J/ψ Production at the LHC

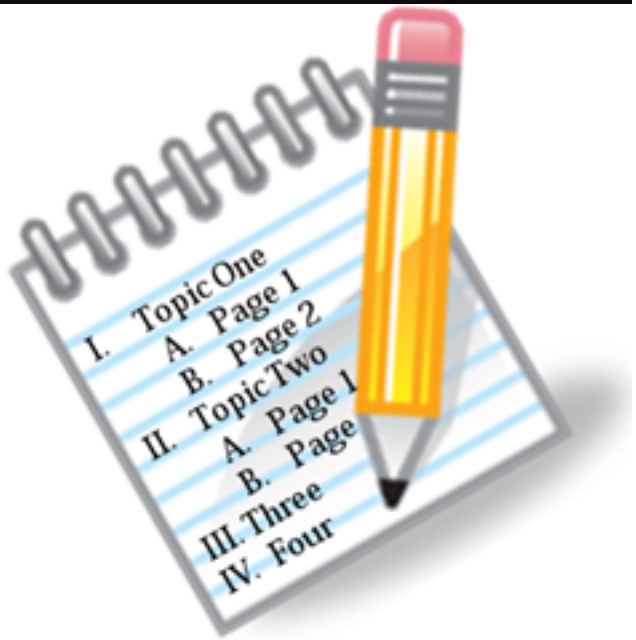
Giulia Manca

(University of Cagliari and INFN , Italy)

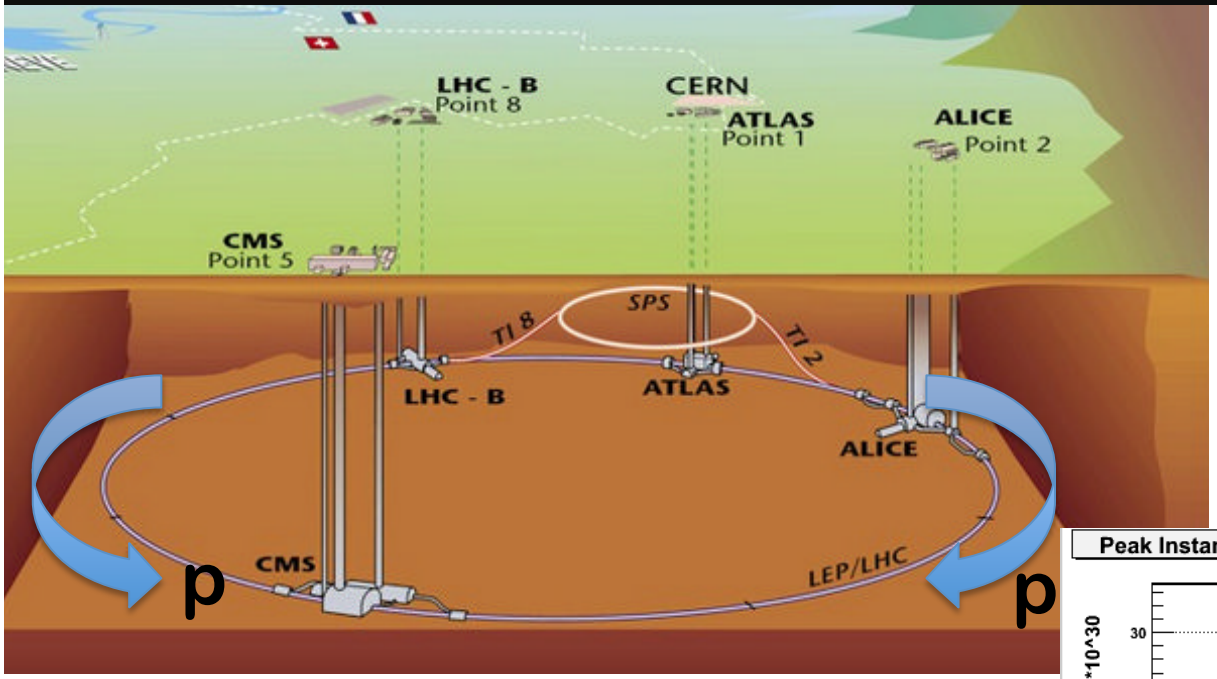
7th Workshop on B Physics
Orsay, France 4th–5th October 2010

Outline

- Motivation
- Cern and the LHC
- The experiments
- J/ψ production and results
- Conclusions and outlook



CERN and the LHC



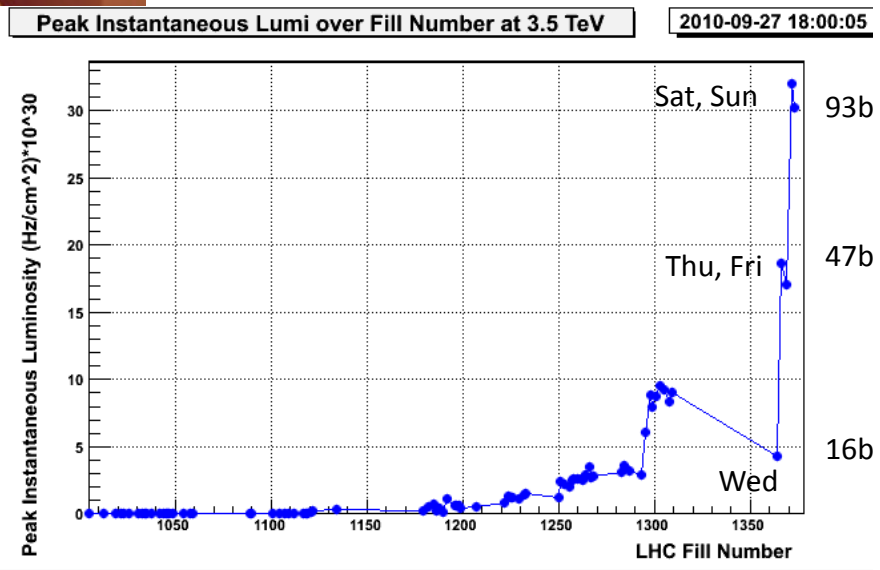
pp collider : NOW :

- @ √s = 7 TeV
- L ≈ 1-2·10^{31} cm^{-2} s^{-1}

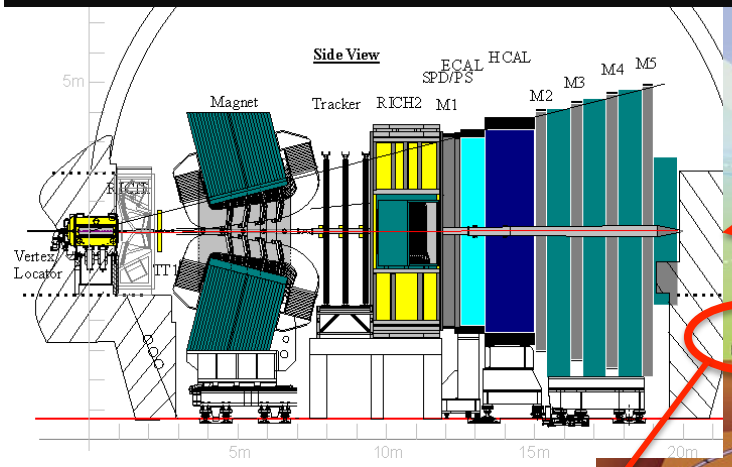
NOMINAL (2011) :

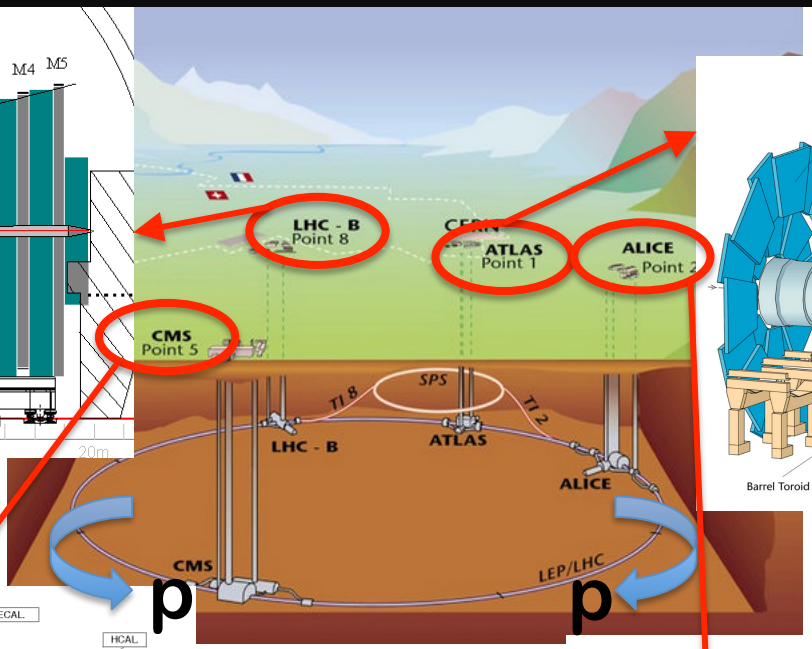
√s =14 TeV

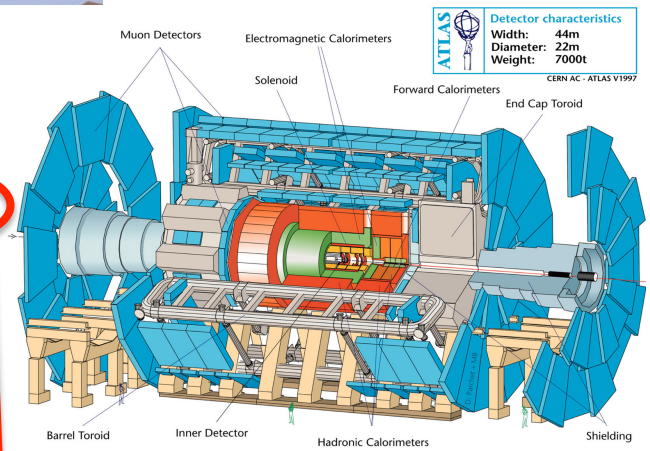
L = 2·10^{32} cm^{-2} s^{-1} (LHCb specific)

