La Thuile 2016

Les Rencontres de Physique de la Vallée d'Aoste

6th – 12th March 2016

B-Physics Measurements at ATLAS

(Recent Results)

Pavel Řezníček

(Charles University in Prague)

on behalf of the ATLAS collaboration

The ATLAS Experiment

General purpose detector

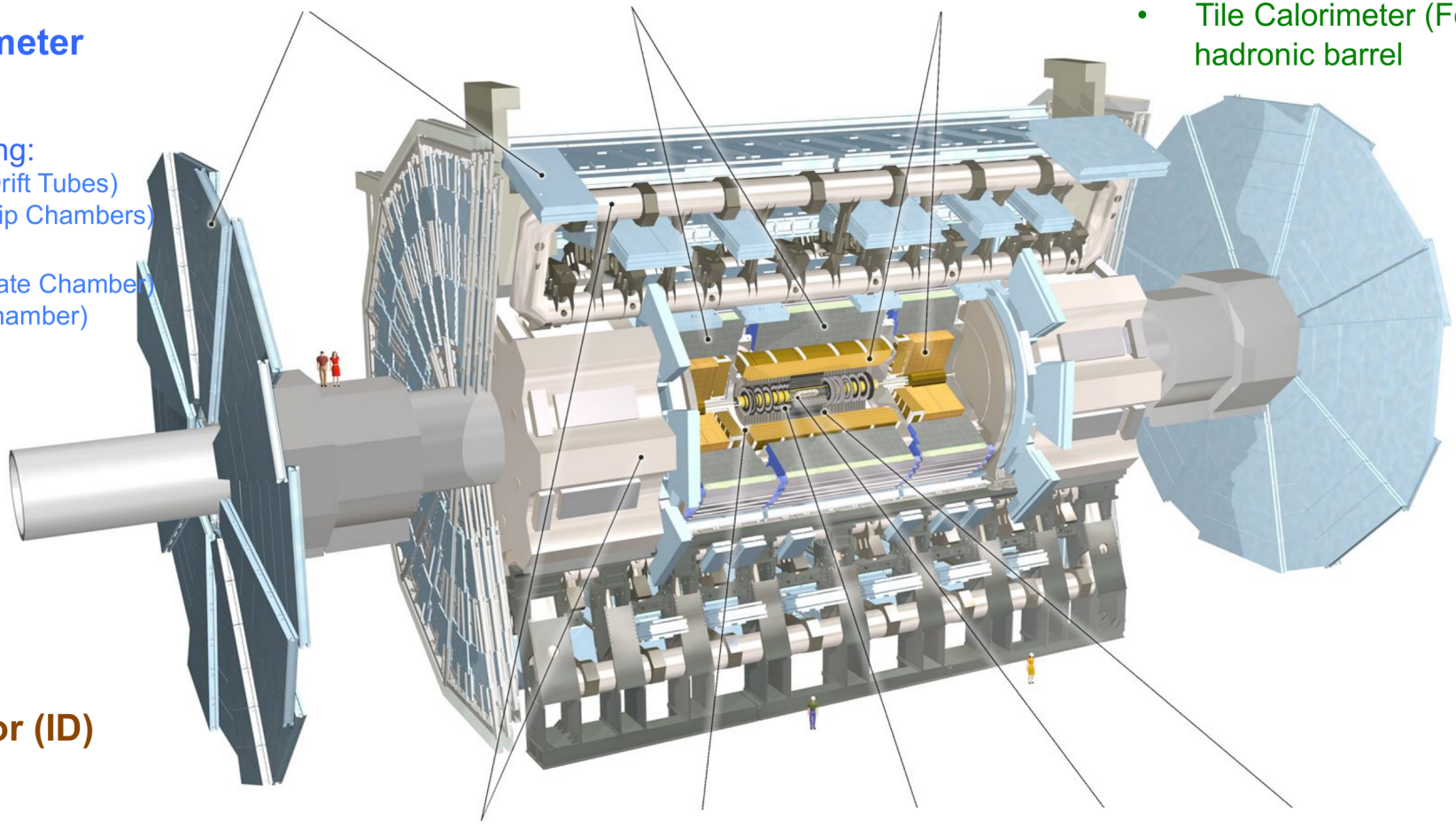
Calorimeter System

EM and Hadronic energy
- LAr EM barrel and EC
- LAr Had. Barrel
- Tile Calorimeter (Fe-Scin.) hadronic barrel

Muon Specrometer

Toroid Magnets
Precision μ tracking:
- MDT (Monitored Drift Tubes)
- CSC (Cathode Strip Chambers)

Trigger:
- RPC (Resistive Plate Chamber)
- TGC (Thin Gas Chamber)



Inner Detector (ID)

Tracking
2T Solenoid Magnet
- Silicon Pixels, 50x400 μm^2
- Silicon Strips (SCT), 80 μm stereo
- Transition Ratiation Tracker (TRT) 36 points/track

The ATLAS Experiment

- Triggering $|\eta| < 2.4$
- Precision Tracking $|\eta| < 2.7$

B-Physics

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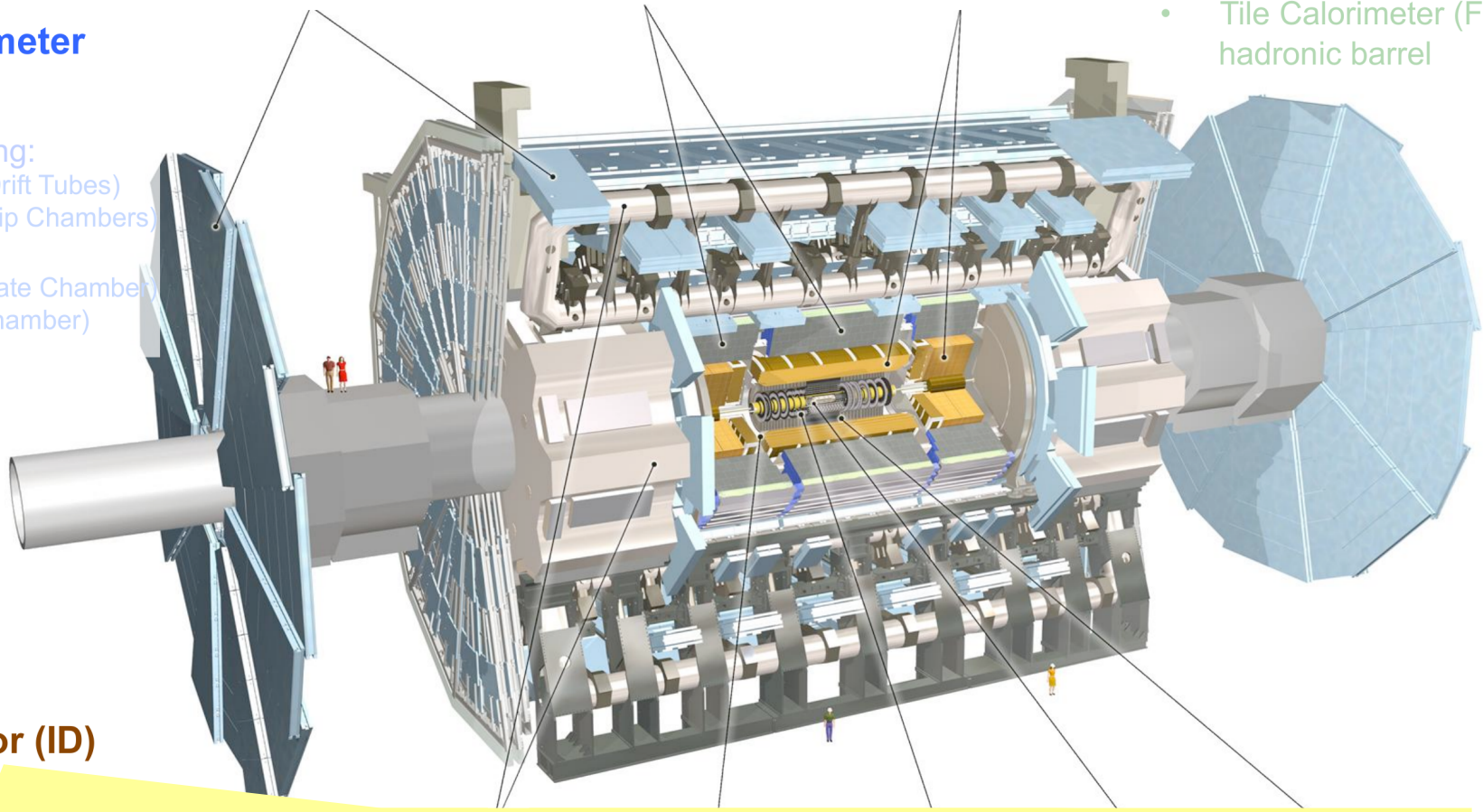


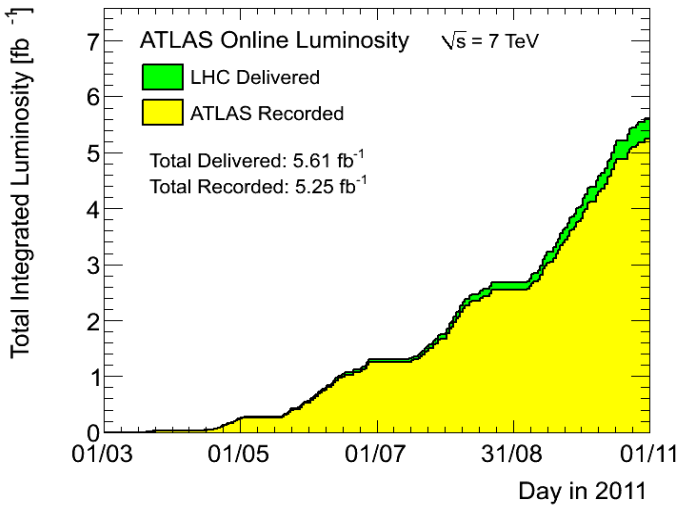
Inner Detector (ID)

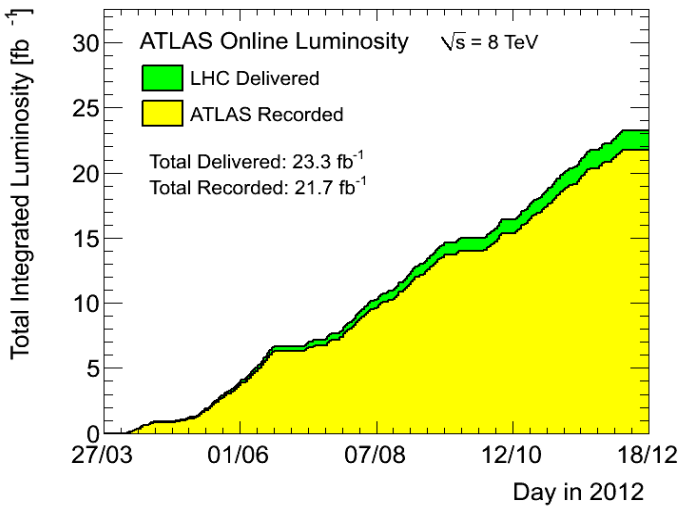
- $p_T > 0.4$ GeV, $|\eta| < 2.5$
- New for Run2: Insertable B-Layer (IBL) an additional inner-most pixel layer (r = 33mm) and lower x/X_0 beam pipe

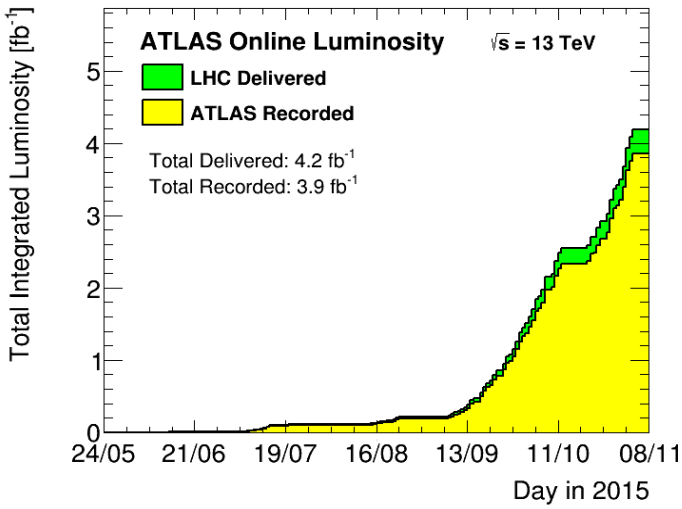
- Resolution in $m_{\mu+\mu-}$: around 50 MeV for J/ψ and 150 MeV for ϒ(nS)
- Resolution in b-hadron proper decay time around 100 fs (no IBL, ~30% improvement expected)

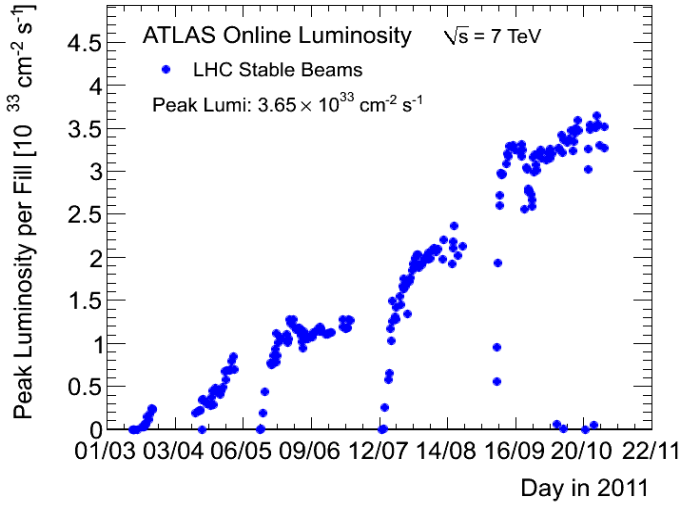
Data Taking

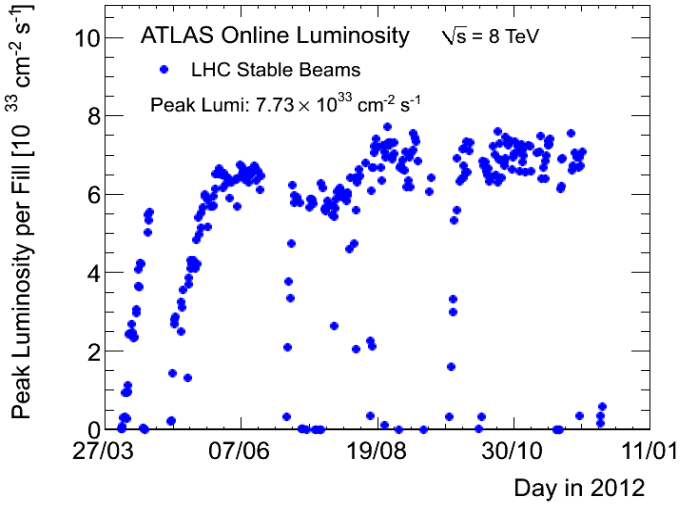
- **Datasets (pp):** 7 TeV data, 5.08 fb^{-1} 50ns, 3.7×10^{33} $cm^{-2}s^{-1}$ | 8 TeV, 21.3 fb^{-1} 50ns, 7.7×10^{33} $cm^{-2}s^{-1}$ | 13 TeV, 3.9 fb^{-1} 50/25ns, 5.0×10^{33} $cm^{-2}s^{-1}$

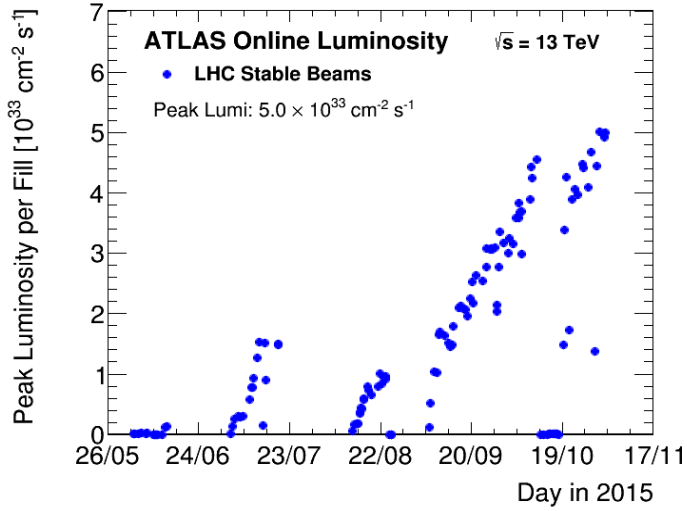






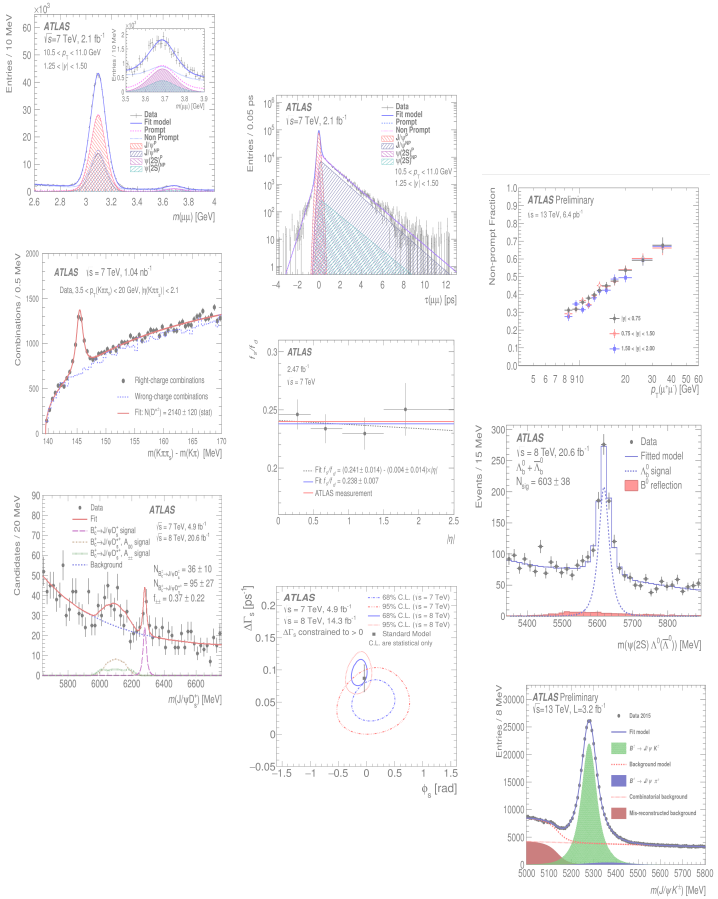






ATLAS B-Physics Programme

- **ATLAS B-physics programme includes precision measurements (rare decays, b-hadron decay properites, CPV), heavy flavour production (b-hadrons, quarkonia, associated quarkonia producion) and spectroscopy (new states and decay modes)**
  - Mostly in exclusive decays with single/di-/multi-muon final states, which allows to trigger low-p_T objects
- **Only recent results (since last La Thuile) to be presented:**
  - J/ψ and $\psi(2S)$ production at 7 and 8 TeV
  - J/ψ non-prompt fraction at 13 TeV
  - D-meson production at 7 TeV
  - f_s/f_d fragmentation fractions at 7 TeV
  - Observation of $\Lambda_b \to \psi(2S)\Lambda^0$
  - Study of $B_c \to J/\psi D_s^{+(*)}$ decays
  - CPV analysis in $B_s \to J/\psi\phi$ decay (full Run-1 data)
  - B-hadron reconstruction at 13 TeV



