Perspectives de physique avec les saveurs lourdes avec le détecteur ALICE

Premières journées QGP-France

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for the ALICE collaboration

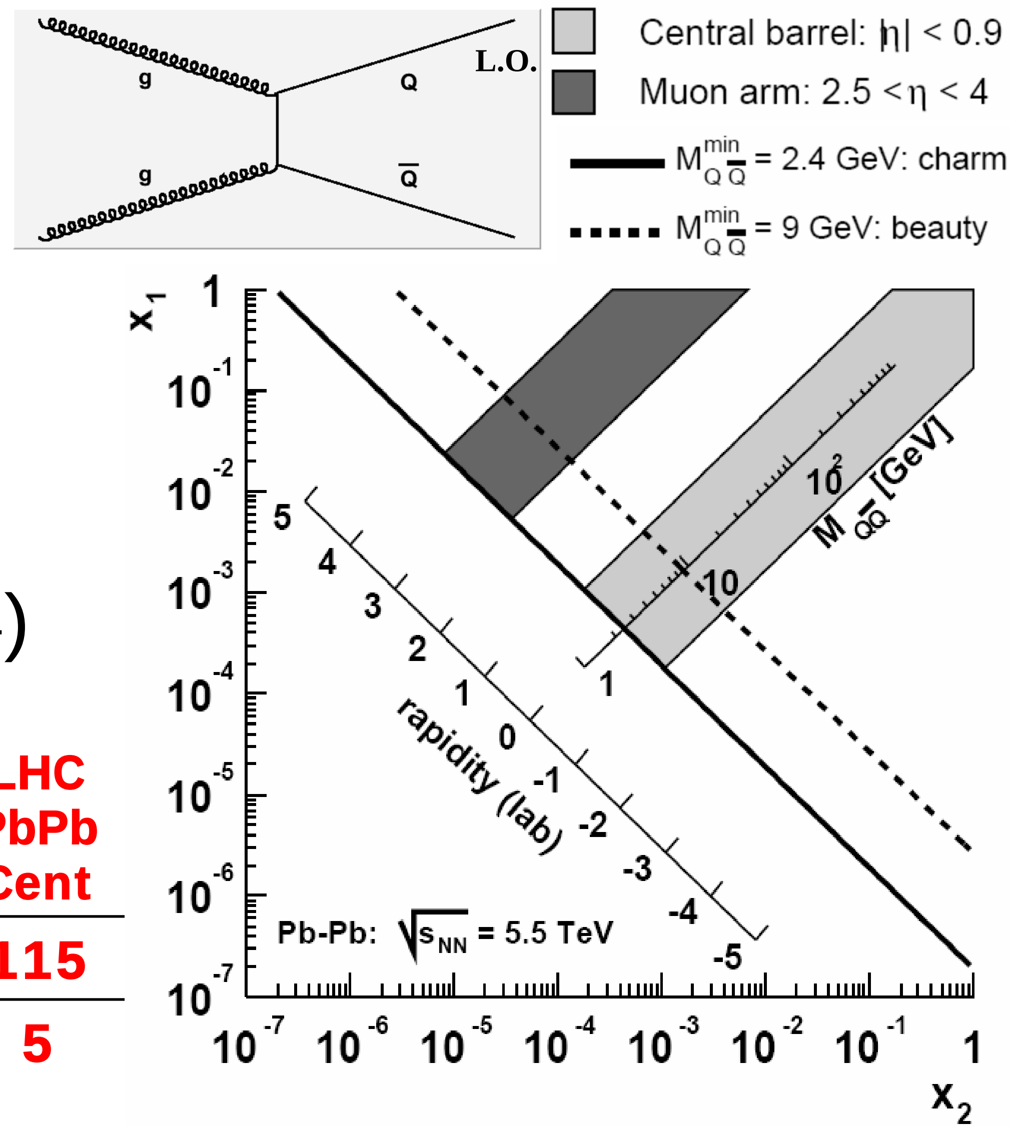
Etretat, July 5th 2006

Physics Motivations

- Energy loss of Heavy Quarks (HQ) in hot and high density medium formed in AA central collisions.
- *Brownian motion* and coalescence of low p_T HQ in the quark gluon plasma (QGP).
- Dissociation (and regeneration) of quarkonia in hot QGP.
- Heavy flavour physics in pp collisions: small x physics, pQCD, HQ fragmentation functions, gluon shadowing, Quarkonia production mechanism.

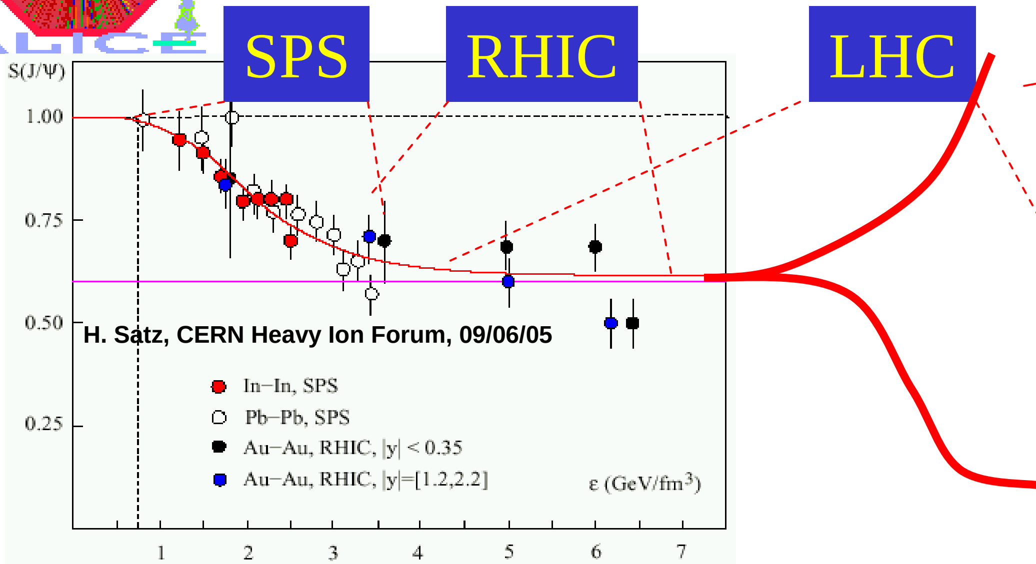
Heavy Quarks in AA coll.

- Small x_{Bj} (10^{-3} –10^{-5})
- $\Delta\tau_Q \sim 0.04$ –0.15 fm/c
- $\Delta\tau_Q << \tau_{QGP} << \tau_Q$
- Shadowing / Saturation
- HQ energy loss in QGP
- HQ coalescence (low p_T)



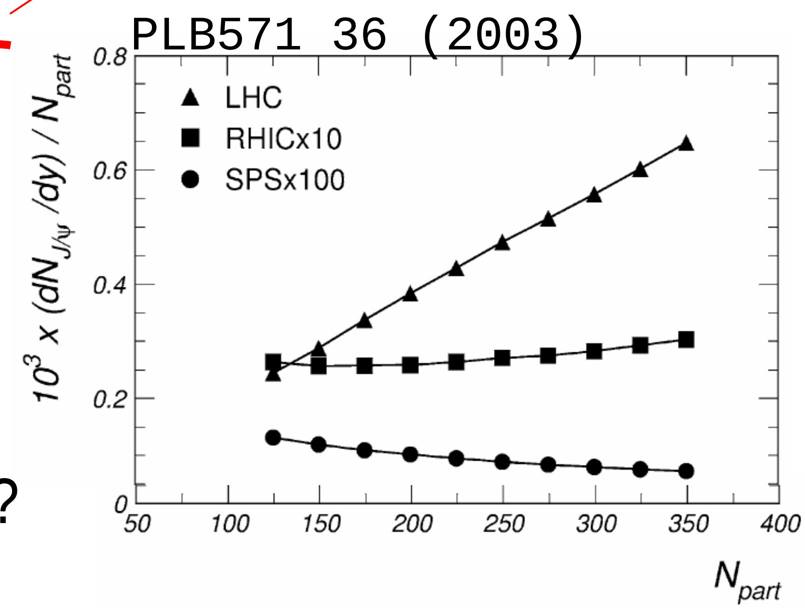
	SPS PbPb Cent	RHIC AuAu Cent	LHC pp	LHC pPb	**LHC PbPb Cent**
N_{cc}/evt	0.2	10	0.2	1	**115**
N_{bb}/evt	-	0.05	0.007	0.03	**5**

Charmonia in AA collisions



J/Ψ regeneration

J/Ψ melting

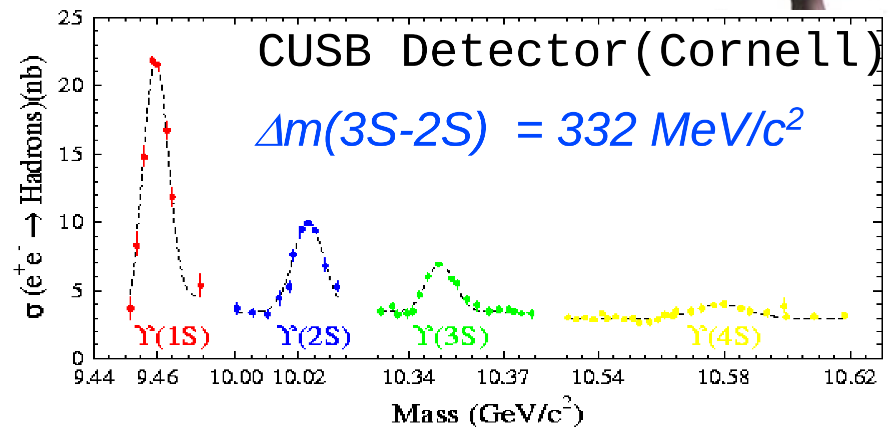


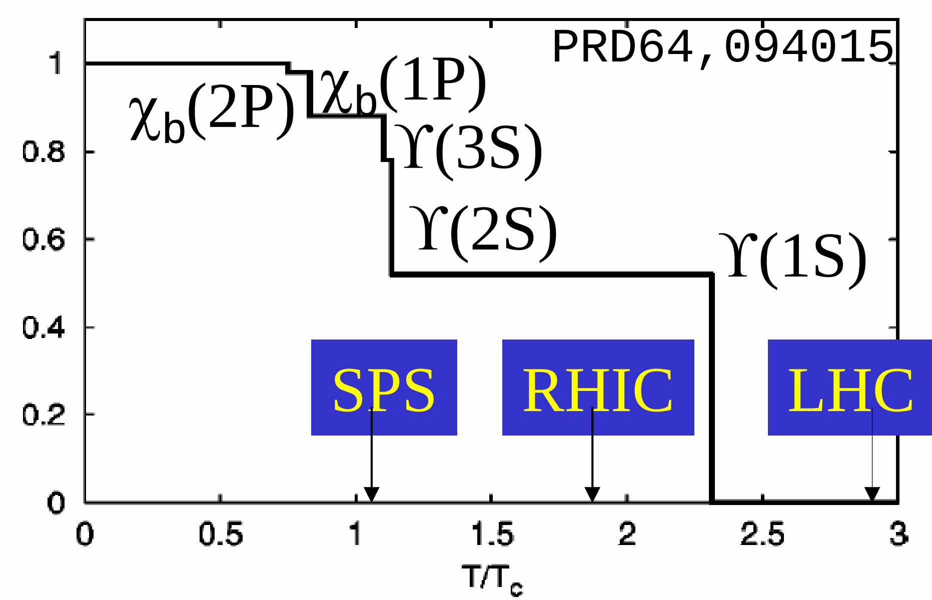
- Melting of Ψ' and χ at SPS and RHIC, and melting of J/Ψ at LHC?
- Magic cancellation between J/Ψ suppression and J/Ψ regeneration?

