Luminosity Detector Studies for the EIC

(CNFS Summer School 2022)

1. Introduction
2. Possible Designs
3. Geant4 Implementation for the design
4. Initial Simulation Results

Aranya Giri & Dhevan Gangadharan

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Introduction

- The performance of particle colliders — Beam Energy and Luminosity.
- Luminosity is the measurement of maximum no. of collision that can be produced in the collider per cm^2 per sec.

Fig.: Schematic diagram of two symmetric bunch in IP.

$$L \sim f N^2 / 4\pi\sigma^2$$

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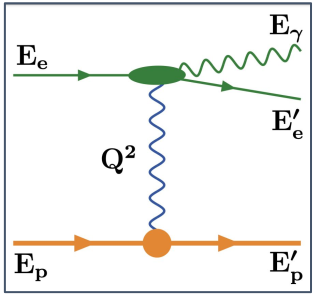
- The rate of an event is proportional to the cross-section (σ_p) of that associated process.

$$R = L\sigma_p$$

- Precise knowledge of luminosity = Precise determination of σ_p
- At EIC, High Luminosity ~ 10^{33-34} per cm^2 per sec & precision(error) ~1 %

Bremsstrahlung radiation

- HERA (predecessor of EIC) measured luminosity via bremsstrahlung radiation (br).
- Radiation due to elastic scattering of electron near strong electric field (p / Nu).
- High rate and precisely calculable cross-section from QED



$$\frac{d\sigma_{BH}}{dE_\gamma} = 4\alpha r_e^2 \frac{E_{e'}}{E_\gamma E_e}\left(\frac{E_e}{E_{e'}} + \frac{E_{e'}}{E_e} - \frac{2}{3}\right)\left(\ln\frac{4E_pE_eE_{e'}}{M_pM_eE_\gamma} - \frac{1}{2}\right)$$

$$d\sigma/d\Theta_\gamma \sim \Theta_\gamma/((M_e/E_e)^2 + \Theta_\gamma^2)^2$$

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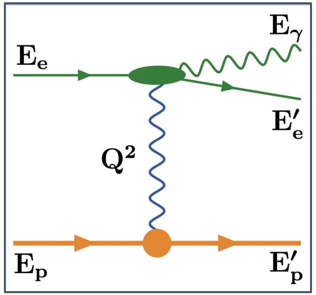

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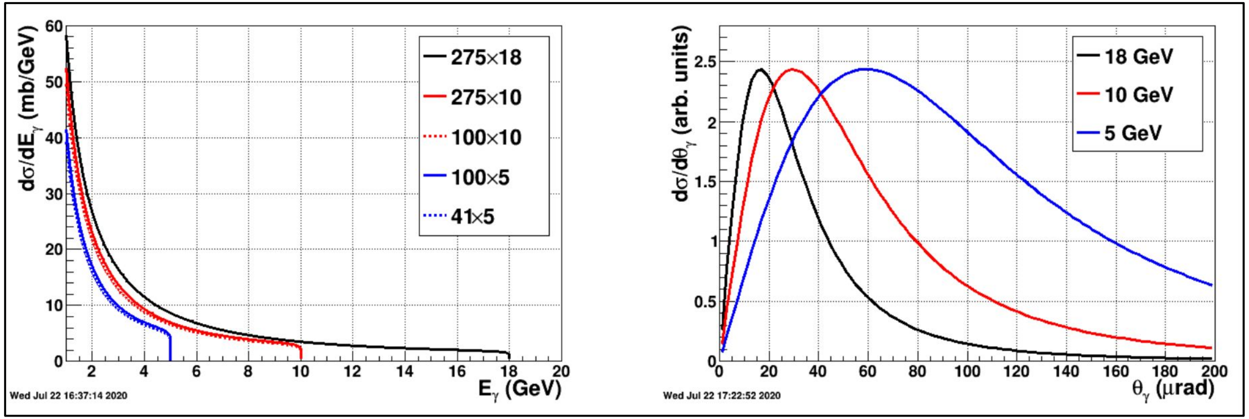

Fig.: Simulated bremsstrahlung photon energy (left) and angular (right) distributions for EIC beam energies (Yellow Report).

