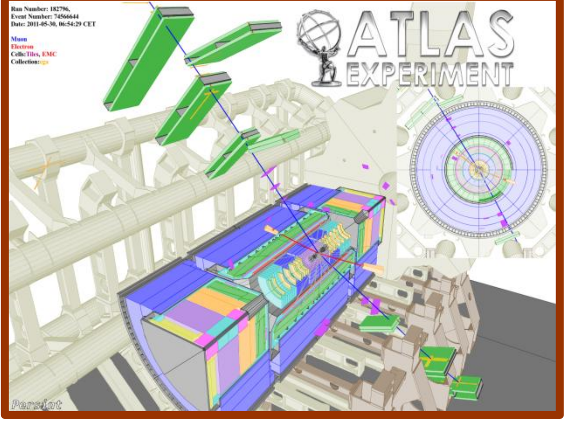
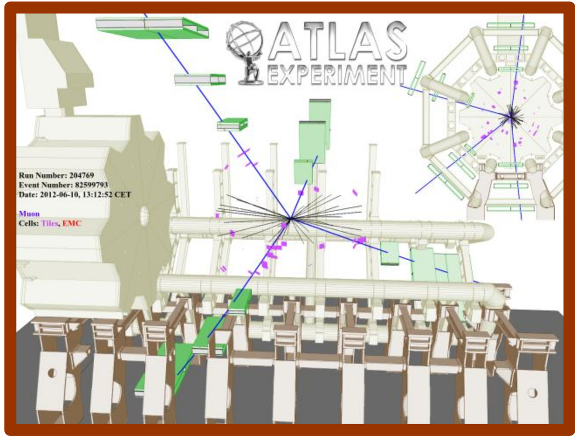
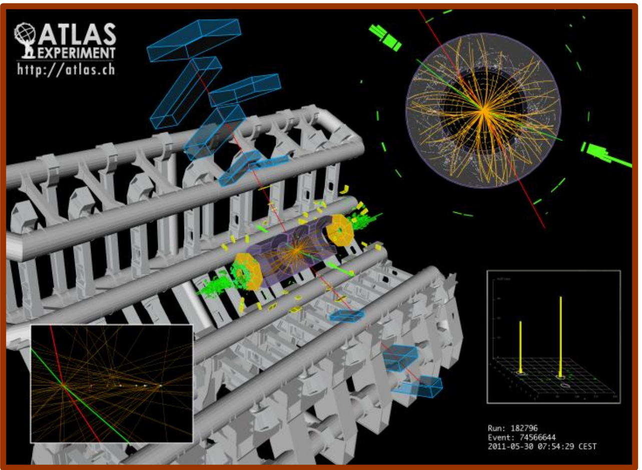


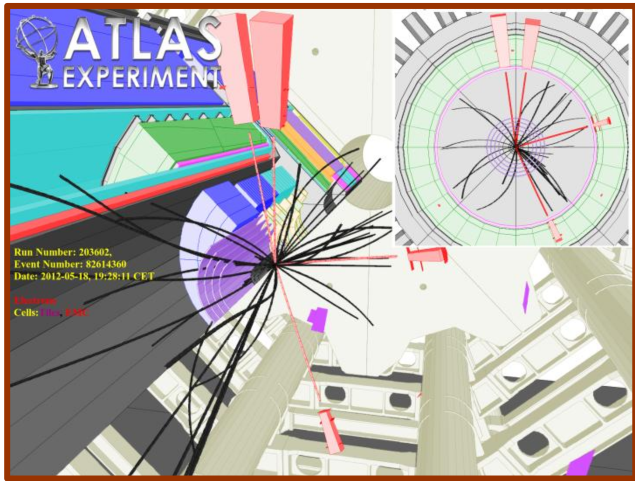


Review of ATLAS experimental results

Rachid Mazini
Academia Sinica Taiwan

CTEQ 2012 summer school
Lima, Peru
30 July -8 August



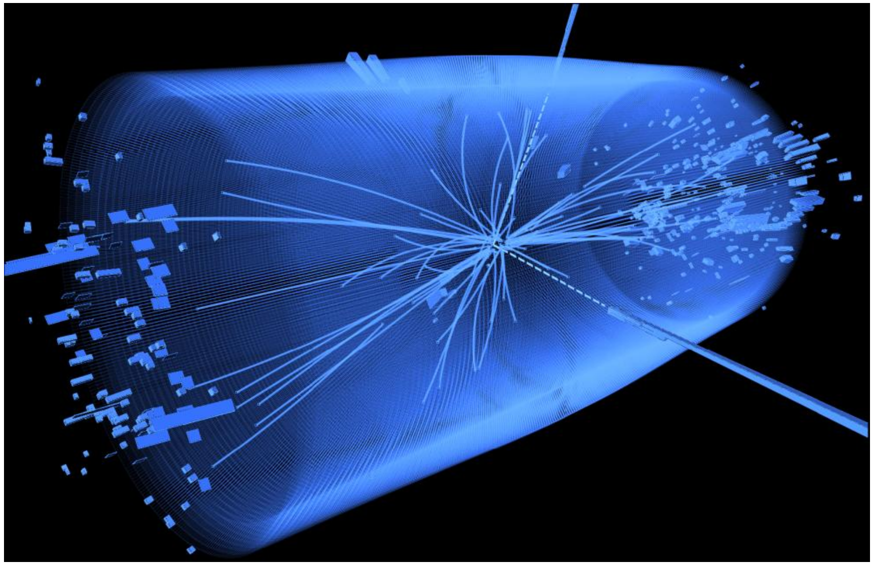


Disclaimer

- This is a personal snapshot of ATLAS experimental results
  - Full list available at https://twiki.cern.ch/twiki/bin/view/AtlasPublic
- There are 166 ATLAS publications on collision data up to now
  - An average of 2 papers/week in 2012
- Material included in this talk is collected from differentes sources
  - Colleagues, previous talks, official ATLAS conference slides
- I tried to be “fair” and not let Higgs searches results monopolize your attention (and mine)

Outline

- Introduction
  - ATLAS, LHC luminosity, trigger
- Perfrmance of the ATLAS detector for physics analysis
  - Physics objects reconstructions: e, μ, hadronic τ decay, jets…
- QCD
- W/Z bosons
- Dibosons
- Top quark
- Higgs searches
- BSM
  - SUSY,
  - Exotics: extra-dimensions, new resonances, everything else(?)

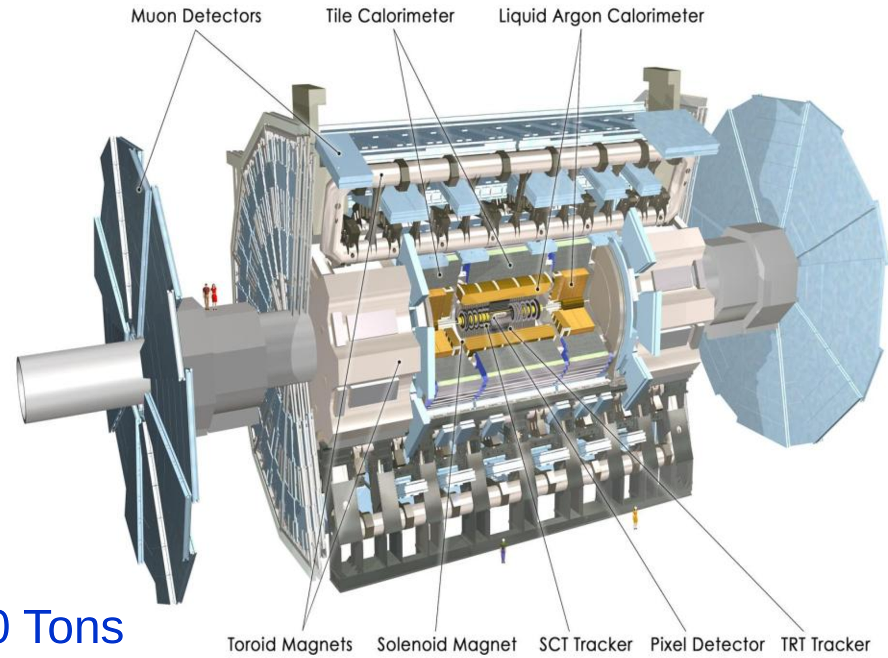


The ATLAS detector

- A general purpose detector
- Inner detector (ID)
  - Pixel
  - Silicon microstrip tracker (SCT)
  - Transition radiation tracker (TRT)
- Solenoid
  - 2T magnetic field
- Calorimeter
  - Electromagnetic (EM)-Liquid Argon (LAr)
  - Hadronic (HAD)
    - scintillating tiles in the central barrel, LAr in end caps (EC)
- Muon Spectrometer (MS)
  - Monitored drift tubes (MDT) and cathode strip chambers (CSC) used for position measurement in bending plane
  - Resistive plate chambers (RPC) and thin gap chambers (TGC) used for triggering and position measurement in non-bending plane
- Three large superconducting toroids
  - One barrel and two EC
  - Eight-fold azimuthal symmetry around calorimeter
  - 0.5T magnetic field

44 m

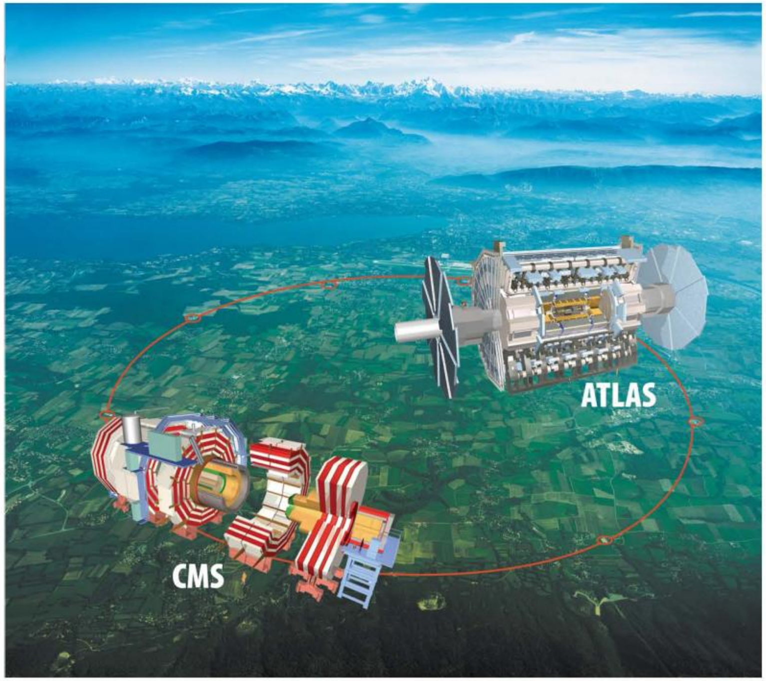
25 m

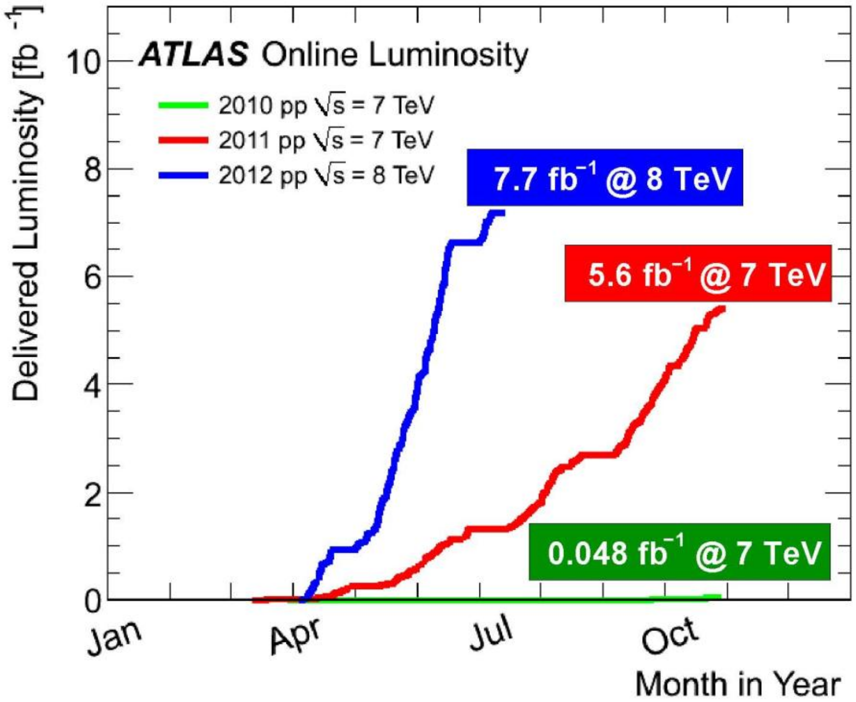


7000 Tons

Detector component	η coverage	
	Measurement	Trigger
Tracking	± 2.5	
EM calorimetry	± 3.2	± 2.5
Hadronic calorimetry (jets)		
barrel and end-cap	± 3.2	± 3.2
forward	$3.1 < \|\eta\| < 4.9$	$3.1 < \|\eta\| < 4.9$
Muon spectrometer	± 2.7	± 2.4

LHC performance

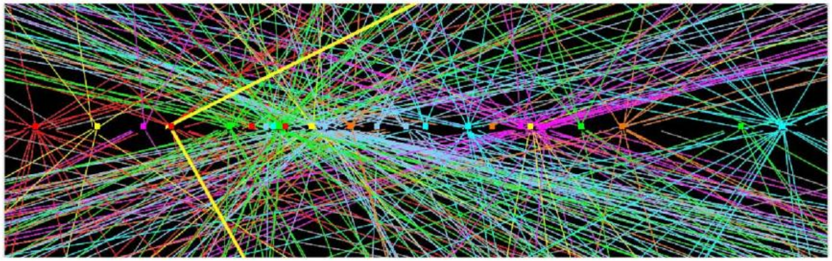




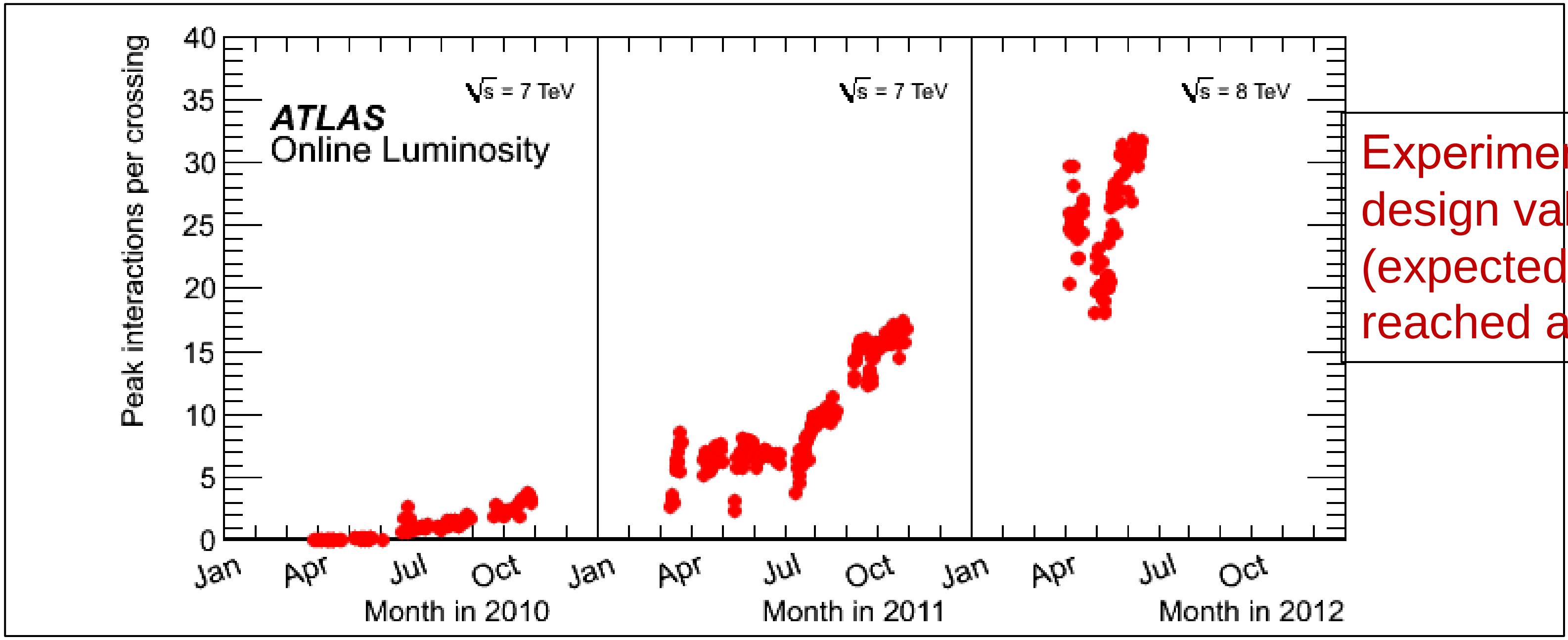
LHC is performing extremely well.
Peak luminosity up to 6.8×10^{33} cm^{-1}s^{-2}.
Expected integrated luminosity by the end of 2012: $\sim$30 fb^{-1}.

More than 90% of delivered *pp* collisions are used in analyses.

High luminosity, but high-pile-up environment:
>20 additional interactions per bunch crossing
(9 interactions on average last year).



The new chalenge: Pile-up



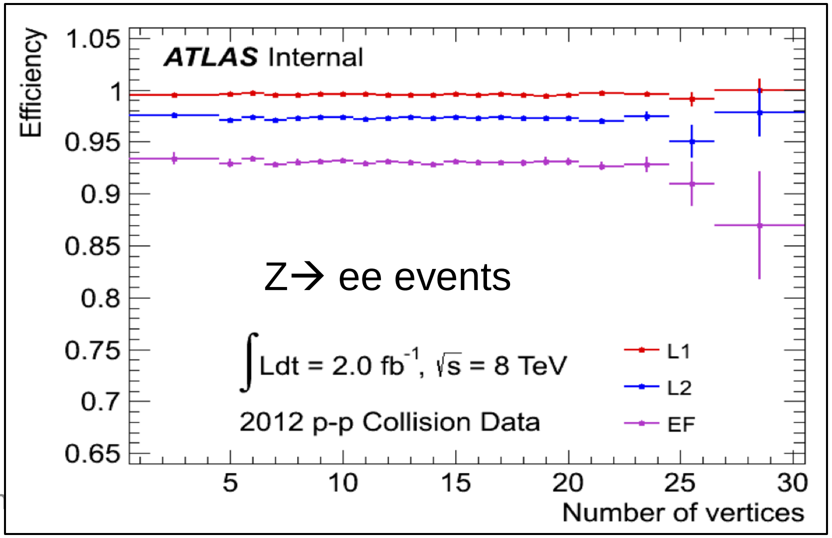
Experiment's design value (expected to be reached at $L=10^{34}$!)

ATLAS and 2012 Pile-up conditions

- Huge efforts over last months to prepare for 2012 conditions and mitigate impact of pile-up on trigger, reconstruction of physics objects (in particular E_T^{miss}, soft jets, ..), computing resources (CPU, event size)

- Pile-up robust, fast trigger and offline algorithms developed
- Reconstruction and identification of physics objects (e, γ, μ, τ, jet, E_T^{miss}) optimized to be ~independent of pile-up → similar (better in some cases!) performance as with 2011 data
- Precise modeling of in-time and out-of-time pile-up in simulation
- Flexible computing model to accommodate x2 higher trigger rates and event size as well as physics and analysis demands

Efficiency of inclusive electron trigger (E_T thresholds as low as 24GeV) as a function of "pile-up"



Performance of the ATLAS detector for physics analysis

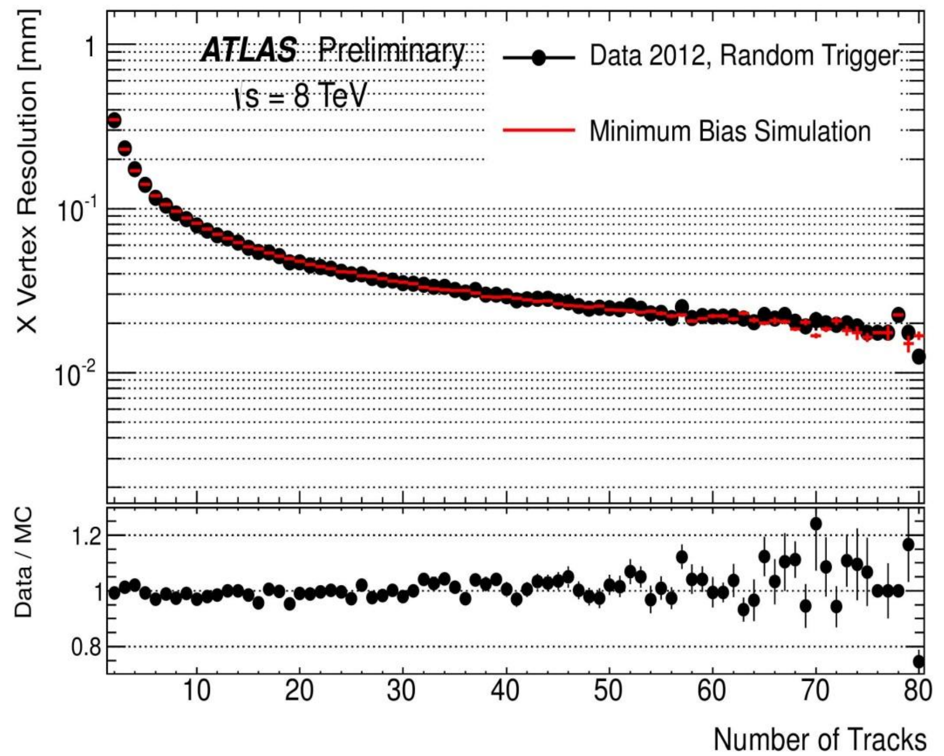
Tracks & vertex reconstruction

Track Reconstruction

- Algorithms based on pattern recognition
  - Inside out
    - Silicon seeds extended out to TRT
    - Reconstructs most primary tracks
  - Back-tracking:
    - TRT seeded with inward extension
    - Recovers secondary tracks (conversions, hadronic interactions, V0 decays)

Primary Vertex (PV) Reconstruction

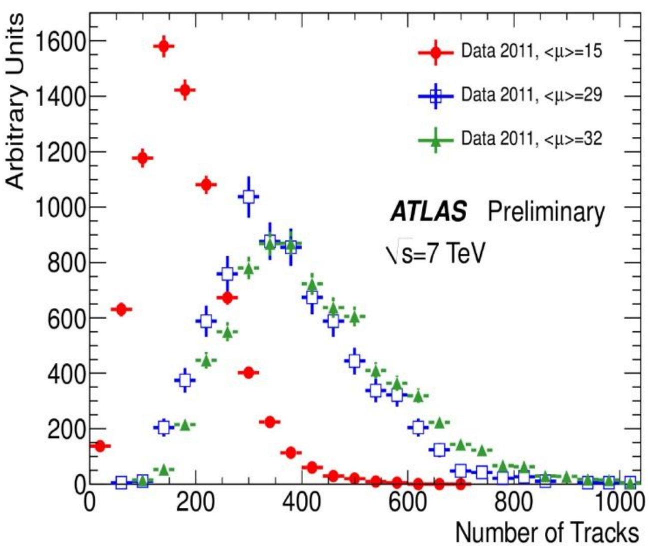
- Iteratively fit tracks consistent with interaction region
- Choose physics PV based on $\Sigma(pT^2)$
  - Becomes reference PV for b-tagging
  - Physics object association is also used

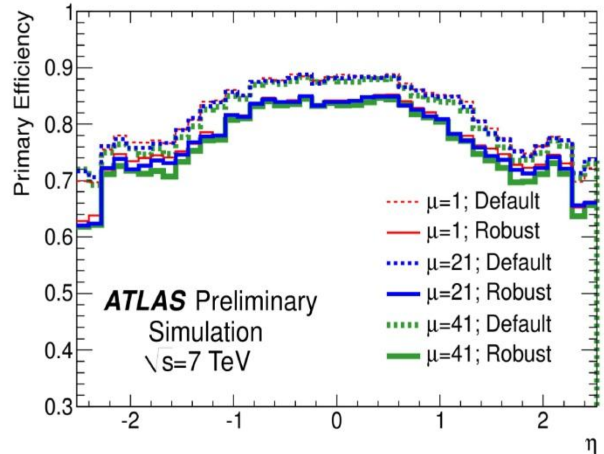


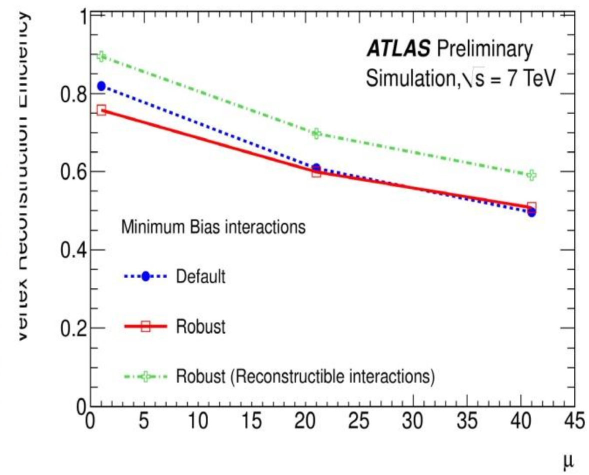
PV resolution in data from 'split vertex' method: well modelled in 2011 & 2012

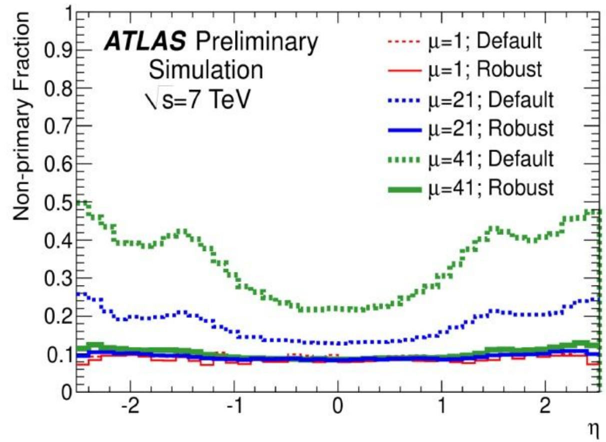
Impact of pile-up

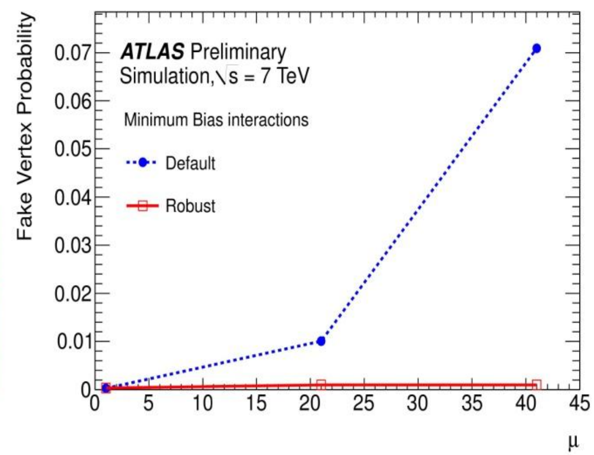
- Higher pileup means higher charged particle multiplicity
- More inner detector hits
- Higher probability of fake tracks and hence fake PVs
- Decrease in PV reconstruction efficiency
- Robust tracks: >=9 Si hits, 0 pixel holes







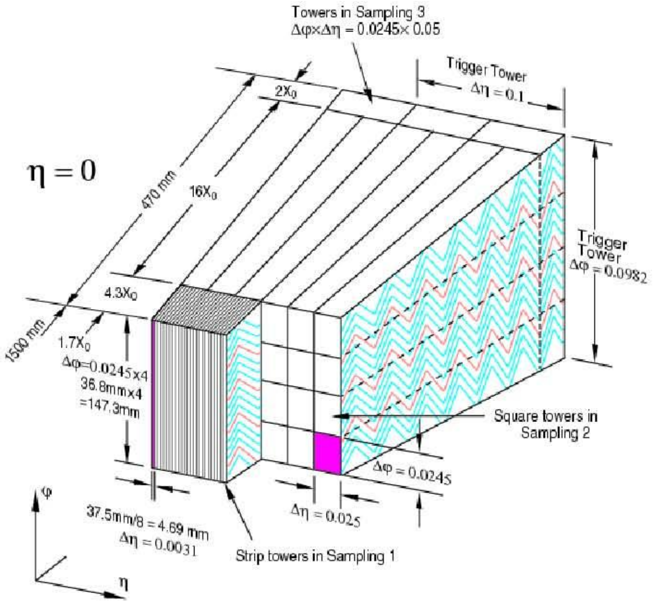


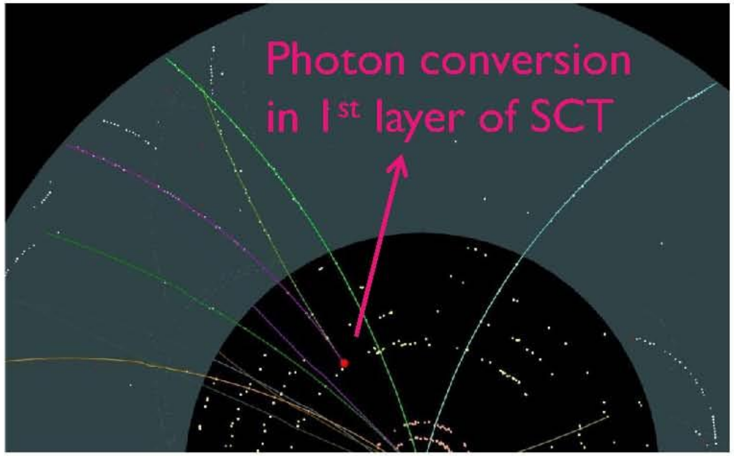


Robust track reconstruction cuts shown to significantly reduce impact of pileup for moderate efficiency loss

