DIS 2012
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Bonn

Heavy Flavour Production from ATLAS

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On behalf of the ATLAS collaboration

Introduction

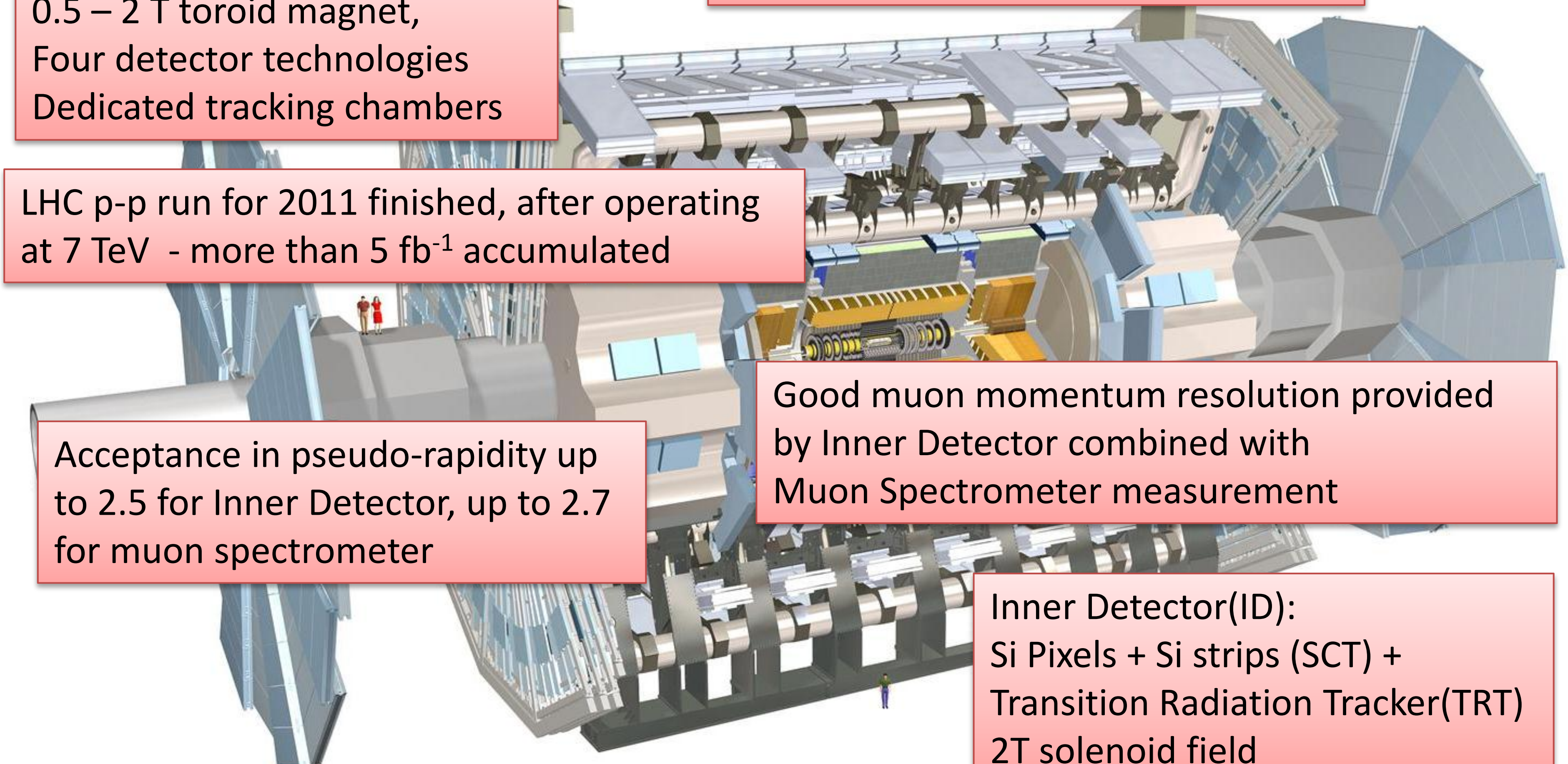
- Objectives of ATLAS heavy flavour physics programme:
- Test theoretical models for production within the Standard Model
- Search for new physics, such as rare decays and source of CP violation in B-decays
- I will present
  - the non-prompt J/ψ cross-section/fraction measurement
  - The D meson cross-sections
  - The average B meson lifetime measurement
  - The mass/lifetime measurements of some Exclusive decays
- There will be separate talks on
  - B-jets
  - rare exclusive decays such as $B_s \to \mu\mu$
  - quarkonium production

The ATLAS detector

Three Level trigger System:
L1(Hardware) + HLT (L2 + EF software)

Muon Spectrometer (MS)
0.5 – 2 T toroid magnet,
Four detector technologies
Dedicated tracking chambers

LHC p-p run for 2011 finished, after operating at 7 TeV - more than 5 fb^{-1} accumulated



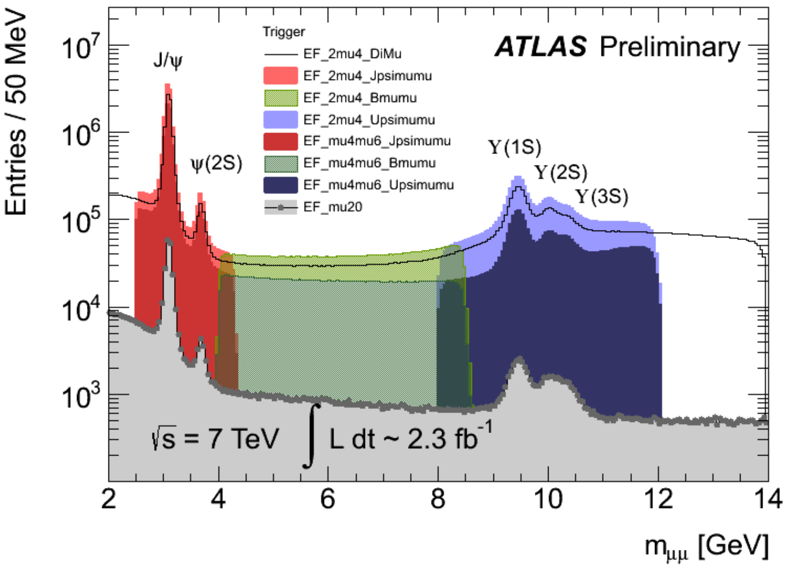
Good muon momentum resolution provided by Inner Detector combined with Muon Spectrometer measurement

