# Far Backward Pair Spectrometer TIC meeting

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PS DSC

Pair Spectrometer Wiki Page:

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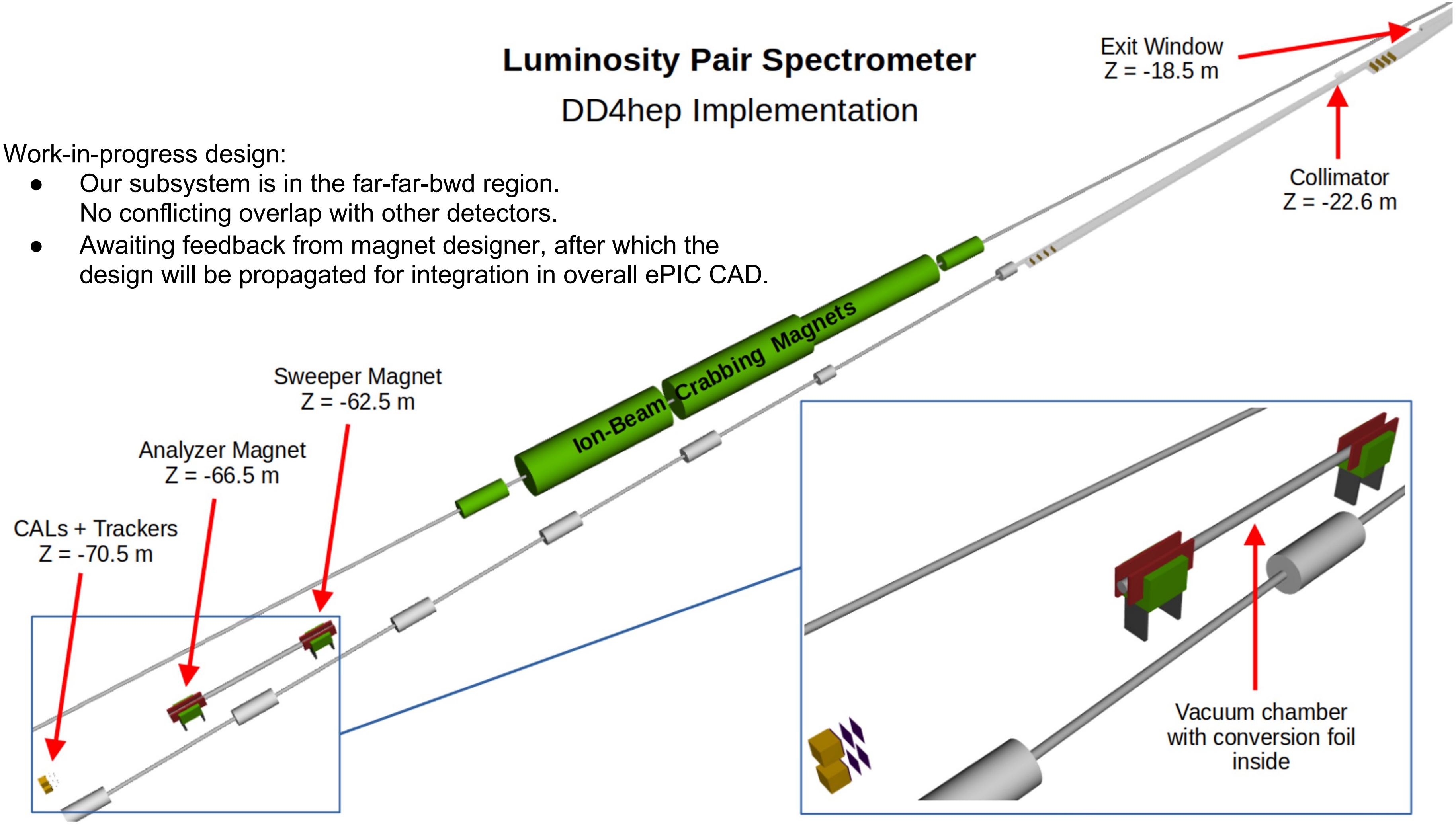
# Luminosity Pair Spectrometer

