Update on low-Q^2 tagger

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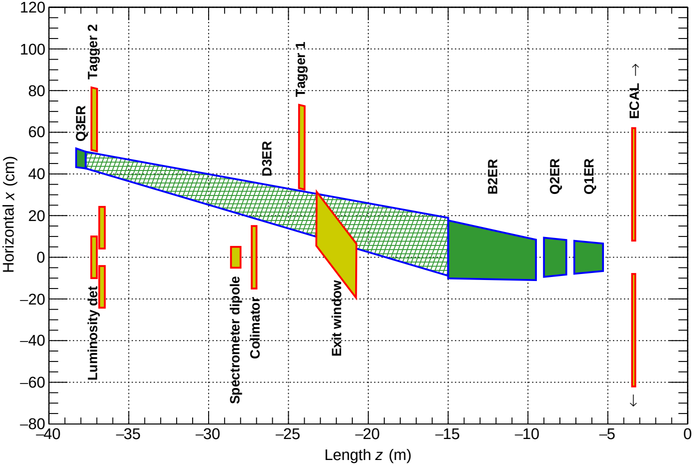
IR Meeting

Outline

1. Possibility for two low-Q^2 tagger placements between B2eR and Q3eR - could be both detectors at the same time
2. Comparison of 1.5 T central solenoid to the default 3 T field
3. Change in Q^2 acceptance for geometry when Q1eR and Q2eR are moved towards the central detector

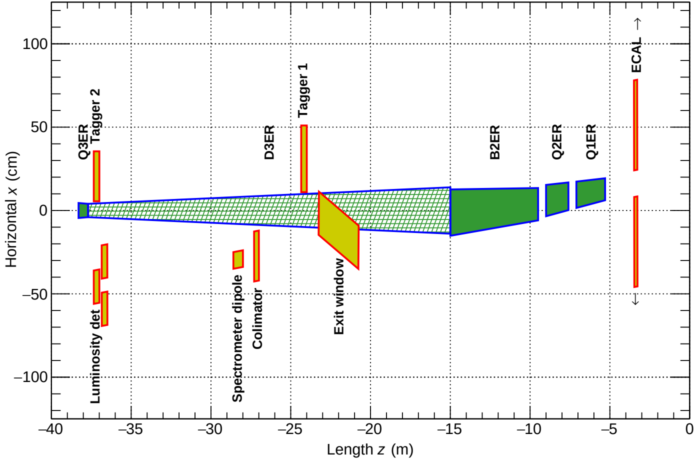
- Main updates in Geant4 model for the acceptance study:
  - Central 3 T solenoid field based on BeAST field map
  - Model for backward electromagnetic calorimeter (ECAL)
- Resources used to create the geometry:
  - Default IR layout in 200309-er-ip6-95832bb - thanks Scott and Holger for help
  - Modified IR with Q1eR in central detector in presentation by Bob Palmer on April 10
  - Position of ECAL from drawing in presentation by Mark Breitfeller at Temple meeting
  - BeAST solenoid field map from interface by Alexander: https://github.com/eic/BeastMagneticField

IR layout with two taggers and backward ecal



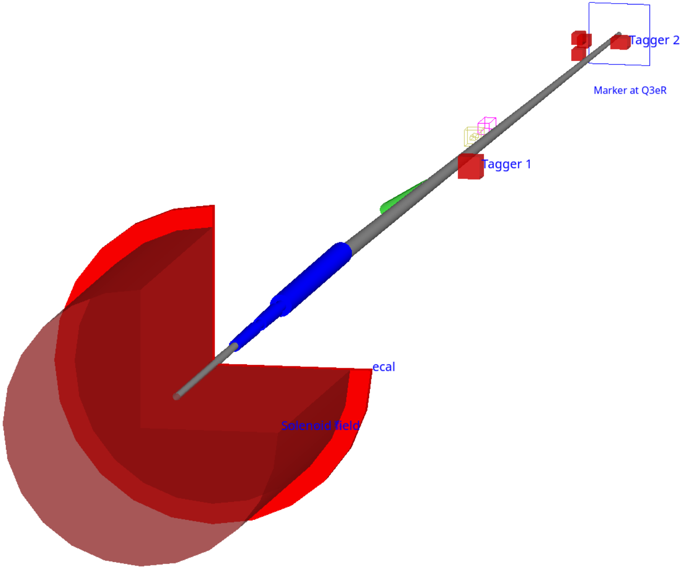
- The ECAL is placed at $z = -3.28$ m, inner and outer radii of 8 cm and 2.87 m provide pseudorapidity η in [-4.4, -1], approx. matching the handbook detector
- Inner apertures of the magnets are shown

