Jet and Photon Results from ATLAS

PAOLA GIOVANNINI

on behalf of the ATLAS Collaboration

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MAX-PLANCK-INSTITUTE FOR PHYSICS
MUNICH

MAX-PLANCK-GESELLSCHAFT

Outline

Test of perturbative QCD at the LHC energy regime

Photons-> Higgs, Graviton, excited fermions and SUSY signatures

Jets -> di-jet final state searches, SUSY, QCD large background

this talk -> SELECTED ATLAS MEASUREMENTS

- Photon results
  - photon reconstruction
  - prompt photon cross section
- Jet results
  - jet reconstruction
  - inclusive jet cross sections
  - multi-jet cross sections
  - many more!

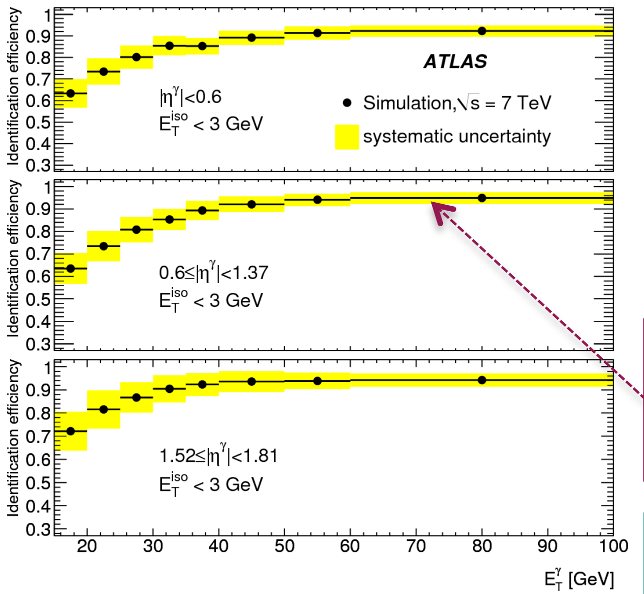
Photon Reconstruction

Phys. Rev. D 83, 052005 (2011)
ATLAS-CONF-2011-058

Photon Candidates

fixed size cluster with E_T> 2.5 GeV
converted photon recovery (associated track)
dedicated calibration for converted and unconverted photons
shape variables (lateral and longitudinal energy profile)
isolation $\Delta r(\eta\Phi)=0.4$, E_T^{iso}< 3 GeV (corrected UE, pile-up)

Prompt Photons
small had leakage
narrow profile
isolated

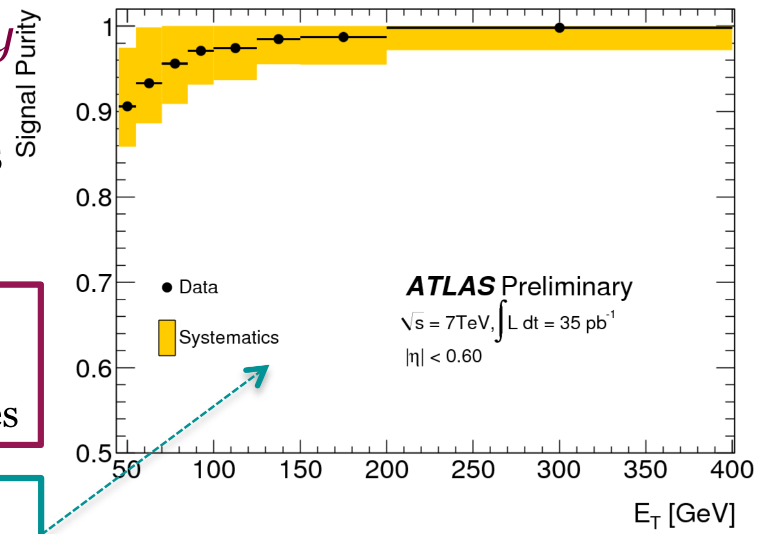


Very good signal efficiency and purity

main background is η/π^0-> $\gamma\gamma$ from jets

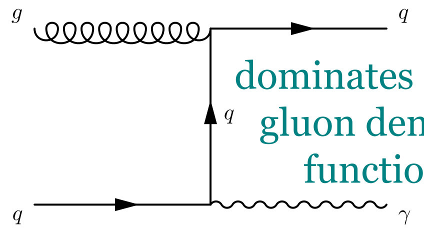
Efficiency from Monte Carlo corrected for data/MC discrepancies

Purity data-driven estimated



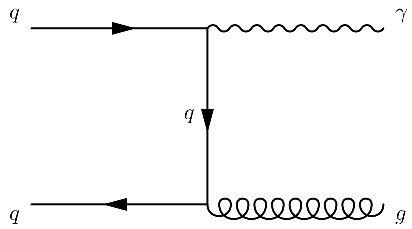
Prompt Photon Cross Section

qg Compton Scattering
(qg -> qγ)

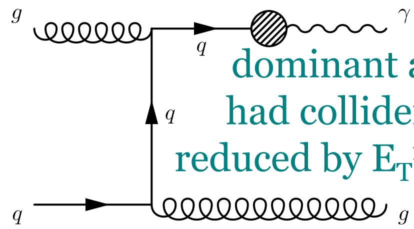


dominates at LO
gluon density
function

$q\bar{q}$ annihilation ($q\bar{q}$ -> gγ)



fragmentation γ from
high p_T partons



dominant at
had colliders
reduced by E_T^{iso} cut

2 complementary measurements
from ATLAS at √s= 7 TeV

880 nb^{-1} int. luminosity
$|\eta|<1.37$, $1.52<|\eta|<1.81$
15$<E_T<100$ GeV

35 pb^{-1} int. luminosity
$|\eta|<1.37$, $1.52<|\eta|<2.37$
$45<E_T<$**400** GeV

theoretical prediction @ NLO
JETPHOX Monte Carlo program

full NLO QCD calculation
isolation $\Delta r(\eta\Phi)=0.4$, $E_T^{iso}<4$ GeV
NLO γ fragmentation function
CTEQ 6.6 (LHAPDF)
MSTW 2008
$\mu_{R,F,f}$ scales $=p_T$ of the γ
non-p. corrections (PYTHIA/HERWIG)

Prompt Photon Cross Section

Phys. Rev. D 83, 052005 (2011)
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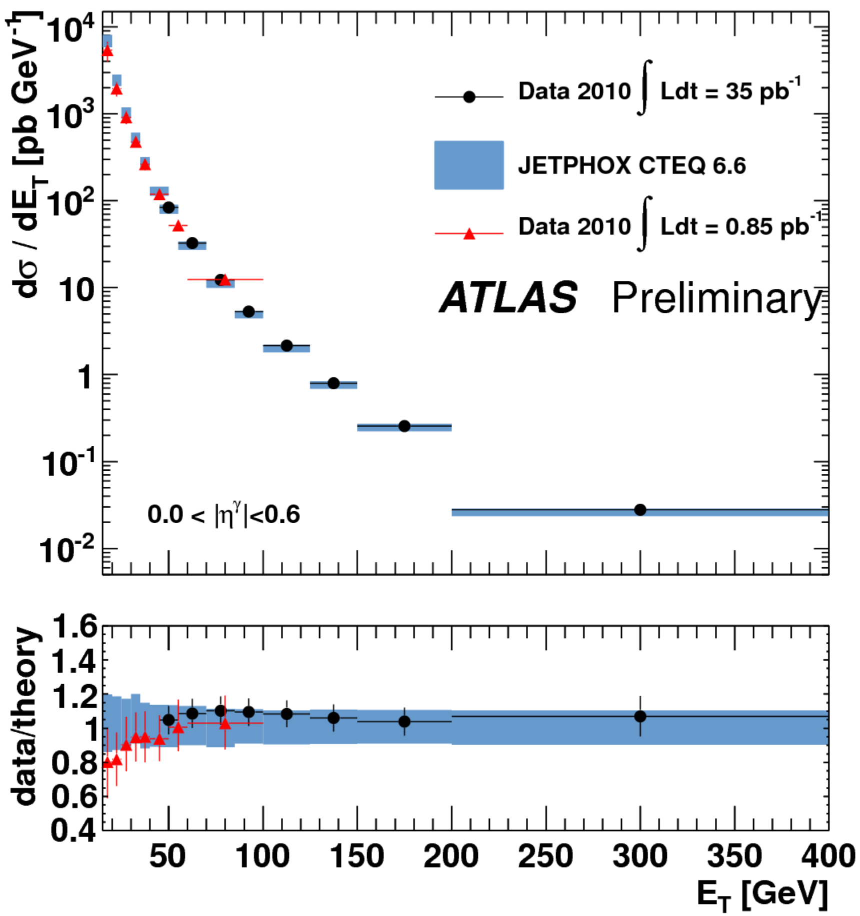


