Phenomenological Energy Interpolation

First Retequarkonii Workshop, Nantes

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Outline

- The situation : it is not planned to have p+p data at the same energy as A+B (Pb+Pb) collisions at LHC yet.
  But we need a reference for QGP studies...
- The problematic :
  - Could the evolution of open & hidden charm/beauty vs collision energy be evaluated ?
  - Could their rapidity dependence be modeled ?
  - Could their p_T dependence be extrapolated ?
- Constrains : data
  - There is not so many measurements for which the energy evolution can be studied
  - It is a hard and long task to collect all the information...

[c.f. S. Porteboeuf talk]

- Here we try to discuss a possible "naive" phenomenological approach...

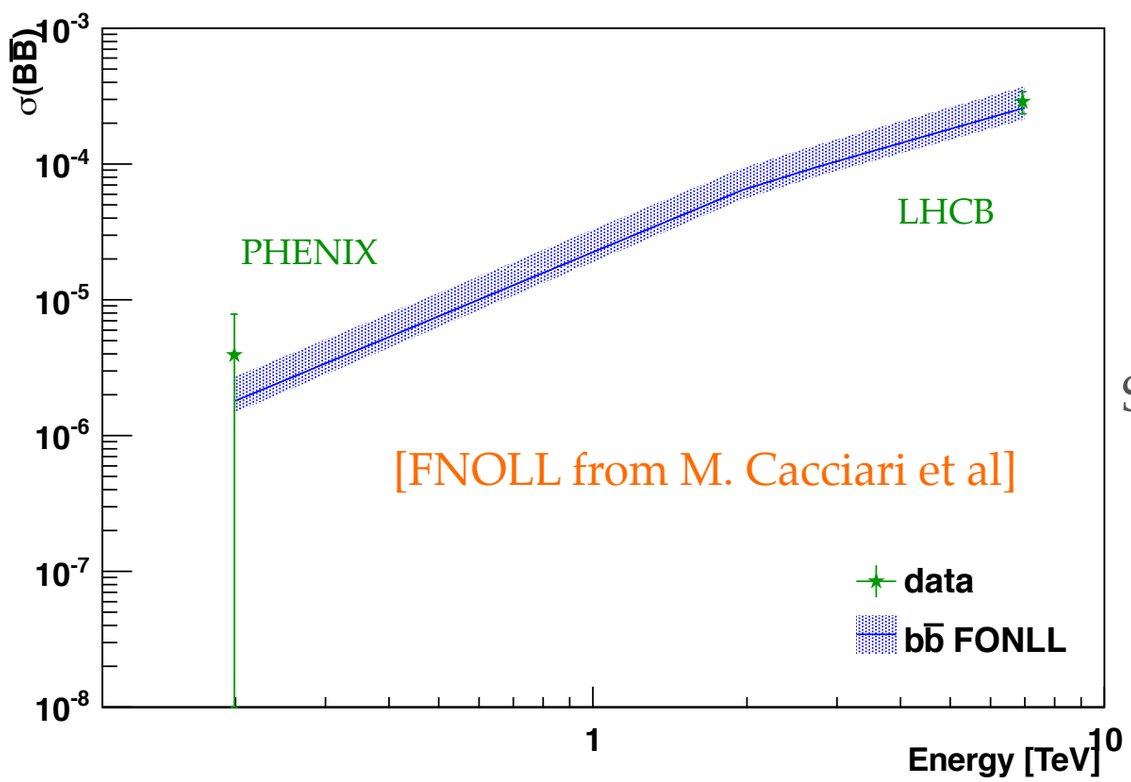
[c.f. M. Cacciari & J.P. Lansberg talks]

- Ideally look at the open/hidden energy evolution

[c.f. M. Gagliardi & A. De Falco talks]

Open Charm & Beauty Data

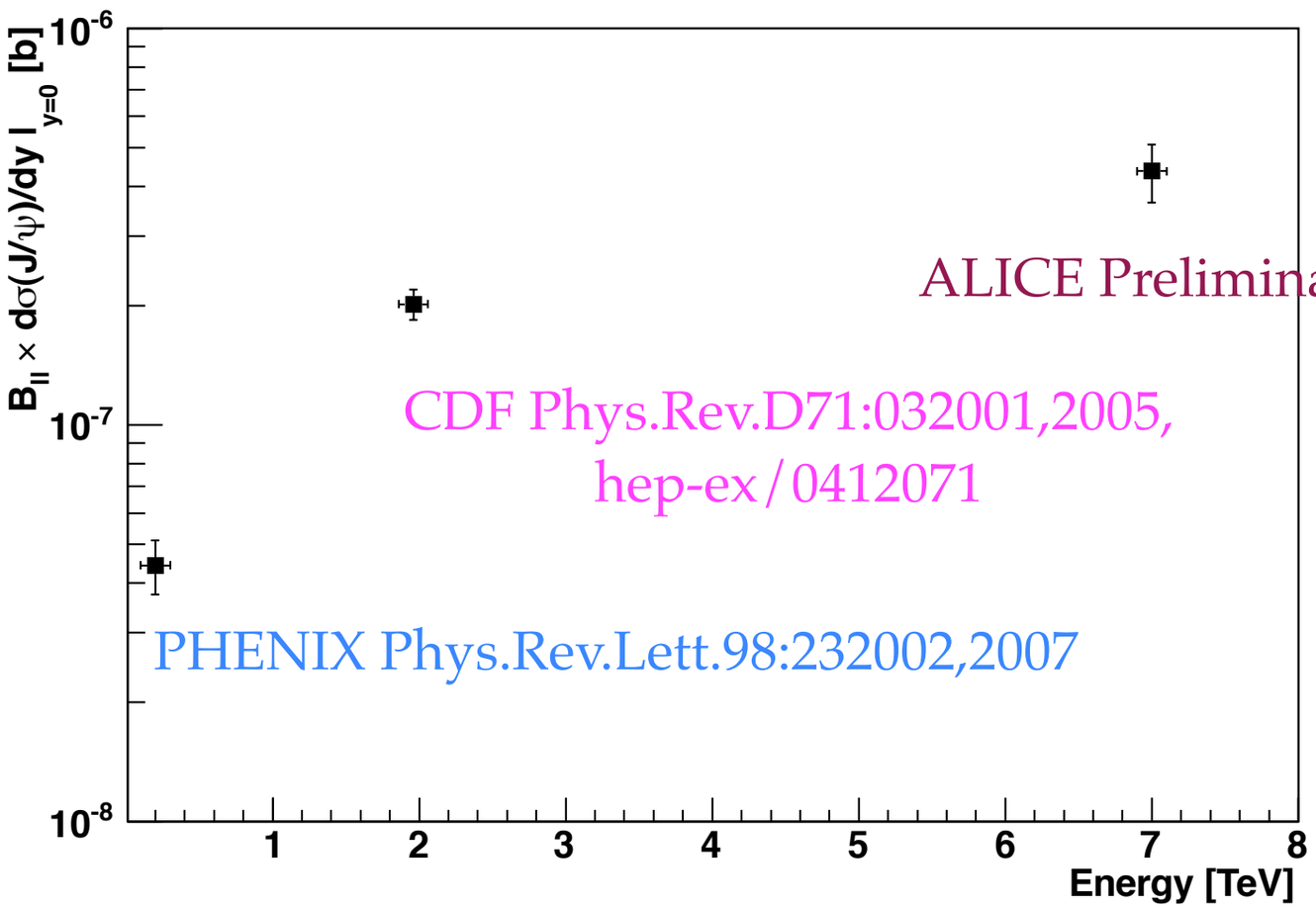
- Measurements (I knew of...) at RHIC, TeVatron & LHC are not easily comparable
  - $d\sigma/dy|_y$ at different rapidities
  - $d\sigma/dp_t$ with different minimum pt
- Many ongoing analysis... stay tuned ! [ALICE, ATLAS, CMS & LHCB talks]
- No phenomenological interpolation on the open heavy flavor land yet !



Integrated BBbar cross section vs energy
Statistical and systematic uncertainties are added in quadrature.

Charmonia vs energy

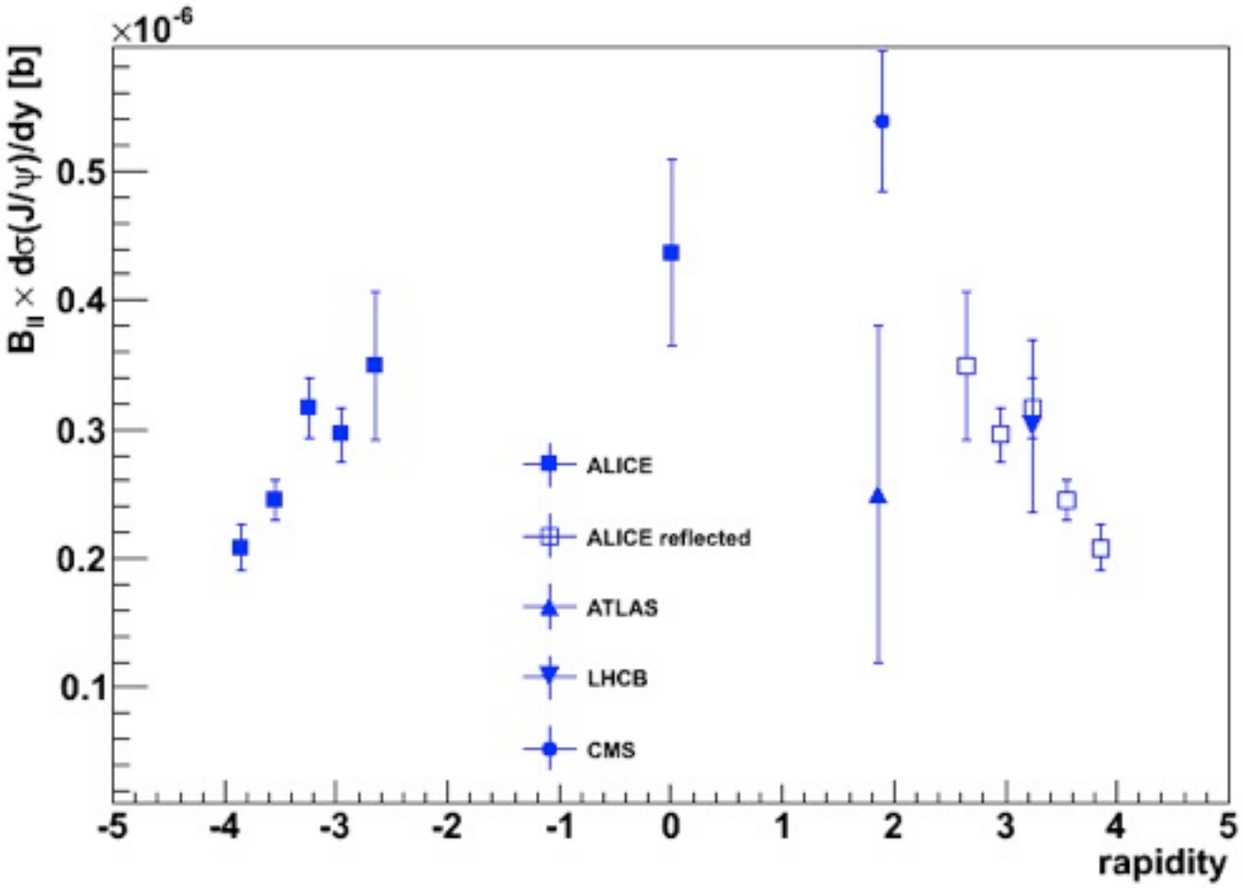
- J/ψ data :
  - dσ/dy (200 GeV @RHIC, 1.96 TeV @TeVatron, 7 TeV @LHC)
- ψ' data : σ (RHIC, TeVatron) not at LHC yet



J/ψ cross section at mid-rapidity vs energy
Statistical and systematic uncertainties are added in quadrature.

Total cross-section, no feed-down subtraction.

