Occupancy in low-Q^2 tagger

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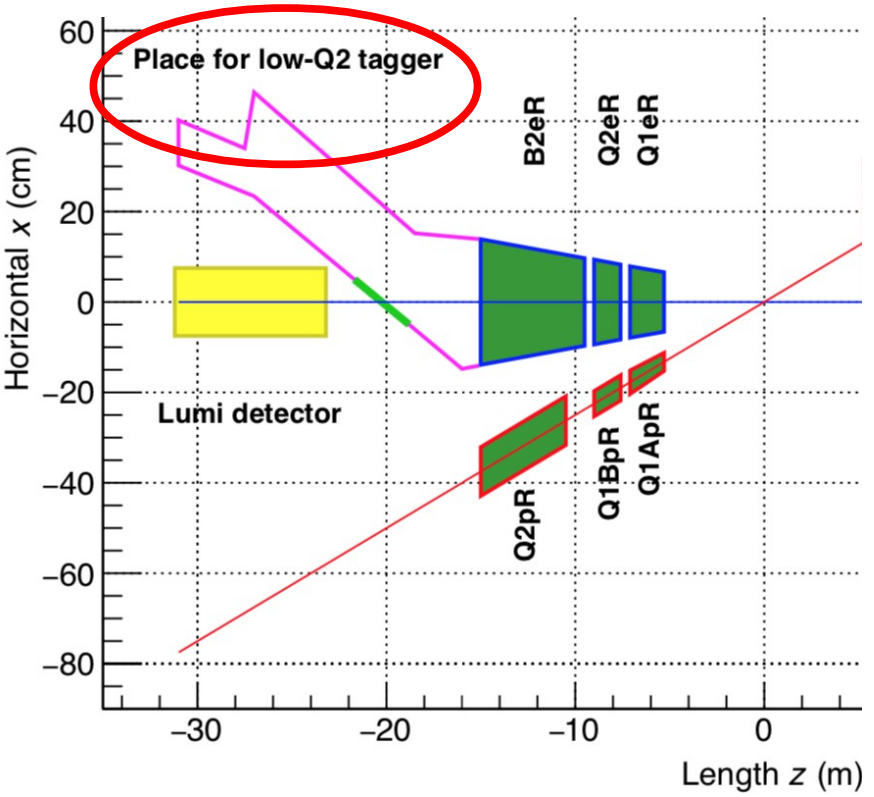
- Preliminary version low-Q^2 tagger:
  - since then updated 2 taggers
  - #s here* based on old version, similar to newer Tagger1

*Original: YR Far Fwd. Det. Mtg. 27.04.20

- Possibilities:
  tagging/measuring electrons from very low-Q^2 DIS (photoproduction)
- These processes will compete with the high cross section bremsstrahlung process (used for LUMI measurement)



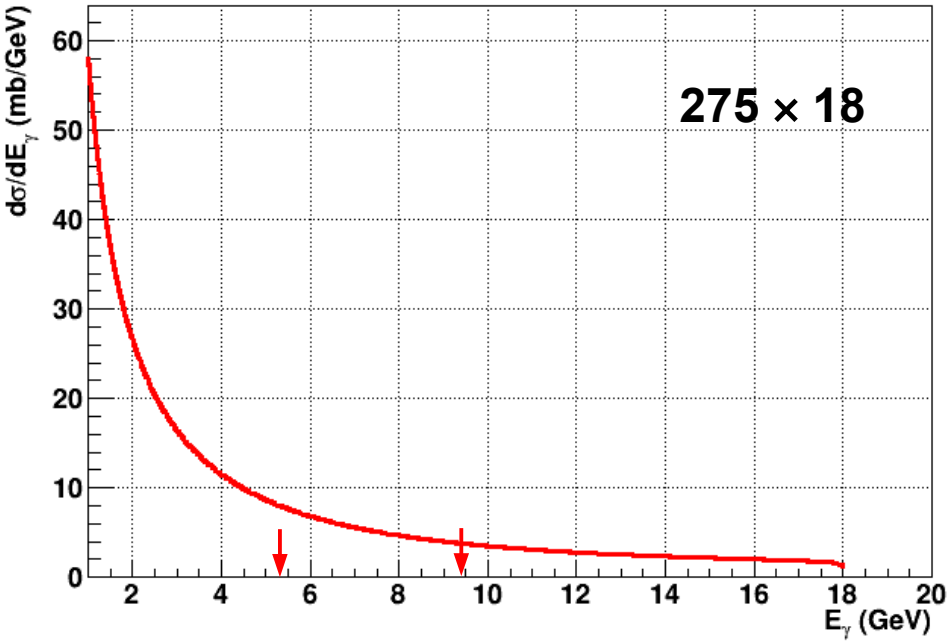
Here:

- Check brems. per bunch occupancy of tagger (it's high)
- Mitigation for possible physics use ⇒ tagger design
- Reminder:
  tagger for LUMI measurement cross check / calibration

Bethe-Heitler

- High cross section Bethe-Heitler bremsstrahlung ep→epγ
- Photons used for LUMI measurement (pair spectrometer)

$$\frac{d\sigma}{dE_\gamma} = 4\alpha r_e^2 \frac{E'_e}{E_\gamma E_e}\left(\frac{E_e}{E'_e} + \frac{E'_e}{E_e} - \frac{2}{3}\right)\left(\ln\frac{4E_pE_eE'_e}{m_pm_eE_\gamma} - \frac{1}{2}\right)$$



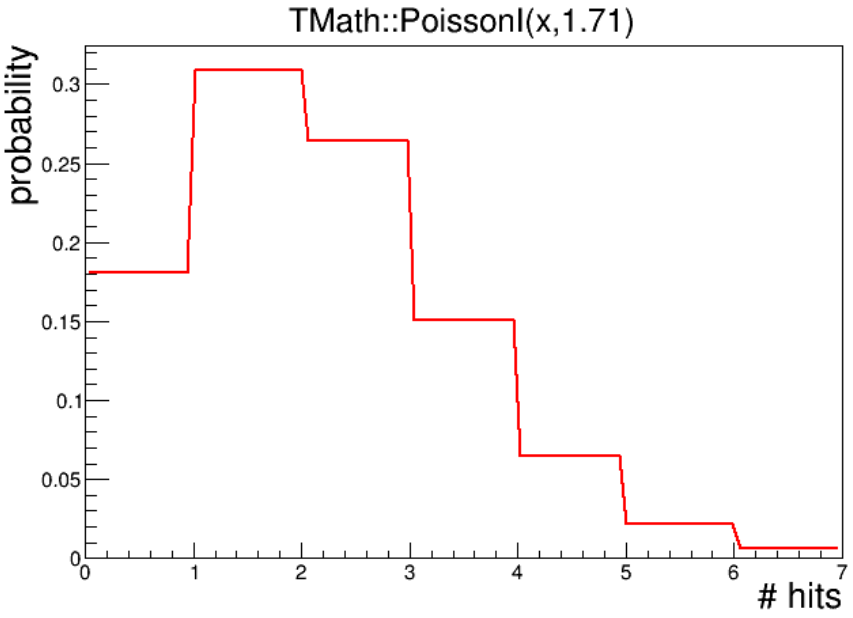
- Final state electron may hit tagger:
  $E_e' = E_e - E_\gamma$
- From Jarda's older slides* estimate tagger range for 275×18:
  $8.5 < E_e' < 12.75$ GeV $\Rightarrow$ $5.25 < E_\gamma < 9.5$ GeV (red arrows)
- Integrate B-H formula over this range: tagger cross section
  σ(tagger) = 23.1 mb
- Rather large cross section; how often tagger hit? ↘

*sl.7 https://indico.bnl.gov/event/8288/contributions/36673/attachments/27602/42258/JA-Low_Q2_tagger_20200413.pdf

Luminosity, hits / bunch ×ing

- Handy conversion for cross sections: 1 mb = 10^{-27} cm^2
- EIC 275×18 high divergence configuration:
  - $L = 1.65 \times 10^{33}$ cm^{-2} sec^{-1} = 1.65×10^{6} mb^{-1} sec^{-1}
  - 290 bunches, bunch spacing $T_b \approx 13$ μsec/290 = 44.8×10^{-9} sec
- $L = 0.074$ mb^{-1} / bunch ×ing

- Tagger hits / bunch ×ing = $L \cdot \sigma$(tagger) = 1.71
- This is mean (λ) of a Poisson distribution:



- Only 18% ($e^{-\lambda}$) of bunch ×ings have no tagger hit from B-H brems.
- 82% ($1-e^{-\lambda}$) have one or more tagger hits, ~50% multiple hits

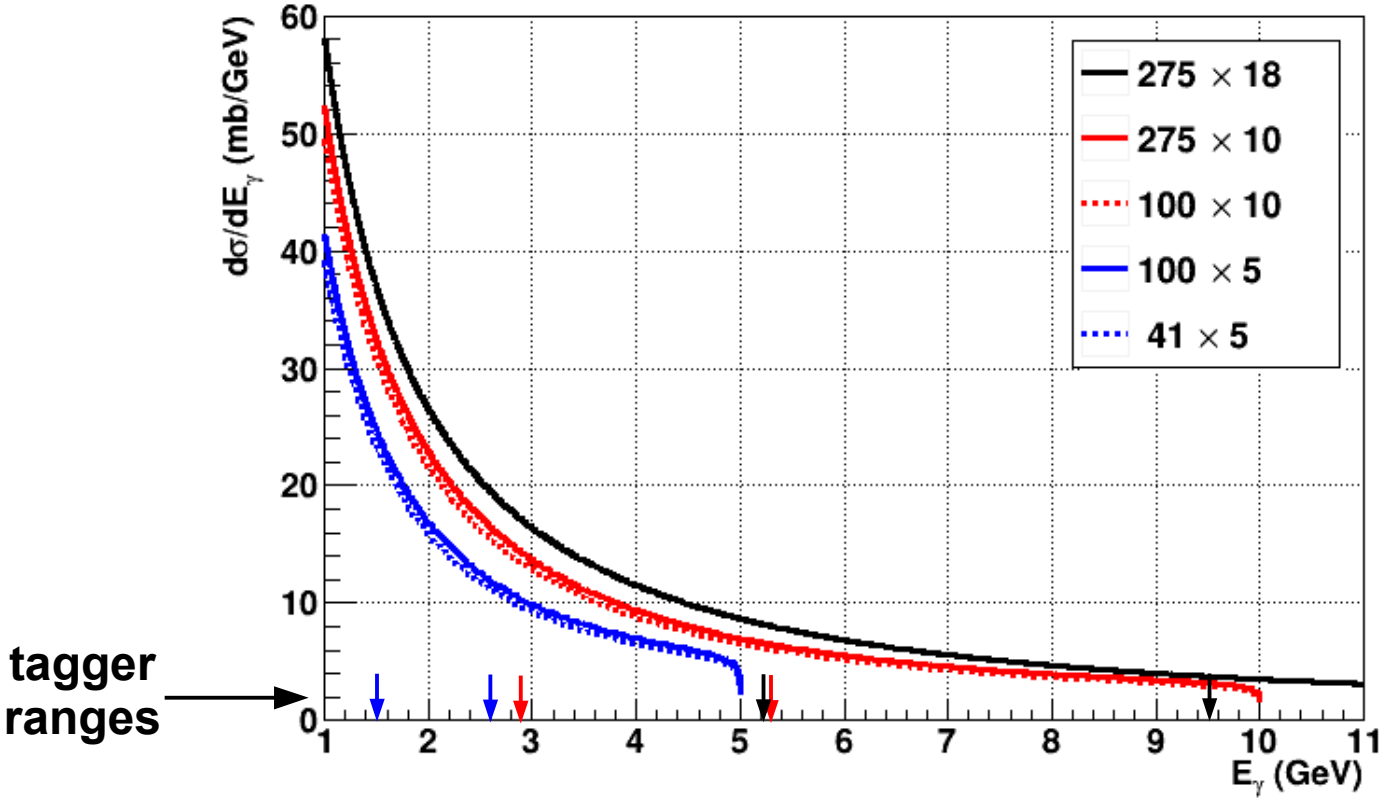
- These will overlap with any other photoproduction / low-Q^2 DIS we want to measure with the tagger

Other EIC energies

- Tagger E_e' range defined by dipole in e-ring
  $\Rightarrow E_e'$, E_γ ranges scale with beam E_e:

E_e (GeV)	18	10	5
min. E_γ (GeV)	5.25	2.9	1.5
max. E_γ (GeV)	9.5	5.3	2.6

- B-H spectra all EIC energies:



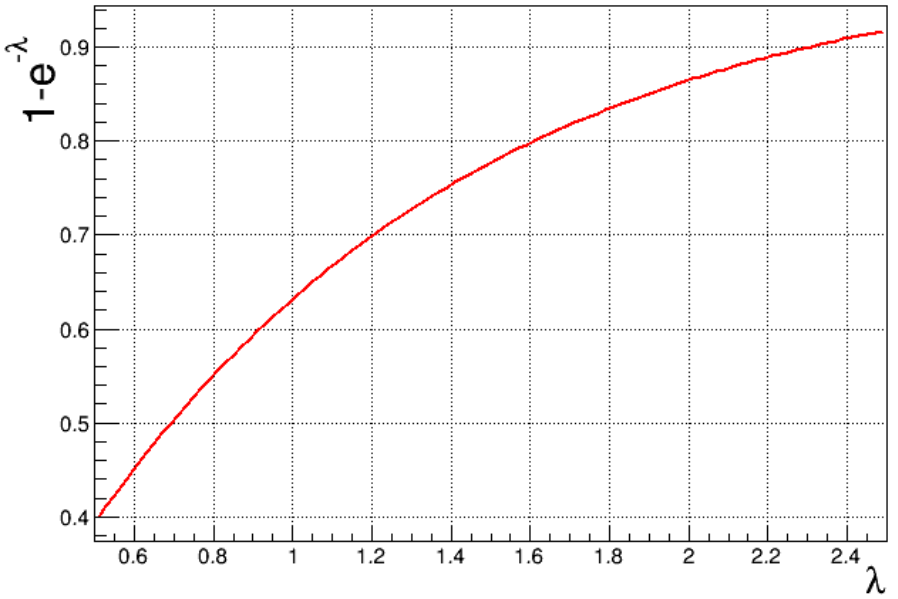
- Similar integral over tagger range all energies: 17-23 mb

Other EIC energies

- From EIC tables for high divergence (acceptance) configurations:

$E_p \times E_e$ (GeV × GeV)	275 × 18	275 × 10	100 × 10	100 × 5	41 × 5
L (10^{33} cm^{-2} sec^{-1}) = (10^{6} mb^{-1} sec^{-1})	1.65 (0.83)	10.05 (6.4)	4.35 (4.07)	3.16	0.44
# bunches	290	1160	1160	1160	1160
T_b(10^{-9} sec)	44.8	11.2	11.2	11.2	11.2
L (mb^{-1}/bunch)	0.074 (0.037)	0.112 (0.072)	0.049 (0.046)	0.035	0.005
σ(tagger) (mb)	23.1	22.8	21.4	18.6	17.5
tagger hits / bunch	1.71 (0.85)	2.55 (1.62)	1.05 (0.98)	0.65	0.088

- The bottom line (except for lowest √s configuration): always have mean λ = 0.65-2.5 B-H brems. hits in tagger / bunch ×ing
- 50-90% of bunch ×ings have one or more B-H brems. hits in tagger:
- Complications for physics analyses



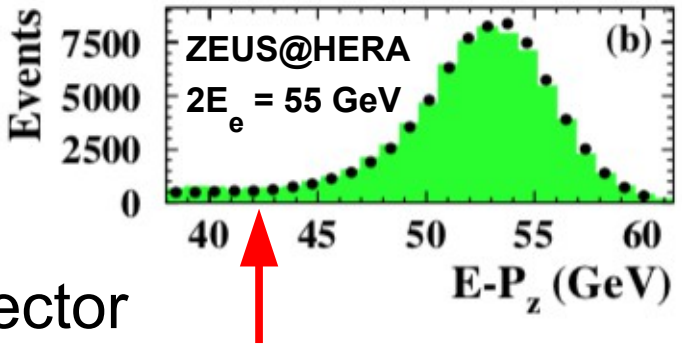
Mitigation

HERA: tagged photoproduction, vetoed γ in zero-degree calorim.