MSTW and other η in back-up

Experimental uncertainties
efficiencies (dead material, shower shape)
background estimation (cut variation)
unfolding (energy resolution)
luminosity (11% and 3.4%)

Theoretical uncertainties
variation of the PDF within 68% CL
variation of the μ scales (0.5, 2.0) [10-20%]
variation of isolation (2-6 GeV)
MSTW Pdf give 3-5% higher values

NLO pQCD prediction agree with data for E_T> 25 GeV, for smaller E_T values prediction limited by small x_T (μ scales) and by the fragmentation component

Jet Reconstruction

ATLAS-CONF-2011-032
ATLAS-CONF-2011-028

anti-k_T algorithm (R= 0.4, **0.6**) *infrared and collinear safe*
calorimeter jets from 3D noise-suppressed topo-clusters
Monte Carlo true jets from particles τ> 10 ps

EM+JES calibration:

- average pile-up energy subtraction (η,N_{PV})
- jet position corrected w.r.t. primary vertex
- jet energy corrected with weights (E, η)

2% final closure

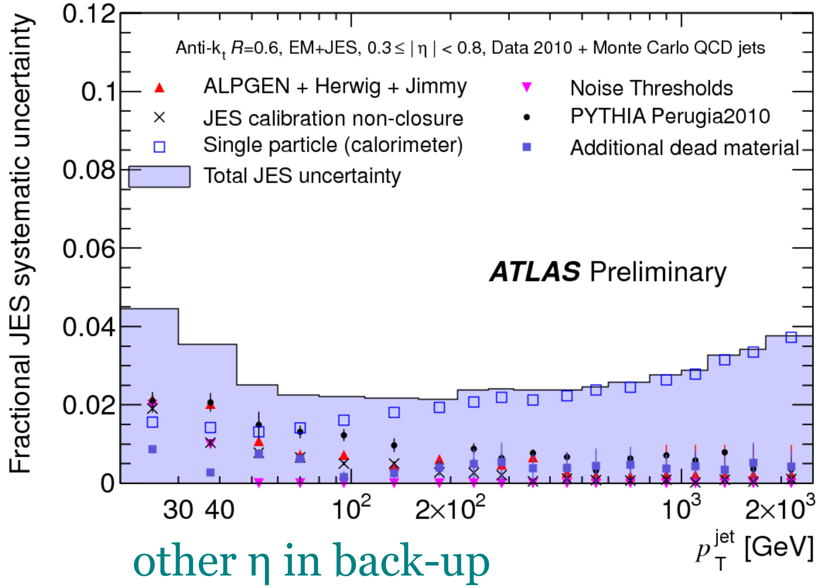
JES systematic uncertainty:

- calorimeter response (E/p and beam test)
- noise and dm description in MC
- event generator (ALPGEN/PHYTIA)
- pile-up uncertainty (N_{PV}) [~ 1.5% * PV]

Extended to End-Cap and Forward region via η intercalibration (additional uncertainty)

Typical JES systematic uncertainty

4-2 % barrel
7-3 % end-cap
13-3% forward



other η in back-up

Jet Reconstruction

ATLAS-CONF-2011-032
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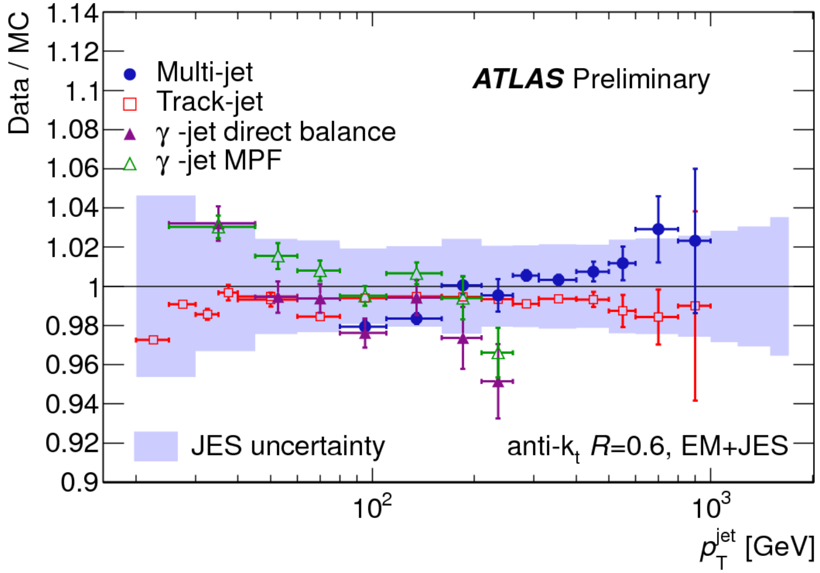


Systematic uncertainty validation

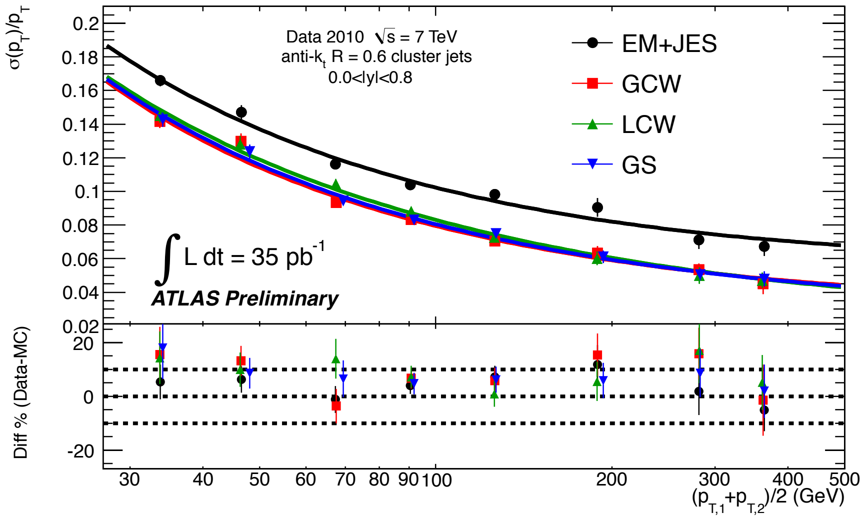
- energy recoil in multi-jet events
- energy balance in γ+ jet events
- energy measurement with tracks

GOOD AGREEMENT

Jet energy resolution

- measured on di-jet events
- improvement by sophisticated calibrations
- Monte Carlo description inside 10%
- consistent with systematic uncertainty (on the resolution measurement)

