Double J/ψ production in pion-nucleon scattering at COMPASS

Andrei Gridin (JINR, Dubna)
andrei.gridin@cern.ch

2nd COMPASS "Analysis Phase" mini-workshop (COMAP-2023 II)
07.03.2023

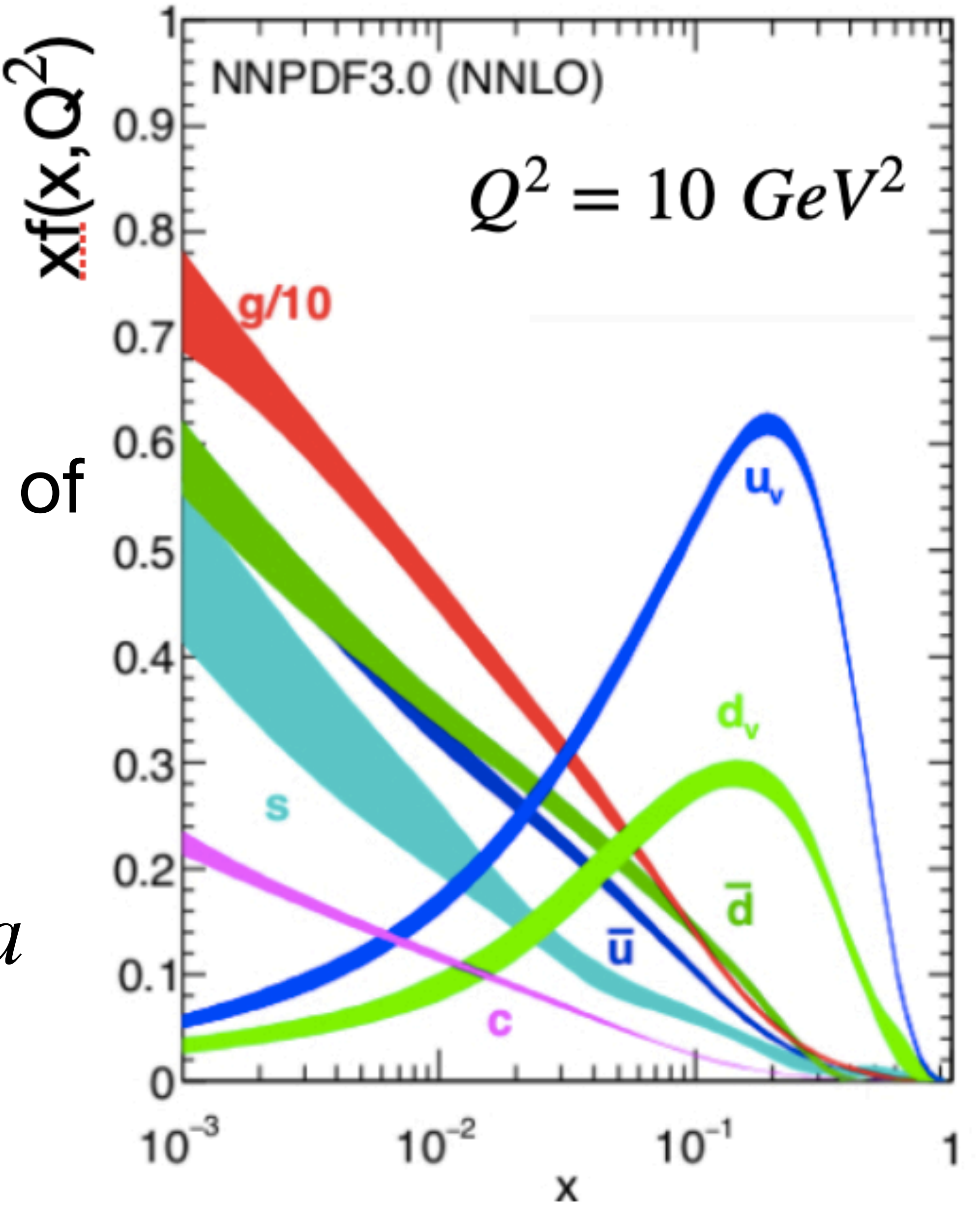
Motivation

J/ψ pair production process allows to study:
— production mechanisms: single parton scattering (SPS), double parton scattering (DPS);
— intrinsic charm of hadrons (IC);
— decay of high mass states (η_b, $\chi_{b_{0,1,2}}$) to J/ψ pair;
— exotic states that decay to J/ψ pair.

Hadron structure

The quark-parton model: inside of a hadron there are

- valence quarks,
- gluons,
- sea quarks.



QCD describes the processes at $\alpha_S(Q^2) < 1$.

At large distances the cross section of interaction of A and B hadrons could be written as

$$\sigma_{AB} \sim \sum_{a,b} \int dx_a \int dx_b f_a^A(x_a) f_b^B(x_b) \hat{\sigma}_{ab},$$

where $\hat{\sigma}_{ab}$ — hard cross section of interaction of a and b partons.

Intrinsic charm of hadron

- The original model of IC was developed for proton to explain CERN ISR data.
- The existence of non-perturbative (intrinsic) Fock component in a hadron with c-quarks is postulated:

$$|p\rangle \sim |uud> + |uudg> + |uudc\bar{c}\rangle + \dots$$

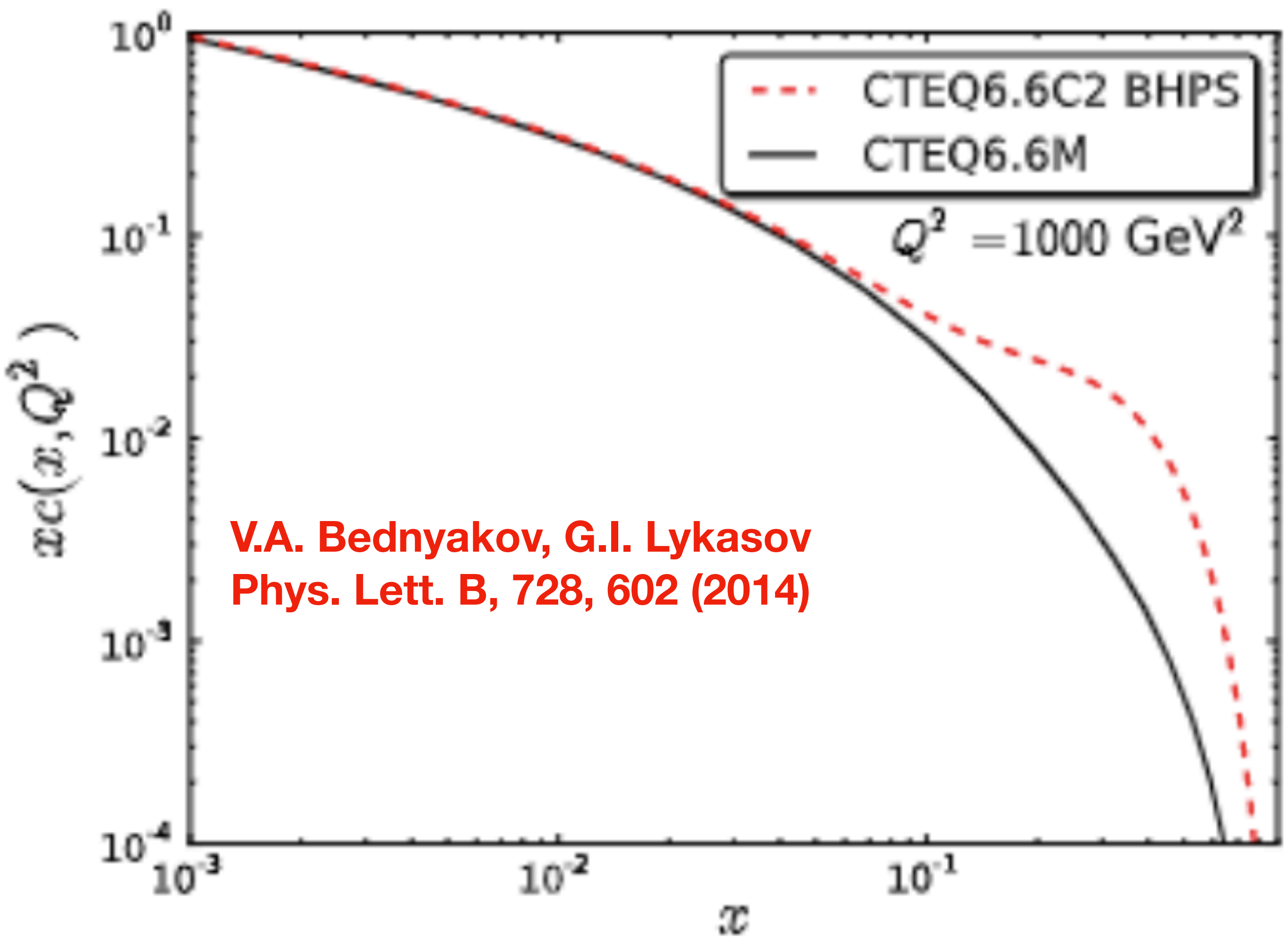
- Intrinsic charm contribution is generated non-perturbatively via $gg \to Q\bar{Q}$.
- The probability to find intrinsic charm in a proton was estimated to be $1\,\%$.

BHPS model:
S.J. Brodsky et al,
Phys. Lett. B 93, 451 (1980)

S.J. Brodsky et al,
Phys.Rev.D 23 (1981) 2745

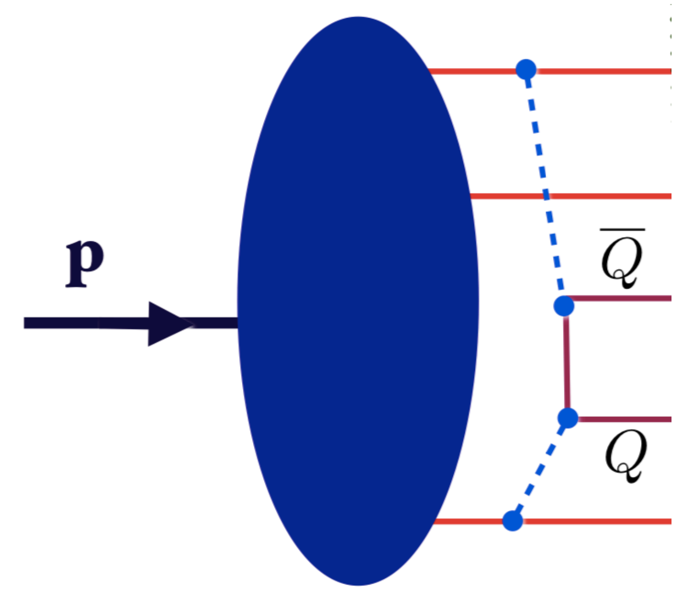
Intrinsic charm of a proton

- Beside of intrinsic charm ($gg \to Q\bar{Q}$) there is extrinsic charm component in hadrons that arises from gluon splitting ($g \to Q\bar{Q}$).
- Valence-like intrinsic charm quarks carry the most part of hadron momentum.

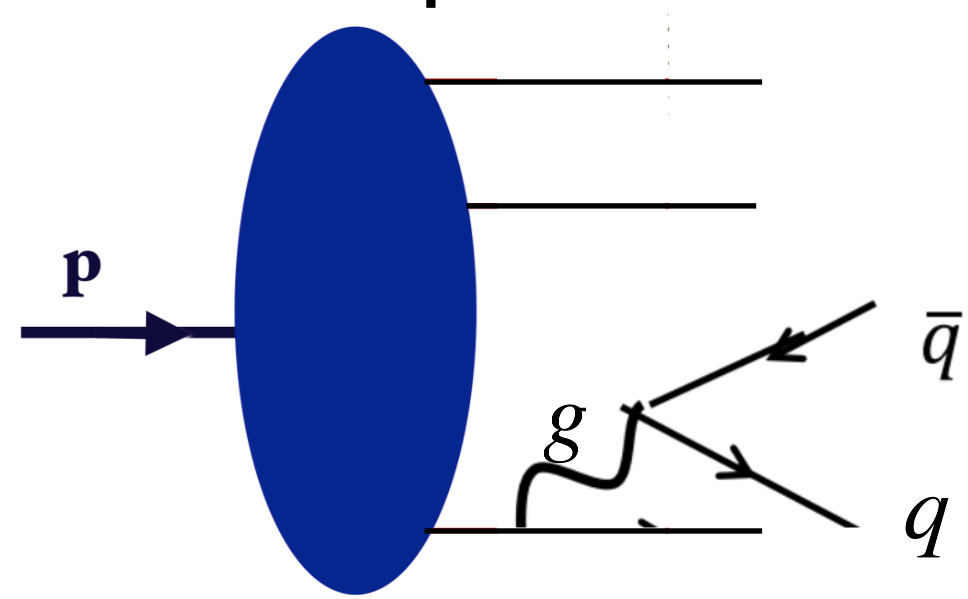


V.A. Bednyakov, G.I. Lykasov
Phys. Lett. B, 728, 602 (2014)

Intrinsic charm



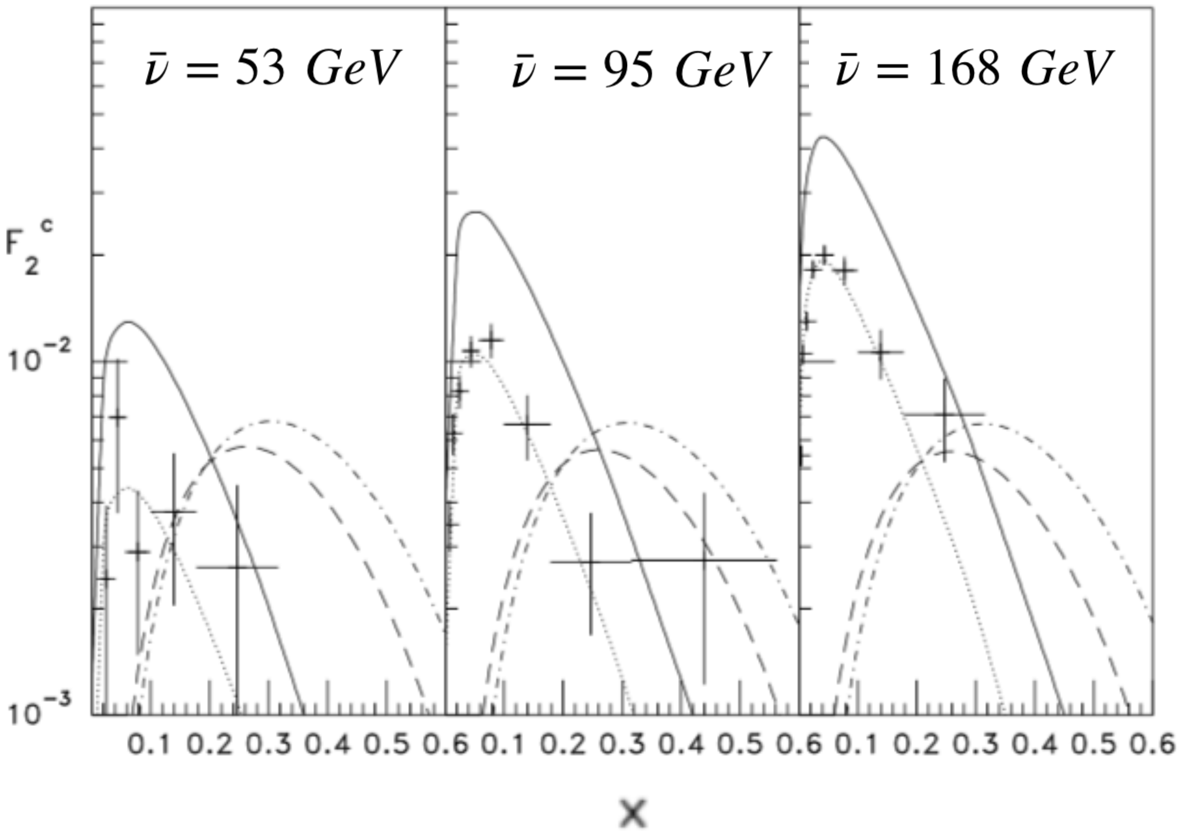
Sea quarks



IC and baryon structure

- **EMC experiment:** an evidence for an intrinsic charm component in the proton was found from the comparison of EMC data for $F_2(x, Q^2, m_c^2)$ with NLO predictions at large x.

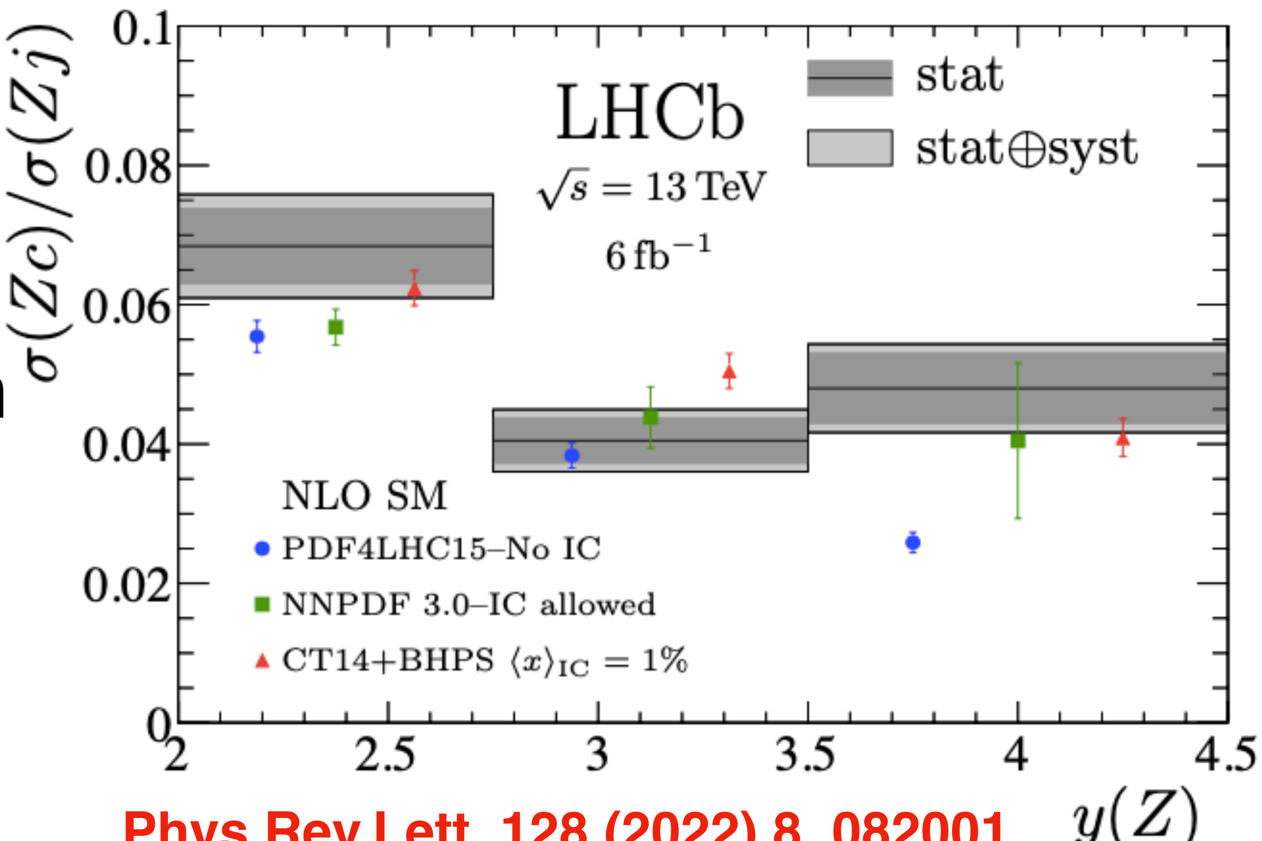
B. W. Harris, J. Smith, R.Vogt
Nucl.Phys.B 461 (1996) 181-196