Tagger detectors alignment



- Taggers 1 and 2 are placed at z of -24 m and -37 m, just outside the drift region D3ER
- The D3ER starts at exit radius of B2eR and ends at entry radius of Q3eR

Geant4 model for electron-outgoing IR



- Drift spaces in grey are transparent to all particles
- Tagger 1,2 and ECAL detectors mark hits by incoming particles
- Solenoid field uses the BeAST parametrization
- Beam magnets are shown in blue
- Components of luminosity monitor are on the opposite side to the taggers
- The layout ends with a marker at Q3eR position

Hit positions on the taggers and ECAL

- Simulation of scattered electrons from 5M Pythia6 events, energy 18x275 GeV
- Beam effects of vertex spread and angular divergence in x and y are included
- Positions where the scattered electrons hit the front face of the detectors are shown below

Figure: Hits in tagger 1

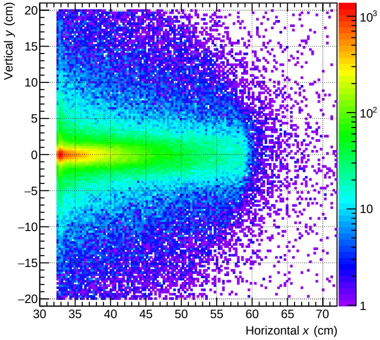


Figure: Hits in tagger 2

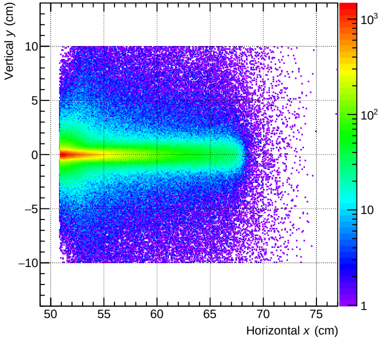
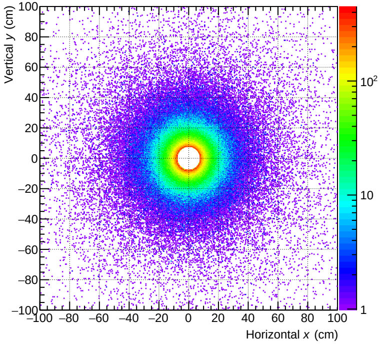
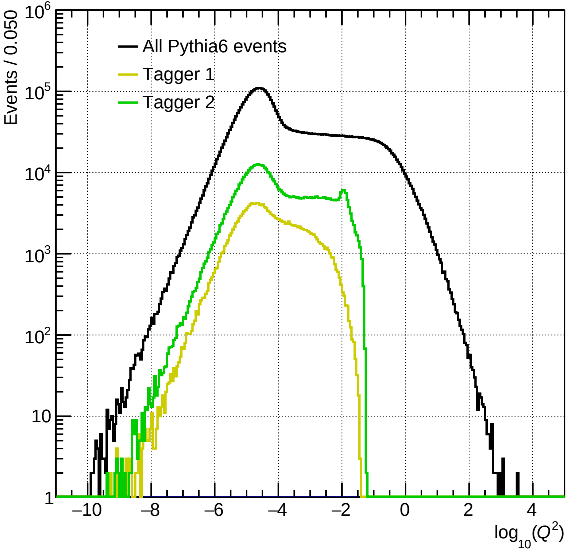
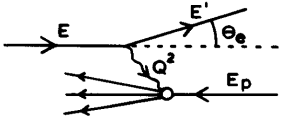


