Transverse single spin asymmetry measurement for (very) forward neutron production at the RHICf experiment

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on behalf of the RHICf collaboration

Programs for Junior Scientists

RBRC
RIKEN BNL Research Center

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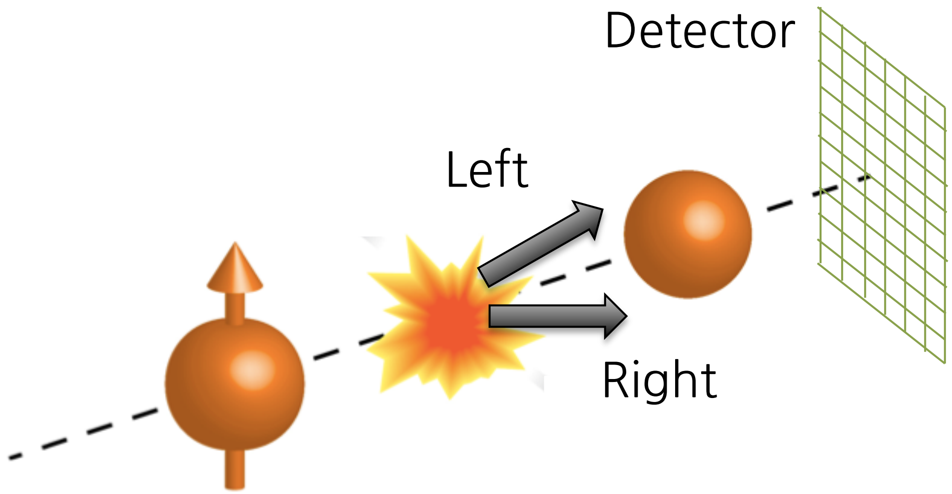
Transverse single spin asymmetry

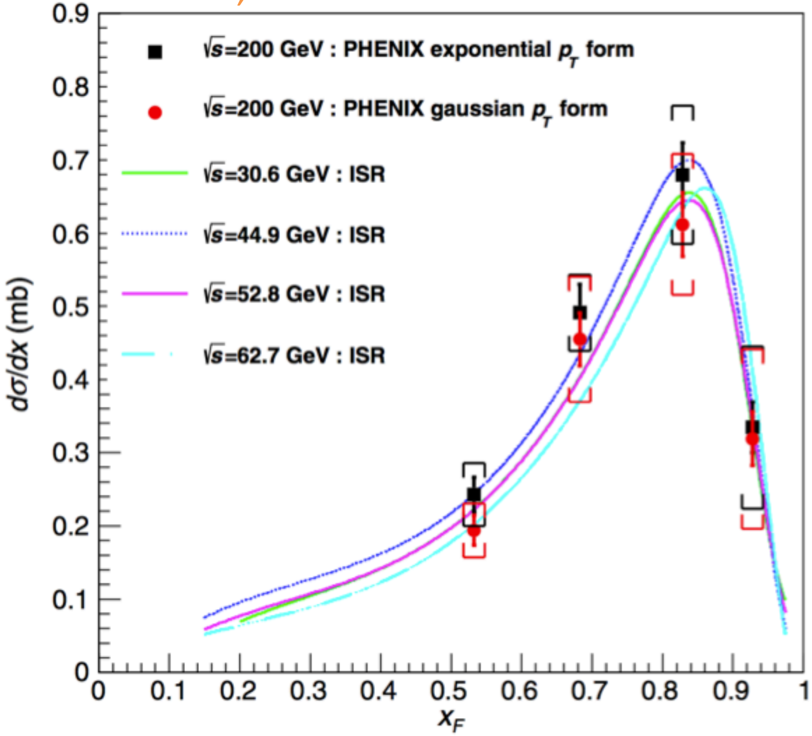


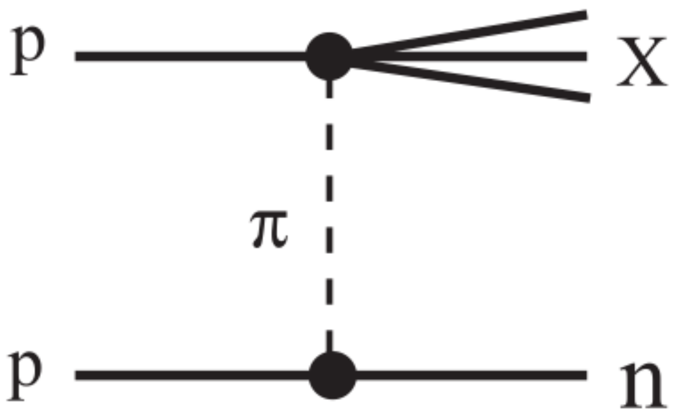
$$A_N = \frac{\sigma_L^{\uparrow} - \sigma_R^{\uparrow}}{\sigma_L^{\uparrow} + \sigma_R^{\uparrow}} = \frac{\sigma_L^{\uparrow} - \sigma_L^{\downarrow}}{\sigma_L^{\uparrow} + \sigma_L^{\downarrow}}$$

- In the polarized p + p collision, the A_N is defined by a left-right cross section asymmetry of a specific particle or event.
- A_N of the forward ($6 < \eta$) neutron enables us to study the spin-involved diffractive production mechanism.

Forward neutron production

PRD 88, 032006.