22 (39)% of J/Ψ (Ψ') from open beauty meson decays.

Bottomonia in AA collisions

- First measurement of Bottomonia.
- Regeneration is expected to be small at LHC.
- $\Upsilon(2S)$ behaves as J/ψ : $T_D^{\Upsilon(2S)} \sim T_D^{J/\psi}$
- $\Upsilon(1S)$ melts only at LHC.
- $\Upsilon(2S)/\Upsilon(1S)$ as a function of p_T.





45 (30)% of feed-down from higher resonances for $\Upsilon(1S)$ ($\Upsilon(2S)$)

ALICE capabilities

- ALICE combines electronic, muonic and hadronic channels
- ALICE covers down to p_T ~ 0 for quarkonia and open charm
- ALICE covers central ($|\eta|<0.9$) and forward ($2.5<\eta<4.0$) regions
- High precision vertexing in the central barrel

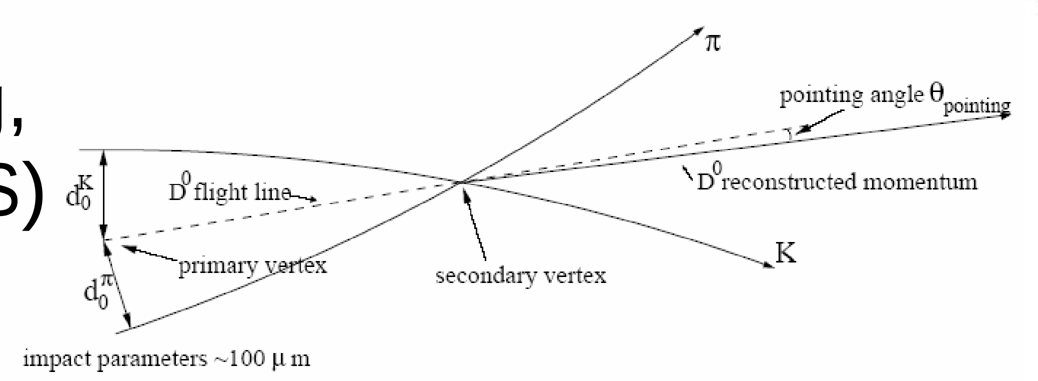
Physics Analysis

- Hadronic decays:
  - $D^0 \rightarrow K\,\pi$, $D^{+-} \rightarrow K\,\pi\,\pi$, $D_s \rightarrow K\,K^*$, $D_s \rightarrow \phi\,\pi$, ...
- Leptonic decays:
  - $B \rightarrow$ l (e or μ) + anything.
  - Invariant mass analysis of lepton pairs: $B\bar{B}$, $D\bar{D}$, $B\bar{D}_{same}$, J/Ψ, Ψ', Υ family, $B \rightarrow J/\Psi$ + anything.
  - $B\bar{B} \rightarrow \mu\,\mu\,\mu$ ($J/\Psi\,\mu$).
  - e-μ correlations.
  - $W^{+-} \rightarrow l^{+-}\,\nu$, $Z^0 \rightarrow l^+ l^-$.

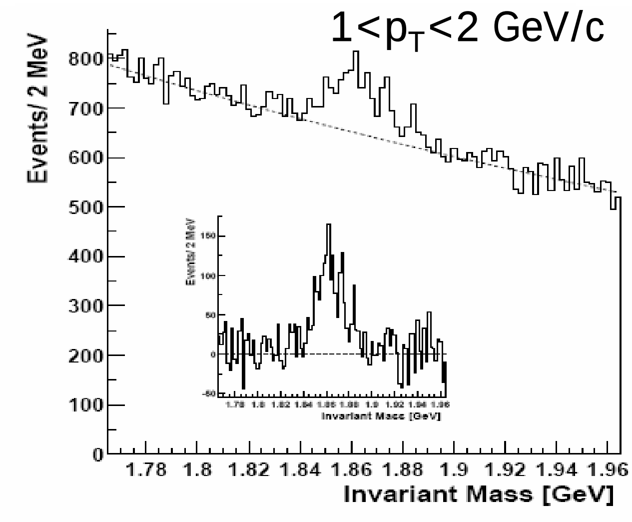
In red channels studied in the ALICE PPR Vol.2 (to be published in J.Phys. G)
In black under study

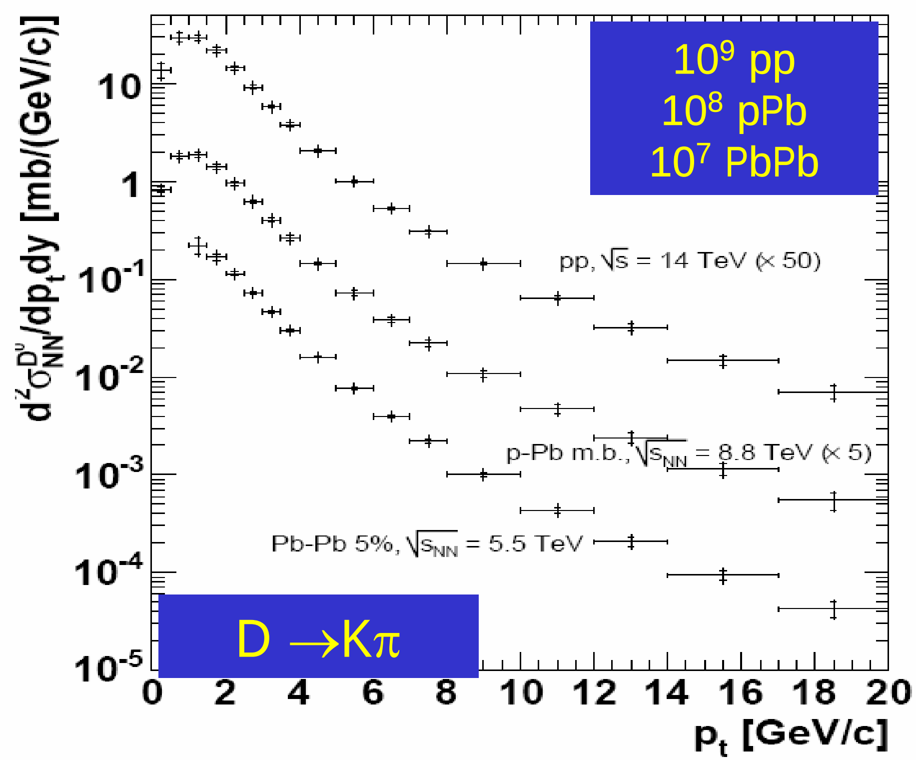
$D^0 \to K\pi$ channel

- High precision vertexing, better than 100 μm (ITS)
- High precision tracking (ITS+TPC)
- K and/or π identification (TOF)



