Direct Photon Studies in the ATLAS Detector

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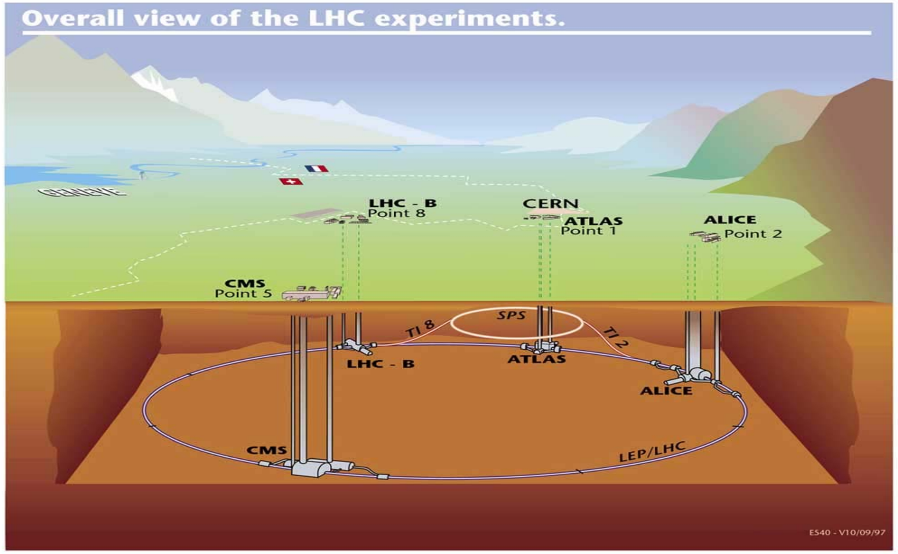
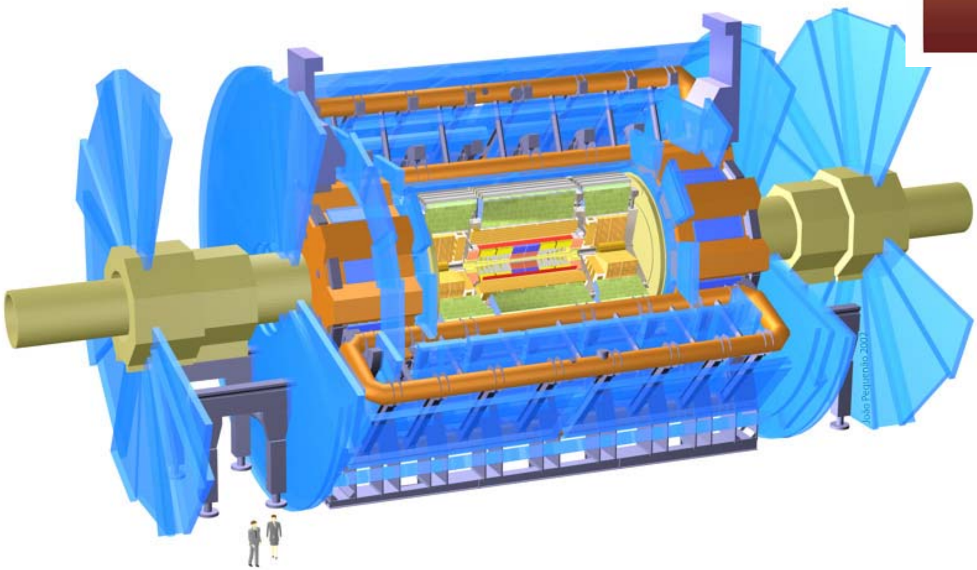
Outline

- 1) A very quick overview of the LHC and the ATLAS detector
- 2) Motivation for looking at Direct Photon
- 3) Event Kinematics and pdfs
- 4) Rejecting Background
- 5) Conclusions

(1) A very quick overview of ATLAS and the LHC



- Proton-proton collider, centre of mass = 14TeV
- Commissioning end 2007
- Studies currently devoted to feasibility issues

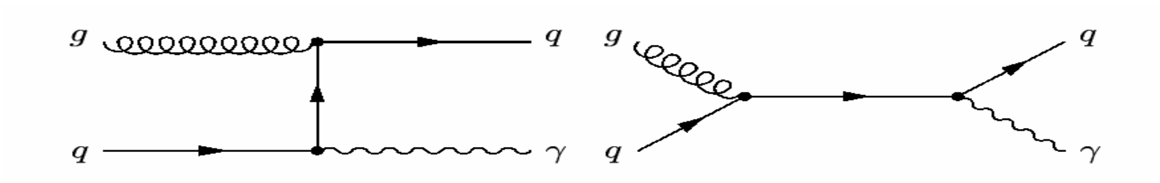


- ATLAS is general purpose detector
- 4 main subsystems
  - Inner Detector
  - Electromagnetic Calorimeter
  - Hadronic Calorimeter
  - Muon Chambers

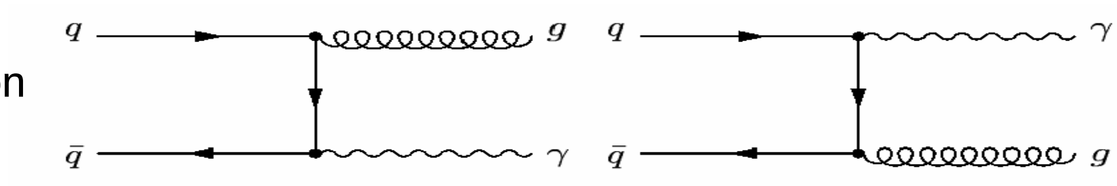
(2) Motivation for looking at γ-jet events

- Use γ-jet events to probe the gluon, γ gives clean access to the partonic event
- Aim to use this probe to discriminate between pdf sets
- Measurement of direct photon cross-section

Compton

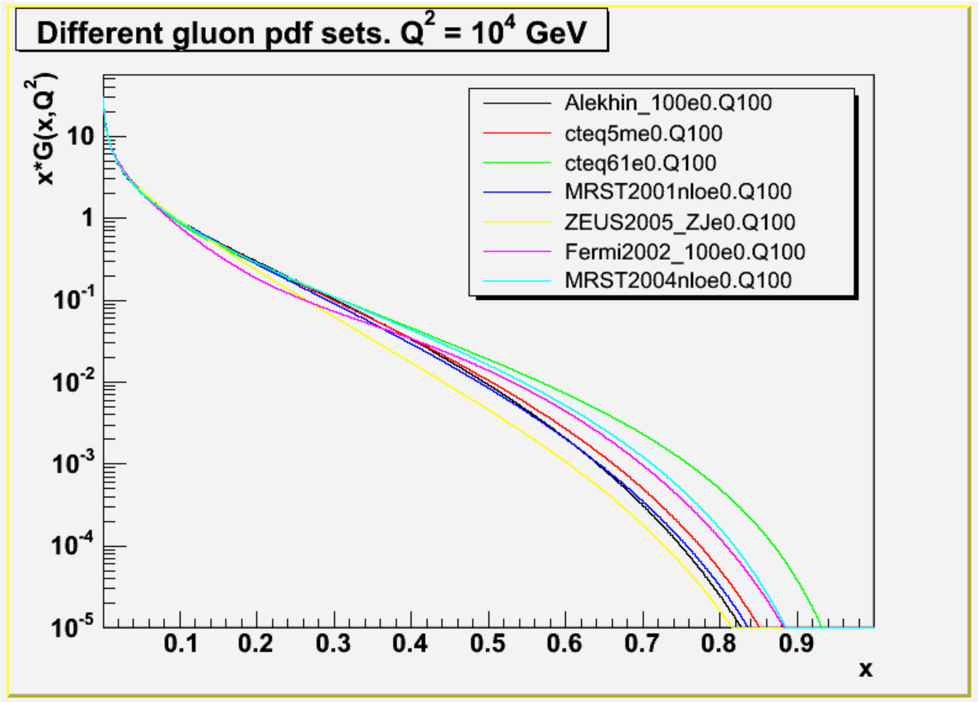


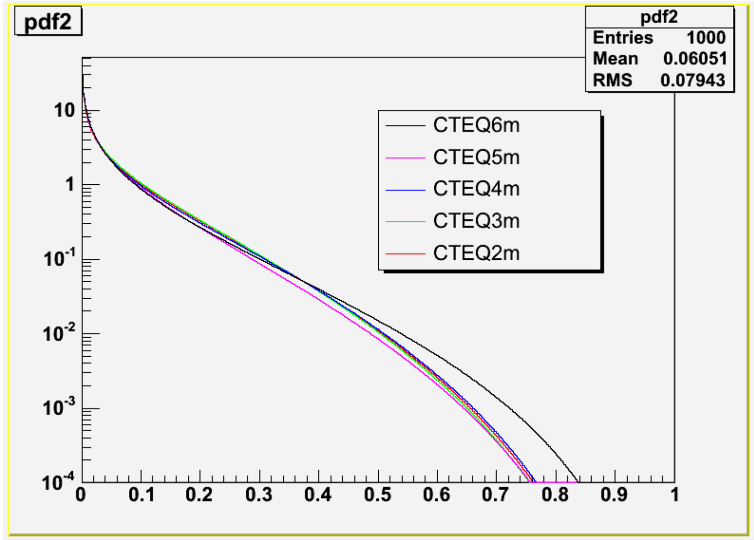
Annihilation



- Compton process ~90%, Annihilation ~10%

Gluon pdfs for various pdf fits





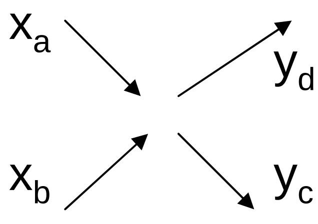
- Evolution of CTEQ sets at $Q = 10^4$

- Gluon pdf not well constrained at high x
- Differences noticeable x > 0.2 (Zeus2005) and for the others at x>0.3

(3) Event Kinematics – where are we most sensitive to pdf difference?

