RHICf
Beam Use Request 1

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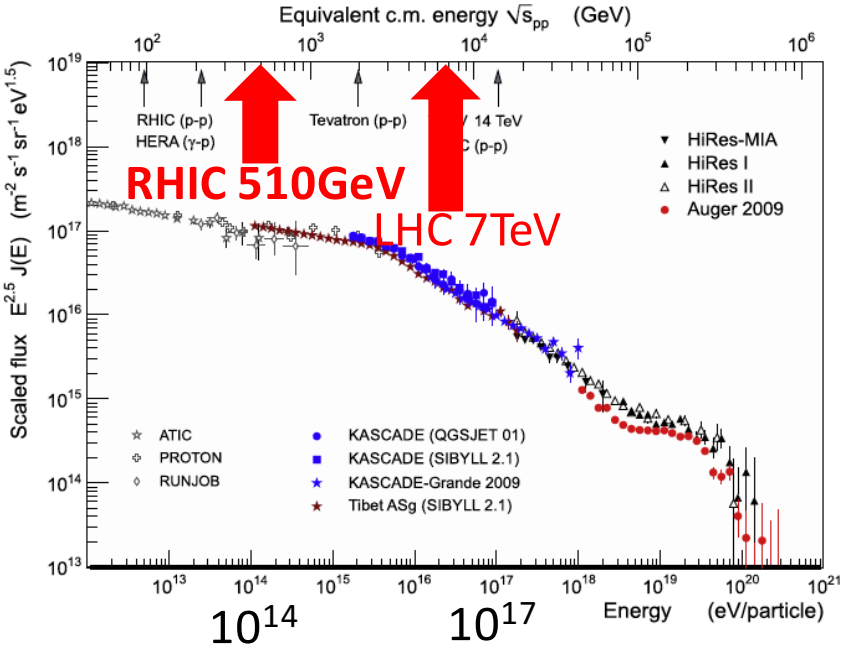
for the RHICf Collaboration

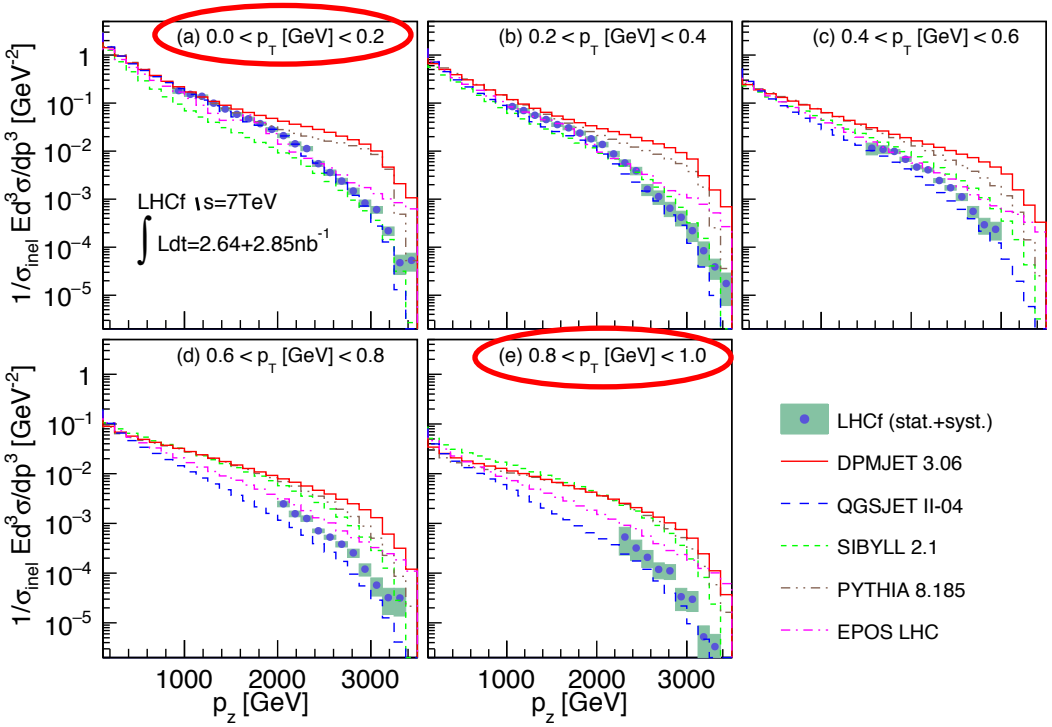
Outline

- RHICf physics targets
  - Cross section measurement for CR physics
  - Single-spin asymmetry of forward particles
- RHICf experiment
- Progress since last PAC – discussions with STAR –
- Beam Use Request for RUN17
  - Expected statistics
  - Backup scenario with vertical polarization
- Summary

Cross section measurements for CR physics



Air shower analysis relies on MC simulation assuming a hadronic interaction model

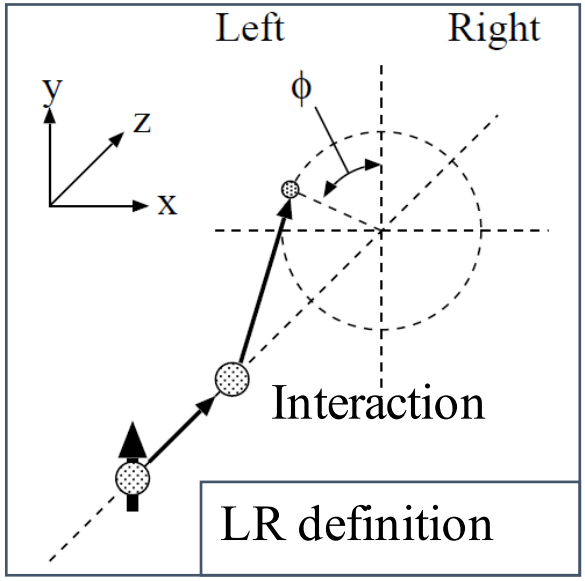


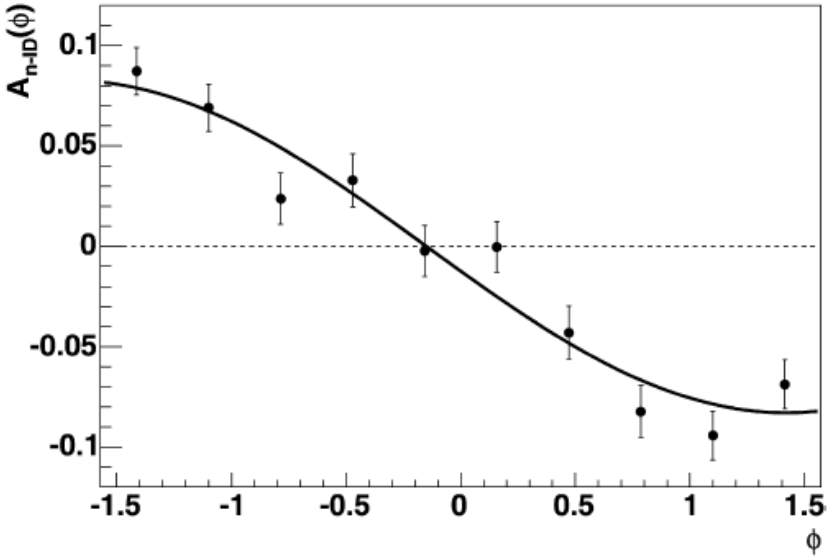
Cross section of forward π^0 production measured by LHCf at √s=7TeV

- RHICf uses one of the LHCf detectors
- RHIC configuration allows almost same x_F-p_T coverage to the LHCf 7TeV data ($x_F=2p_Z/\sqrt{s}$)
- √s dependence in forward hadron production can be understood with a wide √s reach