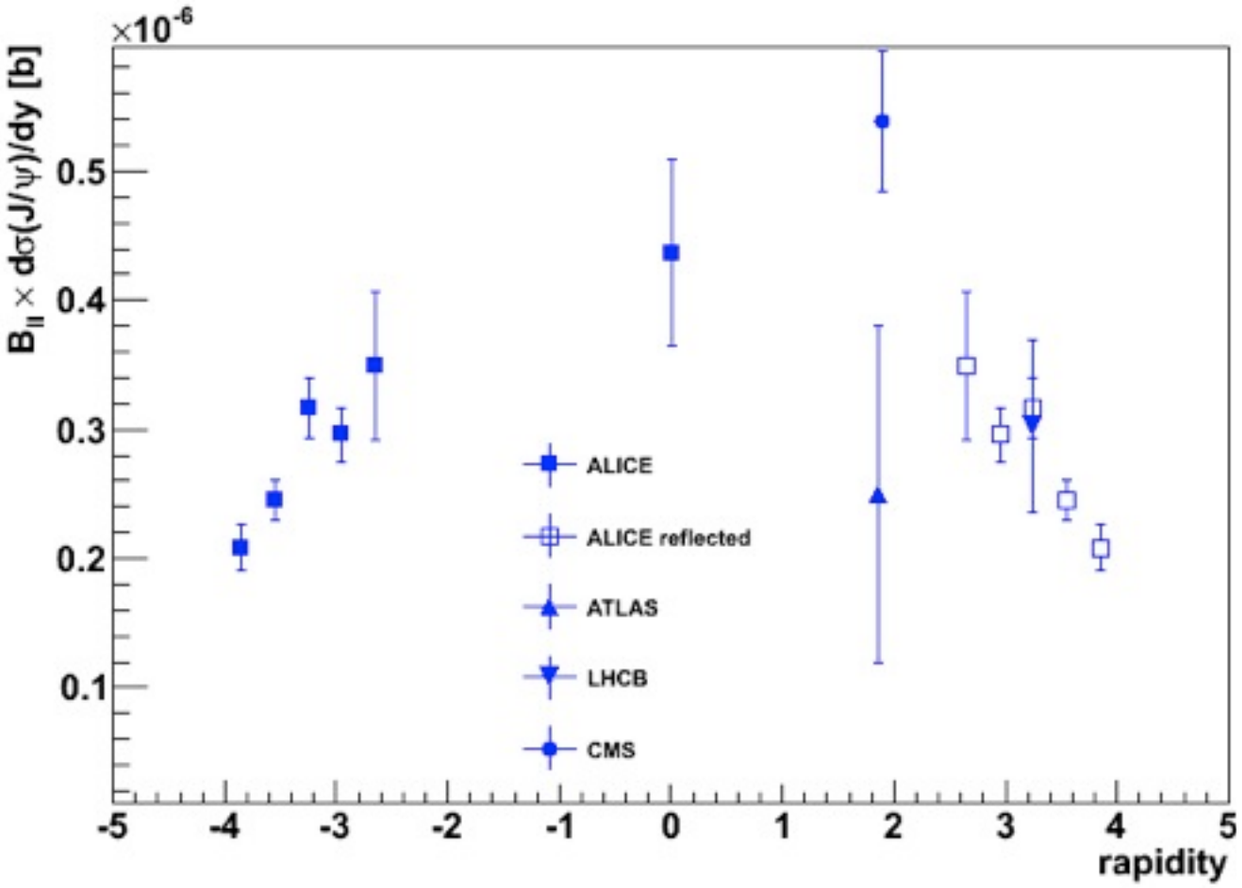
J/ψ measurements at LHC



- Different experiments differential rapidity cross-section distribution agree (worst case is within 2σ)

[ALICE Preliminary, HP2010]
[CMS PAS BPH-10-002]
[ATLAS-CONF-2010-062]
[LHCB ICHEP 2010]

J/ψ measurements at LHC



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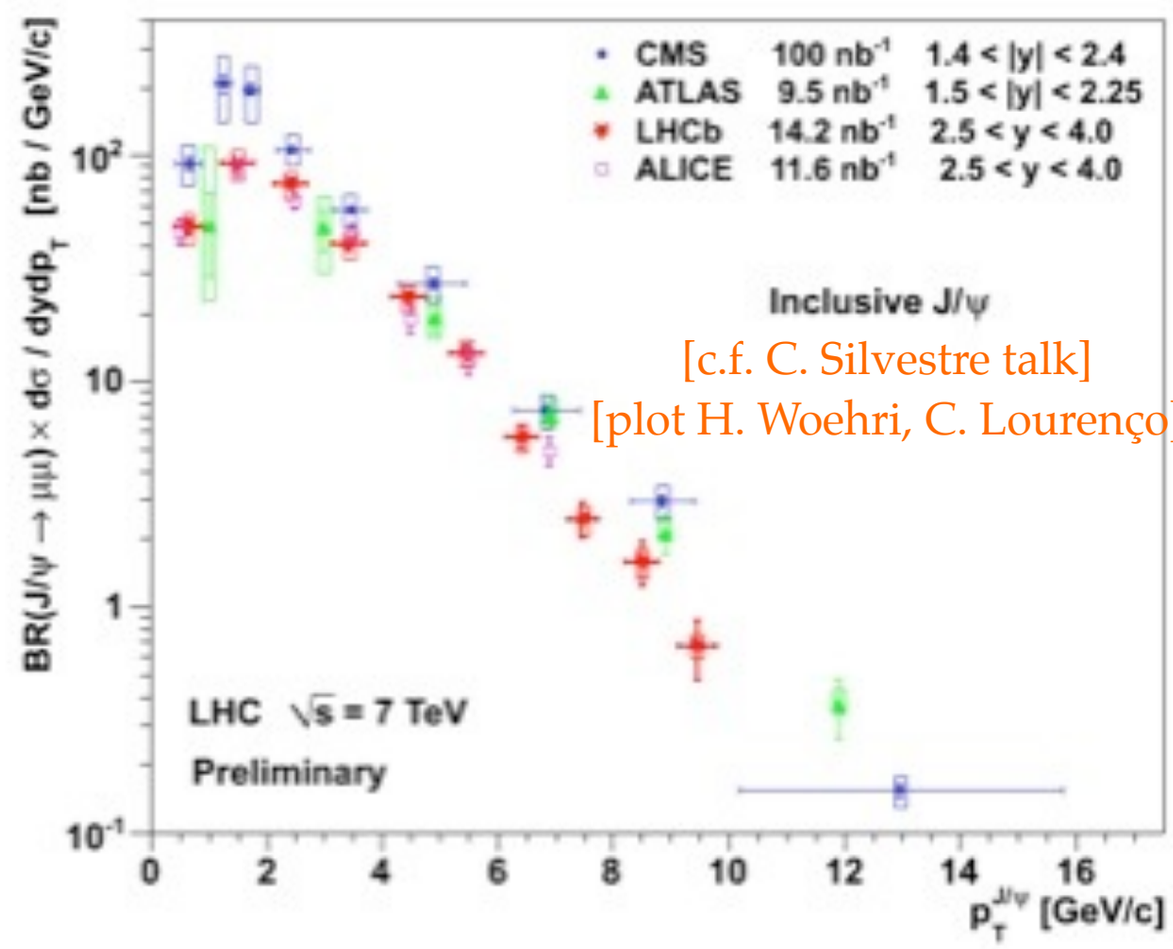
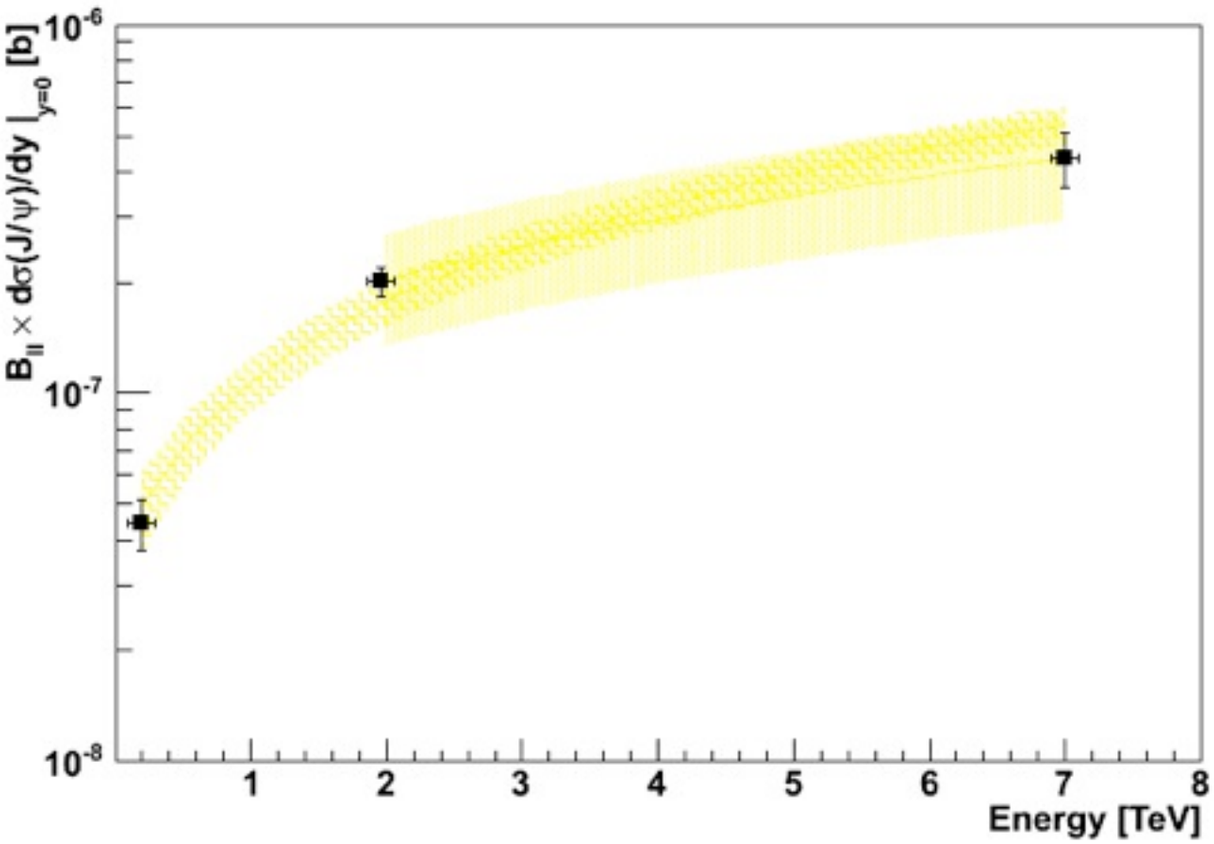


[c.f. C. Silvestre talk]
[plot H. Woehri, C. Lourenço]

- The differential pt cross-section are compatible
- At large pt the agreement within spectra at the same rapidity is more evident

J/ψ vs energy Interpolation



- Scenarii: Phenomenological linear and second order polynomial fit functions.
  Another idea ? log(E) dependence ?
- Uncertainties from the fit (extreme approach)

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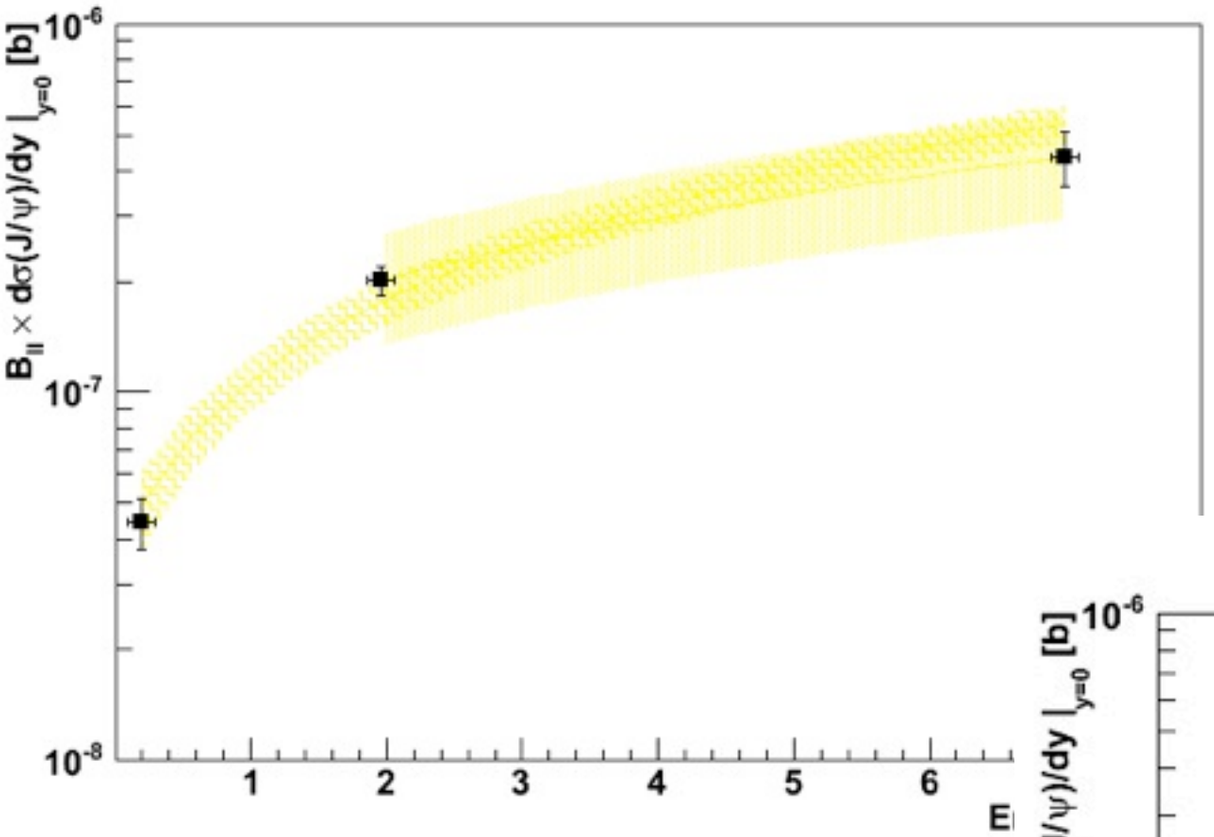

