Luminosity from QED Compton

Stefan Schmitt, DESY
for the H1 collaboration

- Luminosity measurement at ep Colliders
- Elastic QED Compton scattering
- Reconstruction of elastic QEDC events
- Results

Luminosity at ep colliders

- Instantaneous luminosity

$$L = \frac{f\, n\, N_p\, N_e}{A}$$

f : revolution frequency
n : number of bunches
N_p : number of protons per bunch
N_e : number of electrons per bunch
A : beam cross section

- Problem: many parameters, some of them difficult to measure precisely

- Relation to cross section

$$\int L(t)\,dt = \frac{N_{ep\to X}}{\sigma_{ep\to X}}$$

$\int L(t)\,dt$: time-integrated luminosity
$N_{ep\to X}$: number of events
$\sigma_{ep\to X}$: cross section

- Measure integrated luminosity from event count, given a well-known cross section

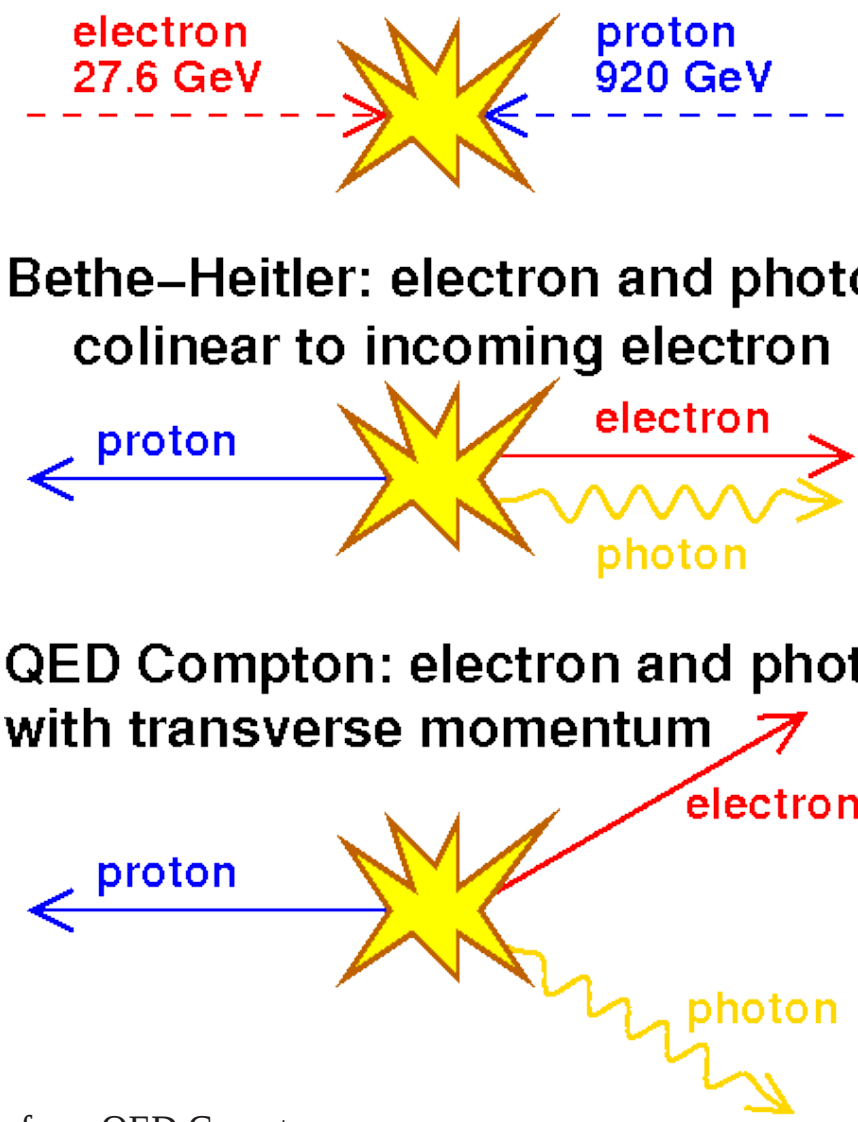
Photons in elastic ep collisions

- Reaction $ep \to e\gamma p$

  (γ radiated from e)
- Calculation in QED
- e and γ colinear to beam: Bethe-Heitler

  cross section at HERA ~100mb (E_γ>3 GeV)
- e and γ with non-zero P_T: QED Compton

  cross section at HERA ~100pb (P_T>2.5 GeV)



ep luminosity measurement

Elastic QED Compton

- Rate ~10^{-3} Hz
- 1% stat.err in 4 years
- Main detector

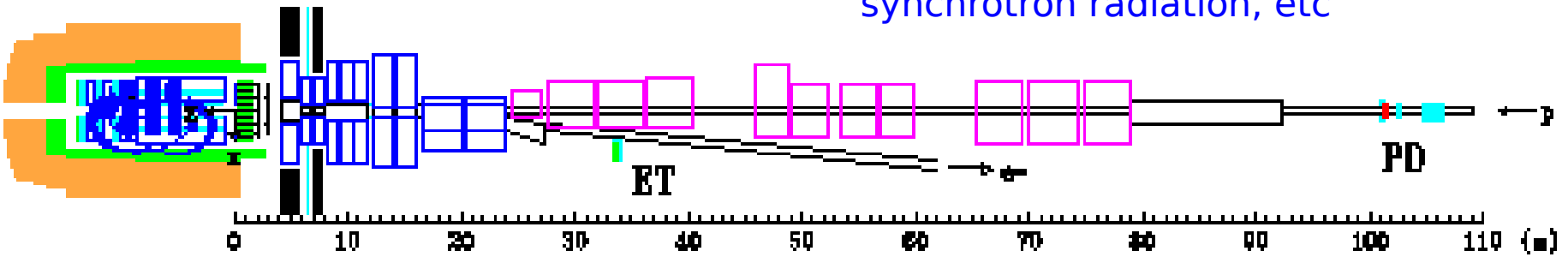
→ systematic uncertainties similar to other H1 analyses

