Low Q^2 Tagger Requirements

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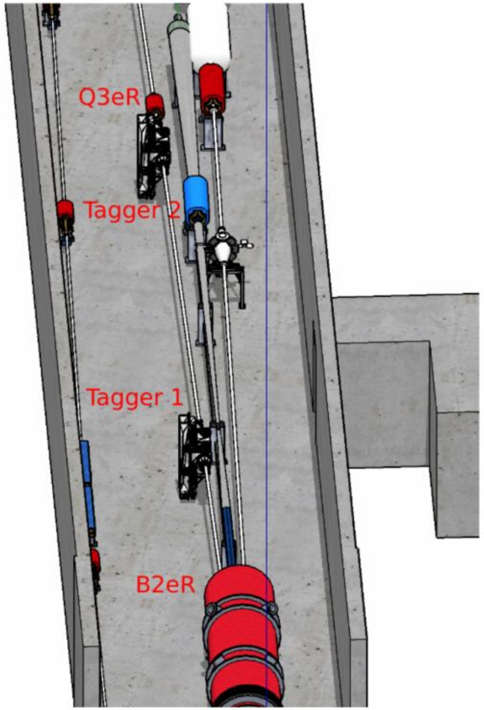
Introduction

- Low Q^2 Tagger summary
- Exclusive spectroscopy use overview
- Tagger design considerations (Examples of ongoing analysis)
  - Vacuum window effects
  - Tracker pixel pitch
  - Background subtraction
- Further studies and next steps

Introduction

Low Q^2 Tagger Summary

- Detects electrons which have lost energy in an interaction.
- Bent away from the recirculating beam by the beamline dipole magnets.
- Detectors are placed beside the beam drift volume between the dipole and next quadrupole magnet.
- Electron energy and momentum will be reconstructed from tracking and calorimeter detectors.
- The reconstructed electron is used to infer the energy and momentum of a virtual/Bremsstrahlung photon.

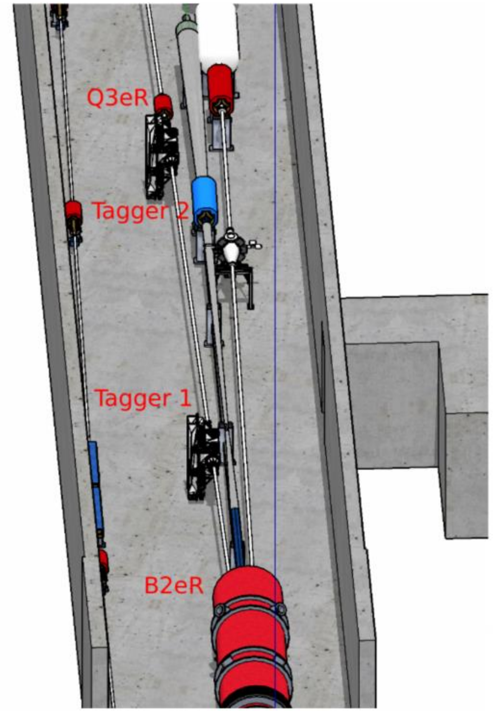


Introduction

Main Design Goals
- Maximize acceptance
- Minimize resolution
- Minimize background

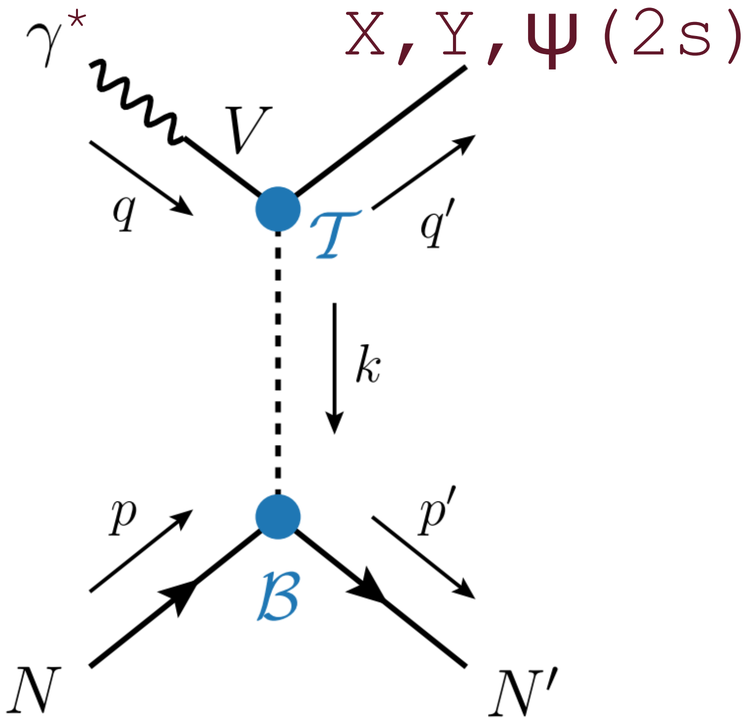
Limiting Factors
- Detector technologies
- Event rates
- Machine vacuum
- Background separation