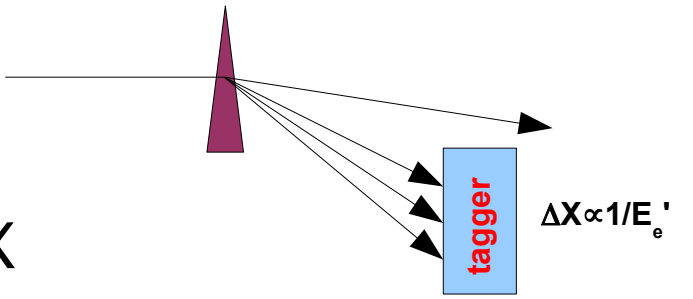
- possible @ lower HERA luminosities, few γ's per bunch ×ing
- not possible @ EIC: many B-H brems. γ's per bunch ×ing
  veto ~everything
- possible @ EIC with special running: low per-bunch luminosity
  unpopular

Segmented tagger ↔ central detector:

- Segment tagger: distinguish a few e' hits, measure energies E_e'
- Central detector:
  - consider $(E\text{-}P_z) = \sum_i E_i\text{-}P_{zi}$ sum i over all track/calorim. objects
  - objects 'leaking' down forward (hadron) beam pipe $E\text{-}P_z \approx 0$
  - initial state (beams): $(E\text{-}P_z) = 2E_e$
  - fully contained DIS: $(E\text{-}P_z) \approx 2E_e$
  - e' down rear beam pipe: $E_e' = E_e - (E\text{-}P_z)/2$
  - compare/match E_e' from tagger, central detector
- Challenging when 3,4,5... hits in tagger

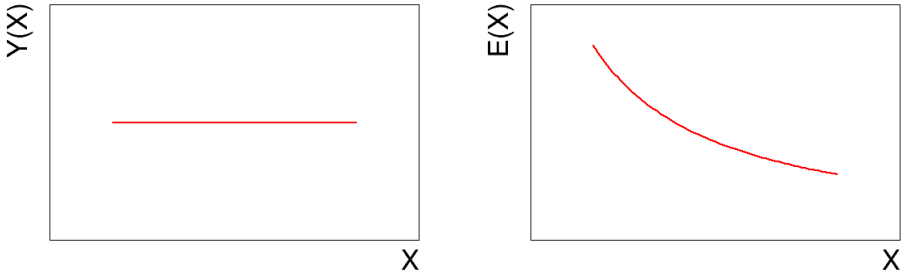


Mitigation: tagger X,Y,E

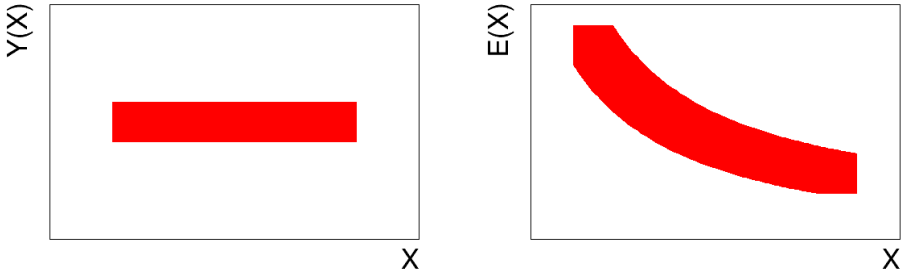


Brems. electrons: $p_T \sim 0$

- Dipole→tagger: no vertical Y deflection
  like spectrometer in horizontal X: E(X) ∝ 1/X



- Distributions Y(X), E(X) in tagger:



- With smearing for beam divergence:

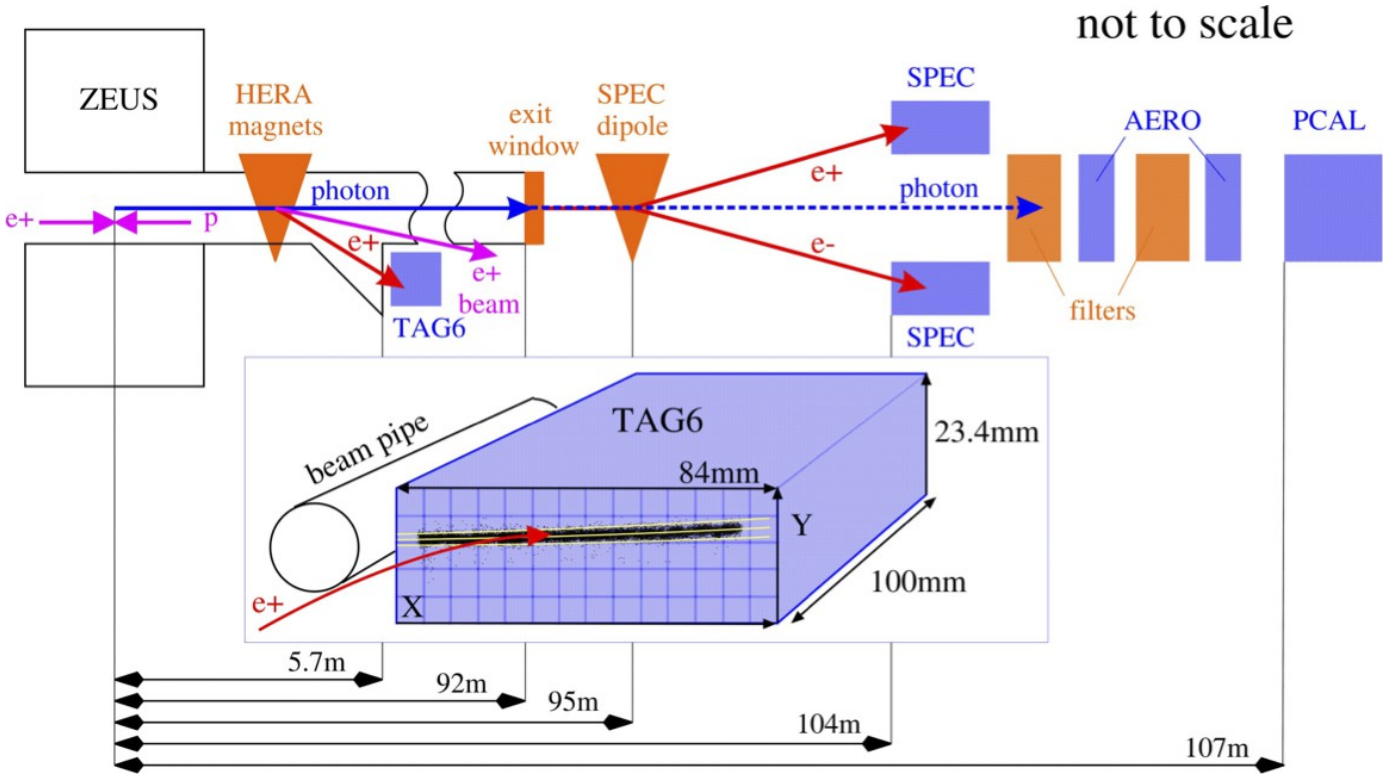
Low-Q^2. electrons: $p_T > 0$

- electrons $p_X \neq 0$: lie outside brems. E(X) band
  $p_Y \neq 0$: lie outside brems. Y(X) band
- Reject hits inside brems. bands: minimum Q^2
- Outer limits tagger acceptance (edges): maximum Q^2
- Should check w/ Jarda's generators, simulation
- We have some (old) data ↘

ZEUS detectors

ZEUS

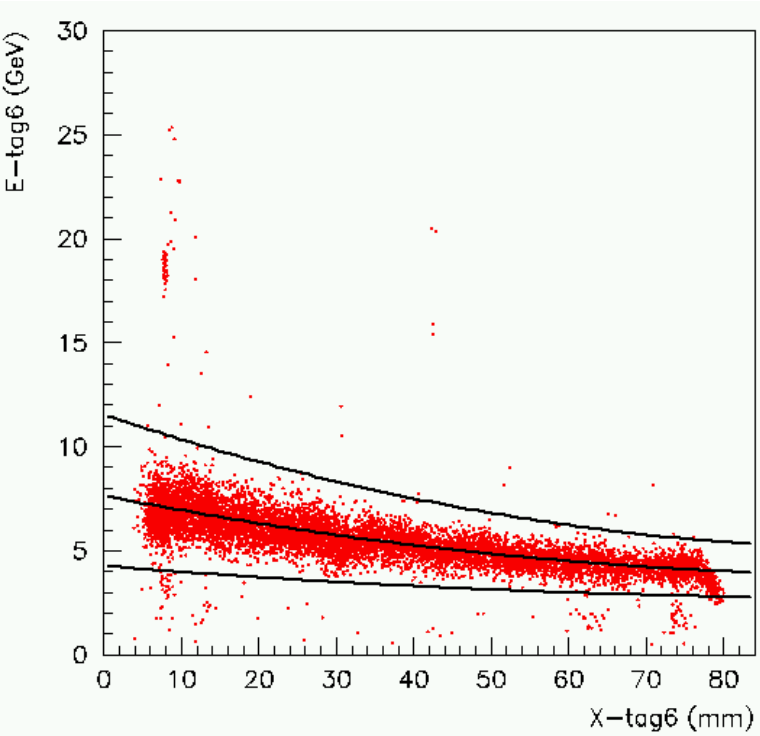
- central detectors (calorimeter CAL)
- positron tagger @ 6m
- LUMI pair spectrometer @ 105m



