# Occupancy in low-Q^2 tagger

W. Schmidke
Far Fwd. Det. Mtg.
27.04.20

- Jarda has outlined a low-Q^2 tagger:

- Discussed 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 per bunch occupancy of tagger (it's high)
- Mitigation for possible physics use $\Rightarrow$ tagger design
- Reminder:
  tagger for LUMI measurement cross check / calibration

1
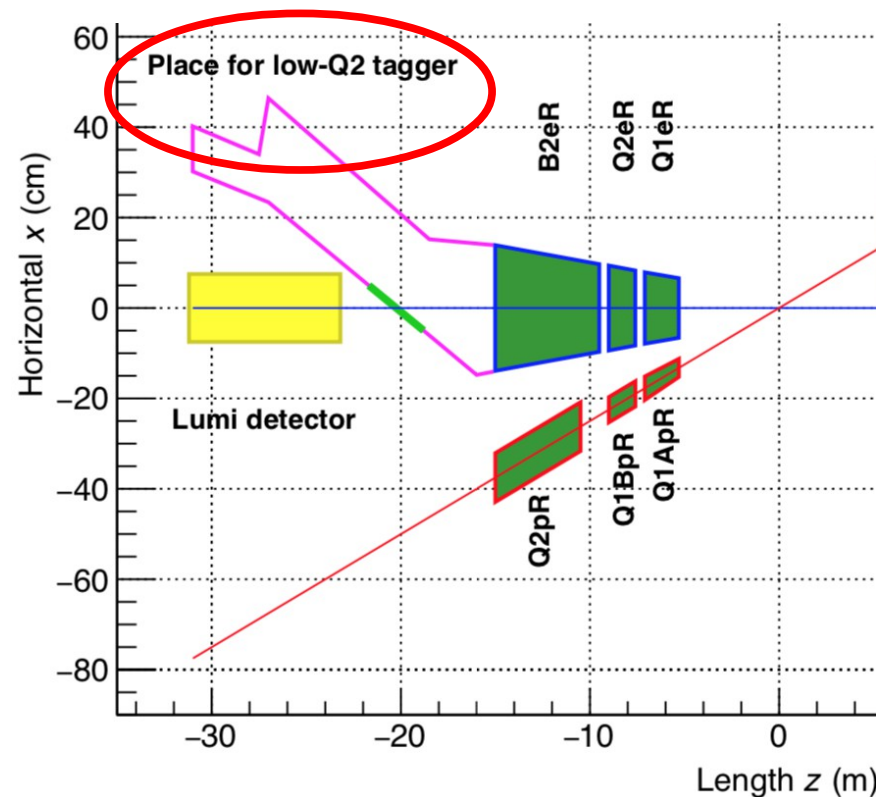
Bethe-Heitler

- High cross section Bethe-Heitler bremsstrahlung $ep \rightarrow ep\gamma$
- Photons used for LUMI measurement (pair spectrometer)

$$\frac{d\sigma}{dE_\gamma} = 4\alpha r_e^2 \frac{E_e'}{E_\gamma E_e} \left(\frac{E_e}{E_e'} + \frac{E_e'}{E_e} - \frac{2}{3} \right) \left(\ln \frac{4E_p E_e E_e'}{m_p m_e E_\gamma} - \frac{1}{2} \right)$$
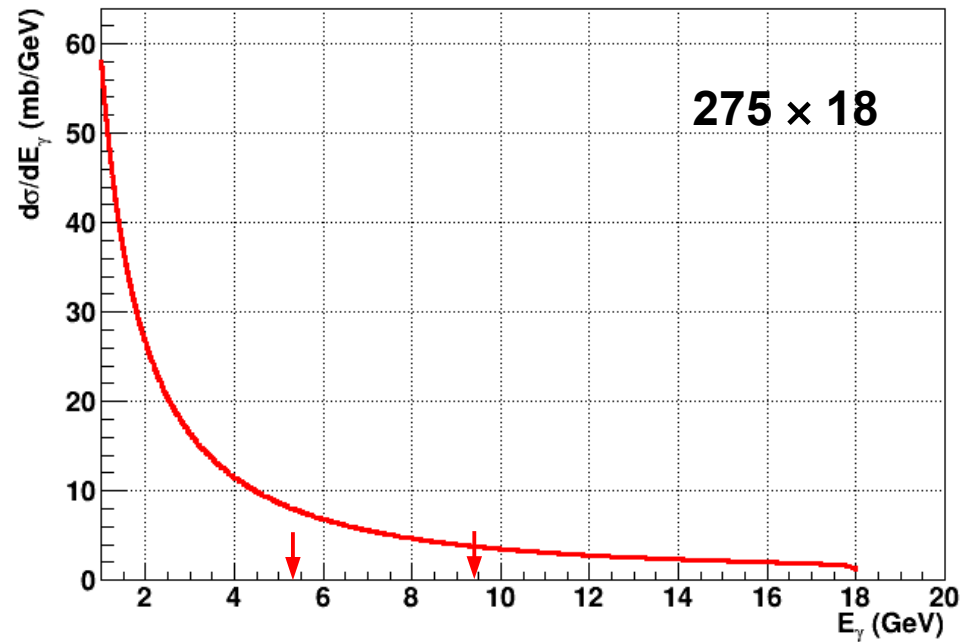
275 × 18

