FCC POLARIMETER

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

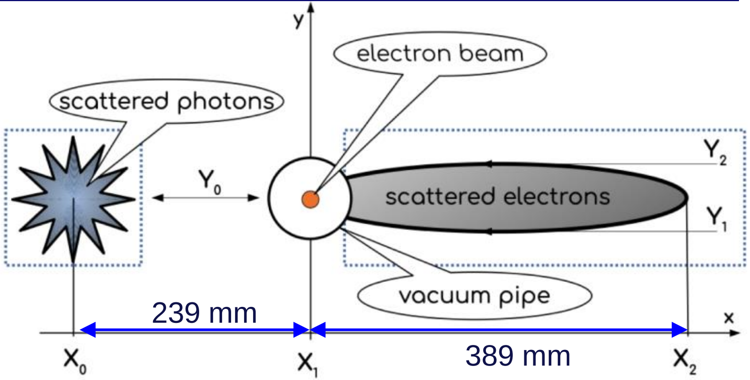
The FCC Compton polarimeter

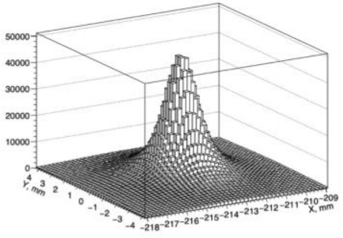
- **Centre of mass energy calibration** is obtained from the resonant depolarization scans (RDP) on pilots.
- **Direct energy measurement** by pattern position
- Precise **longitudinal polarization measurement** on physics bunches (expected to be zero at 10^{-5}).
- **Free spin precession** (looks challenging).

Implementation needs

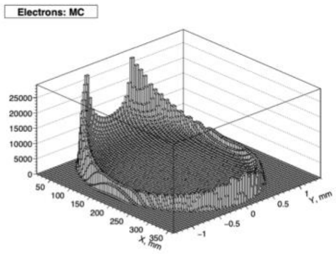
- Dedicated powerful laser and adapted hutch
- Laser Compton interaction chamber LIP
- Spectrometer magnet stuffed with Hall sensors
- Compton electron/photon extraction line chamber
- Particle sensors (silicon pixels detectors)
- Polarizing wigglers to speedup polarization buildup.
- RF kickers to apply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

Profiles At 96 m from Laser IP





8 x 10 mm^2



350 x 2 mm^2

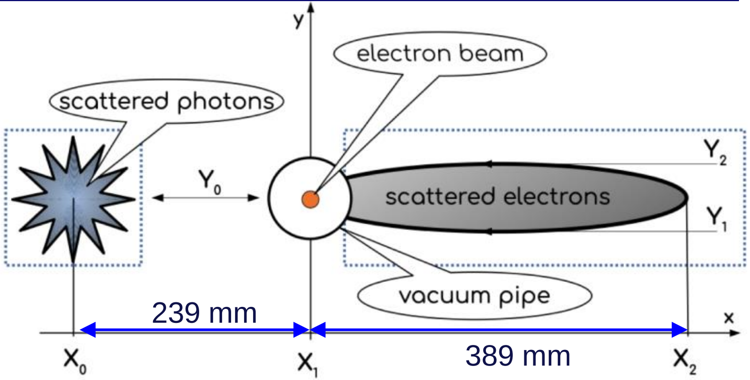
From N.Muchnoi

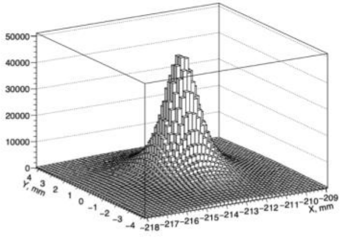
The FCC Compton polarimeter

Main constraints

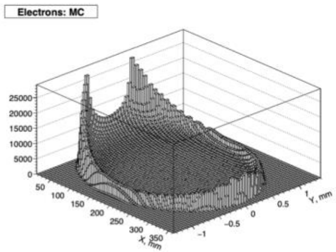
- Space needed for Beam / Compton products separation (several tens of meters).
- Beam to beam distance to fit instruments.
- Lattice configurations (beam e+ , beam e-, booster)
- Multiple sources of backgrounds (SR, thermal photons, Bremsstrahlung)
- The laser hutch need to be accessible 24h/7d while running the polarimeter.
- Minimizing the impact of the Compton products to the experiments.
- Cost of the instruments, and civil engineering.

Profiles At 96 m from Laser IP





8 x 10 mm^2



350 x 2 mm^2

From N.Muchnoi

Polarimeter, Who’s doing what ?

- Specifications of the instrument comes from the EPOL group
- Optics and instrument locations (Robert Kieffer, Ghislain Roy, Katsunobu Oide)
- Wigglers (no responsible iddentified yet), LEP design as baseline
- Kickers (no responsible iddentified yet, discussions started on the topic)
- Laser IP (chamber design Robert Kieffer, laser spec. Aurélien Martens, laser transport line design Eduardo Granados)
- Wake field studies (Mauro Migliorati, Carlo Zannini, Dora Gibellieri ?)
- Separation dipole magnet design (no responsible iddentified yet)
- Detectors development and simulation (Robert Kieffer, Nida Riaz, Aurélien Martens)
- Civil engeneering and integration follow up (Robert Kieffer)

FCCee Polarimeters

Base line: a single polarimeter per beam (2 total)

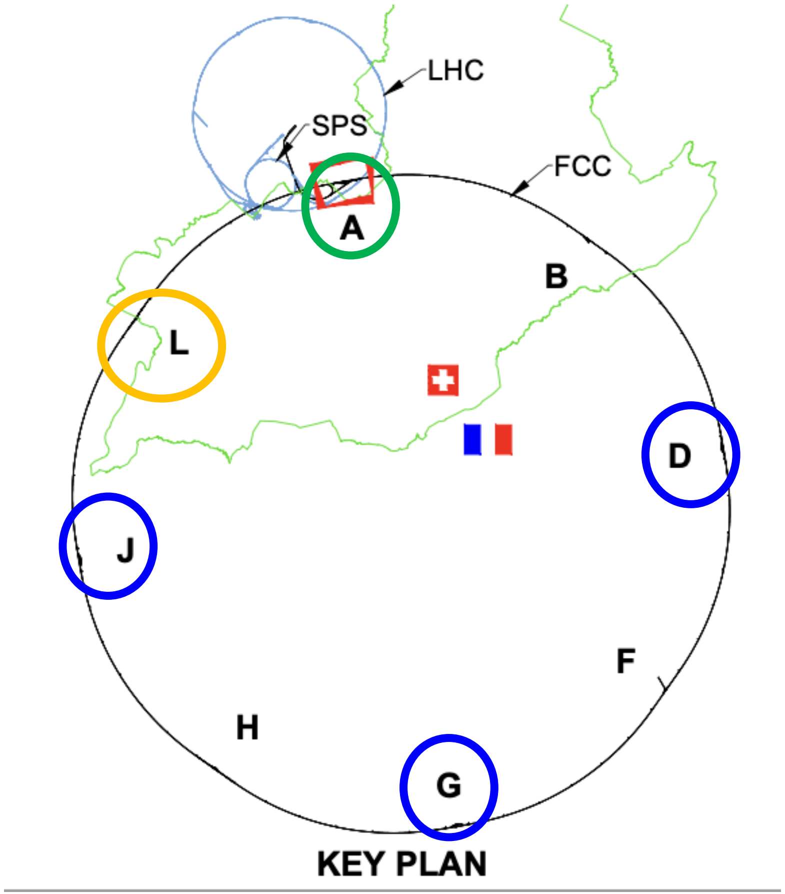
- Instrument location: both ends of LSS on each experimental **IP A.**
- Laser room should have a **24/7 access to insure availability**.
- **Needs dedicated laser hutch and access tunnels.**
- Energy at IPs is inferred from one measurement point.
- Energy loss (Tapering), along the ring **induce systematic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

Redundancy option : four polarimeters per beam (8 total)

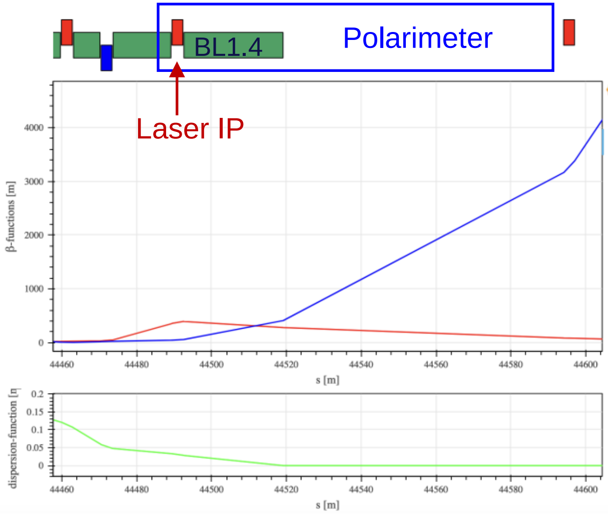
- Instrument location: both ends of LSS on each experimental IP **points A D G J**
- Each exp. IP would need **dedicated hutch and access tunnels.**
- Energy calibration done at each IP, **reduced systematic errors**.

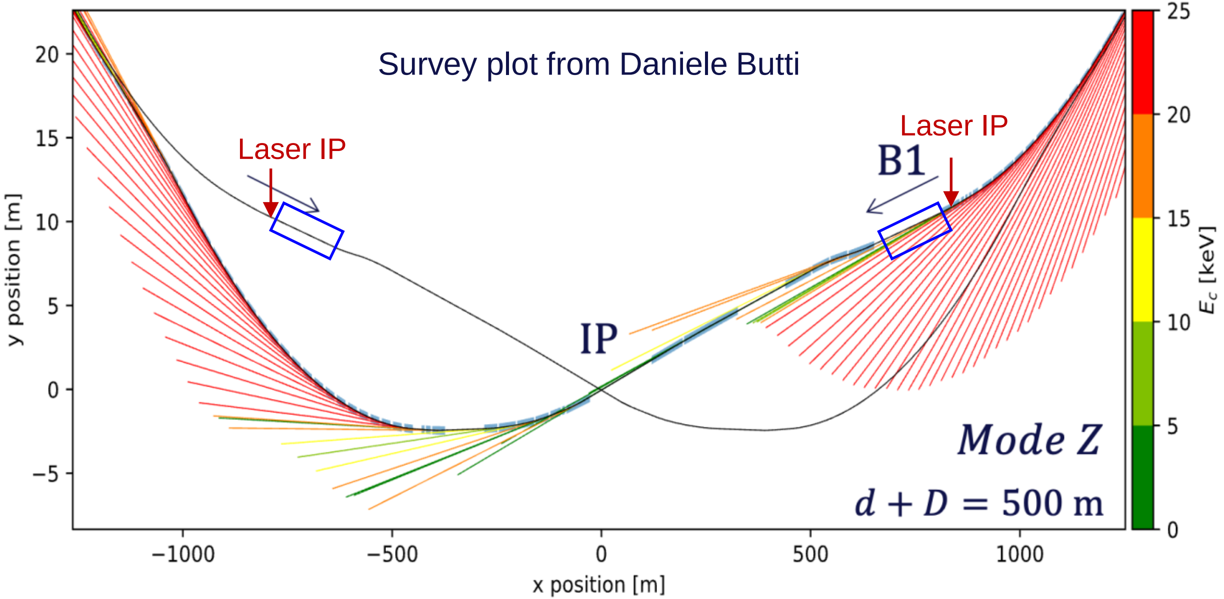
Other option under study: one polarimeter per beam (2 total)

- 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.



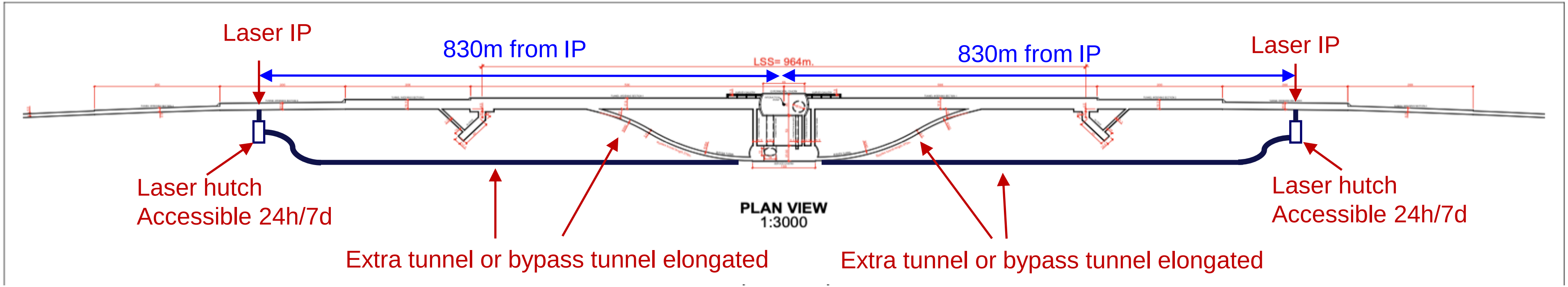
FCCee Polarimeters baseline in Experimental IP A





