Coherent ψ(2S) photo-production in ultra-peripheral collisions at LHC

Michal Broz*

for the ALICE Collaboration

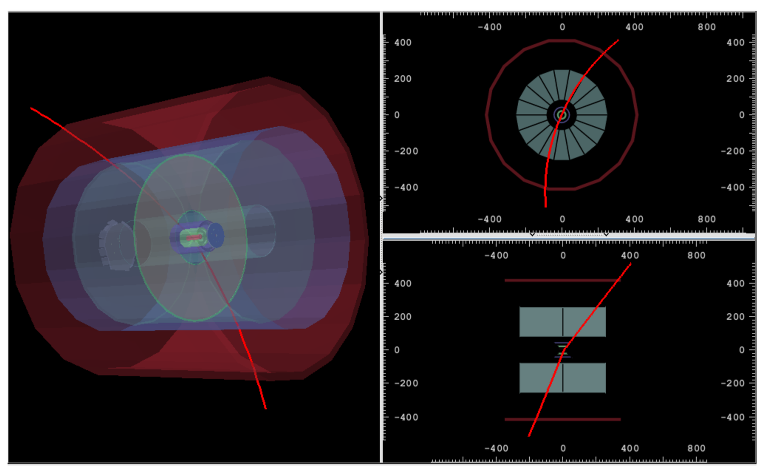
*Czech Technical University in Prague

Event sample

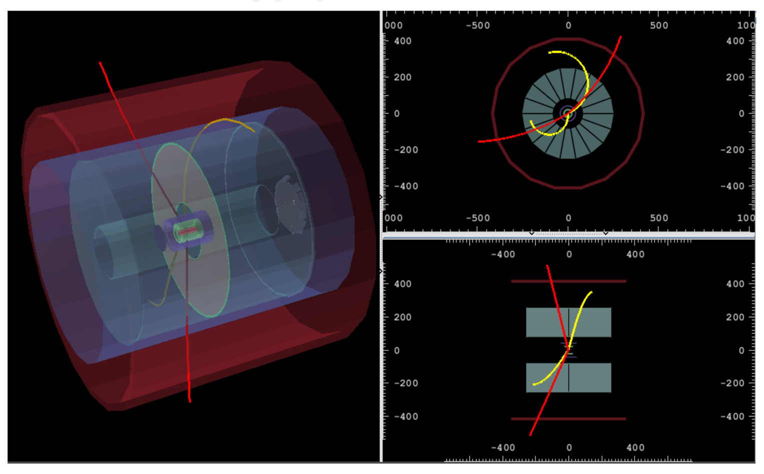
Ultra-peripheral collisions

- ALICE measured photo-production of ψ(2S) in central barrel (mid-rapidity) Pb-Pb UPC
- !! **First measurement of the ψ(2s) photo-production cross section with a nuclear target**
- Impact parameter larger then sum of nuclear radii
- Interaction of photon from electromagnetic field of the nucleus with the other nucleus
- 2 tracks or 4 tracks and nothing else
- Dedicated trigger based on the decay topology
- ~6.3M events corresponds to $\mathcal{L} = 22.4\mu b^{-1}$

