Primi risultati di fisica dei sapori pesanti a CMS

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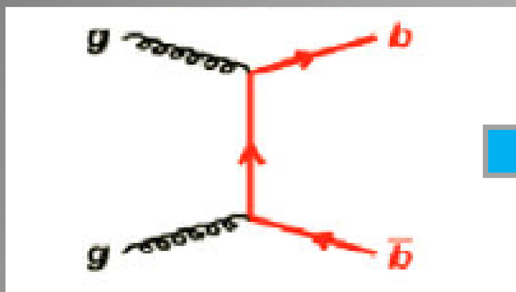
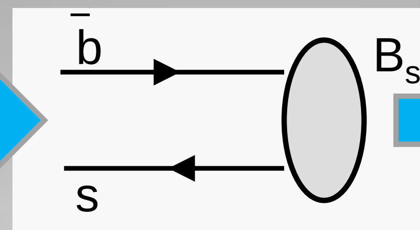
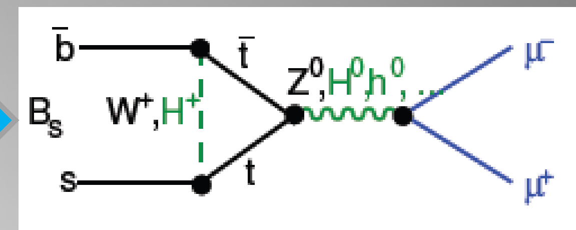
IFAE 2011 – Perugia, 27/04/2011

Heavy flavors at *pp* colliders







Production

- Tests of perturbative QCD
  - Heavy flavor production theories at NLO with logarithm resummation (FONLL)

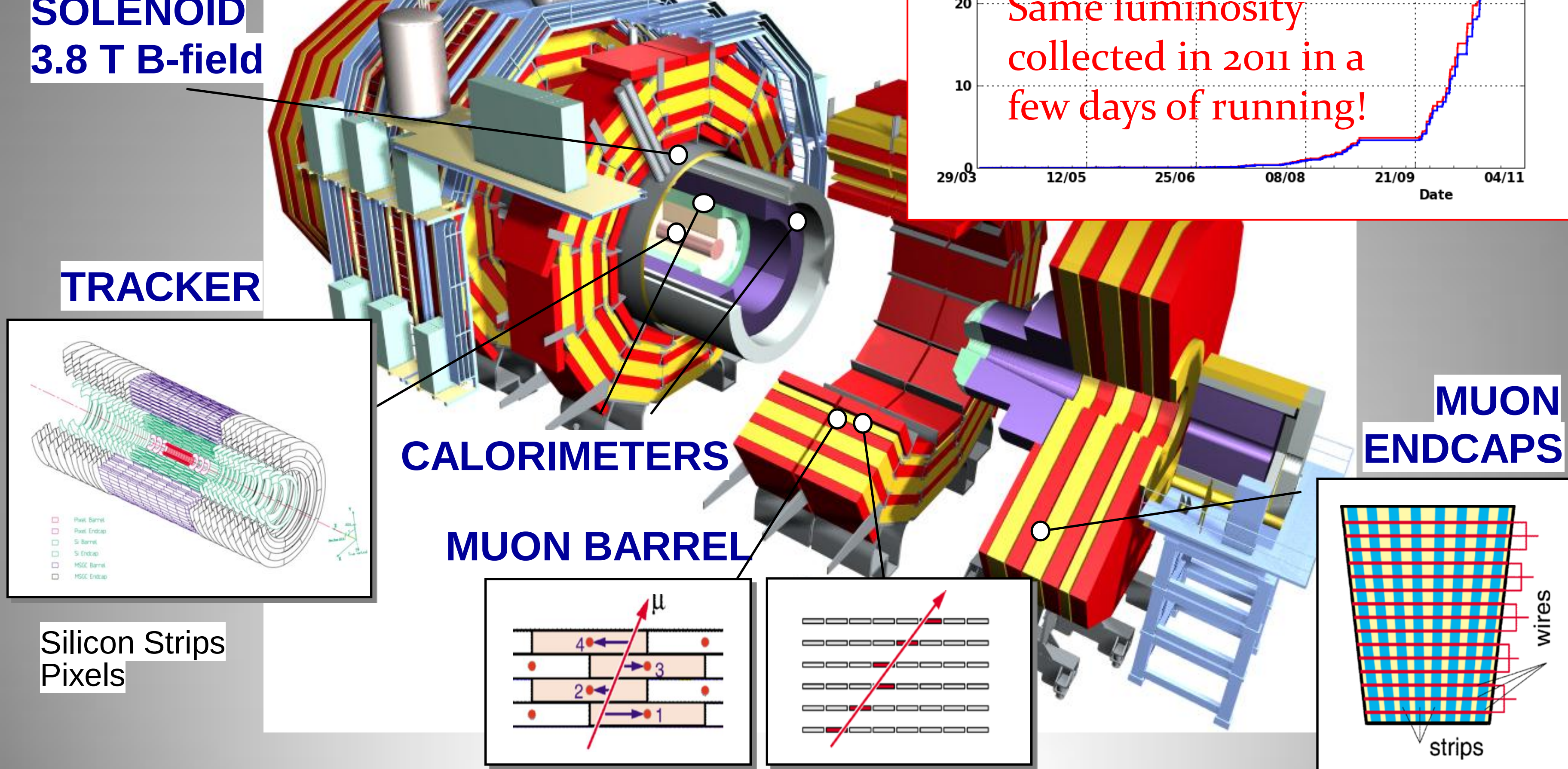
Hadronization

- Fragmentation functions
- In the case of $c\bar{c}$ or bb states (low relative velocity of the bound quarks), test NRQCD approaches