Single-Spin Asymmetry in forward neutrons

- First discovered at RHIC IP12 experiment



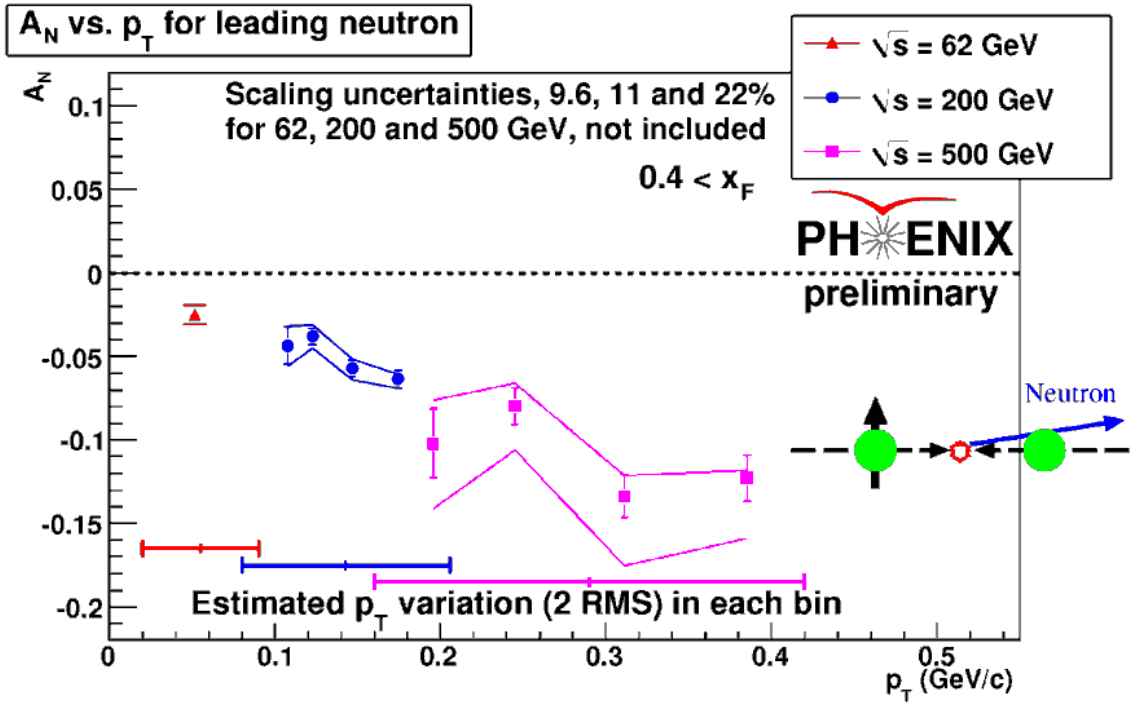


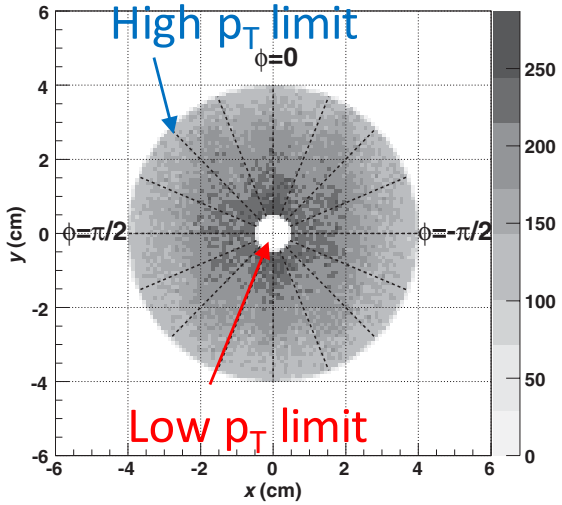
$$A_N \equiv \frac{d\sigma^{\uparrow} - d\sigma^{\downarrow}}{d\sigma^{\uparrow} + d\sigma^{\downarrow}} = \frac{\sigma_L^{\uparrow} - \sigma_R^{\uparrow}}{\sigma_L^{\uparrow} + \sigma_R^{\uparrow}}$$

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

Y. Fukao, et al.,
Phys. Lett. B 650 (2007) 325.

SSA of forward neutron production





Acceptance on the detector plane

- PHENIX measurements suggest p_T scaling of A_N
- Low p_T was limited by the 1cm position resolution 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

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

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

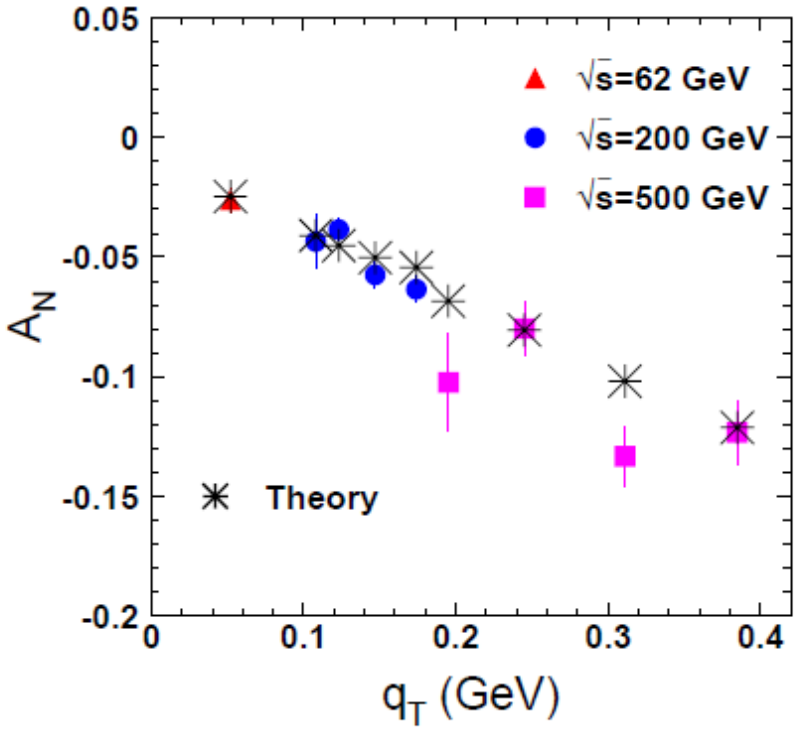
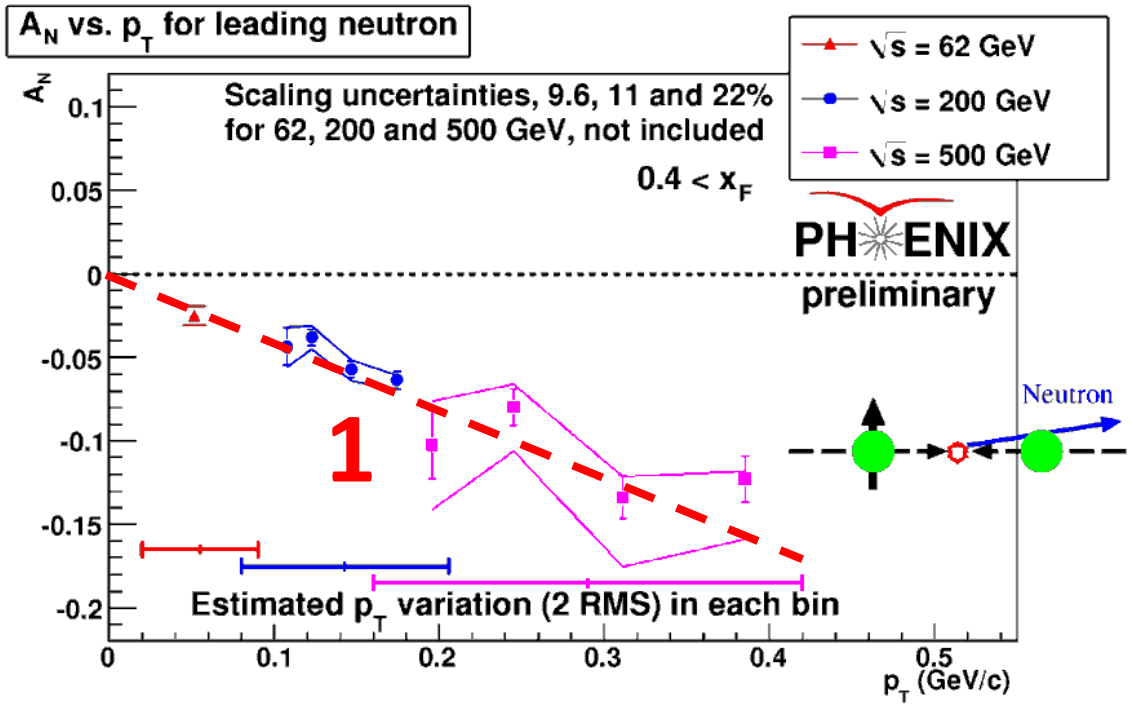


FIG. 1: (Color online) Single transverse spin asymmetry A_N in the reaction $pp \to nX$, measured at $\sqrt{s} = 62,\ 200,\ 500$ GeV [1] (preliminary data). The asterisks show the result of our calculation, Eq. (38), which was done point by point, since each experimental point has a specific value of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

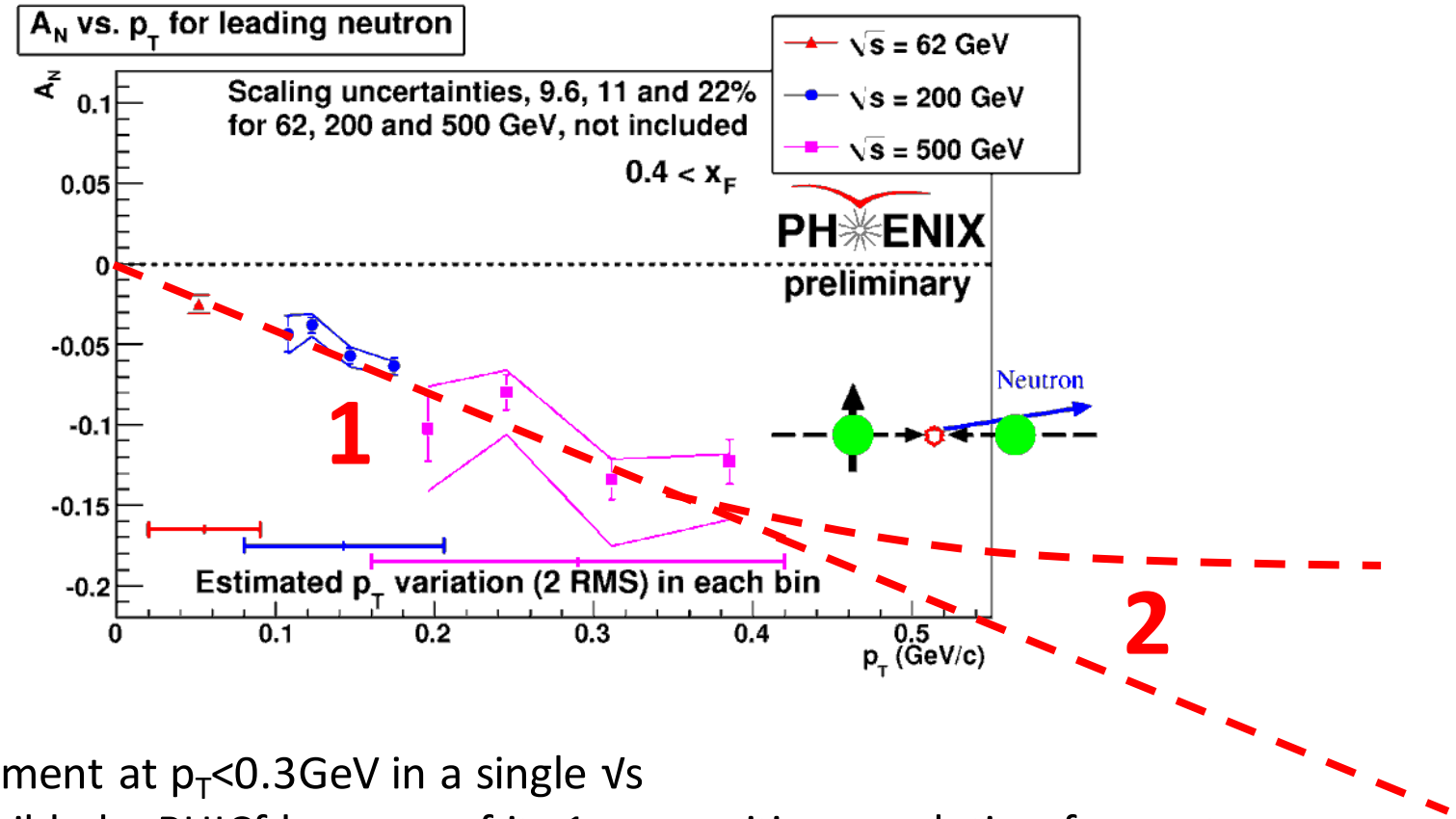
Kopeliovich, Potashnikova, Schmidt, Soffer: Phys. Rev. D 84 (2011) 114012.

