Feasibility Study of Direct Photon Cross Section Measurements and Investigation of sensitivity to the Gluon Density

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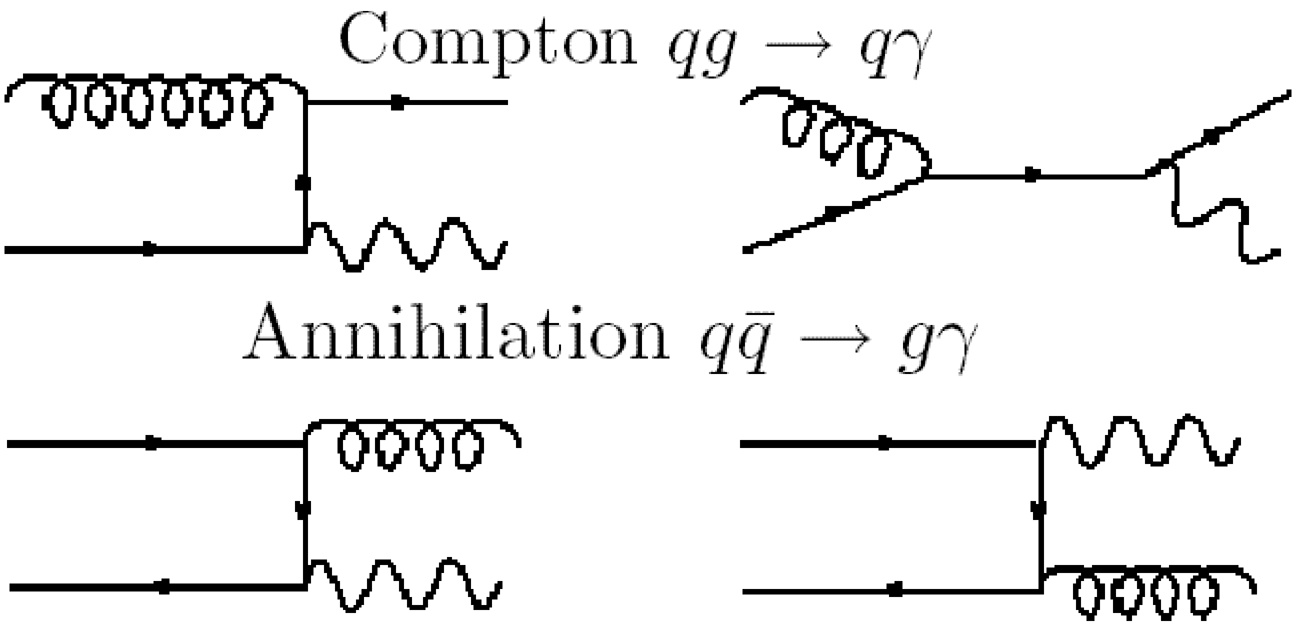
ATLAS UK Standard Model Meeting

Outline

- What are direct (prompt) photons
- Why study direct photons
- Previous study by Ivan Hollins
- My generator level study
- Plans for the future

Direct Photons

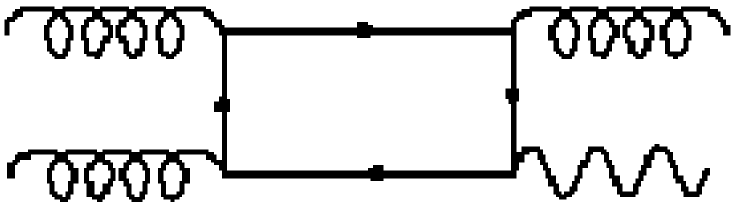
- Leading Order process $O(\alpha,\alpha_s)$



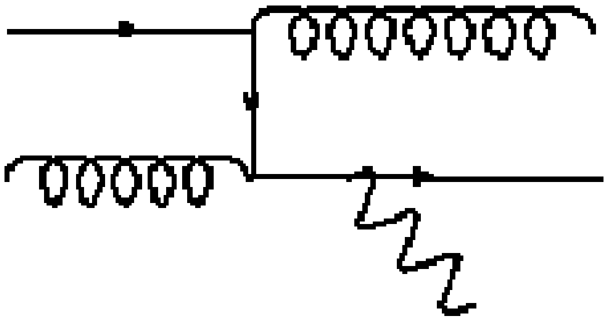
➢ Detect 1 isolated photon and at least 1 jet

Beyond $O(\alpha,\alpha_s)$

- Higher order in α_s: gg->gγ

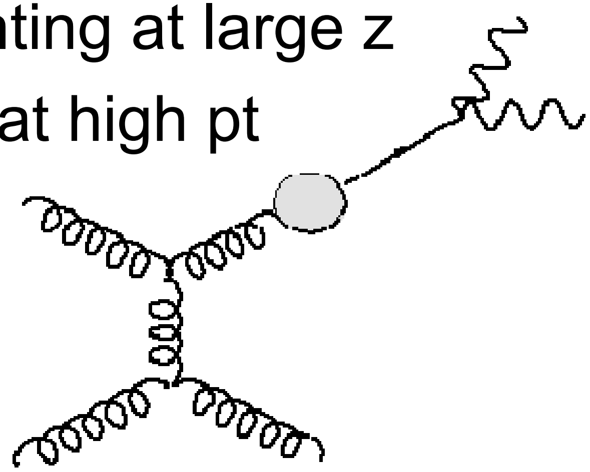


- ISR/FSR (Bremsstrahlung process)
  - Different process as has second jet



Background

- Single photon is faked by $\pi^0 \to \gamma\gamma$
  - Main source are jets fragmenting at large z
  - Less probable to fake signal at high pt



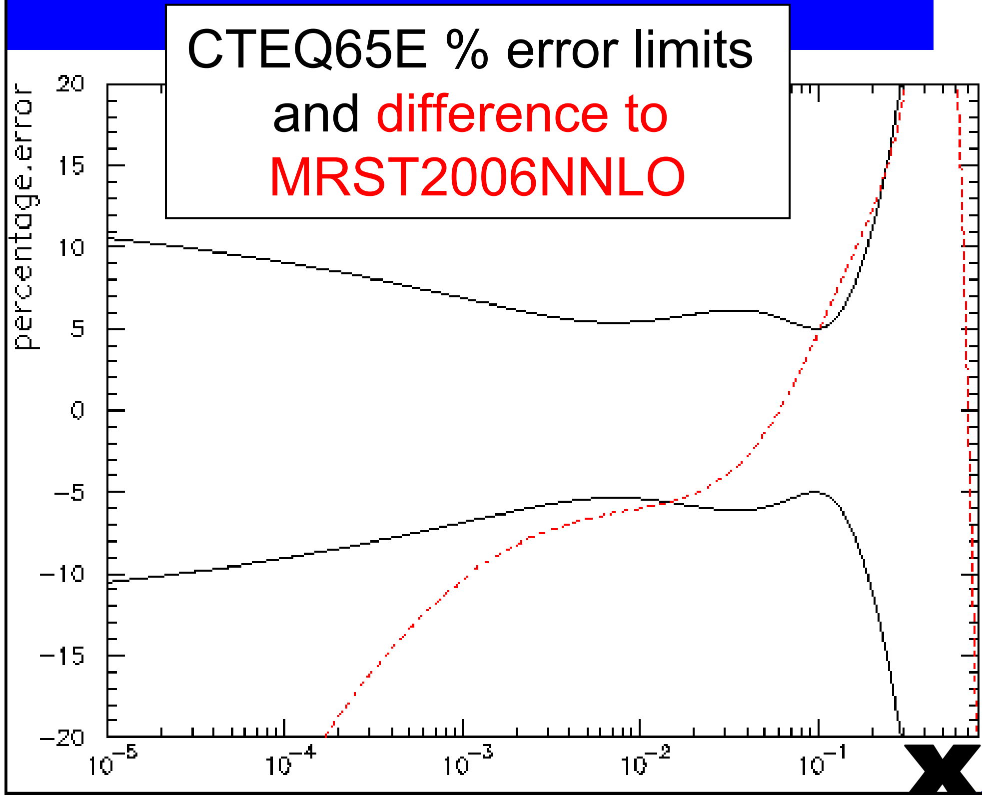
- From Ivan Hollins Study:
- π^0 is the biggest background typically 70% (the rest are mainly η, ω or other single particles)

