Transverse single spin asymmetry for very forward neutral pion production in polarized $p+p$ collisions at $\sqrt{s} = 510$ GeV

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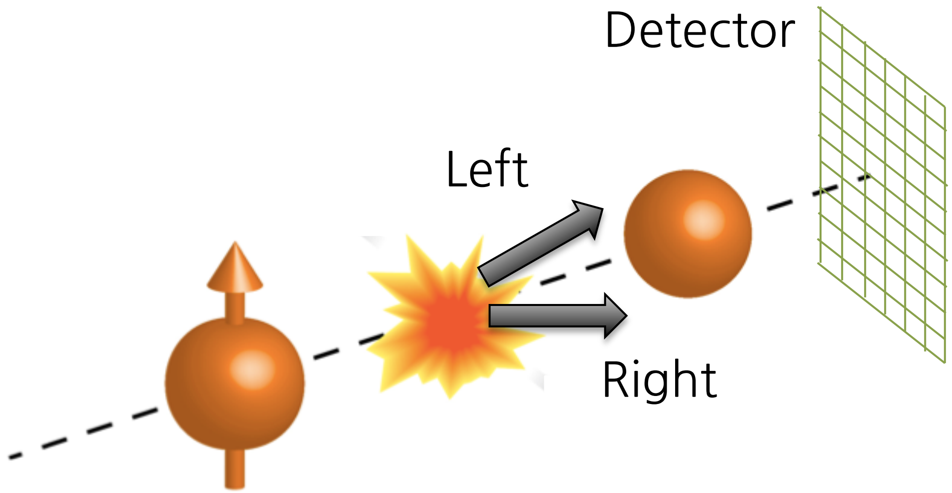
on behalf of the RHICf collaboration

4 Jul. 2020 CENuM workshop

Transverse single spin asymmetry (A_N)

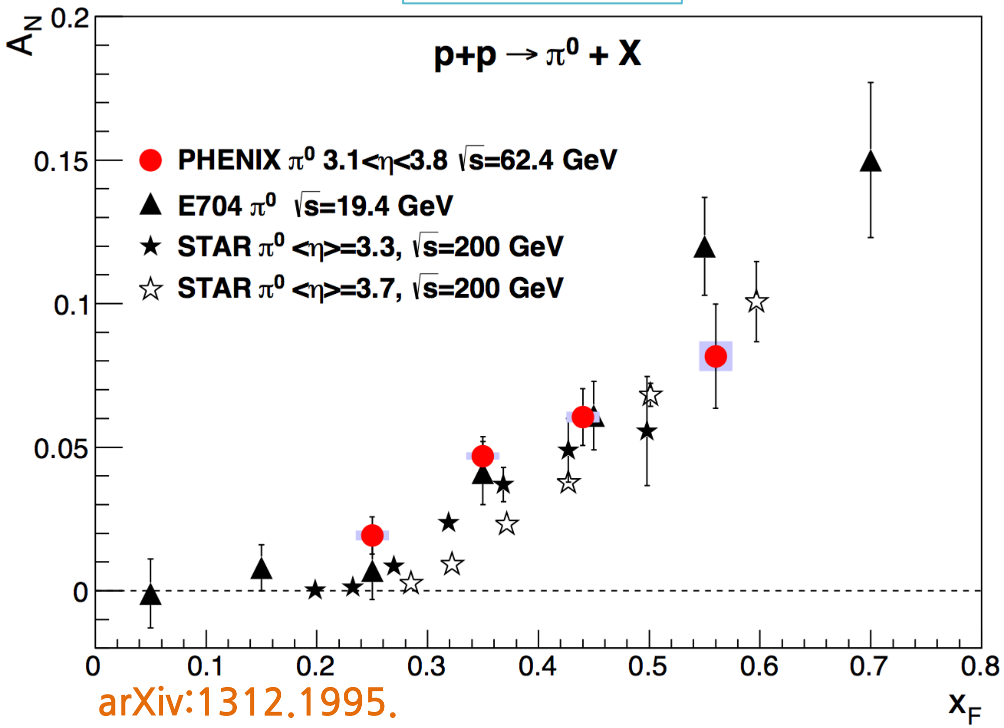


$$A_N = \frac{\sigma_L^\uparrow - \sigma_R^\uparrow}{\sigma_L^\uparrow + \sigma_R^\uparrow} = \frac{\sigma_L^\uparrow - \sigma_L^\downarrow}{\sigma_L^\uparrow + \sigma_L^\downarrow}$$

- In polarized p+p collision, A_N is defined as a left-right cross section asymmetry of a specific particle.
- Non-zero A_N of π^0 has been a starting point of the study for the spin-related interaction of the two protons and the proton spin itself.

A_N in forward π^0 production

$3 < \eta < 4$



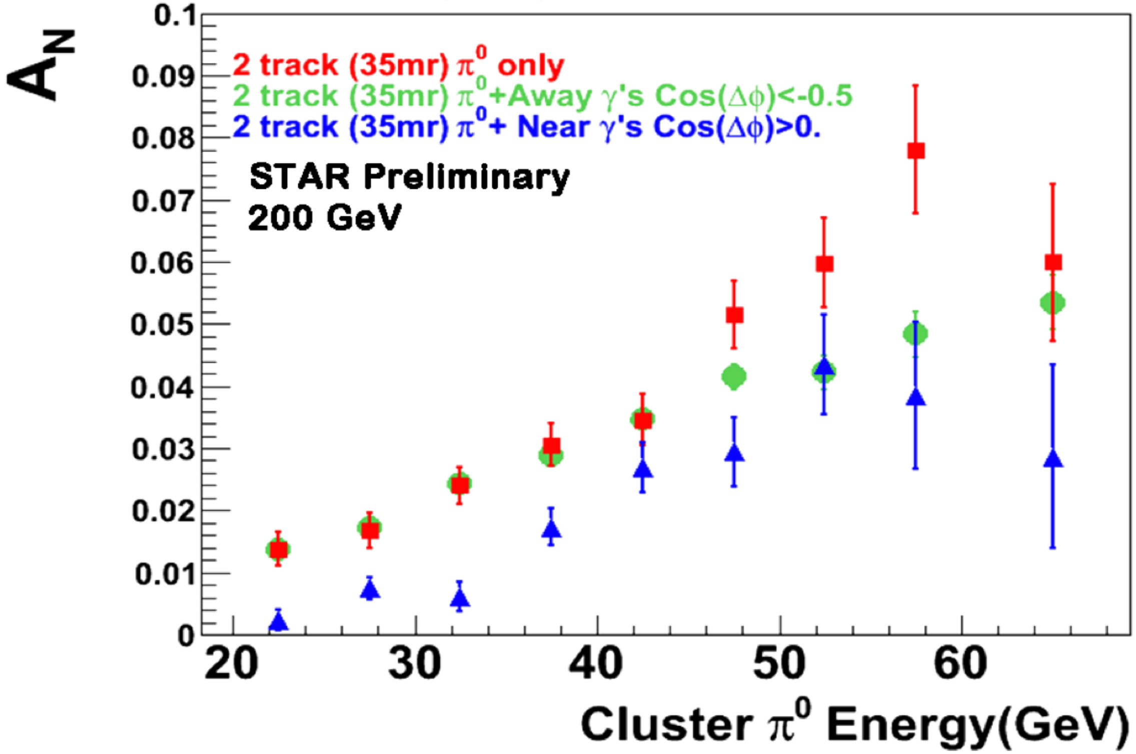
arXiv:1312.1995.

- Observed non-zero A_N of π^0 ever has been interpreted based on only perturbative picture theoretically.

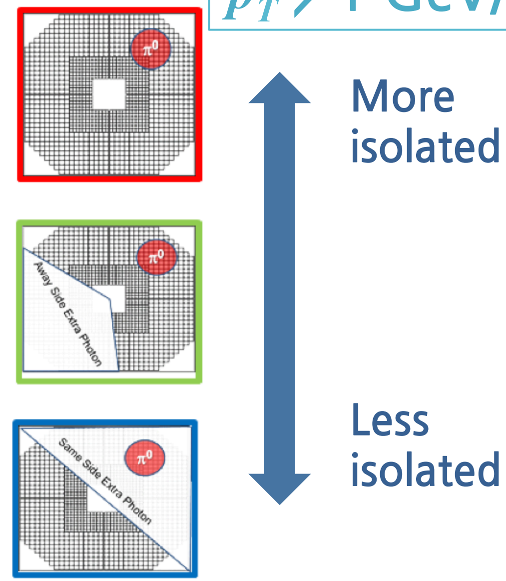
- For example, it has been believed that the non-zero A_N comes from an asymmetry of the partonic-level fragmentation process.

