Quarkonia Measurements in ALICE Experiment

(in the first year of p+p collisions at $\sqrt{s} = 7\,\text{TeV}$)

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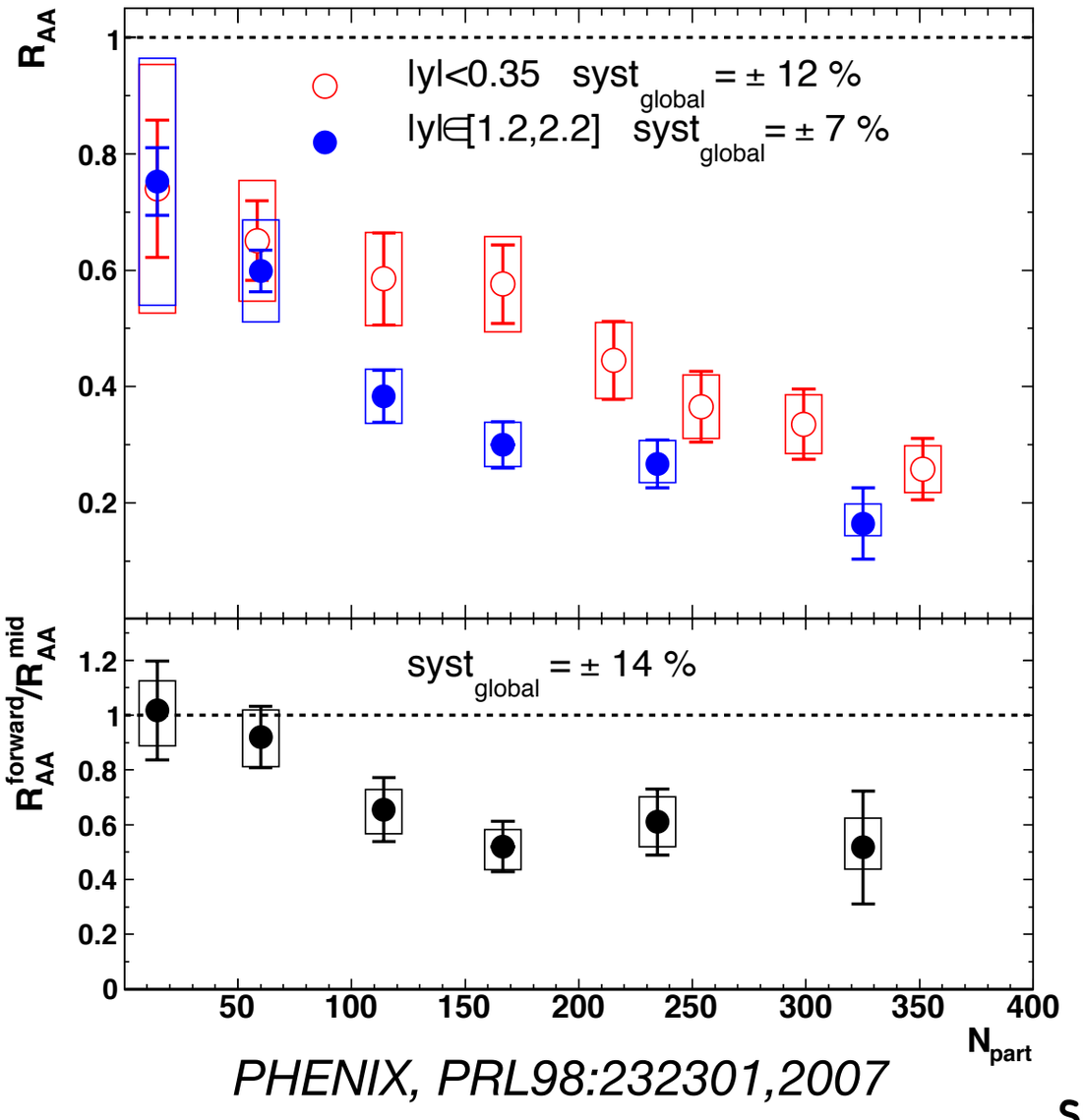
for the ALICE Collaboration

Winter Workshop on Recent QCD Advances at the LHC, Les Houches

Contents

Introduction : Quarkonia in A+A Collisions



PHENIX, PRL98:232301,2007

- *J*/ψ dissociation by color screening could serves as a QGP signature

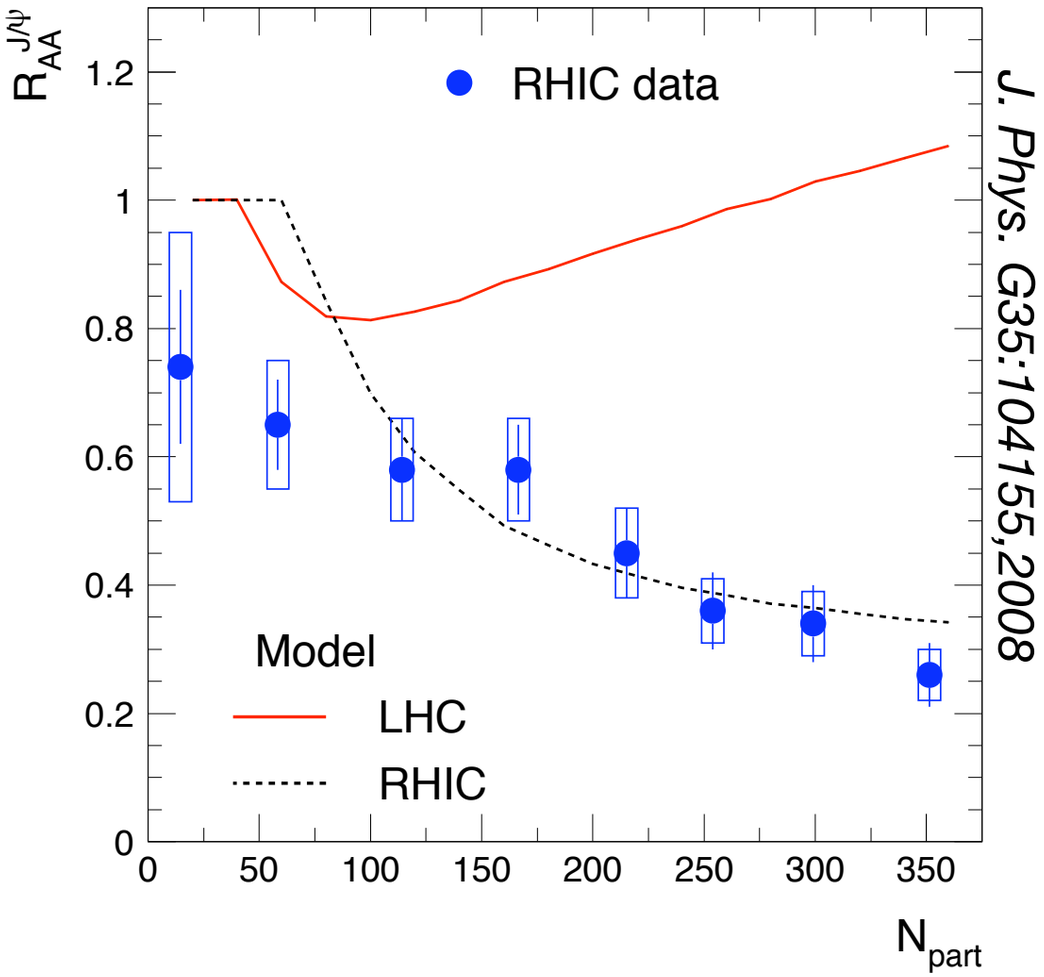
  [Phys. Lett. B 178, 416 (1986)]

- Two big experimental suprises
  - similar suppression at SPS and RHIC
  - stronger suppression at forward rapidity

$$R_{AA}^{J/\psi} = \left(dN_{J/\psi}^{AuAu}/dy\right) \Big/ \left(N_{coll} \cdot dN_{J/\psi}^{pp}/dy\right)$$

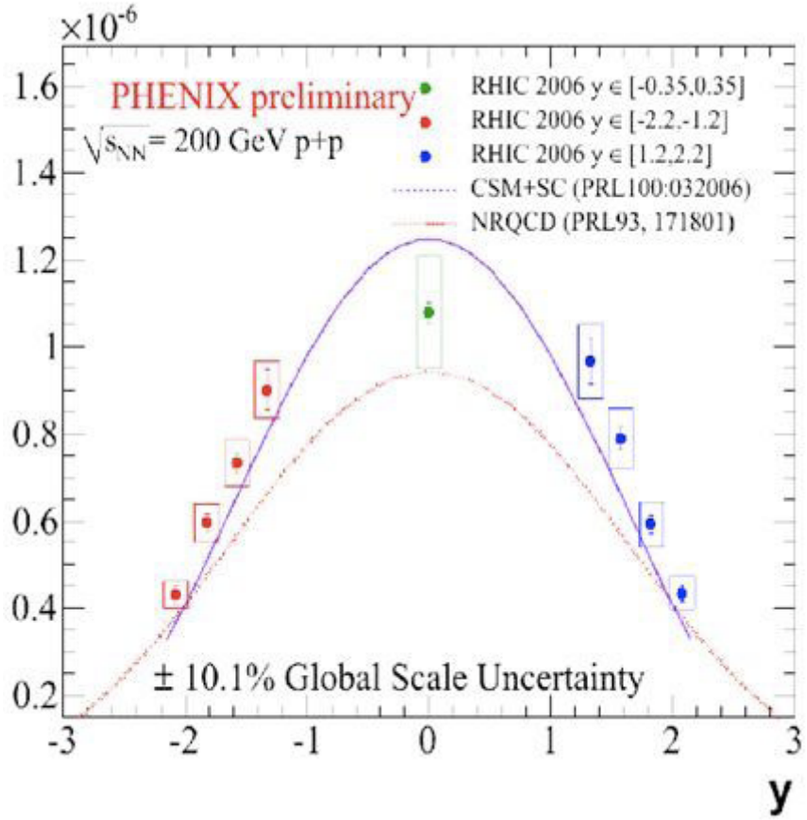
suppression quantified by nuclear modification factor

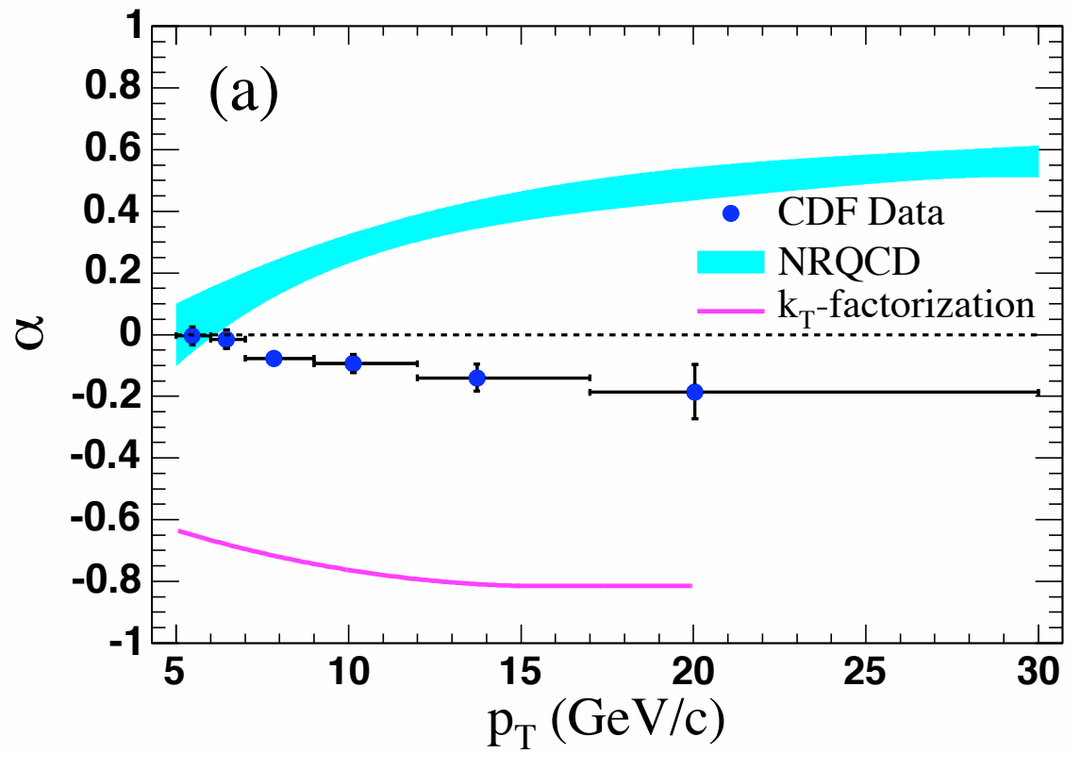
Physics Motivation : J/ψ production at LHC



- Suppression or enhancement?
  - Debye screening vs charm thermalization
- Distinguishable differences @ LHC
  - ~30 times higher $\sqrt{s}$ than RHIC (14 times so far)
  - unexplored x_{Bj} region (10^{-3}~10^{-5})
  - larger statistics
    - σ_{cc} ~ 10 × RHIC
    - σ_{bb} ~ 100 × RHIC
- Secondary J/ψ from B decay

