Hybrid Setup: Interchangeable Cerenkov detectors

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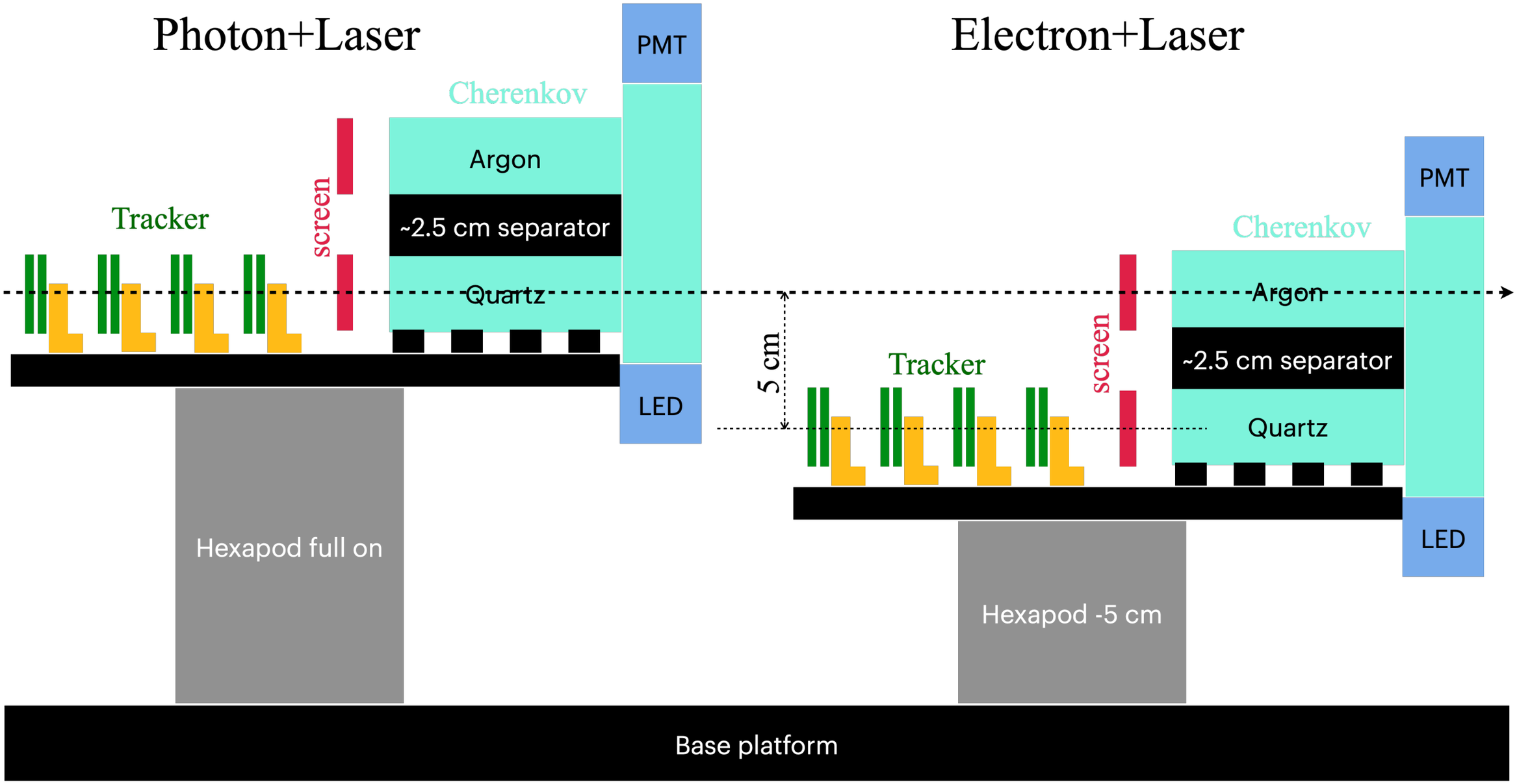
HELMHOLTZ RESEARCH FOR GRAND CHALLENGES

DESY.

Hybrid IP setup

Sketch by Noam

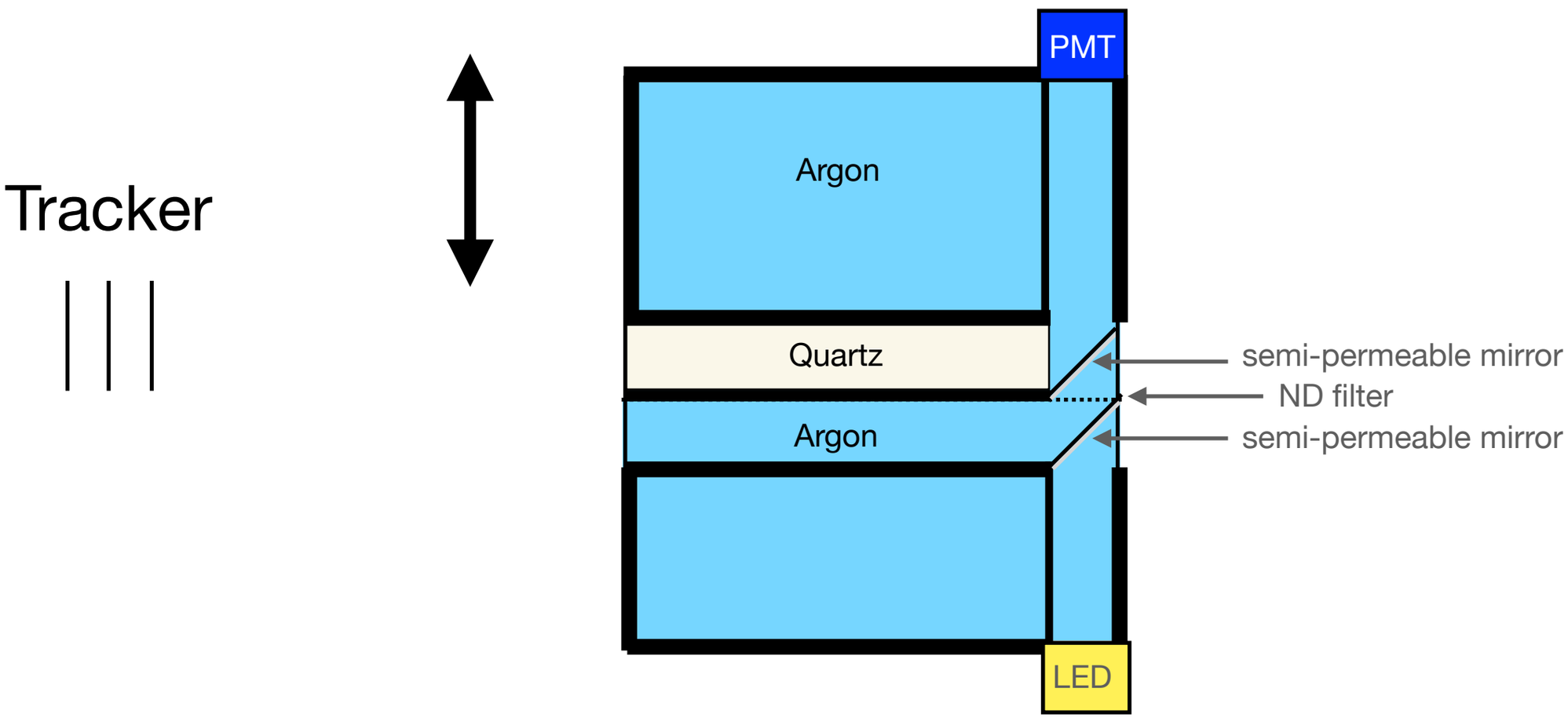


Where does Hybrid IP setup enter? (my understanding)

