Misura di J/ψ nello Spettrometro per Muoni in p-p

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Outlook

Physics motivations for J/ψ study in p-p

The ALICE Muon Spectrometer

First J/ψ paper analysis

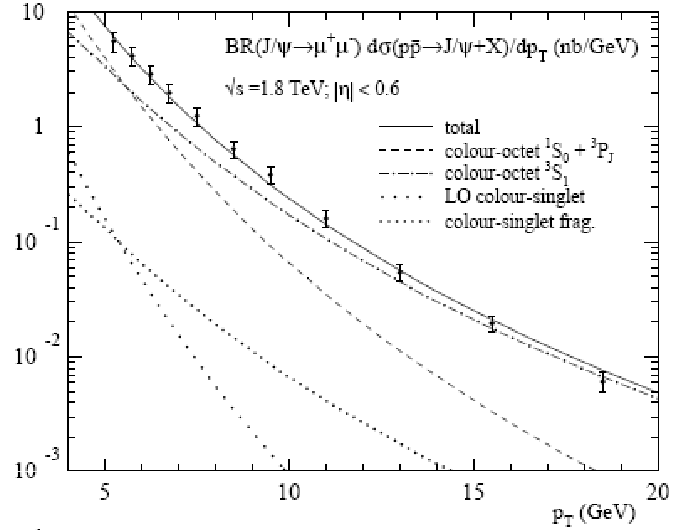
The polarization issue

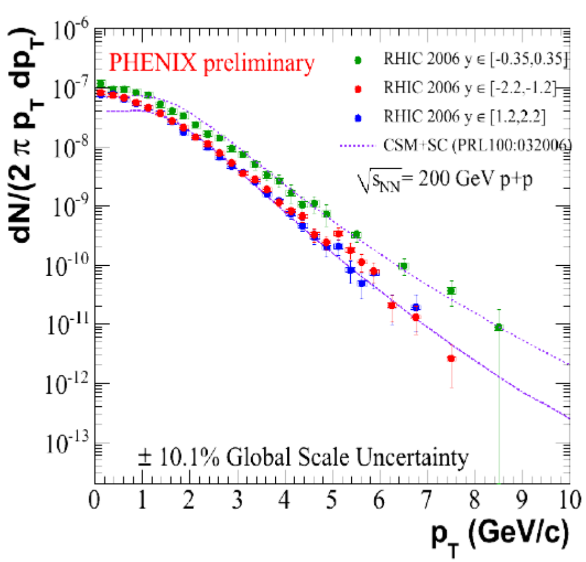
Conclusions and Ongoings

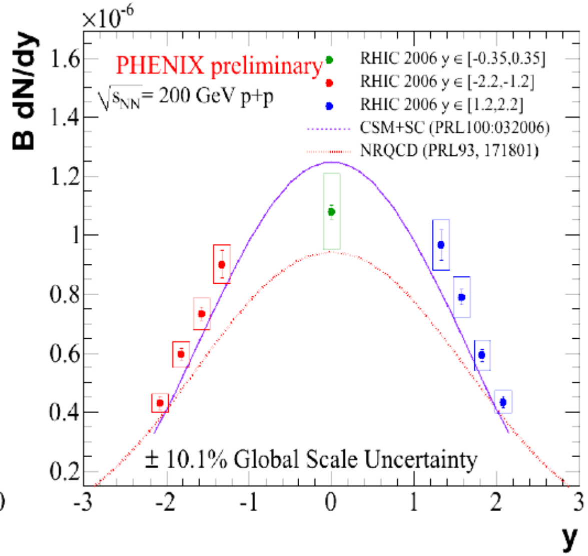
J/ψ in pp: physics motivations (I)

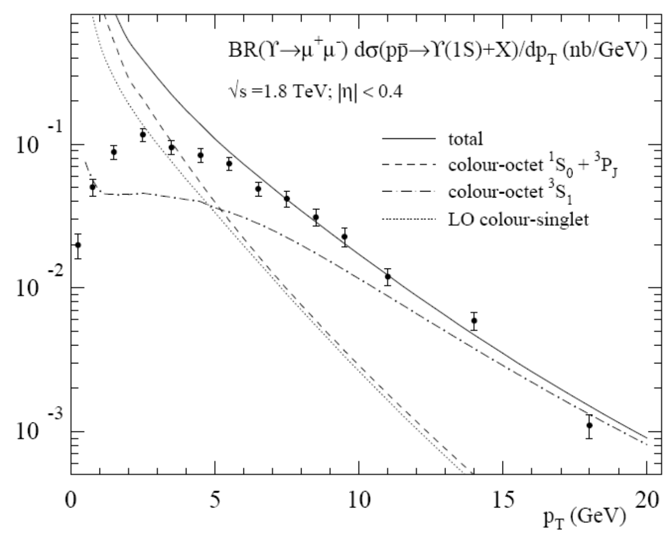
Need to understand the production mechanism.

Several models:
- **CEM**: phenomenological, not so predictive;
- **CSM**: bad x-sect. Fit (ruled out in the '90s);
- **COM (NRQCD)**: good x-sect. fit for all quarkonia;
- **CSM + s-channel cut**: describes polarization data.



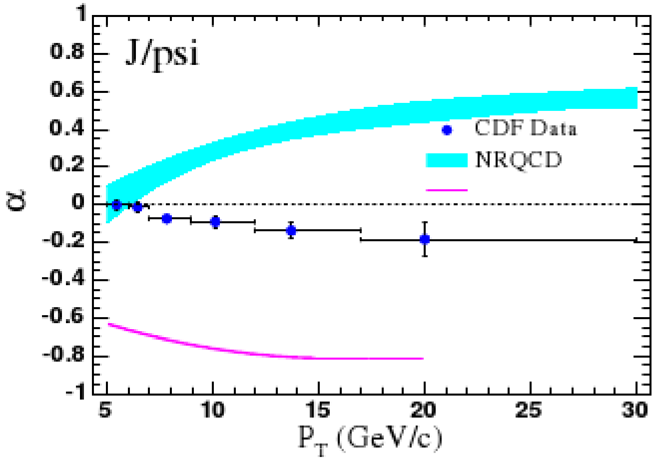


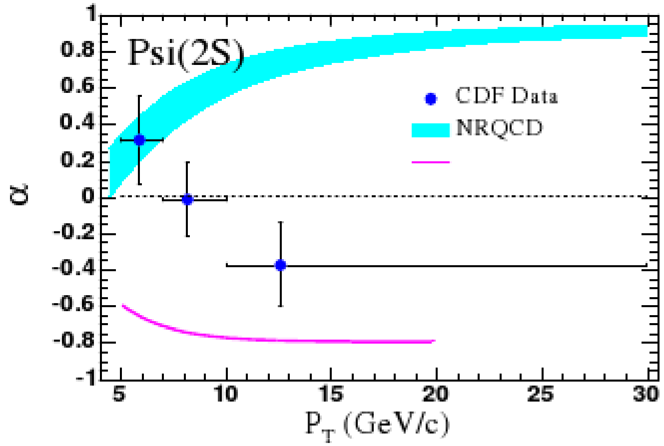




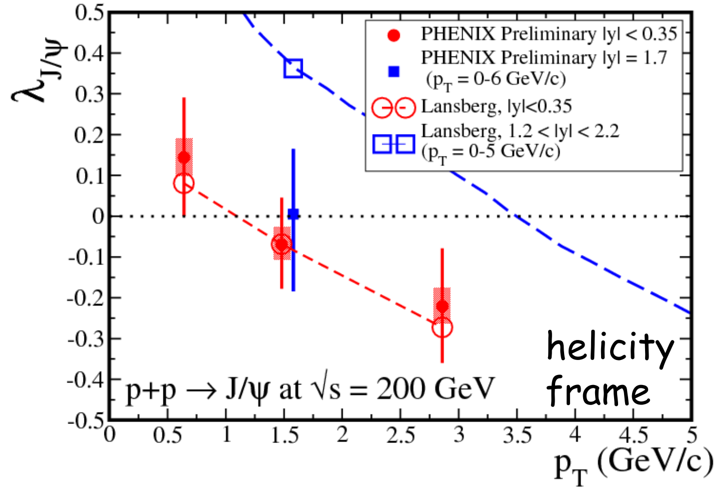
J/ψ in pp: physics motivations (II)

NRQCD fails in predicting polarization at high PT

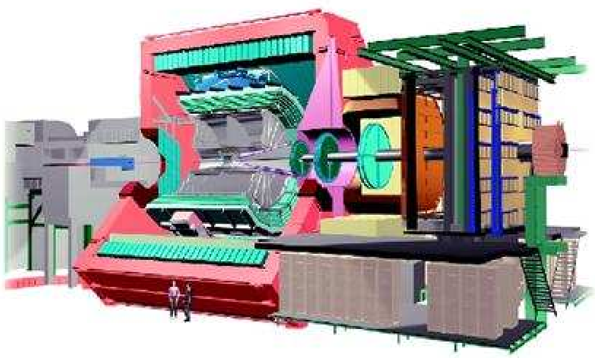


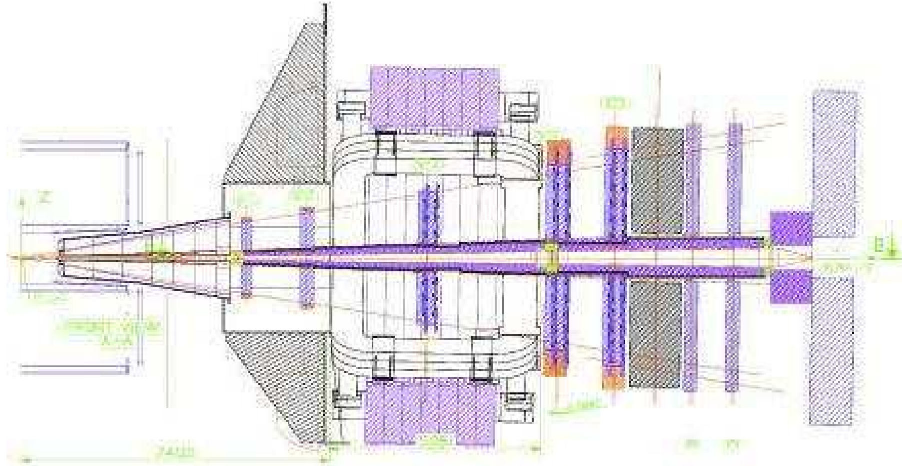


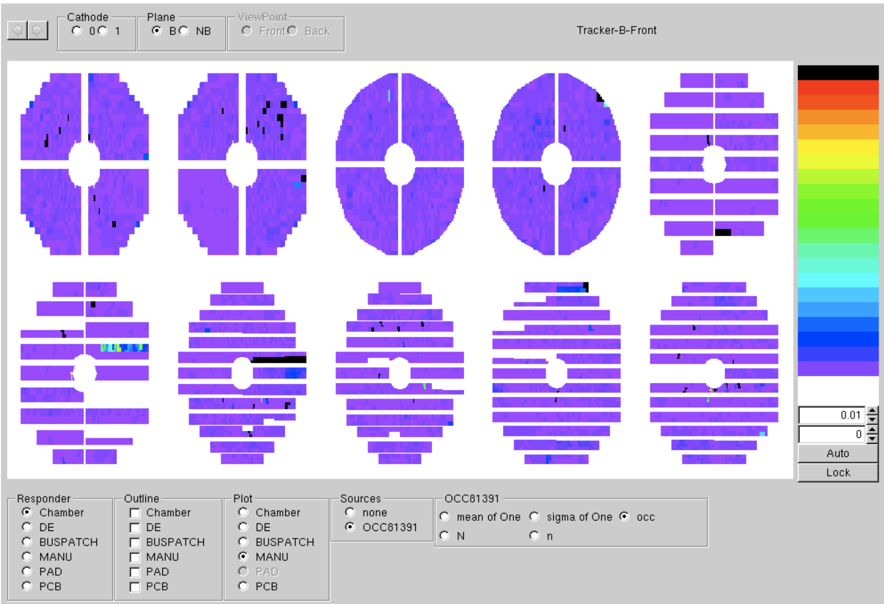
CSM+ s-channel cut (NNLO perturbative calculation): describes polarization data from PHENIX at mid-rapidity. Still problems at forward rapidity.



