Z and J/ψ production in p+p and Pb+Pb collisions at the LHC measured with the ATLAS detector

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(On behalf of the ATLAS Collaboration)

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High-pT physics at LHC 2011
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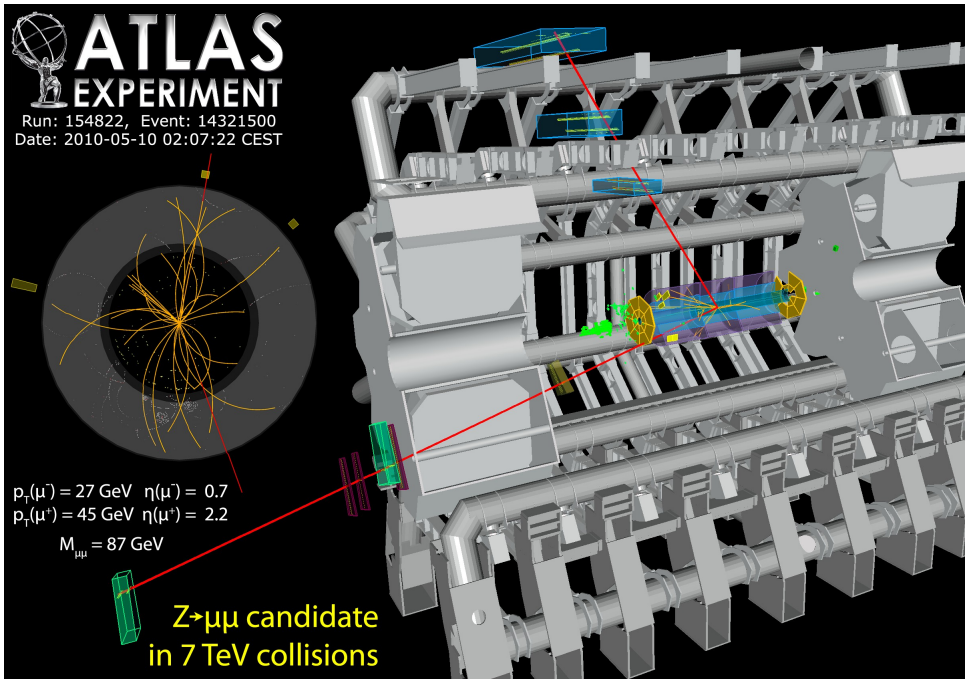
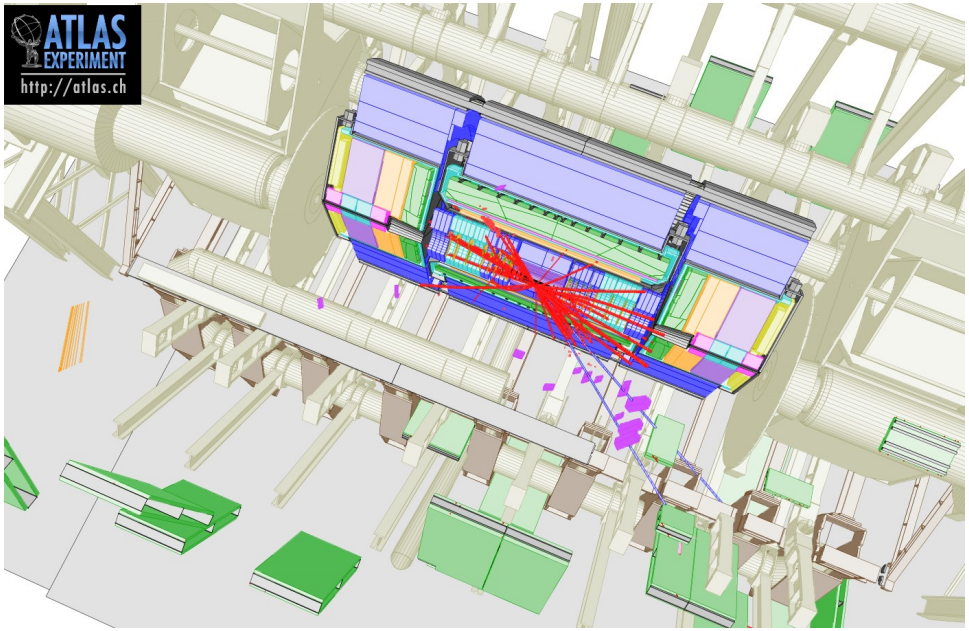
Z and J/ψ at ATLAS

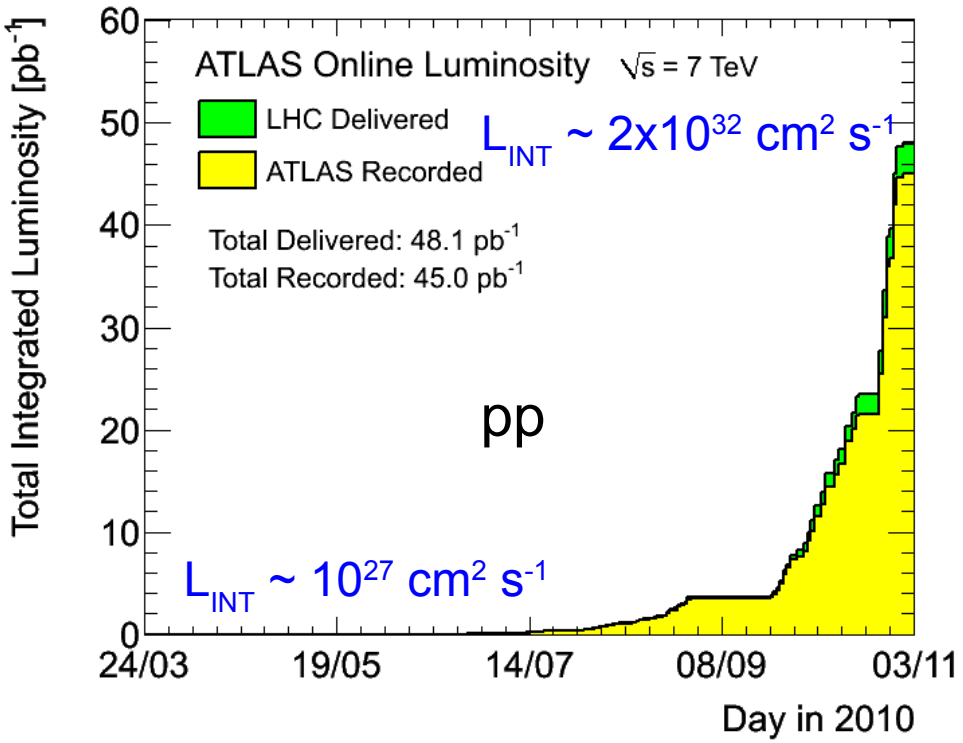


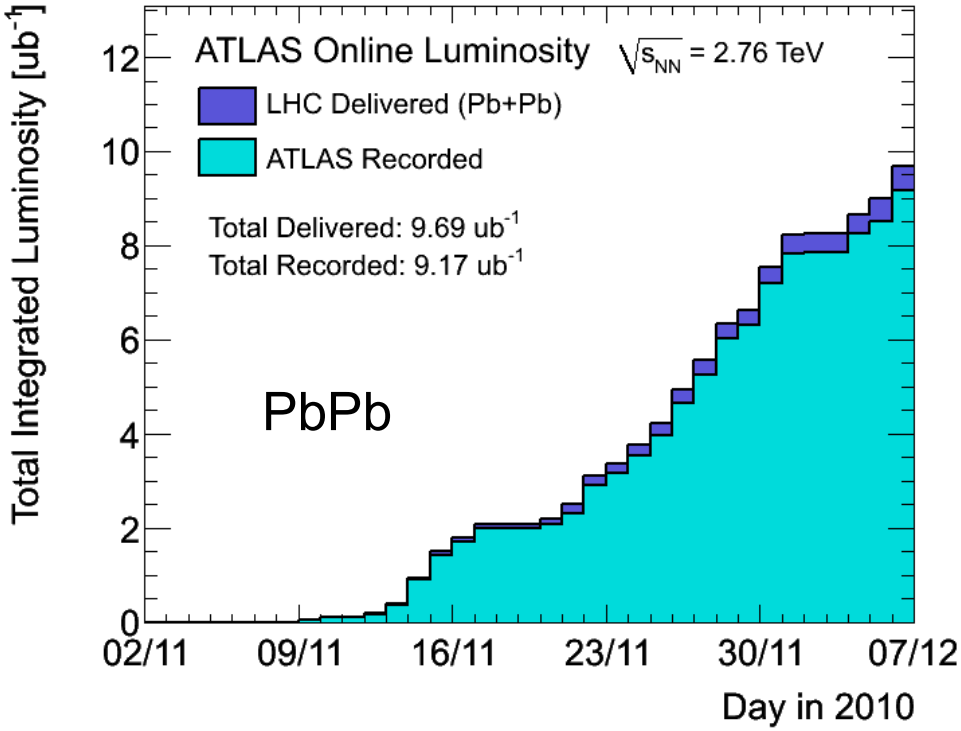


- Measurements of Z and J/ψ production in pp:
  - Important tests of Standard Model at 7 TeV
  - Comparisons to perturbative QCD calculations
  - New constraints on proton PDFs
  - Study detector performance
  - Background processes for searches (eg. Higgs, SUSY)
- Measurements of Z and J/ψ production in PbPb:
  - Probes properties of matter produced in heavy ion collisions

LHC in 2010

- $\sqrt{s}$= 7 TeV pp collisions from March – August 2010
- LHC delivered L = 48 pb^{-1}
- ATLAS recorded 45 pb^{-1} (ε =93.6%)
- Up to 42 pb^{-1} pass data quality requirements

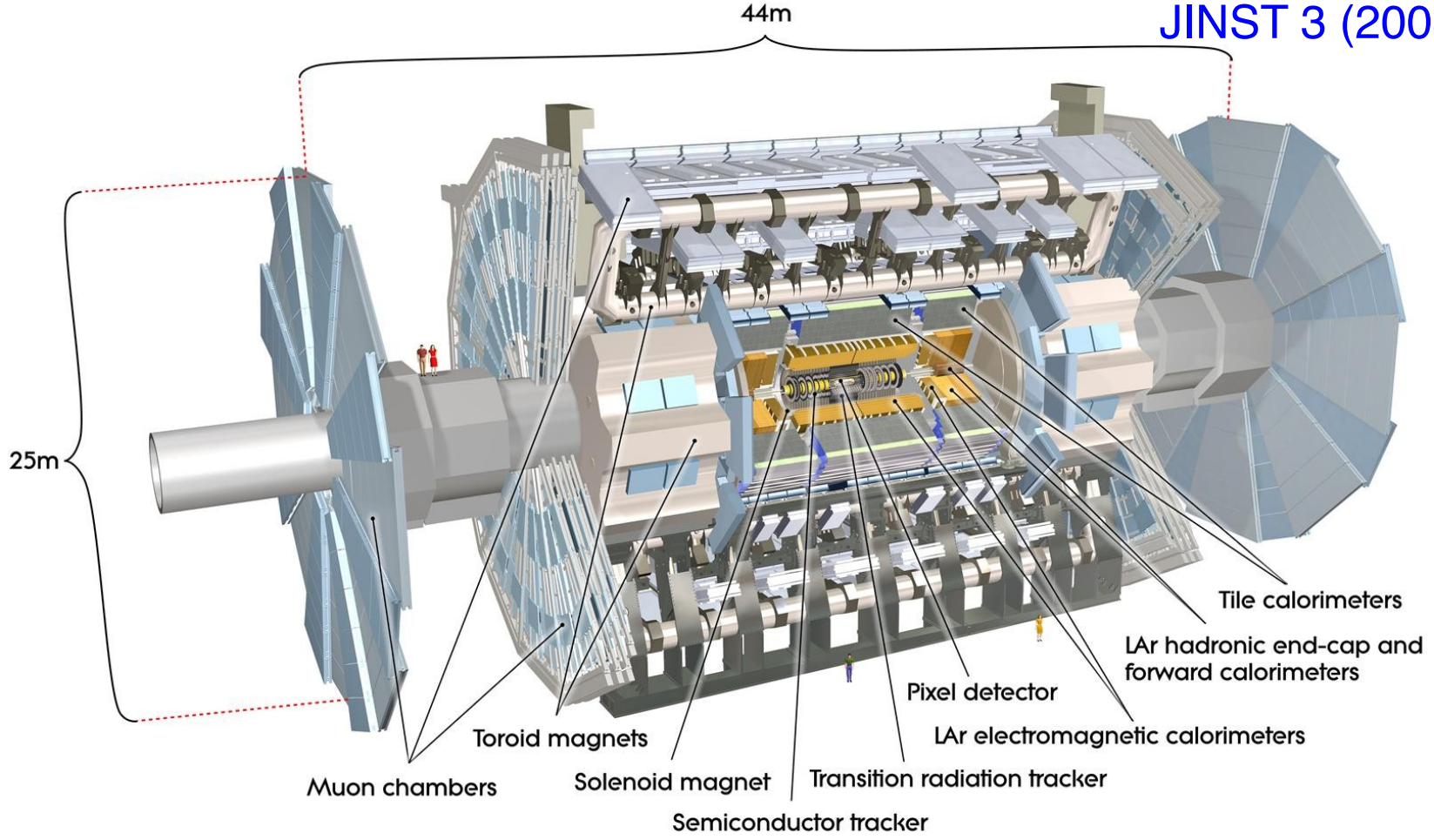




- Pb-Pb ions at $\sqrt{s_{NN}}$= 2.76 TeV from Nov – Dec 2010
- 14 times higher centre of mass energy than RHIC
- L = 9.7 μb^{-1} delivered
  L = 9.2 μb^{-1} recorded (ε = 95%)

The ATLAS Detector

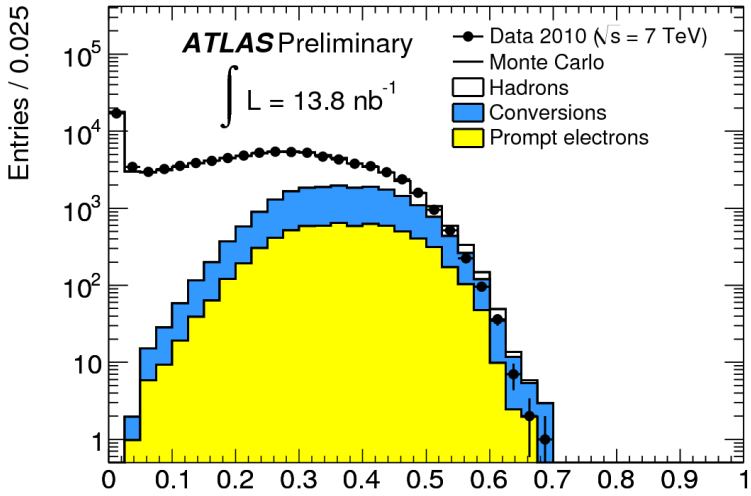
JINST 3 (2008) S08003



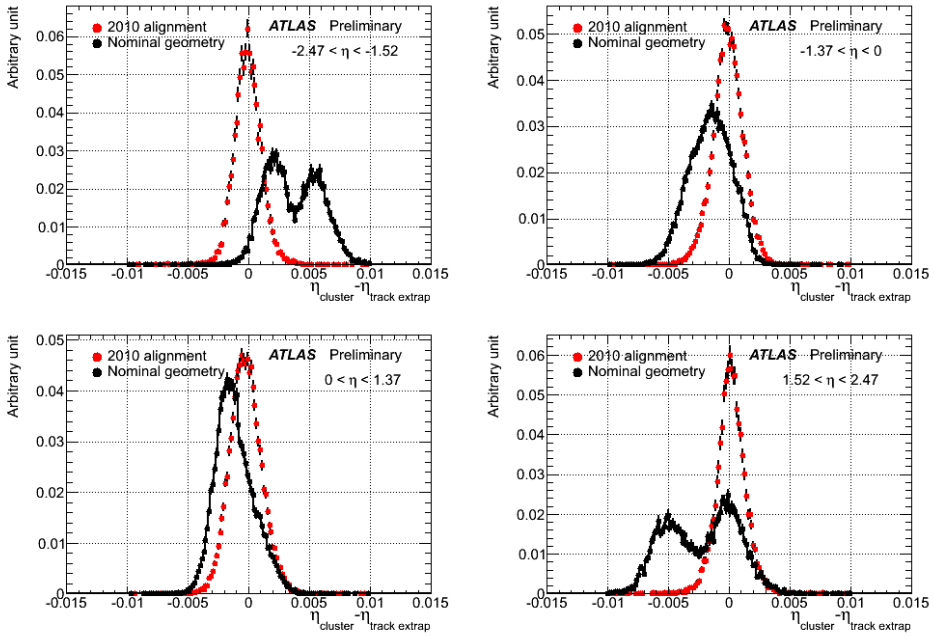
- Muon spectrometer $|\eta|<2.4$ (air core toroids + muon chambers)
- Hadronic Calorimeter $|\eta|<5$ (Fe+scintillator tiles or LAr+W/Cu)
- EM calorimeter $|\eta|<3.2$ (Pb/LAr accordion)
- Inner detector $|\eta|<2.5$ (2 Tesla solenoid, Si pixels, Si strips + TRT)

Electrons in ATLAS

- Electrons: calo cluster matched to a track
- Loose electrons:
  - Shower shape in second EM calo layer
  - Low hadronic leakage
- Medium electrons (in addition):
  - Shower shape in first EM calo layer
  - Tighter track matching
- Tight electrons (in addition):
  - TRT detector requirements
  - E/p

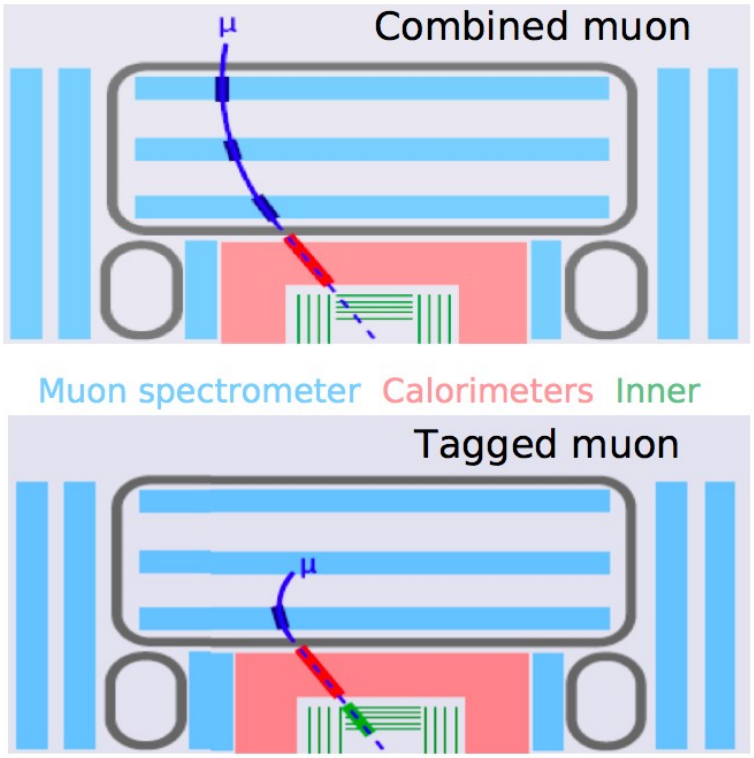


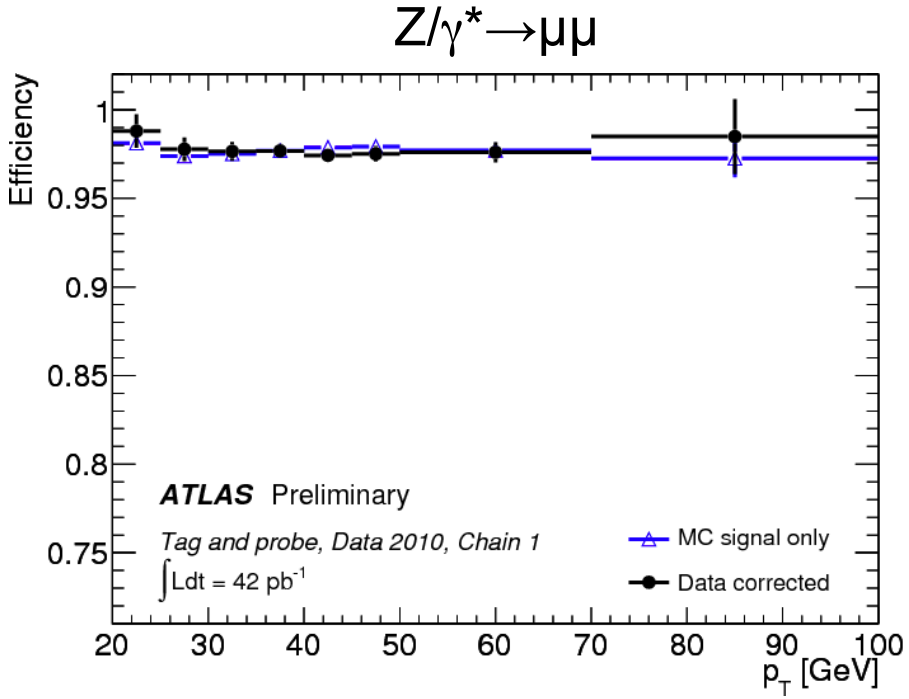
f_1 = Energy fraction in first calo layer

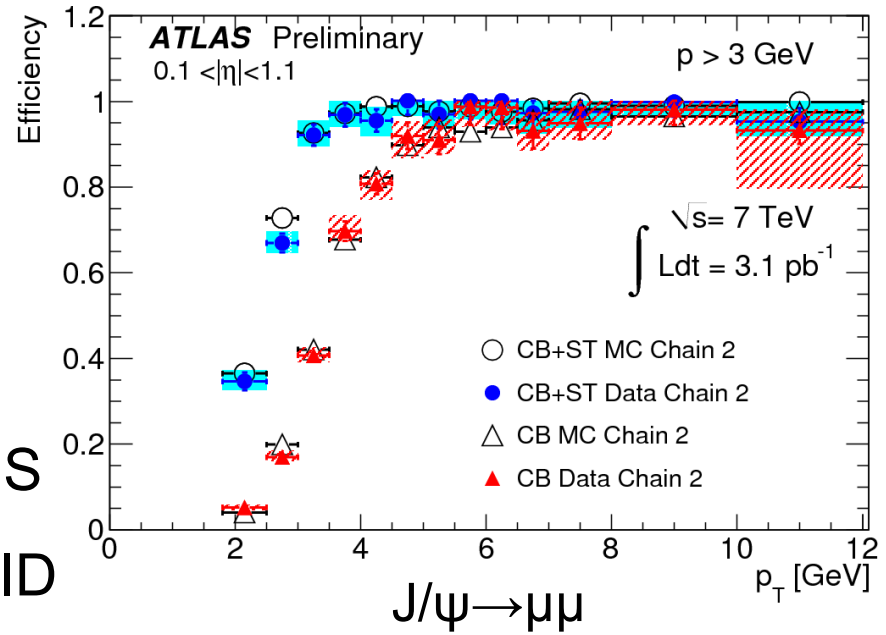


Improvement in track-cluster Δη between nominal and 2010 alignments

Muons in ATLAS

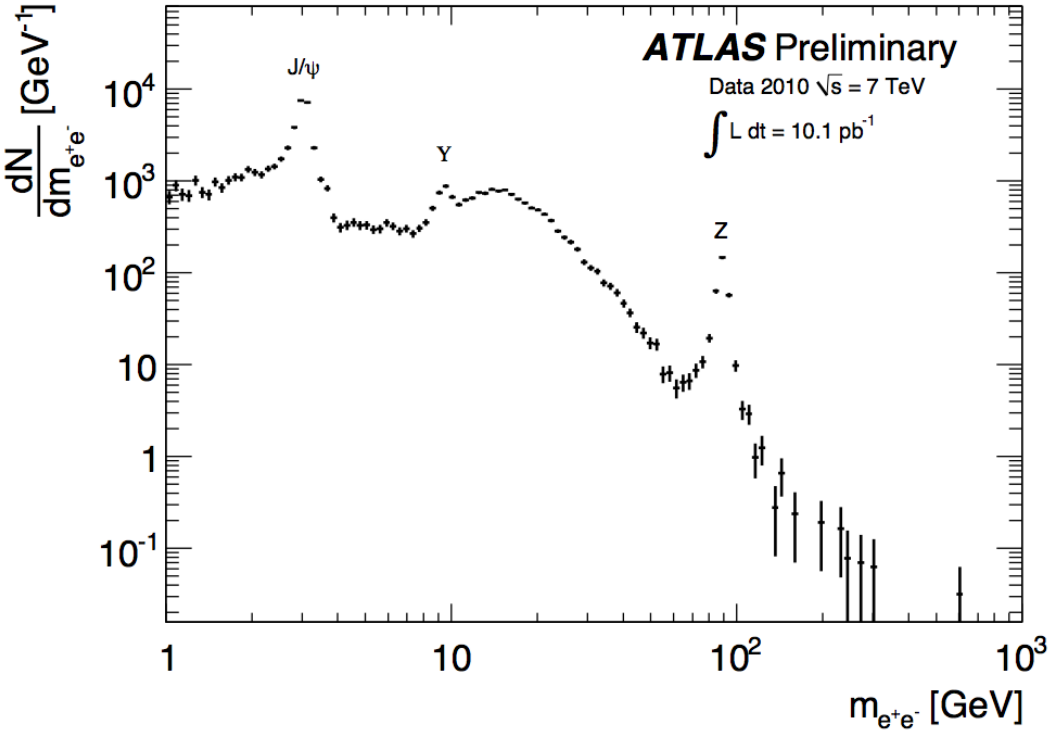


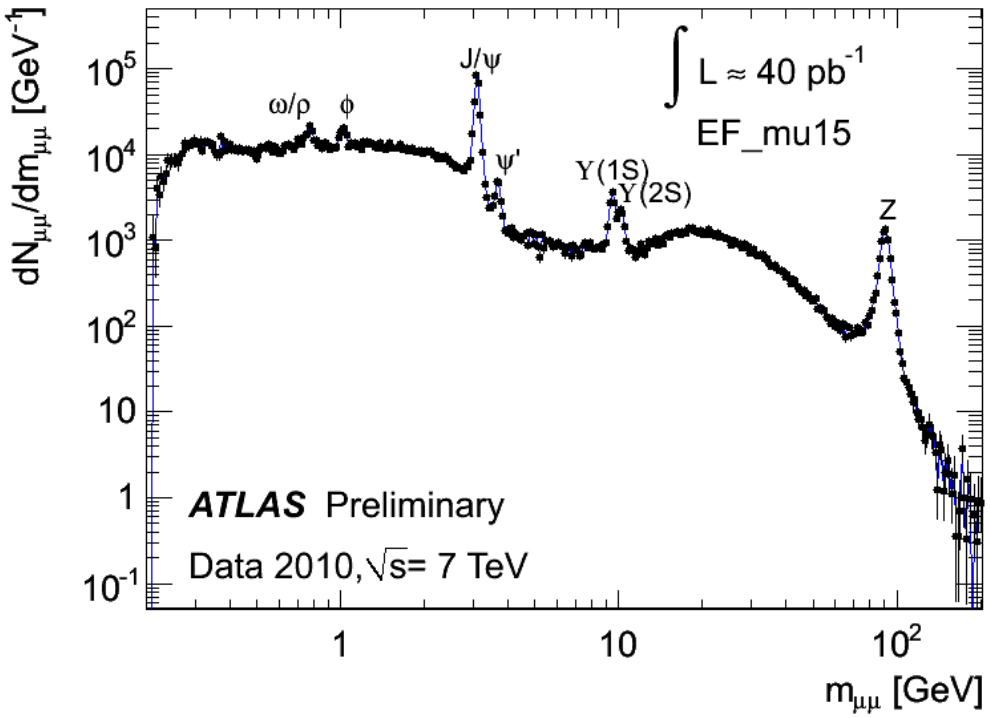




- "Combined Muon": Combination of inner detector (ID) and muon spectrometer (MS) tracks
- "Tagged Muon": MS track segments matched to ID track extrapolated to MS
  - Parameters (eg. p_T) taken from ID

