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Standard Model & Flavour Physics measurements with the ATLAS Detector

on behalf of the ATLAS collaboration

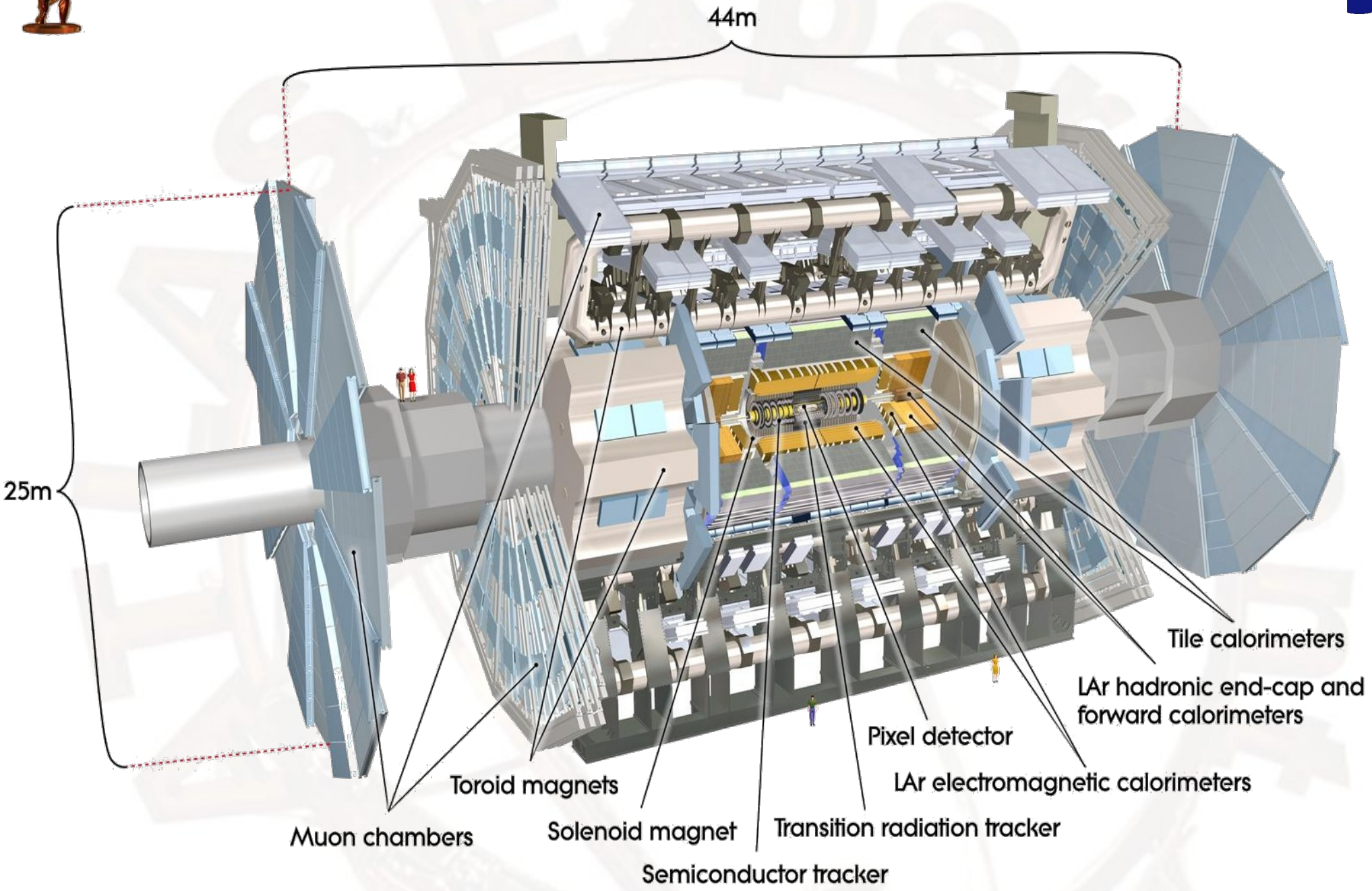
Cracow Epiphany Conference 2014

Introduction

Introduction

- Energy ranges available at the LHC were never explored before.
- Measurements of Standard Model parameters are needed to validate theoretical extrapolations from lower-energy regimes.
- Precision measurements may reveal contributions from New Physics' processes to the studied phenomena.
- Improved precision of known parameters is possible to achieve with large available data samples.
- Data-based understanding of processes which constitute backgrounds for New Physics searches & Higgs observations is required.

The ATLAS detector

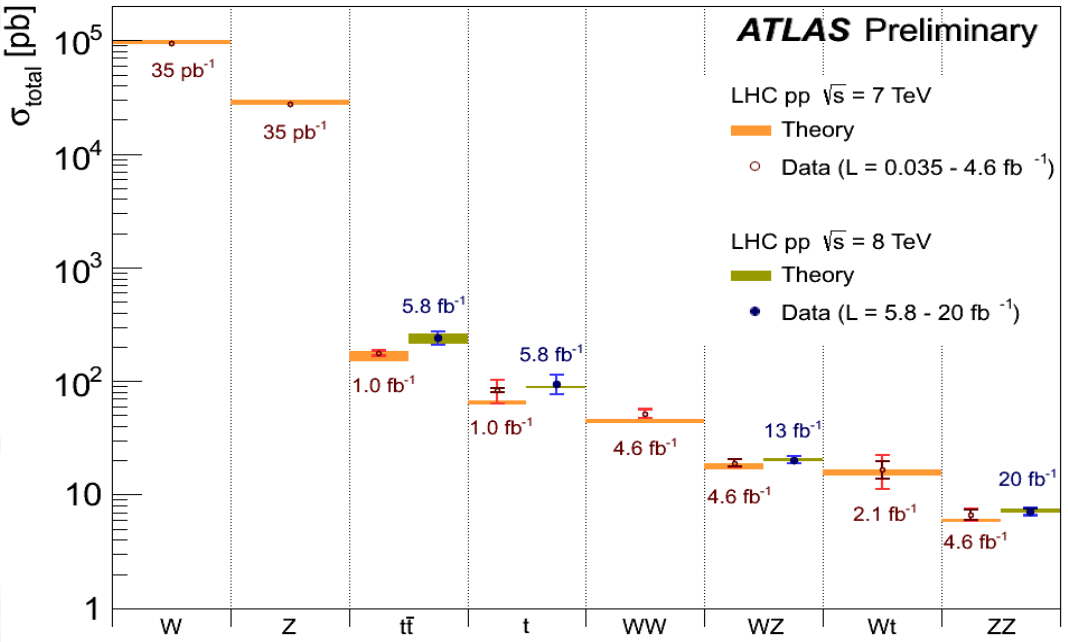


Standard Model results

Standard Model results

ATLAS has published over 70 papers on Standard Model measurements. This talk covers only a small fraction of results:

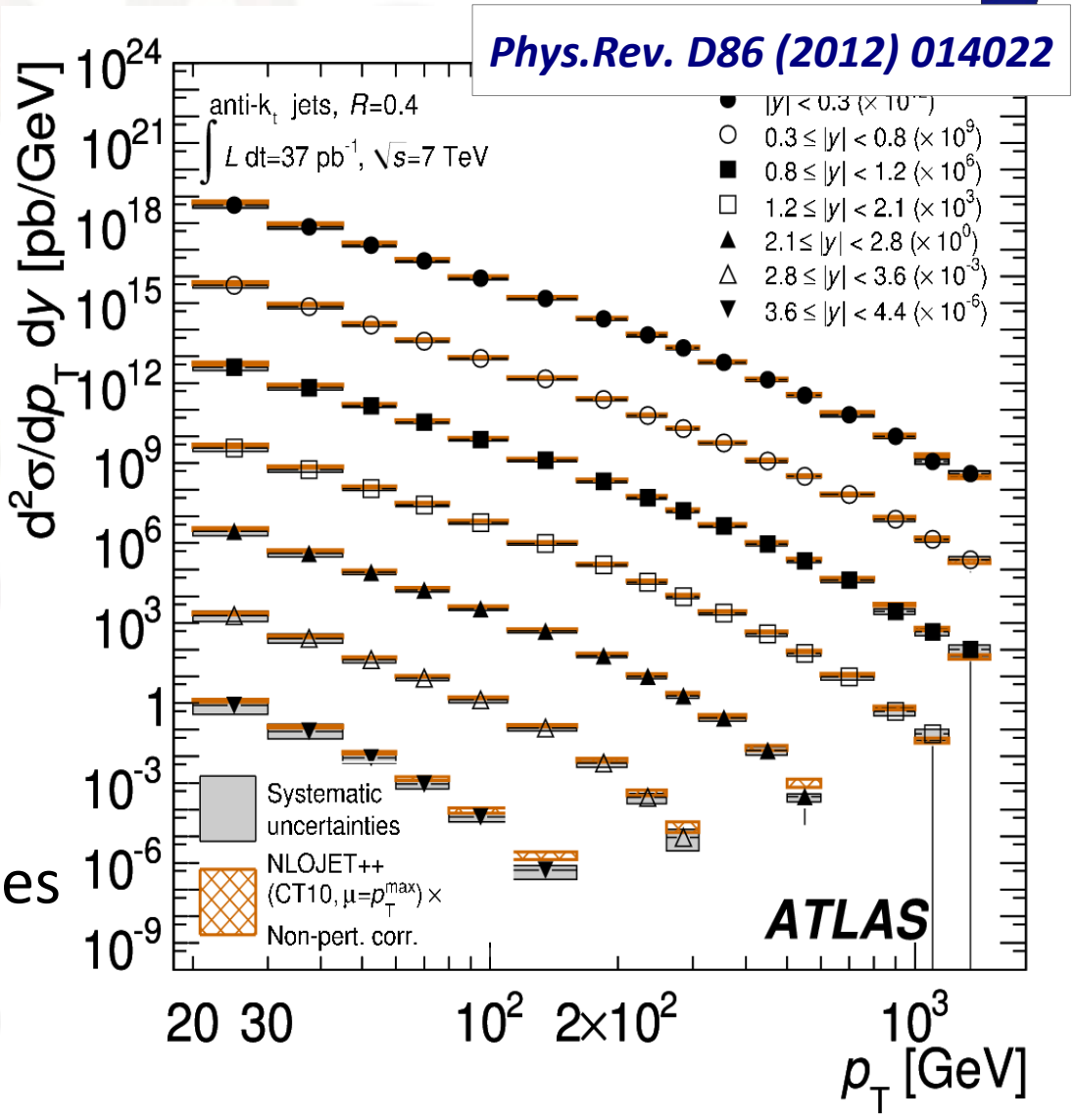
- **QCD**
  - Inclusive jet cross-section
  - Jet cross-section ratio
  - Running of α_s
  - Inclusive photon cross-section
- **Electroweak**
  - W&Z bosons inclusive
  - A_{FB} in Z decays
  - Z + jets production
  - W+charm production
  - High-mass Drell – Yan
  - Dibosons



Inclusive jet cross-section

Phys.Rev. D86 (2012) 014022

- This measurement probes perturbative QCD and Parton Density Functions
- Measured with 2010 dataset of 37 pb^{-1} at $\sqrt{s}$ = 7 TeV
- Double-differential cross-section versus jet p_T and raipdity
- Jets reconstructed with Anti-k_T algorithm with 0.4 and 0.6 cone sizes
- Good agreement with pQCD description is found up to high energies (1.5 TeV)