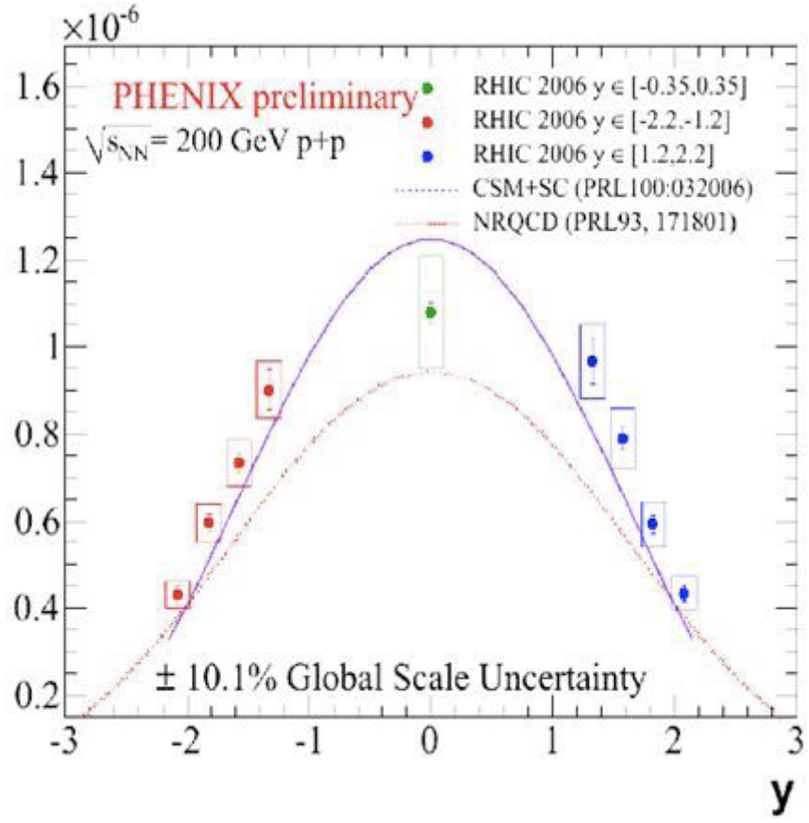
Introduction : Quarkonia in p+p collisions

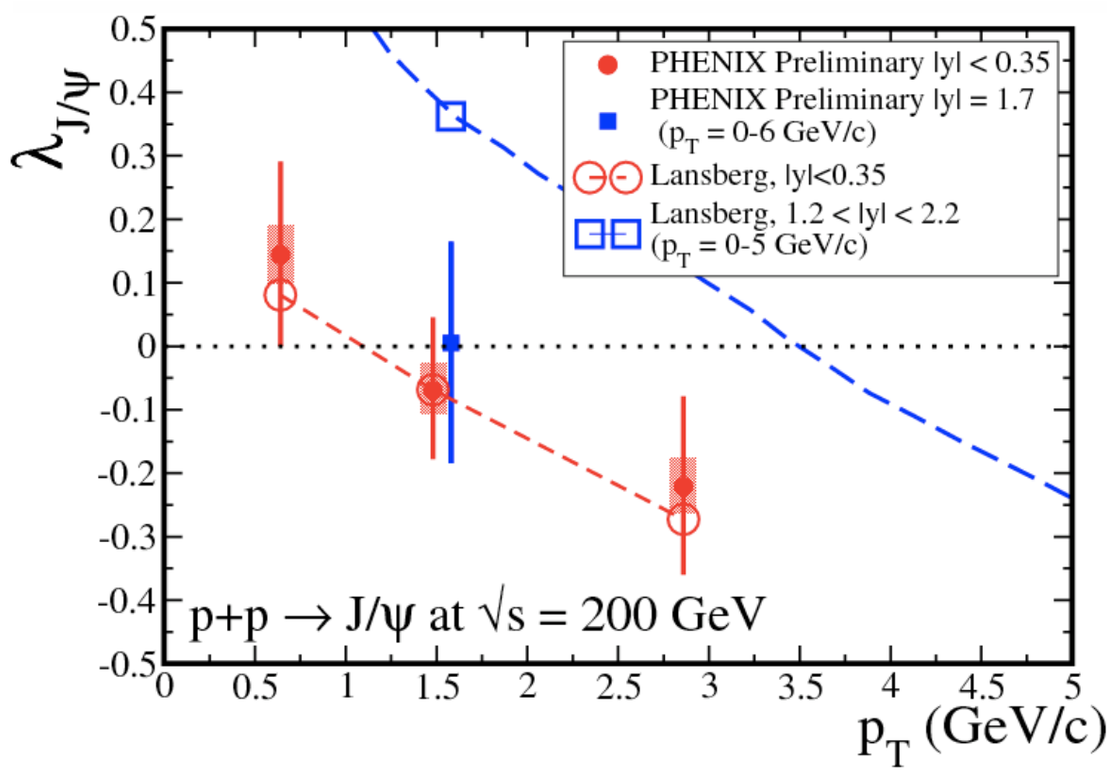




- Reference for heavy ion data
- Still many theoretical uncertainties
  - NRQCD (COM) fails in predicting polarization (CDF Run II)
  - CSM (+ s-channel cut) reproduces dσ/dy (to some extent) and polarization
    - but still over-estimates at forward rapidity

Introduction : Quarkonia in p+p collisions





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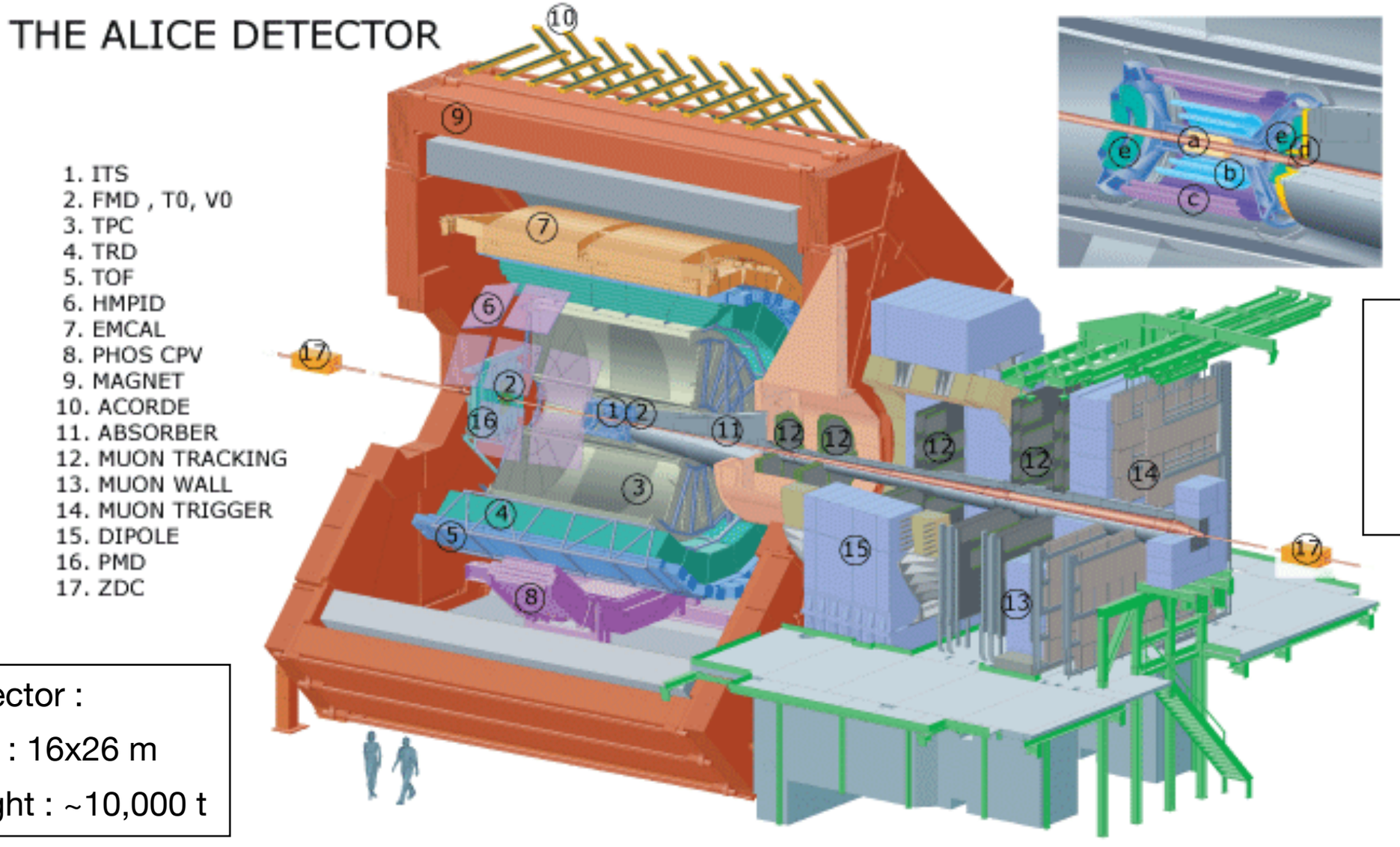
ALICE Detector

A Large Ion Collider Experiment



Collaboration :

>1000 members

> 100 institutes

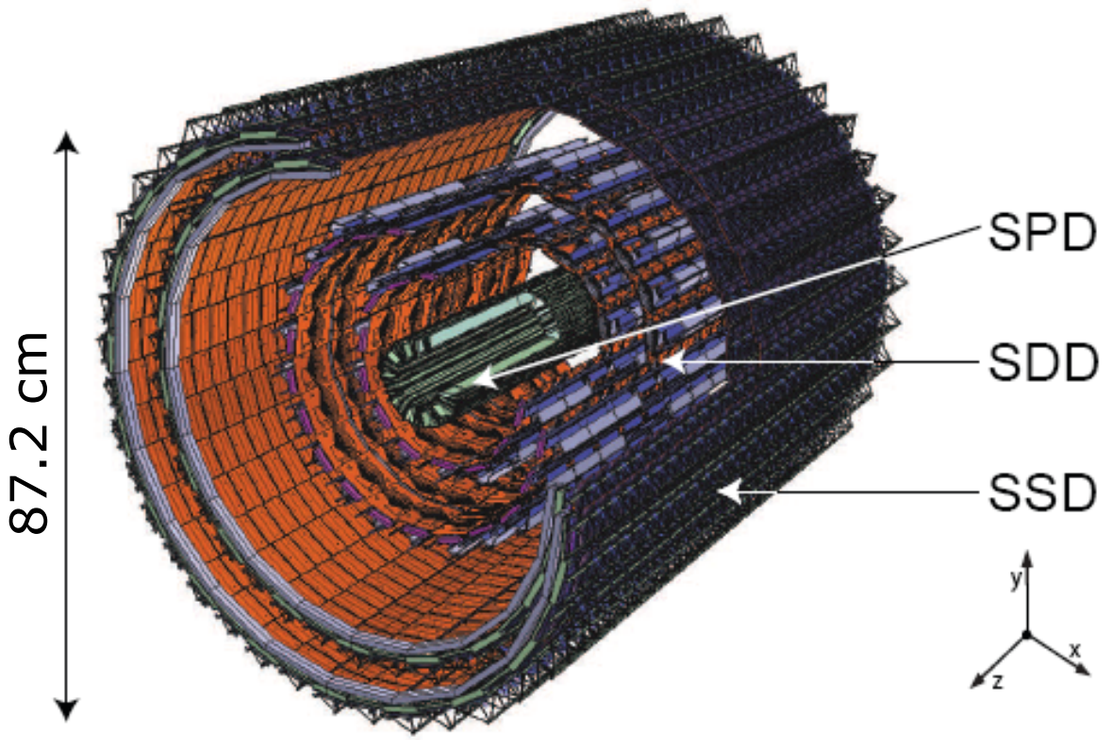
> 30 countries

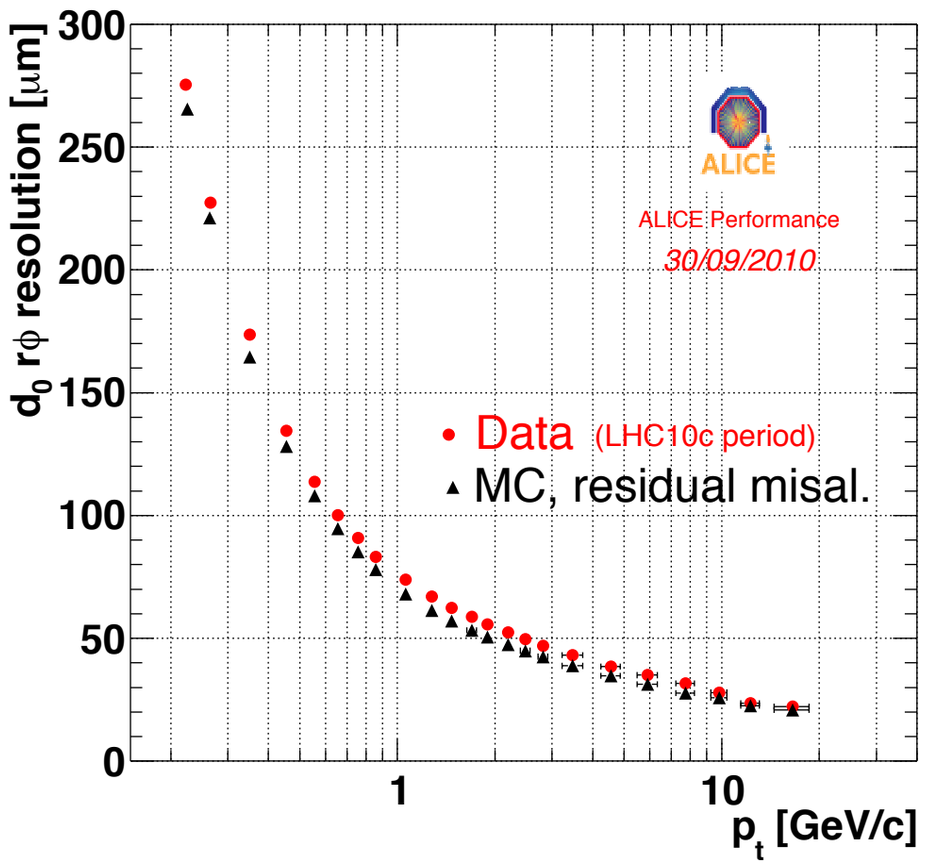
Detector :

