J/ψ-pair events at NICA SPD

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SPD Physics and MC meeting

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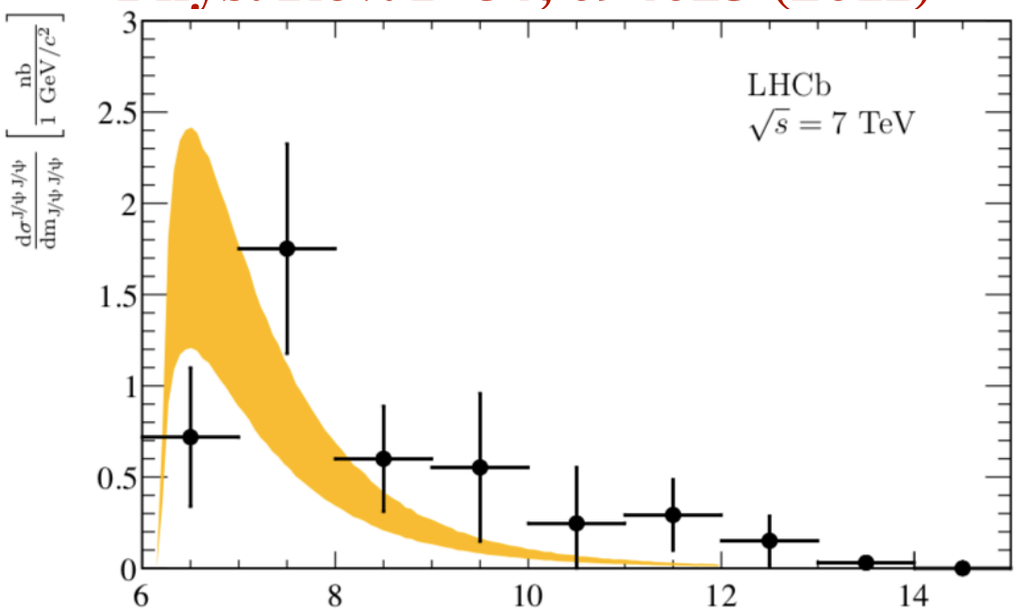
$|c\bar{c}c\bar{c}\rangle$ states

Phys. Rev. D 84, 094023 (2011)



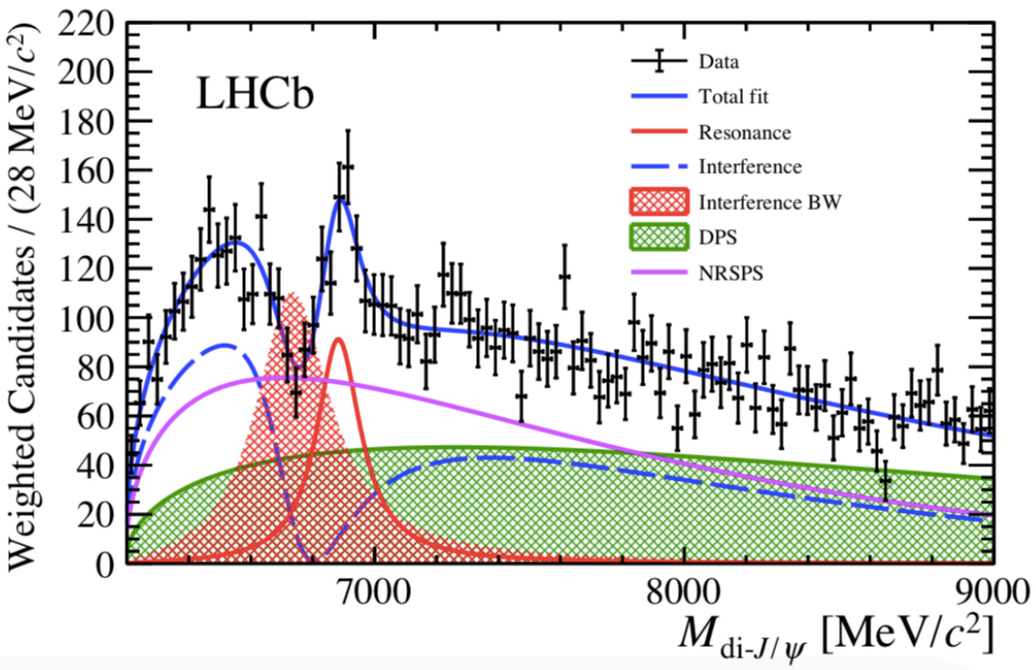
Long history of theoretical studies. Several models of $|c\bar{c}c\bar{c}\rangle$ states have been developed.

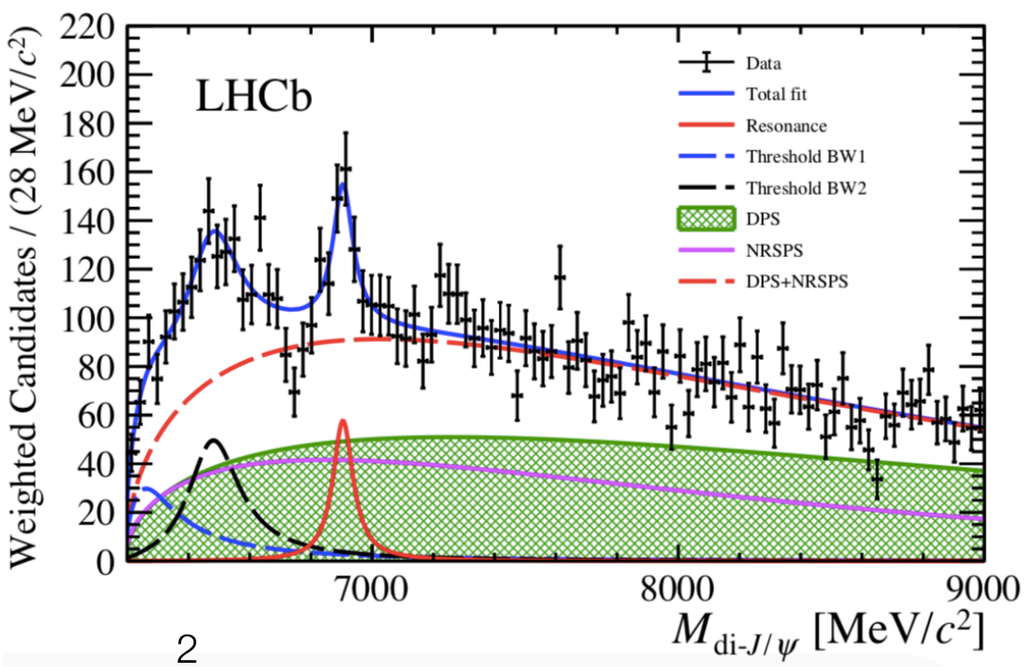
2020: first experimental indication of $T_{4c} \to 2J/\psi$:

$$m[X(6900)] = 6886 \pm 11 \pm 11 \text{ MeV}/c^2$$
$$\Gamma[X(6900)] = 168 \pm 33 \pm 69 \text{ MeV}$$

Fully charm tetraquark is the most popular model to describe the data (X(6200) and X(6900) states). More experimental data is needed.

