Far-Backward WG

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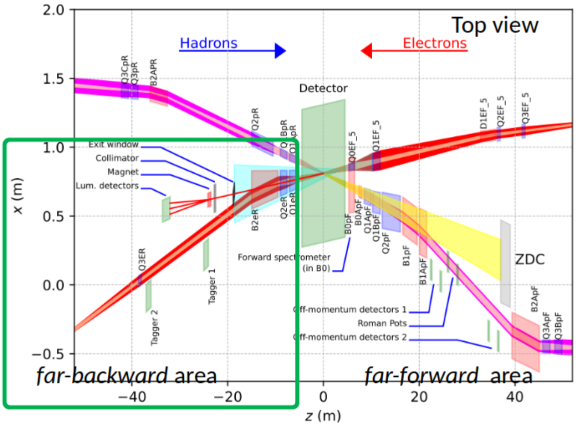
Far-Backward WG

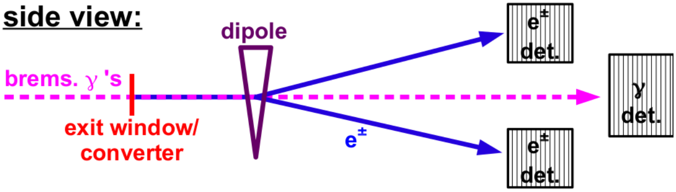
- Far-backward denotes instrumentation in electron outgoing direction
- Involves luminosity measurement and electrons scattered at very small angles
- Group conveners:
  - Igor Korover, `korover@mit.edu`
  - Krzyzstof Piotrzkowski, `piotrzkowski@agh.edu.pl`
  - Nick Zachariou, `nick.zachariou@york.ac.uk`
  - Jaroslav Adam, `adamjaro@centrum.cz`



- Our mailing list: lists.bnl.gov/mailman/listinfo/eic-projdet-farback-l
- Regular meetings are on Thursdays at 10am EDT, main indico: indico.bnl.gov/category/408/

Principle of luminosity measurement

- Process of elastic bremsstrahlung, $ep \rightarrow e\gamma p$, $e\mathrm{Au} \rightarrow e\gamma\mathrm{Au}$
- Large cross section peaked for photons at small angles
- Two methods for γ detection: direct detector and $e^{\pm}$ spectrometer:



The cross section is precisely known from QED

Figure: Cross section

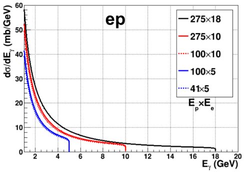
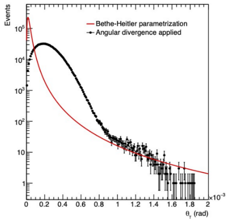
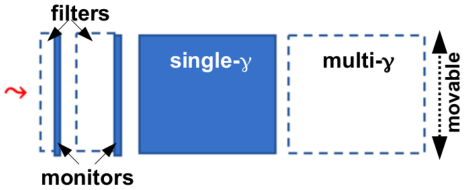


Figure: Angular distribution



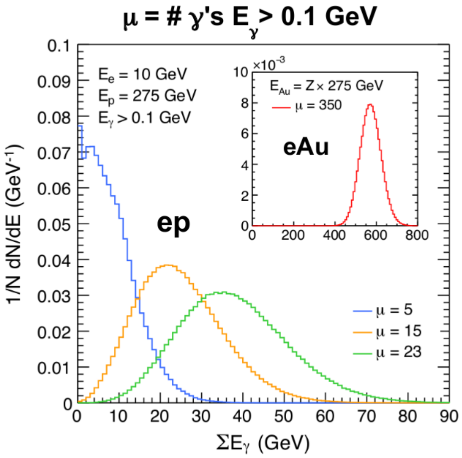
Direct photon detector



- Direct counts of bremsstrahlung photons
- Simple concept, approximate measurement
- More γ are incident in every bunch crossing because of large cross section (and luminosity)

