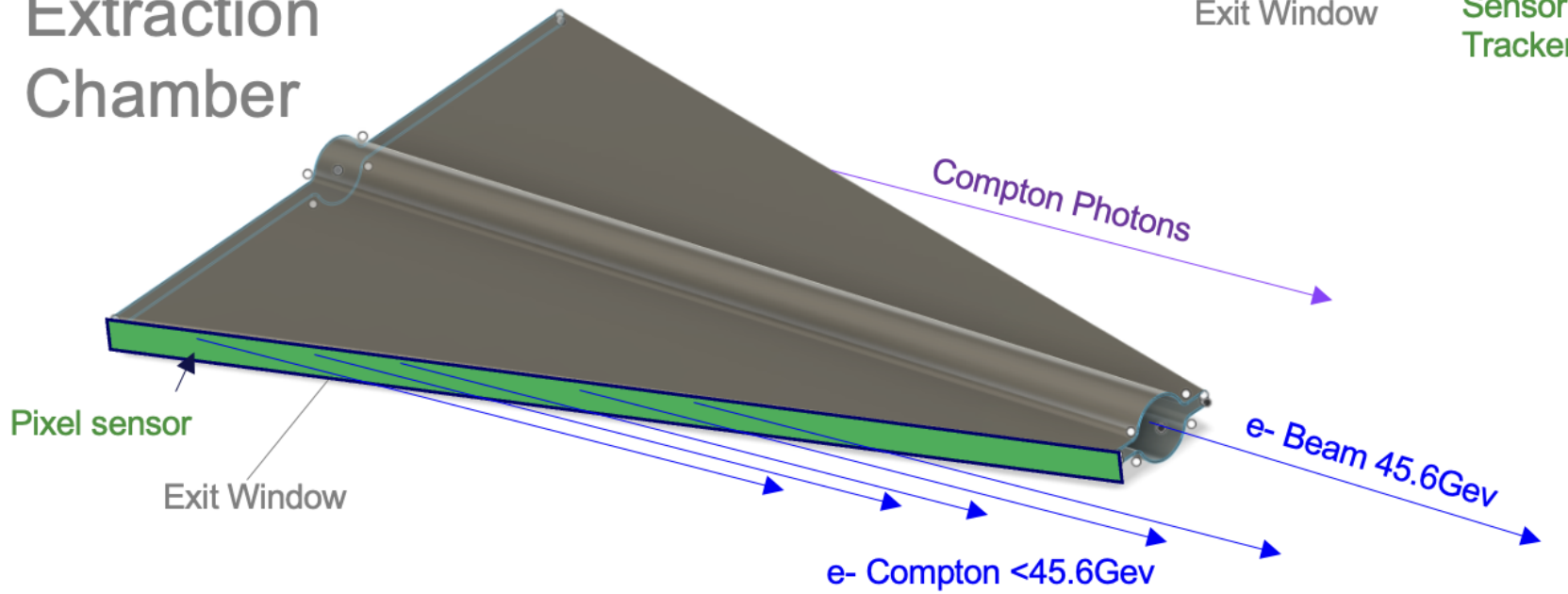
BDSIM Model description of Compton electrons separation



BDSIM Model description of Compton electrons extraction



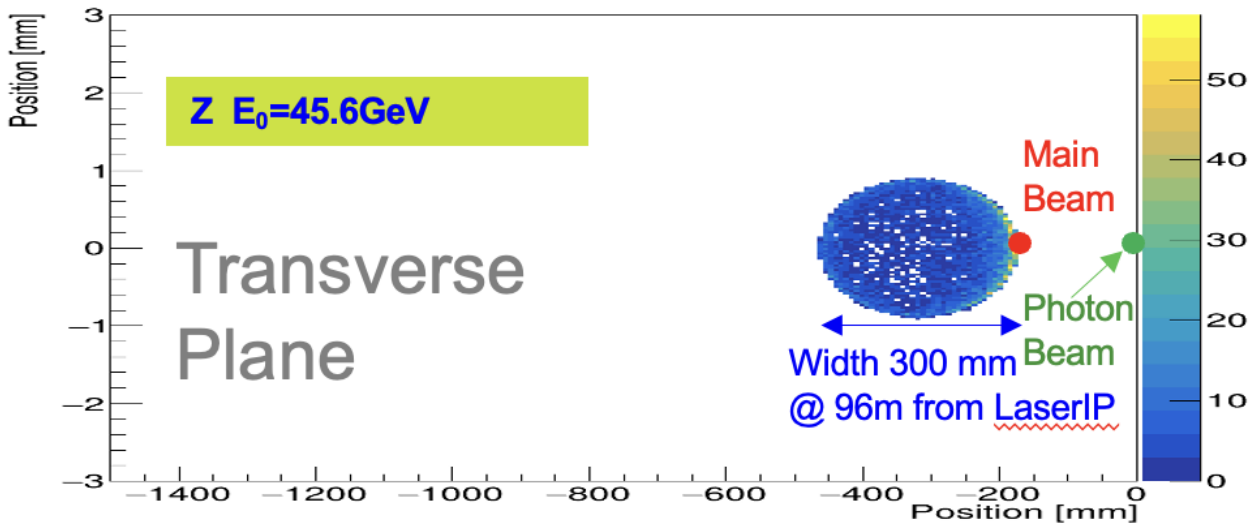
Extraction Chamber

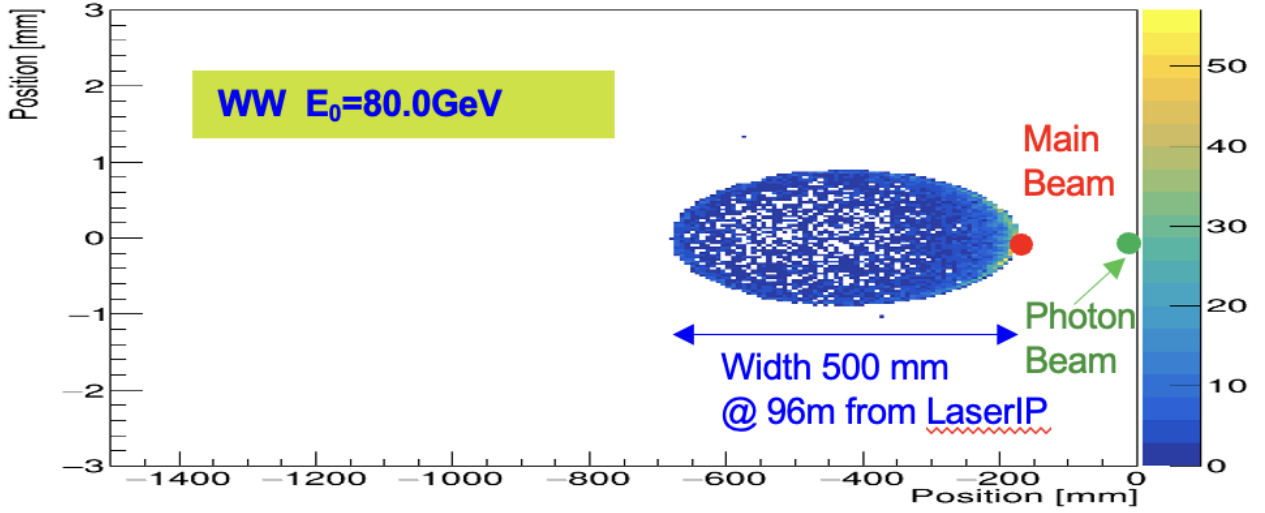


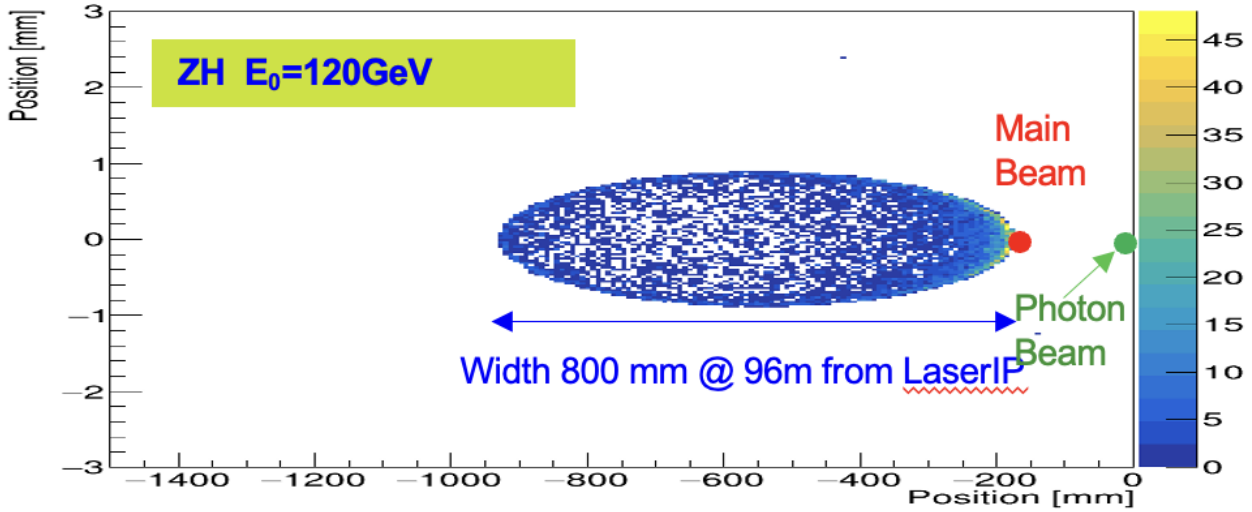
The exit window need to have a small tapering angle to reduce wake fields.

