First measurement of transverse single spin asymmetry (A_N) for very forward π^0 production in polarized p + p collisions at $\sqrt{s}$ = 510 GeV

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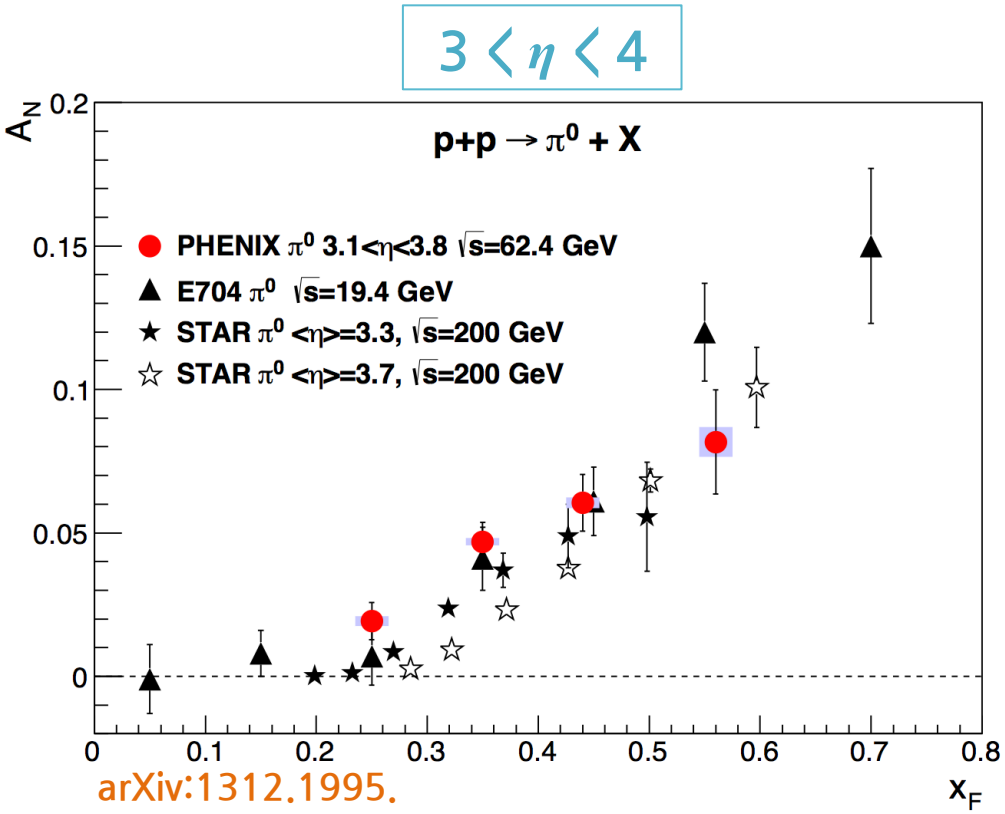
on behalf of the RHICf collaboration

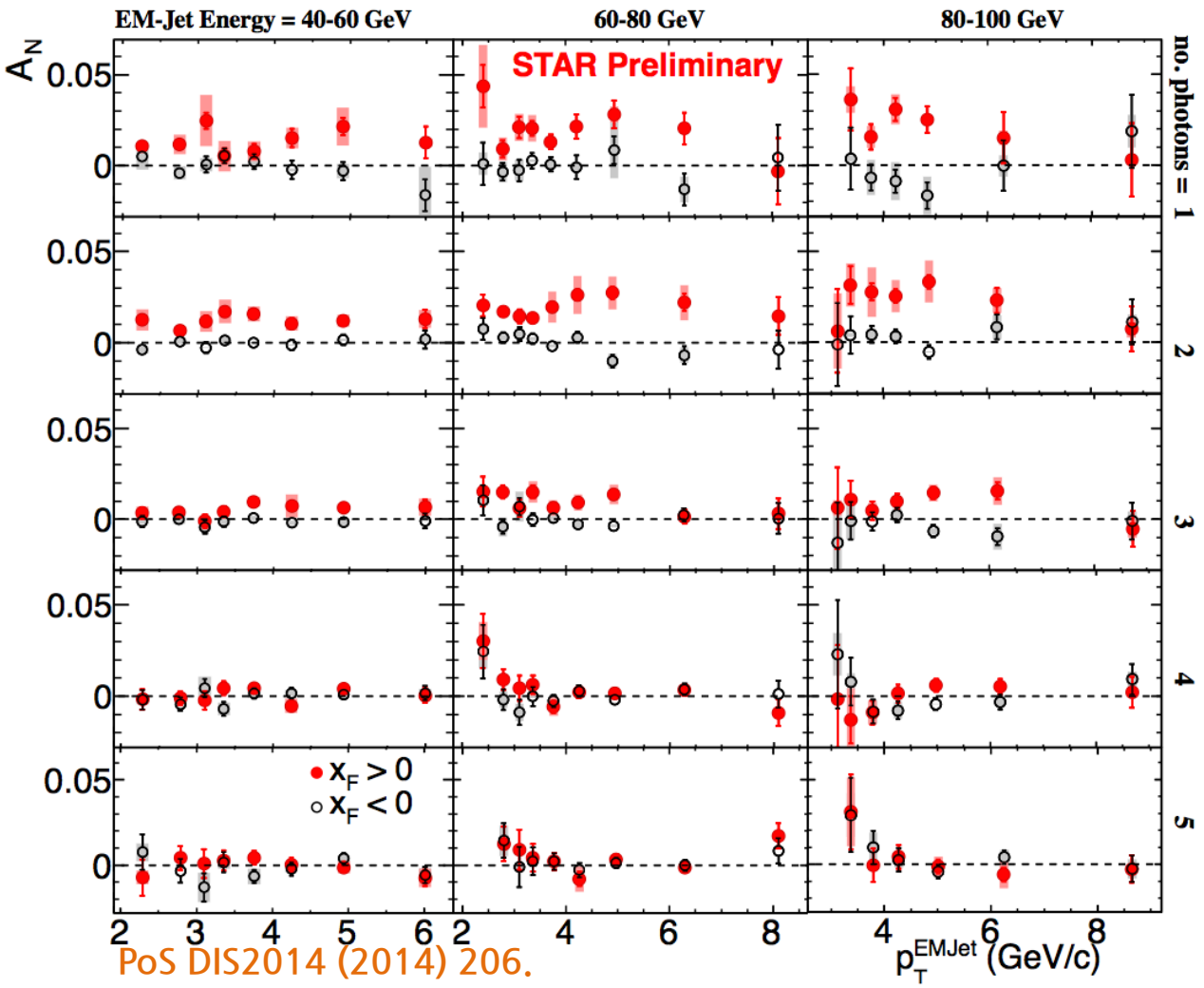
A_N in forward π^0 production



- Observed non-zero A_N of π^0 ever has been interpreted in only hard process regime theoretically.

- Non-zero A_N comes from an asymmetry of the partonic-level fragmentation process or spin-dependent quark-gluon correlations in the proton.

New question to the A_N of forward π^0



PoS DIS2014 (2014) 206.

