Efficiency loss in PbPb due to EMD
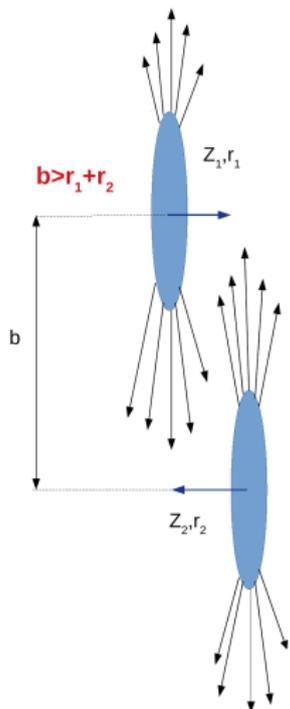
Vendulka Fílová
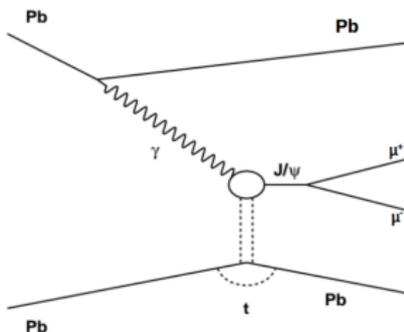
Diffraction and UPC group meeting at Decin 2020

September 16, 2020

Photoproduction of J/ψ

- Photon flux $\propto Z^2$
- $\Rightarrow$ Photon-induced $Pb - Pb$ interactions
- Due to Vector Meson Dominance - vector meson is produced very likely
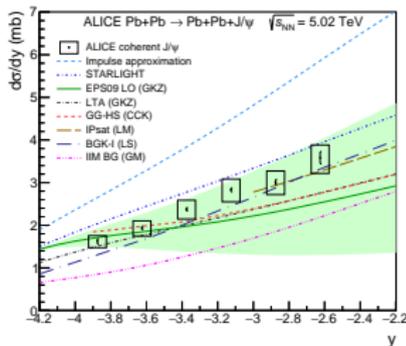- $\Rightarrow$ Photoproduction of J/ψ vector meson

- Measuring cross section of J/ψ photoproduction in UPC

Why is this process interesting to study?

$$\frac{d\sigma_{\gamma Pb \to J/\psi Pb}}{dt}\Big|_{t=0} = \frac{M_{J/\psi}^3 \Gamma_{ee} \pi^3 \alpha_s^2(Q^2)}{48 \alpha_{em} Q^8}[xg_{Pb}(x, Q^2)]^2$$
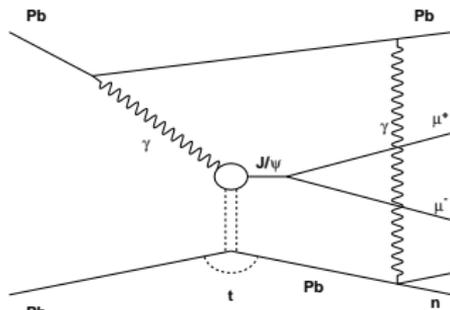
$\rightarrow$ Tool to study gluon densities at small$-x$ values

Shreyasi Acharya et al. arXiv:190406272, can be found here.

Additional process: EMD

Independent additional photon-induced interaction of the same pair of nuclei can occur. One or more neutrons (not only!) are produced.

- We separate data sample into four neutron classes - (0n0n),(0nXn),(Xn0n) and (XnXn)
- Measuring cross section in different neutron classes
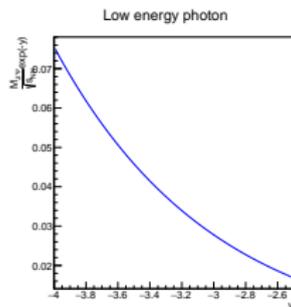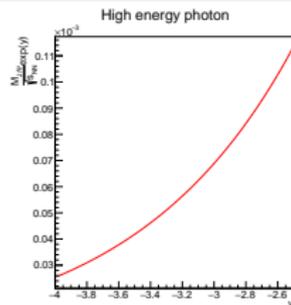
Why separation into neutron classes?