Decay

- Find indirect hints of NP in rare weak decays, e.g.:
  - Non-SM CP violation in $B_s \to J/\psi\phi$
  - Probe MSSM and other 2HD models with $BR(B_s \to \mu\mu)$

The CMS detector

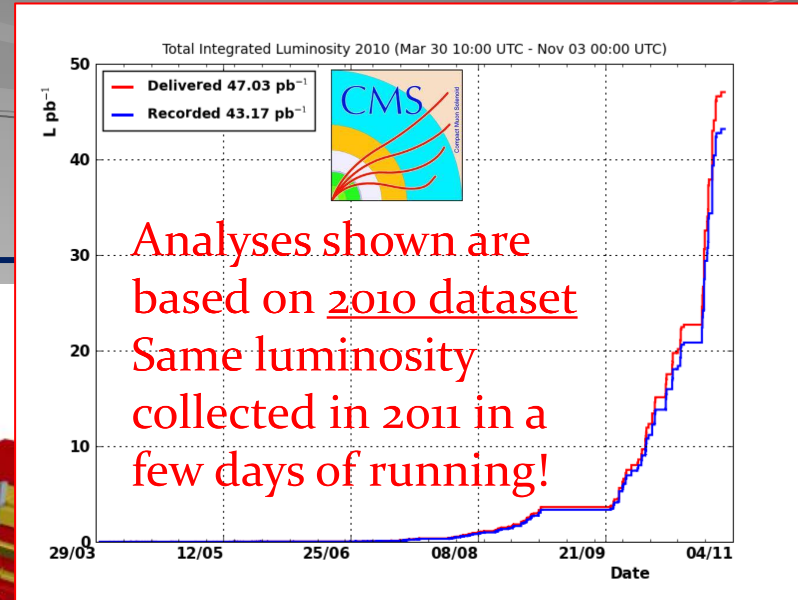


Silicon Strips
Pixels

Drift Tubes (**DT**)

Resistive Plate Chambers (**RPC**)

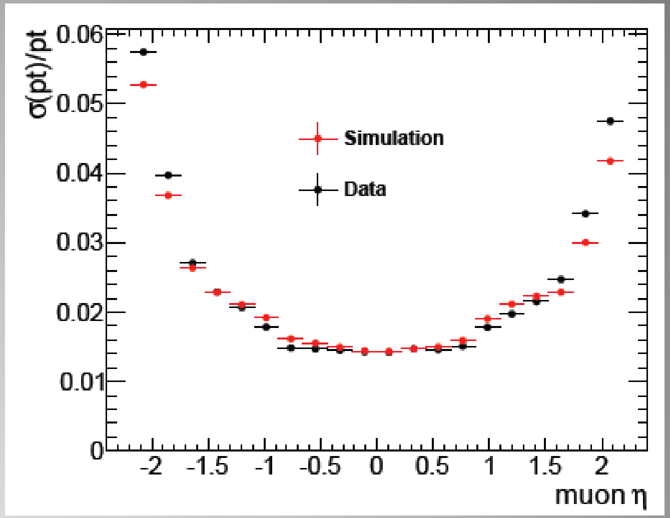
Cathode Strip Chambers (**CSC**)
Resistive Plate Chambers (**RPC**)



Analyses shown are based on <u>2010 dataset</u>
Same luminosity collected in 2011 in a few days of running!

Muon reconstruction and triggers

- Large rapidity coverage:
  - $|\eta| < 2.4$
- Excellent muon momentum resolution down to very low p_T:
  - matching between μ-chambers and in silicon tracker (only using the latter for momentum determination at low p_T)
  - strong solenoidal magnetic field (3.8 T)