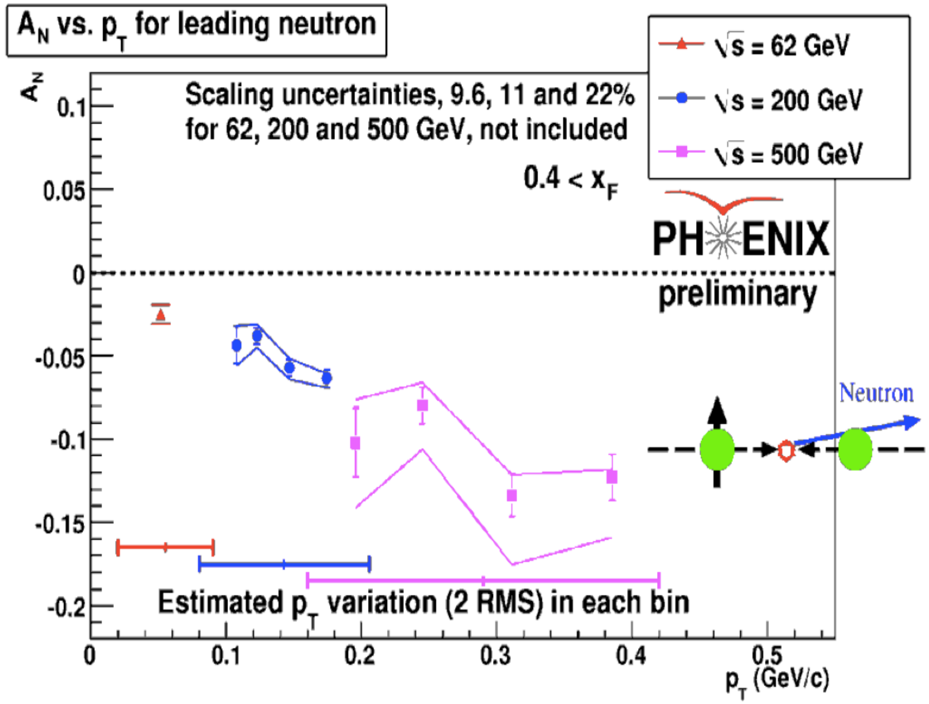


- One pion exchange (OPE) model well explains the forward neutron production with an absorptive correction.

- The pion exchange is dominant rather than ρ and a_2 exchange, and p → Δ → n process.

Forward neutron A_N

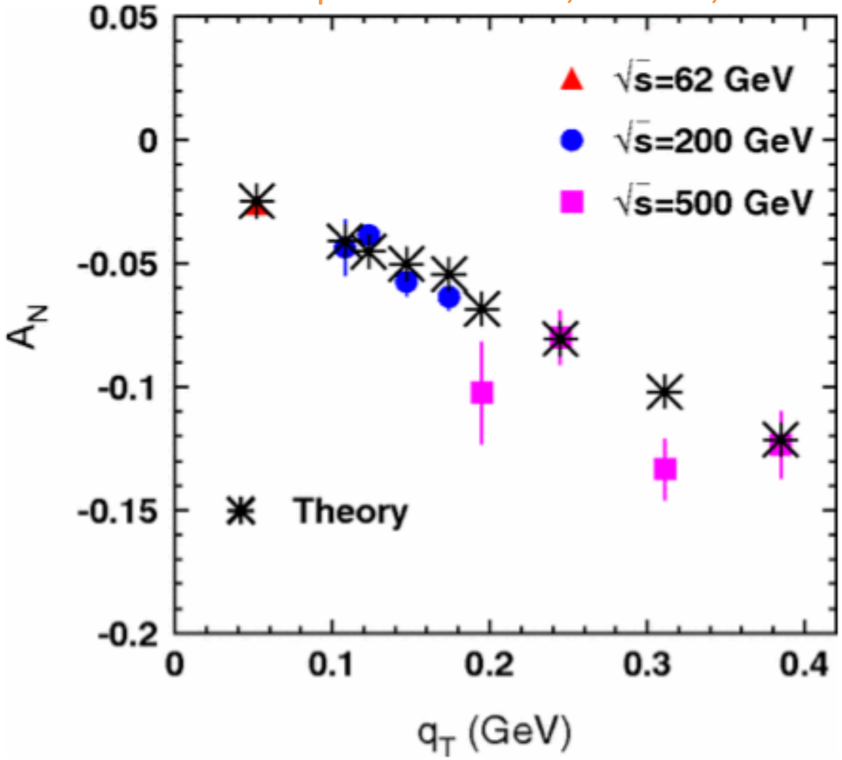
J. Phys. Conf. Ser. 295, 012097.



- Non-zero neutron A_N was observed at the IP12 experiment. However, the OPE model couldn't explain the finite neutron A_N.
- The neutron A_N has been measured by the PHENIX experiment with three different collision energies.

Forward neutron A_N

B. Z. Kopeliovich et al., PRD 84, 114012.



$$A_N = \frac{d\sigma^\uparrow - d\sigma^\downarrow}{d\sigma^\uparrow + d\sigma^\downarrow} = \frac{\sum_X |\langle cX|T|\uparrow\rangle|^2 - \sum_X |\langle cX|T|\downarrow\rangle|^2}{\sum_X |\langle cX|T|\uparrow\rangle|^2 + \sum_X |\langle cX|T|\downarrow\rangle|^2} = \frac{-2\mathrm{Im}\sum_X \langle cX|T|-\rangle\langle +|T^\dagger|cX\rangle}{\sum_X |\langle cX|T|+\rangle|^2 + \sum_X |\langle cX|T|-\rangle|^2}$$

