Summary W/Z + Jets Analyses

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Aim and Motivations

- Work of the W/Z + jets Csc Note Group
- **Goal**:

  Measure W/Z+jets cross section in function of Jet Multiplicity and Leading Jet Pt

- **Why?**
  - SM benchmark (test of perturbative QCD)
  - Background to Higgs searches + Beyond SM Physics
- Look at electron and muon decay channel: $Z \to ee, Z \to \mu\mu$ $W \to e\nu, W \to \mu\nu$
- No complete draft available yet, will present the most finalized analyses

Datasets

- **Signal Samples :**

Alpgen+ Herwig (Athena v. 12)

Sample	Process
6101-6106	$W \rightarrow e\ \nu$ + Np*
6107-6112	$W \rightarrow \mu\nu$ + Np
8130-8135	$Z \rightarrow e\, e$ + Np
8142-8147	$Z \rightarrow \mu\mu$ + Np

* Np = N partons (0 to 5)

Generator Filter:

Leptons: N ⩾1(W)/ 2(Z), Pt >10 GeV

Jets: N ⩾1, Pt >20 GeV

- **Others (Bkg , Systematics):**

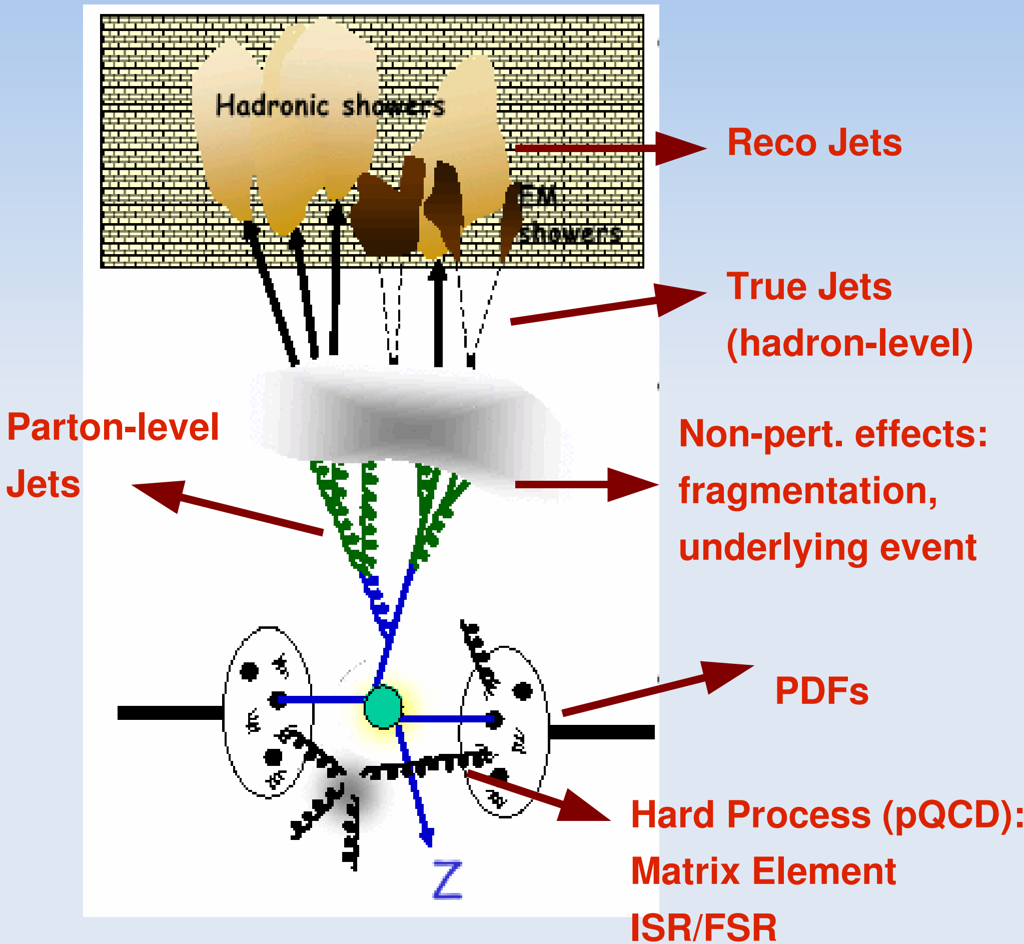
Pythia (Athena v. 12)

Sample	Process
5802	JF17 (Filtered Dijets)
5568	ttbar
5144	$Z \rightarrow ee$
5145	$Z \rightarrow \mu\mu$
5146	$Z \rightarrow \tau\tau$
5104	$W \rightarrow e\ \nu$
5105	$W \rightarrow \mu\ \nu$

For the analysis we use custom ntuples produced at RAL:

- Common Athena Ntuples for Physics Analysis
- SpartyJet Ntuples for study of different jet algorithms

Outline



Many topics covered by the group:

- **Detector effects** in high multiplicity environment:
  - **leptons**: ID/trigger/reco eff., background
    - electrons: RAL/Oxford
    - muons: IFAE (Barcelona)
    - more background studies: BNL, SLAC, USCS (Santa Cruz)
  - **jet** reconstruction: RAL/Oxford/IFAE
  - comparison of **jet algorithms**: MSU (Michigan) + UCL
- **Systematic uncertainties** (JES, PDFs...): RAL/Oxford/IFAE
- **Unfolding corrections** (parton to hadron level): IFAE

Other studies:

- **Streaming Test**: IFAE
- **Z+ bjets**: Roma

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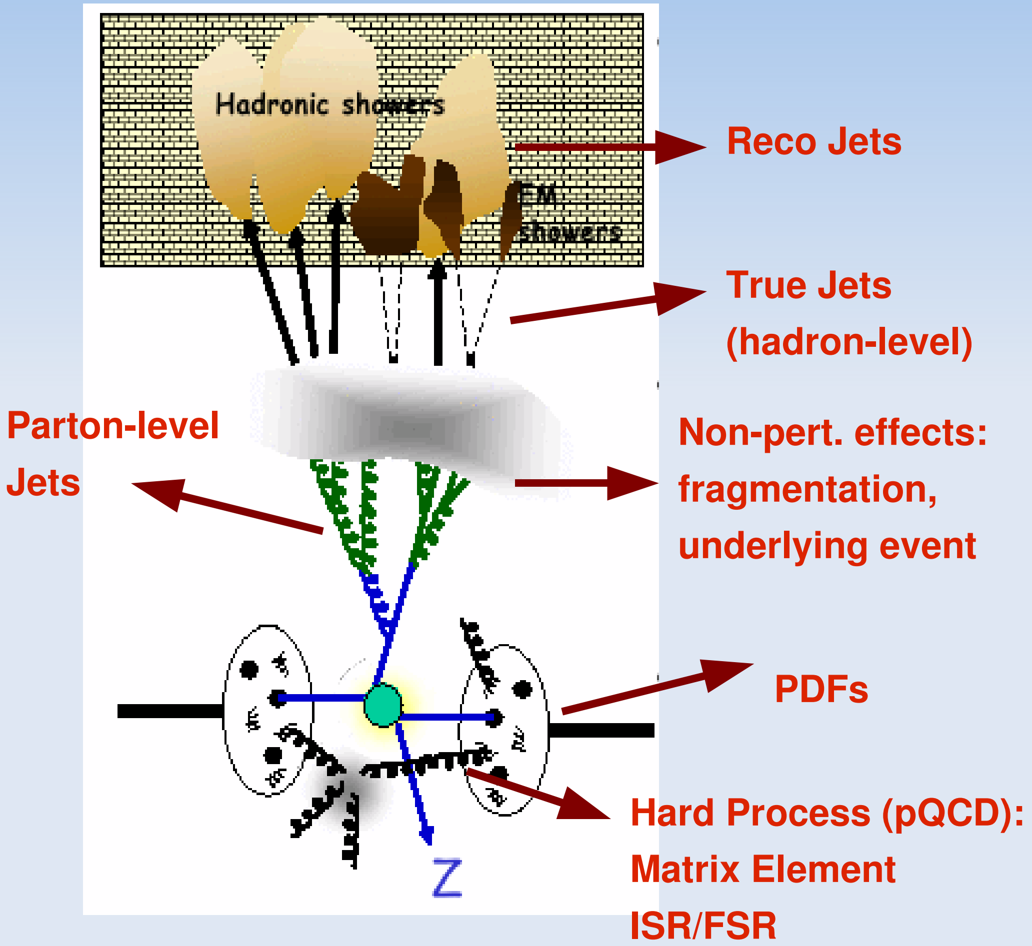