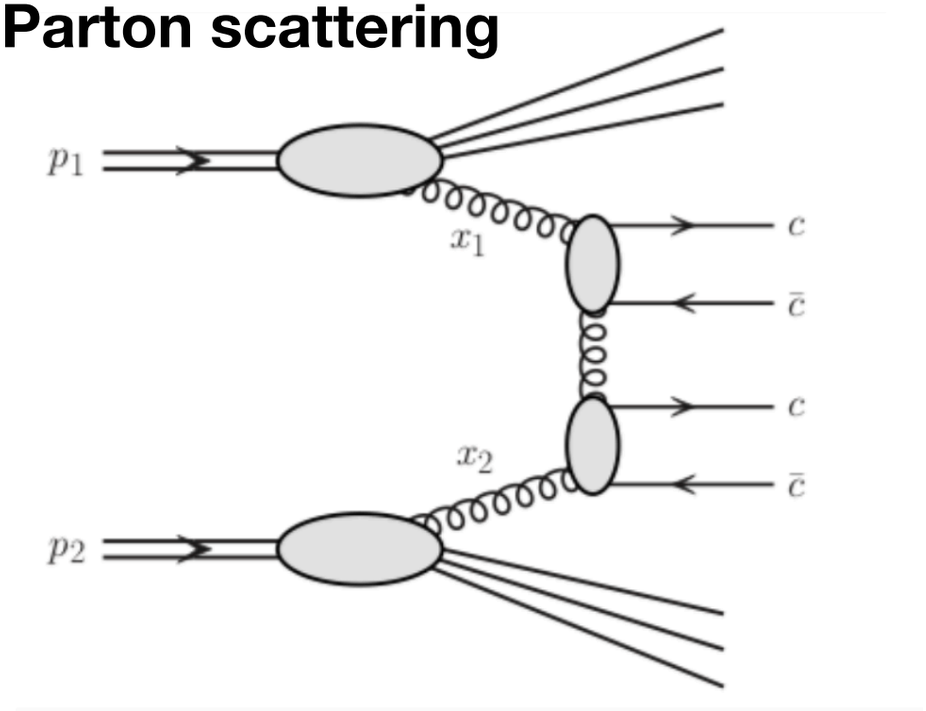
Sci. Bull., V65, №23, p1983-1993 (2020)



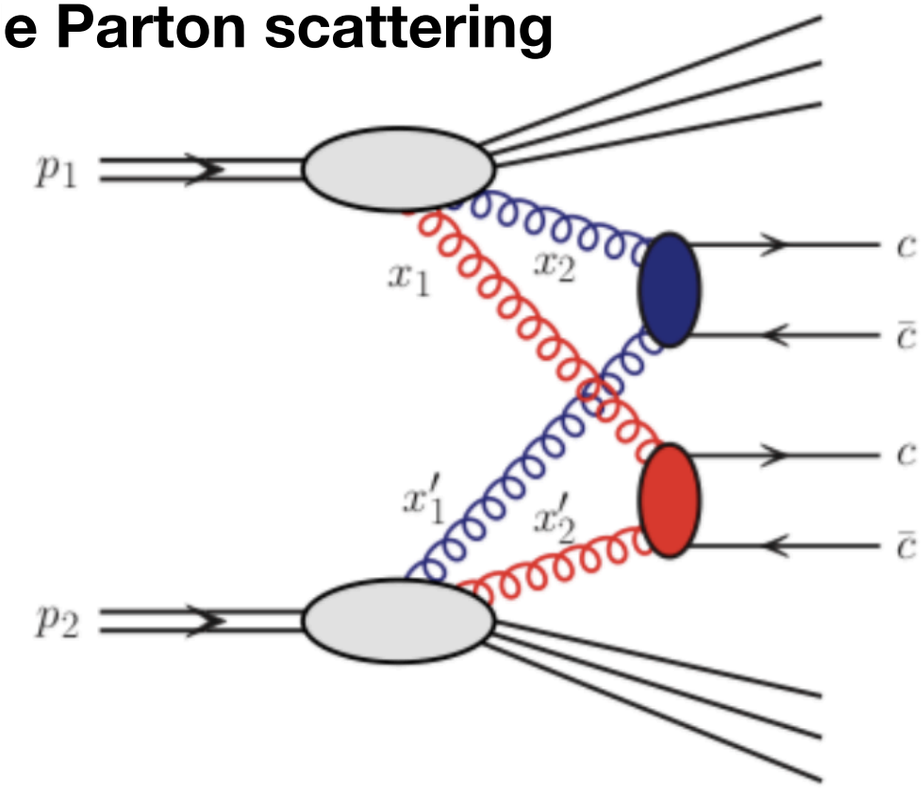


Production mechanisms

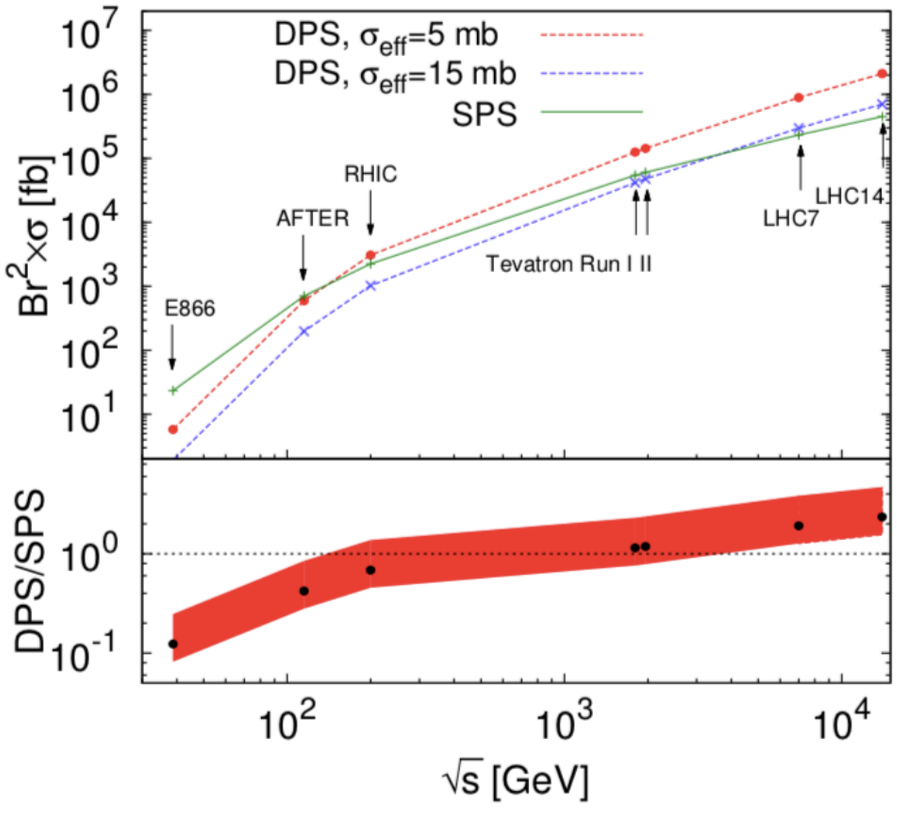
Single Parton scattering



Double Parton scattering



Nucl. Phys. B 900 (2015) 273



The DPS/SPS ratio is poorly known, but SPS is expected to be dominant mechanism at $\sqrt{s} = 27$ GeV. DPS gives an important contribution at LHC energies.

