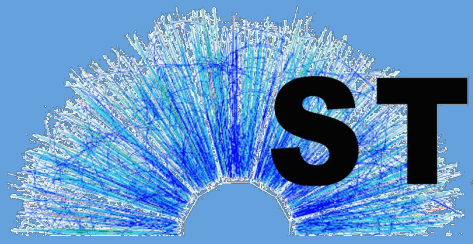

J/ψ polarization measurements in p+p collisions at STAR

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University of Illinois at Chicago

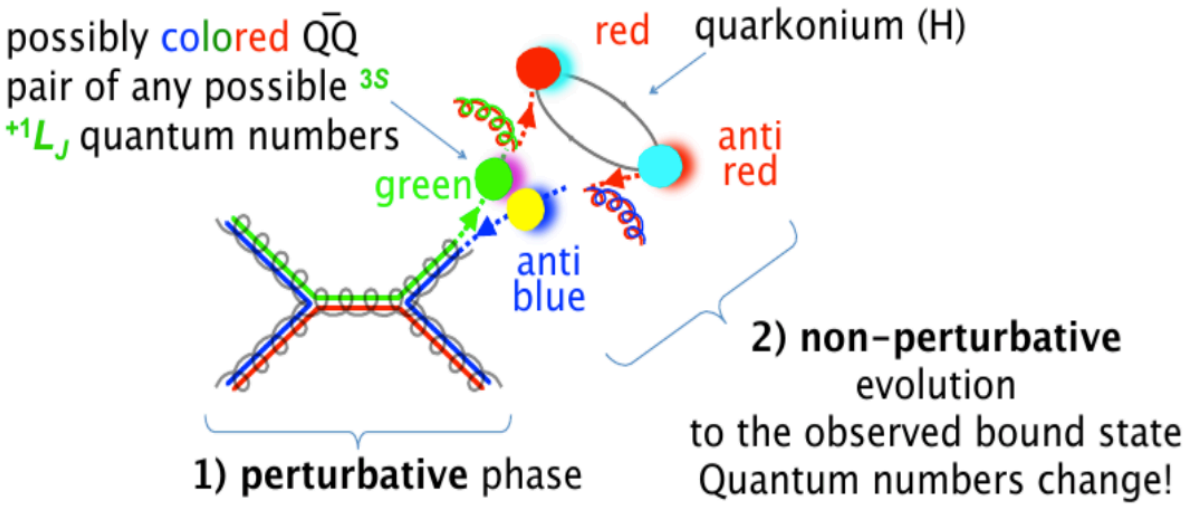
UIC The University of Illinois at Chicago

U.S. DEPARTMENT OF ENERGY

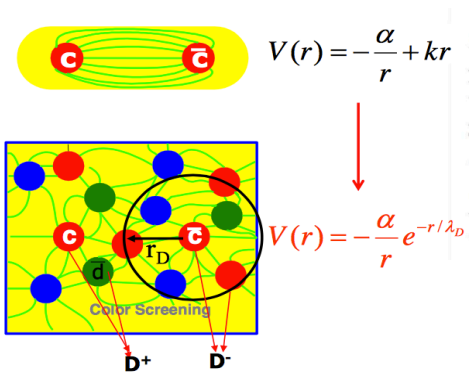
Motivation

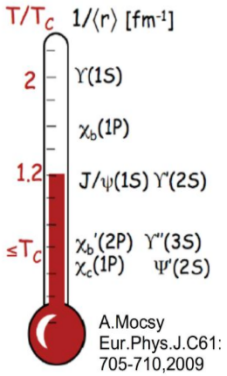
Quarkonium Study

1.Help to understand QCD



2.Help to understand the interaction with Quark-Gluon Plasma, thus probing the properties of QGP.





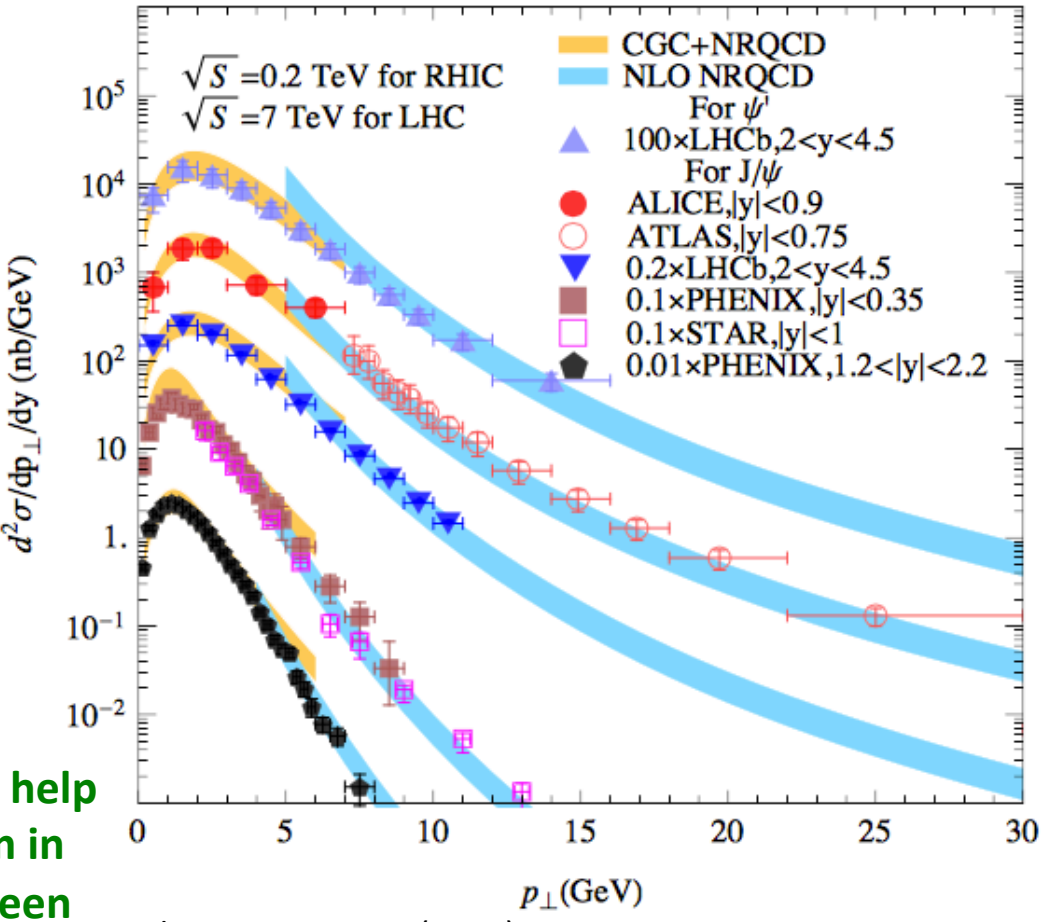
Motivation

Different models can well describe measured cross-sections

- Color Evaporation Model
- NRQCD approach –applicable at high p_T
- Color Glass Condensate+NRQCD – applicable at low p_T

