FCC POLARIMETER INTEGRATION AND CIVIL ENGINEERING

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

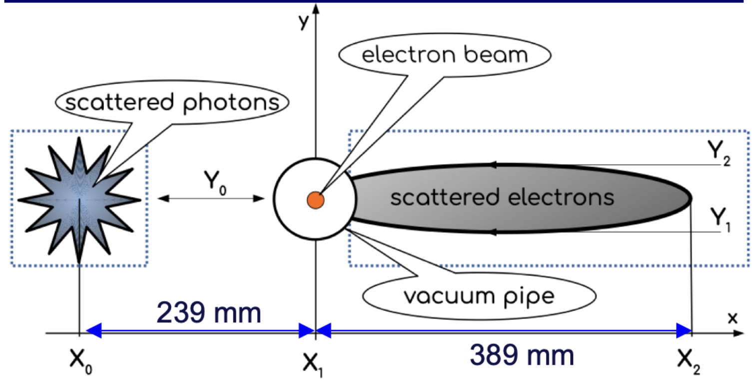
The FCC Compton polarimeter

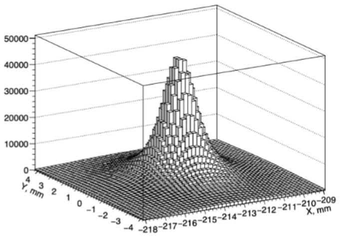
- **Centre of mass energy calibration** is obtained from the resonant depolarization scans (RDP) on pilots.
- **Direct energy measurement** by pattern position
- Precise **3D polarization measurement** on physics bunches (longit. expected to be zero at 10^{-5}).
- **Free spin precession** (looks challenging).

Implementation needs

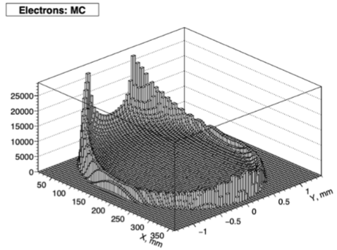
- Dedicated powerful laser and adapted hutch
- Laser Compton interaction chamber LIP
- Spectrometer magnet stuffed with Hall sensors
- Compton electron/photon extraction line chamber
- Particle sensors (silicon pixels detectors)
- Polarizing wigglers to speedup polarization buildup.
- RF kickers to apply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

Profiles At 96 m from Laser IP





8 x 10 mm²



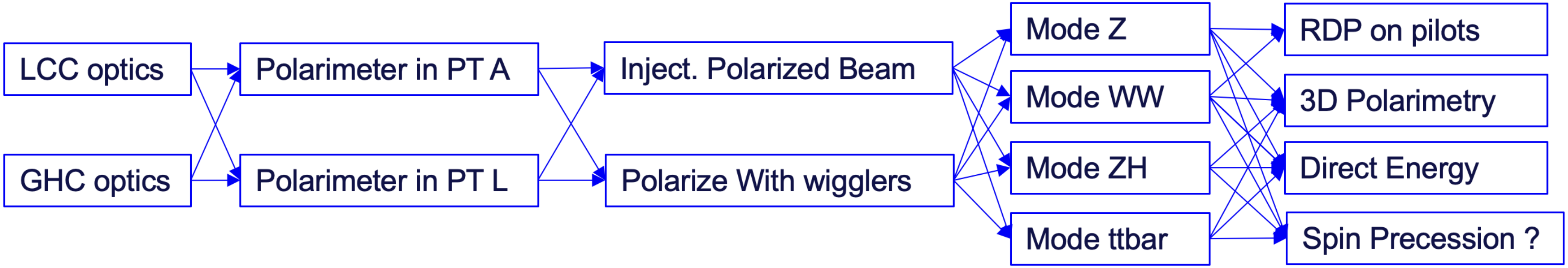
350 x 2 mm²

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, A. Martens)
- Civil engeneering and integration follow up (R. Kieffer, S. Mazzoni)

Almost 128 scenarios to study… for each beam.



Impact on instrument geometry.
Impact on civil engineering.
Impact on background in the polarimeter sensors.

Change polarization amount.
Change on running scenario.

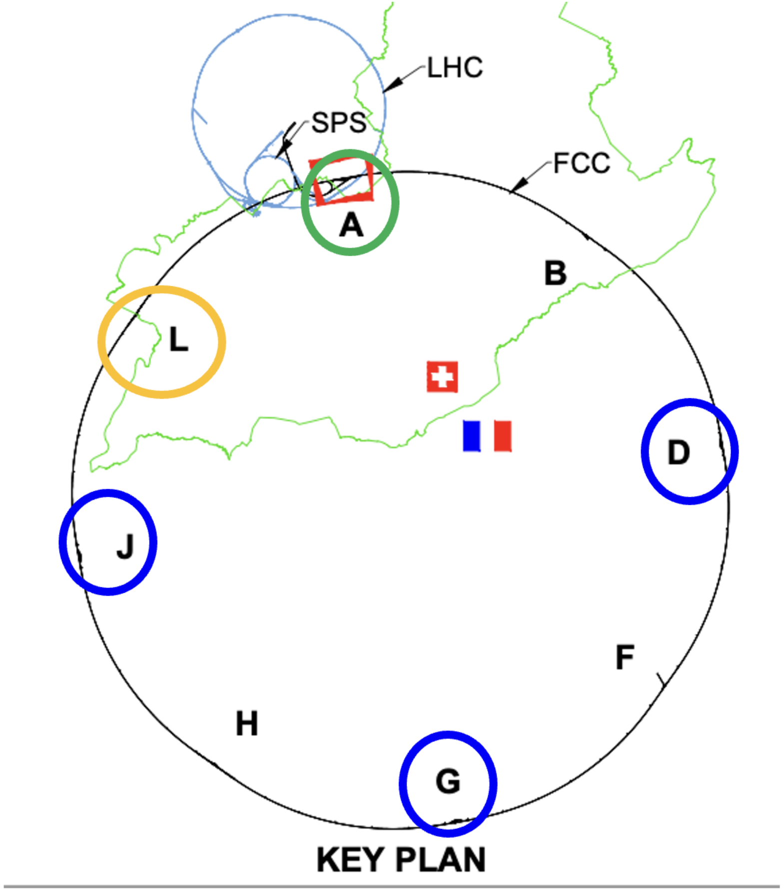
Specification and measurement needs are different for each running scenario.
Impact on the detector (MDI) when probing physics bunch.

FCCee Polarimeters

Base line: a single polarimeter per beam (2 total)
- Instrument location: both ends of **LSS** on experimental **IP A.**
- Laser room should have a **24h/7d access to insure availability**.
- **Needs dedicated laser hutch and access tunnels.**
- Energy at IPs is inferred from one single measurement point.

Option under study: a single polarimeter per beam (2 total)
- Instrument location in **point L booster RF**
- **Optics need to be changed to fit polarimeter requirements**
- **Possible for Z and W**, more difficult to fit for **ZH** and **Ttbar**
- **Difficult** to fit the Polarimeter chamber (transverse size 1-2m).
- Noise and **background from RF** could be a showstopper.
- Laser hutch in Klystron gallerie.

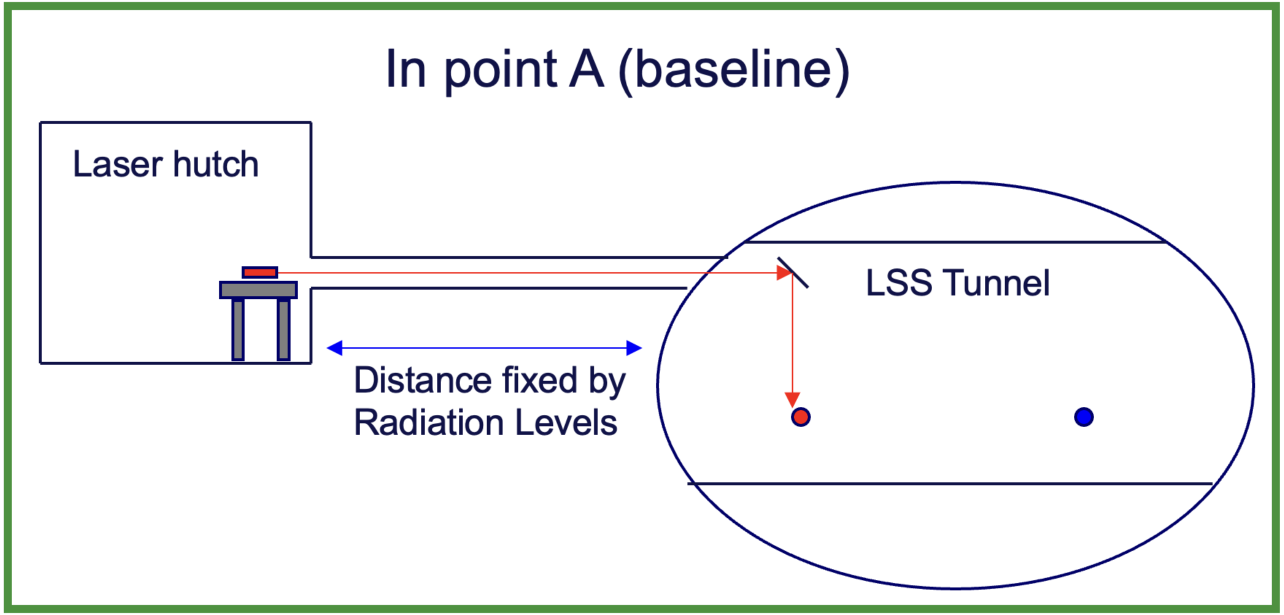
Redundancy option : four polarimeters per beam (8 total)
- Instrument location: both ends of LSS on each experimental IP **points A D G J**
- Each exp. IP would need **dedicated laser hutch.**
- Energy calibration done at each IP, **reduced systematic errors**.