Bethe-Heitler

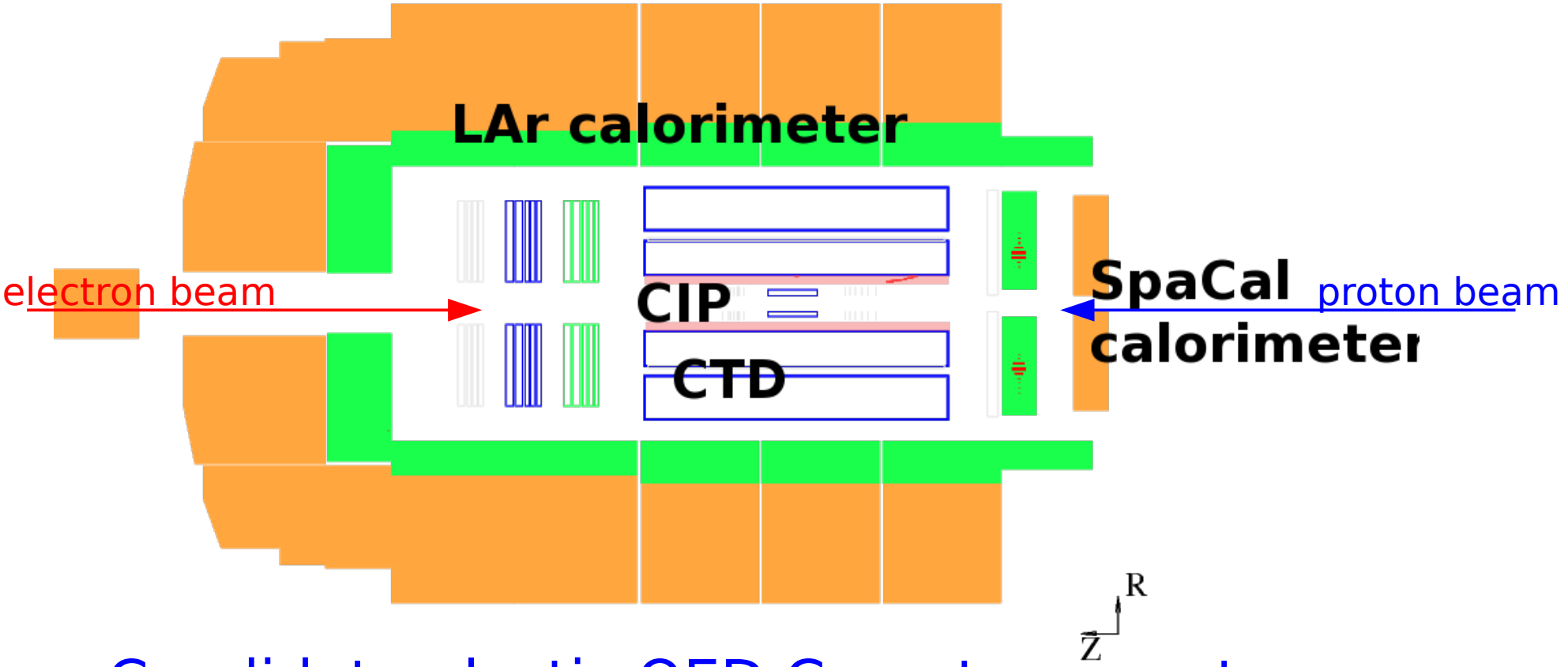
- Rate ~1MHz
- 1% stat.err in 0.01s
- Detector 100m away