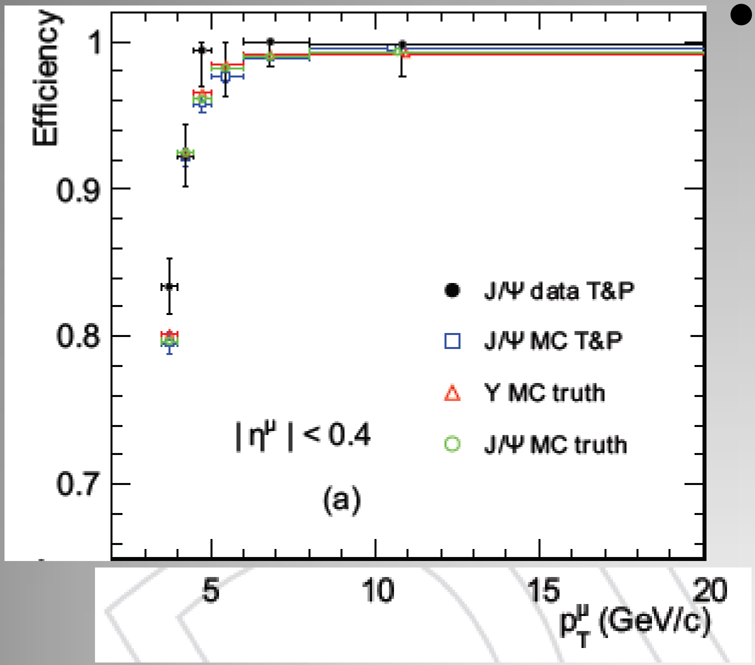


- Triggers could be tuned to the rapidly increasing luminosity, thanks to the great versatility of the High-Level Trigger
  - Single muon triggers
  - Double muon triggers at Level-1 only
  - *Ad-hoc* intermediate solutions:
    - after a single muon is triggered, look for another track and check compatibility with a defined invariant mass region (e.g. J/ψ, Υ's)
    - use single muon at HLT, but with a double muon Level-1 "seed"
  - Double muon HLT with additional requirements

10^{29}-10^{30} $cm^{-2}s^{-1}$

10^{32}-10^{33} $cm^{-2}s^{-1}$

Muon efficiency measurements



- All heavy flavor analyses use data-driven measurements of the muon efficiency ("tag-and-probe" method)
  - In events with a J/ψ candidate, ask for one well-identified muon ("tag")
  - The other muon ("probe") can pass or not pass the selection *S* under investigation
  - Invariant mass plots separate for the two cases
  - The fitted $N_{pass\text{-}S}/N_{all}$ gives an unbiased estimate of the efficiency ε_S
- Limitations of the method:
  - Assumes efficiency factorization: does not take into account physical correlations
  - Requires averaging over large bins due to limited statistics: distortion of di-muon efficiencies