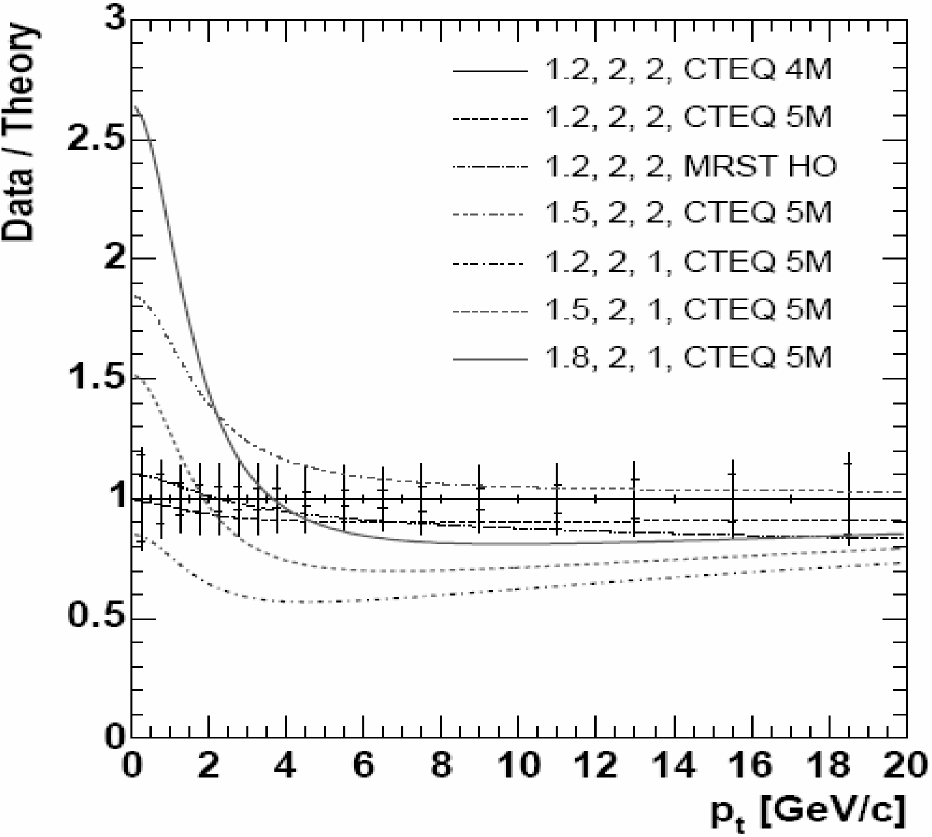
10^7 central PbPb



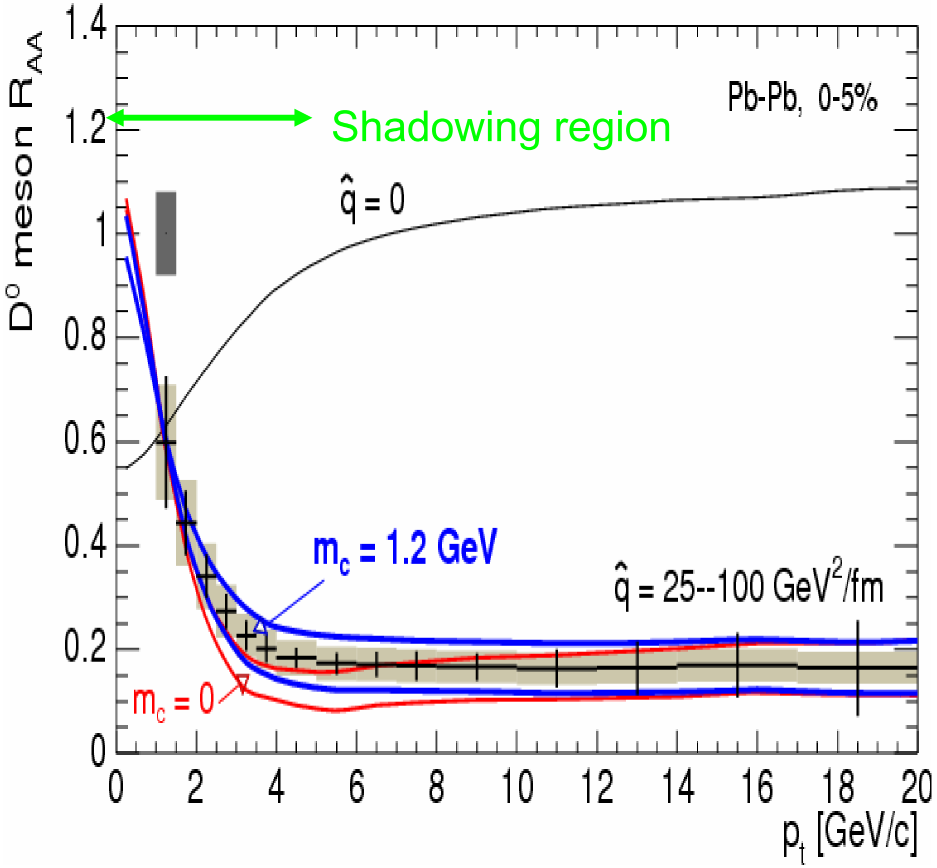


High Precision charm measurement

pp at 14 TeV
Sensitivity to PDF's

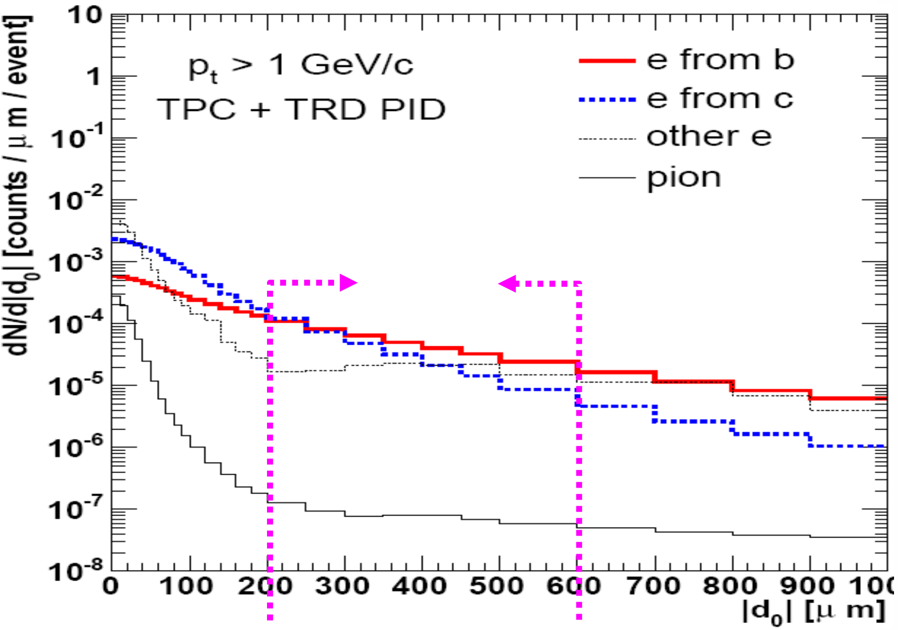


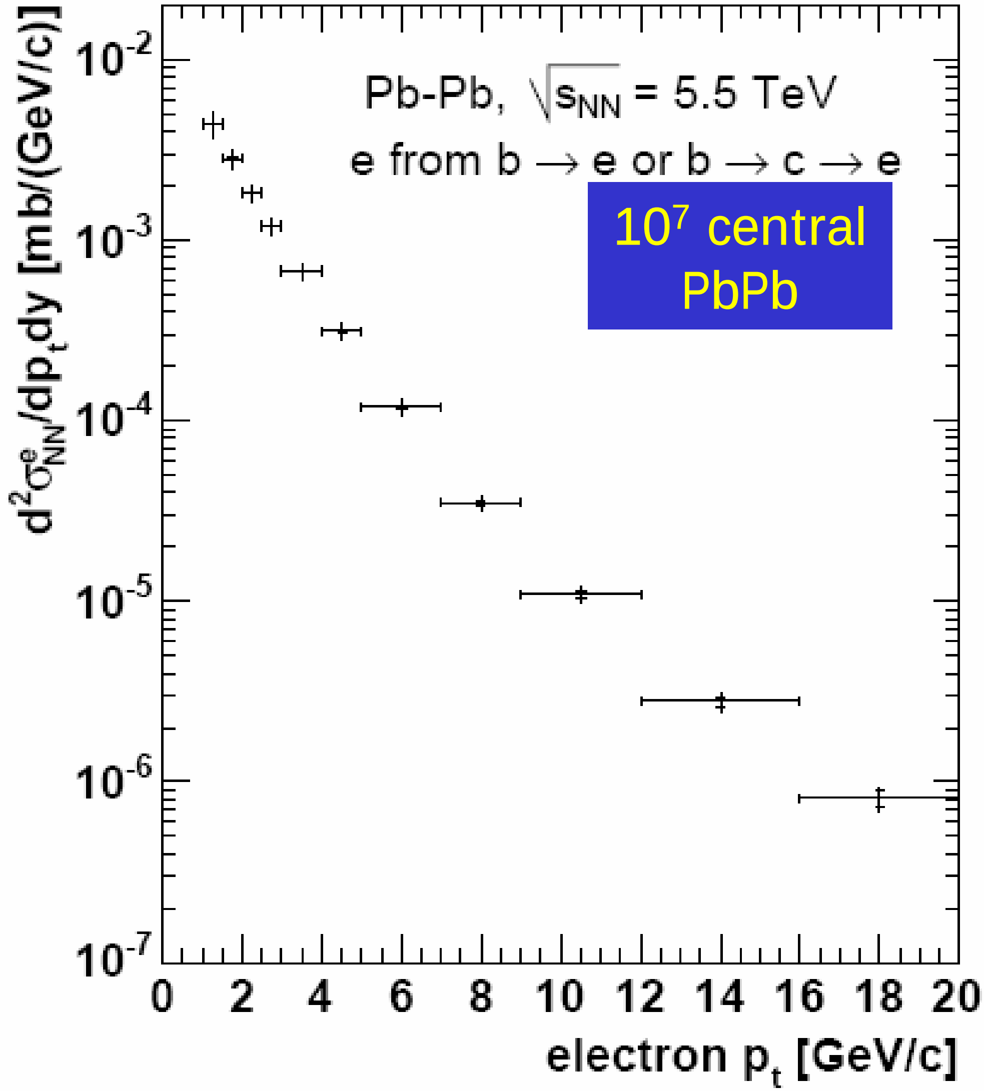
Central PbPb
Shadowing + k_T + energy loss



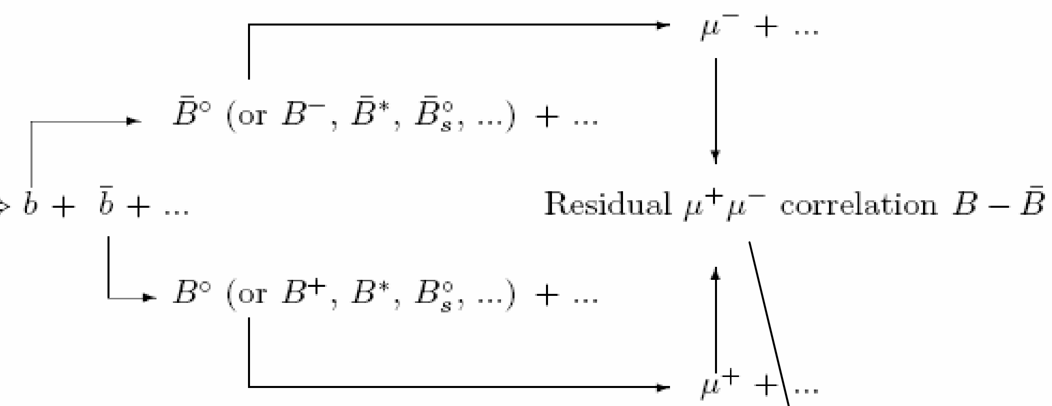
Open Beauty from single electrons

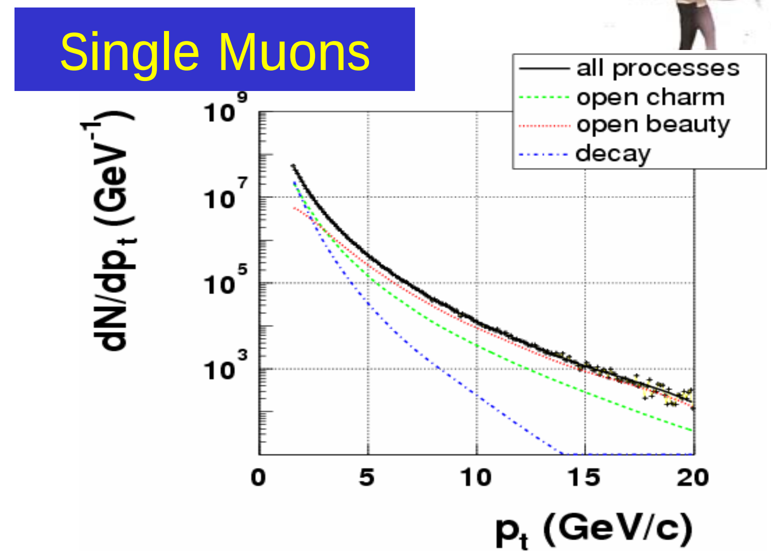
- Electron Identification (TRD+TPC)
- High precision vertexing (ITS)
- Subtraction of the open charm contribution.