Muon Spectrometer: Setup

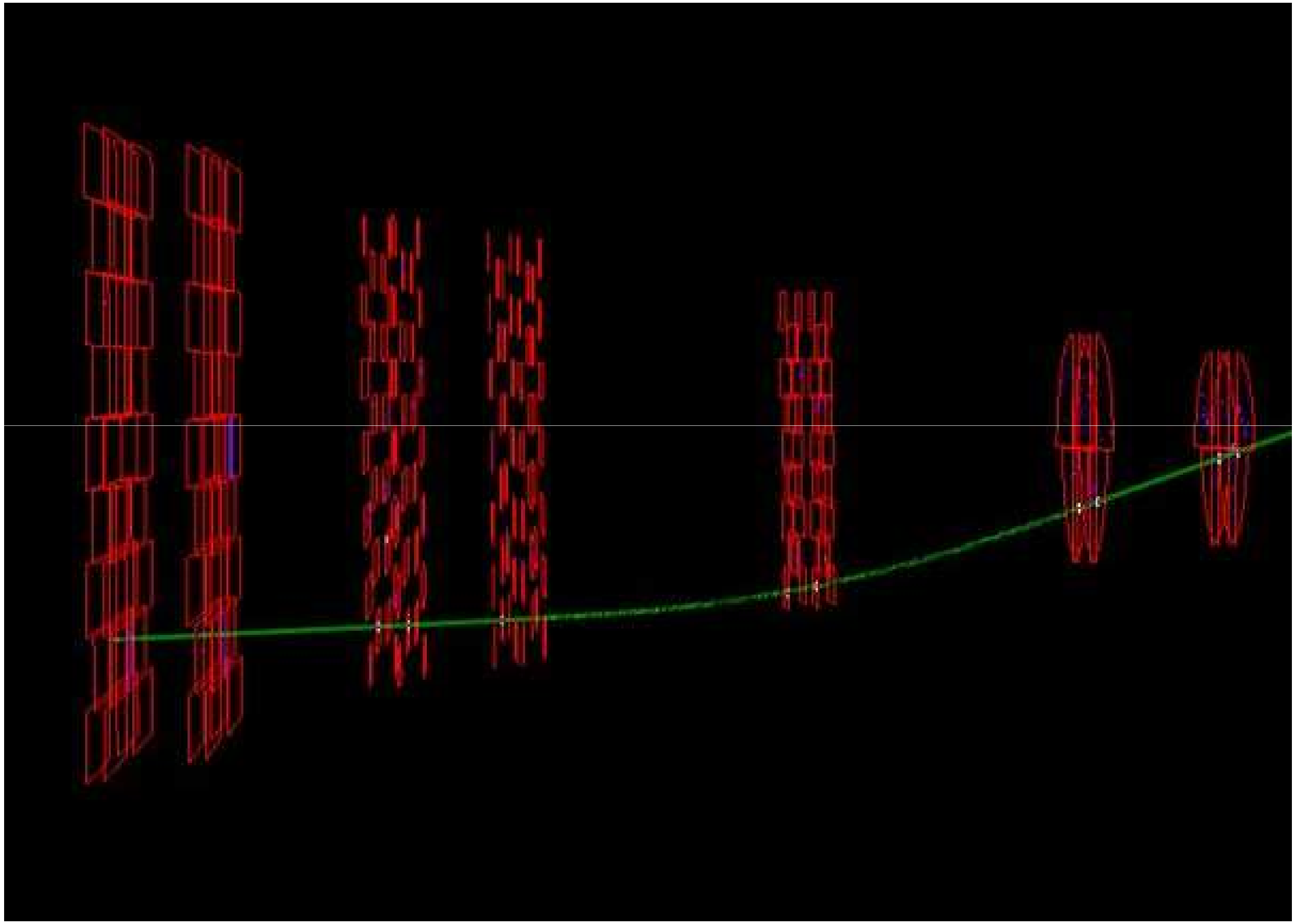






- Front absorber
- Beam Shield
- Dipole magnet (∫Bdl=3Tm)
- 5 tracking stations (MWPCs with bi-cathode pad readout): spatial resolution below 100 μm in the bending plane, around 700 μm in the non-bending plane
- Iron wall (muon filter)
- 2 trigger stations (4 planes of RPCs): fast response (~ 2 ns), spatial resolution ~ 1 cm

Muon Spectrometer: cosmic run



First curved cosmic muon event (tracked and triggered)

Nice view!

But we expect more than 90 couples of this tracks per hour coming from J/ψs during the first run of LHC…!*

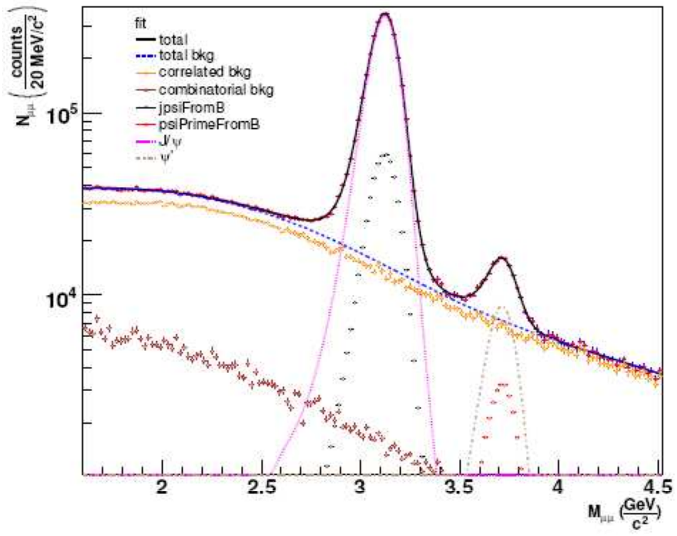
*actually this number refers to the trigger rate.

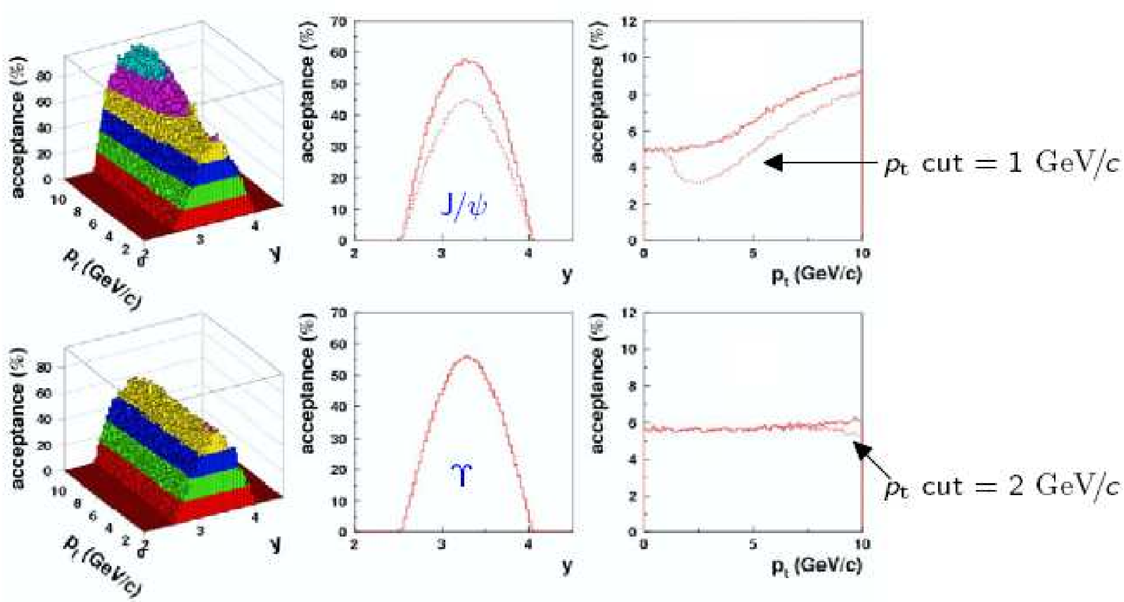
Muon Spectrometer: performances in pp

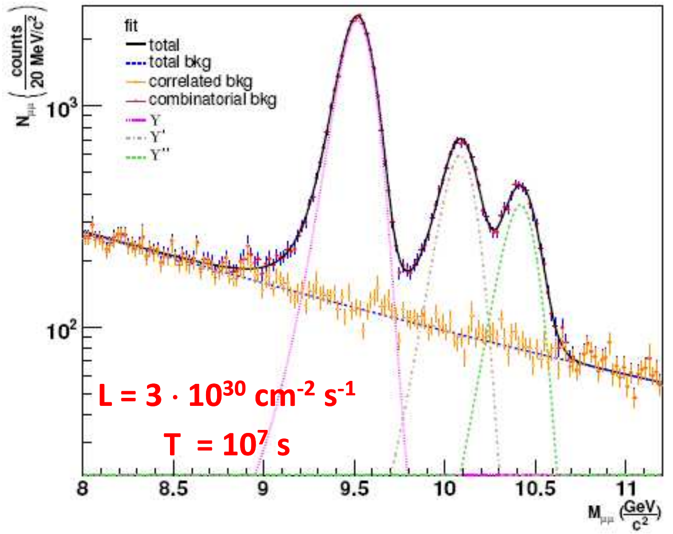
state	S ($\times10^3$)	B ($\times10^3$)	S/B	$S/\sqrt{S+B}$
J/ψ	2807	235	12.0	1610
ψ'	75	120	0.62	170
Υ	27.1	2.6	10.4	157
Υ'	6.8	2.0	3.4	73
Υ''	4.2	1.8	2.4	55

ALICE-INT-2006-029

Mass resolution: 70 MeV for the J/ψ, 100 MeV for the Υ







First Analysis

Assuming $340 \cdot 10^{-3}$ Hz J/ψ trigger rate low p_T at $L=3 \cdot 10^{30}$ cm^{-2} s^{-1} (ALICE-INT-2006-0002), at $L=2.3 \cdot 10^{29}$ cm^{-2} s^{-1} we expect: J/ψ trigger rate ~ $26 \cdot 10^{-3}$ Hz

Assuming 12% running efficiency (F. Antinori - Physics Forum July 2009) we expect from 10^4 to $4 \cdot 10^4$ J/ψs in the first 5 months

For 10^4 J/ψs we expect 100 J/ ψs with p_T >11 GeV → Good for differential studies!

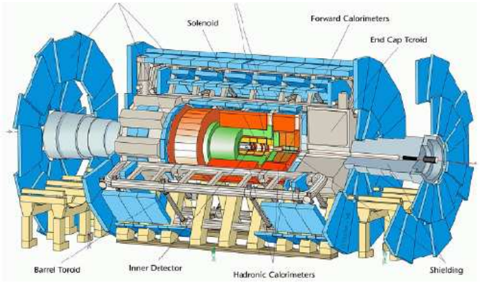
Which measurements can be performed with this statistics?