Different models have different predictions on J/ψ polarization

$P+P \rightarrow J/\psi + X$



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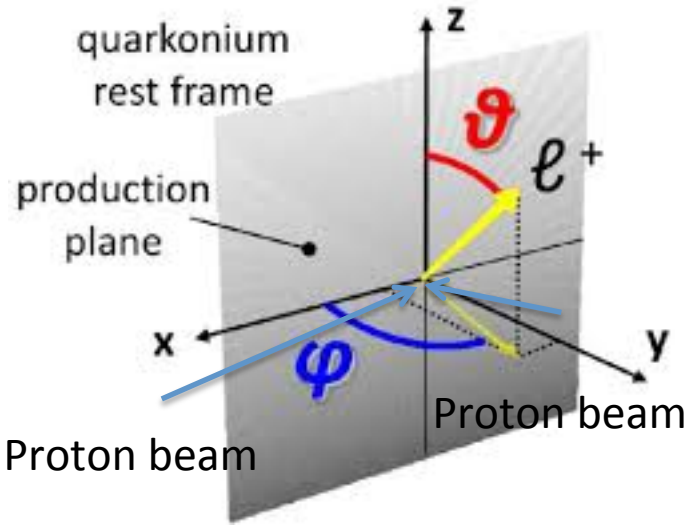
Measurements of J/ψ polarization can help understand J/ψ production mechanism in hadron collisions and distinguish between different models.

J/ψ polarization

J/ψ polarization can be analyzed via the angular distribution of the decayed leptons

$$\frac{d\sigma}{d\cos\theta d\varphi} \propto 1 + \lambda_\theta \cos^2\theta + \lambda_{\theta\varphi} \sin(2\theta)\cos\varphi + \lambda_\varphi \sin^2\theta \cos(2\varphi)$$



$$\lambda_{inv} = \frac{\lambda_\theta + 3\lambda_\varphi}{1 - \lambda_\varphi}$$

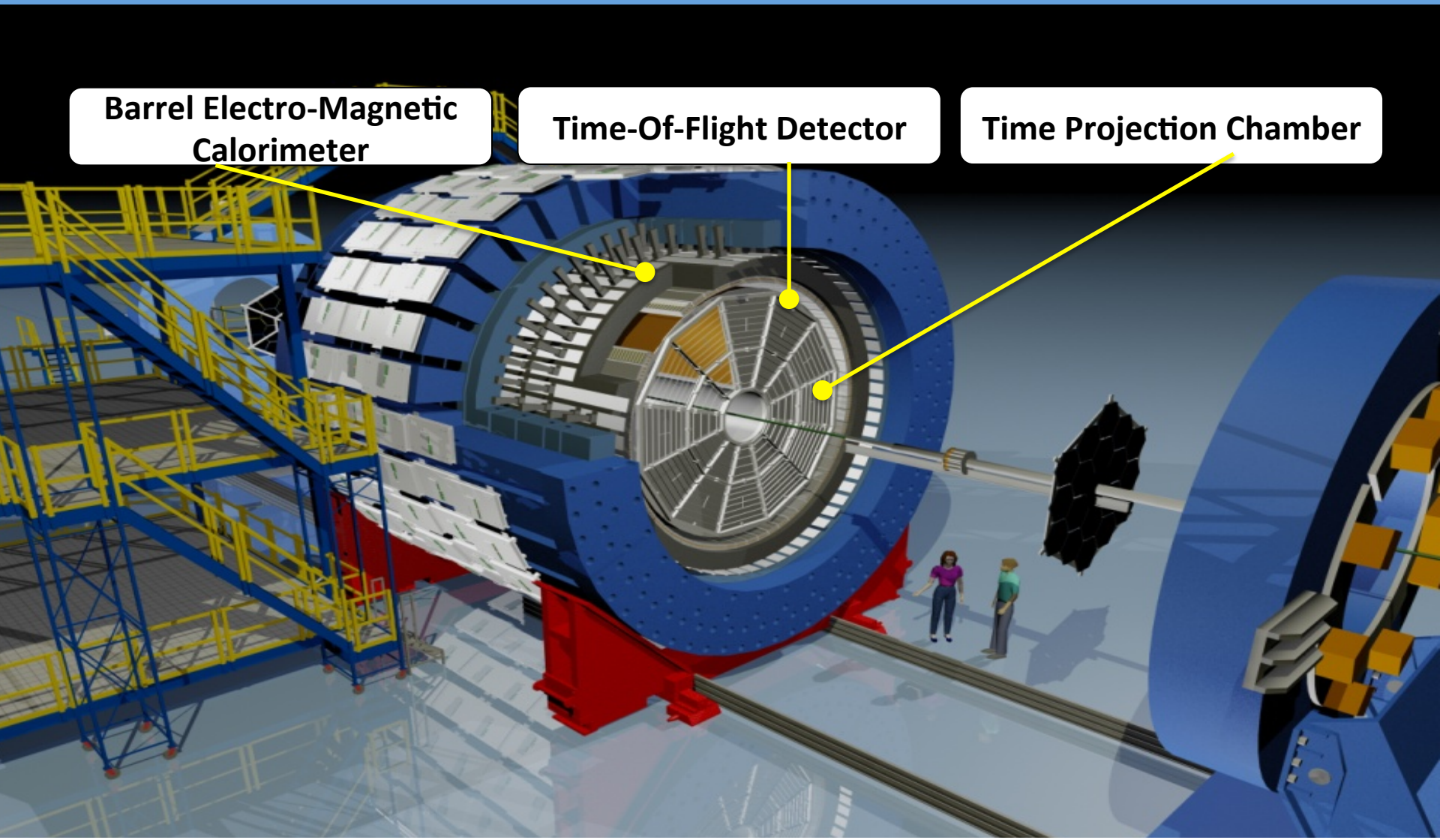
The helicity frame defines ***z axis*** along the *J/ψ* momentum in the center of mass frame.

The Colllins-Soper frame defines the ***z axis*** as a bisector of the angle formed by one beam direction and the opposite direction of the other beam in the *J/ψ* rest frame.

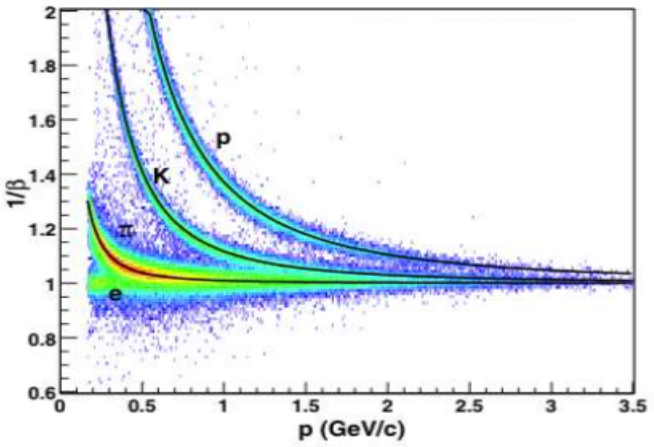
θ: Polar angle between momentum of positron in *J/ψ* rest frame and the polarization axis z