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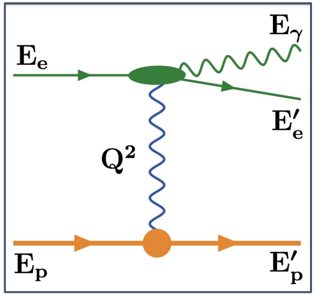

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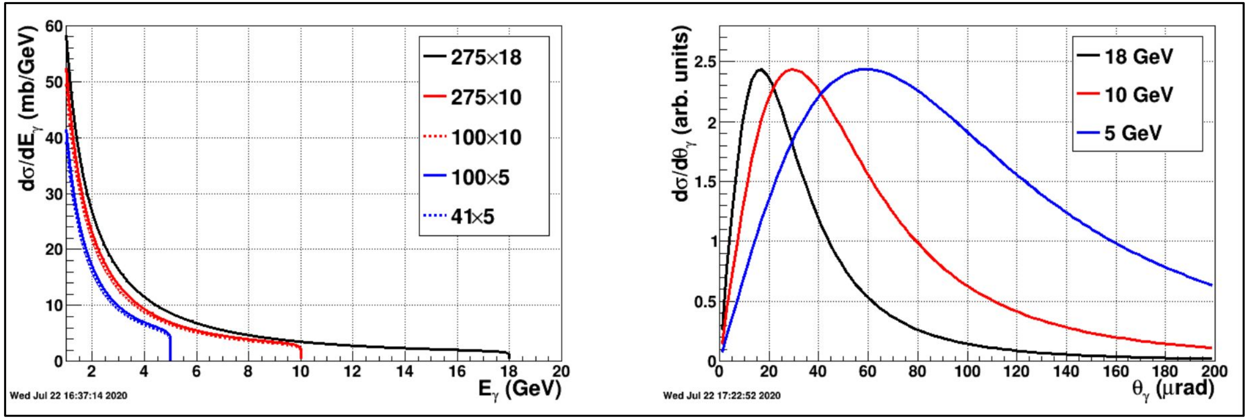

$$\mathcal{L} = R^{ep}/\sigma_{BH}^{obs}$$

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Luminosity Detector position at EIC