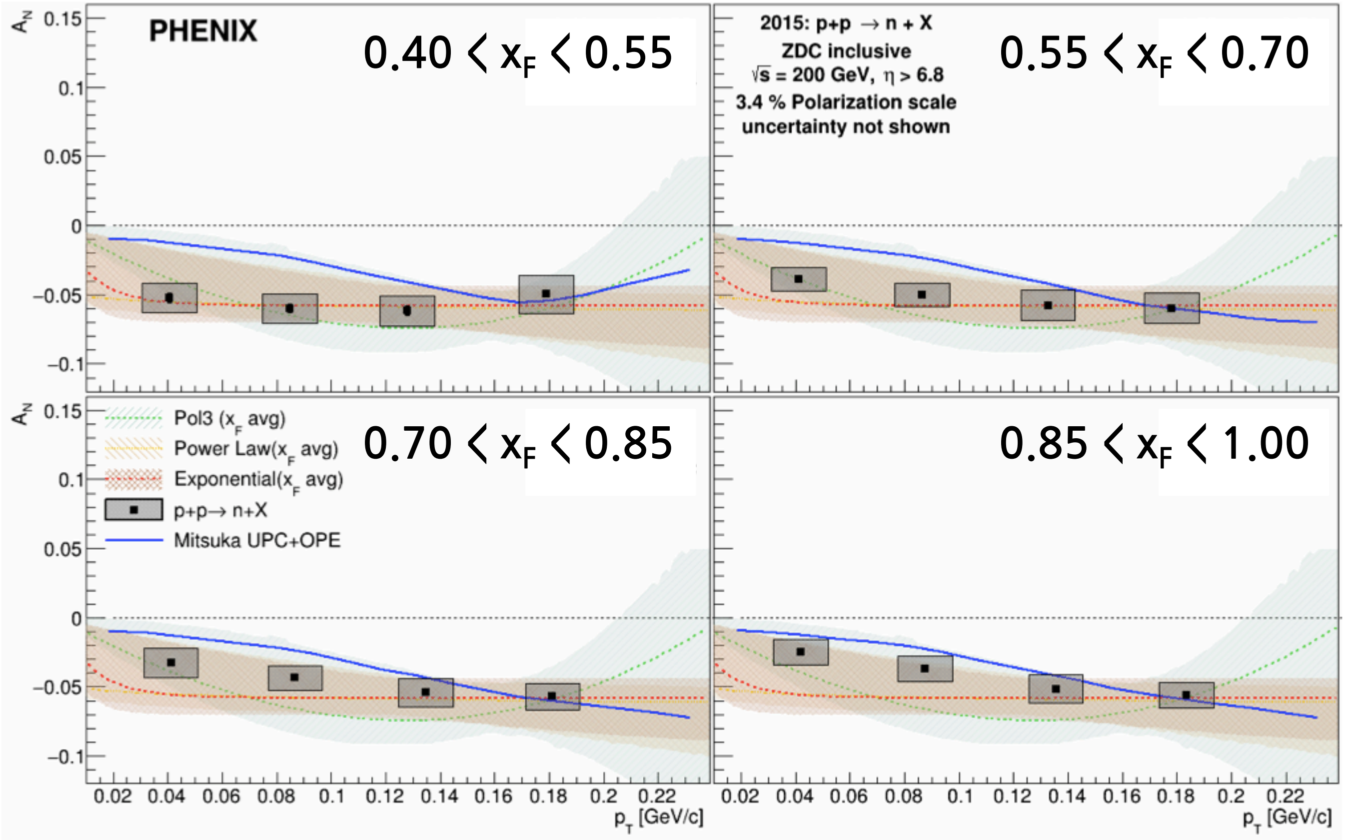
π exchange: spin flip

a_1 exchange: spin non-flip

- The OPE model introduced a_1 exchange to explain the neutron A_N.
- The π and a_1 exchange model predicts that the A_N increases in magnitude with p_T without x_F dependence.

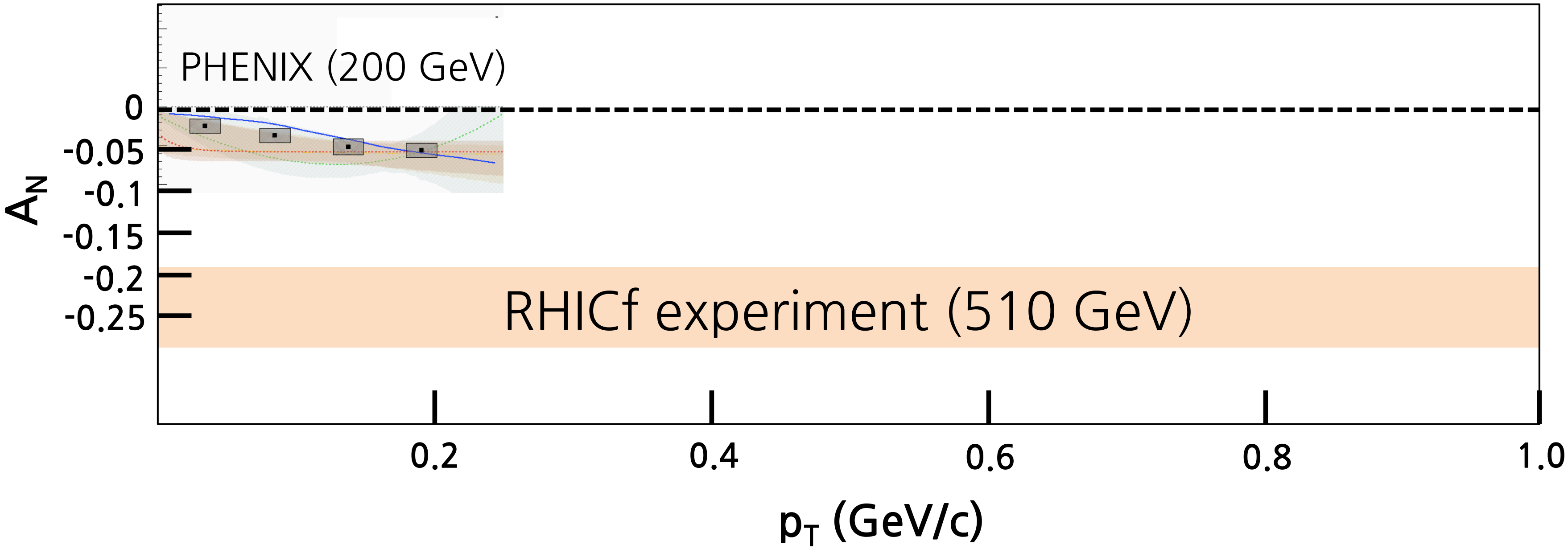
Unfolded forward neutron A_N

PRD 105, 032004.