New question to the A_N of forward π^0

PoS DIS2013 (2013) 240.

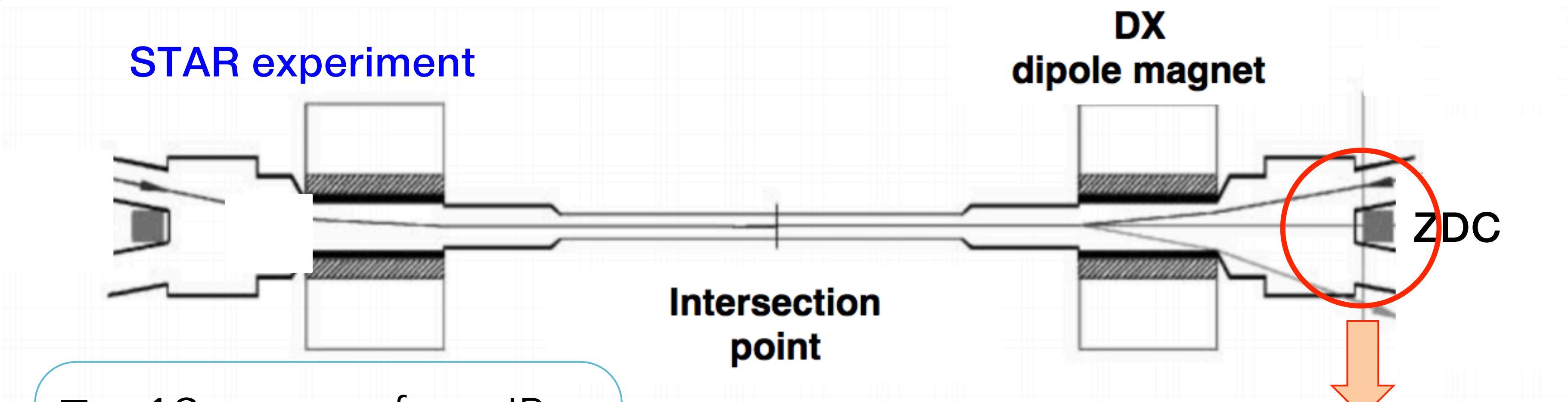


$2.6 < \eta < 4$
$p_T > 1$ GeV/c

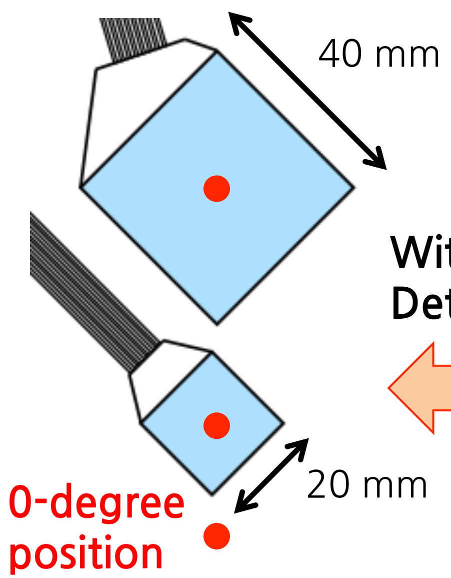


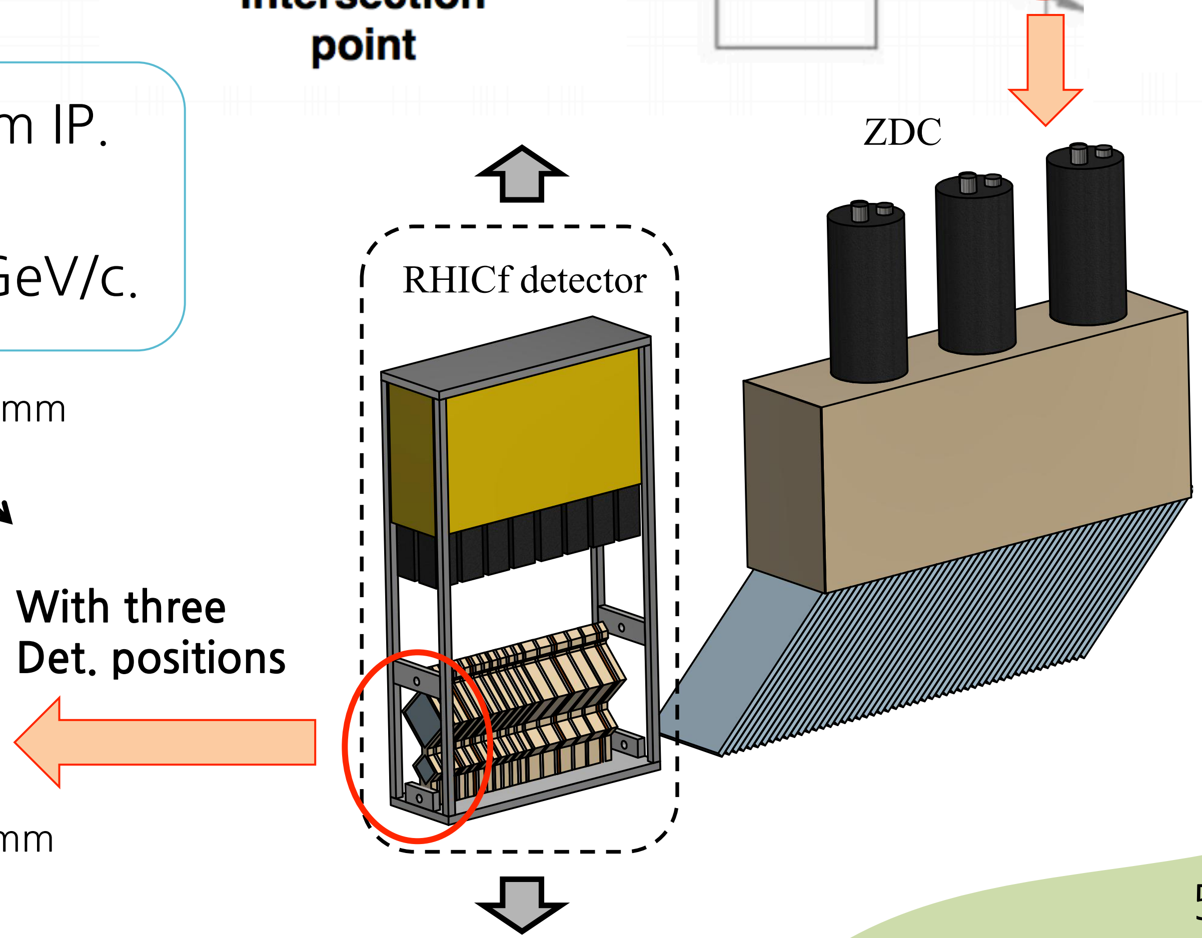
- Larger A_N was observed by more isolated π^0 than less isolated one.
- Non-perturbative process may have a finite contribution to the π^0 A_N as well as perturbative one.

