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Incoherent J/ψ photoproduction in Pb–Pb collisions with forward neutrons with LHC Run 2 data

4. Miniworkshop of diffraction and UPCs in Děčín 2021

September 14, 2021

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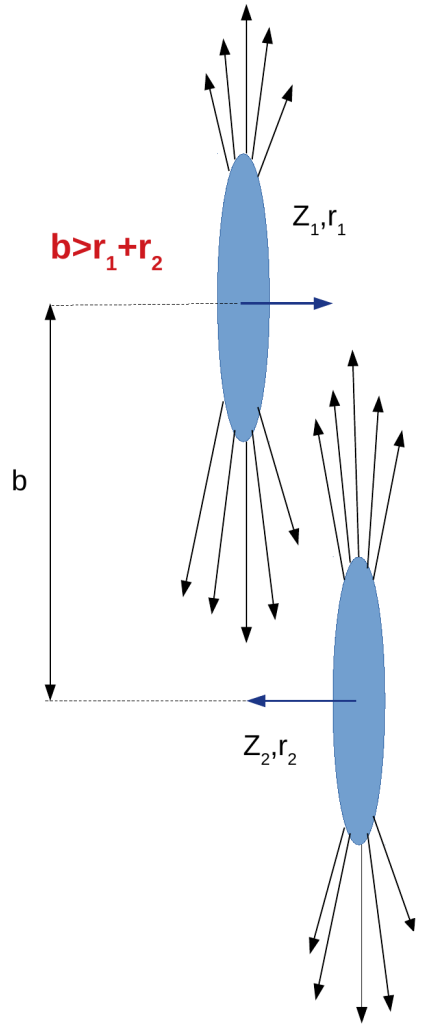
Outline

- Incoherent J/ψ photoproduction with emission of forward neutrons
  - Motivation
  - Paper: Neutron tagging of quasielastic J/psi photoproduction off nucleus in ultraperipheral heavy ion collisions at RHIC energies

    M. Strikman et al. arXiv:hep-ph/0505023, can be found here.
  - Paper: Elastic and Proton-Dissociative Photoproduction of J/psi Mesons at HERA

    H1 Collaboration DOI:10.1140/epjc/s10052-013-2466-y, can be found here.
- Analysis
  - Selection criteria
  - Neutron emission
- Summary.

Incoherent photoproduction of J/ψ in Pb–Pb UPCs

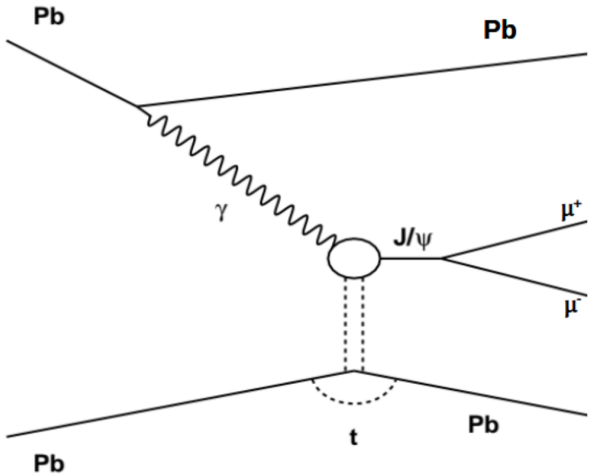


- Impact parameter is larger than the sum of radii in UPCs.
- Photon flux $\propto Z^2$

$\Rightarrow$ Photon-induced $Pb - Pb$ interactions

- Due to Vector Meson Dominance - vector meson is produced very likely

$\Rightarrow$ Photoproduction of J/ψ vector meson



Investigating gluon behavior in nuclei

- Measuring cross section of J/ψ photoproduction in UPC

Why is this process interesting to study?

$$\frac{d\sigma_{\gamma Pb \to J/\psi Pb}}{dt}\Big|_{t=0} = \frac{M^3_{J/\psi}\Gamma_{ee}\pi^3\alpha_s^2(Q^2)}{48\alpha_{em}Q^8}[xg_{Pb}(x, Q^2)]^2$$