Size : 16x26 m

weight : ~10,000 t

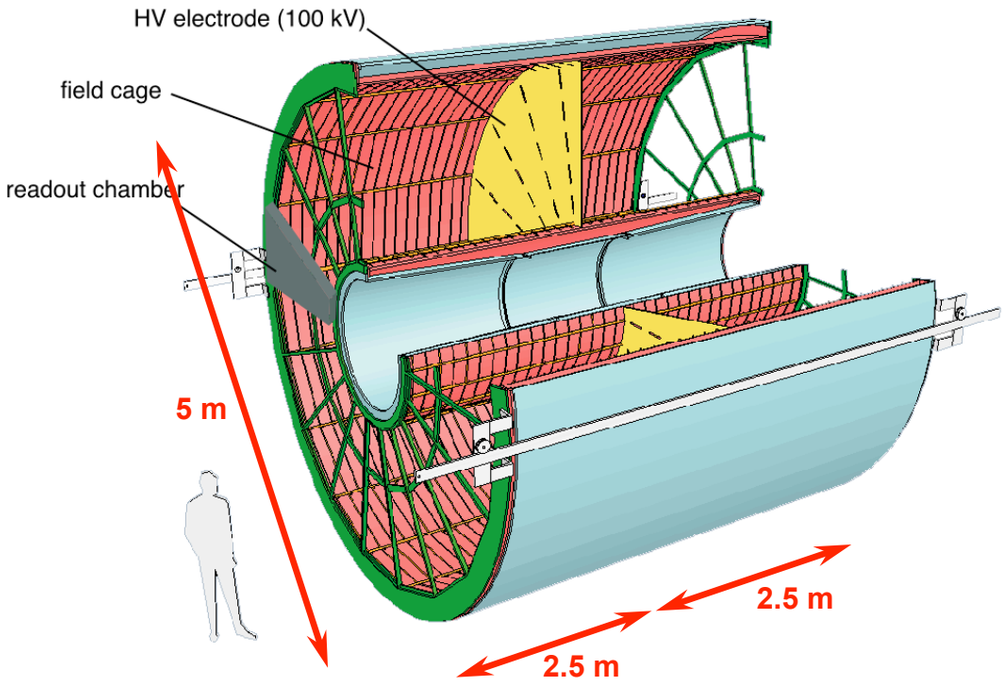
Inner Tracking System (ITS)

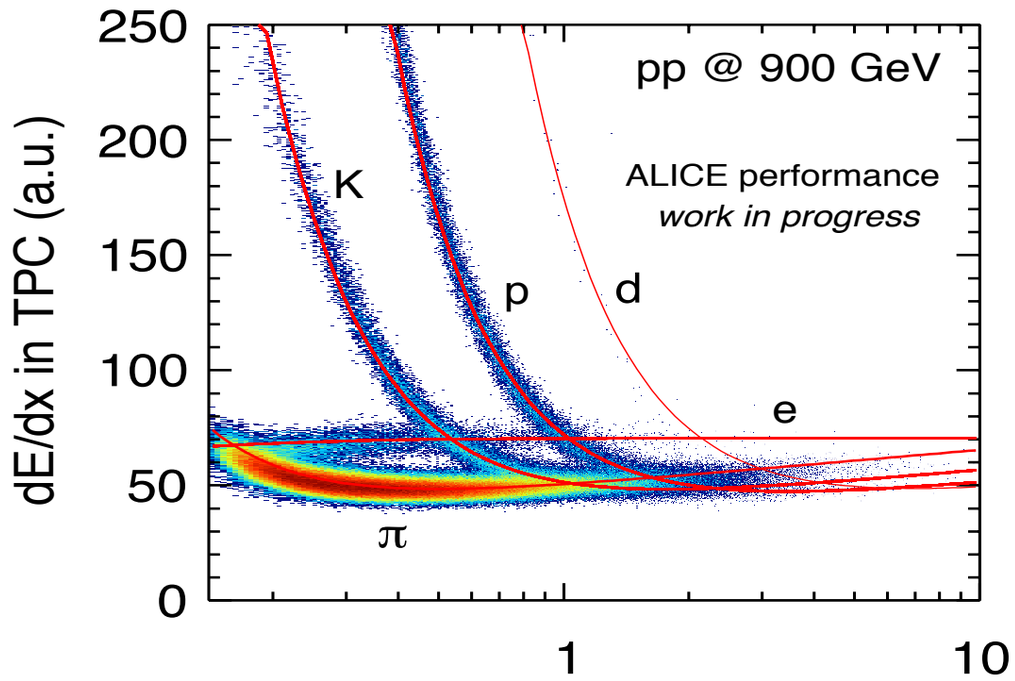




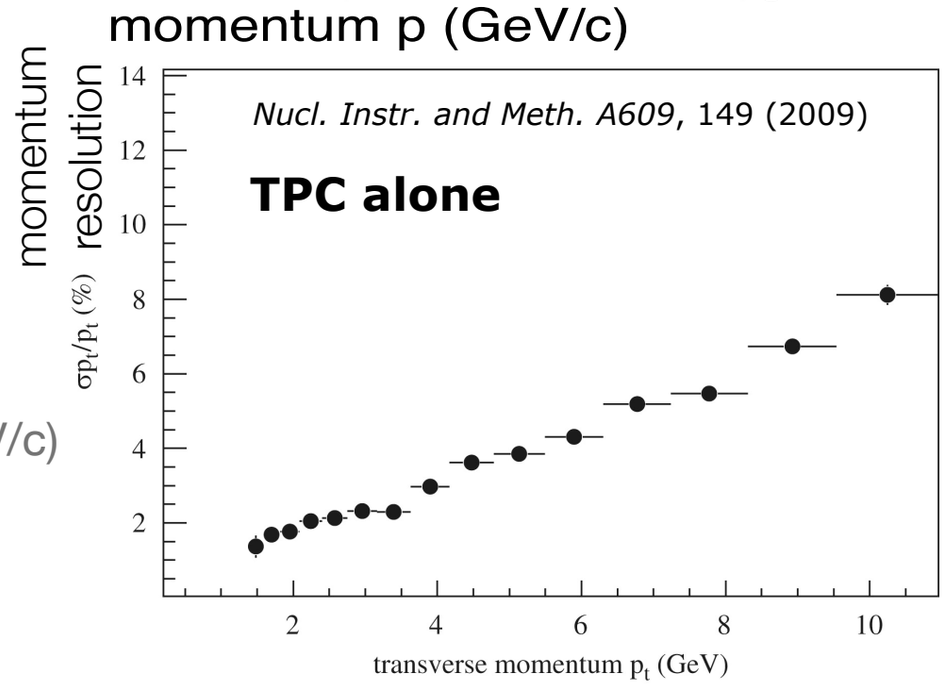
- six layers of silicon detectors
- determination of primary and secondary vertex
- PID and tracking of low momentum particles
- help to improve transverse momentum measurement of the TPC
- help to reject conversion background by requiring hit(s) in first two layers
- impact parameter resolution close to the designed value

Time Projection Chamber (TPC)

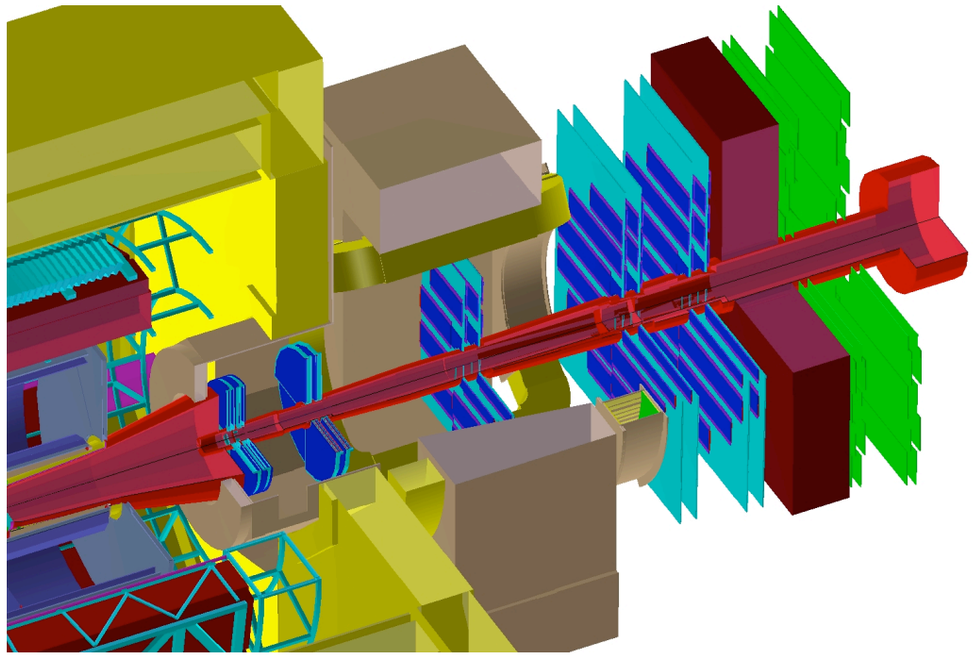


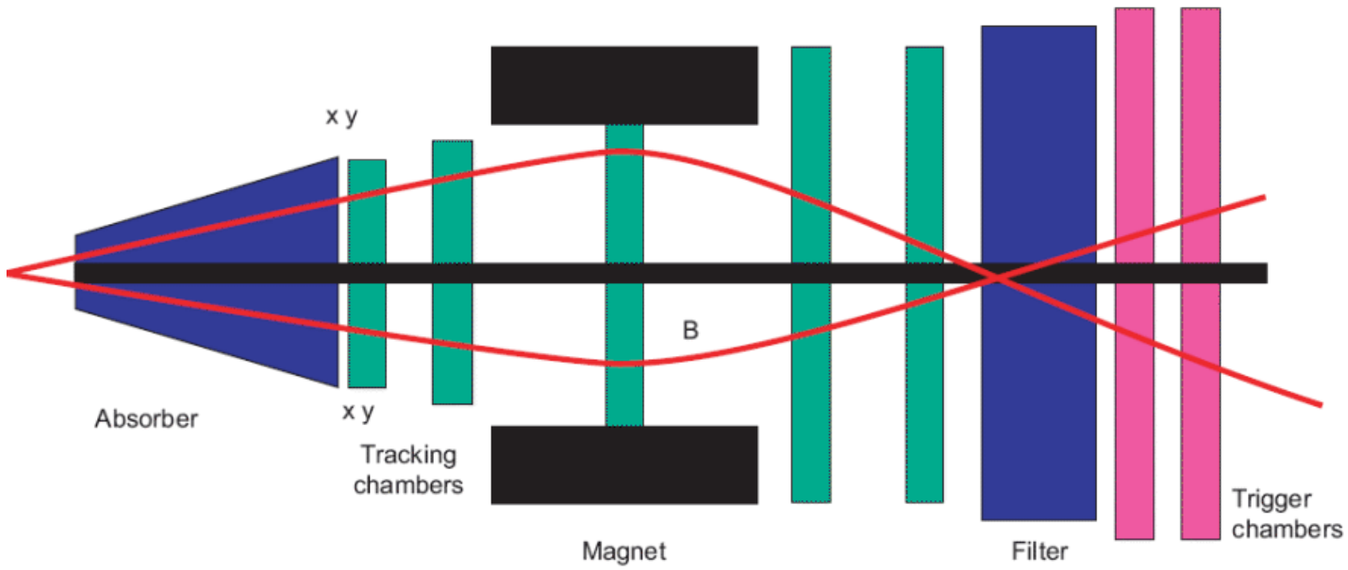


- main tracking device, the largest TPC ever (95 m^2)
- up to 160 space and charge points per track
- precision ~500 μm in all 3-dimensions
- momentum resolution : 7 % at 10 GeV/c (<1 % at p_T < 1 GeV/c)
- allows to distinguish the charged particle species (via dE/dx)



Muon Spectrometer





- 16 m long, $p_\mu \gtrsim 4$ GeV/c , $2.5 < \eta < 4.0$
- front absorber (carbon, concrete and steel), reject primary hadrons
- dipole magnet (3 T·m) : bending plane in y direction
- tracking chambers (5 stations of 2 Cathode Pad Chamber planes, ~100 m^2)
- muon trigger (4 RPC planes)

