QED-Compton events in H1

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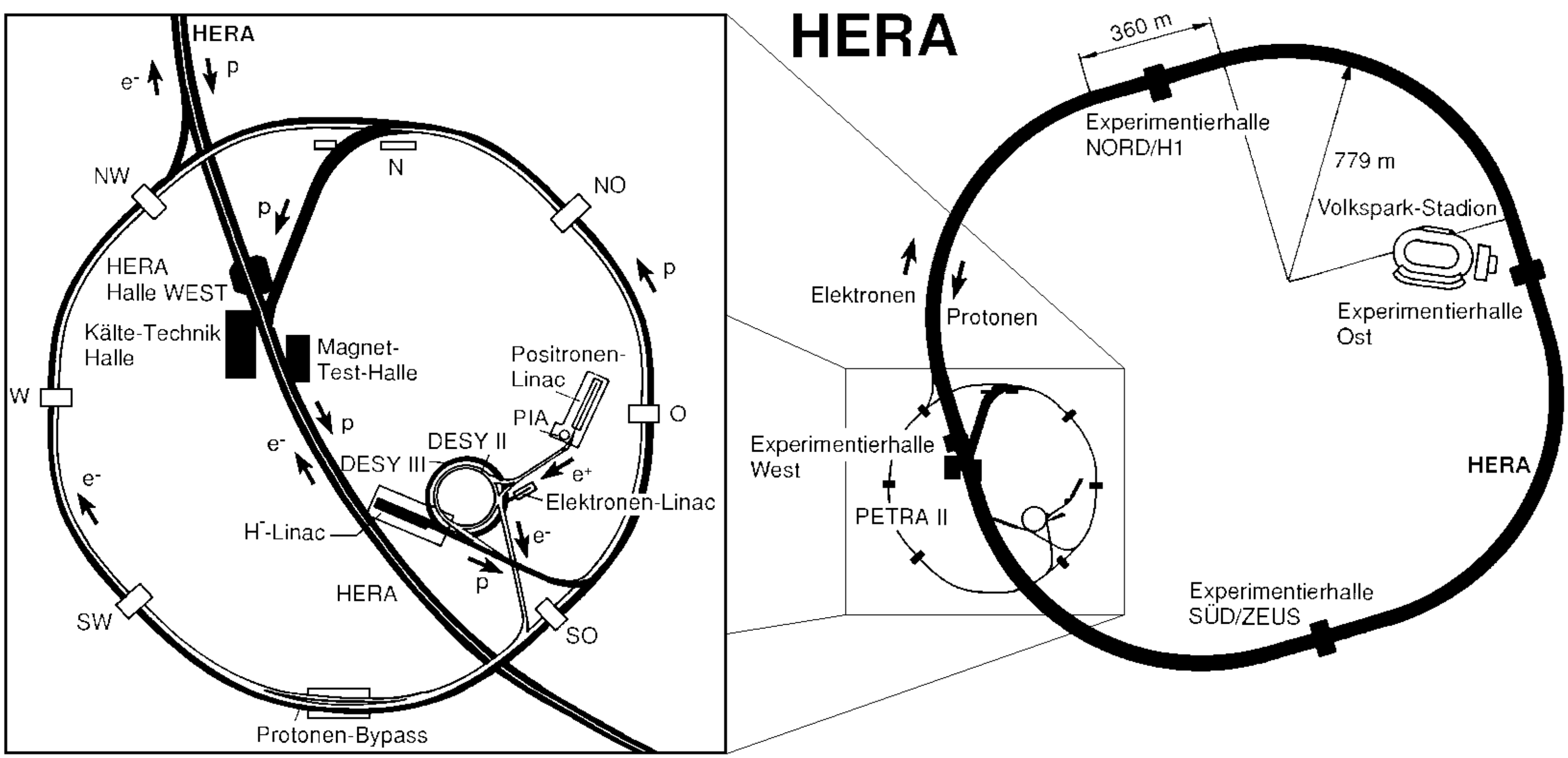
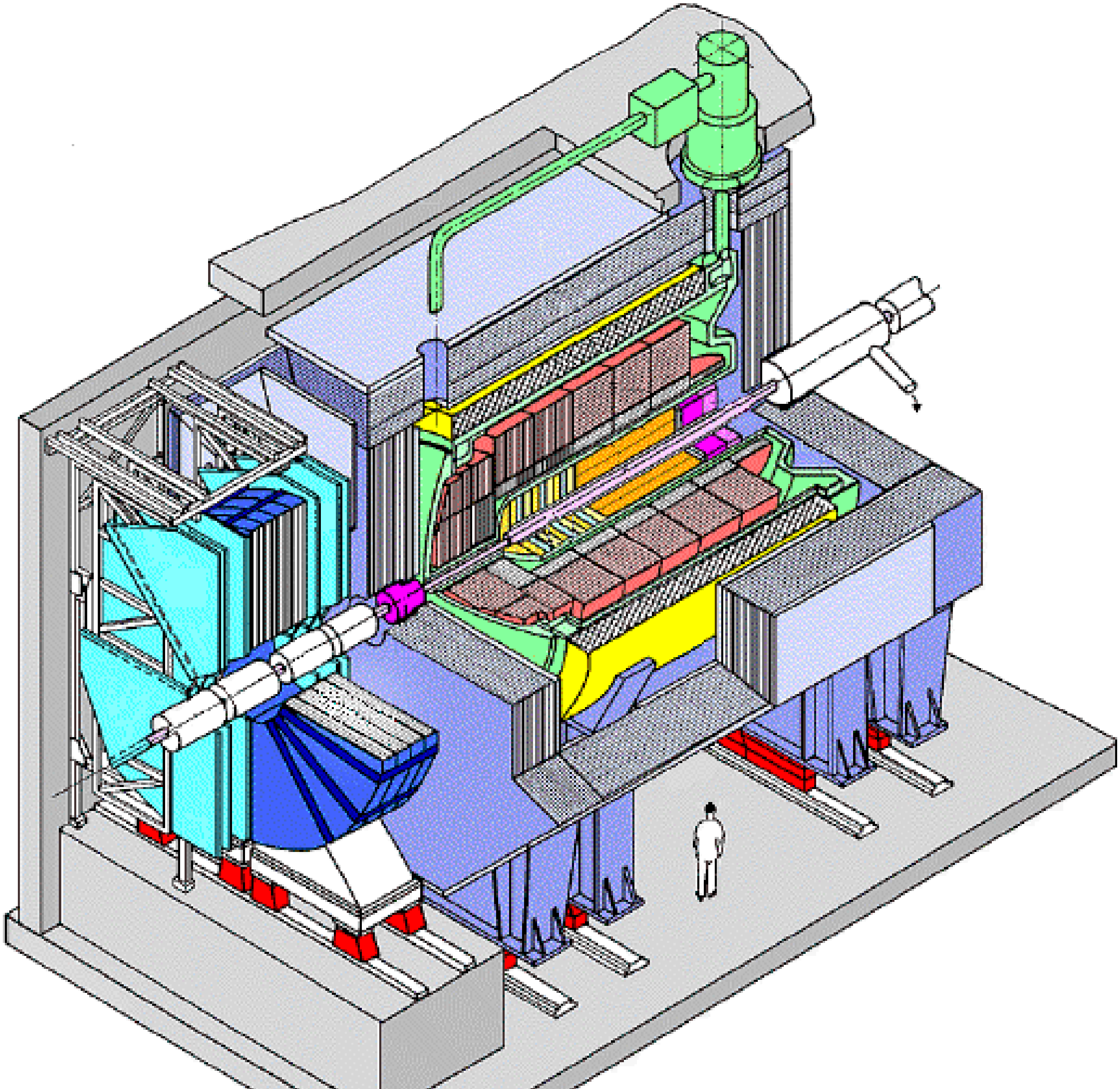
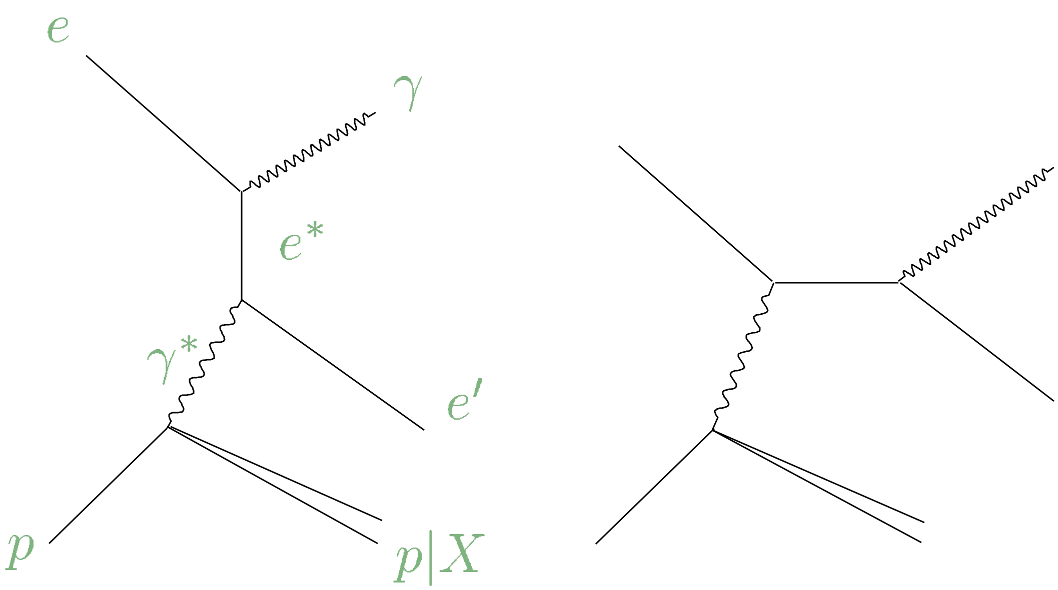
- overview HERA/H1
- the QED Compton process
- calibration
- the photon content of the proton
- analysis aspects