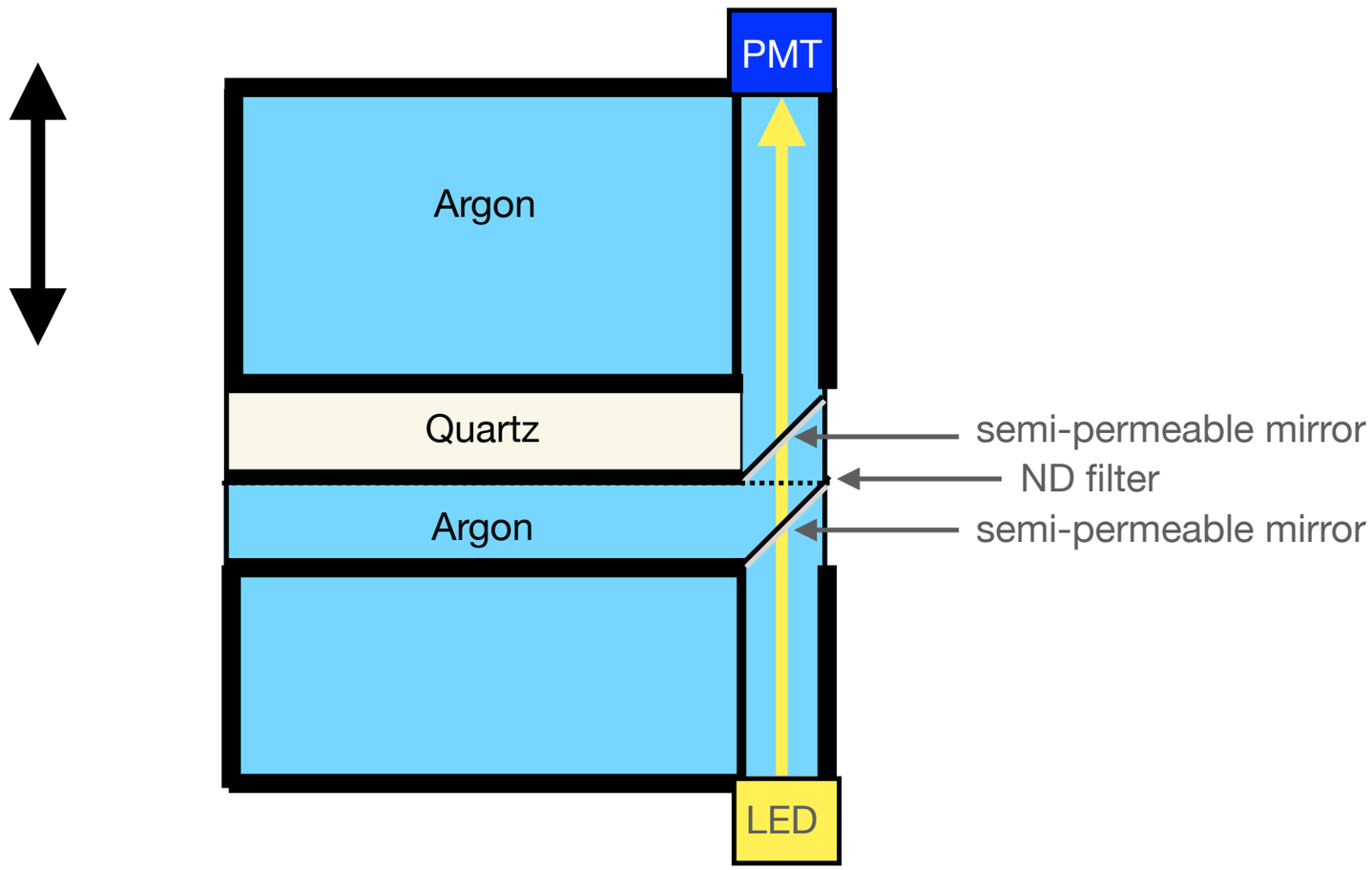
time

Run-mode	IP setup	Comment
$e^-+\gamma_L$-Setup: “dedicated” $e^-+\gamma_L$	1) Tracker + Calo on e^+- arm 2) finely segmented Cerenkov detector on e^- - arm	$e^-+\gamma_L$ goal: physics! (reconstruct Compton edges, Trident electrons)
Shutdown		
$\gamma_B+\gamma_L$-Hybrid-Setup: short $e^-+\gamma_L$ “prep run” followed by $\gamma_B+\gamma_L$ “physics run” moving in the Brems target	1) Tracker + Calo on e^+- arm 2) Tracker + **hybrid** Cerenkov detector on e^- - arm	$e^-+\gamma_L$ goal: LASER calibration, establishing safe conditions $\gamma_B+\gamma_L$ goal: physics

