Heavy Flavor results from CMS

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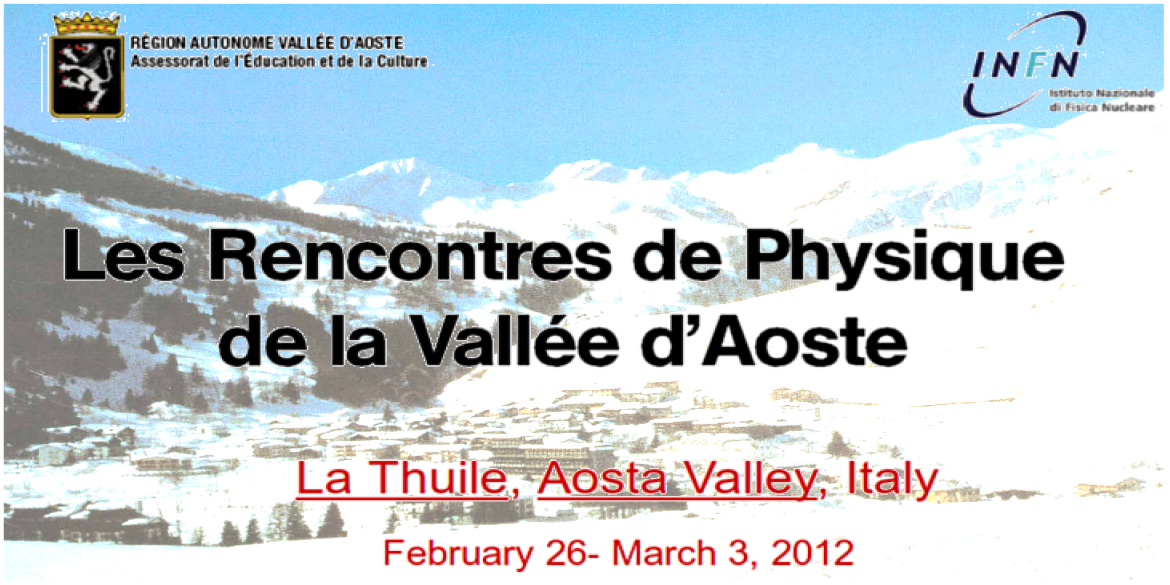
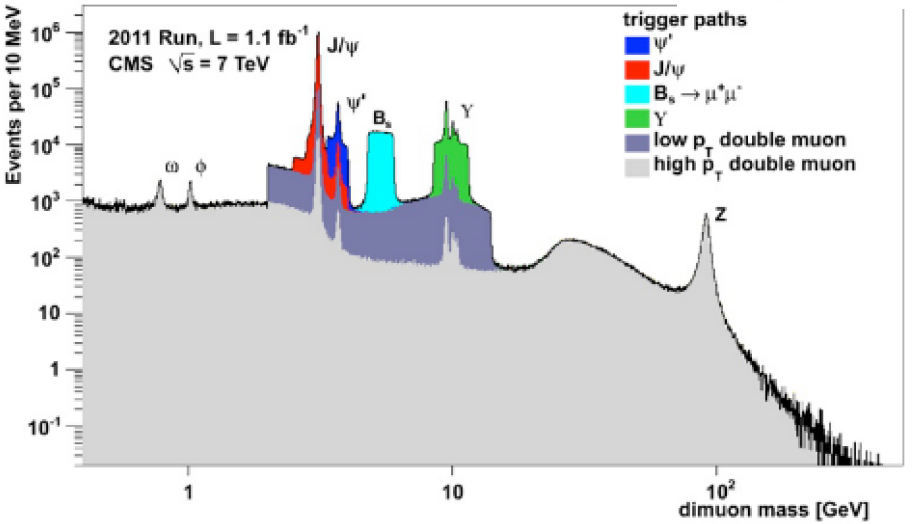
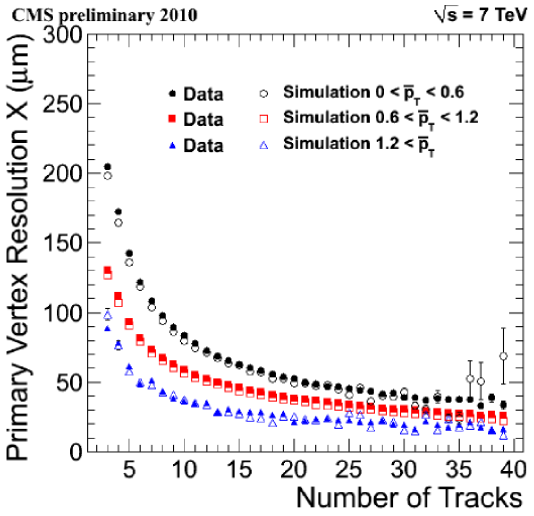
On behalf of the CMS Collaboration

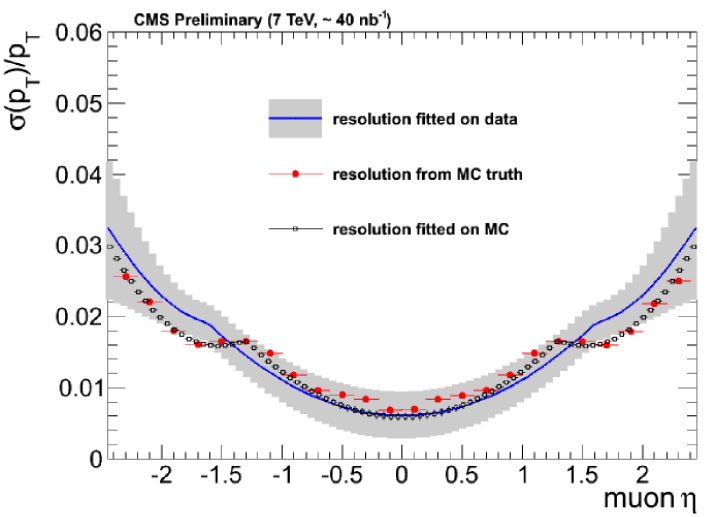


Introduction

- CMS heavy flavor program is taking great advantage from the excellent performance of the CMS detector
- Excellent vertex and p_T resolution
- Very low rate of hadrons mis-identified as muons (O(‰) for π, K and p)
- Flexible HLT which allows to have many specialized di-μ triggers with high efficiency and high purity







Topics covered in this talk:

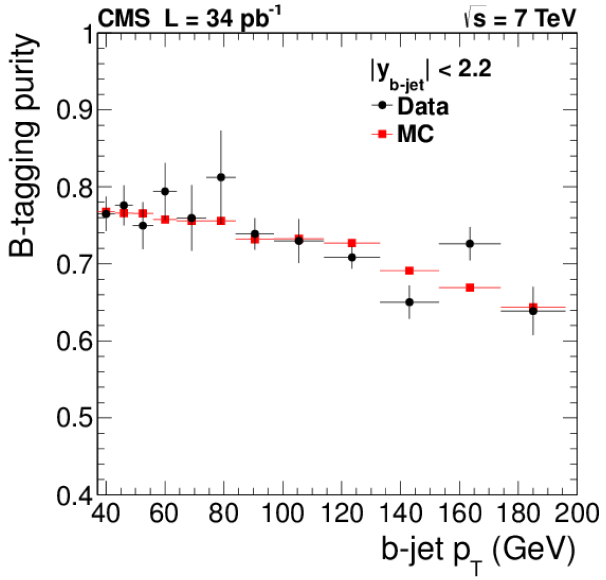
- Inclusive b and $b\bar{b}$ production
- Exclusive B decays
- Properties of $c\bar{c}$ states