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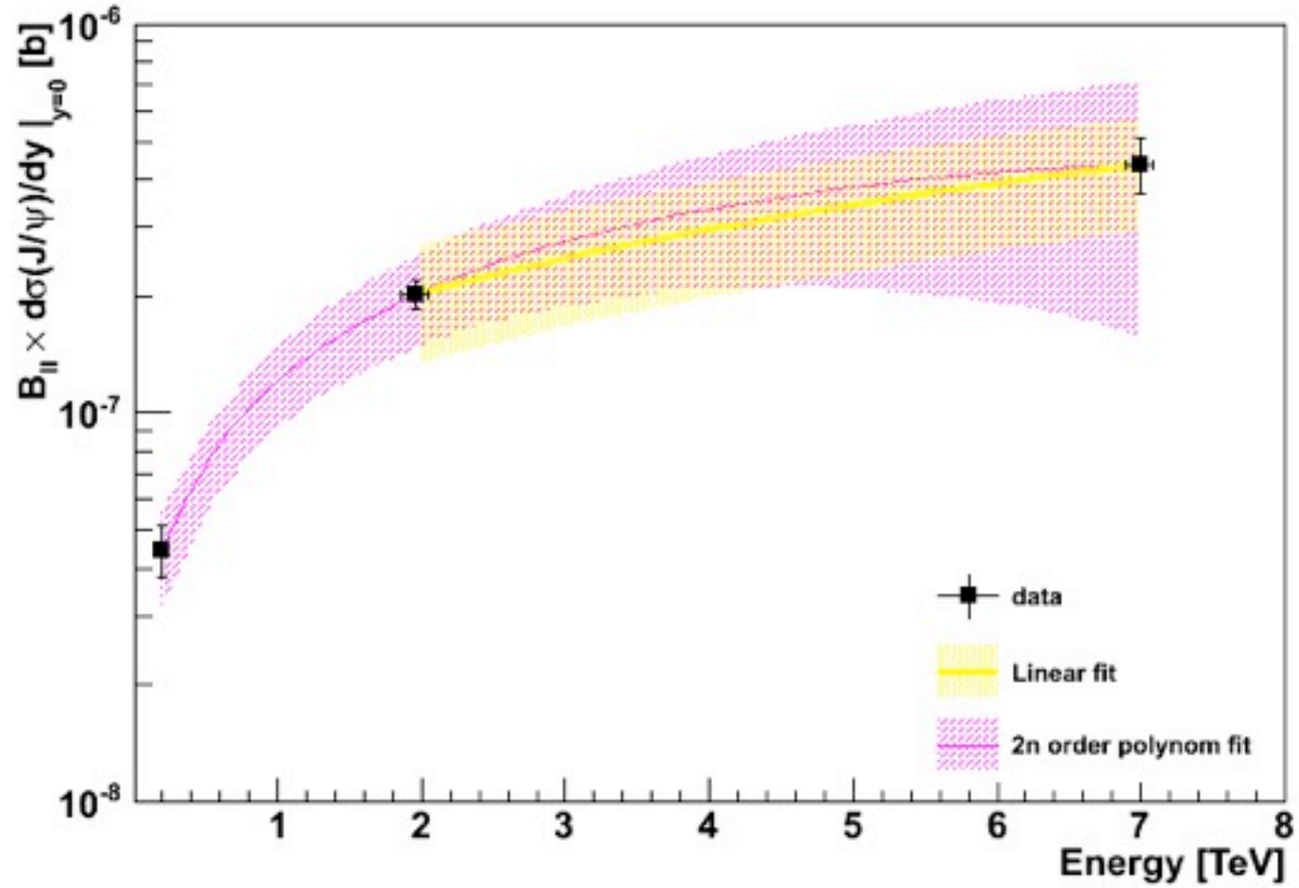

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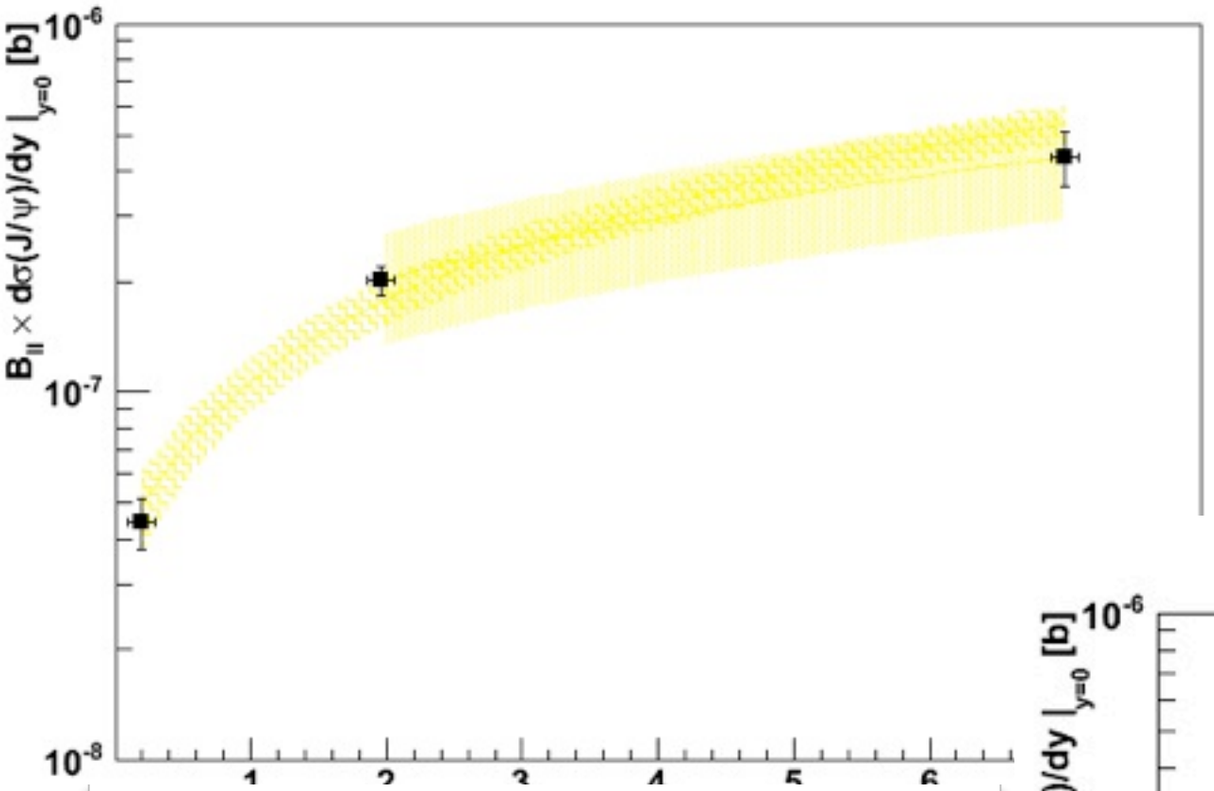

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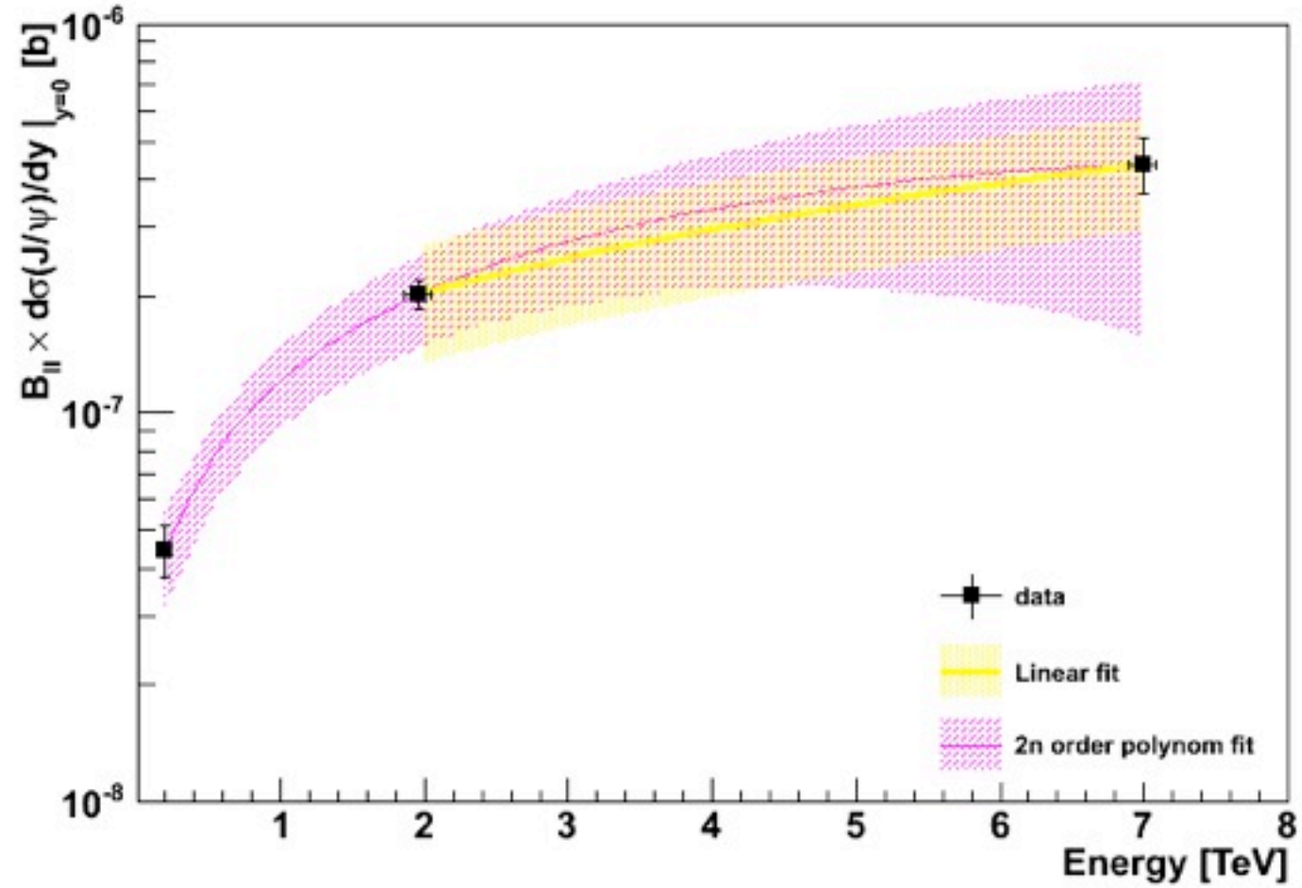
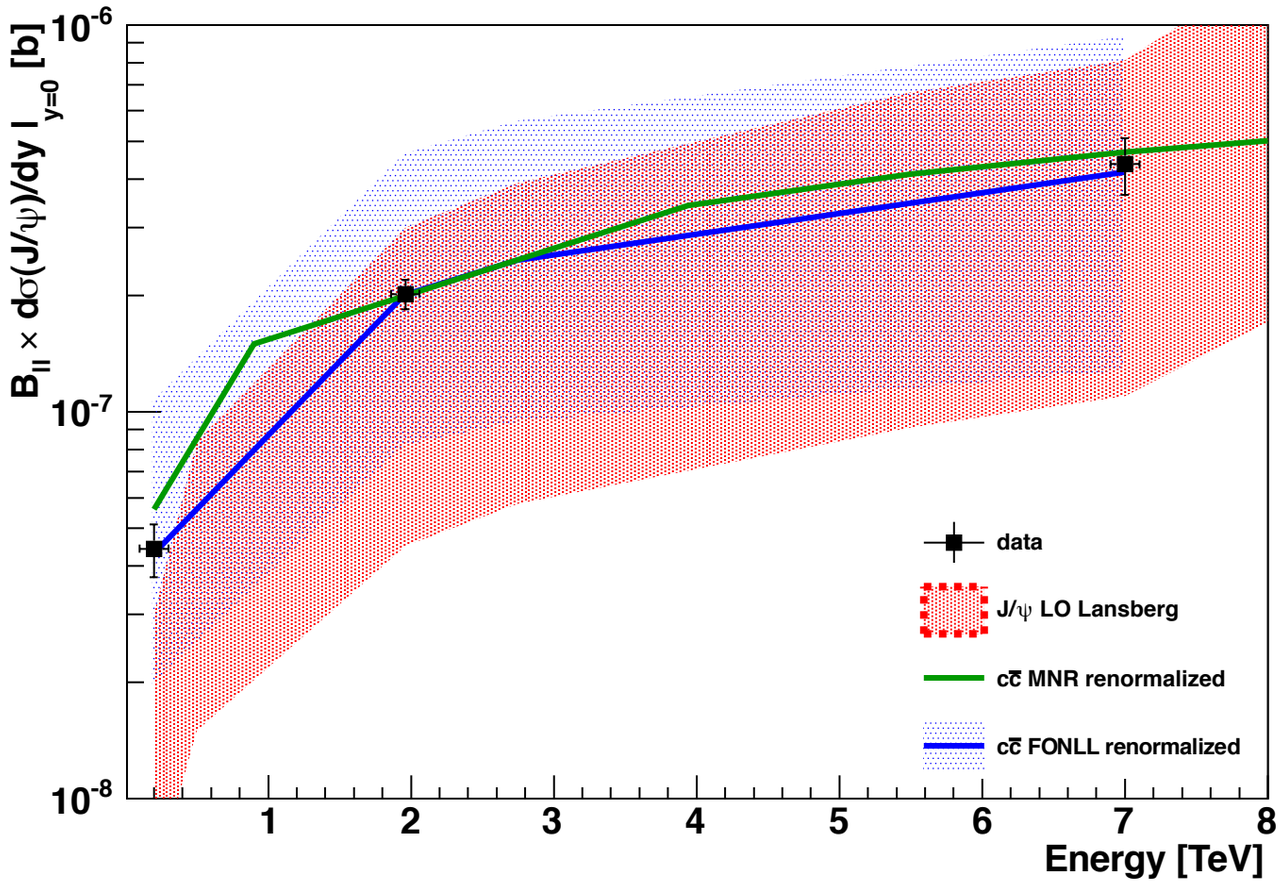
Naive interpolation to 2.75 TeV:
linear $d\sigma/dy\,|_{y=0} \approx 236 \pm 78$ nb
2n.pol $d\sigma/dy\,|_{y=0} \approx 256 \pm 78$ nb
(~30% uncertainty)

