$H \rightarrow \gamma\gamma$: Updates on Rejection of QCD Reducible Background

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Outline

- Motivation
- Jet rejection steps for γ+jet samples
- Jet Rejection for gluons and quarks with and without underlying event.

  What's the main point?
- Jet Rejection of underlying event jets vs. jet rejection of matrix element jets.

  What have we learned?

Motivation

- **Finalize** the study on jet rejection for QCD reducible background in the $H \rightarrow \gamma\gamma$ channel for the γ+jet samples.

- Study the effects of switching on and off the underlying event on background samples.

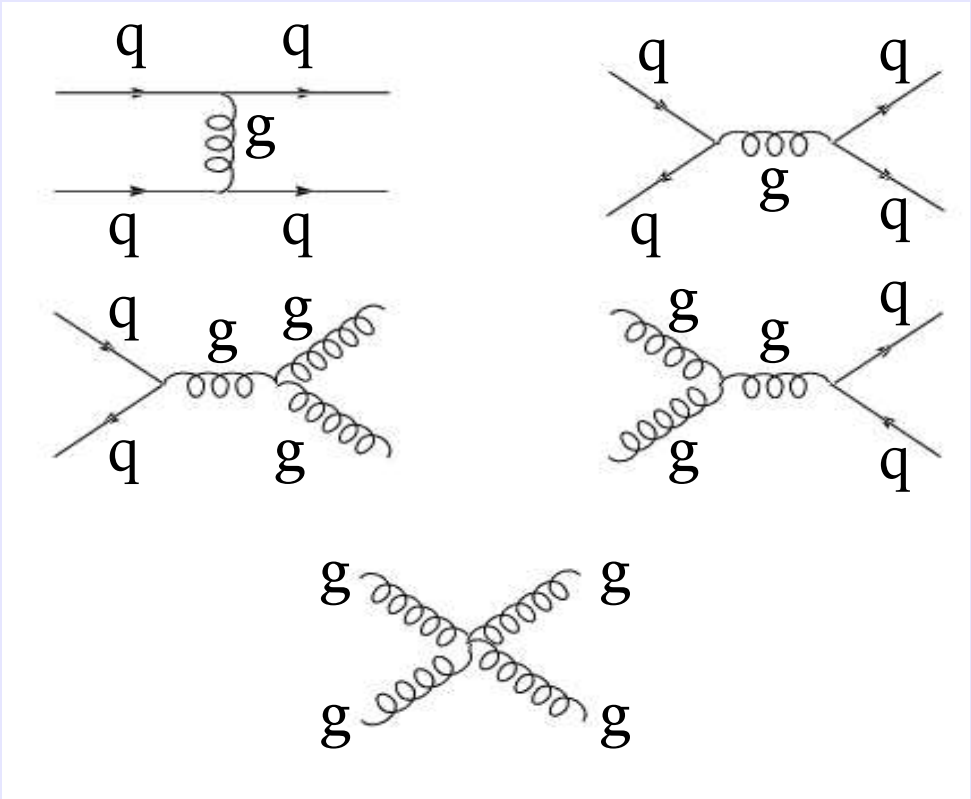
- Previous CDF studies suggest 14% of inelastic ppbar collisions at c.m.e. 1.8 TeV have multiple interactions.

Nice to have:

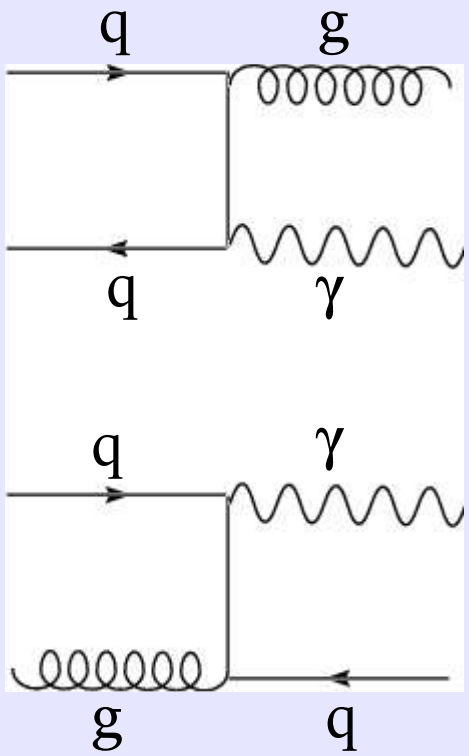
- Re-evaluate the rejection obtained for dijets by:
  - Studying the effects produced by the presence of underlying event or lack thereof.
  - Normalizing to reconstructed jets (if possible).