— EC LO
— EC NLO
— 1% IC LO
— 1% IC NLO

- **LHCb: Z + charm jet**

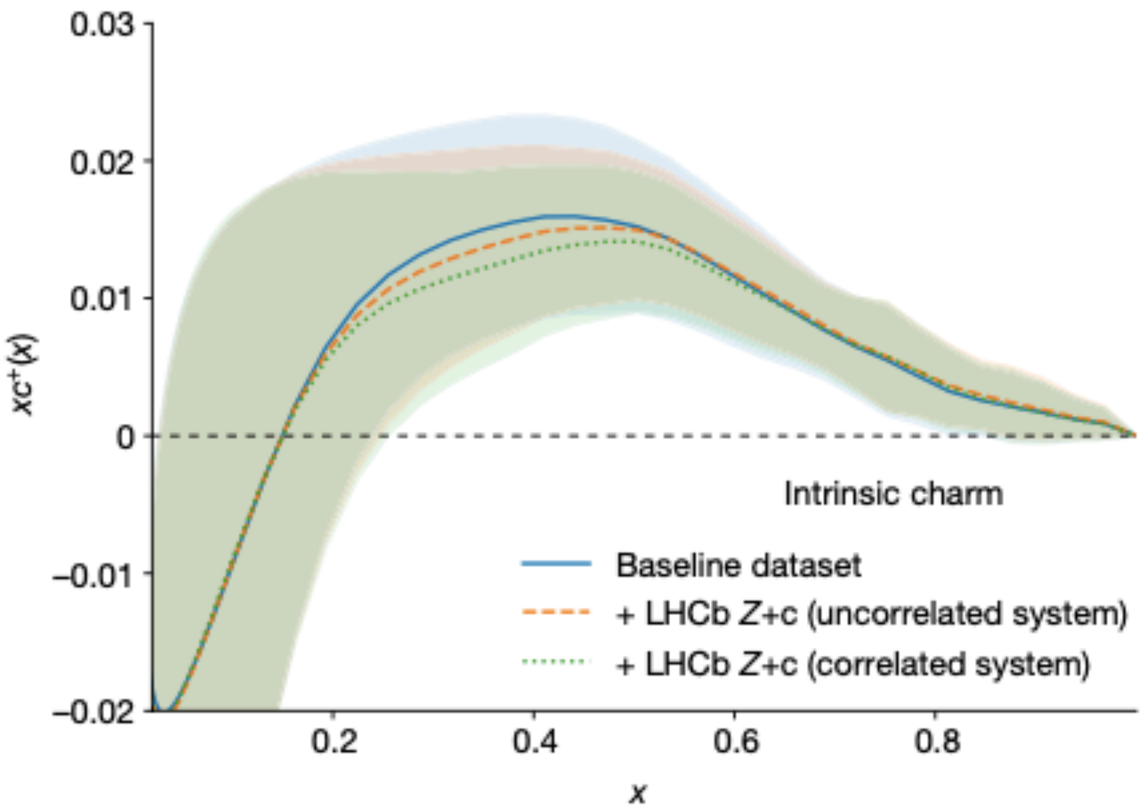
Z-boson and a charm jet production data are consistent with the effect expected if the proton wave function contains the $|uudc\bar{c}\rangle$ component predicted by BHPS.



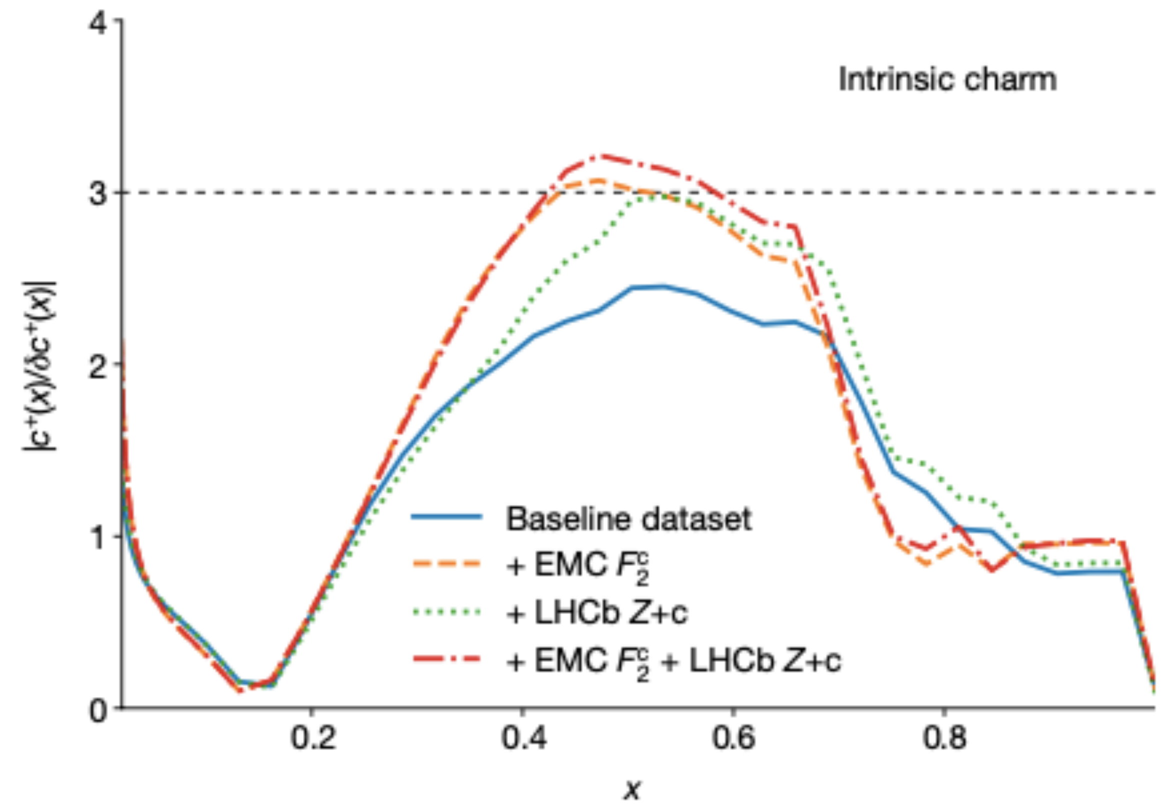
Phys.Rev.Lett. 128 (2022) 8, 082001

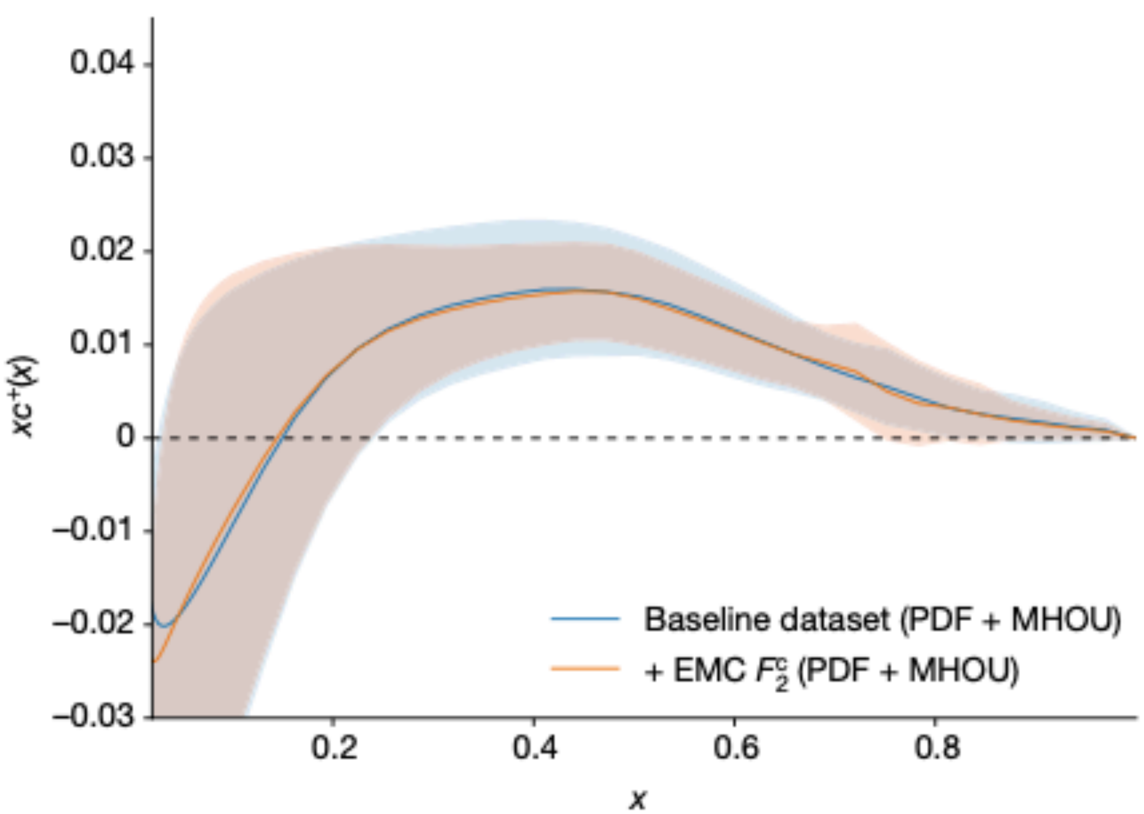
Intrinsic charm of a proton

NNPDF collaboration
Nature 608 (2022) 7923, 483-487



Statistical significance





LHCb and EMC data were included into parton distribution functions NNPDF4.0. The existence of intrinsic charm of proton is established at 3σ level.

J/ψ pair production

J/ψ pair events at NA3

NA3 (1982) Phys Lett B, v114, No6

$$\pi^- N \rightarrow 2J/\psi + X$$

$\sigma_{2J/\psi}(280\ GeV/c) = 30 \pm 10\ pb/nucleon$

$\sigma_{2J/\psi}(150\ GeV/c) = 18 \pm 8\ pb/nucleon$

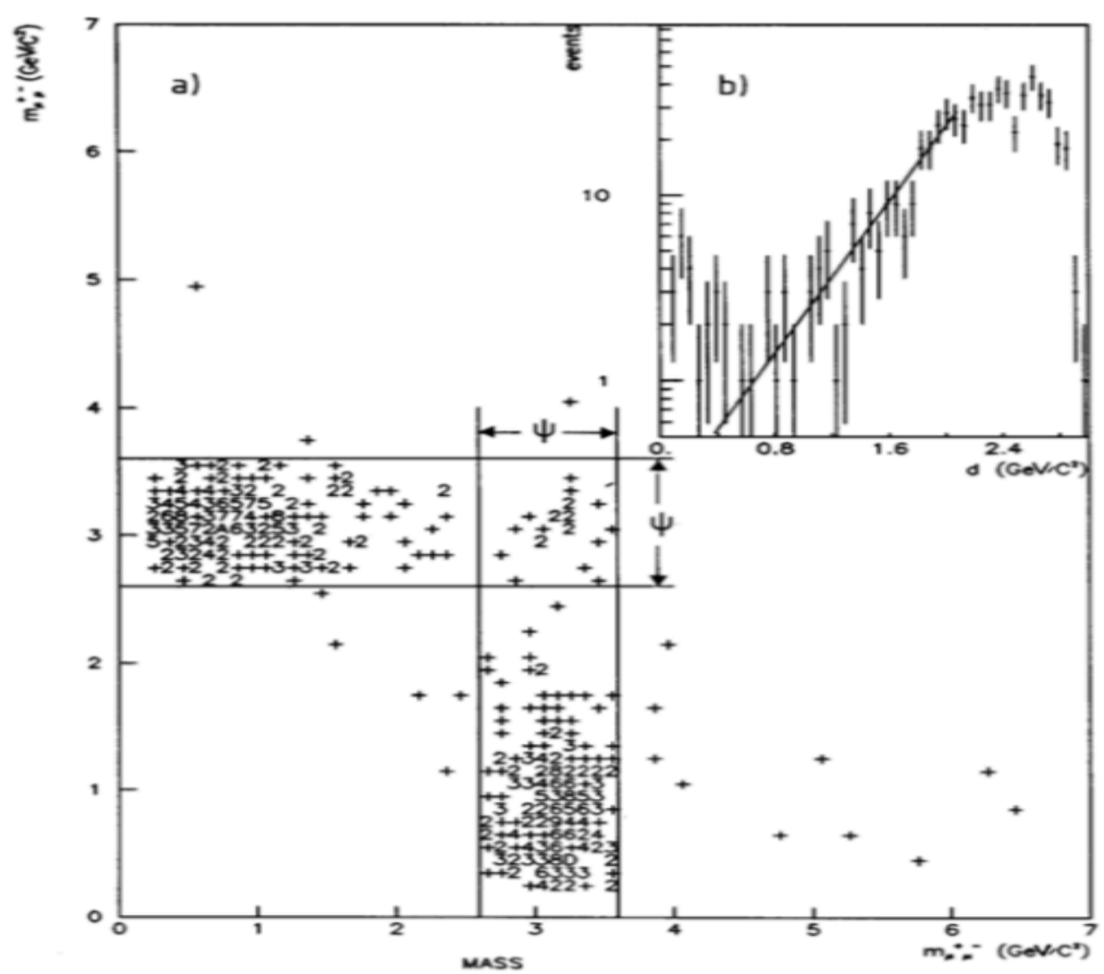
Kinematical properties of the 13 $\psi\psi$ events observed in our experiment. P_z is given in the laboratory frame.

	$P^{\psi}_{x_1}$	$P^{\psi}_{y_1}$	$P^{\psi}_{z_1}$	$P^{\psi}_{x_2}$	$P^{\psi}_{y_2}$	$P^{\psi}_{z_2}$	$M_{\psi_1\psi_2}$	$P^{T}_{\psi_1\psi_2}$
π^- 280 GeV/c	0.90	−1.52	80.15	−0.398	1.67	44.89	7.39	0.52
	−1.41	−0.98	46.52	2.31	0.21	107.04	7.84	1.18
	−0.34	−0.48	43.49	1.01	1.79	105.96	7.18	1.47
	−0.55	−0.13	138.55	1.16	0.55	75.81	6.83	0.74
	1.37	0.58	41.38	−0.87	−0.91	151.79	8.31	0.60
	0.46	0.87	99.72	0.22	−0.49	36.14	7.14	0.78
	−1.27	1.20	78.14	0.09	−0.95	63.28	6.71	1.20
π^- 150 GeV/c	2.86	−1.14	58.15	−1.72	1.93	77.19	8.43	1.39
	0.13	0.36	28.17	−1.09	0.54	87.73	7.28	1.32
	1.59	1.11	48.59	−1.14	−1.19	53.73	7.17	0.46
	1.33	0.54	39.50	−0.61	0.18	78.89	6.99	1.02
	−0.52	1.56	46.78	0.60	−1.65	78.28	7.30	0.12
	0.60	0.49	75.49	−0.84	−1.67	23.62	8.17	1.20

NA3 (1985) Phys Lett B, v158, No1

$$pp \rightarrow 2J/\psi + X$$

$\sigma_{2J/\psi}(400\ GeV/c) = 27 \pm 10\ pb/nucleon$



J/ψ pair events at NA3

Phys.Lett.B349:569-575,1995

All J/ψ pair events observed by NA3 were interpreted using intrinsic charm hypothesis ($|d\bar{u}c\bar{c}c\bar{c}\rangle$ Fock component of pion).

Kinematic distributions are not corrected for the acceptance;

Intrinsic Charm Contribution to Double Quarkonium Hadroproduction*

R. Vogt

Nuclear Science Division, Lawrence Berkeley Laboratory, Berkeley, CA 94720, USA

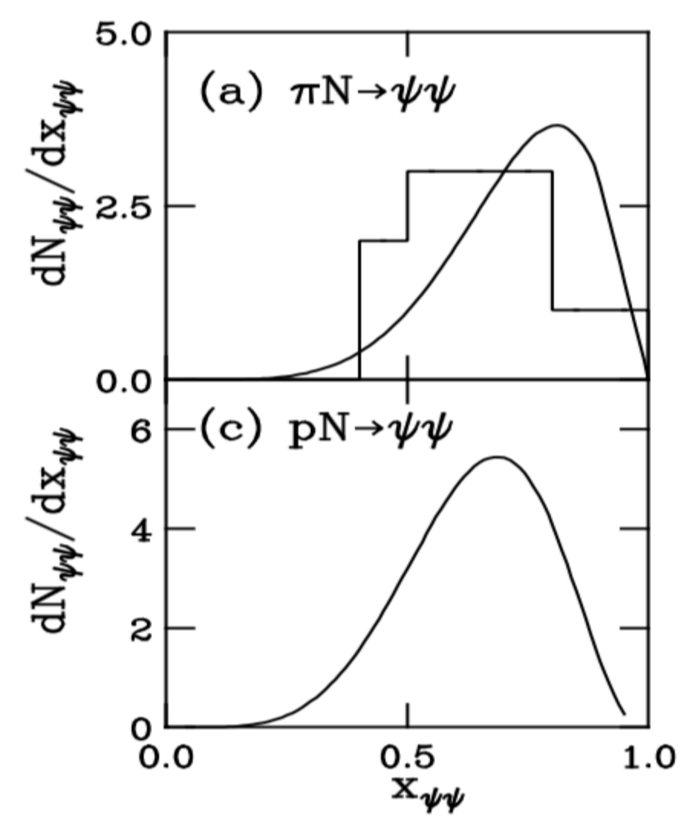
and

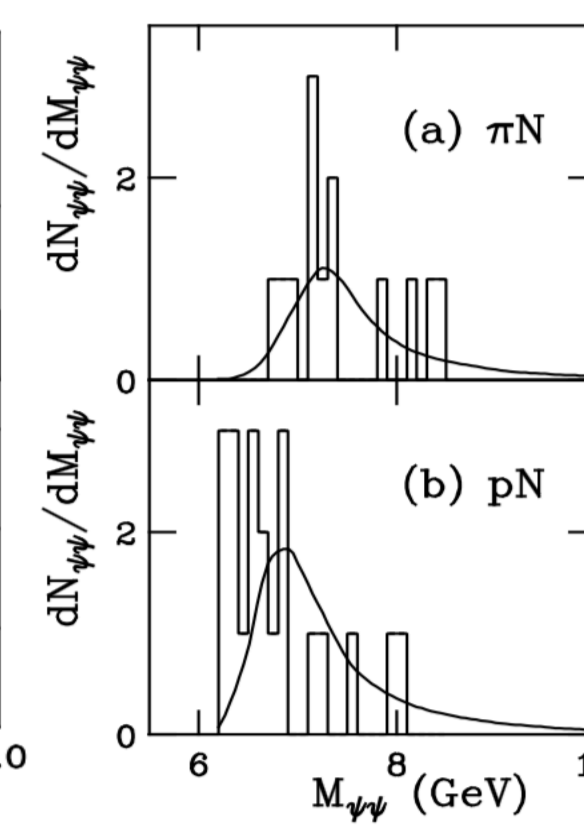
Institute for Nuclear Theory, University of Washington, Seattle, WA 98195, USA

S. J. Brodsky

Stanford Linear Accelerator Center, Stanford University, Stanford, CA 94309, USA

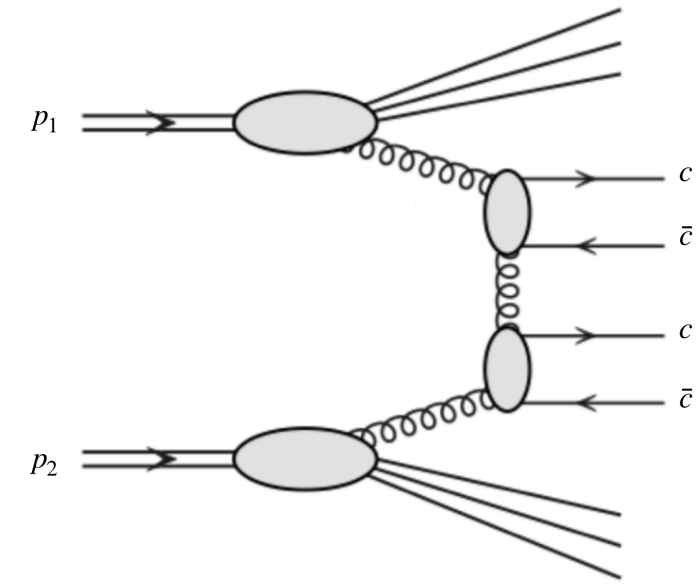
Double J/ψ production has been observed by the NA3 collaboration in πN and pN collisions with a cross section of the order of 20-30 pb. The $\psi\psi$ pairs measured in π^- nucleus interactions at 150 and 280 GeV/c are observed to carry an anomalously large fraction of the projectile momentum in the laboratory frame, $x_{\psi\psi} \geq 0.6$ at 150 GeV/c and ≥ 0.4 at 280 GeV/c. We postulate that these forward $\psi\psi$ pairs are created by the materialization of Fock states in the projectile containing two pairs of intrinsic $c\bar{c}$ quarks. We calculate the overlap of the charmonium states with the $|\bar{u}dc\bar{c}c\bar{c}\rangle$ Fock state as described by the intrinsic charm model and find that the $\pi^- N \to \psi\psi$ longitudinal momentum and invariant mass distributions are both well reproduced. We also discuss double J/ψ production in pN interactions and the implications for other heavy quarkonium production channels in QCD.





