Measurement of the transverse single spin asymmetry for forward neutron production in a wide transverse momentum range

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on behalf of the RHICf collaboration

RIKEN Programs for Junior Scientists

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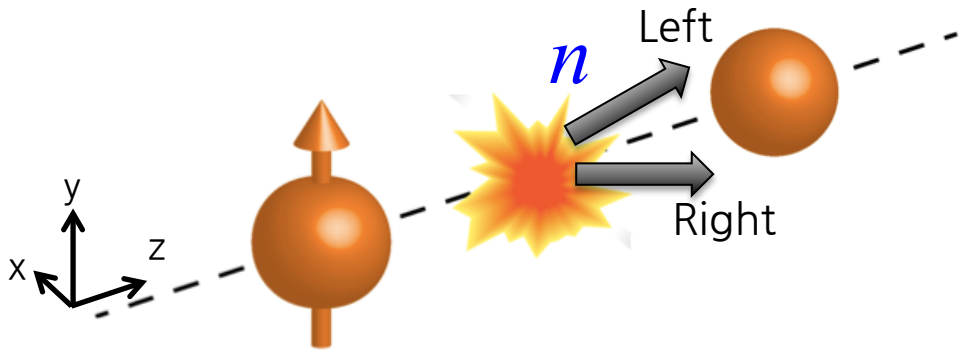
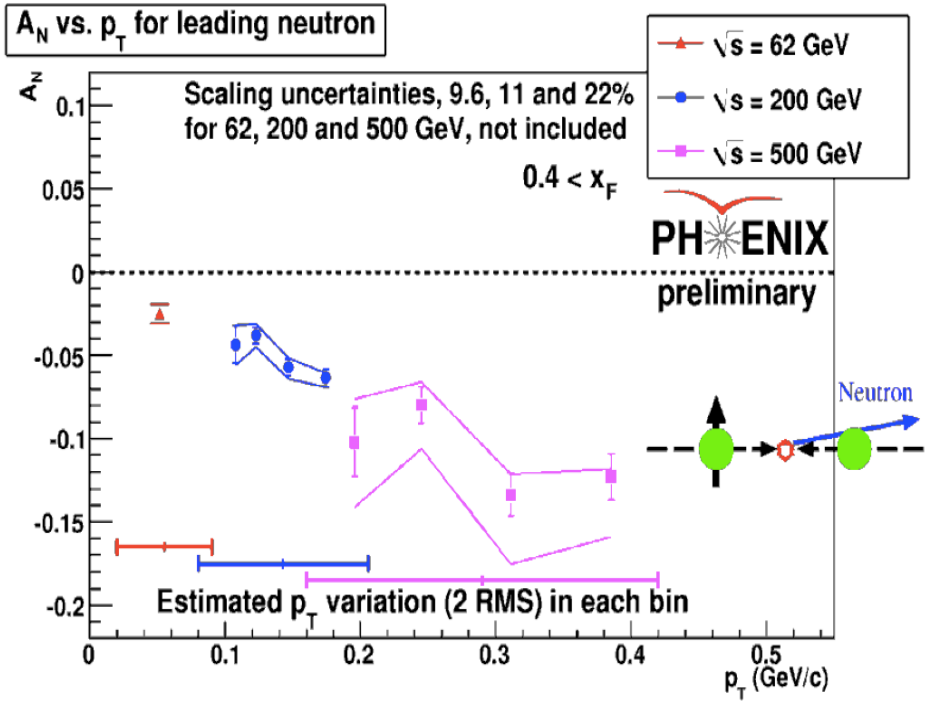
Transverse single spin asymmetry (A_N)



- In the polarized p+p collision, the A_N is defined by a left-right cross section asymmetry of a specific particle or event.
- The RHICf experiment measured the A_N of the forward neutron produced in $\eta > 6$ and $p_T < 1$ GeV/c.
- A_N of the forward particle is especially important to study the particle production mechanism in the regime where the pQCD is not applicable.

A_N for forward neutron production

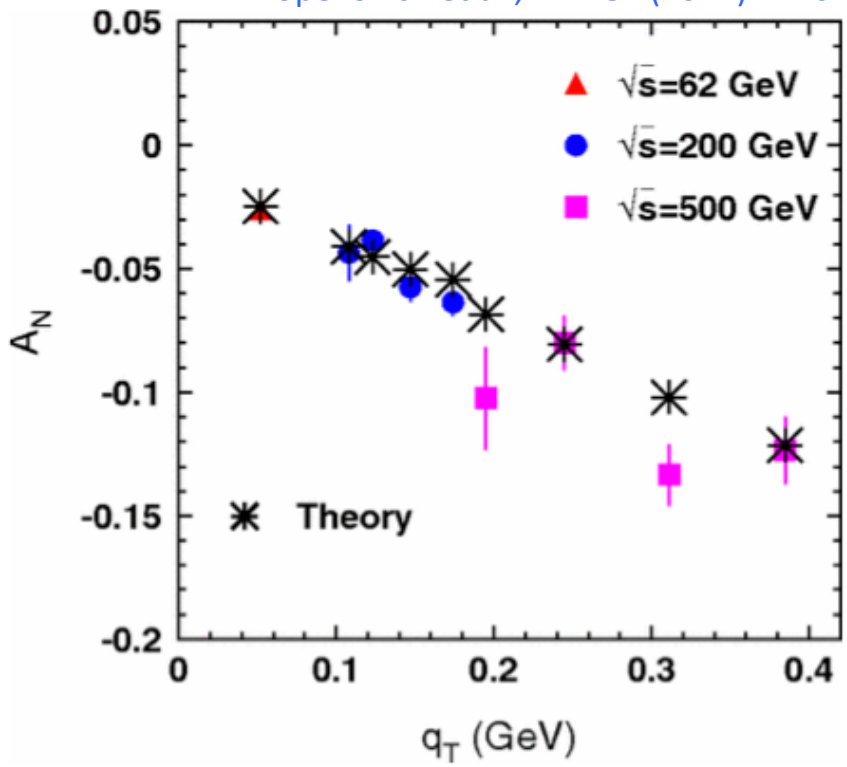
K. Tanida et al., J. Phys. Conf. Ser. 295 (2011) 012097



- Non-zero A_N for forward neutron production was first observed by the IP12 experiment at RHIC. Y. Fukao et al., PLB 650 (2007) 325
- Afterwards, the PHENIX measured the neutron A_N as a function of p_T with three different collision energies.
- The measurement results showed a possible p_T dependence of the neutron A_N.