Electrons and photons reconstruction (I)

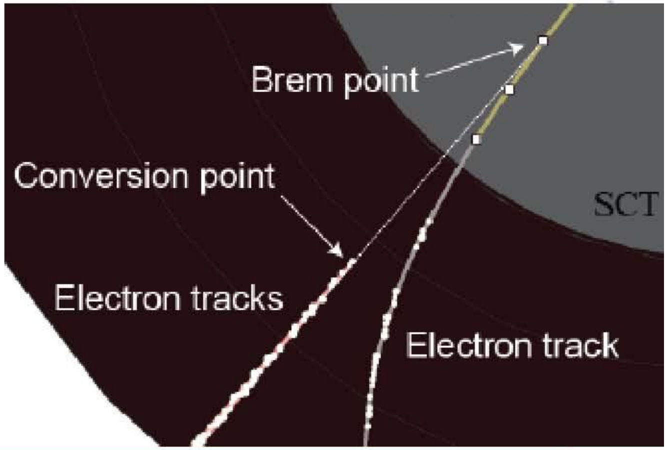
- Use sliding window algorithm
  - Find seed with energy >2.5 GeV
- Form clusters ΔηxΔφ
  - For electrons and converted photons: 0.075x0.175 in barrel and 0.125x0.125 in end-cap
  - For unconverted photons: 0.125x0.125
- Measure cluster energy → Calibrate energy
- Match cluster to an ID track
  - Electron – photon separation
- Match track to a secondary vertex
  - Converted – unconverted photons



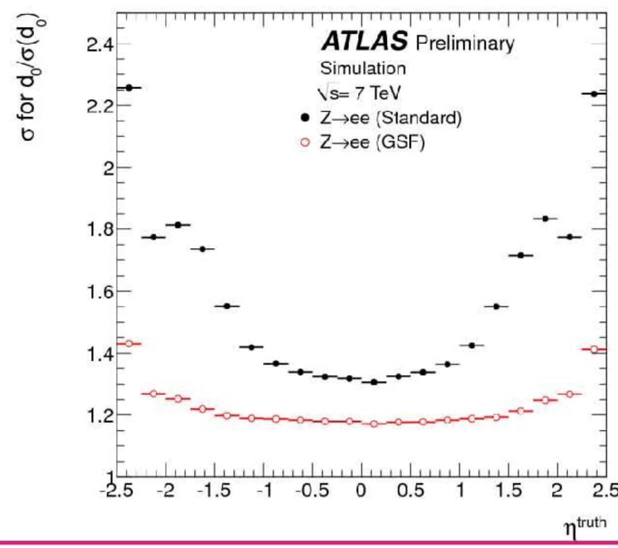


Electron and photon reconstruction (II)

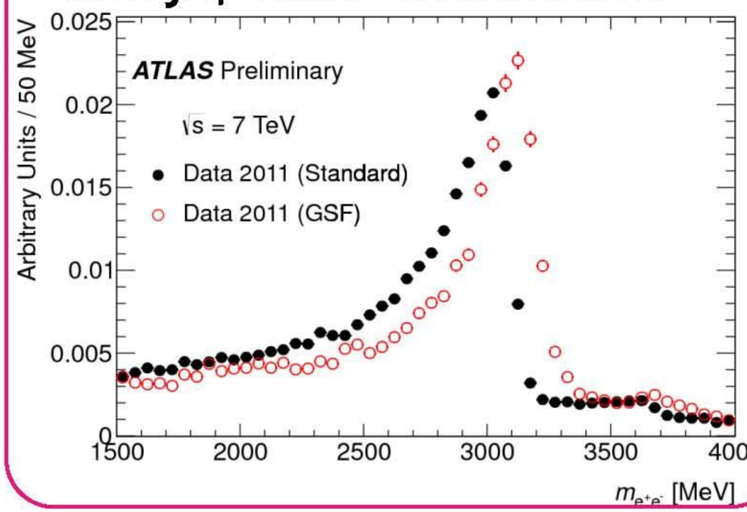
- Electron reconstruction takes into account bremsstrahlung losses at pattern recognition level
  - Gaussian Sum Filter method for improved electron track parameters and cluster-track matching



Improvement on the track transverse parameter significance

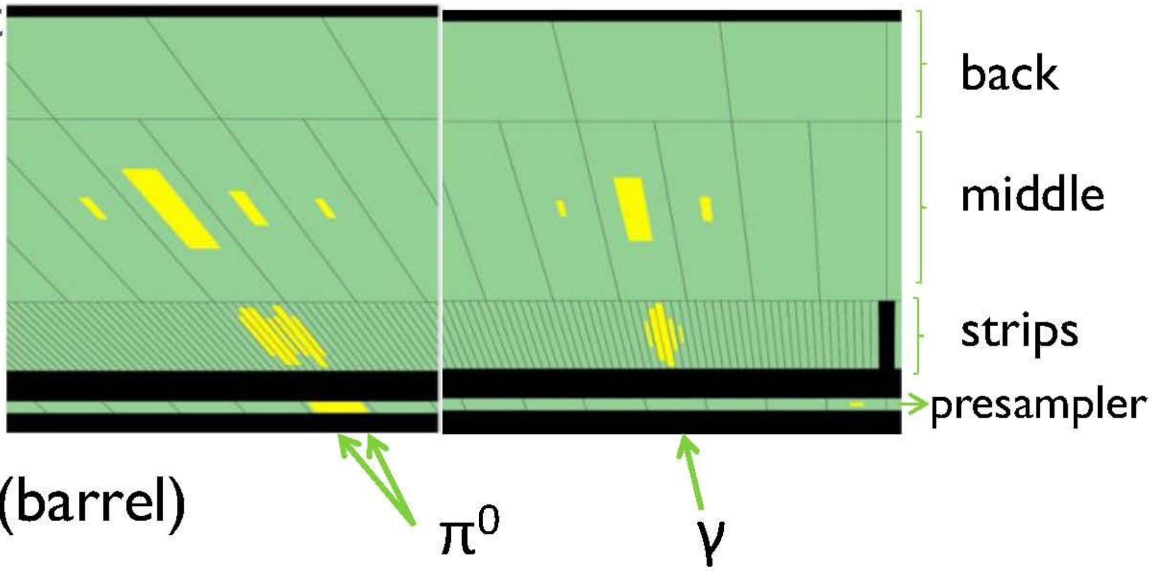


Impact on low-p_T electrons and J/ψ mass distribution



Electrons and photons Identification

- Identification criteria include calorimetric cuts using the information from the different layers of the EM calorimeter, leakage in the hadronic calorimeter, track quality variables and cluster-track matching
- 3 (2) different sets of cuts with increasing background rejection
  - e: loose, medium, tight
  - γ: loose, tight



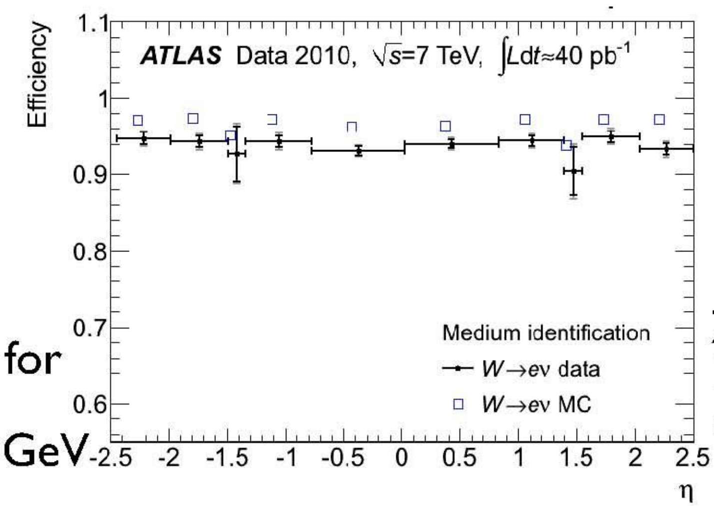
Example: Due to the fine granularity of the strips (EM), it is possible to distinguish between γ and π using strip variables.

Strip granularity in η:0.003 (barrel)

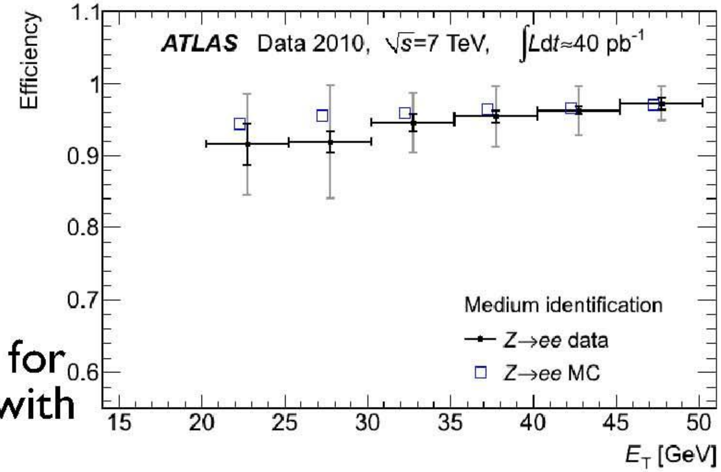
Electrons identification efficicency

Identification efficiencies measured using Tag&Probe method on $Z \to ee$, $W \to e\nu$, $J/\psi \to ee$

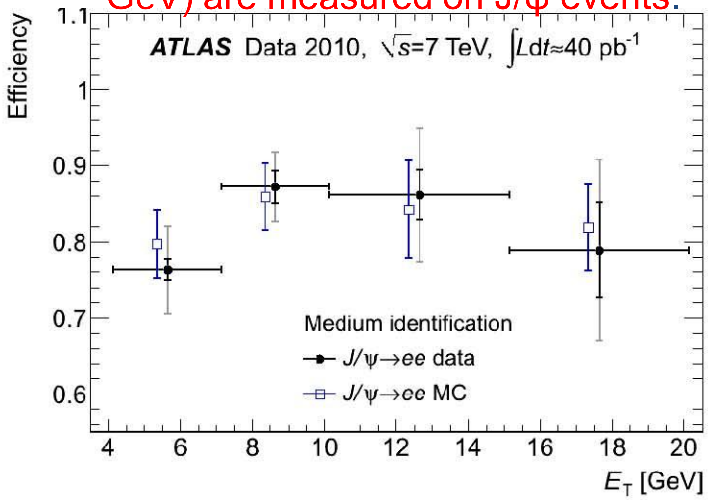
$W \to e\nu$:
Integrated for electrons $20<E_T<50$ GeV



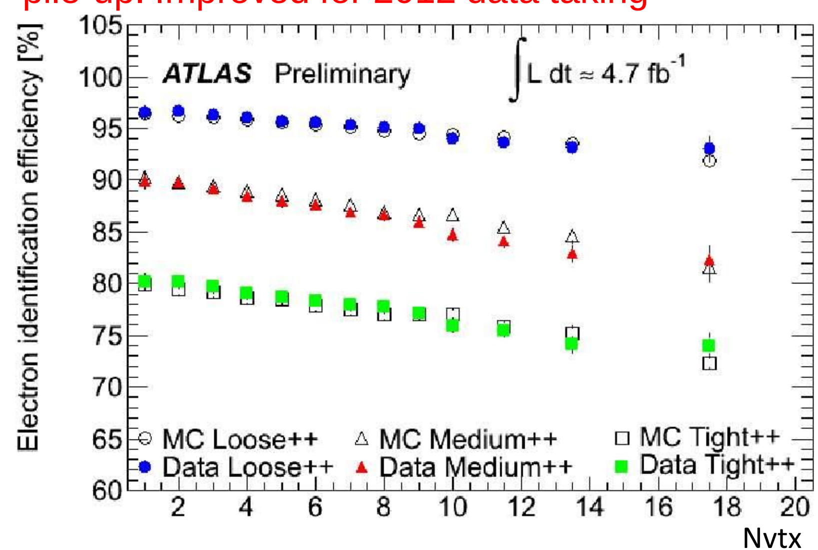
$Z \to ee$:
Integrated for electrons with $|\eta|<2.47$



Low ET electron efficiencies (4-20 GeV) are measured on J/ψ events.

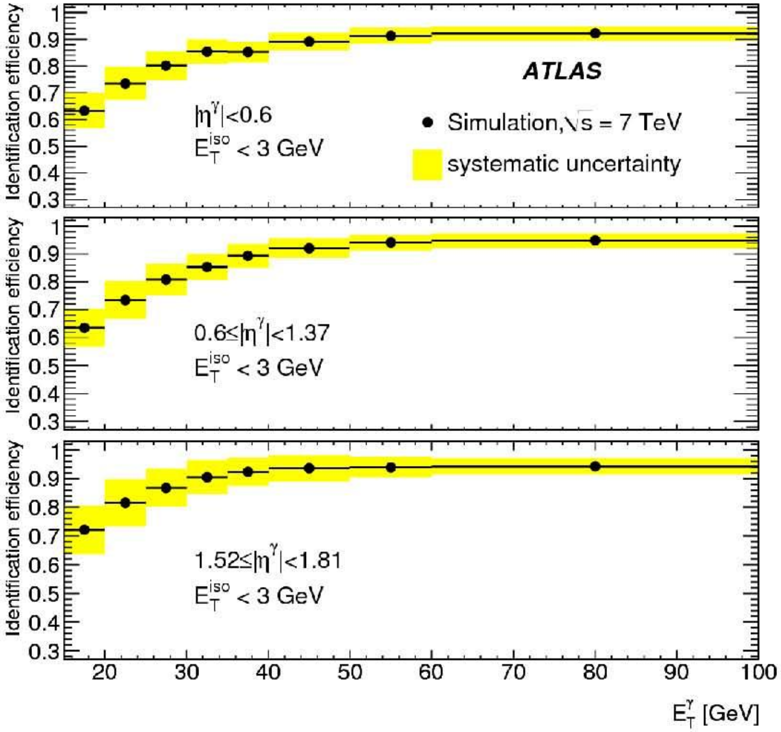


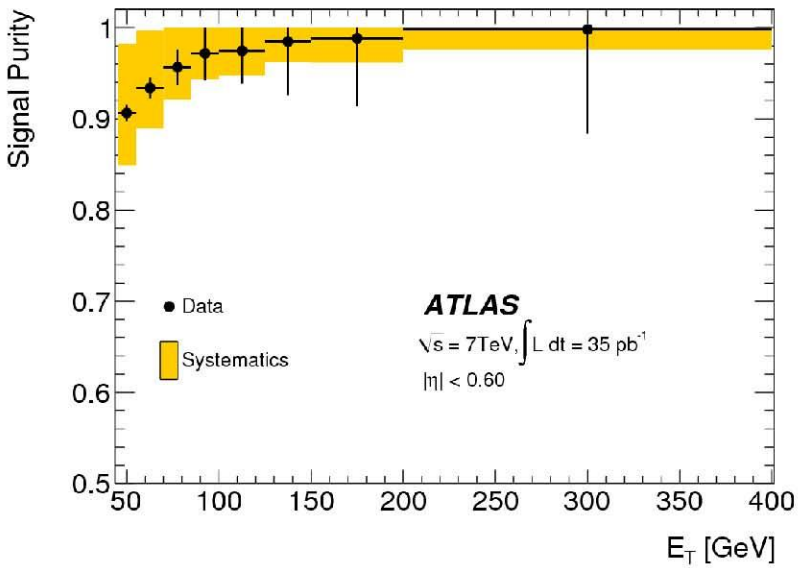
Dependence of the identification efficiencies on pile-up. Improved for 2012 data taking



Photons identification efficiency

- Photon identification efficiency measured on MC events corrected for data-MC differences

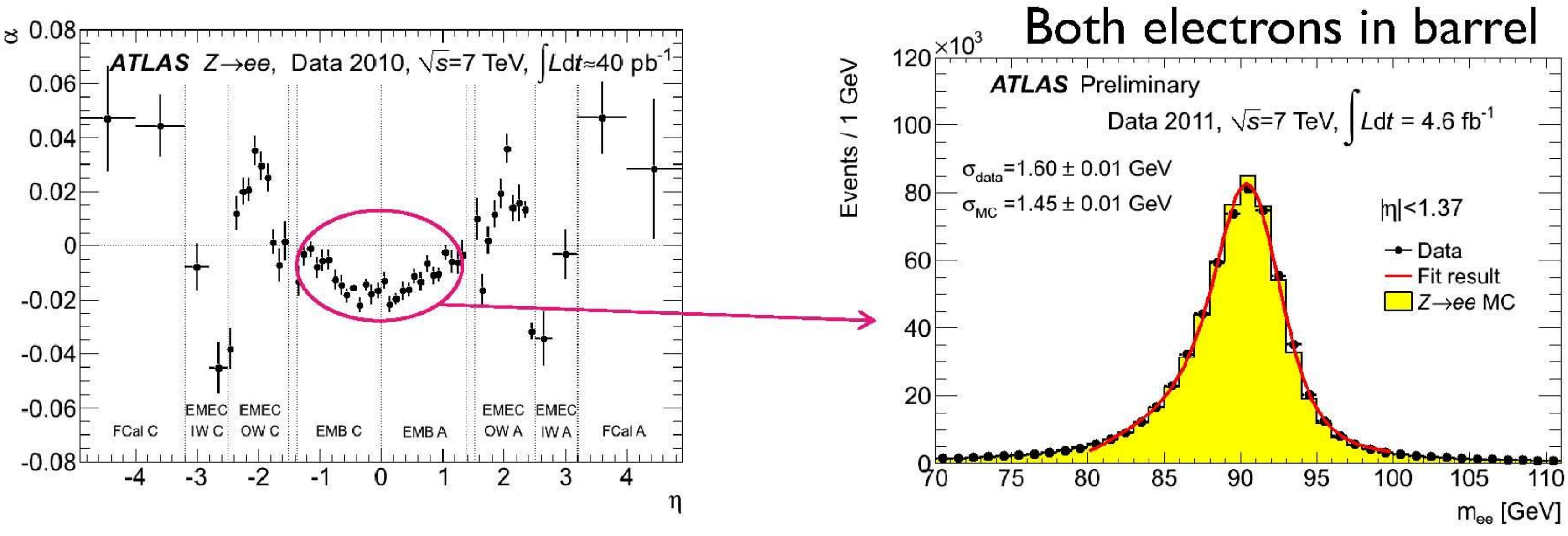




- Photon purity estimated on data using a 2D side-band method (tight identification and isolation)

Electrons and photons energy calibration

- The energy measured in the cluster cells is calibrated using simulation based methods and tuned with test beam results
- Z→ee in-situ calibration is used to correct the EM scale on data
  - Used for the full pseudorapidity region $|\eta|<4.9$
  - Cross-checked for linearity, uniformity and stability with J/ψ and W events
  - Derive constant term to apply to MC resolution
    - Barrel: 1.2% ±0.1%(stat) ±0.5%(syst), End-cap: 1.8% ±0.4%(stat) ±0.4%(syst)

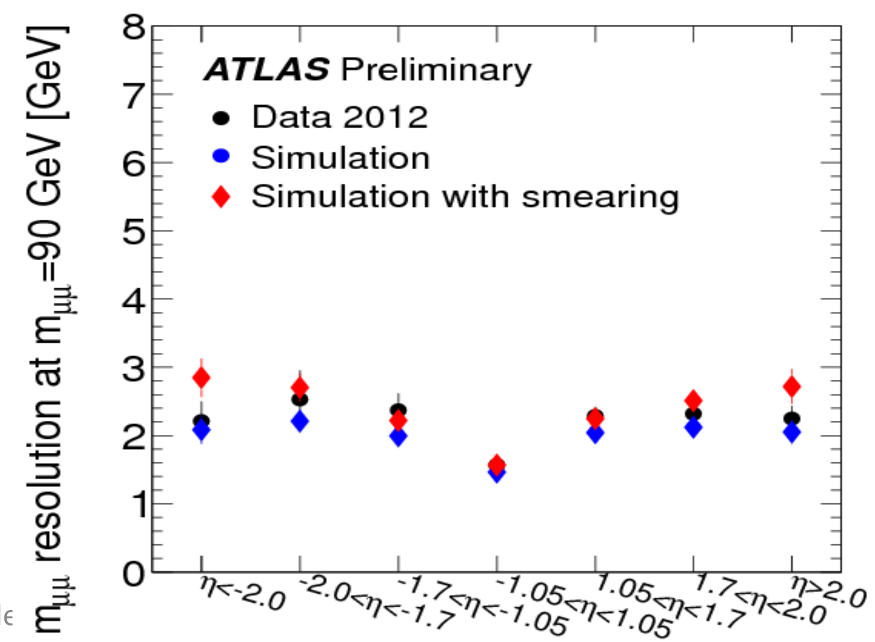


Muons in ATLAS

- Combined (CB)
  - coverage: |η| < 2.5
  - inner detector (ID) and muon spectrometer (MS) contribute to momentum accuracy
  - best momentum resolution
- Stand-alone (SA)
  - coverage: |η| < 2.7
  - high momentum resolution
  - momentum from MS

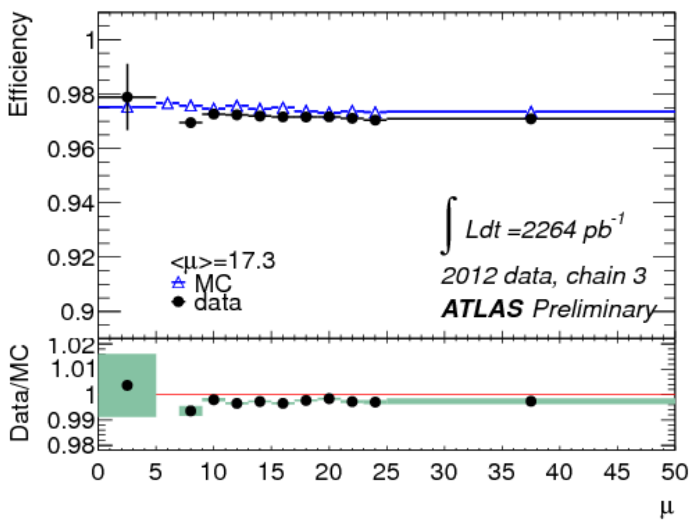
- Segment tagged (ST)
  - coverage: |η| < 2.5
  - momentum from ID
  - needed for low pT to fill acceptance gap at η ≈ -1.2
- Calorimeter tagged (CT)
  - available for |η| < 2.5
  - lowest purity
  - uniform efficiency near MS acceptance gap at η ≈ 0

- Muon momentum resolution
  - Combined muons from Z boson decays
  - Resolution: width of Gaussian convoluted with dimuon mass resolution at generator level
  - Fit range for m(μμ): [75 GeV, 105 GeV]



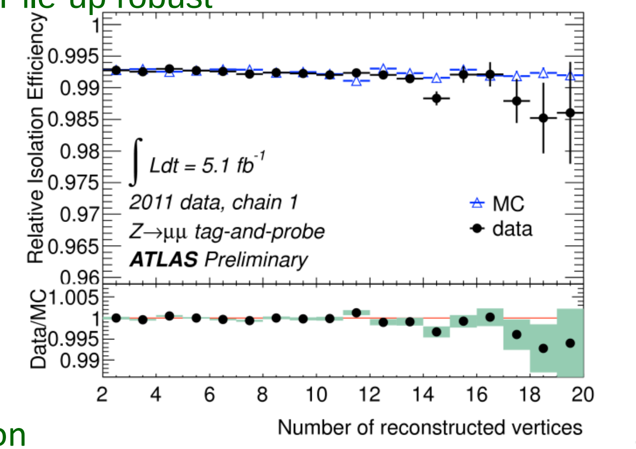
Muon Reconstrucion efficiency and Isolation

- Tag and probe selection
  - One good muon reconstructed in ID and MS selected as tag
  - Second object identified by one of the systems taken as probe muon if invariant mass of two muons is close to
    - J/ψ mass for low p_T range
    - Z boson mass for high p_T range
  - Efficiency = fraction of probe objects identified as muons

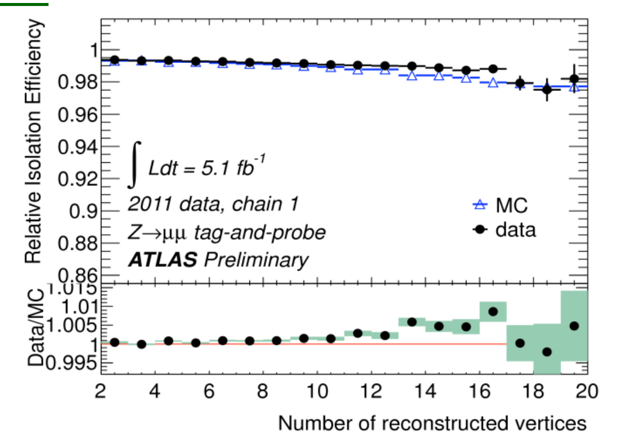


- Muons required to be isolated to suppress background in many analyses
  - Calorimeter based isolation ΣEt(ΔR<0.3)/pt < X
    - Corrections applied to remove pile-up dependence
  - Track based isolation Σpt(ΔR<0.3)/pt < Y
    - Pile-up robust

Track based isolation

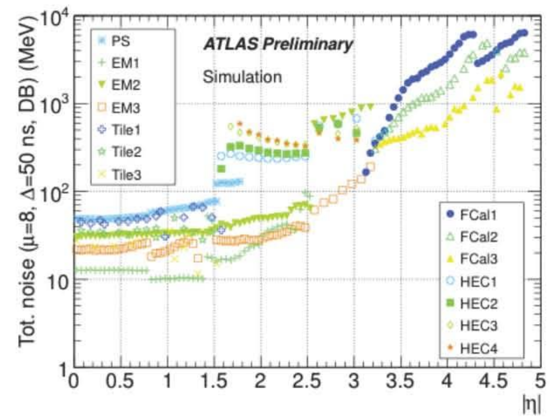


calorimeter based isolation

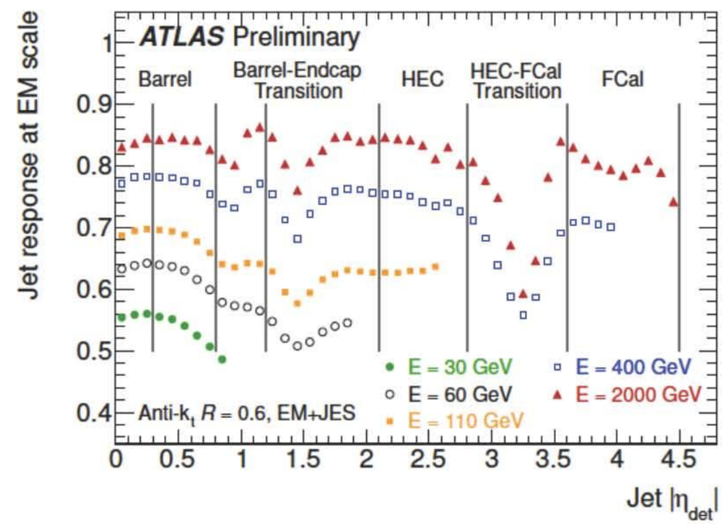


Jets reconstruction and calibration

- **Inputs to jet reconstruction:**
  - 3-dimensional calorimeter topological clusters:
    - Follow shower development
    - Pile-up + electronic noise suppression
    - Local hadron calibration (EM/HAD weights) derived from single pion simulations
  - Tracks
    - Independent from calorimeter
    - Additional z-vertex information



