Heavy Flavour Physics with the ALICE muon spectrometer at the LHC

Outline:

- Physics motivations
- ALICE muon spectrometer overview
- Selected physics channels in:
    - p-p @ 14 TeV
    - Pb-Pb @ 5.5 TeV
- Conclusion & Outlooks

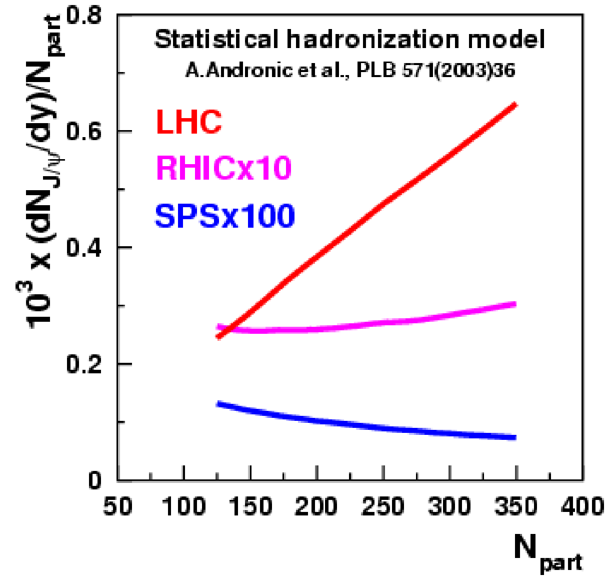
N. Bastid for the ALICE Collaboration,
LPC Clermont-Ferrand

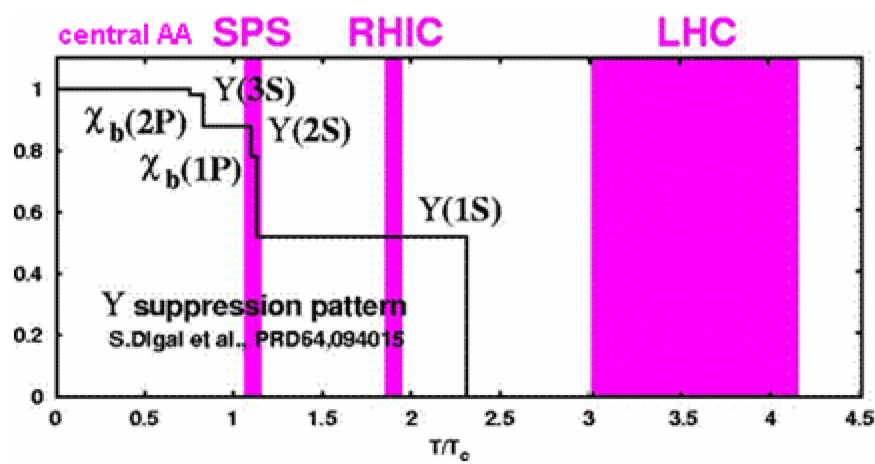
International Workshop on “Heavy Ion Physics at LHC”,
Wuhan, China, May 21-24, 2008

Heavy flavours: what is particular to LHC

central Pb-Pb (Au-Au)

machine	SPS	RHIC	LHC
$\sqrt{s}$ (GeV)	17	200	5500
$(dN/dy)_{y=0}$	500	850	2000-4000
τ^0_{QGP} (fm/c)	1	0.2	0.1
T_{QGP}/T_C	1.1	1.9	3.0-4.2
ε (GeV/fm^3)	3	5	15-60
τ_{QGP} (fm/c)	≤ 2	2 - 4	≥ 10
τ_f (fm/c)	~10	20-30	30-40
V_f (fm^3)	~10^3	~10^4	~10^5
$N_{c\bar{c}}$	0.2	10	115
$N_{b\bar{b}}$		0.05	5





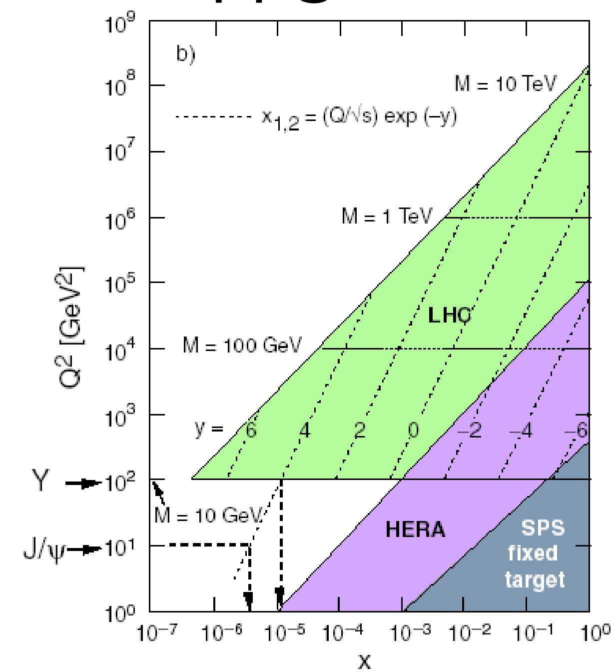
some selected aspects:

- large primary production
- large secondary production of charmonia
- large yield of charmonia from b-hadron decay
- Υ(1S) melts only at LHC, small regeneration

Heavy flavours: motivations

- **p-p collisions:**
  - **baseline for understanding A-A collisions**
  - **important test of pQCD in an unexplored energy domain ($7 \times \sqrt{S_{TEVATRON}}$) associated with low Bjorken-*x* values (down to ~10^{-5})**
- **p-A collisions:**
  - **initial state effects**
    - **shadowing**
    - **k_t broadening (Croning effect)**
    - **parton saturation**
- **A-A collisions:**
  - **final state effects**
    - **in-medium energy loss**
    - **hadronization**

p-p @ 14 TeV



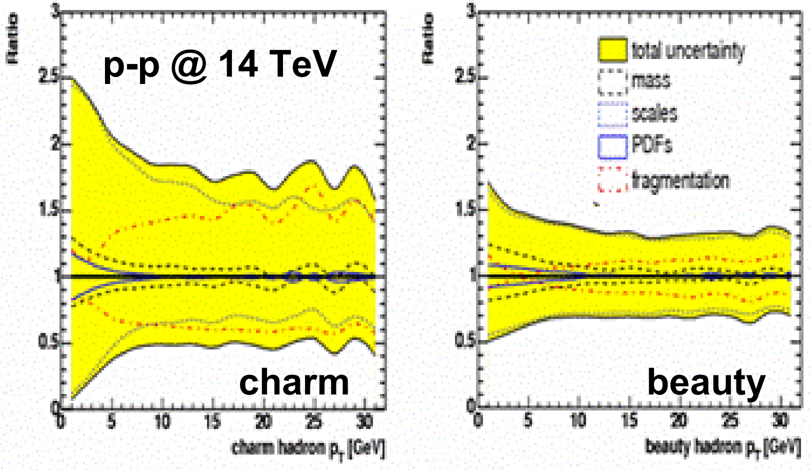
CERN/LHCC 2003-049

Open heavy flavour production cross-section measurement: motivations

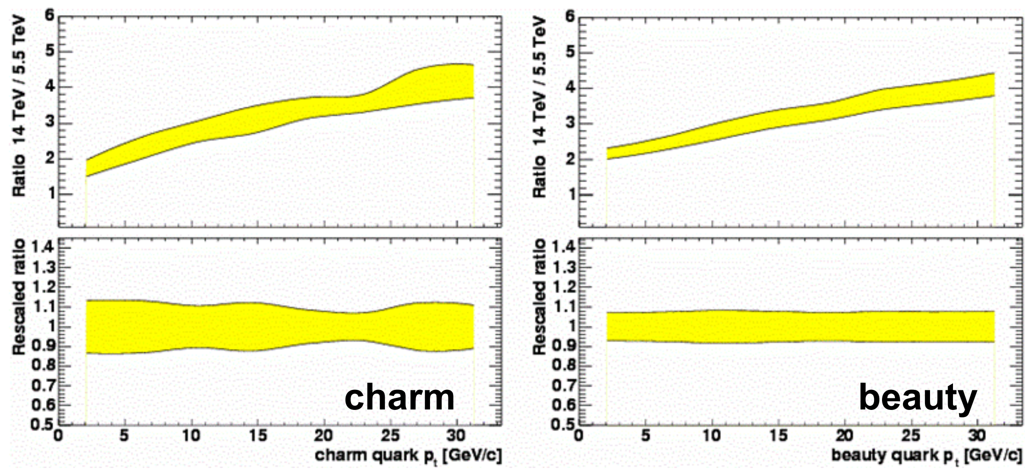
ALICE baseline for charm/beauty:
NLO predictions (+ binary scaling & shadowing in PbPb)

	p-p @ 14 TeV	Pb-Pb (5%) @ 5.5 TeV
$\sigma^{Q\bar{Q}}$ (mb)	11.2/0.51	4.32/0.18
$N^{Q\bar{Q}}$/event	0.16/0.0072	115/4.56
C_{shad}	1/1	0.65/0.84

Yields in p-p @ 14 TeV obtained assuming σ^{inel} = 70 mb



uncertainties on x-sections: factor 2-3



precise extrapolation from 14 TeV to 5.5 TeV

→ measuring σ(c, b) in p-p @ 14 TeV is top priority

CERN/LHCC 2005-014 & ALICE Collab., J. Phys. G: Nucl. Part. Phys. 32 (2006) 1295

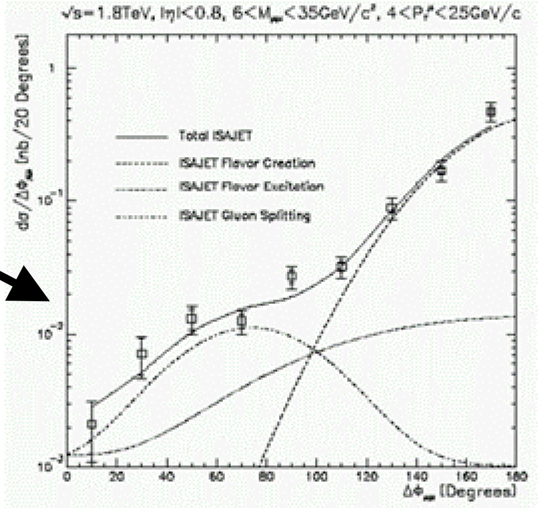
Relevance of measuring σ(b) in p-p collisions in the first days

- **measurement of σ(b) in p-p mandatory for understanding:**
  - **σ(b) in p-A & A-A (shadowing, quenching)**
  - **σ(ϒ) in p-p, p-A & A-A (production, absorption, suppression, recombination?)**
    → most natural normalization for ϒ production
  - **σ(J/Ψ) in p-p (& p-A, A-A): N(b → J/Ψ)/N(direct J/Ψ) ~ 22% (17)% in 4π for p-p @ 14 TeV (Pb-Pb @ 5.5 TeV)**

- **open beauty allows to unravel NLO production processes via correlations**

- **open beauty statistics much larger than bottomonium statistics**

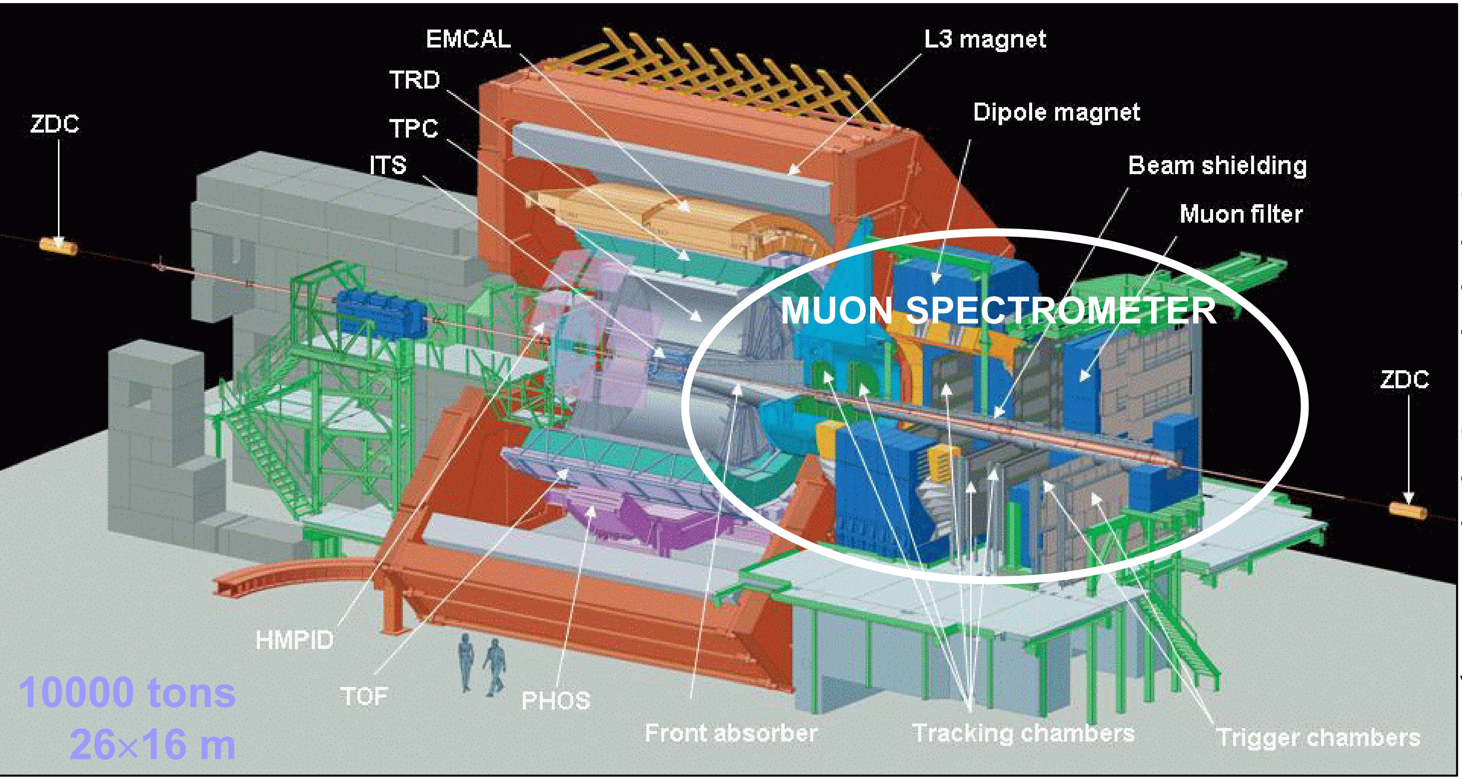
$$\frac{N(\Upsilon \rightarrow l^+ l^-)}{N(b\bar{b} \rightarrow l^\pm)} \approx \frac{1}{570} \times \frac{2.4\%}{20\%} \approx \frac{1}{4700}$$



D.L. Vititoe, PhD, Arizona Univ. (1996) (D0 exp.)