Theoretical model

B. Z. Kopeliovich et al., PRD 84 (2011) 114012



$$A_N = \frac{d\sigma^{\uparrow} - d\sigma^{\downarrow}}{d\sigma^{\uparrow} + d\sigma^{\downarrow}}$$

$$= \frac{\sum_X |\langle cX|T|\uparrow\rangle|^2 - \sum_X |\langle cX|T|\downarrow\rangle|^2}{\sum_X |\langle cX|T|\uparrow\rangle|^2 + \sum_X |\langle cX|T|\downarrow\rangle|^2}$$

$$= \frac{-2\mathrm{Im}\sum_X \langle cX|T|-\rangle\langle +|T^{\dagger}|cX\rangle}{\sum_X |\langle cX|T|+\rangle|^2 + \sum_X |\langle cX|T|-\rangle|^2}$$

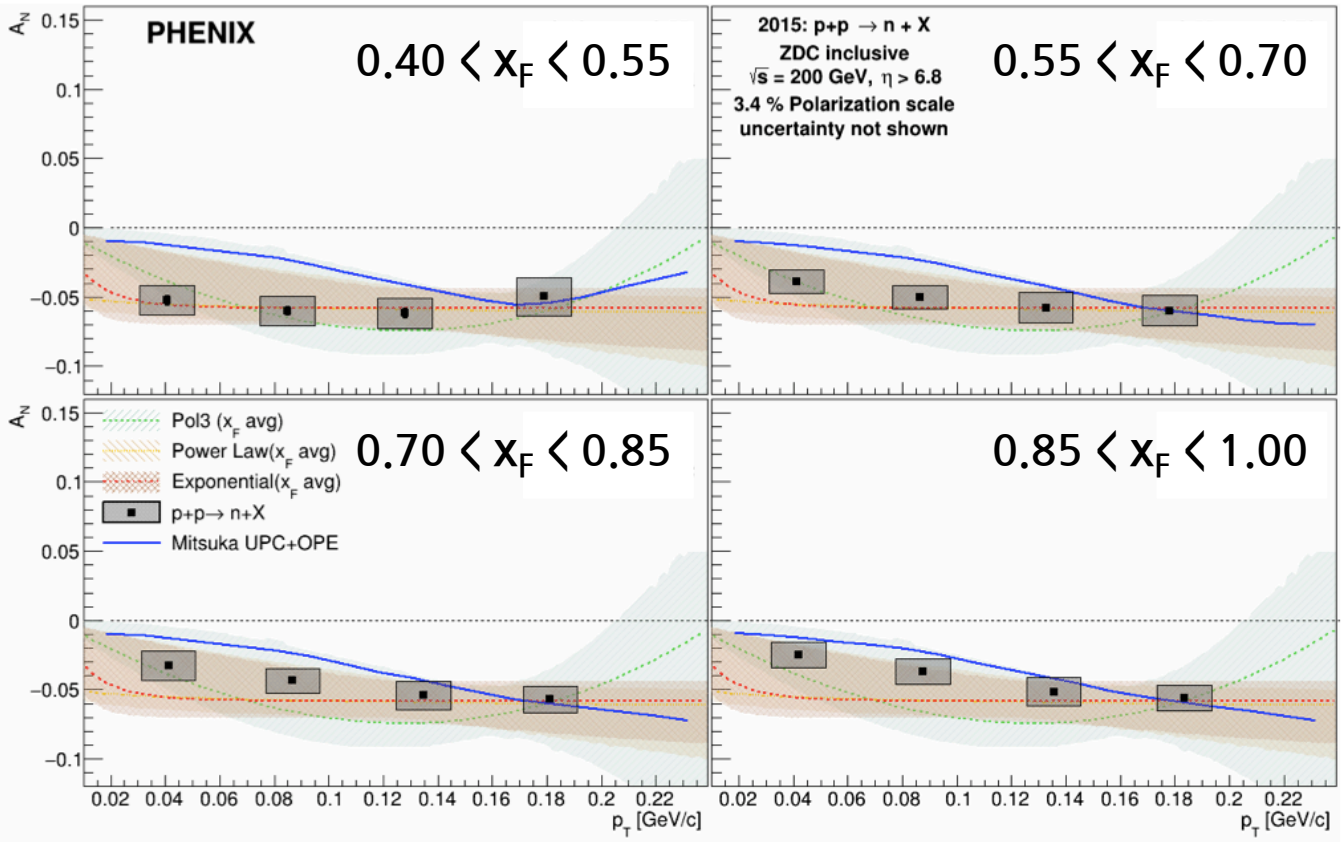
π exchange: spin flip

a_1 exchange: spin non-flip

- Neutron A_N was explained by an interference between the spin flip and spin non-flip exchange leading to non-zero phase shift.
- The π and a_1 exchange model showed that the neutron A_N increased in magnitude with increasing p_T with little $\sqrt{s}$ dependence.