B-Physics Trigger

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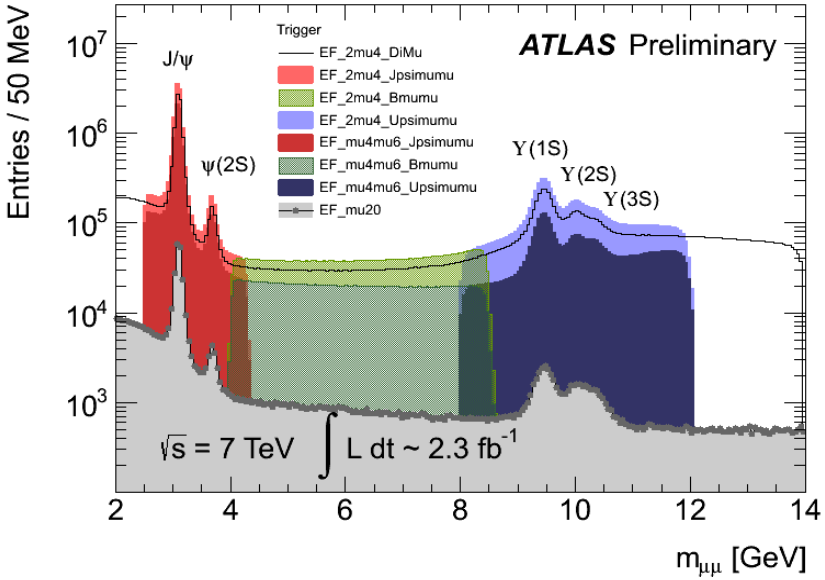
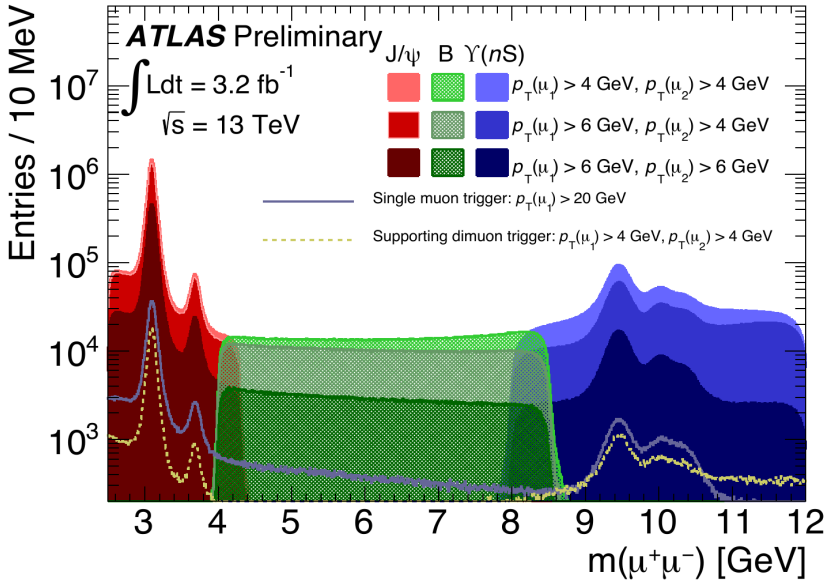
- 20/40 MHz collision rate → ~400 Hz recording
- B-physics concentrates on low-p_T di-muon signatures:
  - Quarkonia: $J/\psi \to \mu\mu$, $\Upsilon \to \mu\mu$, etc.
  - Exclusive $B \to J/\psi(\mu\mu)X$ decays
  - Rare and semi-rare $B \to \mu\mu(X)$ decays
- Trigger on low-p_T (4,6 GeV) di-muon
  - 2 muons at L1 (HW-based)
  - Confirmed at HLT
  - Track vertex fit and mass cuts at HLT
- 8 TeV data: low-p_T maintained introducing barrel triggers
- 13 TeV data: low-p_T maintained using barrel triggers, introduce coarse topological cuts (HW, opening angle, inv. mass) in 2016

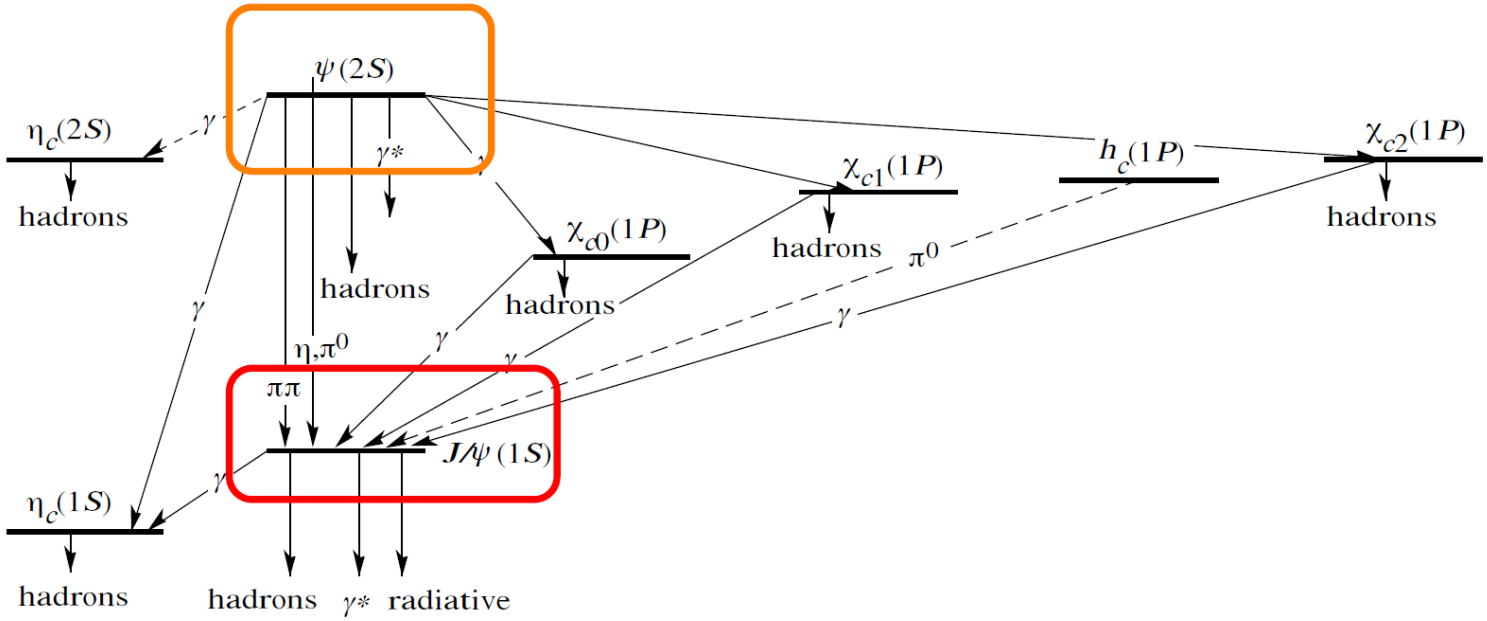




J/ψ and ψ(2S) Production at 7&8 TeV

arXiv:1512.03657, Submitted to EPJC

- Quarkonia production at LHC offers unique windows on understanding strong interactions



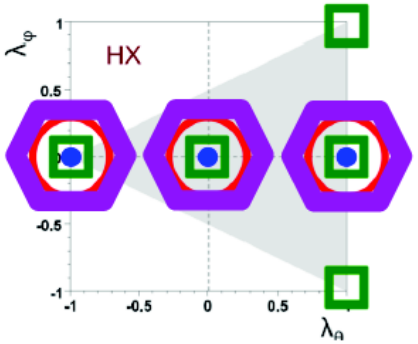
- Two distinct charmonium production mechanisms at LHC:
  - **Prompt:** produced directly in the pp interaction or through feed-down decays of heavier states
    - Theory: Non-relativistic QCD (arXiv:1009.3655) – pQCD $c\bar{c}$ production, soft evolution into quarkonia (data derived)
  - **Non-prompt:** produced in decays of b-hadrons, can be separated experimentally due to the "long" b-hadron lifetime
    - Theory: Fixed Order Next-to-Leading Logarithm (arXiv:1205.6344) – perturbative $b\bar{b}$ prod., data drive fragmentation and b-hadron decay model
- Around 35% of prompt J/ψ come from feed-down, ψ(2S) are almost all prompt

J/ψ and ψ(2S) Production at 7&8 TeV

arXiv:1512.03657, Submitted to EPJC

- Data (2.1 fb^{-1} @ 7 TeV and 11.4 fb^{-1} @ 8 TeV) collected using di-muon triggers
- Basic di-muon selection ($p_T(\mu_{1,2}) > 4$ GeV, $|\eta(\mu_{1,2})| < 2.3$), di-muon tracks vertex fit
- Weights to correct for trigger efficiency, muon indentification and reconstruction and geometrical acceptance
  - probe various spin-alignment scenarious (not yet measured at ATLAS)

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

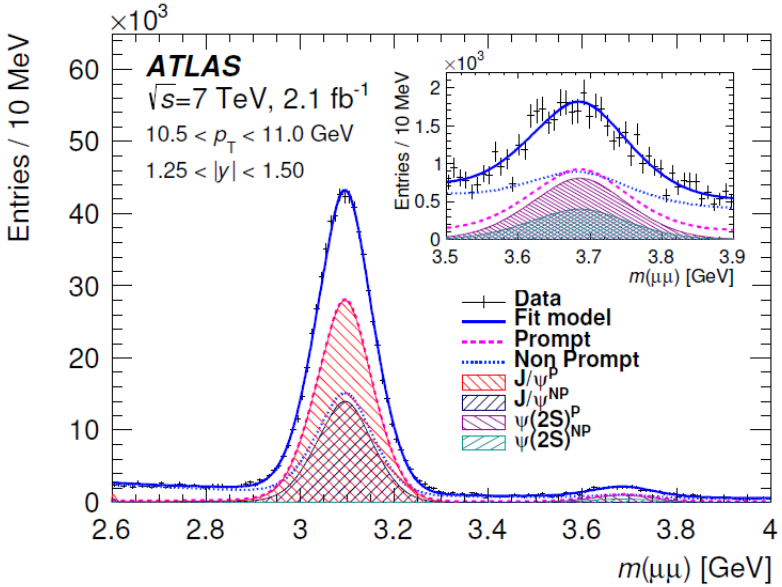


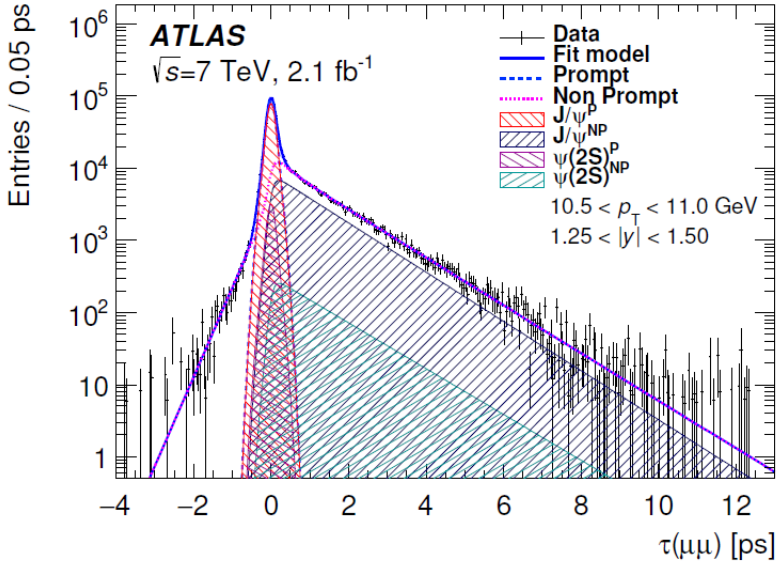
- Corrected prompt and non-prompt J/ψ and ψ(2S) yields determined from an unbinned fit to the 2D di-muon mass and pseudo-proper decay time disitribution
  - in 22 p_T x 8 rapidity bins

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

xy displacement of candidate from PV; Invariant mass of candidate; p_T of candidate

ATLAS CMS LHCb ALICE





J/ψ and ψ(2S) Production at 7&8 TeV

- Prompt J/ψ compared to NRQCD – good agreement across range of p_T, no y-dependence
- Prompt ψ(2S) (no significant feed-down) compared to NRQCD – mostly well describing data, some deterioration at high-p_T
- Non-prompt compared to FONLL – predicts slightly higher p_T spectra
- Ratio of prompt ψ(2S) / J/ψ flat across the whole p_T range
- Prompt J/ψ fraction dominates at low-p_T, but non-prompt exceeds prompt at around 20 GeV

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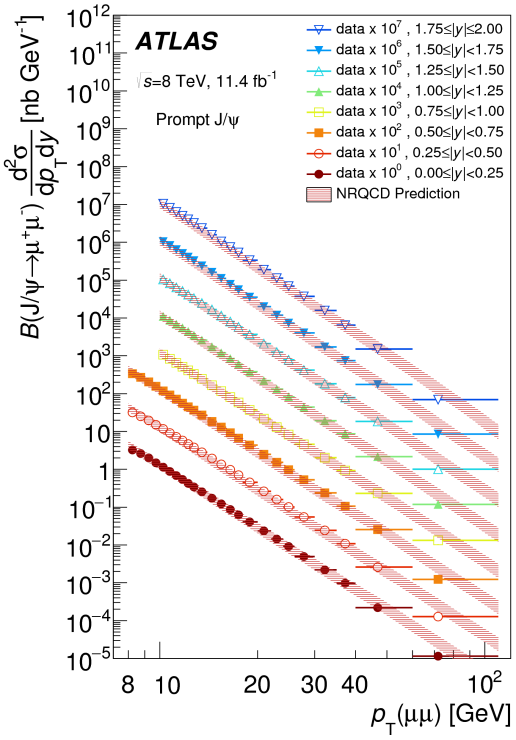

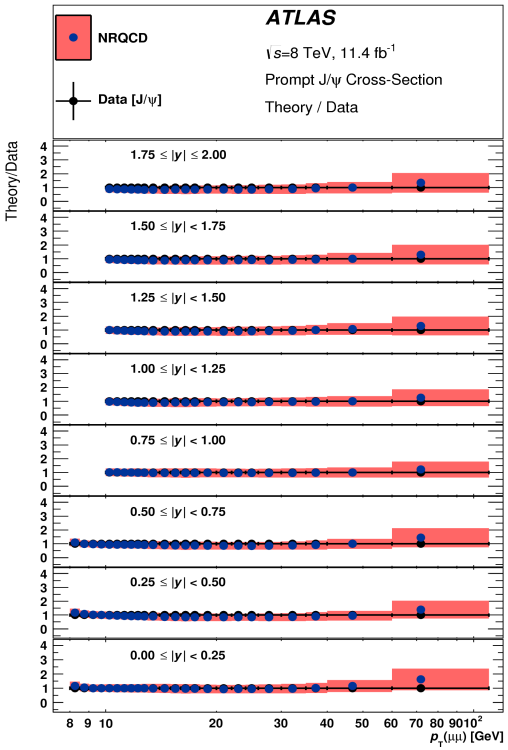

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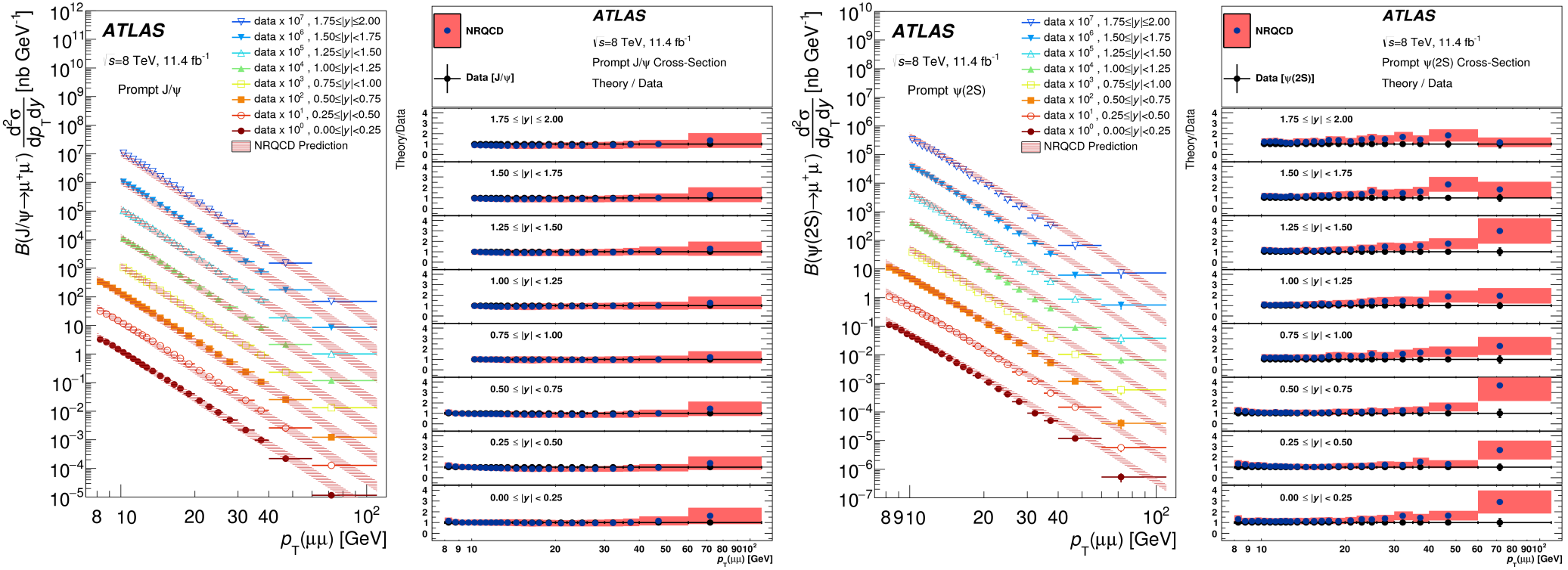