Acceptance in pseudo-rapidity up to 2.5 for Inner Detector, up to 2.7 for muon spectrometer

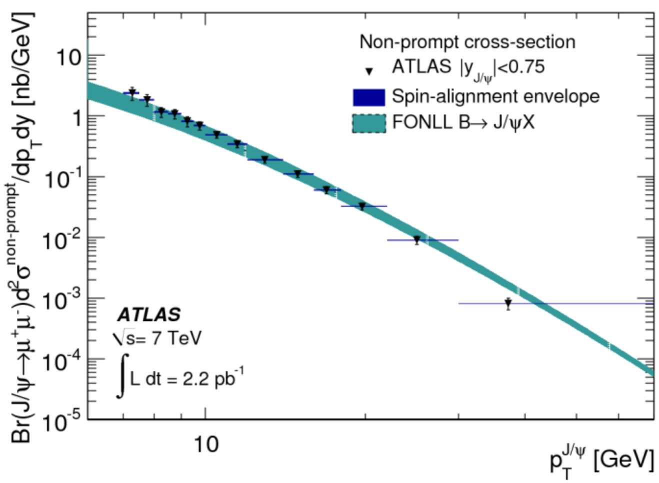
Inner Detector(ID):
Si Pixels + Si strips (SCT) +
Transition Radiation Tracker(TRT)
2T solenoid field

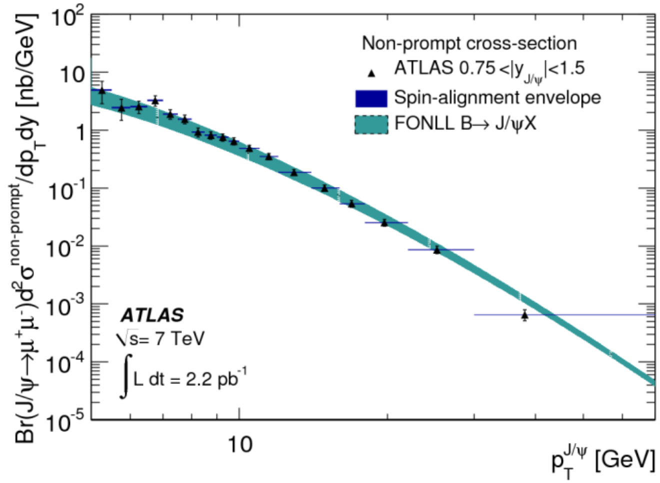
General heavy flavour Strategy

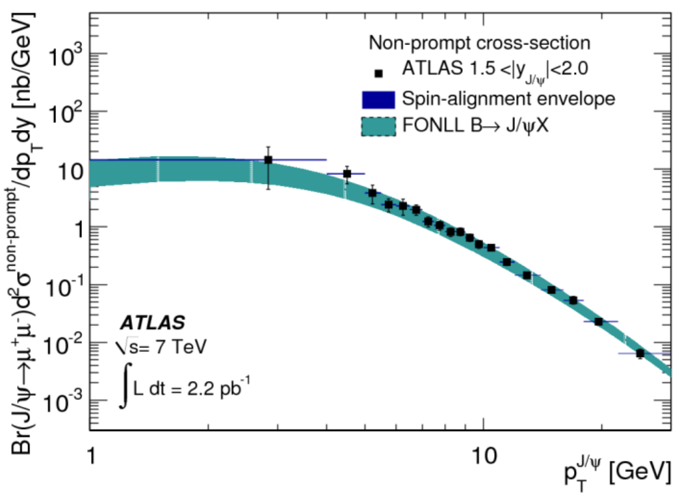
- Exploit the muon spectrometer to reconstruct muons cleanly and efficiently.
- Low p_T B hadrons are reached with di-muon triggers
- Di-muon decays of J/ψ and other onia provide a clean signature to trigger events – very good for $B \rightarrow J/\psi$ and $B \rightarrow \mu\mu$