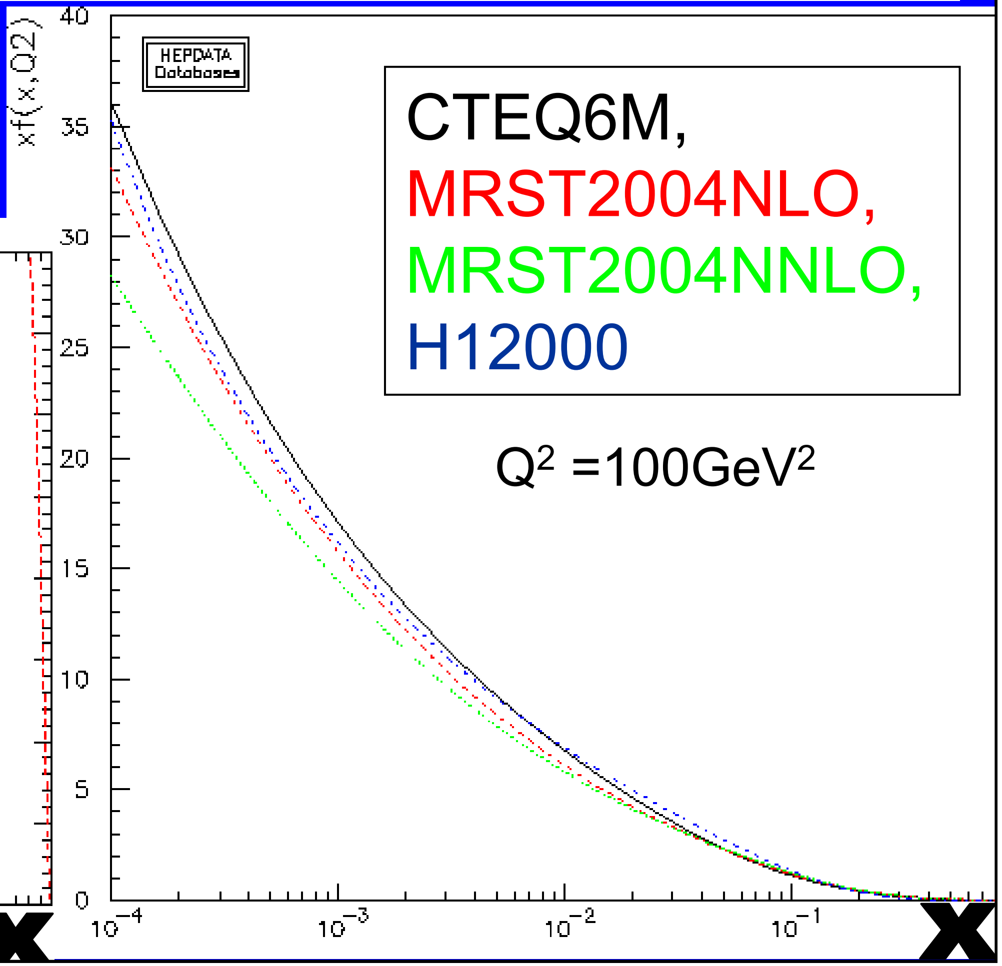
Why Study

1. Calibration of Jet energy scale
   - Gives an in-situ calibration using p_T balance
   - Used at other experiments: D0, CDF, RHIC, CMS and ATLAS
   - Alternatives: jet algorithms, test beam responses, Di-jet and π simulations, in-situ top/W mass

2. Gluon Distribution and Parton Evolution Dynamics

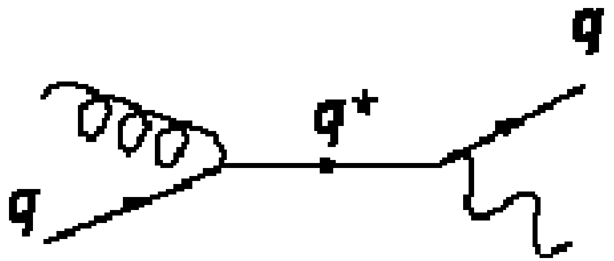
- Large uncertainty at high x
- At low x: Differences to NLO, NNLO?
  Does the gluon saturate?
  Is DGLAP sufficient?





Why Study

3. Improved understanding of the gluon distribution is needed before searches can take place
4. New Physics
   - Excited quark



   - Many other final states containing γ+jet
     - eg SUSY decay chains (delayed photons)
   - Helps with γ in other processes
     - eg photon id helps H->$\gamma\gamma$,

Previous work by Ivan Hollins

- Ivan was a student here at Birmingham until Dec ‘06 who previously studied direct photons with supervisor John Wilson
- Worked on:
  - Photon ID
  - Direct photon cross section
  - Gluon x distribution

Photon ID

- Remove electrons by requiring no charged track linked to calorimeter deposit
- Suppress π^0 to $\gamma\gamma$ etc using shower shape in EM calorimeter
- Further suppress photons in jets using isolation cuts

- Analyse with cuts in flag isEM
- Gives jet rejections of around 10^3
  - ie 1 jet in 10^3 passes cuts

- Ivan optimised the variables to give rejections improved by factors of between 4 and 20

Direct Photon Cross Section

1. Profile method (useful in low Et)
   - By studying the shower shapes of both the γ and π the mixture of a combined γ and π sample can be found to within 1%
2. Conversion method (works at high and low Et)
   - 70% of signal γ convert to e before they reach the ECAL (early conversion)
   - By looking at the deposit in the presampler in front of the ECAL the mixture of a combined γ and π sample can be matched to 1σ

Gluon x distribution

- Used LHAPDF to study differences between PDF's:
  - 5-10% on η distribution
  - Negligible for p_T
- Similar findings from a generation study with Pythia (LO γjet)
- Also found that majority of photons arise from high x quark and low x gluon

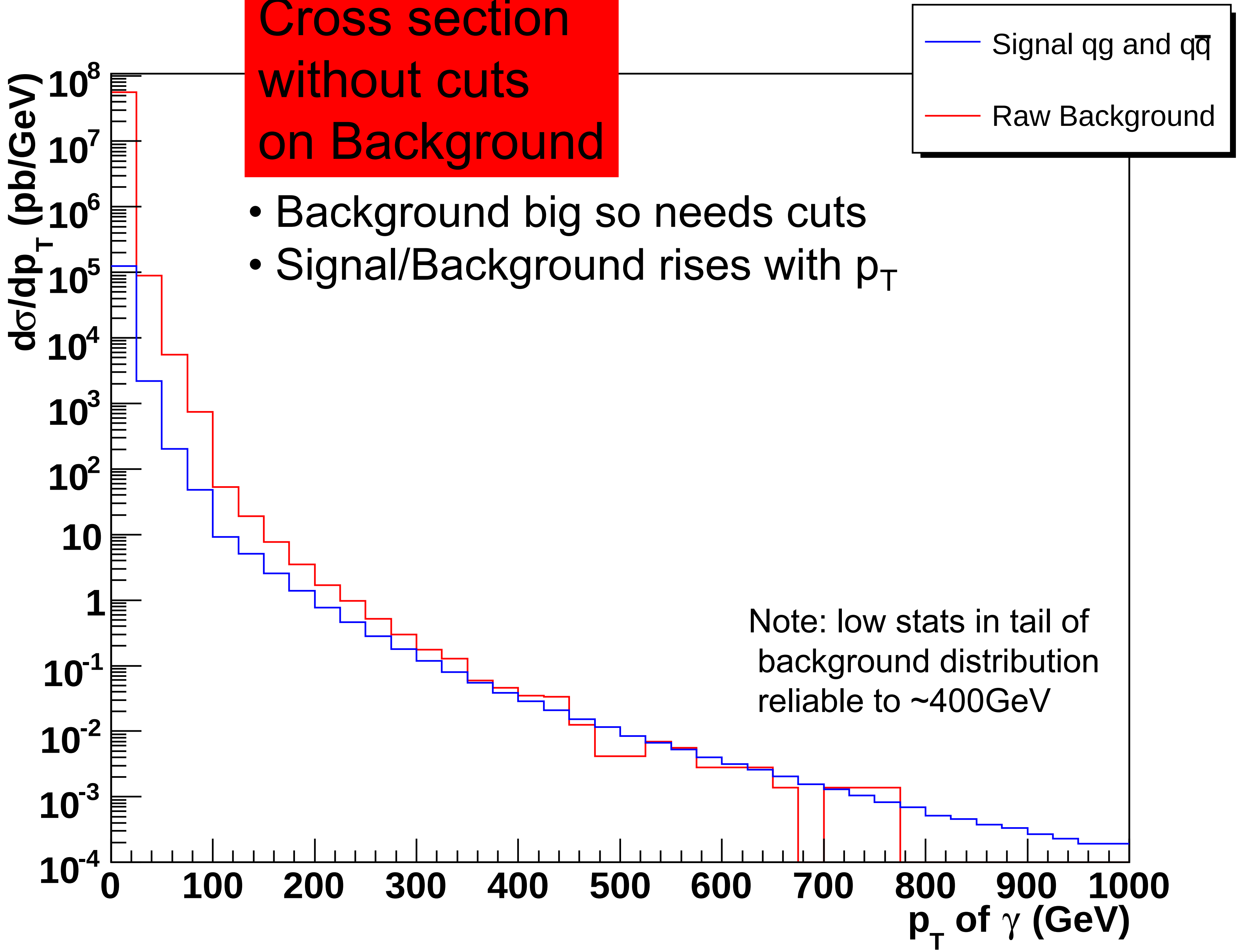
My generator level study

- Used Pythia (6.4.9) standalone to look at σ and gluon x
- Signal LO γjets, Background any real γ from di-jet event
- No isolation or other photon ID cuts against background
- Created η range: |η|<6 (full det |η|<4.7, tracking |η|<2.5)
- Two sets of p_T cut on initial jets 5 or 100GeV
- Event data -> text file -> root macro -> creates plots

# generated ($x10^6$)	p_T> 5GeV	η<2.5	σ(mb)	p_T> 100GeV	η<2.5	σ(mb)
Signal	12	4.3	10^{-3} 10^{-4}	16	11.3	10^{-7} 10^{-8}
Background	32	0.5	10^{1}	38	136 0.06	10^{-3}

