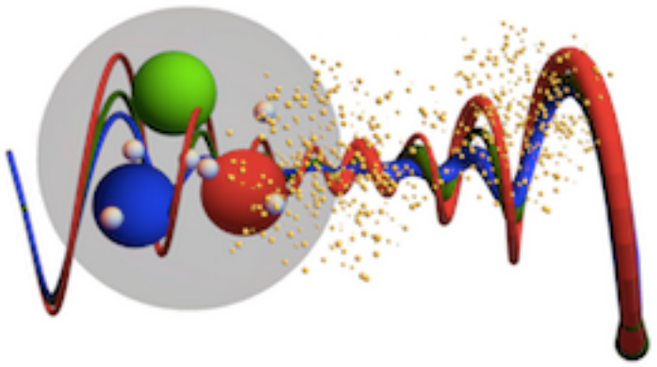


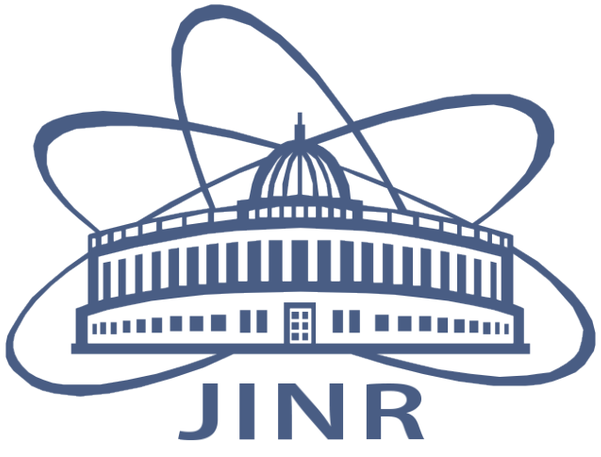
Double J/ψ production in $\pi^- N$ interactions at COMPASS

Gridin Andrei (JINR)

On behalf of the COMPASS collaboration

andrei.gridin@cern.ch

14.11.2022



First evidence of double J/ψ production

The NA3 double J/ψ results:

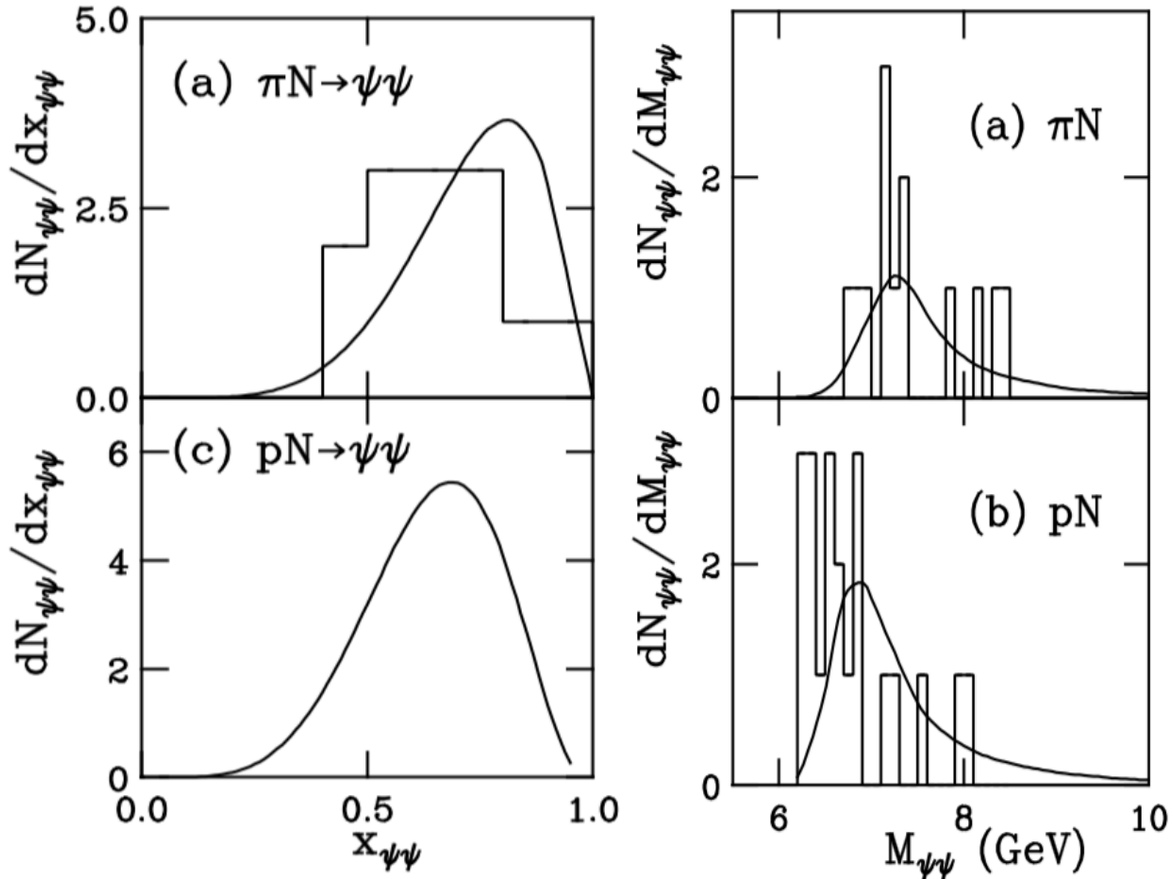
J.Badier et al (NA3)
Phys. Lett. B, v114, No6,1982,
Phys. Lett. B, v158, No1,1985

- π^- (150, 280 GeV) and p (400 GeV) beams;
- interpreted using single parton scattering mechanism ($q\bar{q} \to 2J/\psi$ and $gg \to 2J/\psi$);

R.E. Ecclestone, Phys. Lett. B. V. 120. 1983
B. Humpert, P. Mery, Phys. Lett. B. V. 124. 1983

- 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;

R Vogt, S.J. Brodsky, Phys. Lett. B, v349: 569-575, 1995



Intrinsic charm of hadron

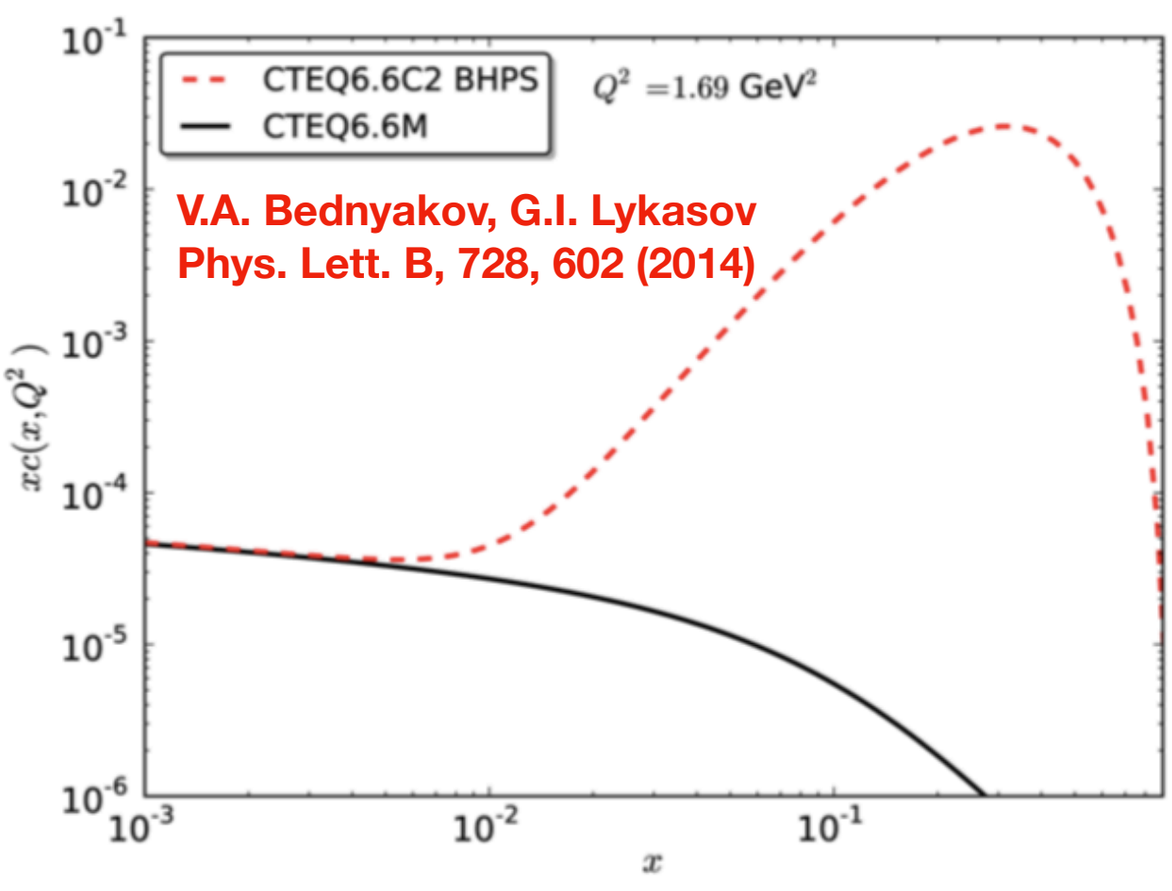
BHPS model: **S.J. Brodsky, Phys. Lett. B 93, 451 (1980)**