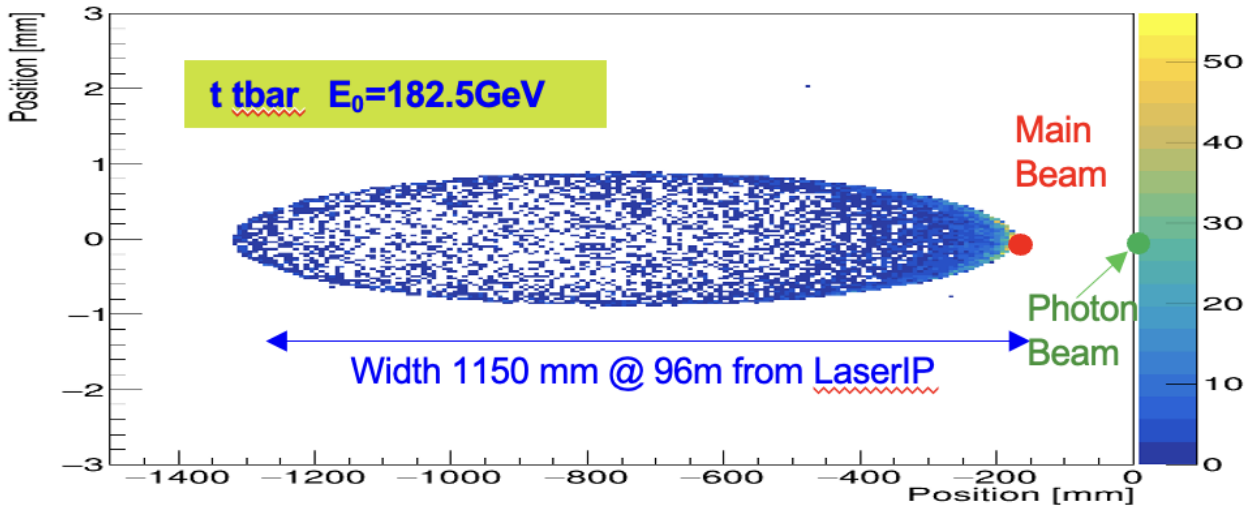
Effectively increase the material thickness crossed by the Compton electrons.

