RHICf: RUN17 Operation and Status of Analysis

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for the RHICf Collaboration

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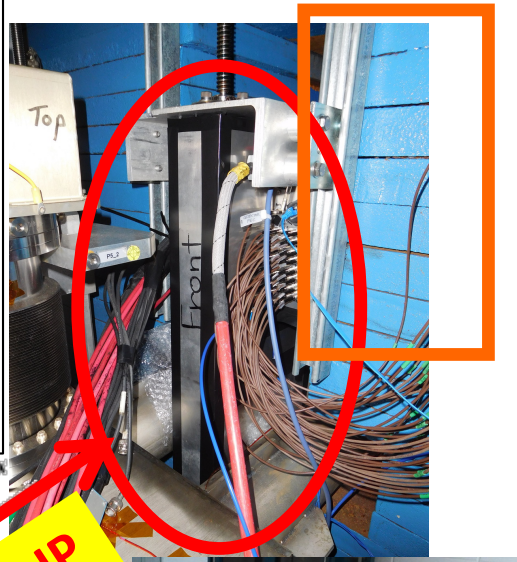
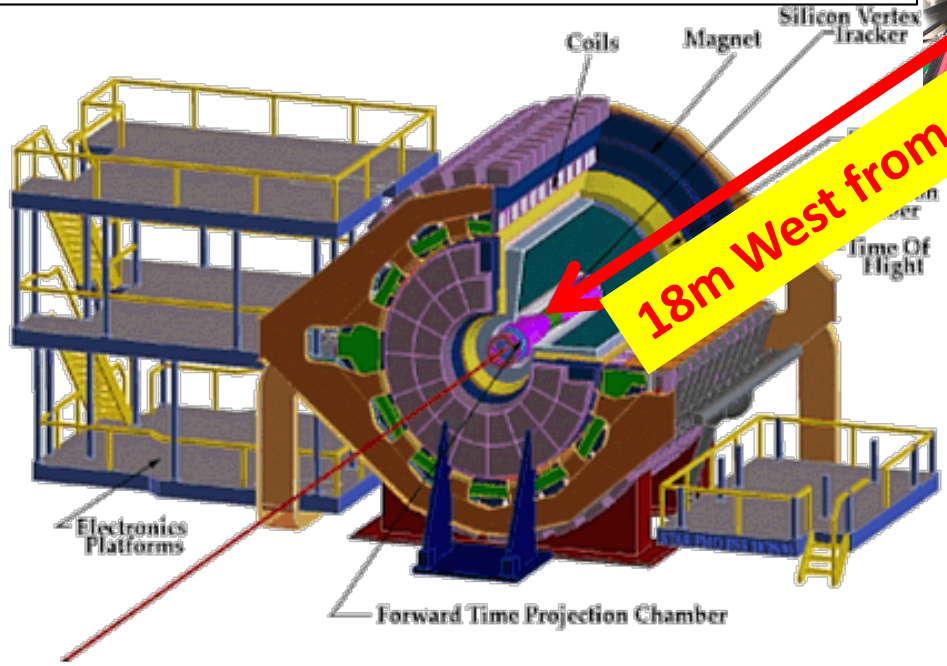
RHIC forward (RHICf) is …
a kind of Zero degree calorimeters @STAR interaction point

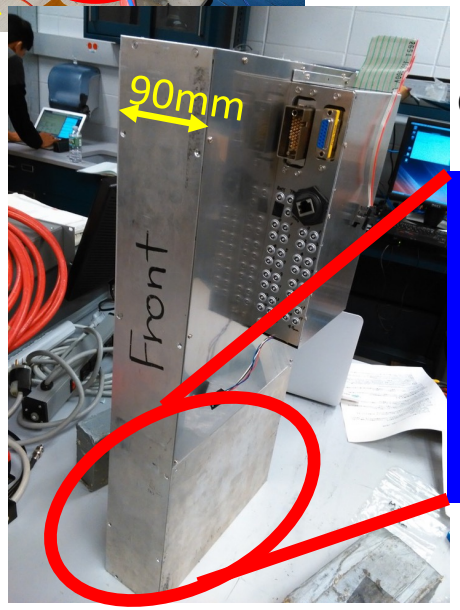
RHICf detector
- Former LHCf Arm1 detector used at LHC
- Two compact sampling calorimeters
- 44 r.l. (1.7 hadron interaction lengths)
- <5% and 40% energy resolutions for EM and hadronic showers, respectively
- <0.2mm and <1mm position resolutions for EM and hadronic showers, respectively



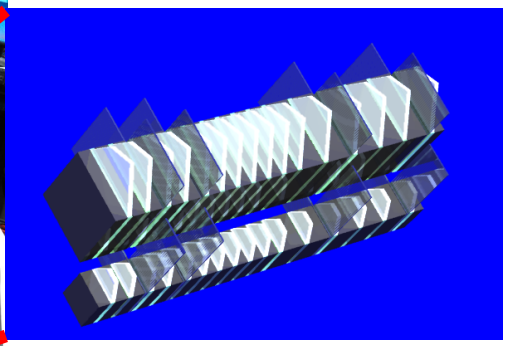
(traditional) Zero Degree Calorimeter behind RHICf



18m West from IP

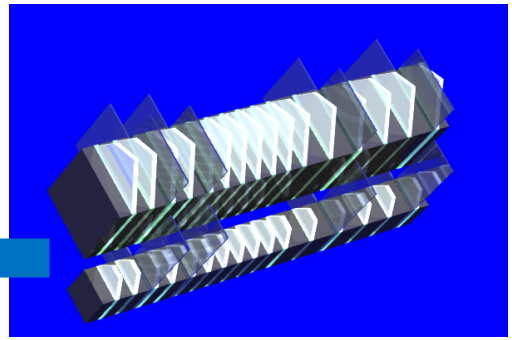


Compact double calorimeters
(20mmx20mm and 40mmx40mm)

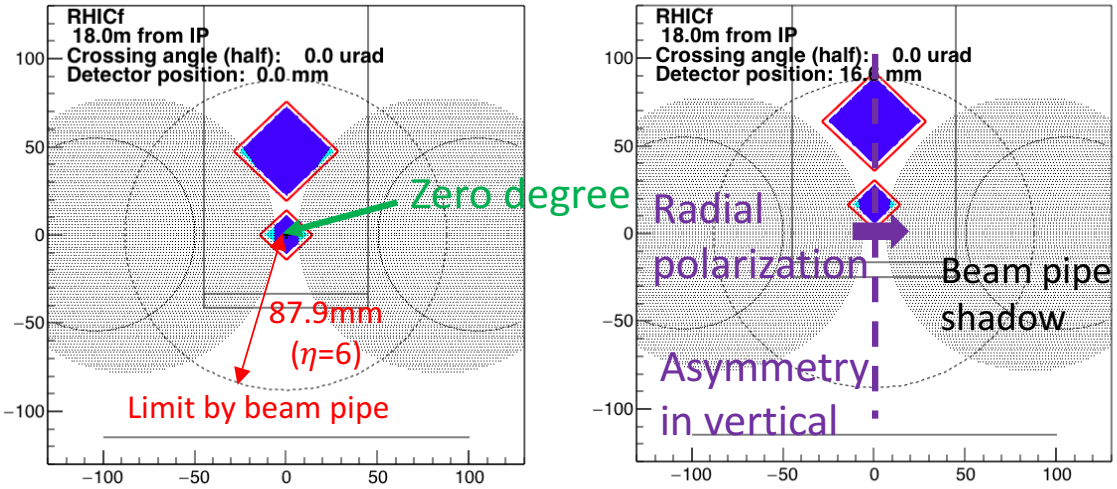


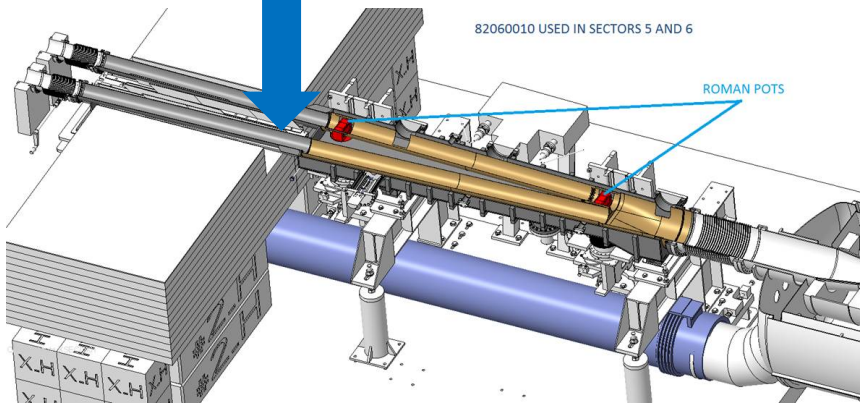
RHICf detector acceptance

Compact double calorimeters
(20mmx20mm and 40mmx40mm)

