LHCb results from the p-A run

LHCP Barcelona, May 13-18, 2013

Burkhard Schmidt for the LHCb collaboration

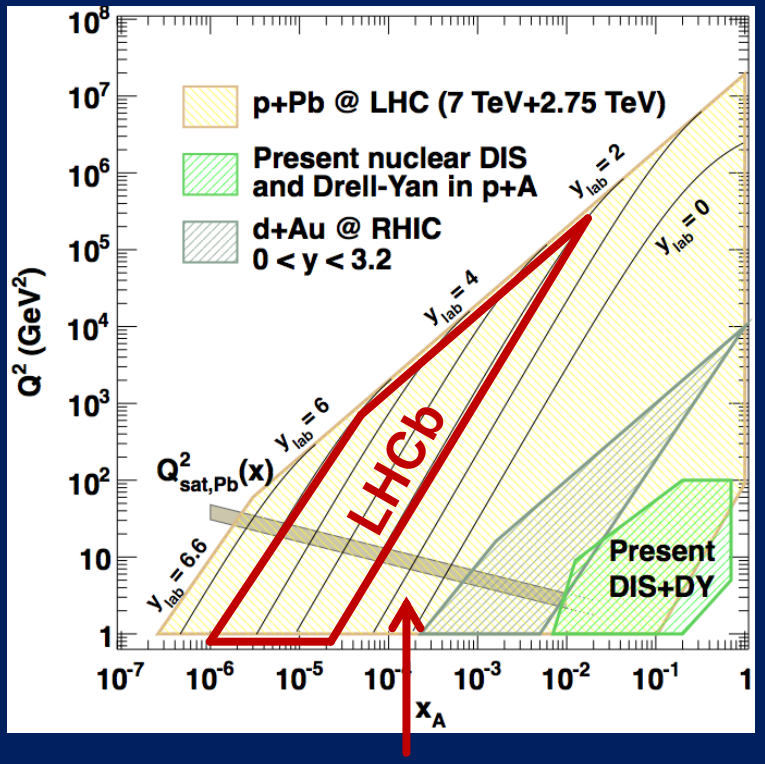
Outline:

- Introduction to p-A physics with LHCb
- Measurement of the J/ψ production cross-section and of the nuclear attenuation factor
- Comparison with theoretical models
- Prospects and conclusions

Physics Motivation

- **Study of p-A collisions is important for HI physics**
  - provides essential input to the under-standing of nucleus-nucleus collisions, e.g. disentangle QGP effects from Cold Nuclear Matter (CNM) effects.
  - provides insight into a yet unexplored region of QCD

- **The LHCb detector can play a unique role**
  - It can study physics processes involving particles at small angles, which are not accessible by other detectors

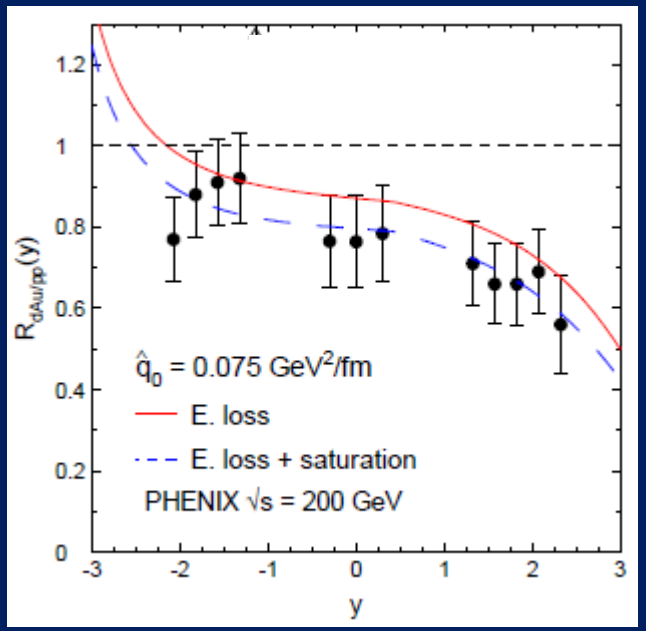


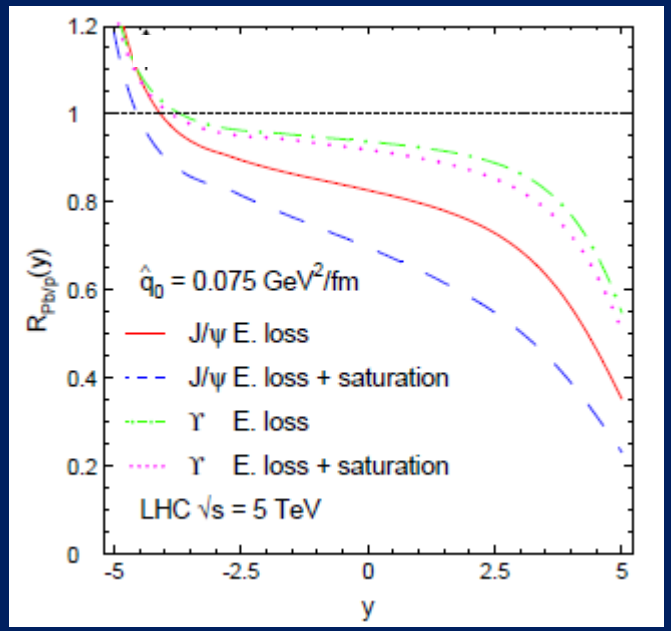
Measurements can constrain PDFs at low x, Q^2 (saturation effects)

Quarkonium production in p-A

- Production of heavy quarkonia at large rapidity strongly suppressed in p-A collisions w.r.t. p-p collisions.
- The nuclear attenuation factor R_{pA} depends strongly on y:

$$R_{pA}(y,\sqrt{s_{\rm NN}}) = \frac{1}{A}\frac{\frac{d\sigma_{pA}}{dy}(y,\sqrt{s_{\rm NN}})}{\frac{d\sigma_{pp}}{dy}(y,\sqrt{s_{\rm NN}})}$$