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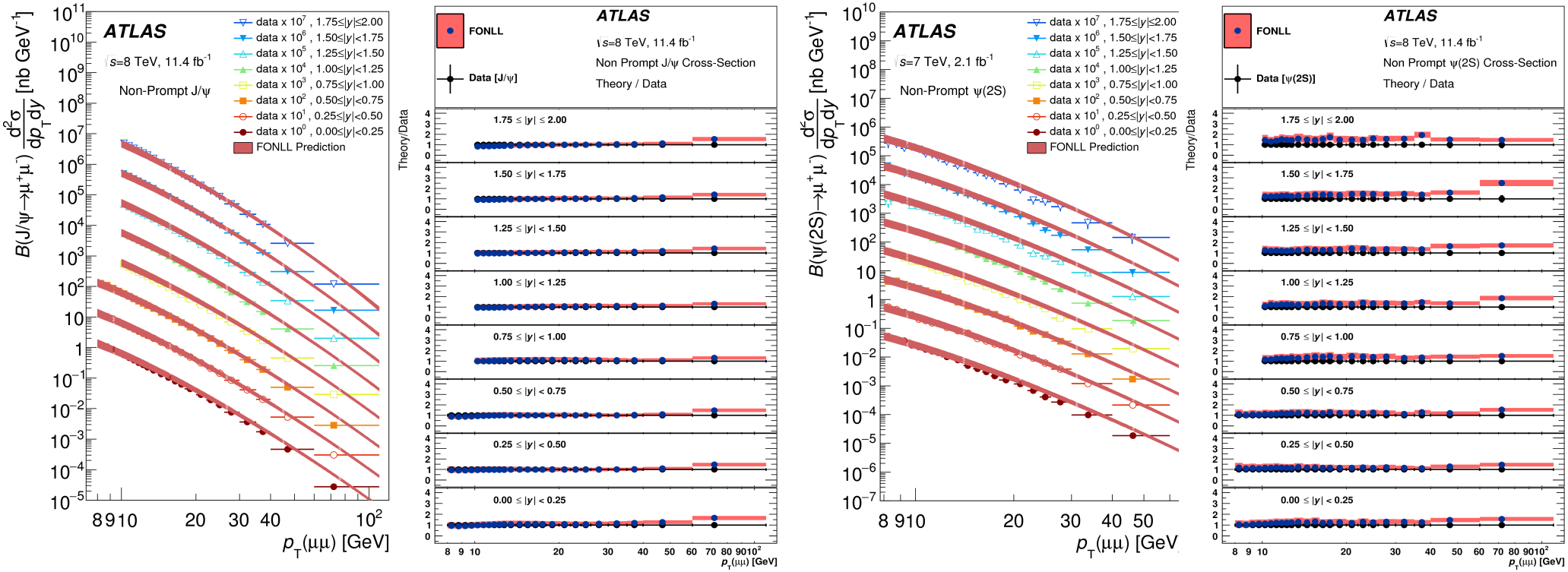

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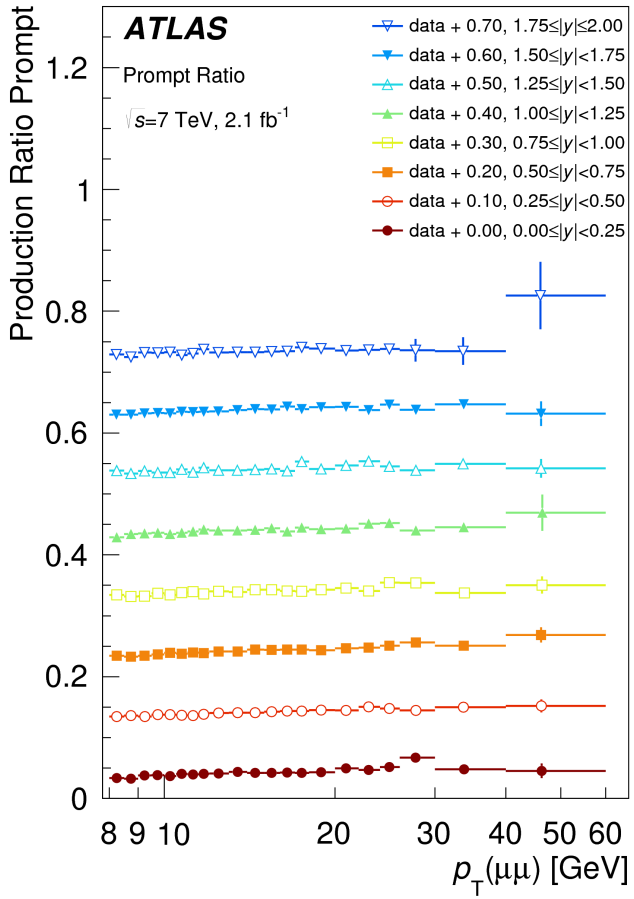

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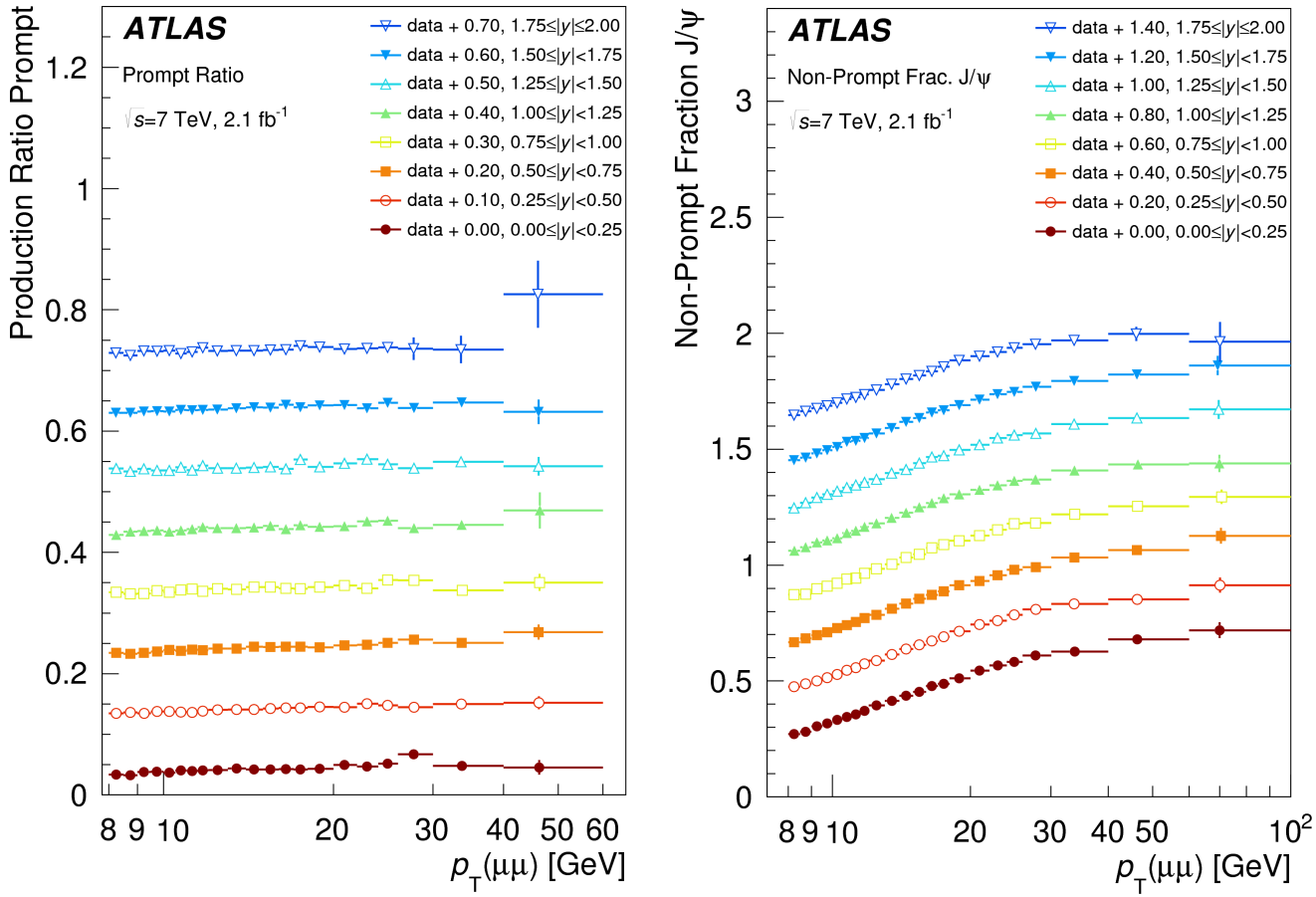
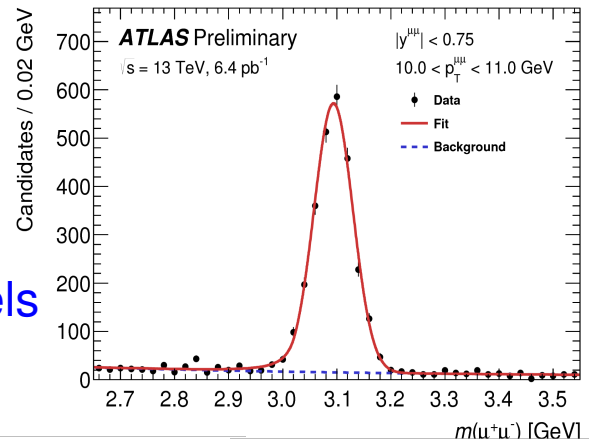


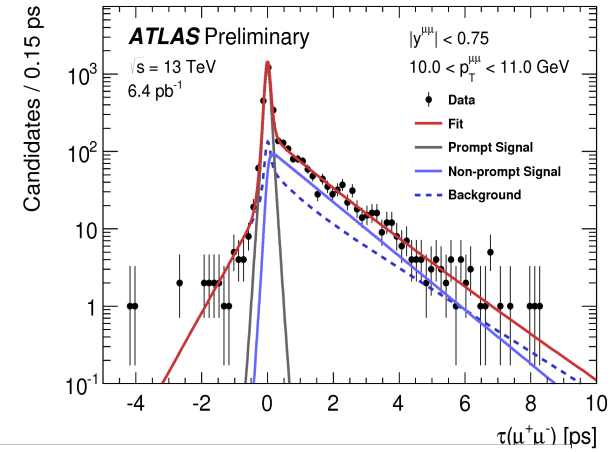
arXiv:1512.03657, Submitted to EPJC

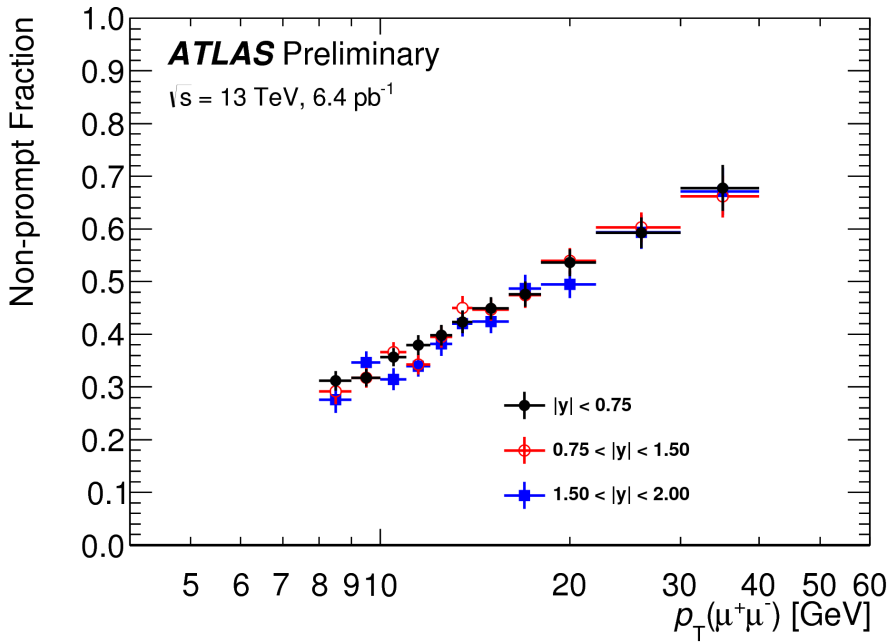
Fraction of Non-Prompt J/ψ at 13 TeV

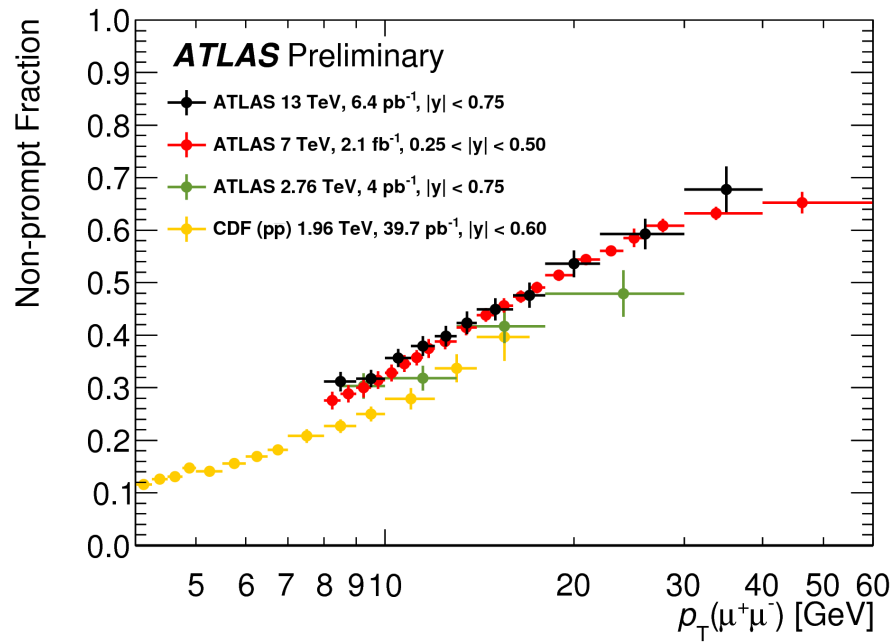
ATLAS-CONF-2015-030

- First ATLAS quarkonium production measurement at 13 TeV (similar techniques to the Run-1 study)
- Early data sample 6.4 pb^{-1} collected with di-muon triggers
- Yields extracted from an un-weighted and unbinned fit to 2D di-muon mass and proper decay time
- Efficiencies and acceptance cancels to a good approximation in the non-prompt fraction









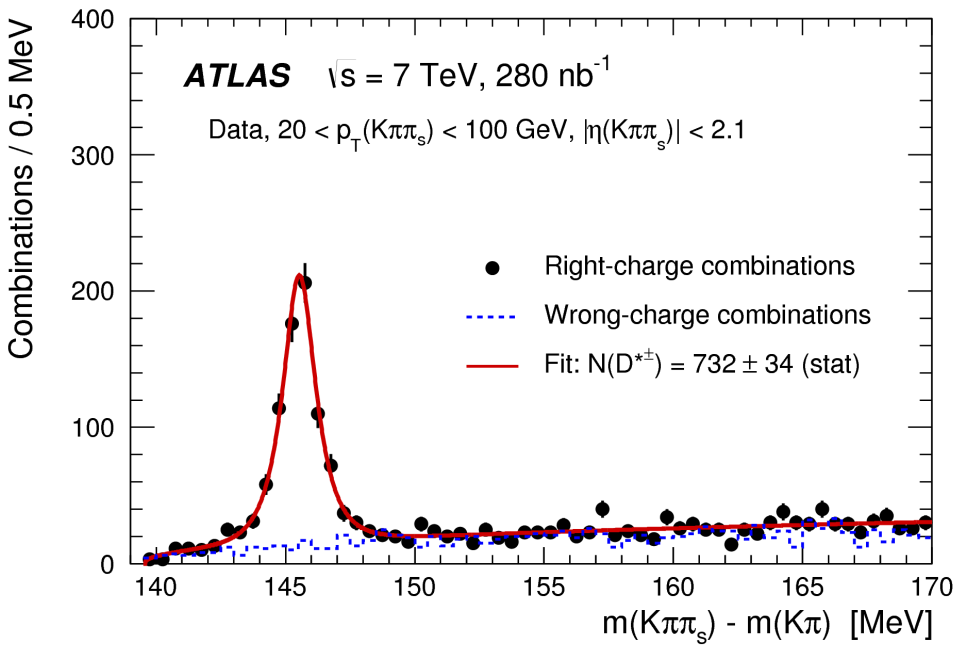
- Interesting trends in dependence on √s, though little change between 7 and 13 TeV

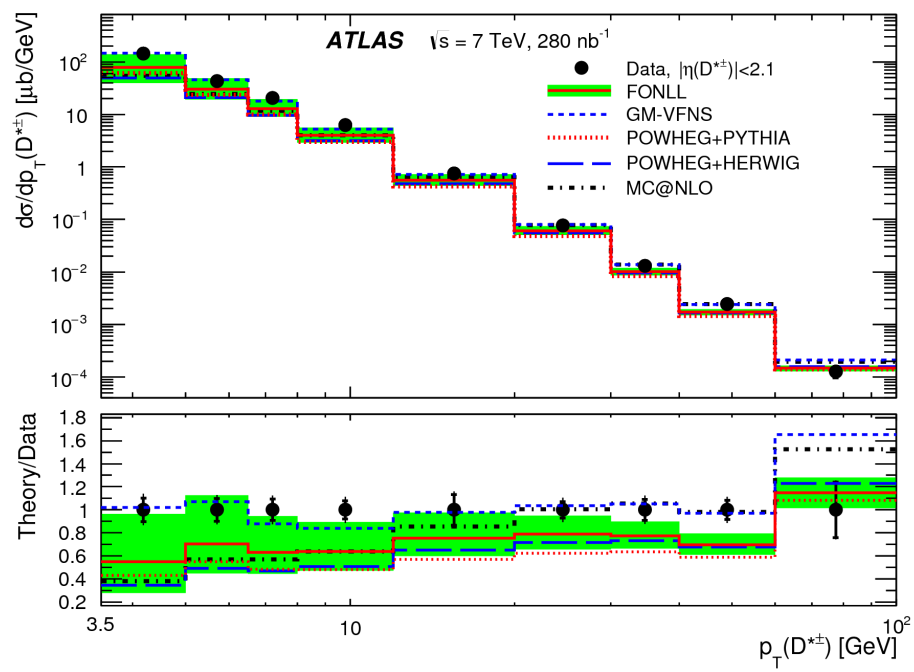
$D^{(*)\pm}_{(s)}$ Production at 7 TeV

- Charm production ($D^{\pm}$, $D^{*\pm}$, $D_s^{\pm}$) studied through reconstruction of exclusive D-meson decays, extending previous measurement in p_T range
- Valuable tool for tuning and validation of MC generators used across LHC physics
- Total and differential x-section compared to theory predictions and MC generators
  - Results within fiducial space ($3.5 < p_T < 100$ GeV, $|\eta| < 2.1$) extrapolated to a measurement of the total charm x-section:

$$\sigma_{c\bar{c}}^{\text{tot}} = 8.6 \pm 0.3\,(\text{stat}) \pm 0.7\,(\text{syst}) \pm 0.3\,(\text{lum}) \pm 0.2\,(\text{ff})^{+3.8}_{-3.4}\,(\text{extr})\,\text{mb}$$

