Status of the RHIC forward experiment

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The RHICf Collaboration

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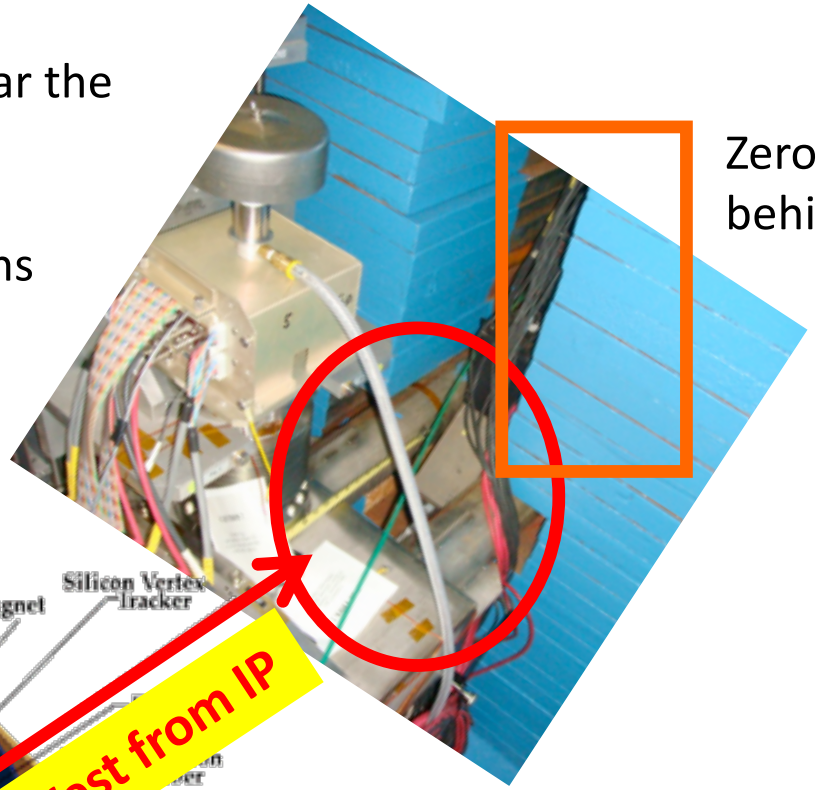
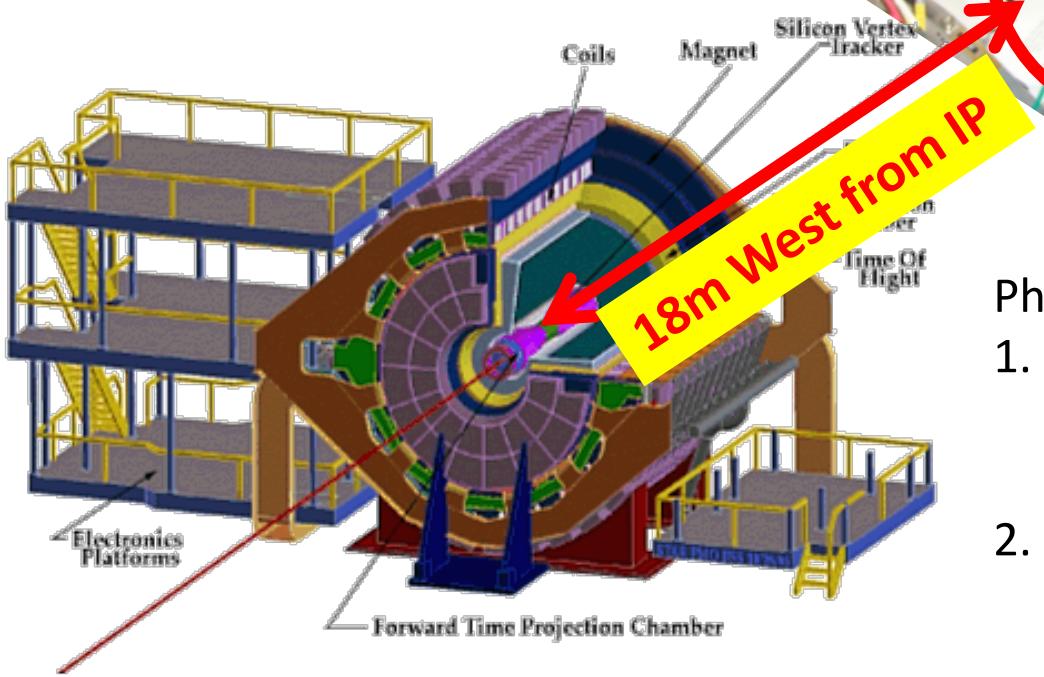
RHICf is…

- Zero degree measurement near the STAR interaction point at RHIC
- Operation during transversely polarized 510GeV p+p collisions
- Using the former LHCf Arm1 detector



Zero Degree Calorimeter behind RHICf

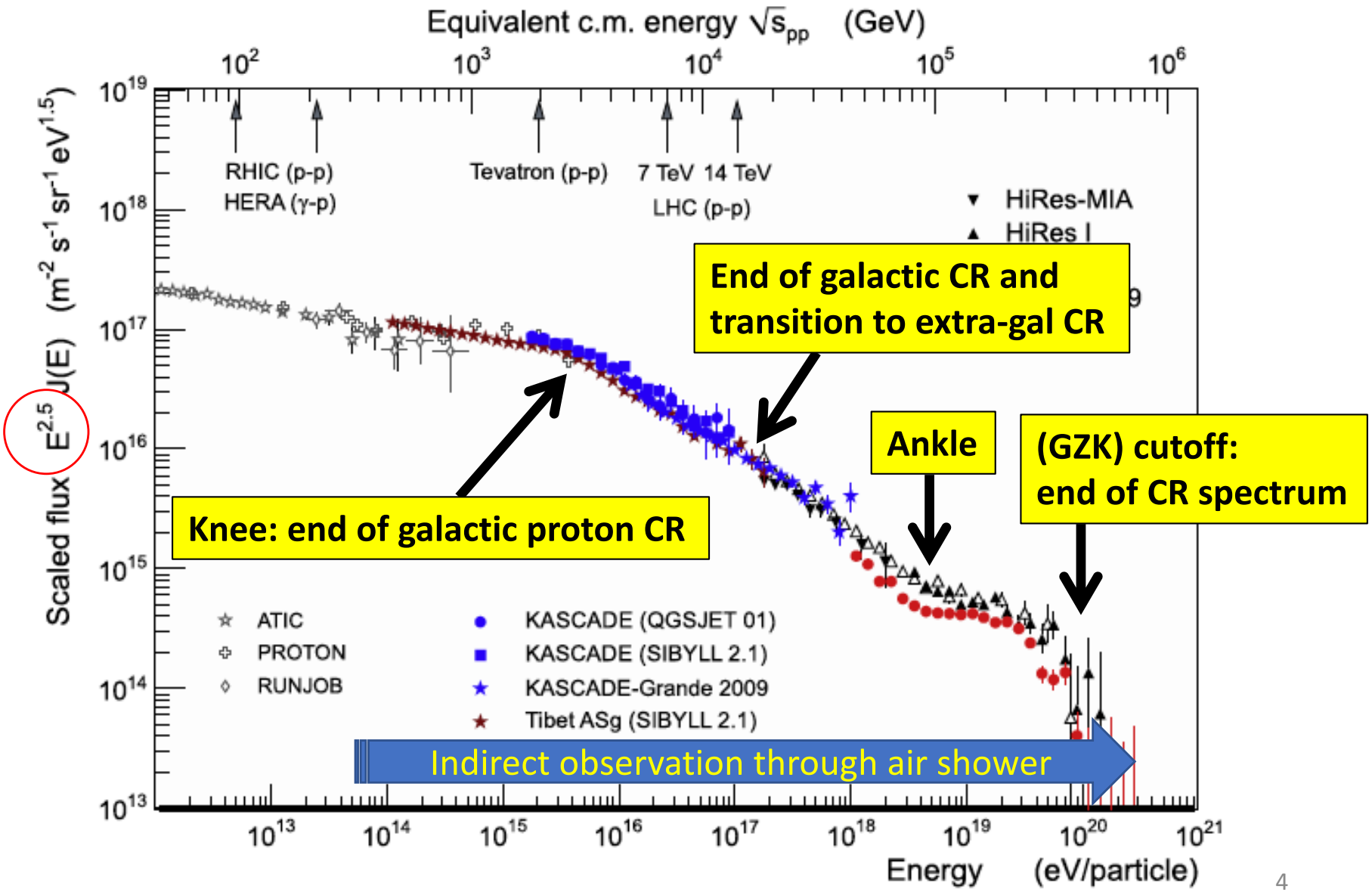


Physics targets:

1. Cross section measurement for forward particle production to improve cosmic-ray air shower modeling (extension of LHCf)
2. Single-spin asymmetry measurement with high p_T resolution and wide p_T coverage (many talks tomorrow)