- **Jet algorithms: anti-k_t R=0.4, 0.6**
  - anti-k_t R=1.0, C/A R=1.2

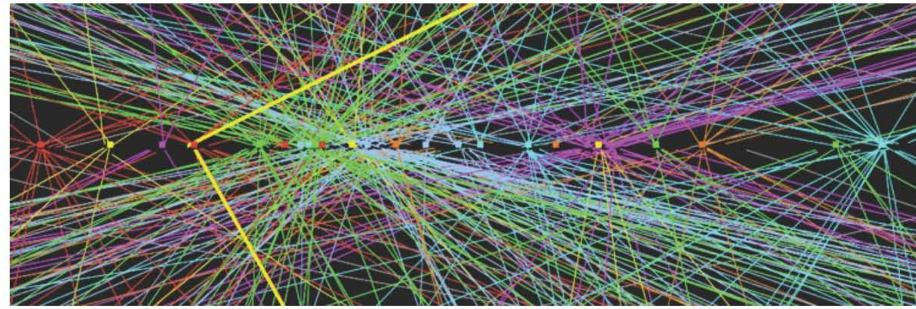


- **Factorized jet energy calibration**
  - Pile-up, non-compensation, inactive material, shower leakage
  - Residual insitu calibration

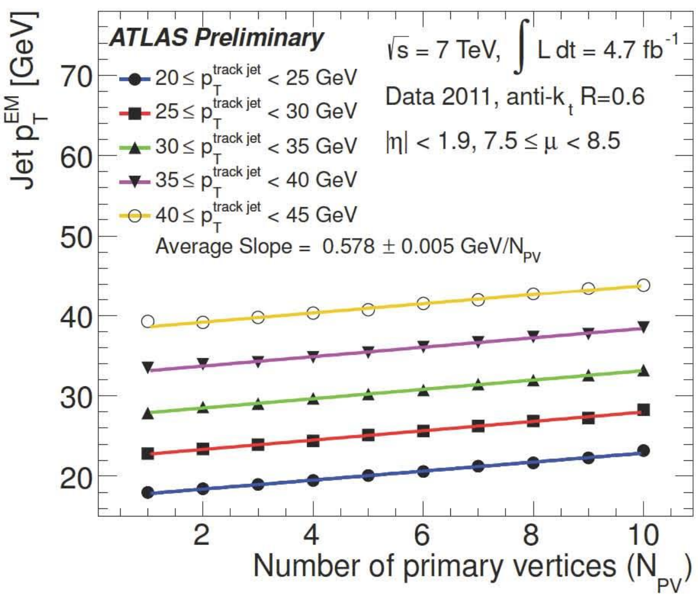
Pile-up subtraction → Monte Carlo JES calibration → Jet-by-jet Post-calibration corrections → In-situ residual calibration

Pile-up substruction and uncertainty

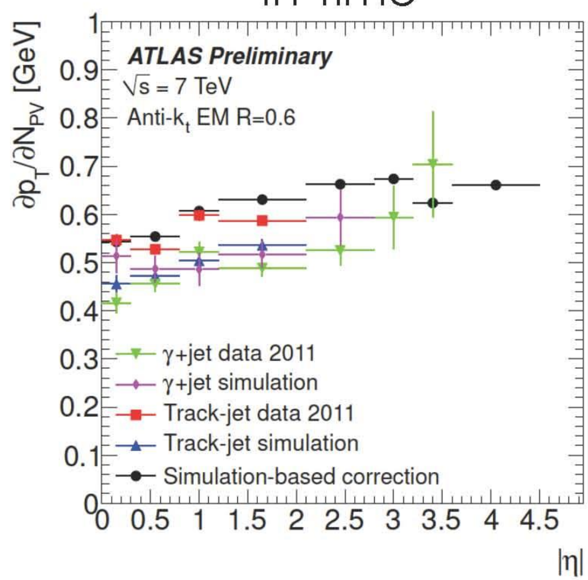
- Offset correction to account for **in-time** and **out-of-time** pile-up
- Determined from Monte Carlo
- Uncertainty from data/MC differences in dijet and γ+jet insitu offset measurements



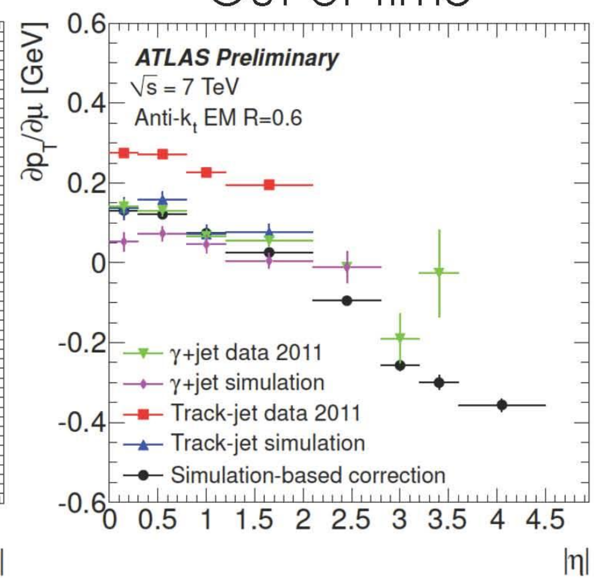
$$\mathcal{O}(N_{\mathrm{PV}},\mu,\eta_{\mathrm{det}}) = \frac{\partial p_{\mathrm{T}}}{\partial N_{\mathrm{PV}}}(\eta_{\mathrm{det}})\left(N_{\mathrm{PV}} - N_{\mathrm{PV}}^{\mathrm{ref}}\right) + \frac{\partial p_{\mathrm{T}}}{\partial \mu}(\eta_{\mathrm{det}})\left(\mu - \mu^{\mathrm{ref}}\right)$$



In-time

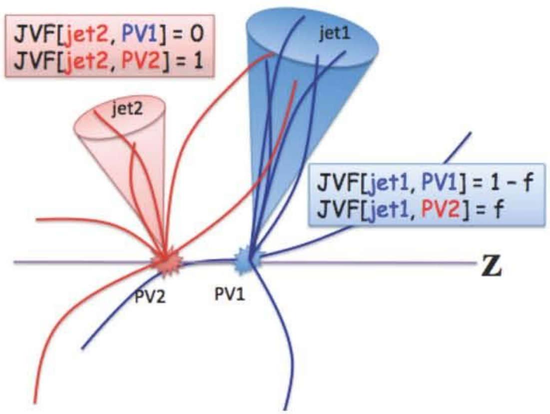


Out-of-time



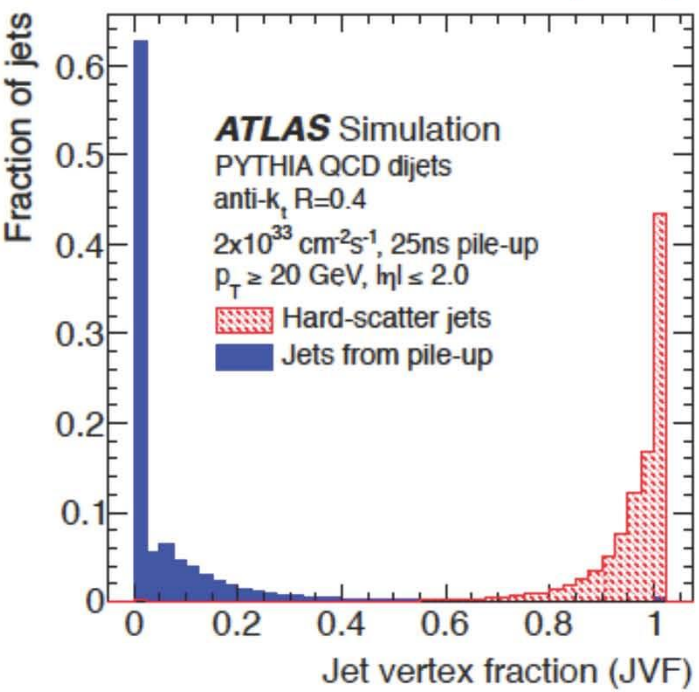
Total pile-up uncertainty <1%/vertex

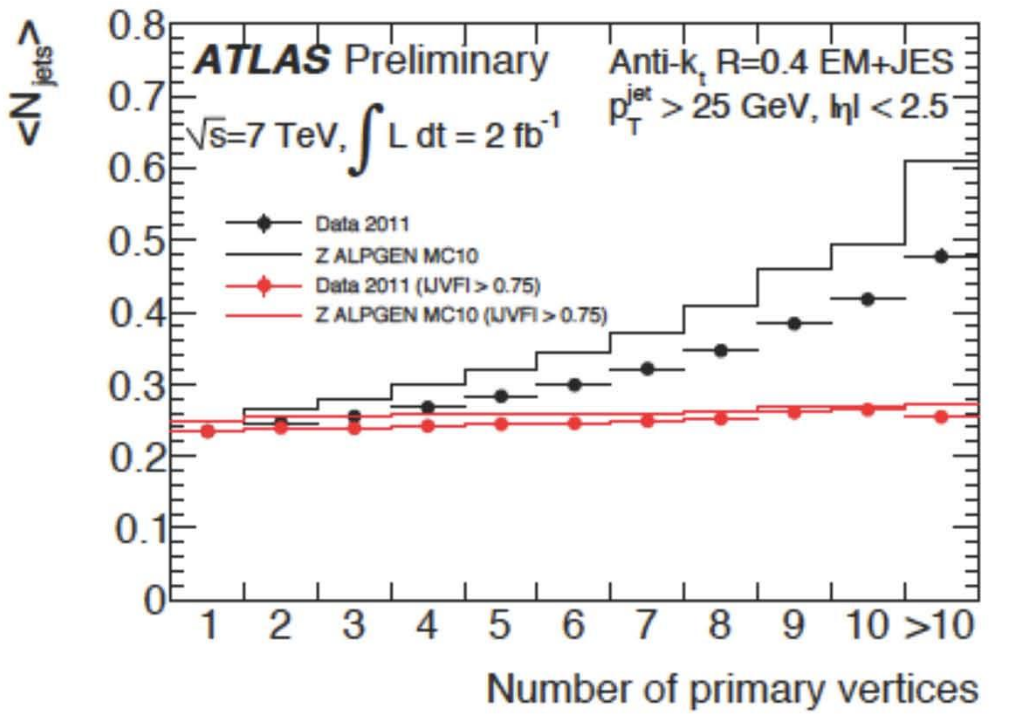
Pile-up suppression



Jet Vertex Fraction (JVF)

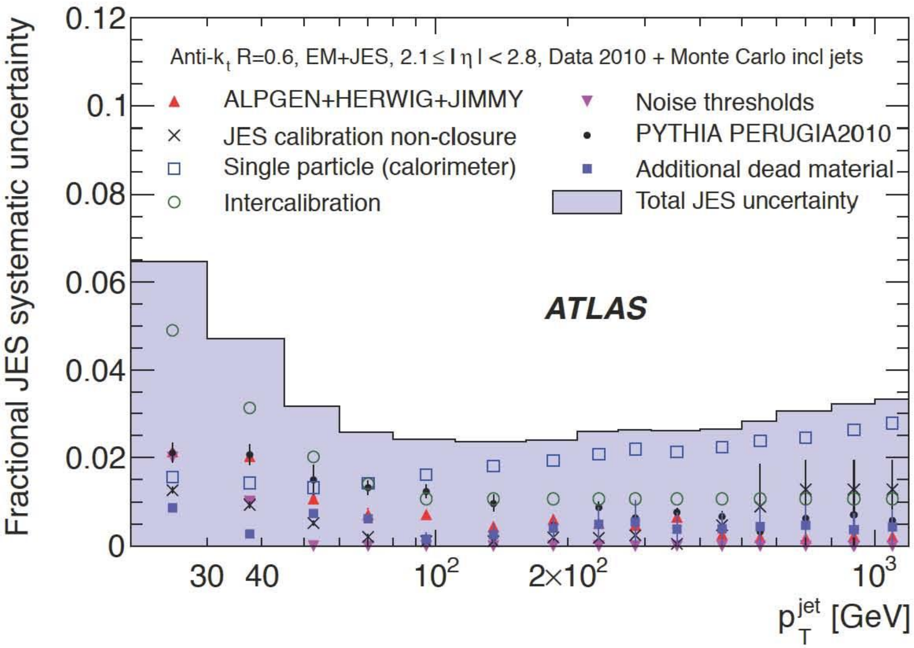
- Reject fake jets from pile-up fluctuations using jet-vertex association
- Similar technique used to suppress pile-up on missing ET

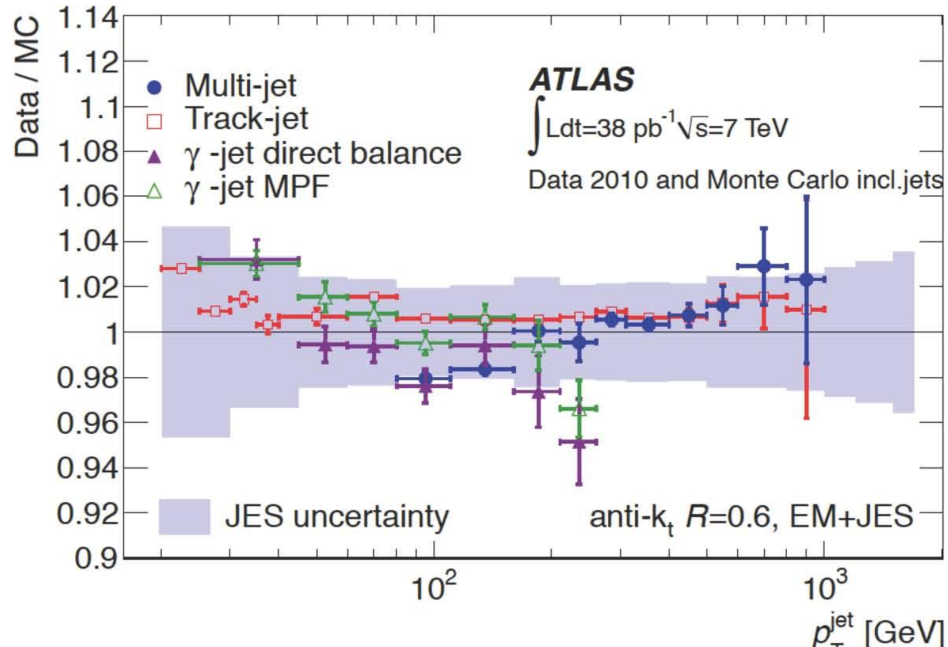




Jets energy scale uncertainty

- Single particle response (test beam / insitu)
- Monte Carlo samples with different physics modeling and detector configurations
- Relative p_T balance in dijet events



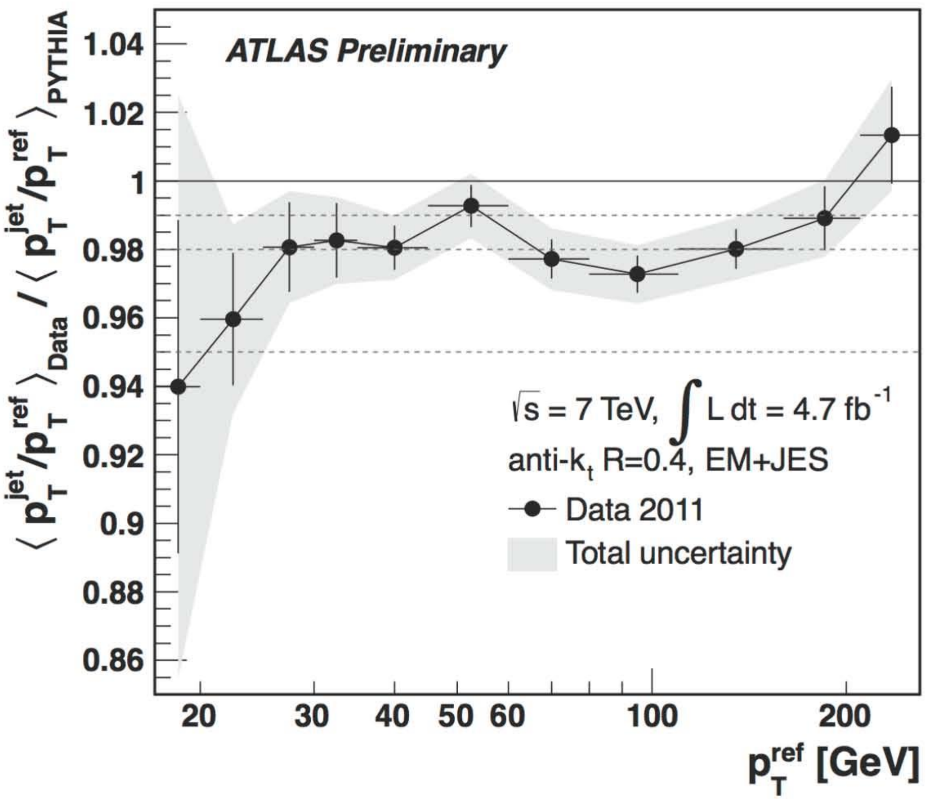


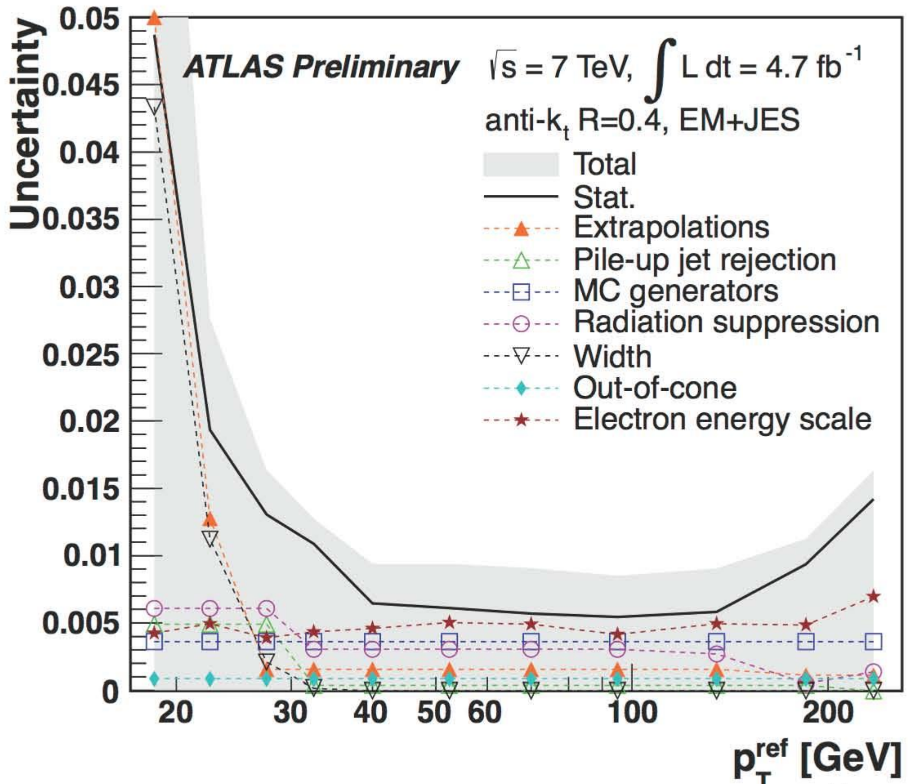
< 2.5% for central jets, p_T>100 GeV
< 7 (14)% for endcap (forward) jets

- **Insitu tests of the jet energy scale:**
  - γ +jets (MPF and direct balance)
  - track/calorimeter jet ratio
  - Multi-jet balance

Insitu jet energy scale: Z+jets

- Use large 2011 datasets to improve the precision of the jet energy scale and to adjust the jet calibration using insitu techniques
- Z+jet balance probes the jet response at low p_T (low background, and low p_T thresholds)
- **Total uncertainty 1% to 2% for jet p_T > 30 GeV**

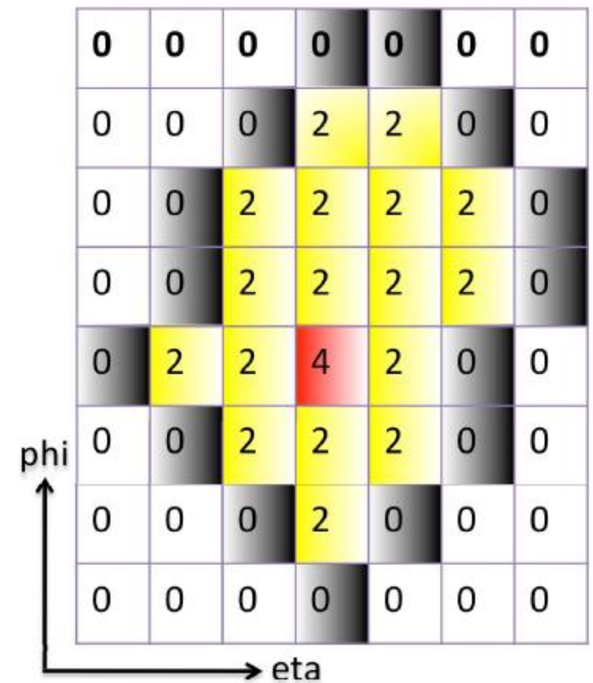


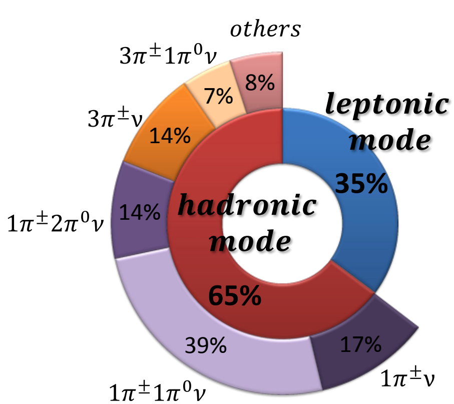


Reconstrucion of Tau hadronic decay

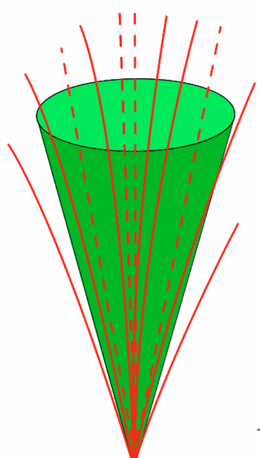
- Hadronic decays of tau: 65%
- Reconstruction seeded by anti-kt jets(R=0.4)
  - p_T > 10 GeV, |η| < 2.5
  - calibrated 3D topological clusters
  - good quality tracks with p_T > 1 GeV
  - discriminating variables
    - combined information from calorimeter and tracking
    - input to multi-variate algorithms

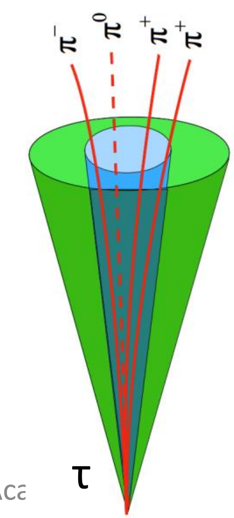
Topological clustering





jet of hadrons





core cone
ΔR < 0.2

isolation cone
0.2 < ΔR < 0.4

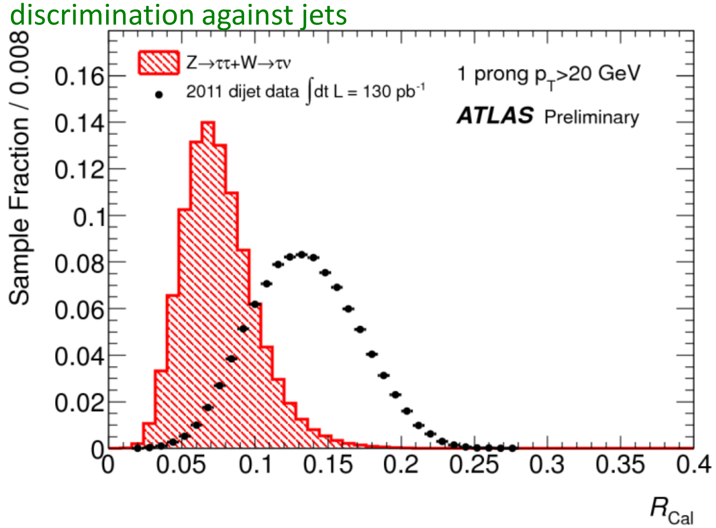
Tau identification

Decay properties of tau	Detector information used
Collimated decay products	Jet width in tracker and calorimeter
Leading charged hadron	Leading track
No gluon radiation	Isolation
Low invariant mass	Invariant mass of tracks and clusters
Lifetime	Impact parameter, secondary vertex
EM energy fraction different from electrons	Longitudinal position of energy deposits
EM component from π^0	LAr strip
Less transition radiation than electrons	TRT

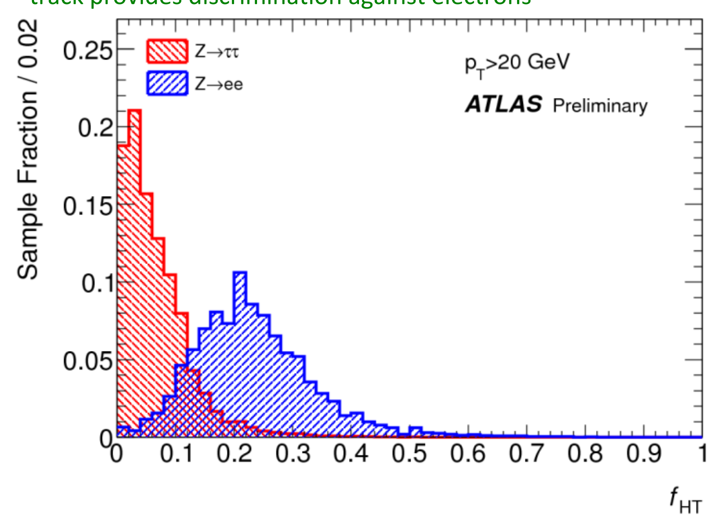
Discrimination against Jets

e

Energy weighted calorimeter radius provides discrimination against jets

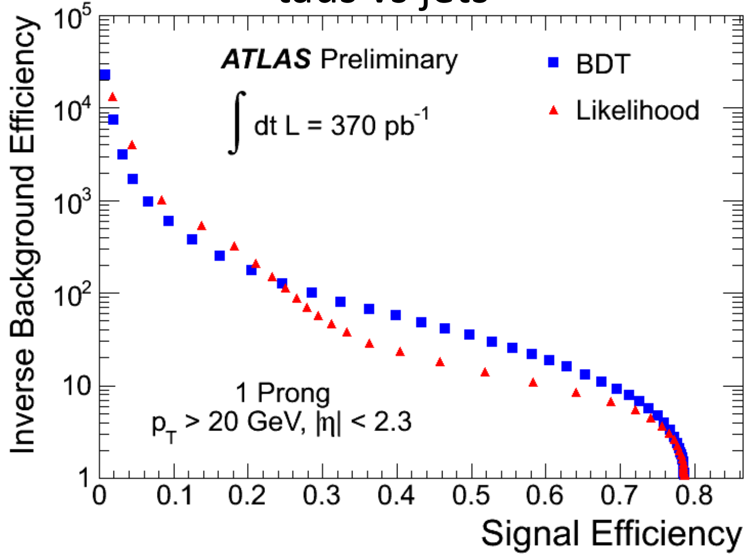


Ratio of high threshold to low threshold hits in TRT for leading track provides discrimination against electrons