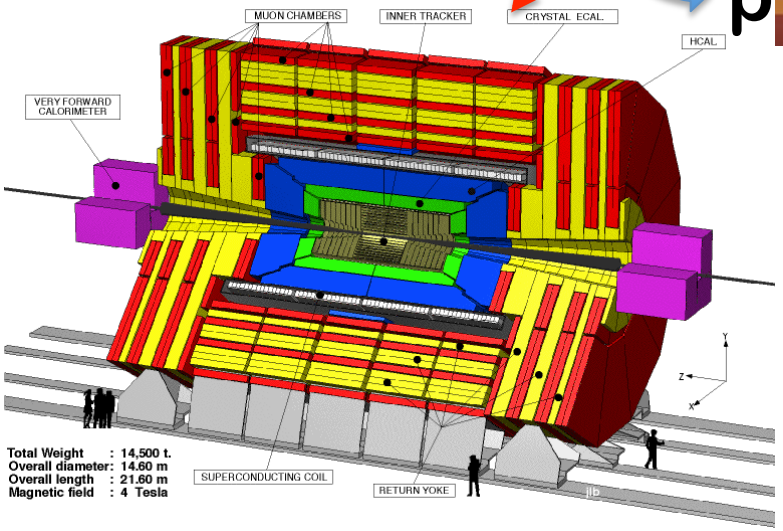


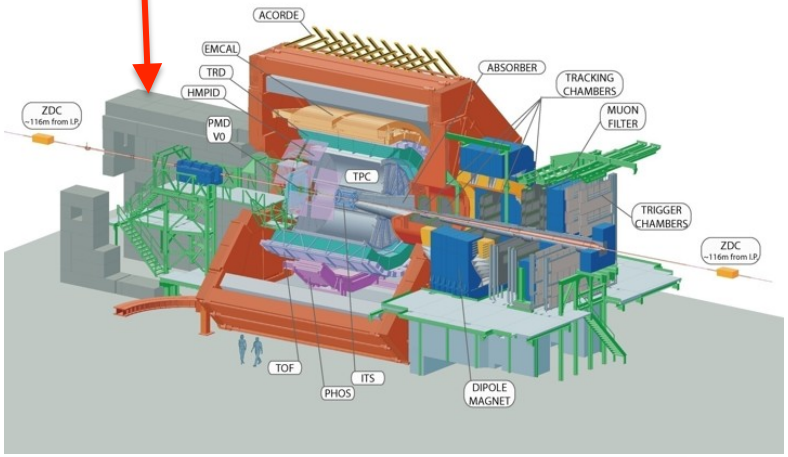
The four LHC Detectors



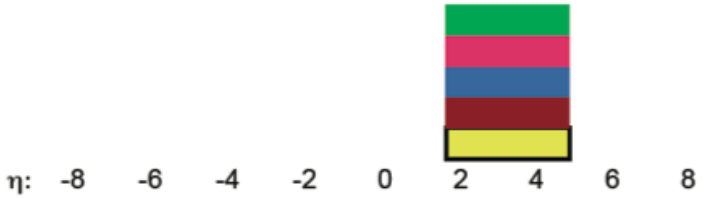




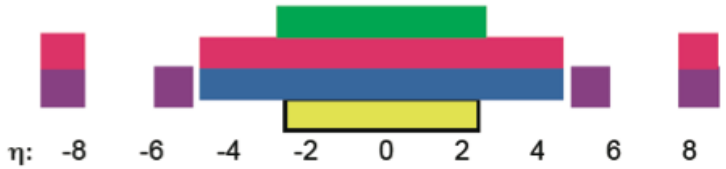




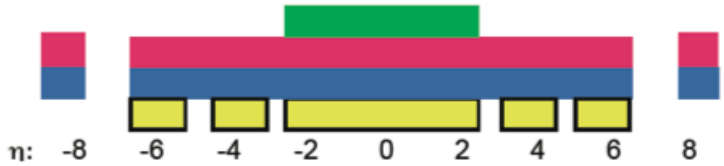
Rapidity Range



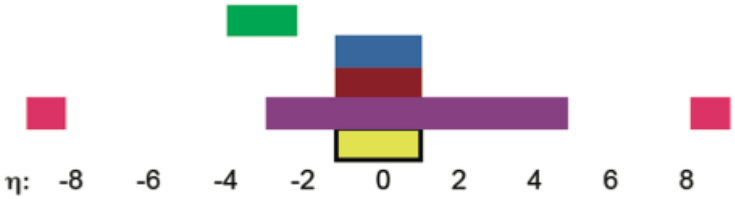
LHCb



ATLAS



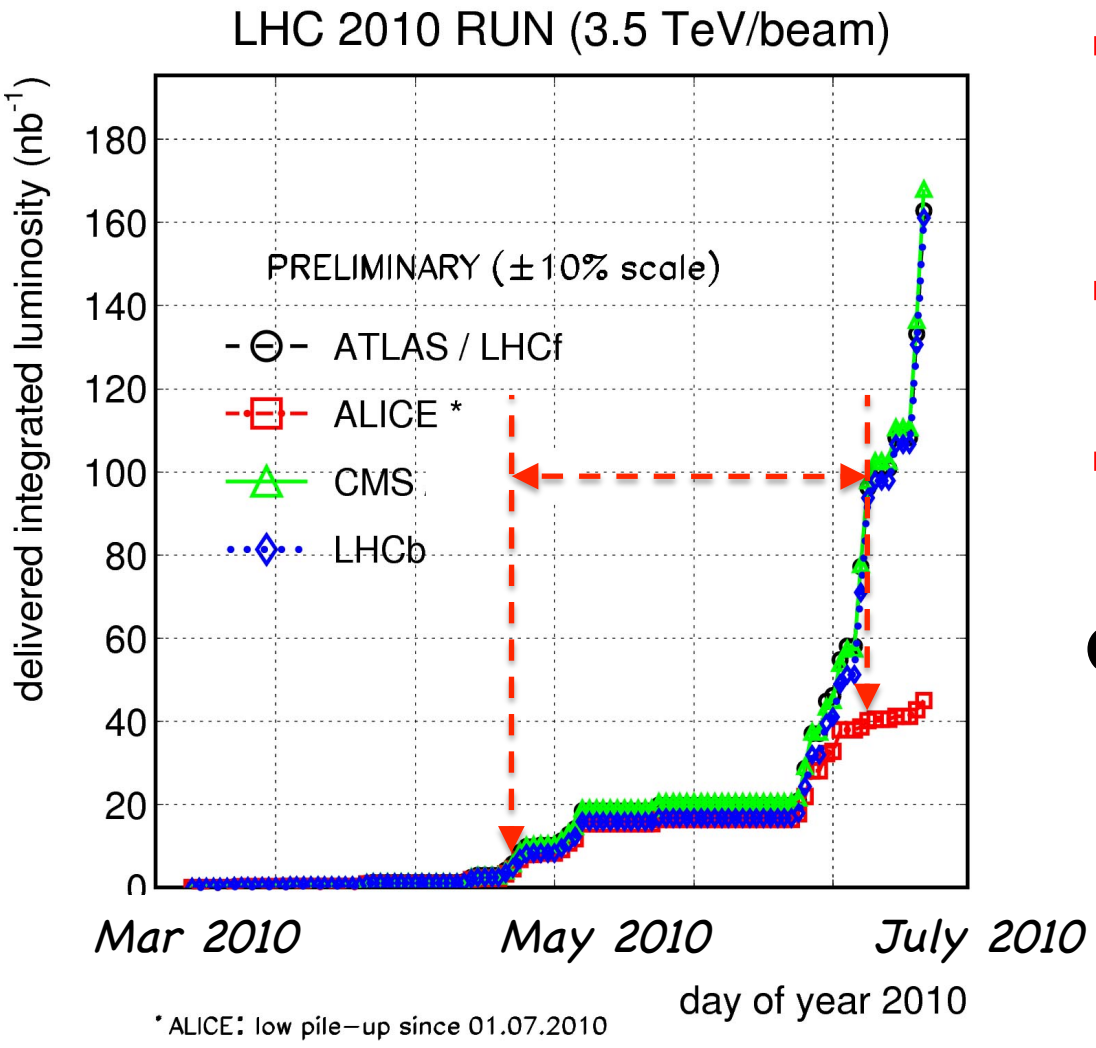
CMS



ALICE

tracking, ECAL, HCAL, counters lumi, muon, hadron PID

Luminosity



- LHC running well, all experiments have an efficiency ≈90%
- Already more than 3 pb^{-1} on tape
- These analyses :

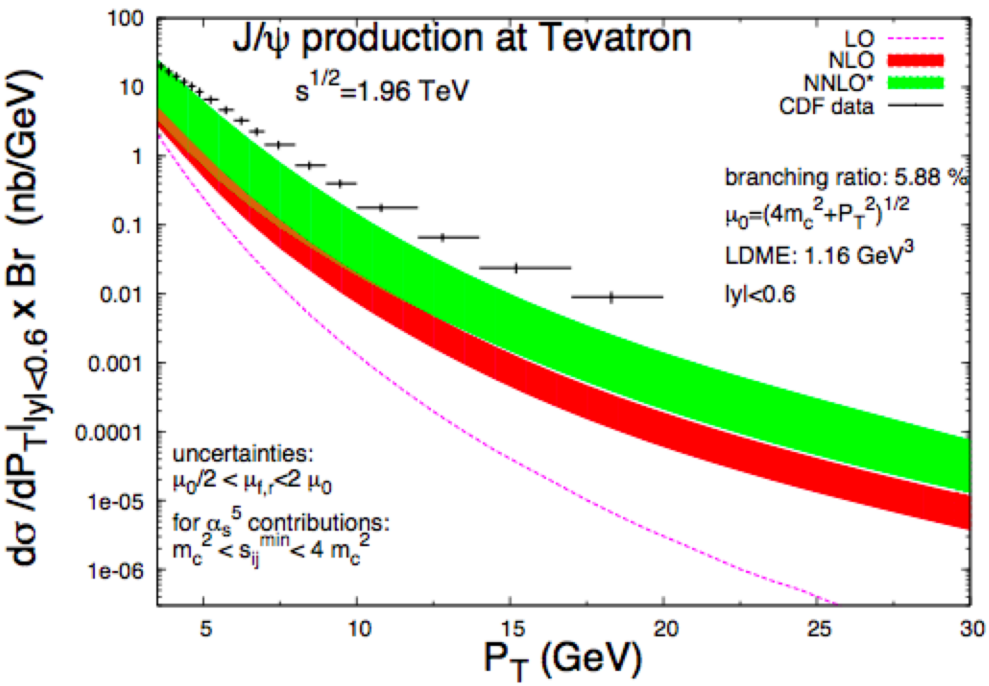
  L ≈ 9-100 nb^{-1}

Goals :

- ✓ 1 pb^{-1} (August 2010)
- 100 pb^{-1} (end of 2010)
- 1 fb^{-1} (end of 2011)

Motivations

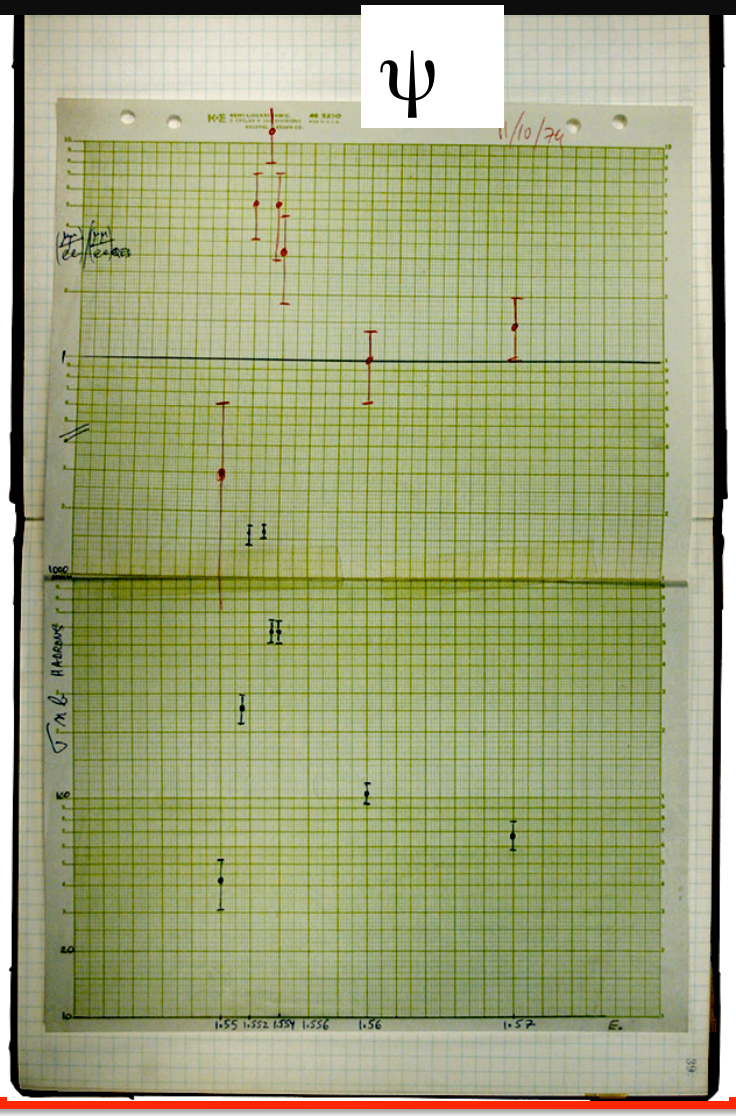
- The production mechanism in pp collisions still unclear
- Several models around :
  - Color singlet and color octet mechanisms (NRQCD) describe the p_T spectrum and cross section of the J/ψ as measured by Tevatron, but not the polarization (and has other failures)
  - Other models such as color evaporation model, kt factorization, soft color interaction model cannot describe the data either
- New data from LHC experiments will help to resolve this issue



J/ψ cross section crucial milestone in understanding detector and first step to B cross section measurement

J/ψ Production

ψ



J

PHYSICAL REVIEW LETTERS 2 DECEMBER 1974

one with approximate-
d with a lead convert-
n planes ($2\times A_0$, $3\times A$,
chambers rotated ap-
t to each other to re-
To further reduce the
ambers at high rate,
izontal hodoscope
chambers A and B.
C (1 m×1 m) there
ass counters of 3 ra-
ed by one bank of
ther reject hadrons
ove track identifica-
t all the counters are
5 computer and all
very 30 min.
red with a three-di-
tal of 10^5 points were
settings. The accep-
s $\Delta\theta = \pm 1°$, $\Delta\varphi = \pm 2°$,
trometer enables us
n from 1 to 5 GeV in

e-of-flight spectrum
in the mass region
peak of 1.5-nsec width
us to reject the acci-
nstruction between the
ain we have a clear-

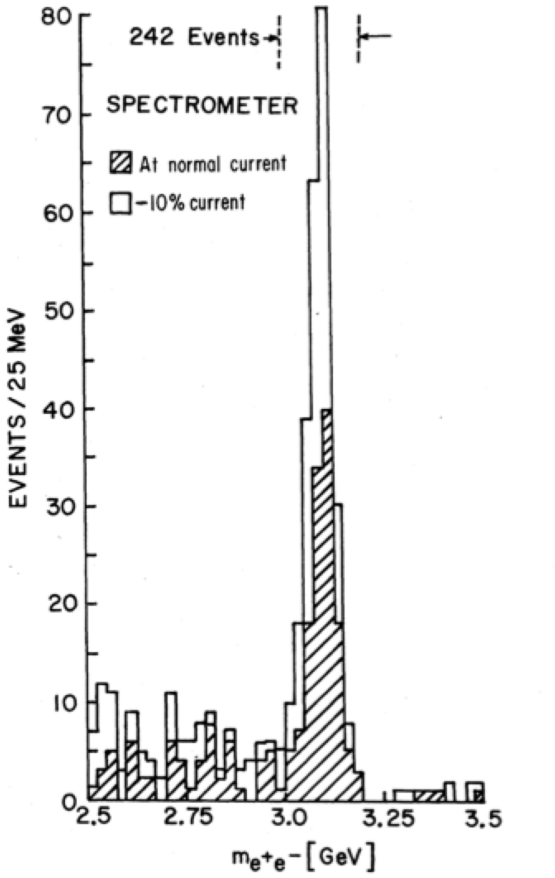
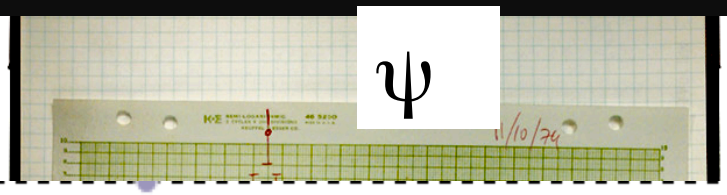


FIG. 2. Mass spectrum showing the existence of J.