RHIC forward (RHICf) experiment

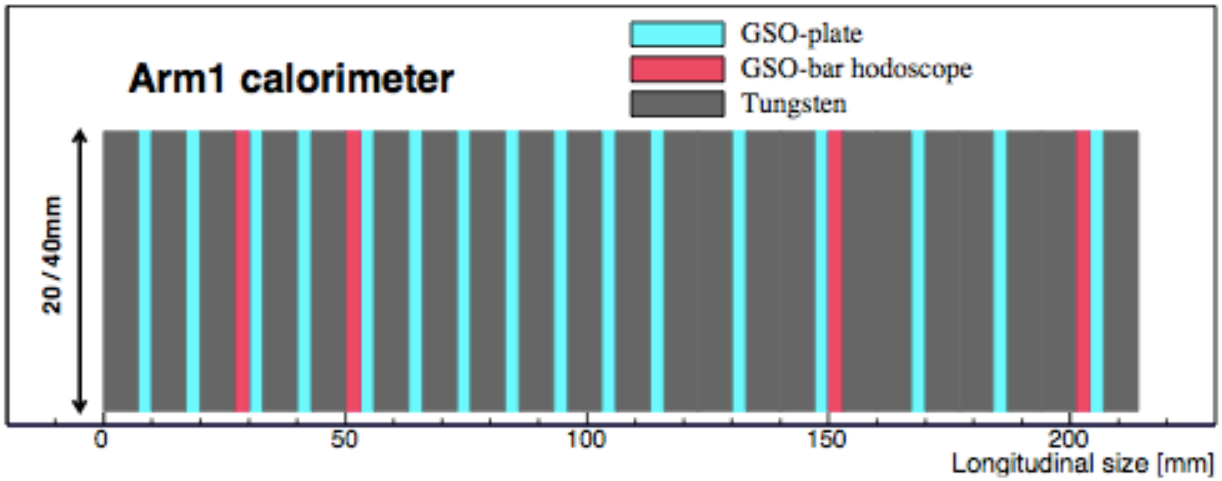


- 18 m away from IP.
- $0.2 < x_F < 1.0$.
  $0.0 < p_T < 1.0$ GeV/c.





RHICf detector & π^0 measurement

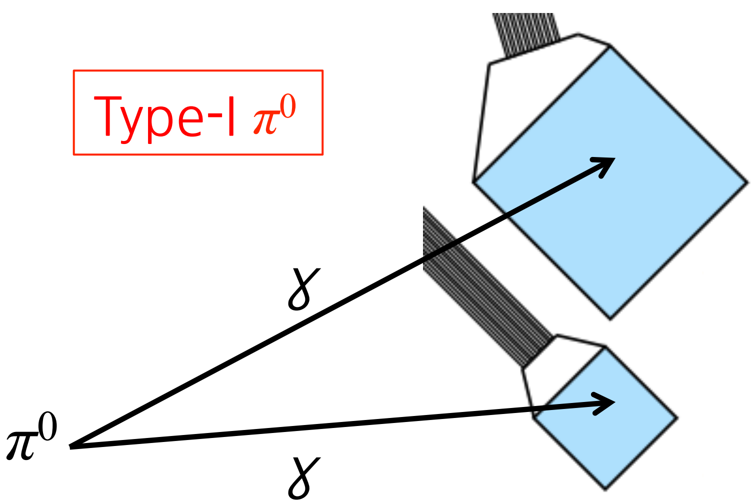


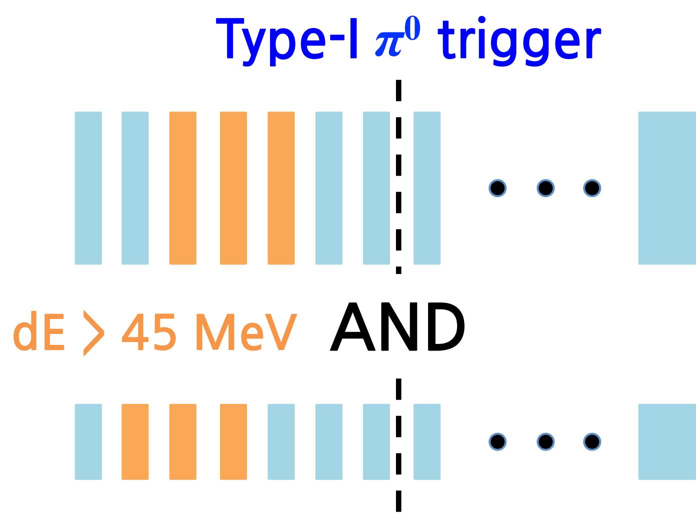
Small tower: 20/20 mm
Large tower: 40/40 mm

17 Tungsten absorbers
(44 X_0, 1.6 λ_{int})

16 GSO plates for energy measurement

4 GSO bar layers for position measurement





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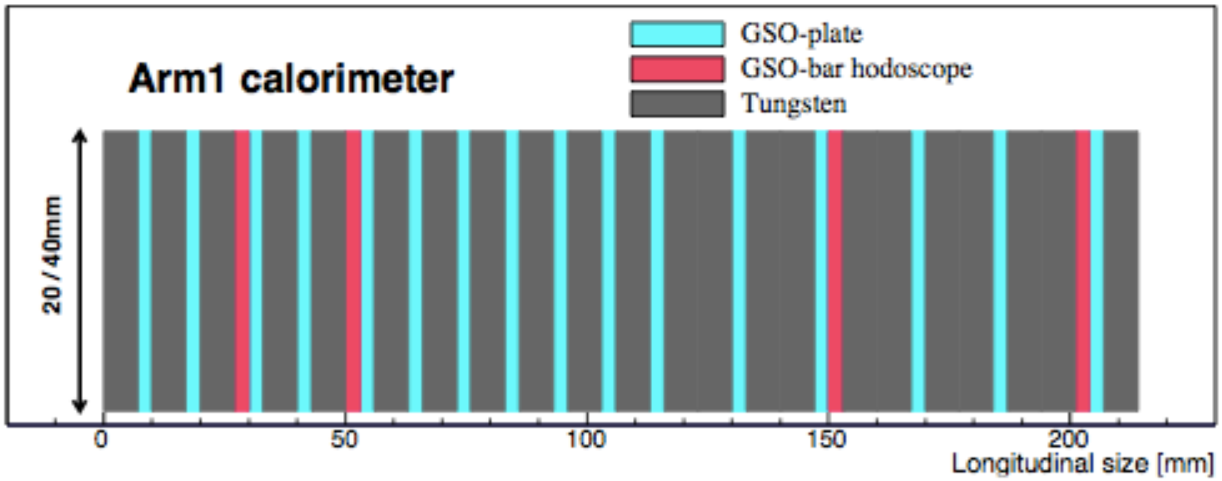

