Recent Heavy-Flavour Results from CMS

2nd International Conference on Particle Physics

in Memoriam Engin Arık and Her Colleagues

Doğuş University, İstanbul, Turkey

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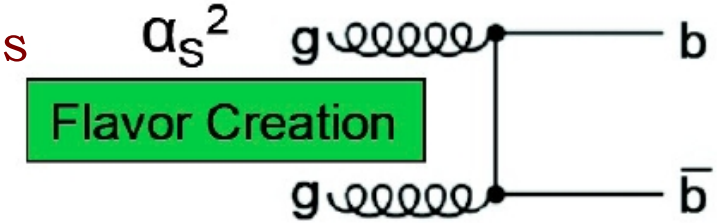
Outlook

- Motivations
- The CMS experiment
- Physics results :
  - Inclusive b-jets production properties
  - Semi inclusive b->J/Y X production rates
  - Exclusive B decays to J/Y X final states
  - Other heavy hadrons
- Conclusions

B-Physics @ LHC

Heavy Flavour Production:

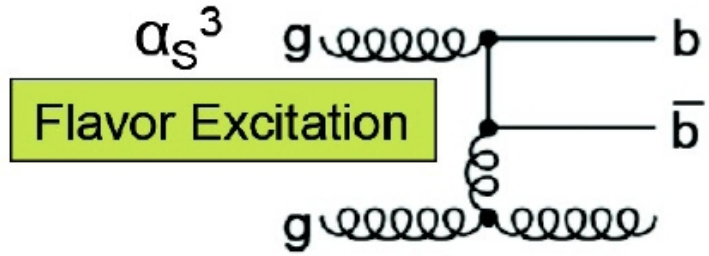
- high energy scale allows reliable perturbative calculations –> test QCD @ NLO, uncertainties from renormalization and factorization scales
- b-jets closely correlated to original parton

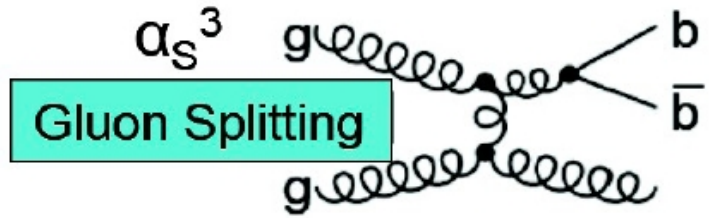


Heavy Flavour Properties:

- Top Physics
- Weak Decays and CP violation:

$$B_s \rightarrow \mu^+\mu^-,\ B_s \rightarrow J/\psi\,\Phi,\ \mathcal{A}_{fb},\ \ldots$$

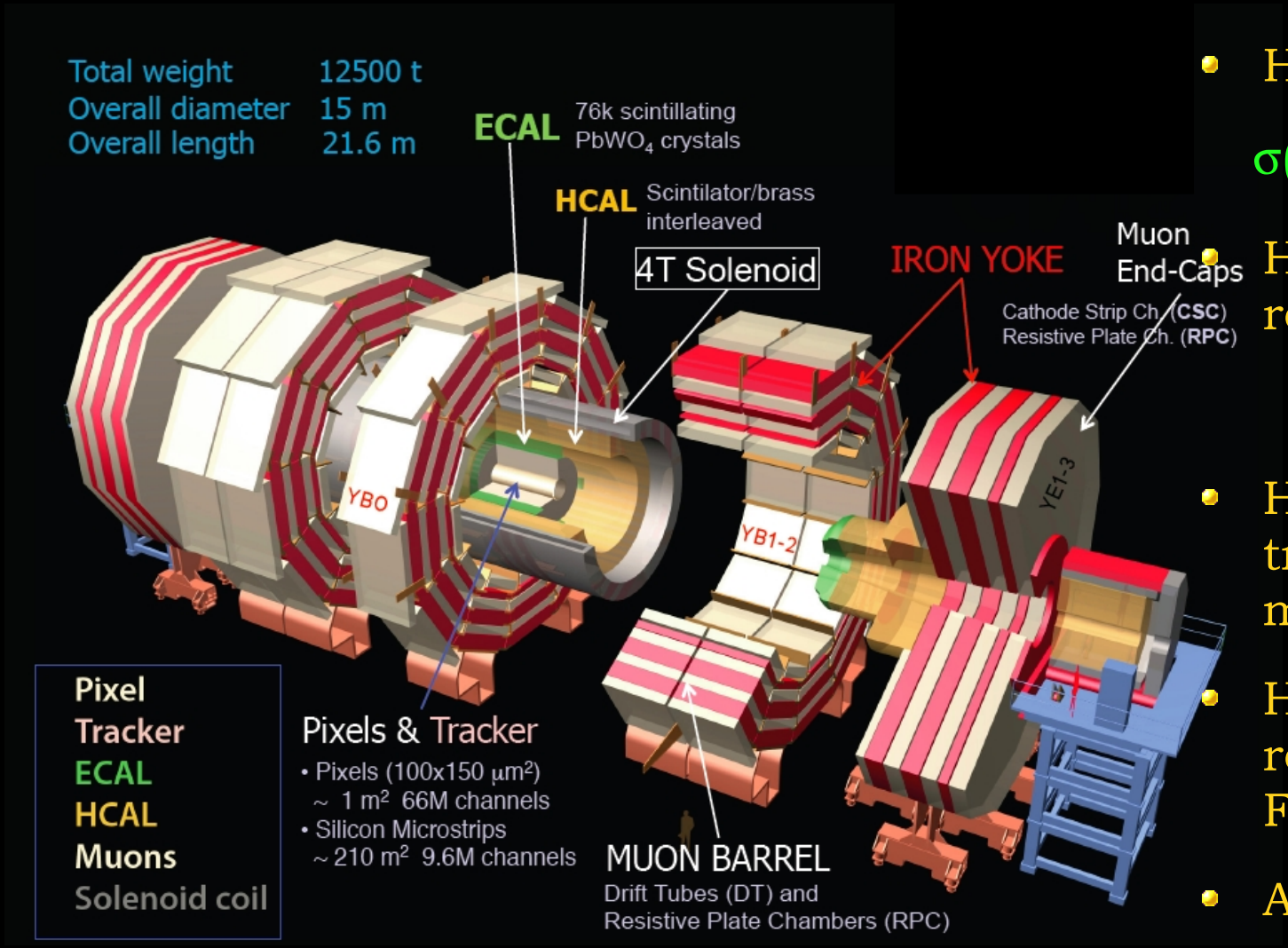




New Physics Search

- b-jets final states may flag new particle production: $h \rightarrow b\bar{b},\ A \rightarrow b\bar{b},\ Z' \rightarrow b\bar{b}$
- Standard bb production is the main background source

The CMS Detector



- High precision tracking

  $\sigma(p_T)/p_T \sim 1\%$ @ 50GeV

- High resolution vertex recontruction

  σ(II Vtx) ~ 10 μm

- High efficiency, self triggering, redundant muon system
- High resolution jet reconstruction (Particle Flow)
- Acceptance complementary to *LHCb*'s