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

FCCee Polarimeters baseline in Experimental IP A



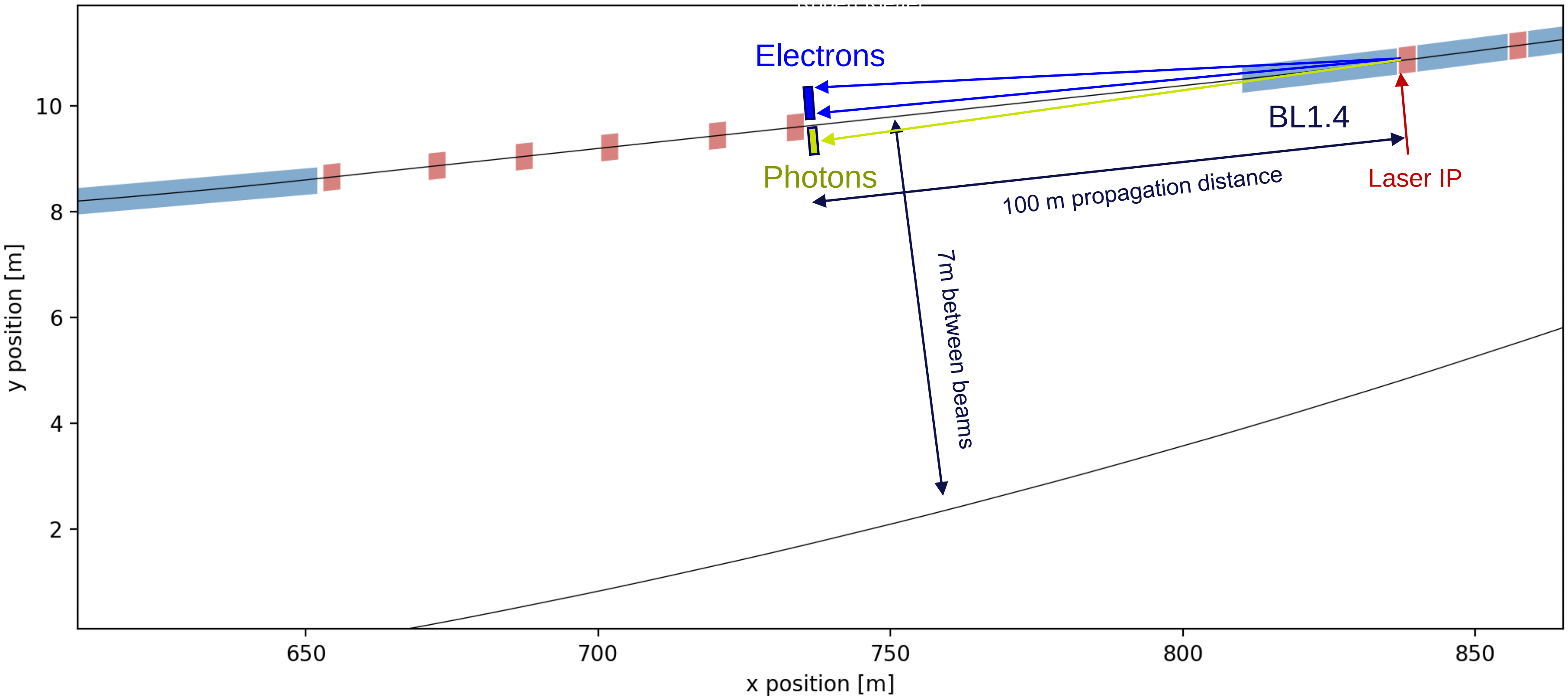
The base line is to use the magnet BL1.4 as spectrometer on each beam, followed by 75m of free beam propagation to separate the compton photons and compton electrons from the main beam.

In order to insure full time availlabilty of the RDP energy calibration the **Laser hutch need to be accessible 24h/7days**.

The transport line between the Laser hutch and Laser IP need to be less than 50 meters lenght. As few mirror folds and view ports as possible to maintain a good **laser circular polarisation**.

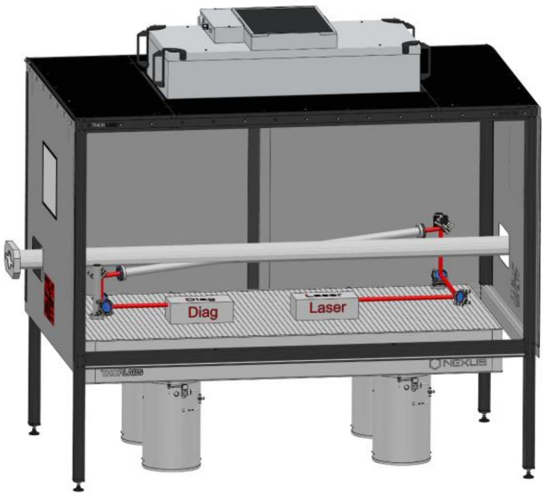
Only **one experimental IP need such extra civil engeenering** since the base line is for one polarimeter per beam. **Point A** would be the best choice for a faster response in case of failure.

FCCee Polarimeters baseline in Experimental IP A

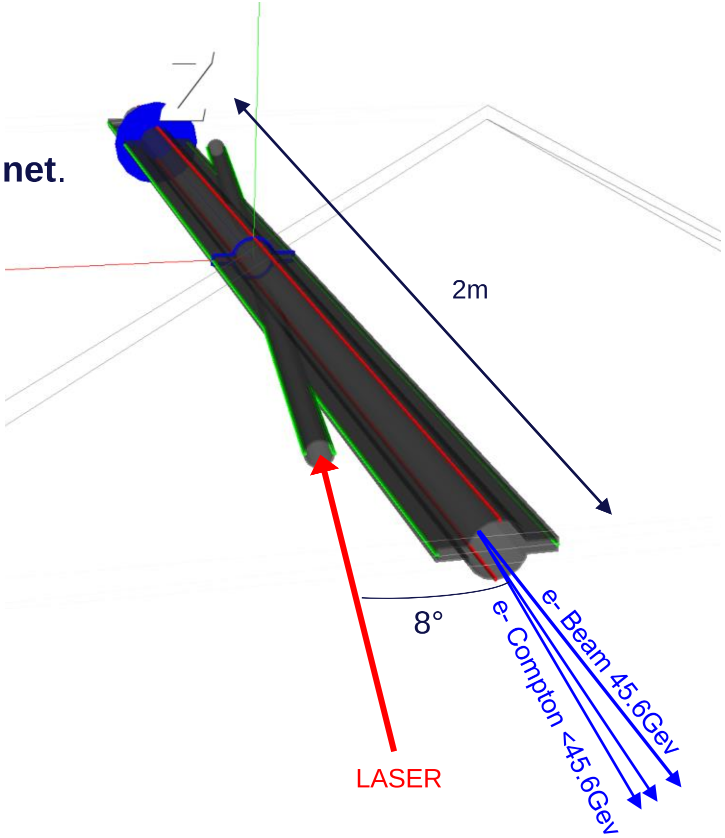


Laser interaction chamber (LIP)

Design like the SuperKEKB polarimeter LIP
Chamber length **2 meters**, placed just **before the spectrometer magnet**.
Laser incidence angle **2° to 8°**
Laser hutch situated away from radiation, accessible **24h/7d**
Very precise **circular polarization** control needed.

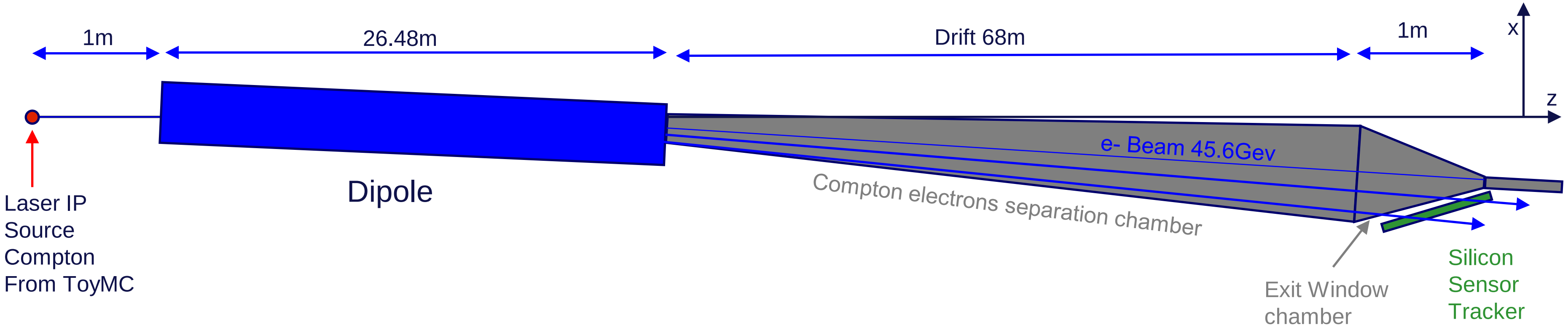


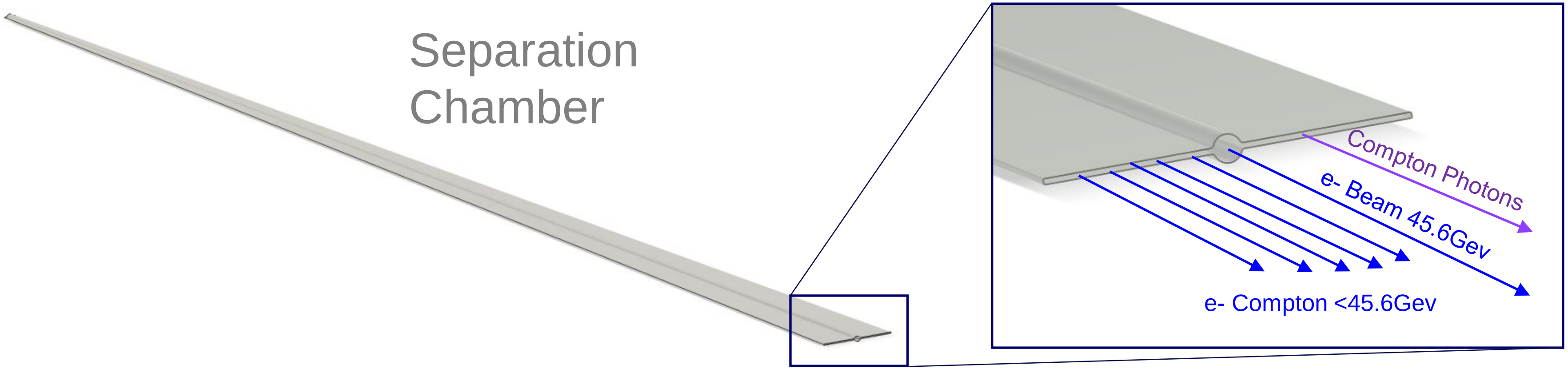
SuperKEKB polarimeter laser interaction chamber
DOI 10.1088/1748-0221/18/10/P10014



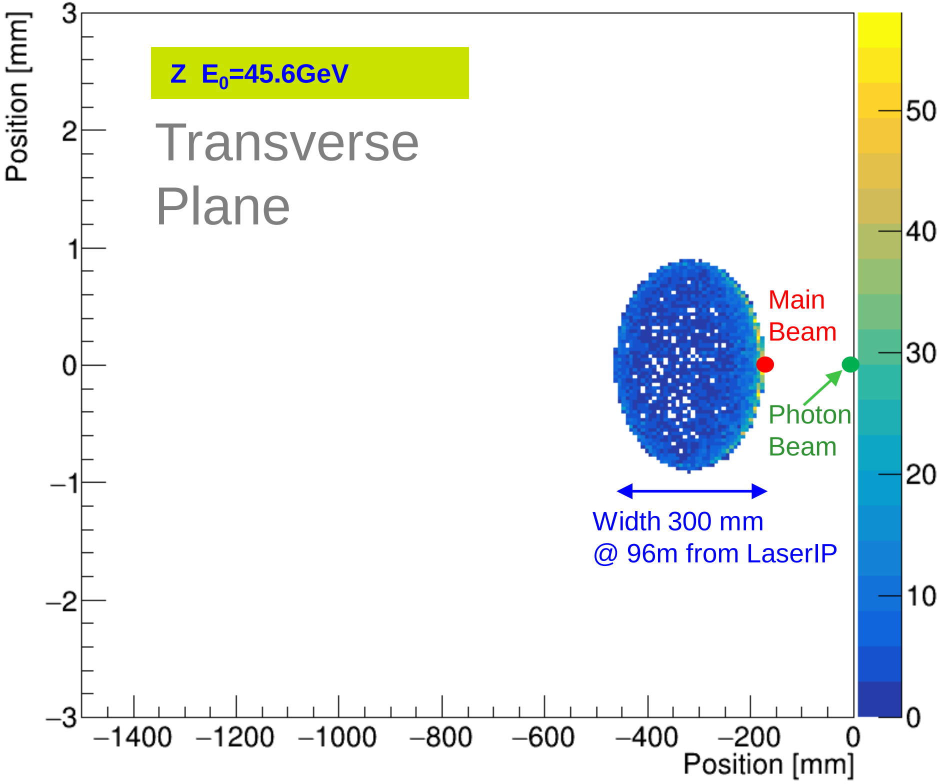
BDSIM model of the polarimeter LIP chamber

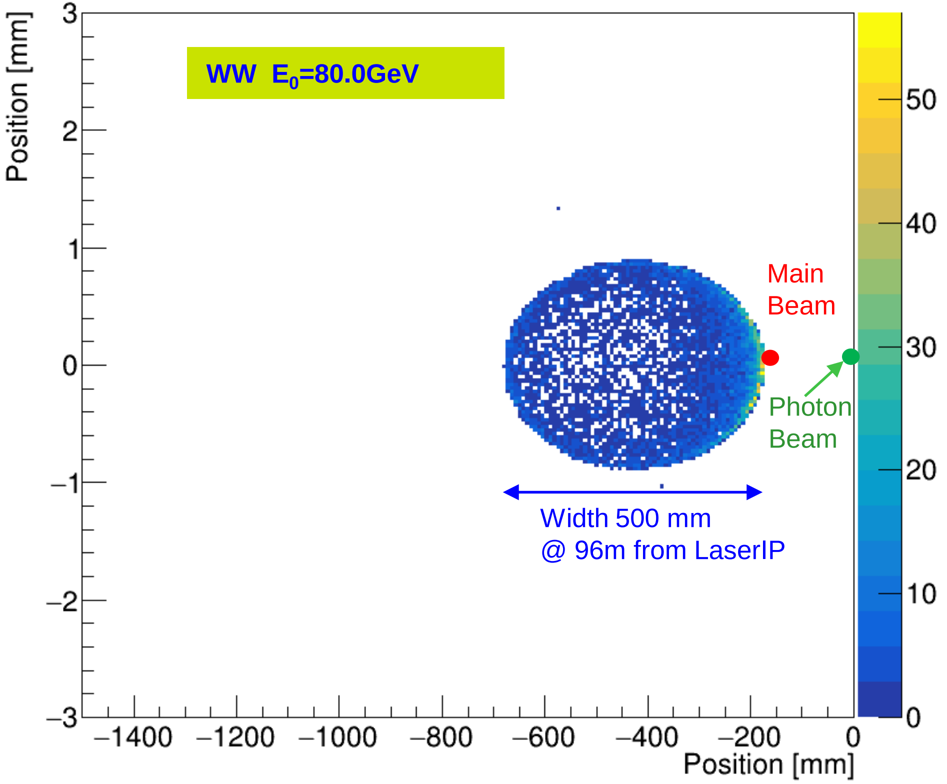
BDSIM Model description of Compton electrons separation