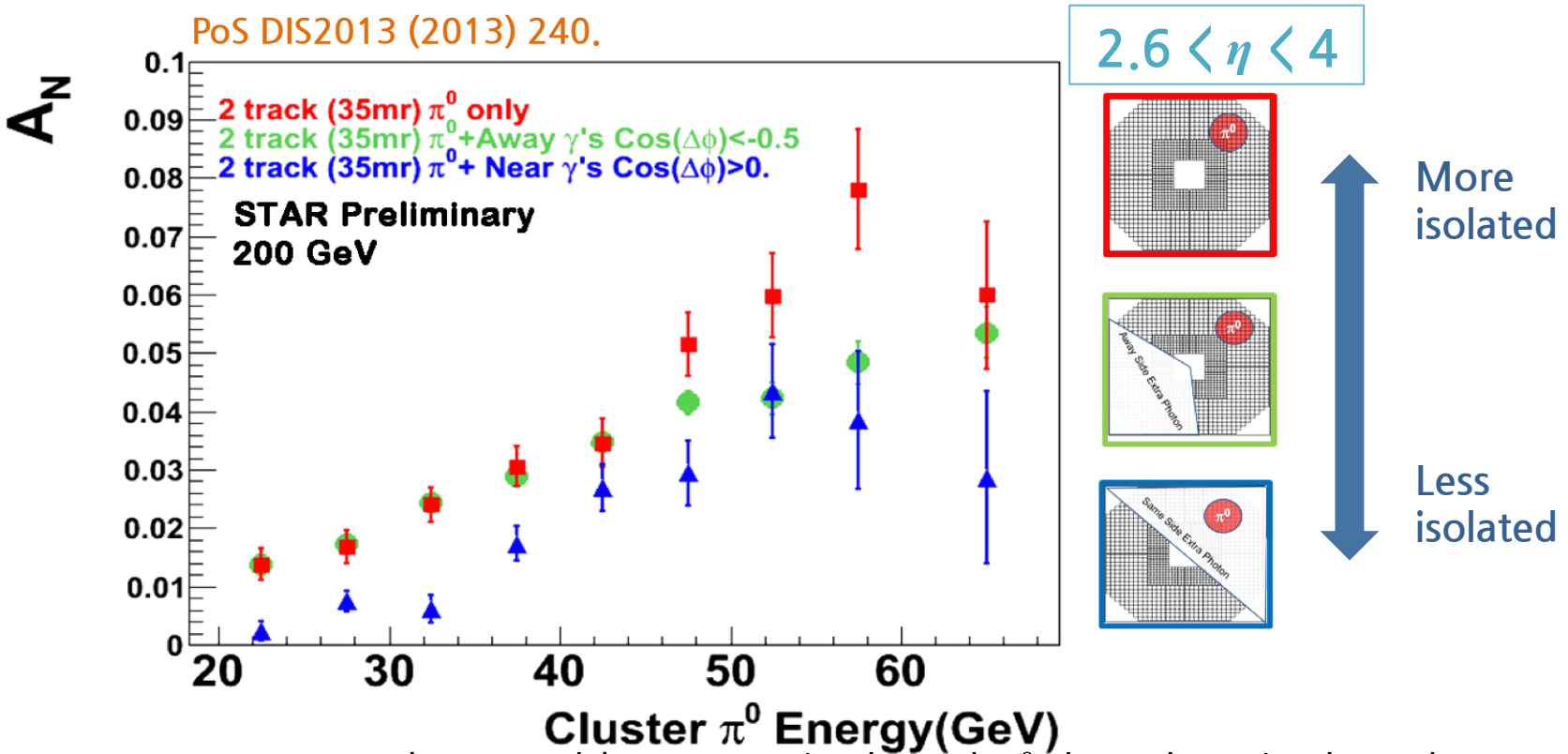
$2.6 < \eta < 4$

Large contribution from π^0

Complexity increases

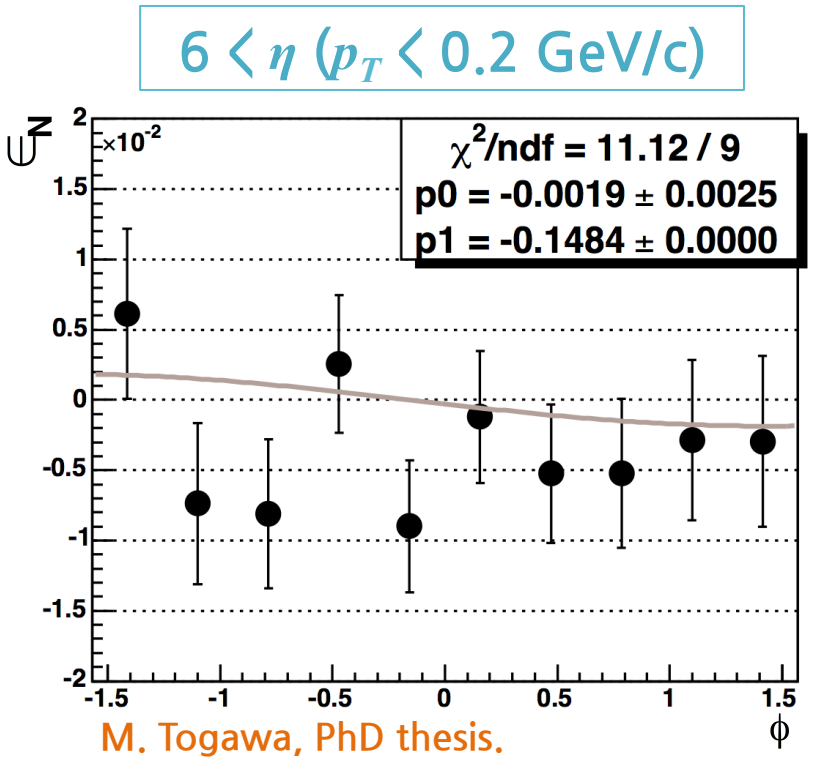
- Smaller A_N was observed with increasing multiplicity of photons (closer to hard scattering event topology).

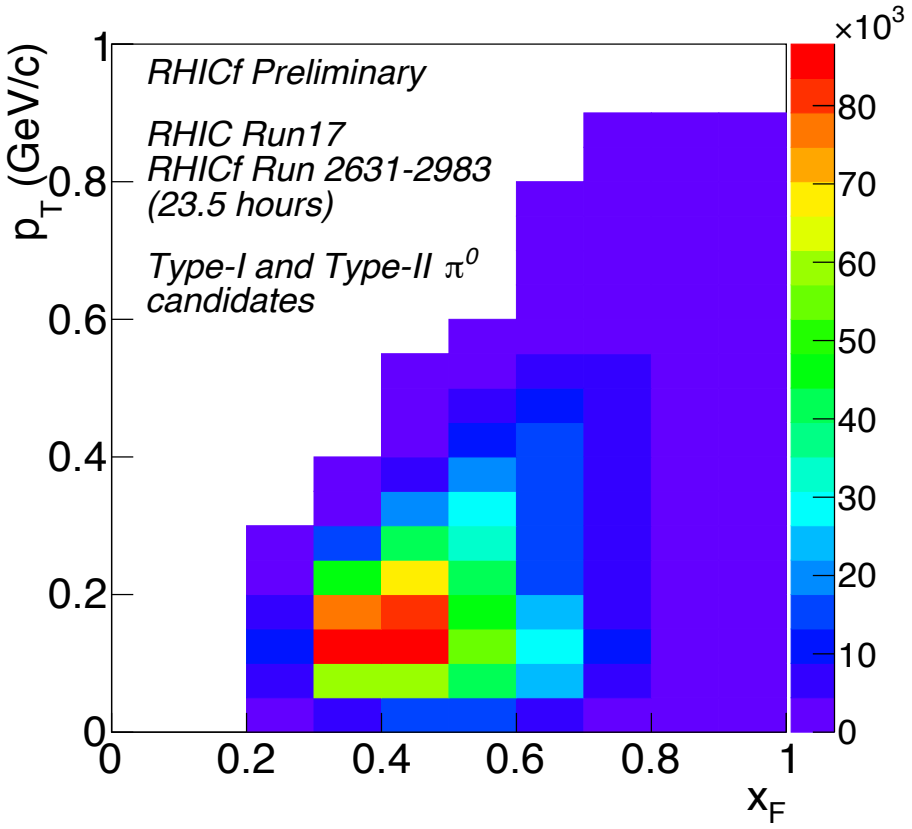
New question to the A_N of forward π^0



- Larger A_N was observed by more isolated π^0 than less isolated one.
- Smaller A_N in more hard scattering-like event and larger A_N in more diffractive-like event?
- Diffractive process may have a finite contribution to the non-zero A_N of π^0 as well as partonic-level one.

A_N in very forward π^0 production

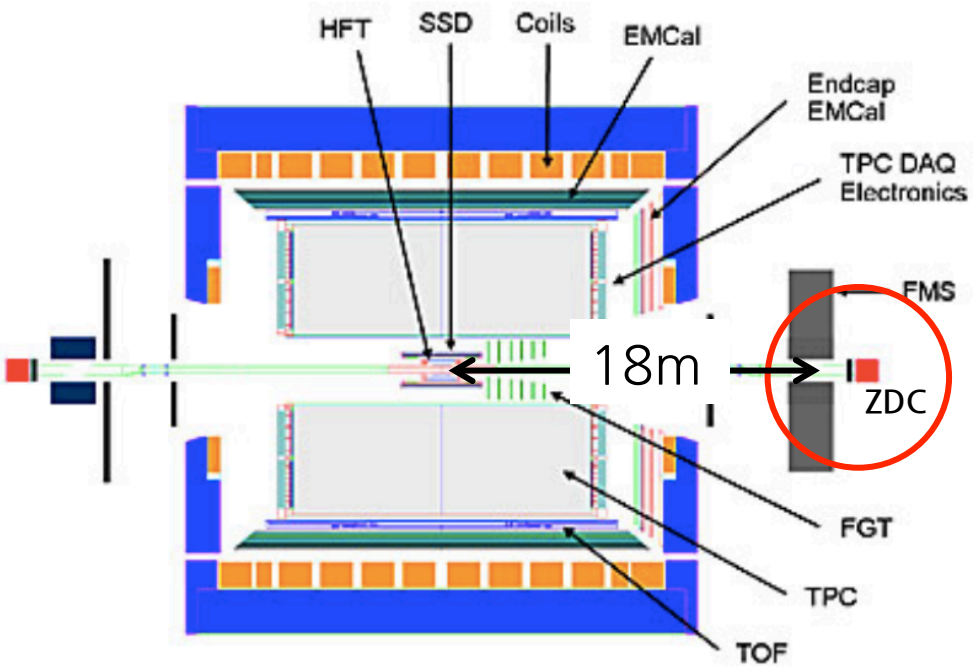




- Once A_N of very forward π^0 was measured by RHIC IP12 experiment. It was consistent with zero but in very narrow kinematic range.