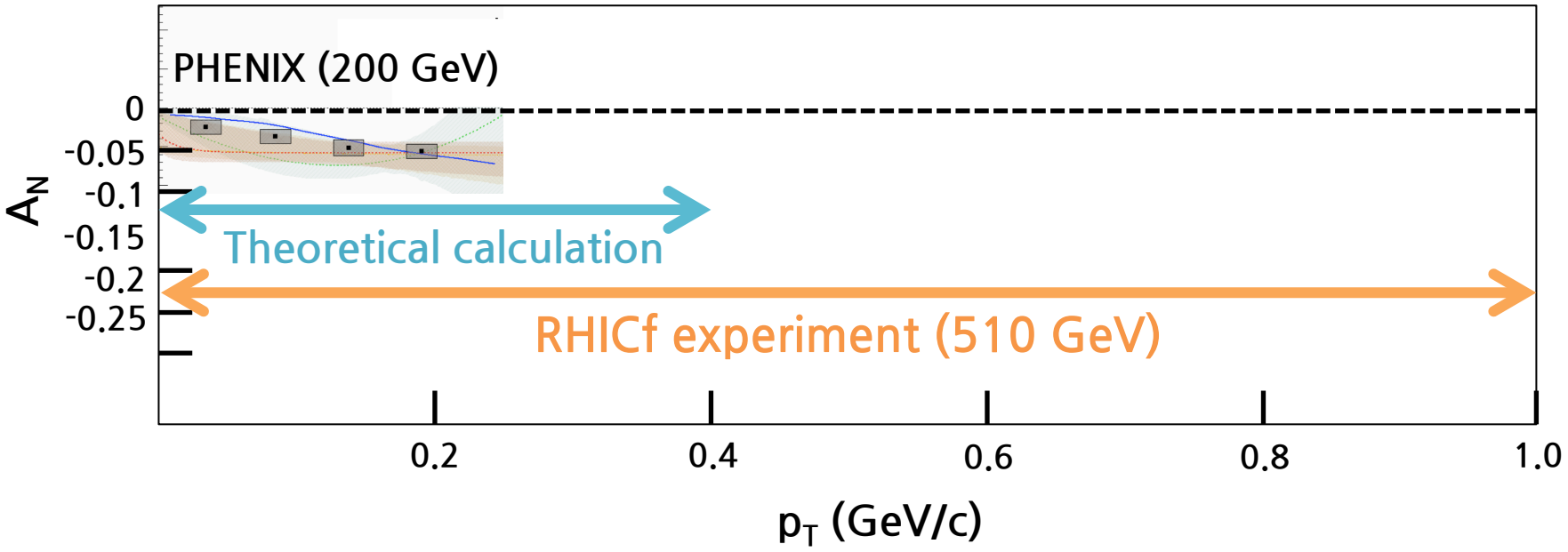
Unfolded neutron A_N at PHENIX

PHENIX, PRD 105 (2022) 032004



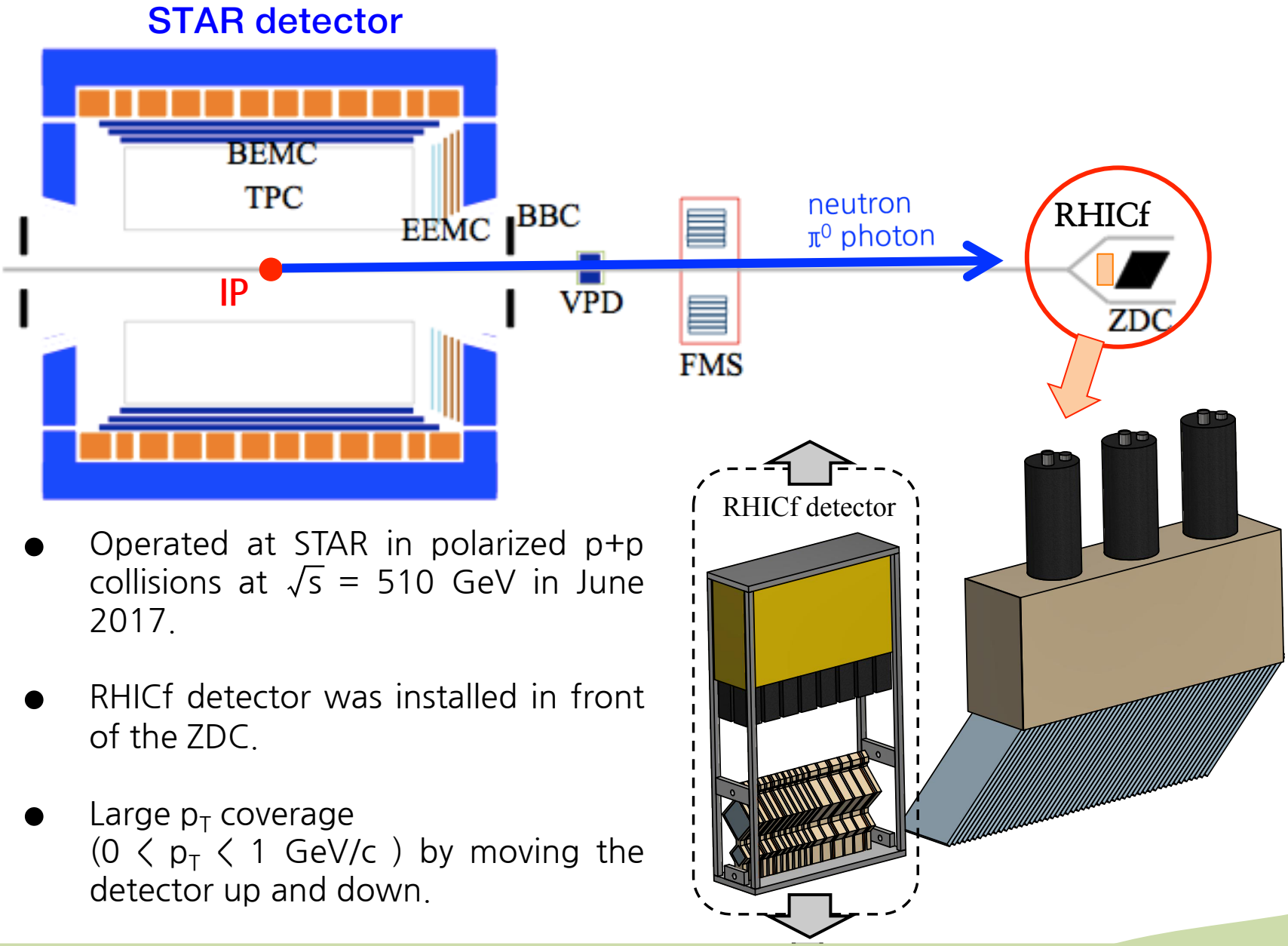
- Recently, p_T dependence of the PHENIX neutron A_N at $\sqrt{s}$ = 200 GeV was obtained by unfolding the data.
- The unfolded data showed the same tendency with the model calculations.

Neutron A_N measurement at RHICf



- RHICf the experiment has extended the previous measurements up to 1 GeV/c to study the kinematic dependence of the neutron A_N in more detail.
- We used a detector with one order of better position resolution (1 cm → 1 mm).
- We can also study the $\sqrt{s}$ dependence of the neutron A_N by comparing the RHICf data with that of the PHENIX.