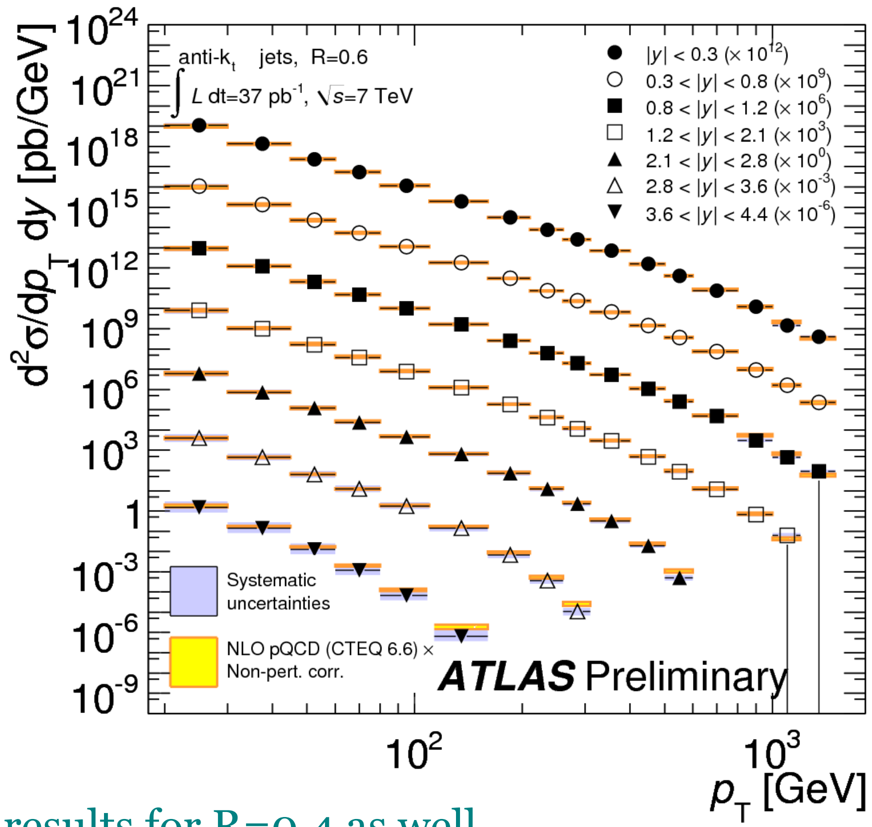
  different generators, varied cuts



Inclusive Jet Cross Section

ATLAS-CONF-2011-047

pQCD in a new kinematic regime
very forward coverage



results for R=0.4 as well

measurement @ √s= 7 TeV

37 pb^{-1} int. luminosity
$|y|<4.4$
20 GeV $<p_T<$1.5 TeV

steeply falling p_T spectrum

theoretical prediction @ NLO

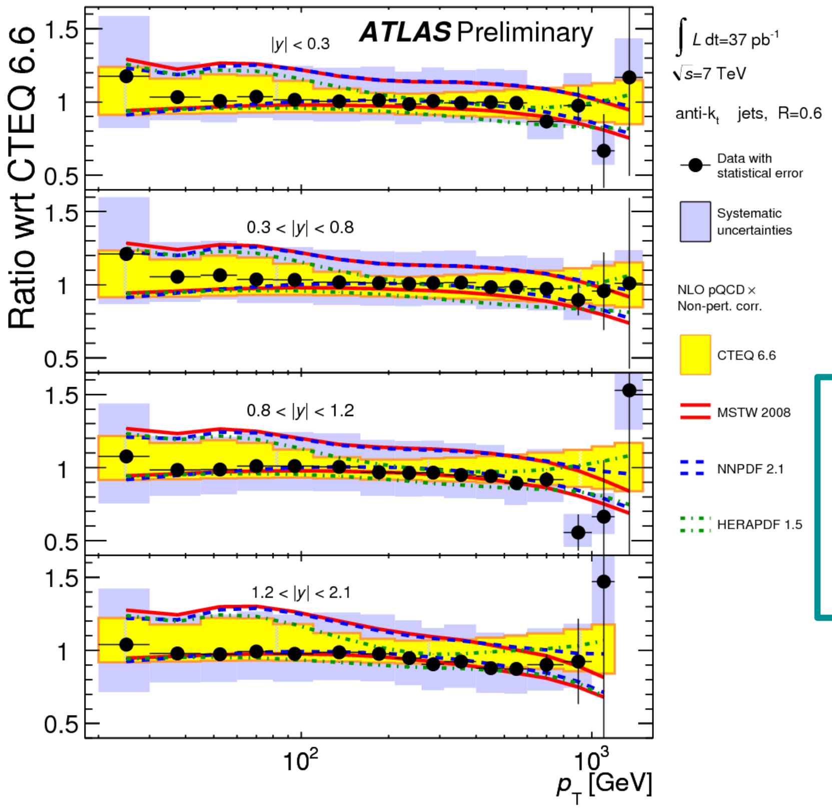
NLOJet++
CTEQ 6.6 (default)
non-p corrections (PYTHIA)

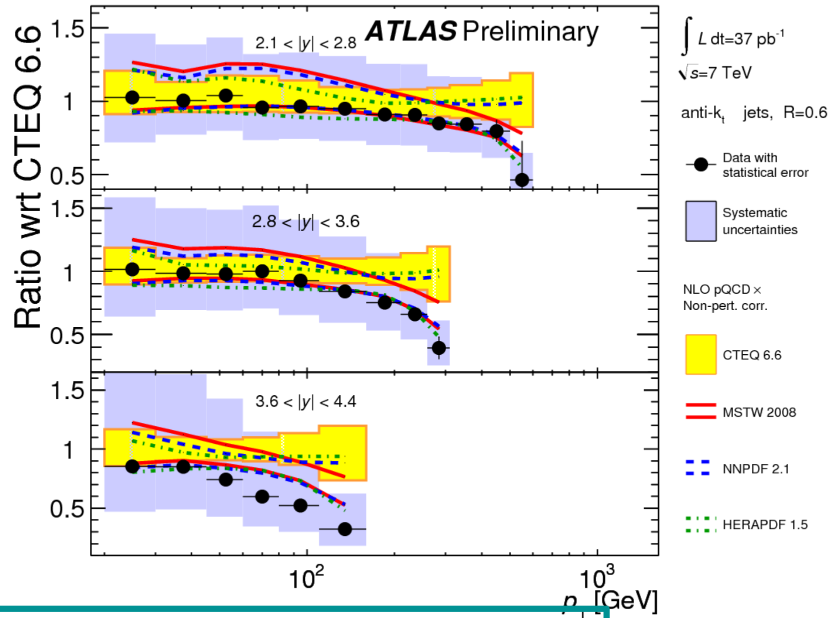
POWHEG + PYTHIA/HERWIG
NLO 2-> 2 processes
MSTW 2008

Inclusive Jet Cross Section

ATLAS-CONF-2011-047

data and theory (NLOJet++)
agree within uncertainties





Experimental uncertainties
dominant JES uncertainty
unfolding (resolution 10%)
luminosity (3.4%)

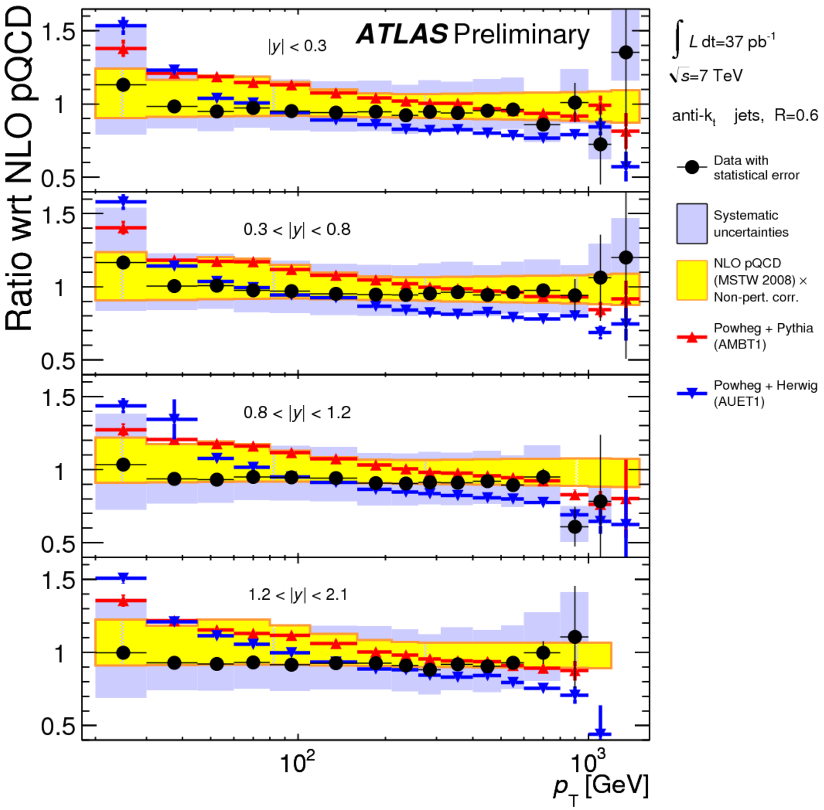
Theoretical uncertainties
PDF and μ_{RF} scales (2.0) [APPLGRID]
α_S uncertainty

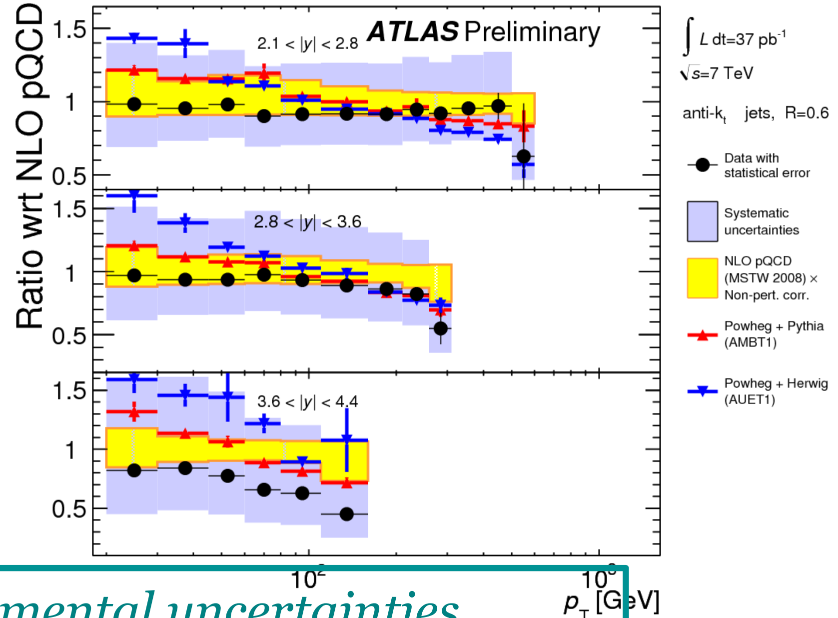
Inclusive Jet Cross Section

ATLAS-CONF-2011-047

comparison with POWHEG

- agreement with NLOJET++ at ME (same PDF)
- differences due to PS
- agreement within uncertainties