σ(b) = "day-one" physics in p-p collisions @ LHC

The ALICE experiment



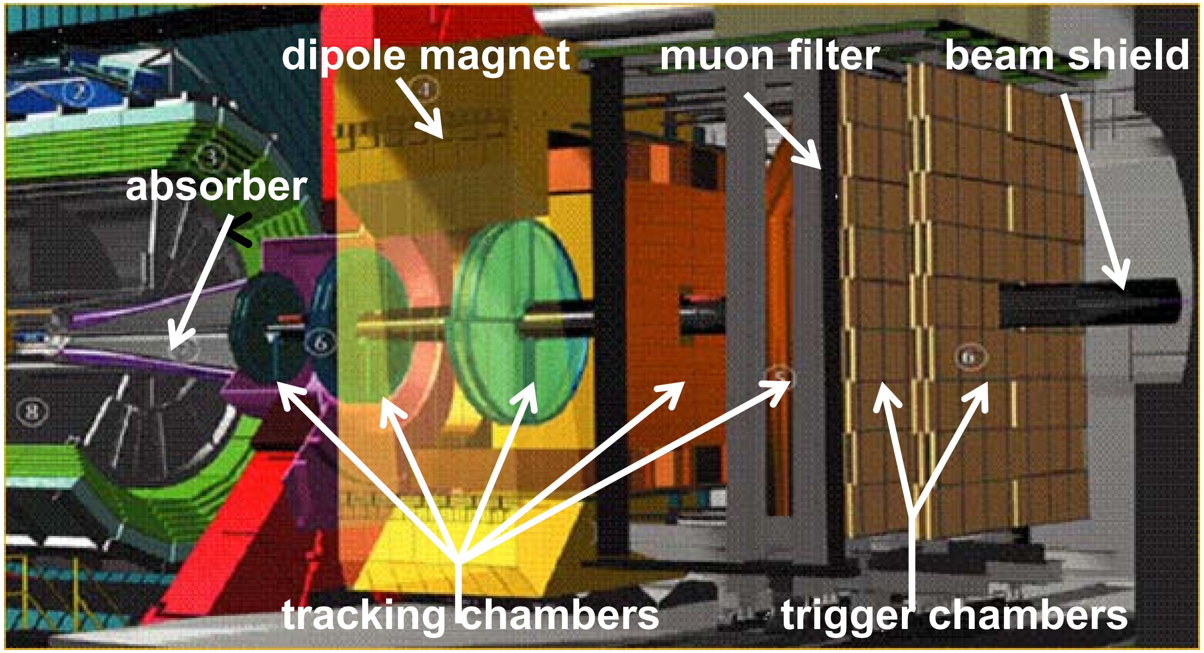
Heavy flavours:

channels:
- muonic ($-4 < \eta < -2.5$)
- electronic ($|\eta| < 0.9$)
- hadronic ($|\eta| < 0.9$)

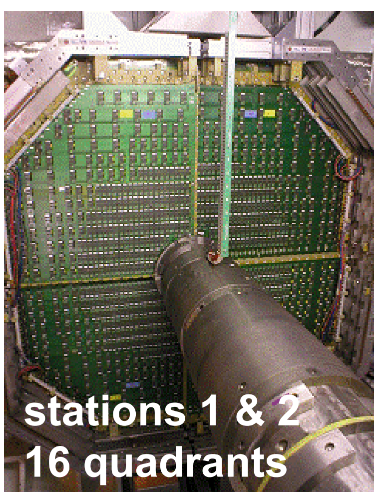
coverage:
- forward/central regions
- down to very low p_t

high precision vertexing ($|\eta| < 0.9$)

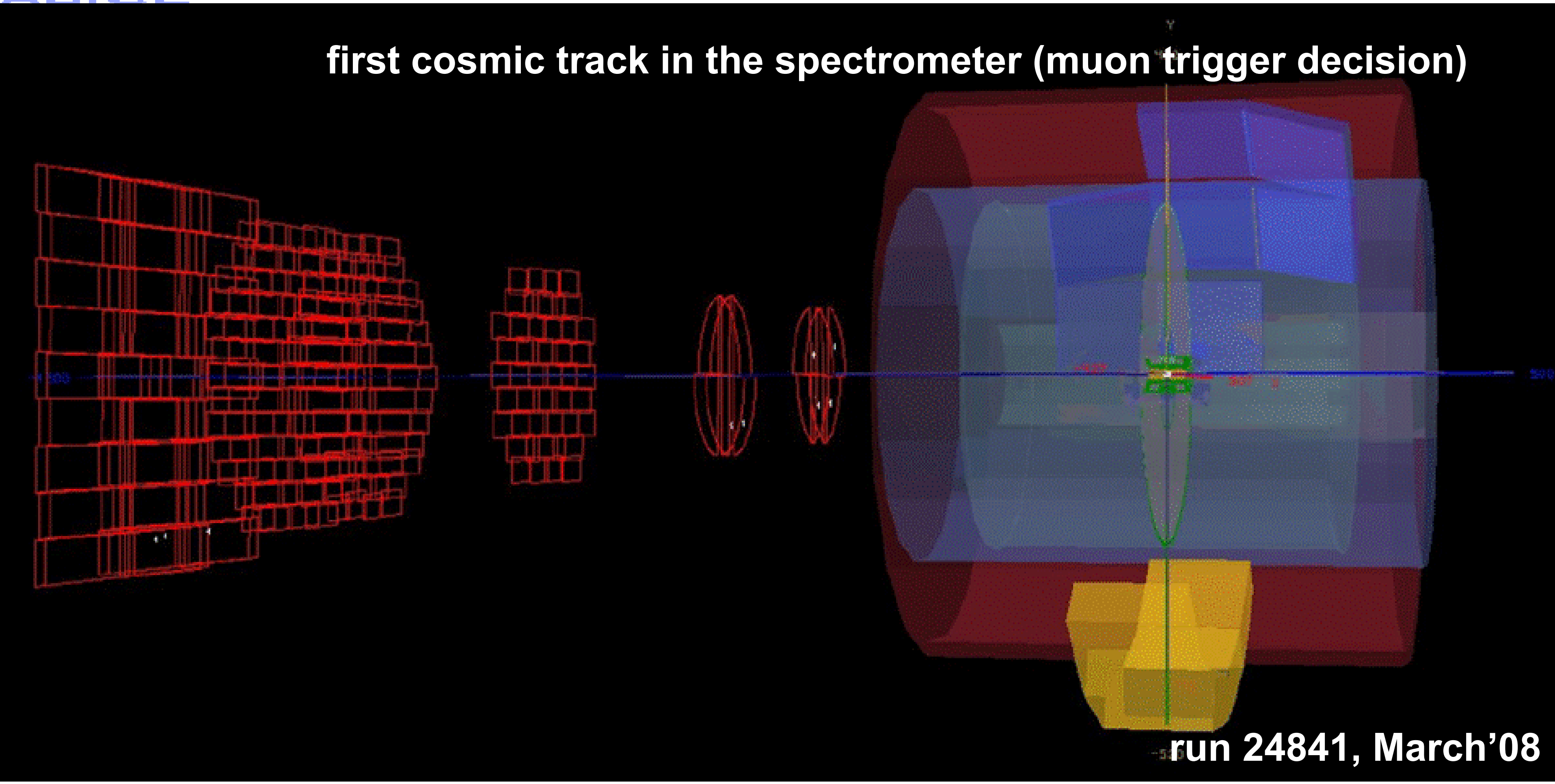
The ALICE muon spectrometer



- acceptance: $-4 < \eta < -2.5$
- 500 hits on station 1 in Pb-Pb @ 5.5 TeV (5%)
- tracking position resolution: < 100 μm (bending plane) → $\Delta M < 100$ MeV/c^2 @ 10 GeV/c^2
- trigger: time resolution < 2 ns, decision in < 800 ns, rate < 1 kHz



Commissioning of the ALICE muon spectrometer



- successfully operated during cosmic runs of Dec. 2007 & Feb-March 2008
- next commissioning phase in May-June 2008

ALICE data taking conditions

one LHC year = 7 months p-p (10^7 s) + 1 month A-A (10^6 s)

System	$\sqrt{s}$ (TeV)	<L> ($cm^{-2} s^{-1}$) (in ALICE)	Running time (s/year)	σ_{geo} (barn)
p-p	14	3.10^{30}	10^7	0.07
Pb-Pb	5.5	5.10^{26}	10^6	7.7
Ar-Ar	6.3	5.10^{28}	10^6	2.7
p-Pb	8.8	5.10^{28}	10^6	1.9

rapidity shift: $\Delta y = 0.47$ for p-Pb

+ other systems (N-N, O-O, Kr-Kr, Sn-Sn) & energies (e.g. p-p @ 5.5 TeV)

ALICE Collab., J. Phys. G: Nucl. Part. Phys. 30 (2004) 1517

• present LHC status: first collisions end of July & p-p @ 10 TeV two months later
p-p @ 14 TeV foreseen in 2009 run

(di)muon trigger rates in Pb-Pb@ 5.5 TeV & p-p @ 14 TeV

trigger rates (Hz)	all p_t's	low p_t cut (1 GeV/c)	high p_t cut (1.7 GeV/c)
single muons	1700/1850	1100/510	450/225
unlike-sign dimuons	930/27 $\pm$ 10	330/10 $\pm$ 5	65/5 $\pm$ 3

F. Guérin, F. Yermia et al., ALICE-INT-2006-0002

Physics analysis with the ALICE muon spectrometer

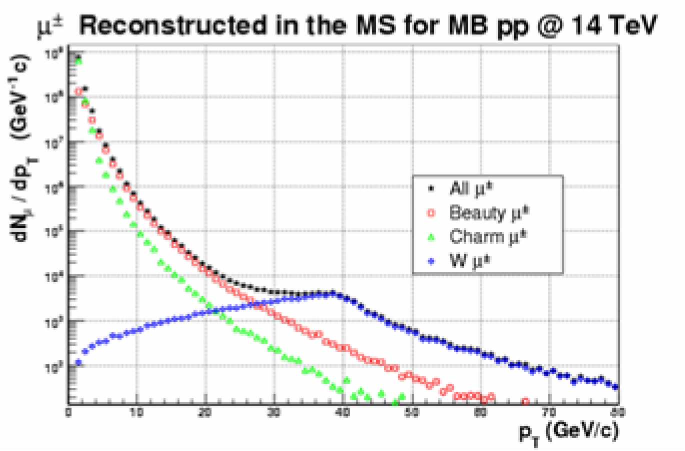
- p_t of single muons:
  - open charm & open beauty
  - electro-weak $W^{\pm}$ bosons
- invariant mass of muon pairs:
  - unlike-sign dimuons: charm
  - unlike-sign dimuons @ low mass: B-chain (BD_{same})

    $X \leftarrow B\bar{B} \rightarrow \mu^{-} + D + X$ & $D \rightarrow \mu^{+} + X$
  - unlike-sign dimuons @ high mass: BB_{diff}

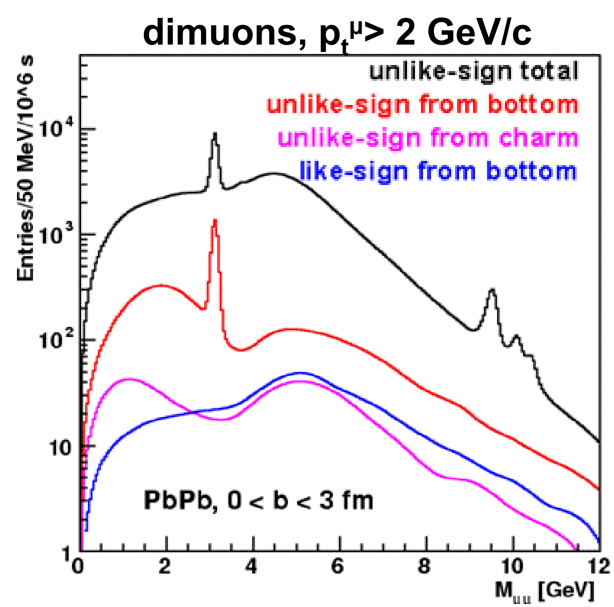
    $X + \mu^{+} \leftarrow B\bar{B} \rightarrow \mu^{-} + X$
  - like-sign dimuons

    $B \rightarrow D$ decay & B^0 oscillations
  - charmonia (J/Ψ, Ψ'), bottomonia (Υ states), $B \rightarrow J/\Psi + X$
  - electro-weak Z^0 bosons
  - low mass resonances: ρ, ω, ϕ (see F. Nendaz talk)
- multi-muons:

  $B\bar{B} \rightarrow J/\Psi + \mu \rightarrow \mu\mu\mu$
- electron-muon coincidences



Z. Conesa del Valle et al., Eur. Phys. J. C49 (2007) 149

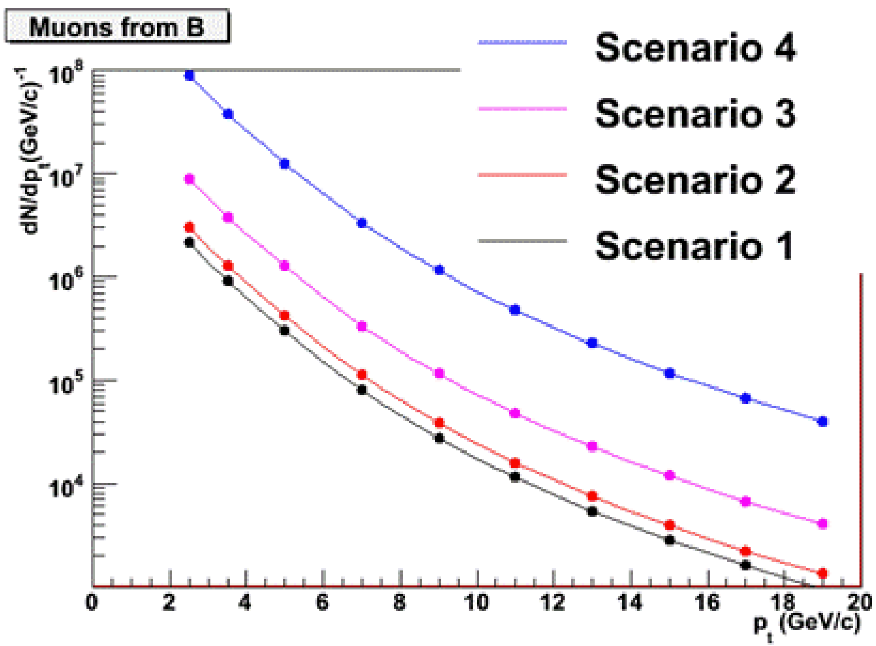


S. Grigoryan (2004) & Eur. Phys. J. C (2005) 437

Open beauty in p-p @ 14 TeV (I)

UA1 method[1] used by CDF & D0 and applied on simulated data in ALICE for electrons (p-p, Pb-Pb) & (di)muons (Pb-Pb)

1- μ ← b yield extracted from a combined fit with fixed shapes for p_t distributions of μ from charm & bottom and b yield as free parameter



1- L = 10^{30} cm^{-2} s^{-1}, t = $7.2.10^5$ s
2- L = 10^{30} cm^{-2} s^{-1}, t = 10^6 s
3- L = 3.10^{30} cm^{-2} s^{-1}, t = 10^6 s
4- L = 3.10^{30} cm^{-2} s^{-1}, t = 10^7s (nominal)

- huge statistics of μ ← b over a wide p_t range (2 - 20 GeV/c)
- small statistical errors (< 2.5% at high p_t in scenario 1)
- p_t > 20 GeV/c: μ ← $W^{\pm}$ stick out

[1] *C. Albajar et al., Phys. Lett. B 213 (1988) 405*
ALICE: L. Manceau, N. Bastid, P. Crochet, ALICE Physics week, Prague (2008)

Open beauty in p-p @ 14 TeV (II)

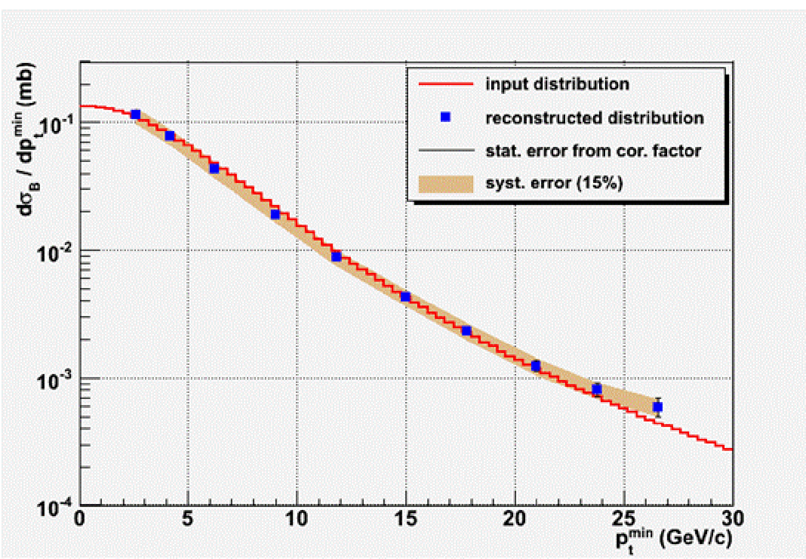
2- convert $N_{b\to\mu}$ (corrected for efficiency & luminosity) to b-hadron x-section:

$$\left.\frac{d\sigma^B}{dy}(p_t^B > p_t^{min})\right|_{-4\le y\le -2.5} = \frac{N_{\mu\leftarrow B}(\Phi^\mu)}{\int L dt} \times \frac{1}{\varepsilon} \times \left[\frac{\left.\frac{d\sigma^B}{dy}(p_t^B > p_t^{min})\right|_{-4\le y\le -2.5}}{\sigma^B(\Phi^\mu)}\right]_{MC}$$

integrated luminosity

efficiency

Φ^μ: -4.0 < η < -2.5, p > 4 GeV/c, p_t^μ range
p_t^{min}: 90% of B $\to$ μ in Φ^μ

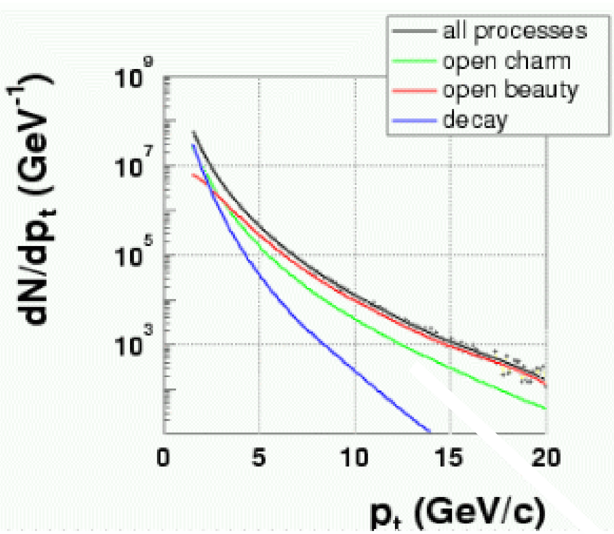


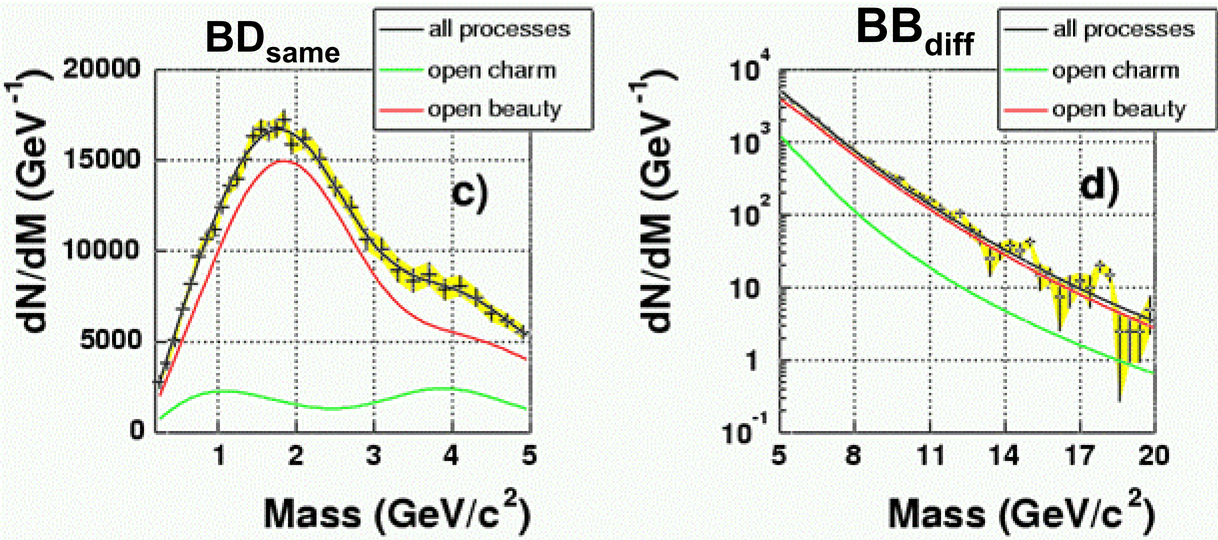
- input distribution well reconstructed
- huge statistics
- systematic uncertainties < 15%

