Spin physics in RHICf

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Outline

1. Brief Introduction for RHICf experiment

2. Spin Physics in RHICf
   - Forward neutron A_N
   - Forward π0 A_N

3. Operation
   - RHICf detector
   - DAQ system
   - DATA taking
   - RHIC & Radial Polarized beam
   - Run

4. Comparison with proposal

5. Status of Analysis

RHICf experiment

- Targets in detection: Very forward neutral particles(photons, π0, and neutrons)

- Detectors: STAR ZDC, TPC, Roman pot and VPD + RHICf

- Physics motivations:
  - Cross sections of forward π0 and neutrons
  - A_N of forward π0 and neutrons

- Advantage:
  - Usage of radial polarized beam and various detector position
  → Measurement of neutral particles over wider pT range with higher position resolution

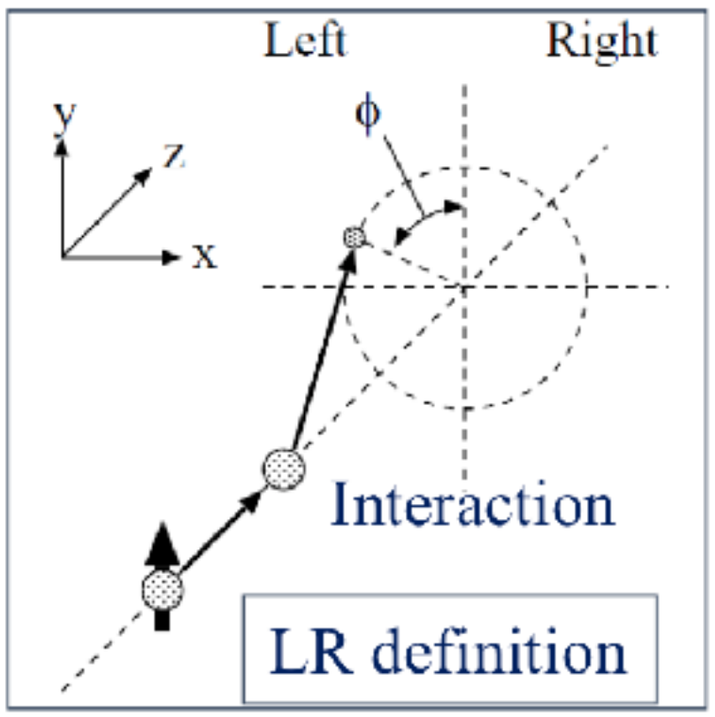
Spin Physics in RHICf

- Definition of A_N:

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

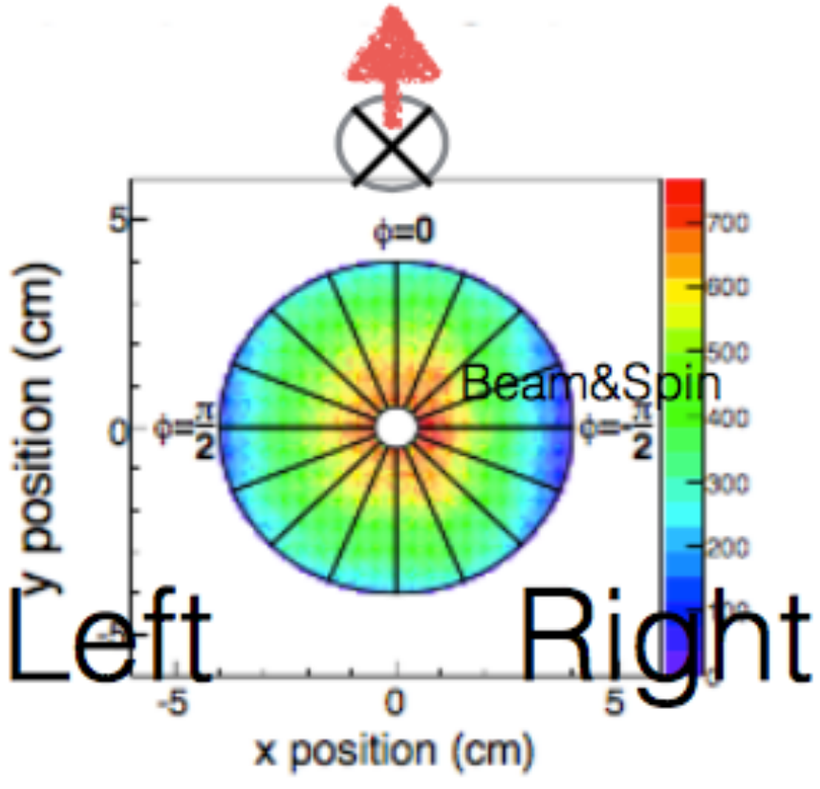
- $\sigma_L^{\uparrow}$, $\sigma_L^{\downarrow}$: cross section for particles produced on left side when spin of incident particle is up(down)

- Also called Left-Right asymmetry

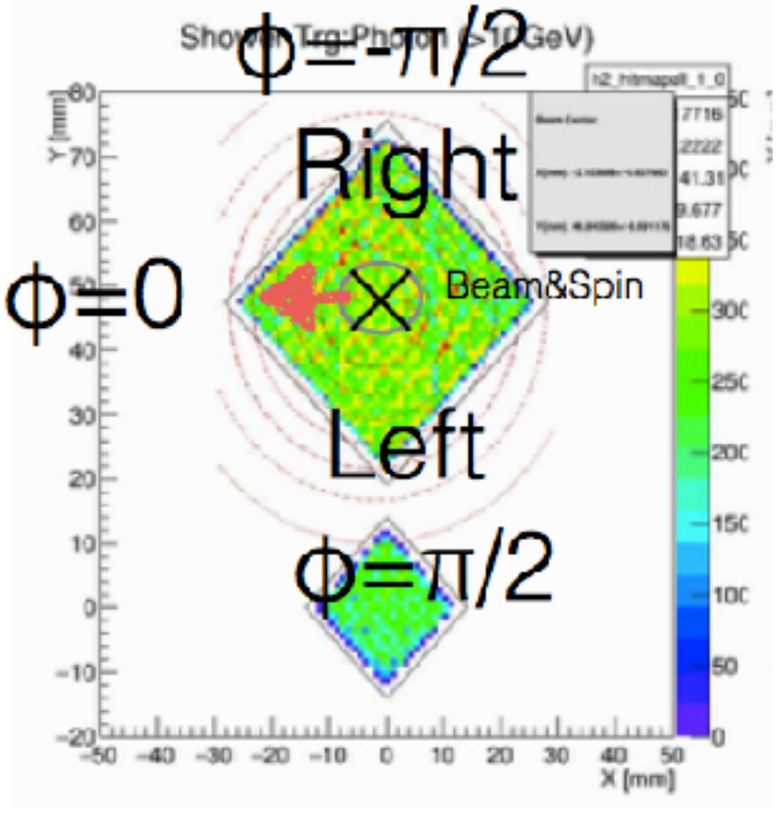


Spin Physics in RHICf

- Measurement of A_N (1): raw asymmetry $\epsilon_N(\phi) = \frac{\sqrt{N_\phi^\uparrow N_{\phi+\pi}^\downarrow} - \sqrt{N_{\phi+\pi}^\uparrow N_\phi^\downarrow}}{\sqrt{N_\phi^\uparrow N_{\phi+\pi}^\downarrow} + \sqrt{N_{\phi+\pi}^\uparrow N_\phi^\downarrow}}$
- $N_\phi^\downarrow$, $N_\phi^\uparrow$: Number of particles going through specific area when spin of incident particle is down(up)



SMD



RHICf

Spin Physics in RHICf

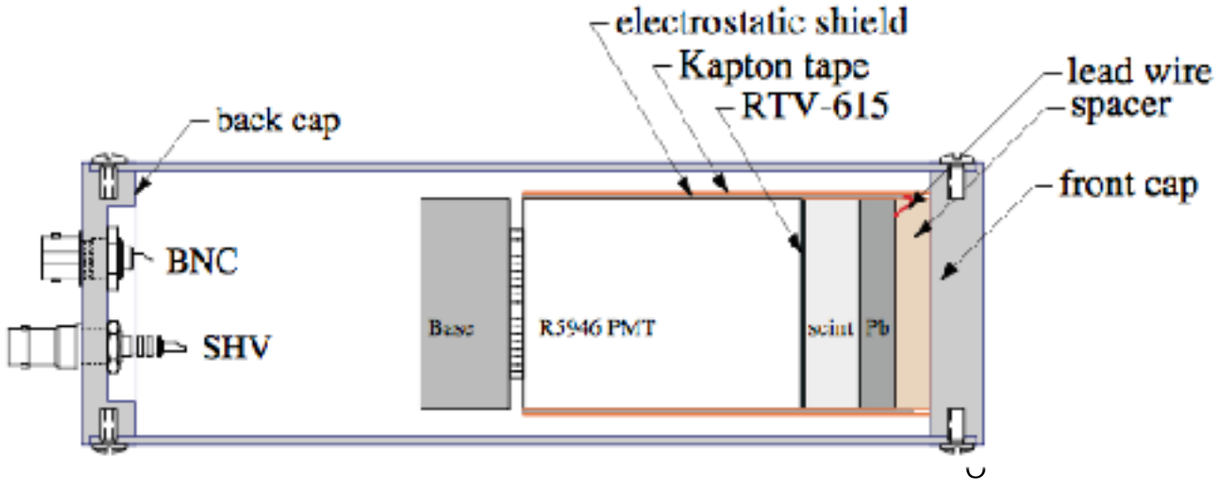
- Measurement of AN(Modular measurement not applicable): Relative luminosity
  → Point: Present AN with measurable quantities

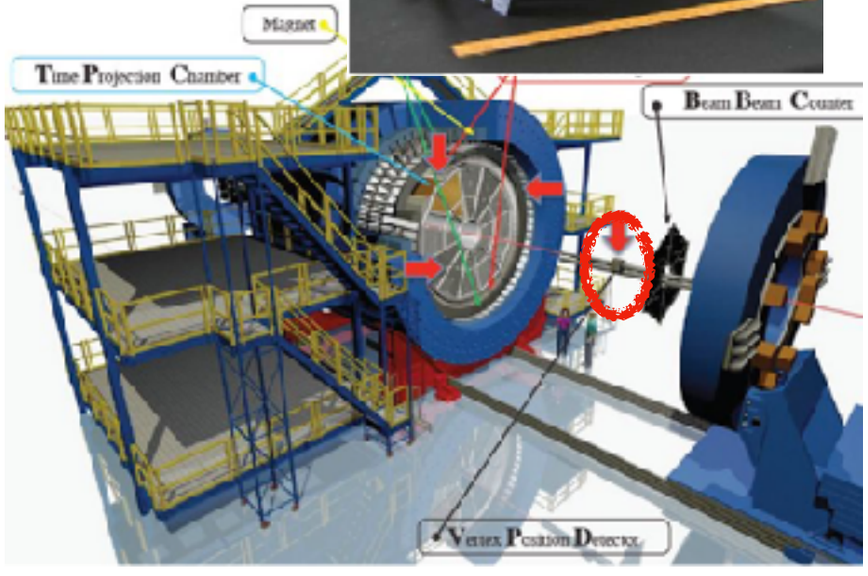
$$A_N = \frac{\sigma_L^{\uparrow} - \sigma_L^{\downarrow}}{\sigma_L^{\uparrow} + \sigma_L^{\downarrow}} = \frac{N_L^{\uparrow} - RN_L^{\downarrow}}{P(N_L^{\uparrow} + RN_L^{\downarrow})}$$