Select

- bremsstrahlung: coincidence tagger hit & γ in pair spectrometer
- low-Q^2: coincidence tagger hit & energy in ZEUS CAL e^+ direction

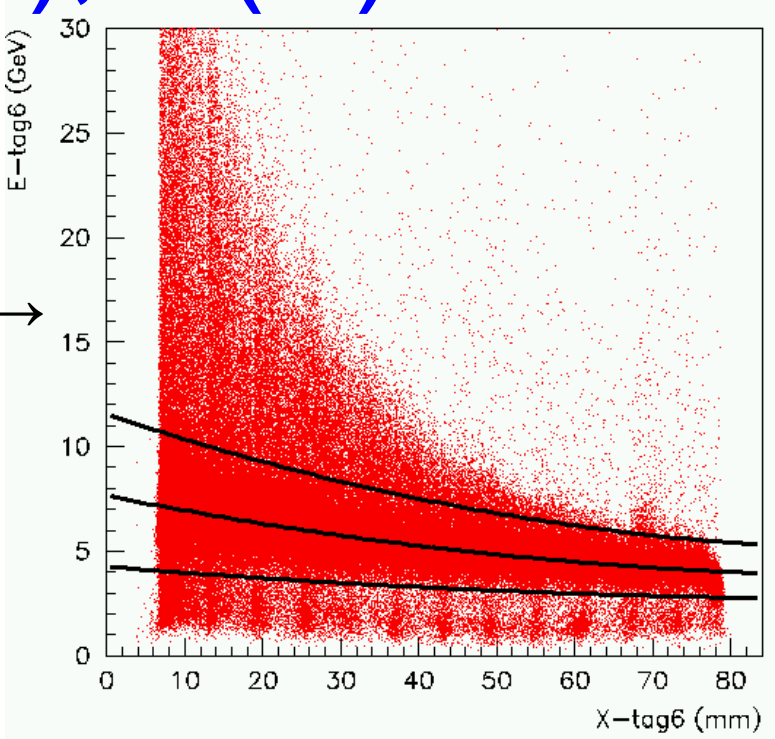
ZEUS tagger E(X), Y(X)