- Solving the Kinematics for the hard sub-process ab->cd and ignoring parton masses…

$$x_a = \frac{P_T}{\sqrt{s}}(e^{y_c} - e^{y_d})$$



$$x_b = \frac{P_T}{\sqrt{s}}(e^{-y_c} - e^{-y_d})$$

P_T = transverse momentum
x = fraction of proton momentum carried by parton
y = rapidity
$\sqrt{s}$ = centre of mass energy
Q^2 = 4 momentum transfer = $x_a x_b$ / s

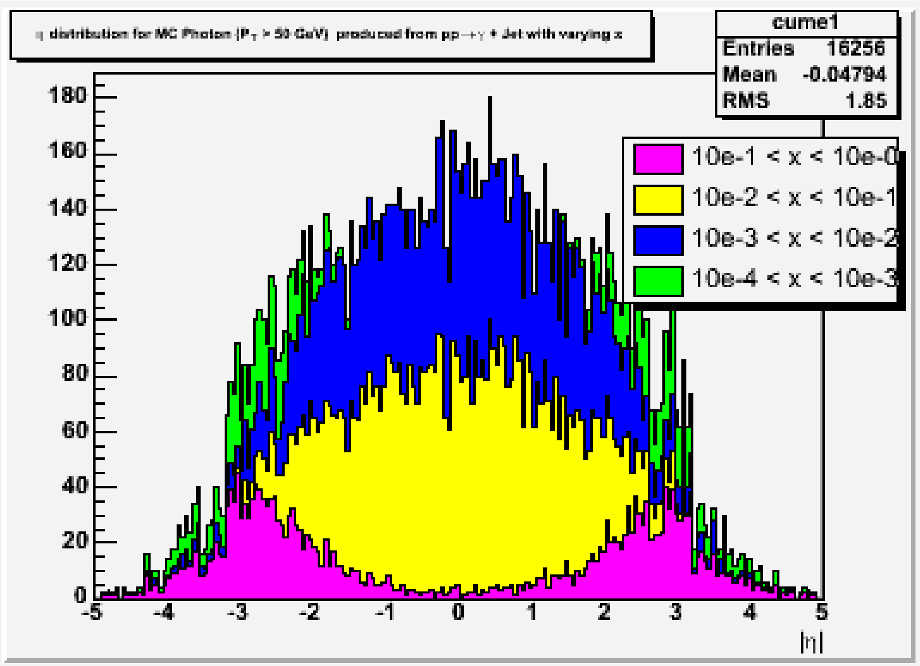
- Using pdfs for x_a and x_b can build up an expected event profile
- As Q increases will increase x_a / x_b used in the scatter, but where will these events appear?
- Use Pythia to profile these events appear

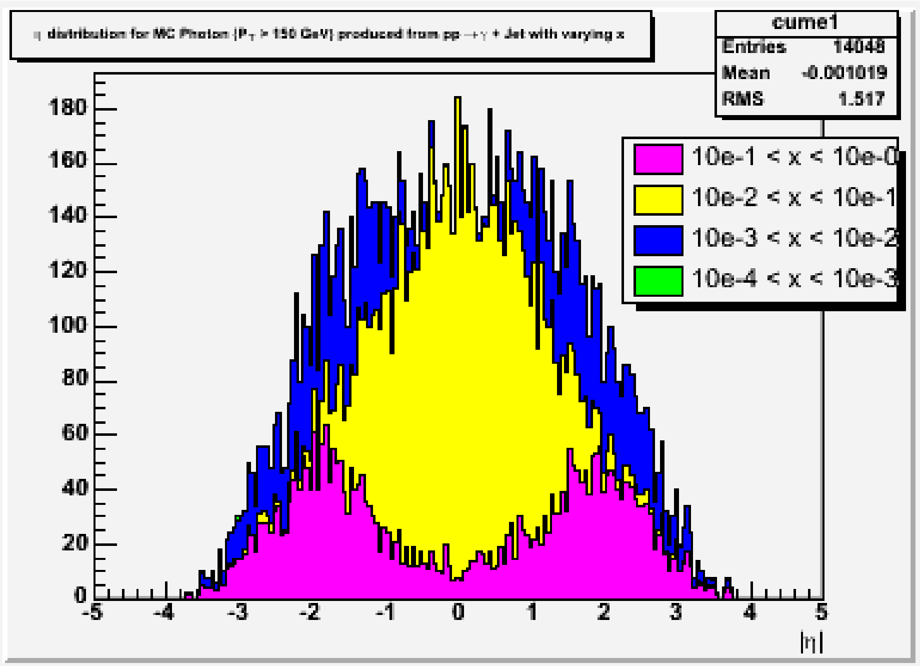
ATLAS coordinate system

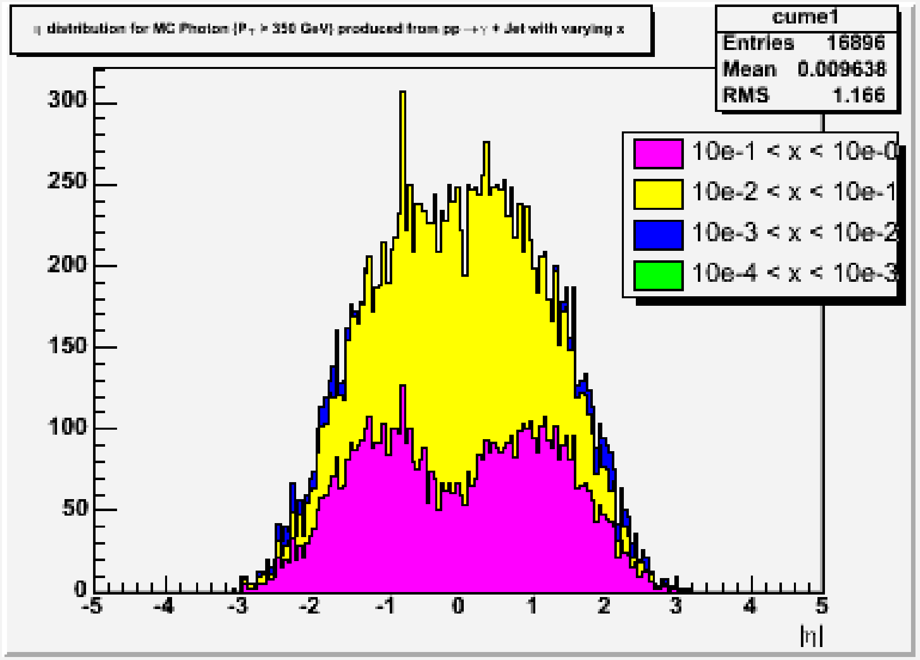
θ = angle from the beam axis

η= -ln (tan θ/2)

φ = angle around the beam axis







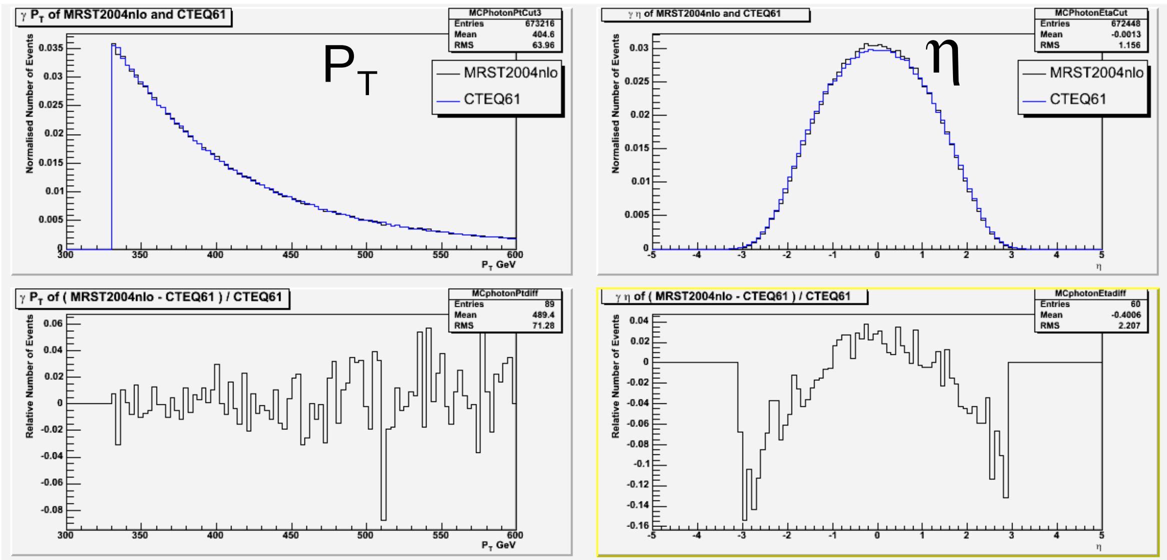
- η distributions for events with γ and jet

  P_T > 50, 150, 350 GeV.

- Each plot shows x_a and x_b associated with an event twice. Once for η_{jet} and once for η_γ.
- Events typically combine one high x and one low x parton.
- At increasing energy events become narrower in η
- Sensitivity to high x events comes at high energies and high η.