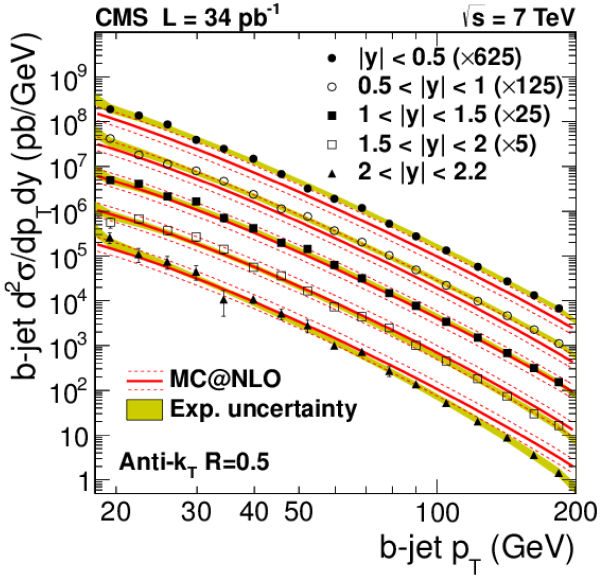
DISCLAIMER: I will NOT talk about the rare $B_{s,d} \to \mu\mu$ decay → Seminar at CERN with new results this week (28/2/2012)!

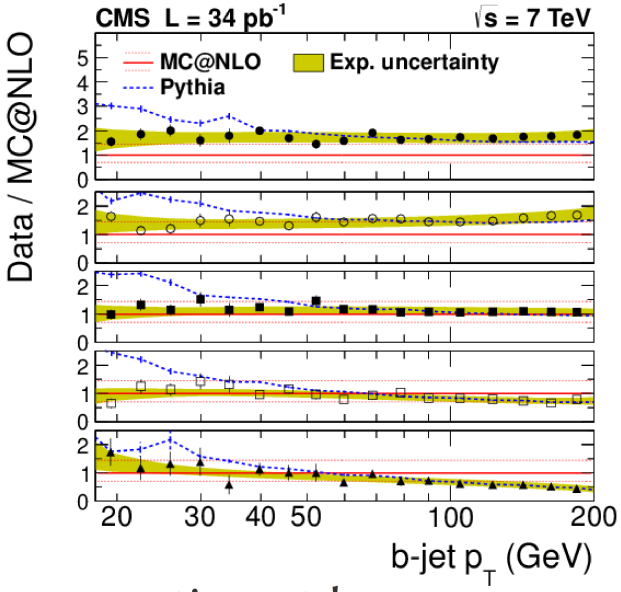
CMS-PAS-TRK-10-004/5
Eur.Phys.J C70 (2010) p. 1165

Inclusive b cross section with jets

arXiv:1202.4617







- Use jets b-tagged with high-purity discriminator based on secondary vertex
- Sample composition well described by simulation

- Pythia overestimates the cross section at low p_T
- MC@NLO prediction lower than data at low |y|, higher at high |y| and high p_T

$\sigma(p_T > 18\ \text{GeV}, |y| < 2.2) = 9.75 \pm 0.32 \pm 1.67 \pm 0.39\ \mu b$

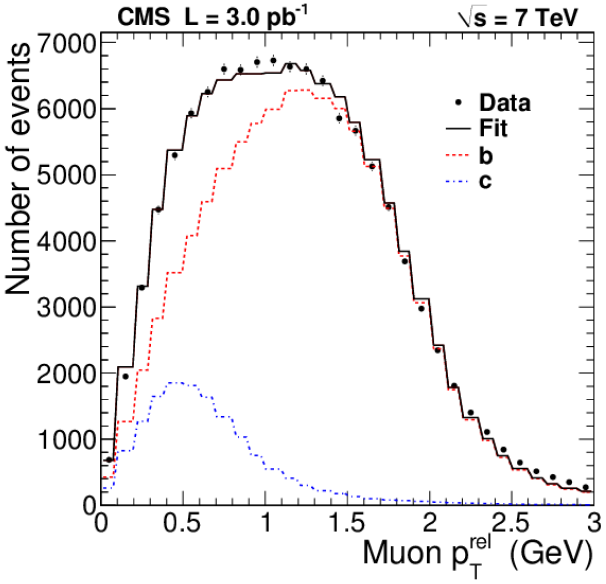
$\sigma_{MC@NLO} = 7.3\ ^{+2.9}_{-1.8} \pm 1.2 \pm 0.7\ \mu b$

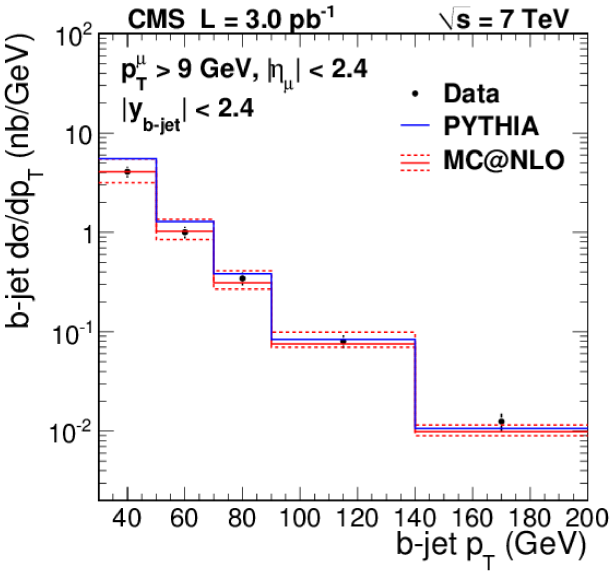
$\sigma(p_T > 32\ \text{GeV}, |y| < 2.2) = 1.73 \pm 0.07 \pm 0.20 \pm 0.07\ \mu b$

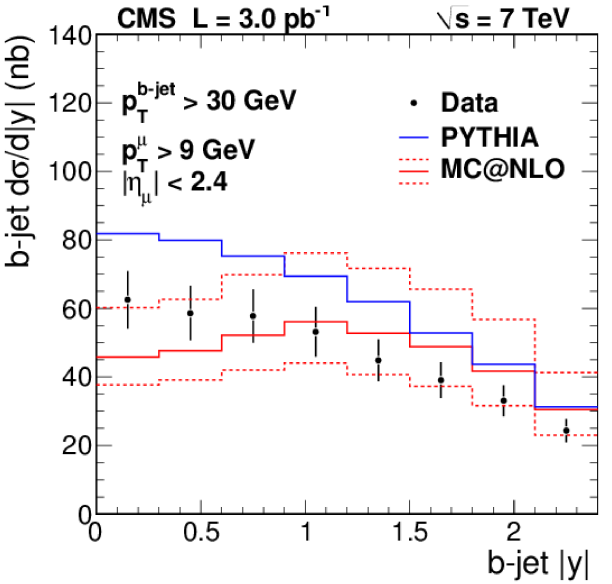
$\sigma_{MC@NLO} = 1.3\ ^{+0.5}_{-0.3} \pm 0.2 \pm 0.1\ \mu b$

Inclusive b cross section with muons and jets

arXiv:1202.4617







- Use b-tagged jets containing muons
- b fraction found with a fit on the muon p_T with respect to the jet axis (p_T^{Rel})

p_T^{jet} > 30 GeV, $|y^{jet}|$ < 2.4, p_T^{μ} > 9 GeV, $|\eta^{\mu}|$<2.4

σ = 0.113 ± 0.001 ± 0.014 ± 0.005 μb

$\sigma_{MC@NLO}$ = 0.113 $^{+0.04}_{-0.023}$ ±0.003 ± 0.005 μb

Extr. to full μ phase space and corr. for BR(b→μX)