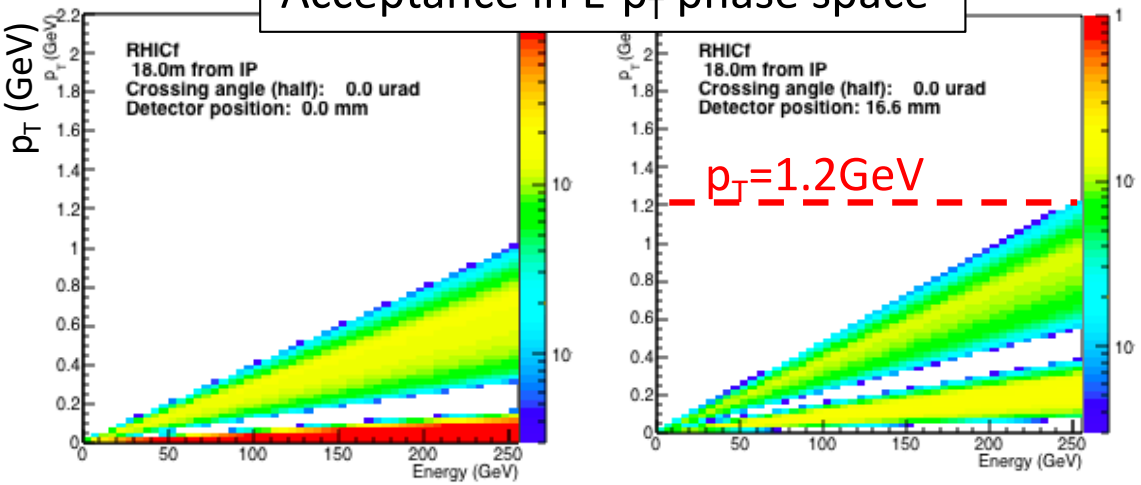


Cross section view from IP





Acceptance in E-p_T phase space

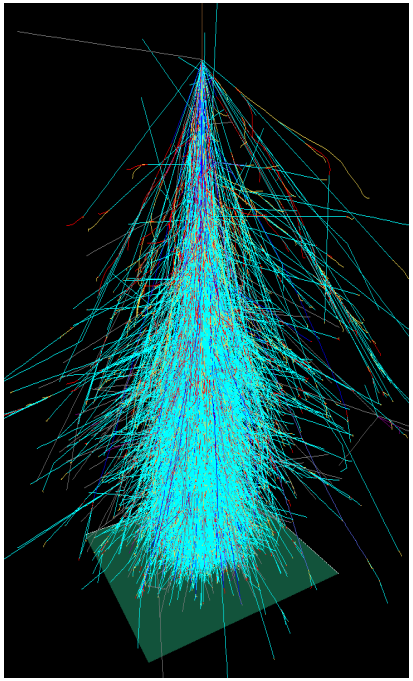


- ✓ Neutral particles, photons (including $\pi^0 \rightarrow 2\gamma$) and neutrons, are observed
- ✓ Widest and gapless coverage by moving the detector in vertical
- ✓ Radially polarized beams maximized asymmetry in the vertical direction

Physics Goals

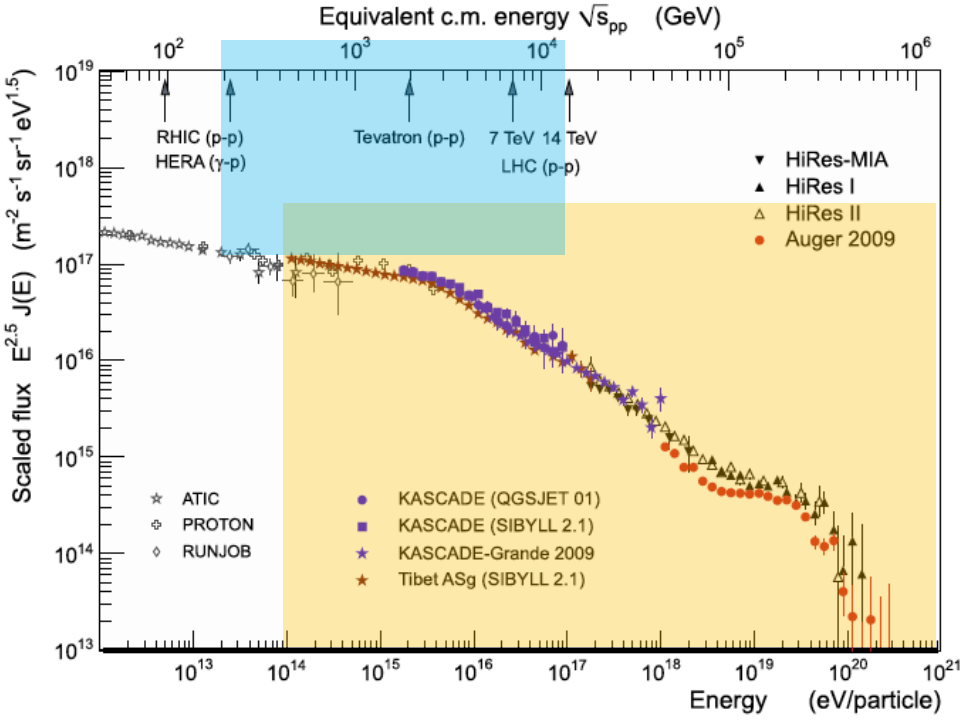
1. Cross section measurements for cosmic-ray physics
   - RHICf energy corresponds to 1.4×10^{14}eV CR
   - √s scaling will be tested with LHCf data at 10^{17}eV
2. Single-spin asymmetry measurement in transversely polarized proton-proton collisions
   - Asymmetry discovered by the RHIC experiments will be precisely measured
   - Thanks to excellent position resolution of RHICf, coverage in p_T will increase

CR air shower and √s dependence



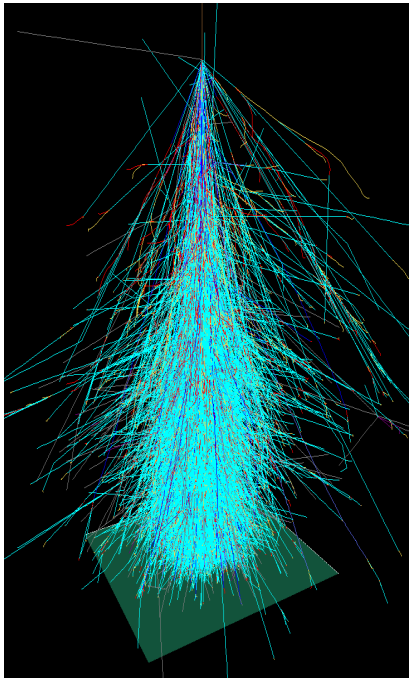
- Hadronic interaction and forward particle production is important to understand the air shower analyses

Covered by RHIC and LHC



Measured by atmospheric air shower

CR air shower and √s dependence

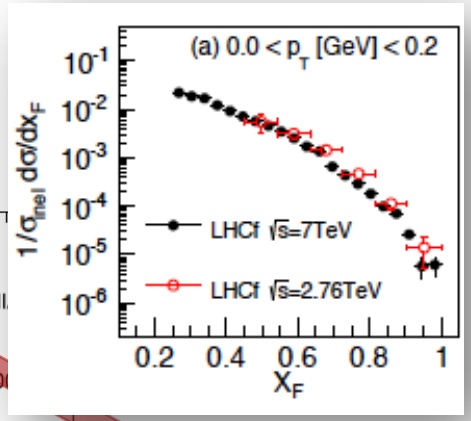


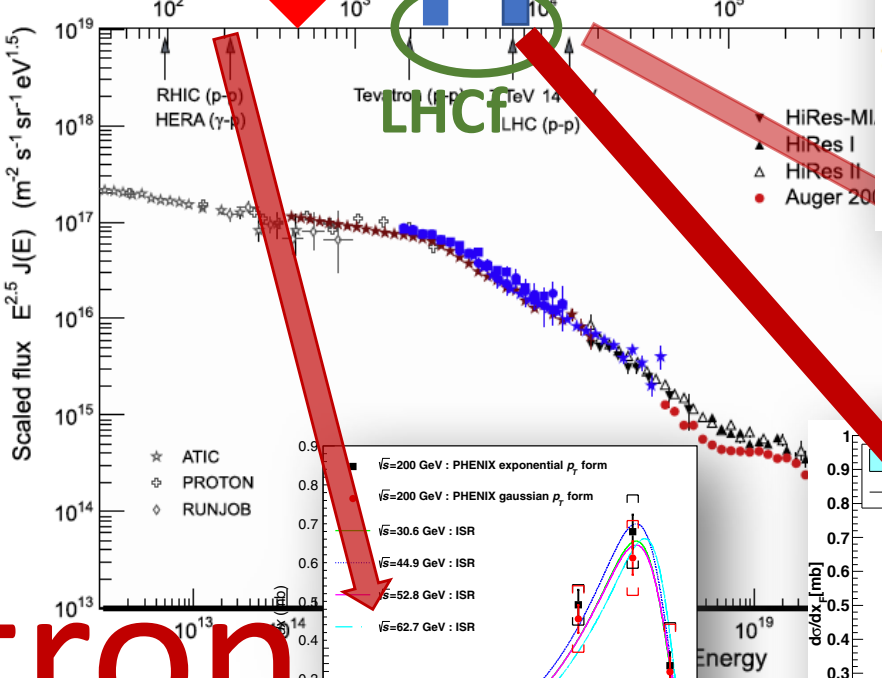
LHCf 2.76TeV and 7TeV data shows √s scaling of ***forward π^0***