$$\frac{d\sigma_{PbPb \to J/\psi PbPb}(y)}{dy} = N_{\gamma Pb}(y)\sigma_{\gamma Pb \to J/\psi Pb}(y) + N_{\gamma Pb}(-y)\sigma_{\gamma Pb \to J/\psi Pb}(-y)$$

High energy photon

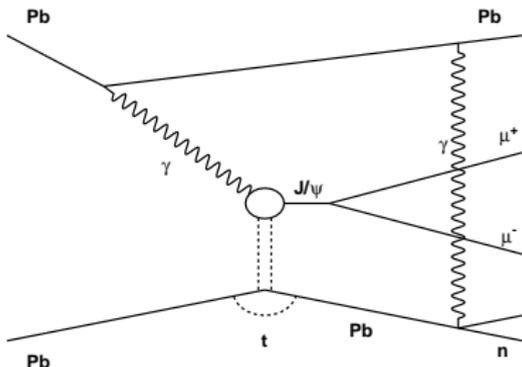- We believe it helps us to disentangle these
- $x = \frac{M_{J/\psi}}{\sqrt{s_{NN}}}exp(\pm y)$
- $\Rightarrow$ And reach even lower values of $x \sim 10^{-5}$!
- **All good. Where is the problem then?**

Low energy photon

Electromagnetic dissociation

Taken from I. Pshenichnov talk, can be found here.
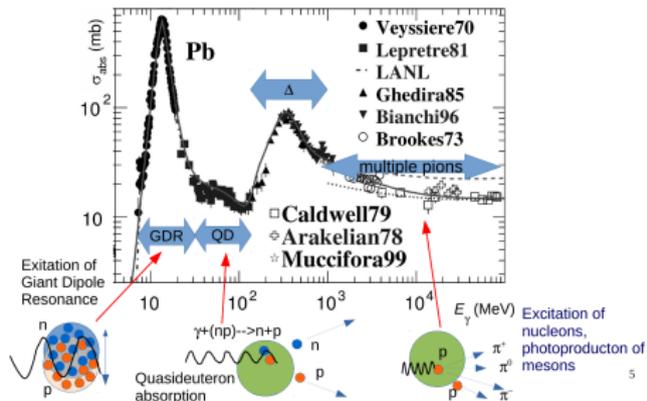

- In EMD $\sim 70\%$ emission of one or more neutrons, but..
- Less frequent production of charged particles has not been taken into account.

We are losing these events!

ALICE subdetectors

Problem
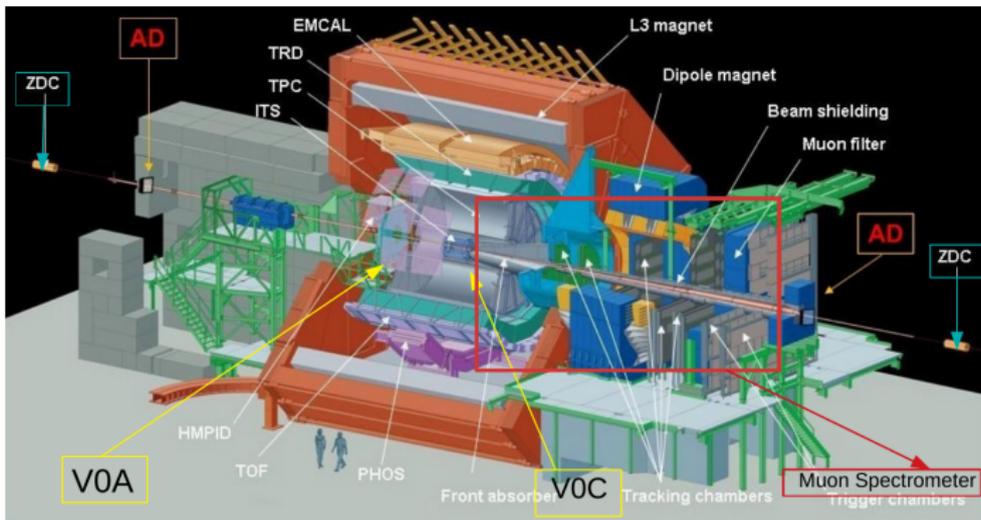
- Main trigger used in the published analysis:
- $\star$ CMUP11-B-NOPF-MUFAST = !0VBA & !0UBA & !0UBC & 0MUL
- Veto on V0A, ADA and ADC - detection of charged particles produced
- Additional offline veto applied

- No control trigger allowing the correction!