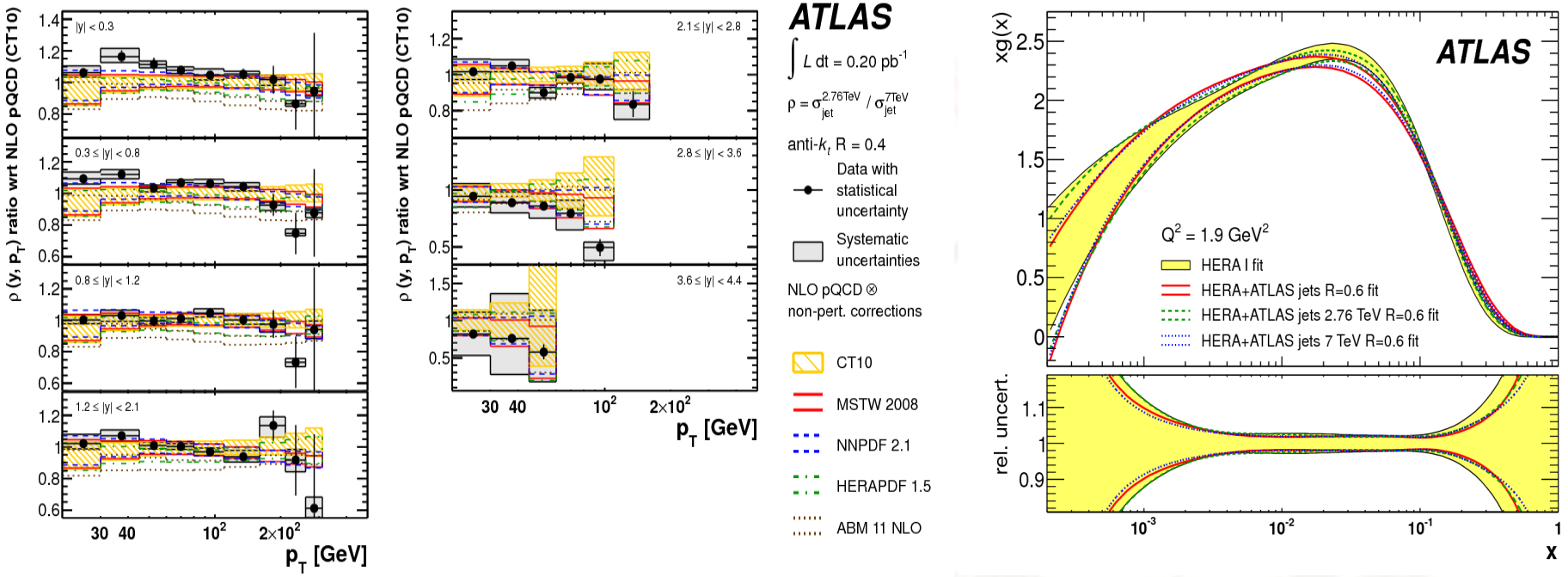


- Main source of systematics: Jet Energy Scale

Jet cross-section ratio

EPJC (2013) 73 2509

- Measured the ratio of double-differential cross-sections vs p_T in bins of jet rapidity for $\sqrt{s}$ = 7 TeV and $\sqrt{s}$ = 2.76 TeV
- Large reduction of systematic uncertainties in the ratio – better sensitivity to PDFs
- May be used to fit PDFs together with HERA data

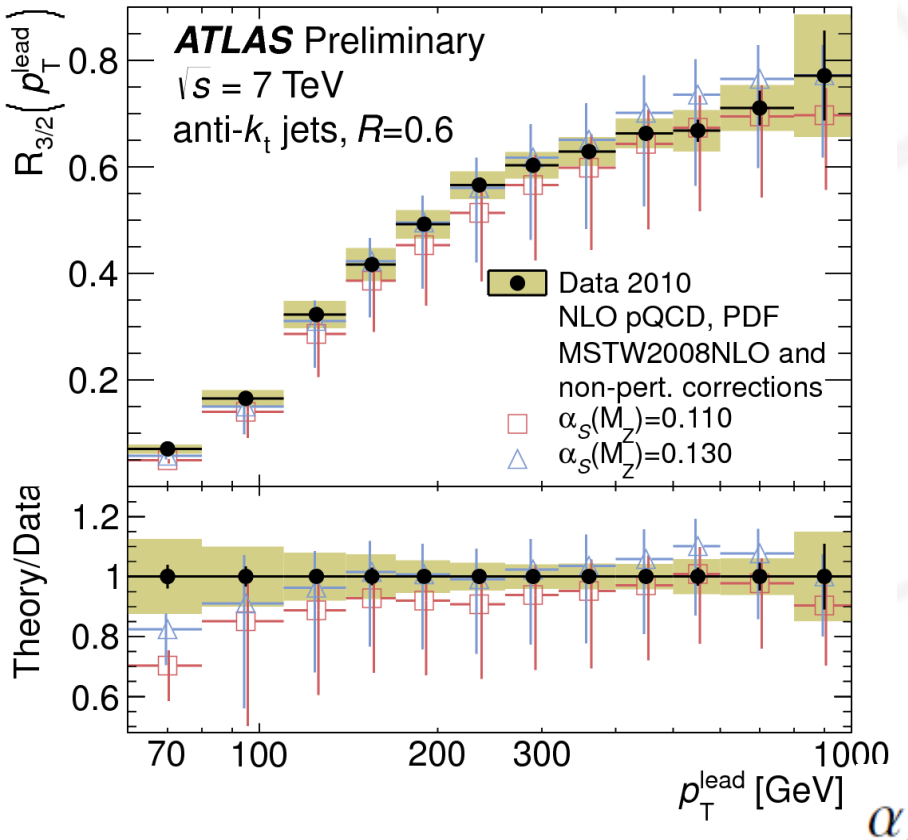


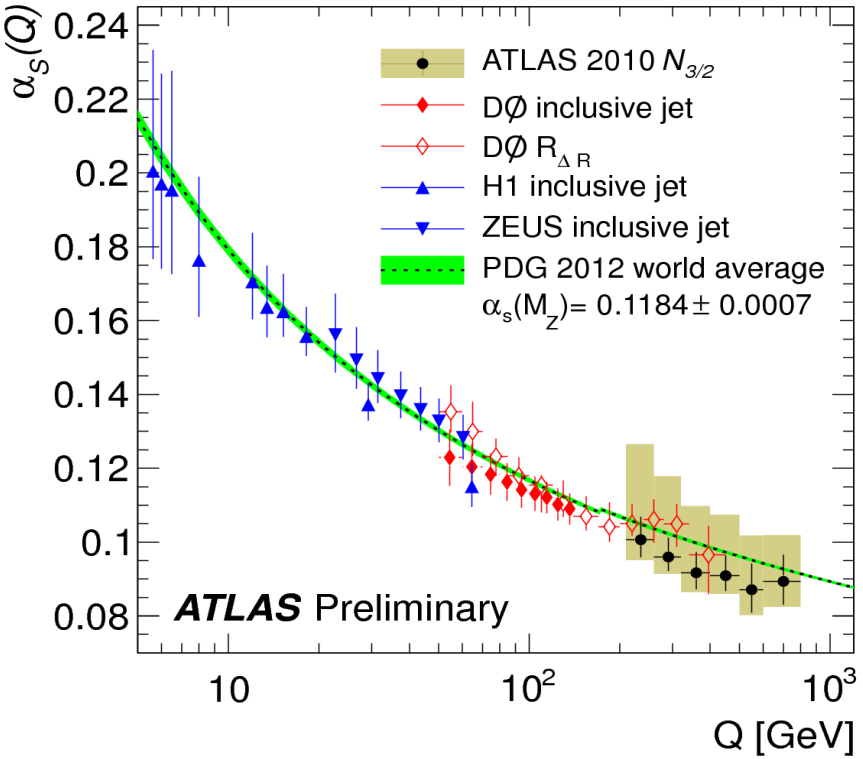
Running of α_s

ATLAS-CONF-2013-041

- Number of events with additional radiated parton is proportional to α_s
- Measured a ratio of 3-jet vs 2-jet events with respect to leading-jet p_T:

$$R_{3/2}(p_T^{\text{lead}}) = \frac{d\sigma_{N_{\text{jet}}\geq 3}/dp_T^{\text{lead}}}{d\sigma_{N_{\text{jet}}\geq 2}/dp_T^{\text{lead}}}$$





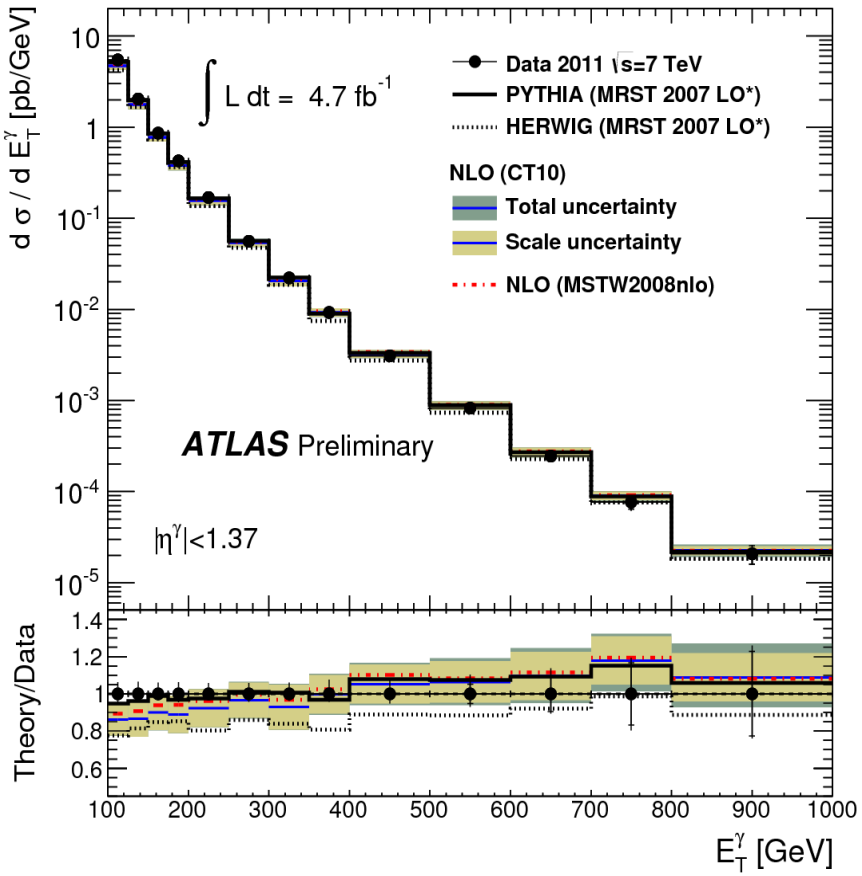
- Extraction of α_s with a fit to theory as a function of $\alpha_s(M_Z)$

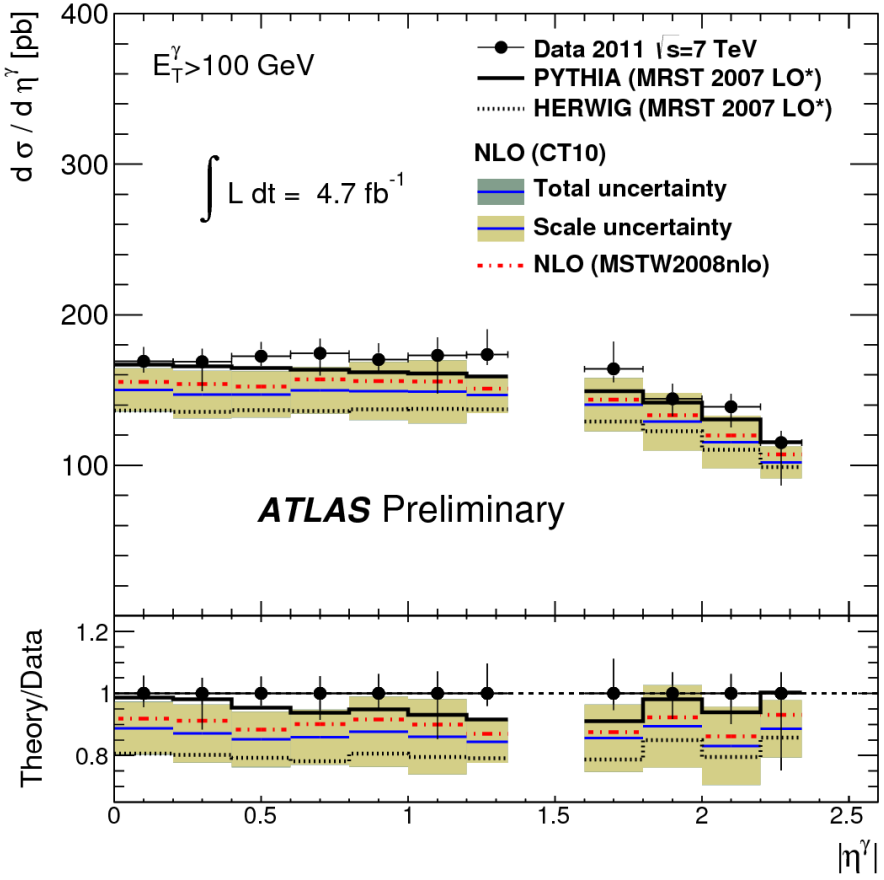
$$\alpha_s(M_Z) = 0.111 \pm 0.006(\text{exp.}) \,{}^{+0.016}_{-0.003}(\text{theory}).$$

Inclusive photon cross-section

ATLAS-CONF-2013-022

- Cross-section for isolated prompt photons production measured with 7 TeV data (4.9 fb^{-1}) as a function of photon transverse energy.
- Comparisons to NLO pQCD calculations show good agreement in differential cross-sections.