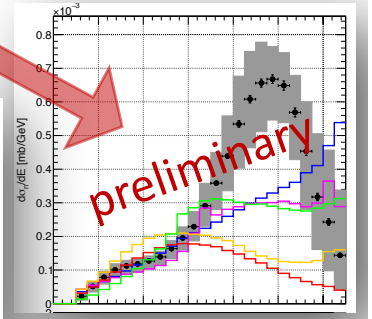
π^0

RHICf

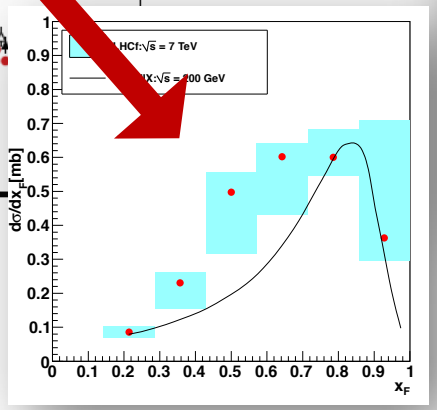
LHCf





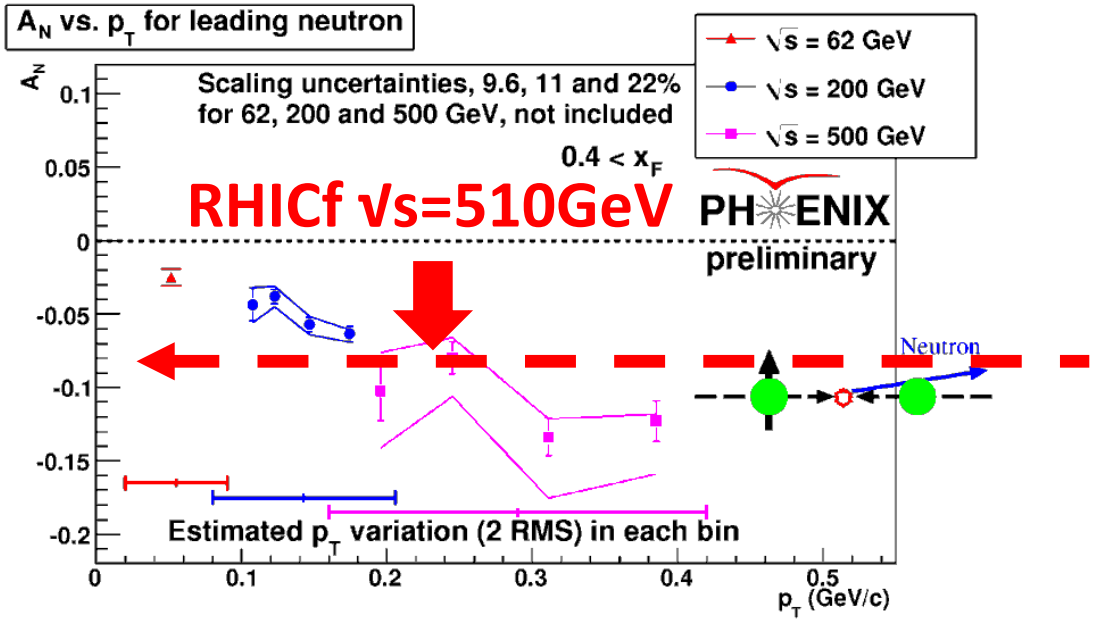


neutron

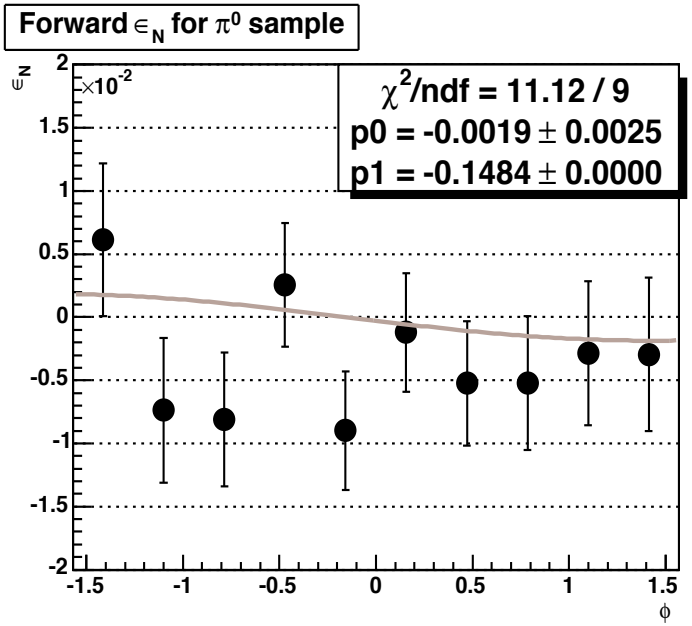


ISR (30-60GeV), PHENIX (200GeV) and LHCf (7-13TeV) data can test √s scaling of ***forward neutrons***

SSA of forward particle production



Neutron asymmetry by PHENIX



π^0 asymmetry RHIC-IP12 √s=200GeV

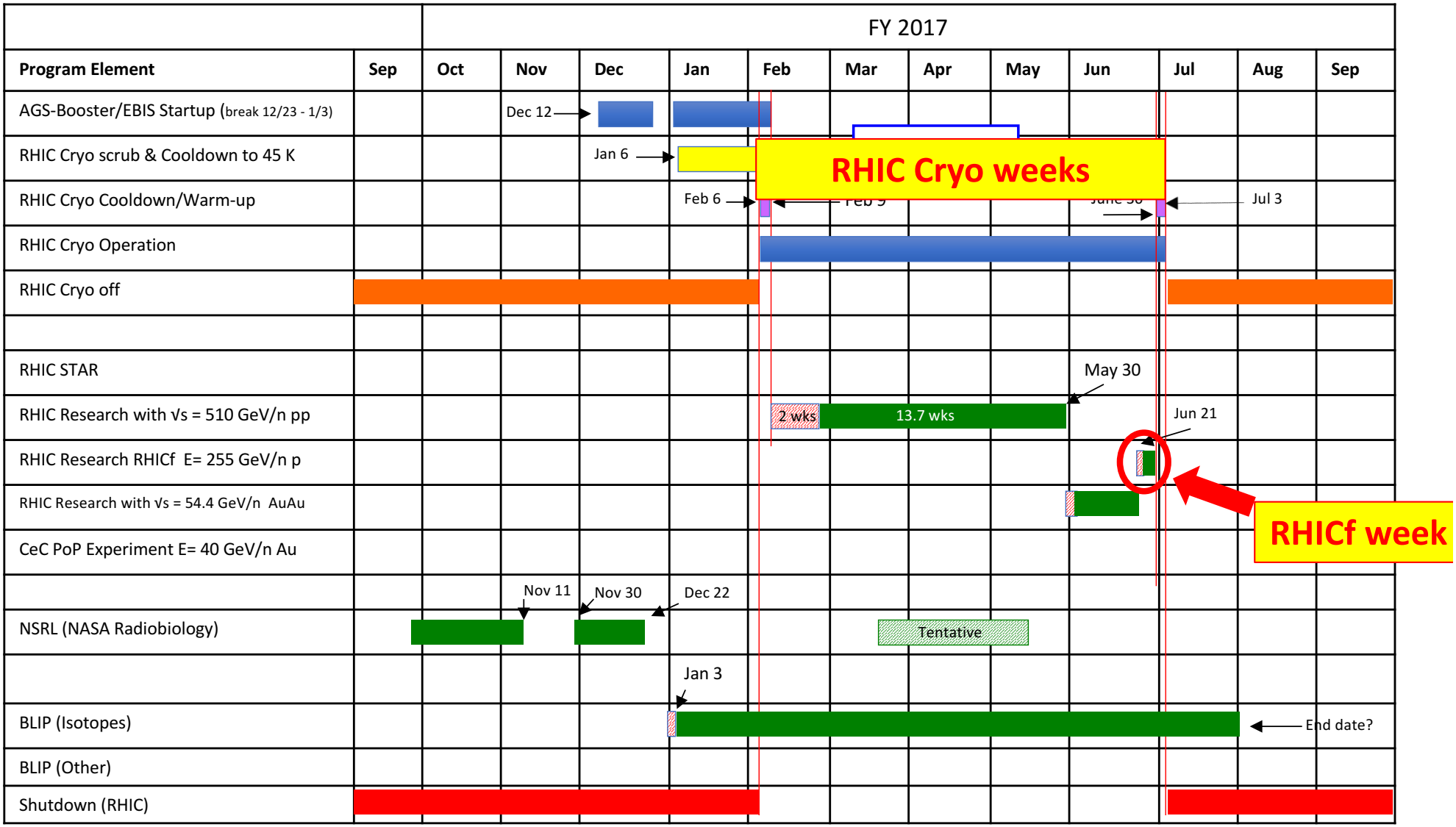
(A_N= -0.024 ± 0.031)