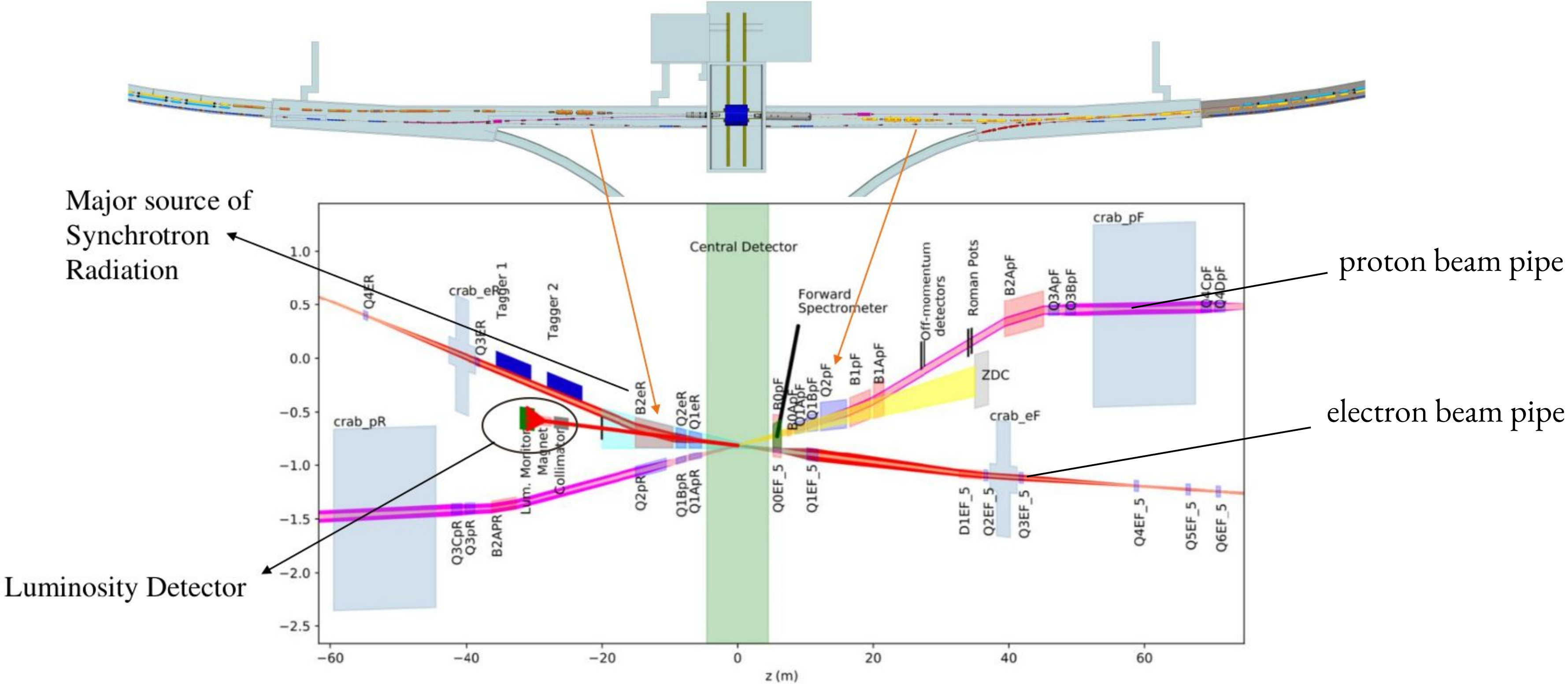


Fig.: Schematic layout of the EIC interaction region

Preview of HERA Luminosity detector

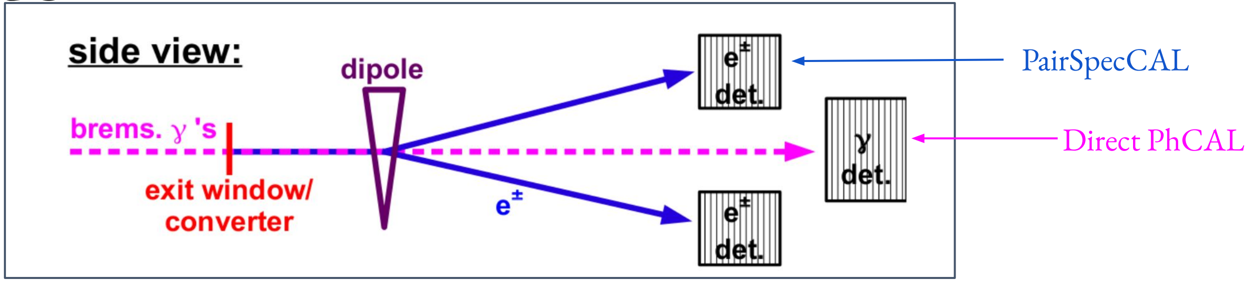
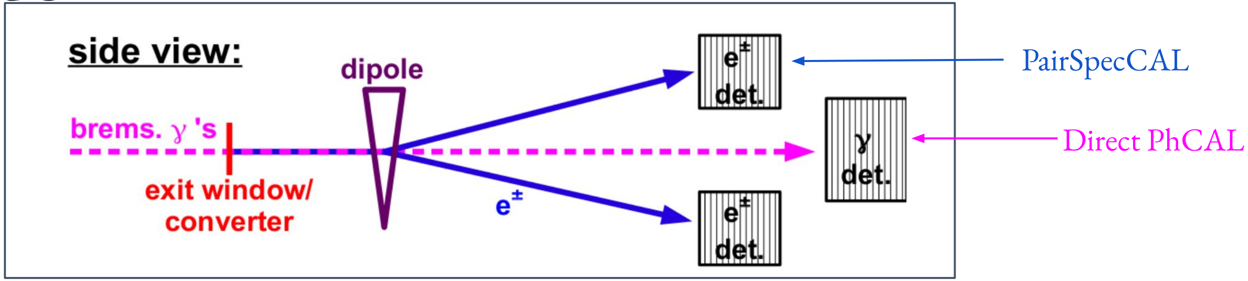


Fig.: Schematic diagram of HERA (ZEUS Exp) luminosity monitor

Two Independent Approach complementing each other

Preview of HERA Luminosity detector



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Two Independent Approach complementing each other