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

SSA of forward neutron production



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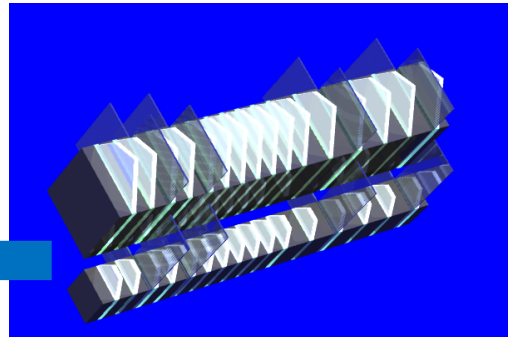
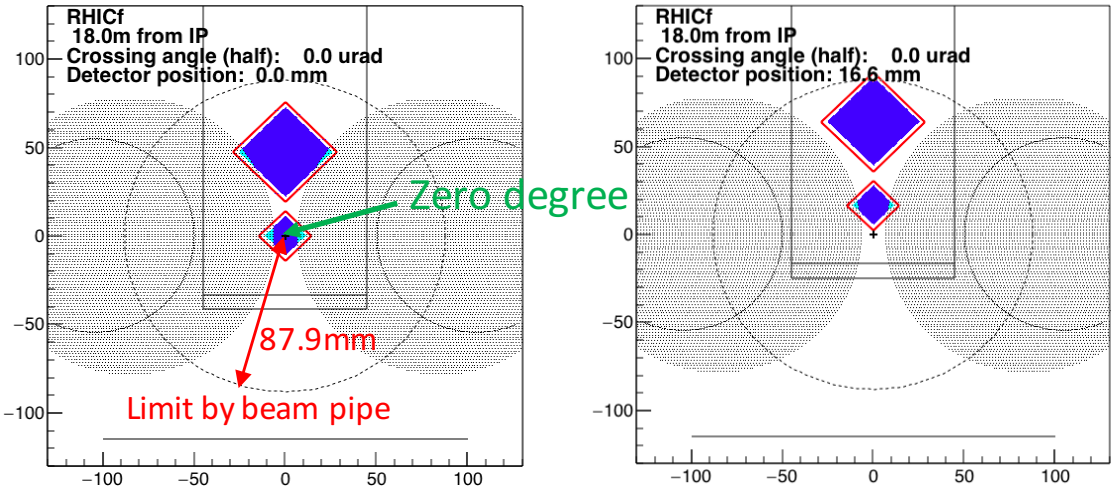
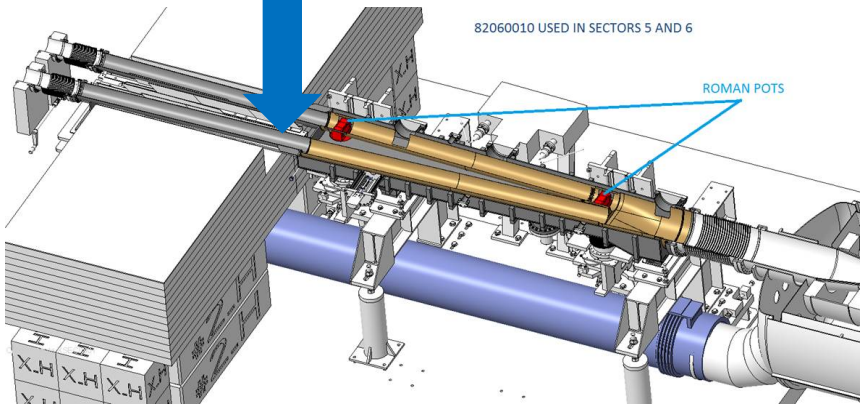
RHICf detector acceptance

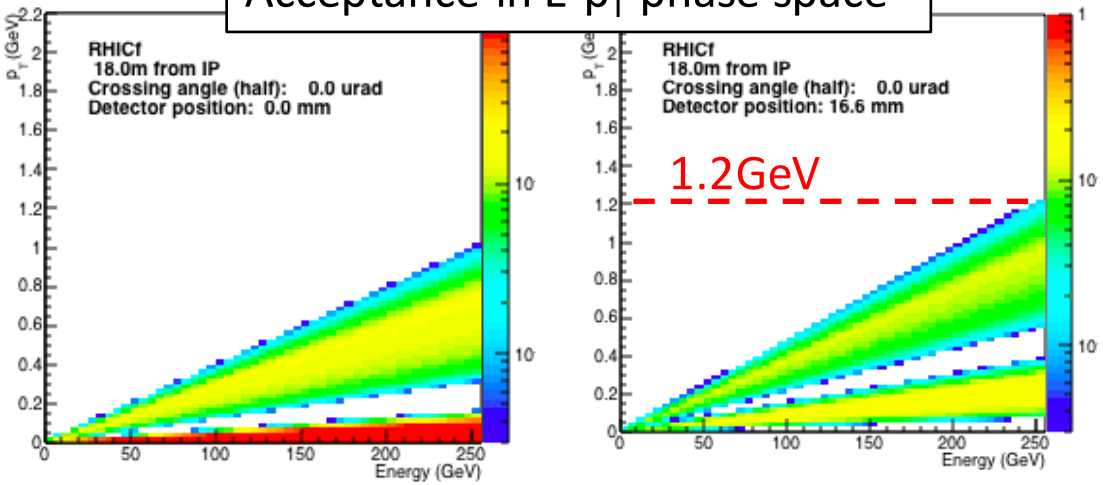
Compact double calorimeters
(20mmx20mm and 40mmx40mm)







Acceptance in E-p_T phase space



Widest and gapless p_T coverage is realized by moving the vertical detector position.

Radial polarization (vertical asymmetry) maximizes the advantage of this wide p_T coverage

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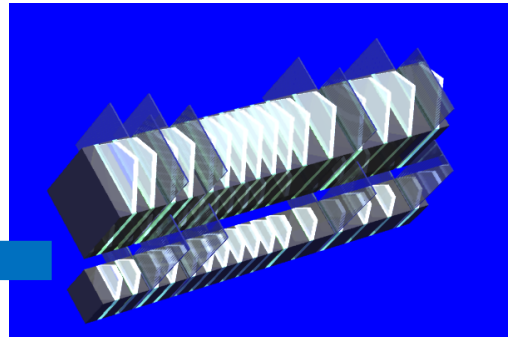

