RHICf:
RUN17 Operation and Status of Analysis

Takashi Sako (ICRR, Univ. of Tokyo)
for the RHICf Collaboration


Institute for Space-Earth Environmental Research, Nagoya University, Kobayashi-Maskawa Institute, Nagoya University, Graduate School of Science, Nagoya University, ICRR, University of Tokyo, Riken/Riken BNL Research Center, JAEA, Waseda University, Tokushima University, Japan, Seoul National University, Korea University, Korea, INFN, Univ. di Firenze, INFN, Univ. di Catania, Italy
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

Compact double calorimeters (20mmx20mm and 40mmx40mm)
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 $1.4 \times 10^{14} \text{eV}$ CR
   • $\sqrt{s}$ scaling will be tested with LHCf data at $10^{17} \text{eV}$

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
• 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 $\sqrt{s}$ dependence

LHCf 2.76TeV and 7TeV data shows $\sqrt{s}$ scaling of forward $\pi^0$

neutron

ISR (30-60GeV), PHENIX (200GeV) and LHCf (7-13TeV) data can test $\sqrt{s}$ scaling of forward neutrons
SSA of forward particle production

1. Wider pT coverage with a single vs
2. First detection (or stricter upper limit) of forward $\pi^0$ asymmetry

Neutron asymmetry by PHENIX

$\pi^0$ asymmetry RHIC-IP12 vs=200GeV
($A_N = -0.024 \pm 0.031$)
**C-A Operations FY17**

**May 8, 2017**

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<th>Program Element</th>
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**End date?**

**RHIC Cryo weeks**

**RHICf week**
Collision rates in RHICf days

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

RHICf DAQ rate
- Max rate was limited \(~1\text{kHz}\)
- 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 $\pi^0$ trigger)

Total acquisition time 1659min = 27.7 hours
Quick look (polarization & spectrum)

- Energy spectrum of EM-like showers in a 30 minutes run
- High-energy EM showers and $\pi^0$ were selectively triggered to compensate the limited DAQ speed.
- Polarization angle is 0 in usual RHIC operation (vertical pol)
- Radial polarization ($90^\circ$) was required for RHICf operation
- Stable radial pol and asymmetry was observed by ZDC

Trigger efficiency MC taking into account the final experimental setups

Energy spectrum of EM-like showers in a 30 minutes run

- Trigger efficiency MC taking into account the final experimental setups
Quick look
(basic performance)

Hit maps of $>200\text{GeV}$ hadron–like events at different detector positions
$\Rightarrow$ Determination of “zero degree”

Invariant mass of photon pairs
$\Rightarrow$ 135 MeV peak by $\pi^0$

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 $\pi^0$
- $A_N$ of very forward $\pi^0$

PHENIX, STAR $\sqrt{s}=200\text{GeV}$

PHENIX Collaboration, PRD 90, 012006 (2014)
Summary

• Operation of RHICf in RUN17 was successfully done
  • Special setup, $\beta^*=8$m 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
  • $\pi^0$ identification
  • Beam center determination
  • Correct event matching with STAR
• Ongoing analyses
  • EM shower events => forward $\pi^0$ asymmetry

We appreciate supports by PAC, C-AD, STAR and PHENIX Collaborations
Backup
\[ \pi \] production by different models at different \( \sqrt{s} \)

\[
\begin{align*}
\text{EPOS-LHC} & & \text{QGSJET-II-04} \\
\text{PYTHIA 6} & & \text{SIBYLL 2.3}
\end{align*}
\]

\( \sqrt{s} = 0.1, 1, 10 \text{TeV} \)

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

\[
A_N \approx \frac{2 \text{Im}(fg^*)}{|f|^2 + |g|^2}
\]

\(f\) : 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).

SSA of forward particle production

1. Measurement at $p_T < 0.3 \text{GeV}$ in a single $\sqrt{s}$
   • possible by RHICf because of its 1mm position resolution for neutrons
2. Measurement at $p_T > 0.3 \text{GeV}$ 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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