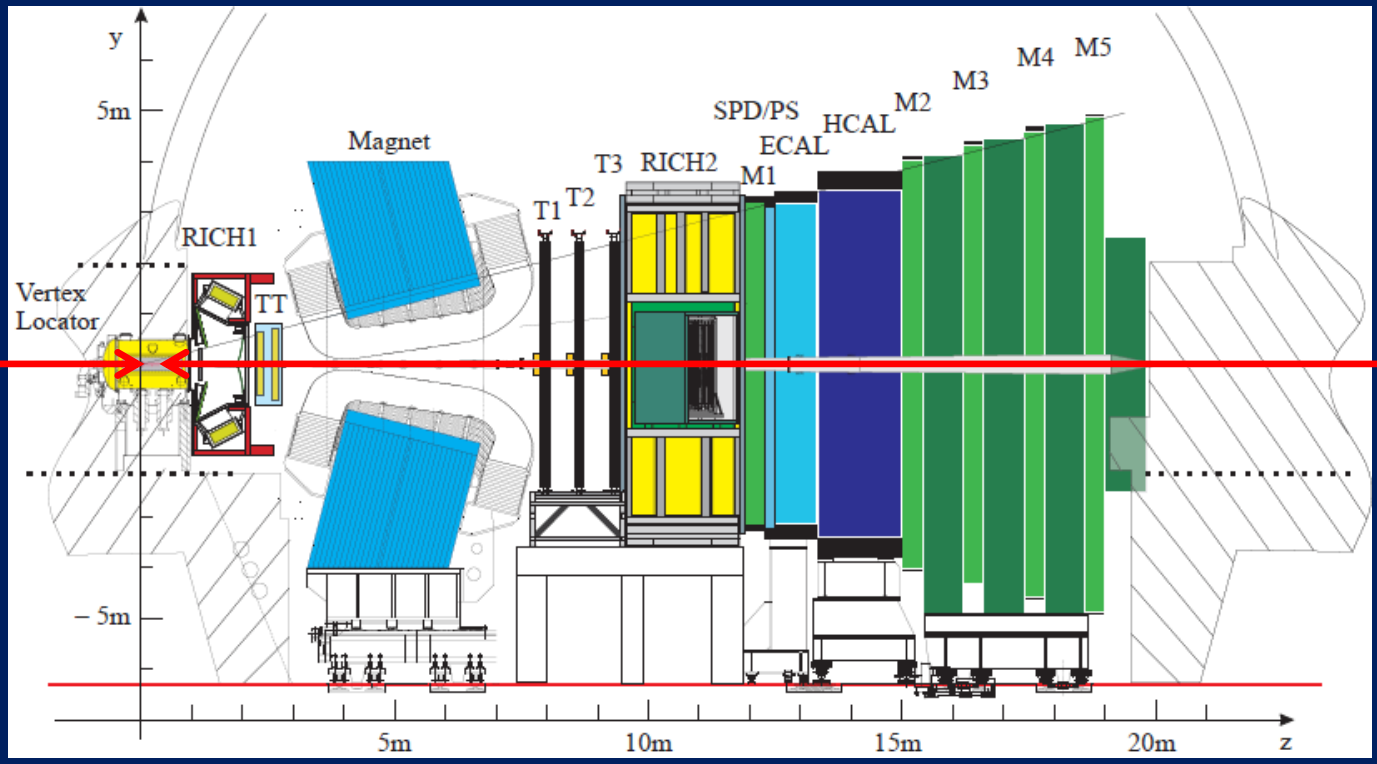
JHEP 1303 (2013) 122
[arXiv:1212.0434]

- Measurement of R_{pA} (y) in J/ψ production tests modeling of cold nuclear effects
- The ratio of the attenuation factors $r_{FB}(y) = R_{pA}(y) / R_{Ap}(-y)$, can be measured