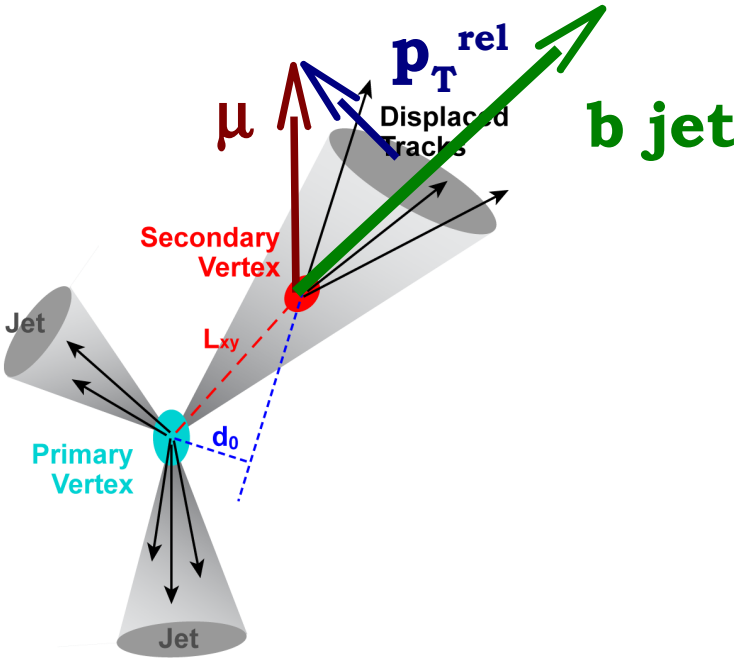
Physics Results

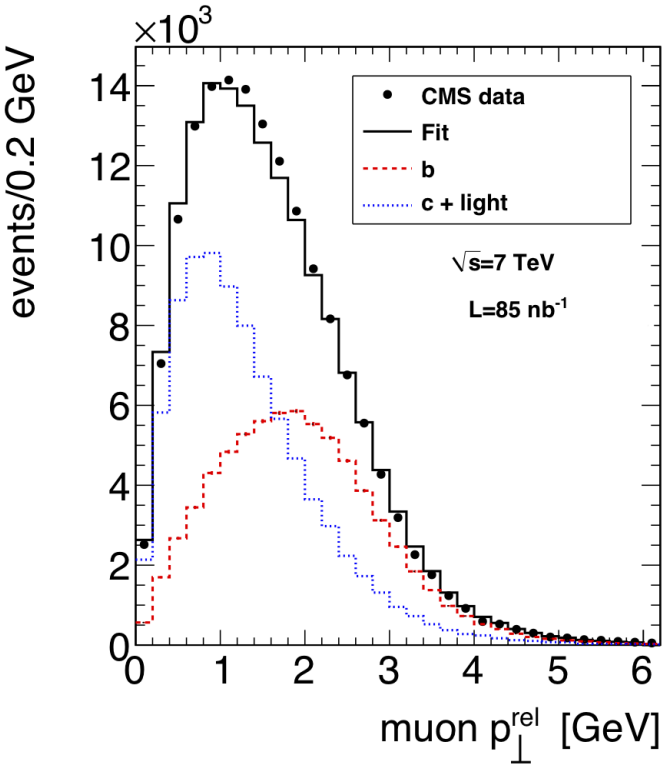
- Inclusive b-jets production properties:
  - $\sigma(pp \to b\bar{b}X,\ b \to \mu Y)$ — JHEP 1103 (2011) 09, 85 nb^{-1}
  - $\sigma(pp \to b\bar{b}X)$ with b-tagged jets — CMS-PAS-BPH-10-018, 60 nb^{-1} (prel)
  - b-jets angular correlations — JHEP 1103 (2011) 136, 3.1 pb^{-1}
- Semi inclusive $b \to J/\psi X$, production rates — Eur.Phys.J.C71(2011), 1575, 314 nb^{-1}
- Exclusive B decays to J/Y X final states
  - $\sigma(pp \to B \to J/\psi K,\ J/\psi K_s,\ J/\psi \phi,\ J/\psi \Lambda)$ — PRL 106:112001,2011, arXiv:1104.2892, CMS-PAS-BPH-10-013, CERN-CMS-DP-2011-007
- Other heavy hadrons:
  - $\chi_{c1,2}$, $X(3872)$, bottomonium, ... Not here, due to time constraints

$\sigma(pp \to b\bar{b}X \to \mu Y)$

- $p_T(\mu)>6$ GeV, $|\eta|<2.1$
- track-only jet, $p_T(\text{jet})> 1$ GeV
  ($p_T(\text{track})> 300$ MeV, anti-k_T, R = 0.5)

- fit to p_T^{rel} (μ/jet) determines relative amounts of *b* signal and (*udsc*) background
- signal shape validated in lifetime-tagged jets





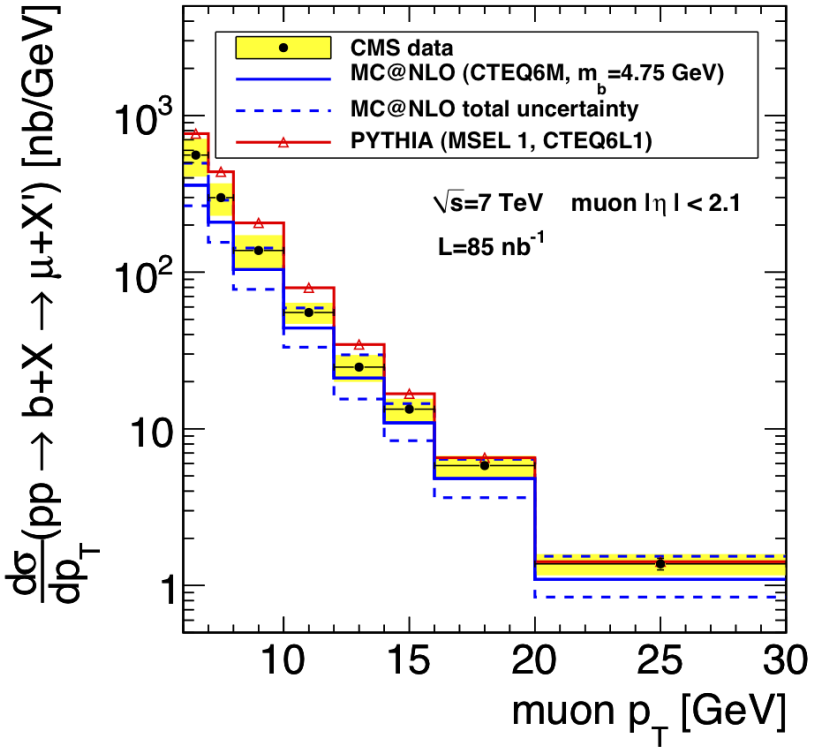
Results

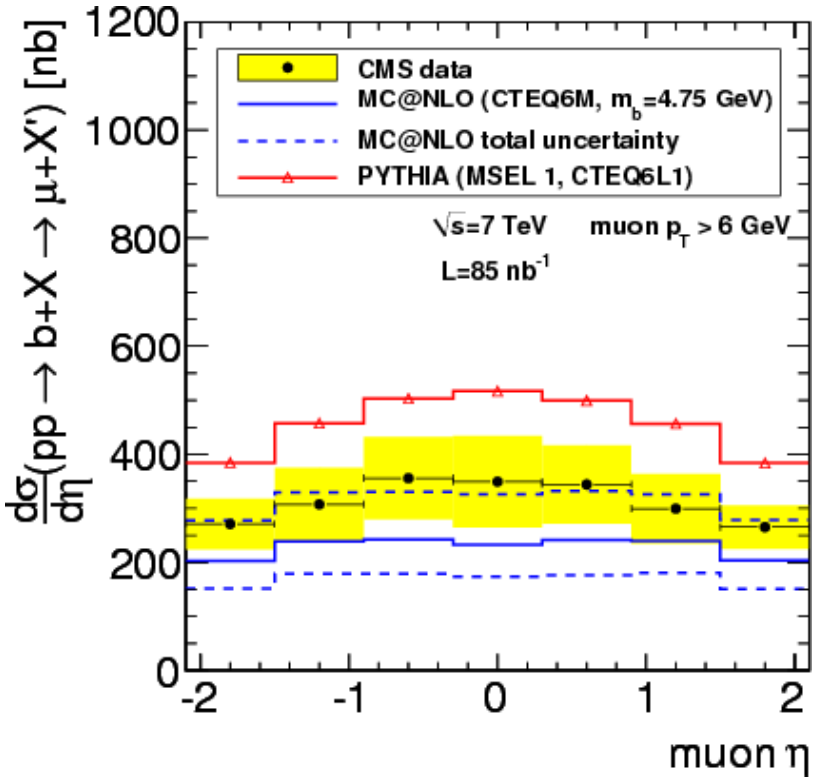
JHEP 1103 (2011) 09 (85 nb^{-1}):

$$\sigma(pp \to b\bar{b}X \to \mu Y) = 1.32 \pm 0.01_{stat} \pm 0.15_{syst.} \pm 0.15_{\mathcal{L}} \ \mu b$$

$$\sigma(MC@NLO) = 0.95^{+0.42}_{-0.21\ scale} \pm 0.09_{m(b)} \pm 0.05_{pdf} \ \mu b$$