- Relative luminosity :

$$R = \frac{L^{\uparrow}}{L^{\downarrow}} = \frac{N^{\uparrow}}{N^{\downarrow}}$$

- Measurement of R : STAR ZDC, BBC and VPD(vertex position detector)



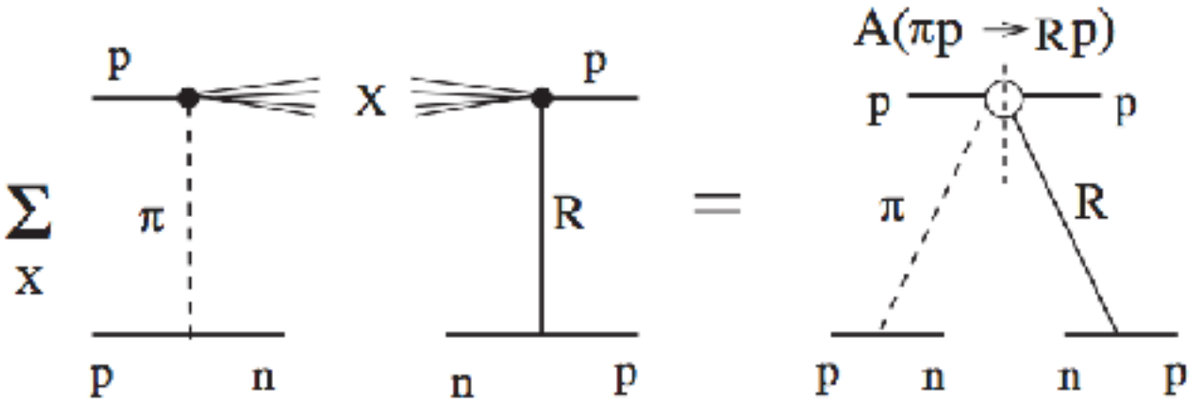


A_N for forward neutron

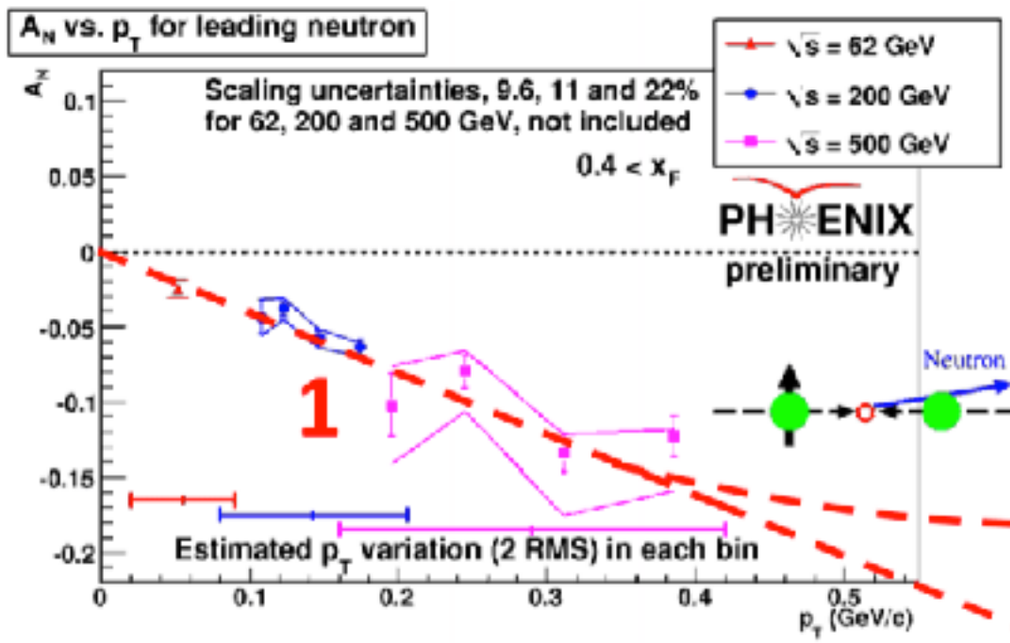
- Previous result:
  2002:RHIC IP12 experiment
  2006: PHEINX

- Origin of A_N for forward neutrons?
  → Some of interaction models explain it

- π-a1 reggeon interference model:



Kopeliovich, Potashnikova, Schmidt, Soffer
PRD84, 114012 (2011)



- One-Pion exchange model
  → Cross section is okay, But can't explain large A_N

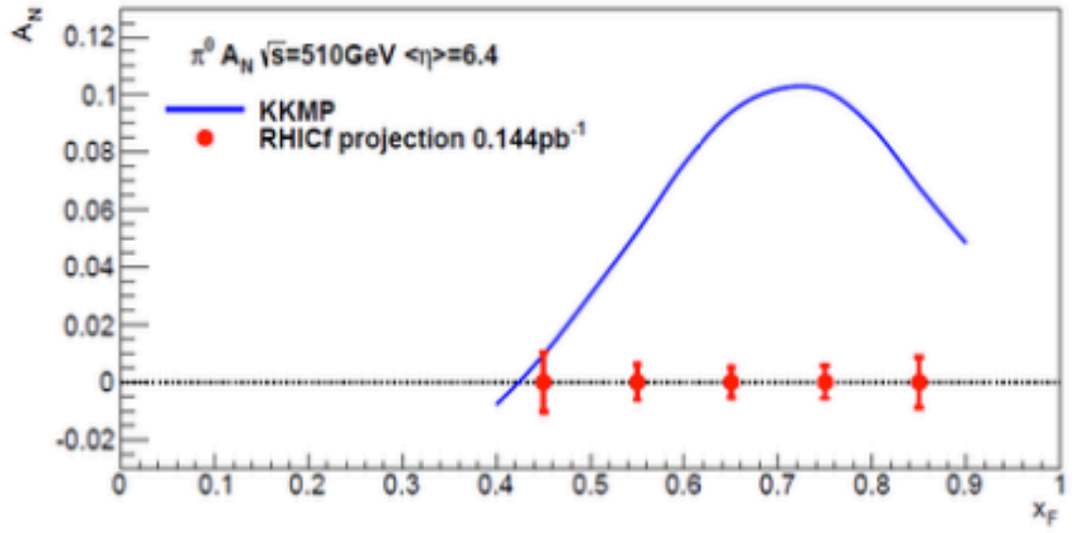
AN for π± and π0

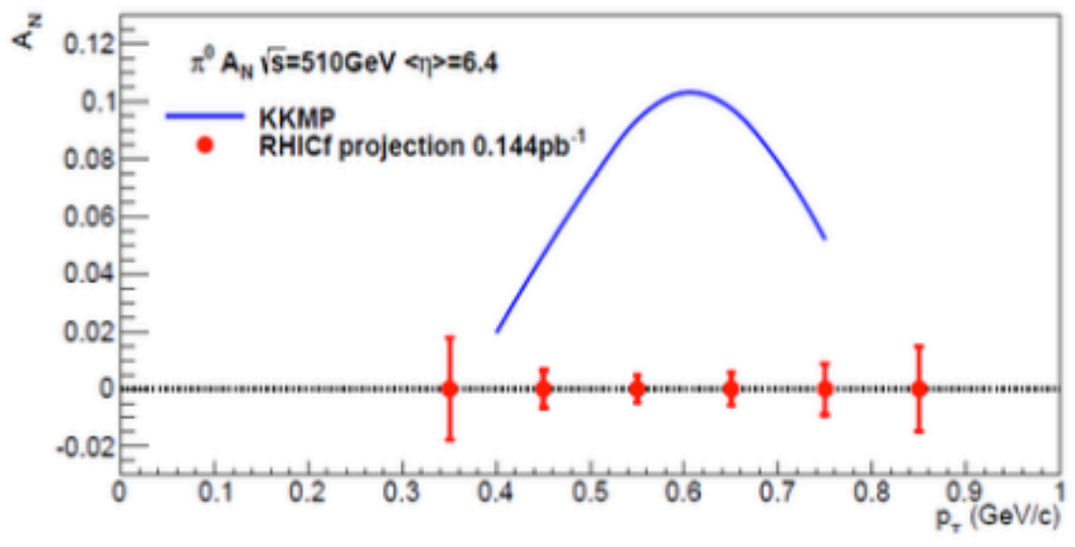
- Previous result:
  1991 : 704 collaboration reported unexpected large AN (~30%) in p + p → X + π±,0 over large XF at √s=19.4GeV
  2006 : PHENIX confirmed small AN(~3%) of π0 over mid pseudo-repidity(3.1<η<3.7) at √s=62.4GeV

D. L. Adams et al. (FNAL-E581 and E704 Collabora- tions), Phys. Lett. B 261, 201 (1991).
D.L. Adams et al. (E704 Collaboration), Phys. Lett. B264, 462 (1991)

- Higher Twist contribution explain these data

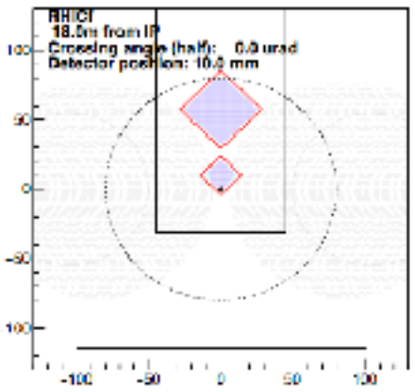
- When it comes to AN within range covered but SMD, AN is 0 (Due to systematic error ΔX of SMD ~1cm)