Naive interpolation to 5.5 TeV:
linear $d\sigma/dy\,|_{y=0} \approx 353 \pm 115$ nb
2n.pol $d\sigma/dy\,|_{y=0} \approx 390 \pm 182$ nb
(30-40% uncertainty)



J/ψ vs $\sqrt{s_{NN}}$ Theoretical expectations



- Theoretical evolutions are compatible
  - direct J/ψ from Lansberg (LO)
  - ccbar from FONLL scaled (CEM like scaling)
  - ccbar from MNR scaled (CEM like scaling)

[FONLL from M. Cacciari et al private comm.]
[LO Lansberg, Moriond proceedings]

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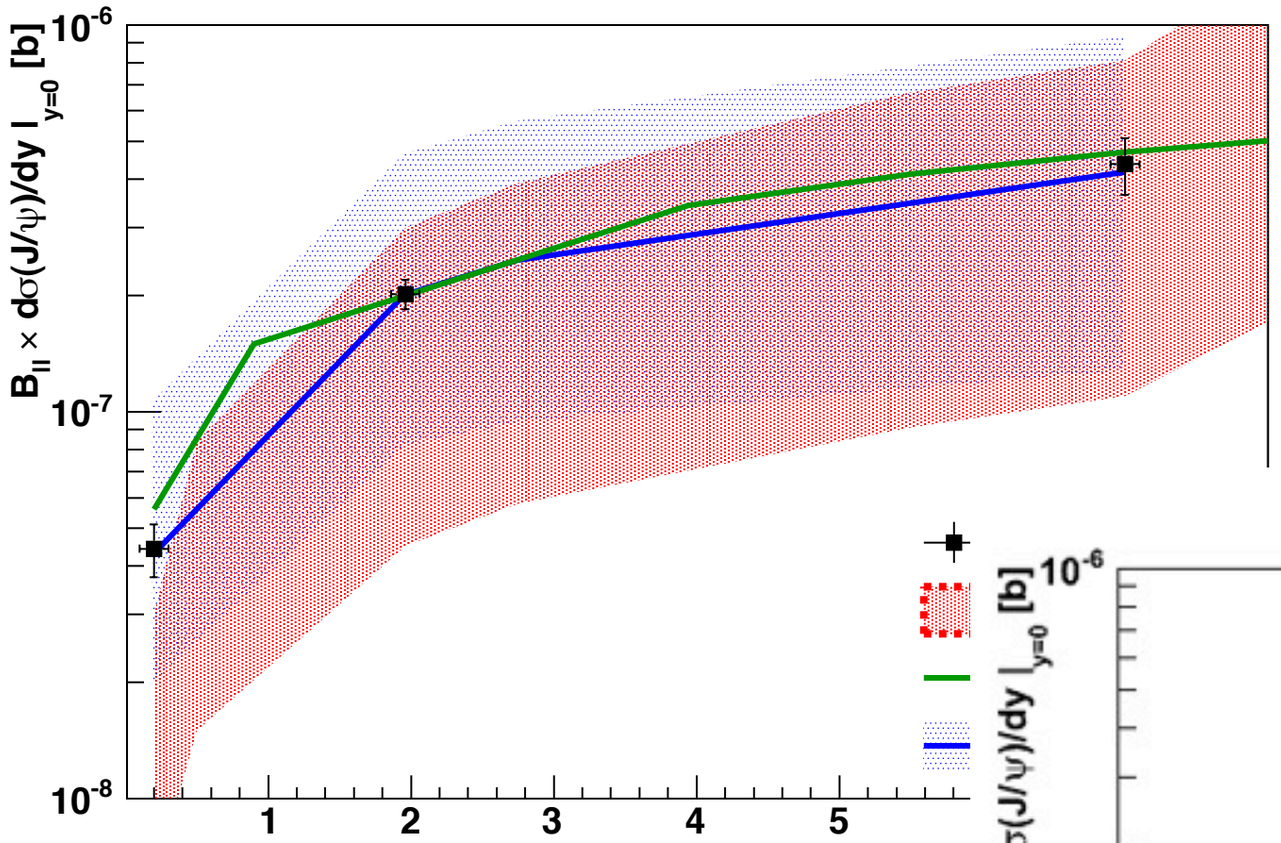

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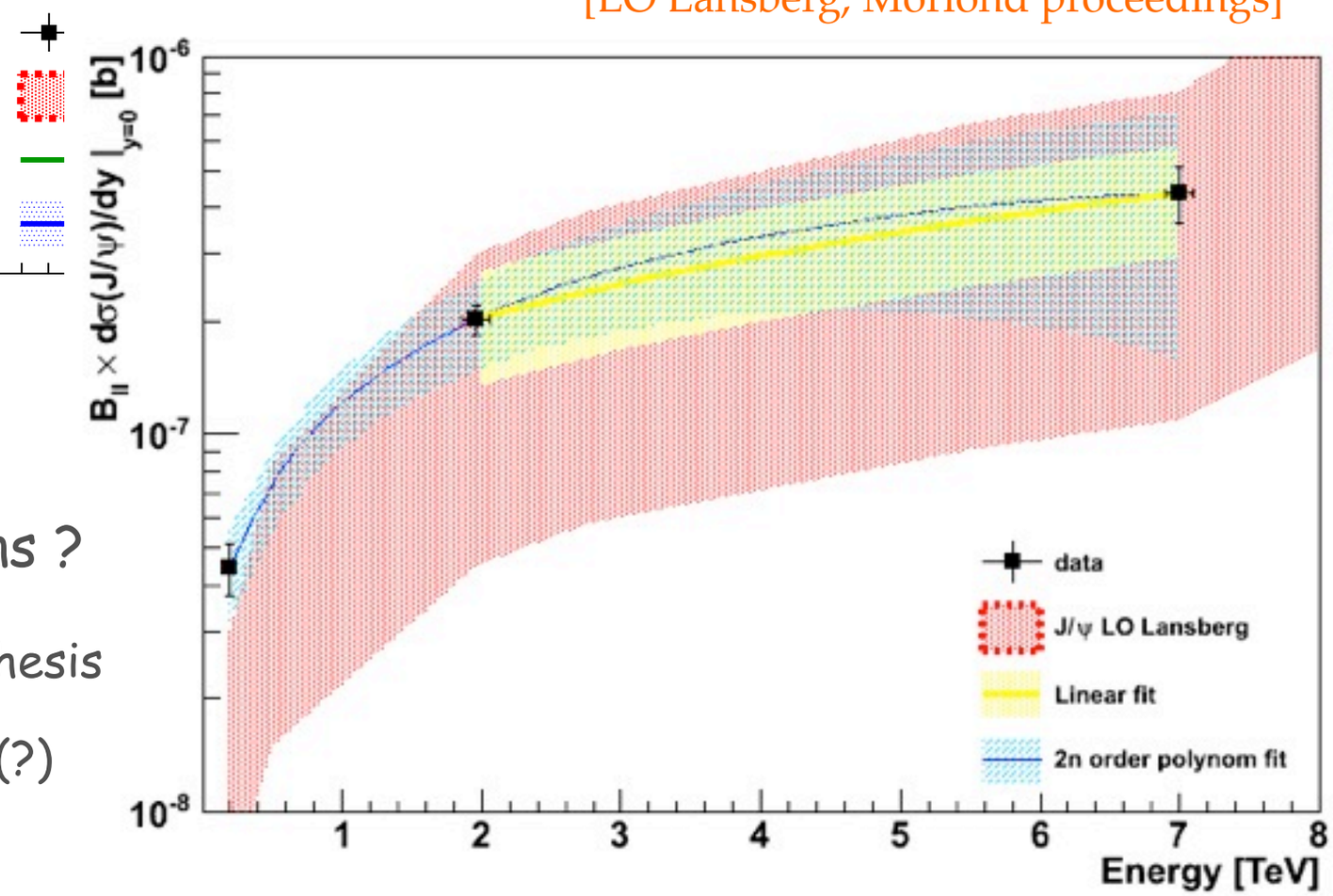
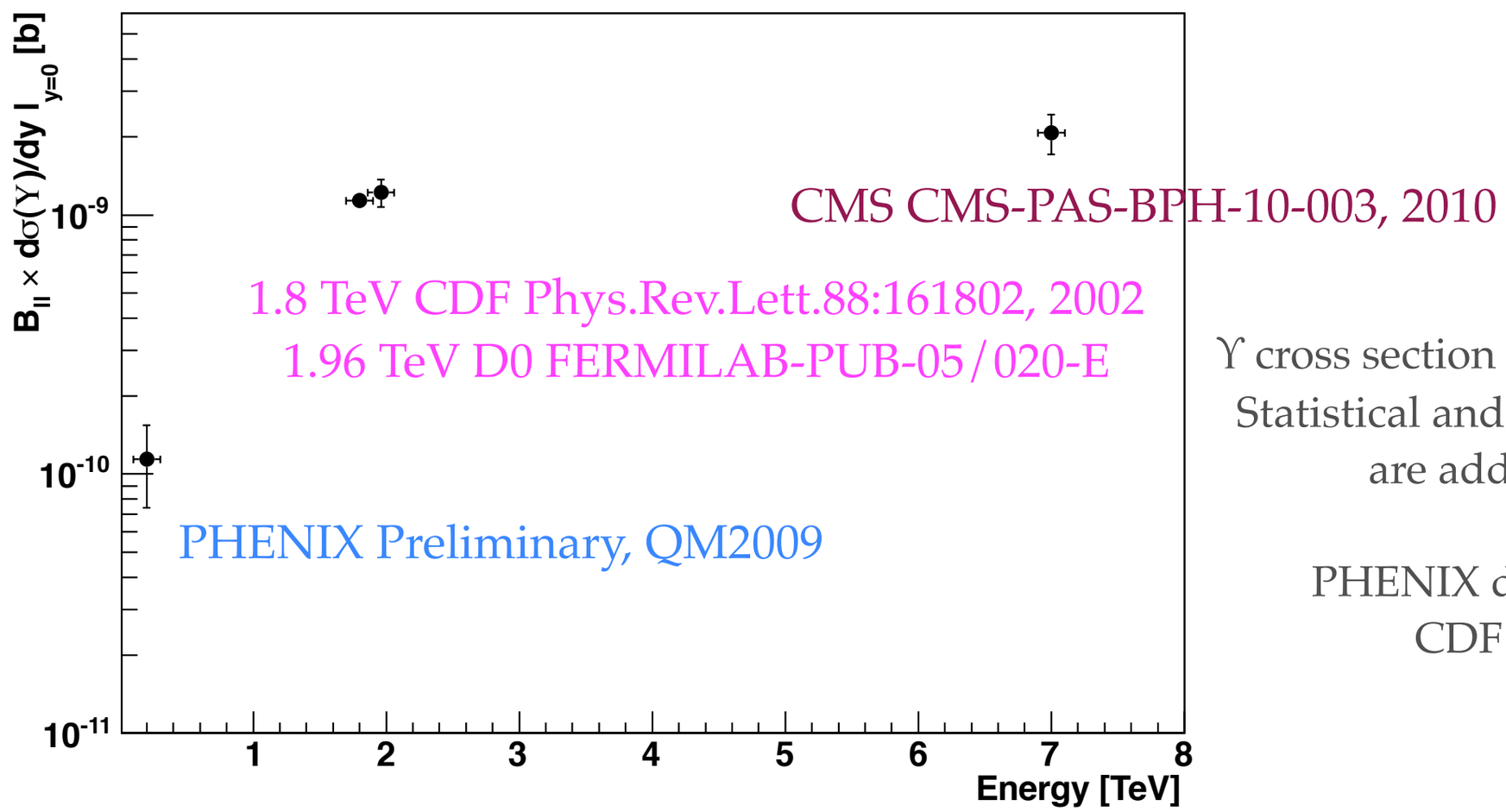


