Status and near-term Prospects of the ATLAS experiment

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CERN and ATLAS Collaboration

The landscape of Flavour Physics towards the high intensity era
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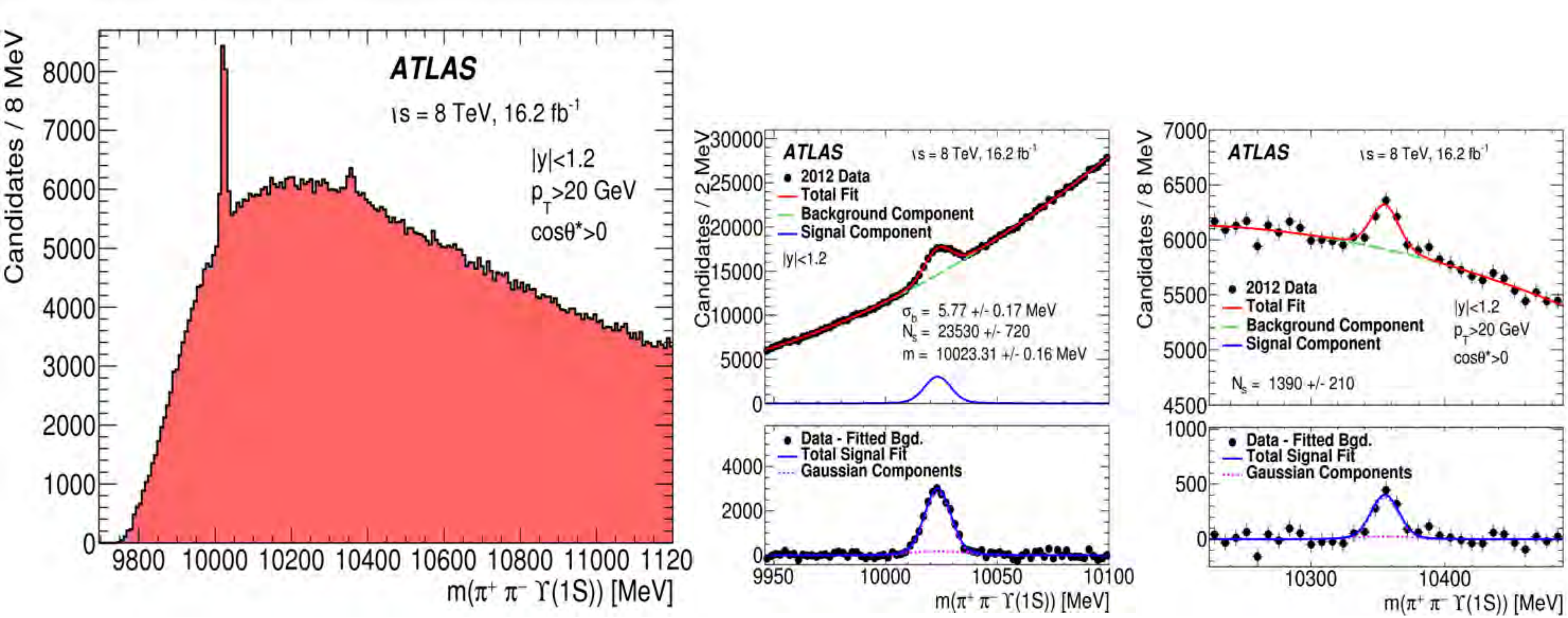
Content

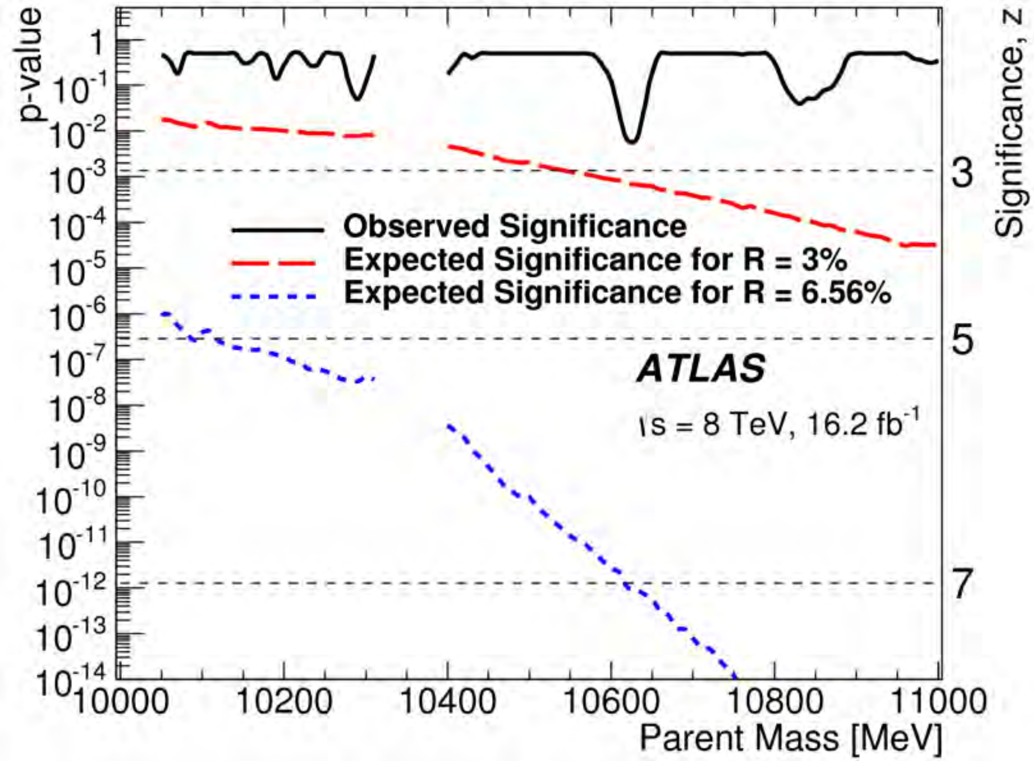
- Recent results and from Run-I
- Detector upgrades for Run-II
  - IBL
  - B-physics triggers
  - Muon trigger and measurement in the end-cap
- A physics case for Run-II

$X_b \to \Upsilon\pi\pi$ search (8TeV data)