Important for online machine performance

Figure: Energy spectrum in direct photon detector



Pair spectrometer

Figure: Spectrometer layout

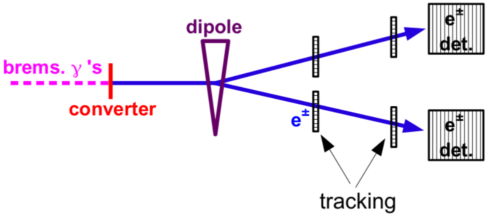


Figure: Acceptance in E_γ

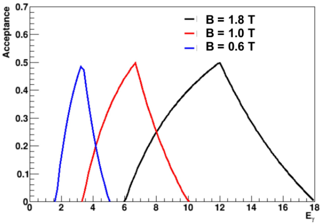
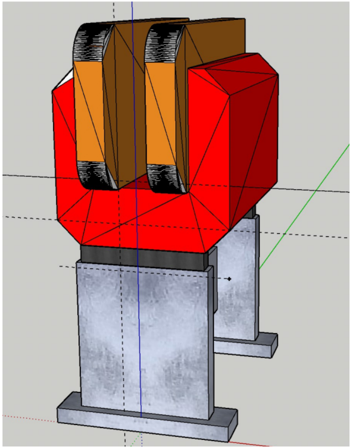


Figure: Dipole magnet



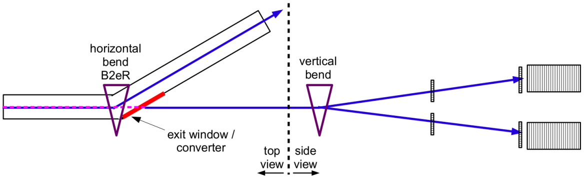
- Spectrometer detects e^+e^- pairs from converter layer
- Acceptance is given by dimensions and dipole field
- Detection is not affected by low energy synchrotron radiation

The spectrometer provides precise measurement for physics results

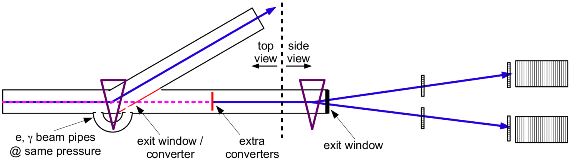
Vacuum system for pair spectrometer

- Conversion layer is part of beam layout
- Need for precise knowledge of conversion probability
- Heat load from synchrotron radiation is incident on the layer
- Several considerations for the design:

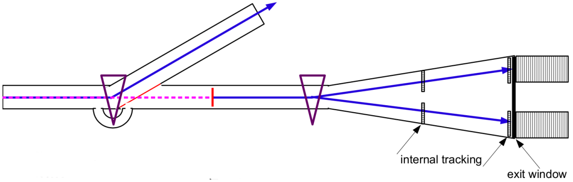
I: baseline design, converter holds the vacuum