ψ(2s) -> l⁺ l⁻



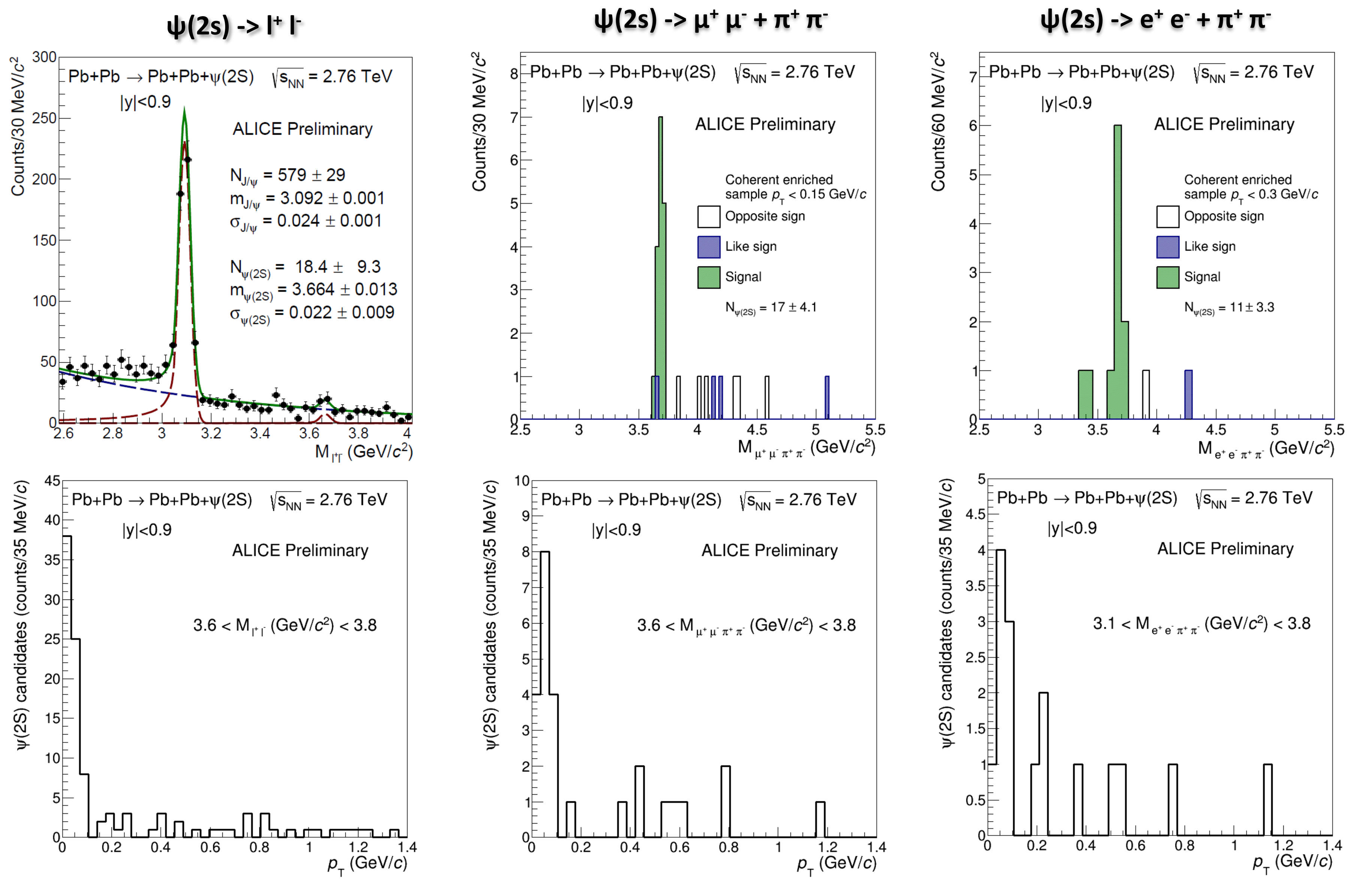
ψ(2s) -> l⁺ l⁻ + π⁺ π⁻



Analysis

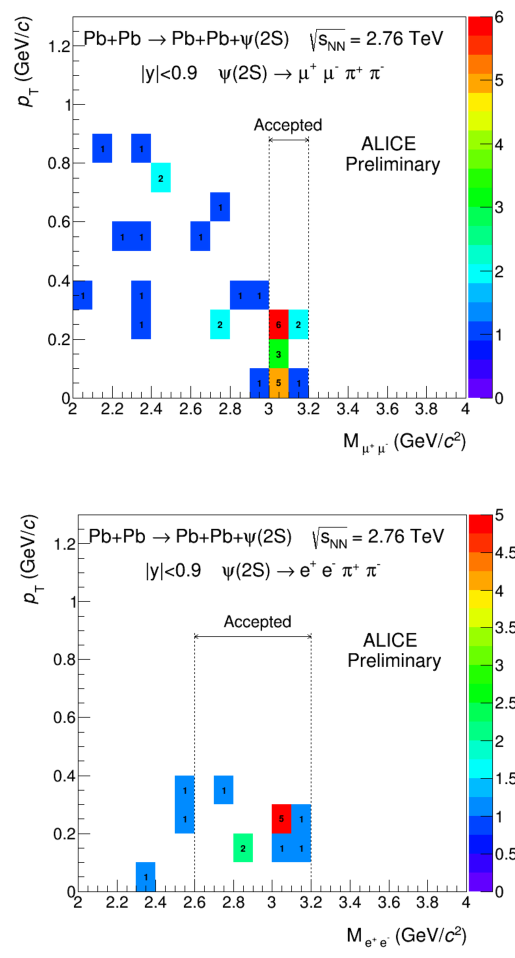
Signal extraction

- Four decay channels were used for analysis
- Clear low-p_T peak from coherent contribution is visible
- Signal was extracted from coherent-enriched samples (low-p_T restriction)
- Due to low statistics the di-muon and di-electron channels were summed together
- Di-lepton invariant mass is fitted with sum of two Crystal Ball functions and exponential background
- The cascade decay channels have very clean invariant mass spectra
- Signal extracted by bin-counting with like sign rejection