Each polarimeter need a laser source

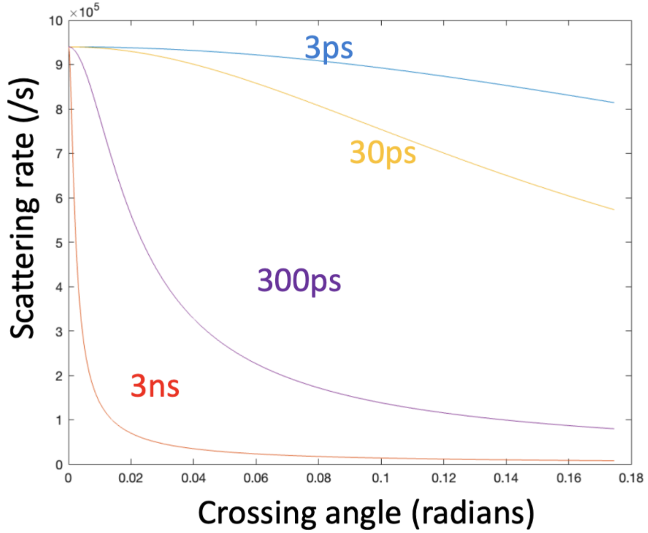
To insure full time availability of the FCCee energy measurement, the polarimeter laser lab need to be installed away from radiation source, close to Laser IP and accessible while the machine is running.

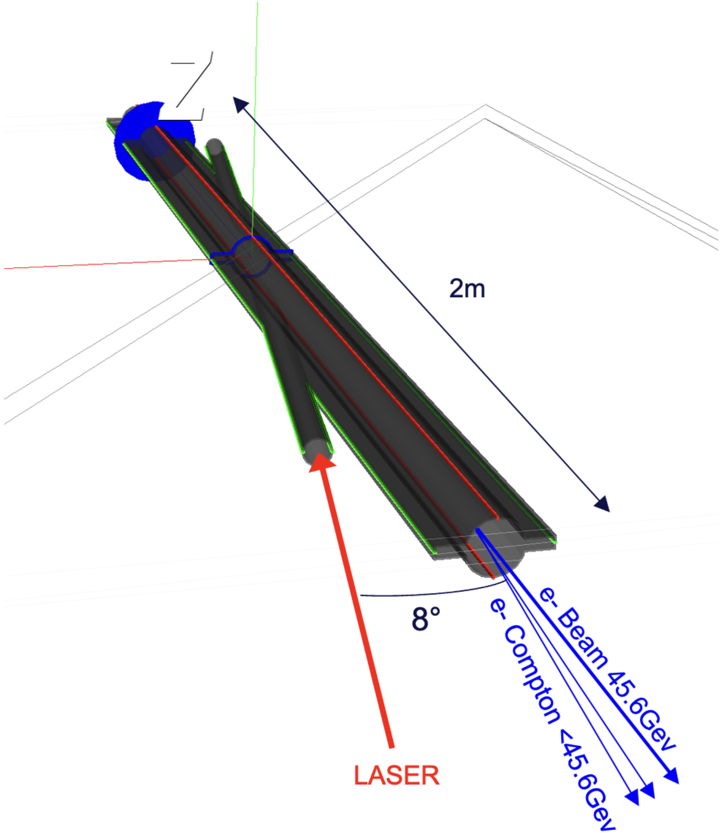
The 10E-5 precision aimed in the laser circular polarization is the main stringent requirement and it will probably need regular access to be maintained at this level of precision.



Laser interaction chamber (LIP)

Chamber length **2 meters**,
Placed just **before the spectrometer magnet**.
Laser incidence angle **2° to 8°**
Laser power **1mJ** within **30ps** pulses
Laser beam size **600um** sigma
Laser hutch situated away from radiation, accessible **24h/7d**
Very precise **circular polarization** control is needed.





BDSIM model of the polarimeter LIP chamber

“Laser uptime” discussion with laser expert E.Granados

Based on previous experience, even though laser systems are more reliable than in the past, for 24/7 operation they **still require regular maintenance and interventions that are usually performed on-site.**

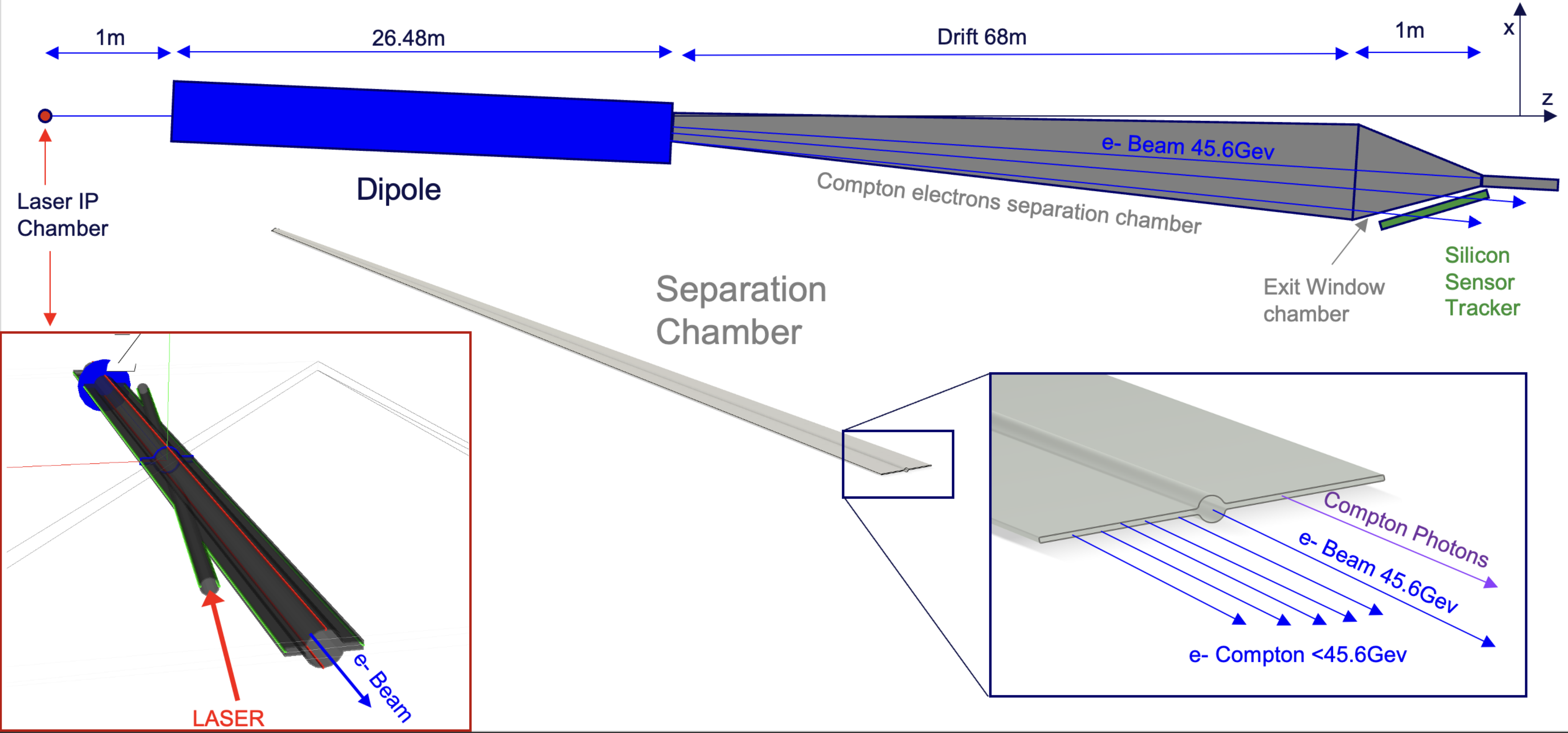
These includes cooling systems, maintenance and repairs, perishable element replacement, optical elements replacement, alignment of items that are not motorized or fully remotely controlled, and overall laser beam optimization. **Often the operational problems encountered cannot be remotely solved.**

A fully automated system with 24/7 up-time over many months (near 100% up-time) requires an extensive R&D effort to **develop a minimum risk system**, this would **require dedicated personnel and material resources through the next coming years for such development**, but it is an approach that needs to be considered.