- J/ψ integrated production cross section
- J/ψ differential cross section
- J/ψ polarization (integrated over the other kinematical variables?)

First J/ψ papers

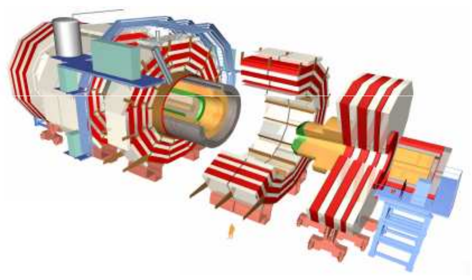
CDF	Paper based on 889 J/ψ	→ Integrated cross section Differential cross section $d\sigma/dp_T$
PHENIX	Paper based on 65 J/ψ in $\mu^+\mu^-$	→ Differential cross section $d\sigma/dp_T$, $d\sigma/dy$

Other LHC experiments



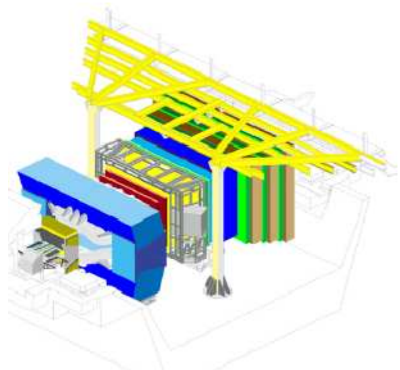
ATLAS:

- $-2.5 < \eta < 2.5$
- mass resolution ~ 50MeV
- prompt J/ψs separated with fit to proper time distribution
- 10^4 J/ψ for $1pb^{-1}$ at $\sqrt{s}$=10TeV (high p_T trig)
- can cover the full cosθ range reaching very high p_T



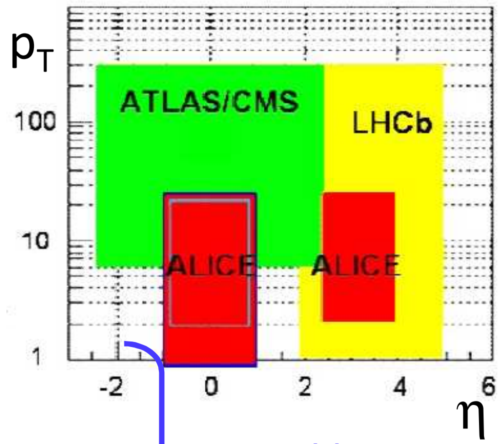
CMS:

- $-2.5 < \eta < 2.5$
- mass resolution ~ 30MeV
- $2 \cdot 10^4$ J/ψ for $1pb^{-1}$ at $\sqrt{s}$=10TeV (high p_T trig)



LHCb:

- $2 < \eta < 5.5$
- vertex tracking detector (VELO) covering the forward region ->very good mass resolution σ(M)~ 11MeV
- $2 \cdot 10^5$ J/ψ for $1pb^{-1}$ at $\sqrt{s}$=10TeV (larger acc.)



Very competitive wrt ALICE

Polarization: basic concepts

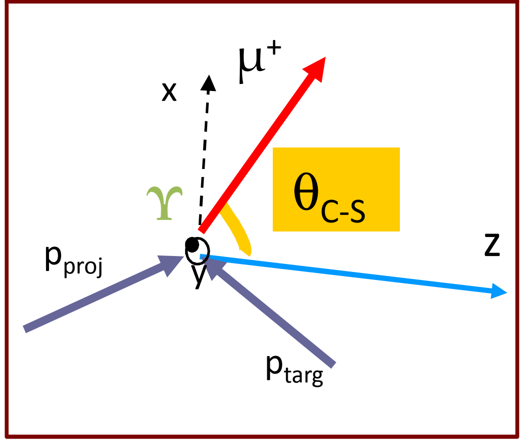
The polarization of Quarkonium is gleaned through the analysis of the angular distribution of daughter particles (e.g. $\mu^+\mu^-$) which follows the trend:

$$\frac{1}{\sigma}\frac{d\sigma}{d\cos(\theta)d\phi}=1+\lambda\cos^2(\theta)+\mu\sin(2\theta)\cos(\phi)+\frac{\nu}{2}\sin^2(\theta)\cos(2\phi)$$

$\lambda = 1$ **Transverse polarization**

$\lambda = -1$ **Longitudinal polarization**

Collins-Soper

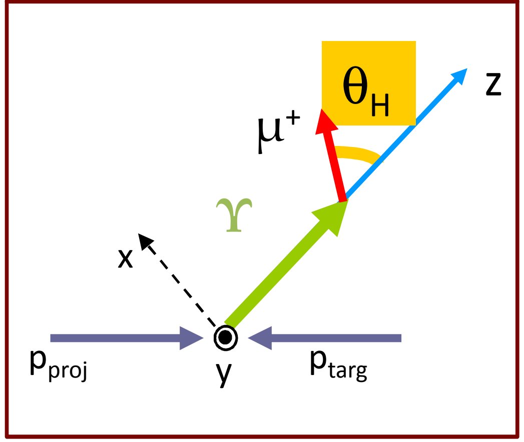


Reference frames:

Collins-Soper (CS):
The z-axis is the bisector of the projectile and - the target in the quarkonium rest frame.

Helicity (HE):
The z-axis is the direction of the quarkonium in the CM frame.

Helicity

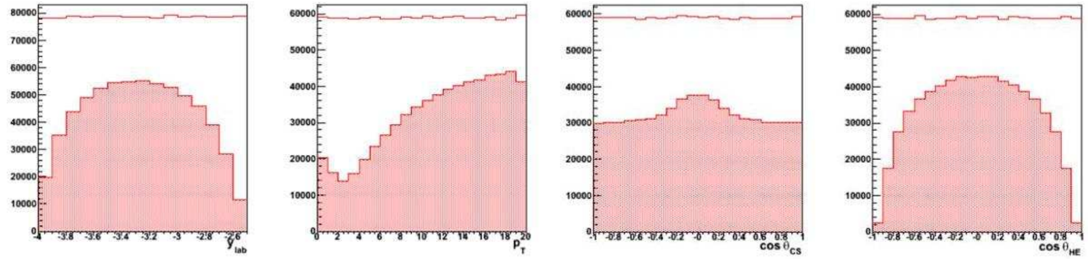


J/psi polarization in pp: acceptances

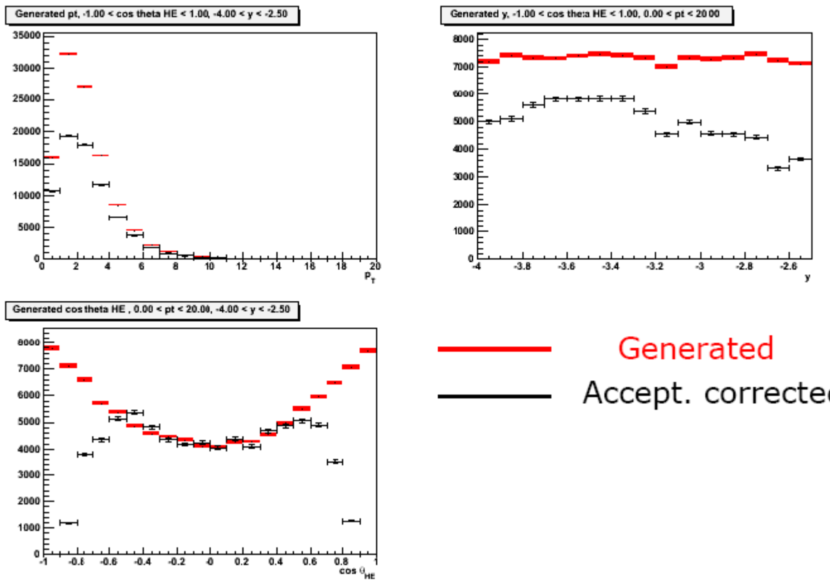
High S/B: bkg. neglection

state	S ($\times 10^3$)	B ($\times 10^3$)	S/B	$S/\sqrt{S+B}$
J/ψ	2807	235	12.0	1610
ψ'	75	120	0.62	170
Υ	27.1	2.6	10.4	157
Υ'	6.8	2.0	3.4	73
Υ''	4.2	1.8	2.4	55

3-D acceptance correction: flat y, p_T, cosϑ.

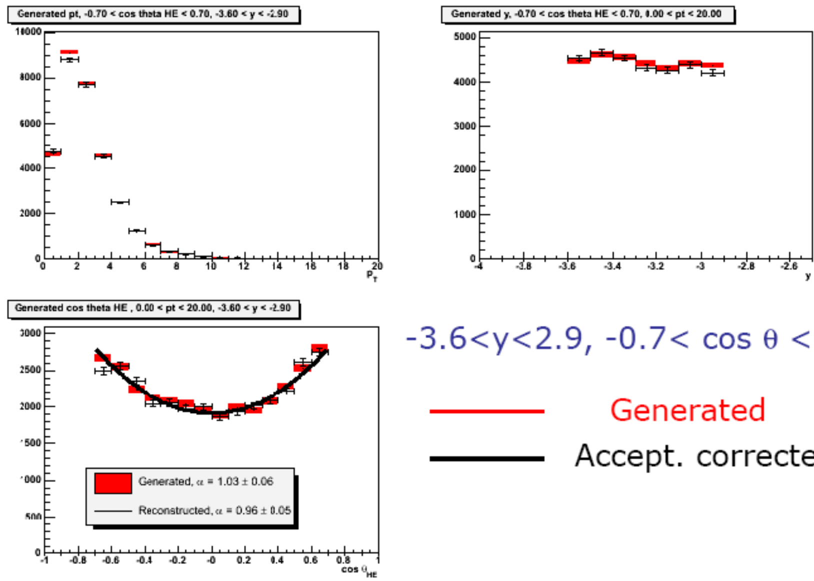


The correction has to be made in fiducial regions where the 3D acceptance do not range over too many orders of magnitude.