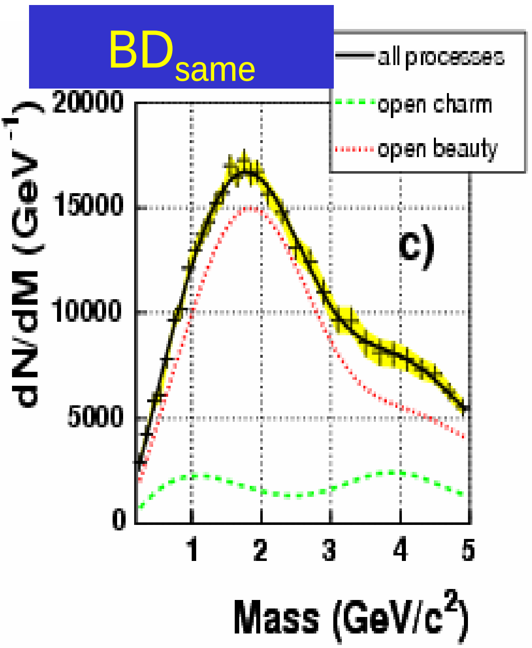


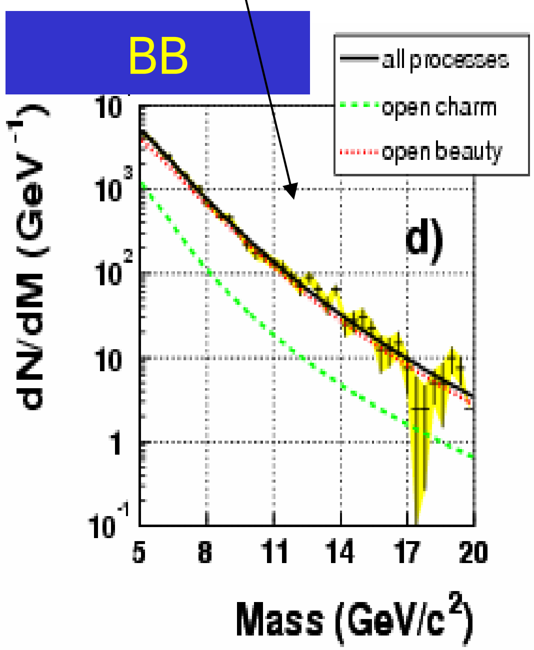


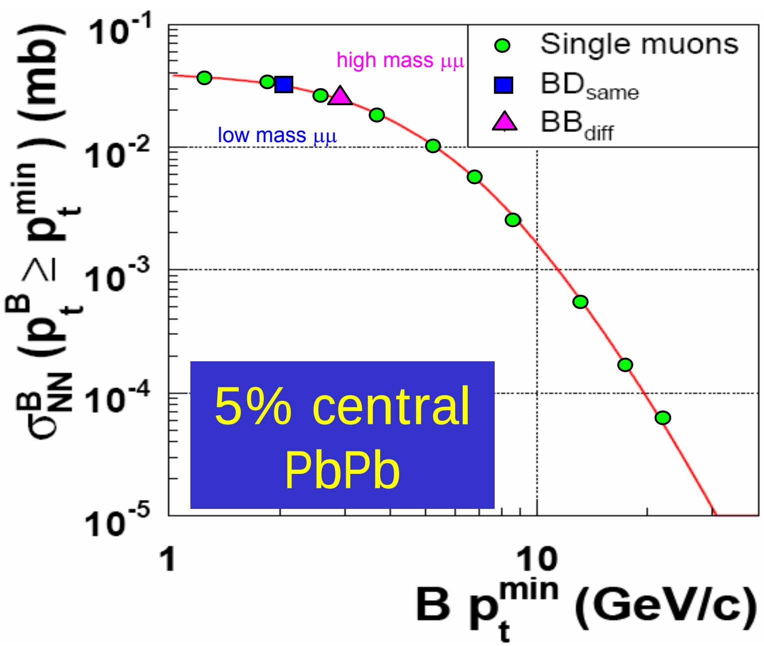
$\mu^+\mu^-$ correlations





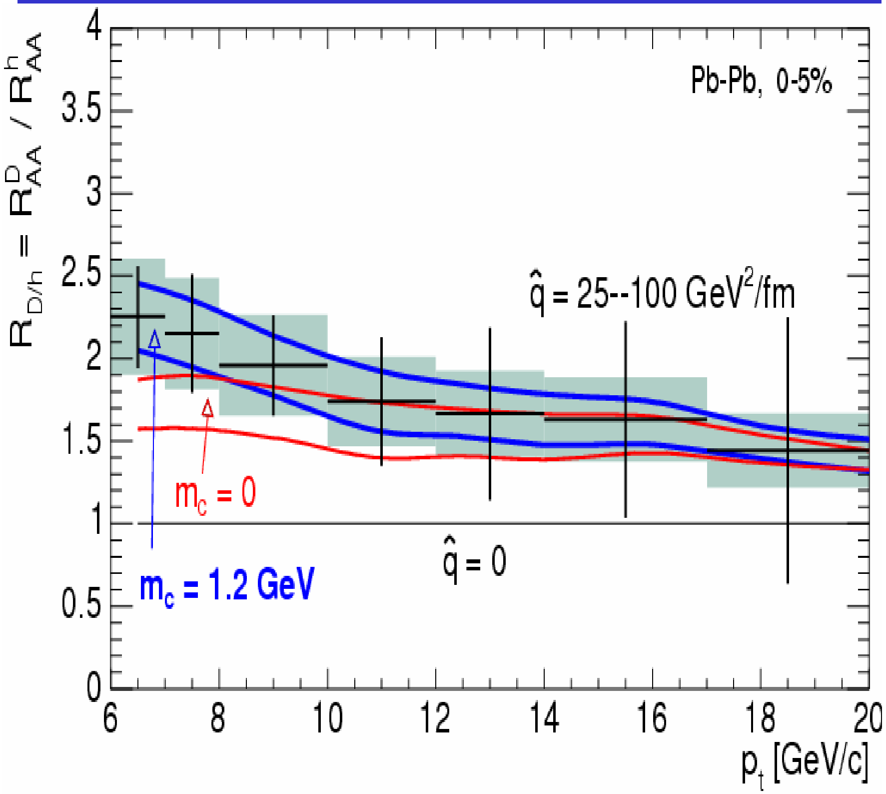




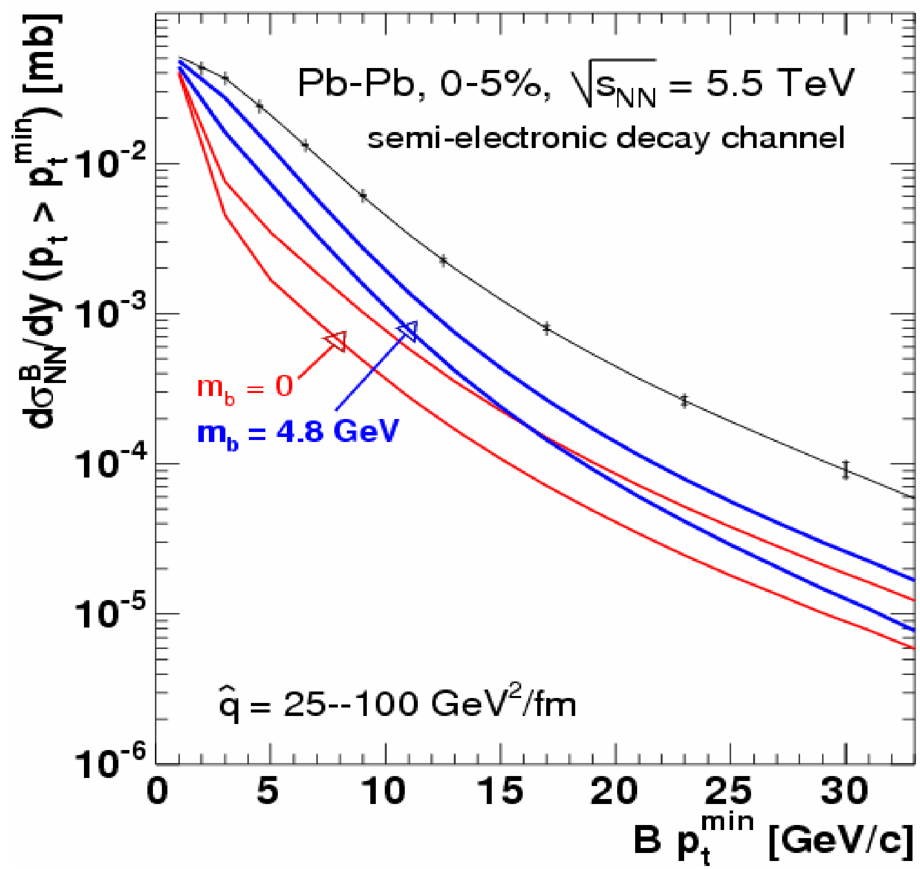


Energy loss physics

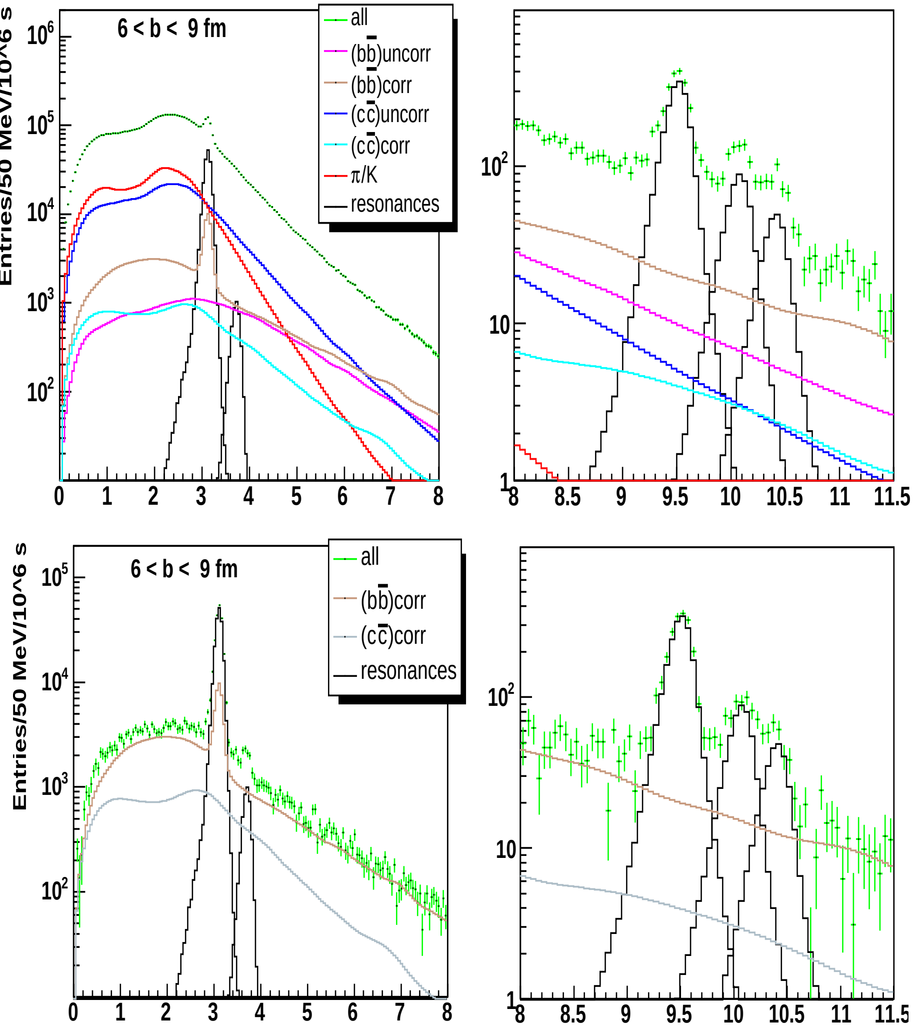
Charm Production:
Quark versus gluon Energy Loss
Higher gluon coupling