- The existence of non-perturbative (intrinsic) Fock component in a hadron with c-quarks is postulated:

$$|p\rangle = a_0|uud\rangle + a_1|uudg\rangle + a_2|uudc\bar{c}\rangle + \ldots$$

- In perturbative QCD the extrinsic charm component in hadrons arises from gluon splitting.

- Intrinsic charm contribution is generated non-perturbatively via $gg \to Q\bar{Q}$;



Allows to solve inconsistency of Ξ_{cc}^{++} and Ξ_{cc}^{+} production rates with QCD predictions at SELEX.

S.Koshkarev, V.Anikeev, Phys.Lett.B765,171 (2017)

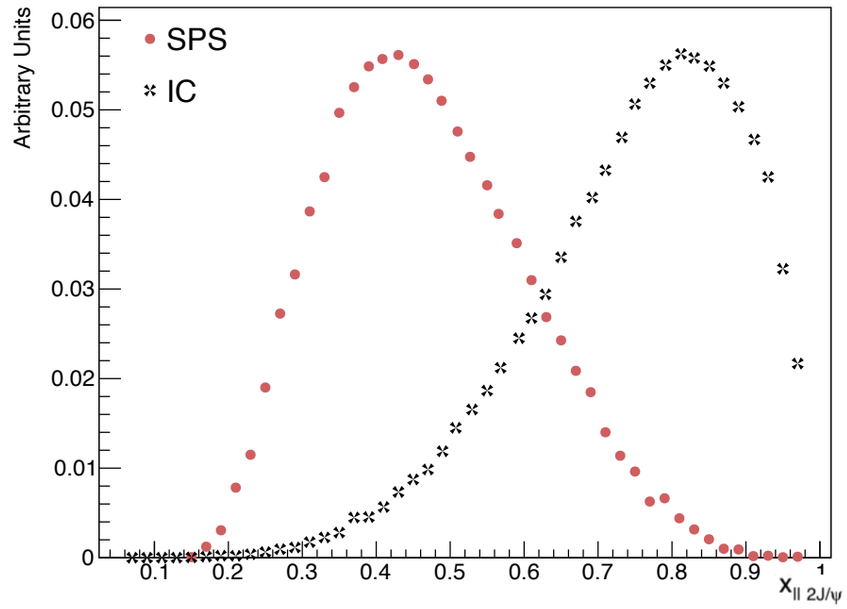
Double J/ψ production via single and double parton scattering

- SPS: expected to be dominant for J/ψ pair production at COMPASS;

- SPS-IC interference is negligible;

A. Gridin, S. Koshkarev,

B. Phys. Part. Nucl. Lett. 17 (2020) 826–833.

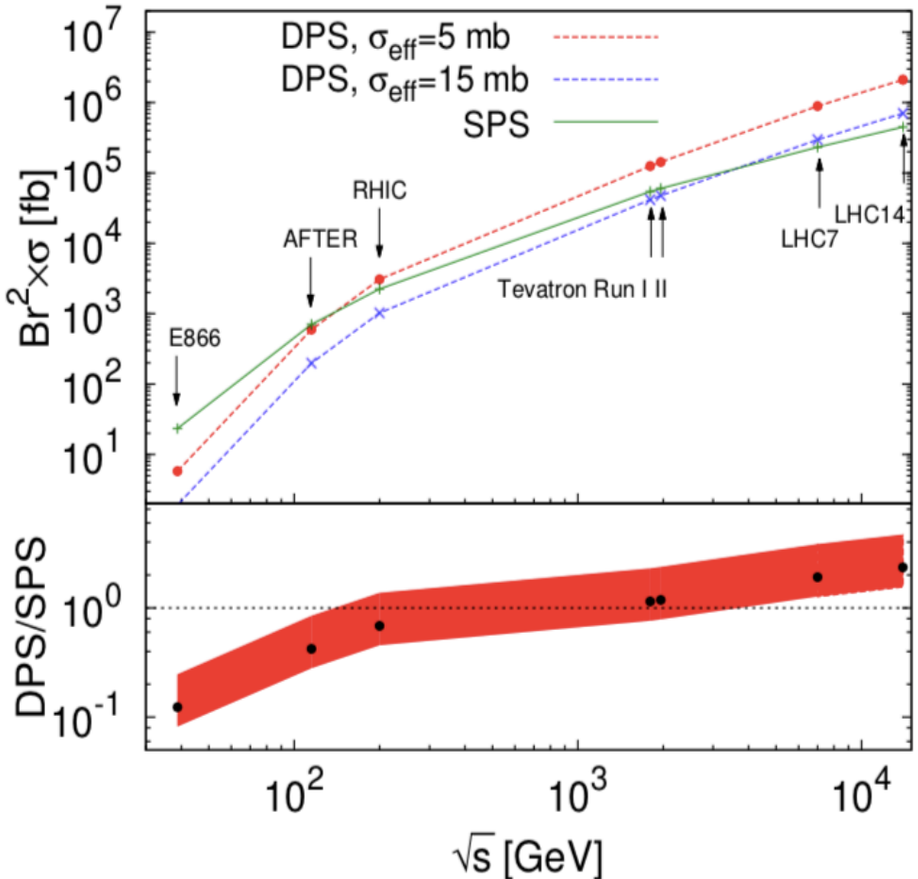


- DPS: does not exhibit of 8% of SPS at $\sqrt{s} = 18.9$ GeV: $\sigma^{\pi^- N}_{DPS}(J/\psi J/\psi) < 1\ pb/nucleon$;

S. Koshkarev, Proceedings of: DSPIN-19:

arXiv:1909.06195 [hep-ph]

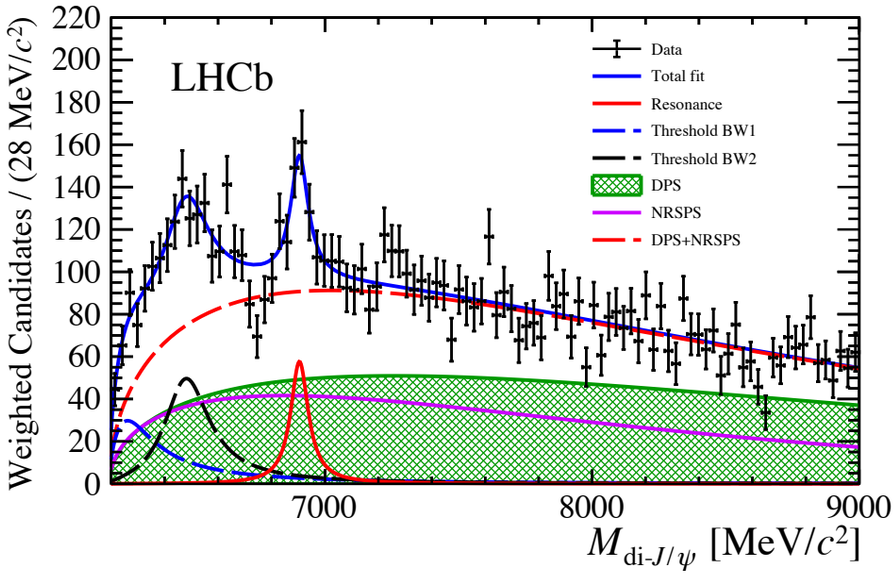
J.-P. Lansberg, Nucl. Phys. B 900 (2015) 273