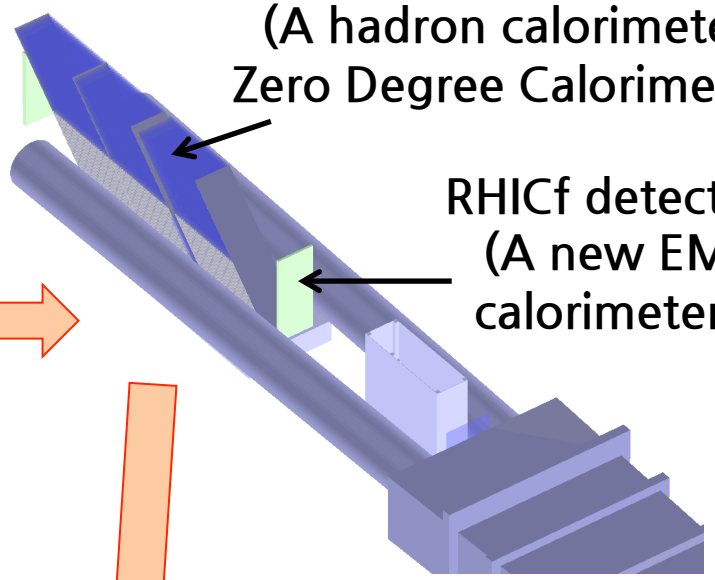
- RHICf experiment will unveil the role of the diffractive process to the A_N of π^0 by measuring the very forward π^0 ($\eta > 6$) in wide kinematic range ($0.2 < x_F < 1.0$ and $0.0 < p_T < 1.0$ GeV/c).

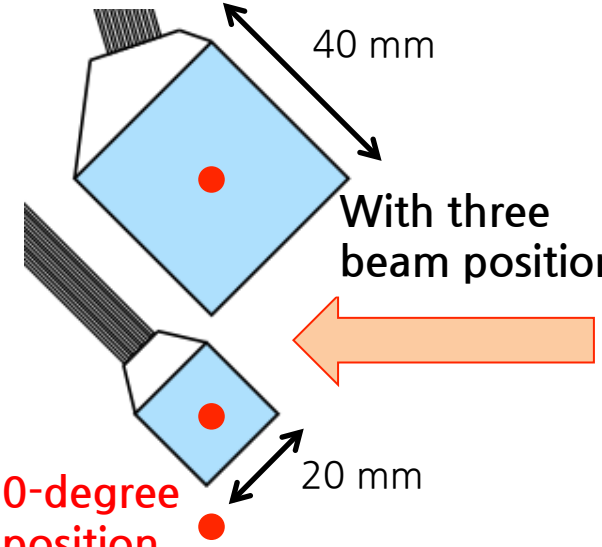
RHIC forward (RHICf) experiment



ZDC
(A hadron calorimeter,
Zero Degree Calorimeter)

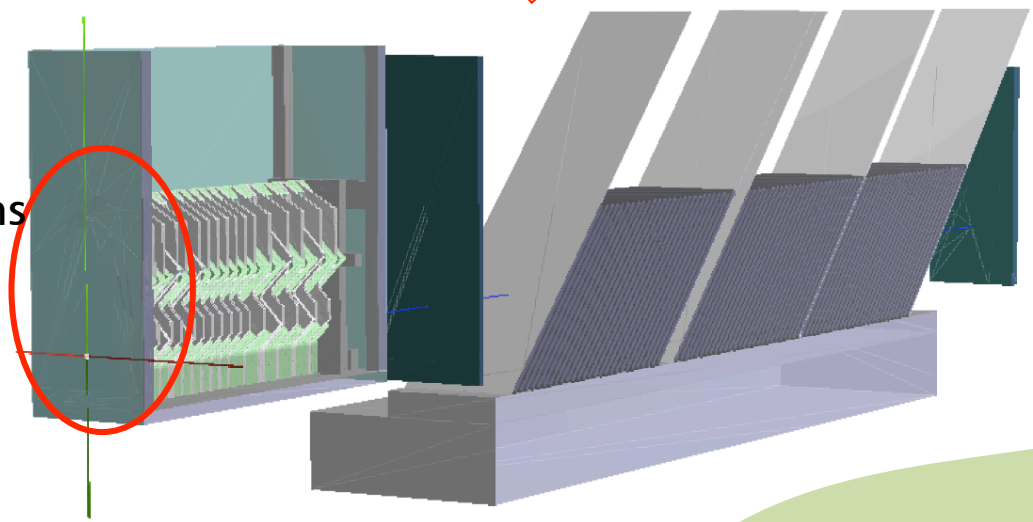
RHICf detector
(A new EM calorimeter)



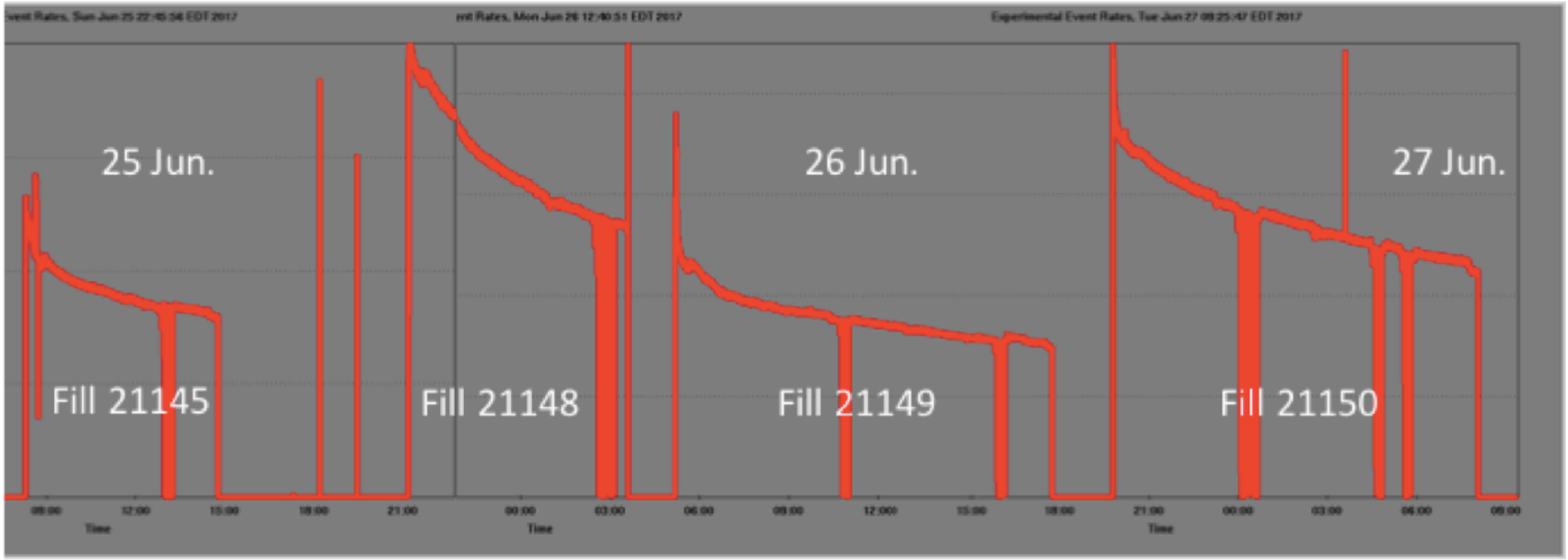


RHICf detector

ZDC

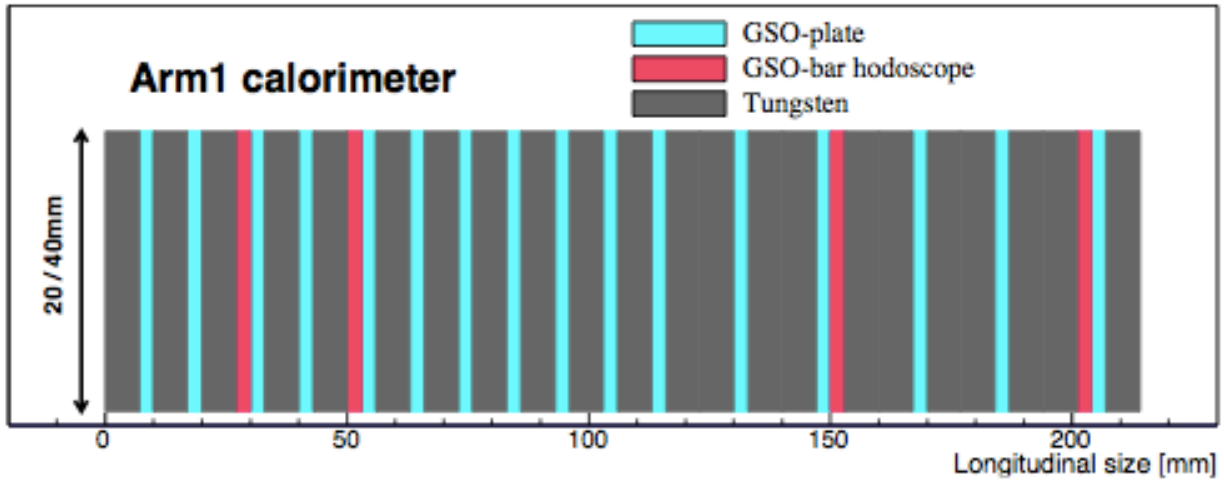


Operation summary



- 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.