$\rightarrow$ Tool to study gluon densities at small$-x$ values

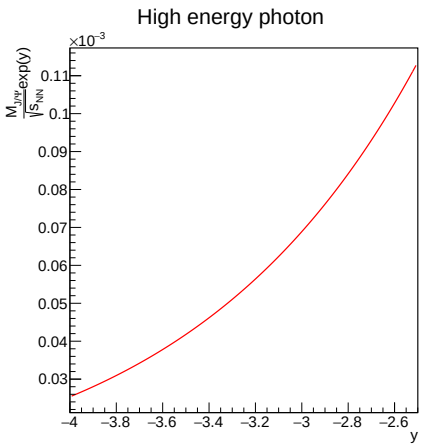
- Measuring the cross section in dependence on rapidity y.

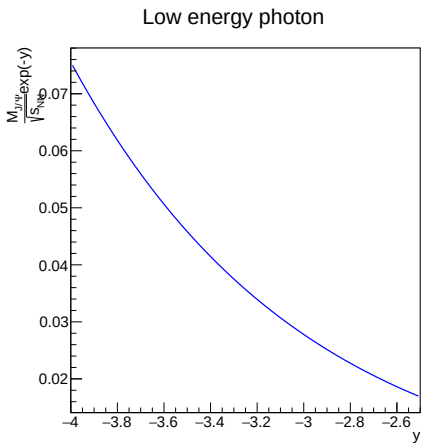
Two contributing terms in measured cross section

- $x = \frac{M_{J/\psi}}{\sqrt{s_{NN}}} exp(\pm y)$

Measured cross section of J/ψ

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

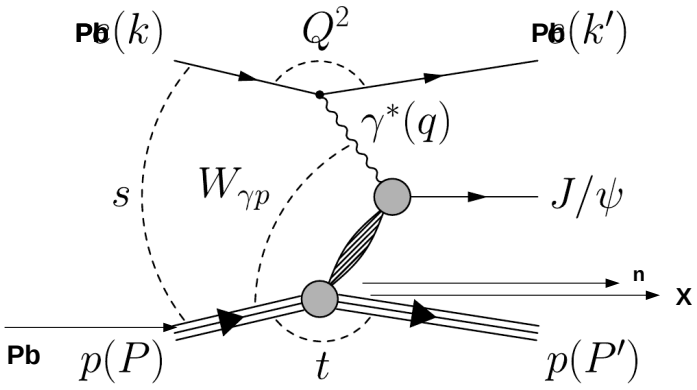




$\Rightarrow$ If we disentangle them, we reach the **full range** of $x \in (10^{-2}; 10^{-5})$!