→ complicated, time-dependent effects

Acceptance, energy-calibration, pileup, synchrotron radiation, etc

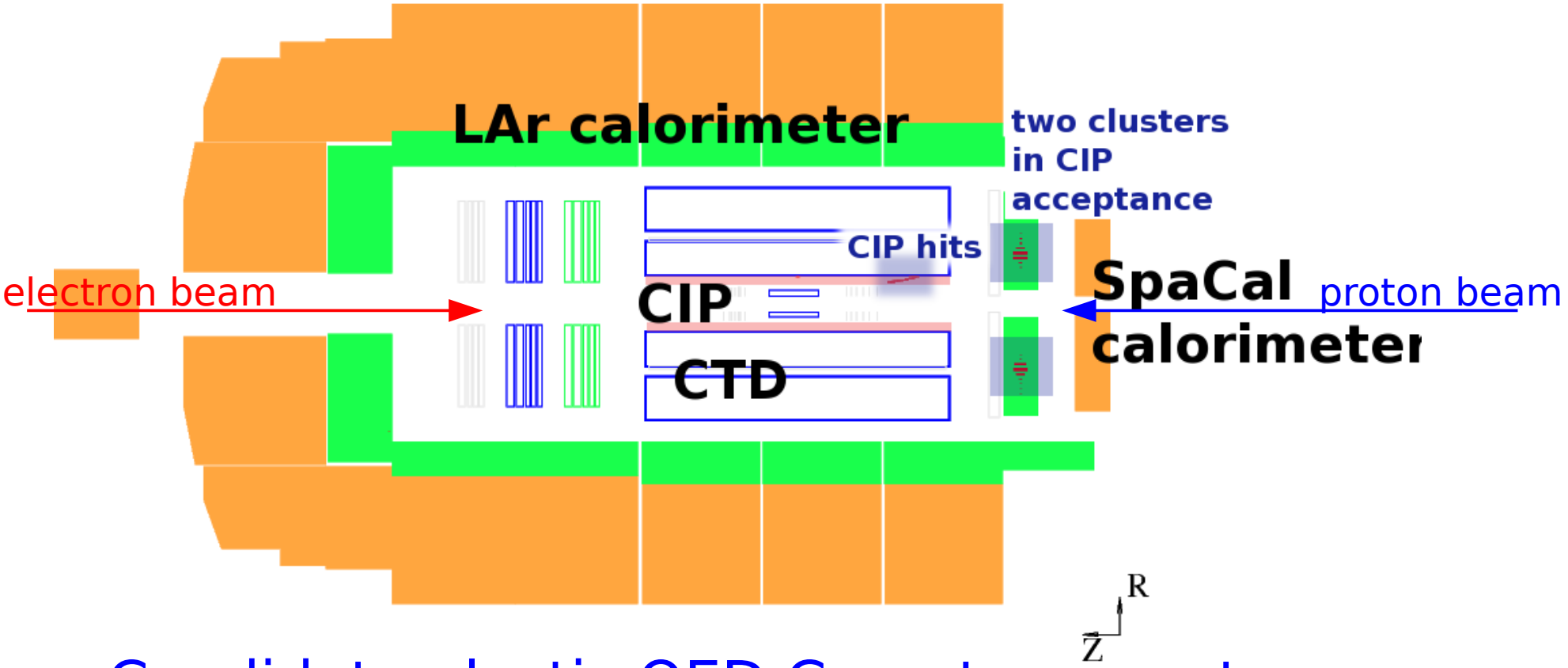


Elastic QED Compton in H1



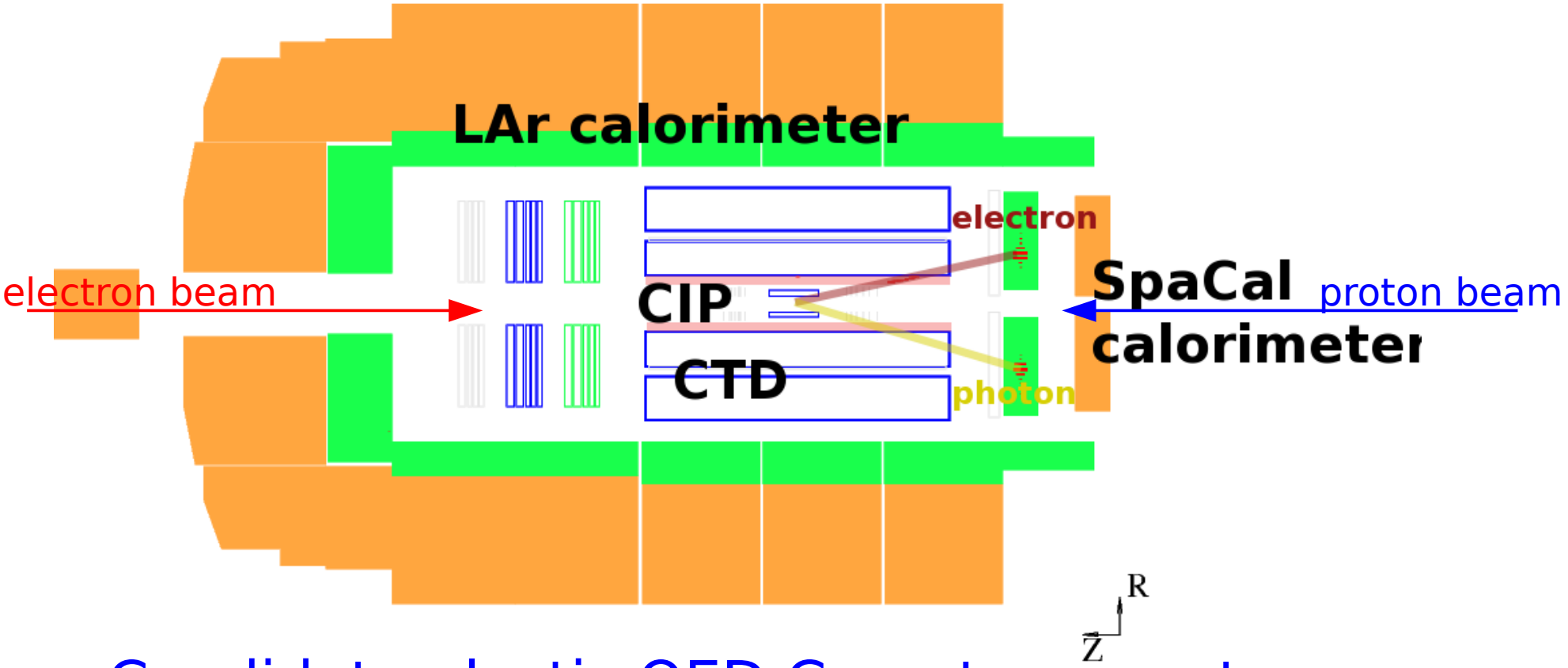
- Candidate elastic QED Compton event
- Detector is almost empty

Elastic QED Compton in H1



- Candidate elastic QED Compton event
- Two clusters in SpaCal calorimeter + CIP hits