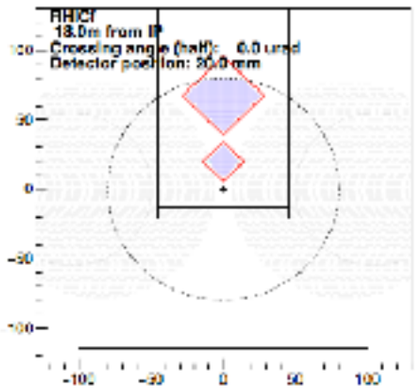


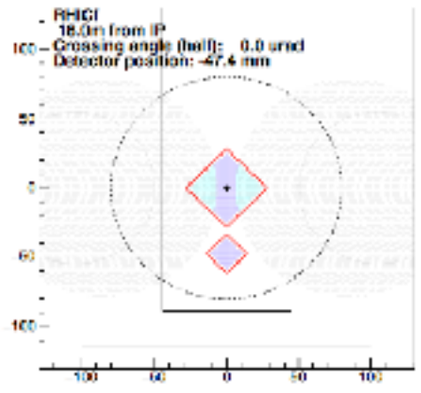


Operation

- Measurement Location: 18m away from STAR IP
- 3 different detection position
- Common data taking with STAR(ZDC, Romanpot, BBC and TPC)
- Radial Polarizated beam with $\sqrt{s}$=510GeV and β^*=8m



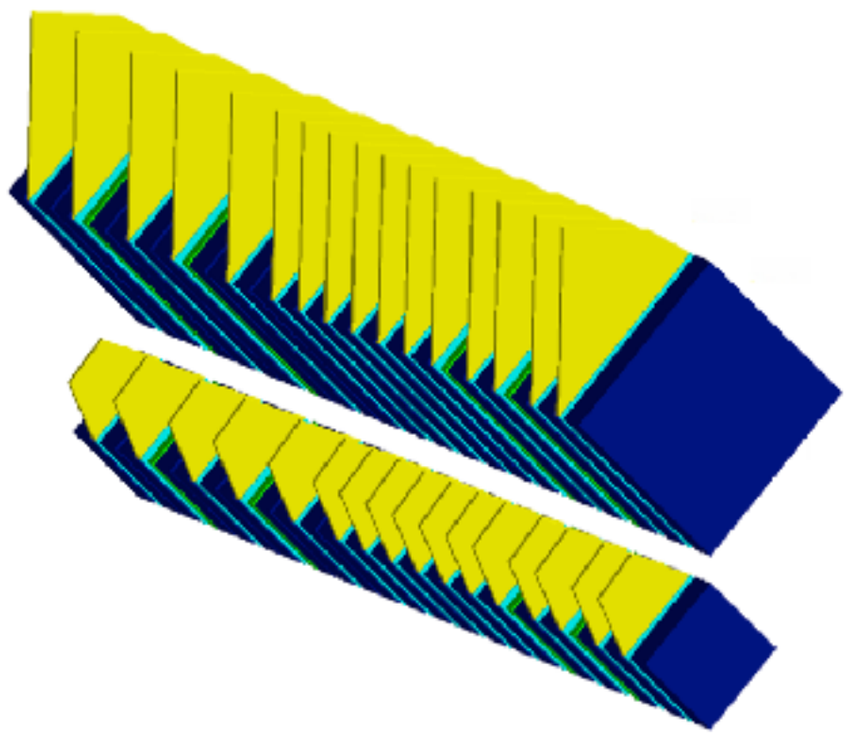


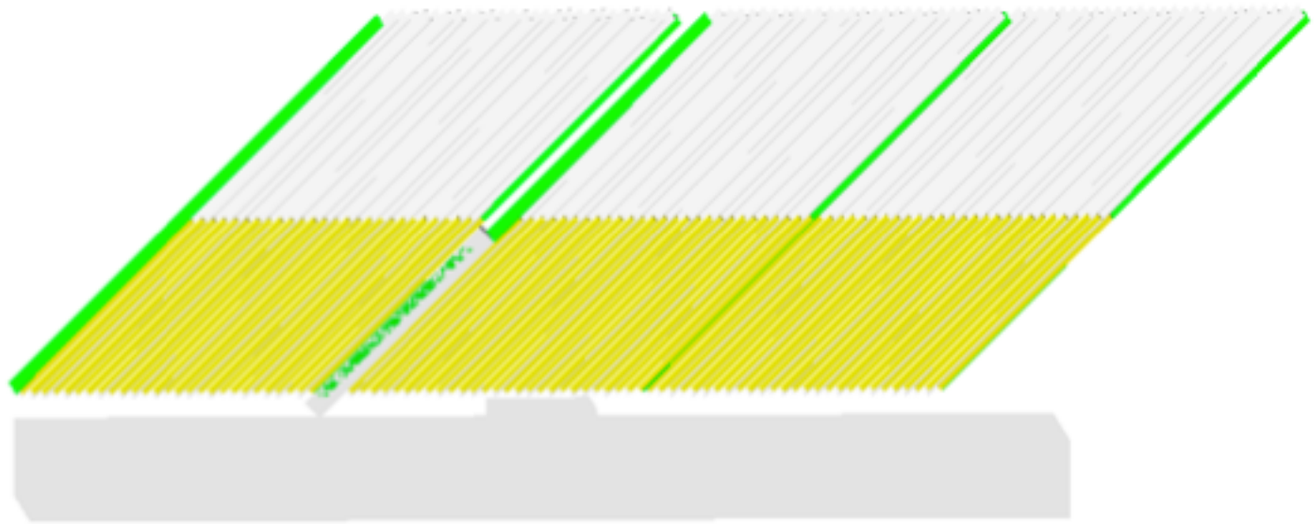


Detector

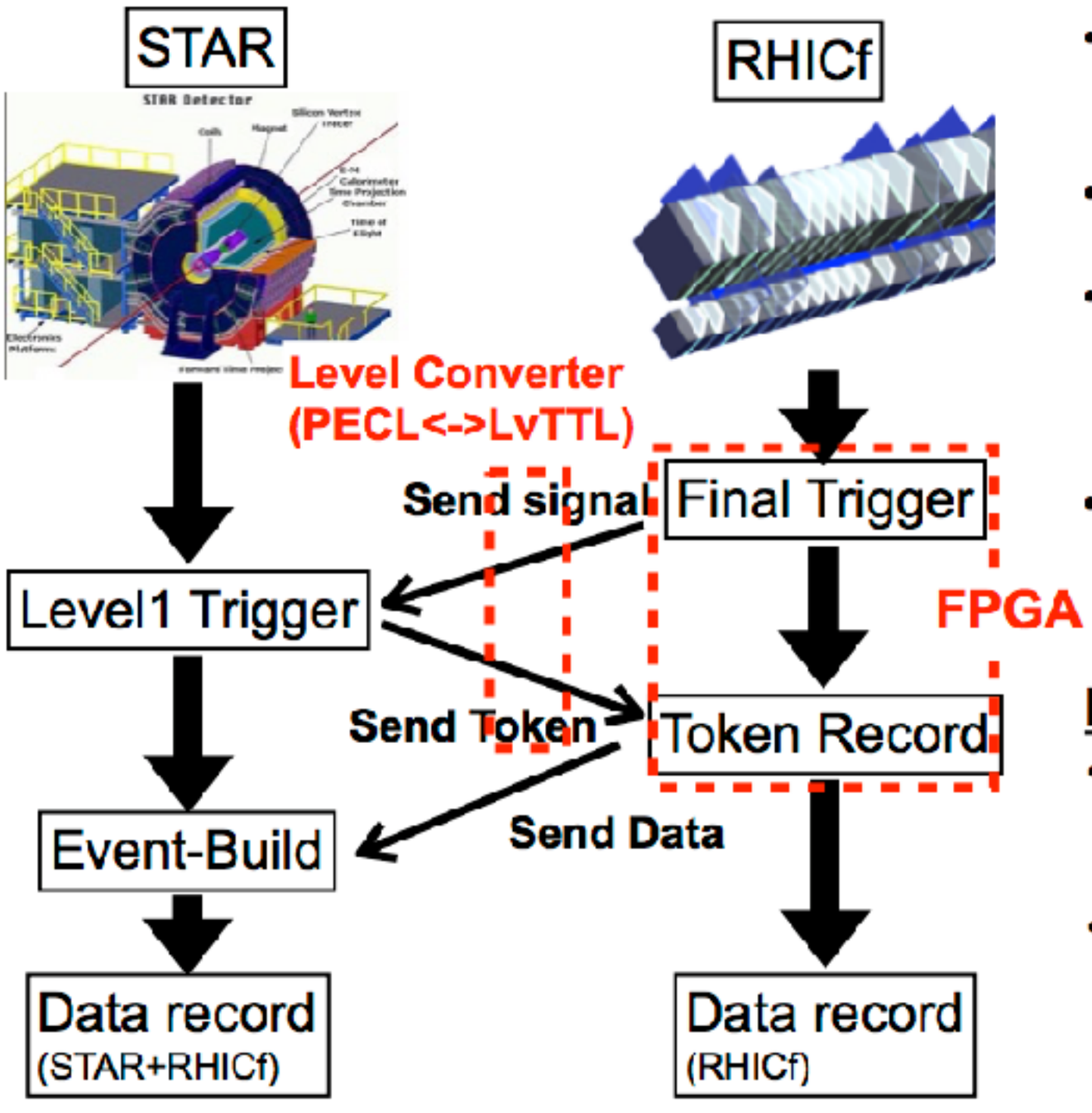
- ZDC&SMD : Hadron calorimeter with 5.1 λ_I & 153 X_0 (3 modules)
  - Energy resolution : σ_E/E ~ 20% at 100GeV incident neutron
  - Position resolution : ~ 1cm

- RHICf : EM calorimeter with 1.7 λ_I & 44 X_0
  - Energy resolution : $(\sigma_E/E)_\gamma$ ~ 5% and $(\sigma_E/E)_n$ ~40%
  - Position resolution : ~ 1mm





