Au + Au $\sqrt{s_{NN}} = 4.5$ GeV
Fixed-Target Results from STAR

Kathryn Meehan for the STAR Collaboration
University of California-Davis
and
Lawrence Berkeley National Laboratory
Outline

1. Introduction to STAR Fixed-Target (FXT)
2. Results
   - Hadron spectra and yields
   - Directed flow of hadrons
   - Elliptic flow
   - HBT
   - Fluctuations
3. Future work
4. Conclusions
Why a Fixed-Target Program?

- FXT could provide control measurements for searches for critical point and onset of deconfinement.
- Kurtosis measurement is one of the future program goals and not in this talk.
- Test run focused on demonstrating STAR FXT capabilities.

Preliminary HADES result

0-10% (QM 2017)

Need data here!

First Dedicated Au + Au FXT Test Run In 2015

$$\sqrt{s_{NN}} = 4.5 \text{ GeV}$$

- 1.3 million events, top 30% central trigger
- Filled trigger bandwidth $\Rightarrow$ DAQ limited
- 1 mm thick (4% interaction probability) gold foil target

$\mathbf{\nu N = 4.5 G e V}$
Physics Results

$\text{Au} + \text{Au} \quad \sqrt{s_{NN}} = 4.5 \text{ GeV}$
• Amplitudes and widths of the rapidity densities are consistent with AGS
• $m_T - m_0$ and $y$ range will be extended with time-of-flight detector

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02/08/2017
Kaon and Lambda Spectra and $dN/dy$

- $K^0_S$ FXT STAR @ 4.5 GeV
- $K^+$ E917 @ 4.30 GeV
- $K^-$ E917 @ 4.30 GeV
- $(K^++K^-)/2$ E917 @ 4.30 GeV

Open symbols are reflected

Gaussian Fit

Statistical errors only

Amplitudes and widths comparable with AGS

02/08/2017
Directed flow of protons and pions at $\sqrt{S_{NN}} = 4.5 \text{ GeV}$

- Proton flow is “positive”
- Pion flow is “negative”
- $\pi^+$ flow twice that of $\pi^-$

Slope near mid-rapidity:

- $0.082 \pm 0.009$
- $-0.021 \pm 0.002$
- $-0.010 \pm 0.003$

Statistical errors only
Directed flow of kaons and lambdas at $\sqrt{s_{NN}} = 4.5$ GeV

- Flow of kaons (mesons) is negative.
- Flow of lambdas (baryons) is positive.
- See D. Tlusty’s poster on directed flow in STAR fixed-target.
Directed Flow Comparison Across Experiments and Energies

- First $\pi$ results shown for this energy range.
- The mesons continue the trend of negative flow seen at higher energies.
- Protons and lamdas are consistent with positive flow indicative of compression.

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**STAR BES**
10-40%

**STAR FXT**
10-25%

**STAR PRELIMINARY**

$\sqrt{s_{NN}}$ (GeV)

**FXT**

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Directed Flow Comparison Across Experiments and Energies

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Elliptic Flow of Pions and Protons

- Mass ordering between pions and protons continues to be observed at this energy.
- Good agreement with E895 supports the known change in behavior between FXT and BES collider regimes.
Pion HBT Results

- Consistency with AGS results
- As the collision energy rises in the FXT regime, compression reduces the source size and increases the baryon density, whereas the BES collider regime shows increased longitudinal expansion.

E866 PRC66 (2002) 054096
E895 PRL84 (2000) 2798
ALICE PLB 696 (2011) 328
STAR BES PRC92 (2015) 14904
Fluctuation measurement shows significant changes between the collider and fixed-target energy regimes.
Plans for the Future
2018-2020
The STAR Upgrades and the FXT program

**iTPC Upgrade:**
- Improves dE/dx
- Extends η coverage from 1.5 to 2.2 (mid-rapidity for FXT)
- Lowers p_T cut-in
- Ready in 2019

*See Chi Yang’s BES-II Upgrades talk Parallel Session 4.1*

**Event Plane Detector**

**EndCap TOF Upgrade:**
- Mid-rapidity coverage is critical
- Needed for PID at mid-rapidity
- Allows higher energy range of FXT program
- Ready 2019

**EPD Upgrade:**
- Independent trigger
- Reduces background
- Allows a better and independent reaction plane measurement critical to FXT physics
- Ready 2018

*J. Ewigleben’s poster on EPD*

*F. Geurts’ poster on eTOF*

*Star Note 0644 : Technical Design Report for the iTPC Upgrade*

*Star Note 0666 : An Event Plane Detector for STAR*

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• Would need 100 Million Events at each energy to make the sensitivity of BES-II, 2 days per energy
• Data rate is DAQ limited
• Detector upgrades required to extend STAR FXT up to 7.7 GeV, an overlap energy with the collider
Conclusions

• We’ve demonstrated STAR operates successfully in FXT mode, despite being optimized as a collider experiment.

• Spectra and yields are comparable to results from the AGS.

• Directed flow of pions has not previously been published for this energy range, and continues the trend of negative flow for mesons.

• First pion elliptic flow measurements have been made for this energy which show mass ordering.

• HBT radii measurements are consistent with results from AGS.

• First dynamical fluctuation measurements (ν_{dyn}) taken for this energy range.

• A FXT energy scan is proposed to extend the reach of the BES-II program down to 3.0 GeV (μ_B ≈ 720 MeV) to include the high baryon density regime.
Backup Slides
Comparison to E895 $\Lambda$ Flow

Au+Au 4.5 GeV 10-25%

**Slope near mid-rapidity**

0.082 ± 0.009

Open symbols are reflected

**$p$ Flow**

$\langle \phi \rangle$ (GeV/c)

**Au+Au 3.8 GeV**

$\Lambda$ Flow ratio at 4.5 GeV → 0.2

Differences:

E895 -- $<p^x>$

STAR-FXT – $v_1$

E895 – 0-18%

STAR-FXT 10-25%

E895 trend: $\Lambda/p$ flow ratio at 4.5 GeV → 0.2

STAR FXT:

$\Lambda/p$ flow ratio at 4.5 GeV → 1.1

### Differences:

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- STAR-FXT – $v_1$

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- STAR FXT: $\Lambda/p$ flow ratio at 4.5 GeV → 1.1