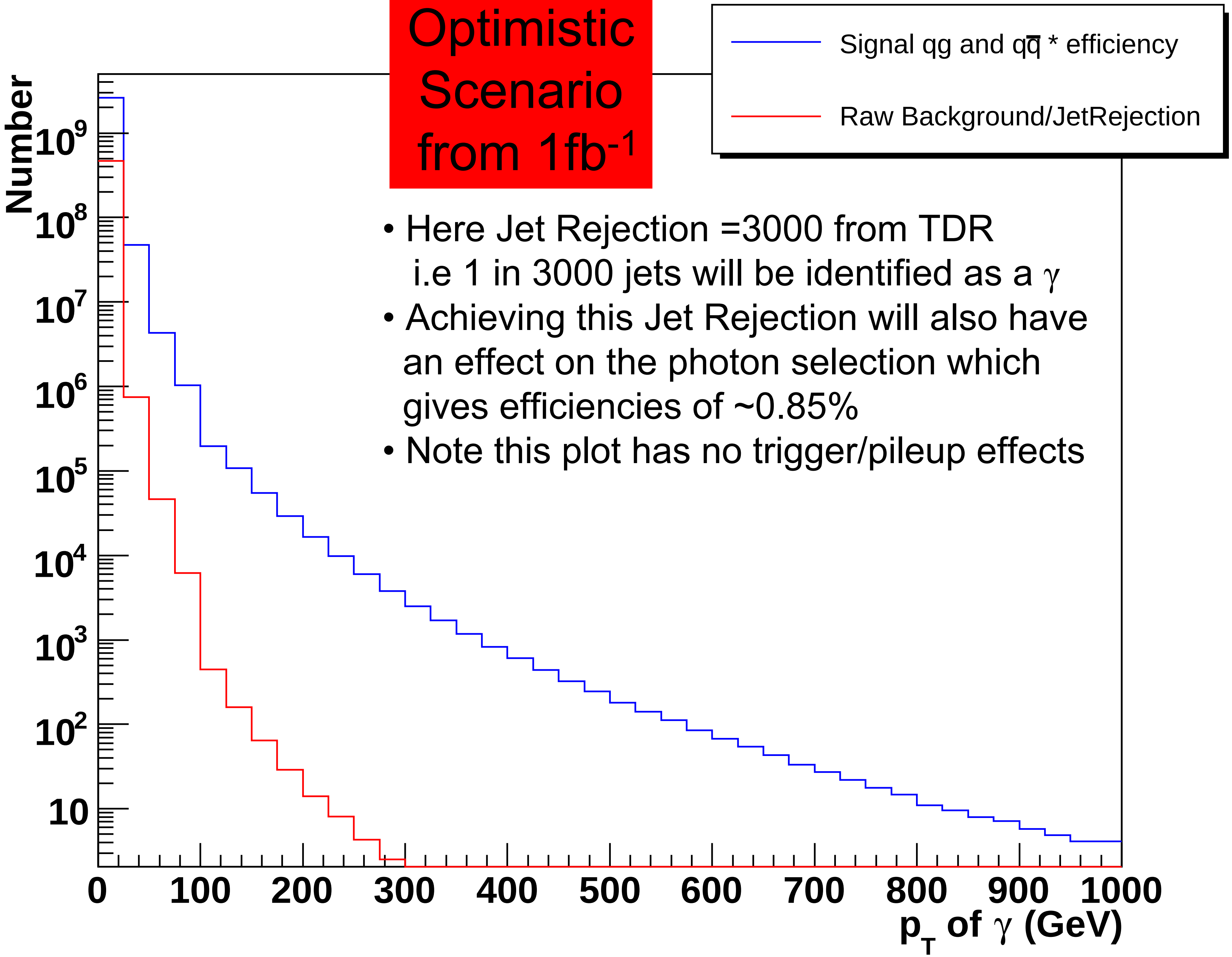
Cross section without cuts on Background

- Background big so needs cuts
- Signal/Background rises with p_T

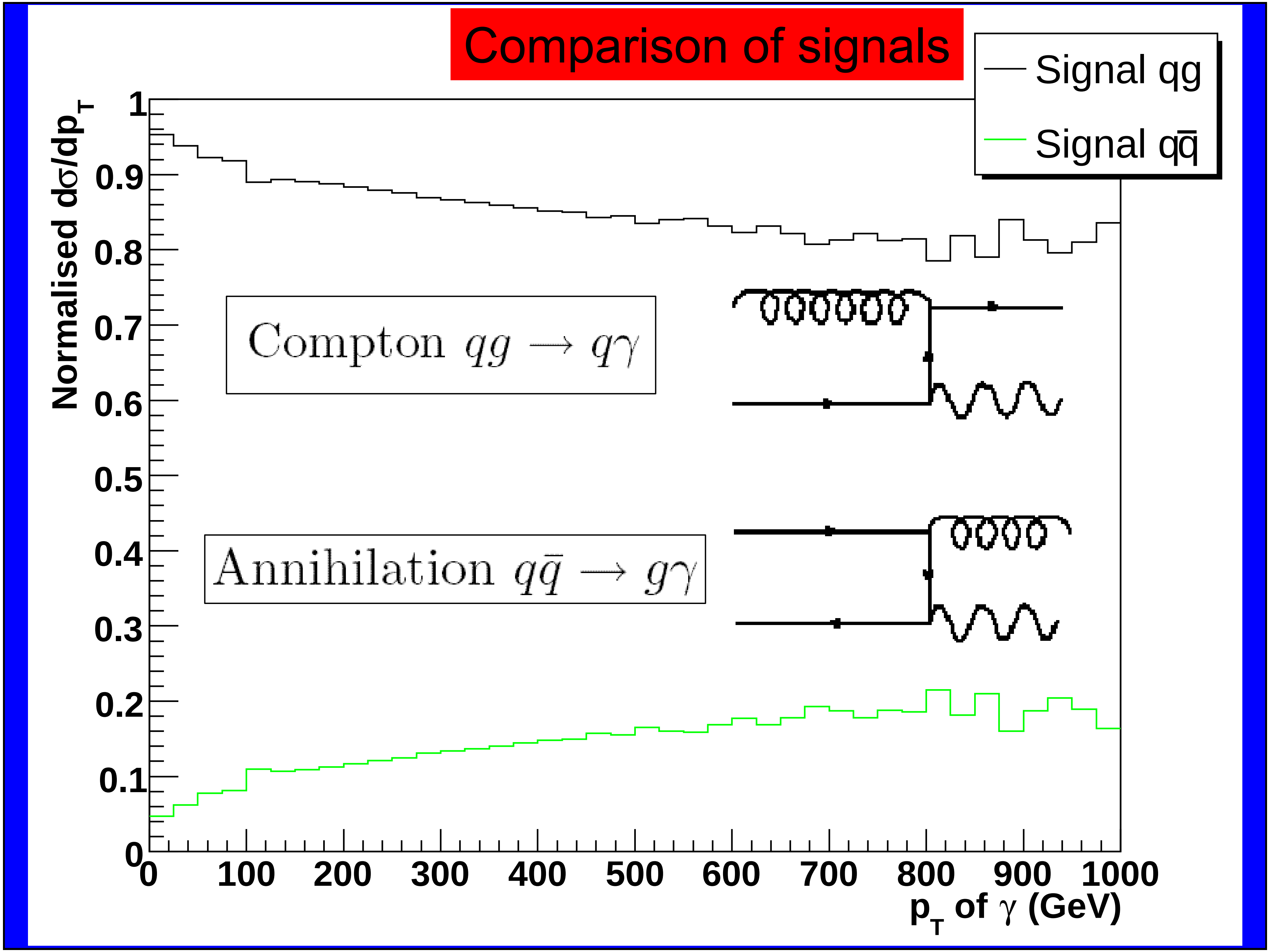


Note: low stats in tail of background distribution reliable to ~400GeV

Optimistic Scenario from $1 fb^{-1}$



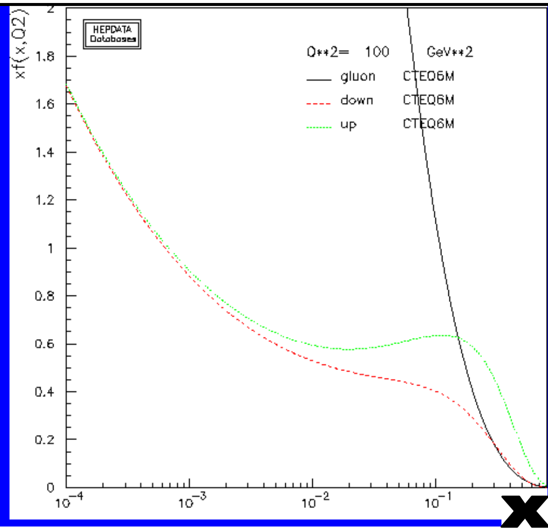
- Here Jet Rejection =3000 from TDR
  i.e 1 in 3000 jets will be identified as a γ
- Achieving this Jet Rejection will also have an effect on the photon selection which gives efficiencies of ~0.85%
- Note this plot has no trigger/pileup effects



Comparison of signals
Signal qg
Signal q$\bar{q}$
Normalised dσ/dp$_T$
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
100
200
300
400
500
600
700
800
900
1000
p$_T$ of γ (GeV)
Compton $qg \to q\gamma$
Annihilation $q\bar{q} \to g\gamma$