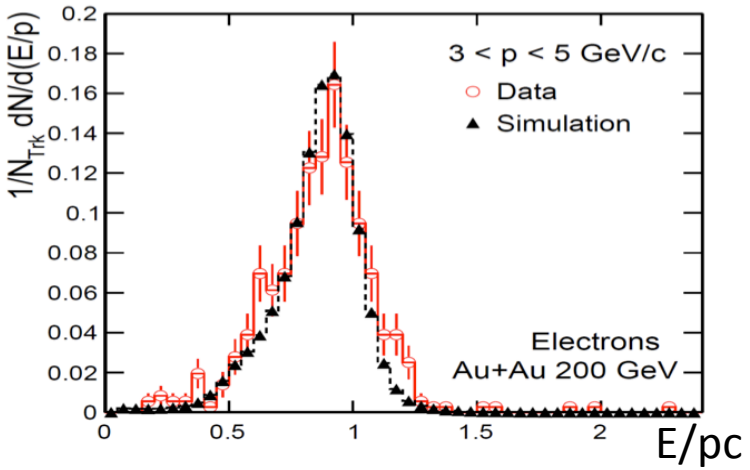
φ: Azimuthal angle

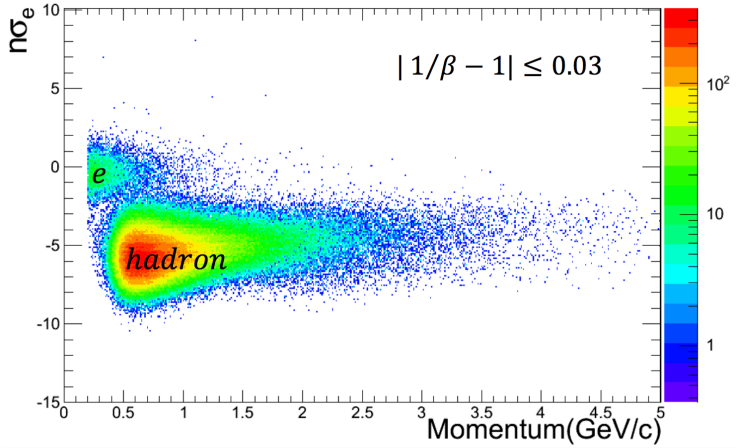
Solenoidal Tracker At RHIC



Electron identification



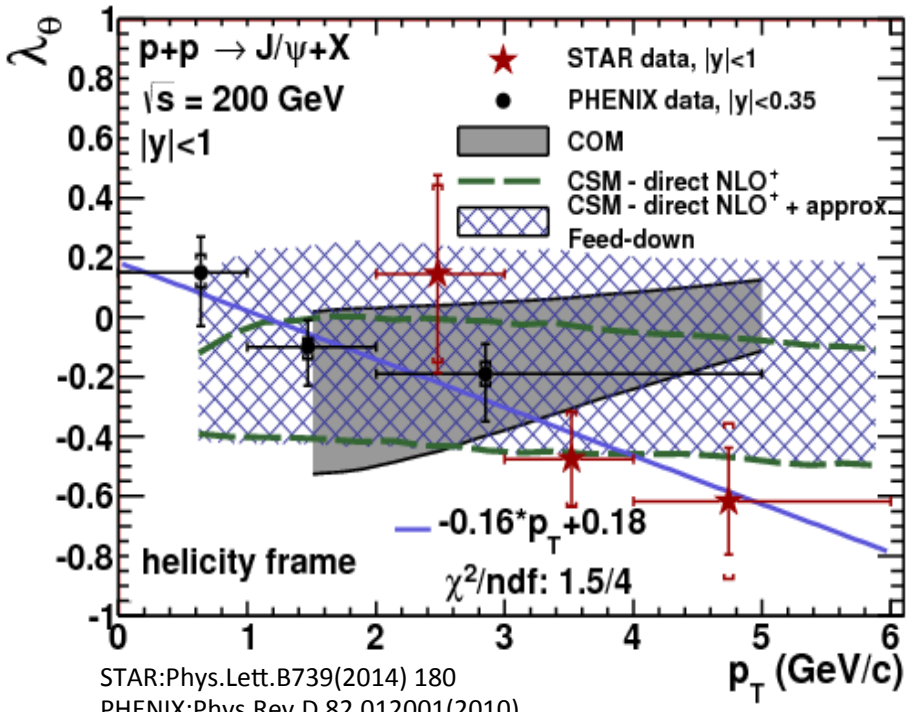




1/β: time of flight(TOF)
$n\sigma_e$: normalized ionization energy loss(TPC)
E/pc: ratio of energy(BEMC) and momentum(TPC)

Electron identification with 1/β, $n\sigma_e$ and E/pc measurements.

STAR Run9 200 GeV published results



STAR:Phys.Lett.B739(2014) 180
PHENIX:Phys.Rev.D 82,012001(2010)
COM:Phys.Rev.D 81, 014020(2010)
CSM NLO+: Phys.Lett B 695 149(2011)

Measurement of better precision can be made to higher p_T.

Run9 data Indicates a negative trend of λ_θ towards higher p_T.

Can not really distinguish different models within the precision and kinematic reach of STAR 2009 data.

To make improvement:

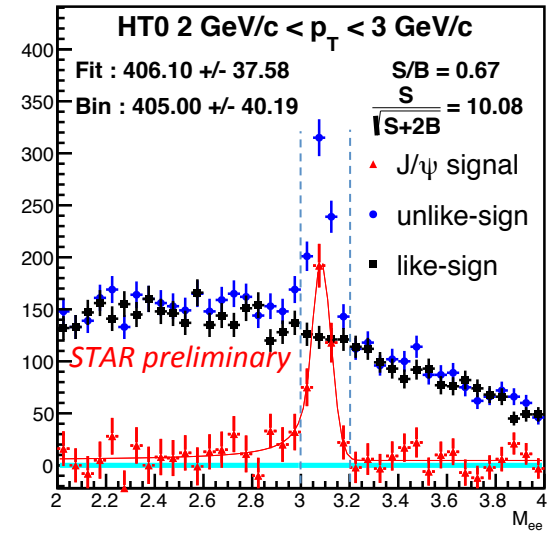
- Need more data sample.
- Need to extend measurements to higher p_T.