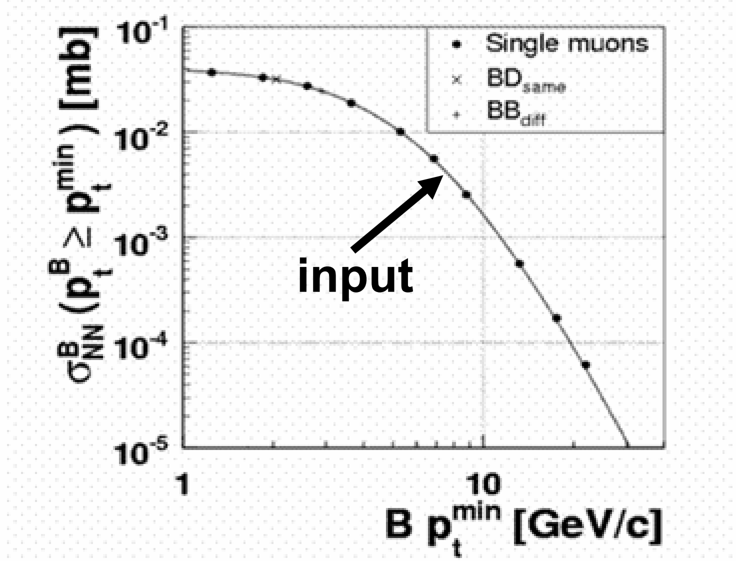
$\to$ should allow to strongly constrain theoretical predictions

b-hadron inclusive differential x-section from single muons: very promising channel to be investigated in first days of data taking

Open beauty in Pb-Pb @ 5.5 TeV







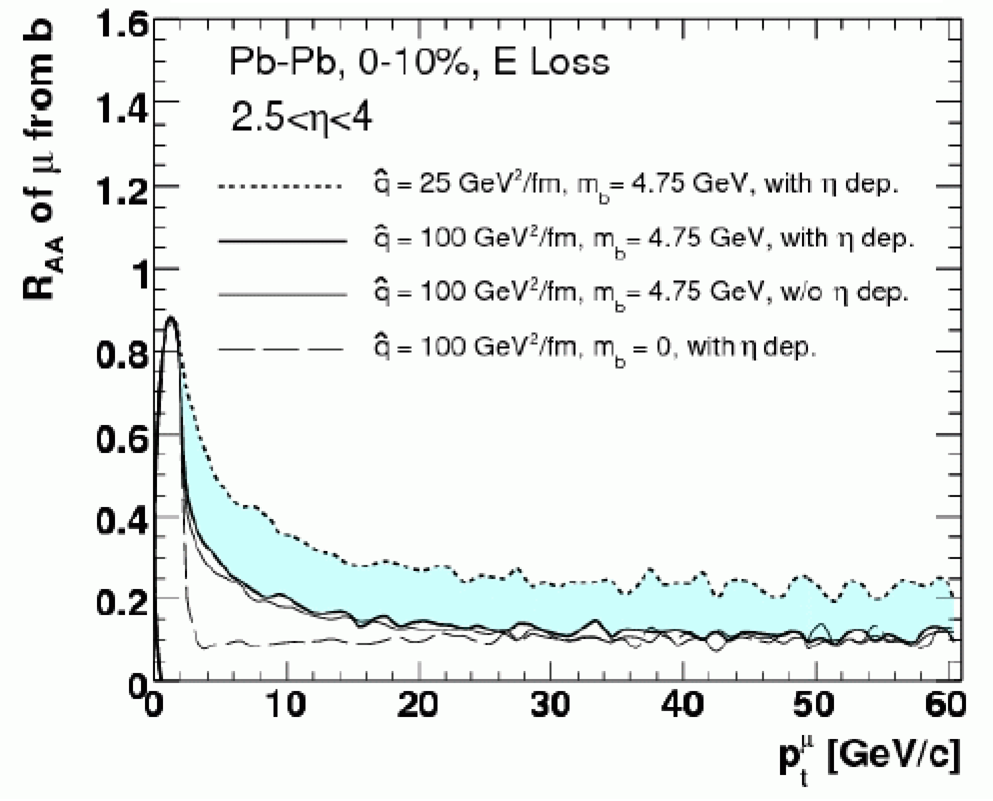
- input distribution well reconstructed
- nice agreement between the 3 channels
- large statistics

- statistics: one month (L = 5.10^{26} cm^{-2} s^{-1}, t = 10^{6} s)
- assumption: no energy loss effects

R. Guernane et al., ALICE-INT-2005-018 &
ALICE Collab., J. Phys. G: Nucl. Part. Phys. 32 (2006) 1295

b-quark energy loss in Pb-Pb @ 5.5 TeV

$$R_{AA} = \frac{d^2N^{AA}/dydp_t}{<N_{coll}^{AA}> \times d^2N^{pp}/dydp_t}$$



- **in-medium energy loss effect:**

$N_{\mu \leftarrow b}$ reduced by a factor up to 3-6 for $2 < p_t < 20$ GeV/c, depending on transport coefficient

- **b-quark mass effect:**

$N_{\mu \leftarrow b}$ increased by a factor up to 3 for $p_t \leq 5$ GeV/c & still affected even at 15 GeV/c

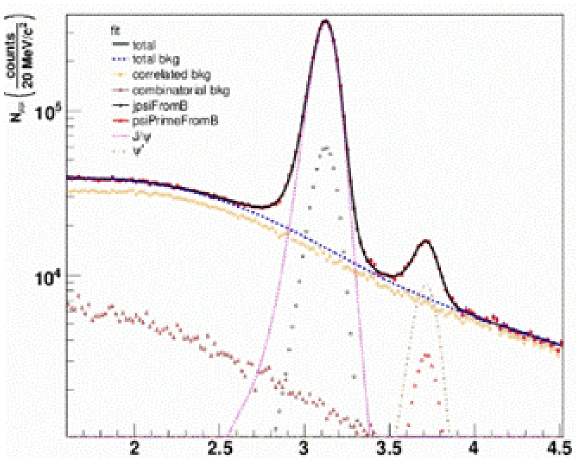
Parton Quenching Model: Phys. Rev. Lett. 89 (2002) 092303

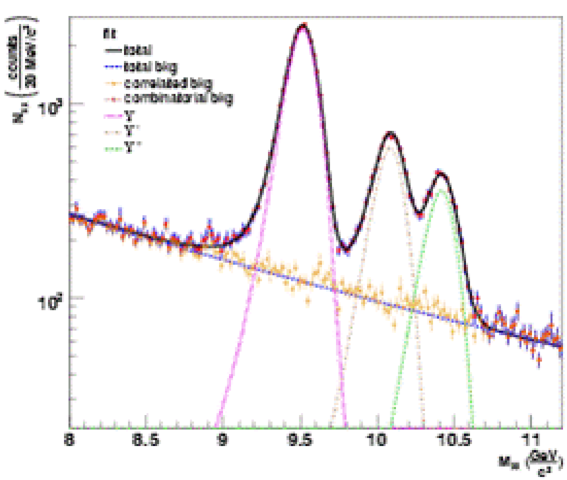
ALICE: Z. Conesa del Valle, A. Dainese, H.T. Ding, G. Martínez-García, D.C. Zhou, Phys. Lett. B 663 (2008) 202

Quarkonium production in p-p @ 14 TeV (I)

- information on production mechanisms
- insight on PDF at very small Bjorken-x

- relevant observables: yields, differential distributions, polarization





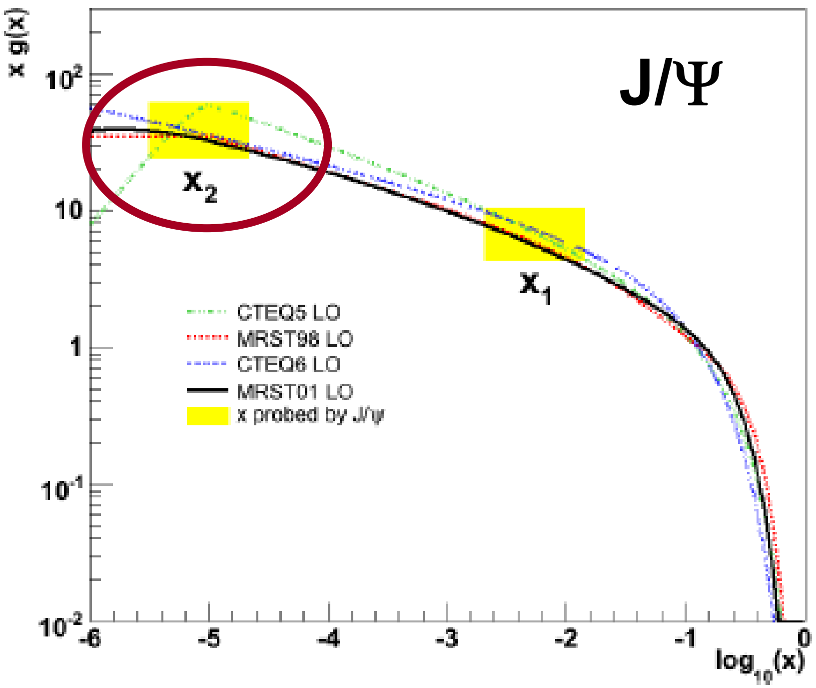
	S	S/B	Signif.
J/Ψ	2.8.10^6	12.0	1610
Ψ’	0.075.10^6	0.6	170
ϒ (1S)	27.10^3	10.4	157
ϒ (2S)	6.8.10^3	3.4	73
ϒ (3S)	4.210^3	2.4	55

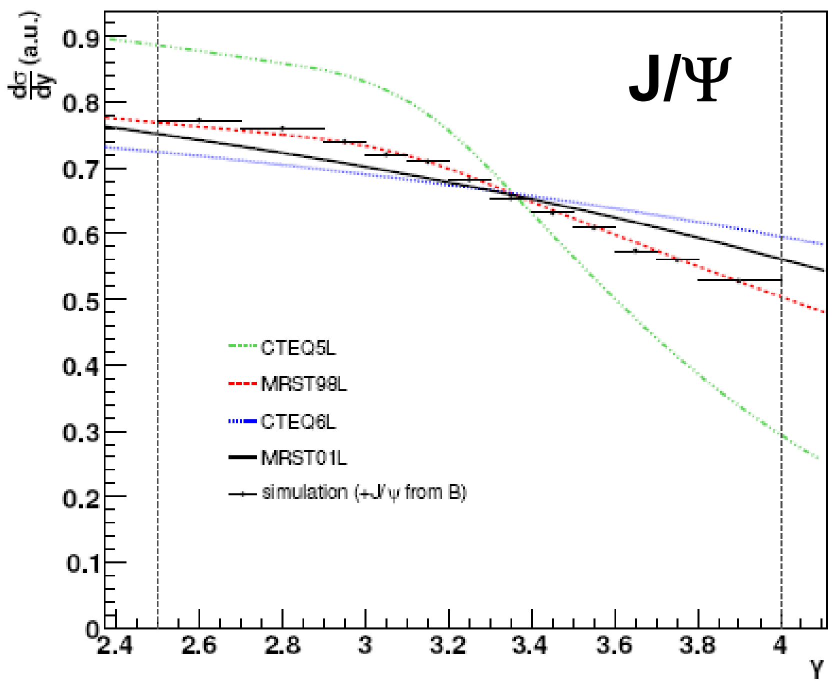
statistics: L = 3.10^{30} cm^{-2} s^{-1}, t = 10^7 s
cross-sections: hep-ph/0311048

- quarkonium states well separated with good significance & S/B > 1 (except for Ψ’)
- huge statistics for J/Ψ, p_t range: 0-20 GeV/c

D. Stocco et al., ALICE-INT-2006 &
ALICE Collab., J. Phys. G.: Nucl. Part. Phys. 32 (2006) 1295

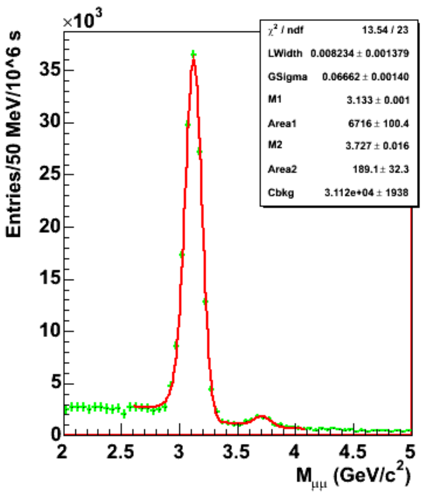
Quarkonium production in p-p @ 14 TeV differential distributions (II)

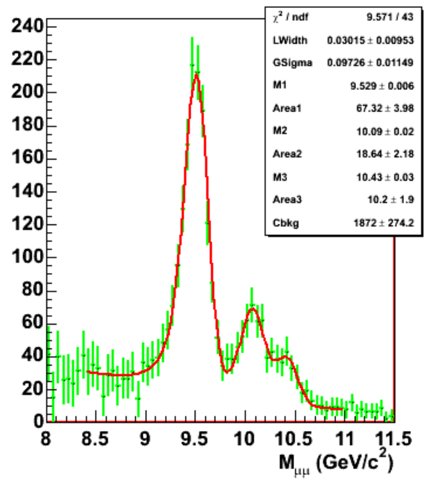




- **sensitivity of shape of J/Ψ *versus* y to gluon distribution functions**
- **possible to discriminate among different gluon distribution functions in the region of Bjorken-*x* < 10^{-5}**

Quarkonium production in Pb-Pb @ 5.5 TeV





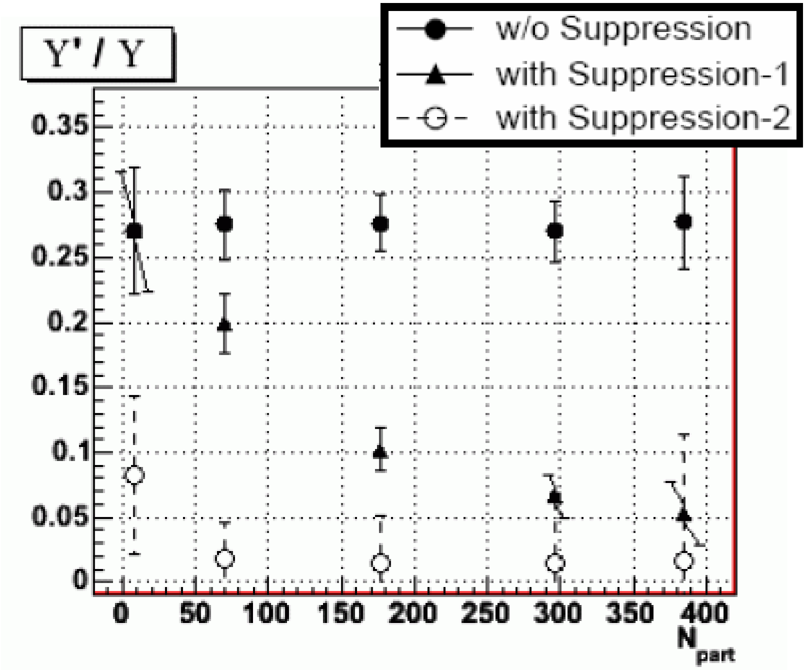
$L = 5.10^{26}$ cm^{-2} s^{-1}, $t = 10^6$ s,
with shadowing, w/o absorption/suppression/enhancement