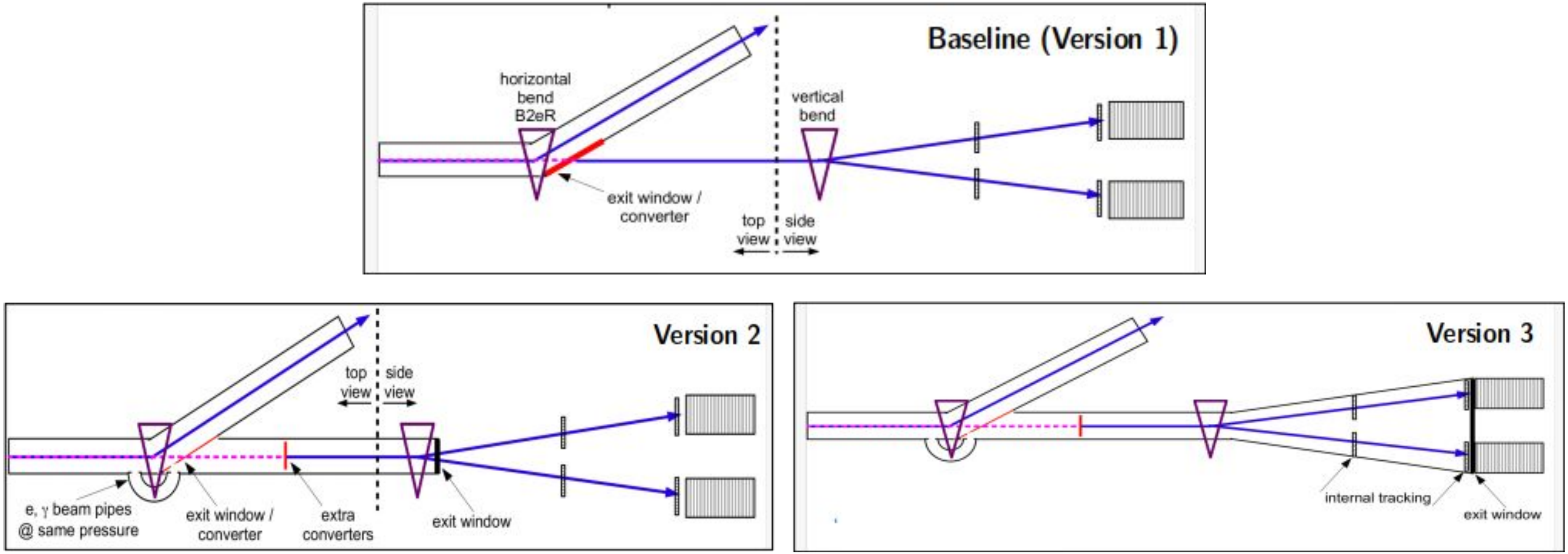
Direct PhCAL :

1. Sensitive to synchrotron radiation
2. Pileup, high rate of γ per bunch crossing, 10/23 for 18/10 GeV. (350 for Nu)
3. Simple Implementation

PairSpecCAL :

1. Outside the direct synchrotron radiation fan; Natural low E_γ cutoff ($\gamma \rightarrow e^- e^+$)
2. Deals with pileup, Adjusting the Converter, Dipole |B| & Geometry.
3. Complex Implementation