LHCb Detector & beam configurations

pA: p

Ap: Pb



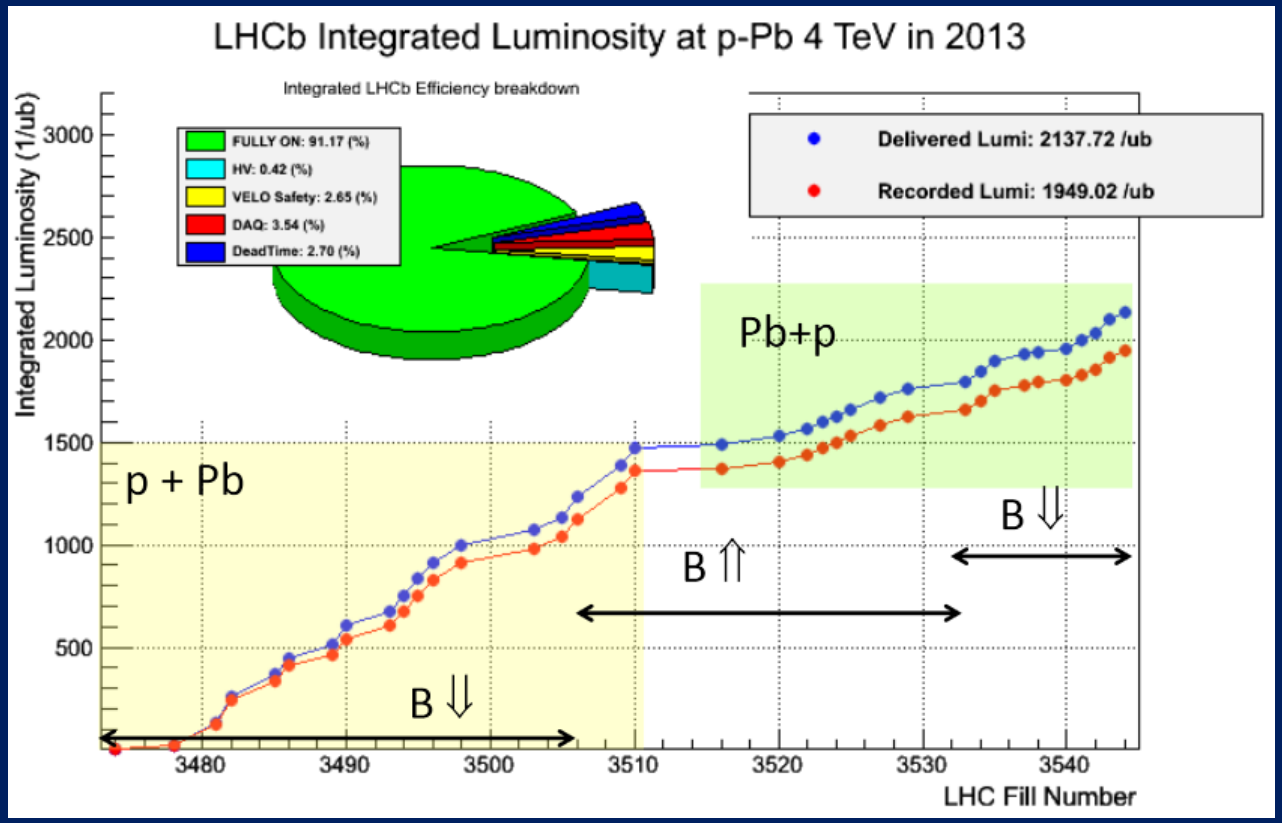
pA: Pb

Ap: p

Beam energy and beam configurations:

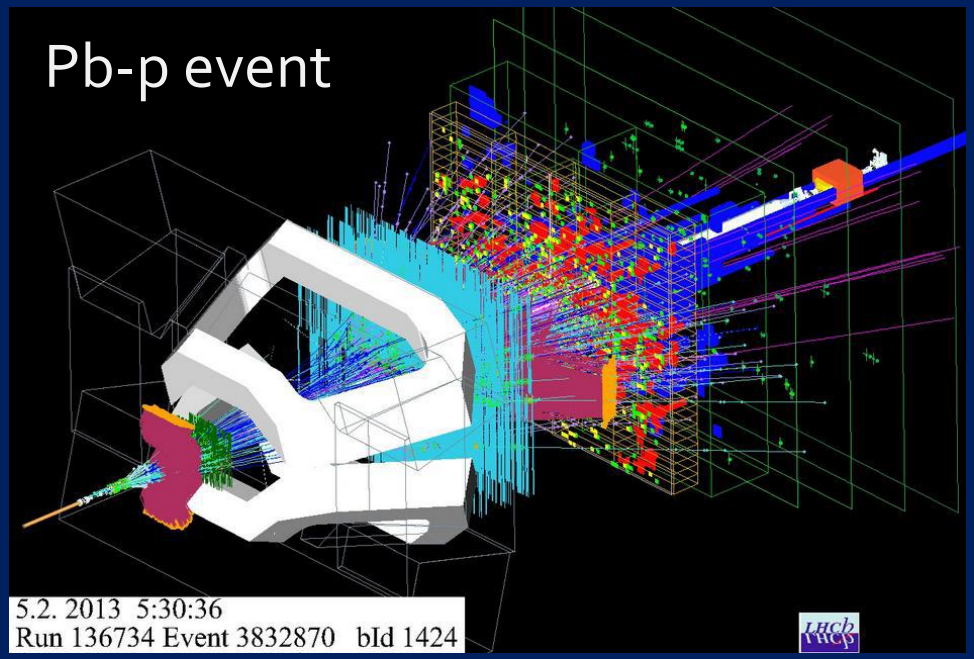
- p: E_p=4TeV , Pb: $E_{p/n}$=1.58TeV → $\sqrt{S_{NN}}$= 5TeV
- rapidity coverage : (in c.m.s)
  - pA: 1.5 < η < 4.5 forward production, y > 0
  - Ap: -5.5 < η < -2.5 backward production, y < 0
  - pp: 2 < η < 5

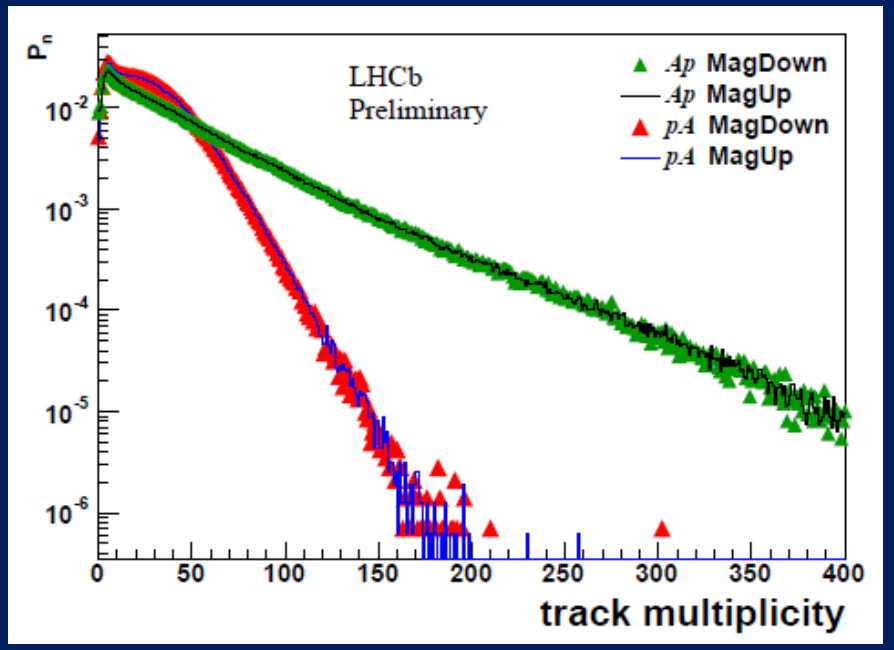
proton - lead run 2013



- Integrated luminosity : ~2/nb
- Instant. luminosity ~ 5 x 10^{27} /cm^2/s (very low pile-up)
- Data taking with four different configurations:
  p-Pb / Pb-p ; magnet up (B⇑) / down (B⇓)
- Results shown here are based on 0.75/nb p-Pb and 0.3/nb Pb-p data, B⇓