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

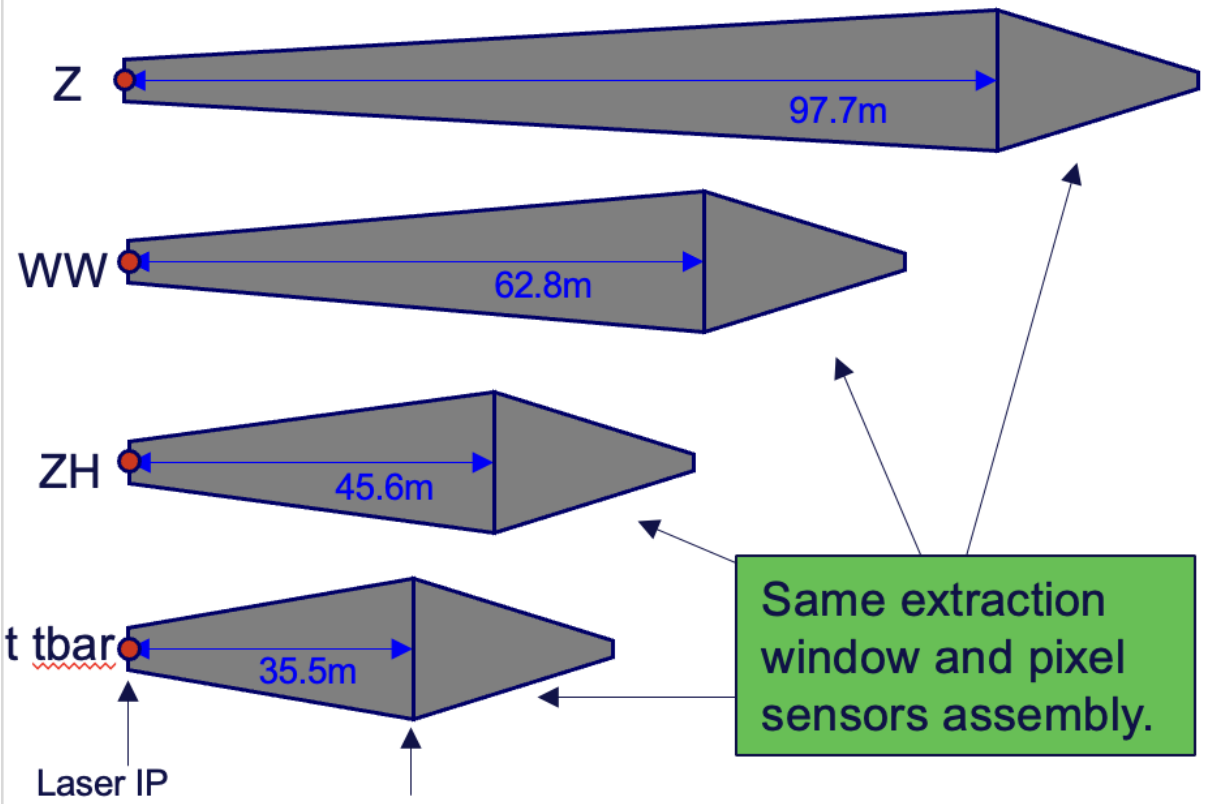


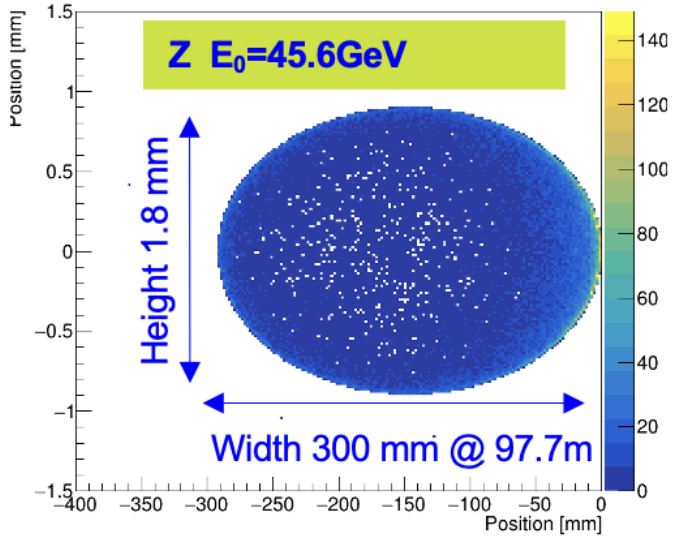


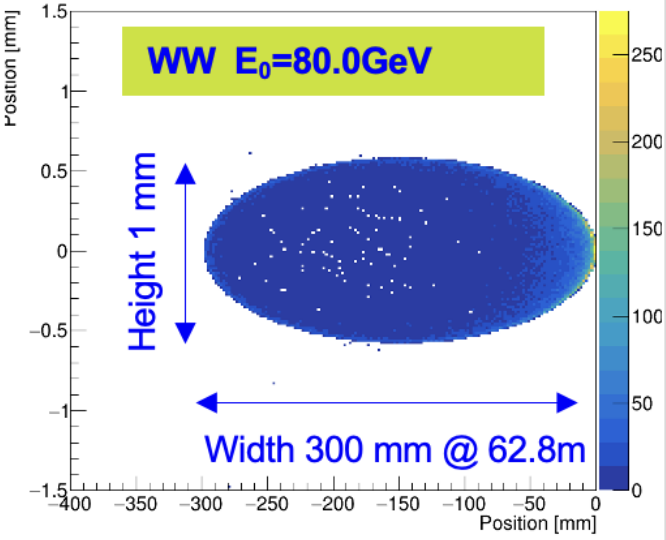


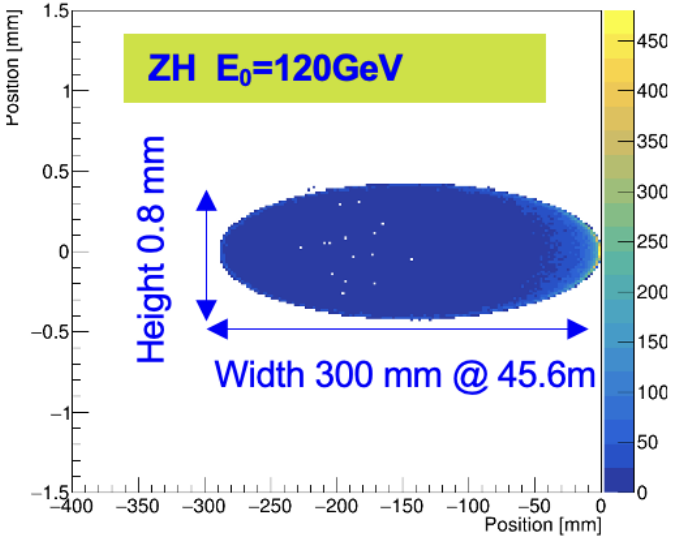


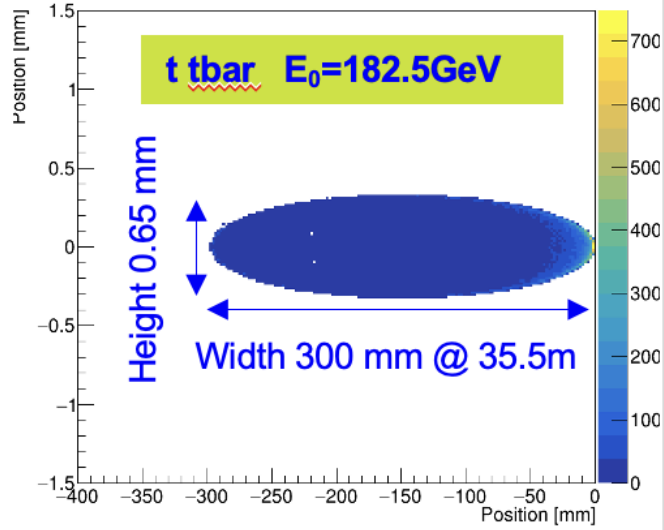
Optimizing on the separation chamber lenght