Experimental uncertainties

dominant JES uncertainty
unfolding (resolution 10%)
luminosity (3.4%)

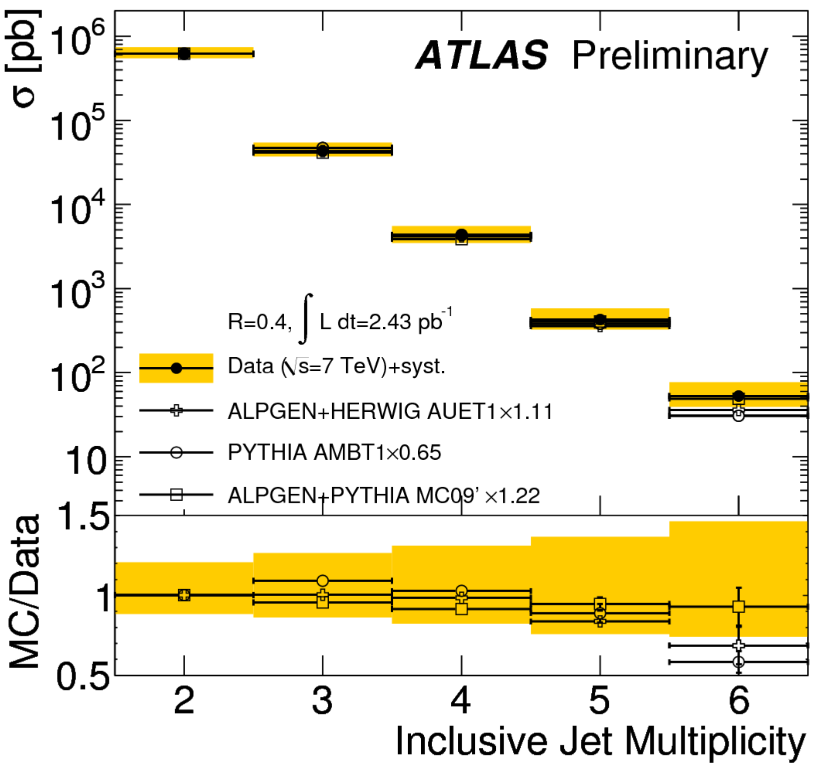
Theoretical uncertainties

difference between PYTHIA and HERWIG is a measure of the uncertainty on the POWHEG predictions

Multi-Jet Cross Section

ATLAS-CONF-2011-043

test of pQCD and non-p effects
relevance for new particle searches



anti-kt R=0.4 to reduce UE

measurement @ √s= 7 TeV

2.43 pb^{-1} int. luminosity
$|y|<2.8$
$p_T > 60$ GeV, $p_T^{lead} > 80$ GeV

steeply falling n_{jet} spectrum

theoretical prediction @ LO

ALPGEN (2->6)+ PYTHIA/HERWIG
CTEQ6L1

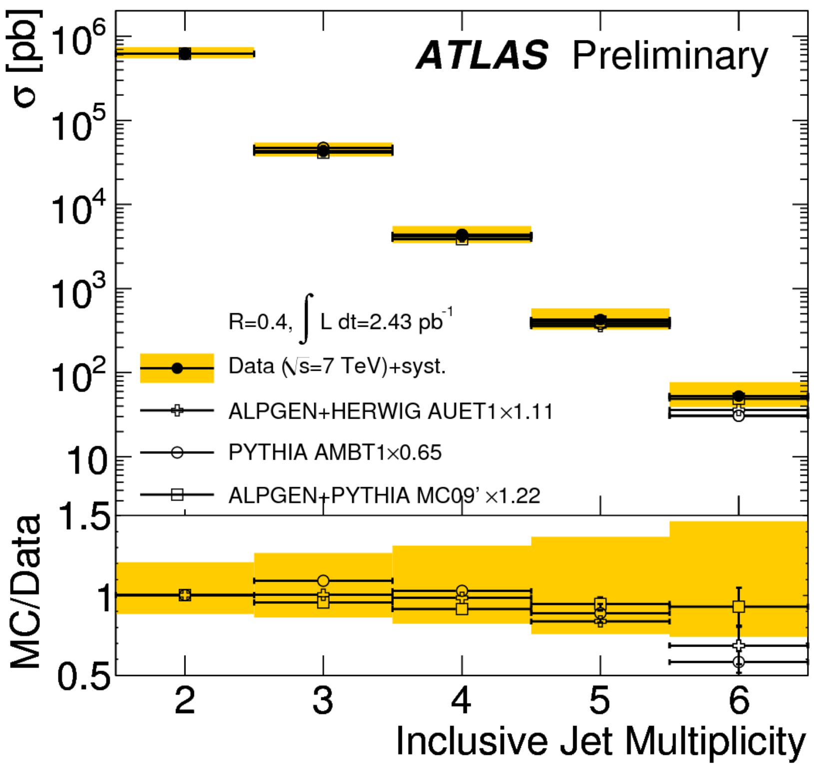
PYTHIA (2->2)
CTEQ5L

shape comparison
normalization to inclusive di-jet
no systematic error assessment

Multi-Jet Cross Section

ATLAS-CONF-2011-043

test of pQCD and non-p effects
relevance for new particle searches



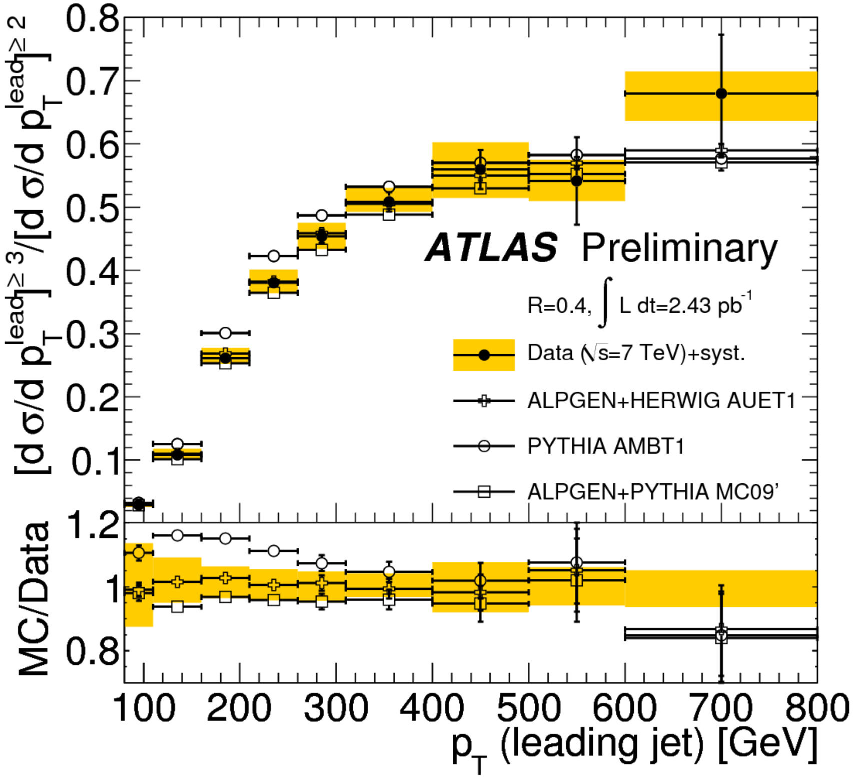
Experimental uncertainties
dominant JES uncertainty [20-40%]
(larger for *non-isolated* topologies!)
unfolding (resolution 10%)
luminosity (3.4%)

Monte Carlo LO predictions fall on the data distributions across the multiplicity spectrum