Find a balance between goals and limits, driven by the physics groups



ECCE Spectroscopy Simulations

Meson → J/ψ (e^+e^-) $\pi^+\pi^-$



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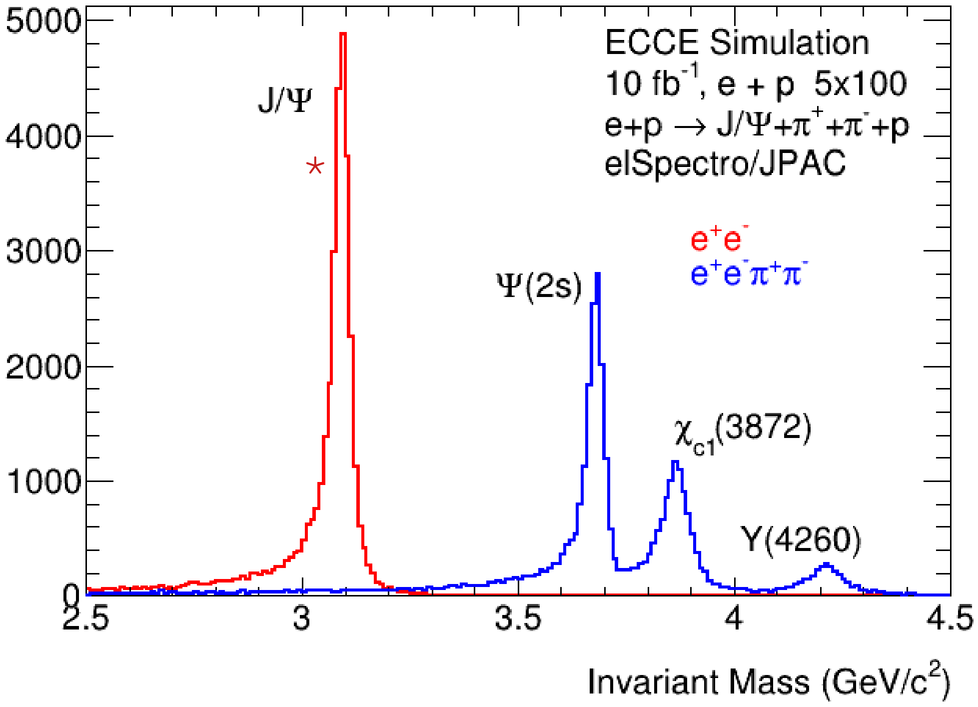
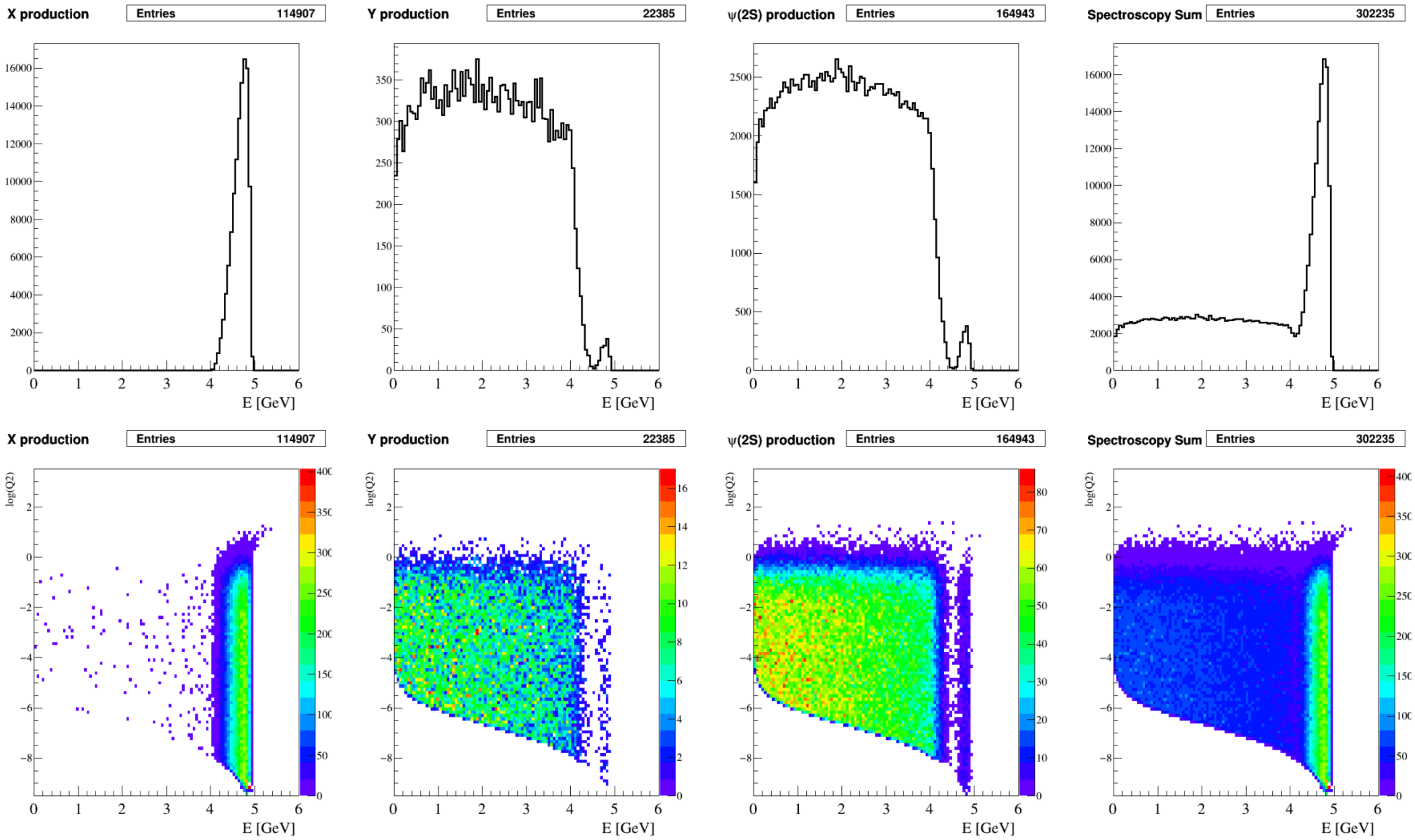


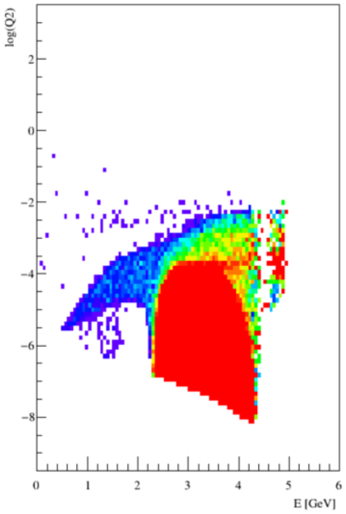
Low Q^2 => Far *ward very important
Low t e-' and nucleon detection

* only J/ψ from Meson decays

ECCE Spectroscopy Simulations



Example tagger acceptance



Useful Exclusivity variables

γ= (e- beam) – (e'- scattered) Here we take e-' in Low Q2 Tagger

ΔP_t difference : Here we take proton in Far Forward

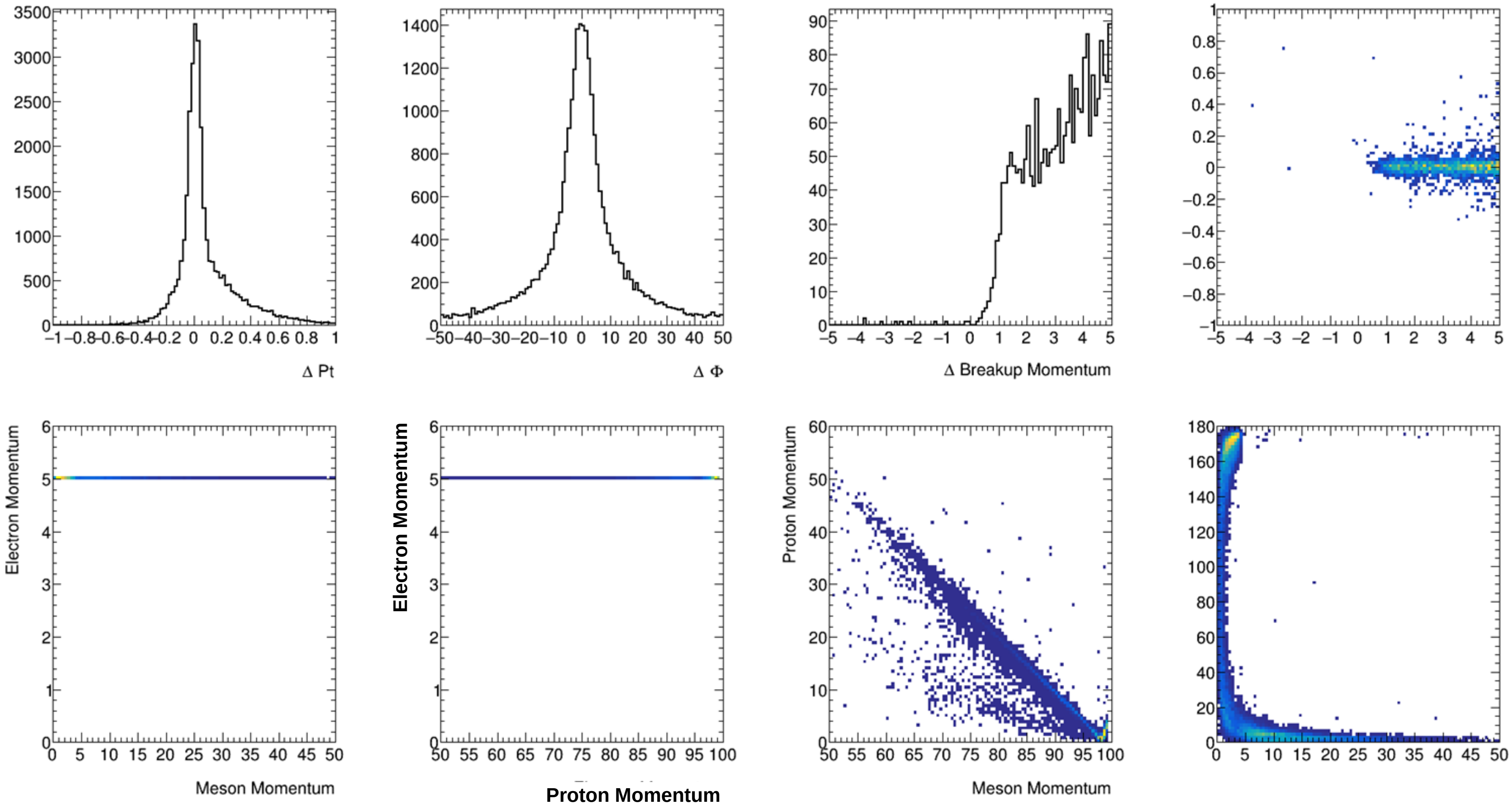
ΔPt : Pt {calculated proton – measured proton}