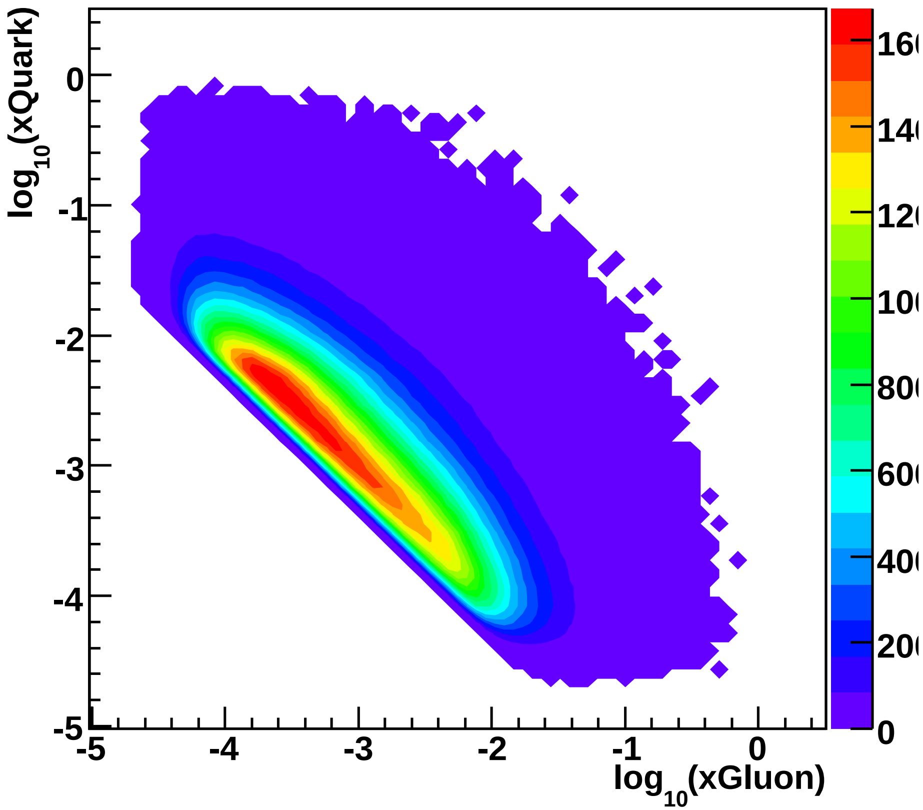
The interacting q and g

- More often involves low x gluon and high x quark
- Quark x reaches higher values