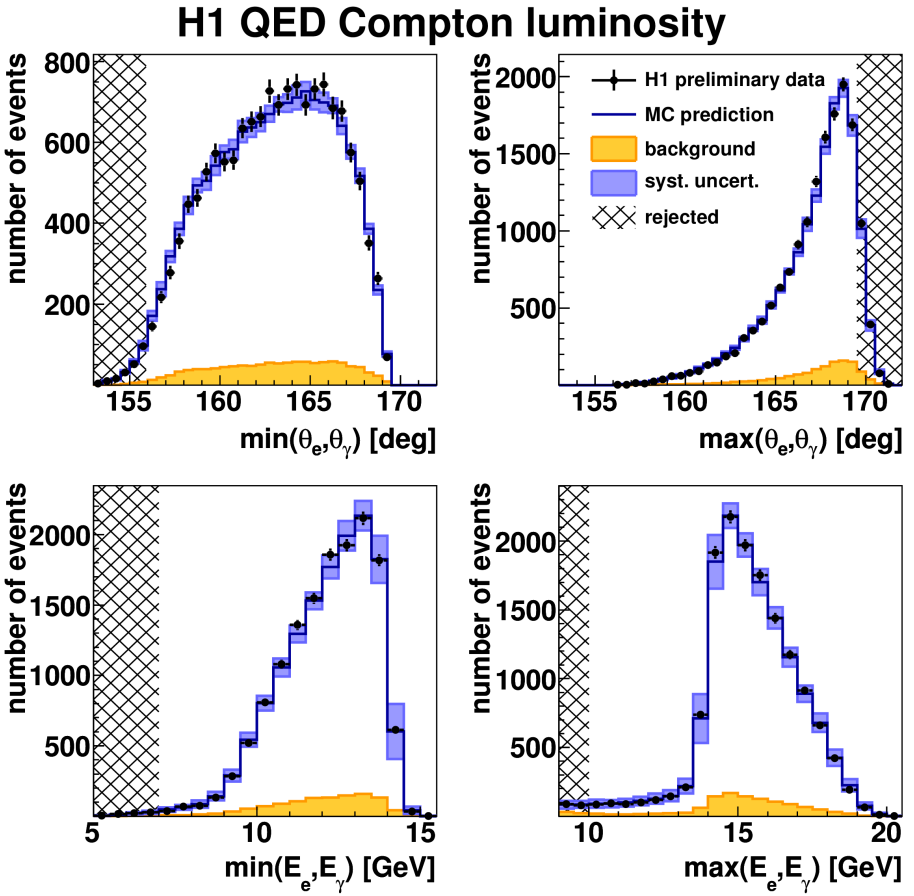
Elastic QED Compton in H1



- Candidate elastic QED Compton event
- Electron has CIP hits

Elastic QEDC selection

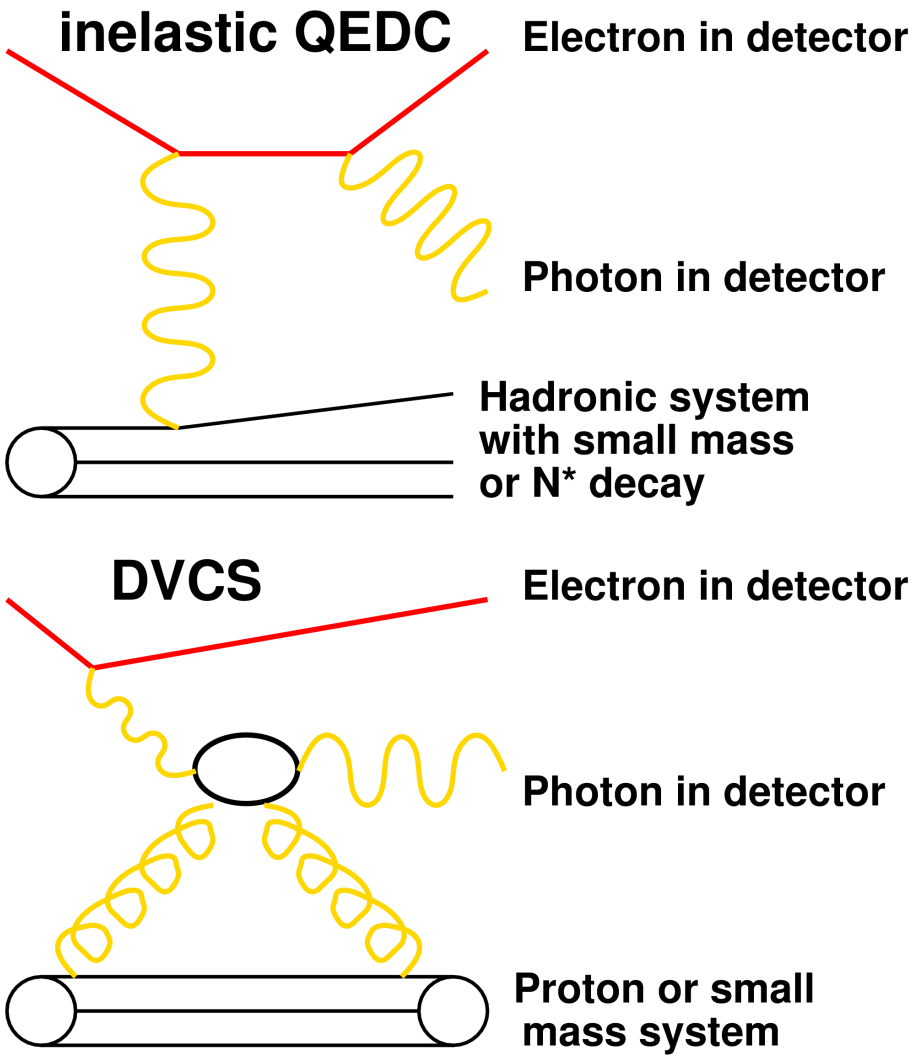
- Two SpaCal clusters, radial distance from beam 30<R<72 cm
- CIP hits → $|z_{vertex}|$<35 cm
- Otherwise empty detector
- E_1>7 GeV, E_2>10 GeV
- 155.9°<θ<169.5°
- Transverse momentum balance: $P_{T,miss}$<0.3 GeV



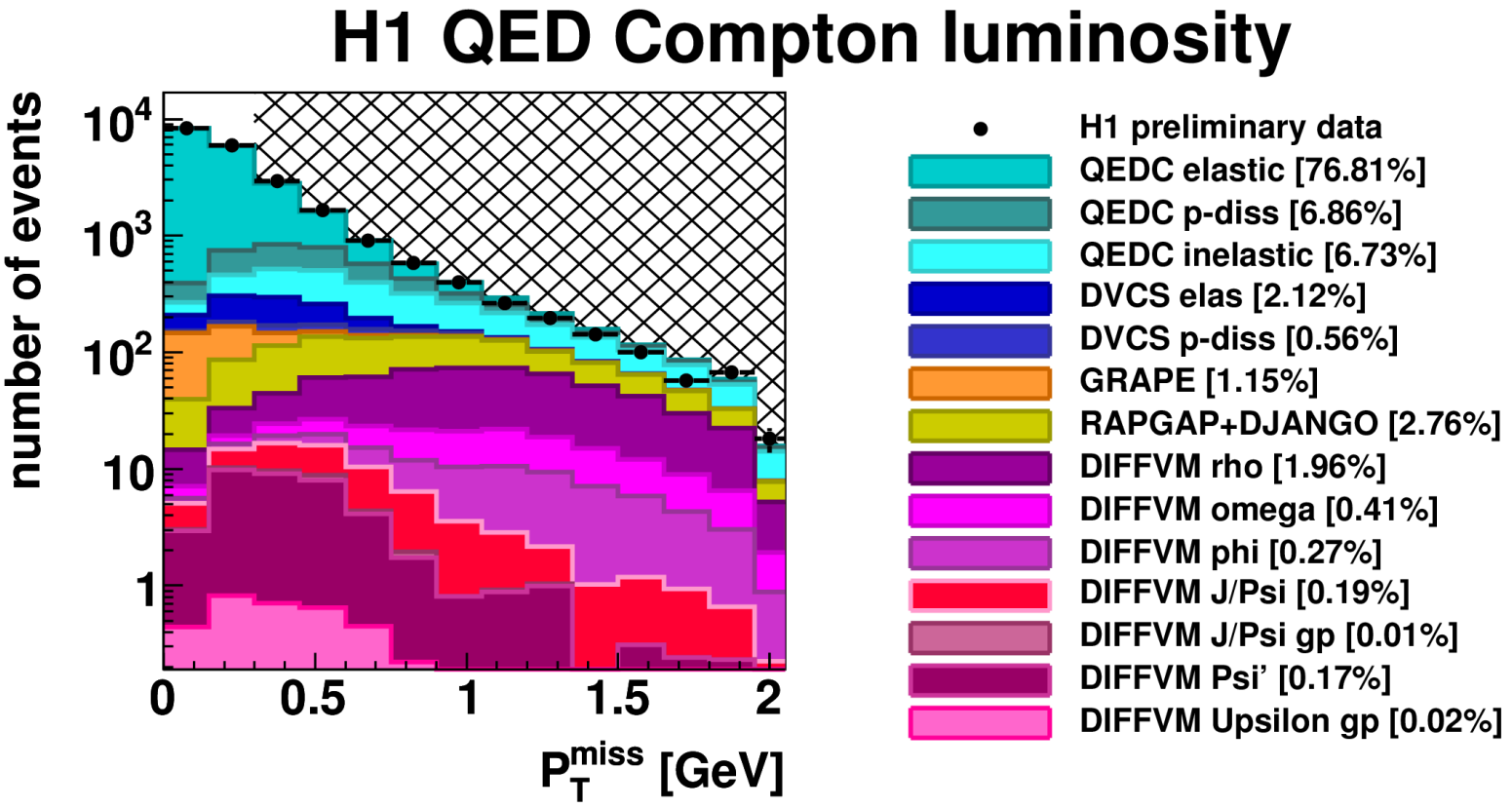
Control plots: polar angle and energy

Background

- Main background source: inelastic QEDC and DVCS
- Other background
  - $\gamma\gamma \rightarrow$ lepton pair
  - diffractive DIS
  - diffractive vector meson production
- Discriminating variable: $P_{T,miss}$