Incoherent J/ψ photoproduction

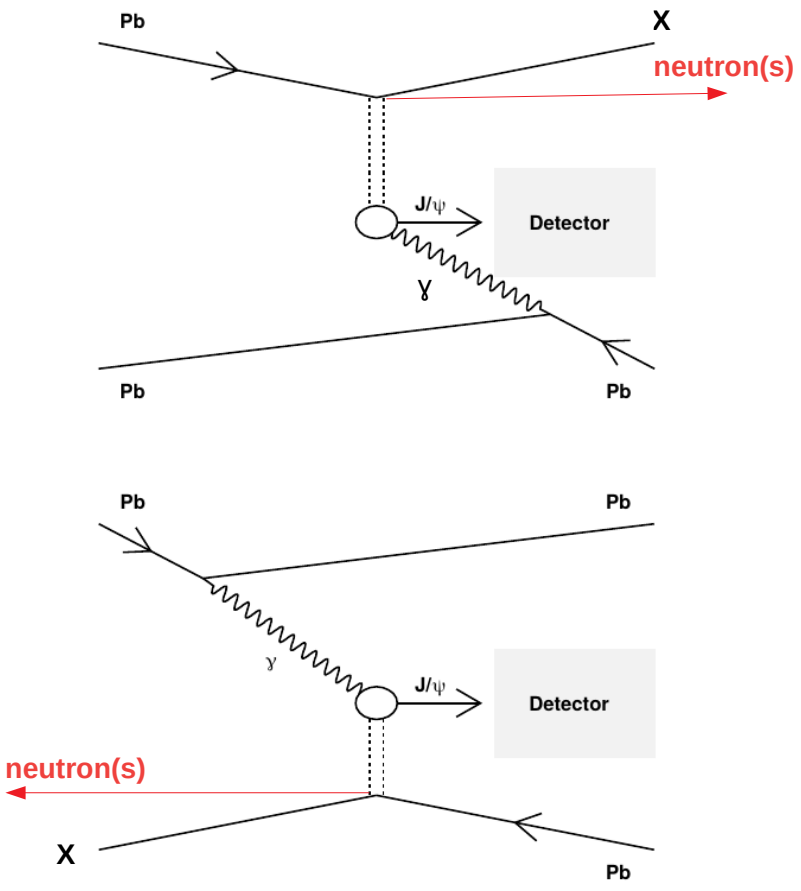
- A photon couples to a single nucleon inside a target nucleus.
- Characterized by the J/ψ transverse momentum larger than $p_T > 300$ MeV/c.
- Recoiled nucleon re-scatters and causes a break-up of the target nucleus, one or more neutrons are emitted in the forward rapidity.



A tool to study gluons at small-x

- The probability of neutron emission in incoherent process is close to 1.
- There is a correlation between the direction of the produced J/ψ and the direction of neutrons.

$\Rightarrow$ It gives us a tool to disentangle high and low-energy photon contributions. (The direction of J/ψ produced by a high-energy photon and, hence, low-x gluons from the target, is opposite to the direction of the nucleus and thus, the direction of the neutrons.)



Paper 1

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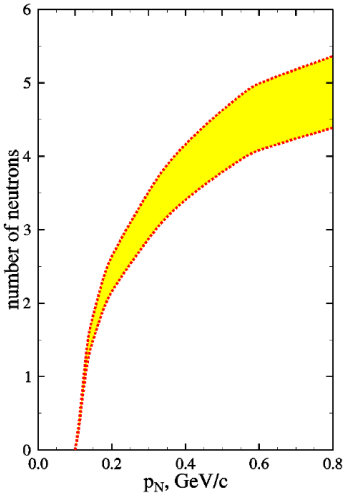
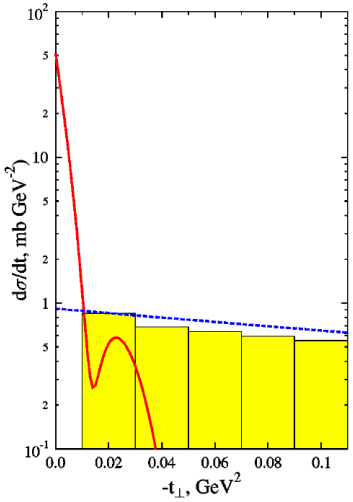
Neutron tagging of quasielastic J/ψ photoproduction off nucleus in ultraperipheral heavy ion collisions at RHIC energies

M. Strikman [a], M. Tverskoy [b], M. Zhalov [b]

- The dependence of the average number of the emitted neutrons in dependence on the nucleon momentum.