Dilepton Mass Spectra

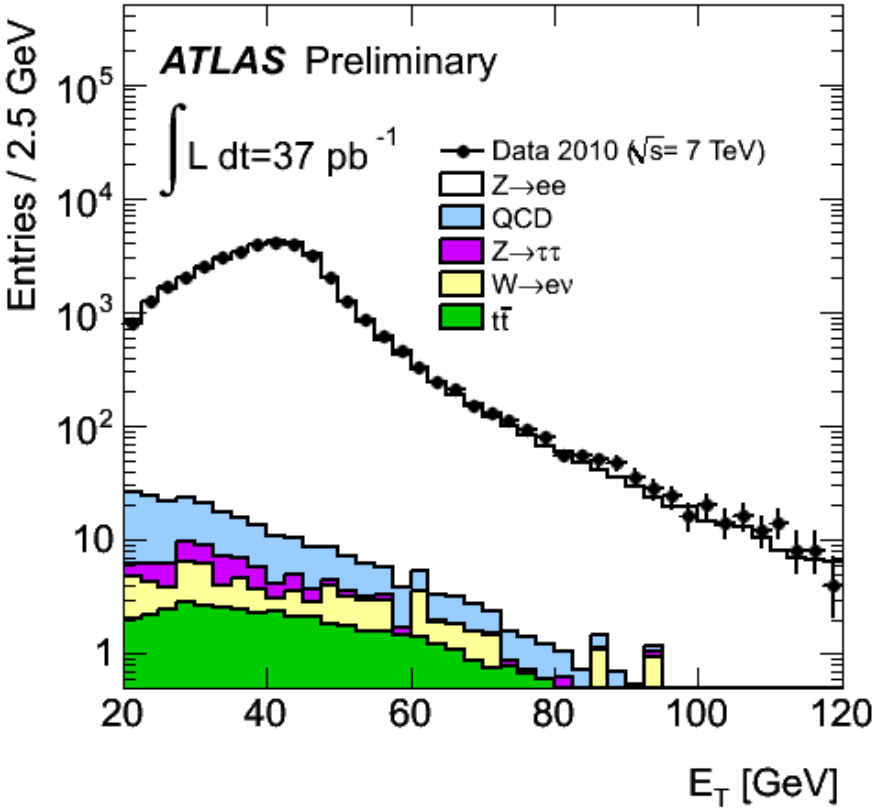


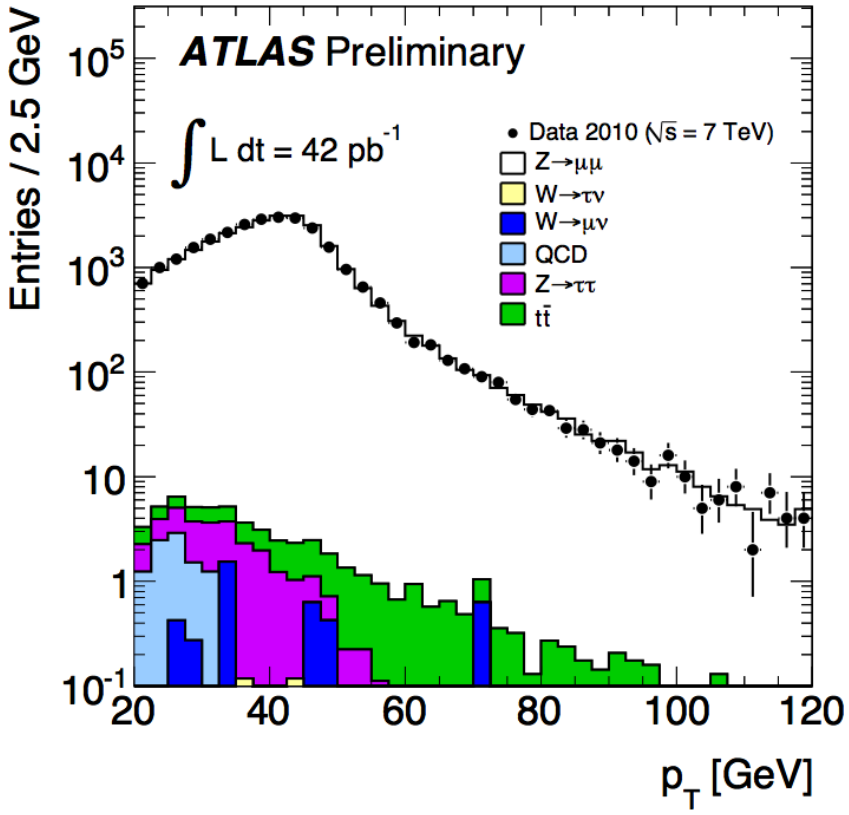


- Dielectron trigger (2 electrons, E_T > 5 GeV)
- Two offline Medium electrons E_T > 5 GeV, |η| < 2.0

- Single muon p_T > 15 GeV trigger
- Two offline combined muons p_T > 15 (2.5) GeV, |η| < 1.05

Z Selection



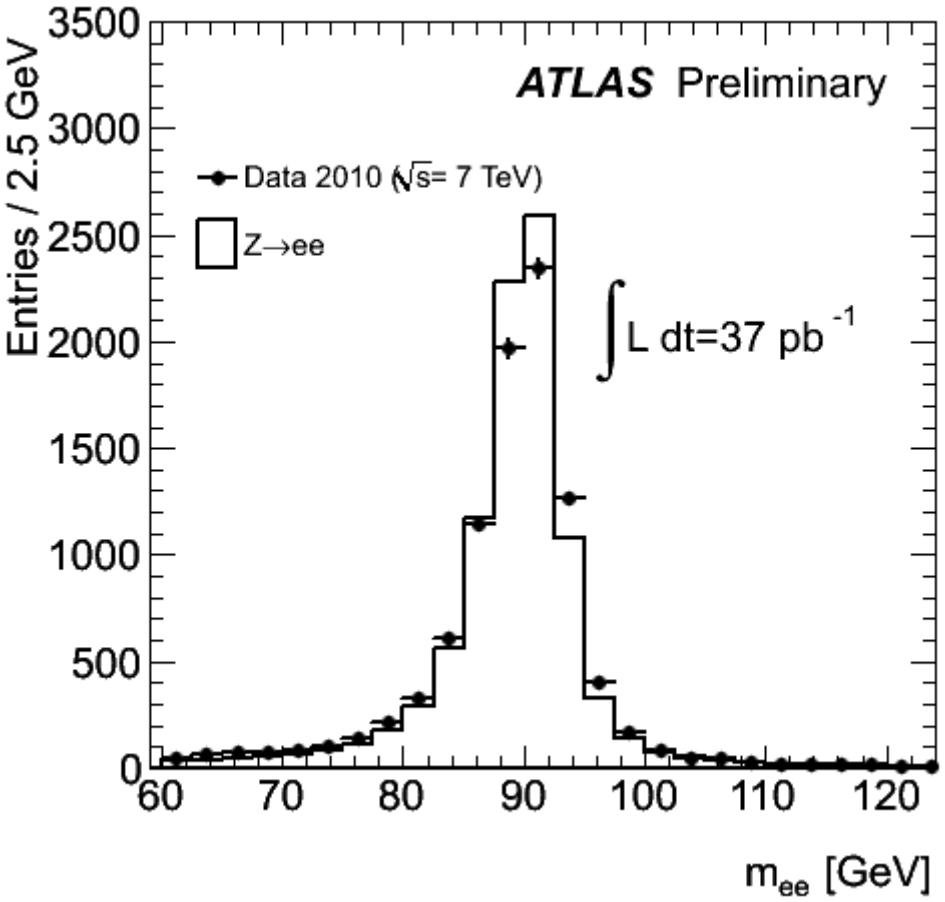


- Electron channel:
  - 2 “medium” electrons,
  - $p_T > 20$ GeV,
  - $|\eta|<2.47$, $|\eta| \notin [1.37,1.52]$
  - opposite charges
  - $66 < m_{ee} < 116$ GeV

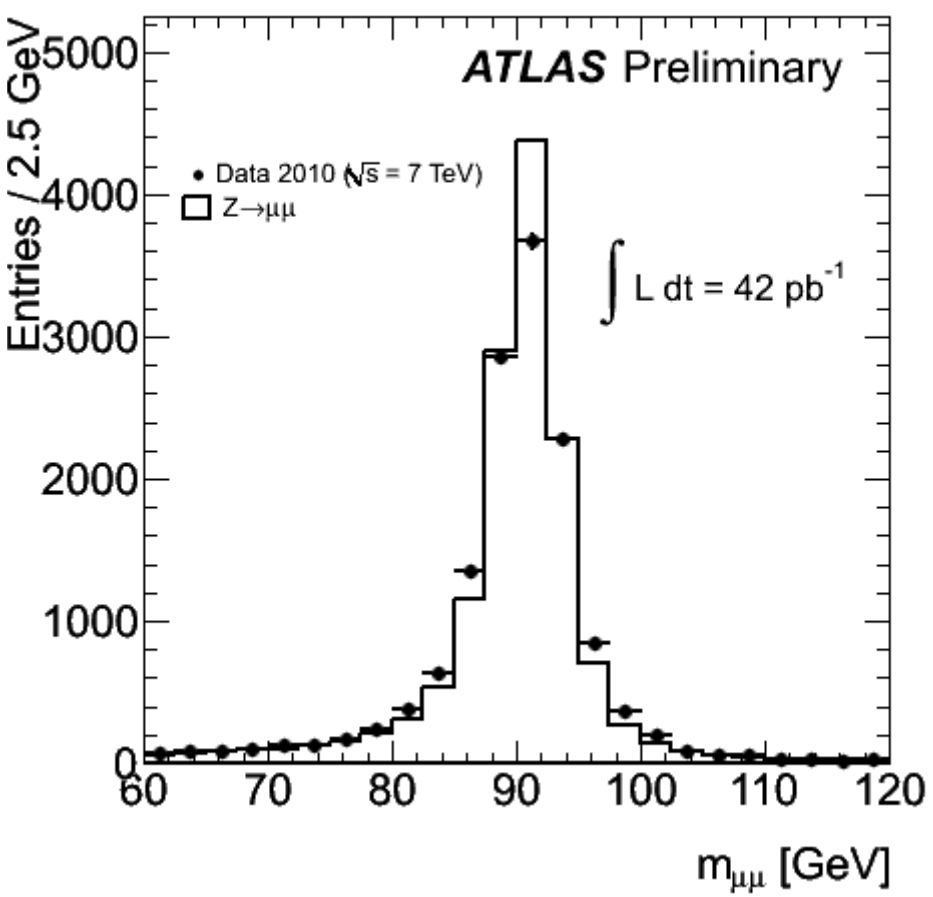
- Muon channel:
  - 2 isolated “combined” muons,
  - $p_T > 20$ GeV,
  - $|\eta|<2.47$,
  - opposite charges,
  - $66 < m_{\mu\mu} < 116$ GeV

Z Invariant Mass

$Z/\gamma^* \rightarrow ee$



$Z/\gamma^* \rightarrow \mu\mu$



- Update of first published result with full 2010 dataset

CERN-PH-EP-2010-037, JHEP 12 (2010) 060

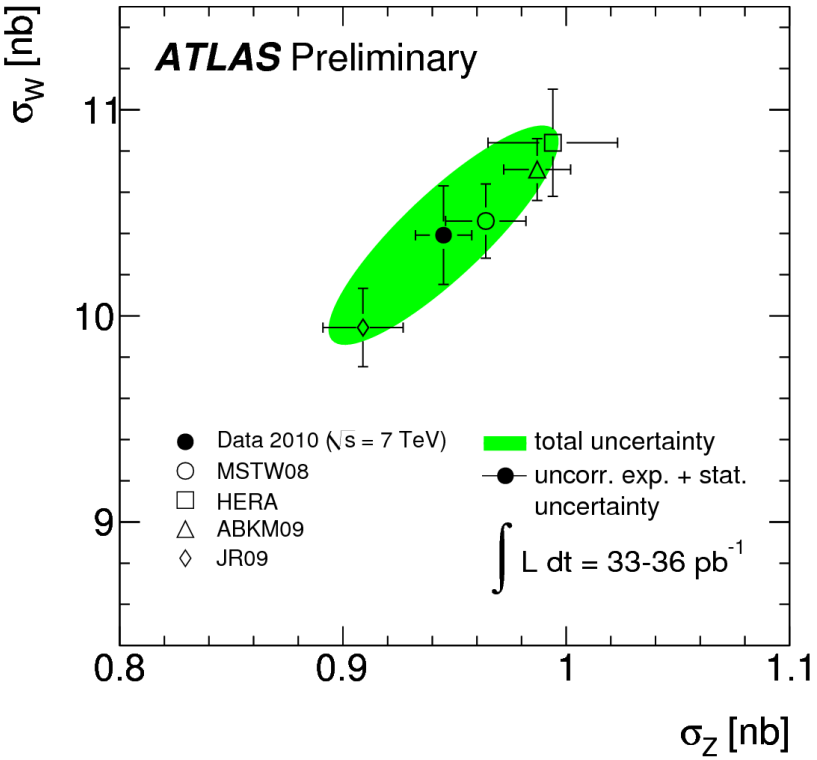
Z Cross Section

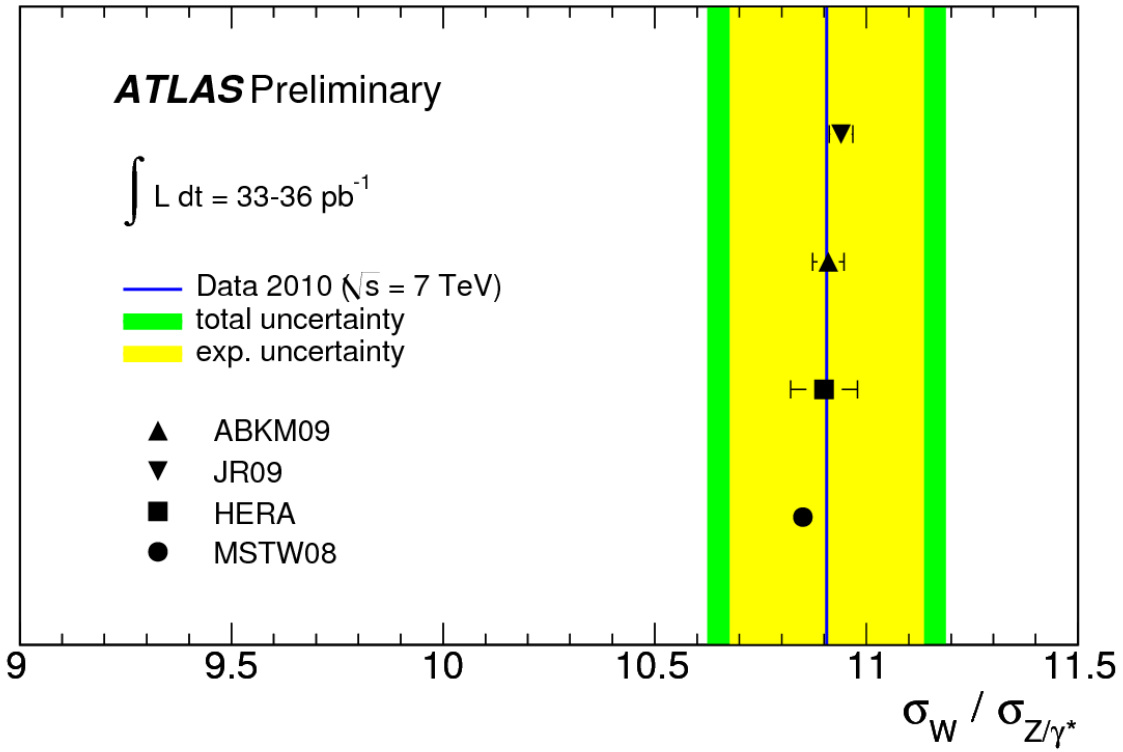
- Cross section definition: $\sigma \times BR(Z \to ll) = \frac{N^{OBS} - N^{BG}}{A_Z C_Z L}$
- Fiducial Acceptance A_Z:
  - $66 < m_{ll} < 116$ GeV
  - Electron channel: $p_T > 20$ GeV, $|\eta|<2.47$, $|\eta| \notin [1.37,1.52]$
  - Muon channel: $p_T > 20$ GeV, $|\eta|<2.47$
- QCD background measured in data, EW and tt backgrounds from MC
- Efficiency corrections C_Z (wrt. fiducial acceptance):
  - determined in data using Z→ll and W→lν events
  - lepton reconstruction, identification (and isolation) efficiencies
  - trigger efficiencies

Z Systematics

- Dominant experimental systematics:
  - reconstruction efficiency (3% elec channel, 0.8% muon)
- A_Z systematic = 4%:
  - Uncertainty within CTEQ6.6 PDF set (error eigenvector sets at 90% CL)
  - Uncertainty (maximal difference) between CTEQ 6.6, MRST LO* and HERAPDF 1.0 PDFs
  - Uncertainty due to MC@NLO vs. PYTHIA with CTEQ 6.6 PDFs
- Luminosity uncertainty 3.4%

Z Cross Section





$66 < m_{ll} < 116$ GeV

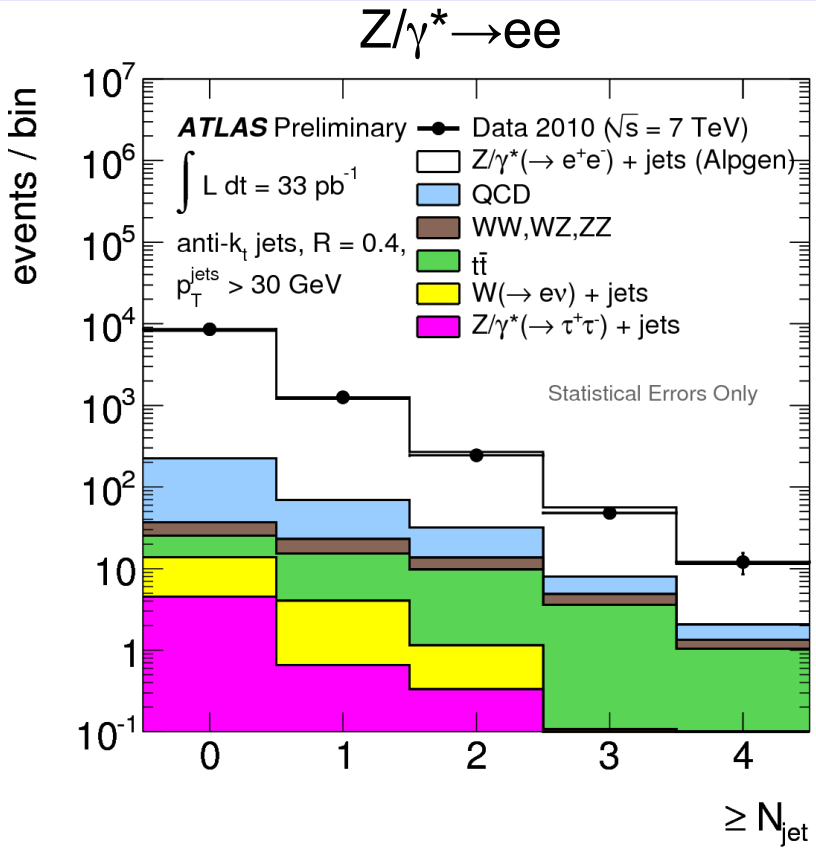
- Cross sections consistent with NNLO QCD (ZWPROD + FEWZ) with different PDFs

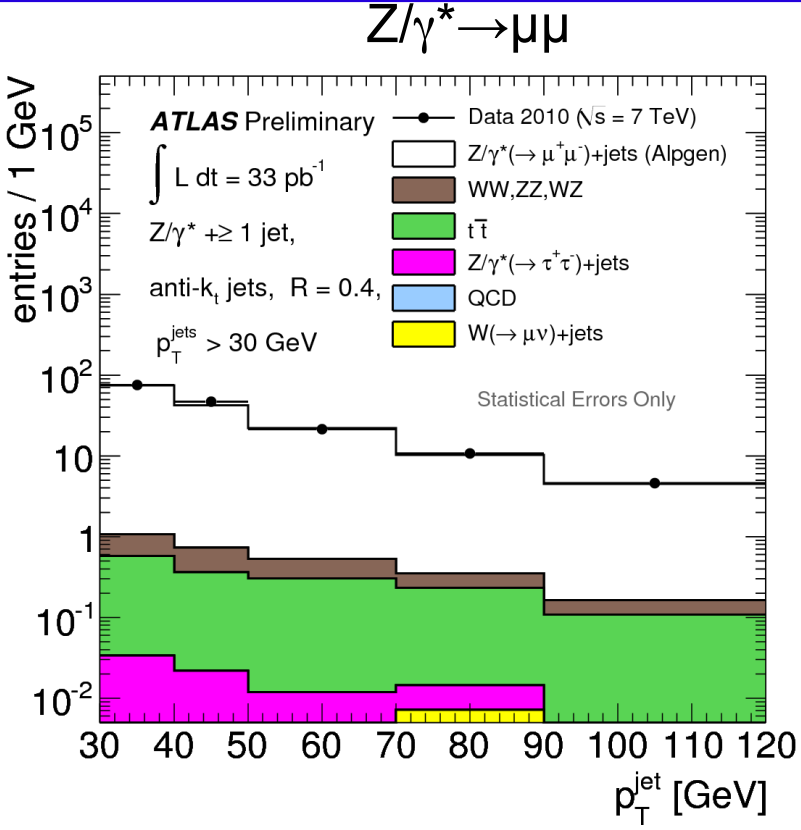
$\sigma(Z \rightarrow ee) = 0.972 \pm 0.010\,(stat.) \pm 0.0034\,(sys.) \pm 0.033\,(lumi.) \pm 0.038\,(acc.)$ nb

$\sigma(Z \rightarrow \mu\mu) = 0.941 \pm 0.008\,(stat.) \pm 0.011\,(sys.) \pm 0.032\,(lumi.) \pm 0.037\,(acc.)$ nb

$\sigma(Z \rightarrow ll) = 0.945 \pm 0.006\,(stat.) \pm 0.011\,(sys.) \pm 0.032\,(lumi.) \pm 0.038\,(acc.)$ nb

Z + Jets

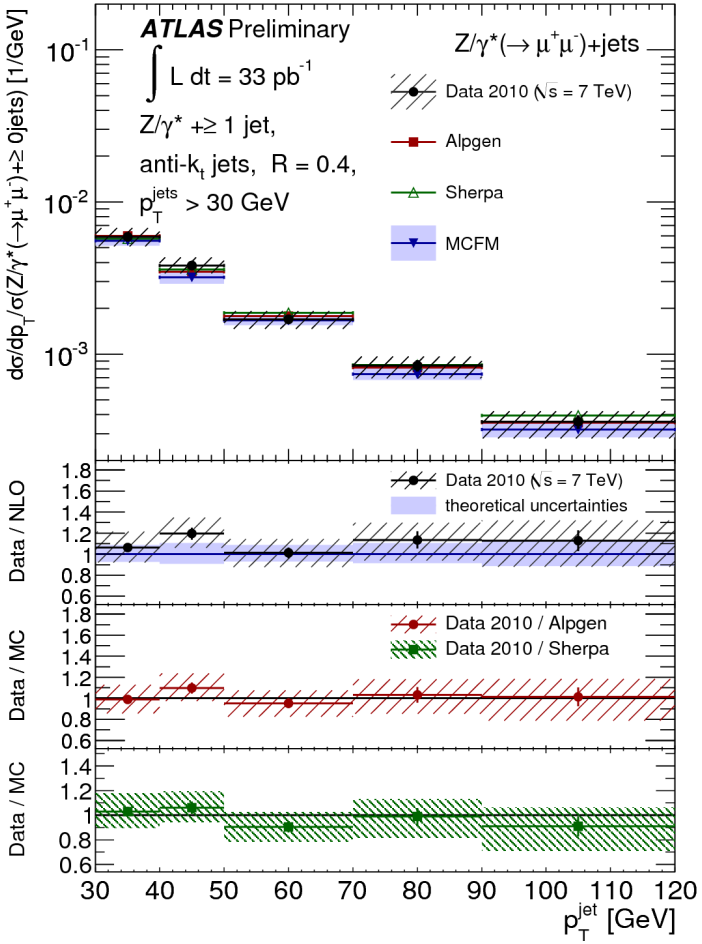




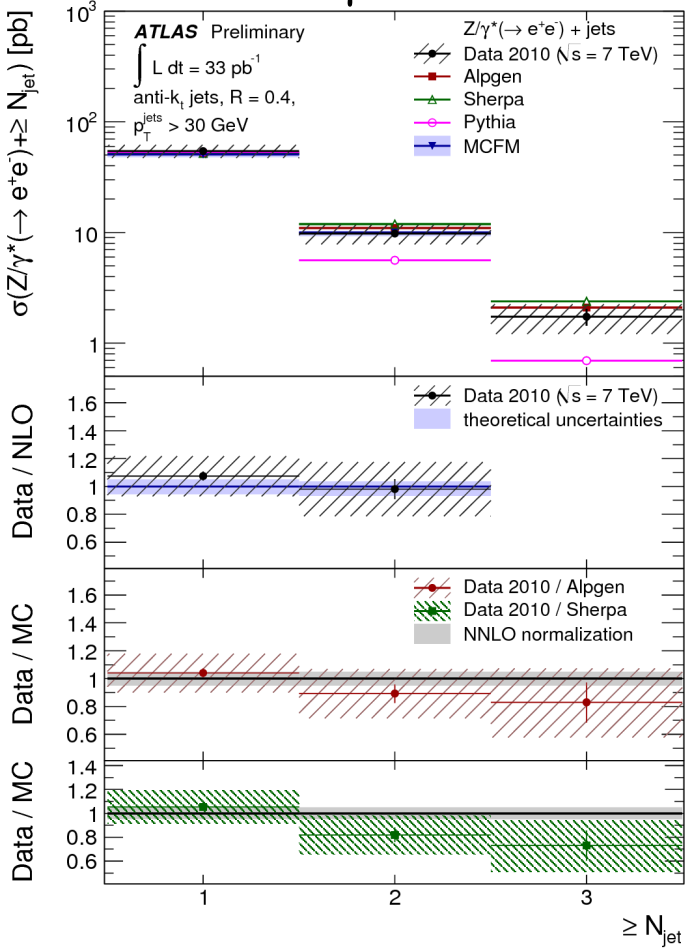
- Inclusive Z analysis selection and phase space with additional N(jet) ≥ 1
- Test against pQCD models and important background to LHC searches
- Jet selection: anti-k_T (R=0.4), pT > 30 GeV, |η| < 2.8,
  ΔR(jet-lepton) > 0.5, veto against pileup jets
- Largest cross section systematic: jet energy scale + resolution (10-20%)

