Quarkonium and Heavy Flavour Physics with the ALICE muon spectrometer at the LHC

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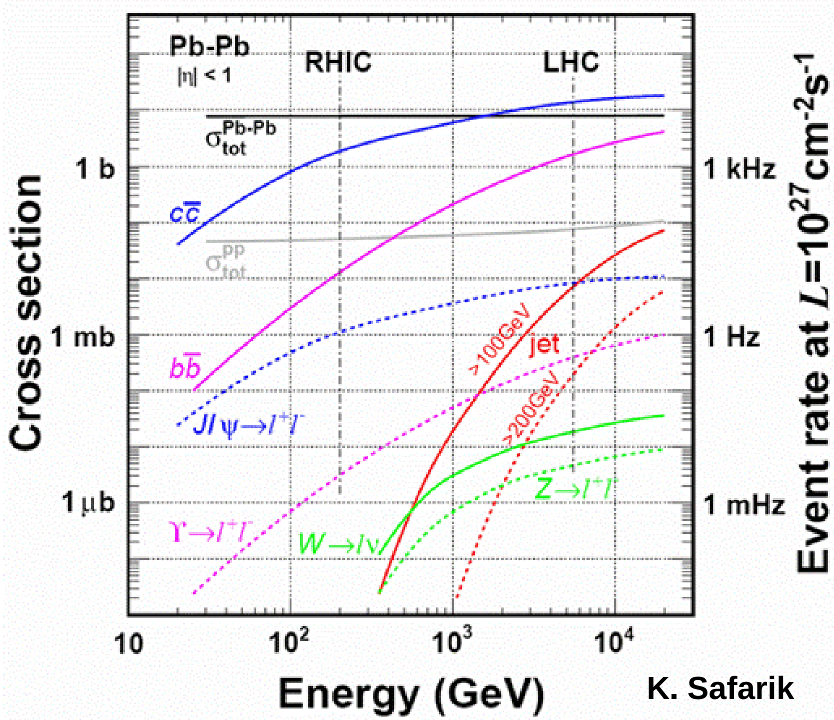
Outline:

- Physics motivations
- The ALICE muon spectrometer
- Feasibility studies in p-p & Pb-Pb for selected channels
- First heavy flavour & quarkonium measurements
- Conclusion & Outlooks

Heavy flavour cross-sections @ LHC



Pb-Pb (LHC) *vs* Au-Au (RHIC)

- σ_c(LHC) = σ_c(RHIC)×10
- σ_b(LHC) = σ_b(RHIC)×100
- σ_W(LHC) = σ_Υ(RHIC)×10
- σ_Z(LHC) = σ_Υ(RHIC)

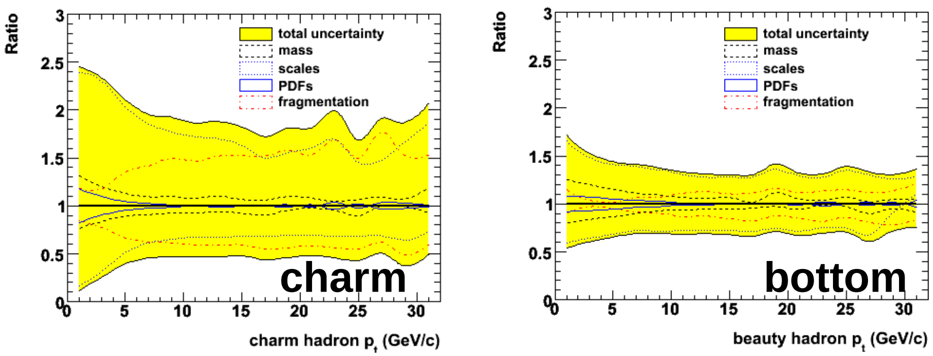
ALICE baseline for charm/bottom:
NLO predictions (+ binary scaling & shadowing in PbPb)

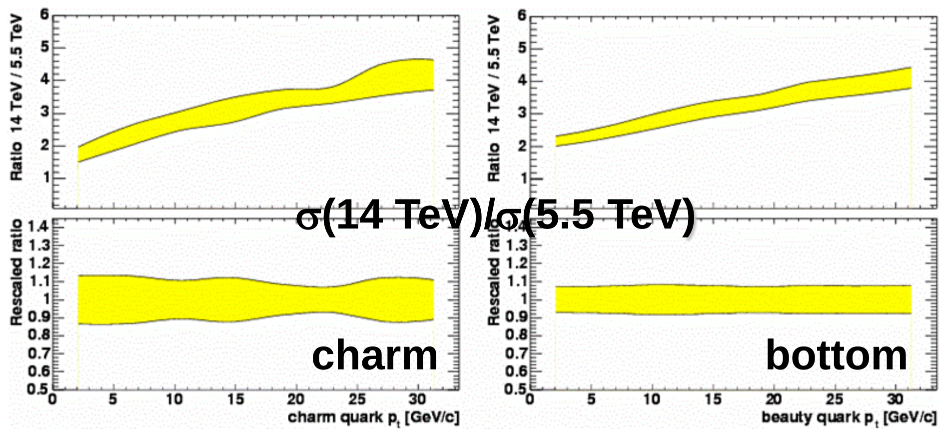
	p-p @ 14 TeV	p-p @ 7 TeV	Pb-Pb (5%) @ 5.5 TeV
σ_{qq} (mb)	11.2/0.445	6.91/0.232	4.32/0.18
N_{qq} (/event)	0.16/0.0064	0.099/0.0033	115/4.56
C_{shad}	1/1	1/1	0.65/0.84