HERA
HERA
e-
p
NW
N
NO
p
p
HERA
Halle WEST
Kälte-Technik
Halle
Magnet-
Test-Halle
W
Positronen-
Linac
PIA
O
p
e-
DESY II
DESY III
e+
Elektronen-Linac
e-
H--Linac
e-
p
HERA
SW
SO
Protonen-Bypass
360 m
Experimentierhalle
NORD/H1
779 m
Volkspark-Stadion
Elektronen
Protonen
Experimentierhalle
Ost
Experimentierhalle
West
PETRA II
HERA
Experimentierhalle
SÜD/ZEUS



general graphs for radiative e-p scattering



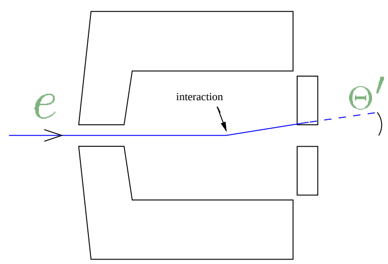
$$e^*: \quad q^2_{e^*} = (p_\gamma - p_e)^2 \ , \ (p_\gamma + p_e)^2$$
$$\gamma^*: \quad q^2_{\gamma^*} = (p_X - p_p)^2$$

matrix element: $\mathrm{d}M \sim \frac{\mathrm{d}q_{e^*}}{q^2_{e^*} - m_e^2} \frac{\mathrm{d}q_{\gamma^*}}{q^2_{\gamma^*}}$

$\lvert q^2_{e^*} \rvert$	$\lvert q^2_{\gamma^*} \rvert$	
≈ 0	≈ 0	Bremsstrahlung
≈ 0	> 0	radiative DIS
> 0	≈ 0	QED Compton

QED-Compton Scattering

H1/HERA:

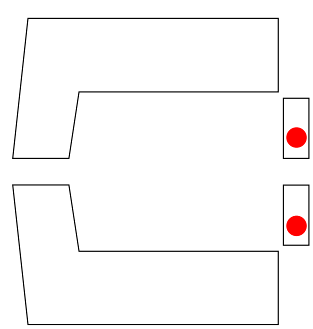


$|q^2_{e*}| > (E_e\Theta')^2 \approx 3.5$ GeV^2

γ^* is quasi-real in $\gamma^* + e \to \gamma + e'$

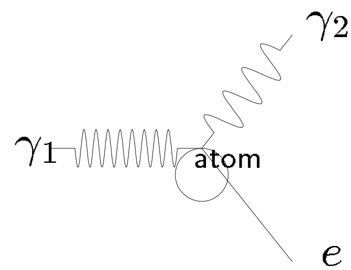
$\Rightarrow$ small momentum transfer to the proton
$\Rightarrow$ proton (or remnant) near the beampipe

Event signature:



$\Rightarrow$ detector (almost) empty except for two clusters.

classical Compton process:

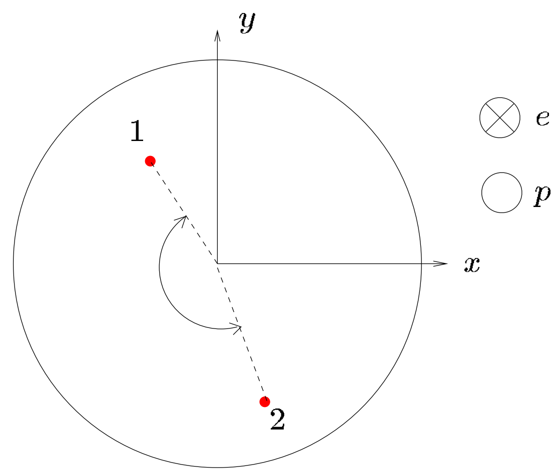


Calibration I - energy

use an overdetermined set of observables:
electron- $\Theta_{e'}$, $\Phi_{e'}$, $E_{e'}$
photon- Θ_γ, Φ_γ, E_γ

define acoplanarity:
$\Delta\Phi = |\Phi_1 - \Phi_2|$
$\vec{p}_{1,T} \approx -\vec{p}_{2,T}$

$\Rightarrow$ $\Phi_{1,2}$ are correlated



relation between polar-angle & energy of both e.m. clusters:

$$E_{e'} = \frac{2E_e \sin\Theta_\gamma}{\sin\Theta_{e'} + \sin\Theta_\gamma - \sin(\Theta_{e'} + \Theta_\gamma)}$$

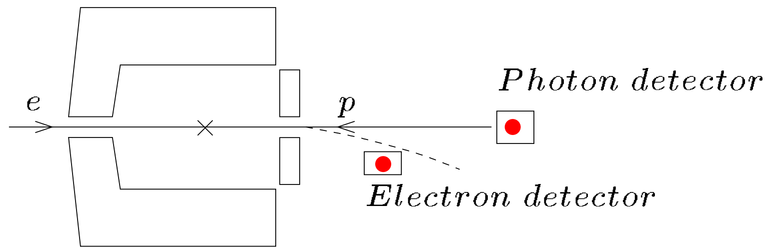
$$E_\gamma = \frac{2E_e \sin\Theta_{e'}}{\sin\Theta_{e'} + \sin\Theta_\gamma - \sin(\Theta_{e'} + \Theta_\gamma)}$$

$\Rightarrow$ allows calorimeter calibration by comparison of
Double-Angle-energy vs. reconstructed energy

Calibration II - luminosity measurement

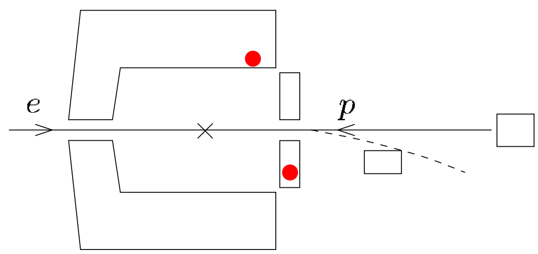
measure over some runperiod integrated Luminosity $L = \frac{N_A}{\epsilon_A \sigma_A}$
A: well-known reaction, such as in H1...

... by Bremsstrahlung:

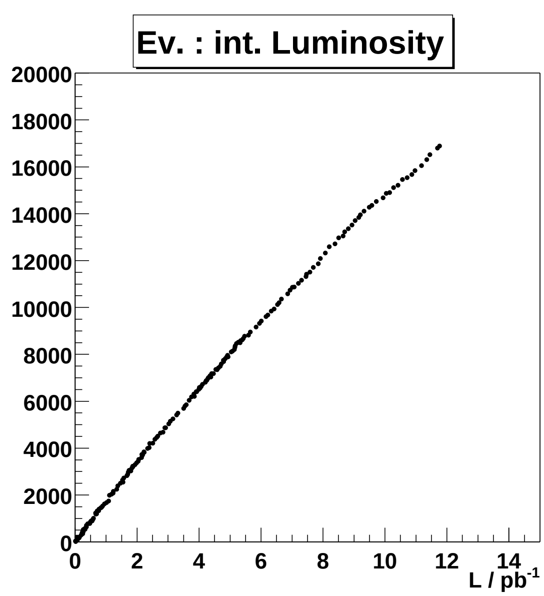


or in main-apparatus...