Figure: Hits in ECAL



Shape of Q^2 with the two tagger detectors





- Simulation of 5M scattered electrons from Pythia6, 18x275 GeV
- Virtuality Q^2 is given by electron energy and scattering angle:

$$Q^2 = 2EE' \left(1 - \cos(\theta_e)\right)$$

- Shape in black shows distribution of Q^2 from all generated events
- Q^2 of events with hit in one of the taggers is shown in green and yellow

Complementary kinematics for the two taggers

- Scattered electron energy and angle for events with a hit in one of the taggers

Figure: Tagger 1

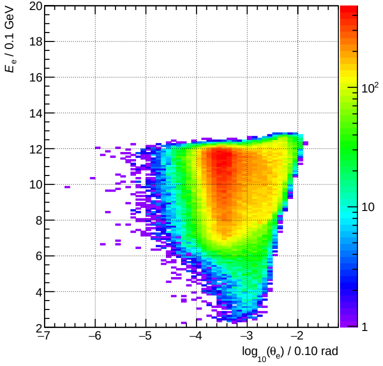
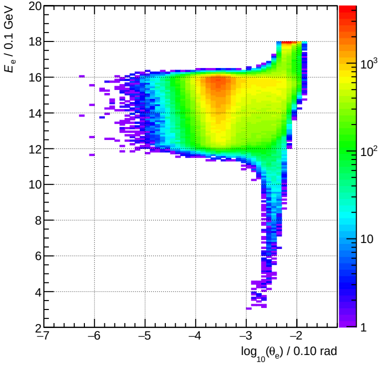
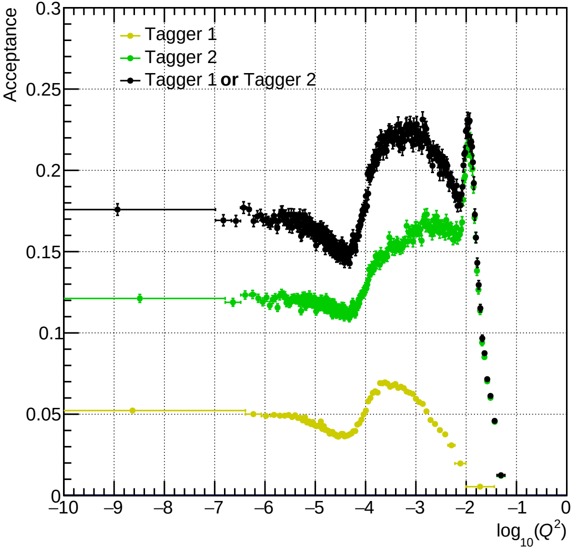


Figure: Tagger 2



- Although both taggers largely overlap in Q^2, they cover different energy and angular range
- Tagger 1, closer to the IP, is sensitive only to energies below $\sim$12 GeV
- Both detectors would be affected by bremsstrahlung (and other) background in a different way

Acceptance in Q^2 with both taggers



- Acceptance is a ratio of number of events with hit in the tagger to all generated events, in a given interval of Q^2
- Shown separately for both taggers and as a combined acceptance
- Combined acceptance (black) counts hit in any of the two taggers for the ratio