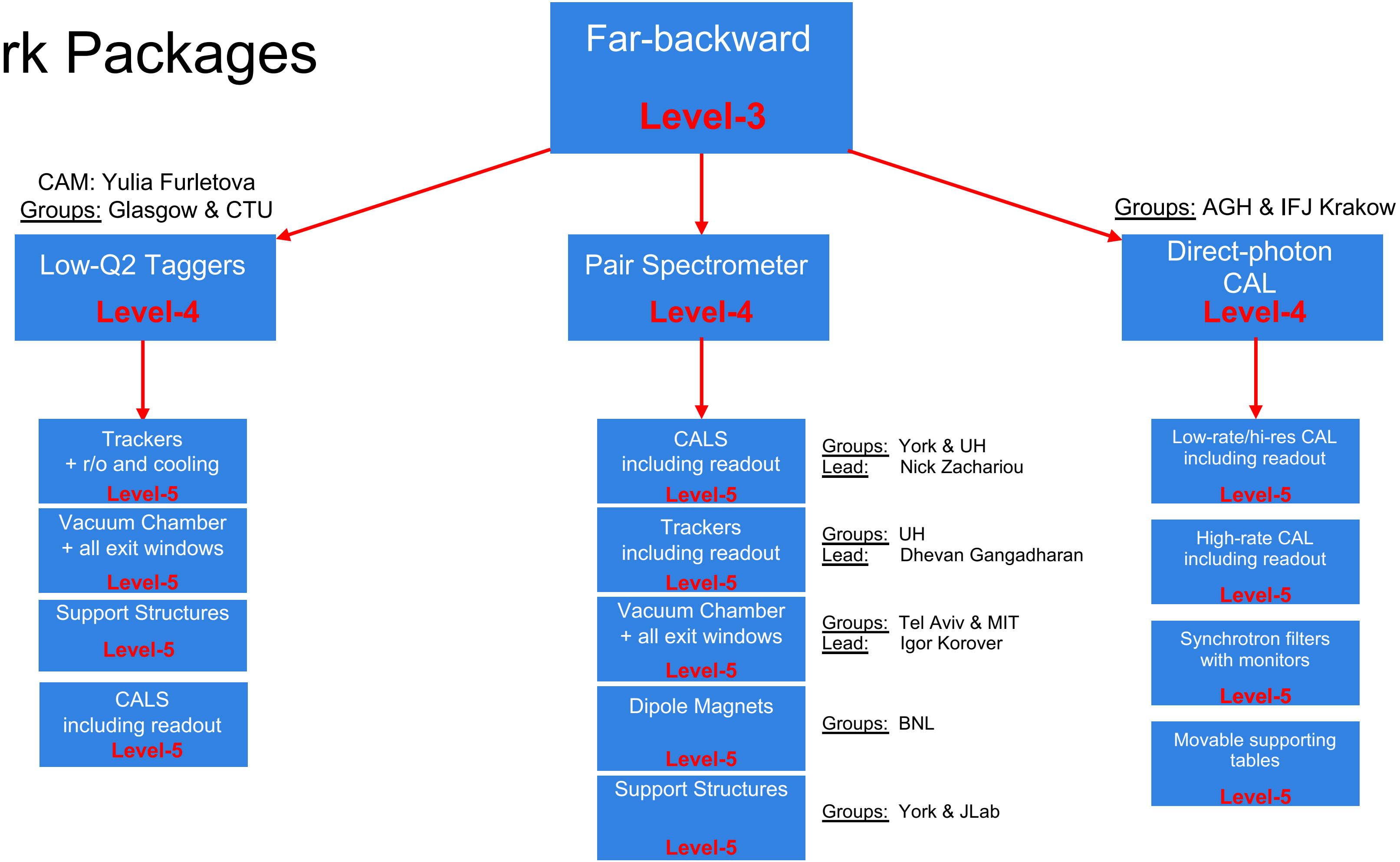
## DD4hep Implementation

Work-in-progress design:

- Our subsystem is in the far-far-bwd region.
  No conflicting overlap with other detectors.
- Awaiting feedback from magnet designer, after which the design will be propagated for integration in overall ePIC CAD.



# Work Packages



# General Pair Spectrometer Requirements

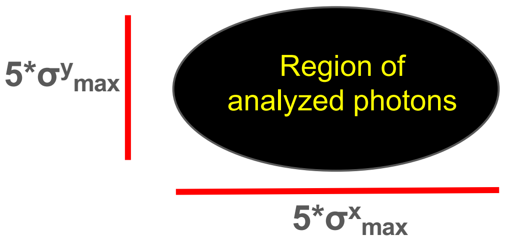
## Well-understood Acceptance:

Need to provide an unobscured path for Bremsstrahlung photons to propagate from the IP to the lumi exit window, and then from the exit window to the Pair Spectrometer.
Photon beam width ∝ electron beam angular divergence.
Photon beam width $\sigma(Z) = \Delta\theta * Z$.
Max beam divergence $\Delta\theta_{max}$ = 211e-6 rad.
$3*\sigma_{Gaus}$ covers 99.7%, but beam may not be Gaussian and it's preferable not to extrapolate.
**$5*\sigma_{max}(Z)$ conical region should provide adequate acceptance.**

*From IP to lumi exit window:*
Need to ensure that there are **no beam pipe walls** within the $5*\sigma_{max}(Z)$ cone.

*After exit window:*
Need to ensure that there are **no obstructions whatsoever** within the $5*\sigma_{max}(Z)$ cone.

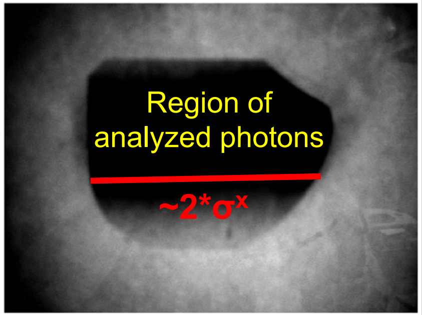
Need a simple and well-understood aperture!