Data taking



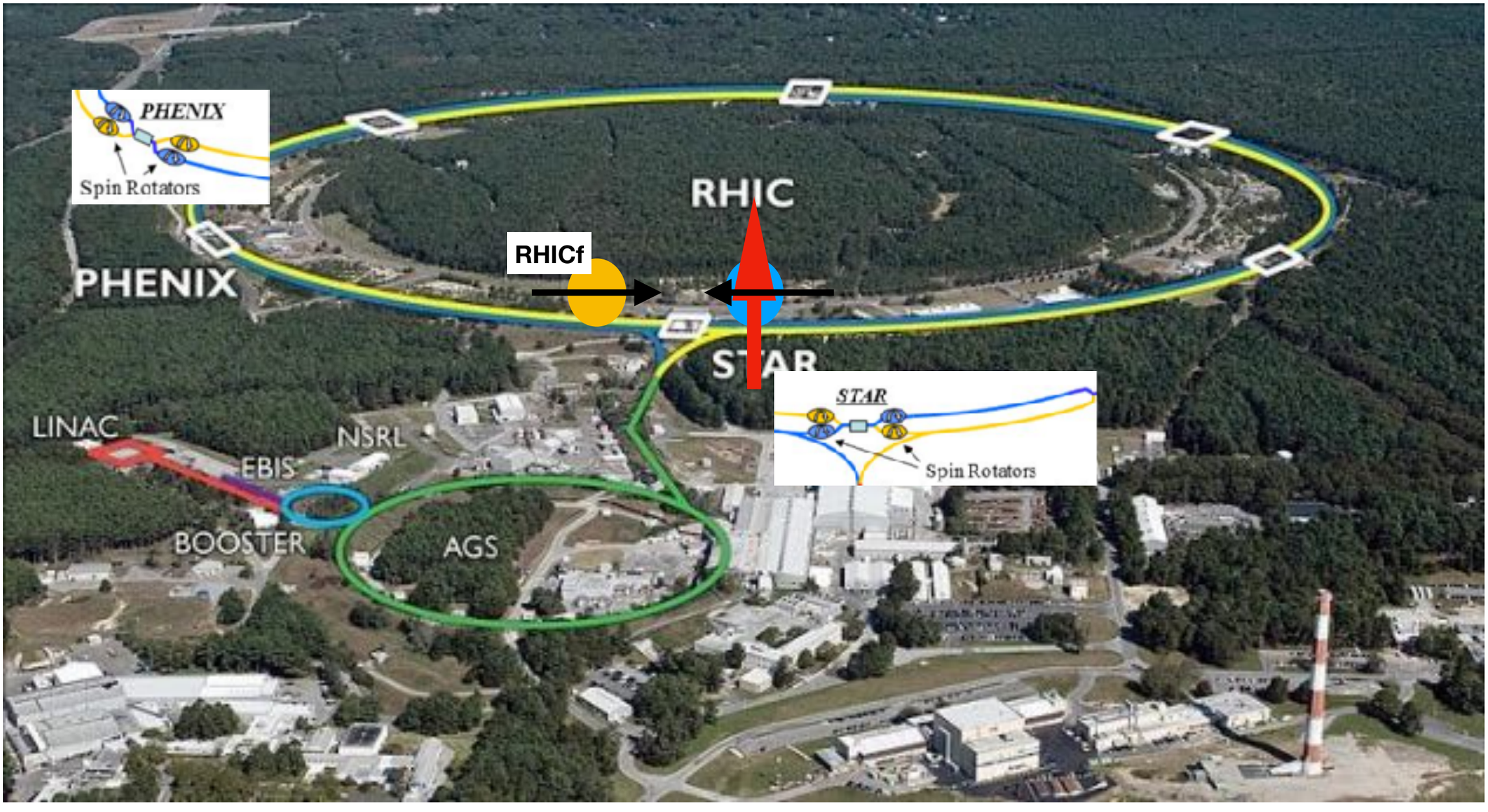
- RHICf send all final trigger signals to STAR DAQ including pedestal triggers.
- STAR issues a Event-ID: Token (12 bits) for each L1 triggers
- RHICf records the Token+DAQ commands (20 bits in total) and send data with the Token via network.
- STAR makes event-build and records into a disk.

Hardware setup

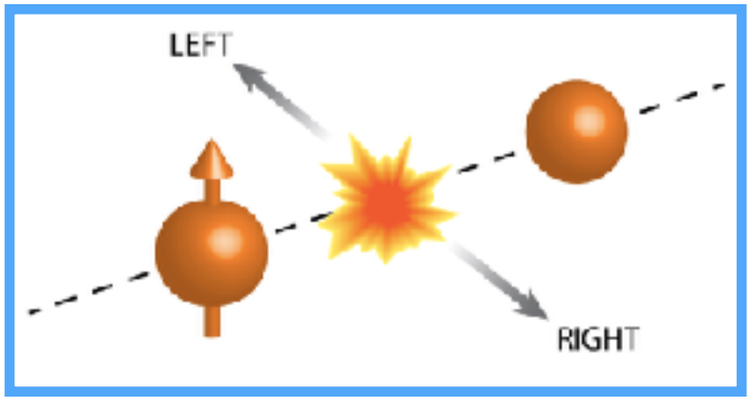
- FPGA boards managed both sending trigger and recording Token.
- A level converter converts the signal level PECL <-> LvTTL.

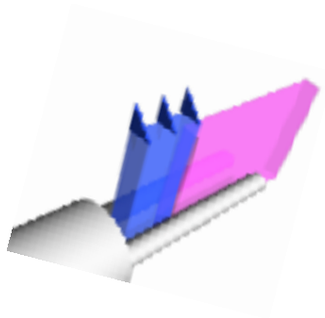
RHIC(Relativistic Heavy Ion Collider)

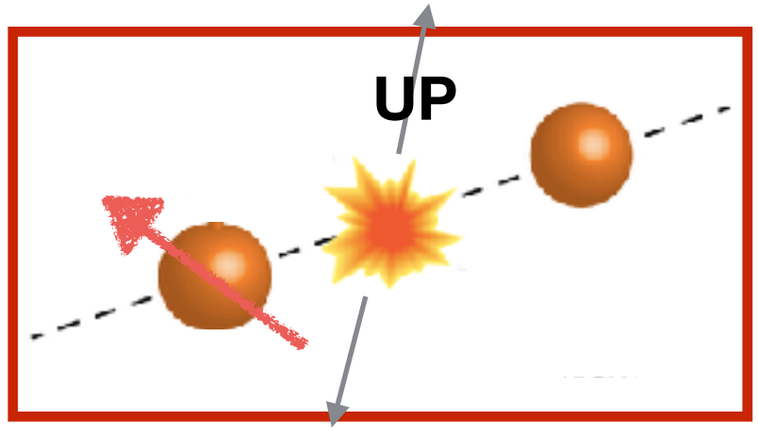
- World 1st high energy polarized beam collider