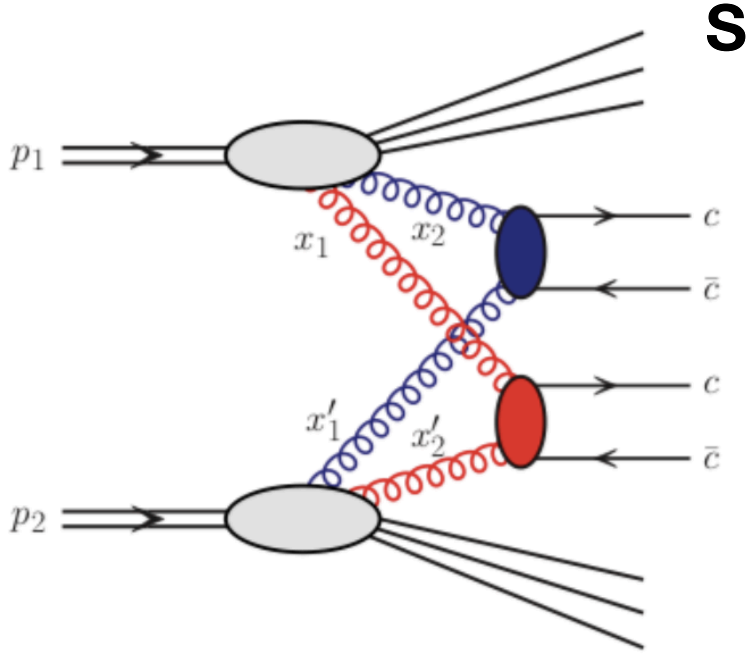
Associative production of J/ψ

Single parton scattering (SPS, $gg \to J/\psi J/\psi$, $q\bar{q} \to J/\psi J/\psi$) is one of the most important production mechanisms of J/ψ pairs.



However, DPS cross section is increasing with the energy:

$$\sigma_{AB}^{DPS} = \frac{m}{2}\int \underbrace{dx_1 dx_1' f^i(x_1) f^k(x_1') \hat{\sigma}^A(x_1, x_1')}_{\text{SPS(A)}}\ \underbrace{dx_2 dx_2' f^j(x_2) f^l(x_2') \hat{\sigma}^B(x_2, x_2')}_{\text{SPS(B)}} \underbrace{F_j^i(b) F_l^k(b) d^2 b}_{\text{Transverse component}}$$



$\sigma_{eff} = \left[\int d^2 b (F(b))^2\right]^{-1}$ - characterizes effective area of parton-parton interactions.

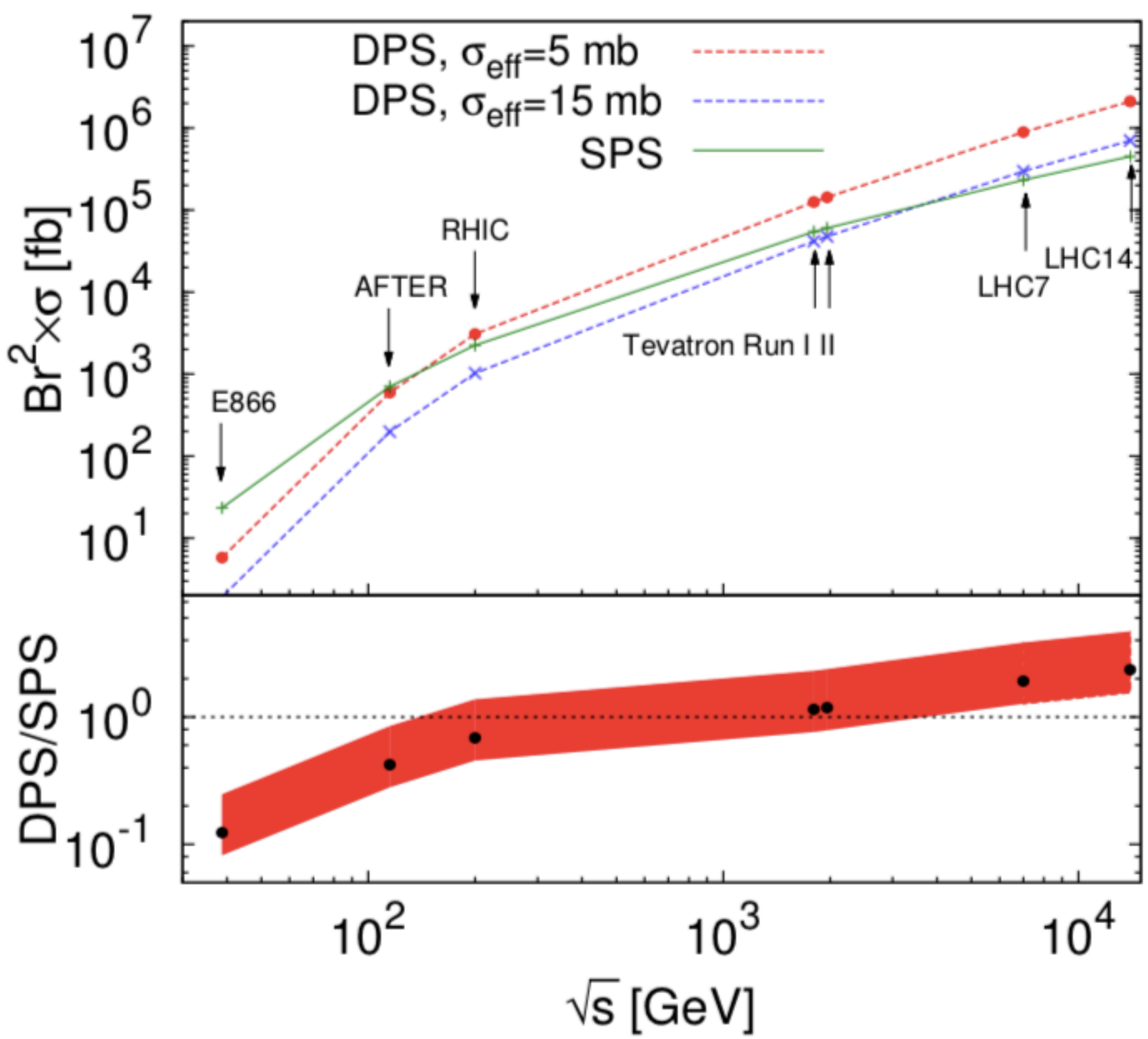
$$\sigma_{AB}^{DPS} = \frac{m}{2}\frac{\sigma_A^{SPS}\sigma_B^{SPS}}{\sigma_{eff}}$$

J.R. Gaunt et. al.
Eur.Phys.J.C 69 (2010) 53-65

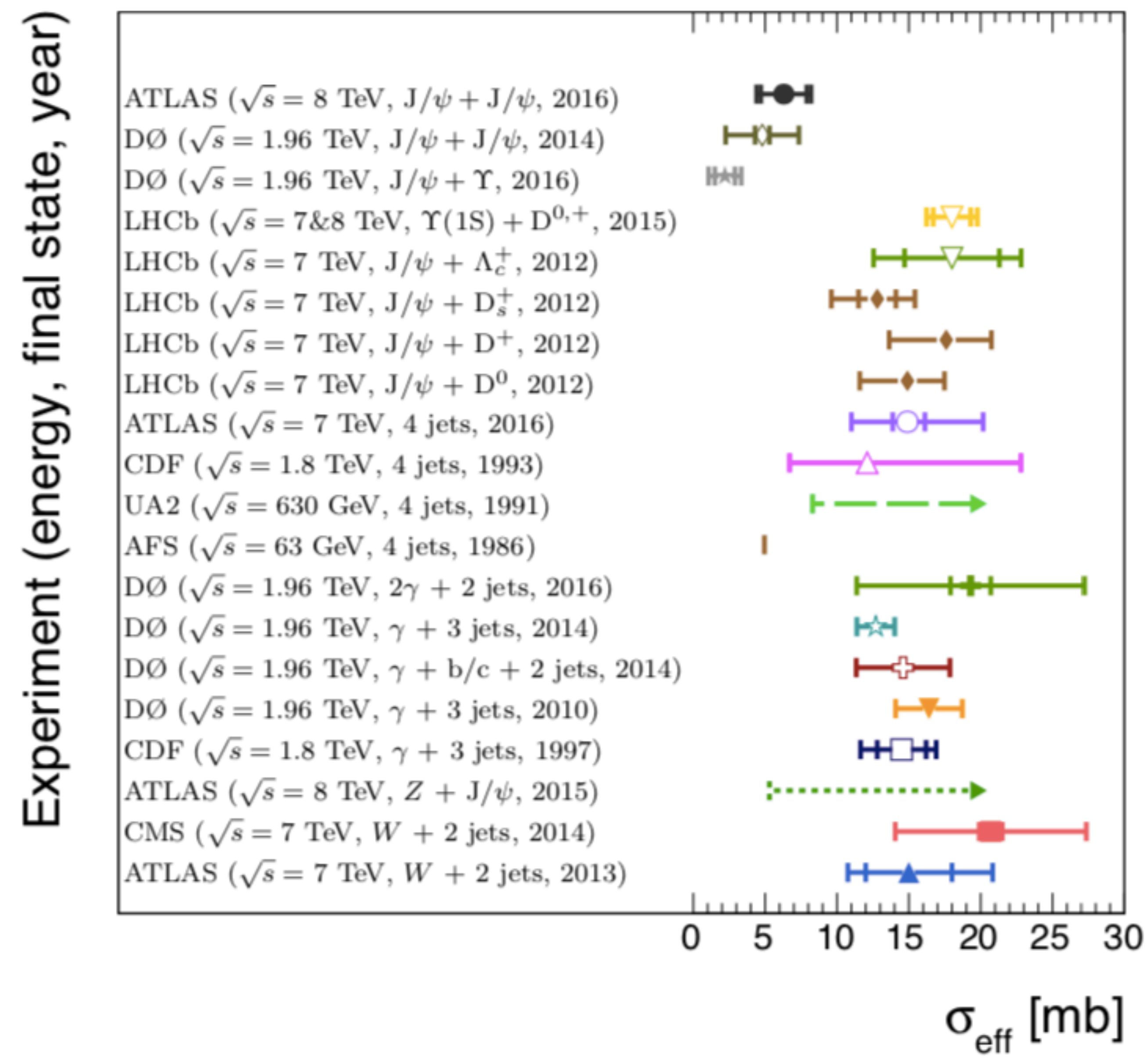
J/ψ pair production allows to study double parton scattering.

SPS and DPS at different experiments

Nucl. Phys. B 900 (2015) 273



Eur. Phys. J. C 77 (2017) 76



Effective cross section at LHC in double J/ψ production channel has been calculated with k_T– factorization approach. Obtained values are $\sigma_{eff} = 17.5 \pm 4.1\ mb$ and $\sigma_{eff} = 13.8 \pm 0.9\ mb$

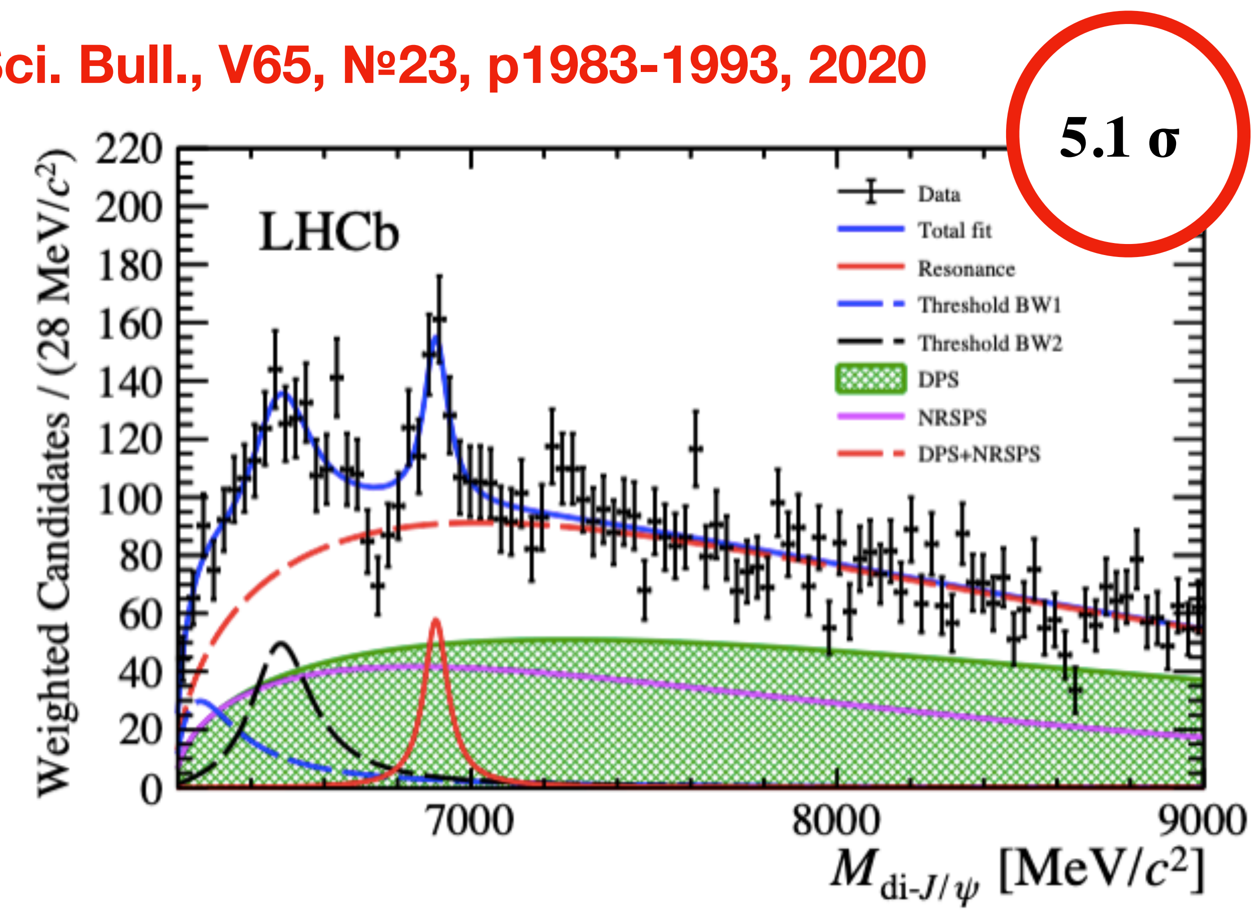
A.A. Prokhorov, A.V. Lipatov, et al.
Eur.Phys.J.C 80 (2020) 11, 1046

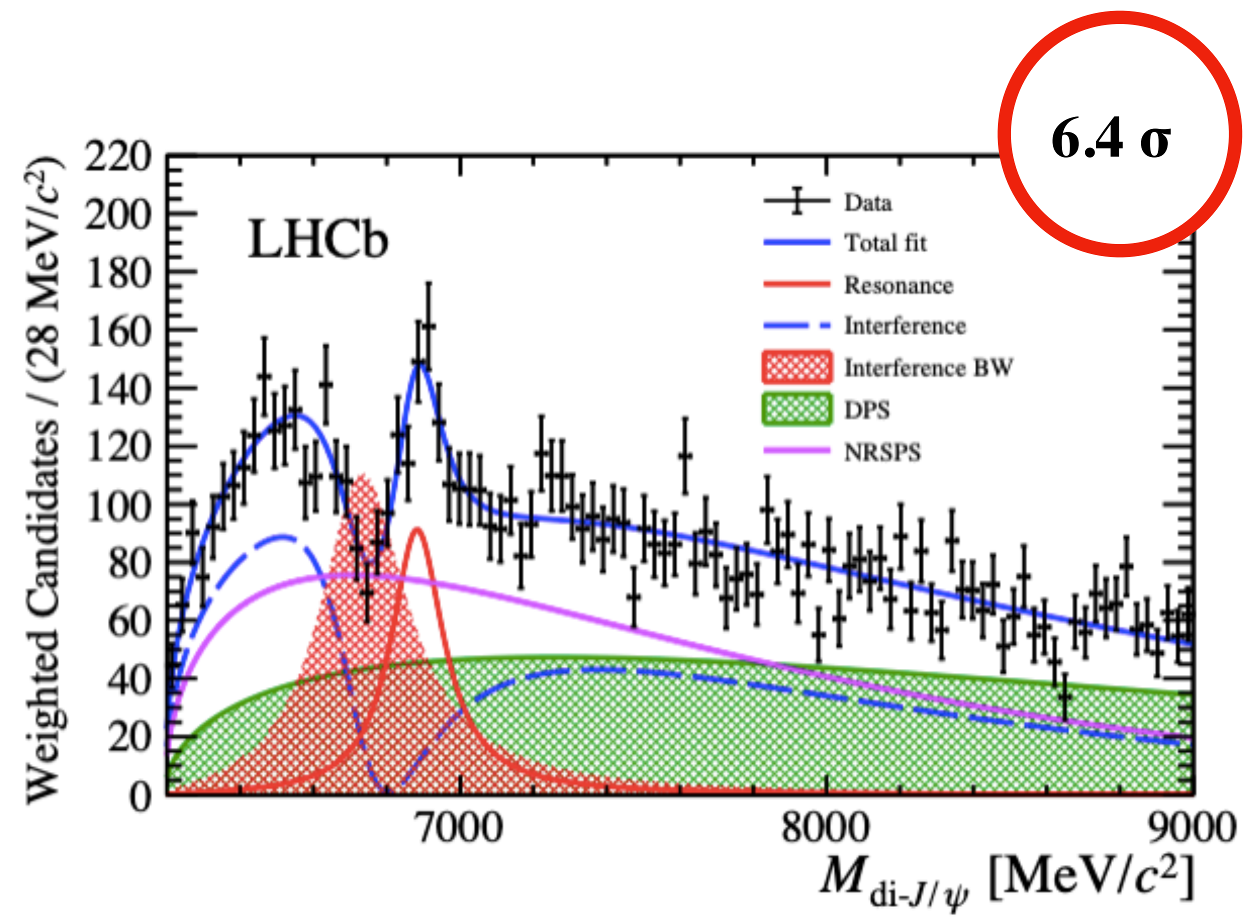
Exotic $|c\bar{c}c\bar{c}\rangle$ states

Y. Iwasaki,
Prog. Theor. Phys. V.54, 492 (1975)

- 1975: first prediction of $|c\bar{c}c\bar{c}\rangle$ tetraquark states that could decay to J/ψ pair.
- 2020: LHCb reported the X(6900) structure in the $M_{2J/\psi}$ spectrum ($\sqrt{s} = 7,\ 8$ and 13 TeV).