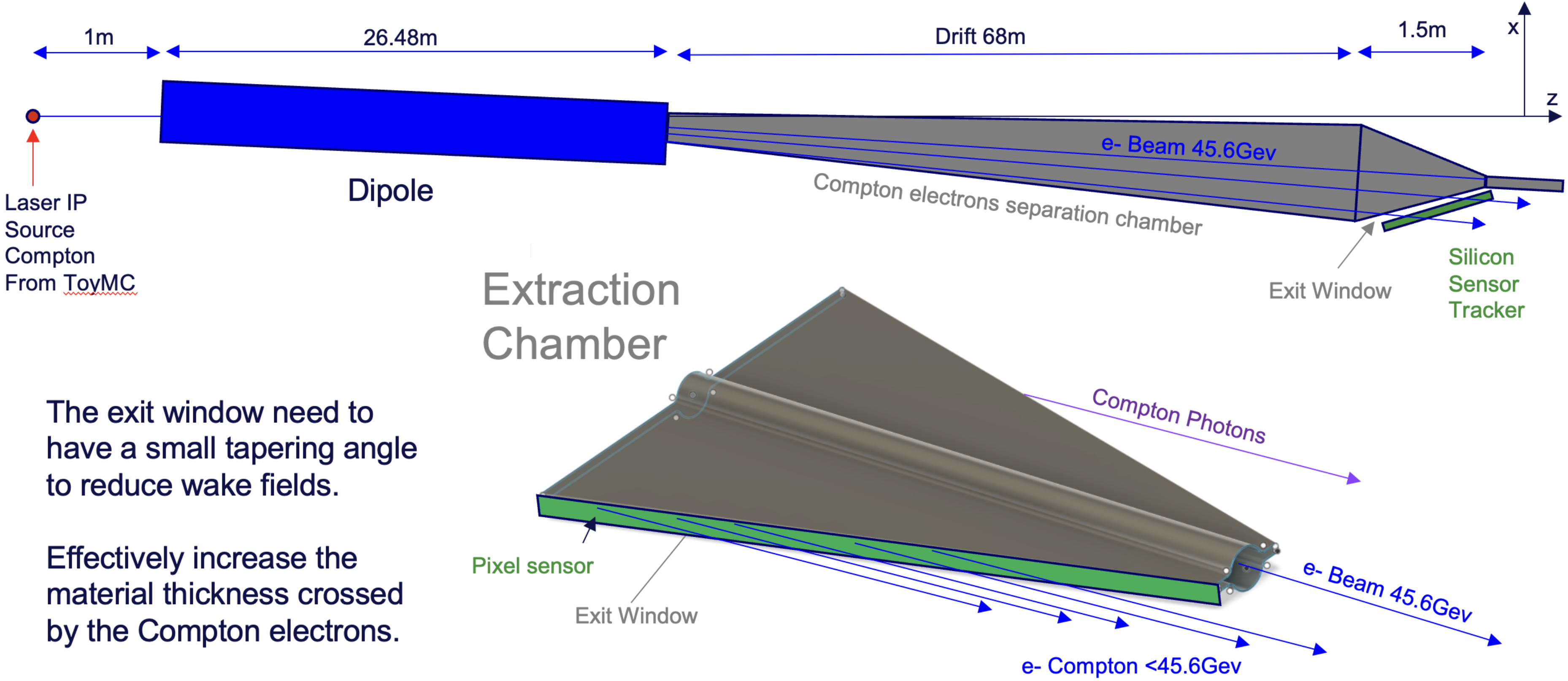
"It is customary to provide 24/7 access to laser rooms in accelerator facilities, a typical example is for photoinjector lasers in accelerators worldwide”

Depending on the **actual cost of down-time**, then the continuous access to the laser hutch may be not be fully justified. That study is part of a **necessary study or risk assessment**, with options in one column, costs on another one, and risk in another one, then **compare these costs with the dedicated tunnel cost**.

BDSIM Model description of Compton electrons separation



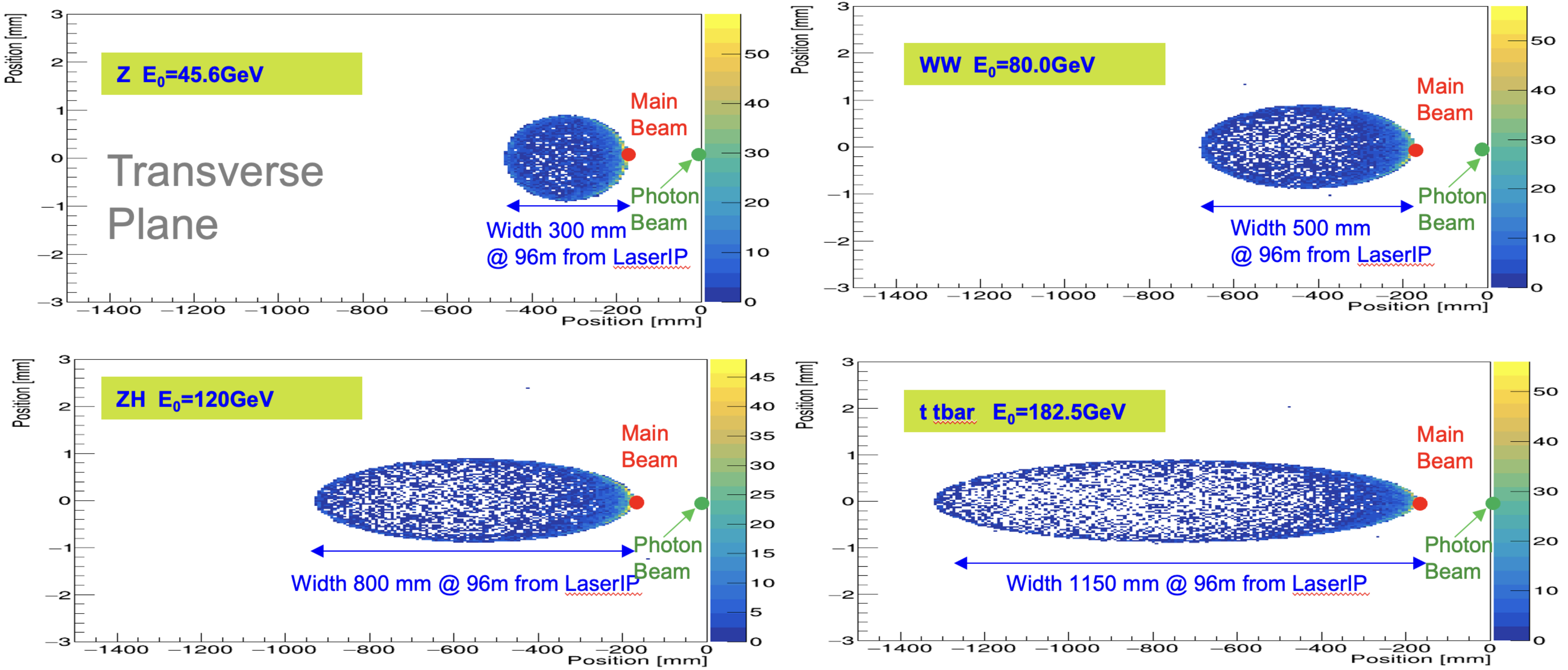
BDSIM Model description of Compton electrons extraction



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

Effectively increase the material thickness crossed by the Compton electrons.

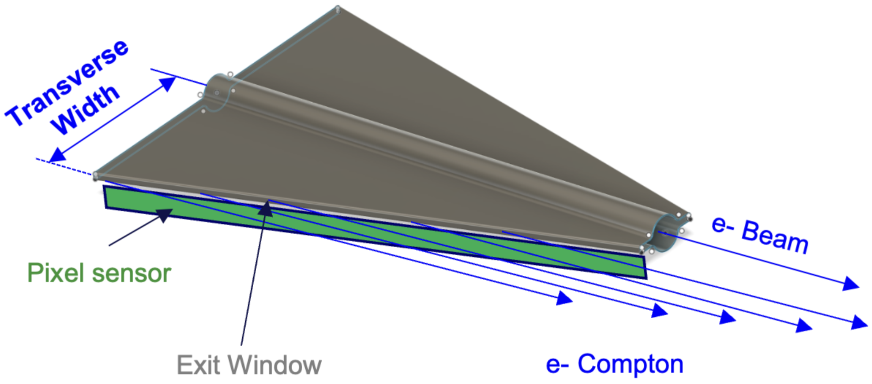
Compton electron pattern at different run energies Exiting the Separation Chamber (96m from LIP)



Capturing the compton electrons pattern

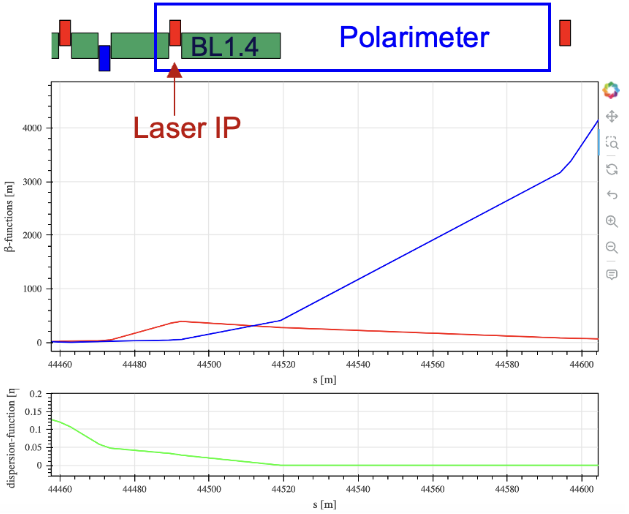
The detector need to be placed collinear with the exit window **as close as possible.**