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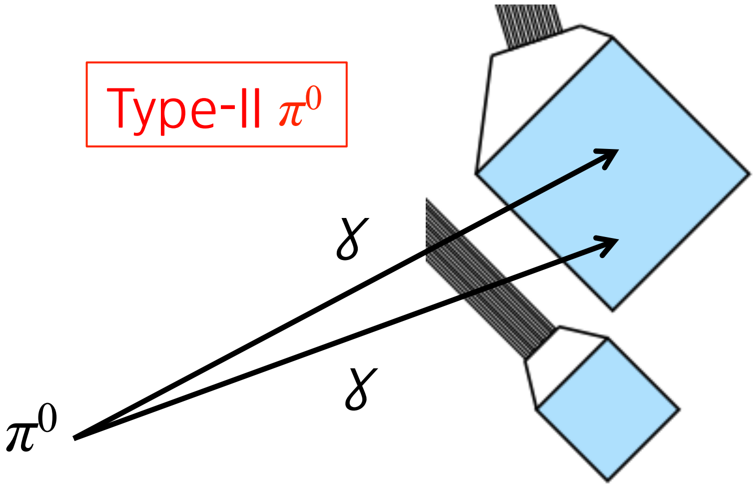
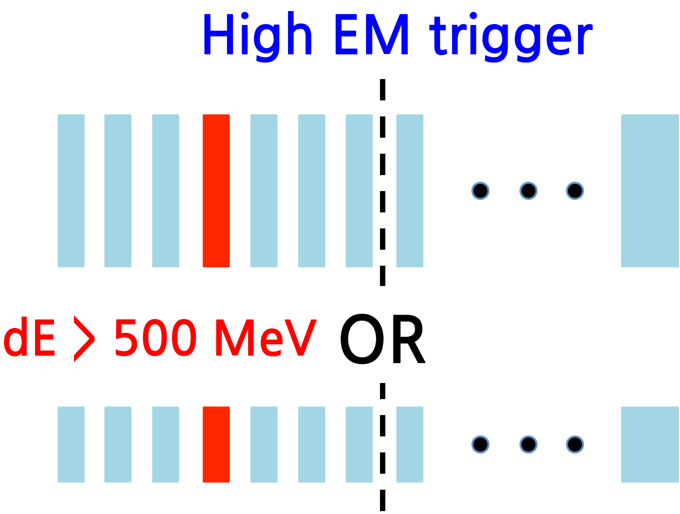
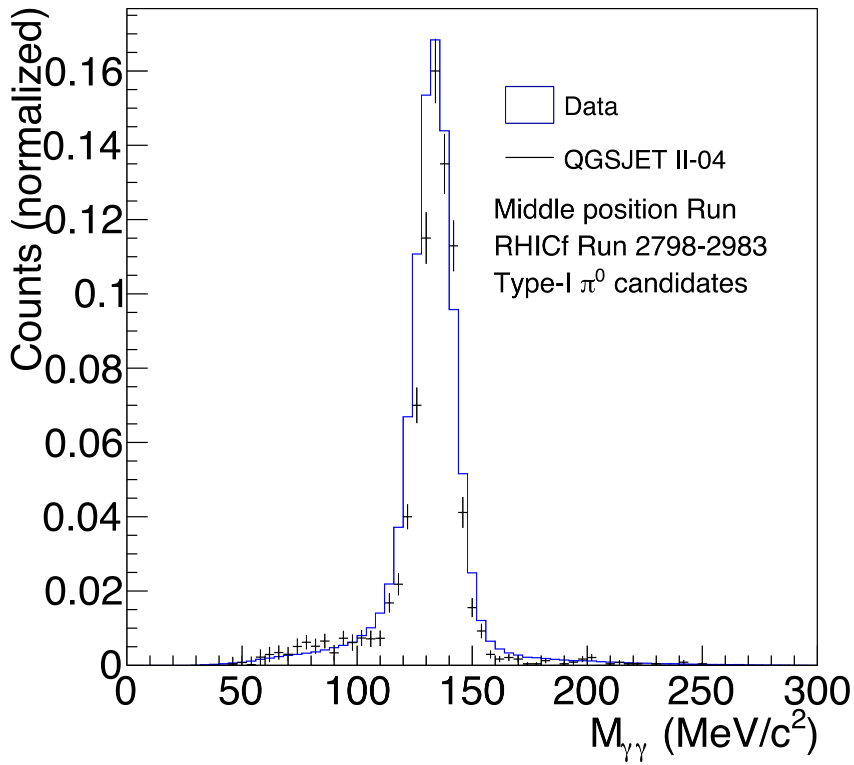
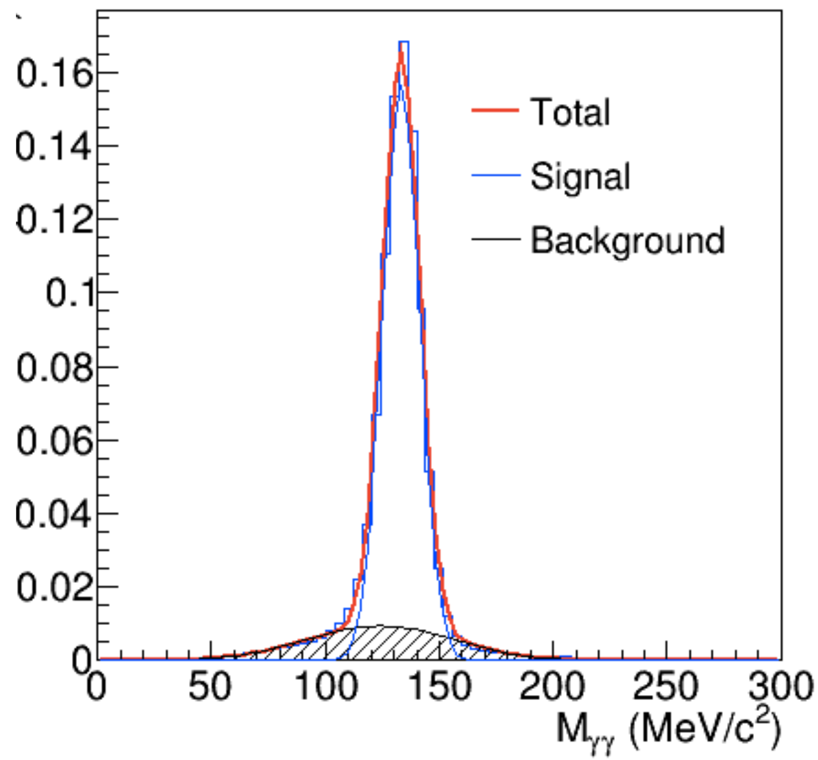




Invariant mass of two photons

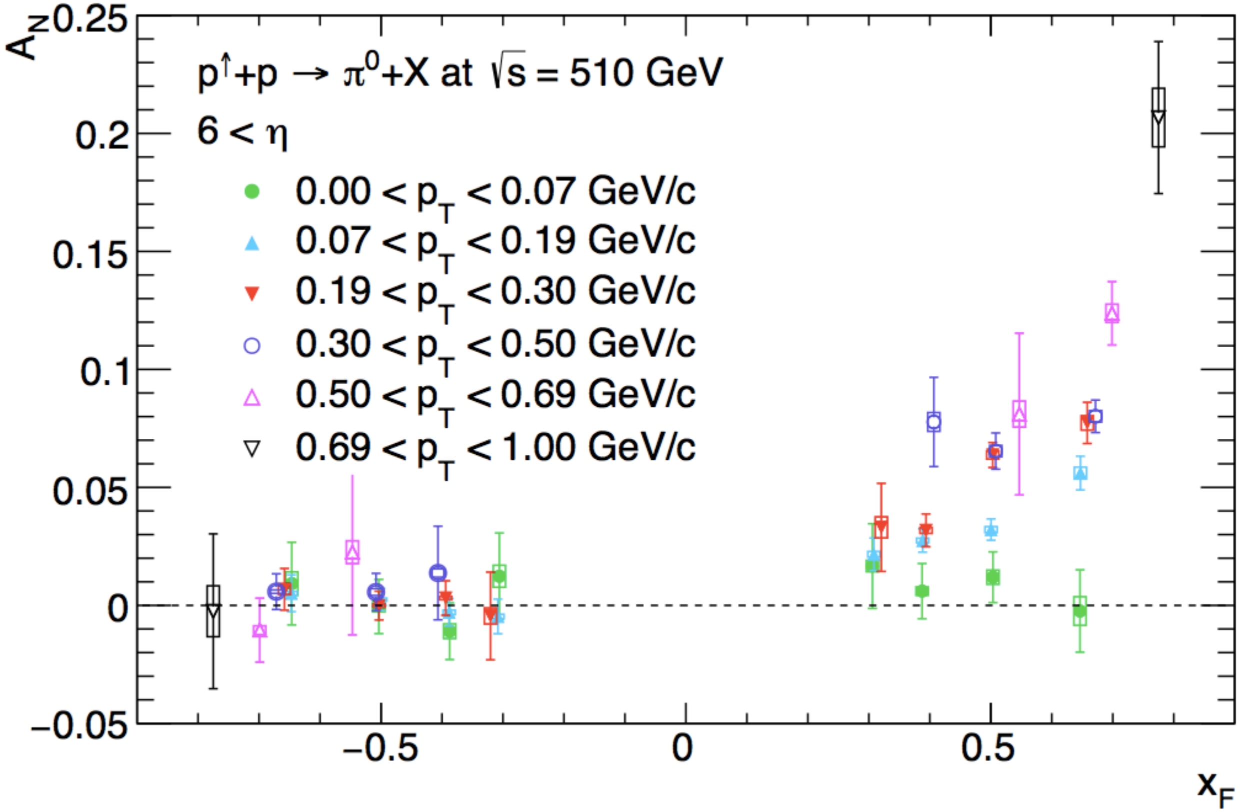




- Data is well matched with simulation showing clear π^0 peak around 135 MeV/c^2 with ~8 MeV/c^2 peak width.
- Invariant mass was fitted by polynomial for background and Gaussian for π^0.