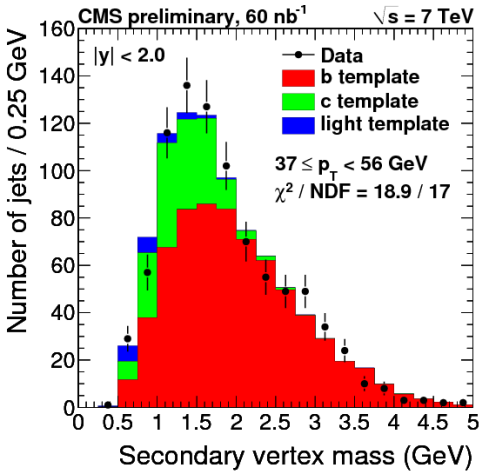
$$\sigma(PYTHIA) = 1.9 \ \mu b$$

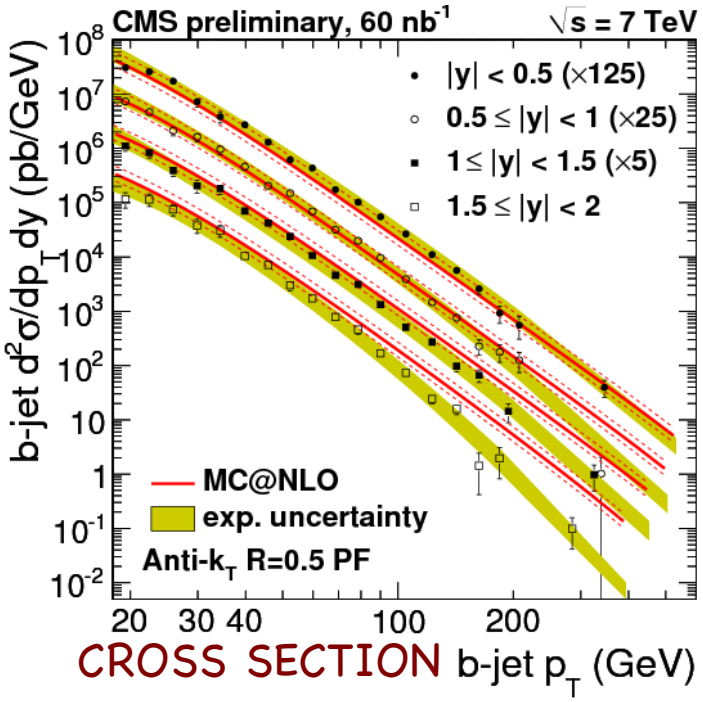


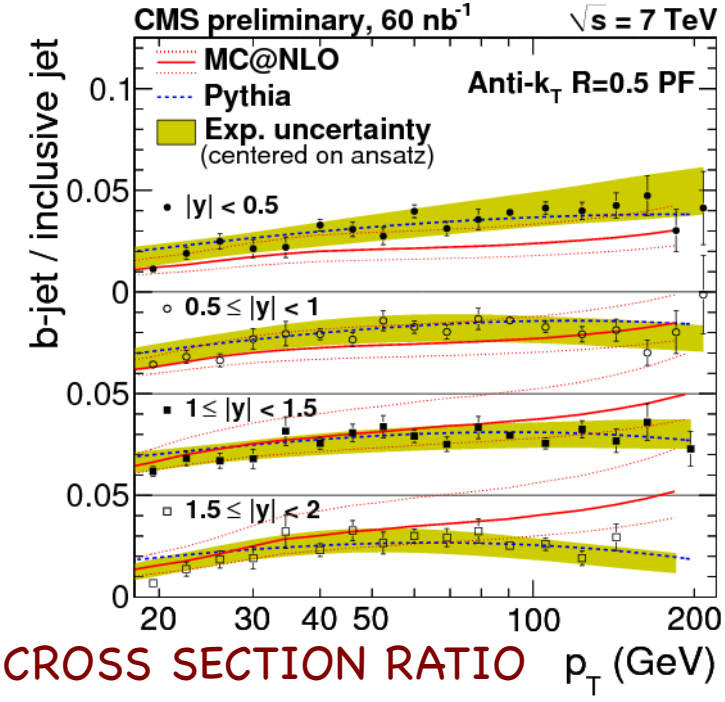


Inclusive x-section for b-tagged jets

- Particle flow jets : "optimal" combination of tracker and calorimetric informations
- Wide acceptance : 18 < p_T(Jet) < 300 GeV
- Secondary Vertex tag, b-purity ~ 70 %
- Compute ratio of b-jets to inclusive jets, compare to QCD
- CMS-PAS-BPH-10-018:

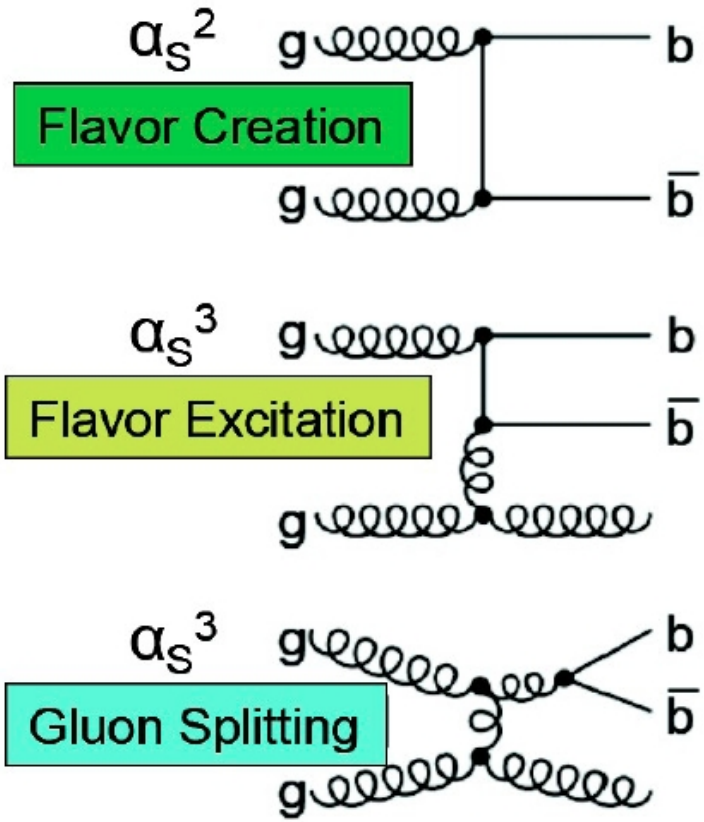






b-jets angular correlation

- b-jets pair produced
- angular correlation clarifies dominant production mechanism:
  - gluon splitting -> collinear production
  - flavour creation -> well separated jets



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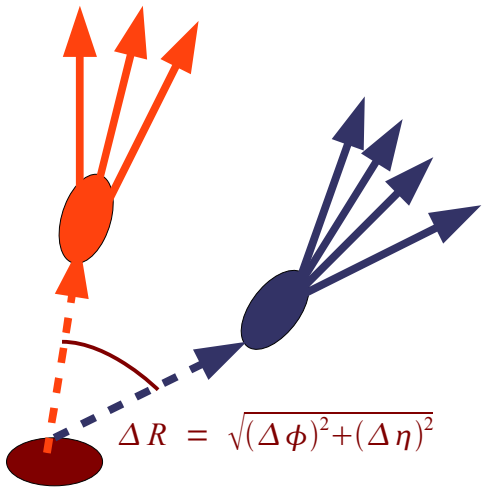
- use direction primary to secondary vertex to improve angular resolution