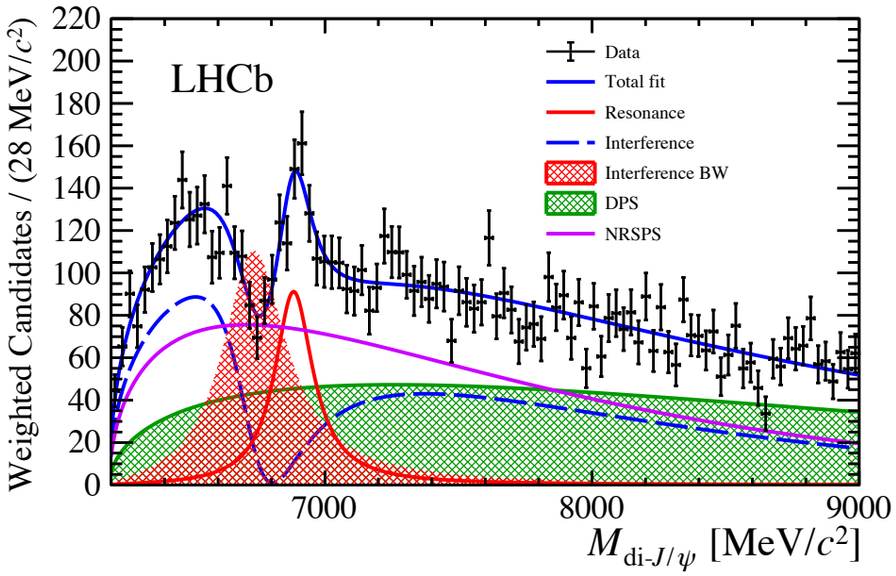


T_{4c}-tetraquarks

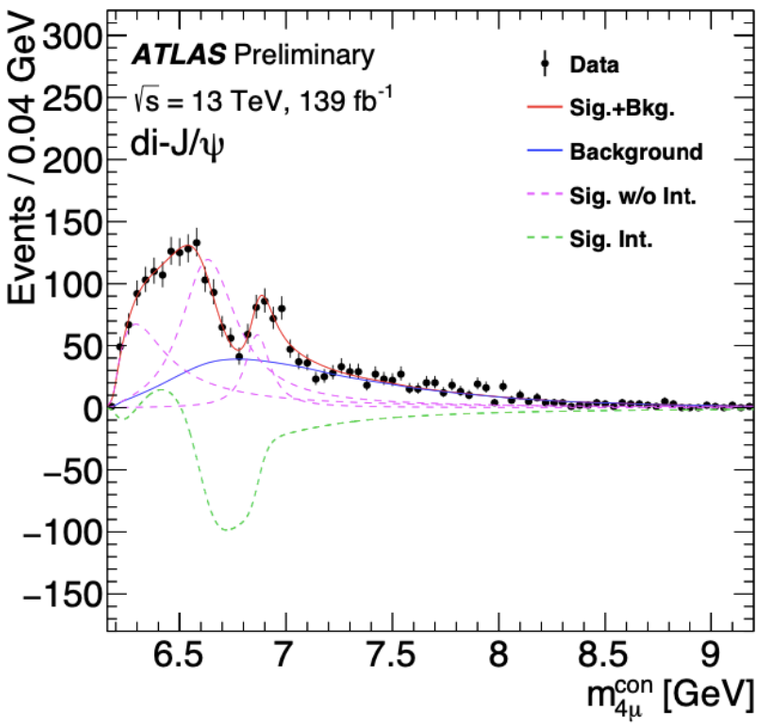
- 1975: first time T_{4c} states were predicted;
  Y. Iwasaki, Prog. Theor. Phys. V.54, 492 (1975)
- 2020: LHCb reported the X(6900) structure in the $M_{2J/\psi}$ spectrum ($\sqrt{s} = 7,\ 8$ and 13 TeV).
- 2022: ATLAS has confirmed the LHCb observation using a 3-resonance model with interference.