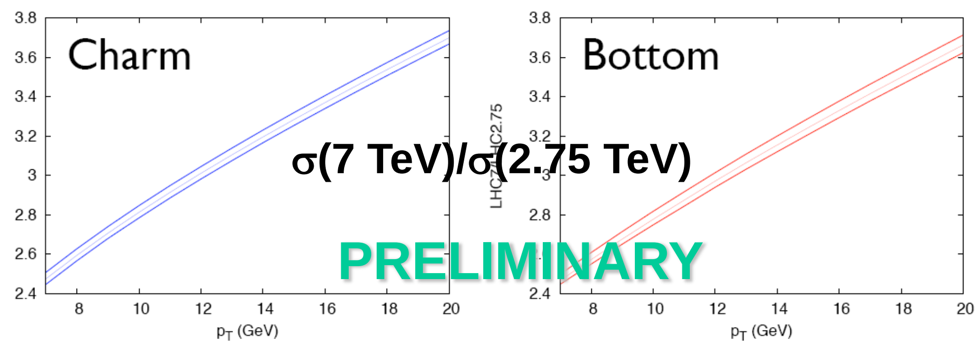
yields assume σ^{inel} (pp) = 70 mb

Heavy flavours: cross-sections

p-p @ 14 TeV





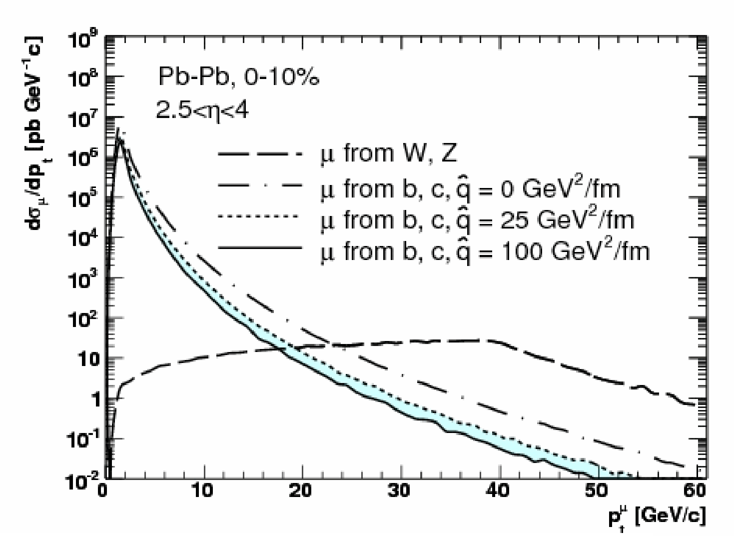


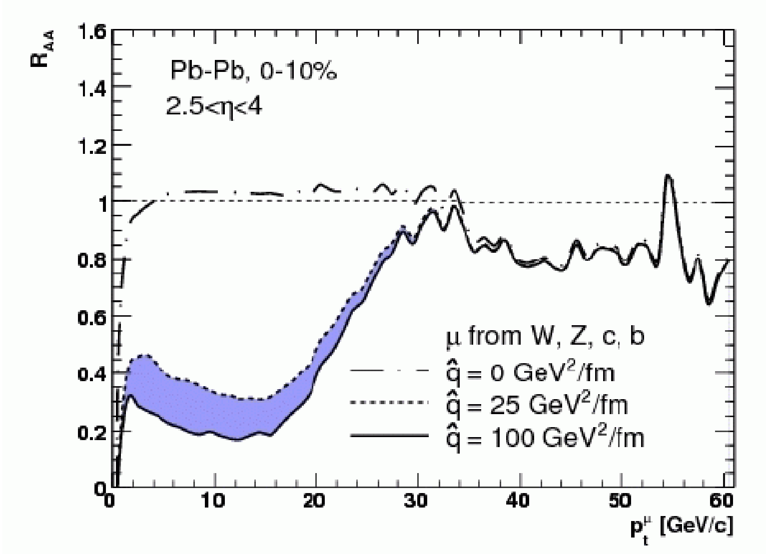
- **stringent test of pQCD calculations**
- **NLO uncertainties on x-sections at 14 TeV: a factor 2-3**
- **uncertainties on extrapolation: ~10%**
- **similar uncertainty expected for σ(7 TeV)/σ(2.75 TeV)**

measuring σ(c), σ(b) in p-p @ 7 (and 14) TeV is top priority

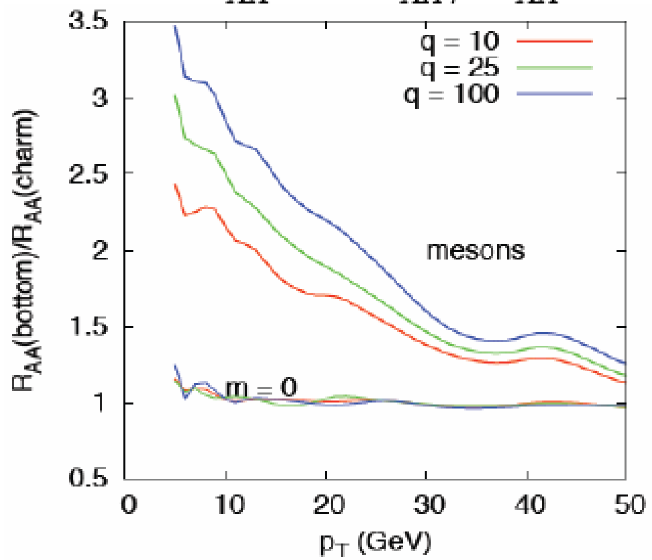
14 TeV: J. Phys. G 32 (2006) 1295
7 TeV: M. Cacciari, private communication

Heavy flavours: energy loss effects





$$R_{AA}^{B/D} = R_{AA}^{B} / R_{AA}^{D}$$



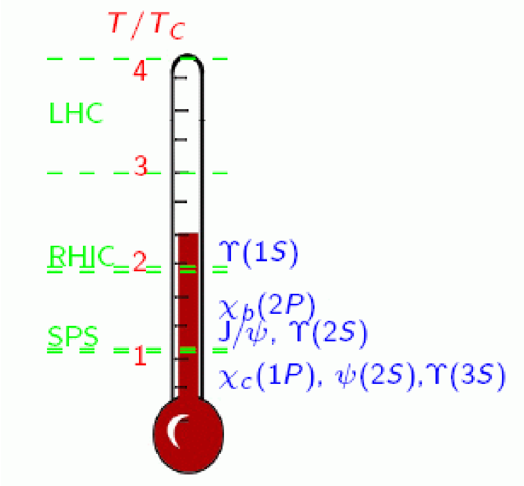
- dN/dp_t: **crossing point** of μ from (c, b) & W shifted down by **5-7 GeV/c**
- **new medium-blind reference available**: W affected by shadowing, only
- R_{AA} **reduced by a factor 2-5** for 2 <p_t <20 GeV/c

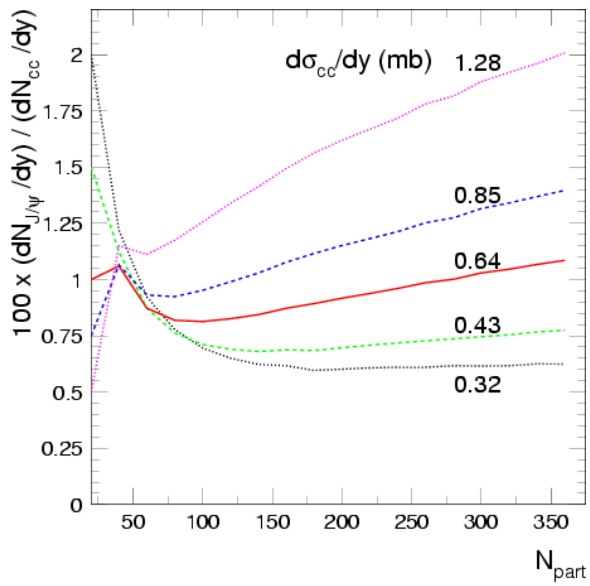
- new ratio **R_{AA}(B)/R_{AA}(C) available**: isolate mass dependence of ΔE

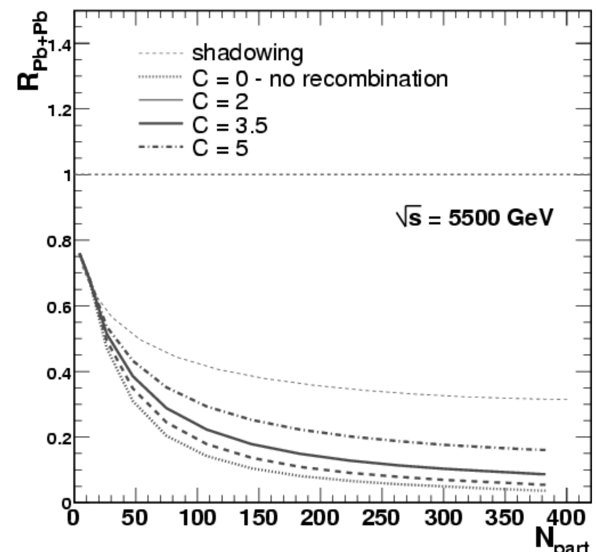
Z. Conesa del Valle et al., Phys. Lett. B 663 (2008) 202
Phys. Rev. Lett. 89 (2002) 092303, J. Phys. G 35 (2008) 054001

Quarkonium production scenarios

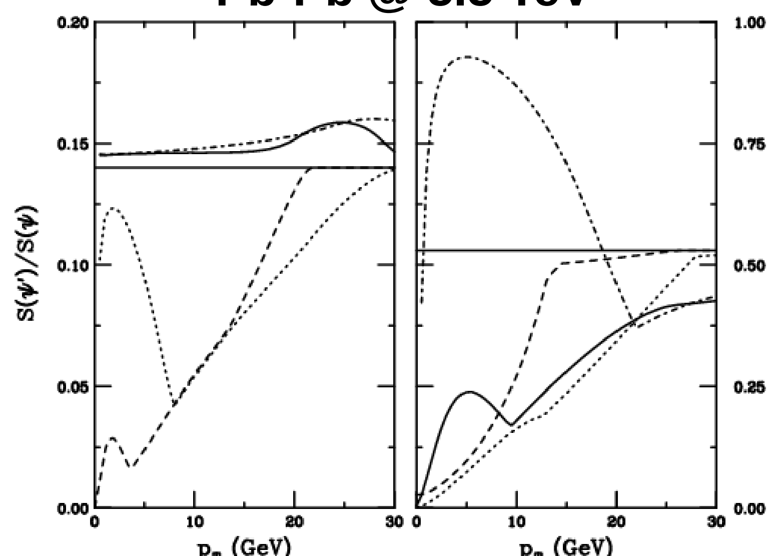
dissociation temperatures | **re-combination** | **re-dissociation by comovers**