M. Togawa, PhD thesis (2008)

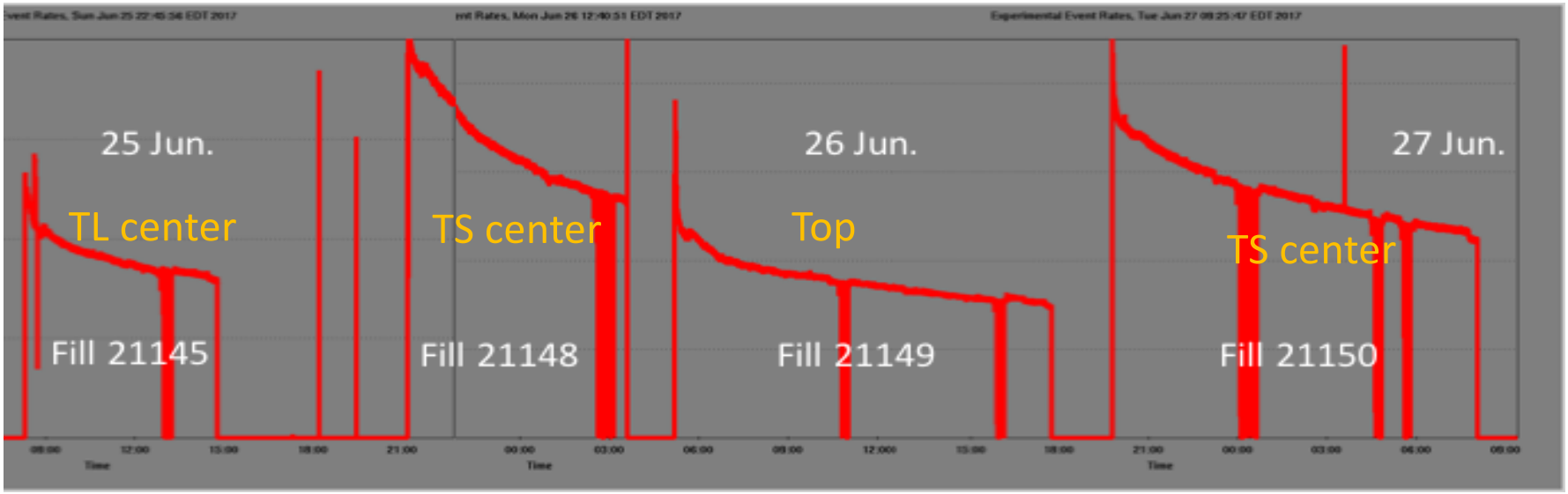
1. Wider pT coverage with a single √s
2. First detection (or stricter upper limit) of forward π^0 asymmetry

