QCD Studies at LHC with the Atlas detector

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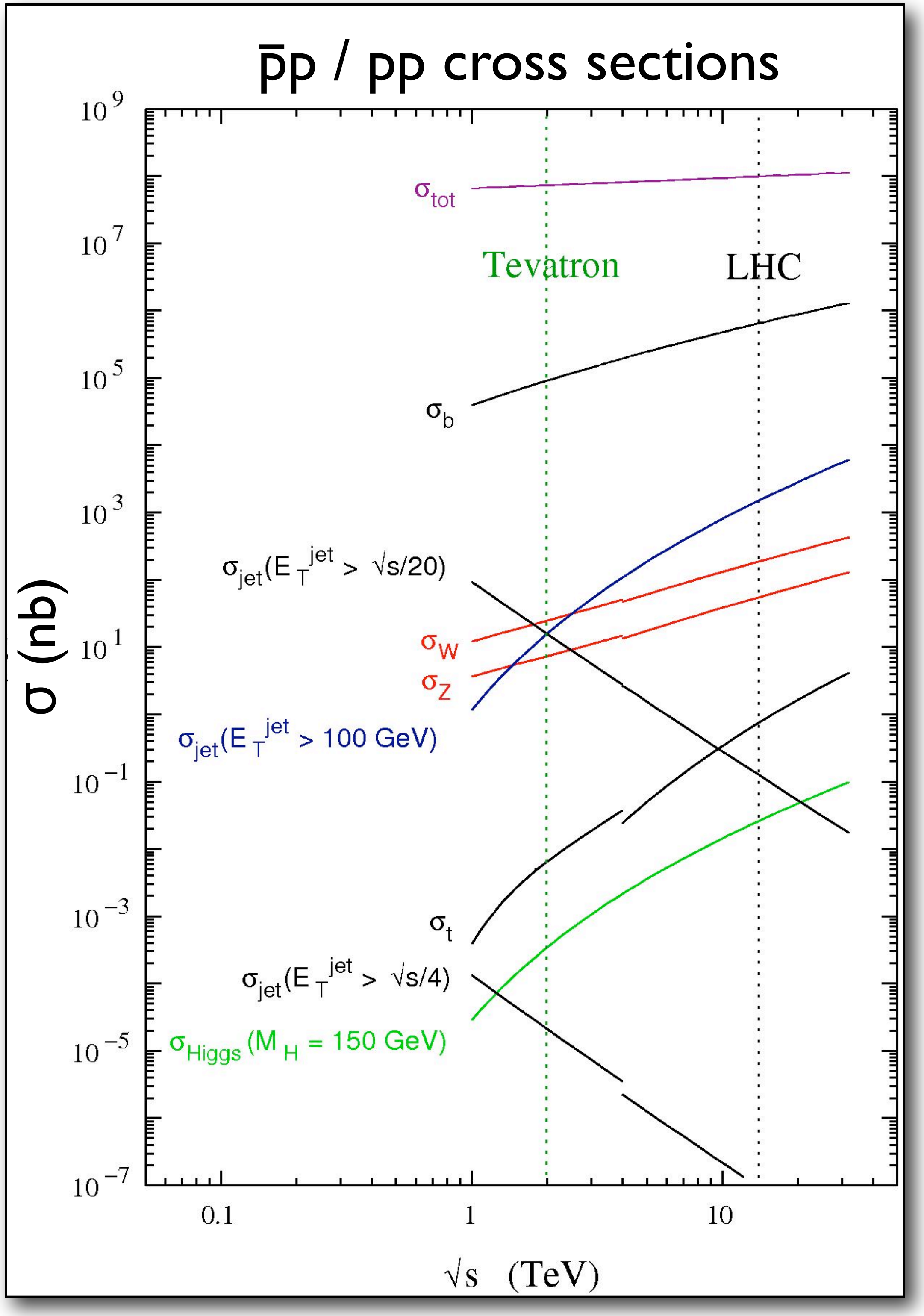
(on behalf of the ATLAS Collaboration)

- Introduction
- Examples of QCD studies
  - Minimum bias & underlying event
  - Jet-physics
  - W/Z + Jets
- Summary

Introduction

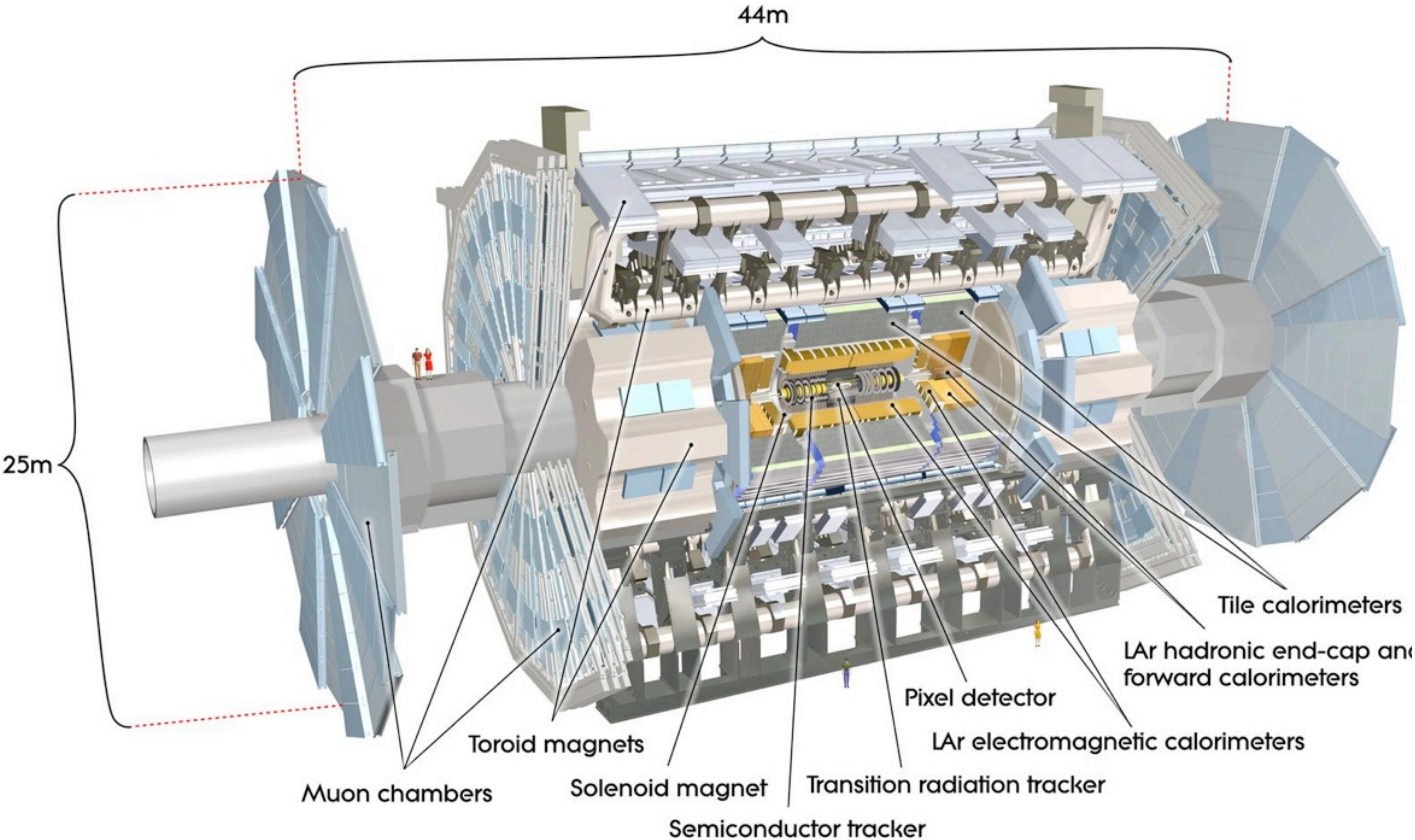
- The Large Hadron Collider
  - p-p collision up to $\sqrt{s}$ = 14 TeV (x7 wrt Tevatron)
  - Luminosities up to $10^{34}cm^{-2}s^{-1}$ (x30 wrt Tevatron)
  - ~100 fb^{-1} per year at design luminosity
  - Huge QCD cross sections -
    σ_{jet}(E_T > 700 GeV) ~ 0.1 nb



- Current schedule
  - Start-up by mid-November
  - First physics run in 2010 at $\sqrt{s}$ = 7-10 TeV and lower luminosity
  - Aim to collect ~100pb^{-1} in first physics run:

Determines possible first physics!

The Atlas experiment



What can be done with early data?

Process	σ(nb)	$\mathcal{L}=10pb^{-1}$	$\mathcal{L}=10fb^{-1}$
Minimum bias	10^8	10^{12}	$\sim 10^{15}$
Inclusive jets – p_T>200GeV	100	10^6	$\sim 10^9$
$W \rightarrow e\nu$	15	10^5	$\sim 10^8$
$Z \rightarrow e^+e^-$	1.5	10^4	$\sim 10^7$
Dibosons	0.2	10	10^4

(Numbers for $\sqrt{s}$ = 14 TeV)

- Short term plans:
  - Minimum bias & underlying event:
    - constrain uncertainties in MC generators from extrapolations to LHC energies in the very beginning
    - baseline for understanding of pile up corrections
  - Jets:
    - Angular de-correlation: early benchmark of MC generators
    - Inclusive Jets: Reach beyond Tevatron energy regime already in first data
  - Studies presented used $\sqrt{s}$ = 14 TeV and full detector simulation

- Medium & long term plans:
  - Use W, Z and top for calibration of detector and trigger
  - Study W, Z, top and QCD multi-jets for proper background-estimation
  - Improve current SM measurements to provide consistency tests of the underlying theory

few pb^{-1}

several fb^{-1}

Minimum bias measurements

- Experimental definition: any inelastic collision of two protons
- Usually also referred to as 'non-single-diffractive' (nsd):