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

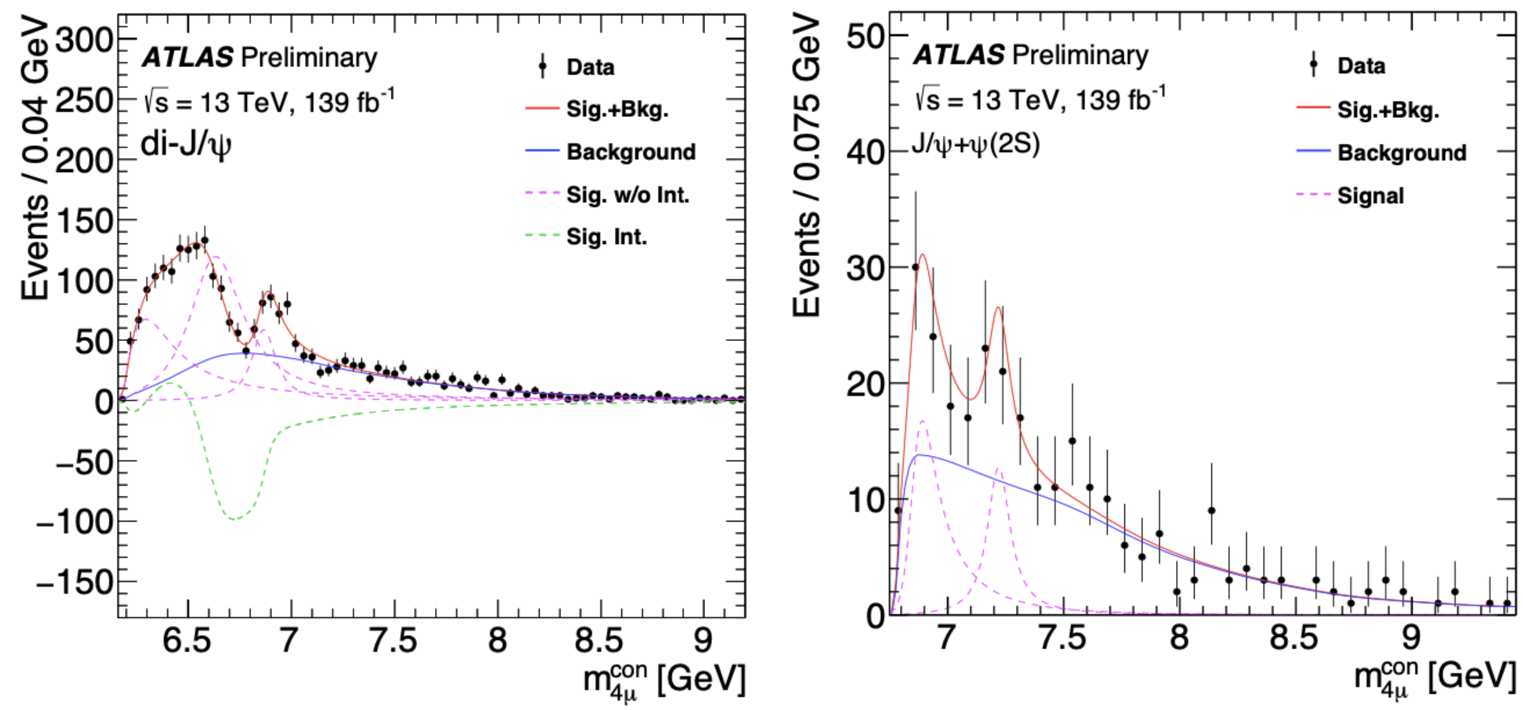




Exotic $|c\bar{c}c\bar{c}\rangle$ states

- 2022: ATLAS has proved the resonance with the mass of 6.9 GeV in the $2J/\psi$ mass spectrum, and has shown the $J/\psi\psi'$ spectrum.

ATLAS-CONF-2022-040

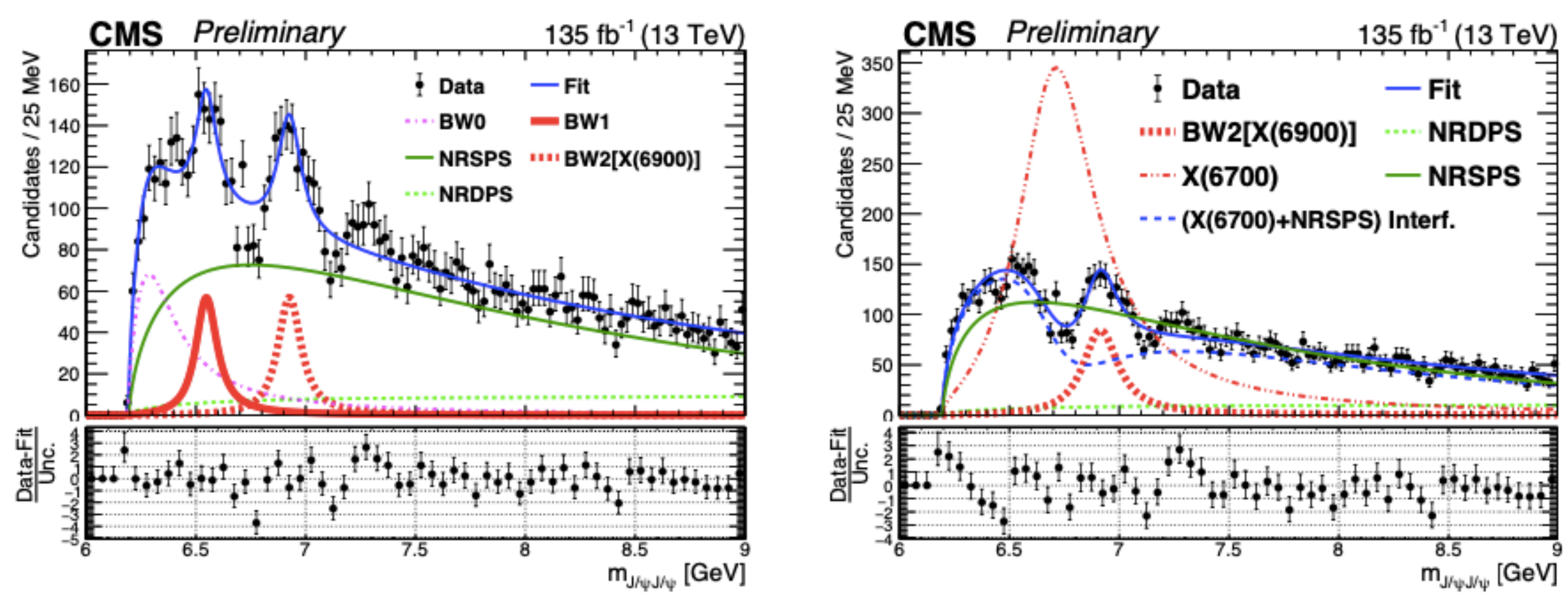


- 2022: CMS has proved the resonance with the mass of 6.9 GeV in the $2J/\psi$ mass spectrum and announced two more resonances:

$$M(X(6600)) = 6552 \pm 10_{stat} \pm 12_{syst} \text{ MeV}$$

$$M(X(7300)) = 7287 \pm 19_{stat} \pm 5_{syst} \text{ MeV.}$$

CMS PAS BPH-21-003



J/ψ pair production at COMPASS

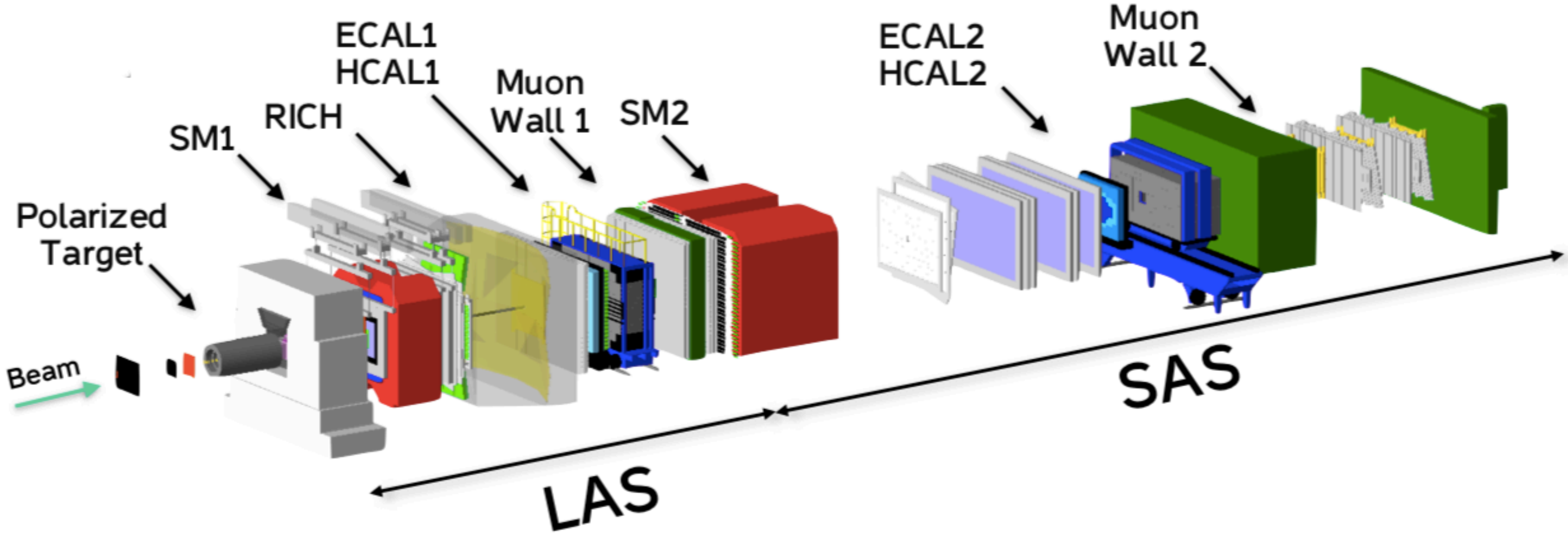
J/ψ pair production at COMPASS

The only experimental observation of J/ψ pair production in pion-nucleon interactions was done by the NA3 experiment more than 40 years ago.

The new measurement by COMPASS allow:

- To estimate contribution of different production mechanisms (including IC) into double J/ψ production cross section.
- To check the hypothesis that intrinsic charm of pion is dominant J/ψ pair production mechanism in the NA3 data.
- To search for exotic states that decay to J/ψ pair.

COMPASS Drell-Yan setup (2015, 2018)

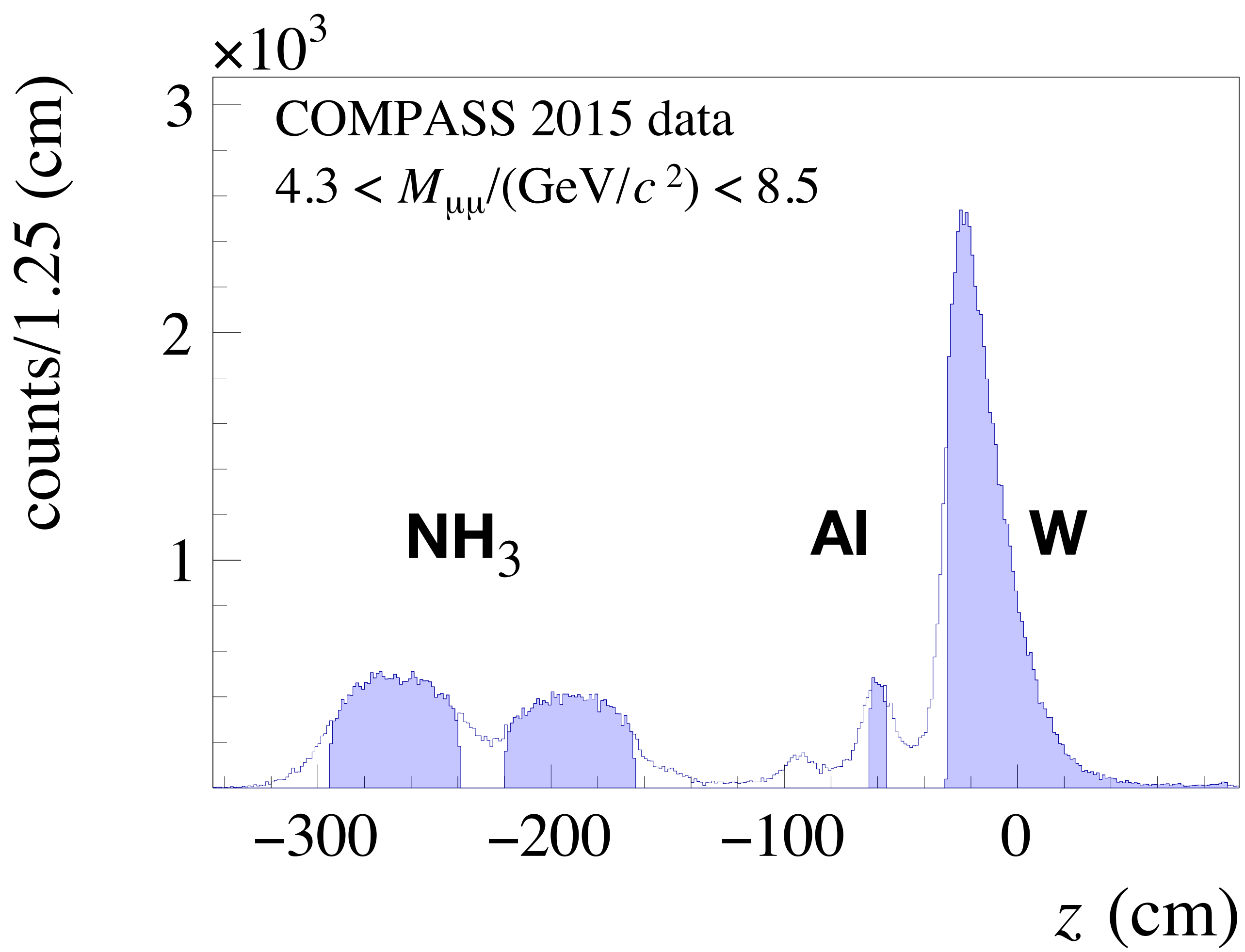


Beam dump configuration:

- Optimized for muon registration;
- > 6M J/ψ in NH_3 target;

Unique hadron beam in DY runs :

- hadron beam composition: 96.80% π^-, 2.40% $\bar{K}$, 0.80% $\bar{p}$;
- beam momentum : **190 ± 3 GeV/c**;
- intensity: up to **7x10⁷ hadrons / sec**;

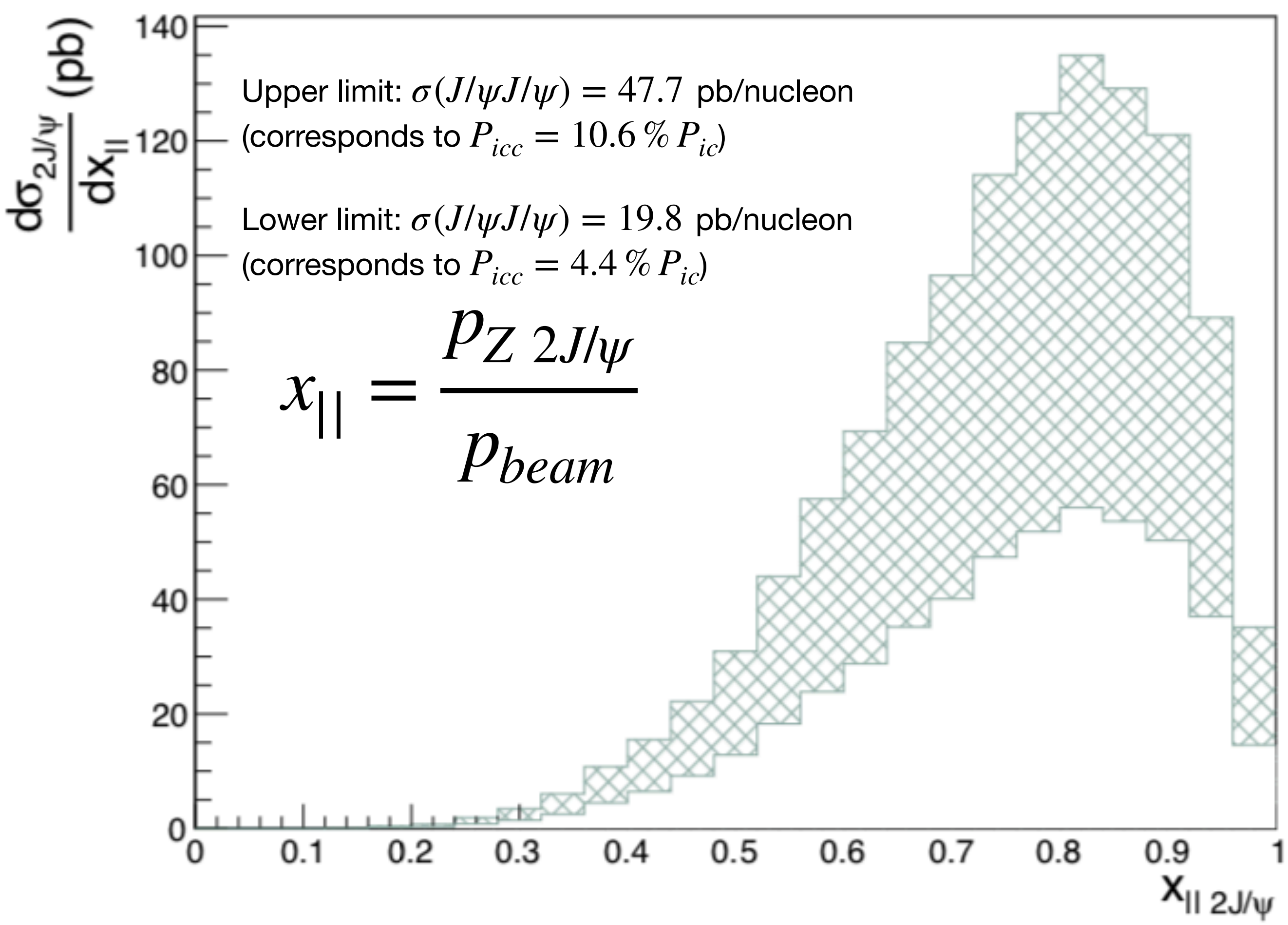


Intrinsic charm of pion at COMPASS

$|d\bar{u}c\bar{c}c\bar{c}\rangle$ Fock component of pion could be materialized into J/ψ pair;

$\sigma^{NA3}_{2J/\psi}(150\ GeV/c) = 18 \pm 8$ pb/nucleon

$\sigma^{NA3}_{2J/\psi}(280\ GeV/c) = 30 \pm 10$ pb/nucleon



$$\sigma_{2J/\psi} = f^2_{\psi/\pi} \frac{P_{icc}}{P_{ic}} \sigma_{ic}$$

To estimate J/ψ pair production cross section at COMPASS the values of $P_{icc} = 4.4\,\%\,P_{ic}$ and $P_{icc} = 10.6\,\%\,P_{ic}$ (probabilities to obtain Fock states with $c\bar{c}c\bar{c}$ and $c\bar{c}$) were taken from **Phys.Lett.B349:569-575,1995**.

