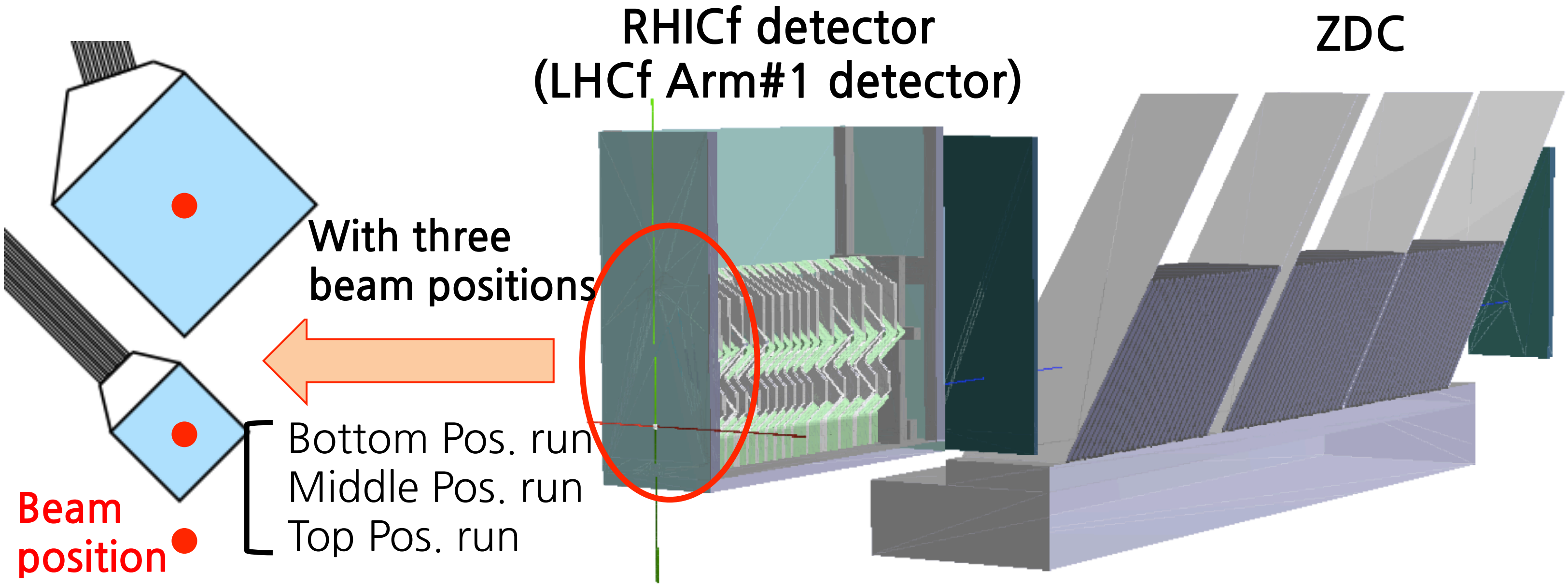
Analysis status:
A_N of very forward π^0 production

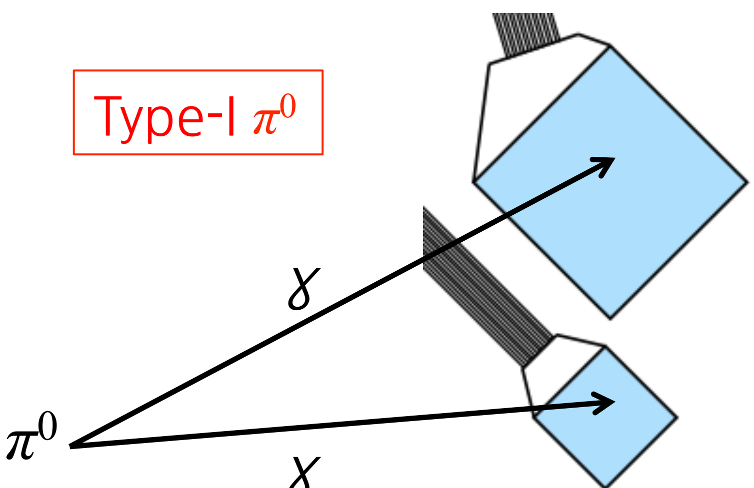
LHCf-RHICf joint meeting

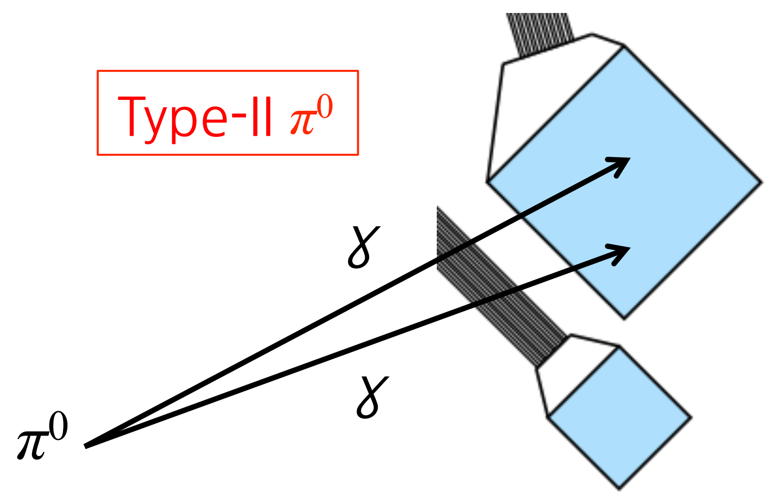
27 Nov 2018

Minho Kim

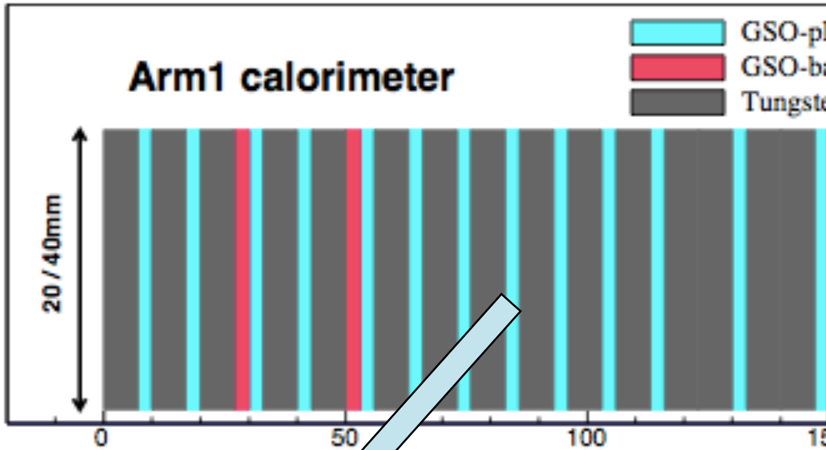
RHICf experiment & π^0

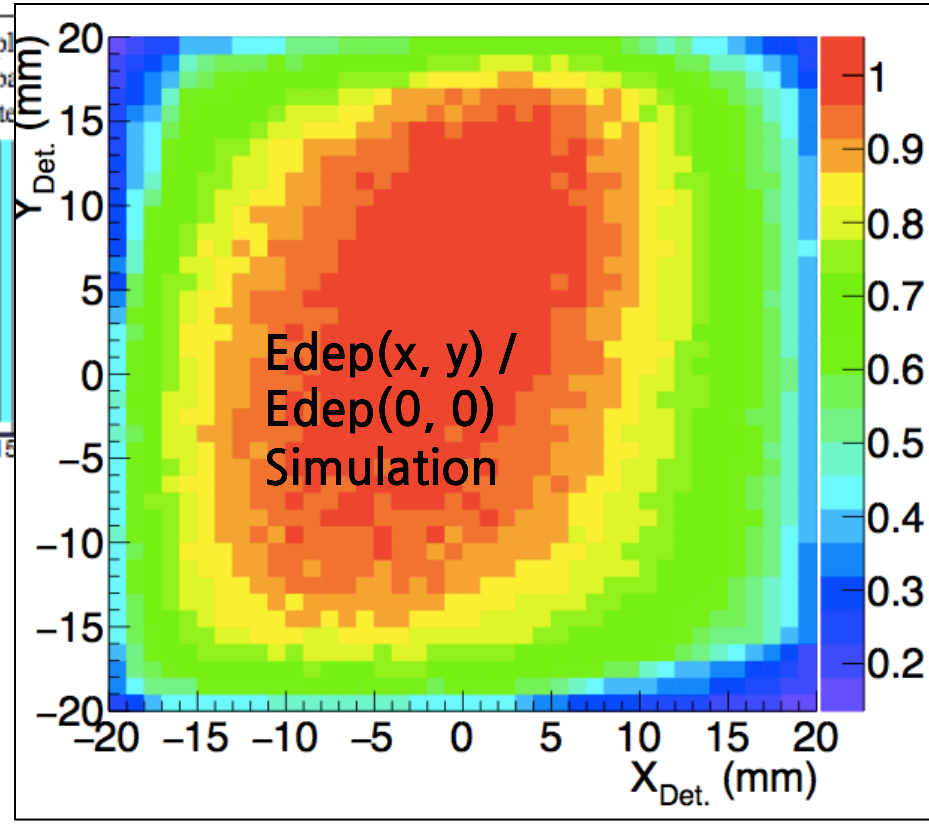






One photon energy reconstruction





dE(x, y)

↓ Shower leakage, Light collection Eff.

dE(0, 0)

↓

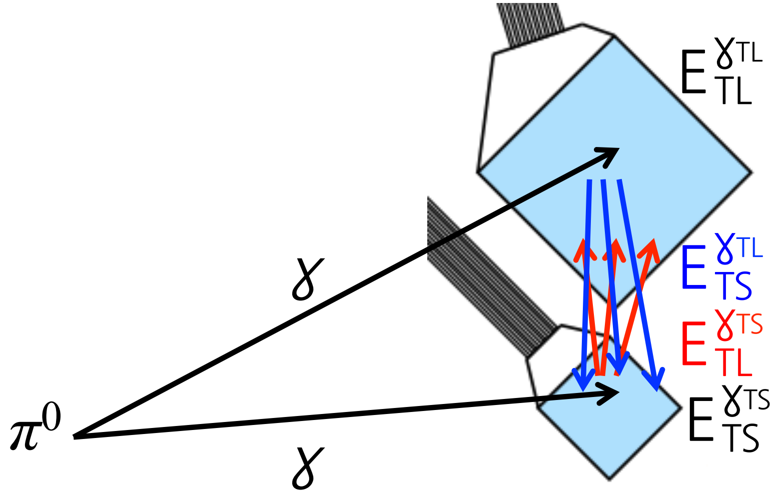
SumdE

↓

E_{photon}

- Up to 12th plate was used for leakage-out correction.
- Leakage-out map of neutron ver. is also applied to neutron case.