Z + Jets

Z/γ*→μμ



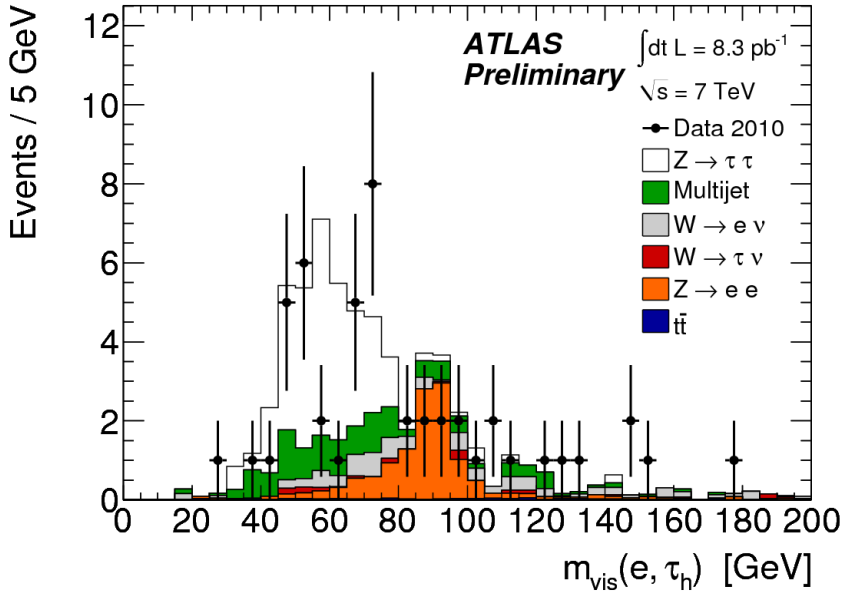
Z/γ*→ee

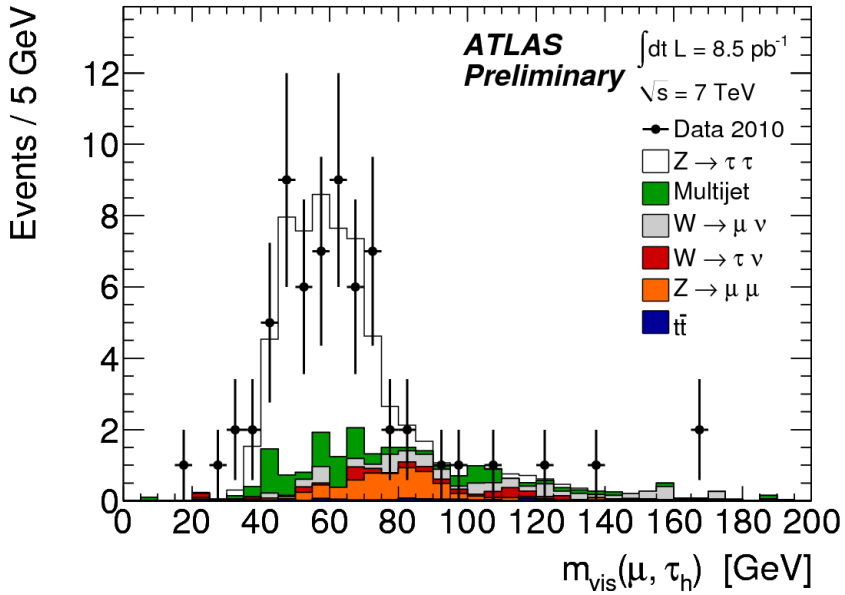


$66 < m_{ll} < 116$ GeV,
p_T(lep) > 20 GeV,
$|\eta|<2.47$
(elec: $|\eta| \notin [1.37,1.52]$),
p_T(jet) > 30 GeV,
ΔR(jet-lepton) > 0.5

- Unfolded for detector effects to particle level
- Described by MCFM NLO pQCD prediction and LO + parton shower (in ALPGEN and SHERPA MC)
- PYTHIA LO pQCD (x1.17) undershoots data at large N(jet)

$Z \rightarrow \tau\tau$ Observation: Lep Had Channel

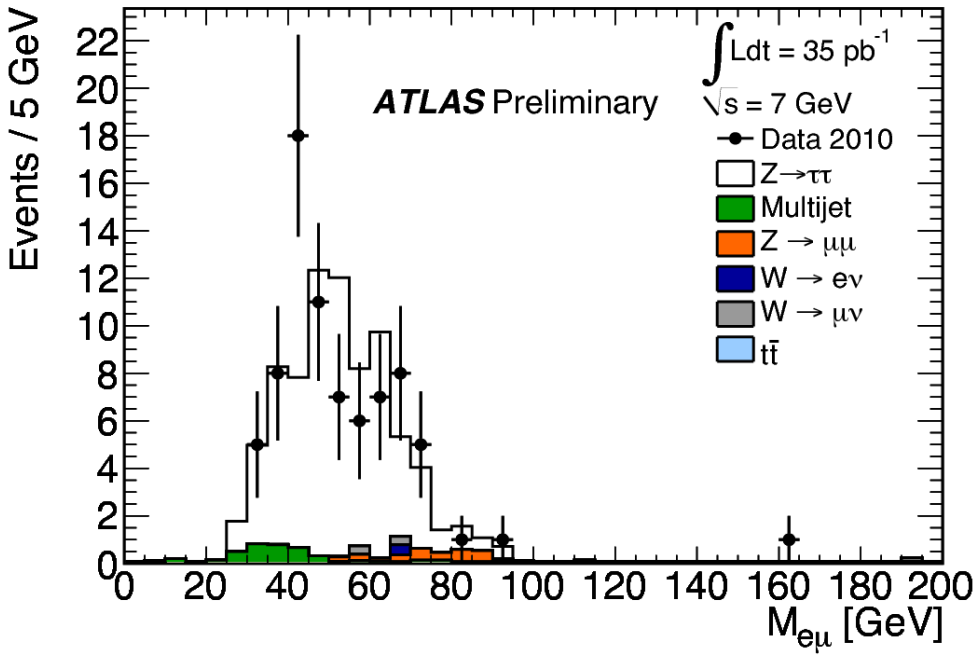




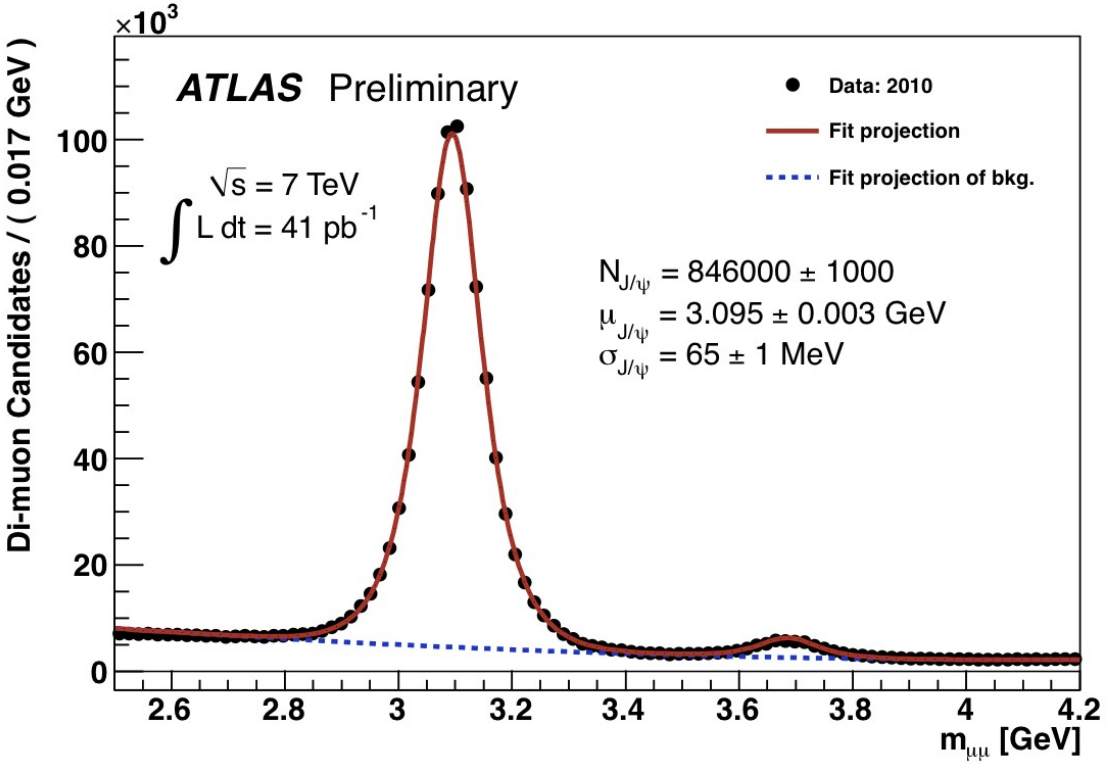
- Channel with one leptonically and one hadronically decaying tau
- Last $Z \rightarrow ll$ channel to be measured
- Important background for searches (eg. Higgs$\rightarrow\tau\tau$, SUSY)
- Isolated electron (muon), p_T>15 GeV
  Hadronic tau, p_T>15 GeV, N_{tracks}=1 or 3
  $\Sigma\cos(\Delta\Phi(lep, E_T^{Miss}))$ >-0.15
  $m_T(lep, E_T^{Miss}) < 50$ GeV
  $35 < m_{Lep\text{-}tau} < 75$ GeV
- QCD background estimated from data, EW and tt from MC
- Clear data excess over background compatible with SM expectation

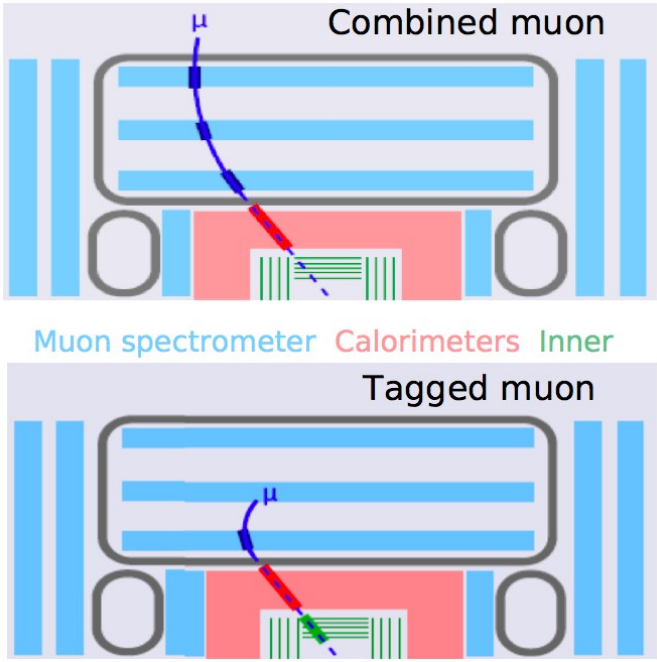
$Z \rightarrow \tau\tau$ Observation: eμ Channel

- Channel with two leptonically decaying taus
- Isolated electron (muon), p_T>15 (10) GeV with opposite charges
  $\Sigma\cos(\Delta\Phi(\text{lep}, E_T^{\text{Miss}}))$ >-0.15
  $E_T(\text{elec+muon+jets}) + E_T^{\text{Miss}} < 150$ GeV
  $25 < m_{ll} < 80$ GeV
- QCD background estimated from data, EW and tt from MC
- Clear data excess over background compatible with SM expectation
- Combined $Z \rightarrow \tau\tau$ cross section measurement underway



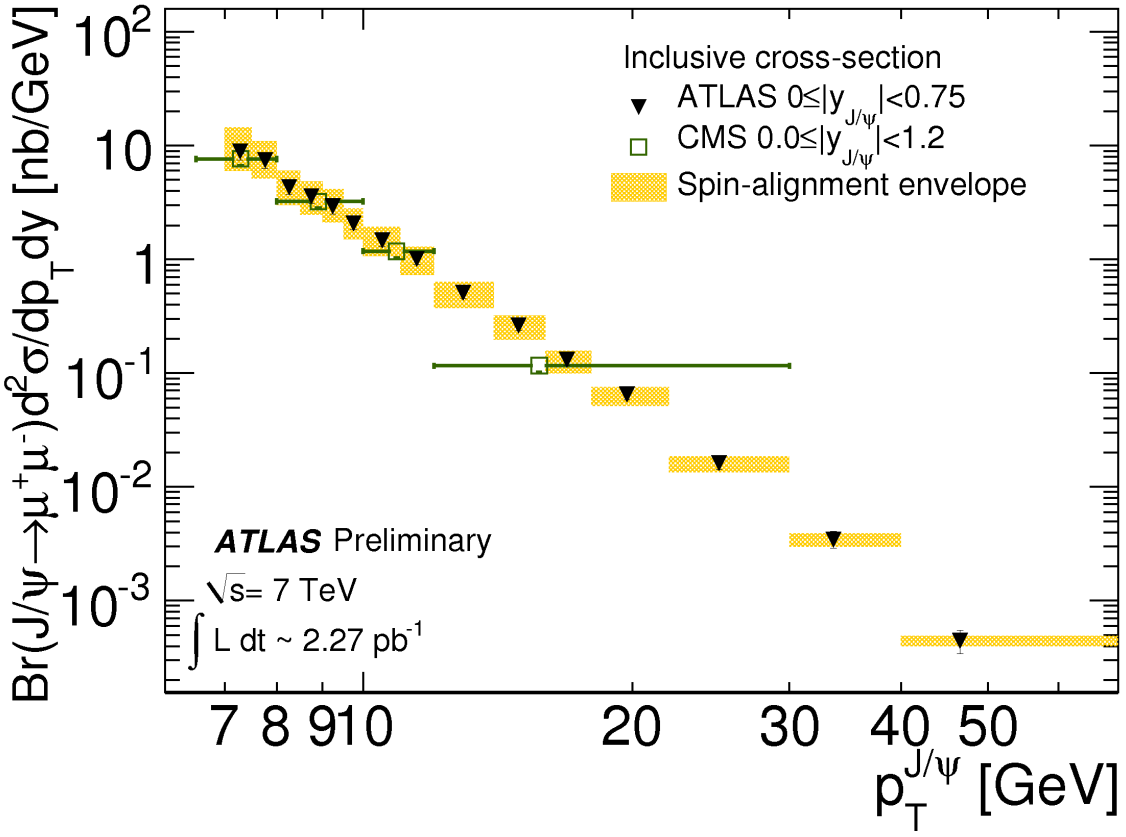
J/ψ→μμ





- Key signatures of B- meson decays contain J/ψ
- J/ψ “standard candle” for detector understanding
- Trigger: single muon (p_T>4/6/8 GeV), dimuon (p_T>4/6 GeV + m(μμ) cut)
- Two muons p_T > 4 (2.5) GeV, opposite charged pair, fitted to same vertex
- At least one “combined” muon

J/ψ Inclusive Cross Sections



- Weight each J/ψ→μμ candidate by weight

  $w^{-1} = A(p_T,y)$
  $\times \varepsilon_\mu(p_T1,\eta1) \times \varepsilon_\mu(p_T2,\eta2)$
  $\times \varepsilon_{Trig}(p_T1,p_T2,\eta1,\eta2)$

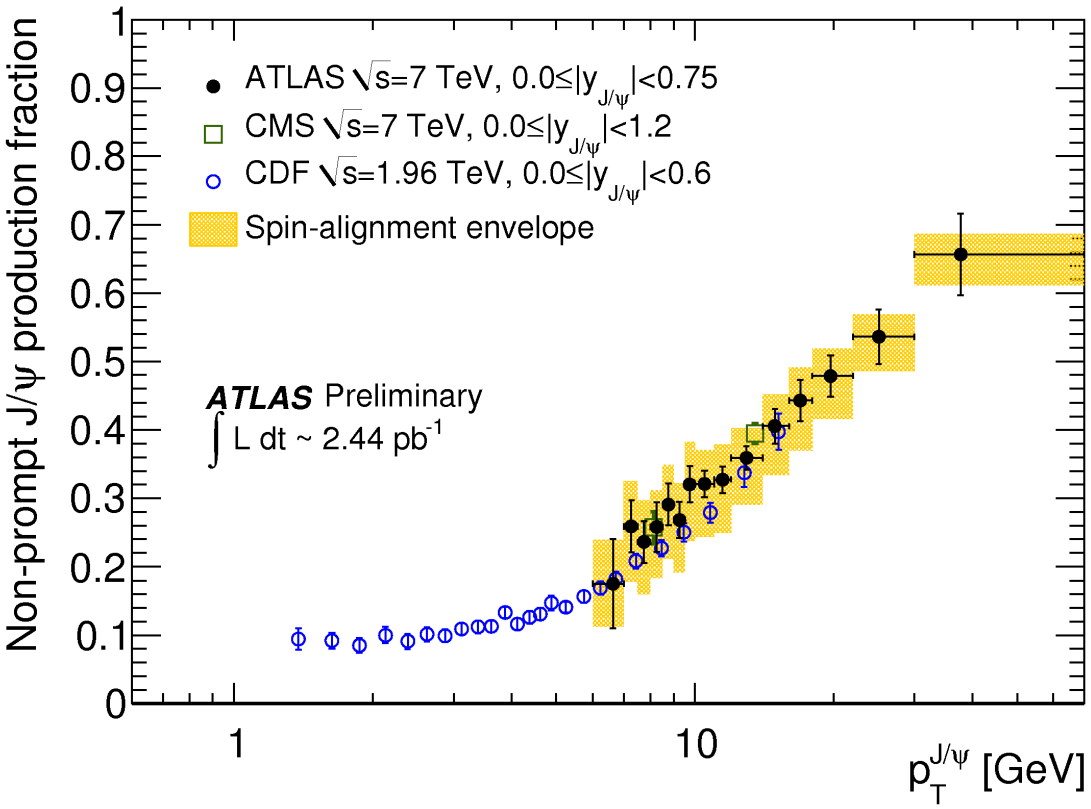
  A = kinematic acceptance (including spin alignment effects)

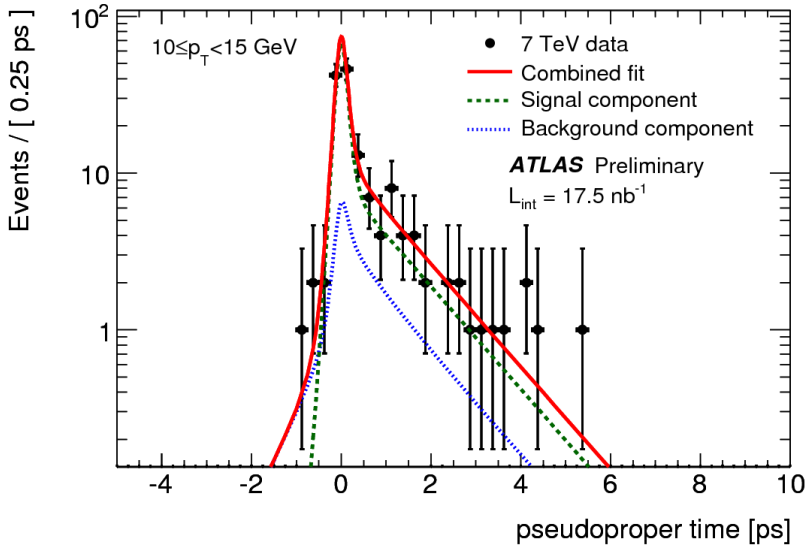
  ε_μ = offline muon reco efficiency

  ε_{Trig} = trigger efficiency

- Central cross section assuming isotropic spin alignment
- Good agreement with CMS measurements
- ATLAS (higher p_T) complementary to CMS (lower p_T) measurements

J/ψ Non-Prompt Fraction



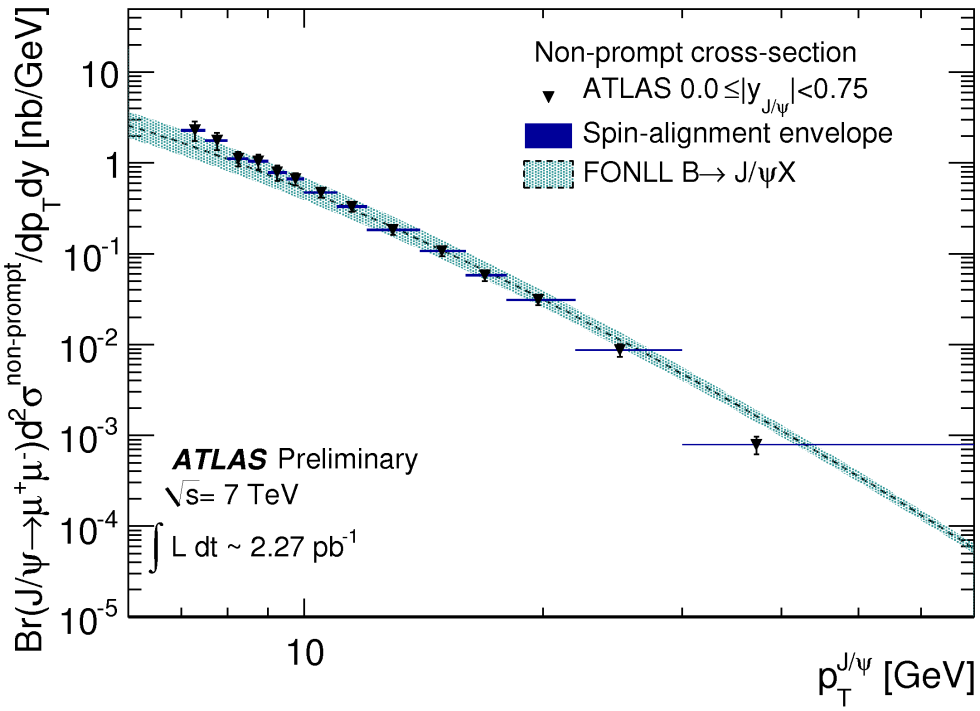


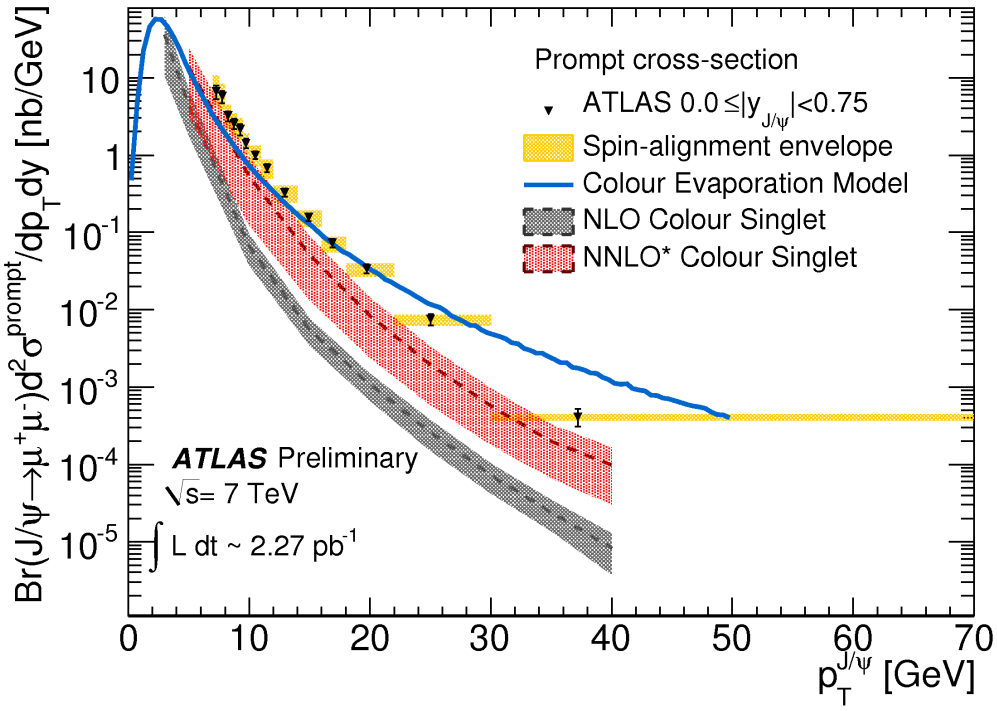
$$\tau = \frac{L_{xy} \times m(J/\psi)}{p_T(J/\psi)}$$

L_{xy} = transverse decay length

- Use "pseudo-proper decay time" (τ) to separate prompt production and B-meson decays with J/ψ
- Simultaneous maximum-likelihood fit to τ and m(μμ) for two components
- Strong p_T (but no η) dependence observed

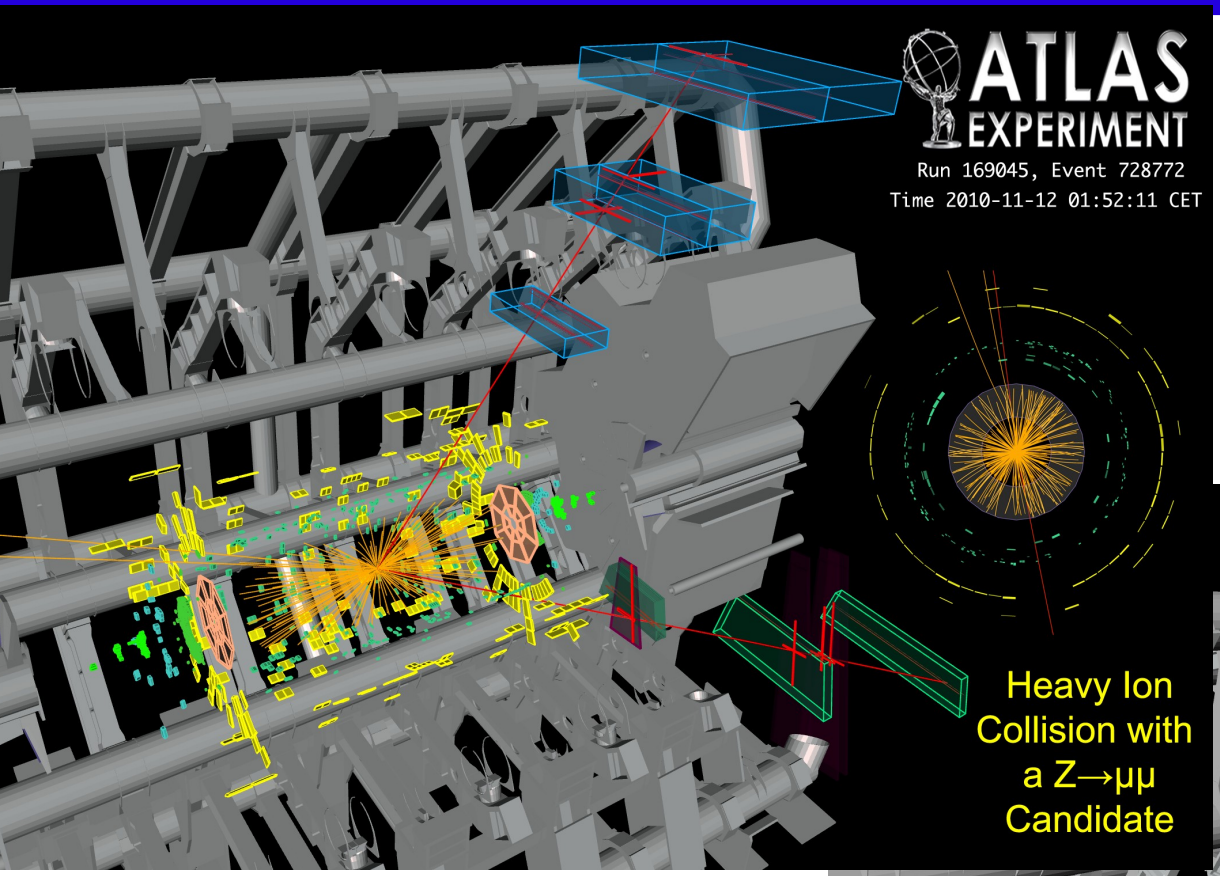
J/ψ (Non-)Prompt Cross Section



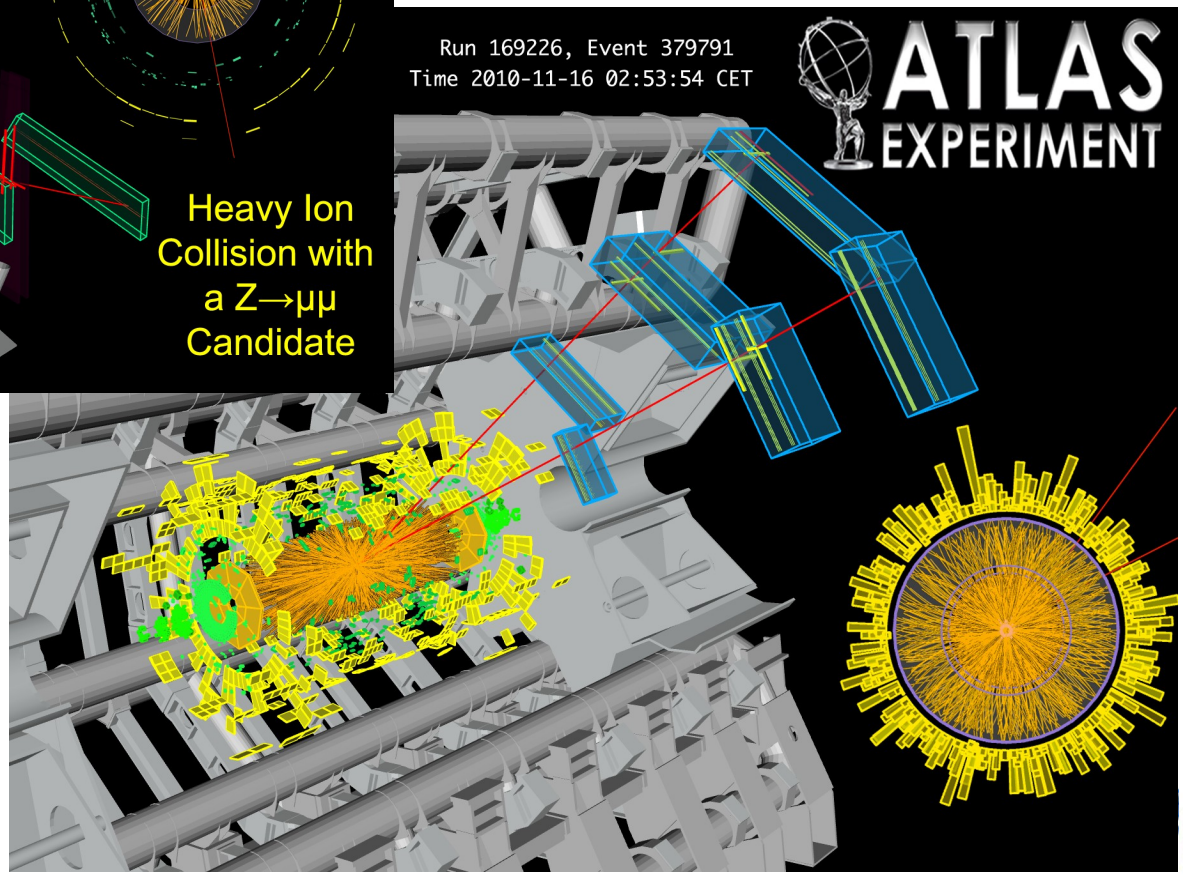


- (Non-)Prompt cross sections from inclusive ⊗ (non-)prompt fractions in same η, p_T binning
- Non-prompt well described by Fixed Order Next-to-Leading Logarithm
- Good description of prompt by Colour Evaporation Model at low p_T
- Reasonable agreement between prompt and colour singlet NNLO*