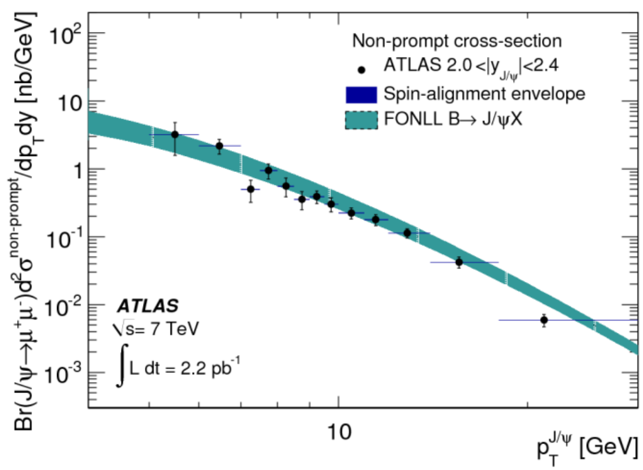


ATLAS open beauty cross-section with $bb \to J/\psi$



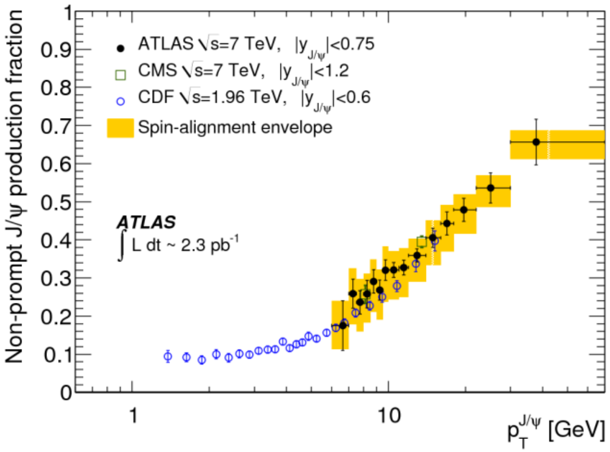


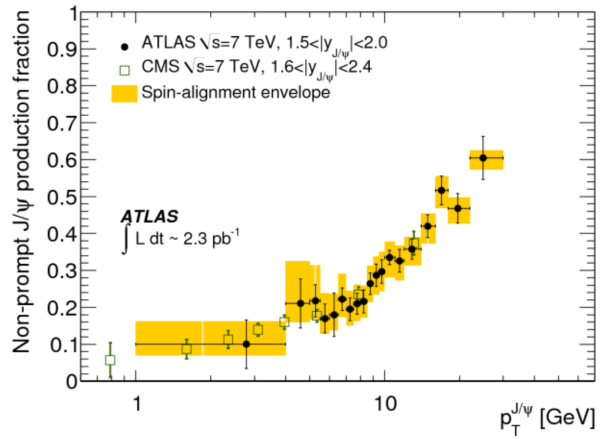


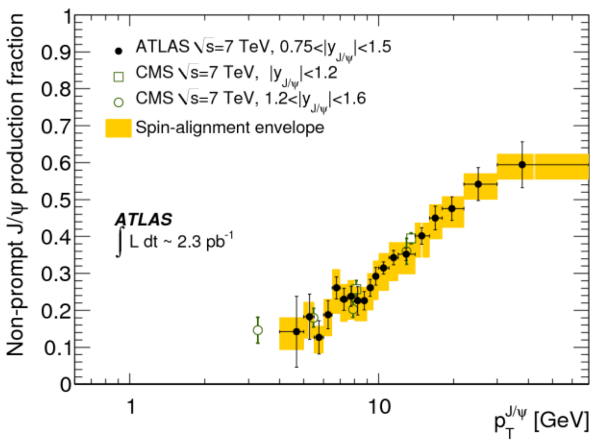


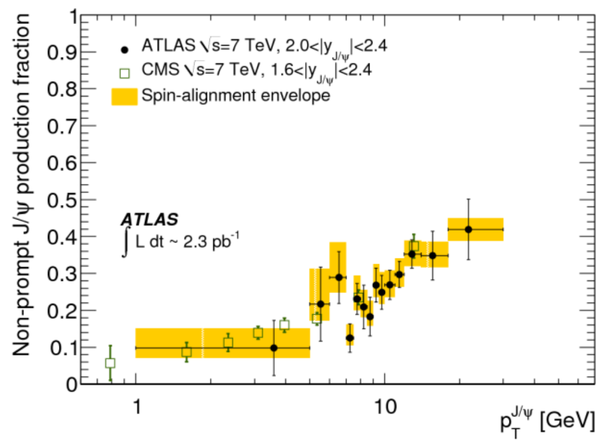
Non Prompt J/ψ Fraction

- Along with this cross-section the fraction of $\frac{bb\rightarrow J\psi}{pp\rightarrow J/\psi}$ was measured





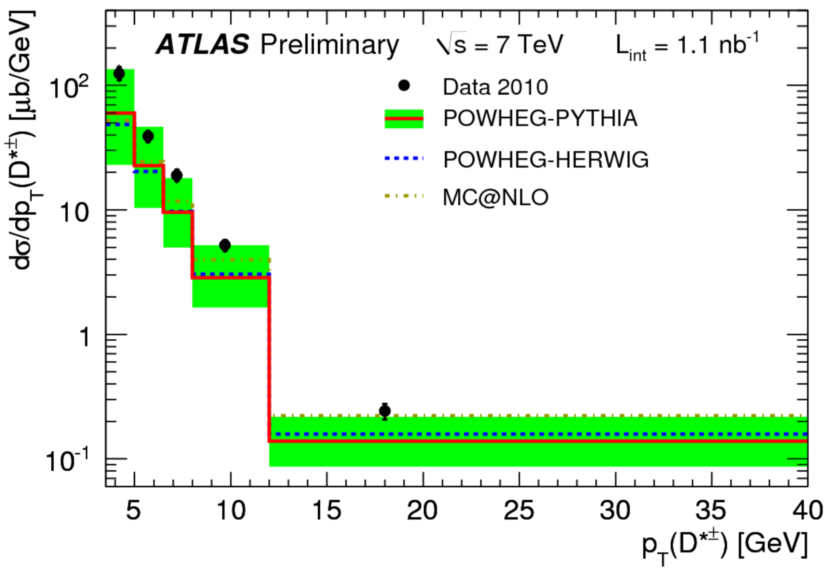


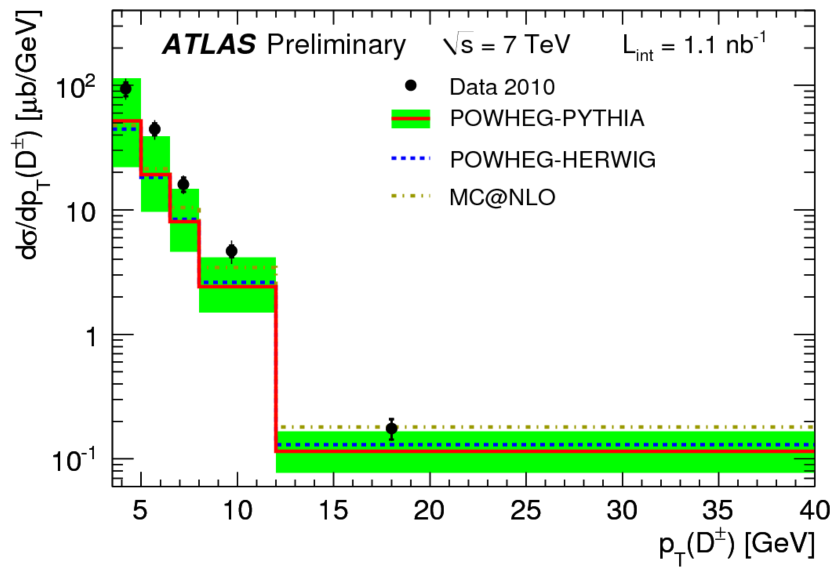


pT dependence
Agreement with CMS
Agreement with CDF – no dependence on collision energy

ATLAS open charm cross-section with D meson decays

- $D^{*\pm}$,$D^{\pm}$,$D^{\pm}{}_{s}$ charmed mesons reconstructed for pT > 3.5 GeV and $|y| < 2.1$
- Efficiency and acceptance taken from MC