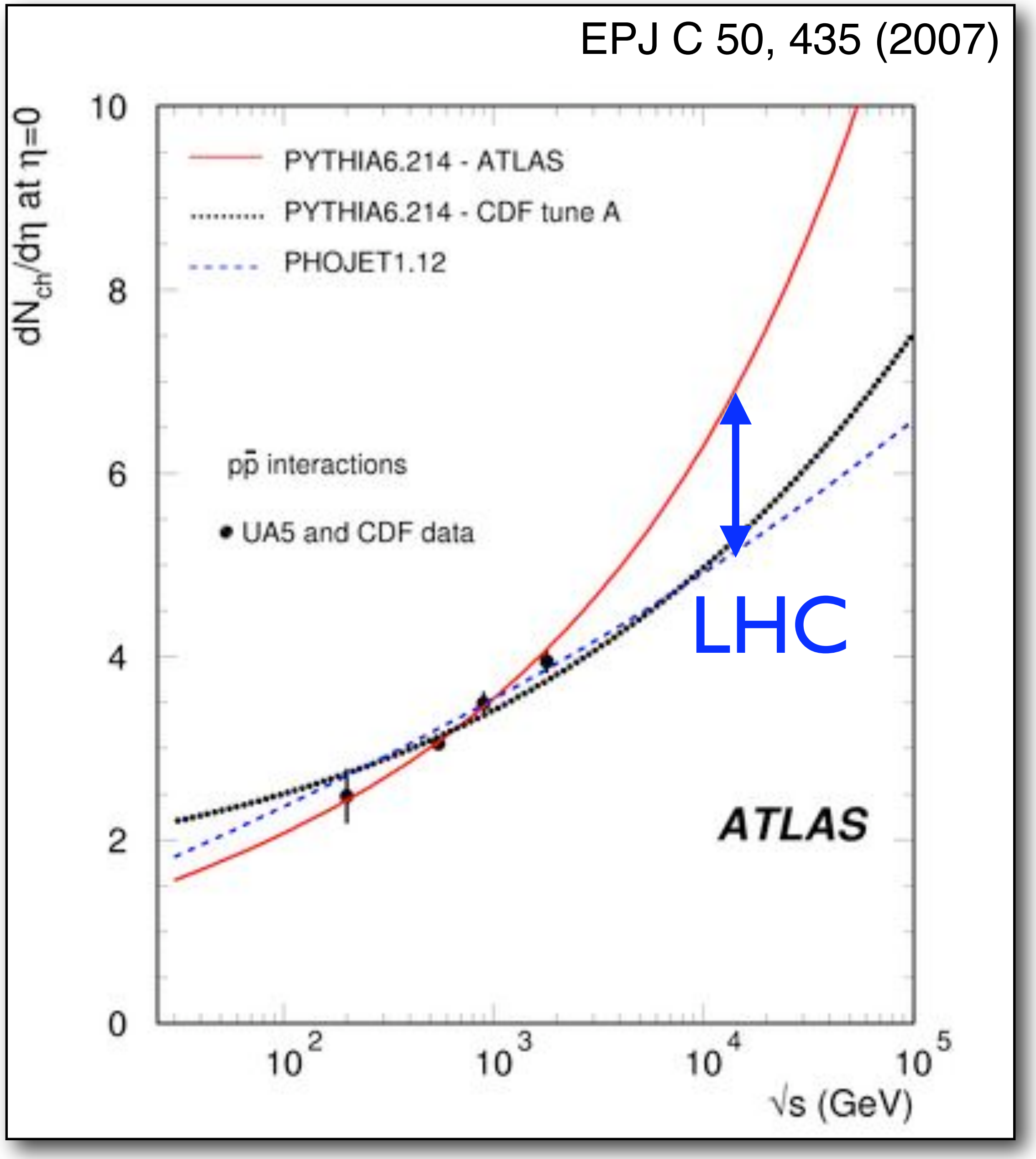
$$\sigma_{tot} = \sigma_{elas} + \sigma_{sd} + \sigma_{dd} + \sigma_{nd}$$

$$\Downarrow$$

$$\sigma_{nsd}$$

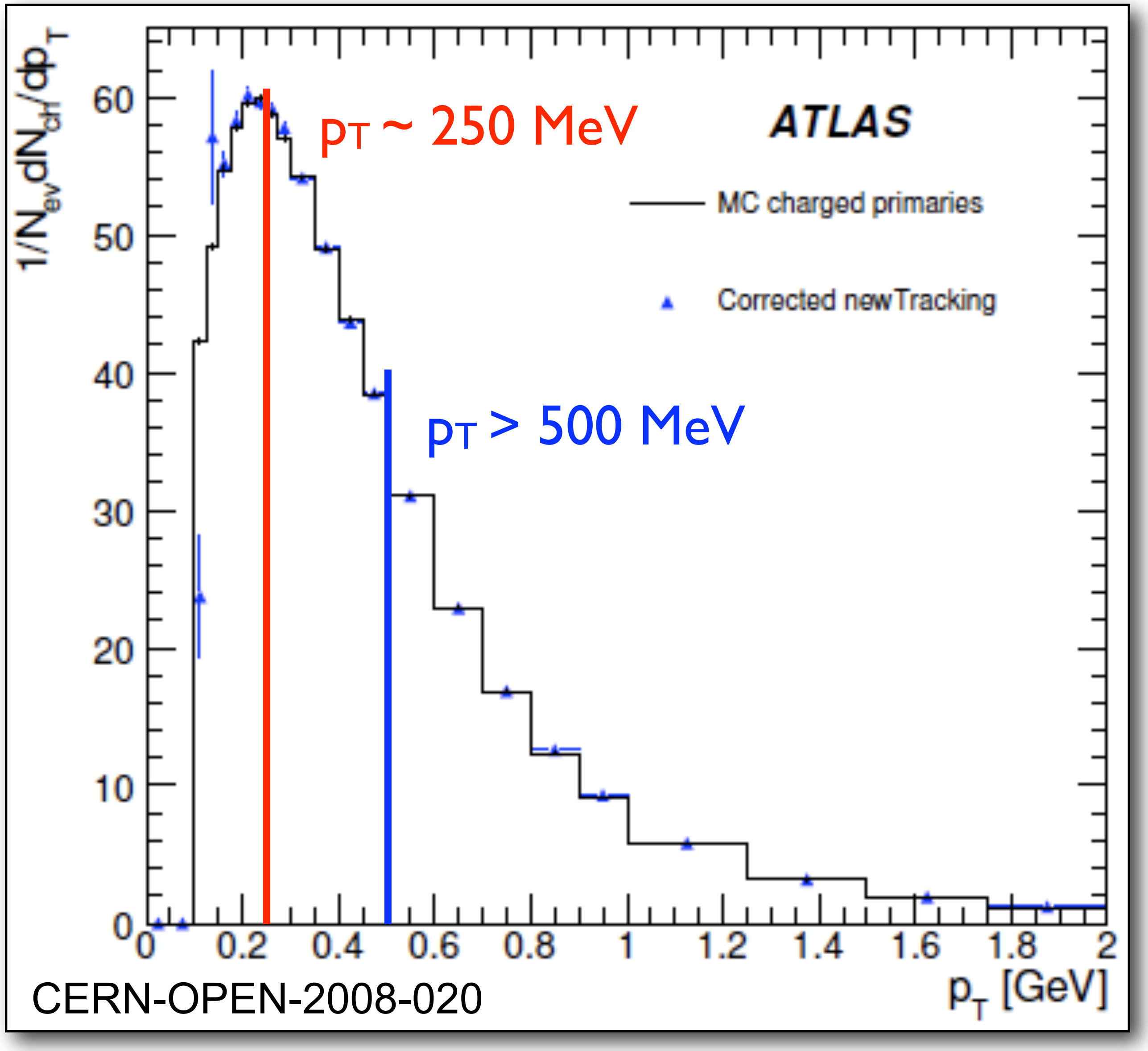
- ‚Removal' of σ_{sd} very difficult
- Extrapolations to LHC energies suffer from large energy gap in data
  - σ_{tot} ~ 102 - 118 mb
  - σ_{nsd} ~ 65 - 73 mb

- Proper modeling of min. bias pile-up and underlying event requirement for high p_T physics!
- Minimum bias studies should be done at low luminosity to minimize effects from pile-up
- Statistics only limited by allocated trigger bandwidth!



Minimum bias measurements

- Reconstructing minimum bias events:
- Need to recover all charged particles
  -> main challenge: tracking!
- Default reconstruction only for track p_T > 500 MeV
  (lower energy particles curl up in magnetic field)