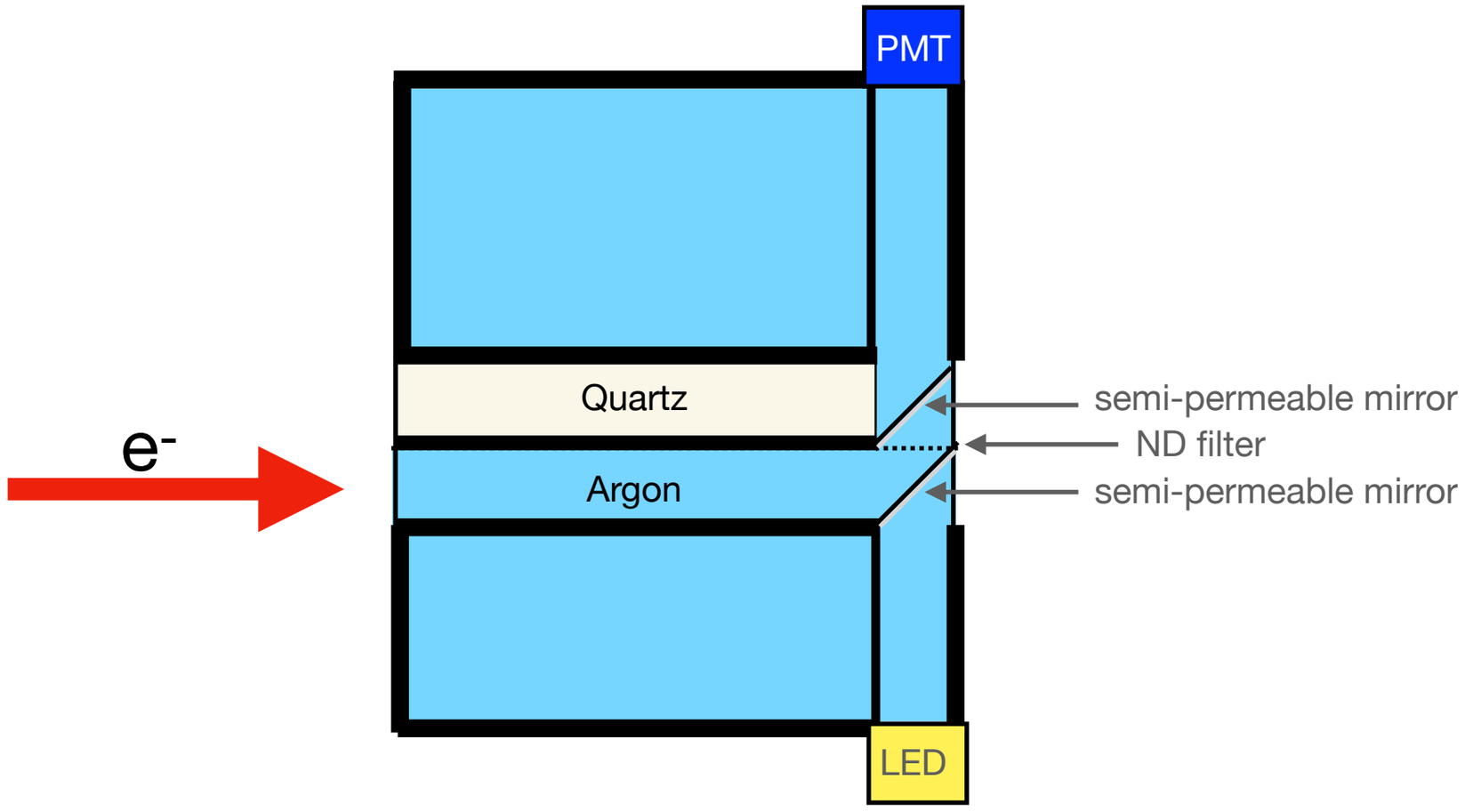
General Idea for Cerenkovs



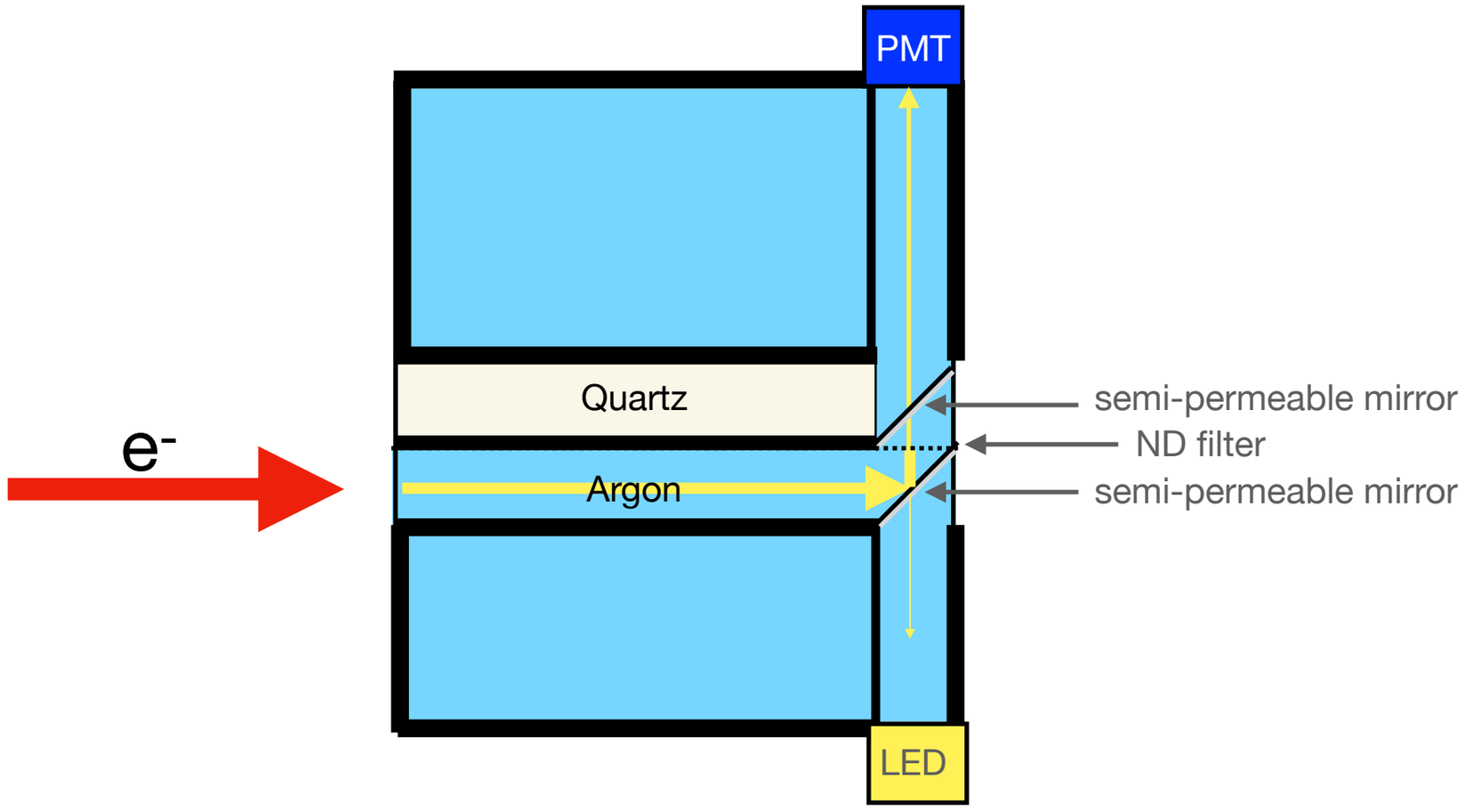
Calibration by LED



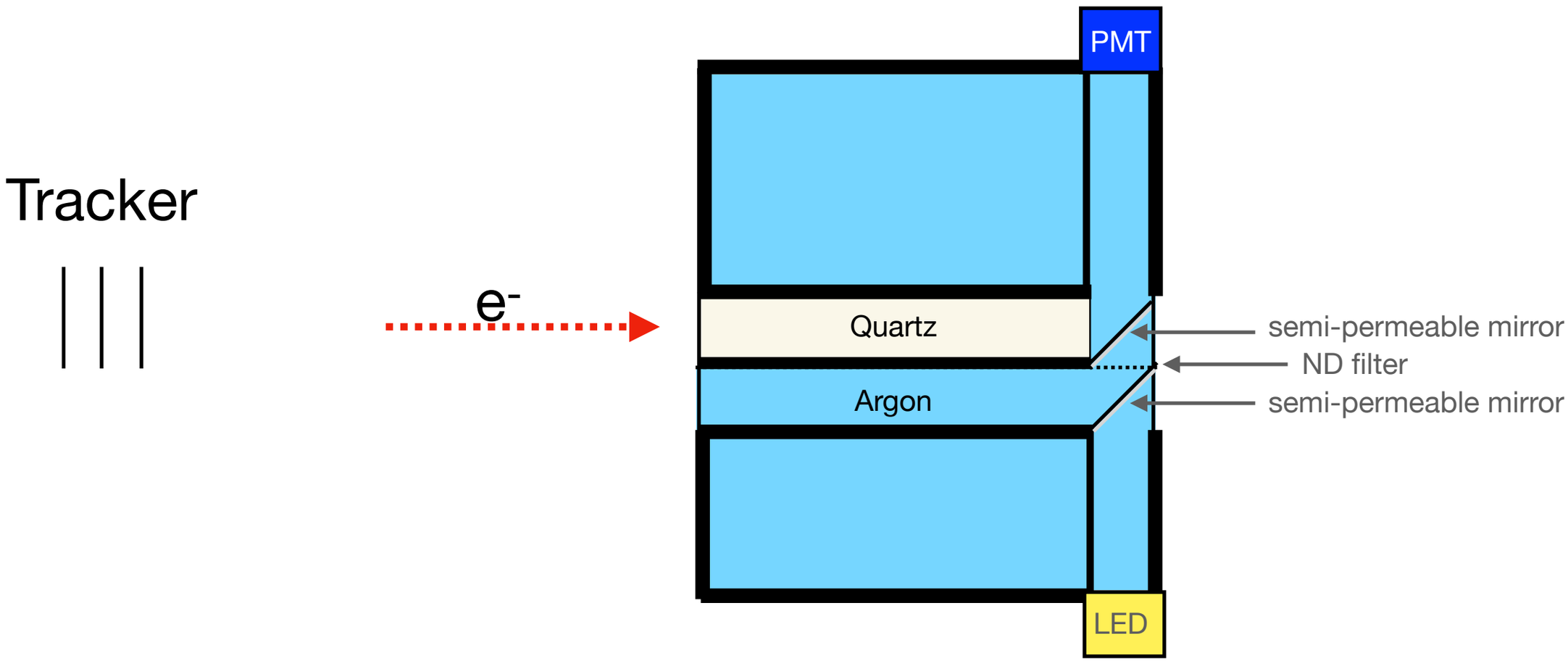
Compton Setup



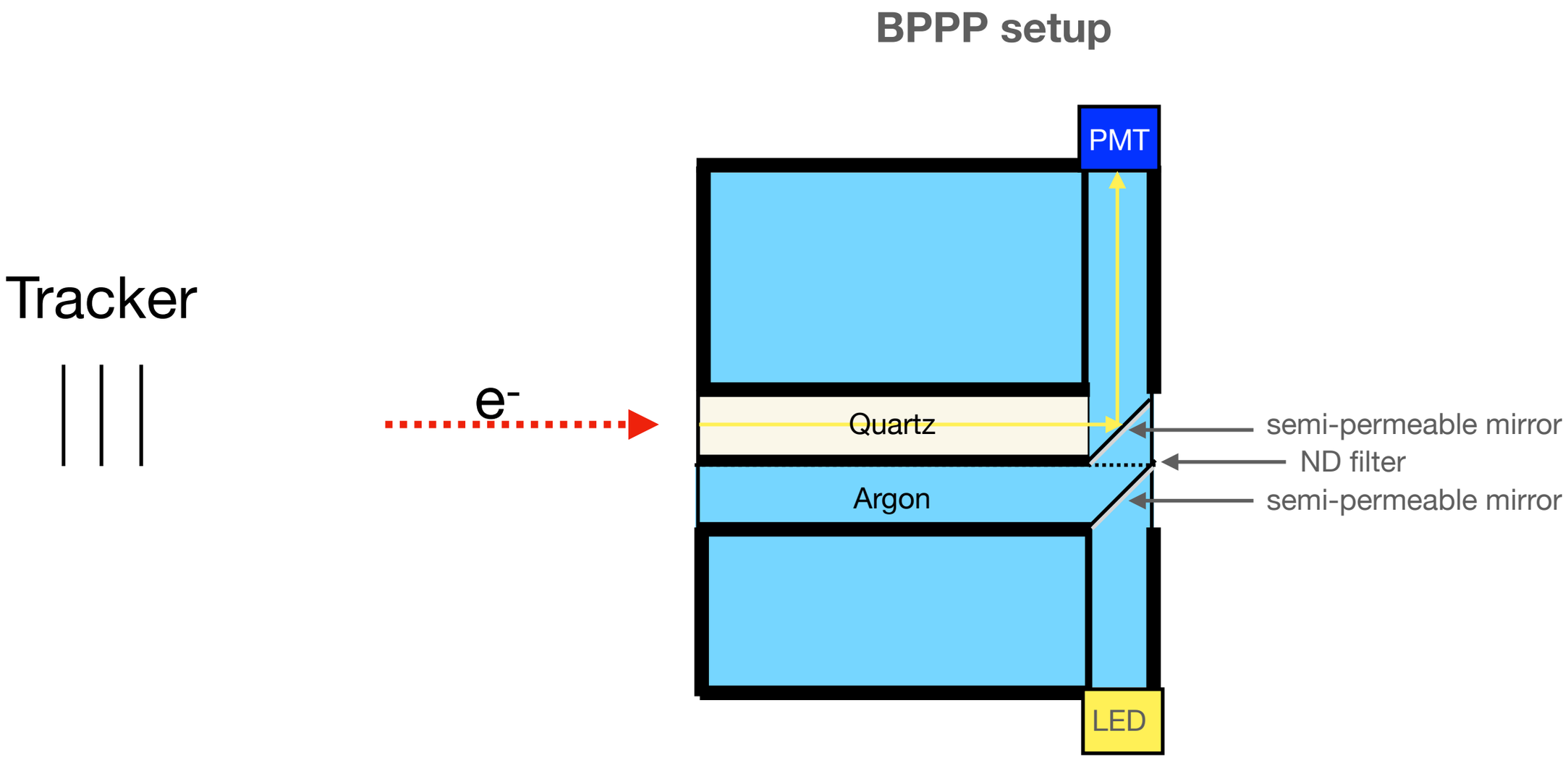
Compton Setup