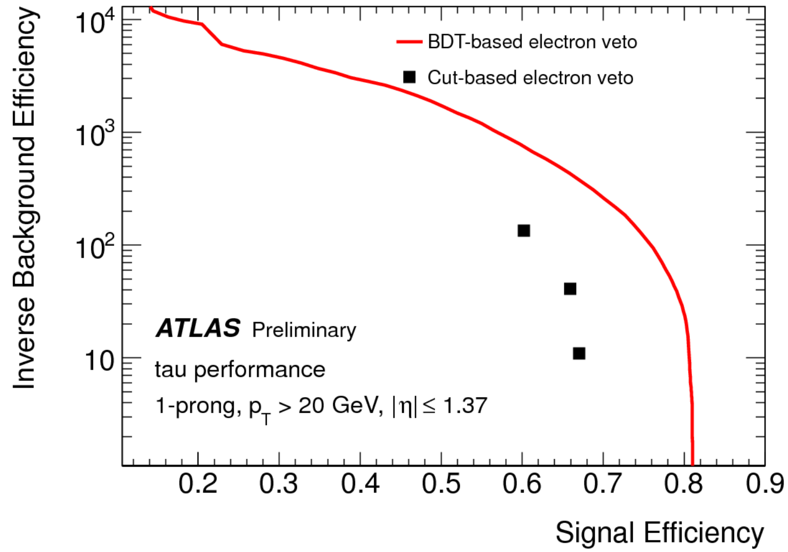


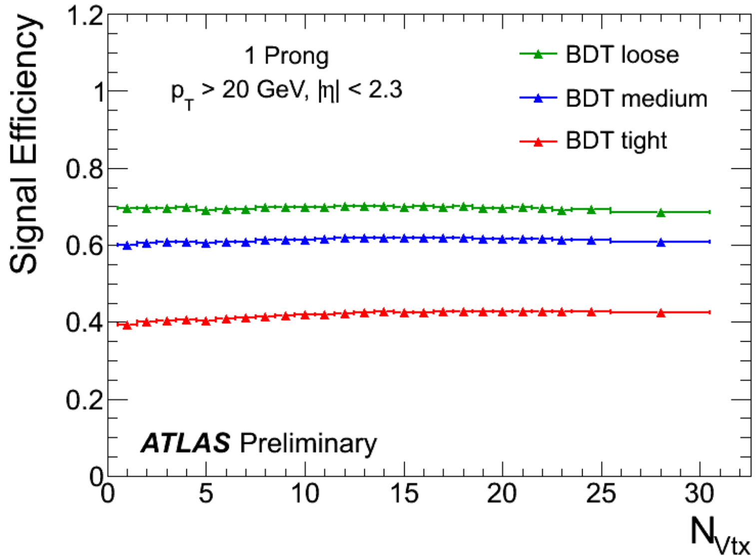
Tau (1P) identification performance

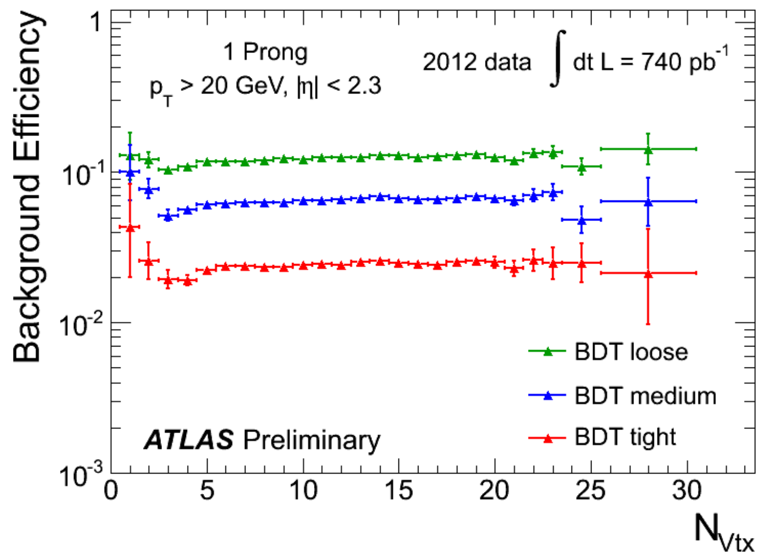
taus vs jets



taus vs electrons





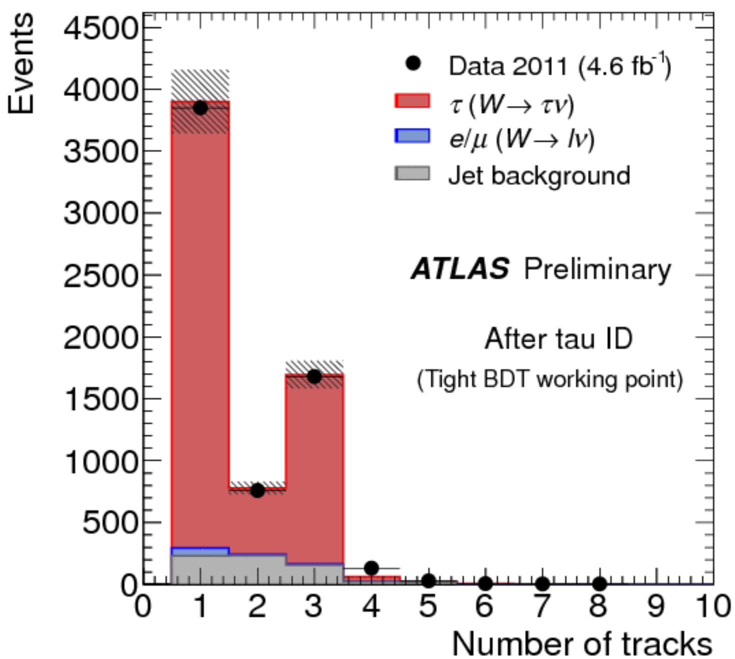


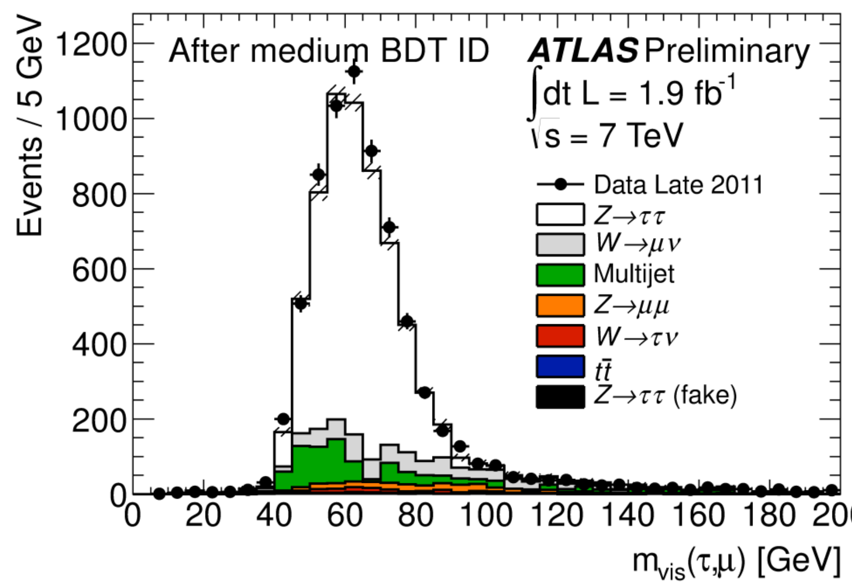
Same procedure applied to identify three prong taus using additional information on lifetime

Tau identification efficiency measurement

- Efficiency measured in data using
  - Z -> $\tau_\mu \tau_h$ and W-> τν events with tag and probe selection
    - require events to pass muon/MET trigger to tag a tau
    - probe hadronically decaying tau
  - Data/MC scale factors (SF) consistent with 1

Tau ID	$p_T > 22$ GeV Inclusive	1-prong	3-prong
LLH Loose	5	4	10
LLH Medium	4	5	10
LLH Tight	5	5	11
BDT Loose	4	4	8
BDT Medium	4	5	8
BDT Tight	4	4	7





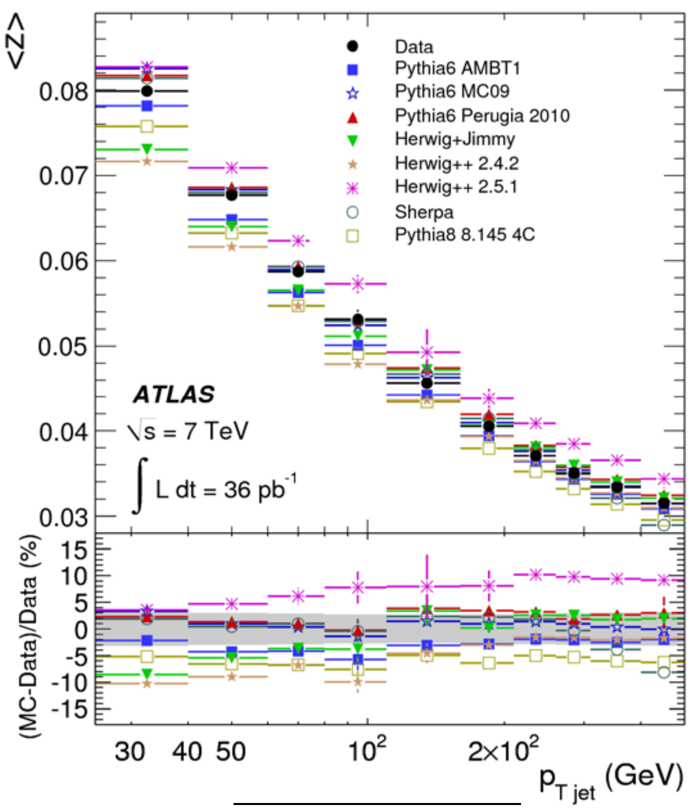
QCD at work

The issue with QCD is Calculations can be extraordinarily difficult. Many quantities need to be measured at the LHC for QCD predictions tests.

Jet structure: Fragmentation and shape

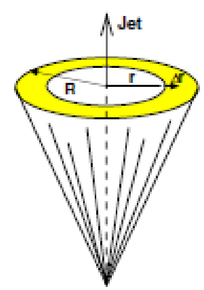
- Understand the hadronization process
- Benchmark for the simulation

Fragmentation function

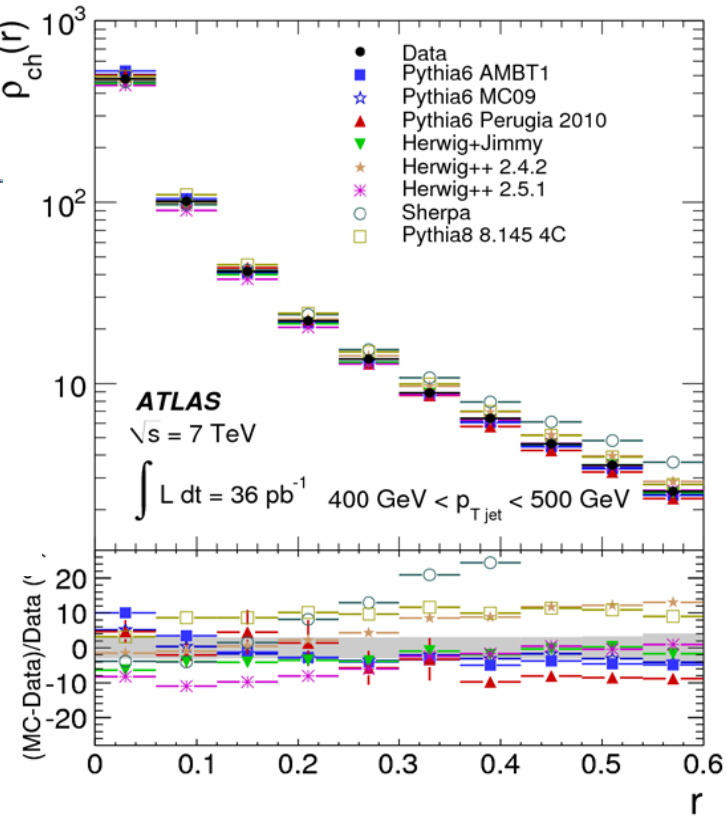


$$z = \frac{\mathbf{p}_{\mathrm{jet}} \cdot \mathbf{p}_{\mathrm{ch}}}{\mathbf{p}_{\mathrm{jet}}}$$

$$\rho_{ch}(r, p_{\mathrm{T\,jet}}) \equiv \frac{1}{N_{\mathrm{jet}}} \frac{dN_{ch}}{2\pi r dr}.$$

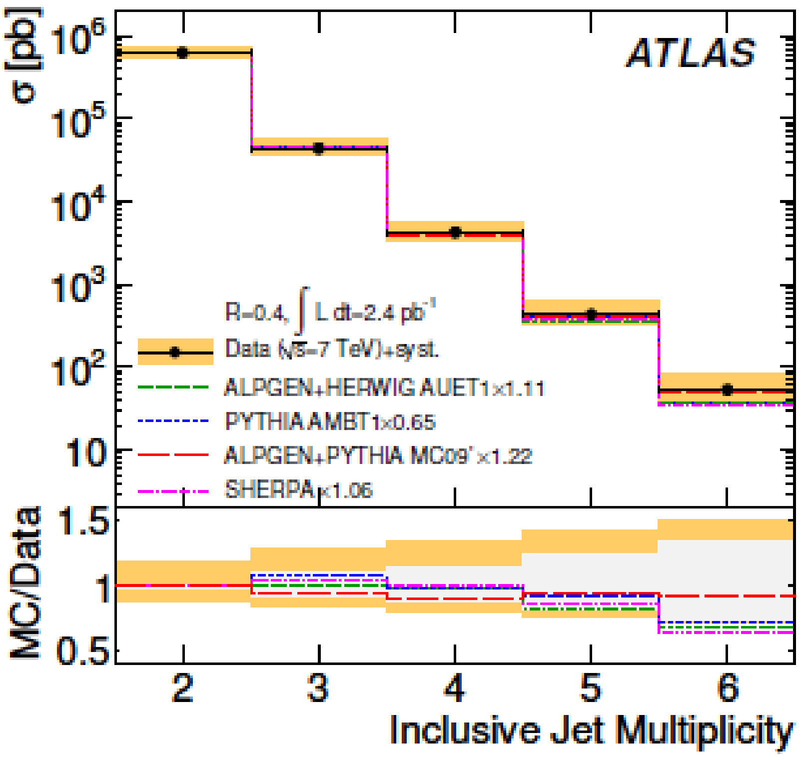


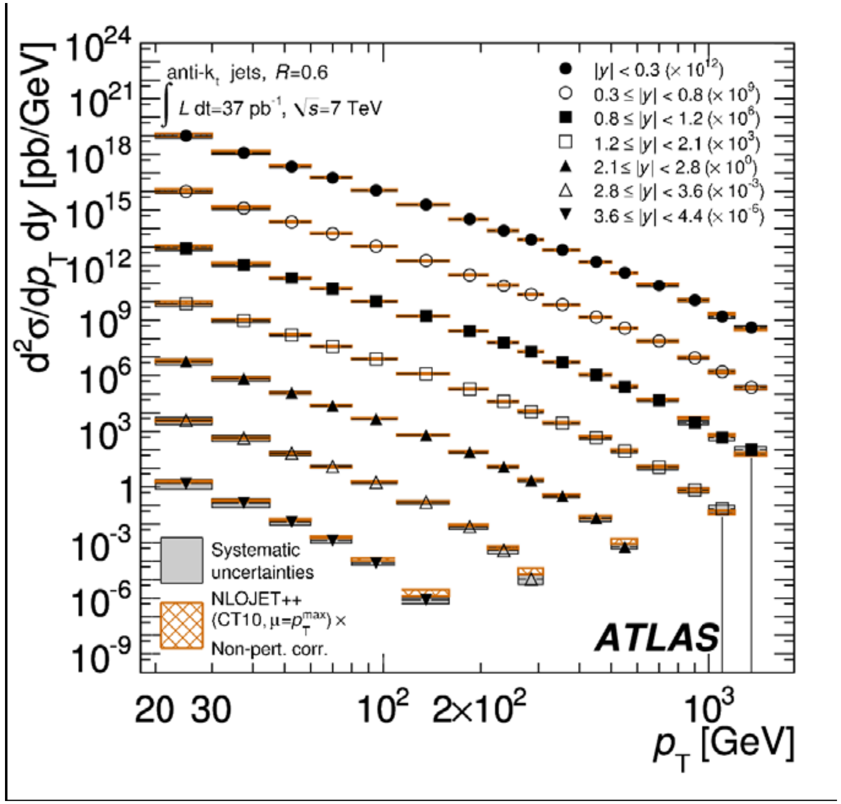
Particle density around jet axis



$$r = \Delta R(ch, jet) = \sqrt{(\phi_{ch} - \phi_{jet})^2 + (y_{ch} - y_{jet})^2}$$

Jets production cross section

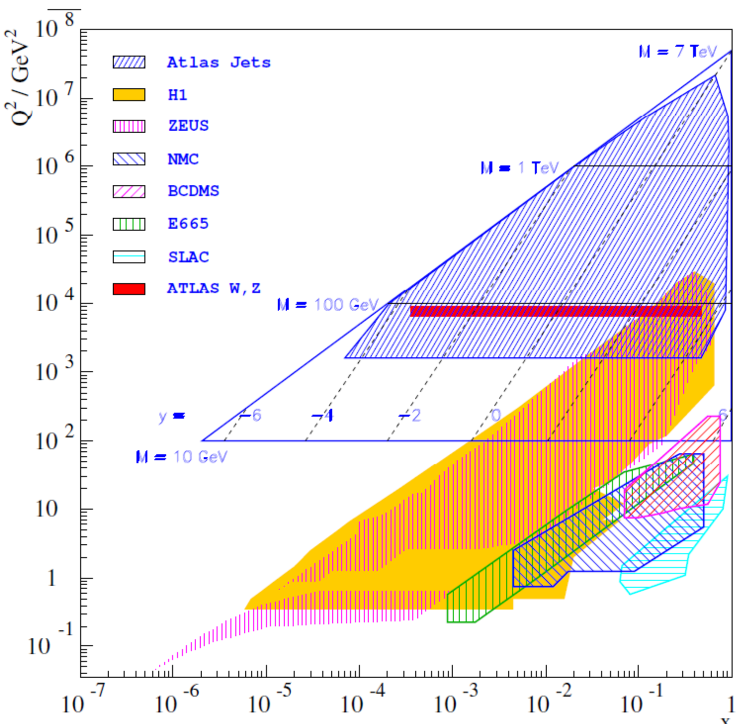




p_T interval 20 GeV-1.5 TeV. 10 orders of magnitude in cross-section

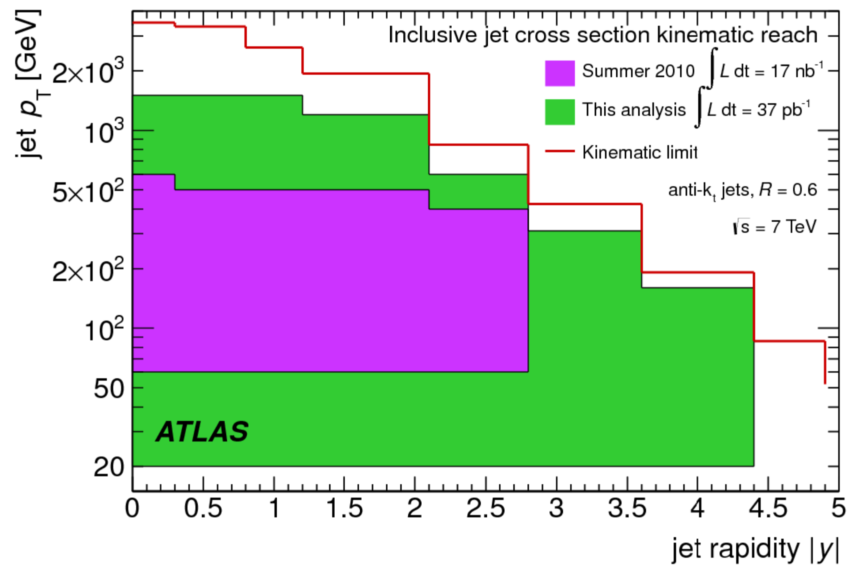
<u>Source of systematic uncertainties:</u>
jet energy scale, luminosity, unfolding, jet matching, jet angular resolution, reconstruction efficiency, pile-up, trigger, jet ID

Parton kinematics



$7 \,.\, 10^{-5} < x < 0.9$

$Q^2 < 2 \,.\, 10^{7}$



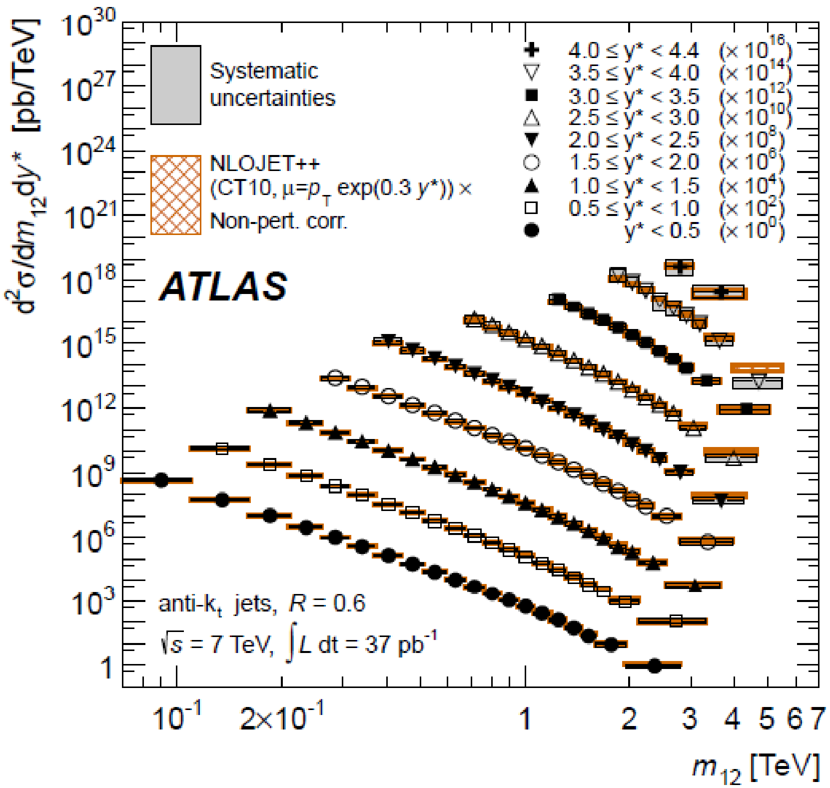
$$20 \text{ GeV} < p_T^{jet} < 1.5 \text{ TeV}$$

$$70 \text{ GeV} < m_{12} < 5 \text{ TeV}$$

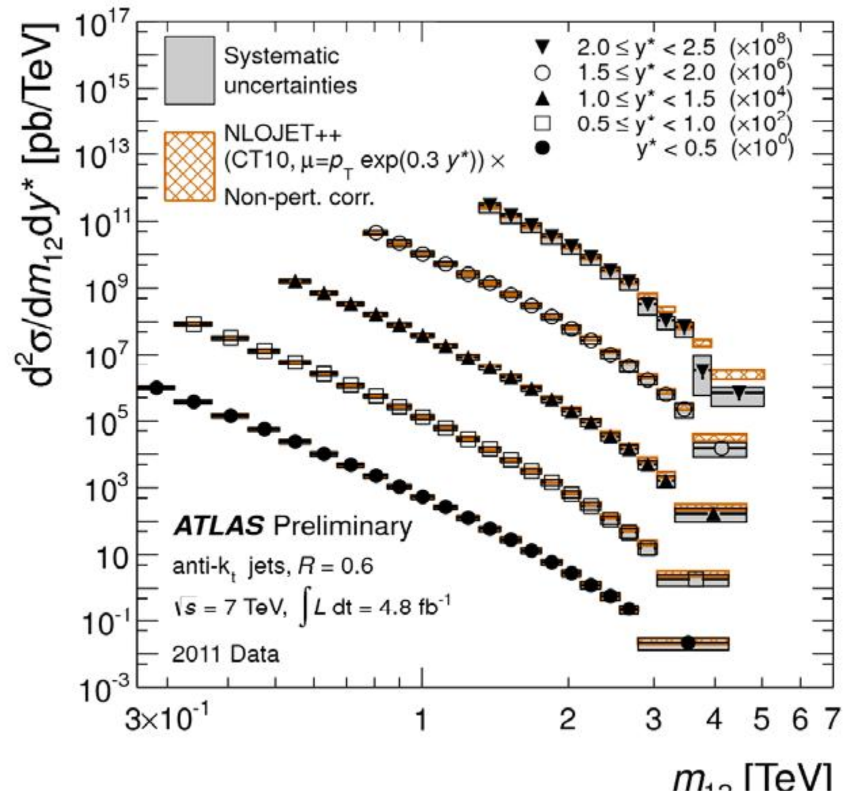
$$|y| < 4.4$$

High mass dijet

2010 dataset : 37 pb^{-1}



2011 dataset : 4.8 fb^{-1}



Very large dijet mass range investigated: 260 GeV-4.6 TeV: no significant deviation from QCD observed

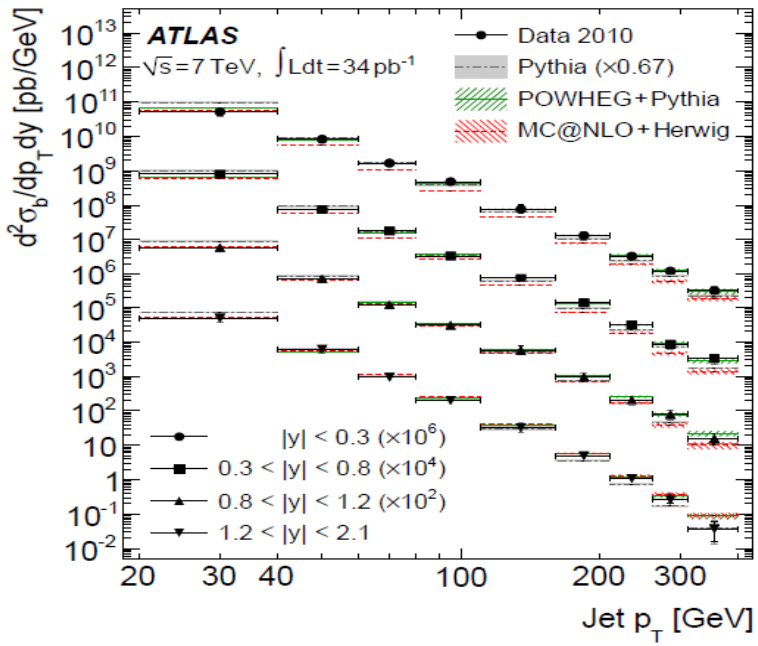
b-jets

Jets with a b-hadron

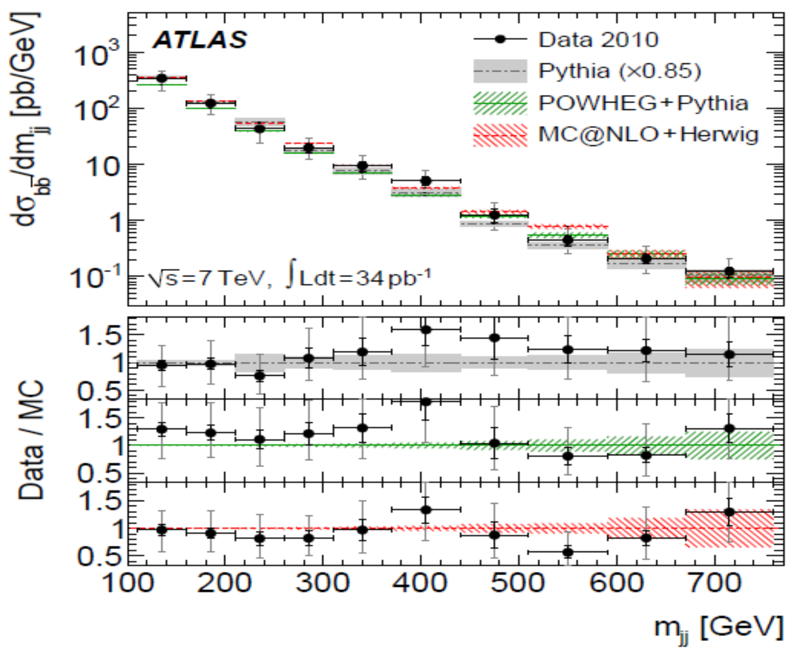
- Verify QCD with heavy-floavou quarks
- Precise knowledge of cross sections necessary for discovery physics: Higgs, new physics
- b-jets identified with both secondary vertices and leptonic decays.