RHICf detector & π^0



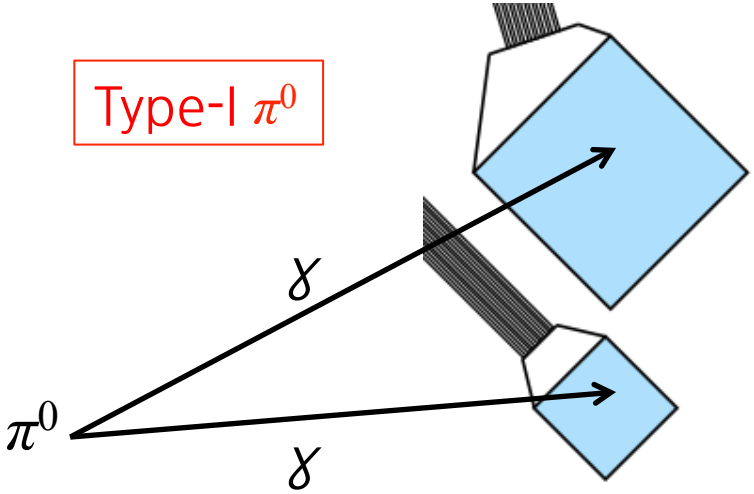
Small tower: 20/20 mm
Large tower: 40/40 mm

Tungsten absorber
(44 X_0, 1.6 λ_{int})

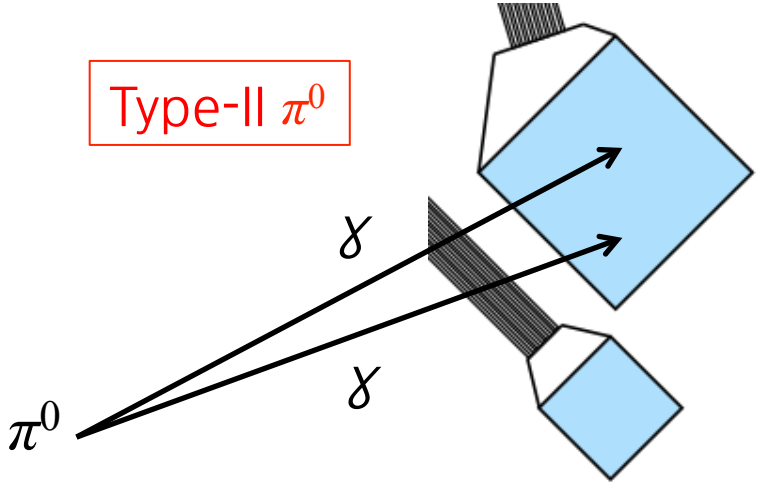
16 GSO plates for energy measurement

4 GSO bar layers for position measurement

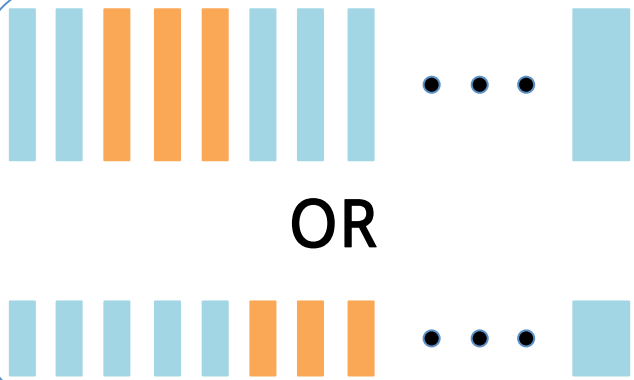
Type-I π^0



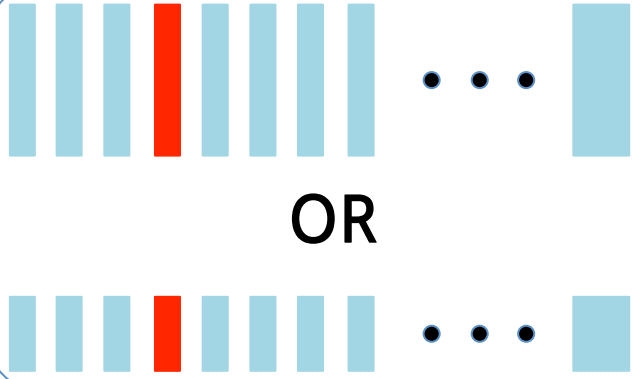
Type-II π^0



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)

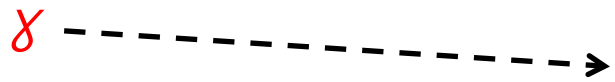


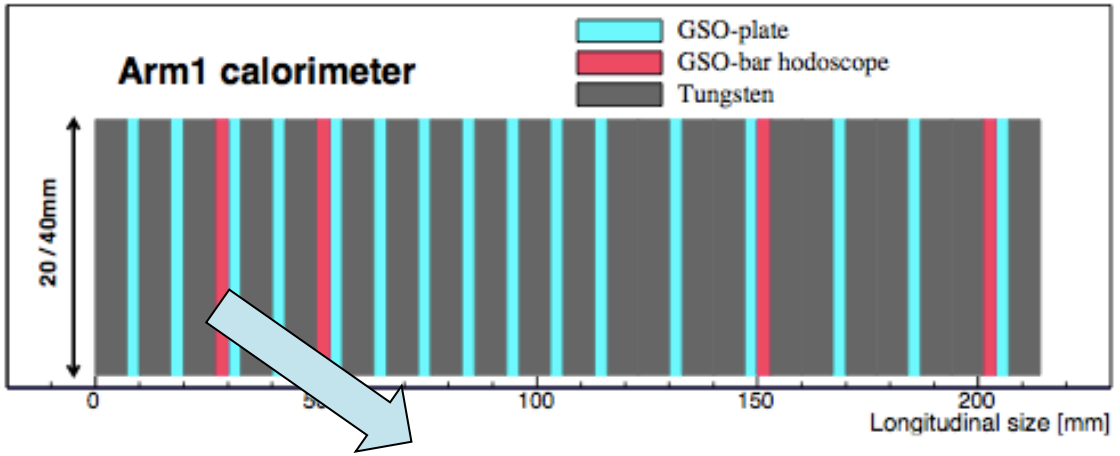
High EM trigger: Energy deposit of 4th layer at large or small tower is larger than 500 MeV.
(for high energy photon and Type-II π^0)

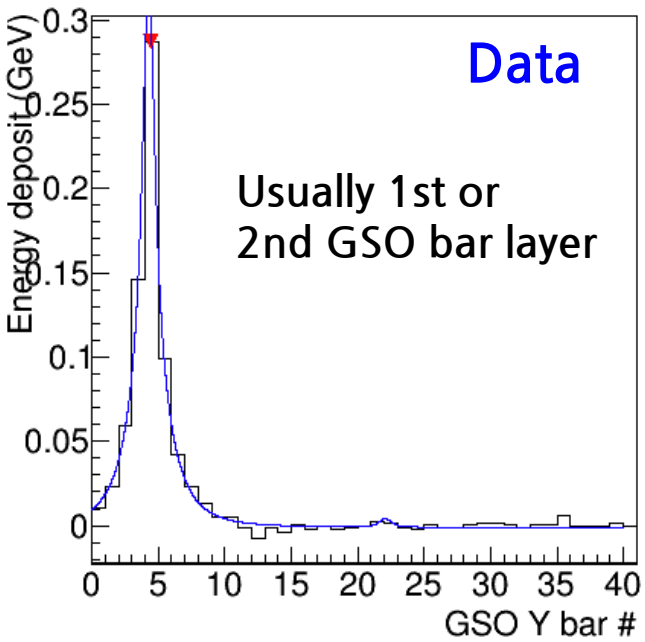
π^0 enhanced trigger: Energy deposits of three forward (up to 7th) successive layers at large and small tower are larger than 45 MeV.
(for Type-I π^0)

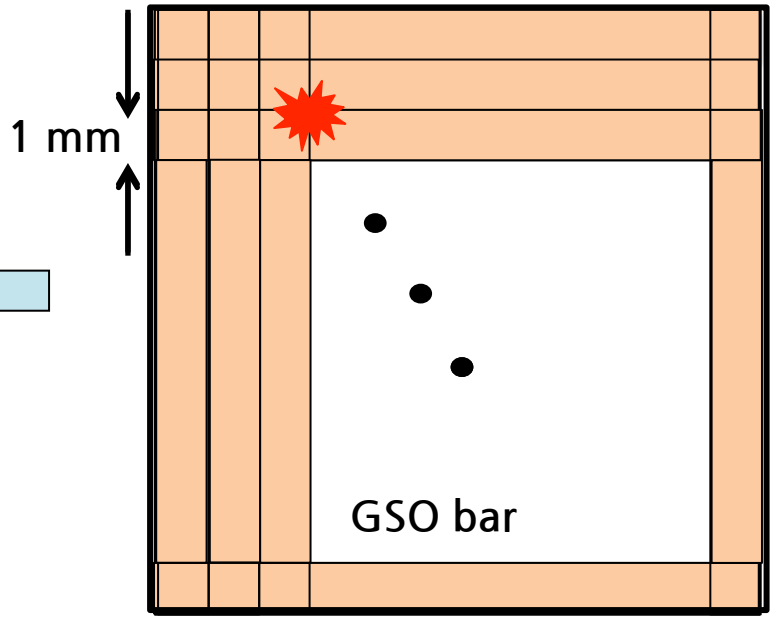
How did we reconstruct the π^0?