BPPP Setup

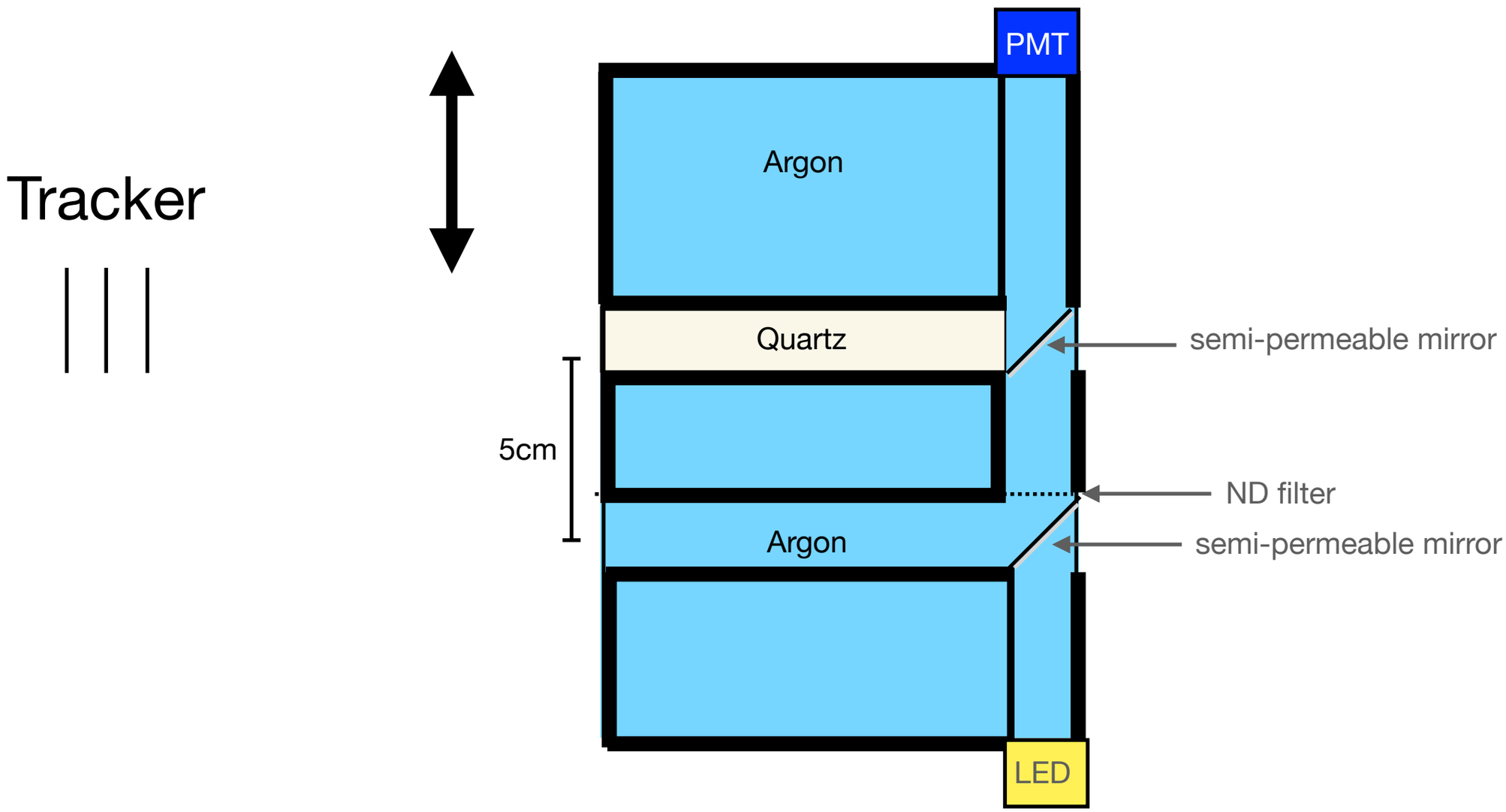

Tracker
e-
PMT
Quartz
Argon
LED
semi-permeable mirror
ND filter
semi-permeable mirror

BPPP Setup


BPPP setup
Tracker
e-
PMT
Quartz
Argon
LED
semi-permeable mirror
ND filter
semi-permeable mirror