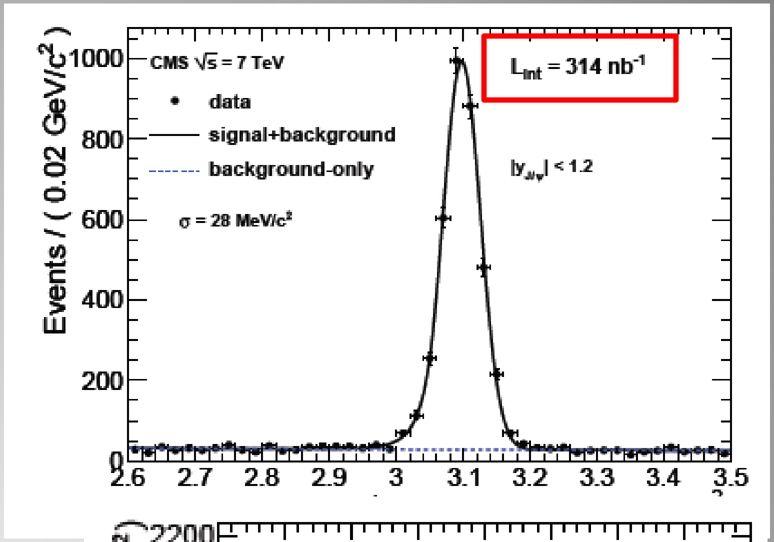
MC corrections required

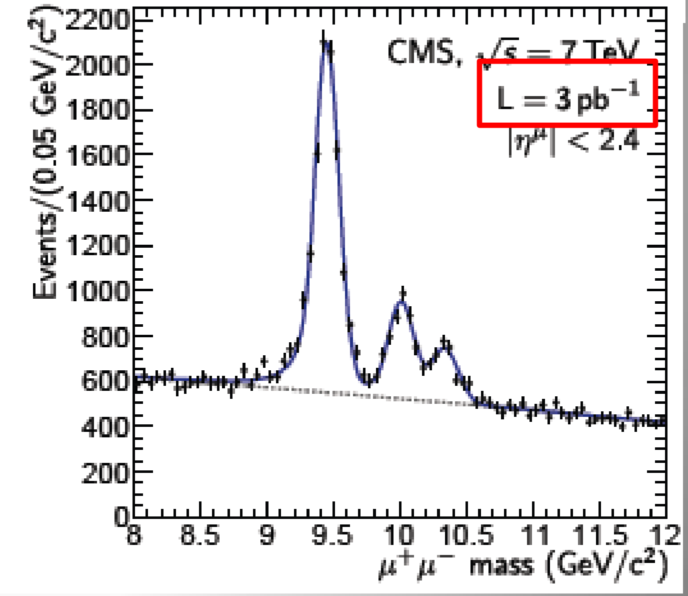
CMS heavy-flavor results

- Published or accepted in journals:
  - Prompt and non-prompt J/ψ differential cross-section
  - Y cross-section and σ[Y(2S)] + σ[Y(3s)] / σ[Y(1S)] ratio
  - Production cross-section of $B^{\pm}$ and B^{0} mesons
  - Inclusive b-hadron production with muons
  - $b\bar{b}$ angular correlation based on secondary vertex reconstruction
- Preliminary:
  - X(3872) / ψ(2S) cross-section ratio
  - Production cross-section of B_s mesons
  - Inclusive $b\bar{b}$ production with b-tagged jets
- Other studies ongoing:
  - J/ψ polarization, χ_{cJ} production, $\Lambda_b \rightarrow J/\psi\ \Lambda$ … and many more

J/ψ and Υ cross-sections

- Double L1-trigger stream
- Signal selection based on:
  - Global muon quality
  - Muon track quality (χ^2, n_{hits}...)
  - Di-muon vertexing probability
  - Muon p_T (for Υ only)
- Acceptance is determined using simulation in five benchmark polarization scenarios
- Muon efficiencies from tag-and-probe method
- Yields from invariant mass fits

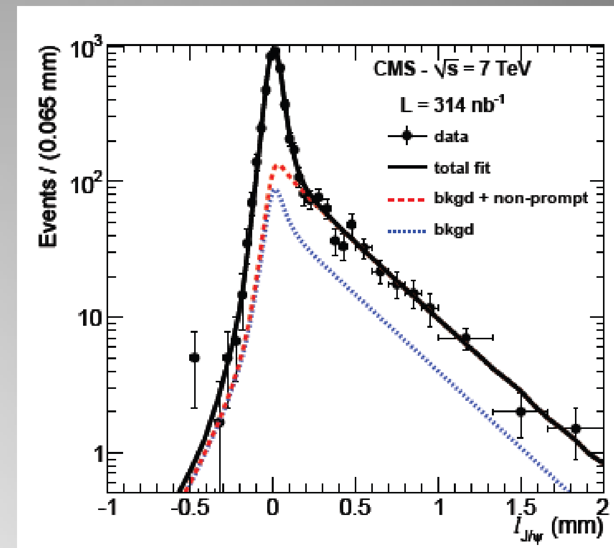




arXiv : 1011.4193, accepted by EPJC
arXiv : 1012.5545, accepted by PRD

Prompt / non-prompt J/ψ

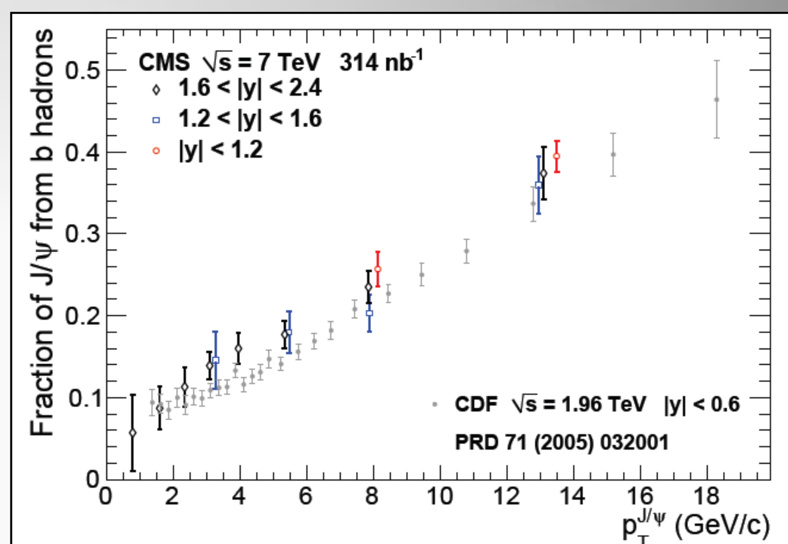
- In the case of J/ψ, 2-dimensional fit to invariant mass and proper decay time of the dimuon yields the fraction of J/ψ from B decays
- MPV of proper decay time is given by $l_{J/\psi} = L_{xy}\, m_{J/\psi} / p_T$, where



$$L_{xy} = \frac{\mathbf{u}^T \sigma^{-1} \mathbf{x}}{\mathbf{u}^T \sigma^{-1} \mathbf{u}}$$