J/ψ-pair MC

Two processes contribute to J/ψ pair production: $q\bar{q} \to J/\psi J/\psi$ and $gg \to J/\psi J/\psi$.

generator	$\sigma_{2J/\psi}$
Pythia8	$q\bar{q}$: $5.592 \cdot 10^{-3} \pm 1.804 \cdot 10^{-4}$ pb
	gg: $2.960 \cdot 10^{-3} \pm 1.372 \cdot 10^{-4}$ pb
HELAC-Onia	$q\bar{q}$: $3.328 \cdot 10^{-2} \pm 4.955 \cdot 10^{-5}$ pb
	gg: $4.772 \cdot 10^{-1} \pm 1.163 \cdot 10^{-3}$ pb

The calculation of cross-section is based on paper:

Humpert and Mary, Phys, Lett. 124B (1983) 265

***Comput.Phys.Commun.* 198 (2016) 238-259**

Pythia8 (Color Singlet model) used for simulation of J/ψ pair events.

NA3 measurement:

Experiment	Energy ($\sqrt{s}$)	Process	Cross-section ($\sigma_{J/\psi J/\psi}$)
NA3	16.8 GeV	$\pi^- N \to 2J/\psi + X$	18 ± 8 pb
NA3	22.9 GeV	$\pi^- N \to 2J/\psi + X$	30 ± 10 pb
NA3	27.4 GeV	$pp \to 2J/\psi + X$	27 ± 10 pb

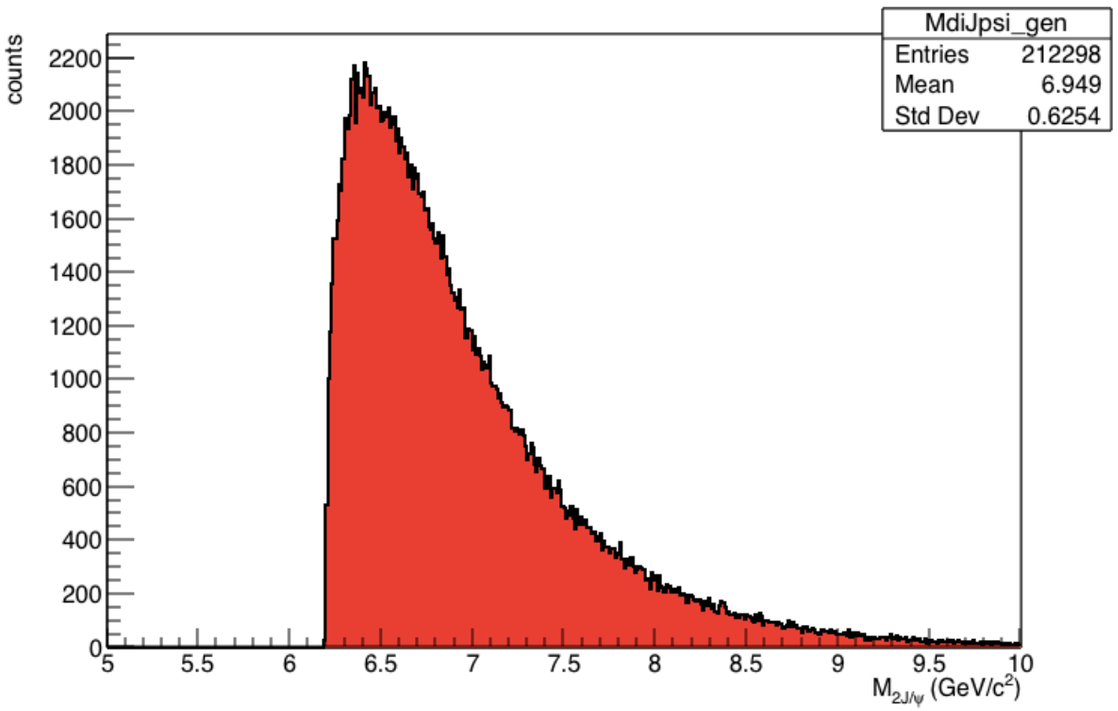
Phys Lett B, v114, No6 (1982)

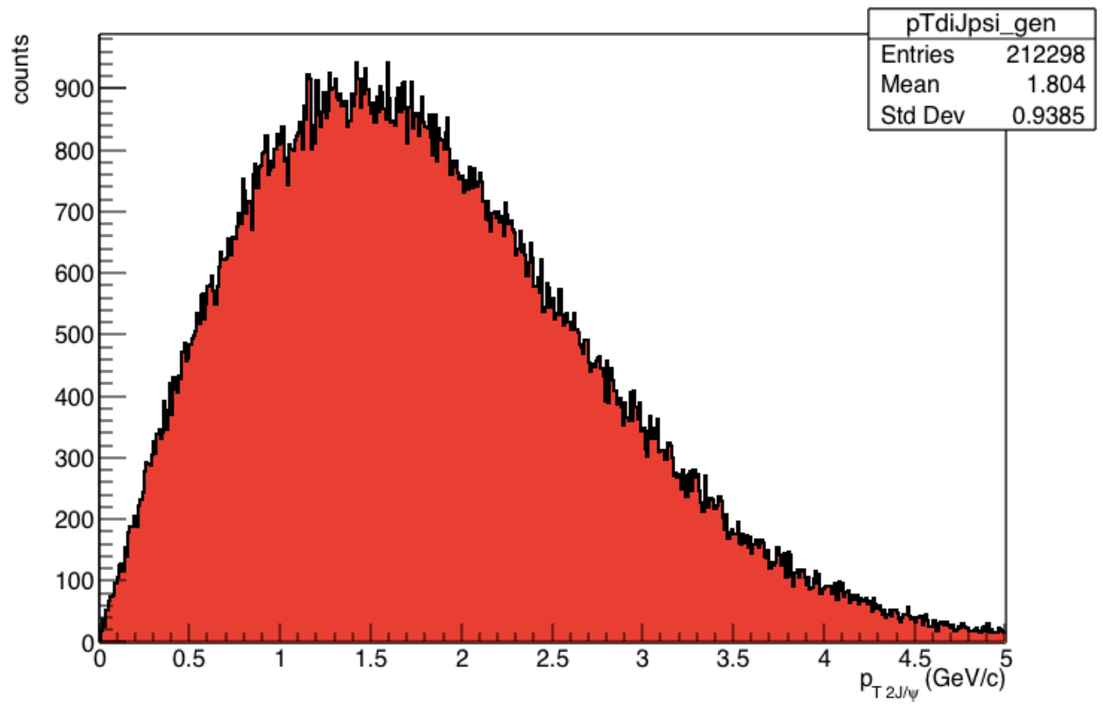
Phys Lett B, v158, No1 (1985)