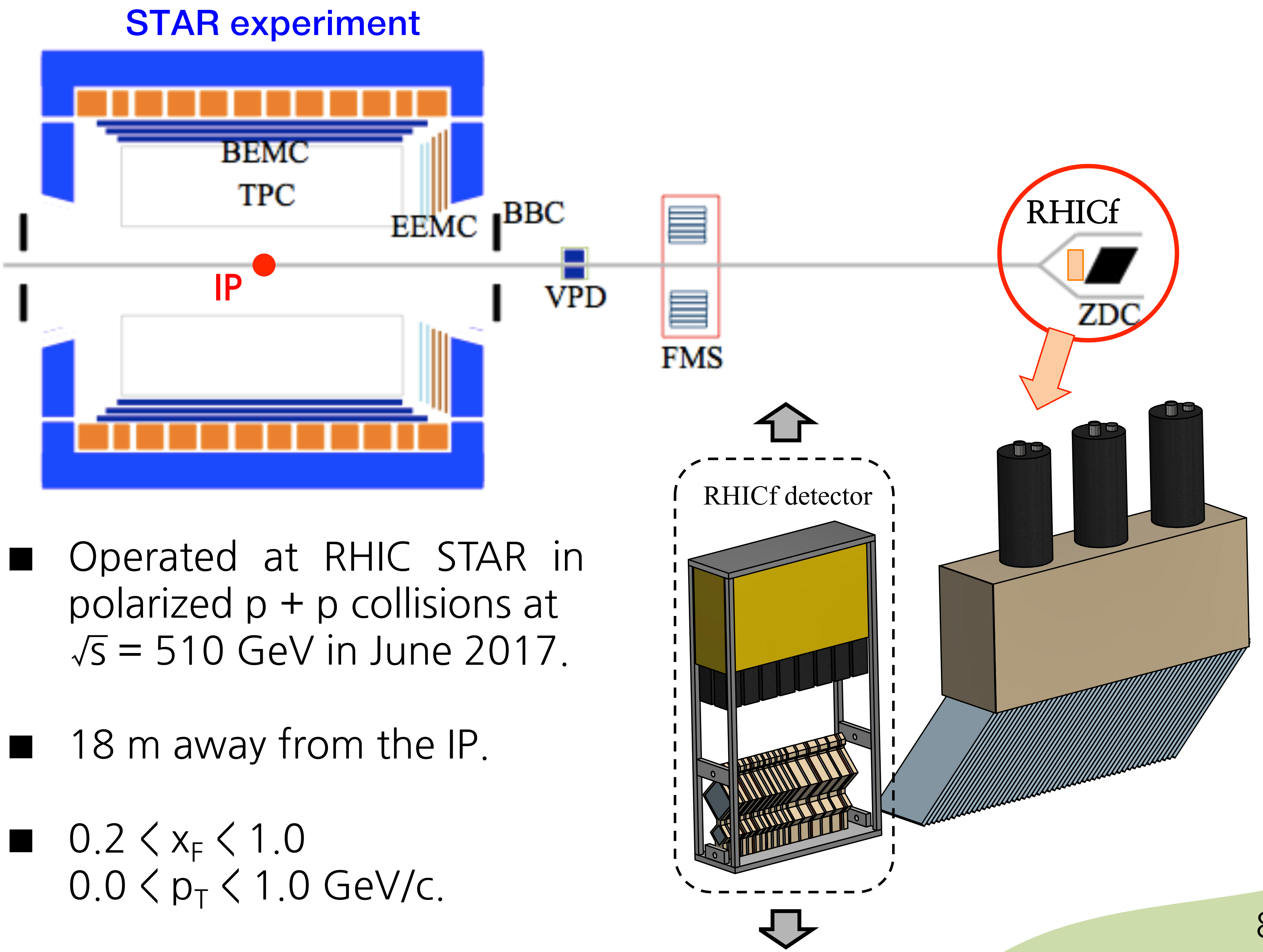
- Recently, the neutron A_N at 200 GeV has been unfolded.
- The unfolded data explicitly shows the increasing A_N following the p_T without a clear x_F dependence as the model predicted.

Neutron measurement at RHICf



- RHICf experiment measured the neutron A_N in the highest p_T coverage ever measured ~ 1 GeV/c.
- RHICf data can not only be compared with the PHENIX data but also test the π and a_1 exchange model in a wide p_T coverage.