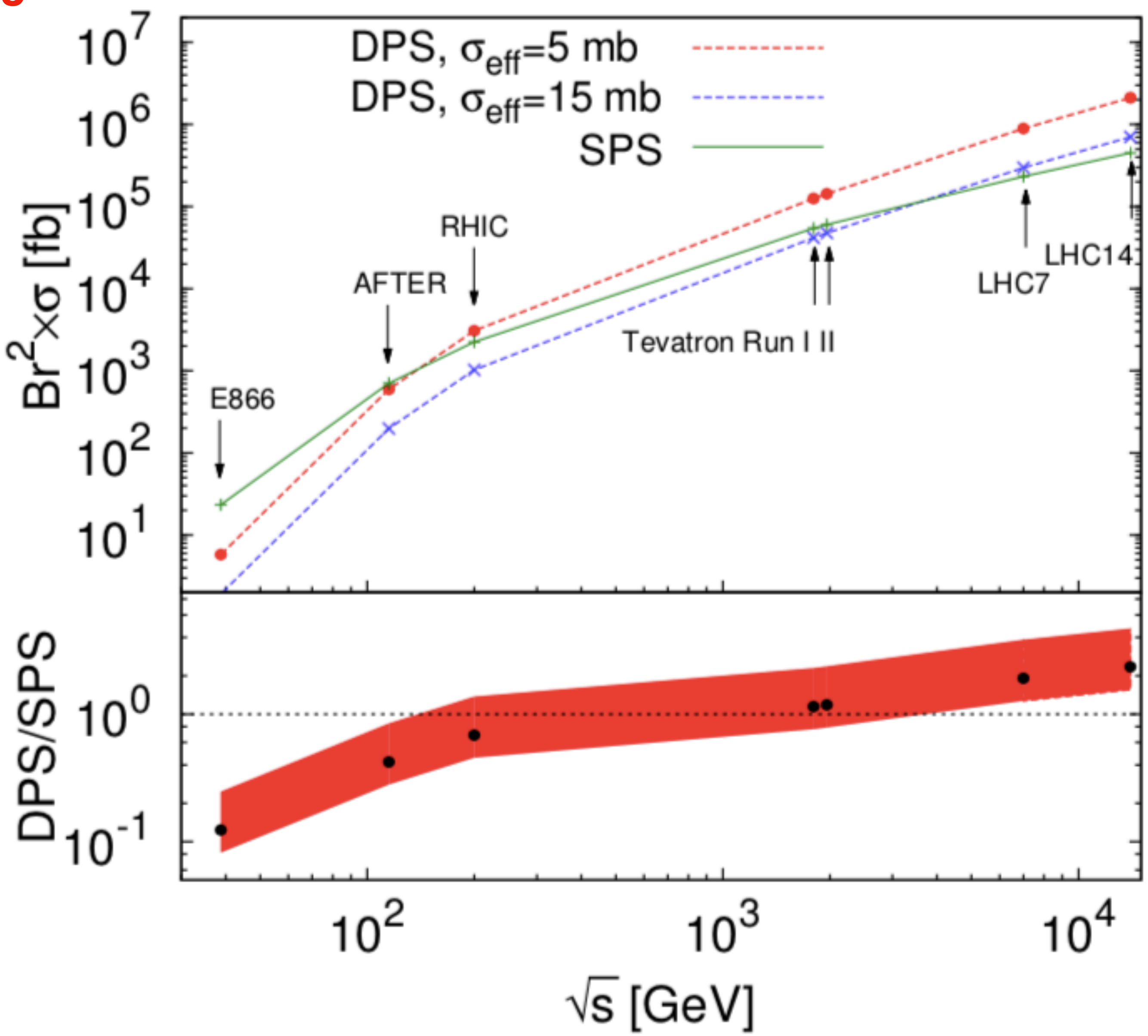
Double J/ψ production cross section at COMPASS energy estimated to be 19.8 - 47.7 pb/nucleon.

$\sigma_{ic} = 0.5\ mb$ - **IC cross section for π^- at 200 GeV/c.**

$f_{\psi/\pi} \approx 0.03$ - **fraction of $c\bar{c}$ quark pairs producing J/ψ**

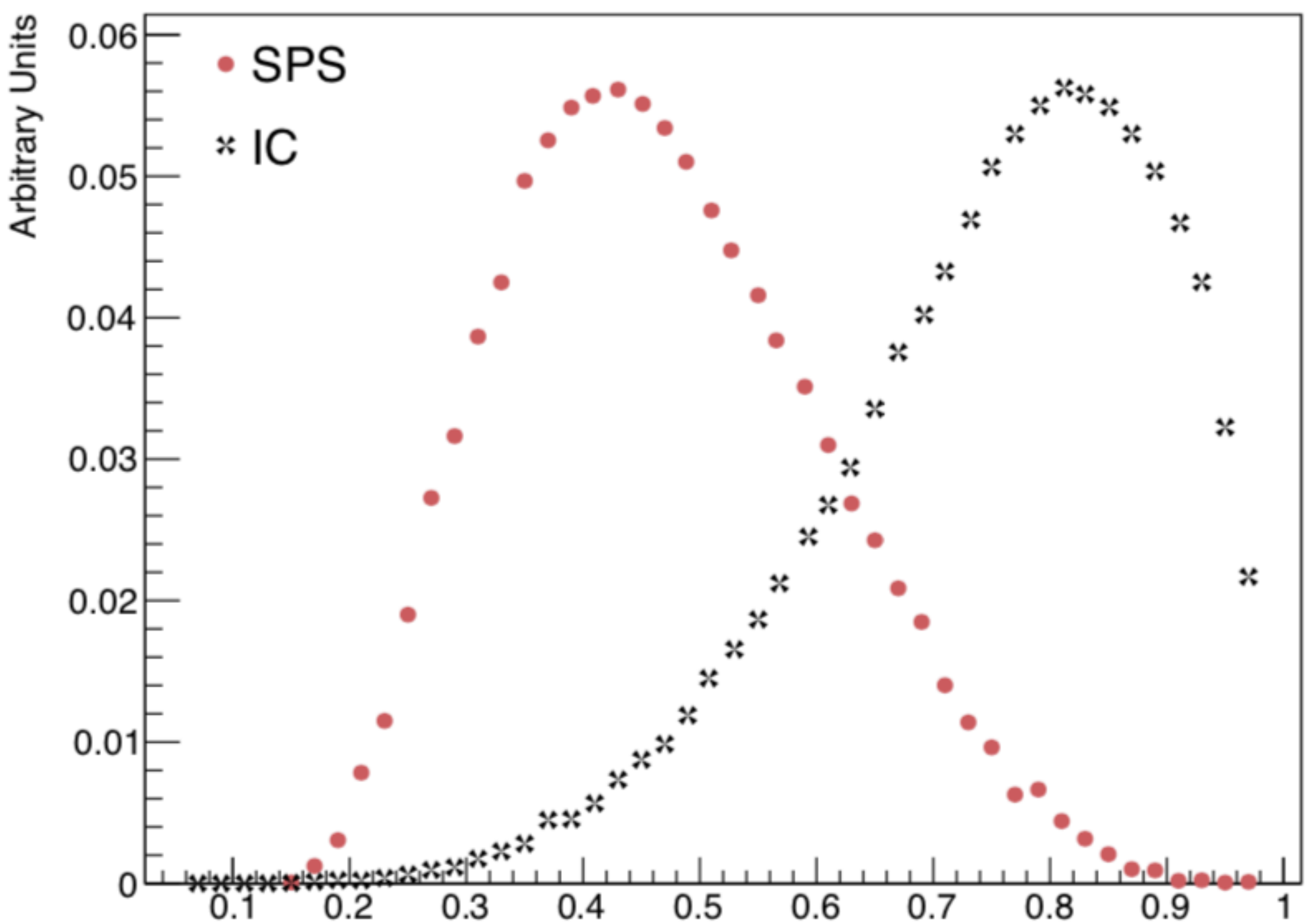
DPS at COMPASS

J.P.Lansberg, H.S.Shao,
Nucl. Phys. B 900 (2015) 273



The ratio of $\sigma^{DPS}/\sigma^{SPS} \approx 0.1$ at $\sqrt{s} = 19.7\ GeV$.

J/ψ pair production at COMPASS



$$x_{\parallel\ 2J/\psi} = \frac{p_{Z\ 2J/\psi}}{p_{beam}}$$

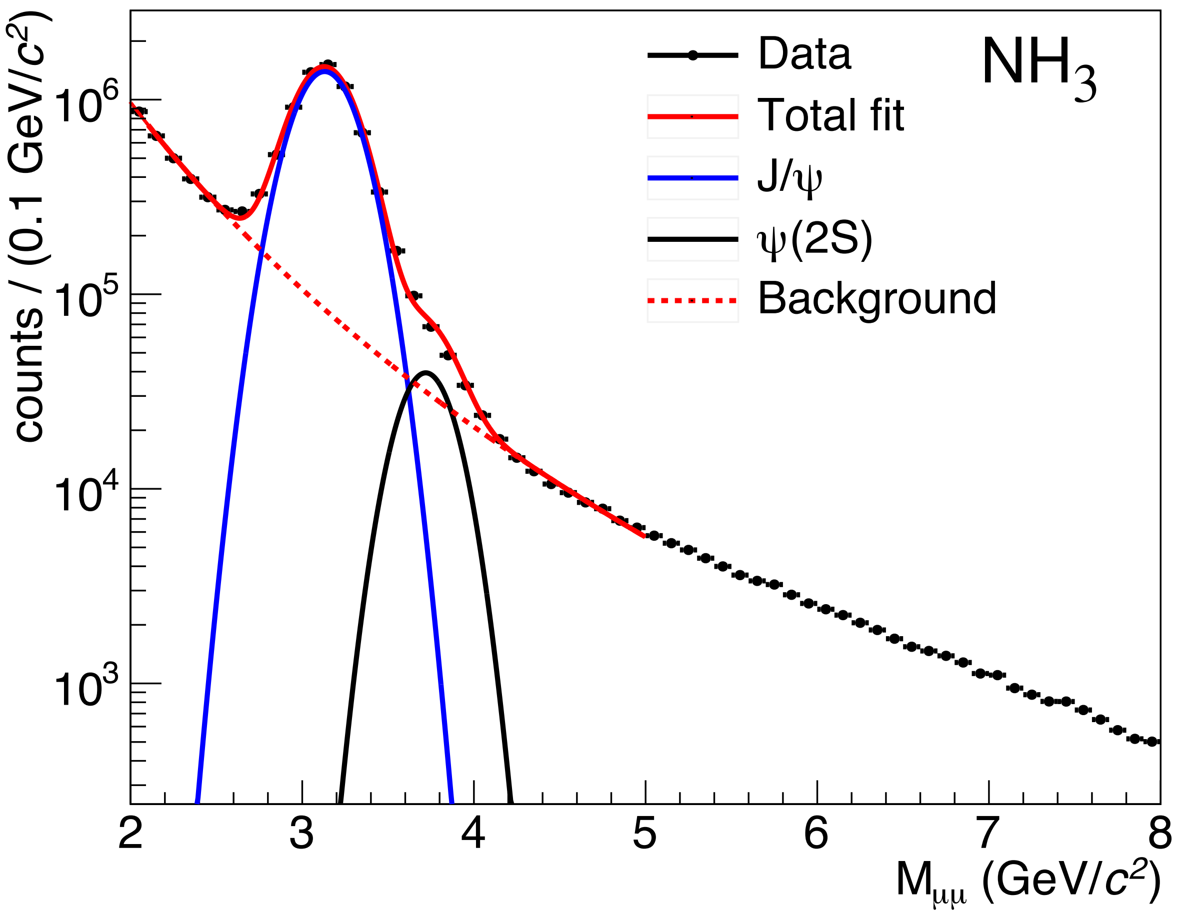
- SPS and IC are the leading J/ψ pair production mechanisms at COMPASS energies.

- The distribution of longitudinal momentum fraction of J/ψ pair in the lab frame can be used to determine the relative weights of double J/ψ production mechanisms (IC, single parton scattering).

- COMPASS can check the double intrinsic charm hypothesis of pion (materialization of Fock $|d\bar{u}c\bar{c}c\bar{c}\rangle$ component);

Data analysis

Single J/ψ events at COMPASS



2015+2018: large statistics of single J/ψ events collected

NH_3: $6.23 \cdot 10^6$

Al: $0.46 \cdot 10^6$

W: $2.51 \cdot 10^6$

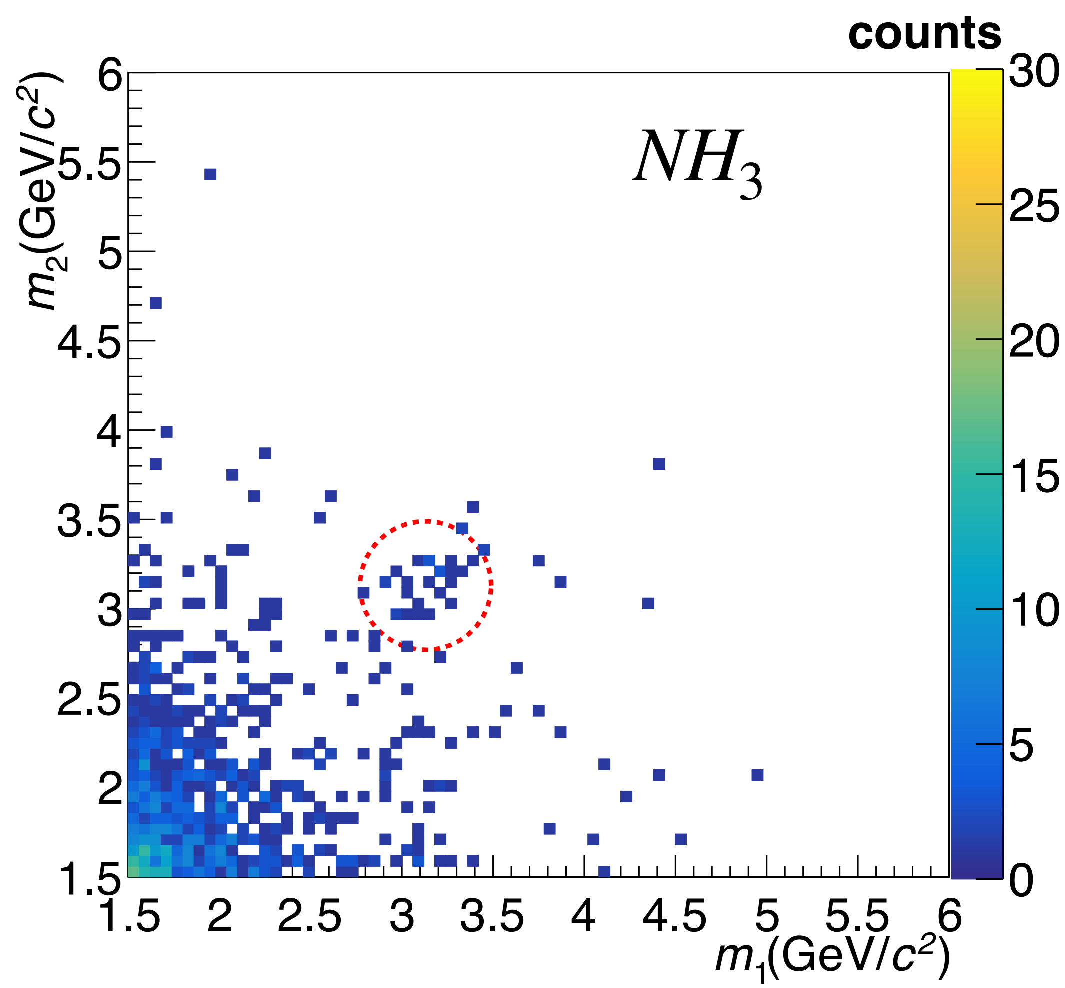
All the events are selected in kinematic region:

$$x_{F\ J/\psi} = \frac{2p_L^*}{\sqrt{s}} > 0.$$

	NH_3	Al	W
$M_{J/\psi}$, GeV$/c^2$	3.141 ± 0.009	3.138 ± 0.010	3.078 ± 0.009
$\Delta_{J/\psi}$, GeV$/c^2$	0.182 ± 0.008	0.202 ± 0.009	0.299 ± 0.011

J/ψ pair events at COMPASS

$$\pi^- N \rightarrow J/\psi J/\psi + X \rightarrow (\mu^+\mu^-)(\mu^+\mu^-) + X$$



COMPASS double J/ψ data:

NH_3: 28 events

Al: 2 events

W: 13 events

All the events are selected in kinematic region: $x_{F\ J/\psi} = \frac{2p_L^*}{\sqrt{s}} > 0.$

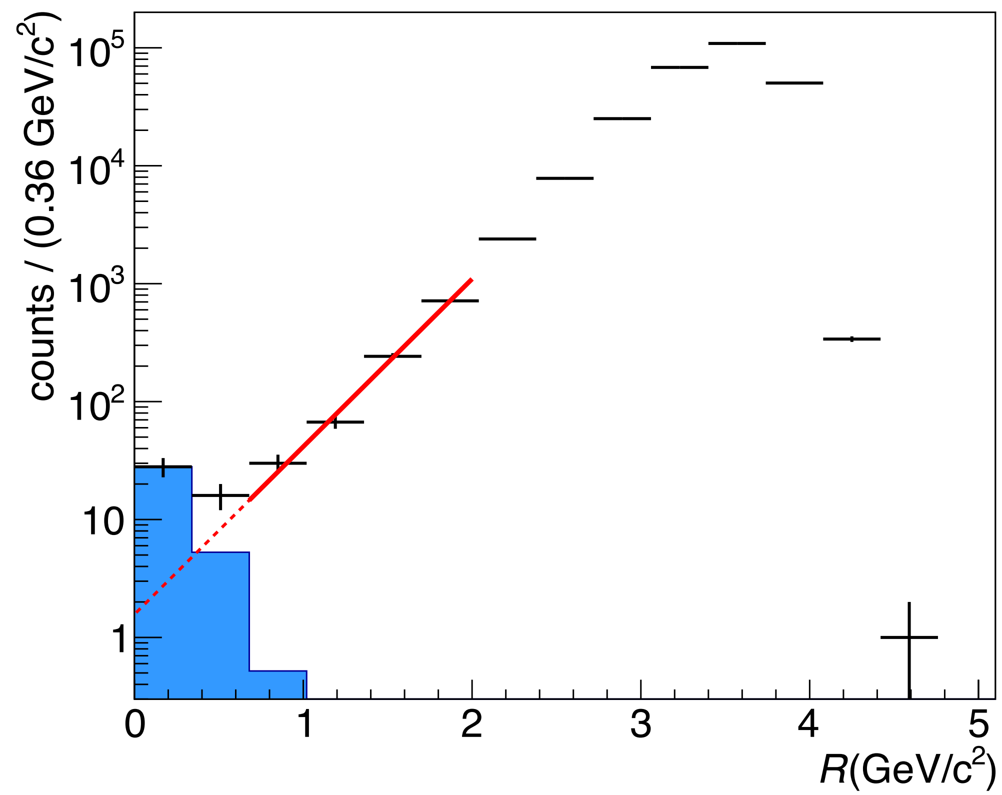
Signal and background events

Signal events: two J/ψ reconstructed in the same vertex, these 2J/ψ should appear as a result of a process: $\pi^- N \to J/\psi J/\psi + X$

Background events:

- **Pileup:** two J/ψ reconstructed in the same vertex, but produced in different interactions - estimated to be negligible;
- **Combinatorial background: J/ψ+2μ or 4μ;**
- **B-meson pair decay: $B\bar{B} \to J/\psi J/\psi + X$**

	NH_3	Al	W
$N_{J/\psi}/10^6$	6.23	0.46	2.51
$N_{2J/\psi\ candidates}$	28	2	13
$N_{2J/\psi\ background}$	2.9 ± 0.5	1.4 ± 0.4	8.5 ± 2.0
$N_{2J/\psi}$	25.1 ± 0.5	0.6 ± 0.4	4.5 ± 2.0



Statistics of J/ψ pair events in NH_3 target at COMPASS approximately two times higher than NA3 statistics.

