Measurement of J/ψ Polarization in Polarized Proton-Proton Collisions at $\sqrt{s}$ = 200 GeV with PHENIX

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for the PHENIX Collaboration

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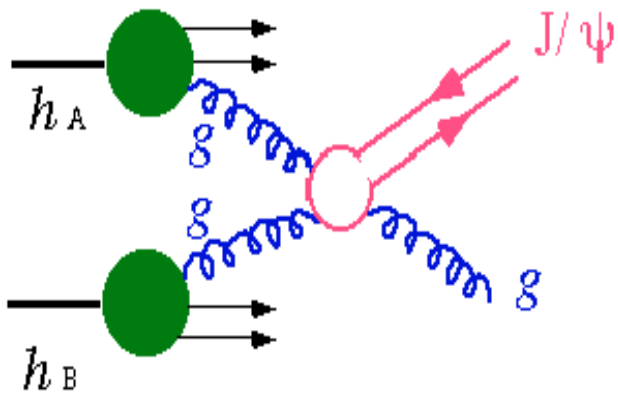
Physics Motivation

Spin Structure of Proton

$$\frac{1}{2} = \Delta\Sigma + \Delta g + L_q + L_g$$

$$A_{LL}^{J/\psi} = \frac{\sigma_{++}^{J/\psi} - \sigma_{+-}^{J/\psi}}{\sigma_{++}^{J/\psi} + \sigma_{+-}^{J/\psi}} = \frac{\Delta g(x_1)}{g(x_1)} \frac{\Delta g(x_2)}{g(x_2)} a_{LL}^{g+g\to J/\psi}$$



Cross section for J/ψ production, J/ψ Polarization

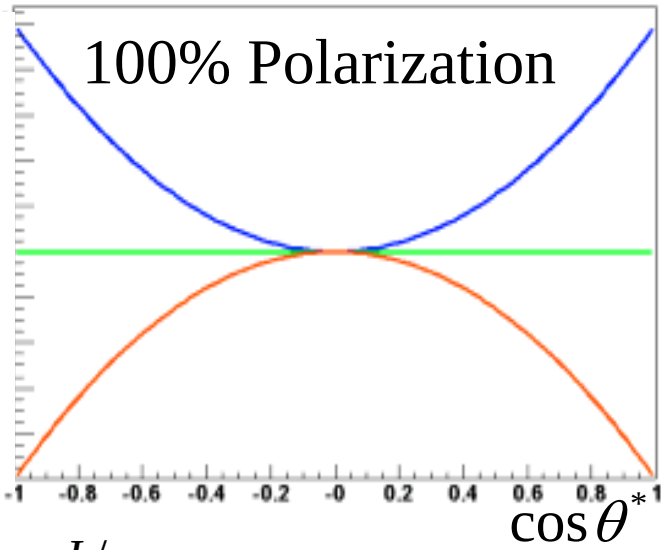
J/ψ Production and decay, Polarization

There are three J/ψ production models.