Heavy Ions

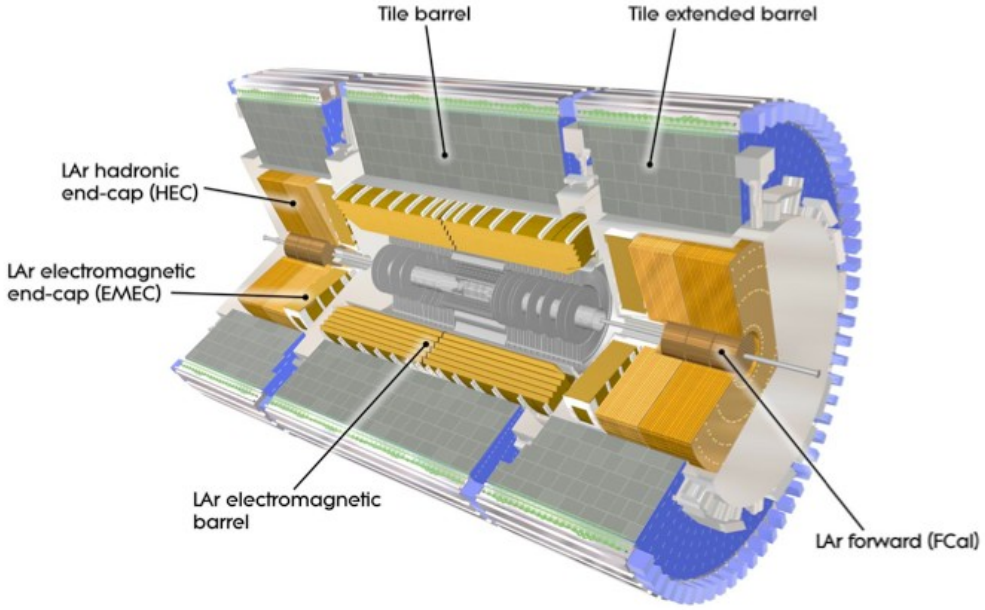


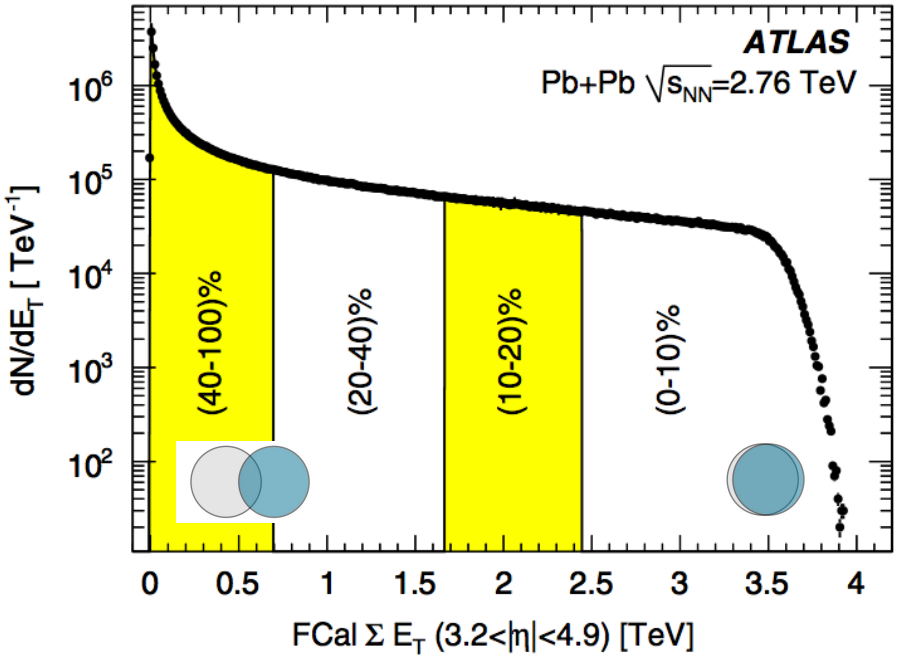
Z→μμ Candidate
in Pb-Pb



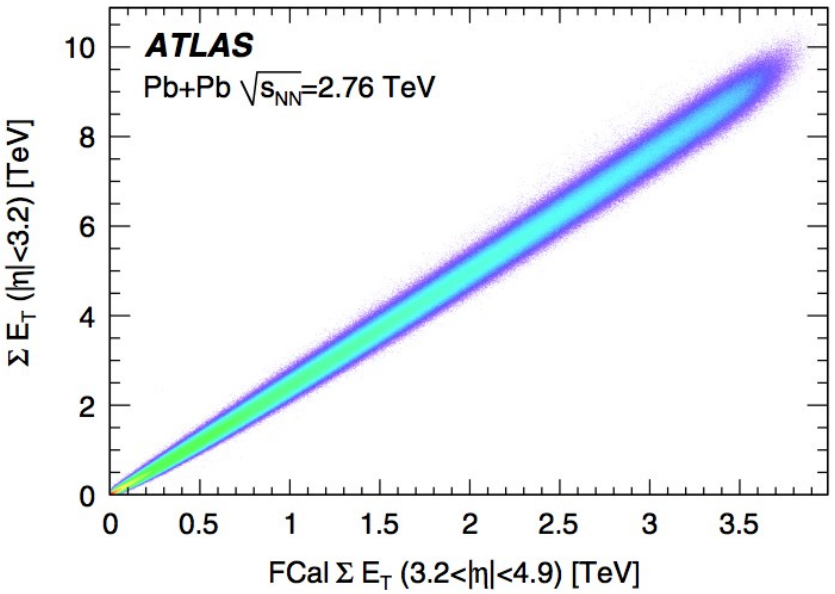
J/ψ→μμ Candidate
in Pb-Pb

Centrality in Heavy Ions

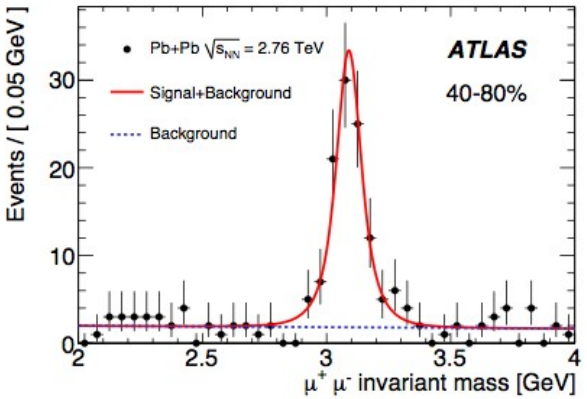


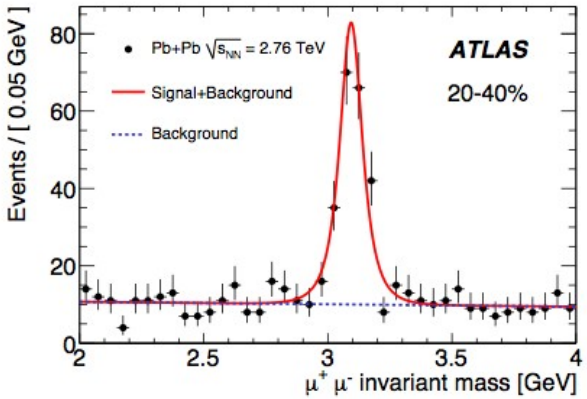


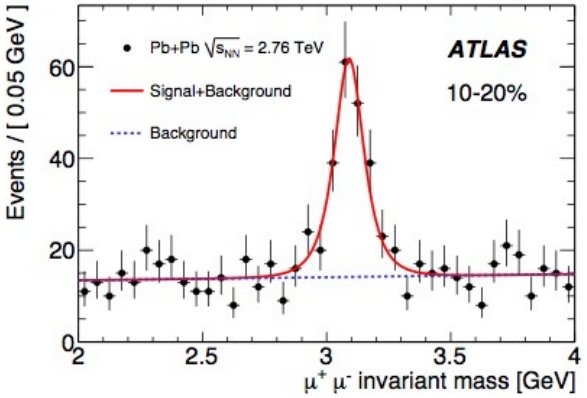
- Particle multiplicity increases with decreasing impact parameter
- Use percentiles of total transverse energy distribution in FCAL to determine event centrality
- "peripheral": large impact parameter (40-100% percentile)
- "central": small impact parameter (0-10% percentile)

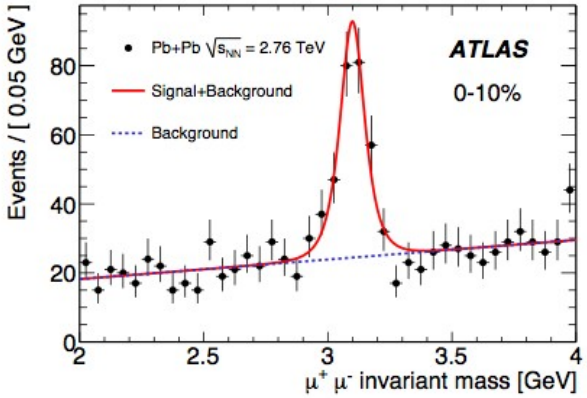


J/ψ→μμ in Heavy Ions



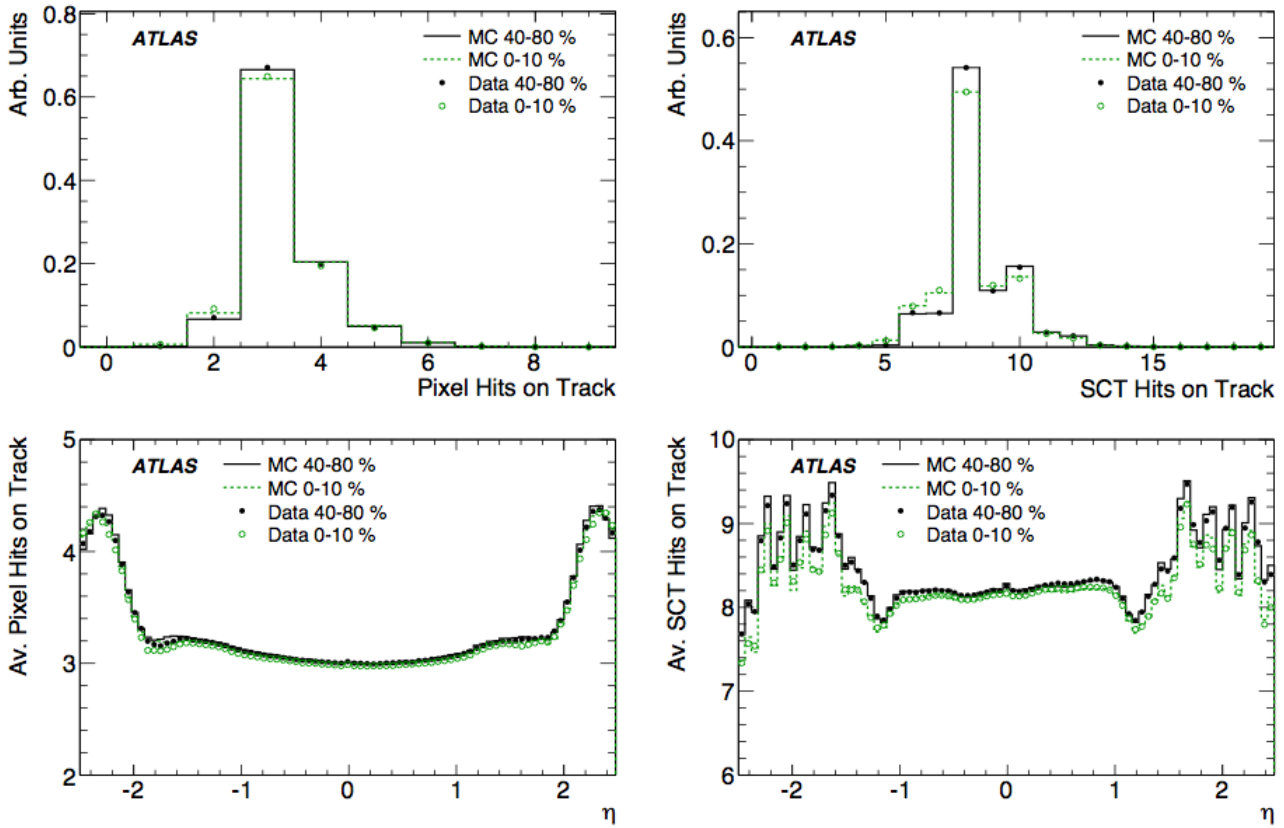






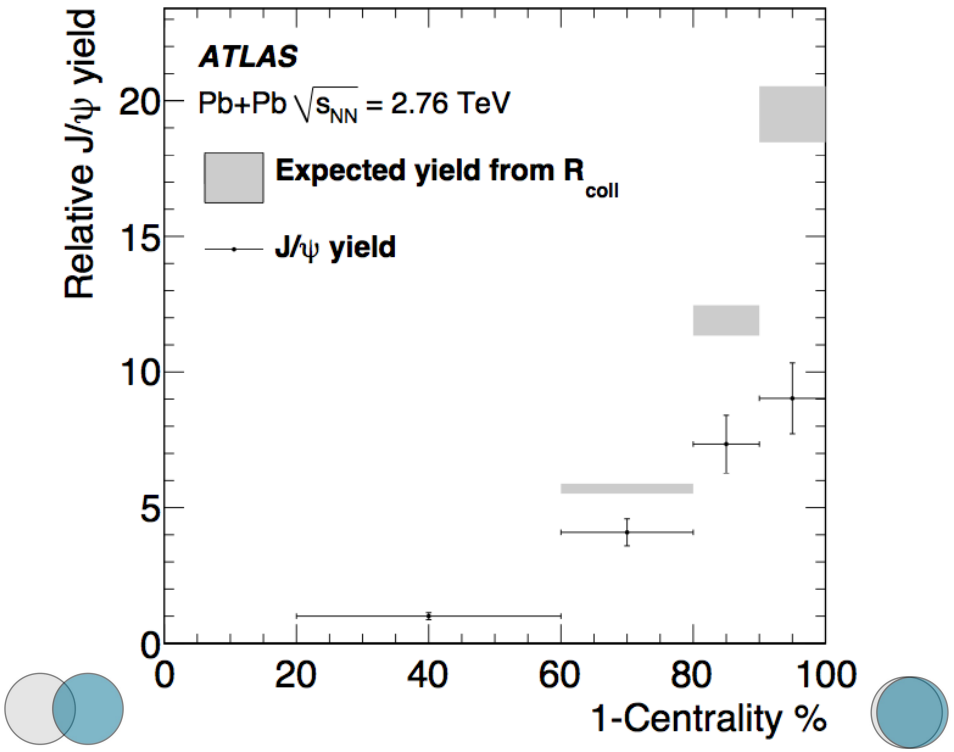
- Suppression of J/ψ yield with centrality seen at SPS and RHIC
- Select two opposite sign muons ($|\eta|<2.5$, $p_T>3$ GeV)
- Signal yield from sideband subtraction
  - cross check from unbinned maximum likelihood fit with mass resolution as free parameter

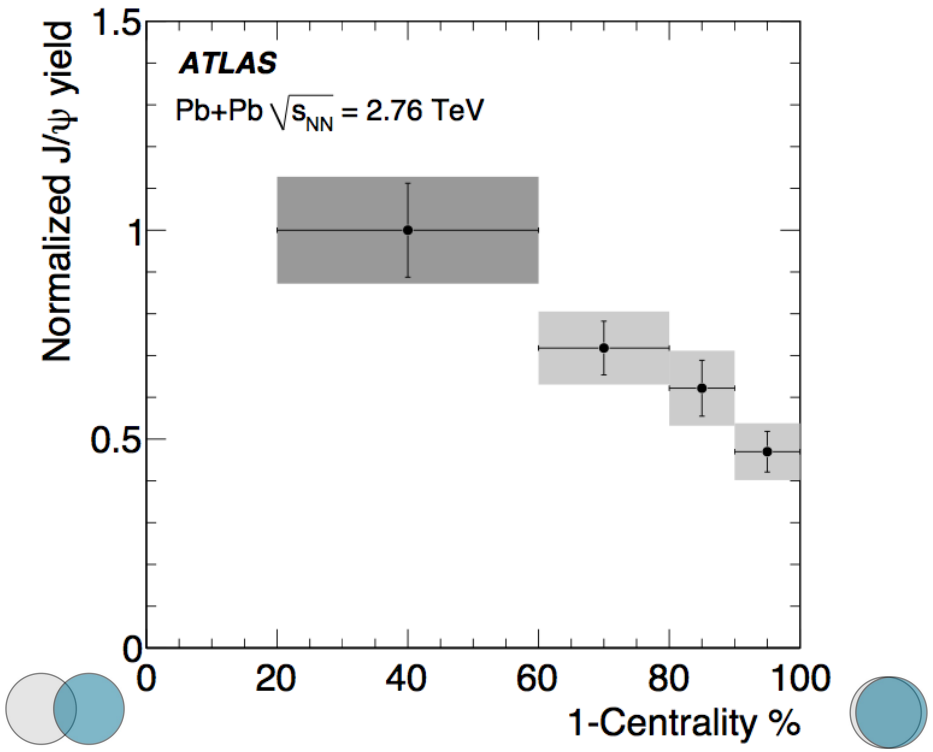
J/ψ→μμ in HI Systematics



- Relative yields measured ⇒ systematics vs. centrality important
- Muon spectrometer reconstruction efficiency independent of centrality
- Inner detector quality requirements more stringent than in pp data
- ID tracking efficiency systematic: 1-3% per track depending on centrality
- Up to 7% J/ψ reconstruction efficiency systematic

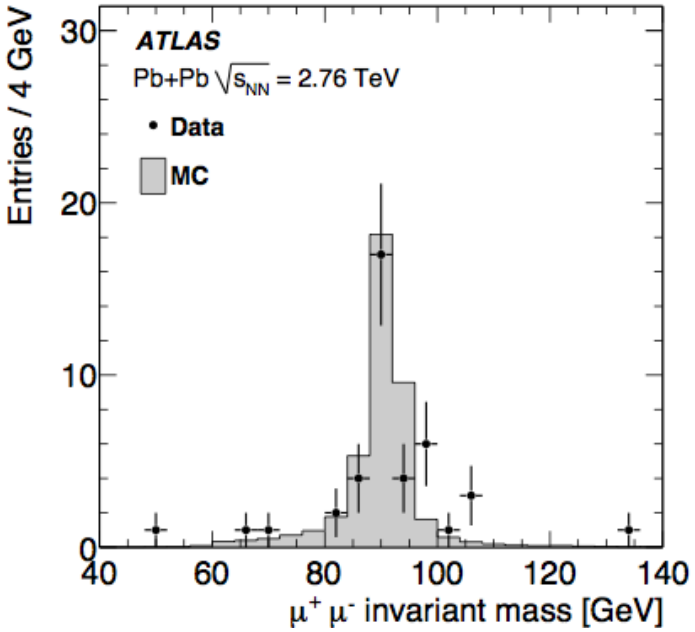
J/ψ→μμ in Heavy Ions

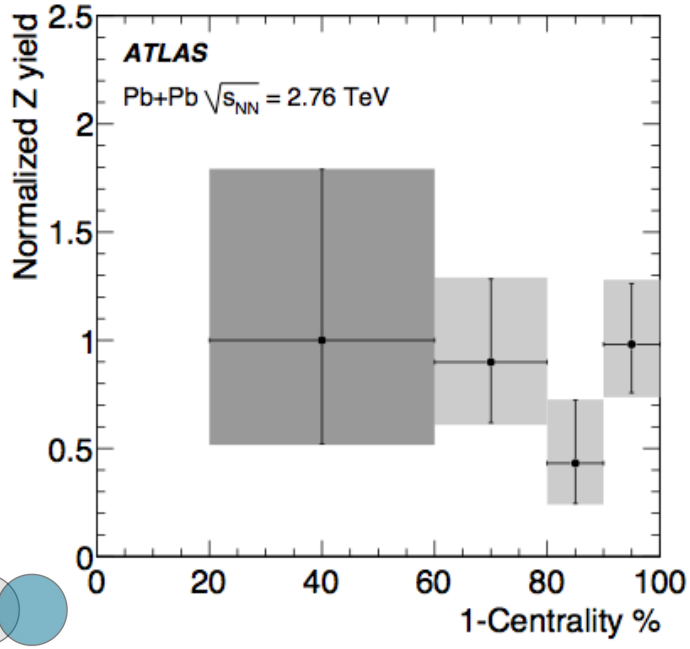




- J/ψ yield normalised to 1-Centrality = 20-60% (most peripheral) bin:
  - systematic shortfall cf. binary nucleon-nucleon yield (Glauber)
- J/ψ yield normalised to expectation:
  - suppression in more central events
  - qualitatively similar to suppression observed at RHIC

Z→μμ in Heavy Ions



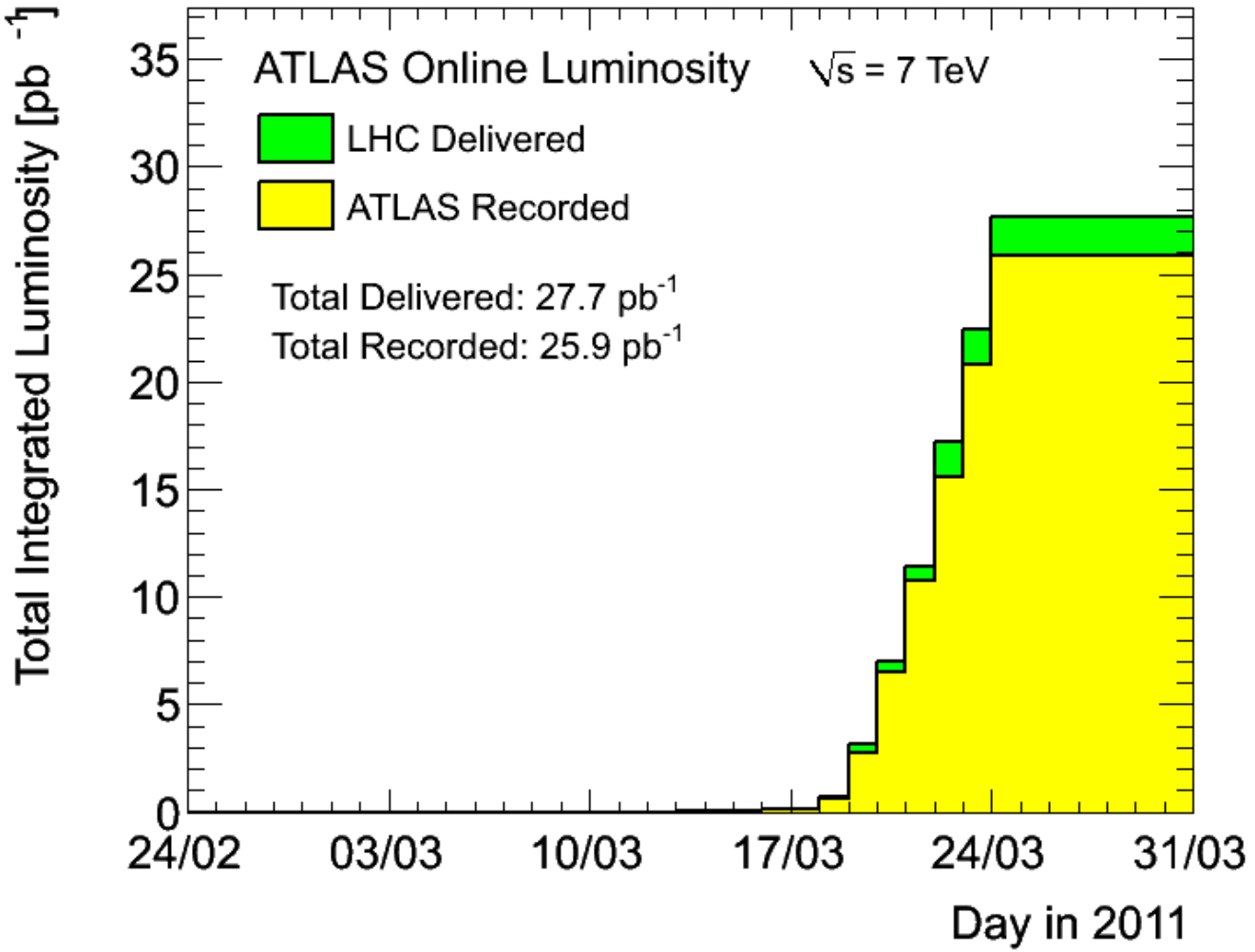


- Use Z→μμ as reference for dimuon production in HI
- Opposite sign combined muon pairs:
  - $|\eta| < 2.5$, $p_T > 20$ GeV
  - $|\eta_1+\eta_2| > 0.01$ (cosmic rejection)
  - $66 < m(\mu\mu) < 116$ GeV
- Normalised yield calculation as for J/ψ
  - also use same systematics
    ⇒ conservative
- Large statistical errors ⇒ can't draw conclusion on centrality dependence

Summary

- Z and J/ψ candles for detector + early physics measurements
- Z cross sections (inclusive and with jets) measured with full 2010 dataset
  - In agreement with NNLO predictions
- Observation of $Z \rightarrow \tau\tau$
- J/ψ prompt and non-prompt cross sections measured
- J/ψ and Z production probing matter produced in PbPb collisions
  - Suppression of J/ψ yields with centrality
  - Statistics too low to determine centrality dependence for Z yields

2011 and beyond



- Already 27.7 pb^{-1} of $\sqrt{s}$= 7 TeV pp delivered by LHC in 2011
- In addition 0.3 pb^{-1} of $\sqrt{s}$= 2.76 TeV data delivered by LHC
- More physics yet to come!