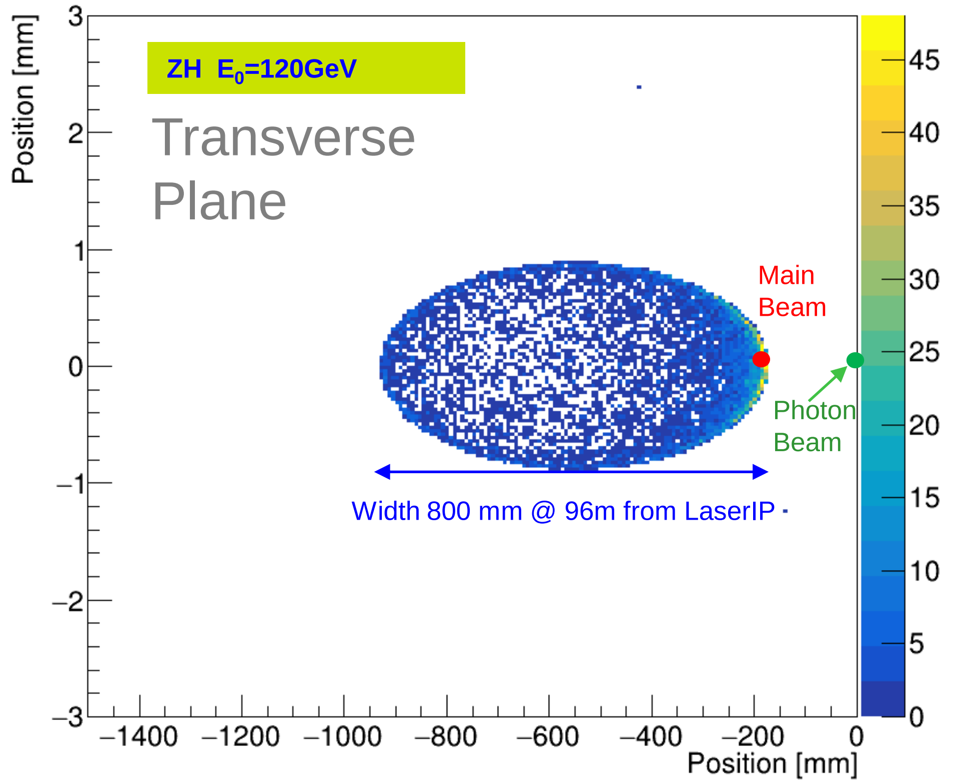


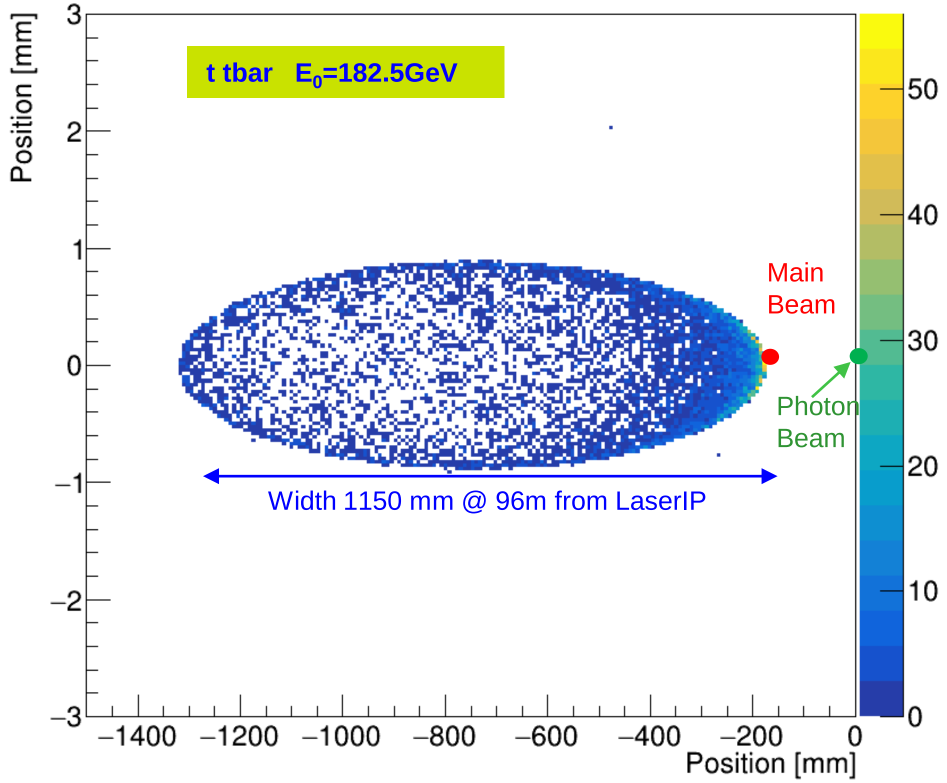
Compton electron pattern at different run energies Exiting the Separation Chamber (96m from LIP)





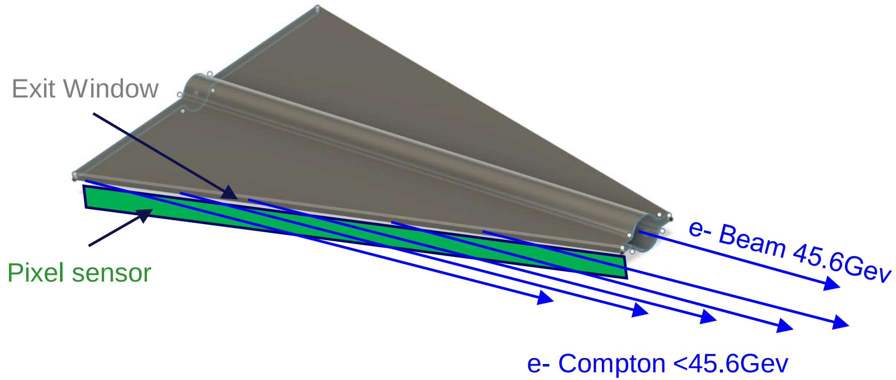
Compton electron pattern at different run energies Exiting the Separation Chamber (96m from LIP)

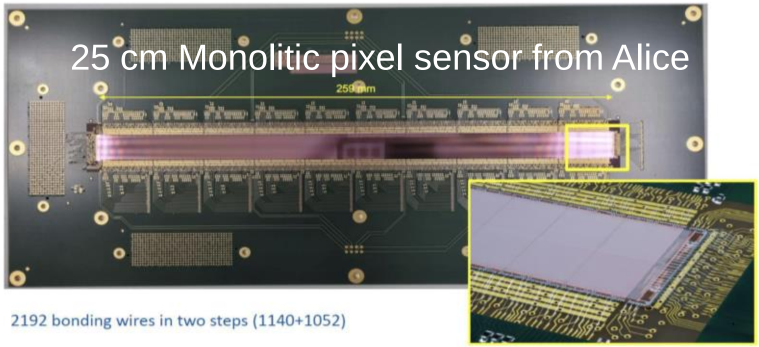




Capturing the compton electrons pattern

The pixel detector need to be placed collinear with the exit window **as close as possible**

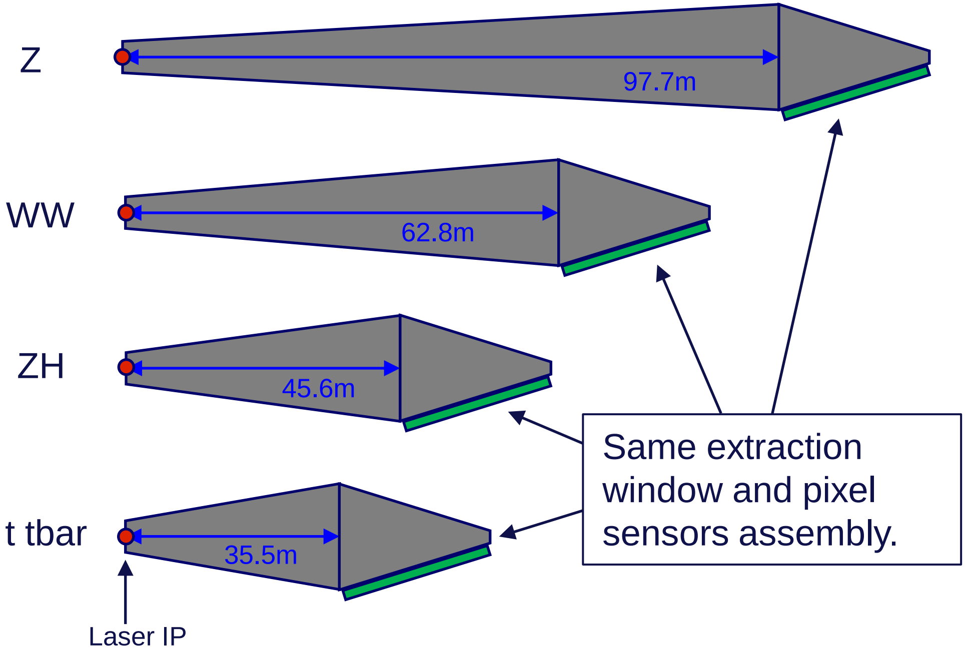




Mode	Width at 96m Transverse	Width at 96m 15deg extraction	Height of the pattern
Z	300 mm	1160 mm	2 mm
WW	500 mm	1931 mm	2 mm
ZH	800 mm	3090 mm	2 mm
t tbar	1150 mm	4443 mm	2 mm

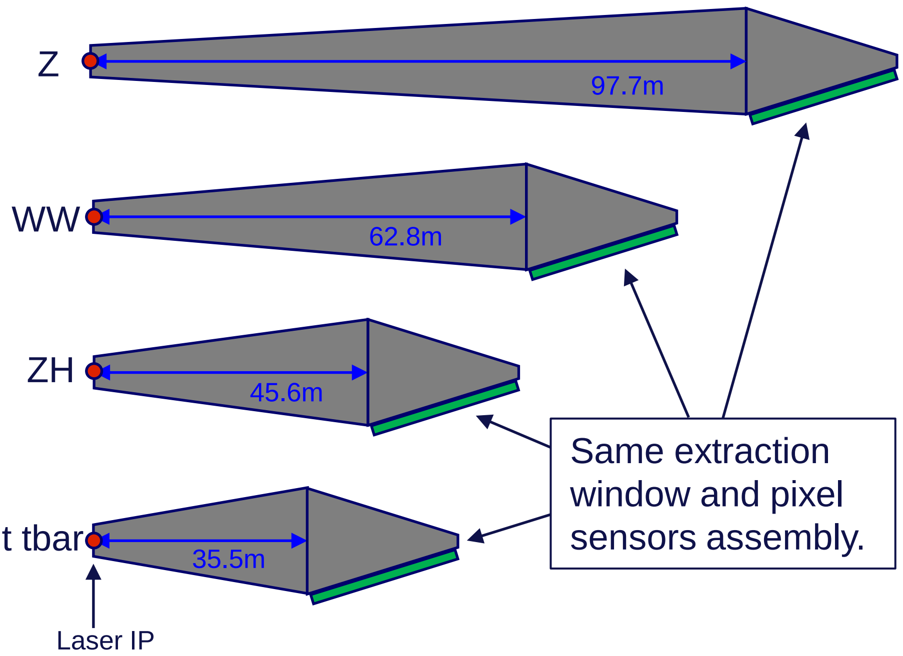
Compton electron pattern at different run energies

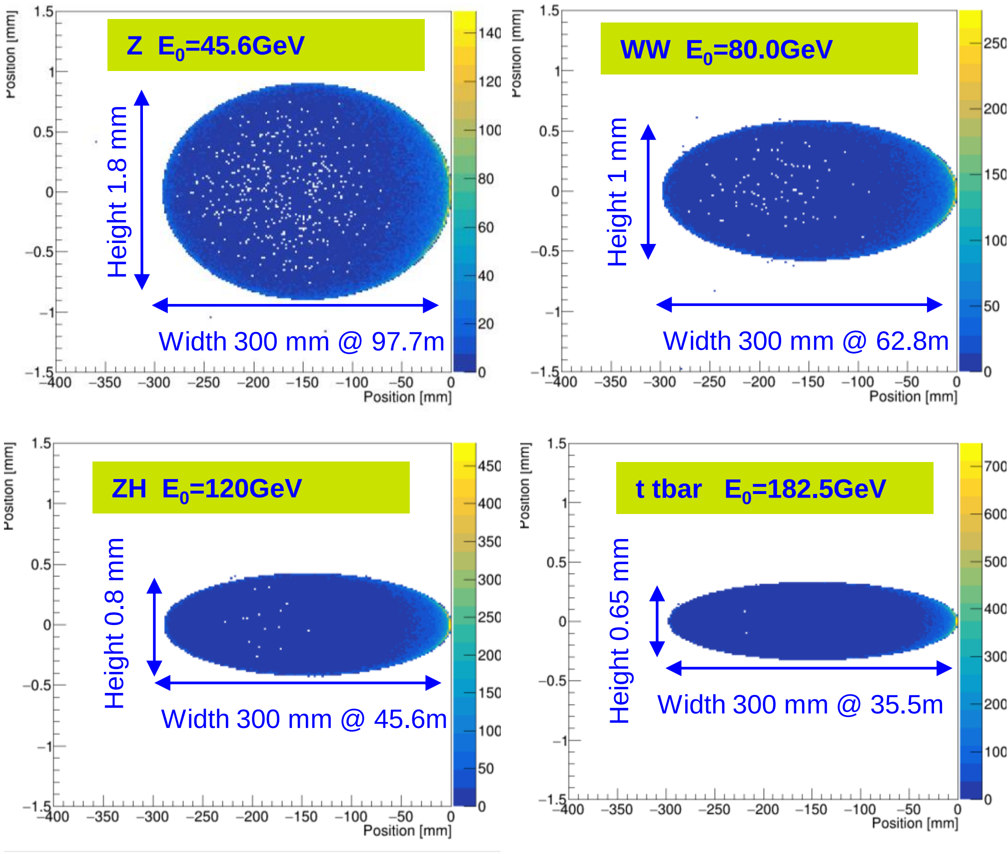
Another solution would be to produce **different separation chambers lengths** keeping the extraction-window/pixel-sensors assembly for all energies.