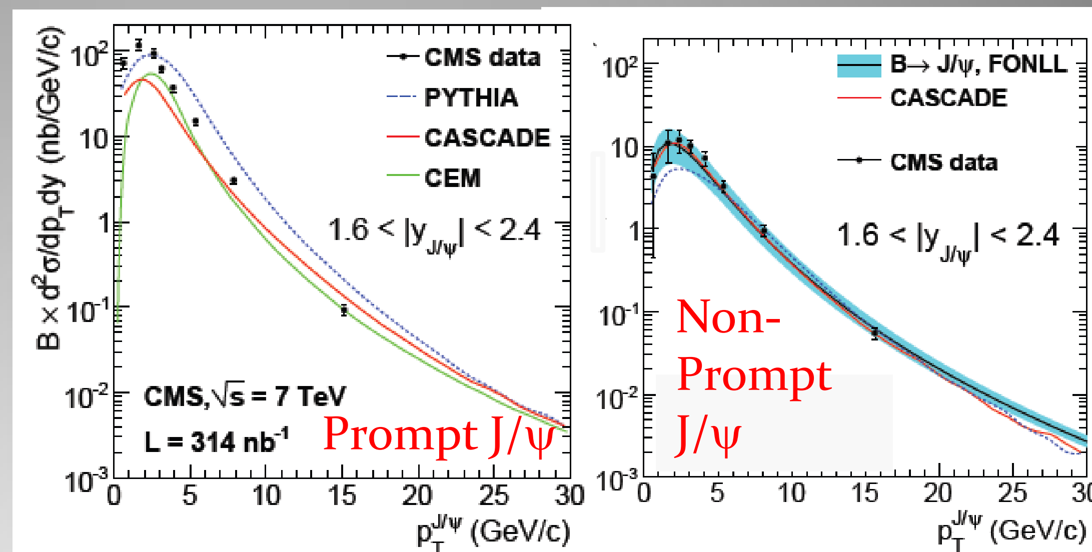
u = unit vector of $\mathbf{p_T}$
x = vector joining the dimuon and primary vertices
σ = sum of covariance matrices

- Main systematics from:
  - Misalignment
  - Primary vertex uncertainties
  - $l_{J/\psi}$ resolution function

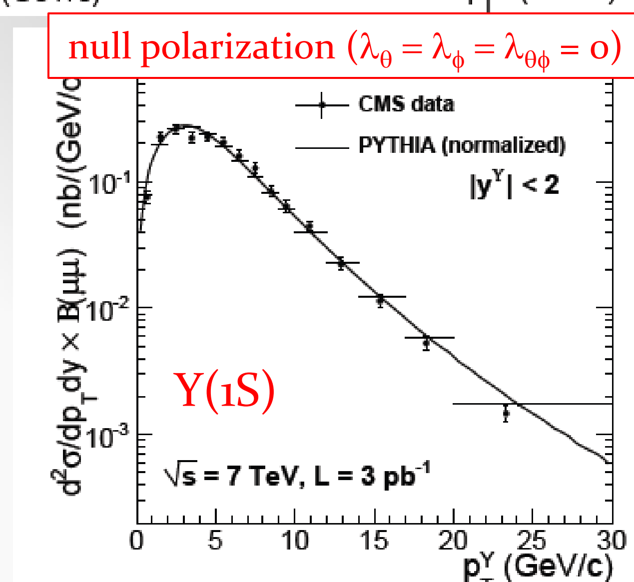


J/ψ and Υ cross-section results

- $B \rightarrow J/\psi$
  - Very good agreement with FONLL theory down to low p_T

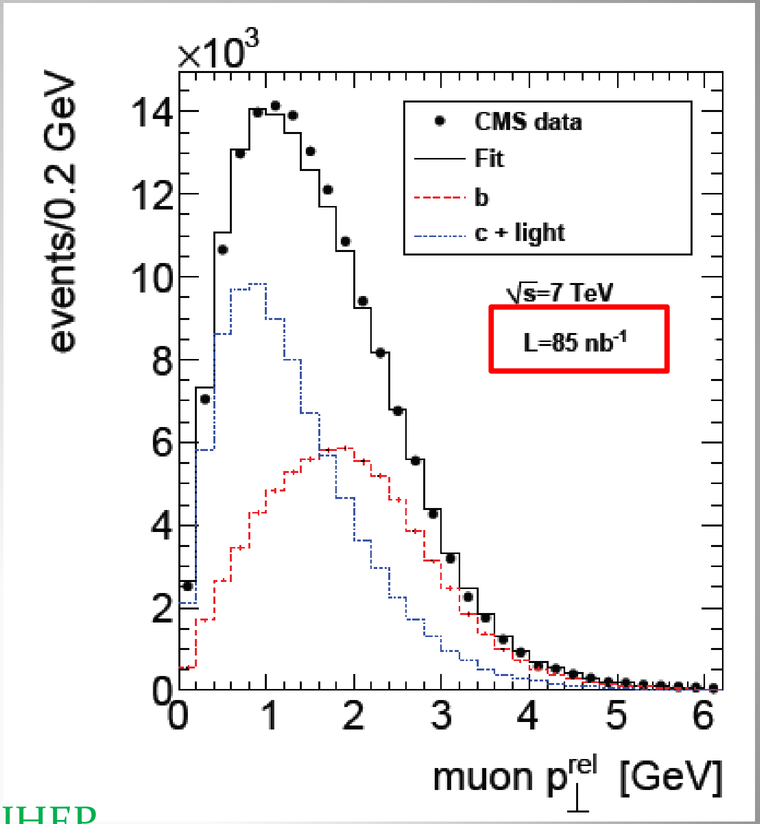


- Prompt quarkonia
  - Pythia (Leading Order / Color Singlet + Color Octet model) gives reasonable agreement in shape, not in normalization → waiting for exact calculation including χ_c, $\psi(2S) \rightarrow J/\psi$
  - All models (including k_T factorization, Color Evaporation) underestimate J/ψ cross-section at low p_T