Type-I π^0 Energy reconstruction



$$E_{\mathrm{TL}} = E_{\mathrm{TL}}^{\gamma \mathrm{TL}} + E_{\mathrm{TL}}^{\gamma \mathrm{TS}}$$

$$E_{\mathrm{TS}} = E_{\mathrm{TS}}^{\gamma \mathrm{TS}} + E_{\mathrm{TS}}^{\gamma \mathrm{TL}}$$

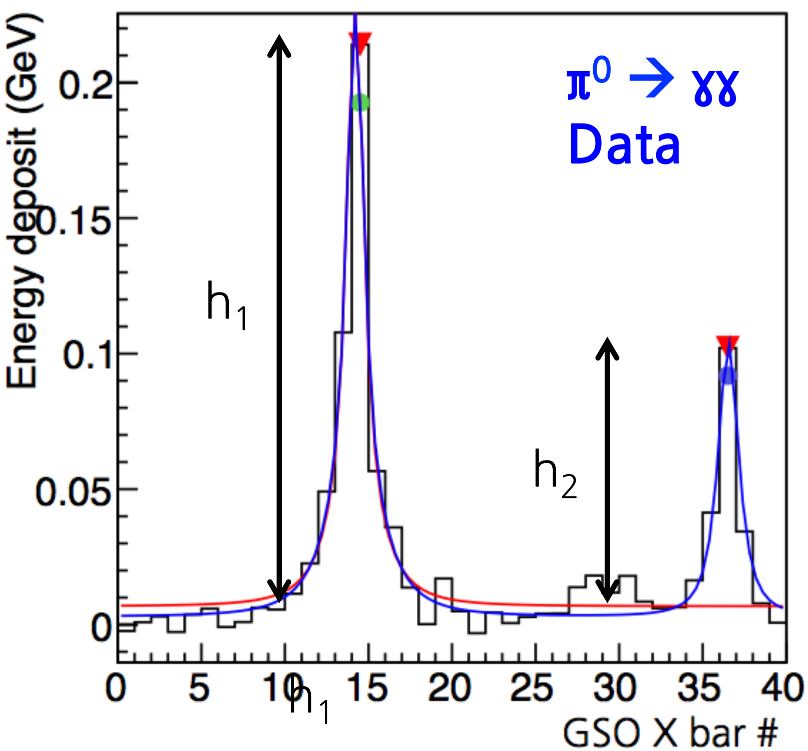
Leakage-in correction

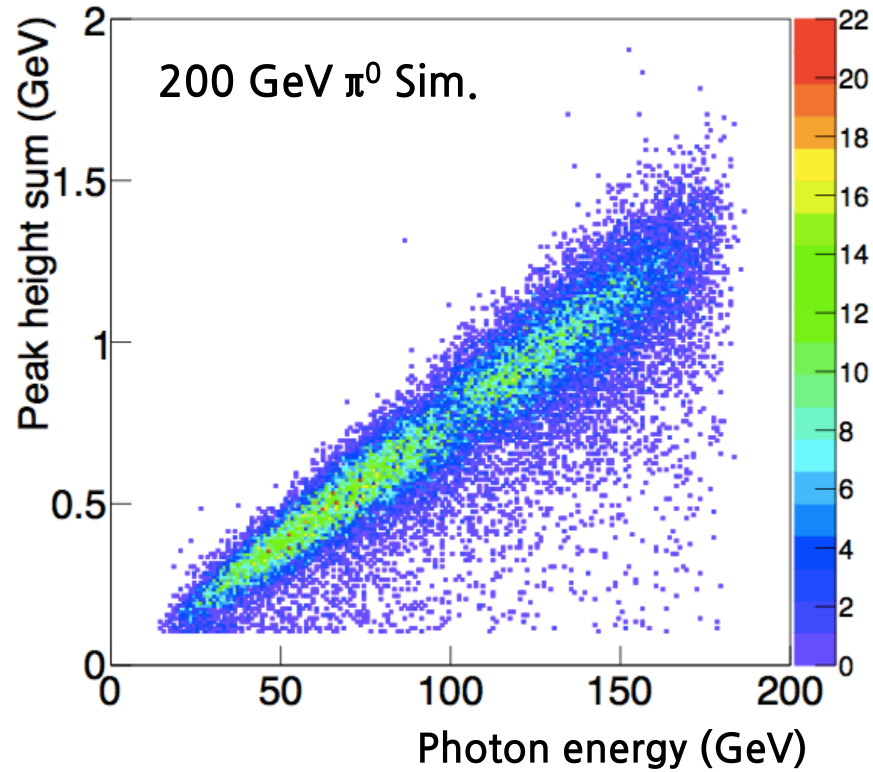
$$a = E_{\mathrm{TS}}^{\gamma \mathrm{TL}} / E_{\mathrm{TL}}^{\gamma \mathrm{C}}$$

$$b = E_{\mathrm{TL}}^{\gamma \mathrm{TS}} / E_{\mathrm{TS}}^{\gamma \mathrm{C}}$$

- In case of Type-I π^0, there should be energy contaminations from the photon hitting the other tower.
- This contamination was corrected by studying the ratio between the energy deposit when a photon hit the center of tower and its contamination to the other tower.

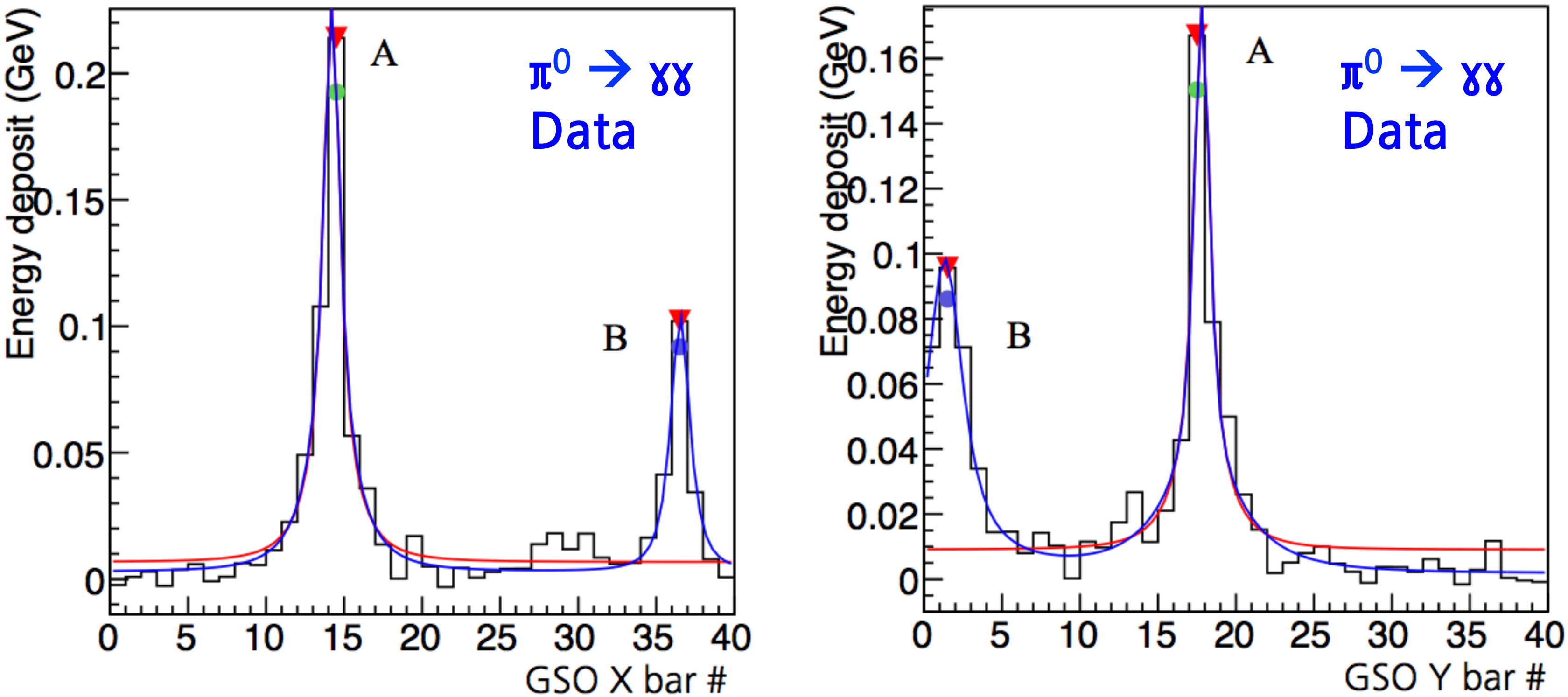
Type-II π^0 energy reconstruction





- Because GSO bar peak height well reproduces the initial photon energy, energy fraction from π^0 to two photon can be studied by it.
- Energy fraction $p = h_1 / (h_1+h_2)$ and $q = h_2 / (h_1+h_2)$ is used for leakage-out correction of Type-II π^0.