  - Extracted strangeness suppression factor in charm fragmentation
  - Extracted fraction of charged non-strange D-mesons produced in a vector state





arXiv:1512.02913, Submitted to Nucl. Phys. B

b-quark Fragmentation Fractions f_s/f_d

Phys. Rev. Lett. 115, 262001 (2015)

- Important for studies like $B_{(s)} \to \mu\mu$
- Using decay modes $B_{(s)} \to J/\psi\phi$ and $B^0 \to J/\psi K^{*0}$
- Measured as a function of p_T and η (no evident dependence found)

$$\frac{f_s}{f_d}\frac{\mathcal{B}(B_s^0 \to J/\psi\phi)}{\mathcal{B}(B_d^0 \to J/\psi K^{*0})} = 0.199 \pm 0.004(\text{stat}) \pm 0.008(\text{sys})$$

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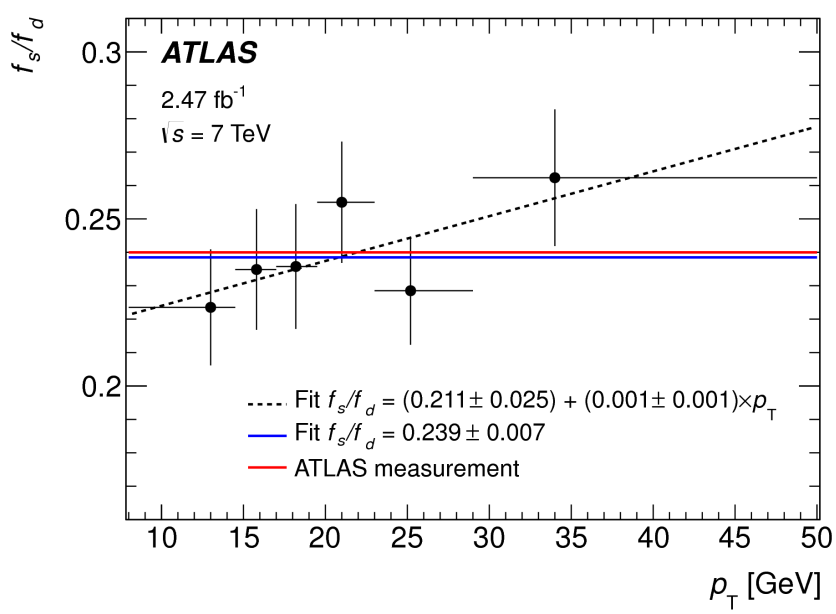
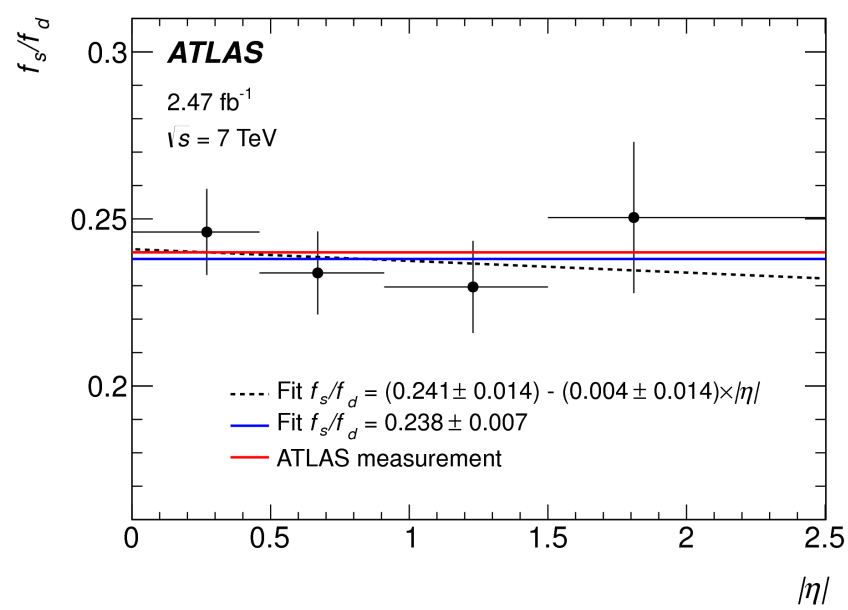
Perturbative QCD prediction: X. Liu, W.Wang, Y.Xie: Phys. Rev. D 89 (2014) 094010, arXiv:1309.0313v2





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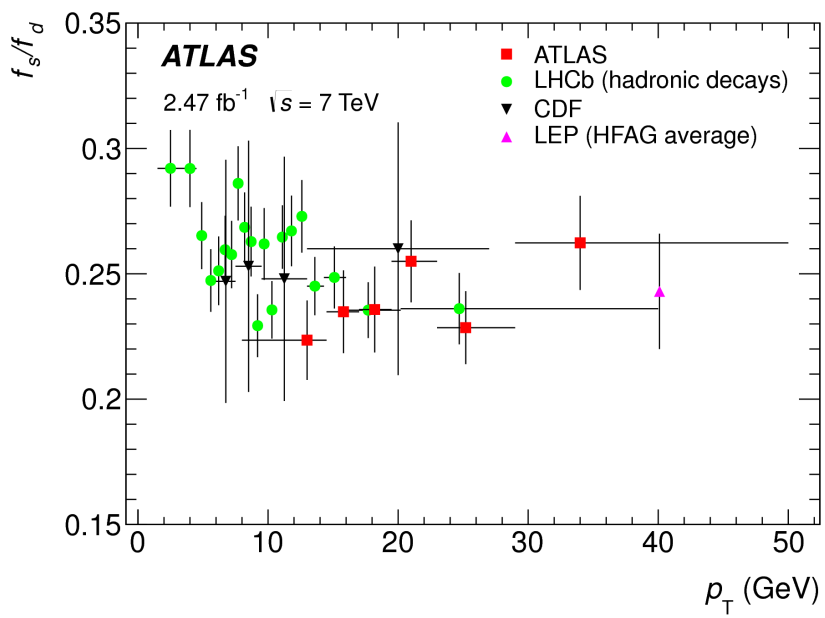
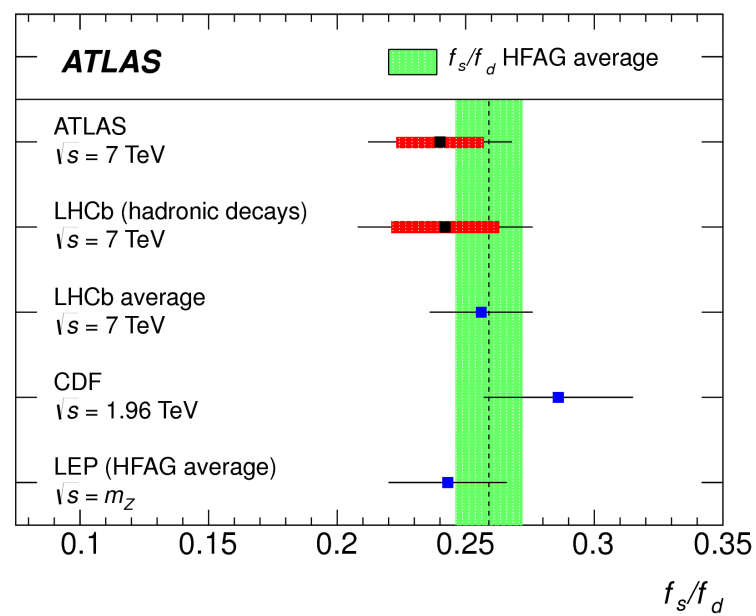
Perturbative QCD prediction: X. Liu, W.Wang, Y.Xie: Phys. Rev. D 89 (2014) 094010, arXiv:1309.0313v2

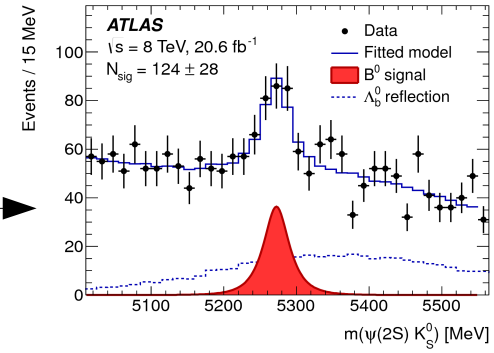


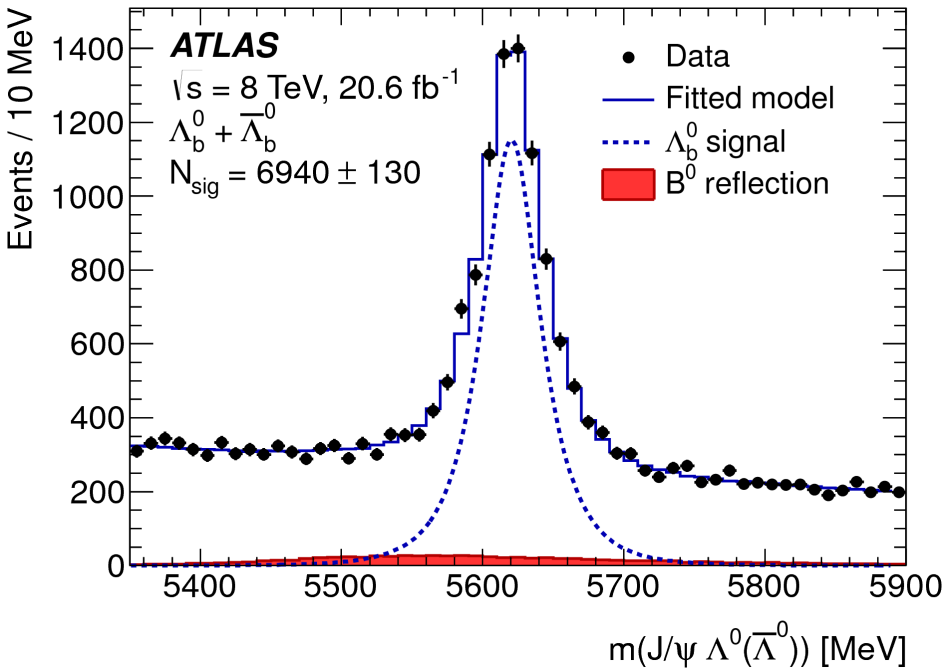


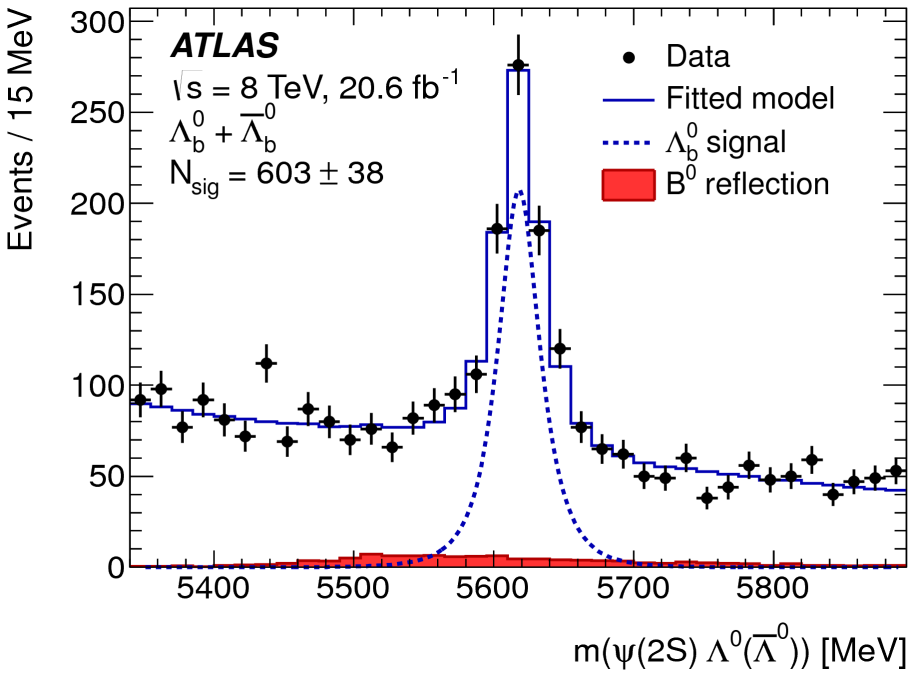
Observation of Λ_b Decay Mode $\Lambda_b \to \psi(2S)\Lambda^0$

Phys. Lett. B 751 (2015) 63-80

- First observation of the decay mode $\Lambda_b \to \psi(2S)\Lambda^0$ (8 TeV pp collisions)
- Measured relative BR to $\Lambda_b \to J/\psi\Lambda^0$:
  - In kinematic range $p_T(\Lambda_b) > 10$ GeV $|\eta(\Lambda_b)| < 2.1$
  - Modeling $B^0 \to \psi(xS)K^0_s$ reflection
  - <0.5 % bias to ratio from $\Lambda_b \to \Lambda^0\mu\mu$







$$\frac{\Gamma(\Lambda_b^0 \to \psi(2S)\Lambda^0)}{\Gamma(\Lambda_b^0 \to J/\psi\,\Lambda^0)} = 0.501 \pm 0.033(\text{stat}) \pm 0.016(\text{syst}) \pm 0.011(\mathcal{B})$$

- Prediction is 0.8 ± 0.1
- 0.5 - 0.8 in analogous B-meson decays

BR & Angular Analysis of $B_c \to J/\psi D_s^{+(*)}$

Eur. Phys. J. C, 76(1), 1 (2016)

- Two heavy quarks, both can decay weakly, affects theoretical prediction of B_c properties

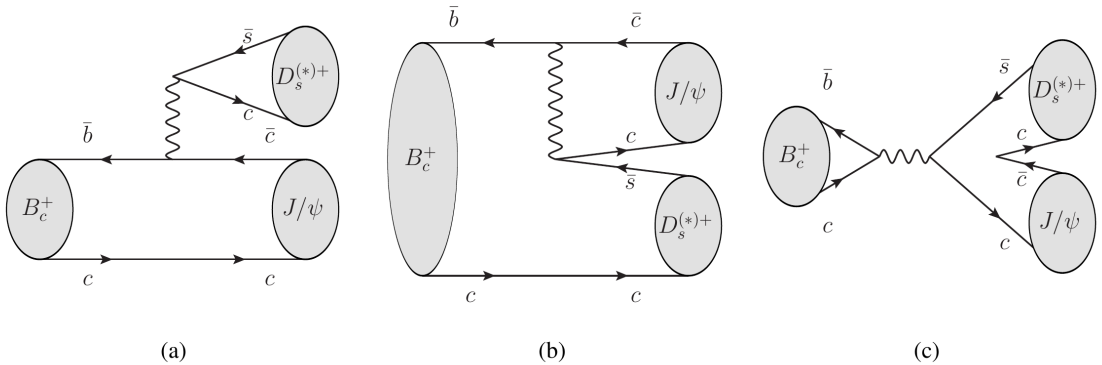


Figure 1: Feynman diagrams for $B_c^+ \to J/\psi D_s^{(*)+}$ decays: (a) colour-favoured spectator, (b) colour-suppres spectator, and (c) annihilation topology.

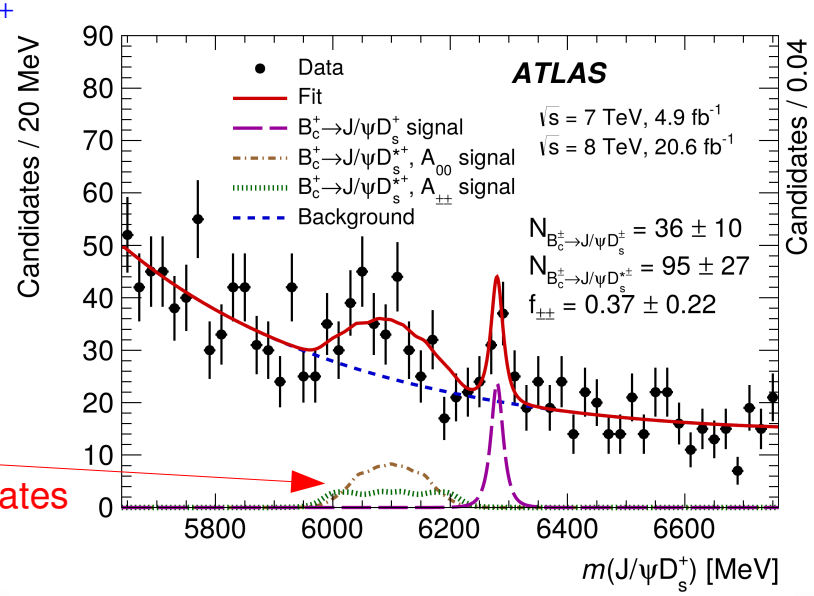
- $B_c \to J/\psi D_s^{+*}$ decay is a transition of PS→ V+V => described by 3 helicity amplitudes
  - Simplified angular analysis, distinguishing A_{00} from (A_{++} and A_{--}) => measuring fraction of transverse polarization Γ^{++}/Γ^{00}
- Measurement of relative BR of $B_c \to J/\psi D_s^+$ w.r.t $B_c \to J/\psi D_s^{+*}$ and of both the decay modes w.r.t. BR of $B_c \to J/\psi \pi^+$

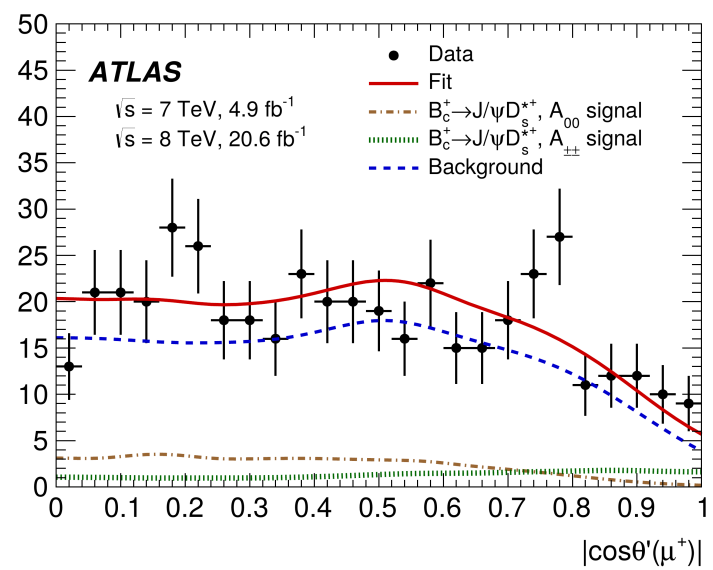
$D_s^+ \to \phi(K^+K^-)\pi^+$

$D_s^{+*} \to D_s^+[\pi^0/\gamma]_{soft}$

(not detected)

MC-based templates





$B_c \to J/\psi D_s^{+(*)}$: Results

Eur. Phys. J. C, 76(1), 1 (2016)

- Ratios of the BR of the decay modes:

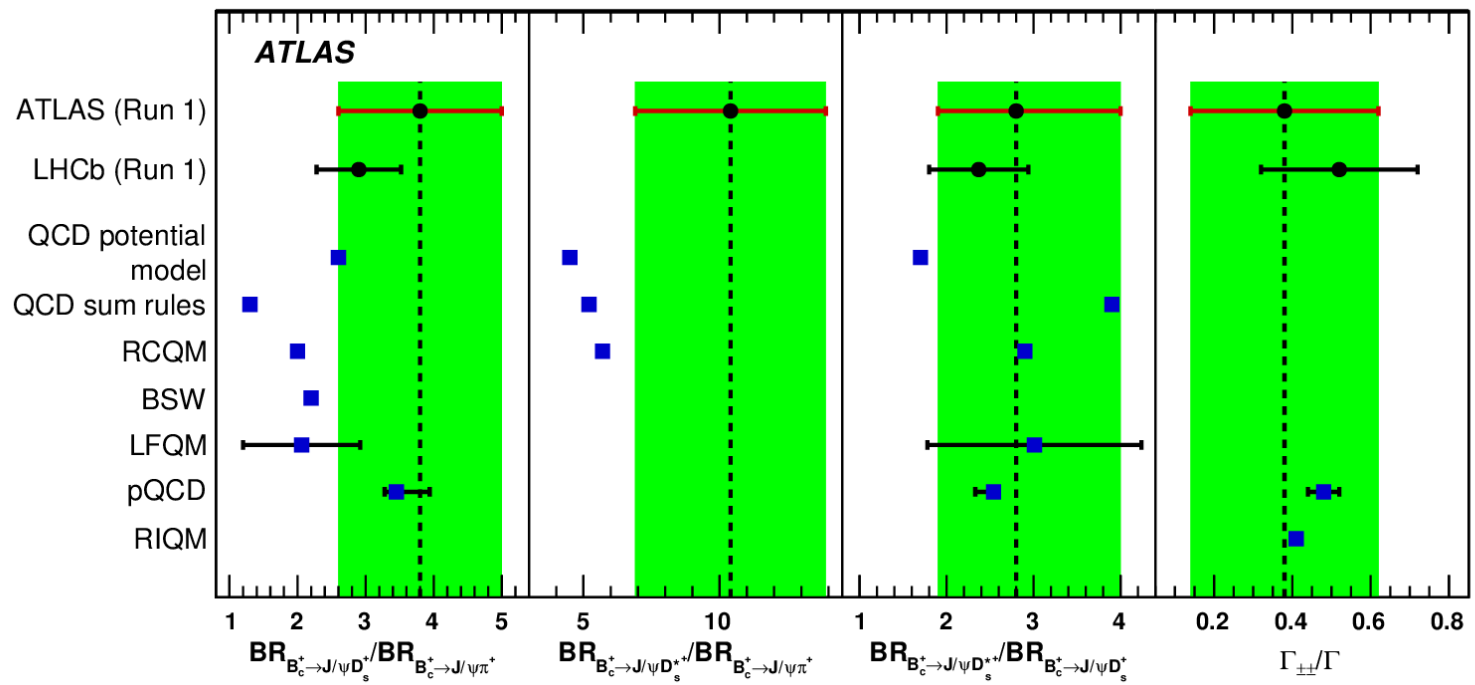
$$\mathcal{R}_{D_s^+/\pi^+} = \frac{\mathcal{B}_{B_c^+\to J/\psi D_s^+}}{\mathcal{B}_{B_c^+\to J/\psi \pi^+}} = 3.8 \pm 1.1\ (\text{stat.}) \pm 0.4\ (\text{syst.}) \pm 0.2\ (\text{BF}),$$

$$\mathcal{R}_{D_s^{*+}/\pi^+} = \frac{\mathcal{B}_{B_c^+\to J/\psi D_s^{*+}}}{\mathcal{B}_{B_c^+\to J/\psi \pi^+}} = 10.4 \pm 3.1\ (\text{stat.}) \pm 1.5\ (\text{syst.}) \pm 0.6\ (\text{BF}),$$

$$\mathcal{R}_{D_s^{*+}/D_s^+} = \frac{\mathcal{B}_{B_c^+\to J/\psi D_s^{*+}}}{\mathcal{B}_{B_c^+\to J/\psi D_s^+}} = 2.8^{+1.2}_{-0.8}\ (\text{stat.}) \pm 0.3\ (\text{syst.}),$$

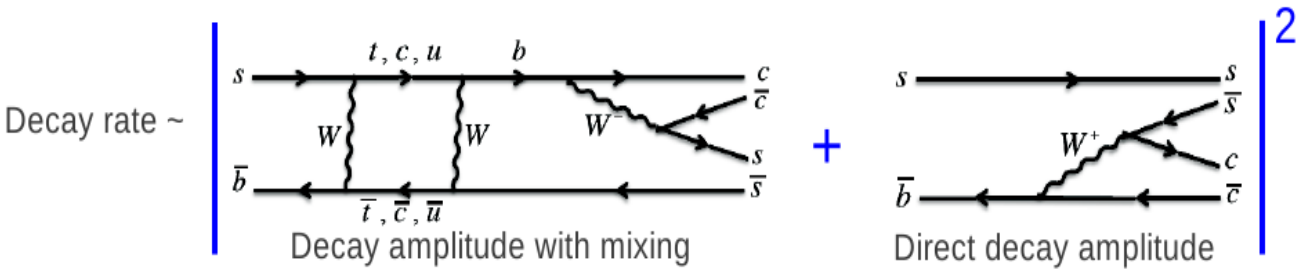
- Transverse polarization fraction: $\Gamma_{\pm\pm}/\Gamma = 0.38 \pm 0.23\ (\text{stat.}) \pm 0.07\ (\text{syst.})$

- Comparison to LHCb result and theory predictions:



Measurement of $\Delta\Gamma_s$ and ϕ_s in $B_s \to J/\psi\phi$

- CP violation in $B_s \to J/\psi\phi$ occurs through the interference in mixing and decay



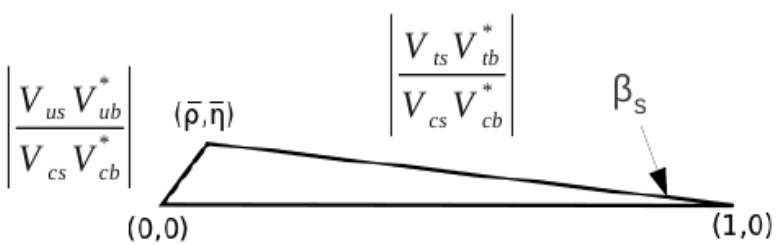
B_s mixing:

- Mass difference $\Delta m = m_H - m_L$
- Mixing phase ϕ_s
- Decay width difference $\Delta\Gamma_s = \Gamma_L - \Gamma_H$

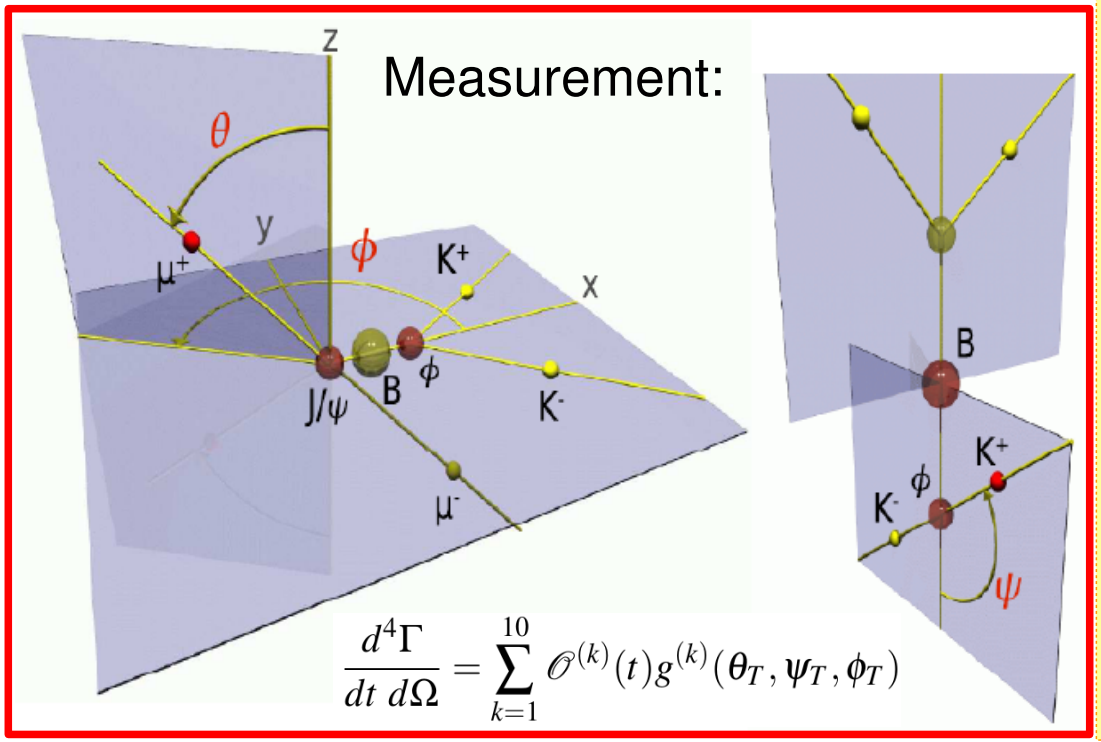
$$|B_s^H\rangle = p|B_s^0\rangle - q|\bar{B}_s^0\rangle$$
$$|B_s^L\rangle = p|B_s^0\rangle + q|\bar{B}_s^0\rangle$$

- Time evolution of flavour tagged $B_s \to J/\psi\phi$ very sensitive to New Physics
- 9 physics parameters to describe $B_s \to J/\psi\phi$ decay

Γ_s, $\Delta\Gamma_s$	decay with and decay width difference
ϕ_s ($\approx 2\beta_s$)	CP violating phase
$\lvert A_0\rvert^2$, $\lvert A_{\parallel}\rvert^2$	CP state amplitudes
$\delta_{\parallel}$, $\delta_{\perp}$	Strong phases
$\lvert A_S\rvert^2$, δ_S	S-wave parameters



ϕ_s small in SM, clear to see potential excess from NP



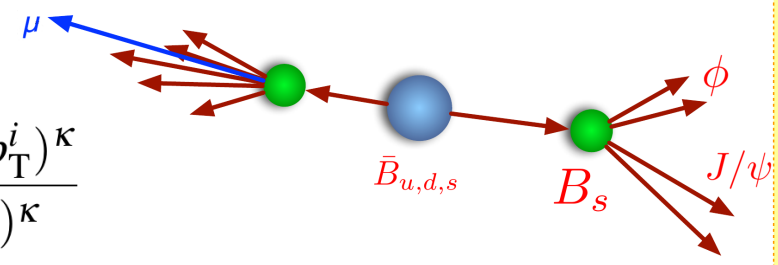
JHEP 12 (2012) 072, PRD 90 052007 (2014), **arXiv:1601.03297 (2016)** submitted to JHEP

B-Flavour Tagging in $B_s \to J/\psi\phi$

- Knowledge of $B_s/\overline{B}_s$ flavour at production significantly increases signal PDF sensitivity to ϕ_s
- Charge of p_T-weighted tracks in a cone (R=0.5) around opposite side muon/electron or in a jet:

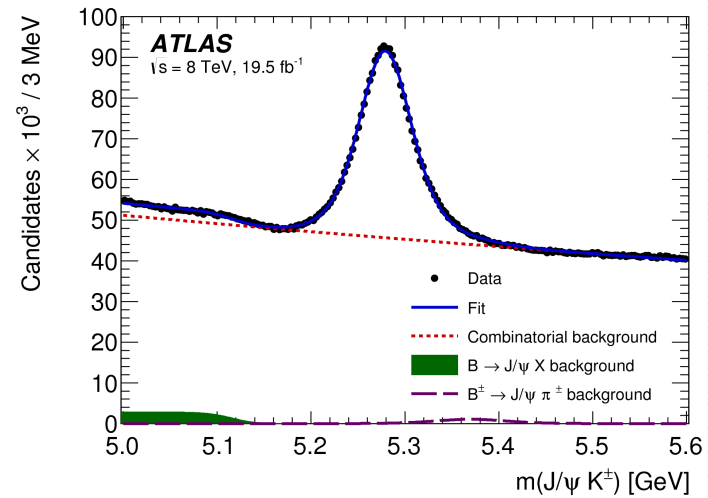
$$Q_\mu = \frac{\sum_i^{N\ \mathrm{tracks}} q^i \cdot (p_T^i)^\kappa}{\sum_i^{N\ \mathrm{tracks}} (p_T^i)^\kappa}$$

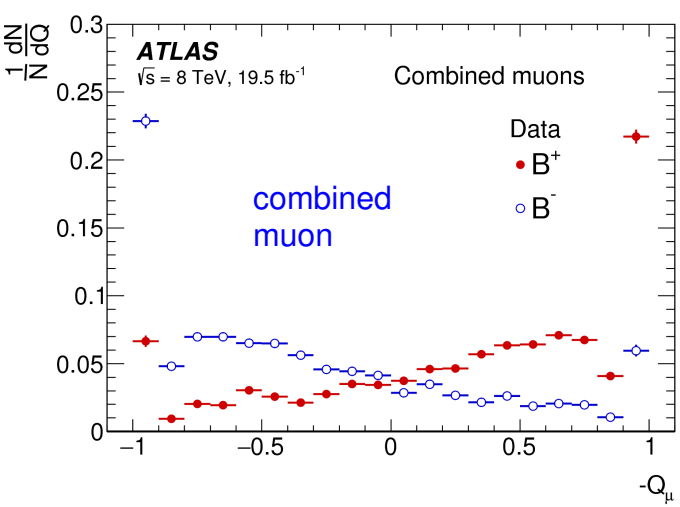
=> build per-candidates B_s tag probability

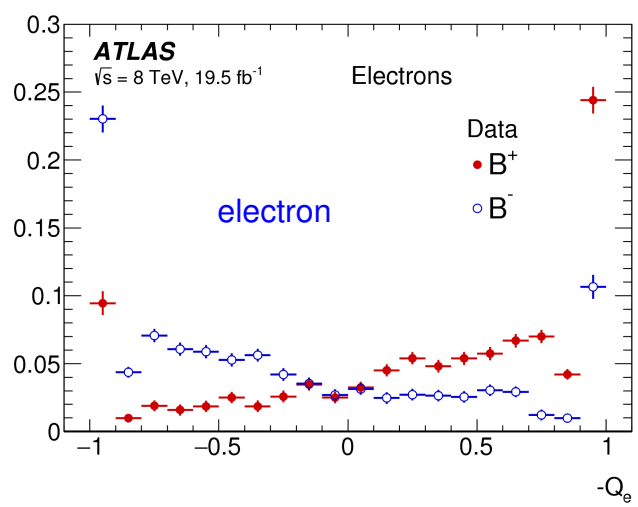


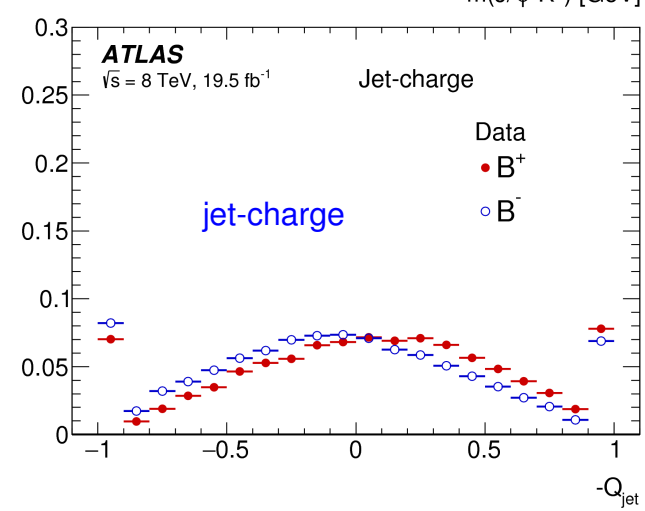
- Calibration on self-tagged $B^+ \to J/\psi K^+$ channel

Tagger	Efficiency [%]	Dilution [%]	Tagging Power [%]
Combined μ	4.12 ± 0.02	47.4 ± 0.2	0.92 ± 0.02
Electron	1.19 ± 0.01	49.2 ± 0.3	0.29 ± 0.01
Segment-tagged μ	1.20 ± 0.01	28.6 ± 0.2	0.10 ± 0.01
Jet-charge	13.15 ± 0.03	11.85 ± 0.03	0.19 ± 0.01
Total	19.66 ± 0.04	27.56 ± 0.06	1.49 ± 0.02





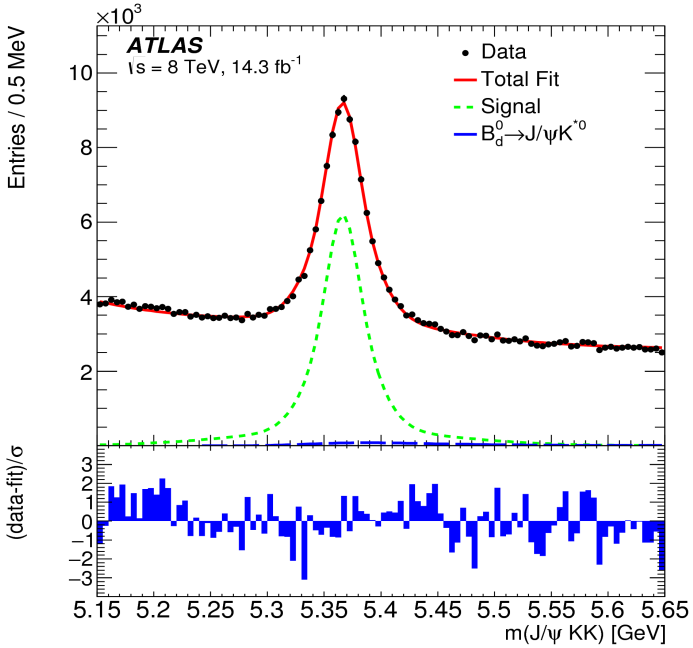


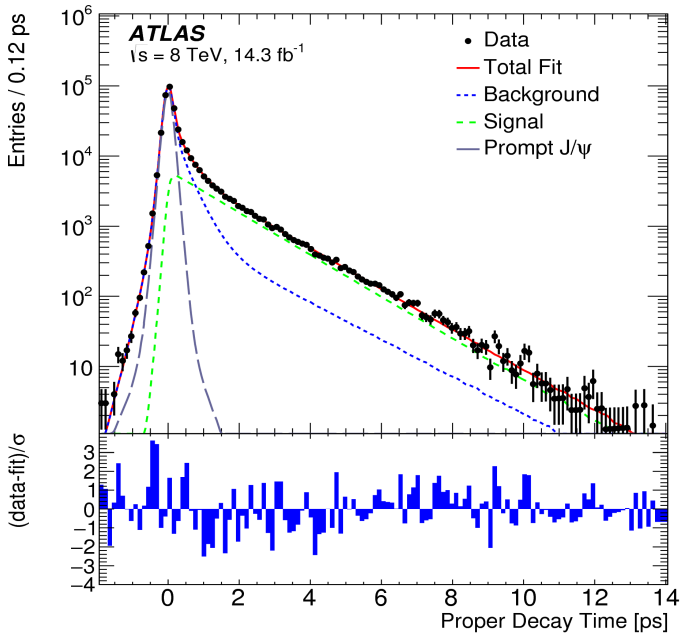


JHEP 12 (2012) 072, PRD 90 052007 (2014), **arXiv:1601.03297 (2016)** submitted to JHEP