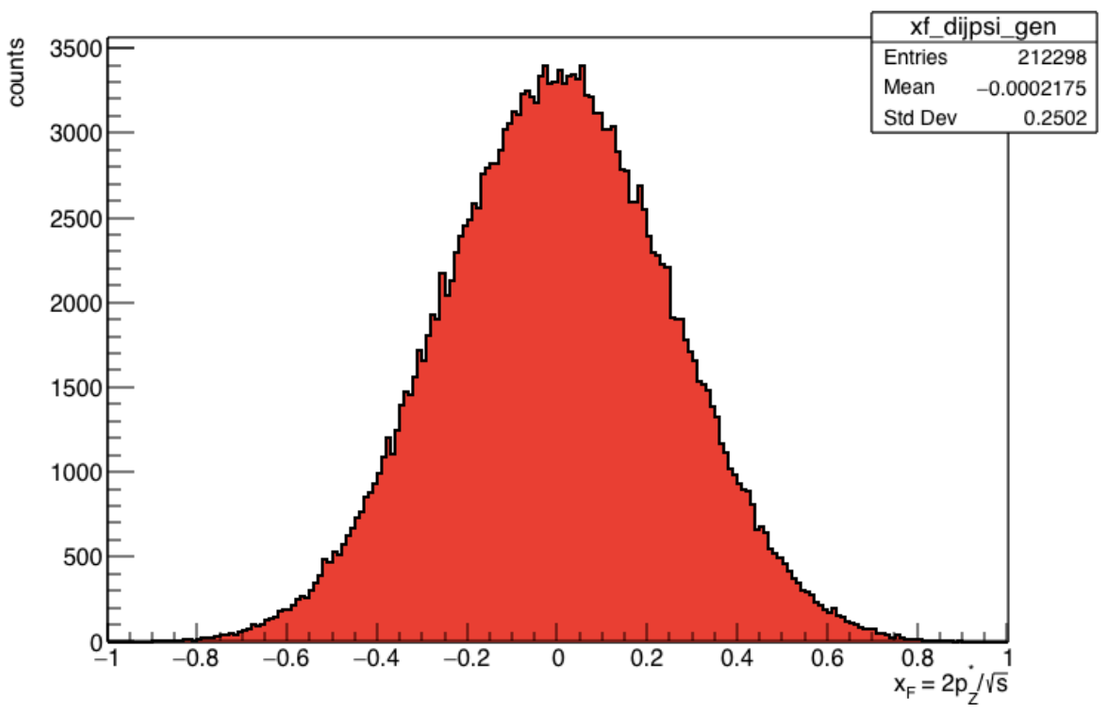
Taking $\sigma_{2J/\psi} = 27$ pb/nucleon, we can detect up to 100 events with $2J/\psi$ at SPD per year.

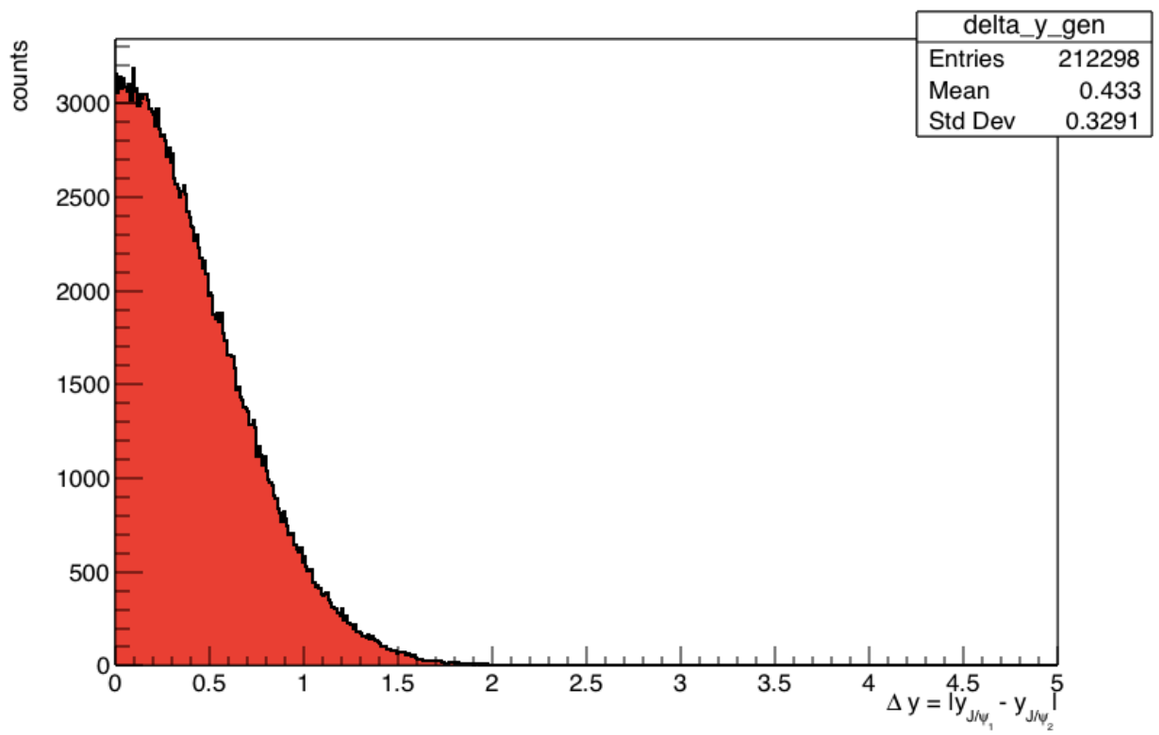
J/ψ-pair MC

Generated distributions:

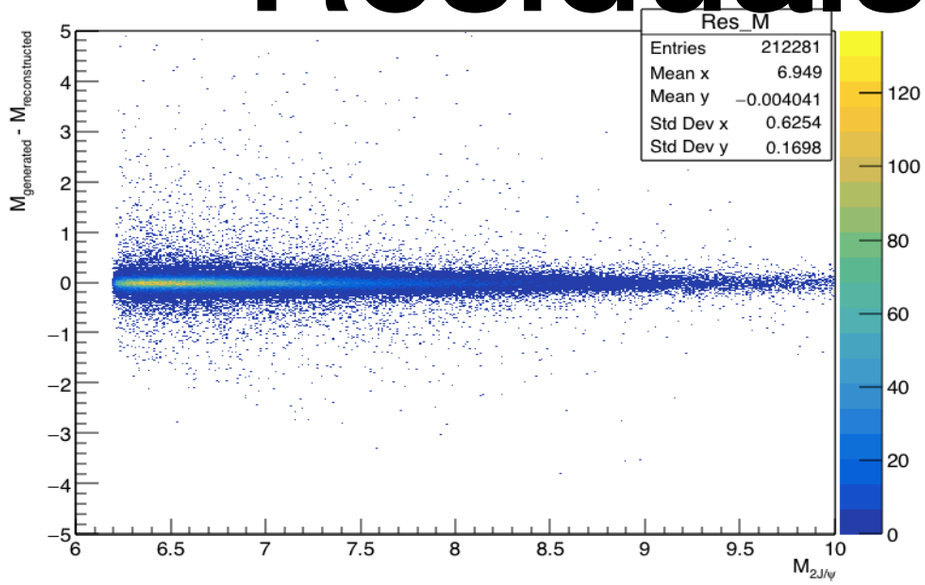


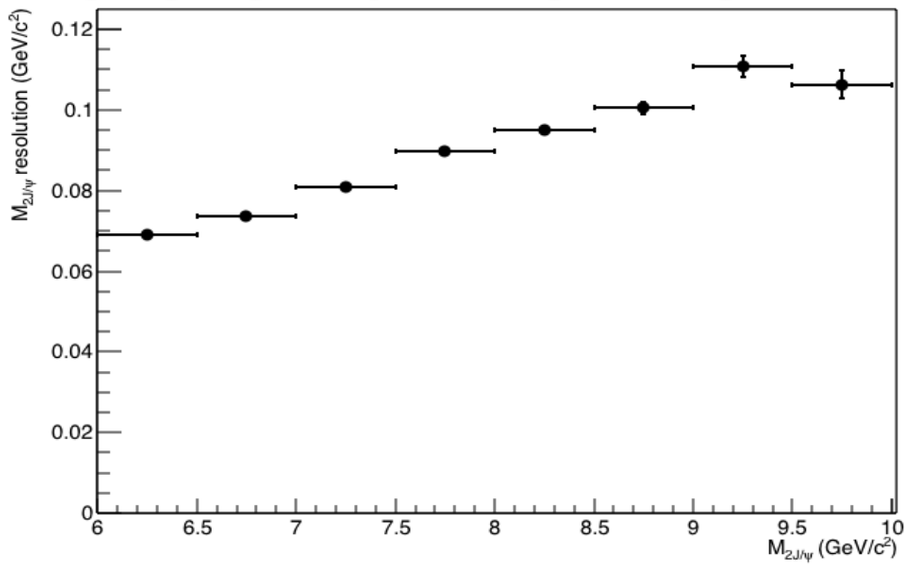


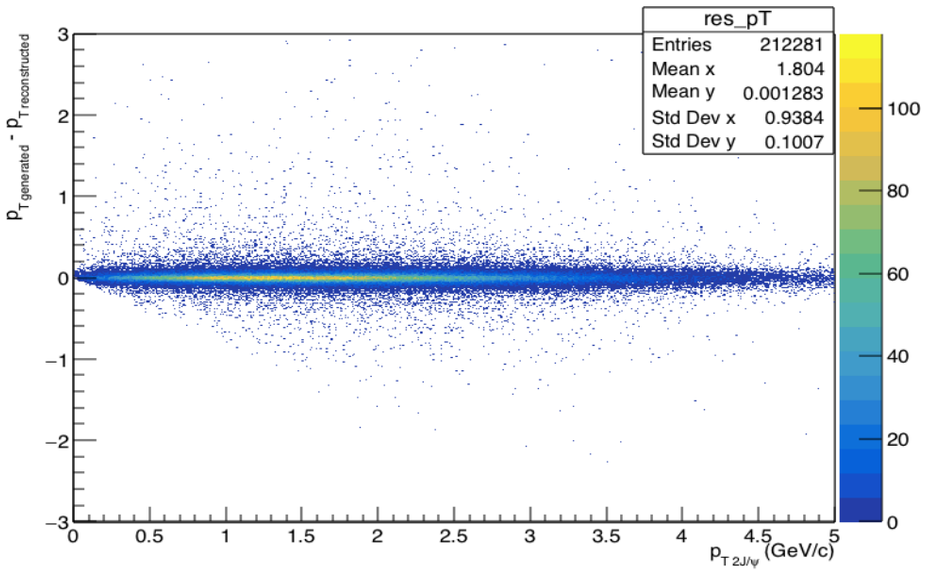


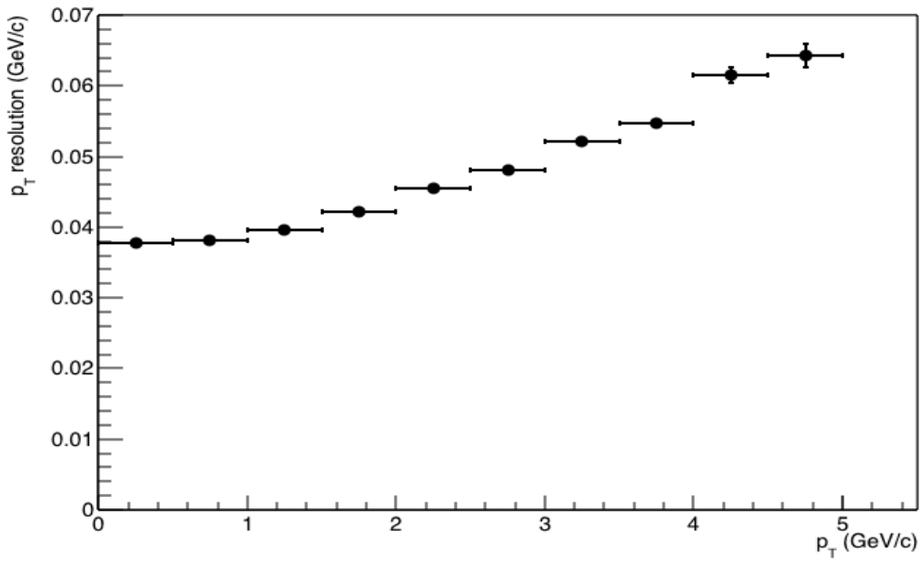


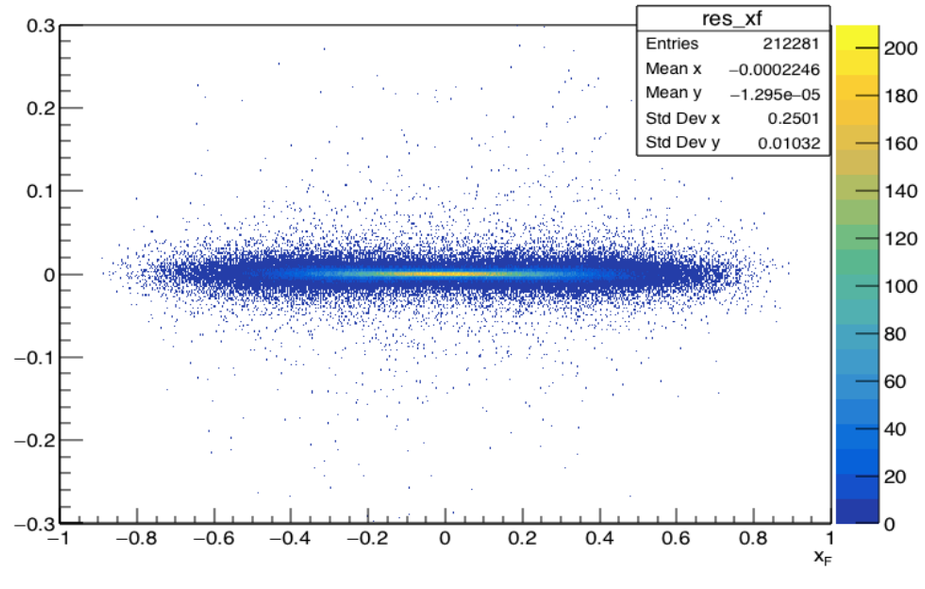
Residuals and resolutions

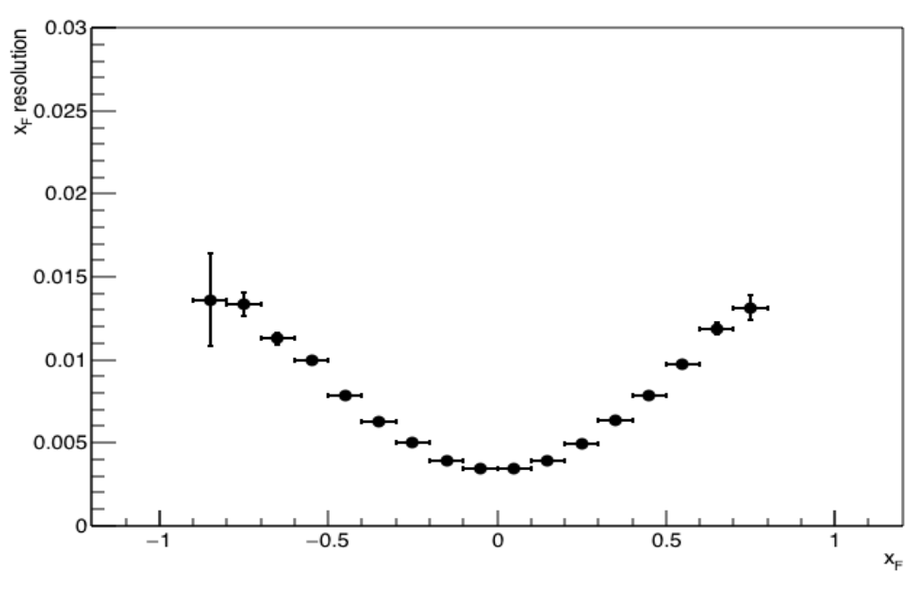




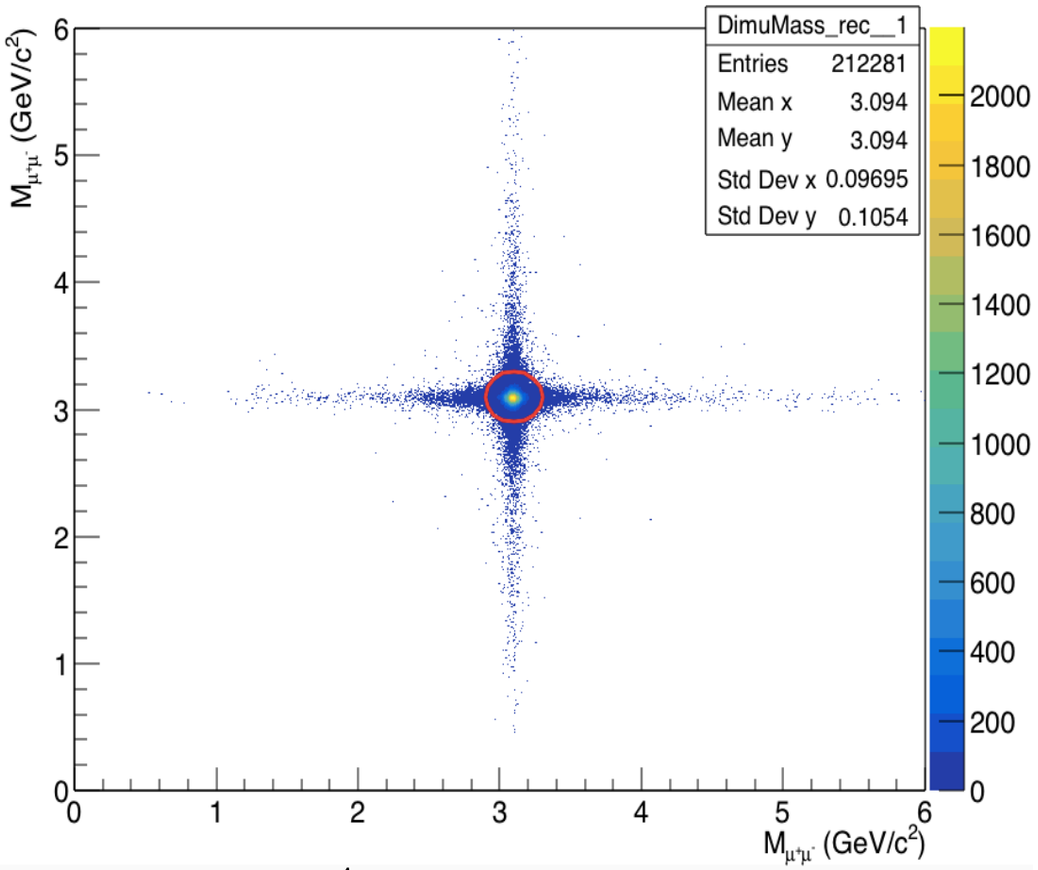