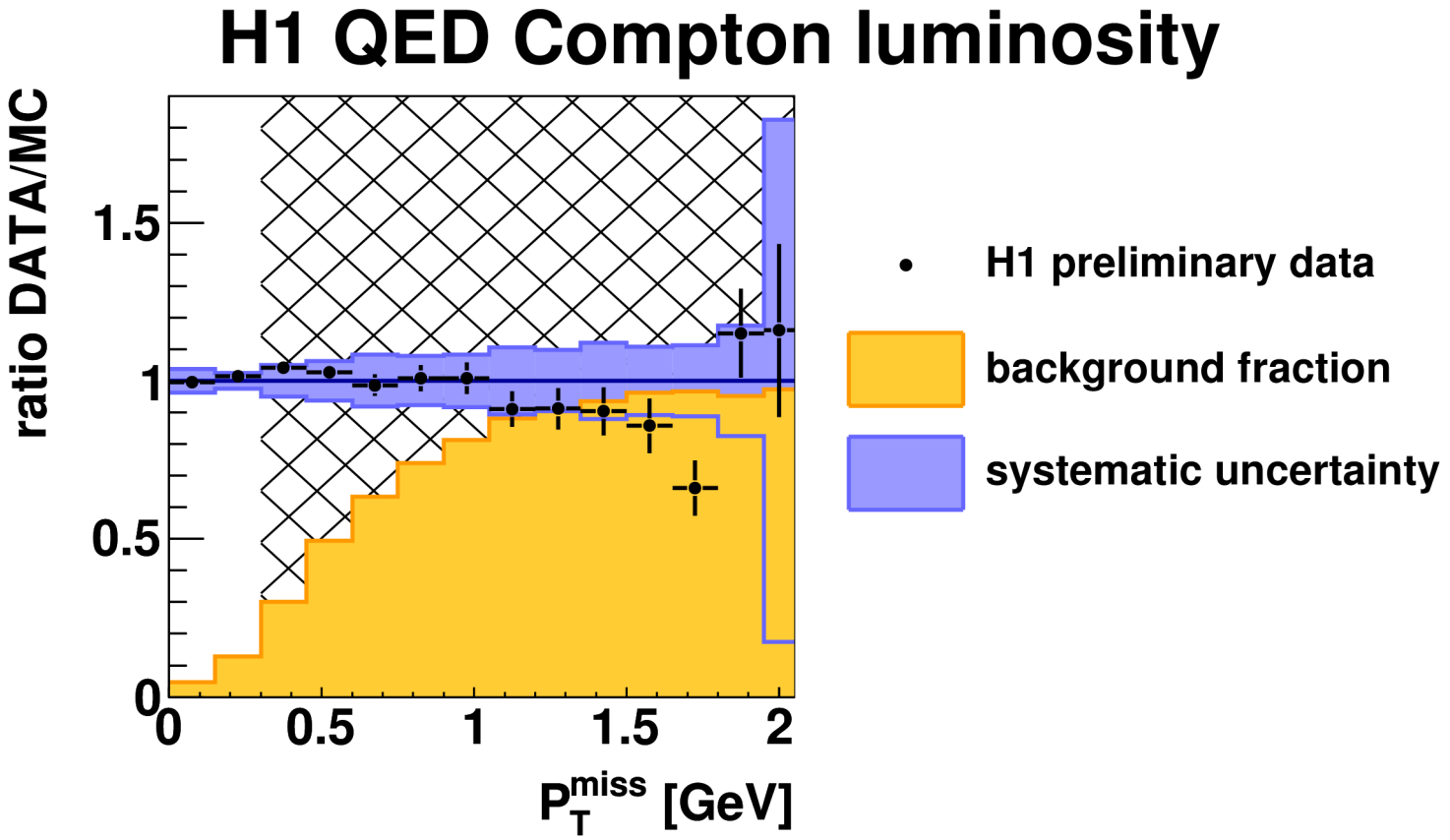


Background composition



- Background normalisation uncertainty ~20-30%
- Region $P_{T,miss}$>0.3 GeV is excluded