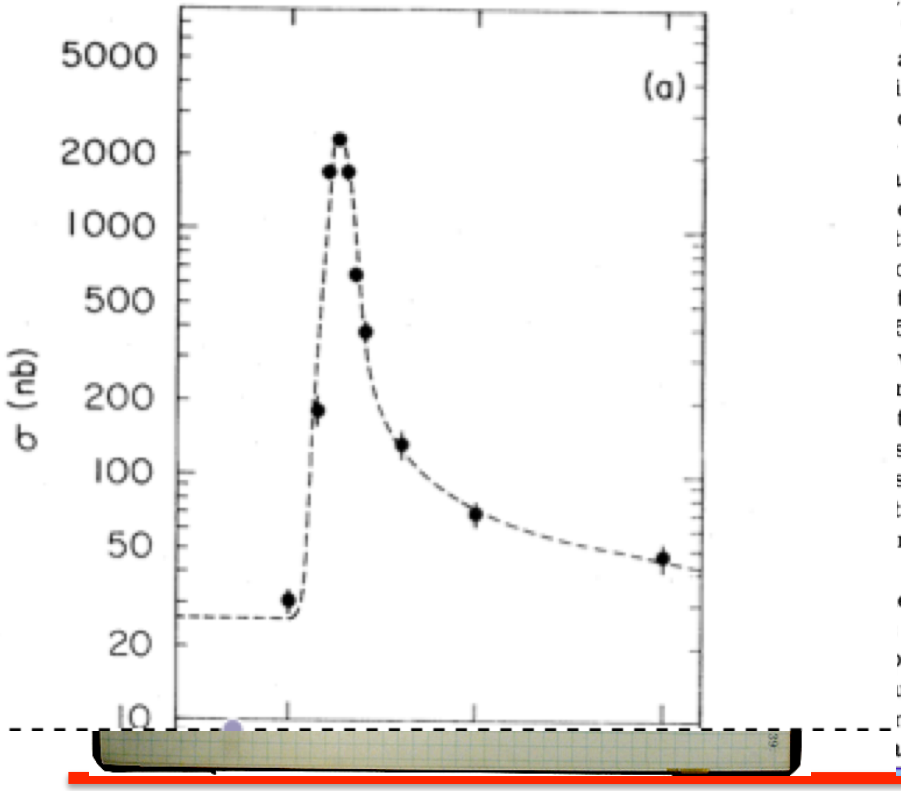
J/ψ Production

ψ

J



W LETTERS 2 DECEMBER 1974



PHYSICAL REVIEW LETTERS 2 DECEMBER 1974

one with approximate-
d with a lead convert-
n planes ($2\times A_0$, $3\times A$,
chambers rotated ap-
t to each other to re-
To further reduce the
ambers at high rate,
izontal hodoscope
chambers A and B.
C (1 m×1 m) there
ass counters of 3 ra-
ed by one bank of
ther reject hadrons
ove track identifica-
t all the counters are
5 computer and all
very 30 min.
red with a three-di-
tal of 10^5 points were
settings. The accep-
s $\Delta\theta = \pm 1°$, $\Delta\varphi = \pm 2°$,
trometer enables us
n from 1 to 5 GeV in

e-of-flight spectrum
in the mass region
eak of 1.5-nsec width
us to reject the acci-
nstruction between the
in we have a clear-

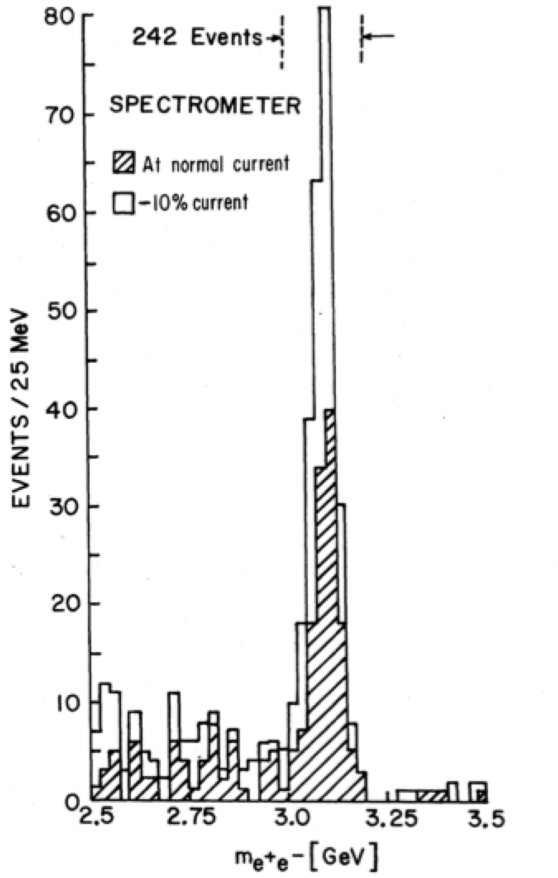
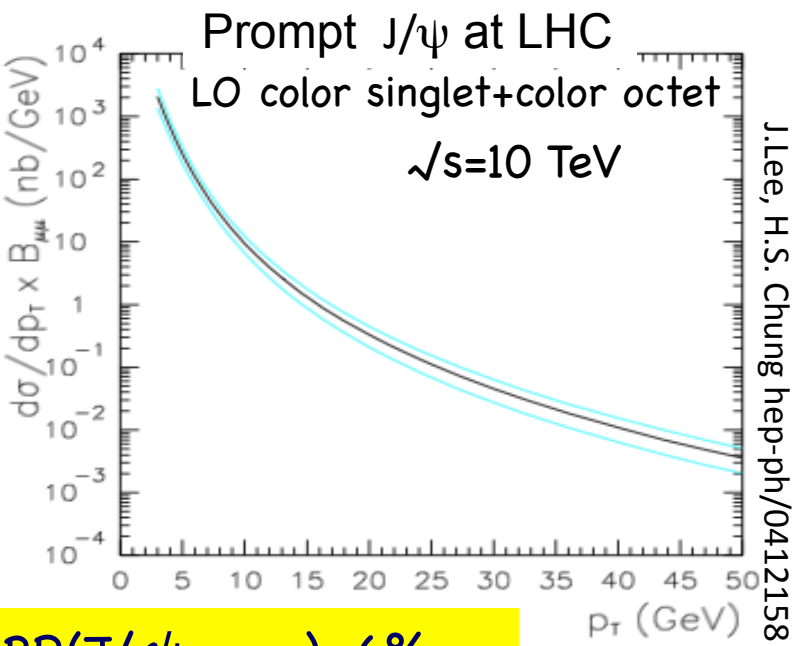


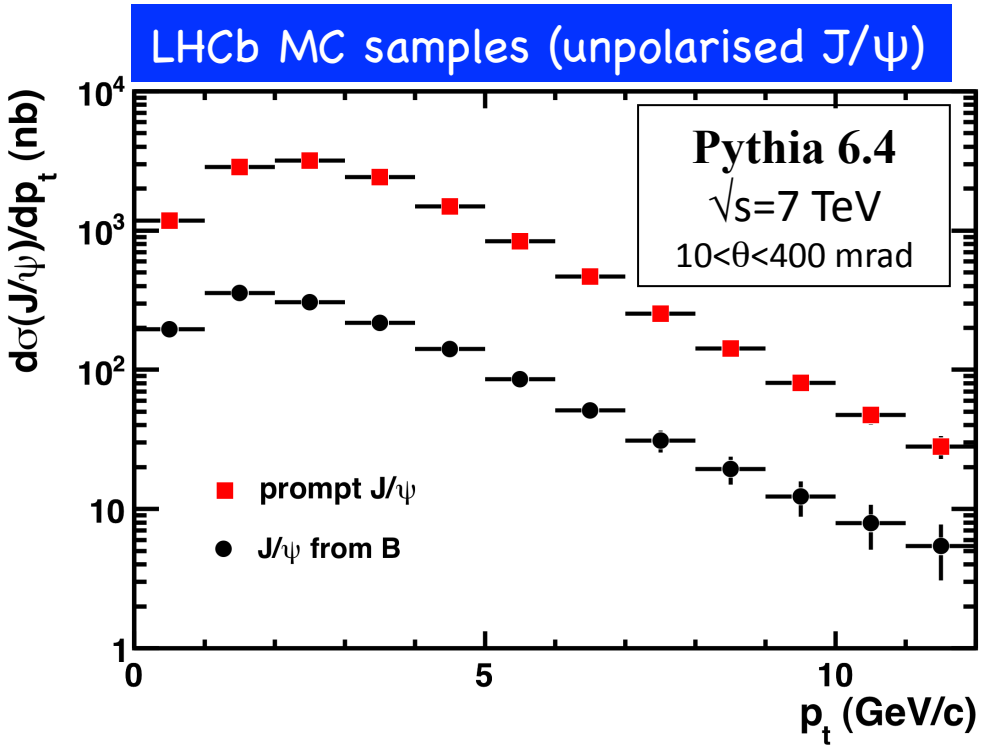
FIG. 2. Mass spectrum showing the existence of J.

J/ψ Production at pp

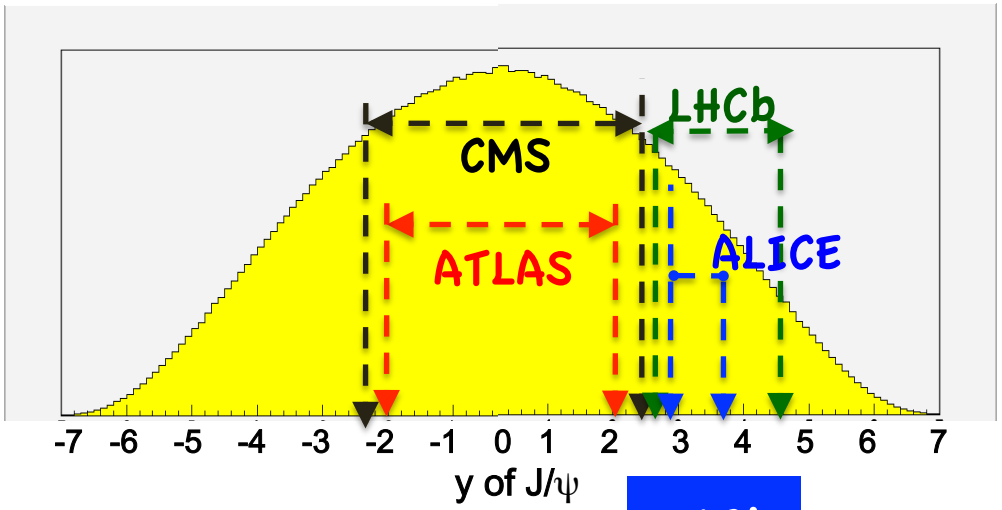
1st step	2nd step	3rd step	Production type
$pp \to c\bar{c}, b\bar{b} + X$	$c\bar{c} \to J/\psi + X$		Prompt,direct
	$c\bar{c} \to \chi_{c1}, \chi_{c2} + X$	$\chi_c \to J/\psi + \gamma$	Prompt,indirect
	$b\bar{b} \to B + X$	$B \to J/\psi + X$	Delayed,indirect