Multi-Jet Cross Section

ATLAS-CONF-2011-043

ratio of the inclusive 3-jets
to the inclusive 2-jets cross section



REDUCED

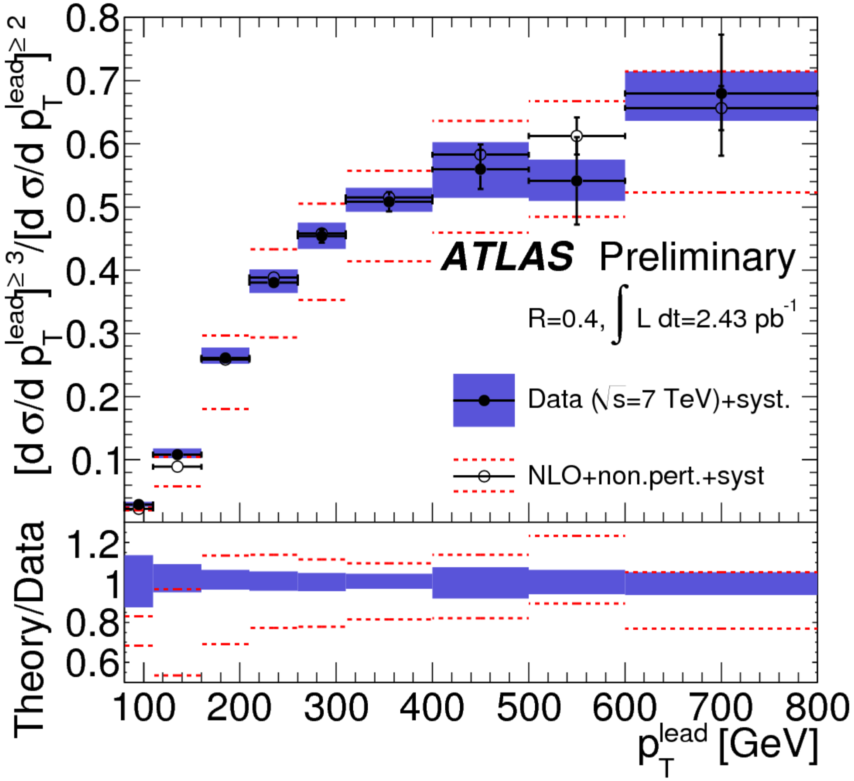
Experimental uncertainties
~~dominant JES uncertainty [20-40%]~~
unfolding dominates ~ 5%
~~luminosity (3.4%)~~

ALPGEN+HERWIG
describes data within uncertainties
PYTHIA overestimates 3-jet
cross section for lower p_T

Multi-Jet Cross Section

ATLAS-CONF-2011-043

ratio of the inclusive 3-jets to the inclusive 2-jets cross section



theoretical prediction @ NLO

NLOJet++
xMSTW 2008
$\mu_{R,F}$ scales = sum of jet p_T
non-p. corrections (ALPGEN+HERWIG)

Theoretical uncertainties
PDF and μ_{RF} scales (0.5,2.0)
α_S uncertainty
non-p. corrections (PYTHIA)

good agreement between data and NLO predictions

(lowest p_T bin-> effective LO calculation)

And Many More

Jet Shape

[Phys. Rev. D 83, 052003 (2011)]

soft gluon radiation, UE, non-p. effects

- ✓ jet shape as p_T density (diff and int)
- ✓ 30 GeV < p_T < 600 GeV, |y|, 2.8
- ✓ compared to PYTHIA (UE tunes), HERWIG++, ALPGEN+HERWIG

PYTHIA-Perugia2010 predicts data
HERWIG++ predicts broader jets
ALPGEN+HERWIG, PYTHIA-DW and PYTHIA-MC09 predicts narrower jets

Di-Jet with Jet Veto [ATLAS-CONF-2011-038]

large jet y separation, wide angle soft g radiation test of pQCD, background for Higgs (VBF)

- ✓ HEJ (BFKL all-order-resummation) and POWHEG

HEJ does not describe data in all regions (match. to PS needed), *POWHEG describes* data but for large Δy where all-order-resummation needed

Di-Jet Azimuthal Decorrelations

[arXiv:1102.2696]

test of multi-jet pQCD without measuring additional jets

- ✓ $\Delta\phi$ between 2 highest p_T jets
- ✓ normalized σ (with inclusive 2-jet)
- ✓ 110 GeV < p_T < 1.3 TeV, |y|< 0.8
- ✓ compared to NLOJet++ (non-p. corrections with PYTHIA)
- ✓ compared to SHERPA, PYTHIA and HERWIG

NLO calculation fails to describe data for $\Delta\phi \rightarrow \pi$ (log terms enhanced)

SHERPA does well in most regions
(higher order tree-level diagrams)
PYTHIA and HERWIG also describe the data (tuned on other measurements)

Conclusions

ATLAS has an extensive program of photon and jet measurements

- test of pQCD in new energy and rapidity regimes
- background for new physics searches
- comparison with NLO calculation and with LO and LL generators
- impressive good agreement between MC and data

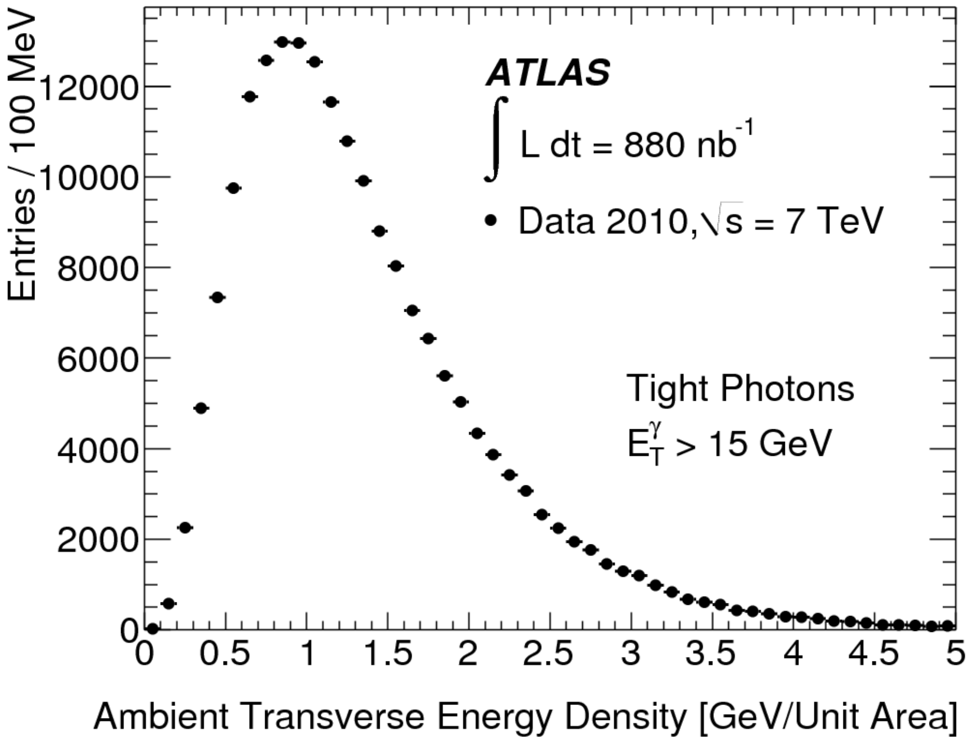
expected improvements with larger statistics and reduced systematics
in particular with an improved JES determination

THANKS

Back-up slides

Photon Isolation Energy

calculation of E_t^{iso} corrected for detector effects to be comparable to parton level NLO calculations



leakage of photon energy outside isolation cone subtracted

underlying event and pile-up contributions subtracted by using the jet area method (DATA-DRIVEN)

p_T density of k_T jets (no lower p_T cut) from noise suppressed topo-clusters * ISO area