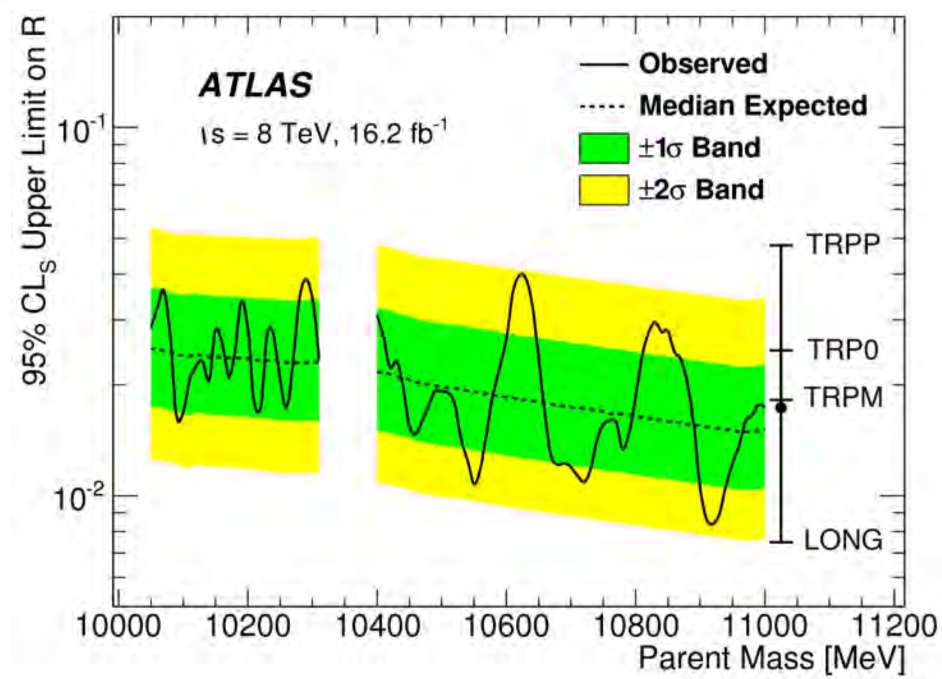
Search for a hidden-beauty counterpart of the X(3872) in the mass ranges 10.05–10.31 GeV and 10.40–11.00 GeV,

in the channel $X_b \to \Upsilon(1S)\pi\pi \to \mu\mu\,\pi\pi$.   (arXiv:1410.4409)





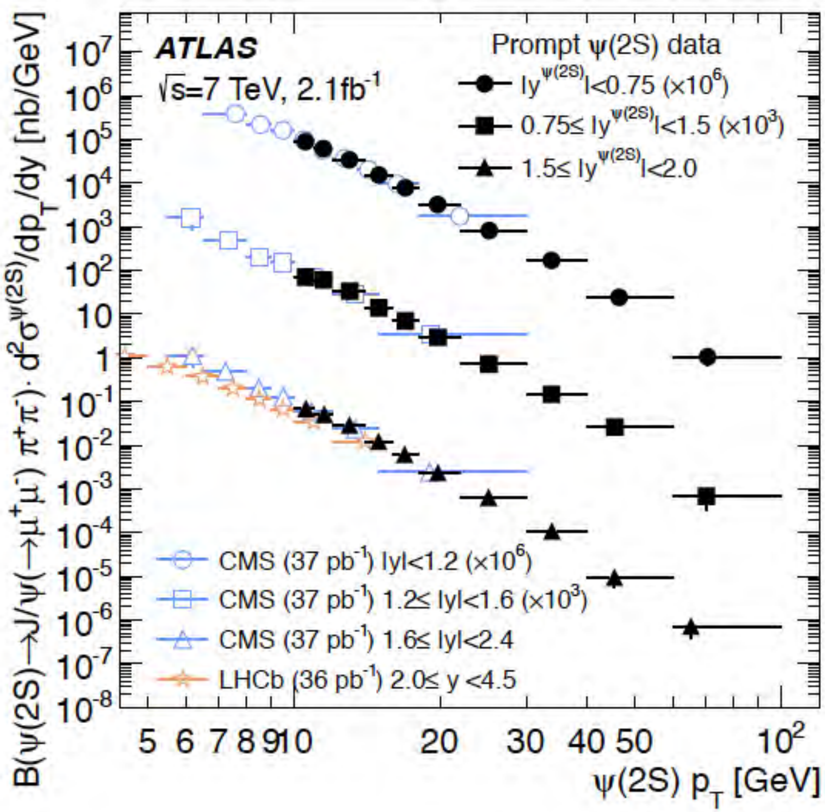
p-value for background-only hypothesis,
$R = (\sigma B) / (\sigma B)_{\Upsilon(2S)}$



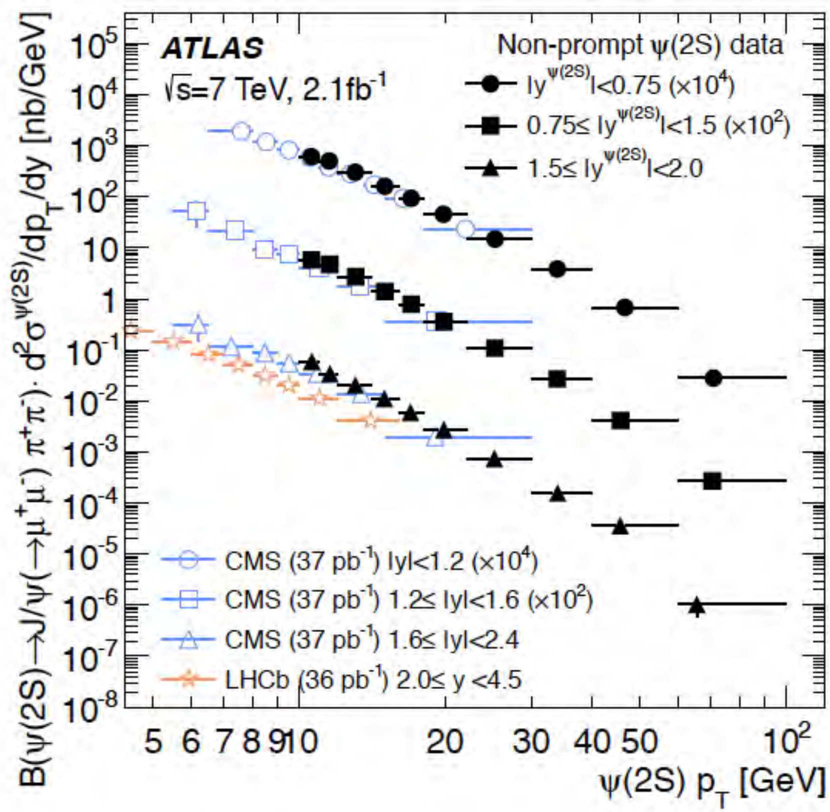
95% CLs upper limit on R, for hypothetical X_b decaying isotropically to $\Upsilon(1S)\pi\pi$.
Also shown the effects extreme spin alignment scenarios for the X_b.
This result is currently the tightest limit for $m(X_b) > 10.1$ GeV.