J/ψ pair production cross section off different nuclear targets

NA3: $\dfrac{\sigma_{2J/\psi}}{\sigma_{J/\psi}} = (3 \pm 1) \cdot 10^{-4}$

$$\sigma^{Pt}_{J/\psi J/\psi}(150\ GeV) = 18 \pm 8\ \frac{pb}{nucleon}$$

$$\sigma^{Pt}_{J/\psi J/\psi}(280\ GeV) = 30 \pm 10\ \frac{pb}{nucleon}$$

The measured by the NA3 $\sigma_{J/\psi}$ was used for the estimation of $\sigma_{2J/\psi}$ at COMPASS.

$$\sigma^{p}_{J/\psi} \times BR(J/\psi \to \mu\mu) = 6.3 \pm 0.8 \text{ нб}$$

$$\sigma^{Pt}_{J/\psi} \times BR(J/\psi \to \mu\mu) = 960 \pm 150 \text{ нб}$$

COMPASS:

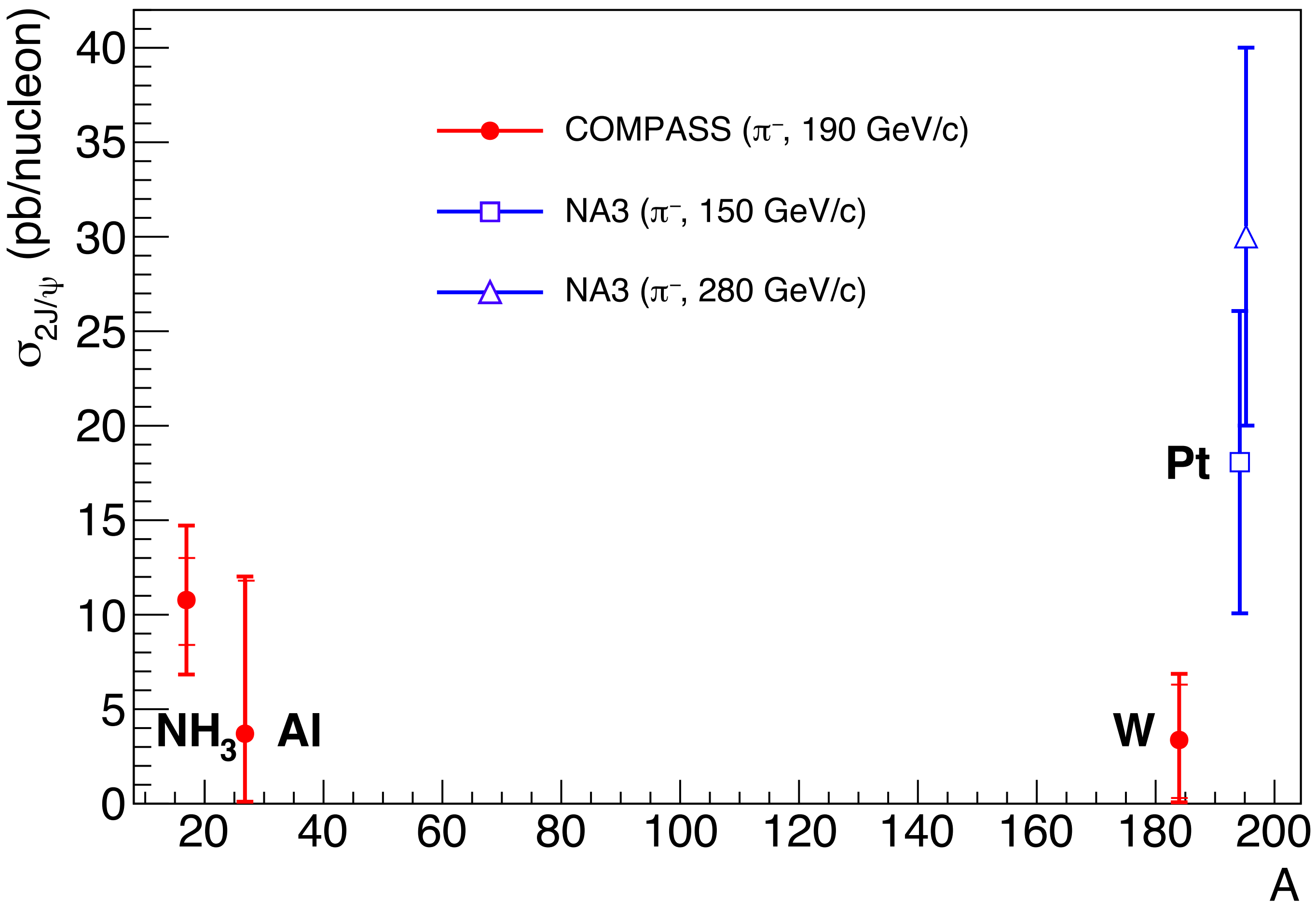
$$\frac{\sigma_{2J/\psi}}{\sigma_{J/\psi}} = (1.02 \pm 0.22_{stat} \pm 0.27_{syst}) \cdot 10^{-4} (NH_3)$$

$$\sigma^{NH_3}_{2J/\psi} = 10.7 \pm 2.3_{stat} \pm 3.2_{syst} \text{ пб/нуклон}$$

$$\sigma^{Al}_{2J/\psi} = 3.6 \pm 8.2_{stat} \pm 1.4_{syst} \text{ пб/нуклон}$$

$$\sigma^{W}_{2J/\psi} = 3.3 \pm 3.0_{stat} \pm 1.8_{syst} \text{ пб/нуклон}$$

$$\frac{\sigma_{J/\psi J/\psi}}{\sigma_{J/\psi}} = \frac{1}{BR(J/\psi \to \mu\mu)} \cdot \frac{N_{J/\psi J/\psi}}{A_{J/\psi J/\psi}} \cdot \frac{A_{J/\psi}}{N_{J/\psi}}$$



Within uncertainties, no significant evidence of nuclear effects in J/ψ pair production is observed.

Systematic uncertainties

Main sources of systematics:

- **Uncertainty of $\sigma_{J/\psi}$:** is taken from NA3 measurement:
  $\sigma^{p}_{J/\psi} \cdot BR(J/\psi \to \mu\mu) = 6.3 \pm 0.8$ nb/nucleon (NH_3, Al)
  $\sigma^{Pt}_{J/\psi} \cdot BR(J/\psi \to \mu\mu) = 4.9 \pm 0.77$ nb/nucleon (W);

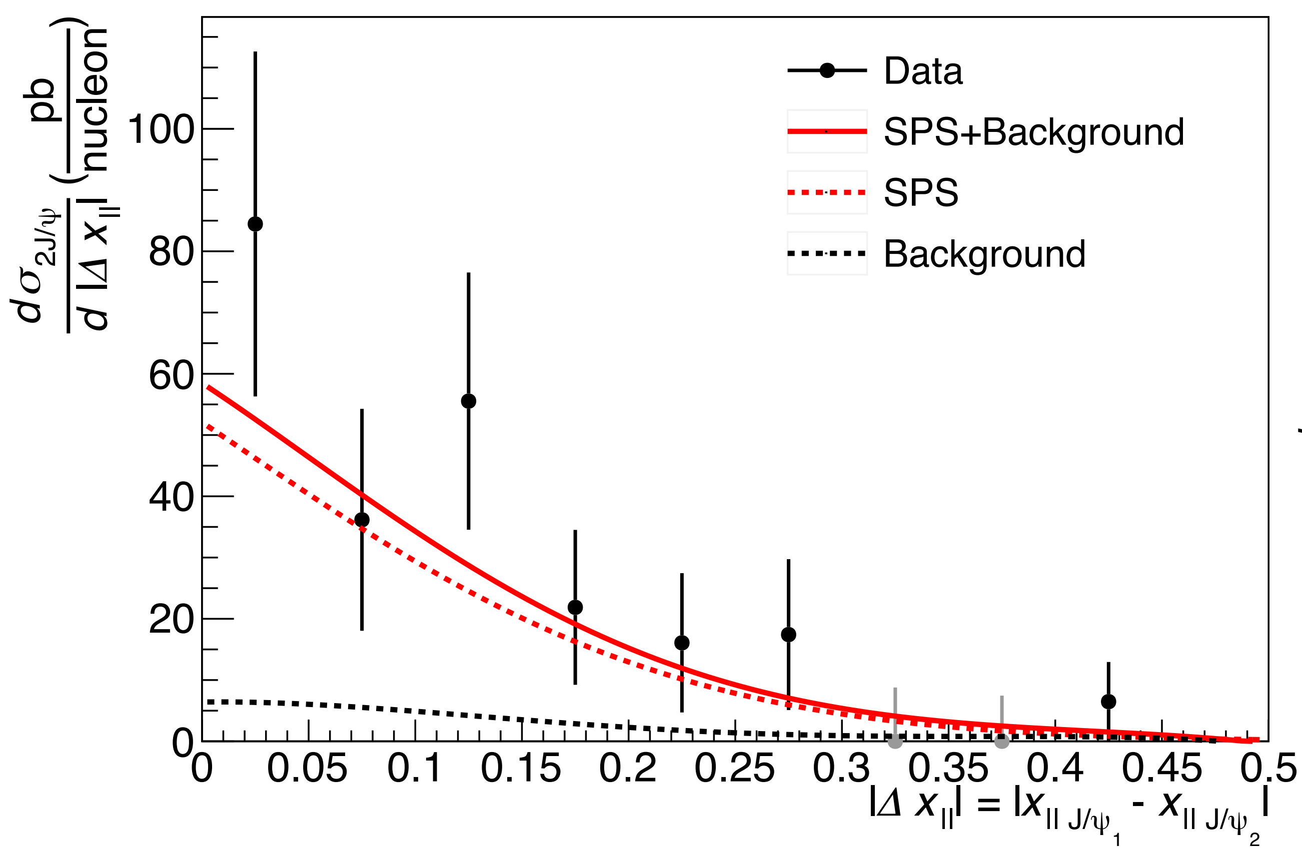
- J/ψ **pair acceptance:** takes into account uncertainty of $\dfrac{q\bar{q} \to J/\psi J/\psi}{gg \to J/\psi J/\psi}$, uncertainty of detector and trigger efficiencies;

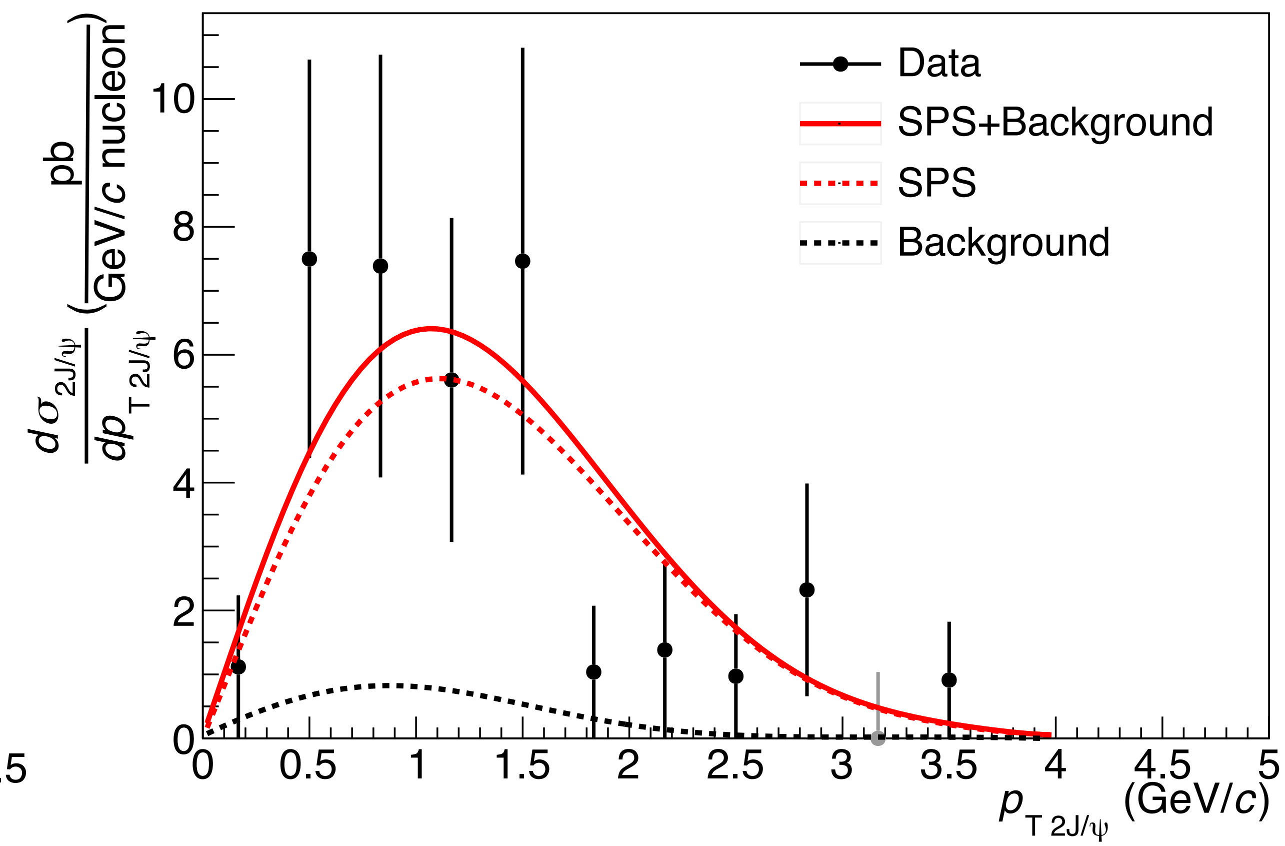
- J/ψ **acceptance:** takes into account uncertainty of detector and trigger efficiencies and uncertainty of PDF selection;

- **combinatorial background:** estimated with a toy MC;

- **Number of single J/ψ :** was estimated from the fit of dimuon mass distribution by different functions (modified Gaussian, Crystall Ball).