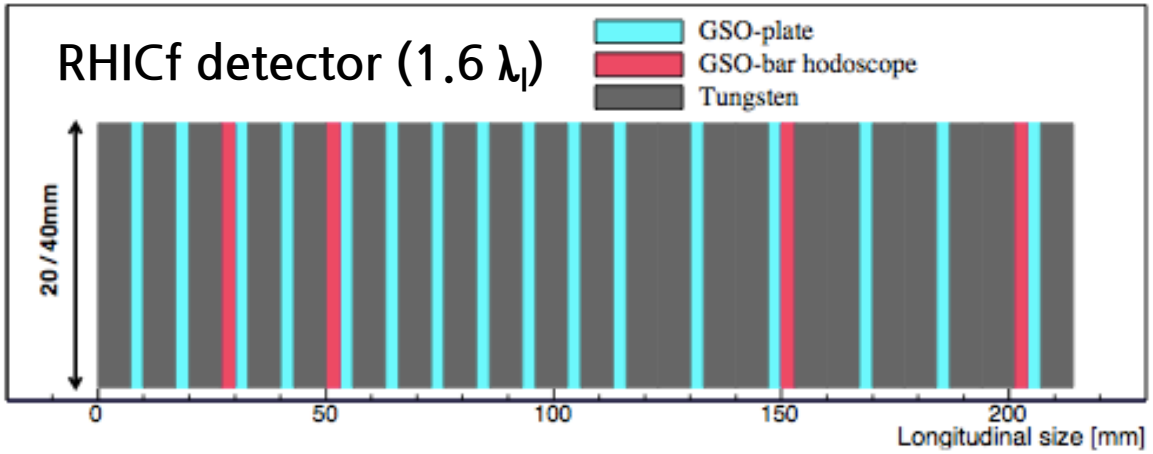
RHIC forward (RHICf) experiment



- Operated at STAR in polarized p+p collisions at $\sqrt{s}$ = 510 GeV in June 2017.
- RHICf detector was installed in front of the ZDC.
- Large p_T coverage
  ($0 < p_T < 1$ GeV/c) by moving the detector up and down.

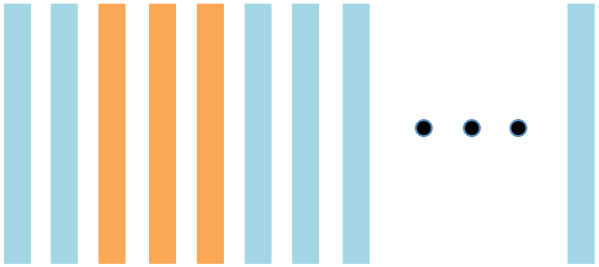
Neutron measurement

Side view



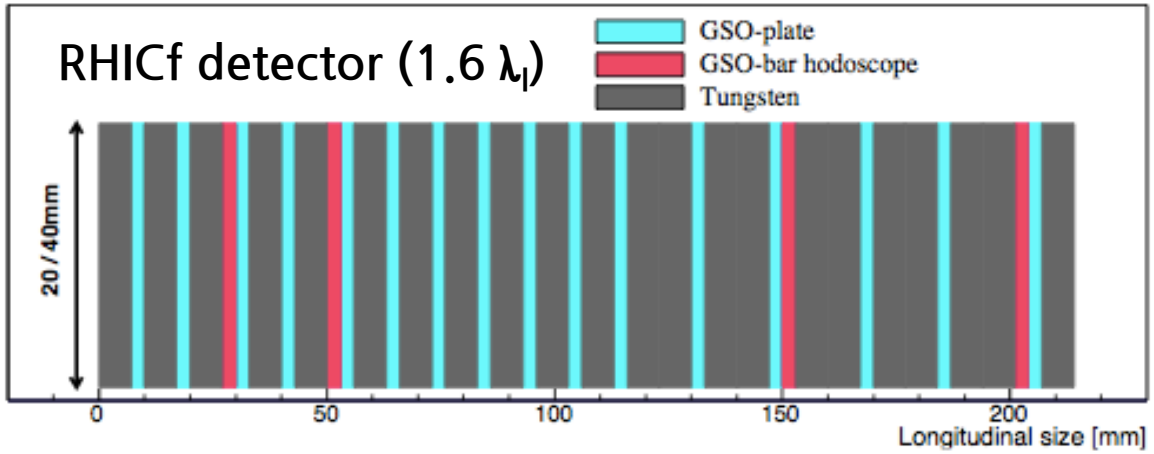
Shower trigger

Energy deposit > 45 MeV



Neutron photon separation

Side view



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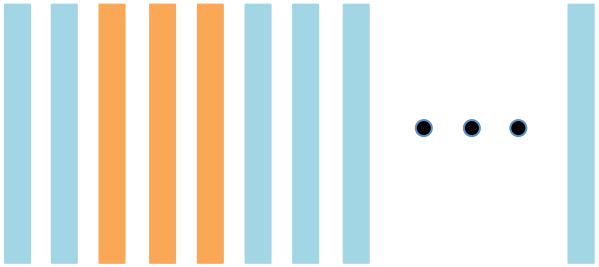