This! ←

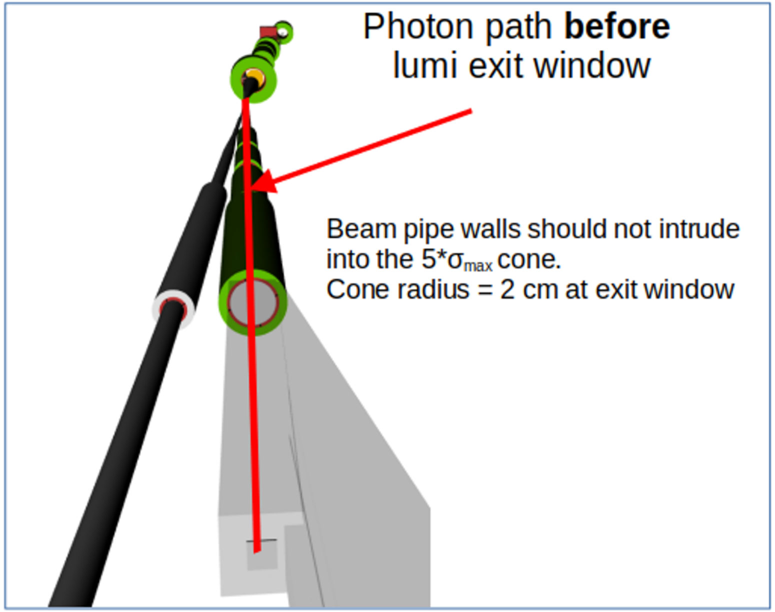
Not this! →

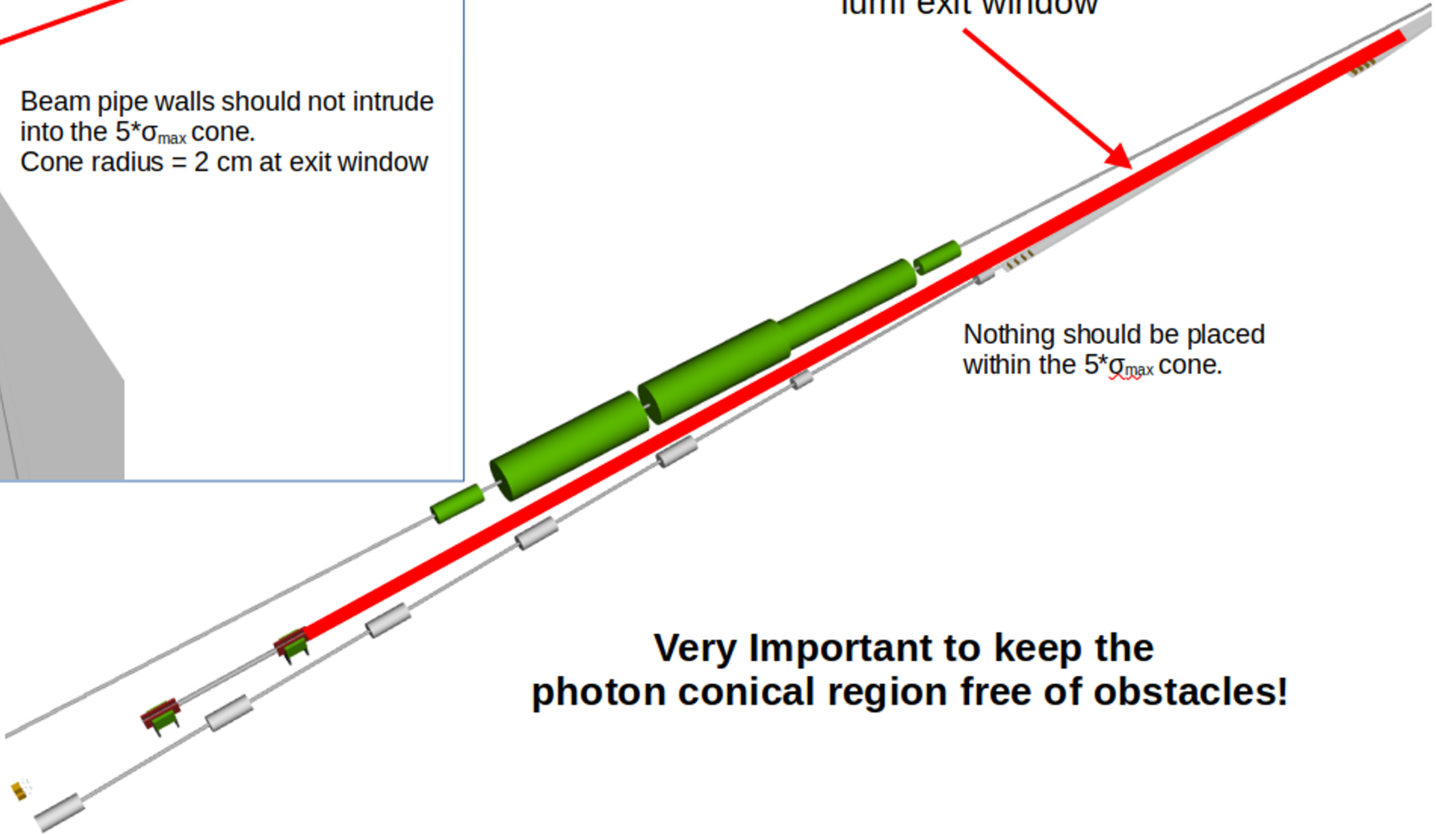
ZEUS photon aperture




This was the dominant source of uncertainties for the HERA luminosity

# General Pair Spectrometer Requirements




**Very Important to keep the photon conical region free of obstacles!**

# General Pair Spectrometer Requirements

## Exit window and conversion foil:

The chemical composition and thickness of the exit window & foil need to be precisely known.
Foil could be 1 mm thick Aluminum -> 1% conversion probabilities (needed in eA to avoid pileup).
Foil needs to withstand the synchrotron heat load.