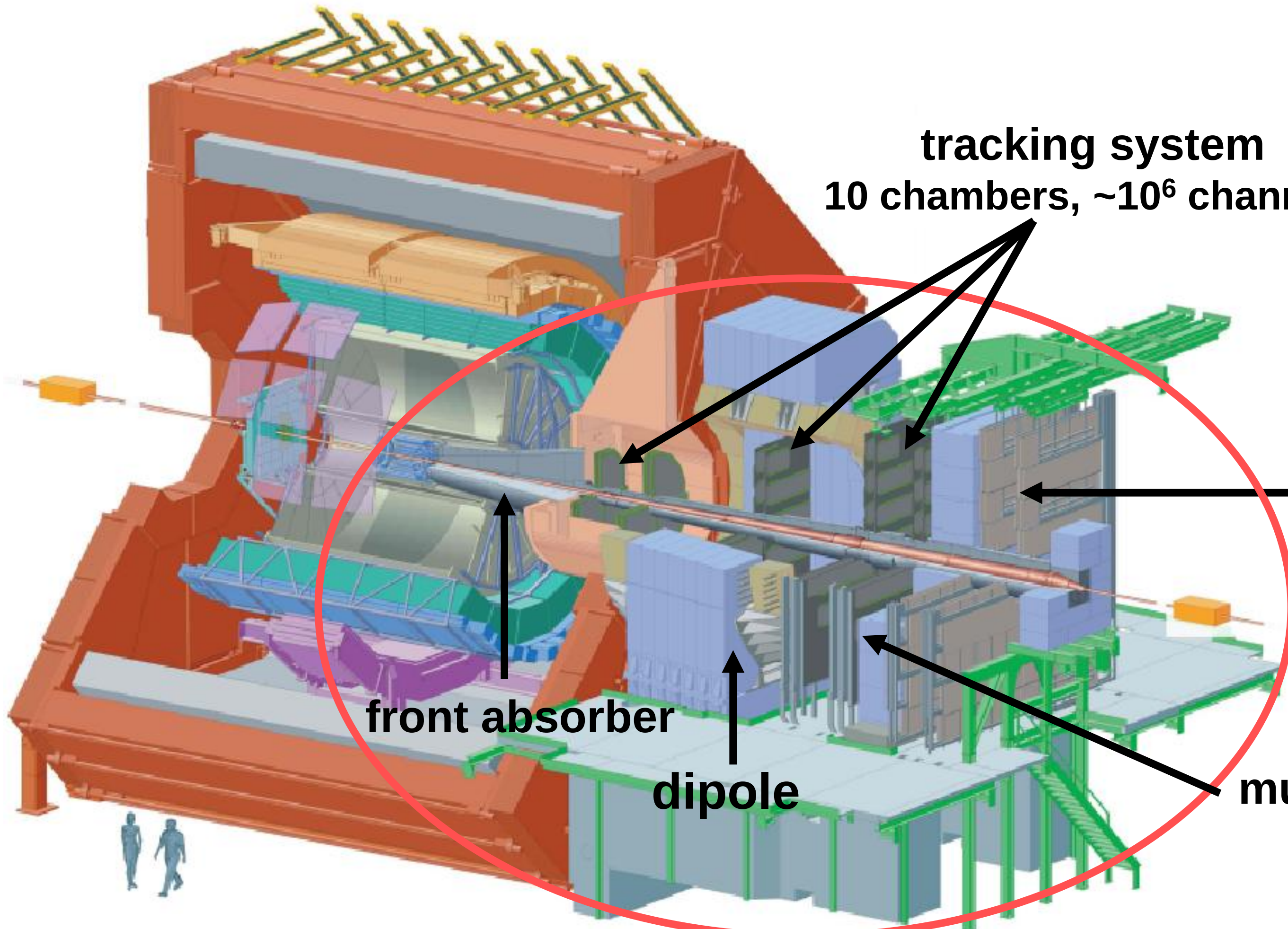
Pb-Pb @ 5.5 TeV



- **ϒ (1S) melts at LHC only**
- **new charmonium production scenarios**
- **predictions depend on σ(c)**
- **relevance of quarkonium ratios vs p_t**

A. Mocsy et al., Phys. Rev. Lett. 99 (2007) 211602
A. Andronic et al., Phys. Lett. B 652 (2007) 259,
A. Capella et al., Eur. Phys. C58 (2008) 437,
R. Vogt in J. Phys. G35 (2008) 054001

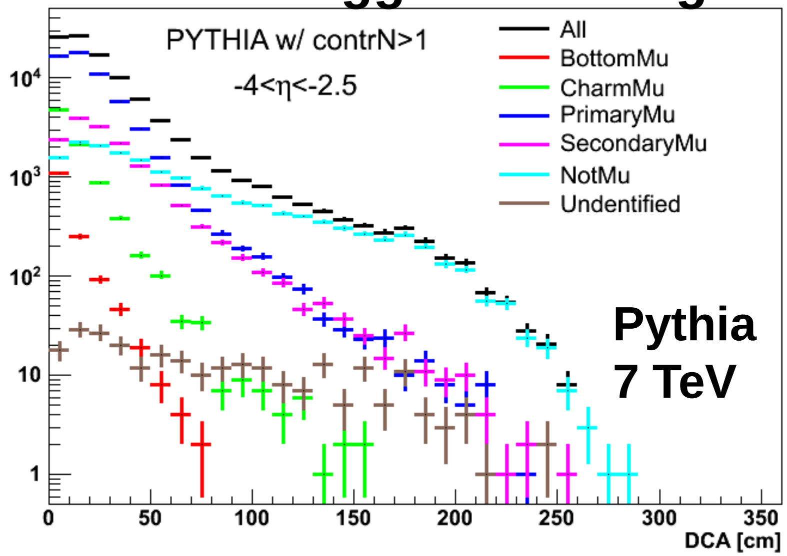
The muon spectrometer of the ALICE experiment



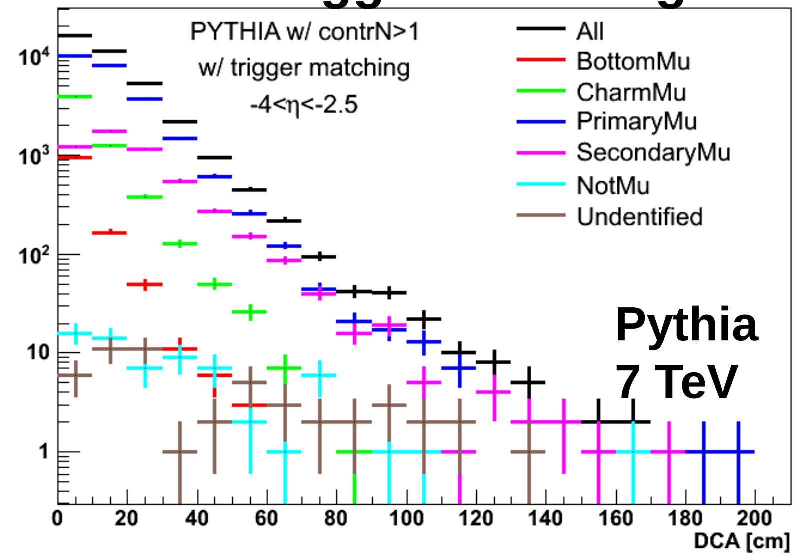
- acceptance: $-4 < \eta < -2.5$
- high resolution tracking system: $\Delta M < 100$ MeV/c^2 @ 10 GeV/c^2
- trigger system: time resolution < 2ns, decision in < 800 ns, rate < 1 kHz