Cosmic-ray spectrum and collider energy

（D'Enterria et al., APP, 35,98-113, 2011 ）



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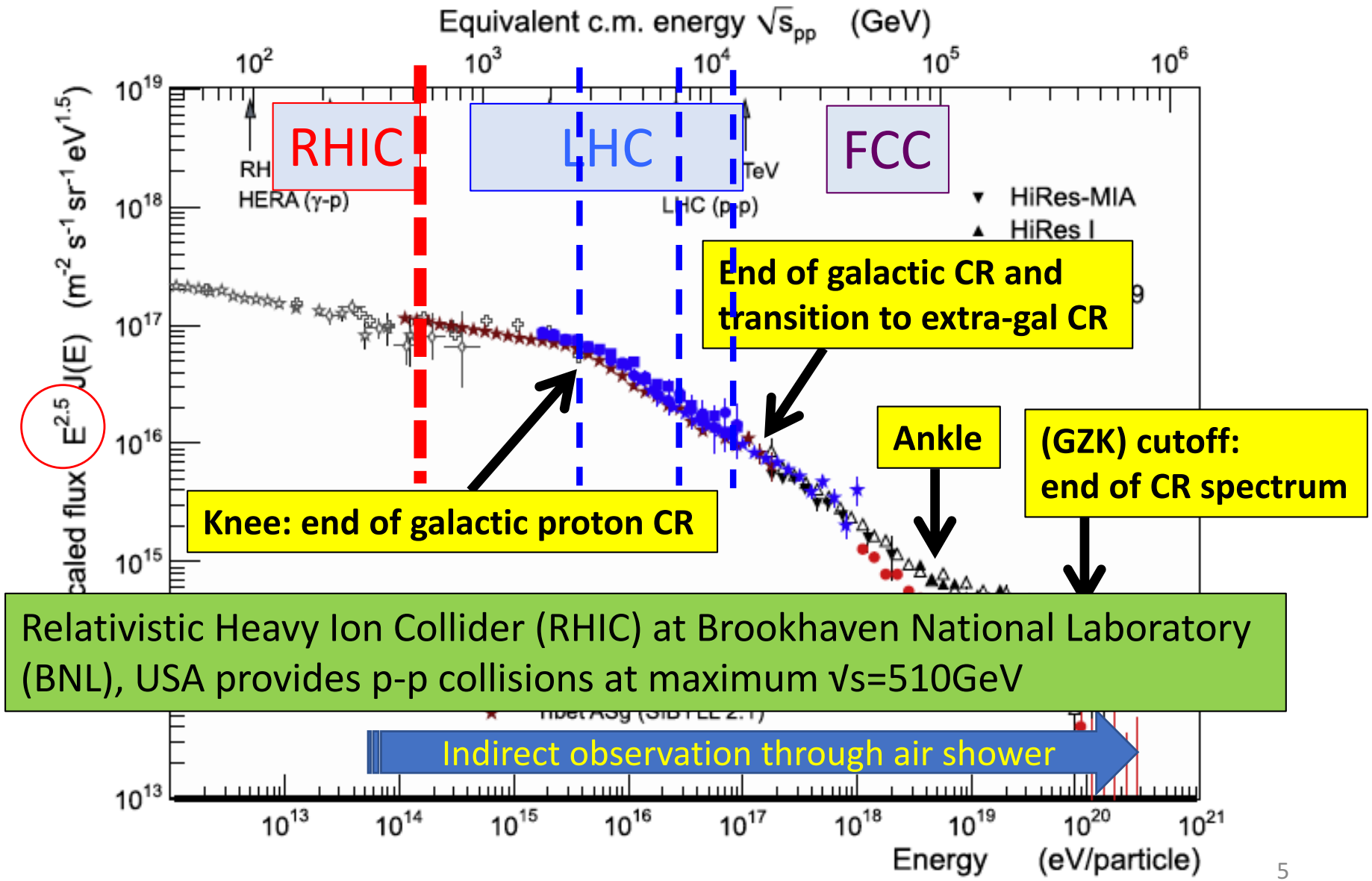
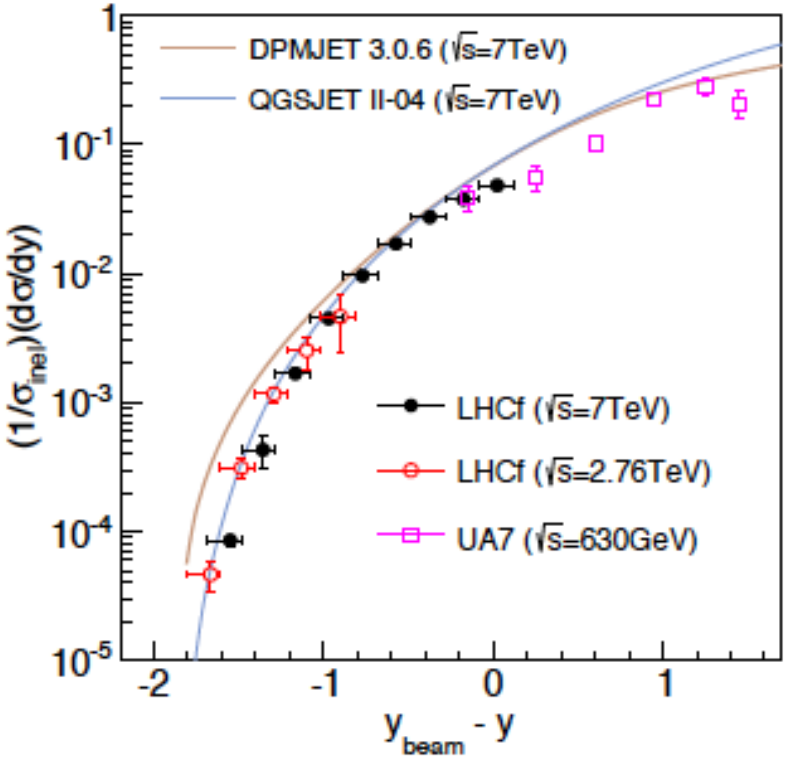
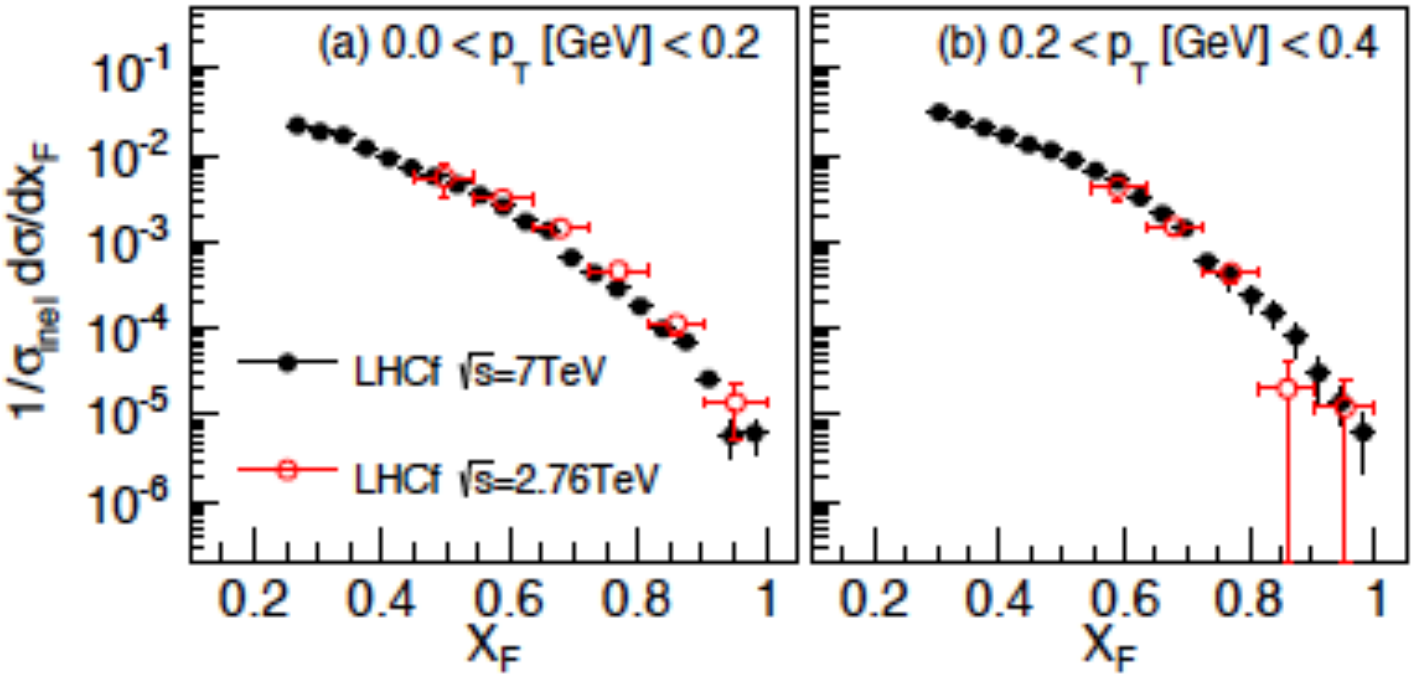


Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory (BNL), USA provides p-p collisions at maximum √s=510GeV

√s scaling ; π^0

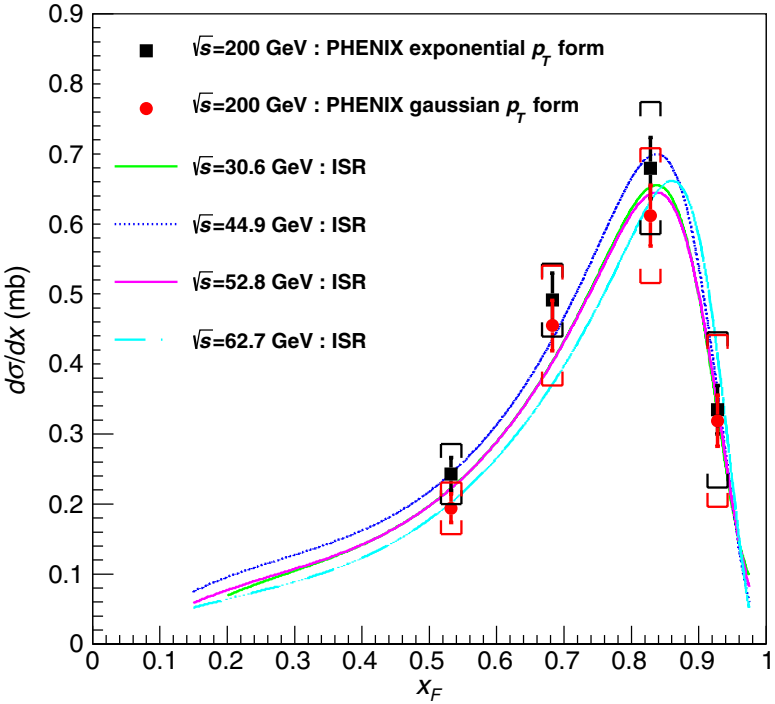
- ✓ Scaling is essential to extrapolate beyond LHC
- ✓ (630GeV –) 2.76TeV – 7TeV
  good scaling within uncertainties
- ✓ Wider coverage in y and p_T with 13TeV data
- ✓ Wider √s coverage with RHICf experiment in 2017 at √s=510GeV

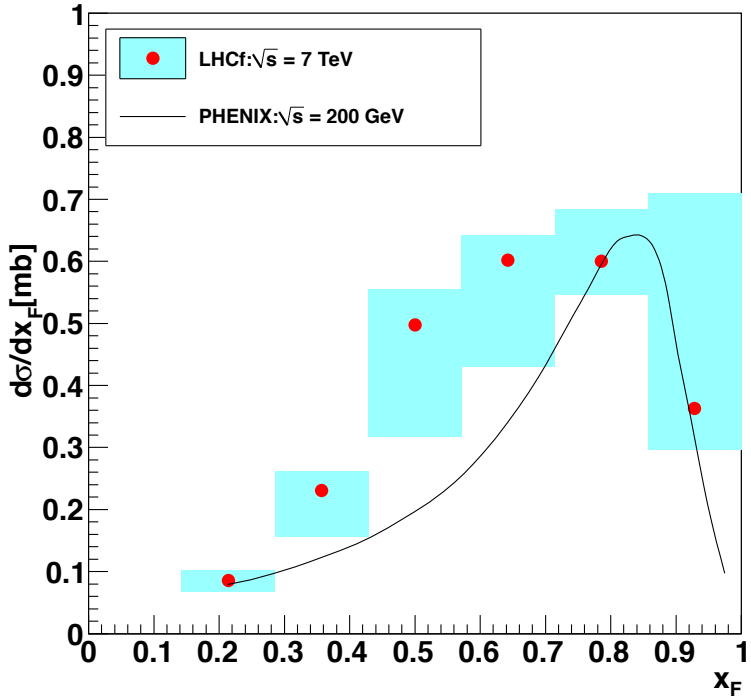




Feynman x;
$x_F = 2p_z/\sqrt{s}$

√s scaling; Neutron @ zero degree





PHENIX, PRD, 88, 032006 (2013)