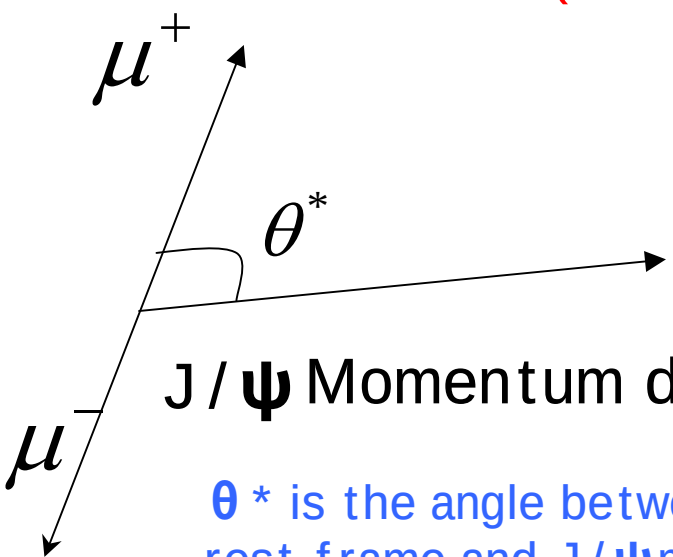
Color Singlet Model (CSM) $\lambda > 0$

Color Evaporation Model (CEM) $\lambda = 0$

Color Octet Model (COM) $\lambda < 0$



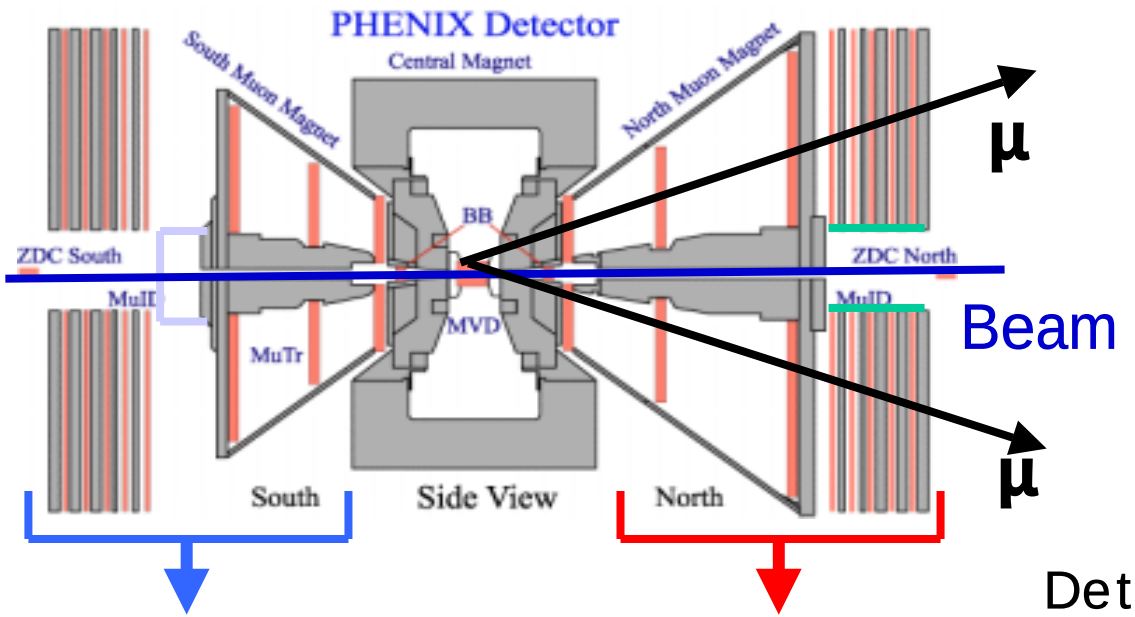
$$\frac{d\sigma^{J/\psi}}{d\cos\theta^*} \sim 1 + \lambda \cos^2\theta^*$$



θ* is the angle between the μ^+ in the J/ψ rest frame and J/ψ momentum direction.

J/ψ polarization can distinguish these models

PHENIX Muon Arm



Muon Tracker (MuTr)
Measurement of momentum

Muon Identifier (MuID)
Muon identification
Trigger Counter

South Muon Arm
2001~

North Muon Arm:
2002~

Detector Geometical Acceptance
North : $1.2 < \eta < 2.4$
South: $-2.2 < \eta < -1.2$
Muon range cut off ~ 2GeV/c