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Selection Cuts

- **Electrons**
  - $p_T^{electron}$> 25 GeV/c
  - Eta cuts
    - $|\eta|<2.4$
    - remove crack region: 1.37-1.52
  - medium isEm
  - $\Delta R_{electron\text{-}jet}>0.4$

- **Muons**
  - $p_T^{muon}>20$ GeV/c
    - 15 GeV/c for Z
  - $|\eta|<2.4$
  - Staco Container
  - Isolation cut
  - $\Delta R_{muon\text{-}jet}>0.4$

- **Jets**
  - main algorithm cone04
  - other algorithms studied for comparison
  - p_T^{jet}> 20 (40) GeV
  - $|\eta|< 5$
    - (although for most plots $|\eta|< 3$)

- **Missing E_T** cut for W
  - 25 GeV/c

Detector Effects (I): Leptons

- Study ID, Trigger, Reconstruction Effiency from **Z+jets**
- What is the effect of a high multiplicity environment? Investigate differential effieciency in:
  - Njets
  - Pt Sum of all Jets
  - Leading Jet Pt
  - DeltaR between lepton and jet
- Comparison to Pythia inclusive sample
- Two approches:
  - **MC method**
  - Data driven method (**Tag&Probe**): here applied on $Z \rightarrow ee$

Tag & Probe:

- to be applied to early data

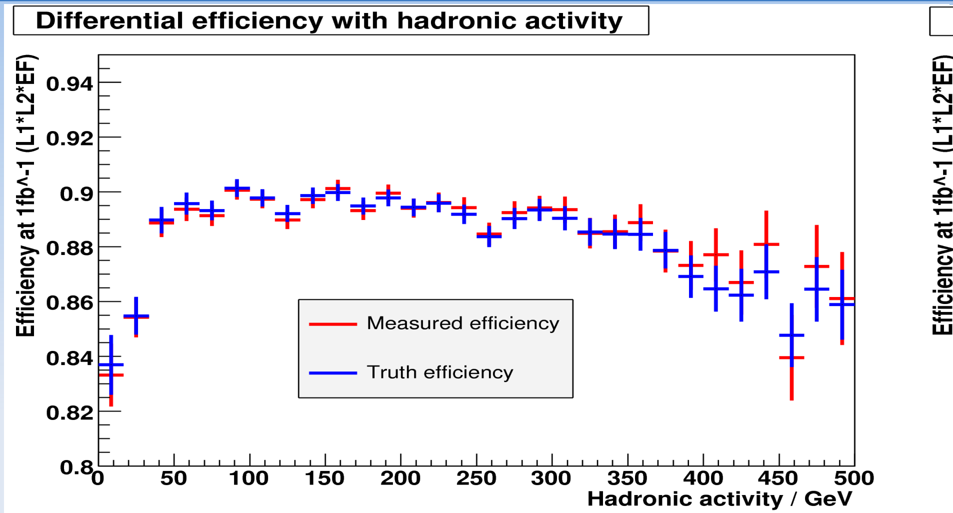
- method:

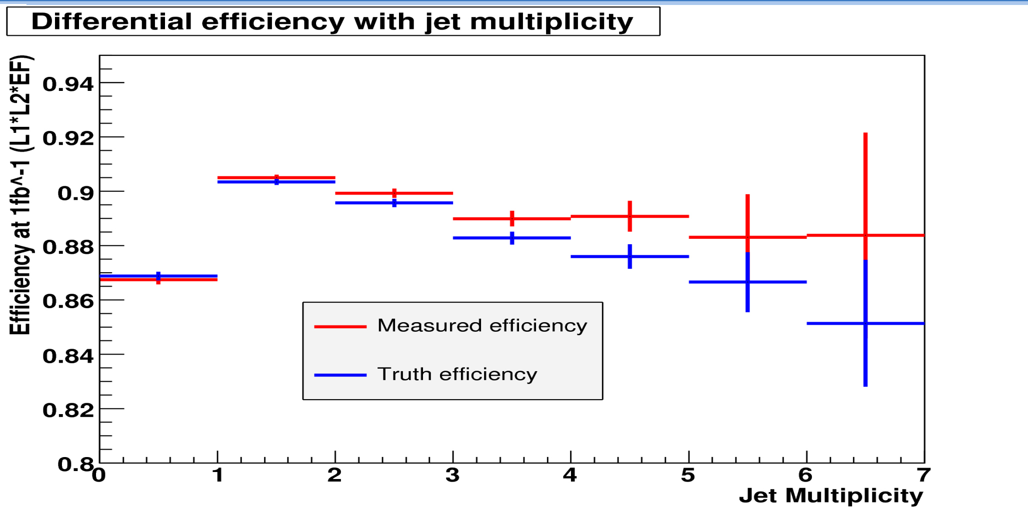
  - tag event by tight cuts on one lepton;

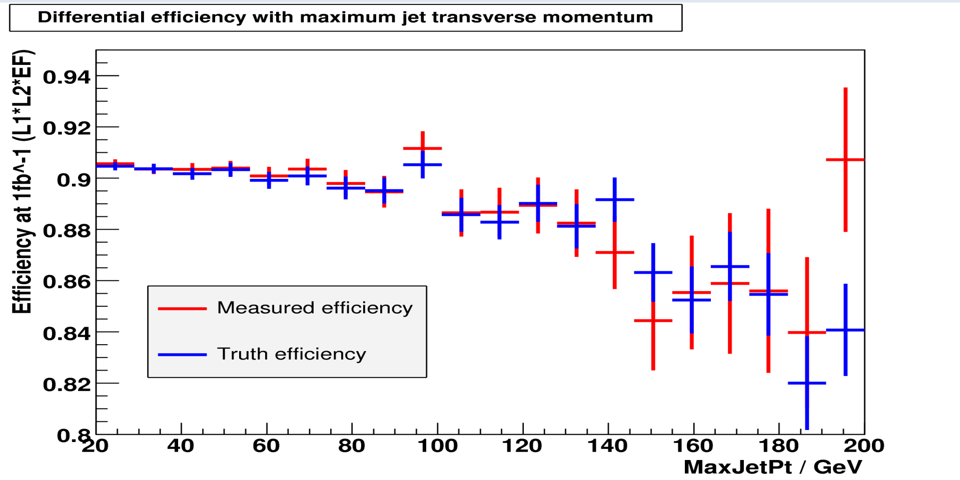
  - efficiency calculated from the 2^{nd} lepton from Z

- more details in yesterday talks (Trigger and Combined Performance)

Electron Trigger Eff. (EM23i/e25i)