- If a photon hit a tower,





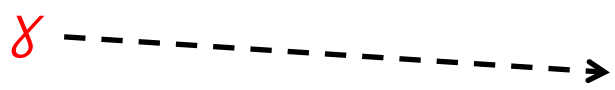


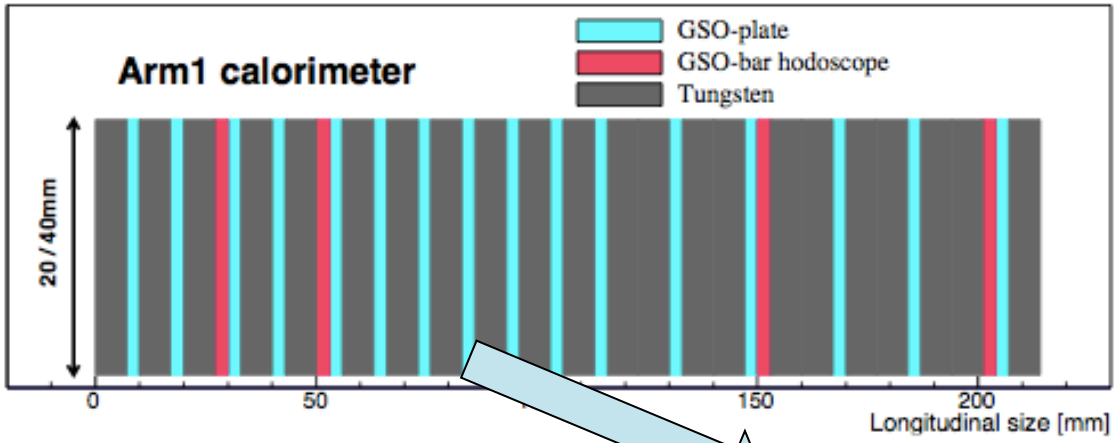


- Positions of decayed photons are measured by 1 mm dimension GSO bars.

How did we reconstruct the π^0?

- If a photon hit a tower,





dE(x, y)