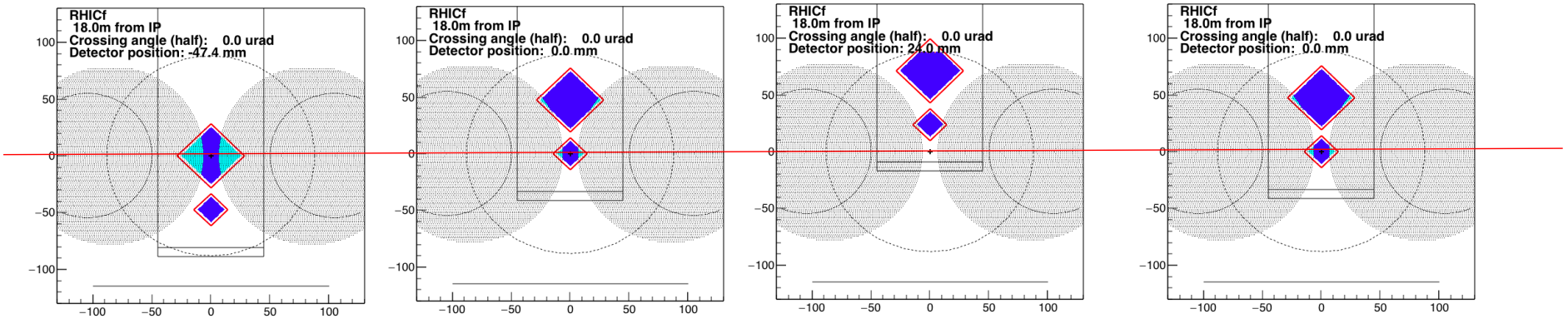
C-A Operations FY17

May 8, 2017



Collision rates in RHICf days



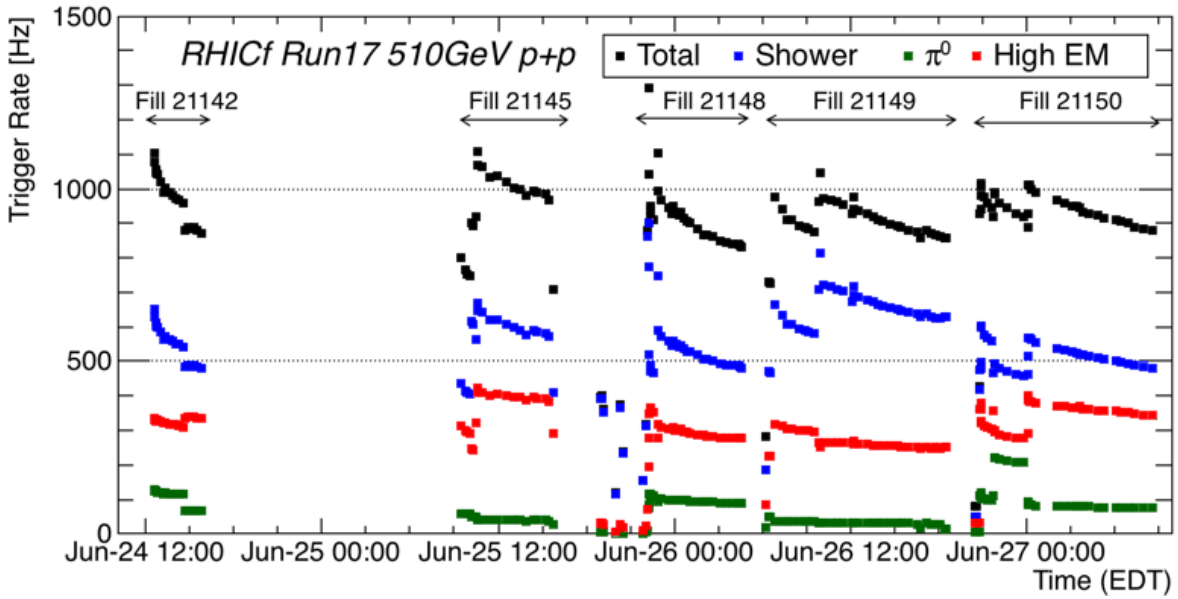


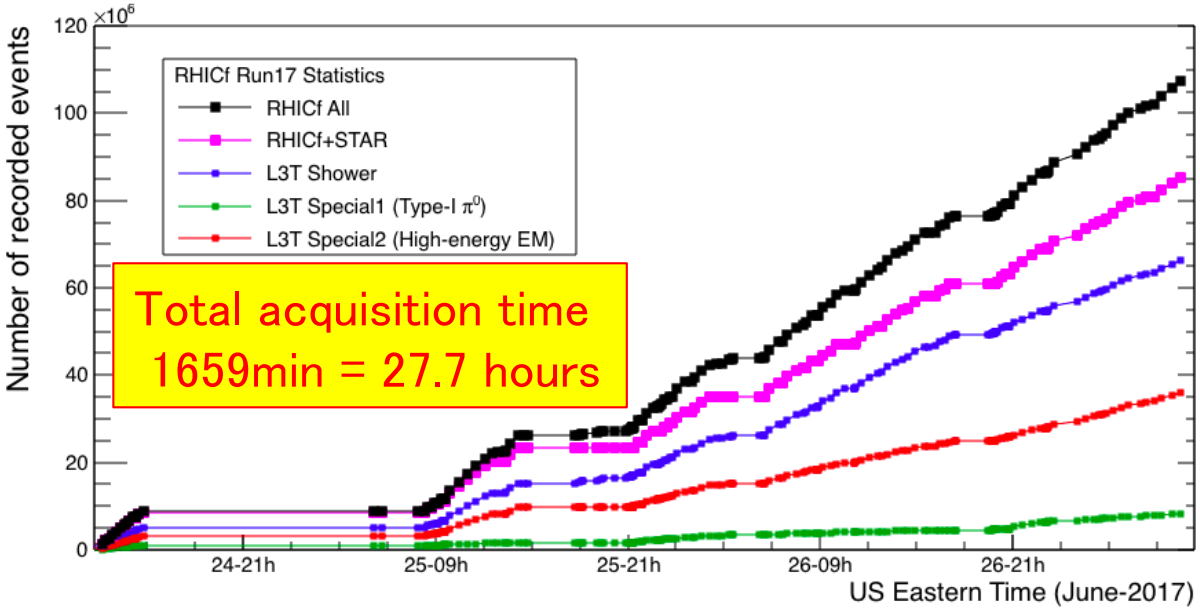
- Higher β^* (=8m) than usual RHIC operation
- Radial polarization (usually vertical) to maximize the single-spin asymmetry in vertical
- Luminosity~10^{31} $cm^{-2}s^{-1}$

Quick look（statistics）

RHICf DAQ rate

- Max rate was limited ~1kHz
- High rate events were prescaled
- Low rate events were enhanced with special triggers
- Prescale factors were optimized from time to time





Total : 110M events

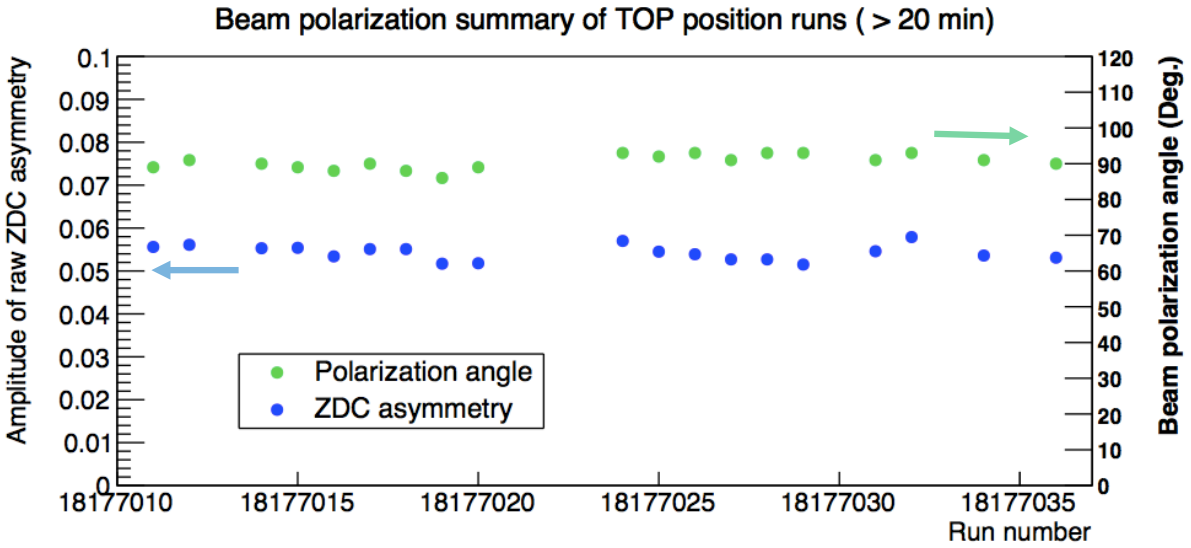
RHICf+STAR

RHICf (shower event)

RHICf (High-energy EM trigger)

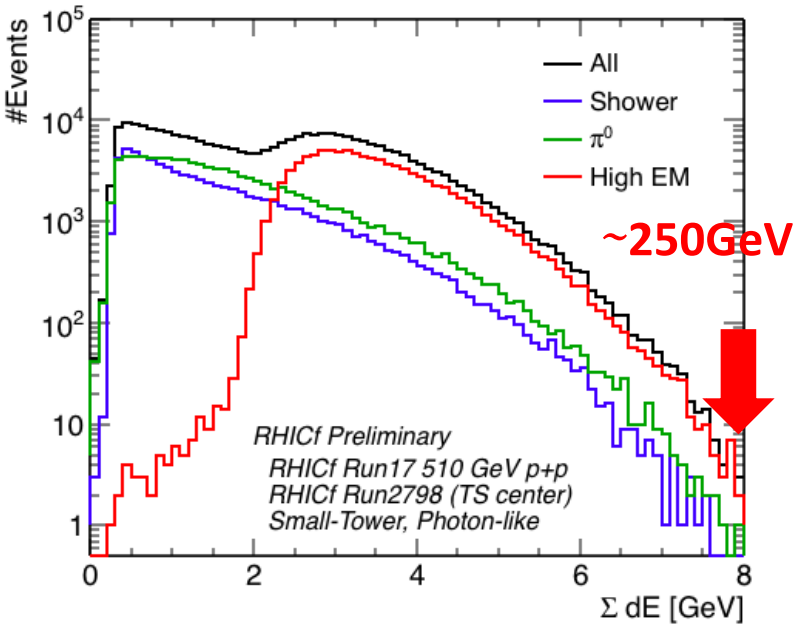
RHICf (Type-I π^0 trigger)

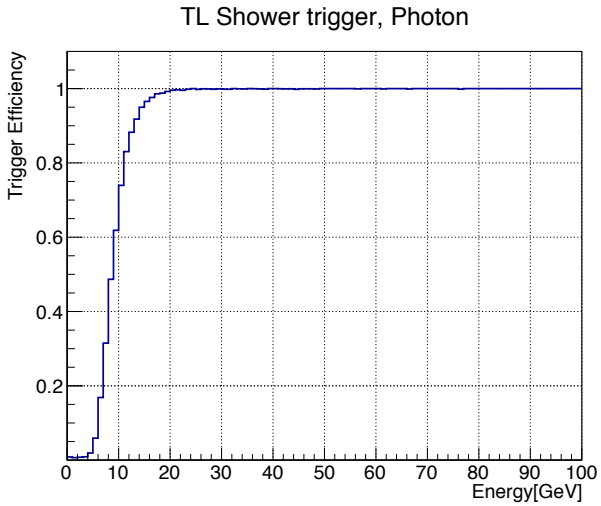
Quick look(polarization & spectrum)



- Polarization angle is 0 in usual RHIC operation (vertical pol)
- Radial polarization (90°) was required for RHICf operation
- Stable radial pol and asymmetry was observed by ZDC

- Energy spectrum of EM-like showers in a 30 minutes run
- High-energy EM showers and π^0 were selectively triggered to compensate the limited DAQ speed.