QED-Compton:

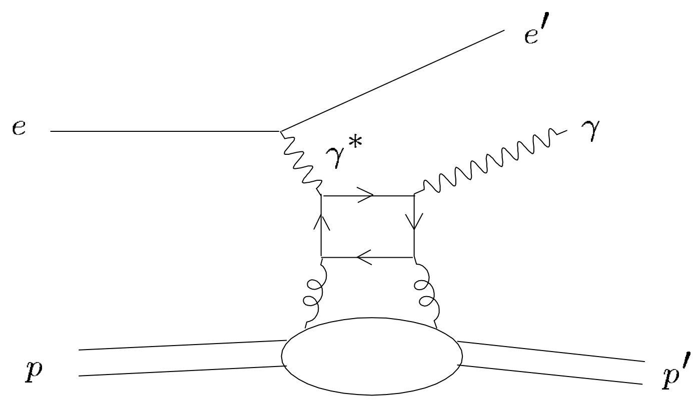


example for 97 data set:



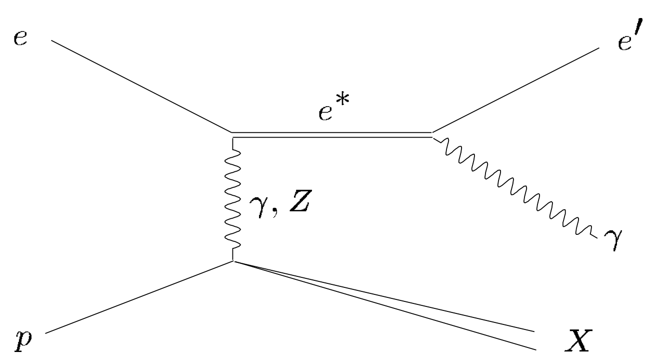
QEDC as background to other processes

I DVCS - Deeply Virtual Compton Scattering

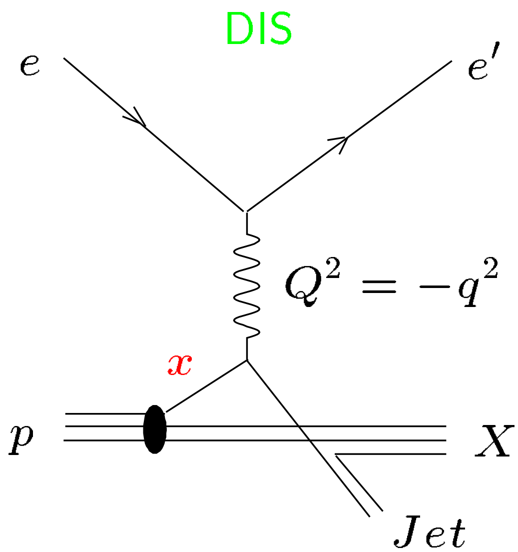


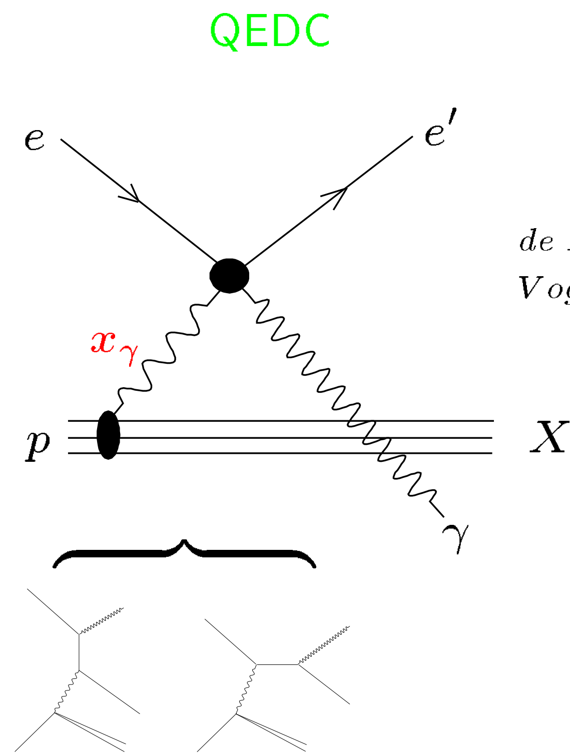
- ▷ process calculable in pQCD (Frankfurt, Freund, Strikman)
- ▷ determination of "skewed parton distributions" (SPDs)

II excited electrons



How to measure the proton's photon content





de Rújula, Vogelsang 98

virtual photon	$\leftrightarrow$	virtual electron
quark	$\leftrightarrow$	quasi-real photon
jet	$\leftrightarrow$	real photon

DIS-analogue kinematic variables (QEDC $\rightarrow$"DICS"):

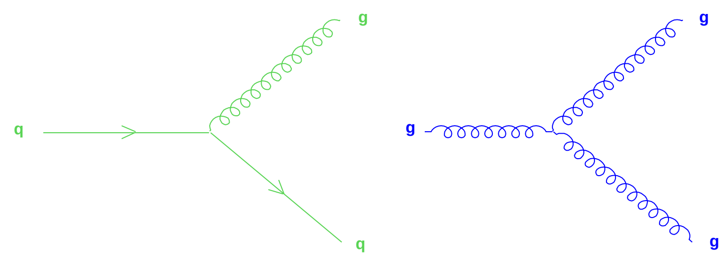
$$q = q_e - q_{e'}\ ,\ \ Q^2 = -q^2\ ,\ \ x = \frac{Q^2}{2Pq} = x_\gamma\ ,\ \ y = \frac{Q^2}{x_\gamma s}$$

$\Rightarrow$ photon density $\gamma(x, Q^2)$

Comparison $\gamma(x, Q^2) \leftrightarrow g(x, Q^2)$

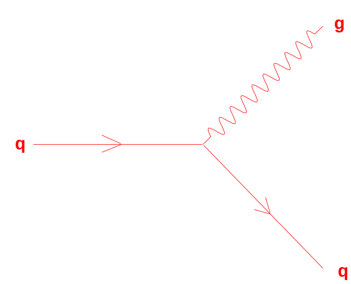
QCD gluon evolution equation:

$$\frac{\mathrm{d}g(x,Q^2)}{\mathrm{d}\ln Q^2} = \frac{\alpha_s(Q^2)}{2\pi}\int_x^1 \frac{\mathrm{d}y}{y}\left[\sum_q \frac{4}{3}\, P_{gq}\left(\frac{x}{y}\right)\left[q(y,Q^2)+\bar{q}(y,Q^2)\right]+P_{gg}\left(\frac{x}{y}\right) g(y,Q^2)\right]$$

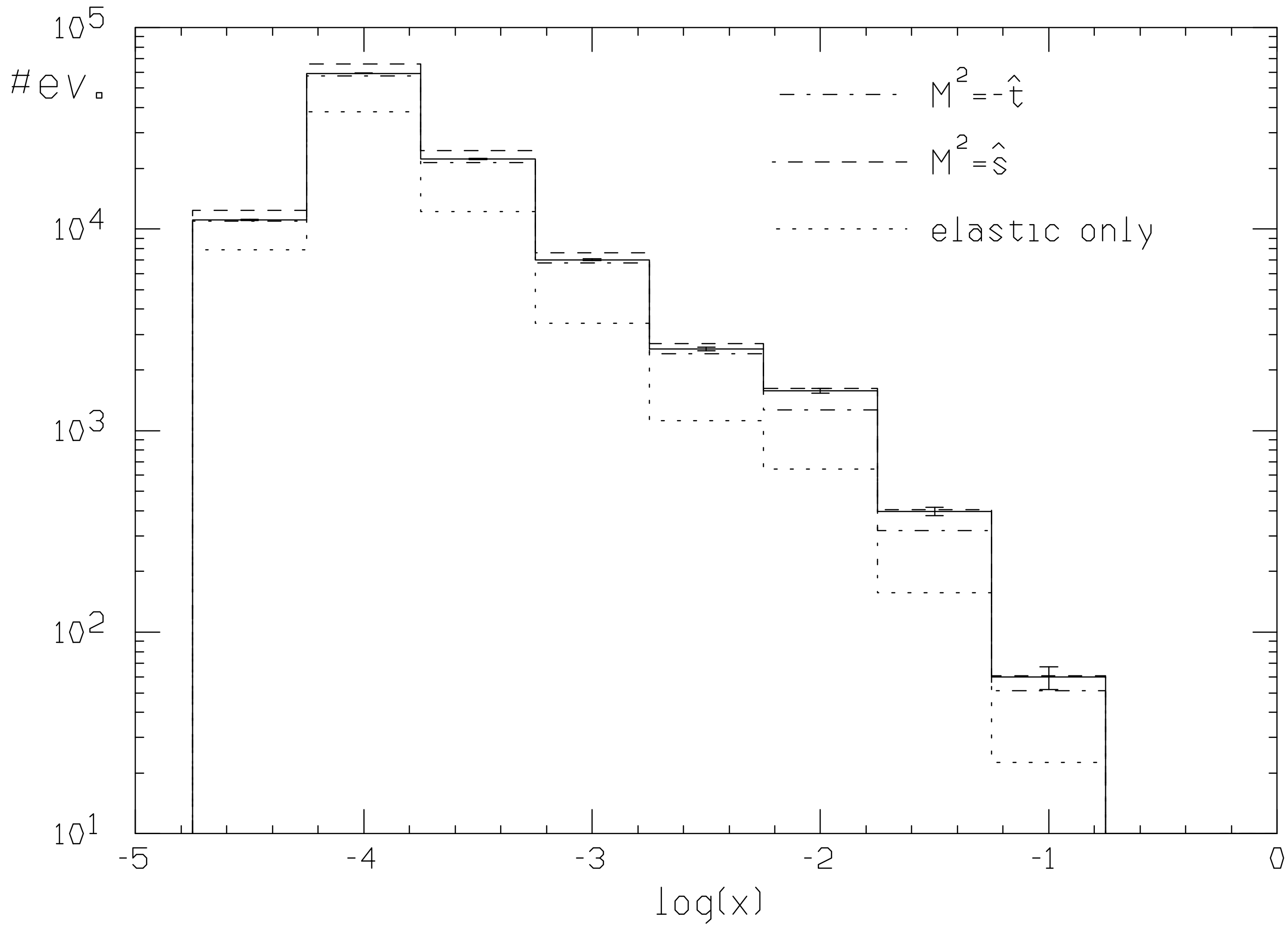


"QED evolution equation":