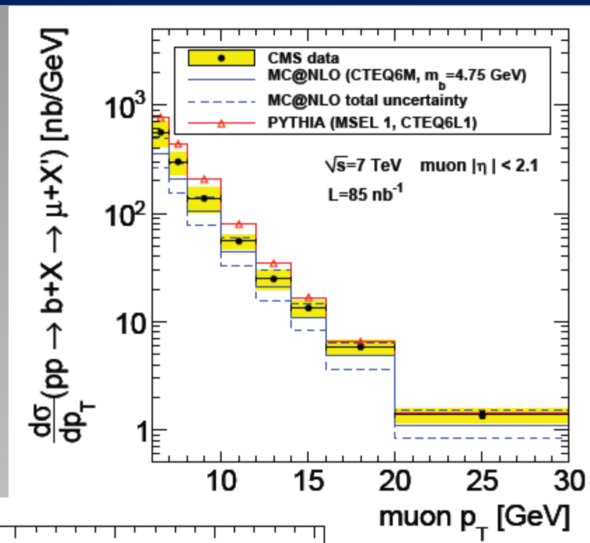
Inclusive $b \rightarrow \mu$

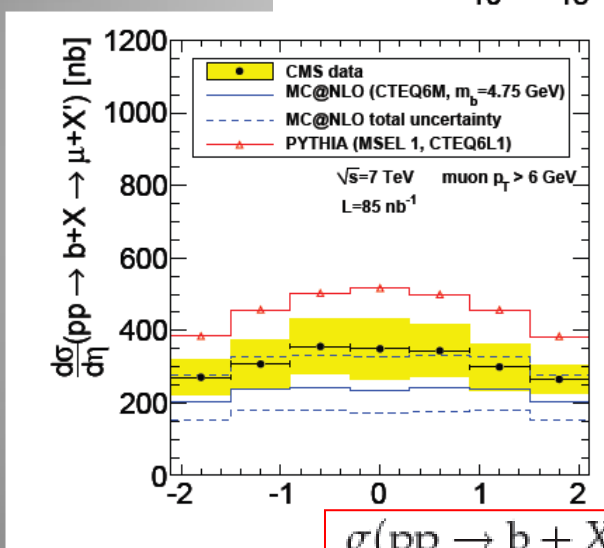
- Technique: after selecting a muon + jet signature, discriminate *b* from light jets using the relative transverse momentum of the muon w.r.t. the jet thrust axis
- Selection:
  - HLT muon with $p_T > 3$ GeV/c
  - Offline $p_T > 6$ GeV/c and muon quality cuts from $W \rightarrow \mu\nu$ selection (except isolation)
  - E_T(jet) (excluding muon) > 1 GeV
- From MC simulation:
  - Template functions for light and *b* jets
  - Muon acceptance



arXiv : 1101.3512, accepted by JHEP

Inclusive $b \rightarrow \mu$: results





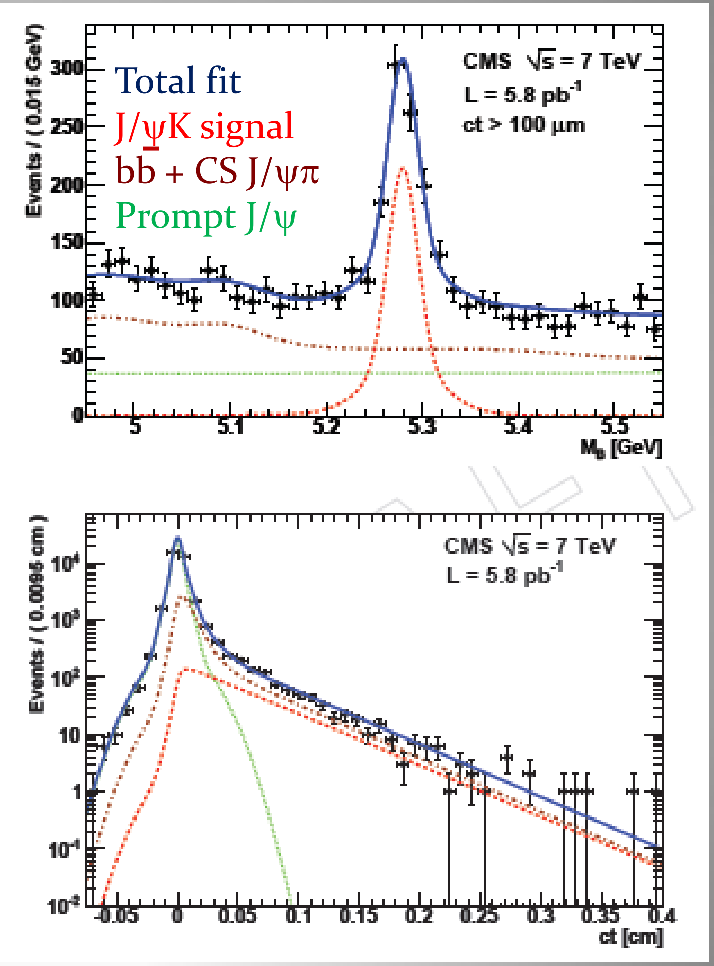
- Differential cross-sections in p_T or rapidity
- Main systematics:
  - *b* and light jets MC templates (2-20%)
  - Luminosity (11%)
- Reasonable agreement with MC@NLO within uncertainties
- Pythia failing both in shape and normalization (predicted cross-section almost double than measured)