$p_T < 0.11\ x_F$ GeV/c

√s = 30-60 GeV @ISR

√s = 200 GeV @RHIC

LHCf, K.Kawade, PhD thesis, CERN-THESIS-2014-315

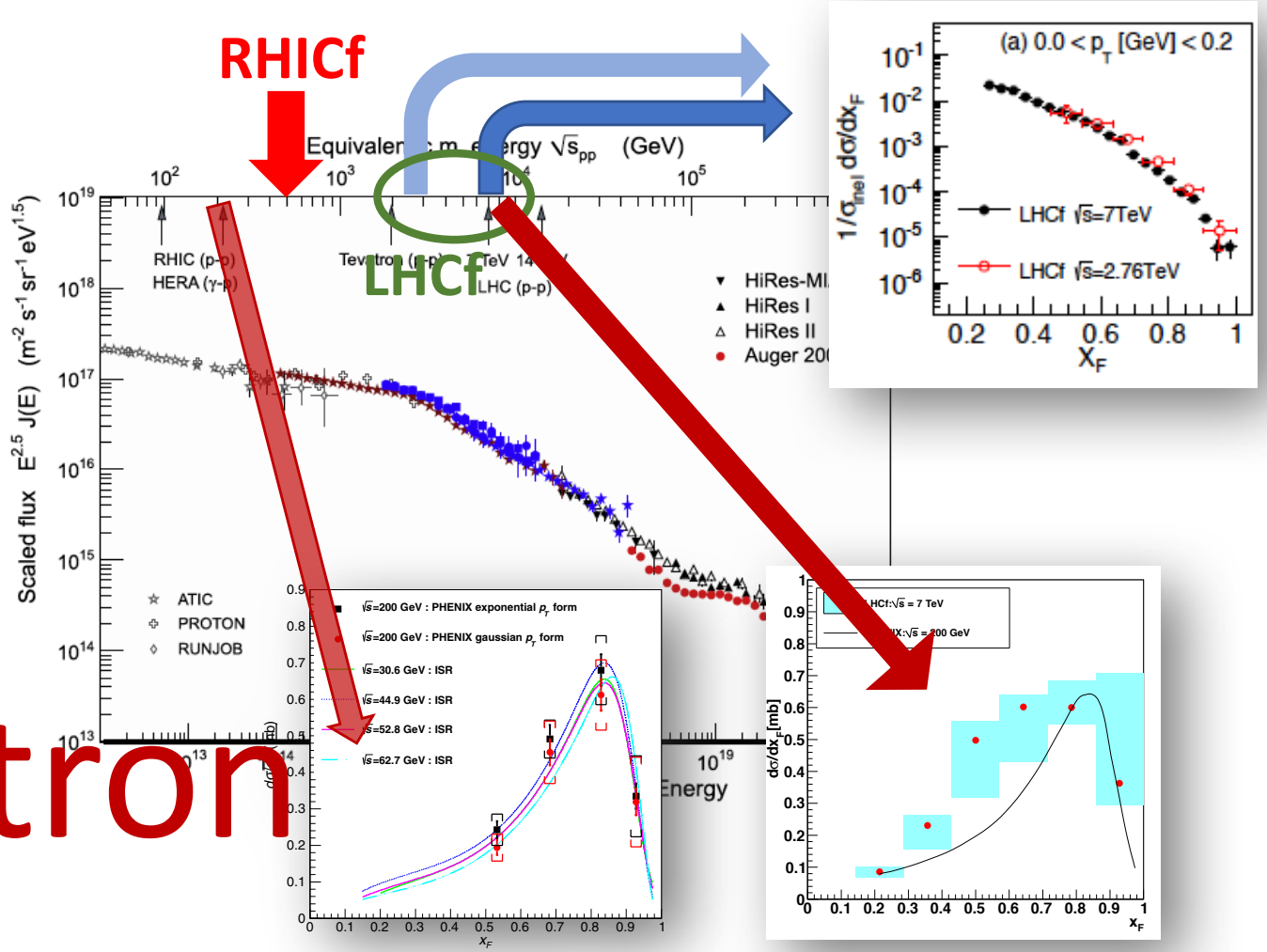
$p_T < 0.11\ x_F$ GeV/c

√s = 7000 GeV @LHC

- ✓ PHENIX explains the result by 1 pion exchange
- ✓ More complicated exchanges at >TeV?
- ✓ LHCf data at 900GeV, 2.76TeV to be analyzed
- ✓ RHICf data at 510GeV will be added in 2017

√s scaling, or breaking?

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



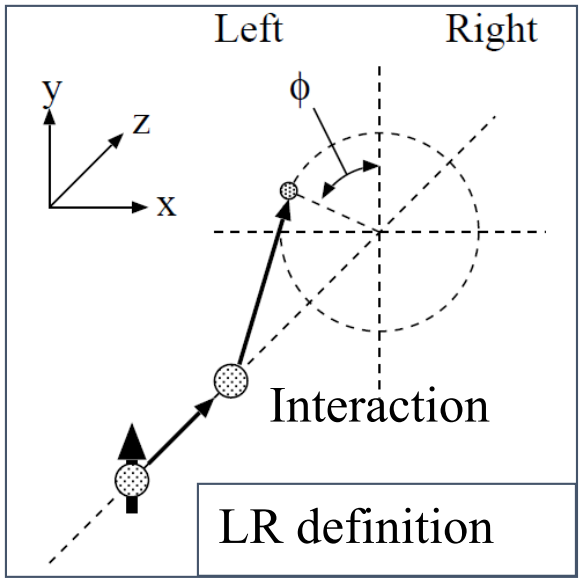
π^0

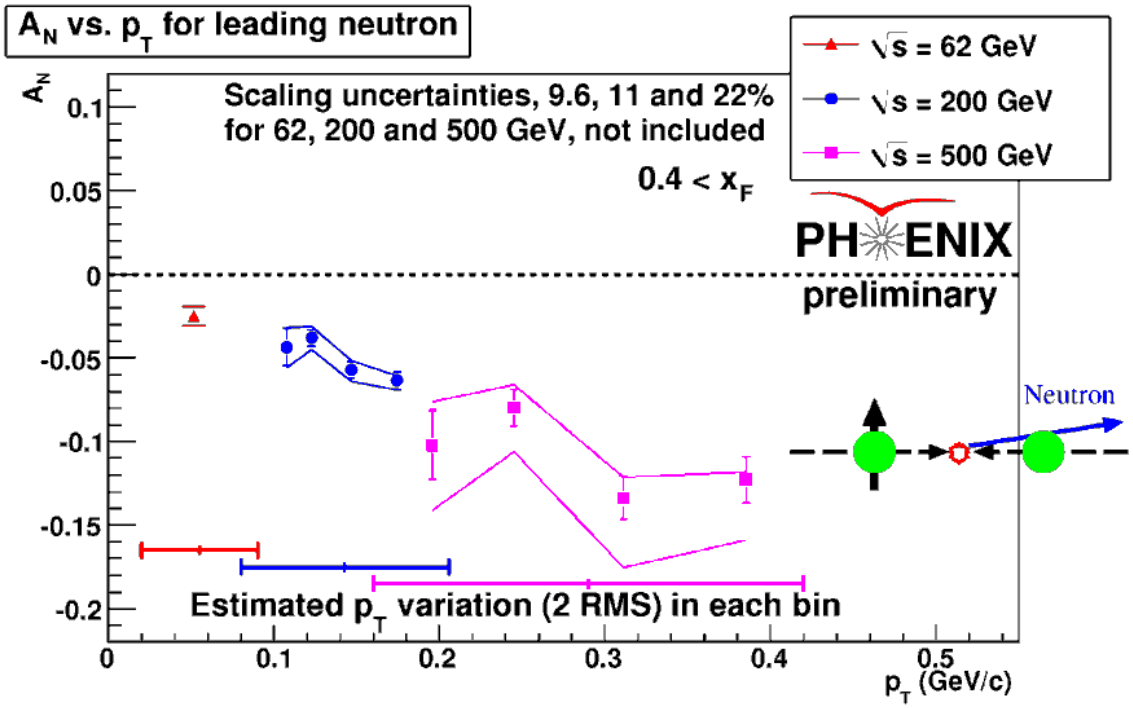
neutron

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

Detail in the talks by Seidl and Park tomorrow

SSA of forward neutron production





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

$$A_N = \frac{1}{P} \cdot \varepsilon_N$$

- PHENIX measurements suggest p_T scaling of A_N
- Low p_T was limited by the <u>1cm position resolution</u> of the detector. Neutrons hit near zero degree was not used in the analysis.