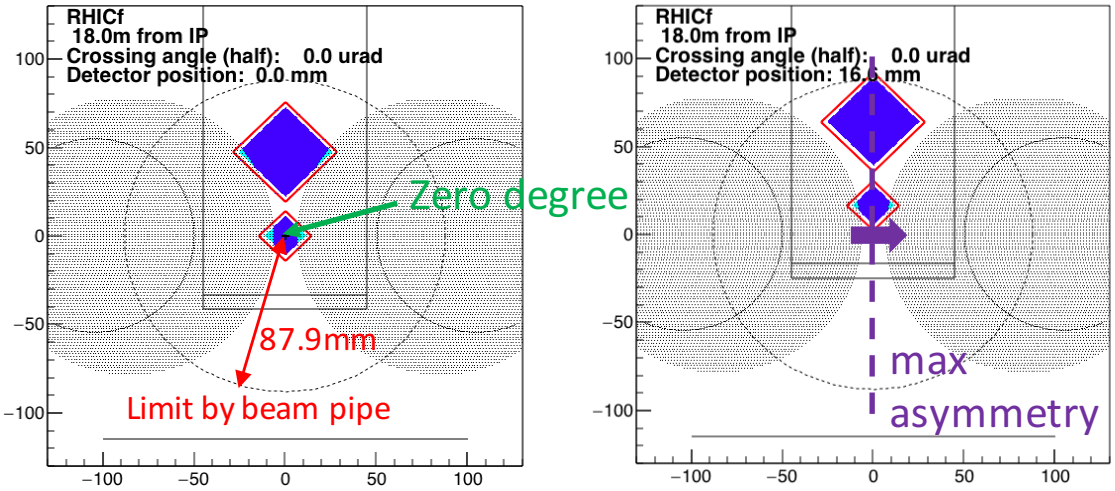

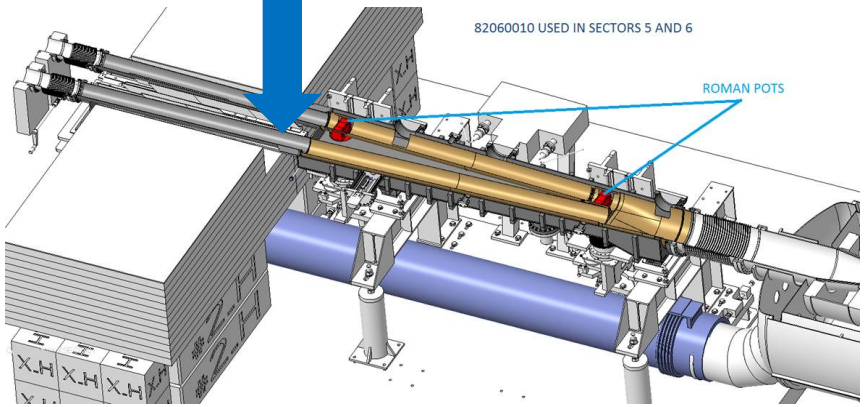

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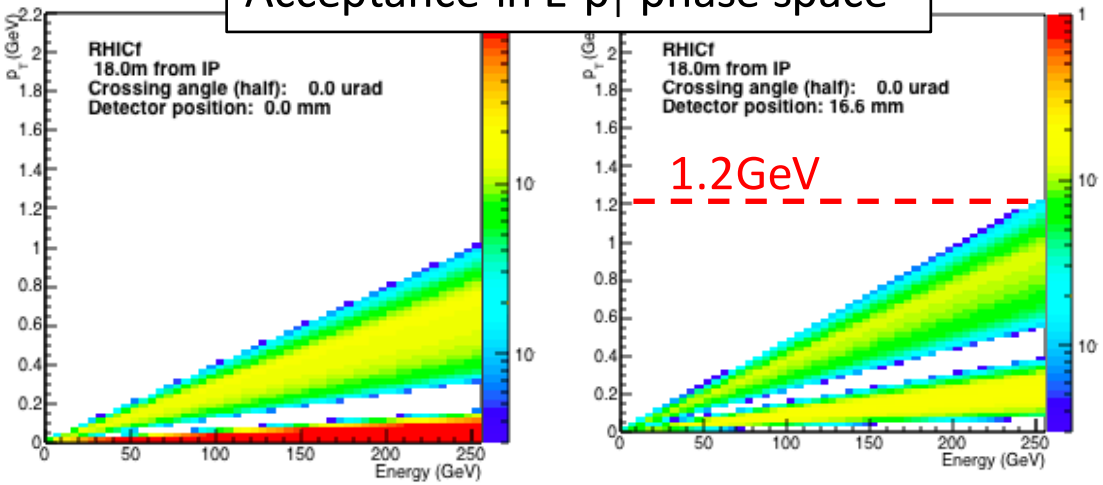


Widest and gapless p_T coverage is realized by moving the vertical detector position.

Radial polarization (vertical asymmetry) maximizes the advantage of this wide p_T coverage

Progress since last PAC
- agreements with STAR -

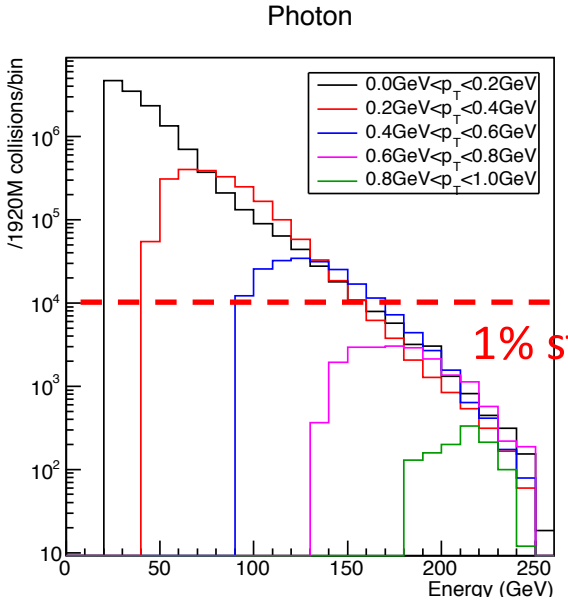
- Installation of the RHICf detector in front of ZDC at West side
- Electronics/cables setup in the tunnel and detector hall, usage of DAQ room and control room
- STAR/RHICf common event recording
  - Custom board to receive STAR event token at RHICf is ready
- Ongoing discussions
  - Online analysis of radial polarization (detail in later)
  - Detector installation timing and procedure
  - Event matching
- MOU between STAR and RHICf was exchanged in Jan-2016
- RHICf detector arrived at the STAR workshop last month

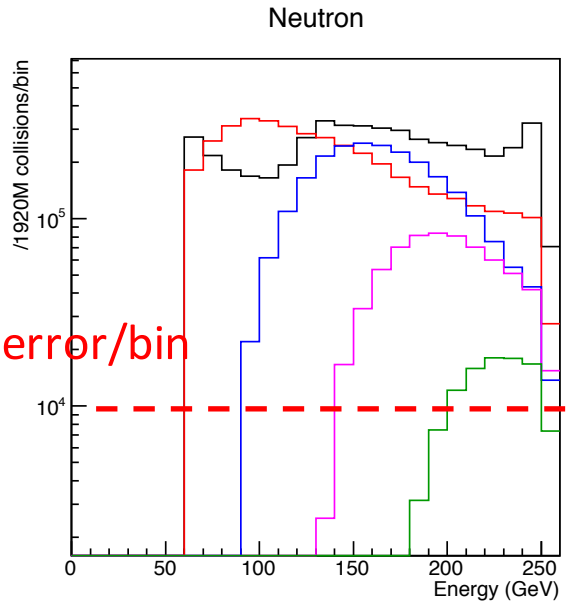
Beam Use Request for RUN17

Parameter	Value
Beam energy (GeV)	255
Beam intensity (protons per bunch)	2×10^{11}
Number of colliding bunch	111
Number of non-colliding bunch	9
Beam emittance (mm mrad)	20
β^* (m)	10
Luminosity ($cm^{-2}s^{-1}$)	2.0×10^{31}
Polarization direction	radial
Polarization amplitude	0.4–0.5
β^* setup time	1 day
Radial polarization setup time	1 day
Data taking time	2 days

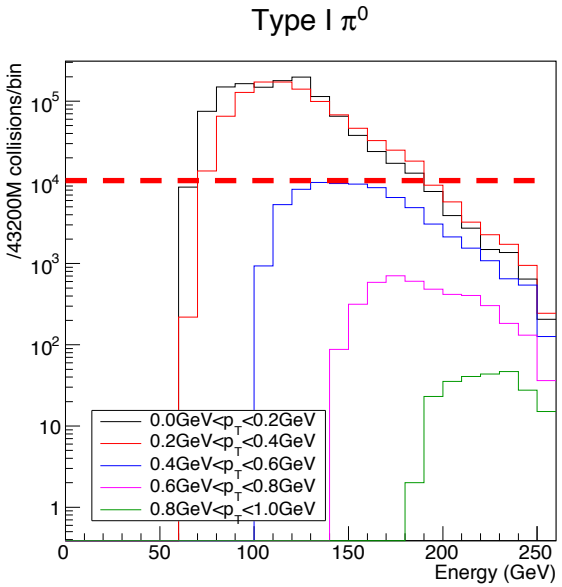
- Beam setup 2 days
  - β^*=10m to keep the beams parallel (σ=1.5mm at detector) 1day
  - Radial polarization to access p_T>0.3GeV in SSA measurement 0.3-1 day [not more than 24 hours in case of any difficulty]
- Physics operation 2 days
  - 12 hours data taking for minimum success both in cross section and SSA measurements **in parallel**
- Backup
  - we hope 24 hours data taking is assured only when we have (recoverable) trouble
- Timing
  - To be discussed, but not very early phase
  - Hope around May 2017

Expected statistics in 12 hours





1% stat error/bin

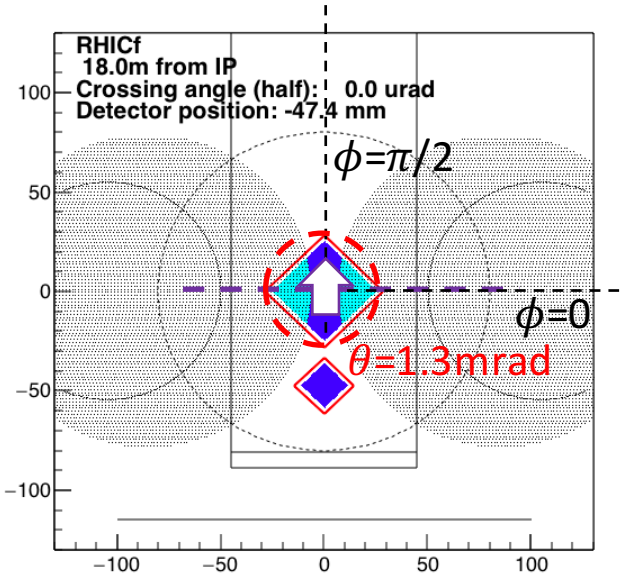


Neutron SSA

$p_T(GeV)$	N $(\times 10^3)$	δA
0.0–0.1	2,310	0.0013
0.1–0.2	2,570	0.0012
0.2–0.3	1,710	0.0015
0.3–0.4	2,190	0.0014
0.4–0.5	1,210	0.0018
0.5–0.6	1,130	0.0019
0.6–0.7	402	0.0032
0.7–0.8	260	0.0039
0.8–1.2	104	0.0062