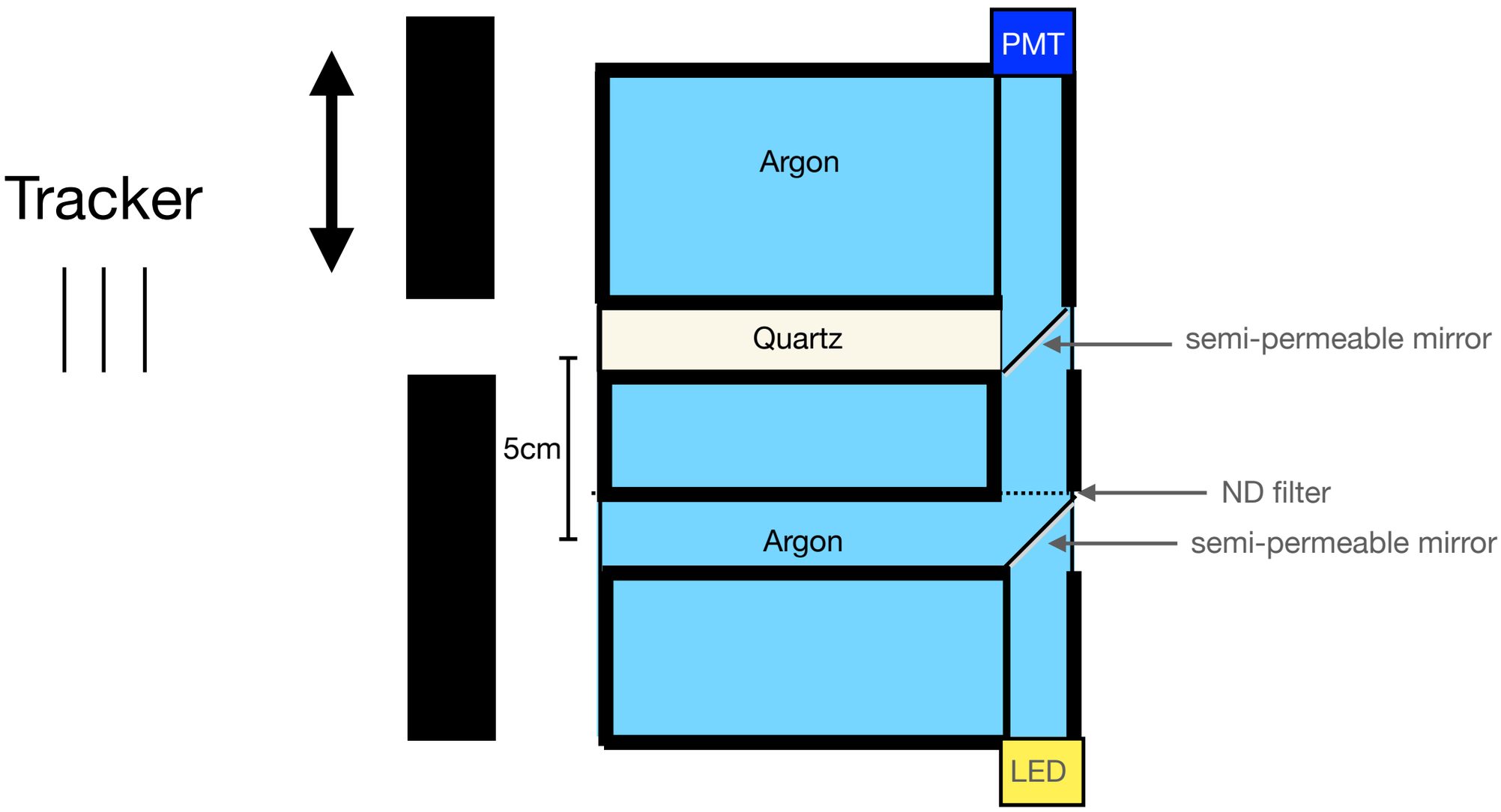
To match with Tracker plane

Tracker needs to be moved ~5cm up and down



Would also protect us against backgrounds!

Shielding?



Problem: Shielding would need to stay fixed

Number of Photons per Primary

$$N_\gamma = 2\pi\alpha l_z \left(1 - \frac{1}{n^2}\right)\left(\frac{1}{\lambda_{\min}} - \frac{1}{\lambda_{\max}}\right)$$

Medium (1cm)	Refractive Index n	N_γ per primary 300-650nm	N_γ per primary 185-650nm
Quartz	1.54	476	1025
C_4F_{10}	1.0014	230	495
Argon (15°, 1atm)	1.00028	46	100

- Quartz should be able to give us enough light yield, even if we lose some light due to the semi-permeable mirror
- we can make the channels l_z longer and add less transmissive ND filter for Argon
- spectrum skewed towards UV for Quartz → UV sensitive PMTs?

Cerenkov Thresholds

Cerenkov condition: $\beta > \frac{1}{n}$

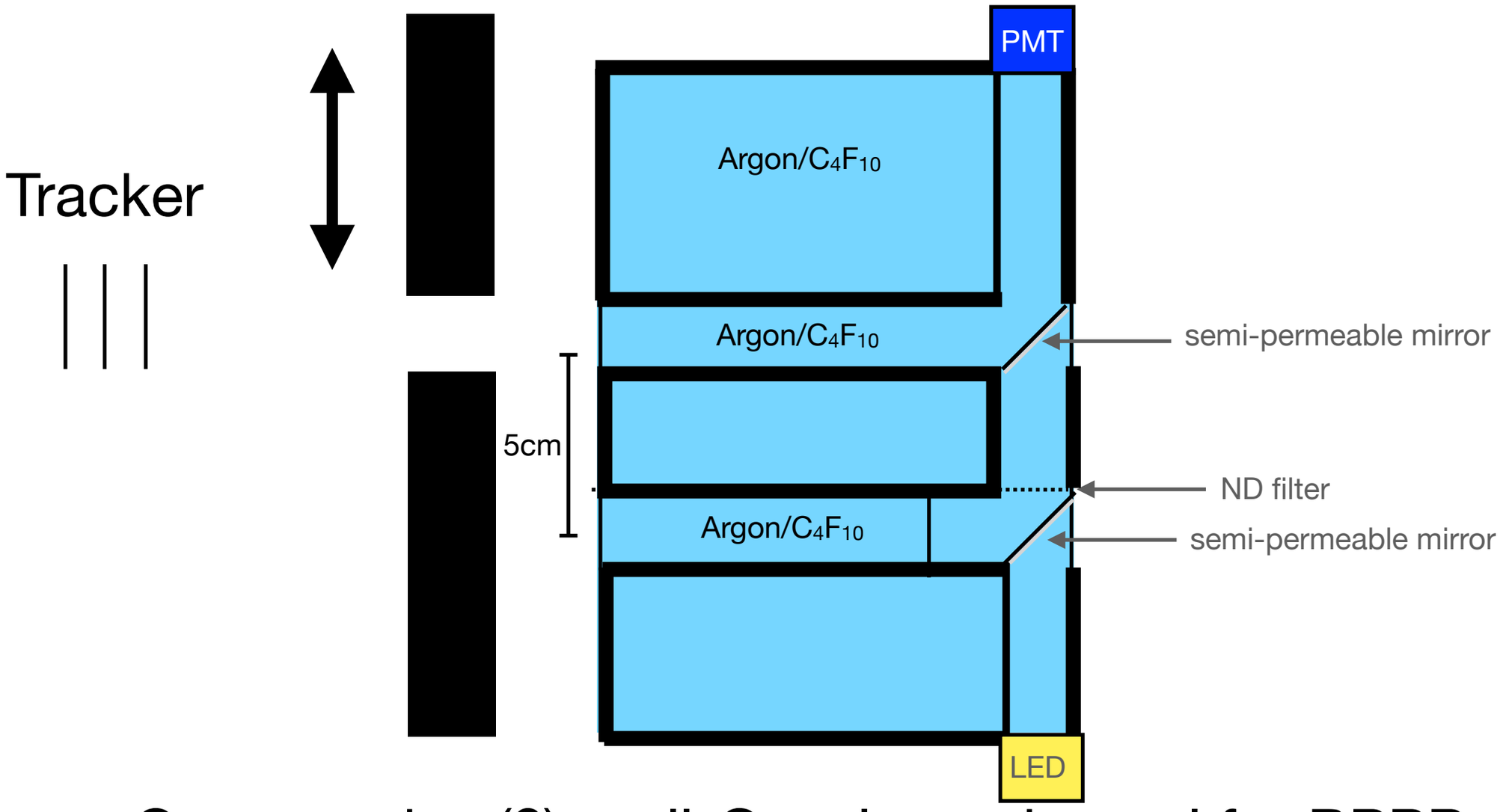
$$\beta = \frac{v}{c} = \sqrt{1 - \left(\frac{m_e}{E_{\text{tot}}}\right)}$$

$$E_{\text{tot}}^{\text{thr}} = \frac{1}{\sqrt{1 - \frac{1}{n^2}}} m_e$$

Medium	Refractive index	Threshold $E_{thr,tot}$	#Events	% of Sig+Bg
Quartz	1.54	0.677 MeV	Need to check	Need to check
C_4F_{10}	1.0014	9.7 MeV	1405940	100 %
Air/Argon	1.00028	21.6 MeV	1162539	82.7 %
Helium	1.00036	60.22 MeV	867479	61.7 %