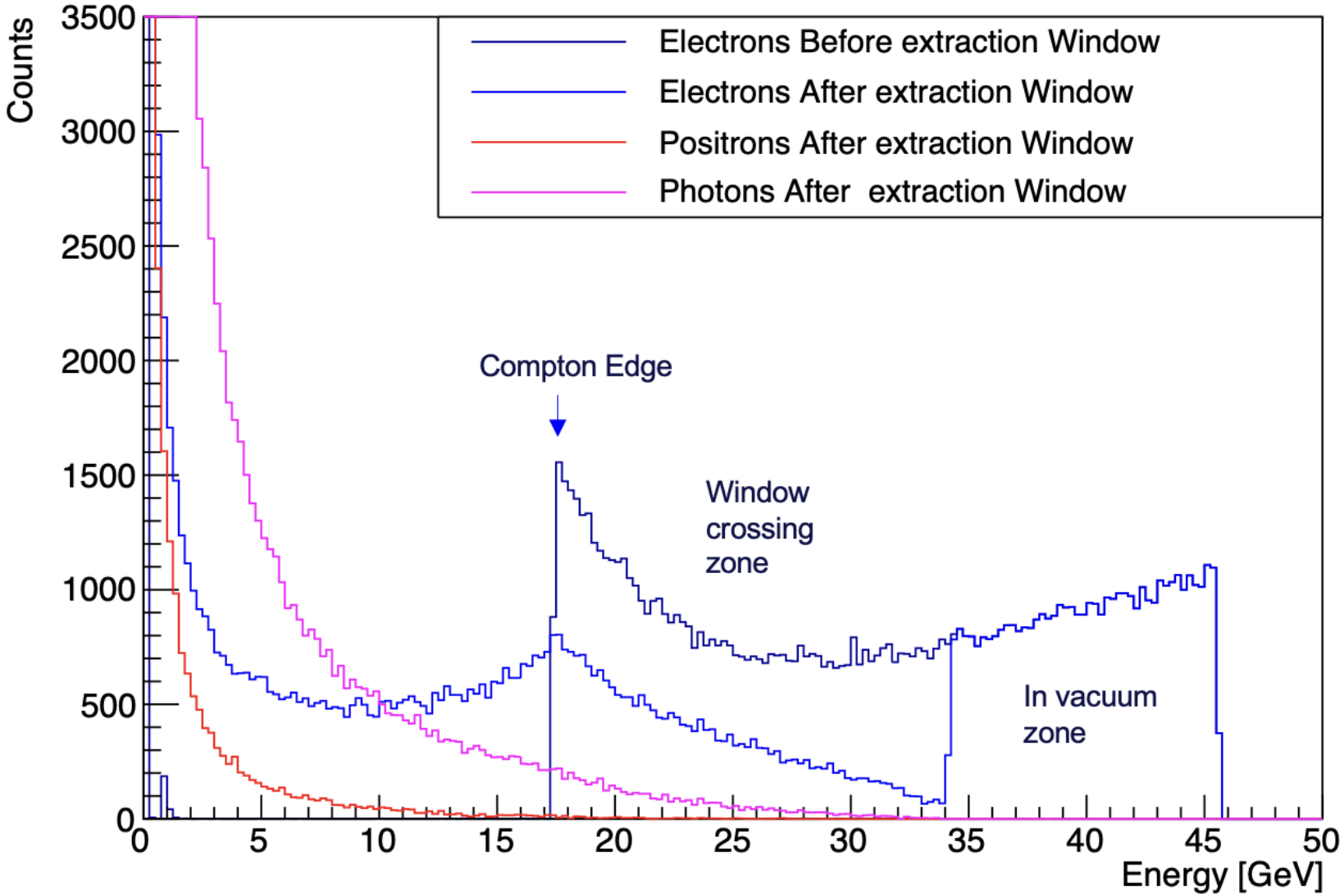




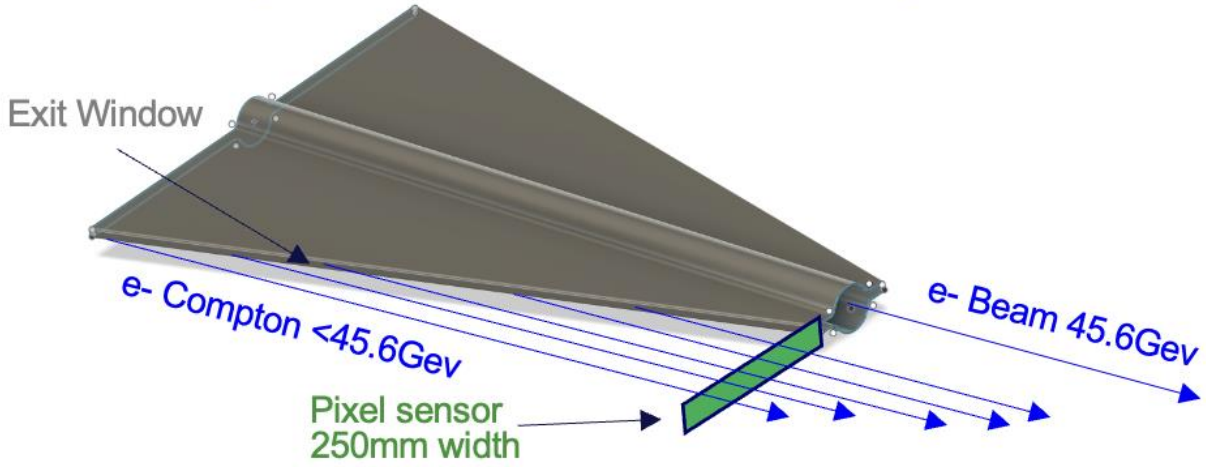
Compton electrons extraction spectra

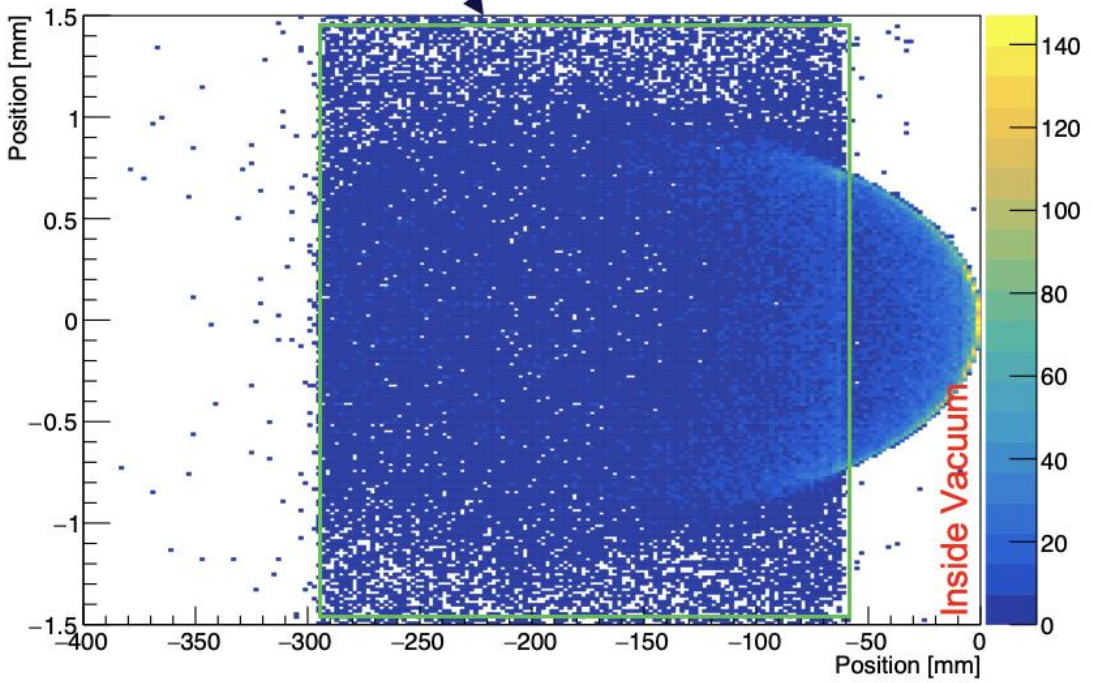
Z mode 45.6GeV beam energy
Extraction window at 15 deg angle
Thickness 2mm copper

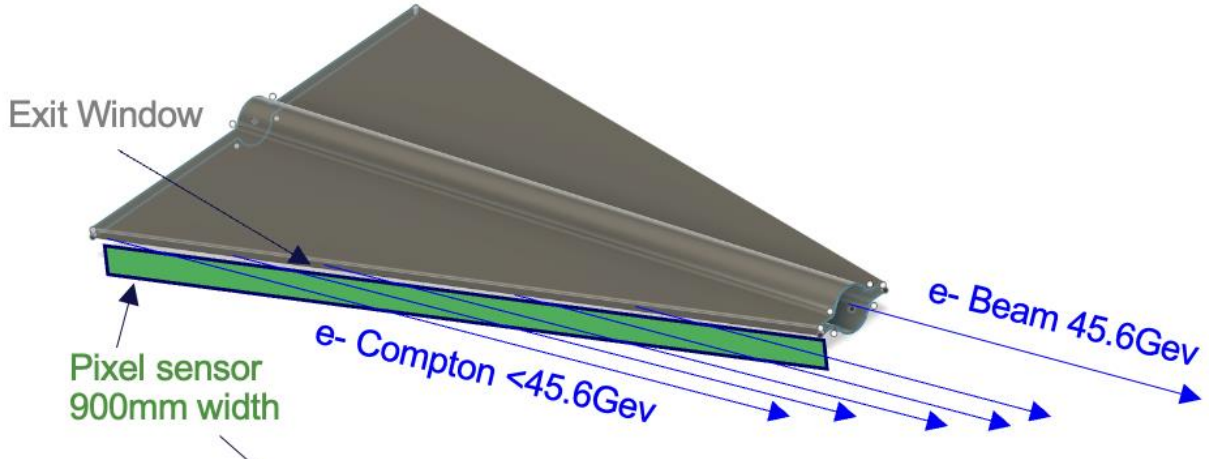
We can see that the Compton electrons are undergoing electromagnetic interaction when crossing the exit window.

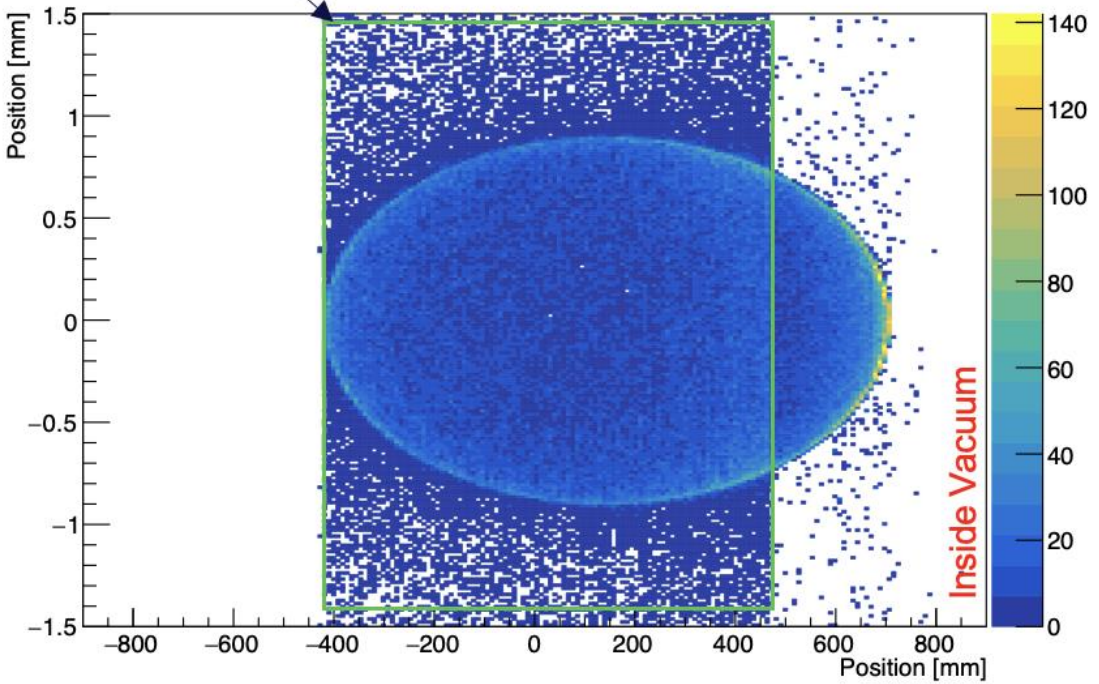


Compton electron pattern pixels plane orientation





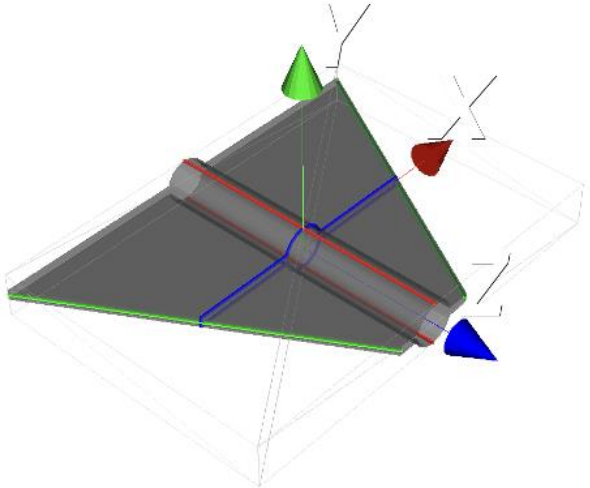




Extraction window chamber tapering (minimize Impedance effect)