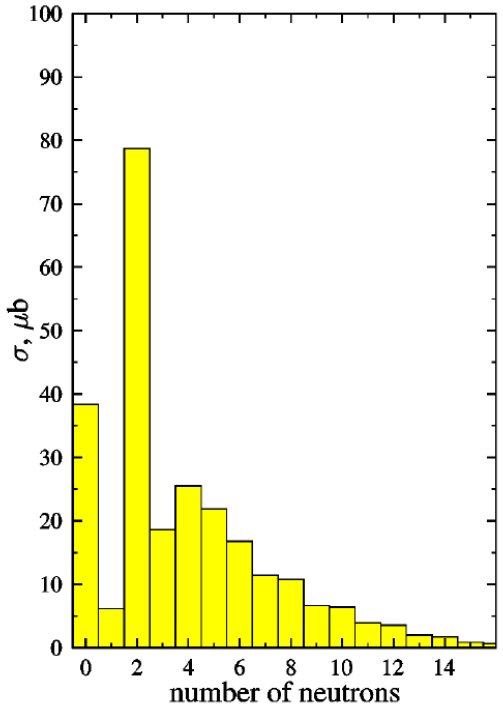


- Integrated over rapidity the momentum transfer distribution for J/ψ and the cross section of the incoherent photoproduction with emission of neutrons.
- The ratio of the cross section with emission of the one or more neutrons to the total incoherent cross section is about 0.8.



Paper 1

- The incoherent cross section integrated over rapidity and momentum transfer in dependence on the number of emitted neutrons.
- Peak at 2 neutrons.