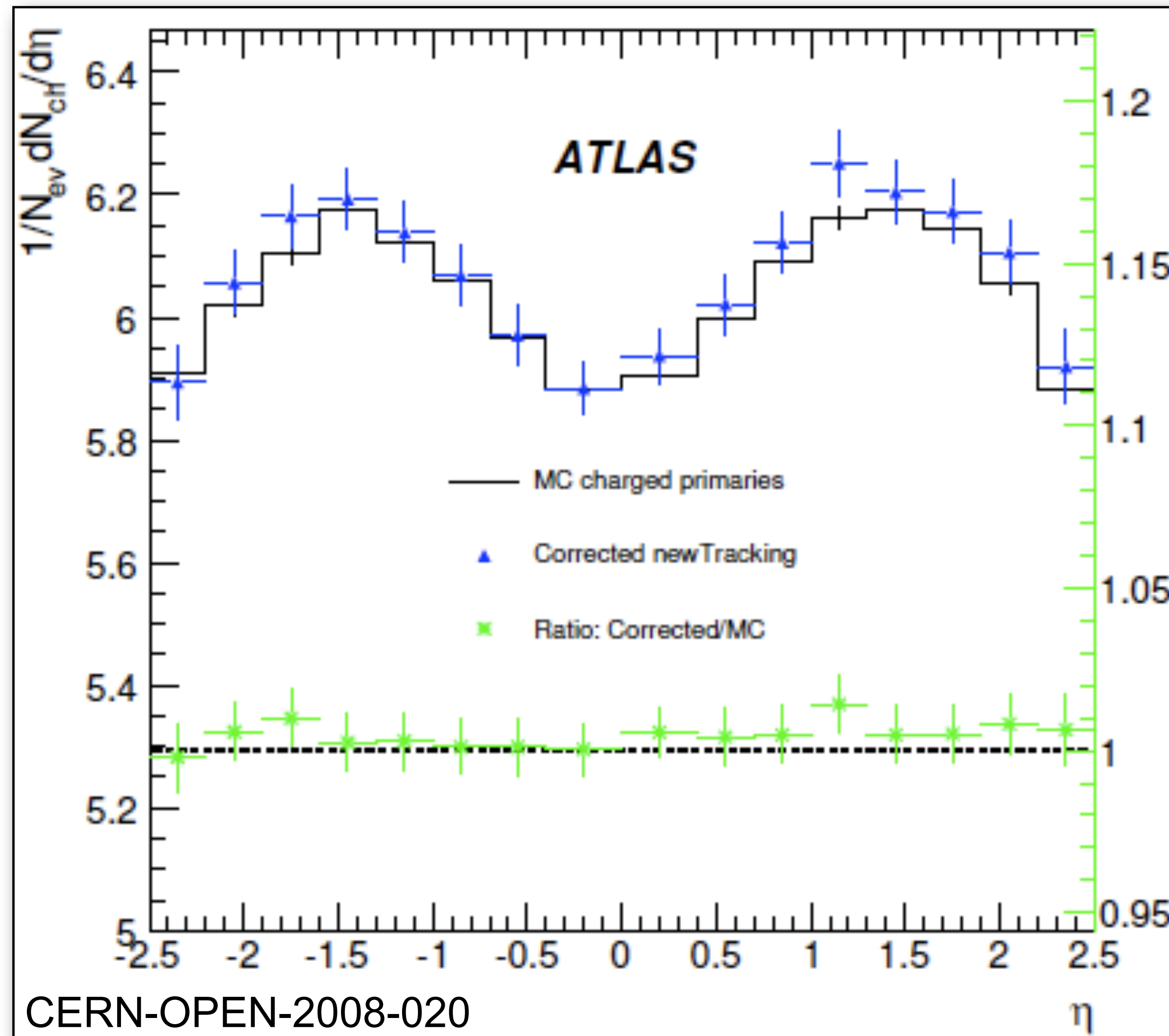
- Dedicated tracking software pushes low p_T limit to ~150 MeV
- Avoids large corrections in uncovered phase space

- Integrated luminosity << 1 pb^{-1}
- Study done for $\sqrt{s}$ = 14 TeV

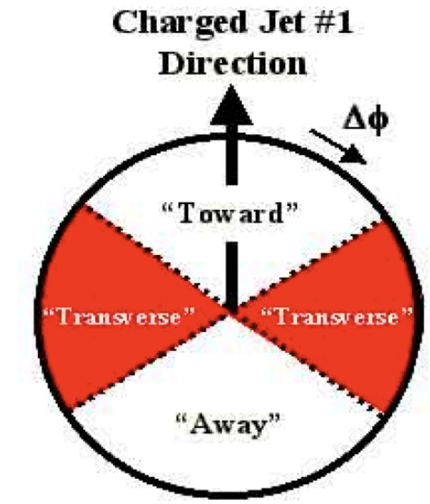
Minimum bias measurements

- Charged particle multiplicity, $p_T > 150$ MeV
- Corrections involve:
  - Track-to-particle correction
  - Vertex reconstruction correction
  - Trigger (in)efficiency
- Systematic uncertainties dominate:

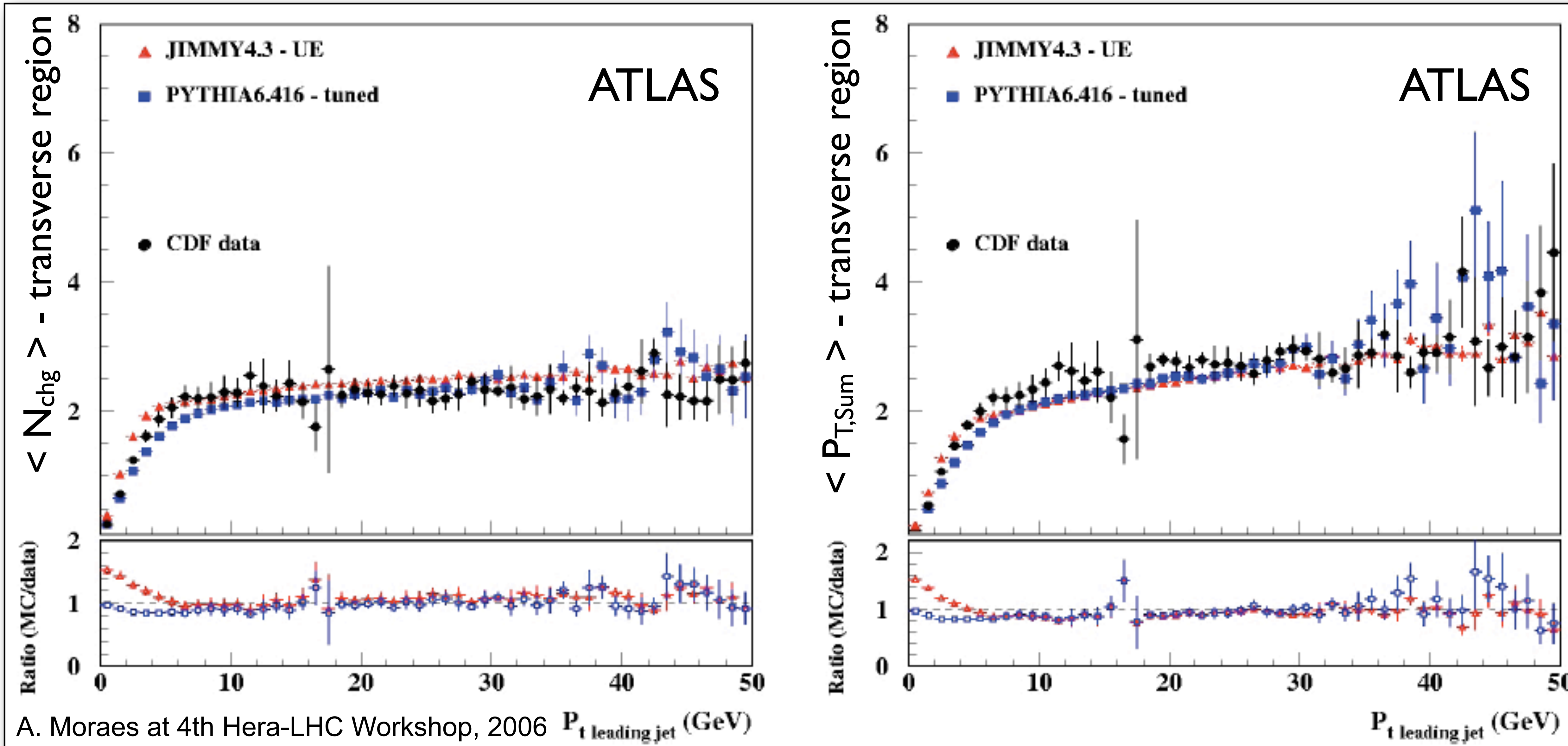
Track selection cuts	2%
Mis-estimate of secondaries	1.5%
Vertex reconstruction bias	0.1%
Mis-alignment	6%
Beam-gas & pile-up	1%
Particle composition	2%
Diffractive cross sections	4%
Total:	**8%**



Underlying event



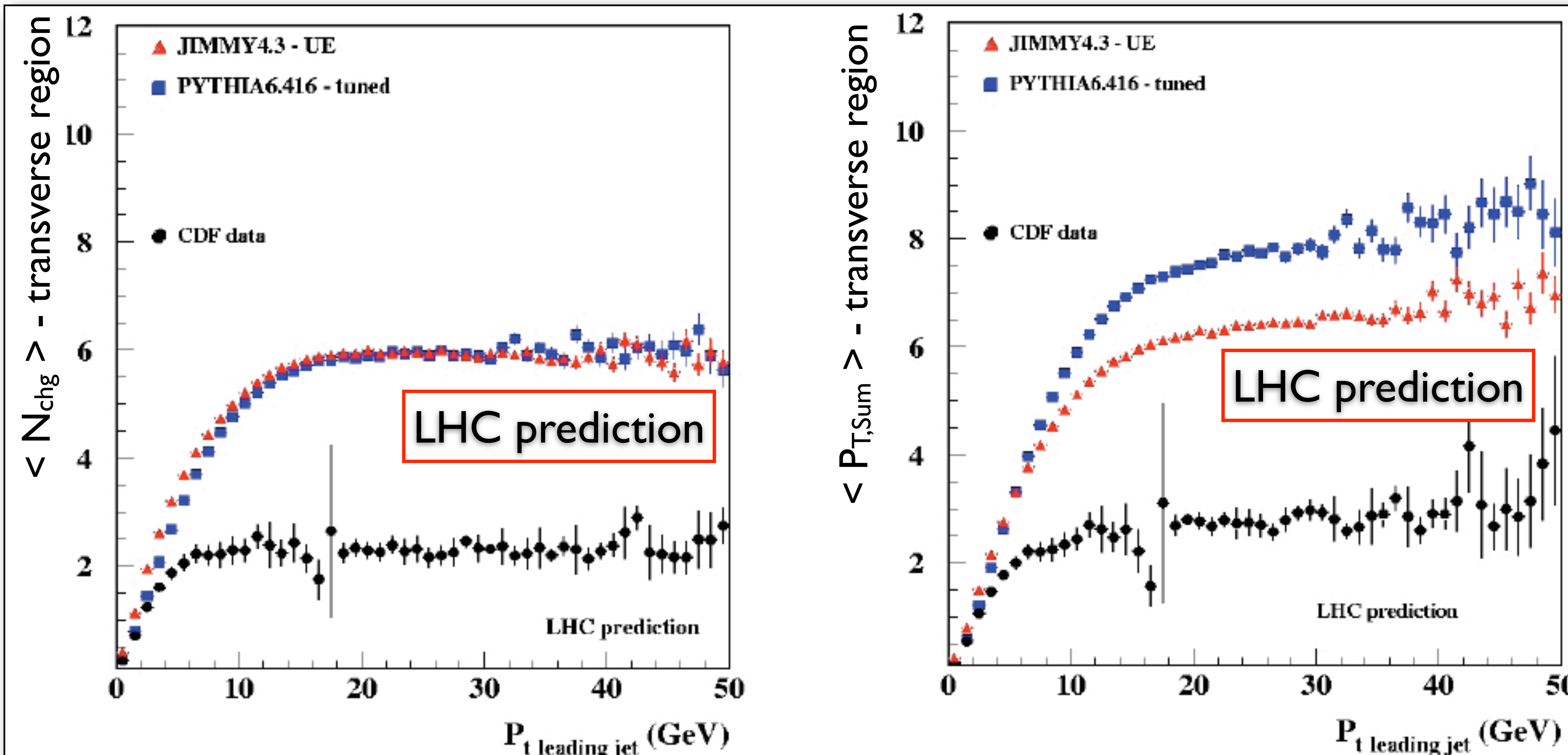
- Important check of MC generators
- ‚jetty‘ environment - understanding needed for jet energy corrections
- CDF-Data used to tune ATLAS monte carlo
  - currently relying on Jimmy4.3 and PYTHIA6.416 (appropriately tuned) to describe UE
  - both generators describe CDF data reasonably well