Integrated Luminosity: 143 nb^{-1}
Number of J/ψ ~ 600

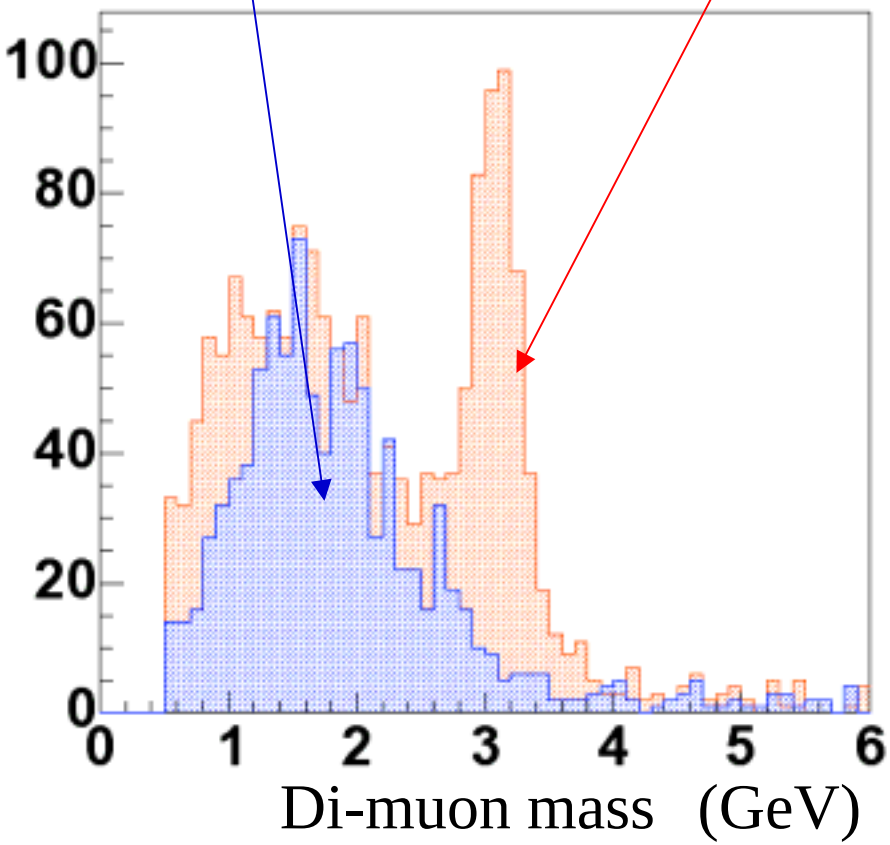
Mass Spectrum in 2003 p-p run

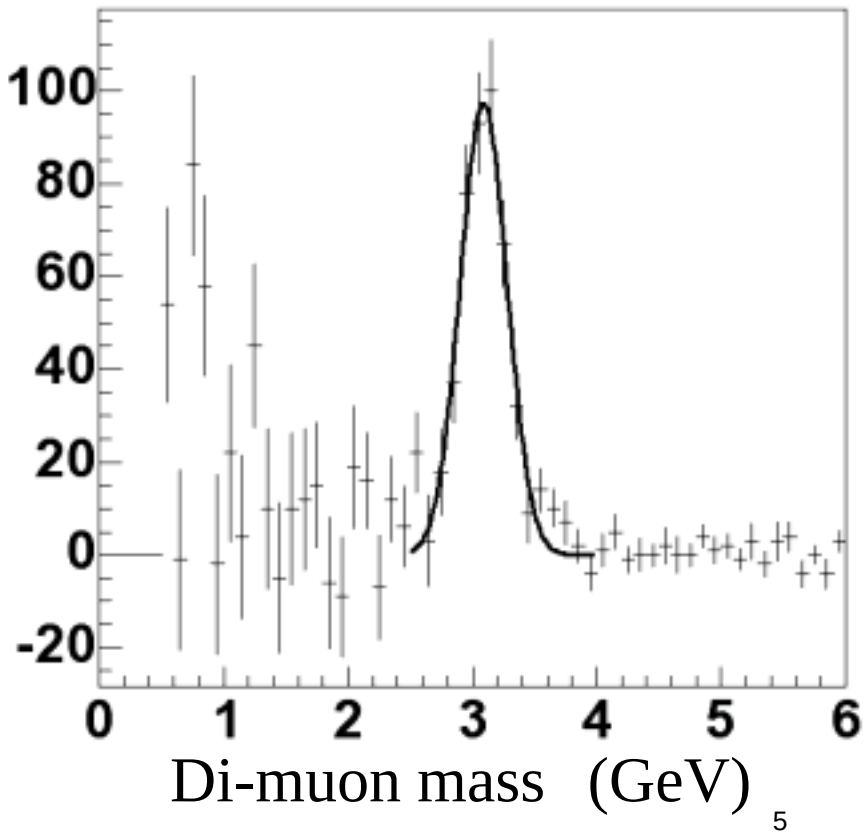
Like Sign (+ +) (− −)