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

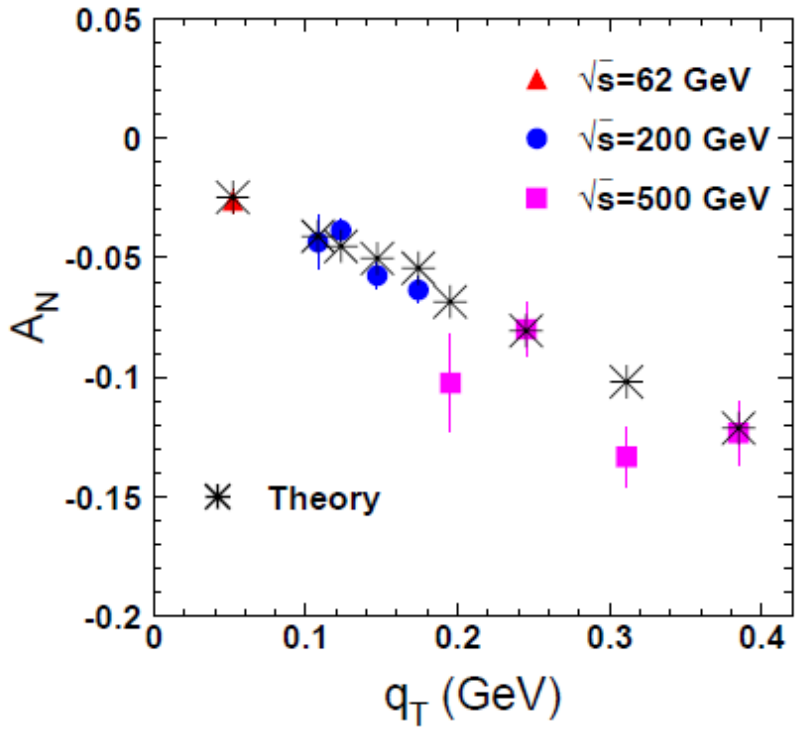
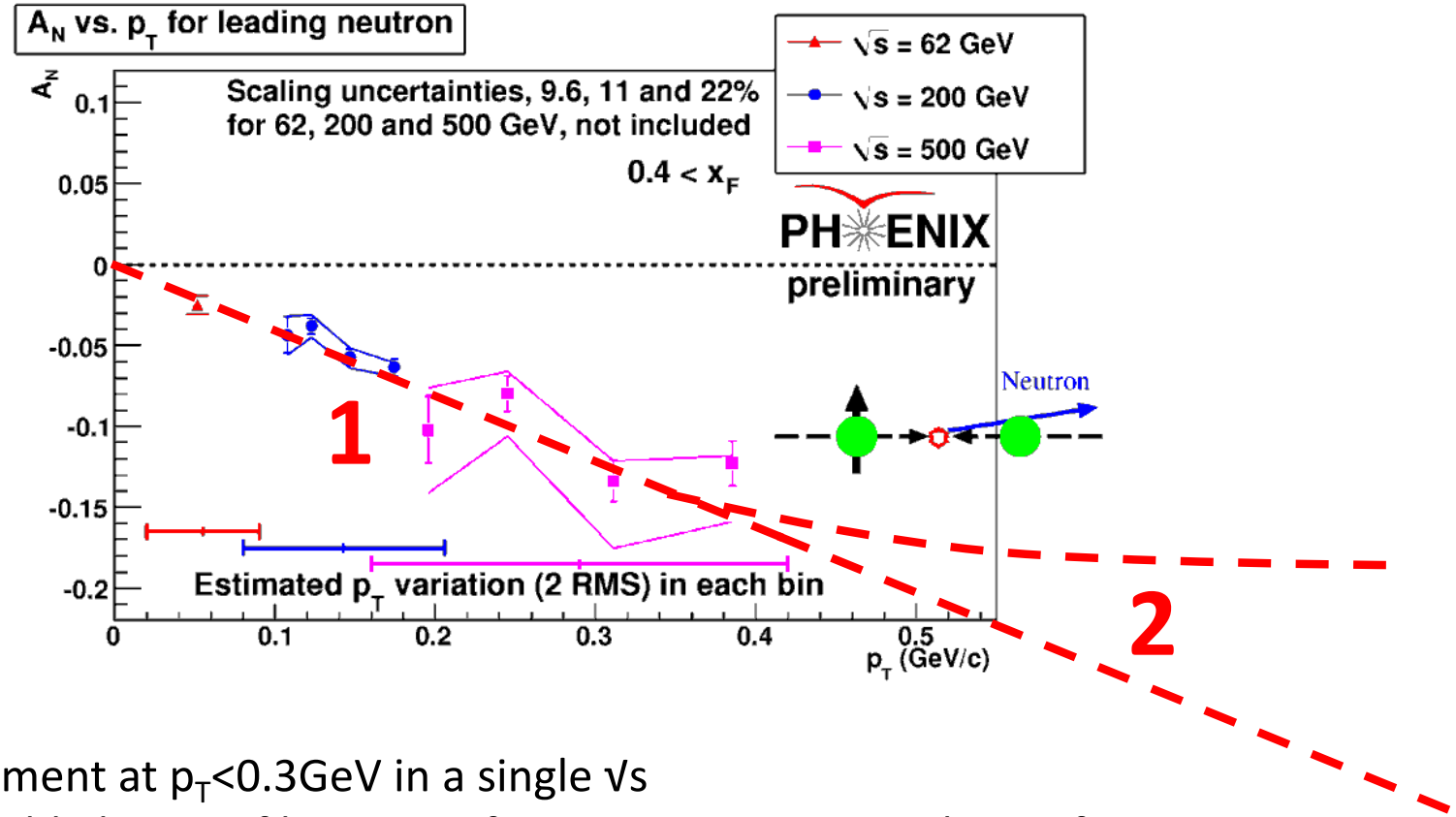


FIG. 1: (Color online) Single transverse spin asymmetry A_N in the reaction $pp \to nX$, measured at $\sqrt{s} = 62,\ 200,\ 500$ GeV [1] (preliminary data). The asterisks show the result of our calculation, Eq. (38), which was done point by point, since each experimental point has a specific value of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

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

Detail in the talk by Park tomorrow

SSA of forward neutron 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

Short history of RHICf

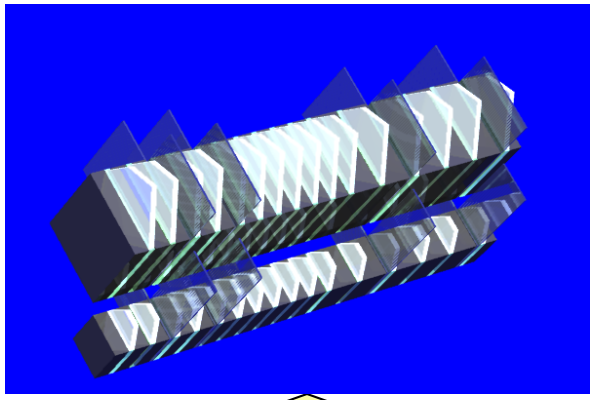
First international presentation at HESZ 2013

Short history of RHICf

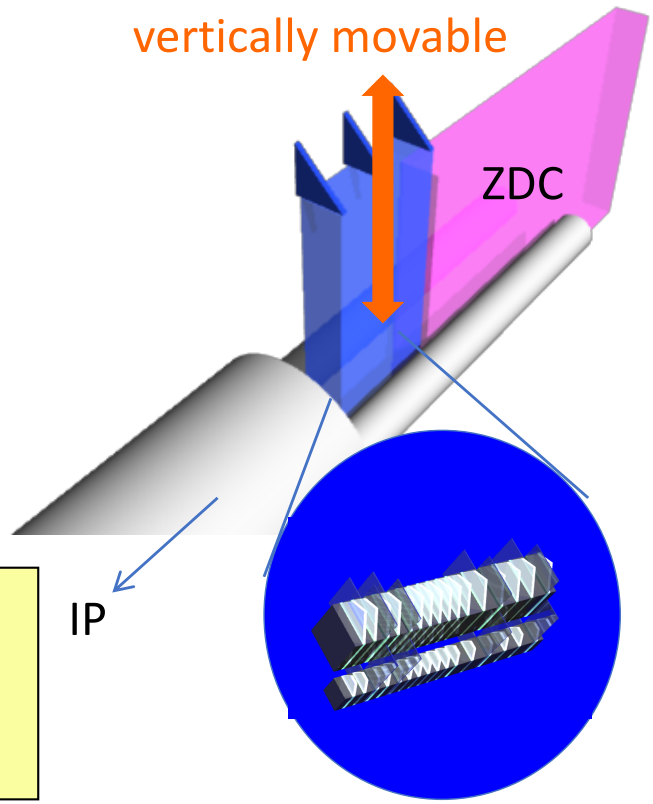
- 2013 Jun: LOI was submitted to PAC
- 2014 Apr: Experiment at PHENIX site was agreed😄
- 2014 June: Proposal to PAC (partly approved)🙂
- 2015 Apr: Inconsistency with the RHIC p-p plan and sPHENIX upgrade plan appeared 😱
- But STAR agreed to host us 😚
- 2015 Jun: 1 week dedicated run in 2017 was approves by PAC 😆
- 2016 Jan: MOU with STAR 😊
- 2016 May: LHCf detector was shipped to BNL
- 2016 Sep-2017 May: Installation and commissioning
- 2017 Jun: Physics operation!! 😃
- 2017 Sep: Detector was shipped out to Japan to complete a world trip

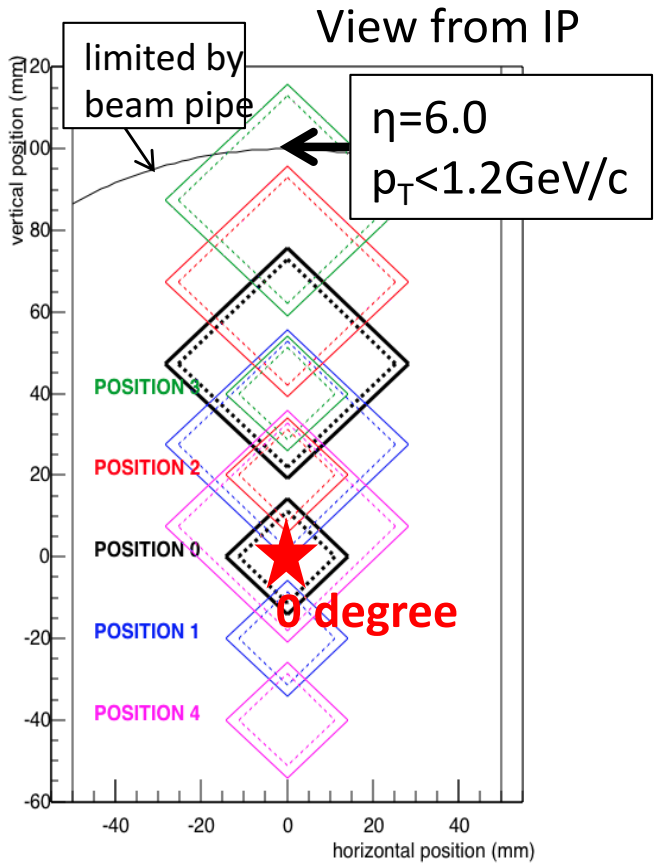
The RHICf Detector

- Former LHCf Arm1 detector
  - Compact imaging calorimeter towers
  - Tungsten 44 r.l. + 16 sampling layers, 4XY pair GSO bar hodoscope
  - Optimized for photon measurements ($\pi^0 \rightarrow 2\gamma$) ($\Delta E/E < 5\%$)
  - Capable of neutron measurement with $\Delta E/E \sim 40\%$
- Wide p_T coverage by vertical movement（up to 1.2GeV/c limited by beam pipe）