A. Moraes at 4th Hera-LHC Workshop, 2006

Underlying event

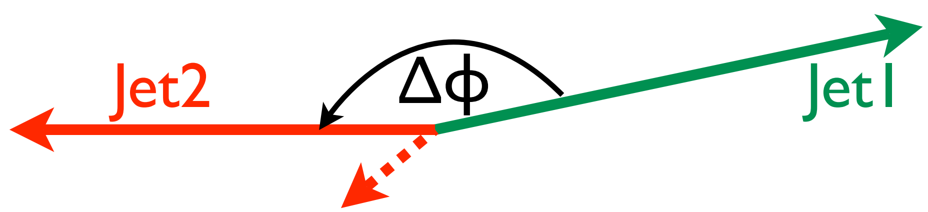
- Extrapolations to LHC (@ 14 TeV) energies differ
- Generators agree in <N_{chg}> in transverse region
- Disagreement in <P_T> in transverse region
- Validation needed with early data - combined with minimum bias description

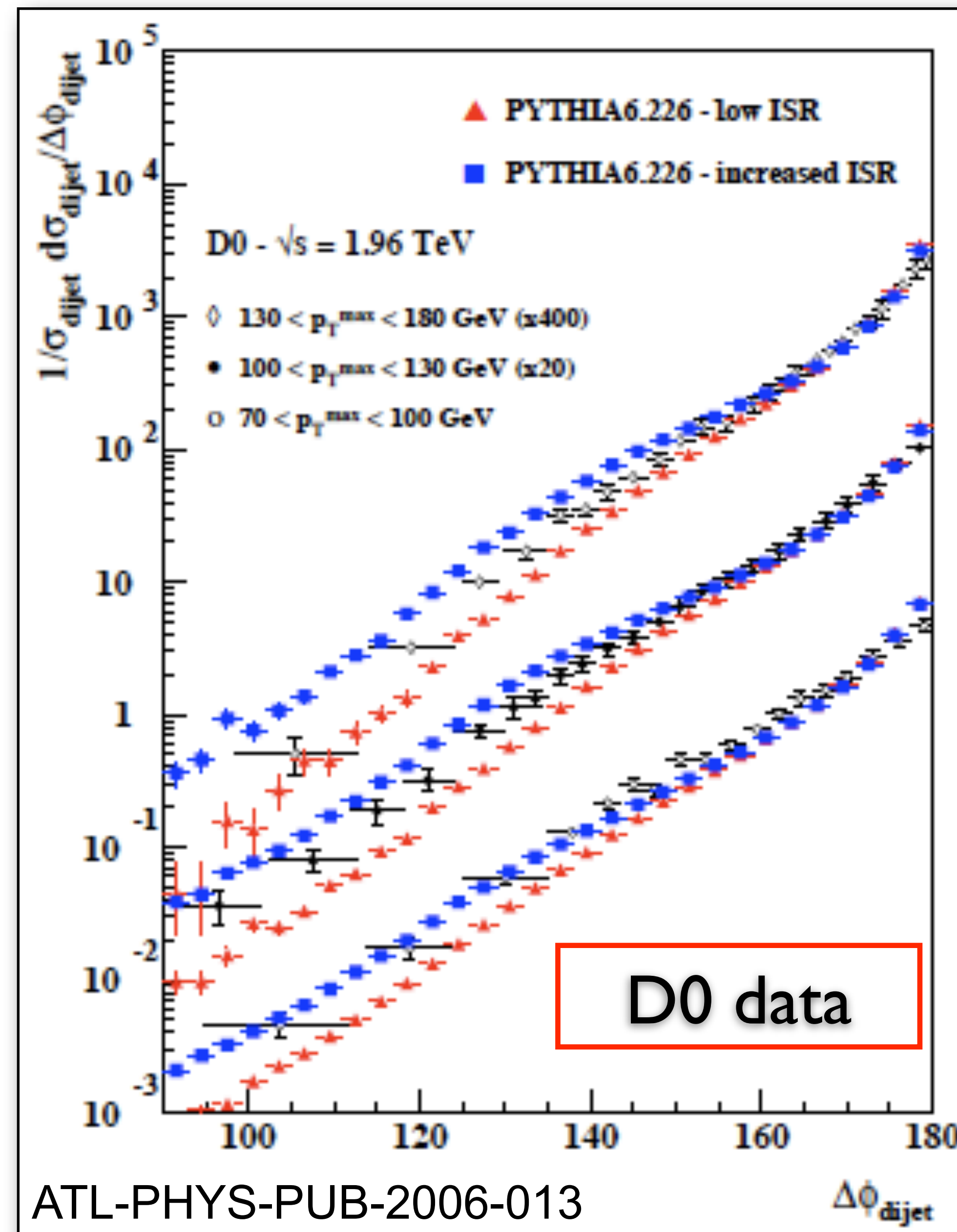


A. Moraes at 4th Hera-LHC Workshop, 2006

Dijet angular de-correlation

- Very early possible check of generators
- Sensitivity mainly to ISR / parton showering
- Uncomplicated measurement of $\Delta\phi = |\phi_{jet1} - \phi_{jet2}|$
    - $\Delta\phi \sim \pi$: clean dijet event, small deviations due to soft radiation
    - $\Delta\phi < \pi$: increasingly harder radation
    - Probes transition from soft to hard radiation





- Analysis divided into regions of leading jet p_T

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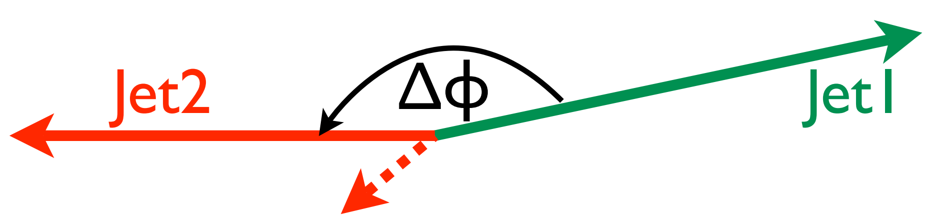
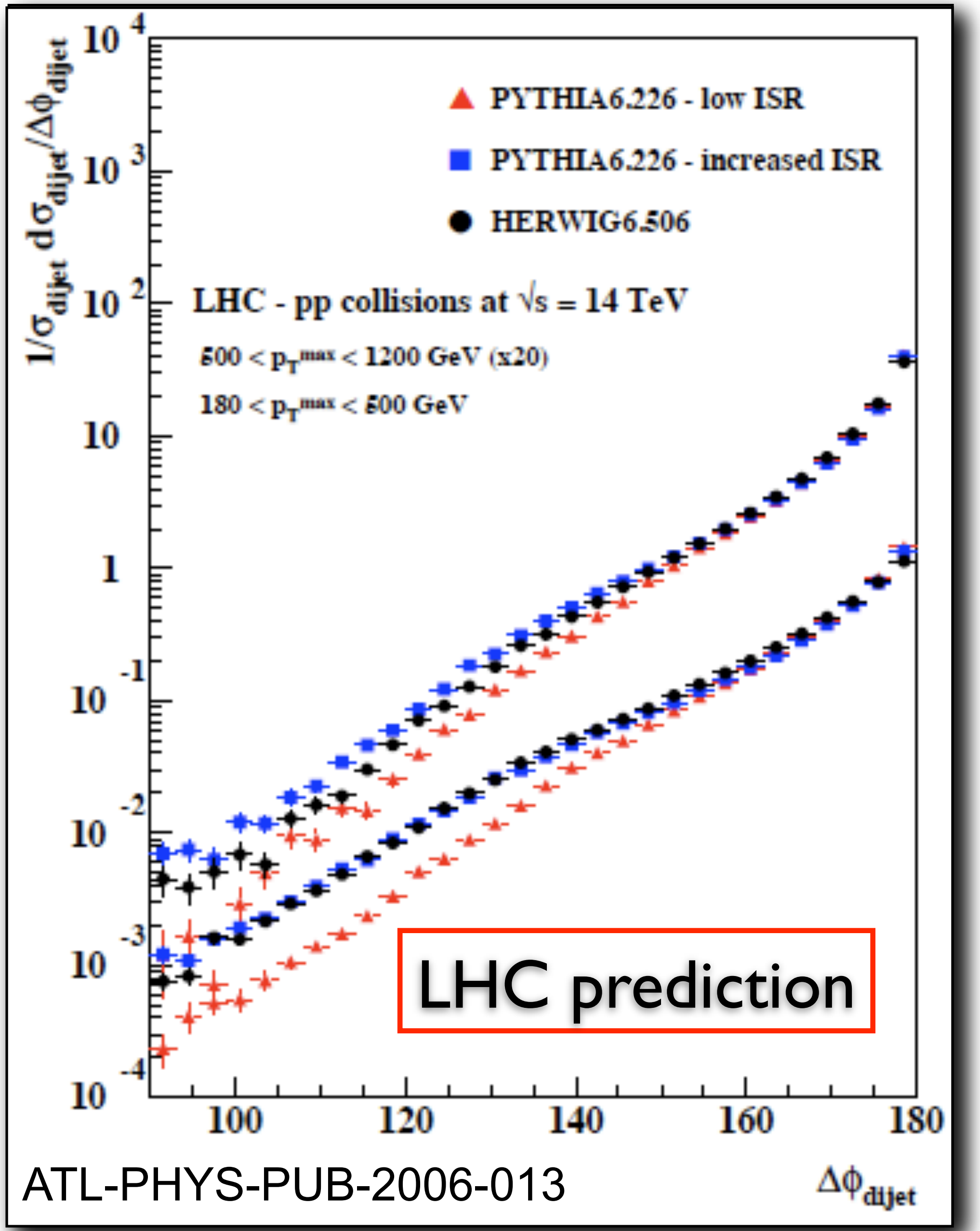