Cor.1

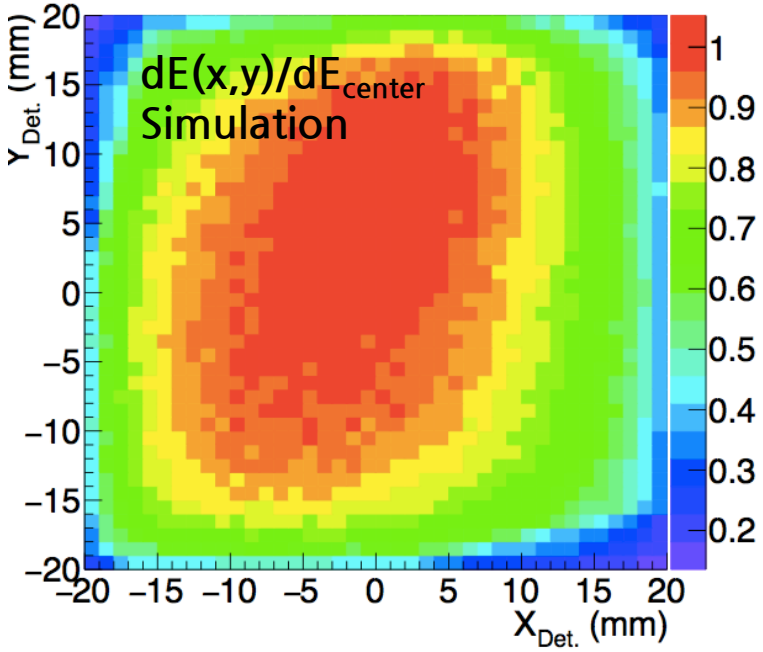
dE_{center}

SumdE

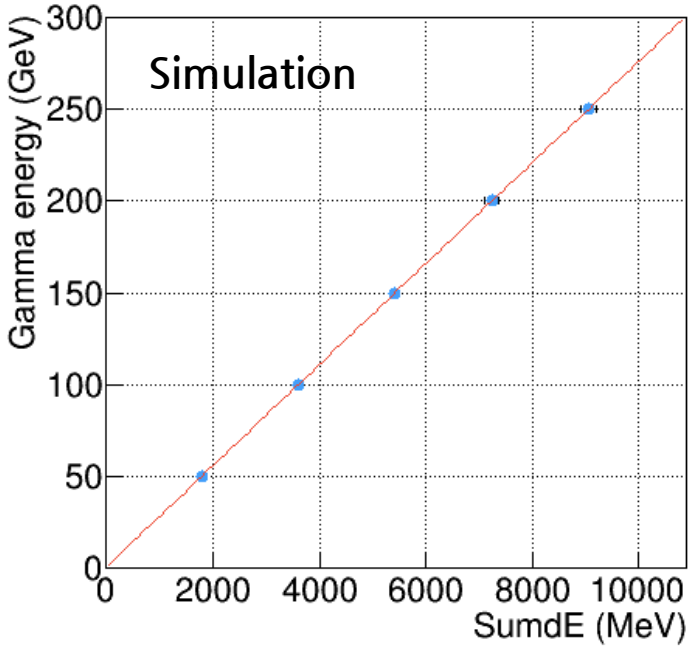
Cor.2

E_{gamma}

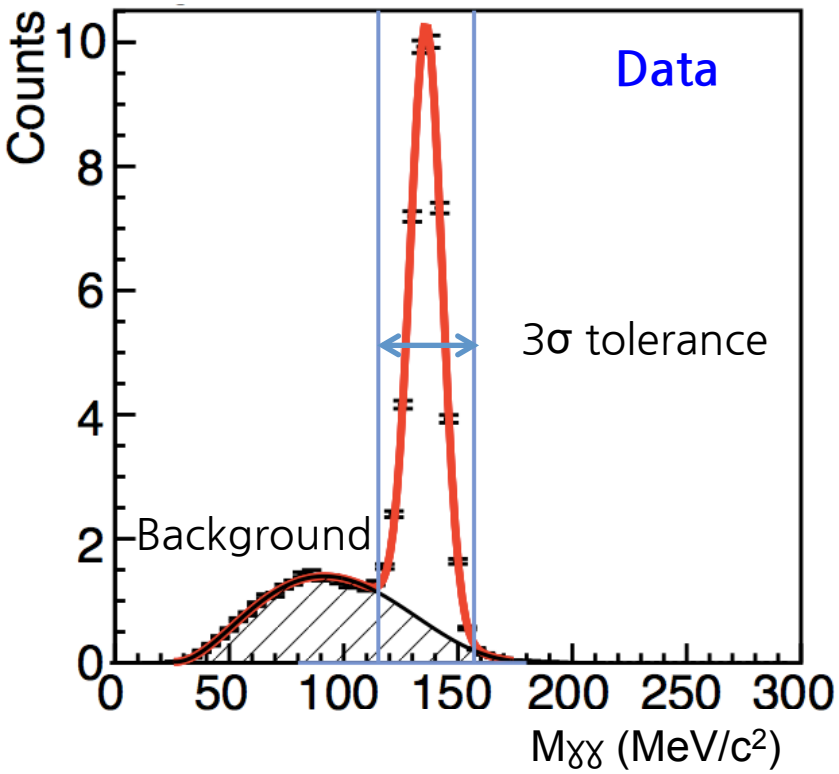
Cor.1



Cor.2

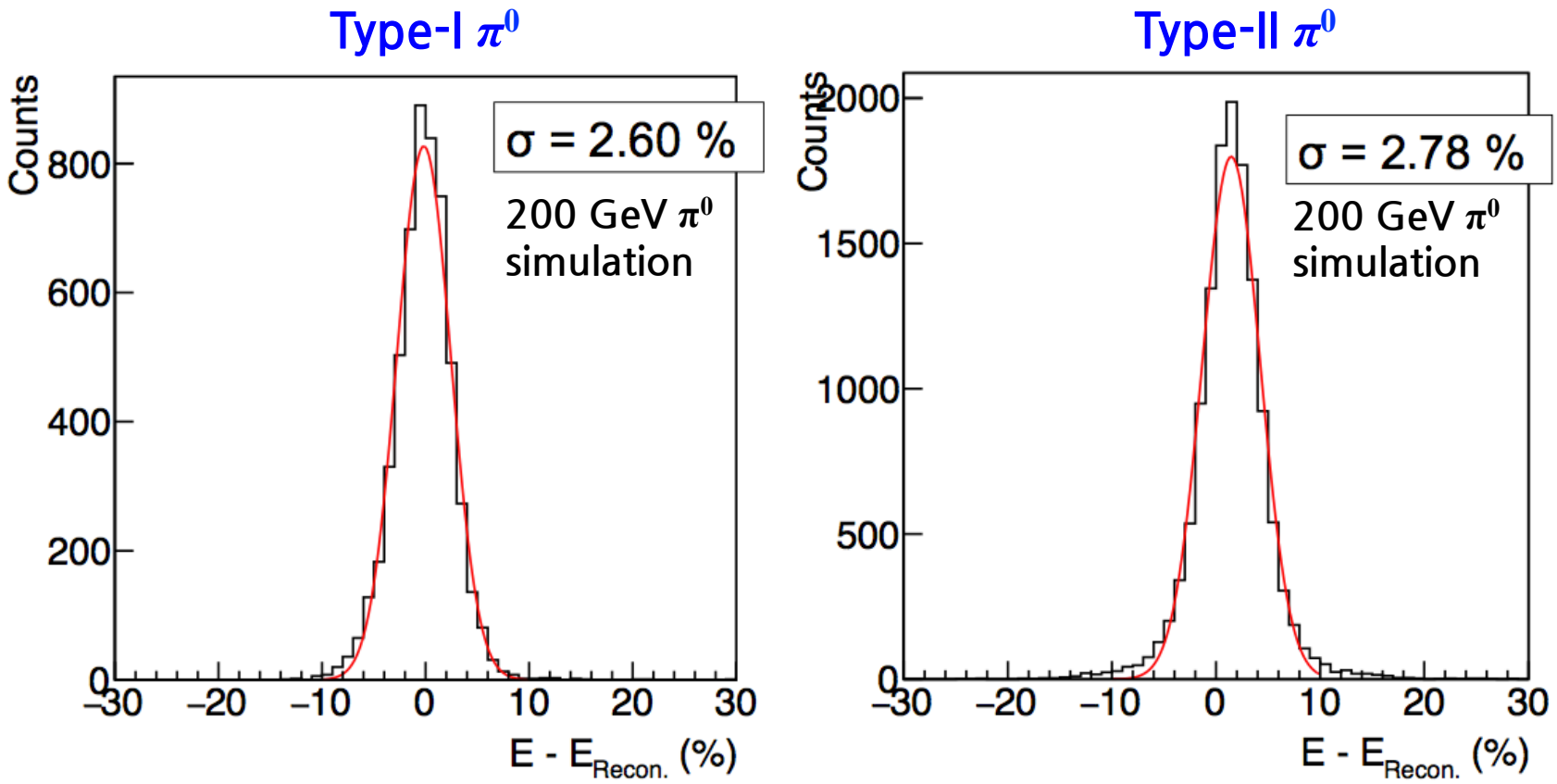


Invariant mass of two photons



- Clear π^0 peak is shown around 135 MeV/c^2 with ~10 MeV/c^2 width.
- Invariant mass was fitted by polynomial for background and Gaussian for π^0.
- Background part usually comes from coincidence of the other particles, not wrong reconstruction.

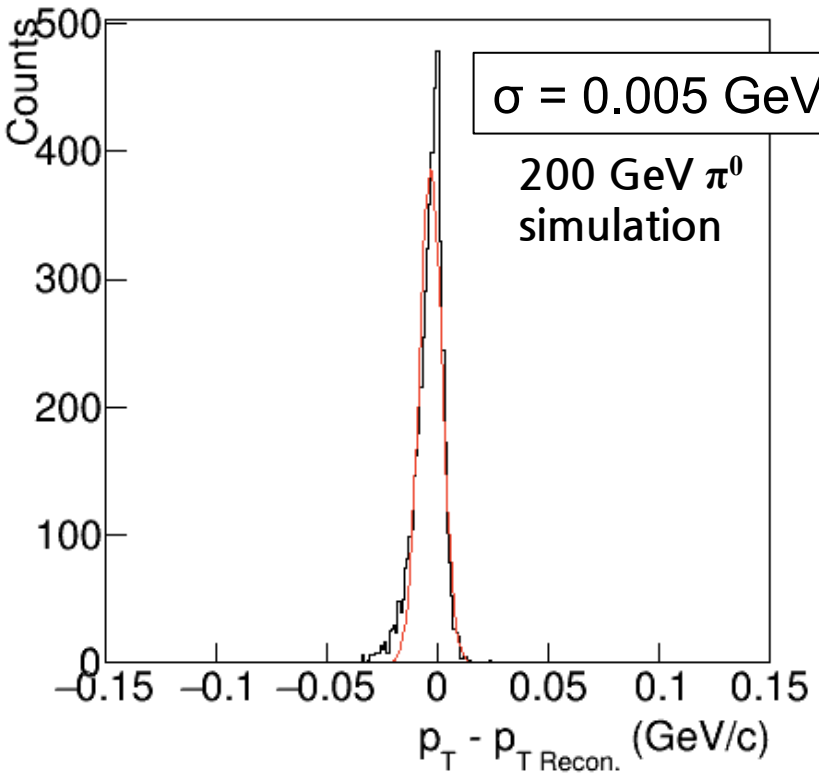
Energy resolution of π^0 reconstruction



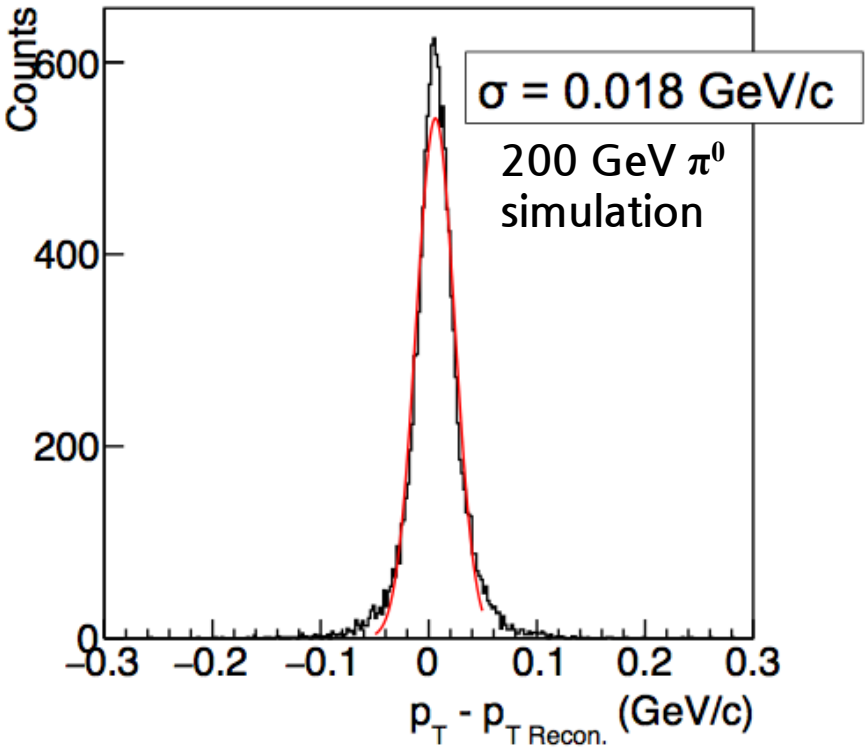
- Around 2.7% energy resolution is expected to both Type-I and Type-II.
- This similar energy resolution is because energy deposit at detector is quite linear to the sum of actual photon energy regardless of the number of photons.