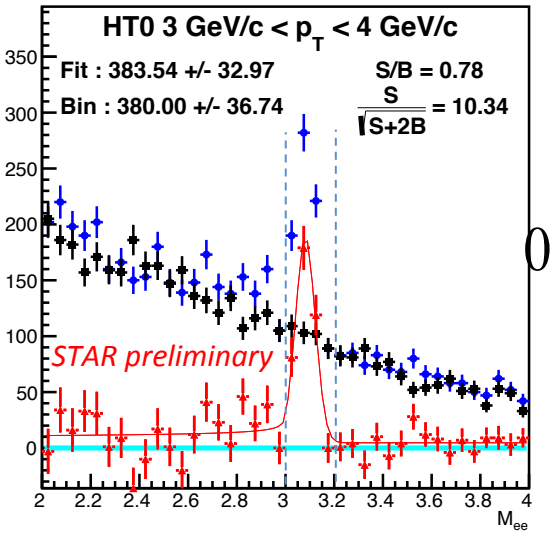
From STAR p+p 200 GeV collisions:

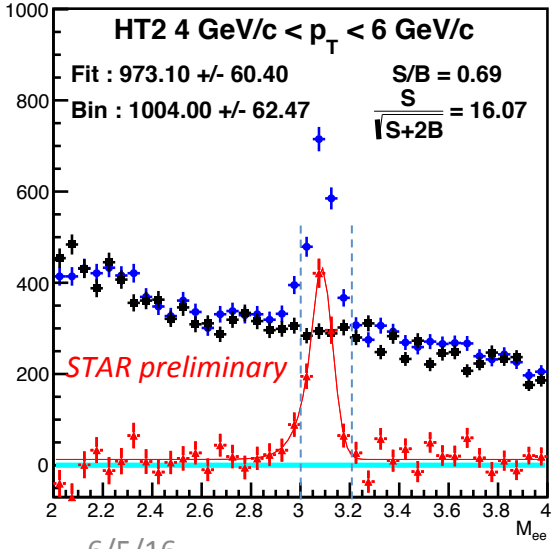
EMC Trigger	Threshold
HT0	E_e>~2.5 GeV
HT2	E_e>~4.3 GeV

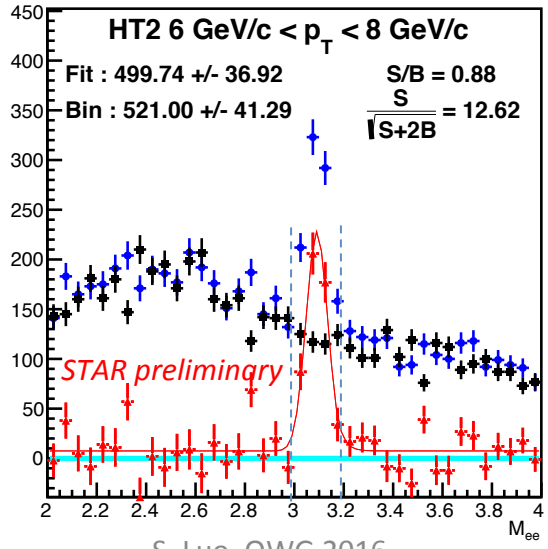
	2009	2012
	TOF 72%	TOF Fully installed
HT0(&&!HT2)	L=1.8pb^{-1}	
HT0		L=1.4pb^{-1}
HT2		L=23.5pb^{-1}

J/ψ signals from 200 GeV pp collisions









EMC electron identification cut

$$-1.5 < n\sigma_e < 3 \quad \&\&$$

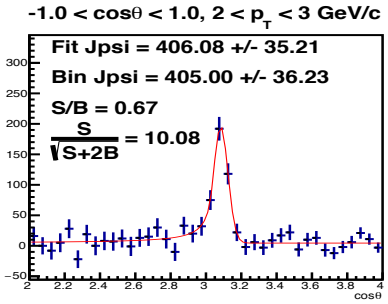
$$0.3 < pc/E < 1.5, pT > 1.4 GeV/c$$

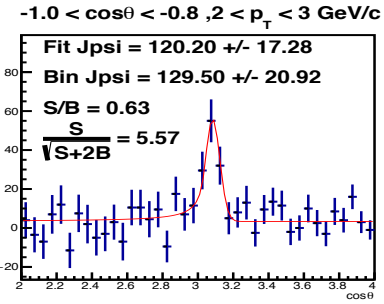
TOF electron identification cut

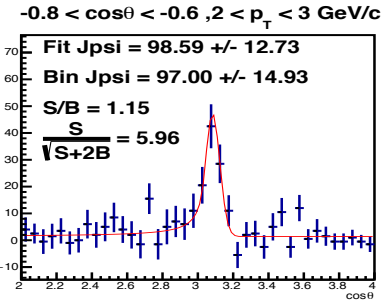
$$-1.5 < n\sigma_e < 3 \quad \&\&$$

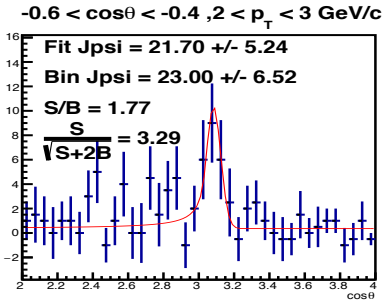
$$|1/\beta - 1| < 0.03$$

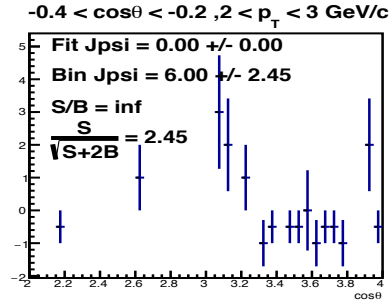
J/ψ signals in different cosθ bin with Crystal-ball function fit