Are there observable differences in pdf sets?

- Now we know where to look can we see can differences in pdfs?
- Plots are for photon distributions only
  - ~700k events in each ~ 100fb-1 at 330 GeV
  - Plots look only at the shape, no comparison made to absolute numbers



γ - distributions for MRST2004 and Cteq61. PT > 330 GeV

Summary of Pdf Differences (η)

Pdf Sets	% Diff in η (γ) central / edge	% Diff in η(jet) central / edge	% Diff in η (γ) central / edge	% Diff in η (jet) central / edge
	Pt > 110 GeV	Pt > 110 GeV	Pt > 330 GeV	Pt > 330 GeV
Zeus2005_ZJ v Cteq61 (central)	4% / 4%	4% / 5%	5% - 7 %	5% / 10%
MRST2001nlo v Cteq61 (central)	1% / 1%	2% / 2%	3% / 10%	3% / 7%
Cteq61e29 v Cteq61e30	2% / 4%	2% / 3%	2% / 8%	1% / 1%

- η distributions are most sensitive different pdfs
- γ experimentally easier to observe, have only EM calibration to worry about. Jets are definition dependent, calibration more difficult as a result.
- Differences are for the range $|\eta| < 3.2$ for both γ and jet
- Increasing P_T / Q gives access to the tail of the η distribution and sensitivity to high x

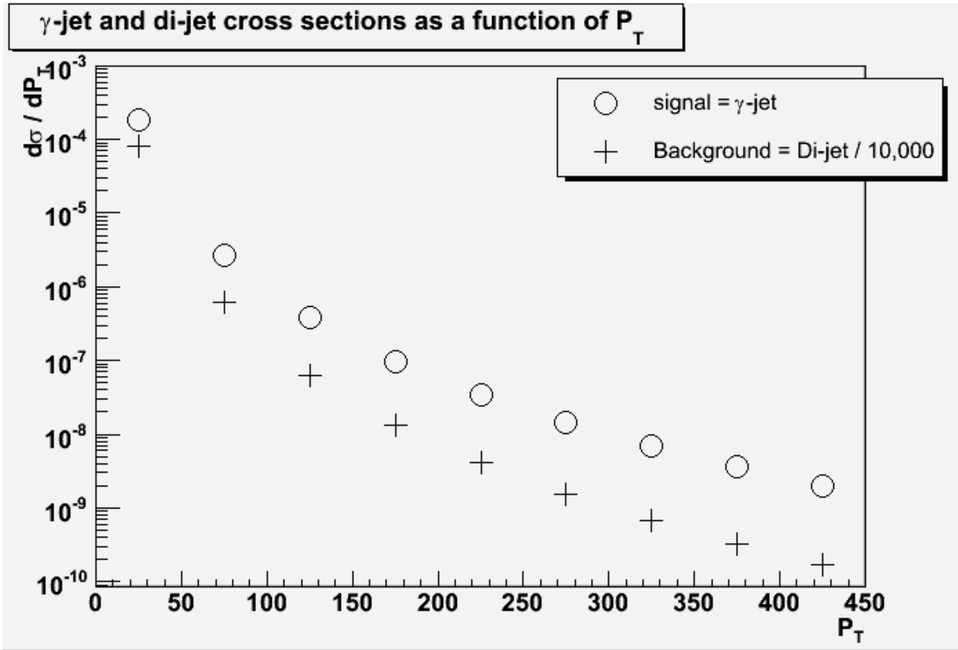
Event numbers for different Q^2 and x values – 100pb^{-1} : $|\eta_{jet}| < 4.9$, $|\eta_{\gamma}| < 3.2$

Q^2 (GeV)^2	~P_T (GeV)	x = 10^{-4} – 10^{-3} (000's)	x = 10^{-3} – 10^{-2} (000's)	x = 10^{-2} – 10^{-1} (000's)	x = 10^{-1} – 10^{-0} (000's)	All
0-1,600	0-40	52± 1.0	122 ± 1.6	112 ± 1.5	19 ± 0.6	305 ± 2.5
1,600-2,500	40-50	131 ± 1.6	436 ± 2.9	402 ± 2.8	57 ± 1.1	1,027 ± 4.5
2,500-5,000	50-71	80 ± 1.3	377 ± 2.7	372 ± 2.7	71 ± 1.2	900 ± 4.2
5,000-10,000	71-100	12 ± 0.5	121 ± 1.5	133 ± 1.6	37 ± 0.9	304 ± 2.4
10,000-20,000	100-141	0.7 ± 0.1	34.6 ± 0.8	44 ± 0.9	16 ± 0.6	95 ± 1.4
20,000-40,000	141-200		8.1 ± 0.4	13.5 ± 0.5	6.2 ± 0.3	27.7 ± 0.7
40,000-80,000	200-283		1.5 ± 0.2	3.8 ± 0.3	1.9 ± 0.2	7.2 ± 0.4
80,000-160,000	283-400		0.3 ± 0.1	0.9 ± 0.1	0.7 ± 0.1	1.9 ± 0.2
160,000+	400+			0.2 ± 0.1	0.2 ± 0.1	0.4 ± 0.1

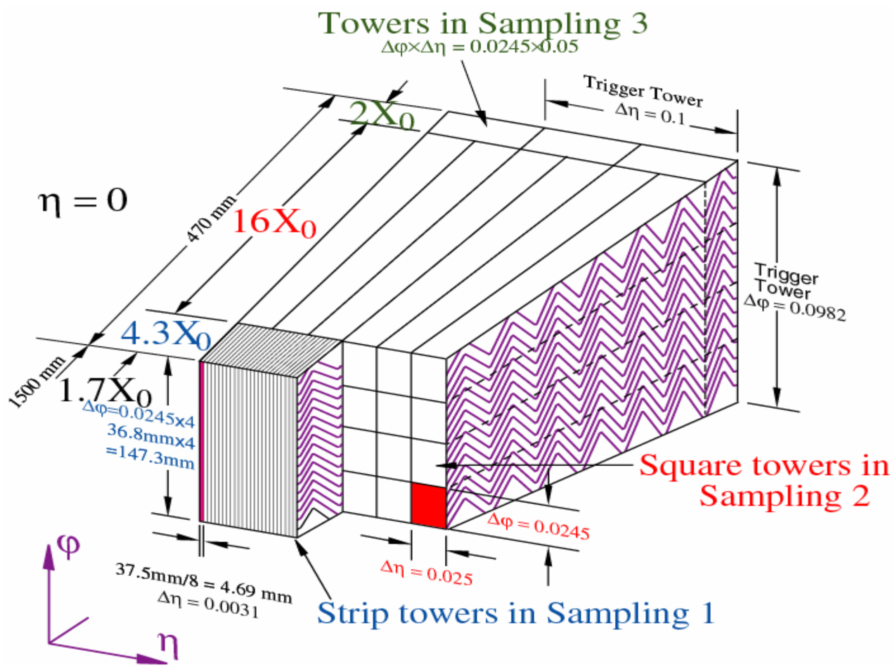
(4) Rejecting against background

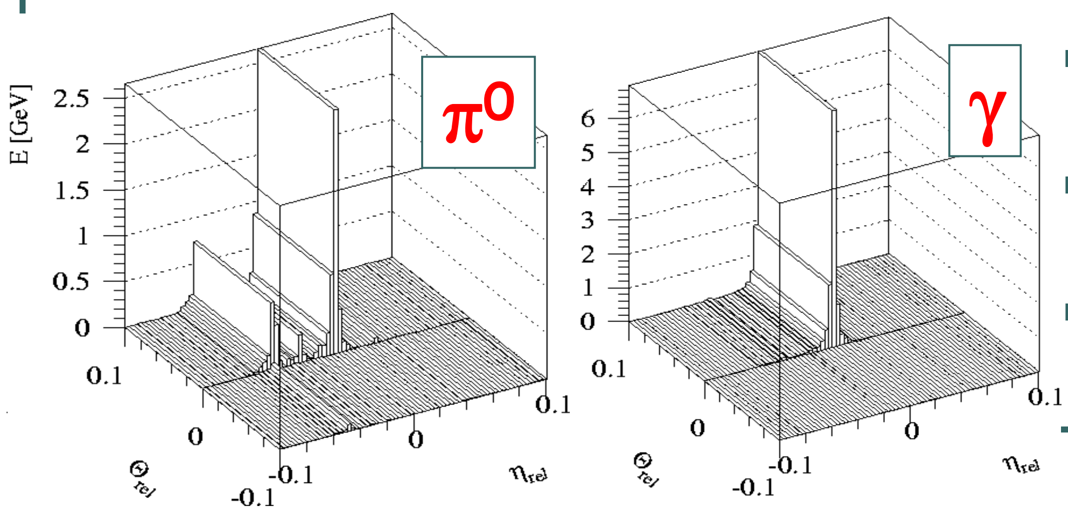
- Background di-jet events where one jet fakes a photon
- Rejection against the background done by looking at shower properties of the events
- Have limited detector coverage
  - $|\eta_\gamma| < 3.2$
  - $|\eta_{jet}| < 4.9$