Differential cross section of J/ψ pair production

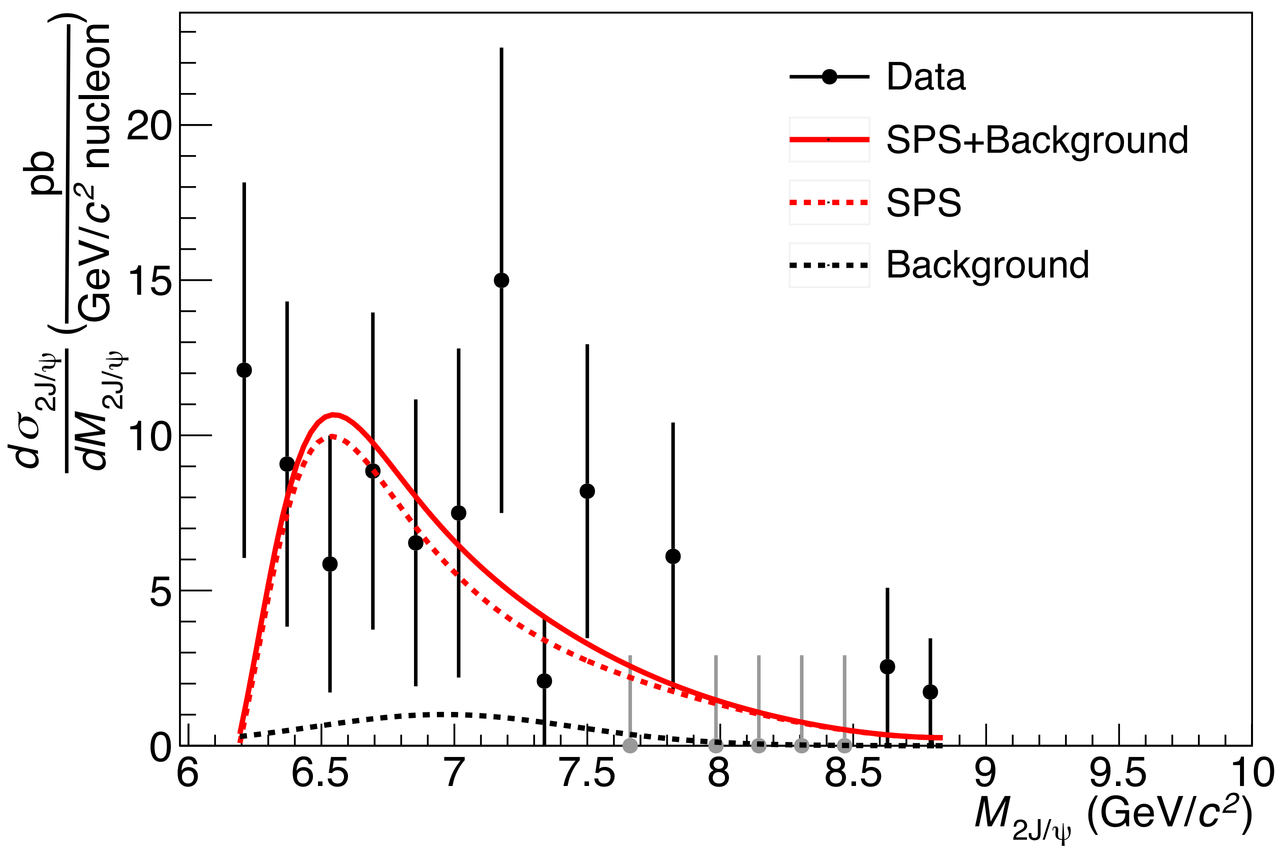


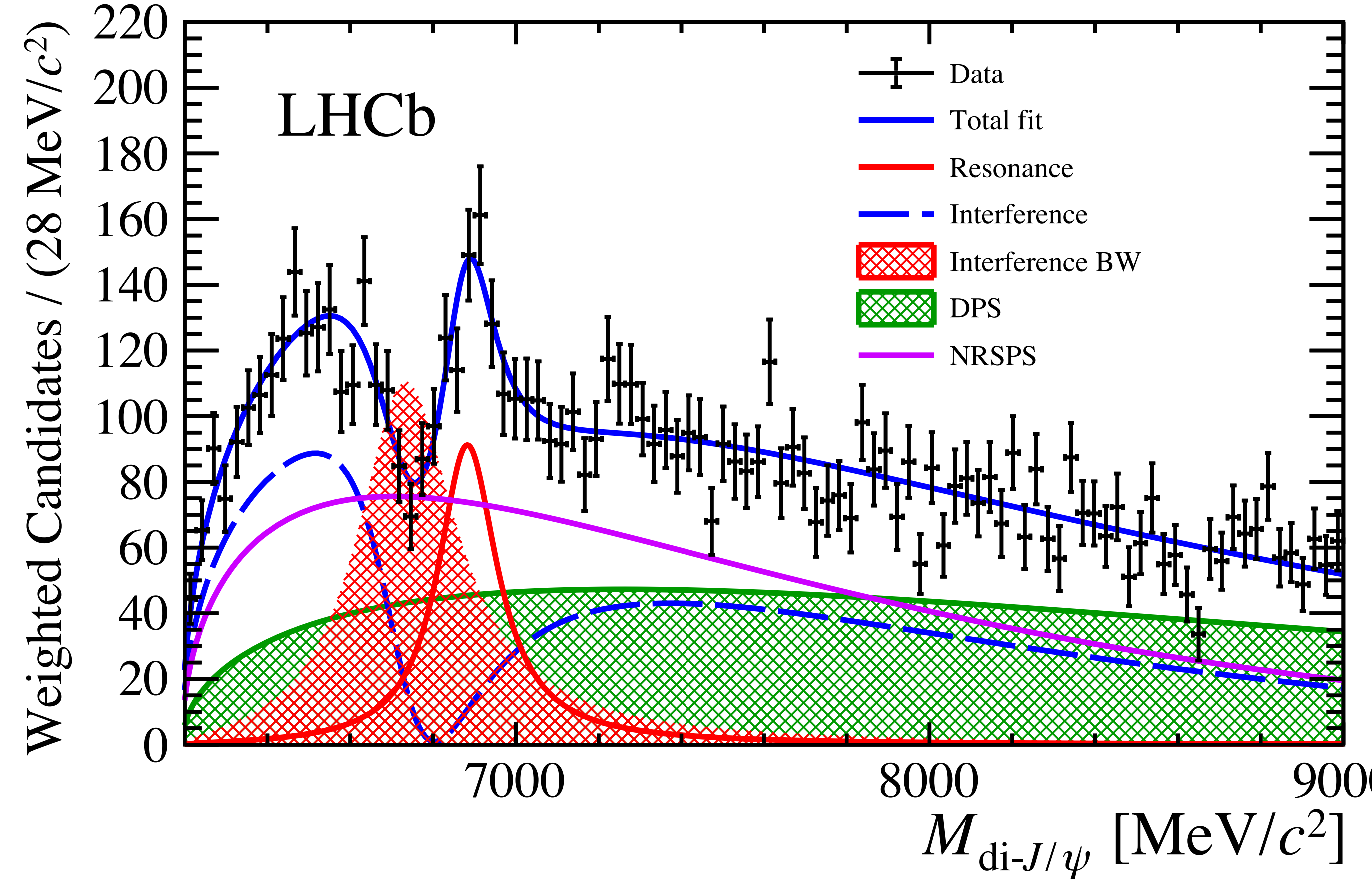


The function with one free parameter (SPS amplitude) is fitted to the data. The background contribution is fixed.

The $p_{T\ 2J/\psi}$ and $|\Delta x_{||}|$ distributions are in agreement with SPS model,

Differential cross section of J/ψ pair production





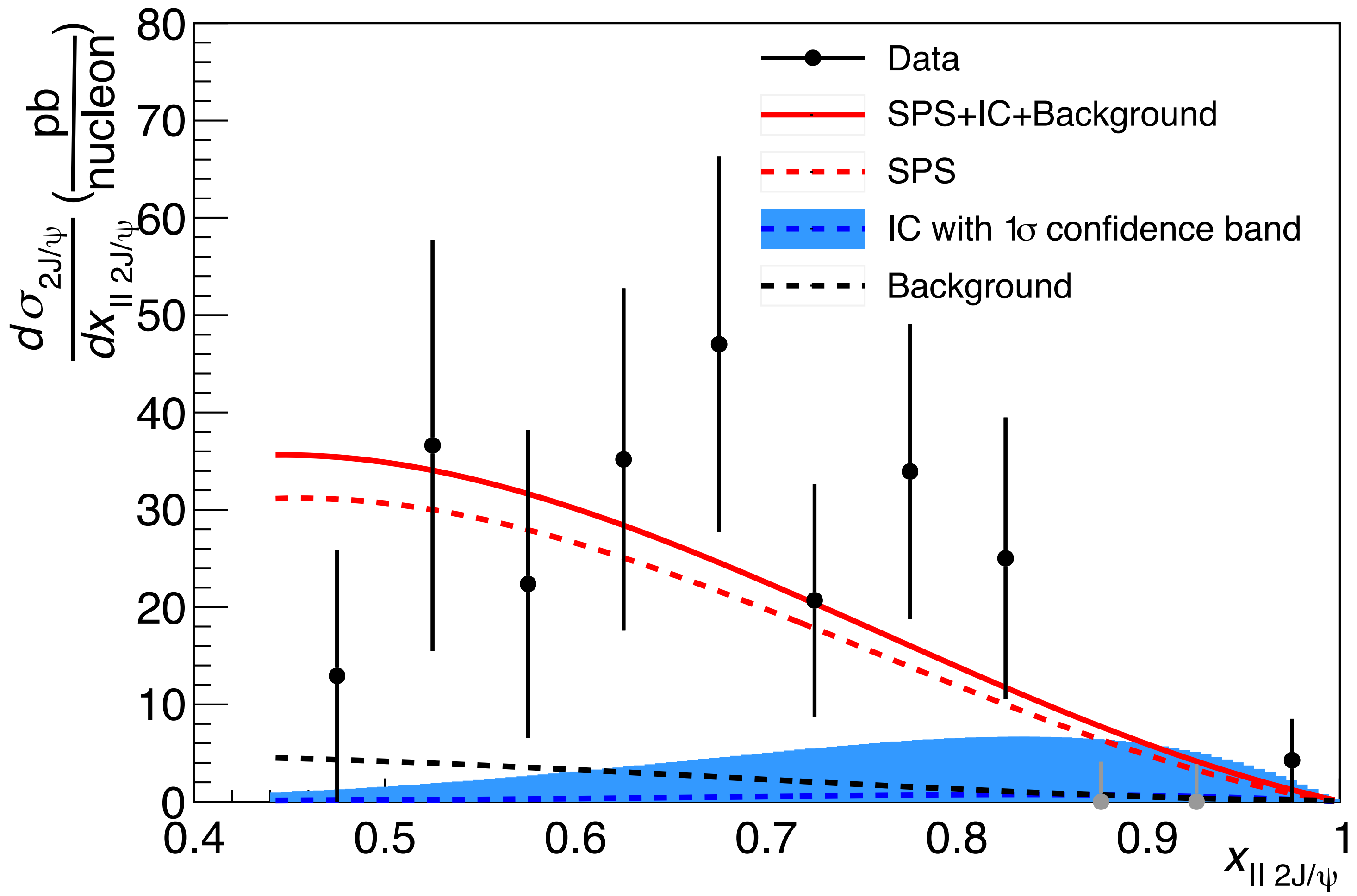
$m[X(6900)] = 6886 \pm 11 \pm 11$ МэВ

$\Gamma[X(6900)] = 168 \pm 33 \pm 69$ МэВ

The $M_{2J/\psi}$ spectrum does not contain any evident signal from exotic states observed by LHCb.

Differential cross section of J/ψ pair production

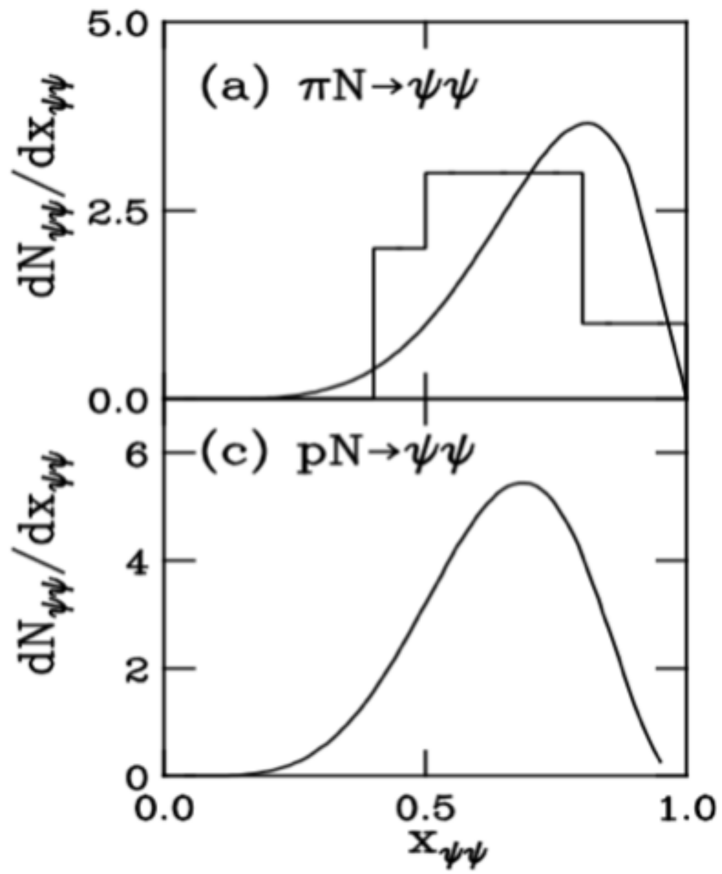
$$x_{F\ J/\psi} = \frac{2p_L^*}{\sqrt{s}} > 0$$

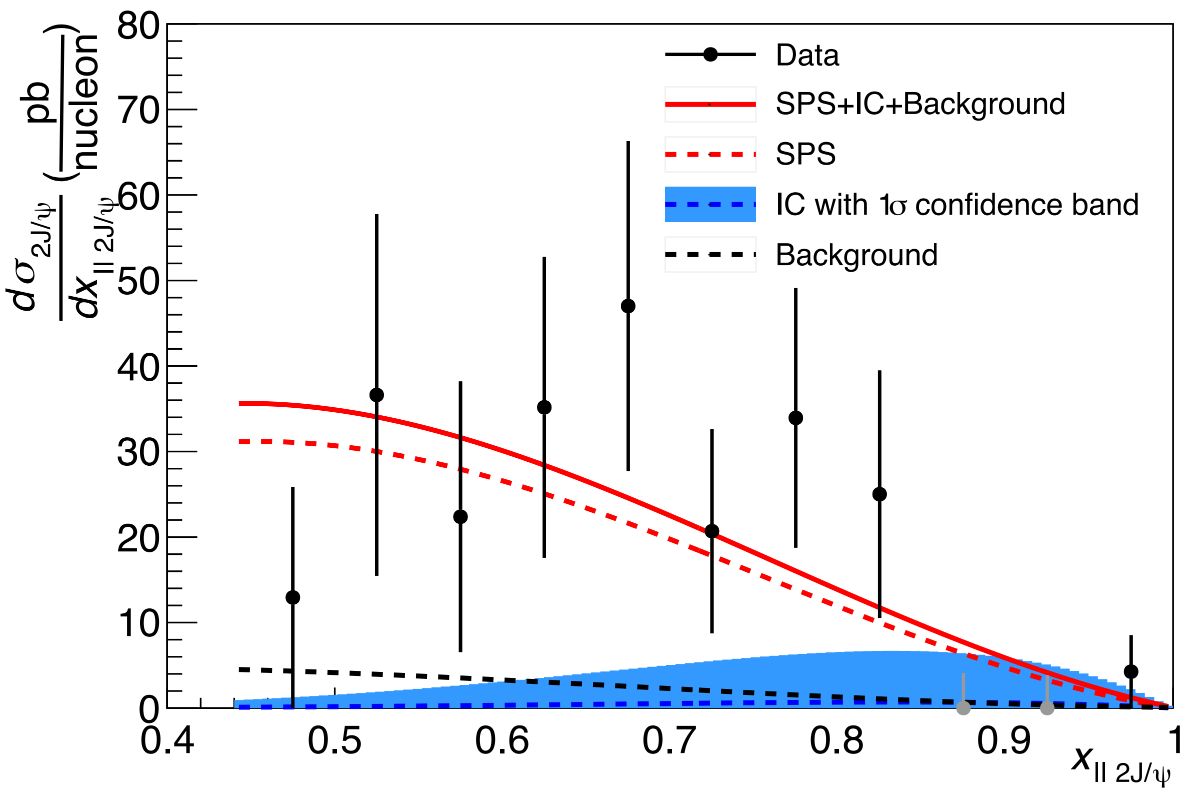


The function $f(x_{||\ 2J/\psi}) = a \cdot f_{SPS}(x_{||\ 2J/\psi}) + b \cdot f_{IC}(x_{||\ 2J/\psi}) + f_{bkg}(x_{||\ 2J/\psi})$ is fitted to the data assuming that SPS and IC are the leading production mechanisms. The DPS contribution is not considered in the fit;

The results are consistent with pure SPS hypothesis. An upper limit on IC production mechanism is established: $\sigma^{IC}_{2J/\psi}/\sigma_{2J/\psi}\Big|_{x_F>0} < 0.24\ (CL = 90\%)$.

J/ψ pair events at NA3 and COMPASS





All double J/ψ events at NA3 (π^-, 150, 280 GeV) were interpreted by S.Brodsky using intrinsic charm hypothesis ($|d\bar{u}c\bar{c}c\bar{c}\rangle$ Fock component of pion): **Phys.Lett.B349:569-575,1995**.

Kinematic distributions provided by the NA3 are not corrected for the acceptance.

COMPASS and NA3 are beam dump experiments, that used π^- 190 GeV and π^- 150 (280) GeV beams, respectively.

Acceptance correction of the NA3 data will change the distributions.

Kinematics of J/ψ pair events at COMPASS (π^-, 190 GeV) do not contradict to the SPS production mechanism. An upper limit on double IC of pion production mechanism is established:

$$\sigma^{IC}_{2J/\psi}/\sigma_{2J/\psi}\Big|_{x_F>0} < 0.24\ (CL = 90\%).$$

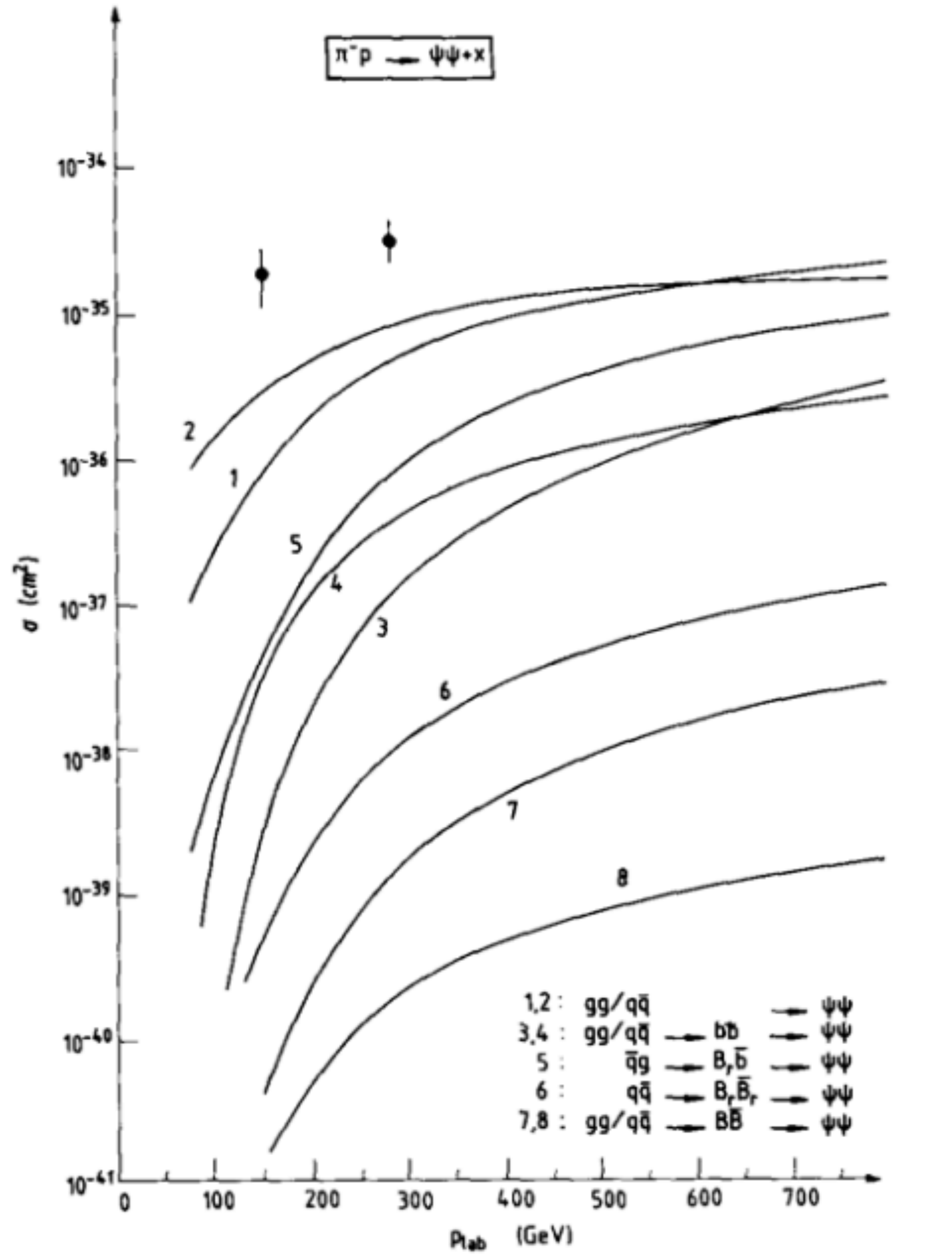
Results

1) COMPASS has measured J/ψ pair cross section in pion-nucleon interactions. Differential cross sections as functions of kinematic variables $p_{T\ 2J/\psi}$, $x_{||\ 2J/\psi}$, $\Delta x_{||\ 2J/\psi}$ are obtained for NH_3 target.
2) Contributions of different J/ψ pair production mechanisms are evaluated at COMPASS energies. The COMPASS double J/ψ data are consistent with SPS production mechanism. An upper limit on IC production mechanism is established in $x_{||\ 2J/\psi} > 0.4$ region: $\sigma^{IC}_{2J/\psi}/\sigma_{2J/\psi} < 0.24\ (CL = 90\%)$.
3) It is shown, that the interpretation of NA3 double J/ψ data using intrinsic charm of pion model is not correct.