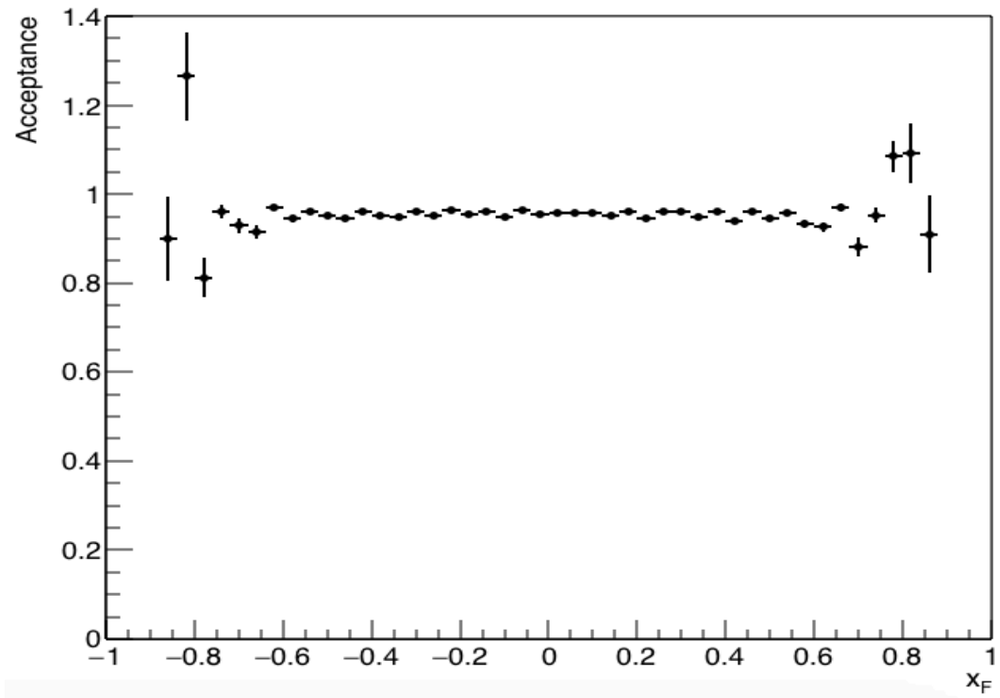




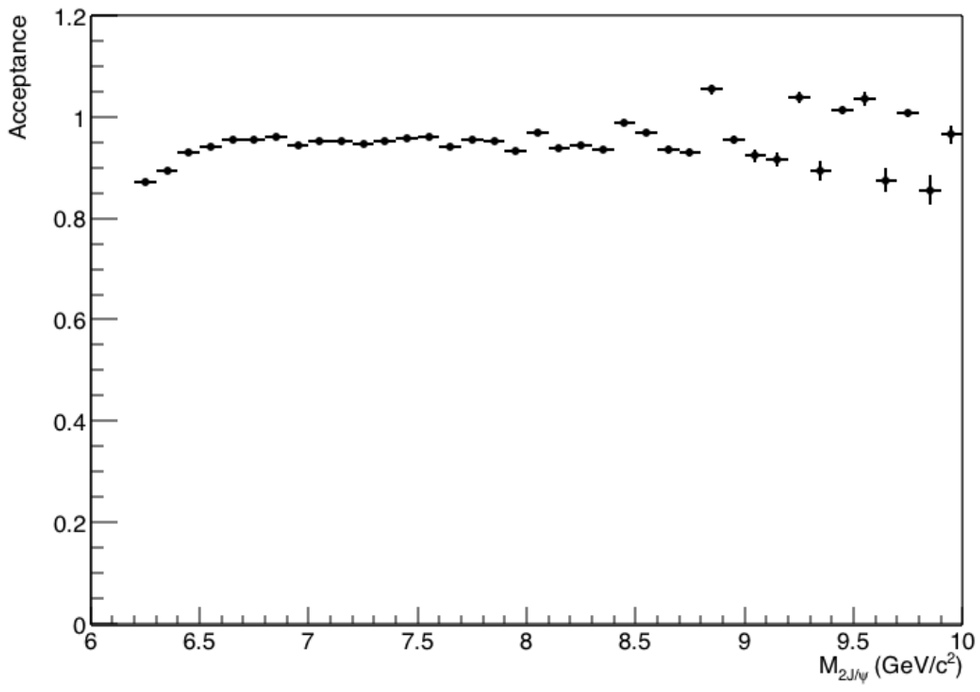
Acceptances

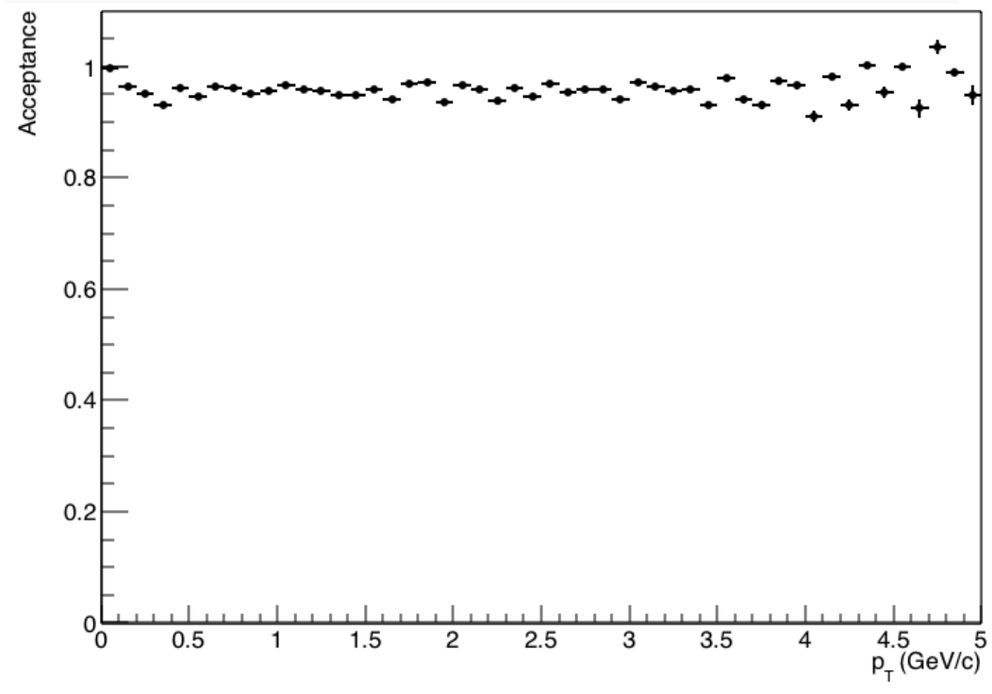


Acceptance value depends on the used selection criteria. A dimuon mass cut $\Delta M = |M_{\mu^+\mu^-} - 3.096| < 0.2\ GeV/c^2$ was applied to the reconstructed data.



Average $A_{2J/\psi}$ is 0.95





Angular distributions

	Unpolarized	Circular	Linear
Unpolarized	g(x) density		$h_1^{\perp g}(x,k_T)$ Boer-Mulders function
Longitudinal		$\Delta g(x)$ helicity	Kotzinian-Mulders function
Transverse	$\Delta_N^g(x,k_T)$ Sivers function	Worm-gear function	$\Delta_T g(x)$ transversity (deuteron only), pretzelosity