Solution

- Another trigger active in 2018 data taking:
- ⋆ CMUP6-B-NOPF-MUFAST = !0VBA & 0MUL
- Separation of the sample into neutron classes (0n0n), (0nXn), (Xn0n) and (XnXn)
    - Defined via activity in ZDC detectors

- No need of correction for classes (0n0n) and (0nXn)
- Classes (Xn0n) and (XnXn) need to be corrected:
    - Correction for events caused by pile-up in V0A
    - Correction for events lost due to online V0A veto
   - ⋆ CTRUE, C1ZED samples to compute correction factors

⇒ **Data sample including EMD processes.**

Selection of J/ψ candidates

- Pb-Pb UPCs at $\sqrt{s_{NN}} = 5.02$ TeV during LHC Run 2
- Event selection
  - Two unlike-sign muons in muon spectrometer
- Muon selection
  - The opposite electric charge
  - The dimuon rapidity: $-4 < y_{\mu\mu} < -2.5$
  - The transverse momentum: $p_{\mathrm{T}} < 250$ Mev/c
  - The invariant mass: $2.8 < M_{\mu\mu} < 3.3$ GeV/c^2
- Separation into neutron classes using information from ZDC detector

Invariant mass distributions

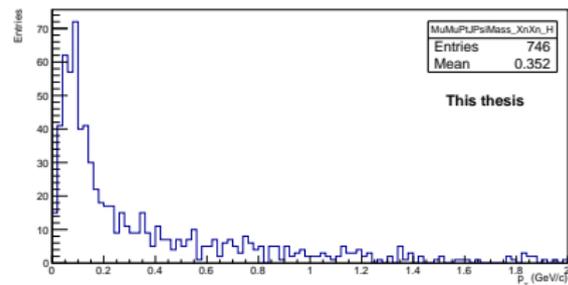- Invariant masses are fitted for all neutron classes and the number of J/ψ candidates is extracted.
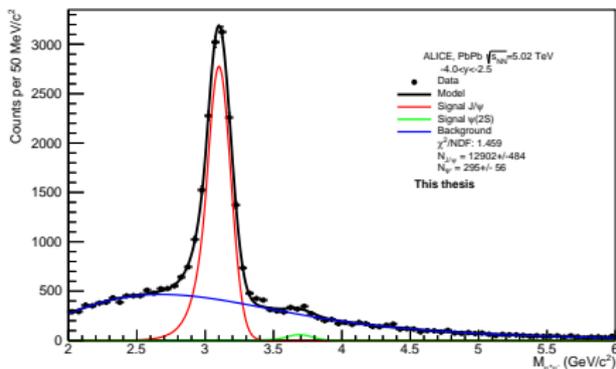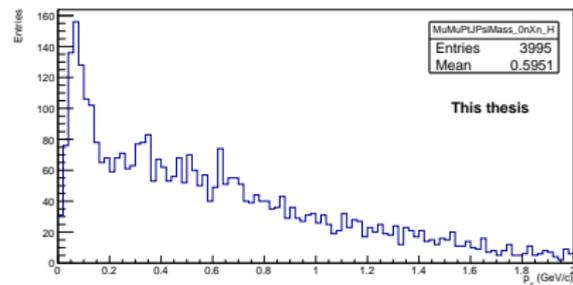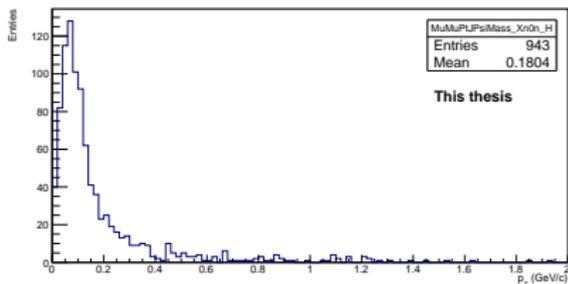