Type-II π^0 peak matching



- X position with higher peak was matched with Y position with higher one.
- If (X, Y) is matched by this rule, right matching ratio is expected to be arou-nd 90%.

Type-II π^0 energy reconstruction

- To reconstruct the Type-II π^0 energy, ideally

$$a(x_1, y_1)dE(x_1, y_1) + a(x_2, y_2)dE(x_2, y_2) = dE_1(0, 0) + dE_2(0, 0)$$

- However, we only measure the inclusive one,

$$dE(x_1, y_1) + dE(x_2, y_2)$$

- Energy fraction p and q can be used to solve this problem.

$$p\,[dE_1(0, 0) + dE_2(0, 0)] = dE_1(0, 0) = a(x_1, y_1)dE(x_1, y_1)$$
$$q\,[dE_1(0, 0) + dE_2(0, 0)] = dE_2(0, 0) = a(x_2, y_2)dE(x_2, y_2)$$

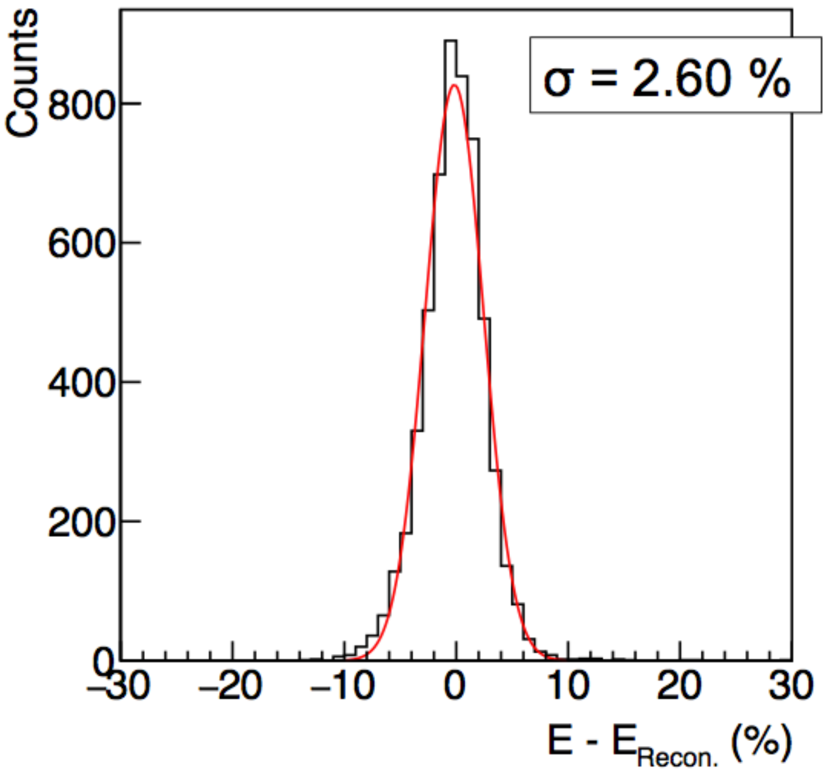
$$dE(x_1, y_1) + dE(x_2, y_2) = [p/a(x_1, y_1) + q/a(x_2, y_2)]\,[dE_1(0, 0) + dE_2(0, 0)]$$

What we already knew — What we want to know

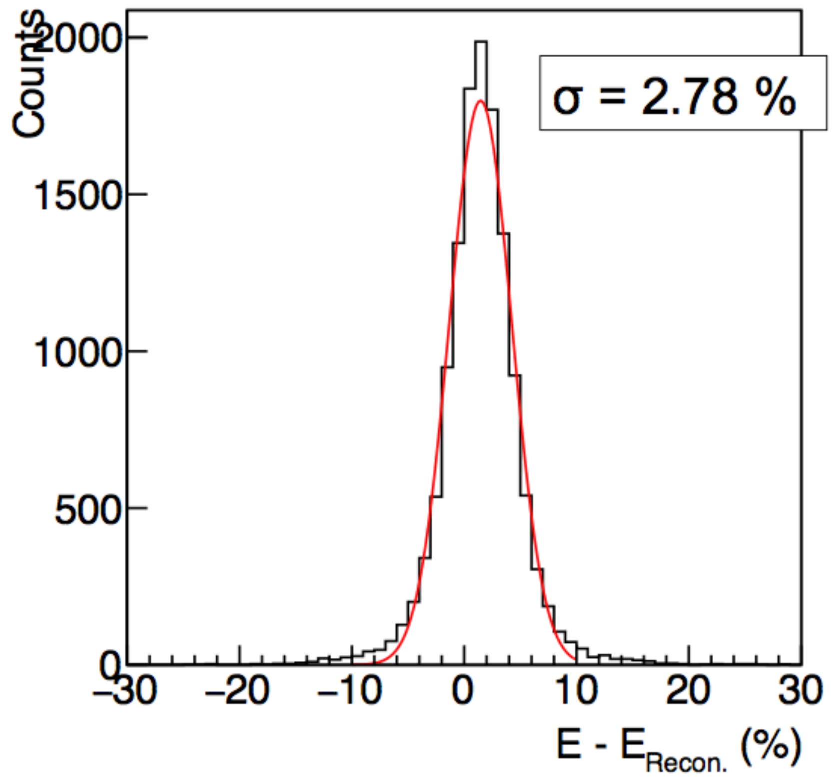
$$dE_1(0, 0) + dE_2(0, 0) \rightarrow SumdE_1 + SumdE_2 \rightarrow E_1 + E_2 = E$$