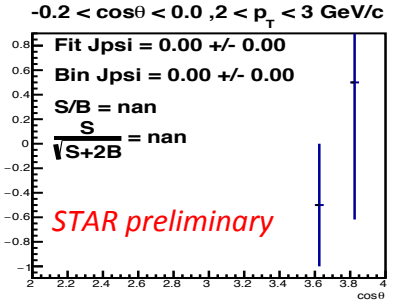


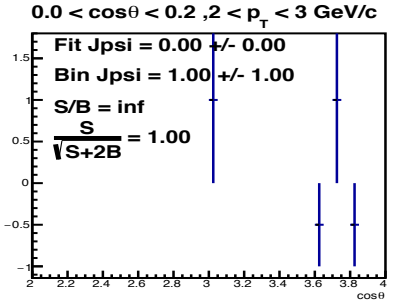


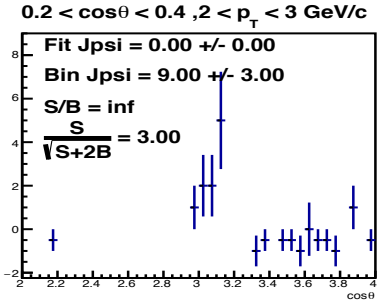


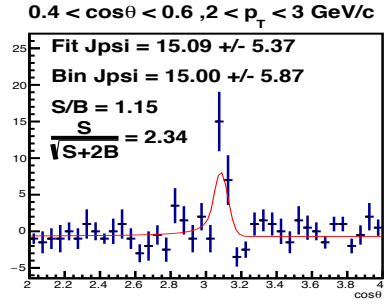


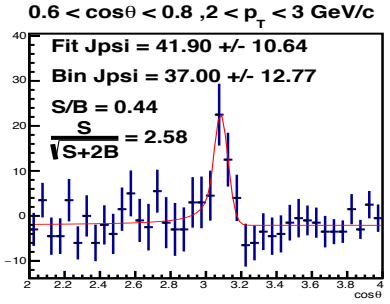


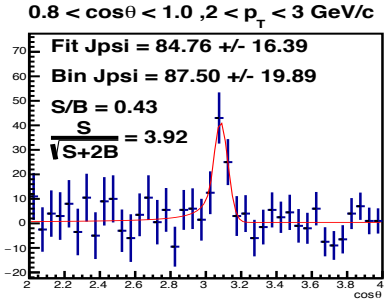






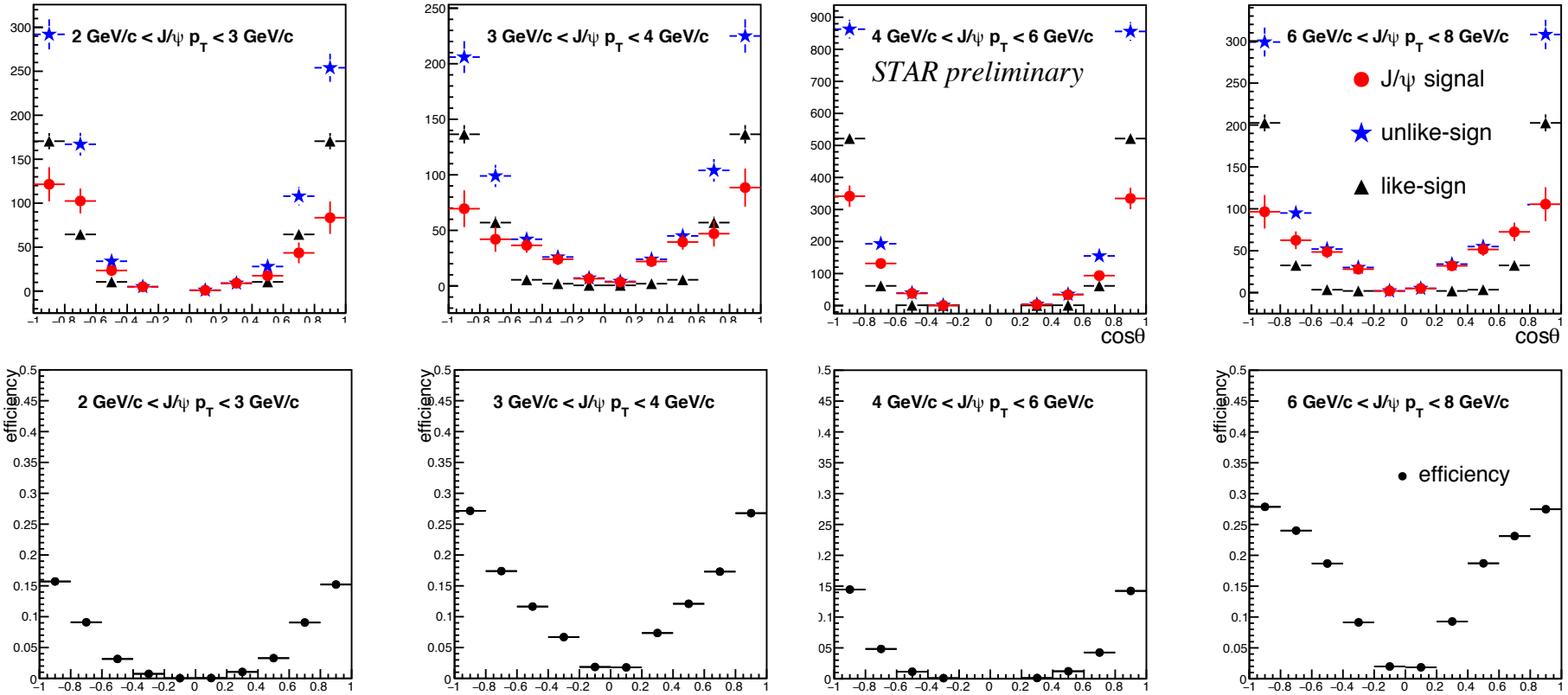






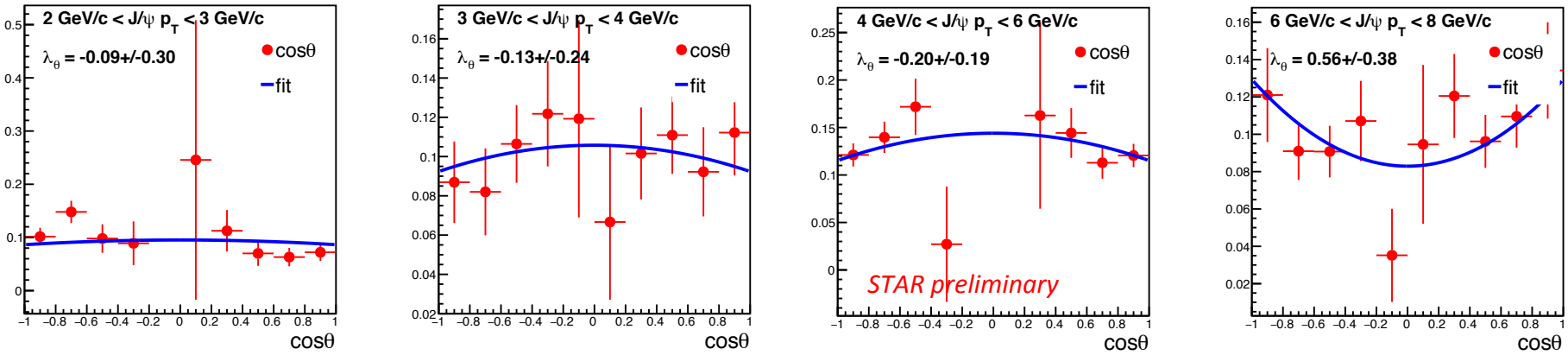
A,B,C and D parameters in Crystal-ball function are fixed in individual cosθ bin to the same as those in inclusive case.

J/ψ yield extraction vs cosθ



1. Raw cosθ distribution of J/ψ is extracted by subtracting the cosθ distribution of like-sign pairs from that of the unlike-sign pairs.
2. Efficiencies are estimated by generating J/ψ signals, decaying them via di-electron channel and propagating the decayed electrons through detector simulations using GEANT.

Polarization parameters



Angular distribution of decayed leptons:

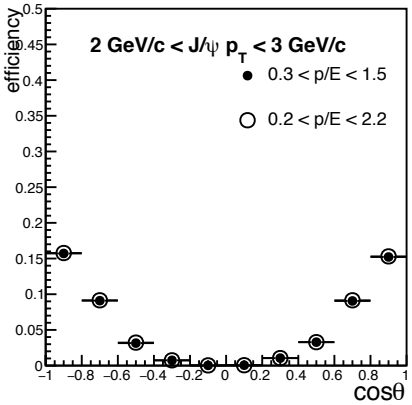
$$\frac{d\sigma}{d\cos\theta d\varphi} \propto 1+\lambda_\theta \cos^2\theta + \lambda_{\theta\varphi}\sin(2\theta)\cos\varphi + \lambda_\varphi \sin^2\theta\cos(2\varphi)$$