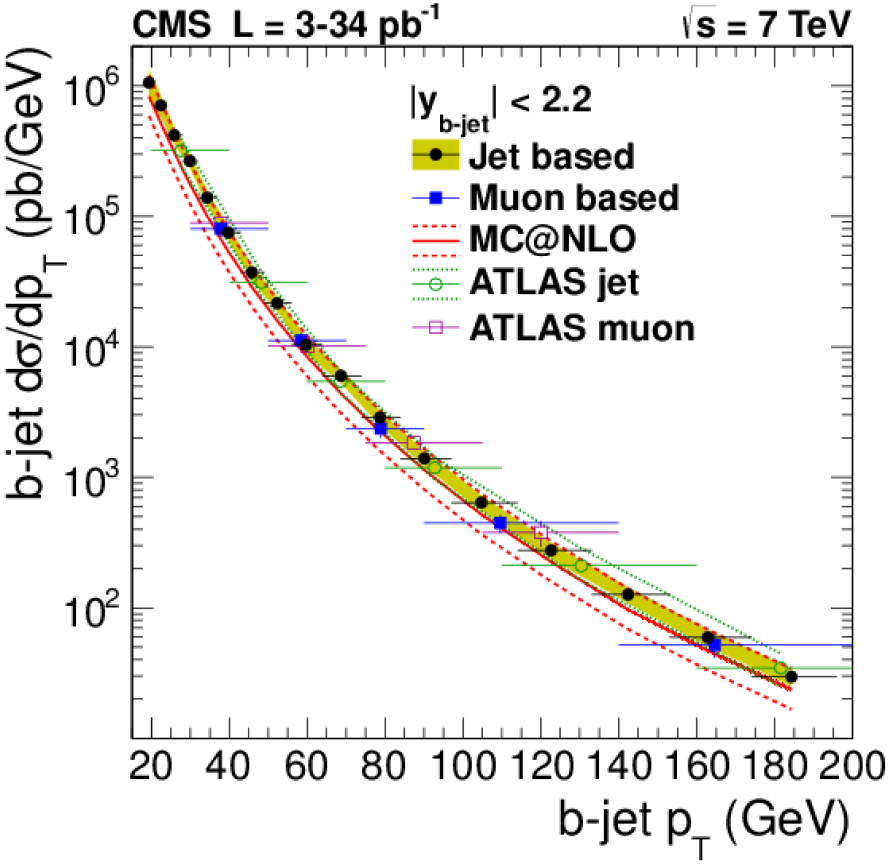
σ = 2.25 ± 0.01 ± 0.31 ± 0.09 μb

$\sigma_{MC@NLO}$ = 1.83 $^{+0.64}_{-0.42}$ ±0.05 ± 0.08 μb

Summary of inclusive b cross section measurements

arXiv:1202.4617

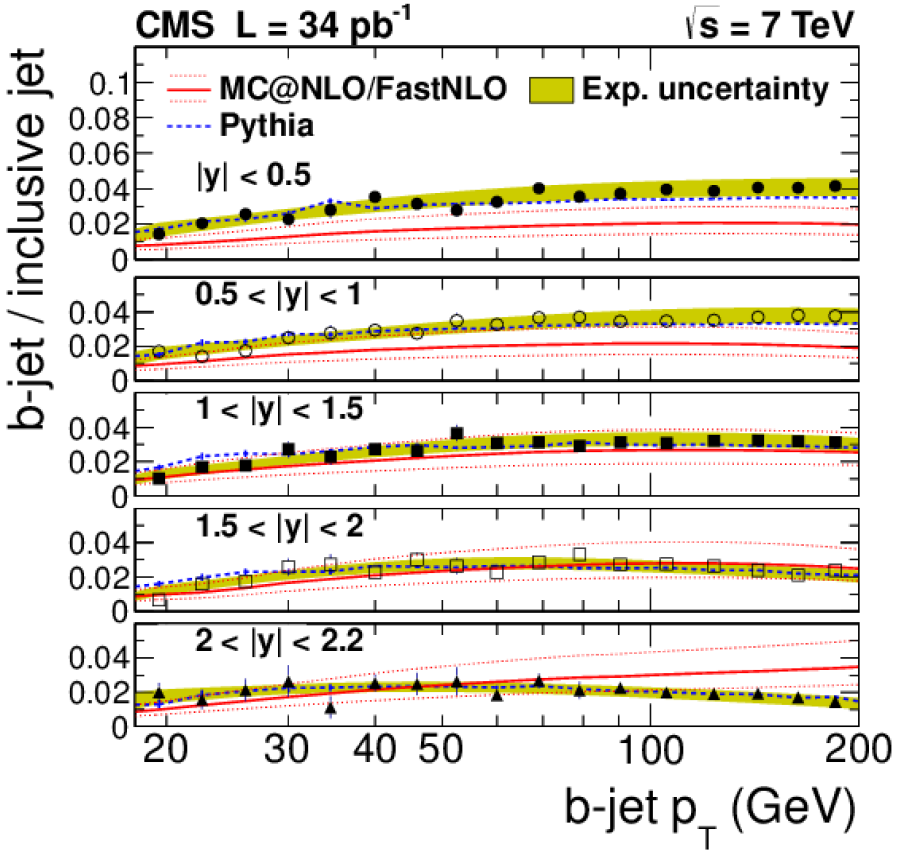
- Muon-based results extrapolated to match the same visible phase space of the jet-based analysis (|y|<2.2)
- CMS results in good agreement with the ATLAS measurements
- Results consistent with the NLO predictions



Fraction of b-jets

arXiv:1202.4617

- Fraction of b-jets increasing as a function of p_T by up to a factor 2
- NLO prediction
  - MC@NLO for b-jets
  - FastNLO for inclusive jet sample
- NLO fraction
  - lower than data in the central region
  - Higher than data for p_T > 100 GeV and |y| > 2
- Pythia in agreement with data in the full kinematical region

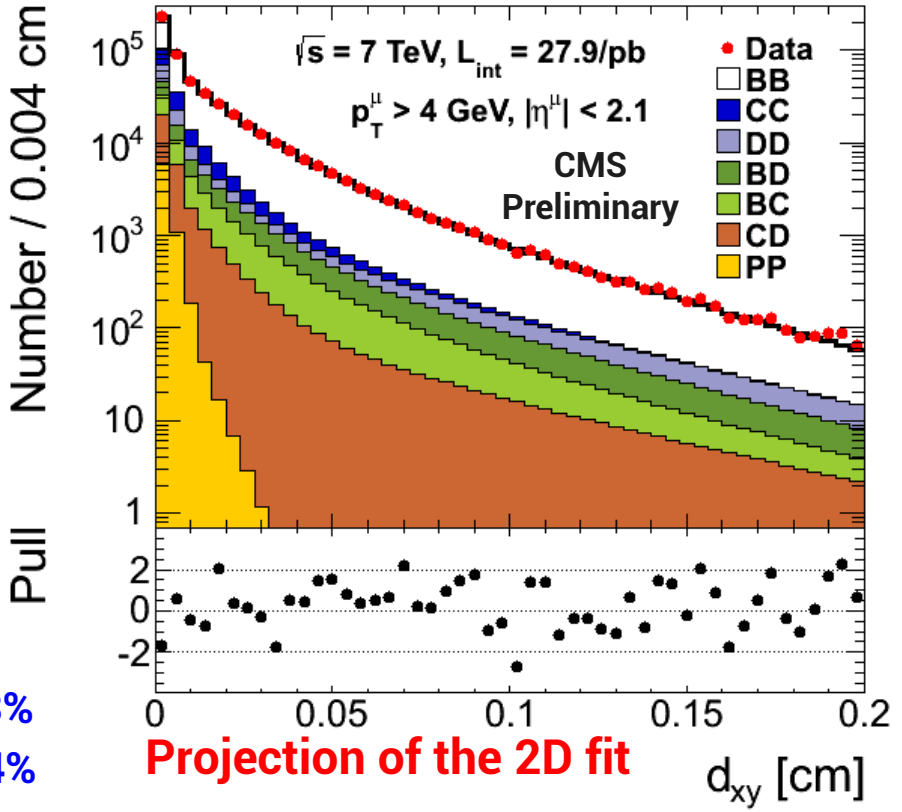


Inclusive $b\bar{b}$ cross section with muon pairs

NEW RESULT!