Neutron class (0n0n)
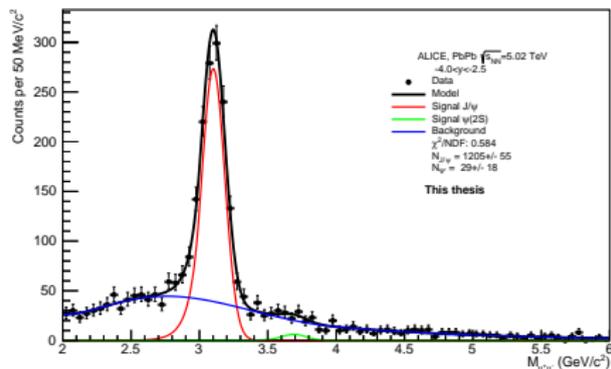
Neutron class (Xn0n)

Transverse momentum distributions

(0n0n)

(Xn0n)

(0nXn)

(XnXn)
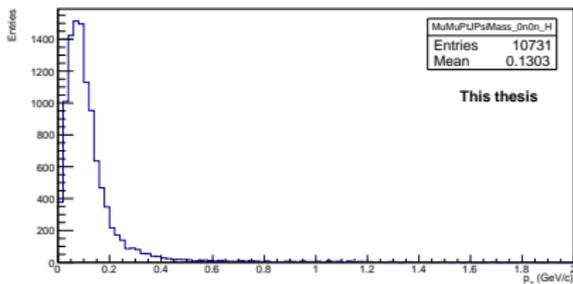
- Very different background in different neutron classes!

Incoherent contribution

- Sample is contaminated by incoherent events.
- Tomas (Thanks!) has produced fractions of incoherent events:
    - ⋆ $f_{\mathrm{I}} = \frac{\mathrm{J}/\psi\mathrm{incoh}+\mathrm{feed\ down J}/\psi\mathrm{incoh}+\mathrm{dissociative J}/\psi\mathrm{incoh}}{\mathrm{J}/\psi\mathrm{coh}+\mathrm{feed\ down J}/\psi\mathrm{coh}}$
    - $\Rightarrow N_{\mathrm{coherent}} = N_{\mathrm{J}/\psi} \cdot \frac{1}{(1-f_{\mathrm{I}})}$
- The samples of four neutron classes have been cleaned up from incoherent contribution.

Coherent J/ψ sample

Sample of J/Ψ with EMD

- Another collision in the same bunch crossing: pile-up
- Lost events due to the online V0A veto

ZNA

Offline V0A Decision

V0A veto

Signal in V0A by offline decision

Signal vetoed by online trigger
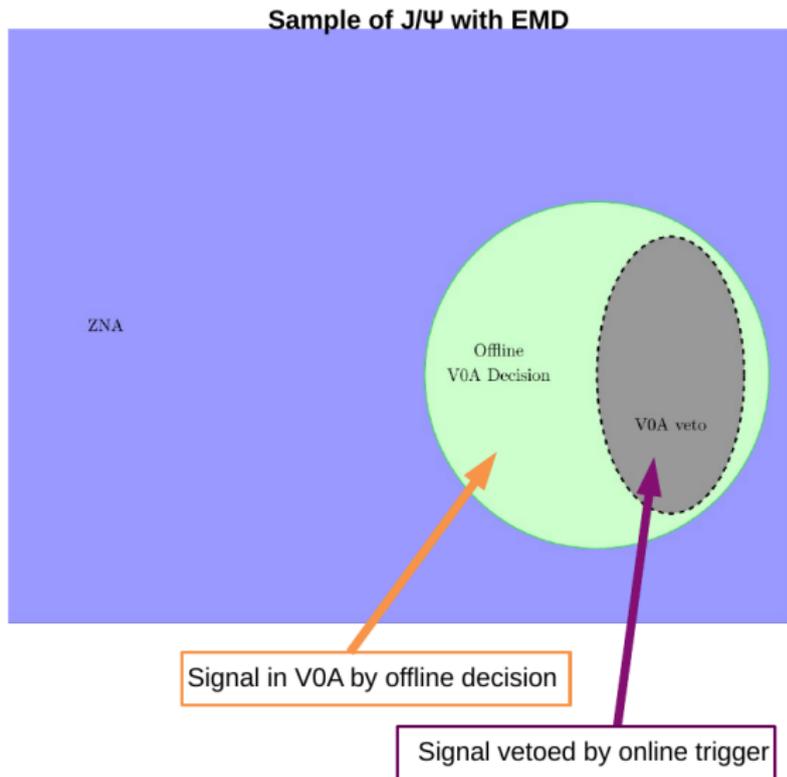
1. Pile-up in V0A