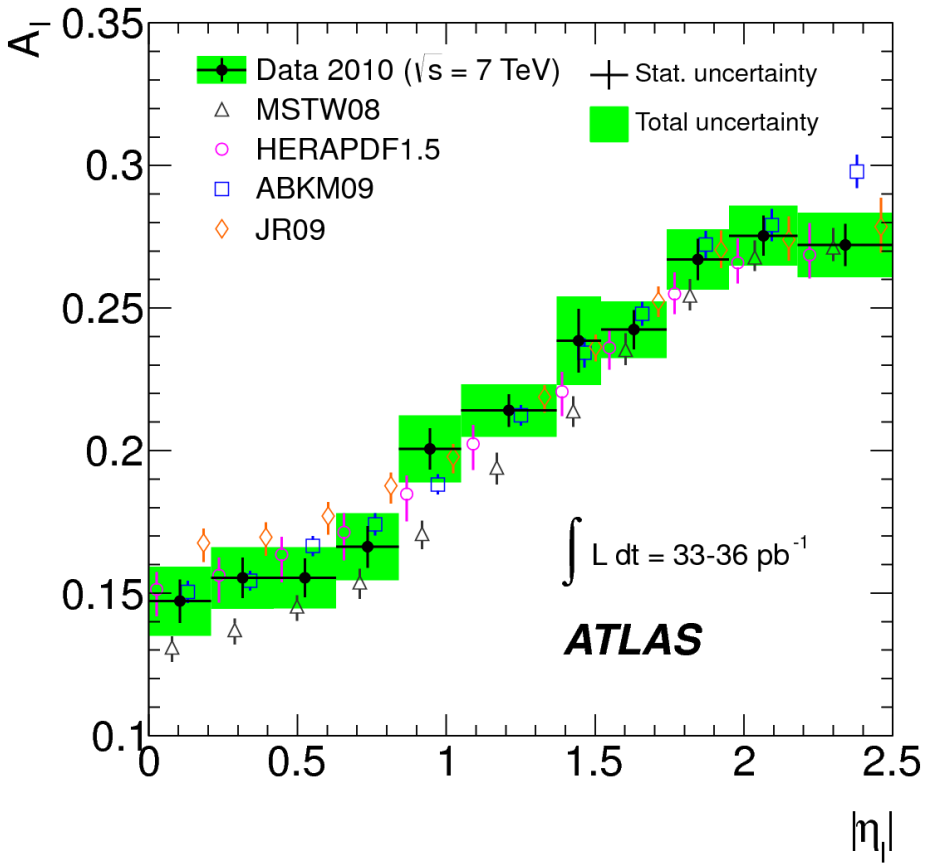


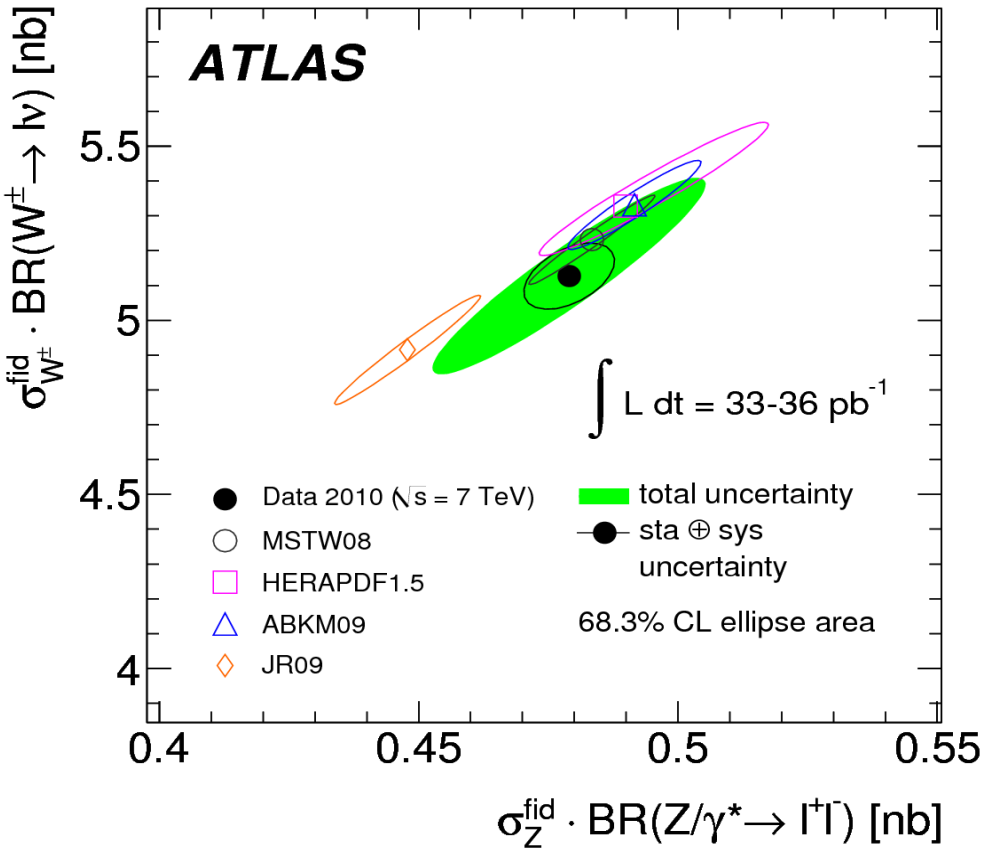


W & Z bosons

Phys. Rev. D85 (2012) 072004

- Measurements performed with 2010 dataset (up to 36 pb^{-1} @ 7 TeV)
- The cross-sections for W & Z boson inclusive production found to be in a good agreement with Standard Model
- W charge asymmetry provides constraints on PDFs

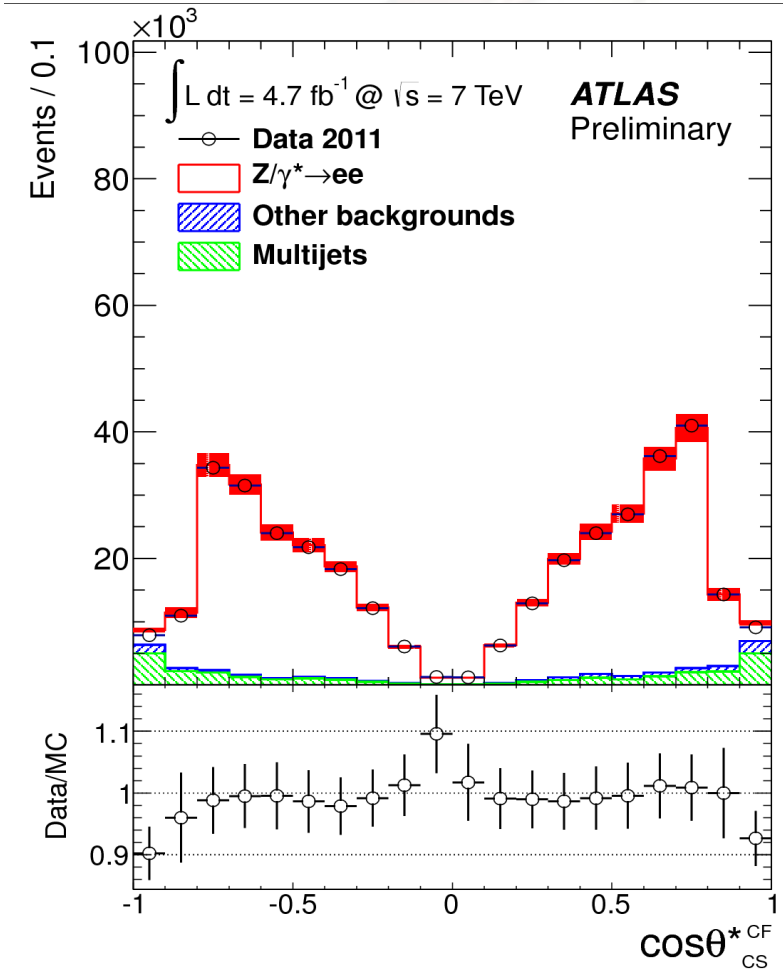




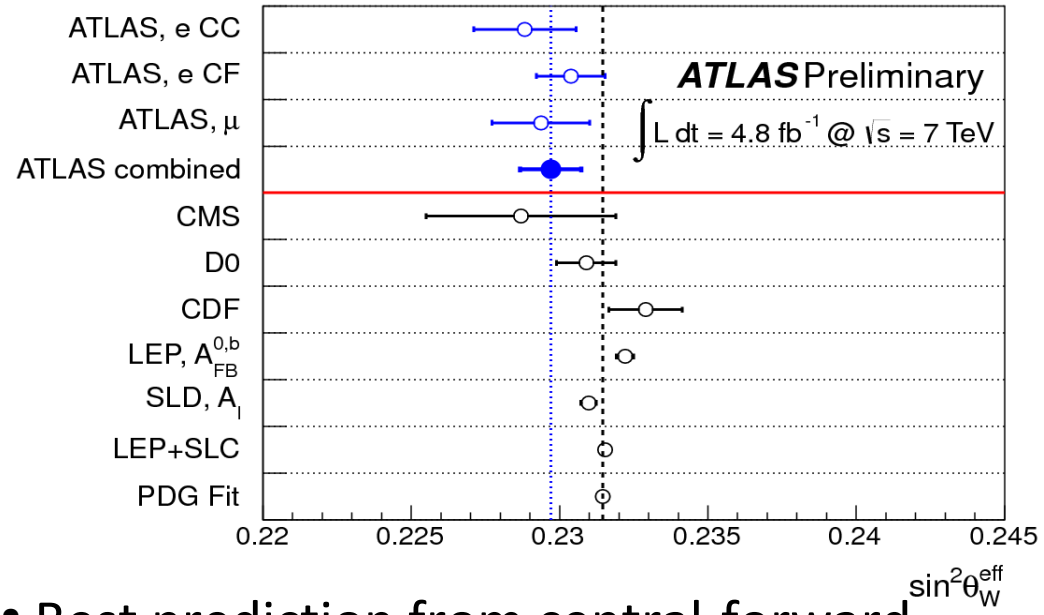
Forward-backward asymmetry in Z decays

ATLAS-CONF-2013-043

- Measured with 4.7 fb^{-1} of data @ 7 TeV
- The Forward – Backward asymmetry of lepton pairs is sensitive to weak mixing angle, $\sin^2\theta_W$



- $\sin^2\theta_W$ is extracted from A_{FB} spectra by comparing to MC predictions with varying initial conditions