$N(tracks) \geq 3$

$L \geq 5\,\sigma(L)$

ΔR , absolute normalization

Ratio to Pythia, normalized ΔR>2.5

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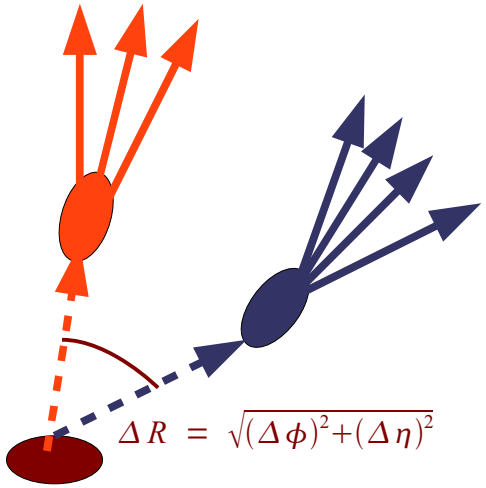

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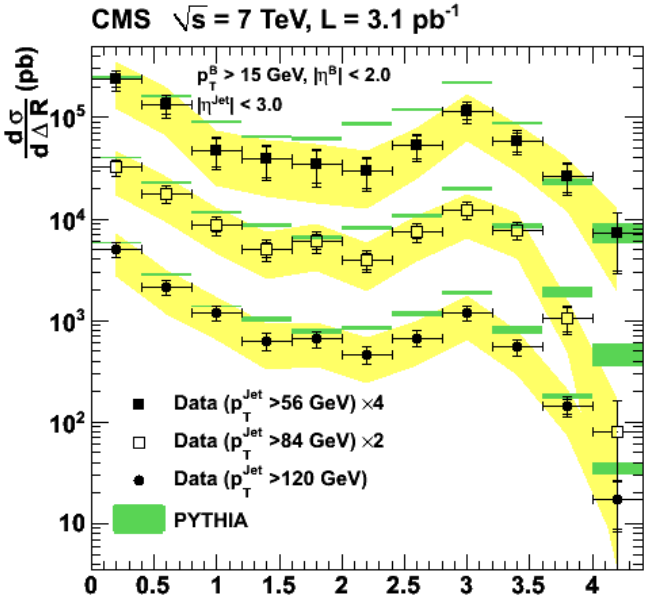
JHEP 1103 (2011) 136 (3.1 pb^{-1}) : excess of collinear jets wrt NLO-QCD expectation



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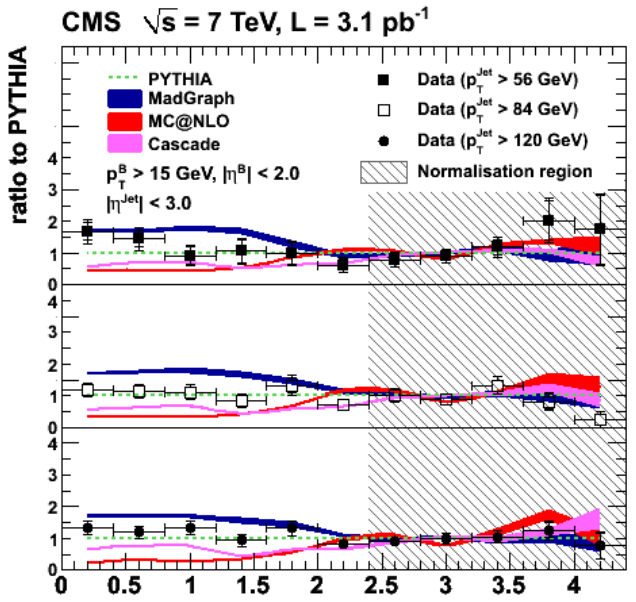
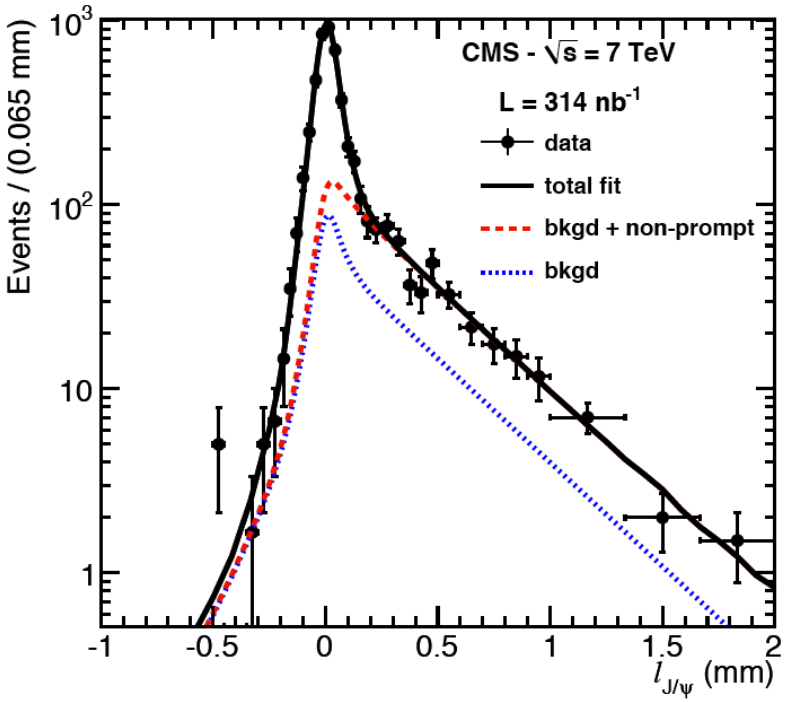
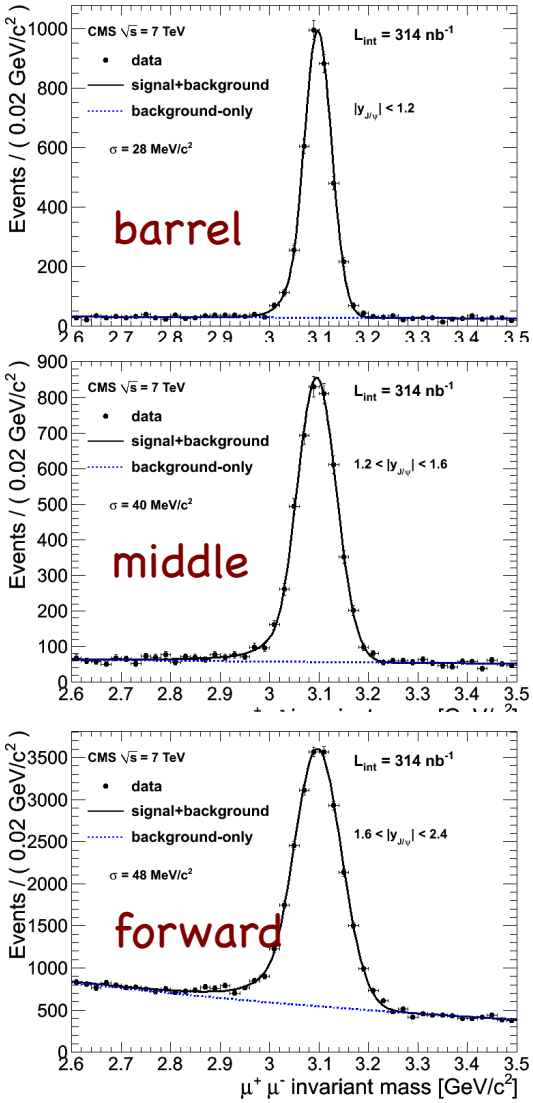


Ratio to Pythia, normalized ΔR>2.5

b -> J/Ψ X

- BR(B –> J/Ψ X) ~ o(few %)
- J/Ψ –> μμ clear , easy to trigger signal
- decay length information tags prompt production from B decays
- prompt includes ~ 30% feed-down from higher charmonium excitations