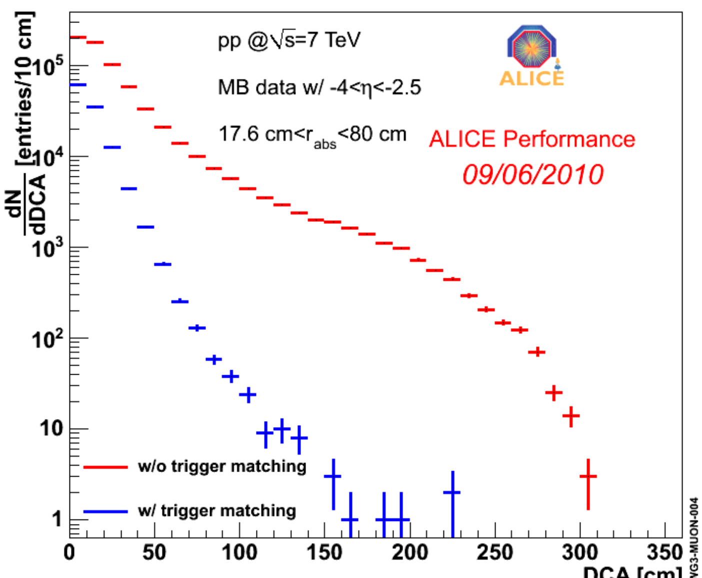
Performance of the system: muon tracking-trigger matching

without trigger matching



with trigger matching





- **muon tracking-trigger matching very powerful to reject the hadronic contribution**

DCA = Distance of Closest Approch
(distance between extrapolated track & interaction vertex in the plane perpendicular to the beam direction & containing the vertex)

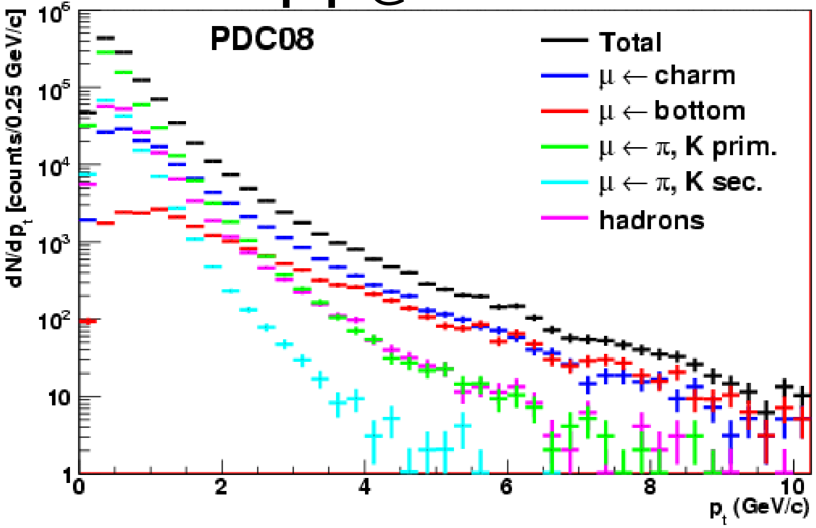
B (D)-hadron cross section from single muon p_t distribution in p-p collisions (I)

First step: extract N(μ) ← B (D)
- subtract background (cuts, unfolding vertex)
- unfold muon p_t distribution via a combined fit

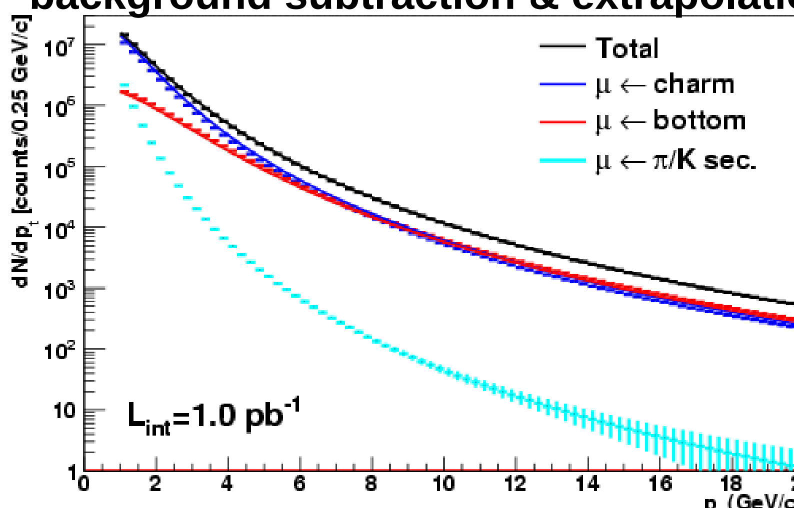
- **large statistics of μ ← B (D) over a wide p_t range** (1.5 – 20 GeV) even with a reduced data sample (L_{int} = 1 pb^{-1}: L = 10^{30} cm^{-2} s^{-1} & t = 10^{6} s)

First p-p run at 7 TeV
- assuming ε_{LHC} = 12% & L = $2.3 \cdot 10^{29}$ cm^{-2} s^{-1}
  - **$9.4 \cdot 10^{5}$ ($1.9 \cdot 10^{5}$) μ ← c (b) $month^{-1}$** with p_t> 1GeV/c
  - should allow to investigate the range [1-12] GeV/c

p-p @ 14 TeV



background subtraction & extrapolation



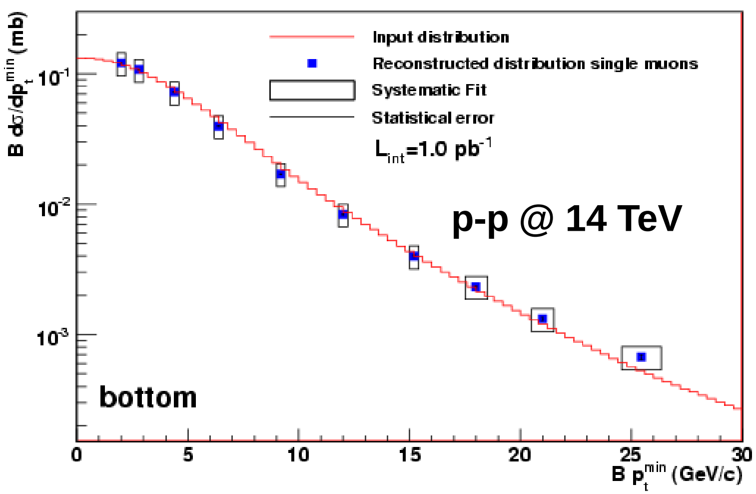
B (D)-hadron cross section from single muon p_t distribution in p-p collisions (II)

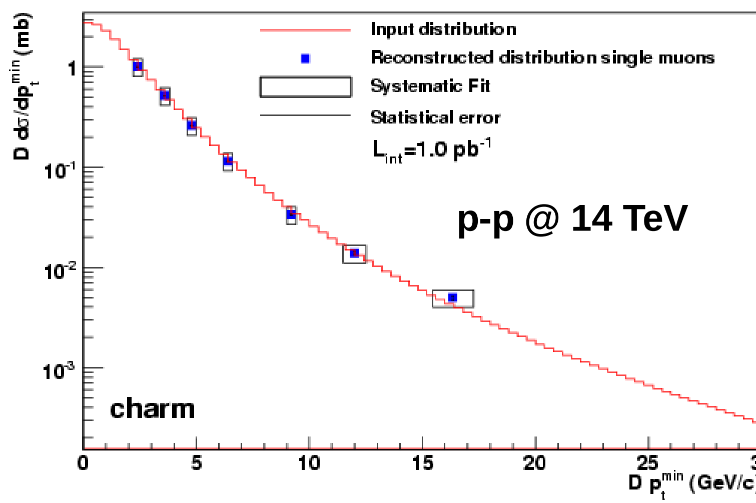
Second step: convert N(μ) ← B (D) into a B (D)-hadron cross section

- **correct for global efficiency, luminosity and decay kinematics**

method developed by UA1: C. Albajar et al., Phys. Lett. B 213 (1988) 405

$$\sigma^{D,B}(p_t^{D,B} > p_t^{min}) = \frac{N_{\mu \leftarrow D,B}}{\int L\,dt} \times \frac{1}{\varepsilon} \times \frac{\sigma^{D,B}(p_t^{D,B} > p_t^{min})}{\sigma^{D,B}(\Phi^{\mu})}\Bigg|_{MC}$$