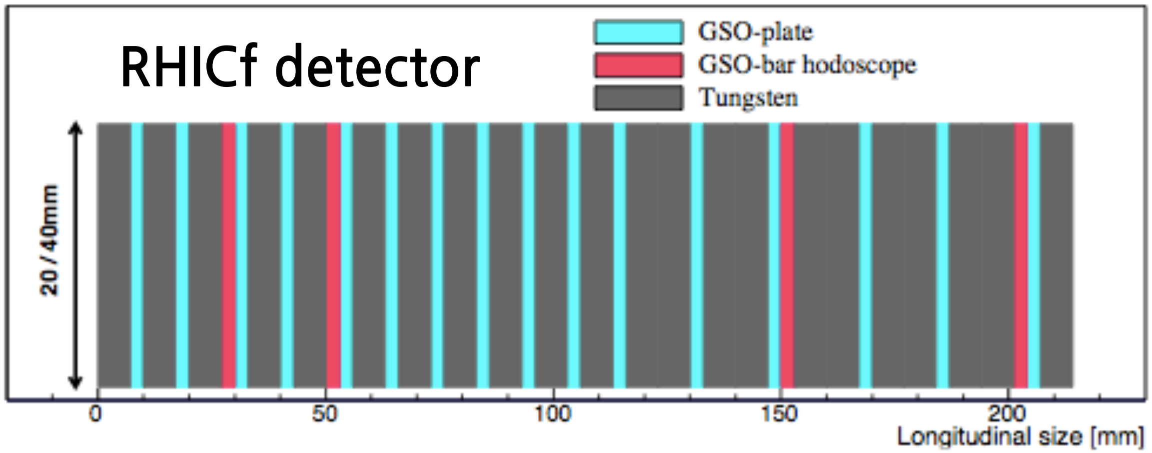
RHIC forward (RHICf) experiment



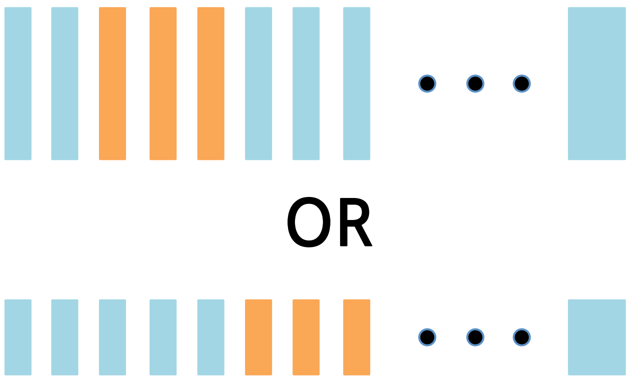
- Operated at RHIC STAR in polarized p + p collisions at $\sqrt{s}$ = 510 GeV in June 2017.
- 18 m away from the IP.
- $0.2 < x_F < 1.0$
  $0.0 < p_T < 1.0$ GeV/c.