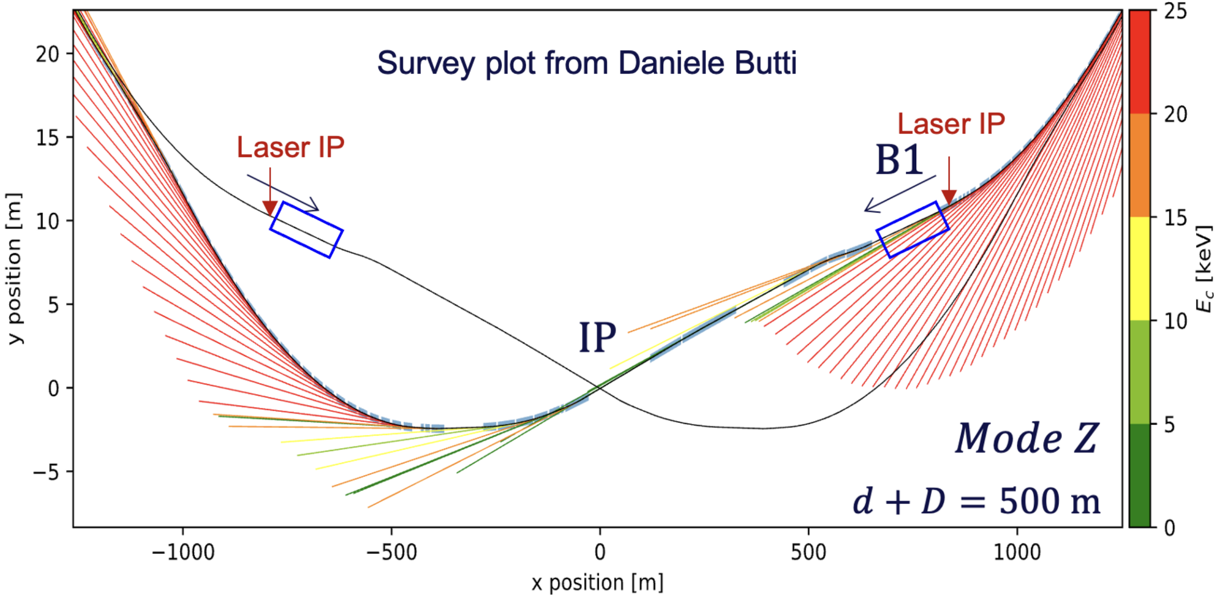
We are talking about a rather large chamber.



Mode	Width at 96m Transverse	Detector Size at 96m 15deg window	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

FCCee Polarimeters baseline in Experimental IP A

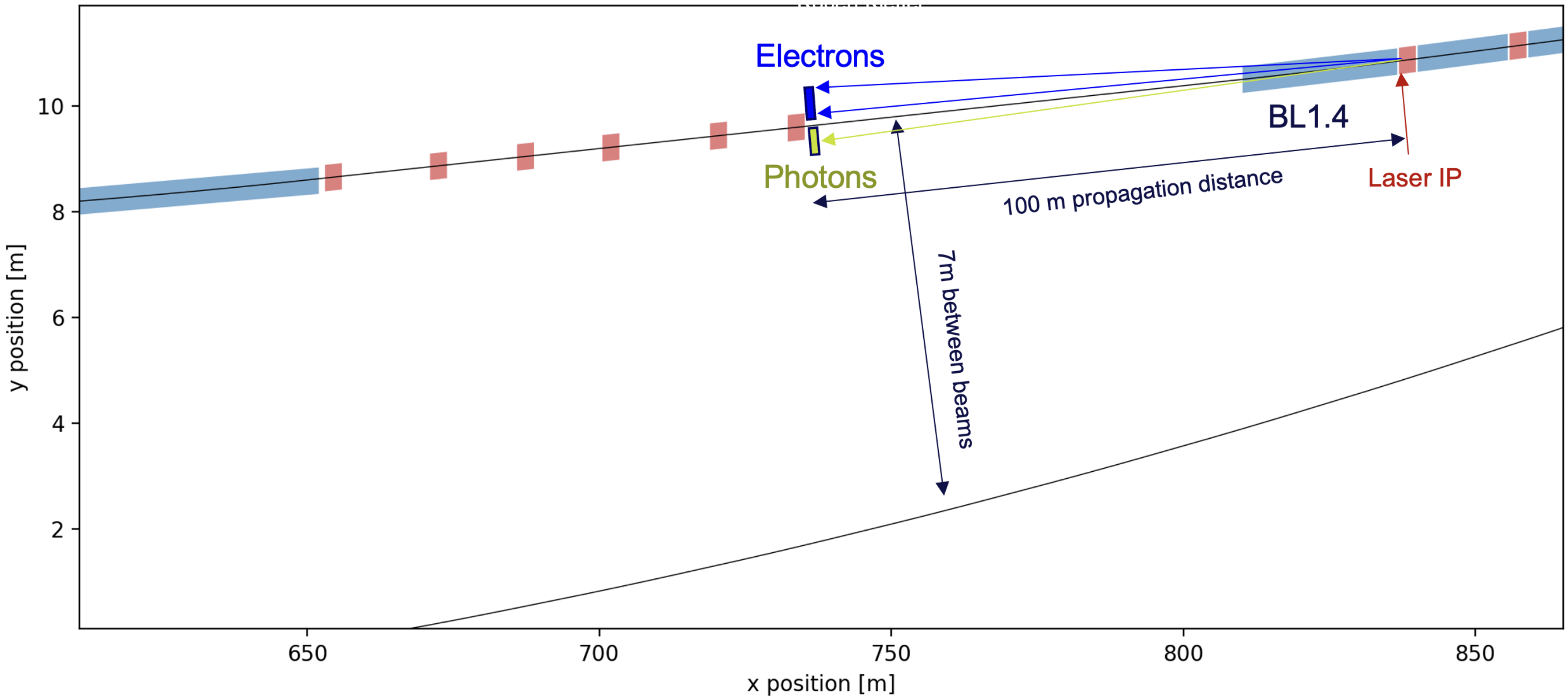




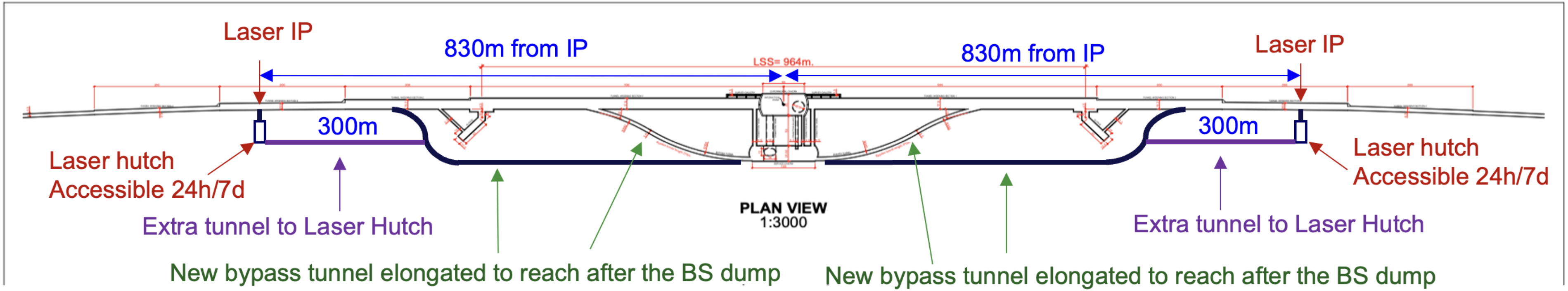
GHC optics is used. The polarimeter is not yet tested in the LCC optics.

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

FCCee Polarimeters baseline in Experimental IP A



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**.

UPDATE from L. Bromiley and T. Watson (after the FCC week)

- **Cost estimate for the two full lenght 830m tunnels 33MCHF**
- **Cost estimate for the two 300m extra tunnels connected to the extended bypass 12MCHF**

Conclusions

- Simulation work started with BDSIM, much more work to be done (digitization, fitting procedure, CST), add the Backgrounds (SR, Bremsstrahlung on residual gas, thermal photons..)
- Then do the same work for the **Compton photons** (Si-Tungsten electromagnetic calorimeter design)
- Instrument specifications and running modes still not fully defined (optics, polarized beam injection..).