Unlike Sign (+ −)

Unlike sign - Like sign

(+ −) - (+ +) - (− −)





Analysis Methods

$$l = \sum_{\text{event}} \log(\mathrm{n} \times Y_i \times \varepsilon_i)$$

Y_i: Likelihood
n: normalization factor

λ: Polarization
B: Pt slope factor

$$Y_i = \frac{\mathrm{d}\sigma}{\mathrm{d}\cos\theta^*} \times \frac{\mathrm{d}\sigma}{\mathrm{dPt}} = (1+\lambda\cos^2\theta_i^*) \times \mathrm{Pt_i} \times (1+(\frac{\mathrm{Pt_i}}{\mathrm{B}})^2)^{-6}$$

$$\varepsilon_i = \varepsilon(\cos\theta_i^*\ \mathrm{Pt_i})$$

$$\mathrm{n}^{-1} = \int_{=-1}^{1} \int_{0}^{\mathrm{Pt\_max}} (1+\lambda\cos^2\theta_i^*) \times \mathrm{Pt_i} \times (1+(\frac{\mathrm{Pt_i}}{\mathrm{B}})^2)^{-6} \times \varepsilon(\cos\theta_i^*, \mathrm{Pt_i})\mathrm{d}(\cos\theta^*)\mathrm{d}(\mathrm{Pt})$$

The Likelihood of each events is calculated and summed up all events.

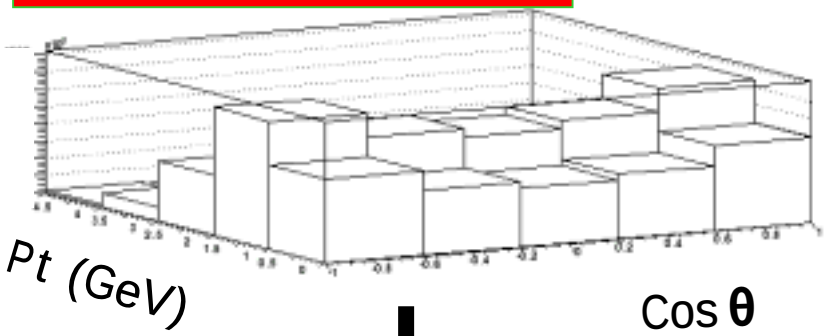
λ is obtained from likelihood.

The value of efficiency as pt and cosθ* function is needed.

Efficiency Correction

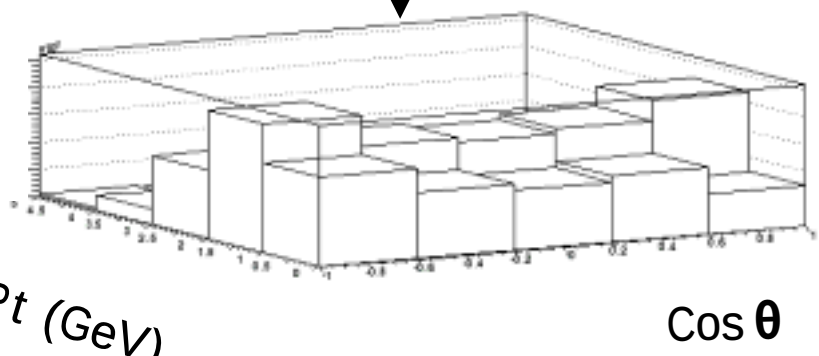
300k events as flat $\cos\theta$ distribution ($\lambda = 0$)