Neutron measurement

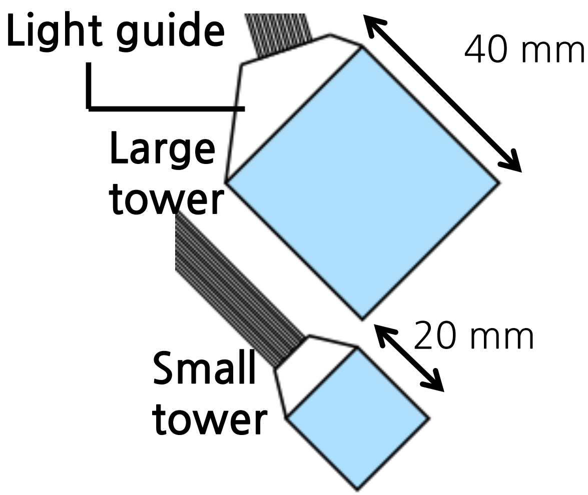
Side view



Shower trigger

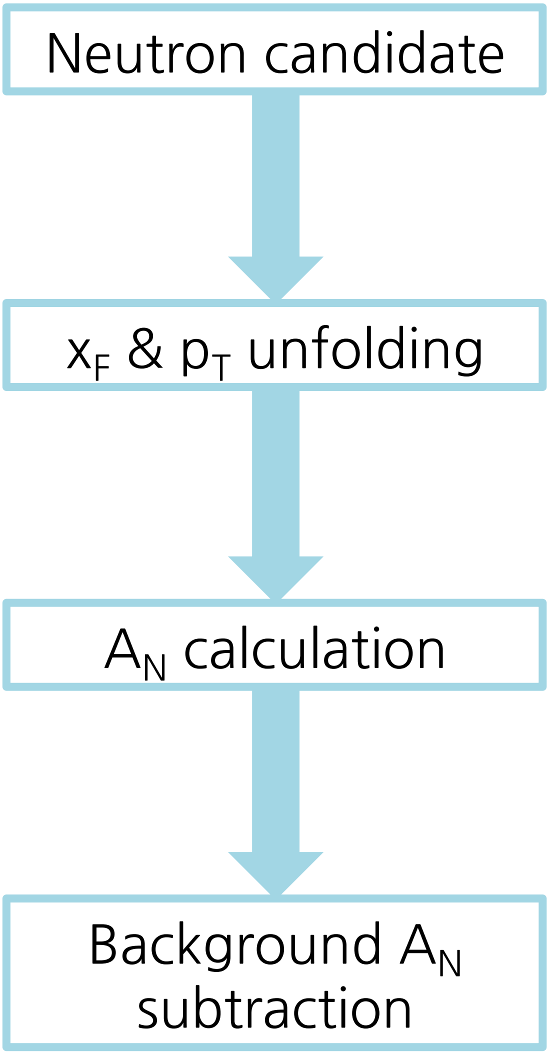


Front view

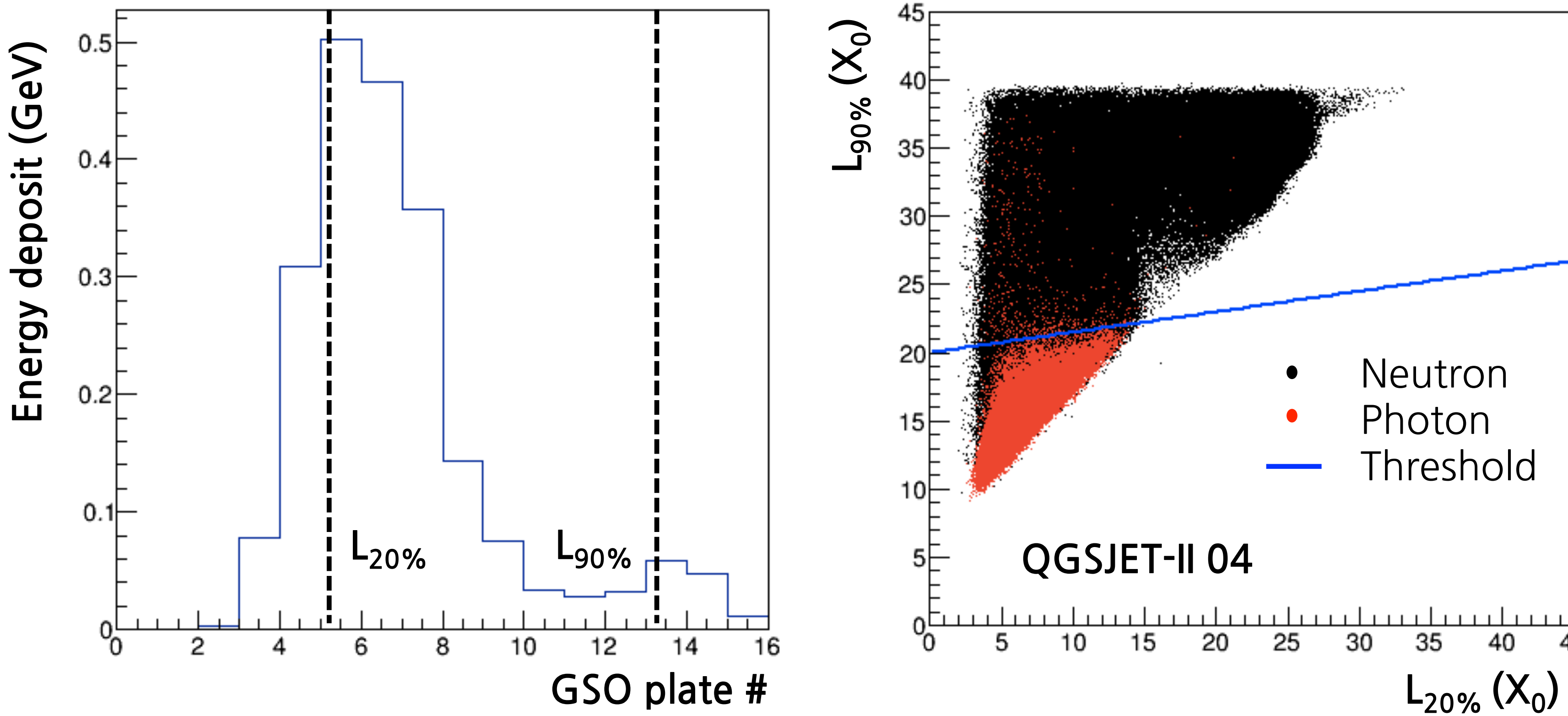


- 17 tungsten absorbers (44 X_0, 1.6 λ_{int}), 16 GSO plates, and 4 layers of GSO bars (1 mm dimension).
- σ_E ~30% and σ_{p_T} ~0.025 GeV/c for 200 GeV neutron.
- Shower trigger is operated when the energy deposits of any three successive layers are larger than 45 MeV.