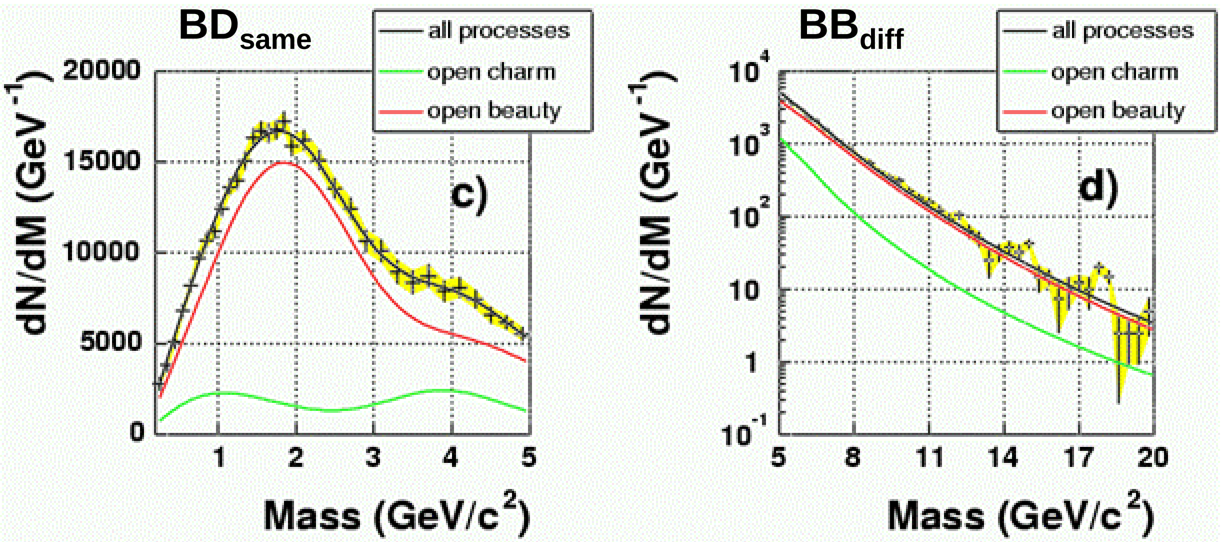
- **B (D)-hadron cross section well reconstructed over a large p_t range**
- **small statistical errors & systematic errors of ~ 20%**

note: analysis strongly model dependent

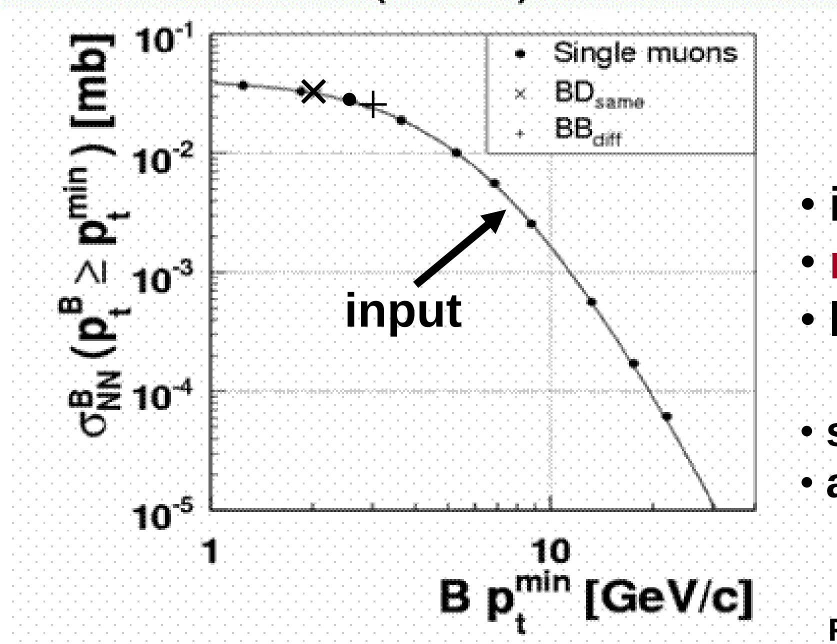
L. Manceau, Eur. Phys. J. C 62 (2009) 9

B-hadron cross section in Pb-Pb @ 5.5 TeV

feasibility study with fast simulations



- **BD$_{same}$: X ← BB → μ^- + D + X**
  with D → μ^+ + X
- **BB$_{diff}$: X + μ^+ ← BB → μ^- + X**



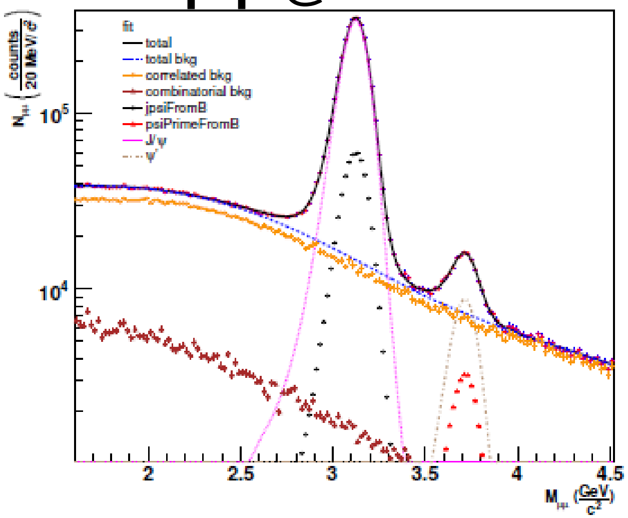
- **input distribution well reconstructed**
- **nice agreement between the 3 channels**
- **large statistics, systematic to be investigated**

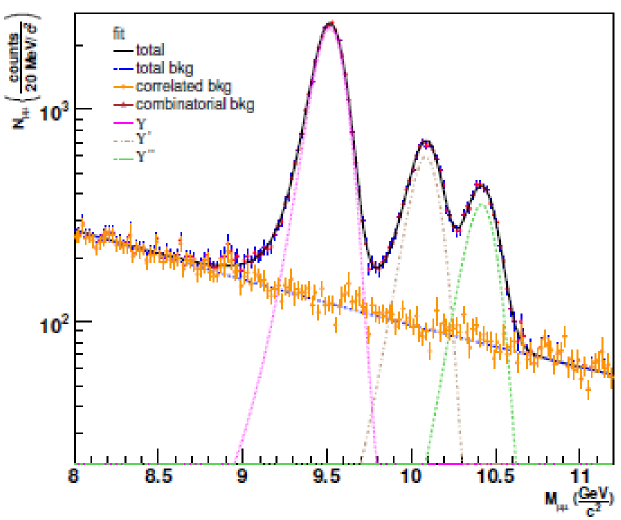
- **statistics: one month (L = 5.10^{26} cm^{-2} s^{-1}, t = 10^6 s)**
- **assumption: no energy loss effects**