- Final state electron may hit tagger:
$$E_e' = E_e - E_\gamma$$
- From Jarda's 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
  - $\sigma(\text{tagger}) = 23.1$ mb
- Rather large cross section; how often tagger hit? ↘

Luminosity, hits / bunch ×ing

- Handy conversion for cross sections: 1 mb = 10^{-27} cm^2
- EIC 275×18 high divergence configuration:
  - L = 1.65×10^{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·σ(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
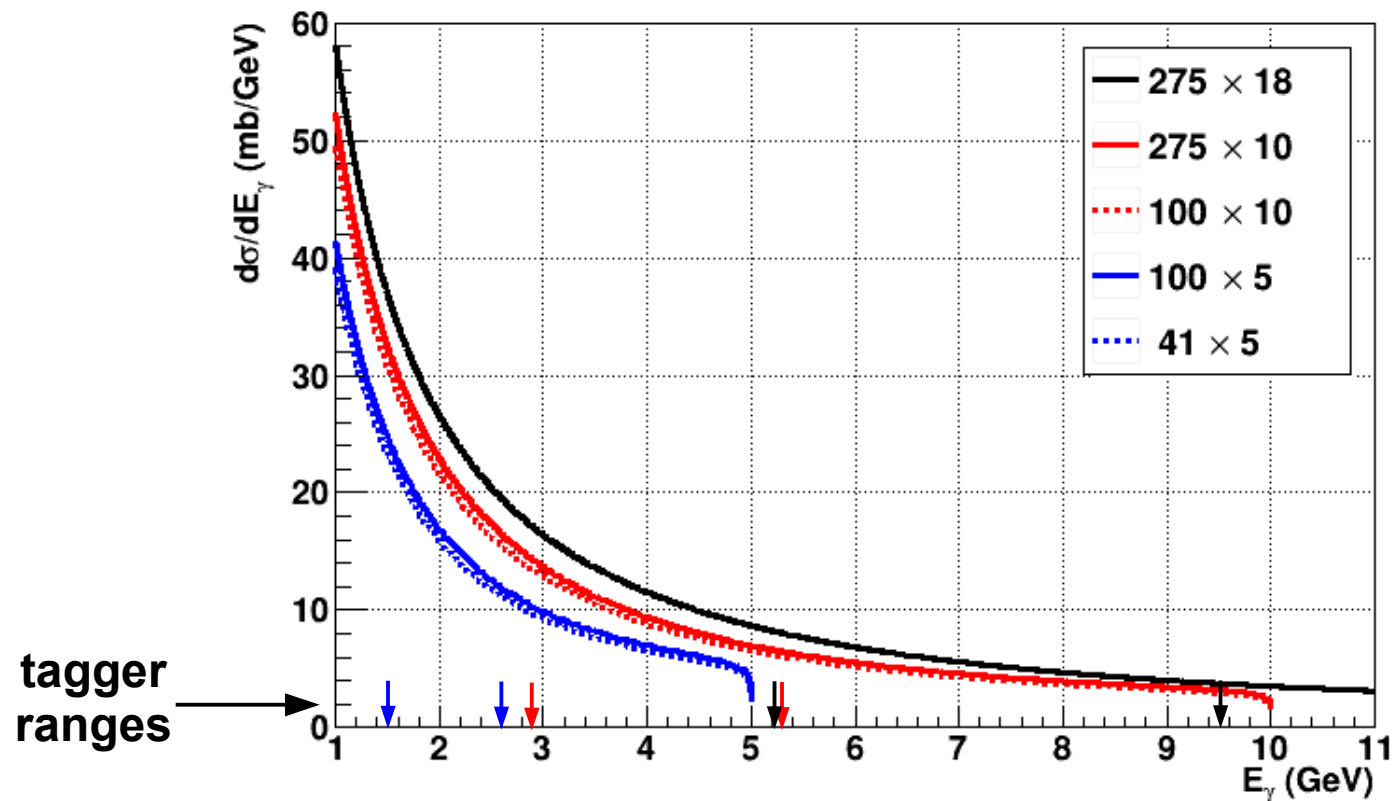 photoproduction / low-Q^2 DIS we
  want to measure with the tagger