Data Analysis Details

J/ψ measurements in ALICE

- prompt J/ψ
  - direct production
  - feed down from higher mass resonances (χ_c, ψ' , …)
- secondary J/ψ — from B-hadron decay
  - possible only in the central barrel
    (impact parameter resolution $\sigma_{r\varphi} < 60$ μm for $p_T > 1$GeV)

Preliminary ALICE results refer to inclusive J/ψ production

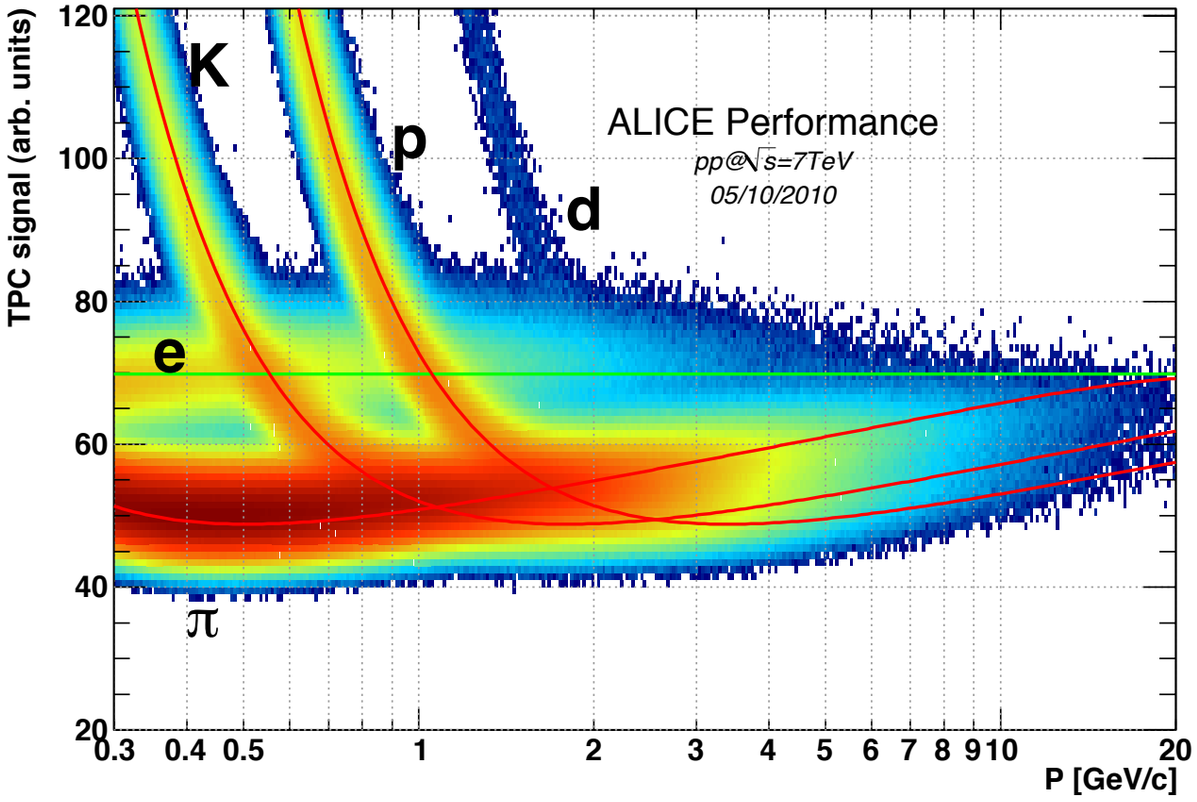
- in ALICE :
  - e^+e^- channel in the central barrel ($|y| < 0.9$)
  - $\mu^+\mu^-$ channel in the forward muon spectrometer ($2.5 < y < 4.0$)

Analysis Strategy for Quarkonium Measurement

	e+e- analysis	$\mu^+\mu^-$ analysis
Tracking	ITS+TPC+(TRD)	muon tracking chamber
PID	dE/dx in TPC TOF and TRD (future)	front absorber / iron wall muon trigger detector
Selecting good tracks	pT > 1GeV, # of TPC cluster>90, etc	1 muon matching the trigger R_{abs} cut, etc
Signal extraction	direct bin counting	Crystal-Ball shape + double gaussian

- Efficiency calculation
  - based on simulation, realistic (CDF scaled) p_T and y distribution adopted
- Systematic error estimation
  - cut variation, two extreme polarizations, MC vs data comparison

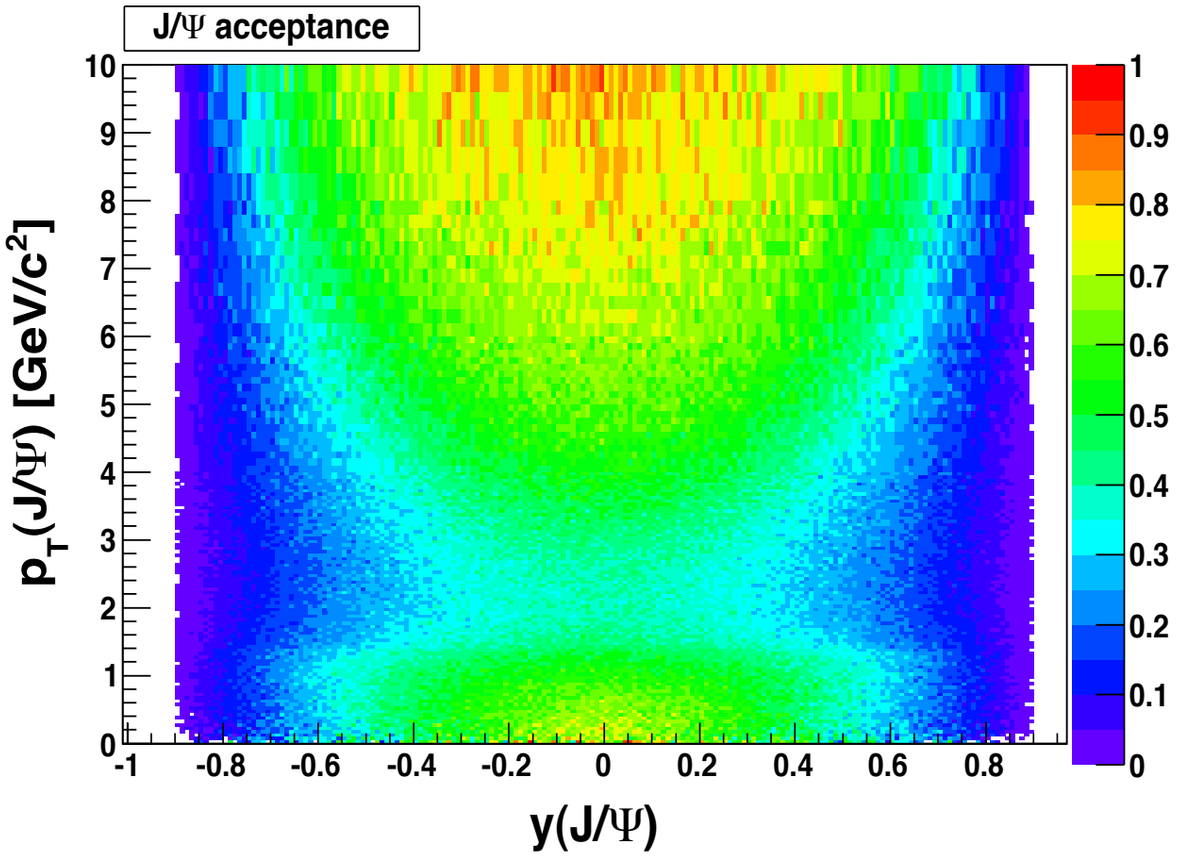
Particle Identification

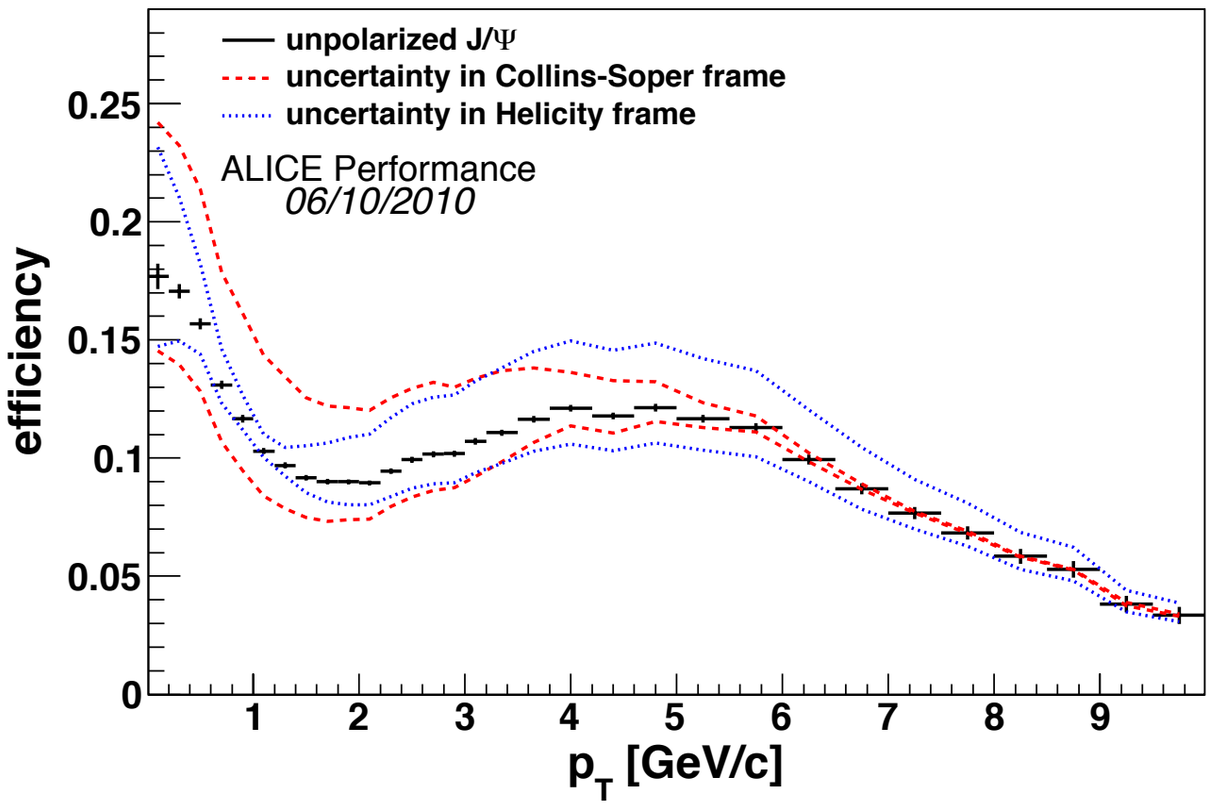


- e⁺e⁻ analysis
  - TPC based PID in this analysis (dE/dx distribution)
  - 3σ bands of π and p line are excluded
- μ+μ- analysis
  - front absorber rejects primary hadrons
  - iron wall removes hadrons emerge from the front absorber

ALICE uses almost all known PID techniques

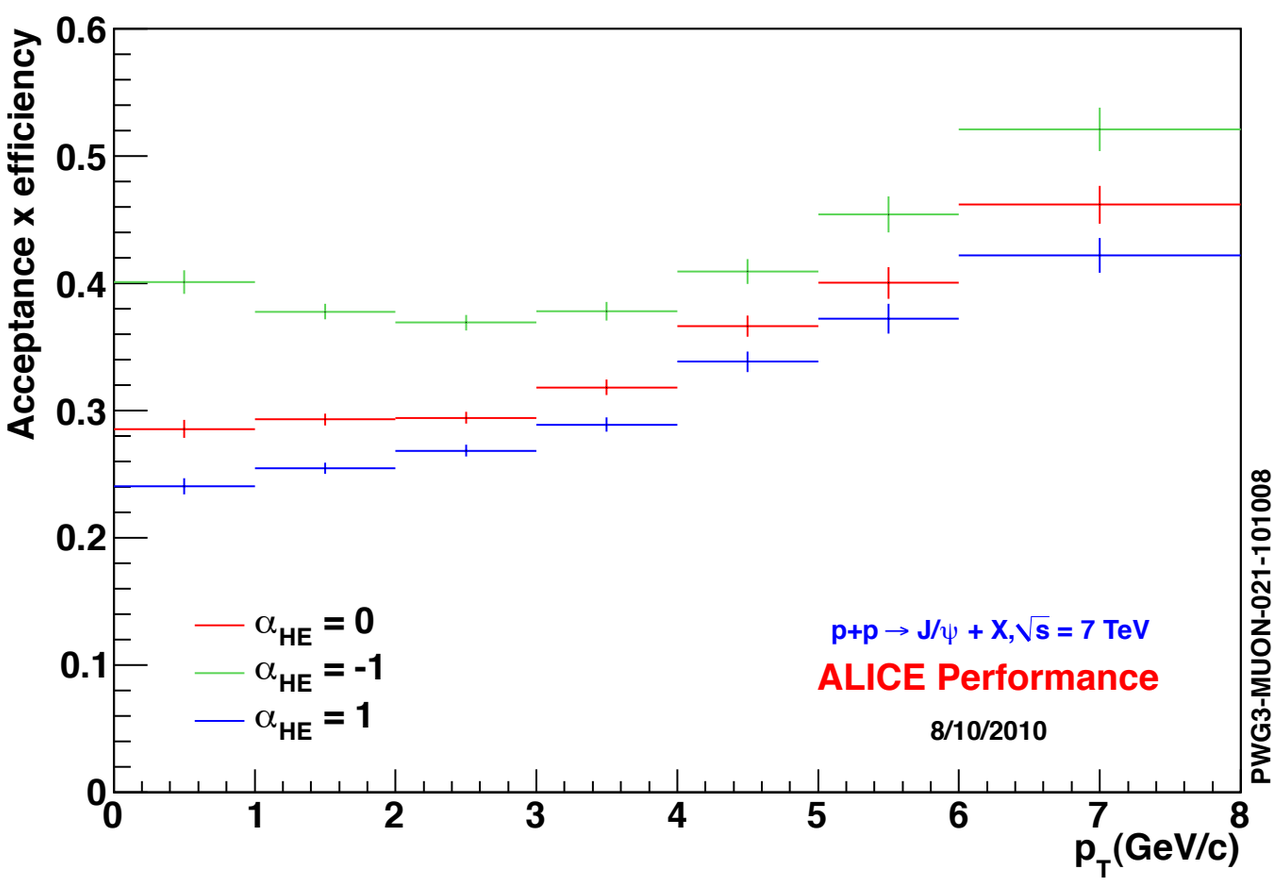
Kinematics and Efficiency - e^+e^- channel