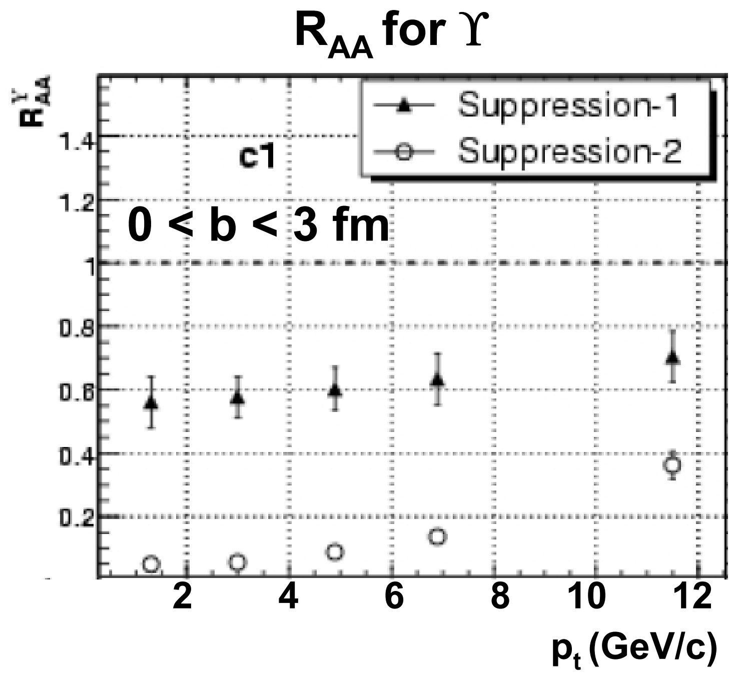
	b (fm)	0-3	3-6	6-9	9-12	12-16	min-bias
	ε (GeV/fm^3)	32	30	28	16	5	
J/ψ	S (×10^3)	132.6	234.6	198.2	94.75	21.66	681.4
	S/B	0.2	0.27	0.48	1.08	3.13	0.33
	S/√S+B	148	224	254	222	128	413
ψ’	S (×10^3)	3.69	6.53	5.5	2.61	0.59	18.92
	S/B	0.012	0.017	0.03	0.063	0.172	0.02
	S/√S+B	6.7	10.4	12.6	12.4	9.3	19.53
ϒ	S (×10^3)	1.349	2.38	1.991	0.932	0.204	6.33
	S/B	1.66	2.31	3.6	6.06	9.12	2.46
	S/√S+B	29	40.8	39.5	28.3	13.6	67.14
ϒ’	S (×10^3)	0.353	0.623	0.522	0.244	0.054	1.8
	S/B	0.65	0.9	1.36	2.25	3.46	1.03
	S/√S+B	11.8	17.2	17.3	13	6.4	30.19
ϒ’’	S (×10^3)	0.201	0.354	0.297	0.139	0.03	1.02
	S/B	0.48	0.63	0.99	1.57	2.22	0.74
	S/√S+B	8.1	11.7	12.2	9.2	4.6	20.85

- **J/Ψ: large statistics (0-20 GeV/c), good significance**
- **Ψ’: small S/B**
- **ϒ (1S): good statistics (0-8 GeV/c), S/B > 1, good significance**
- **ϒ (2S): good statistics (0-8 GeV/c), S/B > 1, good significance**
- **ϒ (3S): low statistics, 2-3 runs needed**

S. Grigoryan & ALICE Collab., J. Phys. G: Nucl. Part. Phys. 32 (2006) 1295

Suppression scenarii





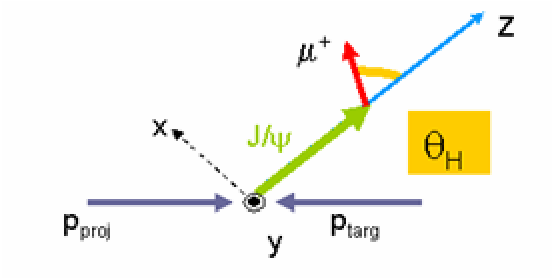
- **Suppression-1 (quenched QCD): T_C = 270 MeV, T_D/T_C = 4.0 (1.4) for Υ (Υ')**
- **Suppression-2 (unquenched QCD):T_C = 190 MeV, T_D/T_C = 2.9 (1.06) for Υ (Υ')**

clear sensitivity of the observables to the QGP temperature

dissociation temperatures: C.Y. Wong, hep-ph/0408020 & W.M. Alberico, hep-ph/0507084
S. Grigoryan, DiMuonNet report (2008) & ALICE Collab., J. Phys. G: Nucl. Part. Phys. 32 (2006) 1295

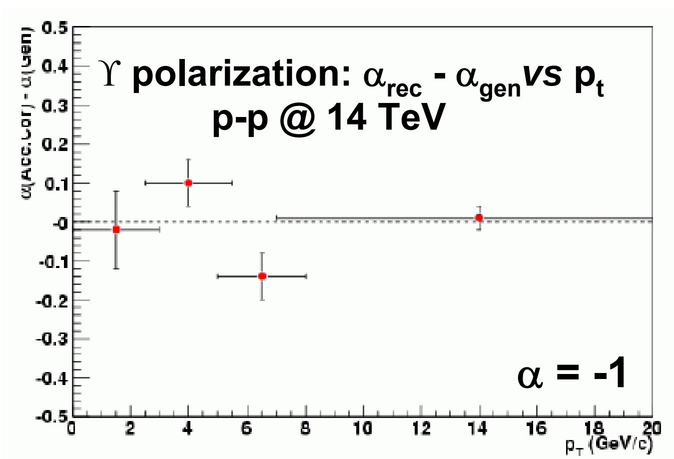
Quarkonia polarization

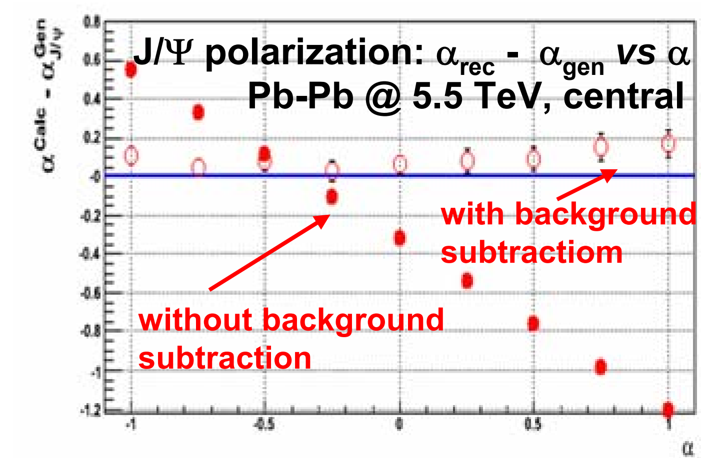
- **p-p**: distinguish between different quarkonium production models
- **A-A**: possible signature of QGP



$$d\sigma/d\cos\theta_H = 1 + \alpha \cos^2\theta_H$$

- $\alpha > 0$: transverse polarization
- $\alpha = 0$: no polarization
- $\alpha < 0$: longitudinal





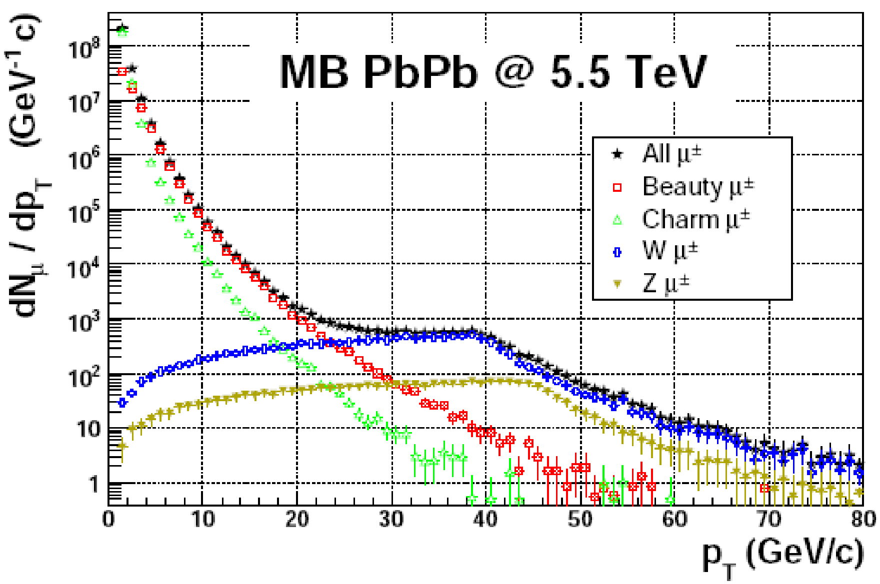
- **p-p @ 14 TeV:** J/Ψ & ϒ polarization *vs* p_t possible, error on α negligible (3-20%) for J/Ψ (ϒ)
- **Pb-Pb @ 5.5 TeV:** J/Ψ polarization *vs* centrality possible (error on α: ~5%),
  ϒ polarization vs centrality: several runs needed

R. Arnaldi & E. Scomparin, DiMuonNet report (2008)

Electro-weak $W^{\pm}$ boson production (I)

measurement of $W^{\pm}$ bosons produced in initial hard collisions:

- **PDF probe in the Bjorken-x range ($10^{-4}<x<10^{-3}$) at $Q^2 \sim m^2_W$**
- **reference for heavy quark energy loss**
- **binary scaling cross-check**
- **luminosity & detector efficiency cross-checks**



statistics: 1 month ($L = 5.10^{26}$ cm^{-2} s^{-1}, $t = 10^6$ s)

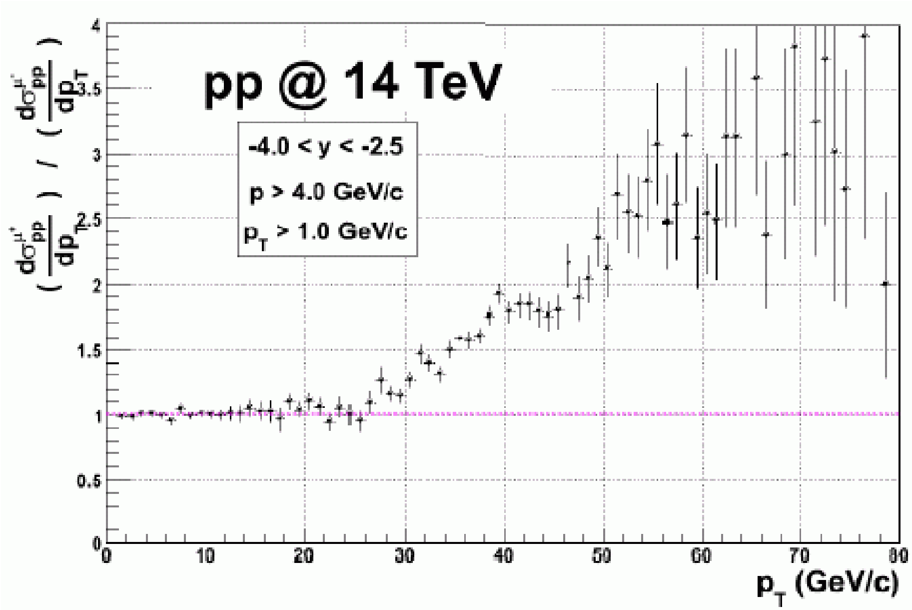
- **$W^{\pm}$ production is maximum at ~ 40 GeV/c and dominates the high p_t range**

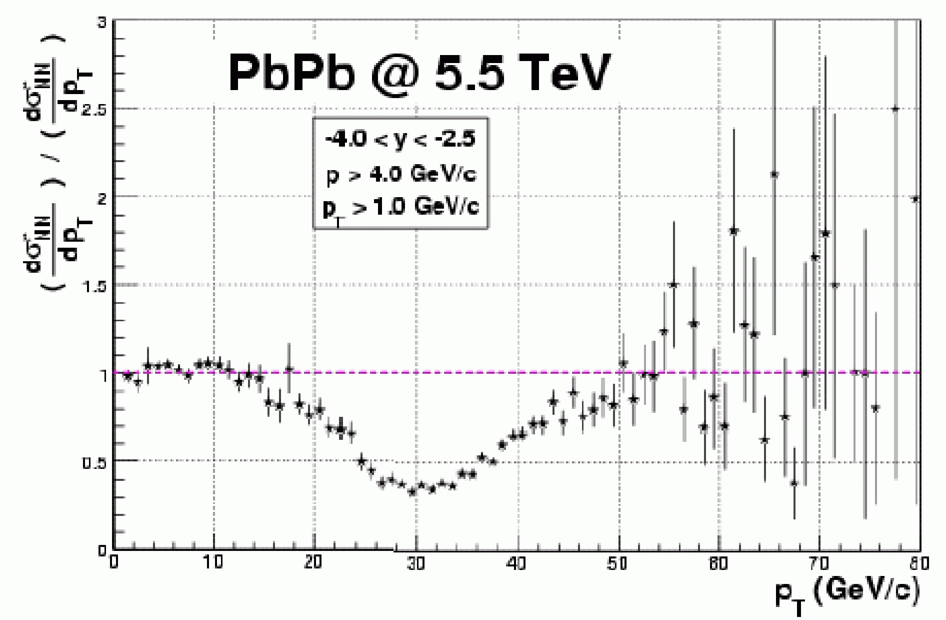
- **expected statistics:**
  p-p @ 14 TeV: ~8.6.10^4 $\mu^{\pm} \leftarrow W^{\pm}$
  Pb-Pb @ 5.5 TeV: ~1.4.10^4 $\mu^{\pm} \leftarrow W^{\pm}$

- **Z^0 can be also reconstructed**

Z. Conesa del Valle et al., ALICE-INT-2006-021 & Eur. Phys. J. C49 (2007) 149

Electro-weak $W^{\pm}$ boson production (II)

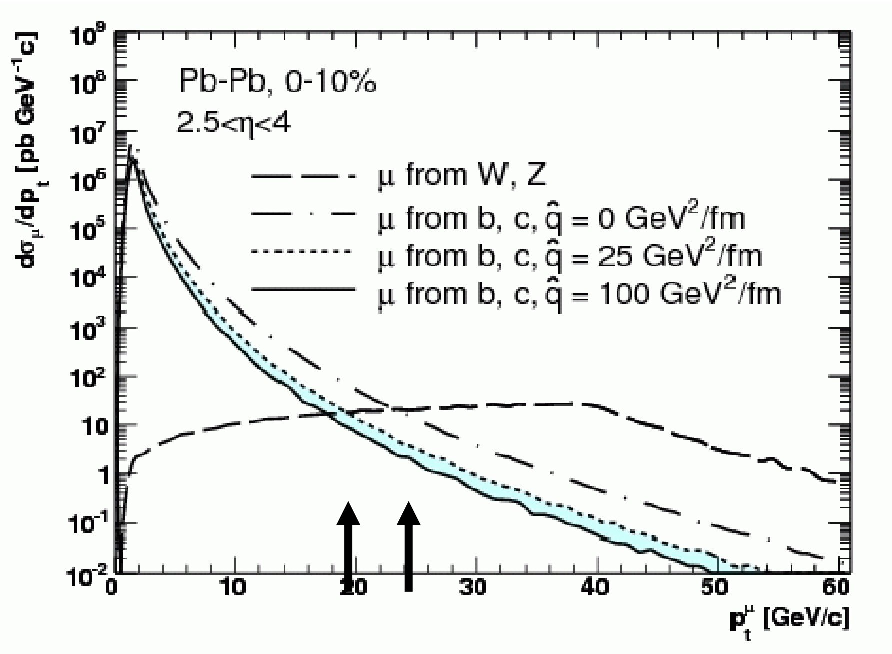


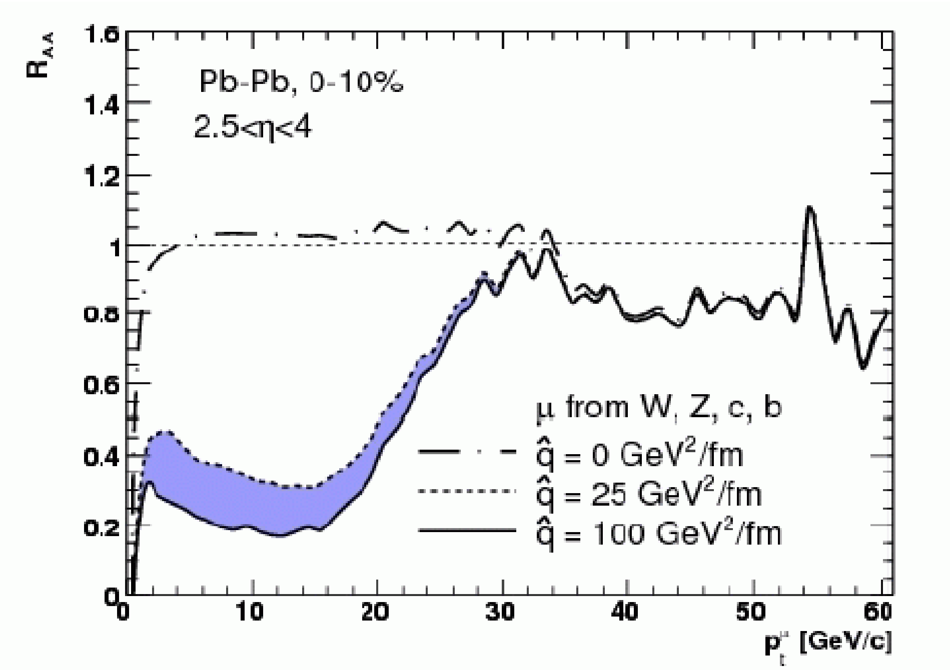


- **charge asymmetry on $W^{\pm}$ production due to the valence quark composition of colliding particles → muon charge asymmetry**
- **different muon charge asymmetry in p-p & Pb-Pb collisions**
- **p_t dependence of $N(\mu^+)/N(\mu^-)$: promising observable for $W^{\pm}$ production**