$$\sigma(\mathrm{pp} \rightarrow \mathrm{b} + X \rightarrow \mu + X') = 1.32 \pm 0.01(\mathrm{stat}) \pm 0.30(\mathrm{syst}) \pm 0.15(\mathrm{lumi})\,\mu\mathrm{b},$$

$$p_{\mathrm{T}}^{\mu} > 6\,\mathrm{GeV}, |\eta^{\mu}| < 2.1$$

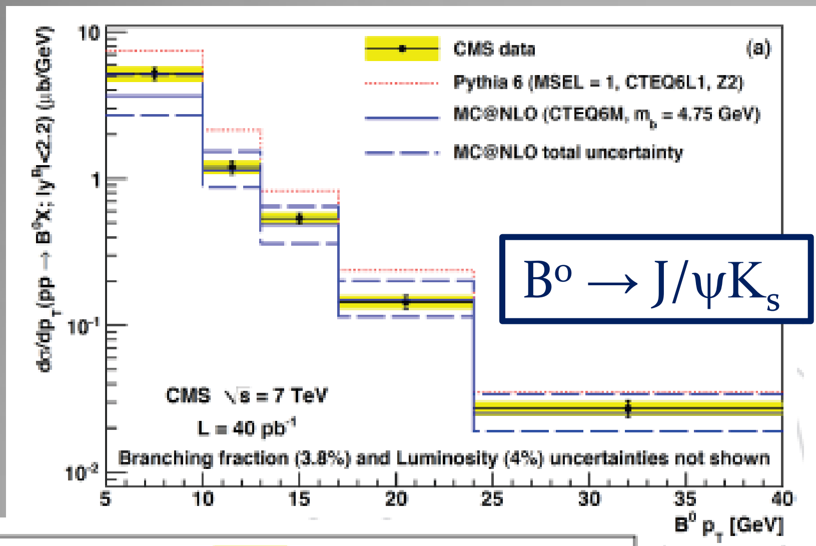
B-meson cross-sections

- Using exclusive decays $B^{\pm} \to J/\psi K^{\pm}$, $B^{o} \to J/\psi K_s$, $B_s \to J/\psi \phi$
- J/ψ selection as in previous studies
- Track selection with quality criteria plus:
  - $K^{\pm}$: $p_T > 0.9$ GeV/c
  - K_s : two tracks with V^o ($l_{xy} / \sigma_{lxy} > 5$) and invariant mass requirements
  - ϕ: two tracks with invariant mass requirements
- Secondary vertex fitting with all tracks and muons and $P(\chi^2)$ cut
- Additional signal-background discrimination from proper decay time

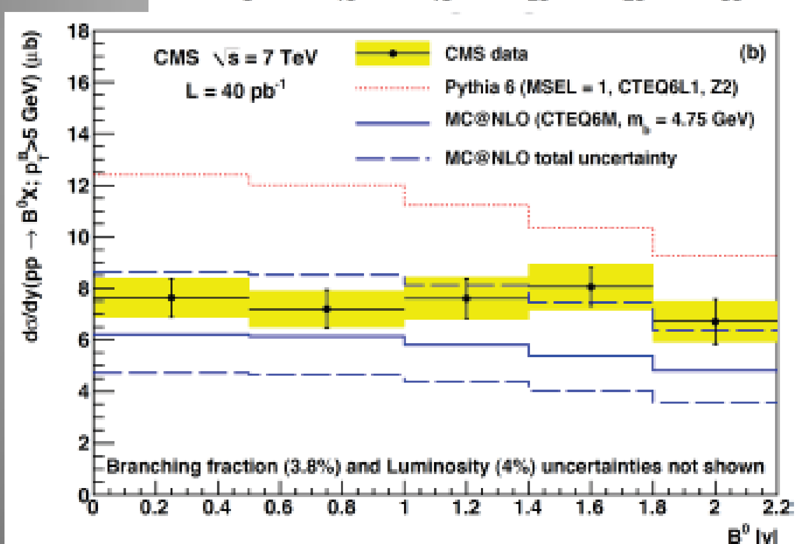


arXiv : 1101.0131, PRL 106, 112001 (2011)
arXiv : 1104.2892, accepted by PRL
PAPER-BPH-10-013, in progress