~ 540 MeV for a typical event but large fluctuations

Prompt Photon Cross Section

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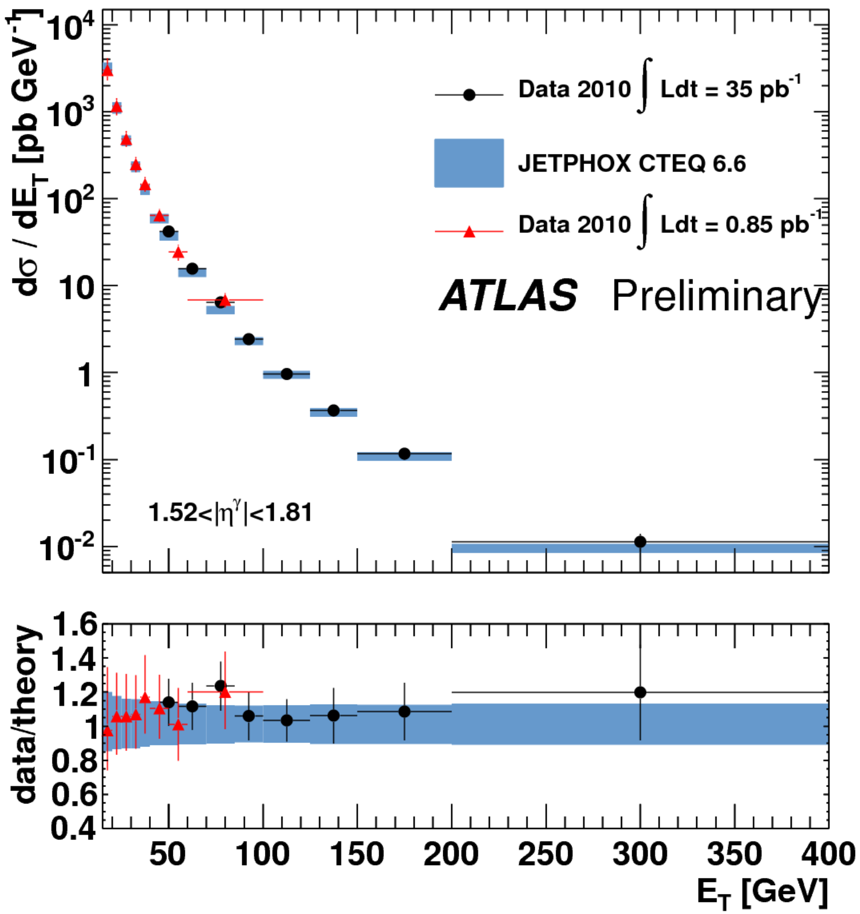
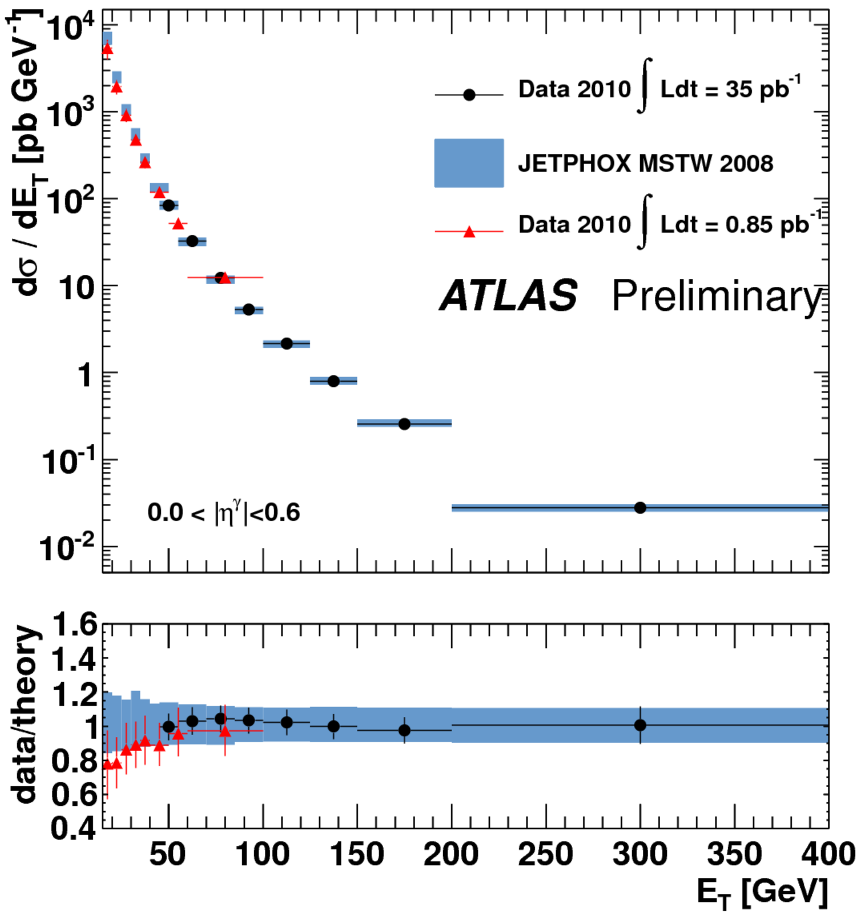
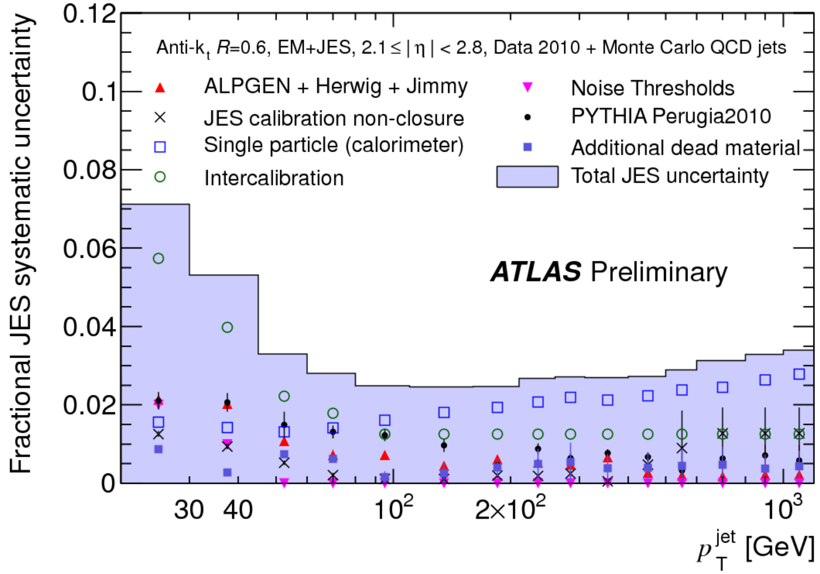


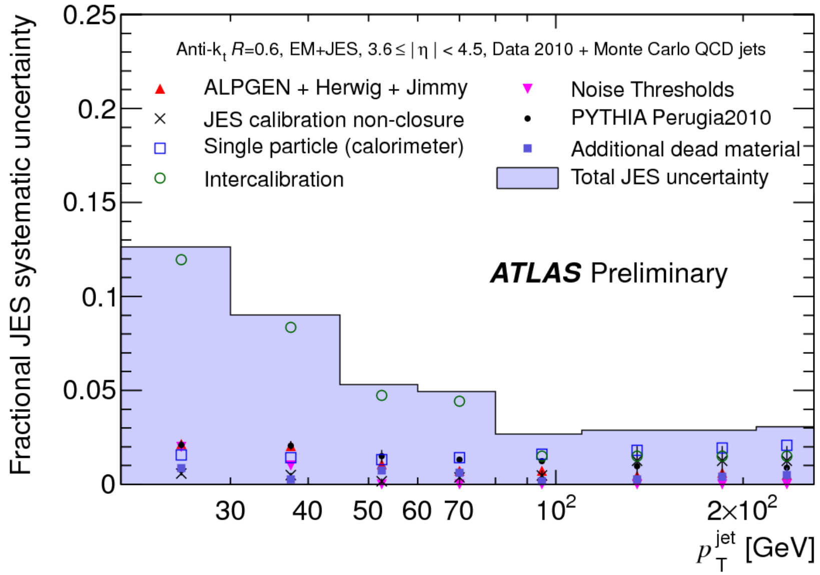


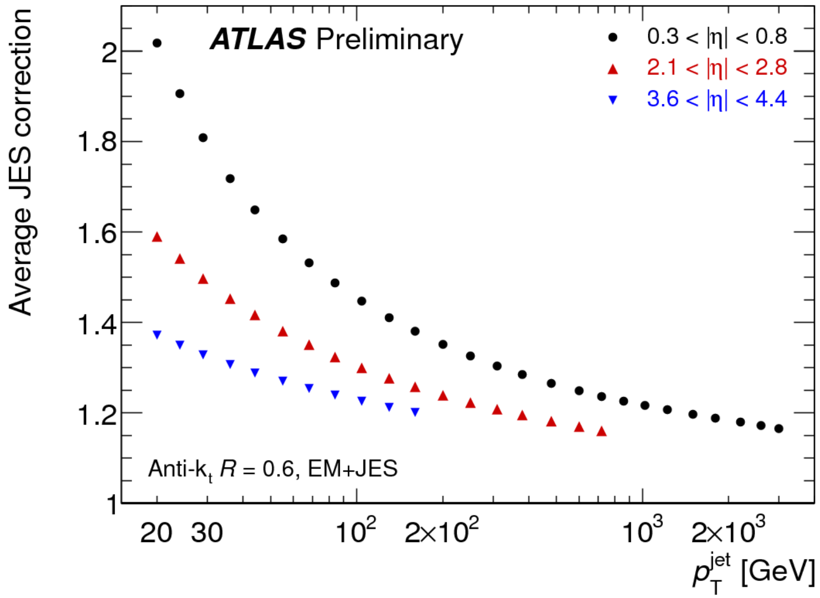
Jet Reconstruction

ATLAS-CONF-2011-032
ATLAS-CONF-2011-028

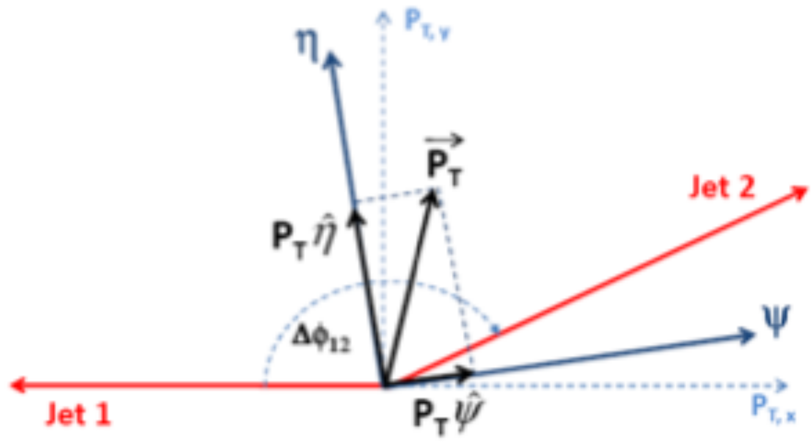


JES systematic uncertainty
for end-cap and forward region
and typical EM+JES weights