Energy resolution of π^0 reconstruction

200 GeV π^0 Sim. (Type-I)

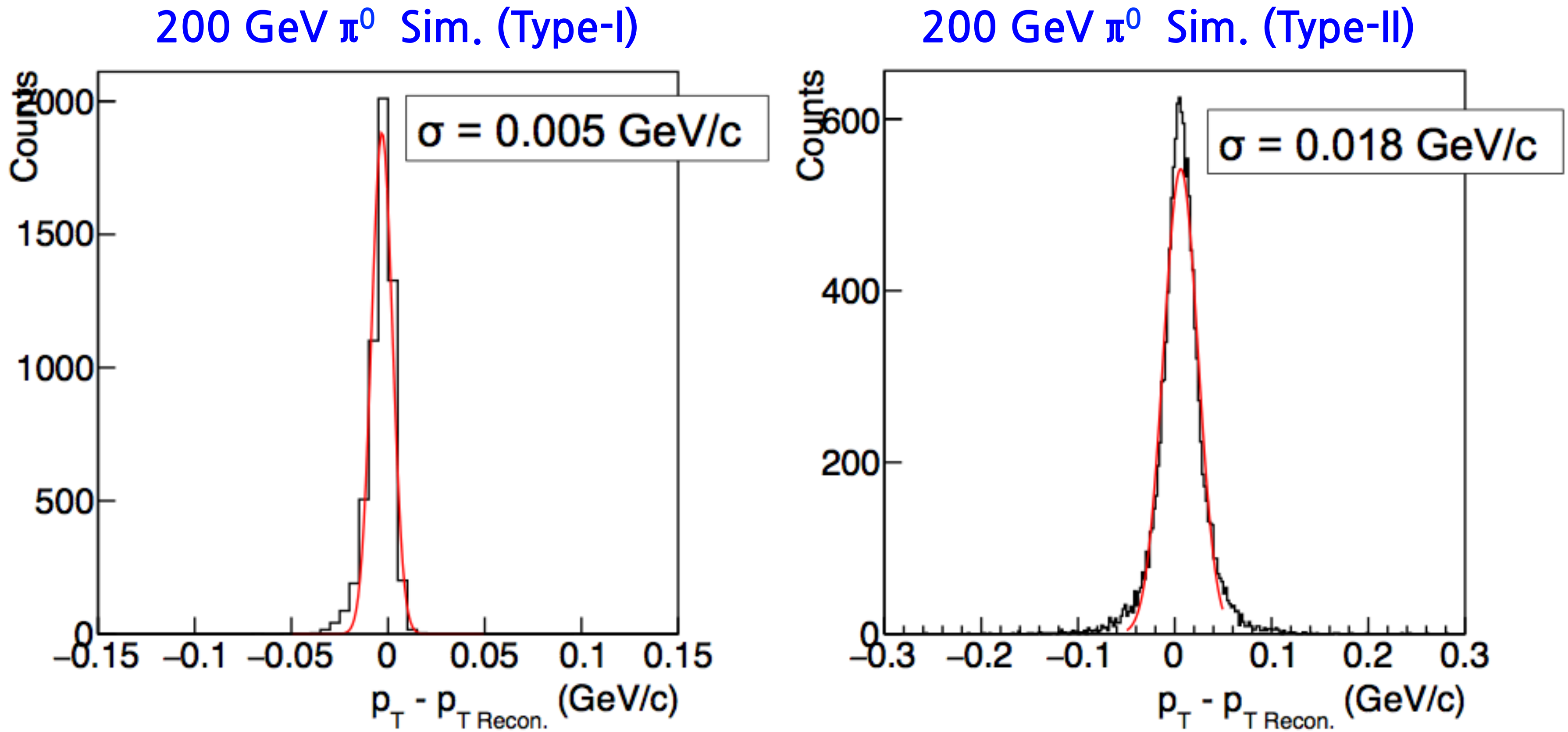


200 GeV π^0 Sim. (Type-II)



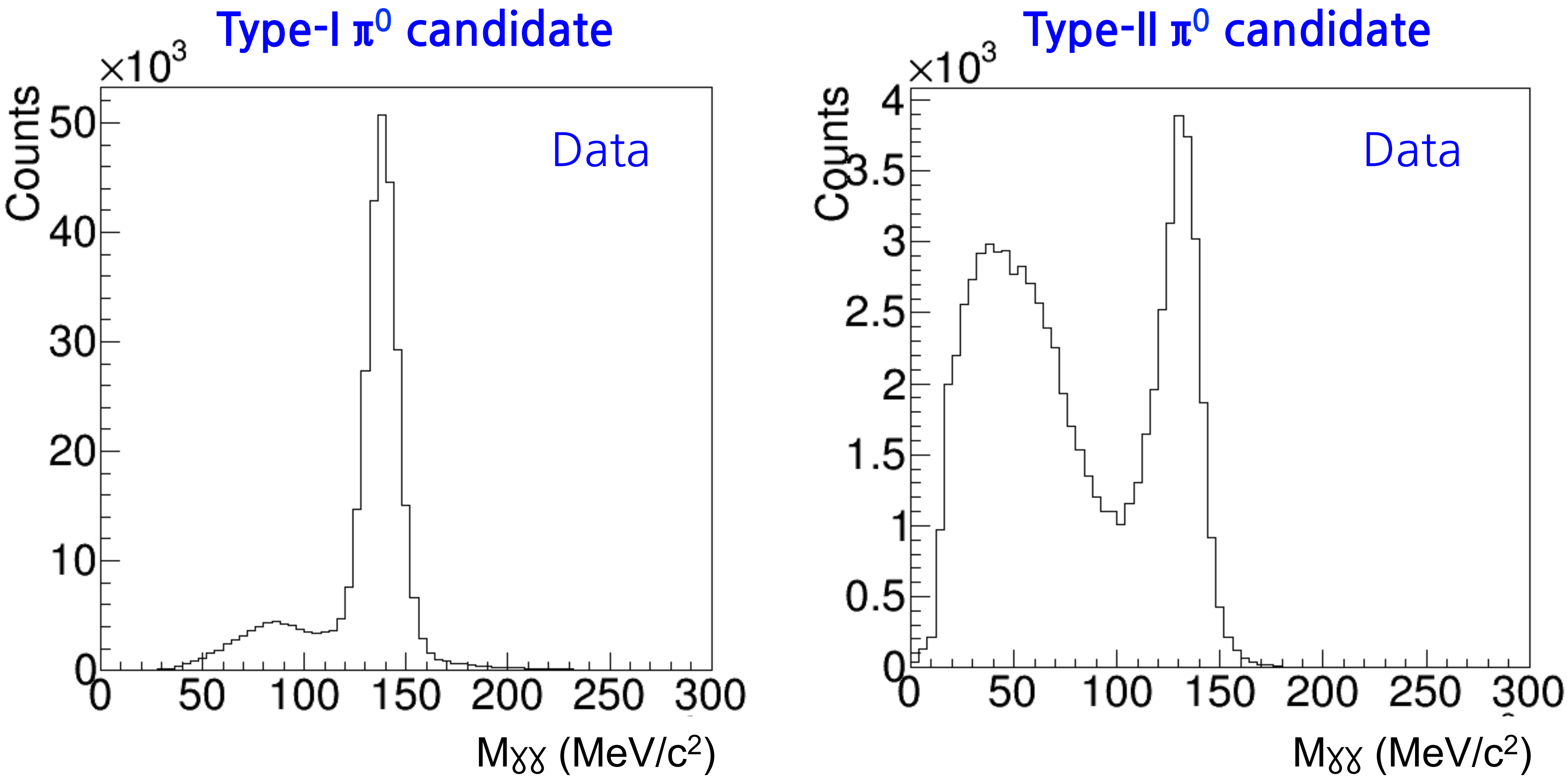
- Around 2.7% energy resolution is expected to both Type-I and Type-II.
- Energy reconstruction procedure for Type-II looks OK.

p_T resolution of π^0 reconstruction



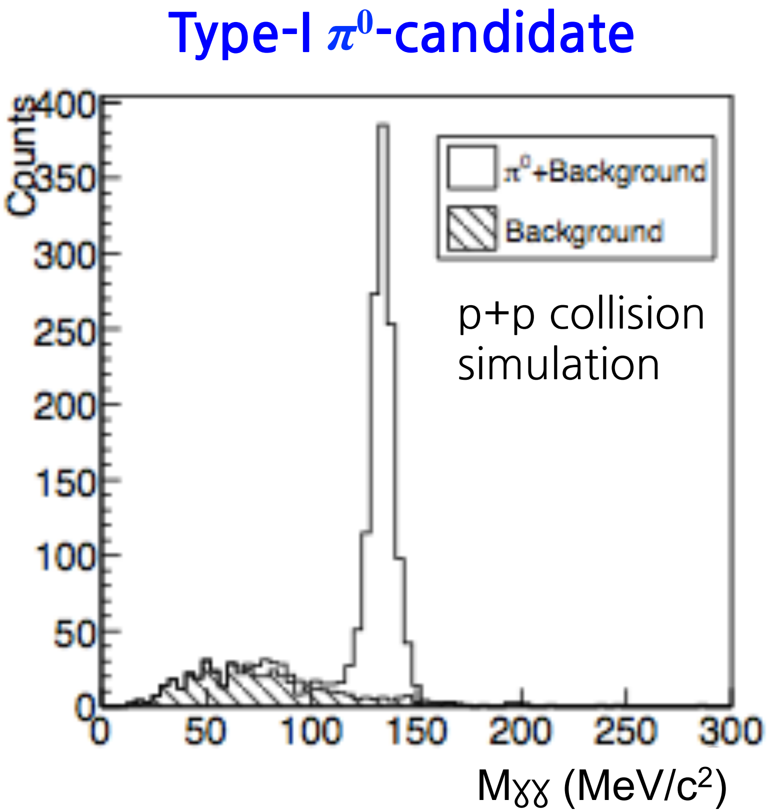
- However, pT resolution of Type-I is much better than Type-II.
- This is because the peak position is more fluctuated when two photons hit the detector than one.
- But This fluctuation is negligible compared to leakage map scale.

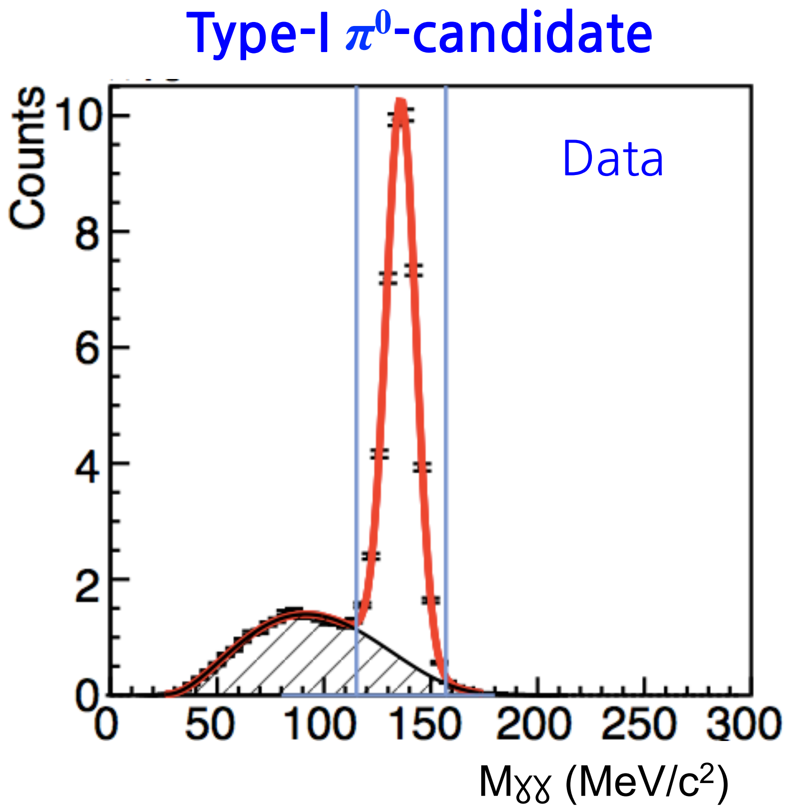
Invariant mass of two photon



- Clear π^0 peak is shown around 135 MeV/c² with ~9 MeV/c² width.
- Background part usually comes from coincidence of the other particles, not wrong reconstruction.

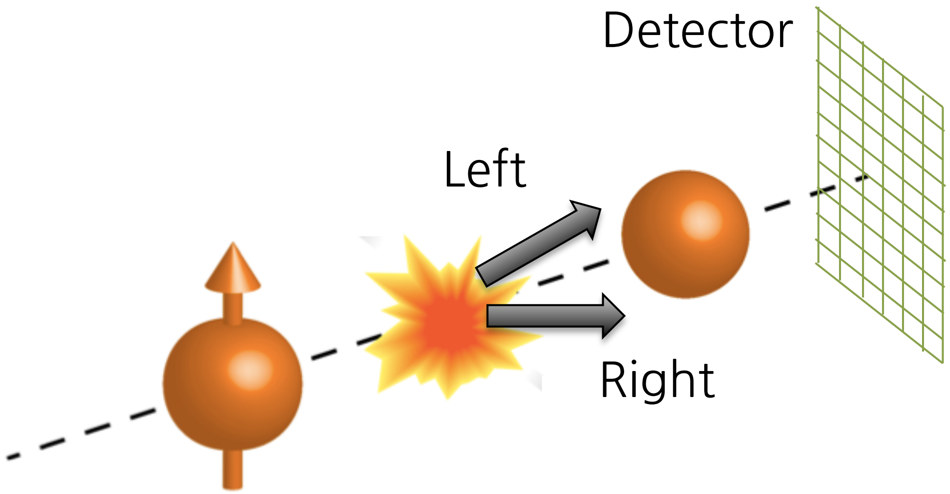
Final π^0 candidate





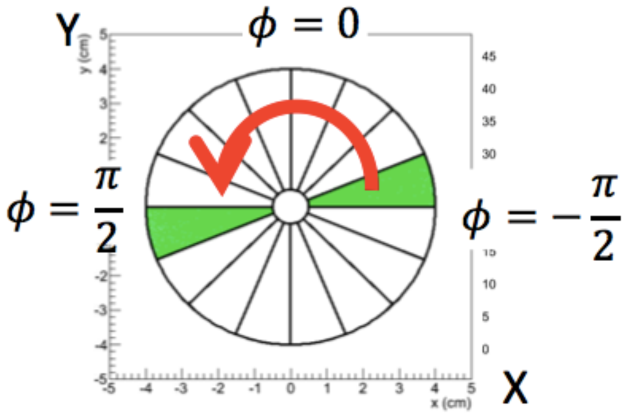
- Invariant mass of two photon was fitted by combination of polynomial for background and Gaussian for actual π^0.
- π^0 peak ± 3sigma was chosen for final π^0 candidate.