- After 12 hours, high threshold energy and EM enhanced trigger to increase statistics in high energy photons and π^0

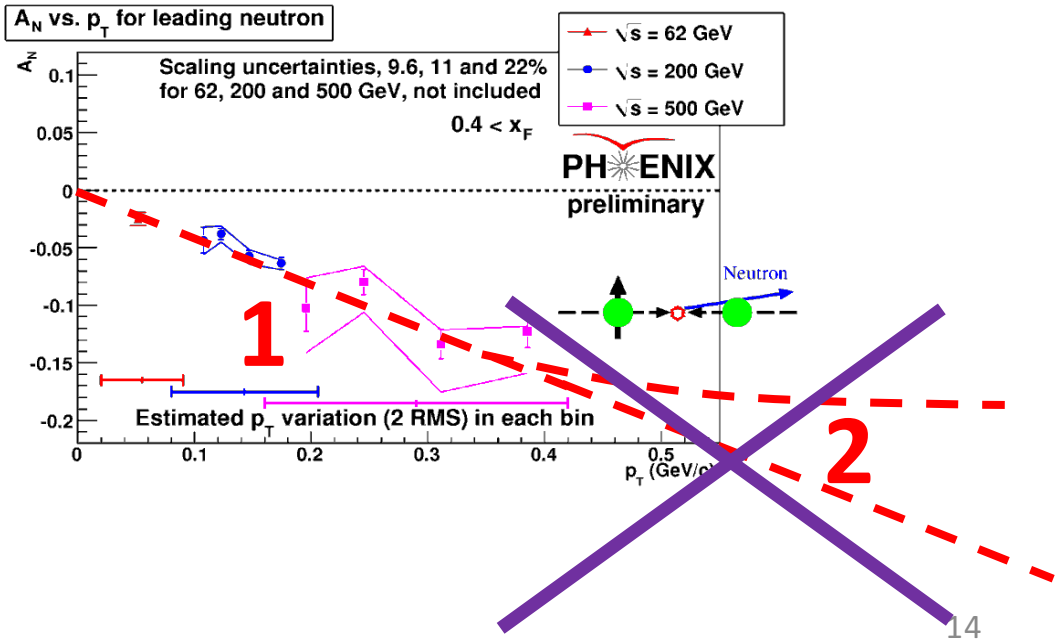
If using vertical pol…



Large calorimeter will be placed to cover zero degree

$p_{T,max}$ = 1.3mrad × 255GeV = 0.33 GeV

We lose p_T>0.3GeV, but still important to see p_T<0.3GeV



Summary

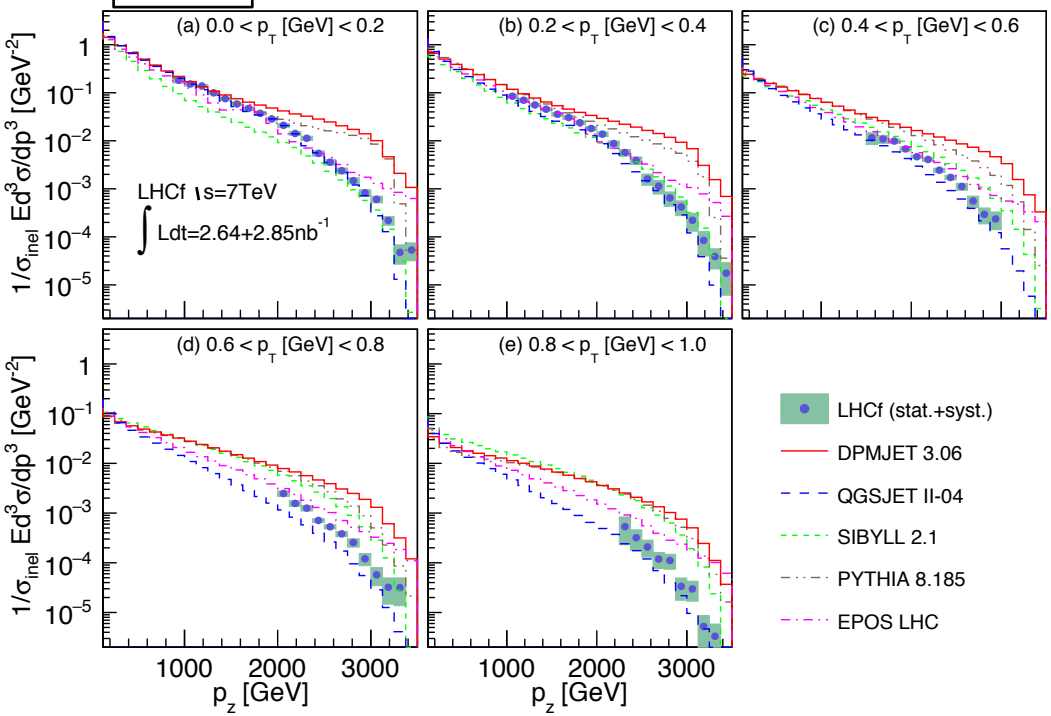
- RHICf measures
  - Cross sections of forward particle production for CR physics
  - Single-Spin Asymmetry of forward particles
    in parallel under the beam condition below
- Beam use request [4 days in total]
  - Not in early RUN17, to be discussed
  - 255GeV proton beams
  - β^*=10m, requires 1 day setup time
  - Radial polarization, requires another 0.3-1 day [max 1 day]
  - 2 days for physics
    - 12 hours for minimum success for 2 physics in parallel
    - Only in case of recoverable trouble, 24 hours of data taking to be assured even after 4 days

We thank C-AD and STAR members for fruitful discussions

Backup

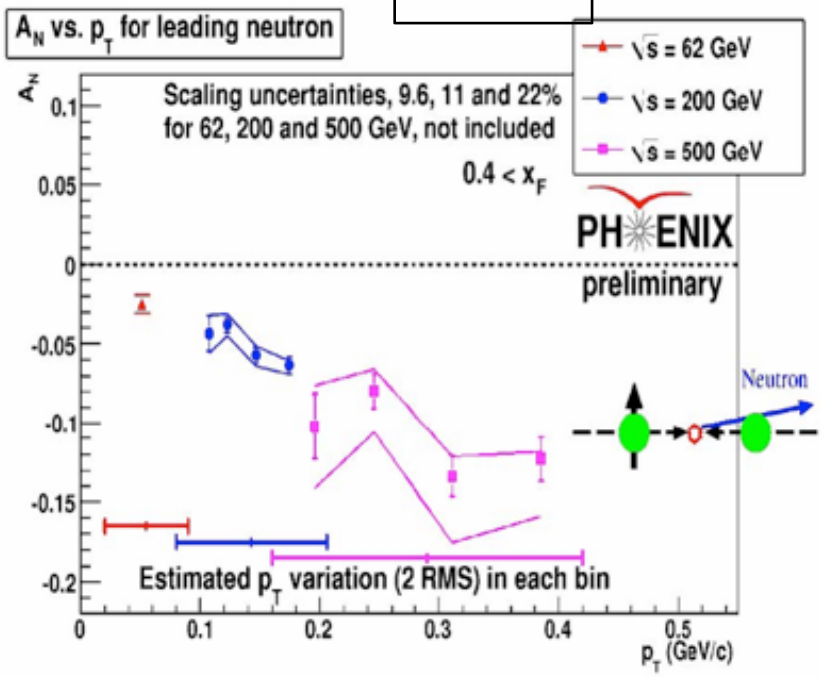
RHICf Physics targets

LHCf



1. Cross section measurement for CR physics

PHENIX



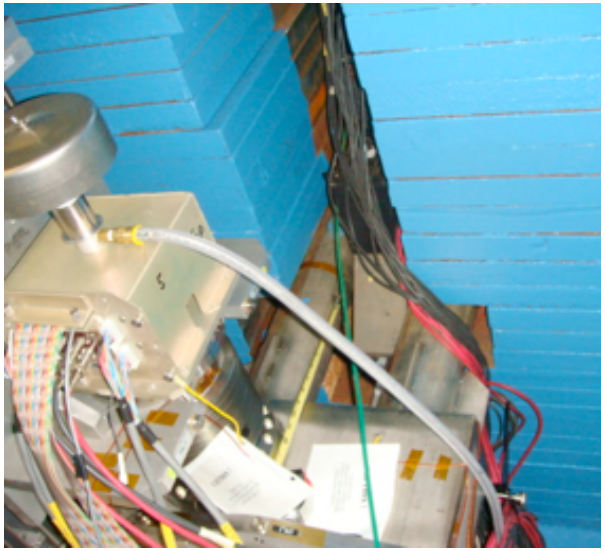
2. Single-Spin Asymmetry (SSA)