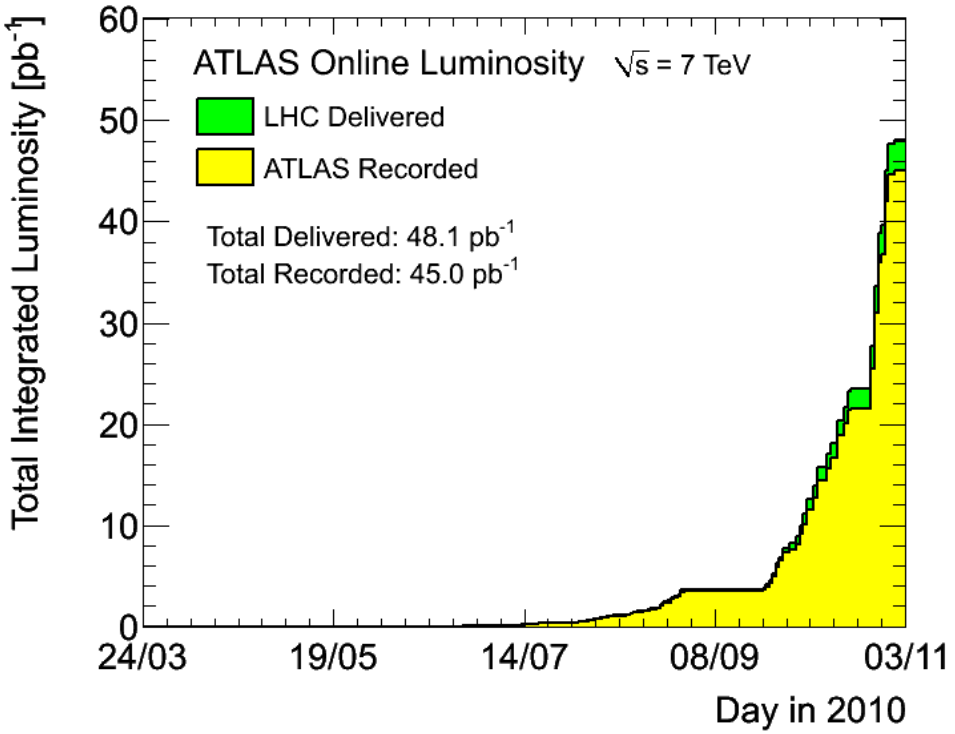
Backup

References

- Muon efficiency — ATLAS-CONF-2011-046 (cdsweb.cern.ch/record/1338575) ATLAS-CONF-2011-021 (cdsweb.cern.ch/record/1336750)
- Electron efficiency
- Dilepton spectra — ATLAS-CONF-2011-003 (cdsweb.cern.ch/record/1326960) ATL-COM-PHYS-2010-882
- Z Cross section — CERN-PH-EP-2010-037 JHEP 12 (2010) 060 ATLAS-CONF-2011-041 (cdsweb.cern.ch/record/1338570)
- Z+Jets — ATLAS-CONF-2011-042 (cdsweb.cern.ch/record/1338571)
- $Z \rightarrow \tau\tau$ — ATLAS-CONF-2011-010 (cdsweb.cern.ch/record/1331795) ATLAS-CONF-2011-045 (cdsweb.cern.ch/record/1338574)
- J/ψ
- J/ψ and Z in HI — CERN-PH-EP-2010-090 Phys.Lett.B697:294-312,2011

Data Taking Summaries

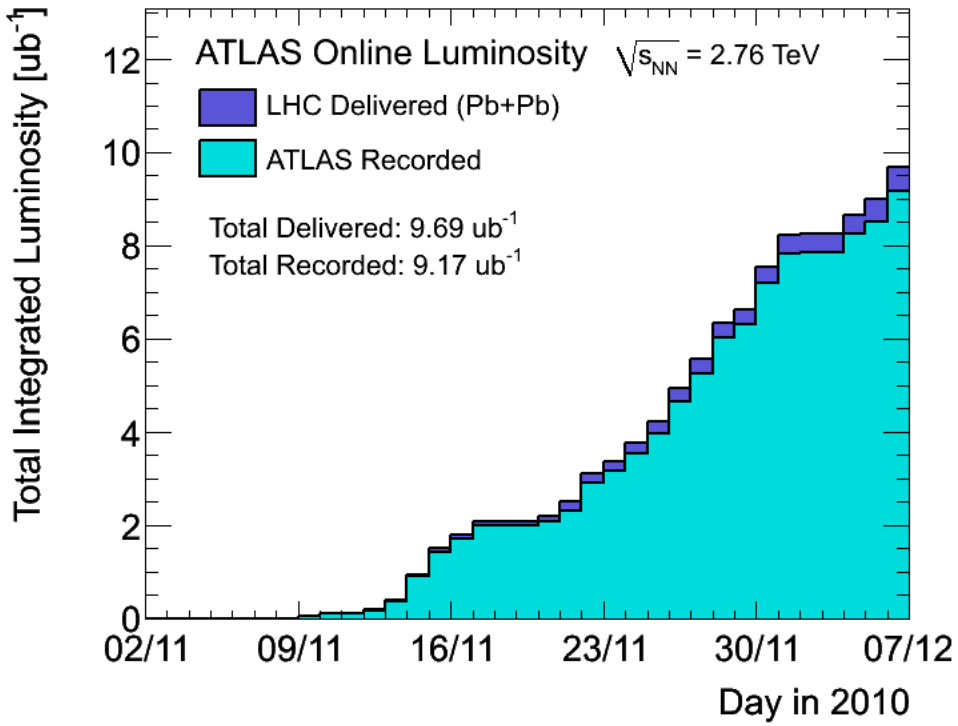
pp running



Inner Tracking Detectors			Calorimeters				Muon Detectors			
Pixel	SCT	TRT	LAr EM	LAr HAD	LAr FWD	Tile	MDT	RPC	CSC	TGC
99.1	99.9	100	90.7	96.6	97.8	100	99.9	99.8	96.2	99.8

Luminosity weighted relative detector uptime and good quality data delivery during 2010 stable beams in pp collisions at $\sqrt{s}$=7 TeV between March 30th and October 31st (in %). The inefficiencies in the LAr calorimeter will partially be recovered in the future.

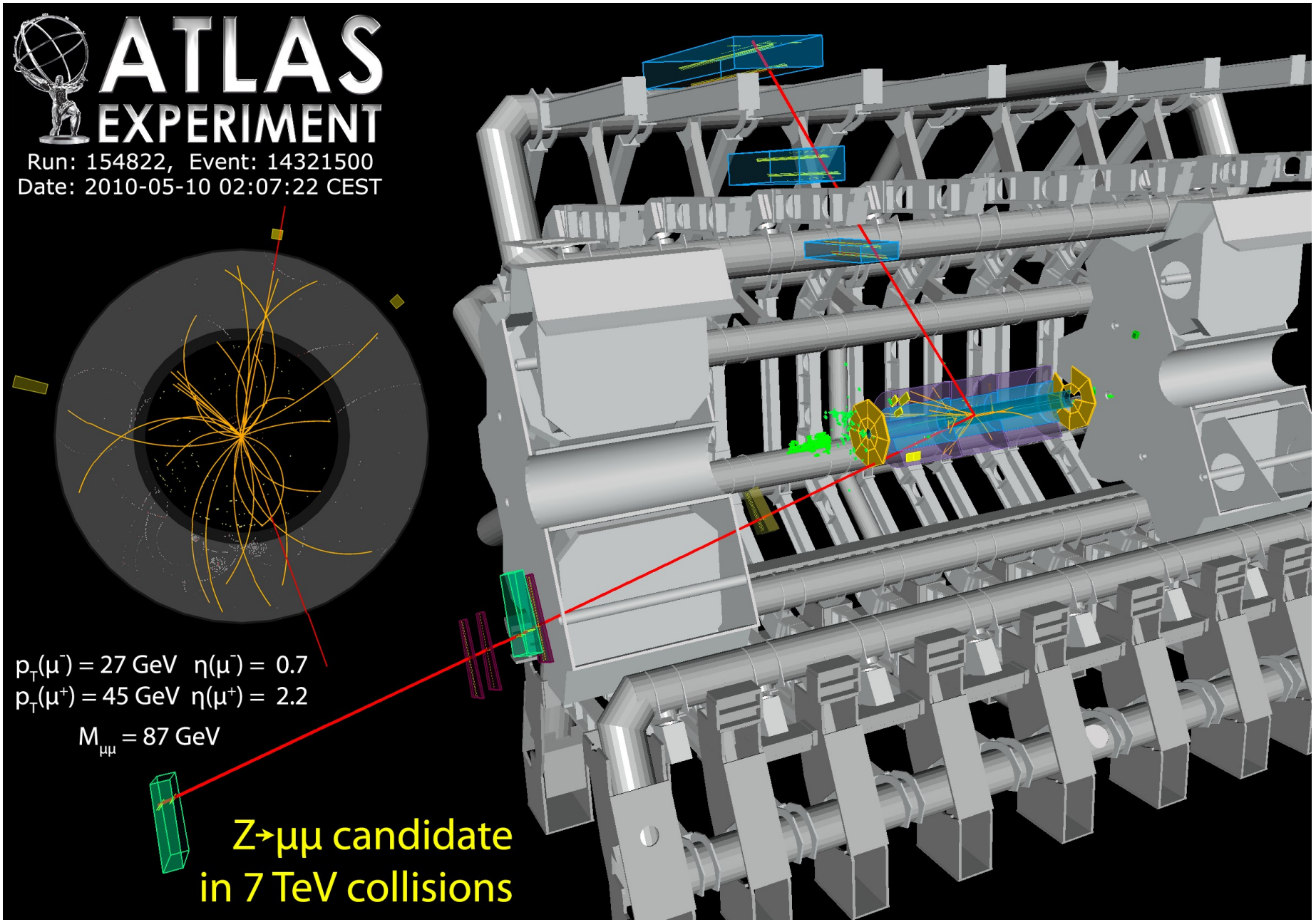
PbPb running



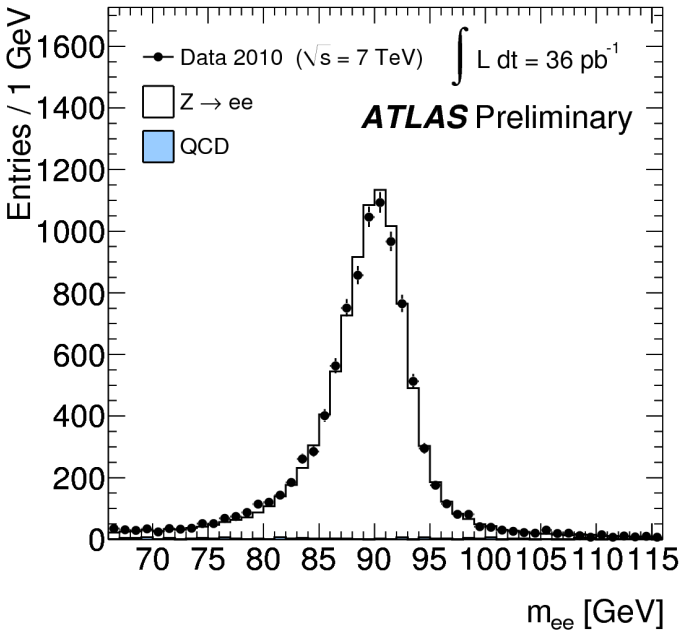
Inner Tracking Detectors			Calorimeters				Muon Detectors			
Pixel	SCT	TRT	LAr EM	LAr HAD	LAr FWD	Tile	MDT	RPC	CSC	TGC
99.7	100	100	99.2	100	100	100	100	99.6	100	100

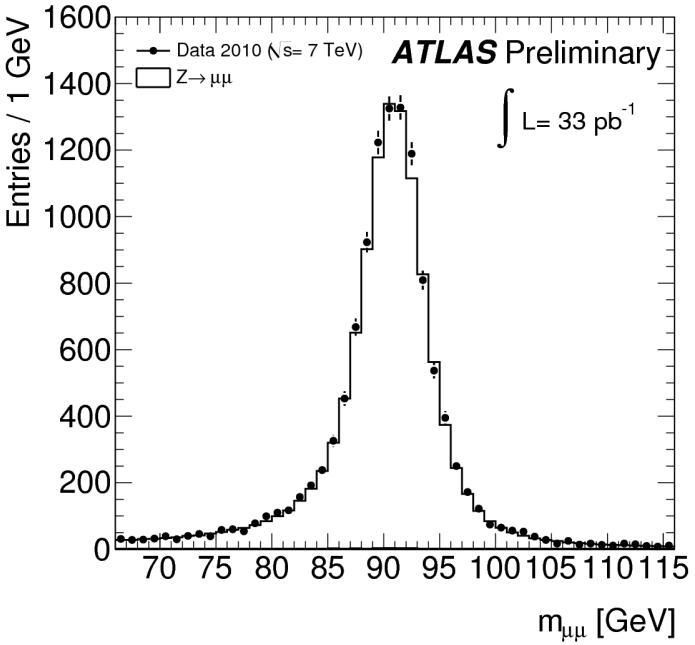
Luminosity weighted relative detector uptime and good quality data delivery during 2010 stable beams in PbPb collisions at $\sqrt{s_{NN}}$=2.76 TeV between November 8th and 17th (in %).

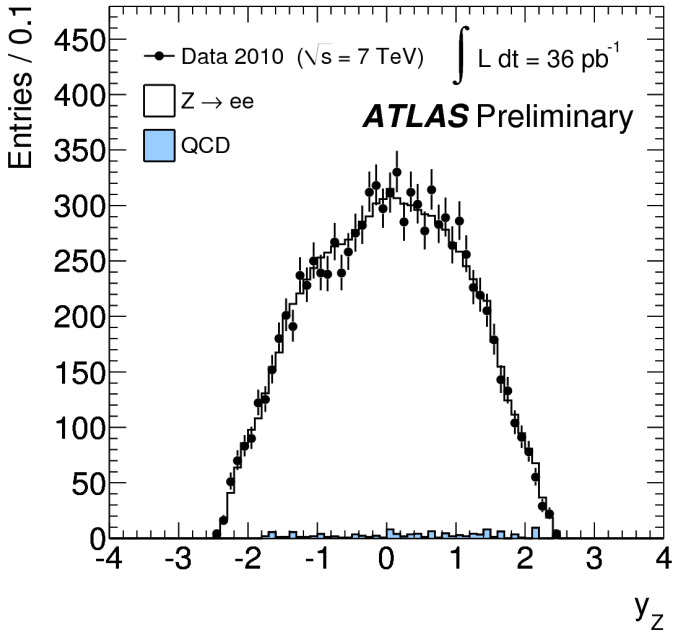
Z→μμ Candidate

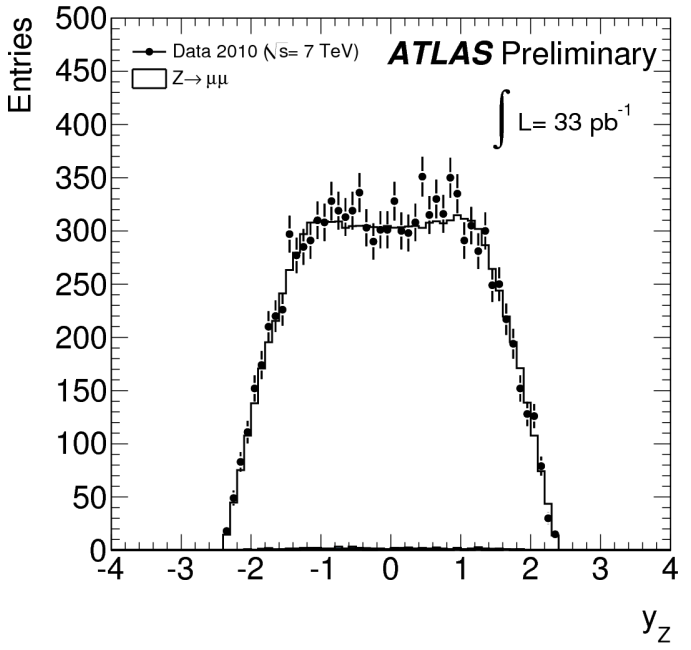


Z Cross Section (36 pb^{-1})









Z Cross Section

Electron channels (36 pb^{-1})

	$\sigma^{\text{fid}}_{Z/\gamma^*} \cdot \text{BR}(Z/\gamma^* \to ee)$ [nb], $66 < m_{ee} < 116$ GeV
Z/γ^* Central	$0.433 \pm 0.004(\text{sta}) \pm 0.016(\text{sys}) \pm 0.015(\text{lum})$
Z/γ^* Forward	$0.179 \pm 0.004(\text{sta}) \pm 0.017(\text{sys}) \pm 0.006(\text{lum})$
	$\sigma^{\text{tot}}_{Z/\gamma^*} \cdot \text{BR}(Z/\gamma^* \to ee)$ [nb], $66 < m_{ee} < 116$ GeV
Z/γ^* Central	$0.972 \pm 0.010(\text{sta}) \pm 0.034(\text{sys}) \pm 0.033(\text{lum}) \pm 0.038(\text{acc})$
Z/γ^* Forward	$0.903 \pm 0.022(\text{sta}) \pm 0.087(\text{sys}) \pm 0.031(\text{lum}) \pm 0.035(\text{acc})$

	N	B	$C_{W/Z}$	$A_{W/Z}$
W^+	72207	4170 ± 345	0.637 ± 0.019	0.466 ± 0.014
W^-	49103	3925 ± 264	0.647 ± 0.019	0.457 ± 0.014
$W^+ + W^-$	121310	8095 ± 532	0.641 ± 0.018	0.462 ± 0.014
Central Z	9721	217 ± 31	0.606 ± 0.021	0.445 ± 0.018
Forward Z	4000	1099 ± 128	0.448 ± 0.039	0.198 ± 0.008

Muon channels (36 pb^{-1})

	$\sigma^{\text{fid}}_{Z/\gamma^*} \cdot \text{BR}(Z/\gamma^* \to \mu\mu)$ [nb], $66 < m_{\mu\mu} < 116$ GeV
Z/γ^*	$0.456 \pm 0.004(\text{sta}) \pm 0.005(\text{sys}) \pm 0.015(\text{lum})$
	$\sigma^{\text{tot}}_{Z/\gamma^*} \cdot \text{BR}(Z/\gamma^* \to \mu\mu)$ [nb], $66 < m_{\mu\mu} < 116$ GeV
Z/γ^*	$0.941 \pm 0.008(\text{sta}) \pm 0.011(\text{sys}) \pm 0.032(\text{lum}) \pm 0.037(\text{acc})$

	N	B	$C_{W/Z}$	$A_{W/Z}$
W^+	84103	6214 ± 784	0.794 ± 0.020	0.484 ± 0.015
W^-	55163	5569 ± 812	0.780 ± 0.019	0.474 ± 0.014
$W^+ + W^-$	139266	11783 ± 1580	0.790 ± 0.018	0.480 ± 0.014
Z	11669	66 ± 21	0.779 ± 0.009	0.486 ± 0.019

	MSTW08	ABKM09	HERA	JR09
W^+	6.16 ± 0.11	6.42 ± 0.09	6.42 ± 0.16	5.92 ± 0.12
W^-	4.30 ± 0.08	4.29 ± 0.07	4.42 ± 0.10	4.03 ± 0.08
W	10.46 ± 0.18	10.71 ± 0.15	10.84 ± 0.26	9.94 ± 0.19
Z/γ^*	0.964 ± 0.018	0.987 ± 0.015	0.994 ± 0.029	0.909 ± 0.018

Z Cross Section Systematics

Electron channels (36 pb^{-1})

	$\delta\sigma_W/\sigma_W$	$\delta\sigma_{W+}/\sigma_{W+}$	$\delta\sigma_{W-}/\sigma_{W-}$	Central $\delta\sigma_Z/\sigma_Z$	Forward $\delta\sigma_Z/\sigma_Z$
Trigger	0.5	0.5	0.5	<0.1	0.5
Electron Reconstruction	1.5	1.5	1.5	3.0	1.5
Electron Identification	1.1	1.2	1.1	1.6	8.2
Electron Energy scale	0.5	0.5	0.4	0.2	1.4
Electron Energy resolution	0.02	0.02	0.02	0.01	<0.1
defective LAr channels	0.4	0.4	0.4	0.8	0.8
Charge misidentification	—	1.1	1.1	0.2	—
E_T^{miss} scale and resolution	2.0	2.0	2.0	—	—
pile-up	0.1	0.1	0.1	0.1	1.7
Background	0.4	0.5	0.5	0.3	3.2
$C_{W/Z}$ Theoretical uncertainty	0.3	0.3	0.3	0.5	0.9
Total experimental uncertainty	2.8	3.0	3.0	3.5	8.6
$A_{W/Z}$ Theoretical uncertainty	3.0	3.0	3.0	4.0	3.9
Total excluding Luminosity	4.1	4.2	4.2	5.3	9.4
Luminosity	3.4				

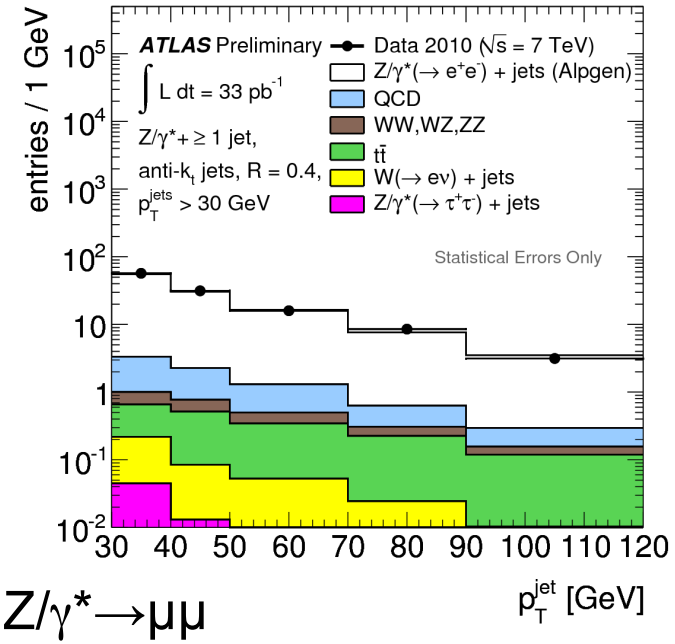
Z Cross Section Systematics

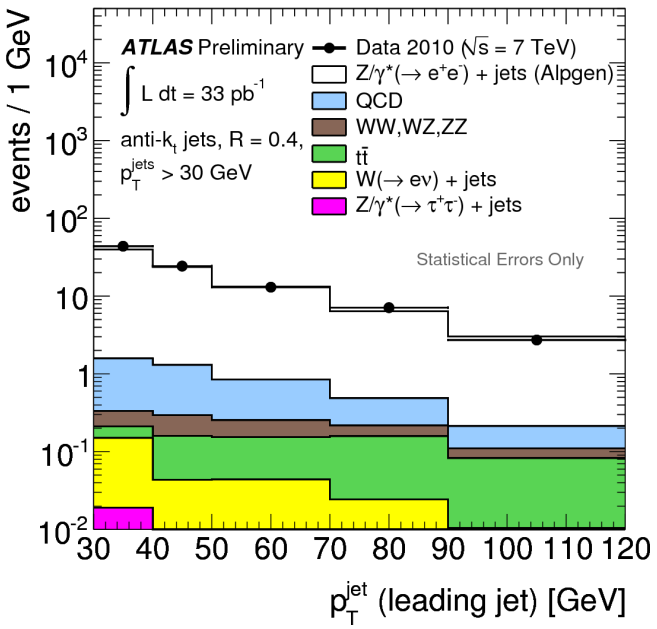
Muon channels (36 pb^{-1})

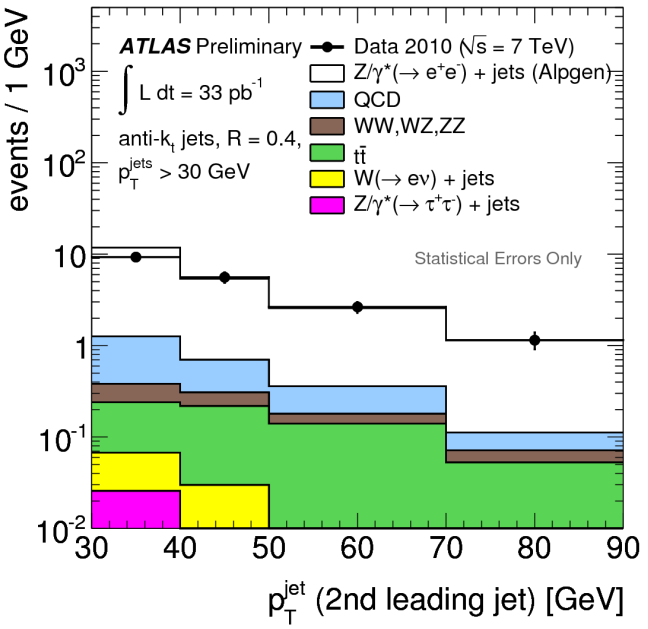
	$\delta\sigma_W/\sigma_W$	$\delta\sigma_{W+}/\sigma_{W+}$	$\delta\sigma_{W-}/\sigma_{W-}$	$\delta\sigma_Z/\sigma_Z$
Trigger	0.7	0.8	0.9	0.1
Muon Reconstruction	0.5	0.6	0.6	0.8
Muon Isolation	0.3	0.3	0.3	0.6
Muon p_T Resolution	0.02	0.03	0.02	0.01
Muon p_T Scale	0.4	1.1	0.8	0.2
QCD Background	0.8	0.7	1.1	0.1
Electroweak Background	0.4	0.4	0.5	0.02
E_T^{miss} Cleaning	0.07	0.07	0.07	-
E_T^{miss} Resolution and Scale	2.0	2.0	2.0	-
$C_{W/Z}$ Theoretical uncertainty	0.3	0.3	0.3	0.3
Total experimental uncertainty	2.4	2.7	2.7	1.1
$A_{W/Z}$ Theoretical uncertainty	3.0	3.0	3.0	4.0
Total excluding Luminosity	3.9	4.0	4.0	4.1
Luminosity	3.4			