R. Guernane et al., from J. Phys. G: Nucl. Part. Phys. 32 (2006) 1295

Quarkonium production in p-p collisions

p-p @ 14 TeV





	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

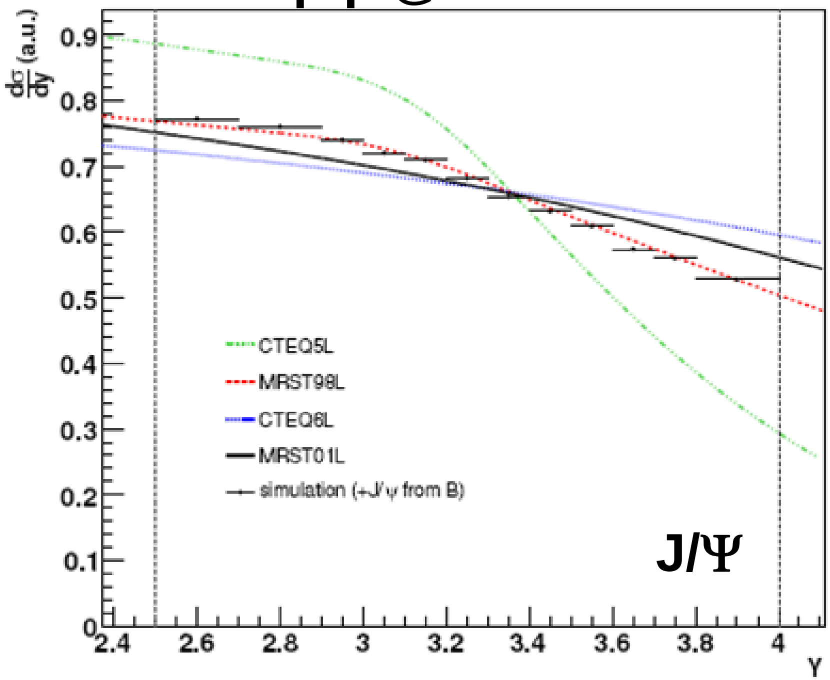
First p-p run at 7 TeV

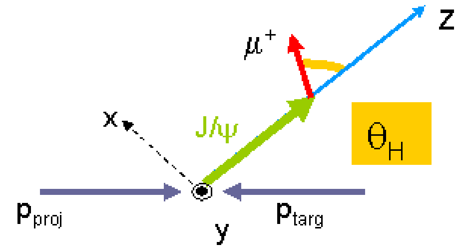
- assuming ε_{LHC} = 12% & L = 3·10^{29} cm^{-2} s^{-1}, one expects **10^4 J/Ψ month^{-1}**
- **ϒ measurement** should be **possible**

D. Stocco et al., from J. Phys. G.: Nucl. Part. Phys. 32 (2006) 1295

Quarkonium differential distributions & quarkonium polarization in p-p collisions

p-p @ 14 TeV



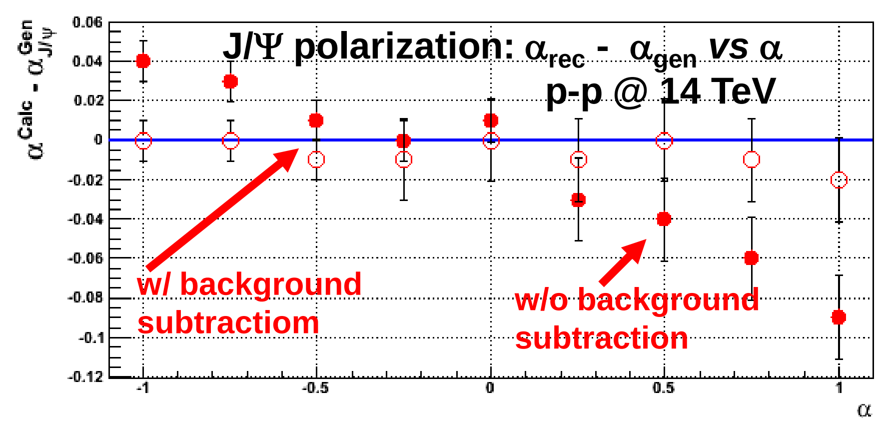


$$d\sigma/d\cos\theta_H = 1 + \alpha \cos^2\theta_H$$

$\alpha > 0$: transverse polarization

$\alpha = 0$: no polarization

$\alpha < 0$: longitudinal



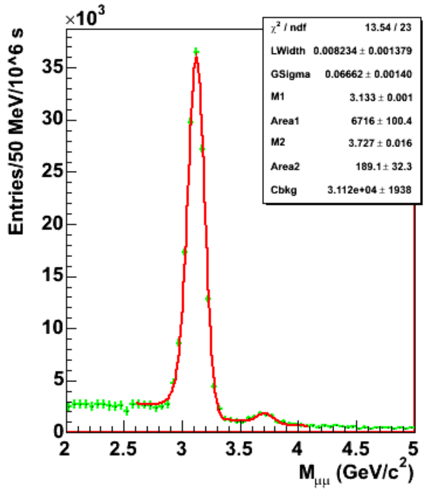
- shape of J/Ψ *vs* y sensitive to gluon distribution functions

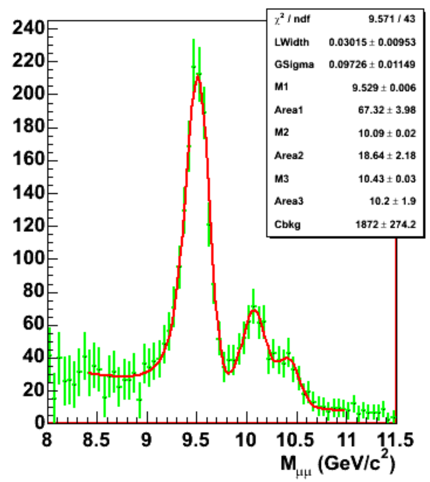
- error on J/Ψ polarization < 2% (with $2 \cdot 10^5$ J/Ψ) after background subtraction

D. Stocco et al., from
J. Phys. G.: Nucl. Part. Phys. 32 (2006) 1295

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

Quarkonium production in Pb-Pb @ 5.5 TeV





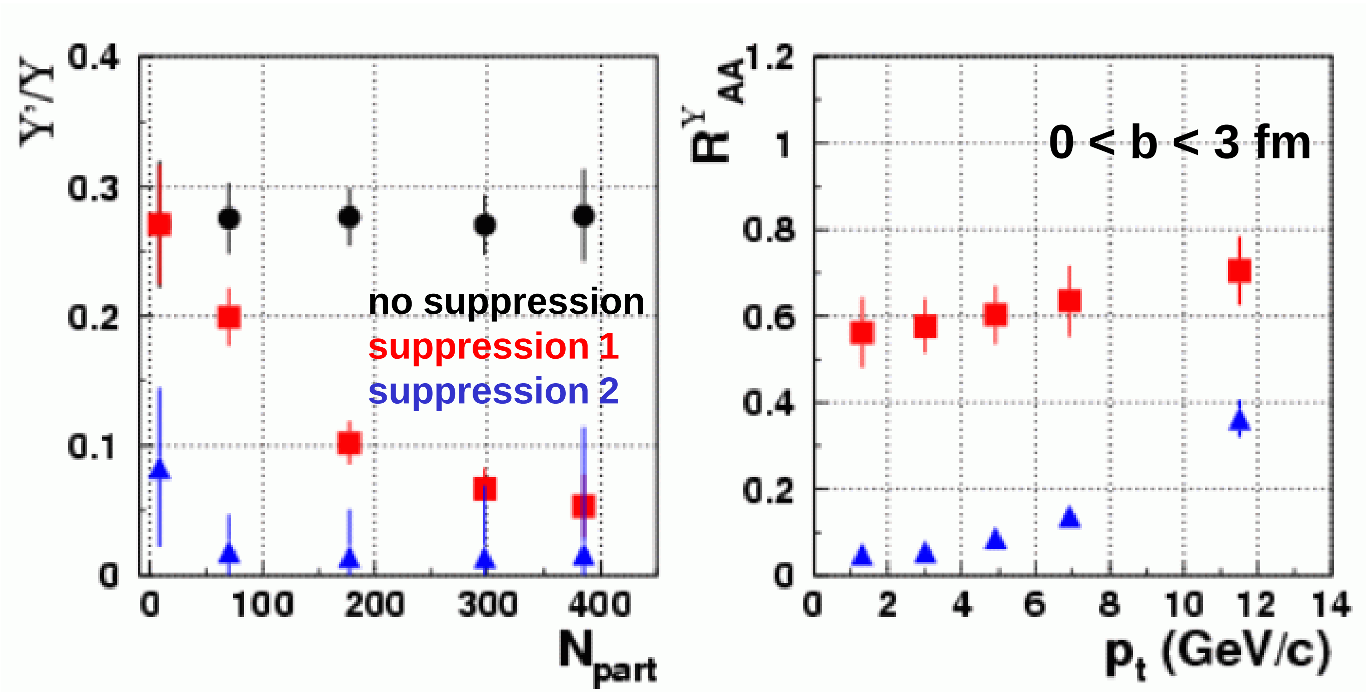
$L = 5.10^{26}$ cm^{-2} s^{-1}, $t = 10^6$ s,
with shadowing, w/o absorption/suppression/enhancement

	b (fm)	0-3	3-6	6-9	9-12	12-16	min-bias
	ε (GeV/fm³)	32	30	28	16	5	
J/ψ	S (×10³)	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 (×10³)	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 (×10³)	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 (×10³)	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 (×10³)	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, J. Phys. G: Nucl. Part. Phys. 32 (2006) 1295