- Focus on γ ID in the region $|\eta| < 2.5$ for precision physics



Separation using EM Calorimeters



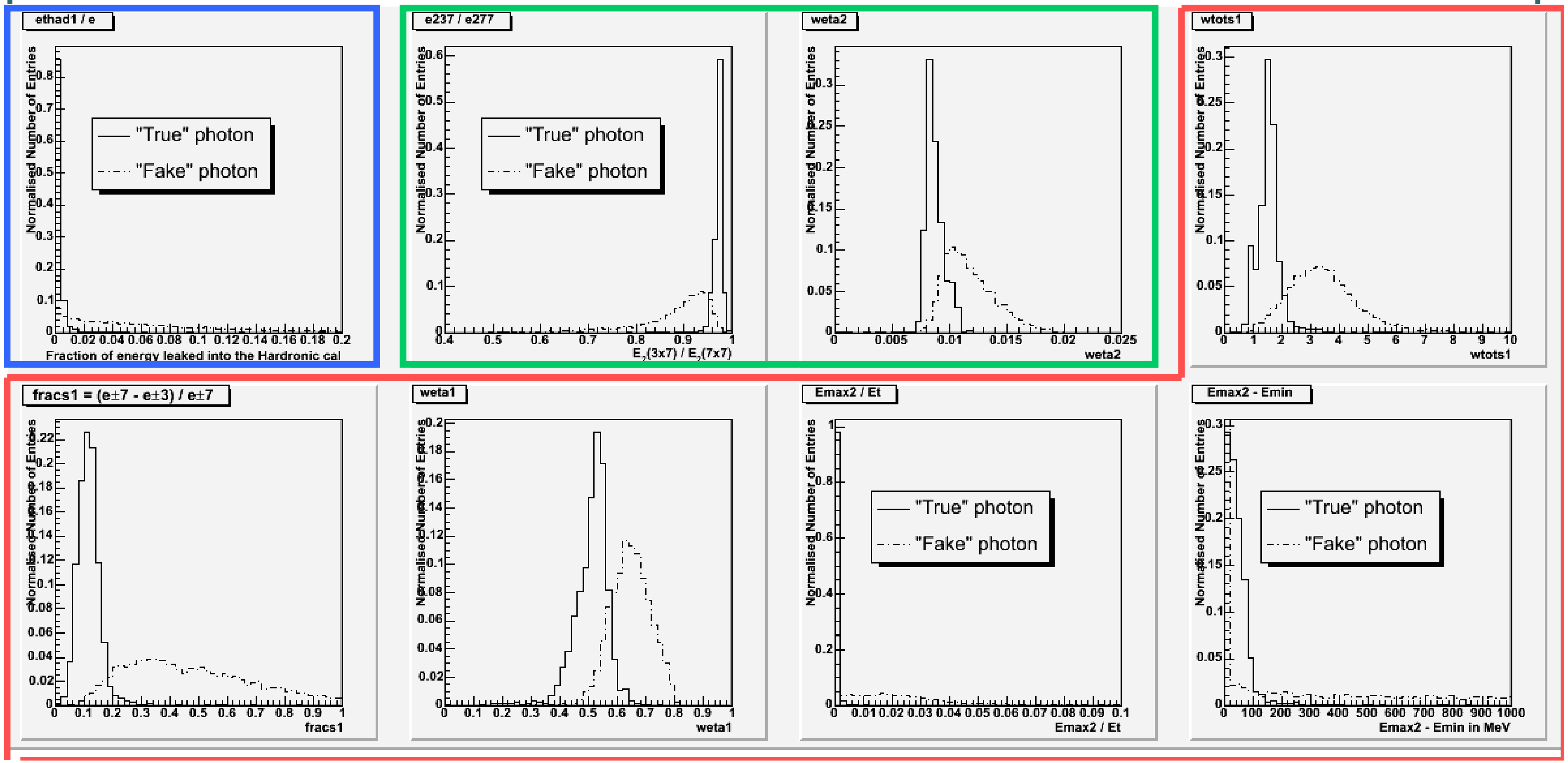


- Separation done using
  - Had Cal
  - EM2
  - EM1 (strips)
- Use Had Cal to reject against jets with hadronic components
- Use EM2 to reject against broad jets
- Should just leave narrow jets with little hadronic activity.
- Mainly consisting of π, η and ω decaying into 2 photons
- Use fine η granularity of EM1 to reject against these

Unconverted True photon v Fakes – all η bins

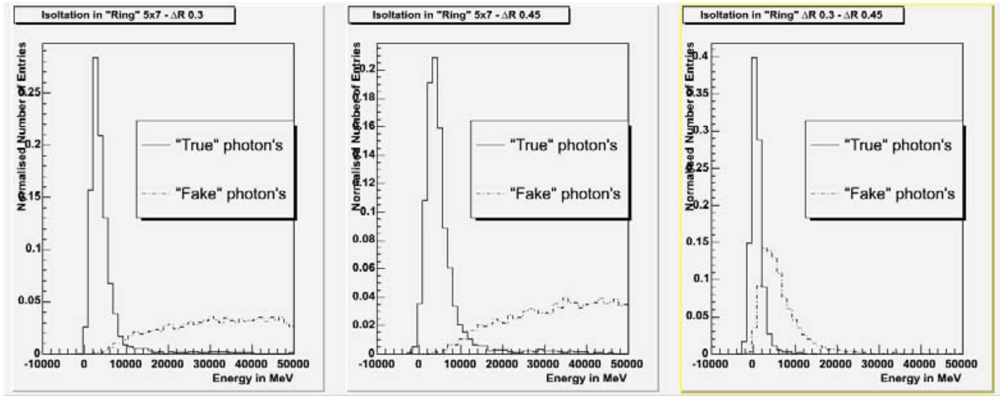
- HadCal
- EM2
- EM1 (strips)

- Different shapes of photons and jets clearly seen
- However some plots have broad spectra with tails...



and finally add an Isolation

- Final stage - place an Isolation criteria upon the photon
- nb plots show candidate photons before shower shape ID cuts



Final Rejections...

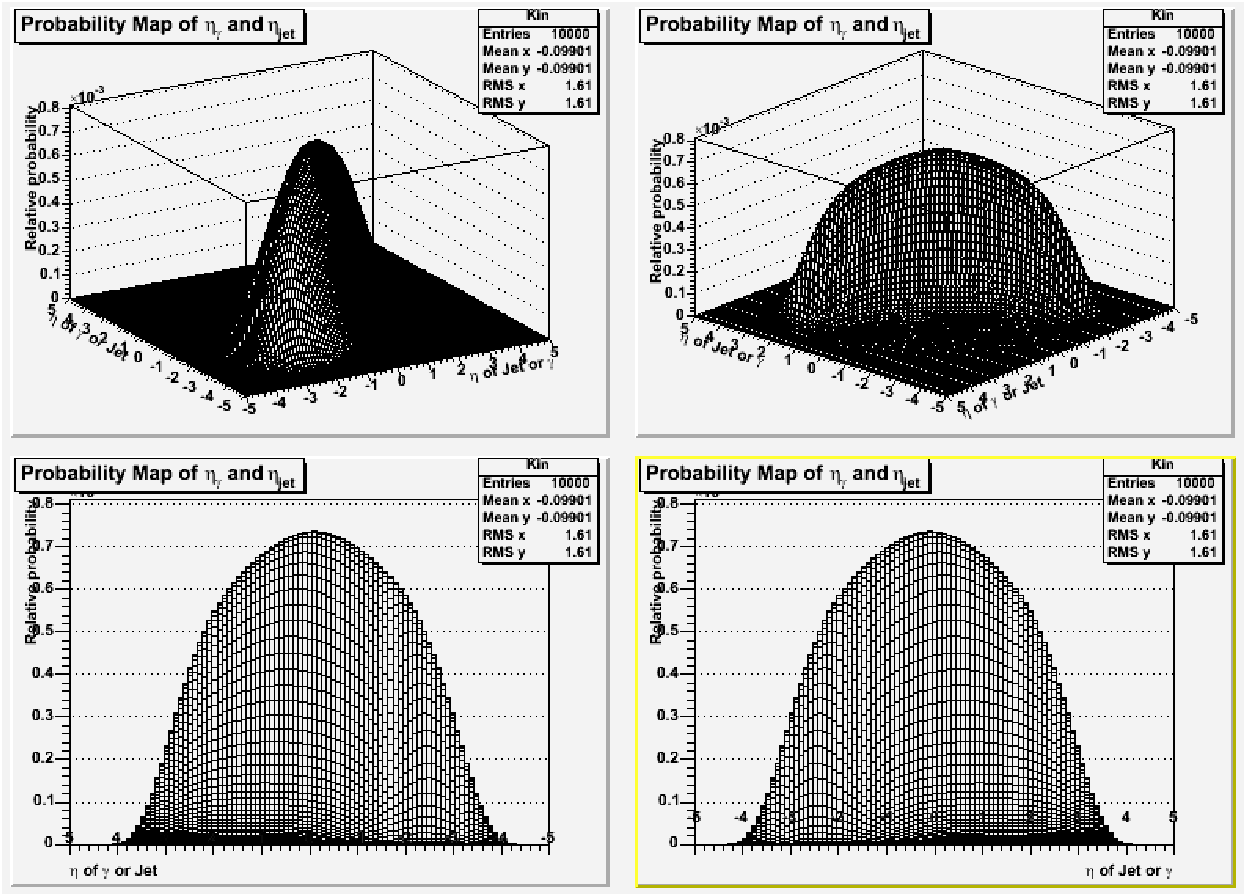
- Rejections of
  - ~5,000 for Pt>25GeV
  - ~10,000 for Pt>100 GeV
  - ~??? for Pt>300GeV

(5) Summary

- High x events are kinematically accessible by looking at high Q and large η
- Difference in pdf's are most apparent at high x and manifest themselves most predominately in the η distributions
- Differences of in the central – edge η distributions of 2 - 6% (110GeV) and 3 -15% (330GeV) are typical.
- Dijet rejection should be sufficient to have S/B > 10 in the region of interest
- Looks feasible to further constrain gluon pdfs