Max. Likelihood Fit of $B_s \to J/\psi\phi$

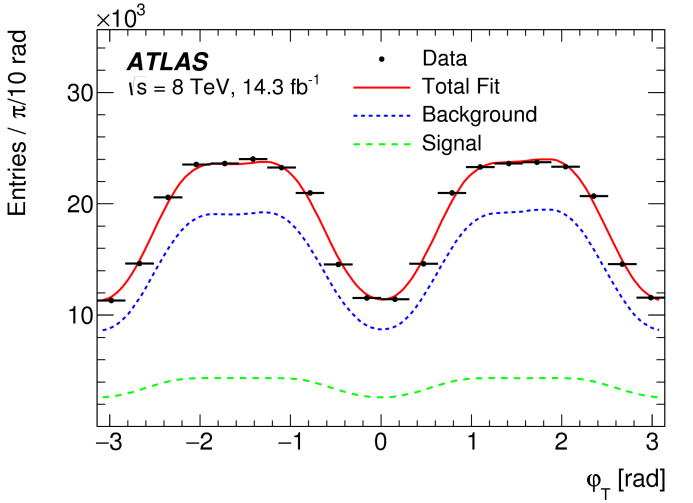
$$\ln \mathcal{L} = \sum_{i=1}^{N} \{ w_i \cdot \ln(f_s \cdot \mathcal{F}_s(m_i, t_i, \sigma_{t_i}, \Omega_i, P(B|Q), p_{T_i}) + f_s \cdot f_{B^0} \cdot \mathcal{F}_{B^0}(m_i, t_i, \sigma_{t_i}, \Omega_i, P(B|Q), p_{T_i}) + (1 - f_s \cdot (1 + f_{B^0})) \mathcal{F}_{bkg}(m_i, t_i, \sigma_{t_i}, \Omega_i, P(B|Q), p_{T_i})) \}$$

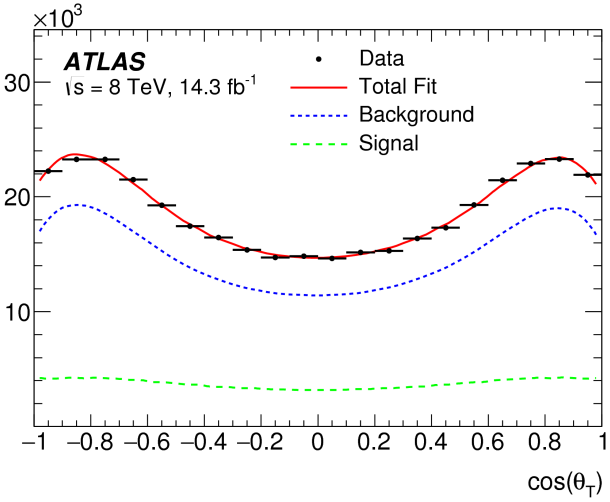


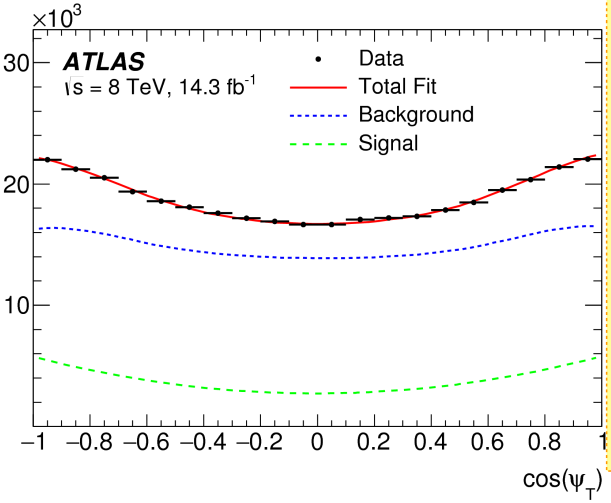


Unbinned max. likelihood fit:

- decay time 1/efficiency
- signal
- $B \to J/\psi K^*$, $B \to J/\psi K\pi$
- combinatorial background





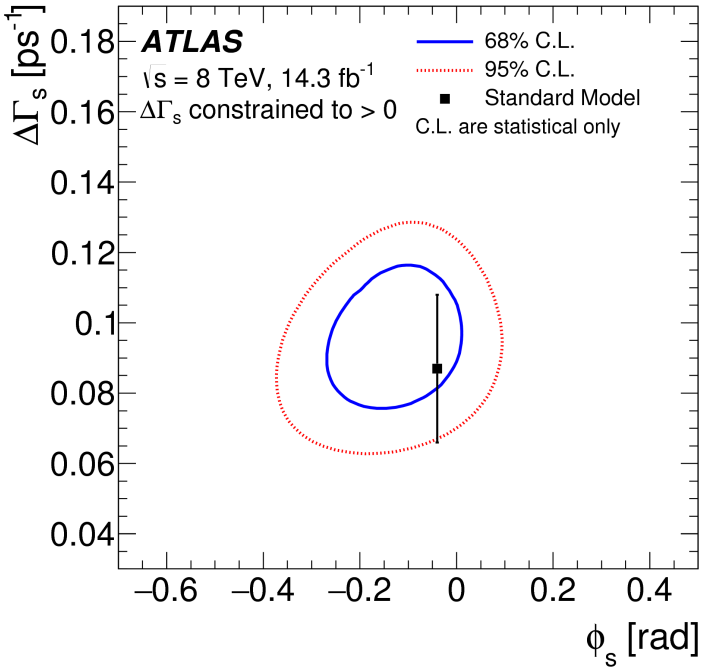


JHEP 12 (2012) 072, PRD 90 052007 (2014), **arXiv:1601.03297 (2016)** submitted to JHEP

Result of the CPV $B_s \to J/\psi\phi$ Study

- Result with 8 TeV data

Parameter	Value	Statistical uncertainty	Systematic uncertainty
ϕ_s[rad]	−0.123	0.089	0.041
$\Delta\Gamma_s$[ps^{-1}]	0.096	0.013	0.007
Γ_s[ps^{-1}]	0.678	0.004	0.004
$\lvert A_{\parallel}(0)\rvert^2$	0.230	0.005	0.006
$\lvert A_0(0)\rvert^2$	0.514	0.004	0.002
$\lvert A_S(0)\rvert^2$	0.090	0.008	0.020
$\delta_\perp$ [rad]	4.46	0.48	0.29
$\delta_\parallel$ [rad]	3.15	0.13	0.05
$\delta_\perp - \delta_S$ [rad]	−0.08	0.04	0.01

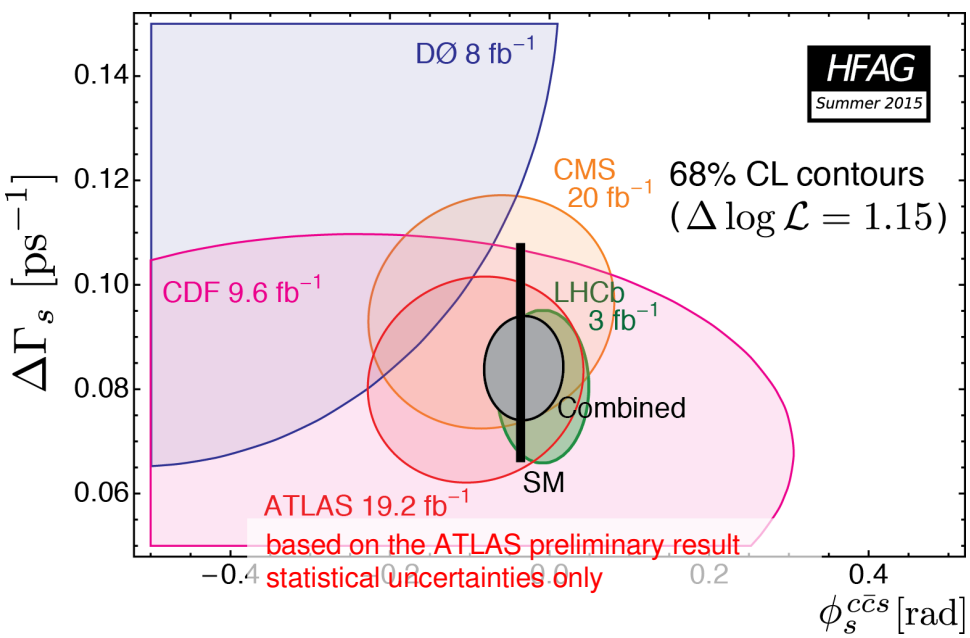


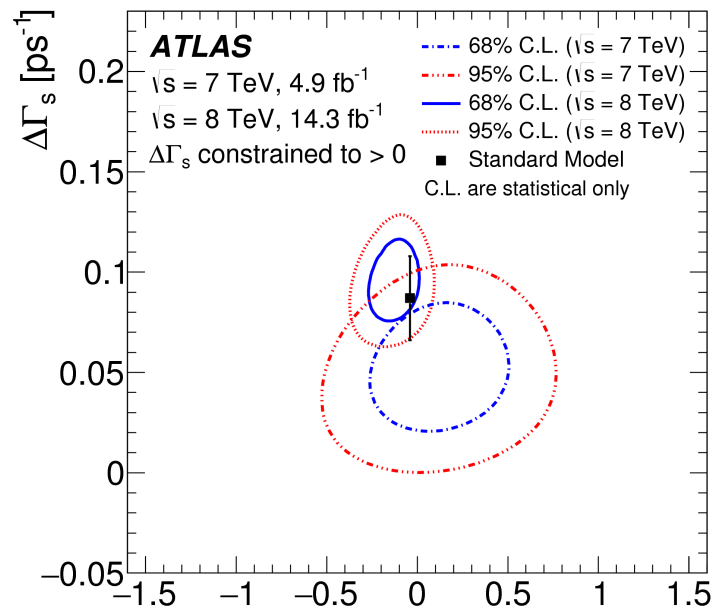
JHEP 12 (2012) 072, PRD 90 052007 (2014), **arXiv:1601.03297 (2016)** submitted to JHEP

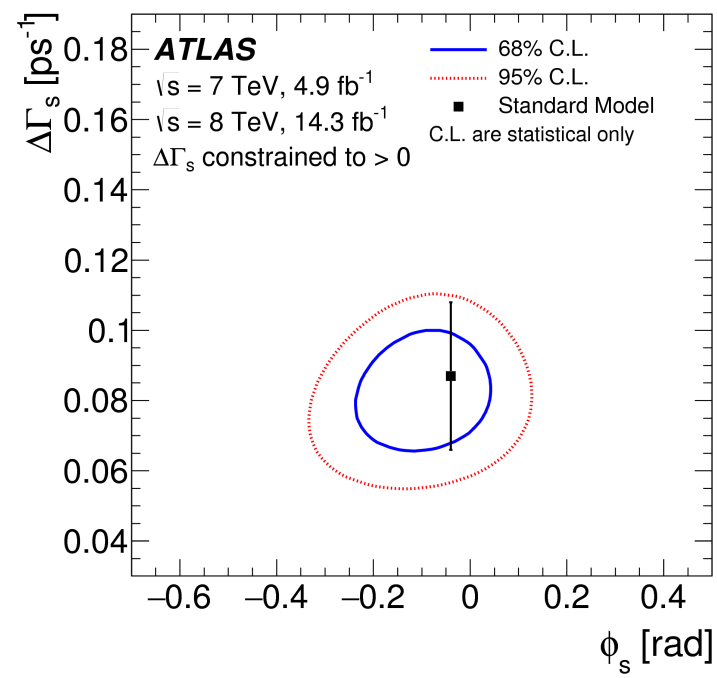
Result of the CPV $B_s \to J/\psi\phi$ Study

- Combination of 7 & 8 TeV results (BLUE comb.)

Par	Run1 combined Value	Stat	Syst
ϕ_s[rad]	−0.098	0.084	0.040
$\Delta\Gamma_s$[ps^{-1}]	0.083	0.011	0.007
Γ_s[ps^{-1}]	0.677	0.003	0.003
$\lvert A_{\parallel}(0)\rvert^2$	0.227	0.004	0.006
$\lvert A_0(0)\rvert^2$	0.514	0.004	0.003
$\lvert A_S\rvert^2$	0.071	0.007	0.017
$\delta_\perp$ [rad]	4.13	0.33	0.16
$\delta_\parallel$ [rad]	3.15	0.13	0.05
$\delta_\perp - \delta_S$ [rad]	−0.08	0.04	0.01





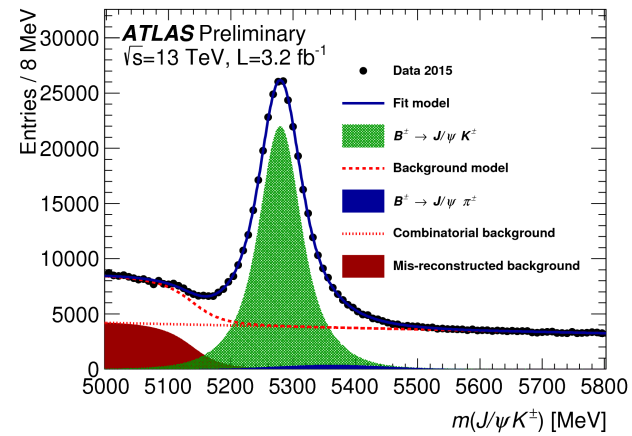


JHEP 12 (2012) 072, PRD 90 052007 (2014), **arXiv:1601.03297 (2016)** submitted to JHEP

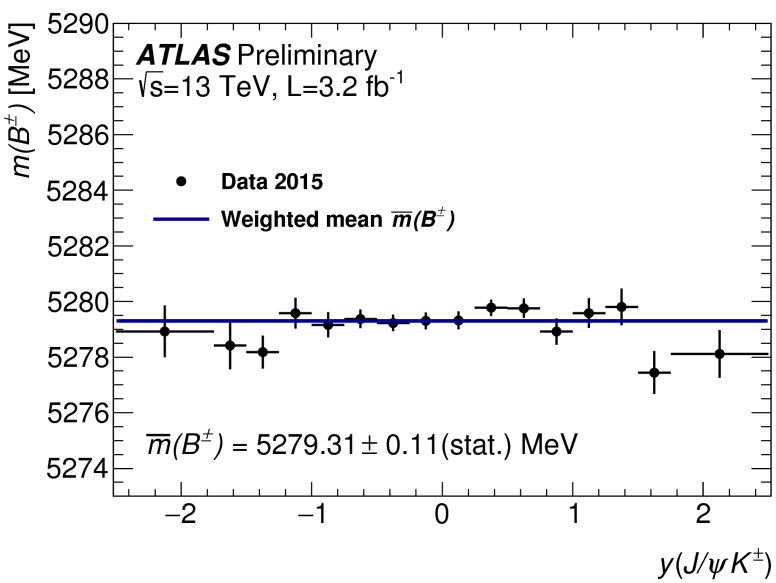
Run2 B-Meson Reconstruction

ATLAS-CONF-2015-064

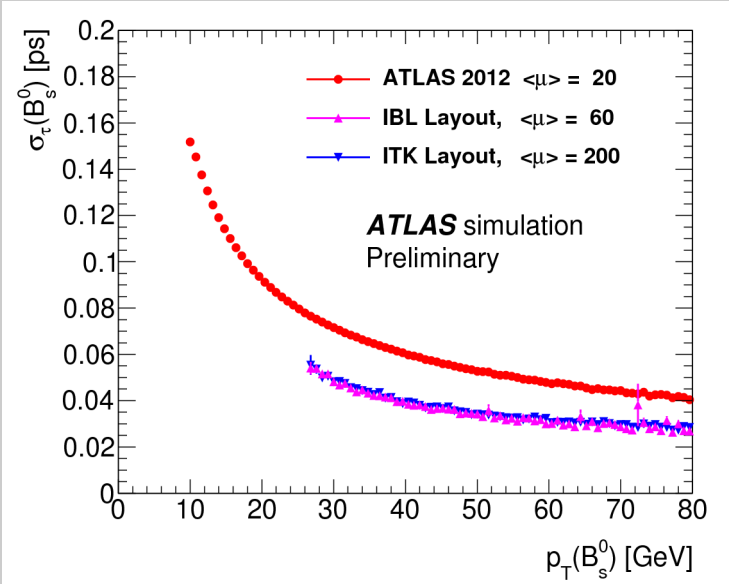
- $B^{\pm}$ meson mass reconstruction using full 2015 pp dataset at 13 TeV
- Preparation for further detailed b-hadron measurements
  - Reconstruction in $B^{\pm} \rightarrow J/\psi K^{\pm}$ decay mode
  - Simple selection ($p_T(\mu) > 4$ GeV, $p_T(K) > 3$ GeV)
  - 3-tracks vertex fit ($\chi^2/NDF < 3$)
  - Independent fits in 16 rapidity regions
  - Model systematics (p_T scale and vertexing not included)



Fit	$B^{\pm}$ mass [MeV]	Fit error [MeV]
Default Fit	5279.31	0.11 (stat.)
$L_{xy} > 0.2$ mm	5279.34	0.09 (stat.)
World Average fit	5279.29	0.15
LHCb	5279.38	0.11 (stat.) $\pm$ 0.33 (syst.)