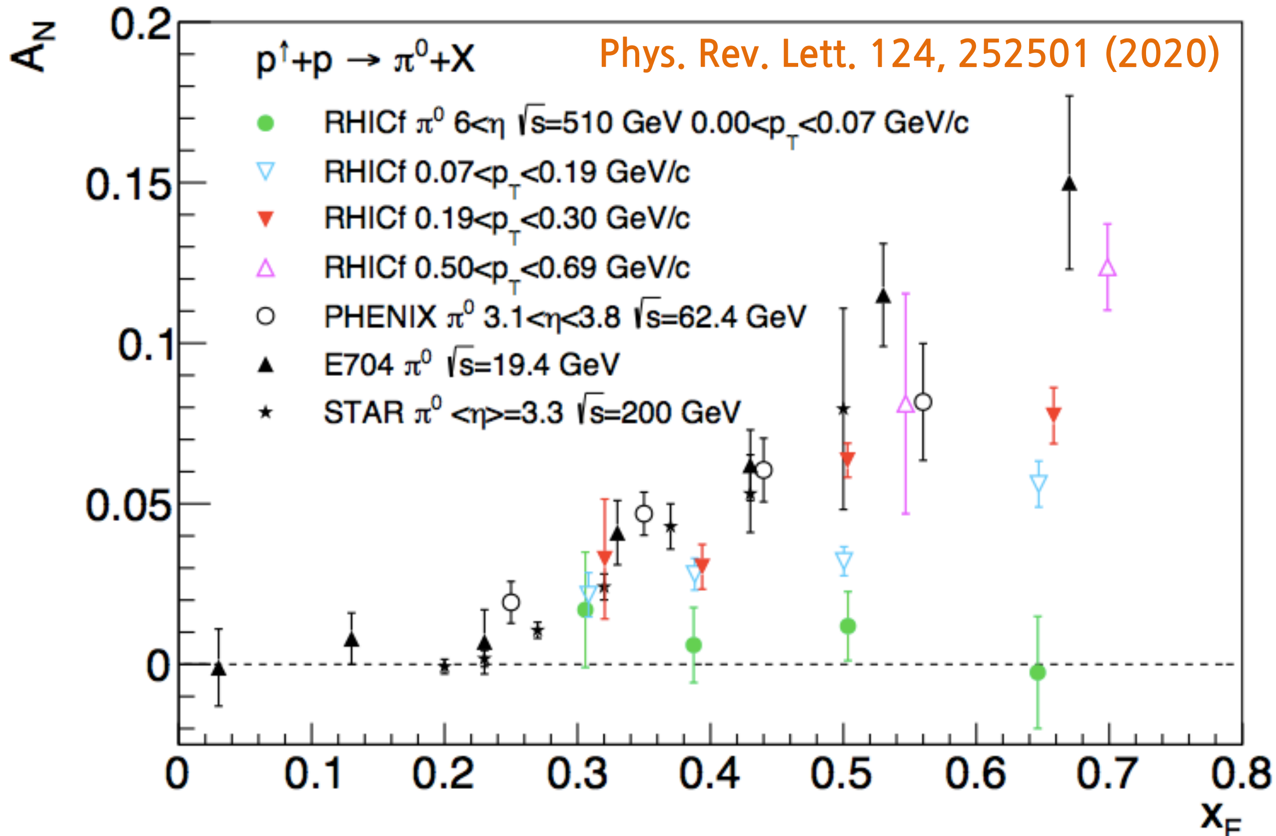
Very forward π^0 A_N as a function of x_F

Phys. Rev. Lett. 124, 252501 (2020)



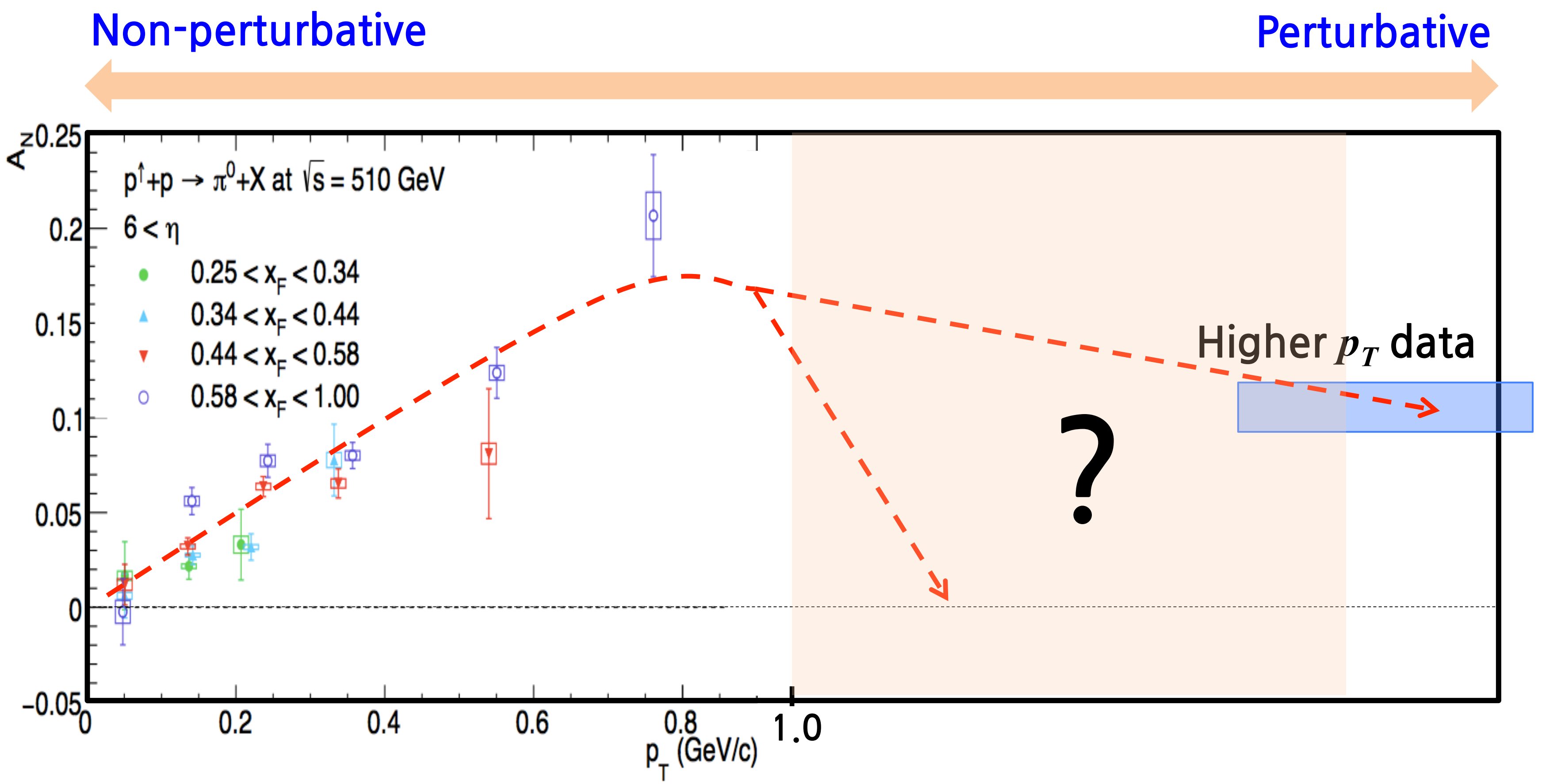
- The higher p_T range the A_N is measured in, the more clearly it increases as a function of x_F.
- Even in very low p_T, the A_N already approaches ~0.1 which is comparable with the previous measurement.

Comparison with previous measurements



- Scenario 1: There is perturbative contribution even in lower p_T area.
- Scenario 2: The origin of x_F scaling is non-perturbative process.
- Scenario 3: Higher (lower) momentum A_N is just mainly due to (non-) perturbative process respectively.

What's the next step?



- How competitively each perturbative and non-perturbative process contribute to the $\pi^0 \, A_N$?

- This will be answered by combined analysis with STAR and another new experiment.

Backup

Subject..