H-> Reducible Background

Di-Jets



γ-Jet



MC Samples for Background (DC1)

20 GeV Samples

No Noise

higgs.002655.bg_gamma_g.dc1.recon.001._0000.root (776K events)

With Noise and LVL1

higgs.002655.bg_gamma_g.dc1.recon.003._0000.root (776K events)

Without Underlying Event

higgs.002822.bg_gamma_gn.dc1.recon.001._0000.root (45K events)

30GeV Samples

No Noise

higgs.002680.bg_gam30_g.dc1.recon.001._0000.root (241K events)

With Noise and LVL1

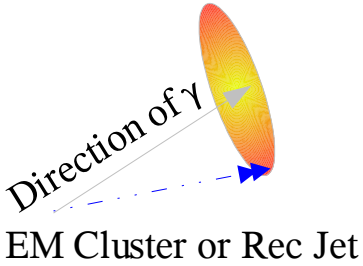
higgs.002680.bg_gam30_g.dc1.recon.003._0000.root (241K events)

Reconstruction done with Offline Release 7.0.2

Gluon/Quark Jet Rejection Steps

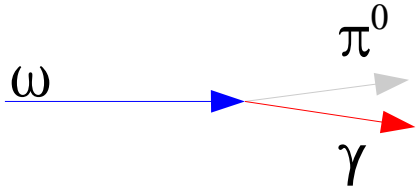
- Identify jets and clusters within fiducial region.
  - $E_T > 24$ GeV for both EM clusters and reconstructed jets.
  - $|\eta| < 2.47$
- Veto photons from the matrix element.

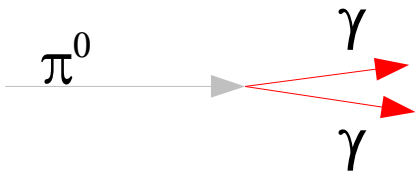
$$\Delta R = ((\Delta\Phi)^2 + (\Delta\eta)^2)^{0.5}$$



$\Delta R_\gamma > 0.15$

- Tag photons coming from π^0 and other decays (i.e., ω decays) but do not veto.





Small ΔR between photons, same ntuple mother.

- Apply offline cuts on EM clusters.
- Calculate rejection.

Cuts Applied to Jets and EM Clusters

Preselection Cuts:

E_T	> 24 GeV
$\|\eta\|$	< 2.47
E_T Truth γ	> 21.5 GeV

Hadronic Cut (EM clusters only):

eg_etha1[i]/eg_et[i] < 0.0425

Second Sampling (EM clusters only):

eg_e237[i]/eg_e277[i] > 0.943
eg_weta2[i] < 0.0113

First Sampling (EM clusters only):

eg_e2tsts1[i]/(1+0.009*eg_et[i]) < 0.22
eg_e2tsts1[i]-eg_emins1[i] < 0.25
eg_fracs1[i] < 0.27
eg_weta1[i] < 0.7
eg_wtots1[i] < 2.8

Definitions of Rejection

$$\textbf{RejectionI} := \frac{\text{Number of Reconstructed or AtlFastB Jets within } E_T \text{ and } \Delta R\gamma > 0.15}{\text{Number of EM clusters surviving all cuts and } \Delta R\gamma > 0.15}$$

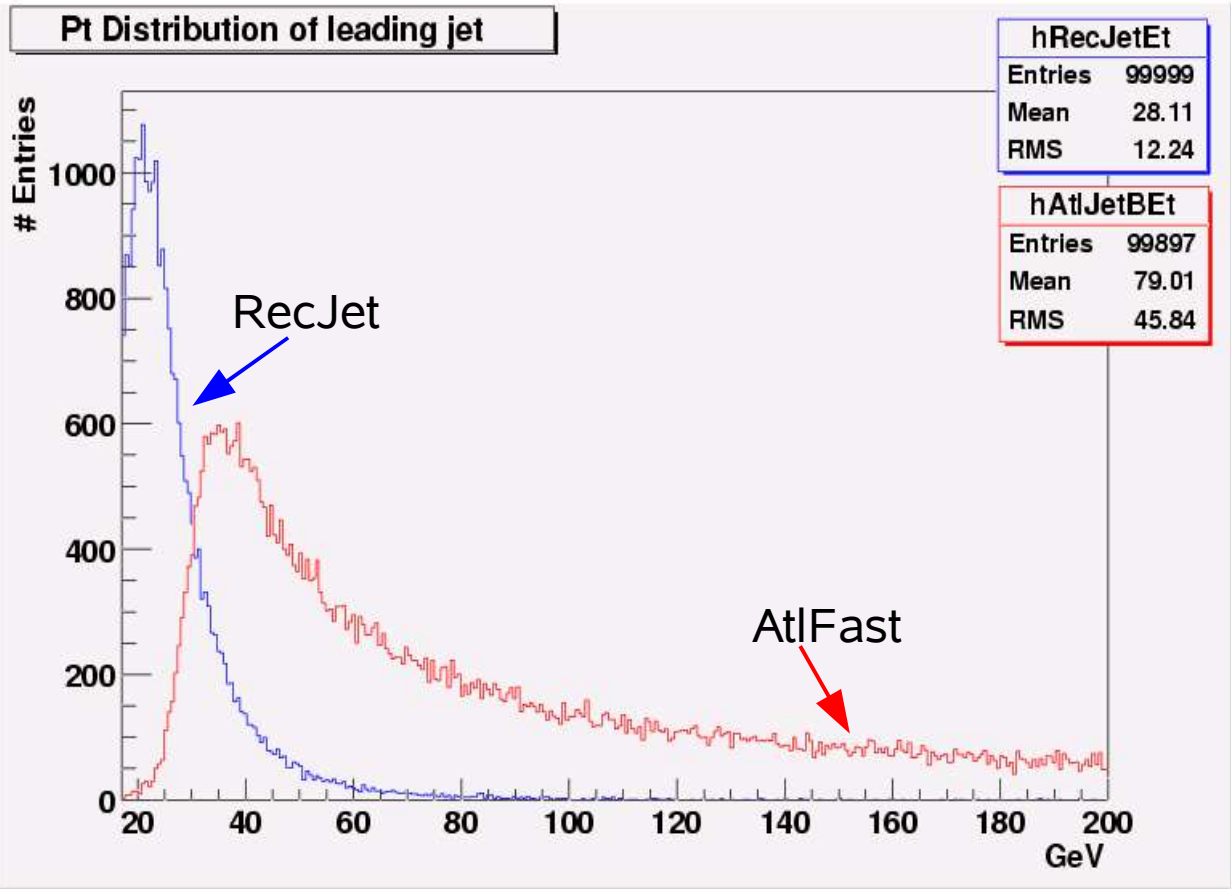
$$\textbf{RejectionII} := \frac{\text{Number of Reconstructed or AtlFastB Jets within } E_T \text{ and } \Delta R\gamma > 0.15}{\text{Number of EM clusters surviving all cuts \& } \Delta R\gamma > 0.15 \text{ matching a jet irrespective of } E_T\text{Jet}}$$