Z. Conesa del Valle et al., ALICE-INT-2006-021 & Eur. Phys. J. C49 (2007) 149

Effect of heavy quark energy loss on muon p_t distribution in Pb-Pb @ 5.5 TeV

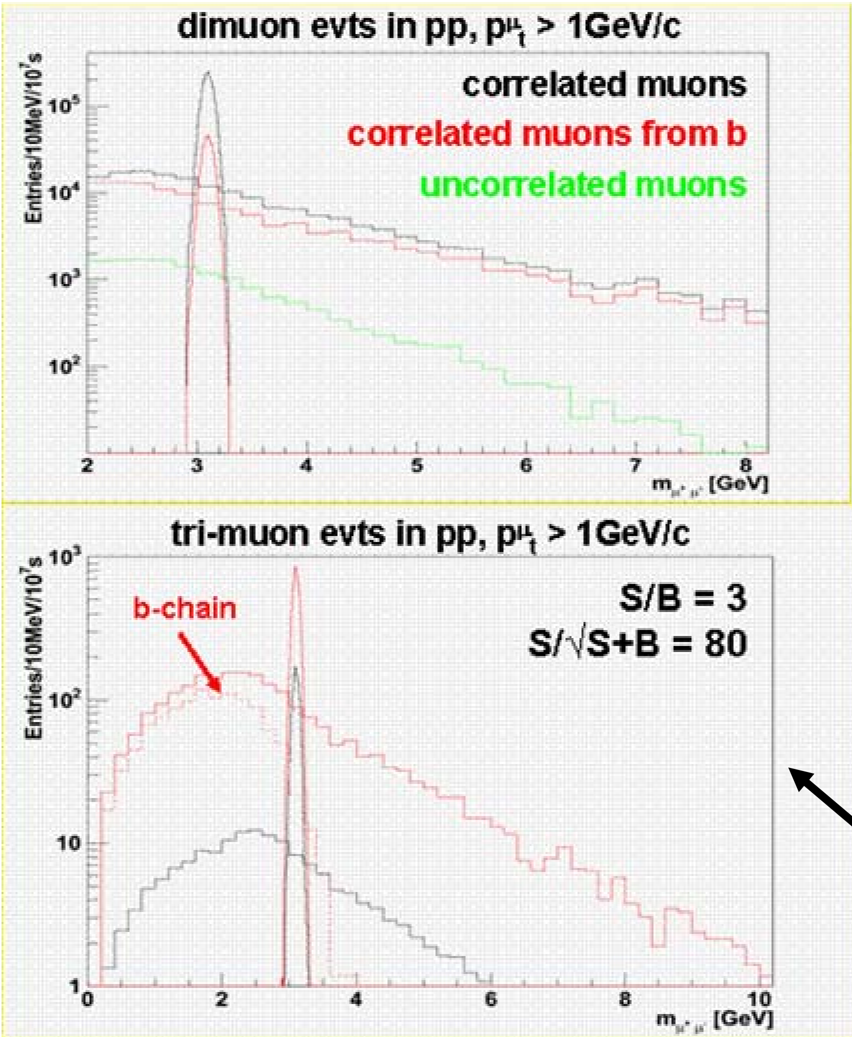




- **b-quark energy loss effects:**
  - **crossing point** between p_t distributions of heavy quarks & electroweak bosons **shifted down by 5-7 GeV/c**
  - **muon yield suppressed** by a **factor of about 2-5** for **$2 < p_t < 20$** (p_t > 30 GeV/c: shadowing of $W^\pm$, Z^0)
  - other promising observable: R_{CP}

Parton Quenching Model: Phys. Rev. Lett. 89 (2002) 092303
ALICE: Z. Conesa del Valle, A. Dainese, H.T. Ding, G. Martínez-García, D.C. Zhou, Phys. Lett. B 663 (2008) 202

A more exotic channel: secondary J/Ψ from b-hadron decay in p-p @ 14 TeV



statistics: 7 months (L = 3.10^{30} cm^{-2} s^{-1}, t = 10^7 s)

- **dimuon events**:
  - 85% of direct J/Ψ
  - 15% of J/Ψ from b-hadron decay

$$\mu^{\pm} + X \longleftarrow B\bar{B} \longrightarrow \mu^{-} + D + X, \quad D \hookrightarrow \mu^{+} + X$$

$$\mu^{\pm} + X \longleftarrow B\bar{B} \longrightarrow J/\psi + X, \quad J/\psi \hookrightarrow \mu^{+} + \mu^{-}$$

- **three-muon events**:
  - 15% of direct J/Ψ
  - 85% of J/Ψ from b-hadron decay

- measurement feasible without secondary vertex reconstruction
- expected statistics: ~ $8.5.10^3$ J/Ψ from b-hadron decay

A. Morsch, International Workshop on Dimuon Physics in Ion-Ion collisions at LHC, Berg-en-dal, South Africa, 2004
ALICE Collab., J. Phys. G: Nucl. Part. Phys. 32 (2006) 1295

Conclusion & outlooks

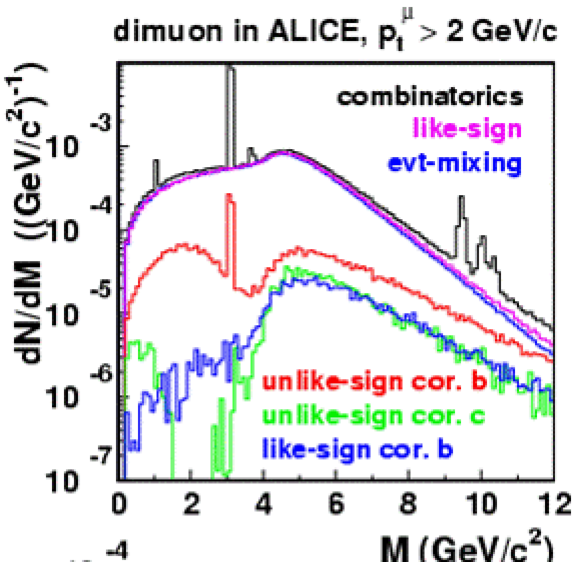
- rich & exciting physics program with the ALICE muon spectrometer @ LHC in the sector of heavy flavours
  - new environment
  - large statistics
  - new observables
  - new analyses
- important contribution to the p-p physics program @ LHC
- promising performances for all physics channels
- the ALICE muon spectrometer will be ready for operation with first p-beams foreseen end of July 2008
- intensive preparation for data taking & analysis is underway

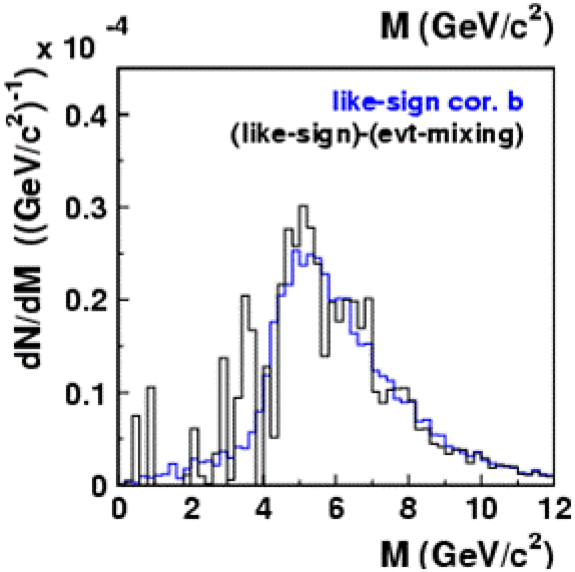
other analyses which should be accessible:

- open charm
- quarkonia & open heavy flavour flow
- like-sign dimuons & dilepton correlations
- Z^0

Backup slides

b cross section from like-sign dimuons





like-sign correlated dimuons originate from:

$B \rightarrow D$ decay:

$$\pi^- + D^0 \longleftarrow B^- B^+ \longrightarrow \mu^+ + \bar{D}^0 + \nu_\mu$$

$$X + \mu^+ \hookleftarrow D^0 \qquad \bar{D}^0 \hookrightarrow \mu^- + X$$

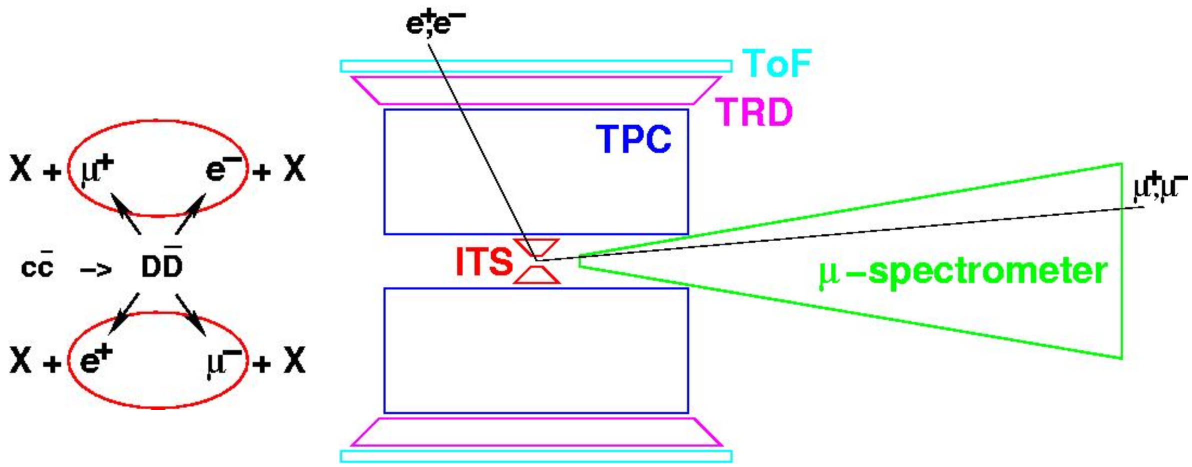
B^0 oscillations:

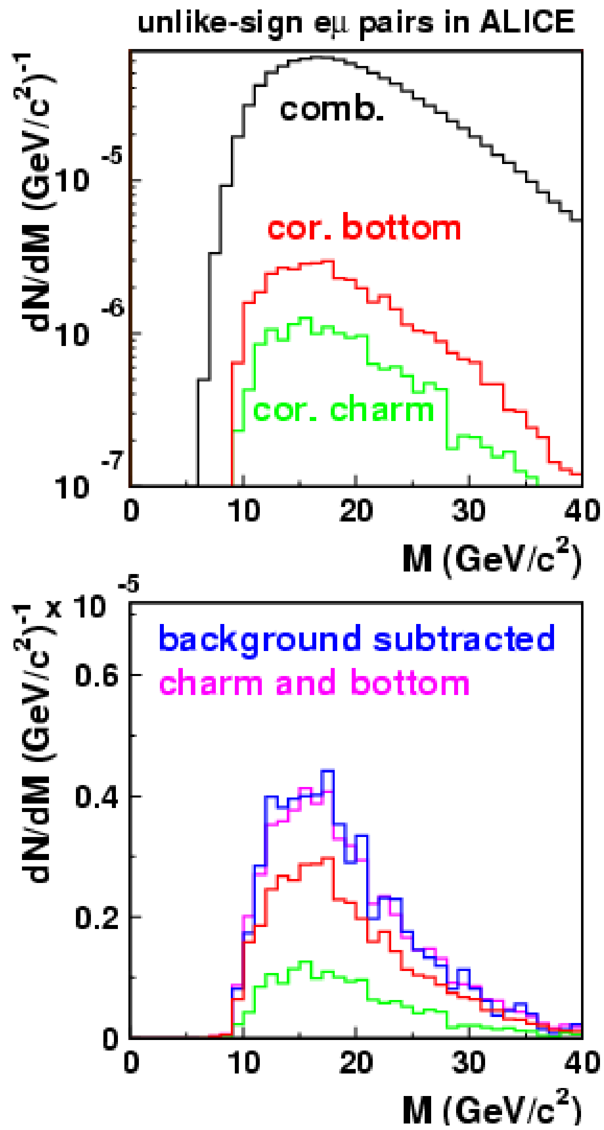
$$X + \mu^- \longleftarrow \bar{B}^0 B^0 \longrightarrow \bar{B}^0 \longrightarrow \mu^- + X$$

- **method relies on characteristics of combinatorial background at high invariant mass**
    - **like-sign correlated b ~ unlike-sign correlated c**
    - **B^0 oscillations ~ 30% of total like-sign correlated**
- **signal accessible via (like-sign) - (event-mixing)**
    - **clean signal (D mesons don't oscillate)**

P. Crochet & P. Braun-Munzinger, N.I.M. A 484 (2002) 564

electron-muon coincidences





- background free signal
- covers intermediate rapidities
- successfully done in pp @ ISR (in 1979!)
- challenging in heavy ion collisions

Open beauty in p-p @ 14 TeV (I)

full simulation: events from PDC'06 (Physics Data Challenge 2006)

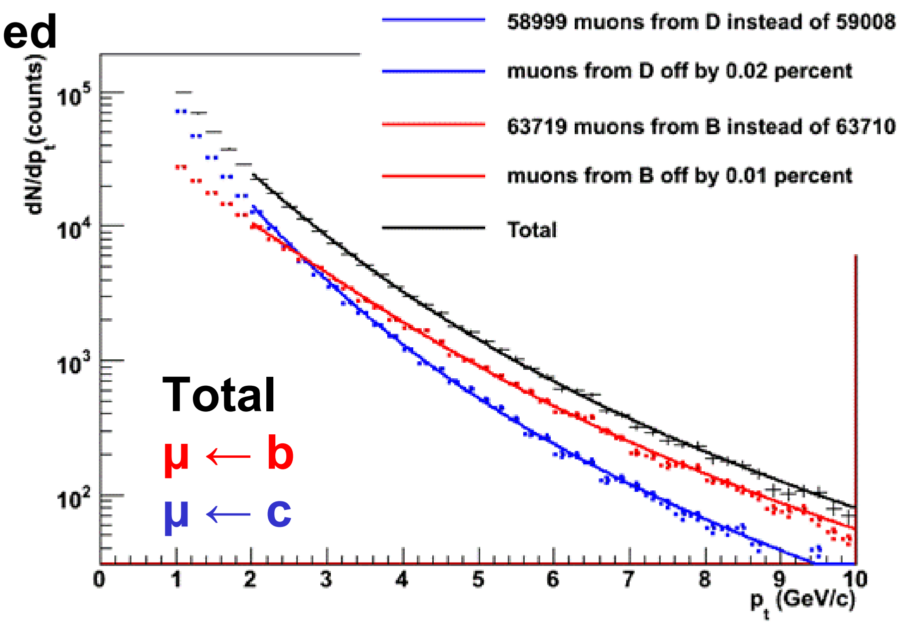
- **cocktail with Pythia minimum bias event & quarkonia**
- **software trigger p_t > 0.5 GeV/c on muons at generation**
- **$\mu \rightarrow \pi$, K perfectly subtracted**

PDC'06: 7.8.10^8 (1.10^6) Pythia (muon) events

UA1 method[1] used by CDF & D0 and applied on simulated data in ALICE for electrons (p-p, Pb-Pb) & (di)muons (Pb-Pb)

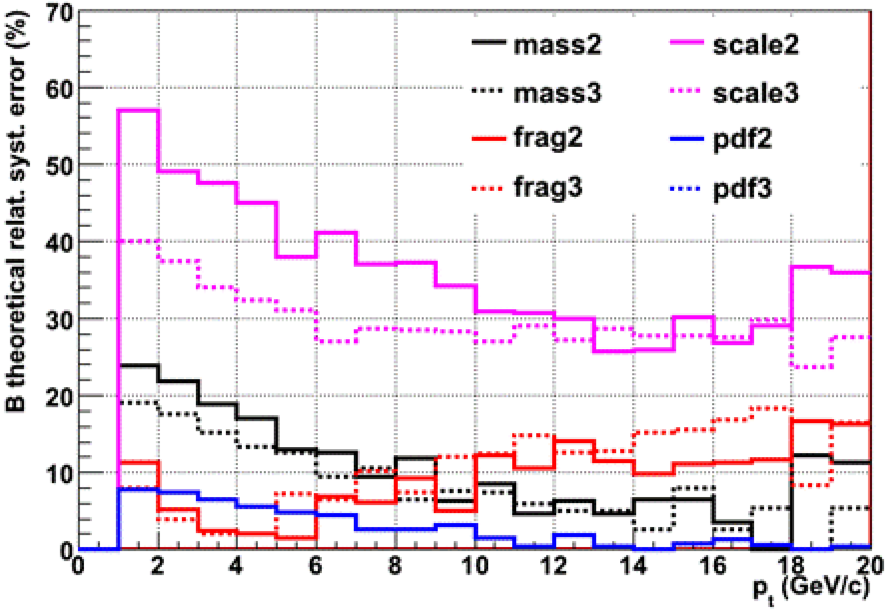
[1]C. Albajar et al., Phys. Lett. B 213 (1988) 405

$\mu \leftarrow$ b yield extracted from a combined fit with fixed shapes for p_t distributions of μ from charm & bottom and b yield as free parameter