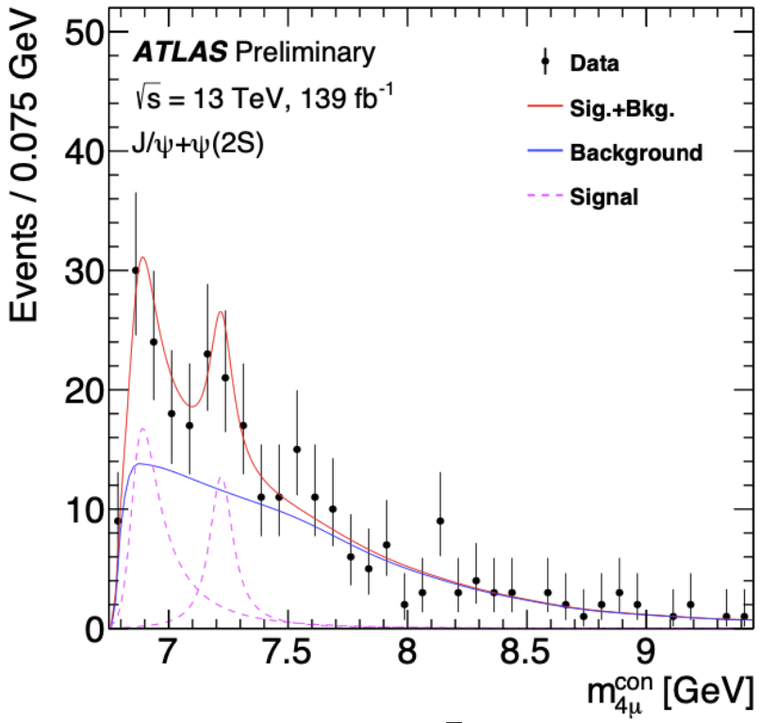
Sci. Bull., V65, №23, p1983-1993, 2020





Guillaume Unal talk at ICHEP 2022





COMPASS experiment at CERN

COmmon **M**uon **P**roton **A**pparatus for **S**tructure and **S**pectroscopy

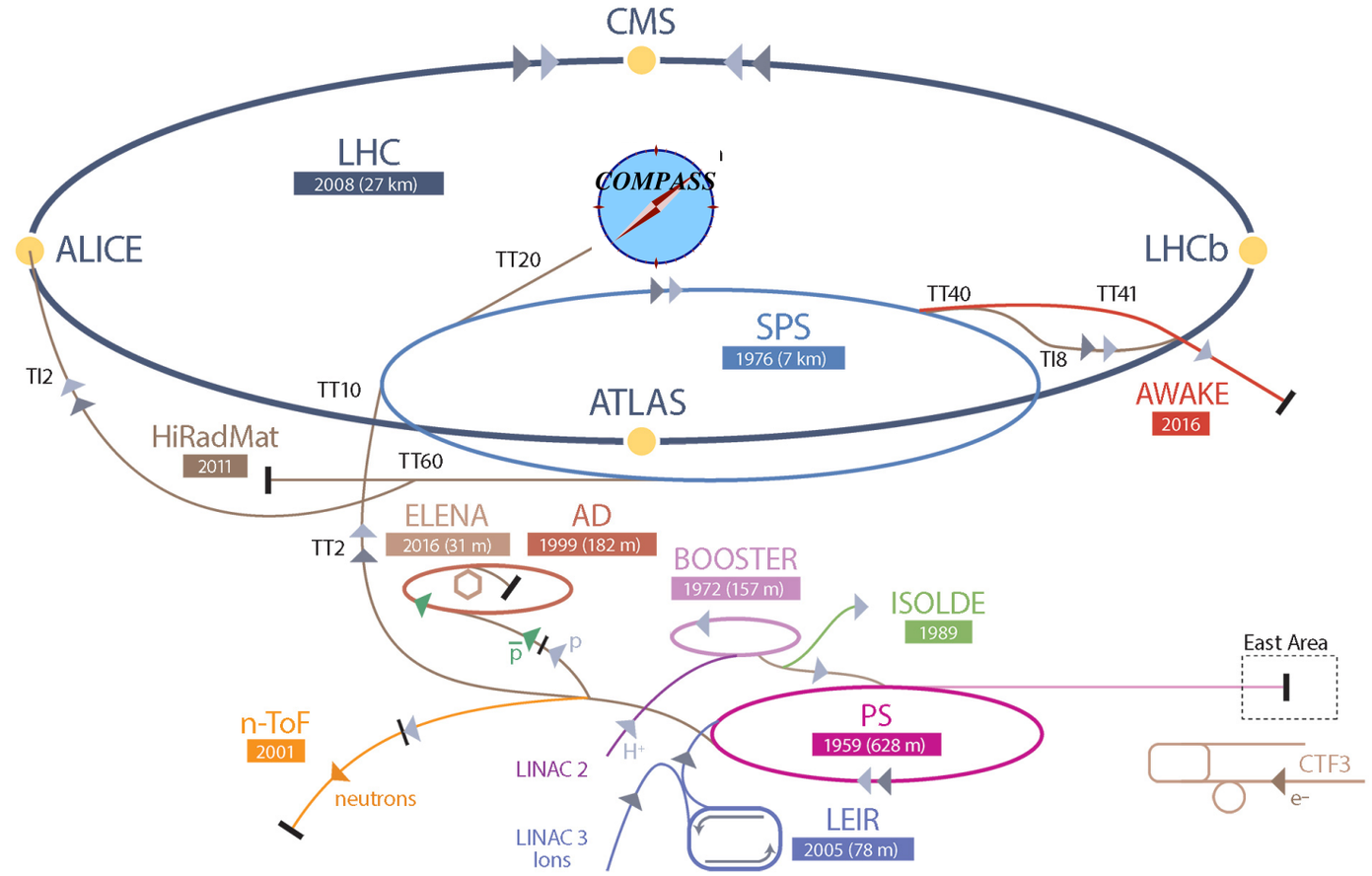
Phase 1:

- Nucleon Spin Structure (2002-2011)
- Hadron Spectroscopy (2008-2009)

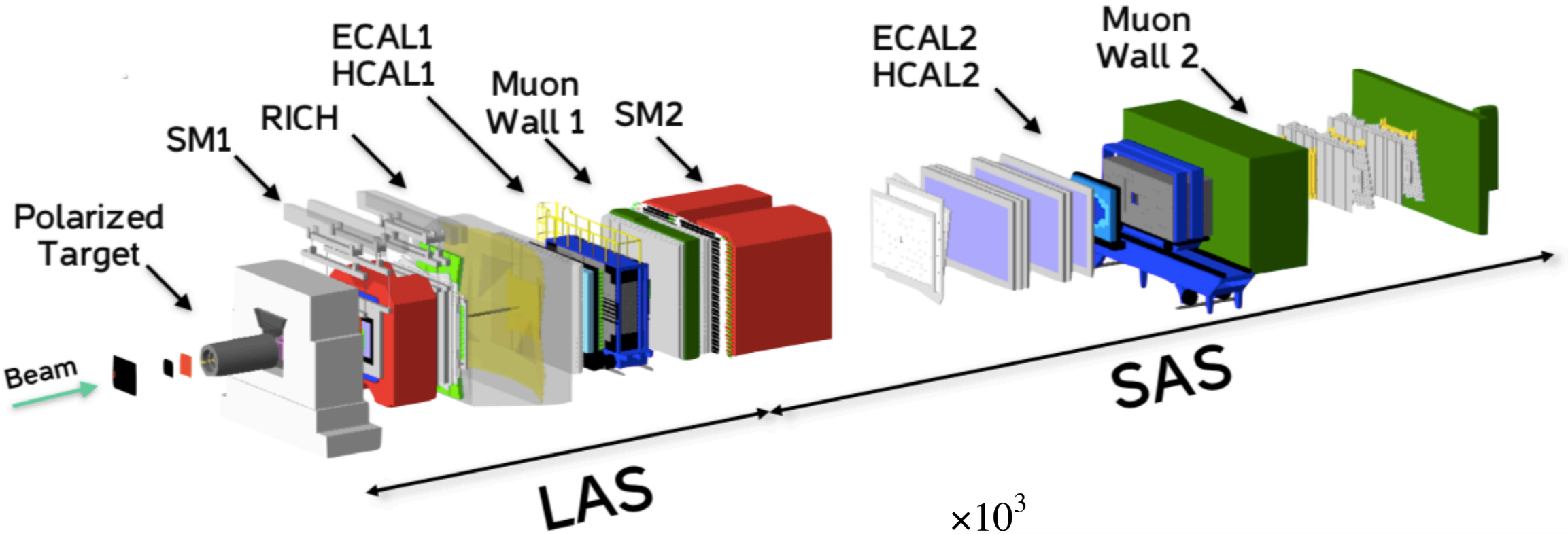
Phase 2:

- Primakoff (2012)
- DVCS, SIDIS (2012, 2016, 2017)
- Drell-Yan (2015, 2018)

CERN's Accelerator Complex

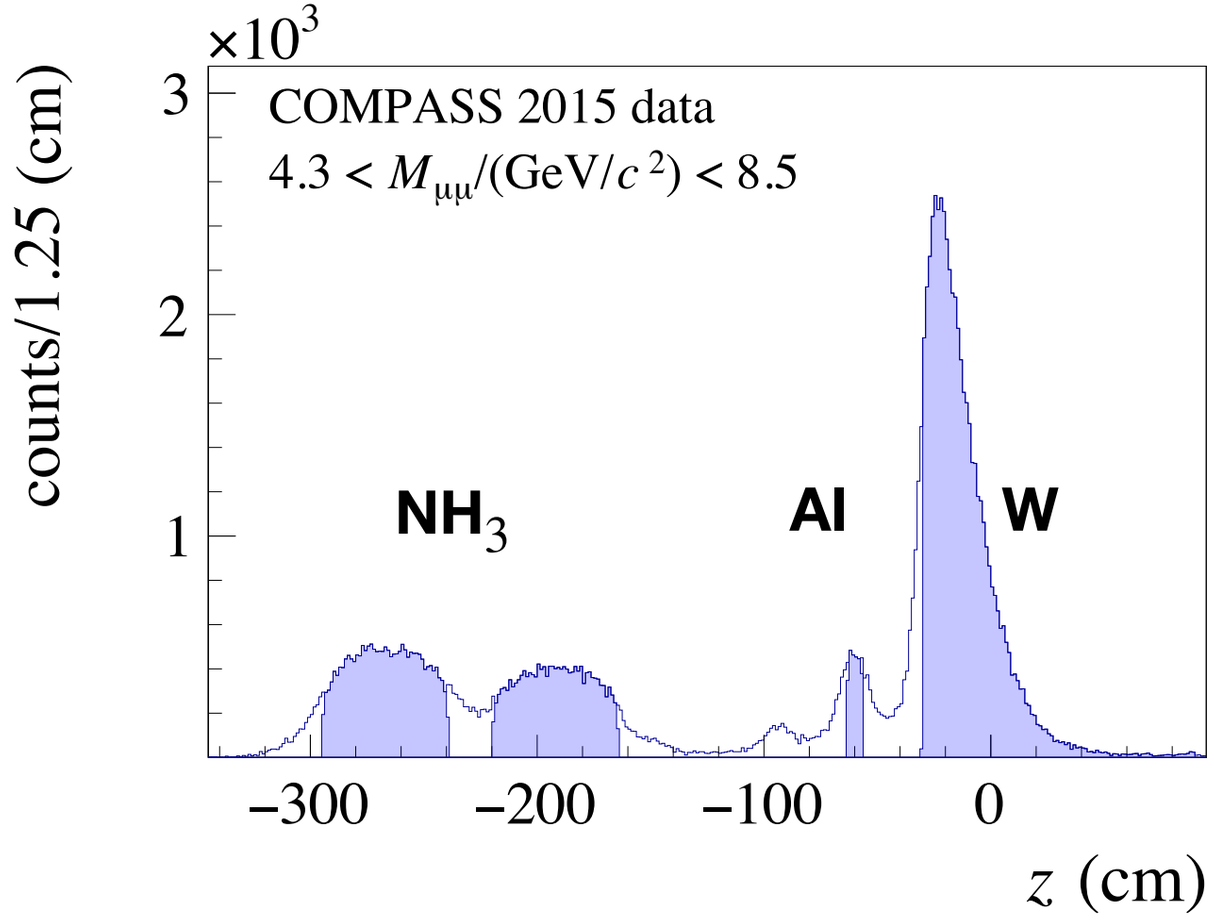


COMPASS Drell-Yan setup



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 **7x10^7 hadrons / sec**;