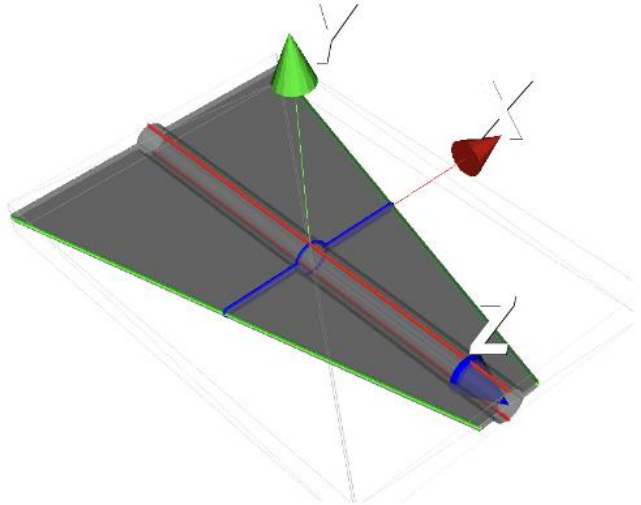
30 degrees angle

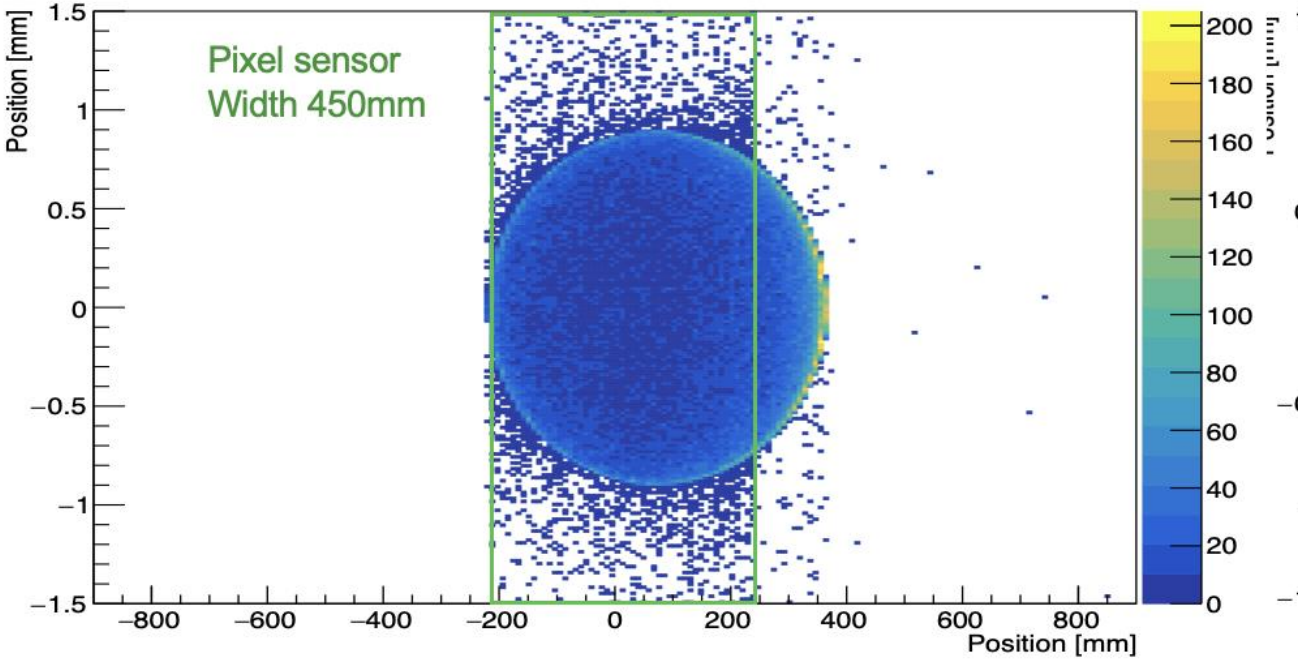
Mat: Copper Thickness: 2mm Mode: Z
Effective Copper Thickness: **3.99mm**

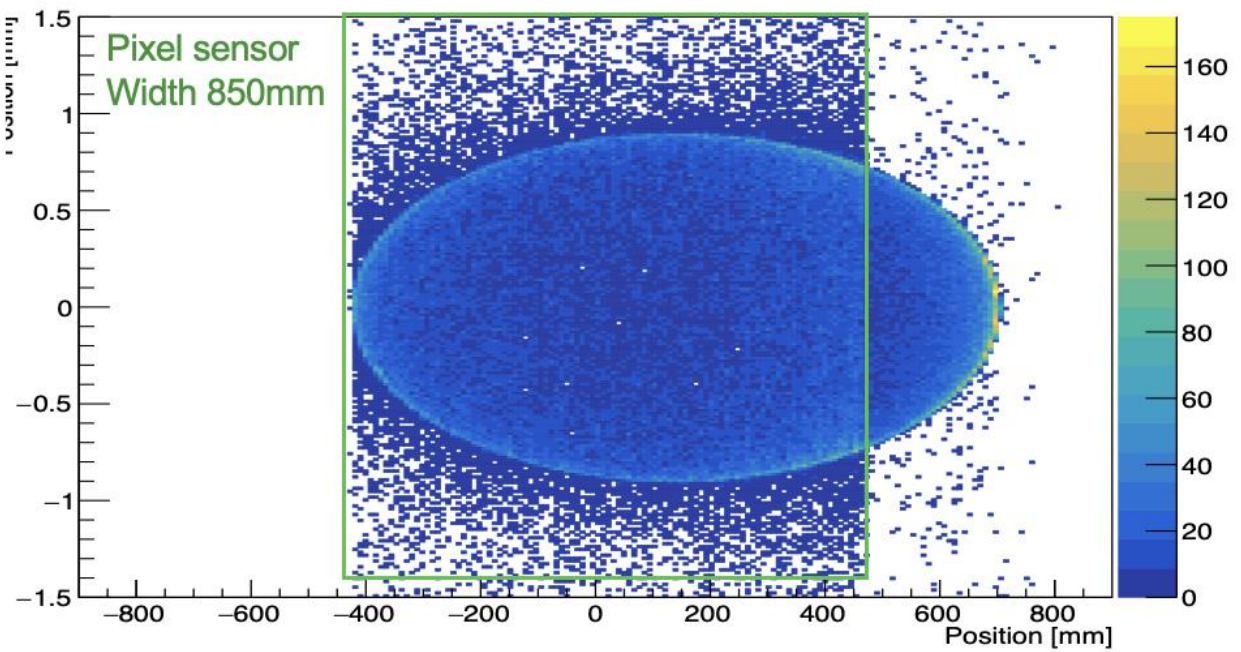


15 degrees angle

Mat: Copper Thickness: 2mm Mode: Z
Effective Copper Thickness: **7.72mm**







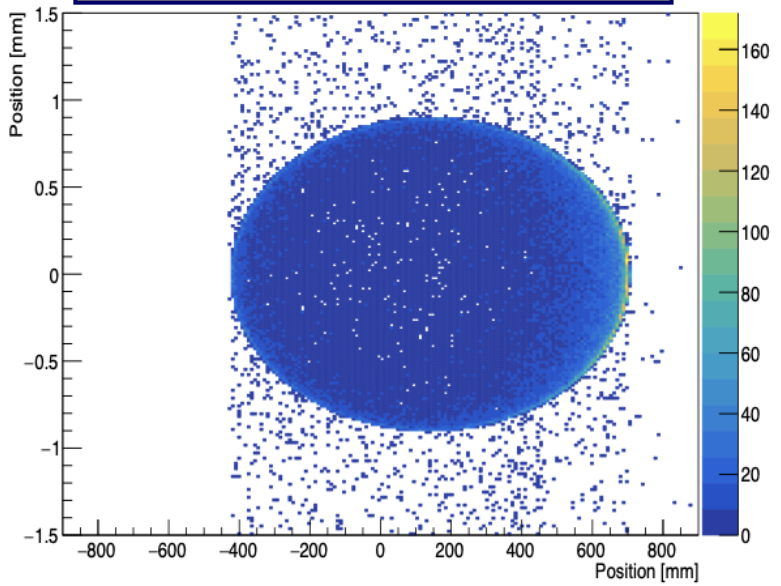
Extraction window material/thickness

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

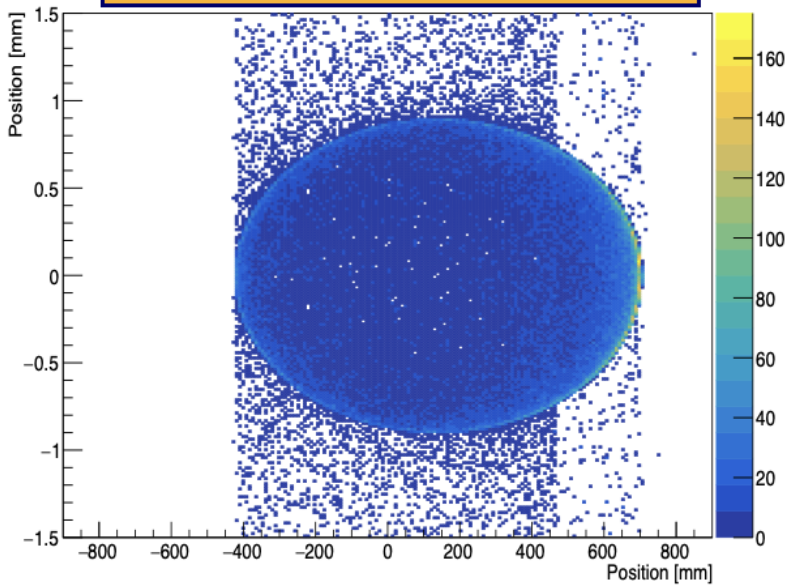
Aluminium and Copper
Two ticknesses 1-2 mm

1 mm Aluminium is the most transparent solution.