Double-differential b-jet cross-section

[ATLAS arXiv 1109.6833, EPJC]



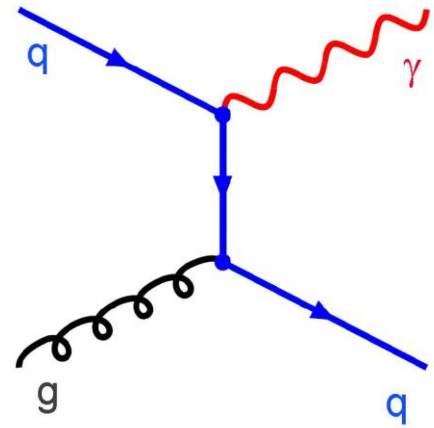
$b\bar{b}$ dijet cross section



Better agreement with POWHEG+Pythia than with MC@NLO+Hervig

Good agreement with NLO predictions

Direct photons

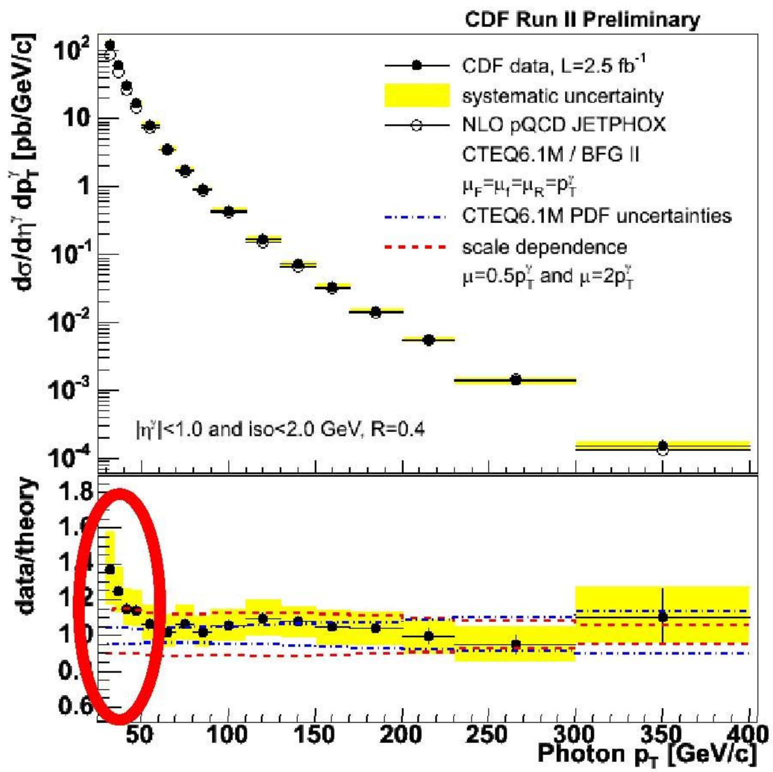


- DIS and Drell-Yan are sensitive to the quark PDFs.
- Gluon sensitivity is indirect
  - The fraction of momentum not carried by the quarks must be carried by the gluon.
- direct photon is useful way to have a direct measurement of the gluon PDFs
- It might less sensitive than the indirect measurements,
- It also has the potential to probe higher Q^2
- his process depends on the (largely known) quark distributions and the (less known) gluon distribution

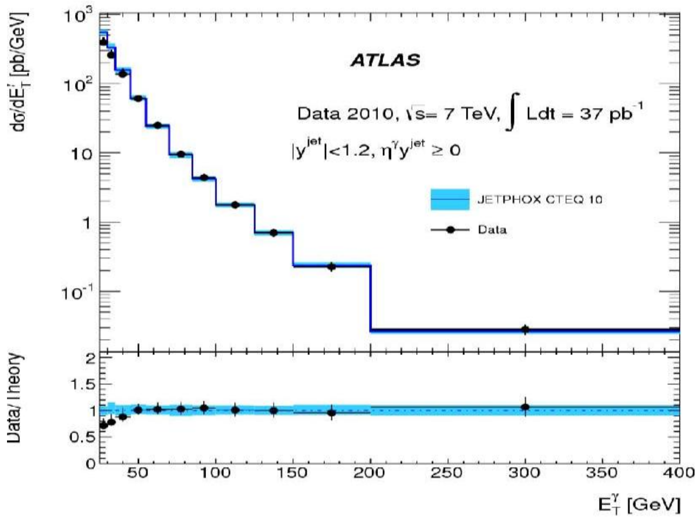
BUT

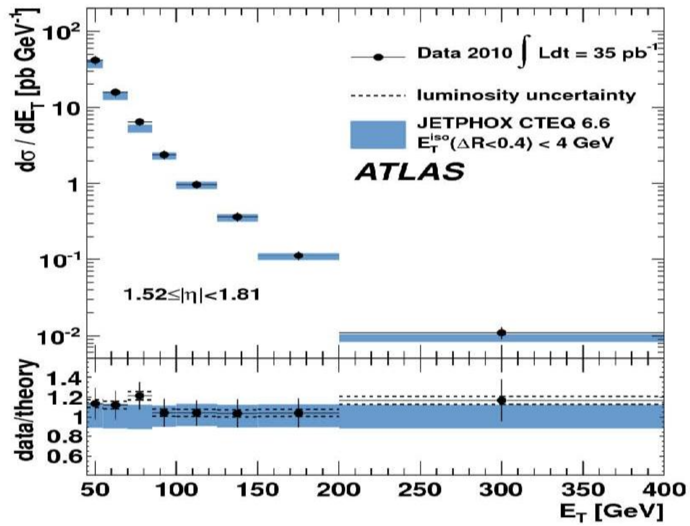
- There is a discrepancy at low pT, seen at the Tevatron experiments

- There are theoretical ideas on how to resolve this, but the cross-section calculation and the PDF measurements have become intertwined.
  - No longer a clean PDF measurement.

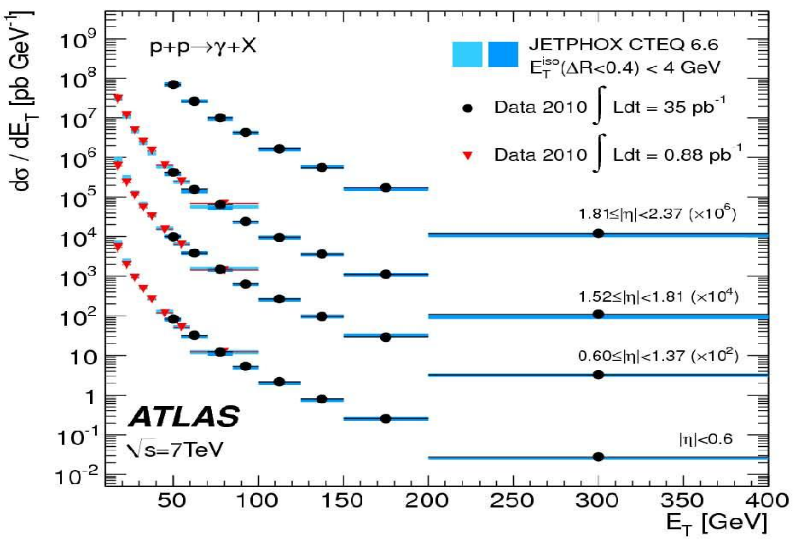


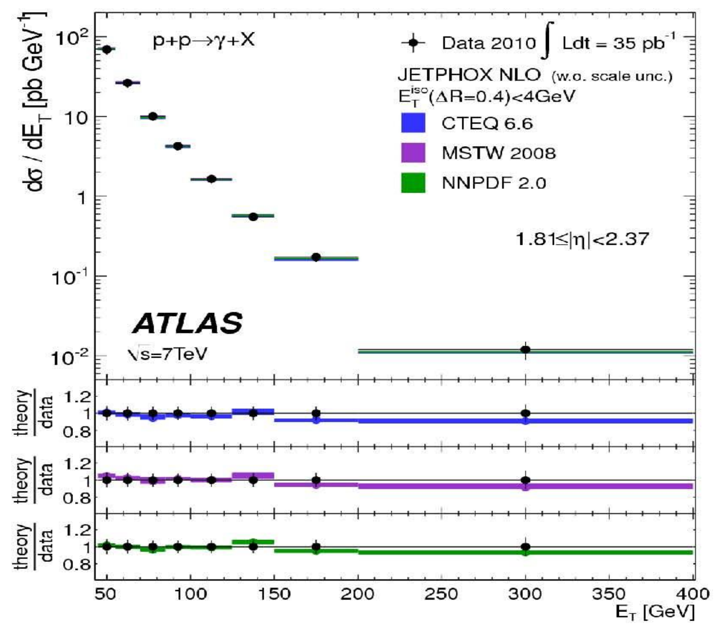
Direct photon measurements in ATLAS





- There is still something not entirely understood going on below 50 GeV
- It appears is a function of E_T. $\rightarrow$ separate PDF effects from the calculational issues.
- Narrower binning in y primordial





W/Z bosons measurements

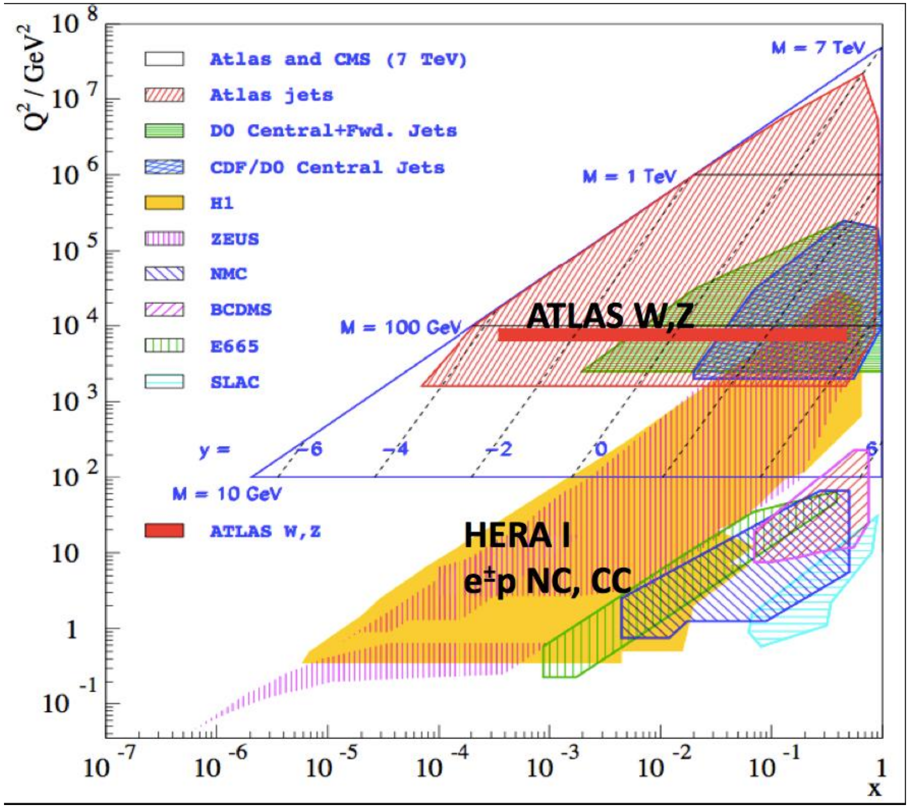
<u>Motivations :</u>

• Important backgrounds for new physics searches

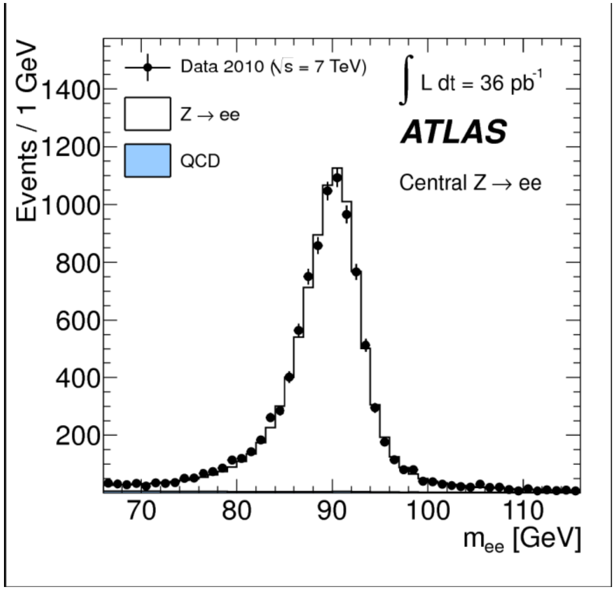
• Advantage – known production cross sections

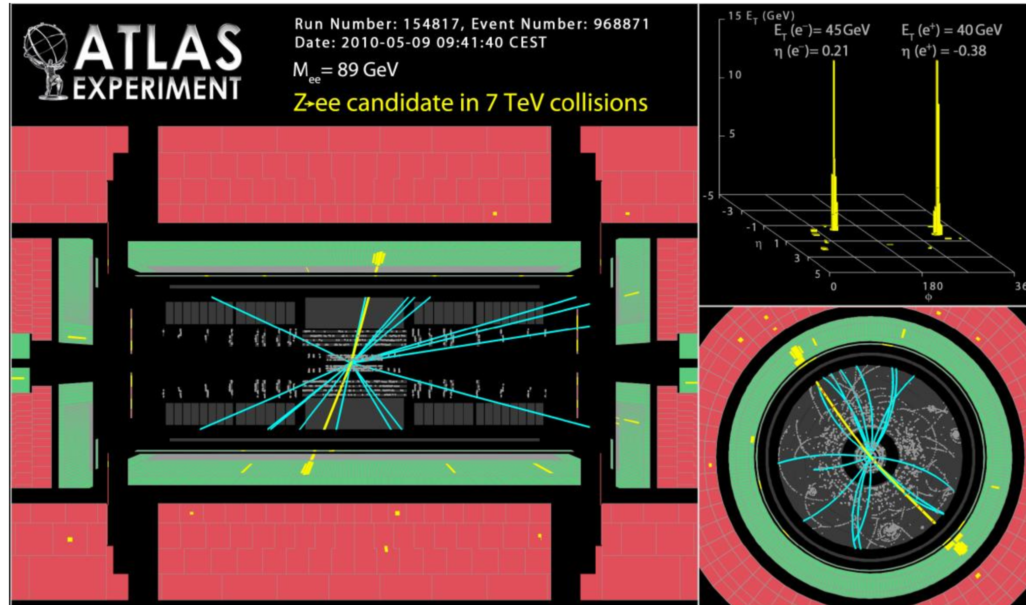
• Provide tests on QCD and understanding of collision environment (PDFs)

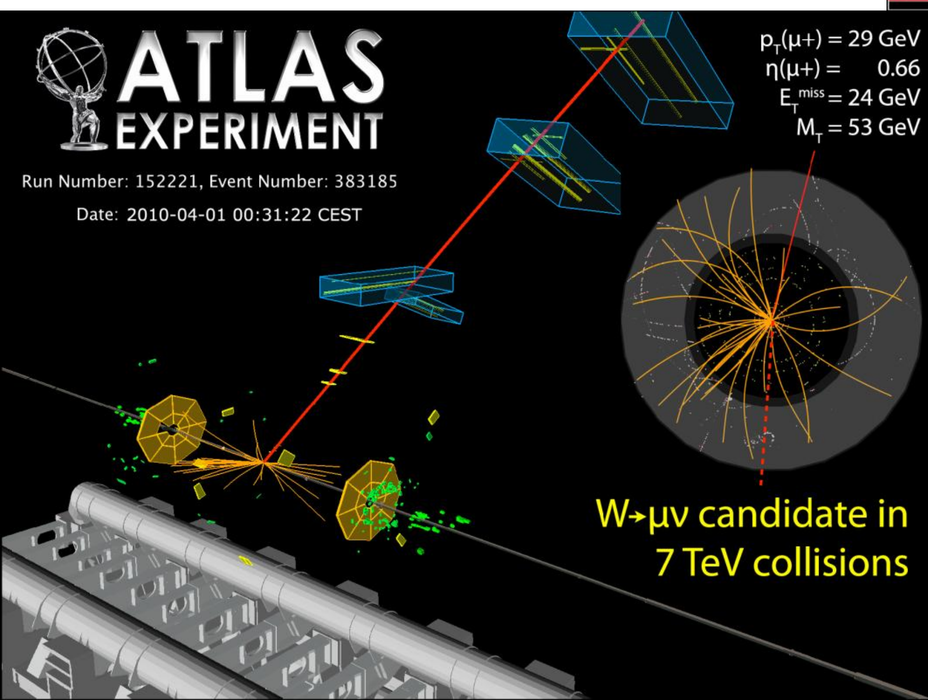
- Low x dominance of gluon and sea quark
- Check evolution of QCD from low scales to high scales
- Test pQCD predictions up to NNLO

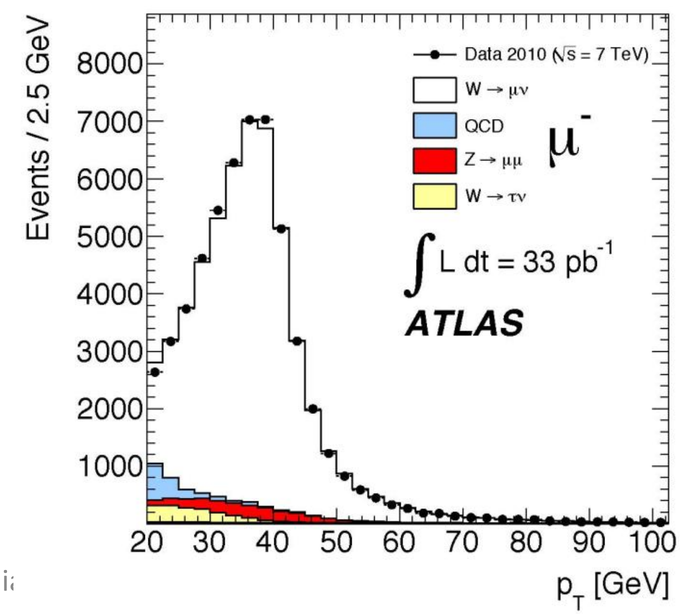


W and Z bosons in ATLAS









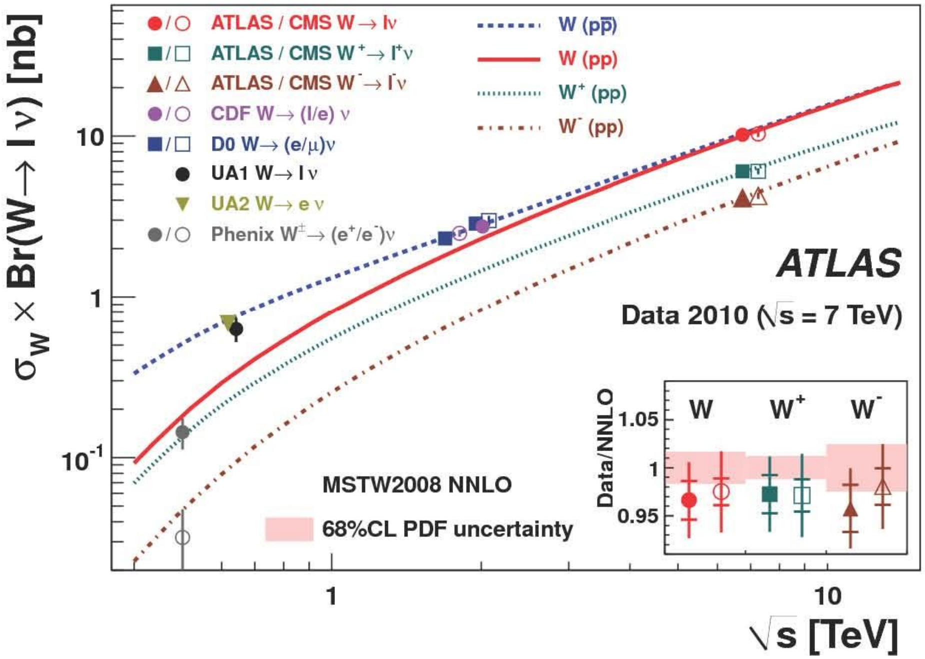
Cross section measurements in ATLAS

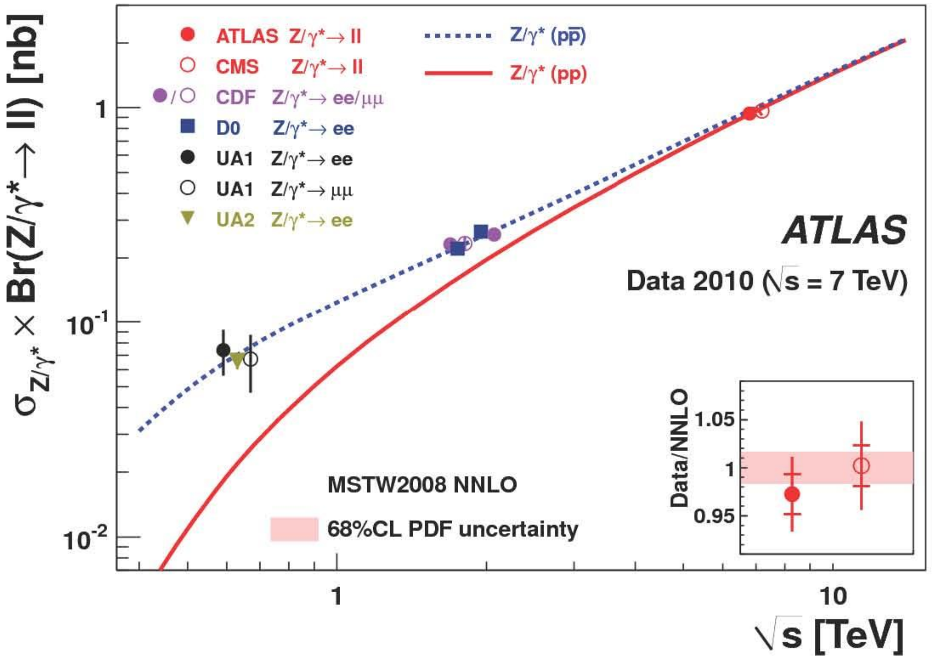
Signal events # Background events

$$\sigma_{tot} = \sigma_{W/Z} \times BR(W/Z \to \ell\nu/\ell\ell) = \frac{N - B}{A_{W/Z} \cdot C_{W/Z} \cdot L_{int}}$$

Signal acceptance Signal efficiencies

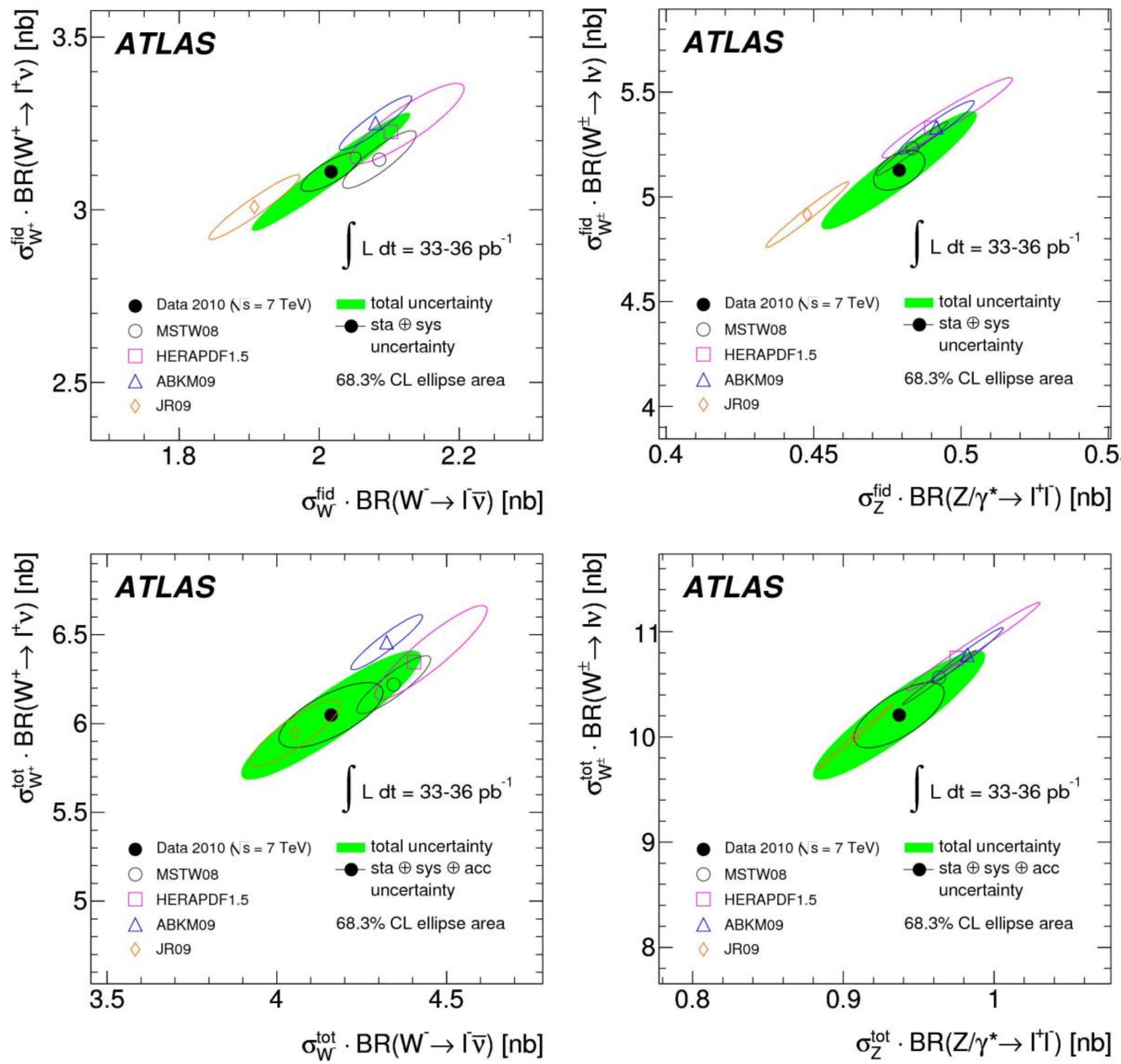
- Extrapolation to total phase space introduces an extra uncertainty of 1.5 – 2.1% but allows comparisons with other experimental results
- Measurements are in good agreement with theory predictions at NNLO QCD





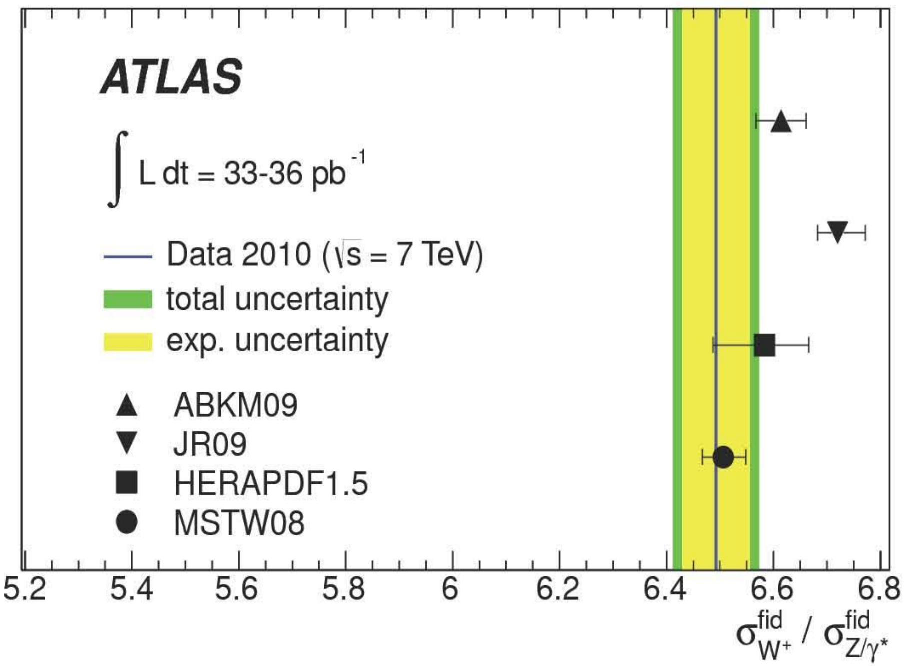
Fiducial Cross sections

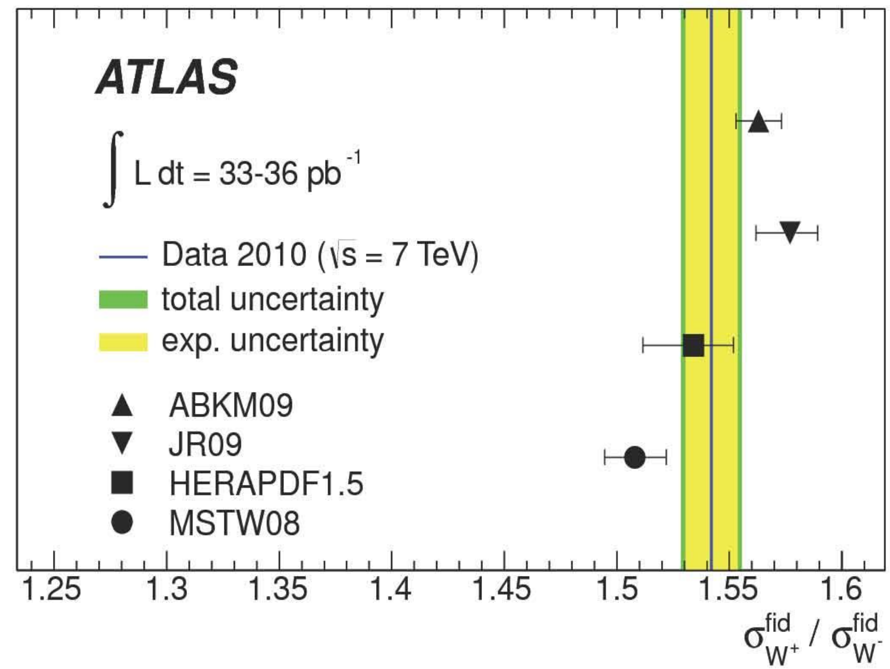
- Comparisons in the common fiducial (|η| < 2.5 and y_Z < 3.6 respectively)
- Regions disentangle theory and experimental effects better
- Detailed comparisons to PDFs, without the additional extrapolation uncertainty.
- Overall, NNLO QCD comparisons in remarkable agreement.