Generated

Accept. corrected



-3.6<y<2.9, -0.7< cos θ <0.7

Generated

Accept. corrected

J/ψ polarization in pp@14TeV

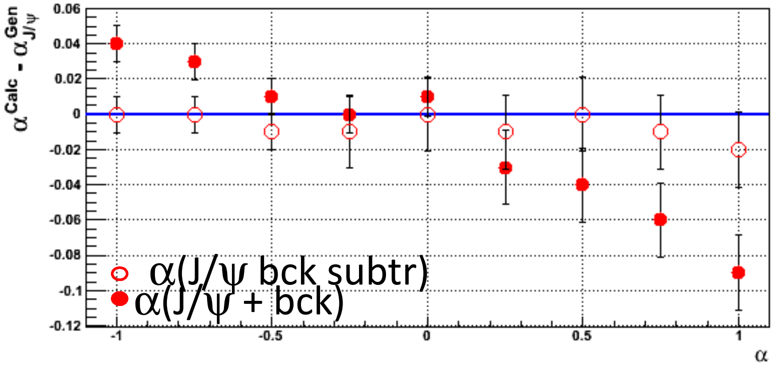
Luminosity = 3 10^{30} cm^{-2} s^{-1}
time = 10^7 s
J/ψ = 2.8 10^6

The number of J/ψ is enough to perform a detailed study as a function of $p_{T.}$

Assuming 200000 reconstructed J/ψ in p-p @ 14 TeV (all the statistics we have)

when injecting α=0 we get:

- $1<p_T<4$ GeV/c: α = -0.02 ± 0.02
- $4<p_T<7$ GeV/c: α = -0.03 ± 0.04
- $p_T>7$ GeV/c: α = -0.03 ± 0.05



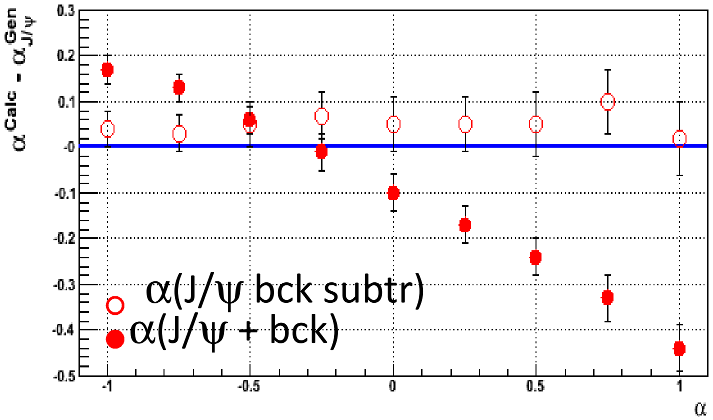
The background contribution is estimated by:
•Adding CORR+UNCORR bkg to the J/ψ peak;
•Using the MC Templates method* to subtract it (see the ϒ case)

The bias of the α parameter estimation depends on α itself (in any case not too big)

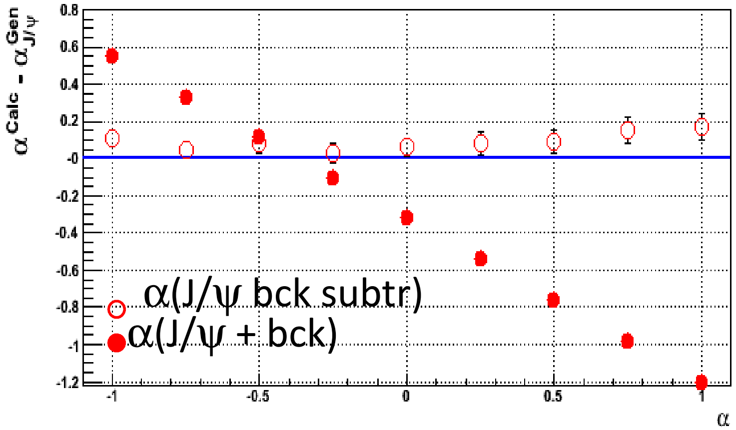
*Robert J. Cropp, *A Measurement of the Polarization of J/psi Mesons Produced in High-Energy pp Collisions*, 2000

J/psi polarization in PbPb@5.5A TeV

Peripheral PbPb: S/B=3.13



Central PbPb: S/B=0.2



In this case the Bkg cannot be neglected. New method for extracting polarization

Luminosity = 5 10^{26} cm^{-2} s^{-1}
time = 10^6 s
J/ψ = 133000 (central events)
J/ψ = 21700 (peripheral events)
Total J/ψ= 6.8 10^5

→

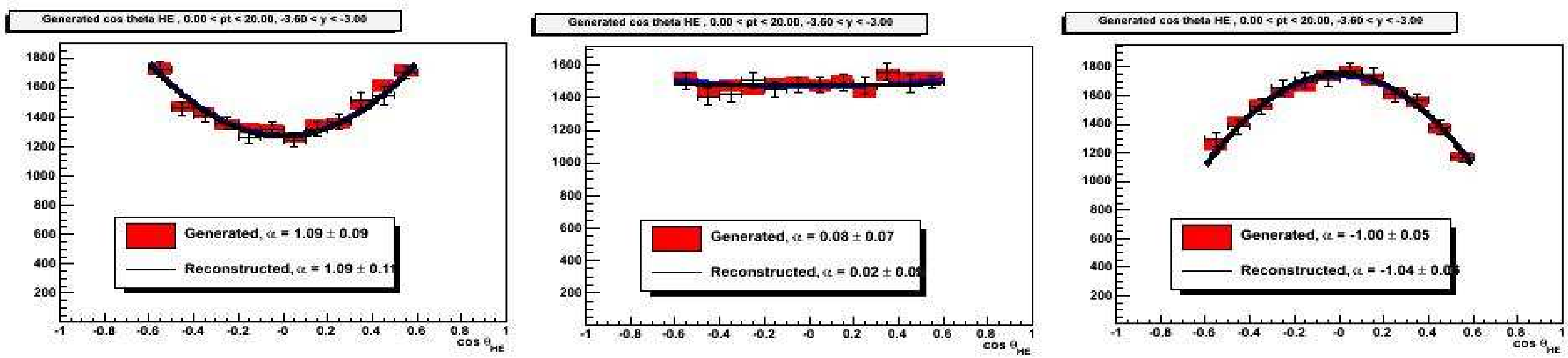
The number of J/ψ is enough to perform a study as a function of centrality.
Absolute statistical error ~0.05 for all centralities (for peripheral, smaller statistics compensated by the smaller background)

Υ polarization in pp: performances (I)

Analysis made on a sample of 27100 Υ (expected yield in pp @ $L=3\cdot10^{30}cm^{-2}s^{-1}$ in 10^7 s (*)).

After kinematical cuts we have 13000 Υ

Elicità



p_T bin (GeV/c)	α_{gen}	α_{rec} (HE)	α_{rec} (CS)
$0 < p_T < 20$	1	1.09 ± 0.11	0.96 ± 0.10
	0	0.02 ± 0.09	0.02 ± 0.08
	-1	-1.04 ± 0.05	-0.94 ± 0.05

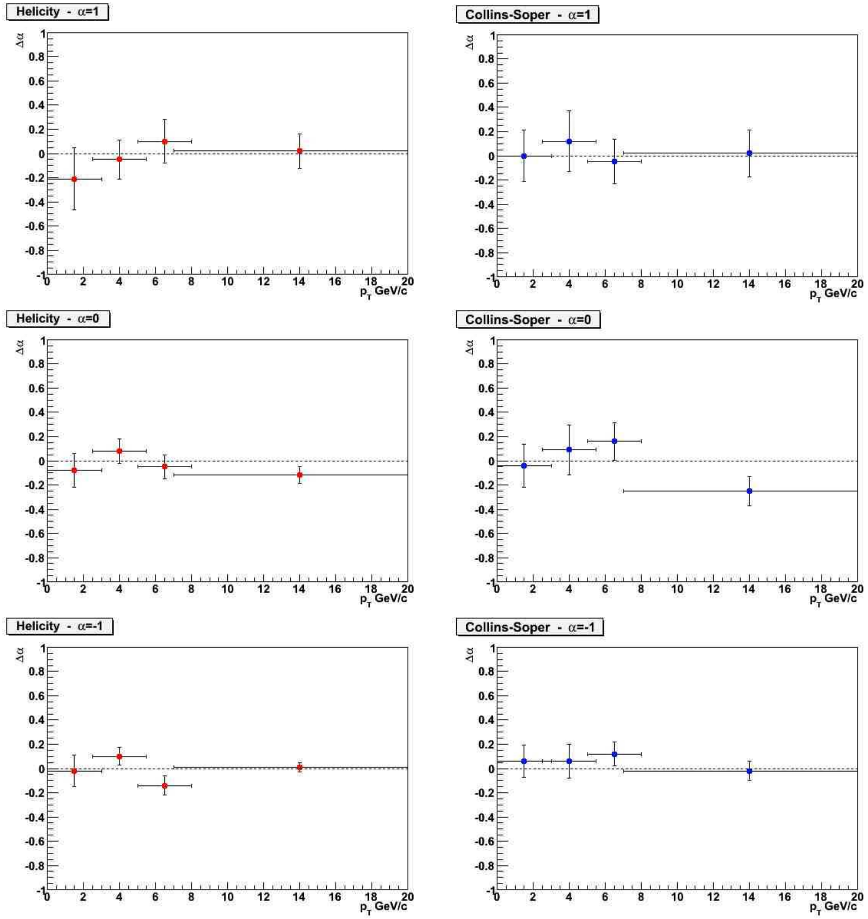
Statistical error ranges from 0.05 and 0.11

Good agreement between α_{gen} and α_{rec} after acceptance corrections

(*) ALICE-INT-2006-029

Υ polarization in pp: performances (II)

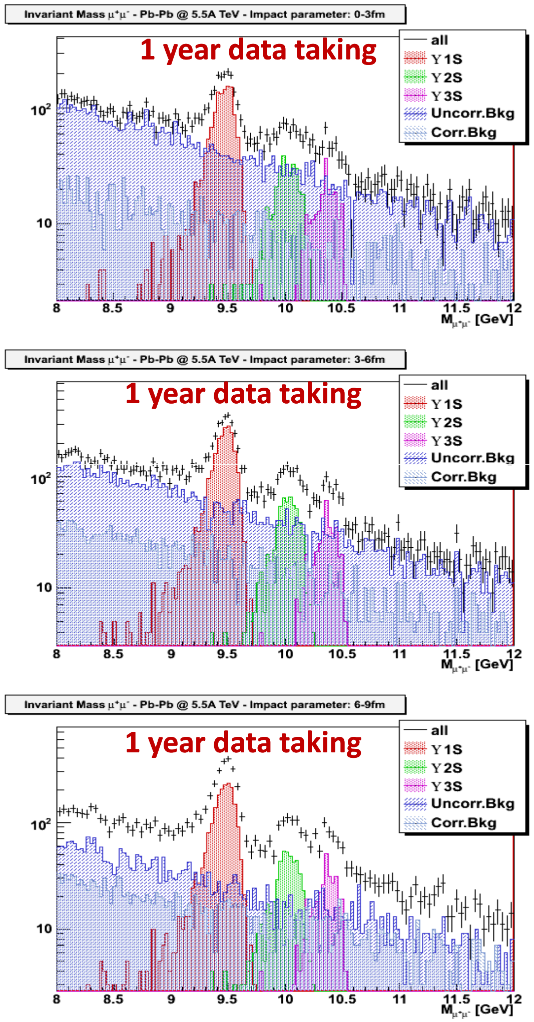
p_T bin (GeV/c)	α_{gen}	$\Delta\alpha_{rec}$		Y_{rec} dopo tagli (#Y_{gen} = 27100)	
		HE	CS	HE	CS
$0 < p_T < 3$	1	-0.21 ± 0.25	0.00 ± 0.21	~5100	~4900
	0	-0.11 ± 0.18	-0.04 ± 0.18		
	-1	-0.02 ± 0.13	0.06 ± 0.13		
$3 < p_T < 5$	1	-0.05 ± 0.16	0.12 ± 0.25	~5600	~4700
	0	0.14 ± 0.12	0.09 ± 0.21		
	-1	0.10 ± 0.07	0.06 ± 0.14		
$5 < p_T < 8$	1	0.10 ± 0.18	-0.05 ± 0.18	~5100	~4600
	0	-0.04 ± 0.12	0.16 ± 0.16		
	-1	-0.14 ± 0.08	0.12 ± 0.10		
$8 < p_T < 20$	1	0.02 ± 0.14	0.02 ± 0.19	~4000	~3500
	0	-0.02 ± 0.09	-0.25 ± 0.12		
	-1	0.01 ± 0.04	-0.02 ± 0.08		