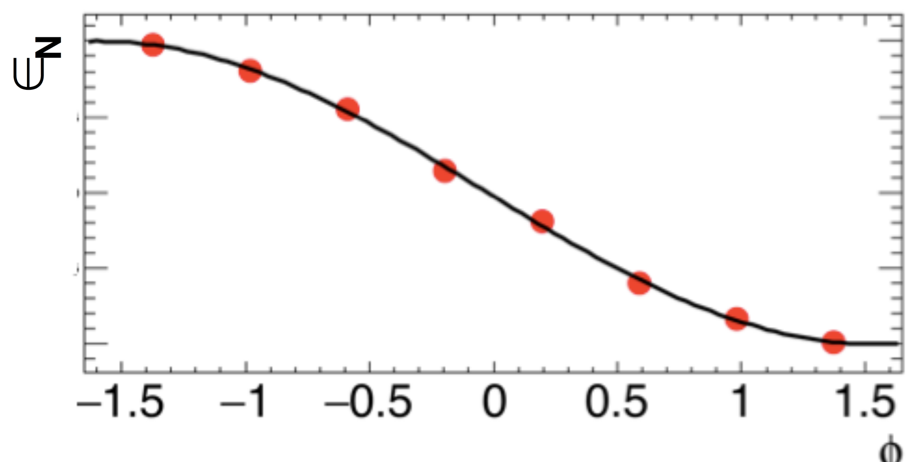
Transverse single spin asymmetry (A_N)



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

- A_N is defined as a left-right asymmetry of the cross section of a specific particle.





- A_N is obtained from azimuthal angle modulation. A_N is sensitive to the normal direction of beam polarization.

A_N calculation

Luminosity ratio between spin up and down

Number of π^0 in specific x_F and p_T range

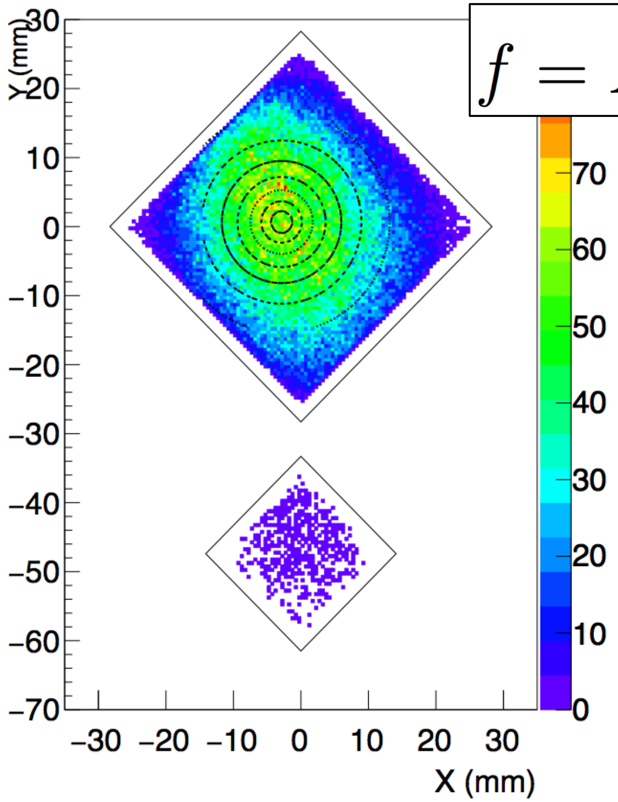
$$A_N = \frac{1}{PD_\phi} \frac{N^{\uparrow} - RN^{\downarrow}}{N^{\uparrow} + RN^{\downarrow}}$$

Beam polarization

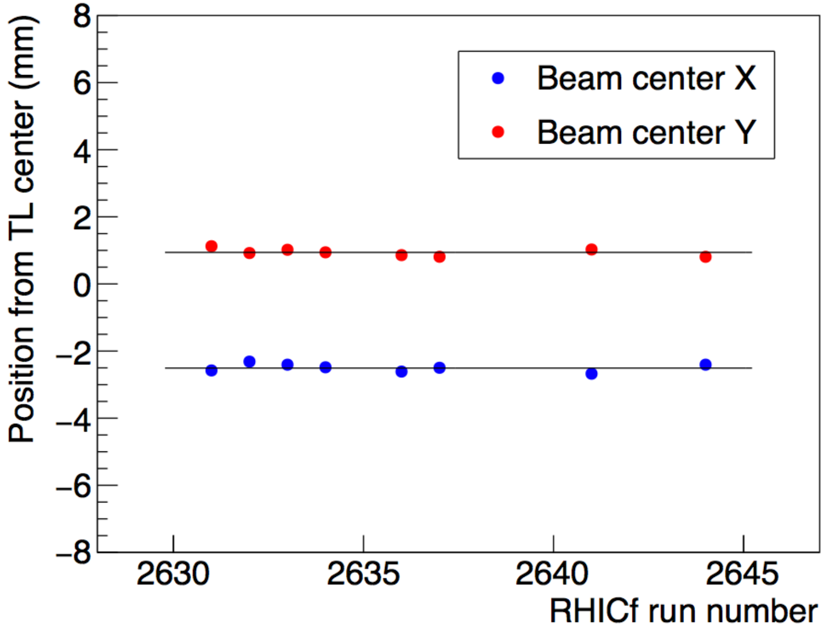
A_N dilution by ϕ distribution of detected π^0

- P was measured by p-Carbon polarimeter.
- R was calculated by luminosity ratio of charged particles near IP.
- D_Φ was calculated referring to the measured Φ distribution of detected π^0.
- Beam center calculation is necessary for the $N(p_T, x_F)$.

Beam center calculation by neutron hit map

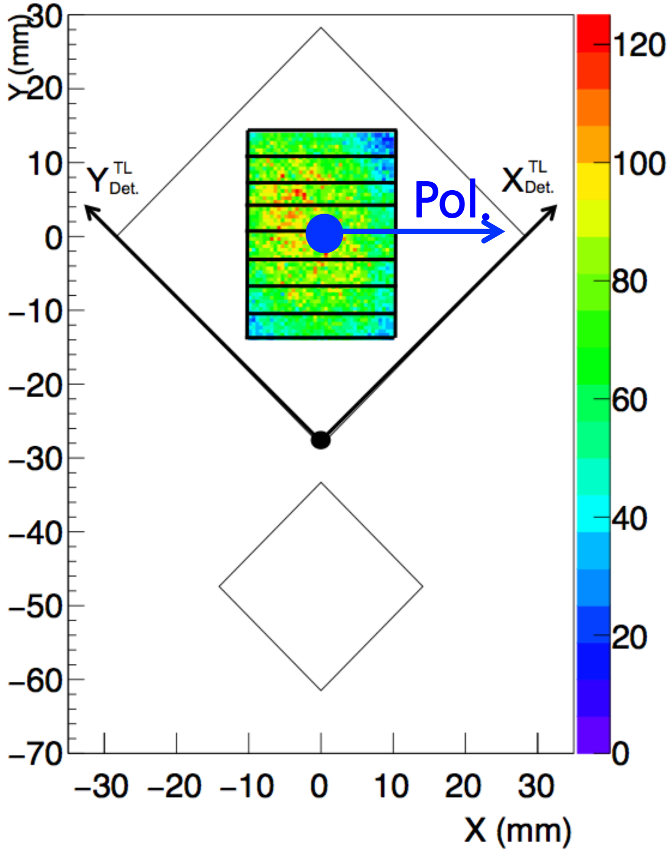


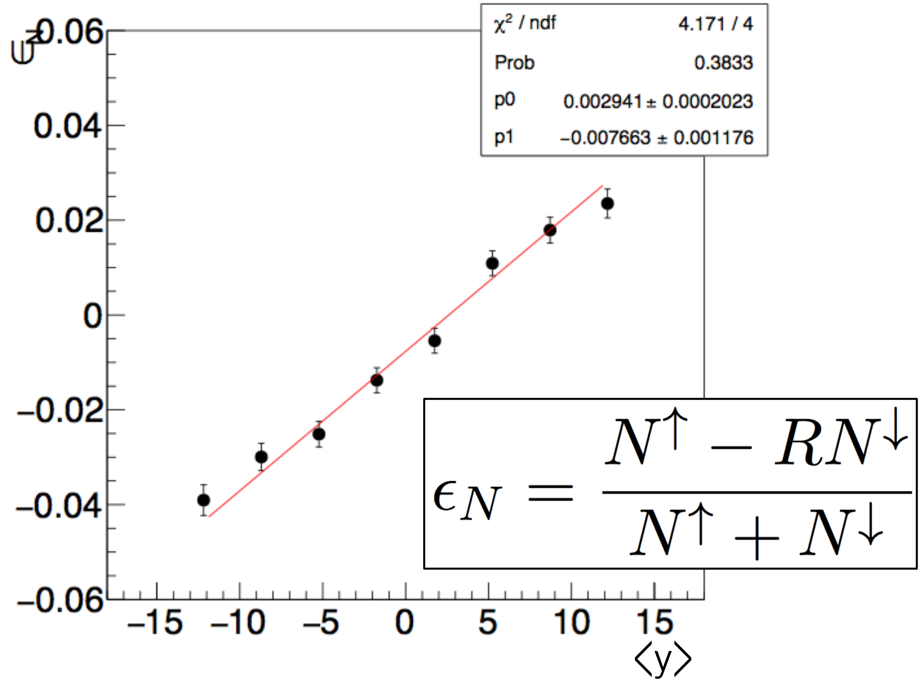
$$f = Ae^{-B\sqrt{(x-x_0)^2+(y-y_0)^2}}$$



- High energy neutron (E_{rec} > 200 GeV) was used.
- Run-by-run calculated beam center shows quite stable values.
- Beam center calculation will be improved in next reconstruction after applying neutron leakage map.