$\psi(2S) \rightarrow J/\psi\ \pi\pi$ cross section at 7 TeV

Prompt and non-prompt production differential cross-sections for $\psi(2S)$ for $10 < p_T < 100$ GeV and $|y| < 2.0$ (arXiv:1407:5532 and JHEP)

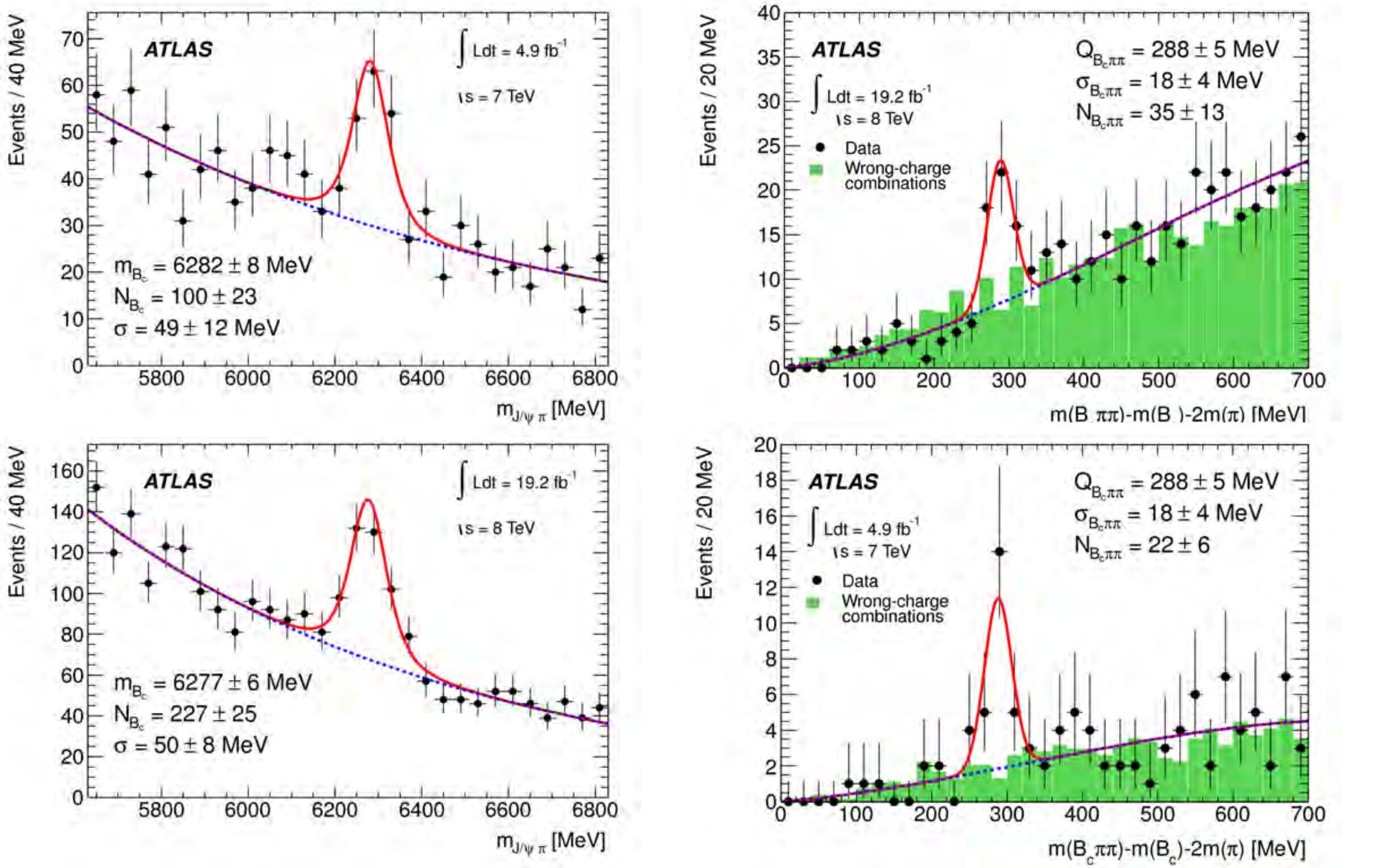


(a) Prompt production vs. $\psi(2S)$ p_T



(b) Non-prompt production vs. $\psi(2S)$ p_T

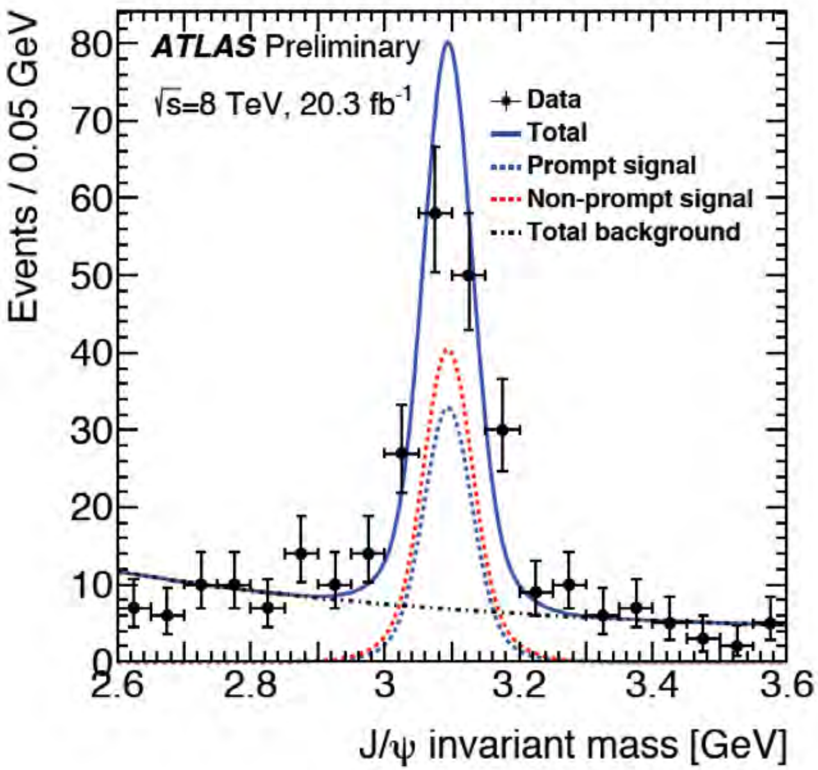
Observation of excited B_c state

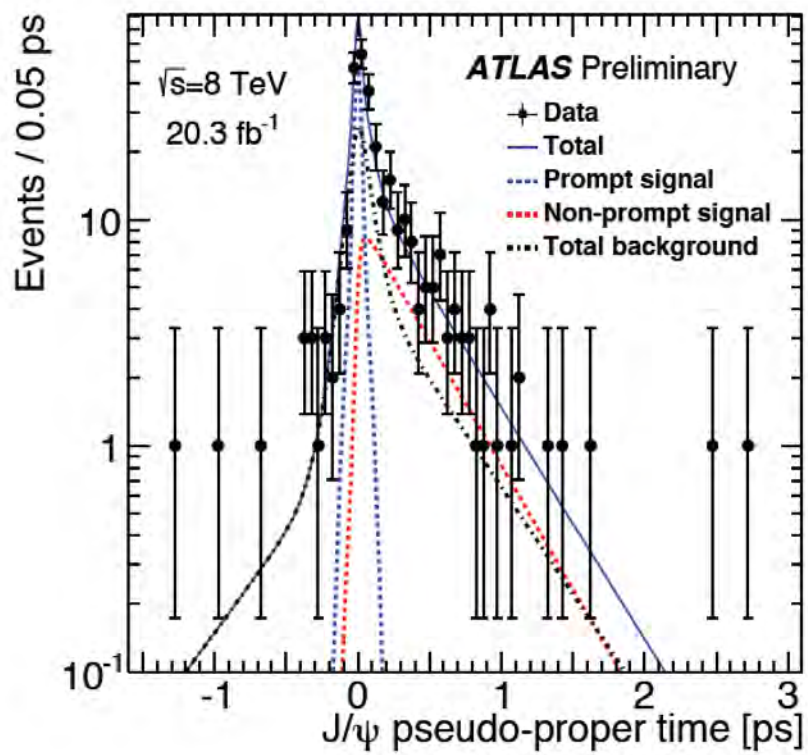