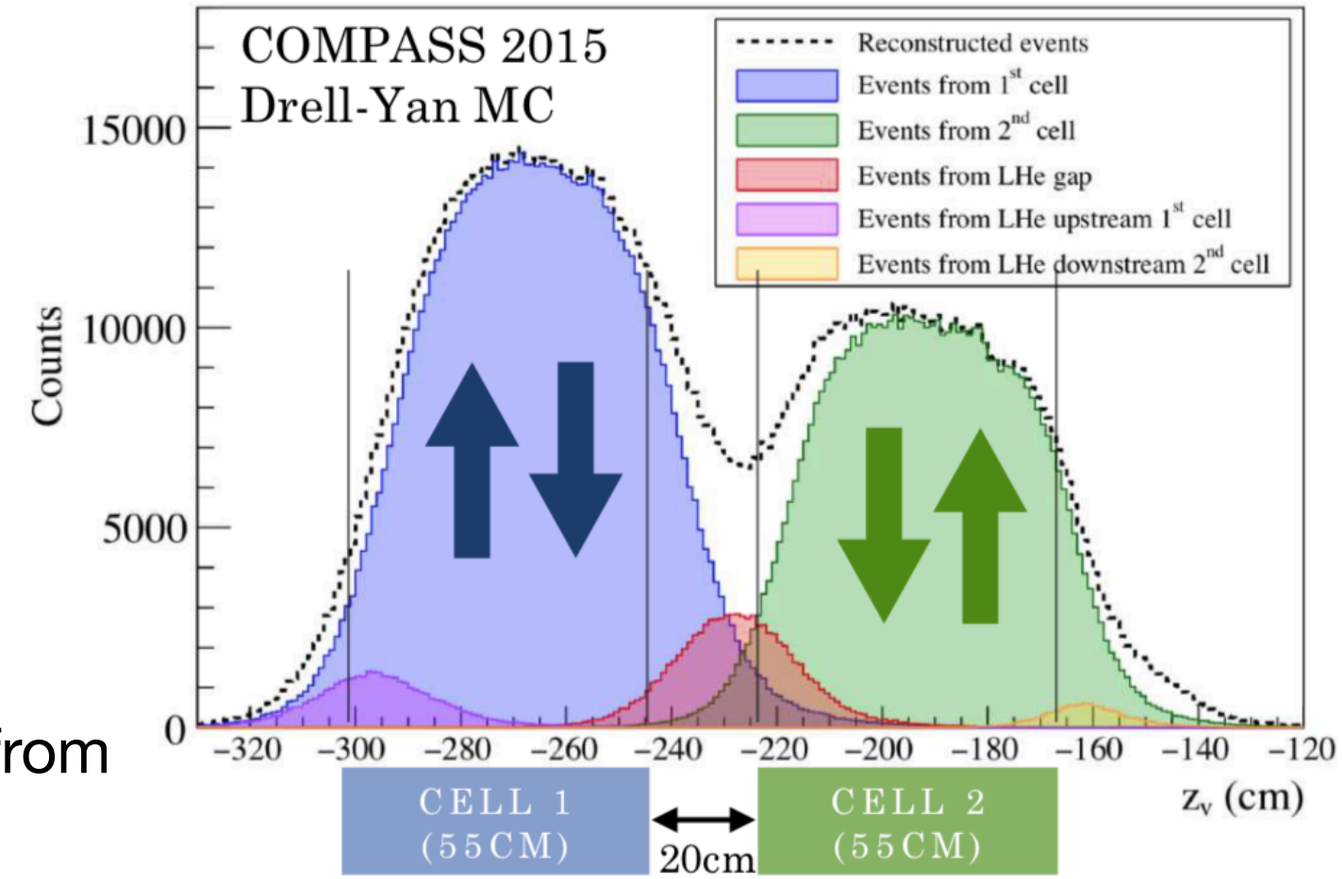
COMPASS Drell-Yan setup

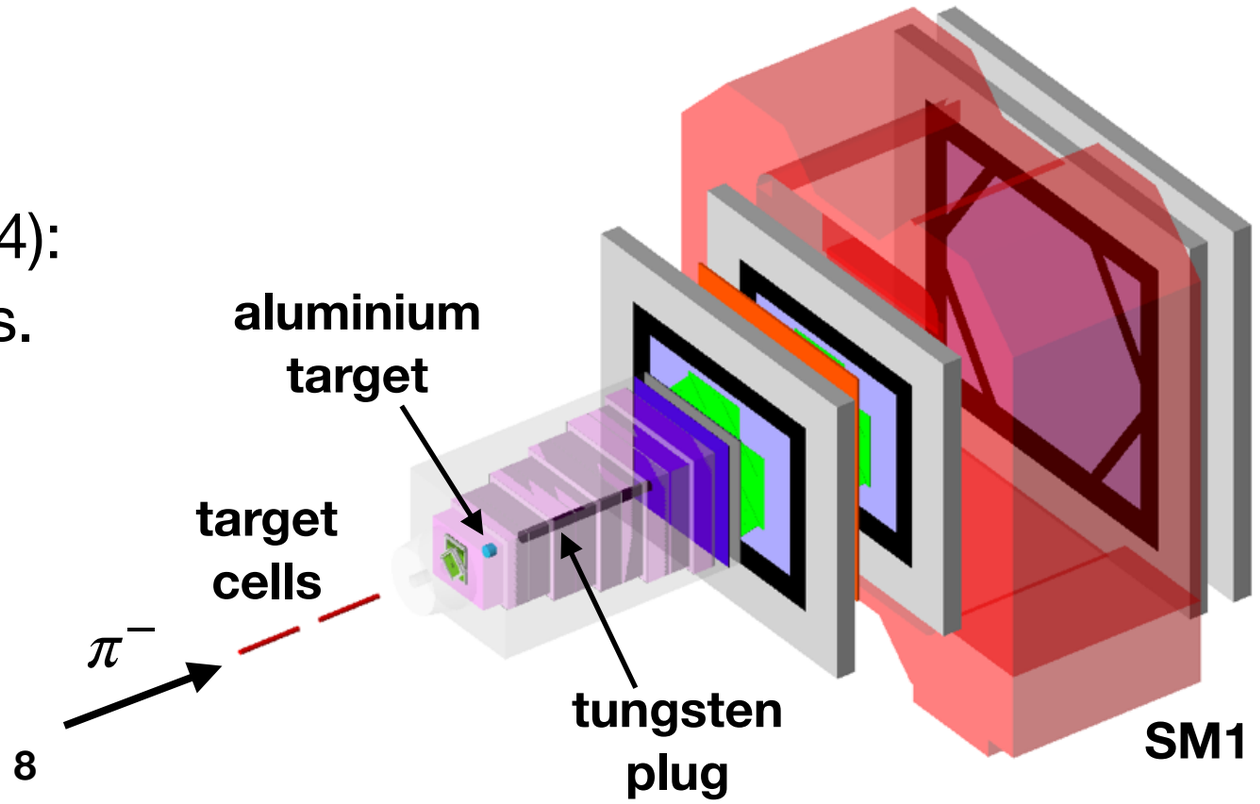
Polarized target:

- two 55 cm long cells filled with NH_3 immersed in LHe used in particular in polarized DY studies.