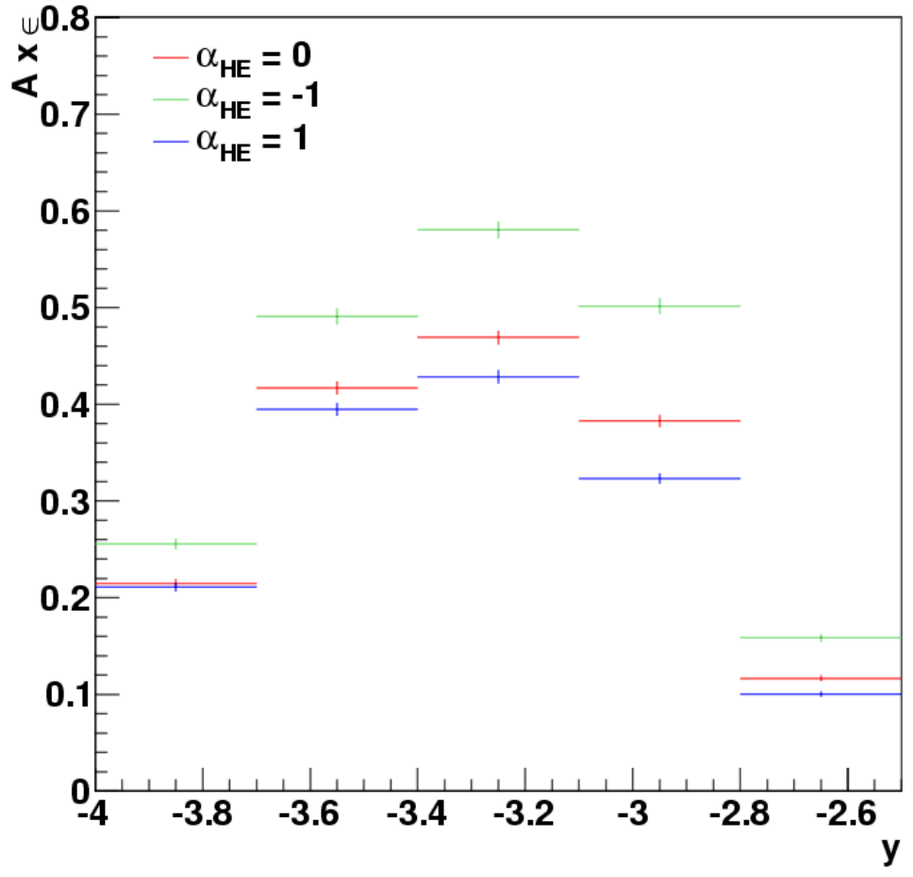




- CDF extrapolated p_T distribution used
- $|y|<0.9$ to avoid detector edge effect, $p_T>1$ GeV to reject conversions
- ALICE can measure *J*/ψ p_T down to $p_T=0$

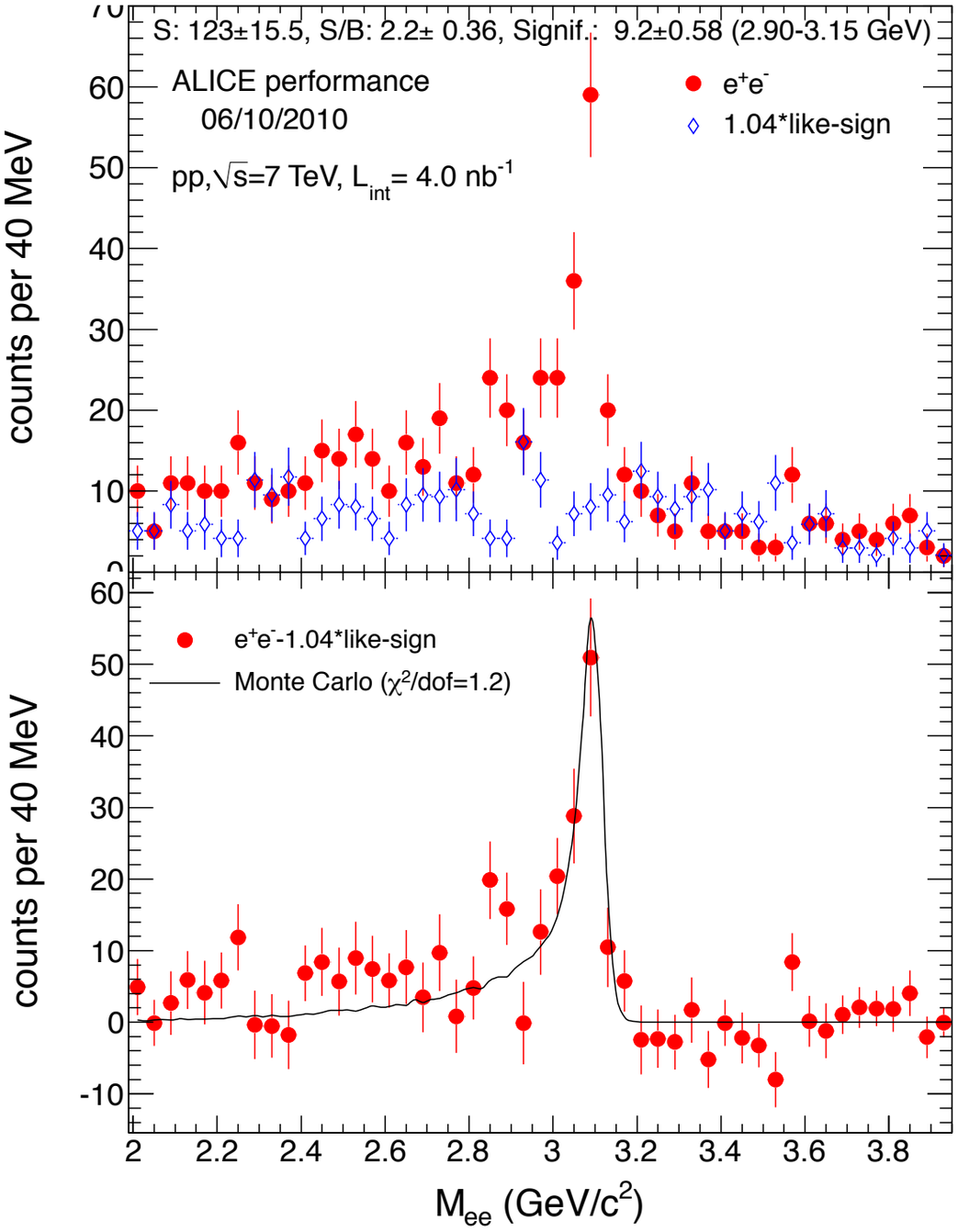
Efficiency - $\mu^+\mu^-$ channel





- Realistic y and p_T distributions of *J*/ψ was used :
  - pT → CDF extrapolation
  - y → CEM calculation

Invariant Mass Distributions - e^+e^- channel



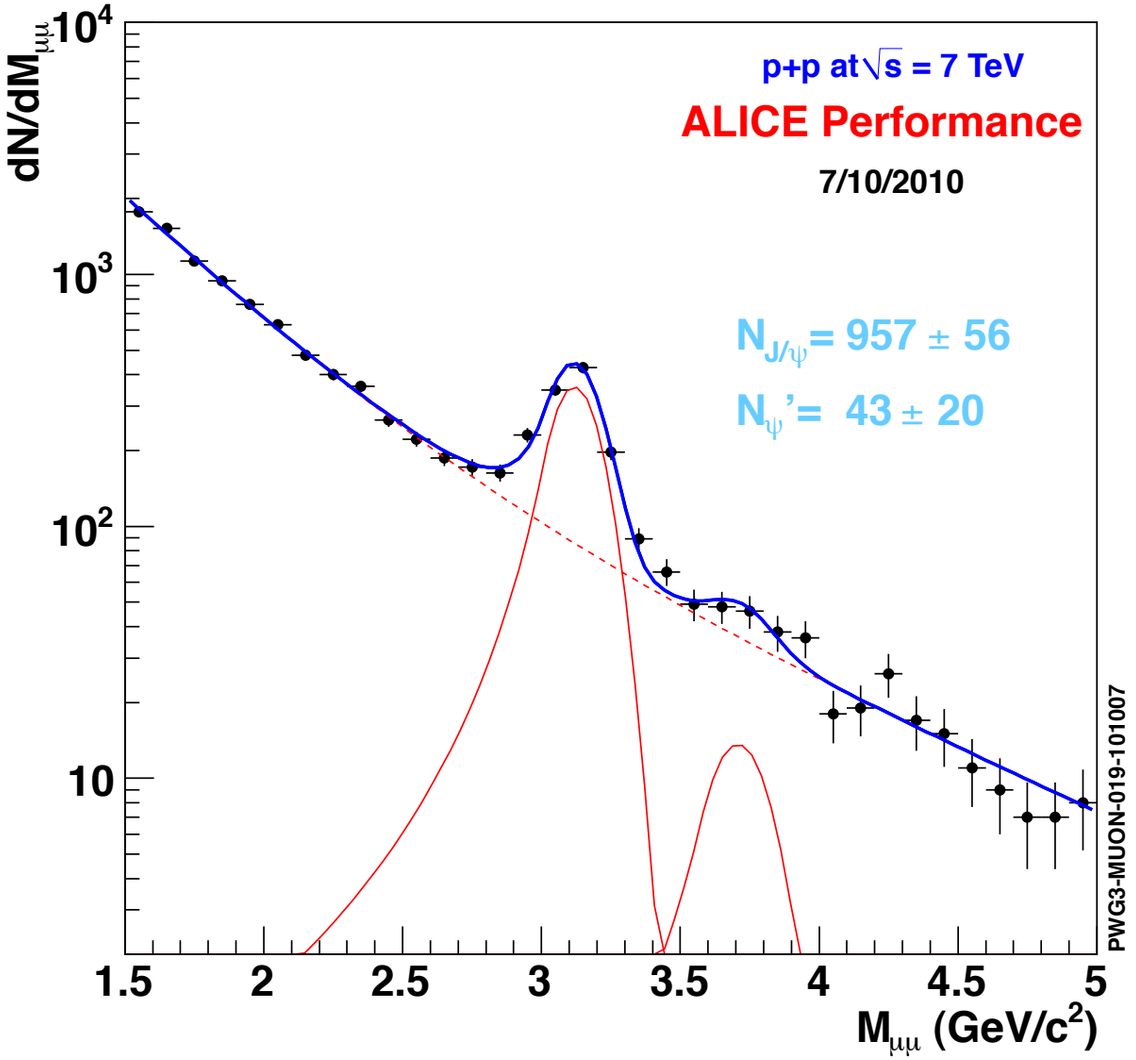
- **Background subtraction**
  - like-sign subtraction method

$$N_{signal} = N_{+-} - 2\sqrt{N_{++} \times N_{--}}$$

  - normalized wrt the range [3.2,4.0]
  - residual background due to correlated charm components

- **Signal extraction**
  - bin counting
  - integral range [2.92, 3.16] GeV/c^2
  - 69% of total J/ψ's (MC line)