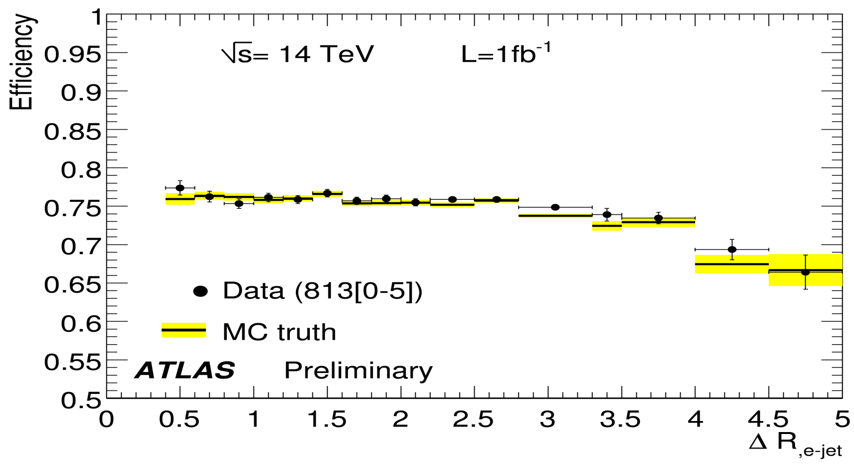


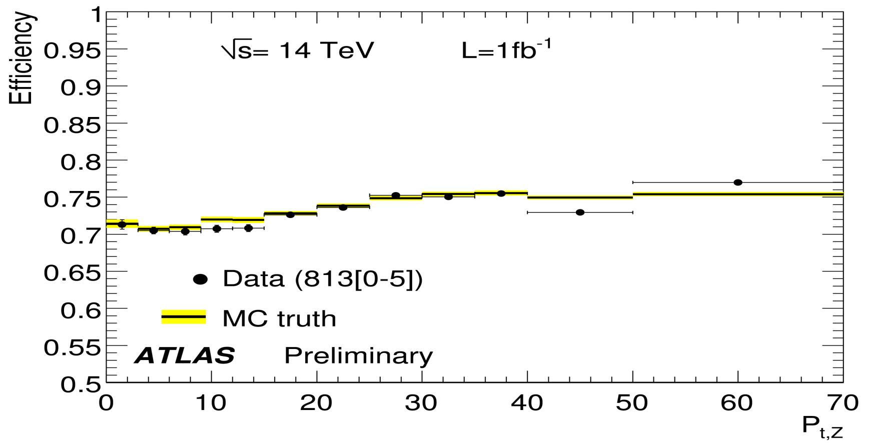


- Eff. from Alpgen Z(ee)+jets with Tag&Probe
- All trigger levels (L1+L2+EF)
- With respect to medium IsEM electron

→efficiency decreases with high hadronic activity (isolation cut)

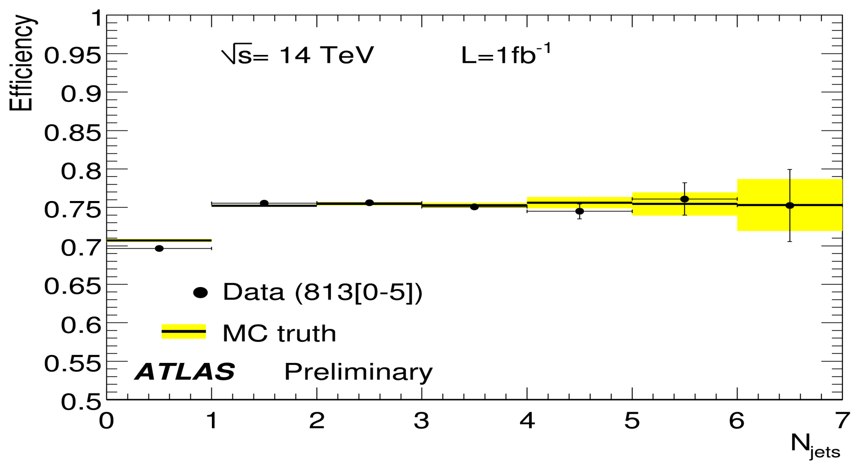
Electron Reco and ID Efficiency





- Eff. from Z(ee) + jets
- Plots for Medium IsEM

(including reconstruction)



→ Efficiency drop with DeltaR could be correlated to drop at high eta

Global Electron Efficiency

Global Efficiency with Tag&Probe:

- **Systematic uncertainties** from :
  - Comparison with MC method
  - Background contribution (Signal – (Signal + BKG)
  - Comparison between Alpgen (Z+jets) and Pythia 5144 (Z inclusive)

Trigger Efficiency (wrt medium IsEM)

Trigger	Signal	MC	S- (S+BKG)	Pythia-Alpgen
L1	97.06 (5)	96.98 (5)	-0.74	0.74
L2	97.13 (5)	97.08 (5)	0.04	0.36
EF	94.86 (7)	95.49 (6)	0.02	0.42
All Trigger	89.42 (9)	89.90 (8)	-0.63	1.42

Reconstruction + ID Effiency (medium IsEM)

Medium Offline	Pure Signal	Signal+Bkg	Monte Carlo
Alpgen	(73.06 ± 0.12)	(74.06 ± 0.11)	(74.07 ± 0.09)
Pythia	(75.11 ± 0.13)	(74.67 ± 0.13)	(75.29 ± 0.09)

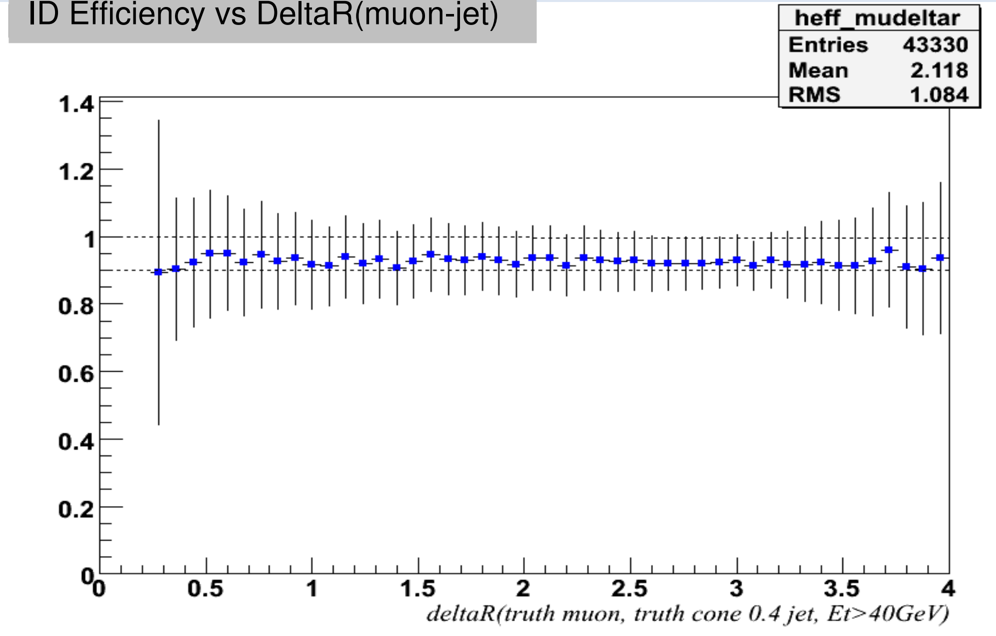
Alpgen Z+ jets samples have **lower** efficiency than Pythia Z inclusive:

- Different EF cuts (generator level)
- Effect of hadronic activity

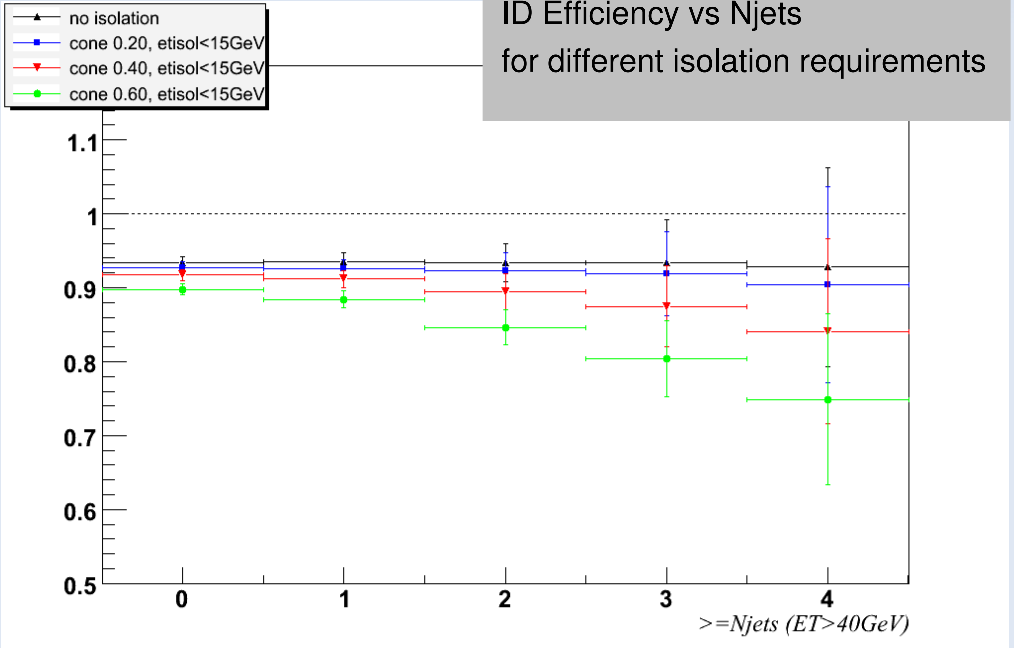
Muons Efficiencies

- **STACO Muon** Container
- Muon ID Efficiency extracted from Z(μμ) + jets
- MC Method
- Muon Cuts: Pt>15GeV
- Jet Pt > 40 GeV