Expected improvement in B-vertex decay time resolution with IBL and ITK (tracking detector upgrades)



ATL-PHYS-PUB-2013-010

Summary: Run1 & Run2 B-Physics Results

Short Title	Int L	Journal	Preprint
NEW CP-violating phase φ_s and the B^0_s meson decay width difference with $B^0_s \to J/\psi\ \phi$	14.3 fb^{-1}	Submitted to JHEP	arXiv:1601.03297
NEW Prompt and non-prompt production of J/ψ and ψ(2S) in pp collisions at $\sqrt{s}$ = 7 and 8 TeV	(2.1 + 11.4) fb^{-1}	Submitted to Eur. Phys. J. C.	arXiv:1512.03657
NEW $D^{*\pm}$, $D^{\pm}$ and $D_s^{\pm}$ meson production cross sections in pp collisions at $\sqrt{s}$=7 TeV	280 nb^{-1}	Submitted to Nucl. Phys. B	arXiv:1512.02913
Measurement of *b*-quark fragmentation fractions f_s/f_d	2.47 fb^{-1}	Phys. Rev. Lett. 115, 262001 (2015)	arXiv:1507.08925
Observation and branching fraction of $\Lambda^0_b \to \psi(2S)\Lambda^0$ decay	20.6 fb^{-1}	Physics Letters B 751 (2015) 63-80	arXiv:1507.08202
Branching fractions of $B_c^+ \to J/\psi D_s^+$ and $B_c^+ \to J/\psi D_s^{*+}$ and transverse polarization fraction in the latter decay	(4.9 + 20.6) fb^{-1}	Eur. Phys. J. C, 76(1), 1 (2016)	arXiv:1507.07099
Associated production of prompt and non-prompt J/ψ mesons and Z boson at $\sqrt{s}$ = 8TeV	20.3 fb^{-1}	Eur. Phys. J. C75 (2015) 229	arXiv:1412.6428
Search for X_b and other hidden-beauty states using $\pi^+\pi^-\Upsilon(1S)$ channel	16.2 fb^{-1}	Phys. Lett. B740 (2015) 199-217	arXiv:1410.4409
Cross-section measurement of $\psi(2S) \to J/\psi\ (\to \mu^+\mu^-)\ \pi^+\pi^-$ at $\sqrt{s}$ = 7TeV	2.1 fb^{-1}	JHEP 09 (2014) 079	arXiv:1407.5532
φ_s and $\Delta\Gamma_s$ from flavour tagged time dependent angular analysis of $B^0_s \to J/\psi\ \phi$	4.9 fb^{-1}	Phys. Rev. D 90 (2014) 052007	arXiv:1407.1796
Observation of an excited $B^{\pm}_c$ meson state with the ATLAS detector	(4.9 + 19.2) fb^{-1}	Phys. Rev. Lett. 113 (2014) 212004	arXiv:1407.1032
Measurement of χ_{c1} and χ_{c2} production at $\sqrt{s}$ = 7TeV	4.5 fb^{-1}	JHEP 07 (2014) 154	arXiv:1404.7035
Parity violating asymmetry parameter α_b and the helicity amplitudes for the decay $\Lambda_b^0 \to J/\psi\ \Lambda^0$	4.6 fb^{-1}	Phys. Rev. D 89 (2014) 092009	arXiv:1404.1071
Associated production of prompt J/ψ mesons and W boson at $\sqrt{s}$ = 7TeV	4.5 fb^{-1}	JHEP 04 (2014) 172	arXiv:1401.2831
Production cross section of B^+ at $\sqrt{s}$ = 7TeV	2.4 fb^{-1}	JHEP 10 (2013) 042	arXiv:1307.0126
Inclusive Υ(nS) differential cross sections and ratios	1.8 fb^{-1}	Phys. Rev. D 87 (2013) 052004	arXiv:1211.7255
φ_s and $\Delta\Gamma_s$ from time dependent angular analysis of $B^0_s \to J/\psi\ \phi$	4.9 fb^{-1}	JHEP 12 (2012) 072	arXiv:1208.0572
Measurement of the Λ_b lifetime and mass	4.9 fb^{-1}	Phys. Rev. D 87 (2013) 032002	arXiv:1207.2284
b-hadron production cross-section from D*μX final states	3.3 pb^{-1}	Nucl. Phys. B 864 (2012) 341-381	arXiv:1206.3122
Search for the decay $B^0_s \to \mu\mu$	2.4 fb^{-1}	Phys. Lett. B713 (2012) 180-196	arXiv:1204.0735
Observation of a new χ_b state in radiative transitions to Υ(1S) and Υ(2S)	4.4 fb^{-1}	Phys. Rev. Lett. 108 (2012) 152001	arXiv:1112.5154
Υ(1S) Fiducial Production Cross-Section	1.1 pb^{-1}	Phys. Lett. B703 (2011) 428-446	arXiv:1106.5325
Differential cross-sections of inclusive, prompt and non-prompt J/ψ production	2.3 pb^{-1}	Nucl. Phys. B 850 (2011) 387-344	arXiv:1104.3038
Analyses performed within other ATLAS Physics Groups:			
$D^{*+/-}$ production in jets	0.3 pb^{-1}	Phys. Rev. D 85, 052005 (2012)	arXiv:1112.4432
Inclusive production of electrons and muons (b/c cross section)	35 pb^{-1}	Phys. Lett. B 707 (2012) 438-458	arXiv:1109.0525
Centrality dependence of J/ψ production in heavy ions collisions	6.7 μb^{-1}	Phys. Lett. B 697 (2011) 294-312	arXiv:1012.5419

Notes containing preliminary or unpublished results based on data, the contents of which may be used in conference talks, are listed below.

Short Title	Int L	Ref./link to ATLAS public pages	Plots
NEW $B^{\pm}$ mass reconstruction in $B^{\pm} \to J/\psi\ K^{\pm}$ decay at ATLAS at 13 TeV pp collisions at the LHC	3.2 fb^{-1}	ATLAS-CONF-2015-064	Link
Differential non-prompt J/ψ production fraction at $\sqrt{s}$ = 13 TeV	6.4 pb^{-1}	ATLAS-CONF-2015-030	Link

Notes based on published or preliminary public results, maybe discussing comparisons with theory or other measurements, or based on ATLAS Monte Carlo (such as feasibility studies)

Short Title	Int L	Ref./link to ATLAS public pages
ATLAS B-physics studies at increased LHC luminosity, potential for CP-violation measurement in the $B^0_s \to J/\psi\ \phi$ decay	(5-3000) fb^{-1}	ATL-PHYS-PUB-2013-010
Comparison of D(*) production cross section at $\sqrt{s}$ = 7TeV with FONLL and GM-VFNS predictions	1.1 nb^{-1}	ATL-PHYS-PUB-2011-012

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/BPhysPublicResults

Summary

- Number of new results in production and decay properties using full Run-1 data finished last year, some still to come
  - Production measurements: important input for theory MC generator tuning
  - NP searches: no evidence for deviations from SM predictions
- First studies of the 2015 pp collision data at 13 TeV – J/ψ production and detector performance in b-hadron reconstruction
- ATLAS will continue its B-physics program in the Run 2,3 and the HL-LHC era, continue focusing on precision measurements, rare decays and heavy flavour production and spectroscopy
  - Detector upgrades (namely in **tracking** and **muon system**) and new **trigger strategies** and tools will help to cope with the high-luminosity environment and achieve precision needed to examine possible beyond-SM effects in the heavy-flavour production and decays

Backup

$B_s \to J/\psi\phi$: Systematics, Correlations

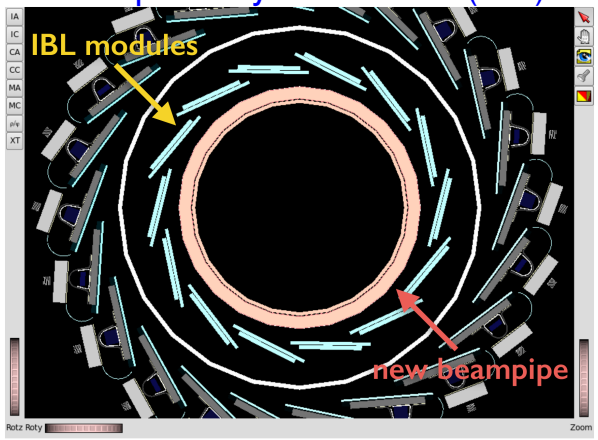
	ϕ_s [rad]	$\Delta\Gamma_s$ [ps^{-1}]	Γ_s [ps^{-1}]	$\lvert A_\parallel(0)\rvert^2$	$\lvert A_0(0)\rvert^2$	$\lvert A_S(0)\rvert^2$	$\delta_\perp$ [rad]	$\delta_\parallel$ [rad]	$\delta_\perp - \delta_S$ [rad]
Tagging	0.025	0.003	$<10^{-3}$	$<10^{-3}$	$<10^{-3}$	0.001	0.236	0.014	0.004
Acceptance	$<10^{-3}$	$<10^{-3}$	$<10^{-3}$	0.003	$<10^{-3}$	0.001	0.004	0.008	$<10^{-3}$
Inner detector alignment	0.004	$<10^{-3}$	0.002	$<10^{-3}$	$<10^{-3}$	$<10^{-3}$	0.112	0.006	$<10^{-3}$
Background angles model:									
Choice of p_T bins	0.020	0.006	0.003	0.003	$<10^{-3}$	0.008	0.004	0.006	0.008
Choice of mass interval	0.008	0.001	0.001	$<10^{-3}$	$<10^{-3}$	0.002	0.021	0.005	0.003
B_d^0 background model	0.023	0.001	$<10^{-3}$	0.002	0.002	0.017	0.090	0.011	0.009
Fit model:									
Mass signal model	0.004	$<10^{-3}$	$<10^{-3}$	0.002	$<10^{-3}$	0.001	0.015	0.017	$<10^{-3}$
Mass background model	$<10^{-3}$	0.002	$<10^{-3}$	0.002	$<10^{-3}$	0.002	0.027	0.038	$<10^{-3}$
Time resolution model	0.003	$<10^{-3}$	0.001	0.002	$<10^{-3}$	0.002	0.057	0.011	0.001
Default fit model	0.001	0.002	$<10^{-3}$	0.002	$<10^{-3}$	0.002	0.025	0.015	0.002
Total	0.041	0.007	0.004	0.006	0.002	0.020	0.29	0.05	0.01

	$\Delta\Gamma$	Γ_s	$\lvert A_\parallel(0)\rvert^2$	$\lvert A_0(0)\rvert^2$	$\lvert A_S(0)\rvert^2$	$\delta_\parallel$	$\delta_\perp$	$\delta_\perp - \delta_S$
ϕ_s	0.107	−0.098	0.041	0.031	0.050	0.094	0.049	−0.010
$\Delta\Gamma$	1	−0.426	0.102	0.138	0.051	0.015	0.009	−0.011
Γ_s		1	−0.122	−0.047	0.154	−0.043	−0.015	0.019
$\lvert A_\parallel(0)\rvert^2$			1	−0.331	0.062	0.173	0.050	−0.018
$\lvert A_0(0)\rvert^2$				1	0.216	−0.016	0.005	0.014
$\lvert A_S(0)\rvert^2$					1	−0.078	−0.007	0.057
$\delta_\parallel$						1	0.226	−0.012
$\delta_\perp$							1	0.011

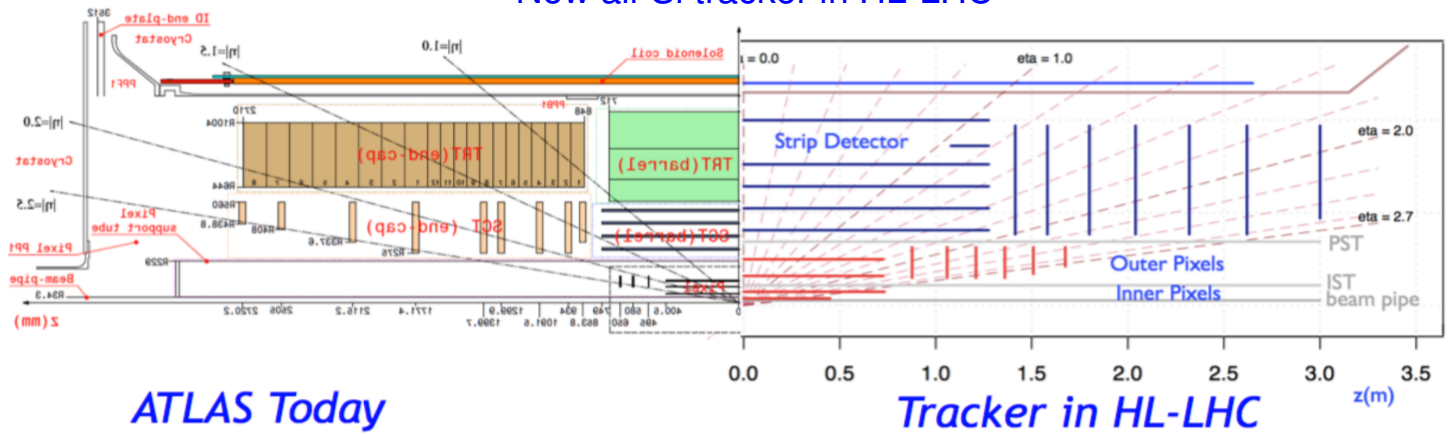
Performance of $B_s \to J/\psi\phi$ in Run-2 and Beyond

- Run-2 detector upgrades: new tracking systems, improved muon coverage, more complex triggers

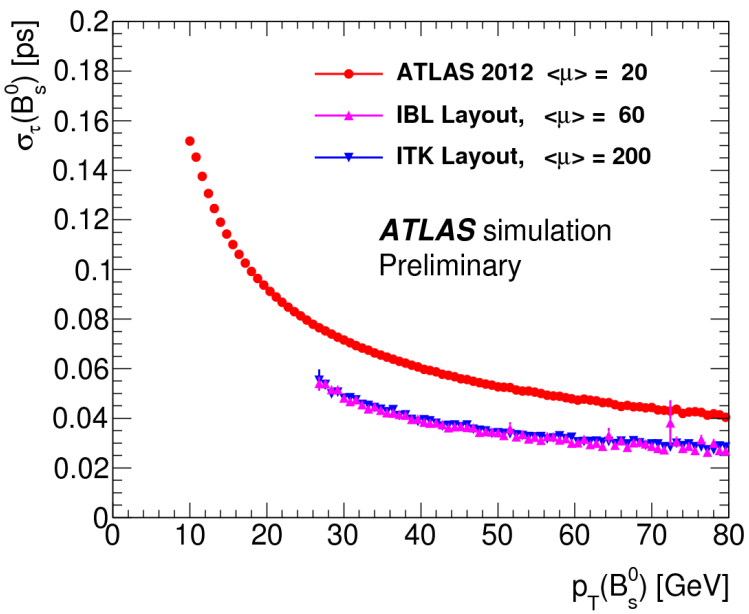
New pixel layer in Run-2 (IBL)

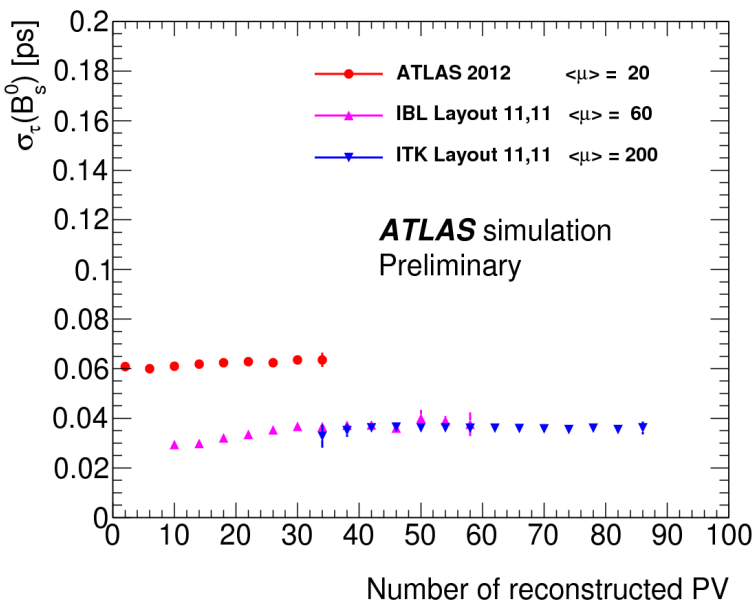


New all-Si tracker in HL-LHC



- Predictions using preliminary (EFCA-2013) simulations of IBL and ITK





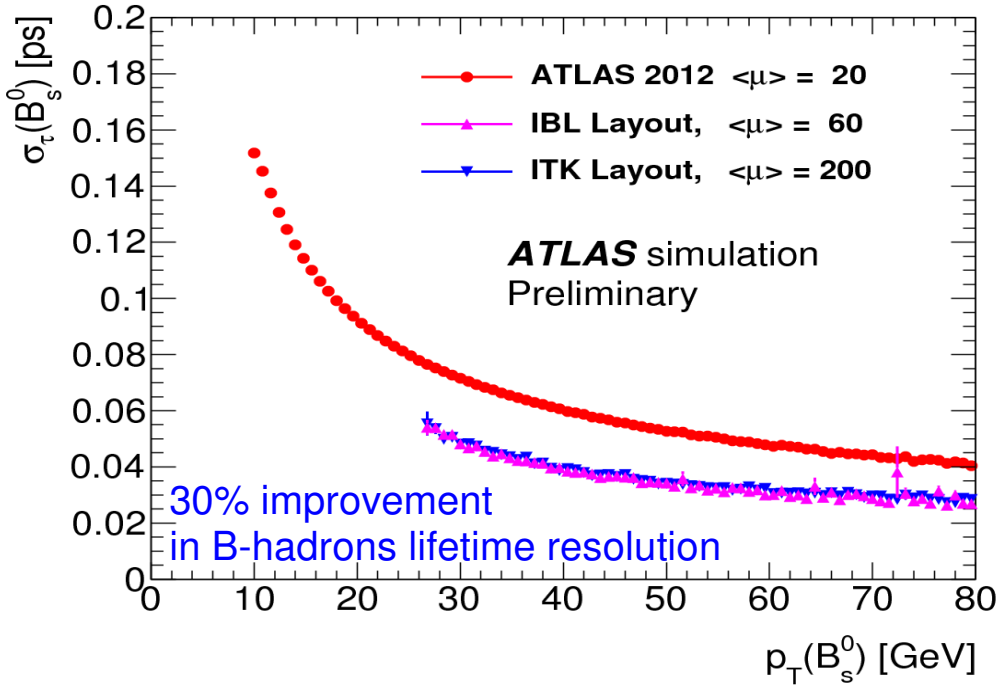
Challenging for an efficient trigger

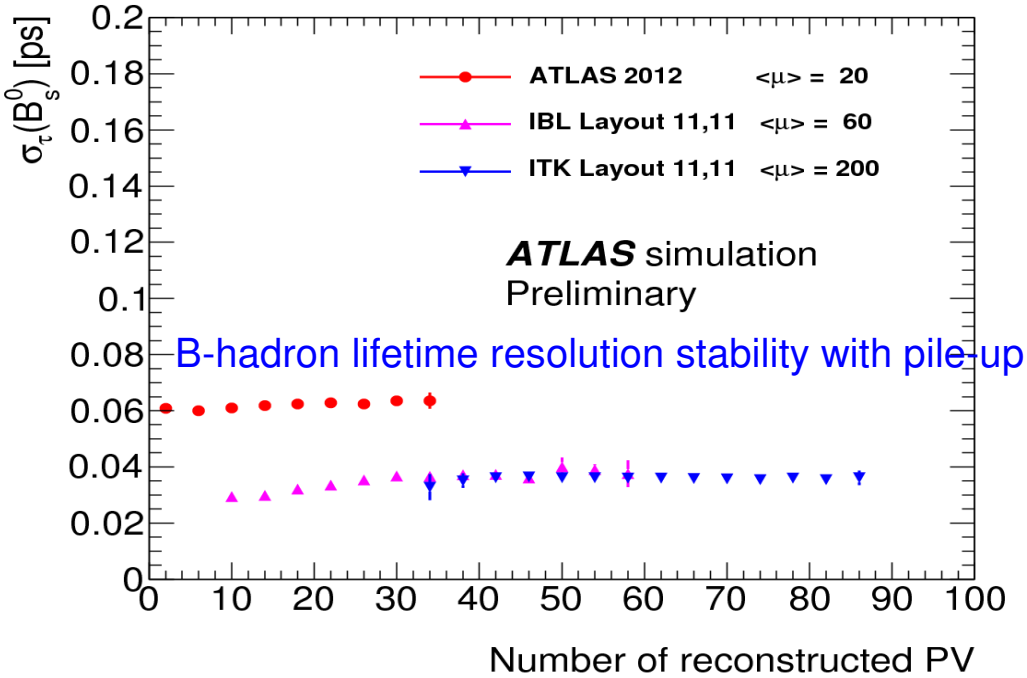
- Run-1 muon p_T thresholds ~4 GeV
- At higher instant. luminosity have to increase thresholds: realistic scenario: 6 GeV, pessimistic 11 GeV (7x less signal events)
- Use of topological constrains at L1