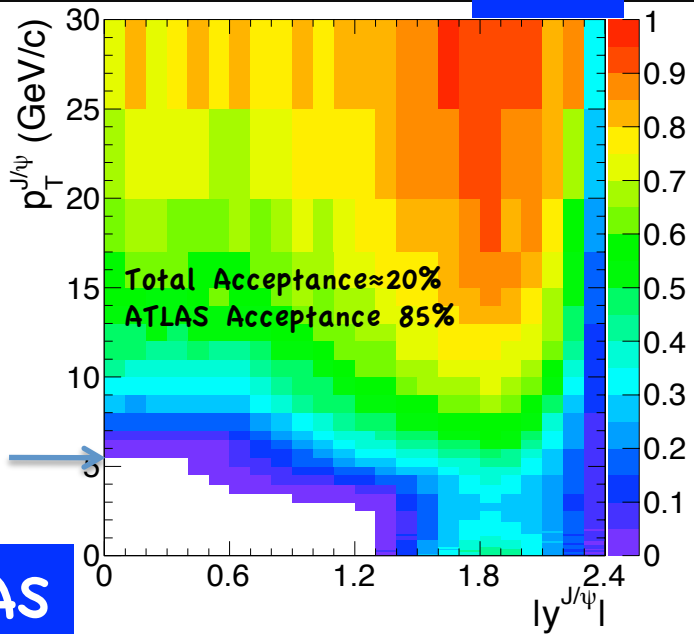
BR(J/ψ →μμ)≈6%



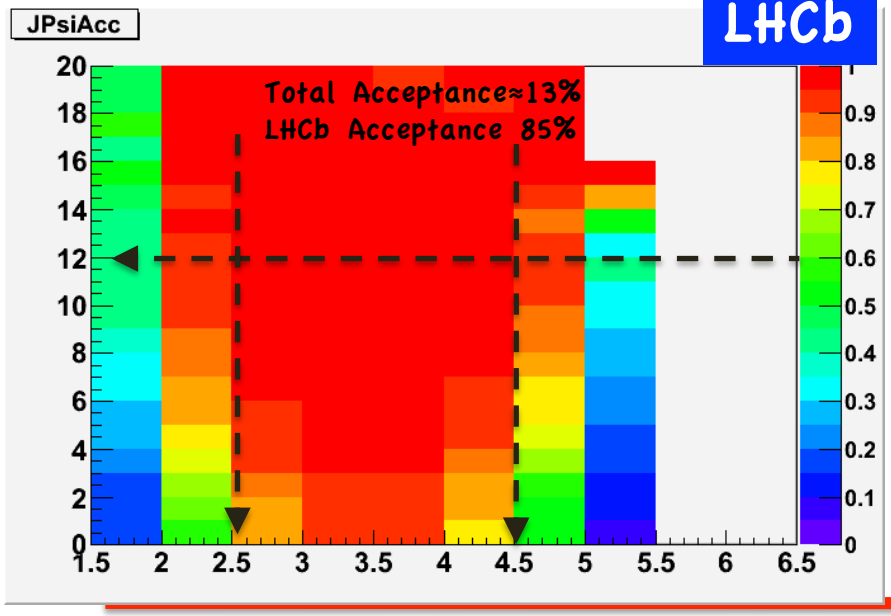
J/ψ Acceptance



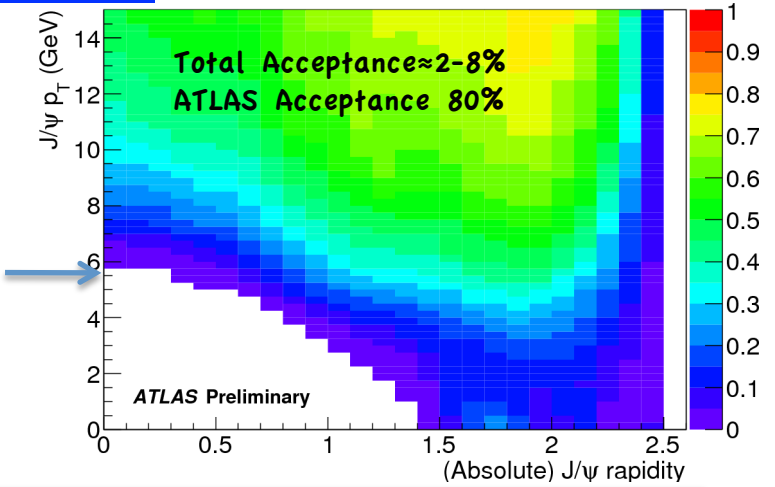
CMS



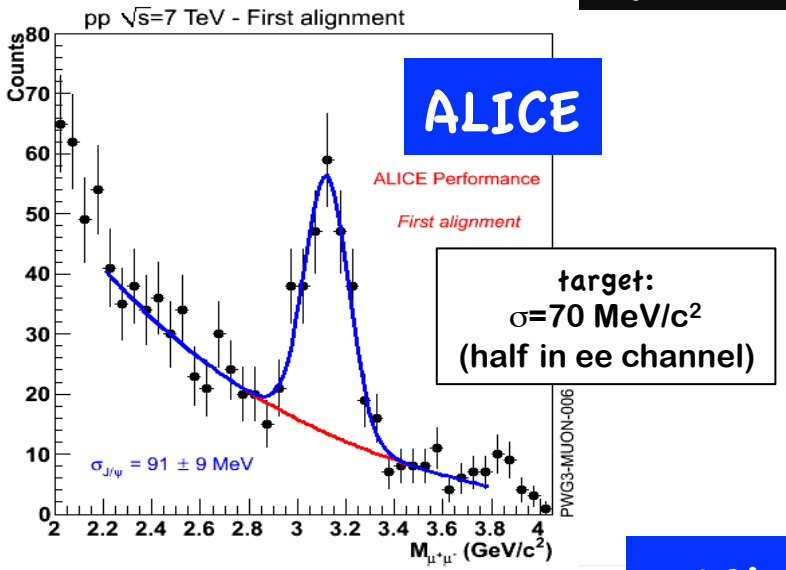
LHCb

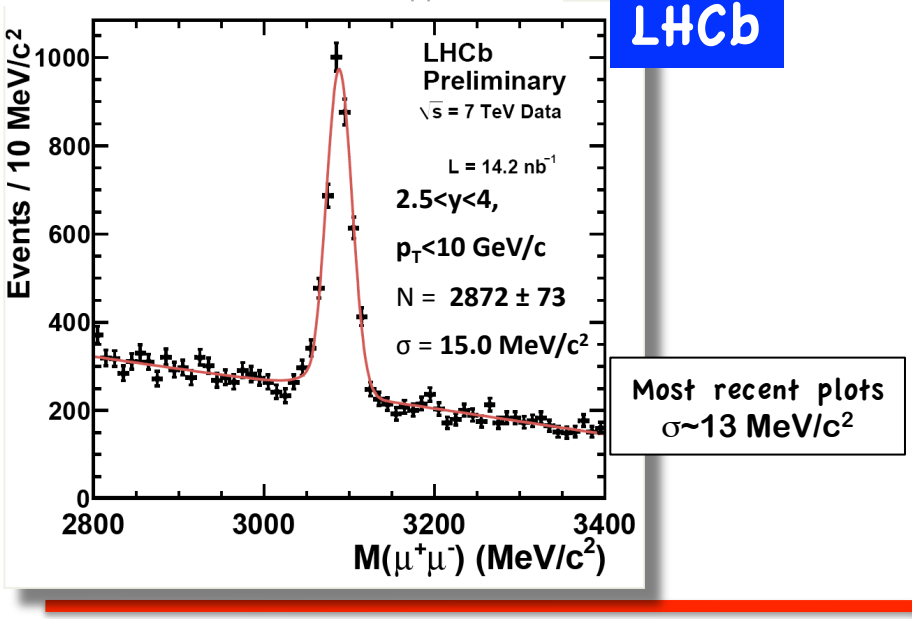


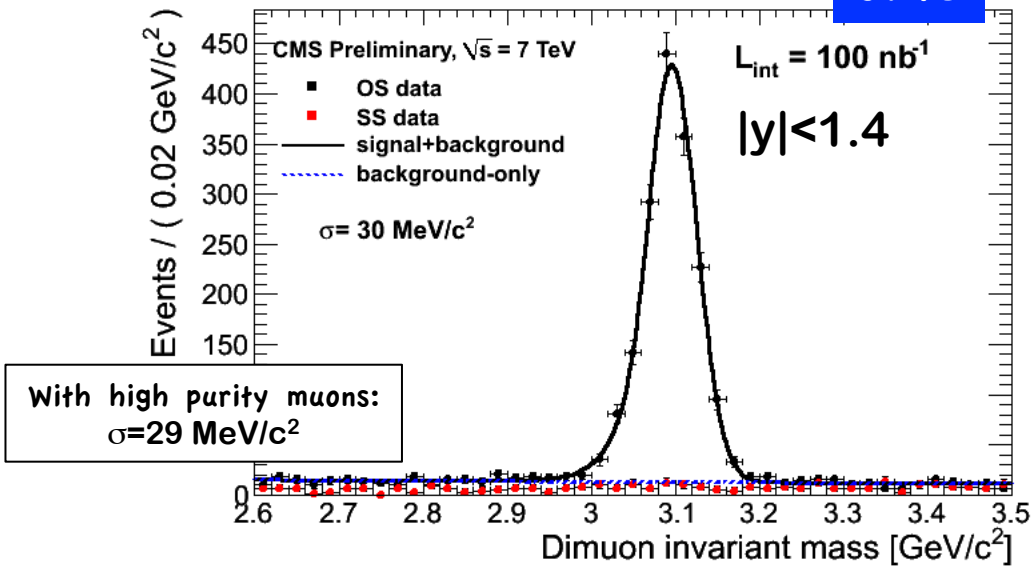
ATLAS

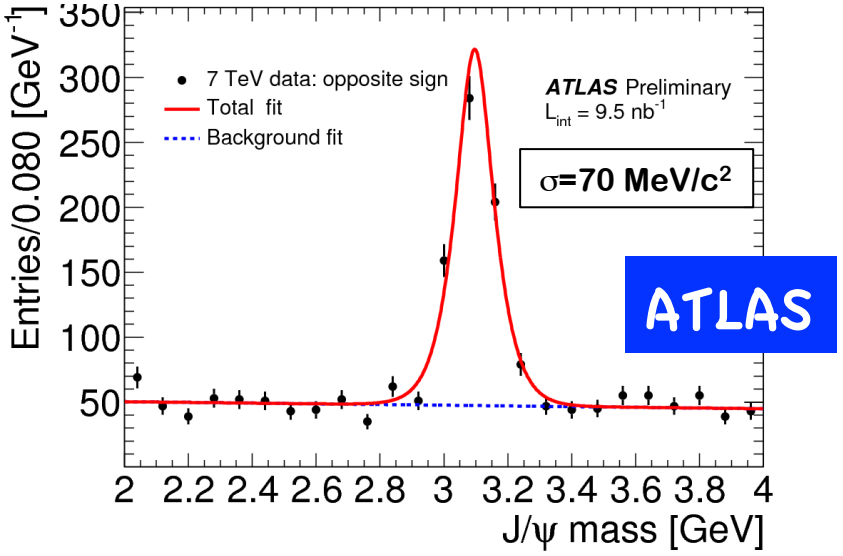


J/ψ→μμ mass distribution

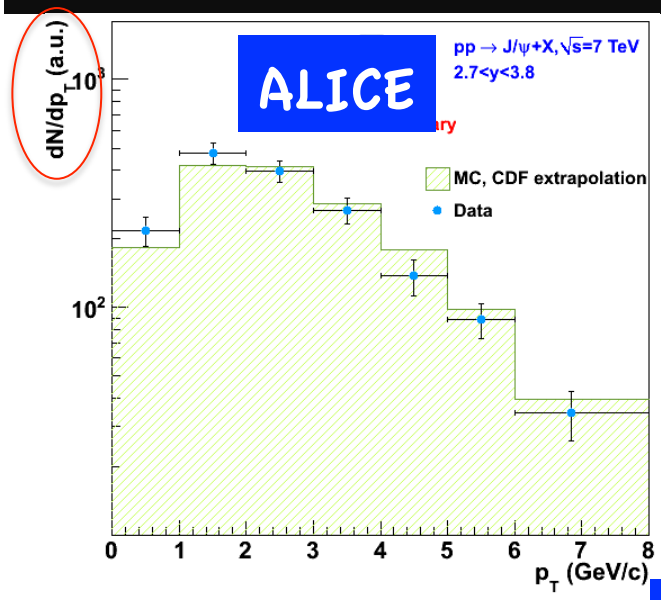


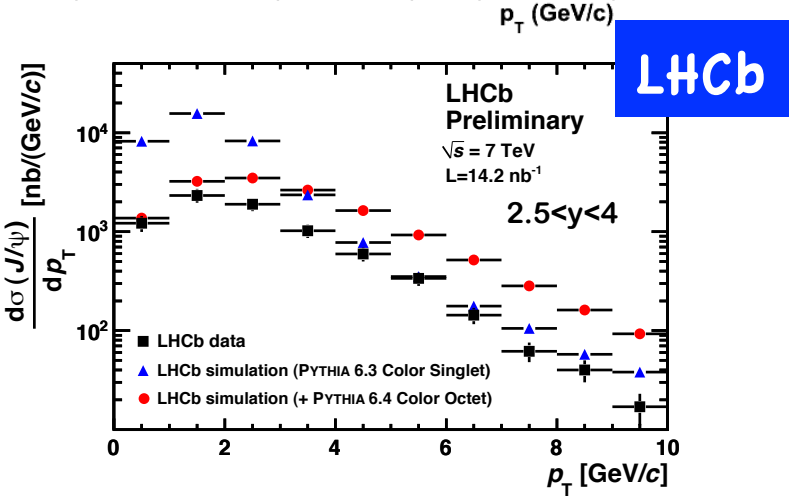


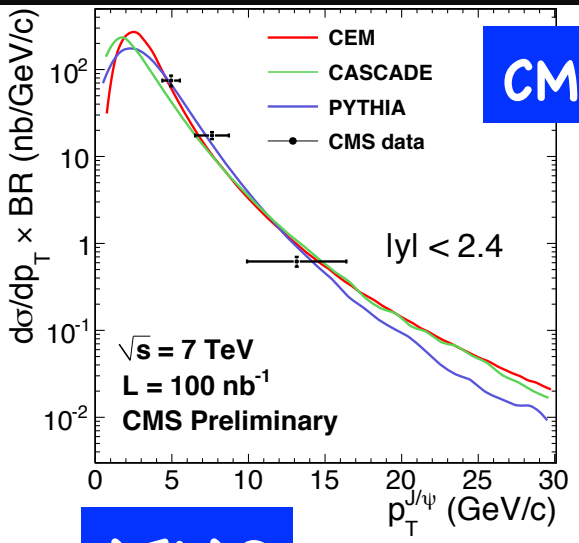


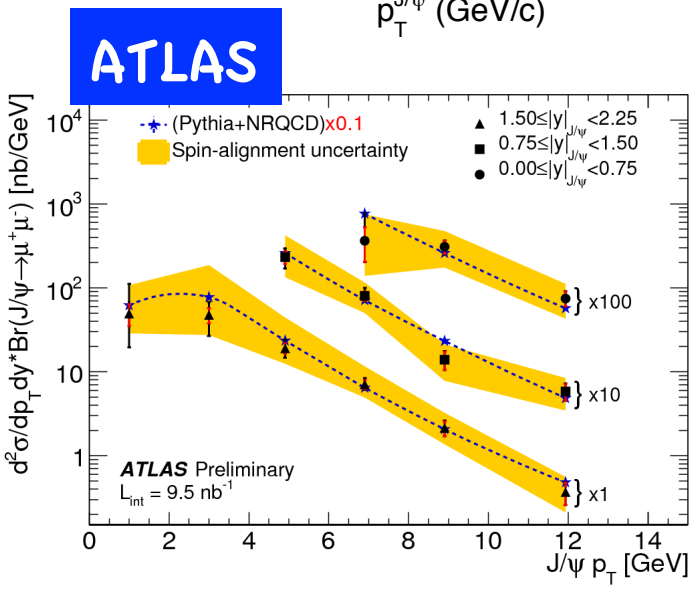


Inclusive cross section measurements

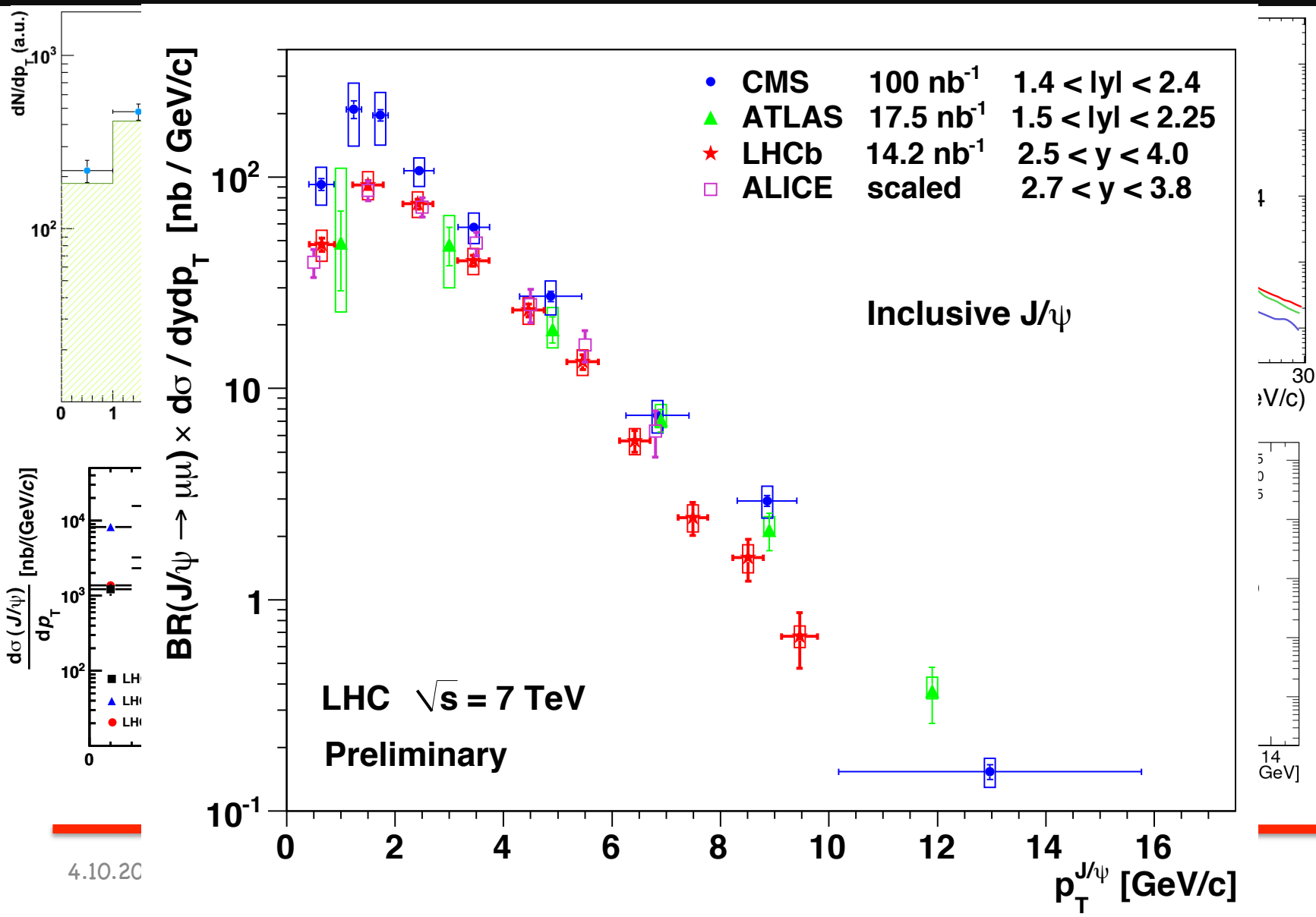






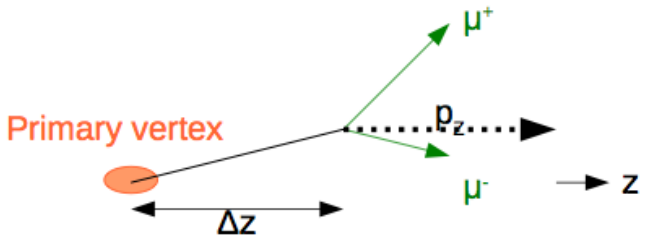


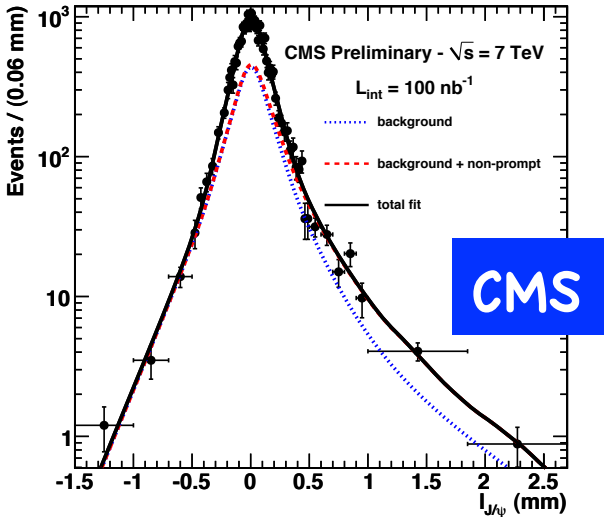
Cross section measurements



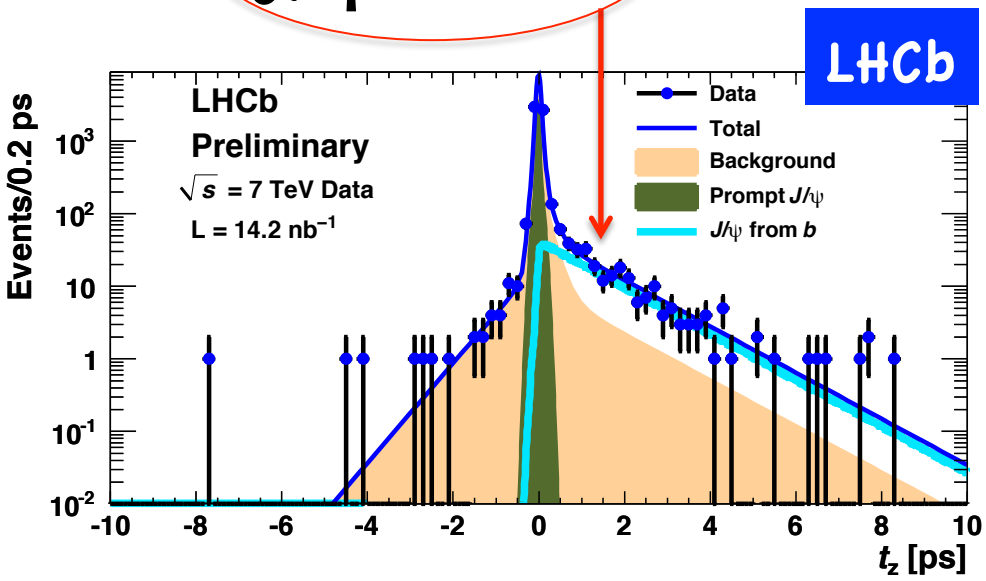
J/ψ proper time/decay lenght

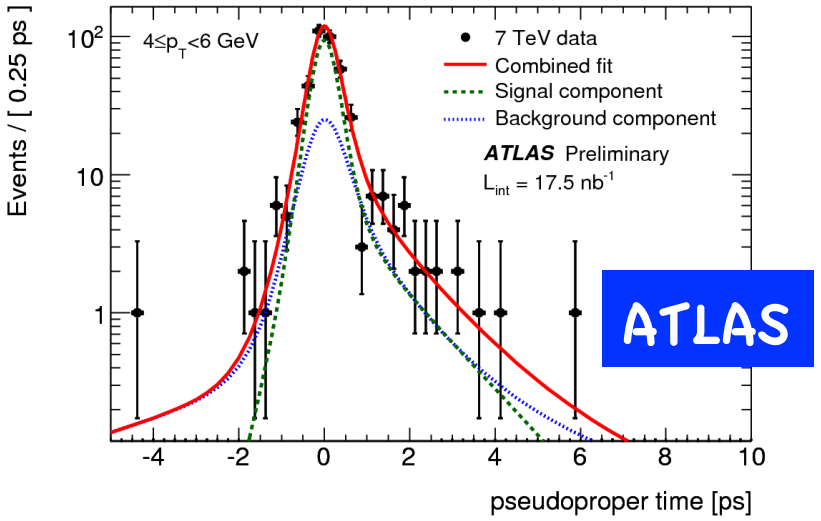
$t_z = \Delta z / p_z * M_{J/\psi}$