$B_c^* \rightarrow B_c\,\pi\pi \rightarrow J/\psi\,\pi\,\pi\pi$, 5 and 19 fb^{-1} (2011 and 2012 data), m = 6842 ± 4 ± 5 MeV, consistent with expectations for $B_c(2S)$ (PRL 113, 212004 (2014))

Z+J/ψ associated production

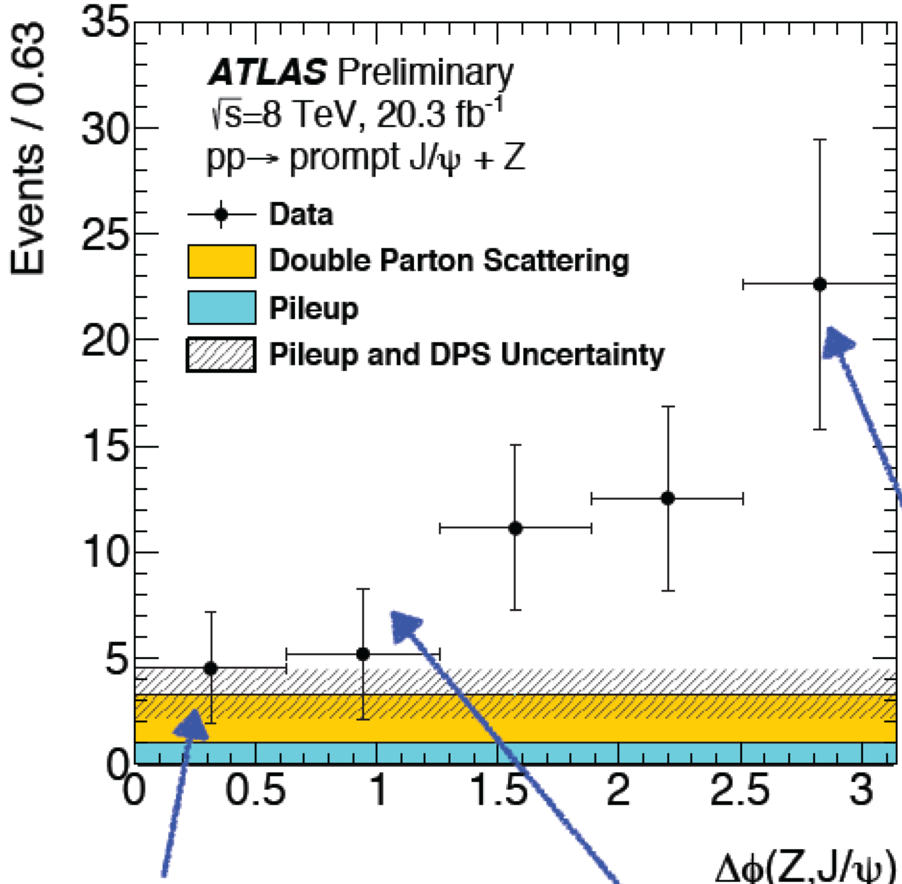
Following W+J/ψ study with 5 fb-1. Select Z(→ll)+J/ψ(→μμ) (trigger on lepton from Z, muon or electron).
Study the distribution in Z, J/ψ masses and J/ψ pseudo decay-time to separate prompt and non- prompt contributions.