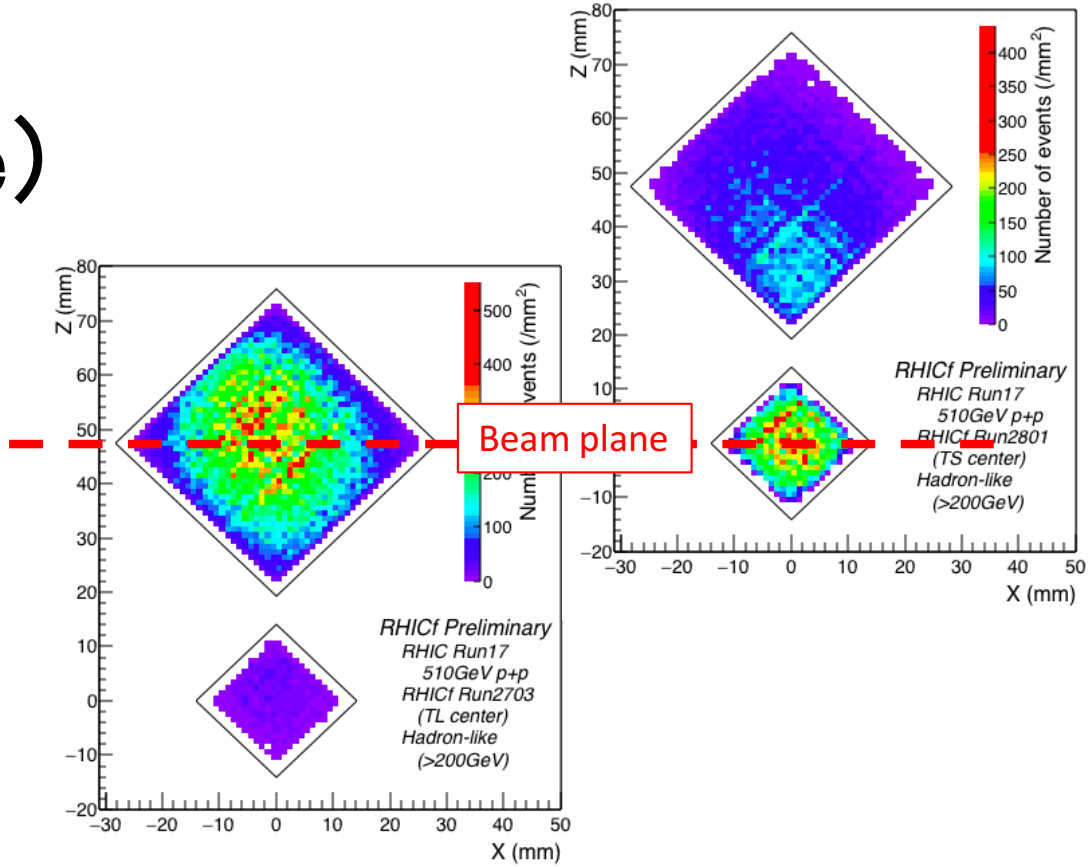


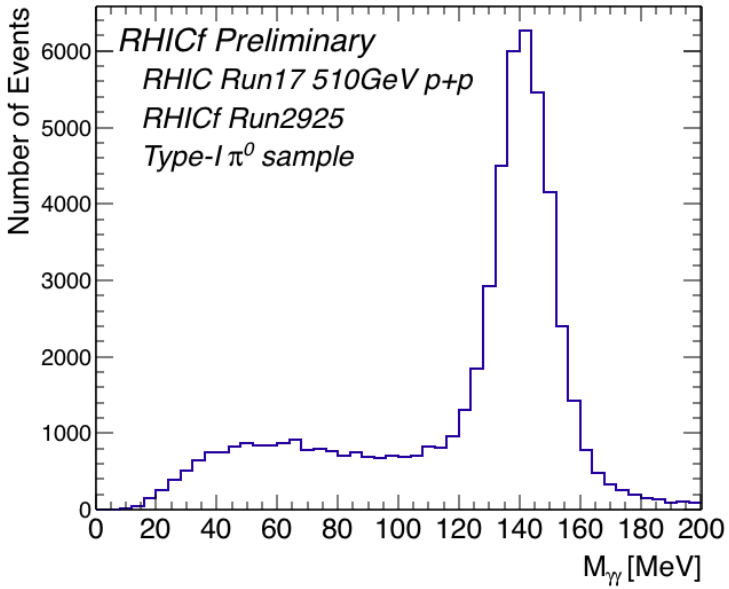


Trigger efficiency MC taking into account the final experimental setups

Quick look (basic performance)

Hit maps of >200GeV hadron-like events at different detector positions
=> Determination of "zero degree"

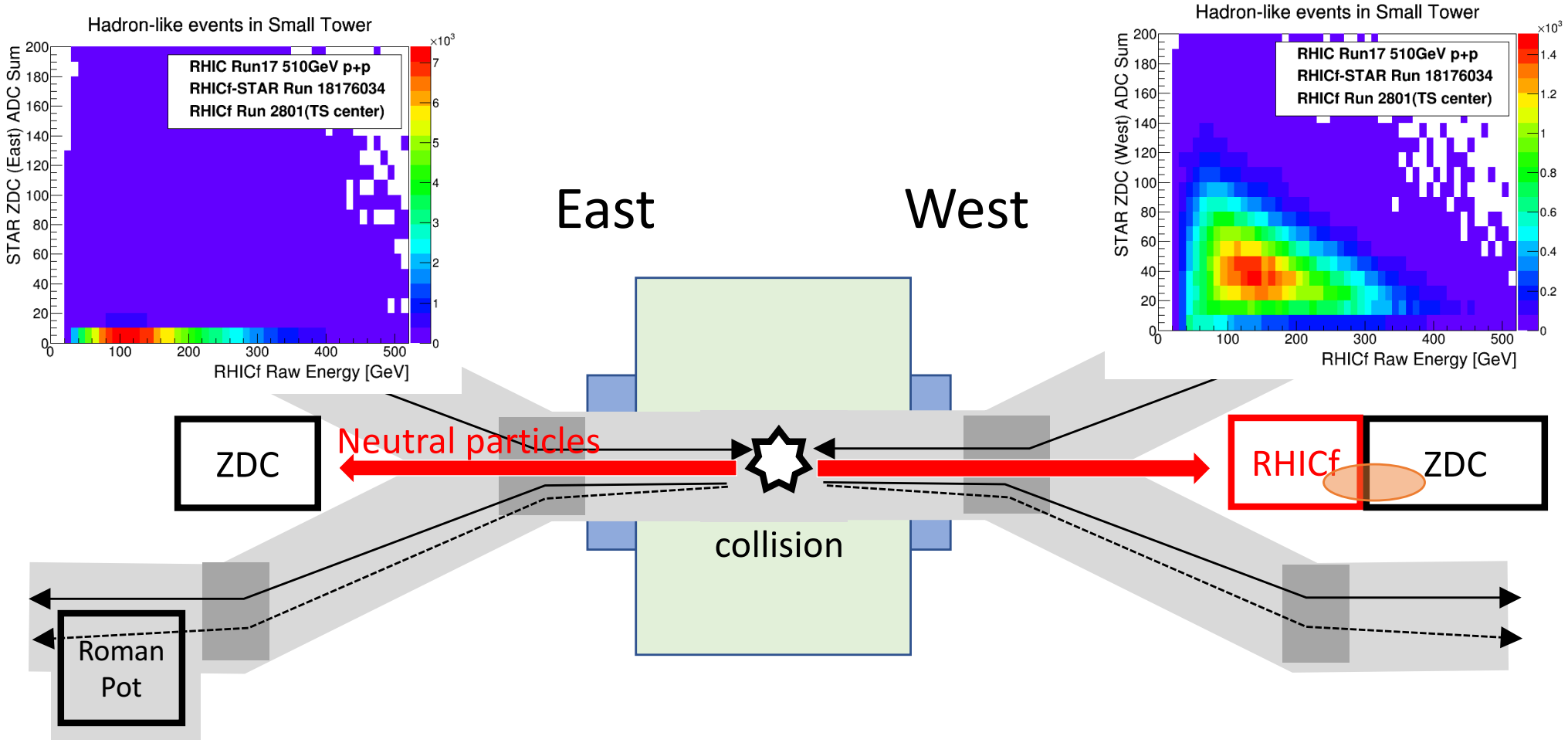




Invariant mass of photon pairs
=> 135MeV peak by π^0

Correction factors considering the final alignment and RHIC energy range are in study.