$\Delta\Phi$, Production Plane difference : $\Phi_{meson} - \Phi_{proton}$

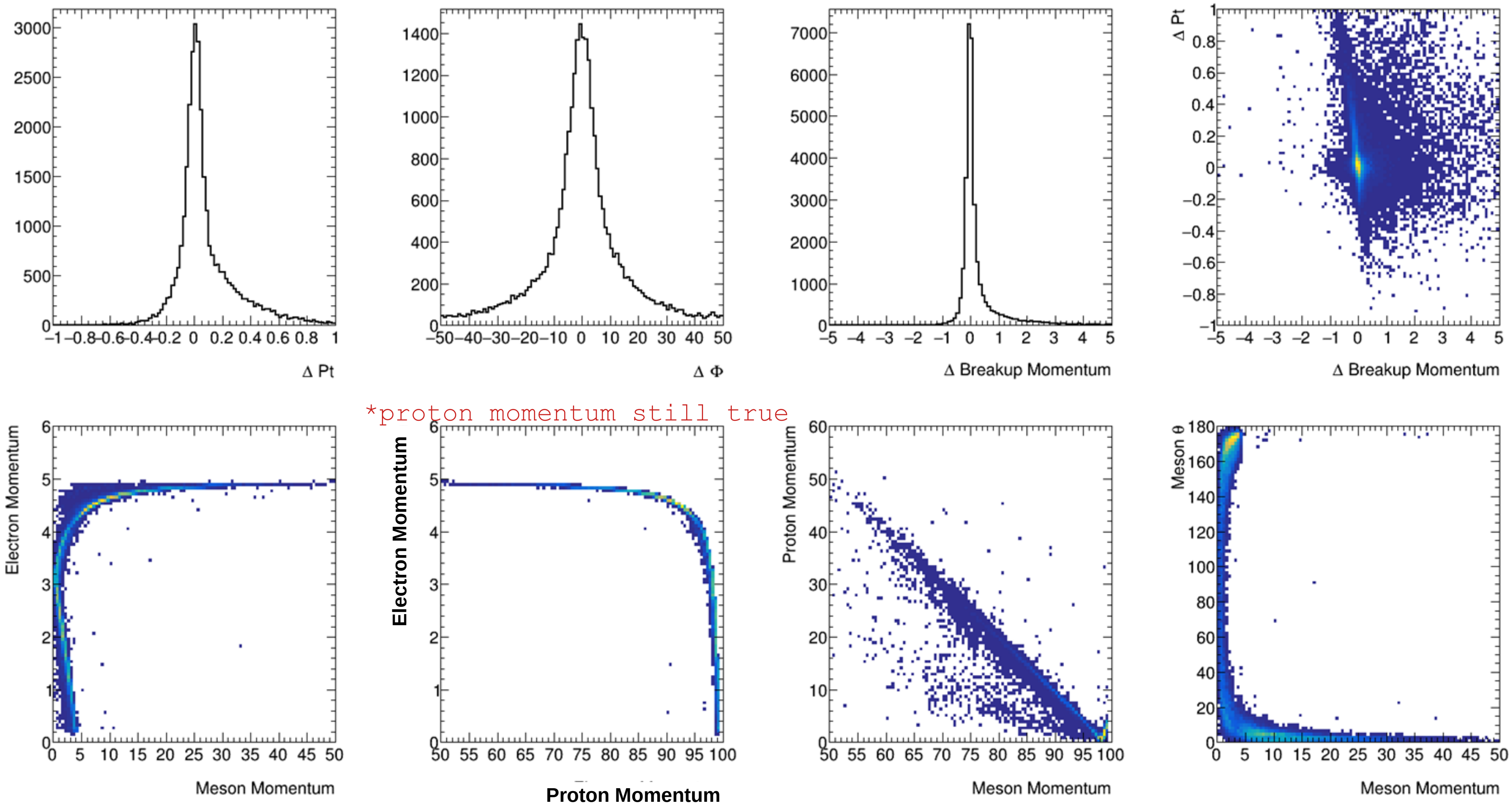
Centre of Momentum frame Δ Breakup Momentum, P_{break} :

$$P_{break}(E_\gamma, M_p, M_{meson}) - P_{break}(meson)$$ second term boosts meson into CM

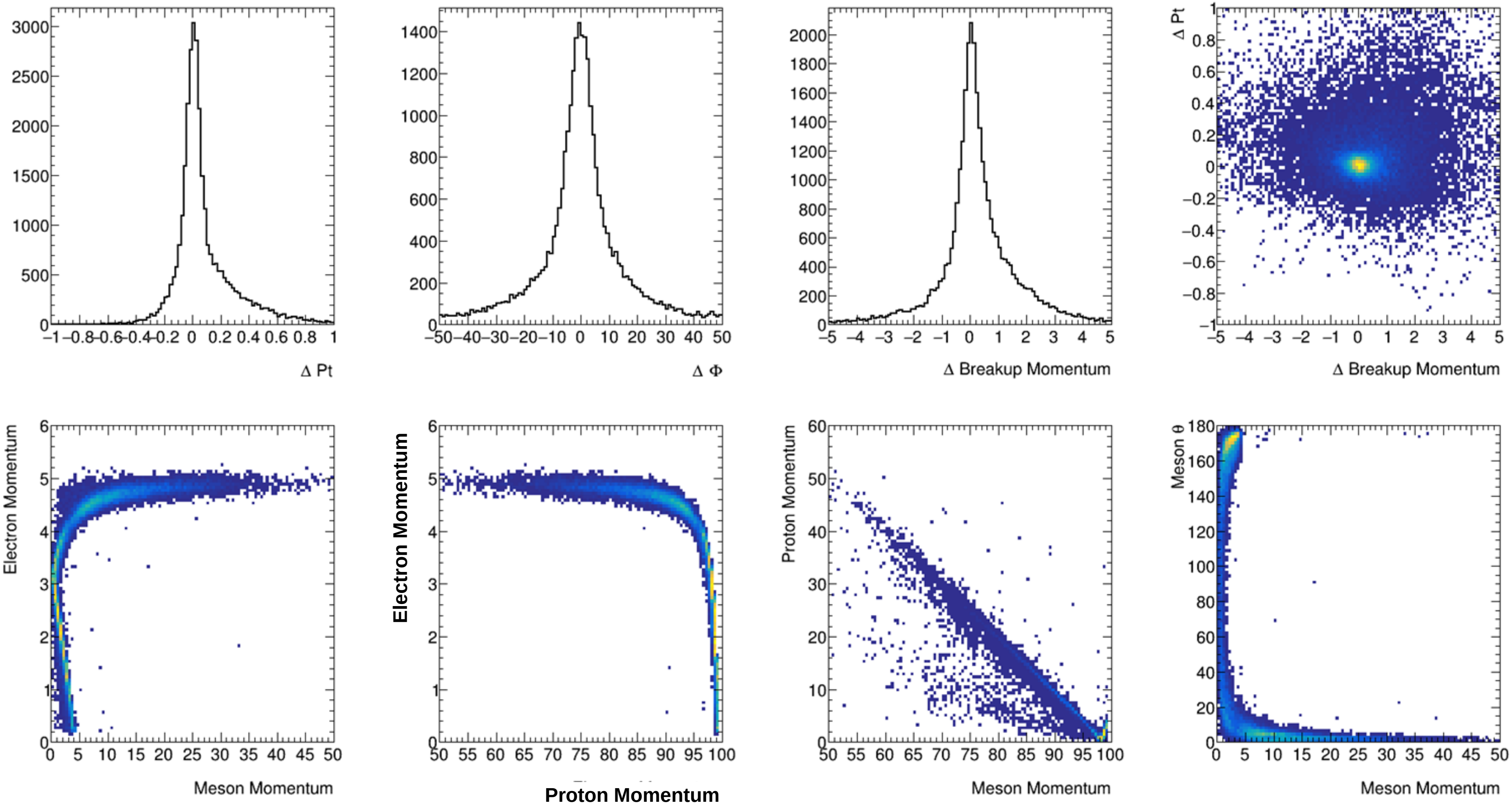
No Electron, True Proton, Realistic Meson