$$\textbf{RejectionIII:} = \frac{\text{Total Number of Events}}{\text{Number of events surviving all cuts*}}$$

* Number of events surviving ~ Number of Clusters surviving

Jet P_T Distributions

qg->q+γ sample



- Substantial differences can be observed in the P_T distributions of the jets(for both samples).
- Reconstructed jets present a more realistic distribution of this background.
- AtlFast (uncorrected jets) display similar results to corrected ones (B).

Gluon Rejection Results

Photon/Gluon Jet Samples $\lvert\eta\rvert < 2.47$		Initial Number of Jets within acceptance (not photons)	Initial Number of EM clusters within acceptance (not photons)	EM Clusters After EM Calorimeter Cuts			Rejection I
				Hadronic	2nd Sampling	1st Sampling	
Reconstructed Jets (776K events) No Noise	24-3000 GeV	639593	8536	2631	260	52	12300 (1700)
Reconstructed Jets (100K events) Noise	24-3000 GeV	Not Available					

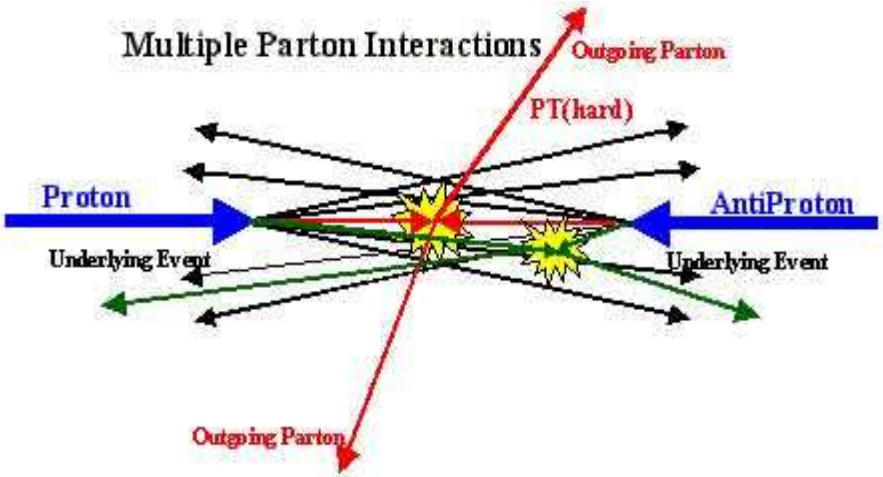
Quark Rejection Results

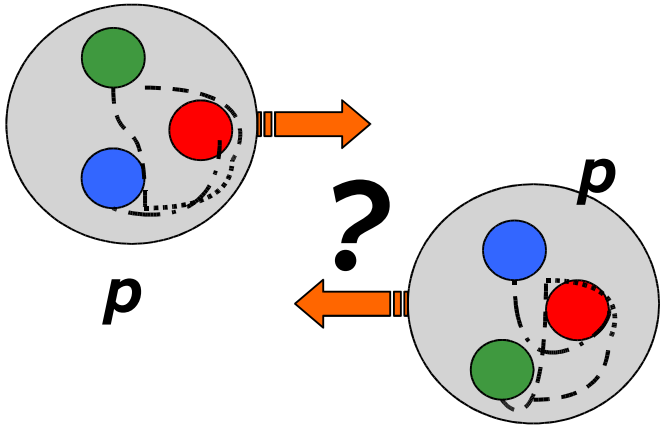
Photon/Quark Jet Samples $\lvert\eta\rvert < 2.47$		Initial Number of Jets within acceptance (not photons)	Initial Number of EM clusters within acceptance (not photons)	EM Clusters After EM Calorimeter Cuts			Rejection I
				Hadronic	2nd Sampling	1st Sampling	
Reconstructed Jets (185K events) No Noise	24-3000 GeV	286398	4489	1764	229	45	4200 (600)
Reconstructed Jets (100K events) Noise	24-3000 GeV	Not Available					

Underlying Event...

Who needs it anyway?