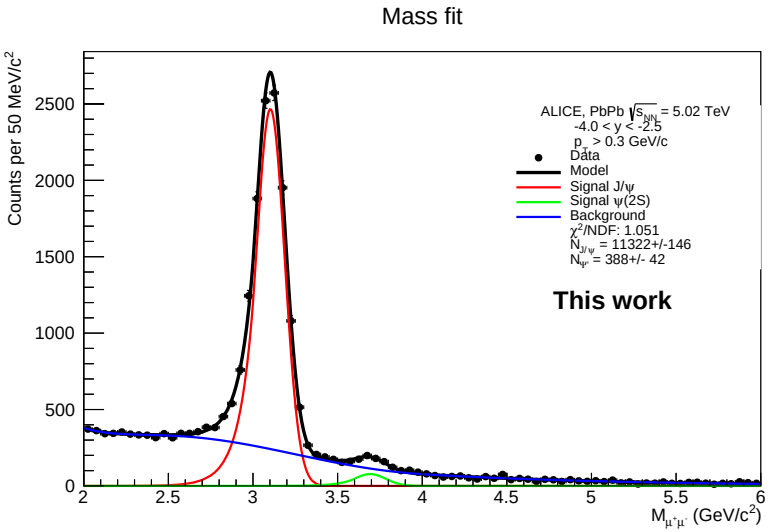
Event selection

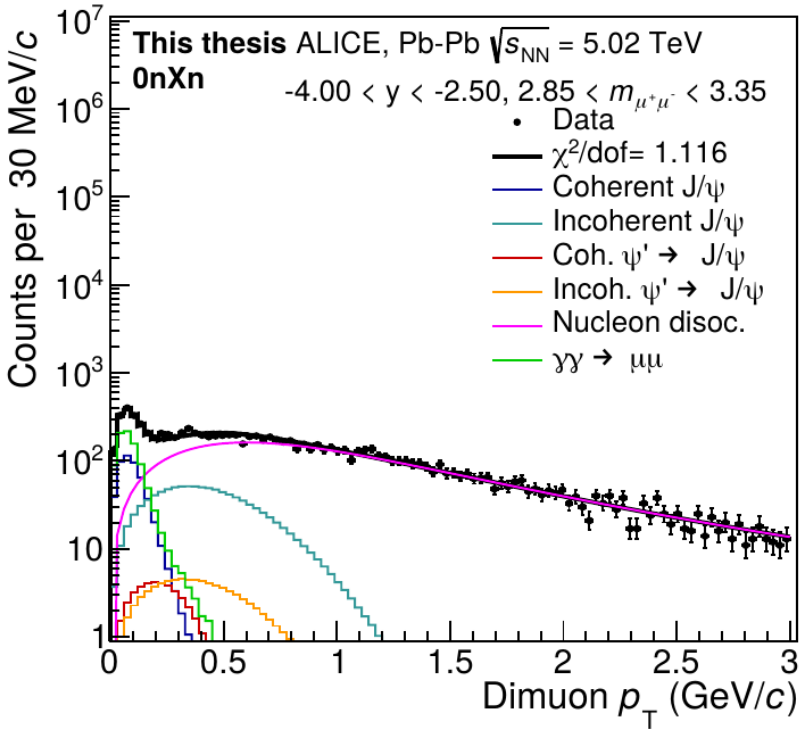
- ALICE Run 2 data

Cut	Number of survivors
AOD events	91025772
Triggered events	40805581
At least one track	18292740
Two good muon tracks	85122
Good runs	84184
CMUP6 trigger	84184
Rapidity $-4.0 < y_{\mu\mu} < -2.5$	84183
Mass cut $2.85 < M_{\mu\mu} < 3.35$ GeV$/c^2$	35949
Cut $p_T > 0.3$ GeV$/c$	13334