Discussion on the civil engineering and the Polarimeters location

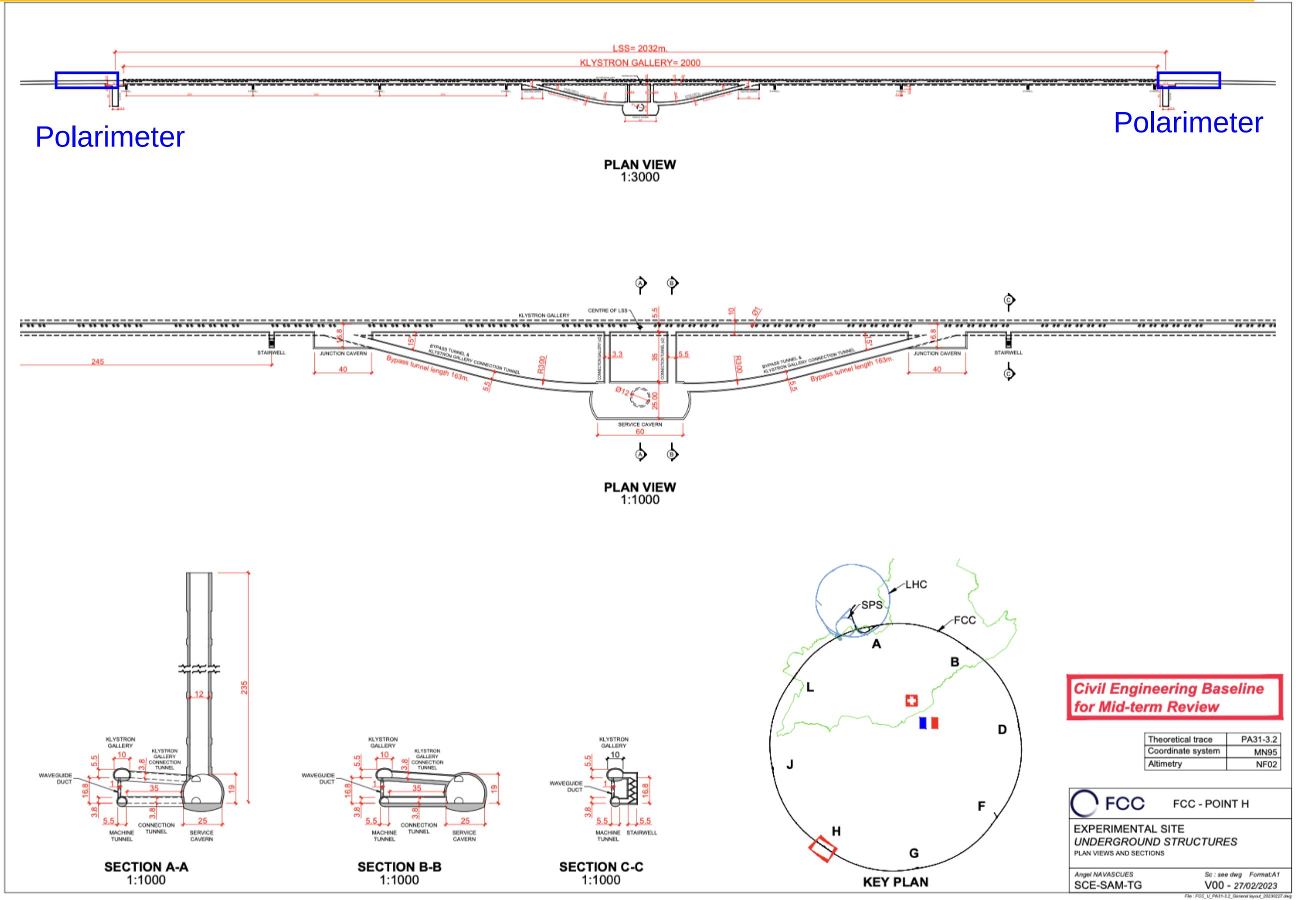
- Up to now the **baseline** is a **pair of polarimeters in point A, with dedicated access tunnels to the laser laboratories accessible while machine is running to ensure maximum availabilty.**
- If we decide to go for **operation with fully remote-controlled laser labs** (without full time access). We will probably need to invest in redundancy, with two pairs of polarimeters at two different experimental IPs, to **ensure full time availability of the FCCee energy calibration**.
- We are looking into **point L option** since it would reduce the civil engineering but as it is for now the instrument would be **extremely difficult to be fitted threre** (beam to beam distance, beam optics..).

Thank you for your attention.

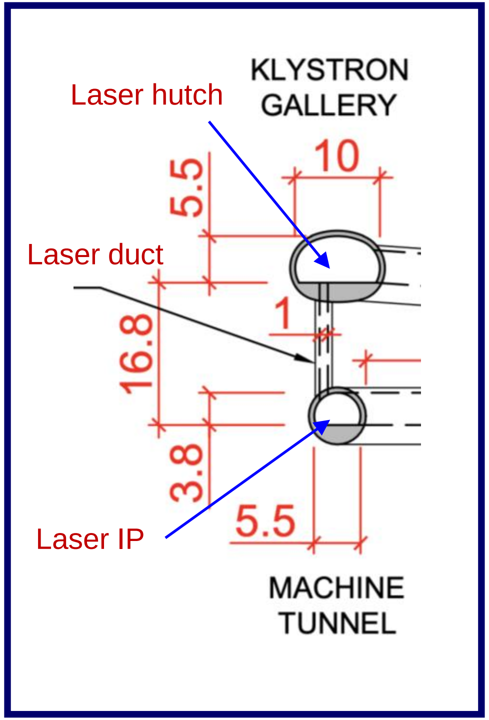
Other option : FCCee Polarimeters in point L

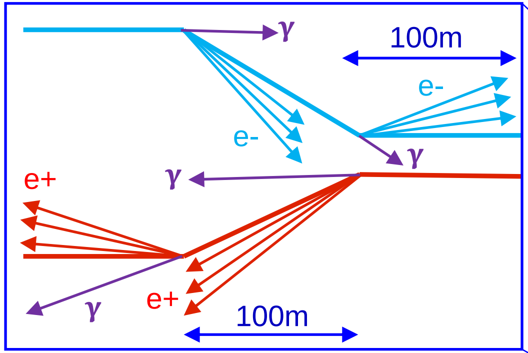
Polarimeter at IP L

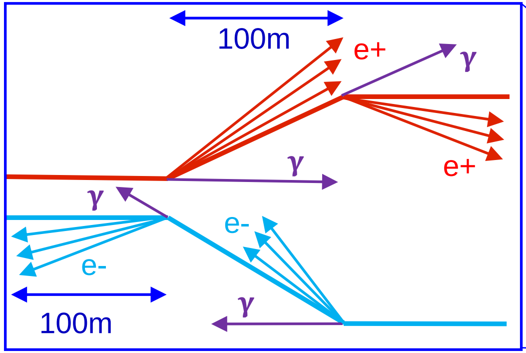
- Laser in Klystron gallery (**may need to extend the gallery at both ends**)
- After the dipole Electrons (positron) need a magnet free path up to the pixel detector (80m long extraction line).
- The machine optics in point L is **not yet defined**.
- As for today, **no simulation** of the polarimeter can be performed here without a proper **survey file**.

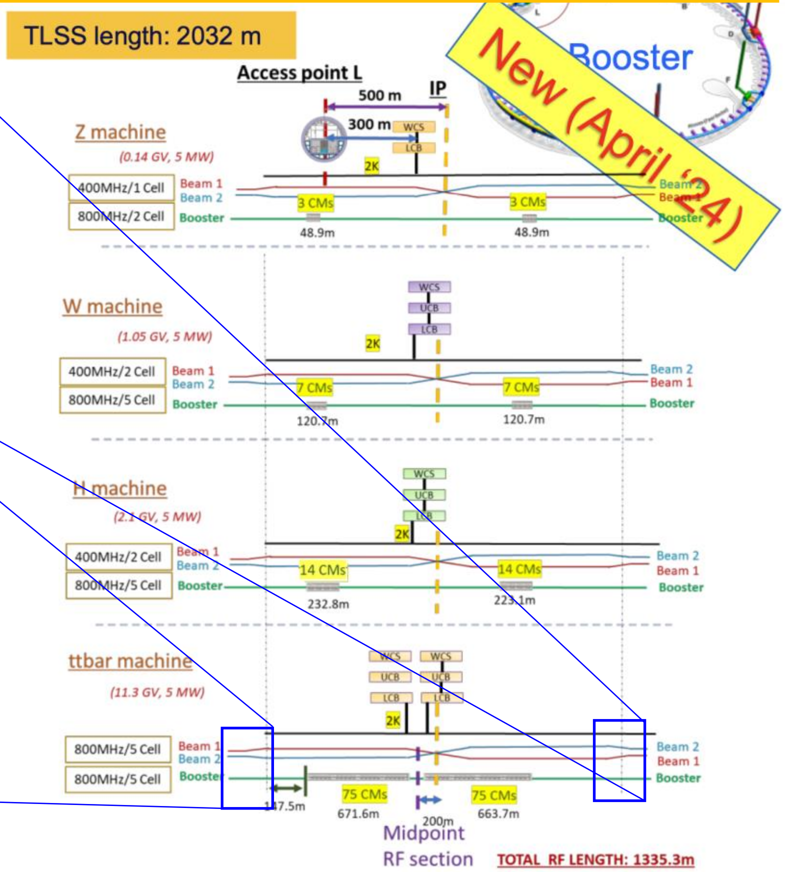


Other option : FCCee Polarimeters in point L







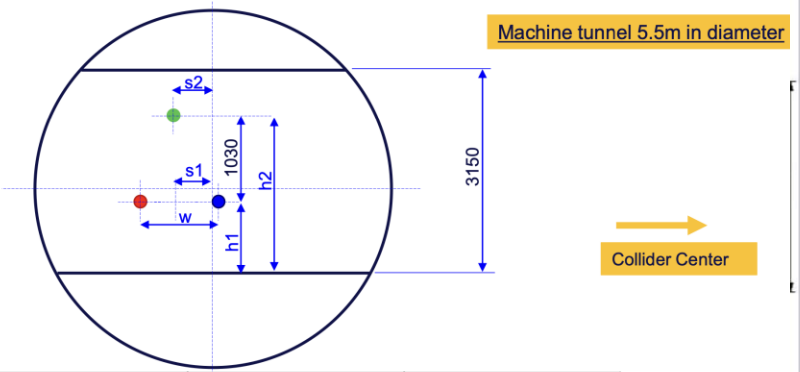


Distance between beams

Slides from Vittorio Parma, FCC week 2024

In order to fit the polarimeter extraction chamber (**900mm total width**) a bare **minimum beam to beam** distance of **500 mm** is required.