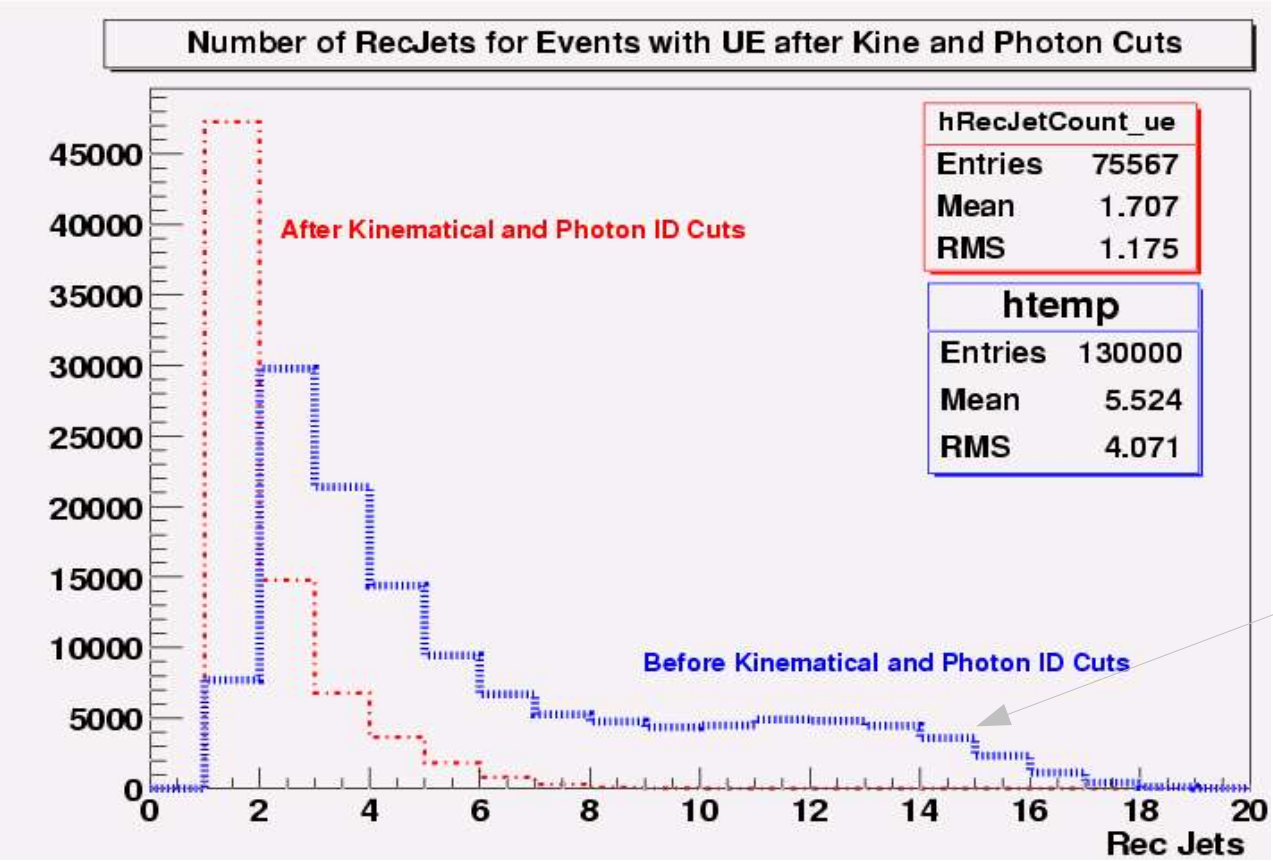
Underlying Event





- **It is not** only minimum bias events!
- Underlying event is everything **except** the two outgoing hard scattered jets.
- In hard scattering processes, the underlying event has a **hard** component (ISR + FSR and particles from the outgoing hard scattered partons) and a **soft** component (beam-beam remnants).
- Underlying event augments the multiplicity of charged hadrons and photons as well.
- Secondary collisions (multiple interactions) occur at lower P_T amongst remaining partons.

Underlying Event: Jet Multiplicity



Kinematical Cuts:

E_T RecJets > 24 GeV

$|\eta| < 2.47$

Photon ID Cuts :