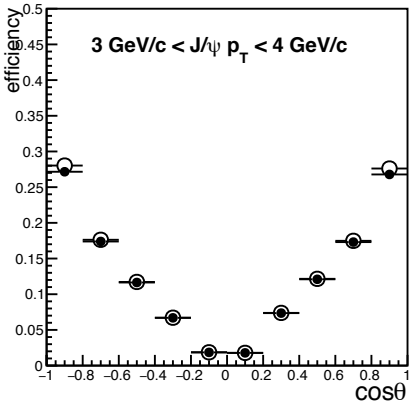
After integration over φ, we get the theoretical cosθ distribution

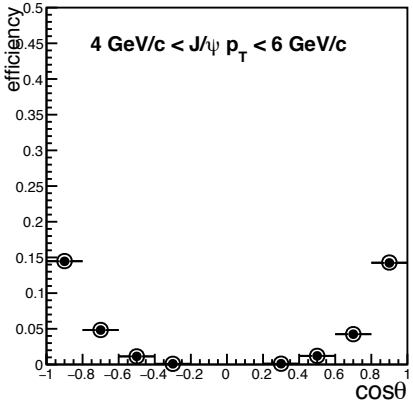
$$w(\cos\theta) \propto 1+\lambda_\theta \cos^2\theta$$

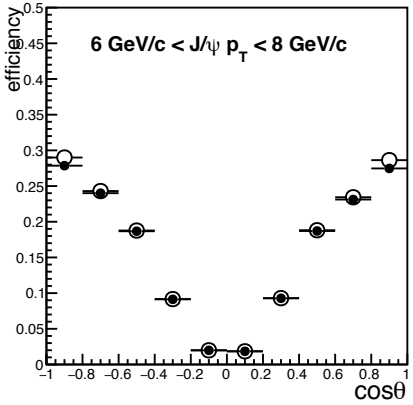
λ_θ is extracted from the fit to the corrected cosθ distribution.

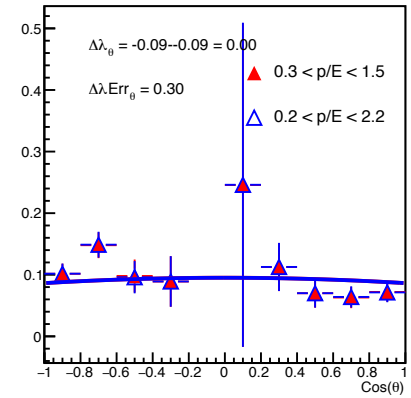
Systematic uncertainty from p/E cut as an example