Mode	Width transverse	Separation chamber lenght	Electron fan opening angle
Z	300 mm	97.7 m	3.4 mRad
WW	300 mm	62.8 m	6 mRad
ZH	300 mm	45.6 m	9.3 mRad
t tbar	300 mm	35.5 m	14.4 mRad

Compton electron pattern at different run energies





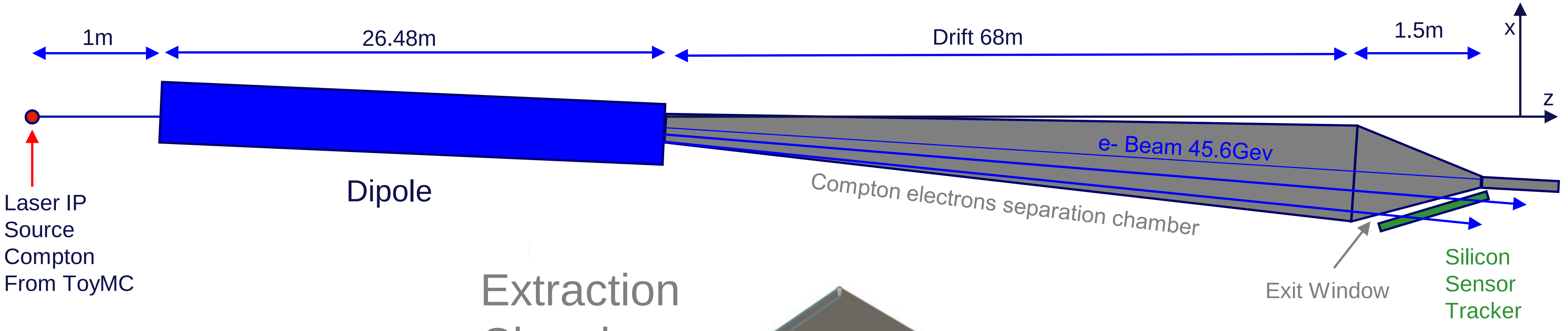
BDSIM geometry modeling with pyg4eometry

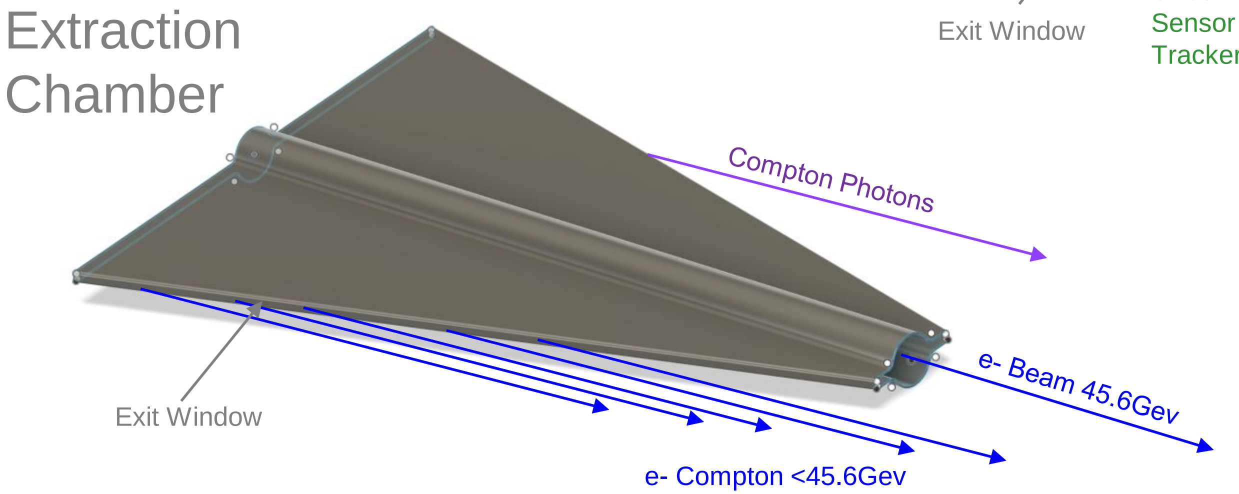
Main concern in terms of design the **extraction angle**

- Constrained by **wakefields** and beam **impedance** effects (need CST cross-check).
- Smaller the **extraction angle**, higher the **thickness of exit window** material crossed by the emerging electrons (more interaction and secondaries).
- Smaller the **extraction angle**, larger the **width of the pixel tracker** needed.
- Crossing a **pixel detector at a small grazing angle** is not the best configuration for spatial resolution.

Ideal would be a thin exit window in the transverse plane…
Two studies are made at **15 and 30 degres** in order to evaluate the needed sensor size.

BDSIM Model description of Compton electrons extraction

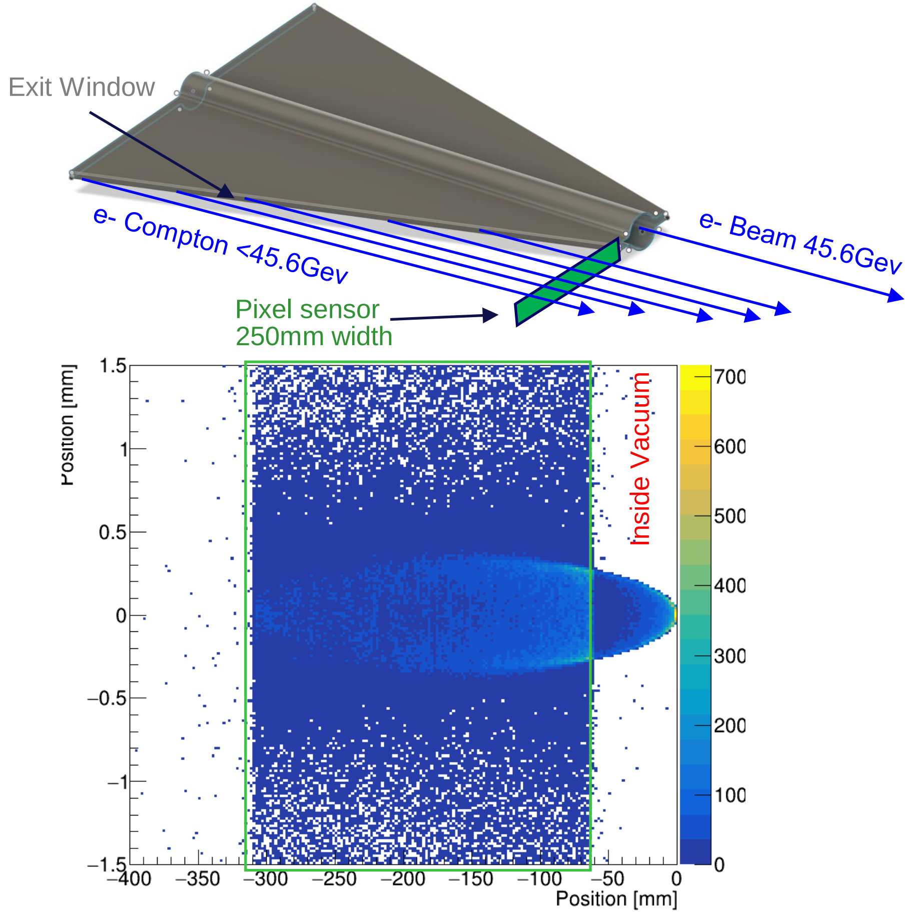


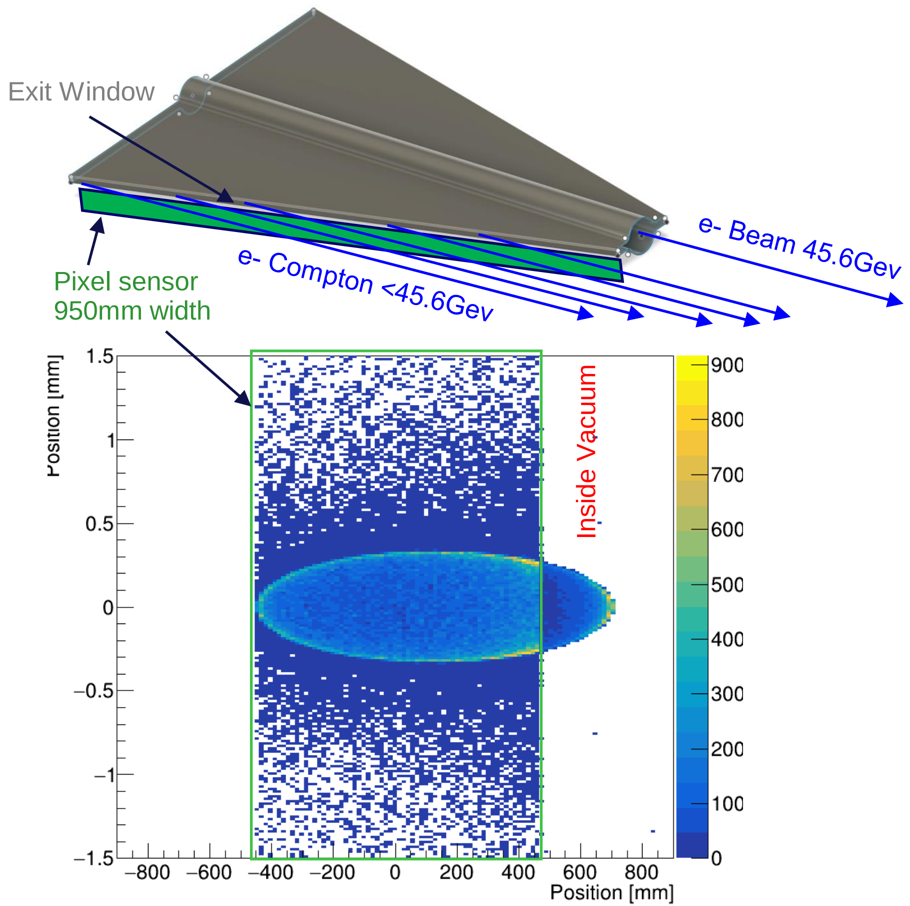


The exit window need to have a small tapering angle to reduce wake fields.

Effectively increase the material thickness crossed by the Compton electrons.

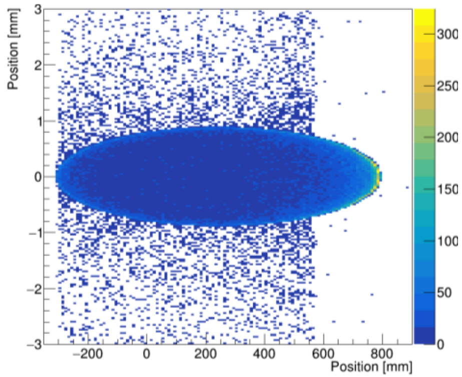
Compton electron pattern pixels plane orientation





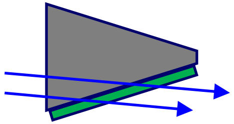
Distance between the extraction window and the pixel sensors

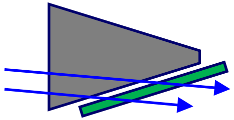
XY Profile **before the extraction window**

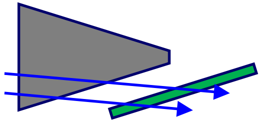


BDSIM simulation of the Compton electrons crossing a **2 mm copper extraction window with 15º angle**. Sampling at different distances from the exit window.

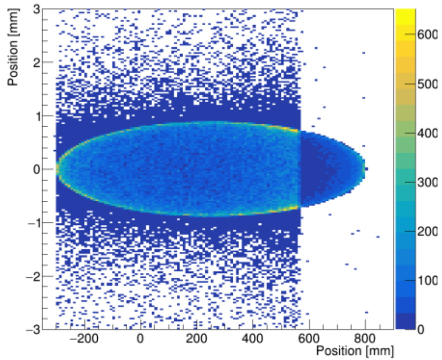
Conclusion: Need to be as close as possible from the extraction window, in order to preserve the profile and fit the distribution accurately.