ID Efficiency vs DeltaR(muon-jet)



ID Efficiency vs Njets
for different isolation requirements

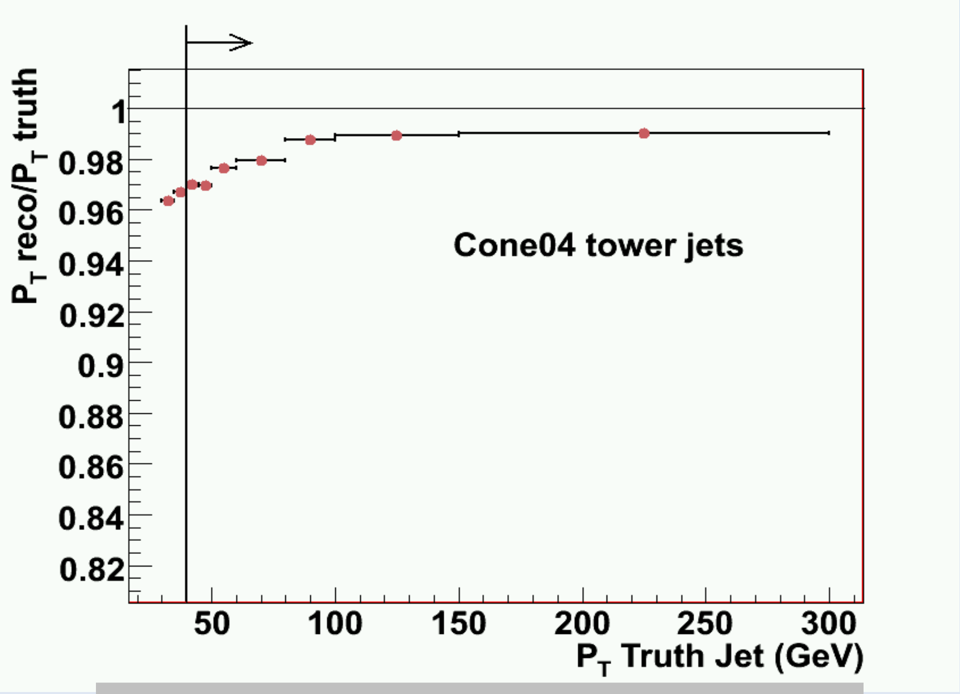


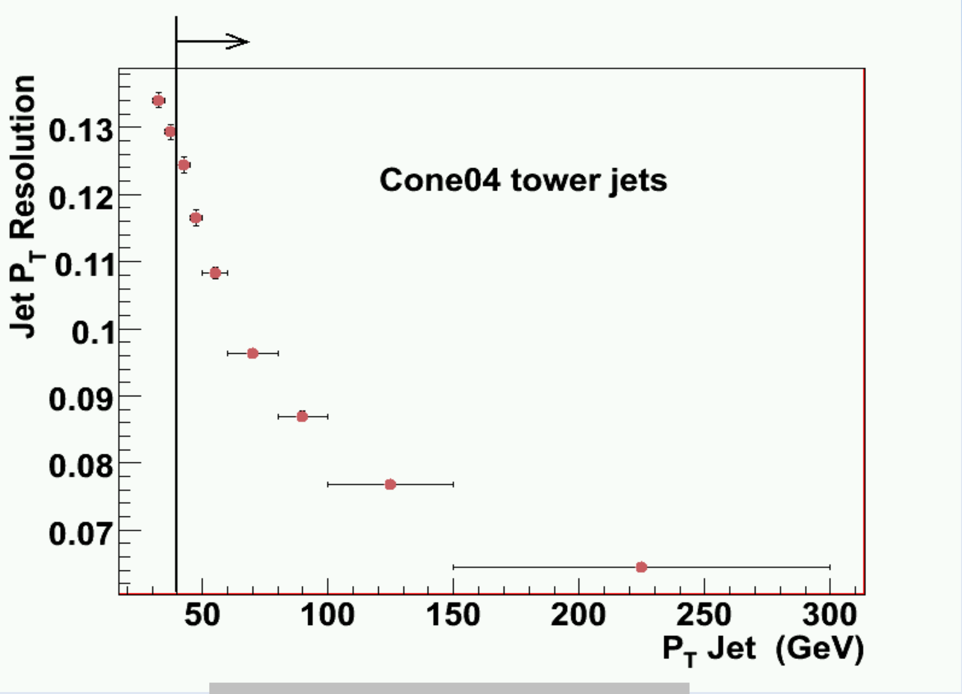
Detector Effects (II): Jets

Jets to be corrected for:

- shift in Jet Energy Scale (non linearity)
- Jet Energy Scale Resolution

From Pt(reco)/Pt(truth) of matched jets





JES: Non-linearity at **low PT(jet)**:
out-of-cone showering up to 3% correction

Jet pT resolution: 6-13%
better at **high Pt**

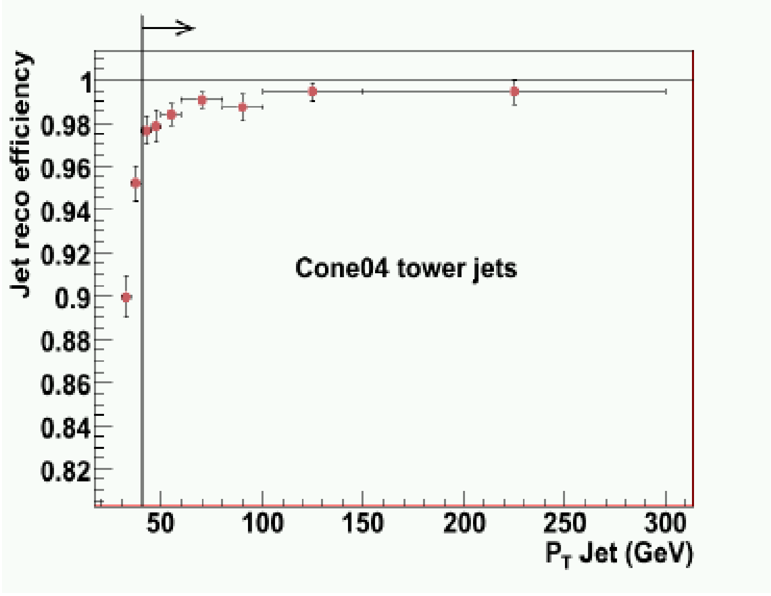
Detector Effects (II): Jets

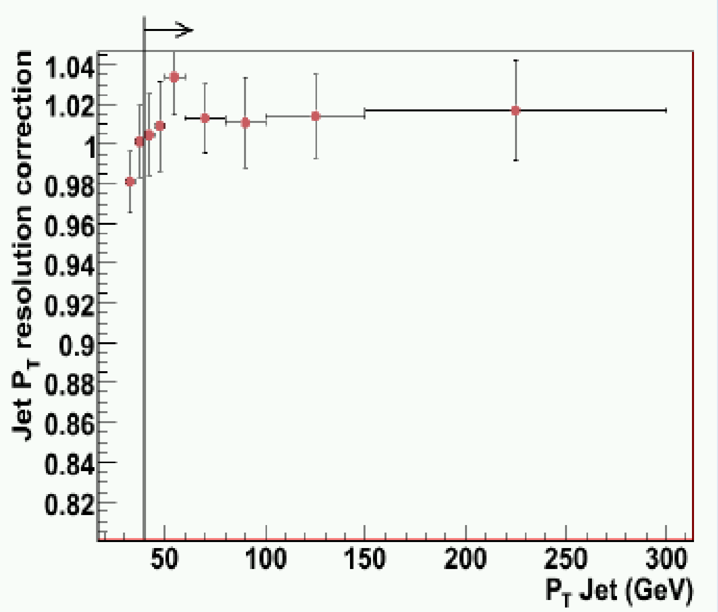
Jet Reconstruction Effieciency:

truth jet matched / # all truth jets

Jet Resolution Corrections:

smear true Jet Pt with Jet Pt resolution. Compare Pt spectrum before and after smearing.