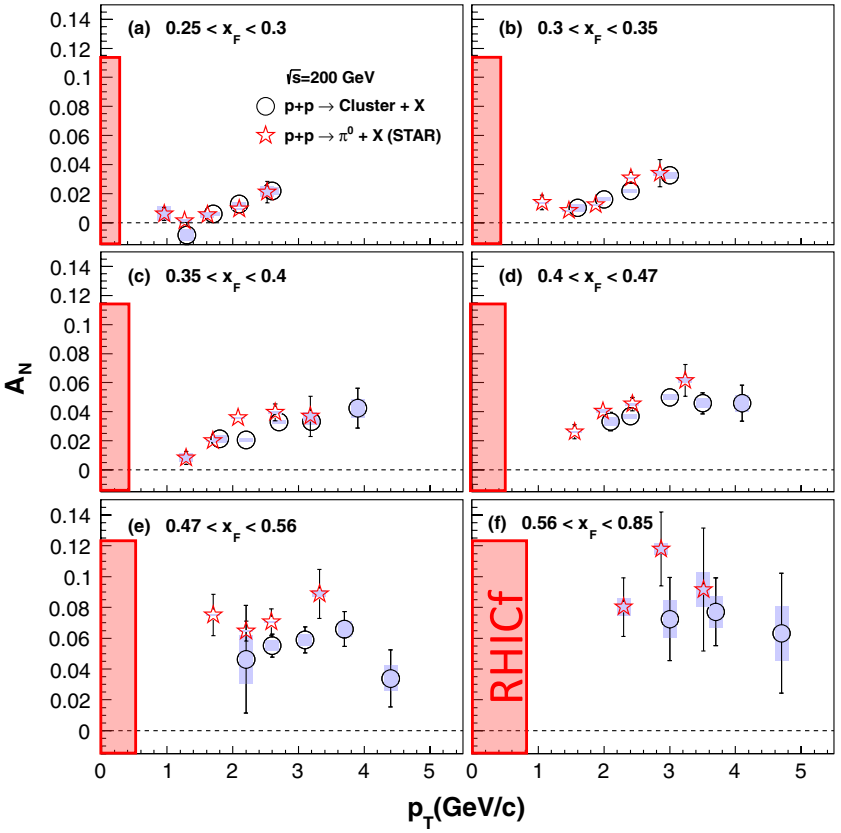
Quick look（common run with STAR）



- Hadron-like (deep penetrating) showers were selected
- Anticorrelation between the RHICf raw (folded) energy and ZDC measured energy (in ADC unit) is confirmed
- (Anti)correlation only with West ZDC as expected => correct event matching

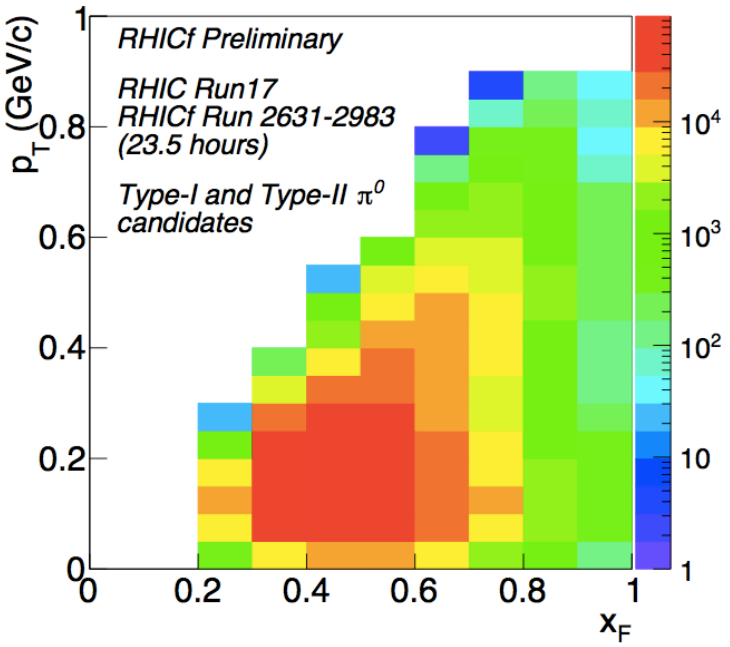
Ongoing Physics Analyses

- Production cross sections of photons and π^0
- A_N of very forward π^0



PHENIX, STAR √s=200GeV

PHENIX Collaboration, PRD 90, 012006 (2014)



RHICf Identified π^0

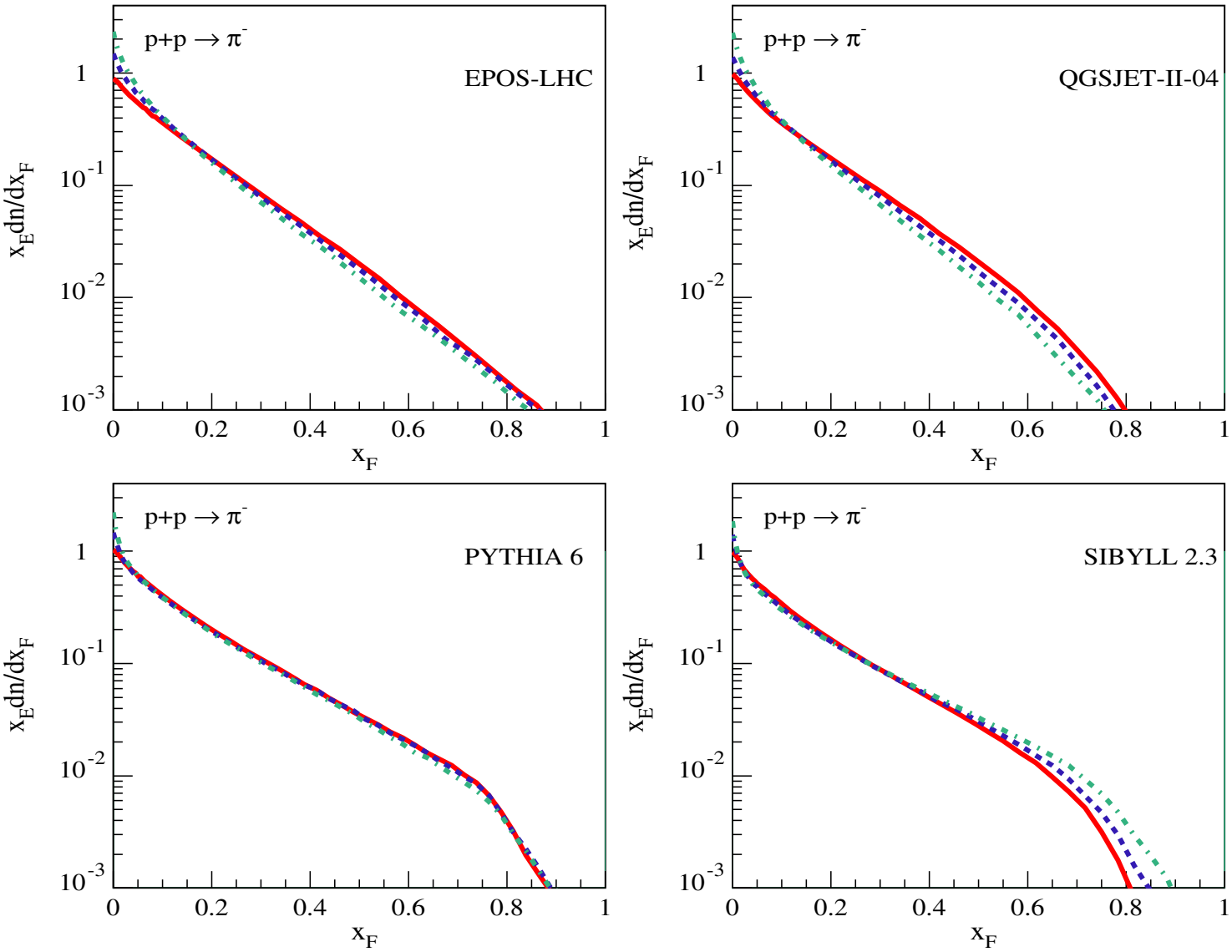
Summary

- Operation of RHICf in RUN17 was successfully done
  - Special setup, β^*=8m and radial polarization
  - 4 fills and 27.7 hours of physics data taking
  - Common operation with STAR, 80% of RHICf triggers were recorded
- Good initial performance
  - π^0 identification
  - Beam center determination
  - Correct event matching with STAR
- Ongoing analyses
  - EM shower events => forward π^0 asymmetry