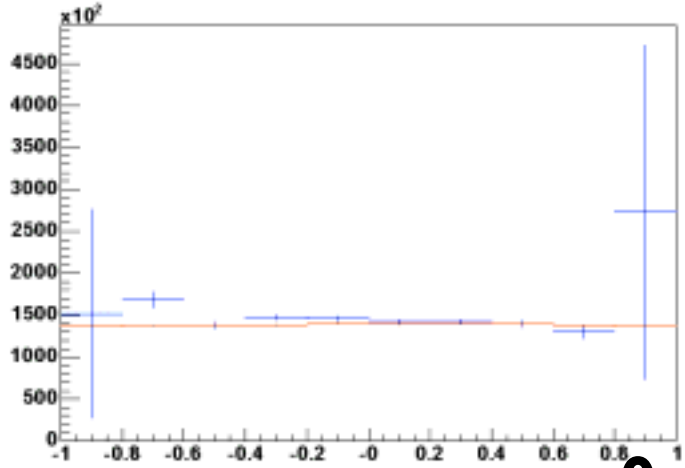
Event Generator Output



Detector Simulator

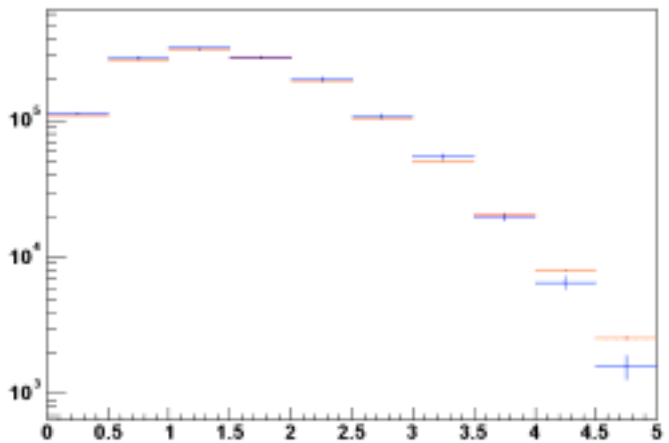
Efficiency Correction



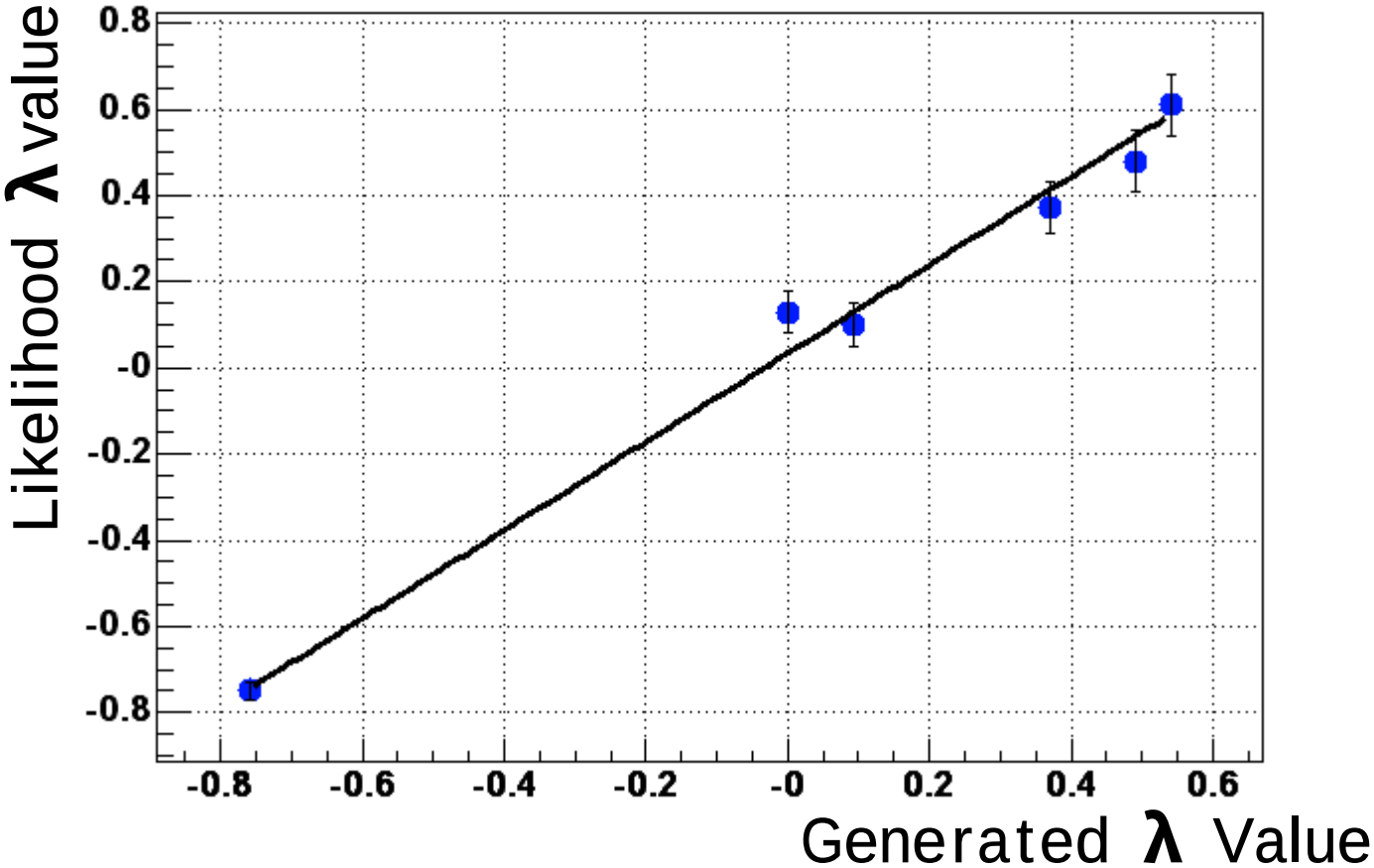


Input simulation data

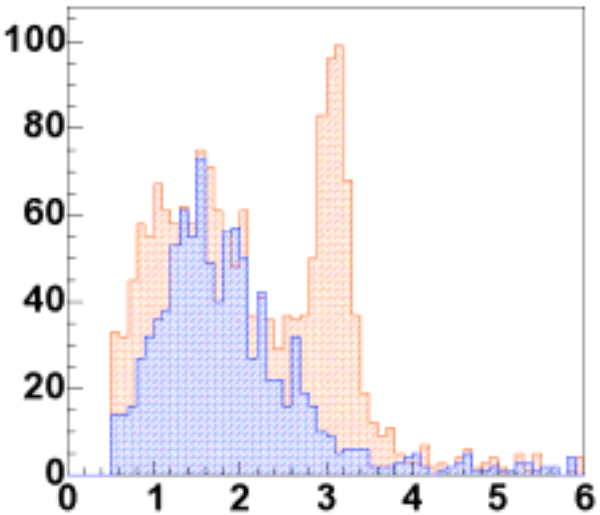
After efficiency correction



Polarization of Likelihood Method



Analysis methods 2



muon pair mass (GeV)

Unlike sign muon pair
(Not 100% J/ψ)
Like sign muon pair
(100% background)

Y_i : Likelihood
n: normalization factor

λ: Polarization
B_{sig} : Signal Pt slope
$f_{B.G}$: Background fraction
$B_{B.G}$: Background pt slope

$$l = \sum_i \log(\mathrm{n} \times Y_i \times \varepsilon_i)$$

$$\mathrm{Y_i} = (1+\lambda\cos^2\theta_i^*) \times \mathrm{Pt_i} \times (1+(\frac{\mathrm{Pt_i}}{\mathrm{B_{sig}}})^2)^{-6} + \mathrm{f_{B.G.}} \times \mathrm{Pt_i} \times (1+(\frac{\mathrm{Pt_i}}{\mathrm{B_{B.G.}}})^2)^{-6}$$

$$\varepsilon_i = \varepsilon(\cos\theta_{\mathrm{i}}\ \mathrm{Pt_i})$$

Summary and Future Plan

- **About 600 J/ψ's were obtained in 2003 p-p run.**
- **The Efficiency and the Maximum likelihood method for J/ψ Polarization were evaluated by the simulation data.**
- **Detector efficiency will be confirmed.**
- **J/ψ Polarization will be measured soon**