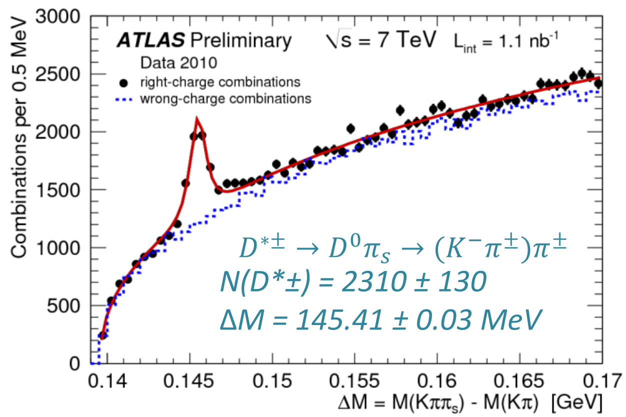


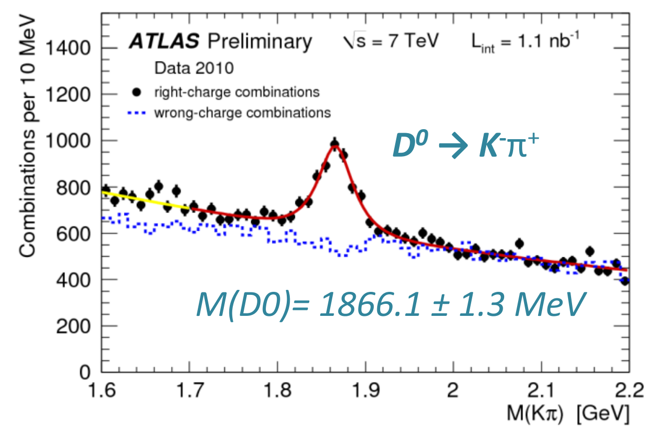


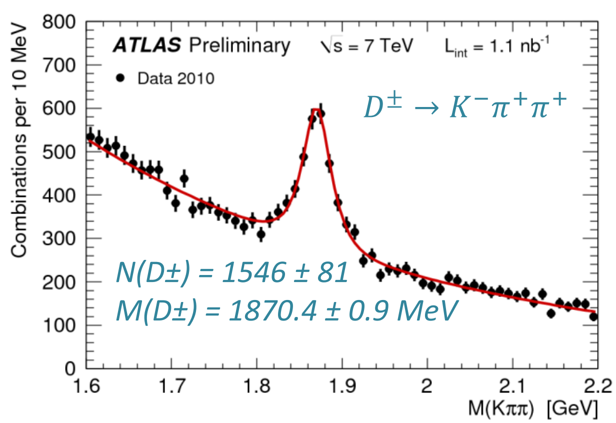
ATLAS measurement shows that the charm cross-section is higher than predicted by models - especially at low pTs

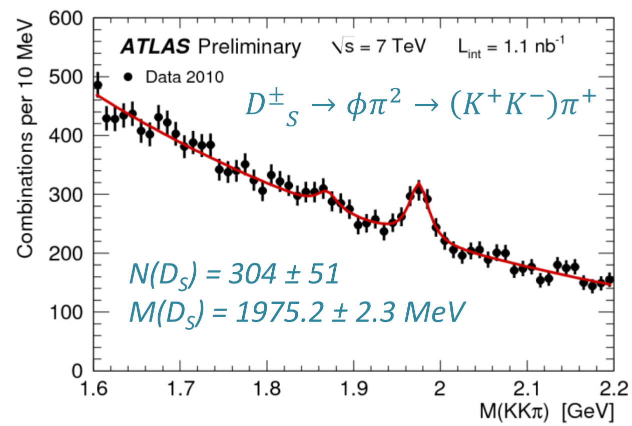
Measurement of D meson production cross-sections - cont

- $D^{*\pm}$,$D^{\pm}$,$D^{\pm}{}_{s}$ charmed mesons reconstructed for pT > 3.5 GeV and $|y| < 2.1$
- ID tracks are used to extract masses & yields with fits to M or ΔM distributions







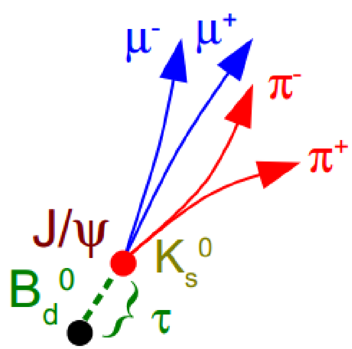


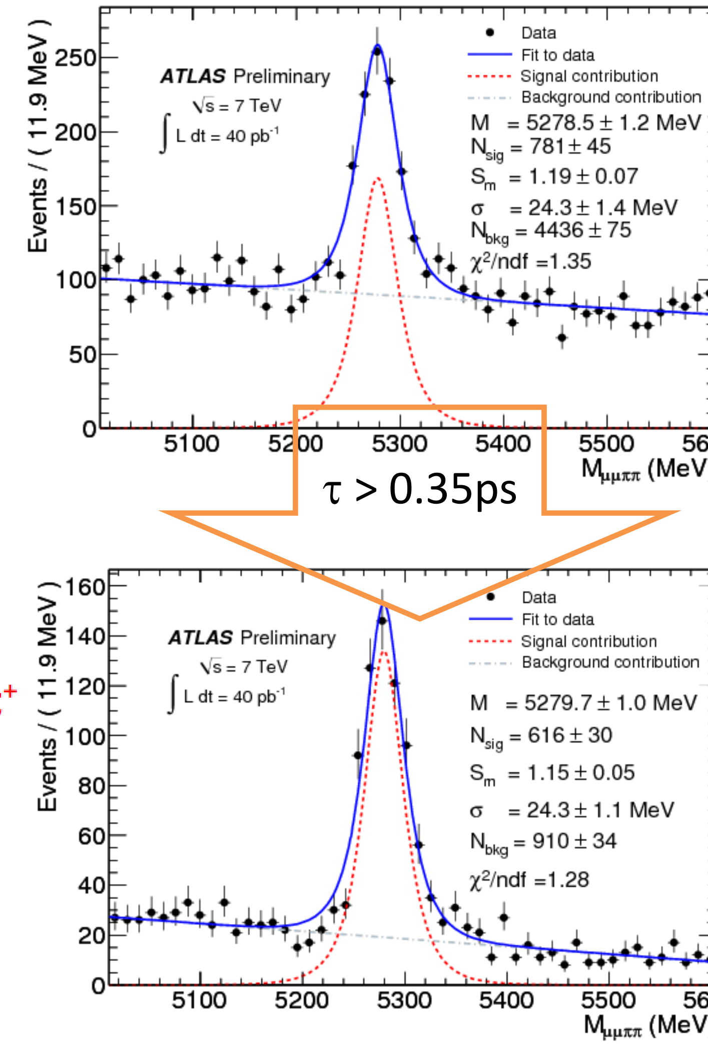
Measurements of properties of B mesons decaying with J/ψ in final state