ATL-PHYS-PUB-2013-10

- 30% better proper decay time resolution, ~stable with higher pile-up

CPV in $B_s \to J/\psi\phi$: Future Projection (EFCA-2013)

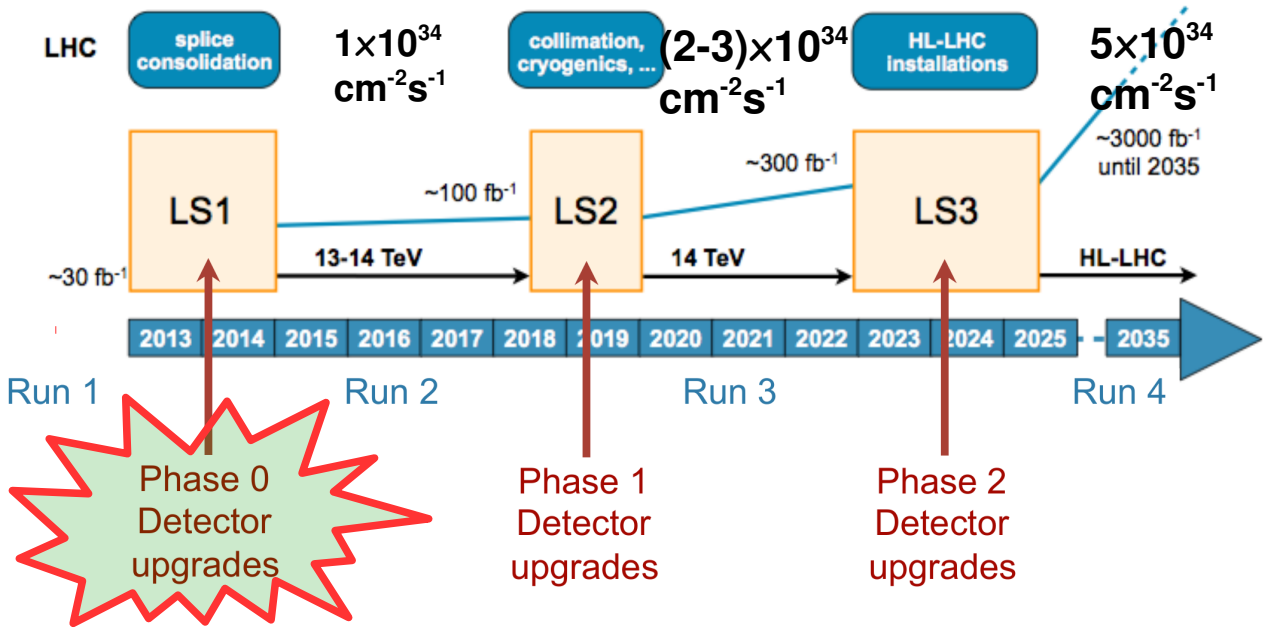




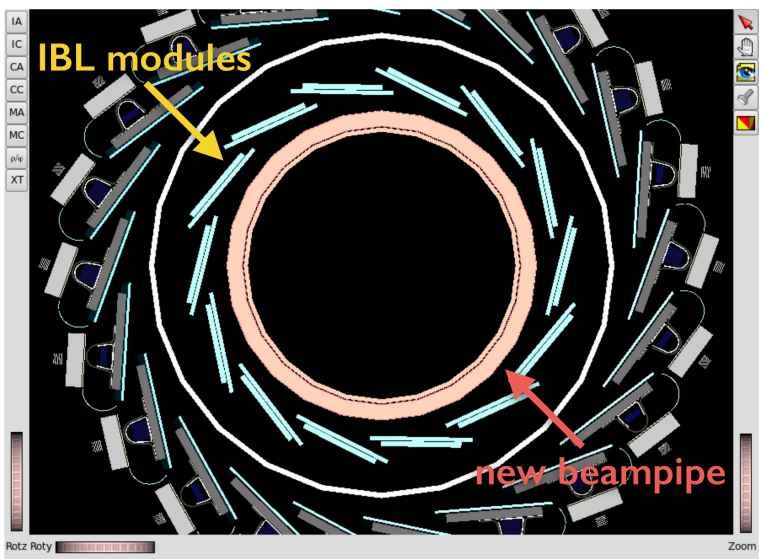
- Muon p_T thresholds 11+11 GeV substantially (7x) decrease number of signal events per fb^{-1} w.r.t. 6+6 GeV thresholds, but improves vertexing resolution

	2011 *)	2012	2015-17		2019-21	2023-30+
Detector	current	current	IBL		IBL	ITK
Average interactions per BX $<\mu>$	6-12	21	60		60	200
Luminosity, fb^{-1}	4.9	20	100		250	3 000
Di-μ trigger p_T thresholds, GeV	4 - 4(6)	4 - 6	6 - 6	11 - 11	11 - 11	11 - 11
Signal events per fb^{-1}	4 400	4 320	3 280	460	460	330
Signal events	22 000	86 400	327 900	45 500	114 000	810 000
Total events in analysis	130 000	550 000	1 874 000	284 000	758 000	6 461 000
MC $\sigma(\phi_s)$ (stat.), rad	0.25	0.12	0.054	0.10	0.064	0.022

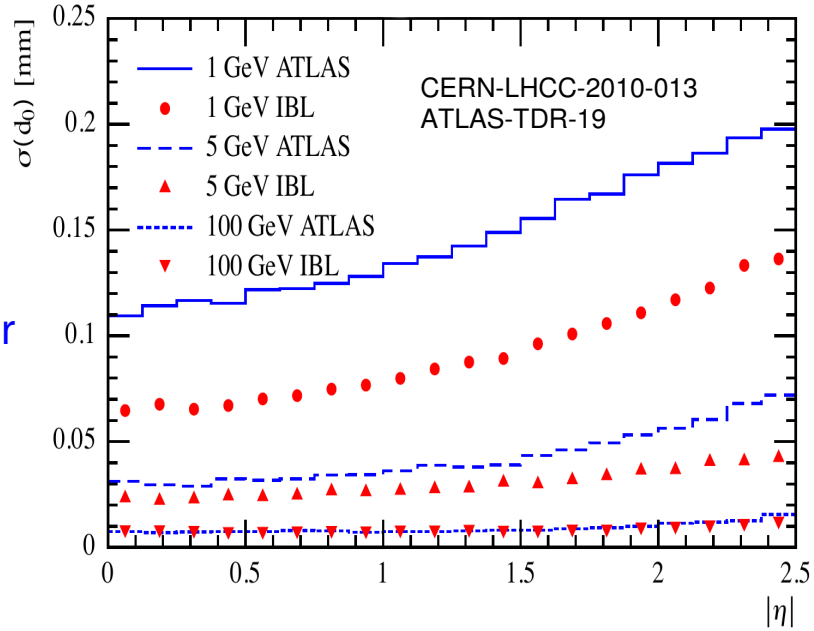
Detector & Trigger Upgrades - Phase 0



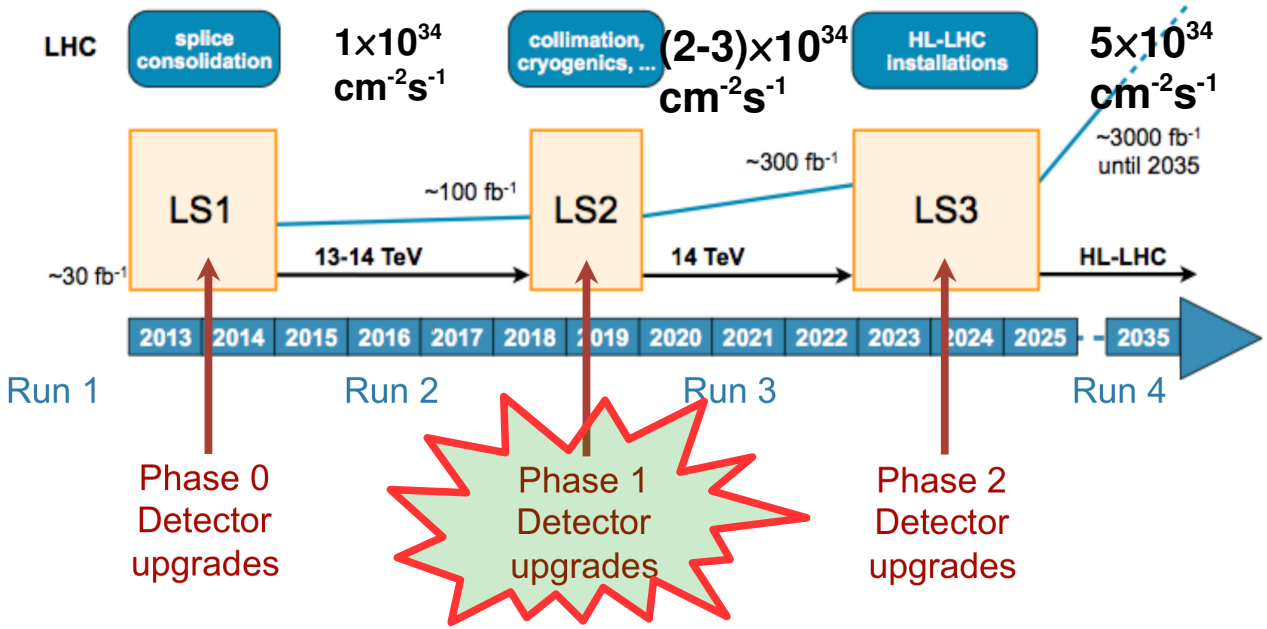
- Long Shutdown (LS) 1 almost over, LHC starts providing physics data in Spring 2015
- **Additional Pixel Layer (IBL)** and Be small radius beam pipe
- **Topological L1 trigger**
- Improved coverage of Muon spectrometer ($1.0 < |\eta| < 1.3$)
- Diamond Beam Monitor, consolidation of some parts of the detector (cooling etc.)



- Small radius (32-38 mm; current B-layer at 50.5 mm), small material budget
- 4th pixel layer => more robust track reconstruction, better impact parameter d_0 and z_0 resolution
- Better θ and ϕ resolution at low p_T ~ 1 GeV



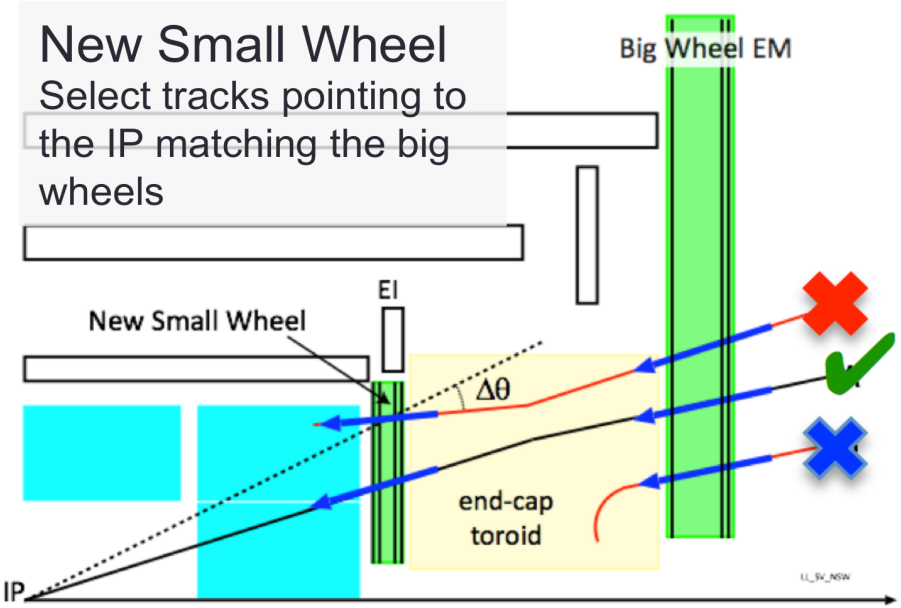
Detector & Trigger Upgrades – Phase 1



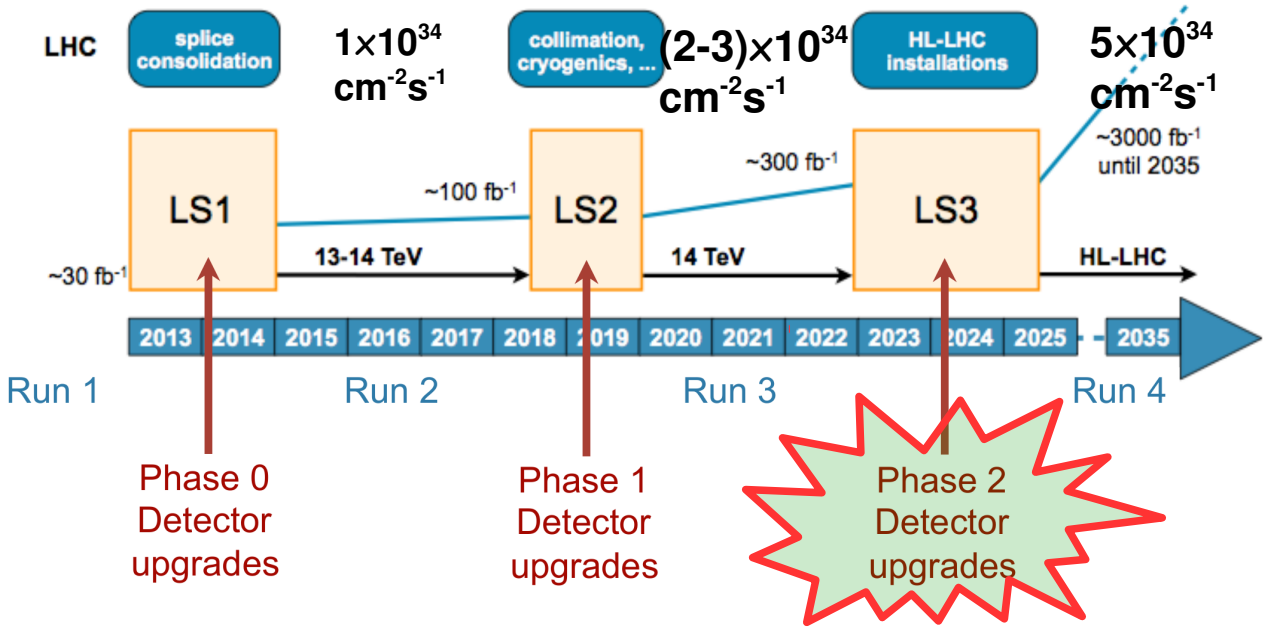
- Goal: no loss of performance when going above LHC nominal luminosity
- **New small muon wheel**
- **New fast-tracking (FTK) at trigger level 1.5. Gradually implemented already during Run 2**
- Higher granularity and precision L1 trigger for calorimeter
- TDAQ improved performance

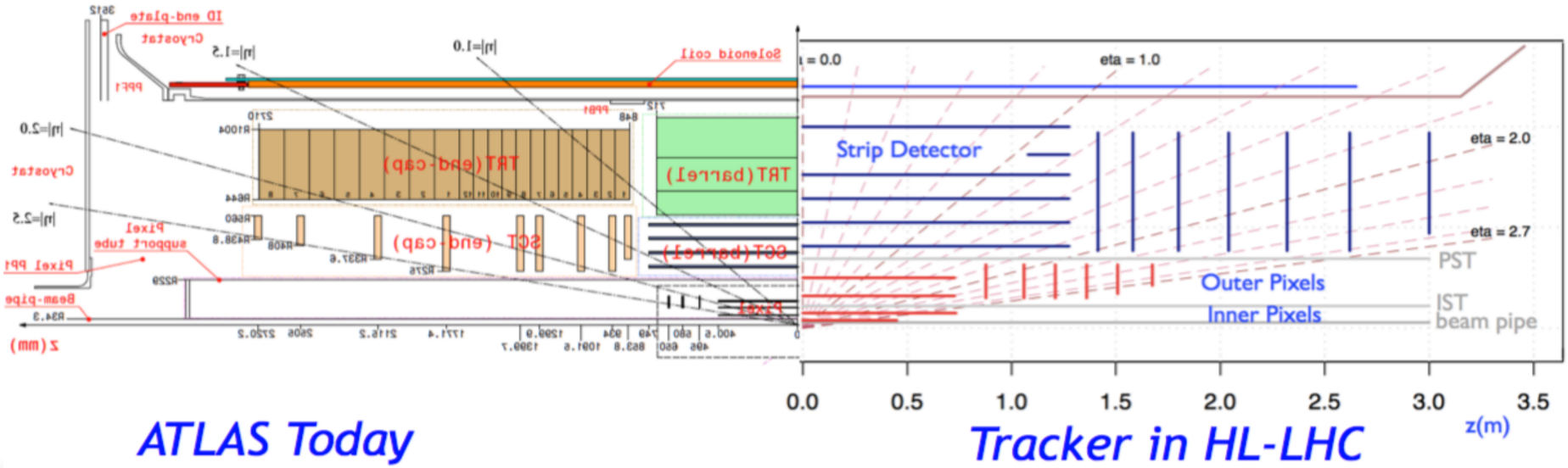
Fast tracking trigger:

- HW based track finder in the Inner Detector silicon layers at "offline precision"
- Provides tracks already before the L2 trigger (first SW based trigger layer)
- Two-step processing: hit pattern matching & subsequent linear fitting in FPGAs



Detector & Trigger Upgrades - Phase 2



- Goal: maintain/improve performance despite high lumi.
- **Completely new Si based tracking (ITK)**
- New trigger system – possibly will include HW-based L1 track trigger
- Full granularity calorimetry information
- Upgrade part of the muon systems, fast trigger

Phase 2 Inner Tracker: current ID will become inefficient due to radiation damage; too high occupancy in TRT; high granularity (~4x better) required to cope with high pileup (~up to 200)