High efficiency at **Pt > 60 GeV**

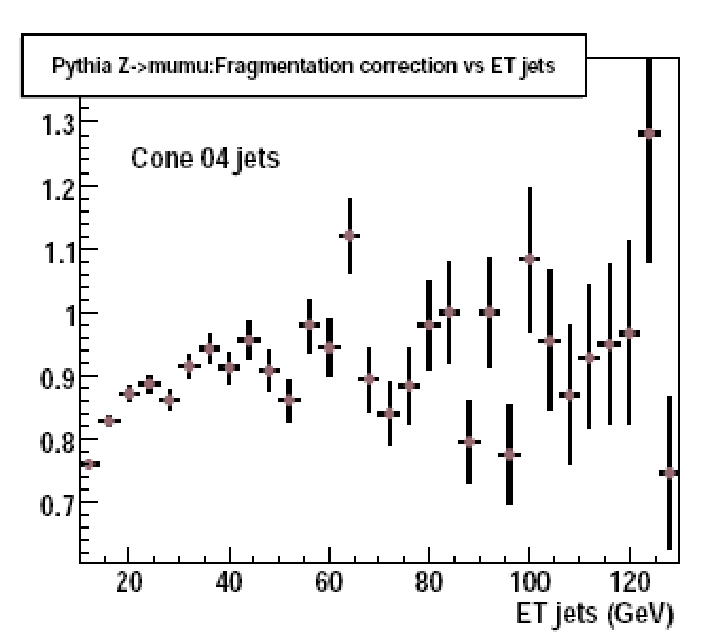
Number of Jets increased by **1%-2%**

From Parton to Hadron Level

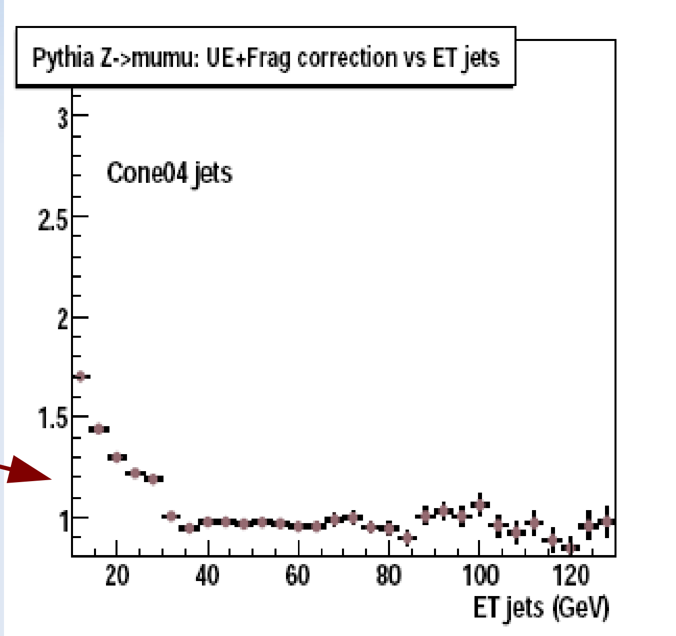
- Want to compare data to pQCD predictions:

  Corrected parton-level predictions to the hadron level for: **UE** and **fragmentation**.
- Corrections derived using the current ATLAS tuning for Pythia 6.4:

  standard Pythia / Pythia without non-perturbative corrections



Negligible non-p. effects for Pt jet> 40 GeV



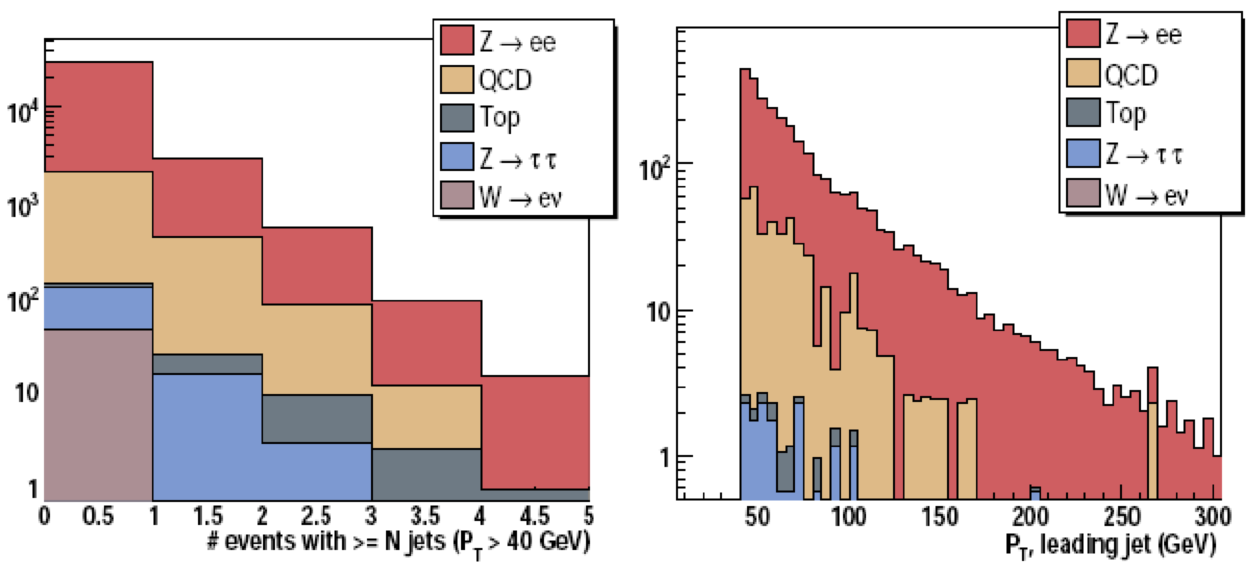
Without fragmetation smaller out-of-cone energy loss for low Pt jet: higher number of low-Pt jets

Without UE energy deposit in cluster decreases: lower number of low-Pt jets

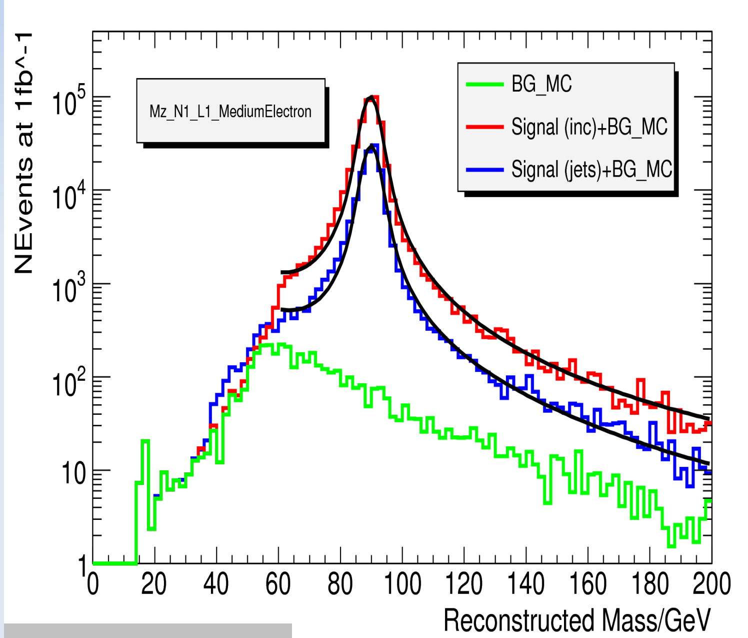
Z(ee)+jets: Background Studies

- Difference sources of background on observables (Njets, Lead Jet Pt):
  - **QCD** background dominates (Dijets)
  - **Top** contribution more impo at high multiplicity

Lum= 100 pb^{-1}



- Background Subtraction method: Fit together Signal+ BKG



Lum= 1 fb^{-1}

Reconstructed mass peak in Dijets, Z(ee) inclusive and Z(ee)+jets.