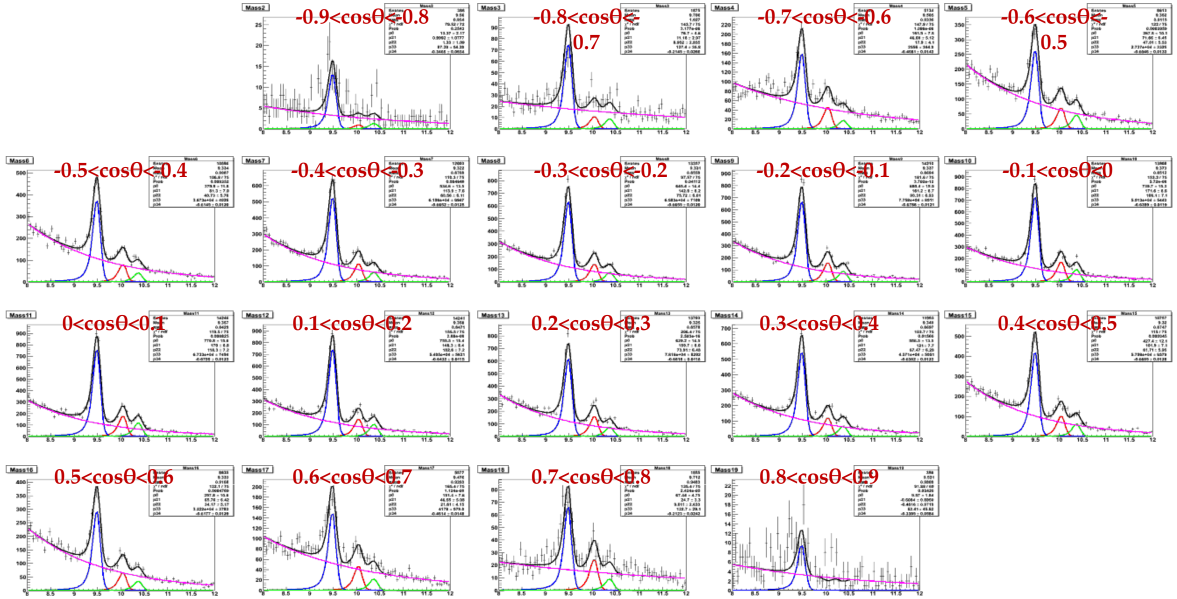


Good agreement between α_{gen} and α_{rec}

Statistical errors: from 0.03 to 0.19

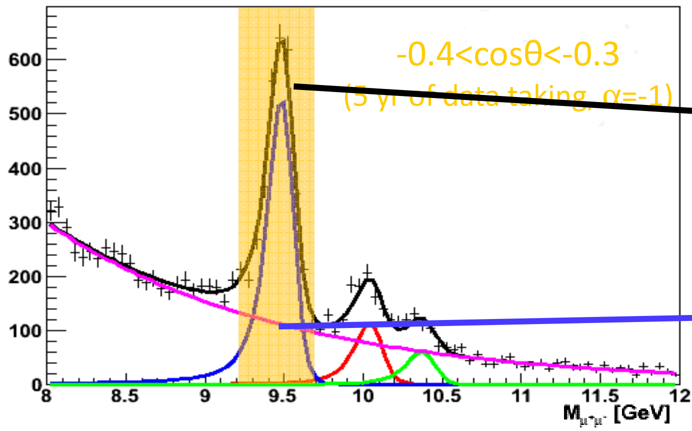
ϒ polar. in PbPb: MC Template Method

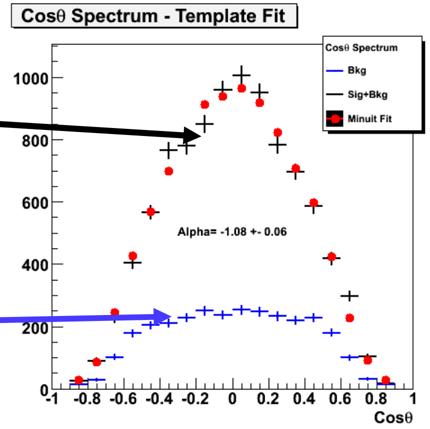


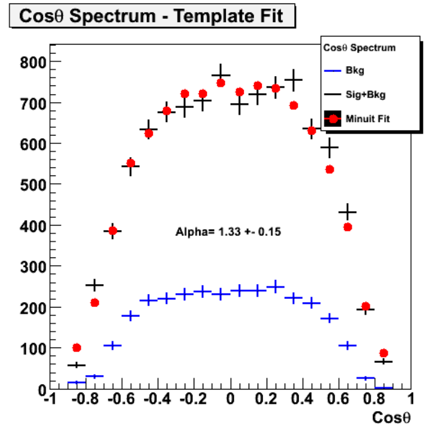


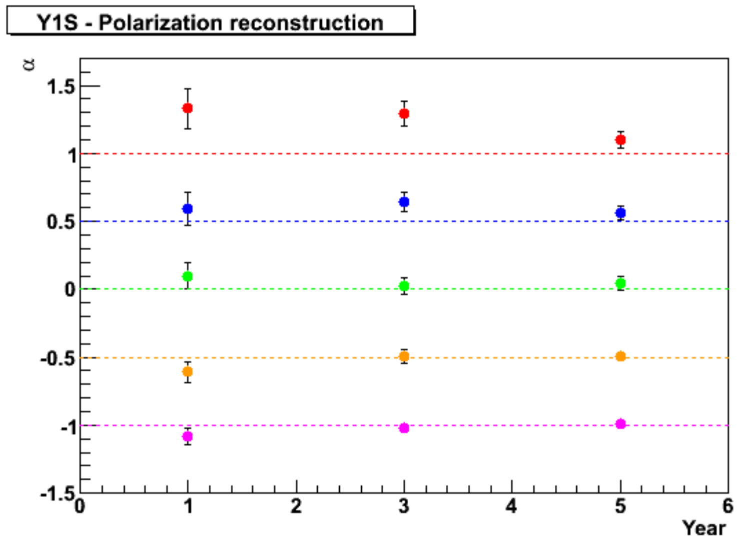
- Sample divided in 20 cosϑ bins;
- For each cosϑ bin a mass spectrum is done and fitted;
- The fits allow the evaluation of the bkg. (B) and of the signal+bkg (S+B) contributions;
- The values of B and S+B are plotted in a cosϑ spectrum;

ϒ polarization in PbPb: performances



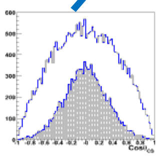


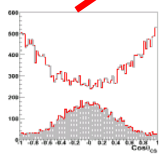




- The S+B cosθ spectrum is fitted with a linear superposition of two templates (one transversly polarized and one longitudinally) plus the Bkg contribution;
- The coefficients of the linear superposition give the value of α.

$$\left\{\left[\frac{1-\alpha}{3+\alpha}\right]\cdot T_L(\cos\vartheta)+\left[\frac{2(1+\alpha)}{3+\alpha}\right]\cdot T_T(\cos\vartheta)\right\}+Bkg(\cos\vartheta)=F_{S+B}(\cos\vartheta)$$





Polarization in PDC09 (pp @10TeV)

Id	cycle	description	software	run range	events per sub-run	events produced	status	request
91	LHC09a10	diμ trigger, w/o polarization, residual	v4-17-Rev-04 (root: v5-24-00, geant3: v1-11)	100400 to 100436	100	3420400	completed	$2\,10^6$
94	LHC09a11	diμ trigger, pol. (.3/.3/0./1./0), residual	v4-17-Rev-05, (root: v5-24-00, geant3: v1-11)	101014 to 101018	100	475400	completed	$4\,10^5$
95	LHC09a12	diμ trigger, pol. (-.3/-.3/0./1./0.), residual	same as 94	102000 to 102005	100	270000	completed	$4\,10^5$
96	LHC09a13	diμ trigger, pol. (0./0./0./1./0.), residual	same as 94	103000 to 103005	100	371900	completed	$4\,10^5$
98	LHC09a16	diμ trigger, w/o pol, full, secret deadmaps & x-sect.	same as 94	111001 to 111005	100		not yet started	$4\,10^5$
99	LHC09a17	1μ trigger, full, w/o field	same as 94	112001 to 112008	100	662700	completed	$6\,10^5$
100	LHC09a18	min. bias, w/o pol., residual	same as 94	113001 to 1000001	400	9856800 (until 113040)	runnning	$2\,10^8$

nicole.bastid @ clermont.in2p3.fr, aug 23th

In particular 3 productions with polarized quarkonia:

- LHC09a11: $\alpha_{J/\psi}= 0.3$, $\alpha_{\psi'}= 0.3$, $\alpha_{\Upsilon}=0.$, $\alpha_{\Upsilon'}=1.$, $\alpha_{\Upsilon''}=0.$
- LHC09a12: $\alpha_{J/\psi}= -0.3$, $\alpha_{\psi'}=-0.3$, $\alpha_{\Upsilon}=0.$, $\alpha_{\Upsilon'}=1.$, $\alpha_{\Upsilon''}=0.$
- LHC09a13: $\alpha_{J/\psi}= 0.$, $\alpha_{\psi'}= 0.$, $\alpha_{\Upsilon}=0.$, $\alpha_{\Upsilon'}=1.$, $\alpha_{\Upsilon''}=0.$

Simulation done using AliGenMUONCocktailpp:

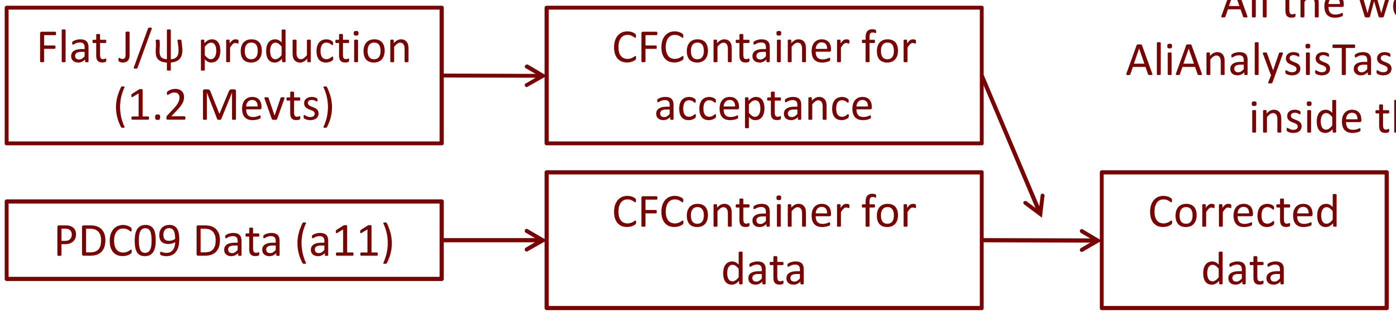
-Pythia mBias

-5 resonances

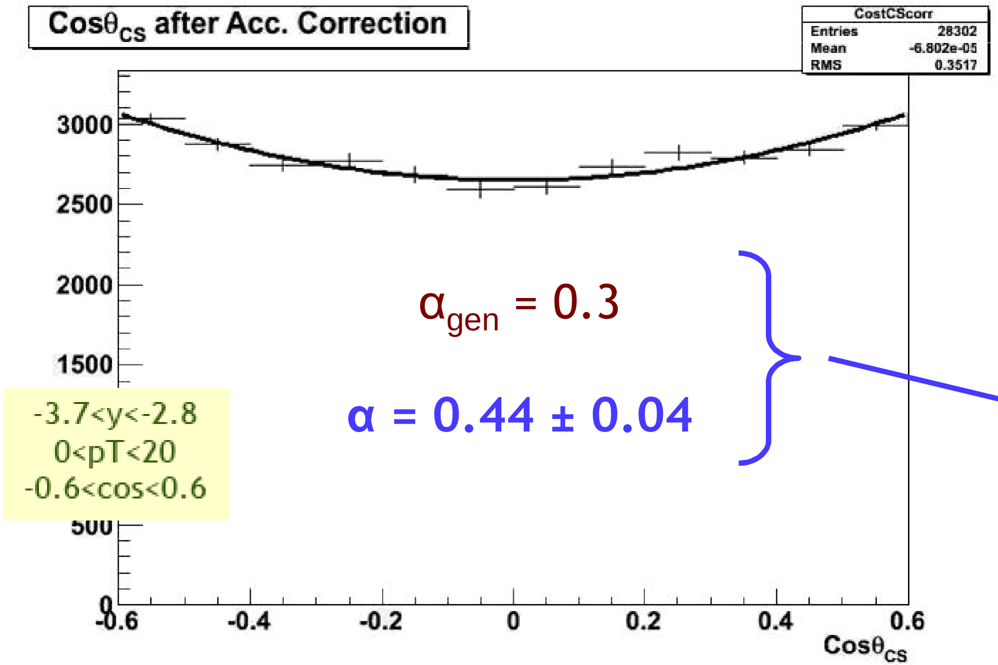
-Open heavy flavors.