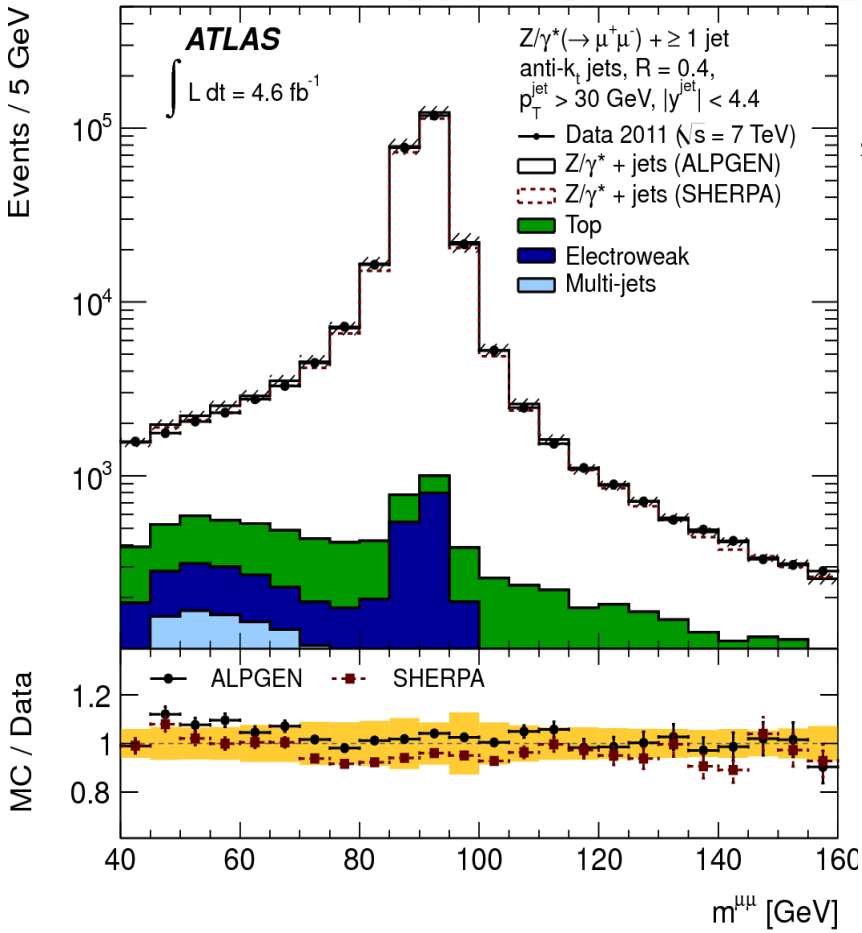


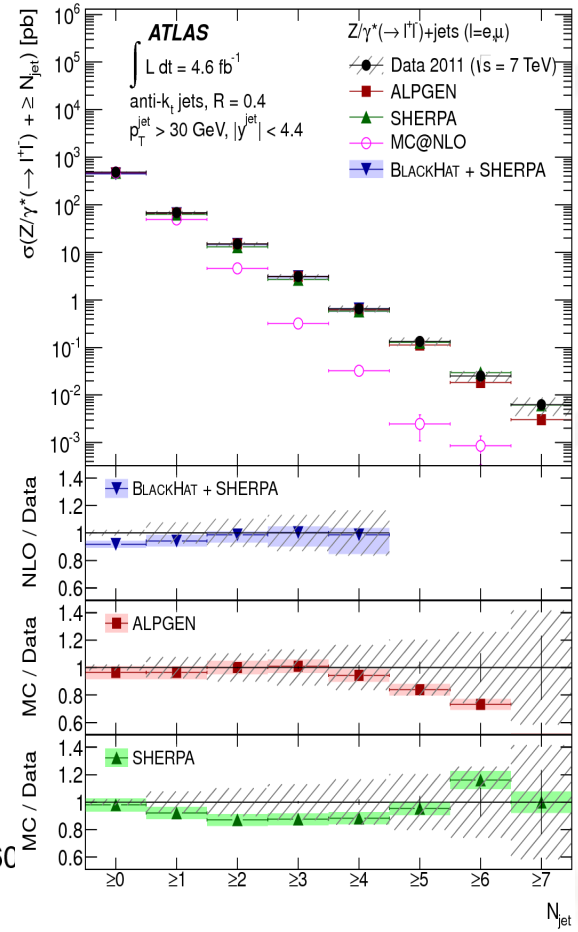
- Best prediction from central-forward electron final state
- $\sin^2\theta_W = 0.2297 \pm 0.0004(stat) \pm 0.0009(syst)$

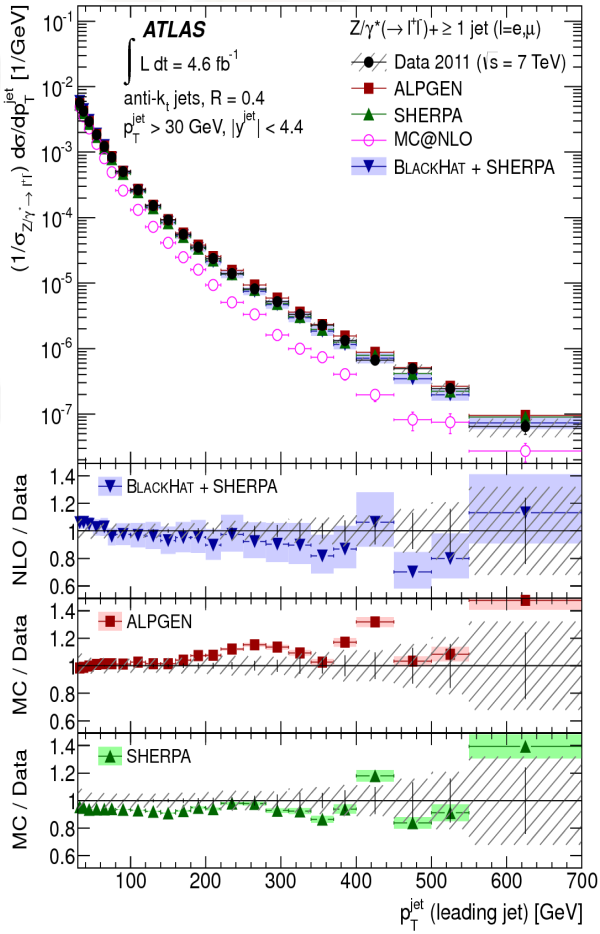
Z + jets production

JHEP07(2013)032

- Measured total and differential cross-section for the production of Z boson in association with jets
- Possible to check NLO predictions of jet multiplicities and momenta



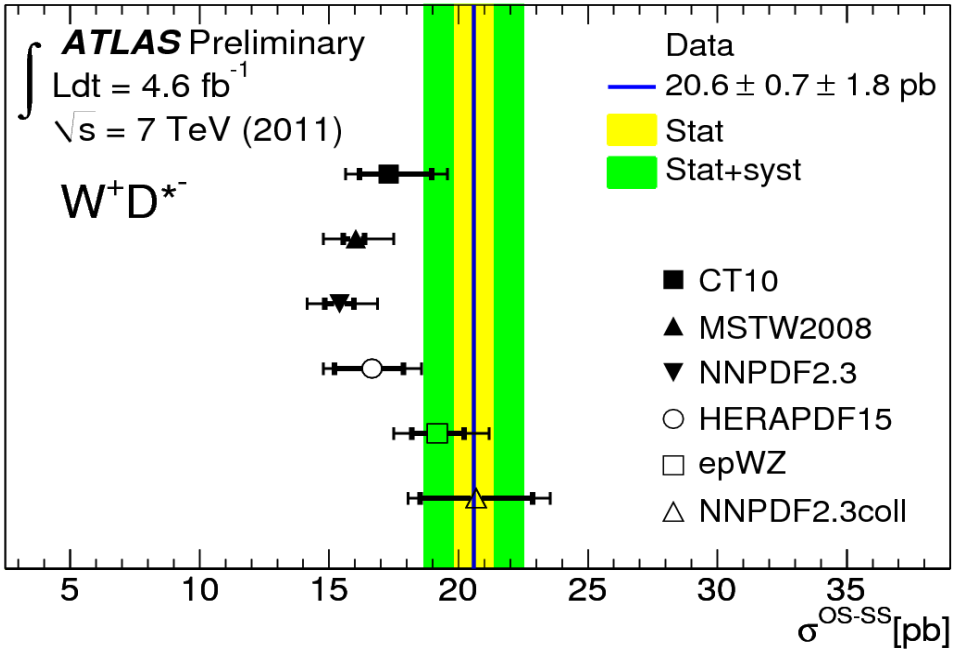


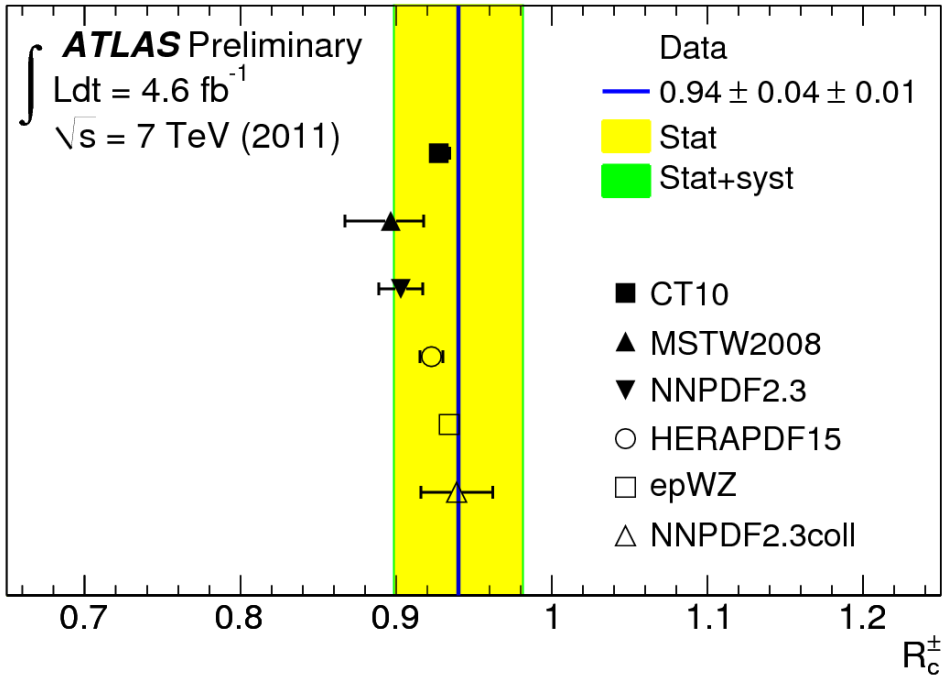


W + charm production

ATLAS-CONF-2013-045

- Measured in 4.6 fb^{-1} of data @ 7 TeV
- Charm quark tagged by the presence of charm hadron decay such as: $D^+ \to K^+\pi^+\pi^-$, $D^{*+} \to D^0\pi^+$ with $D^0 \to K^-\pi^+$, $D^0 \to K^-\pi^+\pi^0$, $D^0 \to K^-\pi^+\pi^-\pi^+$ using track-based reconstruction and charge correlation with W
- Ratio of cross-sections is sensitive to PDFs: $R_c^{\pm} \equiv \sigma(W^+D^{(*)-})/\sigma(W^-D^{(*)+})$