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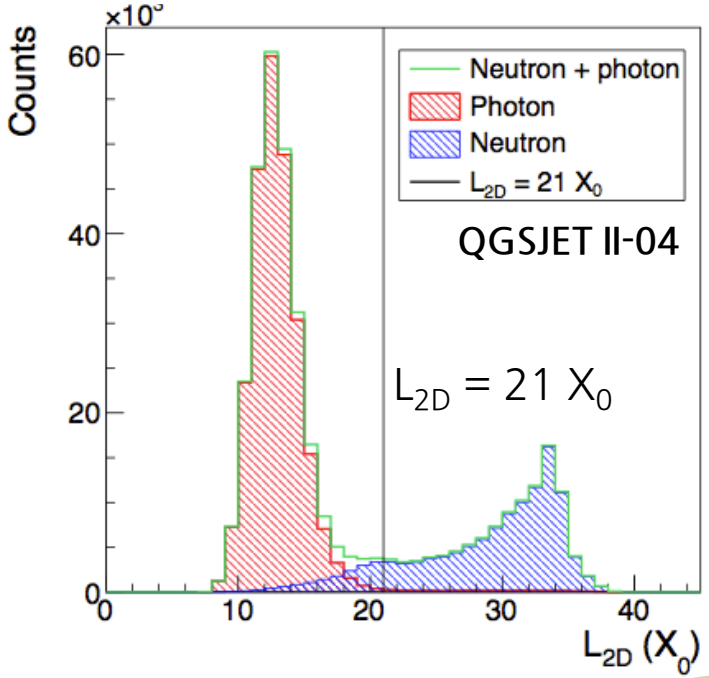
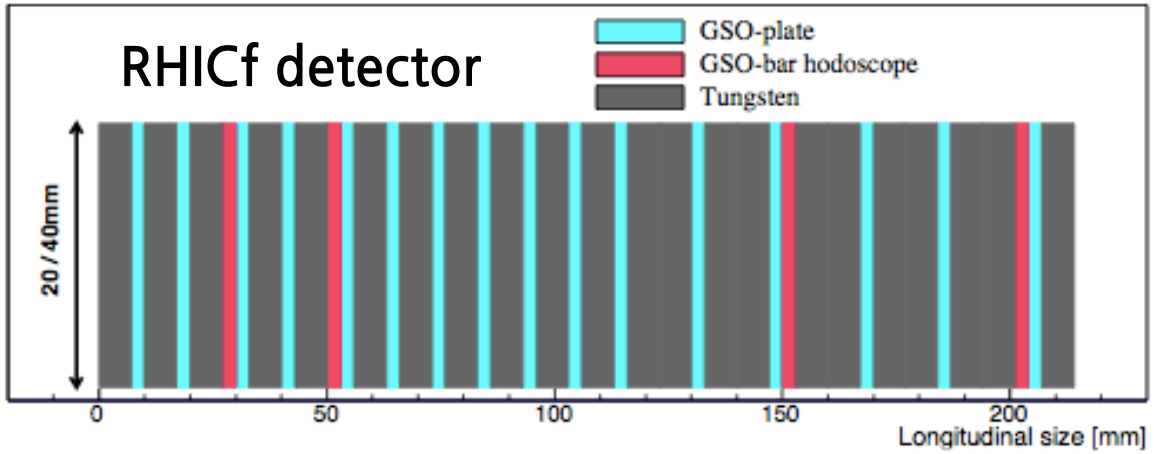


Photon contamination

Side view



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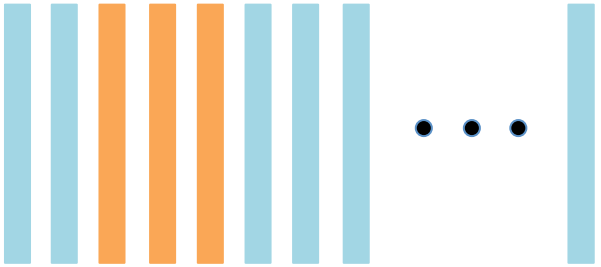
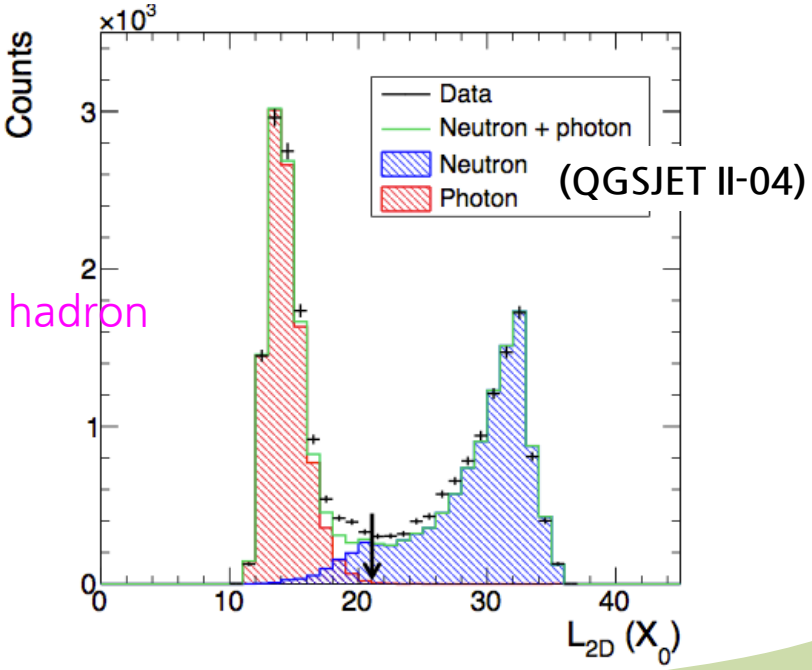


Neutron photon separation

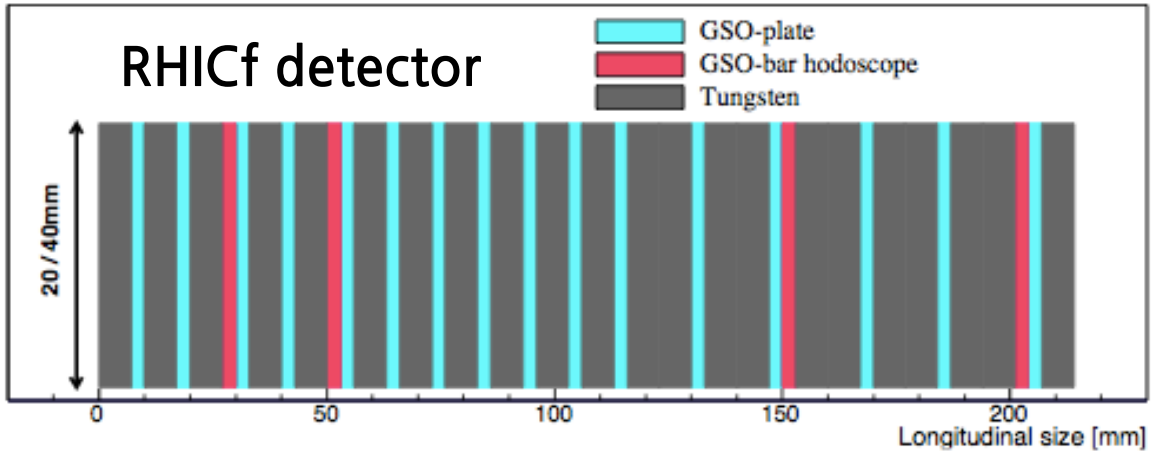
Background subtraction

Photon
Charged hadron



Charged hadron contamination

Side view



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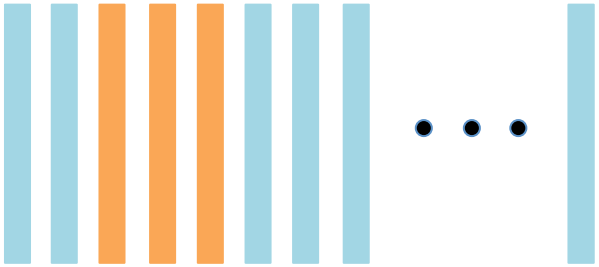