$B_d^0 \to J/\psi K_s$

- Neutral B mesons are ideal for testing predictions of the standard model for CKM matrix
- Tests predictions of HQET and pQCD

Parameter	No proper decay time cut	$\tau_B > 0.35$ ps
M (MeV)	5278.5 ± 1.2	5279.7 ± 1.0
S_m	1.19 ± 0.07	1.15 ± 0.05
N_{sig}	781 ± 45	616 ± 30
N_{bkg}	4436 ± 75	910 ± 34
σ (MeV)	24.3 ± 1.4	24.3 ± 1.1
Fit $\chi^2/N_{\text{d.o.f.}}$	1.35	1.28

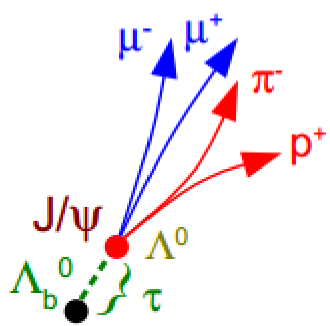


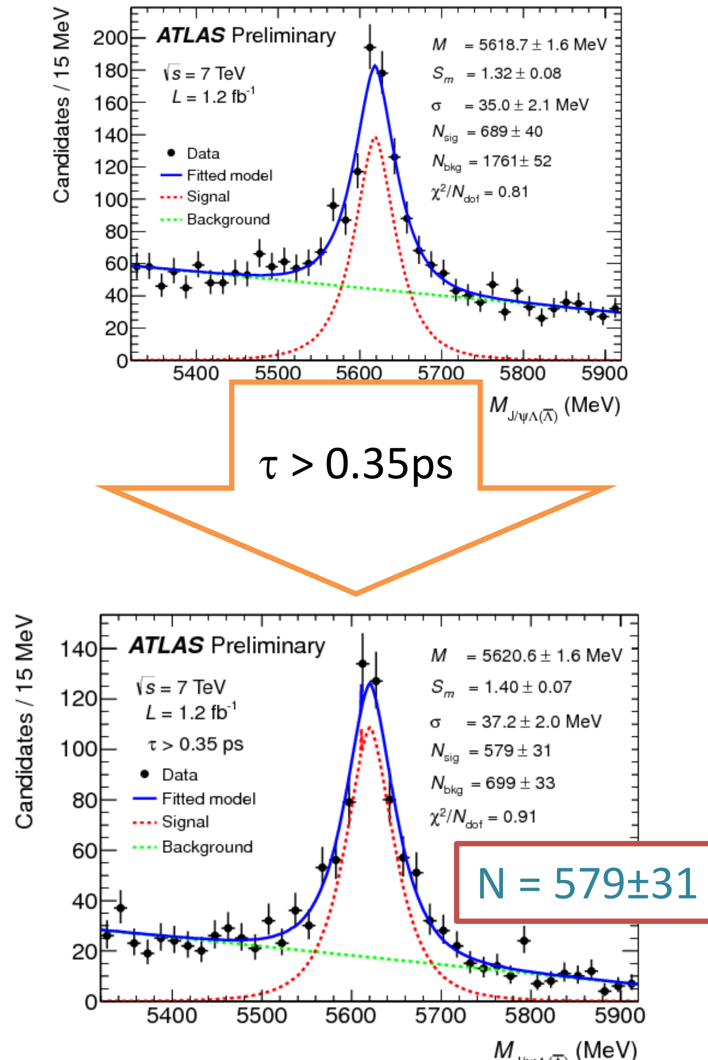


$\Lambda_b \rightarrow J/\psi(\mu^+\mu^-)\Lambda(p^+\pi^-)$

- Tests HQET and pQCD $\left[\Delta\Gamma\left(\Lambda_b^0, B_d^0\right)\right]$
- Can study production polarisation
- Applying the τ cut kills the direct J/ψ background
- Mass consistent with PDG consistent with PDG (5620.2 ± 1.6 MeV)

Parameter	No proper decay time cut	$\tau_B > 0.35$ ps
M (MeV)	5618.7 ± 1.6	5620.6 ± 1.6
S_m	1.32 ± 0.08	1.40 ± 0.07
N_{sig}	689 ± 40	579 ± 31
N_{bkg}	1761 ± 52	699 ± 33
σ (MeV)	35.0 ± 2.1	37.2 ± 2.0



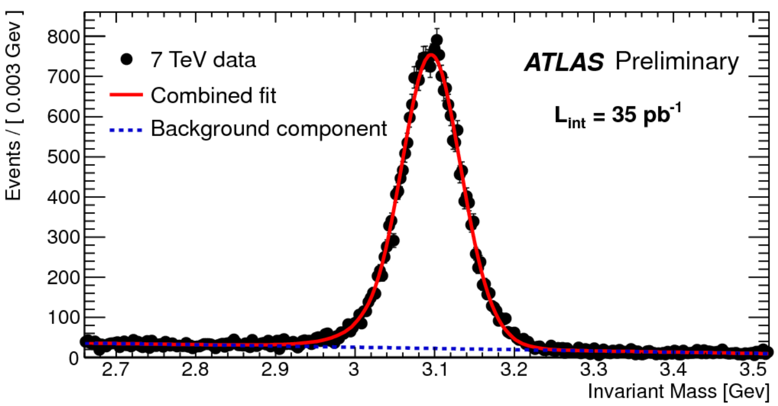


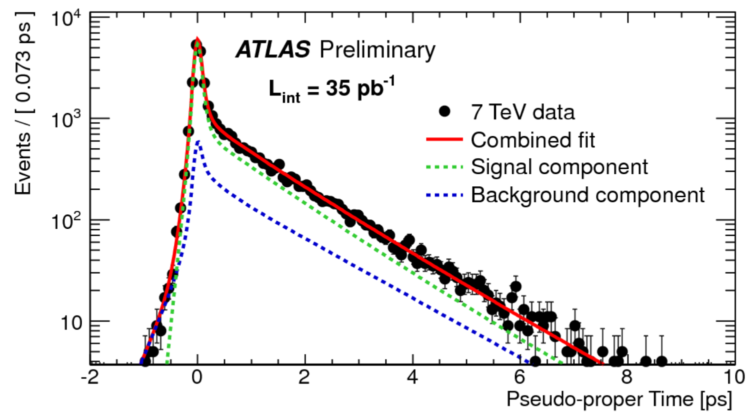
Measurement of Average B lifetime

- Heavy Quark Effective theory (HQET) predicts the lifetime ratio between different species to the order of 1%
- Measuring the average lifetime of a mixture of B-hadron decaying to final states including J/ψ demonstrates measurements for exclusive channels.
- A pseudo-proper-lifetime is fitted and a correction "f-factor" is used to calculated the proper decay time