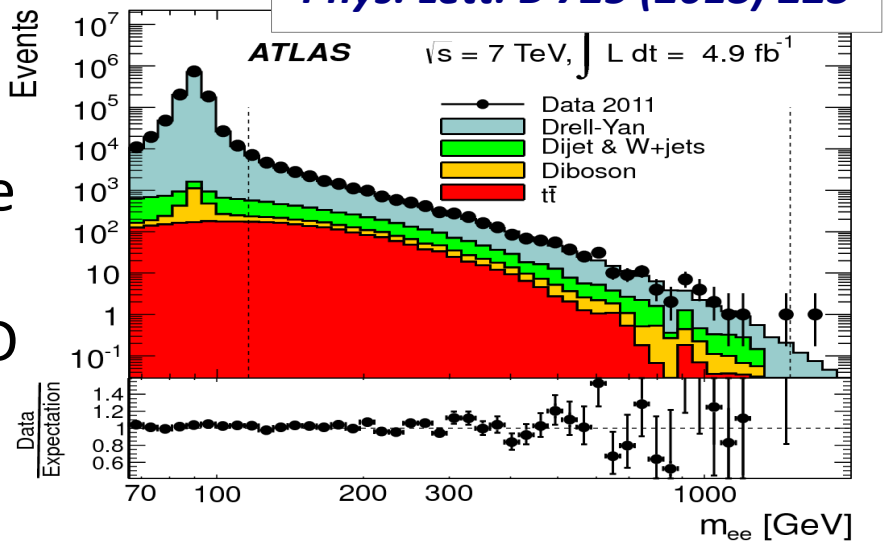


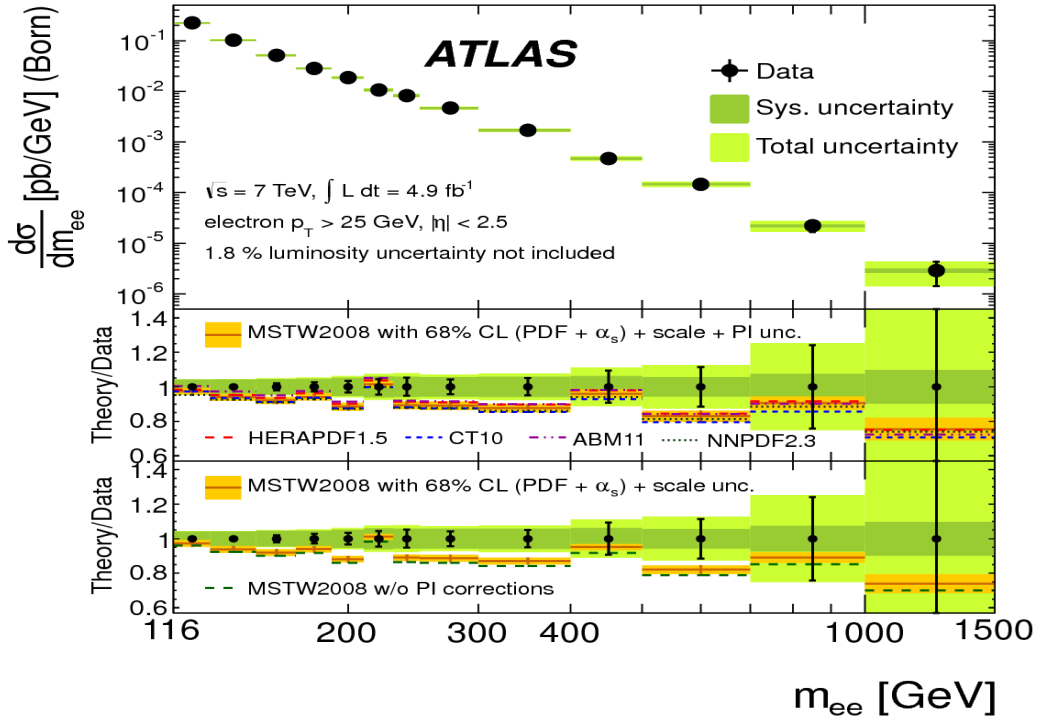


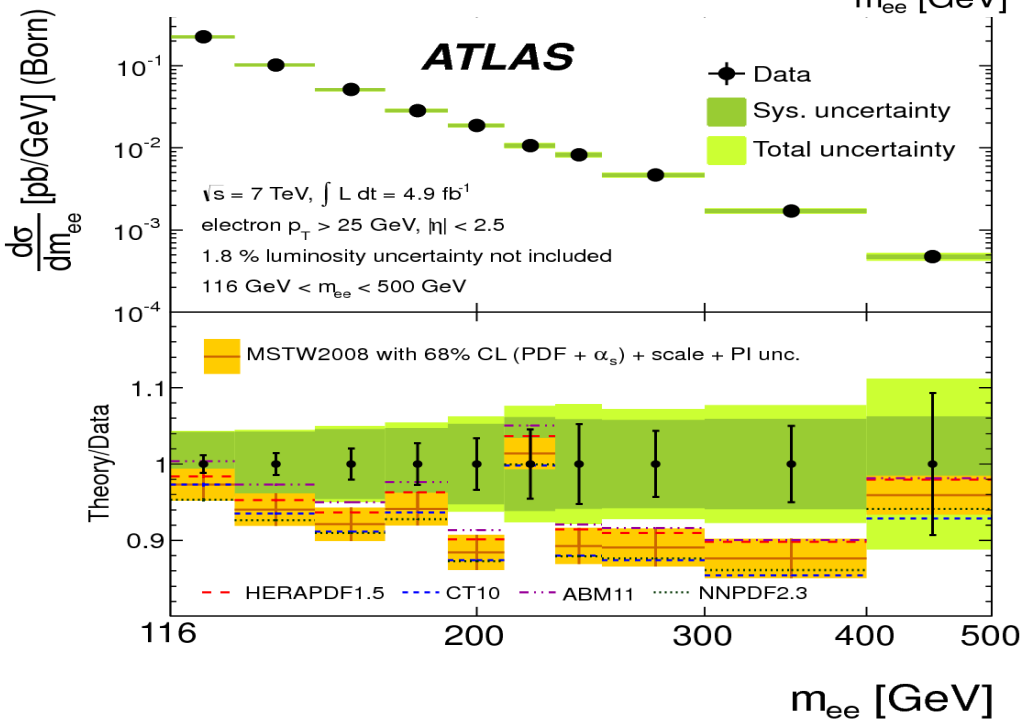
High-mass Drell – Yan processes

- Measurement performed with 4.9 fb^{-1} of data at 7 TeV
- Possible to measure cross-section high above Z-mass peak
- Provides (yet another) precision test of pQCD (NNLO), possible to give some constraints on PDFs (for antiquarks at large *x*)

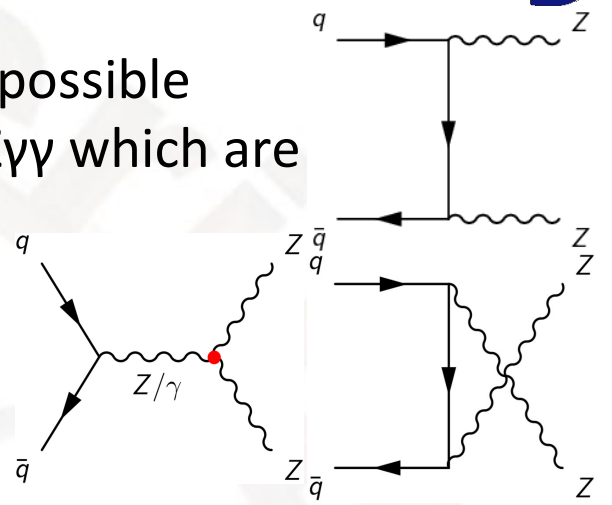
Phys. Lett. B 725 (2013) 223







Diboson production



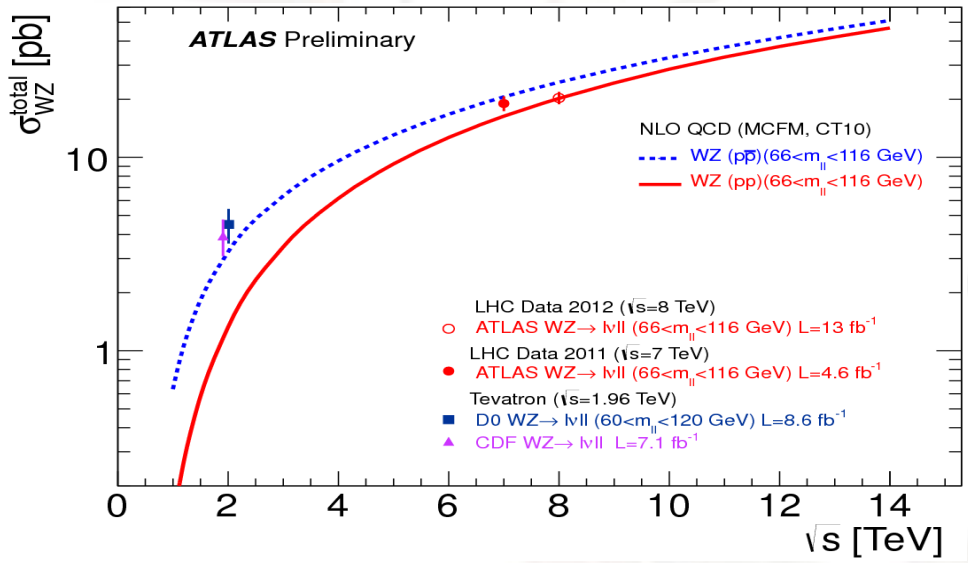
- Diboson production probes Triple-Gauge Couplings (TGC) – possible manifestation of New Physics in neutral TGC's (ZZγ, ZZZ and Zγγ which are not allowed in SM)
- It constitutes a significant irreducible background to Higgs measurements (in WW and ZZ channels)
- Measured cross-sections at 8 TeV (13 – 20 fb^{-1}):

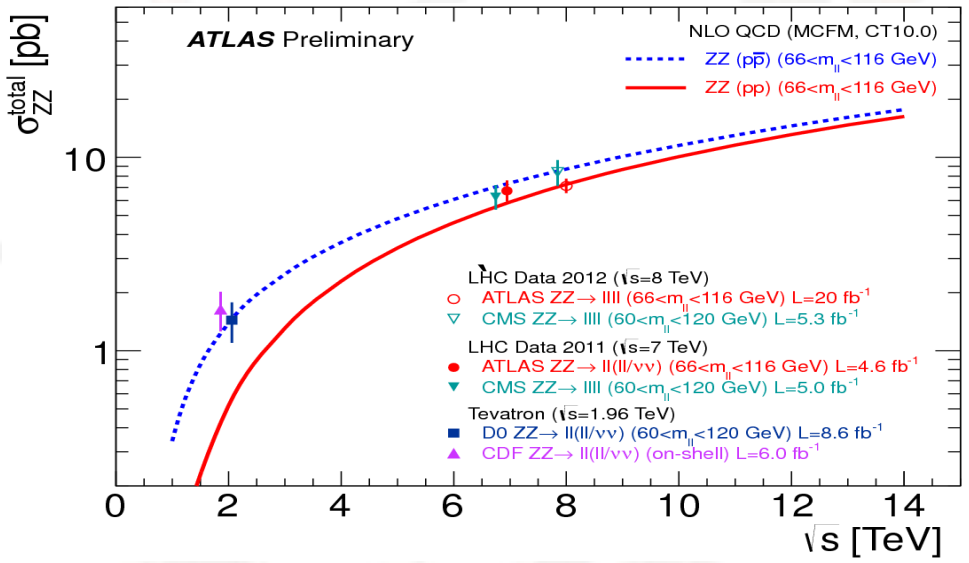
$$\sigma^{tot}_{WZ} = 20.3^{+0.8}_{-0.7}(\text{stat.})\ ^{+1.2}_{-1.1}(\text{syst.})\ ^{+0.7}_{-0.6}(\text{lumi.})\ \text{pb}$$

ATLAS-CONF-2013-021

$$\sigma^{\text{tot}}_{ZZ} = 7.1^{+0.5}_{-0.4}(\text{stat.}) \pm 0.3(\text{syst.}) \pm 0.2(\text{lumi.})\ \text{pb}$$