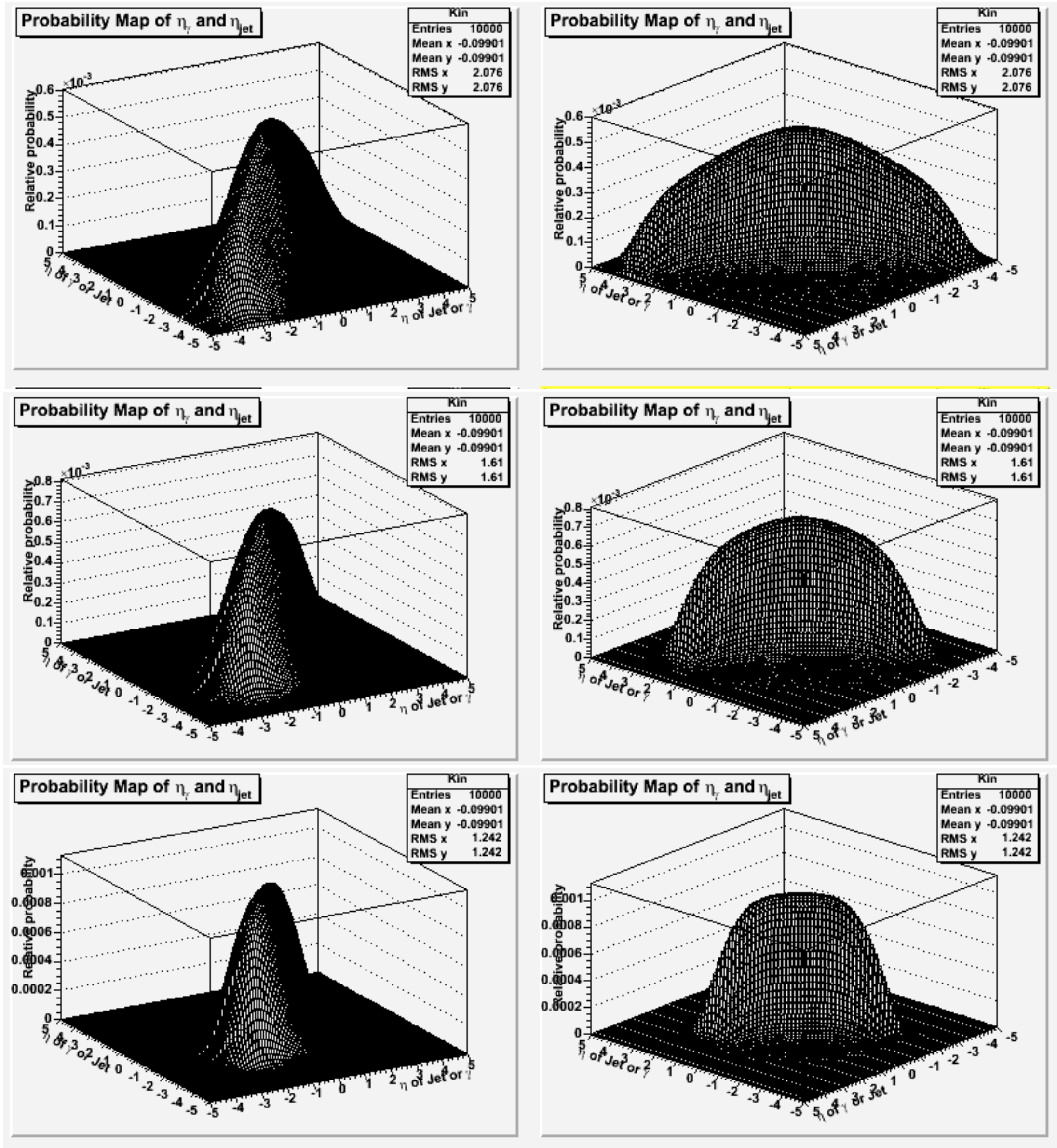
Backup Slides

Probability map of Event distributions in η



Q = 150 GeV

- Compton process only
- Agrees with event shapes as produced by Pythia
- γ-jet occur preferentially in the same η region



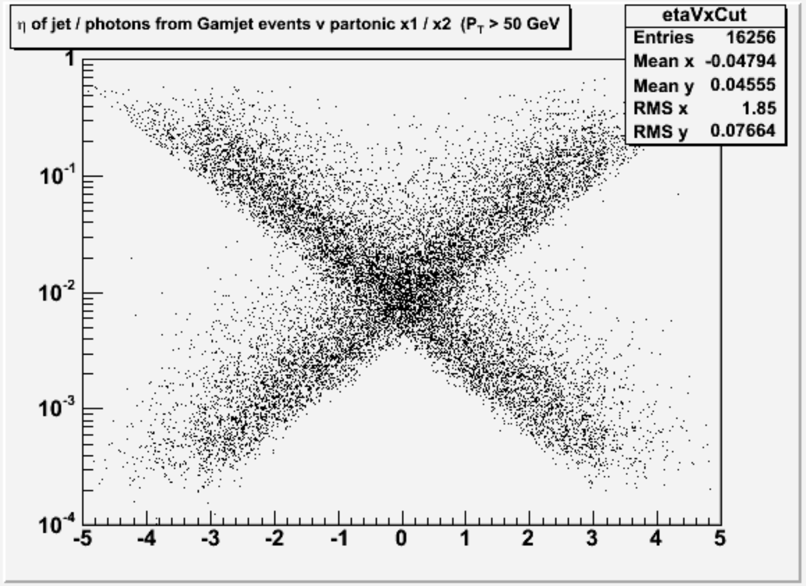
Q = 50 GeV

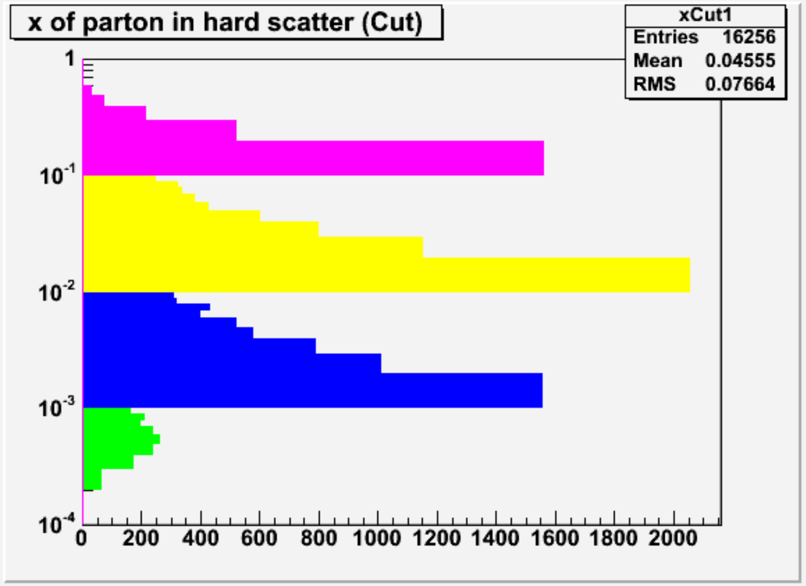
- At increased Q the event shape contracts

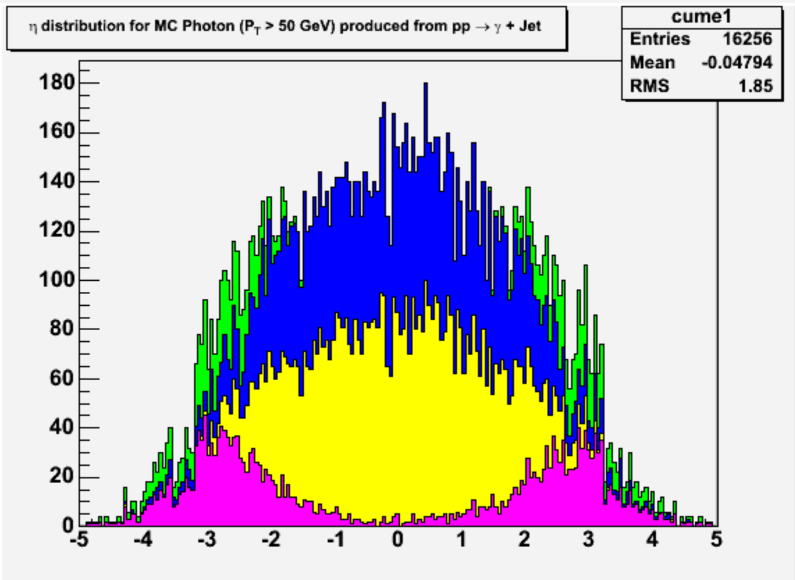
Q = 150 GeV

- At high Q most, if not all the events should be observable in the detector

Q = 350 GeV







- Magenta: $10e\text{-}1 < x < 10e\text{-}0$
- Yellow: $10e\text{-}2 < x < 10e\text{-}1$
- Blue: $10e\text{-}3 < x < 10e\text{-}2$
- Green: $10e\text{-}4 < x < 10e\text{-}3$