B-meson results



$B^0 \rightarrow J/\psi K_s$

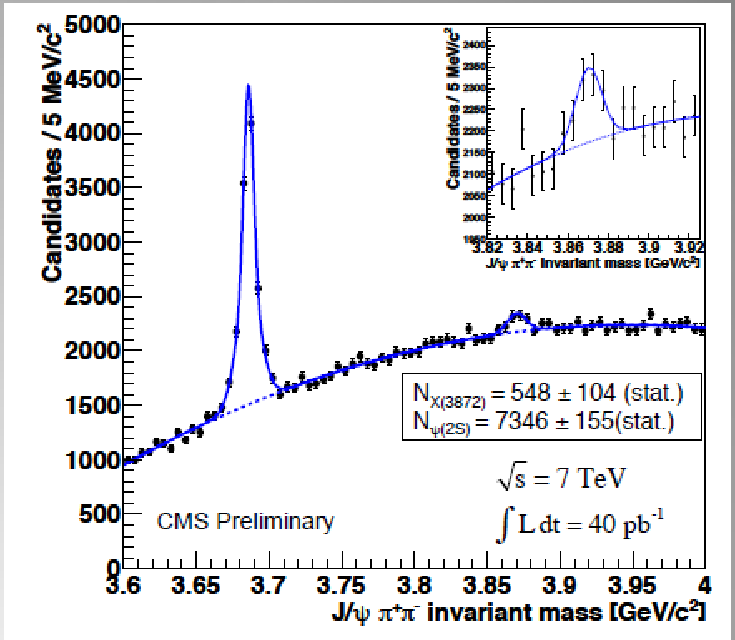


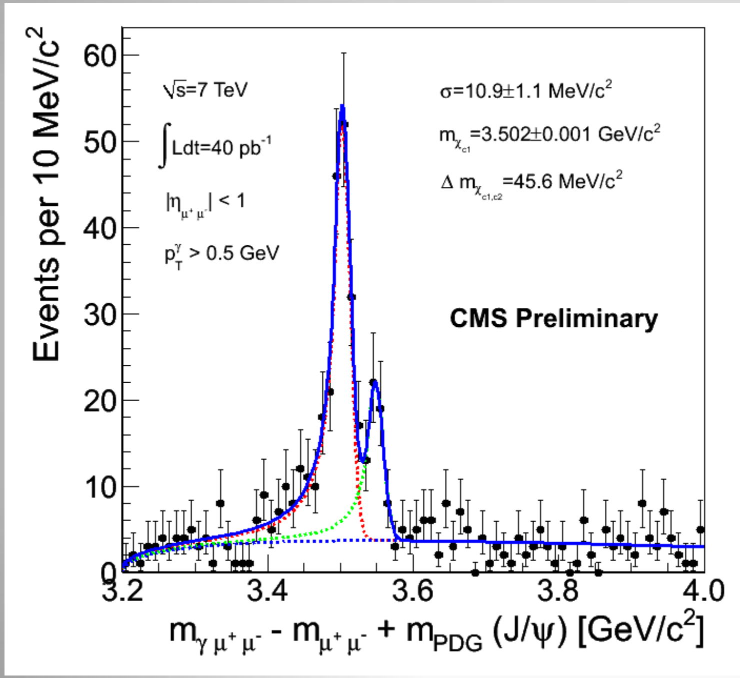
- Differential cross-sections in p_T or rapidity
- Main systematics:
  - Pion/kaon tracking efficiency uncertainty (~4% per track from $D^0 \rightarrow K3\pi$/ $D^0 \rightarrow K\pi$ yield ratio)
  - Luminosity (4%)
- Inclusive results confirmed:
  - Quite good agreement with MC@NLO
  - Pythia failing both in shape and normalization (here with tune "Z2", i.e. improved MPI description)

Brand new stuff…

- Presented by CMS at the Vienna quarkonium workshop last week
  - First measurement of the X(3872) / ψ' [cross-section x BR] ratio at 7 TeV

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





- Separation of χ_{c1} / χ_{c2} states using the J/ψ γ (γ → e^+e^-) final state using a novel tracker-based method to reconstruct very low energy conversions

Conclusion and prospects

- Several production cross-section and related measurements in the field of heavy-flavor physics have already been released by CMS on the 2010 dataset (≤ 40 pb^{-1}), in a large phase space that complements LHCb measurements
  - proving detector excellence in trigger capabilities, tracking and muon reconstruction
  - discriminating between QCD models (both in perturbative and NR regimes) and their implementation in MC generators
- Next steps are high-statistics measurements, including:
    - Quarkonium polarization
    - Neutral-B (B^0, B_s) CP violation and rare decays
  - Keeping up the pace with LHCb results is a challenge
    - Low p_T reach not competitive, but no luminosity leveling in CMS
    - Smart triggering techniques are the essential ingredient