Neutron photon separation

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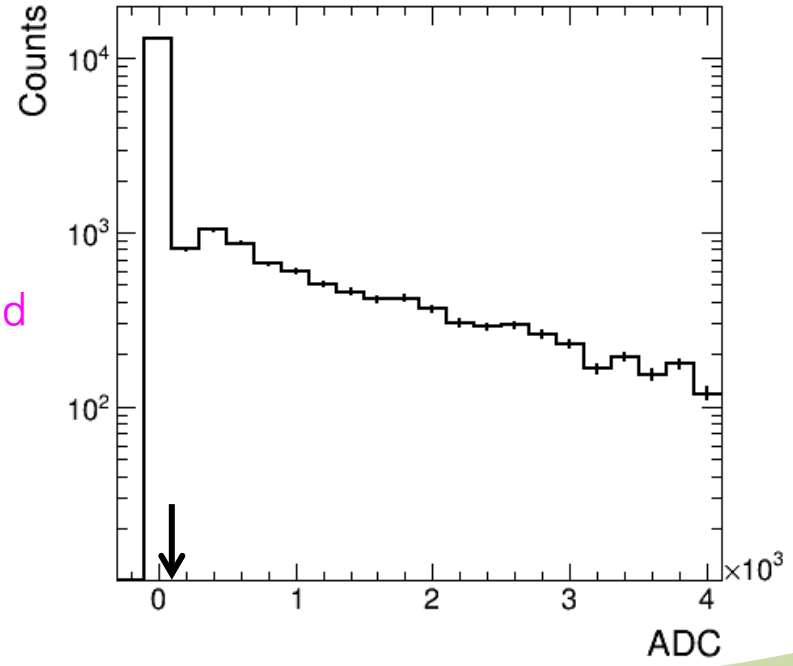
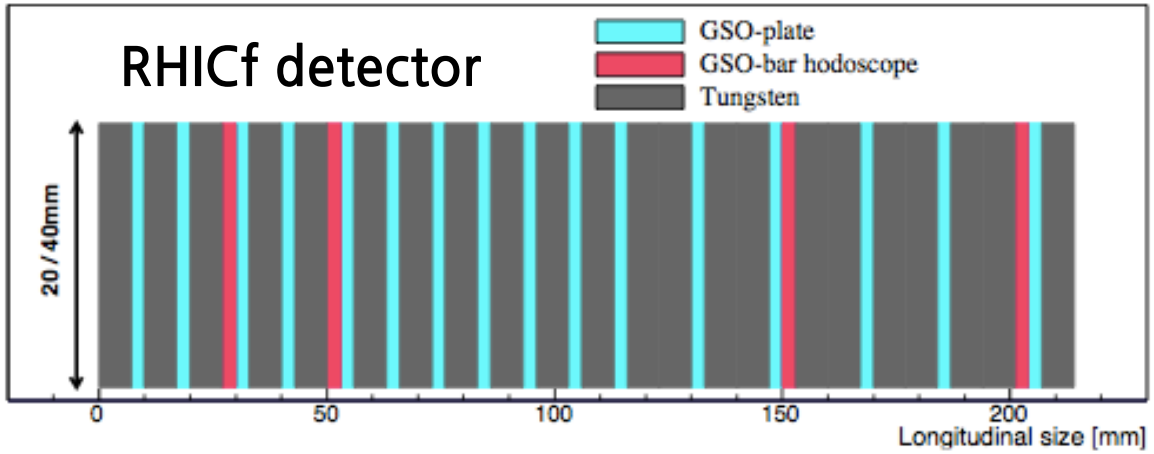


Charged hadron contamination

Side view



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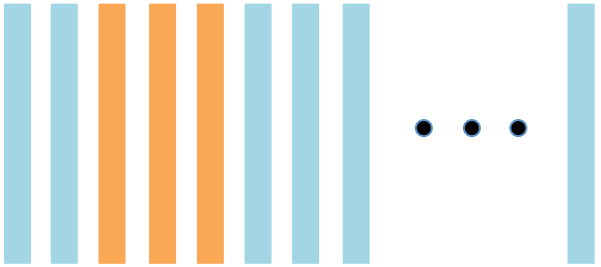
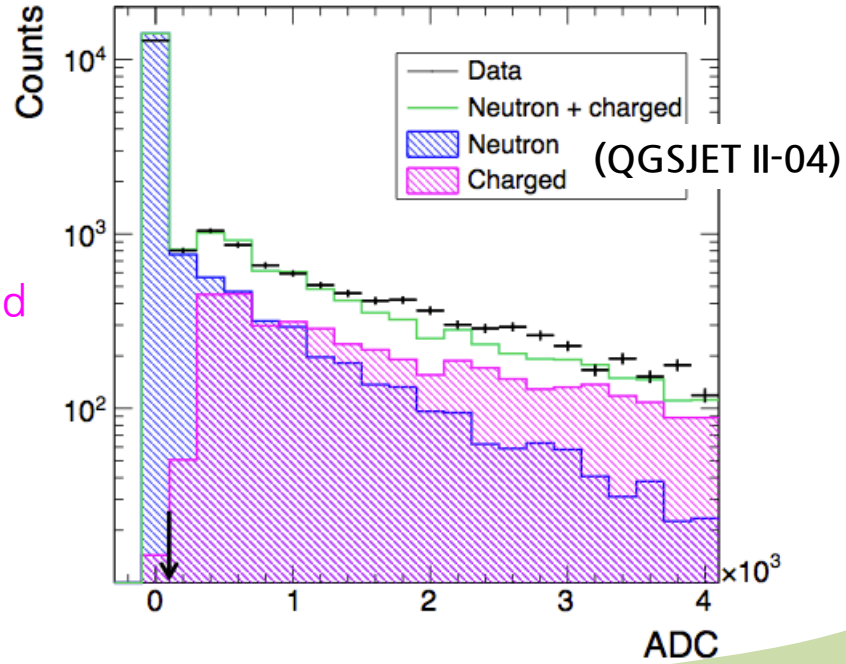