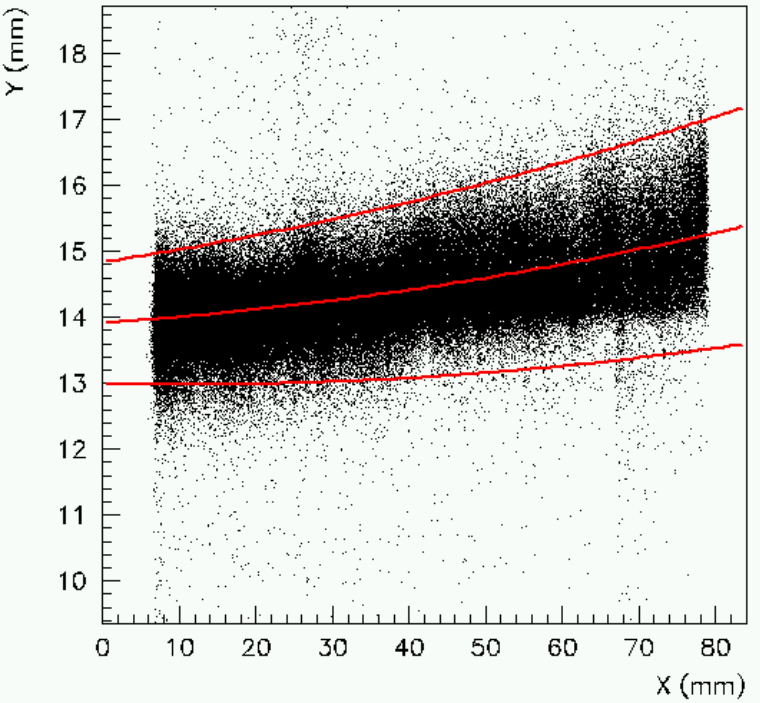


Tagger E(X)

← bremsstrahlung

low-Q^2 →

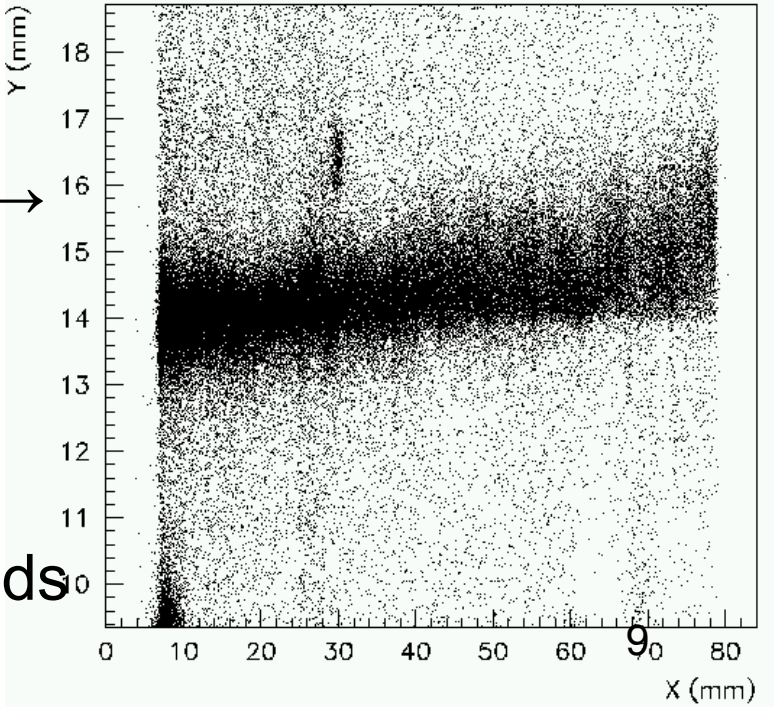




Tagger Y(X)

← bremsstrahlung

low-Q^2 →



- Clear low-Q^2 signal outside brems. bands

Tagger simulation

- Tagger simulation will provide guidance:
  - priority as proposal timeline dictates,
    results will guide tagger design
  - significant overlap w/ Inclusive/Tagging Physics WG; a little help?

- Jarda has the tools ready*:
  - GETaLM generator: brems. & low-Q^2, beam divergence smearing
  - Geant4 simulation: beamline magnets, taggers

- Wish list of plots, do for brems. & low-Q^2:
  - $d\sigma/dE_e'$ for electrons hitting taggers;
    plots show magnitude of problem
    integrals give accurate tagger cross sections, hits / bunch ×ing
  - tagger E vs. X, Y vs X:
    separation of brems. & low-Q^2
    Q^2 range of measurement

* links in:
https://indico.bnl.gov/event/11852/contributions/49812/attachments/34806/56548/JA-Tools_YR_20210526.pdf

LUMI spectrometer acceptance

Important reminder:

- The tagger also has an equally important purpose:
  measurement / ×check lumi spectrometer acceptance
- From ep→epγ: e in tagger ⇒ look for γ in spectrometer
  - check / verify simulation of spectrometer; estimate systematics
  - e.g. measure exit window conversion probability
- Need special (short) low lumi / bunch ×ing runs
  - ensure only one γ in system per bunch ×ing
  - high cross section physics measurements could use these runs

Sad historical note:

- We never completed this analysis on ZEUS
  (due to circumstances...)
- Final systematic on LUMI: 1.7%
- Could have achieved ~1% with tagger measurement
- Must do this for EIC!