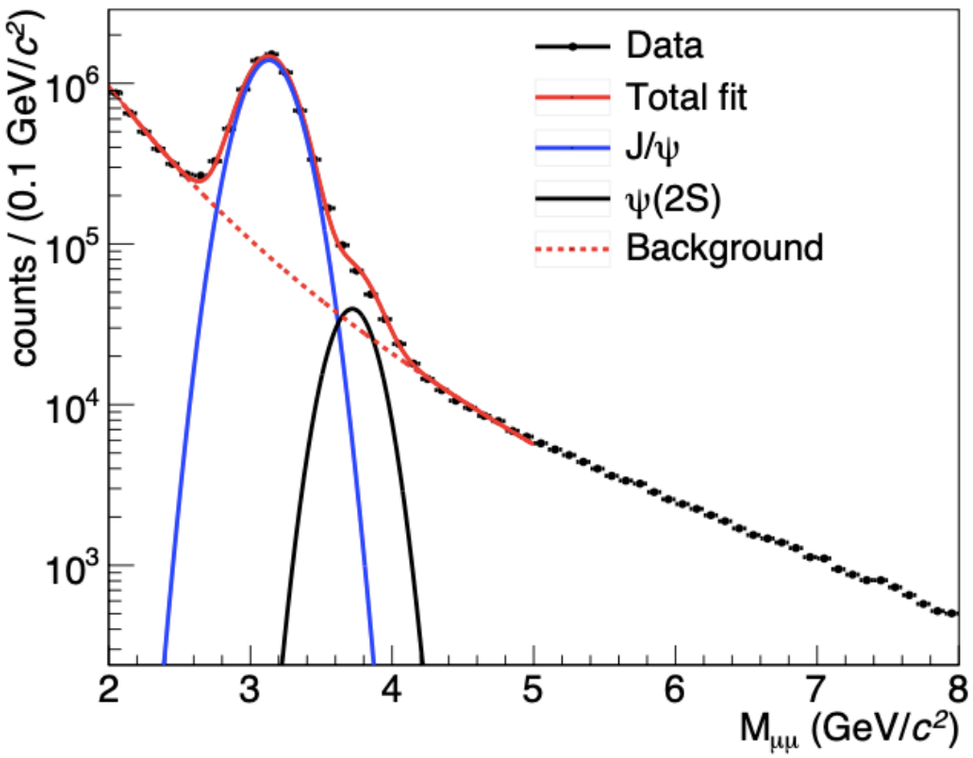
Nuclear targets (Al and W):

- used to remove hadrons originating from target interactions or beam;
- used as an additional nuclear targets:
  — aluminum (A ~ 27): 7cm length;
  — tungsten (beam plug, 120 cm, A ~ 184):
  first 10 cm used for the physics analyses.





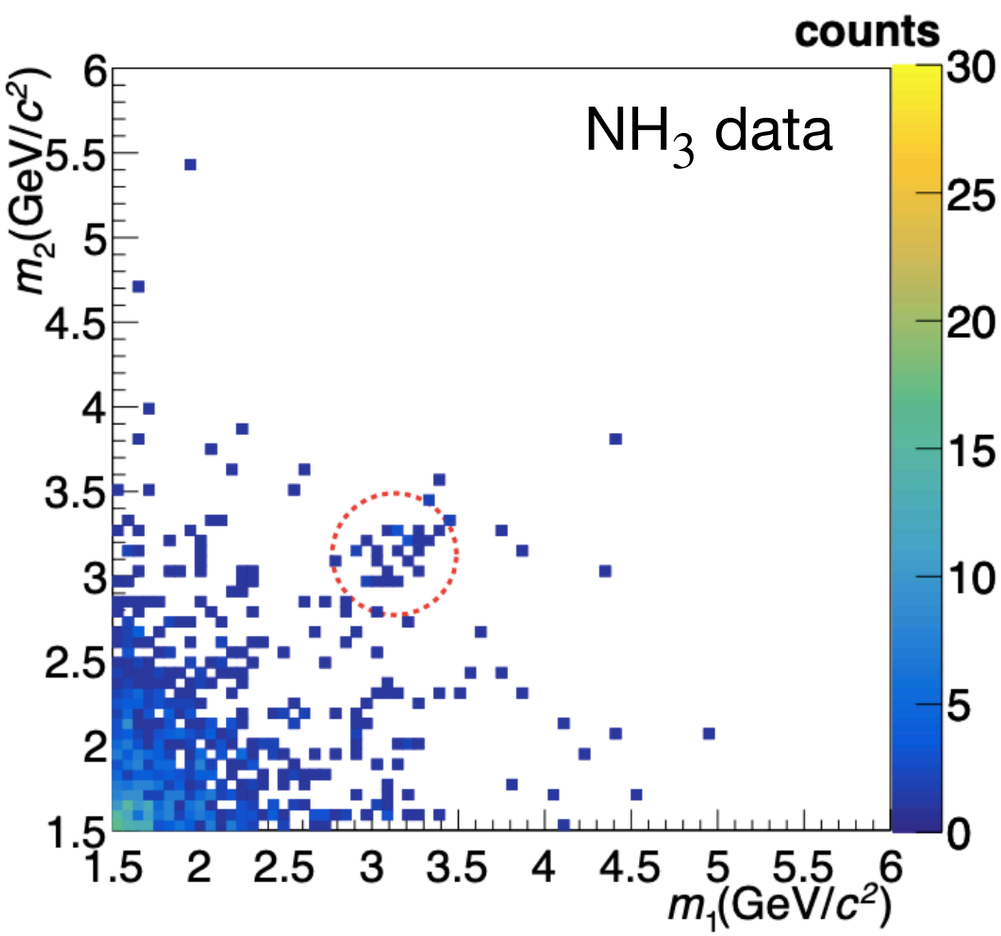
COMPASS data



2015+2018: ~9 months of data taking;

Large statistics of single J/ψ events:

- Mass resolution: $\Delta_{J/\psi}$ = 0.182 GeV/c^2
- A shoulder from $\psi(2S)$ is visible



Double J/ψ events:

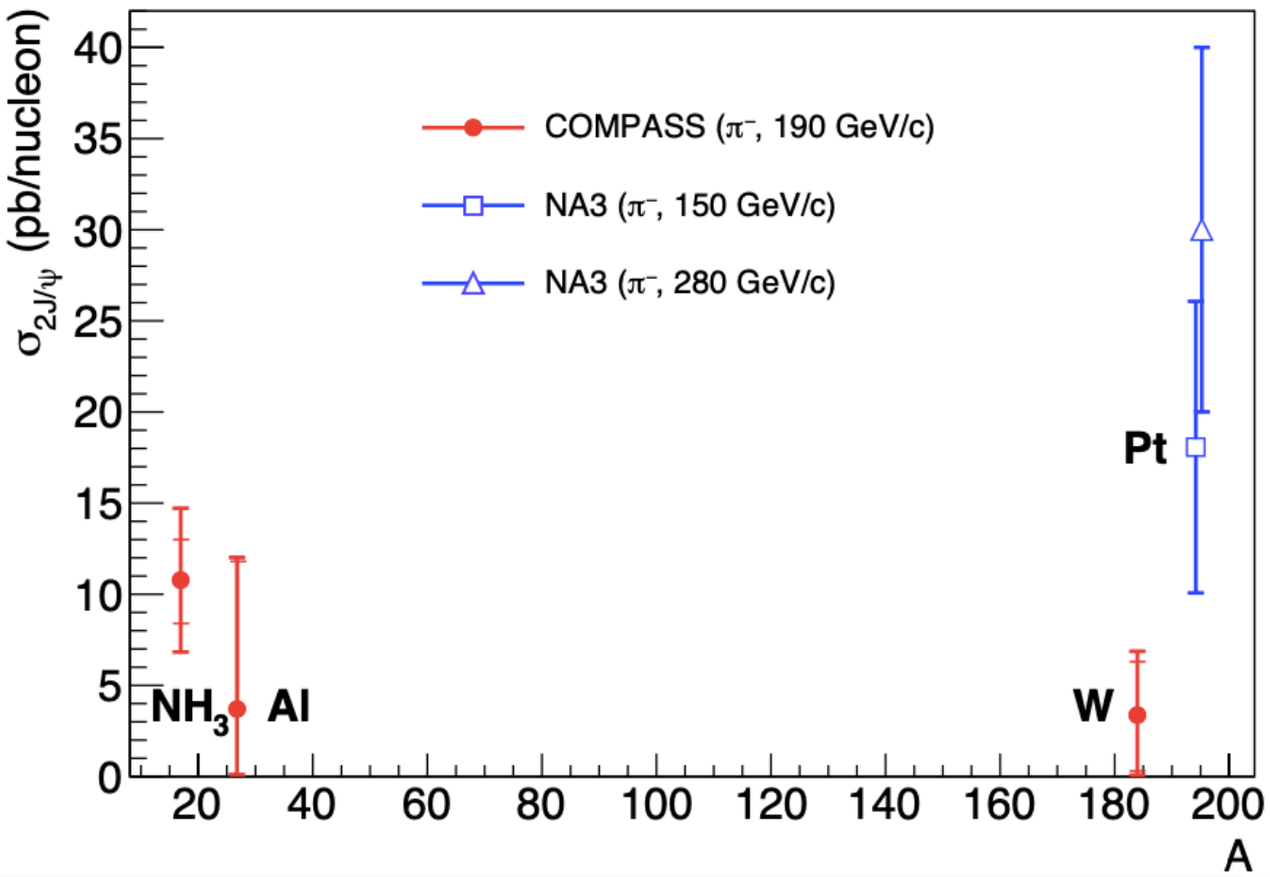
NH_3 target: 28 events (used for the analysis)