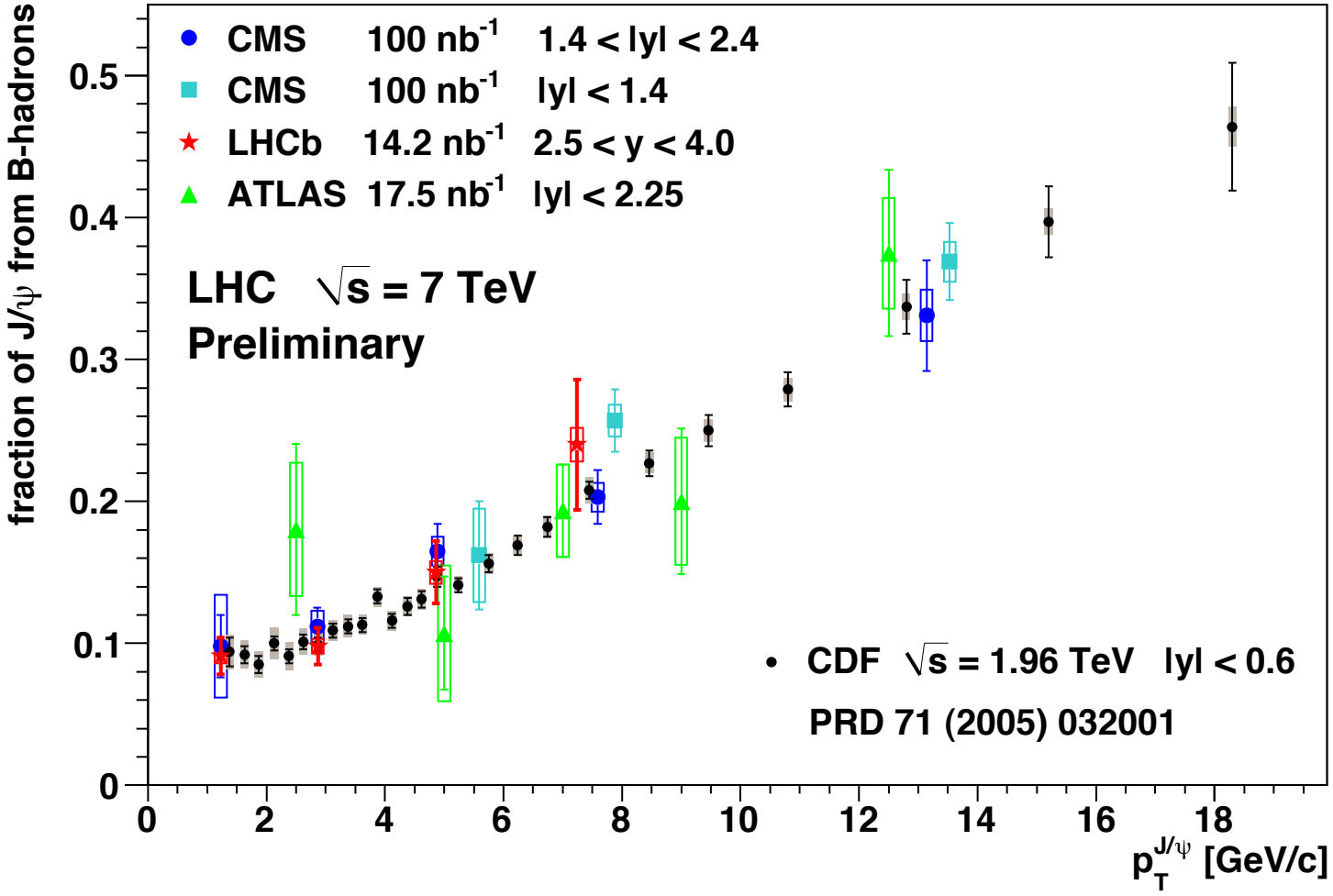


➡ t_z used to separate J/ψ prompt from J/ψ from B





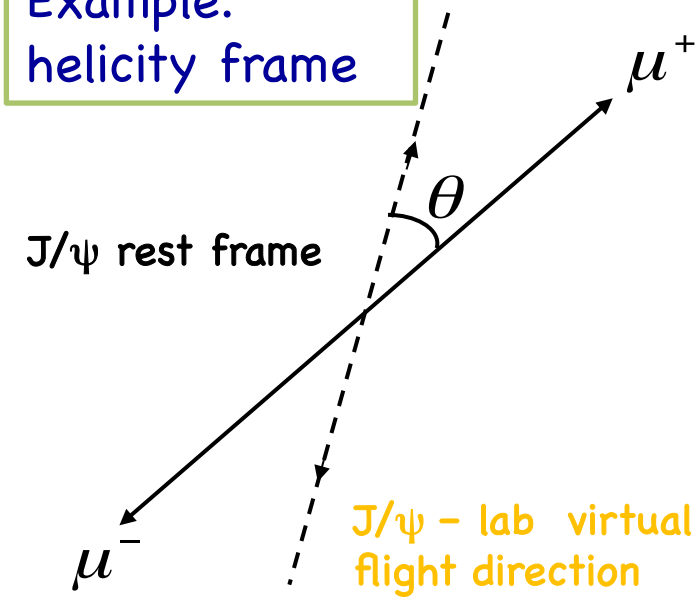
Non prompt J/ψ



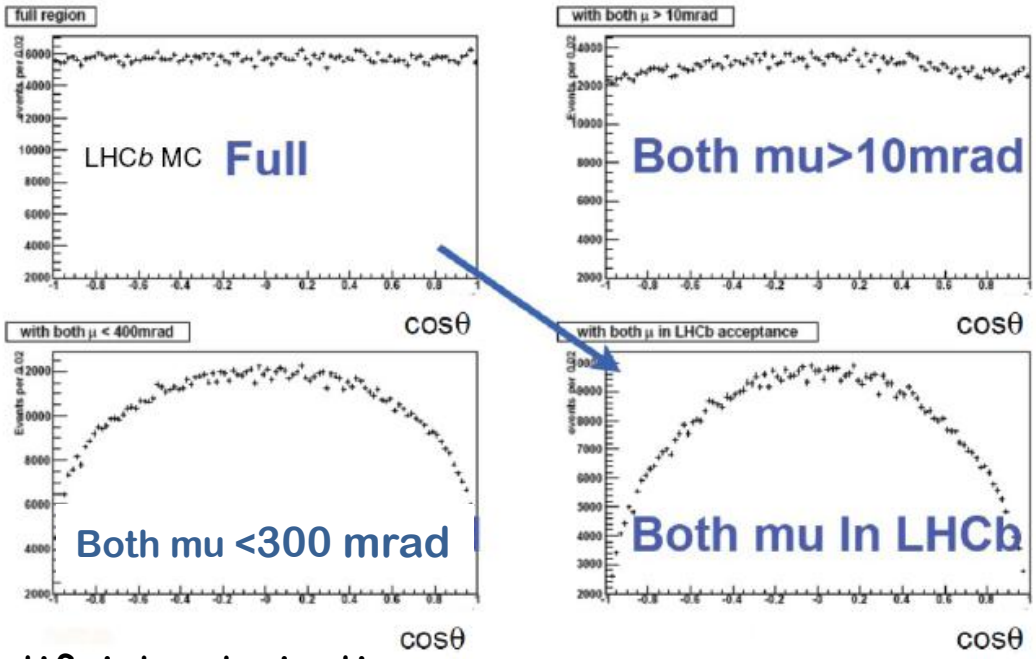
Influence of J/ψ Polarisation

- Detector acceptance as a function of helicity angle cosθ

Example: helicity frame



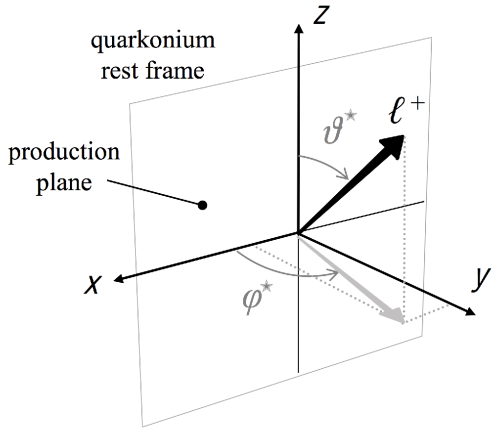
MC with no polarisation:LHCb

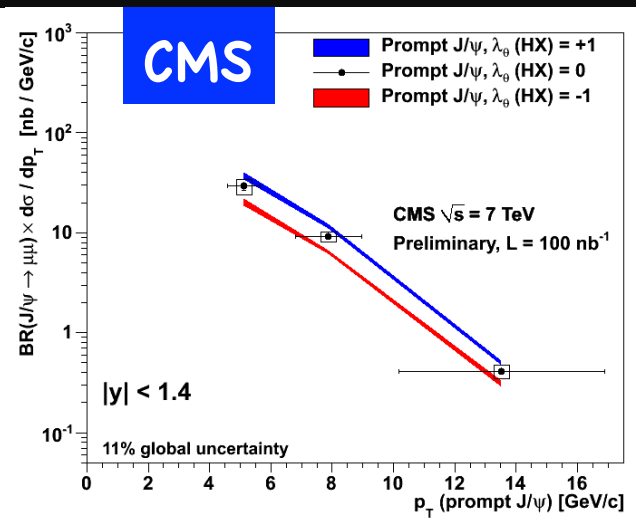


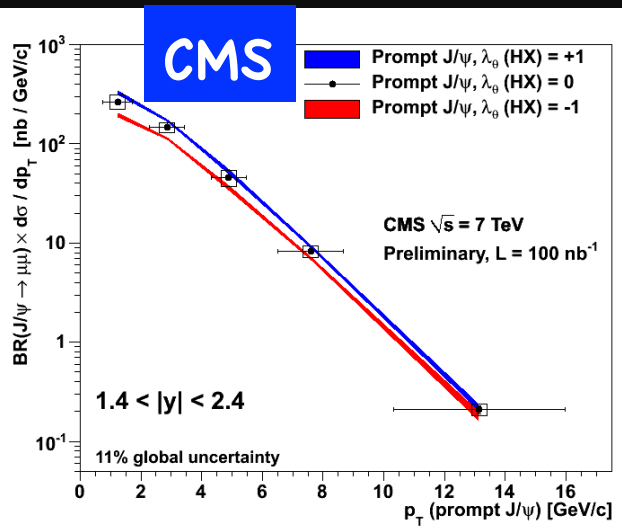
➡ acceptance generates an artificial polarisation
→ large influence of polarisation on measurement

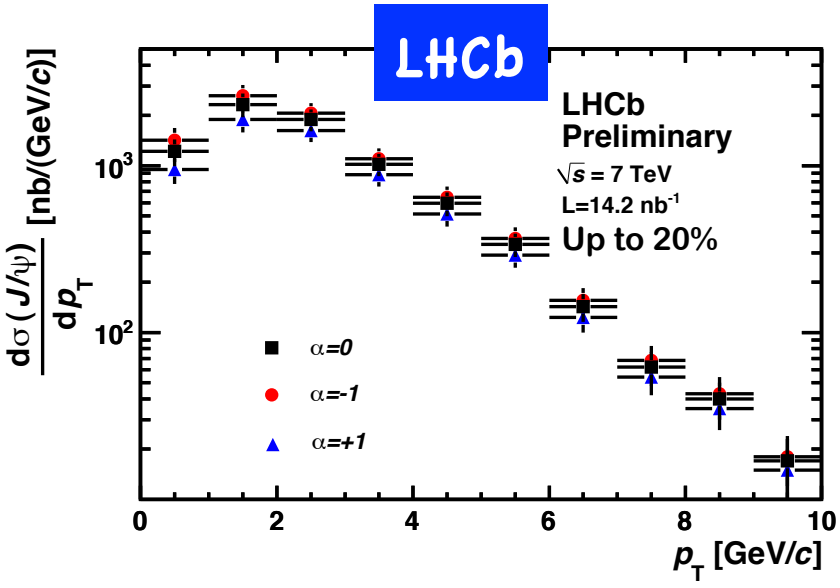
➡ First step: Treat polarisation as systematic error; present results in three different polarisation scenarios

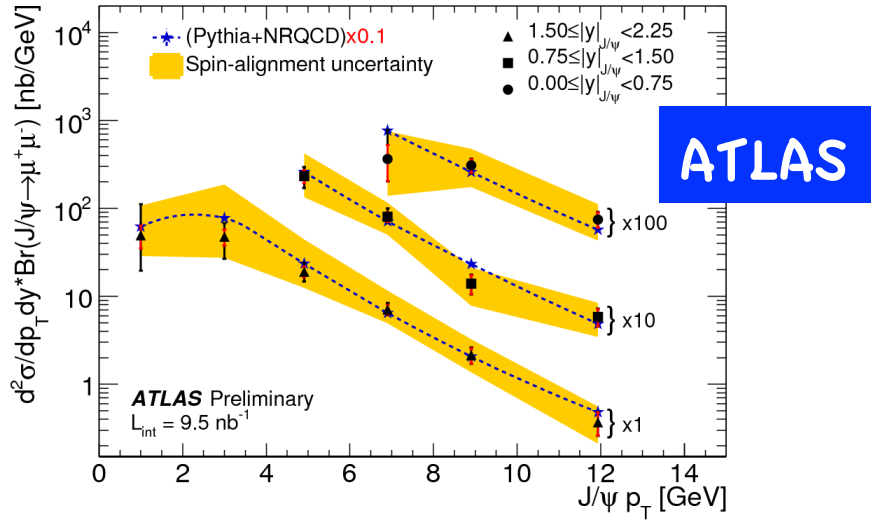
Different polarisation scenarios











Integrated cross section measurements

Experiment Range Luminosity	LHCb (in μb) pT<10 GeV, 2.5<y<4 14.2 nb^{-1}	CMS (in nb) 4<pT<30 GeV,|y|<2.4 100 nb^{-1}	ATLAS (in nb) <y>~1.85 100 nb^{-1}
Inclusive J/ψ	$7.65 \pm 0.19 \pm 1.10^{+0.87}_{-1.27}$	$289.1 \pm 16.7 \pm 60.1$	250^{+130}_{-80}
J/ψ from B	$0.81 \pm 0.06 \pm 0.13$	$56.1 \pm 5.5 \pm 7.2$	
Total bb*	$319 \pm 24 \pm 59$		

* Extrapolating to the LHCb acceptance using Pythia 6.4

Conclusions and Outlook

- LHC is in great shape and all experiments are taking data with high efficiency
- All the analysis tools are in place and start to deliver physics results
- J/ψ events clearly reconstructed
  - Crucial standard candle for detector understanding as well as cross check of luminosity
  - Cross section measurements probe of non-relativistic QCD theories
  - Results in four experiments compatible. Publications expected by the end of the year (with 2-5 pb^{-1}).
- Polarisation measurement next.