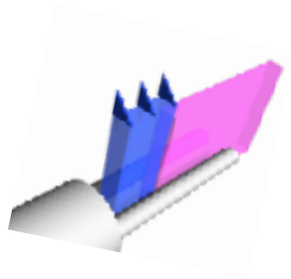


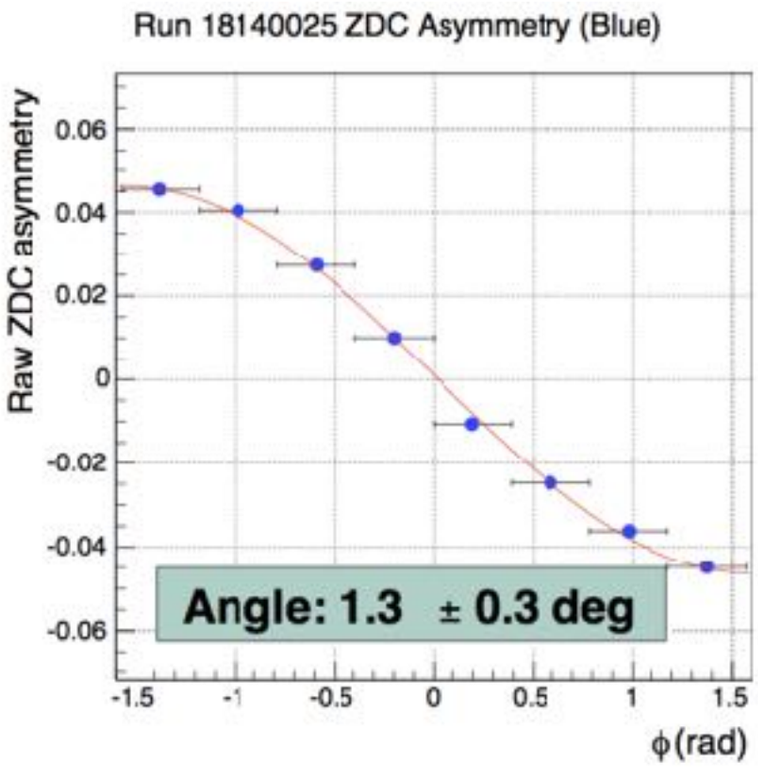
Radial Polarized beam

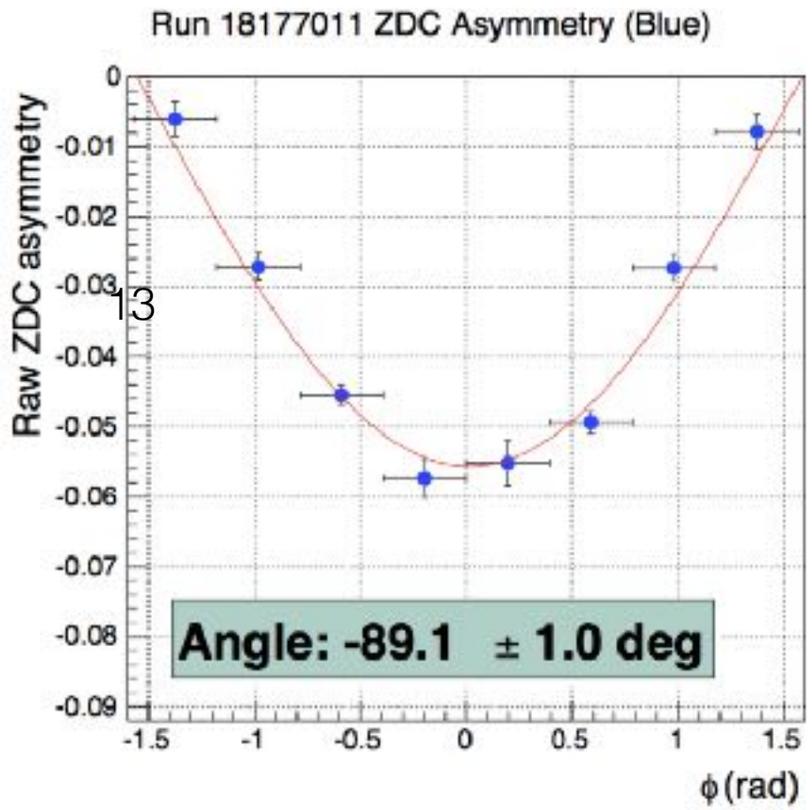












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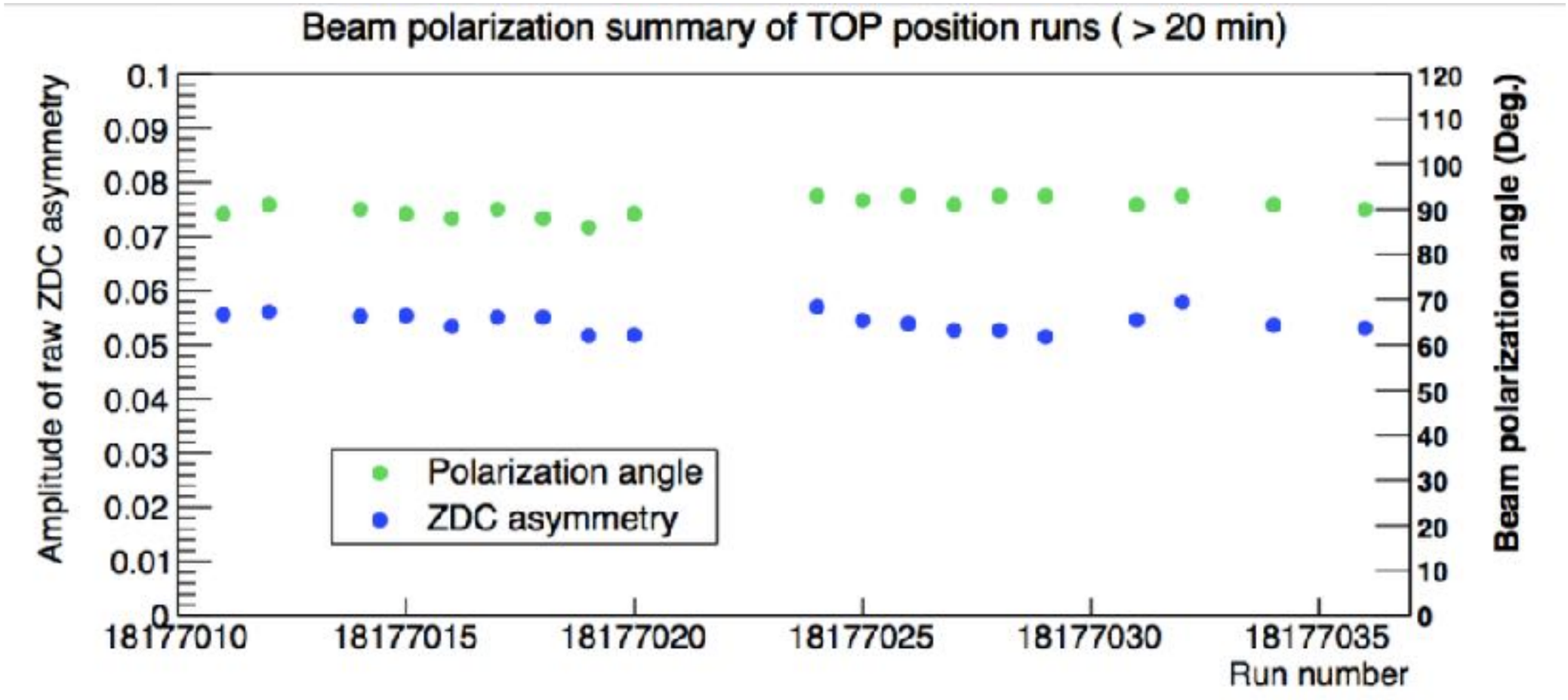
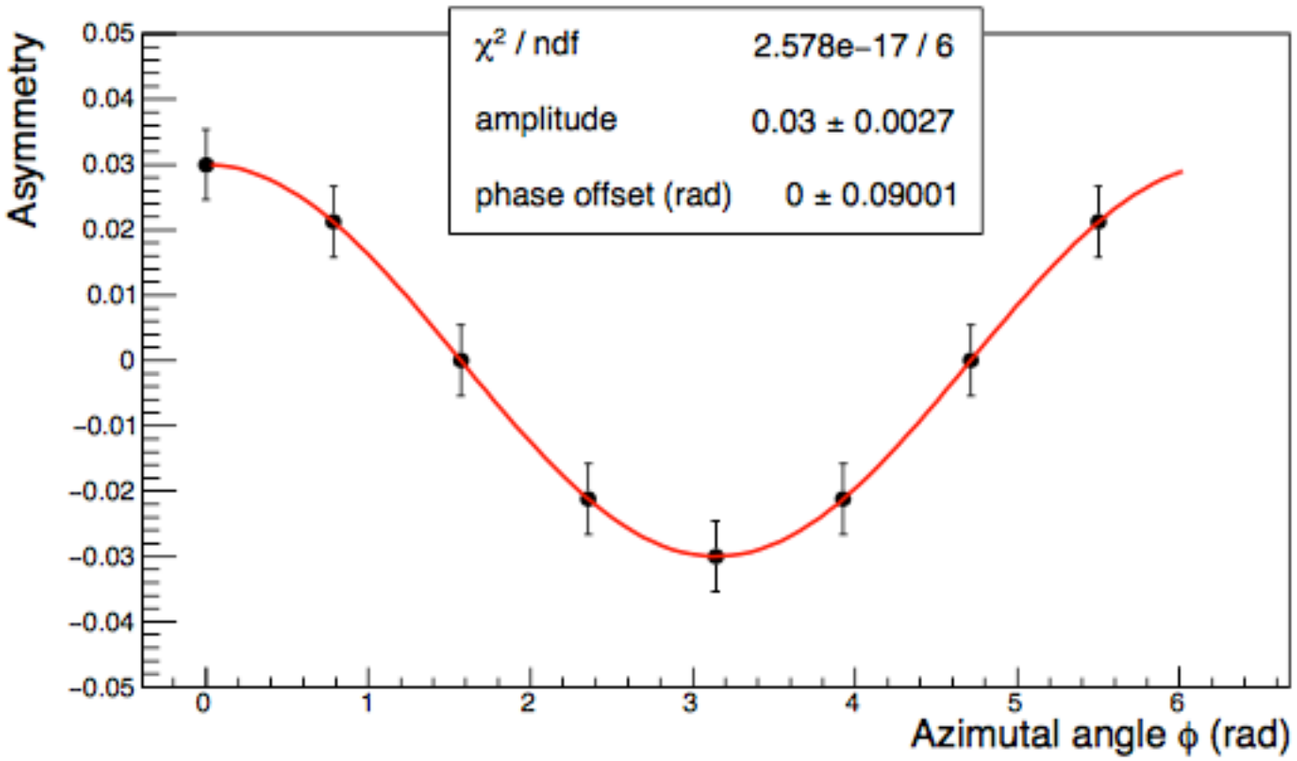
Radial Polarized beam



Comparison with proposal

- Estimates for AN measurement in proposal



detector is at the position-1. Number of neutrons observed in the 3 mm<r<8 mm ring region in the small calorimeter during 4 hours operation at the position-1 is 1.1×10^6. In this case δA=0.0019 is expected.

- Quick result value for number of neutron : ~7×10^5

Status of Analysis

- Current parameters of analysis tool are optimized for LHCf experiment.
- Studying MC simulation for optimization of RHICf
- Making full simulation for RHICf

Summary

- A_N is useful observable as tool in studying intrinsic nucleon structure

- In RHICf experiment, A_N over wider pT range with higher pT resolution can be measured. This will be used in figuring out interaction model in soft QCD range
  - neutron : $pT < 0.3$ & $pT > 0.6$ at $\sqrt{s}$=510GeV
  - pion : measurement in $3.1<\eta<3.7$ → measurement in $6<\eta$

- Common operation with STAR(ZDC, TPC, VPD and Romanpot)

- Comparing with experiment proposal, RHICf experiment is completed successfully.

- MC studies for optimization in analysis are under going

Backup

AN for forward π± and π0

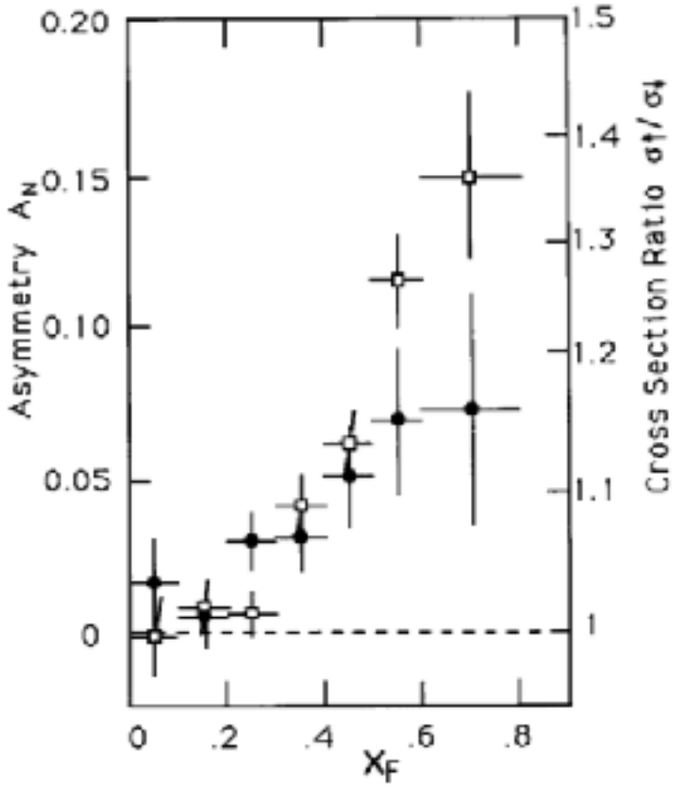


Fig. 3. The asymmetries A_N in the reactions $\bar{p}\uparrow+p\rightarrow\pi^0+X$ (closed circles) and $p\uparrow+p\rightarrow\pi^0+X$ (open squares, see ref. [1]) at 200 GeV in different regions of x_F, integrated over p_t from 0.5 to 2 GeV/c. The quantity $\sigma\uparrow/\sigma\downarrow$ is the ratio of the π^0 production cross sections for opposite beam spins.

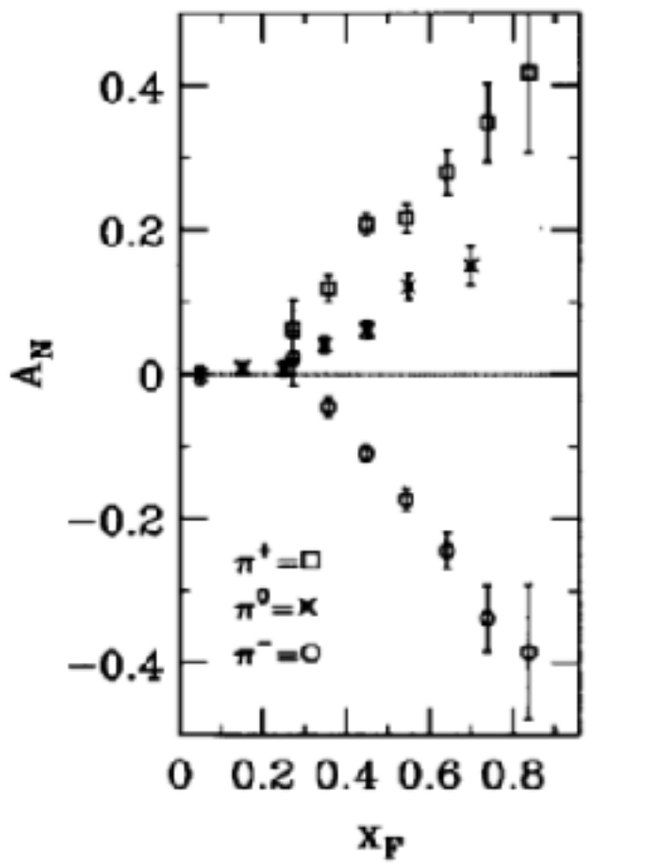


Fig. 4. A_N versus x_F for π^+, π^- and π^0 data.