Results of the work are published in Phys.Lett.B 838 (2023) 137702

Thank you for attention

$q\bar{q} \to 2J/\psi / gg \to 2J/\psi$ ratio

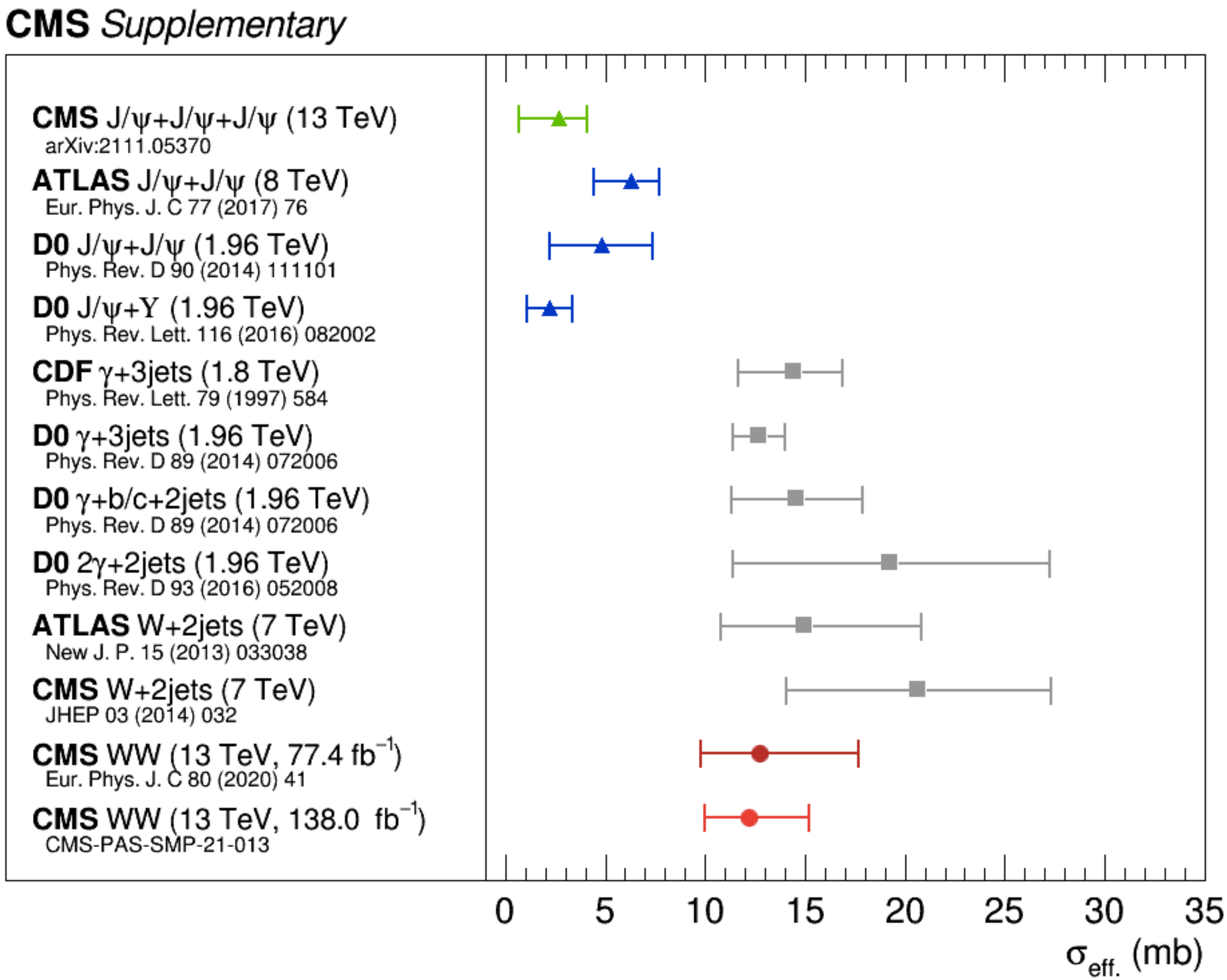


B. Humpert, P. Mery
Phys.Lett.B 124 (1983) 265-270

$$\frac{q\bar{q} \to J/\psi J/\psi}{gg \to J/\psi J/\psi} = 2.8.$$

Uncertainty of the ratio was taken into account as systematic uncertainty.

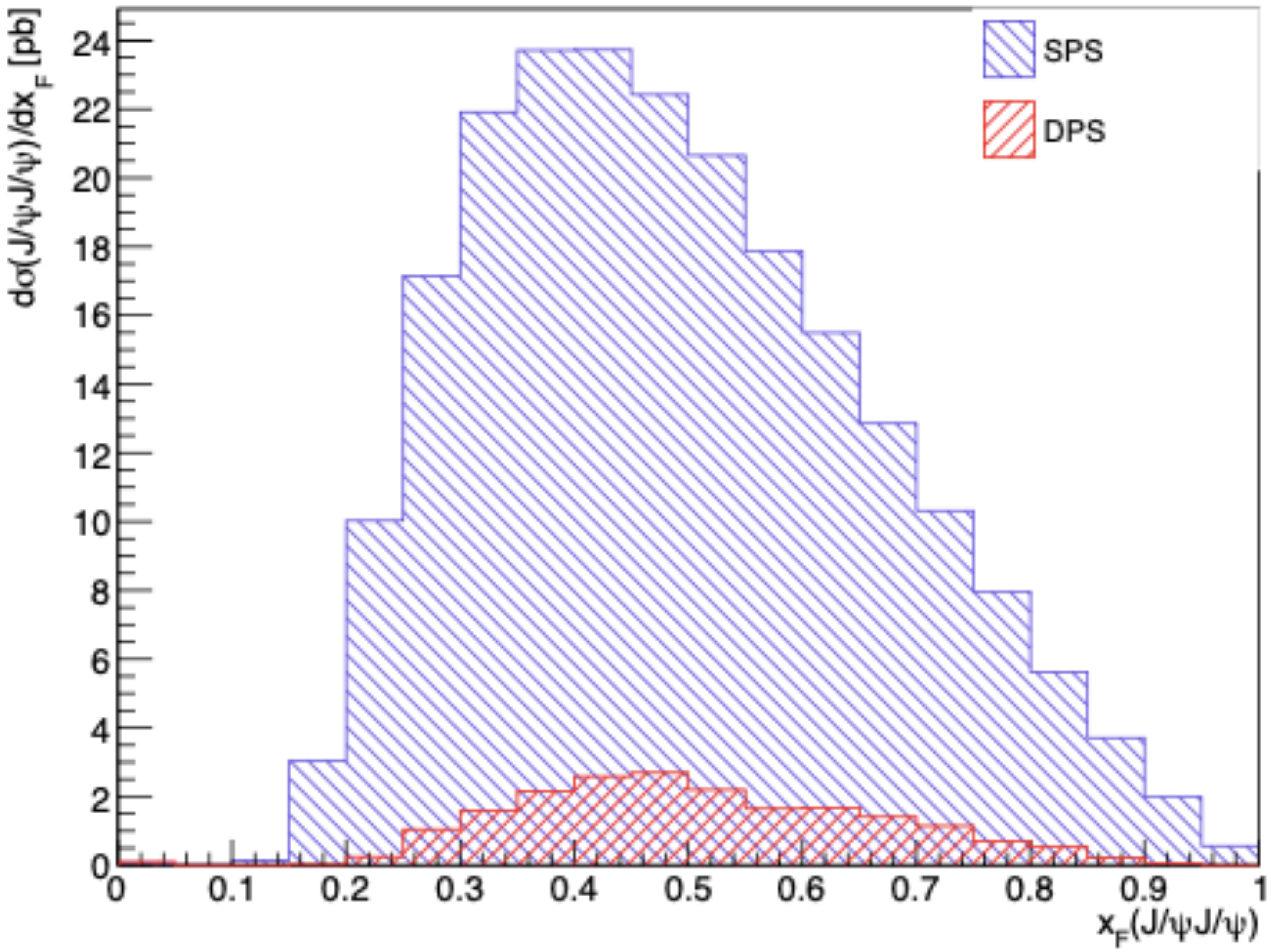
SPS and DPS at different experiments



SPS and DPS at COMPASS

S. Koshkarev, Proceedings of: DSPIN-19:

arXiv:1909.06195 [hep-ph]



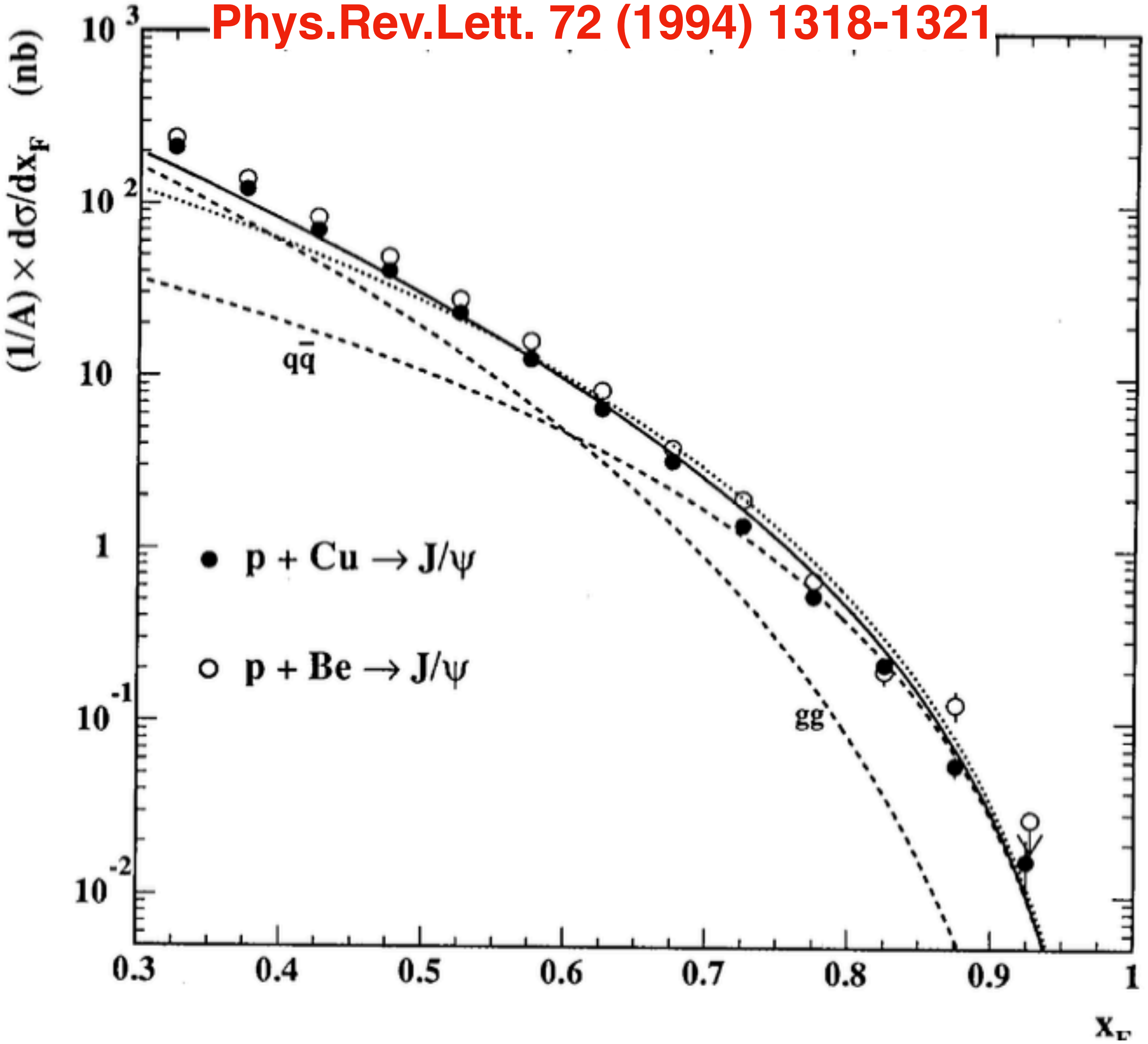
$$\sigma_{J/\psi J/\psi} = 12\ pb/nucleon$$

Selection criteria of J/ψ pair at COMPASS

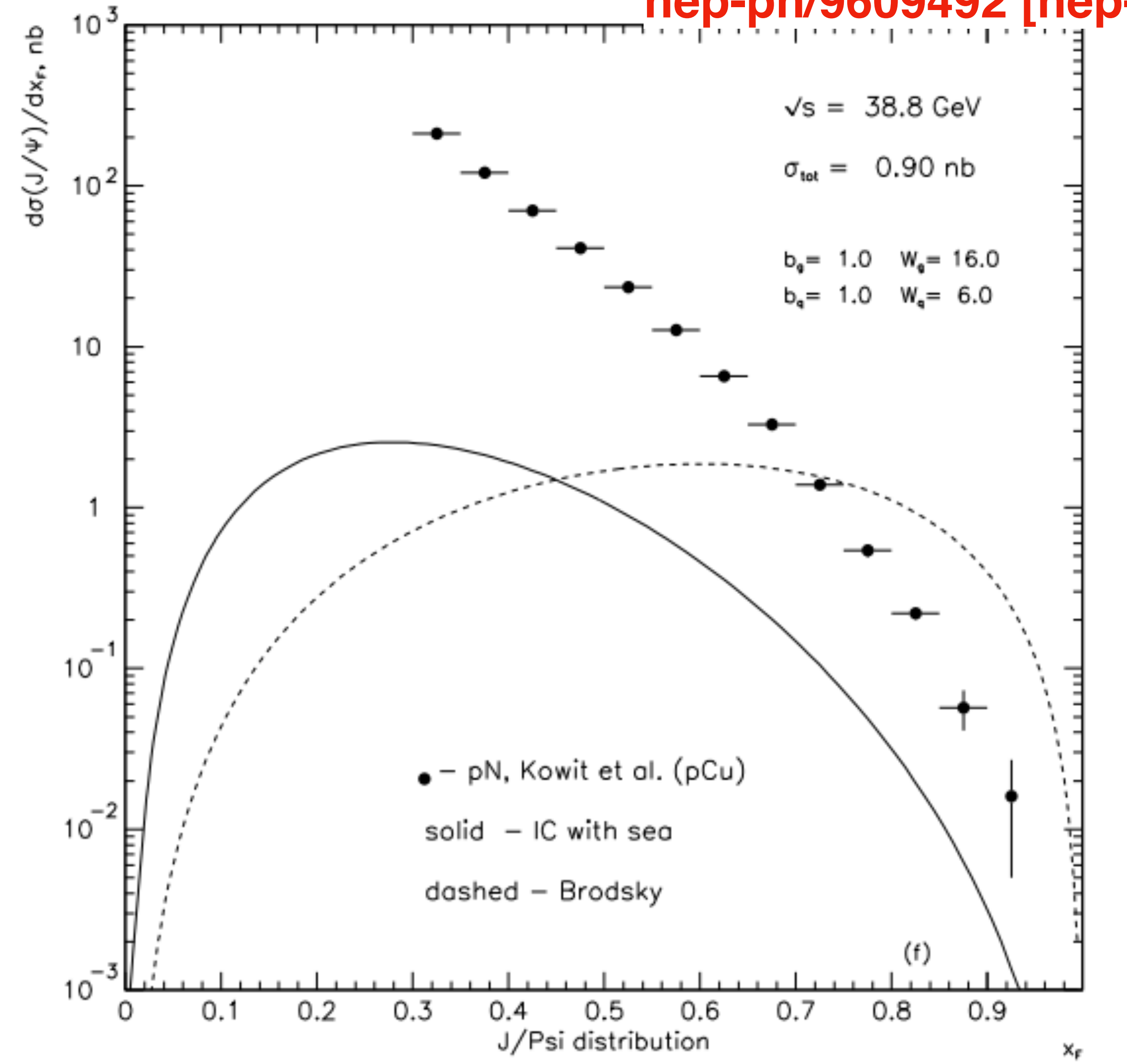
		2015s2		2018t8	
	Cut	N_{events}	$M_{\mu^+\mu^-}$ (2σ) cut	N_{events}	$M_{\mu^+\mu^-}$ (2σ) cut
1	at least 4 tracks with XX0 > 30	$1.62 \cdot 10^7$ (100%)		$2.25 \cdot 10^7$ (100%)	
2	a pv with 4 outgoing muons	595745 (3.68 %)		682452 (3.0%)	
3	$2\mu^+2\mu^-$	324182 (2.00 %)		380502 (1.69%)	
4	$Z_{first} < 300$ cm and $Z_{last} > 1500$ cm	314336 (1.94 %)		364102 (1.61%)	
5	$\chi^2/ndf < 10$	295611 (1.82 %)	59	337619 (1.50%)	72
6	$\theta_{\mu^-} < 12$ mrad && $p_{\mu^-} > 100$ GeV	260554 (1.61 %)	39	295704 (1.31%)	48
7	trigger validation	252340 (1.56 %)	39	284598 (1.26%)	48
8	$\Sigma P_\mu < 190$ GeV/c	251167 (1.55 %)	36	282799 (1.26%)	44
9	time $\chi^2/ndf < 5$	132850 (0.82 %)	30	161169 (0.72%)	36
10	only one combination of 2 J/ψ	132849 (0.82 %)	28	161164 (0.72%)	26
11	$x_F(1J/\psi) = 2p_L^*/\sqrt{s} > 0$		23		20
12	Cut on Z_{PV}:				
	-303 cm < Z_{NH_3} < -157 cm	123005	14	140750	14
	-33 cm < Z_W < -20 cm	5144	8	6727	5
	-66 cm < Z_{Al}(2015) < -54 cm	5477	1		
	-76.5 cm < Z_{Al}(2018) < -63.5 cm			8516	1

Search for IC signal in $p - Cu \to J/\psi$ and $p - Be \to J/\psi$

Kowit et al.
Phys.Rev.Lett. 72 (1994) 1318-1321



INP MSU 96-30/437
hep-ph/9609492 [hep-ph]



A third component was also added to the fit to search for an intrinsic charm (IC) contribution to the cross section, predicted to be 1.8 nb/nucleon in Cu and 3.2 nb/nucleon in Be [3,18]. At the 95% confidence level we obtained an upper limit for the IC contribution of $< 2.3 \times 10^{-3}$ nb/nucleon for Cu ($< 1.3 \times 10^{-2}$ nb/nucleon for Be); these limits are insensitive to the choice of m_c and parton density functions.