Jet Energy Resolution



Bisector technique

✓ $\sigma_\psi^{2(part)} = \sigma_\eta^{2(part)}$ particle level
✓ $\sigma_\psi^{2(part)} - \sigma_\eta^{2(part)}$ is a measure of the detector resolution
✓ method applicable to all di-jet event topologies

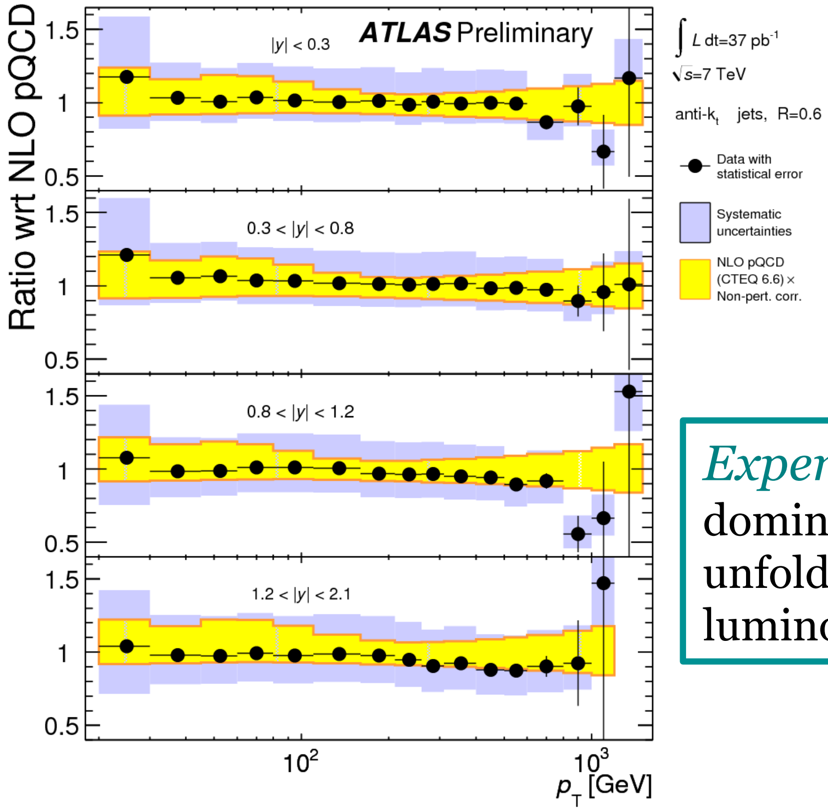
P_T is the imbalance vector between the two jets with highest p_T in the event
σ is the Gaussian spread of the relevant distribution

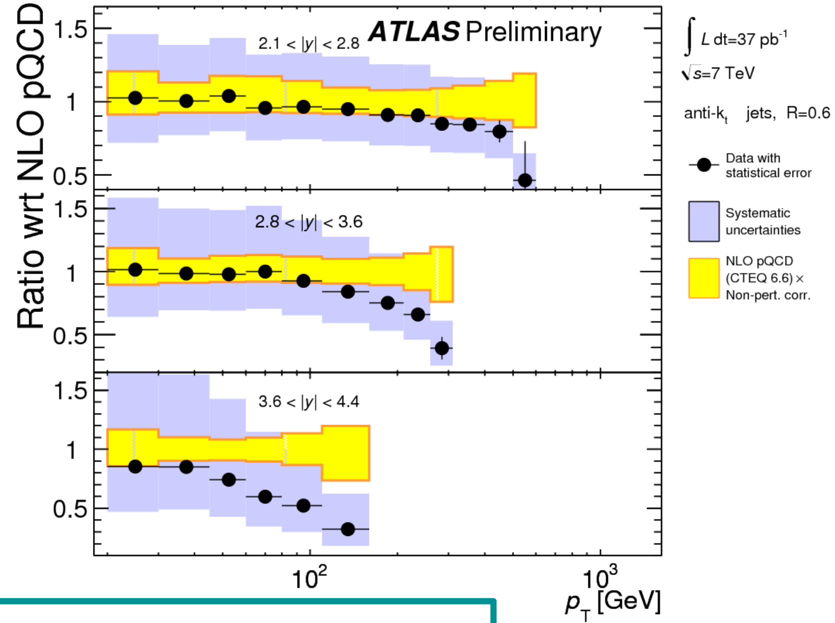
Asymmetry technique used as well, needs back-to-back topologies, leads similar results

Inclusive Jet Cross Section

ATLAS-CONF-2011-047

data and theory (NLOJet++)
agree within uncertainties





Experimental uncertainties
dominant JES uncertainty
unfolding (resolution 10%)
luminosity (3.4%)

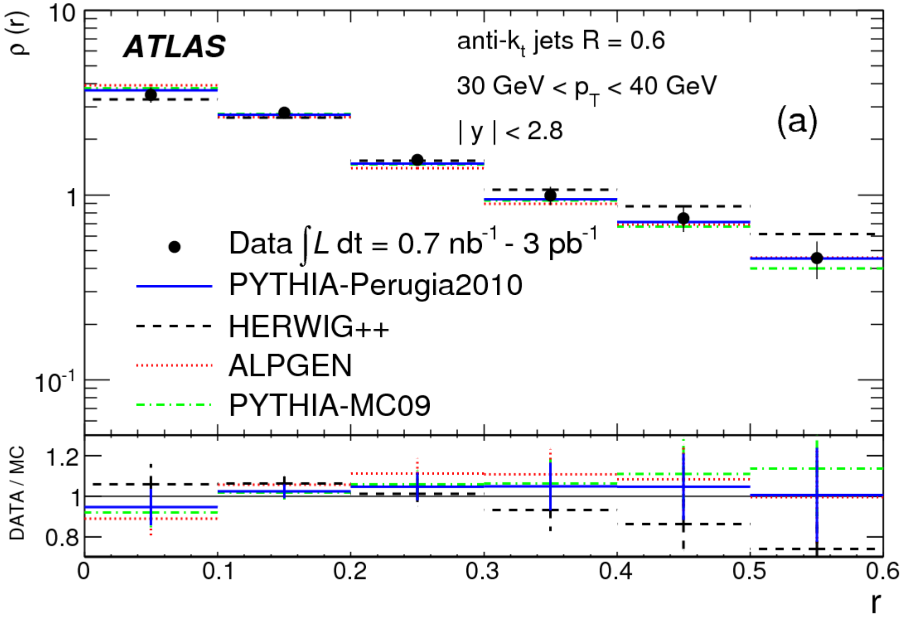
Theoretical uncertainties
PDF and μ_{RF} scales (2.0) [APPLGRID]
α_S uncertainty

other PDF and POWHEG in back-up

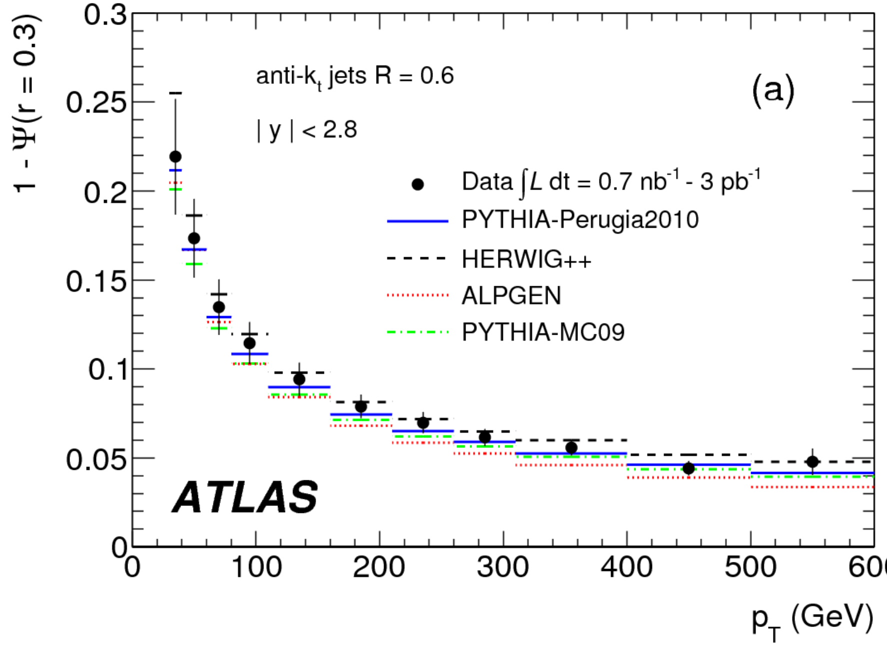
Jet Shape

Phys. Rev. D 83, 052003 (2011)