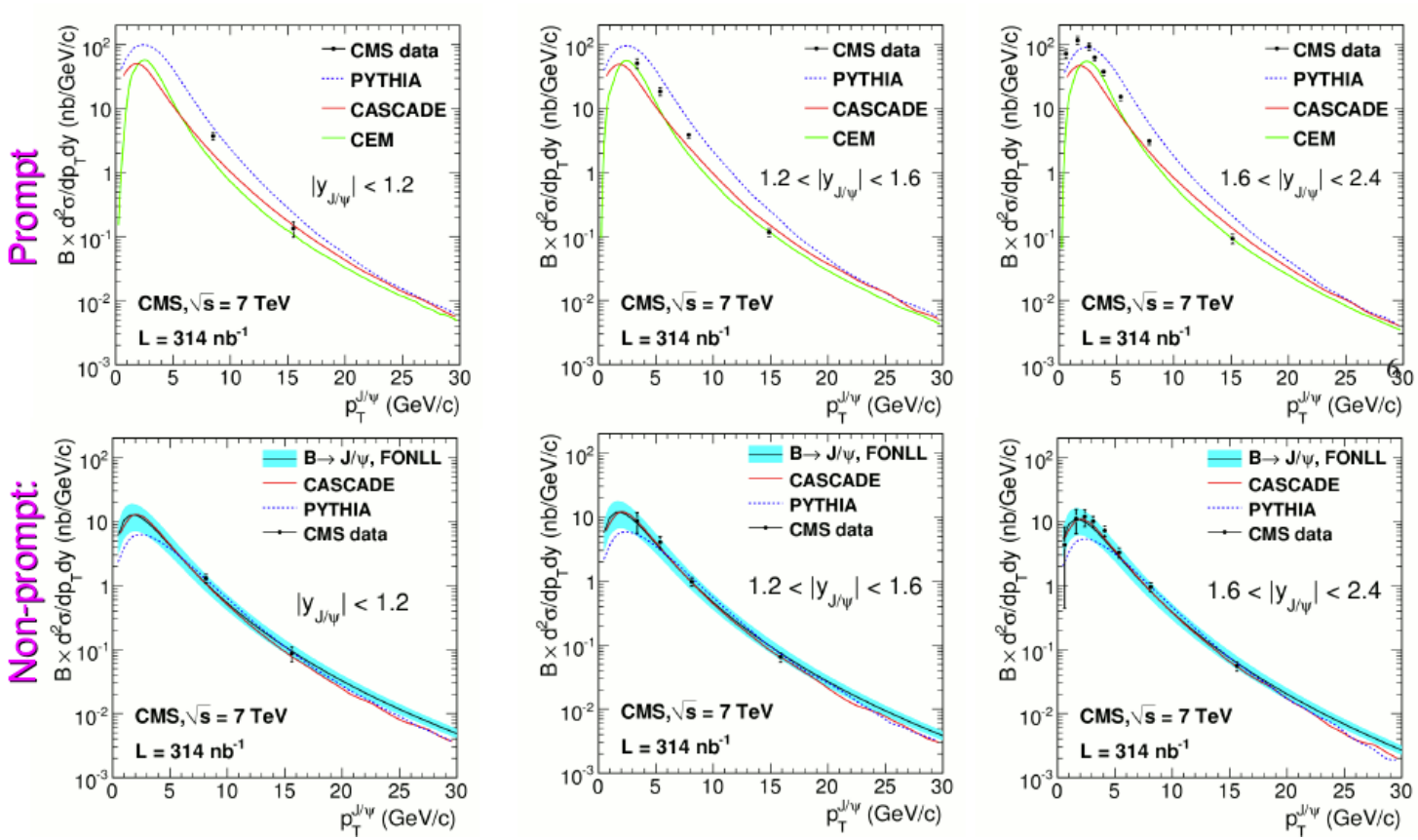
Results

- Eur.Phys.J. C71 (2011) 1575 (314 nb^{-1}) :

Prompt: $\sigma(pp \to J/\psi X) \cdot \mathcal{B}(J/\psi \to \mu^+ \mu^-) = 70.9 \pm 2.1_{stat} \pm 3.0_{syst} \pm 7.8_{lumi}$ nb

$\sigma(pp \to b\bar{b} X \to J/\psi Y) \cdot \mathcal{B}(J/\psi \to \mu^+ \mu^-) = 26.0 \pm 1.4_{stat} \pm 1.6_{syst} \pm 2.9_{lumi}$ nb

σ(syst) not including 20% uncertainty from unknown polarization



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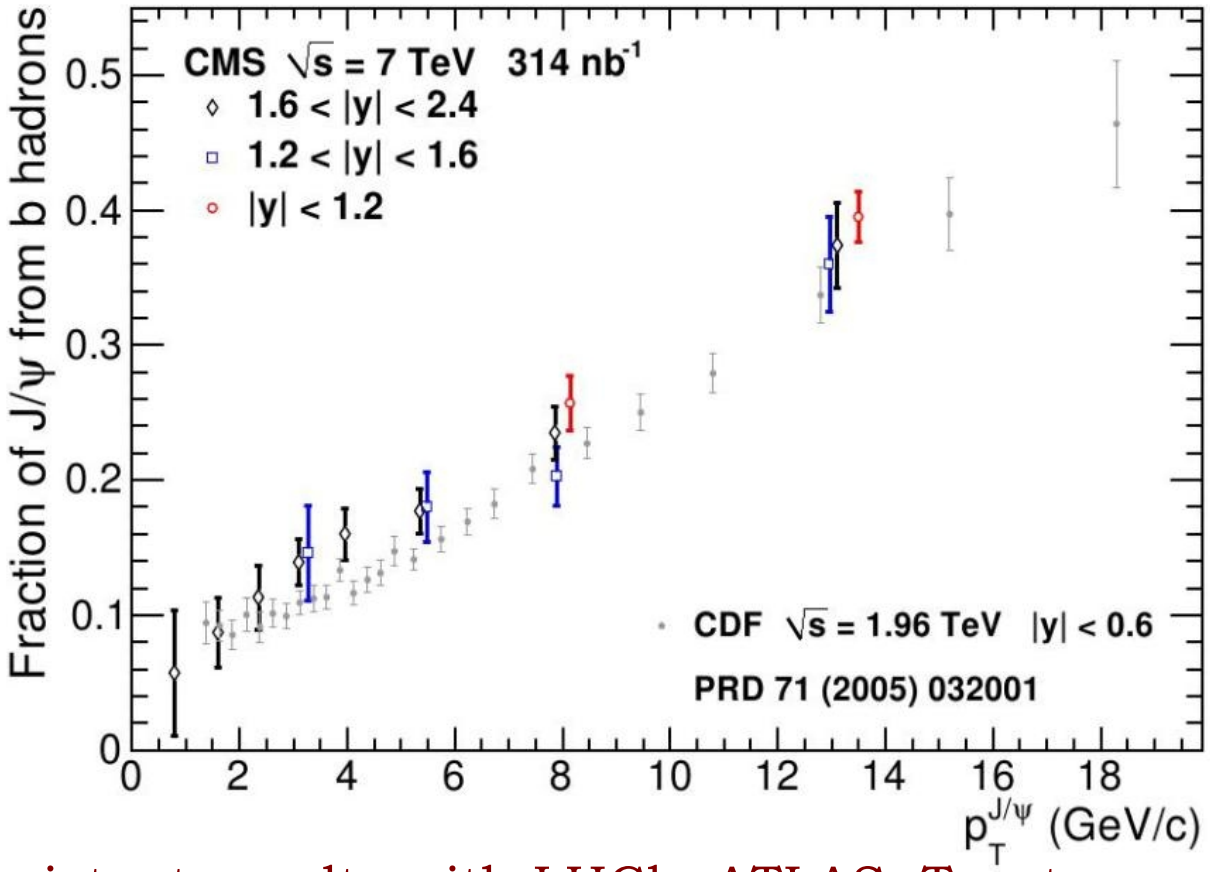