The polarization is given using AliDecayerPolarized. It can be set with different values to each resonance. Only the $\cos\vartheta$ spectrum can be changed (until now).

Polarization analysis from PDC09



All the work done through AliAnalysisTaskMuonCFPolar.{cxx,h}, inside the analysis train



The 3D acceptance correction (y, p_T and cosϑ - 2D and 4D are possible) is made in fiducial regions chosen in order to hace acceptance not rangin on too many orders of magnitude.

Discrepancy:
due to B -> J/ψ + X ?
UNDER STUDY.

Conclusions and Ongoings

Conclusions

The muon spectrometer of the ALICE experiment is ready to take data – cosmic runs show good performances of the entire detector.

The first J/ψ paper could be done using statistics of 10^4 events (less than 5 monts of data taking) allowing the study of integrated and differential ($d\sigma/dp_T$, $d\sigma/dy$) cross sections and (maybe) an integrated over p_T value of polarization.

The polarization analysis can be done both in pp and PbPb. The bkg contribution has been studied and, at least in the second case, a bkg-subtraction strategy has to be implemented.

A first look to PDC09 data gives encouraging results.

Coming next

Full analysis of PDC09 data (polarization & p_T/y spectra)

Study of $B \rightarrow J/\psi + X$ contribution to the $\cos\vartheta$ spectrum

Backup Slides

Muon spectrometer parameters (I)

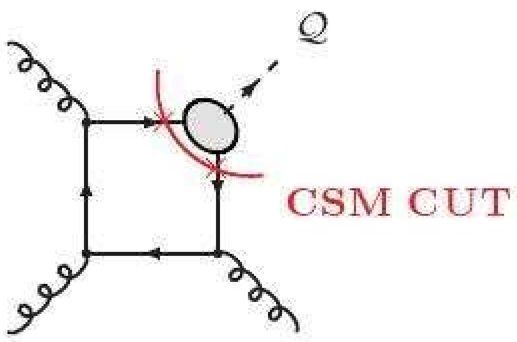
Muon detection		
Polar, azimuthal angle coverage	$2 \leqslant \theta \leqslant 9,\ 2\pi$	
Minimum muon momentum	4 GeV/c	
Resonance detection	J/ψ	Υ
Pseudo-rapidity coverage	$-4.0 \leqslant \eta \leqslant -2.5$	$-4.0 \leqslant \eta \leqslant -2.5$
Transverse momentum range	$0 \leqslant p_t$	$0 \leqslant p_t$
Mass resolution	70 MeV	100 MeV
Front absorber		
Longitudinal position (from IP)	$-5030mm \leqslant z \leqslant -900mm$	
Total thickness (materials)	10λ (carbon-concrete-steel)	
Dipole magnet		
Nominal magnetic field, field integral	0.7 T, 3 Tm	
Free gap between poles	2.972 – 3.956 m	
Overall magnet length	4.97m	
Longitudinal position (from IP)	-z = 9.87m (centre of the dipole yoke)	
Tracking chambers		
Number of stations, number of planes per station	5, 2	
Longitudinal position of stations	-z = 5357, 6860, 9830, 12920, 14221 mm	
Anodecathode gap (equal to wire pitch)	2.1 mm for st. 1; 2.5 mm for st. 2-5	
Gas mixture	$80\% Ar/20\% CO_2$	
Pad size st. 1 (bending plane)	$4 \times 6,\ 4 \times 12,\ 4 \times 24 mm^2$	
Pad size st. 2 (bending plane)	$5 \times 7.5,\ 5 \times 15,\ 5 \times 30 mm^2$	
Pad size st. 3, 4 and 5 (bending plane)	$5 \times 25,\ 5 \times 50,\ 5 \times 100 mm^2$	
Max. hit density st. 15 (central PbPb×2)	$5.0,\ 2.1,\ 0.7,\ 0.5,\ 0.6 \cdot 10^{-2}$ hits cm^{-2}	
Spatial resolution (bending plane)	$\simeq 70\ \mu m$	

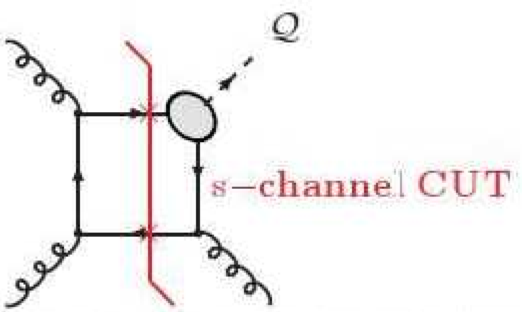
Muon spectrometer parameters (II)

Tracking electronics	
Total number of FEE channels	1.09×10^6
Shaping amplifier peaking time	$1.2\ \mu s$
Trigger chambers	
Number of stations, planes per station	2, 2
Longitudinal position of stations	-z = 16 120, 17 120 mm
Total number of RPCs, total active surface	72, $\sim 150 m^2$
Gas gap	single, 2 mm
Electrode material and resistivity	Bakelite^{TM}, $\rho = 24 \times 10^9$ cm
Gas mixture	$Ar/C_2H_2F_4$/i-butane/SF_6 ratio 49/40/7/1
Pitch of readout strips (bending plane)	10.6, 21.2, 42.5 mm (for trigger st. 1)
Max. strip occupancy bend. (non bend.) plane	3%(10%) in central Pb-Pb
Maximum hit rate on RPCs	3 (40) Hz cm^{-2} in Pb-Pb (Ar-Ar)
Trigger electronics	
Total number of FEE channels	2.1×10^4
Number of local trigger cards	234 + 2

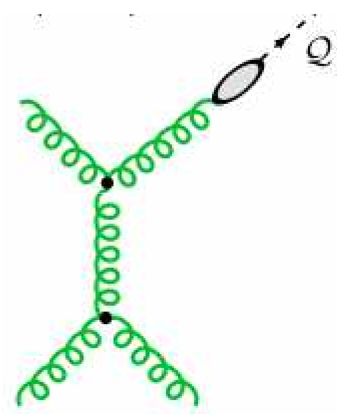
Font: ALICE Physics Performance Report Vol. I, J. Phys. G: Nucl. Part. Phys. 30 (2004)