Beam center calculation by neutron A_N



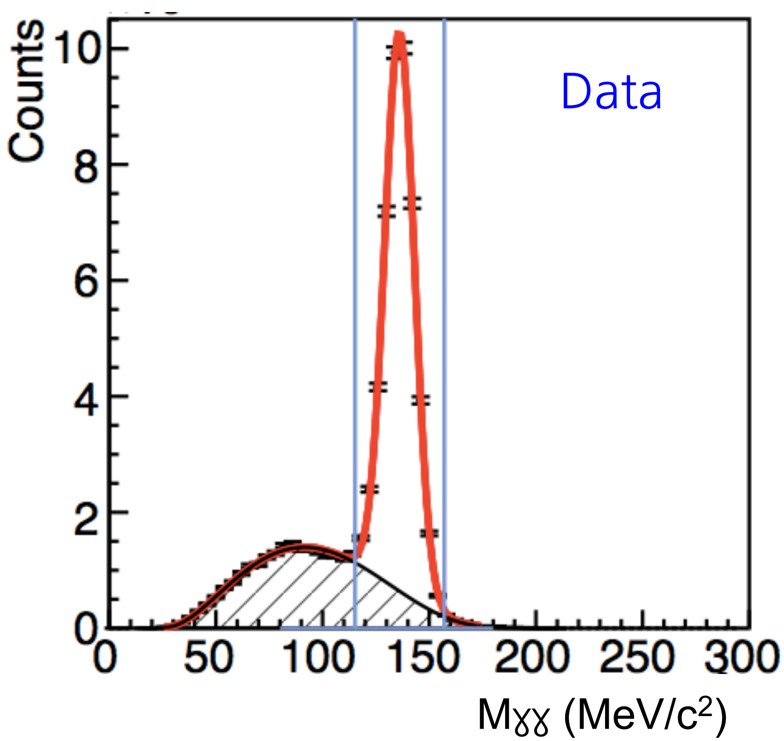


- A_N is sensitive to the normal direction of beam polarization, beam center y can be calculated by A_N scan as a function y.
- Difference of A_N between different beam center: (X_{hit}, Y_{hit} or Y_{scan}) was applied to the systematic uncertainty of A_N.

Background A_N subtraction

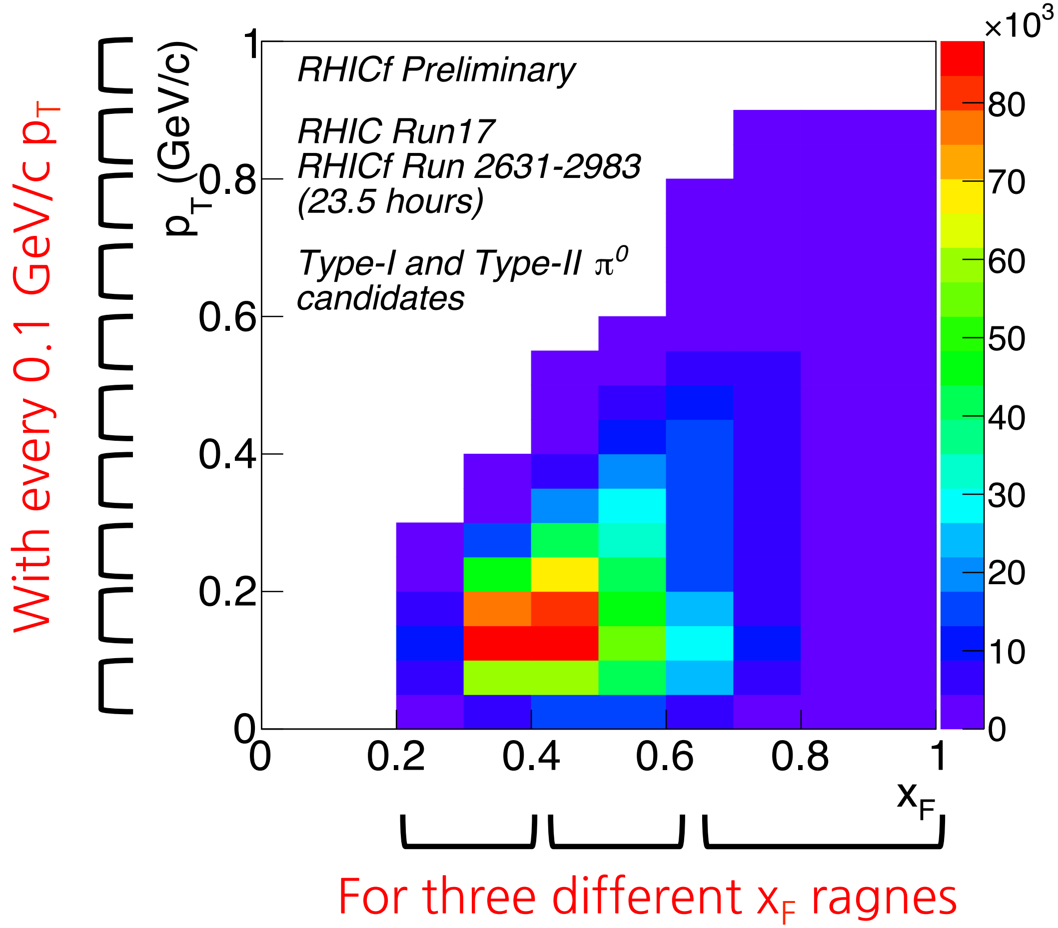
$$A_N^{S+B} = \frac{(N_S^{\uparrow} + N_B^{\uparrow}) - (N_S^{\downarrow} + N_B^{\downarrow})}{(N_S^{\uparrow} + N_B^{\uparrow}) + (N_S^{\downarrow} + N_B^{\downarrow})}$$

$$= \left(\frac{N_S}{N_{S+B}}\right) A_N^S + \left(\frac{N_B}{N_{S+B}}\right) A_N^B$$



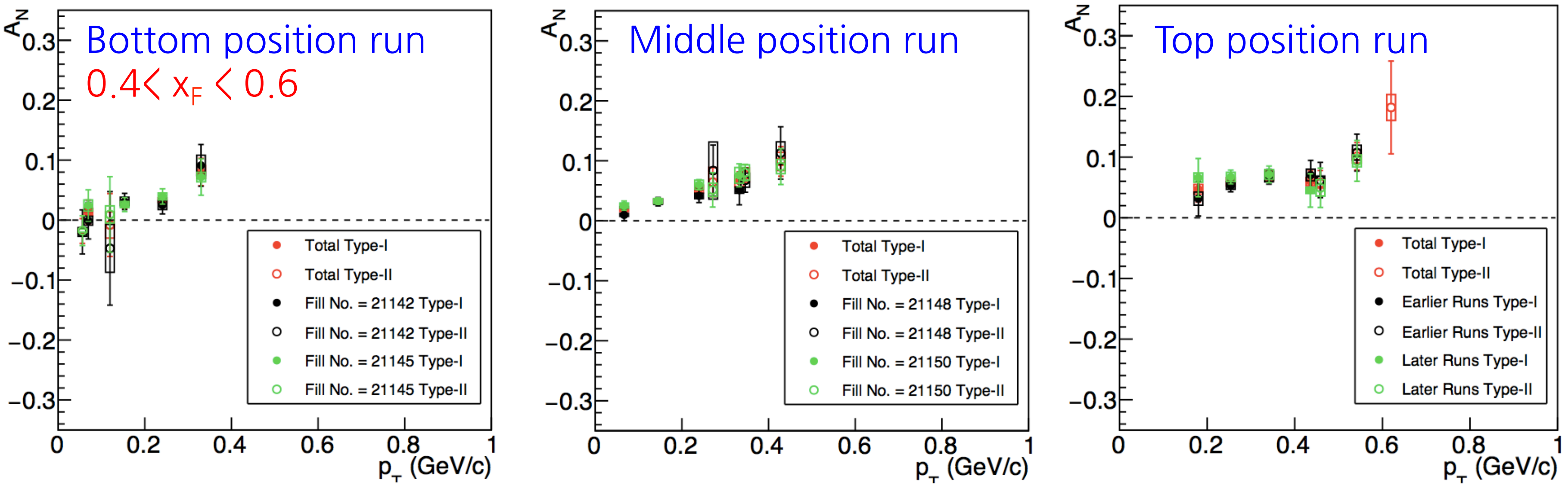
- Due to π^0 tail, if the background fitting completely covers the background area, calculated B/S ratio should be smaller than actual one.
- Actual B/S ratio should be smaller than calculated one, but larger than 0.
- Invariant mass area 5sigma further than π^0 peak was used for background A_N.