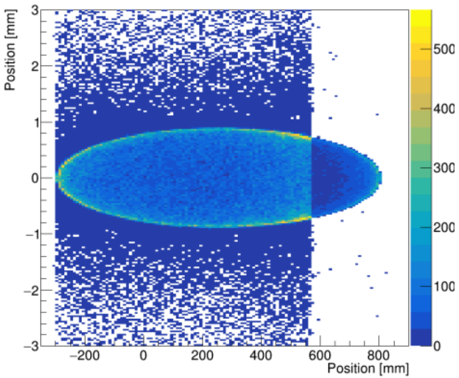




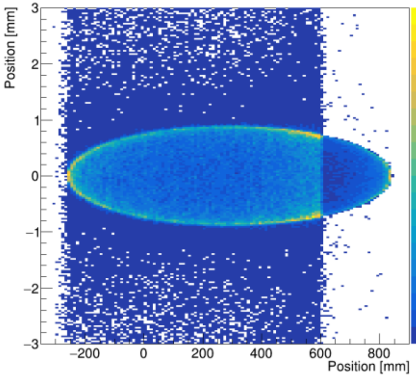
XY Profile at s_XExit



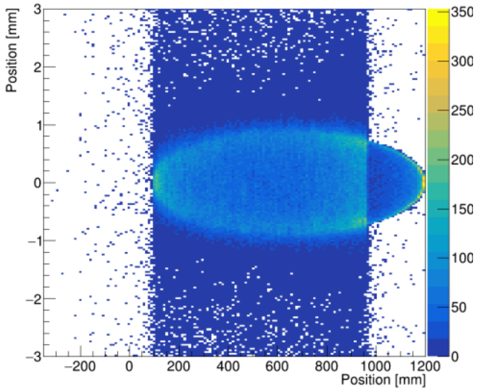
XY Profile at s_X001mm



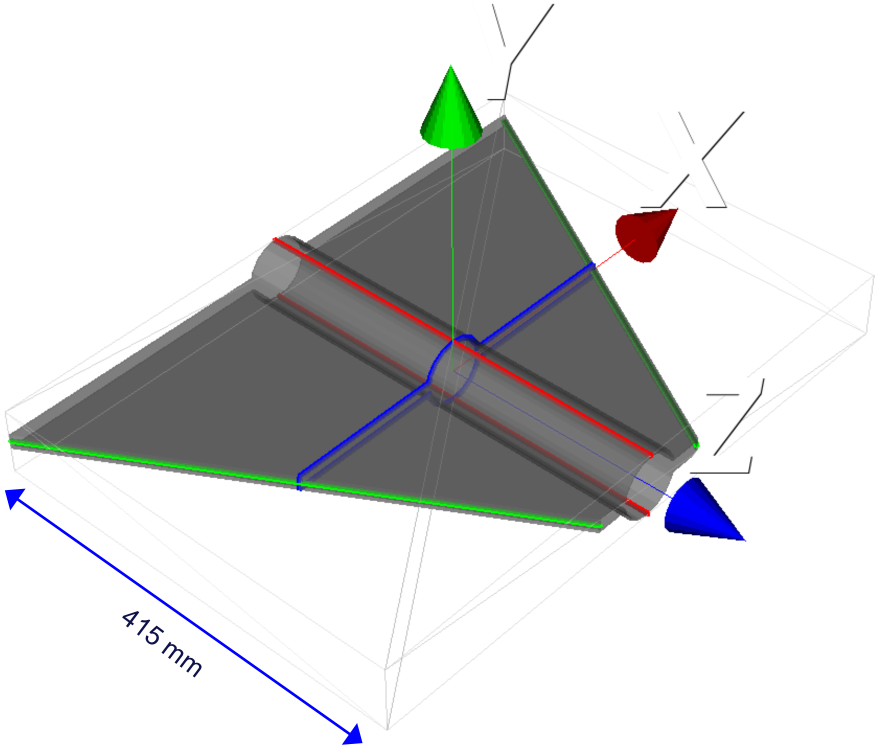
XY Profile at s_X010mm



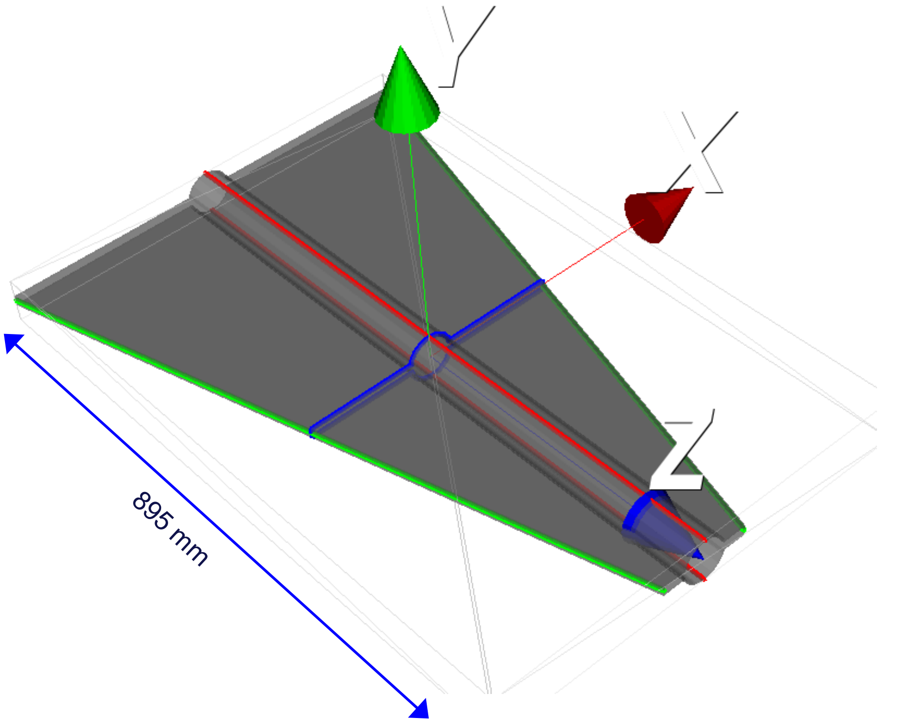
XY Profile at s_X100mm



Extraction window chamber tapering angle

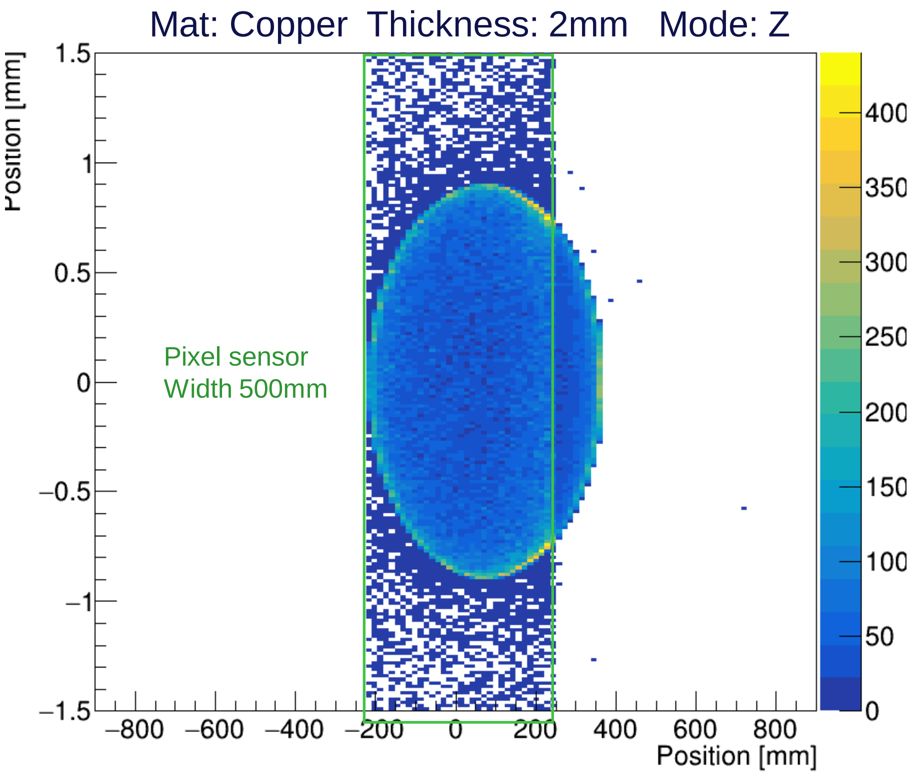


30 degrees angle

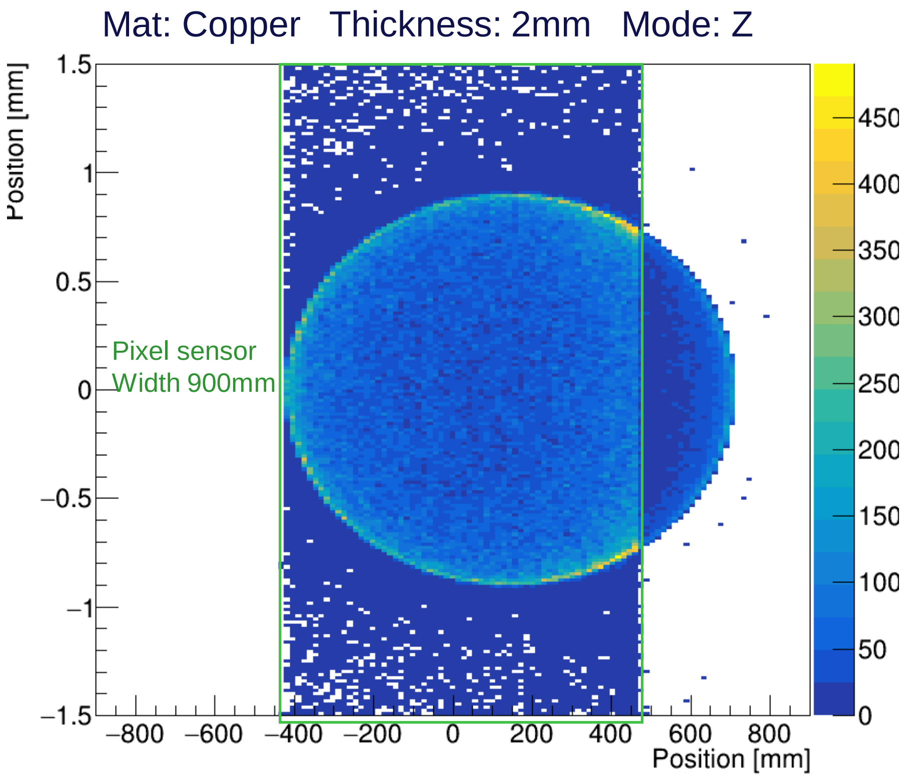


15 degrees angle

Extraction window chamber tapering



30 degrees angle



15 degrees angle

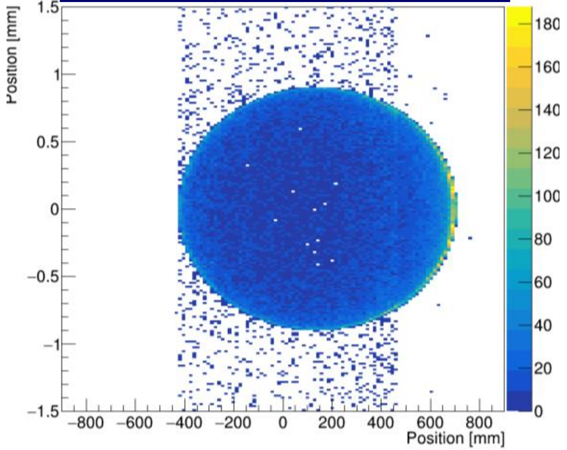
Extraction window material/thickness

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

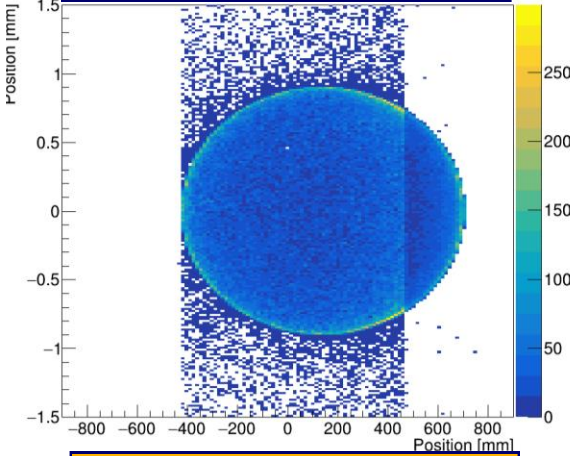
Aluminium and Copper
Two ticknesses 1-2 mm

1 mm Aluminium is the most transparent solution.

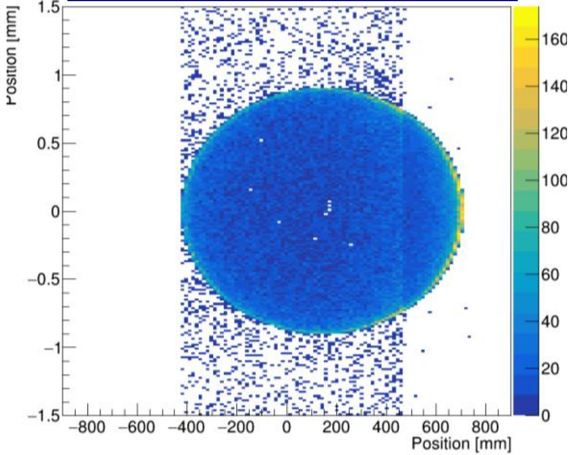
Aluminium 1 mm at 15 degrees



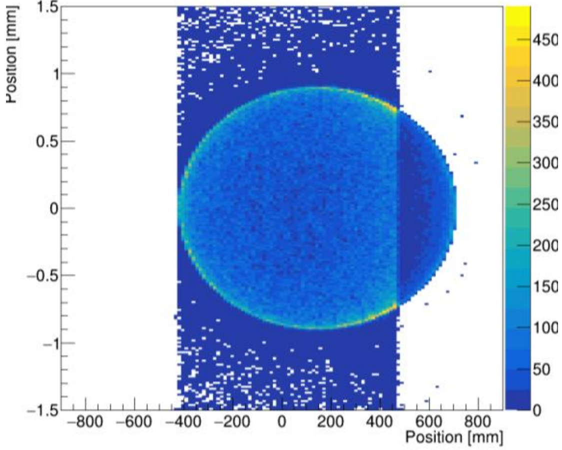
Copper 1 mm at 15 degrees



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

Xsuite

Waiting for spin tracking to be implemented

BDSIM Compton

Missing electron polarization to be added

BDSIM particle transport

Spectrometer Magnet and extraction window particles interaction

AllPixSquared

Silicon sensor modeling and Digitization

Root plot and fitting

Producing phase space profiles of Digitized data

Long term plan

Next steps for the simulations

- Try other **Materials** and **thicknesses** for the extraction window in BDSIM (Cu, Al, C…)
- Parametric BDSIM study of the **extraction window angle** (only 15º and 30º angle tested)
- **CST** simulation of the extraction window chamber designs to evaluate **wake fields**.
- Implement the **pixel detector digitizer** and apply pattern fitting afterward.
- Do the same work for the **Compton photons** (Si-Tungsten electromagnetic calorimeter design)
- Once the chain is validated add **Noise contributions** (SR, bremsstrahlung, thermal photons) and evaluate **background generated by the Compton electrons toward the experiments**.