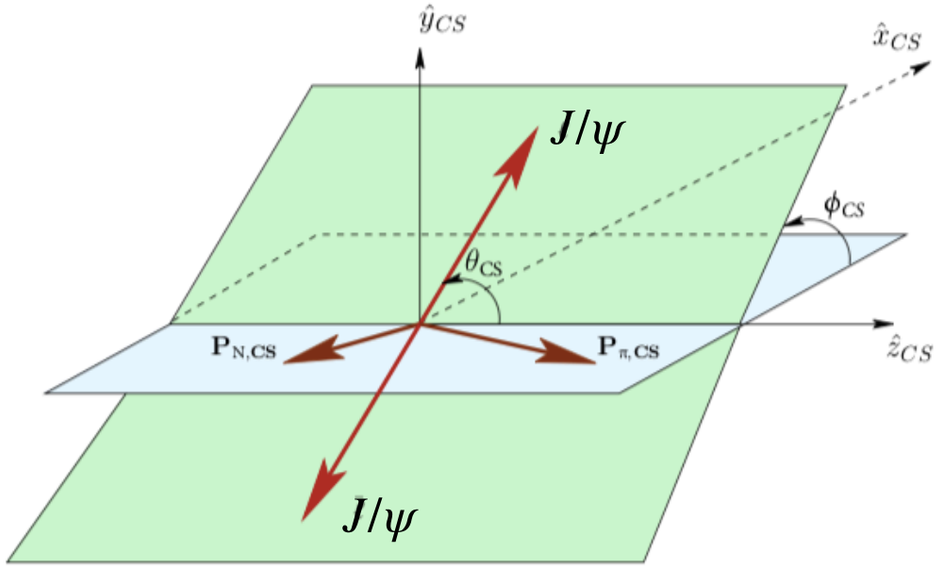
J/ψ pair production process could be used to probe linearly polarized gluons in unpolarized proton ($h_1^{\perp g}(x,k_T)$).

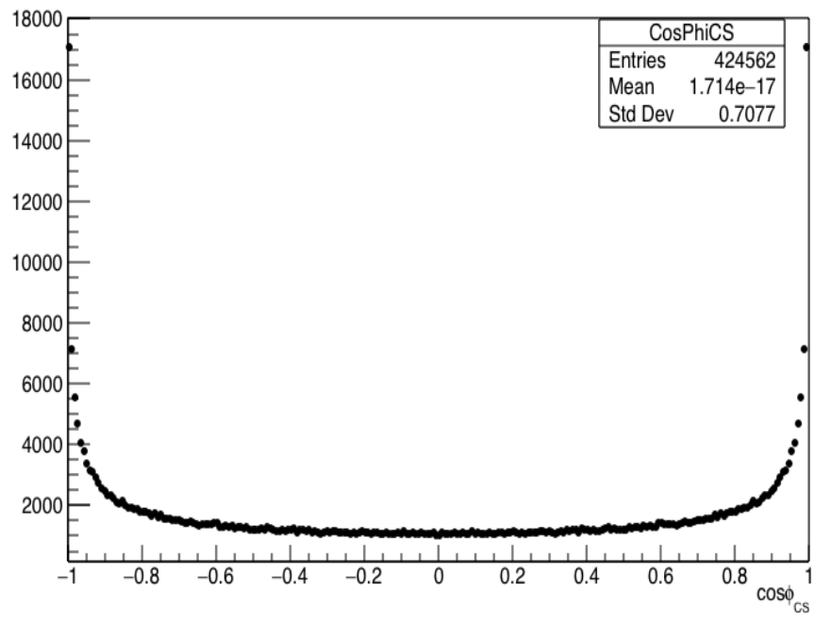
Drell-Yan process allows to access the Boer-Mulders function and characterized by ϕ_{CS}.

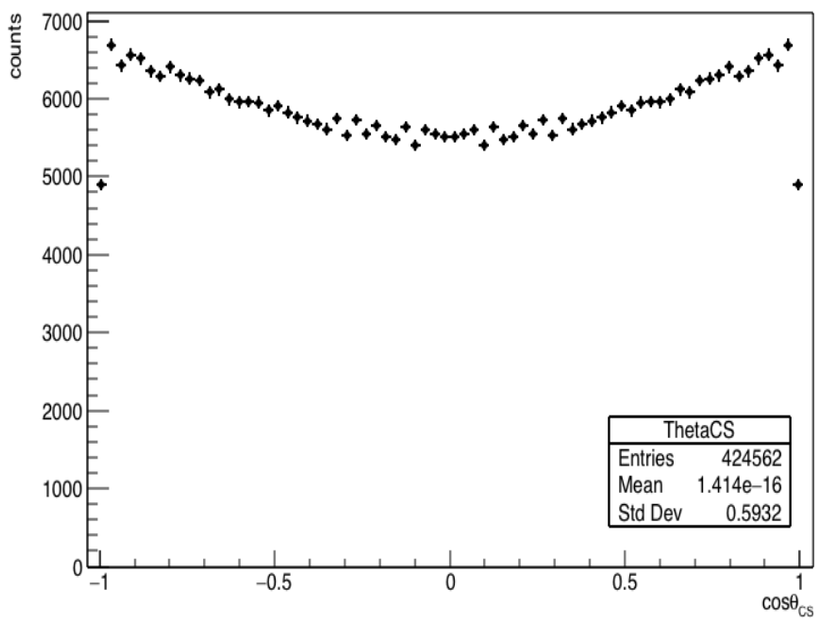
Collins-Soper frame:

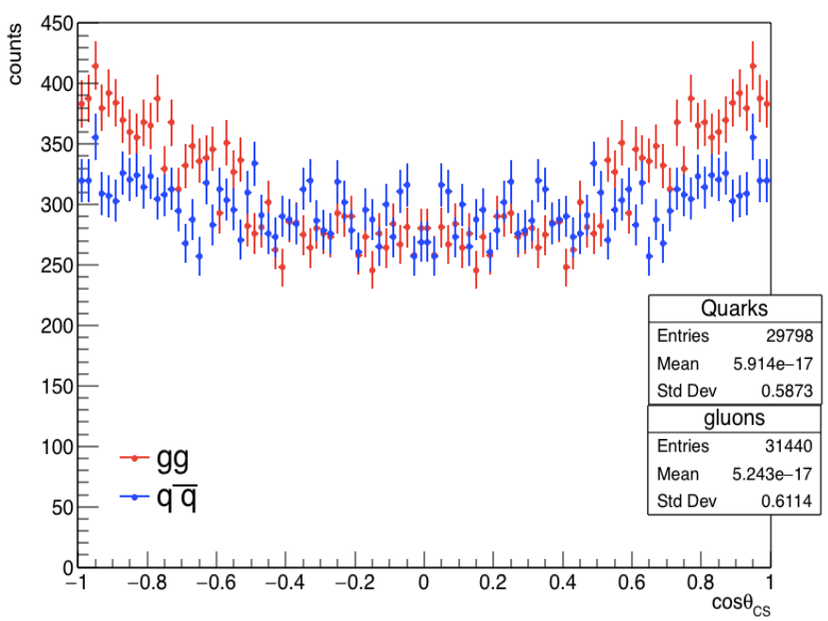
$$\hat{z} = \frac{P_b}{|P_b|} - \frac{P_a}{|P_a|},$$

where $\vec{P}_a$ and $\vec{P}_b$ are the 3-momenta of each beam boosted into 2J/ψ rest frame. θ_{CS} is the angle between J/ψ boosted into double J/ψ rest frame and $\hat{z}$.









Summary

- J/ψ pair production allows to study different physics: production mechanisms, exotic charmonia, gluon TMDs.

- The process is rare. At SPD we can expect not more than 100 double J/ψ events (per year).

- More data on double charmonium and bottomonium production are needed.