CMS-PAS-BPH-10-015

- Fraction of $b\bar{b} \rightarrow \mu\mu$ events in data extracted with a 2D template fit to the di-μ impact parameter
  - Distributions for B (bottom), C (charm) and D (decays in flight) taken from simulation
  - Distribution for P (prompt) from $\Upsilon(1s) \rightarrow \mu^+\mu^-$ decays in data
- **Total uncertainty ~10%**



Projection of the 2D fit

Fraction of $b\bar{b}$ candidates (p_T>4GeV, |η|<2.1) = 65.1±0.3%
coming from the fit (p_T>6GeV, |η|<2.1) = 69.0±0.4%

$\sigma(pp \rightarrow b\bar{b} \rightarrow \mu\mu X, p_T > 4GeV, |\eta| < 2.1) = 25.70 \pm 0.14(stat) \pm 2.20(syst) \pm 1.03(lumi)$ nb

$\sigma_{MC@NLO}(p_T > 4GeV, |\eta| < 2.1) = 19.66 \pm 0.29(stat)\ ^{+6.5}_{-4.1}(syst)$ nb

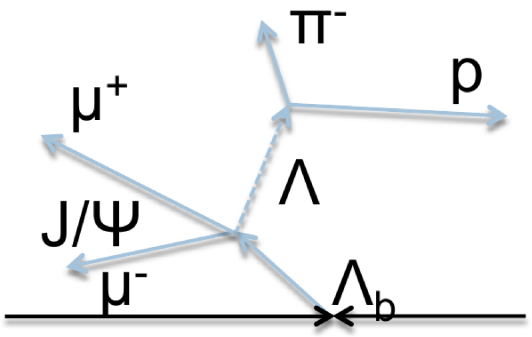
$\sigma(pp \rightarrow b\bar{b} \rightarrow \mu\mu X, p_T > 6GeV, |\eta| < 2.1) = 5.03 \pm 0.05(stat) \pm 0.46(syst) \pm 0.20(lumi)$ nb

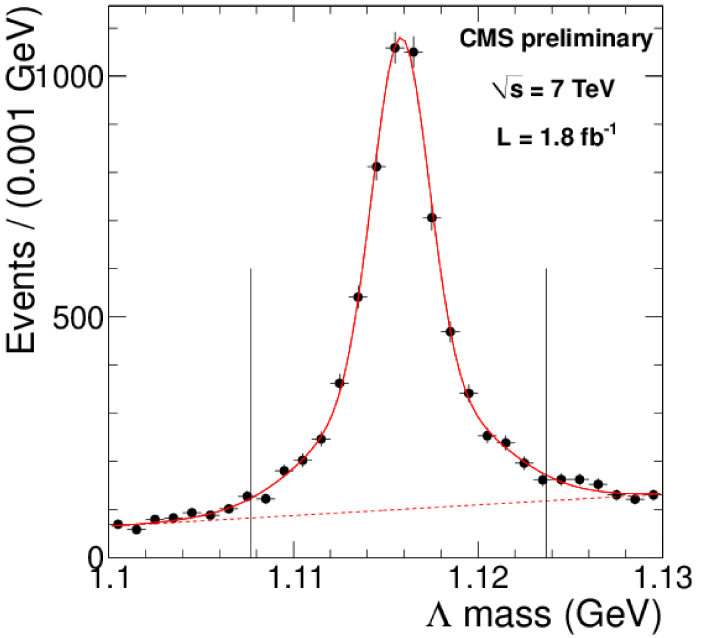
$\sigma_{MC@NLO}(p_T > 6GeV, |\eta| < 2.1) = 4.40 \pm 0.14(stat)\ ^{+1.05}_{-0.84}(syst)$ nb

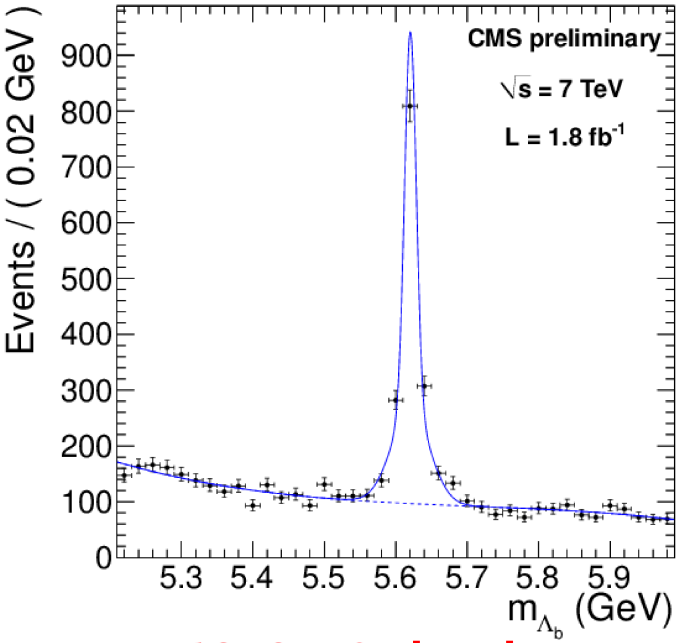
Reconstruction of $\Lambda_b \rightarrow J/\psi \Lambda$

CMS-PAS-BPH-11-007

NEW RESULT!