- Contents..
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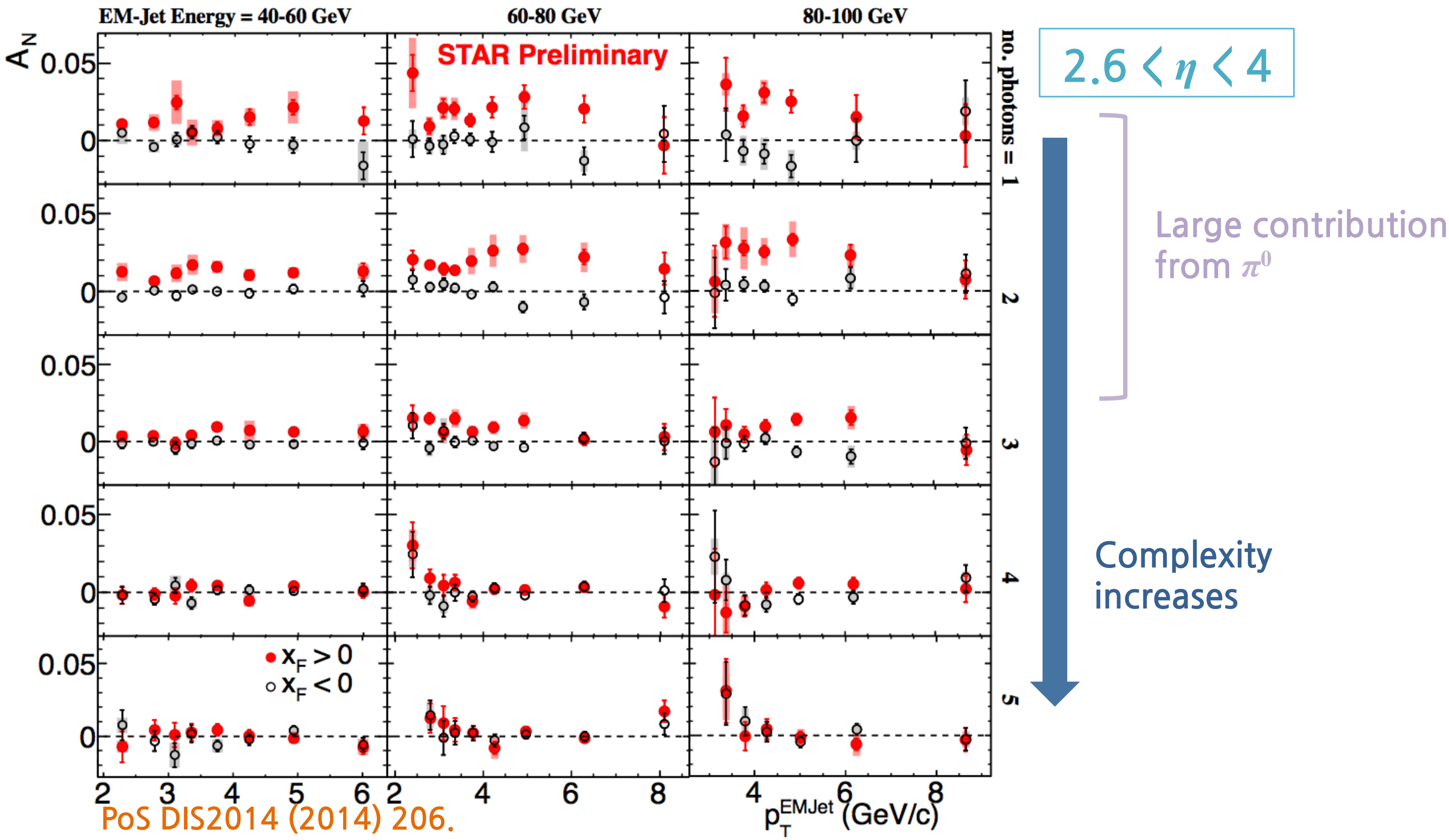
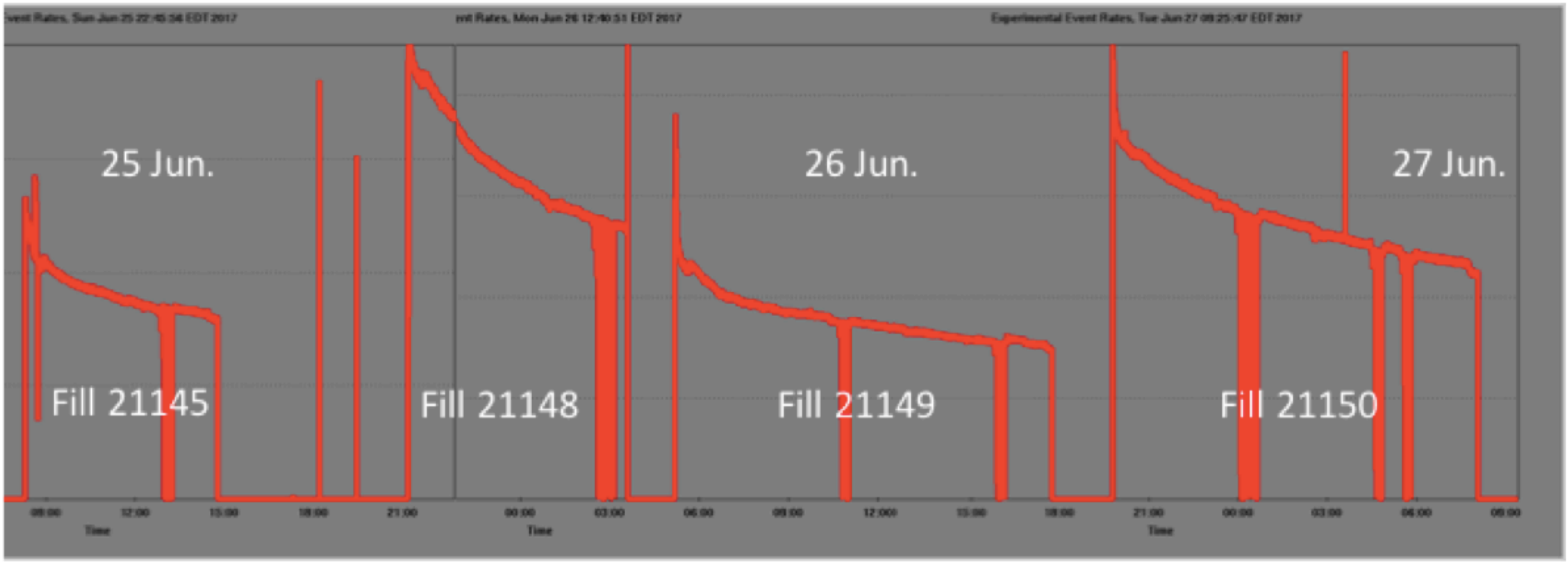
New question to the A_N of forward π^0



PoS DIS2014 (2014) 206.

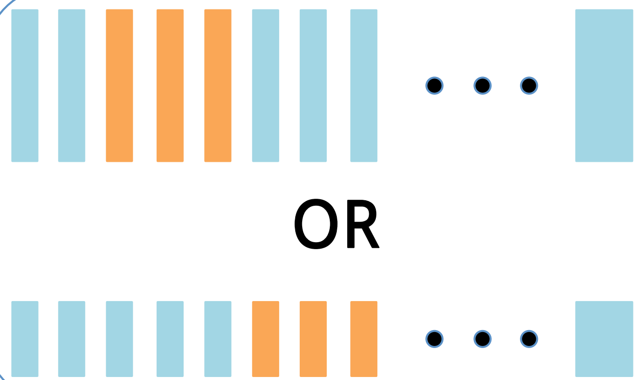
- Smaller A_N was observed with increasing multiplicity of photons (closer to hard scattering event topology).

Operation summary

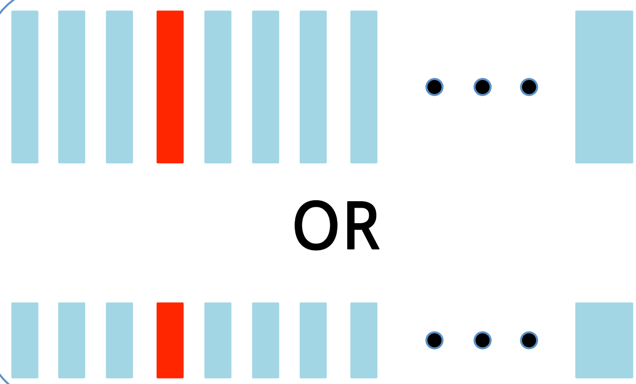


- RHICf experiment was successfully operated in June 2017.
- Total 110 M events were accumulated for neutral particles (neutron, π^0, and single photon) during 28 hours.
- Radial polarization.
- Higher β^*: 8 m and lower luminosity: 10^{31} $cm^{-2}s^{-1}$ than usual.