Back-up

Inclusive cross section measurements

- Extrapolations with PYTHIA 6.4 (LEP hadronization fractions assumed)

1. ½ production cross section for b or b in LHCb acceptance

$$\frac{\sigma(pp \to H_b X, 2 < \eta(H_b) < 6)}{2} = 84.5 \pm 6.3 \pm 15.6\,\mu\text{b}$$

2. Total bb production cross section

$$\sigma(pp \to b\bar{b}X) = 319 \pm 24 \pm 59\,\mu\text{b}$$

An independent σ(bb) measurement by LHCb with results in excellent agreement. Averaging:

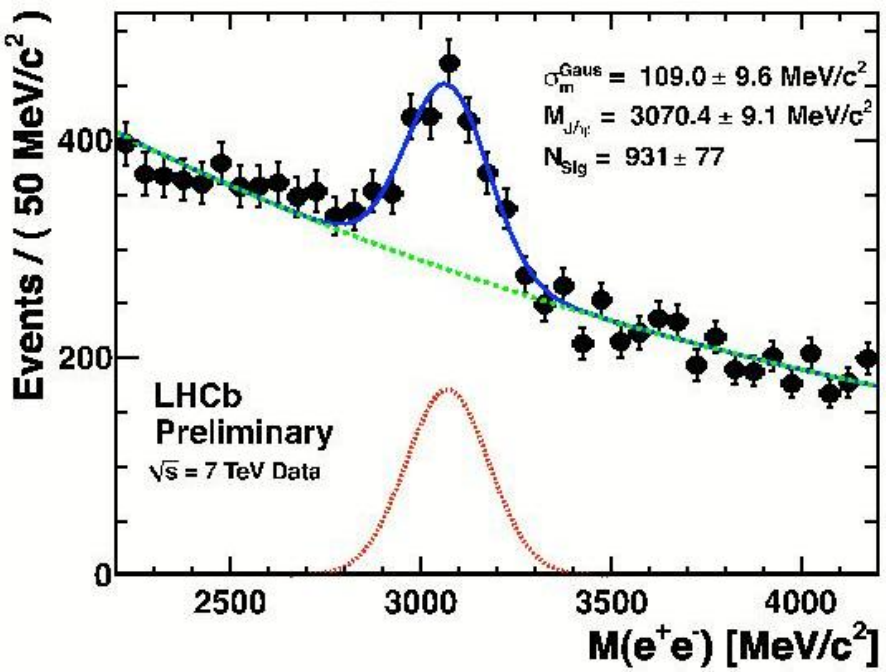
$$\frac{\sigma(pp \to H_b X,\ 2 < \eta(H_b) < 6)}{2} = 77.4 \pm 4.0 \pm 11.4\,\mu\text{b}$$
$$\sigma(pp \to b\bar{b}X) = 292 \pm 15 \pm 43\,\mu\text{b}\,.$$

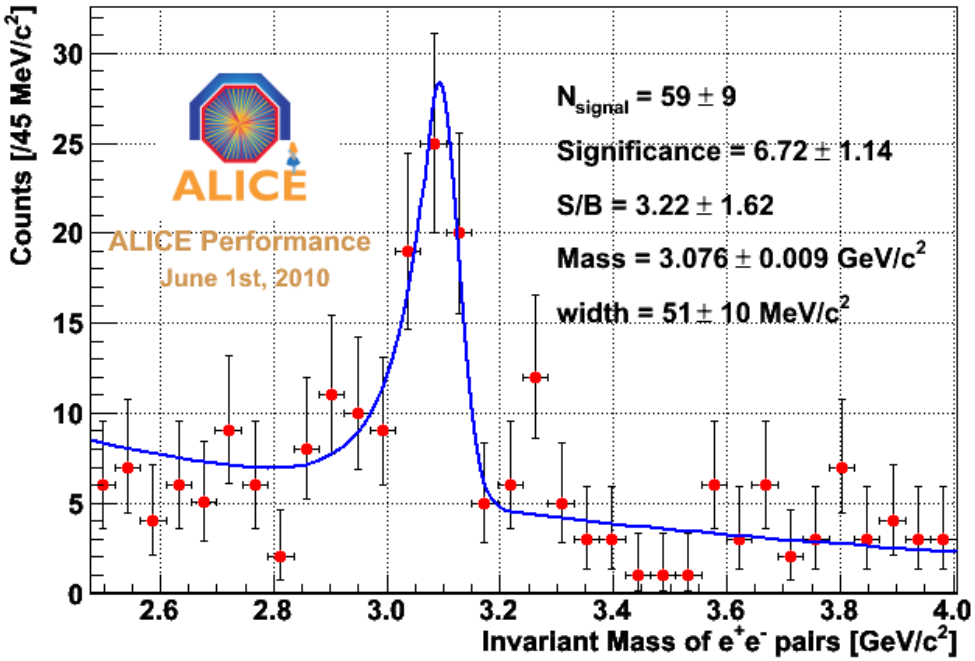
LEP b hadronization fractions

$$\frac{\sigma(pp \to H_b X,\ 2 < \eta(H_b) < 6)}{2} = 88.3 \pm 4.5 \pm 13.0\,\mu\text{b}$$
$$\sigma(pp \to b\bar{b}X) = 333 \pm 17 \pm 49\,\mu\text{b}\,.$$

TeVatron b hadronization fractions

J/ψ→ee mass distribution

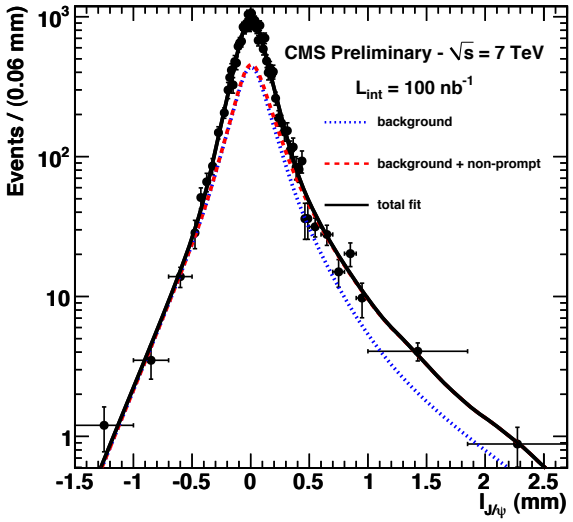


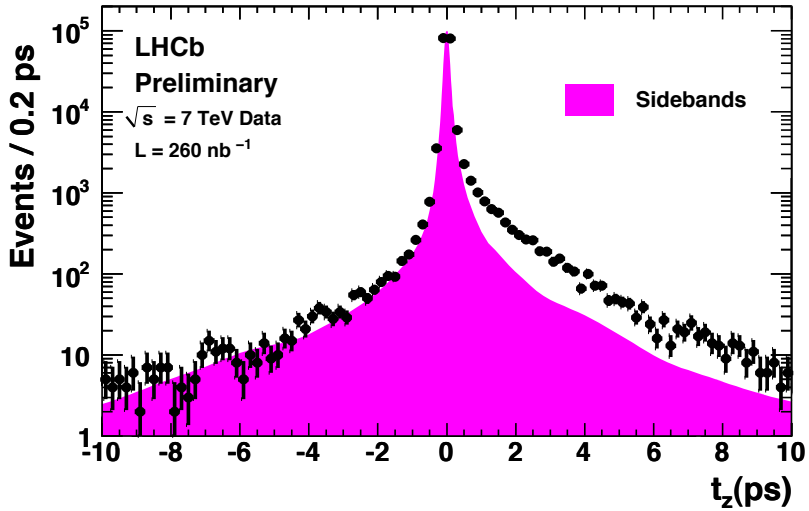


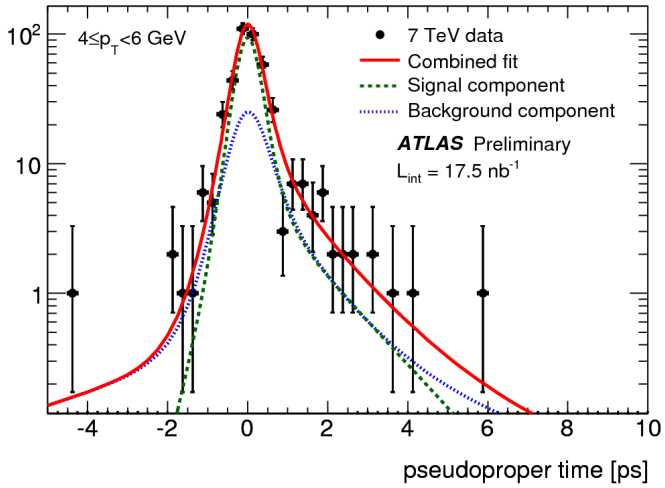
J/ψ proper time/decay lenght

Data Observed

- t_z used to separate J/ψ prompt from J/ψ from B

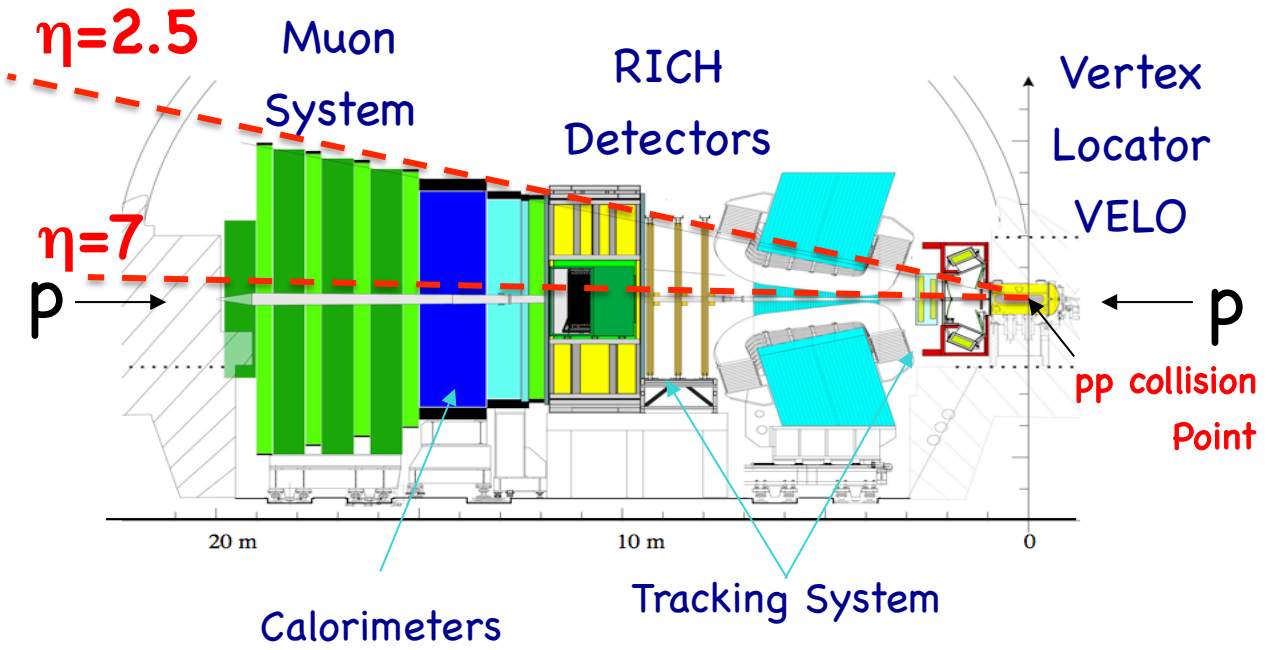






The LHCb detector

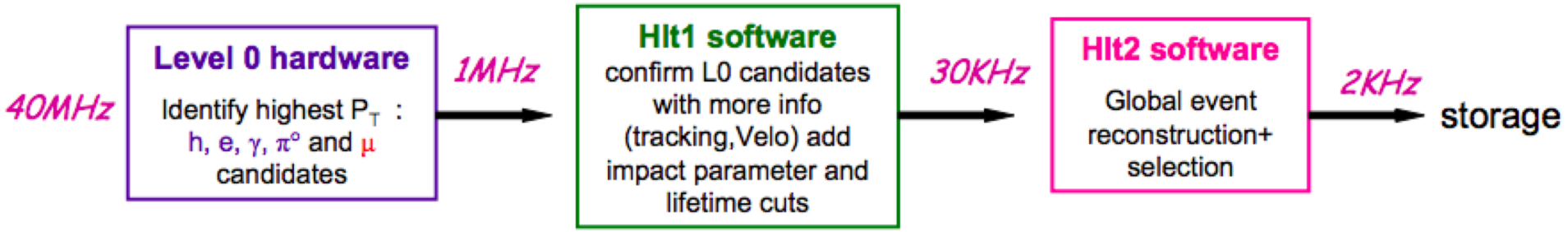
Angular acceptance : $10<\theta<300$ mrad



- Performance numbers relevant to quarkonium analyses:
  - Charged tracks $\Delta p/p$ = 0.35 % - 0.55%, $\sigma(m)$=10-25 MeV/c^2
  - ECAL $\sigma(E)/E$= 10% $(E/GeV)^{-1/2} \oplus$ 1 %
  - Muon ID: $\varepsilon(\mu \to \mu)$ = 97%, mis-ID rate $(\pi \to \mu)$ = 1-3 %
  - Vertexing: proper time resolution 30-50 fs
  - Trigger: dominantly software