Region of Q^2 covered by backward ECAL

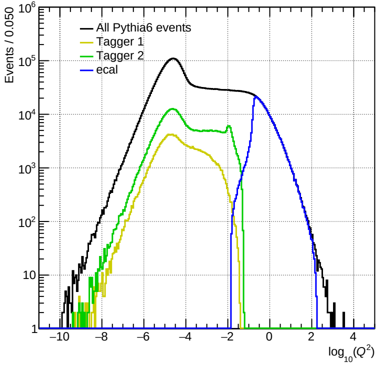


Figure: Q^2 with ECAL added

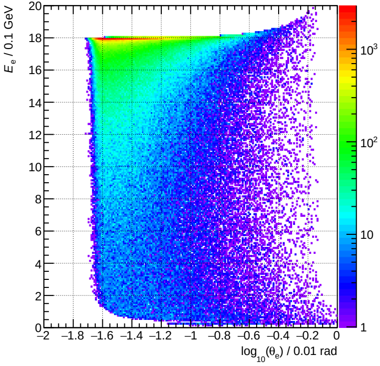
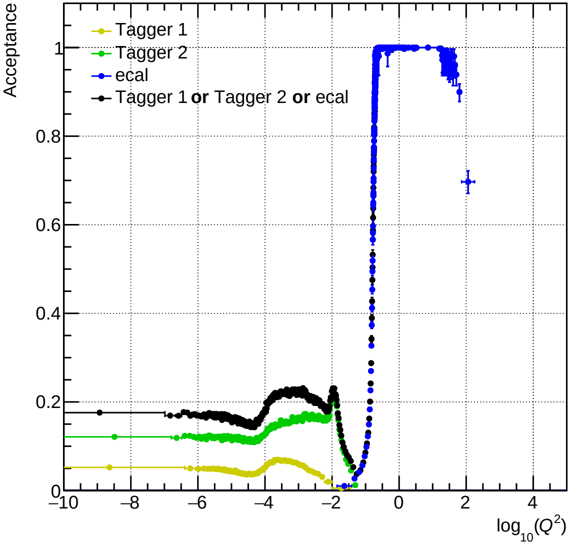


Figure: Energy and angles for ECAL

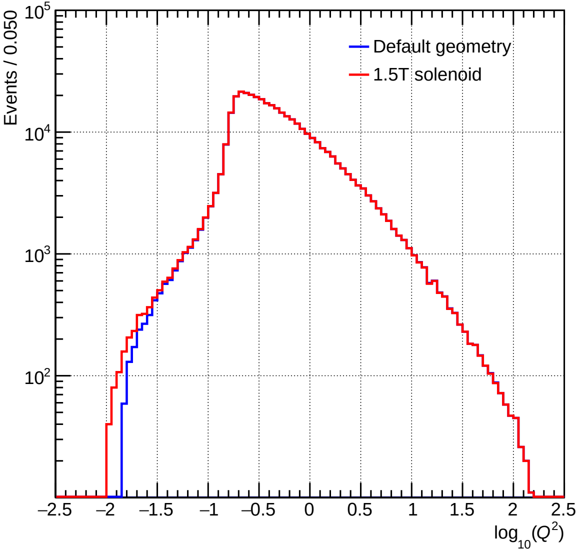
- The ECAL adds acceptance above the taggers
- Region of Q^2 from 10 to 10^{-2} GeV^2 is interesting for physics because it is transition from electroproduction (photon still virtual) to photoproduction (photon acts like real)
- The acceptance is driven by geometry (only solenoid field)
- For a large interval in Q^2 it is unity

Combined Q^2 acceptance with taggers and ECAL



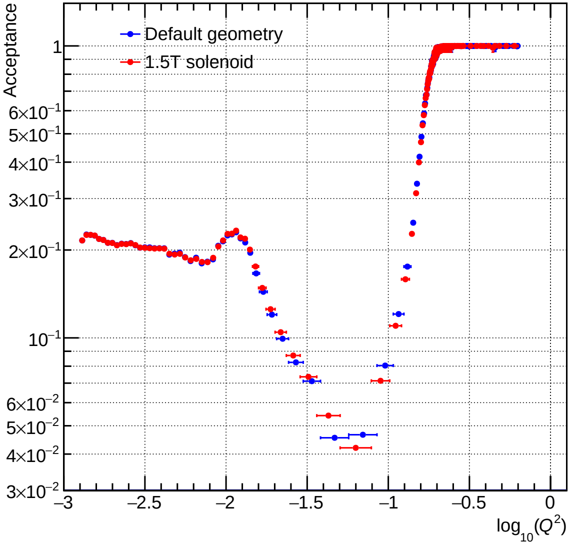
- The acceptance is constructed the same way as for the taggers alone
- Black shape is combined acceptance for the hit in any of the taggers or ECAL
- Drop in acceptance is present between the taggers and ECAL, but does not fall to zero