Invariant Mass Distributions - $\mu^+\mu^-$ channel



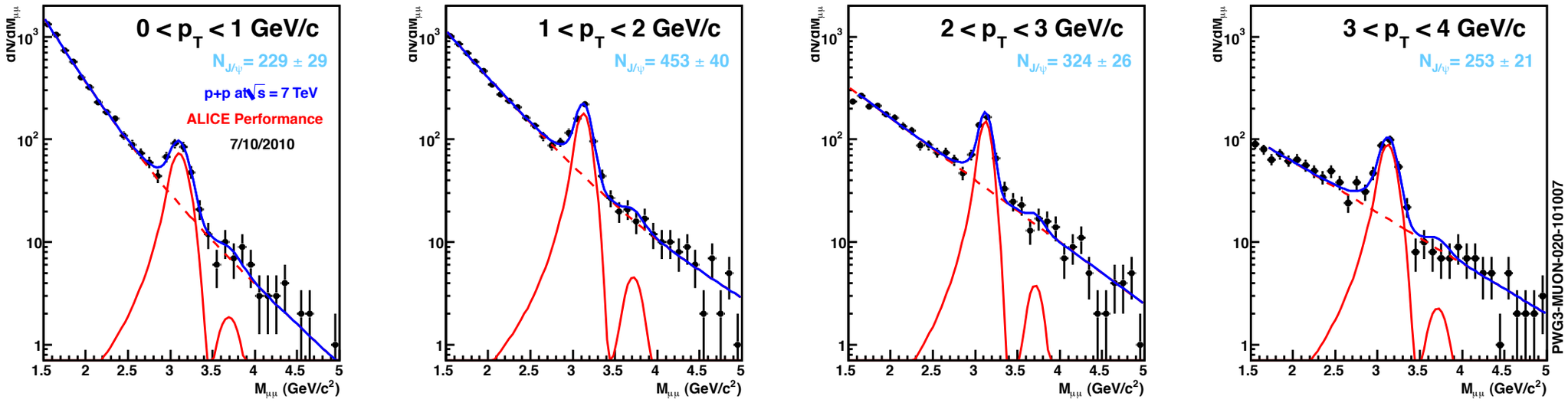
- **Signal fitting**
  - Crystal-Ball function for signal
  - two exponentials for the background
  - ψ(2S) signal is also well visible

- **for the cross section**
  - statistics for this analysis

$N_{J/\psi} = 1909 \pm 78$

S/B (2.9<M<3.3) ~ 2.4

Invariant Mass distributions in 7 p_T bins



- Differential distributions refer to a data sample corresponding to L=11.6 nb^{-1}
- *J*/ψ peaks are clearly visible in each p_T bin

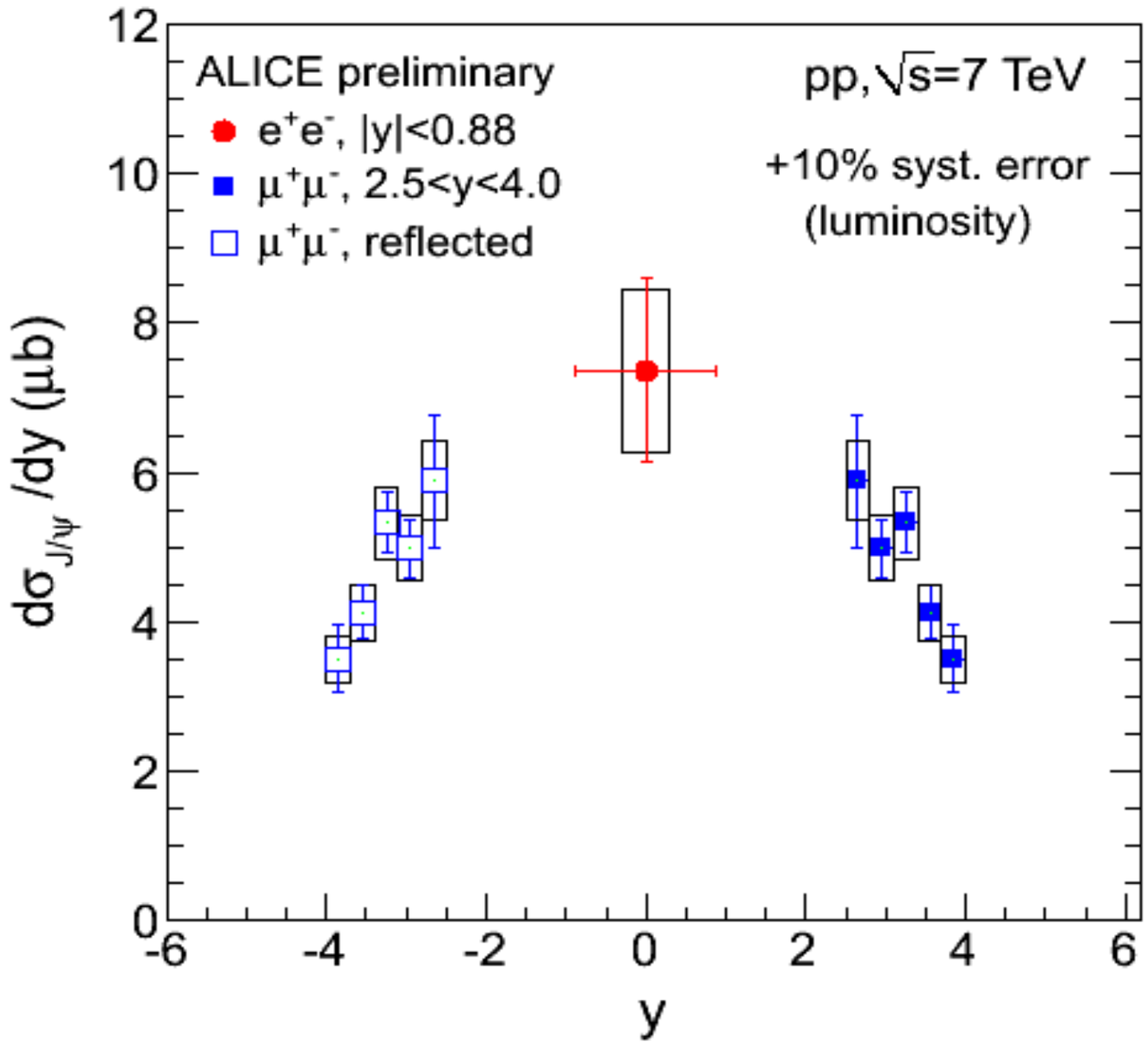
Systematic Errors

channel	**e^+e^-**		**$\mu^+\mu^-$**	
signal extraction	8%		7.5%	
acceptance input	1%		2%	
trigger efficiency	0%		4%	
reconstruction	10%		2%	
luminosity	10%			
branching ratio	1%			
total error	**18%**		**13.5%**	
polarization frame	λ=-1	λ=+1	λ=-1	λ=+1
Collins-Soper	+25%	-12%	+31%	-15%
helicity	+20%	-10%	+22%	-10%

preliminary values!

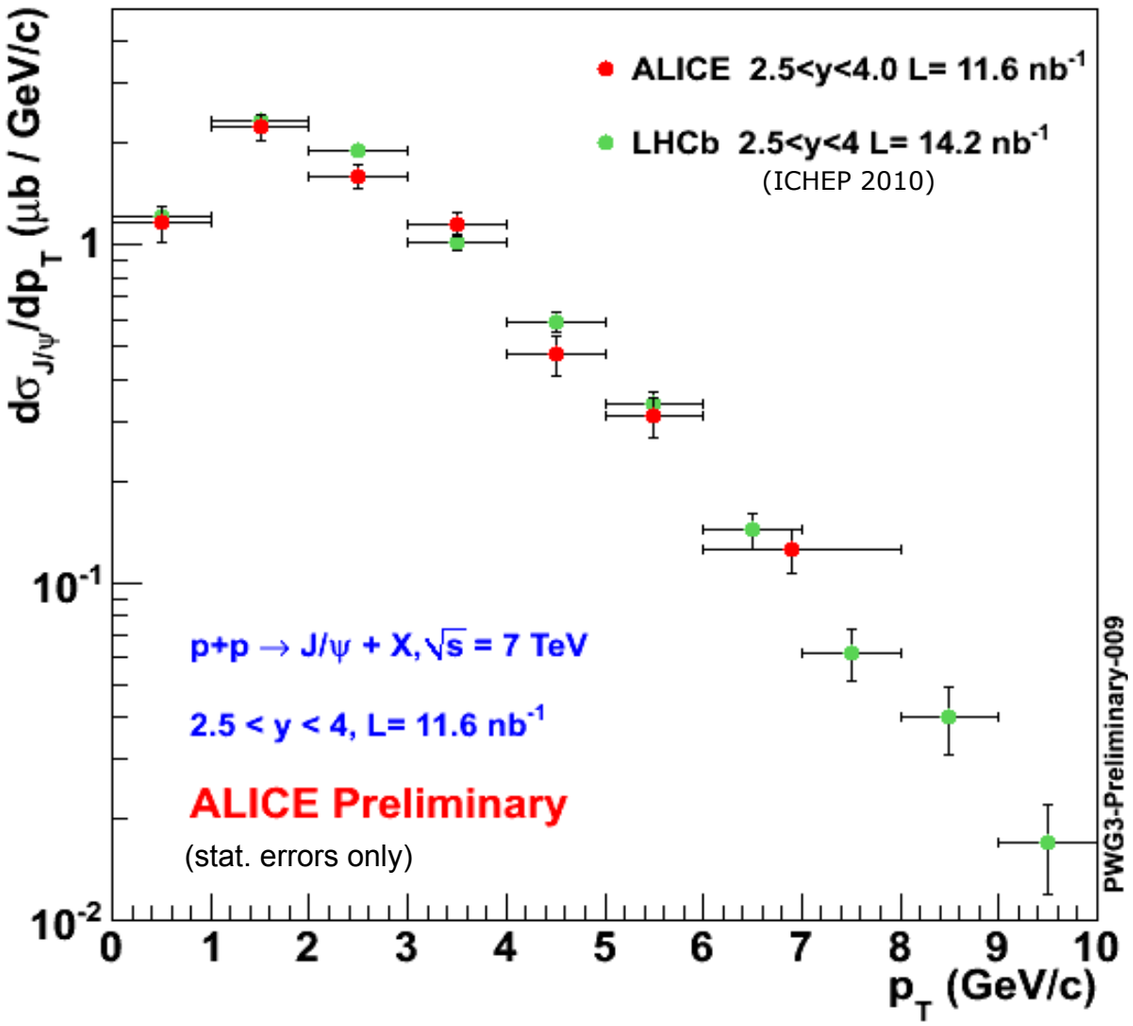
Results

Differential Cross Section : $d\sigma_{J/\psi}/dy$



- *J*/ψ production cross section measured in a broad rapidity range

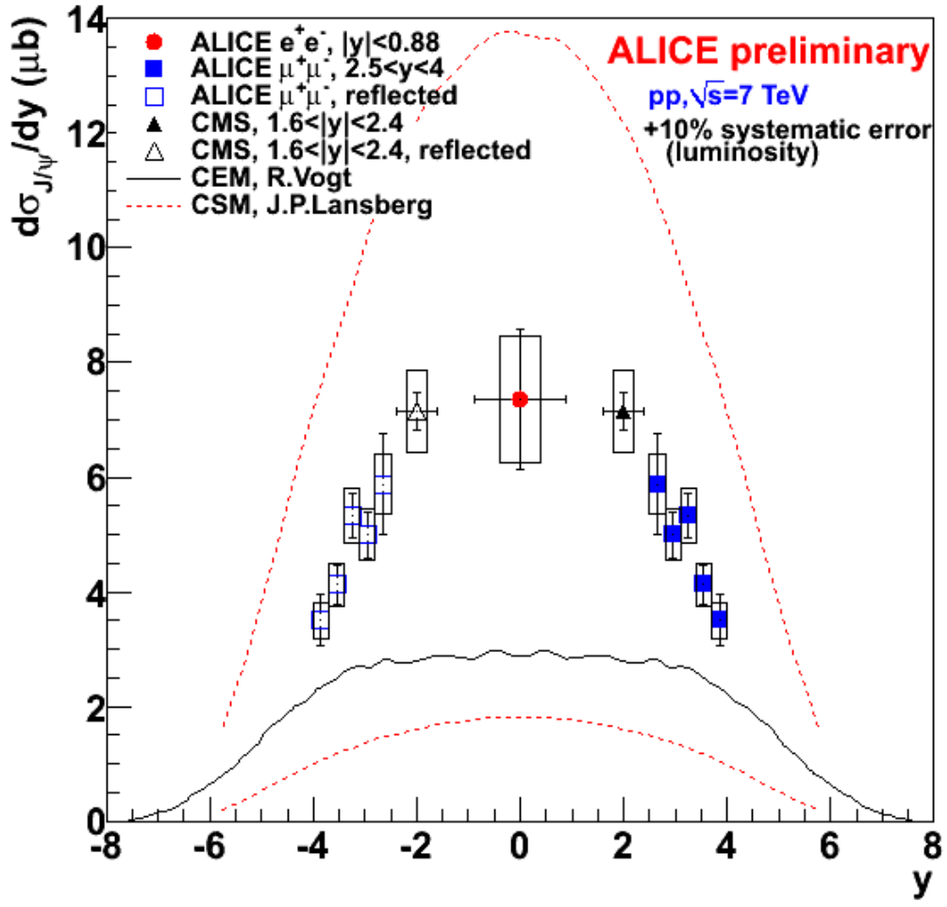
Differential Cross Section : $d\sigma_{J/\psi}/dp_T$