$$t^* = \frac{L_{xy} m^{J/\psi}{}_{PDG}}{p_T(J/\psi)}$$

$$F = \frac{m^B_{PDG}\, p_T^{J/\psi}}{p_T^B\, m^{J/\psi}_{PDG}}$$





$<\tau_b>=1.489\pm0.016\pm0.043$ ps

Consistent with Tevatron values and expected average from PDG

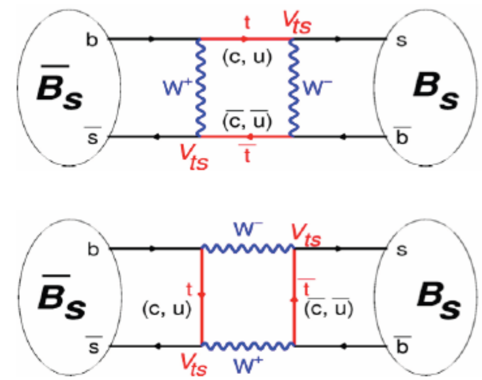
Largest sources of systematic uncertainty from background model and alignment – improved in new analyses from improved understanding

Physics analysis of $B_s^0 \to J/\psi\phi(KK)$

- $B_s^0 \to J/\psi\phi(KK)$ allows measurement of B_s^0 mixing phase responsible for CP violation
- SM prediction for CP asymmetry is small, any observation otherwise = *new physics*
- The width difference $\Delta\Gamma_s$ between light (Bs^L) & heavy (Bs^H) Eigen states
- $B_d^0 \to J/\psi K^{*0}$ has an identical topology and higher cross section - useful test sample
- The B meson is reconstructed in the analysis allowing the full proper decay time to be used

CP violation in neutral B_s system

- Mixing of flavour eigenstates are governed by:



$$i\frac{d}{dt}\begin{pmatrix} B_s^0(t) \\ \overline{B}_s^0(t) \end{pmatrix} = H\begin{pmatrix} B_s^0(t) \\ \overline{B}_s^0(t) \end{pmatrix} \equiv \Bigg[\underbrace{\begin{pmatrix} M_0 & M_{12} \\ M_{12}^* & M_0 \end{pmatrix}}_{\text{mass matrix}} - \frac{i}{2}\underbrace{\begin{pmatrix} \Gamma_0 & \Gamma_{12} \\ \Gamma_{12}^* & \Gamma_0 \end{pmatrix}}_{\text{decay matrix}}\Bigg]\begin{pmatrix} B_s^0(t) \\ \overline{B}_s^0(t) \end{pmatrix}$$

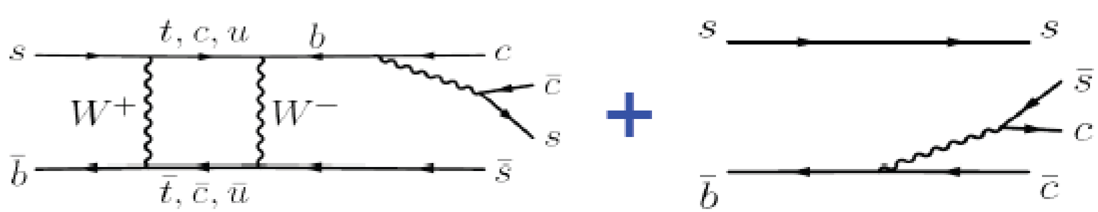
- But there are also the mass eigenstates

$$|B_s^H\rangle = p\,|B_s^0\rangle - q\,|\bar{B}_s^0\rangle$$
$$|B_s^L\rangle = p\,|B_s^0\rangle + q\,|\bar{B}_s^0\rangle$$

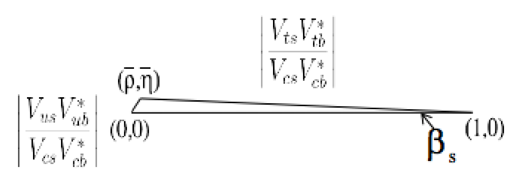
- $\Delta m_s = m_H - m_L \approx 2|M_{12}|$
- $\phi_s^{SM} = \arg\left(-\frac{M_{12}}{\Gamma_{12}}\right) \sim -0.004$
- $\Delta\Gamma = \Gamma_L - \Gamma_H \approx 2|\Gamma_{12}|\cos(2\phi_s^{SM})$

CP violation in neutral B_s system

- CP violation occurs in $B_s \rightarrow J/\psi\phi$ through interference of decays with and without mixing
- An untagged angular analysis can lead to a measure of β_S and $\Delta\Gamma$
- A tagged analysis is more sensitive to New Physics