Analysis procedure



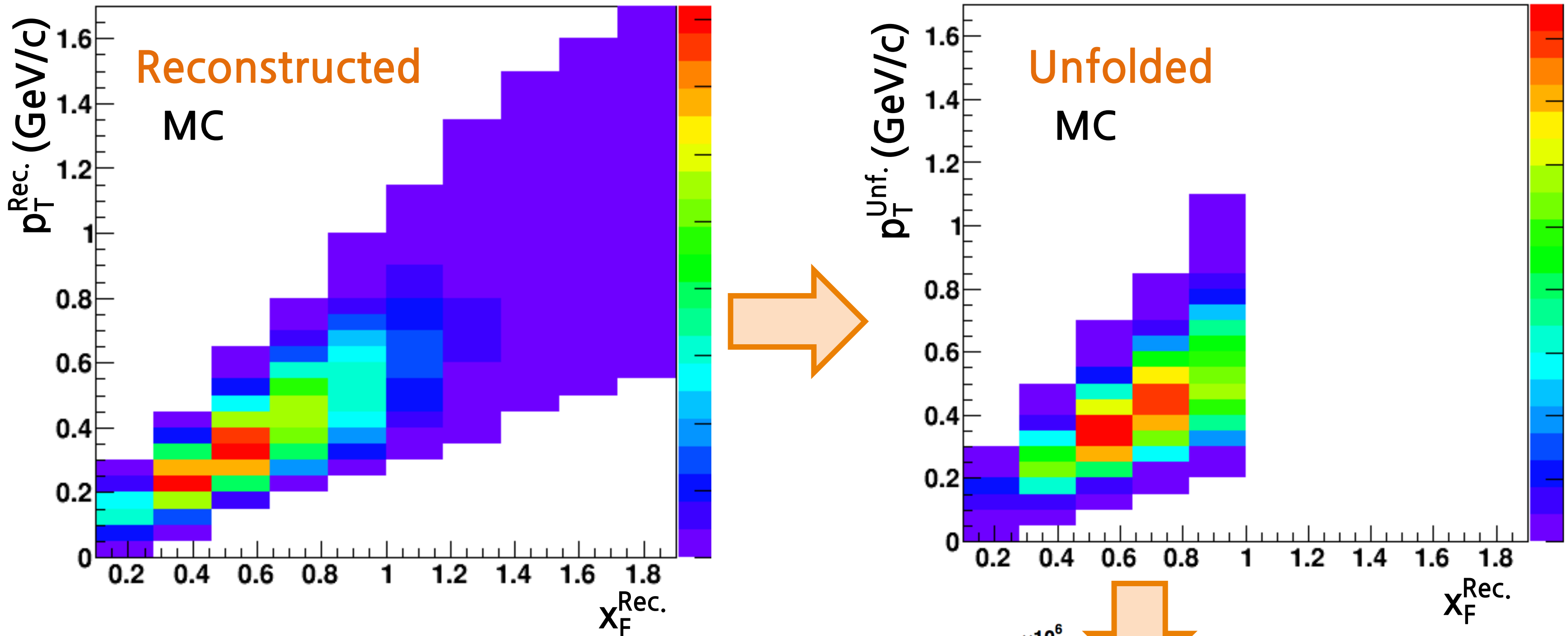
Neutron/photon separation



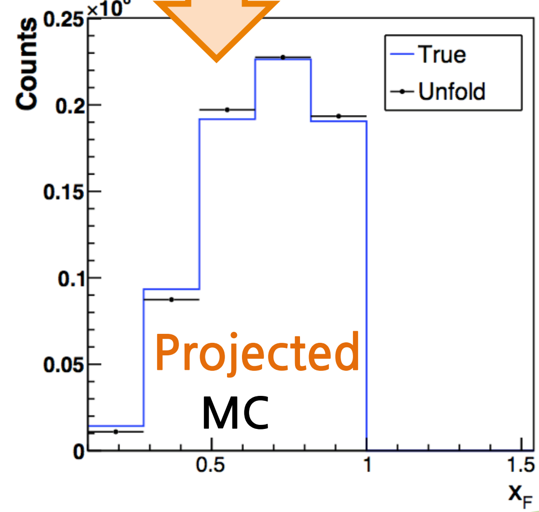
- $L_{20\%}$ and $L_{90\%}$ are defined by the longitudinal depth of the detector where the accumulated energy deposit reaches 20% and 90% of the total energy deposit.

- Neutron was separated from the photon in the $L_{90\%}$ versus $L_{20\%}$ plot.

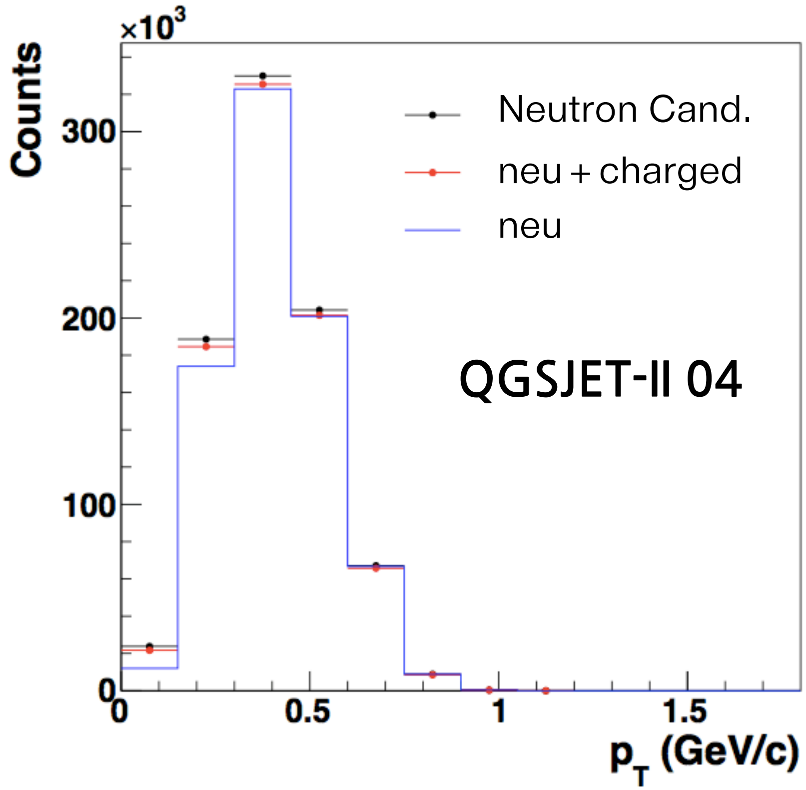
x_F and p_T unfolding



- RHICf detector has insufficient interaction length (1.6 λ_{int}).
- For a prior, neutron was uniformly generated to the detector.
- Two-dimensional Bayesian unfolding was done to get the true distribution.