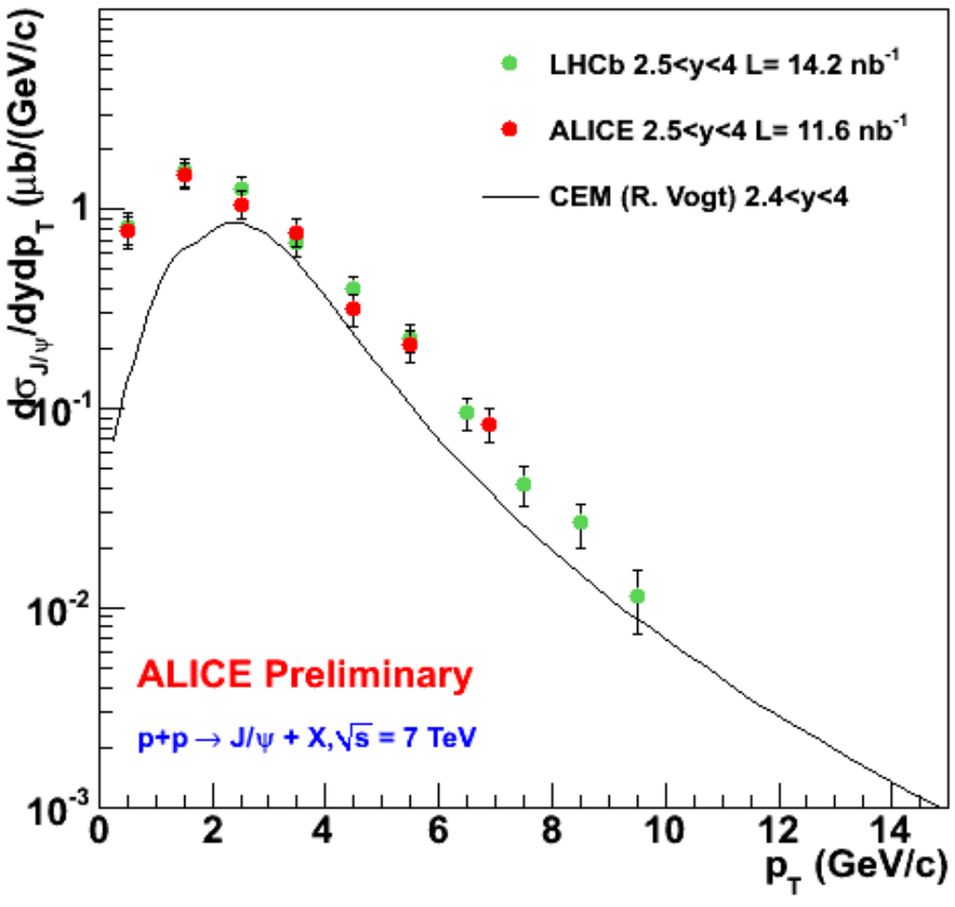


- Syst. error is dominated by polarization
  - two extreme scenarios have been chosen : $\alpha=\pm1$

- Very good agreement with the LHCb result in the same rapidity range

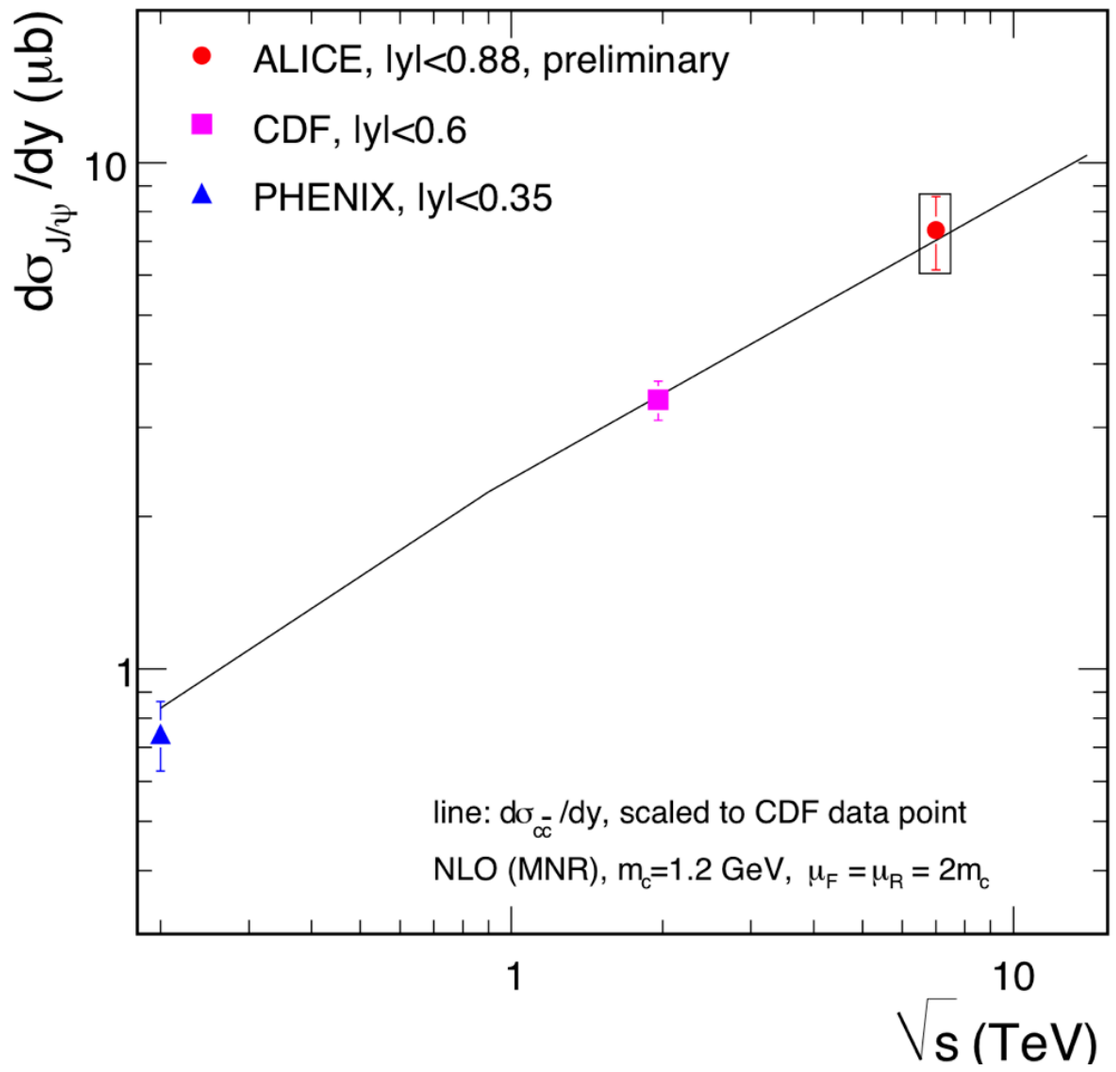
Comparison with two models





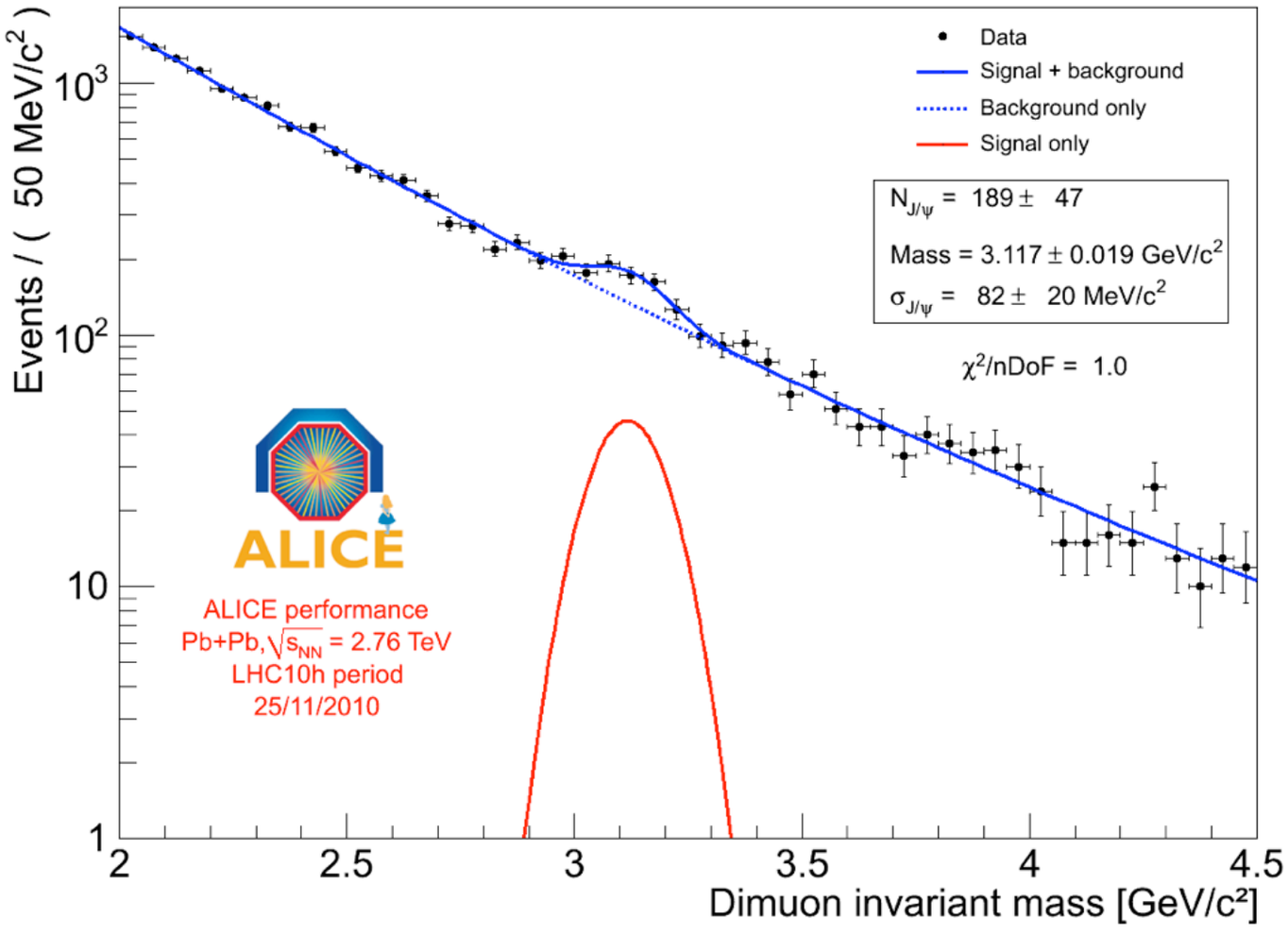
- Model calculations:
  - R.Vogt, Phys. Rev. C 81 (2010) 044903
  - J.P. Lansberg, arXiv:1006.2750
- p_T-integrated cross section 1.6<y<2.4 from CMS (arXiv:1011.4193)

√s-dependence of inclusive J/ψ production



- Open charm NLO calculation, normalized to the CDF point
- Follows the trend of √s-dependence for the inclusive *J*/ψ cross section

J/ψ in Pb+Pb data



- ~2.6M MB events
- Crystal-Ball shape (signal) + 2 exponential (background)

Summary and Outlook

- **Summary**
  - ALICE detector and analysis details introduced
  - ALICE can cover J/ψ p_T down to p_T=0
  - first results on J/ψ production in e^+e^- and $\mu^+\mu^-$ channels presented
  - differential distribution in p_T and rapidity of the inclusive J/ψ shown

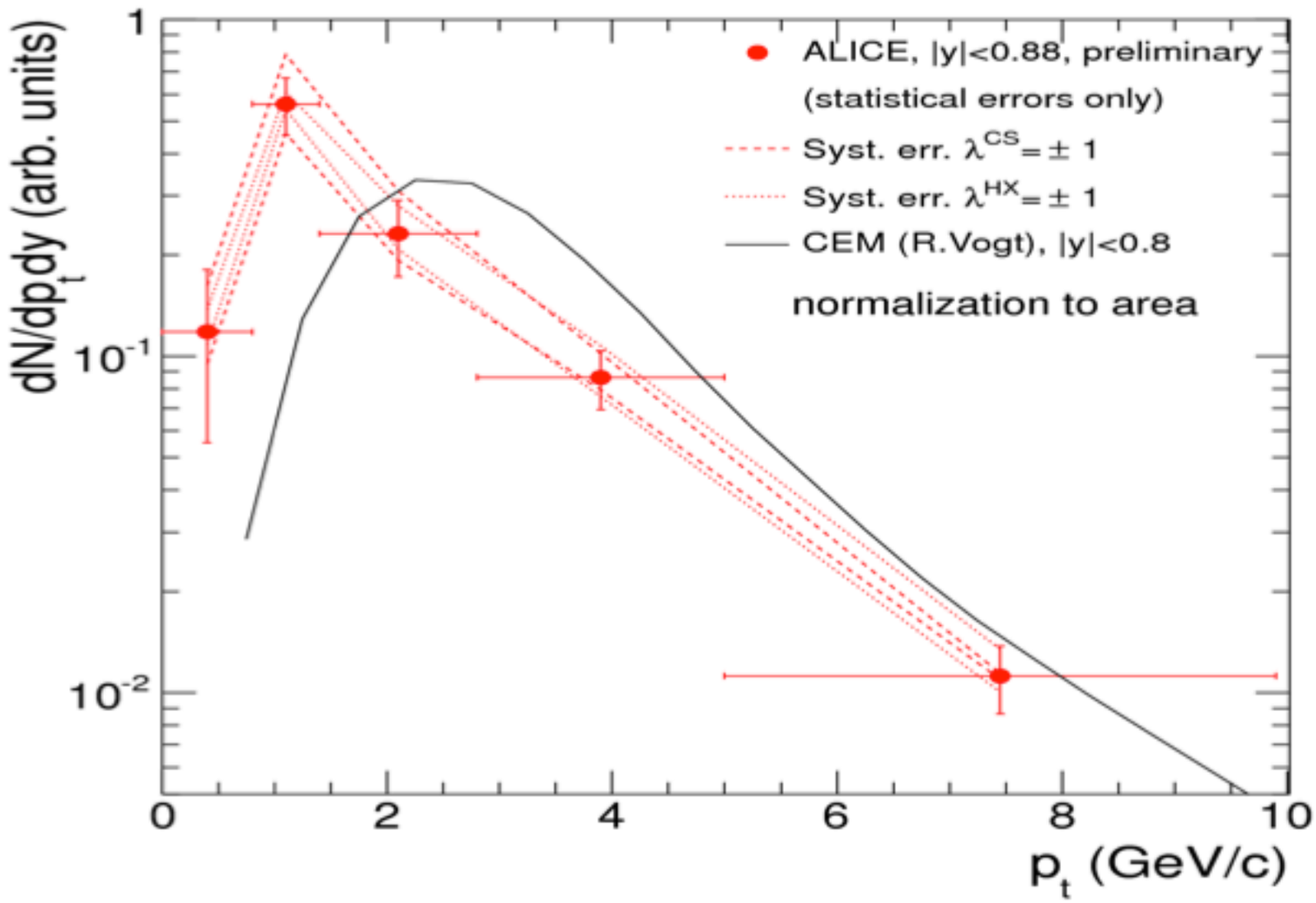
- **Outlook**
  - electron trigger (e.g. track p_T>~2 GeV) can significantly increase the statistics
  - secondary J/ψ is under study
  - J/ψ polarization measurement will follow with high statistics
  - J/ψ measurement in Pb+Pb data is ongoing