## Sweeper and Analyzer Magnet:

Need strong and adjustable fields, B*dL = 1 T*m, so that our system can be as compact as possible. This, along with a vacuum chamber, minimizes the conversions in air within our subsystem. Due to the placement of our system in far-far-bwd region, magnet bore diameters need to be large: 2*5*$\sigma_{max}$ ~ 15 cm. Preliminary discussions with the BNL magnet designer, Peng Xu, suggest that this is feasible. Fringe fields need to be small to avoid degrading the nearby electron beam quality.

## Bunch configurations:

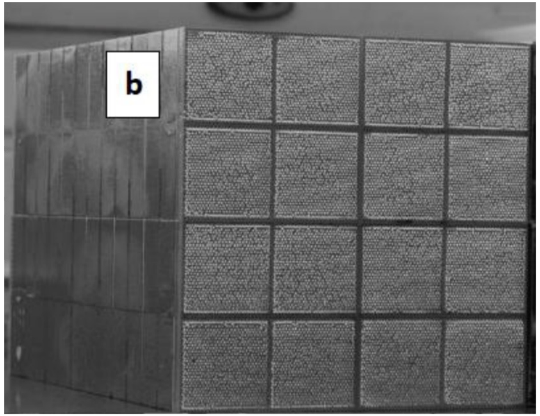
Pilot bunches are needed to assess the beam-gas background!

# CAL

## Requirements:

Past experience from ZEUS indicates that an E resolution of **17%/Sqrt(E)** is sufficient.  A more segmented readout design can improve E resolution and help disentangle pileup.  **~ns timing resolution** to enable luminosity determination on a bunch-by-bunch basis.

Design based on O.D. Tsai (DOI: 10.1088/1742-6596/404/1/012023) fulfills requirements

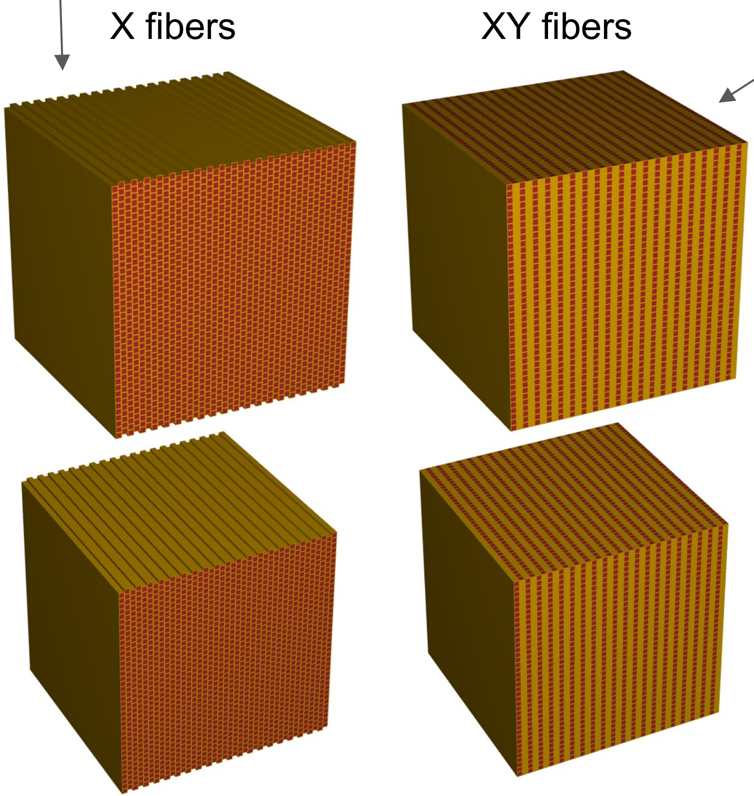


# CAL designs

- Scintillating fiber Calorimeter based on DOI:[10.1088/1742-6596/404/1/012023](https://doi.org/10.1088/1742-6596/404/1/012023)
  - Tungsten Powder and epoxy with embedded Fiber grid
  - Easy to construct/assemble
  - Radiation length 7 mm
  - Molere Radius 23 mm
  - Sampling Fraction 2%
  - Energy resolution of 12%/Sqrt(E)
- Parameters can be tuned by changing volumetric ratio between Sci and W.
- XY or XYZ fibers can provide 5D shower reconstruction (Positions, Energy, and Time) presenting exploitation capabilities with ML techniques