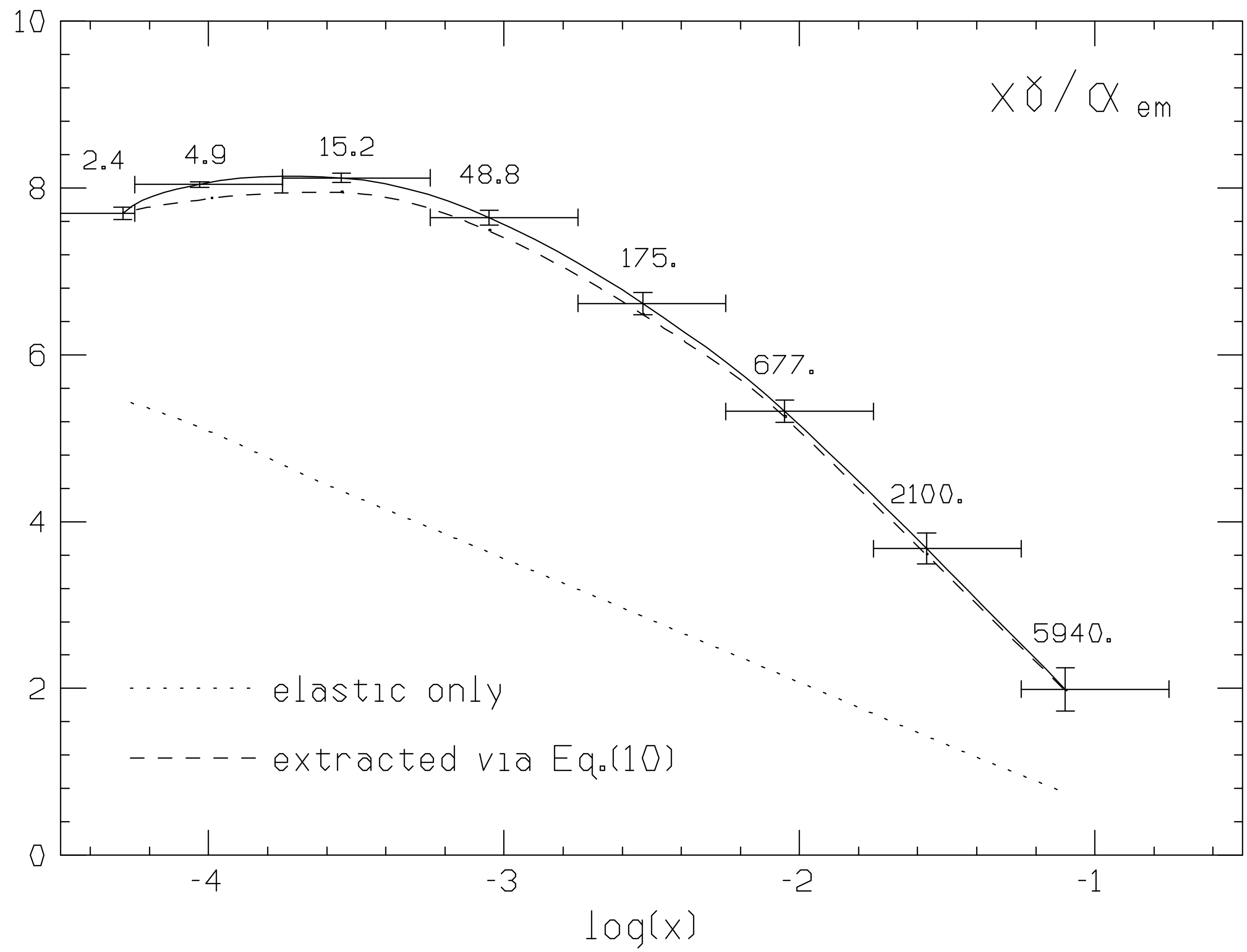
$$\frac{\mathrm{d}\gamma(x,Q^2)}{\mathrm{d}\ln Q^2} = \frac{\alpha_{em}(Q^2)}{2\pi}\int_x^1 \frac{\mathrm{d}y}{y}\sum_q e_q^2\, P_{Aq}\left(\frac{x}{y}\right)\left[q(y,Q^2)+\bar{q}(y,Q^2)\right]$$



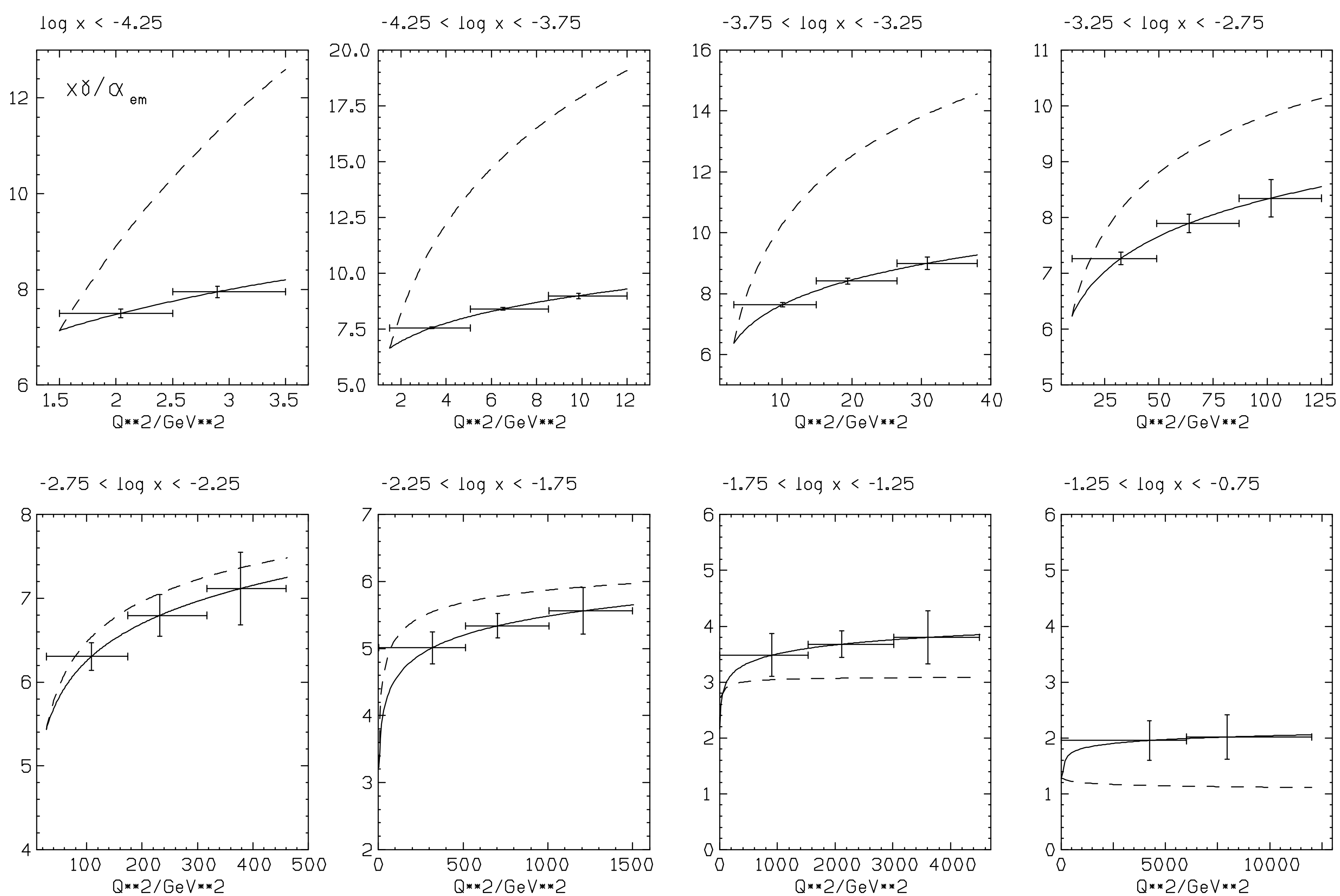
$\rightarrow$ expect different Q^2 dependence