Backup Slides

Collected Data

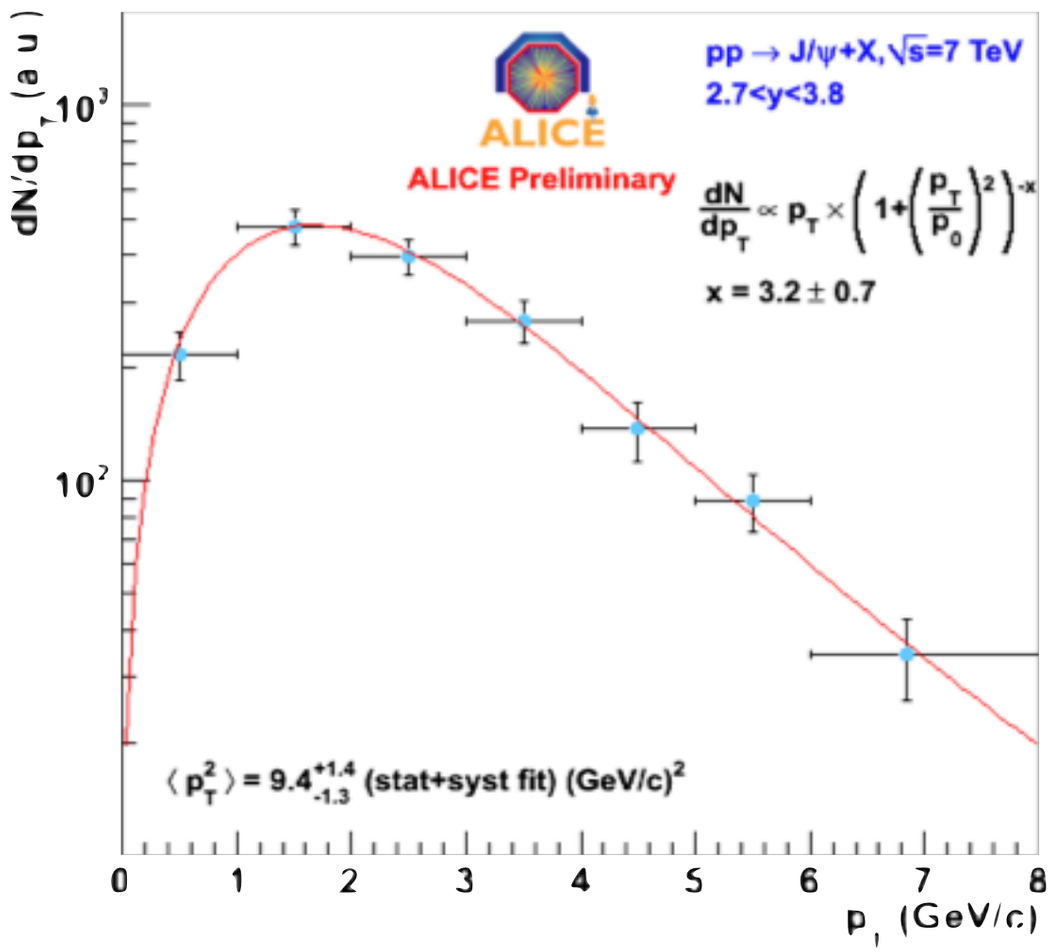
- Data sample:
  - Integrated luminosity = 4.0 nb^{-1} and 13.6 nb^{-1} for e^+e^- and $\mu^+\mu^-$,respectively
  -

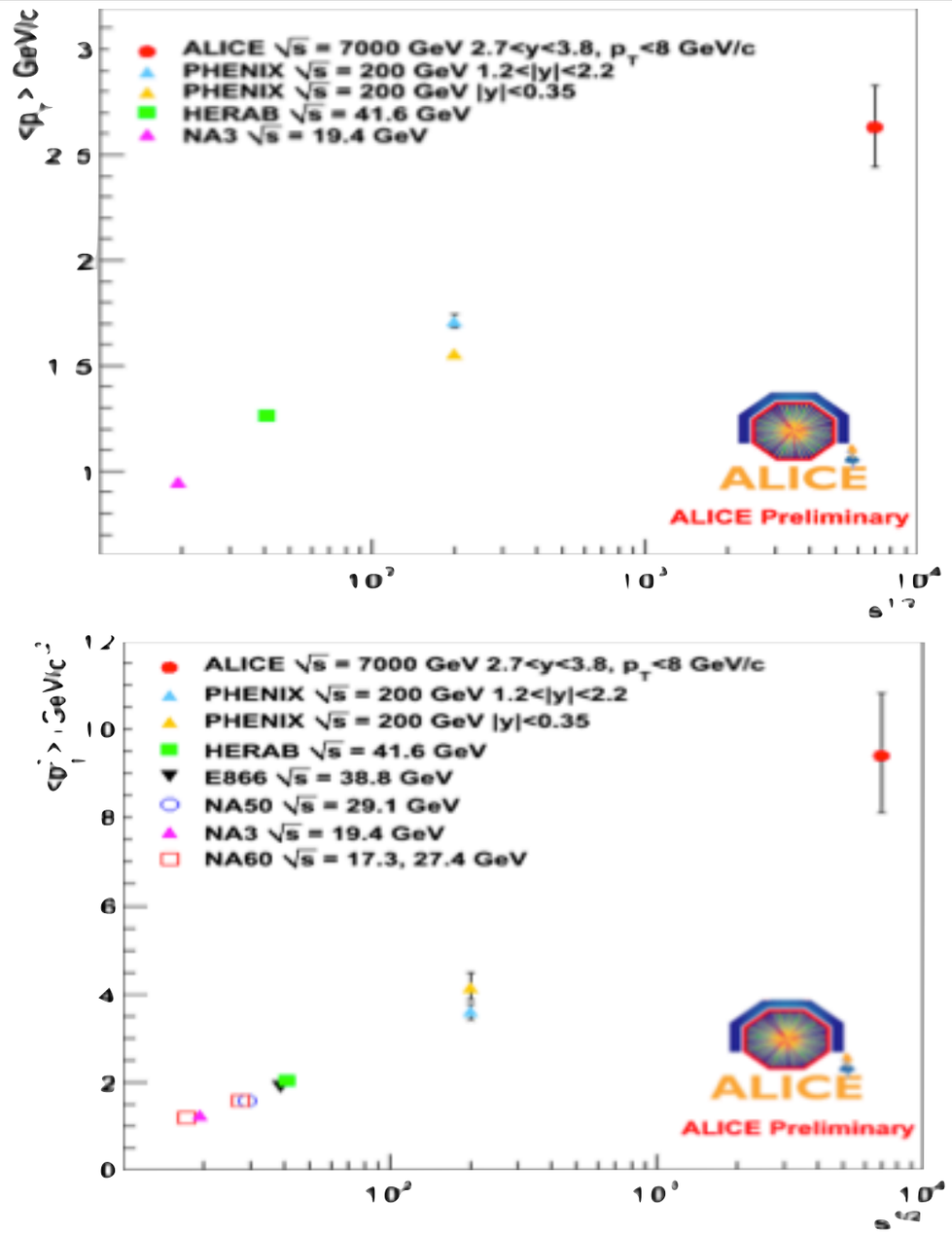
$dN_{J/\psi}/dp_T$ in the mid-rapidity



- Preliminary pT differential distribution, compared to CEM calculation
- Measured spectrum is softer than the calculated one

$\langle p_T \rangle$ and $\langle p_T^2 \rangle$ from $J/\psi \rightarrow \mu^+\mu^-$



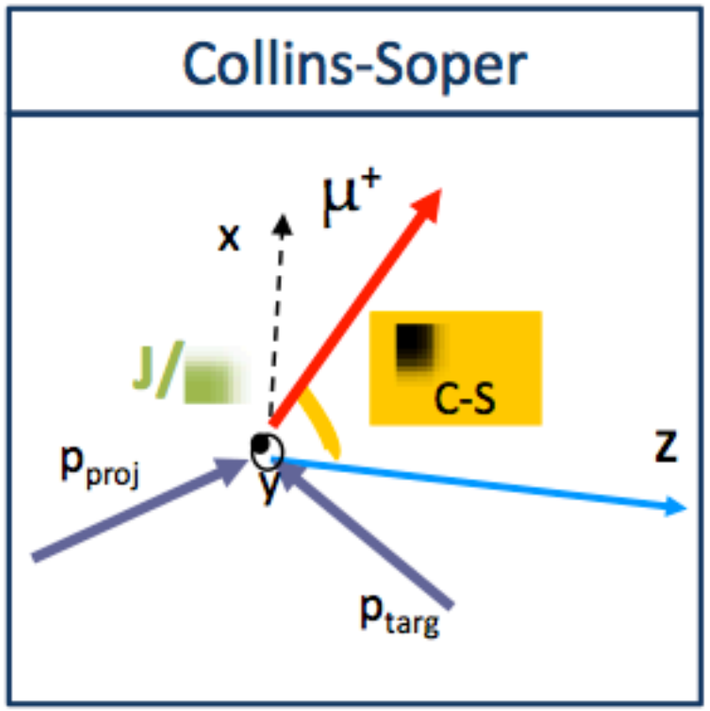


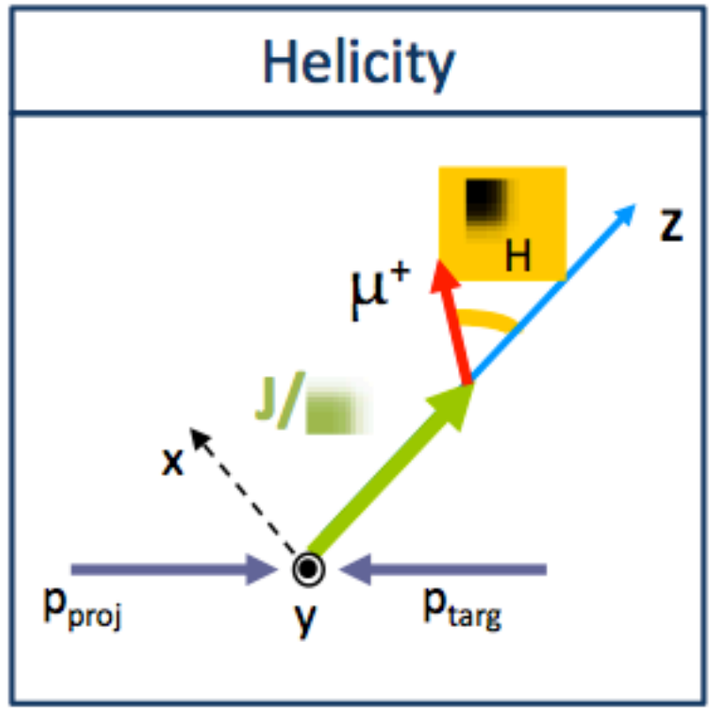
To extract $\langle p_t^2 \rangle$ we use the fit function first proposed by Yoh et al , PRL 41 (1978) 684 and also used by previous experiments

- Approximately linear behaviour of both $\langle p_t \rangle$ and $\langle p_t^2 \rangle$ vs log(√s)

Reference Frames

Livio Bianchi
QGP France
Etretat - 22/09/10





Collins-Soper (CS):
bisector of the angle between proj. and (-) target in the quarkonium C.M. frame.

Helicity (HE):
Direction of the quarkonium in the C.M. frame of the collision.

But don't forget the angle!