Suppression scenarios

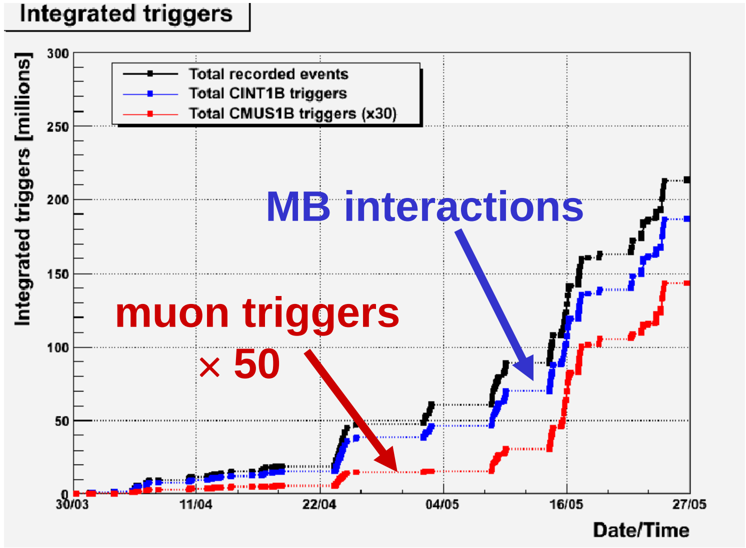


- **suppression 1 (quenched QCD): T_C = 270 MeV, T_D/T_C = 4.0 (1.4) for ϒ (ϒ')**
- **suppression 2 (unquenched QCD):T_C = 190 MeV, T_D/T_C = 2.9 (1.06) for ϒ (ϒ')**

clear sensitivity of the observables to the QGP temperature

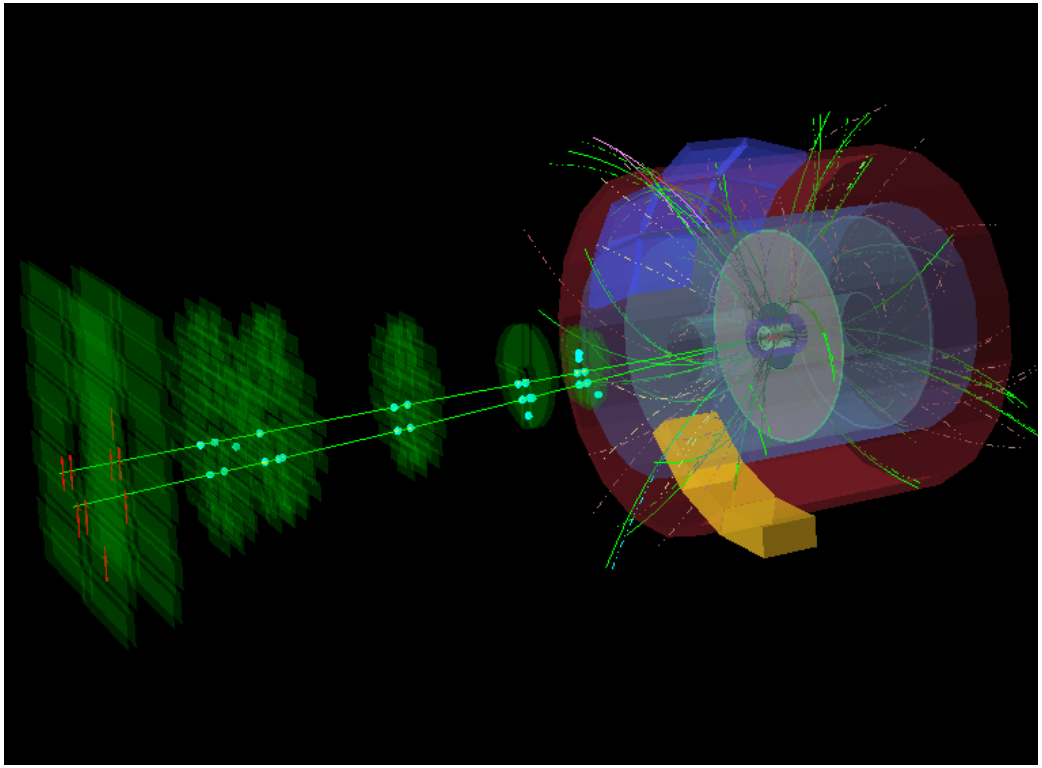
dissociation temperatures: C.Y. Wong, hep-ph/0408020 & W.M. Alberico, hep-ph/0507084
S. Grigoryan from DiMuonNet report (2008) & J. Phys. G: Nucl. Part. Phys. 32 (2006) 1295

First measurements in p-p @ 7 TeV



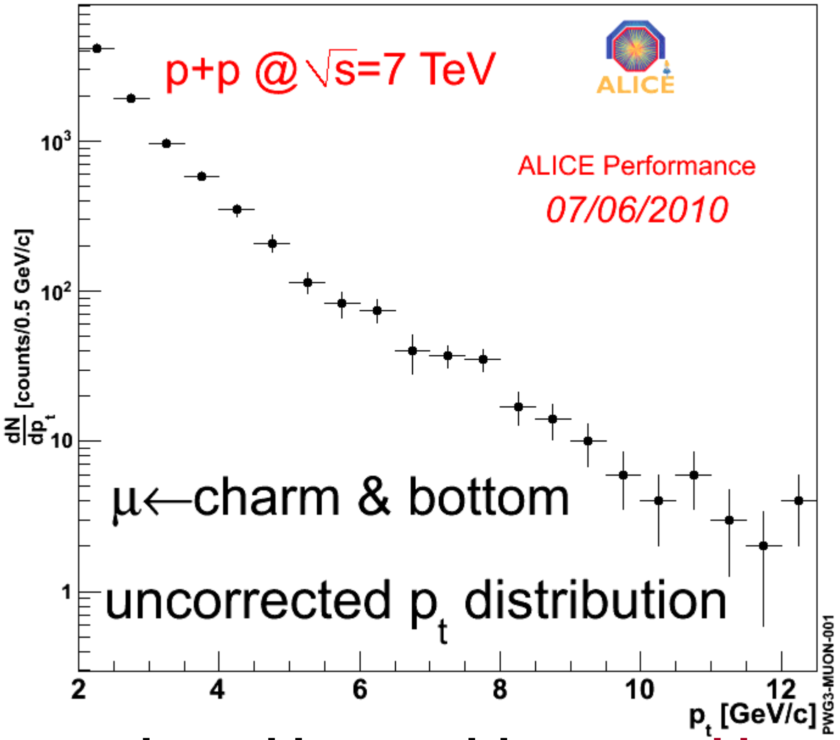
from J. Schukraft & A. Dainese talks at Physics LHC 2010, Hamburg, June 2010