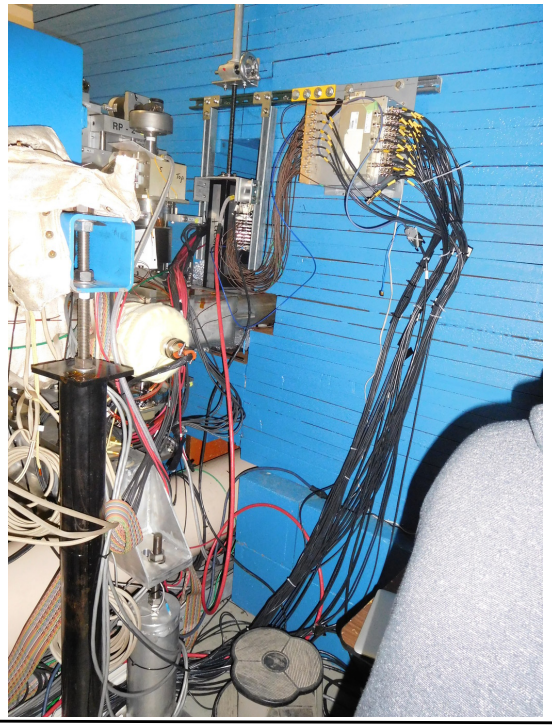
LHCf Arm1 Detector
20mmx20mm+40mmx40mm
4 XY GSO bar hodoscope

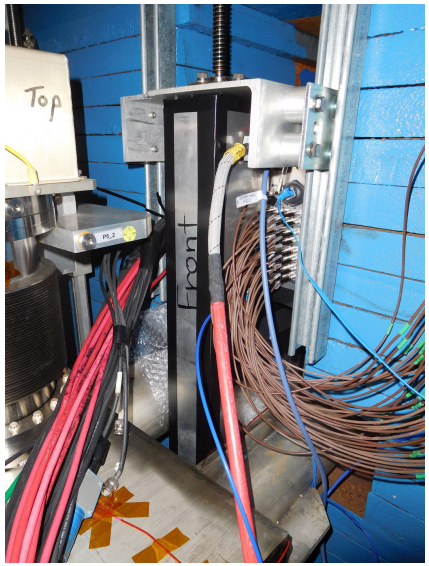


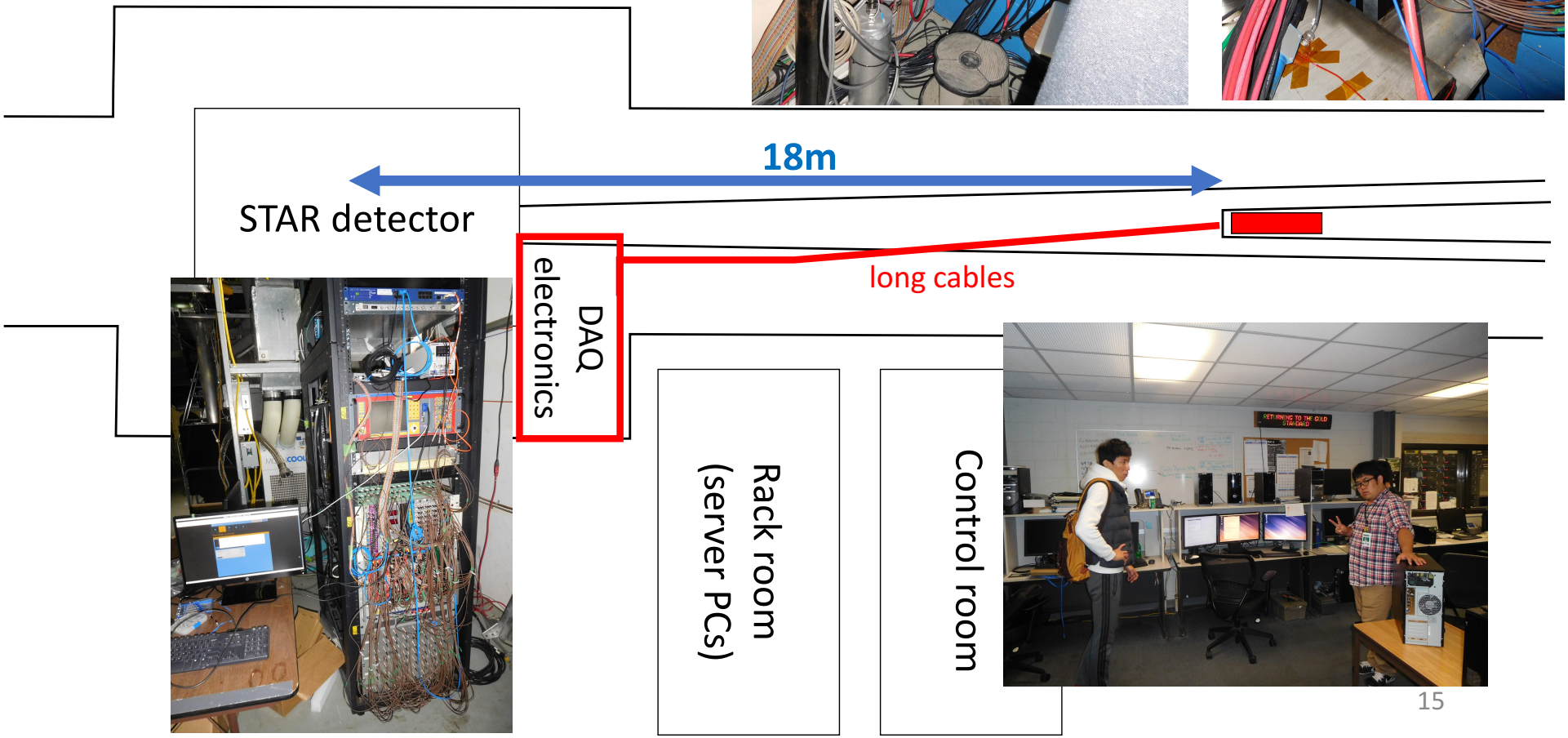


Detector at STAR

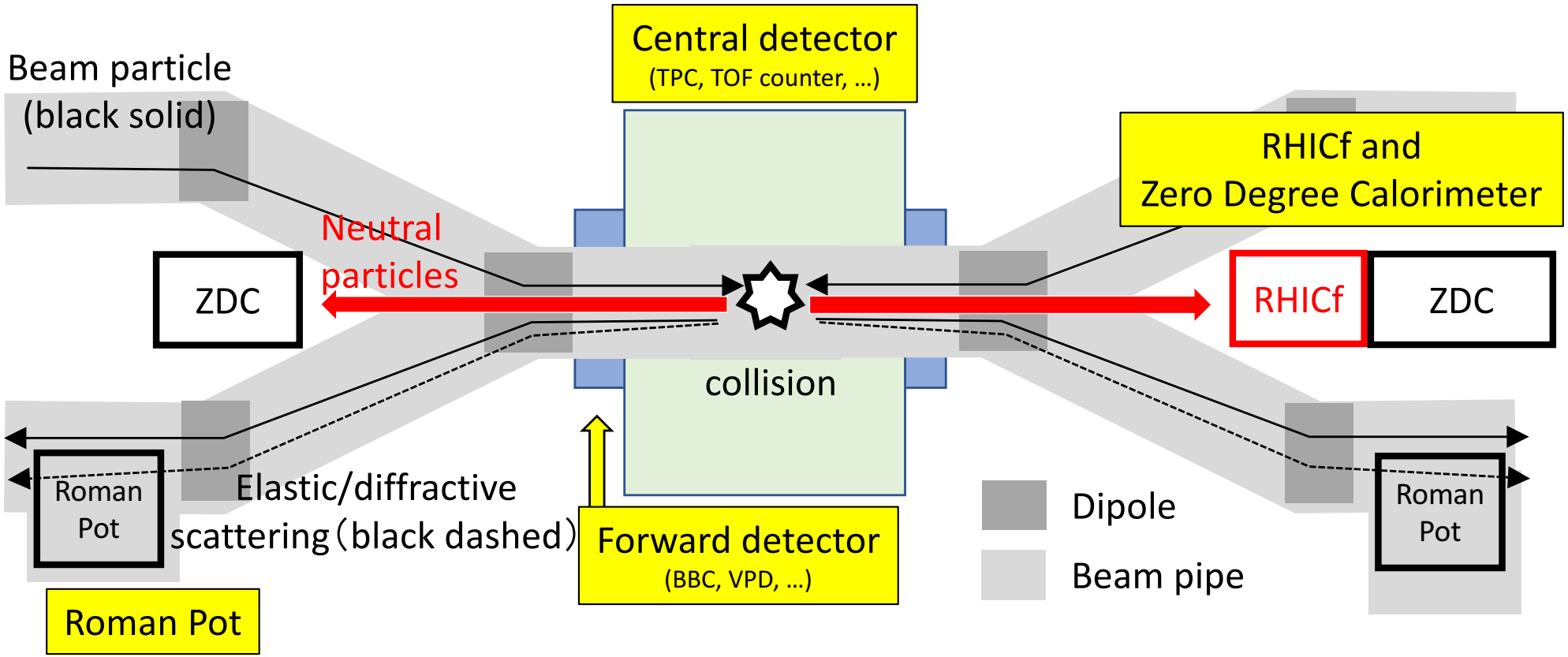
- Installed at 18m west from STAR IP
- Vertically movable structure
- STAR ZDC behind RHICf
- Common operation with STAR => next