Secondary J/ψ

- For ψ(2s) -> l⁺ l⁻ + π⁺ π⁻ channels we see a clear J/ψ peak in the invariant mass spectra of the secondary di-leptons
- Channel dependent restriction is done on the invariant mass
- Di-electron peak is much wider due to the bremsstrahlung



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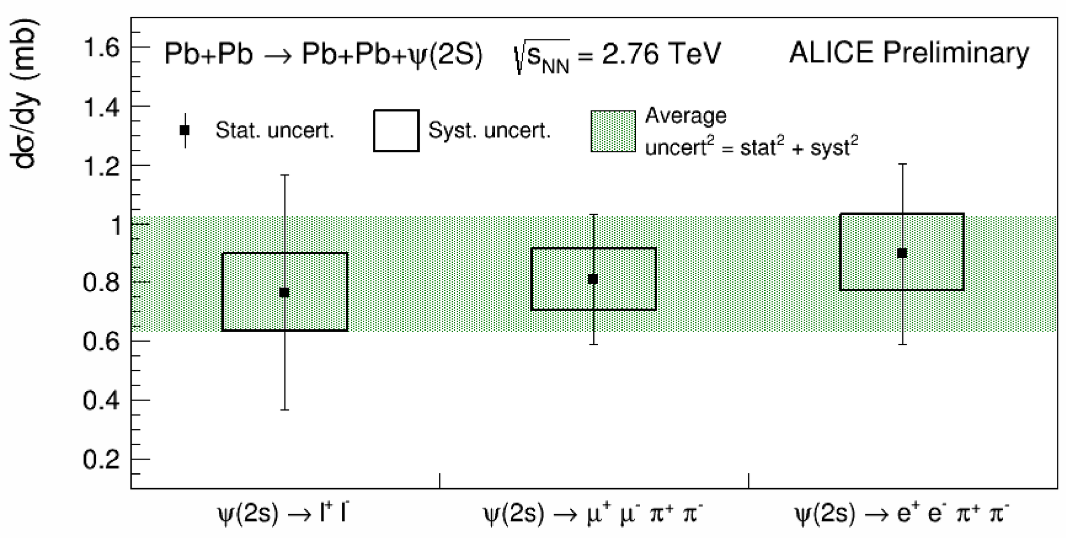
Results