Event display and event properties





- Magnet up/down agree for both beam configurations
- Higher track multiplicity in Ap, as expected

J/ψ production [LHCb-CONF-2013-008]

- Three main sources for J/ψ :
  - direct production
  - feed down from heavier states $\psi(2S)$, χ_c
  - from b-hadron decays

} prompt J/ψ

J/ψ from b

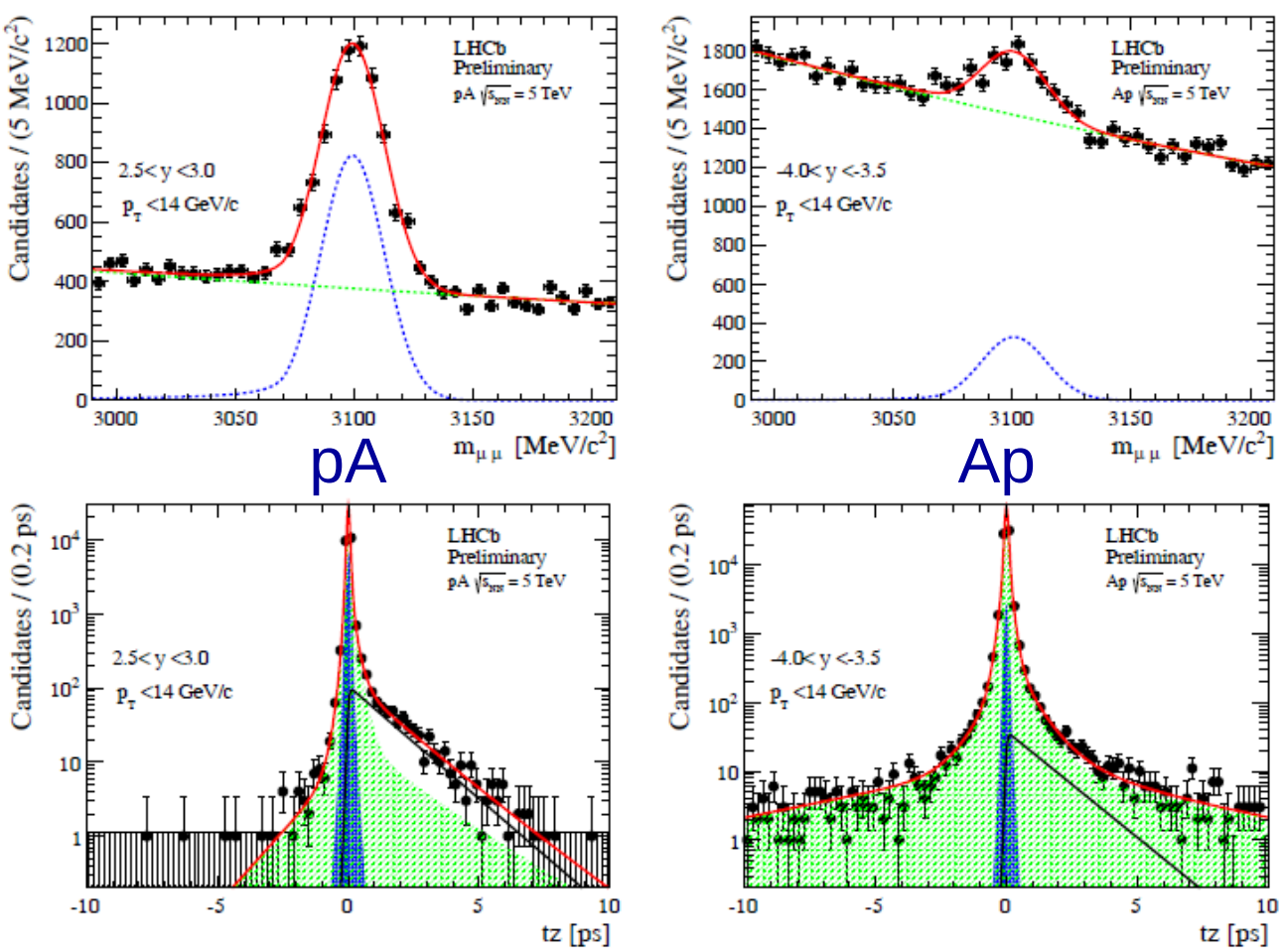
- Analysis strategy:
  - Same method as for J/ψ measurements in previous LHCb studies
  - Measurement of the production cross section both for prompt J/ψ and for J/ψ from b:

$$\sigma = \frac{N(J/\psi \rightarrow \mu^+ + \mu^-)}{L \times \epsilon \times B(J/\psi \rightarrow \mu^+ + \mu^-)}$$

  - Use pseudo-proper time to separate prompt J/ψ and J/ψ from b

J/ψ signal extraction

- Yields of prompt J/ψ and J/ψ from b extracted from simultaneous fit of mass and pseudo-proper time $t_z = \frac{(Z_{J/\psi} - ZP_V) \times M_{J/\psi}}{p_Z}$
- **Fit projections:**



Mass distributions:

- Signal : CB function
- Bkg : exponential

t_z distributions:

- Signal:
  - $\delta(t_z)$ for prompt J/ψ
  - expo. for b-component
- Bkg: empirical function from sideband

blue line: prompt J/ψ
black line: J/ψ from b
Green hatched: comb. bkg

J/ψ cross-sections

Total production of prompt J/ψ and J/ψ from b in LHCb:

- pA: $p_T < 14$ GeV/c, $1.5 < y < 4.0$

  σ_{pA} (prompt J/ψ) = 1028.2 ± 13.6 (stat.) ± 88.6 (syst.) μb

  σ_{pA} (J/ψ from b) = 150.1 ± 4.2 (stat.) ± 12.6 (syst.) μb

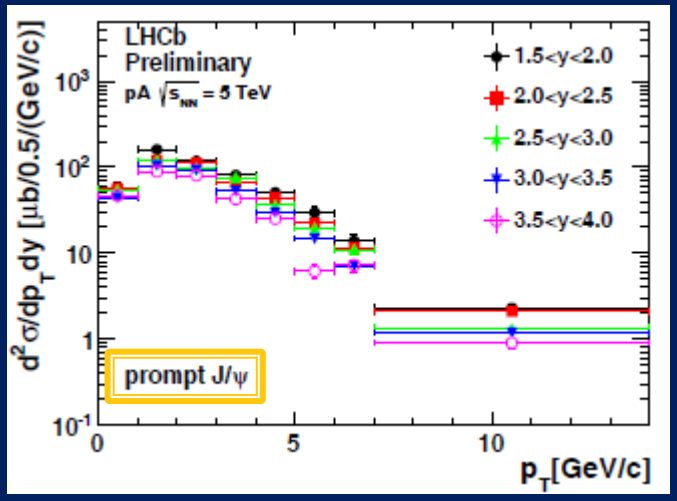
- Ap: $p_T < 14$ GeV/c, $-5.0 < y < -2.5$

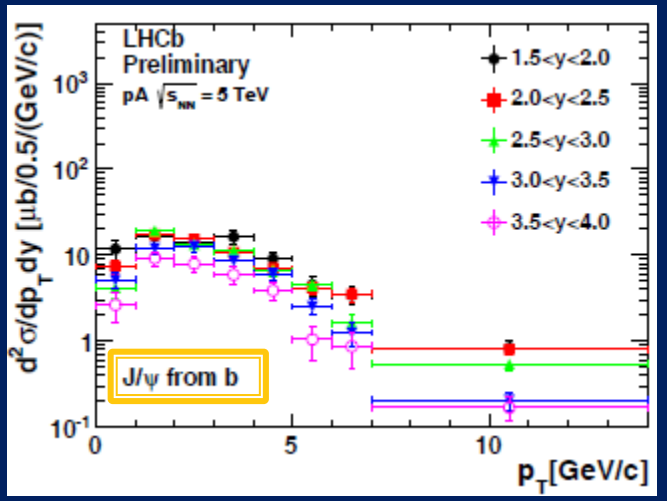
  σ_{Ap} (prompt J/ψ) = 1141.9 ± 49.8 (stat.) ± 98.4 (syst.) μb

  σ_{Ap} (J/ψ from b) = 119.7 ± 8.3 (stat.) ± 10.0 (syst.) μb

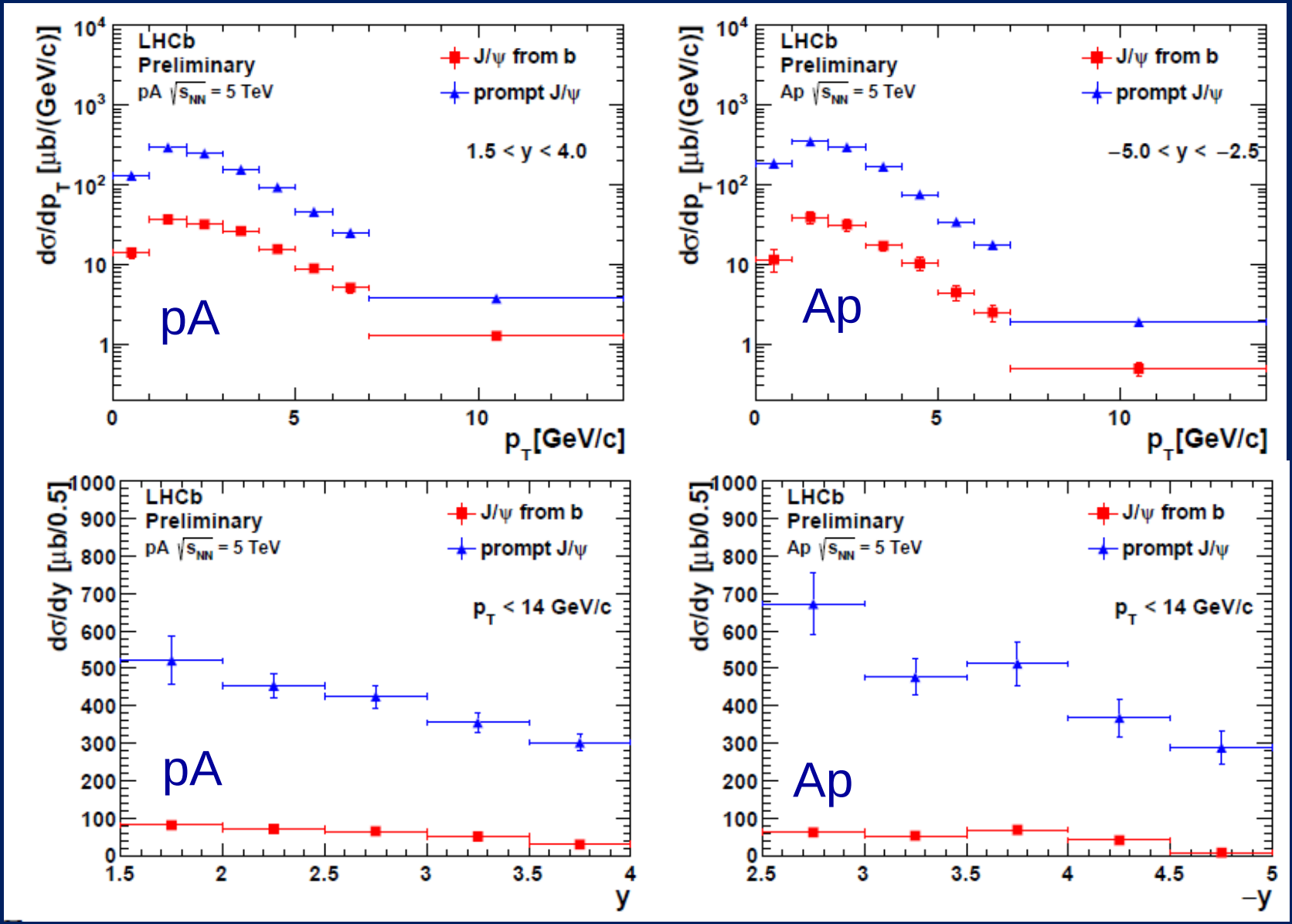
- Systematics dominated by luminosity, fit model and data-MC agreement