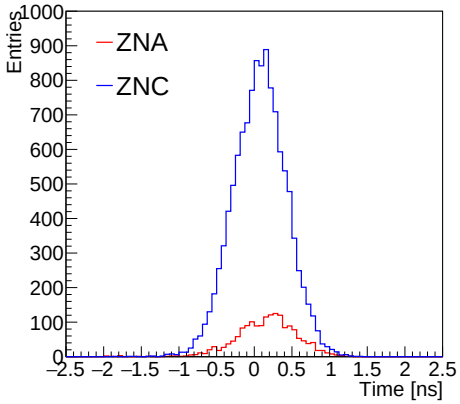
The J/ψ invariant mass

- J/ψ mass distribution for $p_T > 0.3$ GeV/c





ZNA and ZNC signals



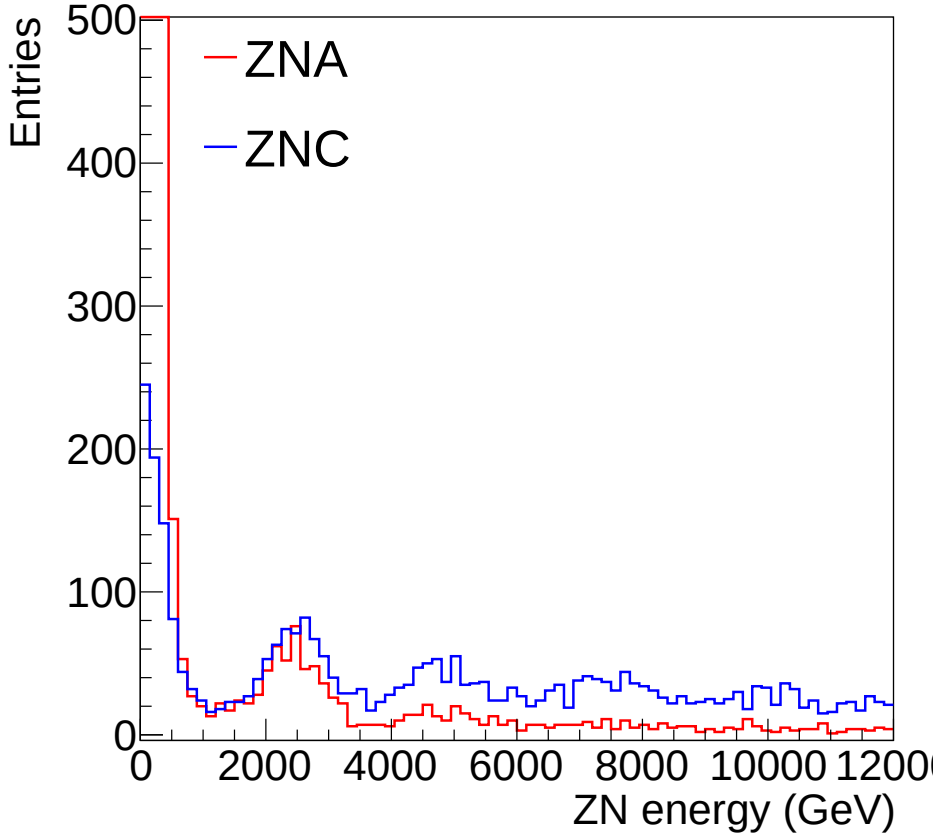


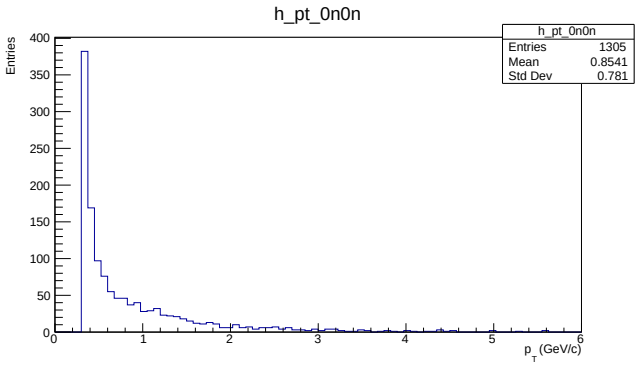
Figure: ZNA and ZNC energy distribution.

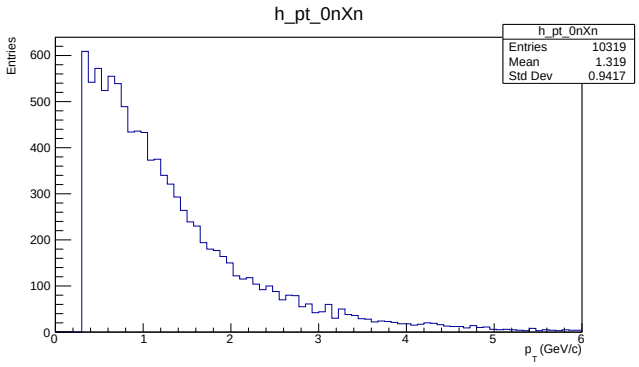
- Neutrons are measured in the ZDC detectors.
- Energy measured in the ZDC corresponds to number of neutrons registered.
- Signal in ZNA and ZNC within an interval (-2ns,2ns).

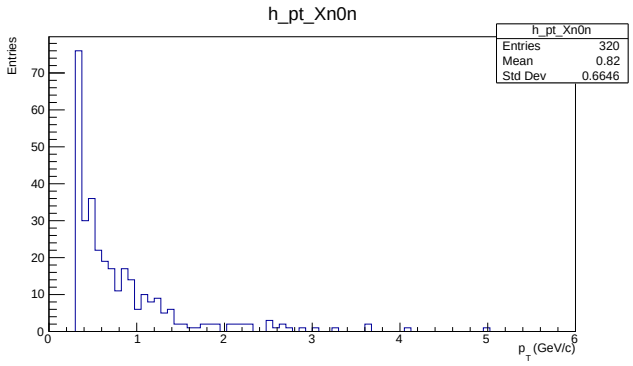
$\Rightarrow$ More neutrons measured in the C side corresponds to the fact that the J/ψ is produced by the low energy photon more frequently.

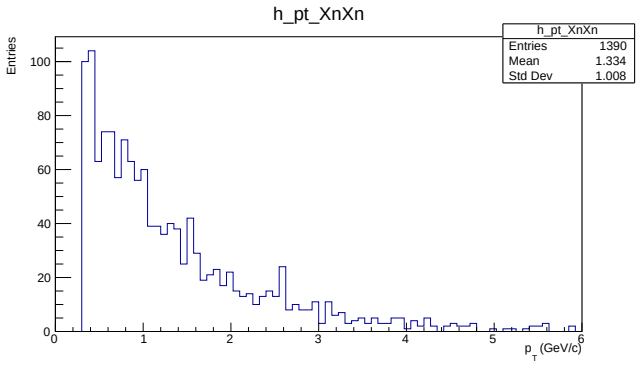
p_T distribution

- Data sample is divided into four neutron classes (0n0n),(Xn0n),(0nXn) and (XnXn).