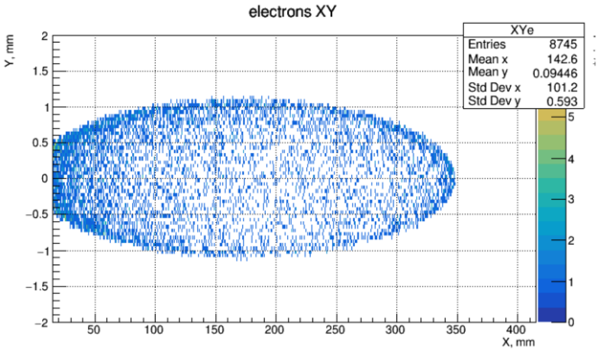
Resonant De-Polarization (RDP) scans

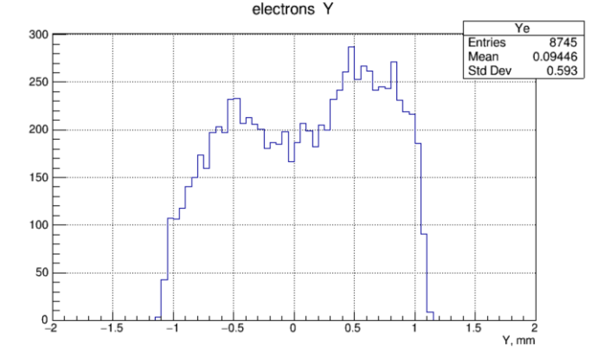
How many turns to detect a de-polarization is happening?

- 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.

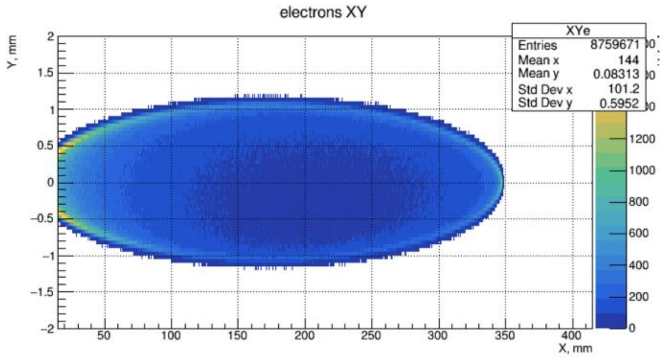
To be compared with the **duration of the RDP kicker sweep** sequence (100-300 seconds).

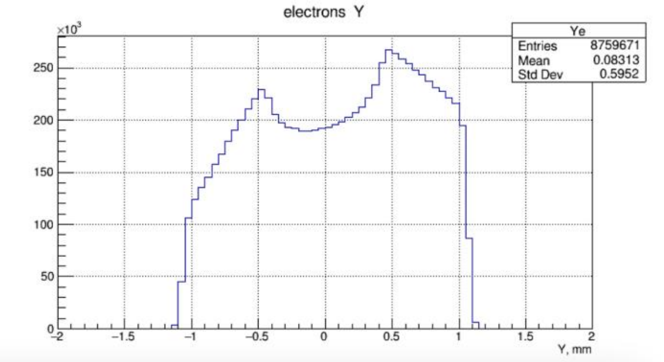
During this sweep we need to detect when the **vanishing of the polarization occurs**.





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





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

Resonant De-Polarization (RDP) scans

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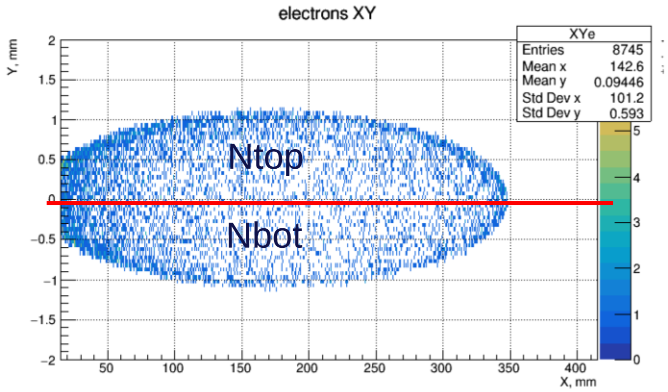
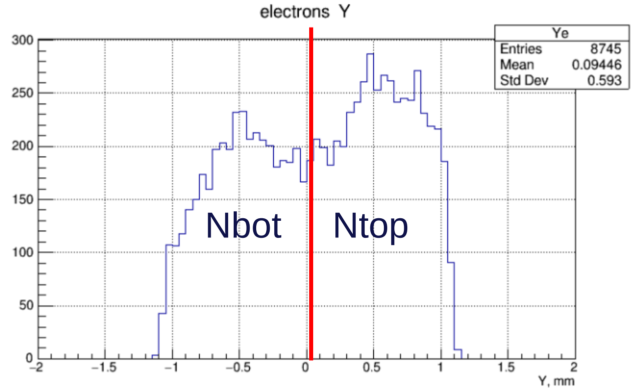
PATTERN ASSYMETRY
Assym = (Ntop-Nbot) / (Ntop+Nbot)

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





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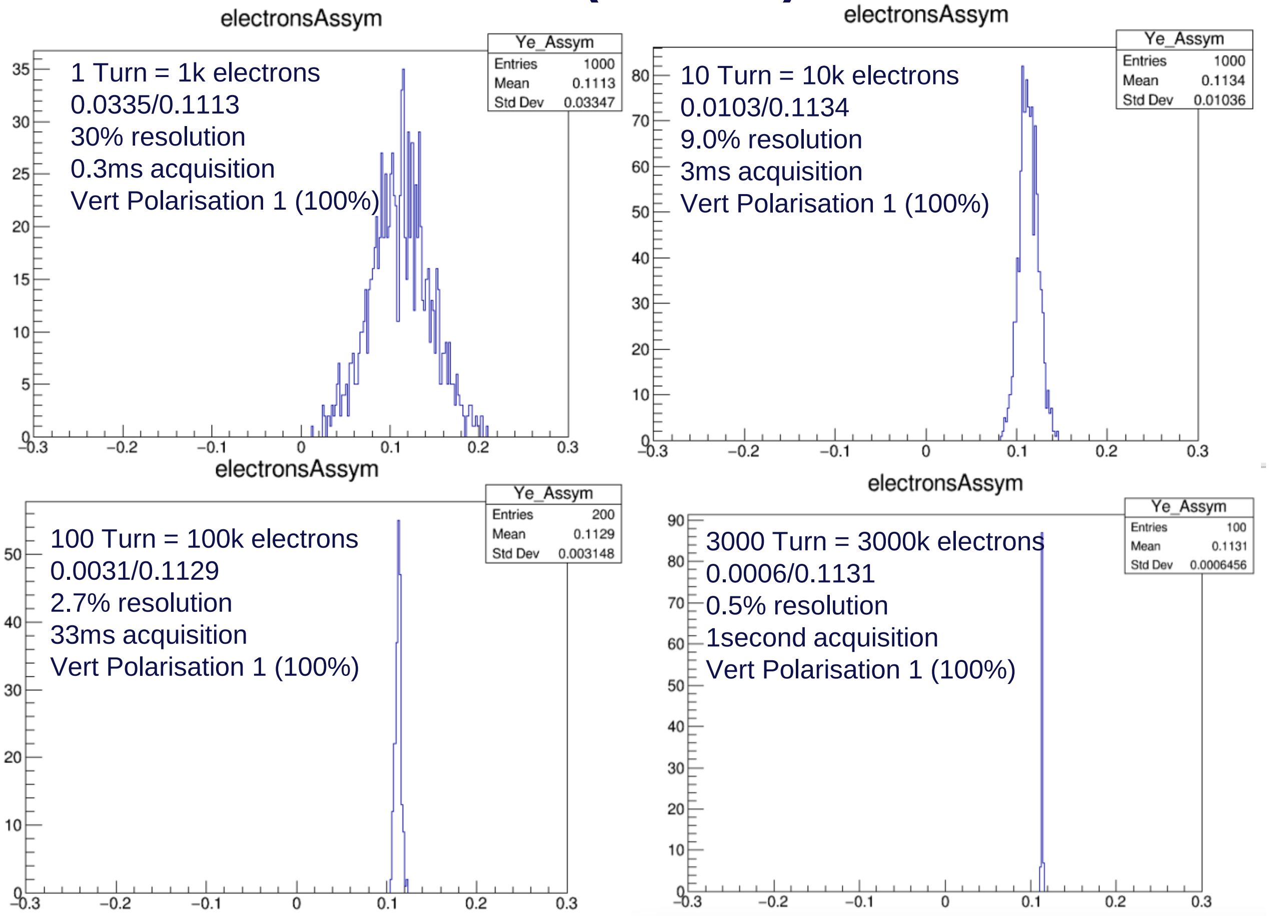
PATTERN ASSYMETRY
Assym = (Ntop-Nbot) / (Ntop+Nbot)

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

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



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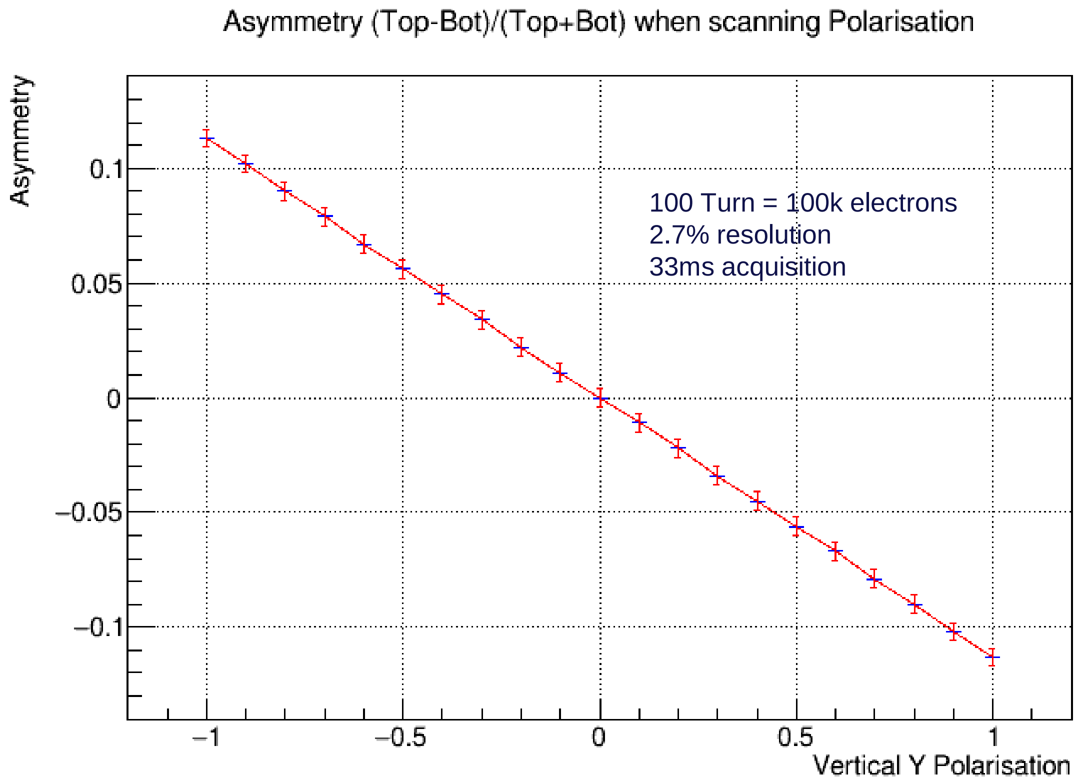
PATTERN ASSYMETRY
Assym = (Ntop-Nbot) / (Ntop+Nbot)

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

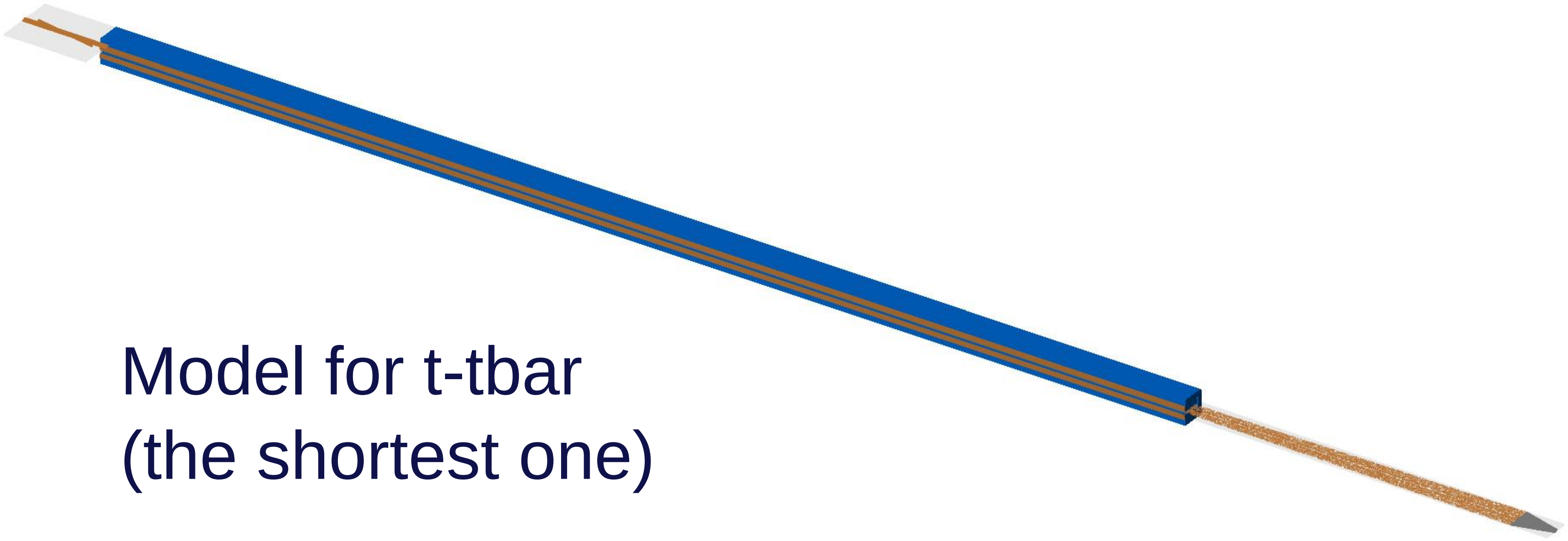
- Simulation work started in BDSIM, much more work to be done (digitization, fitting procedure, CST)
- Instrument specifications and running modes still not fully defined (how often physics bunches need to be probed for **longitudinal polarization**, do we aim for **free spin precession measurement**, etc..).