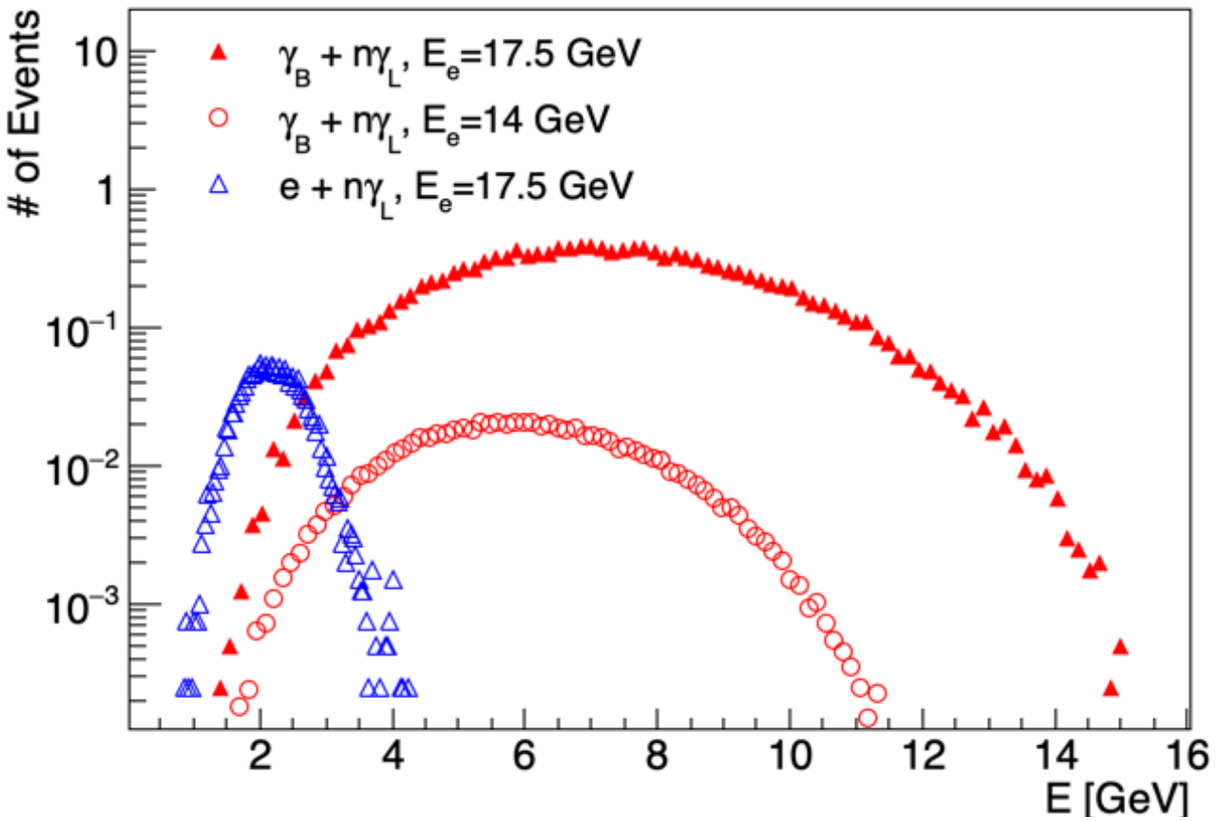
Problem: Quartz has a low Cerenkov threshold!

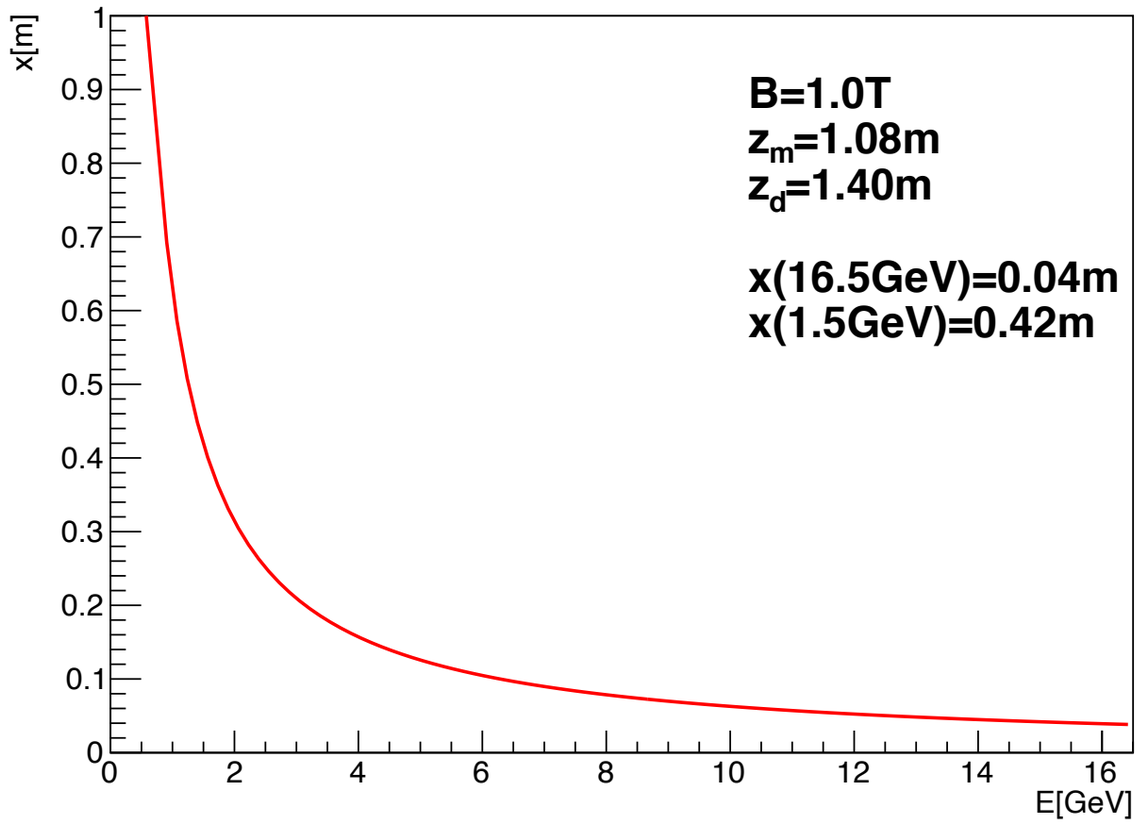
All-Gas Compromise?

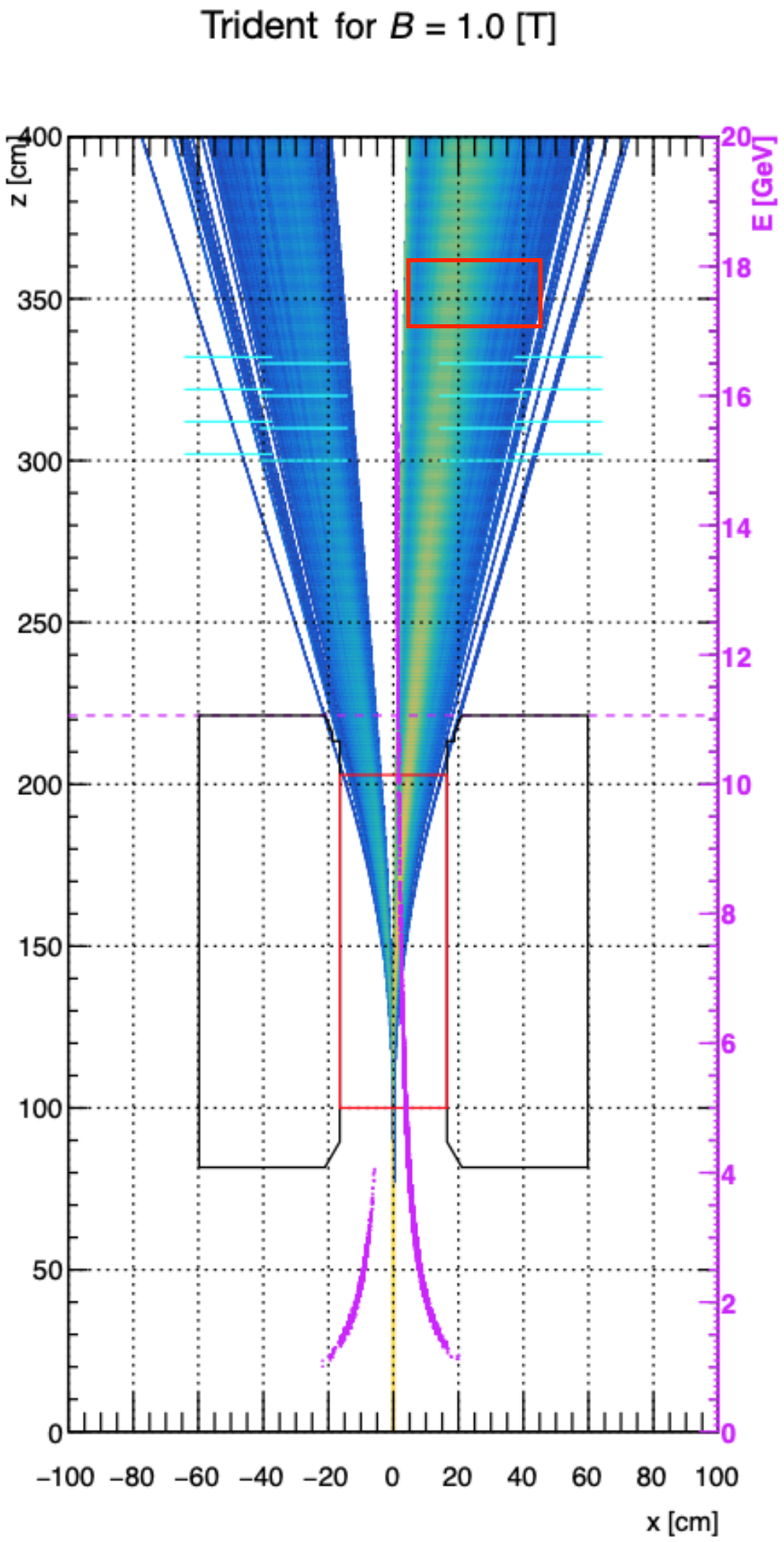


Compromise (?): - all-Gas, long channel for BPPP,
- short channel for Compton
- C_4F_{10}? with (stacked) ND filter might work
- check rates!