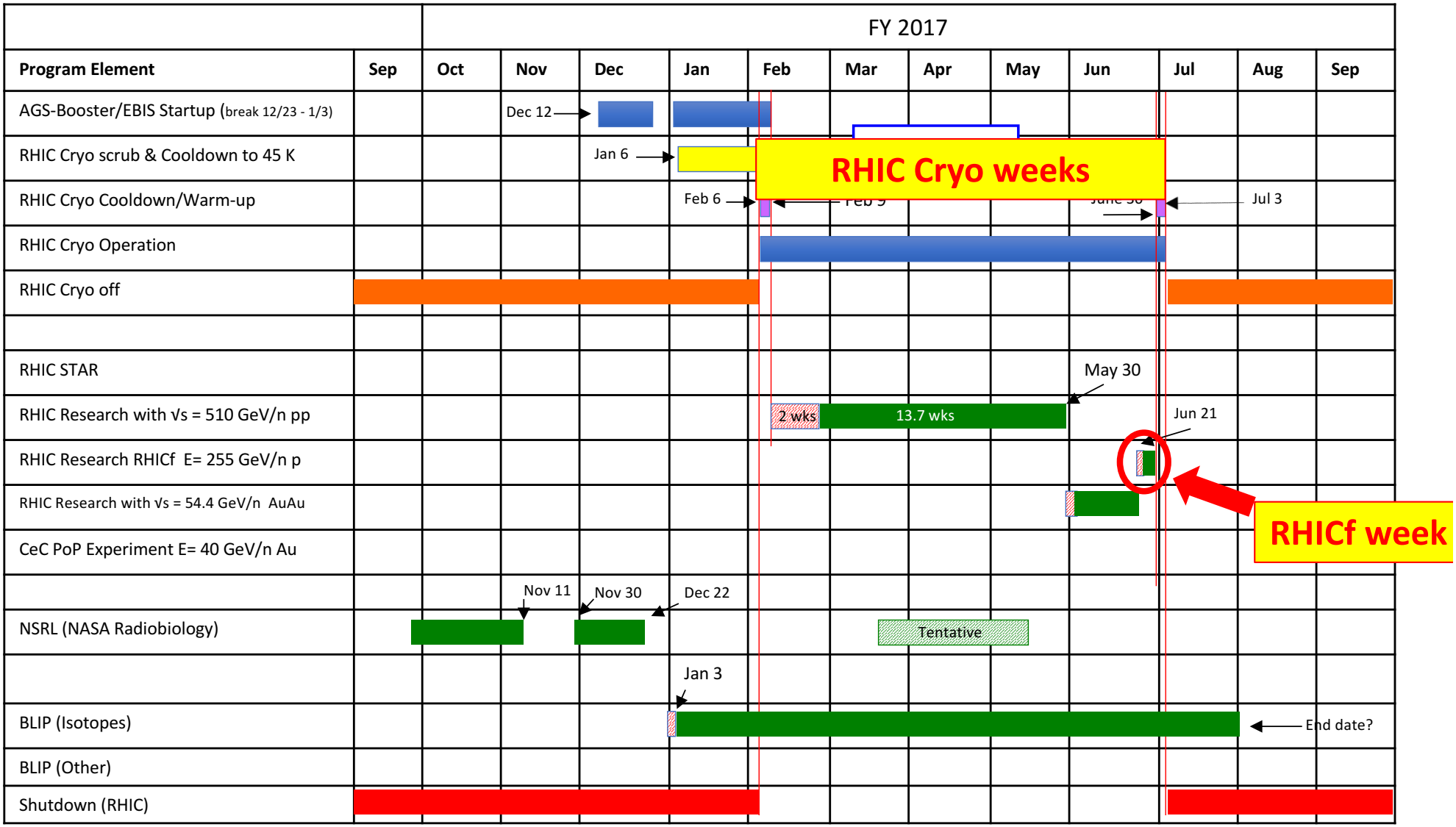
Common Operation with STAR



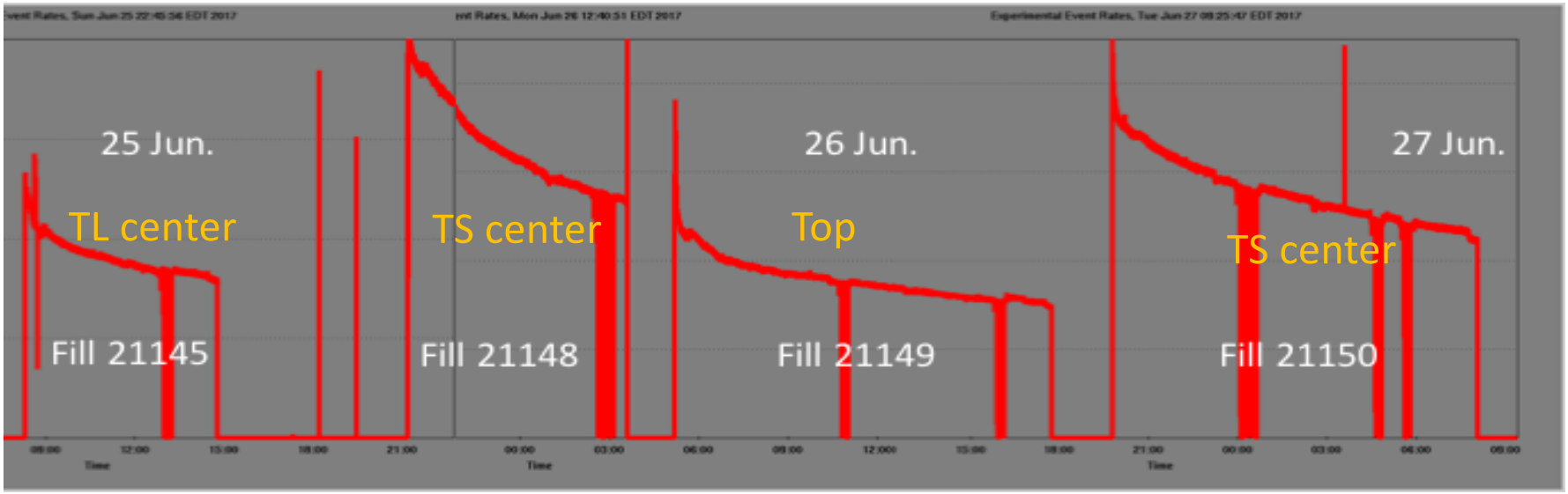
- ✓ STAR recorded data according to the RHICf trigger
  - Correlation with central detector => diffractive/non-diffractive discrimination
  - Coincidence with Roman pots => event-by-event diffractive mass determination, exclusive measurement of $\Delta \rightarrow p\pi^0$ (acceptance not studied)
  - Correlation with ZDC => improving RHICf hadron measurement

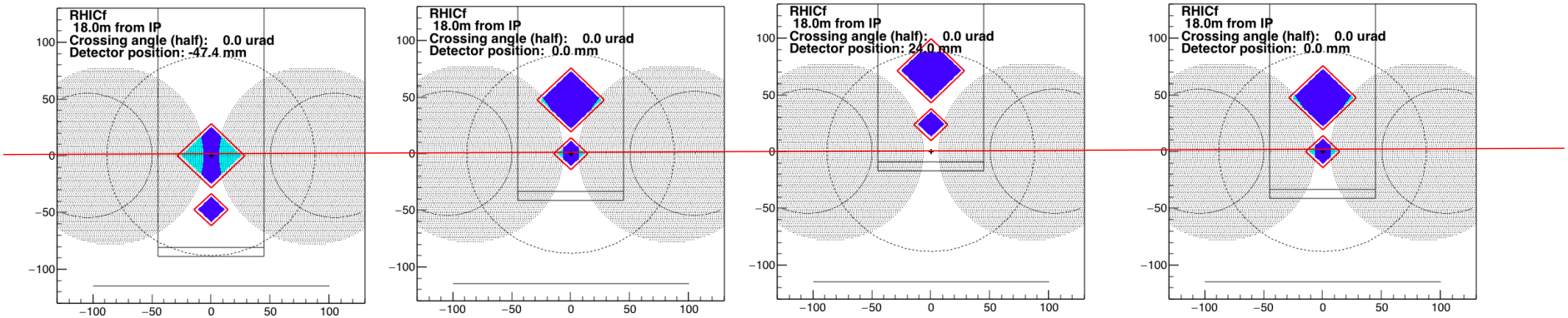
C-A Operations FY17

May 8, 2017



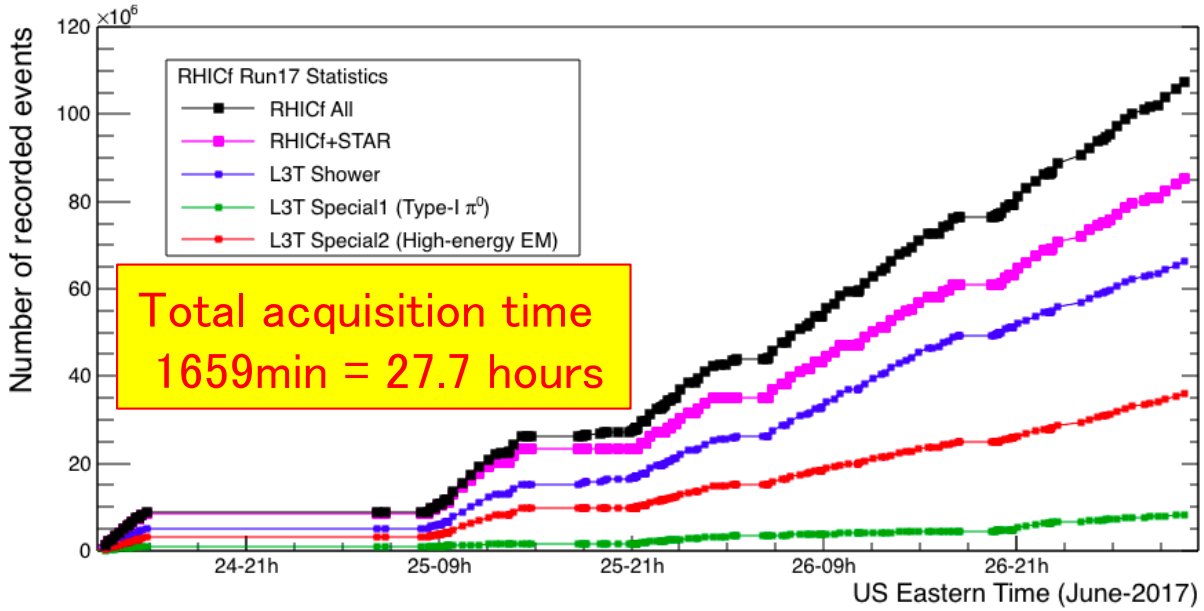
Collision rates in RHICf week





- 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）



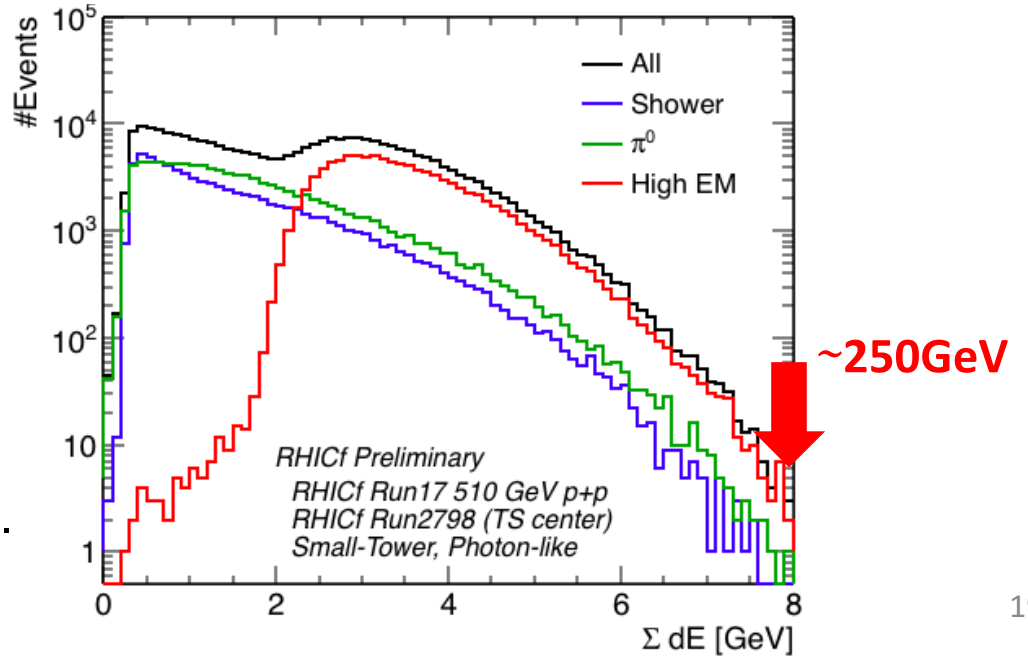
Total : 110M events

RHICf+STAR

RHICf (shower event)