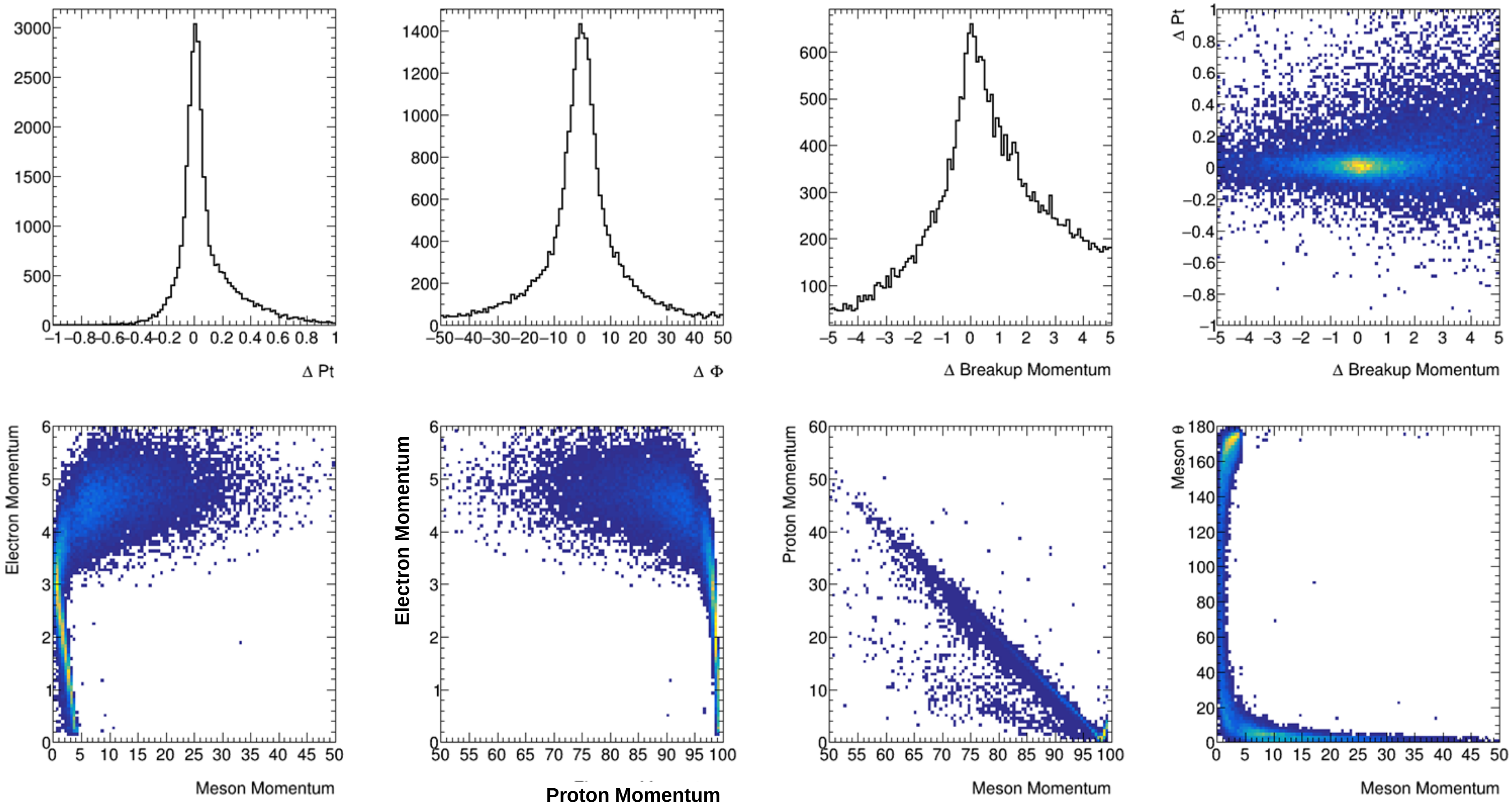
True Electron, “Realistic” Proton



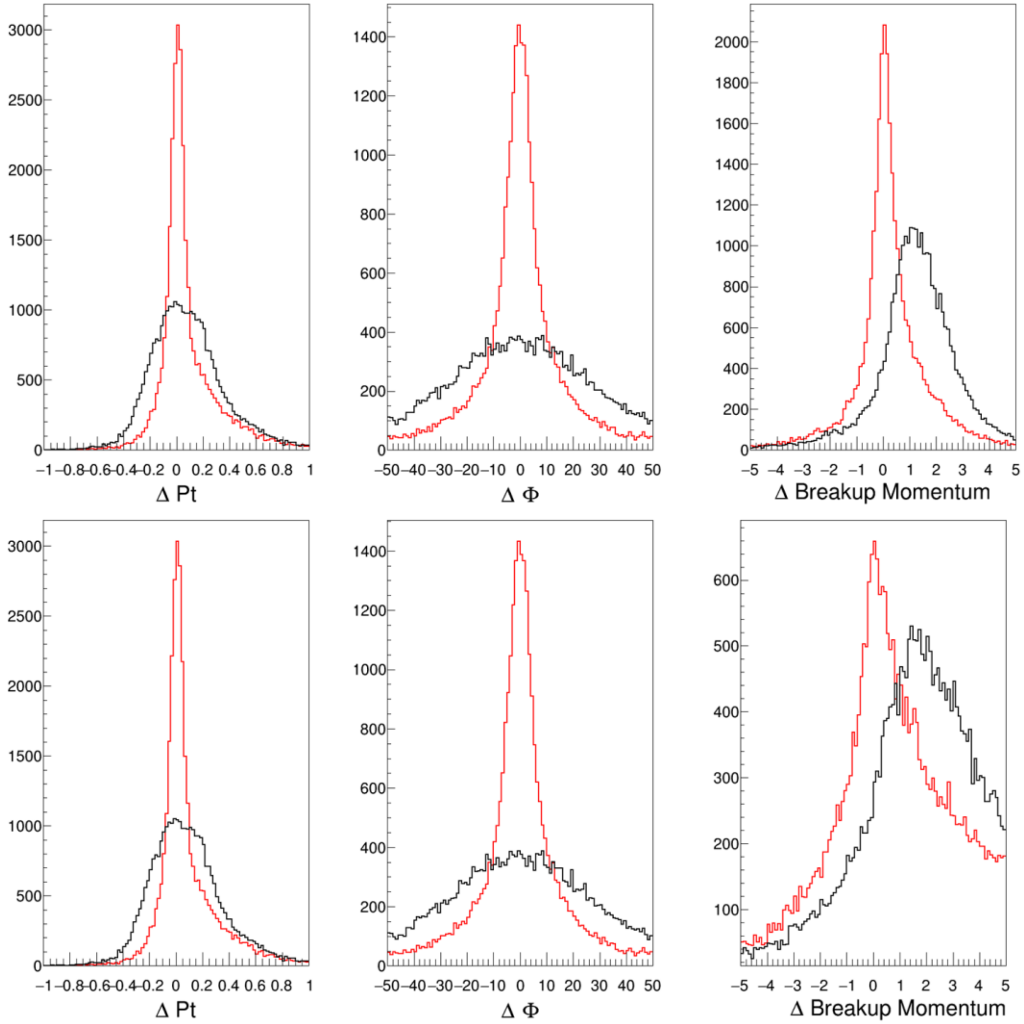
+ Electron 2% energy resolution



+ Electron 10% energy resolution



Missing Pion Background



No simulations of background Channels

Instead create exclusivity variables with missing pion

Top 2% electron resolution
Bottom 10% electron resolution

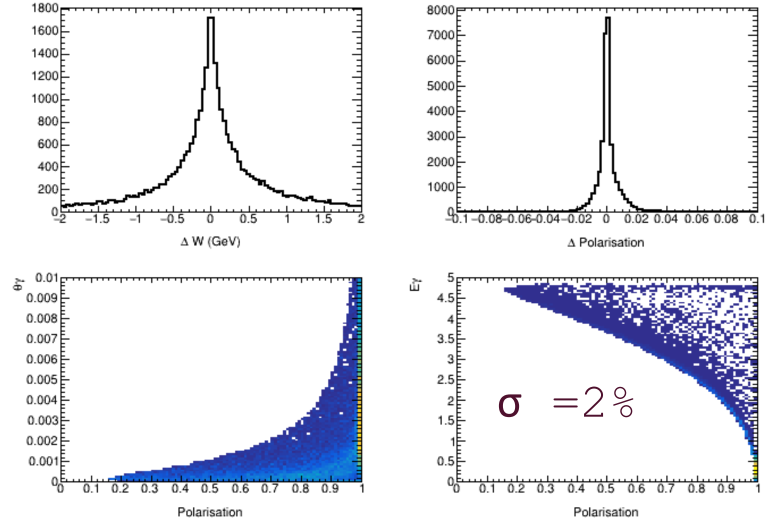
Fully Exclusive
Missing Pion

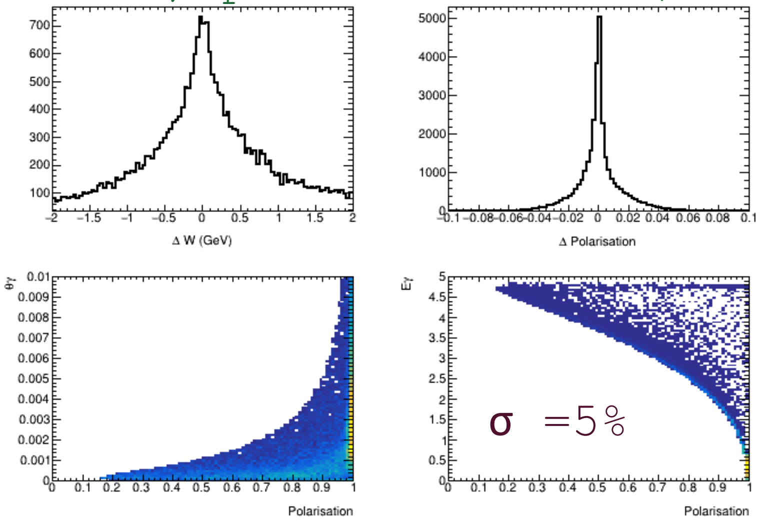
Other Useful Kinematics

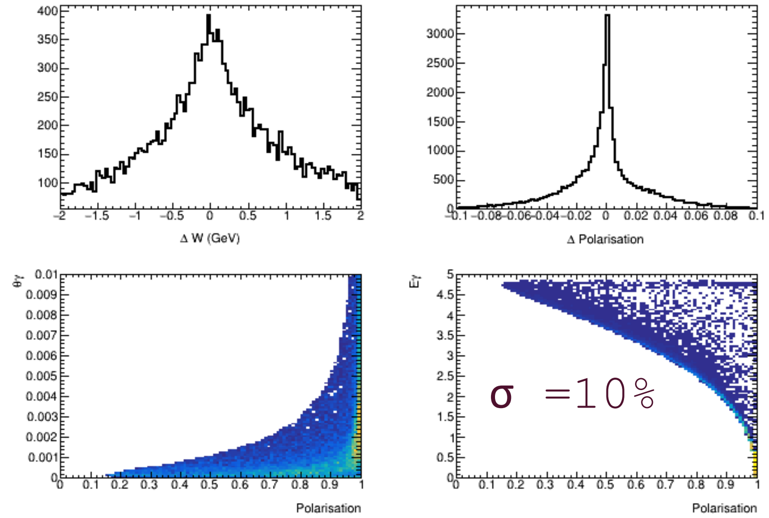
Tagger can also provide
Reaction W

Electron scattering plane
-requires excellent tracking

Transverse Polarisation
=> extra observables
(photon asymmetries, polarised SDMEs)







Spectroscopy Requirement Conclusions