- Phenomenological or theoretical interpolations ?
  - Imposing evolution hypothesis
  - Minimizing uncertainties (?)

Bottomonia vs energy

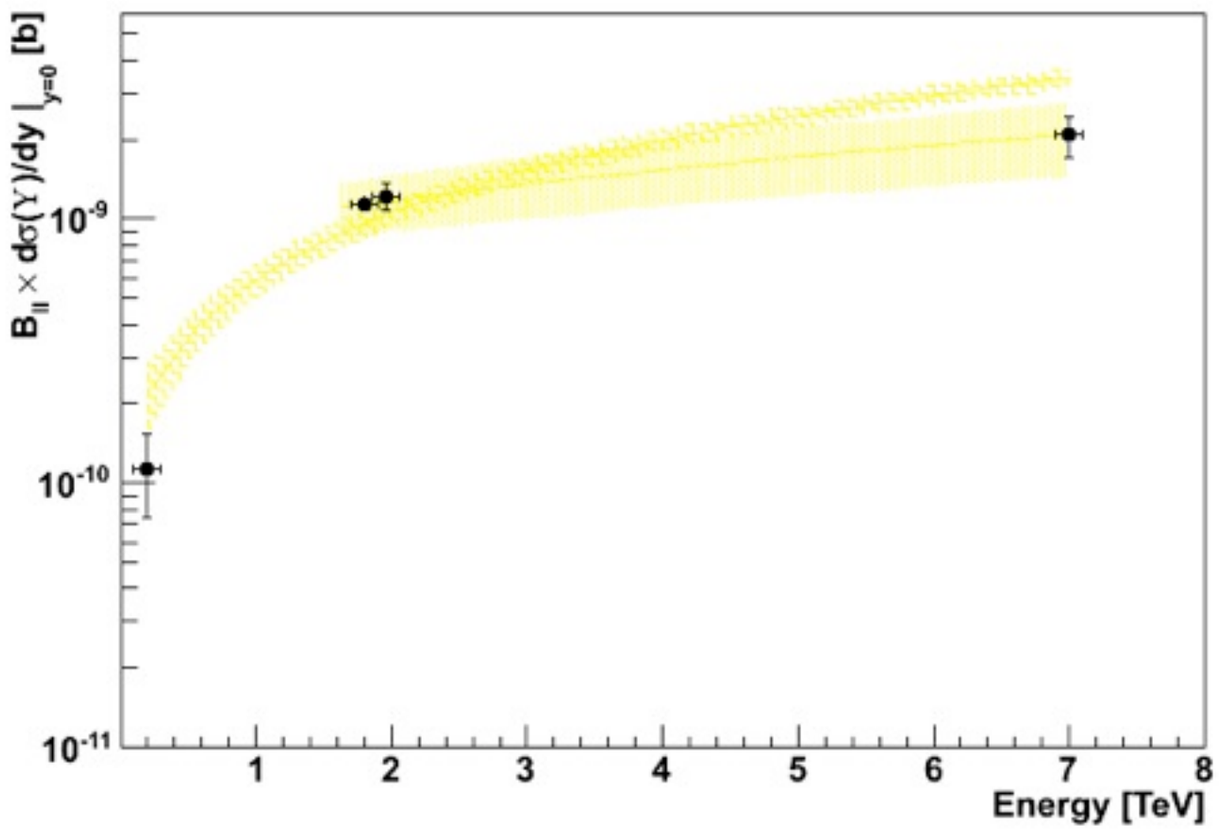
- ϒ data :
  - dσ/dy (200 GeV @RHIC, 1.8 & 1.96 TeV @TeVatron, 7 TeV @LHC)
- ϒ', ϒ'' data : σ (TeVatron) not at RHIC nor LHC yet



ϒ cross section at mid-rapidity vs energy
Statistical and systematic uncertainties are added in quadrature.

PHENIX data includes ϒ' & ϒ''
CDF & CMS only ϒ'

ϒ vs energy Interpolation



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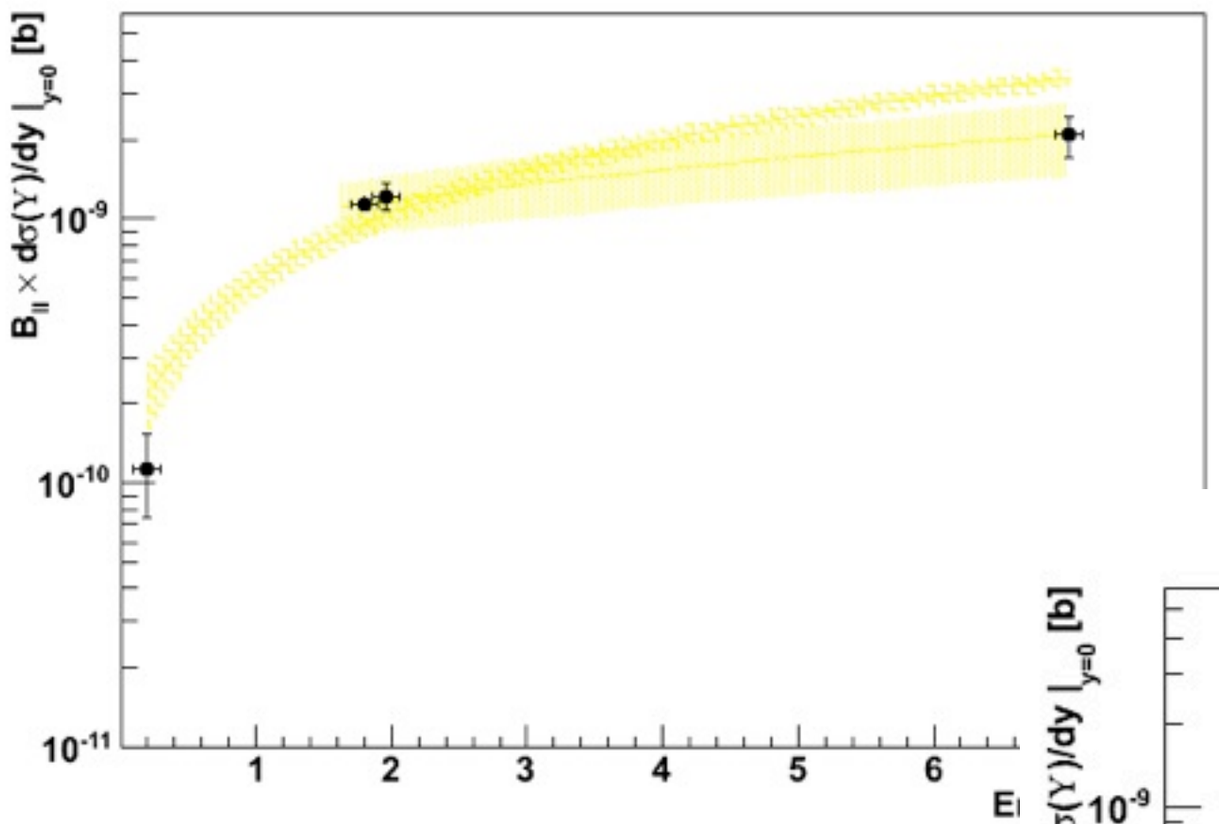

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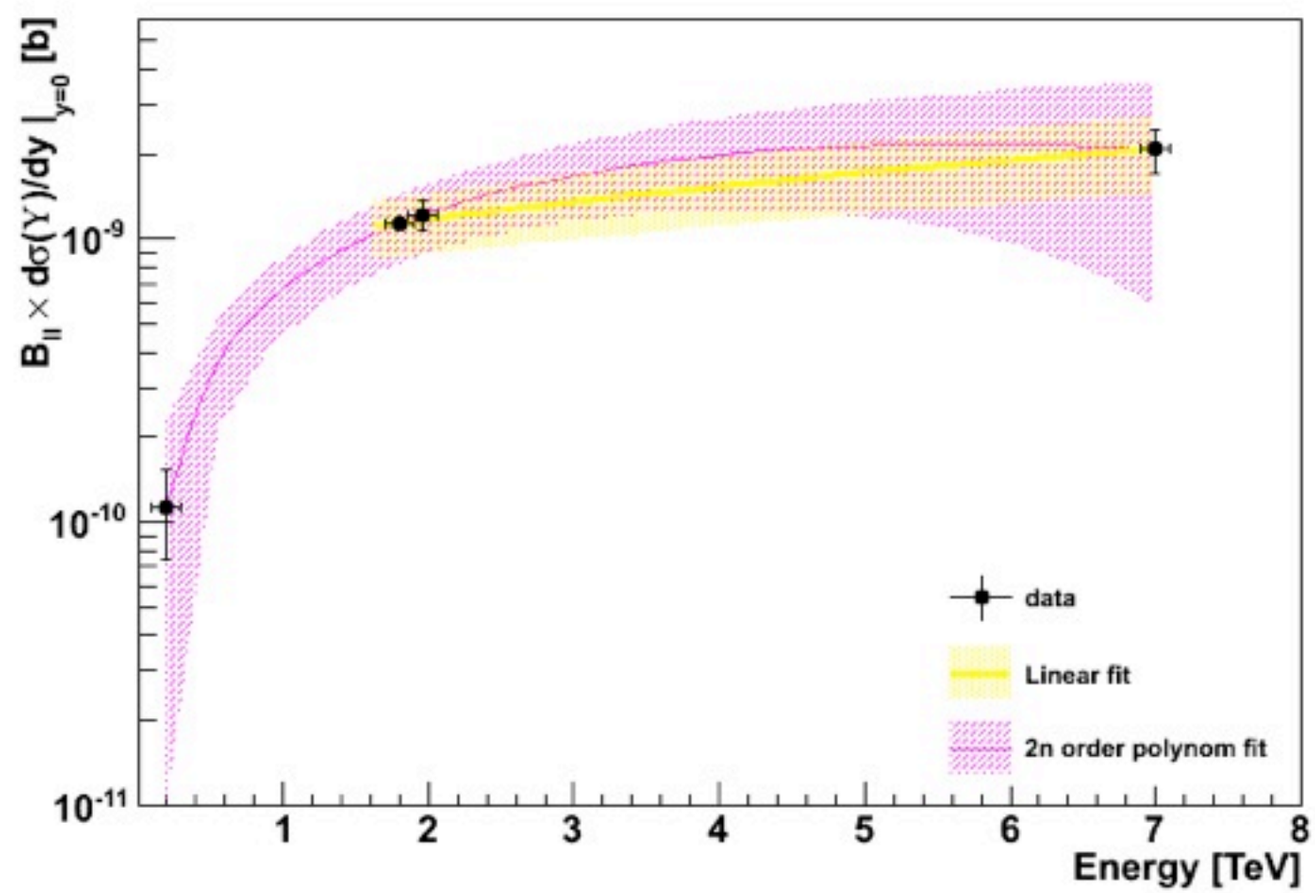