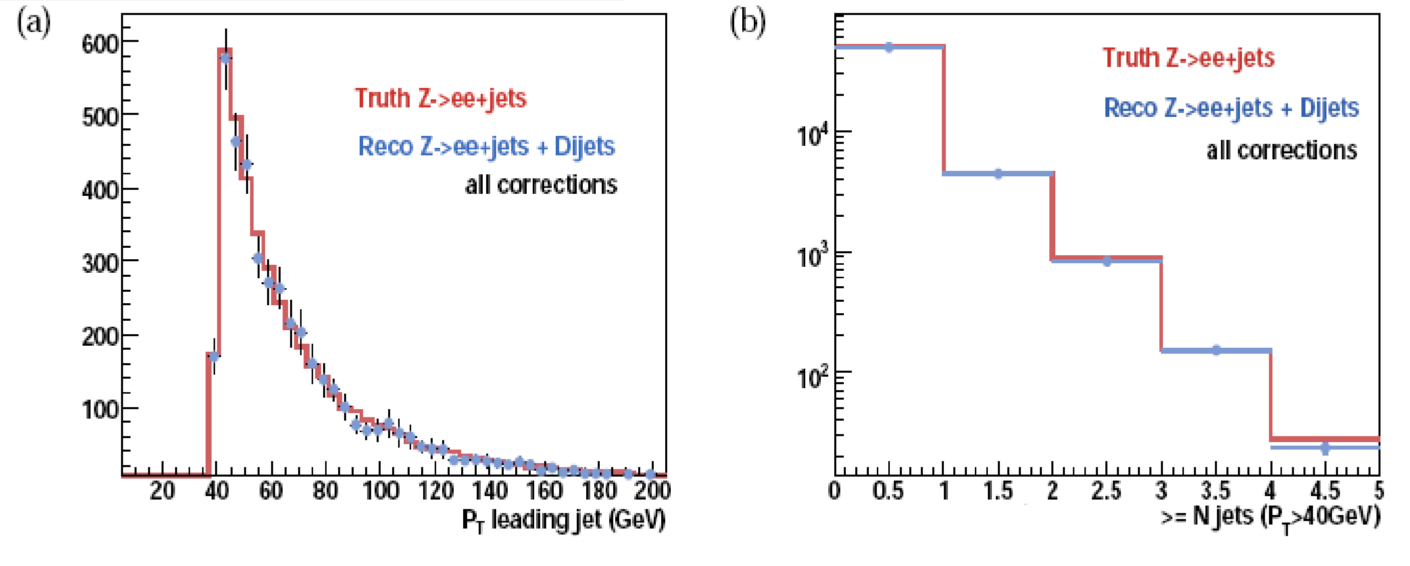
Z(ee)+jets: Data vs. Predictions

Aim:

- Measure Z+jets cross-sections vs. Jet Pt and Njets
- Compare measured cross-section with LO/NLO predictions (from MCFM, a parton-level generator)

- Use Pythia and Alpgen MC samples as pseudo data
- Unfold data for detector effect (jets+EM)
- Unfold MCFM predictions from parton to hadron level
- Compare data and MCFM predictions

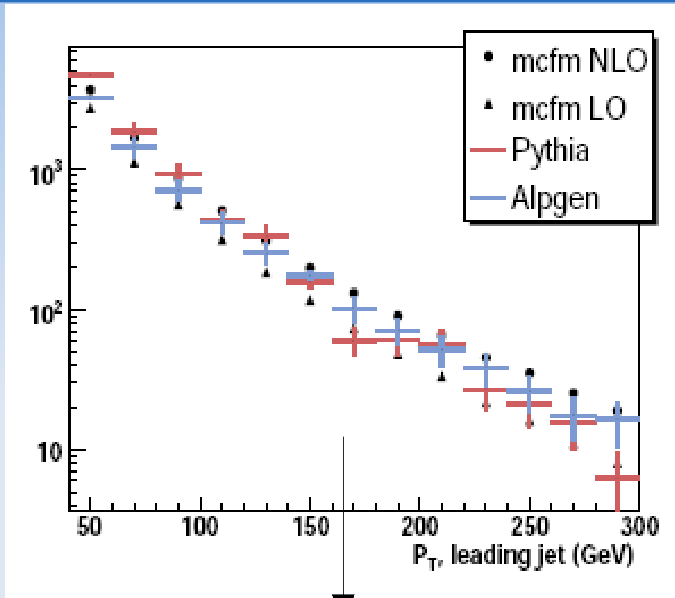
Unfolding Detector Effects



Observables (Leading Jet Pt and Njets spectra): comparison between truth and reconstruction after all corrections (jet+ EM) and Bkg subtraction

→ good agreement

Z(ee)+jets: Data vs. Predictions



Cross section measurement (from Alpgen and Pythia) for Z(ee) + ≥ 1 jet with different Jet Pt Cuts, Luminosities and JES Uncertainties. Comparison to LO/NLO predictions

		$Z \to ee+ \geq 1$jet cross section (pb)			
		JES error: 3%		JES error: 10%	
		jet $p_T > 40$ GeV	jet $p_T > 150$ GeV	jet $p_T > 40$ GeV	jet $p_T > 150$ GeV
	MCFM LO	52.96± 1.99	2.65± 0.10	52.96± 1.99	2.65± 0.10
	MVFM NLO	77.76±2.77±	5.01±0.18±	77.76± 2.77 ±	5.01±0.18±
100 pb^{-1}	Data(Pythia)	87.45±4.61±0.94	3.12±0.17±0.18	87.45±14.15±0.94	3.12±0.51±0.18
	Data(Alpgen)	66.20±3.49±0.81	4.07±0.22±0.20	66.20±10.71±0.81	4.07±0.66±0.20
1000 pb^{-1}	Data(Pythia)	87.45±4.61±0.30	3.12±0.17±0.06	87.45±14.15±0.30	3.12±0.51±0.06
	Data(Alpgen)	66.20±3.49±0.26	4.07±0.22±0.06	66.20±10.71±0.26	4.07±0.66±0.06

- Compare LO/NLO predictions with data at **hadron** level:
  - statistical errors scaled to 100 pb-1
  - systematics errors assuming :
    10% error on JES
    20% on Bkg estimate

→ If **JES** miscalibration is **10%**, cannot distinguish significantly between **LO and NLO** predictions!