Spectroscopy measurements will be greatly aided by :

Good exclusivity variables
Determination of W and t
Transverse photon polarisation (~ Linear Polarisation)

A Low Q2 tagger can provide these with

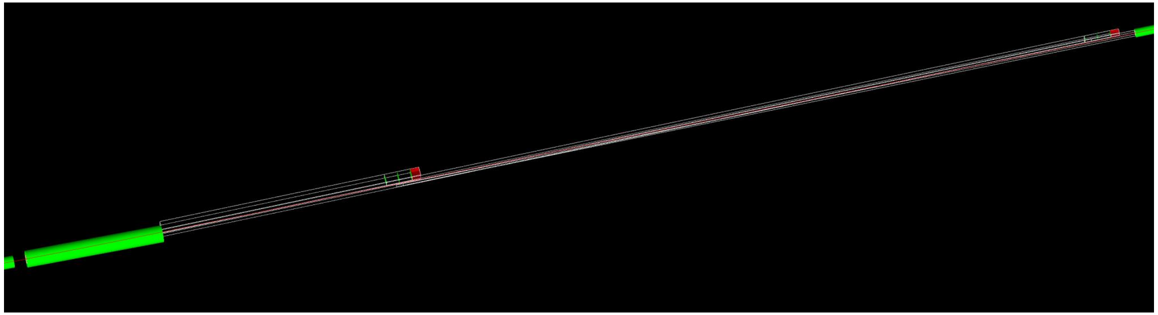
Accurate energy reconstruction of around 2%
Determination of the electron scattering azimuthal angle(say to 10°)
Moderate polar angle resolution for the degree of polarisation
Large acceptance in electron energy
(close to beam energy as possible)

Such features could be possible with a high resolution pixel tracker

Detector Geometries

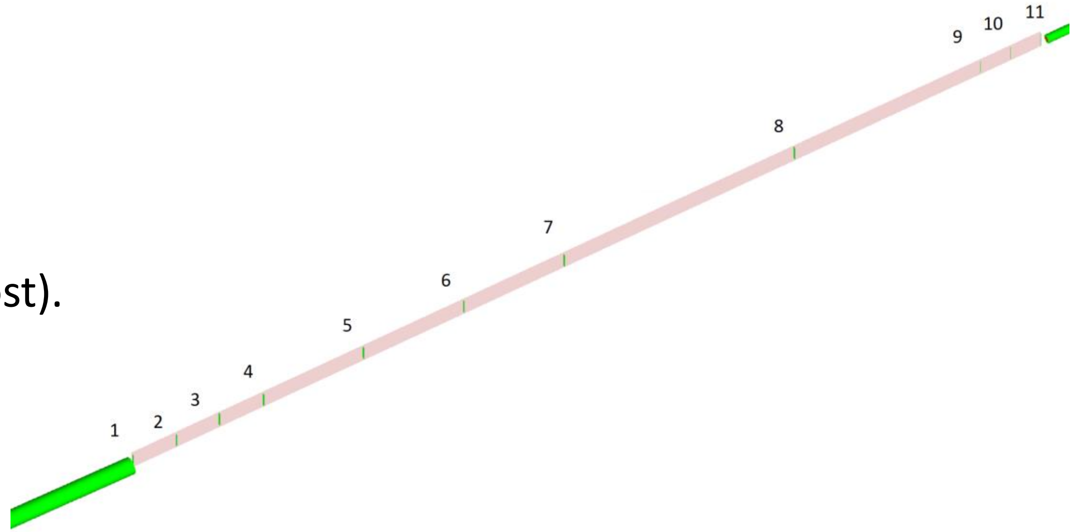
<u>Base Design</u>

- Two tagger stations
  - 40x40 cm @ z=-24 m
  - 30x21 cm @ z=-37 m
- In/out of vacuum options for detectors.
- Calorimeter possible.
- Large beam vacuum box extension