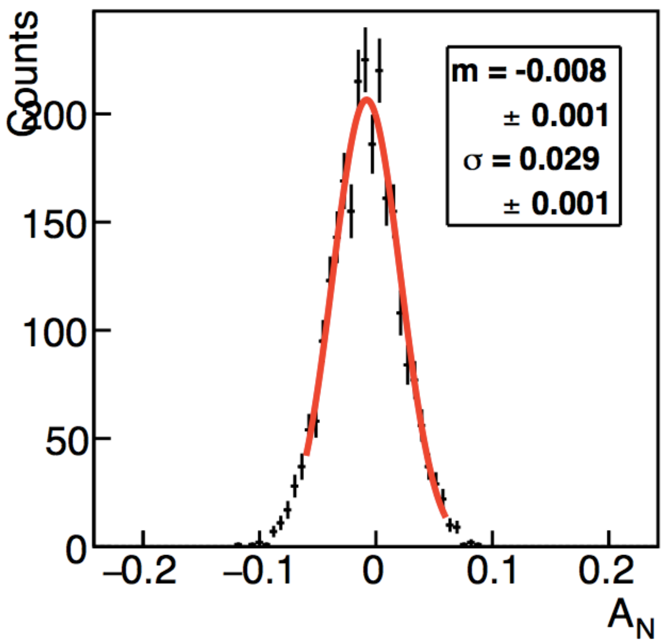
π^0 kinematics



- First, A_N of very forward π^0 was studied as a function of every 0.1 GeV/c p_T for three different x_F ranges.
- π^0's p_T and x_F resolution of the detector is much better than its binning.

Cross check works

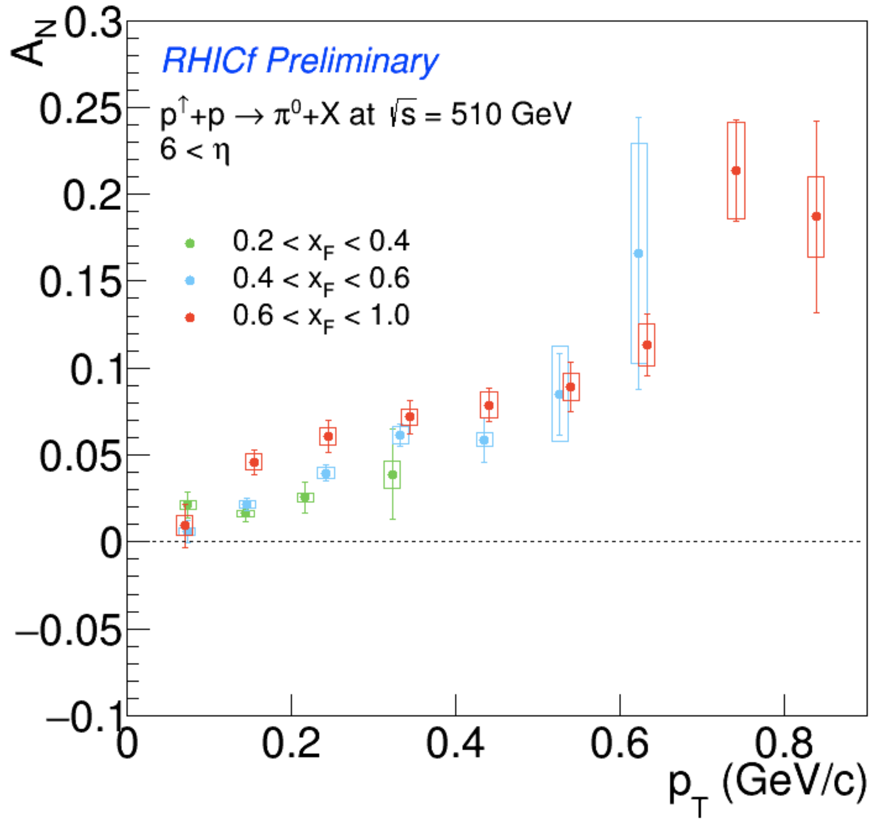


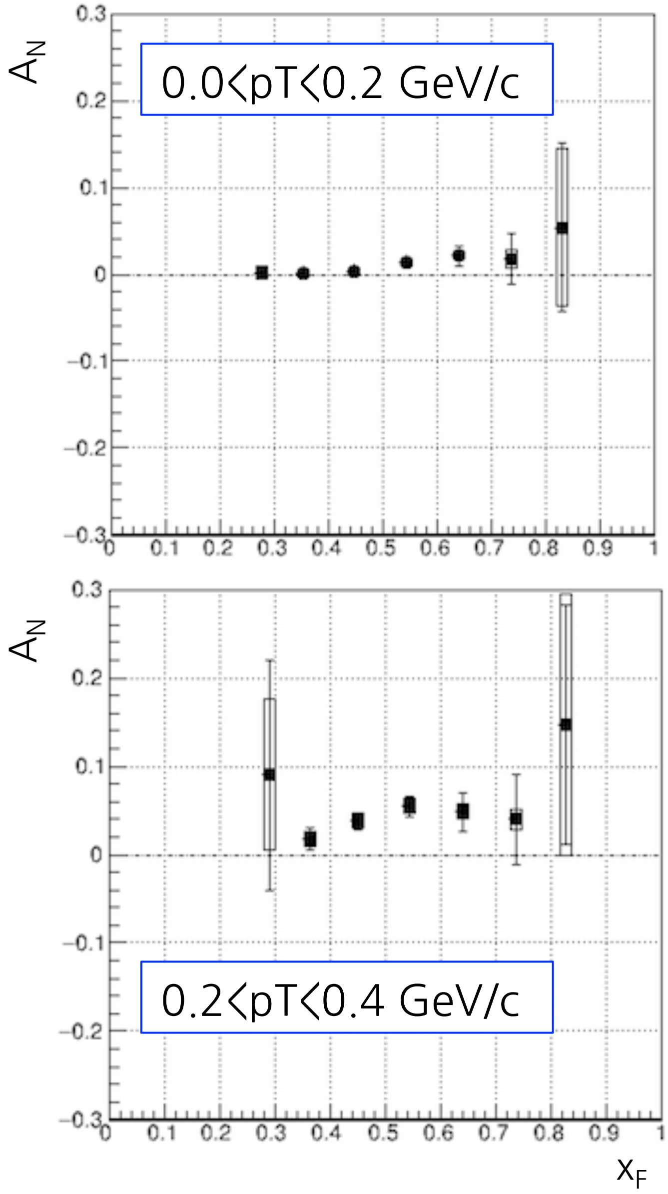


$$\frac{N - RN}{N + RN} \longrightarrow 0 \pm \text{Stat. error}$$

- AN by different run period and π^0 types are all consistent with each other.
- Bunch shuffled AN also shows good agreement with expectation.

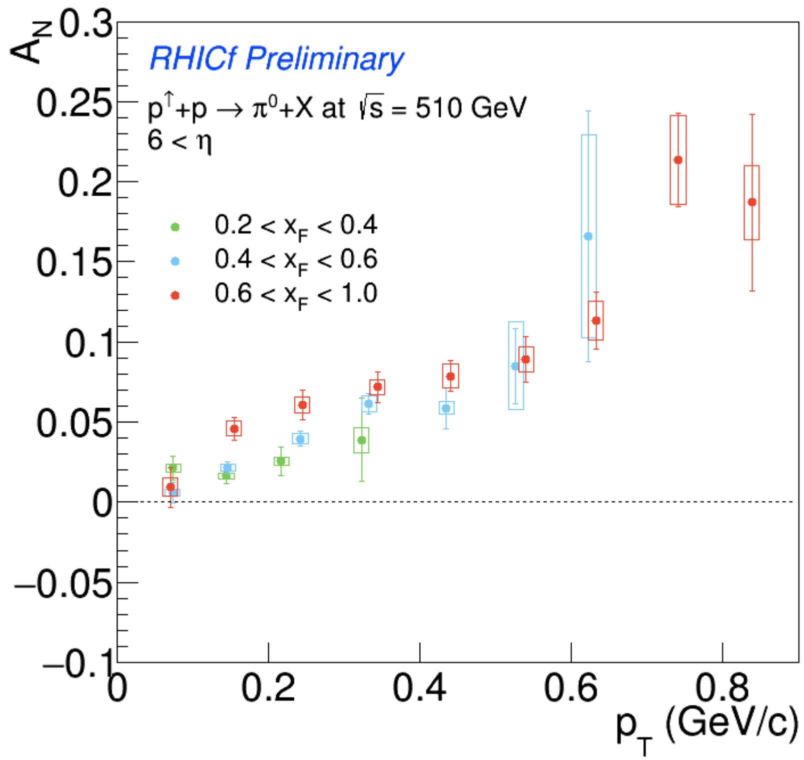
Preliminary result of very forward π^0 A_N