- p_T = 0 - 0.3 GeV coverage with single √s
- p_T >0.3GeV coverage

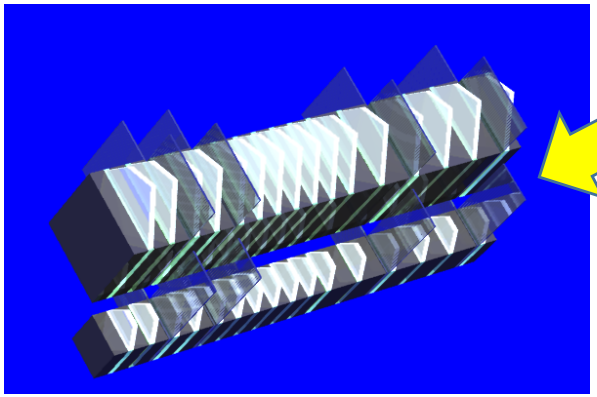
Measurements up to p_T~1GeV is a key for both targets

1. to compare with the LHCf results
2. to improve the previous results by PHENIX

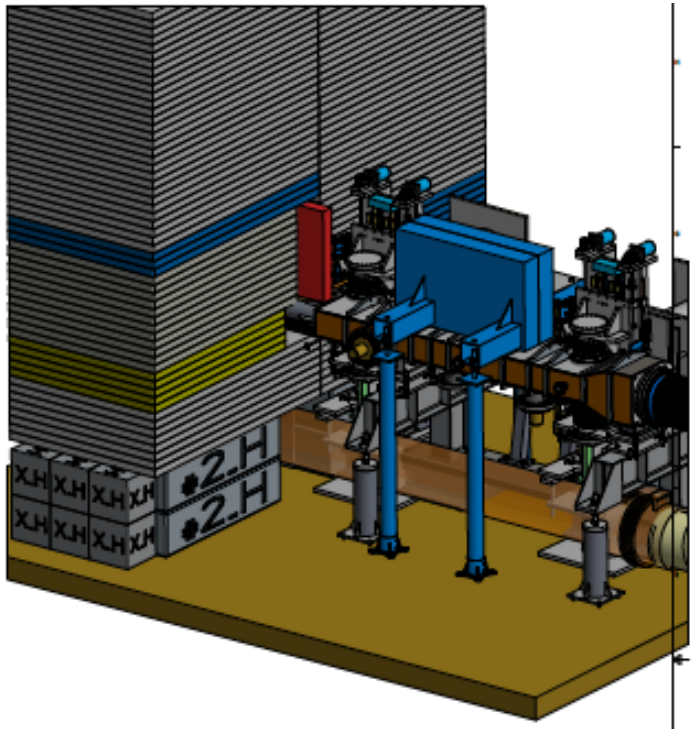
RHICf Experiment



10cm wide gap in front of ZDC



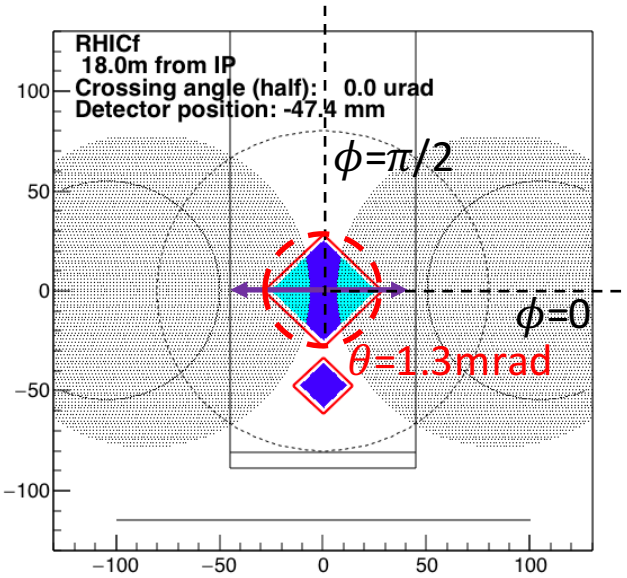
Double tower structure
(20mmx20mm and 40mmx40mm)

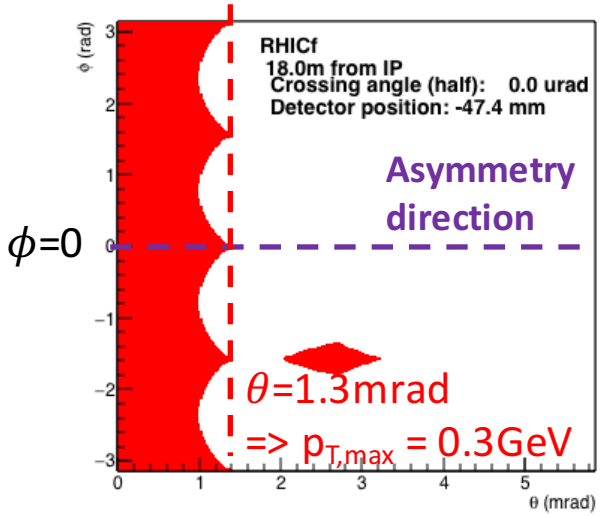


$92mm^{w}x280mm^{l}x610mm^{h}$ package

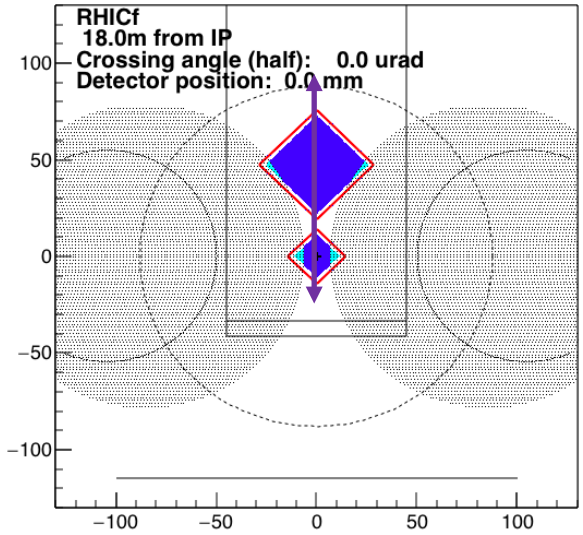
Vertical pol vs. Radial pol

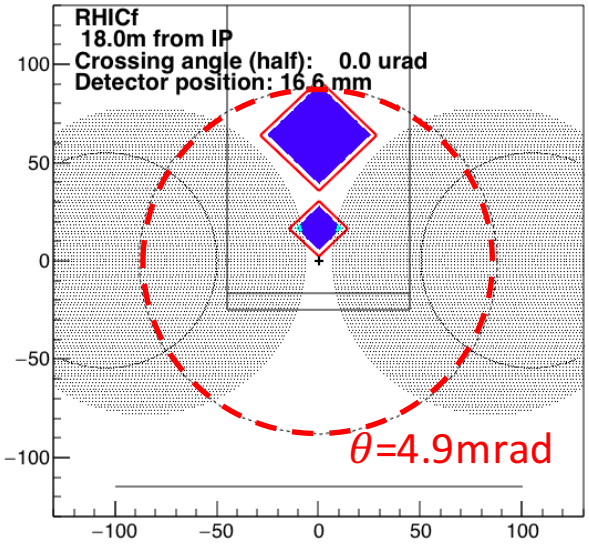
Best configuration in V-pol
= option for CR measurements