Production mechanism

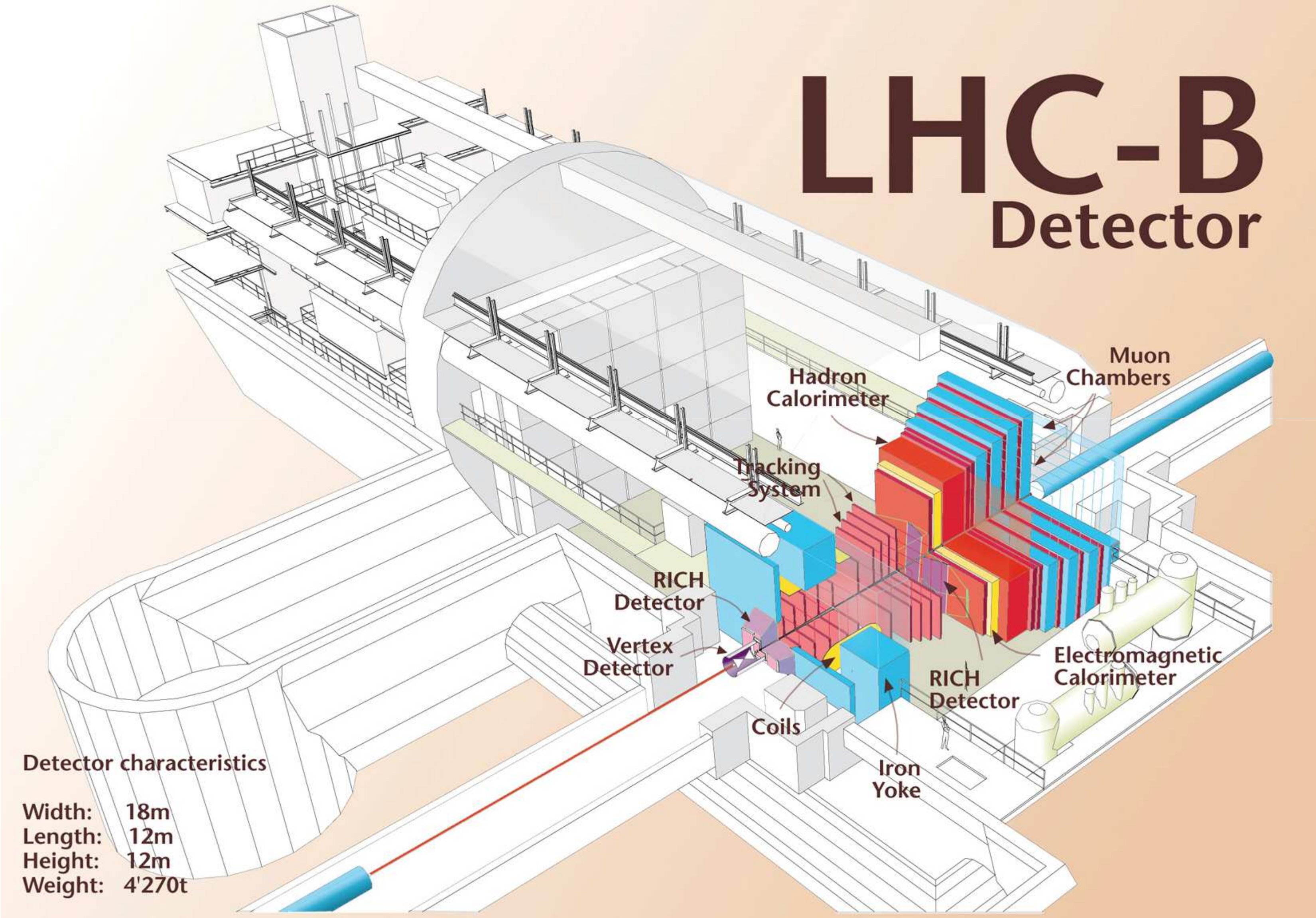




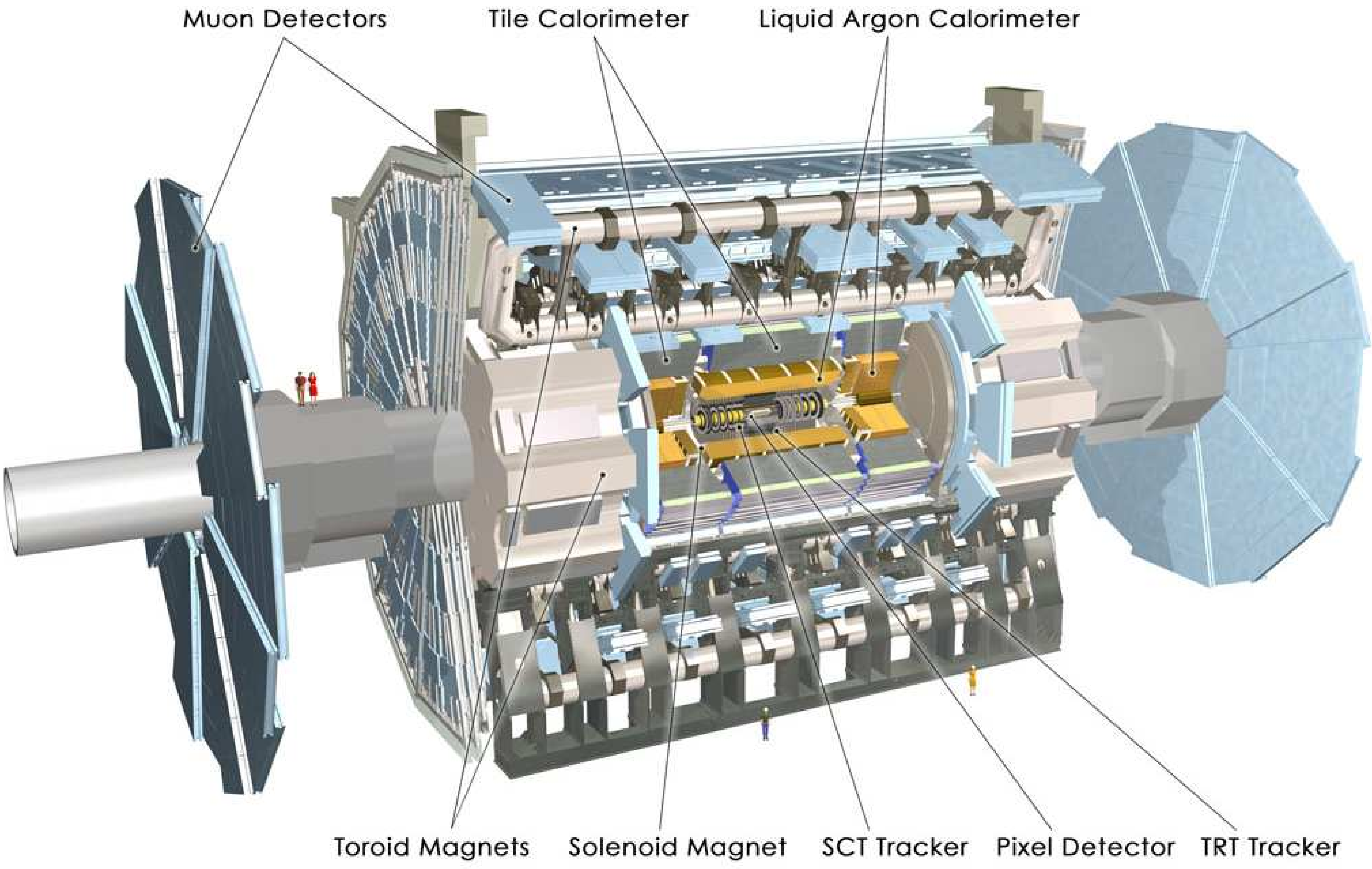
JPL, J.R. Cudell, Yu.L. Kalinovsky, PLB633:301,2006



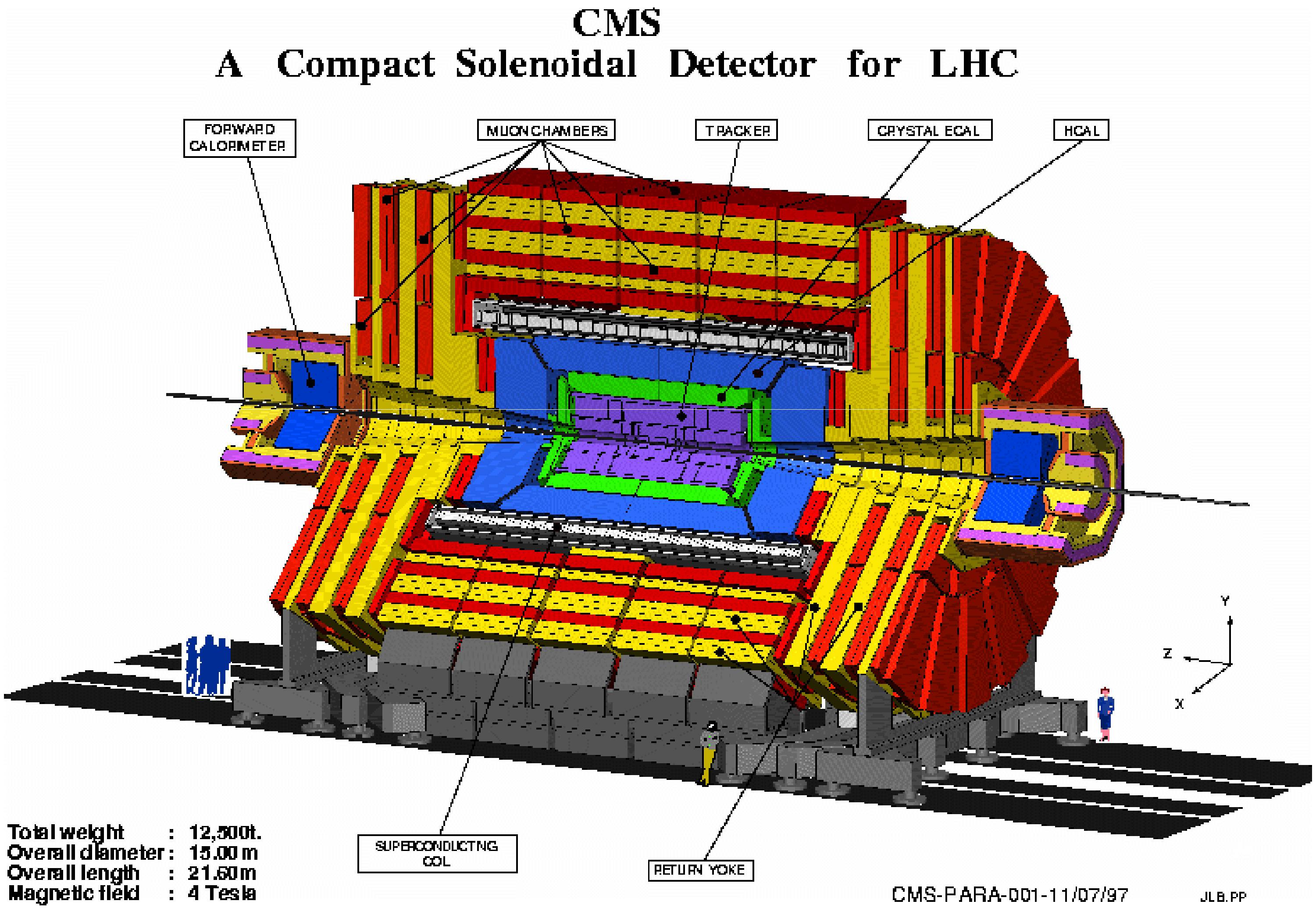
The LHCb Detector



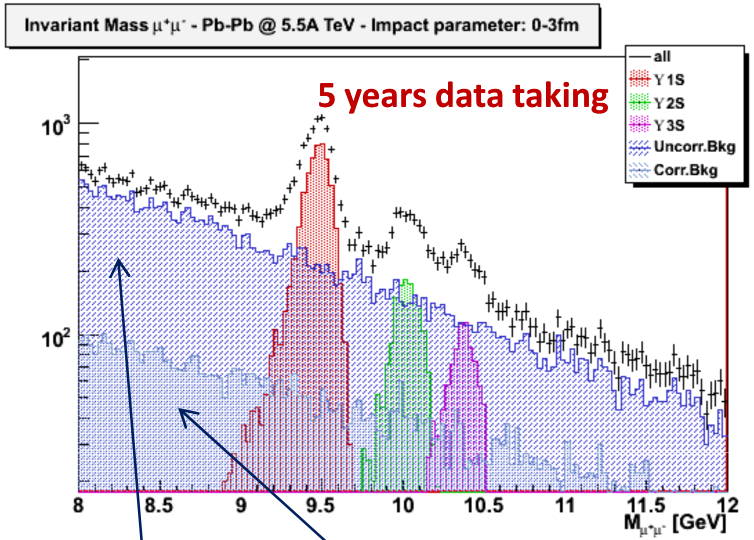
The ATLAS Detector



The CMS Detector



Preparing Data Samples (I)



$b\bar{b} \rightarrow \bar{B}^0 B^+ + X \rightarrow D^+ \mu^- \nu_\mu + \bar{D}^0 \mu^+ \nu_\mu \rightarrow \mu^+ \mu^- \nu_\mu + \mu^- \mu^+ \nu_\mu + X$

$c\bar{c} \rightarrow D^+ + \bar{D}^0 + X \rightarrow \mu^+ \mu^- + X$

bb – cc – bc contributions

- **Signal**: Υ(1S), Υ(2S) and Υ(3S) samples generated with AliGenParam and reconstructed with full-simulation. Generation done with several degrees of polarization: -1, -0.5, 0, 0.5, 1.
- **Correlated Background**: generated with Pythia by Rachid Guernane* and reconstructed with fast simulation
- **Uncorrelated Background**: generated through parametrization and reconstructed with the fast simulation approach (see $ALICE_ROOT/FASTSIM/uncorrBg.C)

π and K contribution to background negligible in 8-12 GeV mass region

1, 3 and 5 years of data taking have been considered (L= $5 \cdot 10^{26}$ cm^{-2} s^{-1})

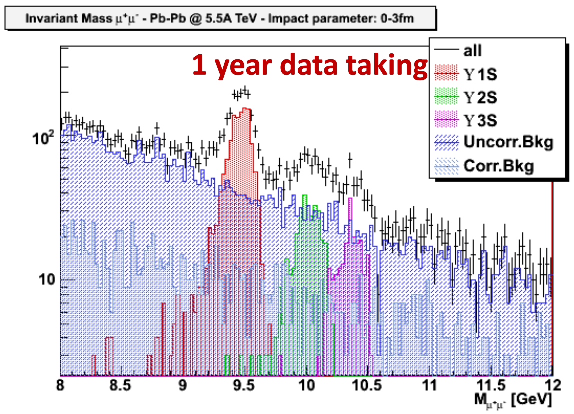
*ALICE-INT-2005-018 version 1.0

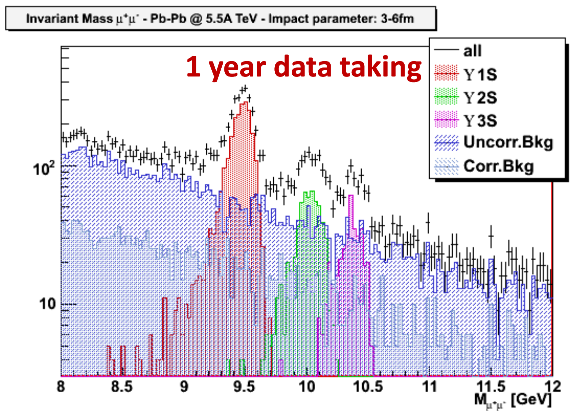
Preparing Data Samples (II)