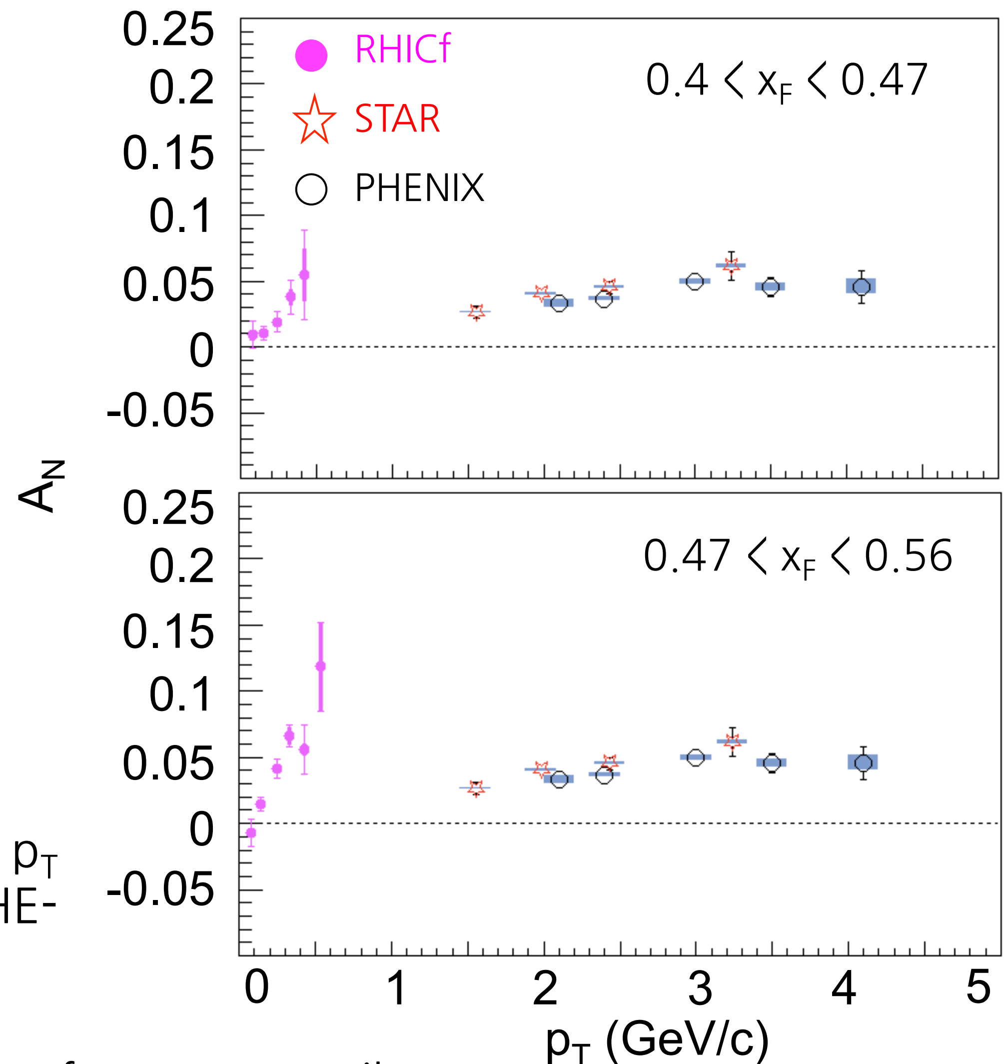




- AN of very forward π^0 looks increasing as a function of p_T, but comparitively flat as a function of x_F.
- Its x_F dependence is also being studied now.

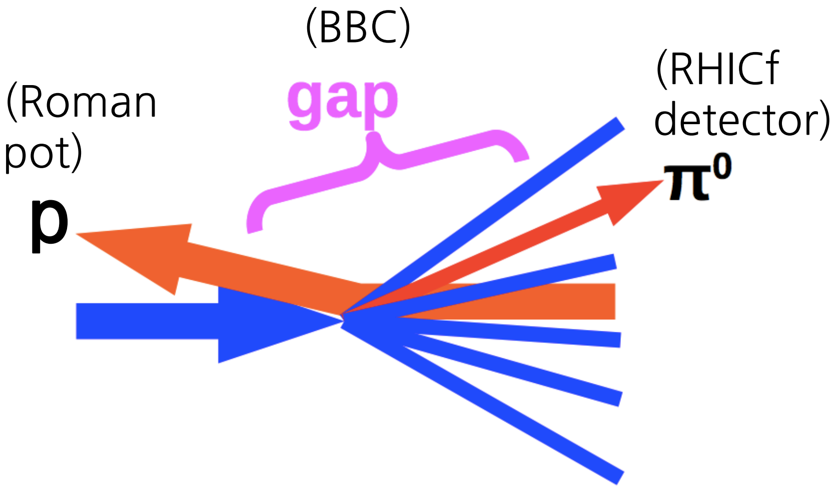
Comparison with forward π^0 A_N

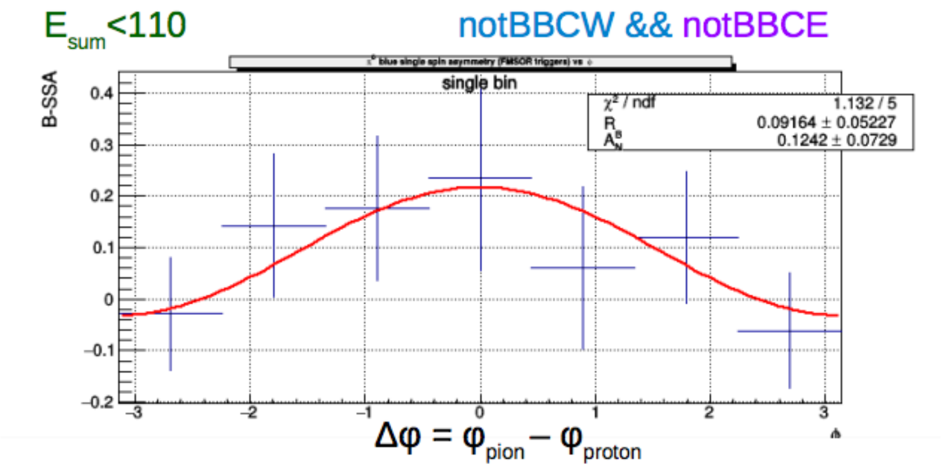


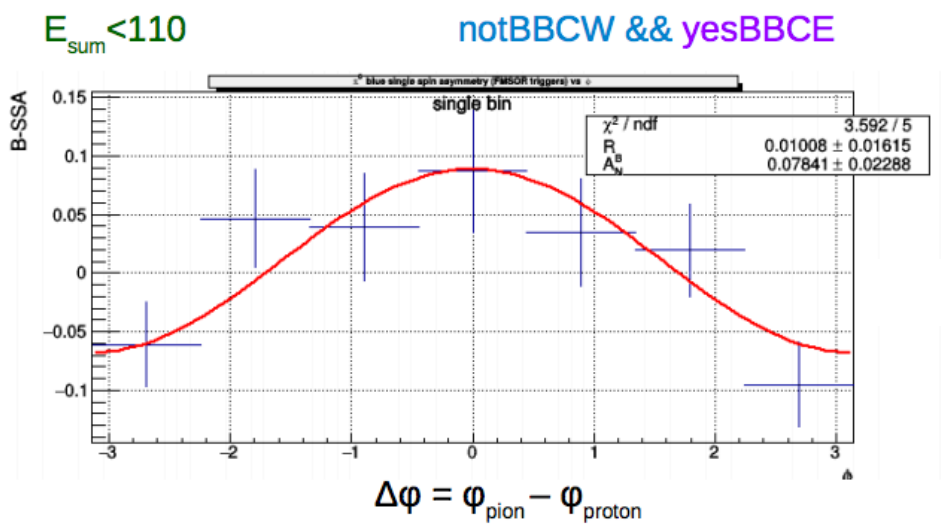


- A_N tendencies as a function of p_T looks different from previous PHENIX & STAR measurement.
- Different η range: Different types of events contribute differently. Event type dependence study is necessary with STAR detectors.

Combined analysis with STAR

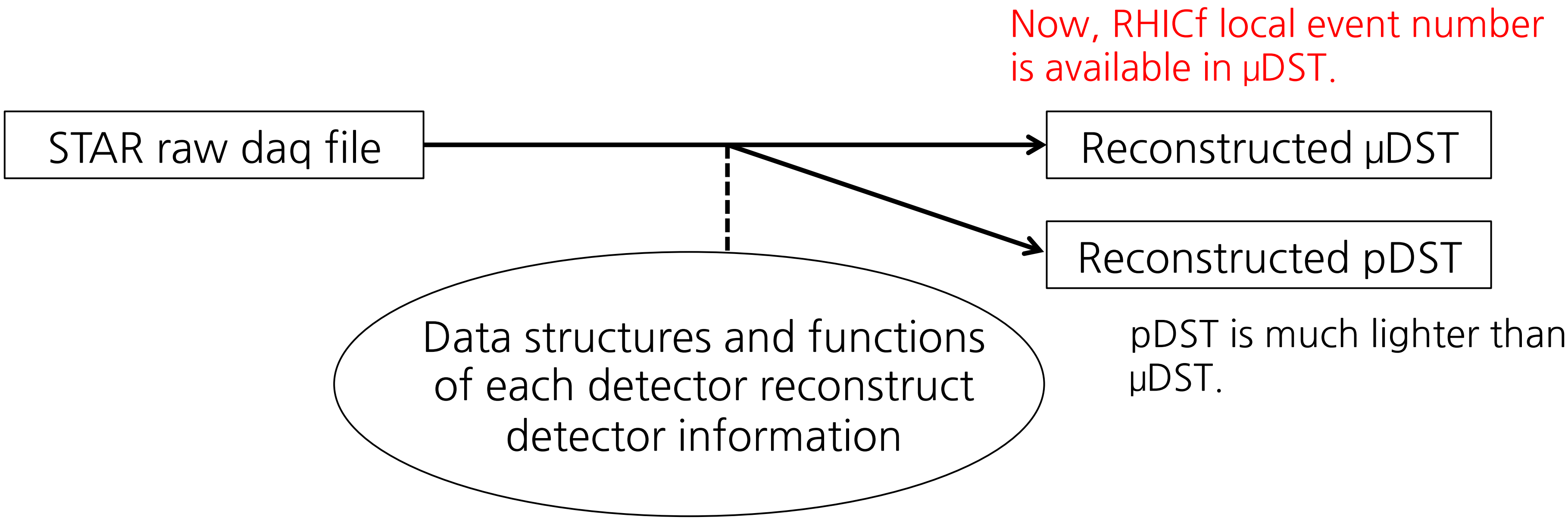






- BBC signal dependence for forward π^0 A_N was already observed at STAR.
- We may identify diffractive event using BBC, TPC and Roman pot.

Status of combined analysis with STAR



- Data structure in STAR library is almost complete. (It was delayed due to thanks giving holidays…)
- Based on this structure, data structure for pDST will be also prepared soon as we can handle at least A1cal2 at μDST.
- Because now RHICf local event number is available in μDST, we'll start making detailed analysis code to see the event type dependence.

Summary

- RHICf experiment successfully measured very forward particle production, mainly neutron, single photon and π^0.

- Recently, preliminary result of the very forward π^0 A_N was released and surprisingly it showed non-zero asymmetry.

- In order to one step further understand the non-zero A_N of (very) forward π^0 production, combined analysis with other STAR detectors is ongoing to see its event type dependence.