$\Delta R_\gamma > 0.15$

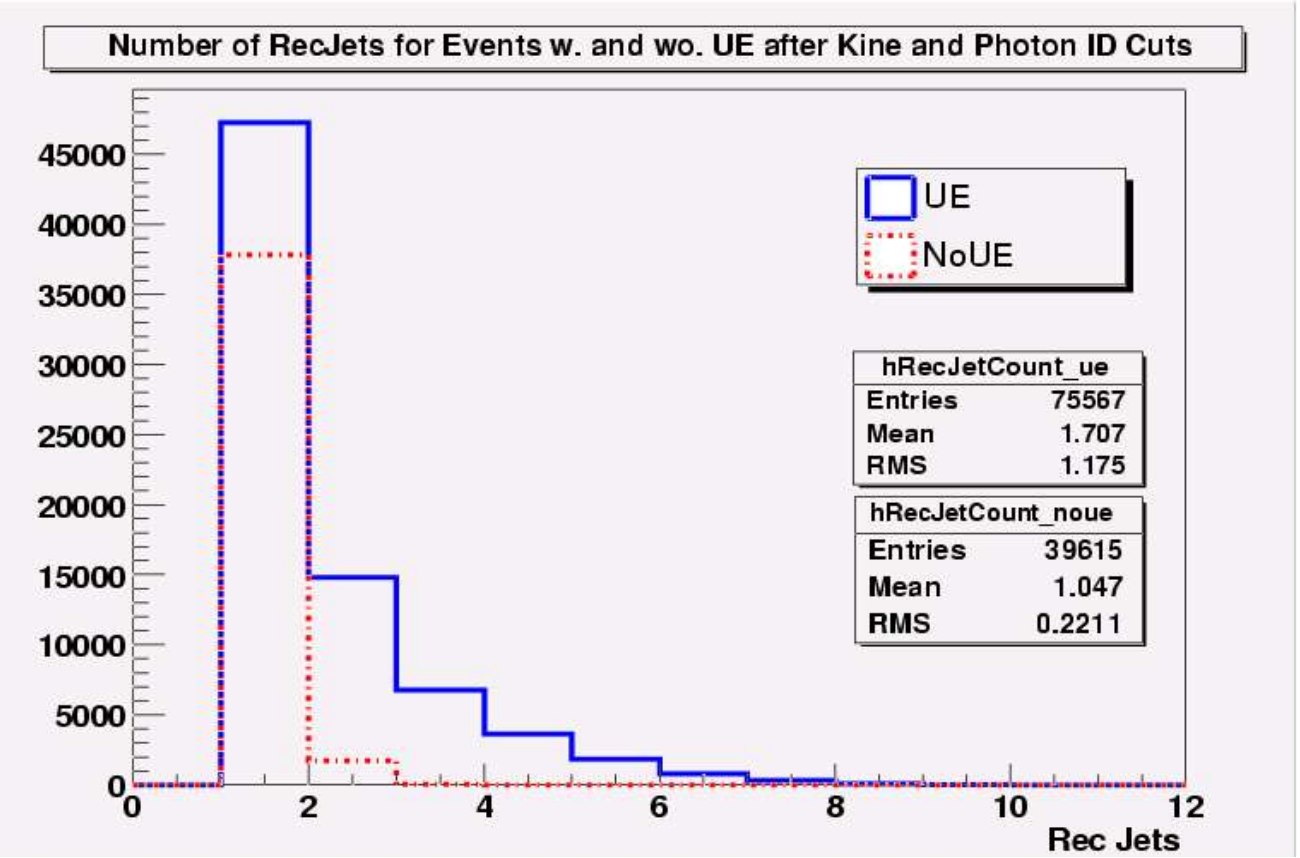
Higher Multiplicity;
low P_T jets due to U.E.

Entire reconstructed jet sample.
$P_T > 3$ GeV

Underlying Event: Jet Multiplicity (cont.)

Observe the higher multiplicity of reconstructed Jets in blue sample w.r.t. the red sample.

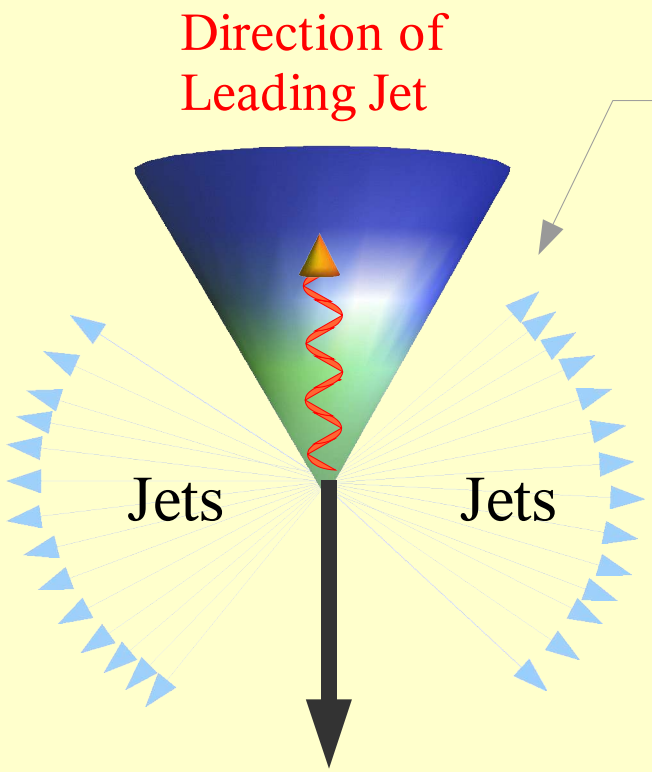
Underlying event has not yet been removed from blue sample.



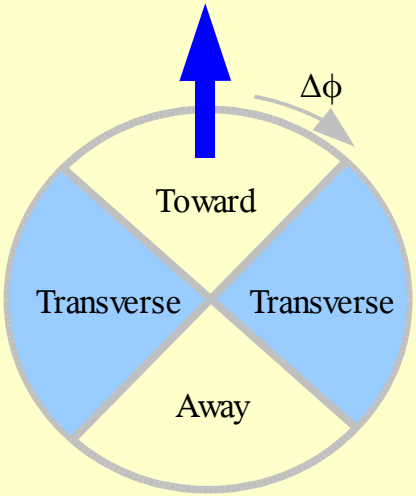
Definition of ΔΦ

Leading Jet can be:

M.E. photon (Truth table)
M.E. gluon (Truth table)
Highest P_T jet from reconstructed block