We appreciate supports by PAC, C-AD, STAR and PHENIX Collaborations

Backup

π production by different models at different √s



√s = 0.1, 1, 10TeV

S. Ostapchenko, M. Bleicher, T. Pierog, and K. Werner, PRD 94, 114026 (2016)

Theoretical explanation

- Pion-a_1 interference: results
  - The data agree well with independence of energy
- The asymmetry has a sensitivity to presence of different mechanisms, e.g. Reggeon exchanges with spin-non-flip amplitude, even if they are small amplitudes

$$A_N \approx \frac{2\,\mathrm{Im}\left(fg^*\right)}{|f|^2 + |g|^2}$$

f : spin non-flip amplitude
g : spin flip amplitude

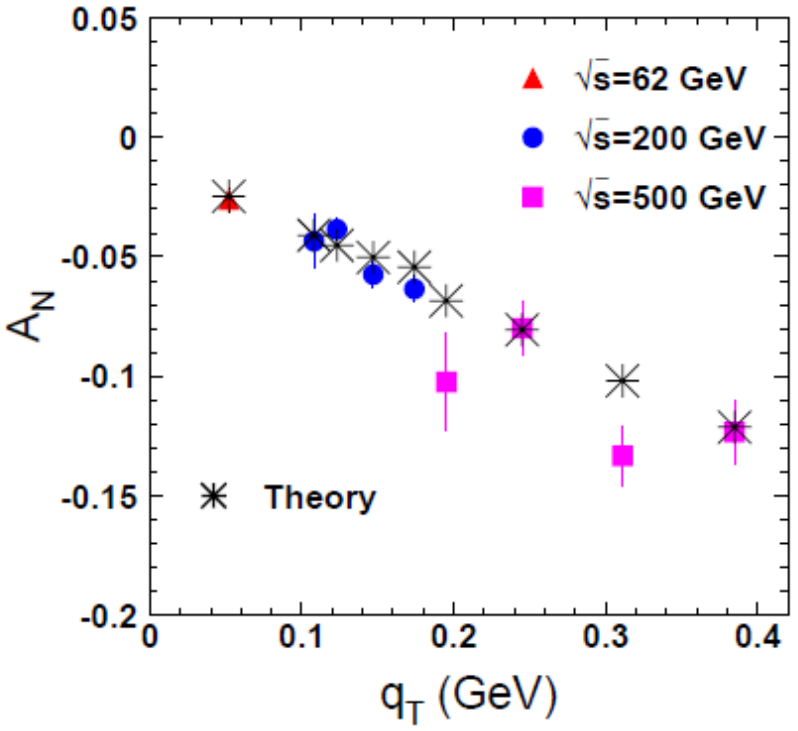
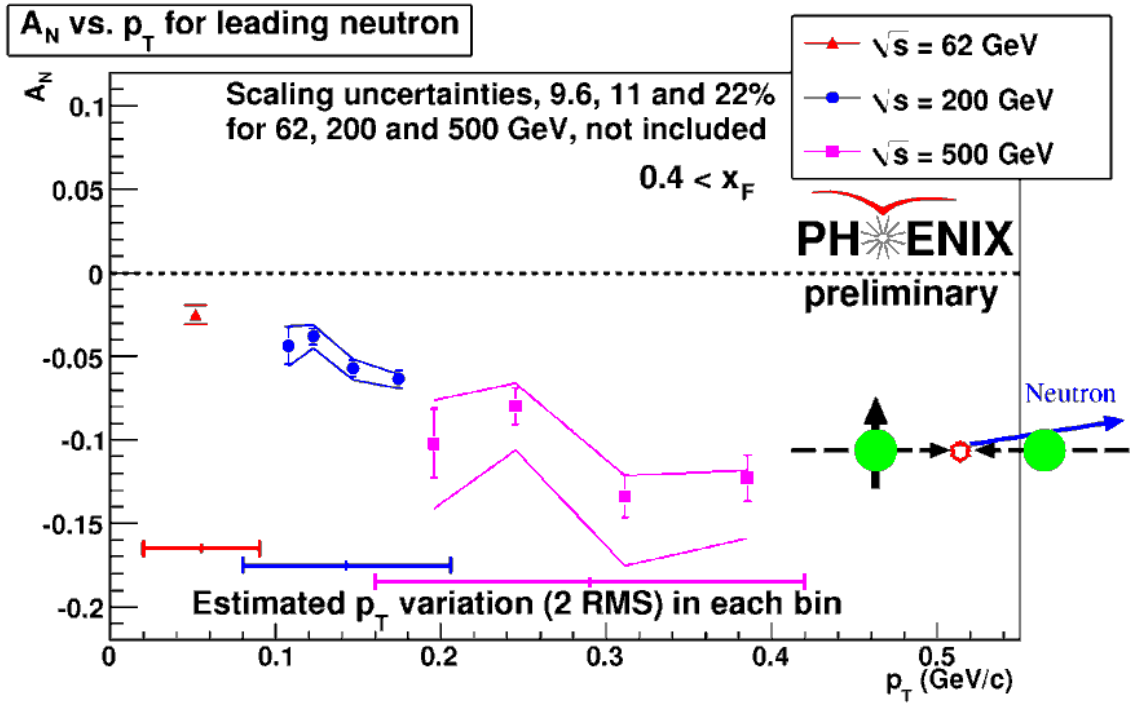


FIG. 1: (Color online) Single transverse spin asymmetry A_N in the reaction $pp \to nX$, measured at $\sqrt{s} = 62,\ 200,\ 500\,\mathrm{GeV}$ [1] (preliminary data). The asterisks show the result of our calculation, Eq. (38), which was done point by point, since each experimental point has a specific value of z (see Table I).

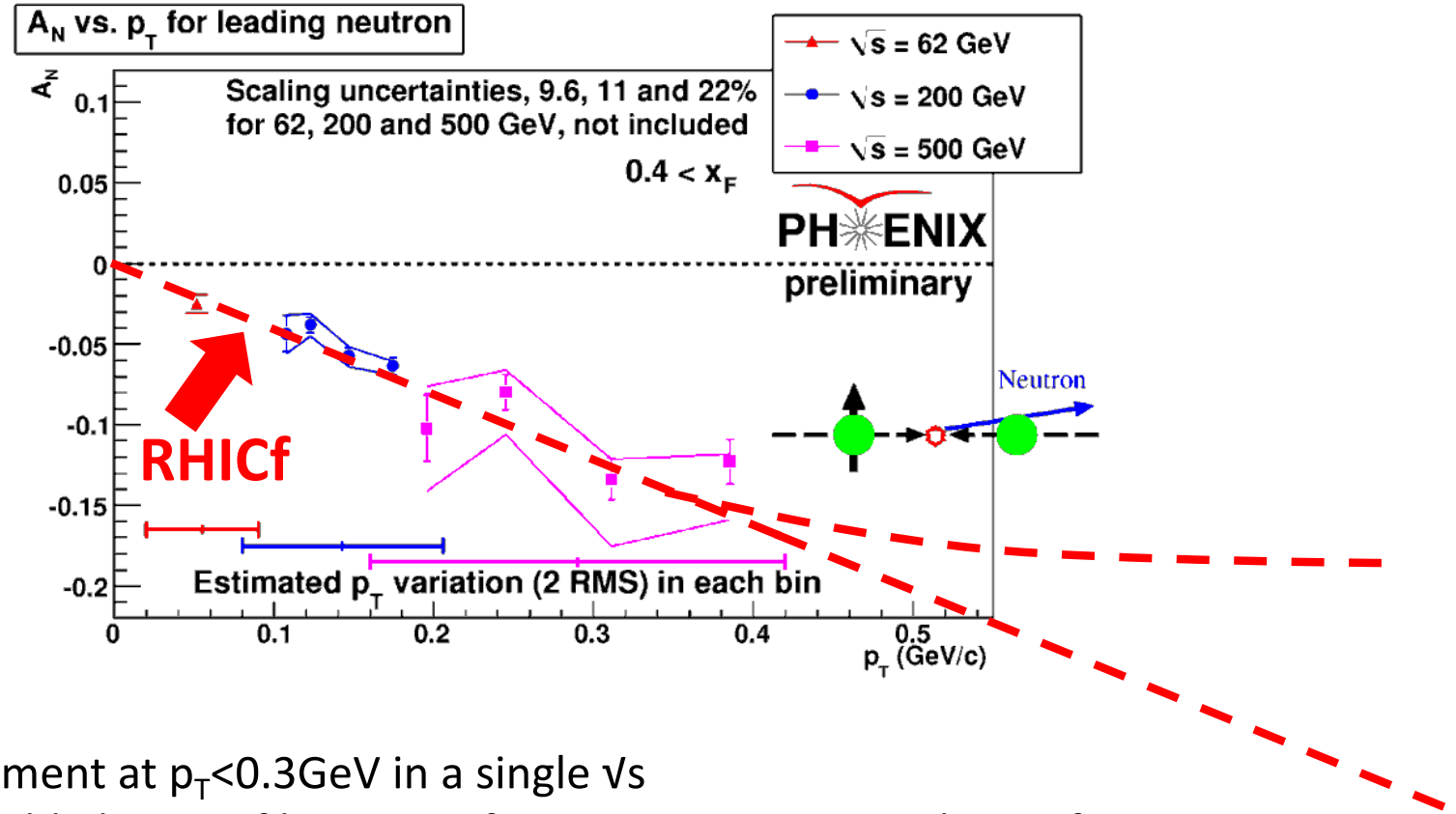
Kopeliovich, Potashnikova, Schmidt, Soffer: Phys. Rev. D 84 (2011) 114012.

SSA of forward particle production



1. Measurement at p_T<0.3GeV in a single √s
   - possible by RHICf because of its 1mm position resolution for neutrons
2. Measurement at p_T>0.3GeV to know A_N evolution
   - possible by RHICf because of its wide p_T coverage required for cross section measurements

SSA of forward particle production



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