ATLAS-CONF-2013-020



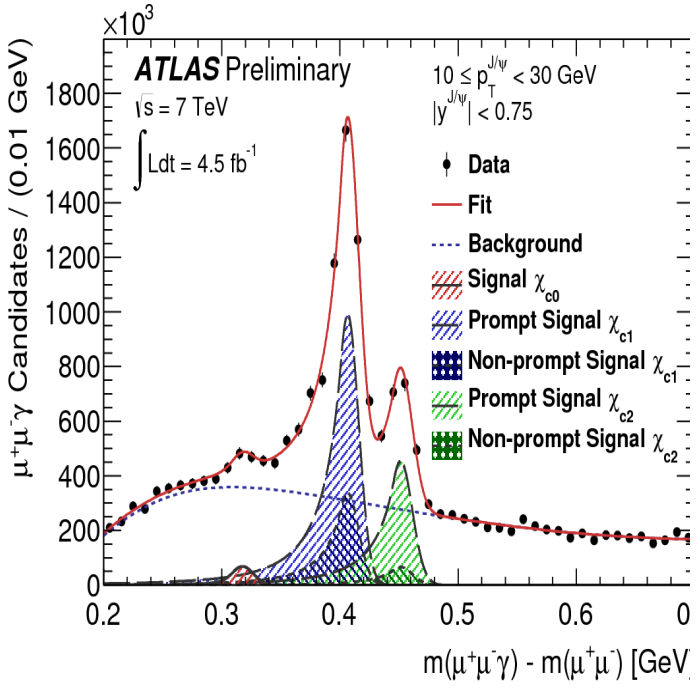


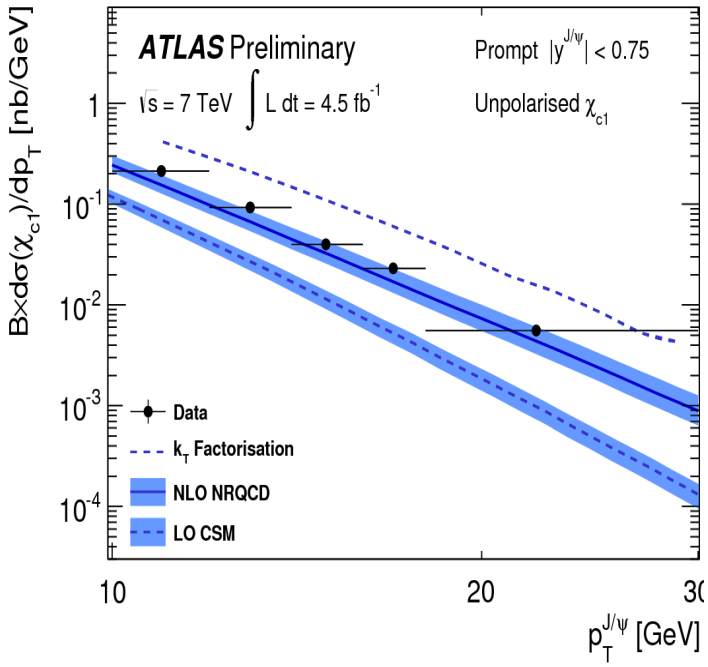
B-physics results

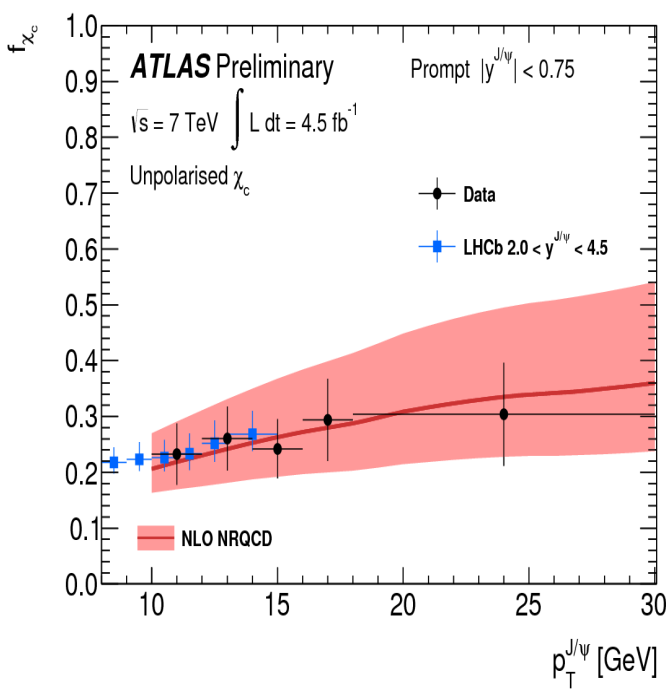
χ_{c1} and χ_{c2} production

ATLAS-CONF-2013-095

- Understanding of χ_{c1} and χ_{c2} (charmonium excited states) production is essential to understand charmonium production at hadron colliders and provides complemenary information to the measurements of J/ψ and ψ(2S).
- Production modes: *prompt* (no displaced vertex, directly in pp or in decays of other charmonium states) and *non-prompt* – in decay chain of a b-hadron (displaced vertex)
- Observed selecting $\chi_c \rightarrow J/\psi(\mu^+\mu^-)\gamma(e^+e^-)$ and using mass difference distribution



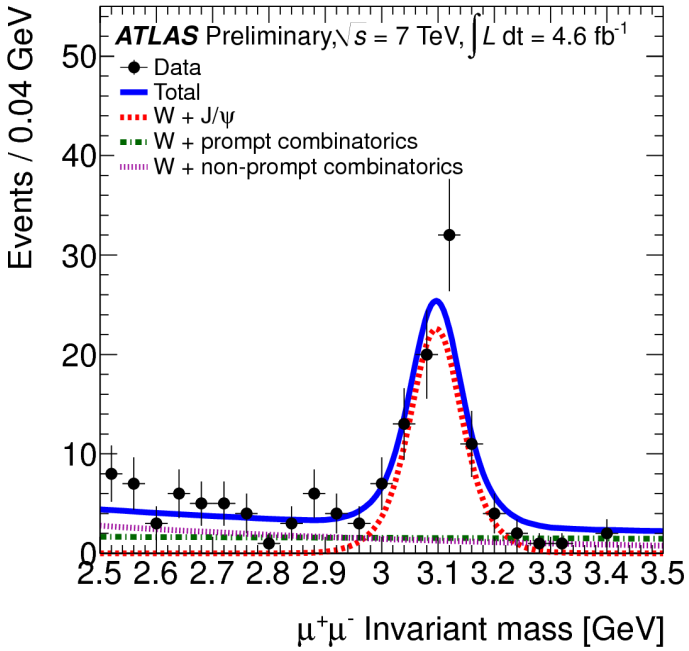


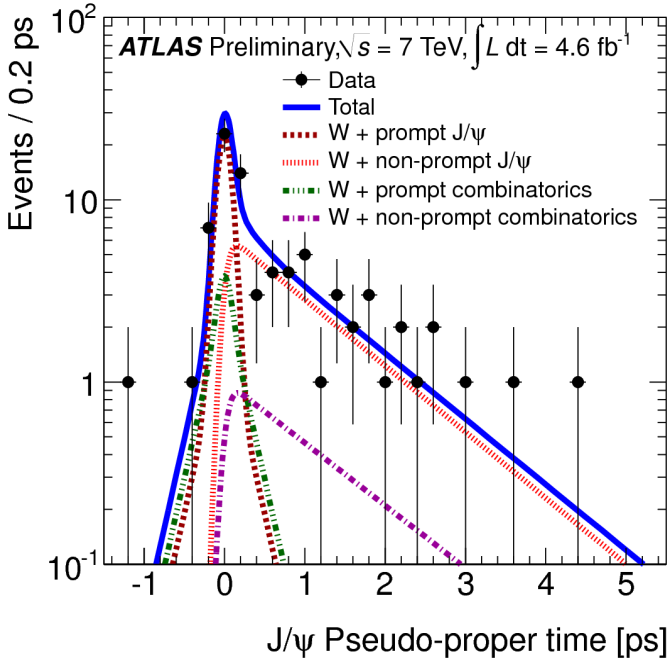


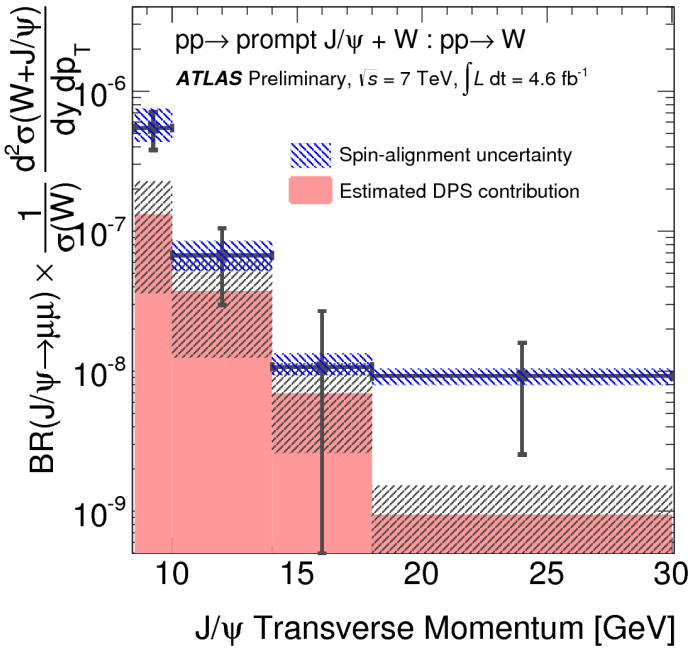
Production of J/ψ with W$^{\pm}$ bosons

ATLAS-CONF-2013-042

- The production of J/ψ still needs to be better understood (discrepancies in terms of differential cross-sections are significant).
- W+J/ψ is quark-initiated and differs from typical gluon-fusion production of J/ψ. A contribution from double-parton scattering (DPS) is also expected.
- Selection: High-energy μ + missing energy + pair of opposedly charged μ's, fit mass & decay time spectra to obtain prompt component



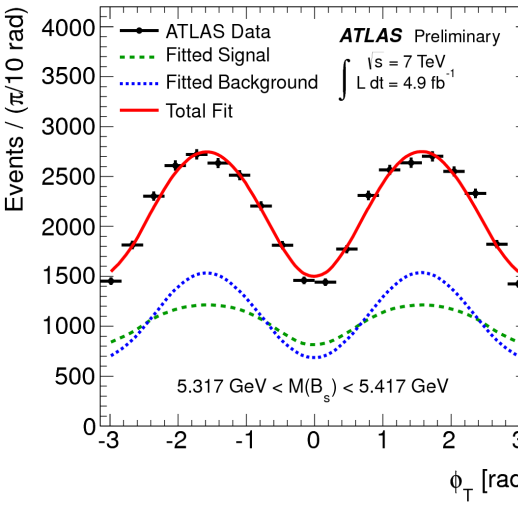


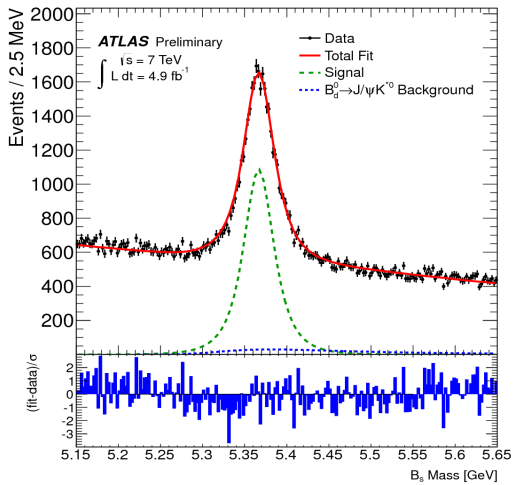


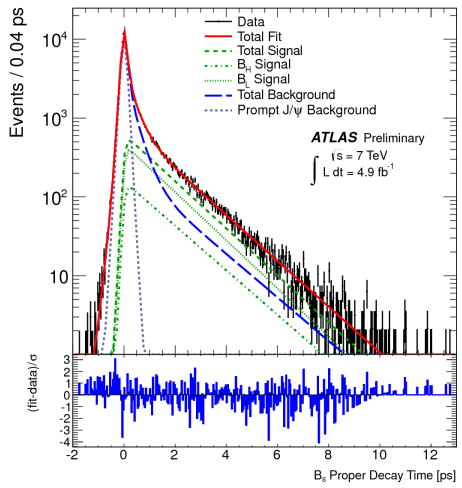
Angular analysis of $B^0_s \to J/\psi\phi$

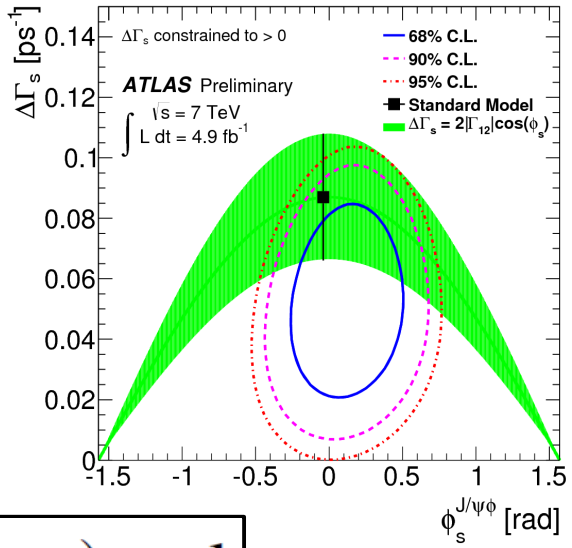
ATLAS-CONF-2013-039

- A measureable CP-violating phase, ϕ_s appears in the interference of decay amplitudes of B^0_s via mixing or to $J/\psi\phi$. It is sensitive to New Physics
- Event selection: J/ψ dimuon trigger with invariant mass around J/ψ mass (2.9 – 3.3 GeV), pair of K^+/K^- tracks with mass in (1.01 – 1.03 GeV) and B-meson mass in (5.15 – 5.65 GeV) in 4.9 fb^{-1} @ 7 TeV
- Flavour tagging to obtain the initial flavour eigenstate of B^0_s (opposite-side tagging with muon tagger or jet-charge tagger)









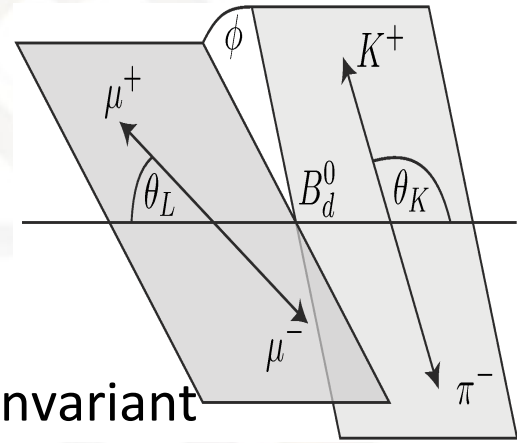
$$\phi_s = 0.12 \pm 0.25\ (\text{stat.}) \pm 0.11\ (\text{syst.})\ \text{rad}$$