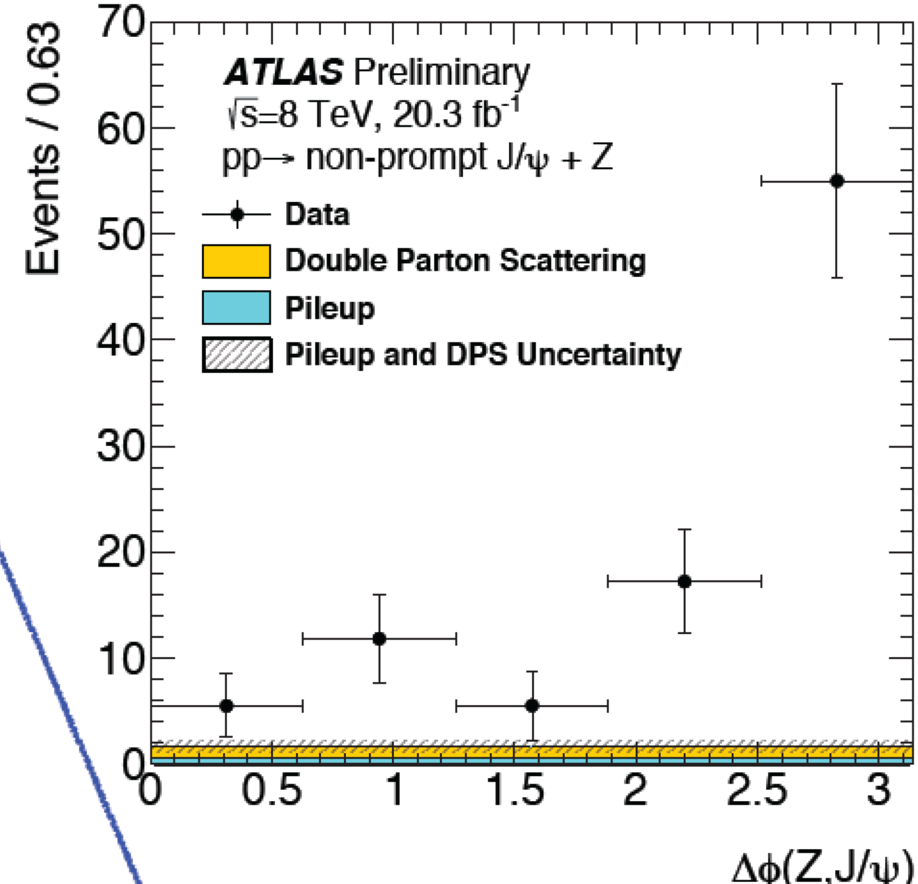


The signal is the sum of *real* associated production, and of *double-parton* interaction - relative contributions hinted by azimuthal angle correlation

Prompt



Non-prompt



DPS dominates this bin

Same pattern is observed in the azimuthal opening angle as with the W

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DPS estimated from W+jet-jet study by ATLAS.

Detector upgrades for Run-II

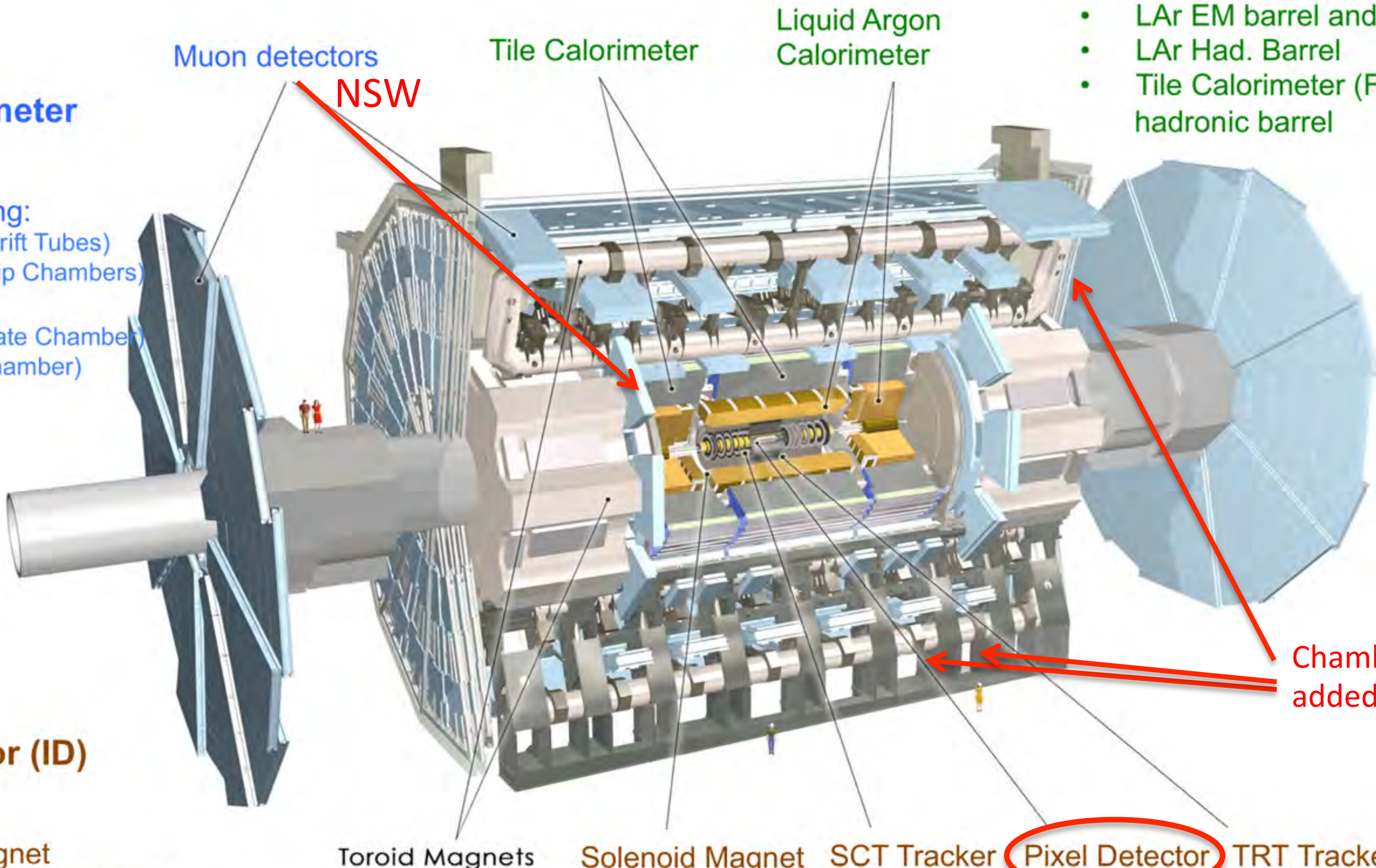
Calorimeter System

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)

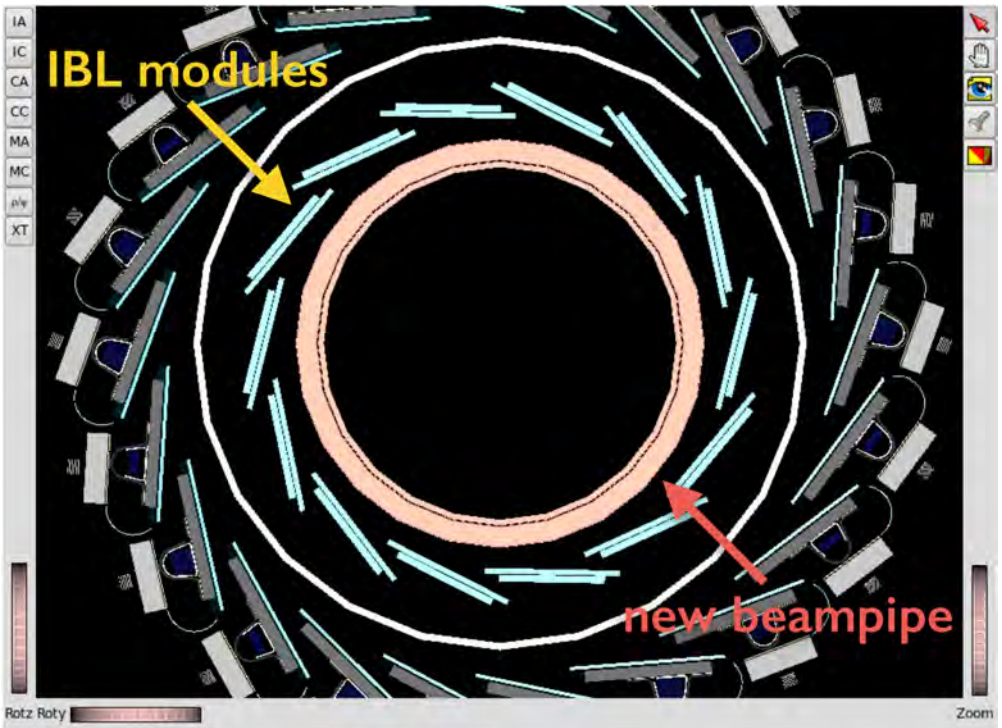
Trigger:
- RPC (Resistive Plate Chamber)
- TGC (Thin Gas Chamber)