Beauty production:
Mass dependence of Energy Loss
Dead cone effect



Quarkonia → e^+e^-, $\mu^+\mu^-$



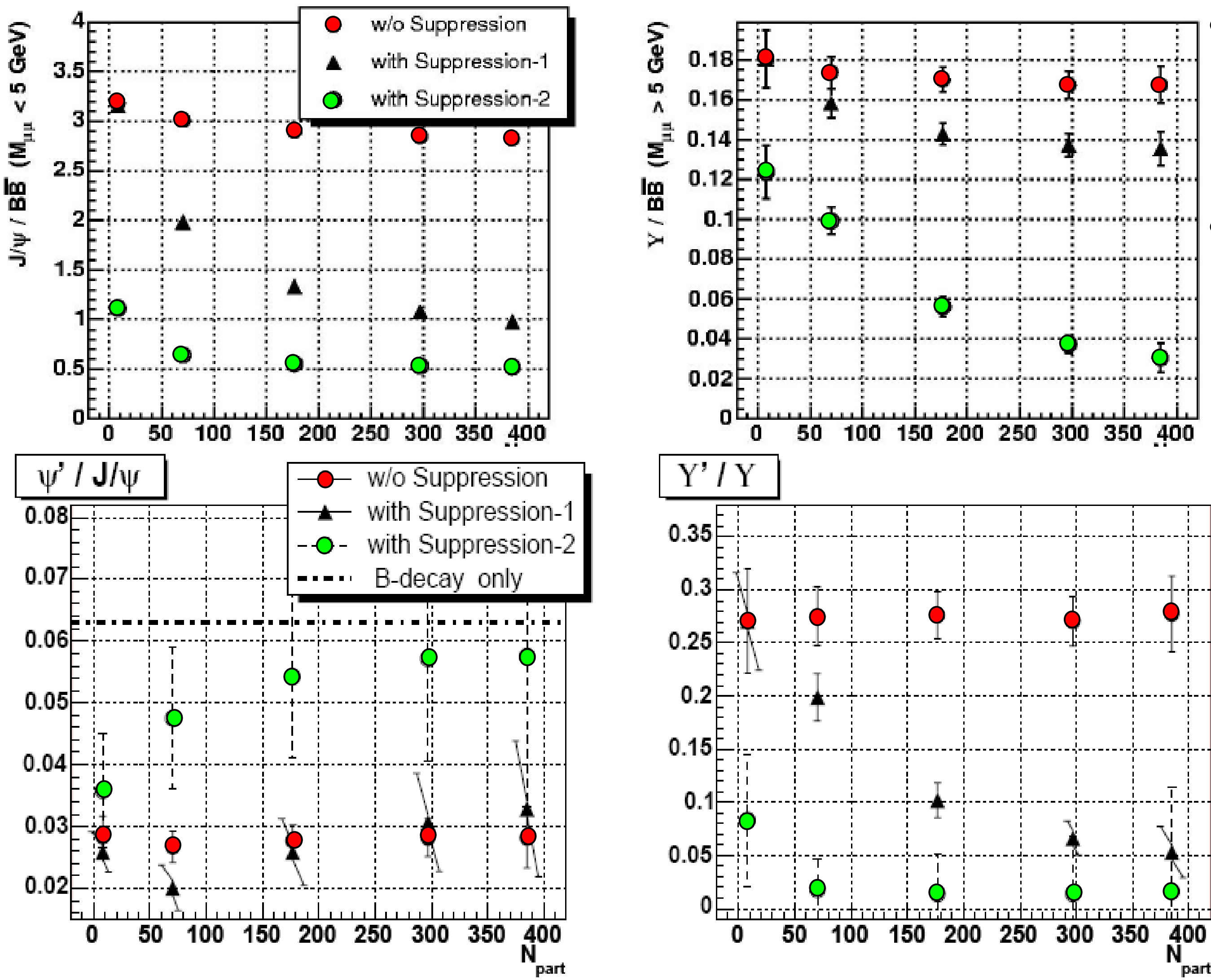
PbPb cent, 0 fm<b<3 fm

State	S[10^3]	B[10^3]	S/B	S/(S+B)$^{1/2}$
J/Ψ	130	680	0.20	150
Ψ'	3.7	300	0.01	6.7
ϒ(1S)	1.3	0.8	1.7	29
ϒ(2S)	0.35	0.54	0.65	12
ϒ(3S)	0.20	0.42	0.48	8.1

Yields for baseline

- ϒ(1S) & ϒ(2S) :   0-8 GeV/c
- J/Ψ high statistics: 0-20 GeV/c
- Ψ' poor significance
- ϒ'' ok, but 2-3 run will be needed.

Suppression scenario



- Suppression-1
  - ✓ Tc =270 MeV
  - ✓ T_D/T_c=1.7 for J/Ψ
  - ✓ T_D/T_c= 4.0 for ϒ.
- Suppression-2
  - ✓ Tc=190 MeV
  - ✓ T_D/T_c=1.21 for J/Ψ
  - ✓ T_D/T_c= 2.9 for ϒ.

PRC72 034906(2005)
Hep-ph/0507084(2005)

Good sensitivity J/Ψ, ϒ(1S) & ϒ(2S)

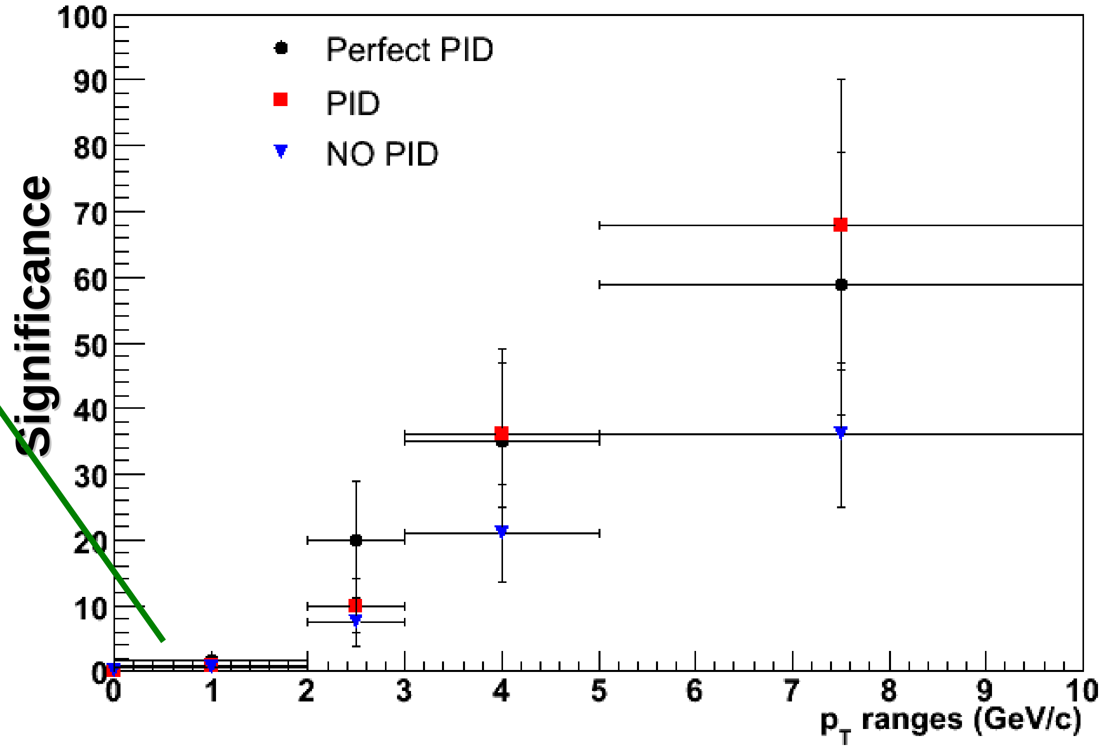
Under-progress

- Measurement of $D^+ => K^-\pi^+\pi^+$;
- Electron-muon coincidences;
- Polarization of the J/Ψ;
- Measurement of beauty J/Ψ;
- Measurement of beauty via tri-muon events;
- Measurement of charm in the muon spectrometer;
- Measurement of electro-weak bosons;