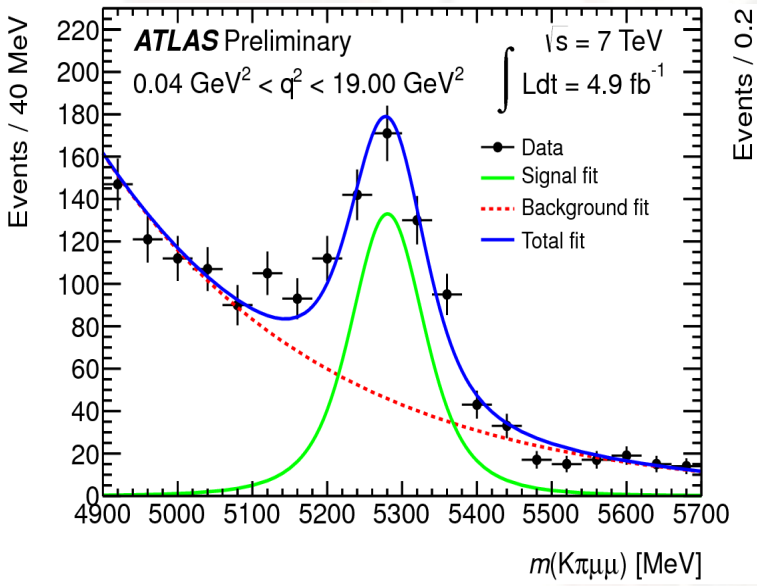
$$\Delta\Gamma_s = 0.053 \pm 0.021\ (\text{stat.}) \pm 0.009\ (\text{syst.})\ \text{ps}^{-1}$$

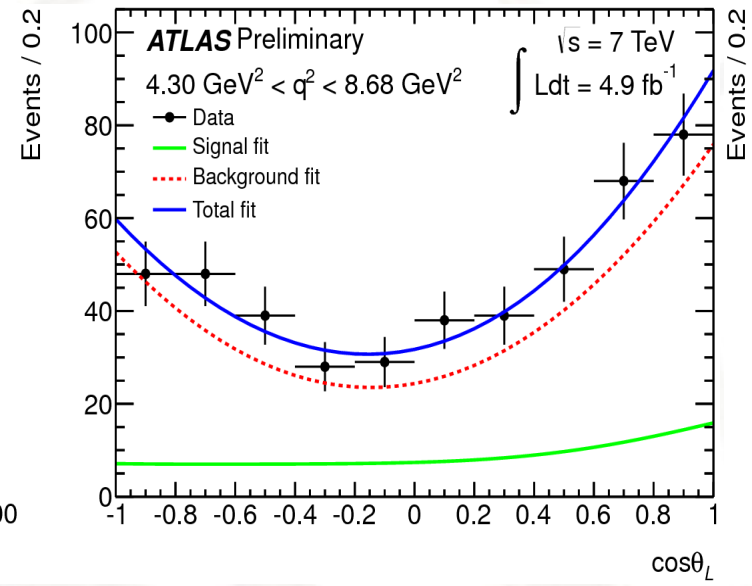
Angular analysis of $B^0_d \to K^{*0}\mu^+\mu^-$

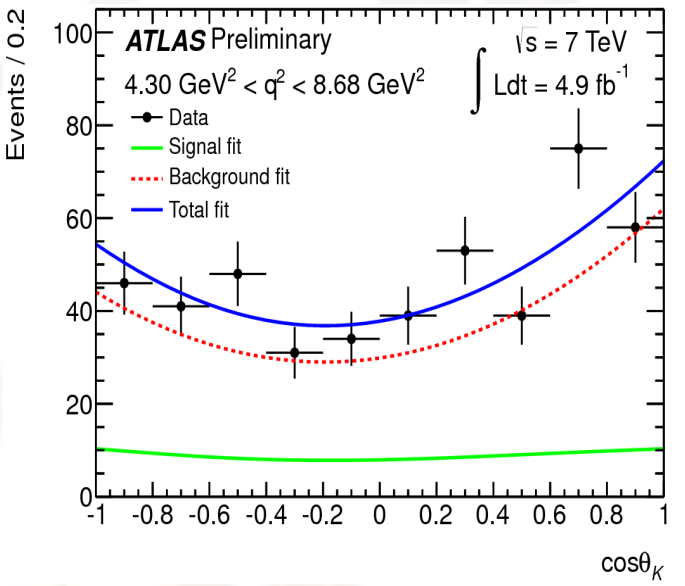
ATLAS-CONF-2013-038

- The transition b → s only possible via loops
- Angular distributions of 4 decay products are sensitive to New Physics (interference of NP diagrams with SM diagrams)
- Analysis based on full 2011 dataset 4.9 fb^{-1} @ 7 TeV
- Selection: Kπ and Kπμμ invariant masses (exclude J/ψ and ψ(2S) mass regions)
- Using unbinned Maximum Likelihood fit, fitting sequentially the invariant mass of B^0_d and then the angular distributions (no full 3D fit due to lack of statistics):





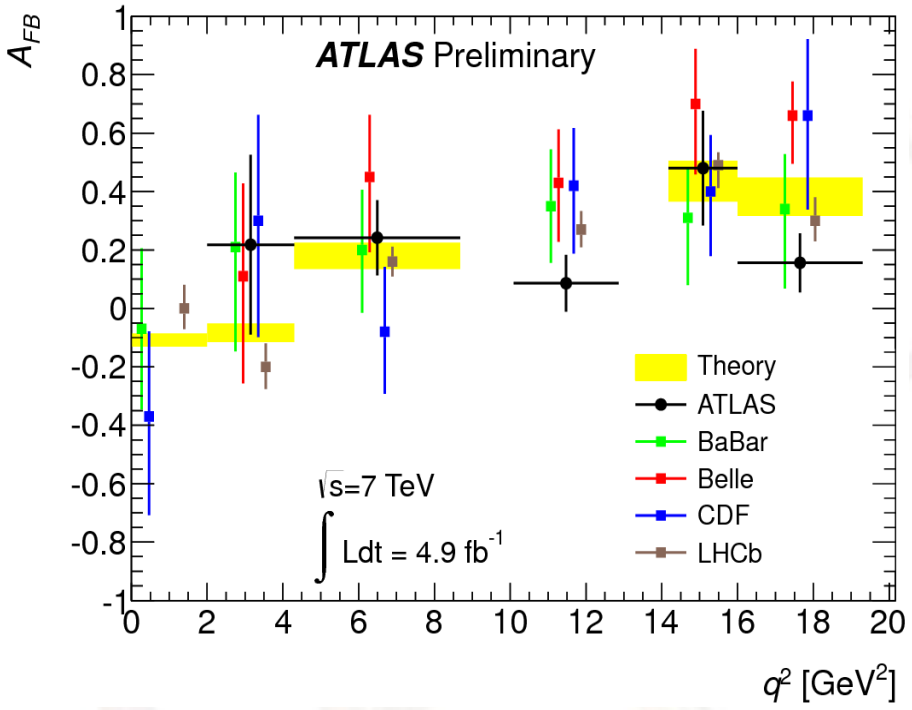


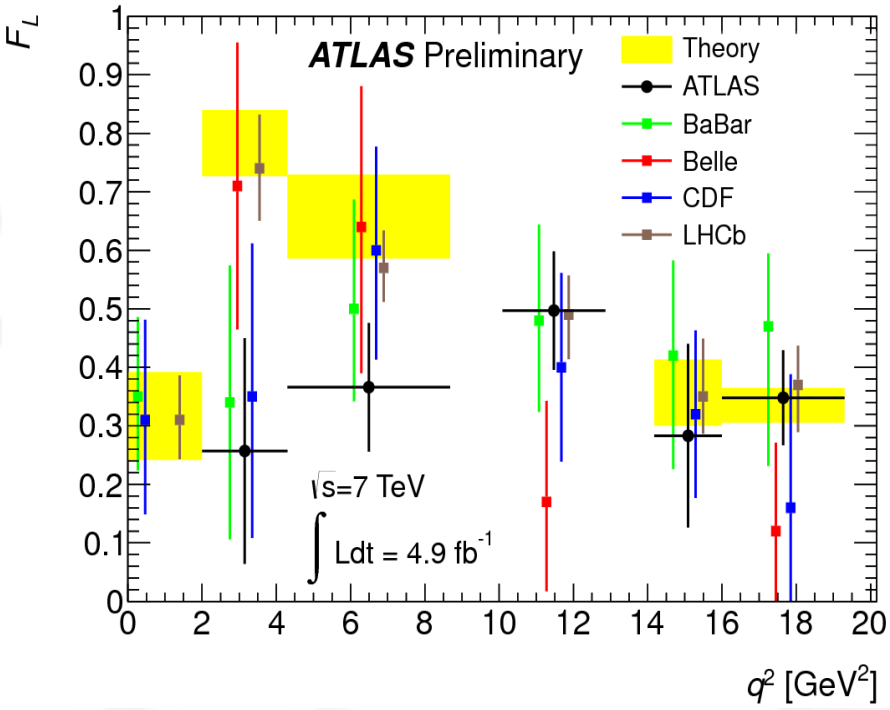


Angular analysis of $B^0_d \to K^{*0}\mu^+\mu^-$

ATLAS-CONF-2013-038

It is possible to extract forward-backward asymmetry A_{FB} and K^{*0} longitudinal polarization fraction F_L:



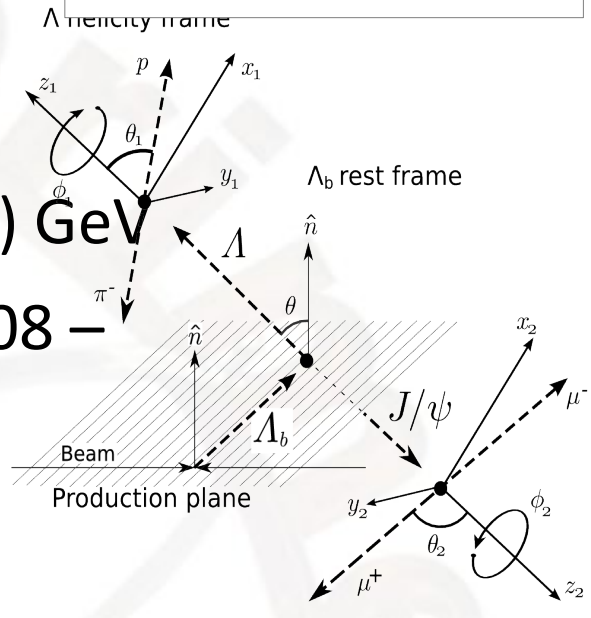


Consistent with SM predictions, uncertainty dominated by statistics. The analysis of 2012 dataset is ongoing.

Parity violation in $\Lambda_b \to J/\psi \Lambda^0$

ATLAS-CONF-2013-071

- Analysis performed with 4.6 fb^{-1} @ 7 TeV
- Event selection:
  - J/ψ decaying into μμ pair with m_{inv} in (2.8 – 3.4) GeV
    - Λ_0 decaying into two hadrons with m_{inv} in (1.08 – 1.15) GeV
    - Λ_b with m_{inv} in (5.56 – 5.68) GeV



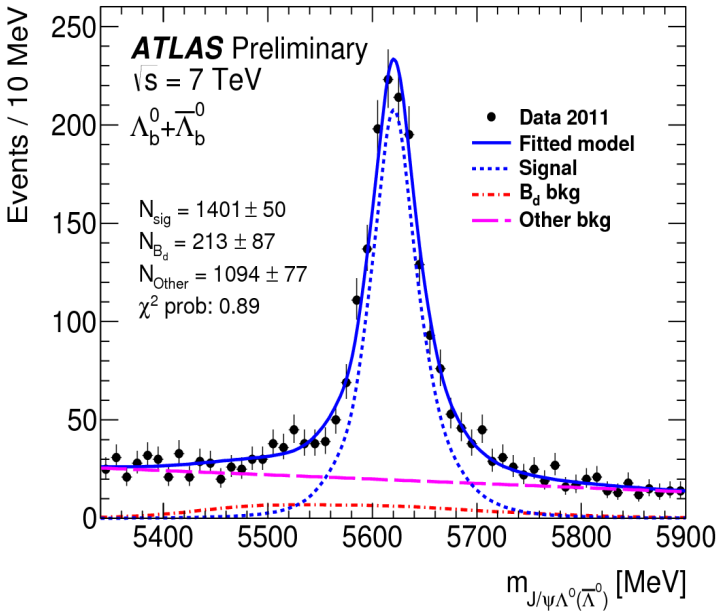
- Decay described by 4 amplitudes, asymmetry parameter:

$\alpha_b = |a_+|^2 - |a_-|^2 + |b_+|^2 - |b_-|^2$

- Fit of full angular PDF
- Results consistent with LHCb:

$\alpha_b = 0.05 \pm 0.17 \pm 0.07$ (Phys. Lett. B 724 (2013) 27)

$$\alpha_b = 0.28 \pm 0.16 \pm 0.06$$
$$|a_+| = 0.17^{+0.12}_{-0.17} \pm 0.06$$
$$|a_-| = 0.59^{+0.06}_{-0.07} \pm 0.04$$
$$|b_+| = 0.79^{+0.04}_{-0.05} \pm 0.02$$
$$|b_-| = 0.08^{+0.13}_{-0.08} \pm 0.05.$$



B Physics: outlook

- Part of the results suffers from the lack of statistics
  - Analysis of 2012 data (20 fb^{-1}, 8 TeV) ongoing
- Currently: installing a new layer of pixel detector: IBL
- Fast-track trigger planned in 2016/2017
- New silicon-only Inner Detector – 2022/2023

Summary

- Good performance of both the LHC machine and ATLAS detector: high luminosity, high efficiency of data-taking, good performance of computing & analysis model allows for detailed studies of many phenomena with high statistics of experimental data.
- Only a small subset of results presented in this talk.
- Very good agreement between Data & MC, measured cross-sections in agreement with NNLO estimations.
- In 2015 a restart of LHC is scheduled at the collision energy of 13 TeV – new exciting results expected to appear!