II: thin converter in vacuum

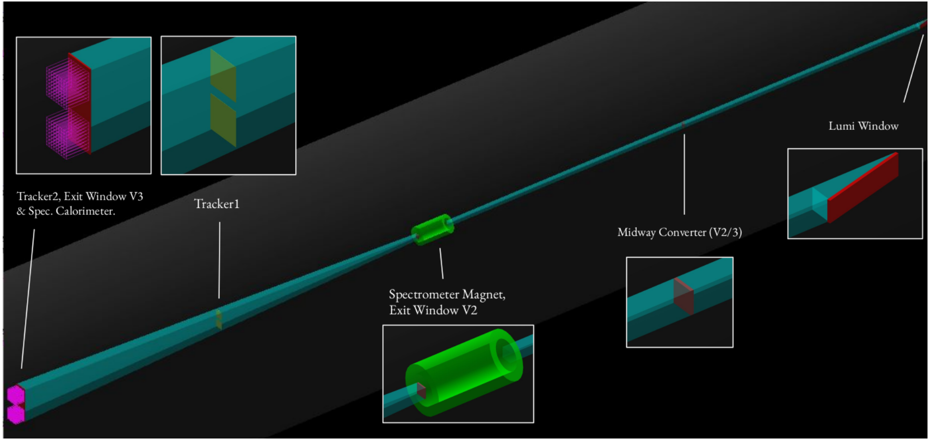


III: vacuum up to detectors



Overall layout in Geant4

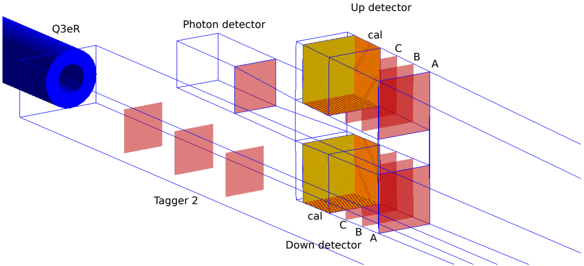
- Several layout concepts are implemented in Geant4
- Studies are ongoing in terms of photon aperture, acceptance and event rates



Spectrometer section in Geant4

- Detailed view at detector part for e^+e^- conversion pairs
- Tracking layers (A, B, C) are followed by calorimeters, both in up and down detectors
- Direct photon detector is placed behind the spectrometer detectors
- Outgoing electron beam passes through the Q3eR magnet besides the detectors

Figure: Detector section in Geant4



Photon reconstruction in the spectrometer

- Prototype machine learning using only tracking information from up and down detectors
- Additional calorimeter data will improve the resolution and/or provide systematics

Figure: Energy

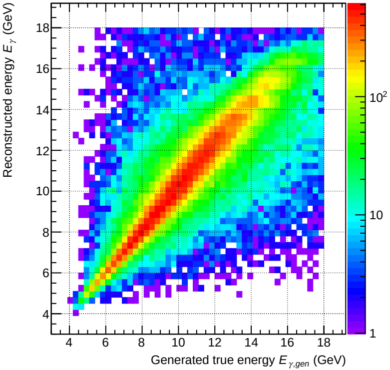


Figure: Polar angle

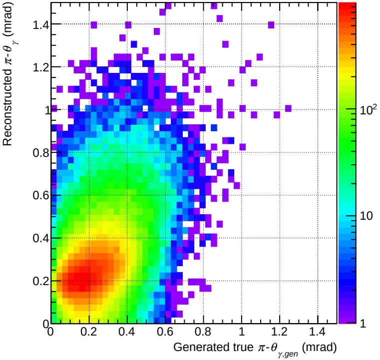
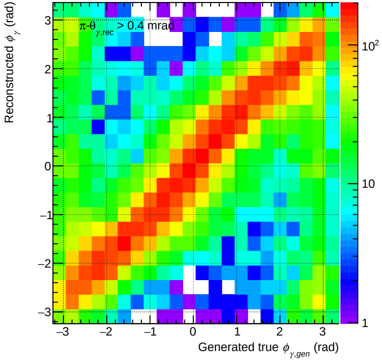


Figure: Azimuthal angle



Low Q^2 taggers

- Two detectors, Tagger 1 and 2 are placed along the outgoing electron beam

Same Q^2 is reached at different energies E_e and angles θ_e:

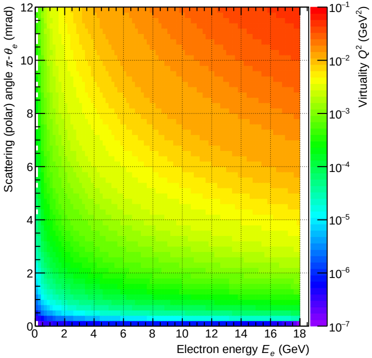


Figure: Towards central detector

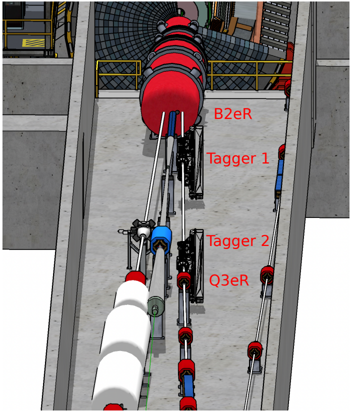
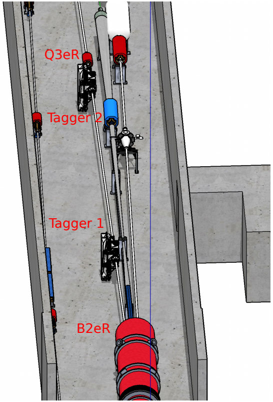