3
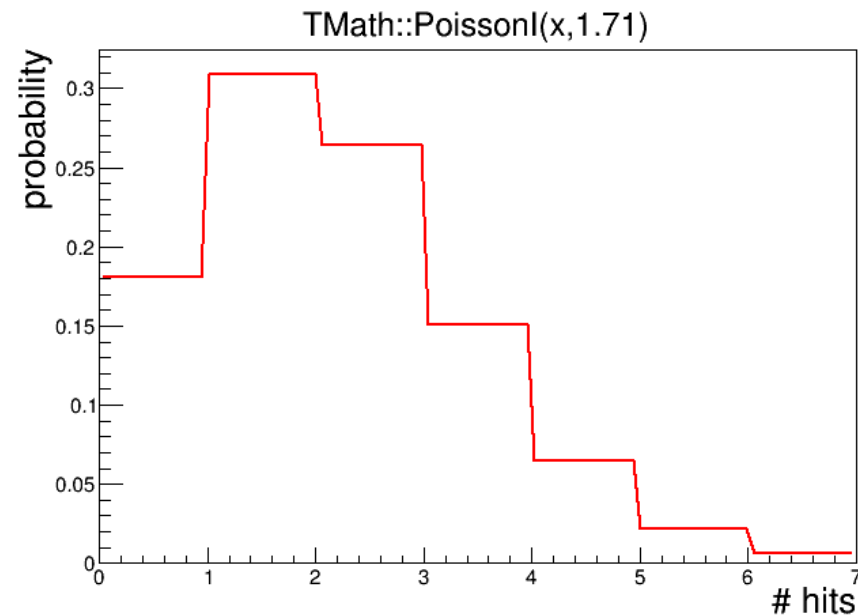
Other EIC energies

- 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

5
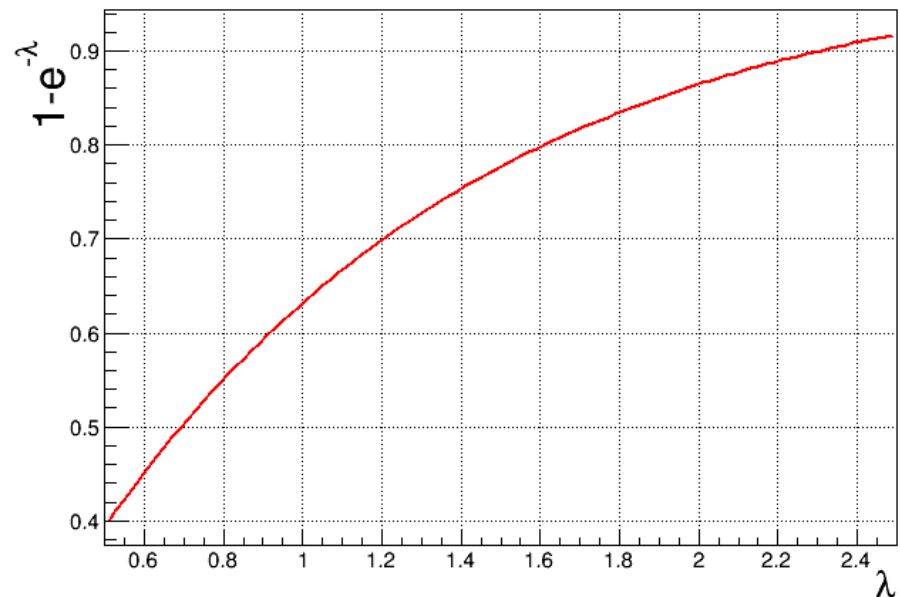
Mitigation

HERA: tagged photoproduction, vetoed γ in zero-degree calorim.
  - possible @ lower HERA luminosities
  - not possible @ EIC; many more B-H brems. γ's, veto everything

Segmented tagger:
- Segment tagger, e.g. like lumi calorims.: 7×7 3 cm PbWO4
- Could distinguish a few e' hits, measure energies E_e'
- Central detector:
  - consider $(E-P_z) = \sum_i E_i - P_{zi}$ sum i over all track/calorim. objects
  - objects 'leaking' down forward (hadron) beam pipe $E-P_z \approx 0$
  - initial state (beams): $(E-P_z) = 2E_e$
  - fully contained DIS: $(E-P_z) \approx 2E_e$ $\longrightarrow$
  - e' down rear beam pipe: $E_e' = E_e - (E-P_z)/2$
  - compare/match E_e' from tagger, central detector
- Challenging when 3,4,5... hits in tagger