- Analysis divided into regions of leading jet p_T
- Again, extrapolations to LHC energies differ between generators

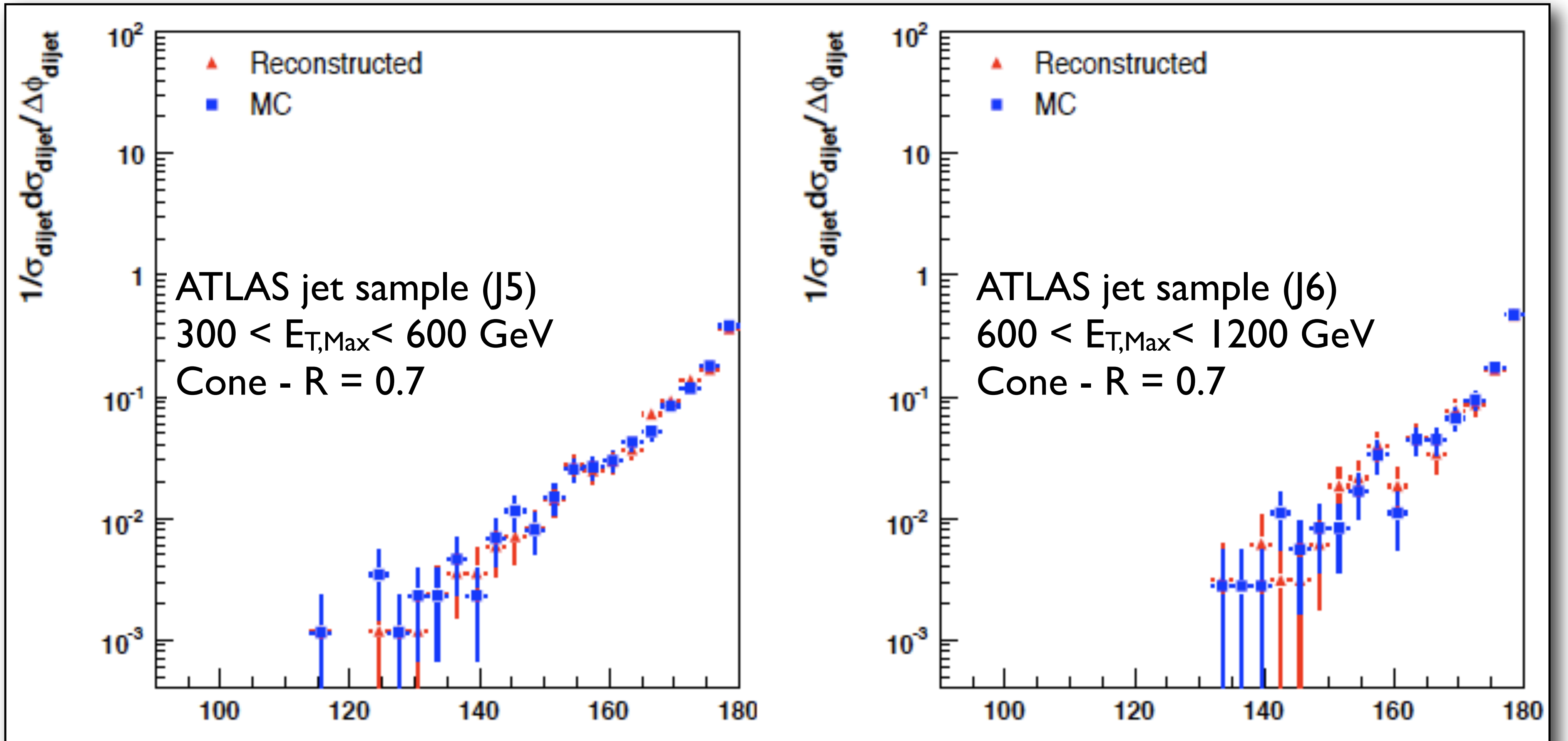


Dijet angular de-correlation

- Cone jet algorithm (R = 0.7), $|y_{Jet}| < 0.5$
- Defined two analysis regions:
  - Simulated 20k events for both regions: 1.6 pb^{-1} / 56 pb^{-1} integrated luminosity -> expect ~50 fold / doubled statistics by end of 2010 run
  - 300 GeV < $E_{T,Jet1}$ < 600 GeV; 600 GeV < $E_{T,Jet1}$ < 1200 GeV
- Only very few further selections applied: $E_{T,Jet2}$ > 80 GeV

Agreement of measured and true distribution.

Practically no corrections necessary!

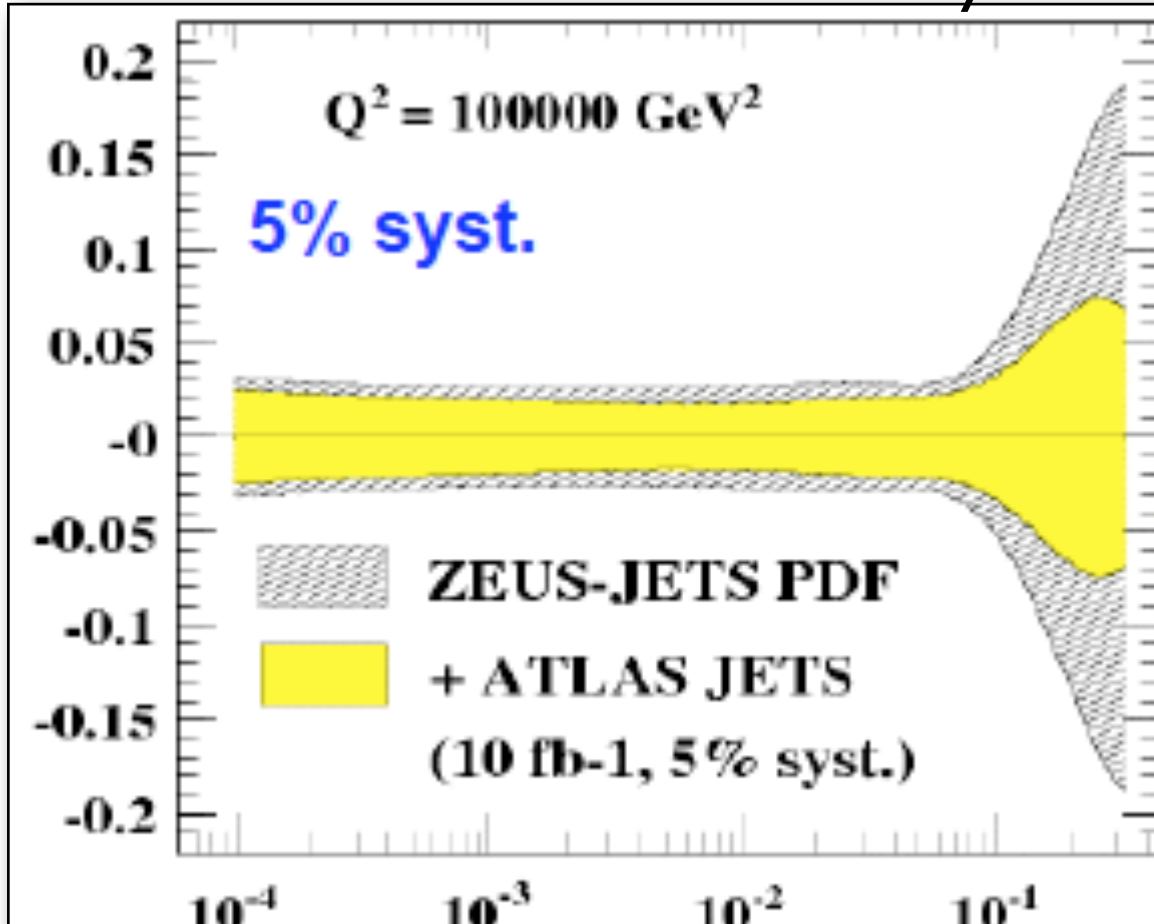


ATL-PHYS-PUB-2006-013

Jet physics

- Jets above 1 TeV will be first ‚new physics': O(100) Jets in 100pb^{-1}
- Di-jets provide easy access to x values of scattered partons
  -> constrain on PDFs esp. at high x and Q^2 possible
- Currently large uncertainties in high x gluon densities - estimated impact of ATLAS jet data
  - Toy-study made using ATLAS pseudo jet data: incl. cross section in bins of |η|
- Not an early data analysis
  - simulated 10 fb^{-1} with 5% syst. uncertainty
- Significant improvement in gluon PDF!
- Systematic uncertainties dominate:
  - Luminosity
  - Jet energy scale & resolution
  - Jet trigger efficiencies
  - Underlying event