Figure: Towards the tunnel



Expected performance of low Q^2 detectors

- Photoproduction cross section is much smaller than bremsstrahlung
- Bremsstrahlung electrons are important to calibrate the luminosity measurement
- Observed spectrum shows bremsstrahlung mainly at lowest Q^2

Figure: Cross section

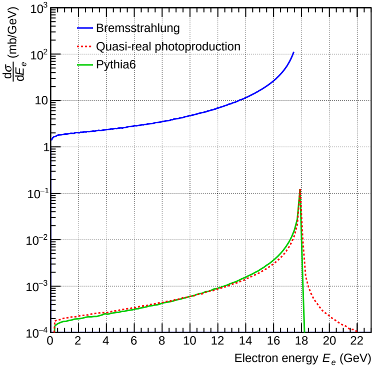
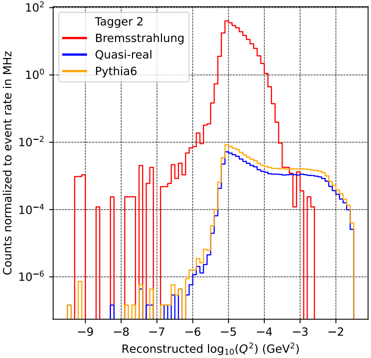


Figure: Observed spectrum



Clean photoproduction signal can be taken over a limited region of $10^{-3} \lesssim Q^2 \lesssim 10^{-1}$ GeV^2

Electron reconstruction in tagger detectors

- Detector tracks are found by a fit to hits in tracking layers
- Two machine learning algorithms (custom built and TMVA (DNN) neural network) are available to relate the tracks to original electrons

Figure: Track fit

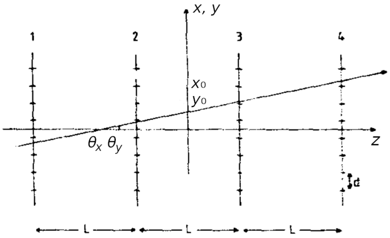


Figure: Energy reconstruction

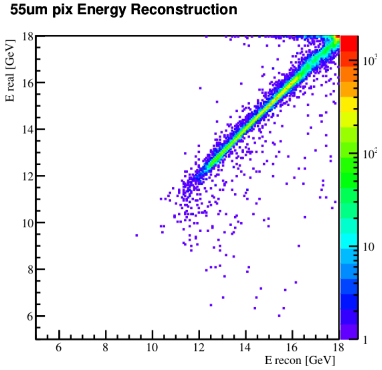
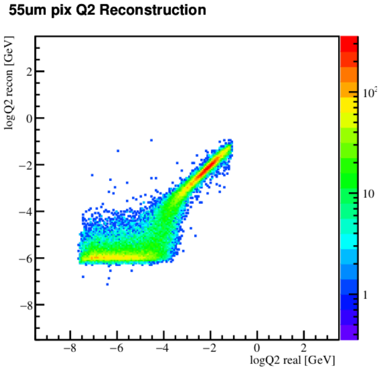


Figure: Q^2 reconstruction



Possible technologies for far-backward detectors

- Data are present at every bunch crossing (rates in $\mathcal{O}(100)$ MHz), demand on rad hardness
- Relatively small channel count because of small size ($\mathcal{O}(10)$ cm) for individual components

Trackers

- Multiple particles from the same bunch crossing
- Small pixel pitch for track separation
- MAPS or AC-LGAD for sensors
- Suitable ASIC for timing capability (Timepix4)

Calorimeters

- Performance stability over the run
- Most of the e^+ and e^- are incident at the edge of the module
- Homogeneous bars of $PbWO_4$
- Sampling W/ScFi, quartz fibers or W-Si
- Readout by fast PMTs or SiPM

- Good timing and short integration time is needed to identify each bunch crossing
- Large data rates and volumes in DAQ, also should provide online machine performance