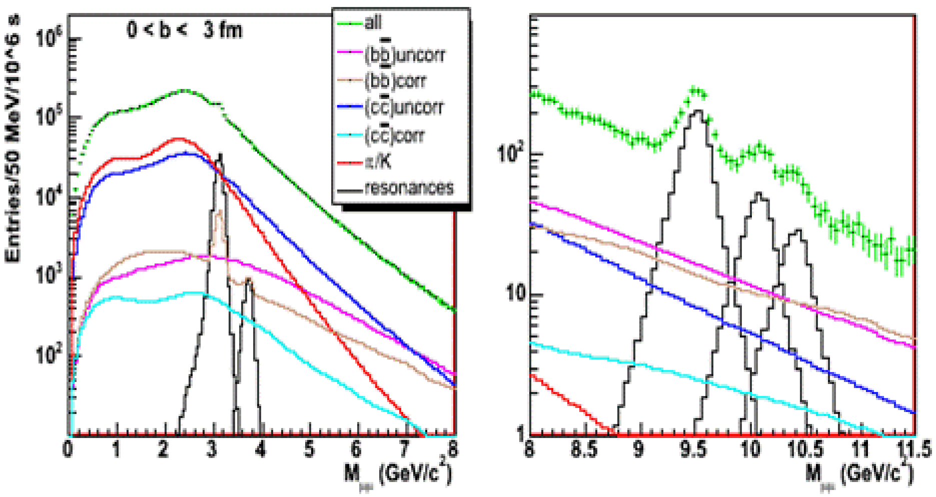


L. Manceau, N. Bastid, P. Crochet, ALICE Physics week, Prague (2008)

Theoretical uncertainties on b-xsection



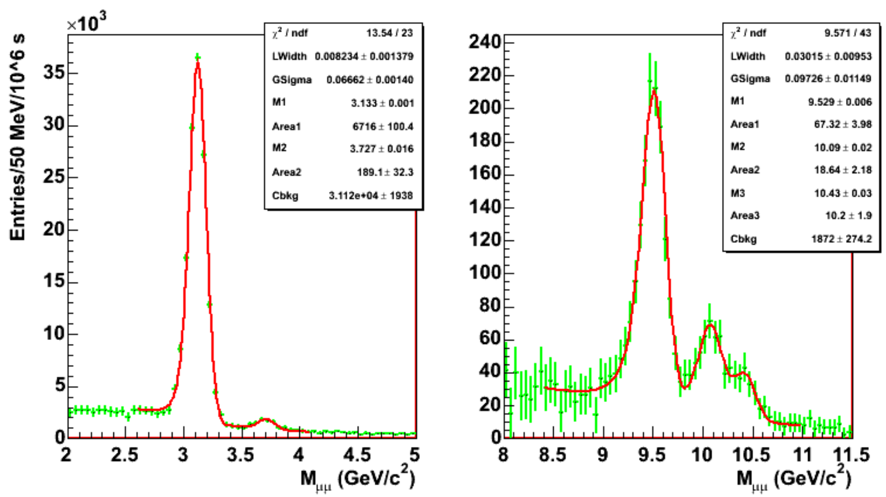
Quarkonium production in Pb-Pb @ 5.5 TeV



0 < b < 3 fm, w/o nuclear effects

	S ($\times 10^3$)	S/B	Signif.
J/Ψ	134 [681]	0.20	150
Ψ’	3.8 [18.9]	0.01	6.7
ϒ (1S)	1.3 [6.3]	1.7	29
ϒ (2S)	0.35 [1.8]	0.68	13
ϒ (3S)	0.20 [1.0]	0.48	8.1

statistics: L = 5.10^{26} cm^{-2} s^{-1}, t = 10^6 s
[ ]: yields for min. bias



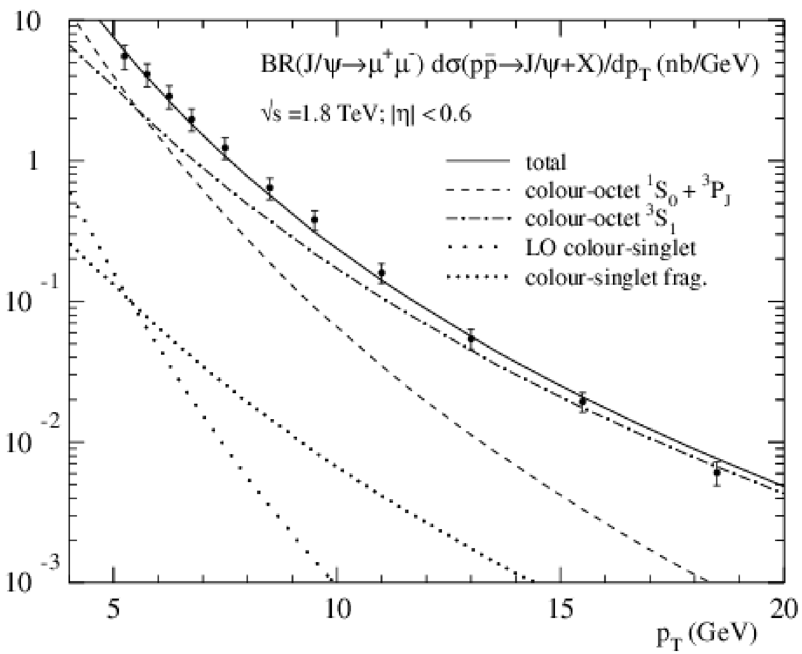
- **J/Ψ: large statistics (0-20 GeV/c) & good significance**
- **Ψ’: small S/B**
- **ϒ (1S): good statistics (0-8 GeV/c), S/B > 1, good significance**
- **ϒ (2S): good statistics (0-8 GeV/c), good significance**
- **ϒ (3S): low statistics, 2-3 runs needed**

S. Grigoryan & ALICE Collab., J. Phys. G: Nucl. Part. Phys. 32 (2006) 1295

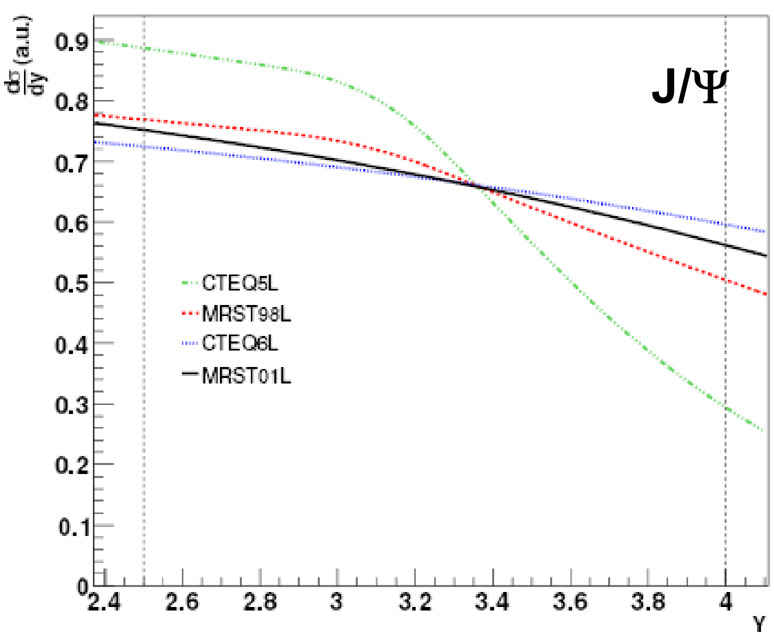
Quarkonium production in p-p collisions: motivations

- information on production mechanisms
- insight on PDF at very small Bjorken-x
- baseline for p-A & A-A collisions

relevant observables: yields, differential distributions, polarization

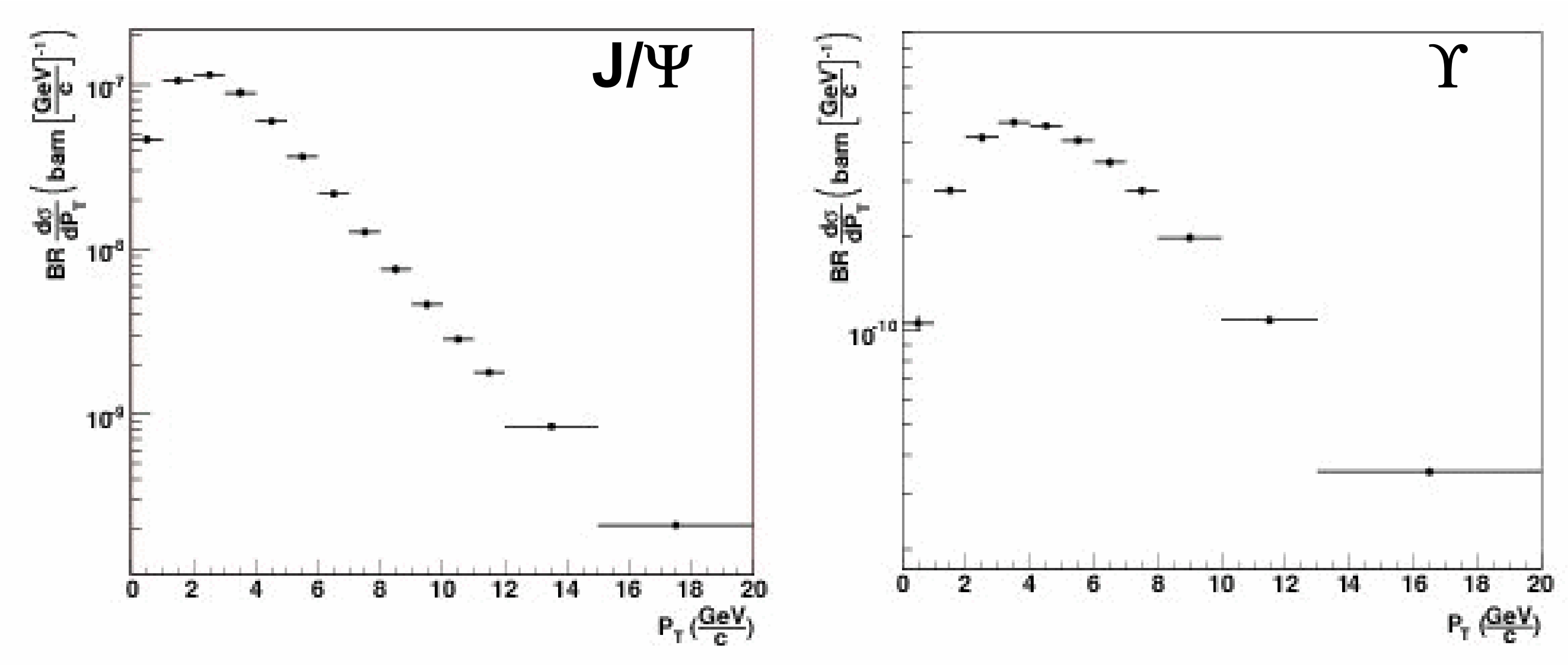


M. Krämer, hep-ph/0106120



D. Stocco et al., ALICE-INT-2006-029 (2006)

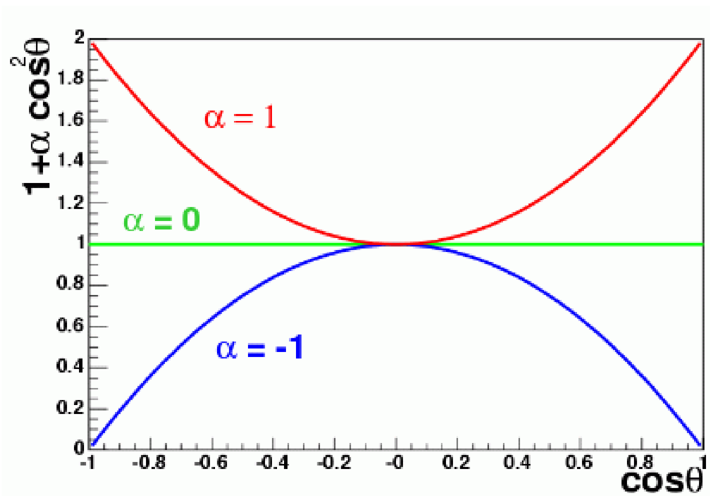
Quarkonium production in p-p @ 14 TeV differential distributions (II)



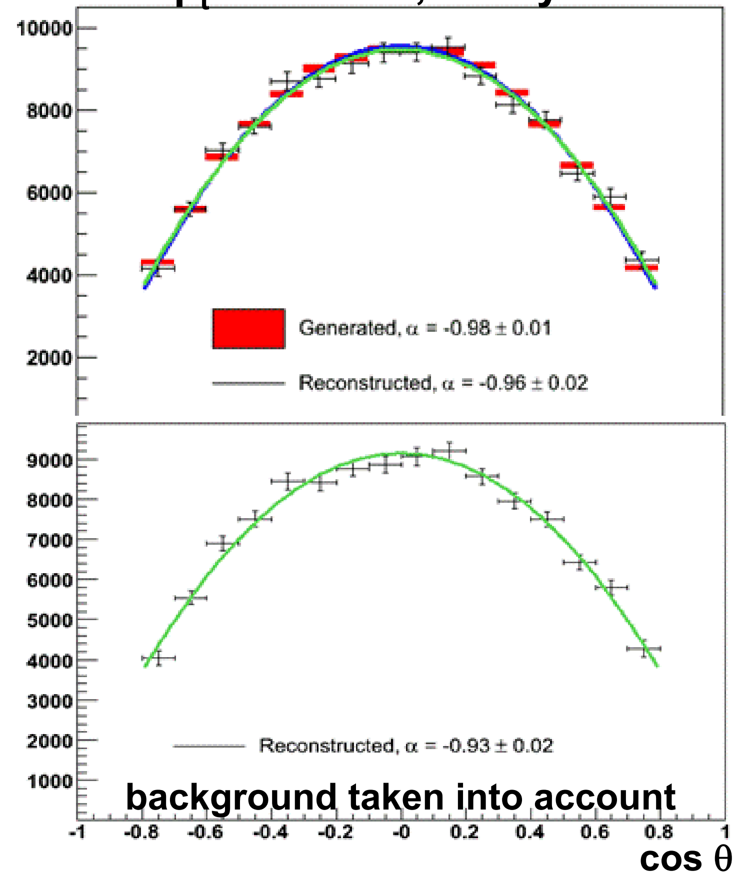
- large statistics expected allows for **differential** analyses
- quarkonia (J/Ψ, ϒ) can be measured over a **wide p_t range**

J/Ψ polarization in p-p collisions @ 14 TeV

polarization reconstructed from the angular distribution of μ+ (from $J/\Psi \rightarrow \mu^+\mu^-$) in the J/Ψ rest frame



0<p_t<20 GeV/c, -3.7<y<-3.3



$d\sigma/d\cos\theta = 1 + \alpha \cos^2\theta$

α > 0: transverse polarization

α = 0: no polarization

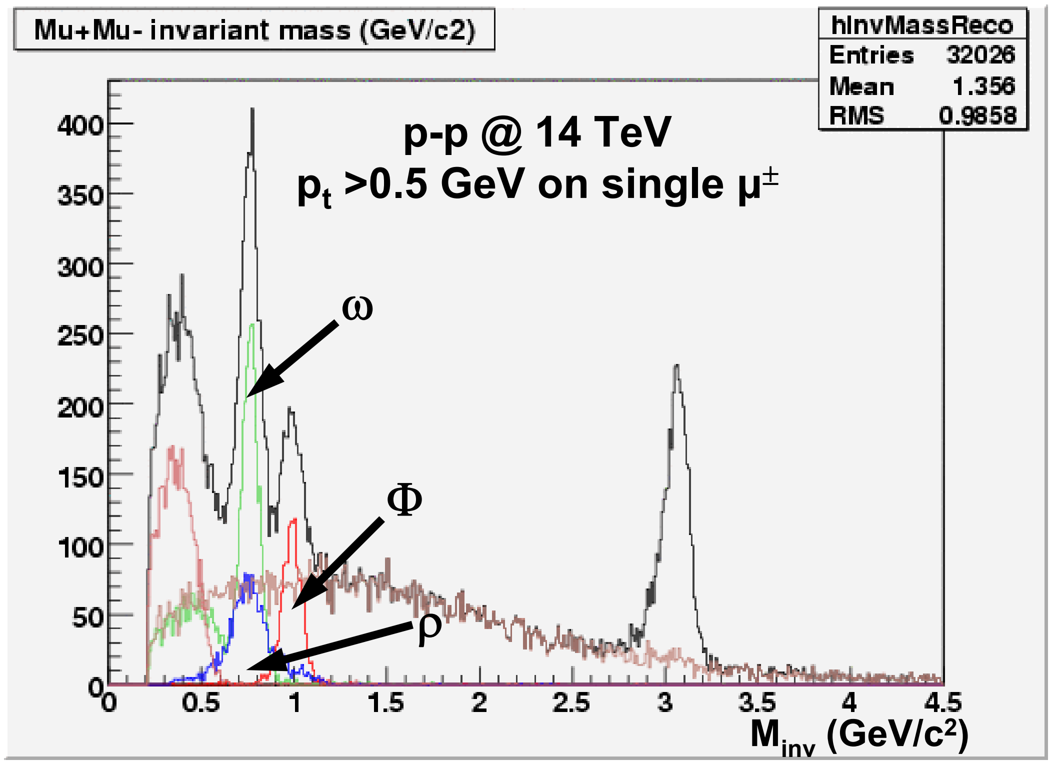
α < 0: longitudinal polarization

- **study possible with > 50000 J/Ψ's**
- **background contribution small**
- **α reconstructed with an error < 10%**