W+ jets: PDF Uncertainties

Important source of systematic uncertaintes:

- **JES** (largest uncertainty at CDF)
- **PDF** uncertainties

Here:

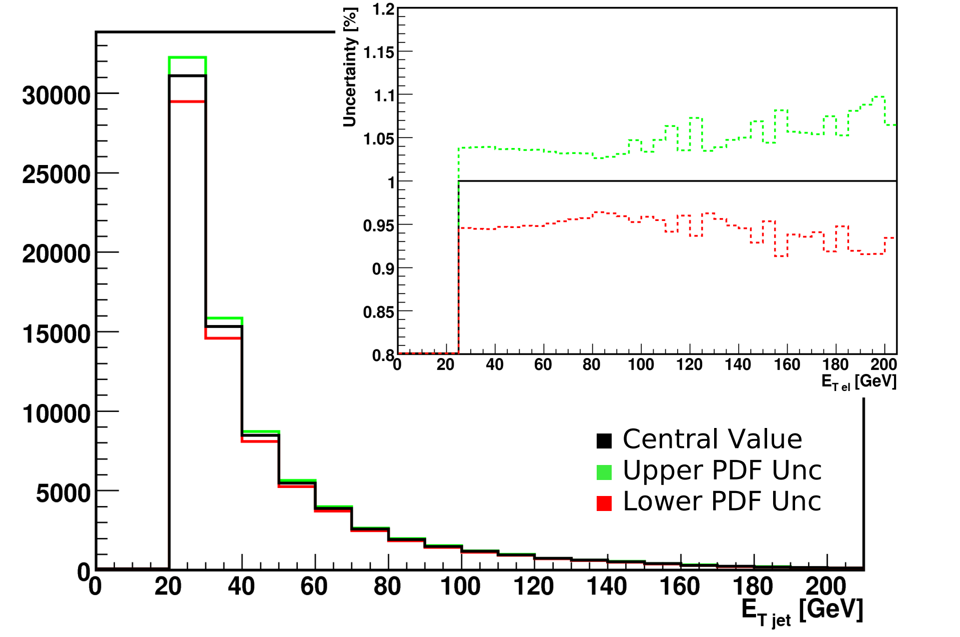
Study of **PDF** and **JES** Uncertainties on W(enu)+ jets

Use PDF Reweighting technique

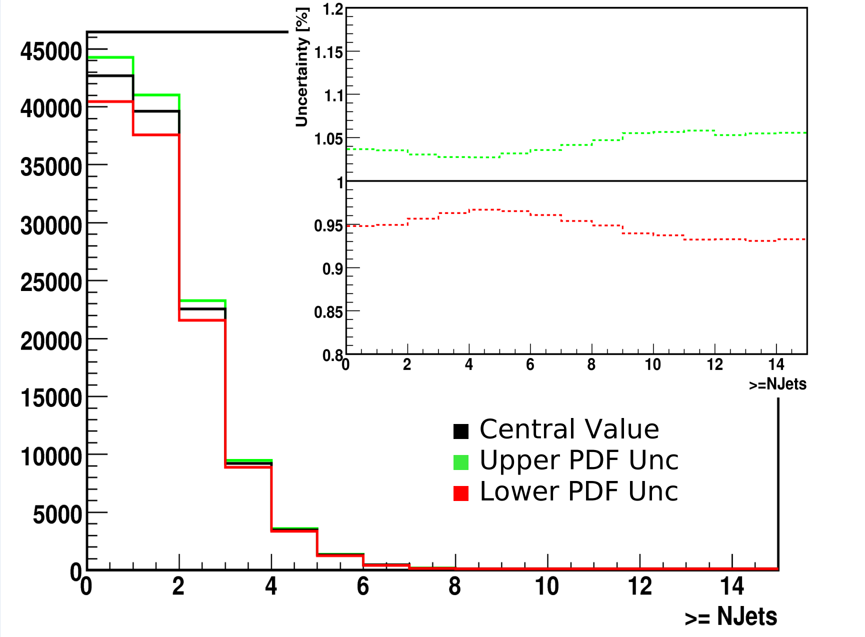
Aim: which uncertainty dominates, JES or PDF?

can we gain information on PDFs?

PDF Unc. on Jet Pt



PDF Unc. on Jet Cumul. Multiplicty

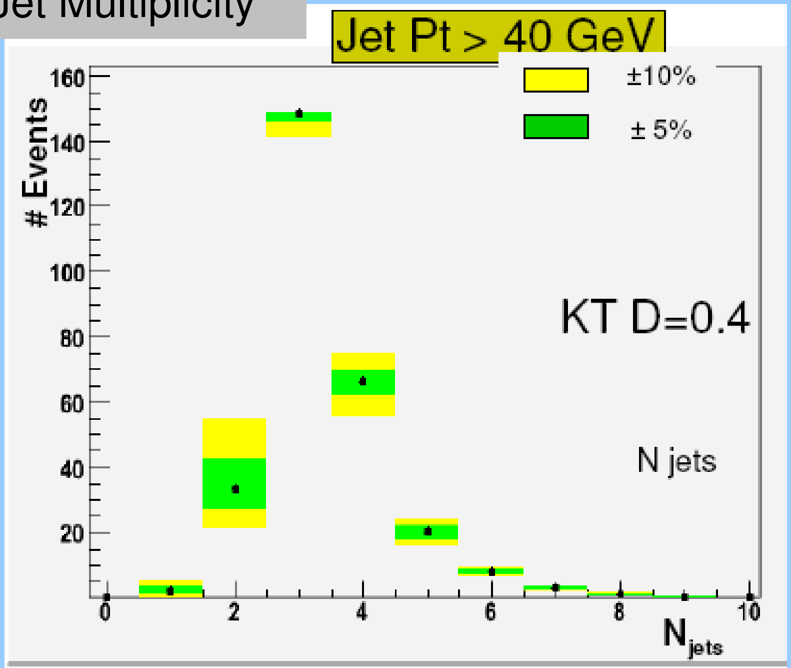


W+jets: JES Uncertainty

- Assume a jet energy miscalibration of **5%** or **10%**: uncertainty on cross section measurement?

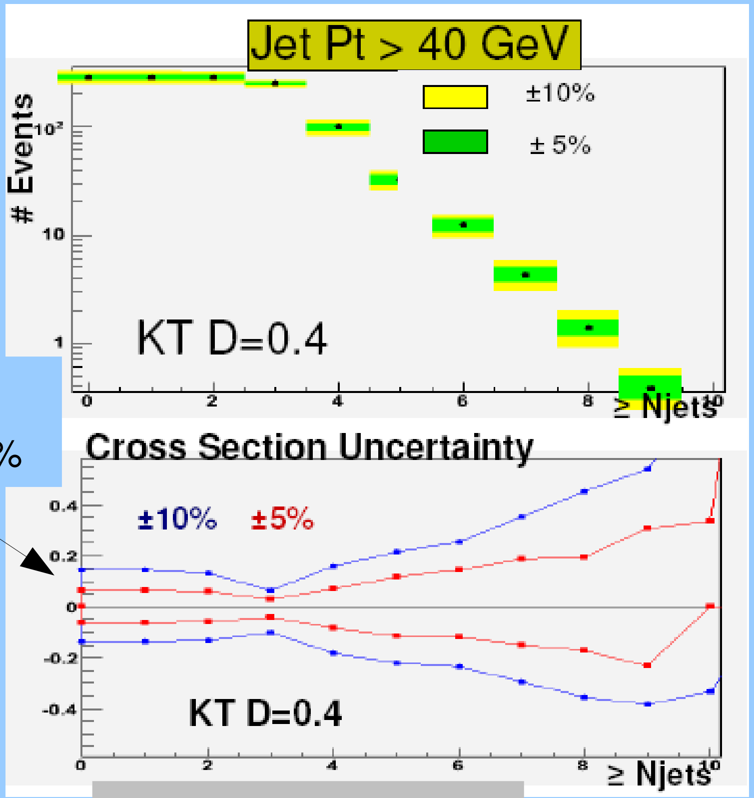
(**Note**: these results are from Alpgen samples (5223-5226) with tight EF cuts)

Jet Multiplicity



Jet Energy Miscalibrated by **+ 5/10%**, more high multiplicity events and viceversa for -5/10%

JES Unc:
6% to 50%



Jet Cum Multiplicity

W+jets: PDF vs JES Uncertainty

- **PDF vs Jet Scale Uncertainty** (**Δ JS**)
  with **10%** **(5%)** jet energy miscal.

(Note: results with tight EF cuts samples)

2.9% < **Δ PDF** < 7.3%
5.8% < **Δ JS** **(10%)**< 23.6%
3.6% < **Δ JS** **(5 %)** < 11.9%

↓

PDF Uncert < Expt. Syst. Uncert

Next: When is JES < PDF Unc?
Try with 1,2,3% jet energy miscal.