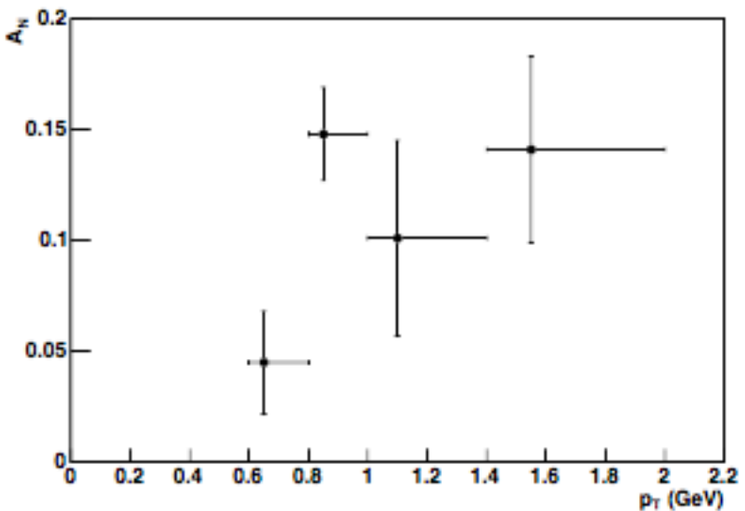
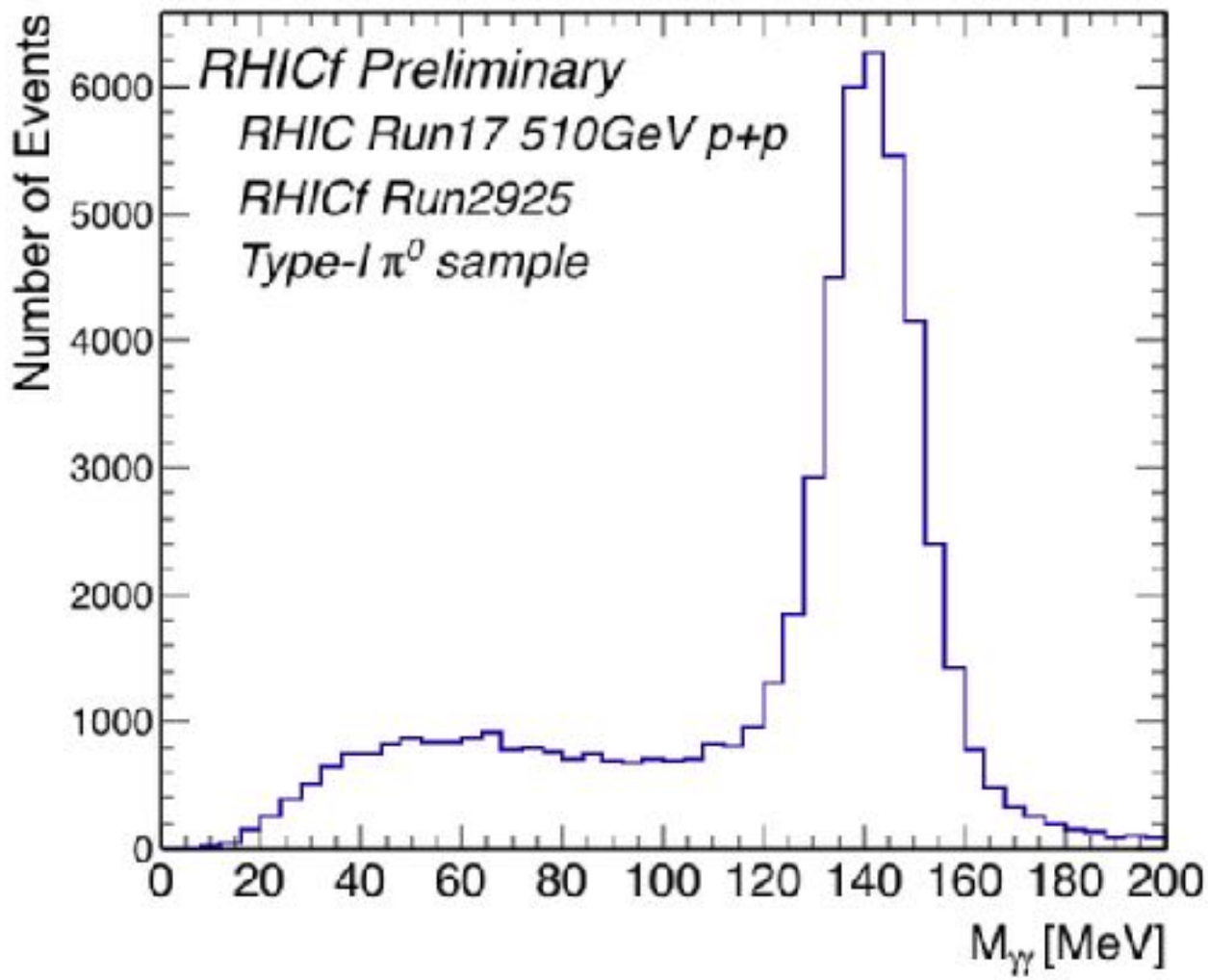
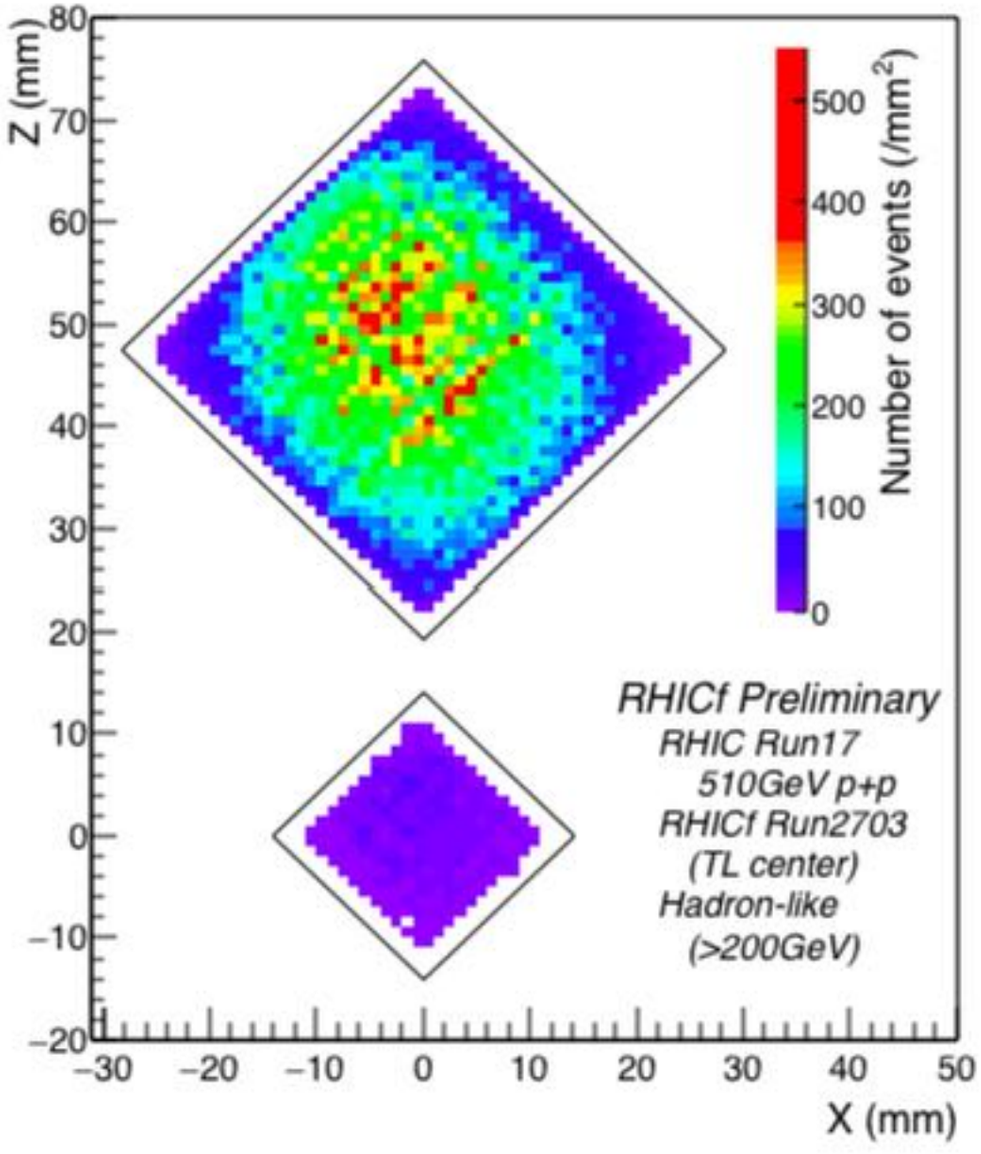