Meson spectroscopy with forward, backward and central detectors

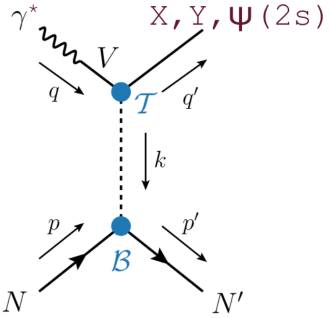


Figure: Scattered e^- in $\psi(2S)$ events

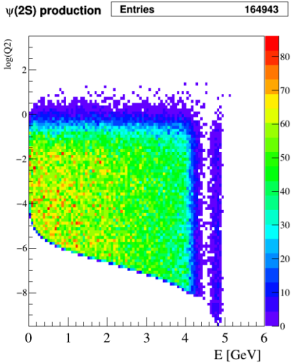
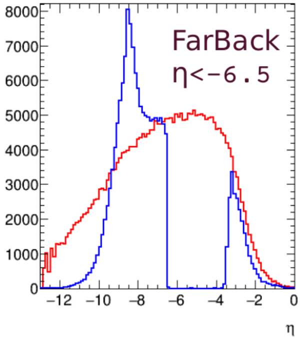
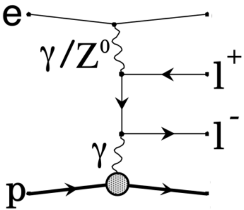


Figure: Electron pseudorapidity



- Final states of $J/\psi + \pi^+\pi^-$ + scattered e^- and nucleons, events both at low Q^2 and low t
- Scattered electrons and nucleons can reach far-backward and far-forward detectors (Taggers and B0 / Roman Pots)

Exclusive lepton pairs with forward, backward and central detectors

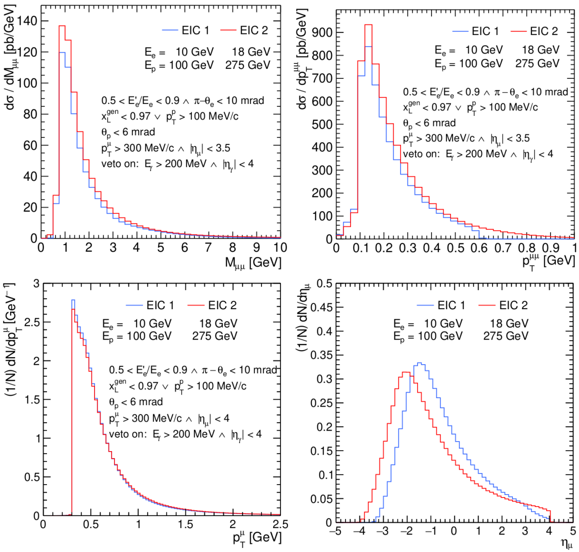


- Far-backward taggers detect scattered electrons, $\pi - \theta_e <$ 10 mrad
- Scattered proton is detected in far-forward, $\theta_p <$ 6 mrad
- All lepton pairs, $e^{\pm}$, $\mu^{\pm}$ and $\tau^{\pm}$ can reach central detector
- Process is implemented in GRAPE generator, arXiv:hep-ph/0012029

- Measurement with $\mu^{\pm}$ pairs is sensitive to proton charge radius
- Opportunity for data-driven calibrations with two-photon exclusive process

Exclusive pairs of $\mu^{\pm}$

- The $\mu^{\pm}$ are detected in central detector
- All constraints for scattered proton and electron are applied
- Cross section at the top energy is $\mathcal{O}(100)$ pb



Summary

- Close contact with machine group on space and mechanical constraints
- Similar concept for luminosity measurement was used at ZEUS, but at much lower event rates
- No previous electron reconstruction was attempted at $Q^2 < 0.1$ GeV^2
- Any help is more than welcome

Figure: Some time ago, a few miles from BNL

Figure: Here we're now

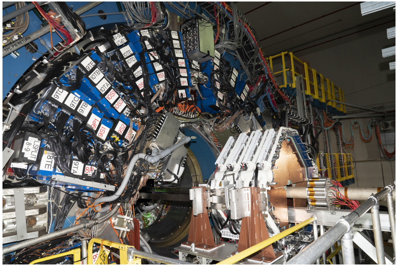


Figure: Some time later?