p_T resolution of π^0 reconstruction

Type-I π^0



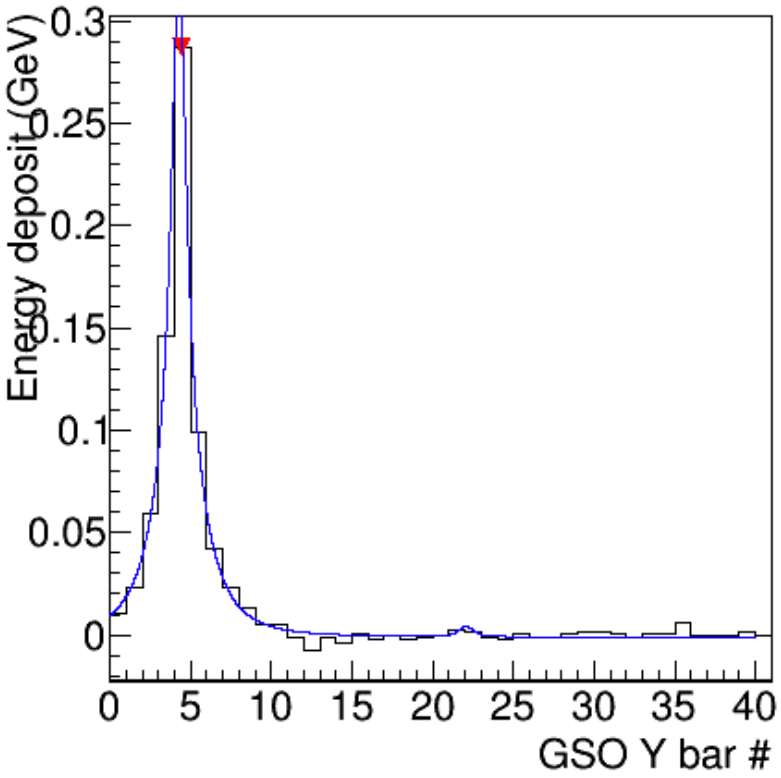
Type-II π^0



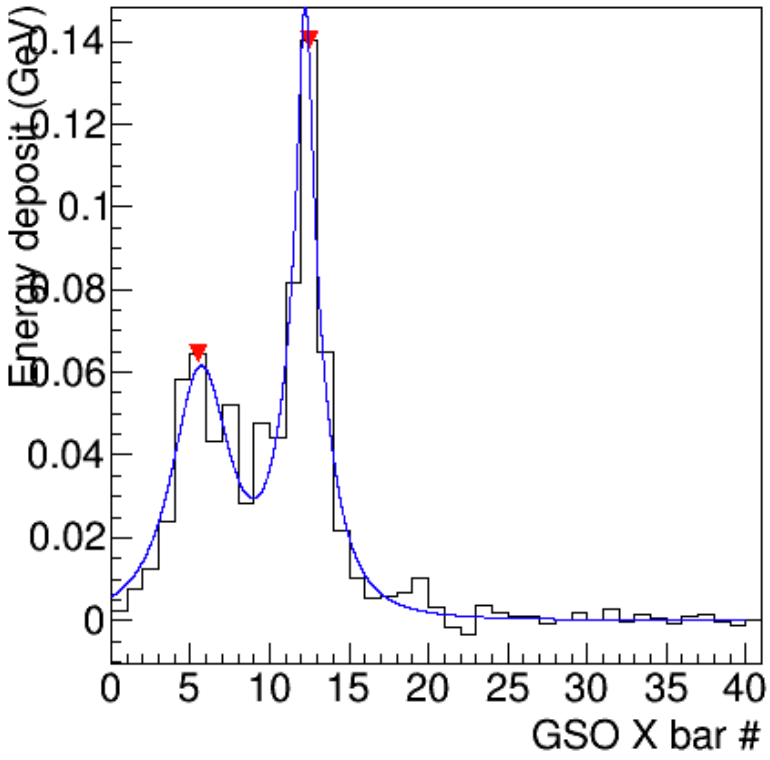
- However, p_T resolution of Type-I is much better than Type-II.

p_T resolution of π^0 reconstruction

Type-I π^0

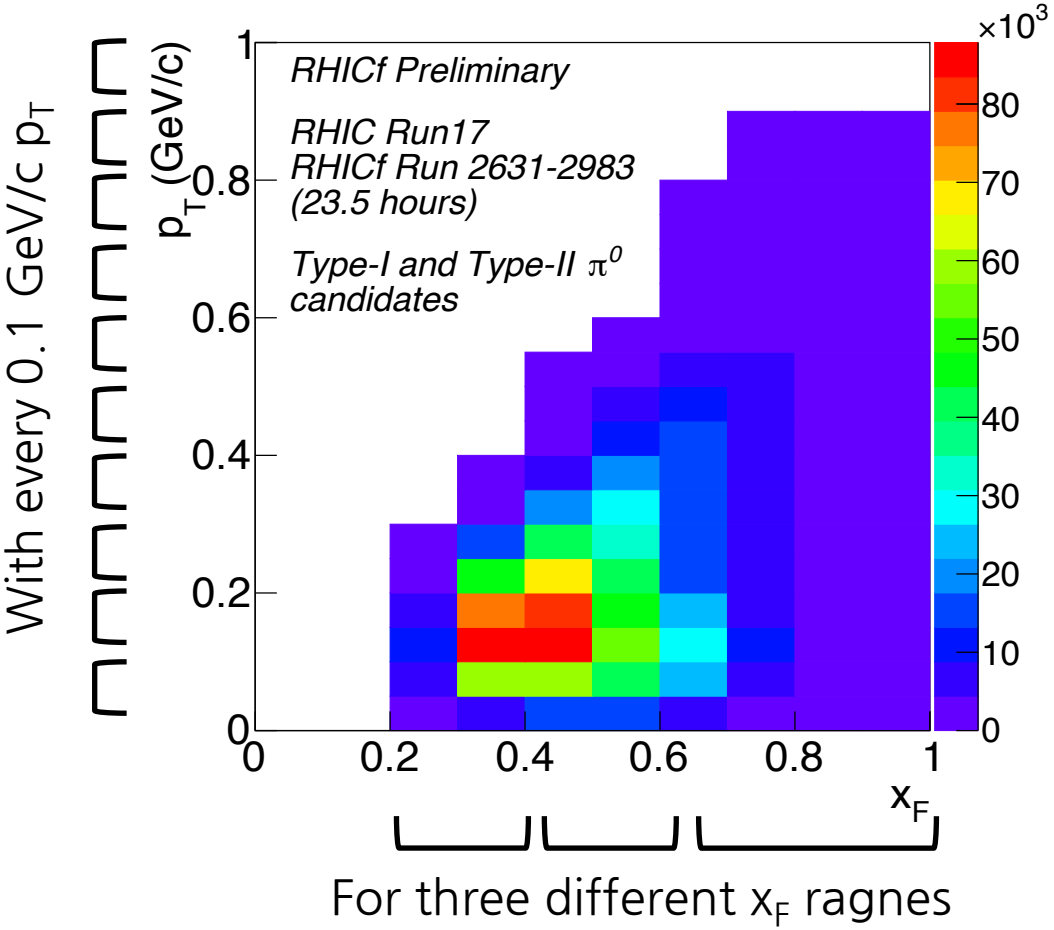


Type-II π^0



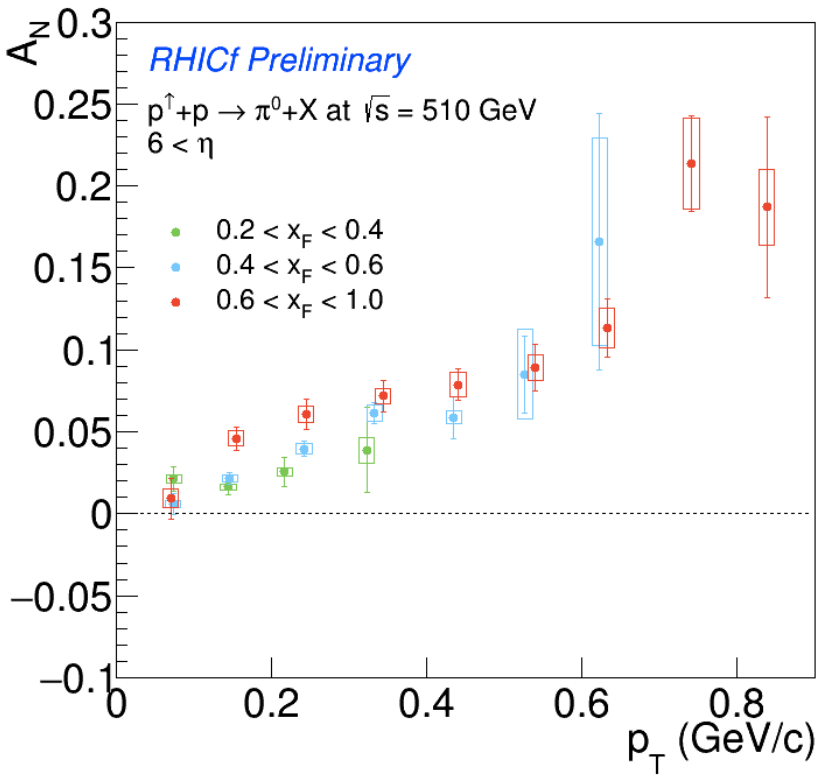
- However, p_T resolution of Type-I is much better than Type-II.
- This different p_T resolution is because peak position is more fluctuated when two photons hit the detector than one.