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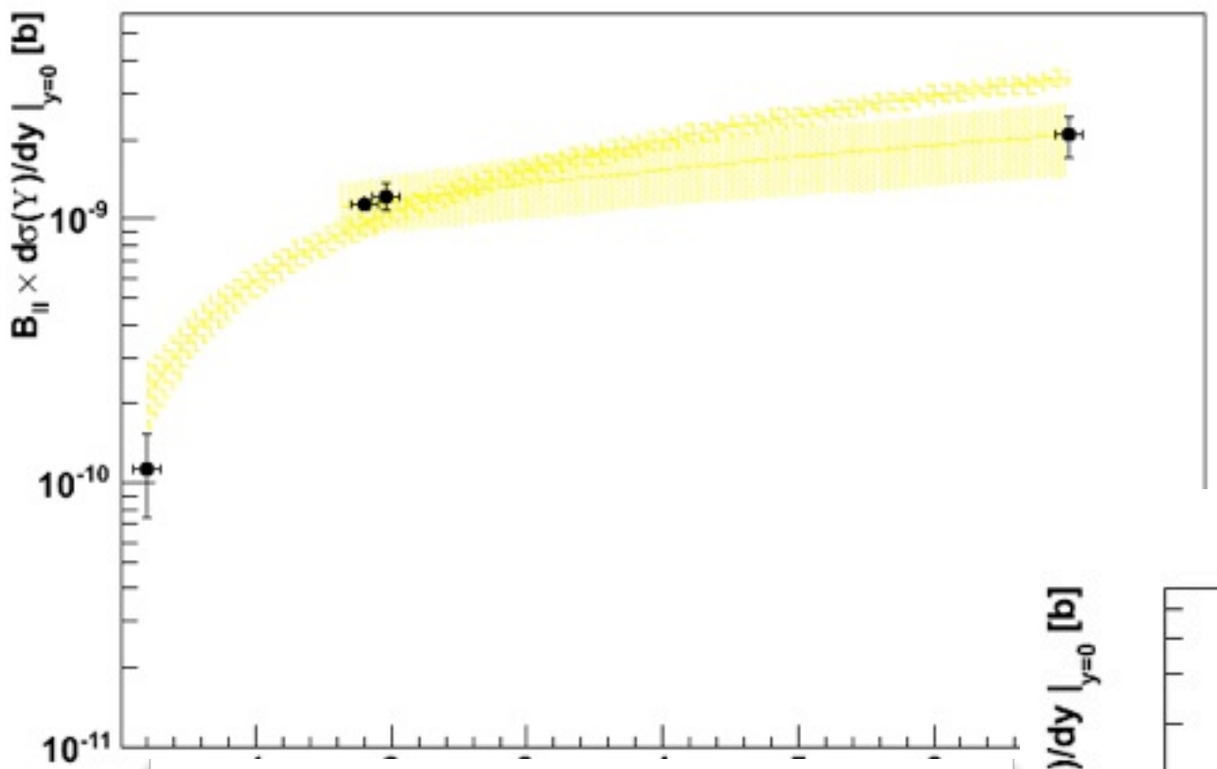

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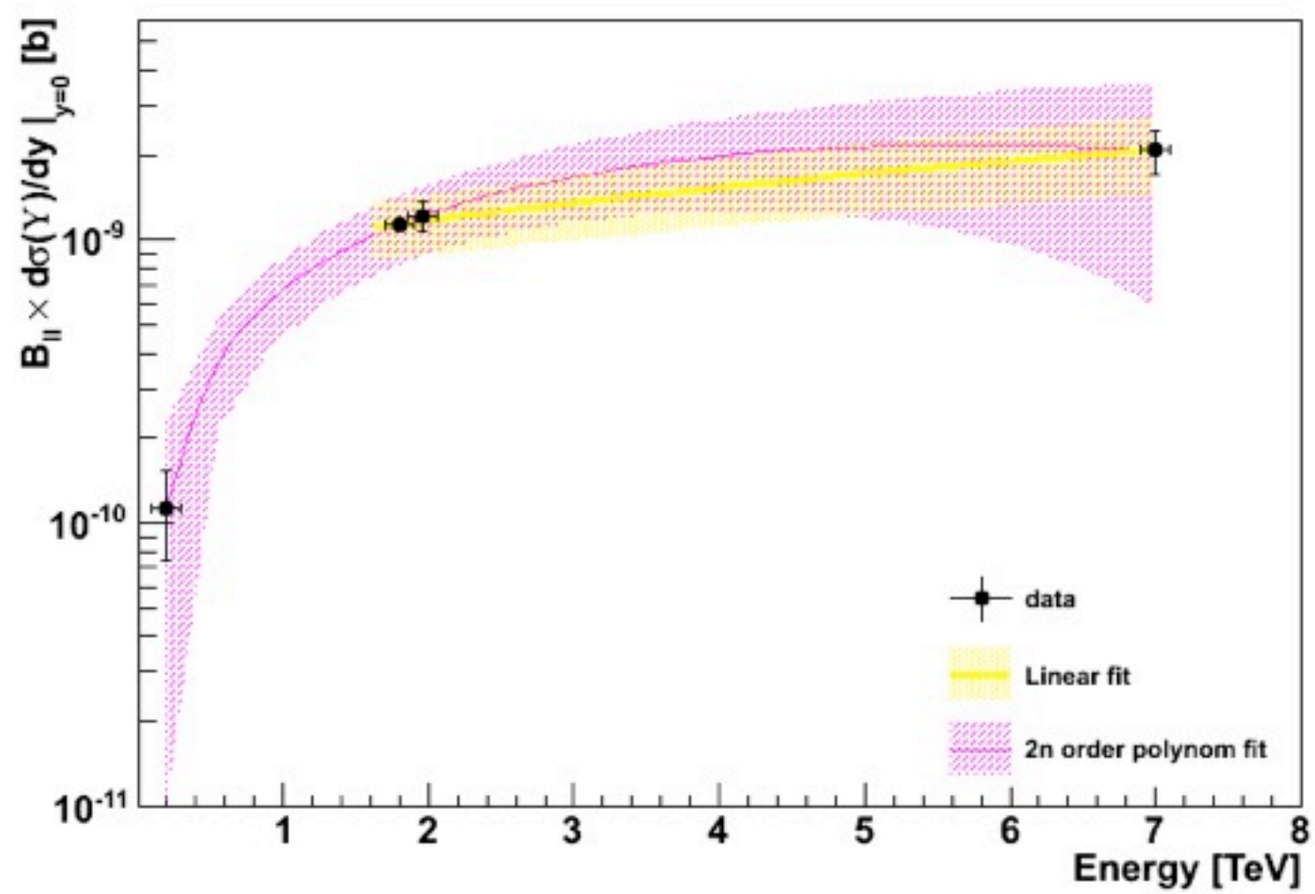
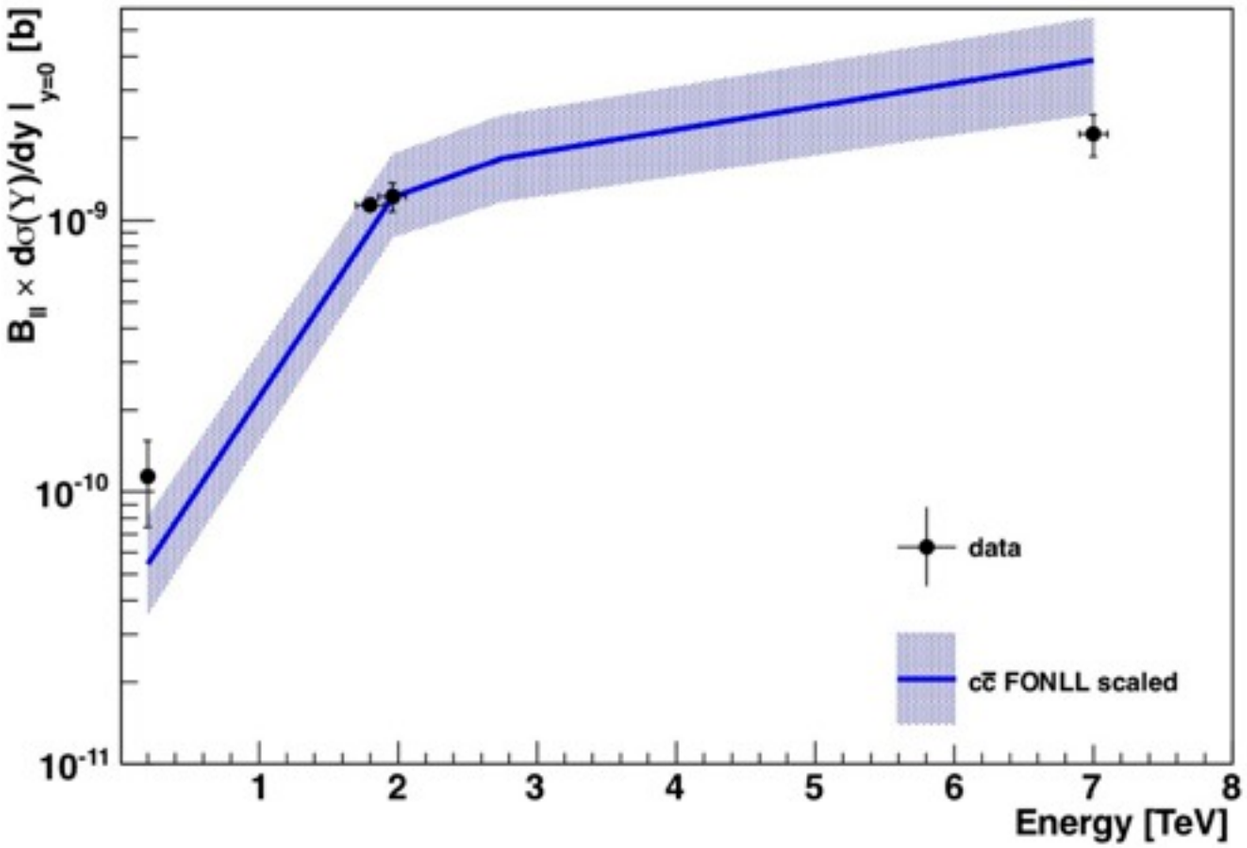
Naive interpolation to 2.75 TeV:
linear $d\sigma/dy\,|_{y=0} \approx 1.4 \pm 0.3$ nb
2n.pol $d\sigma/dy\,|_{y=0} \approx 1.6 \pm 0.3$ nb
(~20% uncertainty)

Naive interpolation to 5.5 TeV:
linear $d\sigma/dy\,|_{y=0} \approx 1.8 \pm 0.5$ nb
2n.pol $d\sigma/dy\,|_{y=0} \approx 2.2 \pm 0.8$ nb
(~>30% uncertainty)



Υ vs $\sqrt{s_{NN}}$ Theoretical expectations



- Comparison with theoretical evolution
  - bbbar from FONLL scaled (CEM like scaling)
  - ...