- We will measure the NP phase $\phi_S^{NP} = -2\beta_S^{NP}$

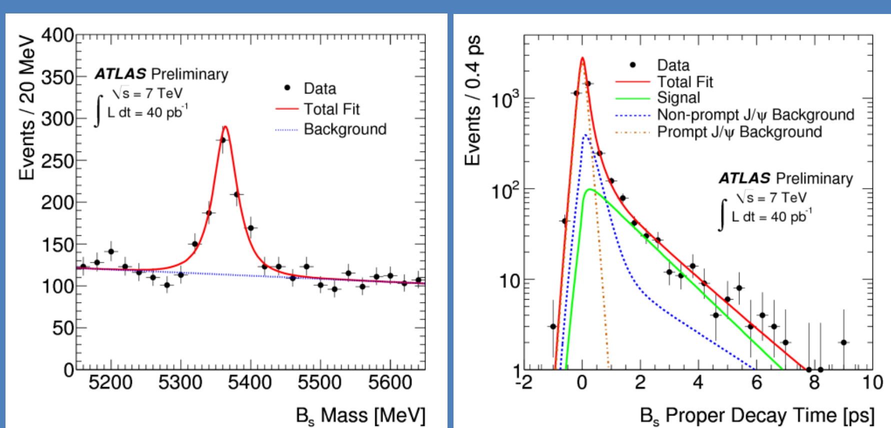


B_d^0 and B_s^0 lifetime with $40pb^{-1}$

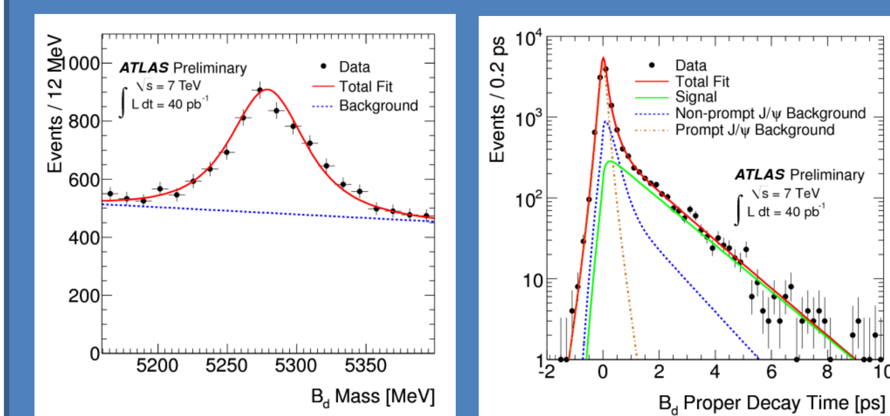
- Simultaneous fit to invariant mass & proper decay time - per candidate error fit
- Testing ground for full angular fit
- Mass and lifetimes agree with world average
- These results will build up to the CP violation analysis

	$\tau_{\rm B}$,ps	m_B MeV	$N_{\rm sig}$
B_d^0	1.51 ± 0.04	5279.0 ± 0.8	2750 ± 90
B_s^0	1.41 ± 0.08	5363.7 ± 1.2	463 ± 26

$B_s^0 \rightarrow J/\psi\phi(KK)$



$B_d^0 \rightarrow J/\psi K^{*0}(K\pi)$



Conclusions and Outlook

- Tests predictions of pQCD and NRQCD models:
  - Λ_B^0 production
  - $B_d^0 \rightarrow J/\psi K_s$
- Tests Heavy Quark Effective Theory (HQET)
  - $\Lambda_\mathrm{b} \rightarrow \frac{J}{\psi(\mu^+\mu^-)\Lambda(\mathrm{p}^+\pi^-)}$
  - $B_d^0 \rightarrow J/\psi K_s$
- High precision measurement of CP violation in $B_s^0 \rightarrow J/\psi\phi(KK)$, $B_d^0 \rightarrow J/\psi K_s$
- See other talks for:
  - $B_s \rightarrow \mu^+\mu^-$ + rare decays
  - B-jet cross sections
  - Quarkonia

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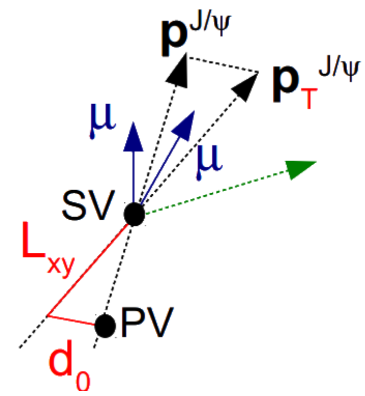
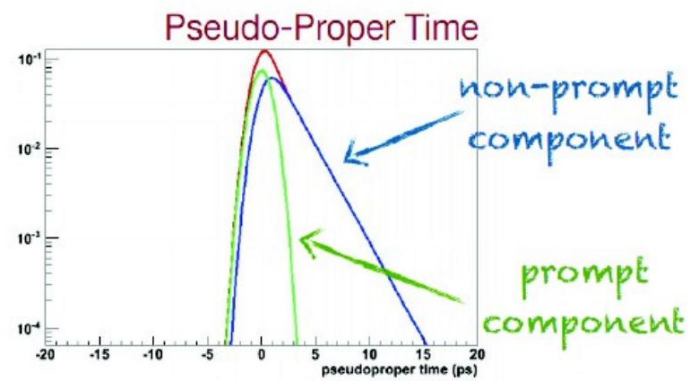
Backups

Non Prompt J/ψ Fraction



- At the LHC J/ψ can be produced *"promptly"* from pp collision or indirectly from B-hadrons.
- Separate out non-prompt component of J/ψ.
- Discriminate using pseudo proper lifetime
- Much of the B-physics studied at ATLAS is through Onia decay channels, allowing us to trigger on the muons in the decay

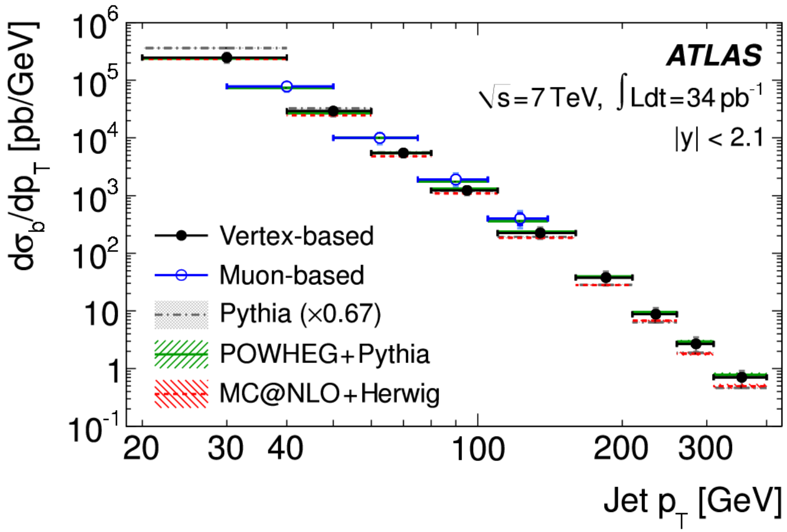
$$\tau = \frac{L_{xy} m_{PDG}^{J/\psi}}{p_T^{J/\psi}}$$