Consistent results with LHCb, ATLAS, Tevatron

$B^{\pm}/B_d/B_s/\Lambda_B$ production

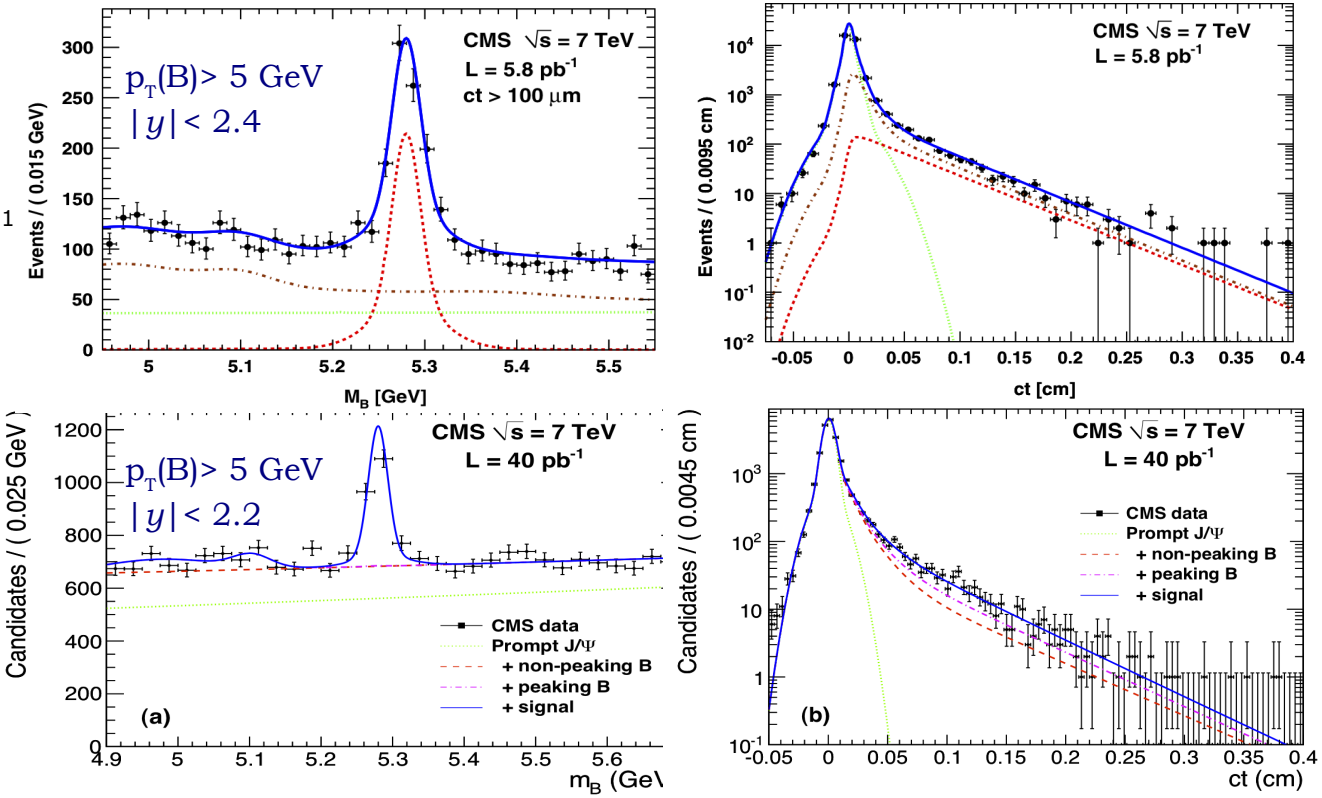
- Sizable $\mathcal{B}(B \to J/\psi h) \sim o(‰)$
- Invariant mass & *ct* tag the signal
- Control prompt (random) and non prompt (feed-down, misreconstruction) background with M sidebands
- Measure cross sections in p_T, y bins

$B^+ \to J/\psi K^+$

PRL 106:112001,2011, 5.8 pb^{-1}

$B_d \to J/\psi K_s$

arXiv:1104.2892 40 pb^{-1}
Accepted by PRL



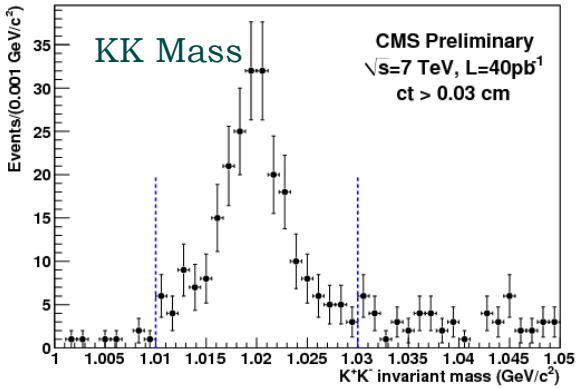
Bs -> J/Ψ φ

- B_s decays provide yet-unexplored bench marks of the SM:
  - CPV in B_s –> $J/\Psi\phi$
  - $\mathcal{B}(B_s \rightarrow \mu^+\mu^-)$
  - CPV in B_s mixing
- CMS potentially competitive due to superb muon identification
- To date : measurement of

$$\sigma(pp \rightarrow B_s X) \cdot \mathcal{B}(B_s \rightarrow J/\Psi\,\phi)$$

$\sigma(pp \to B_s X) \cdot \mathcal{B}(B_s \to J/\Psi\,\phi)$: analysis

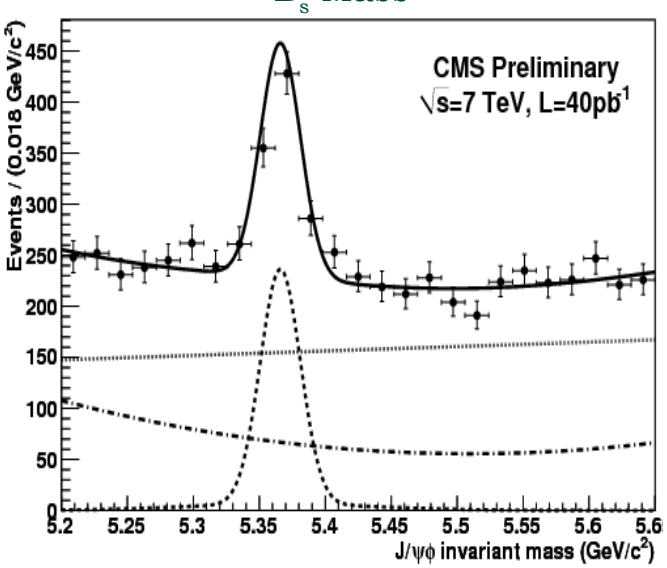
- $p_T(B_s) > 8$ GeV, $|y(B_S)| < 2.4$
- J/ψ (–> $\mu\mu$), ϕ (–>K^+K^-) constrained to a common vertex
- multi stage fit to (M_{Bs}, ct) measuring event yield, background shape parameters and shape of ct distribution



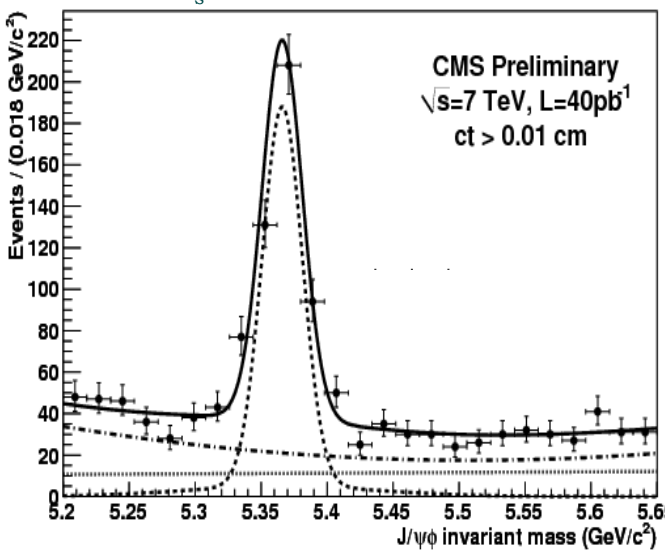
$$c\tau = 478 \pm 26\,\mu m$$

$1.4\sigma(stat)$ from PDG W.A.