Background A_N subtraction



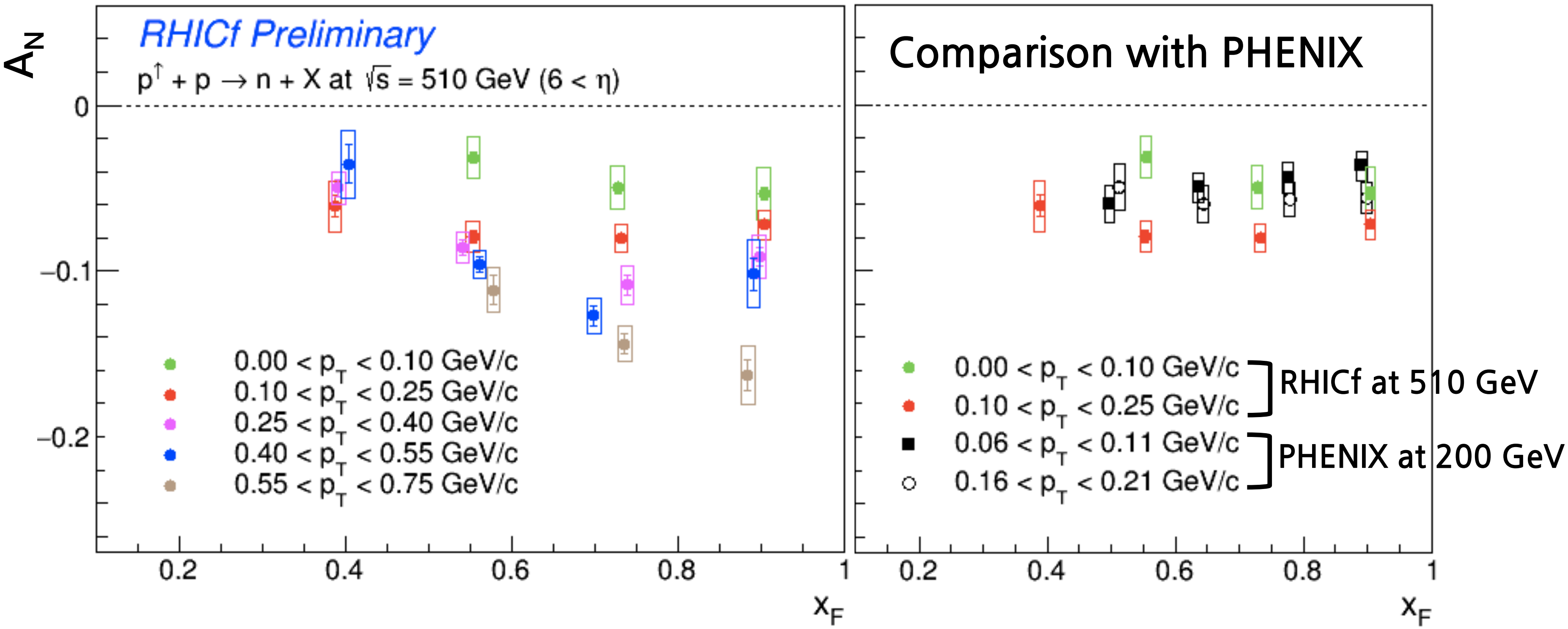
Neutron candidate
= neu + pho + charged

Difference between • and •
→ Background photon ratio.

Difference between • and —
→ Background hadron ratio.

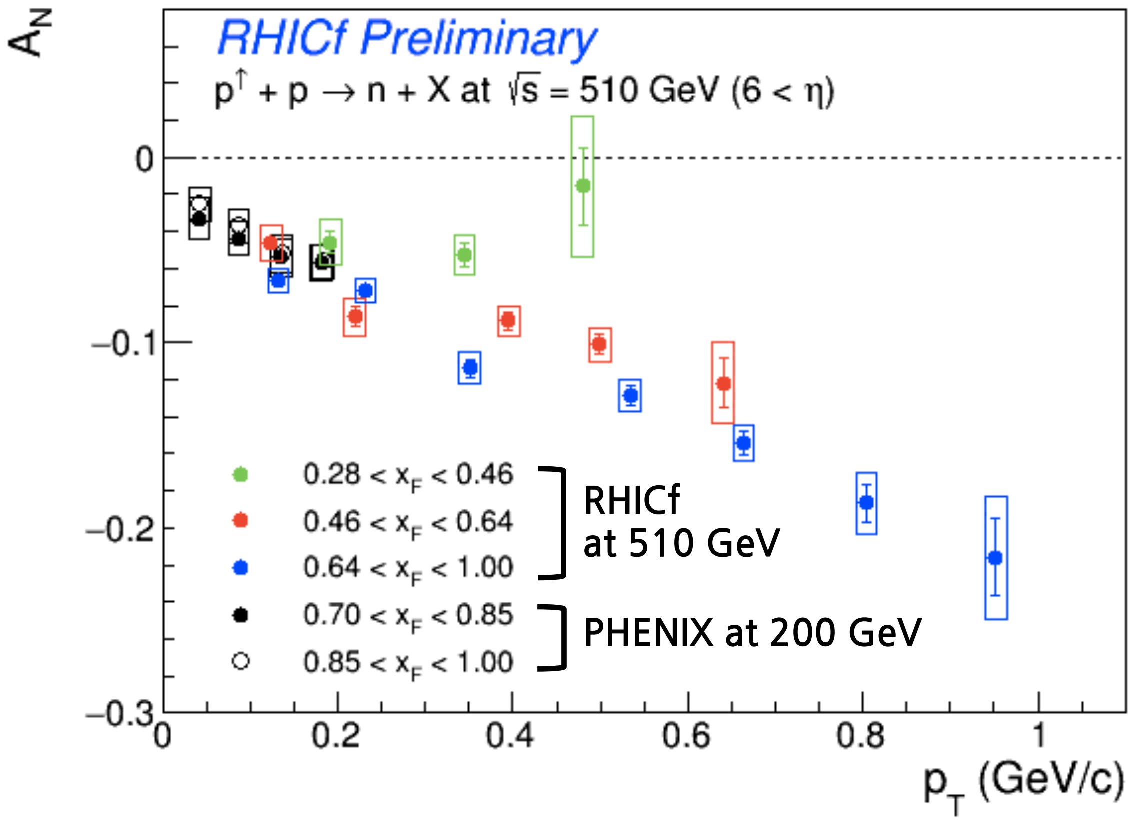
- In this analysis, neutron includes neutral hadrons (Λ~5%, K<1%, ...).
- Three QGSJET-II 04 samples, total, without photon, and neutron, were unfolded to estimate the background ratio.
- Photon background A_N from photon-enhanced sample. Large uncertainty of $A_N^{Meas.}$ ~ 1 to the background hadron A_N.

A_N of the very forward neutron



- Systematic uncertainties of beam center, polarization, background A_N subtraction, and unfolding were considered.
- In the lower p_T region, the A_Ns are flat showing no x_F dependence.
- In the higher p_T region, it seems that there is a x_F dependence.

A_N of the very forward neutron



- In higher x_F, the A_N increases in magnitude with p_T up to 1 GeV/c.
- There seems a x_F dependence in the higher p_T region.

Summary

- In June 2017, the RHICf experiment has measured the A_N for (very) forward neutron production in the highest p_T range ever measured.
- In the higher x_F, the A_N increases almost proportional to the p_T as the model predicted.
- In the lower p_T, no x_F dependence was observed.
- In the higher p_T, a x_F dependence was observed.
- More precise background estimation will be done for the final result.

Backup