$D^+ \Rightarrow K^-\pi^+\pi^+$

- Low p_T under study
  - Rebinning
  - Additional cuts

Analysis feasible also without PID, but more time consuming

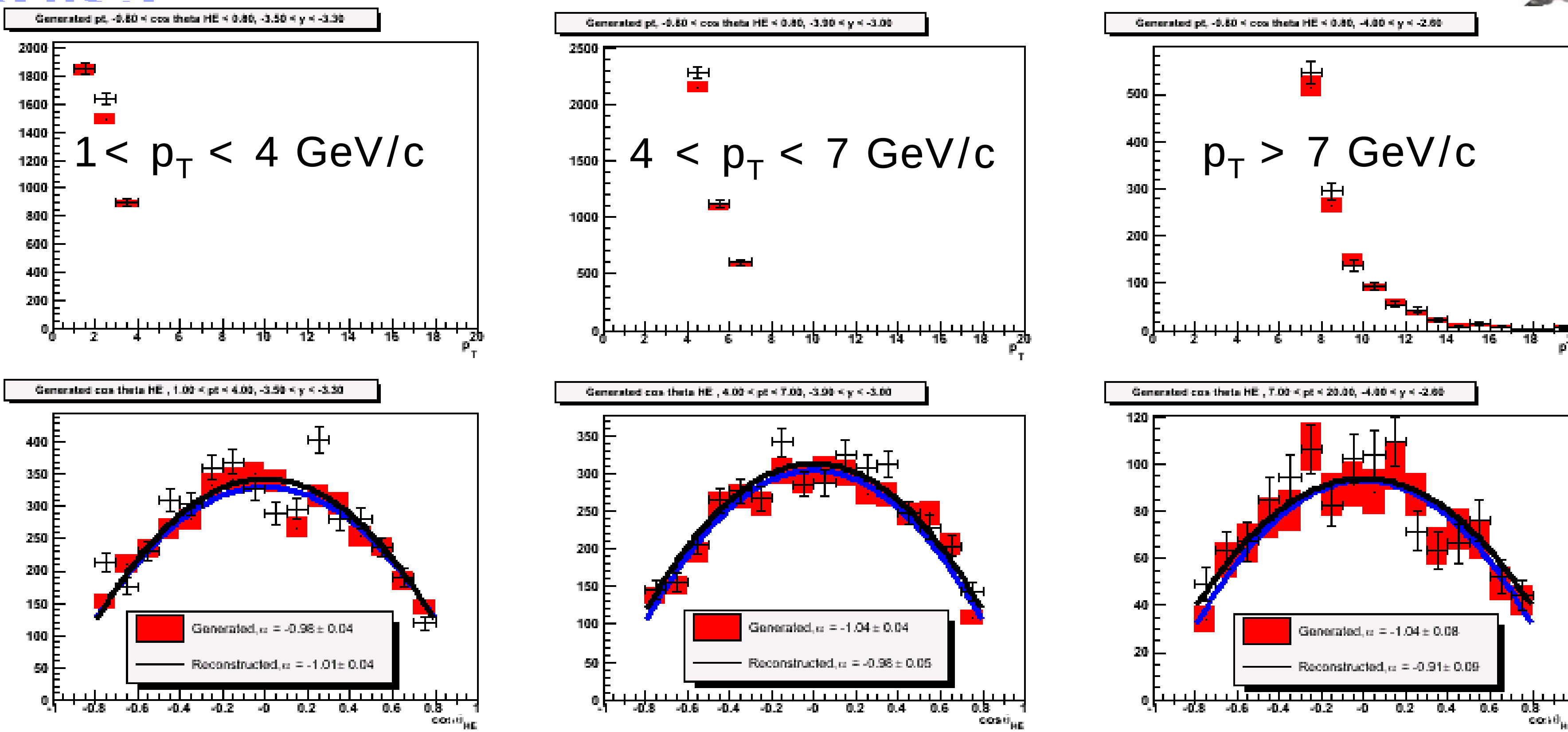


p_T integrated results

	Perfect PID	**PID**	**No PID**
Significance	44 ±11	40 ± 15	39 ± 12

Elena BRUNA et Francesco PRINO, Torino

J/Ψ polarization



$A_{cut} = 0.05$	$1<p_T<4$	$4<p_T<7$	$p_T>7$
$-0.8<\cos\theta<0.8$	-1.01 ± 0.04	-0.98 ± 0.05	-0.91 ± 0.09

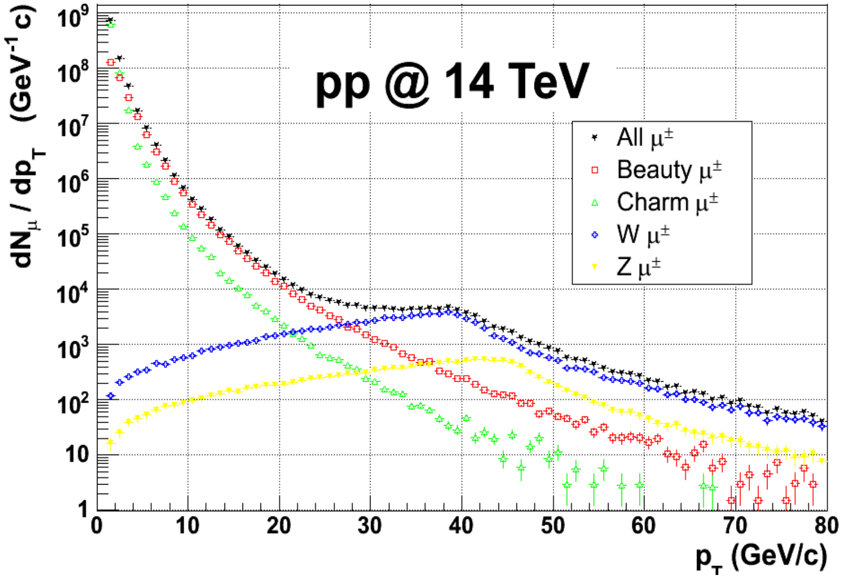
Enrico SCOMPARIN et Roberta ARNALDI Torino

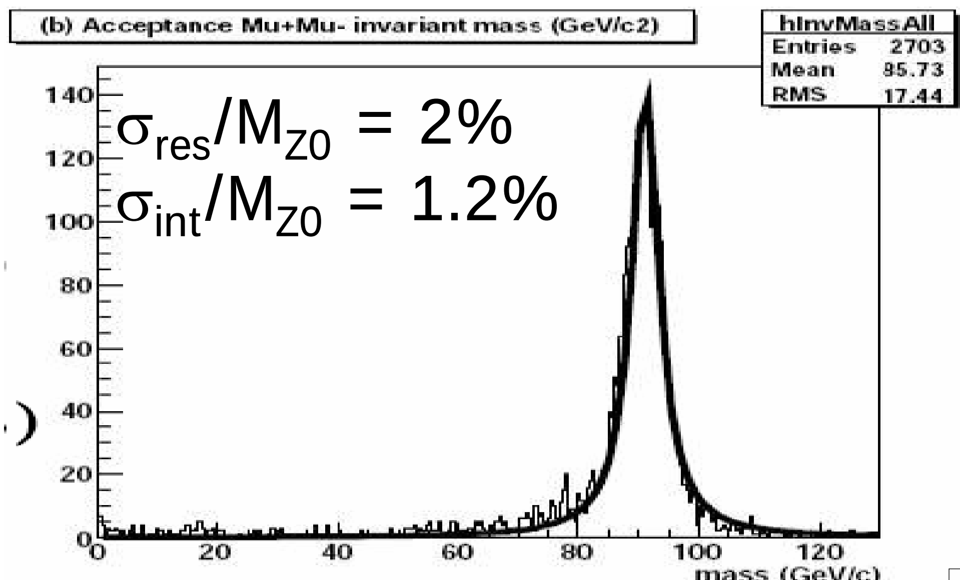
Electro-weak bosons

$W^{+-} => \mu^{+-} + \nu$

$Z^0 => \mu^+ + \mu^-$

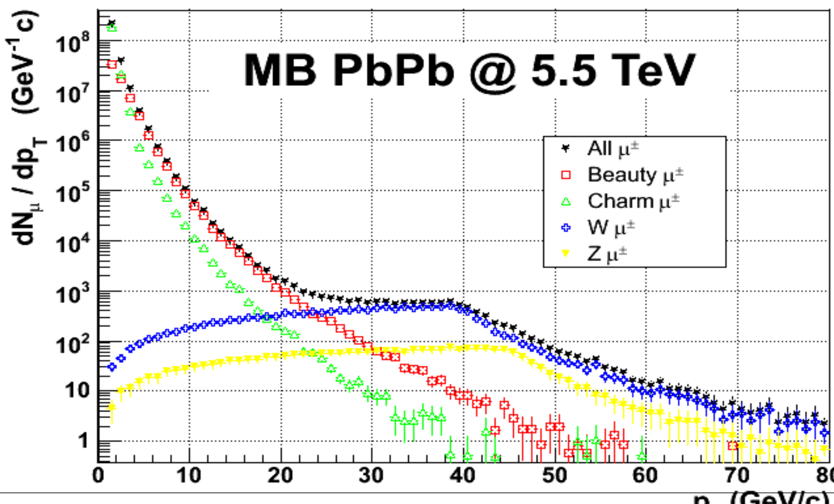
- Cross-checking efficiency, resolution and integrated luminosity;
- (Unique) shadowing measurements;
- Reference for high p_T muon suppression.





$\sigma_{res}/M_{Z0} = 2\%$

$\sigma_{int}/M_{Z0} = 1.2\%$



Zaida CONESA DEL VALLE, Nantes

Running conditions

Lead-lead nominal run

$\int L dt = 5.10^{26}\ cm^{-2}\ s^{-1} \times 10^{6}\ s$

$5.10^{32}\ cm^{-2}$ PbPb run, 5.5 TeV

$N_{PbPb\ collisions} = 2\ .10^{9}$ collisions

Muon triggers:

~ 100% efficiency, ~ 1kHz

Electron triggers:

Bandwidth limitation

$N_{PbPb\ central} = 2\ .10^{8}$ collisions

Hadron triggers:

$N_{PbPb\ central} = 2\ .10^{7}$ collisions

Proton proton nominal run

$\int L dt\ dt = 3.10^{30}\ cm^{-2}\ s^{-1} \times 10^{7}\ s$

$5.10^{37}\ cm^{-2}$ for pp run, 14 TeV

$N_{pp\ collisions} = 2\ .10^{12}$ collisions

Muon triggers:

~ 100% efficiency, < 1kHz

Electron triggers:

~ 50% efficiency of TRD L1

20 physics events per event

Hadron triggers:

$N_{pp\ minb} = 2\ .10^{9}$ collisions

1st day physics scenario

- $\int L dt \, dt = 10^{30}\ cm^{-2}\ s^{-1}\ x\ 7.2x10^{5}\ s$
- $7.2x10^{35}\ cm^{-2}(0.72\ pb^{-1})$ *for pp run at 14TeV*
- $N_{pp\ collisions} = 5x10^{10}$ *collisions*
- *Enough for doing Heavy Flavours and electro-weak physics*
- *Spring 2008*
- *First pp collisions at 0.9 TeV end of 2007*

Conclusions

- D meson physics can be done in the central barrel;
- Beauty physics can be done via single electron (|y|<0.9) and muon (-4.<y<-2.5) measurements, and dimuon continuum;
- Quarkonia physics can be done via dielectron and dimuon. Quarkonia polarization can be measured;
- Beauty J/Ψ can be studied via di-electrons and tri-muons;
- Electro-weak physics (in a unexplored y domain) via muon and dimuons for detector QA, shadowing and baseline.
- Intermediate rapidity studies (–2.5<y<-0.9) via electron-muon correlation studies.