Similar to forward ECAL

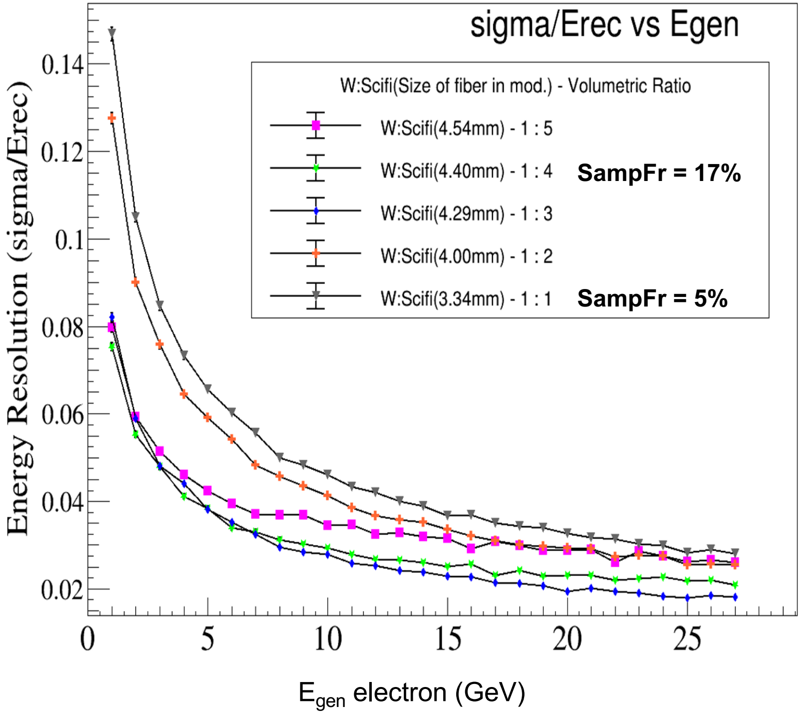
Performance and practicality of construction being studied

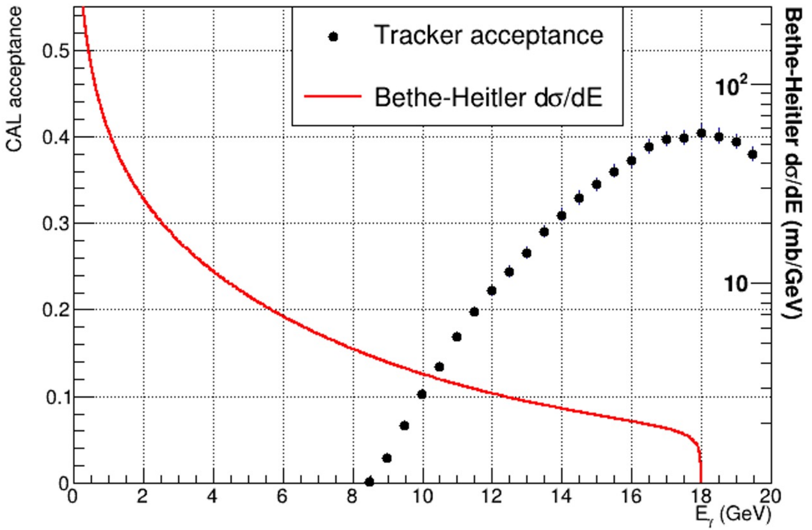



- Size: 20 x 20 x 20 $cm^3$
- >20 radiation lengths
- Large acceptance (8-18 GeV electrons at largest B field)
- Allows for studying beam spot size and beam divergence

University of York In kind contribution (awaiting decision on proposal)

# Current CAL design results (fibers running along X & Y)

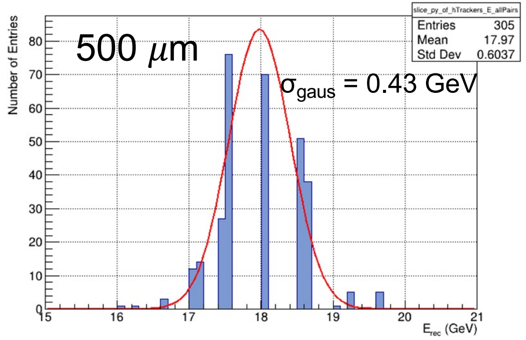


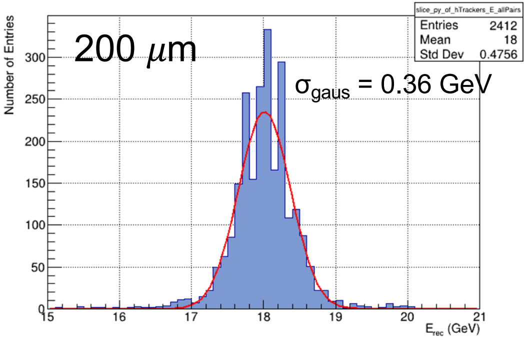



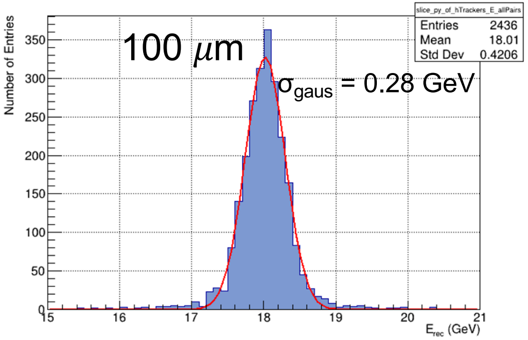

- For the most “bright” eA runs, we want such an acceptance to keep the rates low.
- For dimmer ep runs, we can shift the acceptance curves to the left by lowering our B fields.