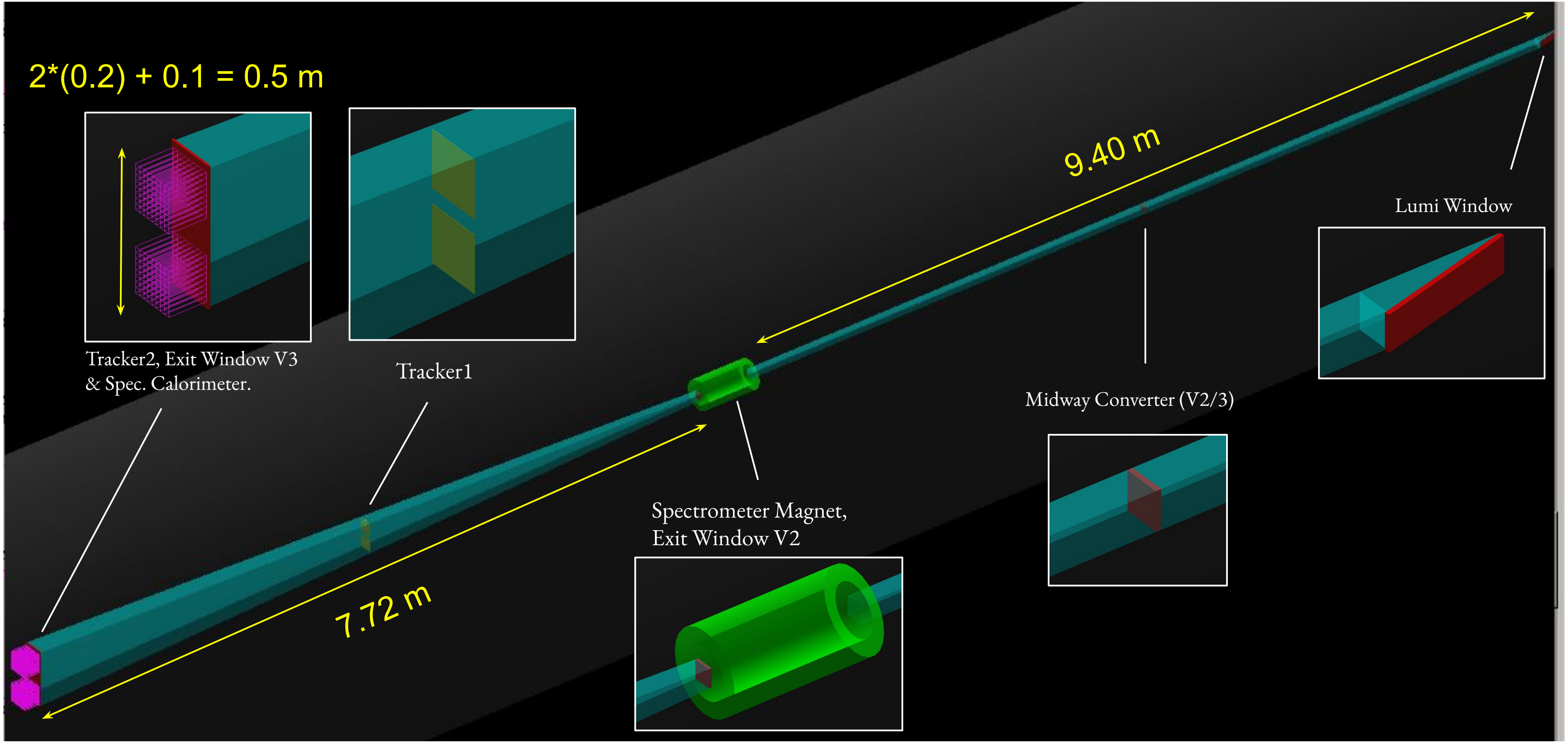
Possible design for Lumi detector



- The designs mainly differ in how far the vacuum region extends and where the thick Aluminum exit window is placed.

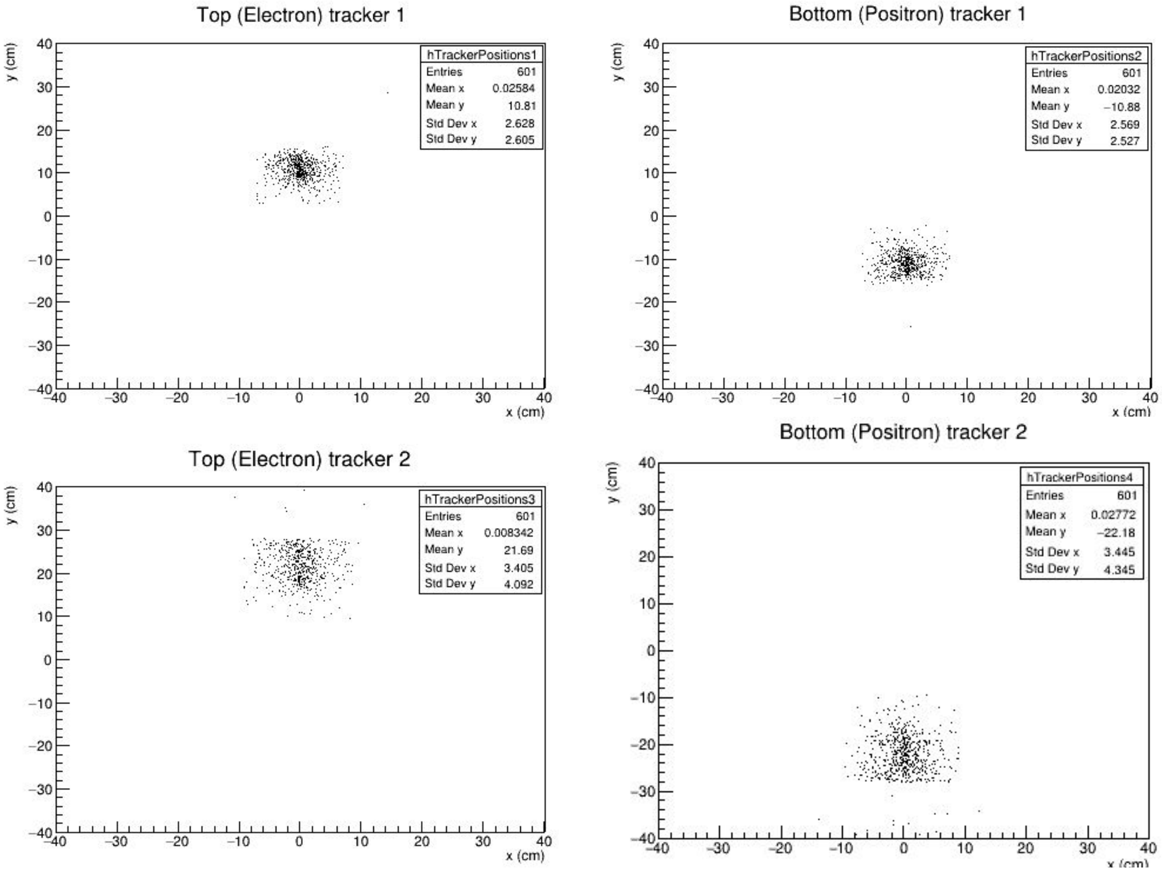
Designs by W. Schmidke @ Far Backward Meeting on 4-28-2022