Z + Jets: Control Plots

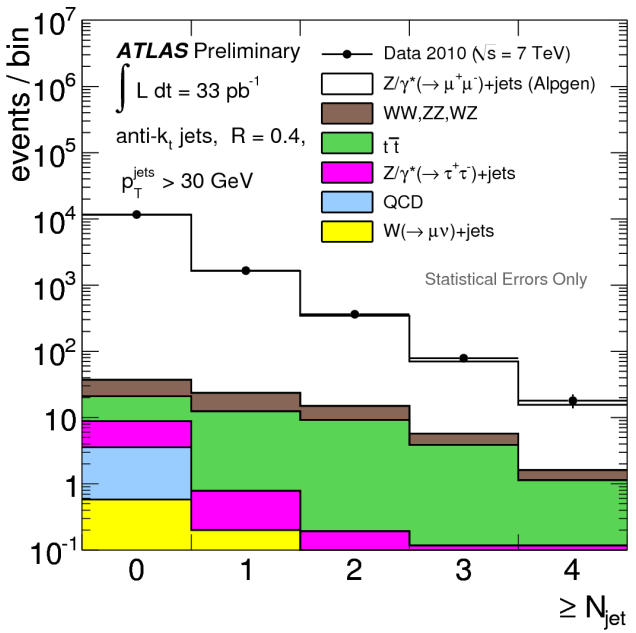
$Z/\gamma^* \rightarrow ee$

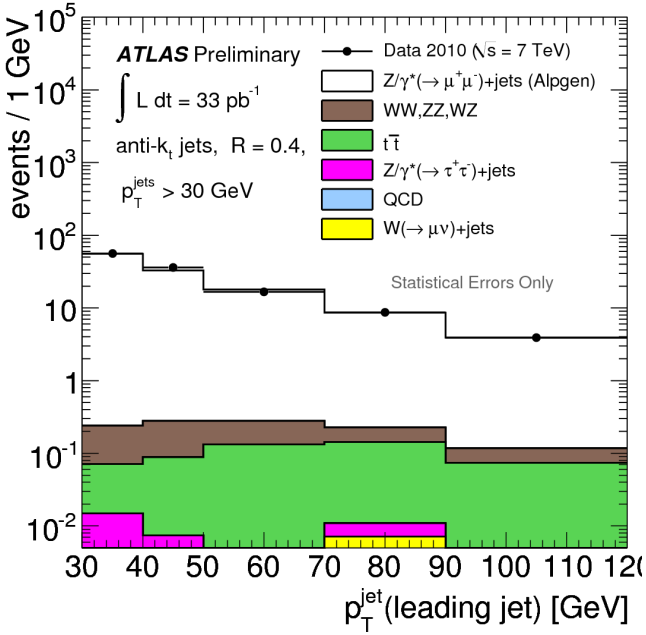


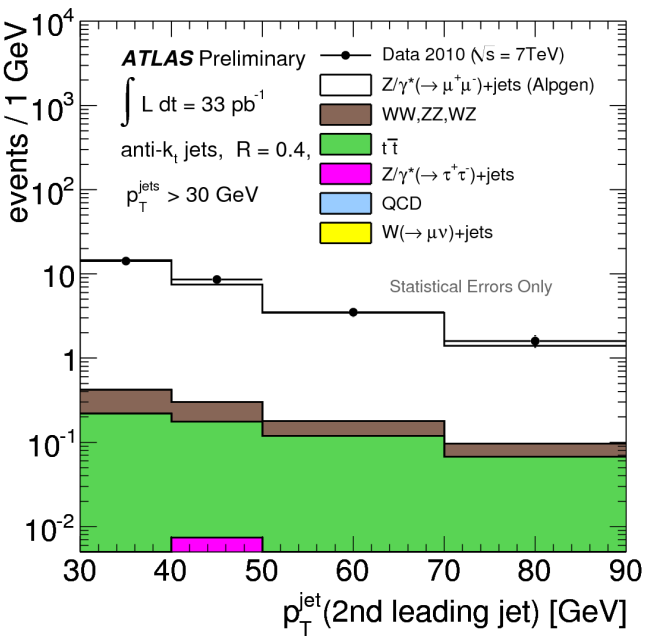




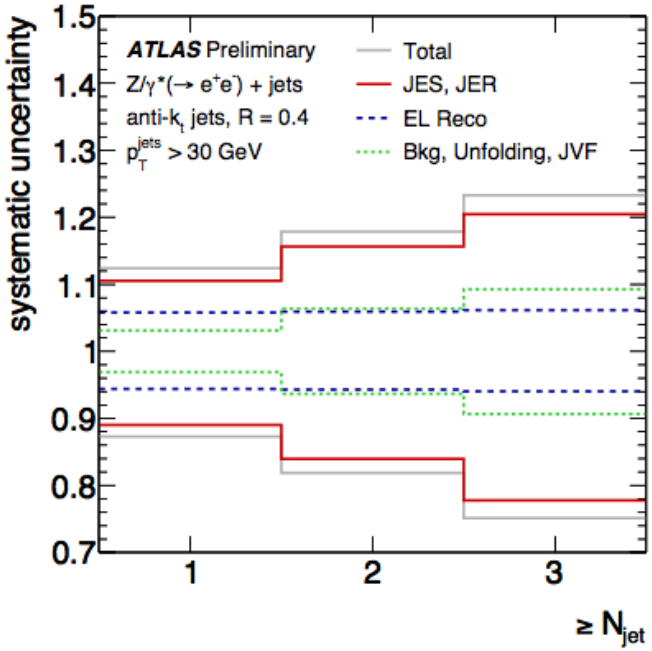
$Z/\gamma^* \rightarrow \mu\mu$

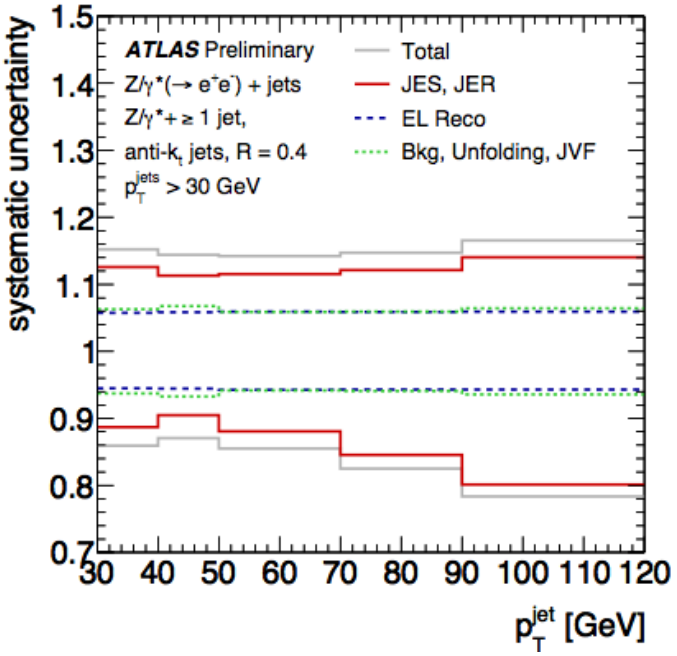


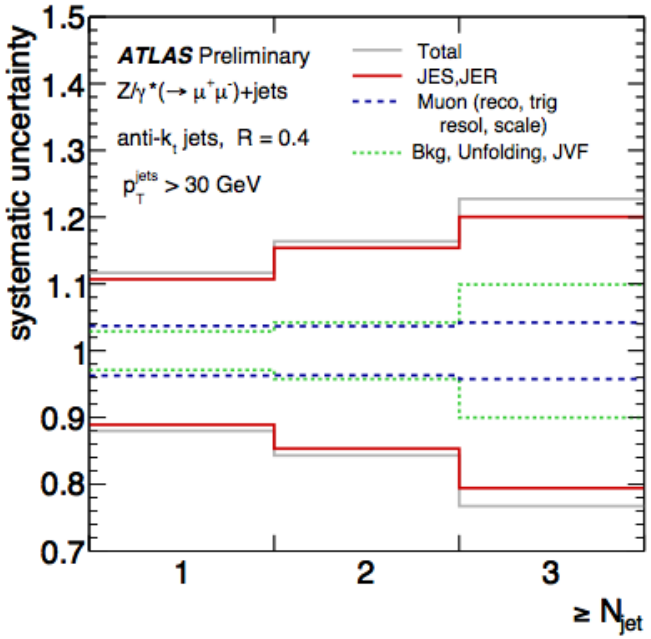


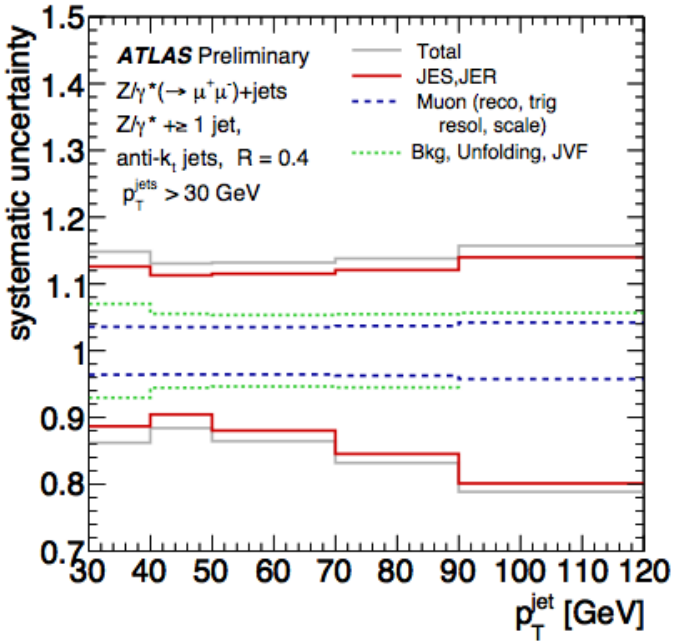


Z + jets: systematics

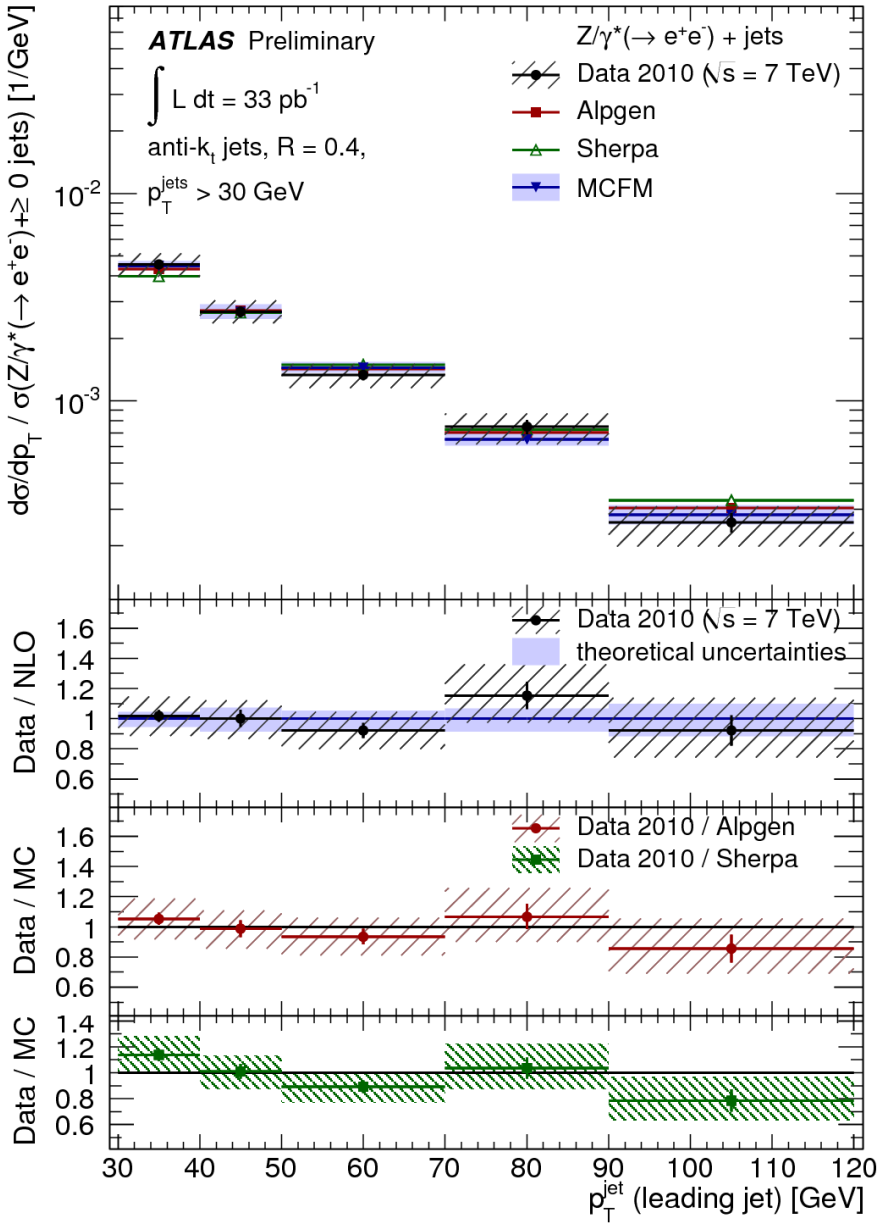


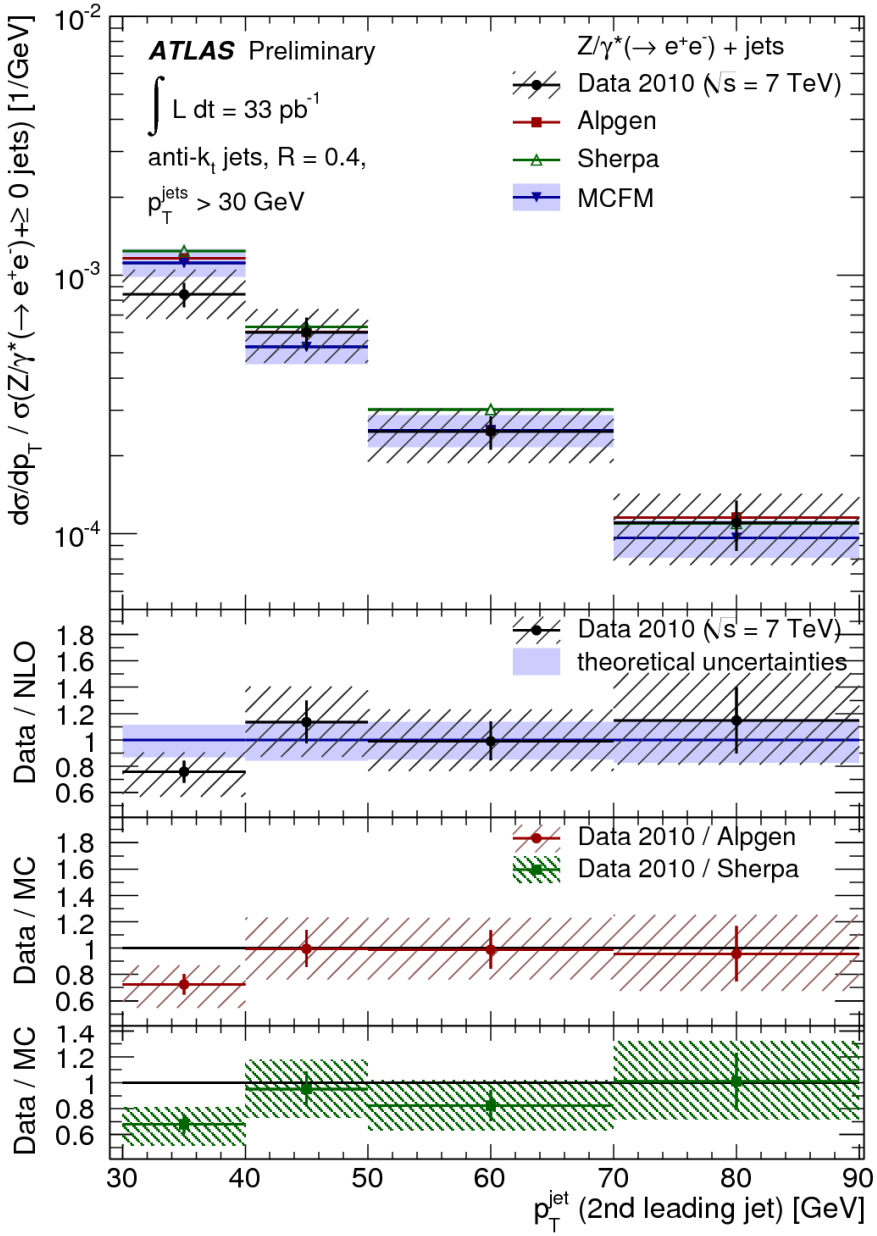






Z + Jets


ATLAS Preliminary
∫ L dt = 33 pb-1
anti-kt jets, R = 0.4,
pTjets > 30 GeV
Z/γ*(→ e+e-) + jets
Data 2010 (√s = 7 TeV)
Alpgen
Sherpa
MCFM
dσ/dpT / σ(Z/γ*(→ e+e-)+≥ 0 jets) [1/GeV]
Data 2010 (√s = 7 TeV)
theoretical uncertainties
Data / NLO
Data 2010 / Alpgen
Data 2010 / Sherpa
Data / MC
Data / MC
pTjet (leading jet) [GeV]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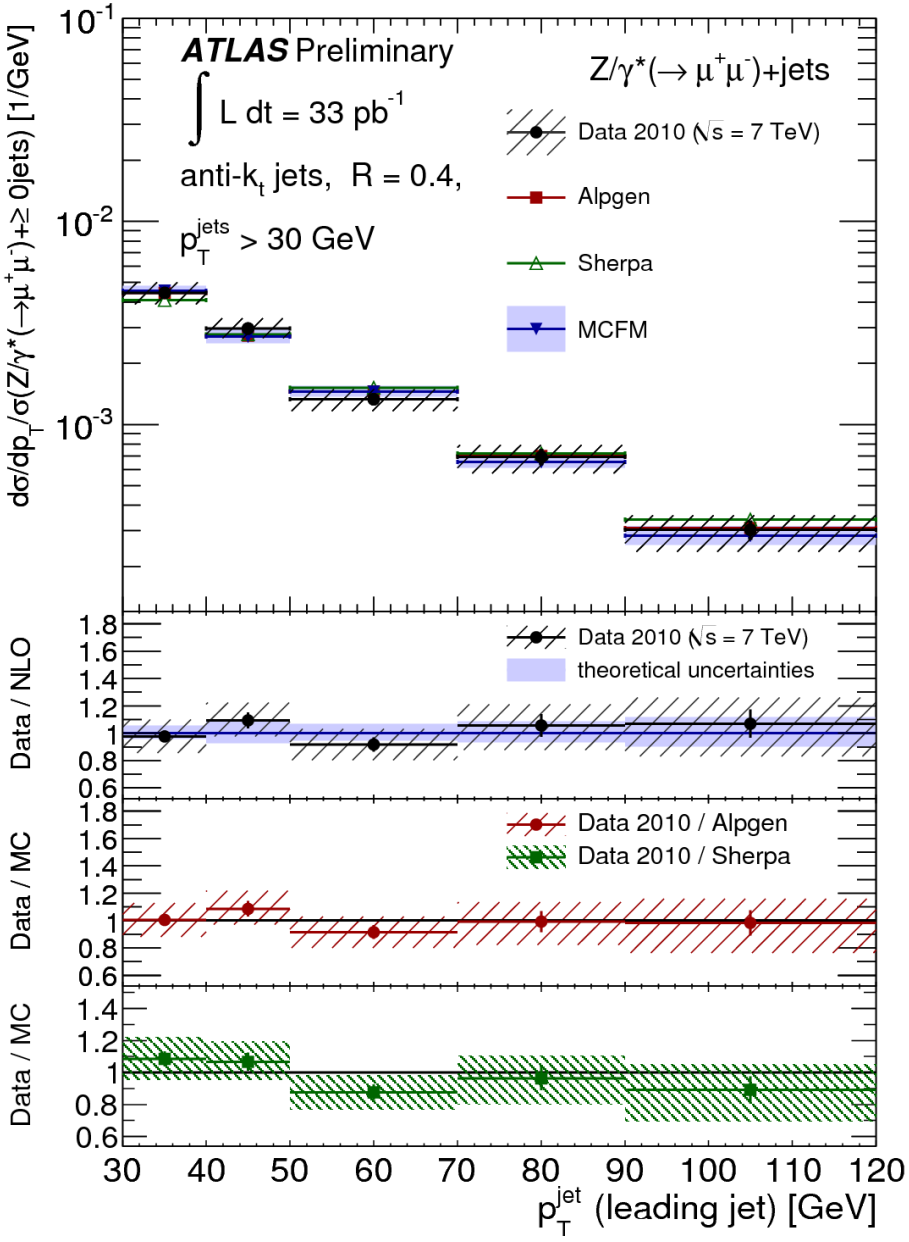
Data 2010 (√s = 7 TeV)
Alpgen
Sherpa
MCFM
dσ/dpT / σ(Z/γ*(→ e+e-)+≥ 0 jets) [1/GeV]
Data 2010 (√s = 7 TeV)
theoretical uncertainties
Data / NLO
Data 2010 / Alpgen
Data 2010 / Sherpa
Data / MC
Data / MC
pTjet (2nd leading jet) [GeV]

Z + Jets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anti-kt jets, R = 0.4,
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Alpgen
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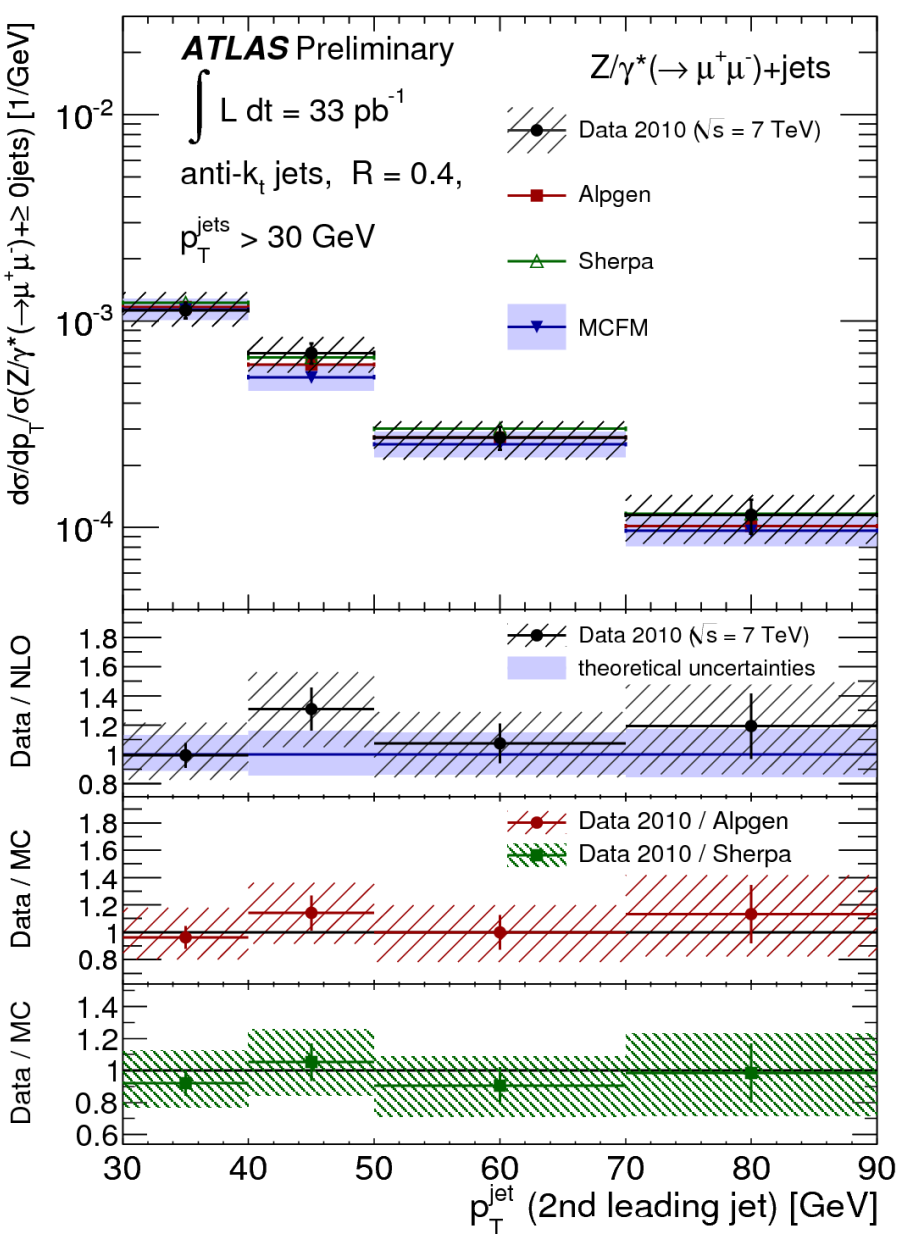
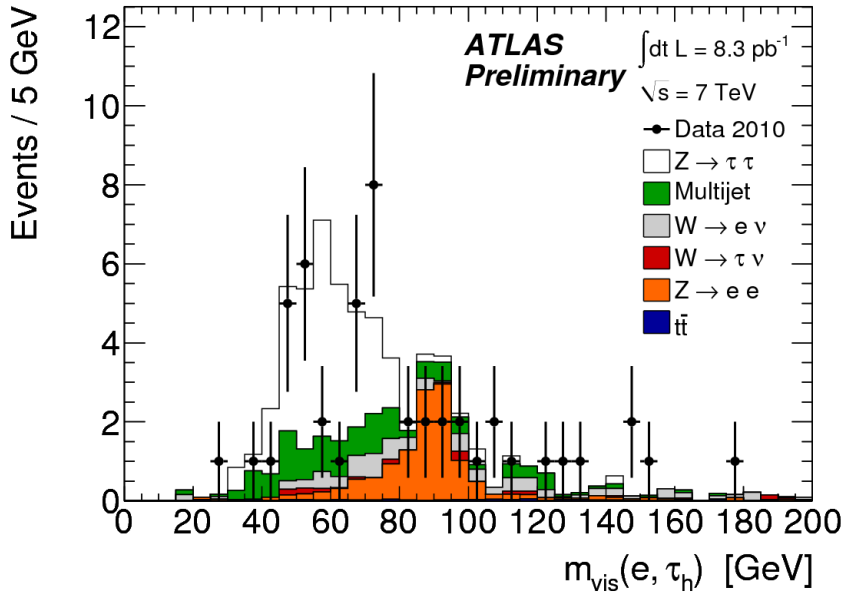
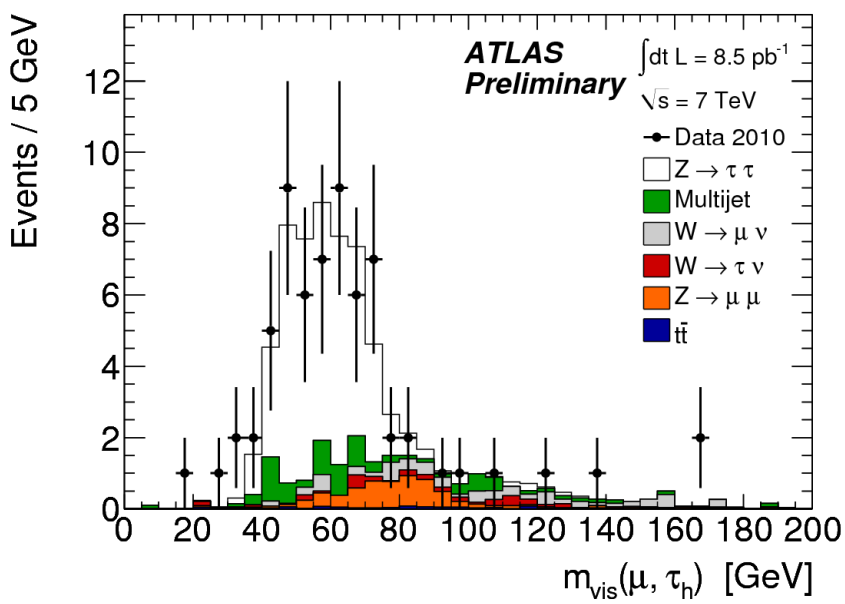
dσ/dpT/σ(Z/γ*(→μ+μ-)+≥ 0jets) [1/GeV]
Data / NLO
theoretical uncertainties
Data / MC
Data 2010 / Alpgen
Data 2010 / Sherpa
pTjet (leading jet) [GeV]