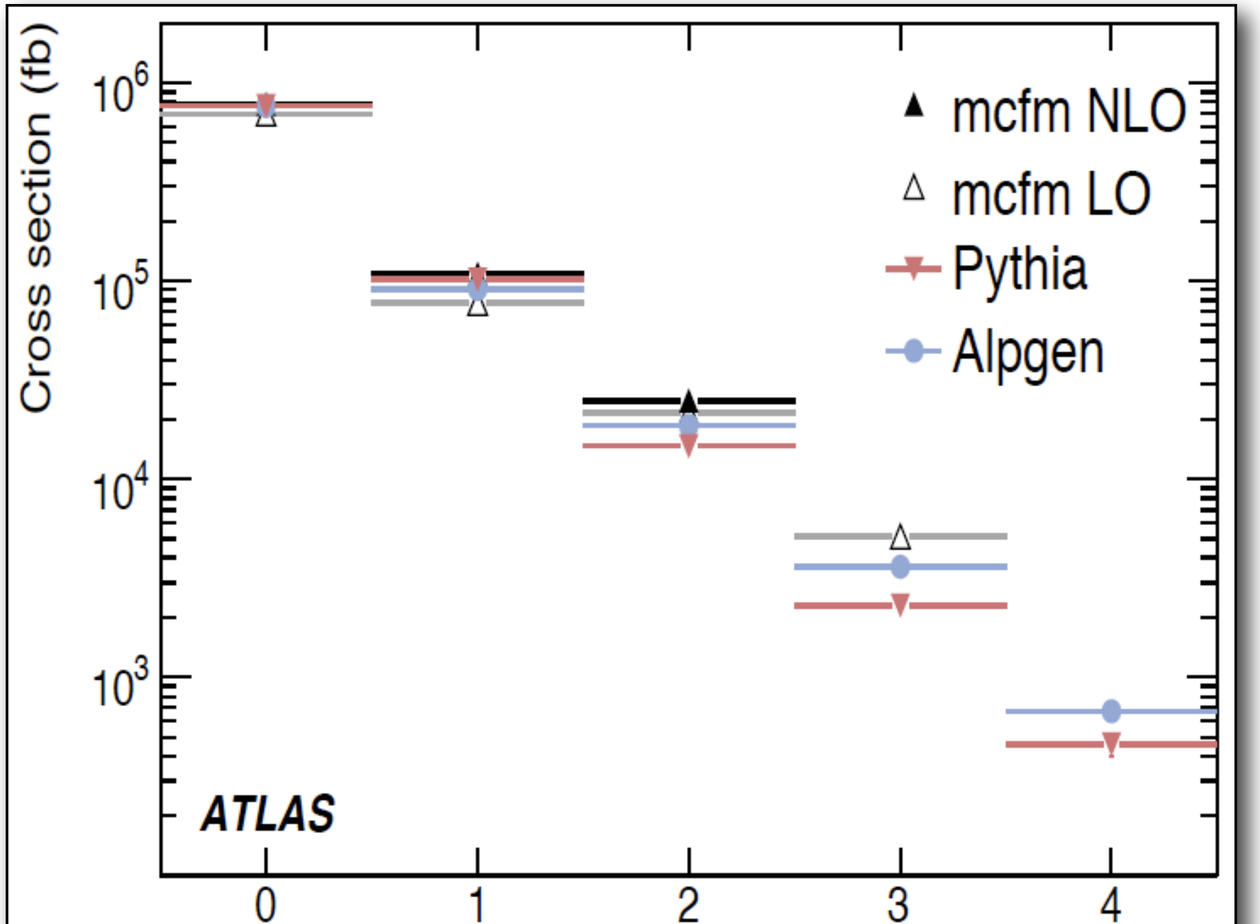
Gluon fractional uncertainty



K. Rabbertz, 4th HERA and LHC Workshop

W/Z + Jets

- Important background in SM analysis & searches for physics beyond the SM
- Current MC generator and calculations differ by 10-60%
- Given 5% jet energy scale uncertainty, we‘ll be competitive with generator-differences!
  - reasonable goal for 1 fb^{-1}
- Comparably small PDF uncertainty



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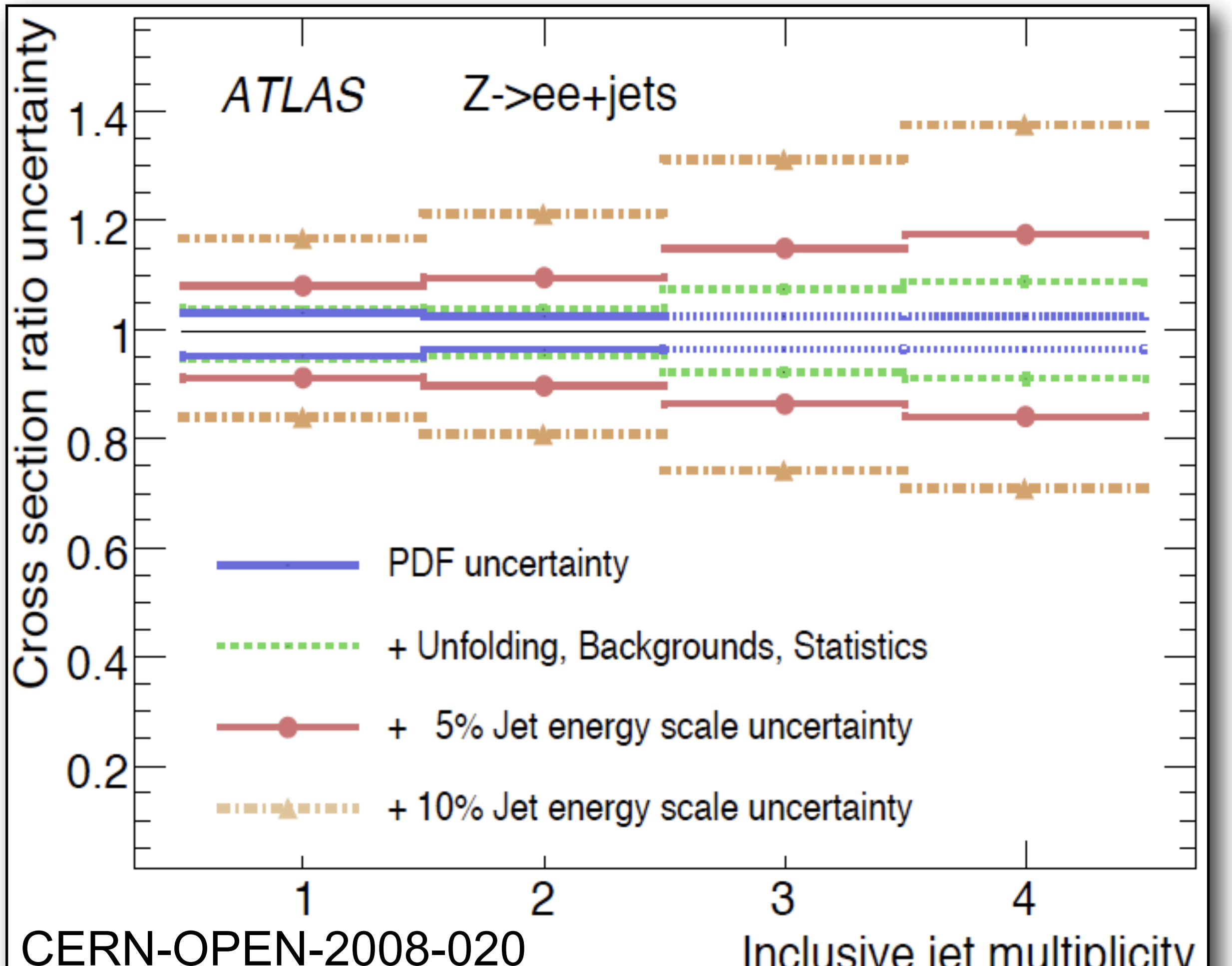

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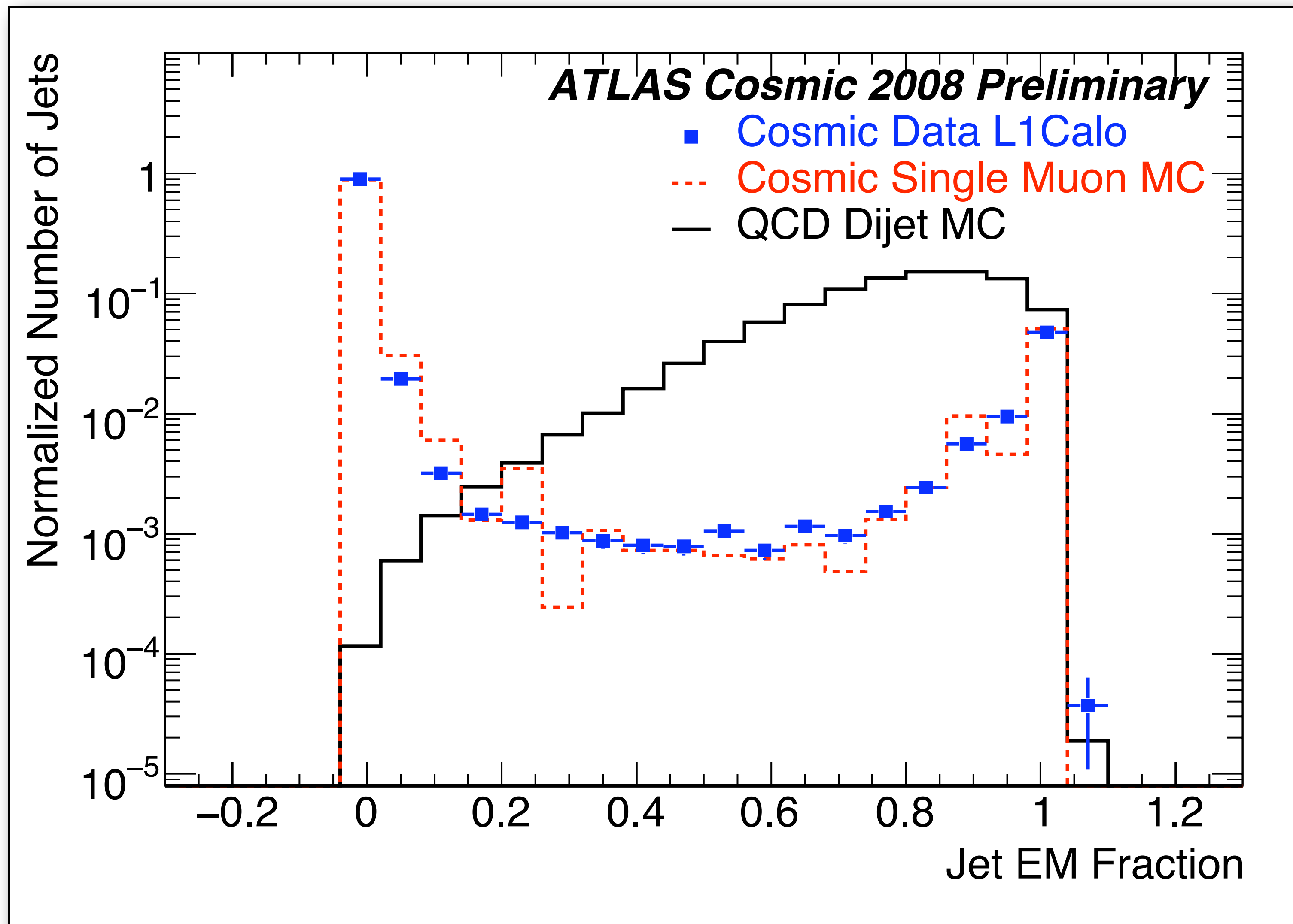
Jets in cosmic ray data