R. Arnaldi & E. Scomparin, 4th DiMuonNet Workshp, Paris, 2006

Production of low mass resonances in p-p collisions @ 14 TeV

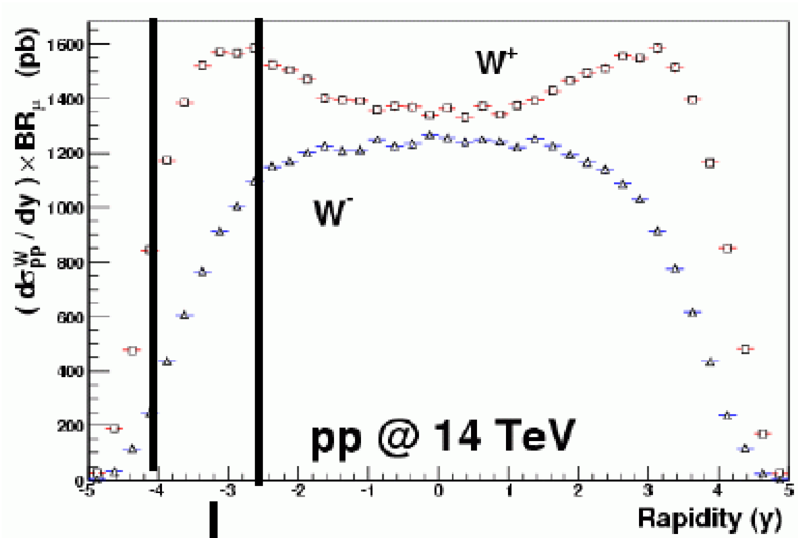
- probe of in-medium effects & chiral symmetry restoration
- p-p: baseline for A-A collisions



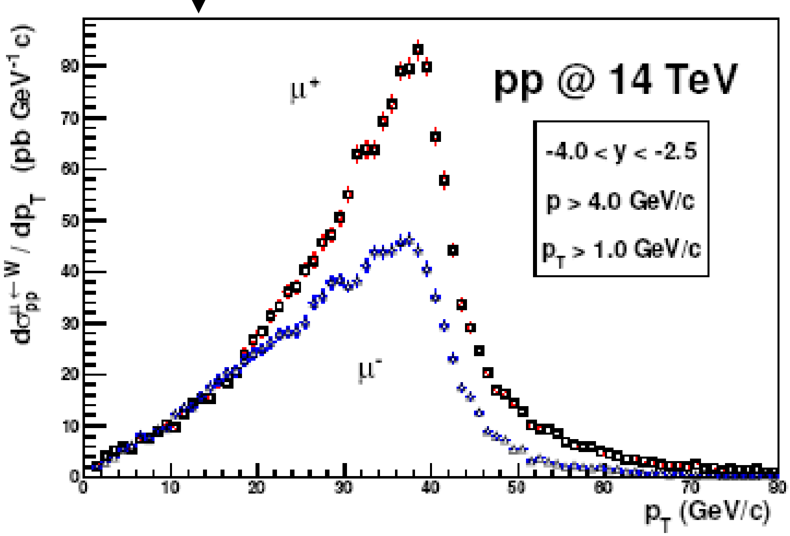
low mass resonances can be measured in p-p @ 14 TeV in the first days

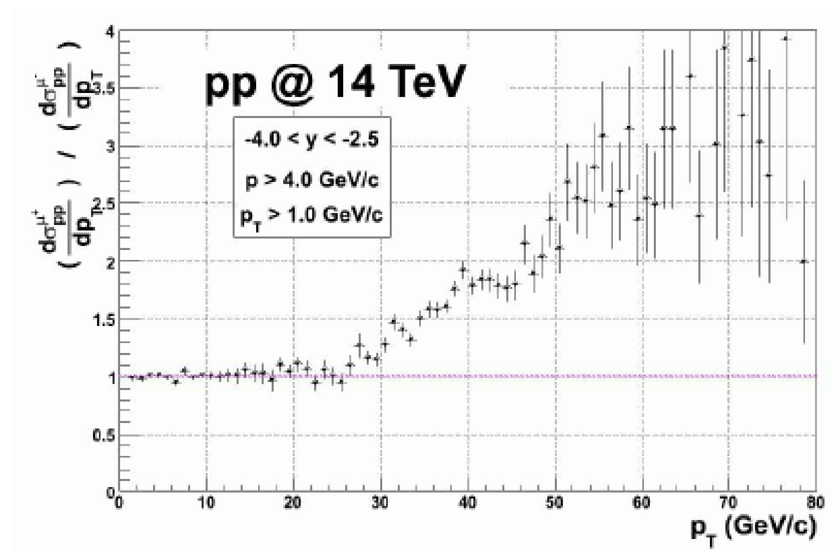
R. Tieulent & F. Nendaz, 4th DiMuonNet Workshop, Paris, 2006

Electro-weak $W^{\pm}$ boson production (II)



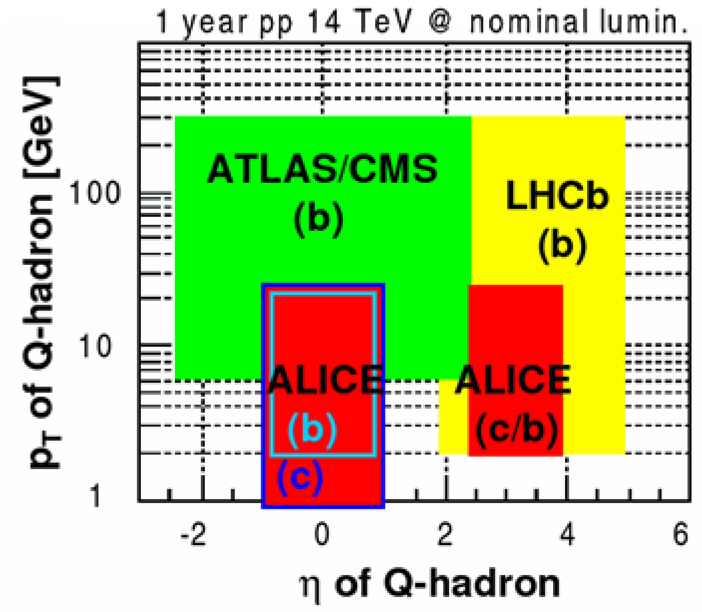
- charge asymmetry on $W^{\pm}$ production due to collision isospin
  → muon charge asymmetry
- p_t dependence of $N(\mu^+)/N(\mu^-)$: promising observable for $W^{\pm}$ production

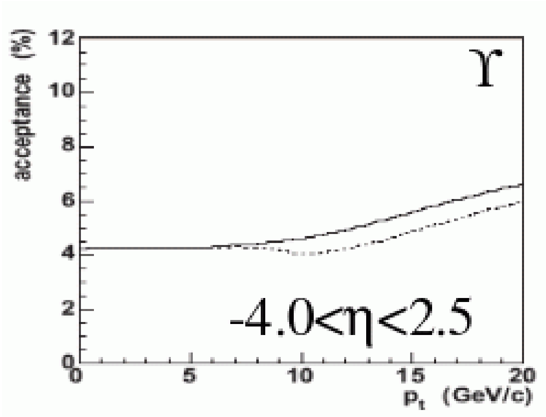




Z. Conesa del Valle et al., ALICE-INT-2006-021 & Eur. Phys. J. C49 (2007) 149

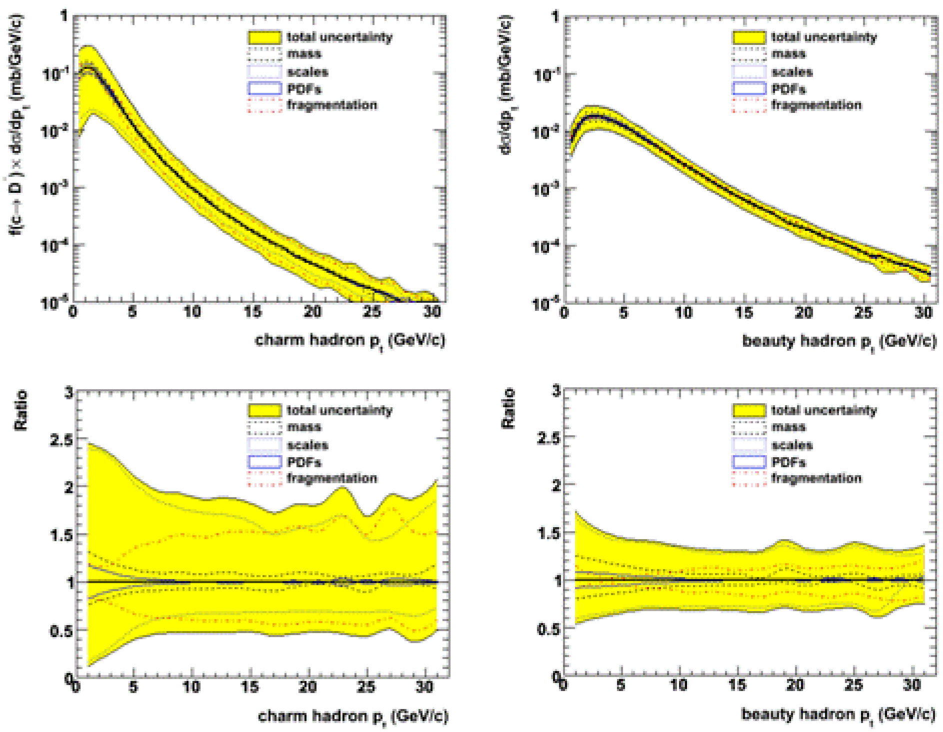
ALICE capabilities for heavy flavour measurement





CERN/LHCC 2005-014 & ALICE Collab., J. Phys. G: Nucl. Part. Phys. 30 (2004) 1517

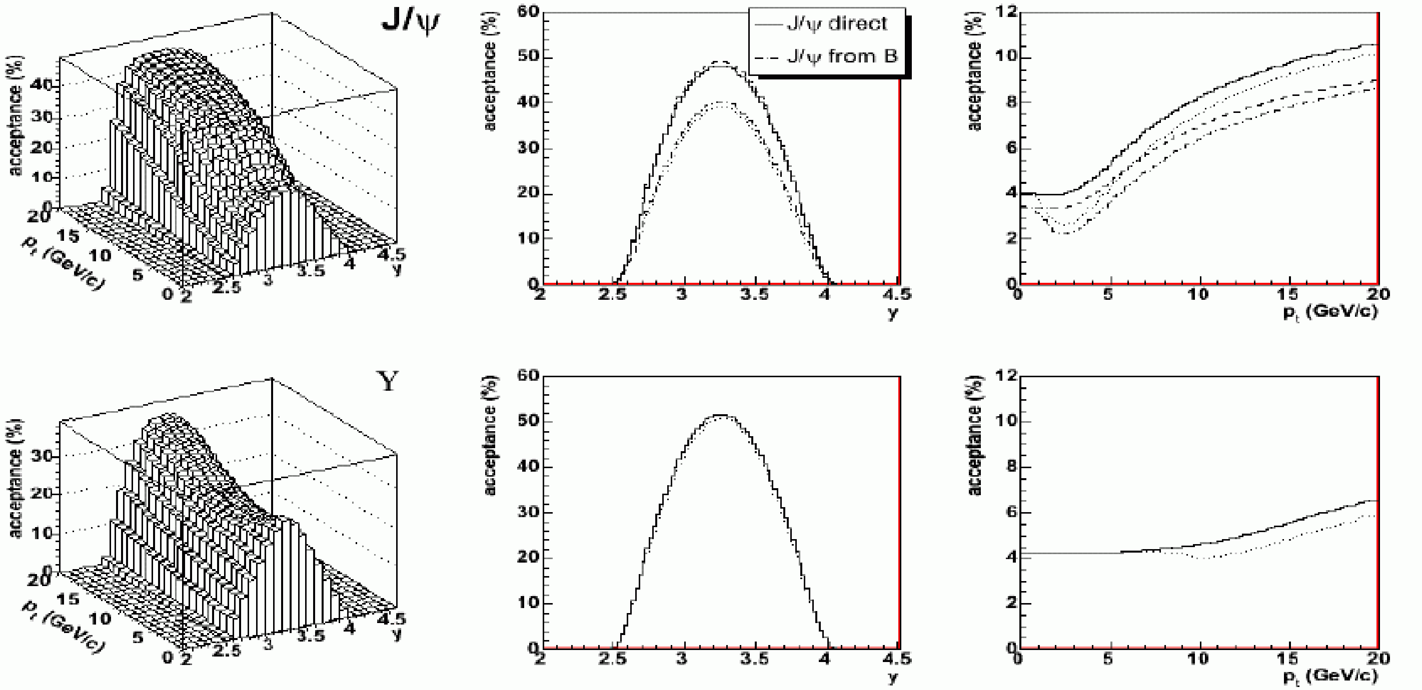
Theoretical predictions (Hera-LHC) in forward region



Geometrical acceptance

Inputs for the simulation (2 /4)

Resonance geometrical acceptances (lower histos – with trigger cut on single muon $P_t(\mu) > 1(2)$ GeV/c for J/ψ(ϒ))



	J/ψ direct	J/ψ from B	ϒ
without trigger cut	4.46	3.88	4.41
with trigger cut	3.47	3.05	4.29

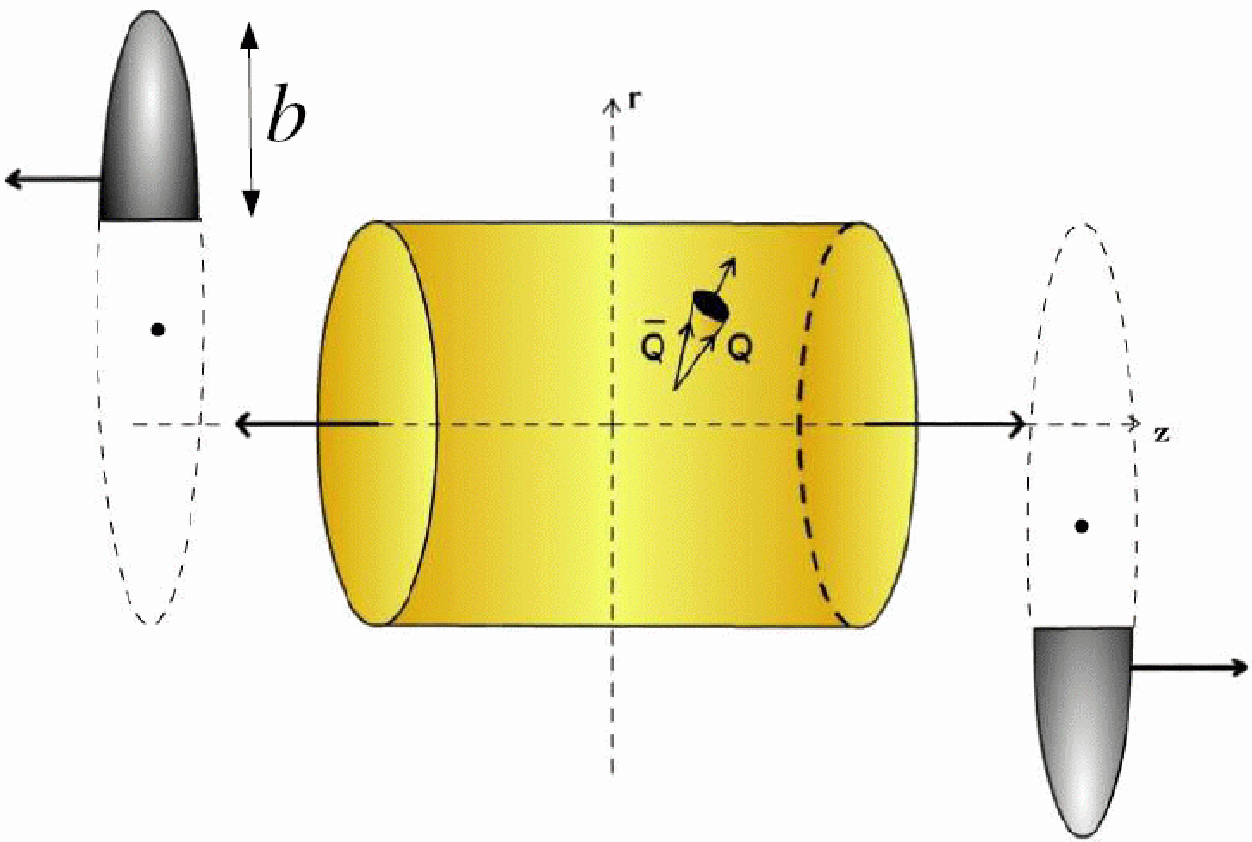
← Integrated acceptances in %

Suppression scenarii

QGP suppression model (1/3)

QGP formation in heavy ion-ion collisions.

$$T^3(\tau, r, b) = \tau_0(r, b) T_0^3(r, b)/\tau$$



Suppression scenarii

QGP suppression model (2/3)

- Due to color screening effects a $Q\bar{Q}$ pair cannot form a bound state in QGP with $T > T_D$ -screening temperature. T_D could be calculated for different quarkonia states in lattice QCD and potential models.