Multipl	Δ+ PDF (%)	Δ- PDF (%)	Δ+ JS (%)	Δ- JS (%)
W+ ≥1 jets	3.2	2.9	10.7 (5.2)	10.7 (5.2)
W+ ≥2 jets	3.2	2.9	10.2 (5.1)	10.7 (5.2)
W+ ≥3 jets	3.3	2.9	5.8 (3.6)	9.0 (4.0)
W+ ≥4 jets	5.0	3.9	14.7 (7.8)	15.6 (7.0)
W+ ≥5 jets	5.9	4.8	20.8 (9.5)	20.5 (10.7)
W+ ≥6 jets	7.3	5.9	22.2 (10.4)	23.6 (11.9)

Conclusions

- W/Z + jets is a broad topic, today I showed some of the work done
- General Topics:
  - Investigation of **detector effects**:
    - Electron and Muon effieciencies → effect of high hadronic activity
    - Jet Reconstruction: Resolution, Jet Energy Scale, Reconstruction Efficiency
  - **Non- perturbative corrections**: UE, Fragmentation → negligible corrections for jet Pt > 40GeV
- Specific Analyses:
  - **Z(ee) + jets** : Background, Comparison data to LO/NLO predictions
  - **W(e nu) + jets**: Systematic Uncertainties (JES vs PDF)

  } JES Uncertainty is the main limitation
- More: Comparison between different Jet Algorithms, Background Studies on W+jets, Generator Filter for QCD Background, etc.
- Still ongoing work...

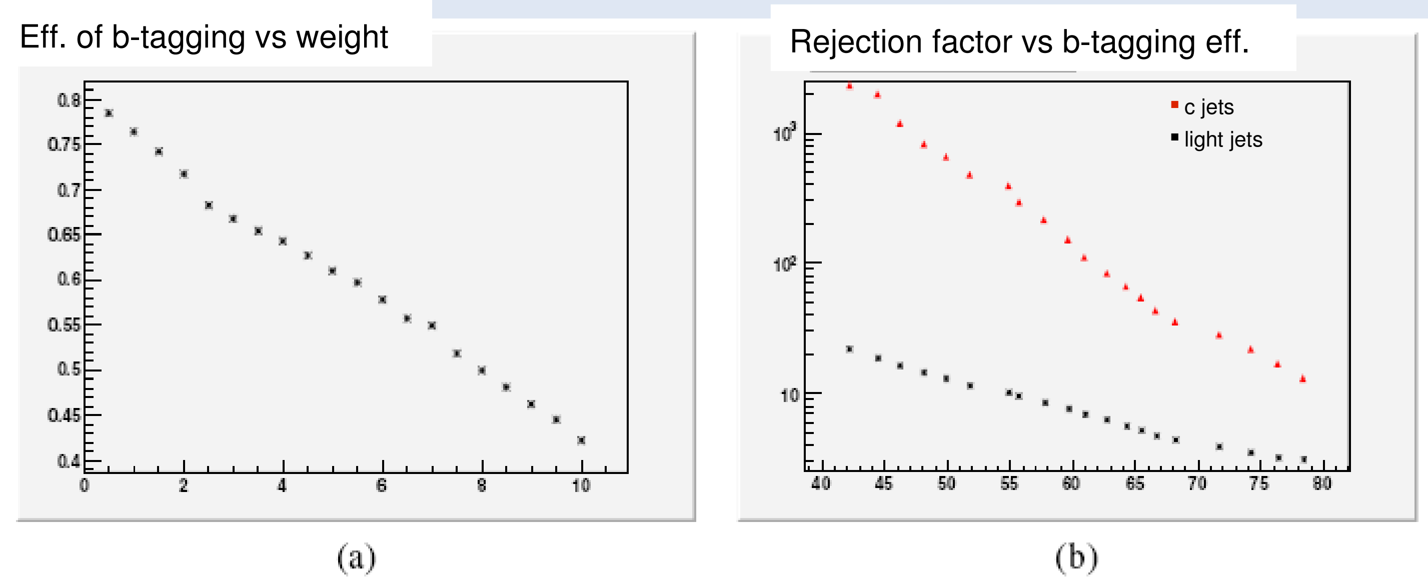
EXTRAS

Z + b jets

- **Why?**
  - Z + b jets cross-section sensitive to b quark density of the proton: help reduce PDFs uncertaintiy.
  - More interesting measurment at LHC than Tevatron (larger signal cross-section by 50, smaller relative BKG)
  - Here : study **selection cut** and **b-tagging efficiency**

Samples (different from rest of note):

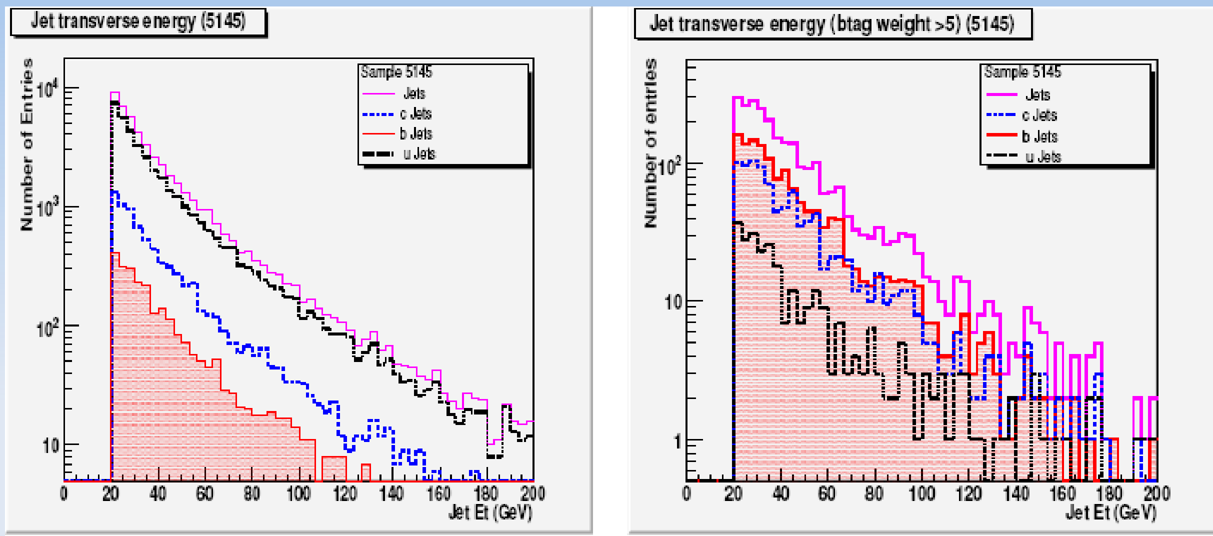
Sample	Process	
6397	$Z \to \mu\mu$ + b jets	Sherpa
6396	$Z \to \mu\mu$ + c or light jets	Sherpa
5568	$t\bar{t}$	Pythia
5105	$W \to \mu\nu$	Pythia
5145	$Z \to \mu\mu$ inclusive	Pythia



(a) (b)

- Standard Cuts on muon and jets
- Z Mass window cut: Mz ± 20 GeV
- b-tagging: weight ⩾5 (comination of secondary vertex and impact parameter)

Z+ b jets



(a) (b)

Effect of cuts:

Jet Pt spectrum for b,c and light jets in the Z inlc. sample, before (a) and after (b) the cut on b-tagging weight.

Results:

Lum=100 pb^{-1}, Signal σ= 41.25 pb

- Jet Pt > 20 GeV: **536± 23** events
- Jet Pt > 40 GeV: **289±17** events
- Contamin. from c and light jets: **30%**
- Other Bkg negligible

Final Effieciencies (all cuts, Pt jet > 20/40 GeV)

Cuts	Z inclusive	Z+b jets	Z+c or light jets
Number of jets >0	18.9 ± 0.1%	36 ± 1%	25± 1%
$E_T^{jet} > 20$ GeV & $\lvert\eta\rvert < 2.5$	10.26 ± 0.08%	24± 1%	25± 1%
b jet weight >5	0.24± 0.01%	12.8± 0.2%	0.2 ±0.1%
$E_T^{jet} > 40$ GeV & $\lvert\eta\rvert < 2.5$	3.94± 0.05%	12.3 ± 0.2%	8.2± 0.8%
b jet weight >5	0.072 ± 0.005%	7.1 ± 0.5%	0.2 ±0.1%