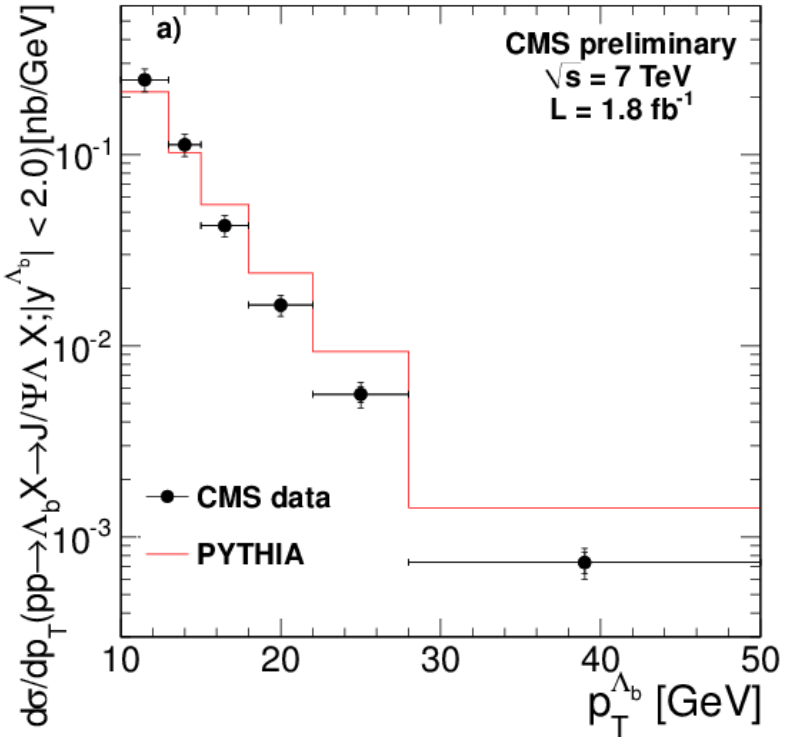


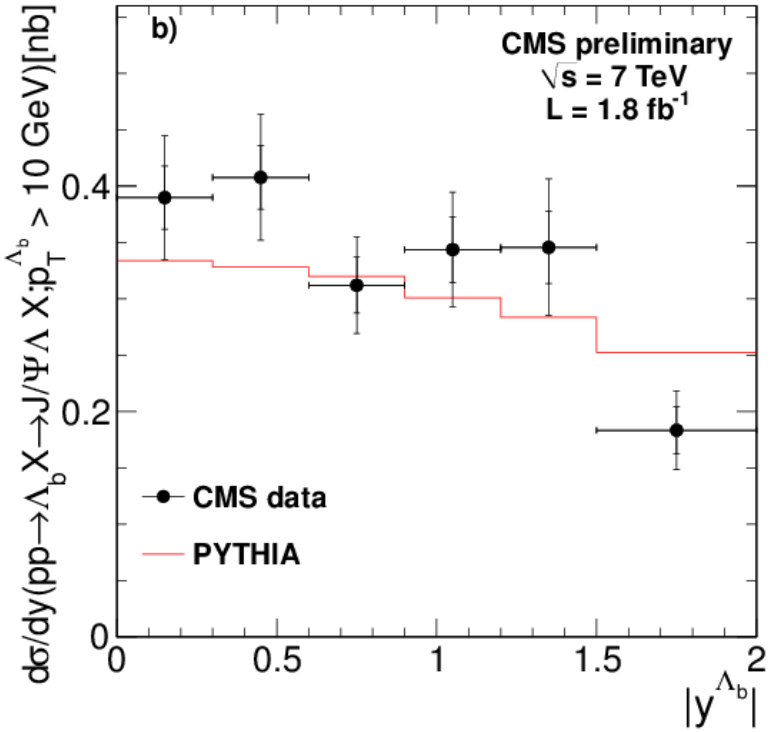
1252±59 signal events (stat. uncert. only)

- $\Lambda_b \rightarrow J/\psi\, \Lambda$ decay reconstructed in the channels $J/\psi \rightarrow \mu^+\mu^-$, $\Lambda \rightarrow \pi^- p$
- Events triggered by μ pairs compatible with displaced $J/\psi \rightarrow \mu^+\mu^-$ decays
- $\Lambda \rightarrow \pi^- p$ reconstructed from displaced 2-track vertices
- Very low combinatorial background

$\Lambda_b \rightarrow J/\psi\Lambda$ cross section

CMS-PAS-BPH-11-007



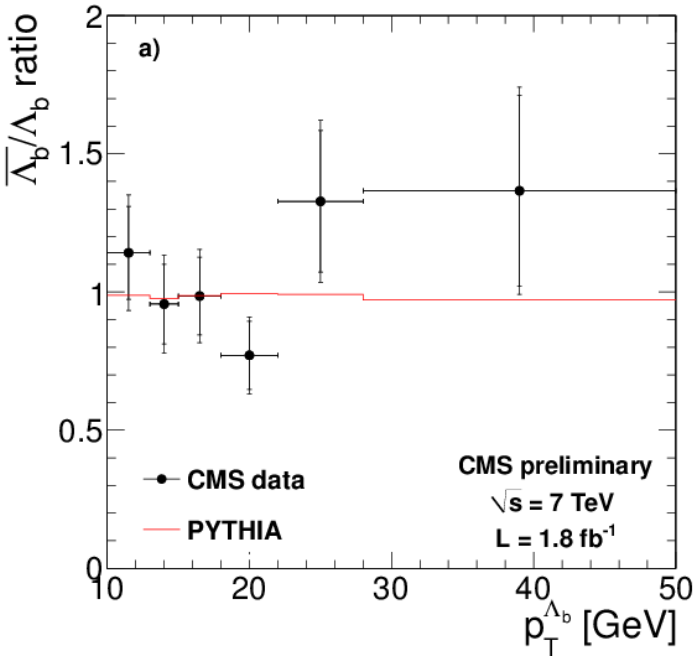


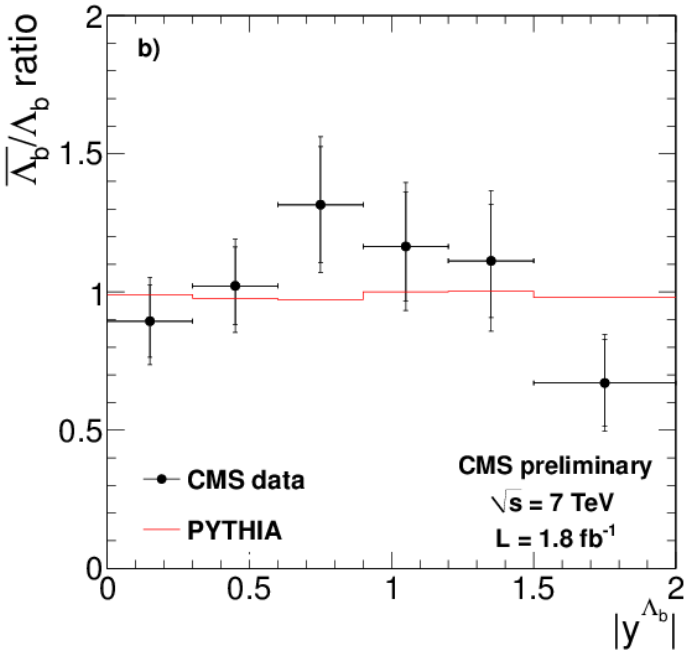
- $\sigma \cdot BR$ binned as a function of p_T and $|y|$
- $BR(\Lambda_b \rightarrow J/\psi\Lambda) = 5.7 \pm 3.1 \cdot 10^{-4}$
  (**54% uncertainty in the Pythia prediction, correlated among bins**)
- $d\sigma/dp_T$ falls faster in data than Pythia
- $d\sigma/dy$ shows no significant deviations