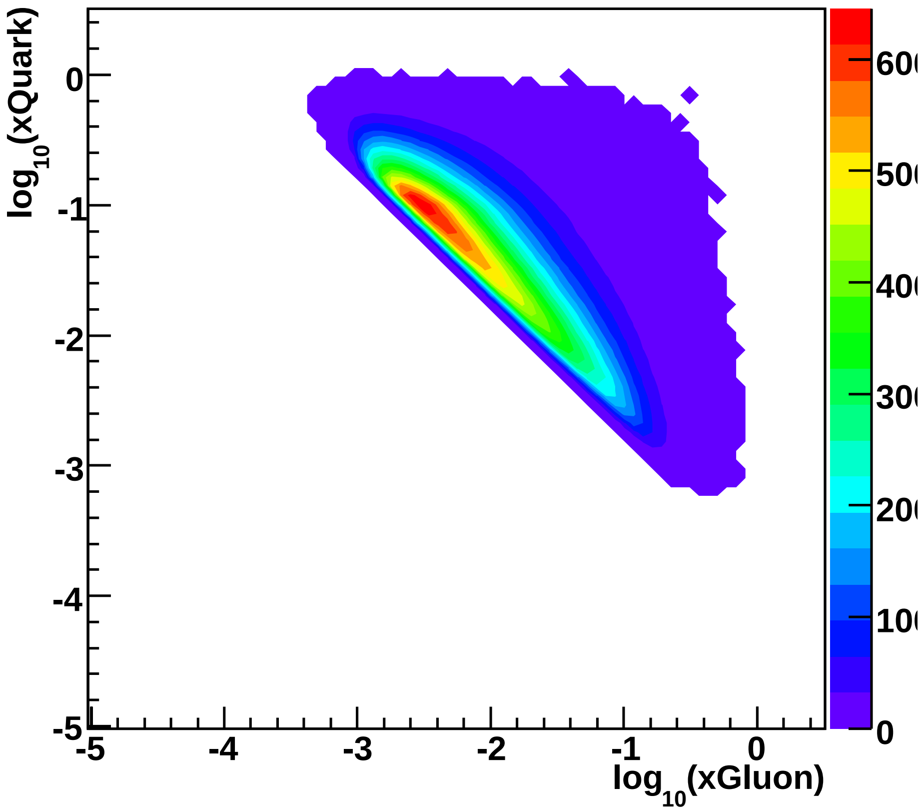


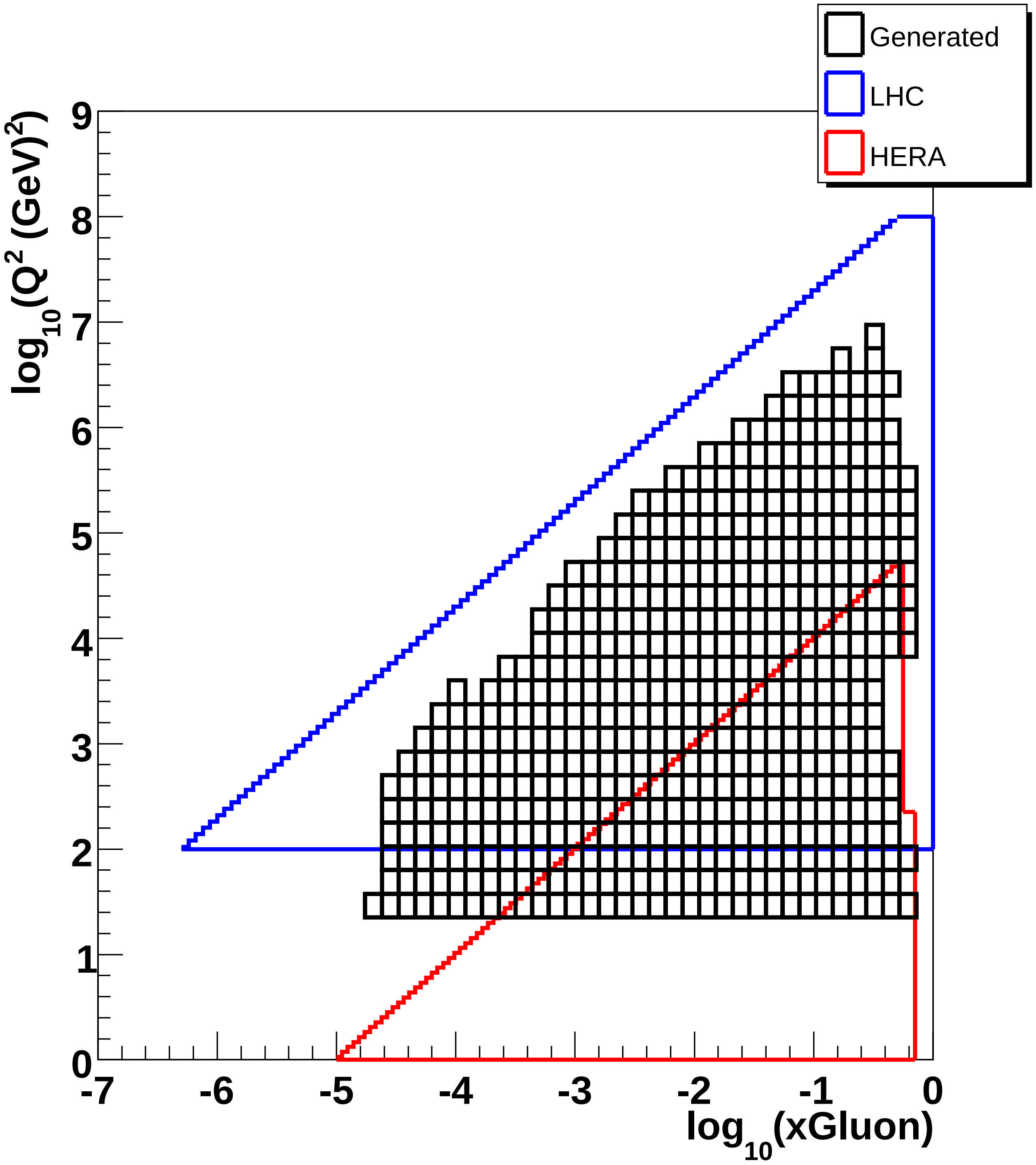
Left:
CTEQ6M
$Q^2=100$
Gluon
Down
Up

$p_T>5$ GeV



$p_T>100$GeV



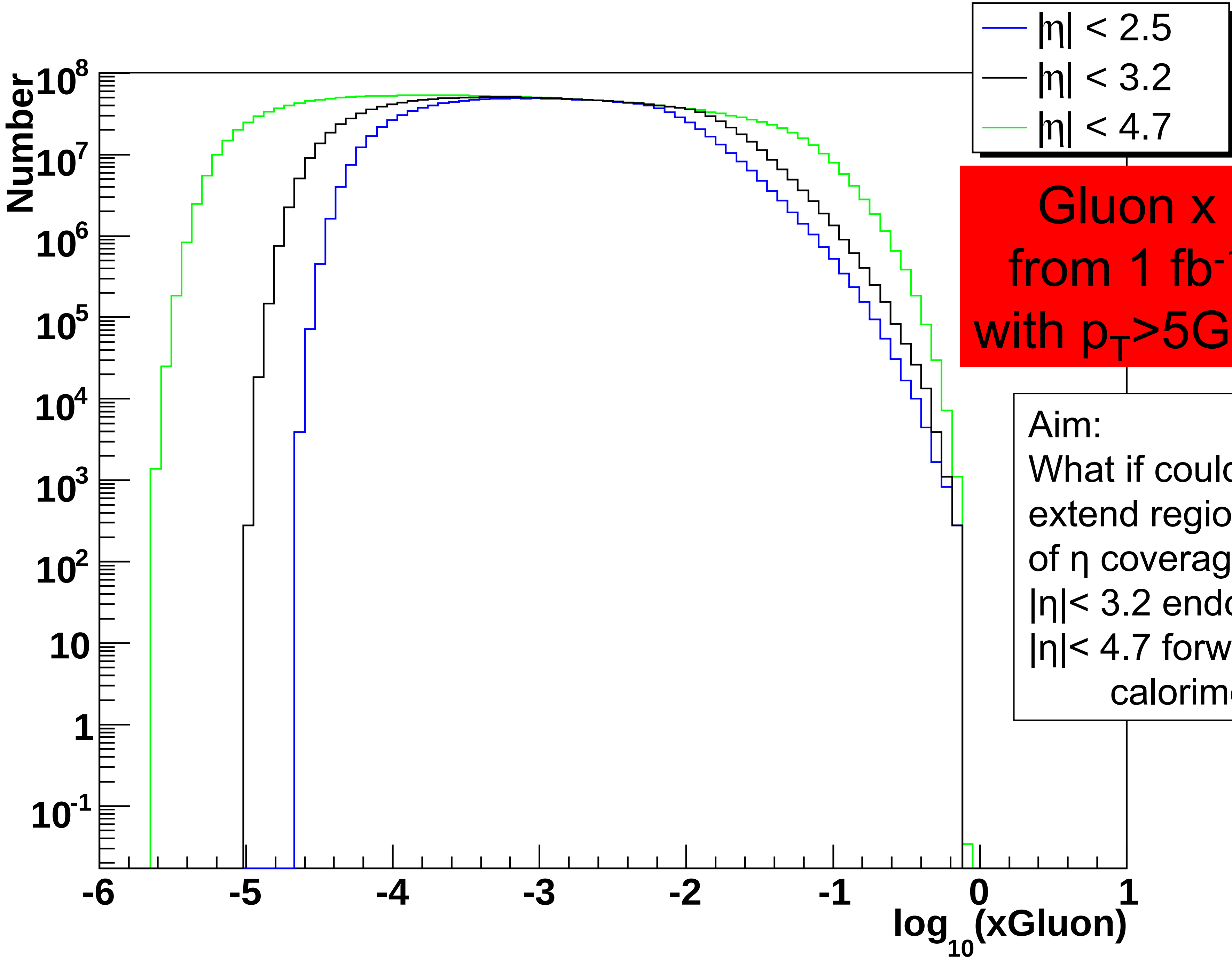


For $\eta<2.5$, $p_T>5$GeV

Conclusions:

- Covers a wide range of x for a large range of Q^2.
- Most of this area has not been observed before
- Low x region $x<\sim10^{-4}$ accessed at scales where perturbative QCD is clearly applicable for the first time

ATLAS Experiment

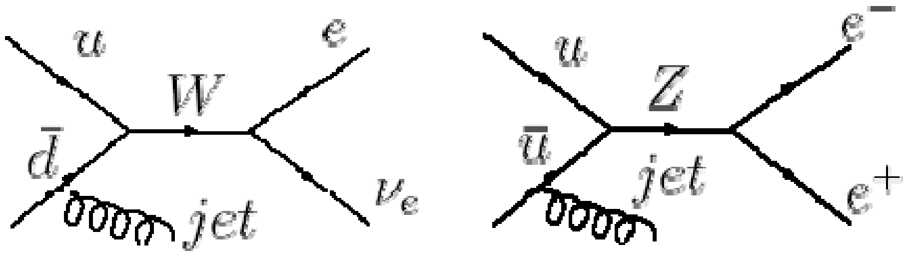


Gluon x from 1 fb^{-1} with p_T>5GeV

Aim:
What if could extend region of η coverage?
|η|< 3.2 endcap
|η|< 4.7 forward calorimeter

Looking at 2.5<η<3.2

- Don't have tracking so cant determine if electron or γ
- How big are electron + jet cross sections?



- If so could cut on miss Et size, secondary e, topology
- Will trigger but on single jet trigger (prescaled at low p_T)
- Background would still be hadron-> γγ
- Sampling 0.1x0.1 in ηxΦ, 2 layers
  - Is this enough to resolve shower shape?

What's Next: AOD analysis

- Use photon jet and jet jet AOD samples
- Look at resolution of variables to reconstruct
- Find values of x and how best to reconstruct x
- Investigate isolation cuts on signal
- Look at topology of γ and jet

AOD details

Data Set Number	Pt range (GeV)
N/A	8-17
8095	17-35
8096	35-70
8097	70-140
8098	140-280
8099	280-560
8078	560-1120