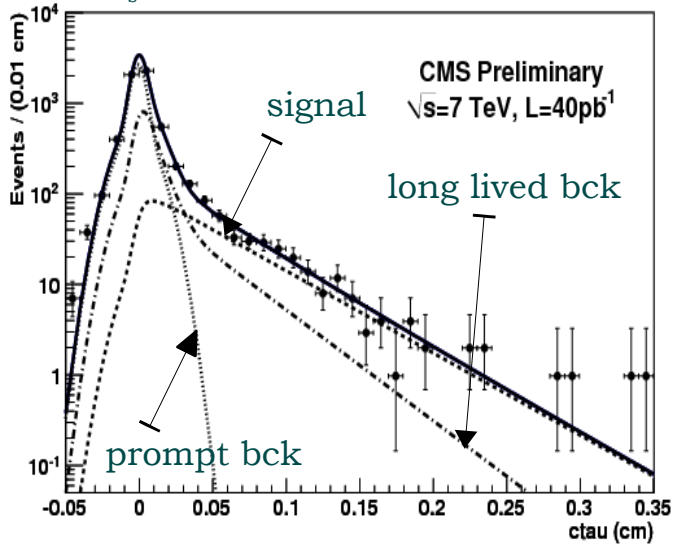
B_s Mass



B_s Mass, ct > 100 μm



B_s proper time on Mass Peak



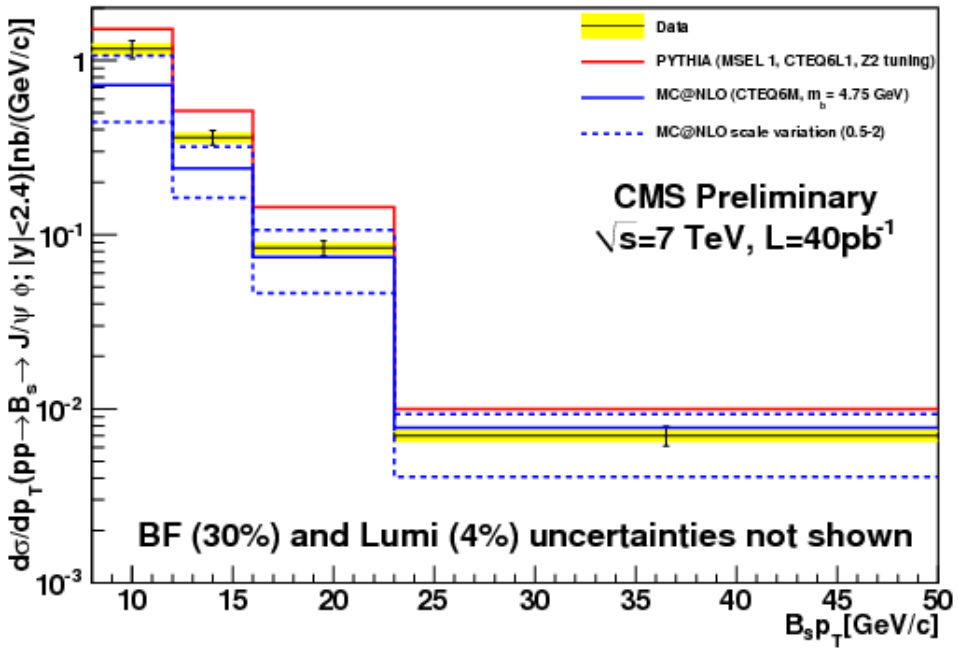
$\sigma(pp \to B_s X) \cdot \mathcal{B}(B_s \to J/\Psi\,\phi)$: results

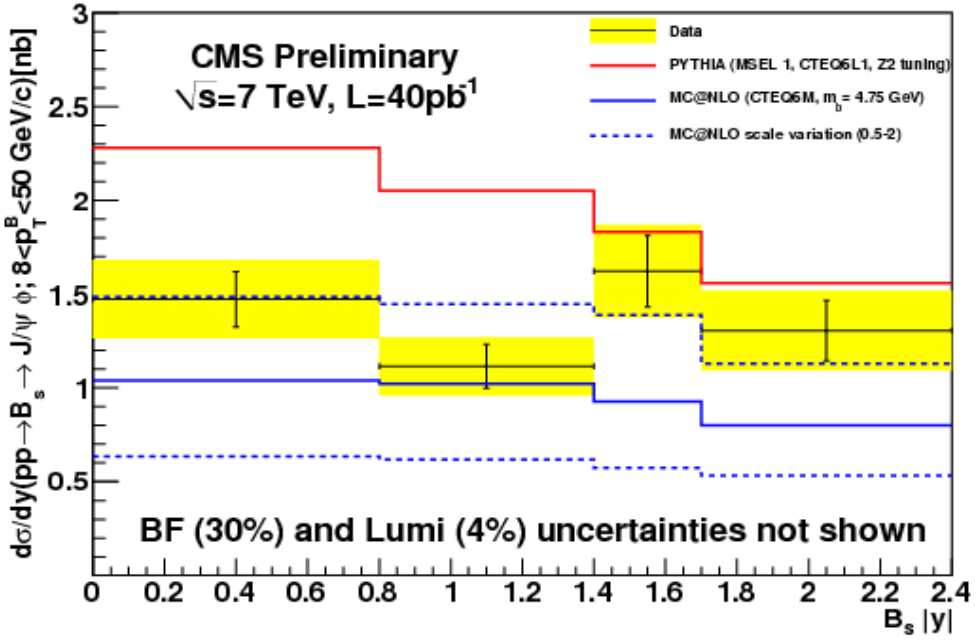
- CMS prel. ($40\ pb^{-1}$, $p_T(B_s) > 8$ GeV, $|y(B_S)| < 2.4$):

$$\sigma(pp \to B_s X) \cdot \mathcal{B}(B_s \to J/\Psi\,\phi) = 6.9 \pm 0.6_{stat} \pm 0.5_{syst} \pm 0.3_{\mathcal{L}}\ nb$$

$$\sigma(MC@NLO) = 4.6^{+1.9}_{-1.7\ QCD} \pm 1.4_{\mathcal{B}}\ nb$$

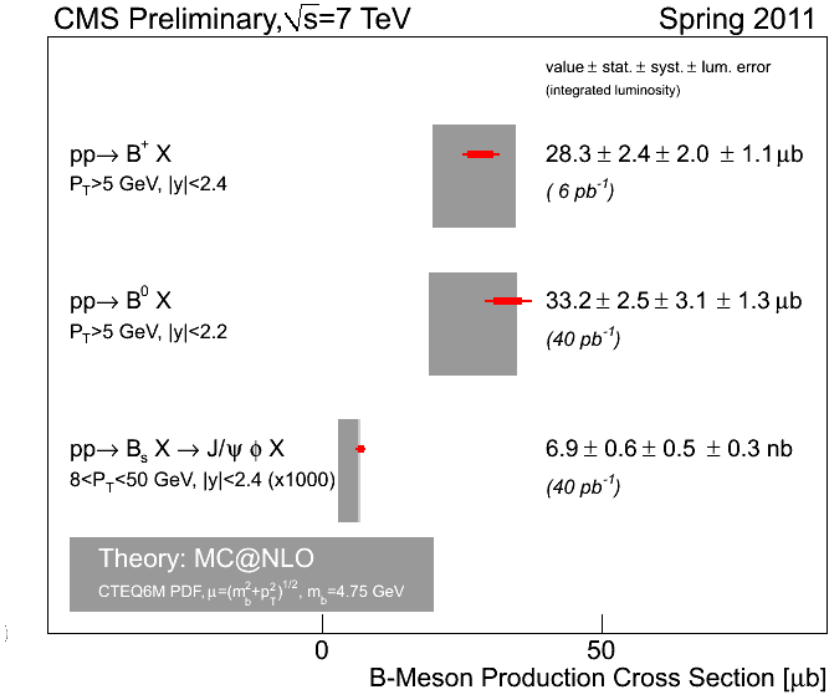
$$\sigma(PYTHIA) = 9.4 \pm 2.8\ nb$$





Exclusive Decays : summary

- Similar analysis performed on B^+,B_d
- Similar precision, similar consistency wrt MC @NLO