ZEUS@HERA
$2E_e$ = 55 GeV
Events
(b)
E-P_z (GeV)
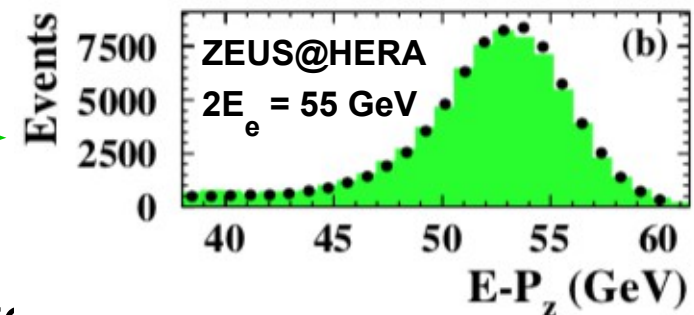
Unpopular: special running w/ low per-bunch luminosity ↘   6

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
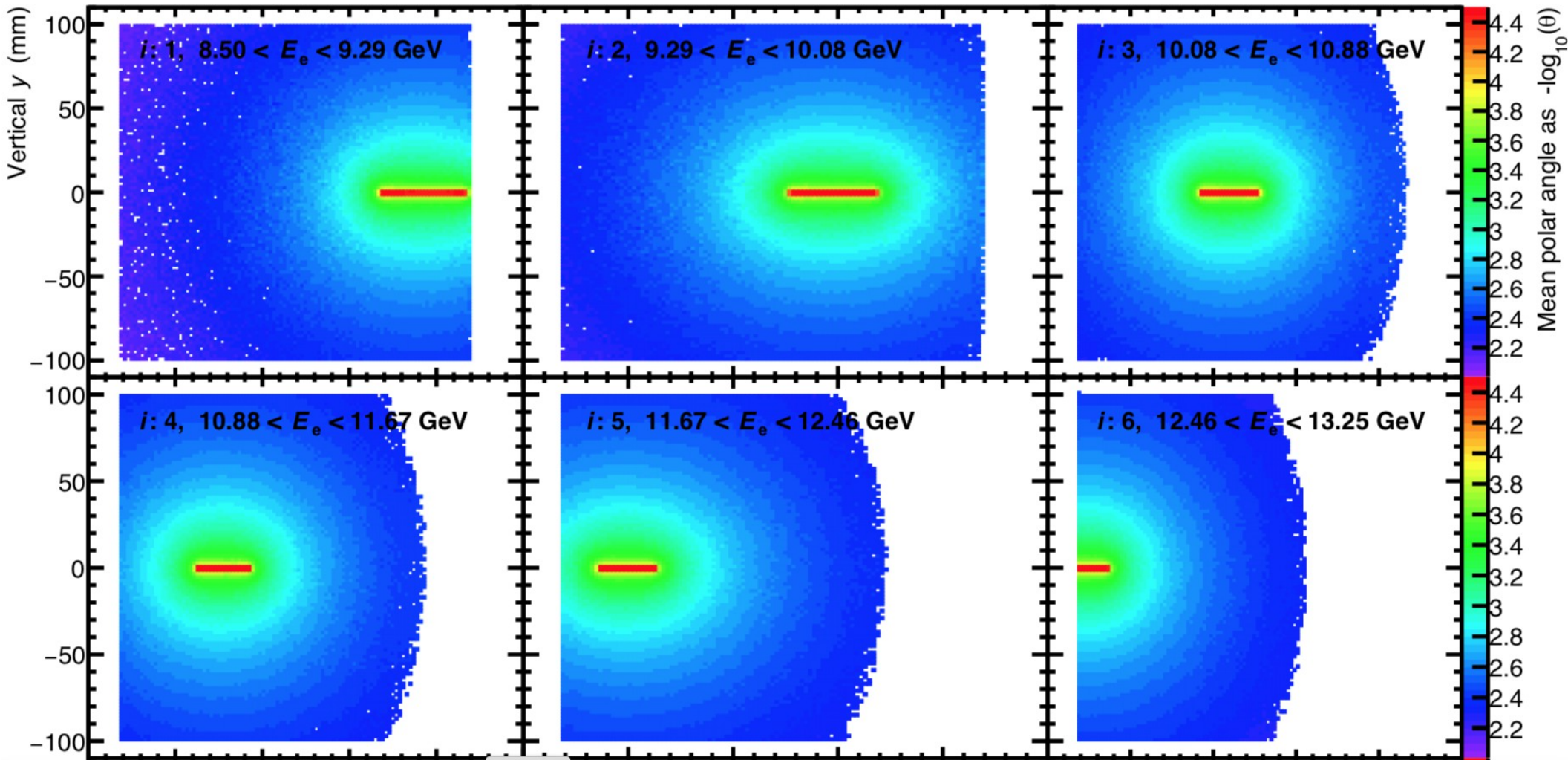 - high cross section physics measurements could use these runs

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!

Extras

Extra

- From slide 7 Jarda's last presentation*:

- Red region shows electrons scattered ~ zero degrees: bremsstrahlung