Discussion on the number of polarimeters needed

- Up to now the **baseline** is a **single pair of polarimeter in point A**
- We are looking into **point L option** since it would reduce drastically the civil engineering (by 50MCHF)
- The discussion about having a **pair of polarimeter at each experimental IP** often comes back.
- A **strong statement from the whole EPOL working group** would be needed to push forward on this.
- The “polarimeter-specific” civil engineering would then be needed at each IP (200MCHF total)
- The civil engineering will be frozen this September, **the statement would need to come beforehand**.

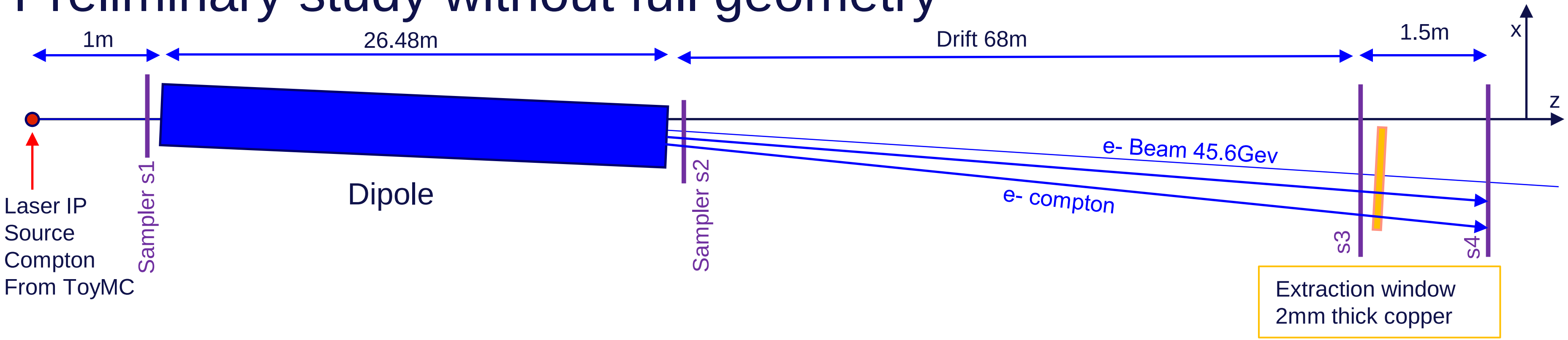
Thank you for your attention.

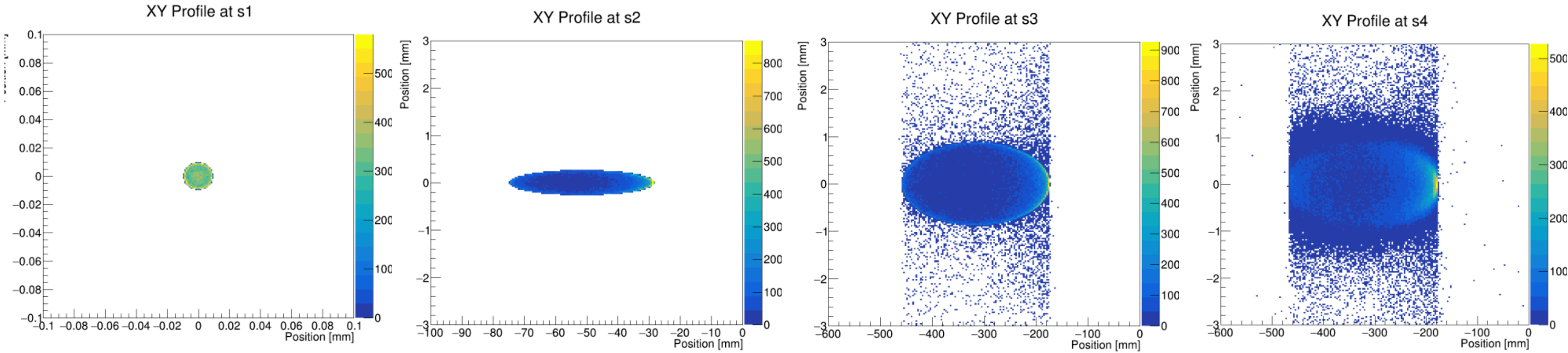
BDSIM Model description of Compton electrons extraction



Model for t-tbar
(the shortest one)

BDSIM Model description of Compton electrons extraction Preliminary study without full geometry

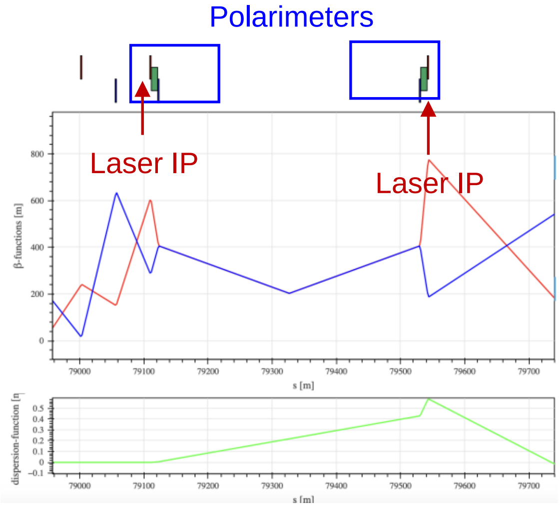


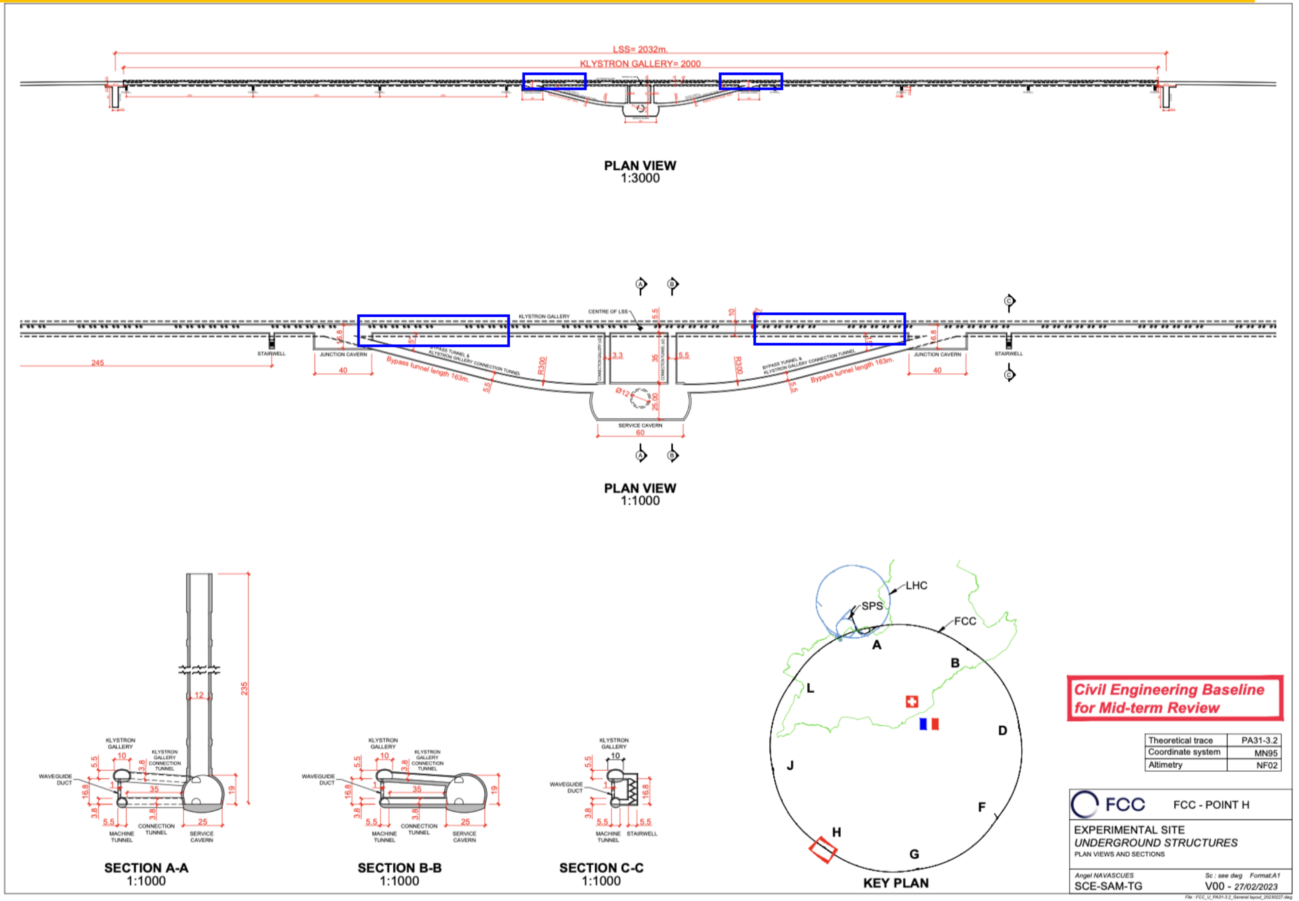


Other option : FCCee Polarimeters in point L

Polarimeter at IP L

- Laser in Klystron gallery
- Instruments installed close to the RF cavities from the booster
- After the dipole Electrons need a magnet free path to the pixel detector (80m long).

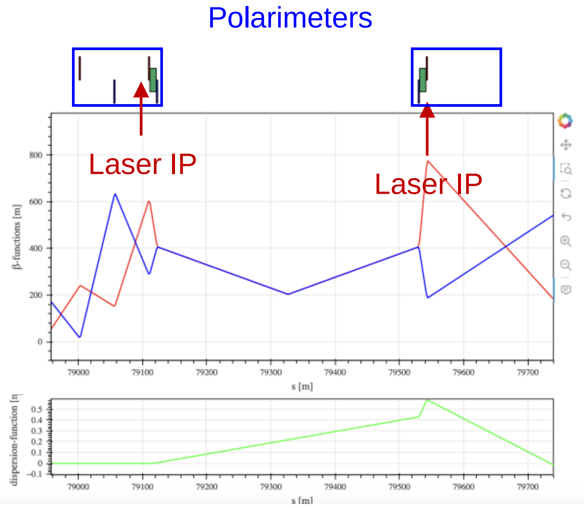


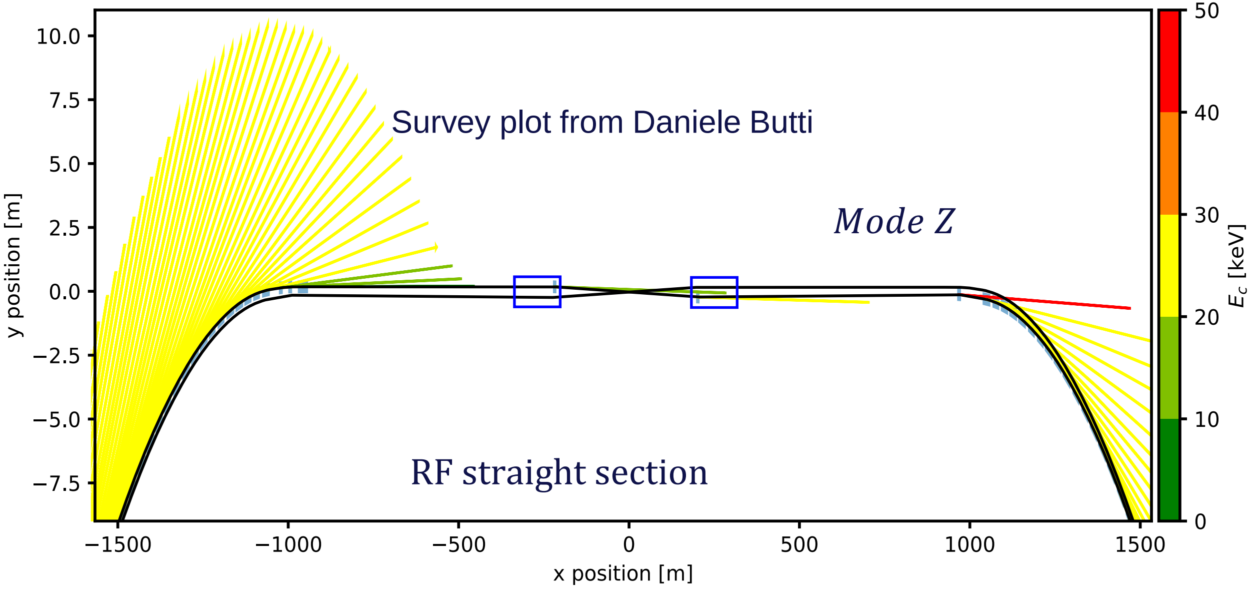


Other option : FCCee Polarimeters in point L

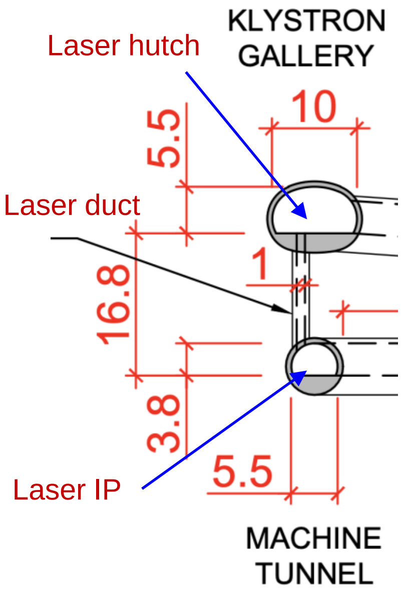
Polarimeter at IP L (RF booster)