Comparison of ECAL Q^2 coverage with reduced central solenoid field



- Q^2 for events with a hit in ECAL
- Default 3 T BeAST solenoid (blue) was replaced by a uniform 1.5 T field (red)
- Slight increase at lower Q^2 reach, but no big change

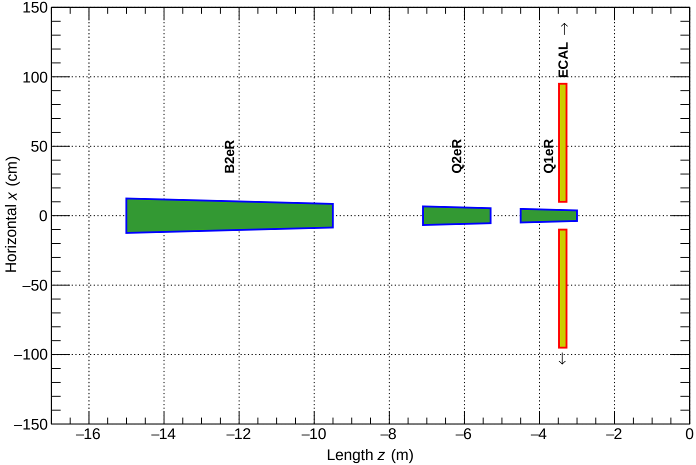
Acceptance with reduced central solenoid field



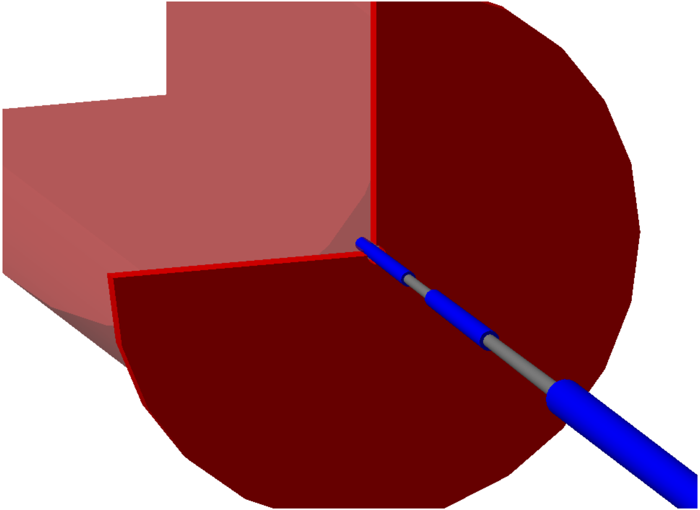
- Closer look to acceptance across the drop between taggers and ECAL
- Default 3 T BeAST solenoid (blue) was replaced by a uniform 1.5 T field (red)
- No substantial change
- Difference is visible thanks to vertical log scale and higher precision in acceptance calculation (1.5% vs. previous 2%)

IR layout with Q1eR inside the central detector

- ECAL inner radius was moved up from 8 cm to 10 cm — very optimistic assumption, pseudorapidity coverage decreased to η in [-4.18, -1]