ATLAS Preliminary
∫ L dt = 33 pb-1
anti-kt jets, R = 0.4,
pTjets > 30 GeV
Z/γ*(→ μ+μ-)+jets
Data 2010 (√s = 7 TeV)
Alpgen
Sherpa
MCFM
dσ/dpT/σ(Z/γ*(→μ+μ-)+≥ 0jets) [1/GeV]
Data / NLO
theoretical uncertainties
Data / MC
Data 2010 / Alpgen
Data 2010 / Sherpa
pTjet (2nd leading jet) [GeV]

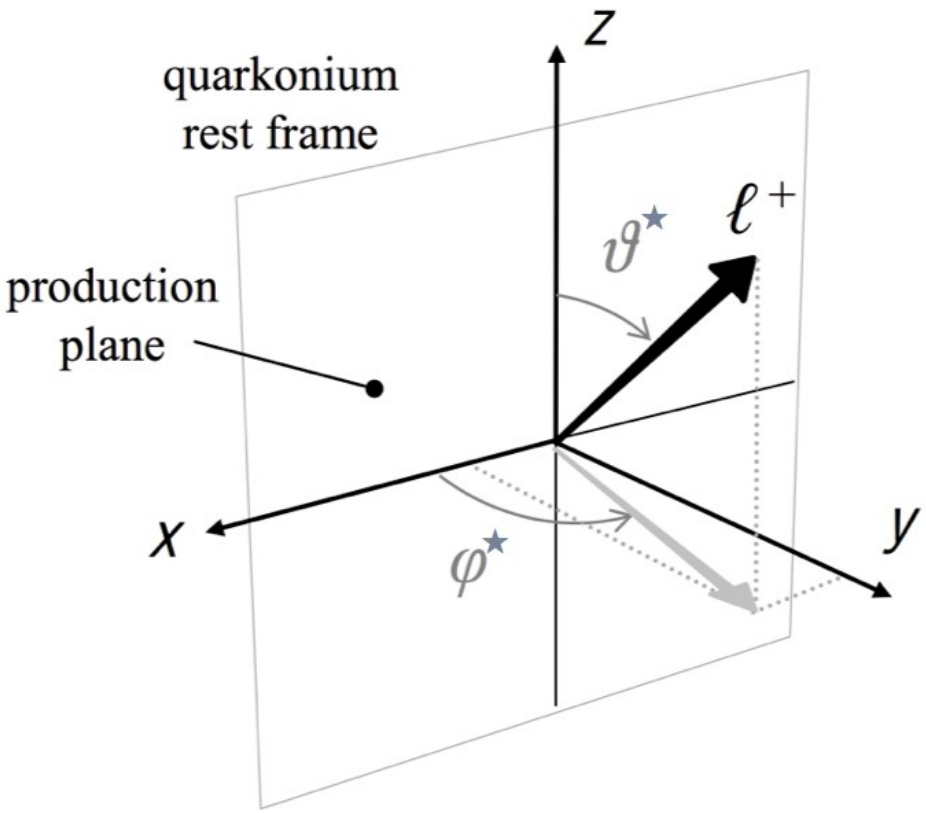
$Z \rightarrow \tau\tau \rightarrow$ lep had Observation

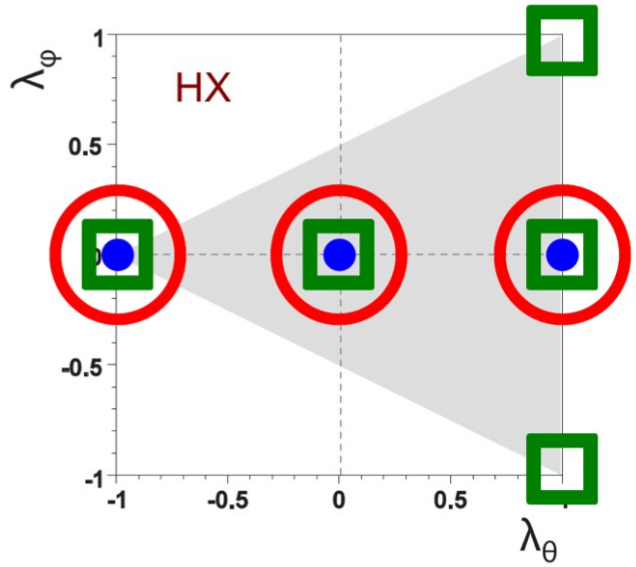




	Muon Channel (8.5 pb^{-1})	Electron Channel (8.3 pb^{-1})
Data (after all selections)	51	29
Total Estimated Background	9.9 ± 2.1	11.8 ± 1.7
Estimated Multijet Background	*5.2 ± 0.7(stat.) $\pm$ 0.7 (syst.)*	*6.8 ± 0.6(stat.) $\pm$ 0.7 (syst.)*
Estimated W, Z, $t\bar{t}$ Background	*4.7 ± 0.5(stat.) $\pm$ 1.5(syst.)*	*5.0 ± 0.6 (stat.) $\pm$ 1.4(syst.)*
Data (after background subtraction)	41.1 ± 7.1(stat.) ± 2.1(bkg. est.)	17.2 ± 5.4(stat.) ± 1.7(bkg. est.)
SM Signal Expectation	39.9 ± 1.8(stat.) ± 6.7(syst.)	24.5 ± 1.4(stat.) ± 7.9(syst.)

J/ψ Spin Alignment

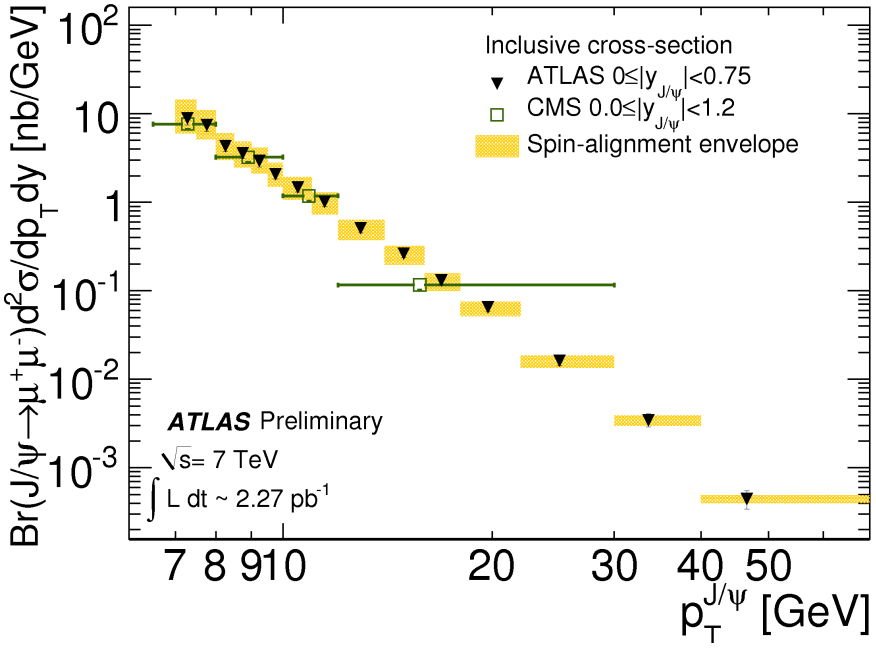


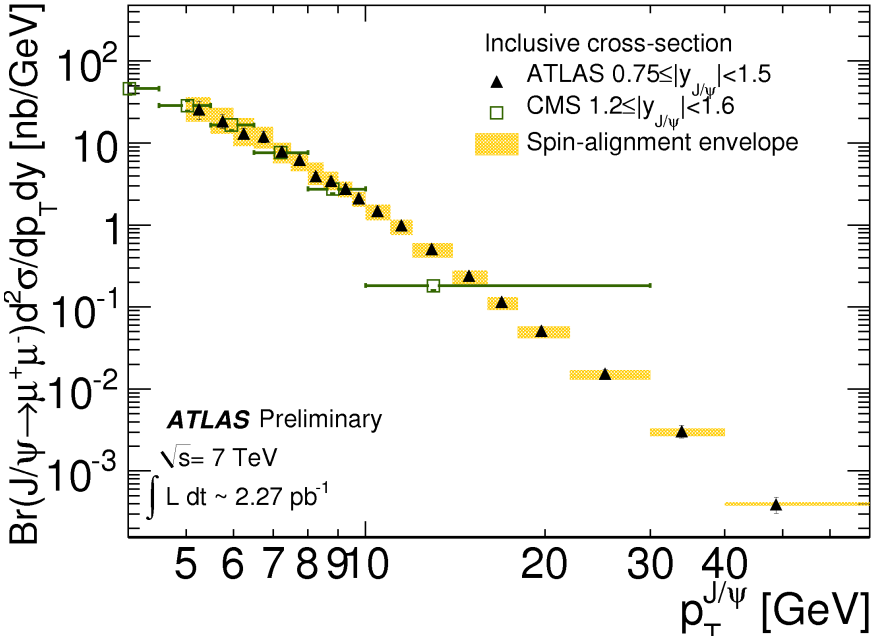


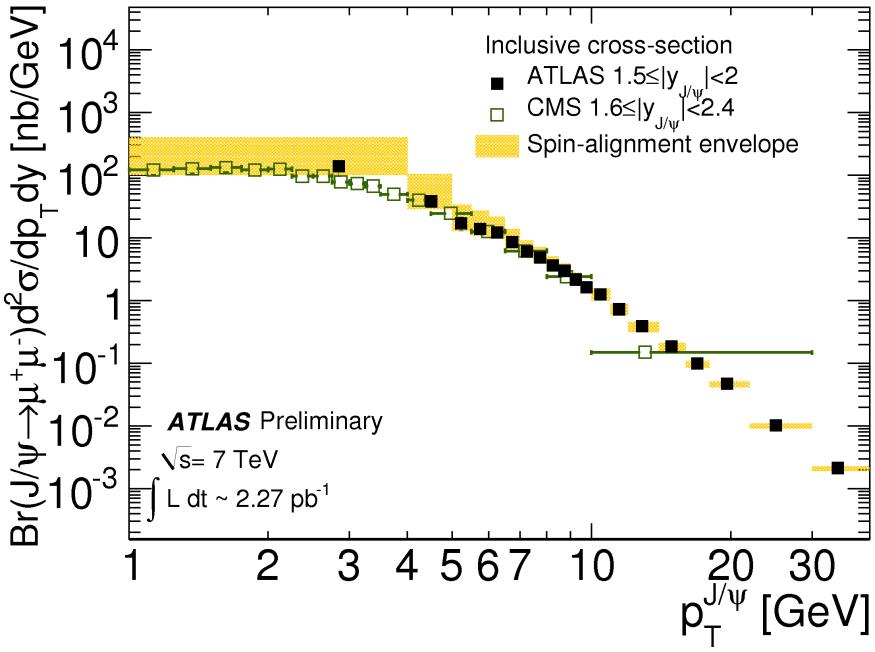
$$\frac{d^2N}{d\cos\theta^\star d\phi^\star} \propto 1 + \lambda_\theta \cos^2\theta^\star + \lambda_\phi \sin^2\theta^\star \cos 2\phi^\star + \lambda_{\theta\phi} \sin 2\theta^\star \cos\phi^\star$$

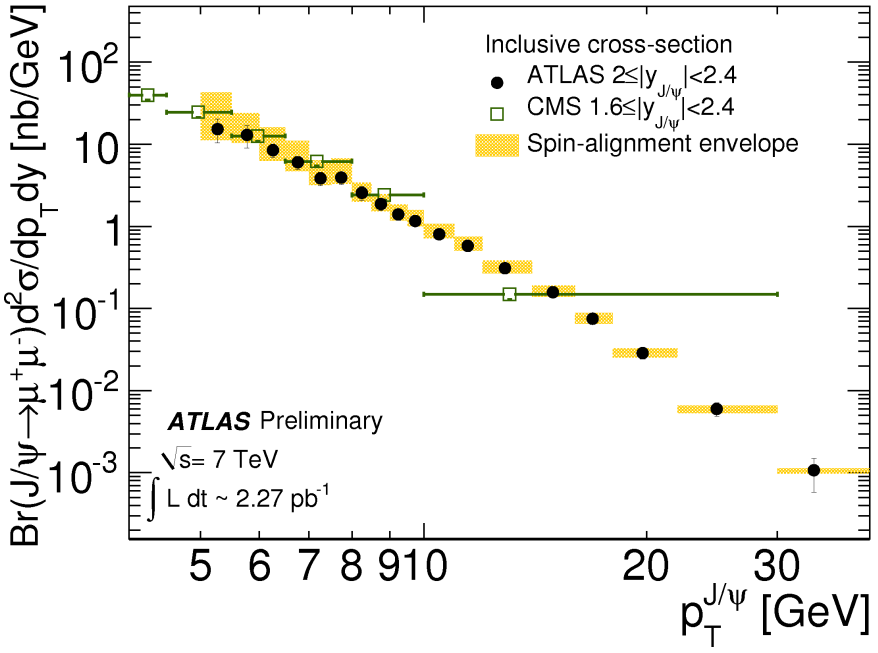
Spin alignment unknown ⇒ take extremes of coefficients as systematic uncertainty