Branching ratio uncertainty not shown in the plots

$\overline{\Lambda}_b/\Lambda_b$ ratio

CMS-PAS-BPH-11-007



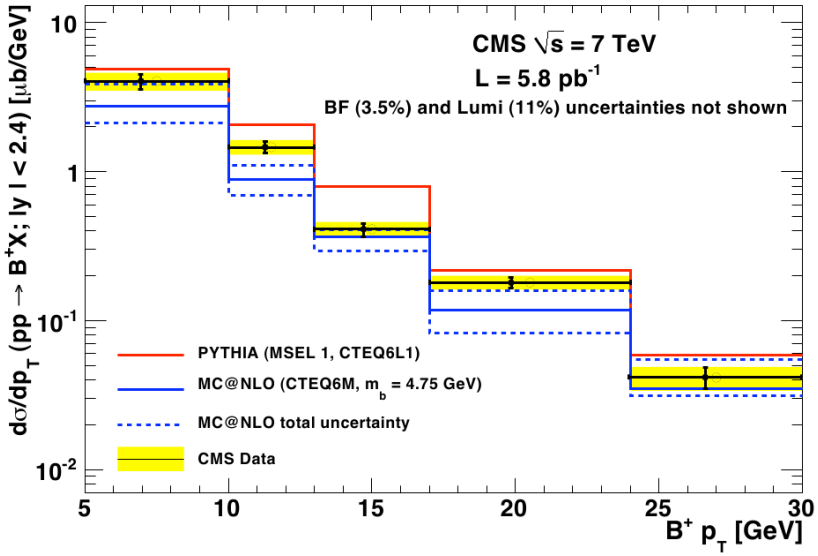


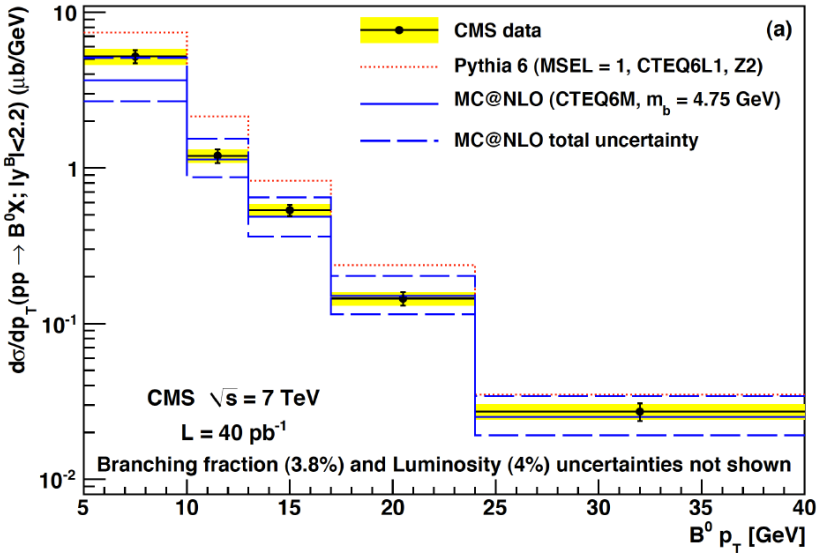
- Ratio calculated as

$$\frac{N(\bar{\Lambda}_b)}{N(\Lambda_b)} = \frac{\sigma(\bar{\Lambda}_b)}{\sigma(\Lambda_b)}$$

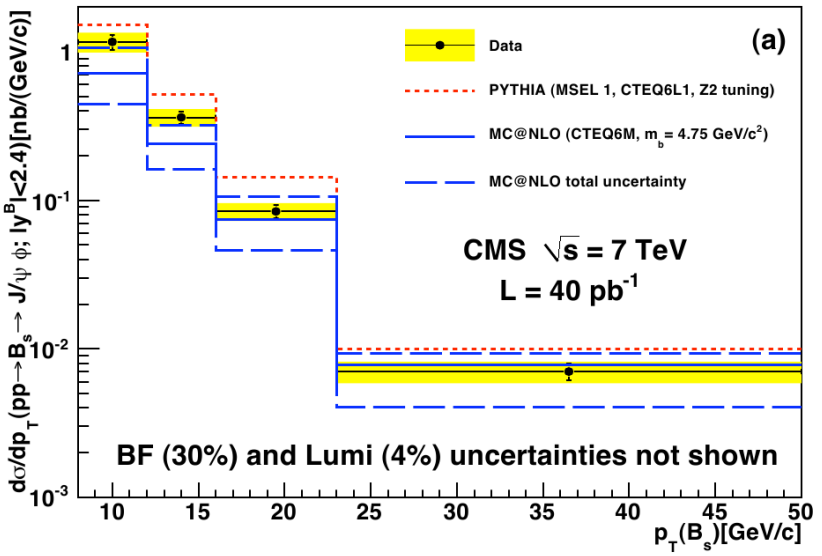
- Constant vs. p_T and $|y|$
- Consistent with 1

Cross section measurements with exclusive B decays

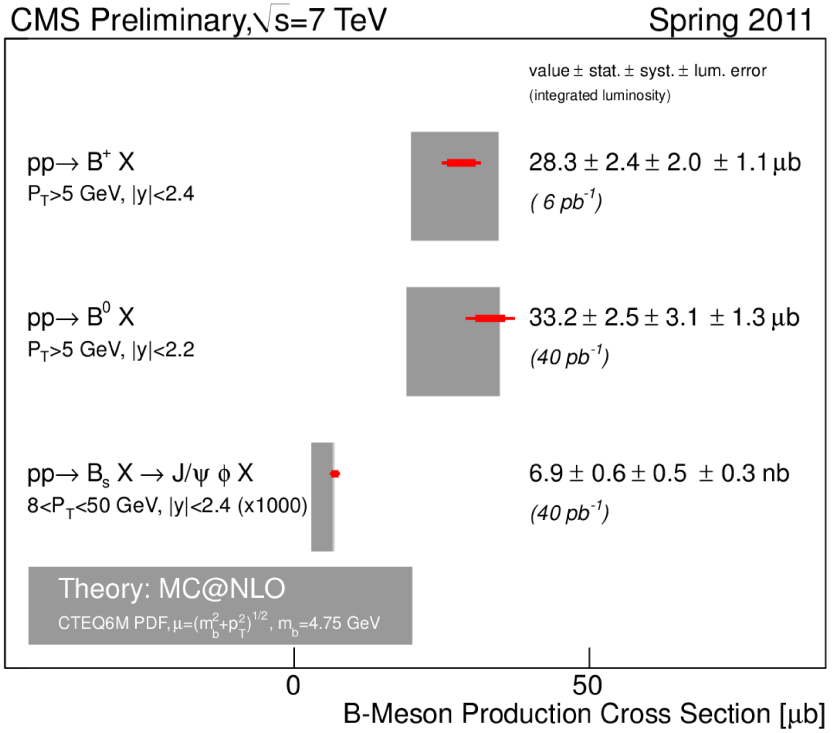


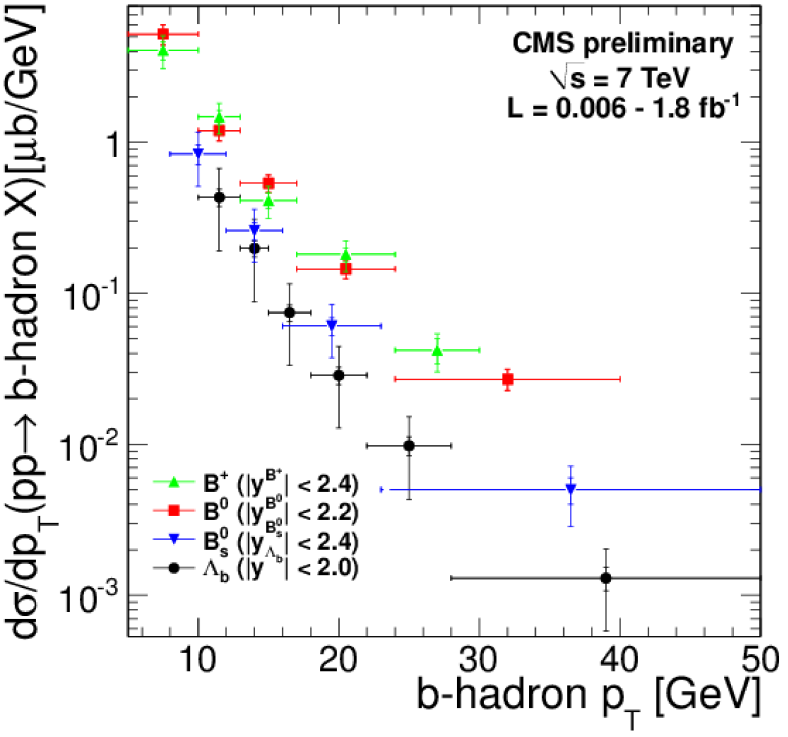


- Several results on b ⟶ J/ψ + X processes (with J/ψ ⟶ $\mu^+\mu^-$)
- $B^+ \longrightarrow J/\psi\, K^+$ **PRL 106, 112001 (2011)**
- $B^0 \longrightarrow J/\psi\, K_S$ **PRL 106, 252001 (2011)**
- $B_S \longrightarrow J/\psi\, \phi$ **PRD 84, 052008 (2011)**