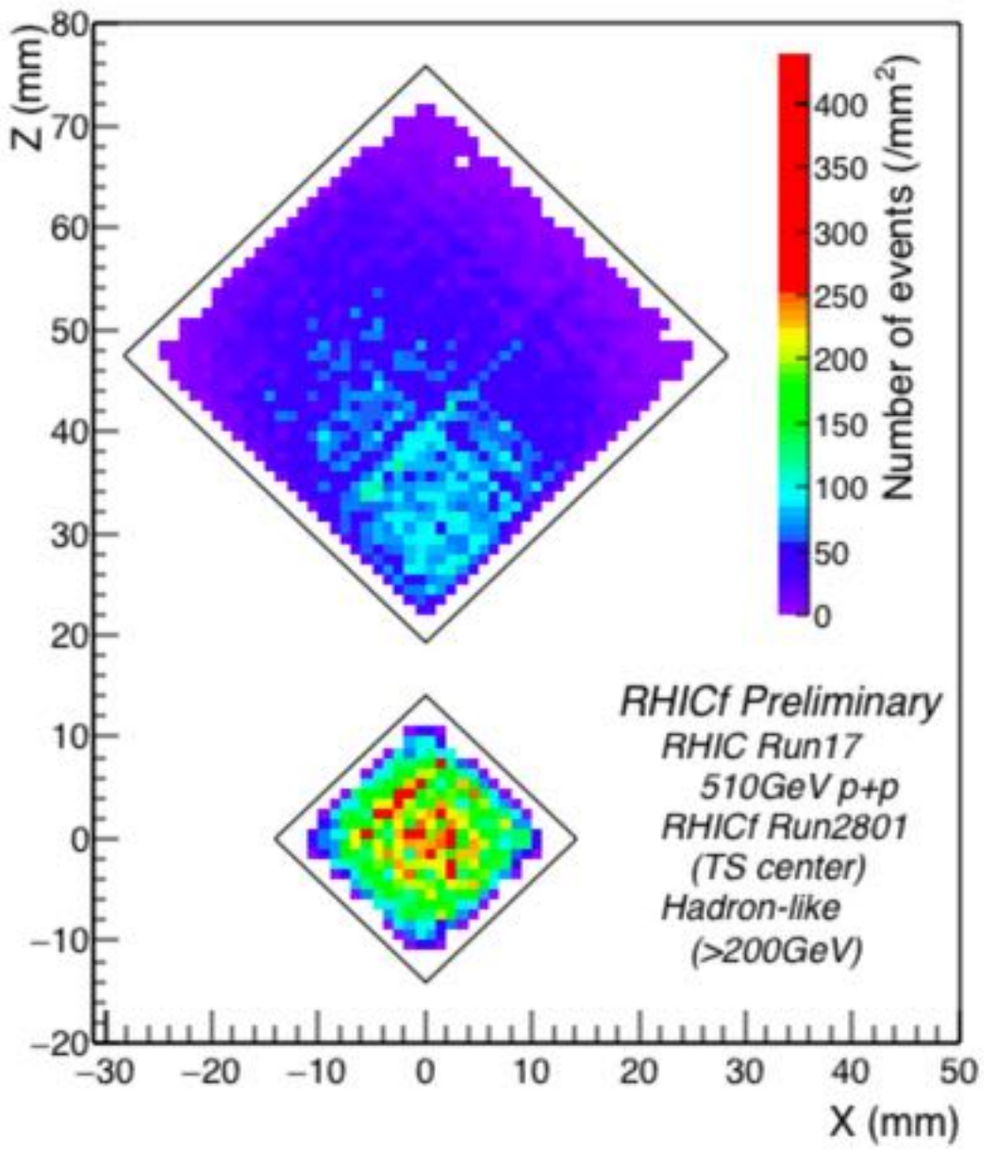
Figure 1.3: A_N *vs.* p_T for inclusive π^0 productions from polarized pp scattering in $\sqrt{s}$=19.4 GeV. The data is shown for $0.5< x_F <0.8$. [26]

Quick result(reconstructed π0 mass)

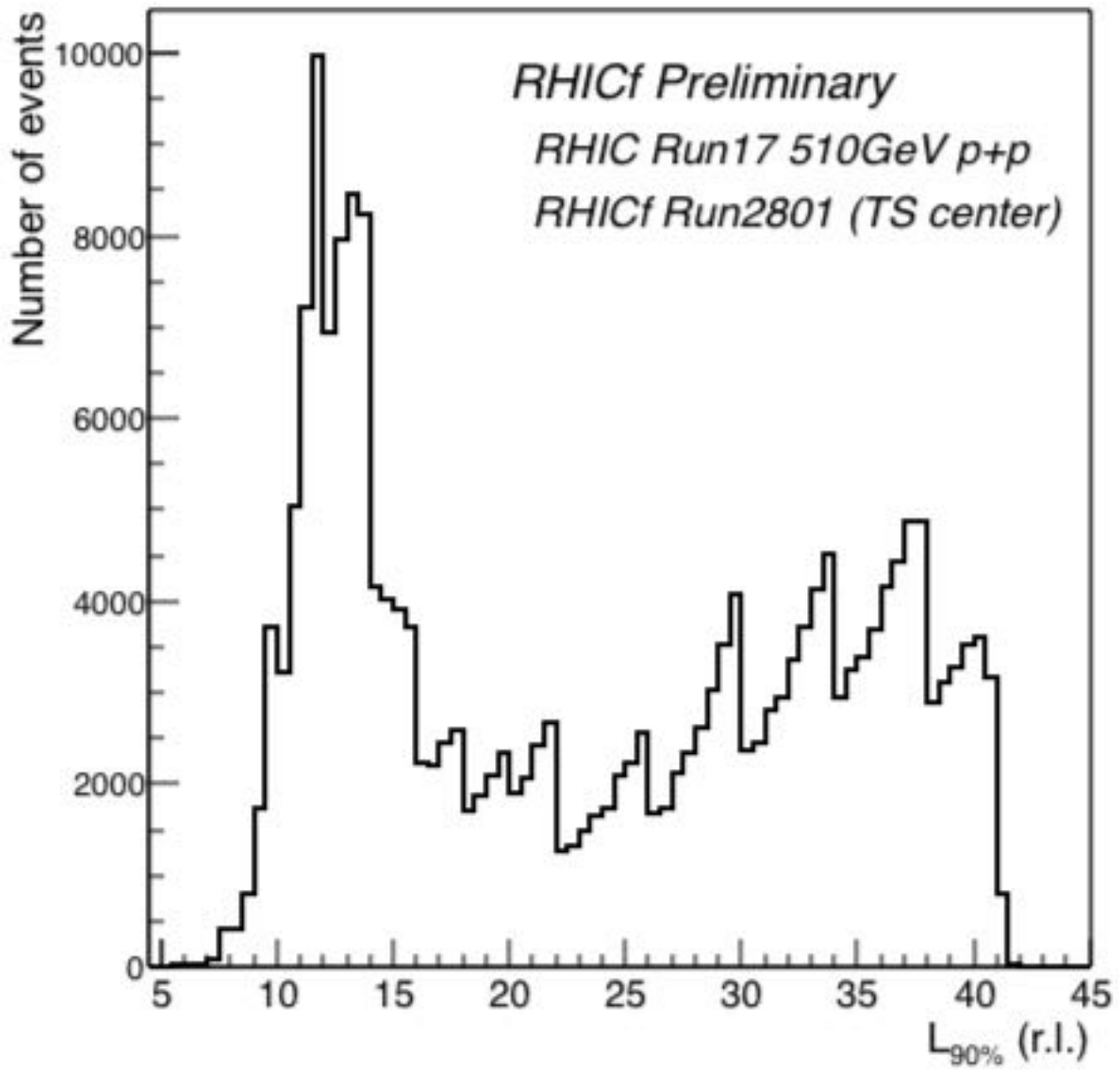


Quick result(Hits map for beam center)