Double differential cross-section in pA:

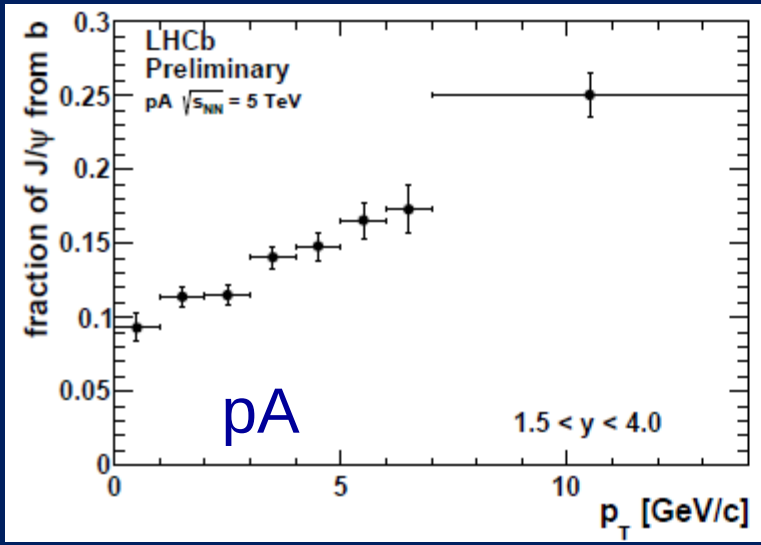


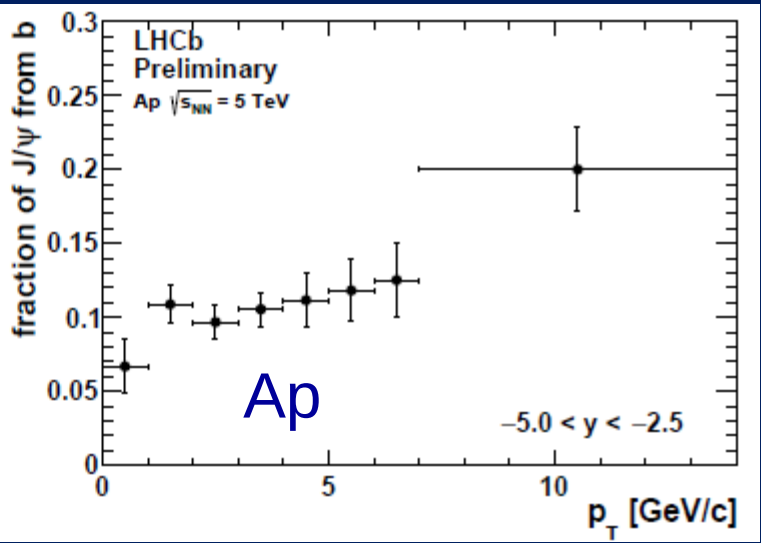


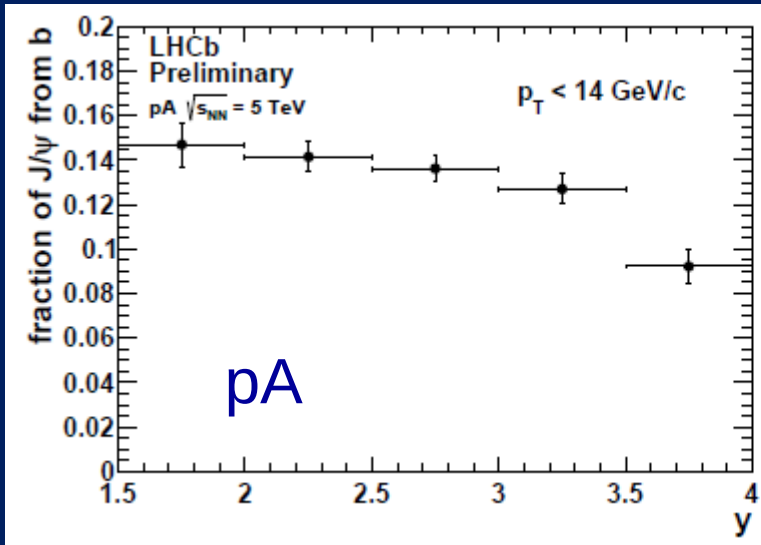
Single differential cross-sections

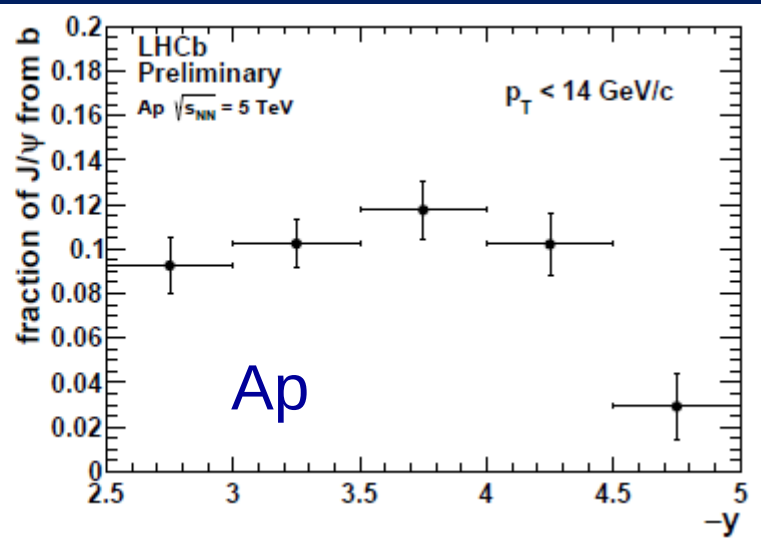


Fraction of J/ψ from b



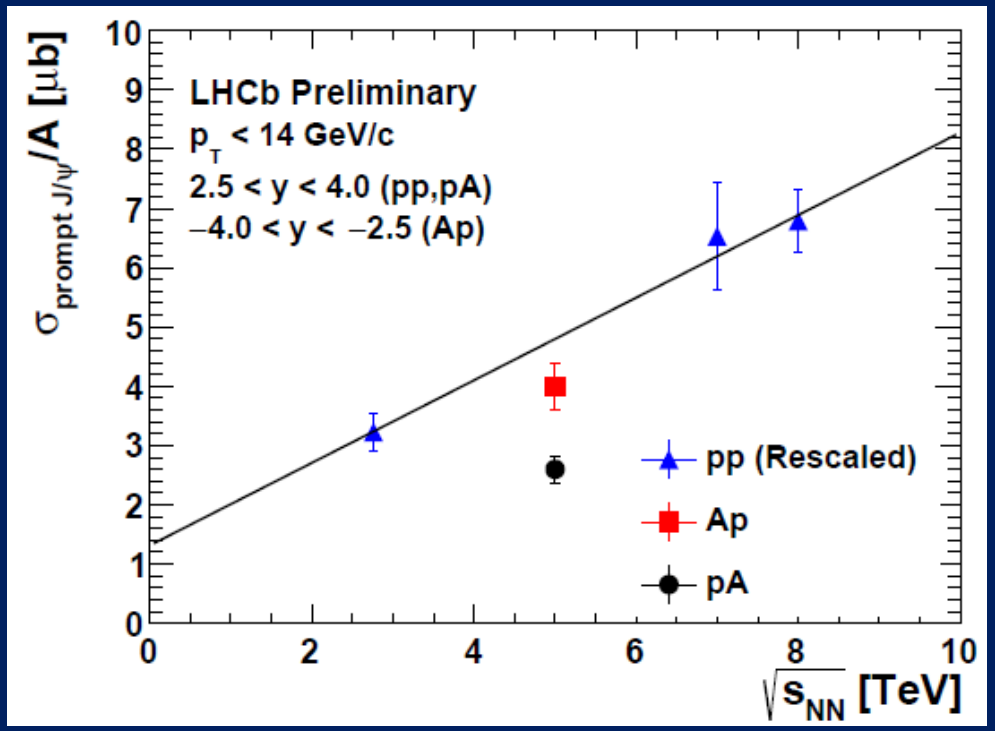






Comparison with other LHCb measurements