Summary of b → J/ψ + X exclusive results

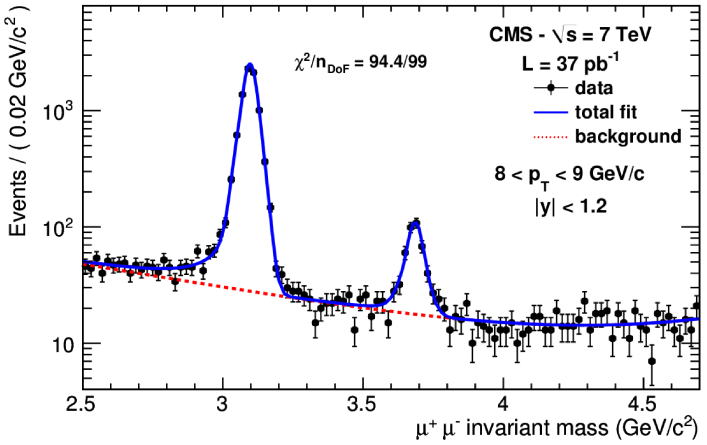


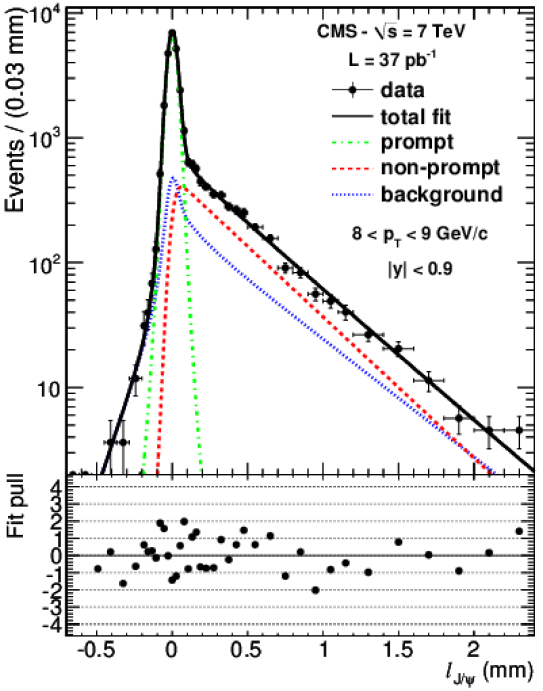


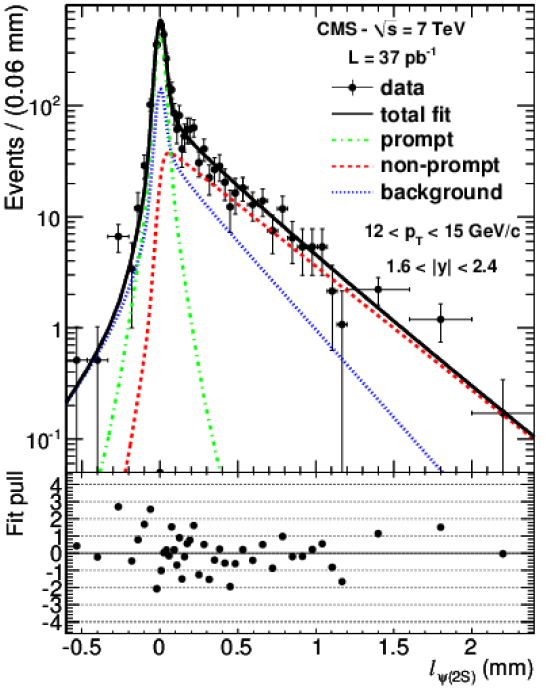
- Integrated cross sections for B mesons decaying into J/ψ+X
- Values compatible with the NLO predictions within uncertainties
- Summary of all four CMS b-hadron cross section measurements vs. p_T
- Λ_b cross section falls faster than B^+ and B^0

Measurement of J/ψ and ψ(2s) production

JHEP02 (2012) 011







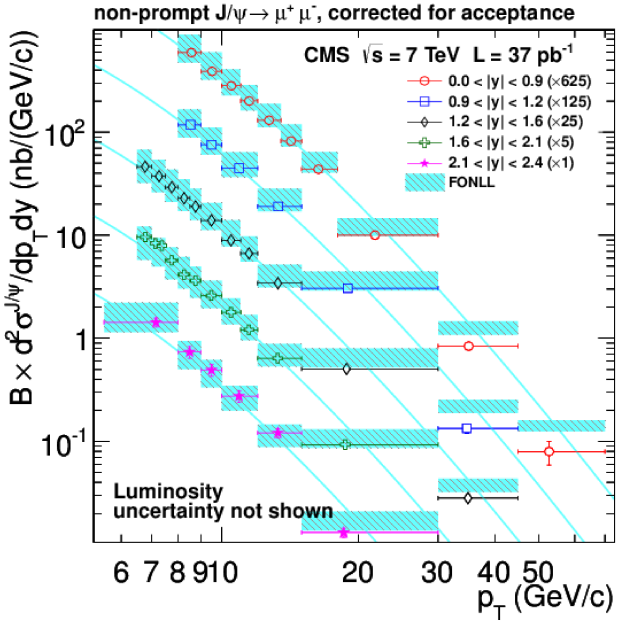
- J/ψ and ψ(2s) reconstructed in the $\mu^+\mu^-$ decay channel

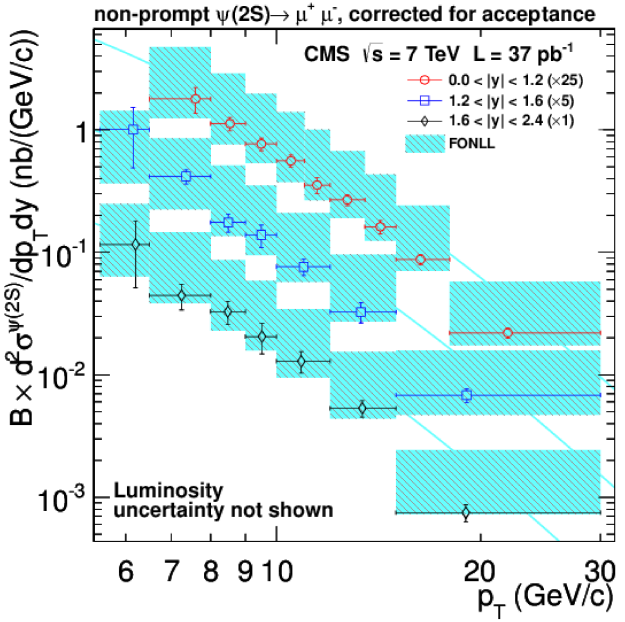
Projections of the 2D fit to $\ell_{J/\psi}$ and $\ell_{\psi(2s)}$

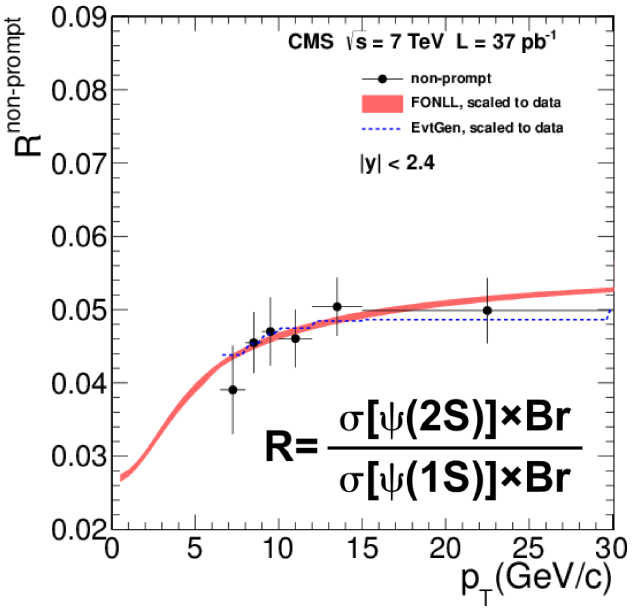
- Prompt and non-prompt fractions of J/ψ and ψ(2s) estimated with a 2D fit to the di-μ invariant mass and $\ell_{J/\psi}$ or $\ell_{\psi(2s)}$(the Lorentz-corrected transverse distance between the μμ vertex and the primary vertex)