- In point A we have 7000mm
- In point L it is 350mm (Not fitting)



	Arcs		Point H (Collider)		Point L (Booster)	
	Present value	New proposed	Present value	New proposed	Present value	New proposed
w	350	350	800	960	350	350
h1	980	1200	980	1200	980	1200
h2	1030	2230	1030	2230	1030	2230
s1	551	551	NA	1240	NA	700
s2	391	391	NA	400	NA	700

Point L: Z to ttbar

Booster

Modification proposal

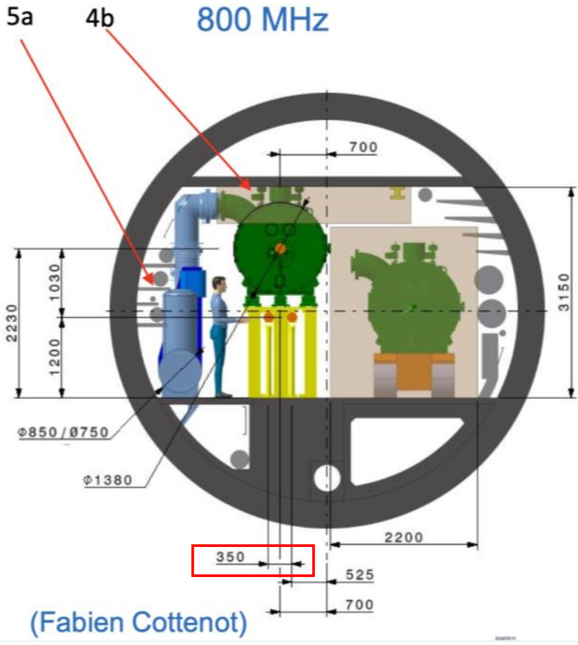
Interferences:
1 : CM/floor
▶ Height 2010 to 2230

2a: CM/QRL Jumper
2b: CM/floor not supported
▶ Distance booster : 930 to 700

3a: Circulating Beam / CM support
▶ Distance beam1/2 : 800 to 350
3b: Beam height
▶ Height beam1/2 : 980 to 1200

4a : CM installation / Robot
▶ To be studied
4b : CM in position / Robot
▶ To be studied

5a: QRL Jumper / Service
▶ To be studied



(Fabien Cottenot)

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

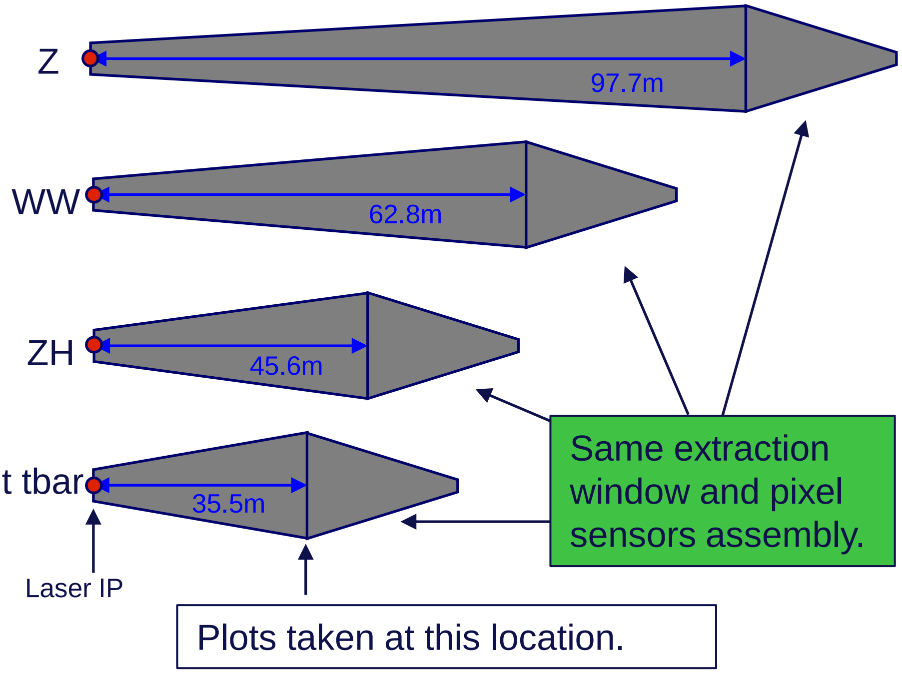
Spectrometer Magnet and extraction window particles interaction