Triggers of RHICf detector



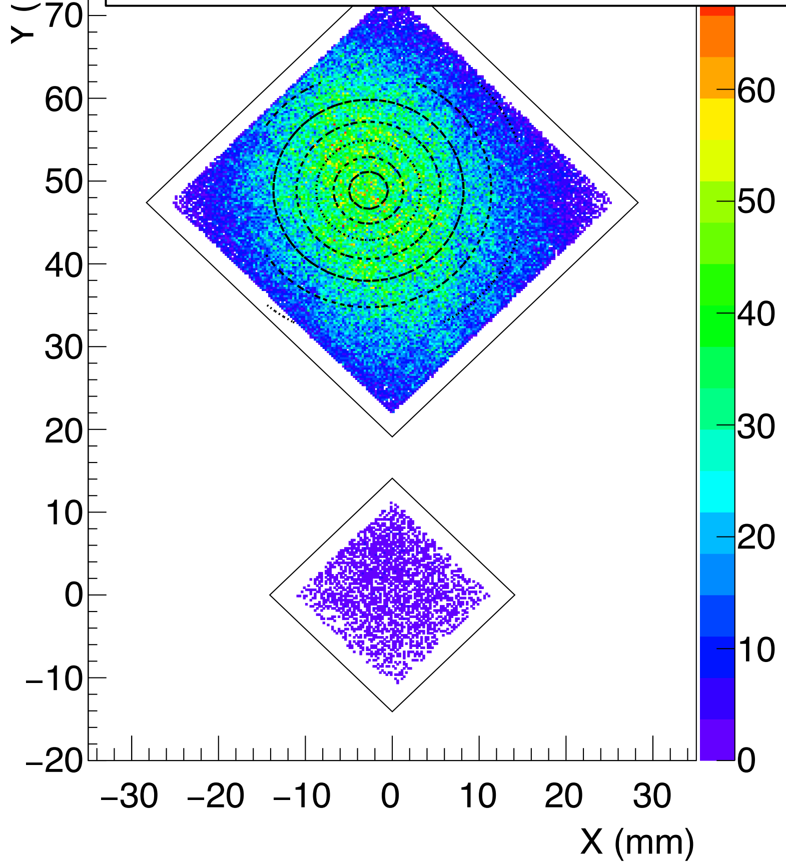
Shower trigger: Energy deposits of three successive layers at large or small tower are larger than 45 MeV.
(for neutron and single photon)



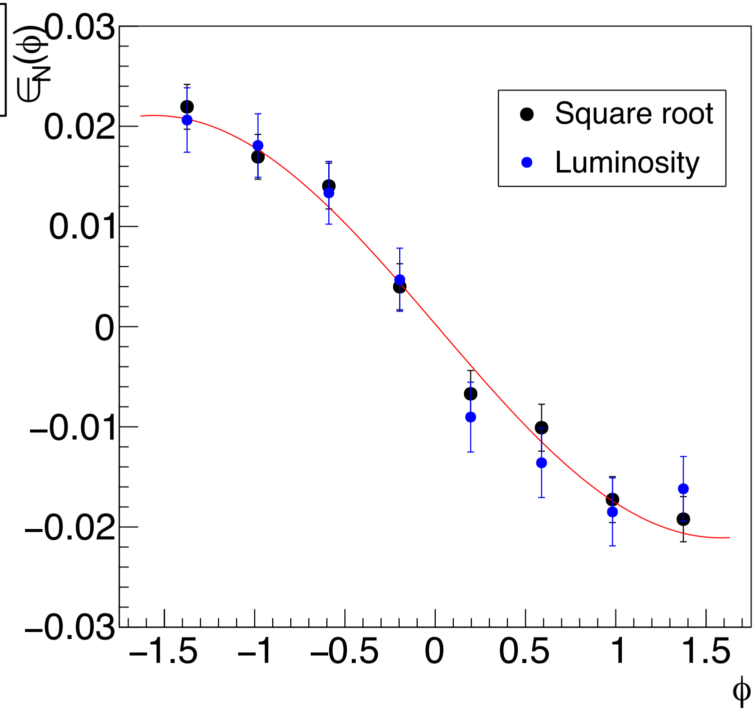
High EM trigger: Energy deposit of 4th layer at large or small tower is larger than 500 MeV.
(for high energy photon and Type-II π^0)

Type-I π^0 trigger: Energy deposits of three forward (up to 7th) successive layers at large and small tower are larger than 45 MeV.
(for Type-I π^0)

Beam center calculation (by neutron)



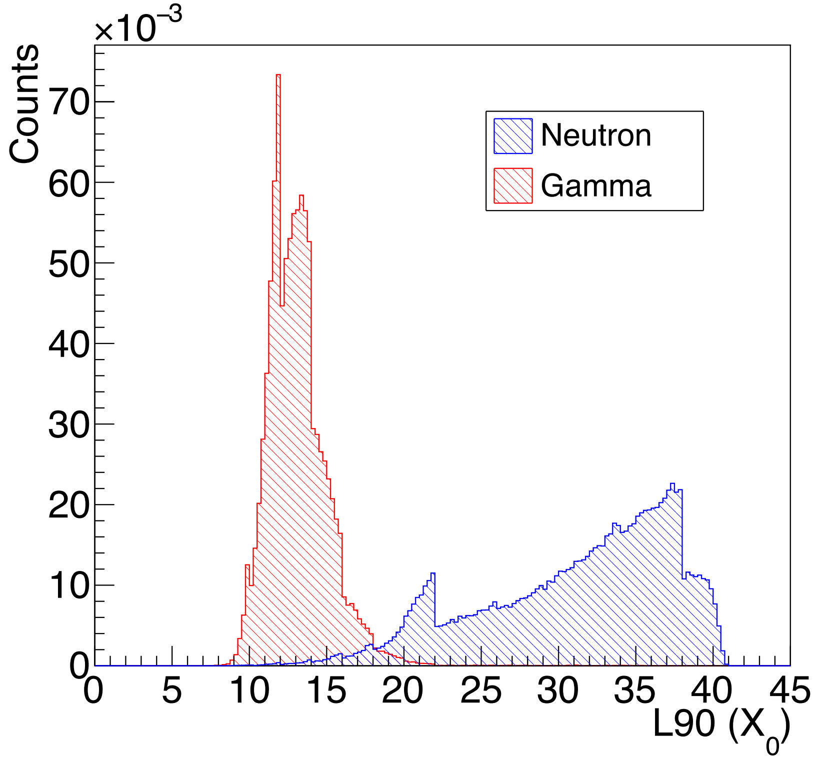
$$f = Ae^{-B\sqrt{(x-x_0)^2+(y-y_0)^2}}$$



$$\frac{N_L^{\uparrow} - RN_R^{\uparrow}}{N_L^{\uparrow} + RN_R^{\uparrow}} = \frac{\sqrt{N_L^{\uparrow}N_R^{\downarrow}} - \sqrt{N_R^{\uparrow}N_L^{\downarrow}}}{\sqrt{N_L^{\uparrow}N_R^{\downarrow}} + \sqrt{N_R^{\uparrow}N_L^{\downarrow}}}$$

- Neutrons were used for beam center calculation.
- Square root formula shows good agreement with luminosity one.

Neutron and gamma PID



- L90 represents the longitudinal depth where the energy deposit reaches 90 % of total energy deposit.
- Gamma events can be distinguished from neutron ones using that EM shower develops more rapidly than hadronic one.

A_N calculation

Luminosity ratio between spin up and down

Number of π^0 in specific x_F and p_T range

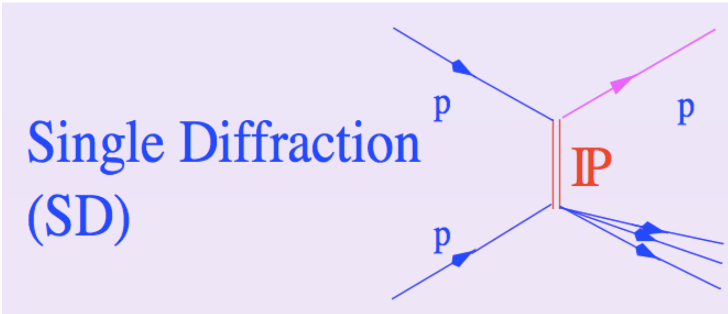
$$A_N = \frac{1}{P\epsilon}\frac{N^{\uparrow} - RN^{\downarrow}}{N^{\uparrow} + RN^{\downarrow}}$$