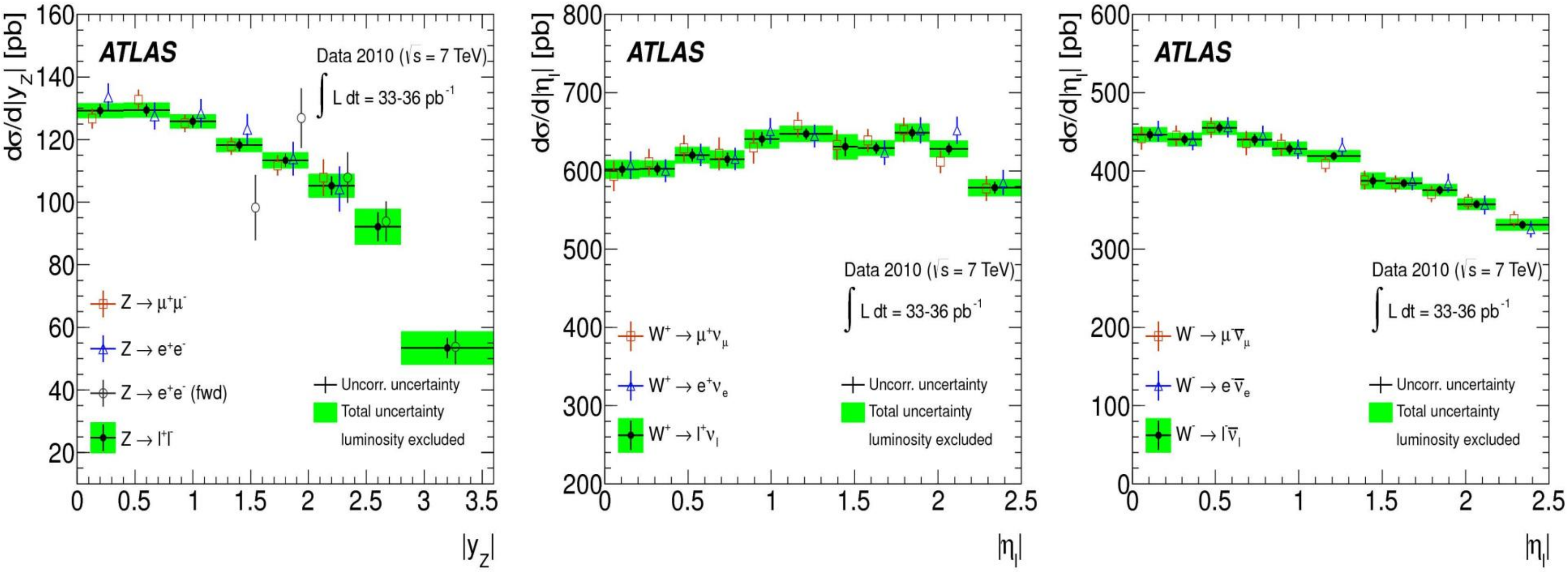
Cross sections ratio

- Correlations due to luminosity measurement cancel at the ratio of the cross sections
- ***(W+ + W-)/Z ratio rather insensitive to PDFs (provided that the sea is flavor*** symmetric)
    - Agreement with measurement → flavor-independent light-quark sea (athigh scale x around 0.01)
- Charge-dependent ratios (eg. W+/W-) more sensitive to *u/d differences*
    - Discrepancies observed between PDF sets





Differential cross sections



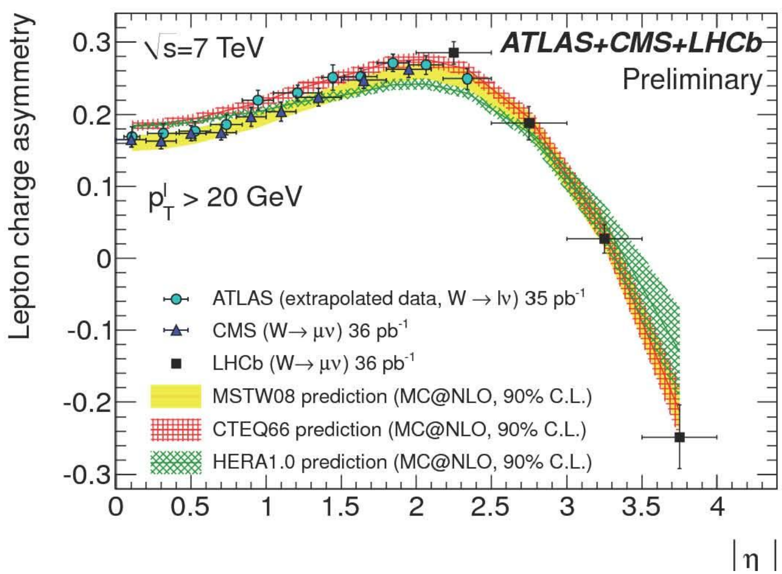
- Electron and muon measurements are consistent in all three channels

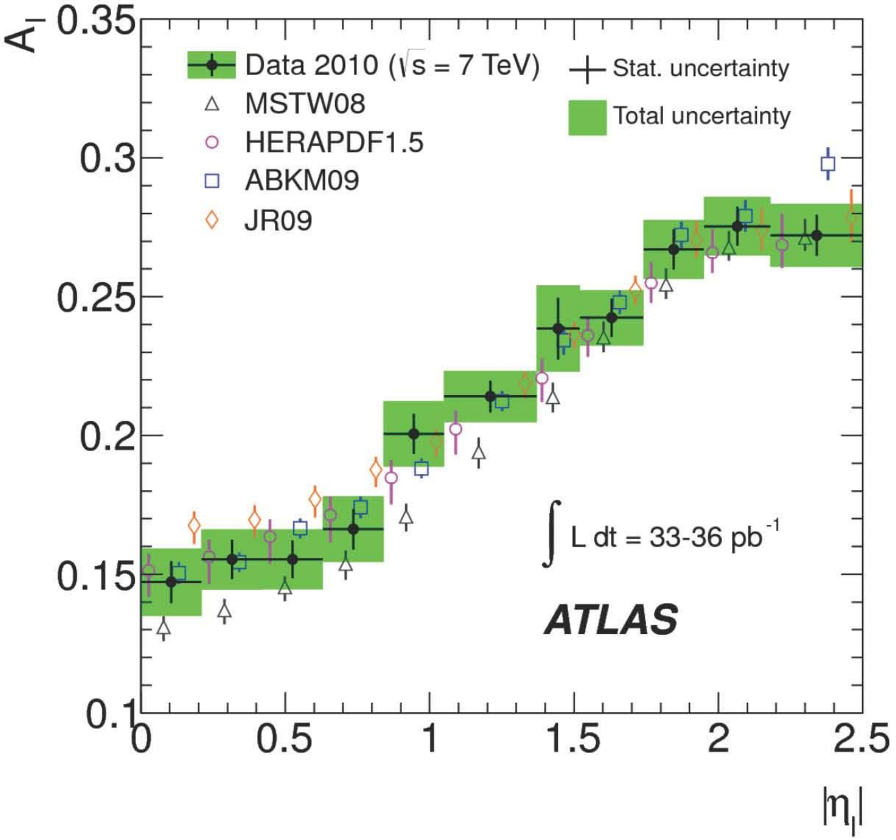
- Datasets are combined taking into account the correlations for the systematics

W charge asymmetry

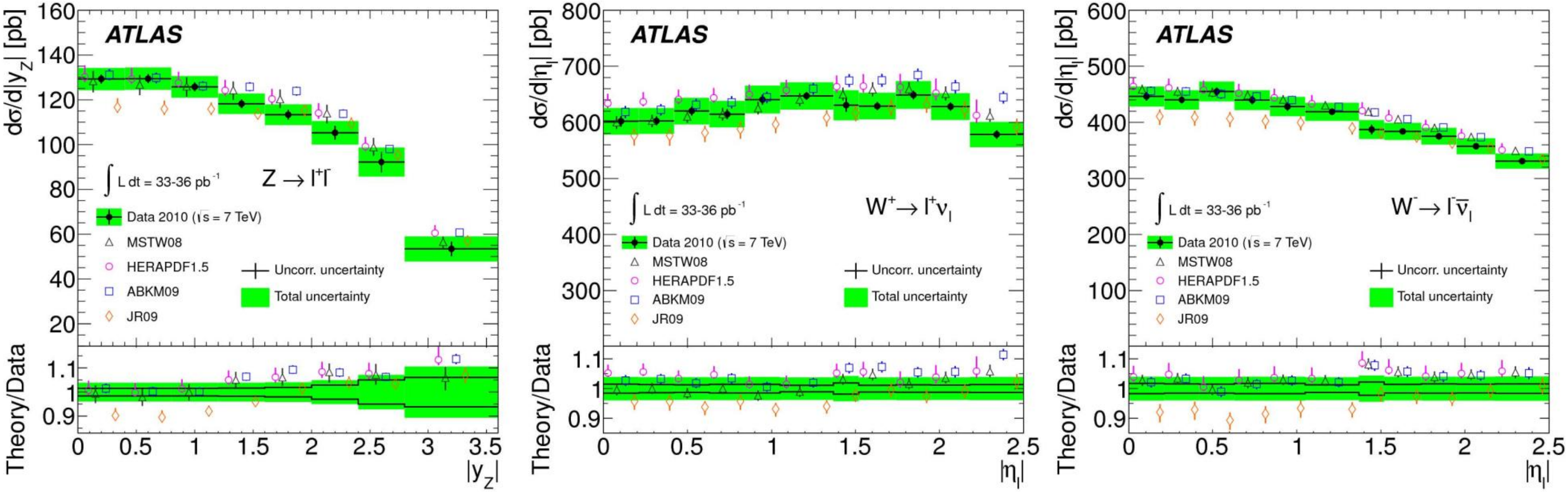
$$A(\eta_\ell) = \frac{d\sigma_{W^+}(\eta_\ell) - d\sigma_{W^-}(\eta_\ell)}{d\sigma_{W^+}(\eta_\ell) + d\sigma_{W^-}(\eta_\ell)}$$

Comparisons with different PDFs with the NNLO predictions. ABKM09 and HERAPDF1.5 give the best agreement.





NNLO comparisons



- Combined measurement of differential cross-sections are compared with NNLO predictions using NNLO PDFs
    - more deviations apparent than in W charge asymmetry
    - good potential to bring impact on PDFs, as there are some differences among the PDFs sets

W →τν and Z→ττ cross sections

W → τ ν with 2010 data (~35 pb^{-1})

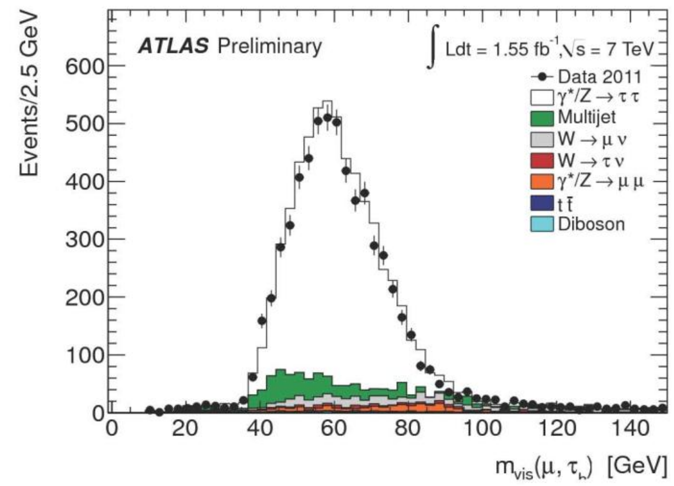
Z → τ τ with 1.32 – 1.55 fb^{-1} in three channels:

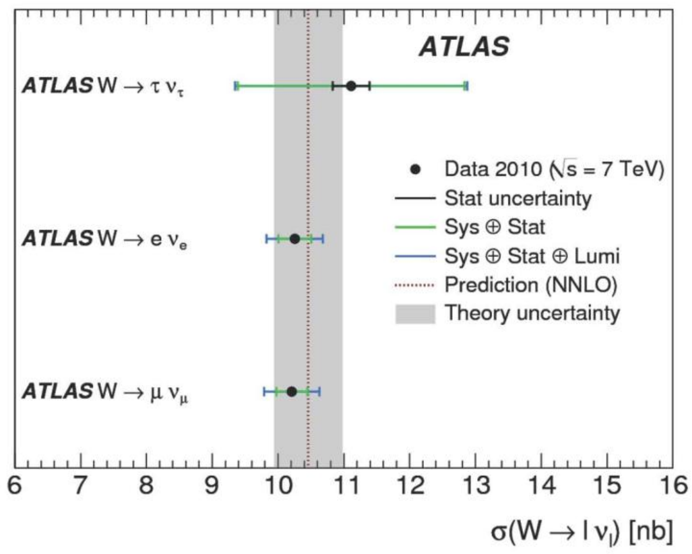
- μ + hadrons + 3υ ($\tau_\mu \tau_h$)
- e + hadrons + 3υ ($\tau_e \tau_h$)
- e + μ + 4υ ($\tau_e \tau_\mu$)

~ 10 % systematic uncertainties

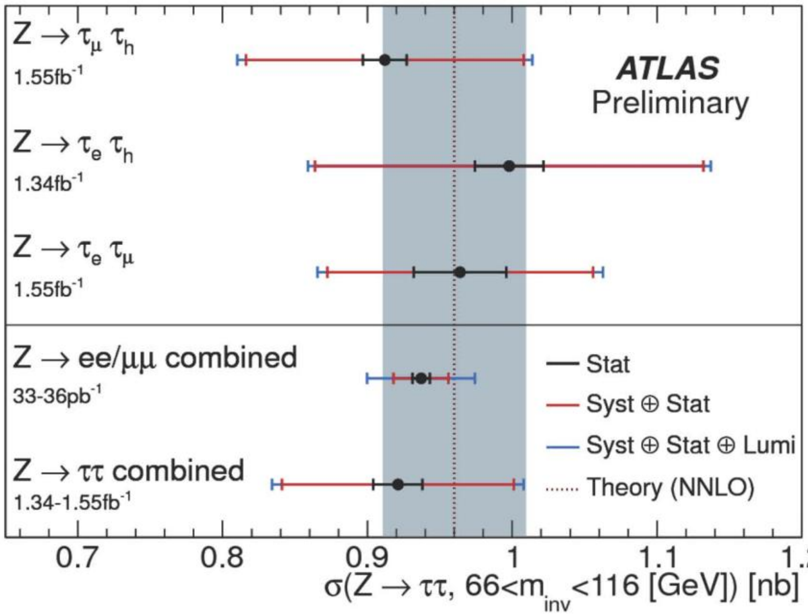
Validation of τ performance critical for searches!

Measurements in agreement with other leptonic channels:





τ



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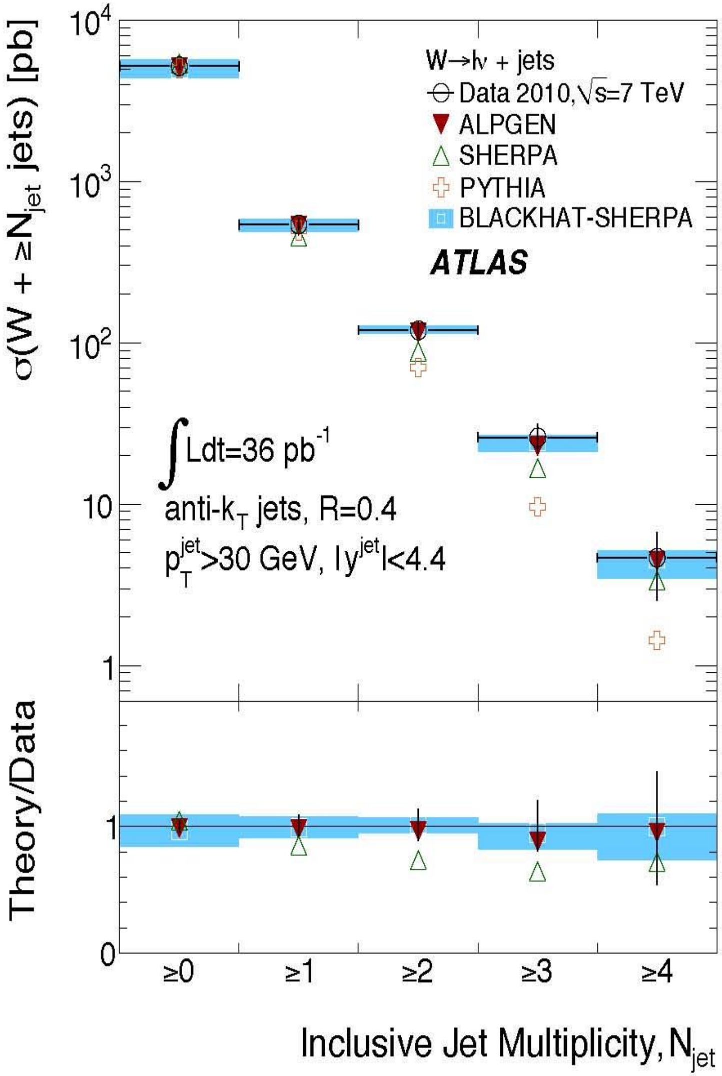
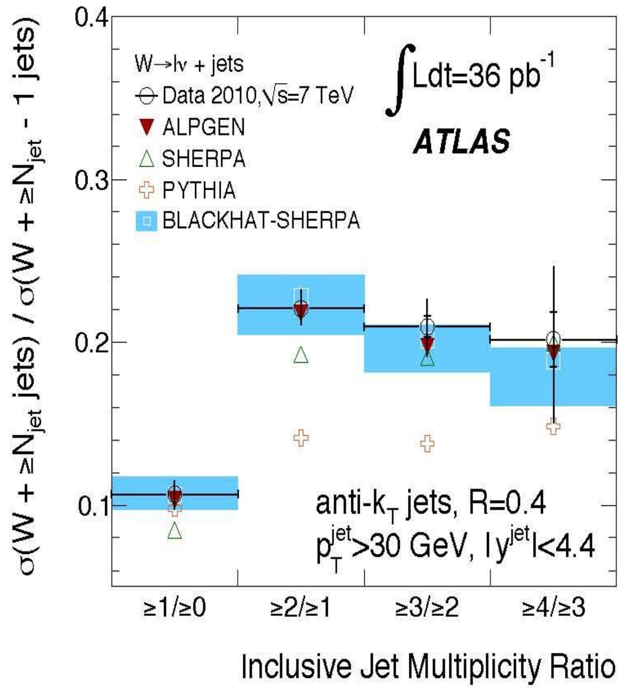
W+jets cross section



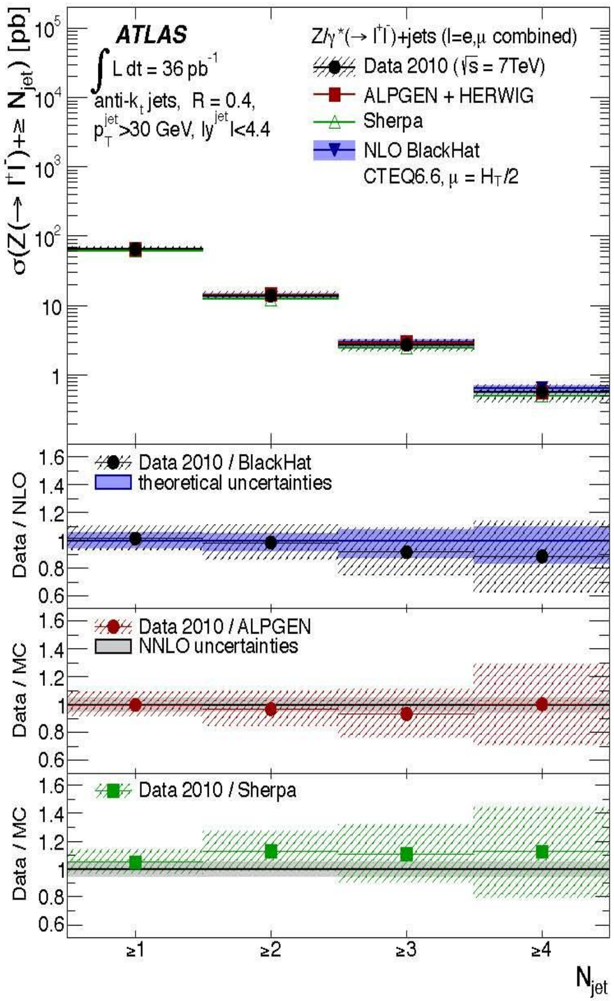
- Good agreement between data and predictions, except Pythia
- Many systematic uncertainties cancel in ratios of cross sections:

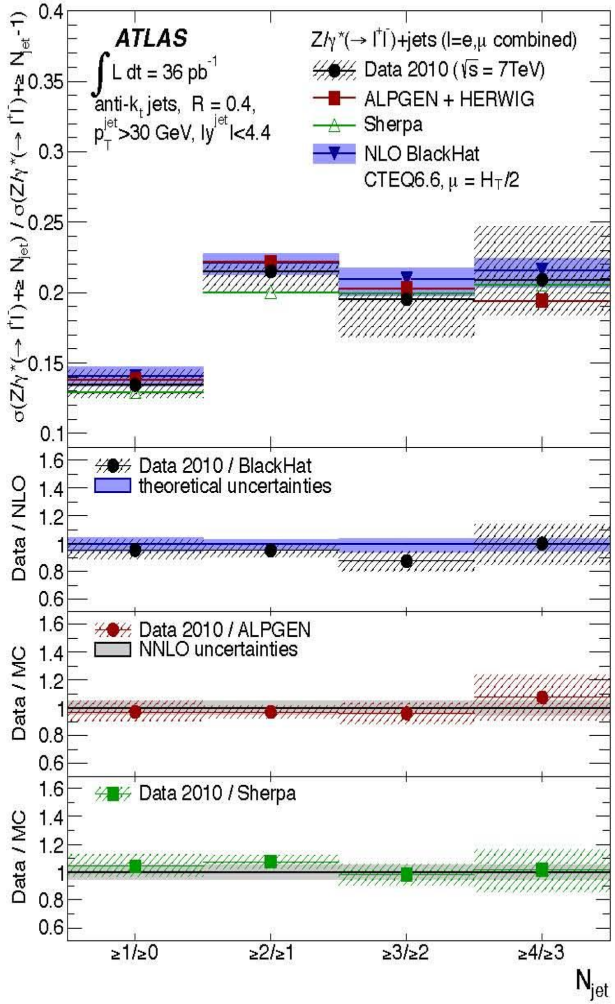
$$\sigma(W + \geq N_{jet})/\sigma(W + \geq N_{jet}-1)$$



Z+jets cross sections

- Data and predictions also agree for Z + jets cross sections and ratios
  - ALPGEN and BLACKHAT-SHERPA configured as for W + jets; SHERPA version 1.2.3



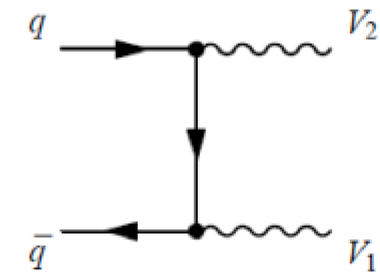


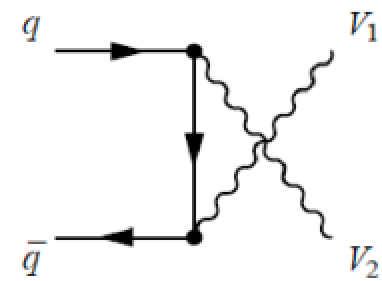
Dibosons in ATLAS

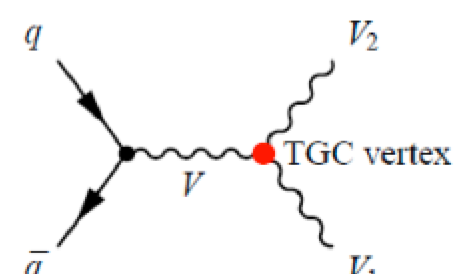
- Diboson production cross-sections are sensitive to the couplings at the triple gauge-boson vertices
  - Provide direct test of SM predictions
  - $WW\gamma$ and WWZ vertices are predicted and have been measured
  - $ZZ\gamma$, $Z\gamma Z$, $Z\gamma\gamma$ and ZZZ vertices are forbidden

- The presence of new physics could:
  - Give anomalous Triple Gauge Couplings (aTGC)
  - Modify cross-sections and/or kinematic distributions

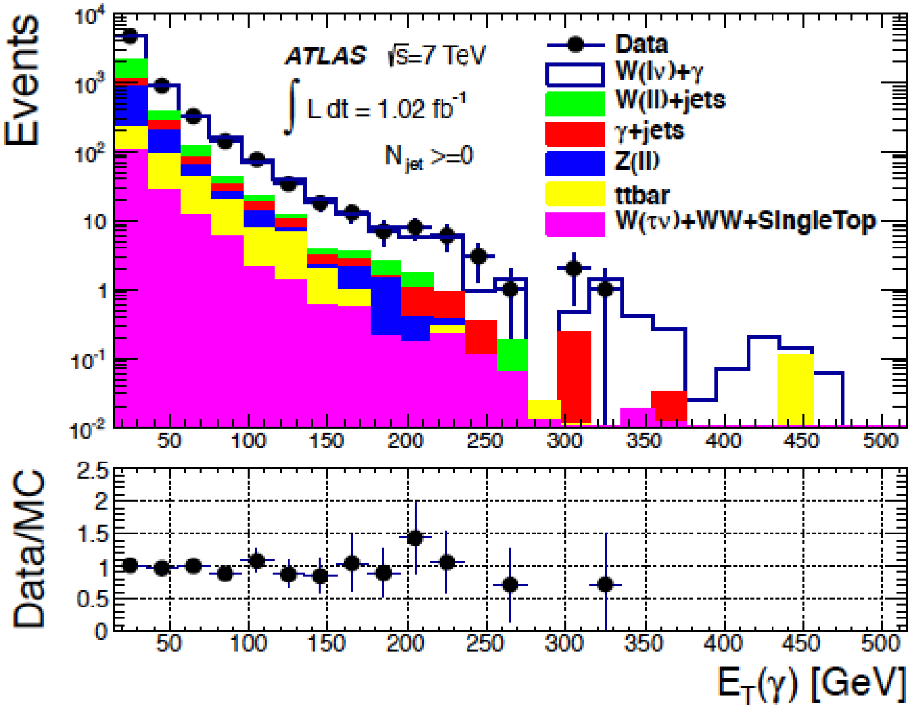
- Di-Bosons are also a background to new physics searches
  - Higgs boson search