- It is assumed that in Pb-Pb collisions an equilibrated QGP is formed which expands along the collision axis according to the Bjorken's hydrodynamics: $\tau T^3(\tau, r) = \tau_0(r) T_0^3(r)$, r - transverse coordinate. For fixed QGP formation time τ_0 and initial temperature T_0 one can calculate the screening time $t_D(r) = \tau_0(r)(T_0(r)/T_D)^3$ and compare it with the formation time for a given resonance. If $t_D(r_R) < \gamma\tau_F$ at the resonance location, it will survive. $t_D(0) < \gamma\tau_F$ means no suppression at all! Using $\gamma = (1 + P_t^2/m^2)^{1/2}$ ⟶ it will always escape the QGP if $P_t > P_t^{max} = m((t_D(0)/\tau_F)^2 - 1)^{1/2}$

- The QGP parameters depend on collision centrality (impact par. b).

DCA method

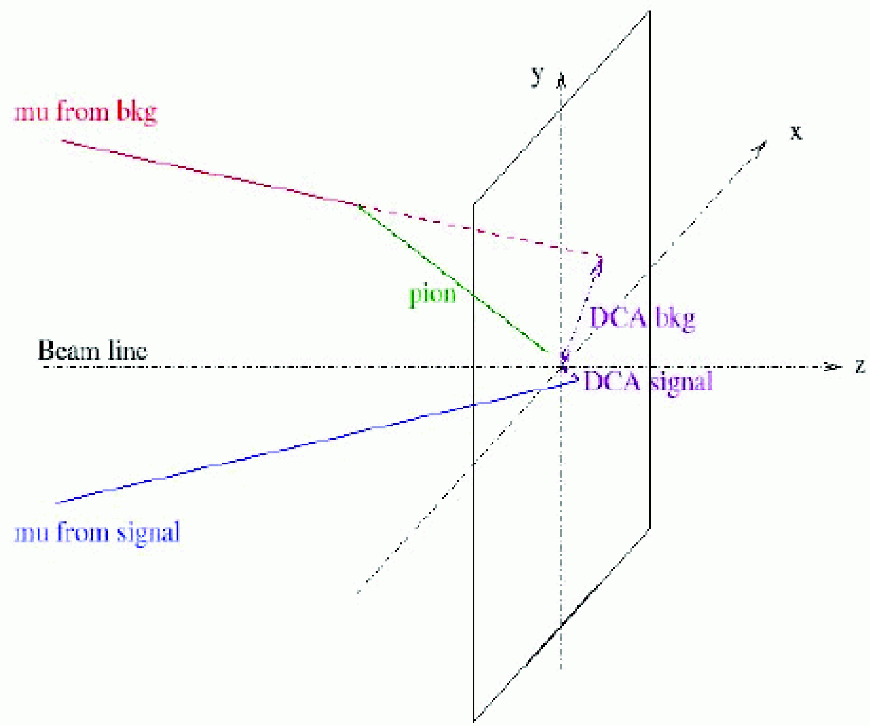
Measurement of single-muon yield using DCA method

DCA definition: Transverse distance of the track extrapolation in the transverse plane of the collision

Real DCA-mean:

~ a few μm for HF muons

~ 1 cm for bkg decay muons

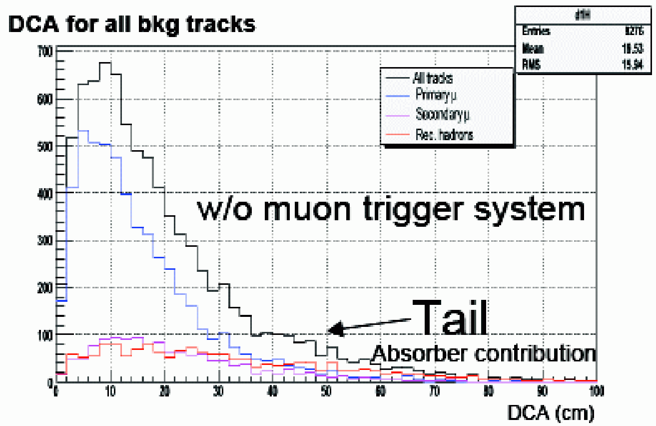


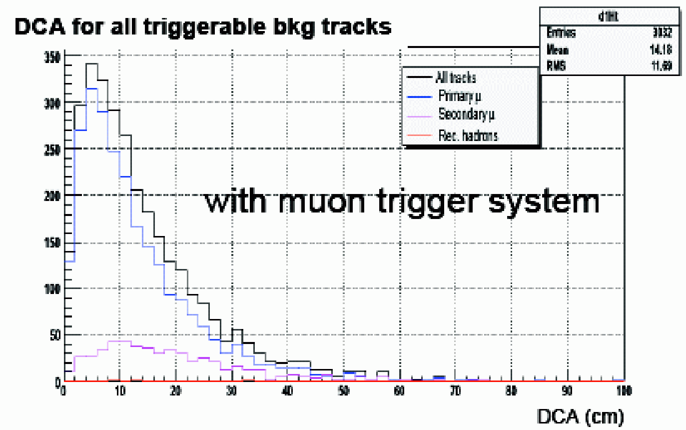
In principle, we can discriminate the muon sources thanks to their DCA due to their specificity, but Coulomb multiscattering in the absorber smears this DCA value.

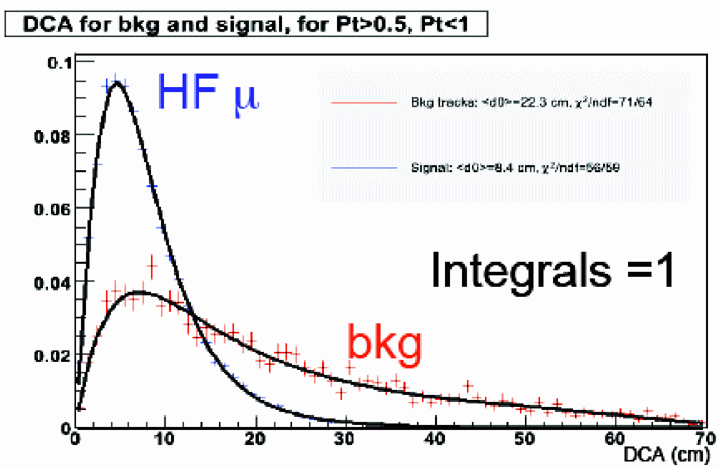
DCA method

DCA distributions $p_t^{rec} \in [0.5 ; 1]$ GeV/c

DCA Background distributions





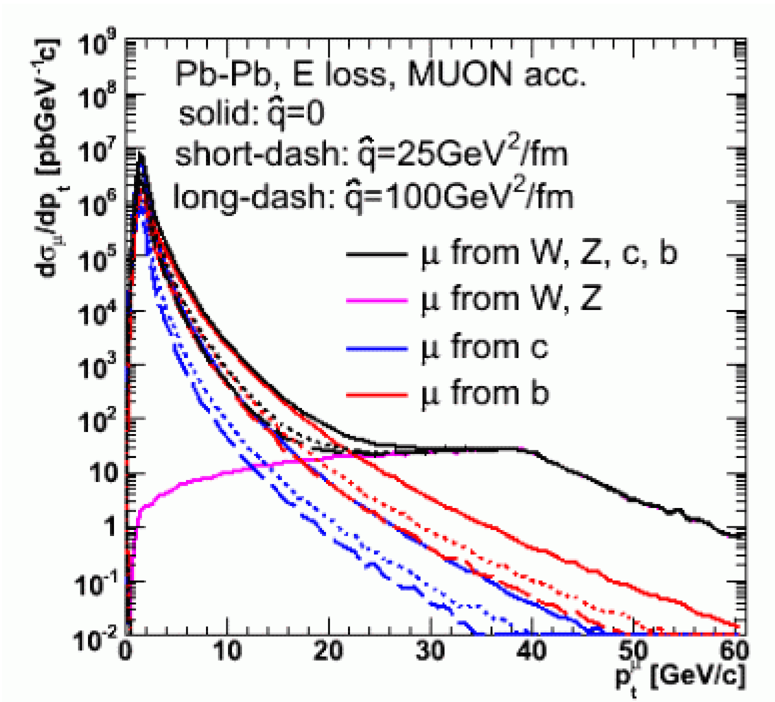


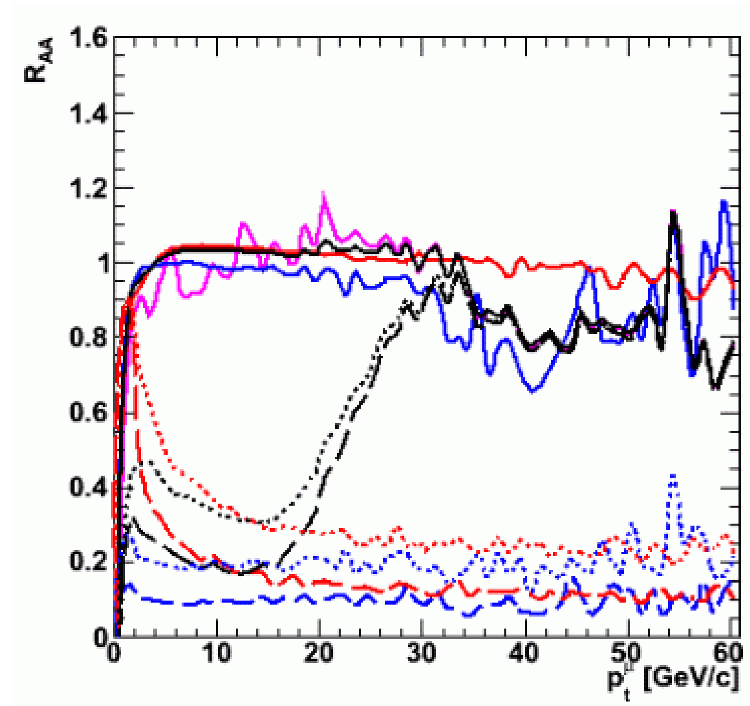
DCA distributions for bkg and signal in the p_t range [0.5;1] GeV/c. Histograms are normalized to 1.

- Charm contribution is larger than Beauty contribution in this range
- 2 different fit functions (f_{sig}, f_{bkg})

Open heavy flavours in p-p collisions: motivations (III)

Pb-Pb @ 5.5 TeV
muon spectrometer acceptance

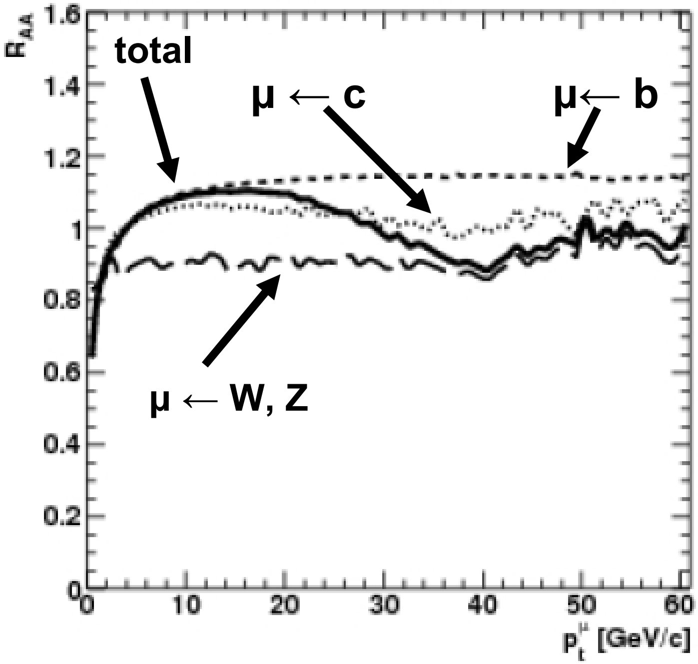




Z. Conesa Del Valle et al., ALICE-INIT-2006-021; A. Dainese, ALICE-Physics-Week (2007) Münster

baseline for the study of in-medium effects in A-A collisions
(energy loss effect on heavy quarks)

Shadowing effects in Pb-Pb @ 5.5 TeV (10%)



Quenching

Heavy quarks decays

- $\frac{d^2\sigma}{dydp_t}$ from MNR (pQCD) code, [Mangano, Nason, Ridolfi, Nucl. Phys. B 373 (1992) 295]
  Parameters : $m_c = 1.2$ GeV, $m_b = 4.75$ GeV. CTEQ4M PDFs.
- The heavy-quarks fragment according to the Peterson fragmentation function,
  Parameters : $\epsilon_c = 0.02$, $\epsilon_b = 0.0012$. [CERN-LHCC 2005-014, hep-ph/0601164]
- The mesons decay within the spectator model,
  It is considered that heavy-quarks decay independently of the light-quark from the meson, so $B \to \mu$ is mimicked by $b \to c + \mu + \nu_\mu$. [Altarelli et al, Nucl. Phys. B 208 (1982) 365]

Weak bosons decays

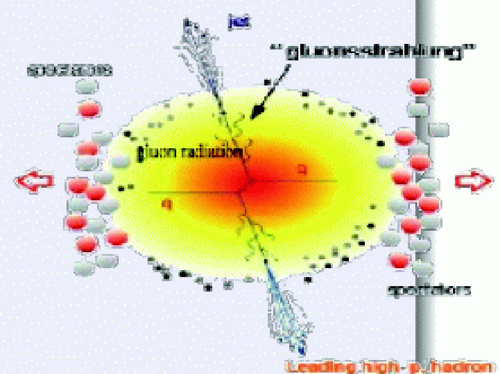
- $\frac{d^2\sigma}{dydp_t}$ distributions and decays from PYTHIA [Sjöstrand, hep-ph/0108264]
  PYTHIA reproduce W and Z TeVatron distributions. We use CTEQ4L PDFs.
- Cross sections from NLO calculations
  [Frixione, Mangano, JHEP 05 (2004) 056 ; Vogt, Phys. Rev. C 64 (2001) 044901]
- Mimicked the influence of the isospin of the colliding system.

Quenching

The BDPMS (Baier-Dokshitzer-Mueller-Peigné-Schiff) formalism

- Allow to calculate heavy-quark radiative energy loss,
- In the process, the gluons from the parton wave fonction could acquire energy and be eventually radiated,
- In this approximation, the energy loss is :

$$-\Delta E = \int^{\omega_c} \omega \frac{dI}{d\omega} \propto \alpha_s C_R \hat{q} L^2$$



Proportional to L^2, $\hat{q}$ and C_R (larger for g than for q)

Independent from the initial parton energy.

[BDPMS, Nucl. Phys. B 484 :265(1997) ; BDPMS, Nucl. Phys. B 483 :291 (1997)]

The dead cone effect

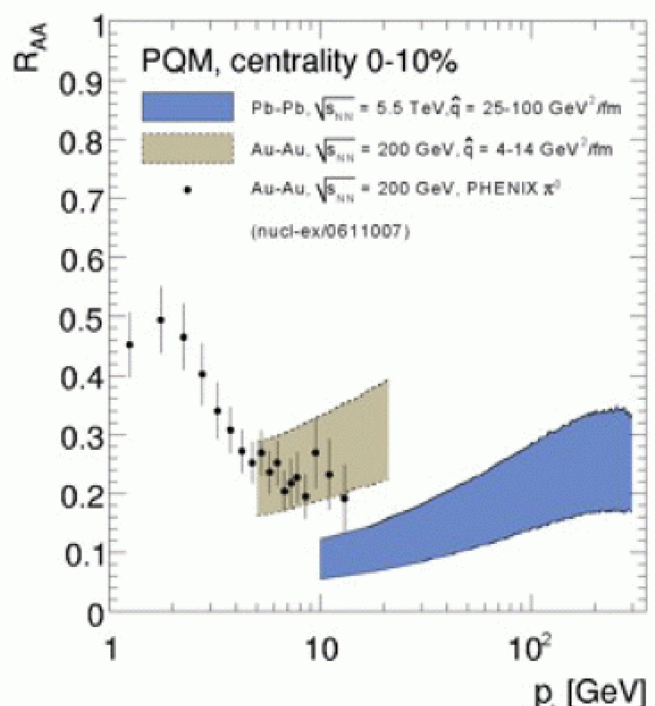
Due to their mass, gluon-bremsstrahlung of heavy-quarks is suppressed for angles $\theta < M/E \equiv \theta_0$. [DKT, J.P.G 17 :1602 (1991) ; DK, P.L.B 519 :199 (2001)]

Quenching

The Parton Quenching Model

The Parton Quenching Model (PQM)

- Quenching weights : BDMPS formalism $\oplus$ dead cone effect $\oplus$ dependence on parton initial energy [P.R.L 89 (2002) 092303]
- Collision geommetry *à la* Glauber model [P.R.D 71 (2005) 054027 ; P.L.B 637 (2006) 362]



Comparison to RHIC data

- ✓ Reproduce R_{AA} of π^0 at high p_t
- ✓ Describe R_{AA} of non-photonic electrons

$\Rightarrow$ $\hat{q}_{RHIC} = 4 \div 14$ GeV^2/fm

Extrapolation to LHC

Assume $\hat{q} \propto \frac{dN_{ch}}{d\eta} \sim 3000$:

[EKRT, N.P.B 570 (2000) 379]

$\Rightarrow$ $\hat{q}_{LHC} = 25 \div 100$ GeV^2/fm.