Geant4 implementation for the Design



Size and calorimeter design by Jaraslav Adam's Code

Initial Simulation Results



- Hit points for Baseline Design.

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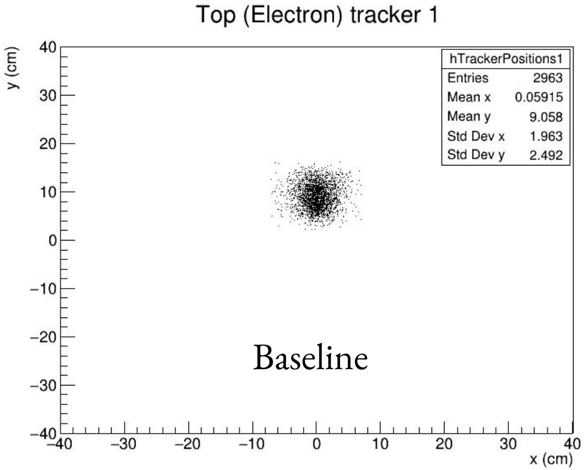

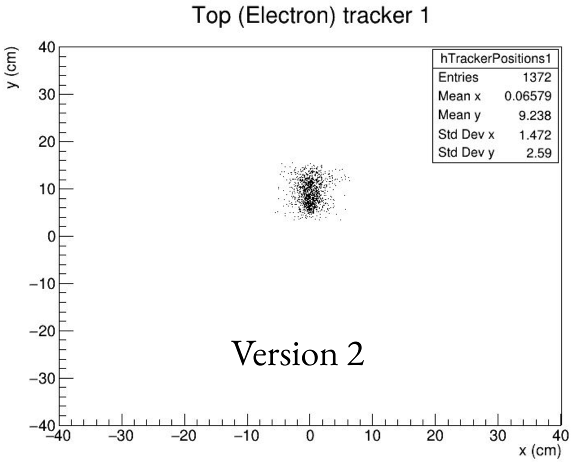

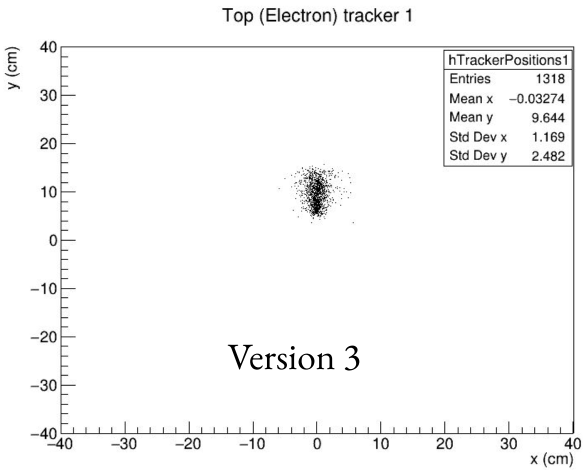

- 5000 events generated
- 5 GeV photon beam without transverse smearing.
- Hit_points considered only when electron crosses top two trackers and its pair produced positron crosses bottom two trackers.

Next Step

1. Calculating the photon energy from the pair spectrometer calorimeter.
2. Compare E_gen to E_rec for each vacuum configuration to assess the advantages of designs 2 and 3 over the baseline.
3. Include beam size effects → 1.

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Thank You