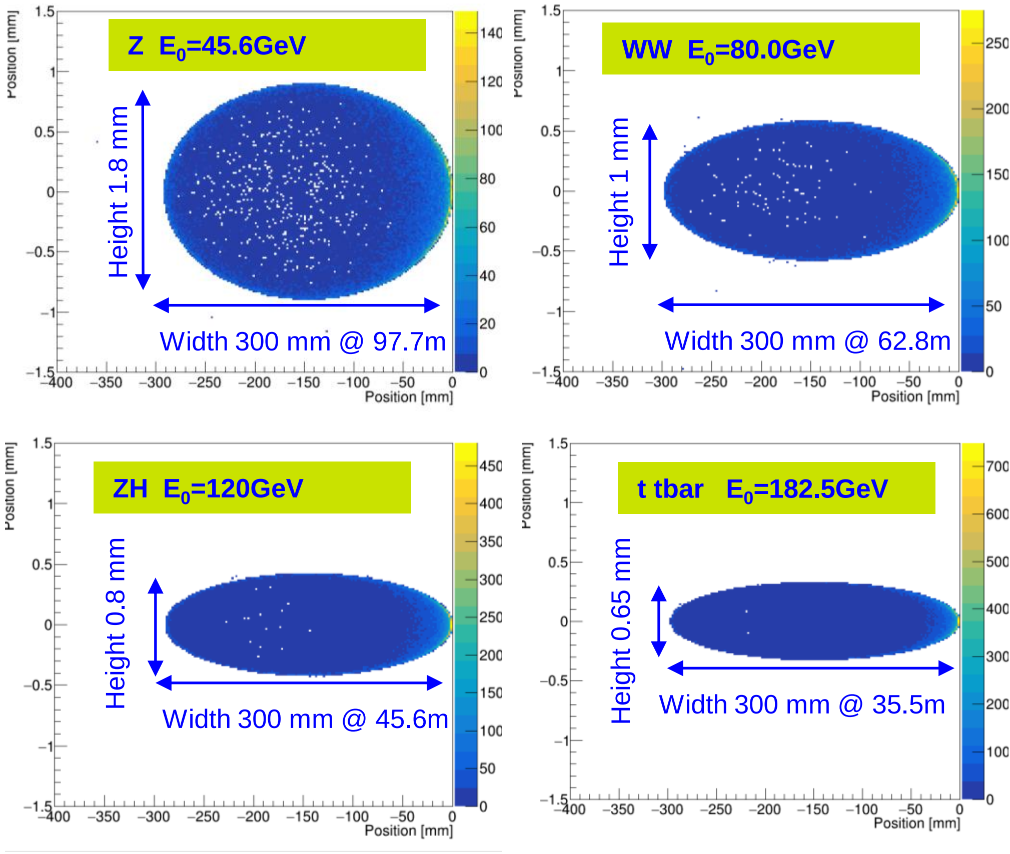
→

Root plot and fitting

Producing phase space profiles of secondary MC particles

Optimizing on the separation chamber lenght

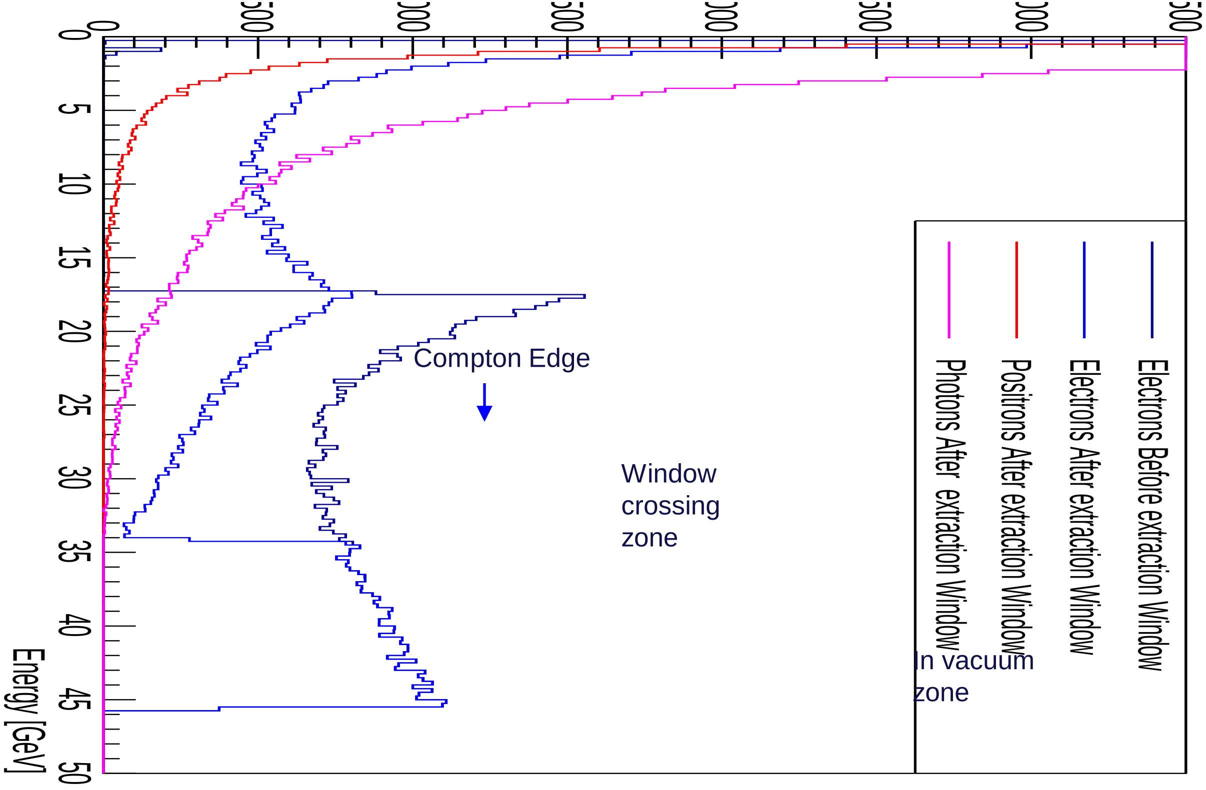




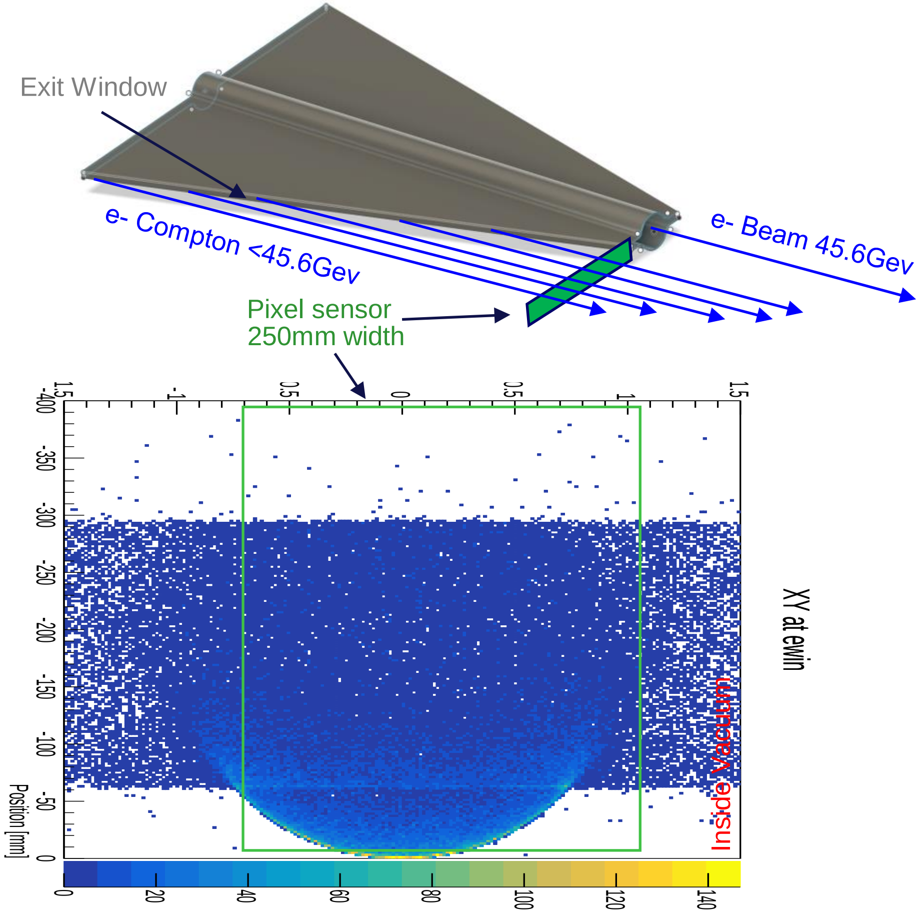
Compton electrons extraction spectra

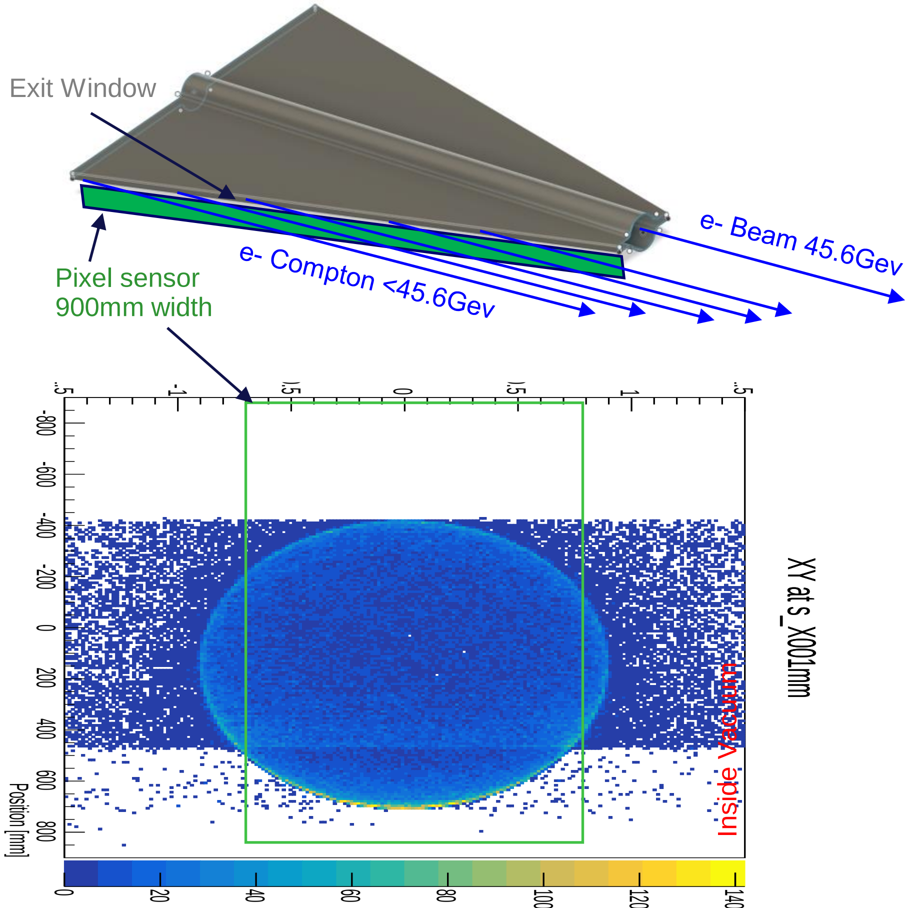
Z mode 45.6GeV beam energy
Extraction window at 15 deg angle
Thickness 2mm copper

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



Compton electron pattern pixels plane orientation

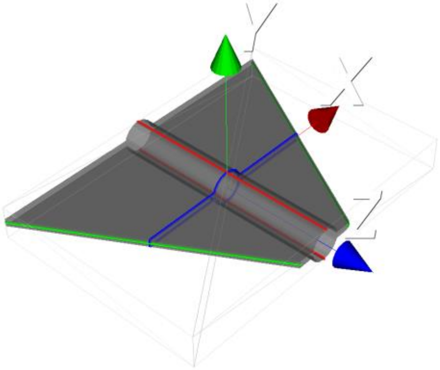




Extraction window chamber tapering (minimize Impedance effect)

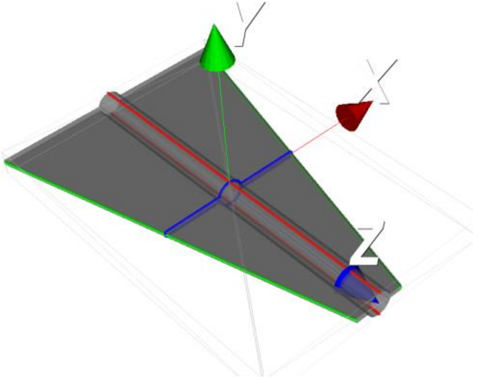
30 degrees angle

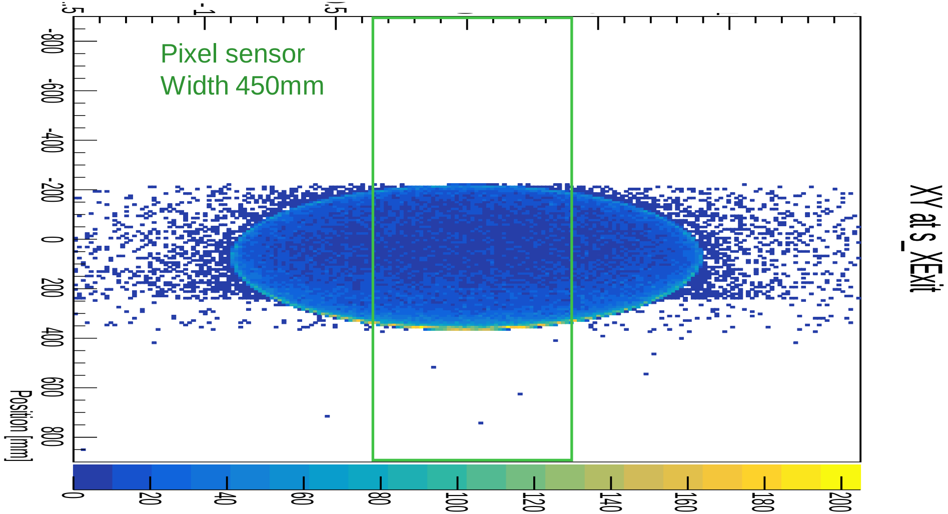
Mat: Copper Thickness: 2mm Mode: Z
Effective Copper Thickness: **3.99mm**