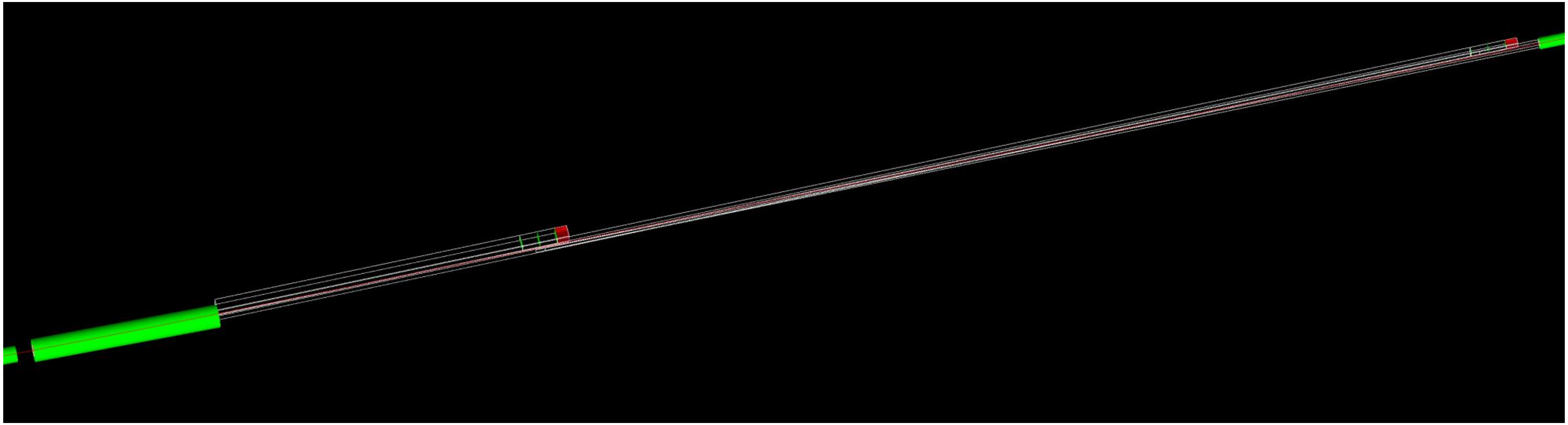
<u>Streamlined</u>

- Designed for electron to hit “any” 3 planes.
- Only in vacuum, no calorimeter.
- Minimize vacuum box and detector surface (cost).
- Resolution reduced at lower electron energies.



Detector Geometries

For maximum acceptance tagger 2 needs to be as close to beam as practical



Vacuum Studies

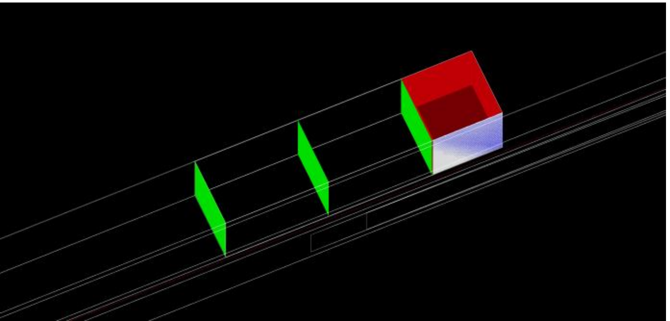
Do advantages of having trackers layers in beam vacuum outweigh the design complications?

Considerations

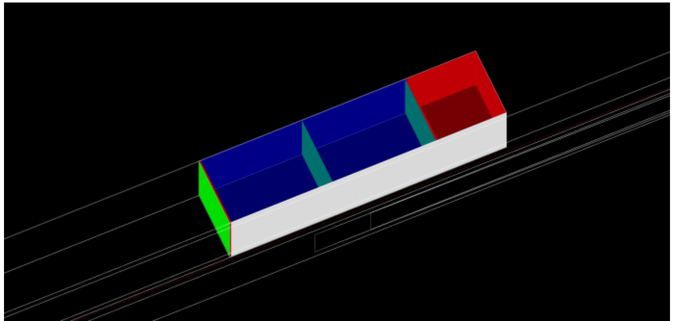
- Scattering by exit window reducing resolution.
- Beampipe wall causes gap in acceptance.
- Both add sources of background.

Red box – Calorimeter
Green plane – Tracker layer
Red plane – 1mm copper window
White(/light blue) - Steel beampipe wall
Blue box - Air

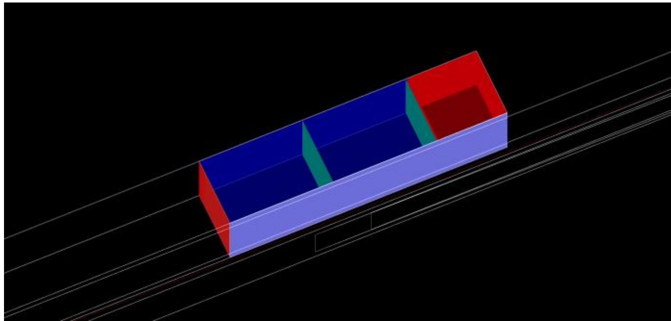
Window before calorimeter

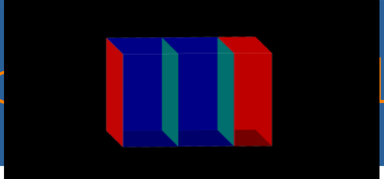
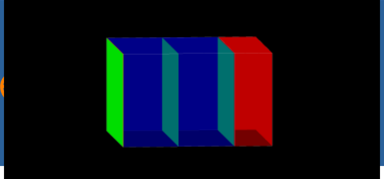
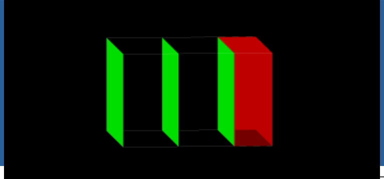