ZNA and ZNC signals

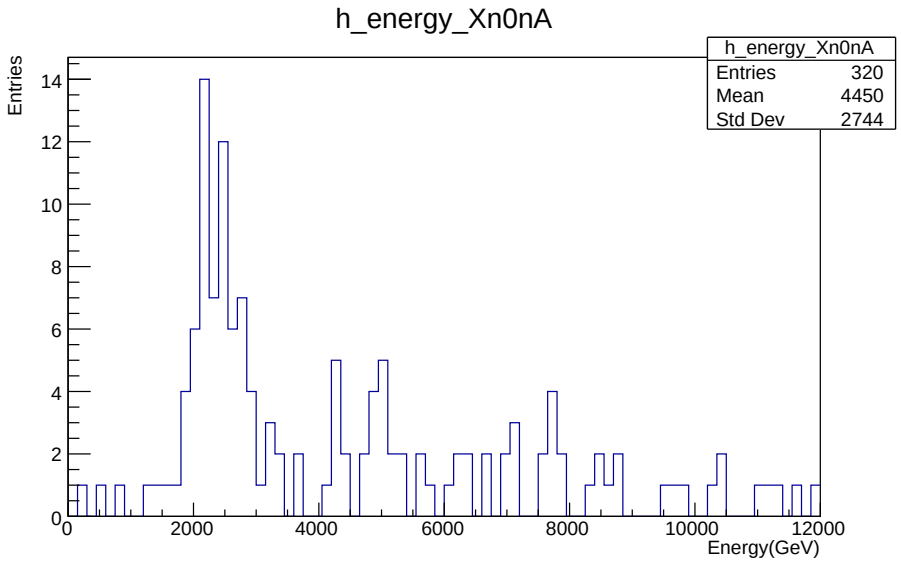


Figure: ZNA energy distribution in the (Xn0n) class.

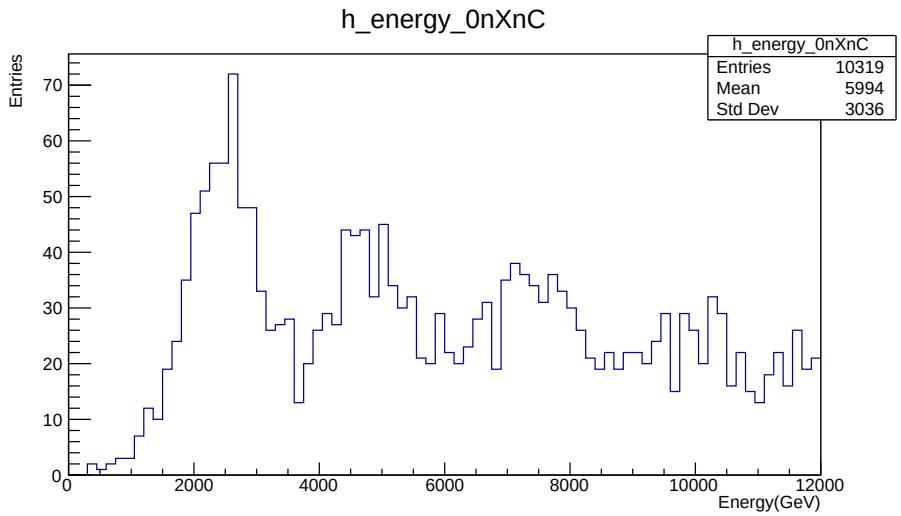


Figure: ZNC energy distribution in the (0nXn) class.

$\Rightarrow$ More events in the (0nXn) class.

Ratios

- The ratio of the incoherent J/ψ with emission of one or more neutrons to the total incoherent $\mathrm{J}/\psi \sim 0.9$.
- The ratio of high energy photon and low energy photon interaction $\frac{(Xn0n)}{(0nXn)} = 0.03$.

$\Rightarrow$ Only 3 % high energy photon interactions because of small photon flux.

- What is hidden behind the (0n0n) and (XnXn) classes?

Summary and outlook

- Low-x gluon behavior can be studied with incoherent J/ψ photoproduction.
- Dividing data into neutron classes disentangle two contributions in the cross section.
- A quick look on the incoherent J/ψ enriched data sample.
- A check of the ZDC signal and different neutron classes.
- Plans for the future?

Thank you for your attention!