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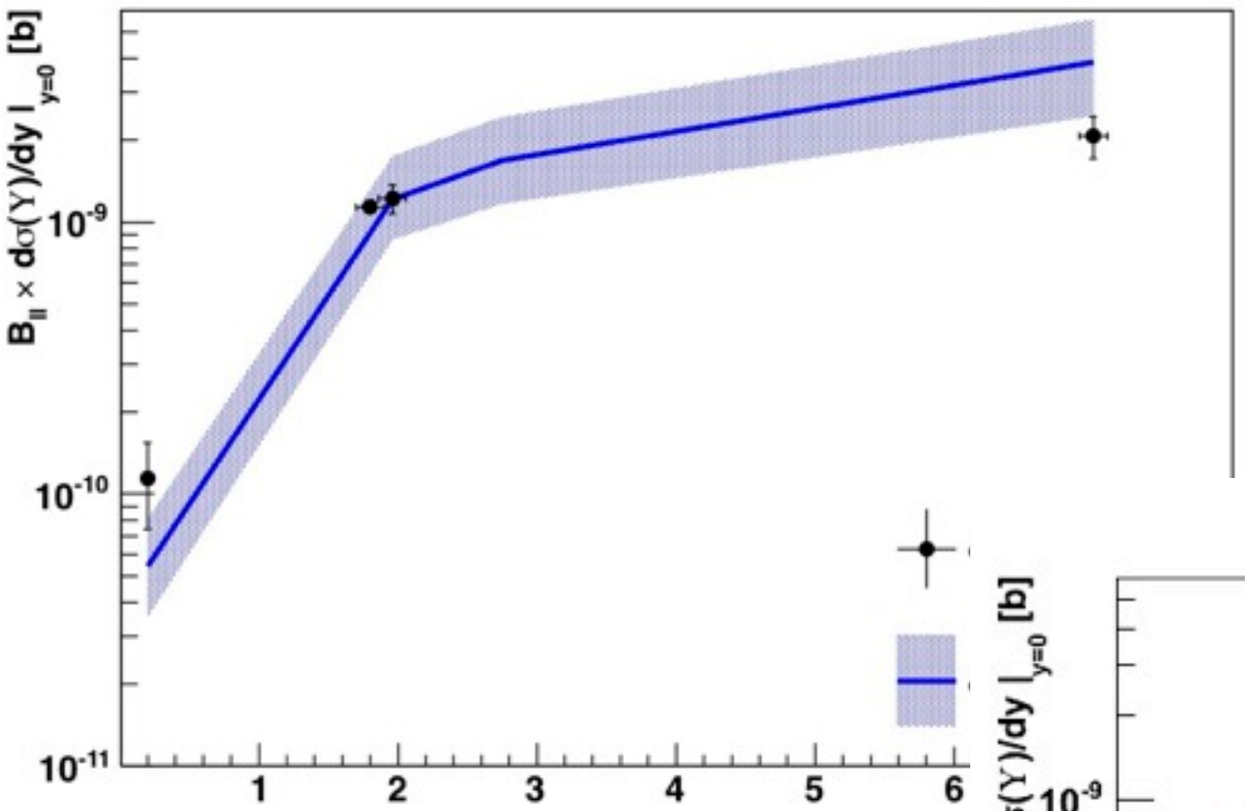

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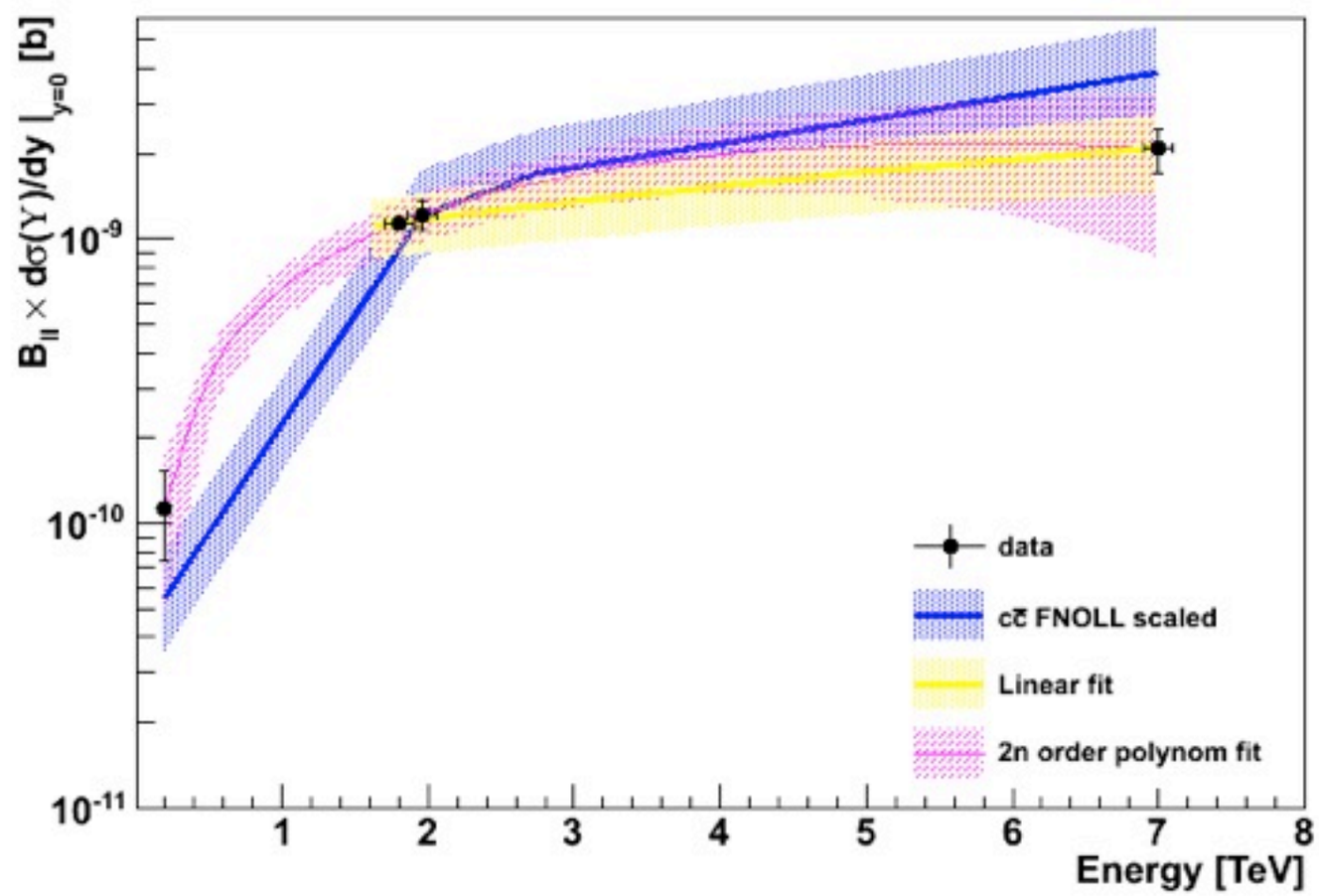
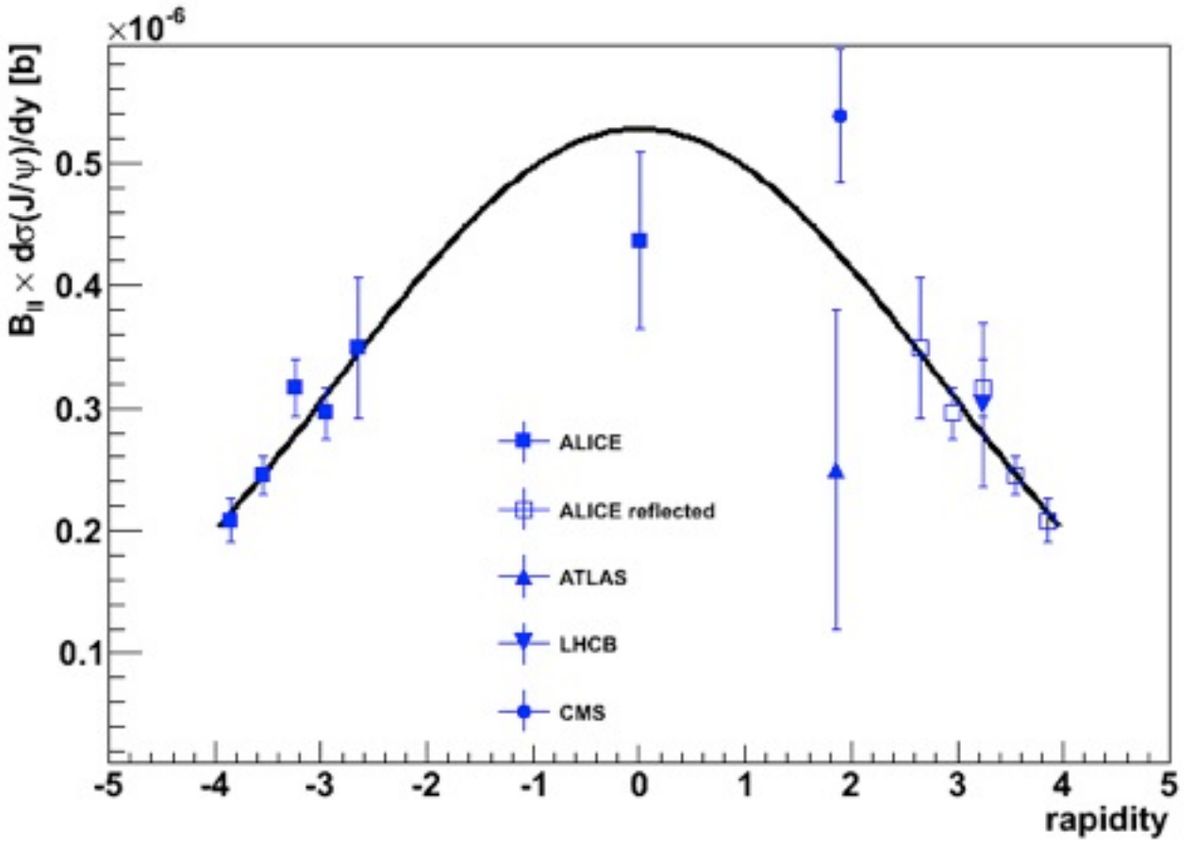


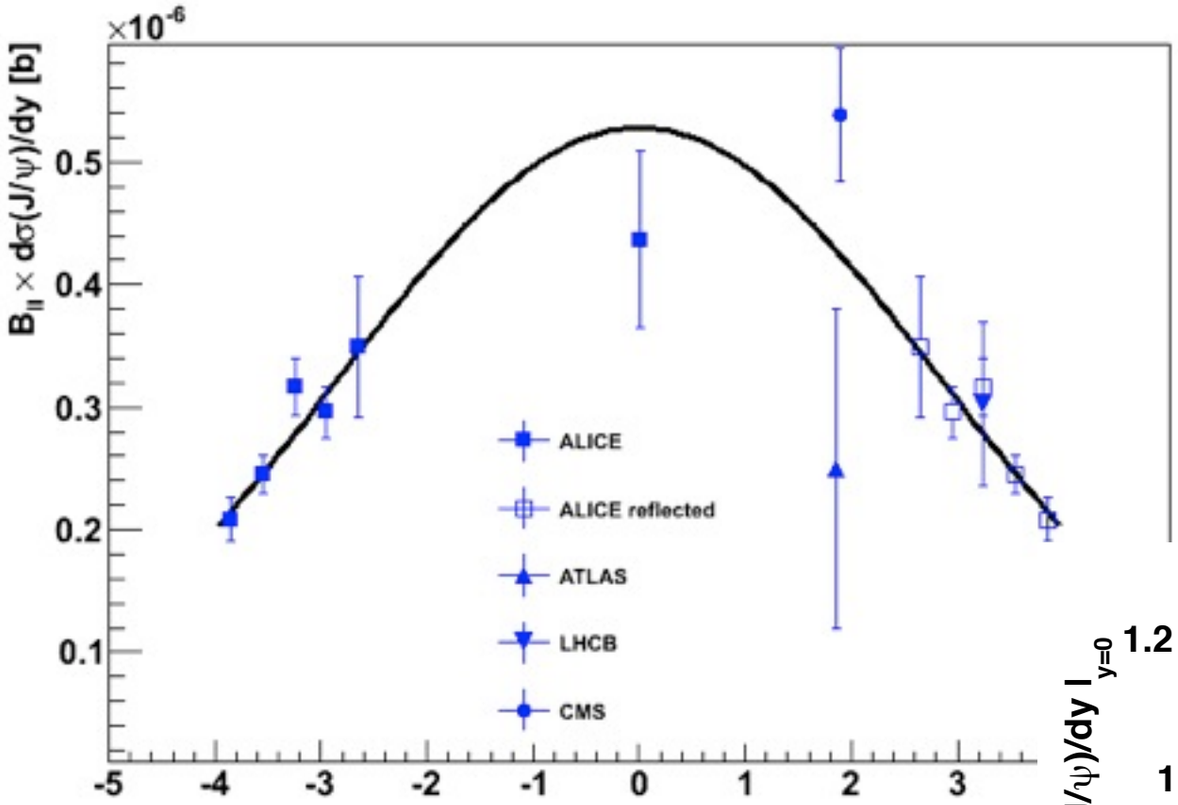
- Difficult to draw any conclusion yet, need input from other calculations