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

Detector upgrade: new innermost layer of Pixel detector (IBL)



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

This detector has been installed in the current shut-down of LHC

Muon triggers for B-physics in Run-I

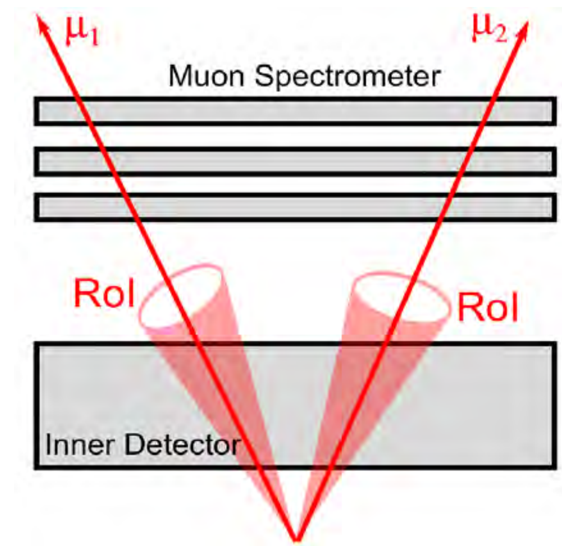
Run-1: Low-p_T triggers based on two-muons selection:

- At Level-1: hardware-based fast selection of muons with pT of 4 or 6 GeV
- Possible to ask one or both muons in the barrel (better momentum resolution and lower trigger rate)
- “4 Gev × 4 GeV” trigger prescaled at beginning of LHC fill in 2012 data (minor prescaling in “4 GeV × 6 GeV” and in “4 Gev × 4 GeV × 1-Barrel”)

  (at 7×10^{33} $cm^{-2}s^{-1}$, rates of 11 kHz (3 kHz) for “4 Gev × 4 GeV” (“6 Gev × 6 GeV), cfr. total ATLAS Level-1 of 75 kHz)

B-phys. triggers in Run-I

- At HLT an *offline-like* reconstruction and selection is performed, first reading a fraction of the inner detector (the *Regions-of-Interest*) defined by the Level-1 trigger, then reading the full detector



RoI ≈ 0.3 × 0.3 (η × φ)

In 2012, the stream of J/ψ based triggers was handled with delayed processing, for computing time limitations.

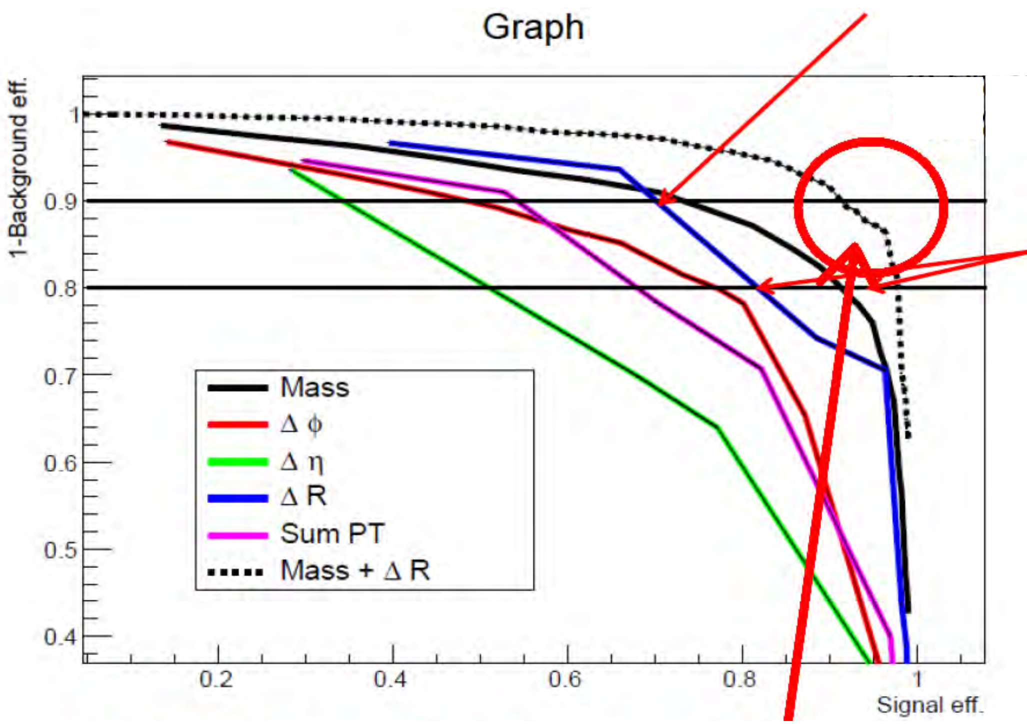
Muon triggers for Run-II: Level-1 *topological trigger*

- Opening angle between triggering muons will be available at Level-1 trigger
- Angle information can be combined with momentum threshold information (p_T of 4, 6, 10 GeV), for an estimate of the invariant mass of the pair.

Optimization studies are being performed on reference channels, including:

$B_s \to J/\psi\ \phi$, $B^0 \to \mu\mu$,

$B_d \to K^*\mu\mu$, Υ studies



We have indications of the effectiveness of combined angle and invariant mass selection for $B^0 \to \mu\mu$

Muon triggers for Run-II: Level-2 FTK

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

It will make tracks from the entire Inner Detector available in the early stage of the High Level Trigger. Gradually implemented during Run-2.

So far, limited studies on B-physics applications, but *b*-tagging has been considered.