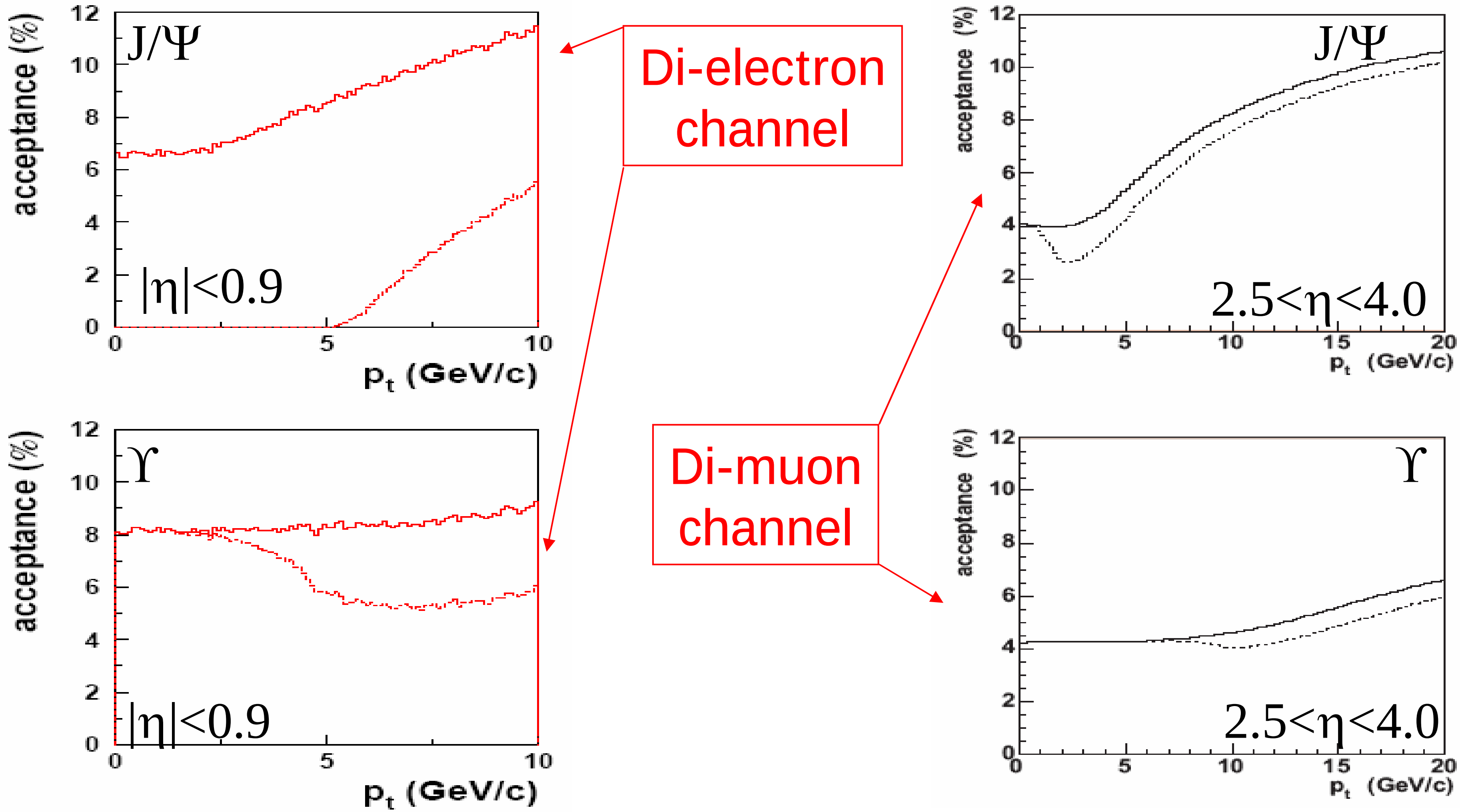
But we can't do

- Open B meson measurements;
- Heavy flavored baryon studies;
- χ quarkonia resonances;
- J/Ψ dimuons from beauty decays;
- Bottom-charmed mesons;
- Higgs measurement in PbPb collisions;
- ....

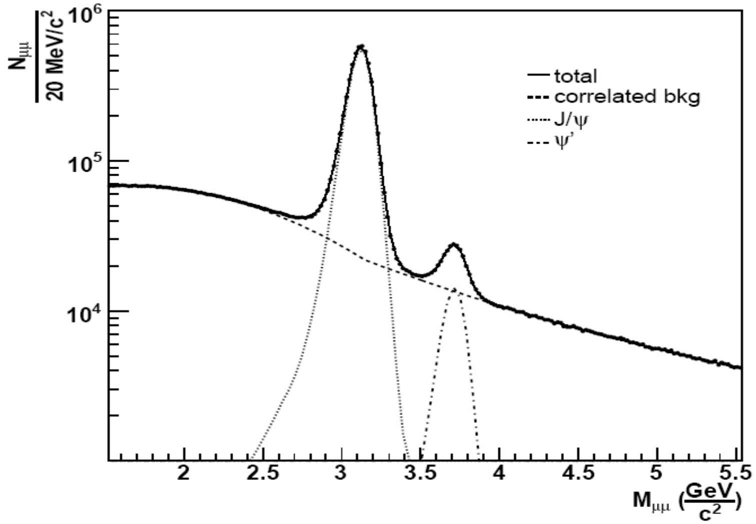
It's time to think about future ALICE upgrades

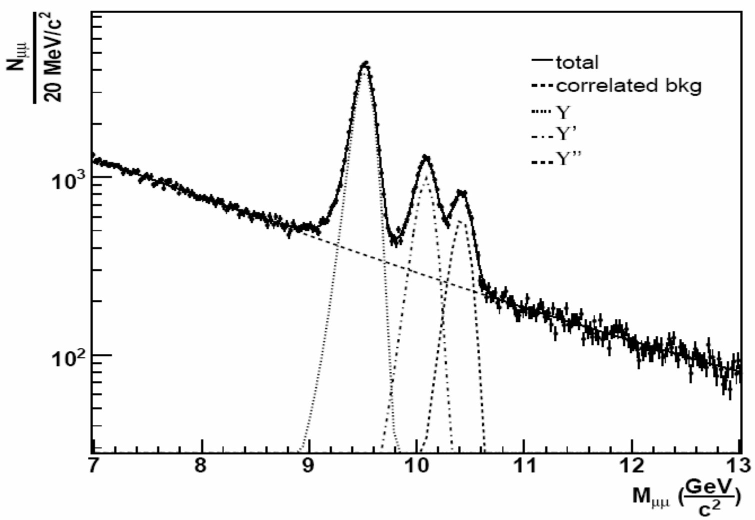
Slides for questions

Quarkonia Acceptances



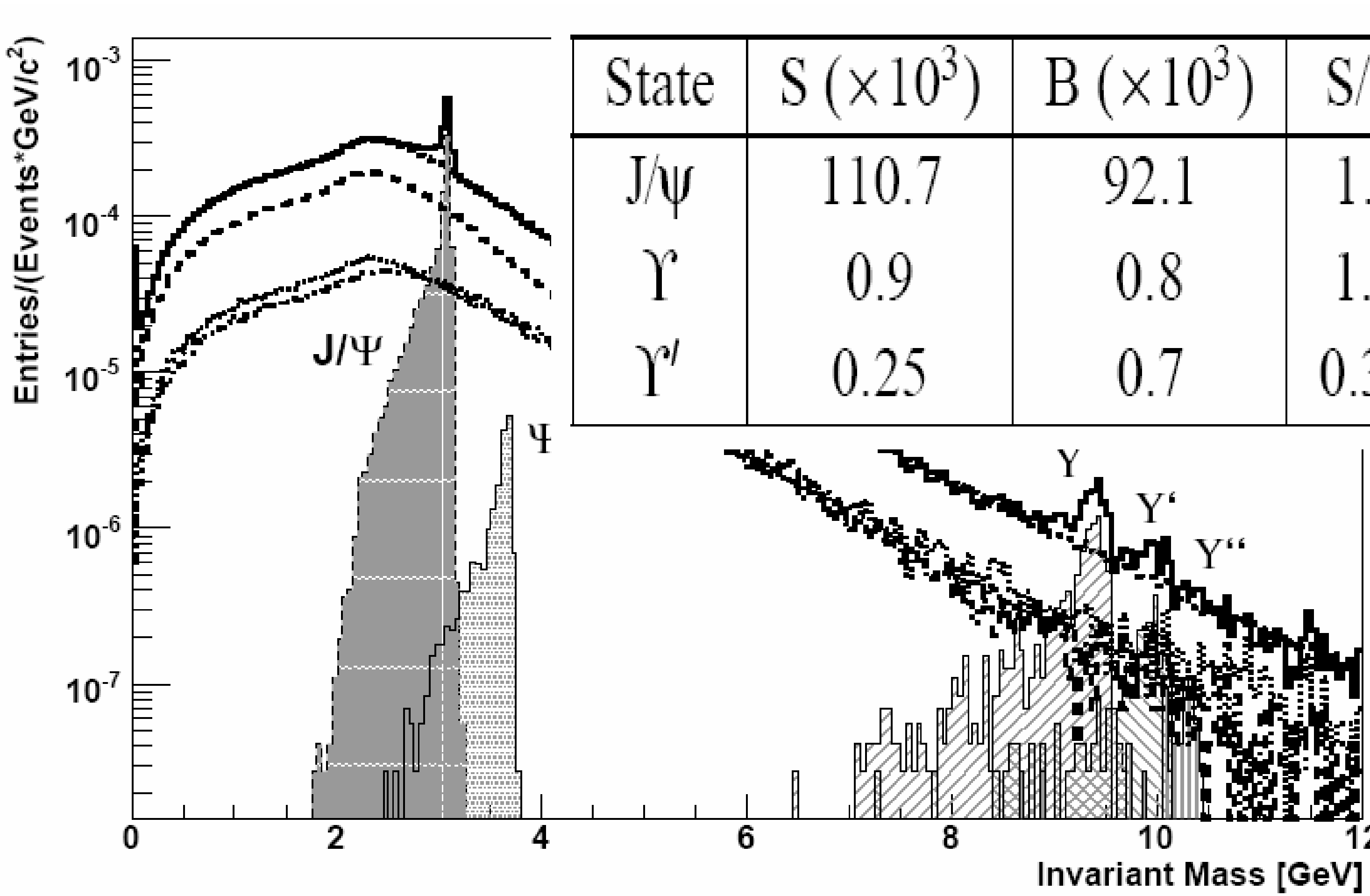
$\mu^+\mu^-$ M_{inv} in pp @ 14 TeV





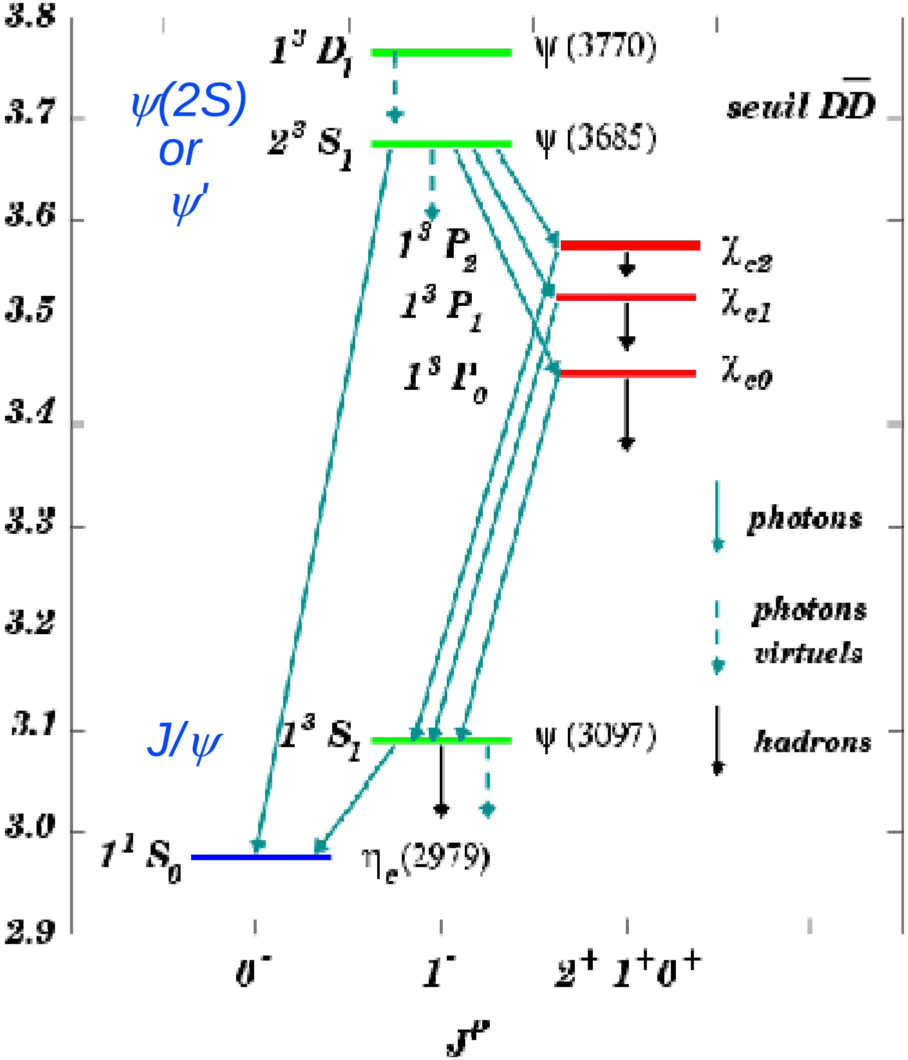
state	$B(\times 10^3)$	$S(\times 10^3)$	S/B	$S/\sqrt{S+B}$
J/ψ	370	4670	12.6	2081
ψ′	220	122	0.55	209
ϒ	7.7	44.7	5.8	195
ϒ′	6.1	11.4	1.9	86
ϒ″	5.4	6.9	1.3	62