Al target: 2 events

W target: 13 events

- large background contamination
- used only for cross-section estimation.

Double J/ψ cross-section measurement



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

$$\sigma_{2J/\psi}^{NH_3} = 10.7 \pm 2.3_{stat} \pm 3.2_{syst} \frac{pb}{nucleon}$$

$$\sigma_{2J/\psi}^{Al} = 3.6 \pm 8.2_{stat} \pm 1.4_{syst} \frac{pb}{nucleon}$$

$$\sigma_{2J/\psi}^{W} = 3.3 \pm 3.0_{stat} \pm 1.8_{syst} \frac{pb}{nucleon}$$

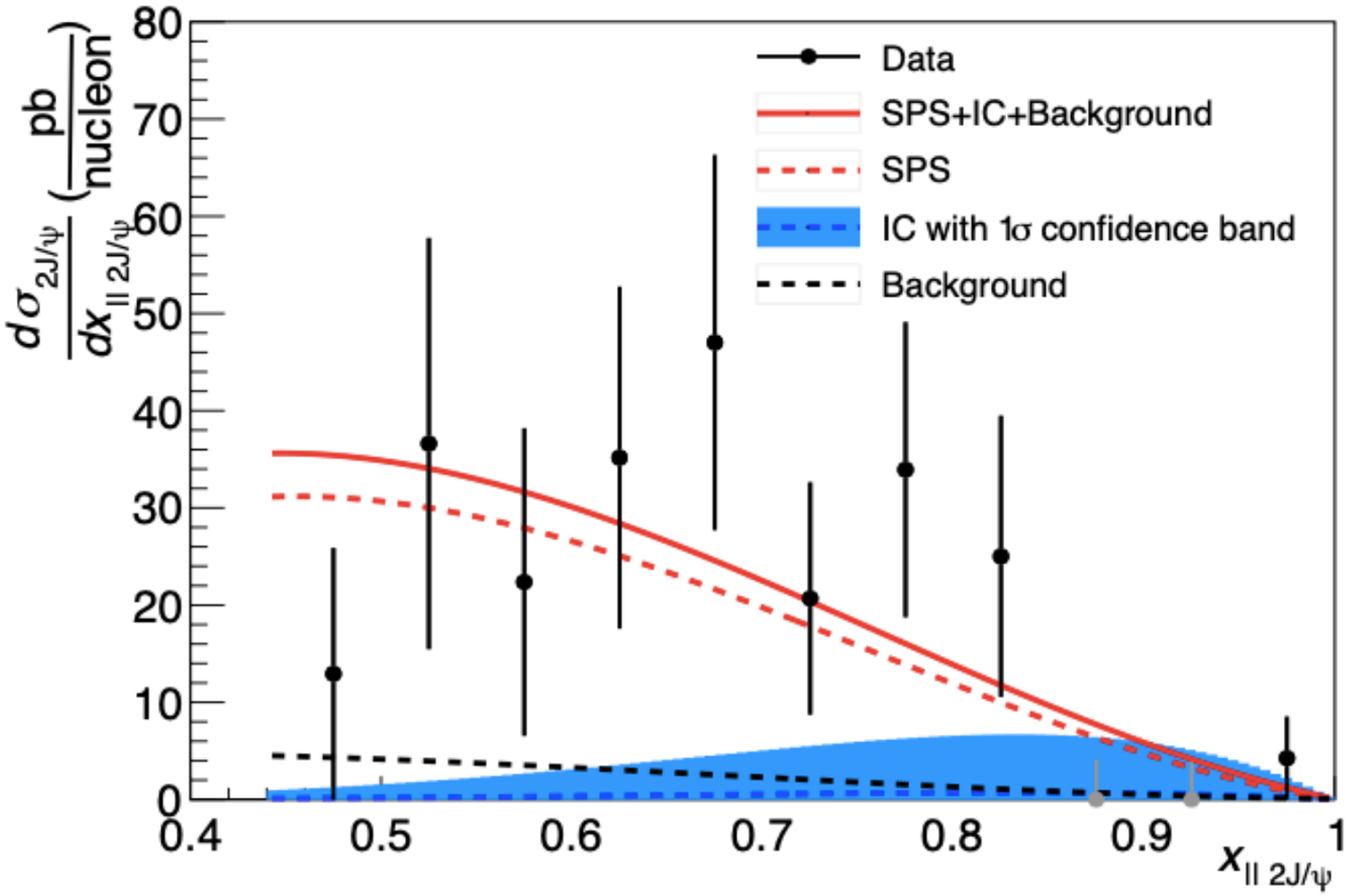
Main sources of systematics:

- uncertainty of $\sigma_{J/\psi}$
- background estimation
- acceptances of single and double J/ψ
- uncertainty of the number of single J/ψ

- COMPASS results do not contradict to NA3 measurement.
- No significant evidence of nuclear effects isobserved.

The measured by the NA3 $\sigma_{J/\psi} = 4.9 \pm 0.77 \frac{nb}{nucleon}$ was used for the estimation of $\sigma_{2J/\psi}$.

Double J/ψ production mechanisms



SPS curve:

- HELAC-Onia generator:
  H.S.Shao, Comput. Phys. Commun., Vol.198, p. 238-259, 2016;
- Color Singlet J/ψ production model.

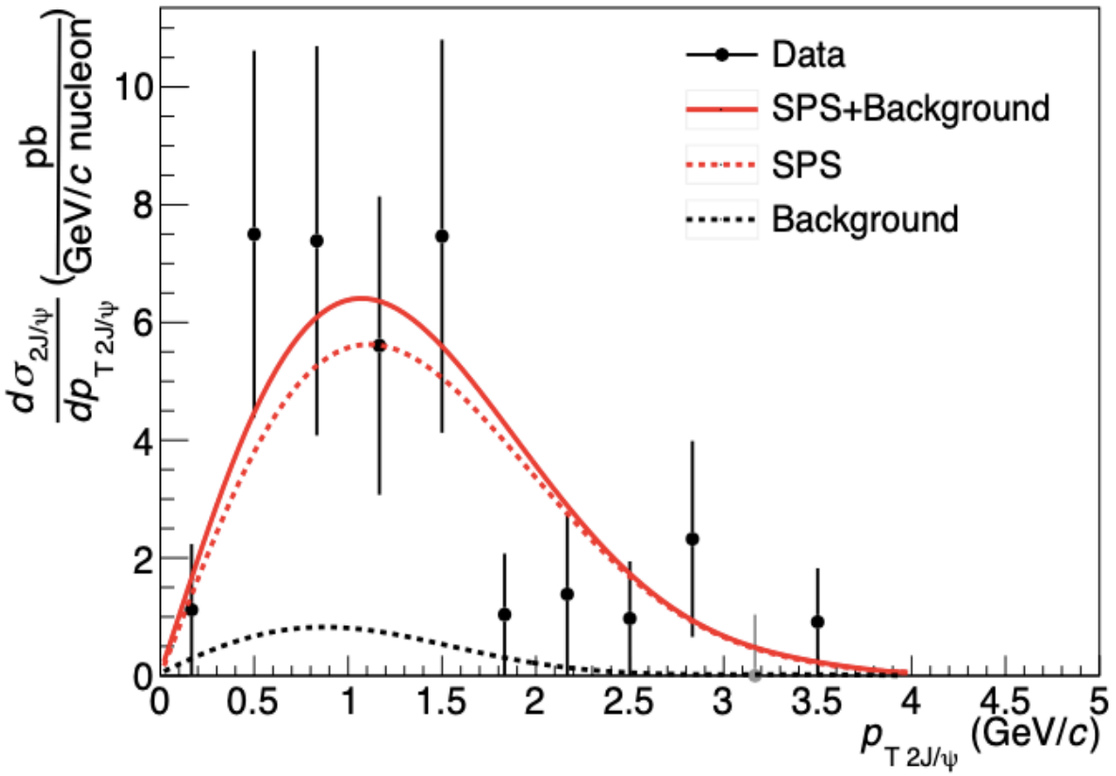
IC curve:

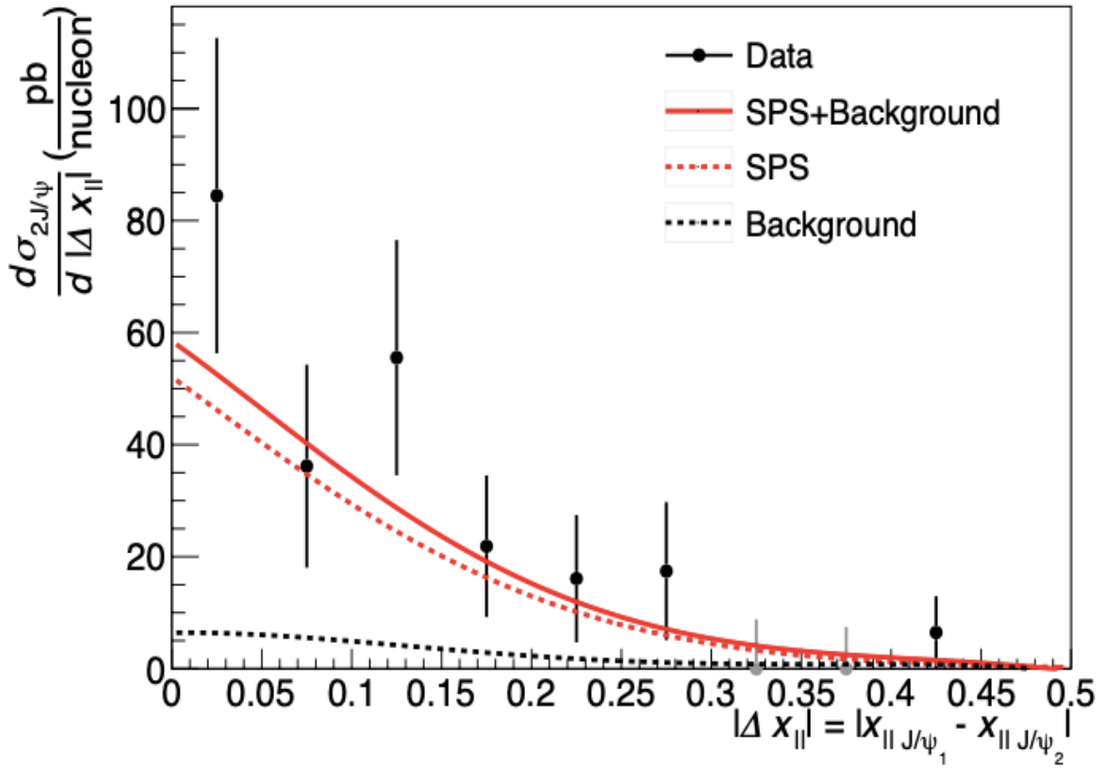
- predictions for COMPASS from
  Phys.Part.Nucl.Lett. Vol17, No6, 2020.

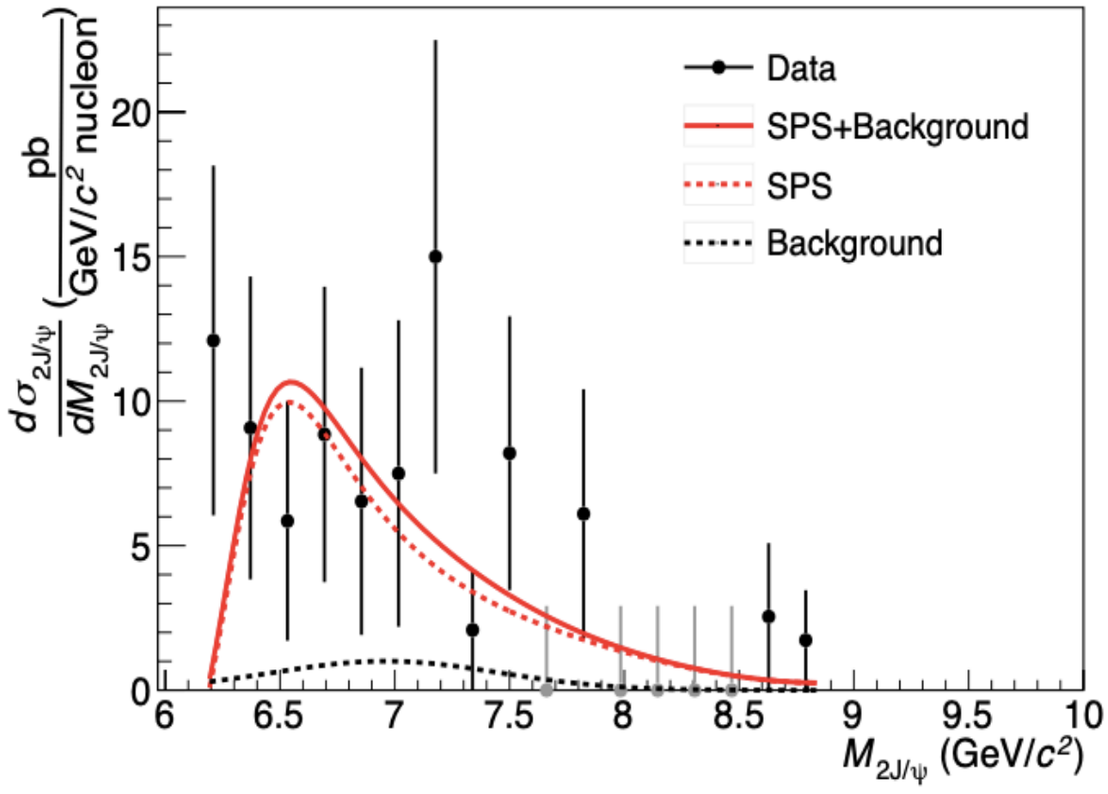
$$f(x_{\|\ 2J/\psi}) = a \cdot f_{SPS}(x_{\|\ 2J/\psi}) + b \cdot f_{IC}(x_{\|\ 2J/\psi}) + f_{bkg}(x_{\|\ 2J/\psi})$$

- the double parton scattering (DPS) is not considered in the fit;
- the data are consistent with pure SPS hypothesis
- $\sigma_{IC}/\sigma_{2J/\psi} < 0.24\ (CL = 90\%)$

Differential cross-sections







The $p_{T\ 2J/\psi}$ and $|\Delta x_{||}|$ distributions

- are in agreement with SPS model,
- cannot be used to disentangle different production mechanisms.

The $M_{2J/\psi}$ spectrum does not contain any evident signal from T_{4c} states.

Summary and conclusions

1. The COMPASS $2J/\psi$ data are consistent with SPS production mechanism.

- the SPS contribution can be the dominant one at NA3 and SELEX.

2. The COMPASS collaboration has estimated $\sigma_{2J/\psi}$ for each nuclear target.

3. An upper limit on double IC production mechanism is established.

4. No statistically significant resonant structures related to T_{4c} states in $M_{2J/\psi}$ spectrum.