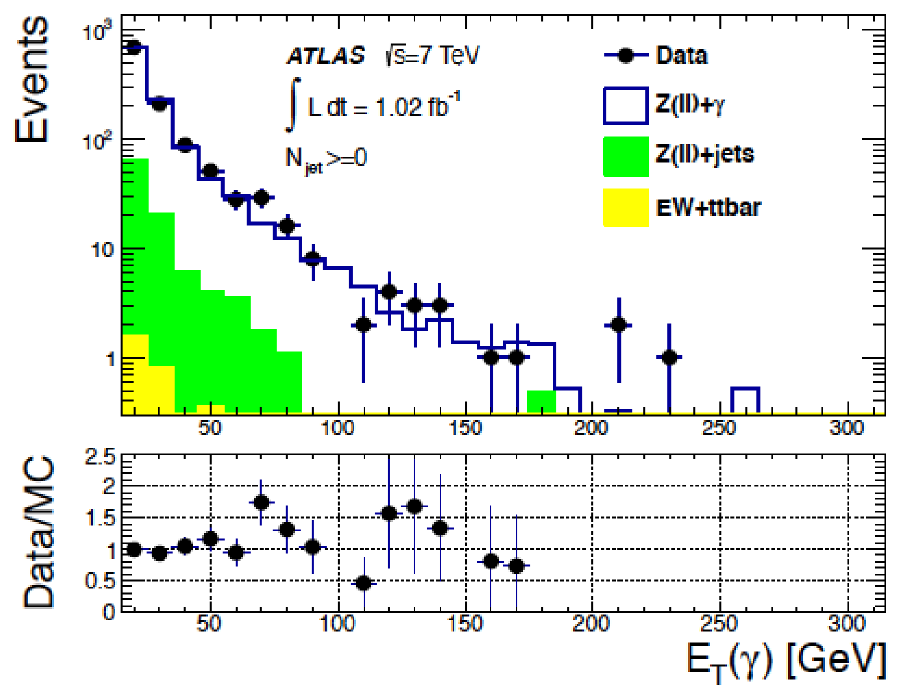




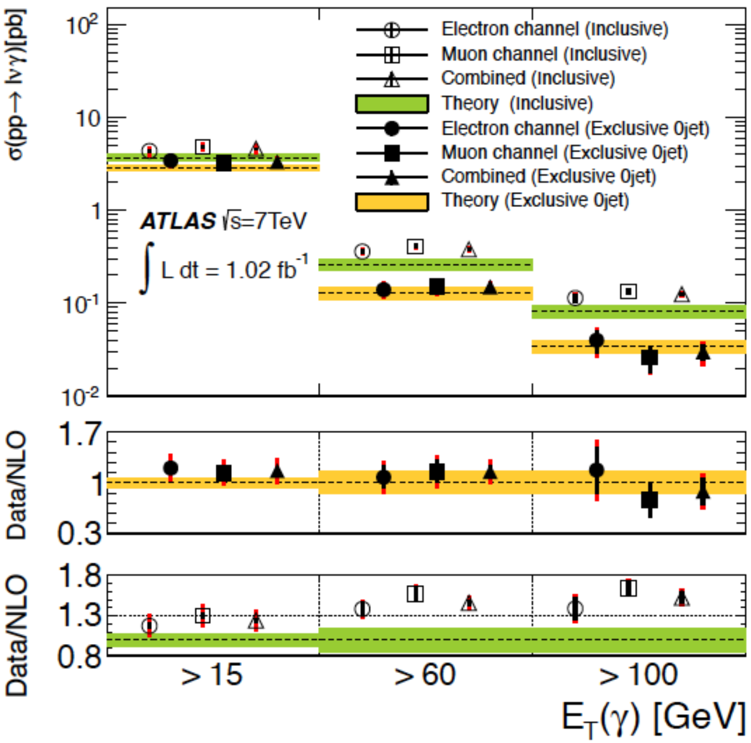


Dibosons: Wγ / Zγ

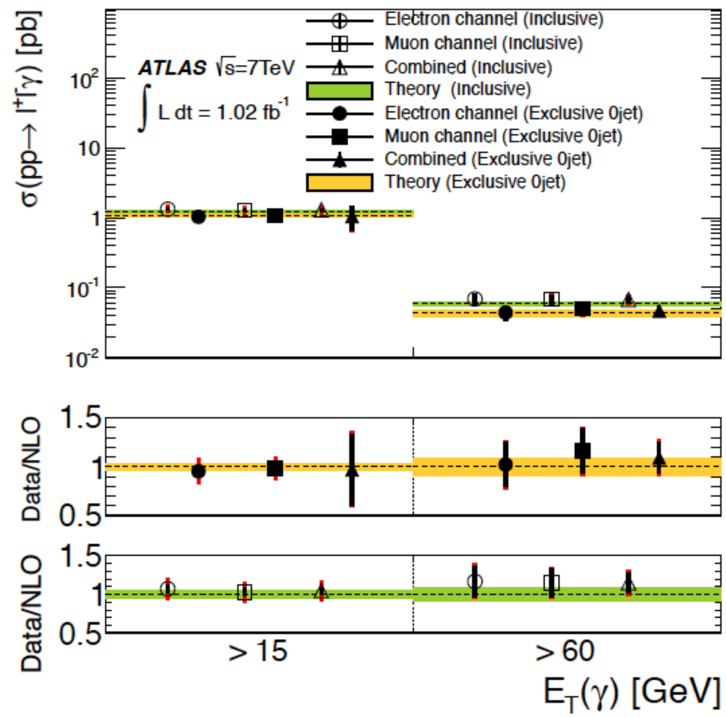




Dibosons: Wγ / Zγ

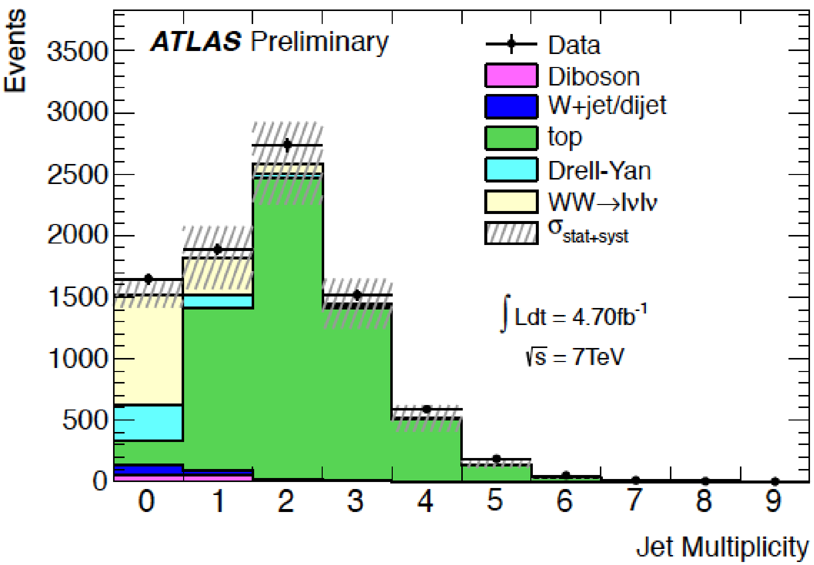


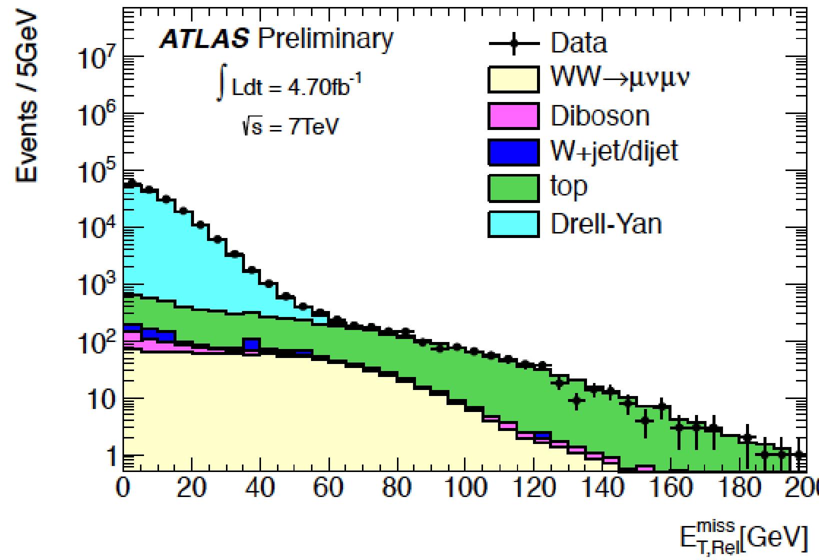
τ



- Statistical uncertainties are dominant
- The measured cross-sections for exclusive (Njet = 0) production agree well with the NLO SM predictions both at low and high photon p_T
- At high p_T, the measured inclusive (Njet ≥ 0) production cross-sections are higher than the NLO calculations
  - Calculations do not include multiple quark/gluon emission

Dibosons: WW

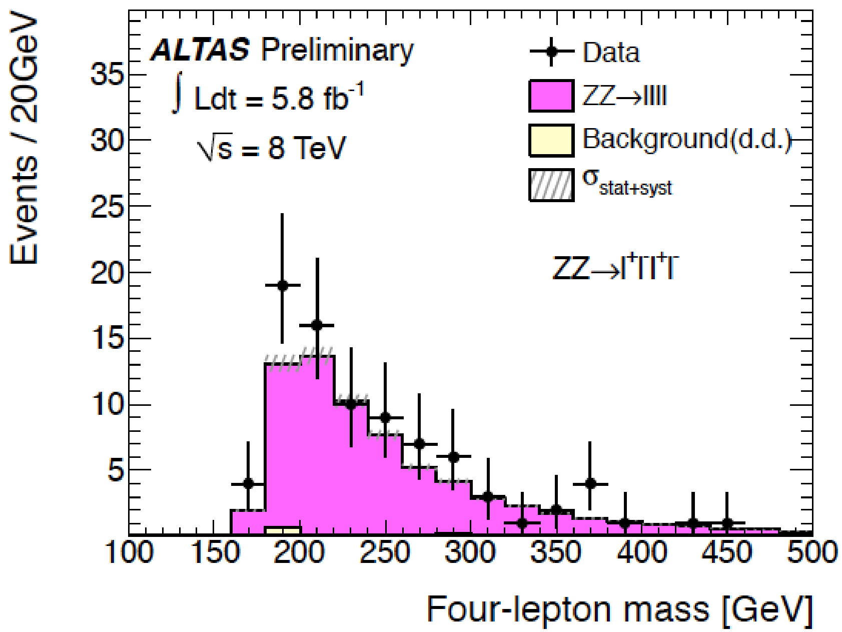




Channels	Total cross-section (pb)	$\Delta\sigma_{stat}$(pb)	$\Delta\sigma_{syst}$(pb)	$\Delta\sigma_{lumi}$(pb)
$e\nu e\nu$	41.5	± 6.5	± 7.8	± 1.6
$\mu\nu\mu\nu$	57.3	± 5.5	± 5.4	± 2.2
$e\nu\mu\nu$	54.3	± 2.4	± 4.4	± 2.1
Combined	53.4	± 2.1	± 4.5	± 2.1

- Good agreement with NLO SM total cross-section ~ 45.1 ± 2.8 pb
  - Measurement already dominated by systematic uncertainties when combining all three channels
  - Systematic uncertainty of ~8.4%, of which: ~6.7% on signal acceptance, and ~5.1% on background estimation

Dibosons: ZZ→4leptons @ 8TeV

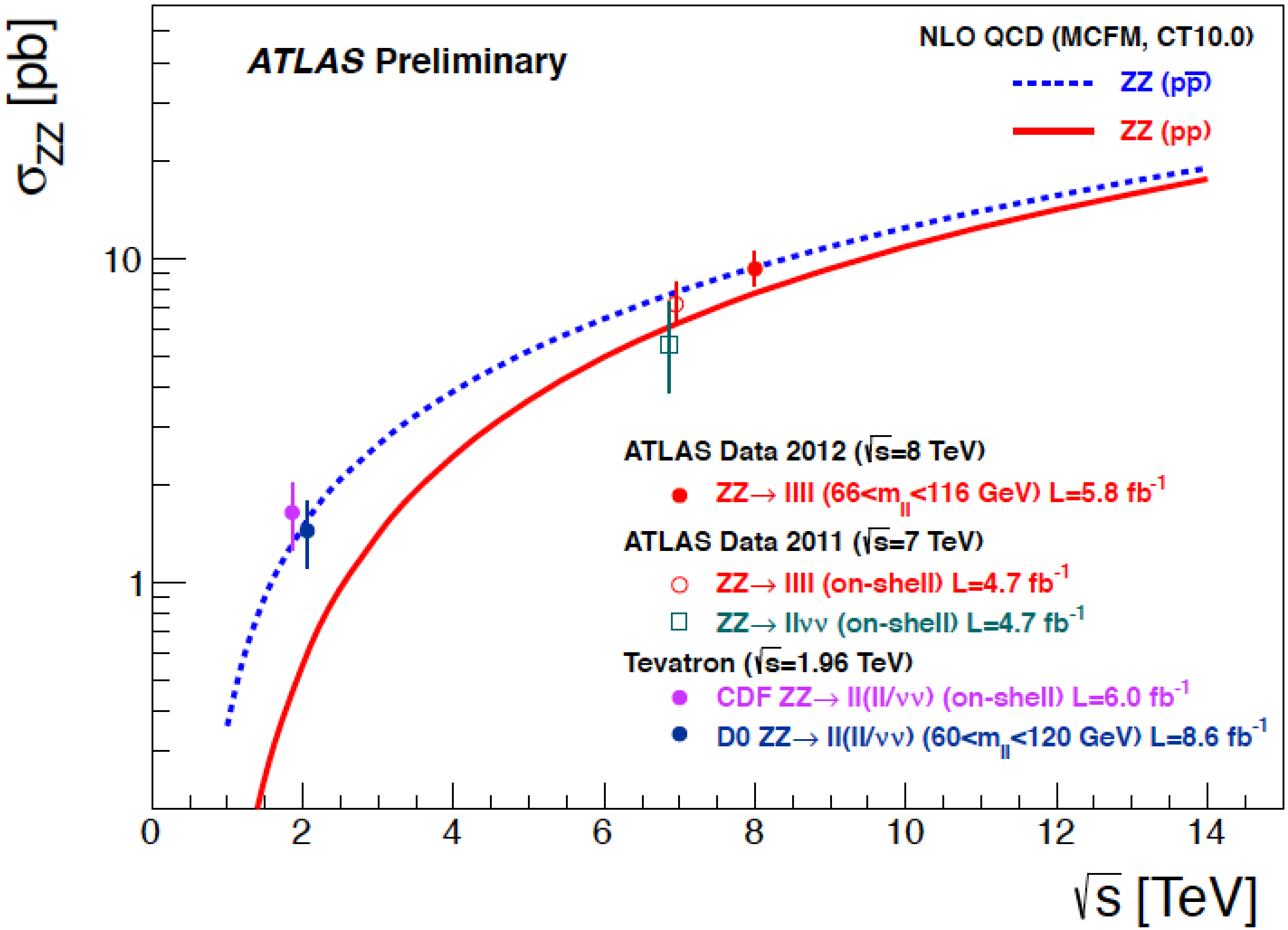


Final state	$e^+e^-e^+e^-$	$\mu^+\mu^-\mu^+\mu^-$	$e^+e^-\mu^+\mu^-$	$\ell^+\ell^-\ell'^+\ell'^-$
Observed	23	22	40	85
Signal (MC)	16.5±0.8	20.9±0.4	33.2±0.9	70.5±1.7
Background (d.d.)	0.6±0.4±0.2	$0.1^{+0.6}_{-0.1}\pm0.1$	$0.6^{+0.9}_{-0.6}\pm0.3$	1.3±1.2±0.5

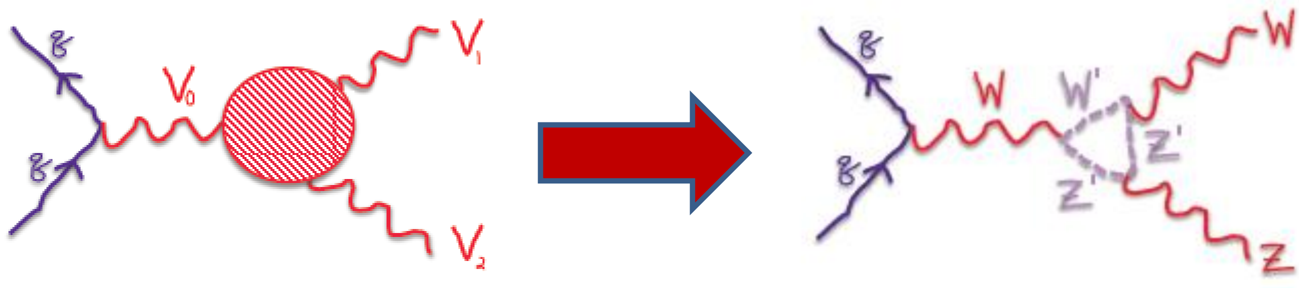
$$\sigma^{\rm fid}_{ZZ\to\ell^+\ell^-\ell'^+\ell'^-} = 21.0^{+2.4}_{-2.2}(\text{stat.})^{+0.6}_{-0.5}(\text{syst.}) \pm 0.8(\text{lumi.})\ \text{fb}$$
$$\sigma^{\rm tot}_{ZZ} = 9.3^{+1.1}_{-1.0}(\text{stat.})^{+0.4}_{-0.3}(\text{syst.}) \pm 0.3(\text{lumi.})\ \text{pb},$$

agreement with the NLO SM prediction: 7.52 +0.39-0.34 pb

Dibosons: ZZ Results comparisons



Anomalous Triple Gauge Coupling (aTGC)



Example: W', Z' could be SUSY, Technicolor, Higgs...

The effective lagrangian for model independent triple gauge couplings depends on a number of parameters:

	coupling	parameters	channel
SM allowed	WWγ	λ_γ, $\Delta\kappa_\gamma$	WW, Wγ
	WWZ	λ_Z, $\Delta\kappa_Z$, Δg_1^Z	WW, WZ
SM forbidden	ZZγ	h_3^Z, h_4^Z	Zγ
	Zγγ	h_3^γ, h_4^γ	Zγ
	ZγZ	f_{40}^Z, f_{50}^Z	ZZ
	ZZZ	f_{40}^γ, f_{50}^γ	ZZ

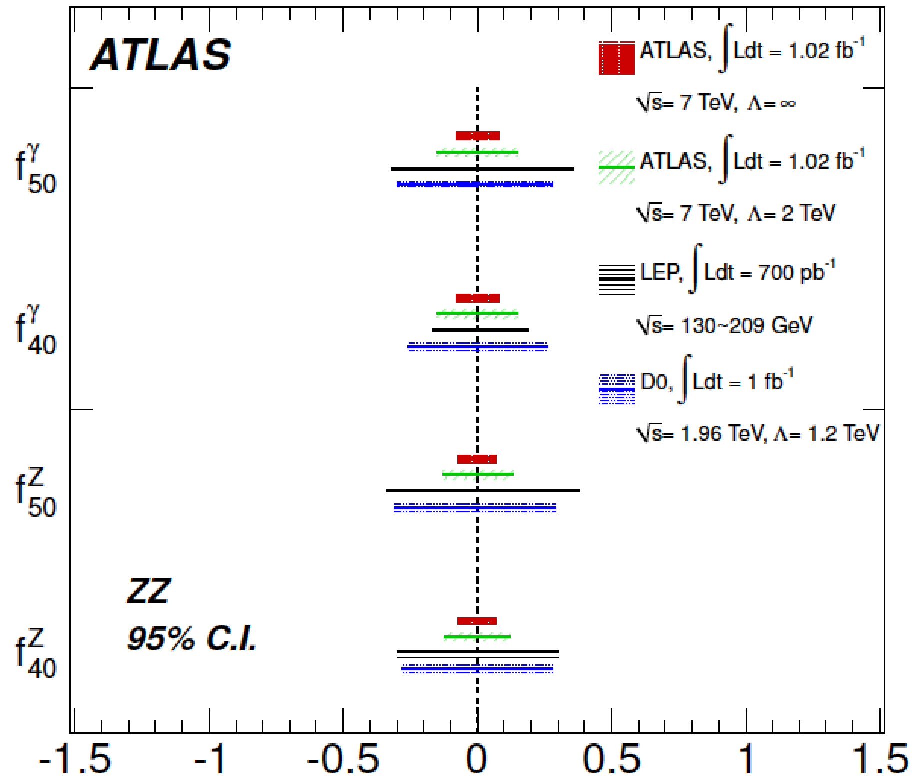
aTGC limits from the ZZ channel

- Using 2011 ZZ cross section measurement.

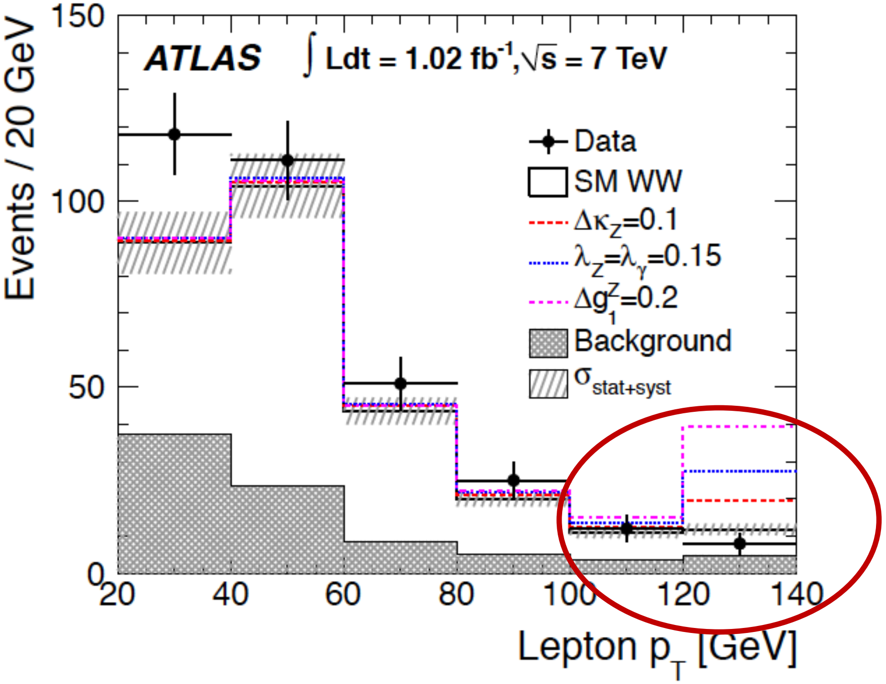
- The measurement is dominated by statistical uncertainty

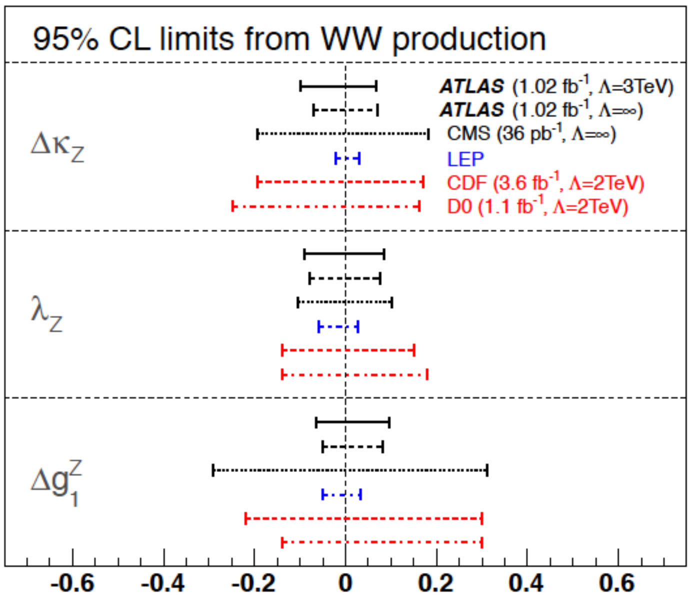
- No significant deviation w-r-t SM predictions is observed

- ATLAS results are more stringent than the LEP and the Tevatron ones



aTGC limits from the WW channel





higher sensitivity
in high pT bins

- Maximum likelihood fit performed for events with $p_T$lep > 120 GeV
- No significant deviation wrt SM predictions is observed
- ATLAS results are more restrictive than Tevatron ones

Top quark physics in ATLAS

- Precision test of theSM predictions
- Establish the different channels separately
- Cross-section $\propto |V_{tb}|^2$
  - Test of the unitarity of the CKM-matrix
- R_t= (t)/t) is sensitive to the u/d –quark PDF
- Test of the b-quark PDF
- Search for new physics BSM
- LHC is a top quark factory

Top quark production and decays

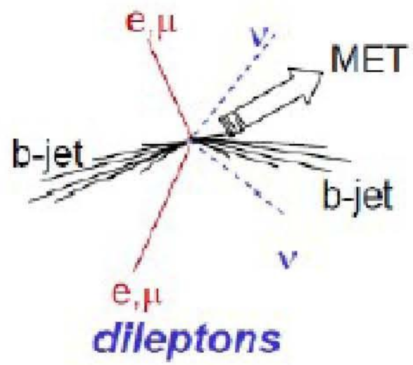
- **Production mechanism**
  - $t\bar{t}$ pair, 85% by gluon fusion, ~15% by $q\bar{q}$ production
  - single top (electroweak)

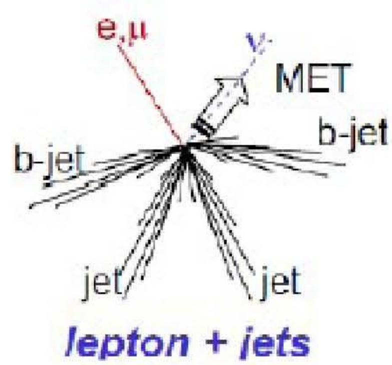
Predictions $\sqrt{s}$= 7 TeV

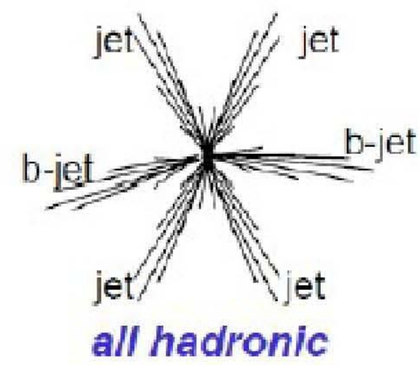
$\sigma(pp \rightarrow t\bar{t})_{NNLOapprox} = 167^{+17}_{-18}$ pb

Computed with: Aliev et. al., HATHOR, arXiv:1007:1327 (2011)

- **Top pair event classification according to W decays**







	dileptons	lepton + jets	all hadronic
Branching ratio	4.9%	29.6%	45.7%
Final state	2 isolated leptons large E_T^{miss} 2 b-jets	1 isolated lepton E_T^{miss} 2 b-, 2 light jets	no lepton no E_T^{miss} 2 b-, 4 light jets
Backgrounds	few (mainly Z+jets)	moderate (mainly W+jets)	huge (mainly QCD)

τ channels : 13.5% for τ+jets and 6.3% for τ+e/μ+jets

Top quark pair production with 2 leptons +jets

<u>Signature</u> :
2 isolated e/μ + E_T^{miss} + jets (1b)

<u>Trigger</u> : 1 single isolated lepton
<u>Offline</u> : opposite sign leptons + E_T^{miss}>30 GeV, $\sum E_T(e\mu)$, m_{ll} (Z veto)
<u>Analysis Strategy</u> : counting experiment
data driven estimation of Z+jets, W+jets
and QCD backgrounds

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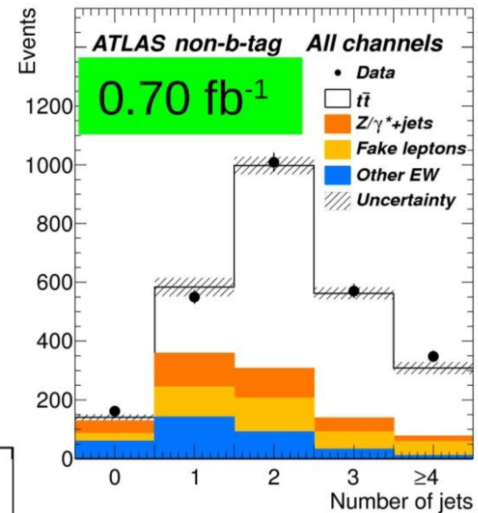
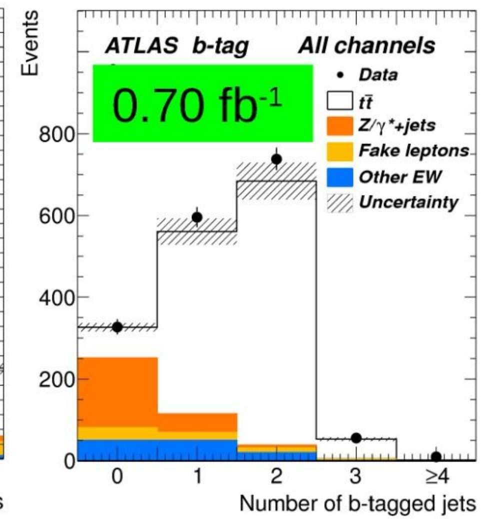
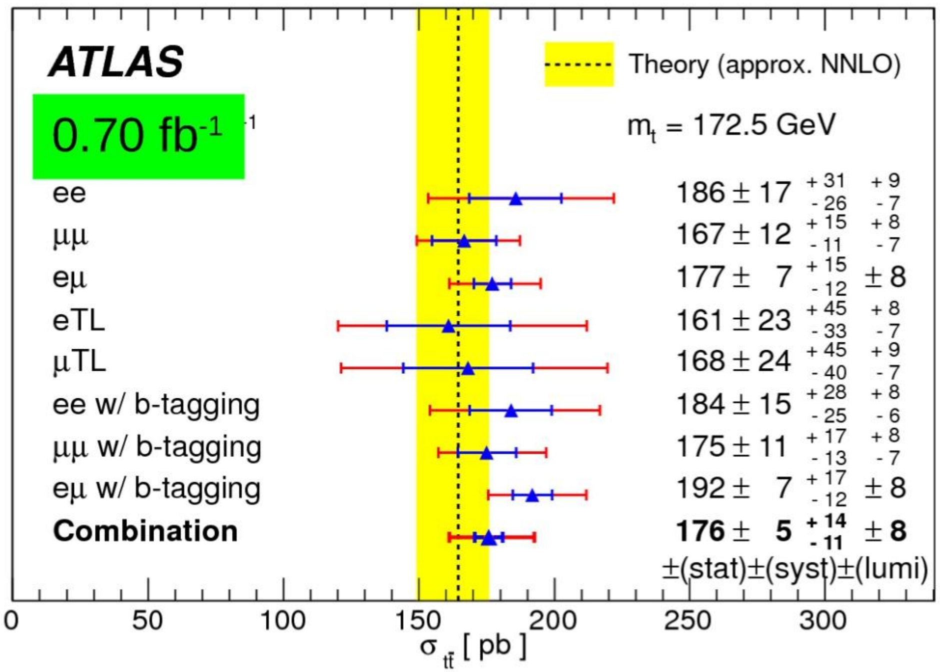




$$\sigma_{tt} = 176 \pm 5\ (\text{stat})\ {}^{+14}_{-11}(\text{syst}) \pm 8\ (\text{lumi})\ \text{pb}$$



overall precision ~9%,
limited by systematic uncertainties

<u>Systematics</u> : in eμ : Jet/E_T^{miss}(~4 pb),
generator (~4.5 pb), fake lepton (~3 pb)