e^+e^- Invariant Masses



State	S ($\times 10^3$)	B ($\times 10^3$)	S/B	$S/\sqrt{S+B}$
J/ψ	110.7	92.1	1.2	245
Υ	0.9	0.8	1.1	21
Υ'	0.25	0.7	0.35	8

Charmonia spectroscopy



$J/\Psi \rightarrow \mu^+\mu^-$, e^+e^- (BR 5.9%)

pp @ 14 TeV $\sigma_{J/\psi}$ ~ 70 μb

~1 J/ψ per 1000 pp collisions

- 27% from χc decay
- 22% from B decay
- 5.6% from $\psi(2S)$

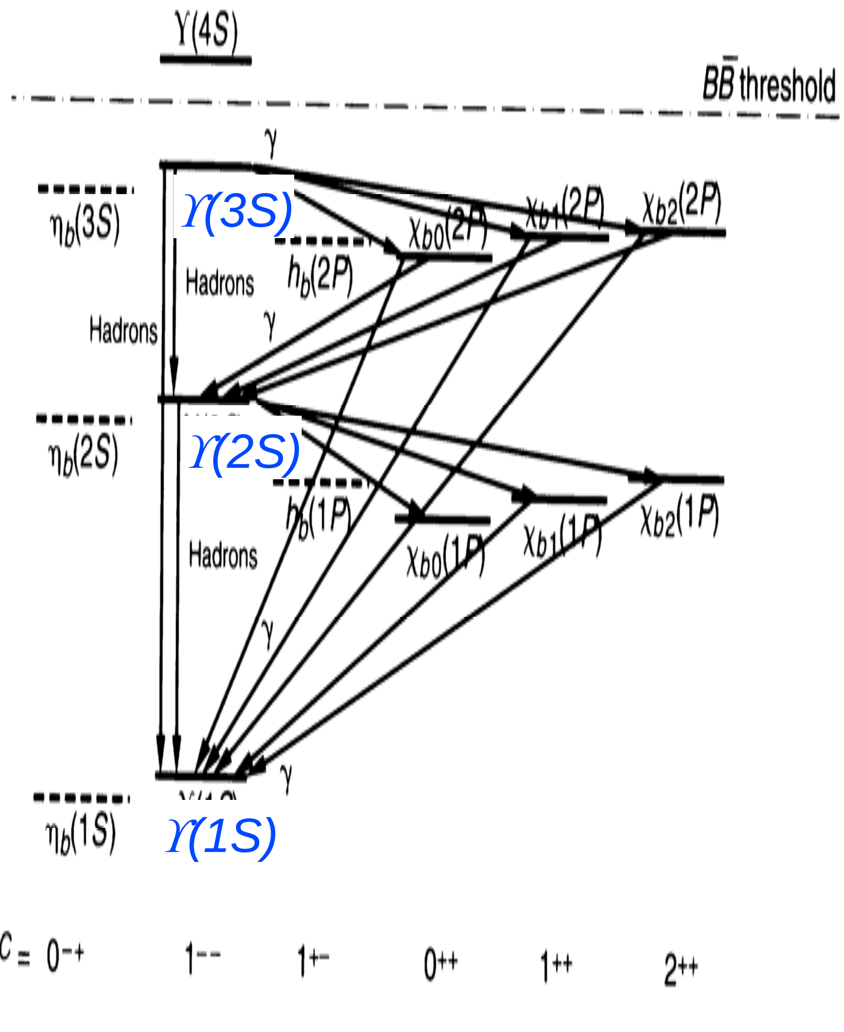
$\psi(2S) \rightarrow \mu^+\mu^-$, e^+e^-(BR~0.8%)

- 60% direct $\psi(2S)$
- 39% from B decay

$\psi(2S)$ / J/Ψ direct ~ 1.7%

$\psi(2S)$ / J/ψ from B ~ 5.2%

Bottomonia spectroscopy



$\Upsilon(1S) \rightarrow \mu^+\mu^-$, e^+e^- (BR 2.4%)

pp @ 14 TeV $\sigma_{\Upsilon(1S)}$ ~ 0.77 μb

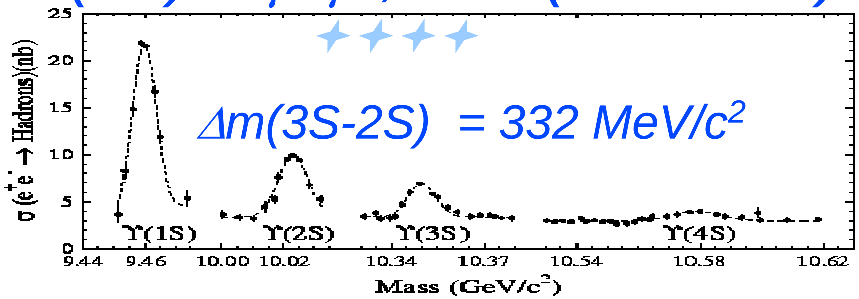
~1 Υ(1S) per 10^5 pp collisions

29.0% from χb(1P) decay
9.5% from Υ(2S) decay
4.5% from χb(2P) decay
1.5% from Υ(3S) decay

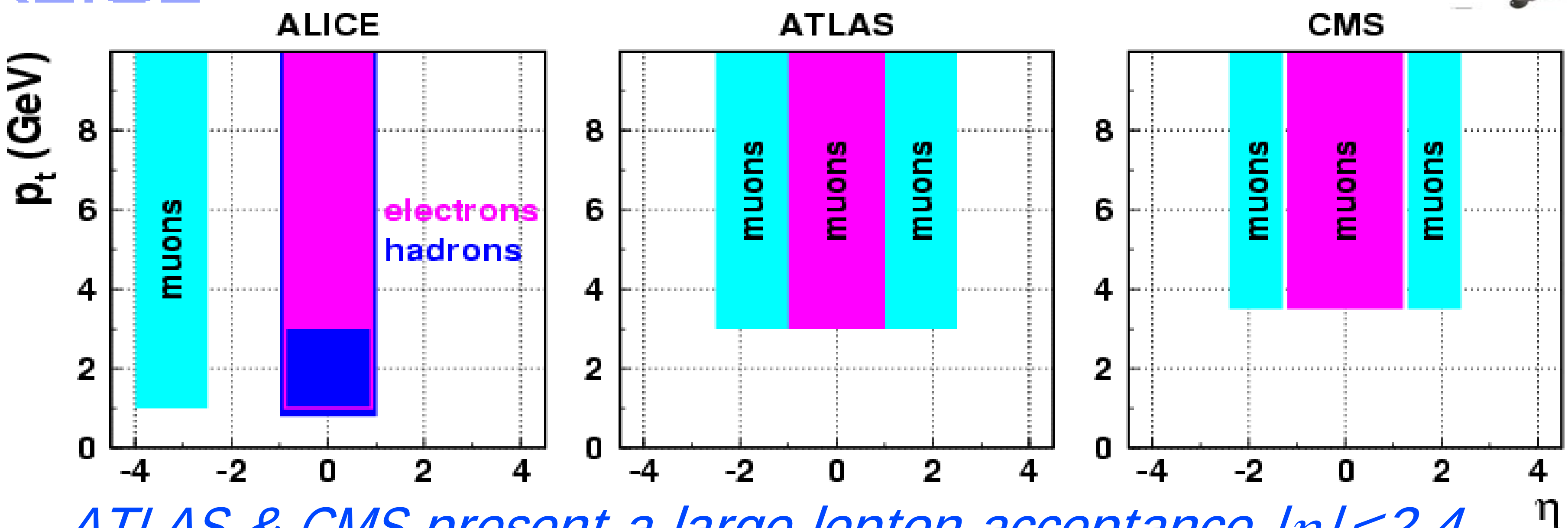
$\Upsilon(2S) \rightarrow \mu^+\mu^-$, e^+e^- (BR 1.3%)

25.0% from χb(2P) decay
4.5% from Υ(3S) decay

$\Upsilon(3S) \rightarrow \mu^+\mu^-$, e^+e^- (BR 1.8%)



Acceptances



ATLAS & CMS present a large lepton acceptance $|\eta|<2.4$

ALICE combines muonic and electronic channels

ALICE covers the low p_T region (p_T=0 for quarkonia)

ALICE covers the forward region $2.5<\eta<4.0$

ATLAS, CMS & ALICE-electron with high precision vertexing

Phenix Factor

There are no "unimportant details".

After we multiply the **geometric acceptance** by the **cross section** by the **delivered luminosity** by the **detector uptime**, we still have to add some **reality factors**. For example:

- Minimum bias trigger efficiency
  (0.75 in pp hard processes for PHENIX, 0.92 in AuAu for PHENIX)
- Collision vertex cut (0.8 of beam in central bucket at RHIC)
- Collision vertex cut (0.7 of central bucket for PHENIX VTX in +/- 10 cm)
- Level 1 trigger efficiency (typically 0.8)
- Pair reconstruction and PID efficiency (typically 0.8 in pp, 0.4 in AuAu).
- **Displaced vertex cut for open B (about 0.4 at 1 mm)**

Example reality factors:

0.75 x 0.8 x 0.7 x 0.8 x 0.8 x **0.4** = **0.11** for pp $B \rightarrow J/\psi$

0.92 x 0.8 x 0.7 x 0.8 x 0.4 x **0.4** = **0.07** for AuAu $B \rightarrow J/\psi$

0.92 x 0.8 x 0.7 x 0.8 x 0.4 = **0.16** for AuAu J/ψ

T. Frawley