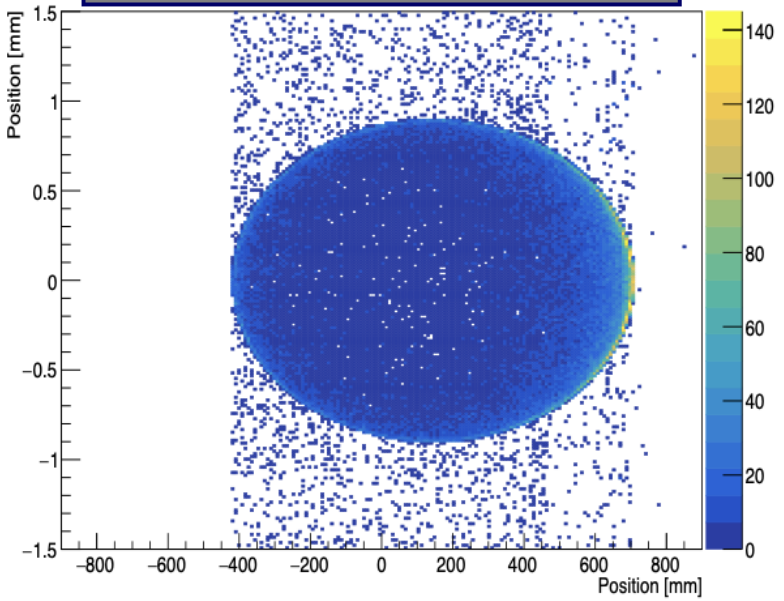
Aluminium 1 mm at 15 degrees



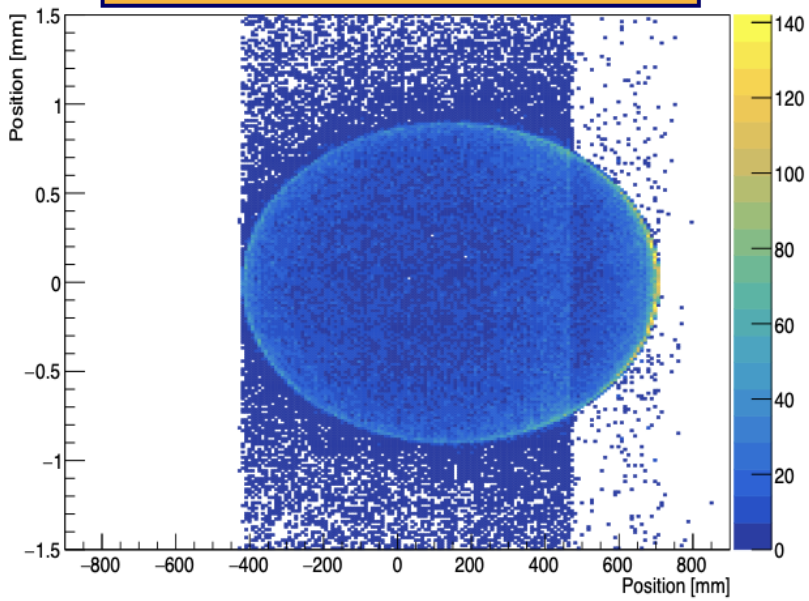
Copper 1 mm at 15 degrees



Aluminium 2 mm at 15 degrees



Copper 2 mm at 15 degrees



Actual Flow

ToyComptonMC from N.Muchnoi

Generate Compton electrons with polarization and beam parameters at Laser IP

→

BDSIM particle transport

Spectrometer Magnet and extraction window particles interaction

→

Root plot and fitting

Producing phase space profiles of secondary MC particles

Simulation toolchain for the polarimeter compton electrons

Long term plan

Xsuite	BDSIM Compton	BDSIM particle transport	AllPixSquared	Root plot and fitting
Waiting for spin tracking to be implemented	**Missing electron polarization to be added**	**Spectrometer Magnet and extraction window particles interaction**	**Silicon sensor modeling and Digitization**	**Producing phase space profiles of Digitized data**

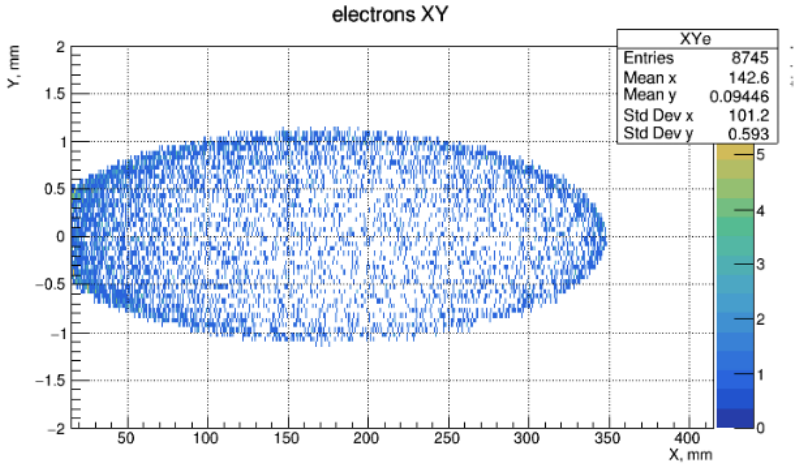
Resonant De-Polarization (RDP) scans

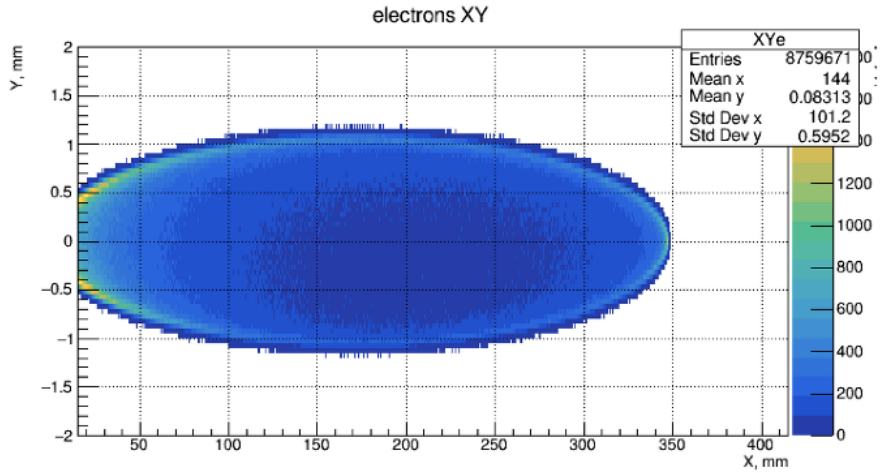
How many turns to detect a de-polarization is happening?

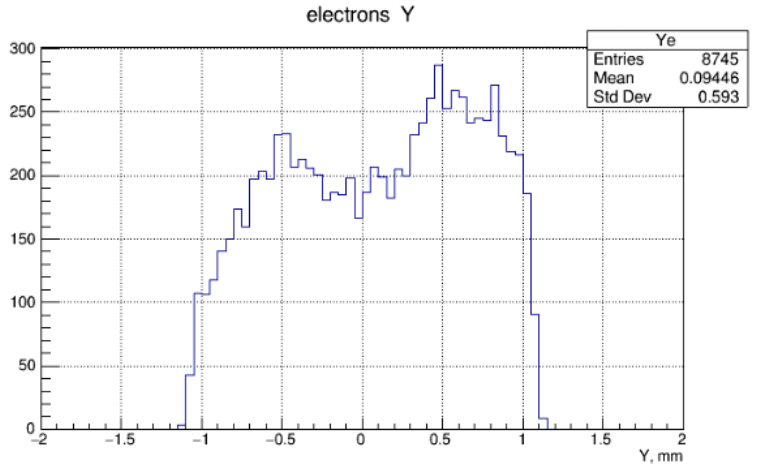
- Expect 1000 Compton electrons per bunch crossing.
- **Not enough** to have a nice Compton profile to **fit**.
- **Enough** to perform some asymmetry measurements on the profile.