p-p @ 7 TeV event with 2 tracks in the muon spectrometer



Heavy flavours from single muons in p-p @ 7 TeV

charm & bottom production via single muons

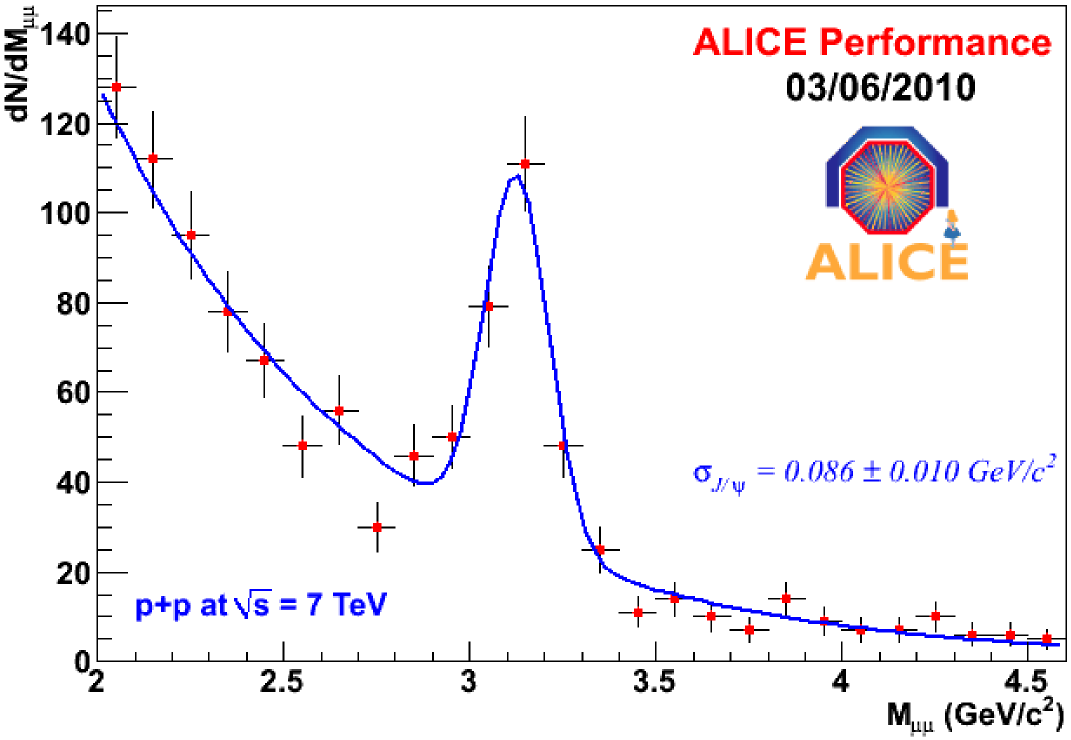


- $7.67 \cdot 10^5$ muon triggers
- $6.7 \cdot 10^3$ $\mu \leftarrow$ b, c

- hadrons rejected by requiring a tracking-trigger matching
- background contribution ($\mu \leftarrow \pi$, K) subtracted according to Pythia (ATLAS-CSC) normalized to data at low p_t
- results still can be improved with better alignment
- on going: unravel charm and bottom components via a combined fit, efficiency correction, systematic errors

First quarkonium signals in p-p @ 7 TeV

PWG3-MUON-002



- $31 \cdot 10^6$ MB events
- S = 177 ± 30 J/Ψ
- σ = 86 ± 10 MeV/c^2

- on-going: improve alignment, efficiency correction, systematic errors, cross section calculation, p_t & y distributions, $\langle p_t^2 \rangle$

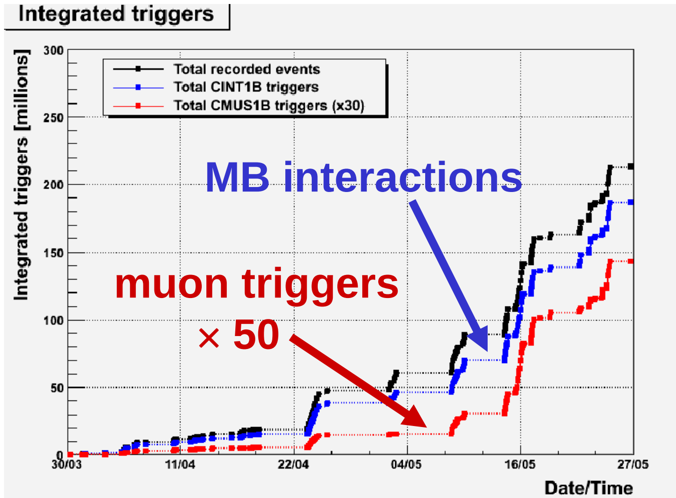
Conclusion & outlooks

- the ALICE muon spectrometer is **successfully operated** since the beginning of data taking
- **promising performance** for heavy flavours and charmonia from analysis of first **p-p data at 7 TeV**
    - first attempt to extract the p_t distribution of $\mu \leftarrow c, b$
    - first $J/\Psi \rightarrow \mu^+\mu^-$ observed
- **more physics results** with the ALICE muon spectrometer expected soon

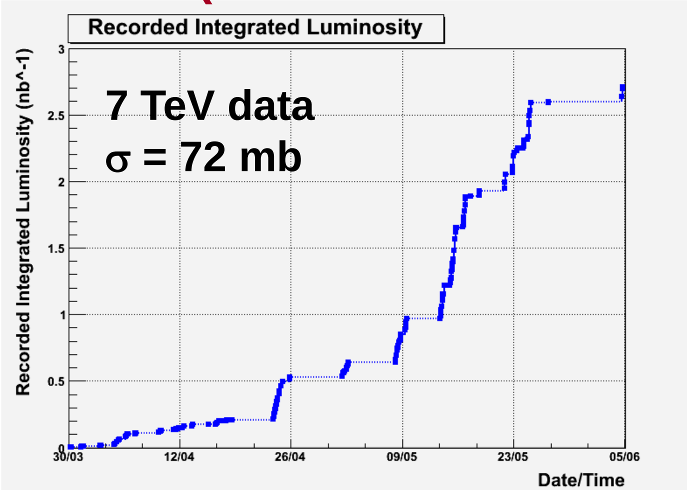
- **Pb-Pb collisions** in ALICE: **November** 2010

Backup slides

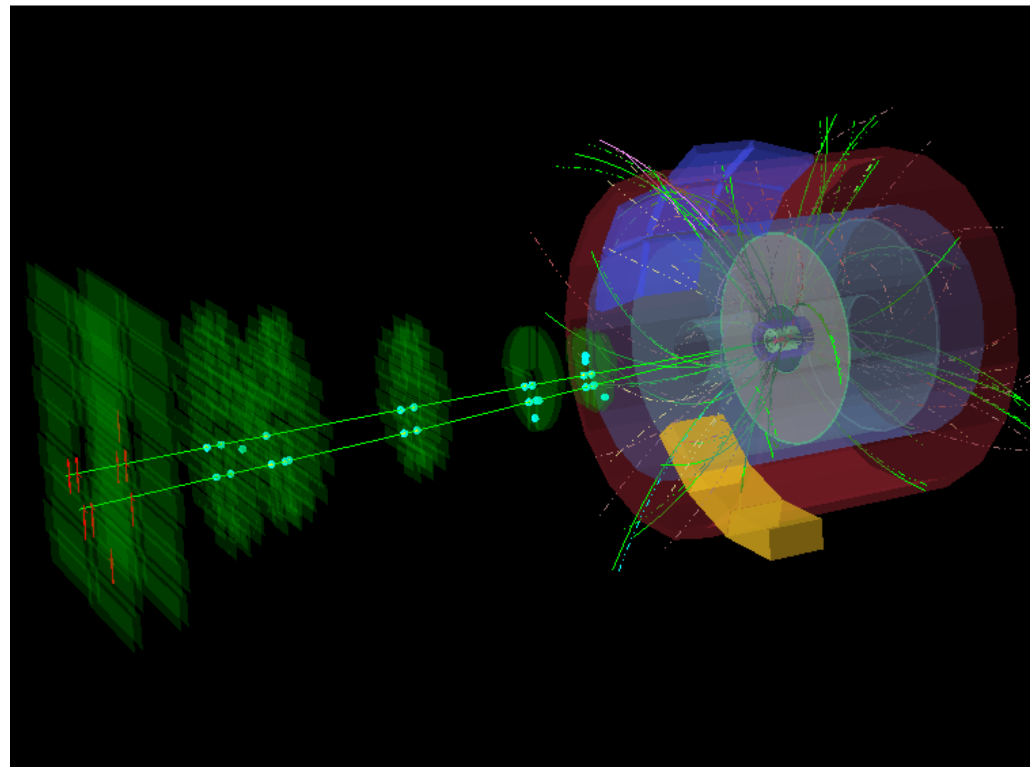
First measurements in p-p @ 7 TeV



~2.7 nb^{-1} ($2 \cdot 10^8$ min. bias events)



p-p @ 7 TeV event with 2 tracks in the muon spectrometer



from J. Schukraft & A. Dainese talks at Physics LHC 2010, Hamburg, June 2010