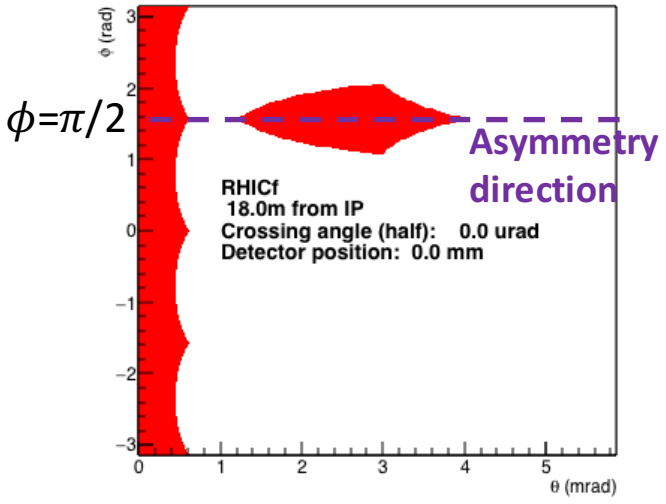


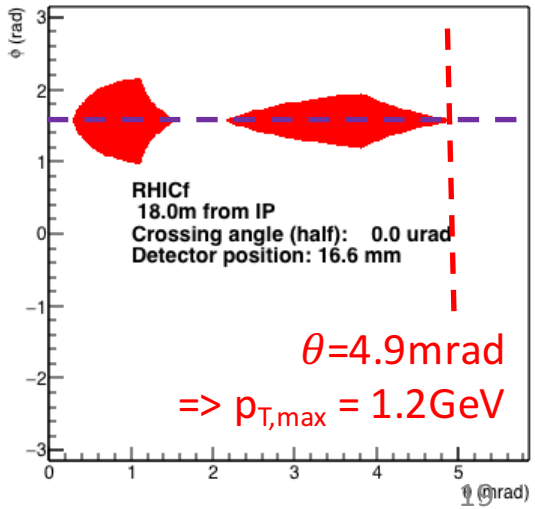


Best configuration for R-pol
= identical to CR measurements

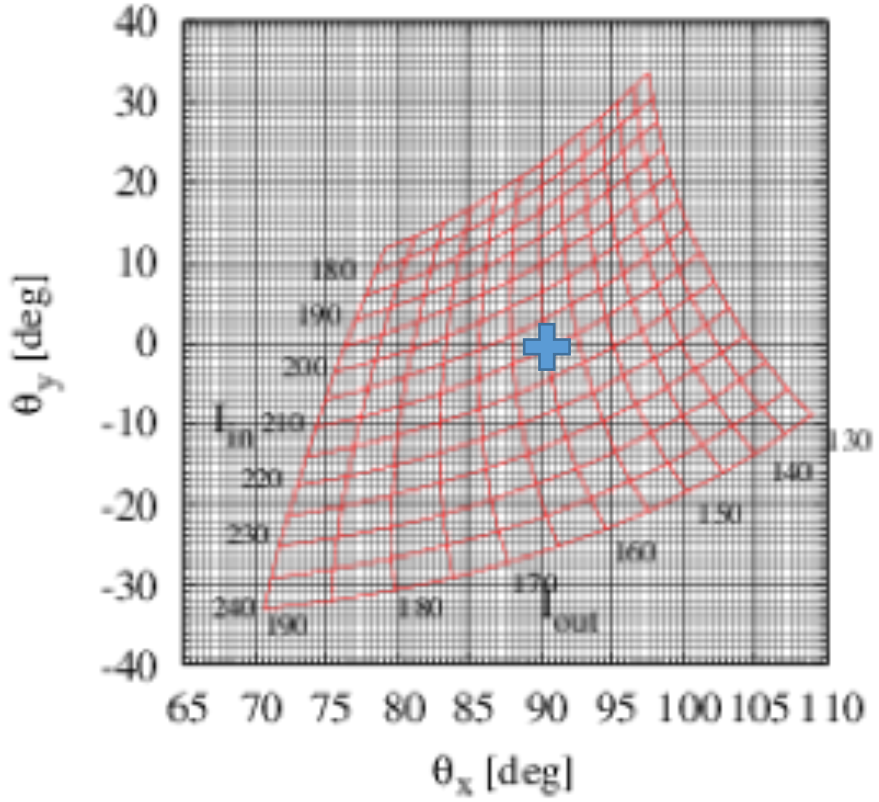






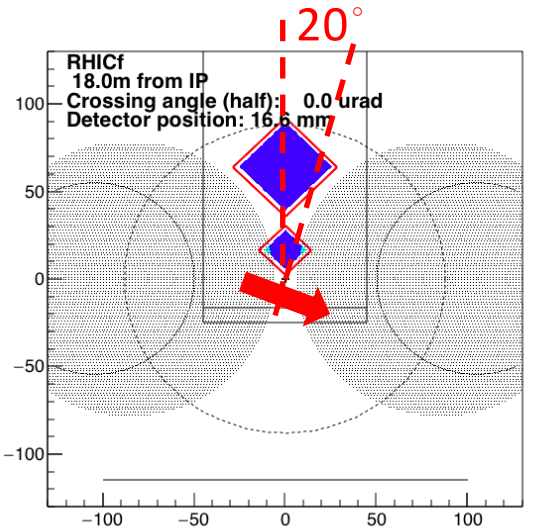


I_{in}-I_{out} calculation by C-AD for radial polarization



Radial polarization setup

- This is not in the regular RHIC program
- Key issues
  1. Fast feedback to C-AD for current tuning
     - STAR ZDC count rates provide real time determination of asymmetry and azimuthal angle [next slide]
     - Under the luminosity of RHICf condition δA=0.003 and $\delta\phi$ =3° in 10 min
  2. (short) Reference measurement with vertical polarization
  3. Tolerances defined by RHICf
     - Residual polarization in longitudinal direction; 25° residual reduces A by 10%
     - Azimuthal direction of polarization; 20° still keeps maximum asymmetry in the RHICf large calorimeter
     - RHICf does not request more than 24 hours for setup in case of any trouble, in this case RHICf concentrates on SSA measurement at p_T<0.3GeV with vertical polarization

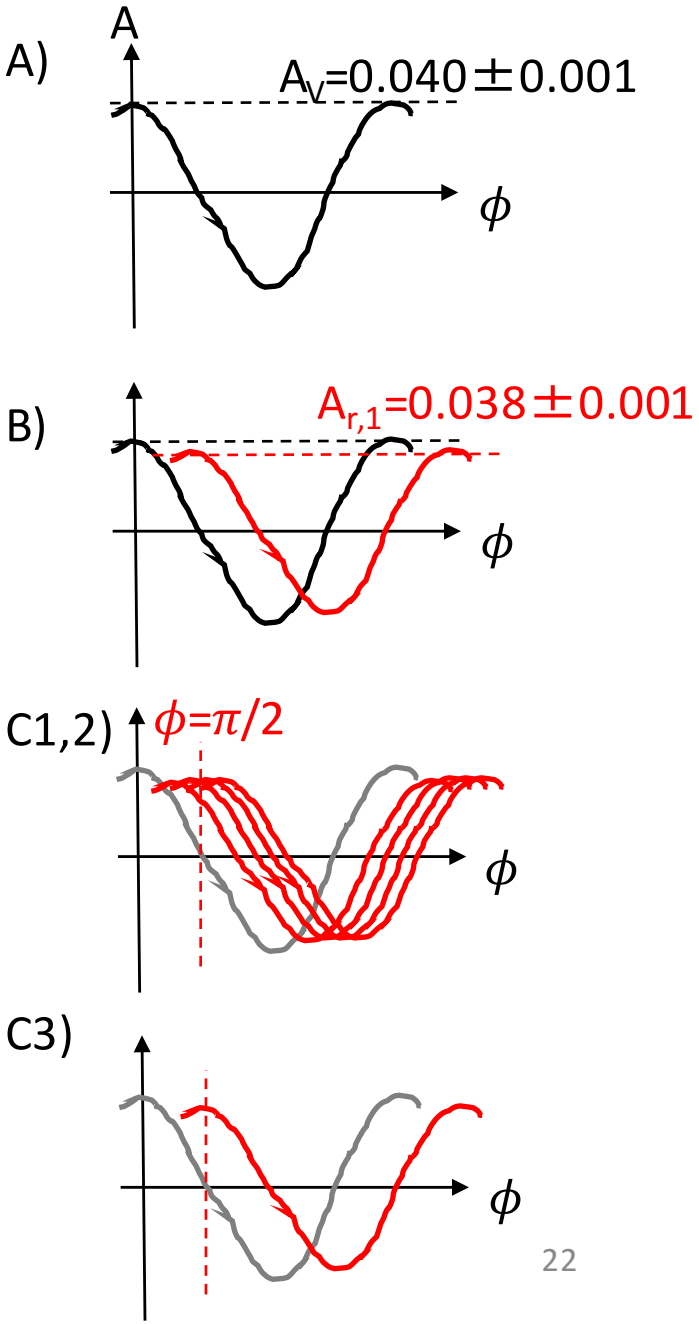


Setup Procedure

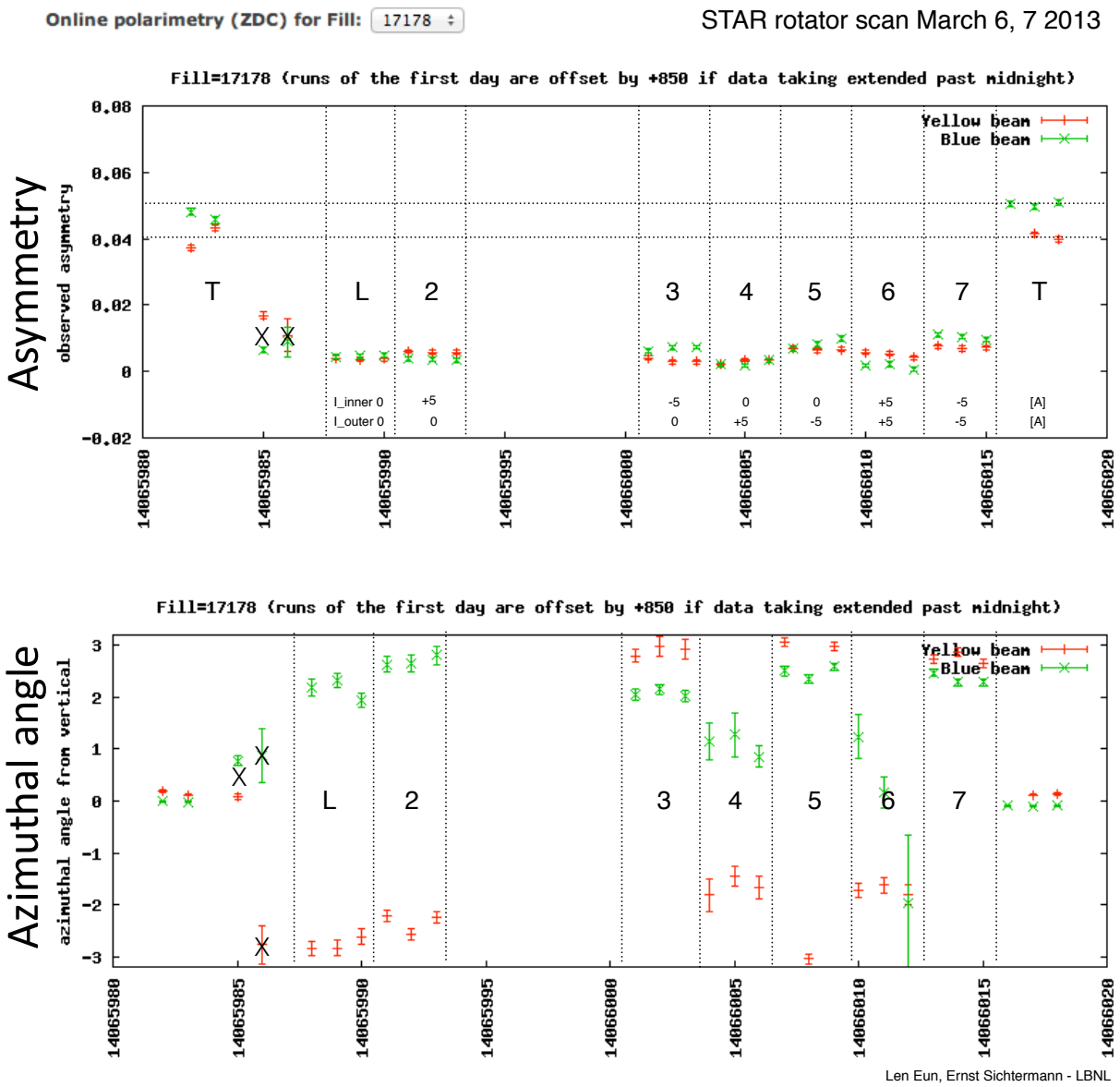
A) Reference data taking [2 hours including analysis]
   1. 1 hour data taking with vertical pol to obtain reference A_V with δA=0.001