More on FTK in the discussion on long-term developments (A.Cerri)

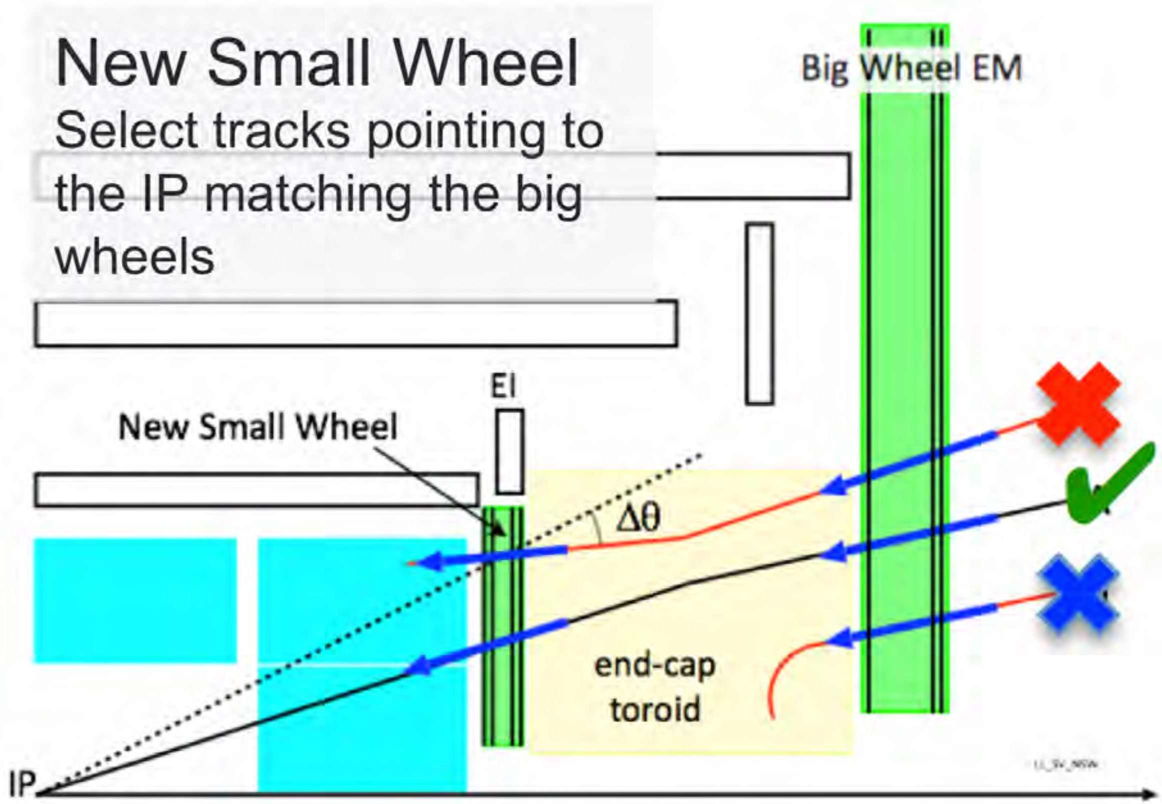
Other detector improvements for Run-II

- Quality of muon Level-1 triggers in the end-cap improved by including Thin-Gap-Chambers in the inner station of the muon Endcap (background triggers will be reduced).
- Muon momentum resolution (HLT and offline) improved significantly in the 1.0<|eta|<1.4 transition region (third muon station completed)
- Acceptance of muon trigger being optimized filling some % not currently covered in the Barrel

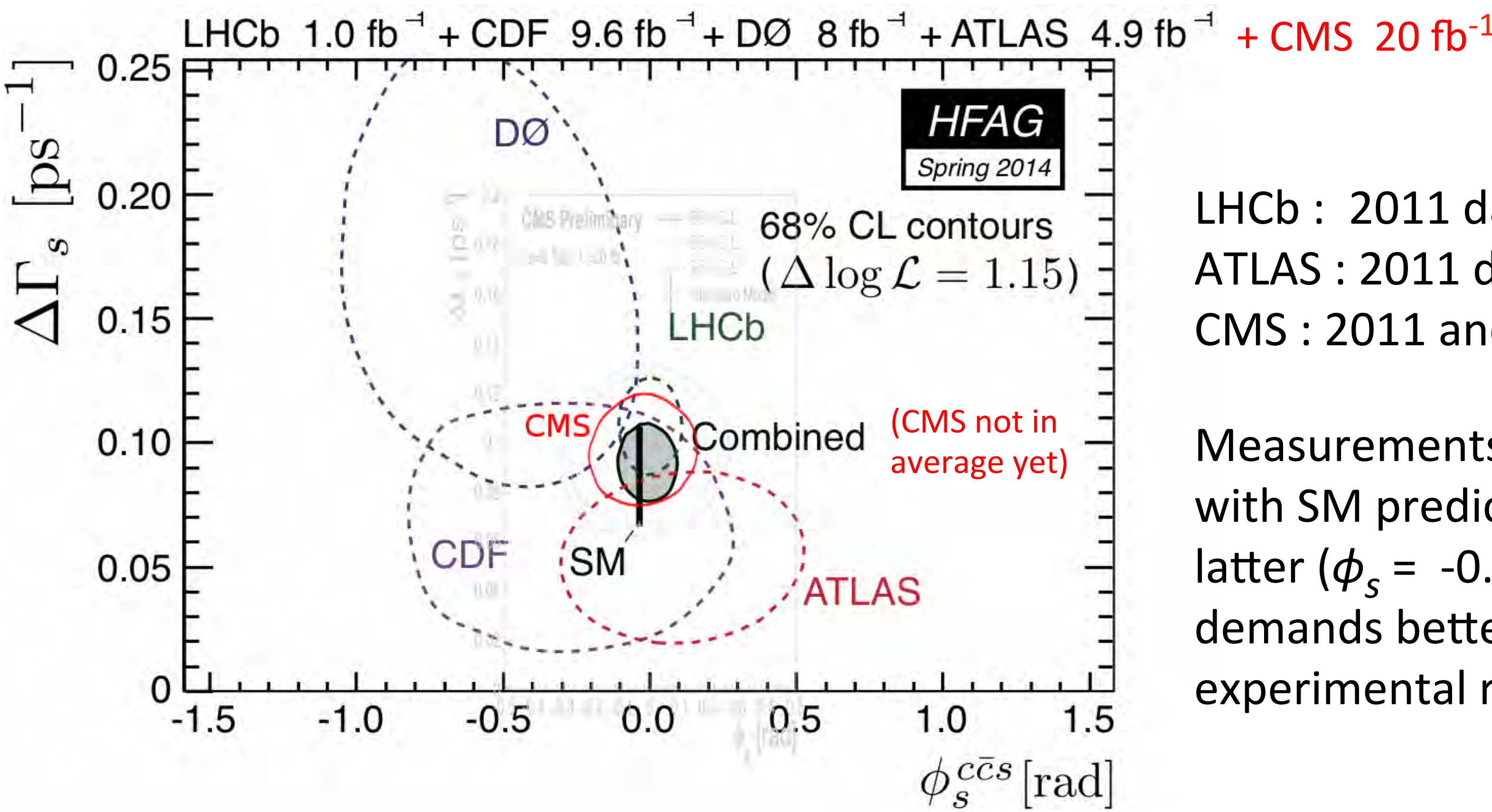
  (eg. near the support structure of the ATLAS Barrel and near the safety access ways to the Barrel muon spectrometer).