J/ψ Inclusive Cross Sections

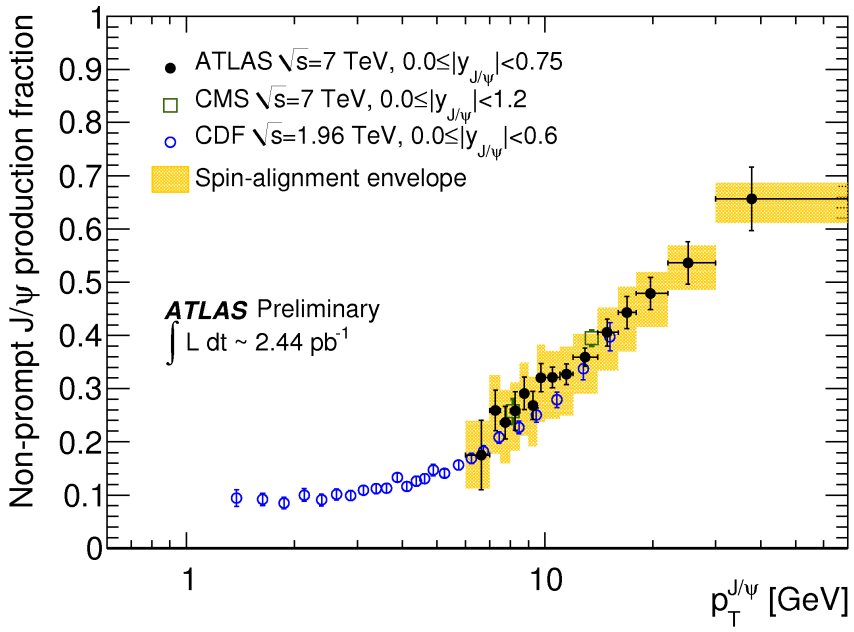


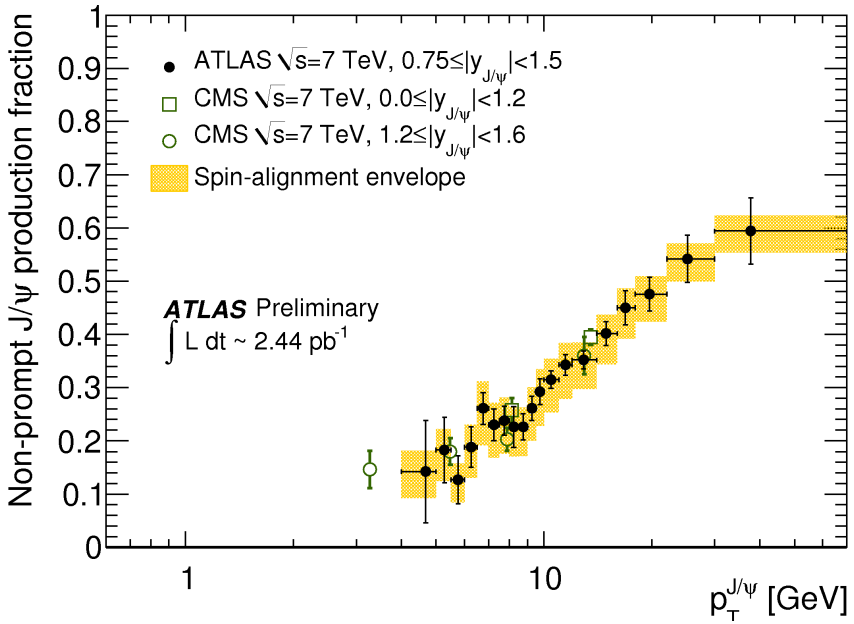


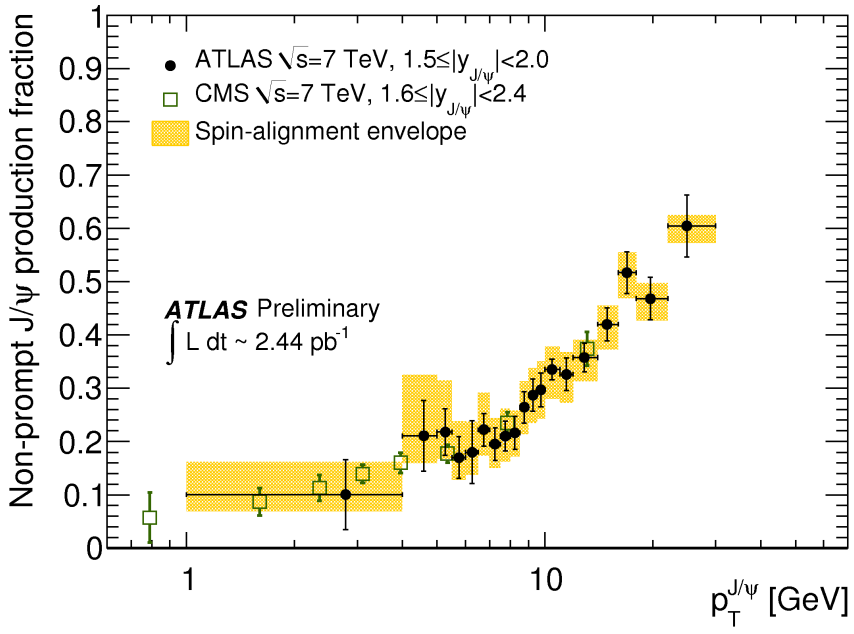


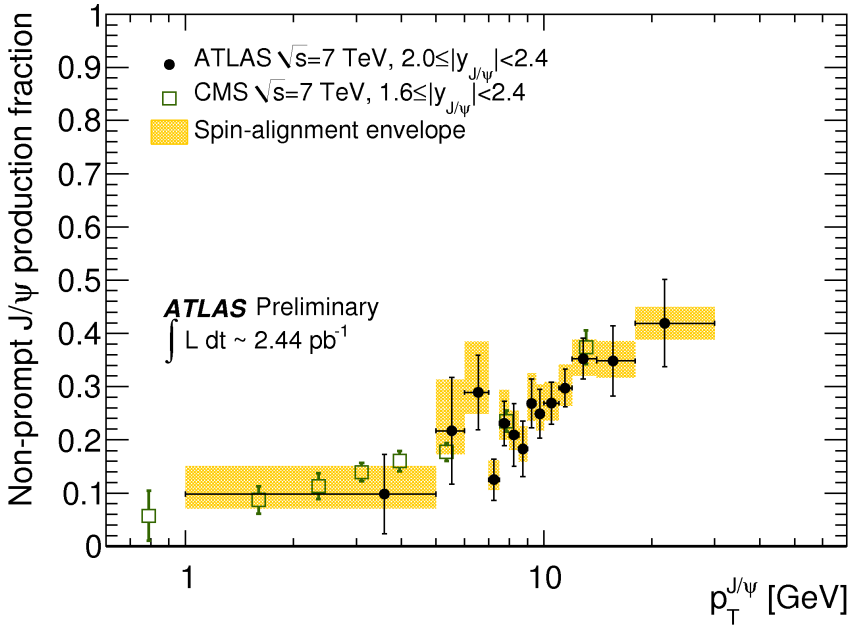


J/ψ Non-Prompt Fraction

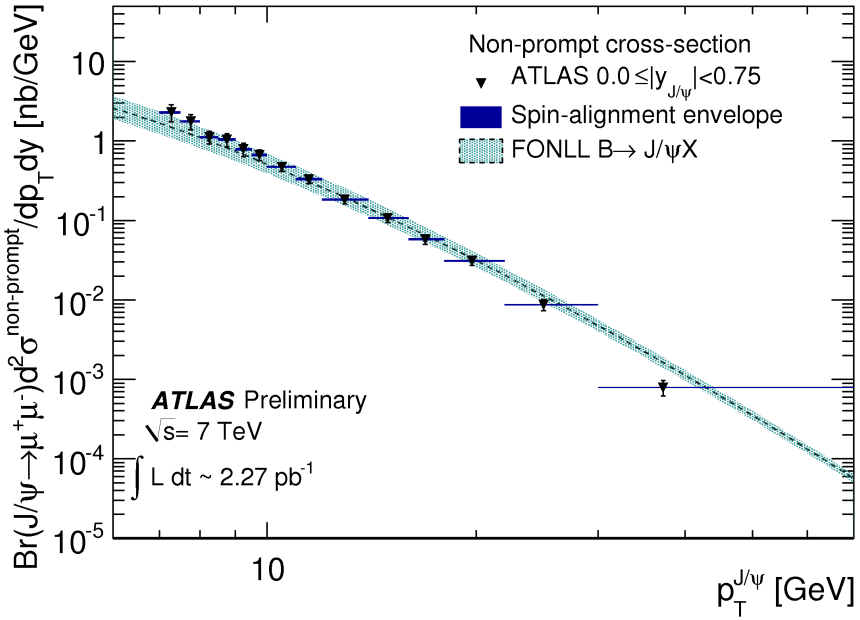


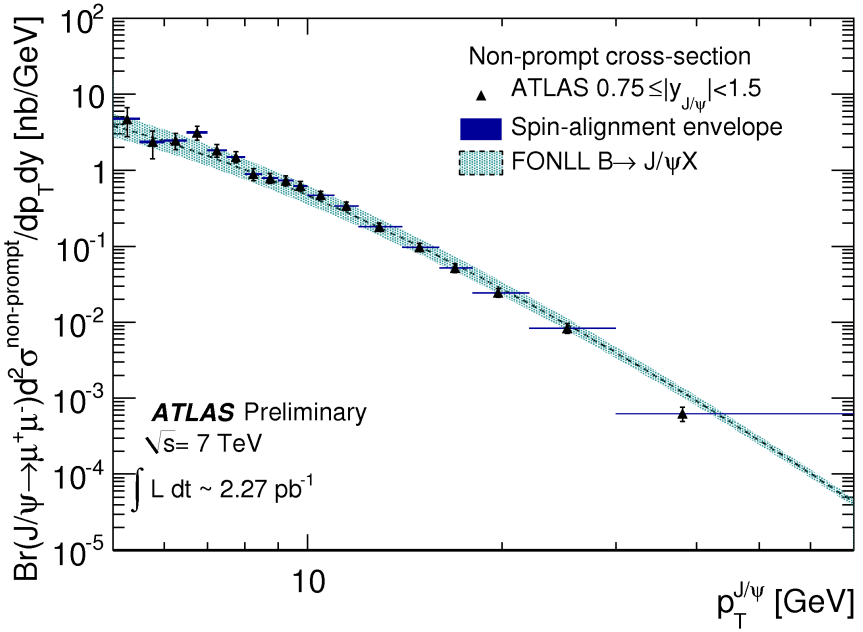


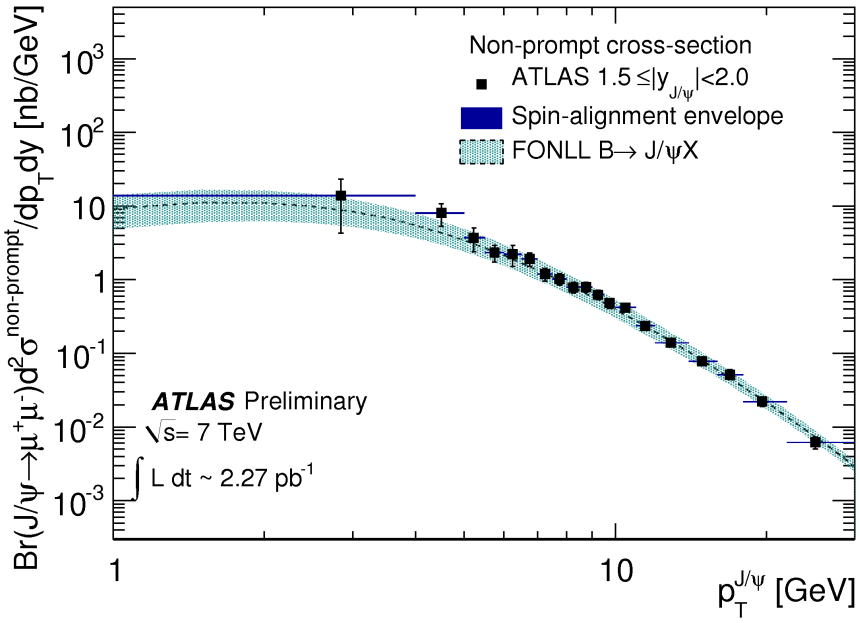


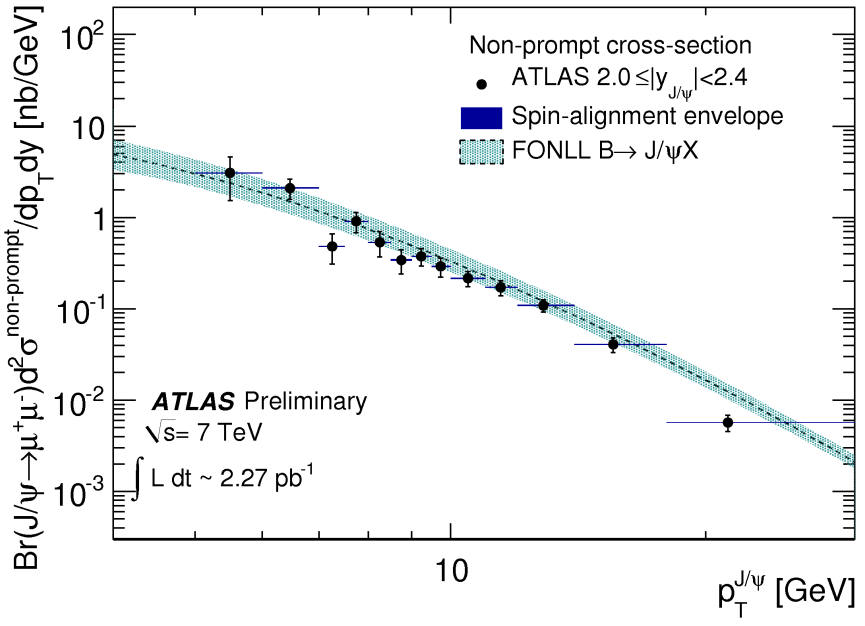


J/ψ Non-Prompt Cross Section

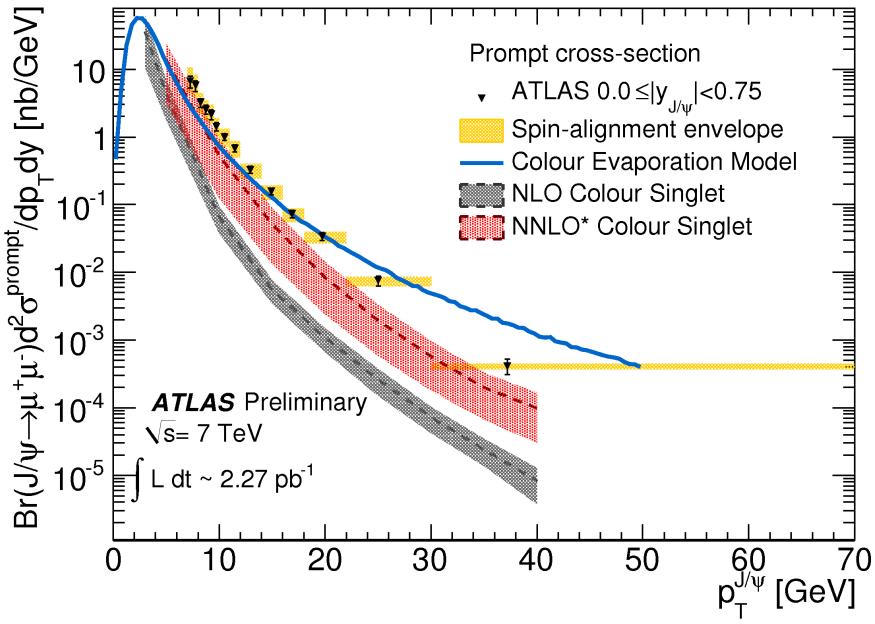


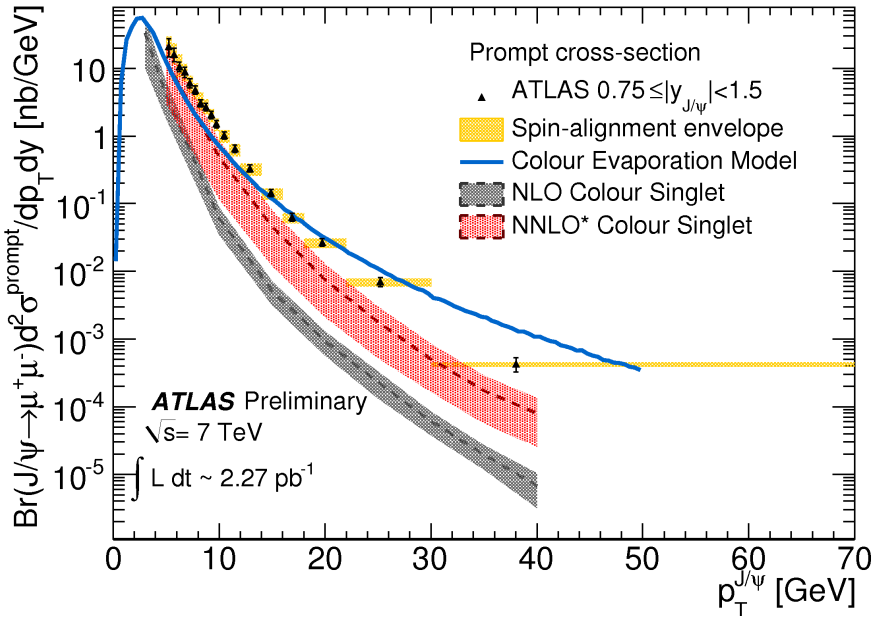


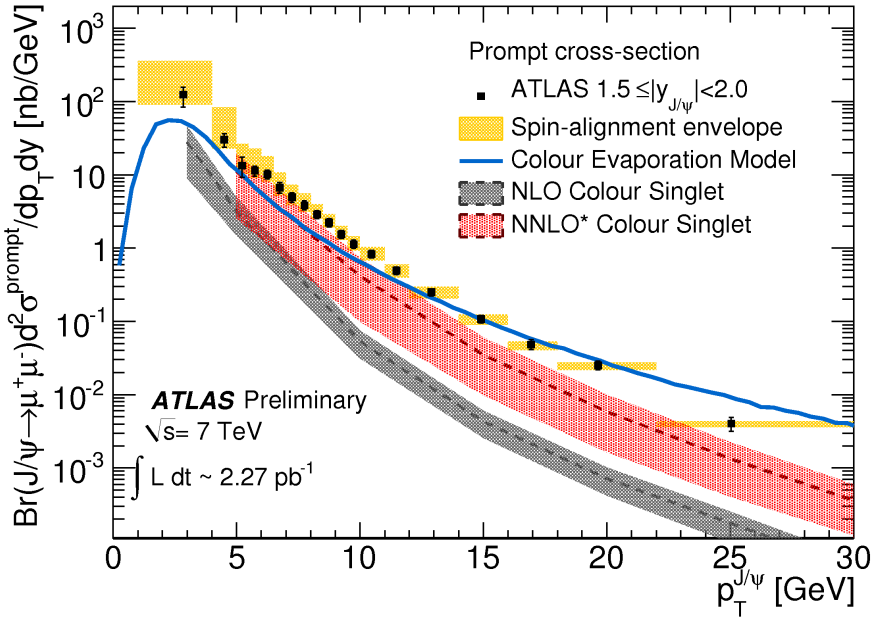


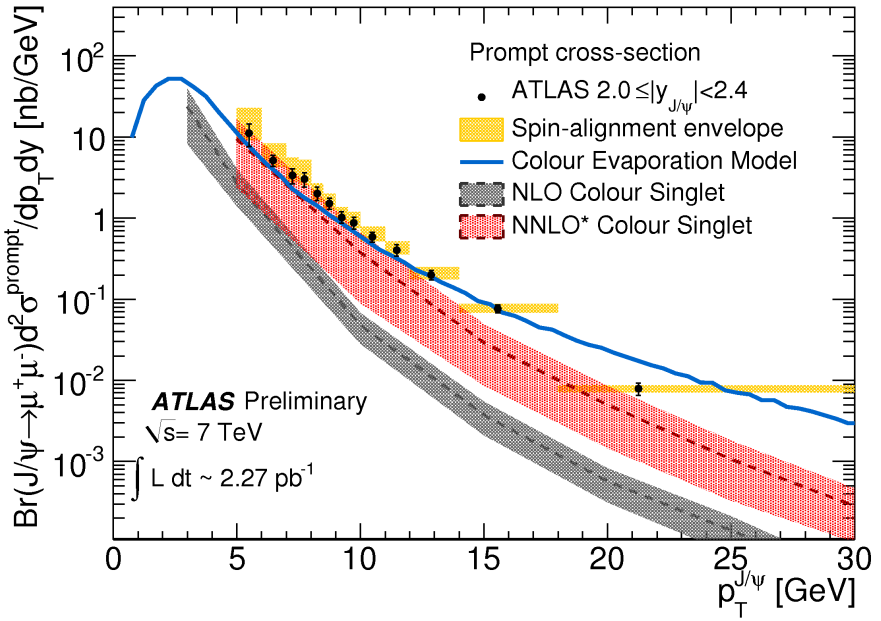


J/ψ Prompt Cross Section

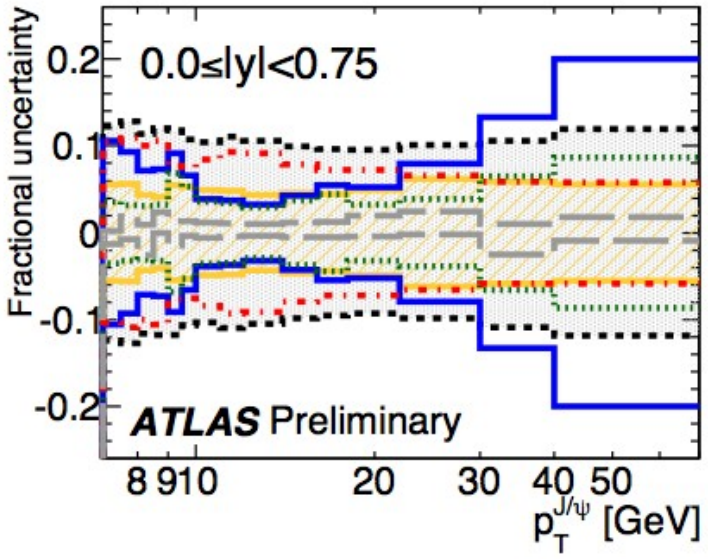


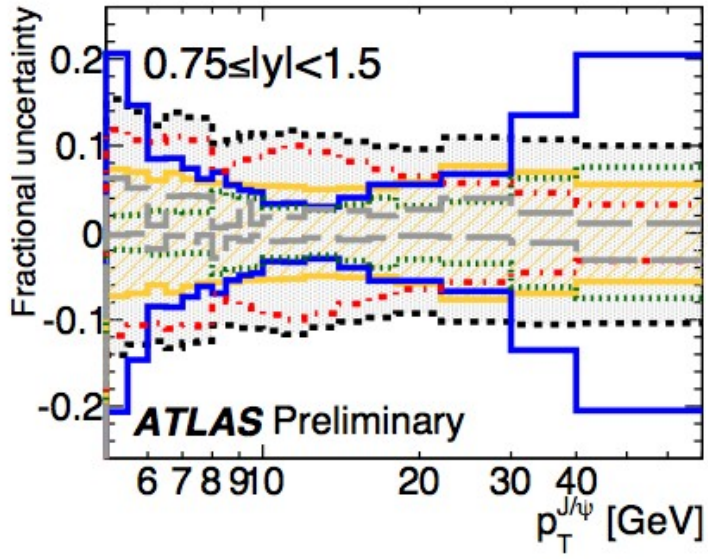


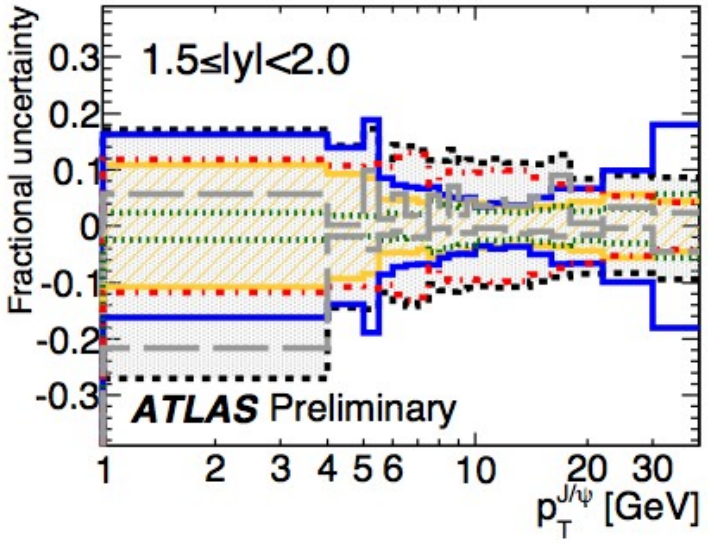


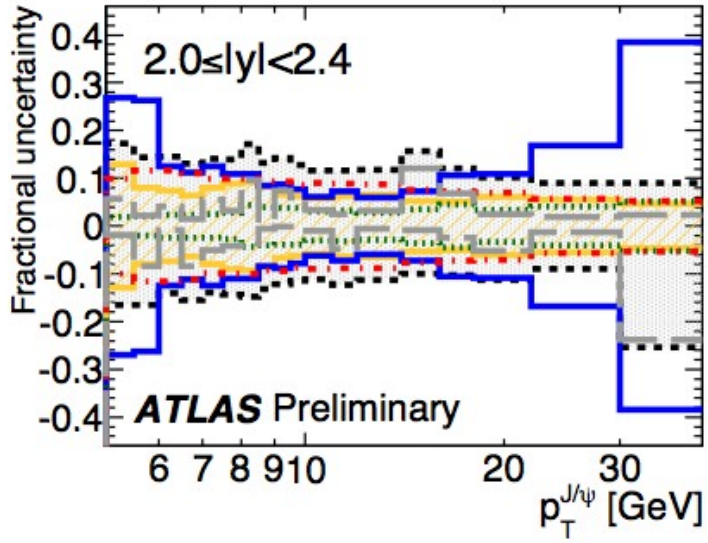


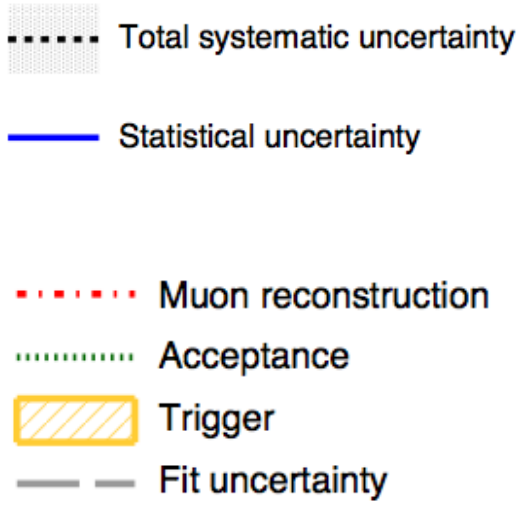
J/ψ Prompt Cross Section



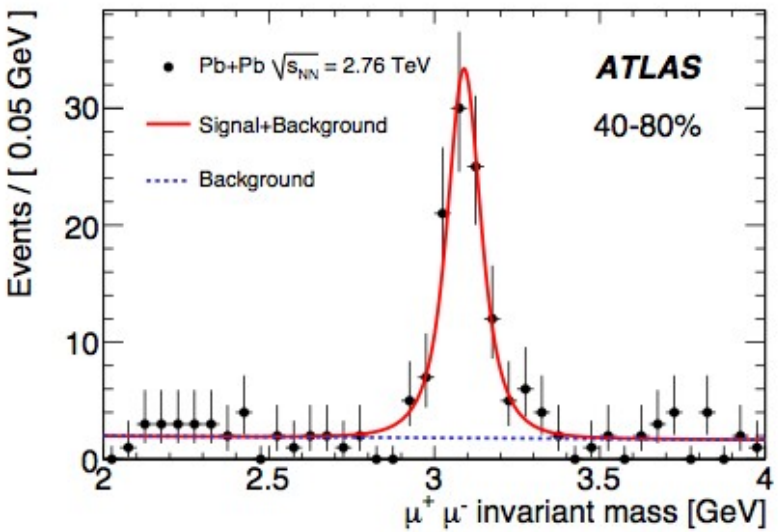


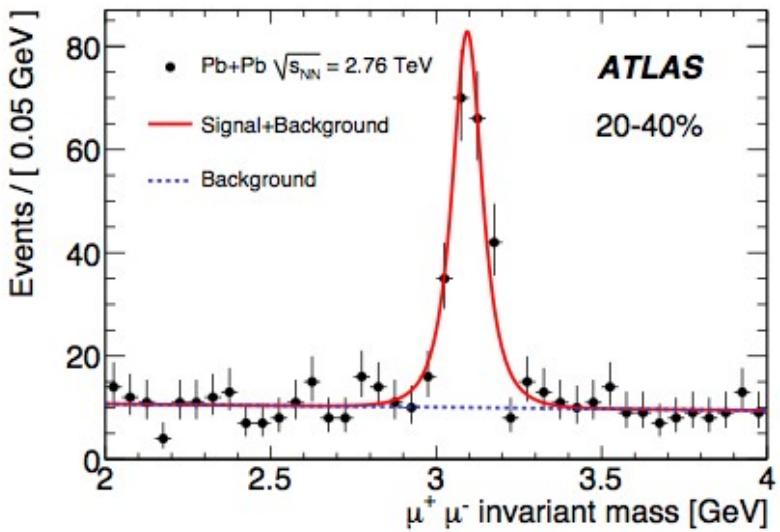


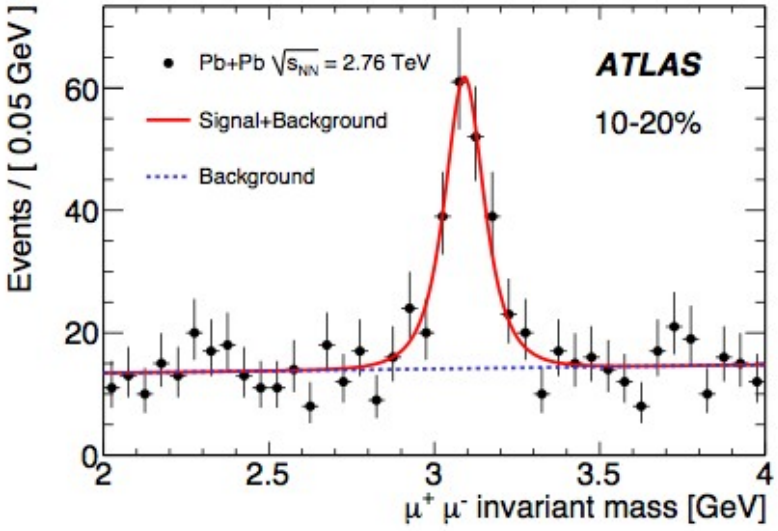


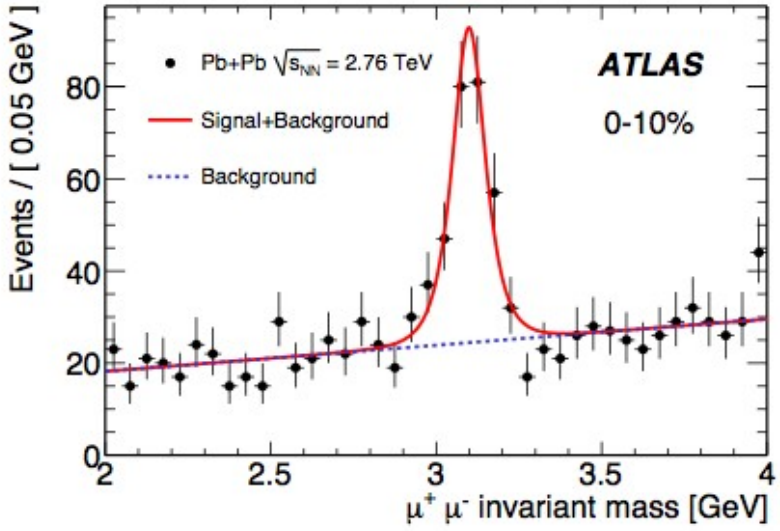


J/ψ in Heavy Ions





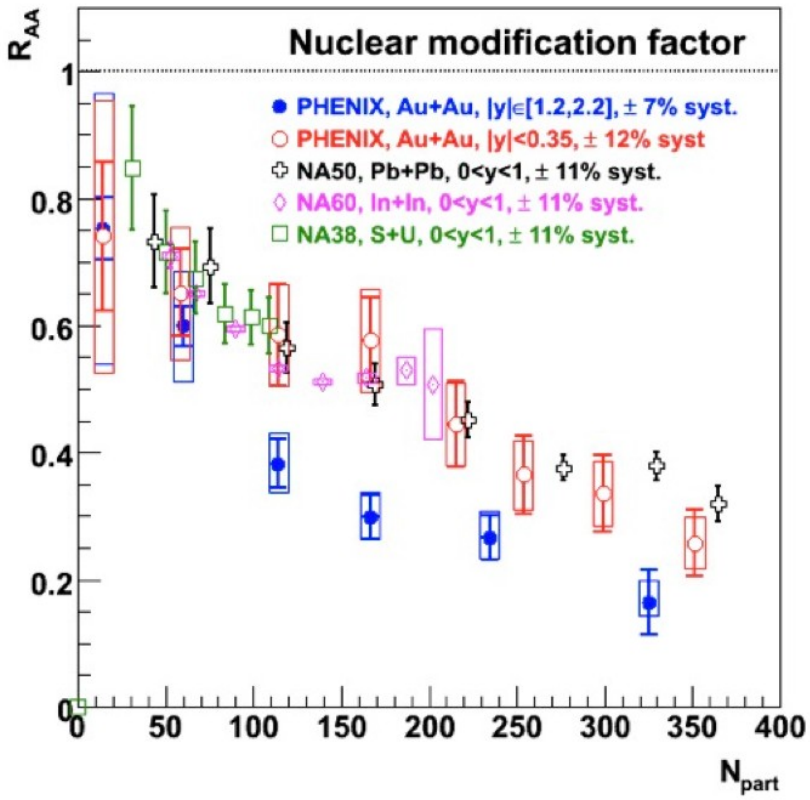


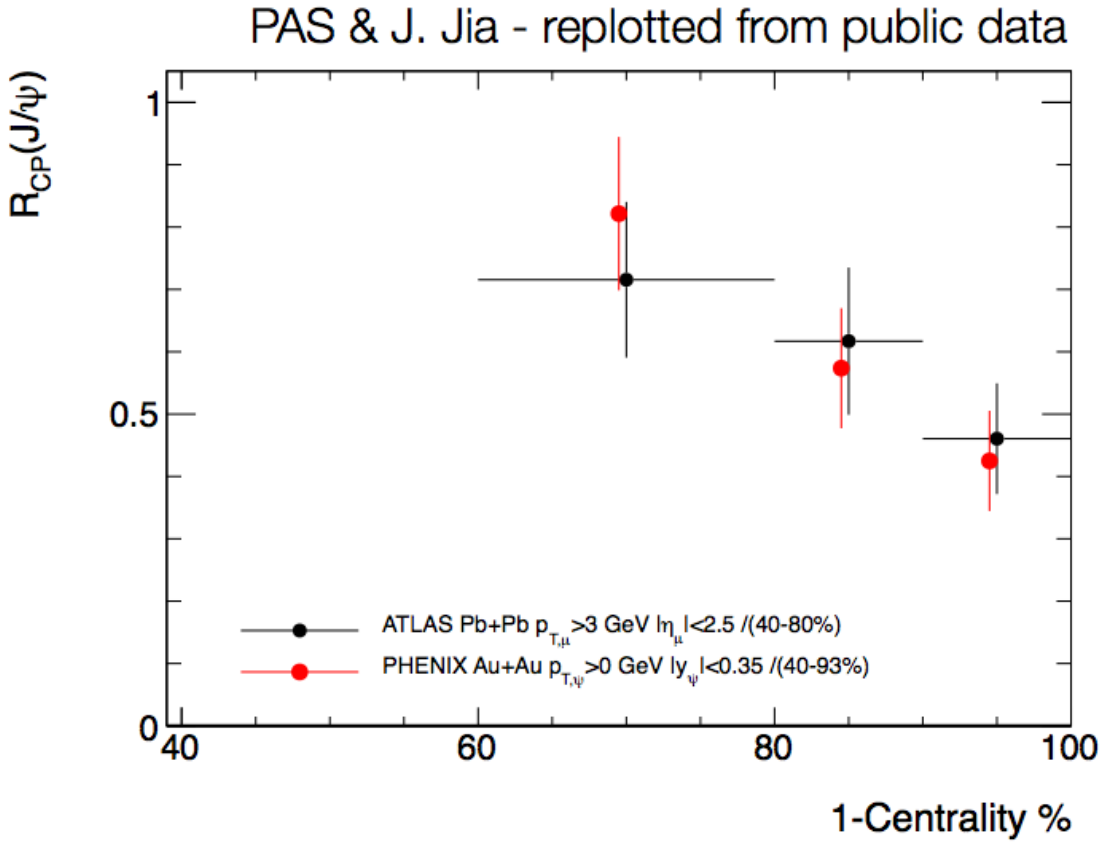


J/ψ→μμ in HI in Numbers

Centrality	$N^{\mathrm{meas}}(J/\psi)$	$\epsilon(J/\psi)_c/\epsilon(J/\psi)_{40-80}$	Systematic Uncertainty		
			Reco. eff.	Sig. extr.	Total
0-10%	190 ± 20	0.93 ± 0.01	6.8 %	5.2 %	8.6 %
10-20%	152 ± 16	0.91 ± 0.02	5.3 %	6.5 %	8.4 %
20-40%	180 ± 16	0.97 ± 0.01	3.3 %	6.8 %	7.5 %
40-80%	91 ± 10	1	2.3 %	5.6 %	6.1 %

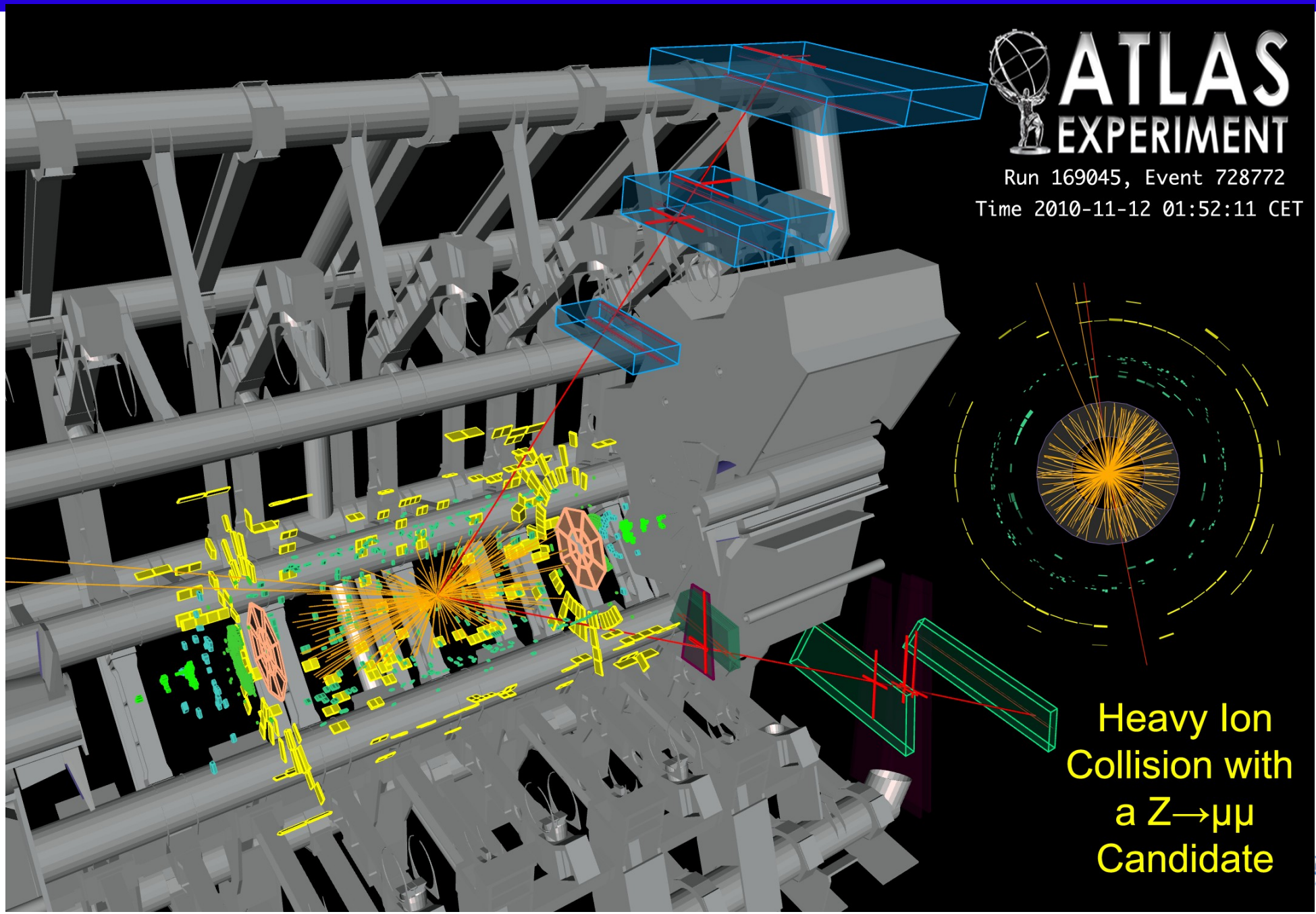
J/ψ→μμ in HI





- PHENIX data on R_{AA} (relative to p+p) recombined and ratios taken w.r.t. 40-93% bin, errors include uncorrelated & estimate of Ncoll errors
- Centrality dependence of suppression appears invariant with beam energy

Z in HI


ATLAS
EXPERIMENT
Run 169045, Event 728772
Time 2010-11-12 01:52:11 CET
Heavy Ion
Collision with
a Z→μμ
Candidate