Prompt J/ψ



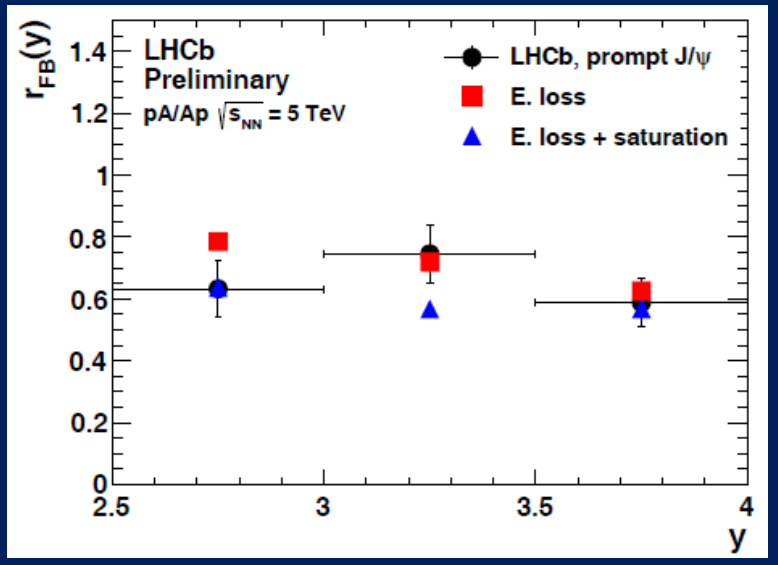
- Rescaled σ_{pp} in common rapidity range: 2.5<y<4.0
- J/ψ cross-section scaled by 1/A :
  A= 208 for p-Pb / Pb-p and
  A = 1 for p-p
- Linear interpolation to obtain $\sigma_{pp}(5\,\text{TeV})$ from prompt J/ψ cross-section in p-p collisions
- Clear suppression in p-A, while slight suppression in A-p.