Neutron photon separation

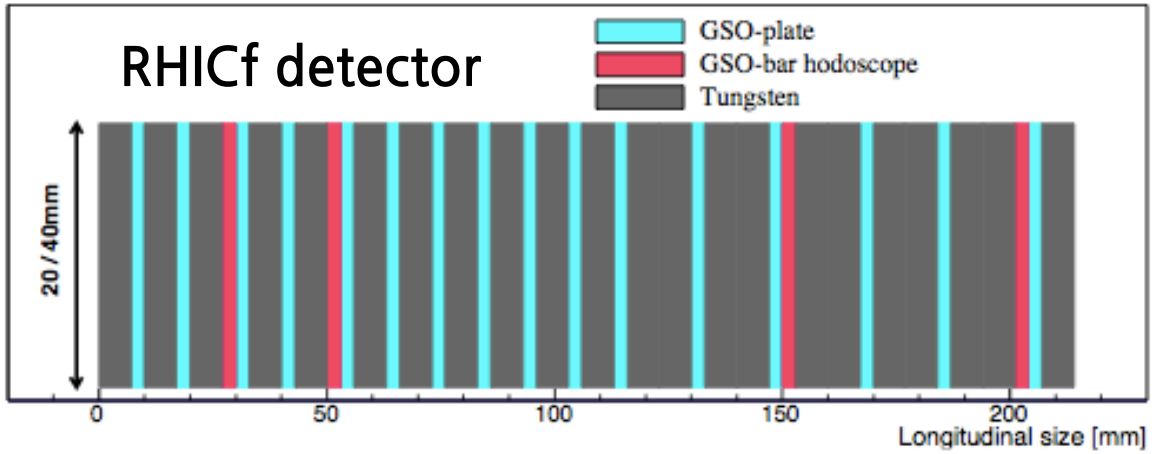
Background subtraction

Photon
Charged



Charged hadron contamination

Side view



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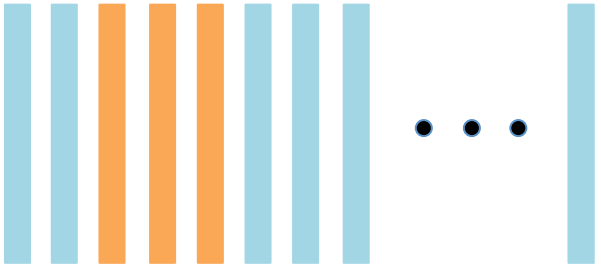