$P_T > 50$ GeV

Jet + γ events generated with Pythia

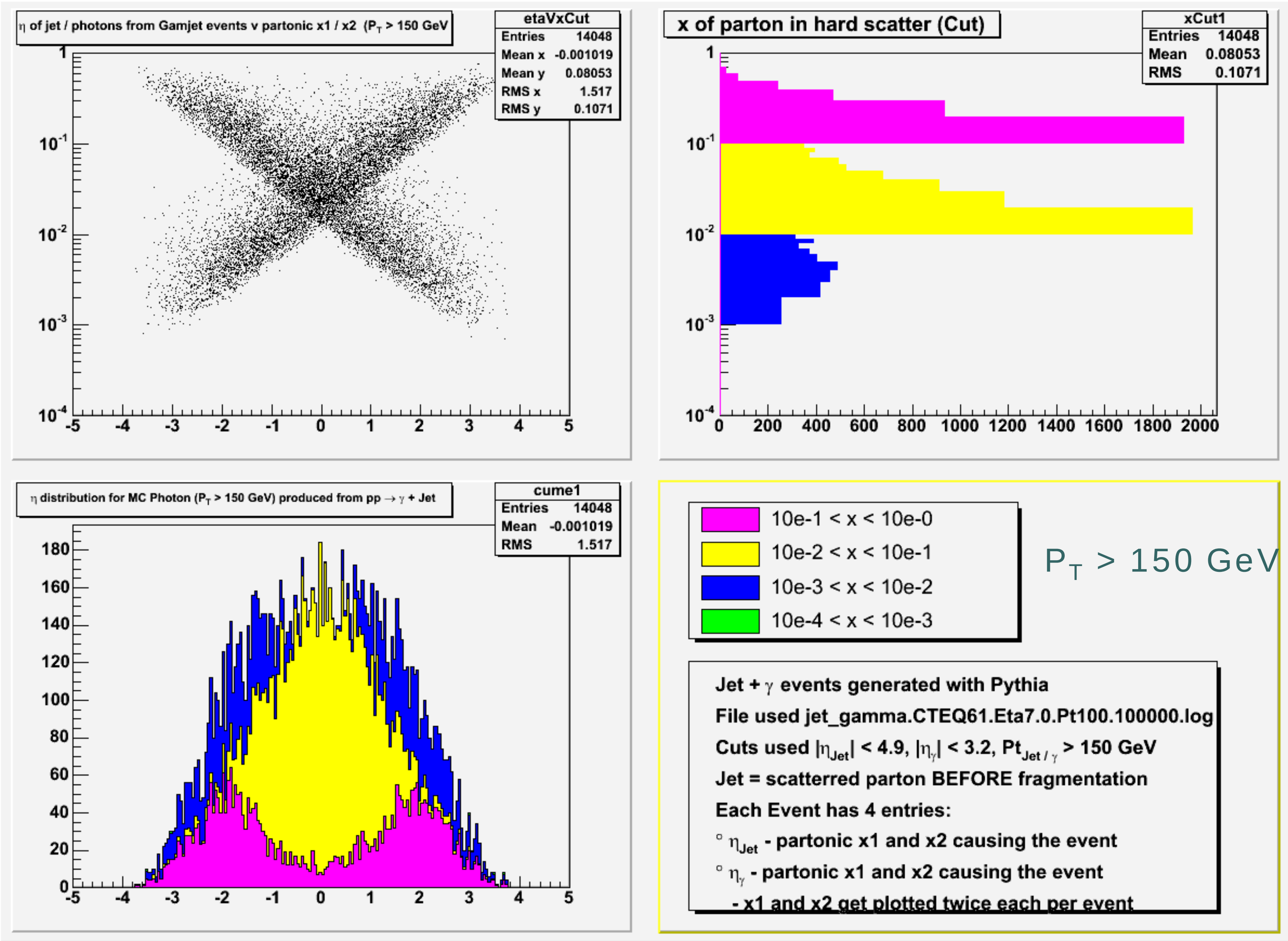
File used jet_gamma.CTEQ61.Eta7.0.Pt20.100000.log

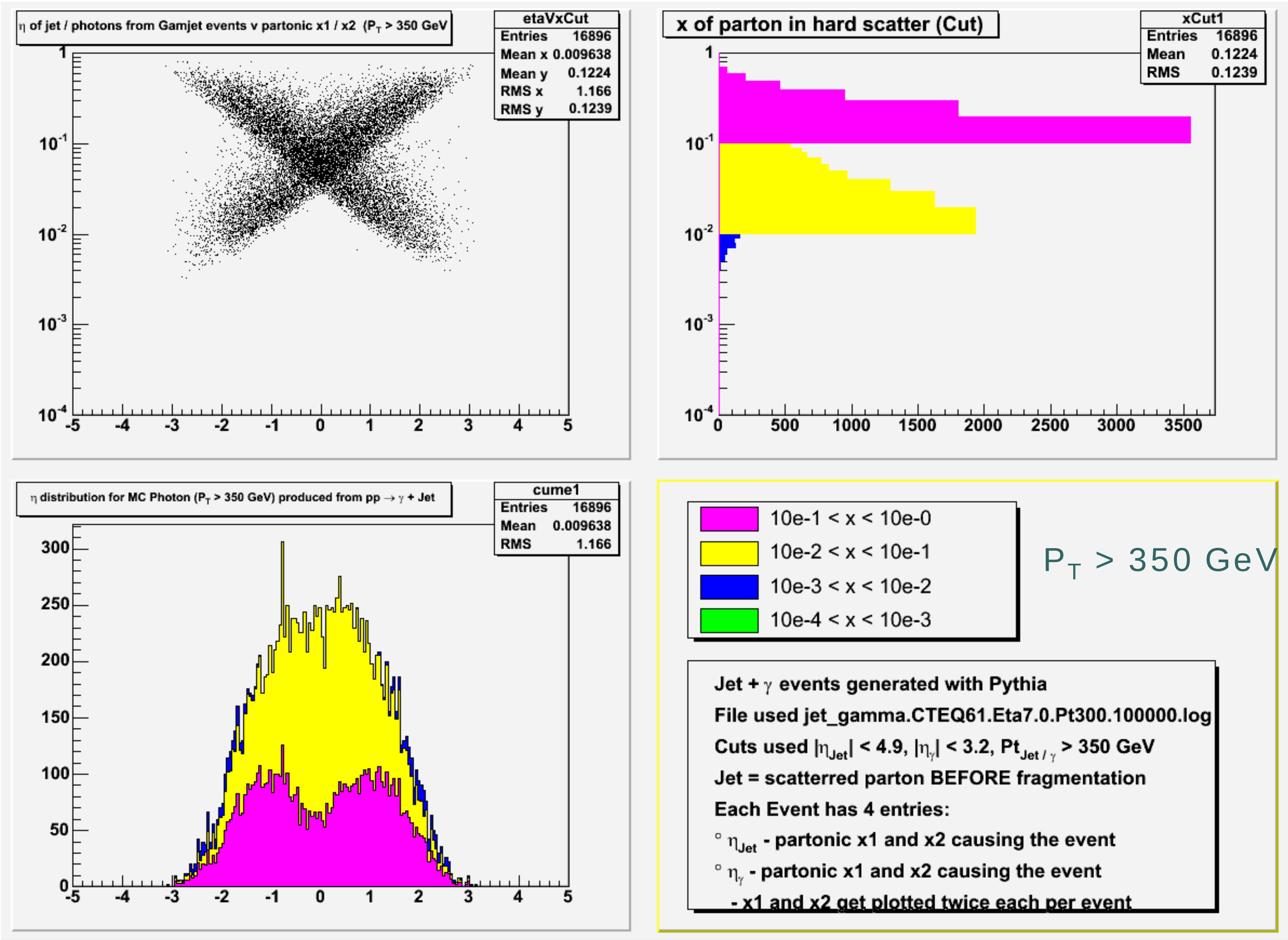
Cuts used $|\eta_{Jet}| < 4.9$, $|\eta_\gamma| < 3.2$, $Pt_{Jet/\gamma} > 50$ GeV