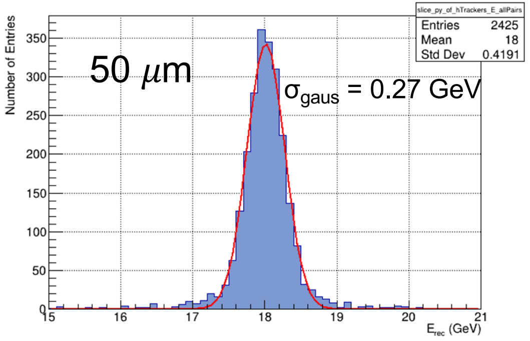
- Need to study the how the Moliere radius changes with W:SciFi ratios (need to keep it small).

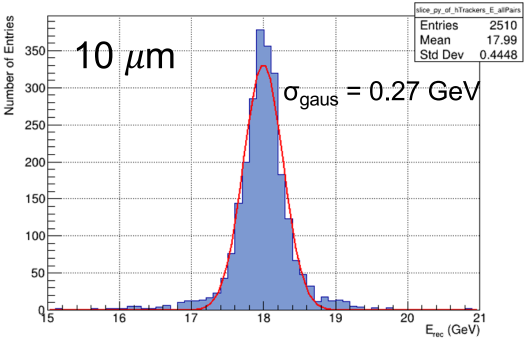
# Trackers - Effective Pixel Size and Energy Resolutions



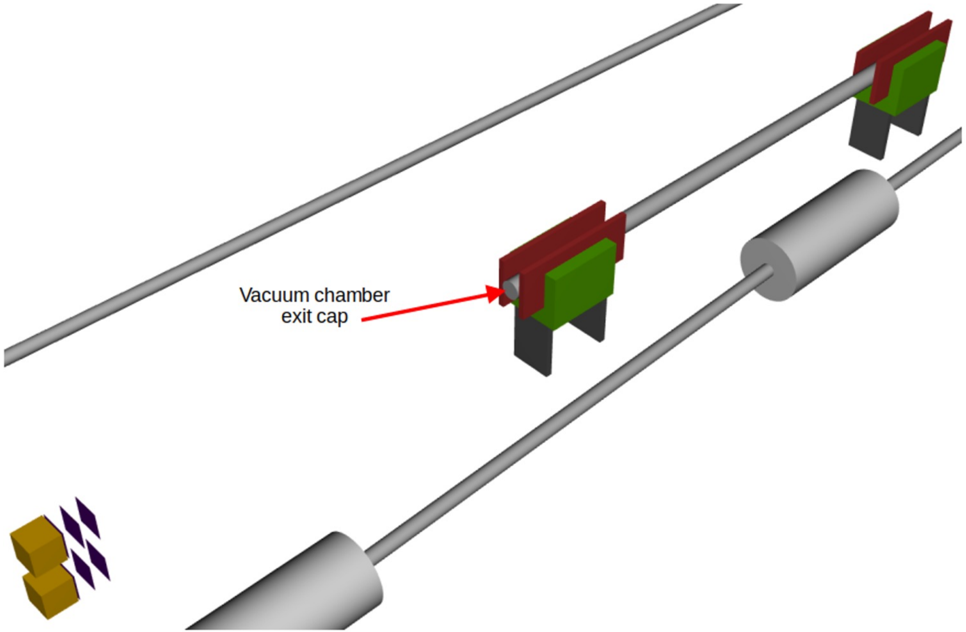



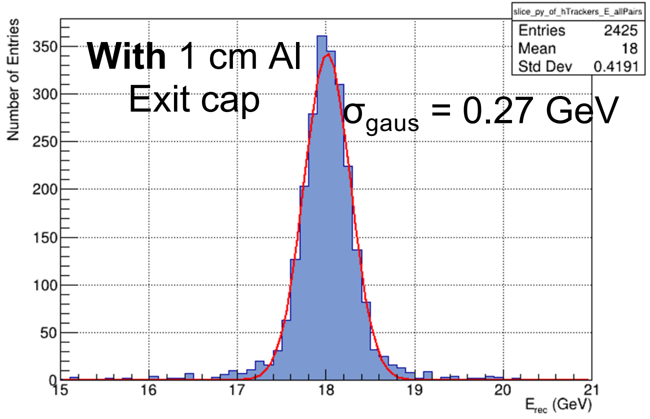

AC-LGAD effective pixel size
w/o charge-sharing:
500 $\mu$m / Sqrt(12) = 144 $\mu$m