To be compared with the **duration of the RDP kicker sweep** sequence (100-300 seconds).

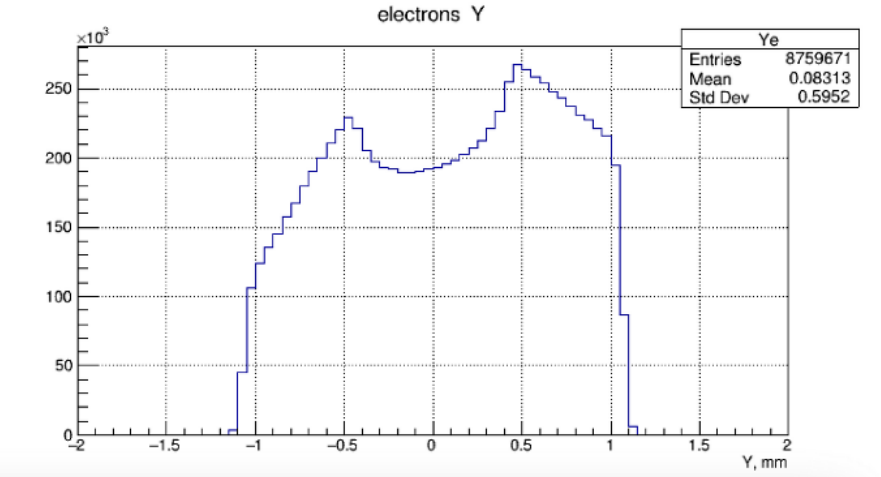
During this sweep we need to detect when the **vanishing of the polarization occurs**.







10k compton electrons
10 turns **3ms acquisition**



10000k compton electrons
10000 turns **3.3sec acquisition**

Resonant De-Polarization (RDP) scans

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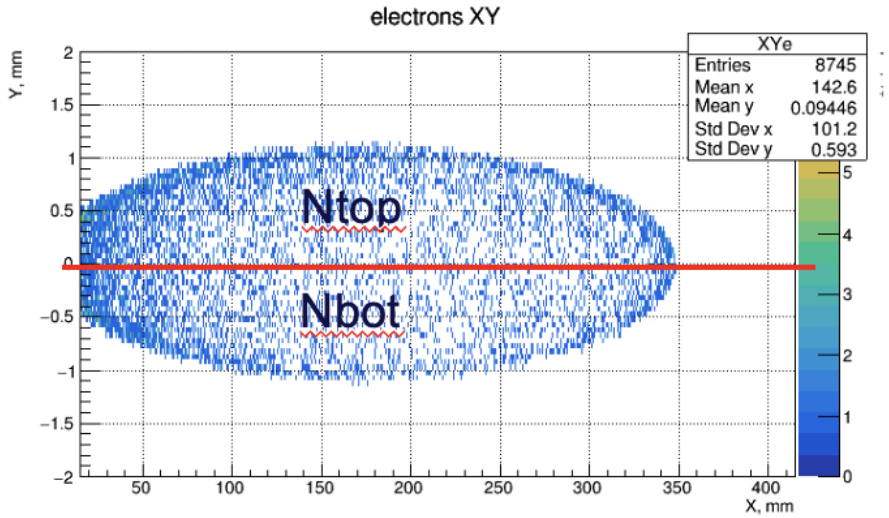
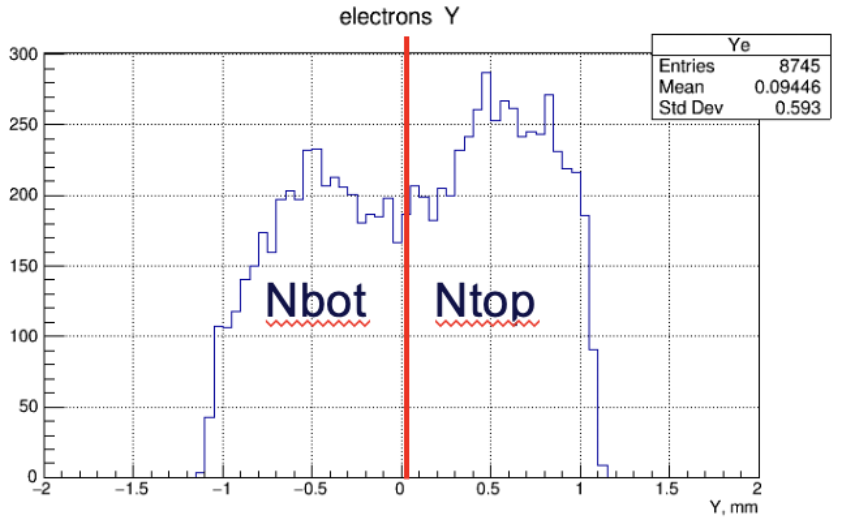
PATTERN ASSYMETRY
Assym = (Ntop-Nbot) / (Ntop+Nbot)

Scales like: $1/\sqrt{N_{turns}}$





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PATTERN ASSYMETRY
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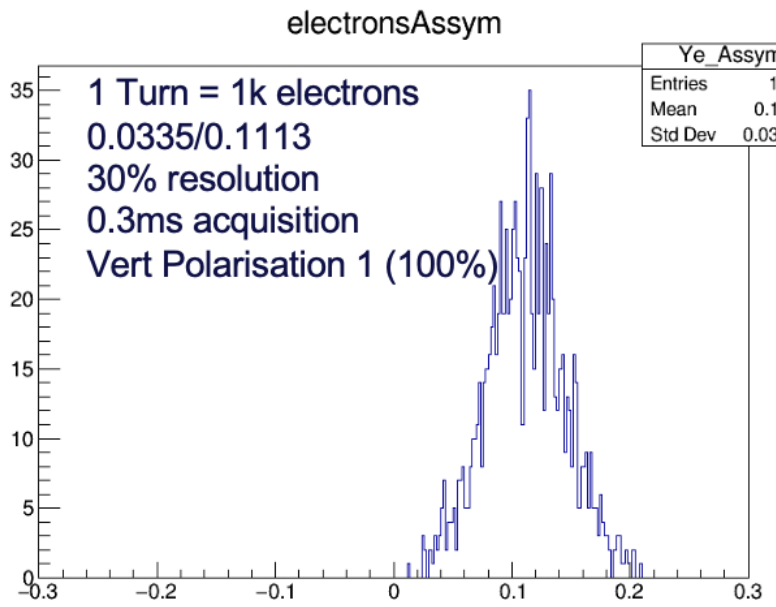
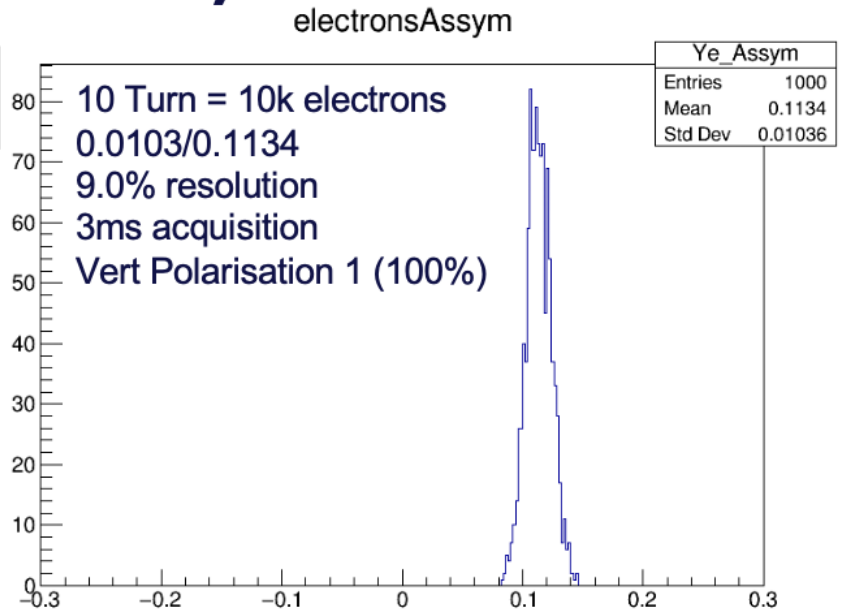
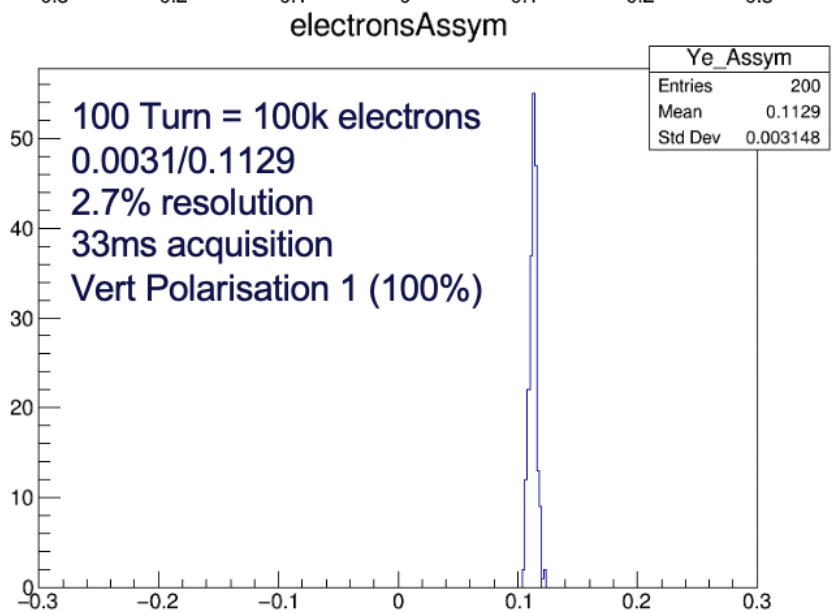
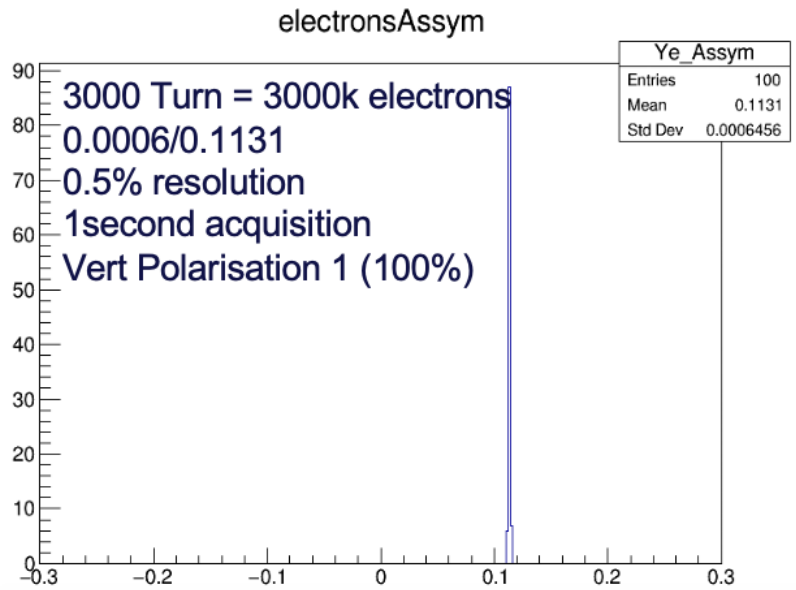
Scales like: 1/sqrt(N_{turns})