- Today's data - tomorrow's background
- Muons experiencing catastrophic energy loss are visible as ‚jets' - study properties for future background rejection
- Good agreement of cosmic monte carlo and data

- Examined jet cleaning cuts:
- Most muon showers either in em. or had. calorimeter
- Fraction of total energy in EM calorimeter: 0.2 < JetEMFraction < 0.97:
- Number of clusters: $N_{Clus} > 6$
- Rejection by factor ~1000



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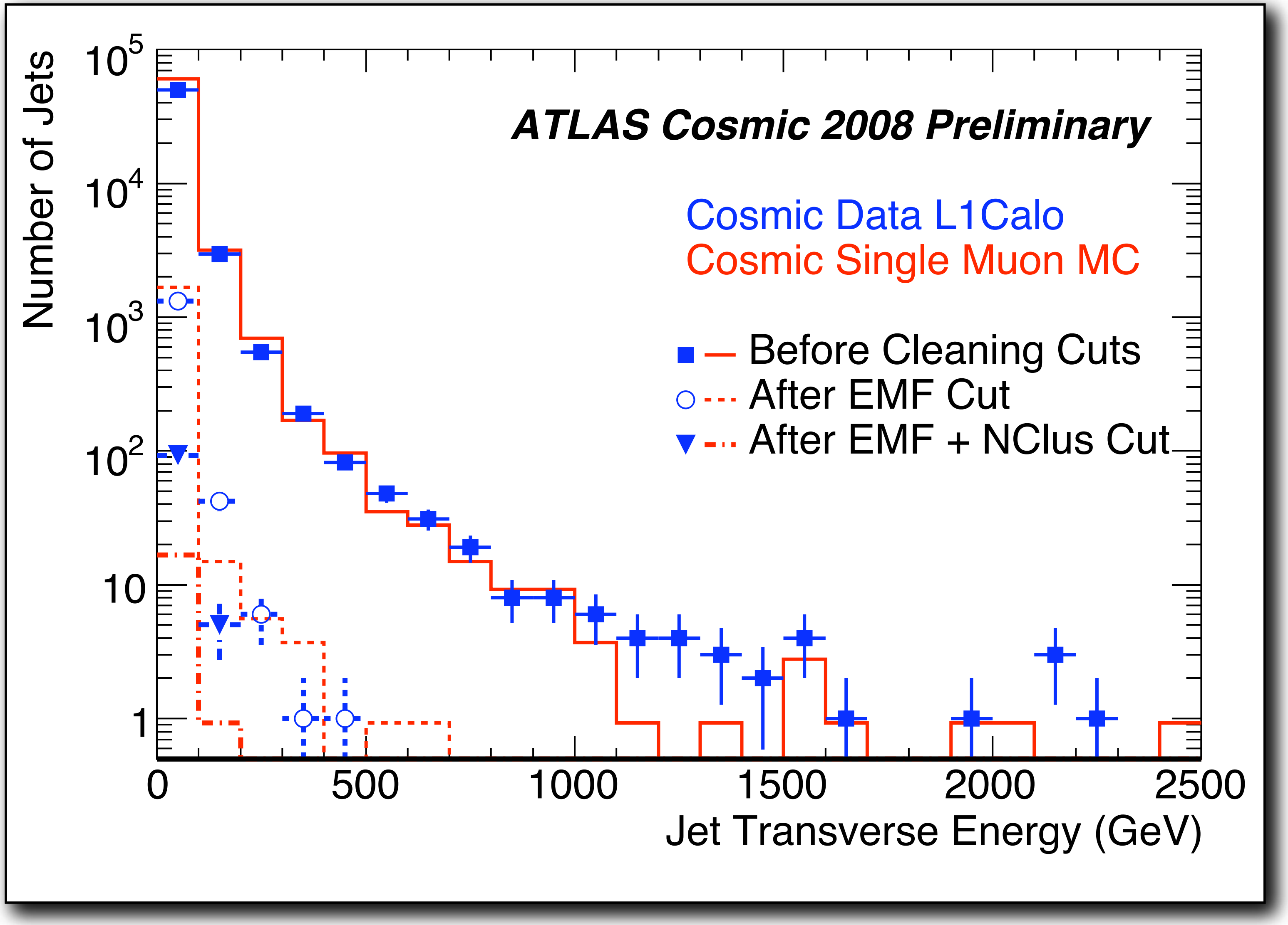
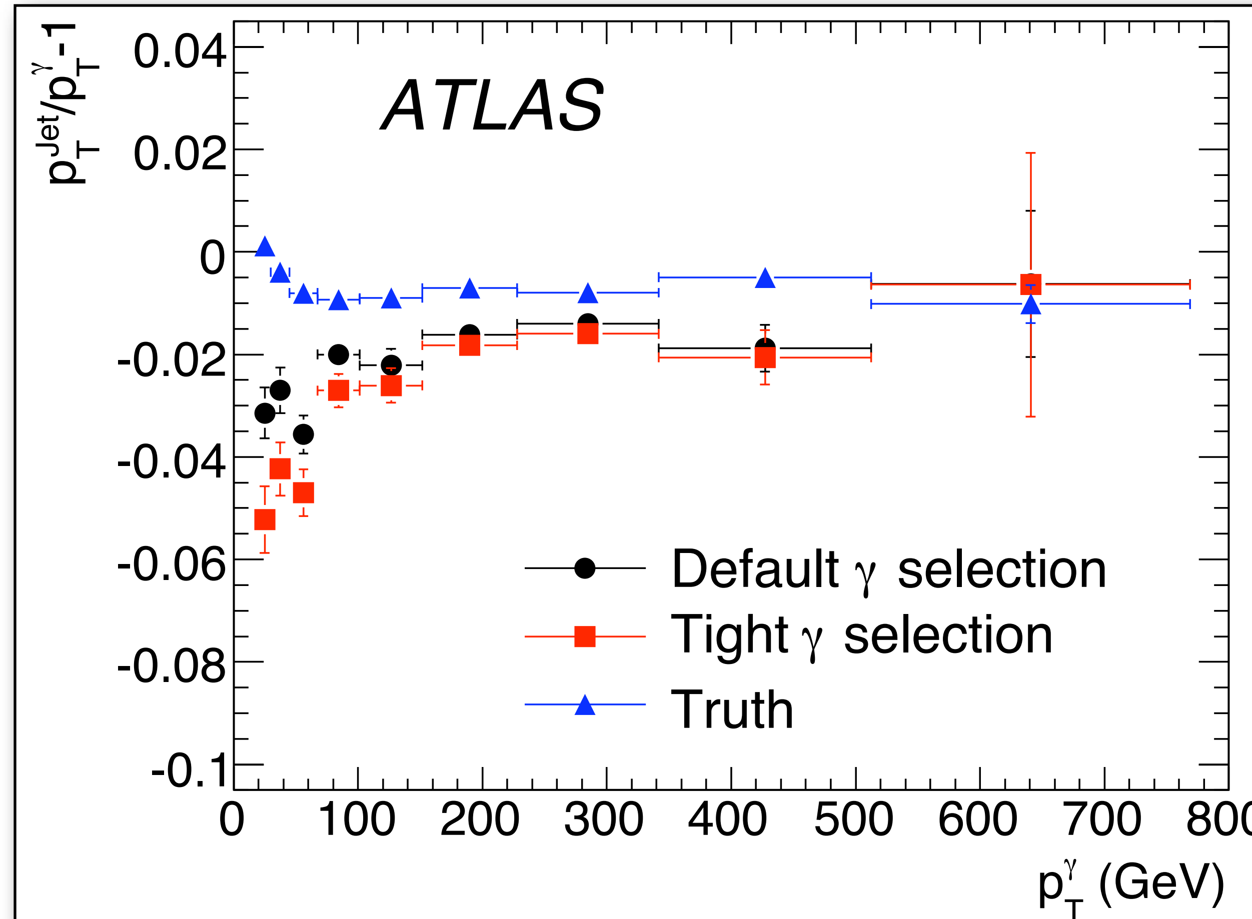