The "Transverse Region" is perpendicular to the plane of the 2-to-2 scattering and is very sensitive to the "ue" component of the QCD MonteCarlo models.



$$\Delta\phi = |\,\phi_{\text{Rec Object}} - \phi_{\text{Truth Object}}\,|$$

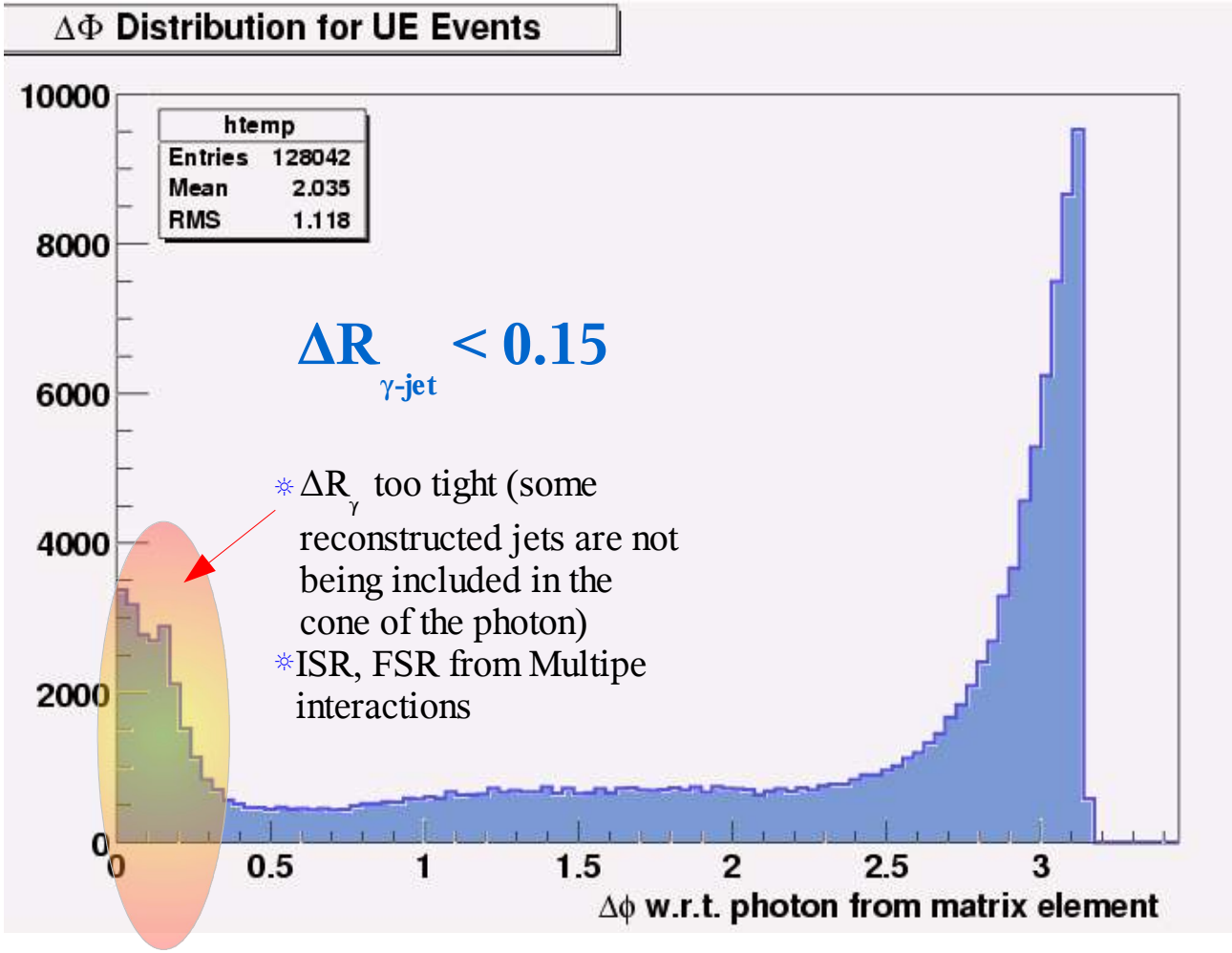
$\phi = 0$ is defined as the ϕ of the leading jet.

ΔΦ Distribution of Rec Jet w.r.t. Photon*

*True Photon from matrix element.