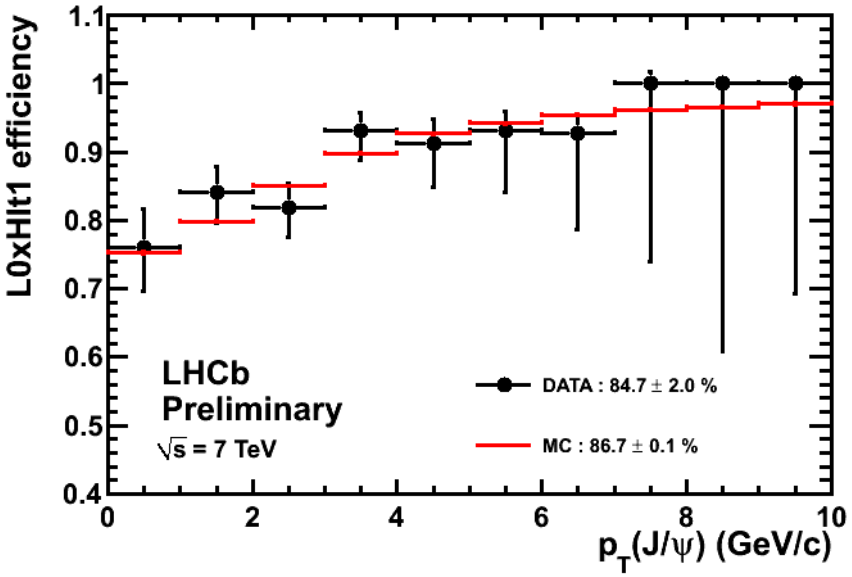
possibility to reverse field polarity to check for detector asymmetries

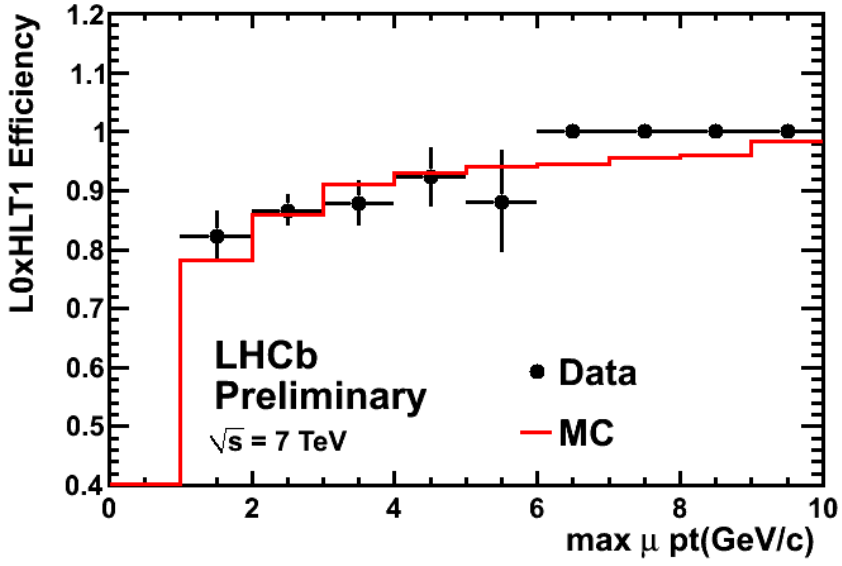
LHCb Trigger



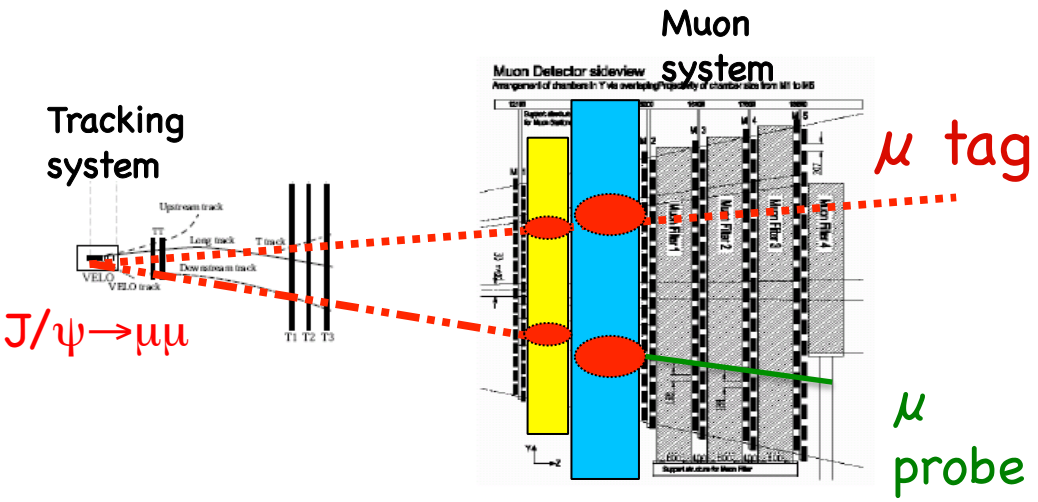
Measure muon trigger efficiencies using trigger lines not involving muons

L0 x HLT1 Efficiency J/ψ->μμ

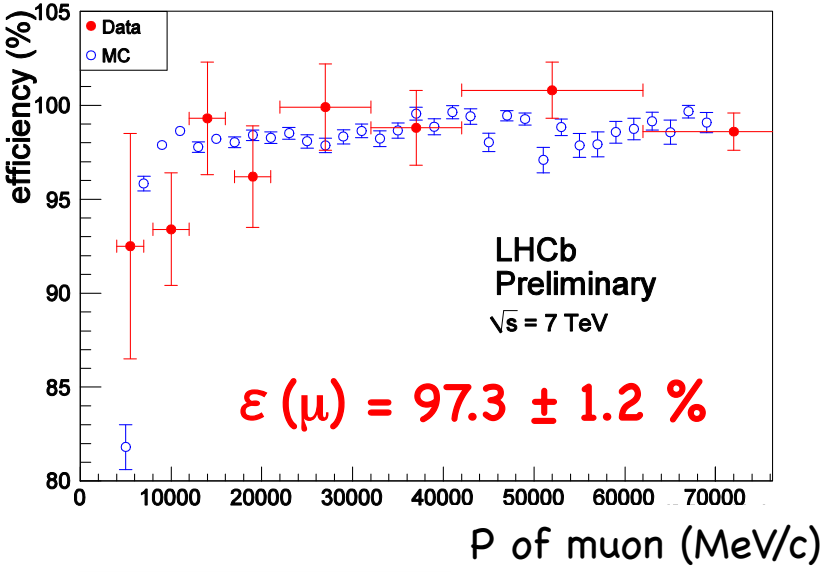


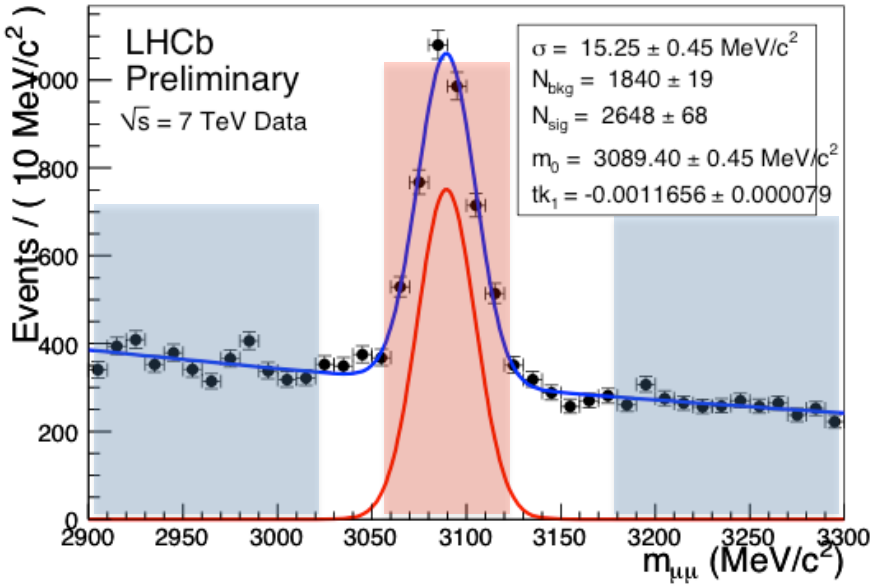


Muon Reconstruction Efficiency

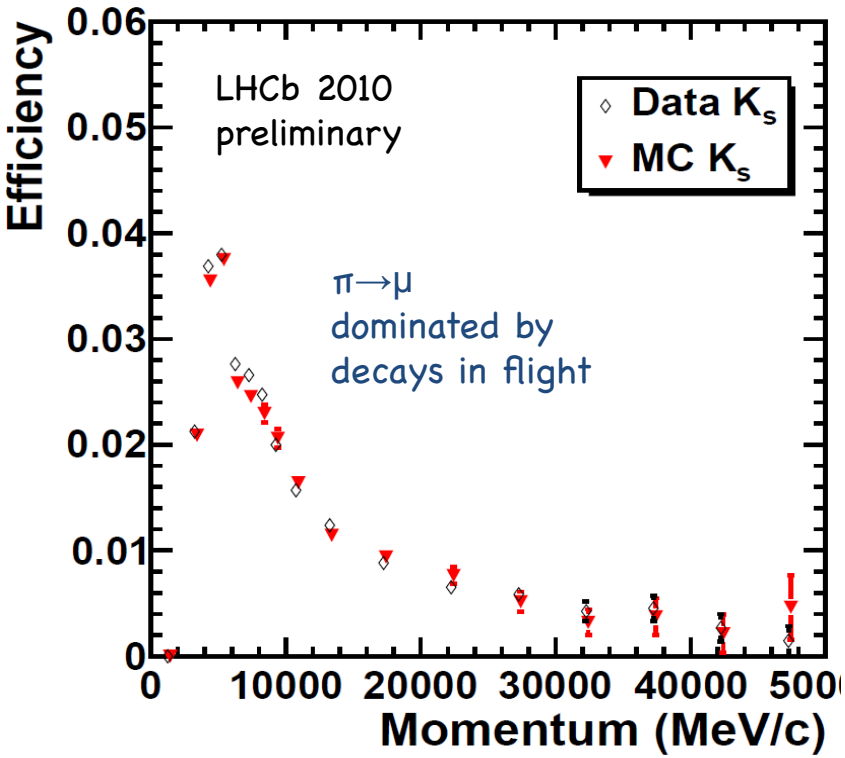


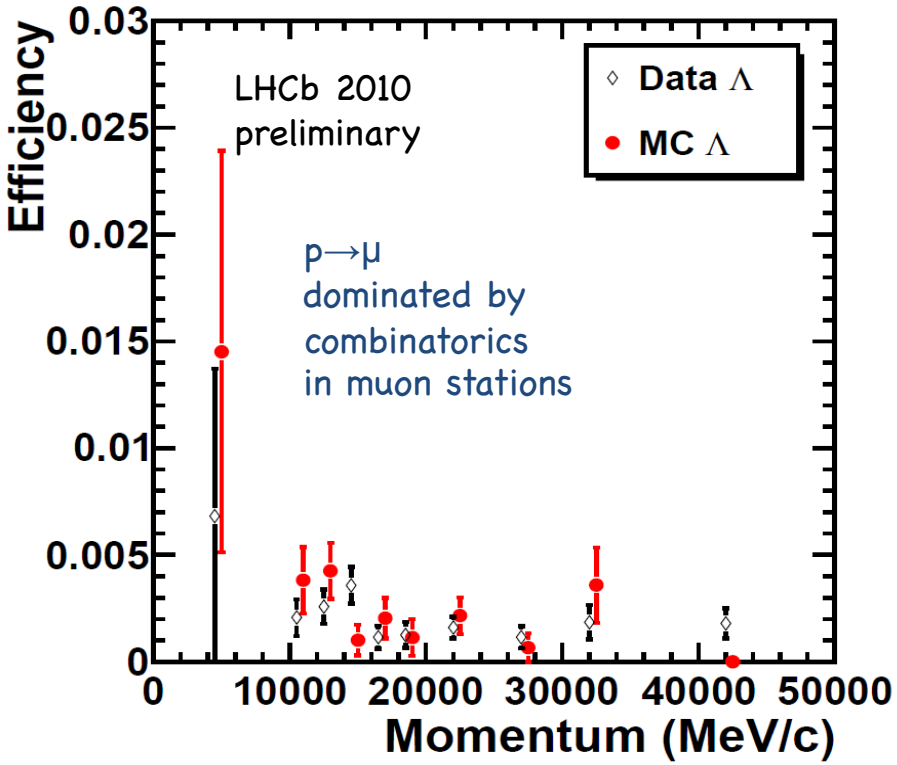
J/ψ used to measure the Muon reconstruction efficiency





Muon mis-identification





This plots shows the probability to misidentify a pion from Ks and a proton from Lambda as a muon as a function of momentum.

Primary Vertex resolution