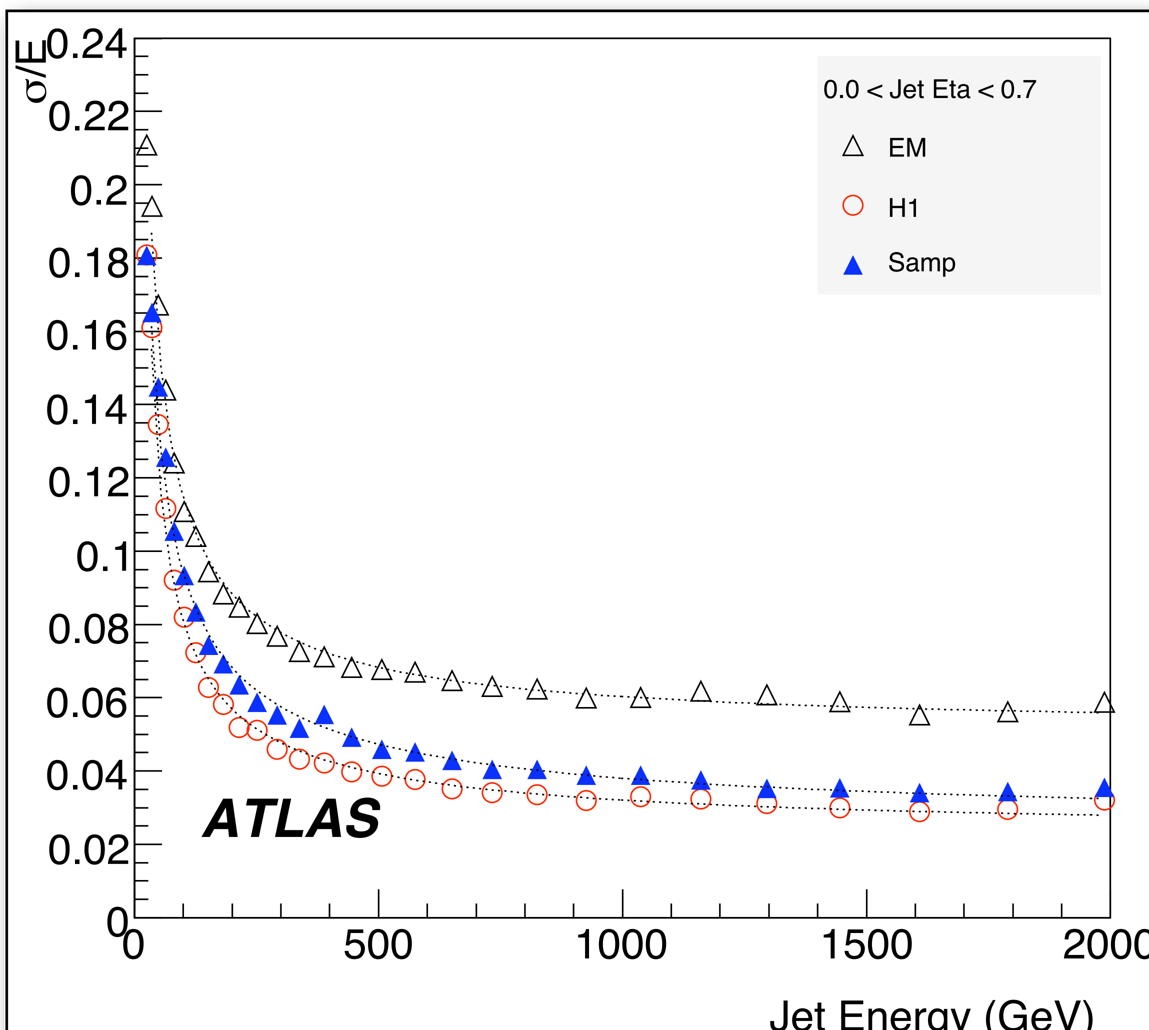
Summary

- ATLAS studied a variety of QCD analysis
- Minimum bias and underlying event studies in early data will help to tune MC generators
- Angular decorrelation will discriminate between ISR models
- Early jet physics will reach beyond Tevatron's kinematic limit
- Ready for the re-discovery of the Standard Model

Jet calibration at ATLAS

- Focus on in-situ calibration procedures in early data
- Use γ/Z+jet events to validate/set jet energy scale



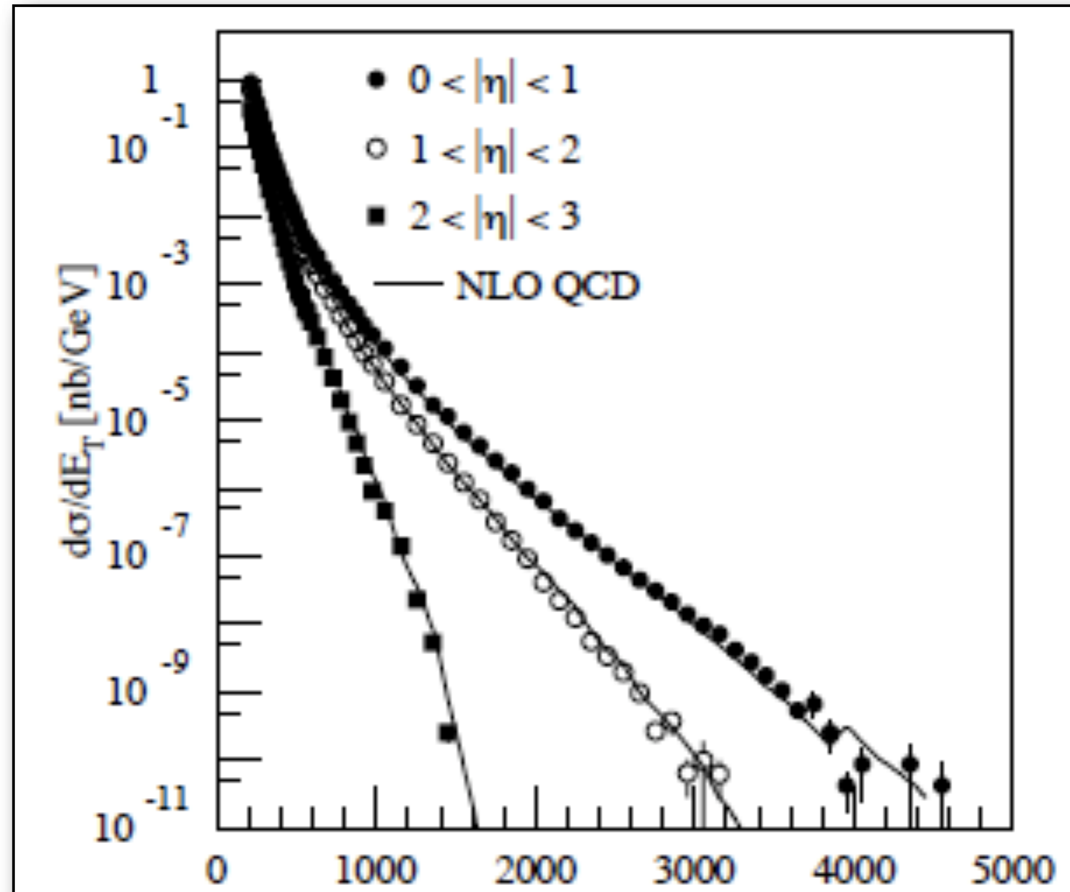


- Longer term plans:
- Validate monte carlo based calibrations
- Based on energy density cell weighting
- Supposed to double energy resolution at high jet energies

Jet physics

- Jets above 1 TeV will be first ‚new physics‘
  - O(100) Jets in $100pb^{-1}$
- Will provide test of pQCD in new energy regime
- Inclusive and multi jet cross section allows α_s measurement
- Multi-jets are significant background for several physics studies

- Statistical uncertainties will be small
- Systematic uncertainties:
  - Luminosity (if applicable): 5 - 10%
  - Jet energy scale - conservative: 10-20% in first data
  - Jet trigger efficiencies
  - Underlying event
  - Theory: PDFs



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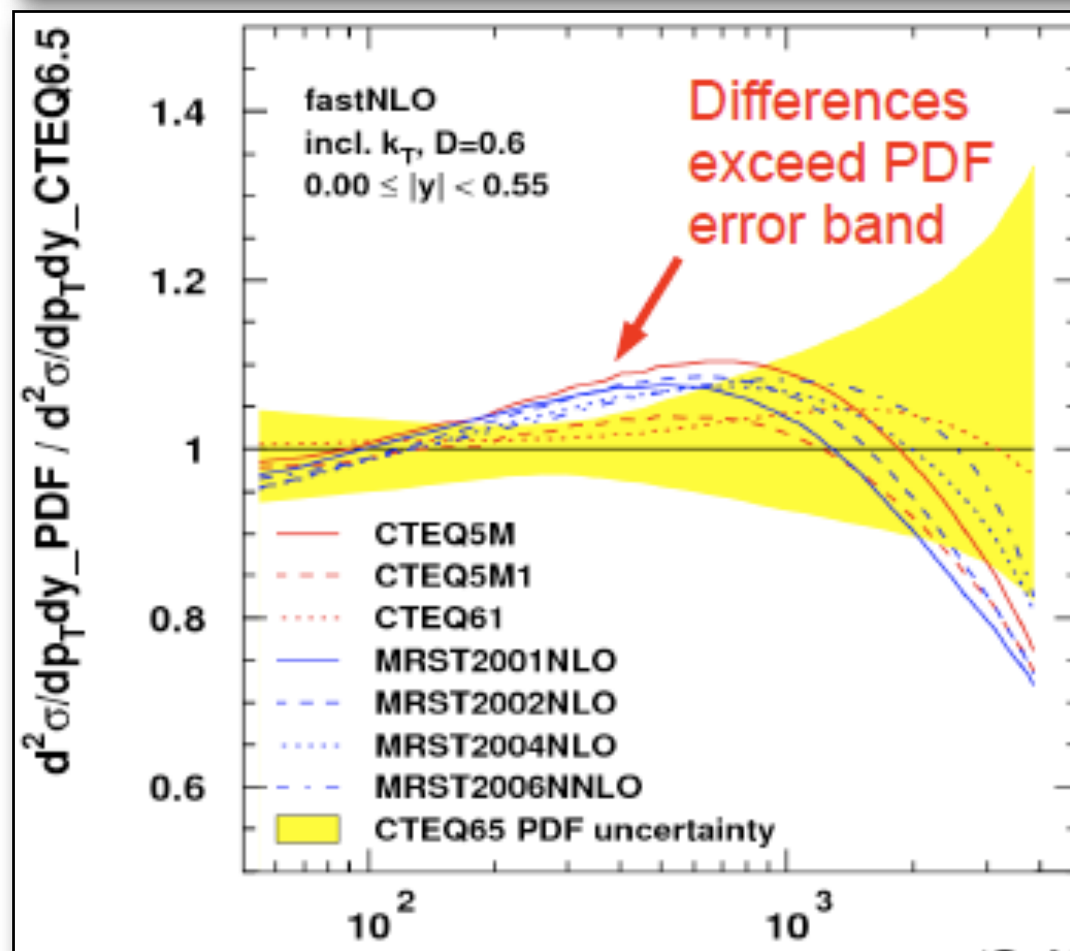

K. Rabbertz, 4th HERA and LHC Workshop