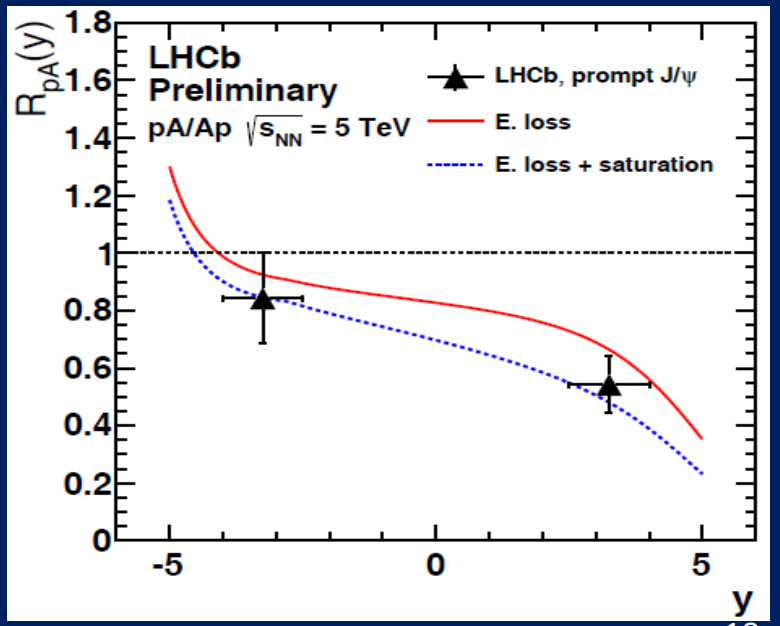
JHEP 02 (2013) 041 [arXiv:1212.1045]
Eur. Phys. J. C71 (2011) 1645 [arXiv:1103.0423]
LHCb-PAPER-2013-016 [arXiv:1304.6977]

Comparison with theoretical predictions

Theoretical predictions from
JHEP 1303 (2013) 122 [arXiv: 1212.0434]

- Forward-backward production asymmetry $r_{FB}(y)$
  - Clear forward-backward production asymmetry
  - Agreement with theoretical predictions
- Nuclear attenuation factor $R_{pA}(y)$:
  - Agreement with theoretical predictions
  - Current precision insufficient to distinguish nuclear effects with or without saturation

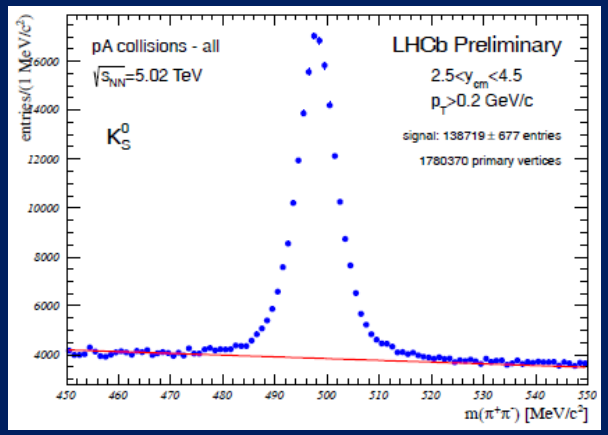


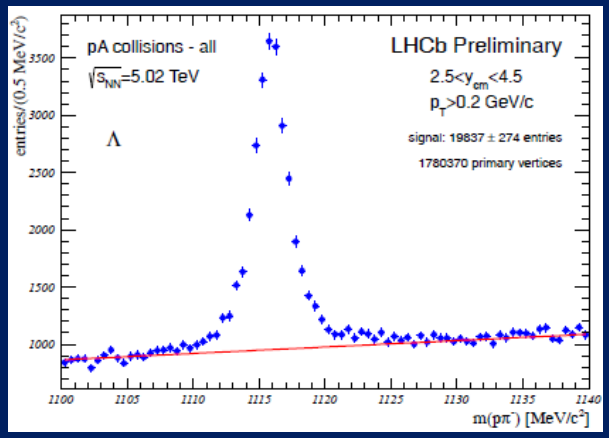


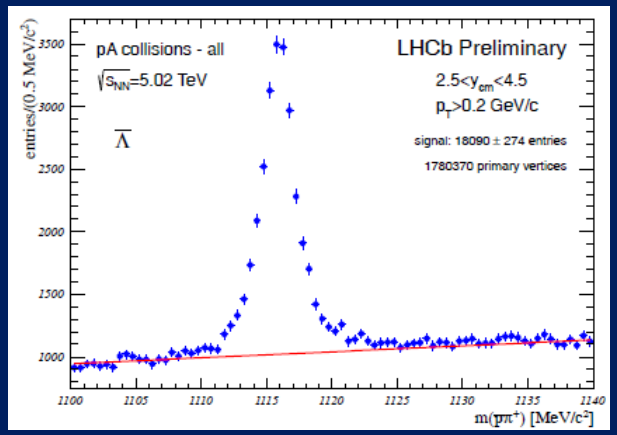
Prospects for p-A physics with LHCb

- The unique angular coverage of LHCb enables us to study strangeness, charm and also beauty production in regions not accessible to the other experiments.
- Preliminary study of V^0 production ratios in p-Pb is promising

[LHCb-CONF-2012-034]







- Further analyses planned with the p-A data sample:
  - Charged particle production
  - Central exclusive production
  - Jet production
  - $\psi(2S)$ and $\Upsilon(nS)$ production
  - Open charm production
  - DIS and Drell-Yan processes
  - Particle correlations
  - Low-x physics

Summary and Conclusions

- LHCb recorded a data sample of ~2/nb of p-Pb / Pb-p collisions, which provides unique opportunities on specific physics measurements, and is important for the understanding of heavy-ion collisions and for probing some particular QCD physics phenomena.

- A number of interesting measurements has been performed so far:
  - J/ψ production cross-section as function of p_T and y
  - Nuclear attenuation factor R_{pA} and forward-backward production asymmetry ratio r_{FB} as a function of rapidity

  → Clear J/ψ suppression is observed, in good agreement with theory

- Many more exciting results are expected soon.

Backup

Summary of systematic uncertainties

Source	Systematic uncertainty (%)
Correlated between bins	
Mass fits	1.8
Tracking efficiency	1.5
$\mathcal{B}(J/\psi \to \mu^+\mu^-)$	1.0
Luminosity	5.0
t_z fit (*only for* J/ψ *from* b)	5.0
Vertexing, track quality, etc.	3.5
Uncorrelated between bins	
Binning	0.1 to 14