#ev.
10^5
10^4
10^3
10^2
10^1
-5
-4
-3
-2
-1
0
log(x)
$M^2=-\hat{t}$
$M^2=\hat{s}$
elastic only



10
8
6
4
2
0
-4
-3
-2
-1
log(x)
xγ/α em
2.4
4.9
15.2
48.8
175.
677.
2100.
5940.
elastic only
extracted via Eq.(10)


log x < -4.25
$x\gamma/\alpha_{em}$
-4.25 < log x < -3.75
-3.75 < log x < -3.25
-3.25 < log x < -2.75
-2.75 < log x < -2.25
-2.25 < log x < -1.75
-1.75 < log x < -1.25
-1.25 < log x < -0.75
Q**2/GeV**2

Analysis aspects

Event selection from the H1-1997 data set (e^+p, 23.7 pb^{-1})

technical conditions:

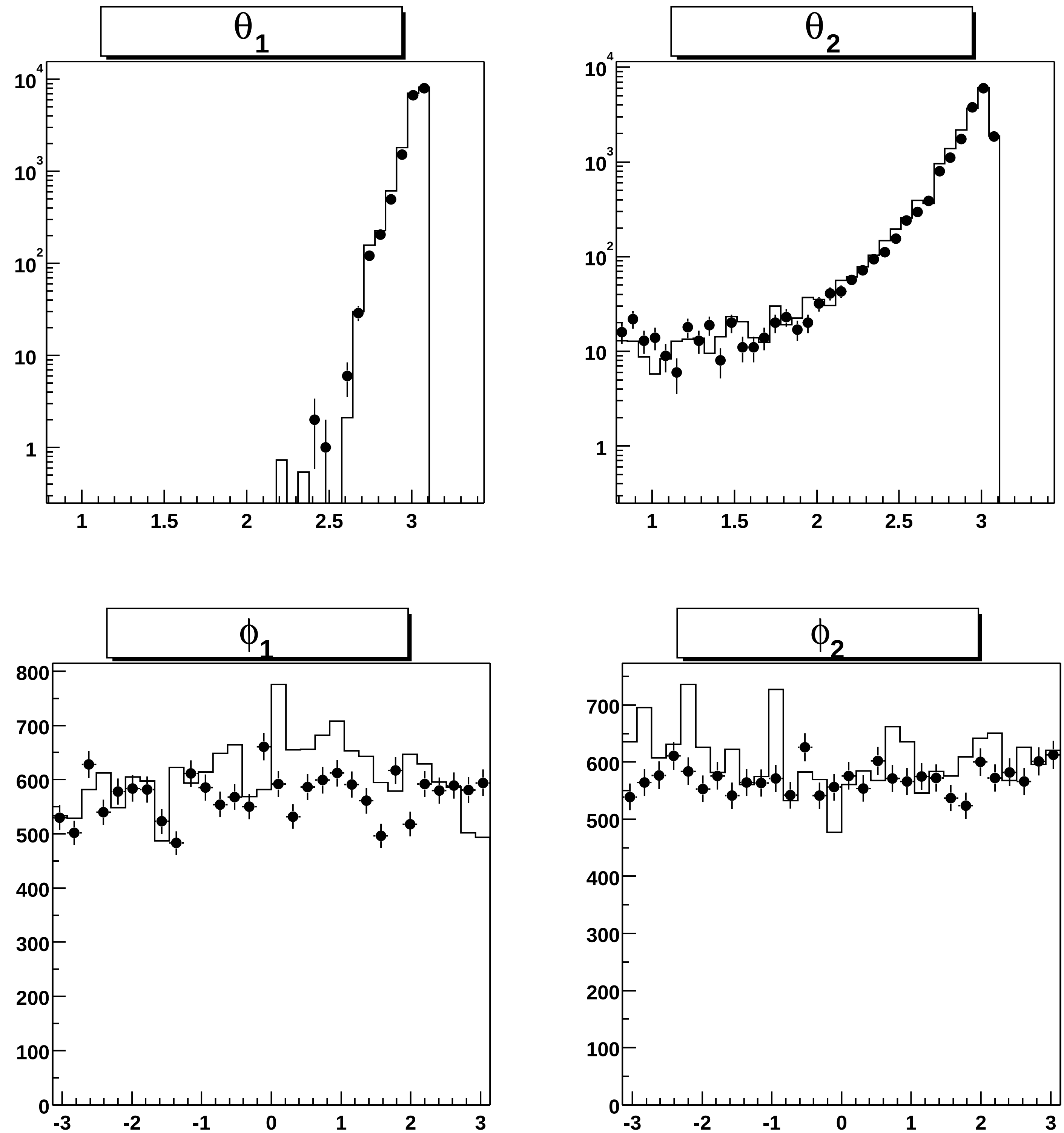
- ▷ only good/medium run quality
- ▷ use ELAN 97 list of bad-quality runs
- ▷ High Voltage 'ok': Trackers, Calo.s, backw./ centr. Silicon
- ▷ corresponding readout branches
- ▷ trigger phase (exclude lumi startup data)

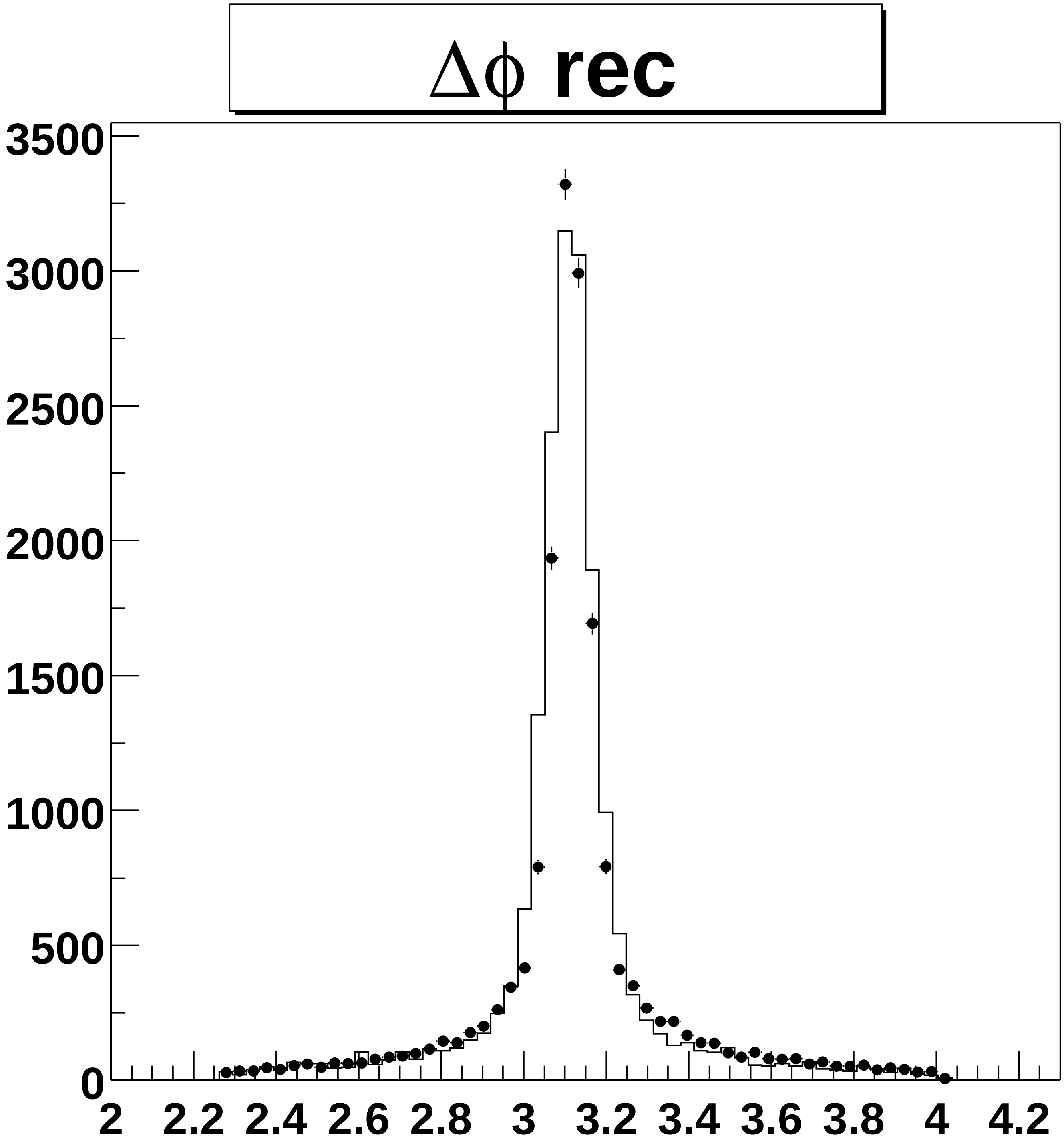
physics conditions:

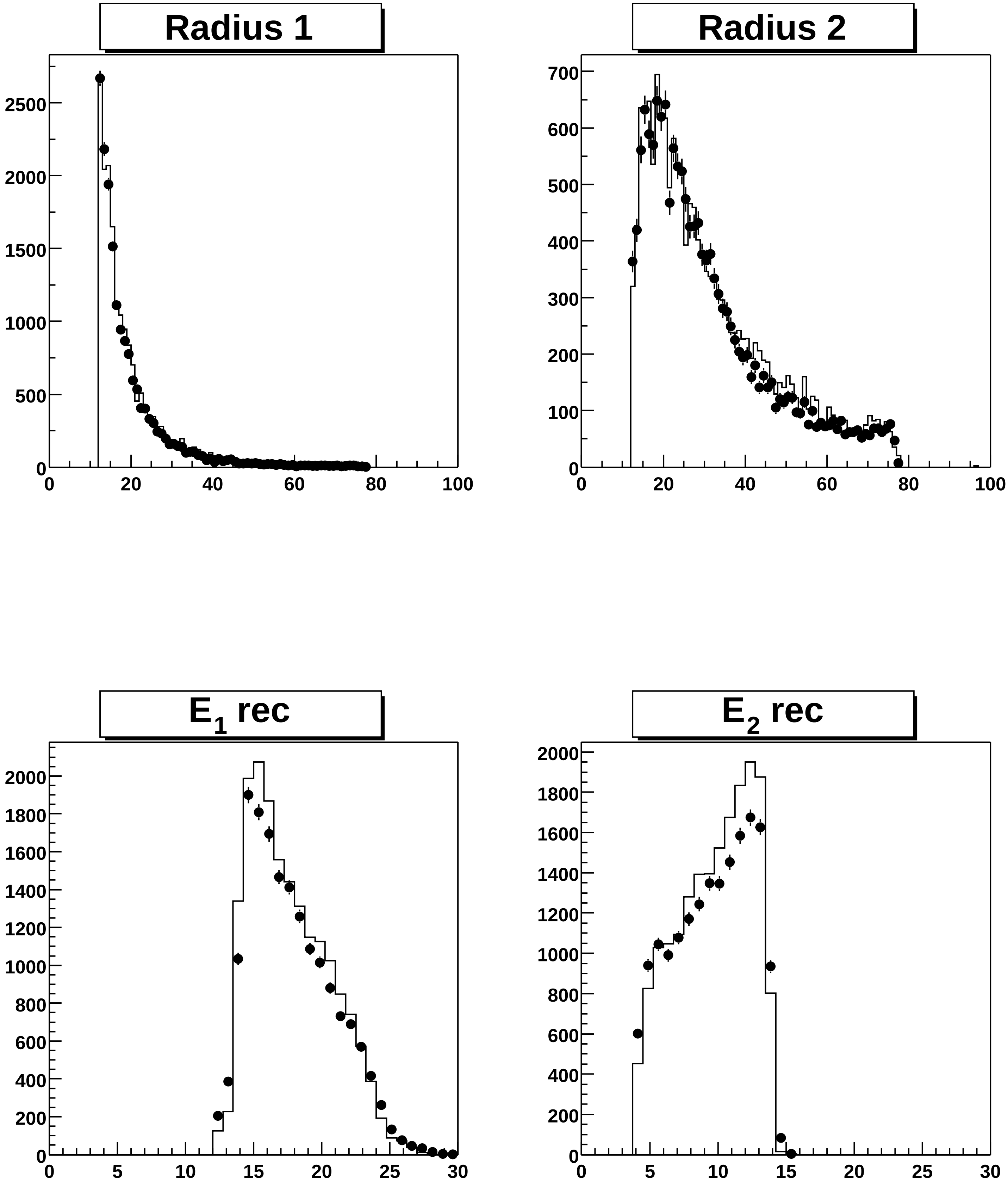
- ▷ $E_1 + E_2 = 20...35$ GeV, $E_1 > 12$ and $E_2 > 4$ GeV
- ▷ backward: $E_{e.m.} - (E_1 + E_2) < 2$ GeV
- ▷ backward: $E_{had} < 0.5$ GeV
- ▷ forward ($\Theta < 45$ Deg): $E_{had} < 5$ GeV
- ▷ $\Theta_{cluster1+2} > 45$ Deg (exclude very forward Calorimeter)
- ▷ minimum cluster-cluster distance > 6 cm
- ▷ number of central tracks < 2
- ▷ select main level-1 triggers
- ▷ $|z_{vertex}| < 35$ cm
- ▷ distance to beam-line, cluster 1 or 2 > 12 cm
- ▷ Acoplanarity < 50 Deg

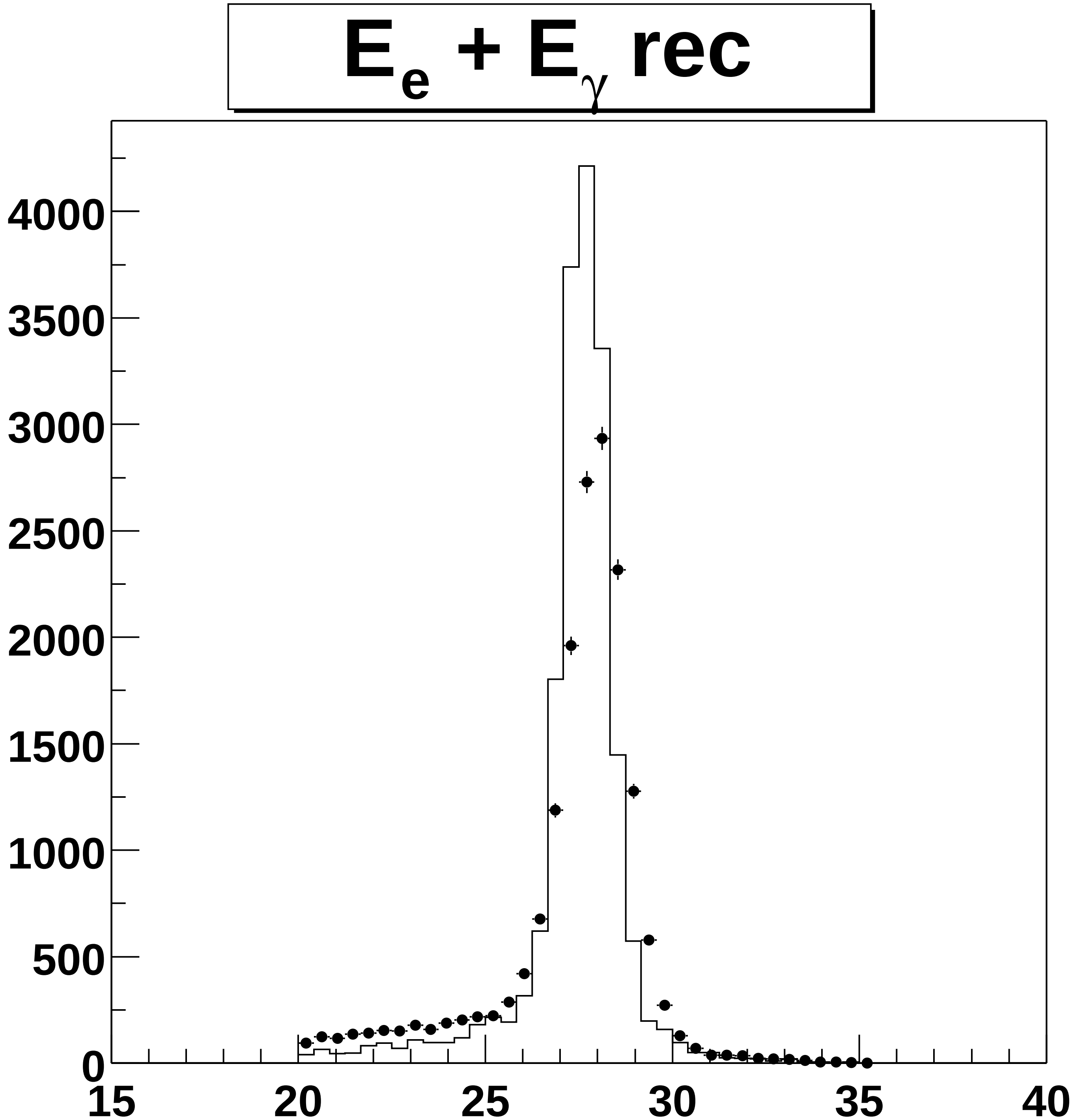
correct for:

- ▷ B-field correction on Φ_e (if e/γ separation available)
- ▷ reweight MC by Lumi$_{Data}$ / Lumi$_{MC}$
- ▷ reweight MC (inelastic part) by $F_{2,ALLM}/F_{2,Compton}$

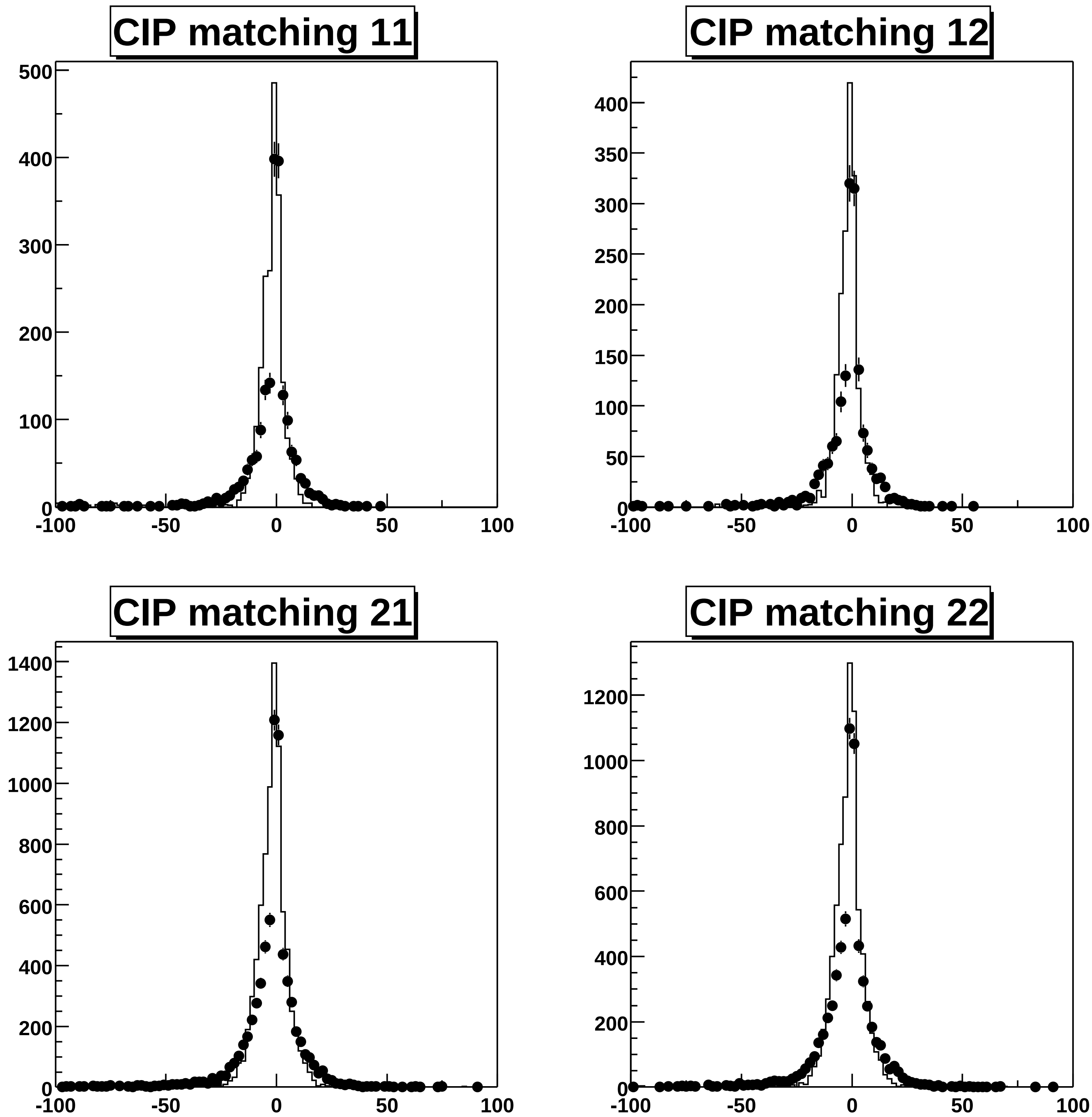

θ1
θ2
φ1
φ2
10^4
10^3
10^2
10
1
1 1.5 2 2.5 3
800 700 600 500 400 300 200 100 0
-3 -2 -1 0 1 2 3

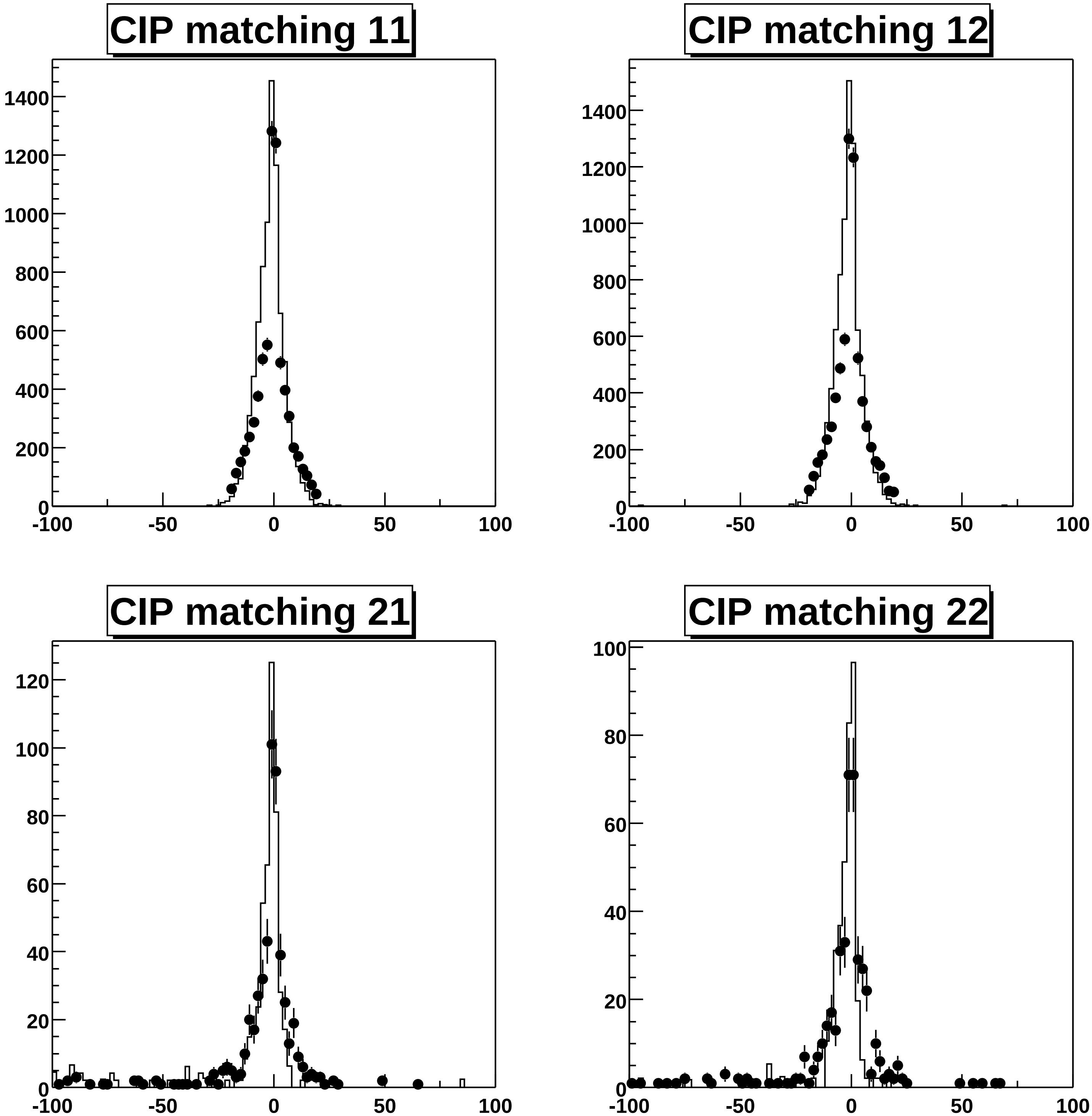

Δφ rec
3500
3000
2500
2000
1500
1000
500
0
2
2.2
2.4
2.6
2.8
3
3.2
3.4
3.6
3.8
4
4.2