U.E. Region
$0.5 < \Delta\phi < 2.1$

Outside U.E. Region
$2.1\ (2.5) < \Delta\phi$
$\Delta\phi < 0.5$

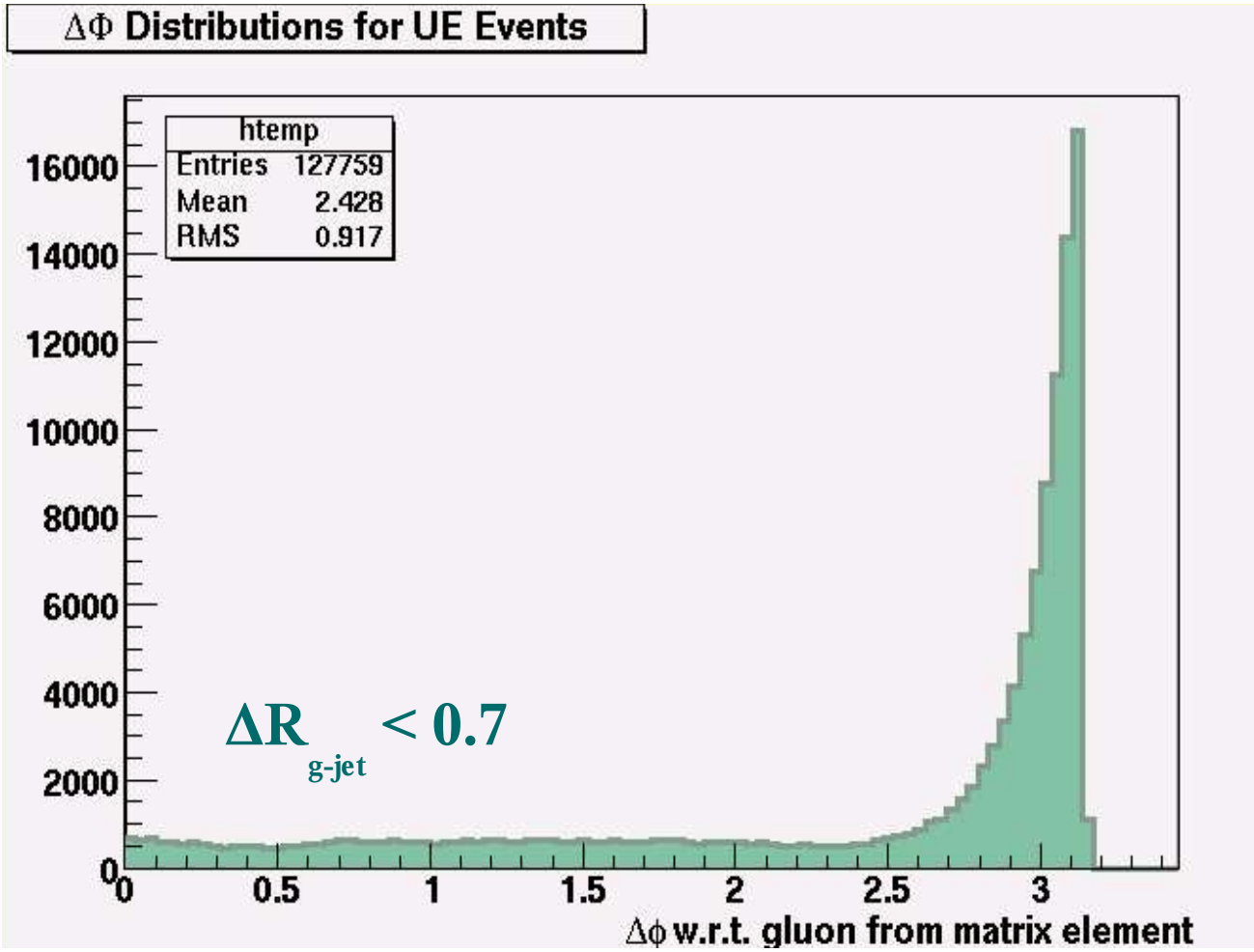


ΔΦ Distribution of Rec Jets w.r.t. Gluon*

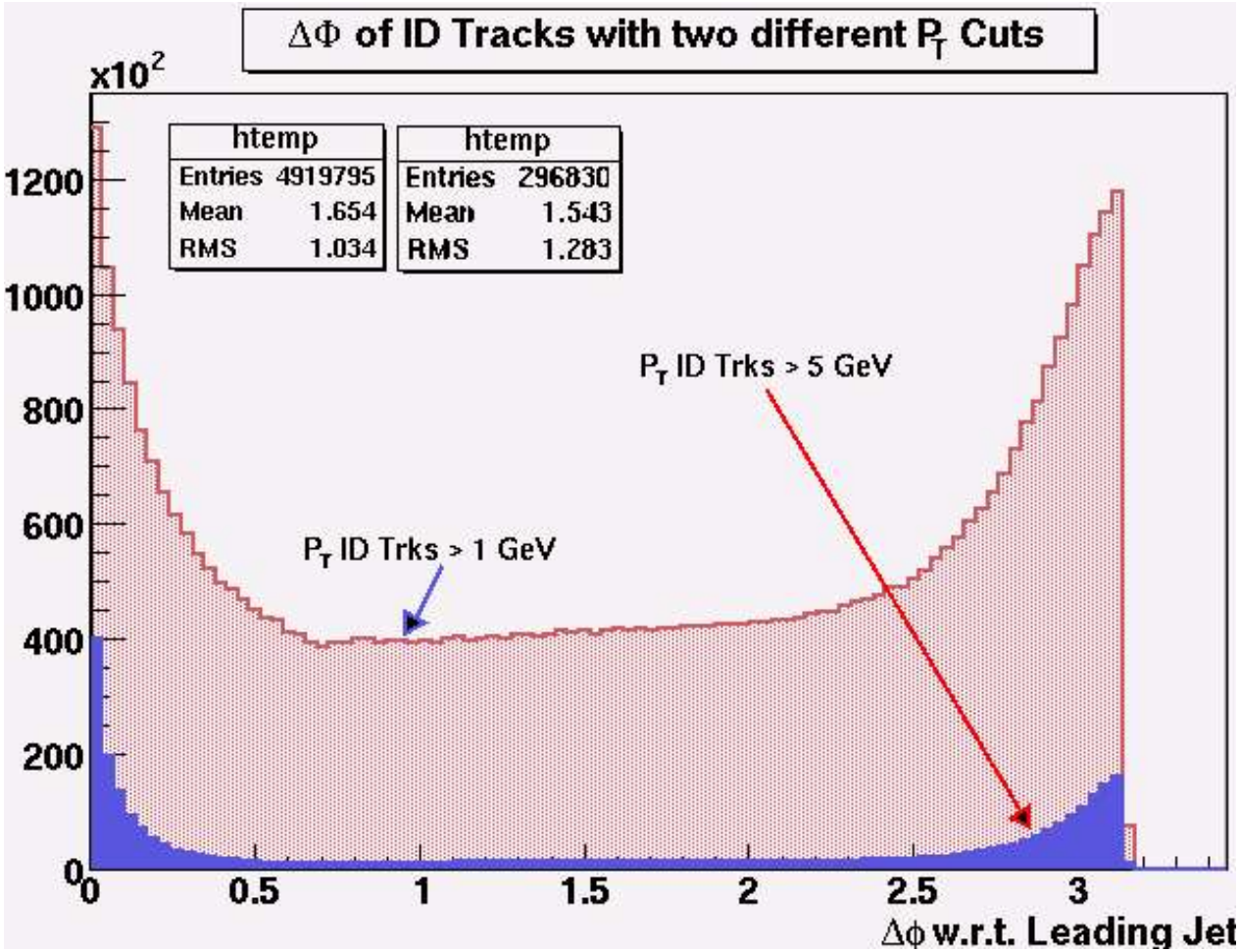
*True Gluon from matrix element.