J/ψ distribution vs Rapidity & $\sqrt{s_{NN}}$



- Phenomenologically, the rapidity distribution can be fitted by a simple Gaussian
  - Fit Gaussian with mean at y=0, consider only points at y>=0 to evict double-counting
  - It works at RHIC & LHC

J/ψ distribution vs Rapidity & $\sqrt{s_{NN}}$



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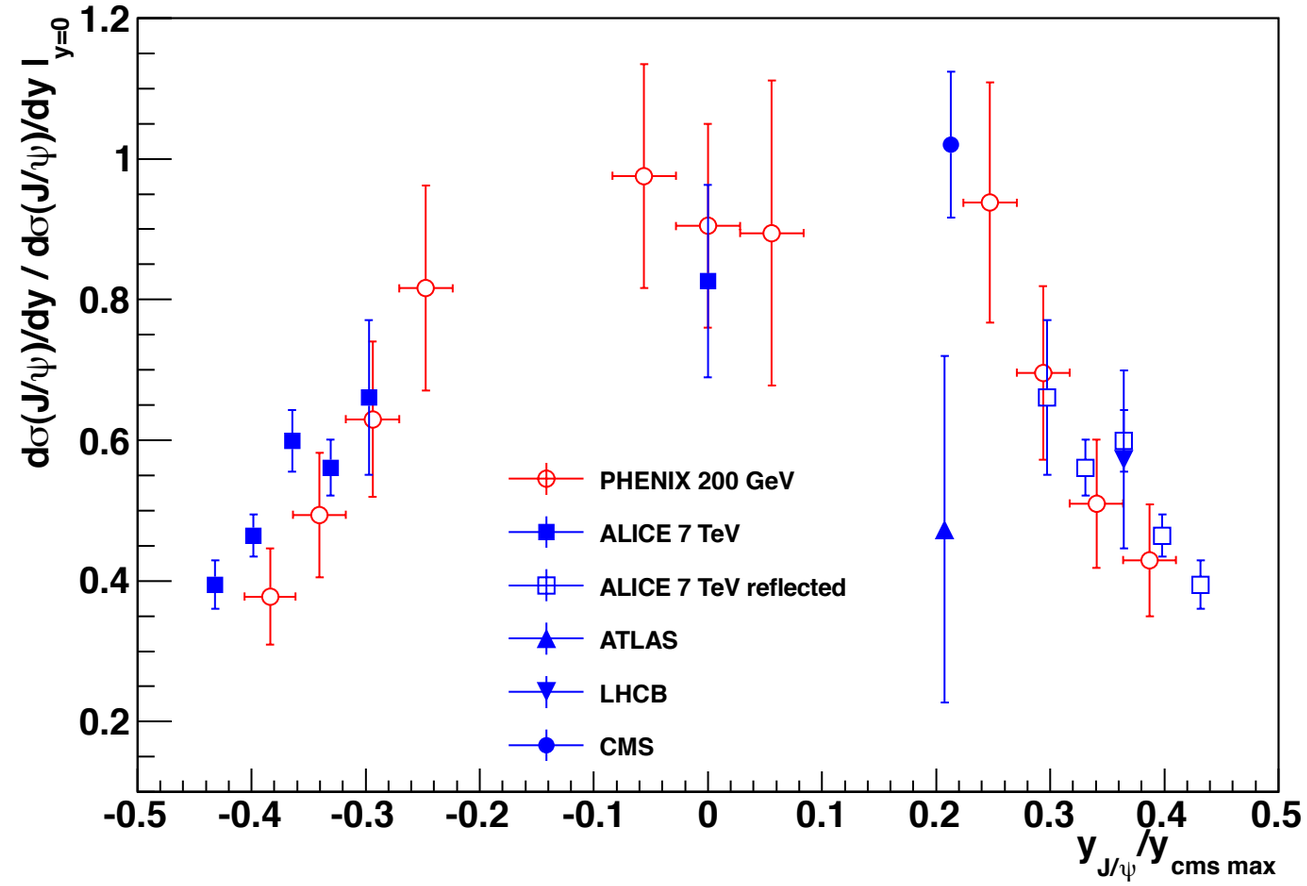
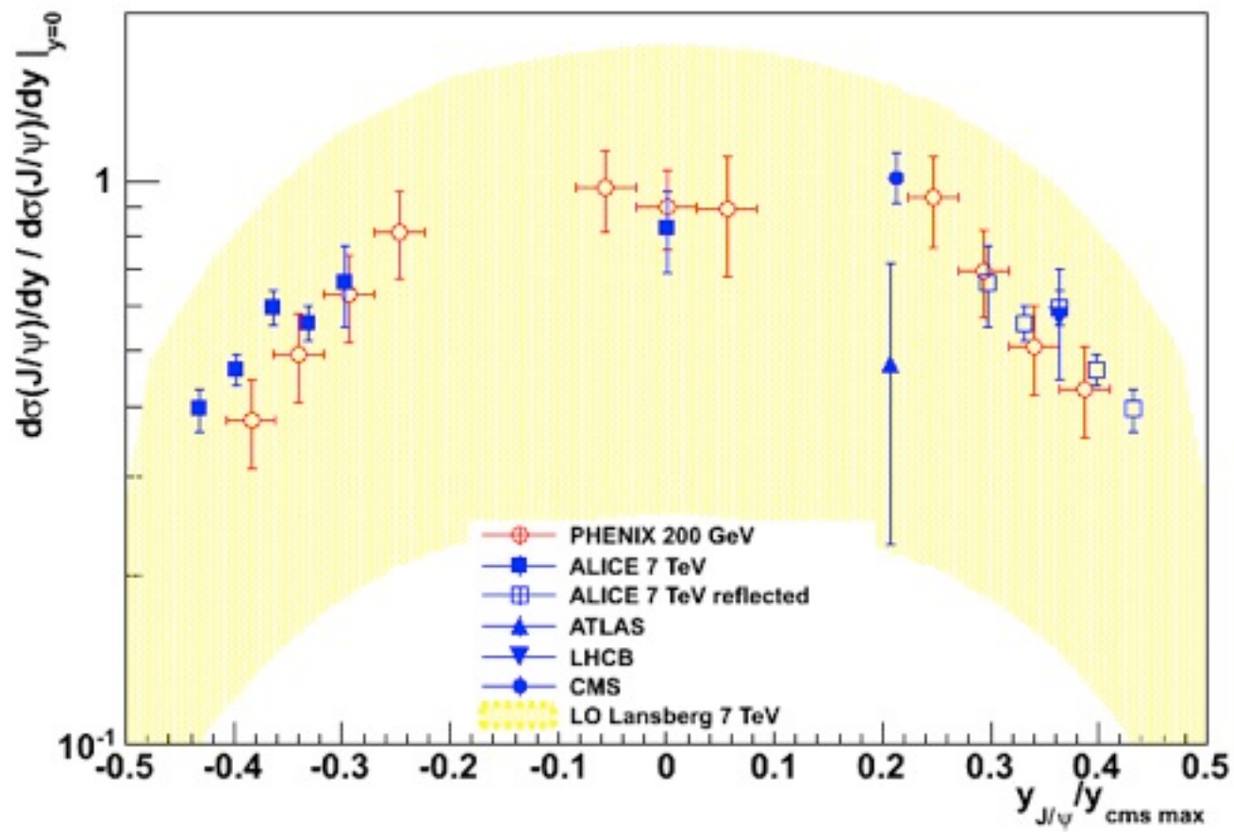
- How to model the rapidity evolution vs energy ?
- **Relative J/ψ cross-section vs its relative rapidity :** σ(J/ψ) / σ(fit y=0) vs $y_{J/\psi}$ / $y_{cms\ max}$ seems to work !!

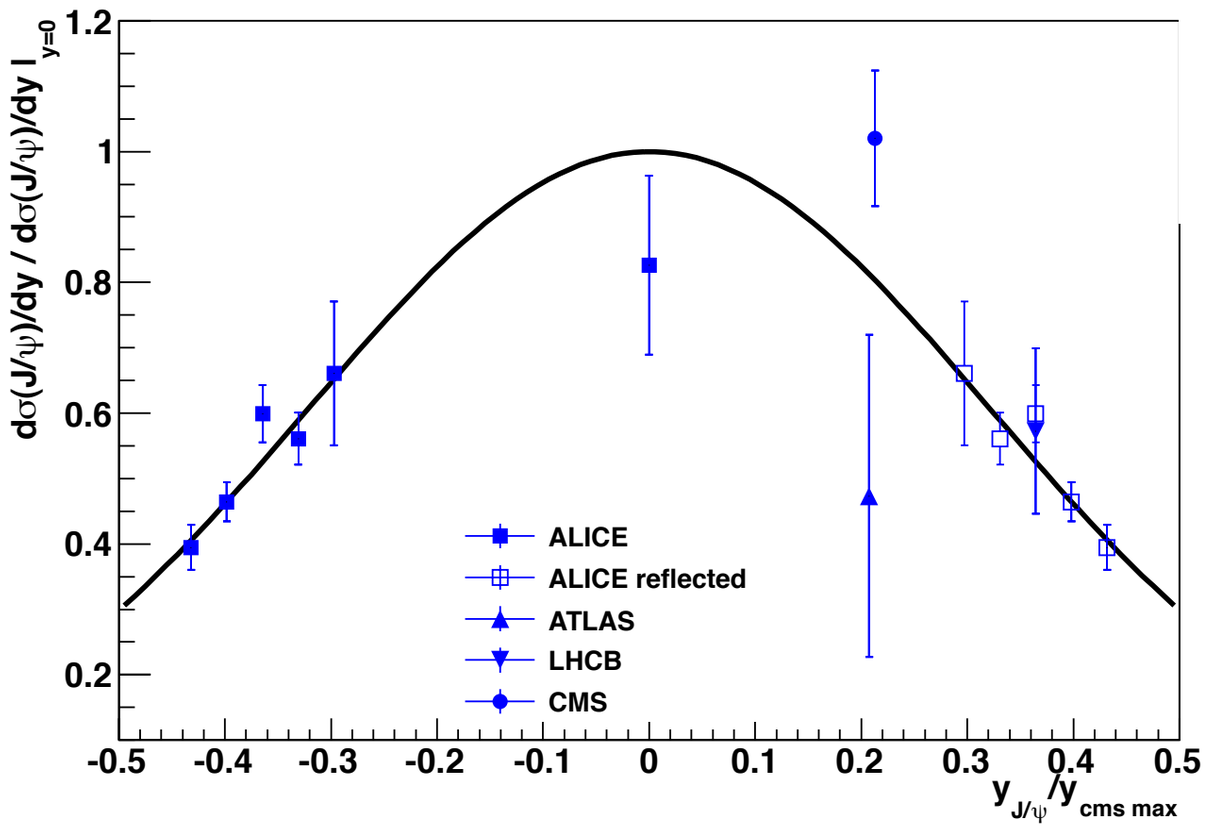
$$y_{cms\ max} = \log(\sqrt{s}/m)$$



J/ψ Rapidity Interpolation

- The shown theoretical calculation (@7TeV) shows a compatible behavior versus the relative rapidity
- The relative rapidity distribution is also well described by a Gaussian





Naive interpolation from y=0 to y=3.25

$d\sigma/dy\,|_{y=3.25}\ /\ d\sigma/dy\,|_{y=0} \sim 0.53$

Uncertainty to be determined...

Summary

- Theoretical uncertainties on the cross-section evolution with $\sqrt{s}$ are large
- Phenomenological approaches can also be explored
  - Two "naive" functions to describe the energy evolution were considered
  - The rapidity evolution can also be modeled
  - Diminish the uncertainties with the cost of imposing the tendency (?)
- Estimates for J/ψ & Υ are in progress.
- The (J/ψ) relative cross section vs the relative rapidity ($y_{J/\psi}$ / $y_{cms\ max}$) is a promising observable for the energy interpolations
- The same method should be applicable to open heavy flavors as soon as measurements will allow to interpolate.

[c.f. M. Gagliardi & A. De Falco talks]

- The pt evolution with the energy was not discussed...
- Open/hidden ratio evolution to be studied...
- Plenty of non-justified hypothesis... it'd be nice to do the measurement !

Comments are most welcome !

Thank you !