Systematic error in $P_{T,miss}$

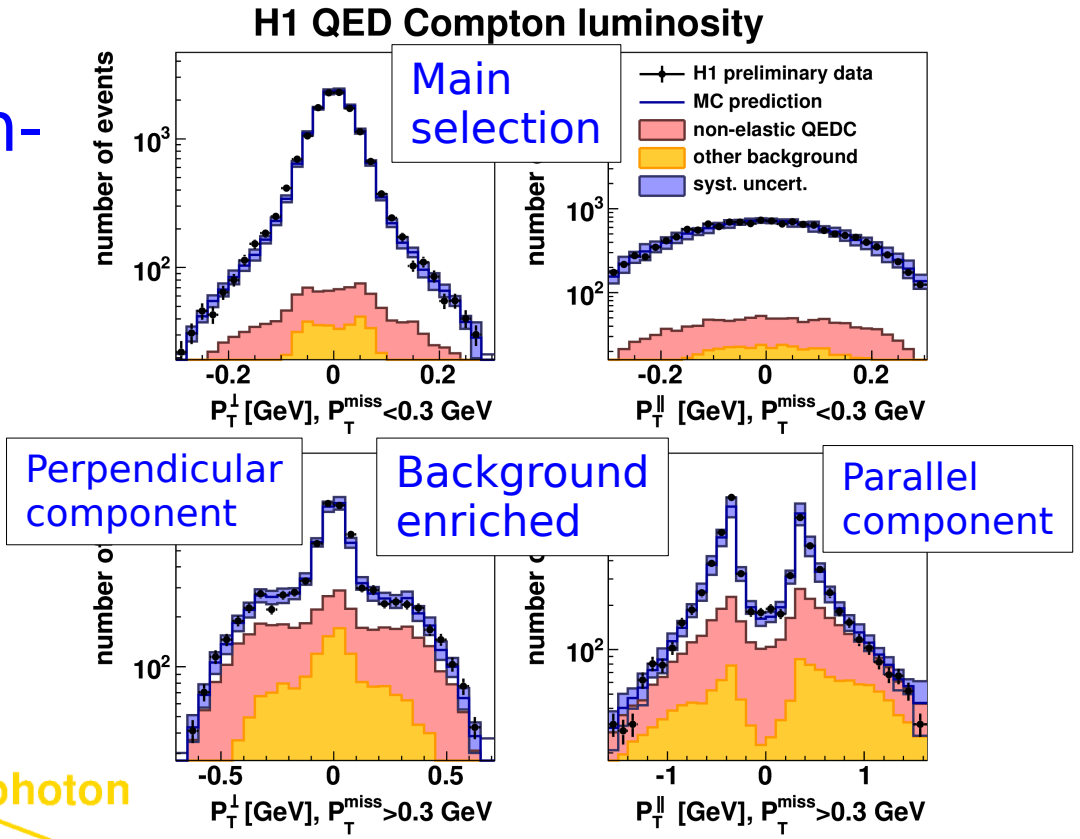


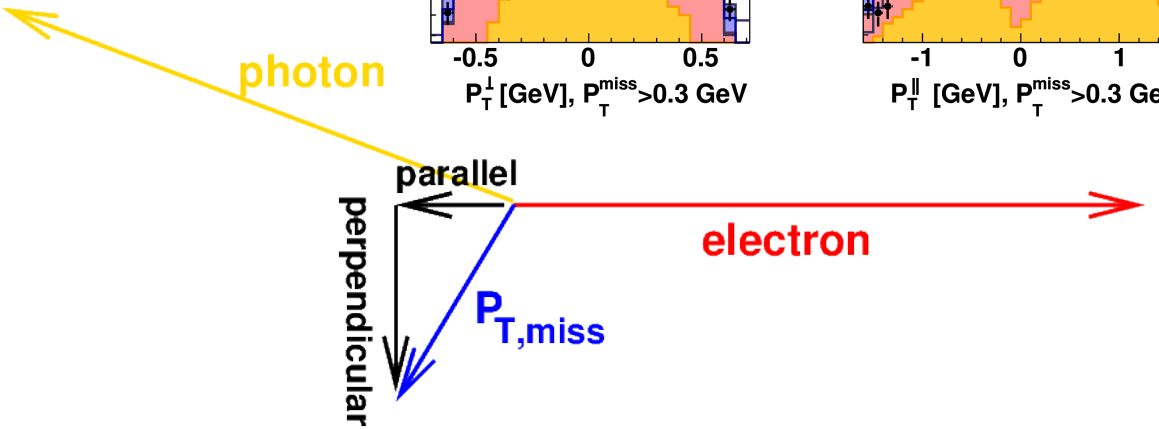
- Region $P_{T,miss}$>0.3 GeV is excluded
- Trade-off: reconstr. wrt backgr. systematic uncert.

Background systematic error

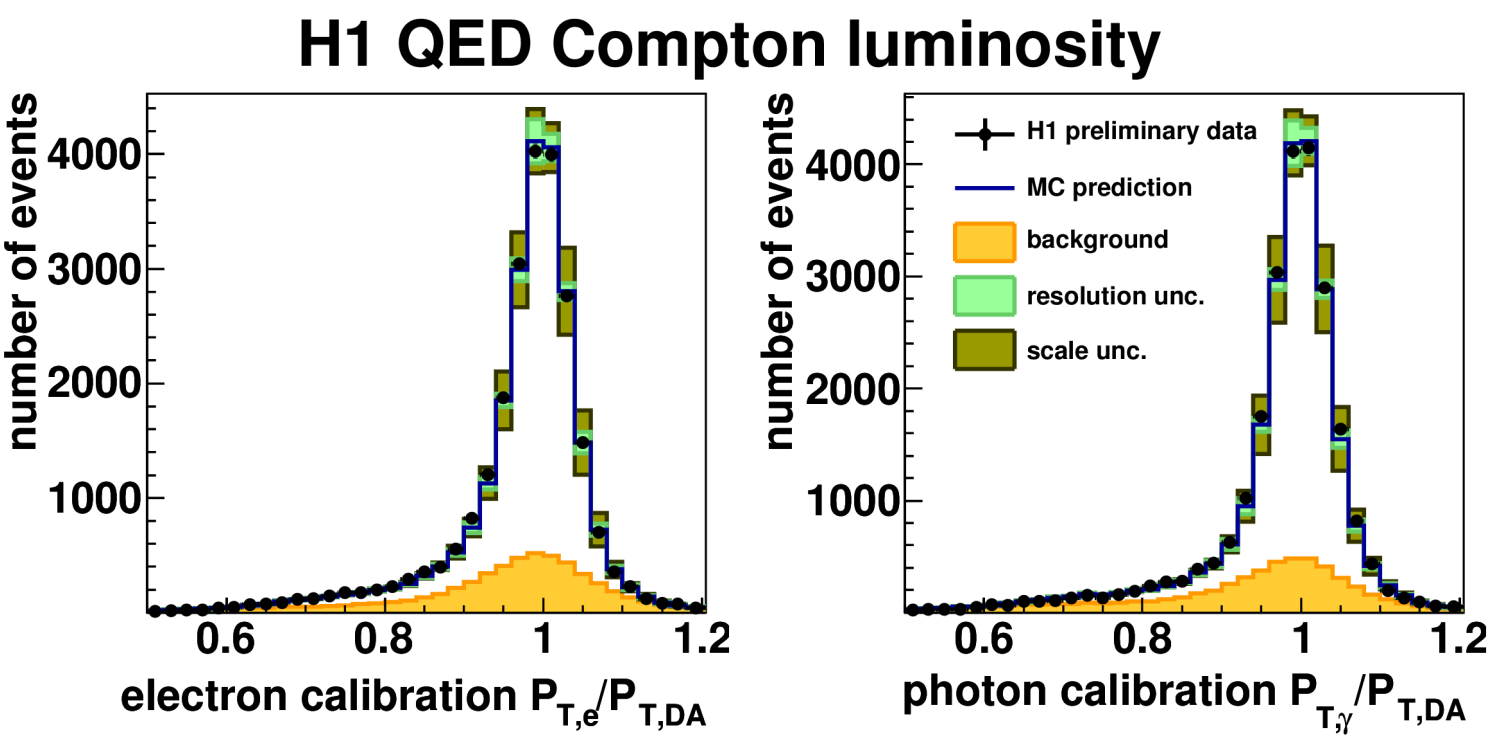
- Main analysis bgnd: non-elastic QEDC
- Parallel/perpendicular components of $P_{T,miss}$
- Described inside and outside phase-space
- Uncertainty