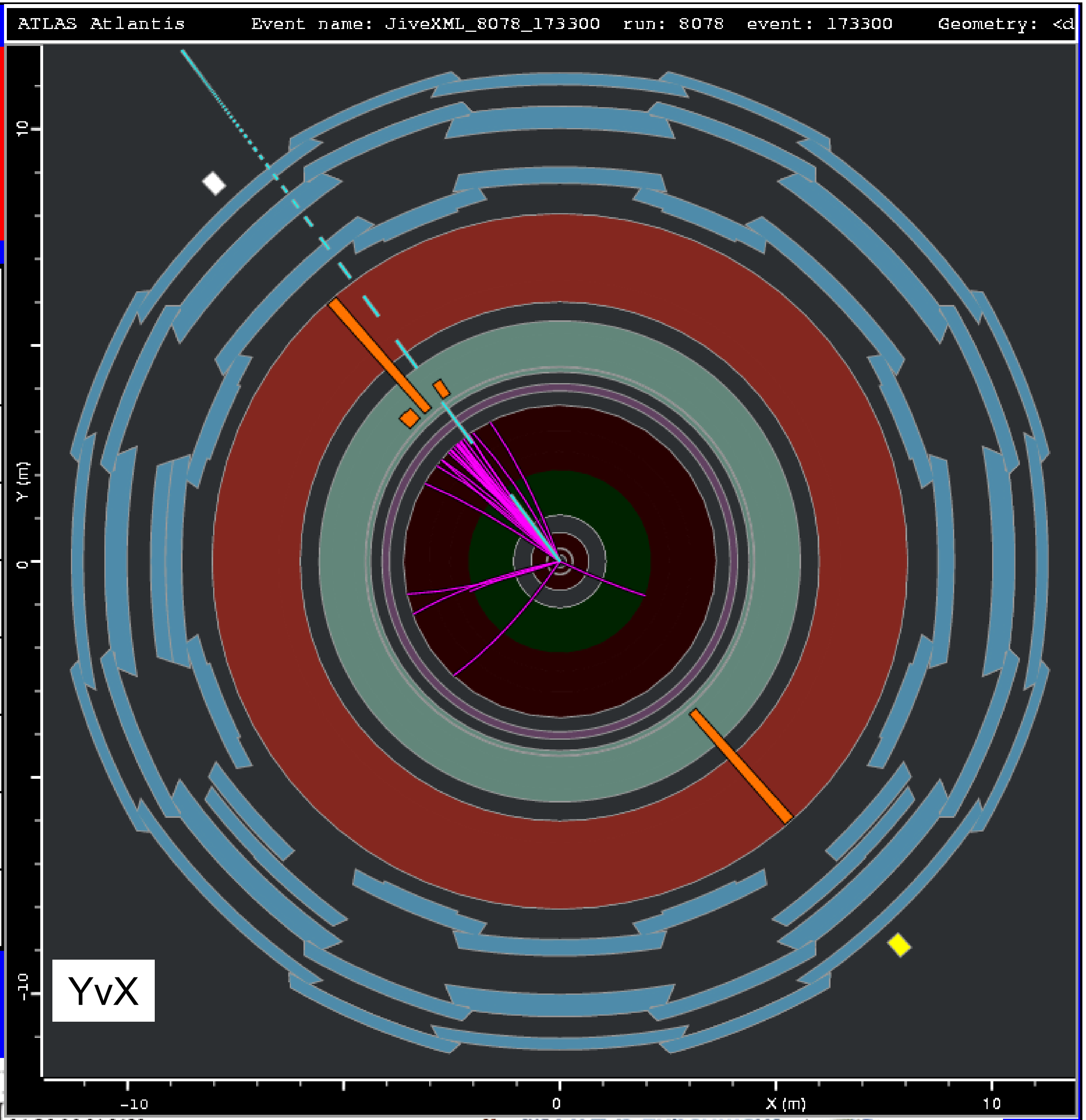


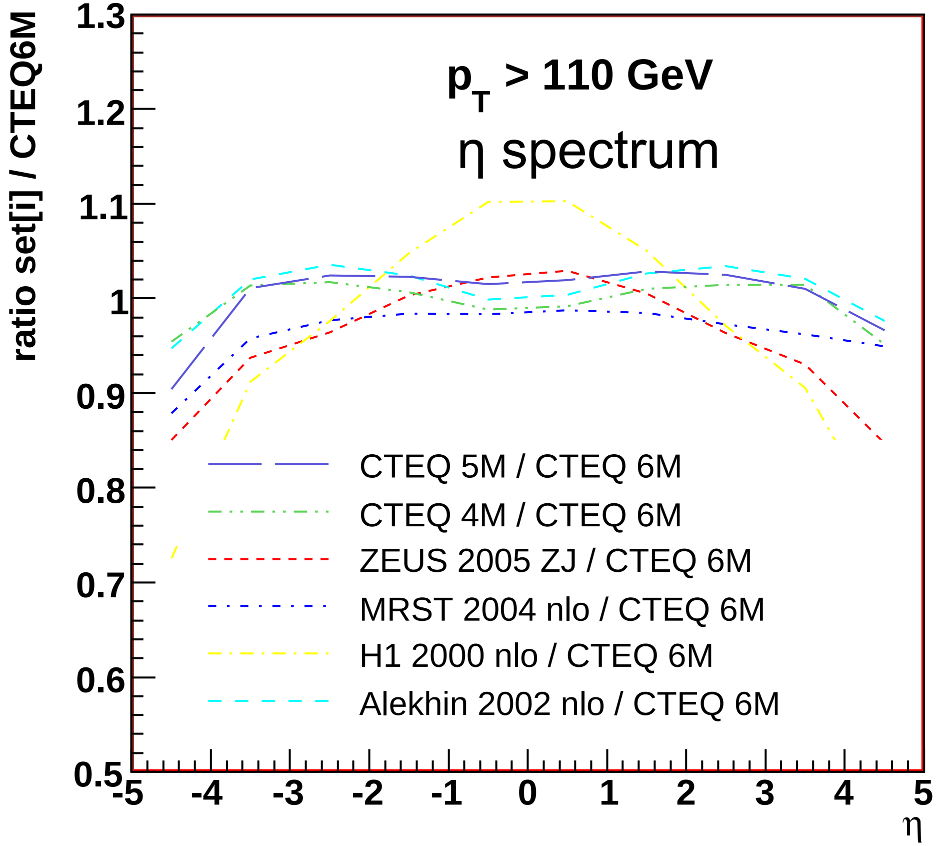
Image from 8078 set

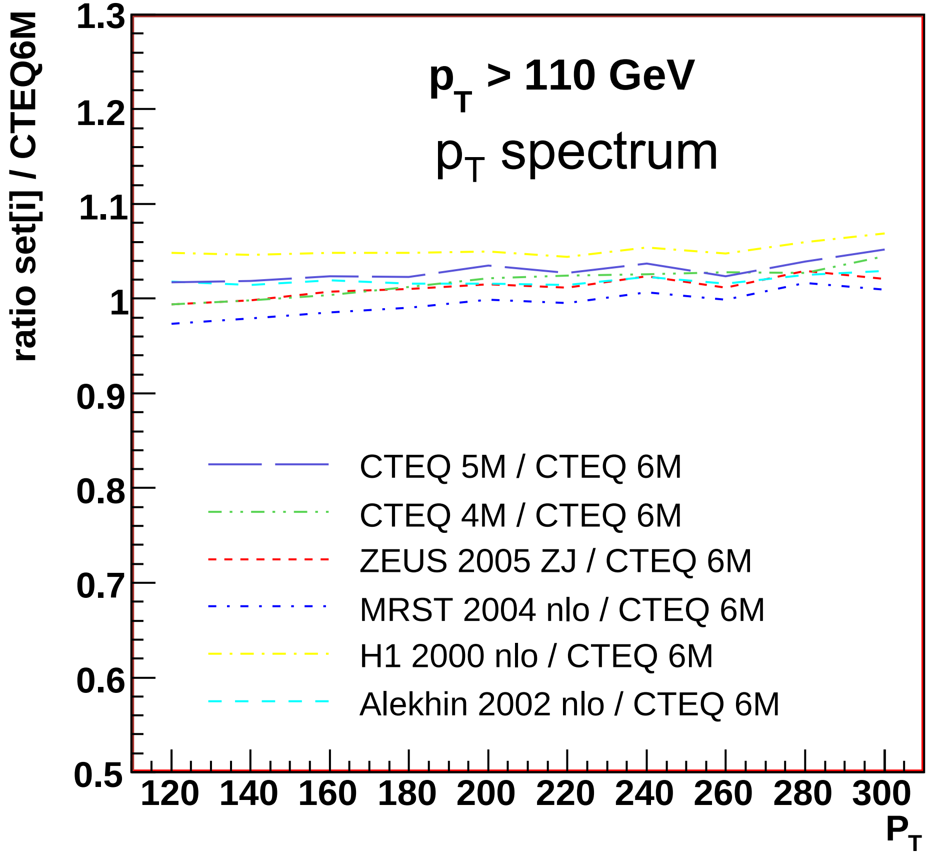
Summary

- Have looked at the usefulness of direct photons in probing the gluon x distribution
- Have compared the direct photon cross section to its main background
- Future:
    - AOD analysis
    - Want to improve work done previously with updated models and hopefully real data
    - Add early conversion σ method into photon id
    - Work on usefulness of the channel in calibration and new physics

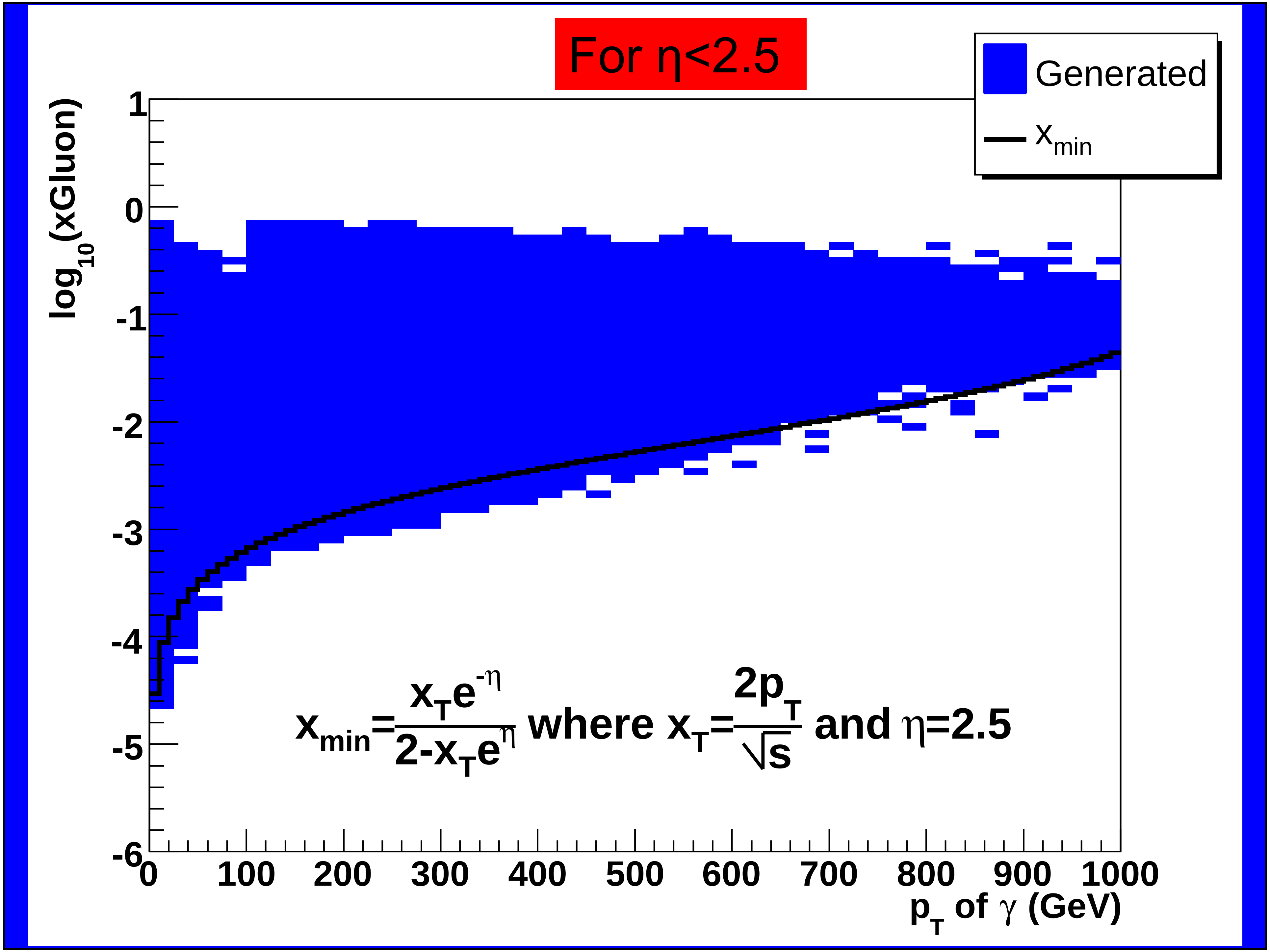
Backup slides

γjet cross section ratios





5-10% measurements look interesting on η spectrum, p_T distribution less useful



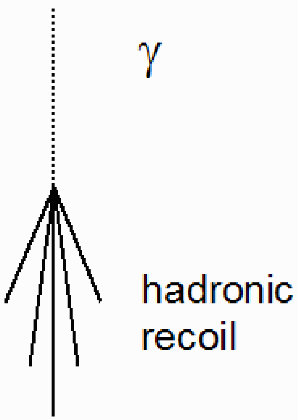
For η<2.5
Generated
x_{min}
$\log_{10}$(xGluon)
1
0
-1
-2
-3
-4
-5
-6
0
100
200
300
400
500
600
700
800
900
1000
$x_{min}=\frac{x_T e^{-\eta}}{2-x_T e^{\eta}}$ where $x_T=\frac{2p_T}{\sqrt{s}}$ and $\eta=2.5$
p_T of γ (GeV)