Jet = scatterred parton BEFORE fragmentation

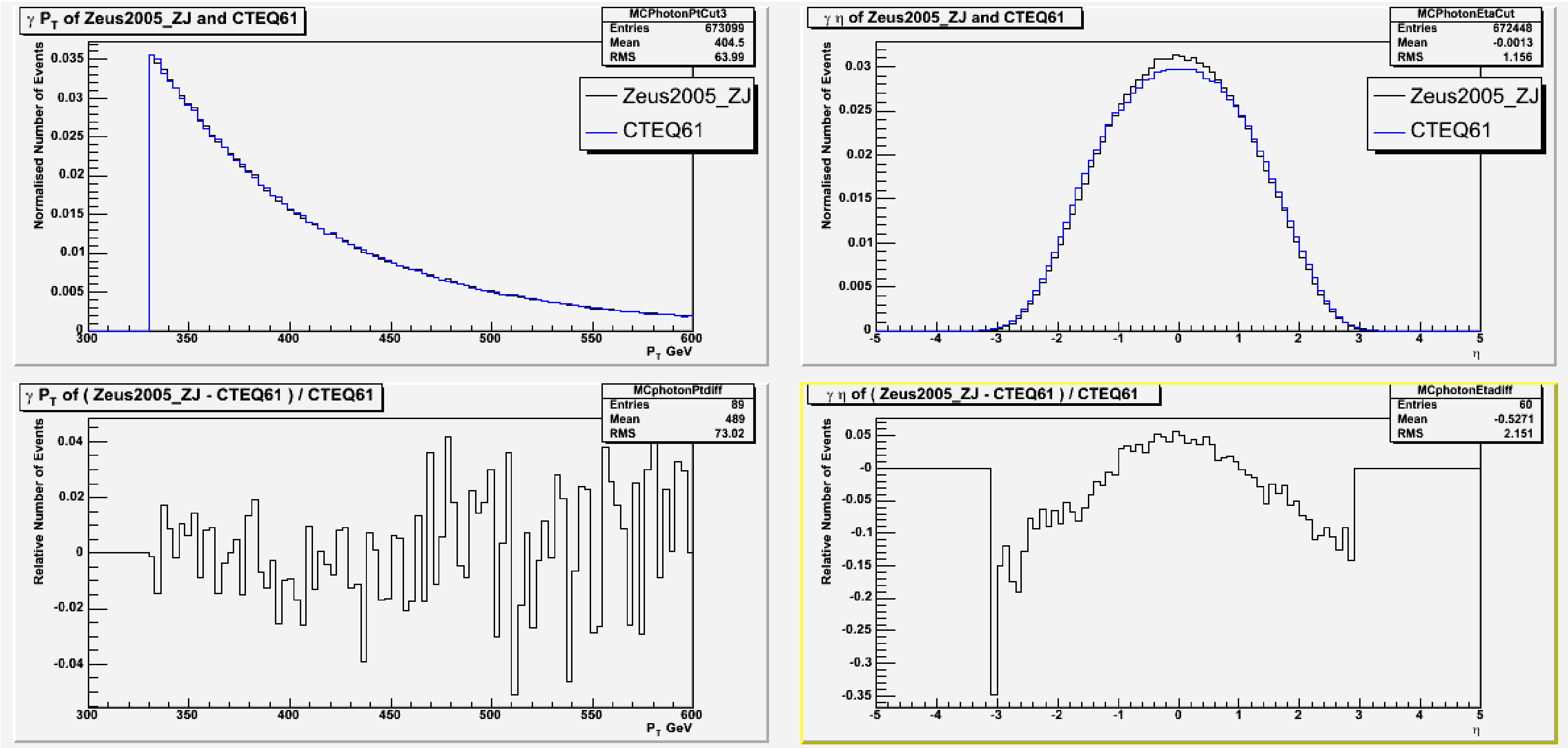
Each Event has 4 entries:

- **η_{Jet} - partonic x1 and x2 causing the event**
- **η_γ - partonic x1 and x2 causing the event**
  - **x1 and x2 get plotted twice each per event**

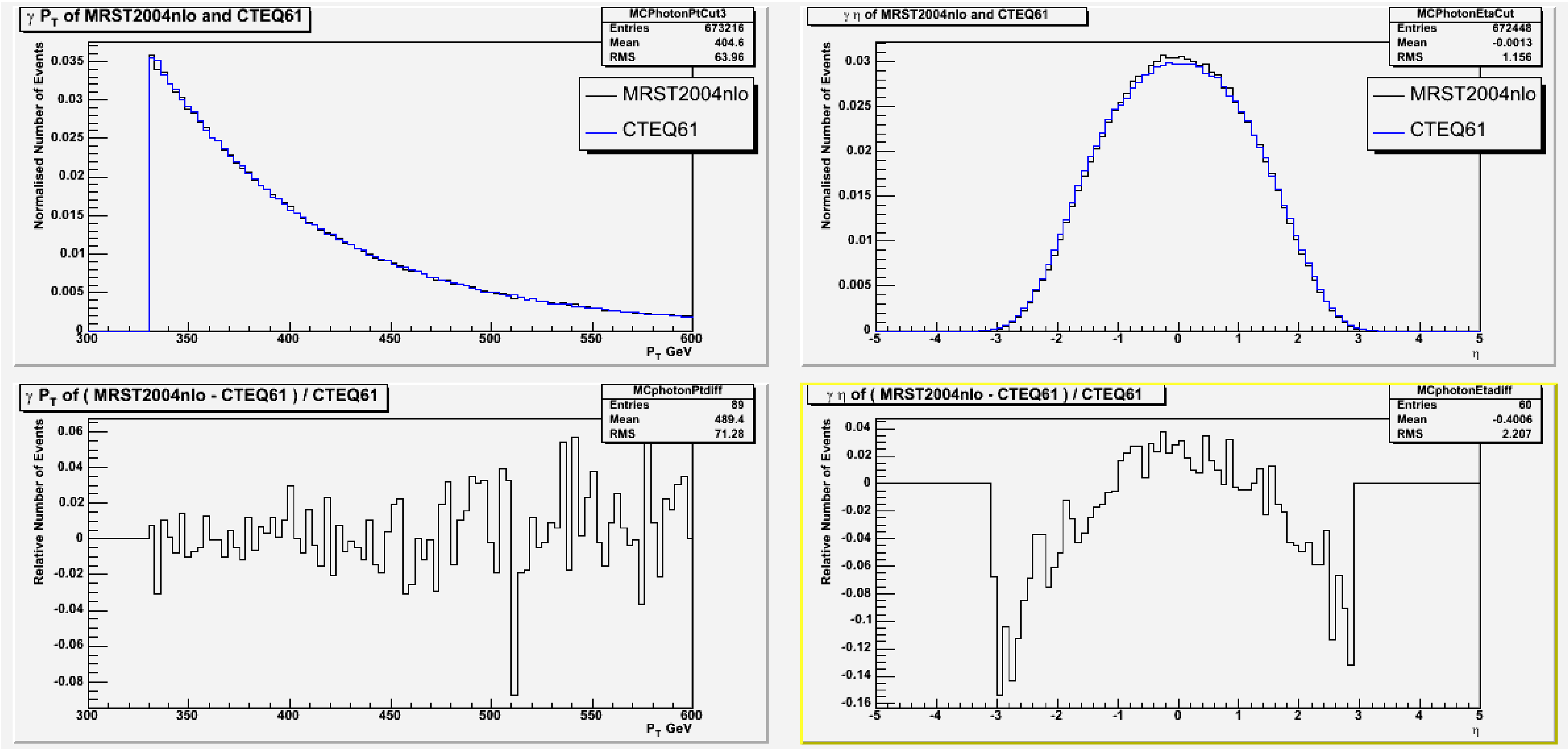

η of jet / photons from Gamjet events v partonic x1 / x2 (P_T > 150 GeV
etaVxCut
Entries 14048
Mean x -0.001019
Mean y 0.08053
RMS x 1.517
RMS y 0.1071
x of parton in hard scatter (Cut)
xCut1
Entries 14048
Mean 0.08053
RMS 0.1071
η distribution for MC Photon (P_T > 150 GeV) produced from pp → γ + Jet
cume1
Entries 14048
Mean -0.001019
RMS 1.517
10e-1 < x < 10e-0
10e-2 < x < 10e-1
10e-3 < x < 10e-2
10e-4 < x < 10e-3
P_T > 150 GeV
Jet + γ events generated with Pythia
File used jet_gamma.CTEQ61.Eta7.0.Pt100.100000.log
Cuts used |η_Jet| < 4.9, |η_γ| < 3.2, Pt_Jet / γ > 150 GeV
Jet = scatterred parton BEFORE fragmentation
Each Event has 4 entries:
η_Jet - partonic x1 and x2 causing the event
η_γ - partonic x1 and x2 causing the event
- x1 and x2 get plotted twice each per event


η of jet / photons from Gamjet events v partonic x1 / x2 (P_T > 350 GeV
etaVxCut
Entries 16896
Mean x 0.009638
Mean y 0.1224
RMS x 1.166
RMS y 0.1239
x of parton in hard scatter (Cut)
xCut1
Entries 16896
Mean 0.1224
RMS 0.1239
η distribution for MC Photon (P_T > 350 GeV) produced from pp → γ + Jet
cume1
Entries 16896
Mean 0.009638
RMS 1.166
10e-1 < x < 10e-0
10e-2 < x < 10e-1
10e-3 < x < 10e-2
10e-4 < x < 10e-3
P_T > 350 GeV
Jet + γ events generated with Pythia
File used jet_gamma.CTEQ61.Eta7.0.Pt300.100000.log
Cuts used |η_Jet| < 4.9, |η_γ| < 3.2, Pt_Jet / γ > 350 GeV
Jet = scatterred parton BEFORE fragmentation
Each Event has 4 entries:
° η_Jet - partonic x1 and x2 causing the event
° η_γ - partonic x1 and x2 causing the event
- x1 and x2 get plotted twice each per event