The New Small Wheel

- As of 2019, a new, high resolution inners station of the muon Endcap (1.4<|eta|<2.5) will be installed. The detector technologies include Thin-Gap-Chambers and Micromegas chambers



Case study for Run-II physics reach: $B_s \rightarrow J/\psi\ \phi$ with IBL upgrade



LHCb : 2011 data
ATLAS : 2011 data
CMS : 2011 and 2012 data

Measurements consistent with SM prediction, but the latter (ϕ_s = -0.037±0.002) demands better experimental resolution.

$B_s \to J/\psi\ \phi$ with IBL

The sensitivity to the CP violating phases is driven by the measurement of the fast oscillation of the tagged Bs decay; it therefore depends on:

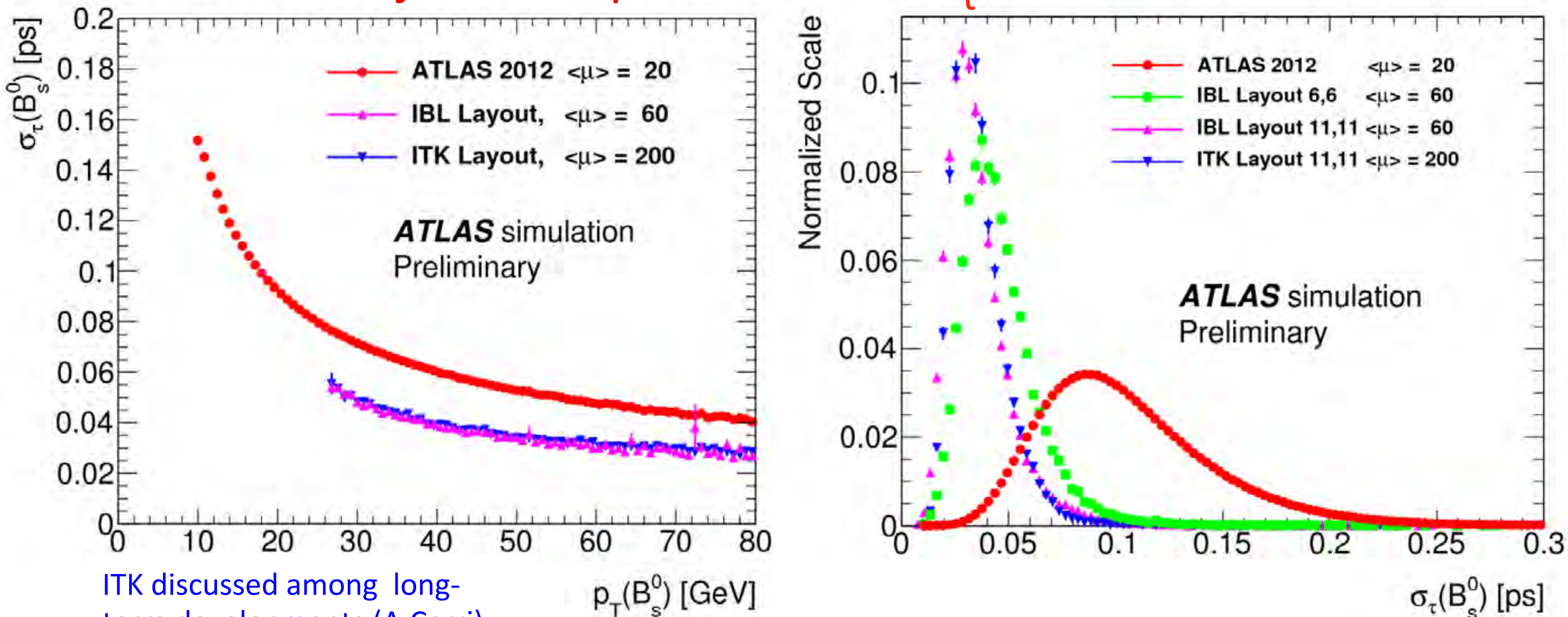
- *tagging power*: $\varepsilon_{tag} \times (1 - 2 \times \delta_{err})^2$ (efficiency and fraction of wrong tags)
- *decay time resolution*: the amplitude of a fast oscillation is reduced if the time resolution σ is not adequate:

$$e^{-i\omega x} \to \int e^{-i\omega x'} \frac{1}{\sqrt{2\pi}\,\sigma} e^{-(x-x')^2/2\sigma^2} dx' \cong e^{-i\omega x}\, e^{-\sigma^2\omega^2/2}$$

$B_s \rightarrow J/\psi\ \phi$ with IBL

- For B_s oscillations, $\omega = \Delta m_s = 18\ ps^{-1}$
- Currently $\sigma \approx 0.10$ ps in ATLAS *(and ≈ 0.04 ps in LHCb)*
- Therefore in ATLAS $e^{-\sigma^2\omega^2/2} \approx 0.20$ *(≈ 0.77 in LHCb)*
- An improvement in σ is very valuable in the measurement of ϕ_s .

Projected improvement in σ_τ with the IBL:



ITK discussed among long-term developments (A.Cerri)

$B_s \rightarrow J/\psi\ \phi$ with IBL

The reduction in σ_τ by ≈25% can improve the sensitivity by a factor approaching 2, but the advantage might be partially offset by a reduced yield of events because of tighter p_T selection at trigger level.

From a study of last year (ATL-PHYS-PUB-2013-010):

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

2011: PR D 90, 052007 (2014), systematic error much smaller
2012: from toy MC, extrapolated from 2011, not from real data and improved analysis
2015-17 and 2010-21: effects of new topological trigger and FTK not included.

Conclusions

- The detector upgrade and the physics agenda of ATLAS for Run2 have not neglected B-physics.
- The main improvements include expanded functionality of the trigger (Level-1 in particular), and the additional inner layer of the Pixel detector, which will increase vertexing capabilities.
- A specific case has been illustrated, but we expect significant contribution also in other areas of B-physics. -