Some open questions:

- What is the best way to define my σ?
  - What is signal and what is background?
- NLO modeling
- Is p_T the best choice of scale?
- Sensitivity to low x dynamics
  - Alternative MC's
- Interest in increasing $|\eta|$ coverage
- Exotic searches

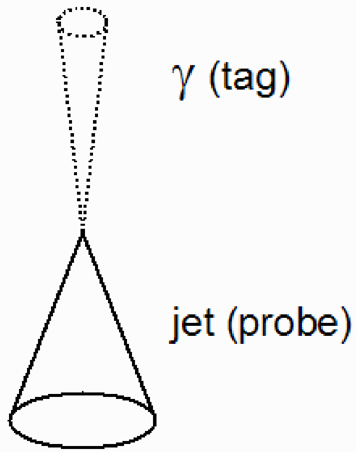
Missing E_T Projection Fraction Method: γ+jet

Particle Level



$$\vec{p}_{T,\gamma} + \vec{p}_{T,had} = \vec{0}$$

Detector Level



$$\vec{p}_{T,\gamma} + R_{had}\vec{p}_{T,had} = -\vec{\not{E}}_T$$

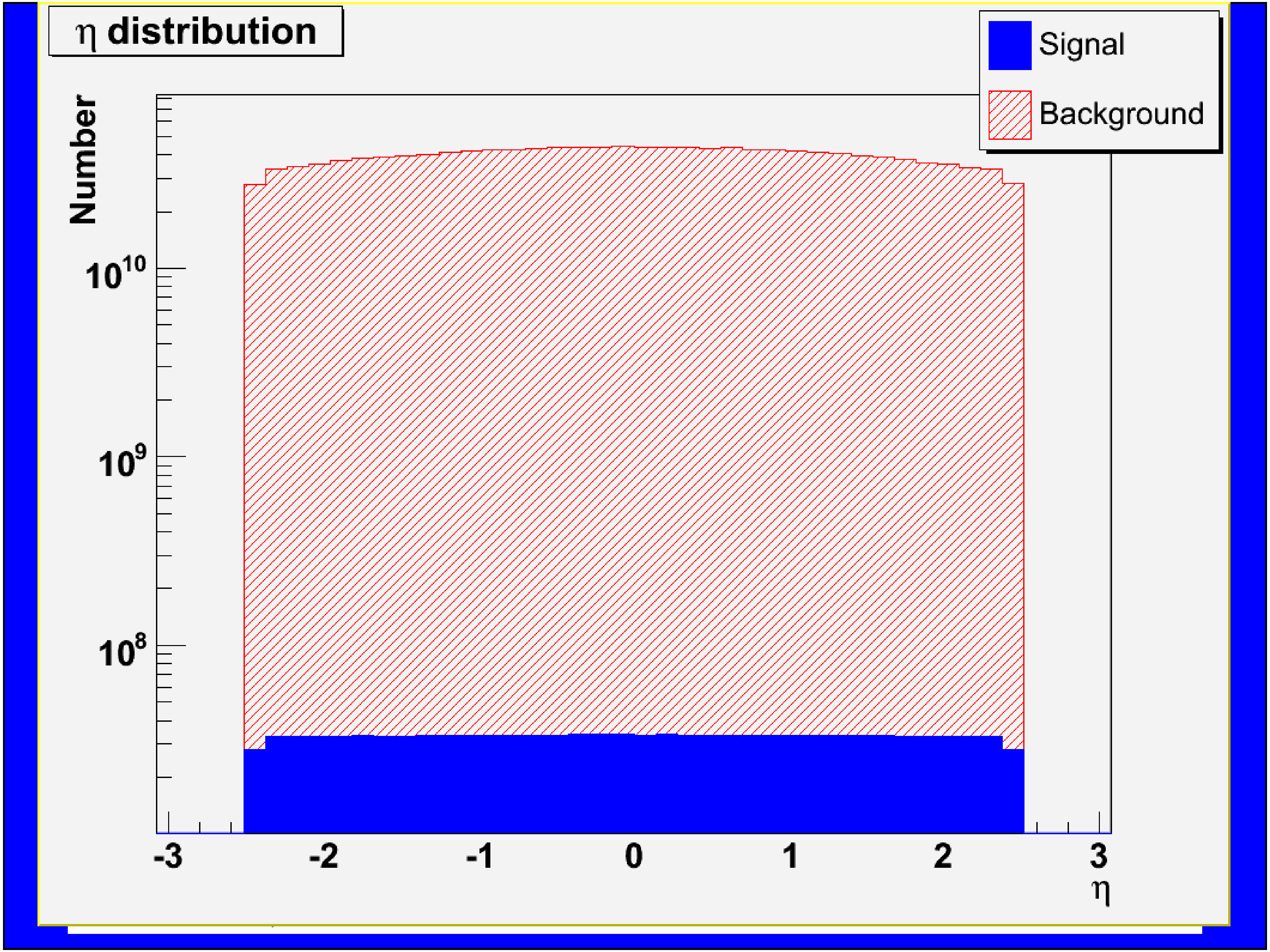
$$R_{had} = 1 + \frac{\vec{\not{E}}_T \cdot \vec{p}_{T,\gamma}}{\vec{p}^{\,2}_{T,\gamma}}$$

For back - to - back events : $R_{jet} \approx R_{had}$

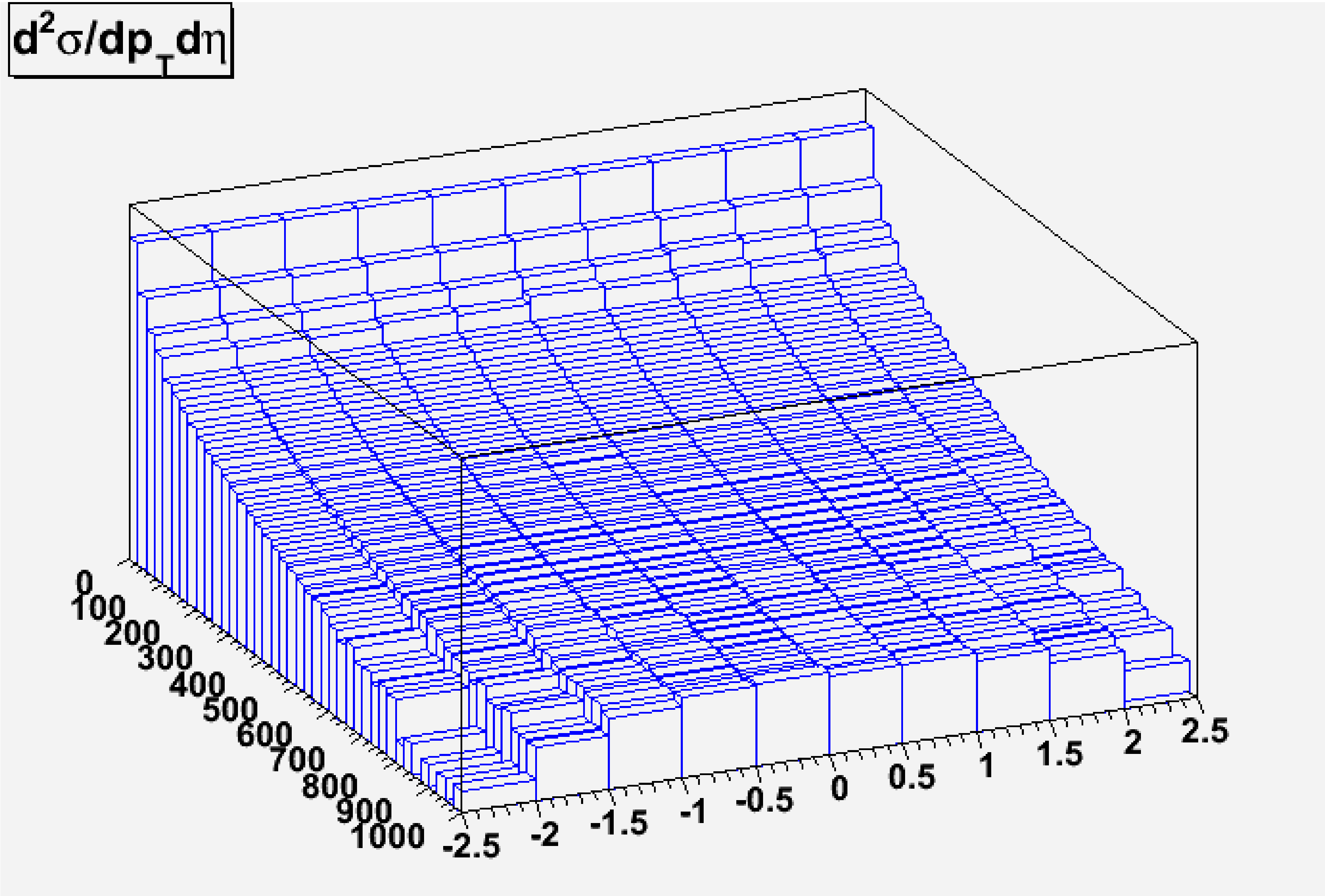
http://www-d0.fnal.gov/phys_id/jes/public/plots_v7.1/mpf_method.gif