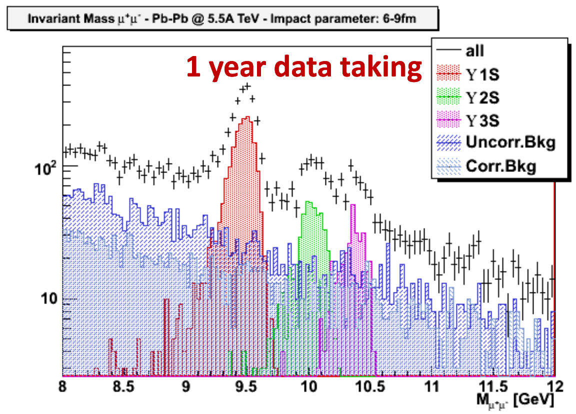
The relative weights of correlated and uncorrelated bkgs have been taken from Smbat Grigoryan's work, published in PPR-Vol.2

The contribution of each type of bkg is different in the 5 centrality classes: 5 different data samples have been prepared for each polarization

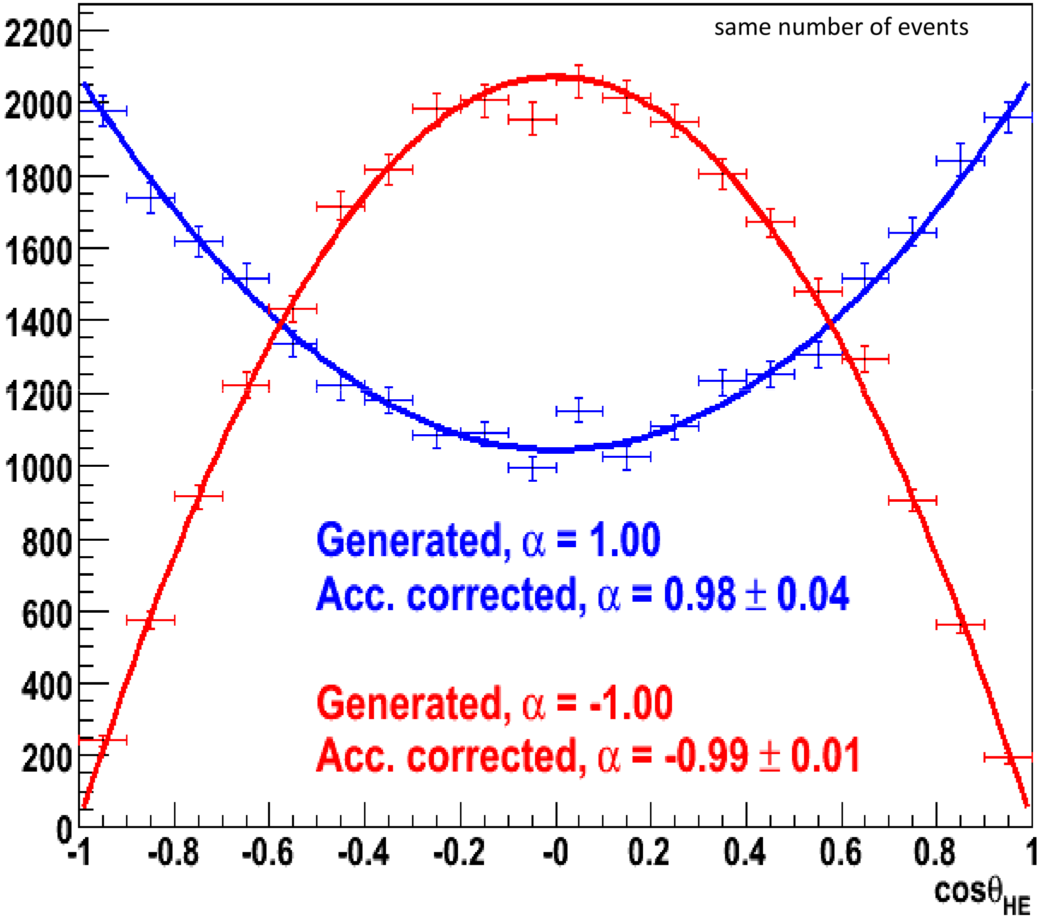
We did all the work integrating over the impact parameter, but in the future a study of the centrality dependence of the α parameter could be done using the same generated data







Angular distribution fit: error on α

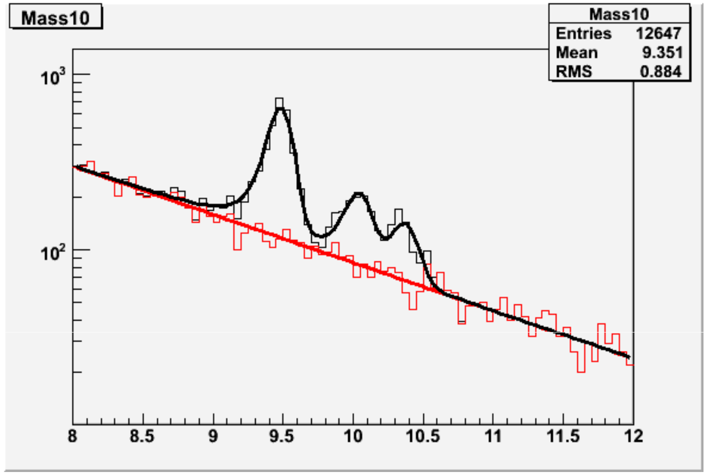


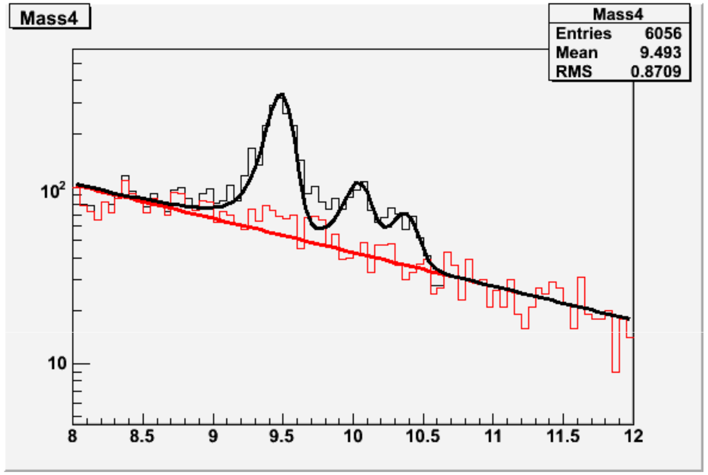
With the same number of reconstructed events the error on α increases while α enhances.

In the Least Squares fitting method if $f(x) = p_0 \cdot (1+\alpha \cdot x^2)$ then for p_0 large $\sigma\alpha \propto 1/p_0$

Bias on high values of α

In peripheral cosθ bins we sometimes underestimate the background contribution:





Central cosθ bins: the Bkg shape seems to be perfectly exponential -> the contribution is well estimated

Only for high values of α because in that case the shape of the cosθ depends more directly on the behaviour of the most peripheral bins

Edges of the cosθ distribution: the Bkg shape is not exponential -> the contribution is underestimated

↓

The spectrum shape is wider

↓

α is bigger

Fit of the cosϑ spectrum: minimization

Template fit to the cosθ spectrum done with MINUIT minimizing the quantity:

$$\chi^2 = 2 \cdot \sum_i \left\{ (E_i + \beta_i - D_i) - D_i \cdot \ln\left(\frac{E_i + \beta_i}{D_i}\right) + (\beta_i - S_i) - S_i \cdot \ln\left(\frac{\beta_i}{S_i}\right) \right\}$$

where:

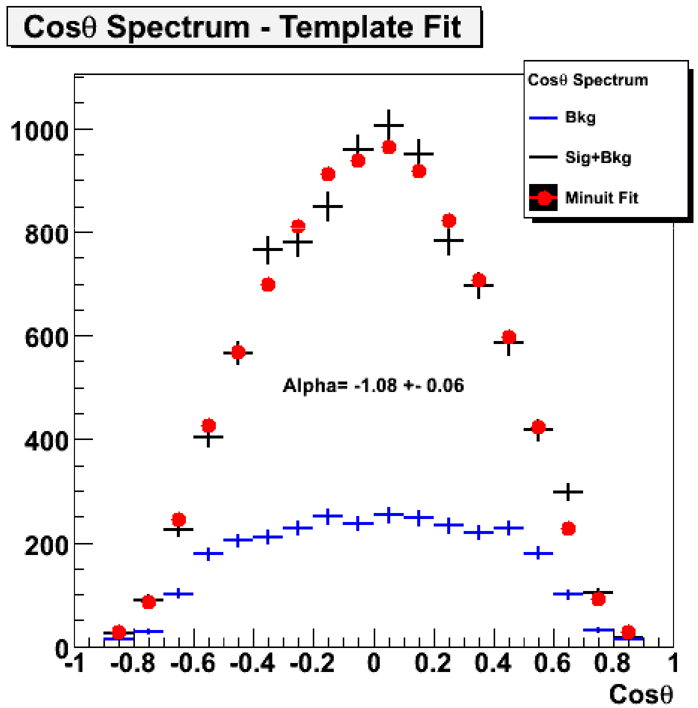
$$\beta_i = \frac{1}{4}\left[-(2E_i - D_i - S_i) + \sqrt{(2E_i - D_i - S_i)^2 + 8S_iE_i}\right]$$

D_i : *Signal + Bkg events* S_i : *Bkg events*

E_i : *expected number of Signal events*

β_i : *expected number of Bkg events*

The formula is correct when signal+background and background errors are both poissonian. We suppose background errors to be poissonian: not completely correct because not obtained from an event counting technique.



T. Devlin, *Correlations from Systematic Corrections to Poisson-Distributed Data in Log-Likelihood Functions*, CDF public note CDF/DOC/JET/PUBLIC/3126 (1995)

How to study polarization

The polarization of Quarkonium is gleaned through the analysis of the angular distribution of daughter particles (e.g. $\mu^+\mu^-$) which follows the trend:

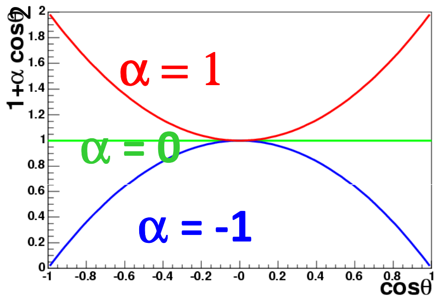
$$\xi_L = \frac{\sigma_L}{\sigma_{TOT}} = \frac{1-\alpha}{3+\alpha}$$

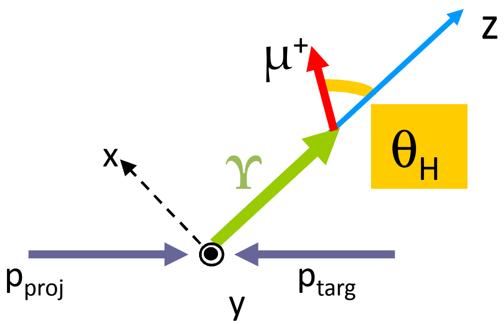
$$\xi_T = 1 - \xi_L$$

$$\frac{d\Gamma}{d\cos\theta^*} \propto \frac{3}{2(\alpha+3)}(1+\alpha\cos^2\theta^*)$$

α=1 Transverse polarization

α=-1 Longitudinal polarization





The angular distribution is usually analyzed in the ϒ C.M. frame. Polarization angle defined as the angle between μ^+ momentum and a “polarization axis” which can be chosen in different ways.

We use the helicity (HE) reference frame, in which the z-axis is the direction of the ϒ momentum in the p-p C.M. frame.