Backup slides

B^+ cross-section in $B^+ \to J/\psi K^+$

Event selection:

- Data: 2.4 fb^{-1} at $\sqrt{s}$ = 7 TeV taken in 2011
- J/ψ candidates with $m_{inv}(\mu^+\mu^-)$ in 2.7-3.5 GeV
- Additional track matching to vertex
- B^+/B^- candidates with $p_T > 9$ GeV and $|y| < 2.25$

Background:

- Resonant $J/\psi\pi$, $J/\psi K^*$
- Combinatorial $J/\psi X$

Results:

- Good agreement with POWHEG+Pythia
- Slight discrepancies in higher p_T for MC@NLO+Herwig

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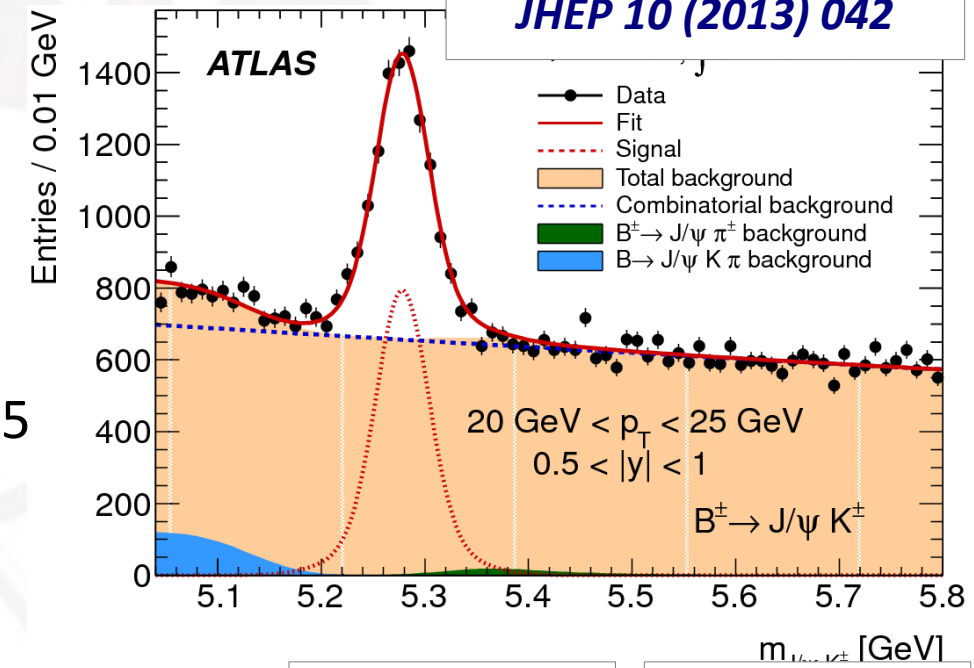
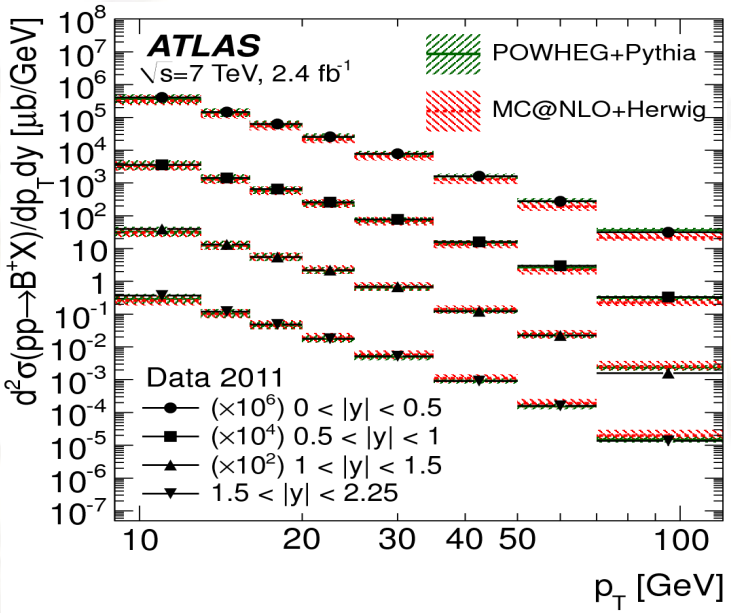
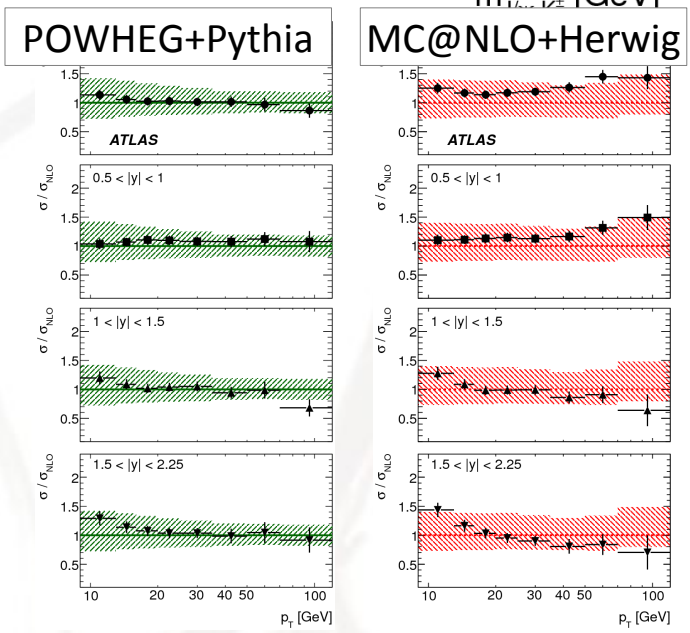
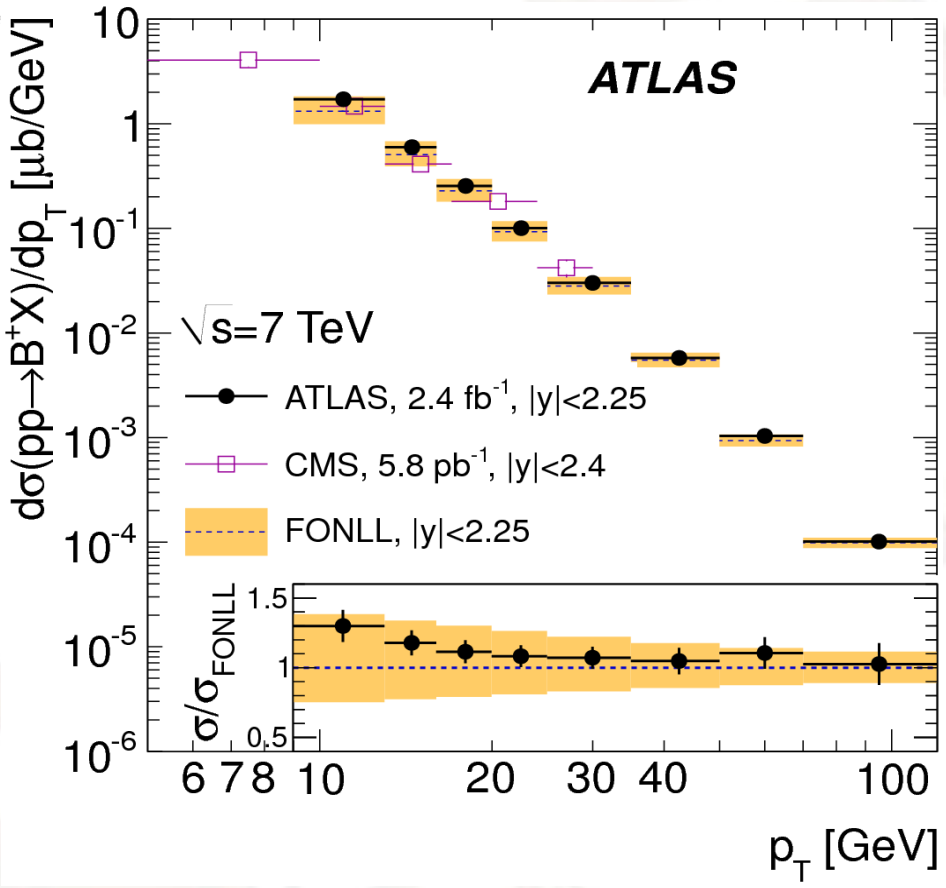
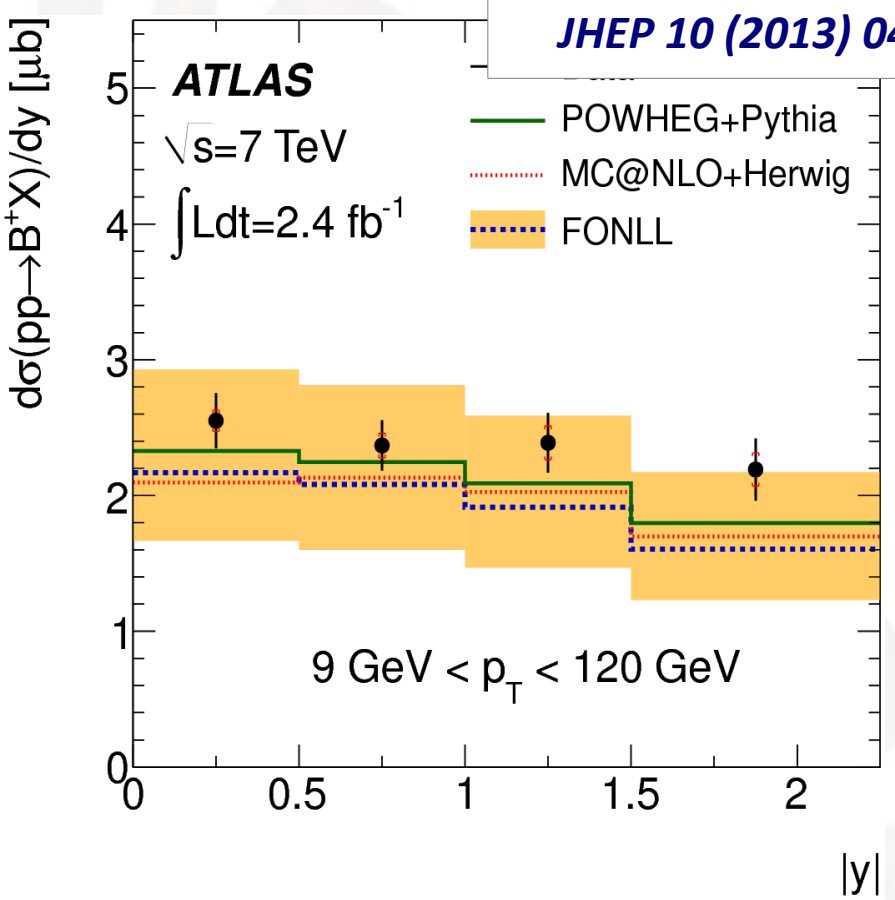






B^+ cross-section in $B^+ \to J/\psi K^+$





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Comparison to Fixed-Order Next-to-Leading-Log (FONLL) shows a good agreement with the data concerning both the behaviour in rapidity and p_T.

B^+ producton integrated cross-section (9 GeV < p_T < 120 GeV, $|y| < 2.25$):

$$\sigma(pp \to B^+ X) = 10.6 \pm 0.3\ (\text{stat.}) \pm 0.7\ (\text{syst.}) \pm 0.2\ (\text{lumi.}) \pm 0.4\ (\mathcal{B})\ \mu\text{b}.$$