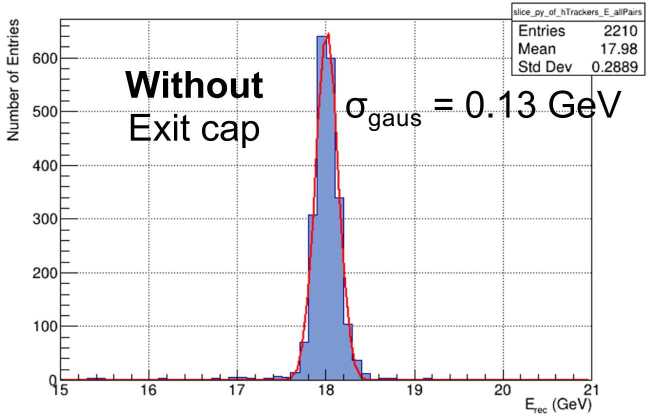
- Clear discretization effects visible for “large” pixels, due to small angular range of tracks: 0.7° to 3.6°. Note, effective pixel sizes are meant to include “1/Sqrt(12)” and charge-sharing effects.

# Trackers - Energy Resolution




50 $\mu$m pixels



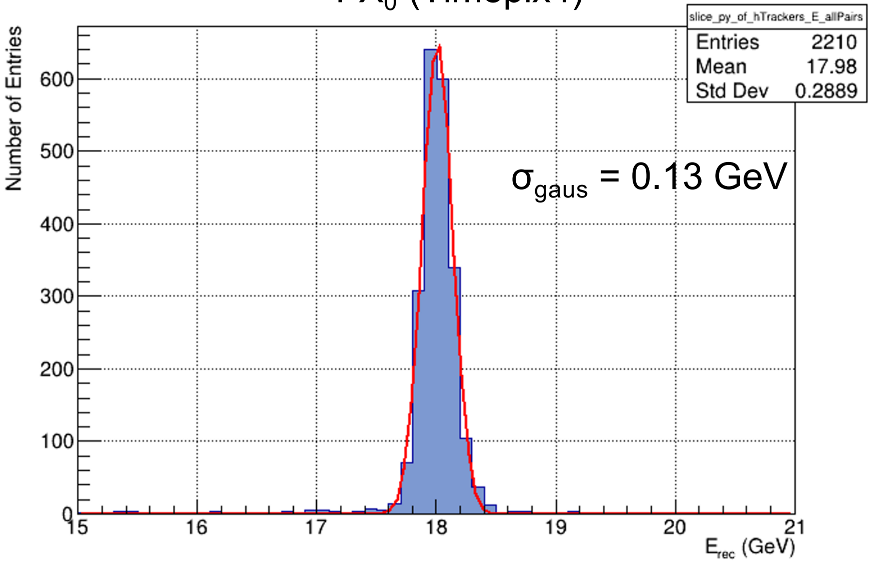

We could possibly obtain ~1% energy resolution from the trackers.
Need to investigate alternative materials and thicknesses for exit cap.
Should choose small effective pixel sizes to exploit this potential.

**Excellent tracking**
**→ excellent E resolution**
**→ excellent pointing resolution (feedback of e beam divergence)**

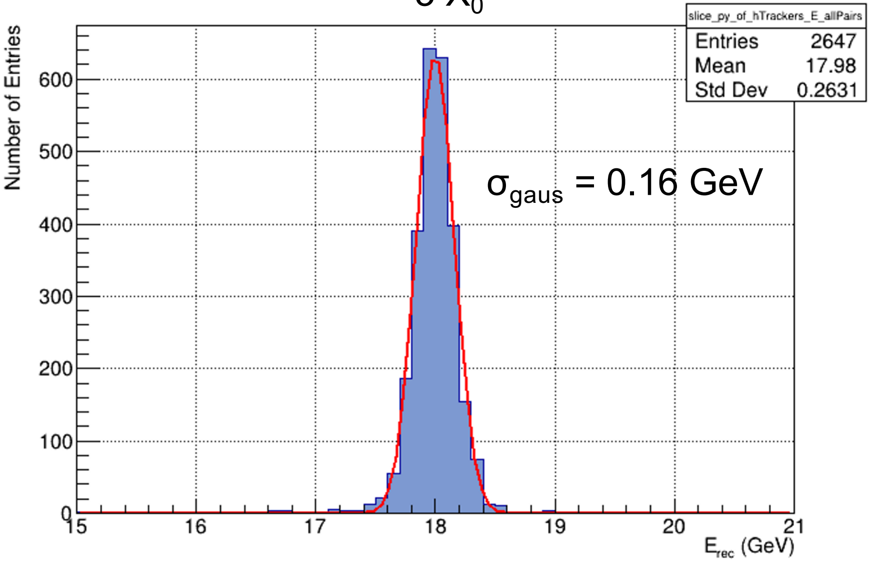
# Trackers - Material Budget

50 $\mu$m without exit cap

1 $X_0$ (Timepix4)