Coherent photo-production cross section

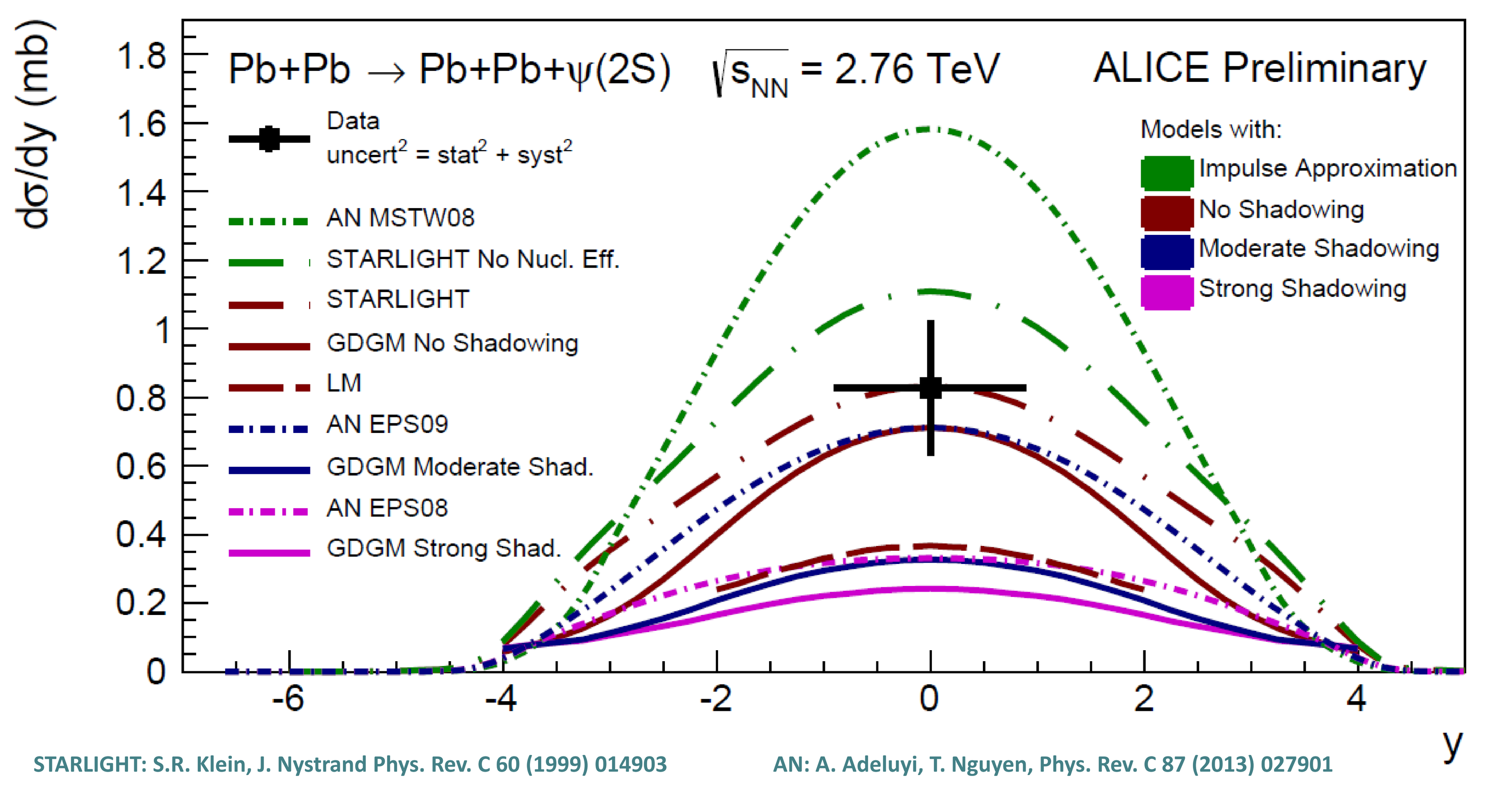


- The cross sections from three decay channels agree very well (<1σ stat)
- Average was weighted considering statistical and (un)correlated asymmetric sources of systematic uncertainties
- $\frac{d\sigma}{dy} = 0.83 \pm 0.19$ mb

	ψ(2s) -> l⁺ l⁻	ψ(2s) -> μ⁺ μ⁻ + π⁺ π⁻	ψ(2s) -> e⁺ e⁻ + π⁺ π⁻
Yield	18.4 ±9.3	16 ±4.2	11 ±3.3
Incoherent fraction	5.6% ±1.8%	3.4% ±1.1%	13.2% ±4.3%
Efficiency	3.7%	2.4%	1.3%
Luminosity	22.4 μb^{-1}	22.4 μb^{-1}	22.4 μb^{-1}
Branching ratio	2*0.78%	2.02%	2.02%
Δy	1.8	1.8	1.8
Cross section (mb)	0.76±0.40(stat)±0.13(syst)	0.81±0.22(stat)±0.10(syst)	0.89±0.31(stat) $^{+0.14}_{-0.12}$ (syst)

Model comparison

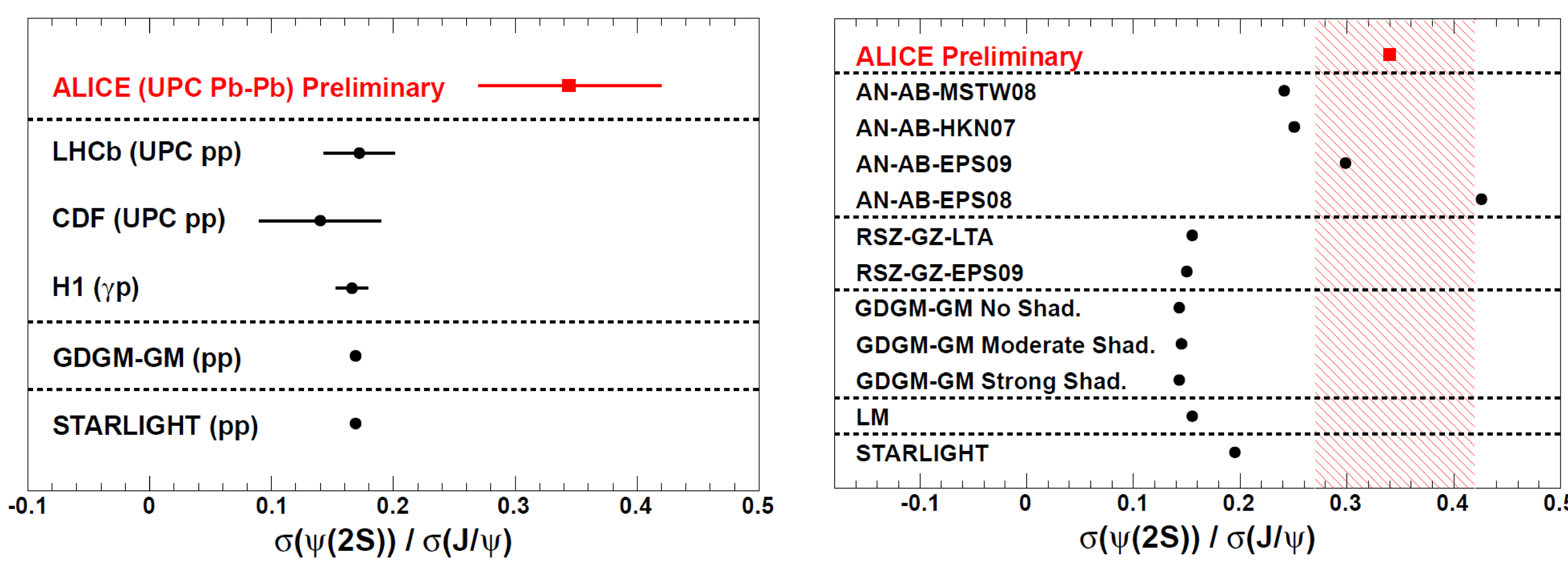
- Difficult to compare due to large uncertainty in γ-p cross section parameterizations
- Data disfavour models using impulse approximation and strong nuclear shadowing