Window after 1st tracker layer

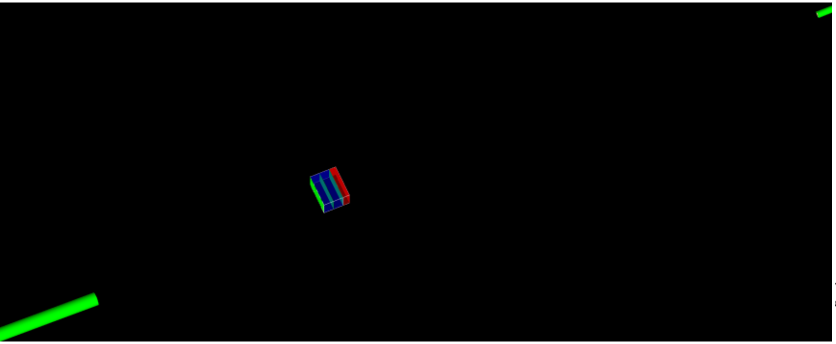


Window before 1st tracker layer



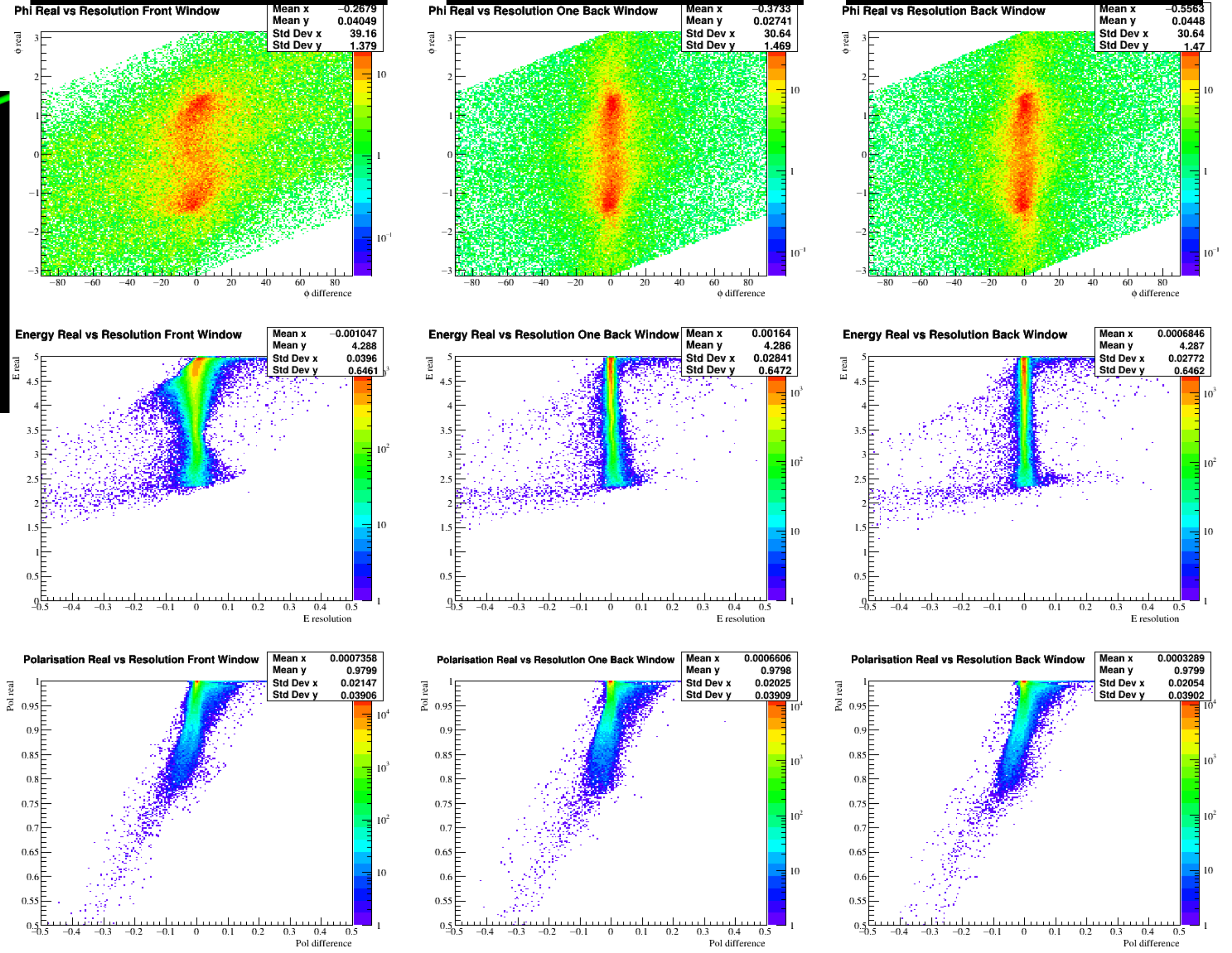
Simplified for window/air effects

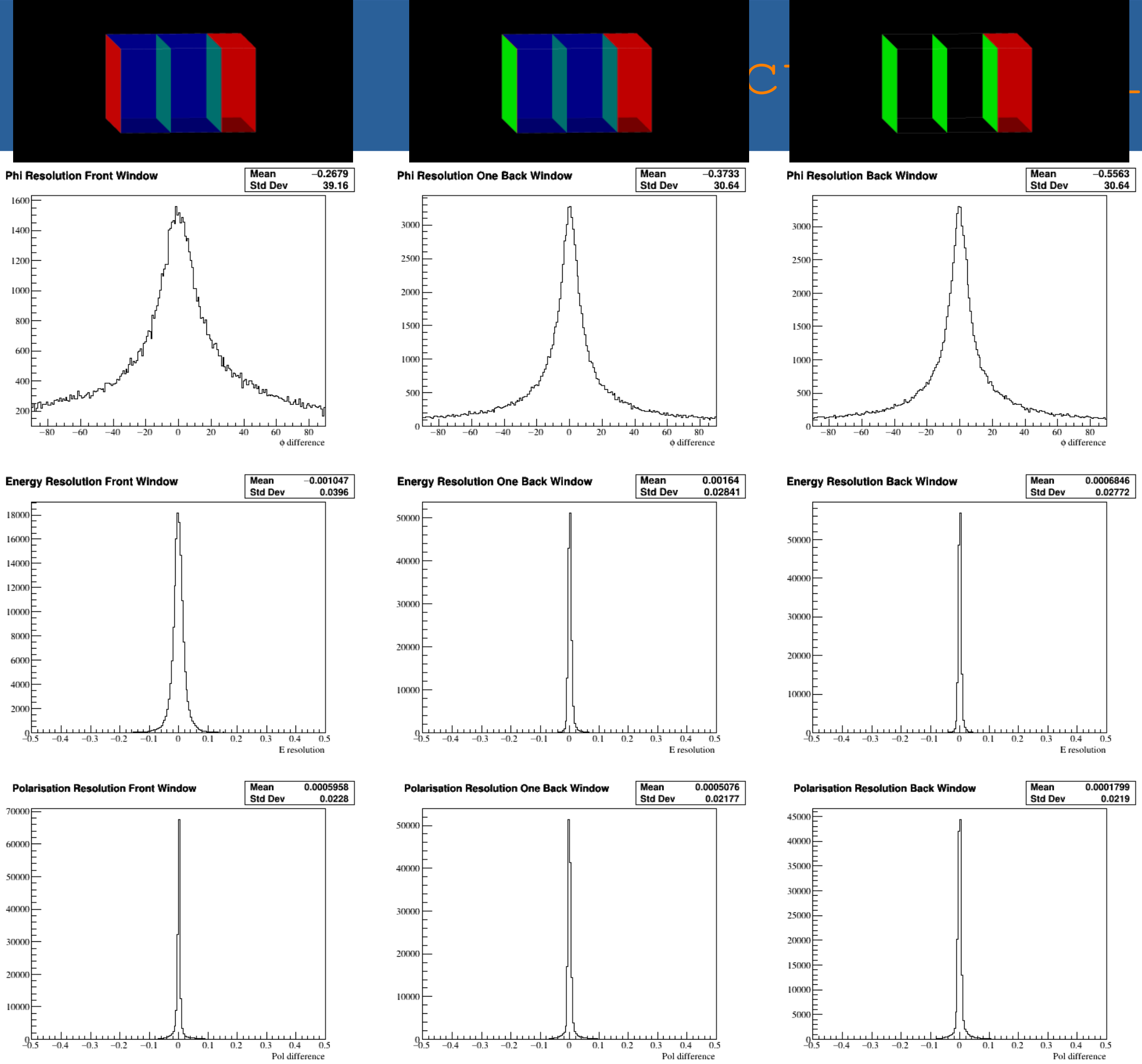


Simple neural network reconstruction using perfect electron hit position and vector

Three Parameters reconstructed:

- Electron energy
- Virtual photon polarisation cos(phi) & sin(phi)
- Virtual photon degree of polarisation





- Most information gained from 1st layer.
- Phi not reproduceable from when scattering polar angle lower than beam divergence
- Polarisation mostly very close to one

Pixel Pitch Studies

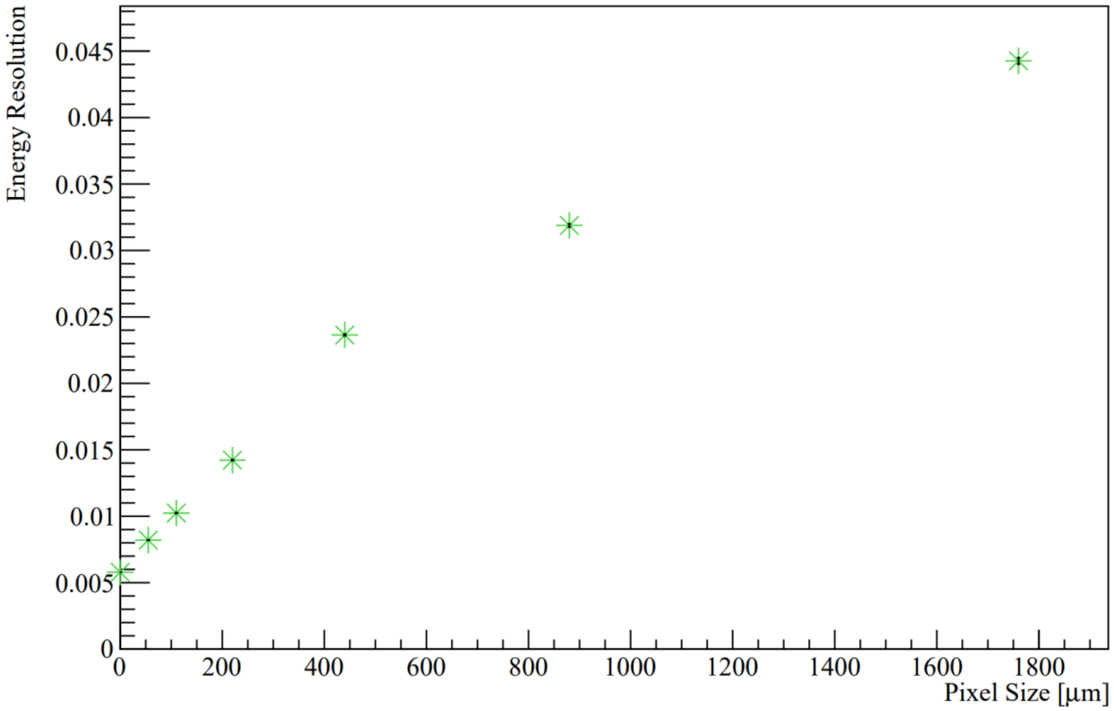
How are the measurement resolutions effected by the detector resolution?