Span?

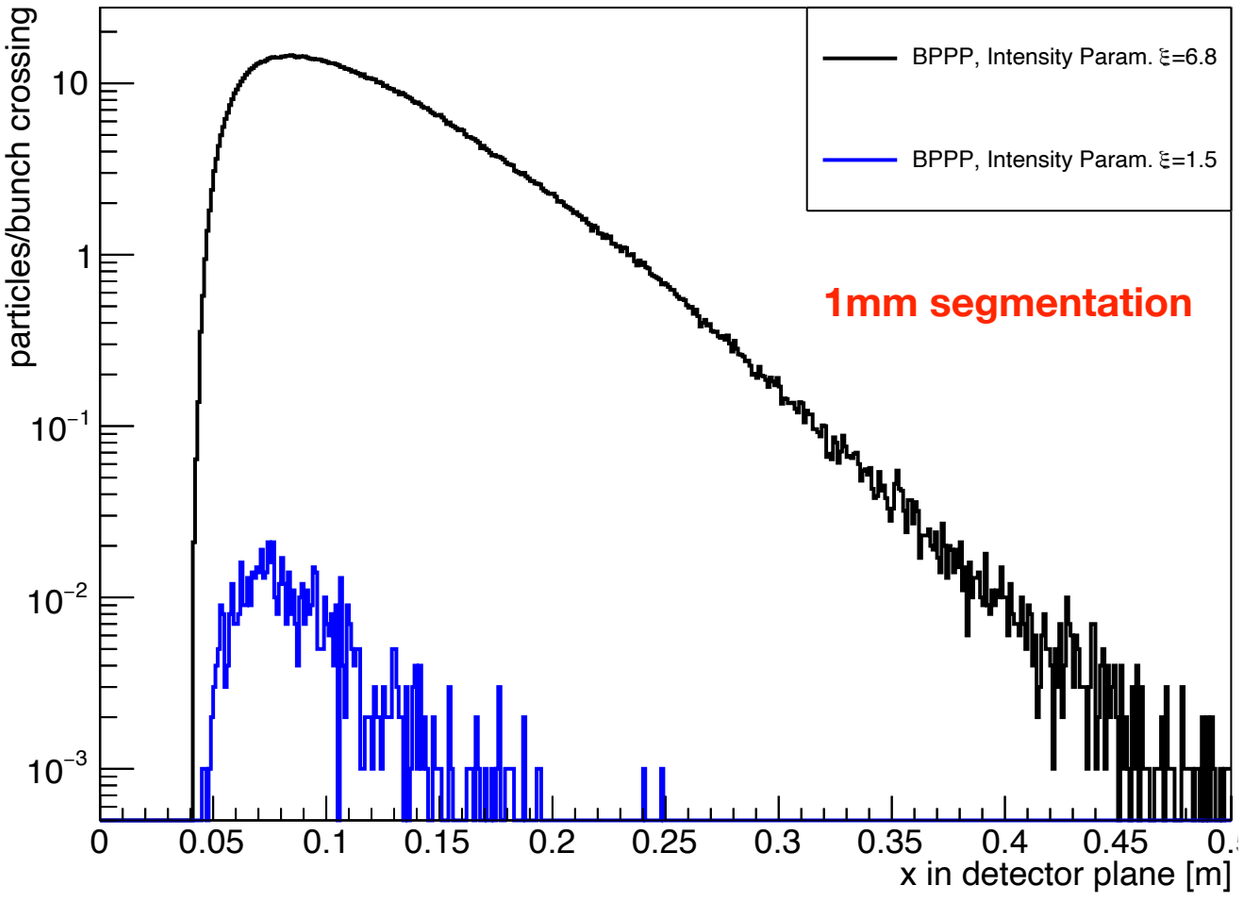

$\gamma_B + n\gamma_L$, E_e=17.5 GeV
$\gamma_B + n\gamma_L$, E_e=14 GeV
$e + n\gamma_L$, E_e=17.5 GeV
# of Events
E [GeV]

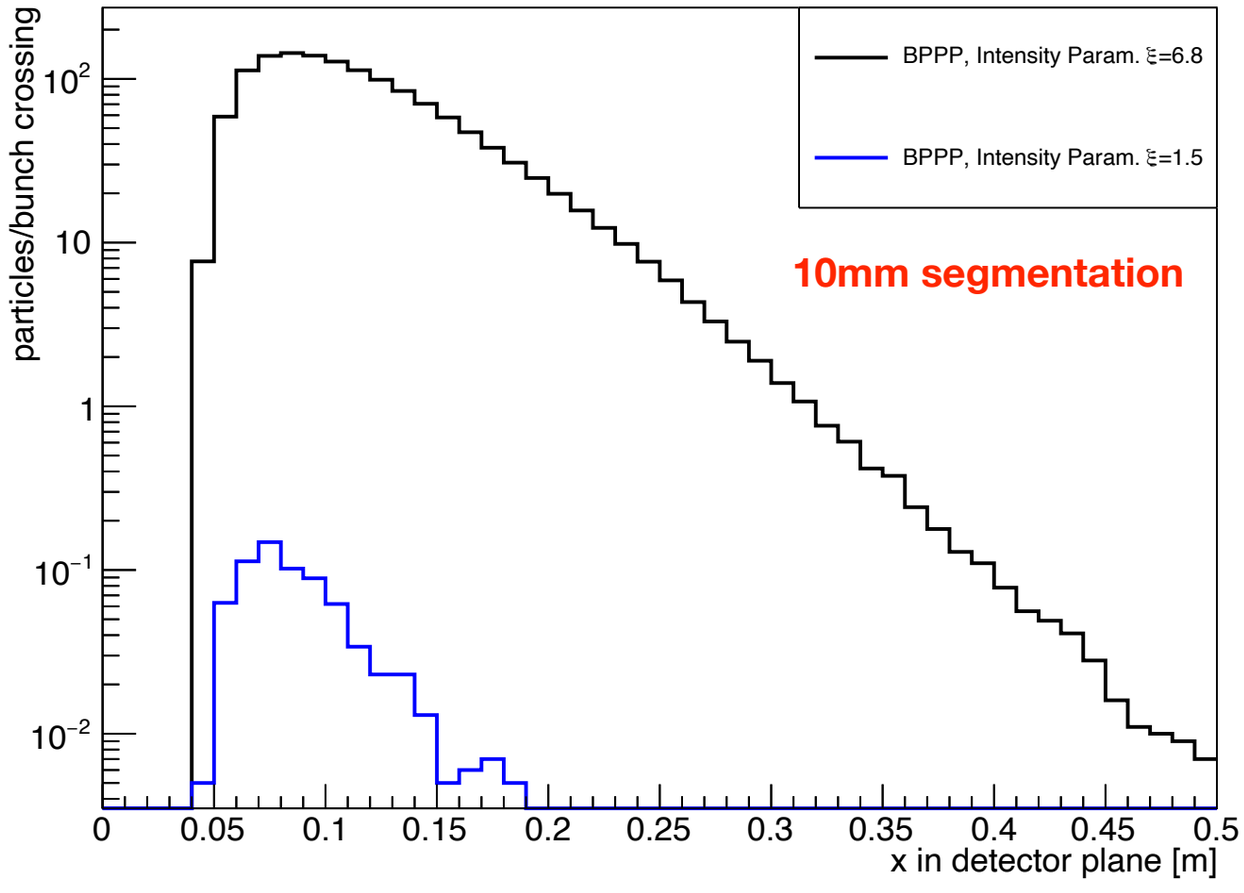

B=1.0T
z_m=1.08m
z_d=1.40m
x(16.5GeV)=0.04m
x(1.5GeV)=0.42m
x[m]
E[GeV]


Trident for B = 1.0 [T]
z [cm]
E [GeV]
x [cm]

Segmentations?