Real time FPGA implementation easy for histogramming (no fit needed)









Resonant De-Polarization (RDP) scans

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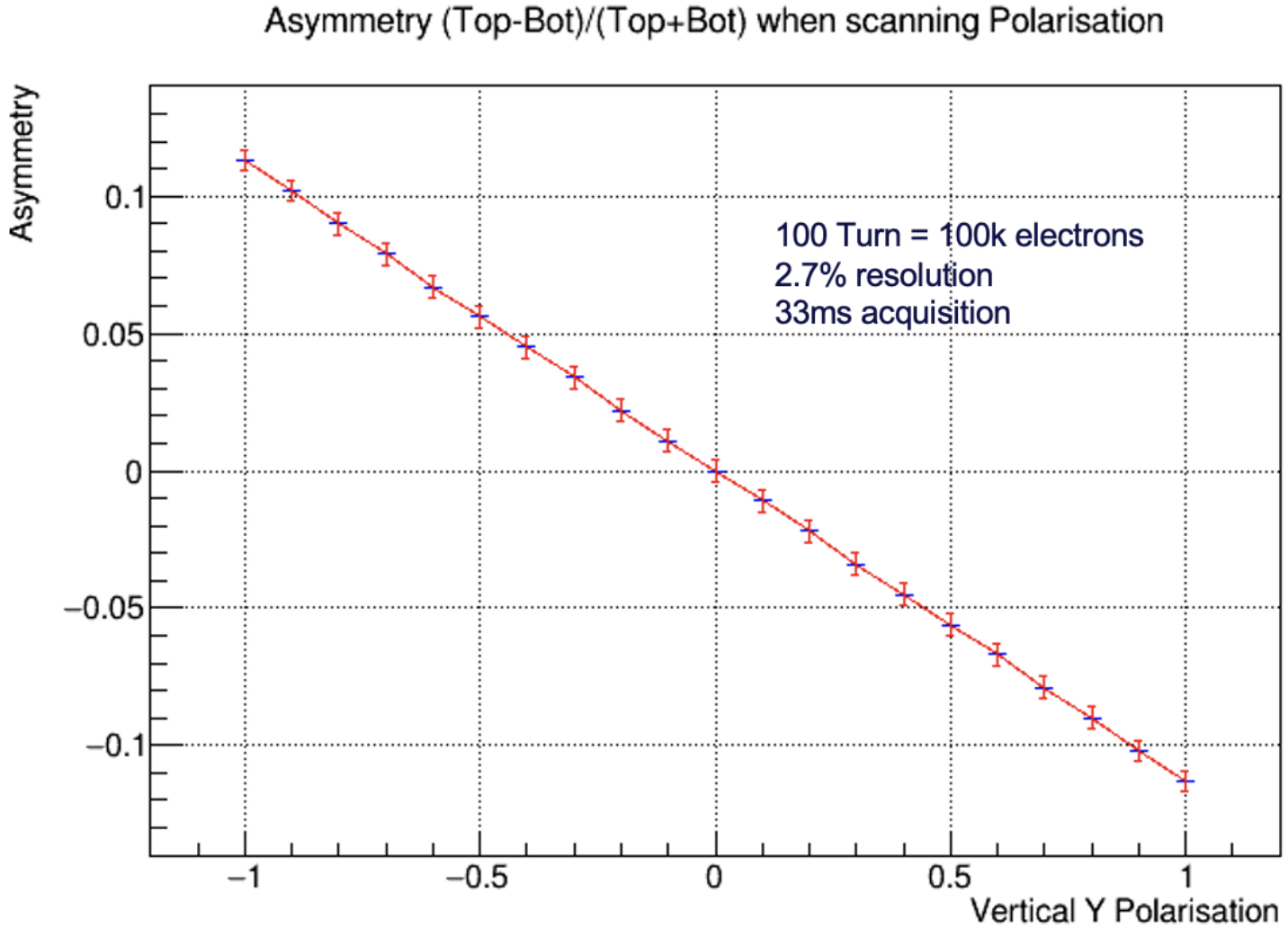
PATTERN ASSYMETRY
Assym = (Ntop-Nbot) / (Ntop+Nbot)

Conclusion: during an RDP scan with initial vertical bunch polarisation of 0.1 (10%) we can accurately detect de-polarisation in about 100 turns (33ms).
Time scale of the RDP sweep 100 seconds, i.e. 3000 measurement points along the scan.



=> 440MeV between RDP peaks gives about 100keV per point

Conclusions

- Simulation work started in BDSIM, much more work to be done (digitization, fitting procedure, CST), add the Backgrounds (SR, Bremsstrahlung on residual gas, thermal photons..)
- Do the same work for the **Compton photons** (Si-Tungsten electromagnetic calorimeter design)
- Instrument specifications and running modes still not fully defined (how often physics bunches need to be probed for **longitudinal polarization**, do we aim for **free spin precession measurement**, etc..).

Discussion on the number of polarimeters needed for FCC-ee

- Up to now the **baseline** is a **single pair of polarimeters in point A with an dedicated access tunnel to the laser laboratory (50MCHF)**
- We are looking into **point L option** since it would reduce drastically the civil engineering
- The discussion about having a **pair of polarimeter at each experimental IP** often comes back.
  - A **strong statement from physic's community to measure polarization at every experiments**
  - Can we find a (budget vs operation) compromise with 4 polarimeters without tunnel access to the laser lab ?
  - The civil engineering will be frozen this September, **the statement would need to come beforehand**.

Thank you for your attention.