Delayed photons

- From Searches in Photon and Jet States A.Soha
- arXiv:0706.2999v1 [hep-ex] 20 June 2007
- Photons delayed w.r.t. primary interaction
- Could stem from decays of heavy, nuetral long-lived particles, eg GMSB scenario $\tilde{\chi}_1^0 \rightarrow \gamma\tilde{G}$
- Signal is photons + missEt + jet
- Where photons have time of arrival 2<t<10ns
- Backgrounds beam halo, cosmic rays and direct photons

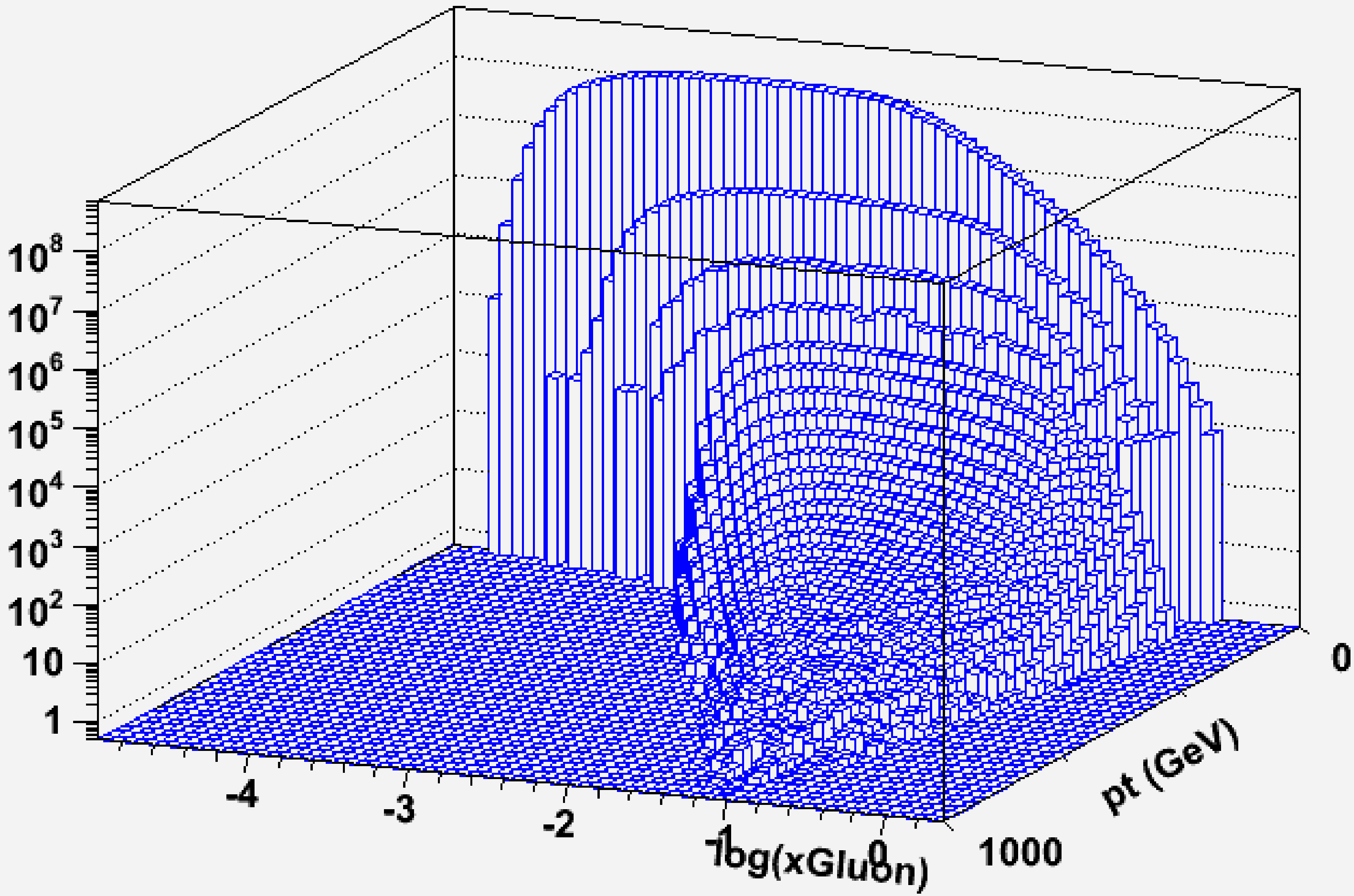


η distribution
Signal
Background
Number
10^{10}
10^{9}
10^{8}
-3
-2
-1
0
1
2
3
η



$d^2\sigma/dp_T d\eta$
0
100
200
300
400
500
600
700
800
900
1000
-2.5
-2
-1.5
-1
-0.5
0
0.5
1
1.5
2
2.5

logxGluon v pt



NLO

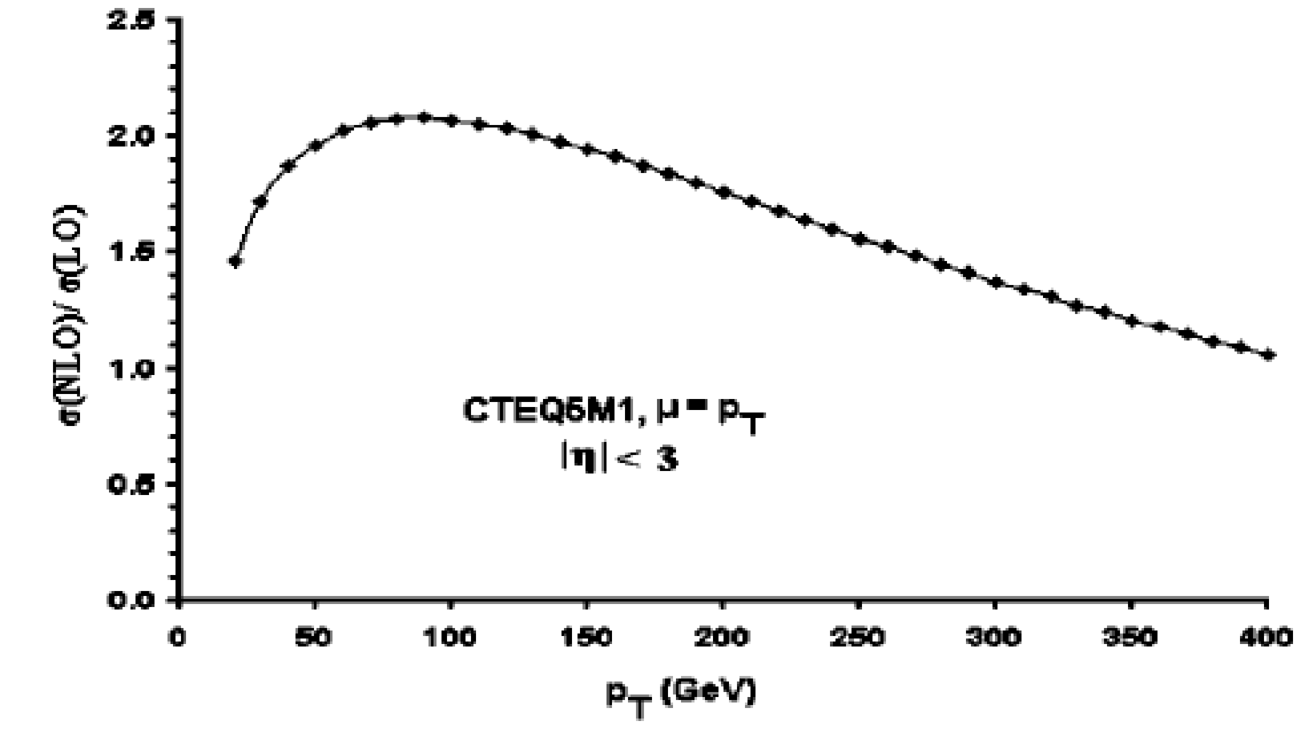


Image from:
Study of direct photon production at the CERN LHC
Kumar et Al
Phys. Rev. D 67, 014016 (2003)

Next-to-leading-logarithm calculation of direct photon production
H. Baer, J. Ohnemus, and J. F. Owens Phys. Rev. D 42, 61 - 71 (1990)

Jet trigger

Proposal for Trigger Menu for Jets for L = 10^31

Notation: PS = Prescale, PT = PassThrough, All rates shown in Hz.

	Level 1				Level 2		Event Filter	
Name	**Raw Rate**	**Prescale**	**Rate**	**Name**	**Prescale**	**Rate**	**Name**	**Rate**
J5	>> 0	1000000	~0	PT	1	~0	PT	~0
J10	45276	42000	1.1	PT	1	1.1	PT	1.1
J18	3880.8	6000	0.65	PT	1	0.65	PT	0.65
J23	3234	2000	1.6	PT	1	1.6	PT	1.6
J35	539	500	1.1	PT	1	1.1	PT	1.1
J42	269.5	50	5.4	PT	1	5.4	PT	5.4
J70	27.3	5	5.5	PT	1	5.5	PT	5.5
J100	8.9	1	8.9	PT	1	8.9	PT	8.9
TOTAL			24.25			24.25		24.25