RHICf (High-energy EM trigger)

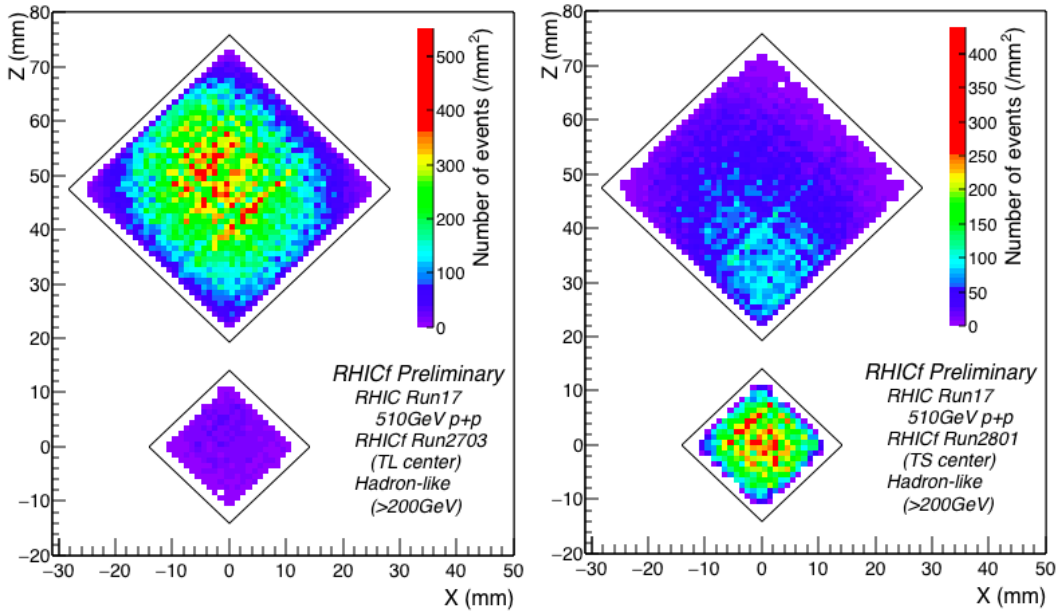
RHICf (Type-I π^0 trigger)

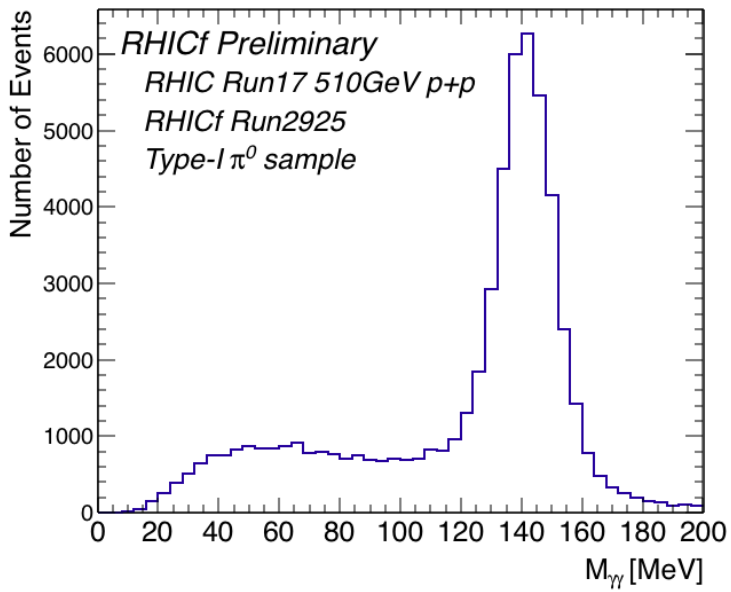


- Energy spectrum of EM-like showers in a 30 minutes run
- High-energy EM showers and π^0 were selectively triggered to compensate the limited DAQ speed.

Quick look（basic performance）

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

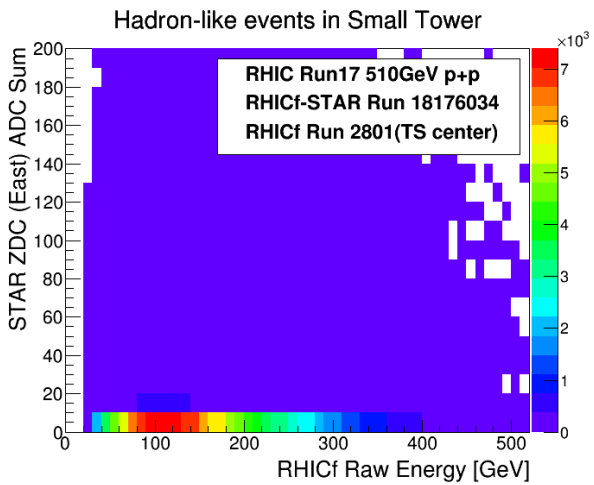


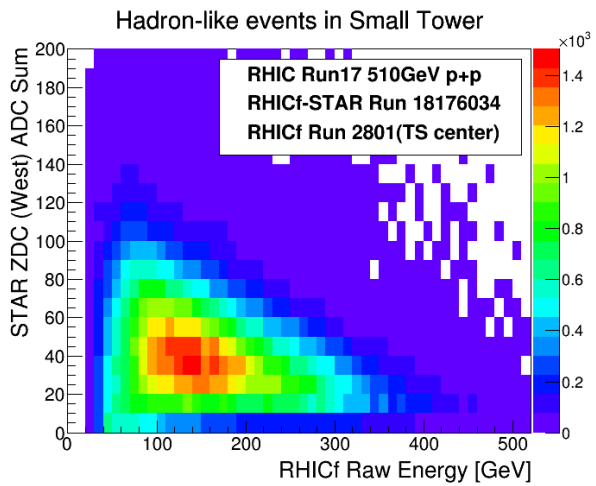


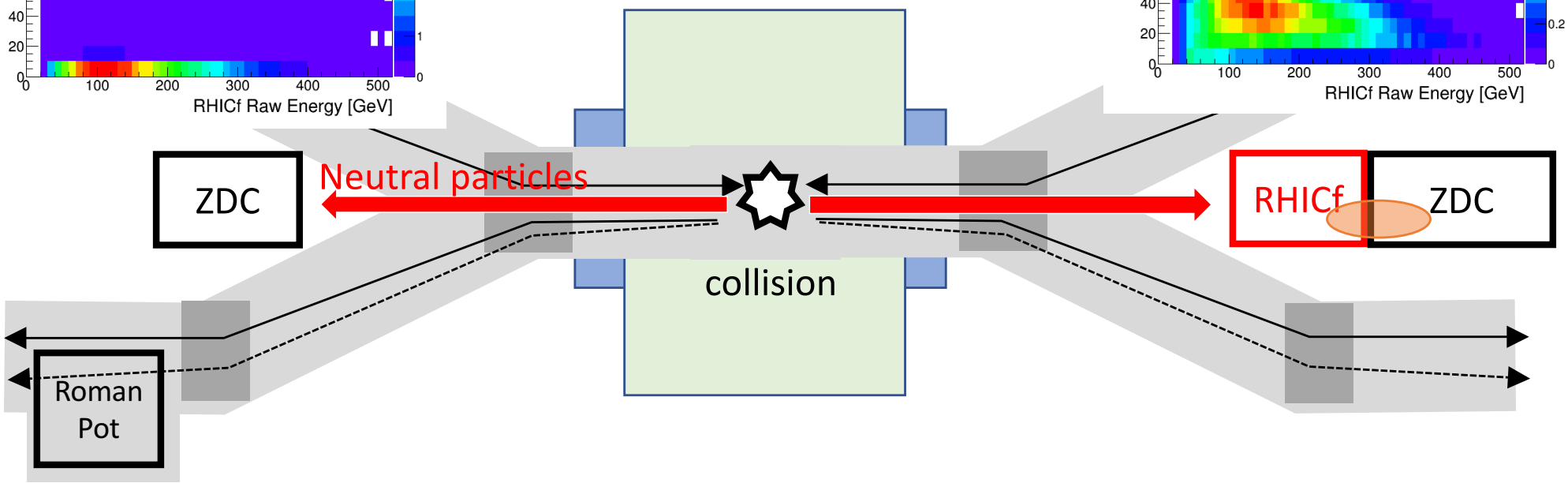
Invariant mass of photon pairs
=> 135MeV peak by π^0