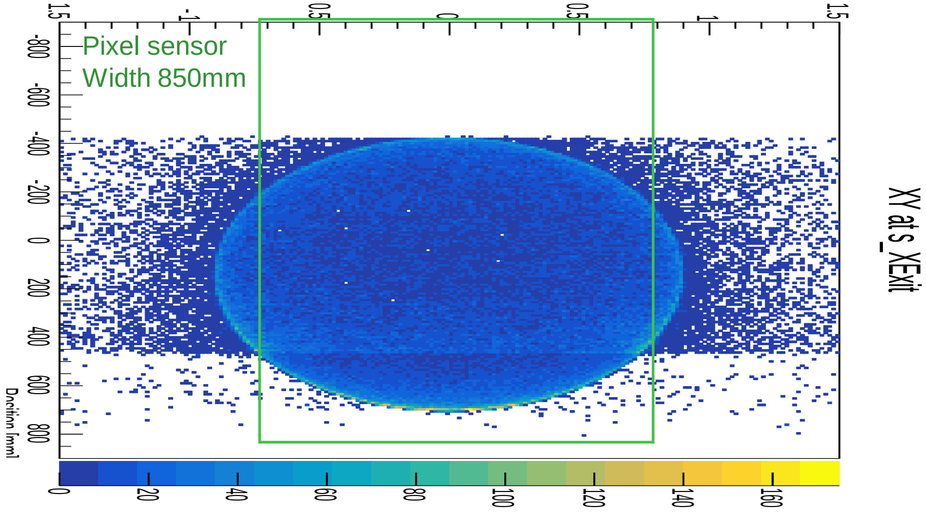


15 degrees angle

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





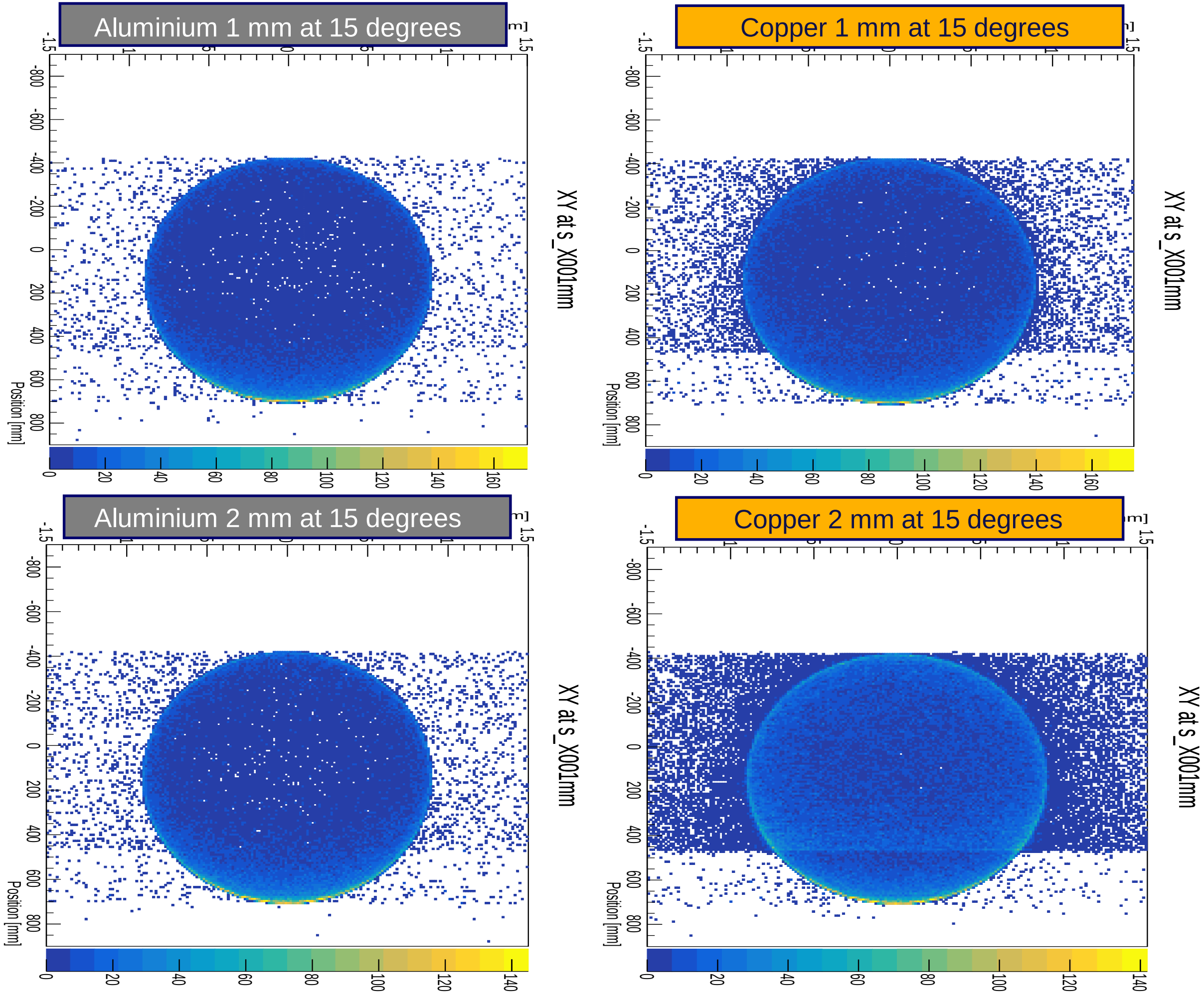


Extraction window material/thickness

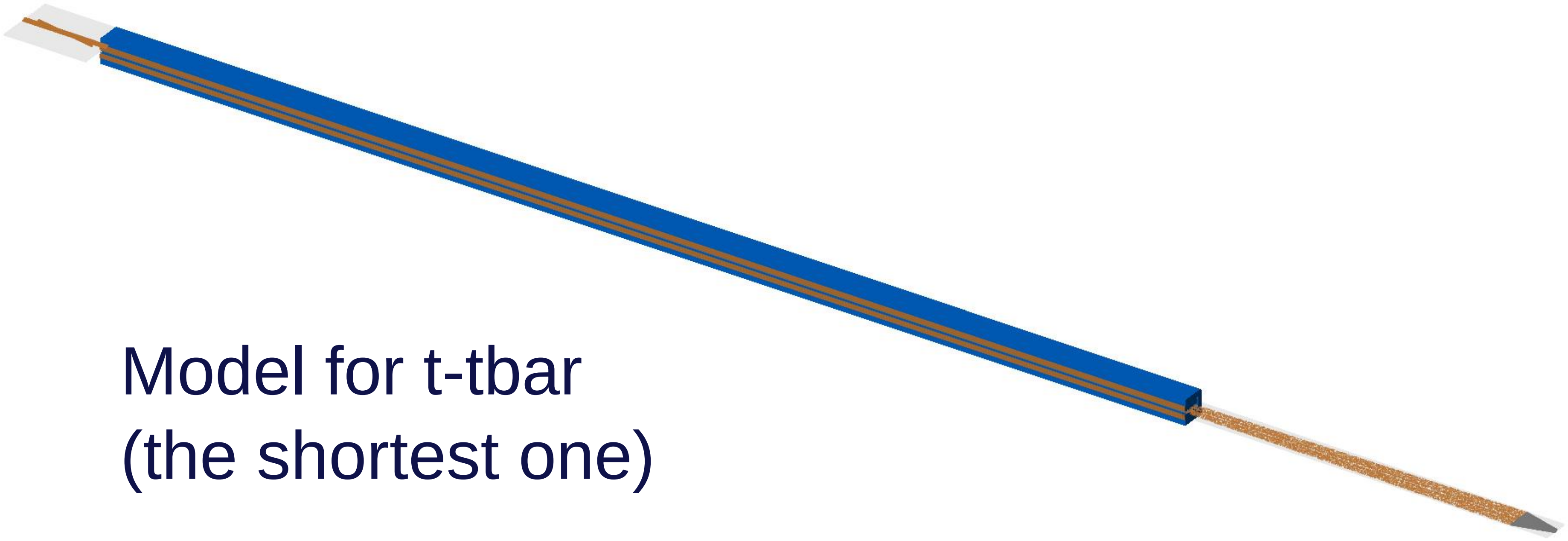
Study at Z pole sampling plane is 1mm after the extraction window.

Aluminium and Copper
Two ticknesses 1-2 mm

1 mm Aluminium is the most transparent solution.



BDSIM Model description of Compton electrons extraction



Model for t-tbar
(the shortest one)