STARLIGHT: S.R. Klein, J. Nystrand Phys. Rev. C 60 (1999) 014903 AN: A. Adeluyi, T. Nguyen, Phys. Rev. C 87 (2013) 027901
GDGM: M.B. Gay Ducati, M.T. Griep, M.V.T. Machado Phys. Rev. D 88 (2013) 017504 LM: T. Lappi, H. Mantysaari, Phys. Rev. C 87 (2013) 032201

Ratio to coherent J/ψ photo-production cross section

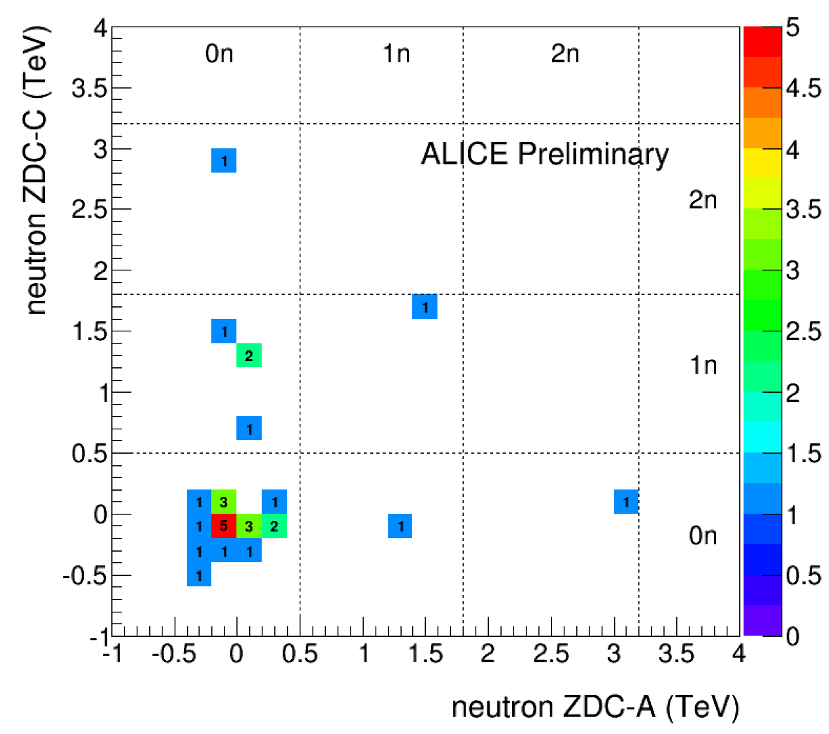
- Many source of systematic uncertainties will cancel in the measured ratio. **R = 0.34 $^{+0.08}_{-0.07}$ (stat+syst)**
- Difficult to compare due to large uncertainty in γ-p cross section parameterizations
- Change of the ratio from pp to Pb-Pb may indicate that nuclear effects affect 1S and 2S states differently



J/ψ Pb-Pb UPC cross section: ALICE Collaboration, EPJC 73 (2013) 2617

Nuclear break-up

- One or both nuclei may get excited due to additional exchange of photons
- In the cascade decay channel we measured number of events with various types of neutron emission using ZDC detector
- As expected for photo-production, most of the events have no neutrons emitted on either side



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