differential shape



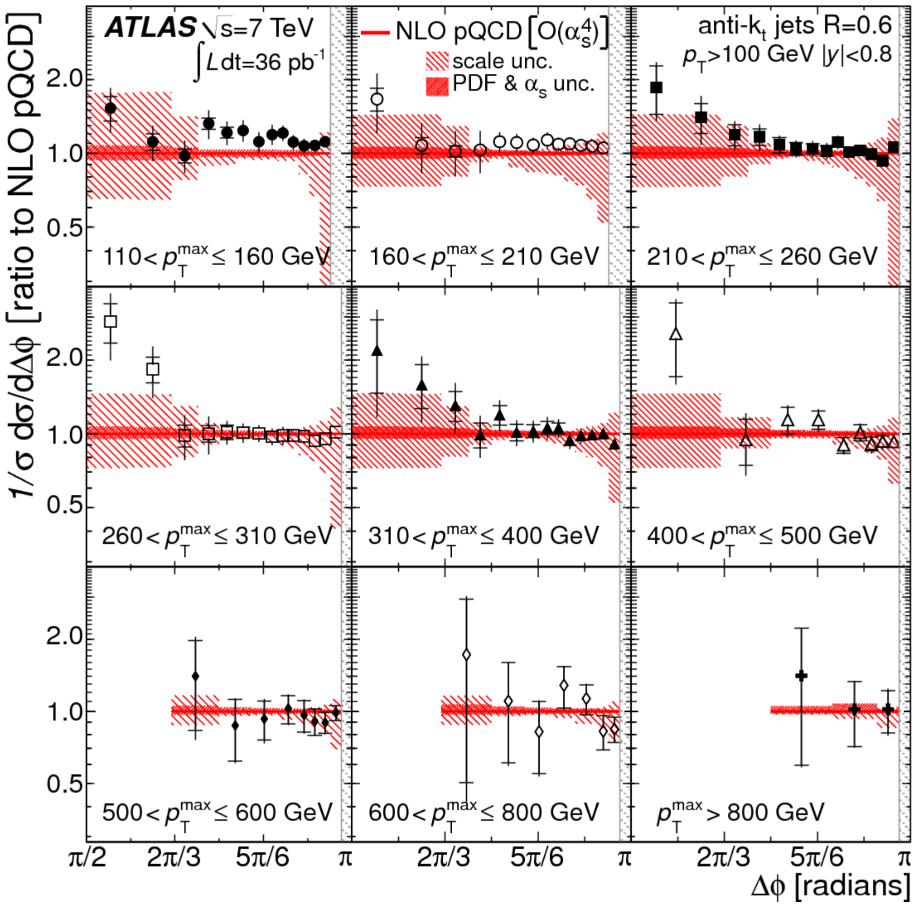
integrated shape



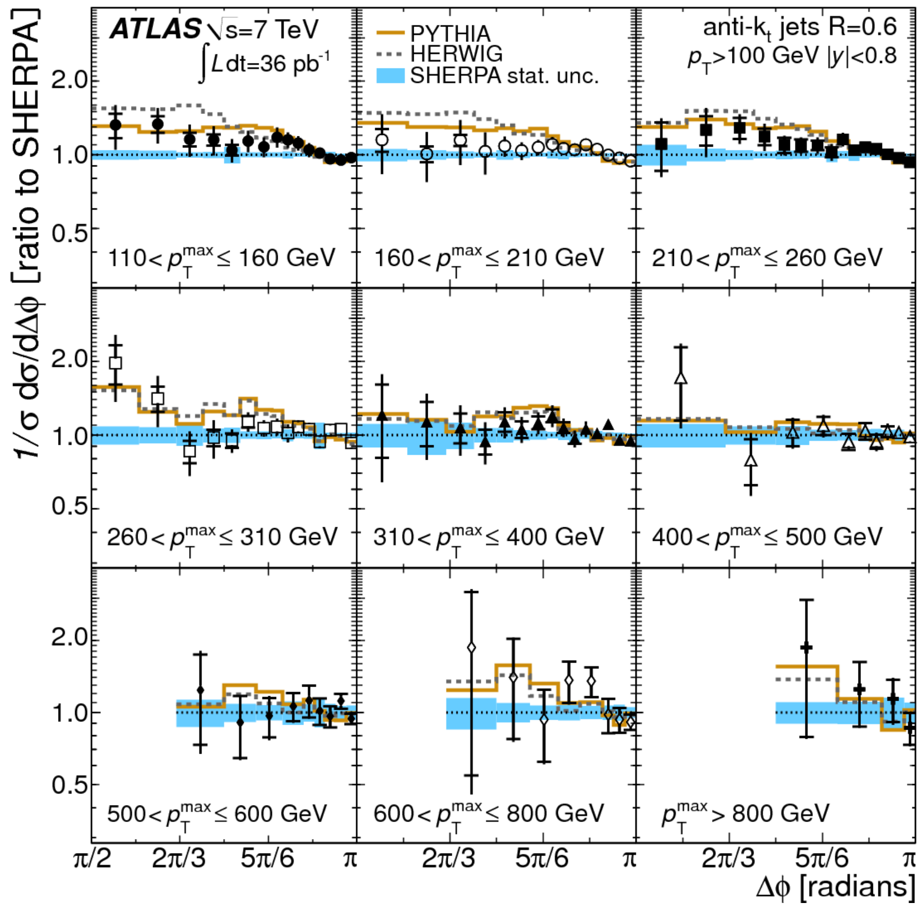
Azimuthal Decorrelations

arXiv:1102.2696

comparison to NLO calculations

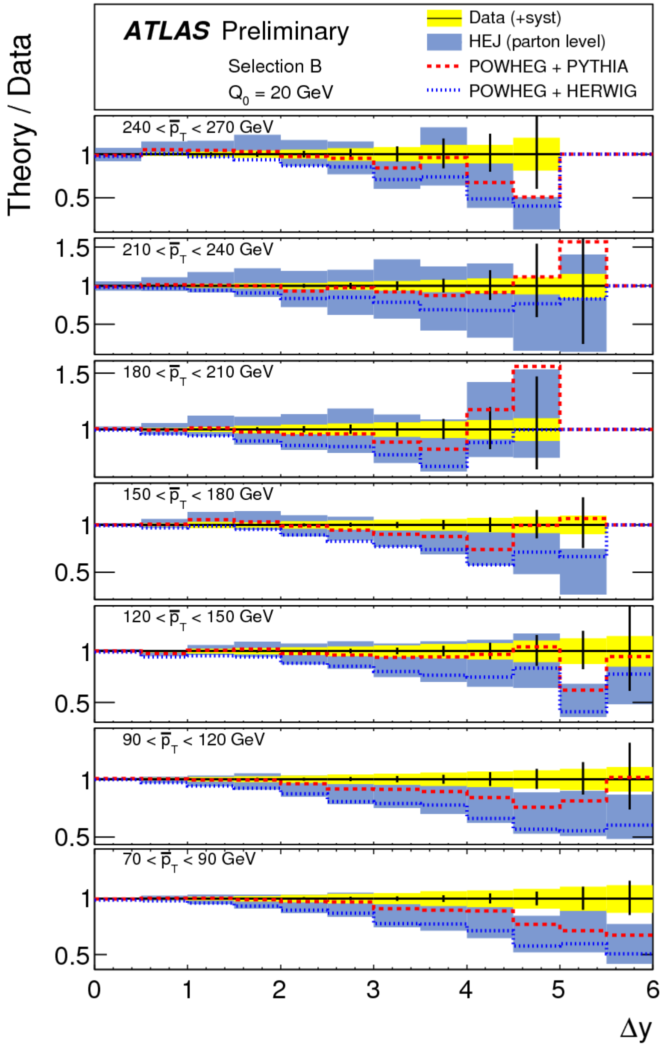


comparison to LO/LL with PS



Di-Jet with Jet Veto

ATLAS-CONF-2011-038



Gap Fraction -> fraction of di-jet events that don't have an additional jet with $p_T > Q_0$ (20 GeV)

Gap Fraction versus Δy calculated between the most forward and backward jets in the event