Inclusive b cross-section by b-tagged jets

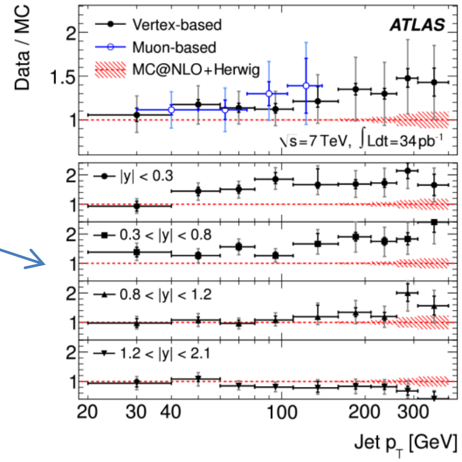
- b-jets are 3.5-5% of all jets
- Two methods for b-tagging
  - Search for *displaced vertex*, calculate the invariant mass of associated tracks
  - Search for muon inside jet for B semi-leptonic decays, calculate the muon pt w.r.t. the jet axis
- Both approaches are consistent

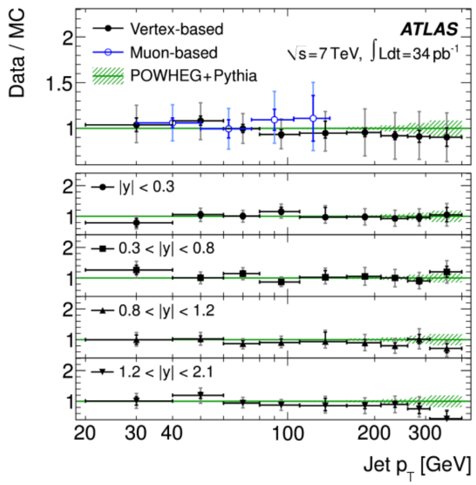
Agrees well with vertex based measurement
POWHEG (NLO) + Pythia is consistent within uncertainties
MC@NLO + Herwig 6 is consistently too low

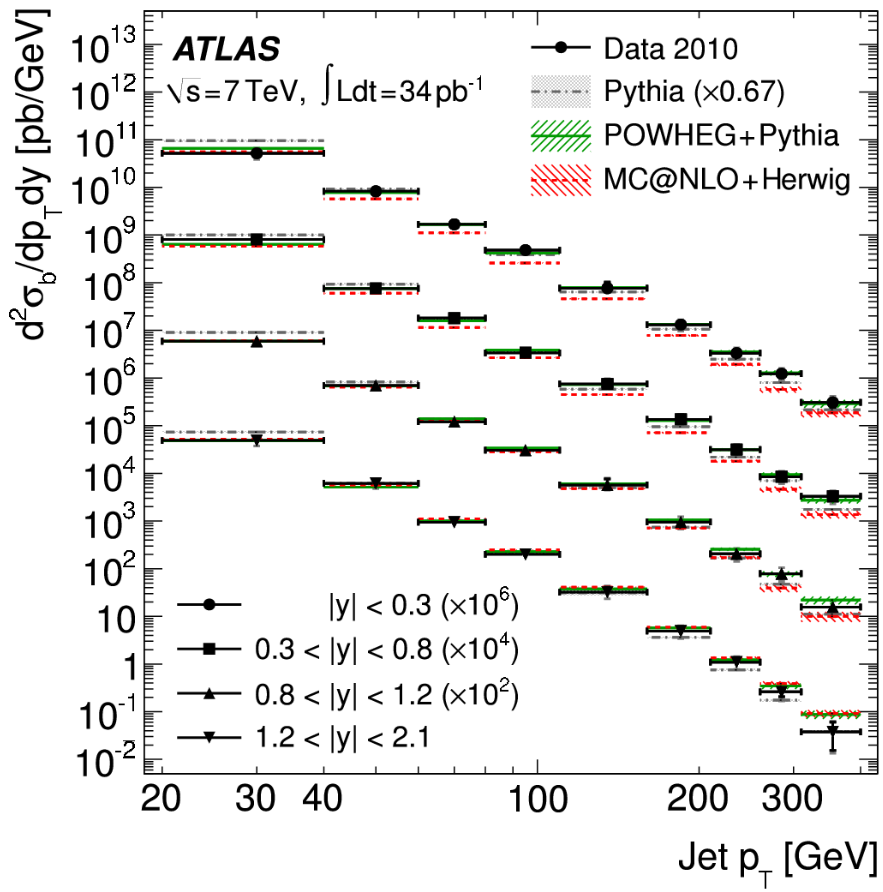


Inclusive b-jet cross section vs pT, data vs MC

Ratios of Data/MC

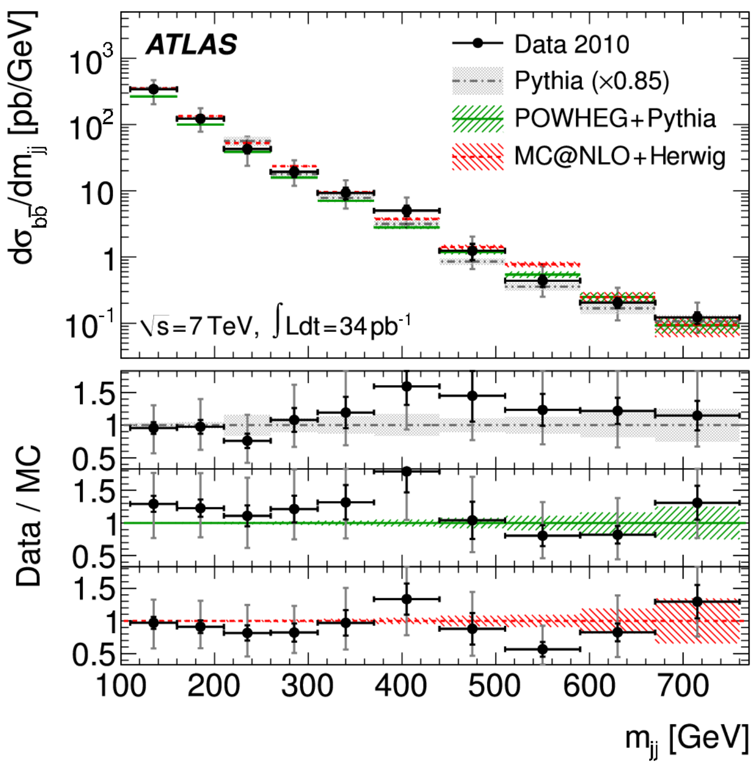






Inclusive bb di-jet cross section vs Mass, Δϕ

Di-jet mass: All theory predictions compatible with measured cross-sections



Di-jet azimuthal angle: enhanced back-to-back behaviour is well reproduced by all generators