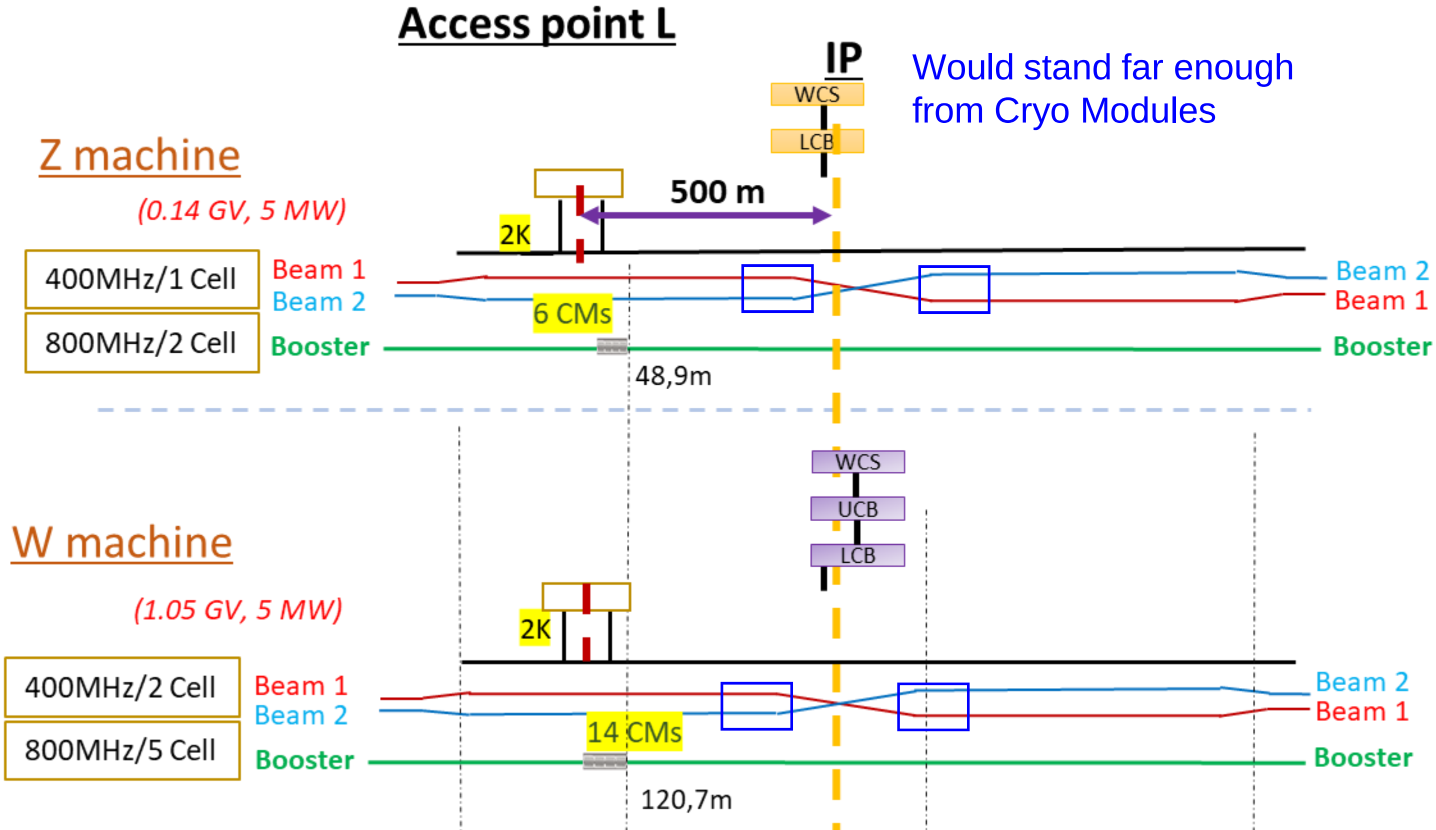
- Laser in Klystron gallery (24/7 access)
- Instruments installed under the RF cavities from the booster.
- After the dipole, electrons need a magnet free path to the pixel detector.





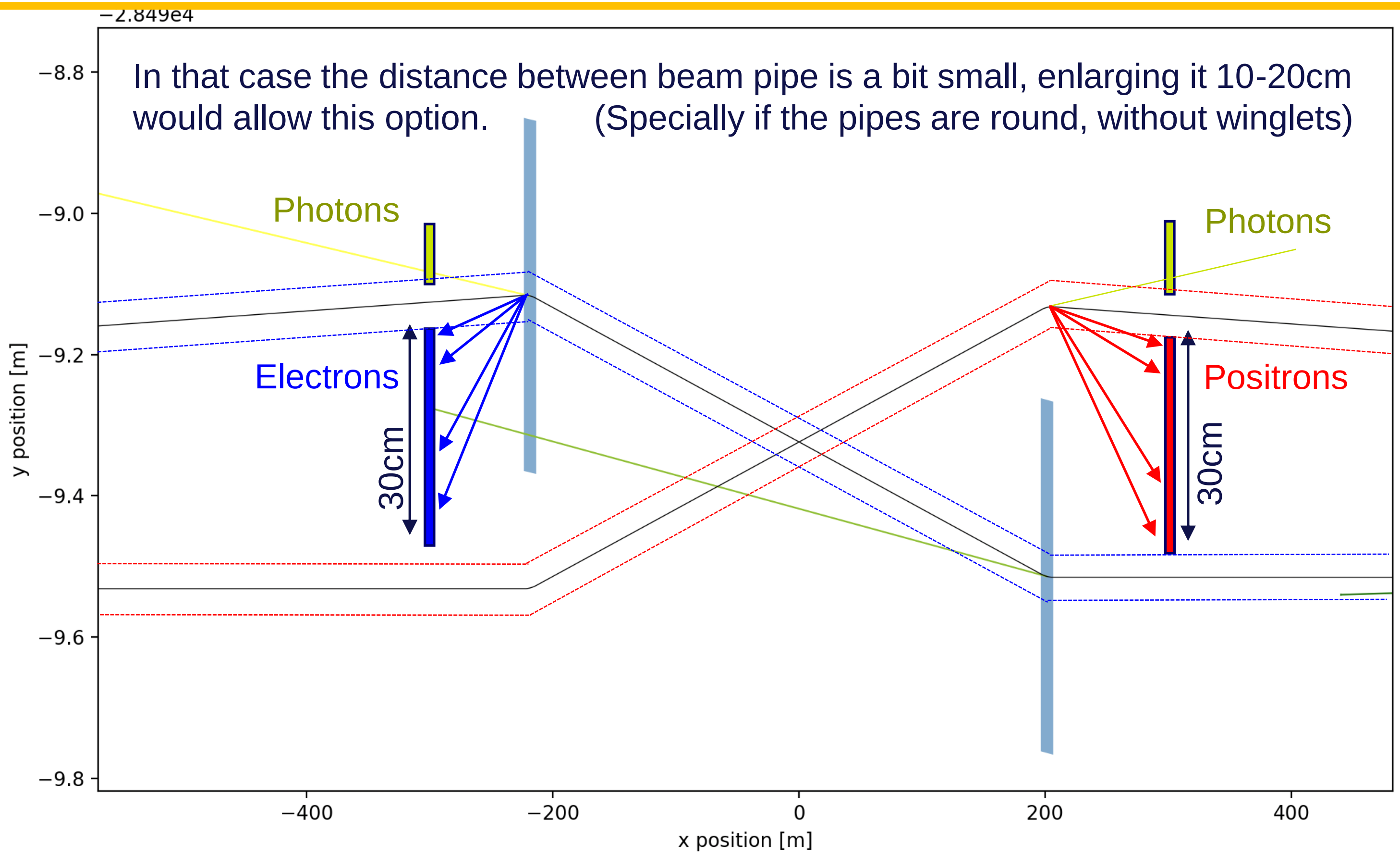
Other option : FCCee Polarimeters in point L



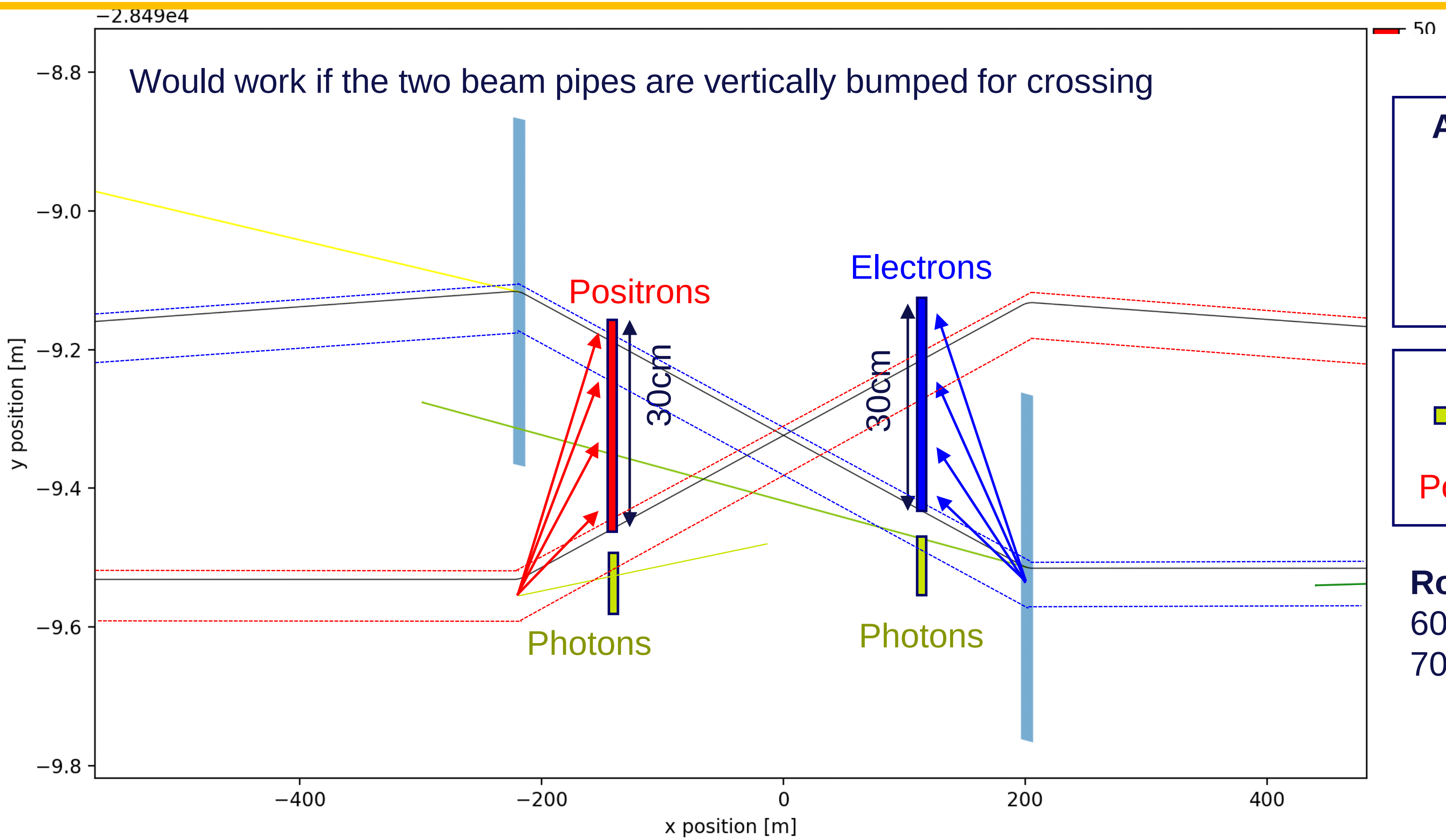


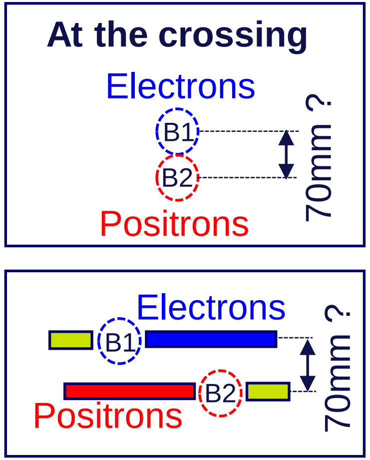
Would stand far enough from Cryo Modules

Other option : FCCee Polarimeters in point L



Other option : FCCee Polarimeters in point L





Round beam pipe ?
60mm inner diam ?
70mm outer diam ?