- Interaction of another nucleus pair caused a signal in V0A - a pile-up event

- Determination of pile-up with CTRUE event sample

- ⋆ CTRUE = unbiased trigger fired in bunch crossing time window

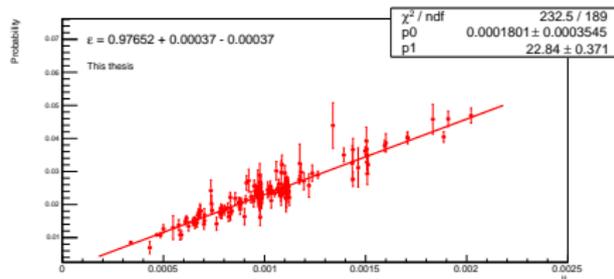- Finding the probability of having signal in V0A in otherwise empty detector

Figure: V0A pile-up in (Xn0n) class.

- ∼ 2.4% of events are caused by pile-up.

2. V0A veto correction

- Data sample triggered by 1ZED is used.
- ⋆ 1ZED = activity in at least one side of ZN in bunch crossing
- To get the correction factor we seek for events that are selected by the offline decision of V0A and not by online trigger:
- Veto correction factor ϵ is obtained: Correction itself: $\frac{1}{\epsilon}$
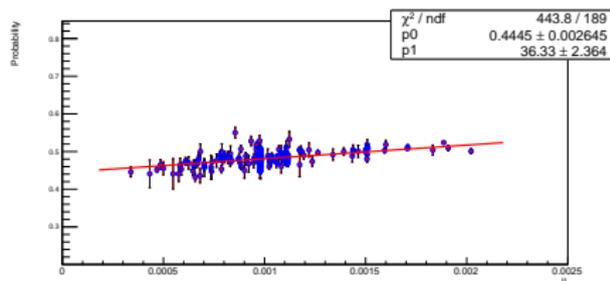- Veto correction is needed for (Xn0n) and (XnXn) classes

Figure: V0A veto correction factor in (Xn0n) class.

- Inefficiency of the V0A online trigger is about ∼ 44%

Results

- Correction factor for each neutron class and for all events is calculated:

  $\star$ $F_{class} = \frac{N_{\mathrm{J}/\psi\mathrm{coherent\ corrected}}}{N_{\mathrm{J}/\psi\mathrm{coherent}}}$

  - $N_{\mathrm{J}/\psi\mathrm{coherent}}$ - number of coherent J/ψ candidates in each neutron class
  - $N_{\mathrm{J}/\psi\mathrm{PU\ corrected}} = N_{\mathrm{J}/\psi\mathrm{coherent}} \cdot \epsilon_{\mathrm{PU}}$
  - $N_{\mathrm{J}/\psi\mathrm{V0A\ veto\ corrected}} = N_{\mathrm{J}/\psi\mathrm{PU\ corrected\ V0A\ Decision}} \cdot \frac{1}{\epsilon_{\mathrm{veto}}}$
  - $N_{\mathrm{J}/\psi\mathrm{coherent\ corrected}} = N_{\mathrm{J}/\psi\mathrm{PU\ corrected\ ZNA}} + N_{\mathrm{J}/\psi\mathrm{V0A\ veto\ corrected}}$

(Xn0n)

$$F_{\mathrm{(Xn0n)}} = \frac{1250.77}{(1069.4 + 102.901)} = \mathbf{1.067}$$

(XnXn)

$$F_{\mathrm{(XnXn)}} = \frac{1031.85}{(763.522 + 125.777)} = \mathbf{1.160}$$

$$F_{\mathrm{all}} = \frac{(12808.8 + 920.905 + 1250.77 + 1031.85)}{(12808.8 + 920.905 + 1069.4 + 102.901 + 763.522 + 125.777)} = \mathbf{1.014}$$

Summary and outlook

- New problem was identified.
- No tools available to solve it, so improvization was needed.
- Corrections are very large for two of the four neutron classes.
- Selection and background subtraction has to be fine-tuned to agree with one to be used in the paper.

Thank you for your attention!