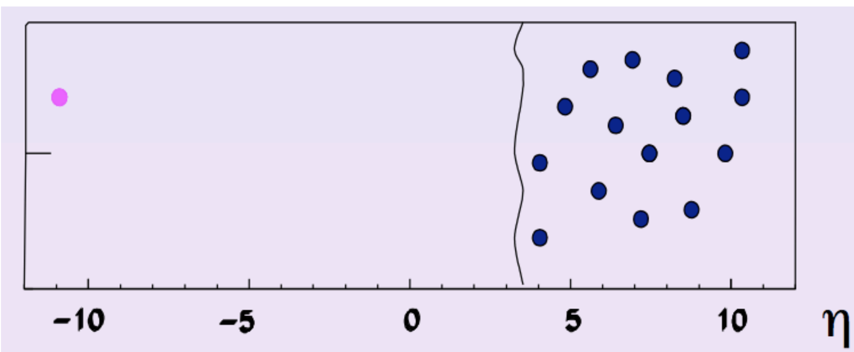
Beam polarization

Smearing by beam emittance, azimuthal angle distribution of π^0, and detector position resolution

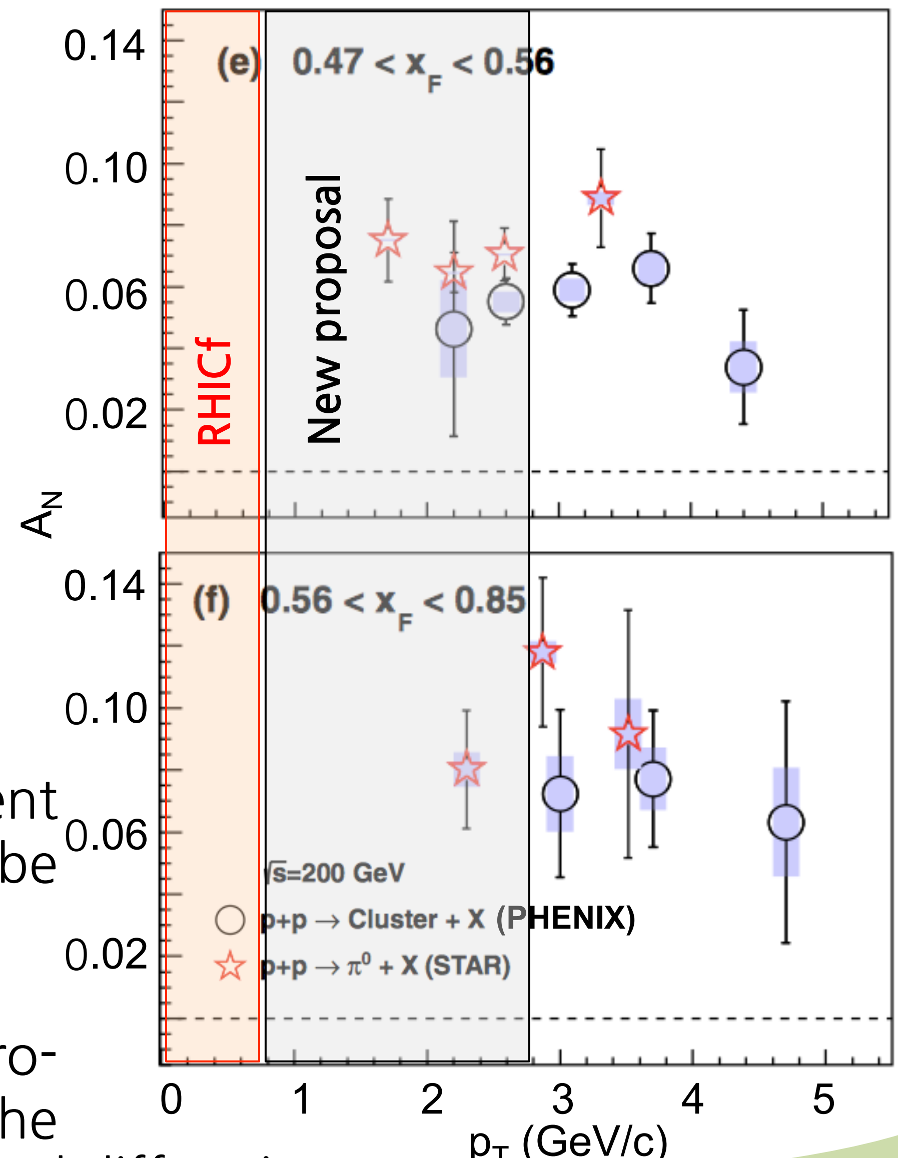
- P (~ 0.55 ± 0.05) can be calculated by polarization monitor.
- R (~ 0.970 ± 0.02) is estimated by luminosity ratio of charged particles near IP.
- ϵ (~ 0.95 ± 0.05) can be studied by comparing actual and diluted A_N in simulation.

What's the next?





Phys. Rev. D90 (2014) 012006.



- Using other STAR detectors, event type dependence for the A_N can be studied.
- A follow-up experiment will be proposed to practically compare the each contribution from partnoic and diffractive process.

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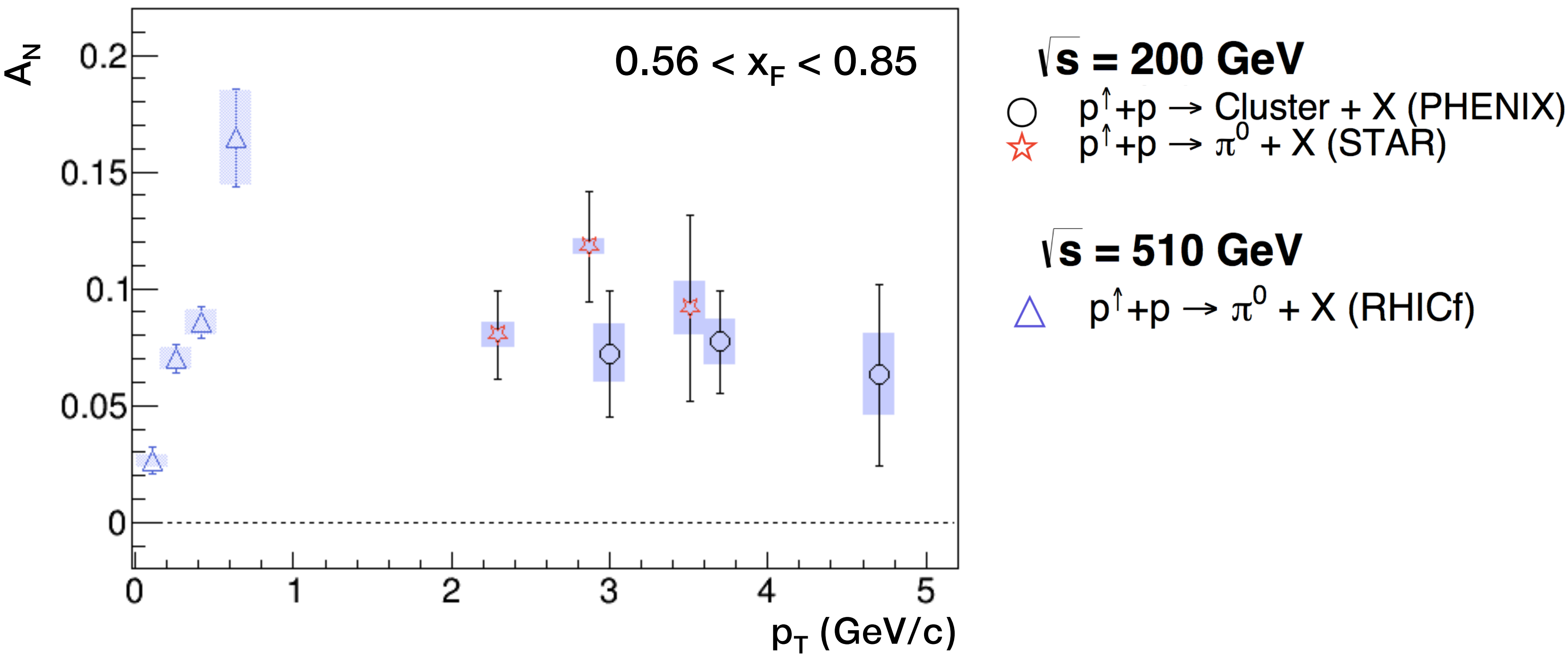

- How much both perturbative and non-perturbative process contribute to the $\pi^0 A_N$ should be exactly studied.
- Combined analysis with STAR will make the comparison of two processes possible.