B) Confirmation of radial polarization [2-6 hours depending on iteration]
   1. Radial pol first trial, 1 hour data taking to determine $A_{r,1}$ with δA=0.001
   2. If $A_v - A_{r,1} > 0.004$, C-AD checks current setup and repeat from B-1

C) Fine tuning of polarization direction ϕ_0 [6 hours]
   1. 10min data taking with 4-5 sets of current to determine $\phi_{0,2}, \phi_{0,3}, \phi_{0,4,\ldots}$ with $\delta\phi$=3°
   2. Find best two sets of current those result $\phi_0 \sim \pi/2$
   3. Define the best current and take 1 hour of confirmation data



STAR online polarization analysis

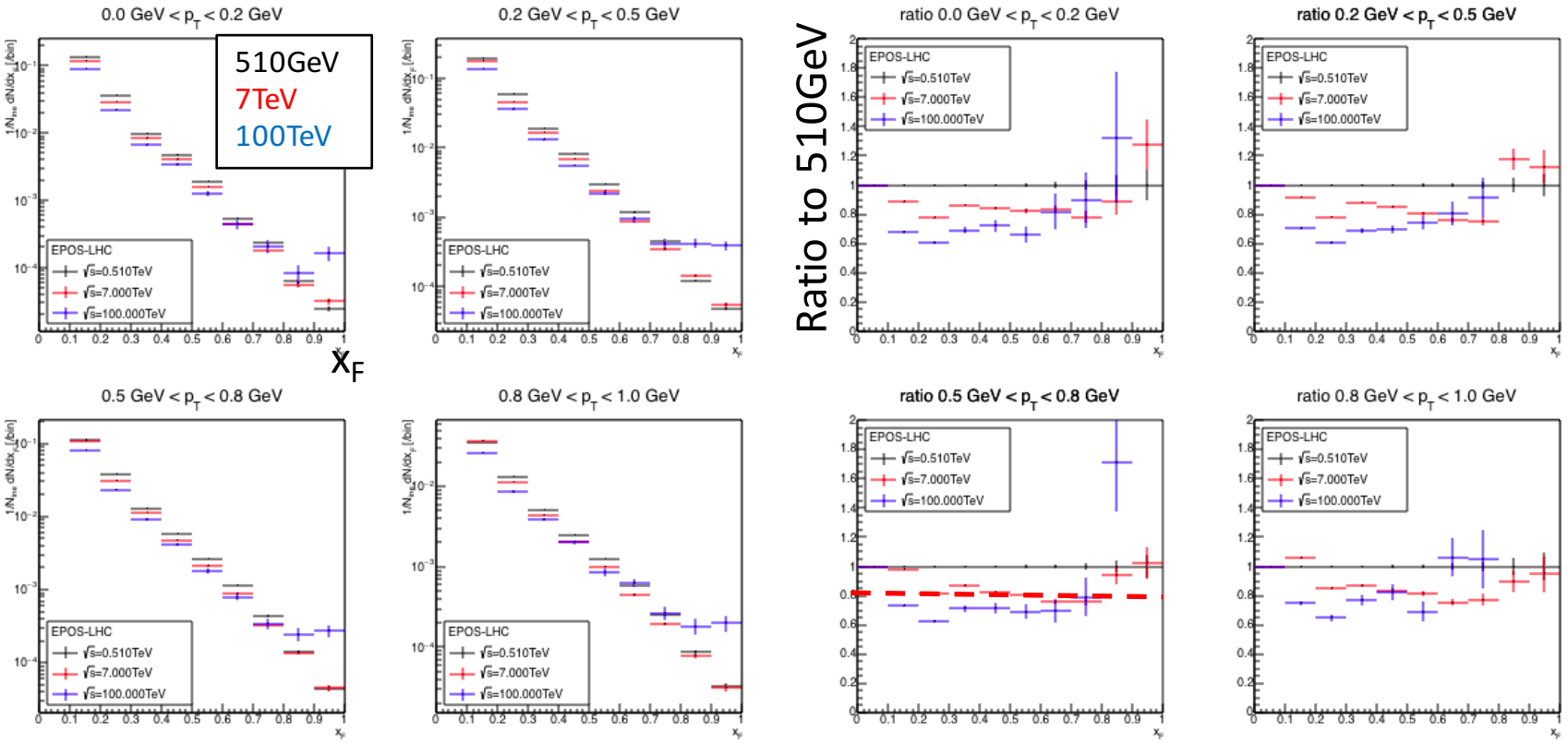


Under RHICf luminosity (β^*)

δA=0.003
$\delta\phi$=3°

in 10 min

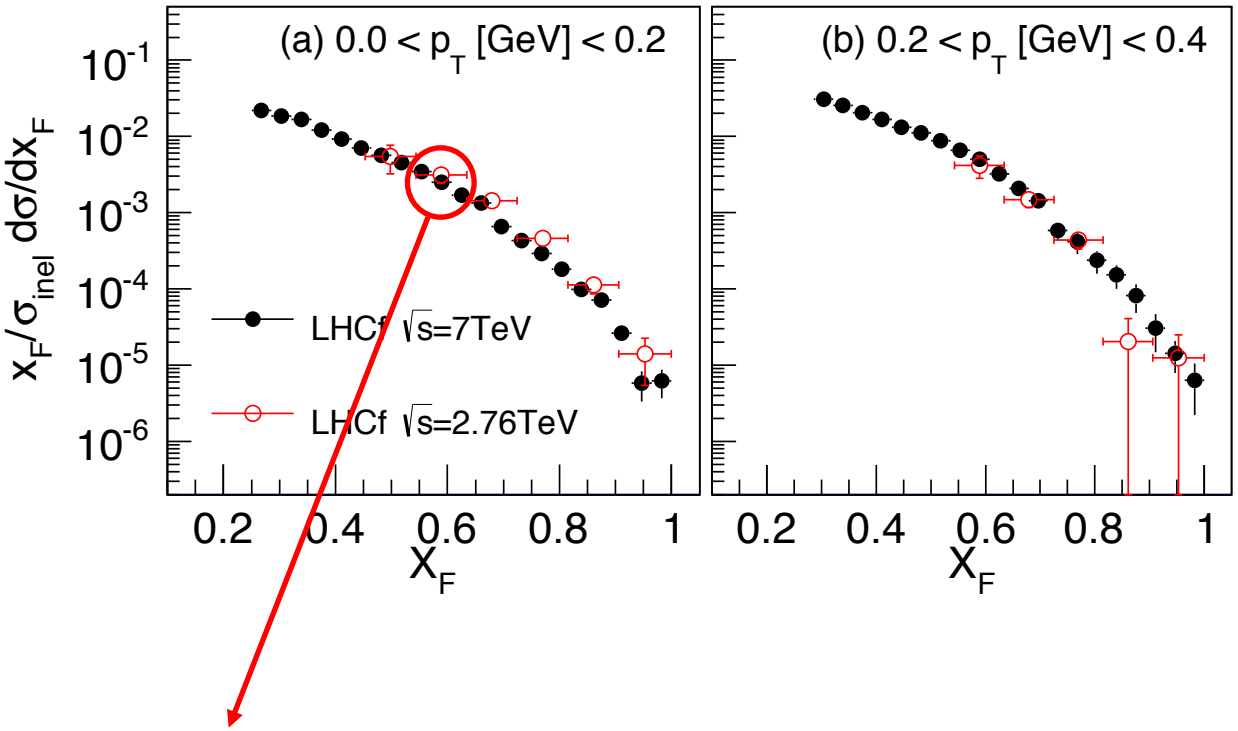
Scaling in interaction model



π^0 cross section by EPOS-LHC model

20% reduction in cross section is predicted from 510GeV to 7TeV

Scaling measured by LHCf



- 8% error including statistical and systematic in 7TeV result
- This will be reduced to ~5% soon by correcting T dependence in PMT response
- RHICf will have similar total error