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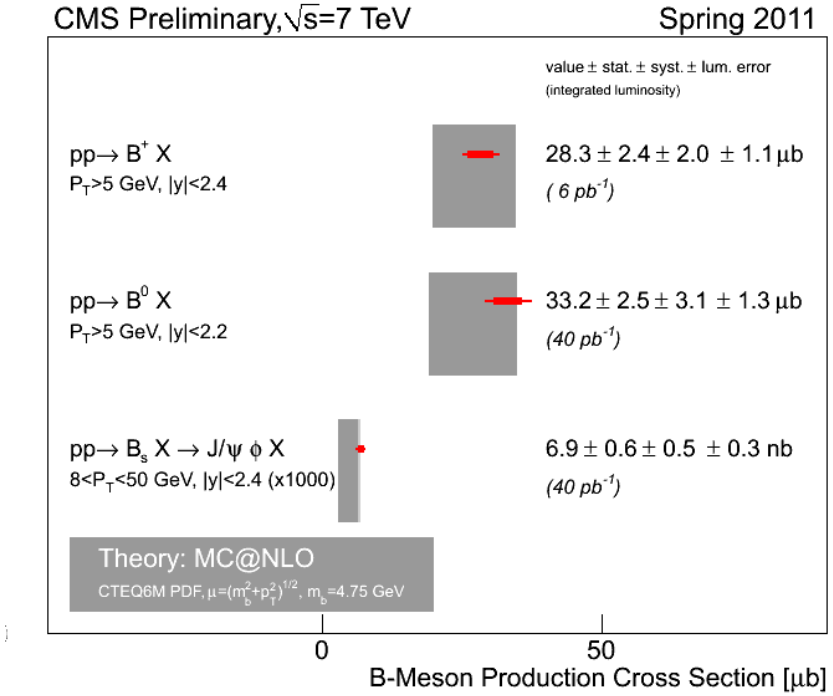
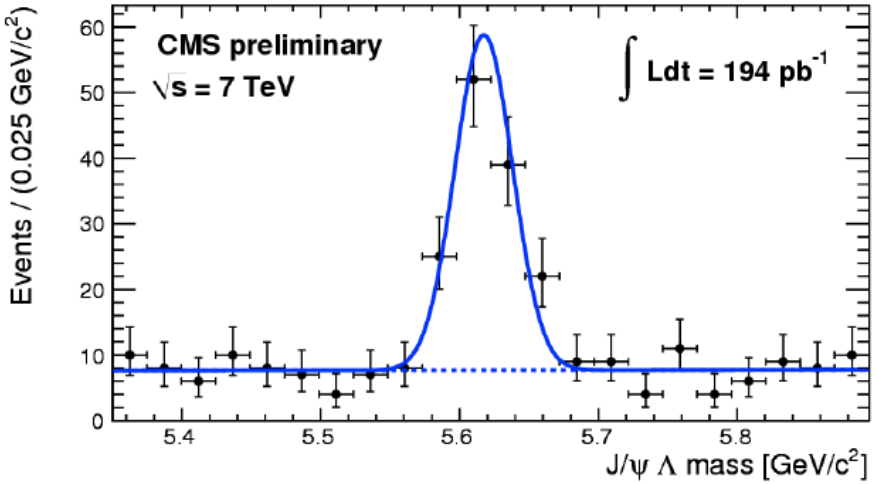
- Λ_b (–> J/Ψ Λ) measurement is on the way





Exclusive Decays : summary

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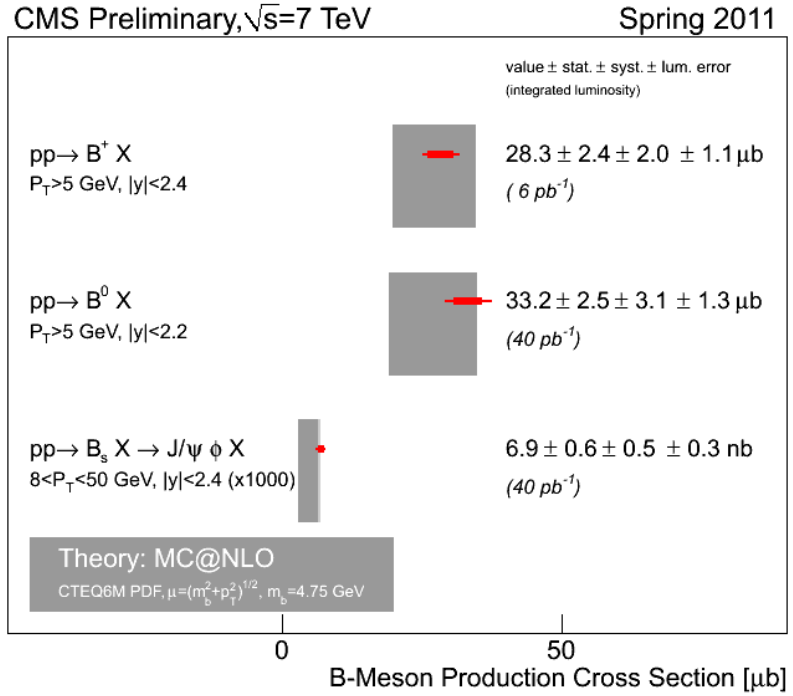
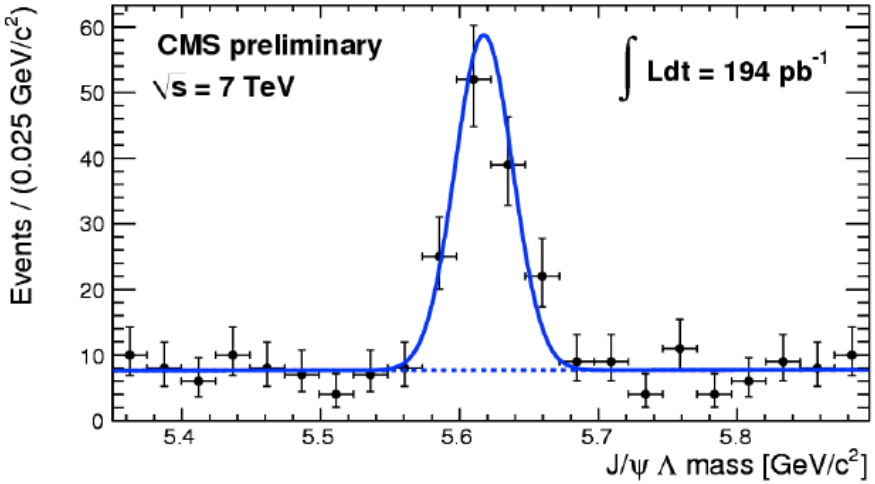
- Similar precision, similar consistency wrt MC @NLO
- Λ_b (–> J/Ψ Λ) x-section measurement is on the way
- Comparison with inclusive and semi-inclusive (b–>J/ΨX) measurements will help shedding light on bb production and fragmentation at the LHC





Conclusion

- CMS has measured the cross section for inclusive, semi-inclusive and exclusive b-production in 7 TeV pp collisions – *sole experiment @ LHC to date*
- Results in rough agreement with NLO QCD, albeit with large theoretical (scale, fragmentation, $\mathcal{B}$) errors
- Increasing $\mathcal{L}$ will improve precision by allowing:
  - further correlation studies
  - polarization measurements
  - closure test : $\sigma_{inc} = \Sigma_{i=u,d,s}\ \sigma(B_i)$
- CPV and rare decays hopefully just beyond the corner