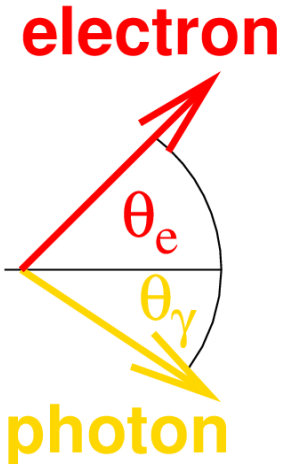
  from fits: 25%





Reconstruction uncertainty





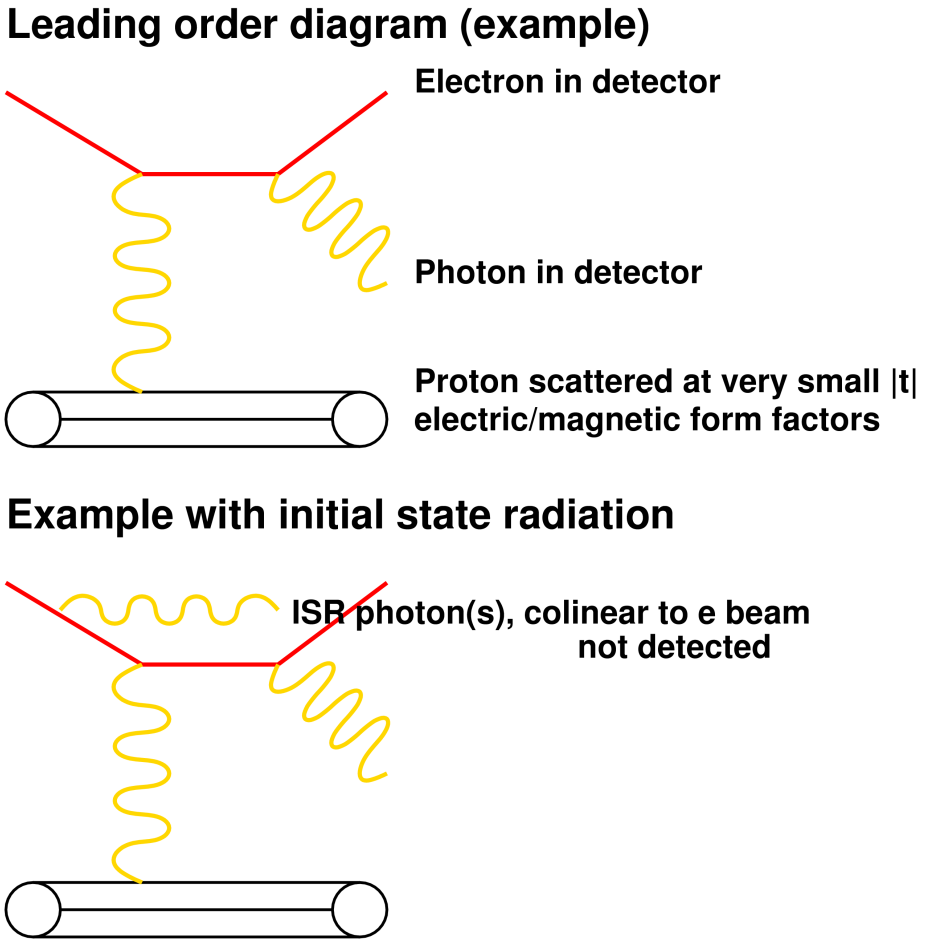
Predict transv. momentum of e and γ from polar angles. (neglect ISR and proton P_T)

$$P_{T,DA} = \frac{2E_0}{\frac{1-\cos\theta_e}{\sin\theta_e} + \frac{1-\cos\theta_\gamma}{\sin\theta_\gamma}}$$

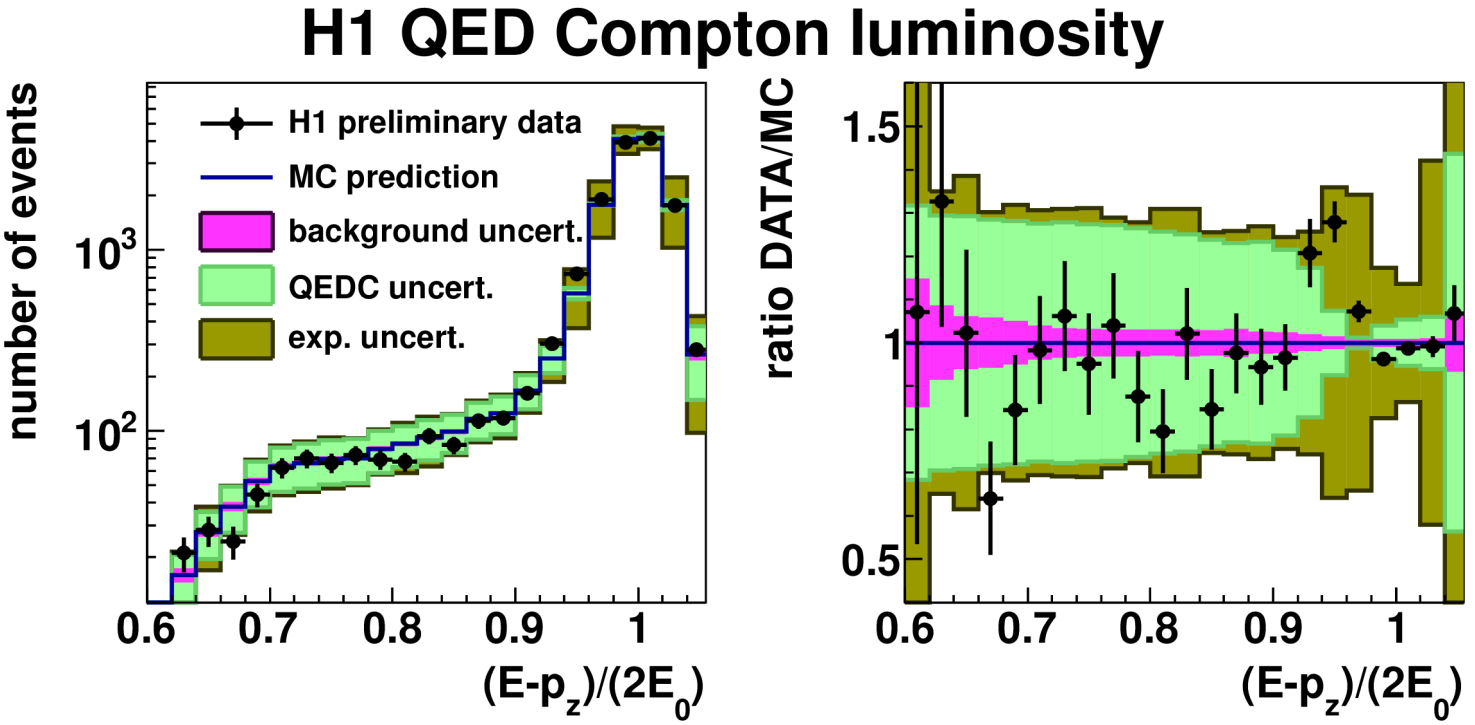
- Energy resolution: dominant uncertainty
- Controlled using double-angle method
- Vary E resolution and E scale in simulation

Theory uncertainties

- Main theory error: initial state radiaton (ISR)
- Compare two calculations
  - Peaking approximation
  - Photon radiator
- Additional uncertainty: proton form factors



Control of ISR uncertainties



- Reconstruct energy fraction carried by $e+\gamma$
- Fraction <1: losses from initial state radiation
- Theory uncertainties dominate below 0.95