Non-prompt J/ψ and ψ(2s)

JHEP02 (2012) 011







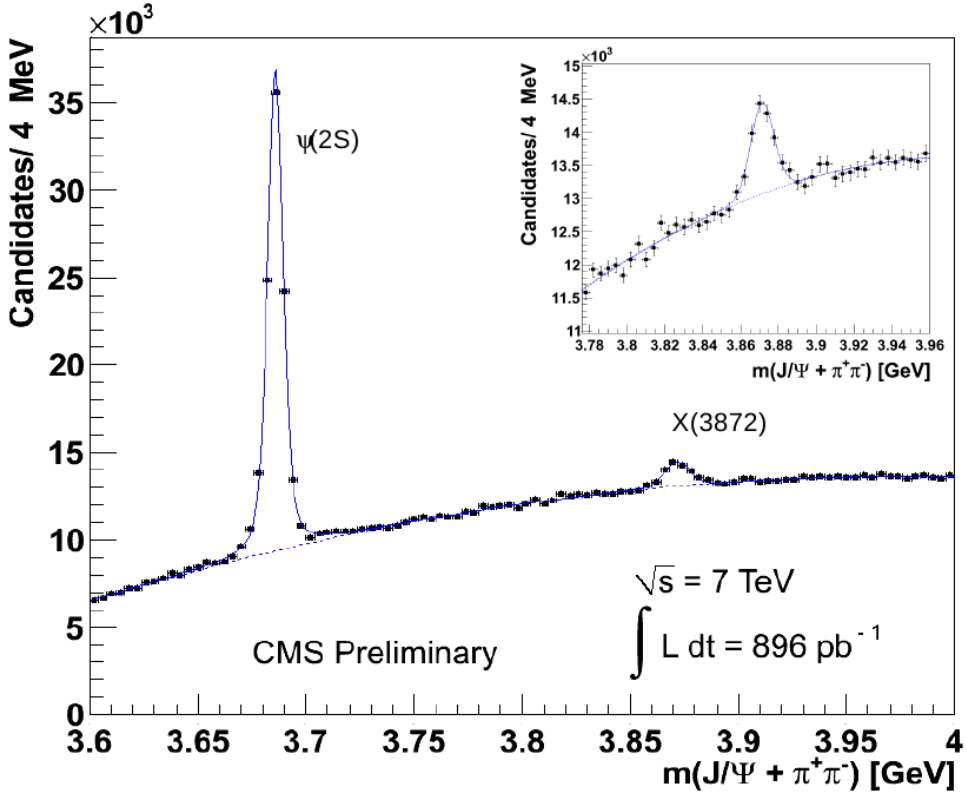
- J/ψ in agreement with FONLL for p_T < 30 GeV, below theory at larger p_T
- ψ(2s) cross section systematically below FONLL expectations
- Extract BR[B ⟶ ψ(2s) + X] from non-prompt cross-section ratio

$BR[B \to \psi(2s) + X] = (3.08 \pm 0.12\ (stat\text{-}syst) \pm 0.13\ (theor) \pm 0.42\ (BR_{PDG})) \cdot 10^{-3}$

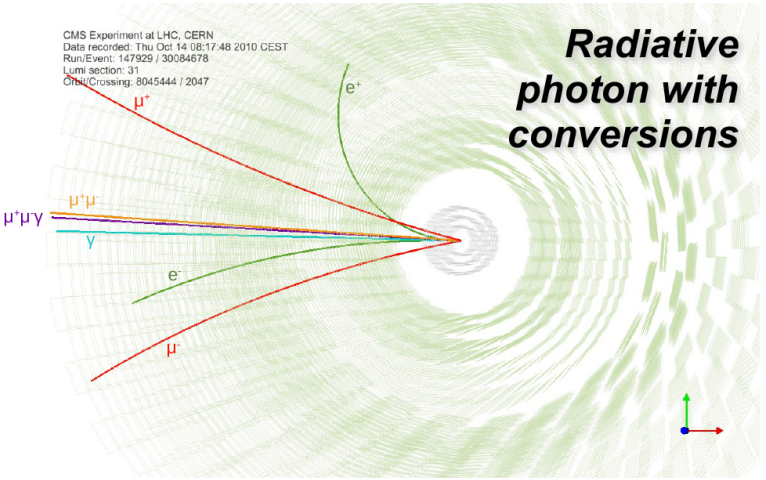
3 times more accurate than previous world average!

X(3872) and $\chi_{c1,2}$

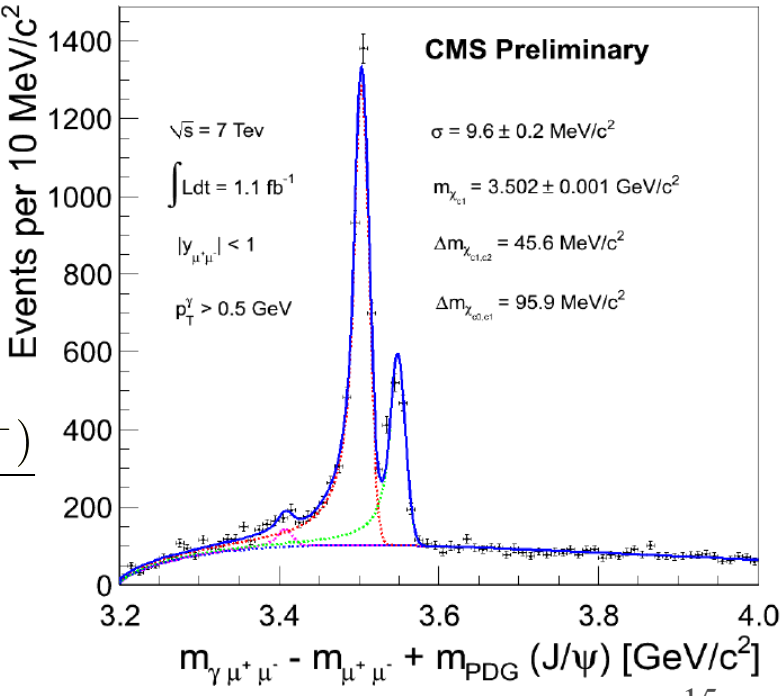
CMS-PAS-BPH-10-018
CERN-CMS-DP-2011-009



CERN-CMS-DP-2011-011



J/ψ + γ mass distribution



$$R = \frac{\sigma(pp \to X(3872) + \text{anything}) \times BR(X(3872) \to J/\psi\pi^+\pi^-)}{\sigma(pp \to \psi(2S) + \text{anything}) \times BR(\psi(2S) \to J/\psi\pi^+\pi^-)}$$

$$R = 0.087 \pm 0.017(stat.) \pm 0.009(syst.)$$

Conclusions and outlook

- The CMS experiment is delivering many important flavor physics measurements
- Differential cross sections for inclusive b production with jets and muons in jets
- Accurate (~10%) measurement of the total correlated $b\bar{b}$ production with di-muons
- New results on Λ_b complementing the cross-section measurements in fully exclusive B hadron decays
  - Λ_b cross section vs. p_T falling faster than the B-meson ones and the shape is not described by Pythia
- Study of prompt and non-prompt J/ψ and ψ(2s) production, with the most accurate measurement of BR[B $\longrightarrow$ ψ(2s) + X] produced so far
  - Other charmonium studies progressing
- Several results published, others in the pipeline, exploiting the larger data samples available with 2011/2012 LHC runs
  - Rare decays (seminar at CERN with new $B_s(B^0)\longrightarrow\mu\mu$ results yesterday!)
- CMS has shown to be competitive in Heavy Flavor physics and will continue to deliver high-quality results also in 2012!