U.E. Region
$0.5 < \Delta\phi < 2.1$

Outside U.E. Region
$2.1\ (2.5) < \Delta\phi$
$\Delta\phi < 0.5$



ΔΦ Distribution ID Tracks w.r.t. Leading Jet



Used CDF Method

U.E. Region
$0.7 < \Delta\phi < 2.1$

Outside U.E. Region
$2.1 < \Delta\phi$
$\Delta\phi < 0.7$

Gluon Rejection Results (with and without underlying event)

Photon/Gluon Jet Samples $\lvert\eta\rvert < 2.47$		Initial Number of Jets within acceptance (not photons)	Initial Number of EM clusters within acceptance (not photons)	EM Clusters After EM Calorimeter Cuts			Rejection I
				Hadronic	2nd Sampling	1st Sampling	
Reconstructed Jets (776K events) No Noise with UE	24-3000 GeV	639593	8536	2631	260	52	12300 (1700)
Reconstructed Jets (776K events) UE Region	24-3000 GeV	n/a					23700 (16800)
Reconstructed Jets (776K events) Outside UE Region (Matrix Element Jet)	24-3000 GeV	n/a					11500 (2200)
Reconstructed Jets (130K events) No Noise without UE	24-3000 GeV	41201	1344	370	29	7	5900 (2200)

Note: Two different ntuple sources are used.

Quark Rejection Results (with and without underlying event)

Photon/Quark Jet Samples $\lvert\eta\rvert < 2.47$		Initial Number of Jets within acceptance (not photons)	Initial Number of EM clusters within acceptance (not photons)	EM Clusters After EM Calorimeter Cuts			Rejection I
				Hadronic	2nd Sampling	1st Sampling	
Reconstructed Jets (185K events) No Noise with UE	24-3000 GeV	188775	4489	1764	229	45	4200 (600)
Reconstructed Jets (185K events) UE Region	24-3000 GeV	n/a					10000 (4900)
Reconstructed Jets (185K events) Outside UE Region (Matrix Element Jet)	24-3000 GeV	n/a					4000 (600)
Reconstructed Jets (48K events) No Noise without UE	24-3000 GeV	22099	1131	439	50	8	2800 (900)

Note: Two different ntuple sources are used.

Results

- Rejection for photon+jet and dijet samples stands as follows:

  - $R_{\gamma+g} = 12300 \pm 1700$ (with ue)
  - $R_{\gamma+g} = 5900 \pm 2200$ (without ue)
  - $R_{\gamma+g} = 11500 \pm 2200$ (matrix element jet)
  - $R_{\gamma+g} = 23700 \pm 16800$ (ue jet)
  - $R_{\gamma+q} = 4200 \pm 600$ (with ue)
  - $R_{\gamma+q} = 2800 \pm 900$ (without ue)
  - $R_{\gamma+q} = 4000 \pm 600$ (matrix element jet)
  - $R_{\gamma+q} = 10000 \pm 4900$ (ue jet)
  - $R_{Dijets} = 1254 \pm 46$ (with ue)

Conclusions & Plans

- $\Delta\phi$ cut effectively removes the majority of reconstructed objects (i.e. Rec jets , EM clusters) associated with an underlying event.
- Results are consistent (within error) amongst samples.
- Preliminary studies (not presented today) show high efficiency of $\Delta\phi$ cut in the inclusive $H \rightarrow \gamma\gamma$ analysis; however, things become more complicated in the $H \rightarrow \gamma\gamma$+ jet channel.
- Need to verify rejection results with samples containing noise (results will be included in note).
- Calculate jet rejection using CDF approach.