Results

- Analysis of all data taken in 2003-2007
- Total luminosity determined from this analysis: 351±8 pb^{-1}
- Total uncertainty 2.3%

Bethe-Heitler analysis:

3.4% for HERA II (2003-2007)

1.5% for HERA I (1994-2000)

Trigger	0.22%
Background	1.17%
Reconstruction	1.41%
Theory	1.05%
Statistical uncertainty	0.85%
Total	2.28%

Time-dependence

- Luminosity of small data samples “runs” is not sufficient for elastic QEDC analysis
- Use inclusive DIS event counts for relative normalisation of runs and overall normalisation from elastic QEDC

$$L_{\text{run}} = \frac{N^{\text{DIS}}_{\text{run}}}{\sum_k N^{\text{DIS}}_k} L^{\text{QEDC}}$$

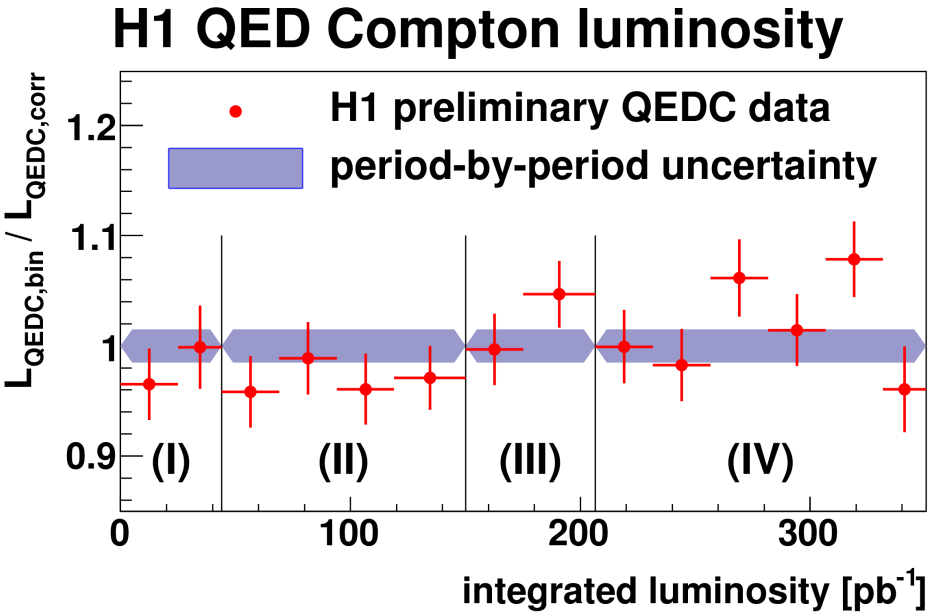
N^{DIS}_i : number of DIS events in run i

L^{QEDC} : luminosity from QEDC analysis

- Time-dependent uncertainty from this procedure: 1.5%

Check of time-dependence

- Repeat QEDC analysis in periods of ~25pb^{-1} each [stat.err: 3%]
- Compare to result from global QEDC analysis with run corrections [sys err: 1.5%]
- Agreement within uncertainties



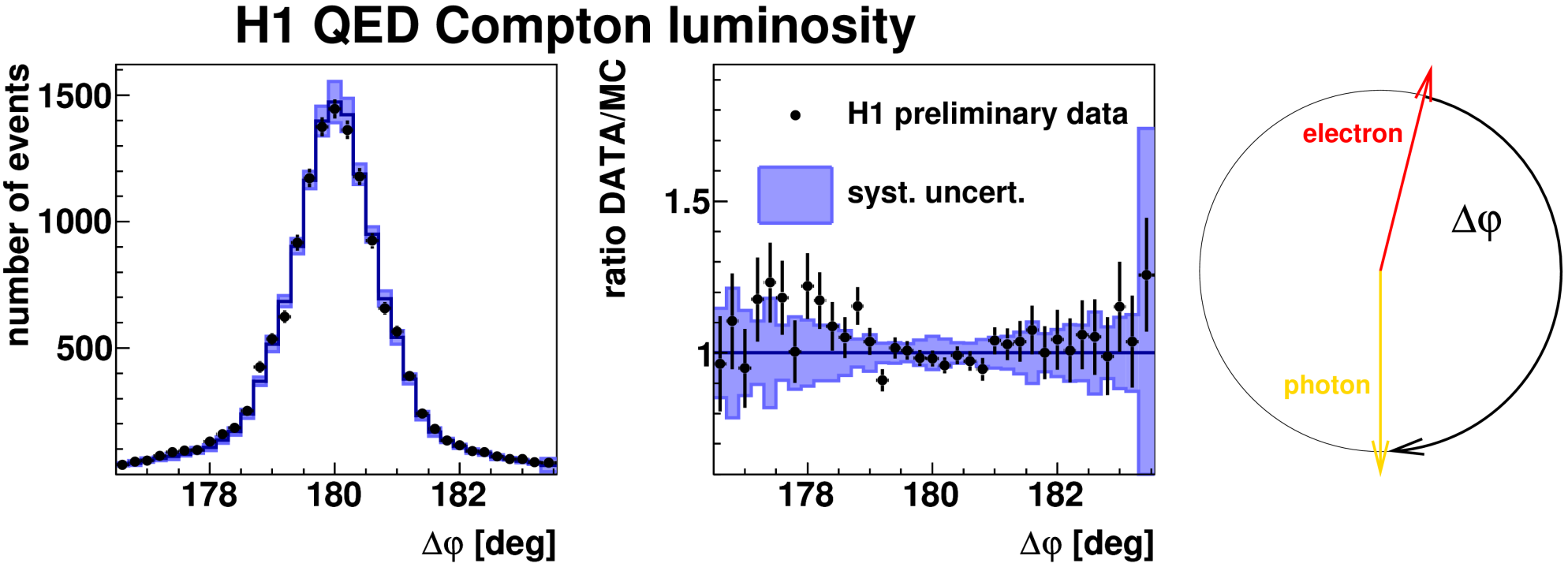
Data periods:
(I) e^+p beam
(II) e^-p beam, detector upgrade
(III) e^-p beam, detector upgrade
(IV) e^+p beam

Summary

- Luminosity measurement at ep colliders is often done using the reaction $ep \to e\gamma p$
- Bethe-Heitler reaction: e and γ are co-linear to e beam → dedicated detectors
- Elastic QED Compton: e and γ have transverse momentum → analysis done using main H1 detector
- Result: about equal uncertainties from theory, background, reconstruction
- Total uncertainty for full 2003-2007 data: 2.3% (Bethe-Heitler for HERA-II: 3.4%, HERA-I: 1.5%)

Backup

Position resolution uncertainty



- Position resolution: difference in azimuth
- Vary resolution in simulation