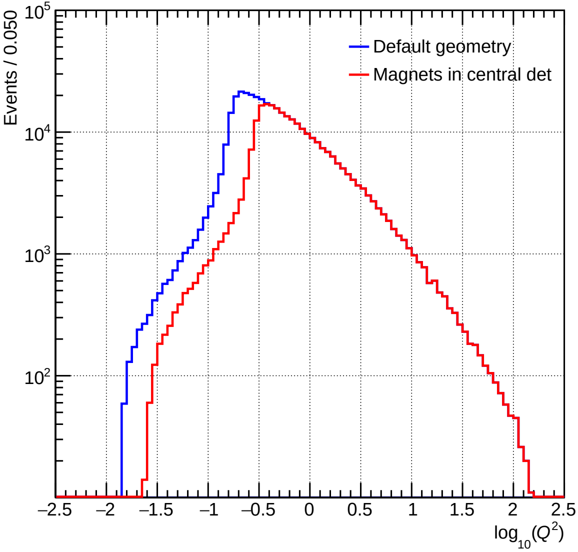


Geant4 model for the layout with Q1eR inside the central detector



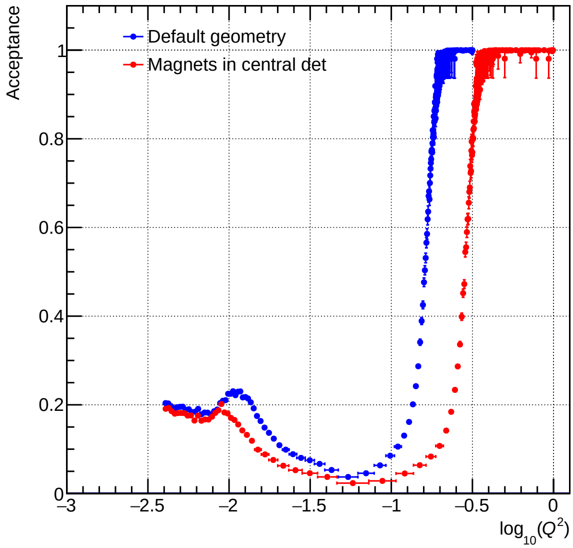
- ECAL has opening for Q1eR, optimistic assumption of 10 cm
- The layout after B2eR remains the same
- Simulation of the same 5M Pythia6 events was repeated for this geometry

Change in Q^2 region covered by ECAL with Q1eR in central detector



- Q^2 for events with a hit in ECAL for both geometries
- Larger inner radius is reducing the acceptance at small angles
- Has a consequence in increase in lower limit of Q^2

Change in acceptance gap between the taggers and ECAL



- Detailed look into transition region between the taggers and ECAL for the acceptance shown on page 11
- Shown the case of combined acceptance, hit in any of the taggers or ECAL counts for the acceptance
- Previous result with default geometry is shown in blue, modification with ECAL larger inner radius is shown in red
- The gap gets wider with a more flat bottom when inner ECAL radius gets increased
- Change in acceptance from taggers at lower Q^2 is caused by different Q1eR and Q2eR arrangement

Summary

- Region in Q^2 from 10^{-2} to 10 GeV^2 is sensitive to physics as it is transition between photoproduction and electroproduction
- Q^2 coverage depends on available inner radius for ECAL — please let me know as 10 cm optimistic radius was used now
- Small change in Q^2 acceptance with reduced central solenoid field
- There is a variation in quadrupoles behavior across Geant4 versions — would be good to know beam size at Q3eR to compare
- Summary on detectors placement, frame with Q1eR to B2eR collinear with electron beam and placed at $x = 0$:

Tagger 1	Tagger 2	ECAL
z_{start} = -24 m	z_{start} = -37 m	z_{start} = -3.28 m
x_{center} = 52.856 cm	x_{center} = 66.188 cm	r_{inner} = 8 cm (default), 10 cm (Q1eR in)
Front size = 40 $\times$ 40 cm^2	Front size = 30 $\times$ 20 cm^2	r_{outer} = 2.87 m
Angle = 18.332 mrad	Angle = 18.332 mrad	

- All Geant4 and analysis codes are here: github.com/adamjaro/lmon