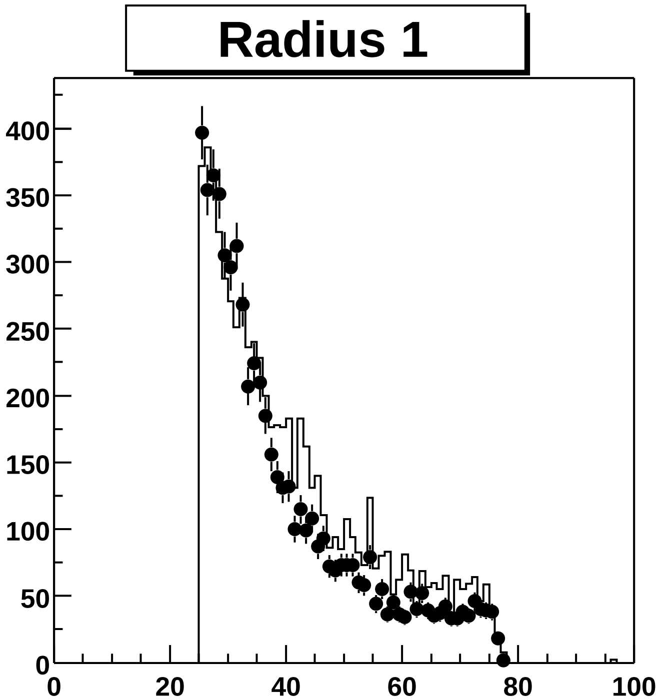

Radius 1
0
500
1000
1500
2000
2500
0 20 40 60 80 100
Radius 2
0
100
200
300
400
500
600
700
0 20 40 60 80 100
E1 rec
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0 5 10 15 20 25 30
E2 rec
0
200
400
600
800
1000
1200
1400
1600
1800
2000
0 5 10 15 20 25 30

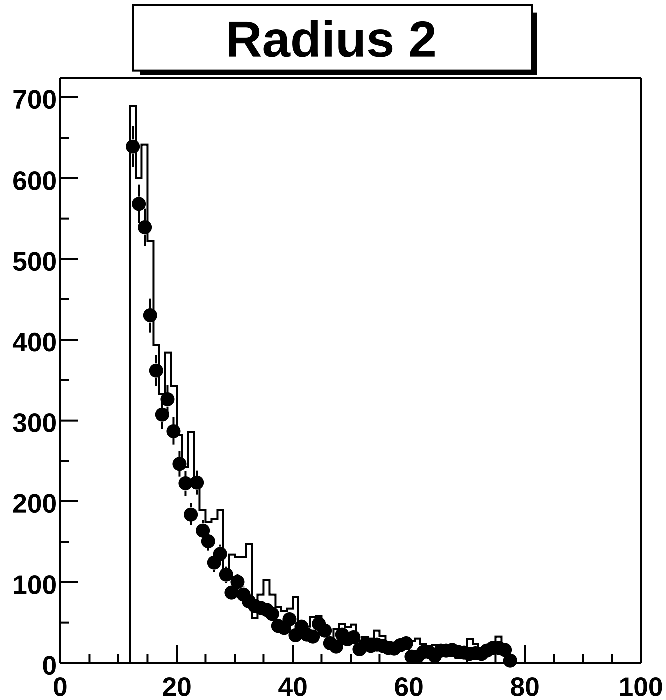


$E_e + E_\gamma$ rec
4000
3500
3000
2500
2000
1500
1000
500
0
15
20
25
30
35
40


CIP matching 11
CIP matching 12
CIP matching 21
CIP matching 22
0
100
200
300
400
500
50
150
250
350
600
800
1000
1200
1400
-100
-50
0
50
100


CIP matching 11
CIP matching 12
CIP matching 21
CIP matching 22


Radius 1
400
350
300
250
200
150
100
50
0
0
20
40
60
80
100


Radius 2
700
600
500
400
300
200
100
0
0
20
40
60
80
100

the question about $e\gamma$ separation...

to observe γ and gluons differently developing in Q^2 (hint by the authors)

Either:

use only events that contain identifiable $e\gamma$ clusters.

Or ("without proof"):

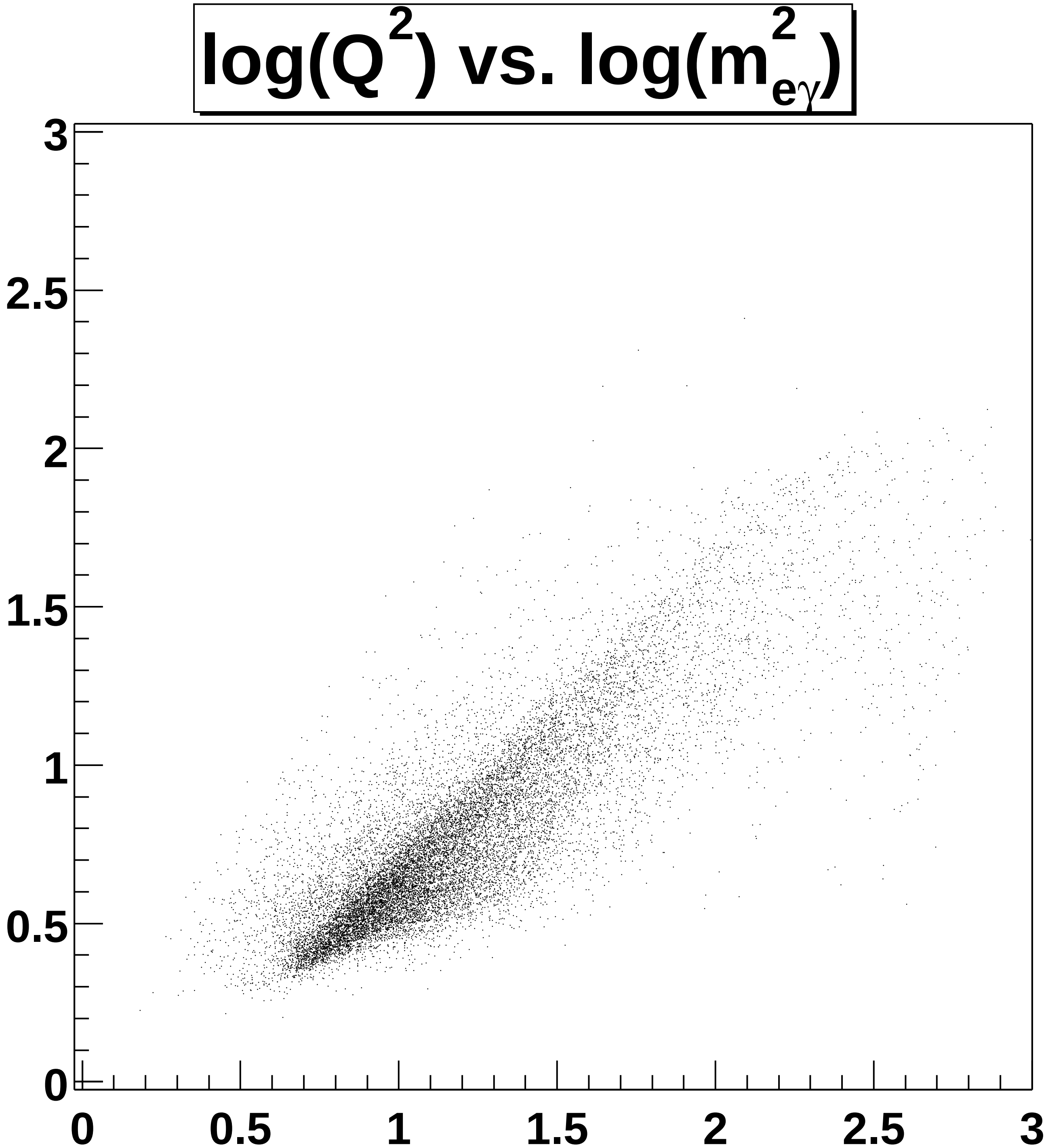
use $\hat{s} = (p + l)^2 \;\; (\approx m_{e\gamma^2})$

$\hat{s} = AQ^2$ with $A \approx$ a few $\approx const.$

$\log \hat{s} \approx \log(AQ^2) = \log A + \log Q^2$

$\Rightarrow$ only a small shift between the two evolutions

$\Rightarrow$ gluons should (still) evolve much faster than γ



log(Q^2) vs. log(m_eγ^2)
0
0.5
1
1.5
2
2.5
3
0
0.5
1
1.5
2
2.5
3

summary and prospect

- QED Compton events are useful for calibration and proton structure
- photon content of the proton: theoretical interesting test of QED/QCD, gluon $\leftrightarrow$ photon behaviour in the proton

to do:

- further corrections, efficiencies (all trigger levels), comisc filter, etc.
- distinguish e/γ, necessary for $\gamma(x, Q^2)$, but difficult
  - first positive indications (CIP-chamber)
  - exploit Backward silicon and drift chamber (also for vertex!)

    or
  - look for e in central calo, use central tracking
- statistics: data under investigation $\approx \frac{1}{3}$ (theory assumption)
  $\Rightarrow$ use data > 1997