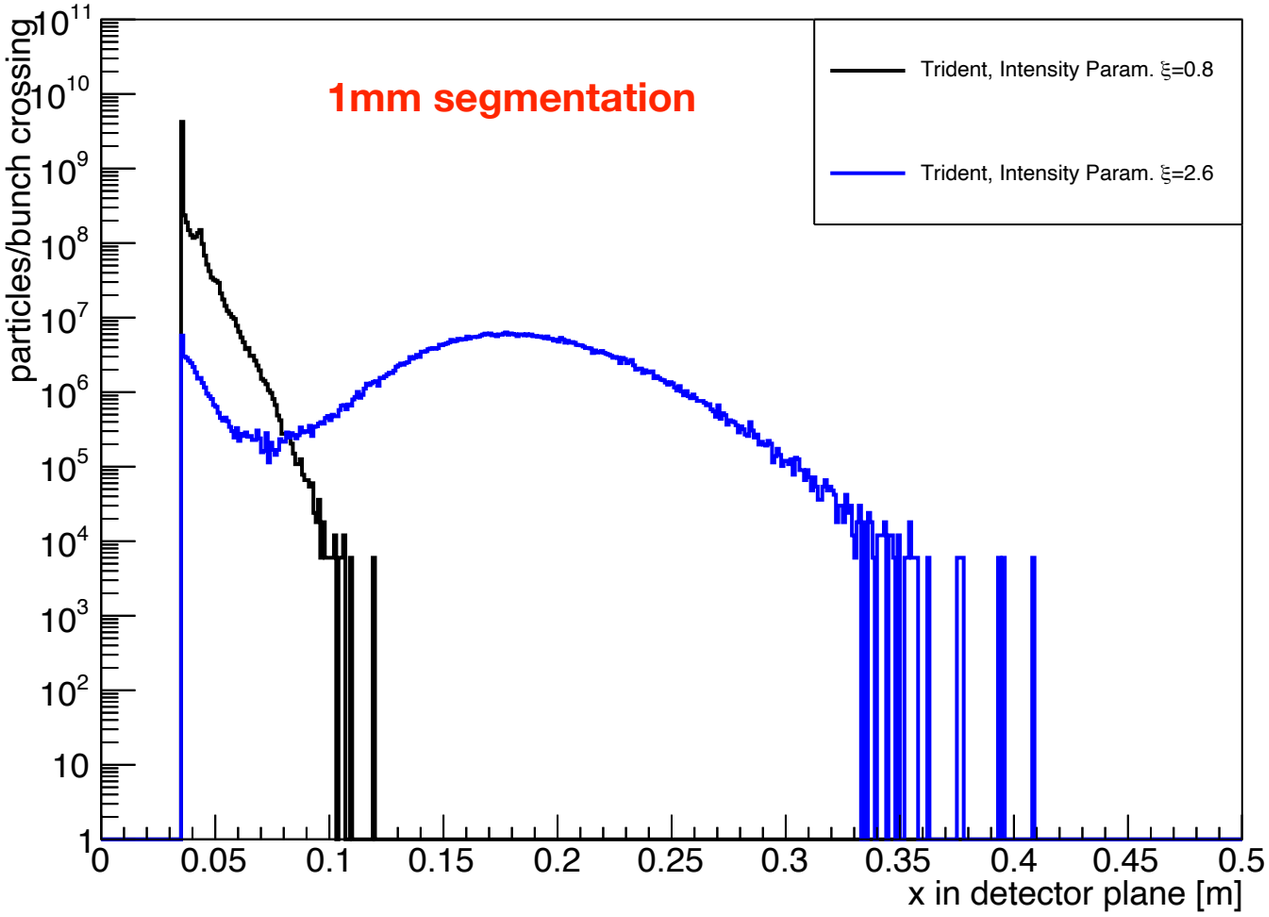
B=1T, z_d=1.40m

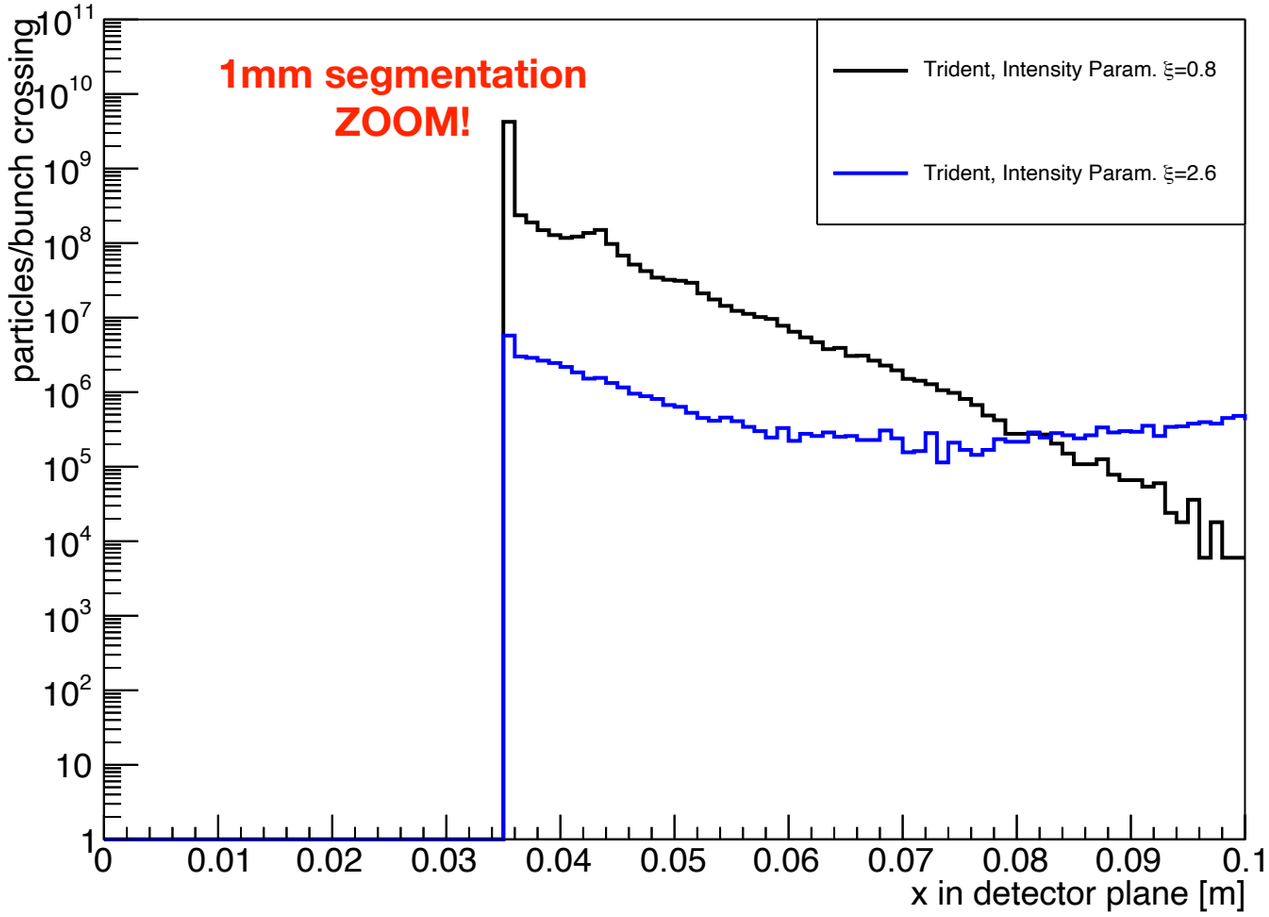




Segmentations?

B=1T, z_d=1.40m





- possibly problematic: very little space between the beam and the first edge!
- probably 10mm resolution enough for lower energies (?)
- Do we really need to reconstruct the edges in the LASER calibration mode before we change to BPPP?

Summary:

- Hybrid setup, two options:

  1) Same gas volume, two channels (one with Quartz/longer channel)
     - ✅: only one PM per channel needed
     - ❌: same segmentation Compton/BPPP needed
     - ❌: possible background due to particles entering “wrong” channel

  2) Two gas volumes (two boxes on top of each other):
     - ✅: more flexibility in segmentation & rates
     - ❌: need one PMT per channel per box
       - (?): can we keep channels 5cm apart only
- lower magnetic field is not optimal for Compton edges, despite Cerenkovs sitting further back from the magnet
- Gas more suitable than Quartz, because of energy threshold
- I think we really need to define clearly what we want to do with the Cerenkovs in the hybrid setup (supplementary to Tracker in BPPP and LASER calibration mode)
- Working on cost estimate per channel to estimate if this option is really cheaper than the Calorimeter