Using single hit pixel numbers in two layers of tagger 2:

20 cm apart

In beam vacuum

Average over 18GeV electron beam



Pixel Pitch Studies

How are the measurement resolutions effected by the detector resolution?

Using single hit pixel numbers in two layers of tagger 2:

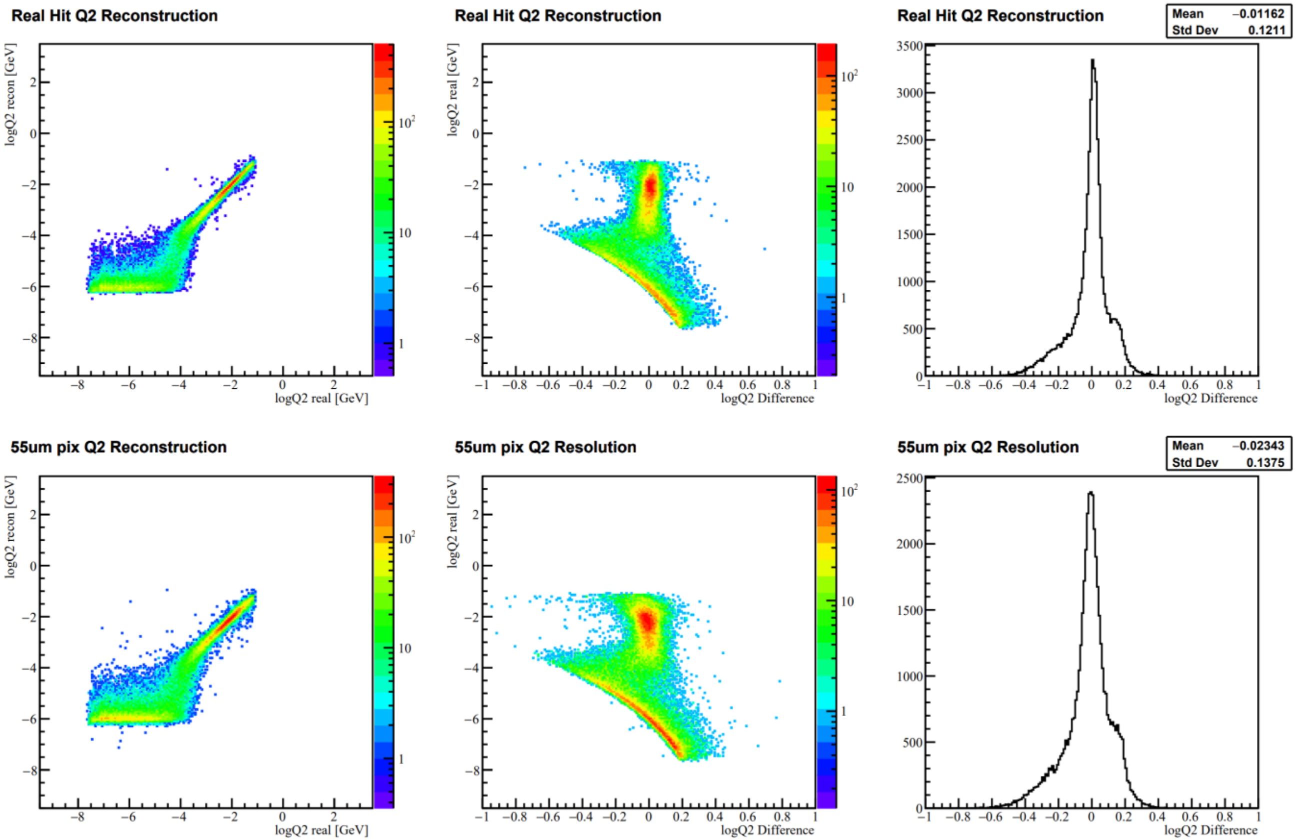
20 cm apart

In beam vacuum

Average over 18GeV electron beam

Q2 reconstruction limited by beam divergence.

Can vertex help?



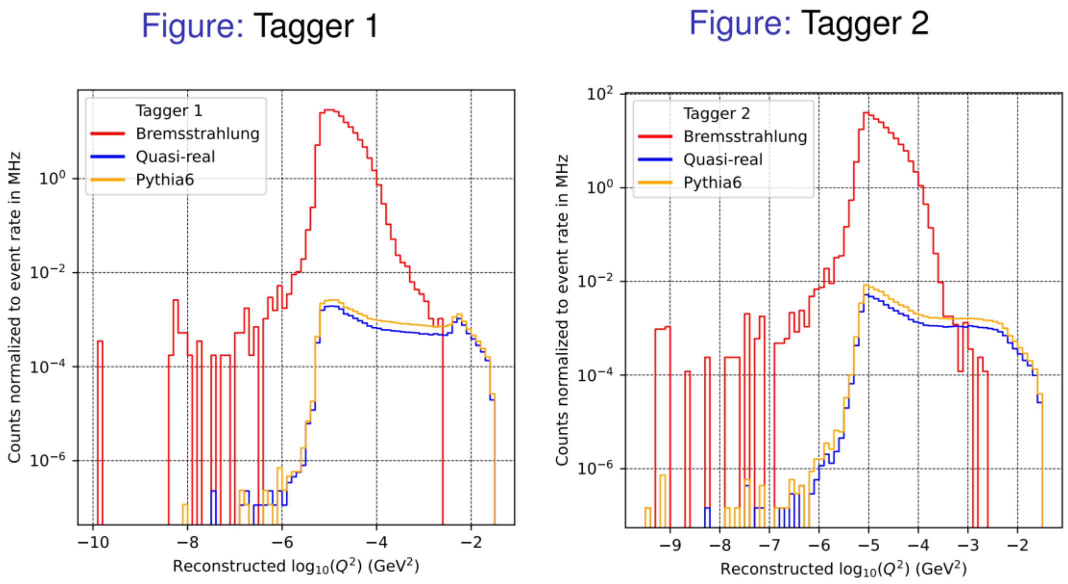
Background Studies

What backgrounds are present and what approaches can handle them?

Backgrounds currently under consideration:

Bremsstrahlung:
Identical signature in tagger to Low Q^2 event.
Worst case only tag to $\log(Q^2) = -3$.
Using information from other detected particles will allow statistical background subtraction to be used.

Synchrotron (direct/scattered):
Expected to be mostly eliminated with multiple tracking layer coincidence and/or calorimeter.
Studies pending.



Jaroslav Adam (FarBackward WG meeting (2 March 2022) · Indico (bnl.gov))

Further Studies Technology Selection

Tracker Considerations:

- Small pixel pitch
  - Improved resolutions
  - Track separation at high rates
  - Background rejection
- Additional layers
  - Background rejection

Calorimeter Considerations:

- Event pile up
- Improve tracker background rejection
- Improve/complement tracker energy.

Further Studies Technology Selection

Tracker:

Timepix(4) ASIC:
- Exists, well supported by CERN based community
- Meets desired criteria
- Bonding to next gen LGADs improving time resolution rate capabilities.

AC-LGAD:
- Planned development for other EIC detectors.
- Could meet desired criteria with correct design.

MAPS
- Under development for other systems/experiments.
- Could meet desired criteria with correct design.

Sci-Fi
- Limited resolution and rate capabilities
- Complementary luminosity measurement

Calorimeter:

- Homogeneous PbWO
- Sampling W-Si
- No calorimeter

Next Steps

Simulation:

- Extend Tagger 2 into C shape to accept low Q^2 events close to beam energy.
- Explore information from other detectors which could improve reconstruction (e.g. vertex).
- Bremsstrahlung simulation with both electron and photon acceptance, energy cross calibration.
- Beampipe wall acceptance effects.
- Work closely with machine group to understand practical limitations.
- Currently run in ATHENA framework.

Reach out to physics cases that have mentioned but not yet studied the Low Q^2 Tagger:

- Timelike Compton Scattering
- J/psi production near threshold
- Further vector meson production

Increase/focus team?