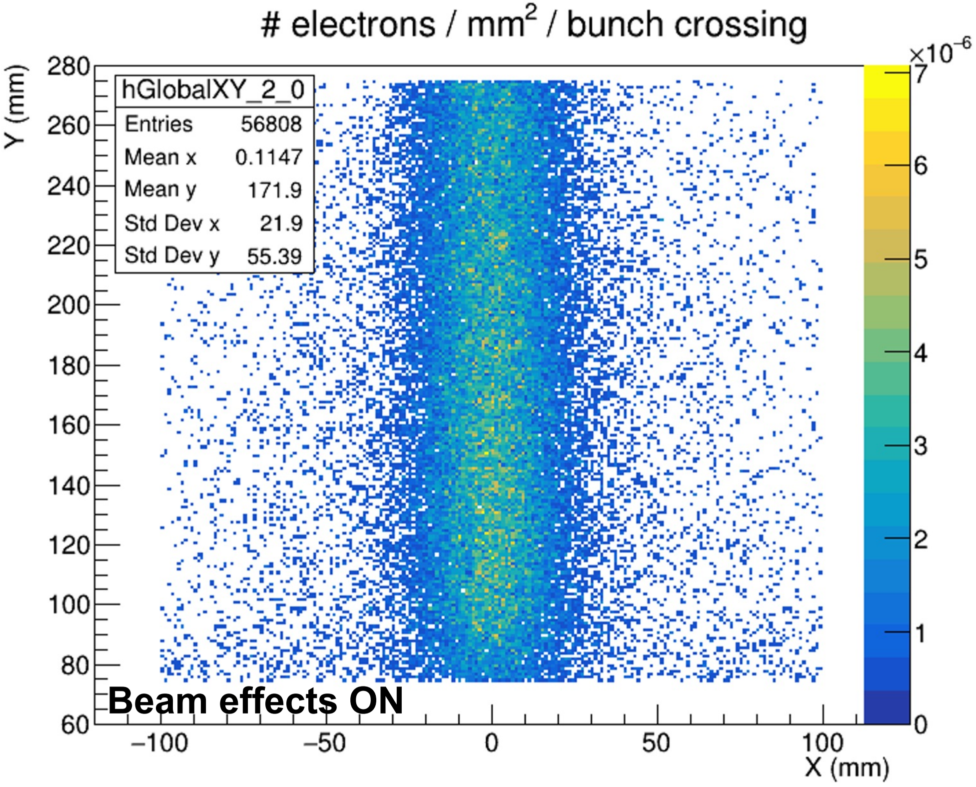

3 $X_0$




No stringent requirement on the sensor material budget.

# Trackers - Occupancies

ep 18x275 (44 ns bunch spacing)




~ $10^{-5}$ electrons per $mm^2$ per bunch crossing.

~ $10^{-5}$ electrons per 55 um pixel per bunch crossing in the “brightest” eA setting.

**Large sensor integration times are not a problem (even $\mu$sec level).**

# Tracker Technology choice - Help Needed

Pair Spectrometer trackers:

| | |
|---|---|
| Total Sensor Area | = 2 sets * 3 layers * 20 cm * 20 cm = 2,400 $cm^2$ |
| Effective pixel sizes: | ~50 um |
| Material budget: | no stringent requirements |
| Integration times: | no stringent requirements |
| Time resolution: | ~nsec, to distinguish bunch crossings. |

Low-Q2 trackers:

They plan to use Timepix4, which would also satisfy our requirements.

| | |
|---|---|
| Total Sensor Area | = 2 stations * 4 layers * 22 cm * 12 cm = 2,112 $cm^2$ |
| Their estimated cost is | ~$2.1M. |

Is there a more affordable solution than Timepix4 for the Pair Spectrometer?  Microstrips?

# ZEUS Lumi Systematics

Yellow Report Requirements:

- ~1% uncertainty for absolute luminosity
- Less than $10^{-4}$ for relative luminosity

NIM A 744 (2014) 80-90

| Component | | Sub-Component systematics |
|---|---|---|
| Acceptance | (**1.6%: Total**) | 1.0%: Aperture and detector alignment |
| | | 1.2%: X-position of photon beam |
| Photon conversion in exit window | (**0.7%: Total**) | 0.1%: Thickness |
| | | 0.3%: chemical composition |
| | | 0.6%: photon conversion cross section |
| RMS-cut correction | (**0.5%: Total**) | Rejection of proton gas interactions |
| **Total** | | **1.8%** |

Greatly reduced for ePIC with:
- a 5*σ obstruction-free aperture
- **low-lumi runs with coincidences of low-Q2 tagger and pair spectrometer: tagger critical for pair spec. calibration/verification**

Greatly reduced for ePIC with:
- trackers with good pointing res.

With the expected reductions, 1% absolute lumi precision within reach.
For relative lumi, need to study which systematics cancel (all?) and estimate the statistical uncertainty

# Path to Review

- Finalise magnet design and positions (underway, Peng Xu)
- Provide CAL designs:
  - Main target design: W powder with fibers running along X & Y (2D).
    Study electron shower profile in X & Y vs E.
    Study pileup mitigation.
  - Fallback design: W powder with fibers running only along X (like fECAL).
- Select appropriate tracker technology (help needed here)
- Support structures of Calorimeters and trackers
  (preliminary design made by York engineers)
- Study beam-gas effects