Top quark pair production in full hadronic mode

Signature :
no E_T^{miss} + jets (2b)

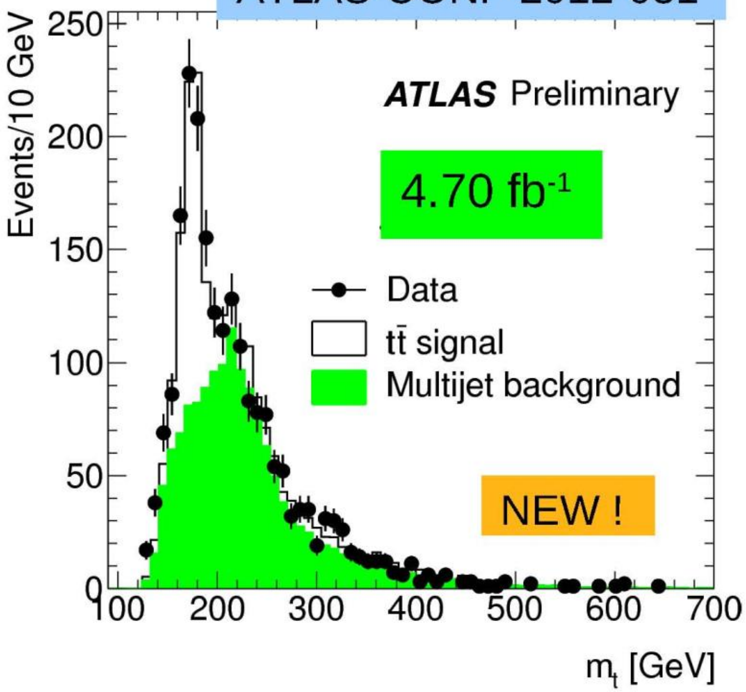
Trigger : 5 jets with p_T>30 GeV

Offline : ≥ 5 jets with p_T > 55 GeV
and ≥ 2 b-tagged jet
- 6^{th} jet with p_T > 30 GeV
- S_{ETmiss} < 3
- Kinematical likelihood fit to find correct association of jets to reconstruct m_t

Signal and background modelling :
data driven estimation of background
35% signal and 65% multijet by the pre-btagged sample in the data

Analysis Strategy :
Unbinned likelihood fit to m_t,
6 ≤ Njet ≤ 10,
χ2 for m_t and m_w is calculated and satisfy χ2 < 30

ATLAS-CONF-2012-031



$\sigma_{tt} = 168 \pm 12\ (\text{stat})\ ^{+60}_{-57}(\text{syst}) \pm 7\ (\text{lumi})$ pb

overall precision ~37%,
limited by systematic uncertainties

Systematics : JES (+20, -17 pb), b-tagging (17 pb), ISR/FSR (17 pb)

First measurement of ttbar + photon

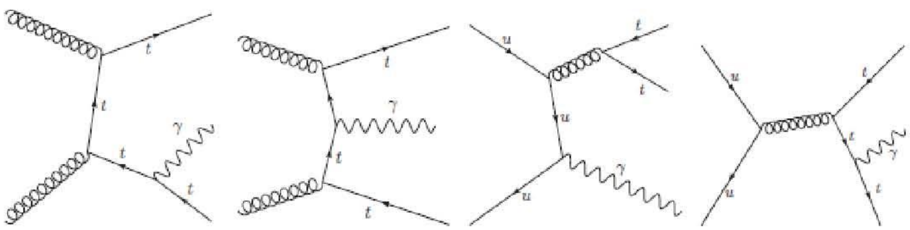
$t\bar{t}$ + photon

Signature : 1 e/μ + E_T^{miss} + jets (1b) + γ

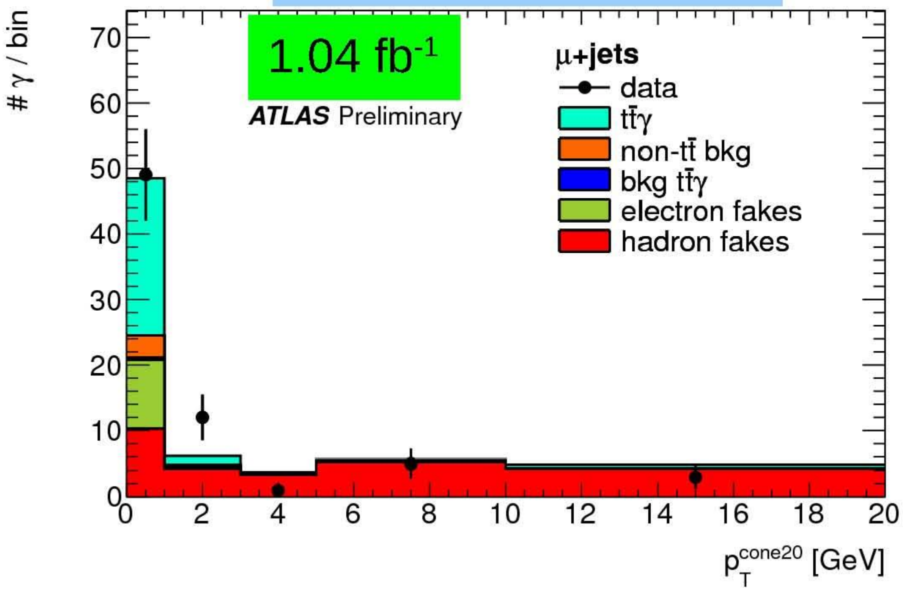
Offline : similar to lepton+jets analysis
tight photon with p_T>15 GeV

Signal and background modelling :
signal, hadron fakes and QCD+γ templates are obtained by data driven methods
electron fakes, $t\bar{t}\gamma$, W+jets+γ templates are obtained from MC

Analysis Strategy : Fit to track isolation of γ



ATLAS-CONF-2011-153



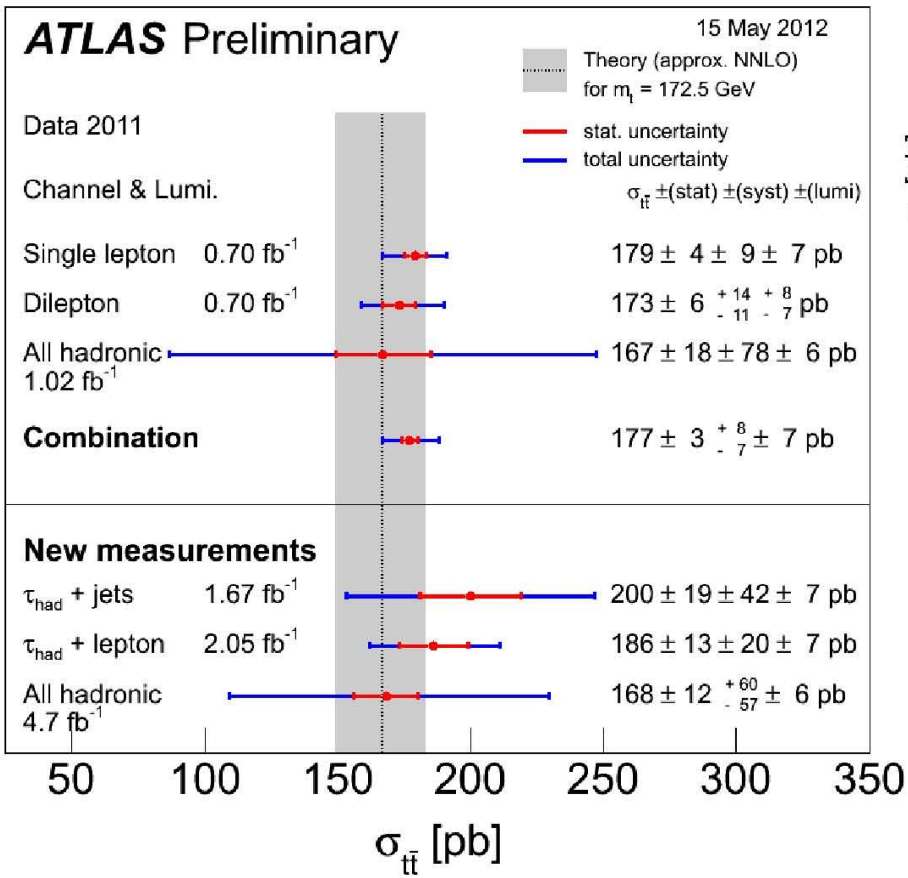
$\sigma_{t\bar{t}\gamma}(p_T,\gamma>8\ \text{GeV})\times BR(LJ,DL)$ =
2.0 ± 0.5 (stat) ± 0.7 (syst) ± 0.08 (lumi) pb
expected (NLO) = 2.1 ± 0.4 pb

overall precision ~43%,
limited by systematic uncertainties

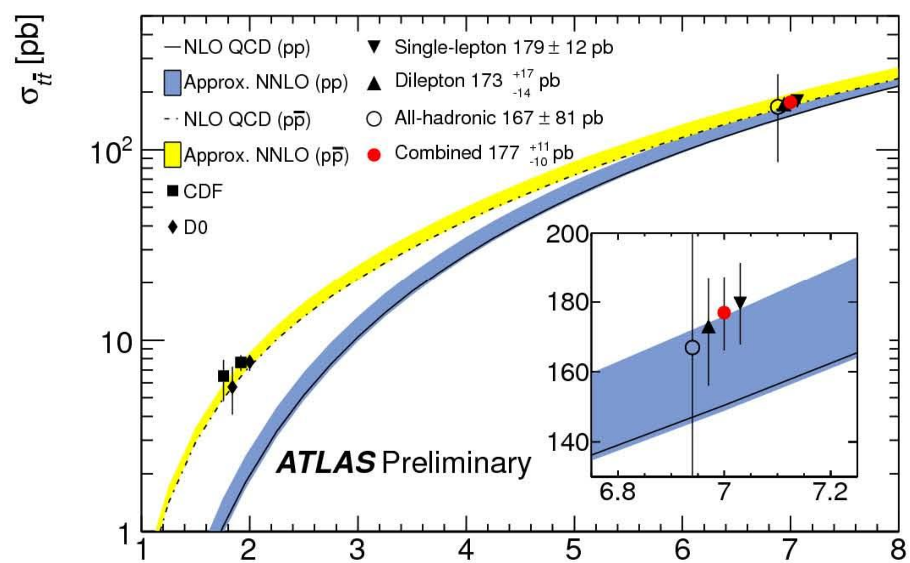
Systematics : γ-ID (0.33 pb),
ISR/FSR (0.31 pb),
JES (0.28 pb)

Summary of ttbar cross section measurements

- measured accuracy < theoretical one
- σ_{tt} is also measured in alternative channels (τ), showing SM is applicable at the LHC
- additional features are explored (tt+jets)

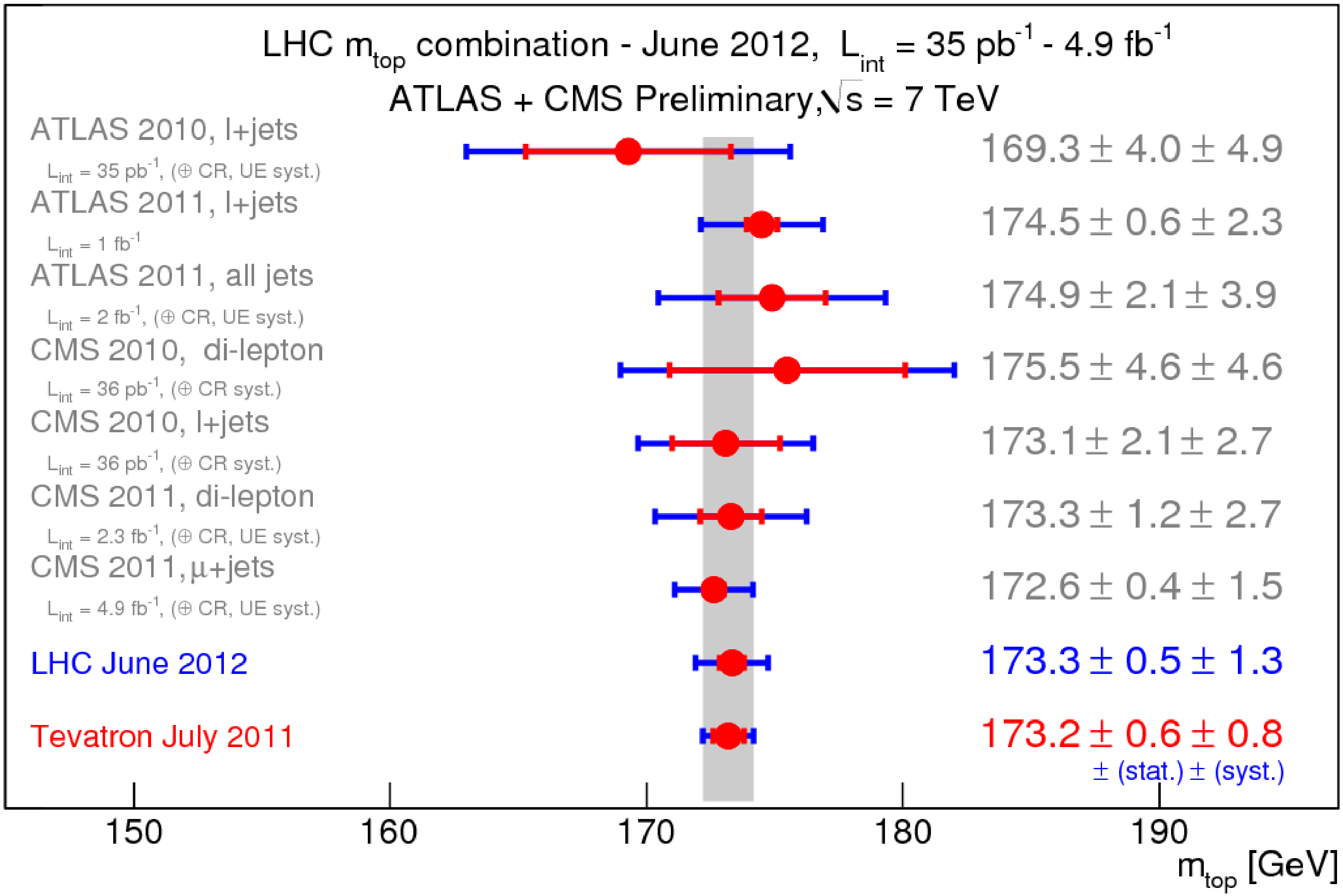


ATLAS-CONF-2012-024

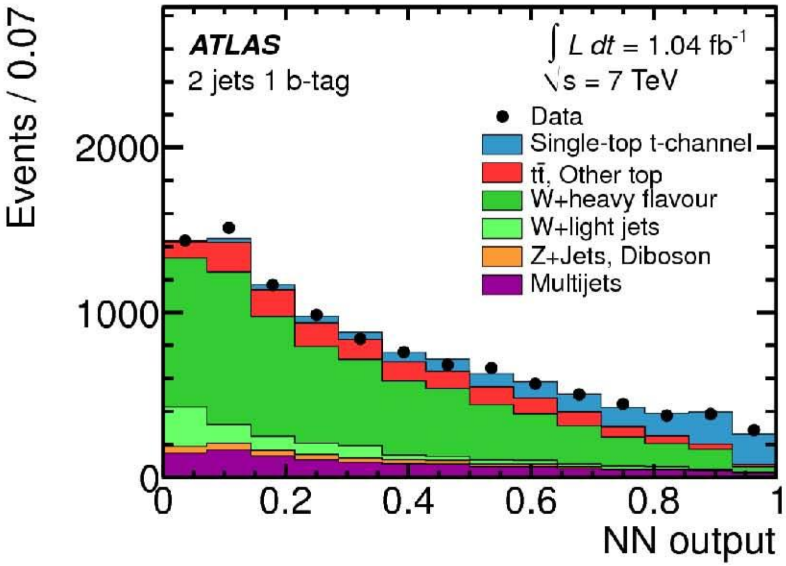


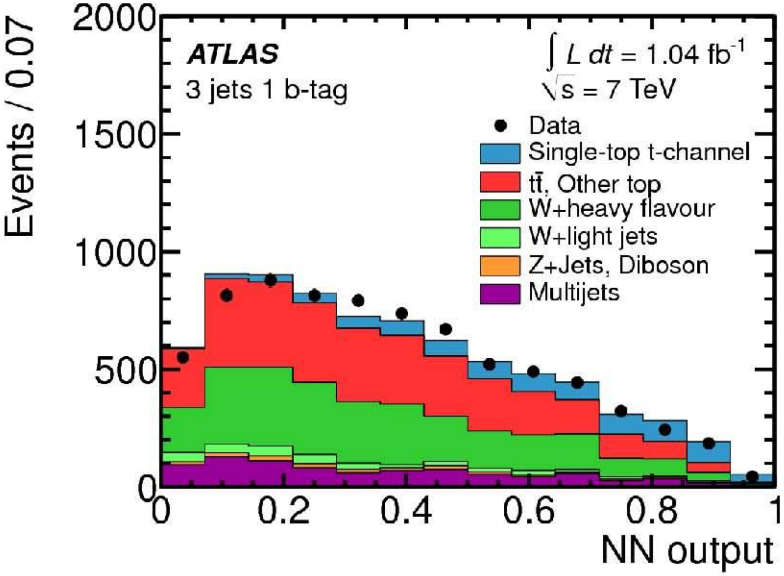
- precision ~6%, half of theory uncertainty
- agreement of channels within uncertainties

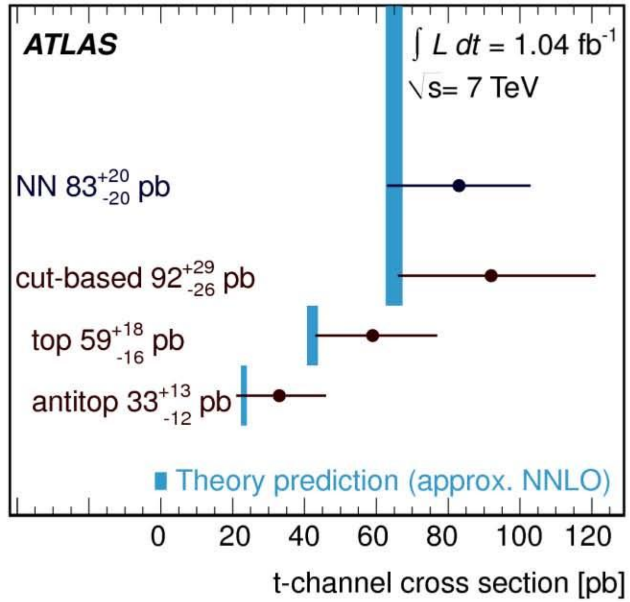
Top quark mass measurements



t-channel cross section with 1 fb^{-1}







- Total relative uncertainty 24%
- Main Systematics:
  - B-tagging efficiency 13%
  - ISR/FSR 14%
- Significance: 7.2σ
- Cut-based analysis as a cross-check

arXiv:1205.3130
Submitted to: Physics Letters B

t-channel cross sections ratio with 5 fb^{-1}

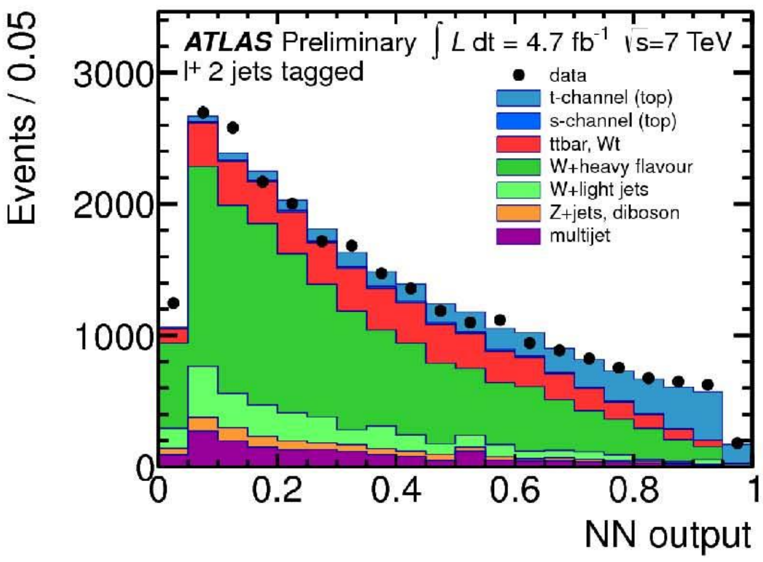
- Flavour of the incoming light-quark defines the top-quark charge
- Measure $R_t \equiv \sigma_t(t)/\sigma_t(\bar{t})$ to constrain the light quark PDF in the momentum fraction range of $0.02 < x < 0.5$
- Separate neural networks for top/anti-top production to measure R_t

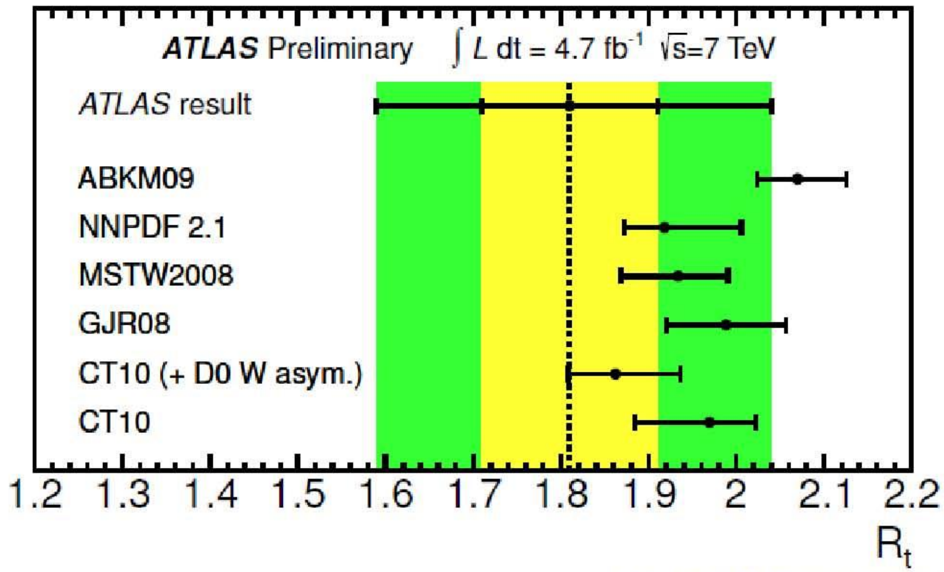
Result:

$$\sigma_t(t) = 53.2 \pm 10.8\,\text{pb}$$
$$\sigma_t(\bar{t}) = 29.5^{+7.4}_{-7.5}\,\text{pb}$$
$$R_t = 1.81^{+0.23}_{-0.22}.$$

Main Systematics:

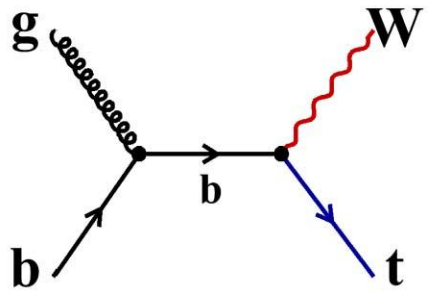
- σ: JES 20% → R_T 4%
- R_t: stat 6%, BG Norm 4%



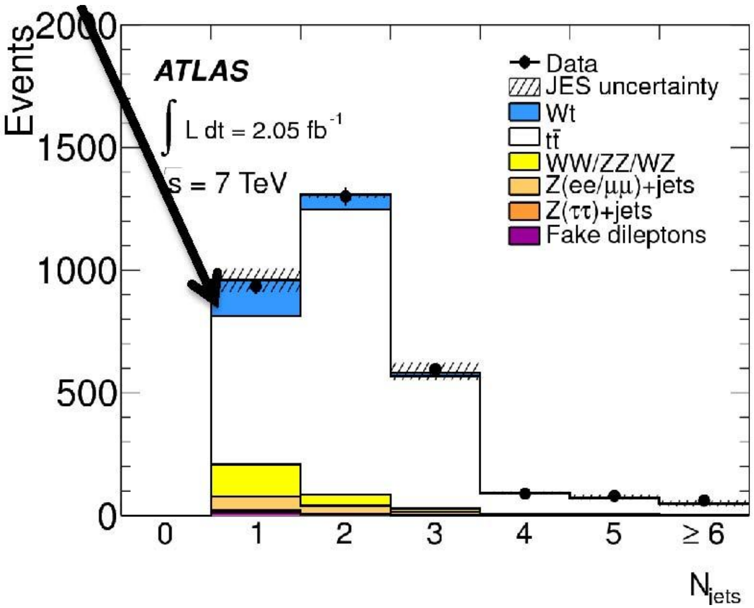


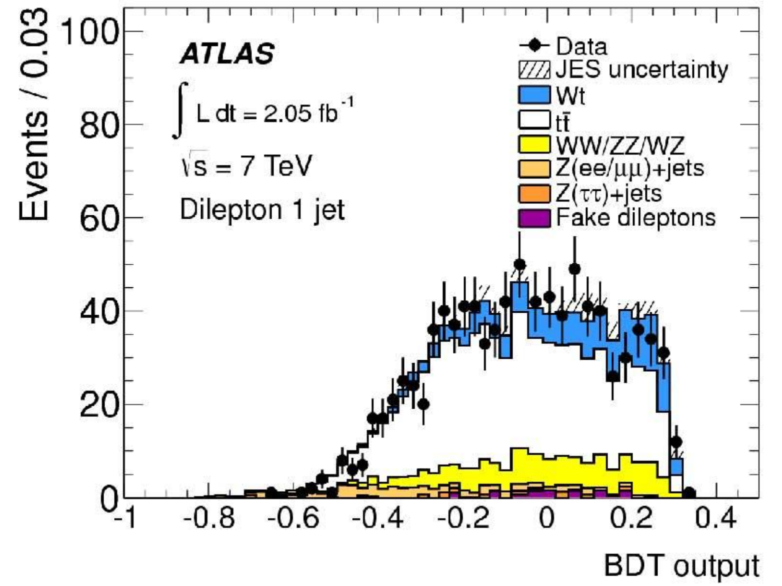
ATLAS-CONF-2012-056

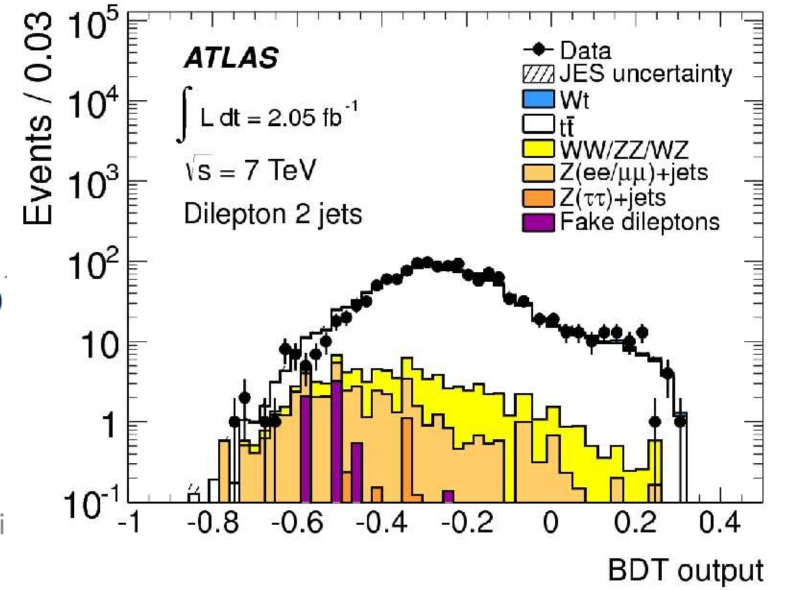
Wt channel cross section



150 signal events expected







$$\sigma_{Wt} = 16.8 \pm 2.9\,(\text{stat}) \pm 4.9\,(\text{syst})\ \text{p}$$

Relative uncertainty. 33%

Evidence for Wt production with an observed significance of 3.3 σ

Summary of part I

- So many topics not covered
  - Soft QCD, heavy mesons physics, b-quark measurements, so W, Z, dibosons, jets…
  - Reminder, more data at 8TeV, many measurements are being redone in 2012. Expect improvements, higher precisions, new channels…
- Main conclusion
  - SM is always valid. EW and QCD predictions are holding through LHC measurements