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

Quick look（common run with STAR）

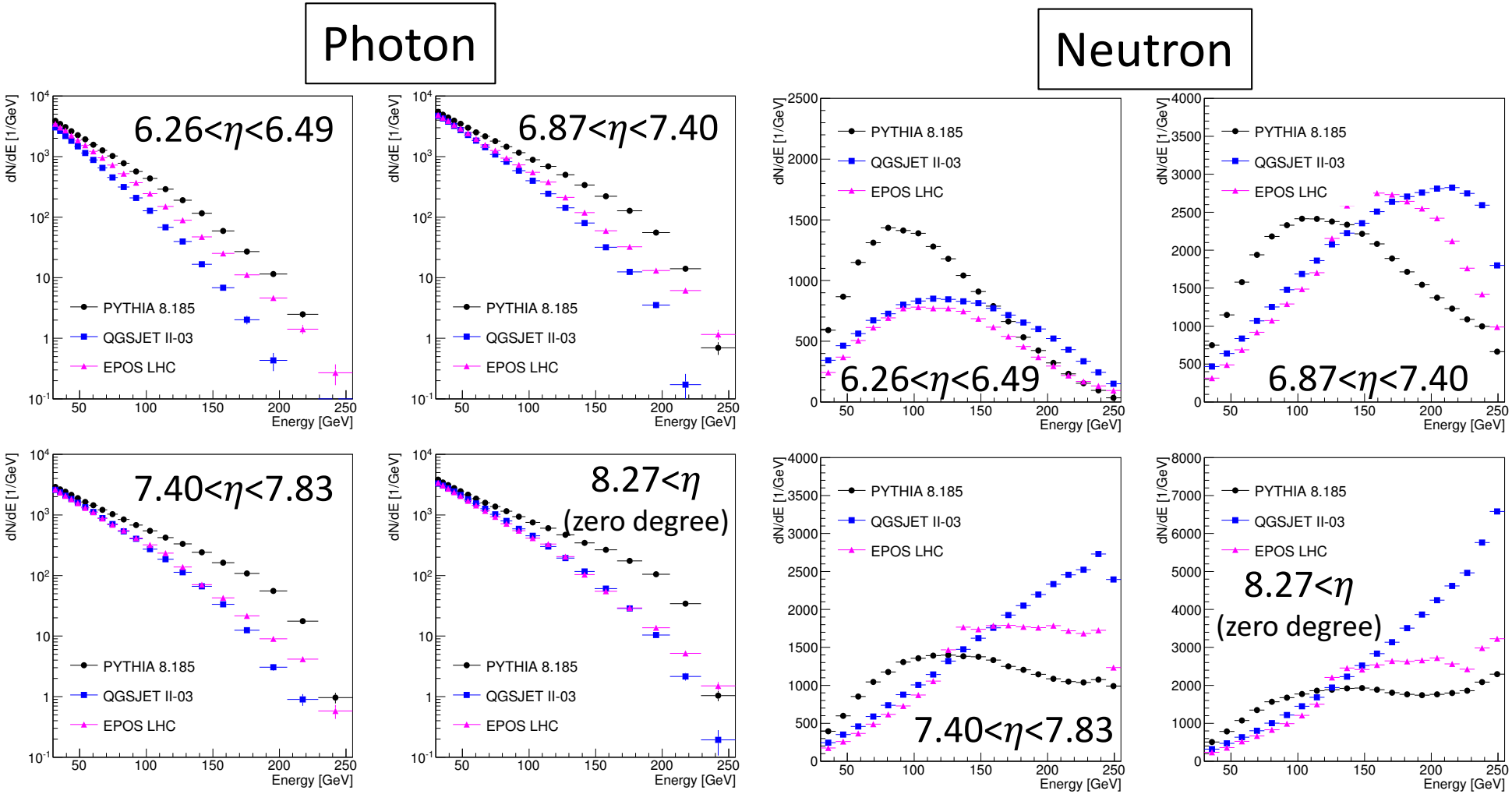






- Hadron-like (deep penetrating) showers were selected
- Anticorrelation between the RHICf raw (folded) energy and ZDC measured energy (in ADC unit) is confirmed
- (Anti)correlation only with West ZDC as expected => correct event matching

MC predictions (12 hours data)



- Large model-to-model difference even at the RHIC energy
- RHICf finally took 27.7 hours data with high-energy EM enhance trigger

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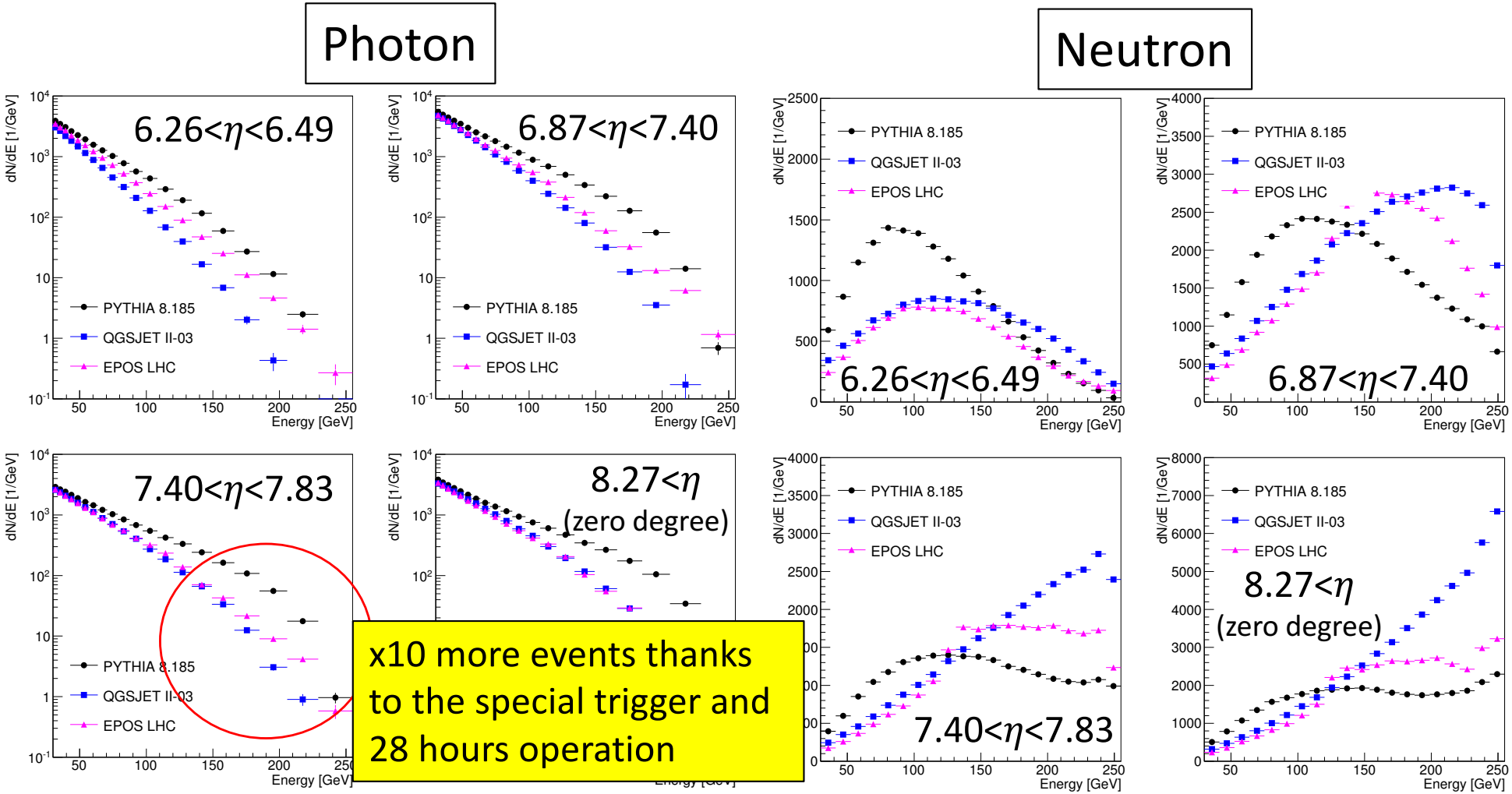


- Large model-to-model difference even at the RHIC energy
- RHICf finally took 27.7 hours data with high-energy EM enhance trigger

Summary

- RHICf is an experiment to measure zero degree particle production in RHIC 510GeV p+p collisions
- Physics targets are
  - Cross section measurements for Cosmic-ray physics (wide √s coverage combined with LHCf)
  - Single-spin asymmetry measurement with wide p_T coverage than the former RHIC experiments

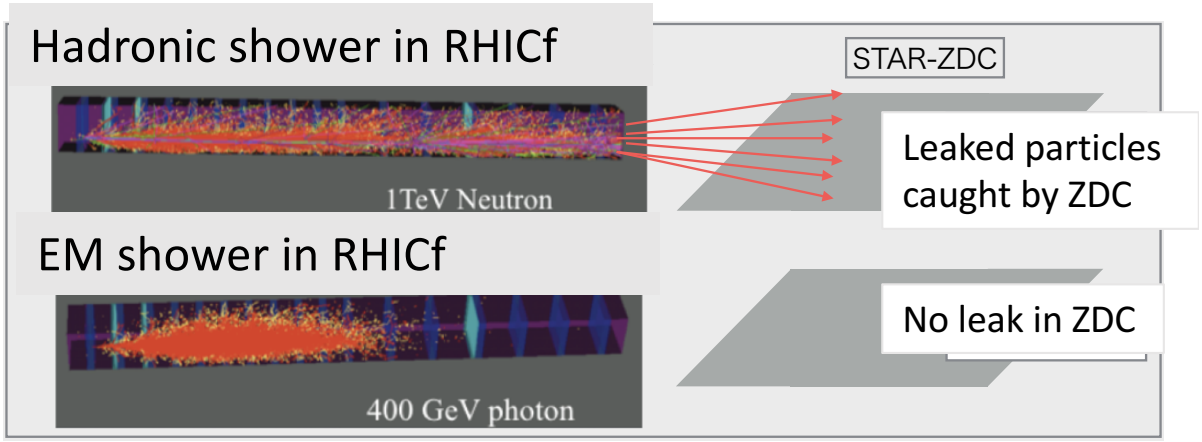
More talks tomorrow

- RHICf took data at RHIC (STAR IP) in this June
  - Successful beam condition (β^*, radial pol)
  - 27.7 hours of data taking
  - Good data quality at the quick check level
    - Energy coverage up to beam energy (255GeV)
    - Zero degree determination
    - π^0 identification
  - Successful common operation with STAR
    - anticorrelation with ZDC assures correct event matching
    - Possibilities of various analyses (diffraction identification, diffractive mass determination, …)

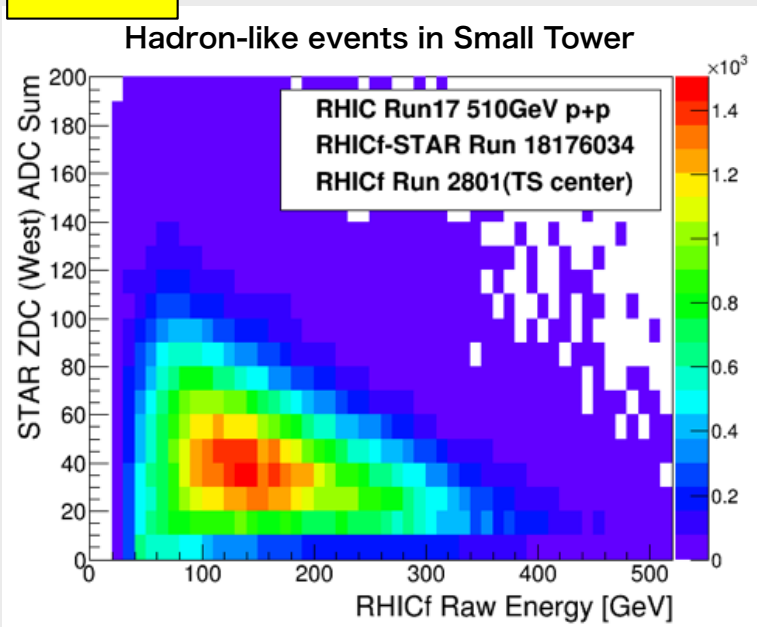
Backup

RHICf-ZDC anti correlation

- Anticorrelation was expected by a MC simulation.



Data



MC