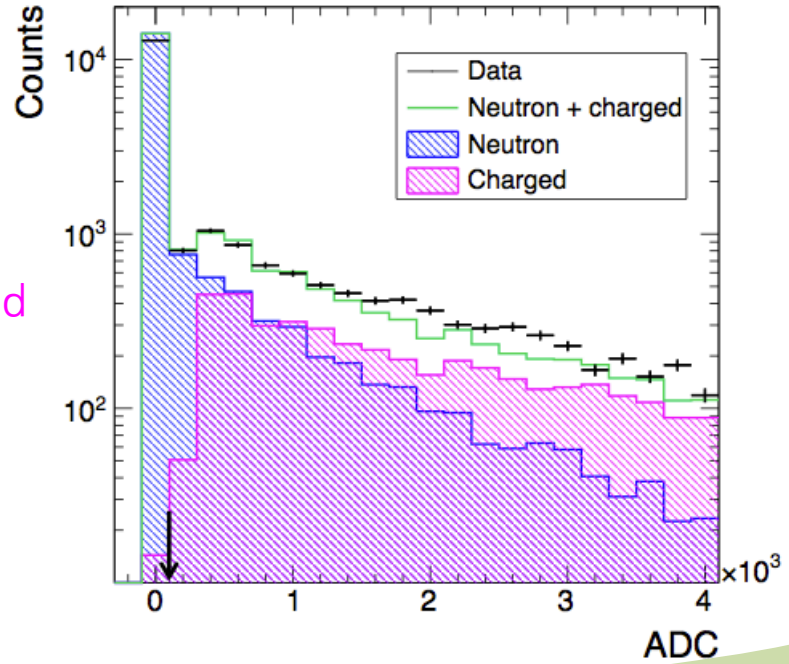
Neutron photon separation

Background subtraction

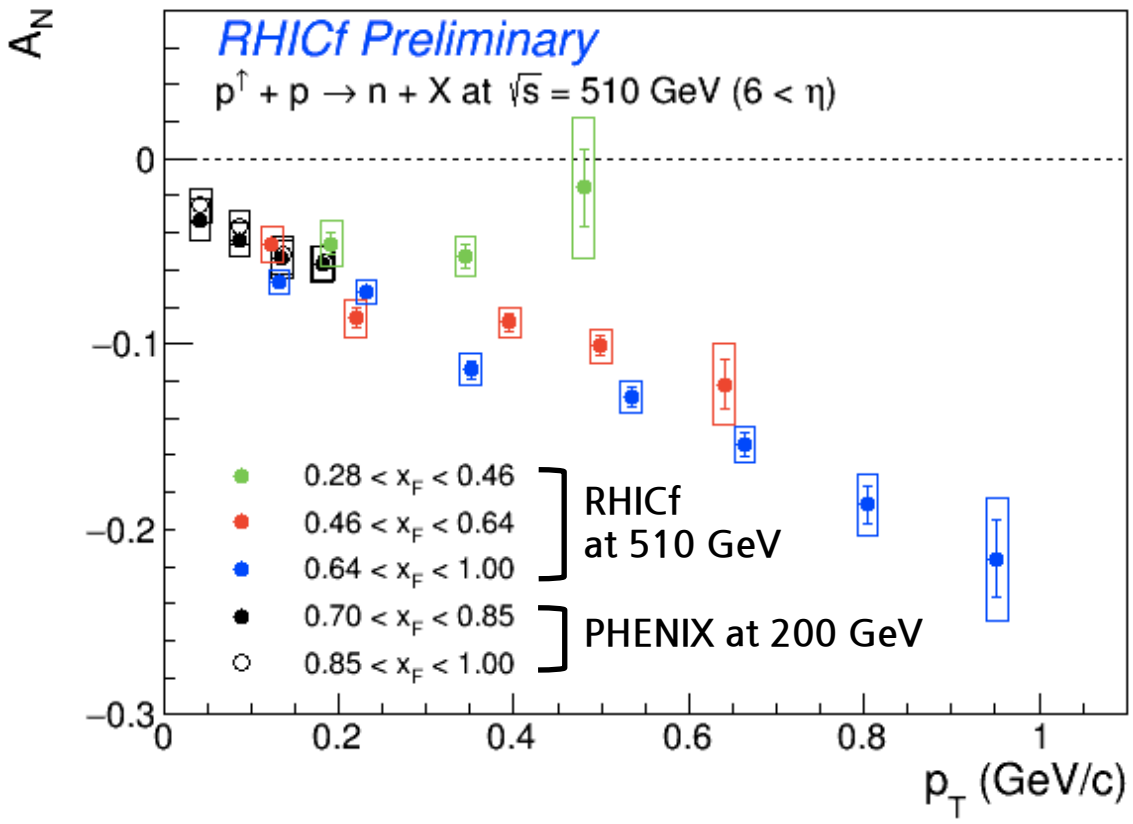
Photon
Charged

Unfolding

A_N calculation

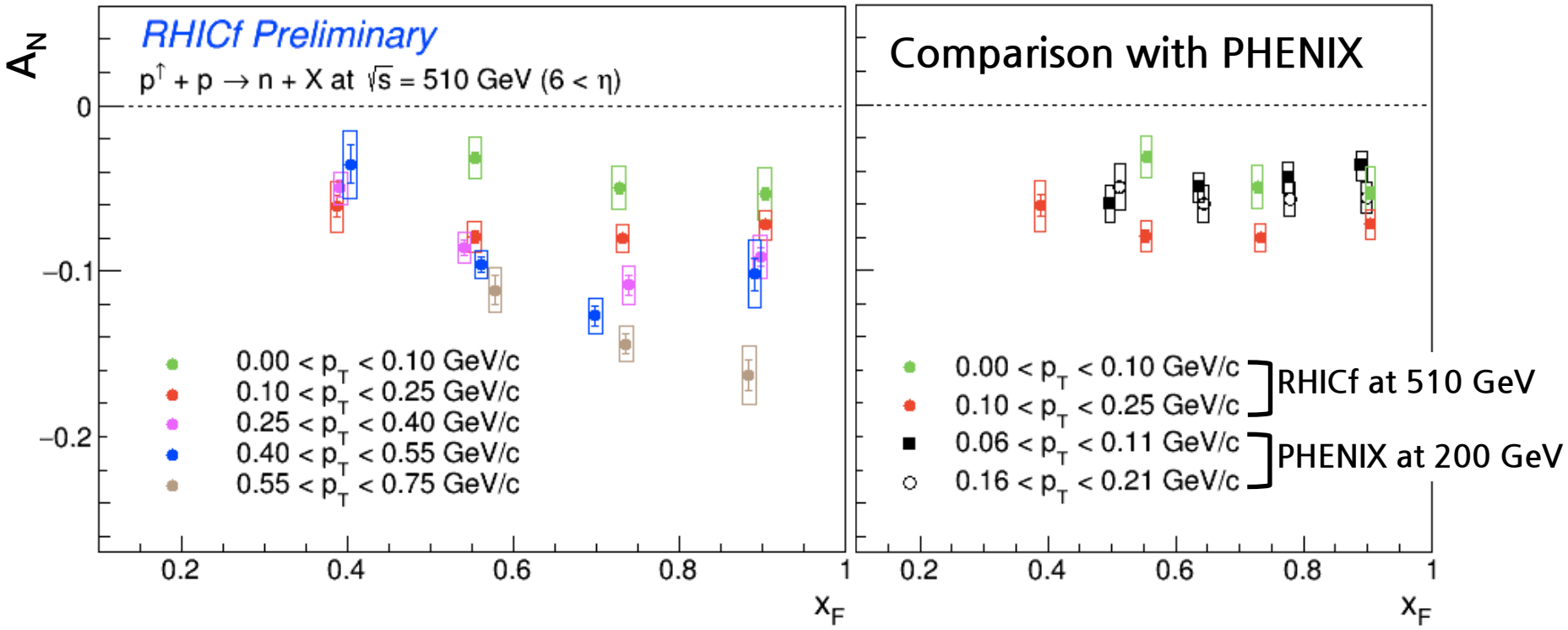


Neutron A_N as a function of p_T



- RHICf data is consistent with the PHENIX one.
- In $x_F > 0.46$, the A_N increases in magnitude with p_T as the model predicted.
- In $x_F < 0.46$, the AN reaches a plateau.

Neutron A_N as a function of x_F



- In $p_T < 0.25$ GeV/c, the A_Ns are flat showing no x_F dependence which is consistent with the PHENIX data.
- In $p_T > 0.25$ GeV/c, the A_Ns show a clear x_F dependence.
- The π and a_1 exchange model reproduces only part of the RHICf data.
  → More comprehensive (absorptive correction, other reggeon exchange) theoretical considerations are necessary to explain the present results.

Summary

- The RHICf experiment measured the A_N for forward neutron production in a wide p_T range of $0 < p_T < 1$ GeV/c in polarized p+p collisions at $\sqrt{s} = 510$ GeV.
- There is no $\sqrt{s}$ dependence in the neutron A_N.
- In $x_F > 0.46$, the neutron A_N increases in magnitude with p_T as the model predicted.
- A clear x_F dependence was observed in $p_T > 0.25$ GeV/c.
- More comprehensive theoretical considerations are necessary to understand the present results.

Backup