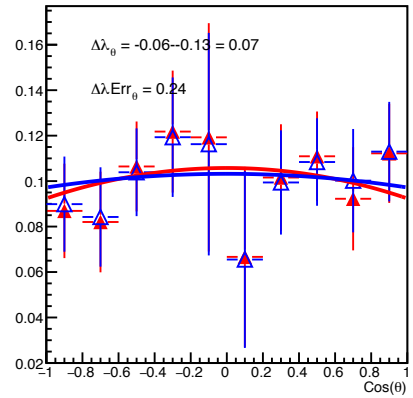


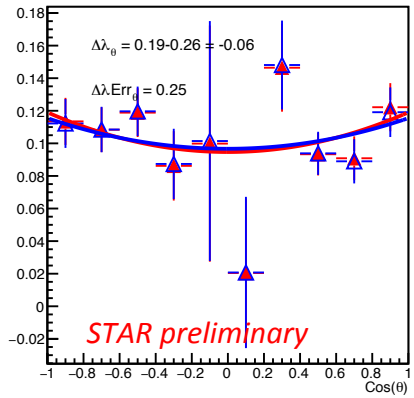


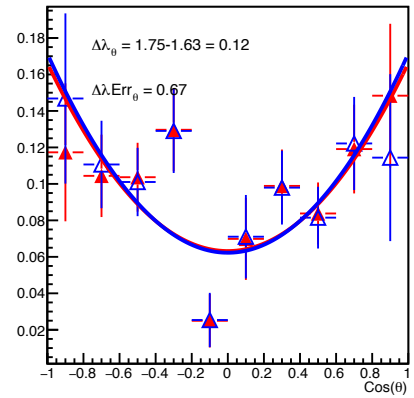






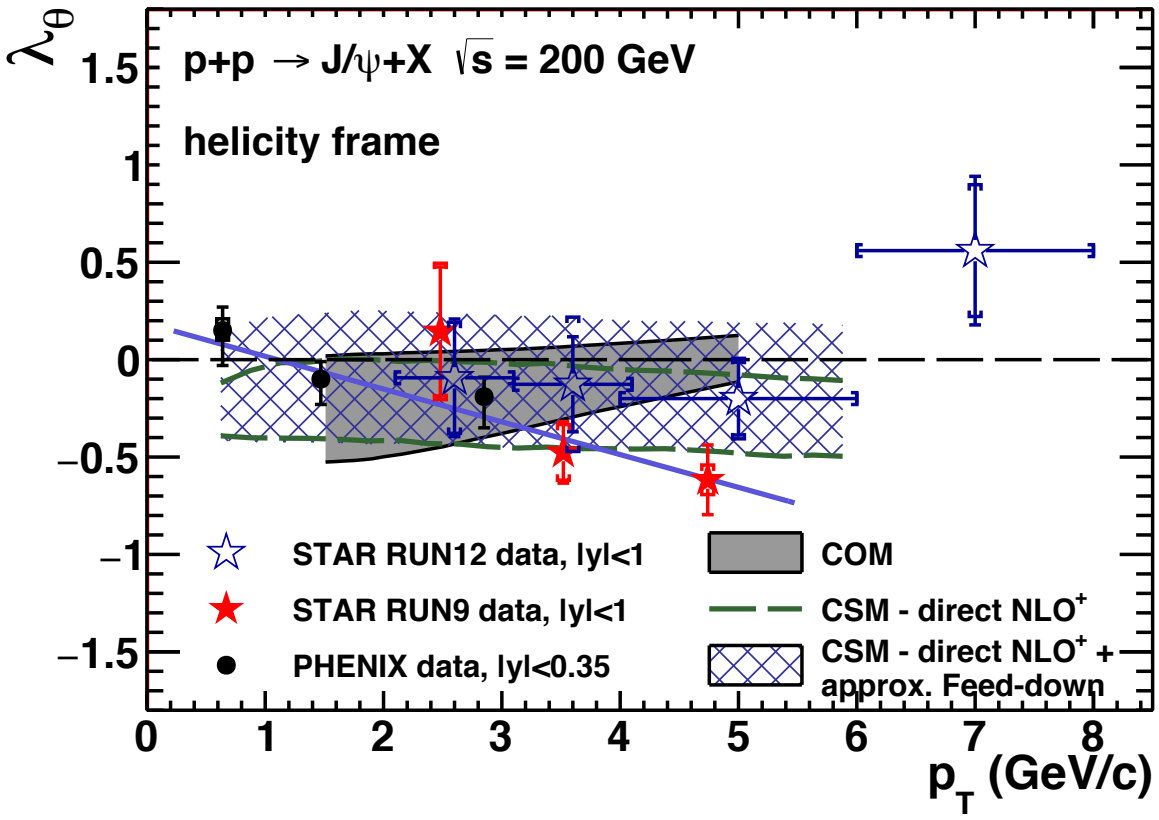






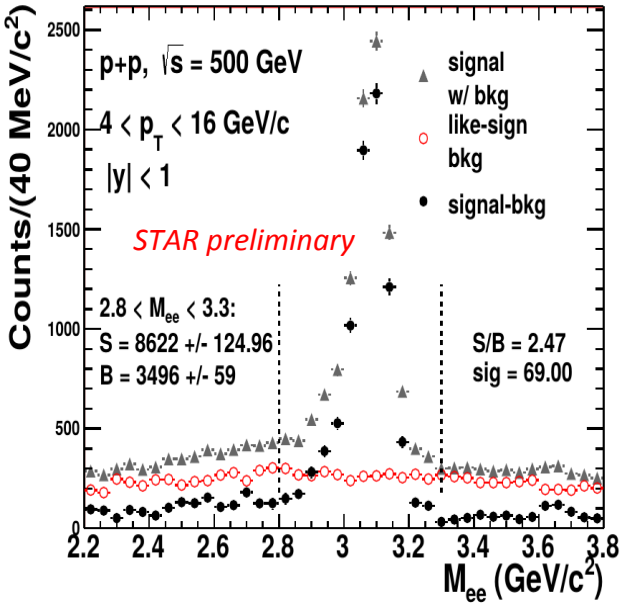
The difference in extracted λ_θ due to changing the p/E cut both in data and simulation is assigned as the systematic uncertainty.

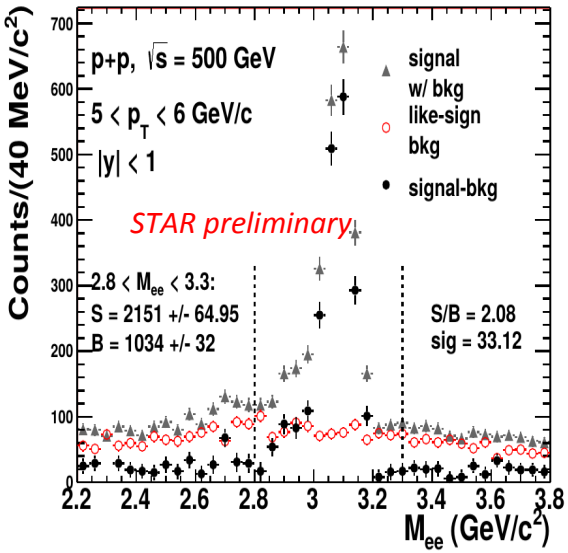
Polarization parameter λ_θ

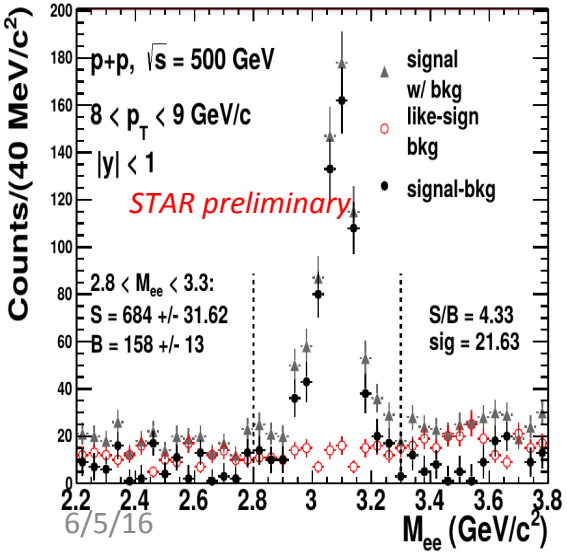


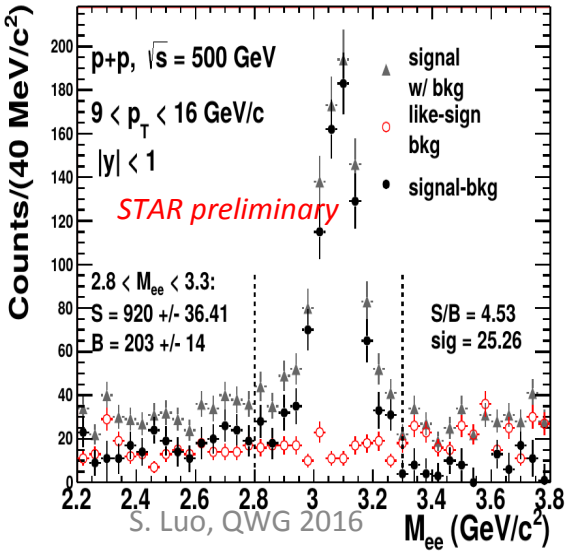
1. The measurements are extended up to 8 GeV/c with Run12 data.
2. The previous measurements indicate a declining trend of λ_θ to high p_T, but the result using Run12 data does not seem to follow this trend.
3. Extraction of λ_θ and λ_φ in Collins-Soper frame is underway.

J/ψ signals from 500 GeV pp collisions









p+p at 500 GeV from RHIC 2011 run

dsmAdc>18 (E > 4.3GeV), p_T > 3.5GeV/c

Luminosity 22 pb^{-1}

Electron identification cuts:

$$-1 < n\sigma_e < 2$$

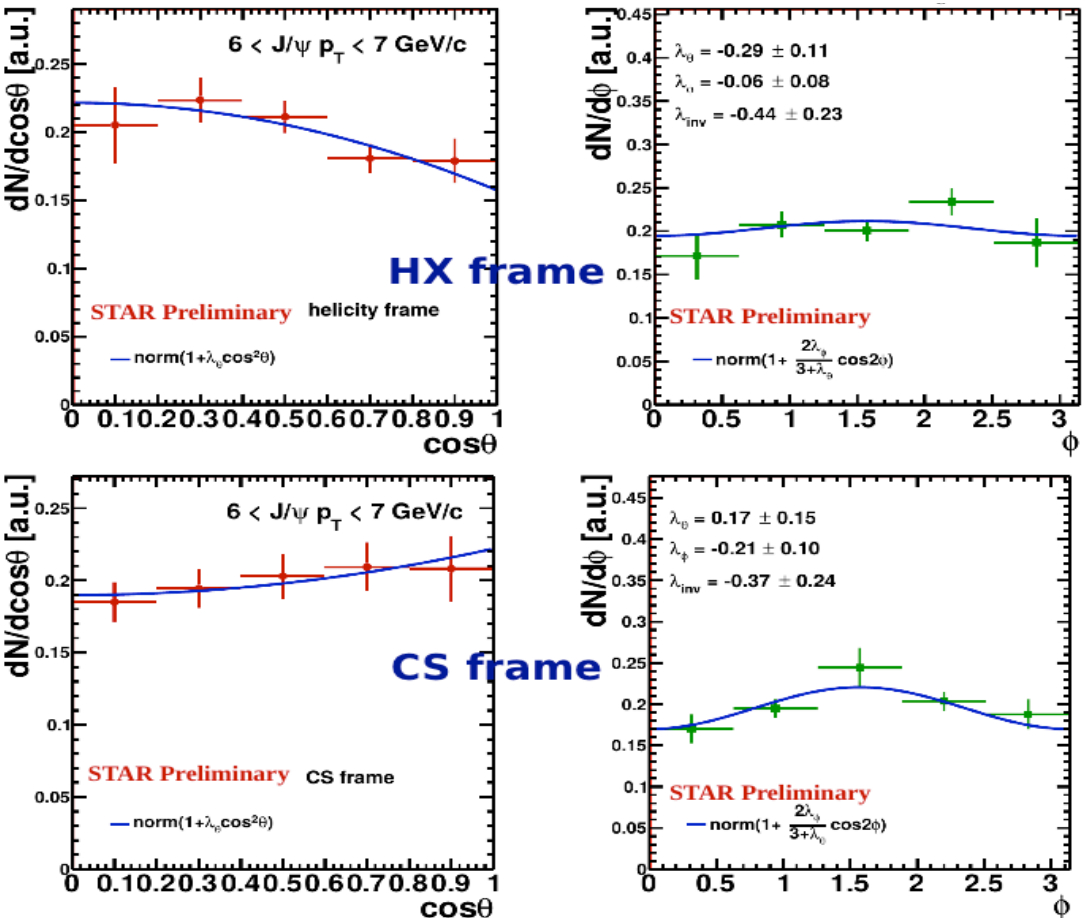
$$E/pc > 0.5 (p_T > 2GeV/c)$$

$$E > 100MeV$$

$$|1/\beta - 1| < 0.03 (p < 2GeV/c)$$

$$|y_{Local}| < 2cm$$

Corrected cosθ and φ distribution in helicity and Collins-Soper frames



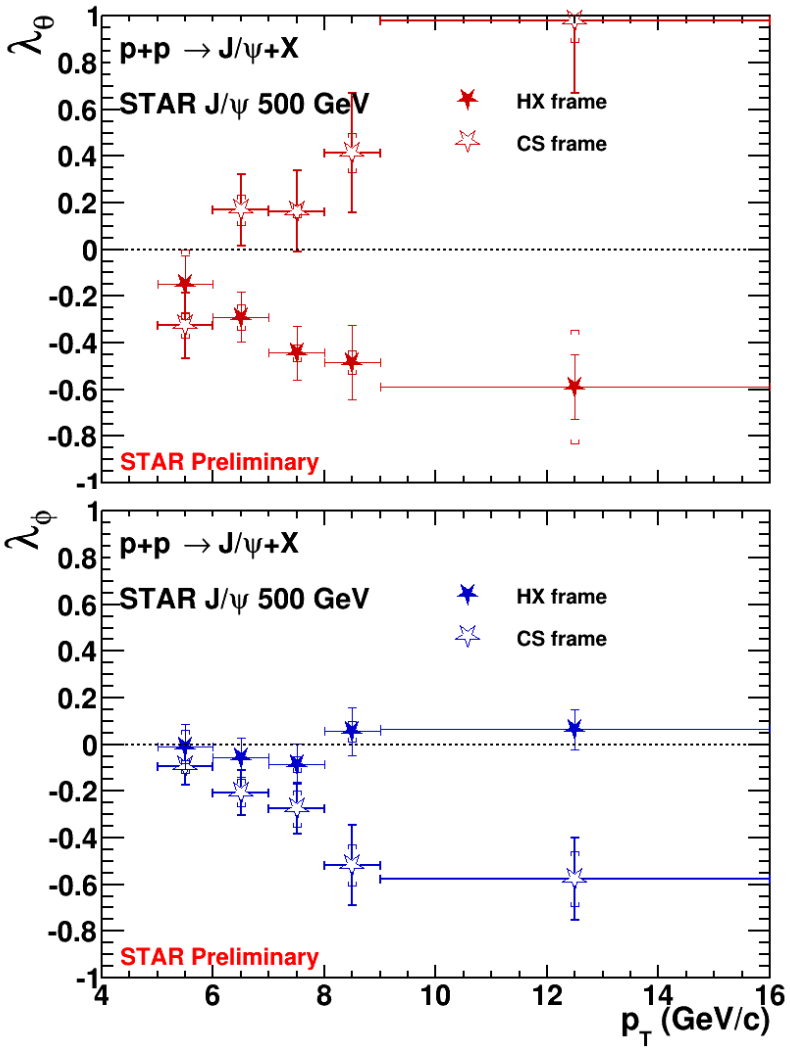
Corrected cosθ distributions in helicity and Collins-Soper frames and are fit to

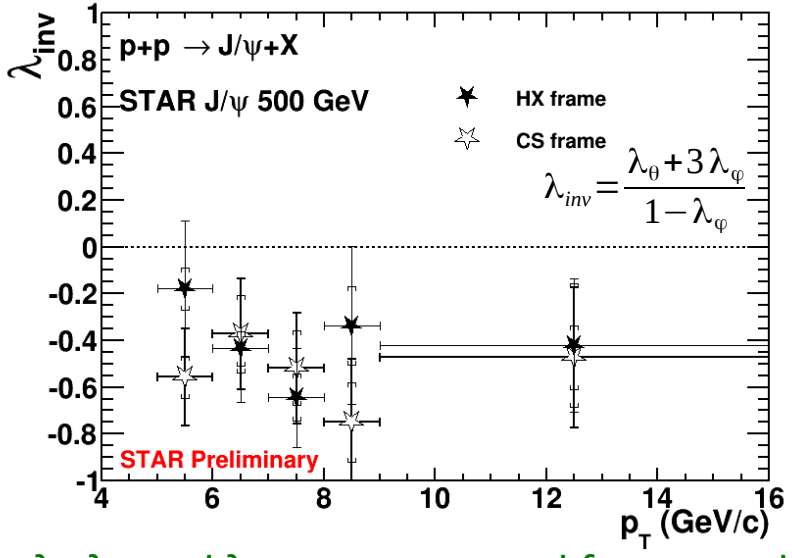
$$w(\cos\theta) \propto 1 + \lambda_\theta \cos^2\theta$$

Corrected φ distributions in helicity and Collins-Soper frames and are fit to

$$w(\varphi) \propto 1 + \frac{2\lambda_\varphi}{3+\lambda_\theta}\cos 2\varphi$$

Polarization parameters results





1. λ_θ λ_φ and λ_{inv} are extracted for p+p collisions at 500 GeV both in helicity and Collins-Soper frame using STAR Run11 data.
2. In helicity frame, λ_θ indicates a negative trend while λ_φ is consistent with 0.
3. In Collins-Soper frame λ_θ increases vs p_T , while λ_φ decreases.
4. λ_{inv} are consistent between helicity frame and Collins-Soper frame.

Summary and outlook

1. λ_θ is extracted using the STAR Run12 data up to 8 GeV/c. Results don't indicate the negative trend at high $p_{T.}$

2. Extraction of λ_φ and λ_{inv} both in helicity and Collins-Soper frames using Run12 data is underway.

3. Run15 200 GeV dataset has significantly more data sample to improve the measurement and possibly distinguish different models.

4. Expect Run17 to take about 10 times more data for pp collisions at 500 GeV.