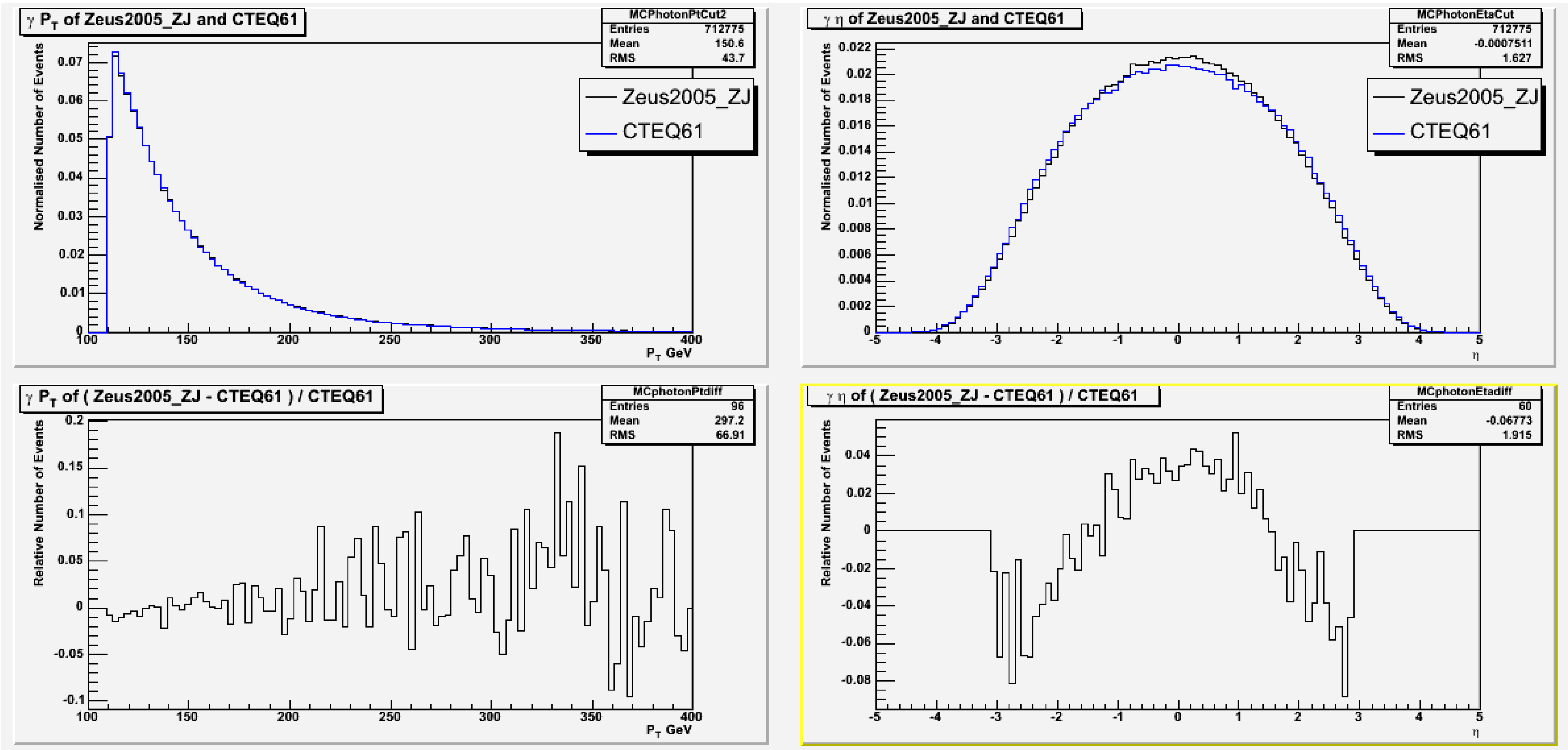
γ - distributions for Zeus2005_ZJ and Cteq61. P_T > 330 GeV



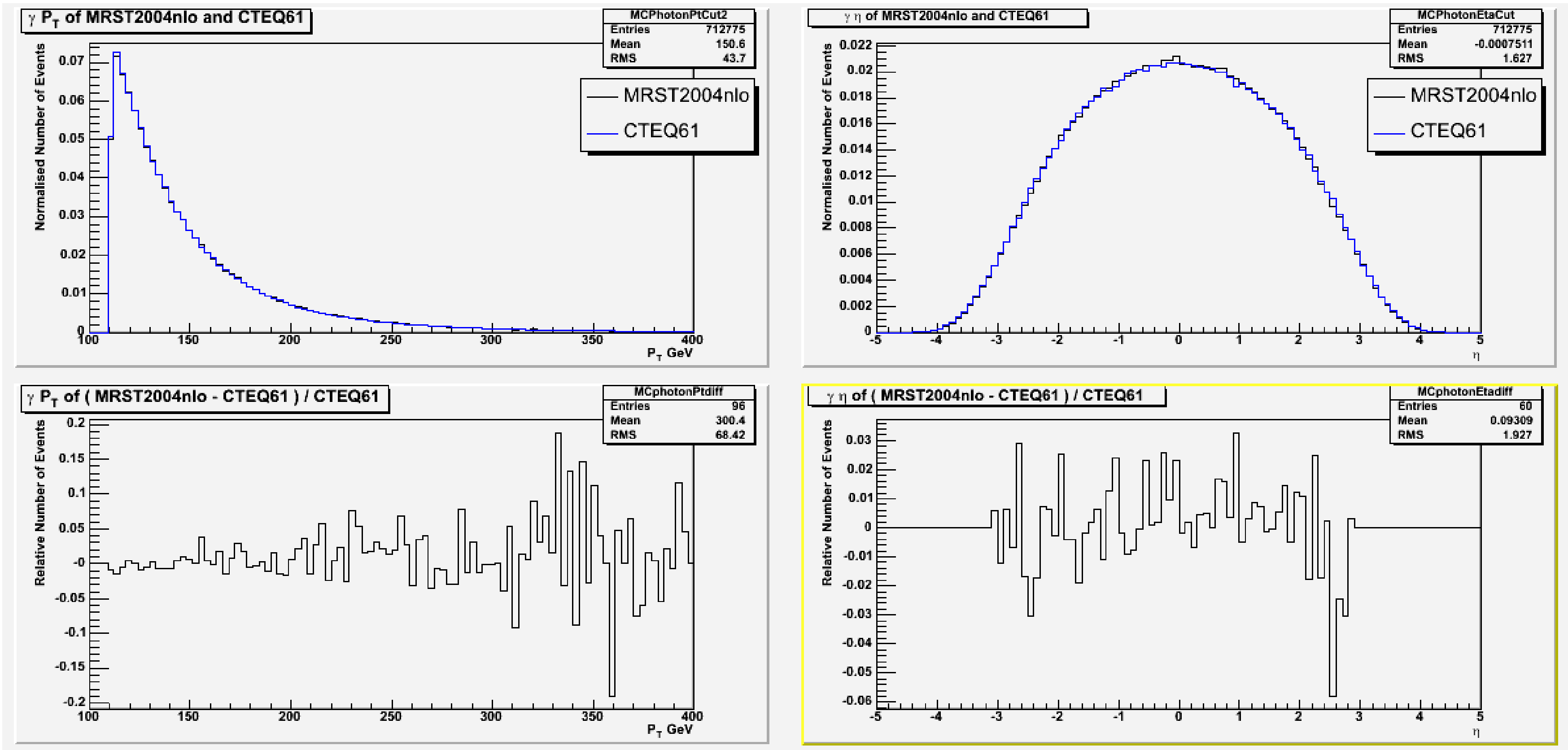
γ - distributions for MRST2004 and Cteq61. P_T > 330 GeV



γ- distributions for Zeus2005_ZJ and Cteq61. P_T > 110 GeV

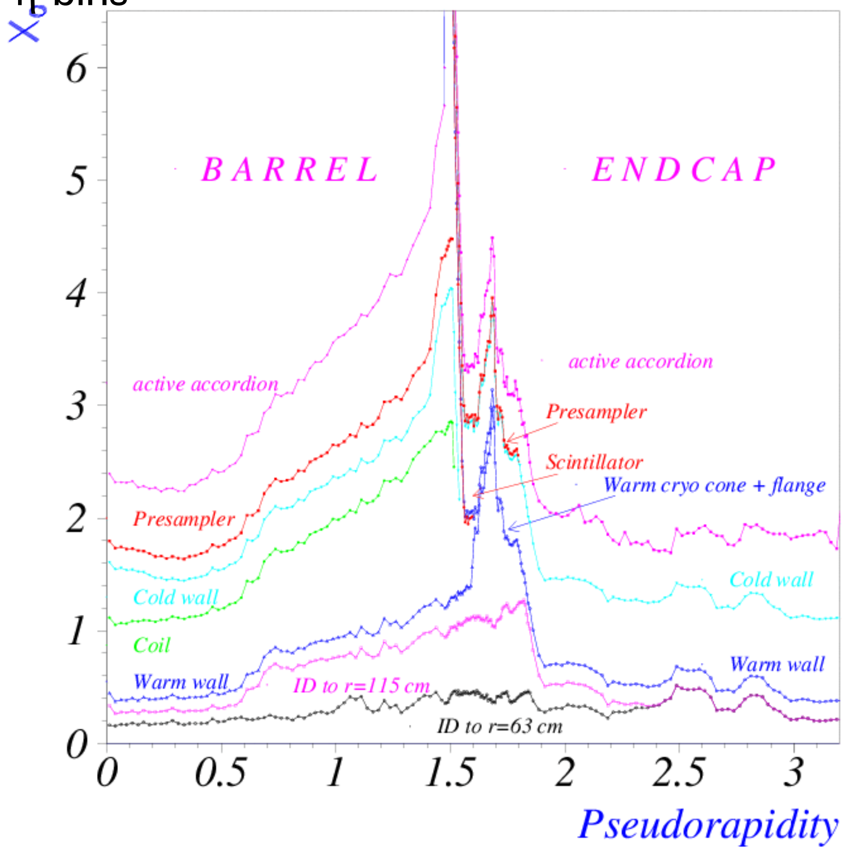


γ - distributions for MRST2004 and Cteq61. $P_T > 110$ GeV



Shower Shape - η dependence

- Shower Shapes are considered in the η bins
  - 0 < |η| < 0.8
  - 0.8 < |η| < 1.37
  - 1.52 < |η| < 1.8
  - 1.8 < |η| < 2.0
  - 2.0 < |η| < 2.40



- Motivation for the η binning is
  - Granularity changes in EM1 Cal
  - Changes thickness in the Lead absorber plates
  - Material budget

- Nb – no ID done in the crack region

Unconverted True photon v Fakes – 0 < |η| < 0.8

- HadCal
- EM2
- EM1 (strips)

- Shapes of the True photons now appear cleaner and easier to cut on them
- Repeat for 5 different η bins...