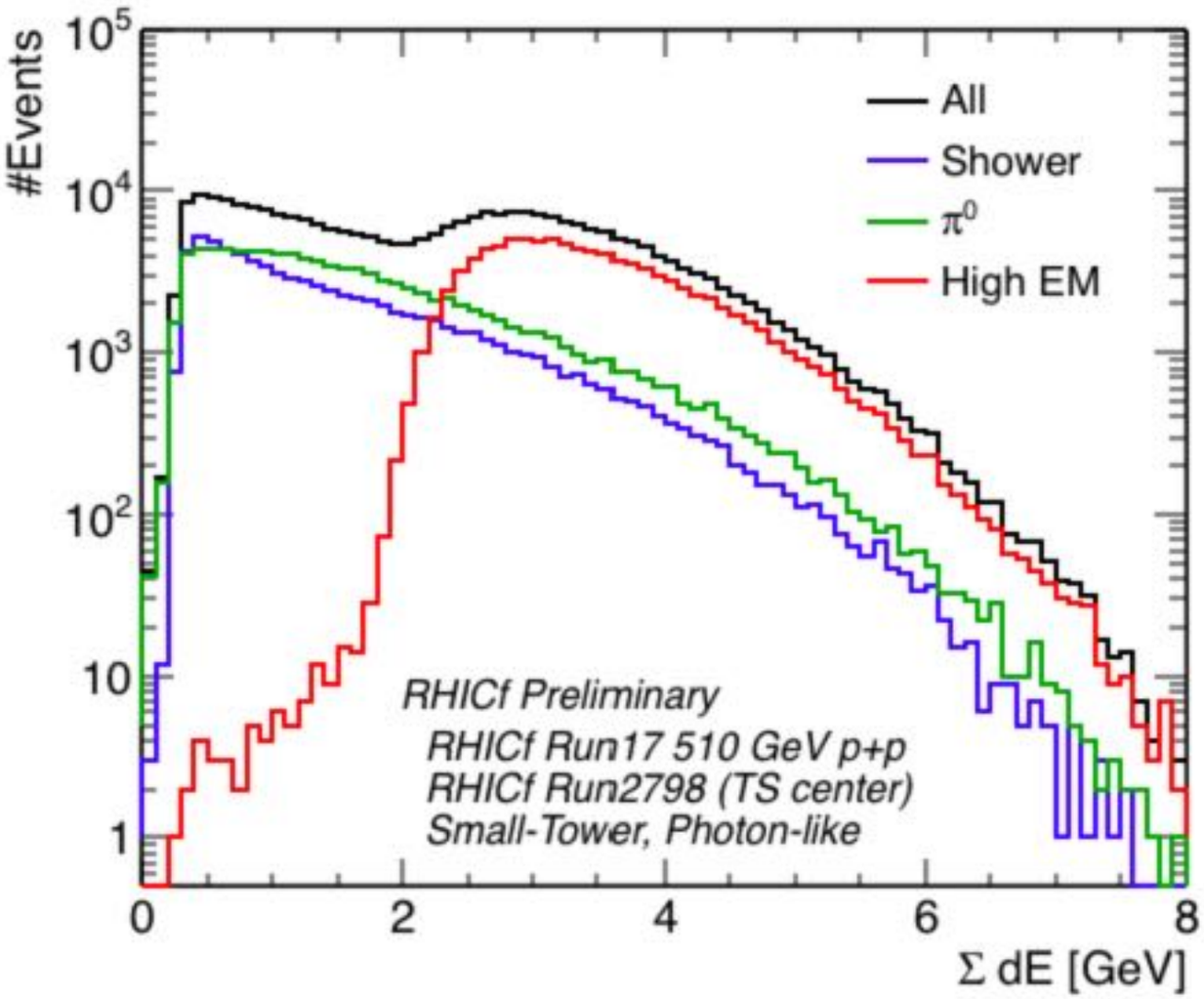


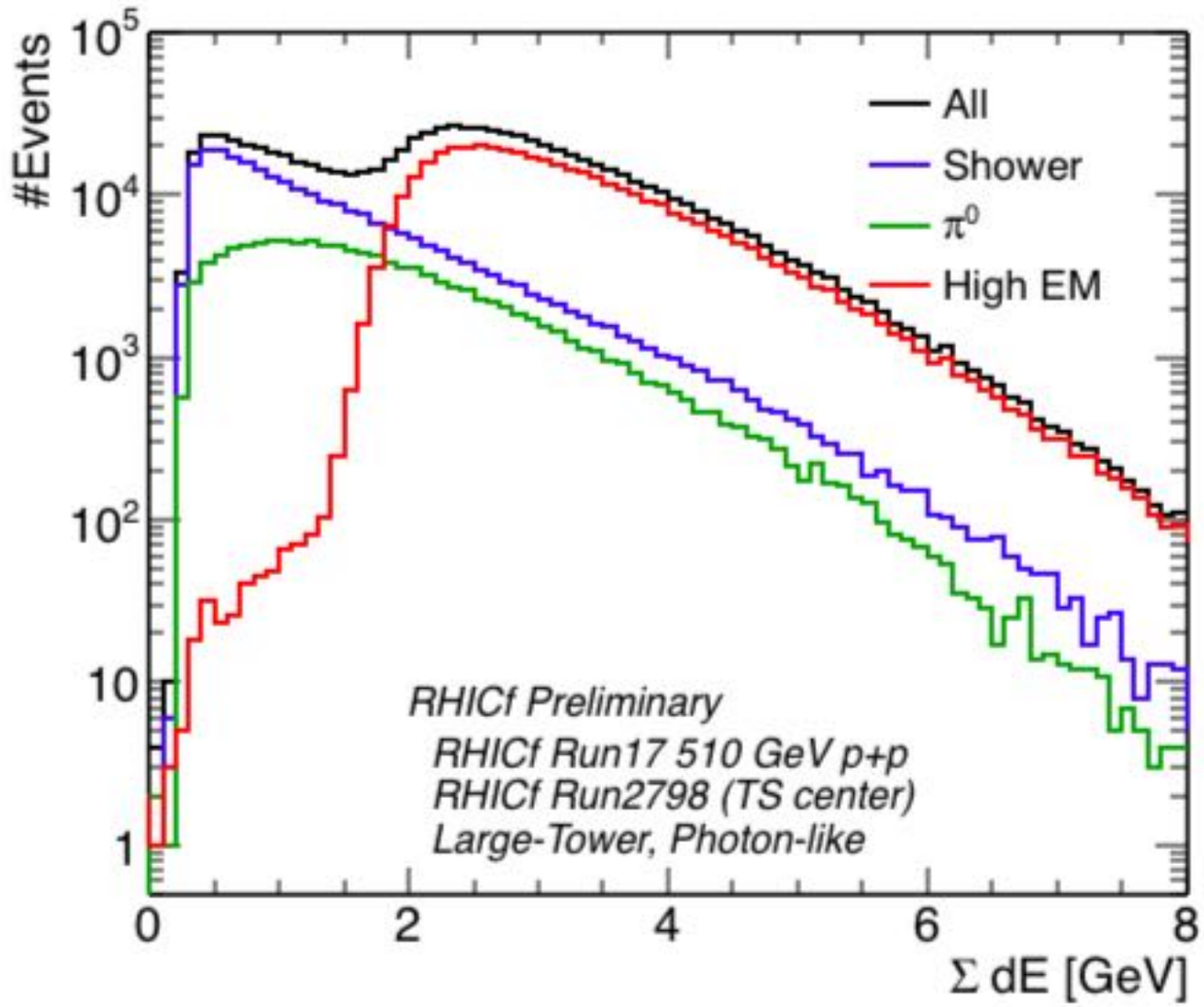


Quick result

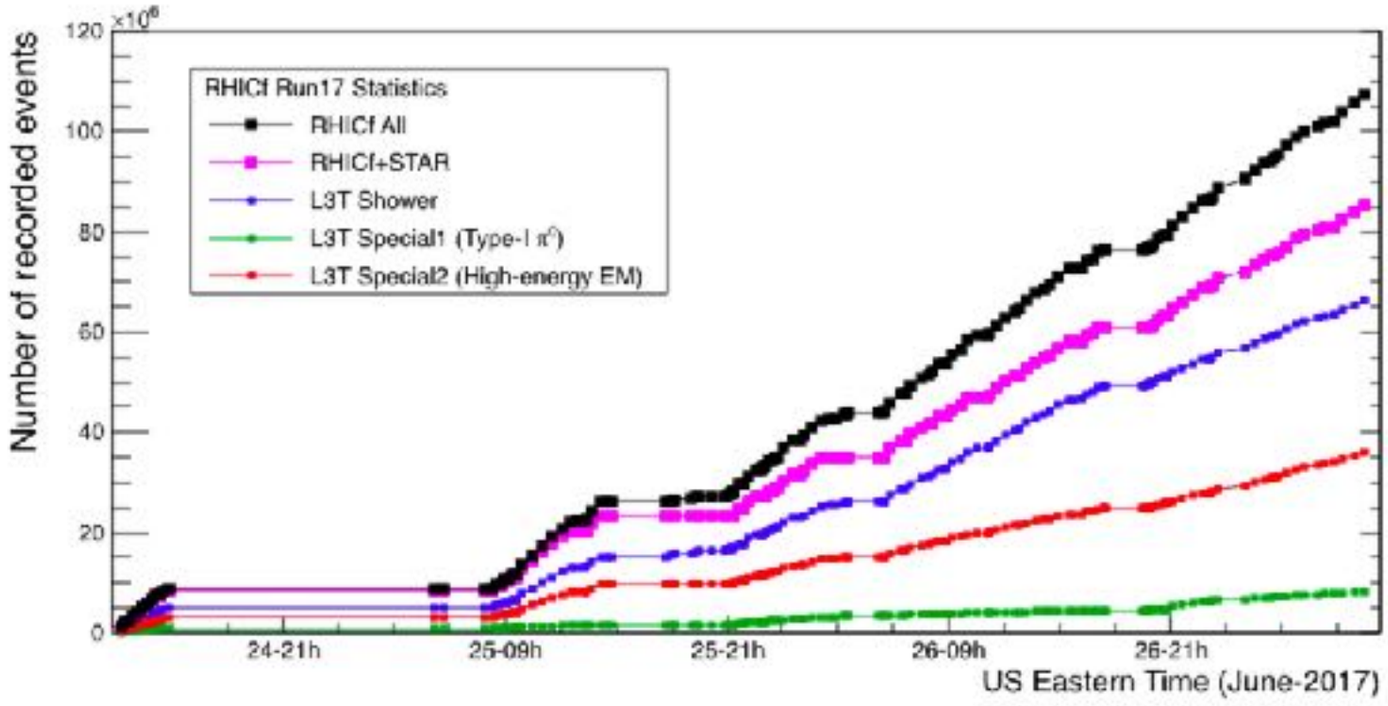


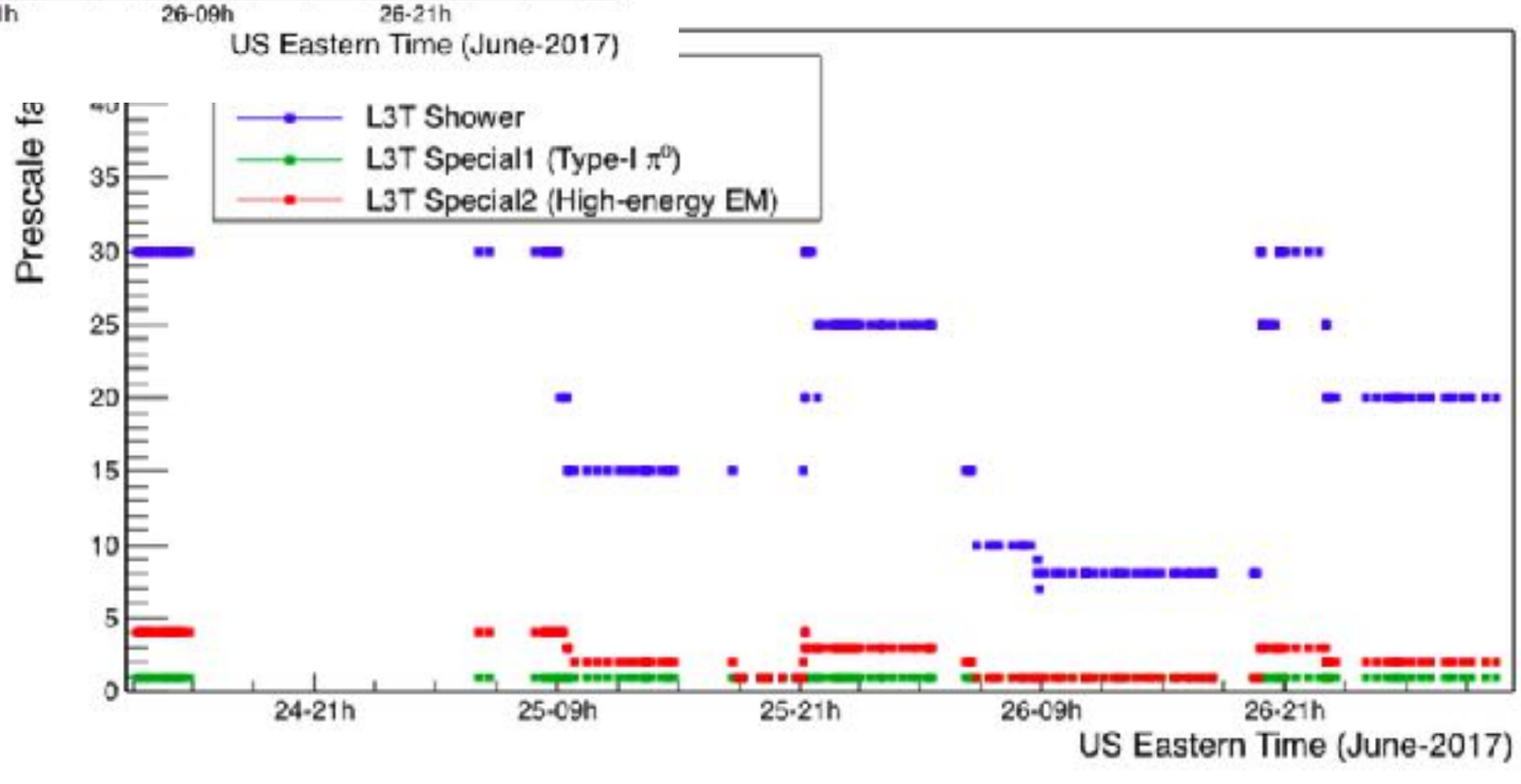
Quick result(Recorded event#)





Quick result(Statistics in various trigger)





Quick result(Event# of RHICf vs of STAR)