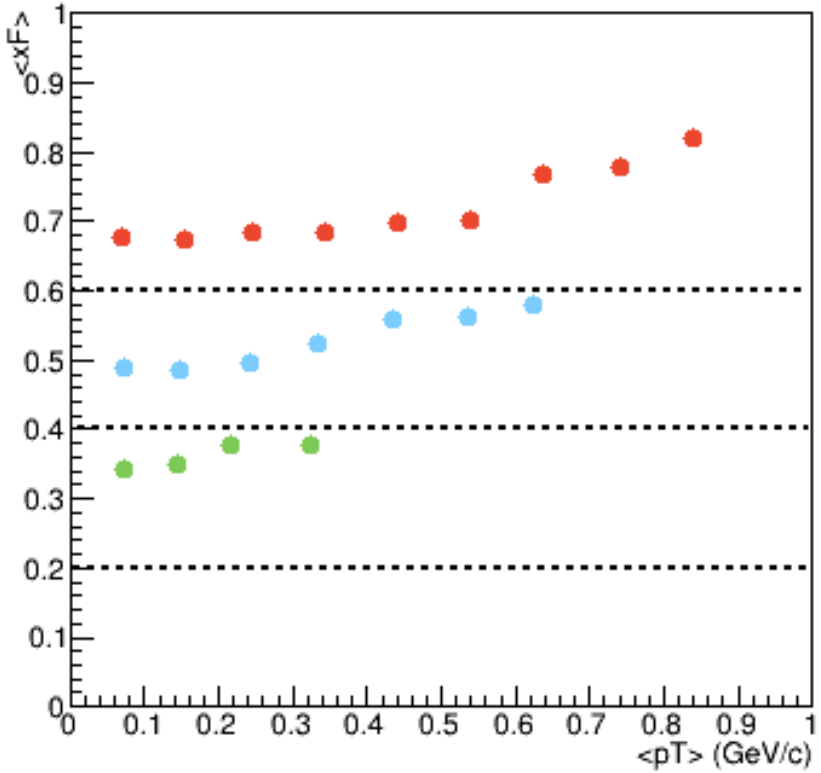
π^0 kinematics



- First, we studied A_N for three different x_F ranges as a function of p_T.
- x_F and p_T resolution of RHICf detector is much better than their binning scale.

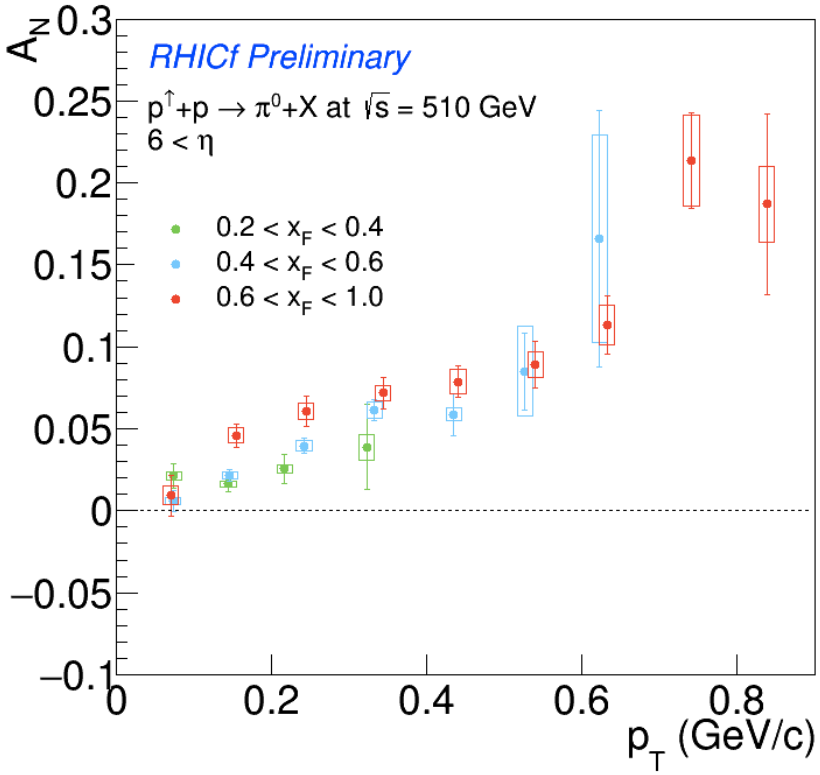
Preliminary result of very forward π^0 A_N



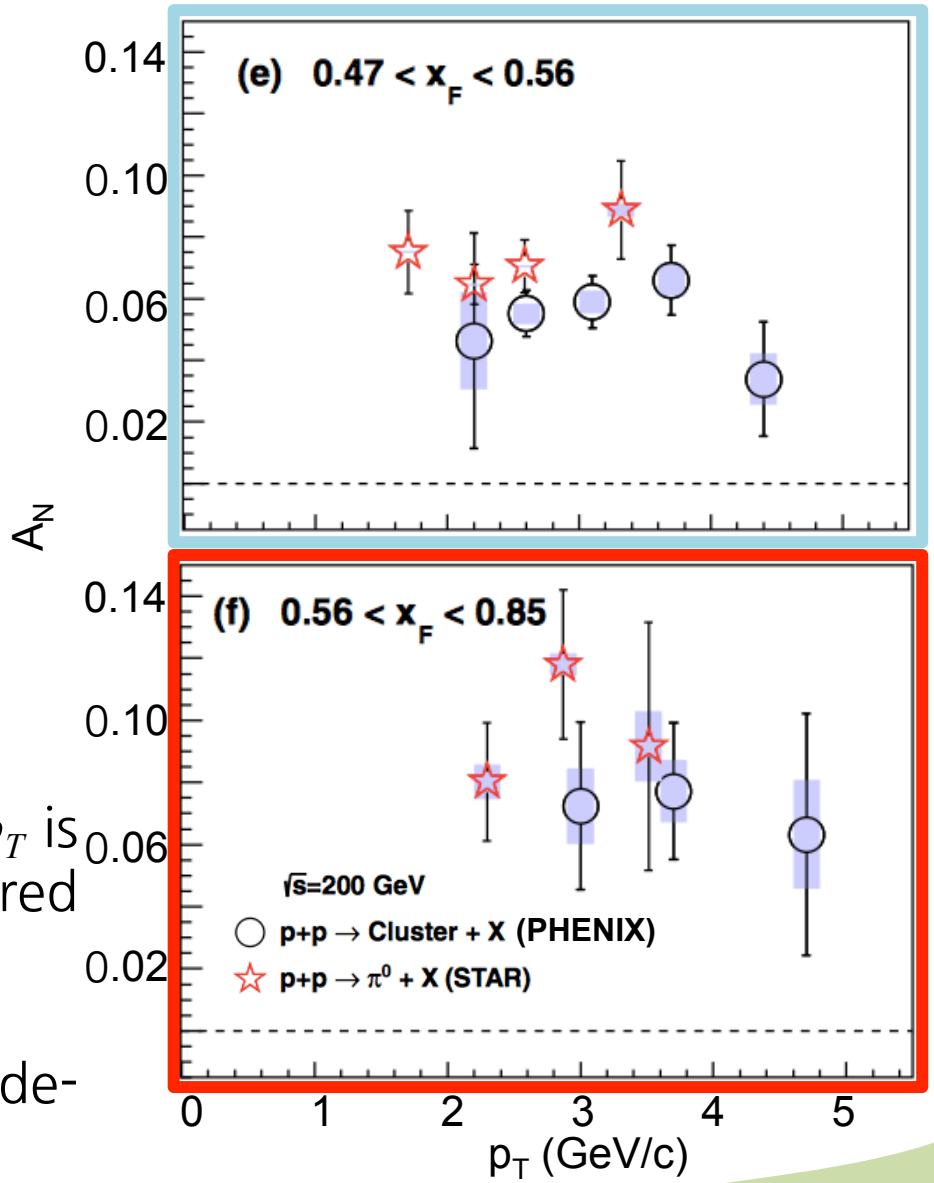


- Systematic uncertainties by polarization, π^0 azimuthal angle distribution, background A_N subtraction, and beam center was included.
- **Non-zero A_N was observed even in very forward π^0 production. Diffractive process may contribute to the A_N of π^0.**
- A_N increases by both p_T and x_F, but more sensitive to p_T.

Preliminary result of very forward π^0 A_N



Phys. Rev. D90 (2014) 012006.



- Calculated A_N at highest RHICf p_T is higher than previously measured ones by PHENIX & STAR.
- Further study with other STAR detectors will be performed soon.

Summary

- RHICf experiment was successfully operated in June 2017.
- A_N of very forward π^0 was measured over the kinematic range of $0.2 < x_F < 1.0$ and $0.0 < p_T < 1.0$ GeV/c.
- Because non-zero A_N was observed even in very forward π^0 production, diffractive process may contribute to the finite A_N of π^0.
- More detailed study with other STAR detectors will precisely unveil the role of the diffractive process to the A_N of (very) forward π^0 production.