U.S. DEPARTMENT OF ENERGY Office of Science
DOE NP contract: DE-SC0013405

Precise Measurement of Di-Pion Azimuthal Correlation Asymmetry (A_{UT}) Using $p^{\uparrow}p$ Data At $\sqrt{s}$ = 510 GeV At STAR

College of Science and Technology
TEMPLE UNIVERSITY

Navagyan Ghimire
for the STAR collaboration
Temple University, College of Science and Technology, Philadelphia, PA

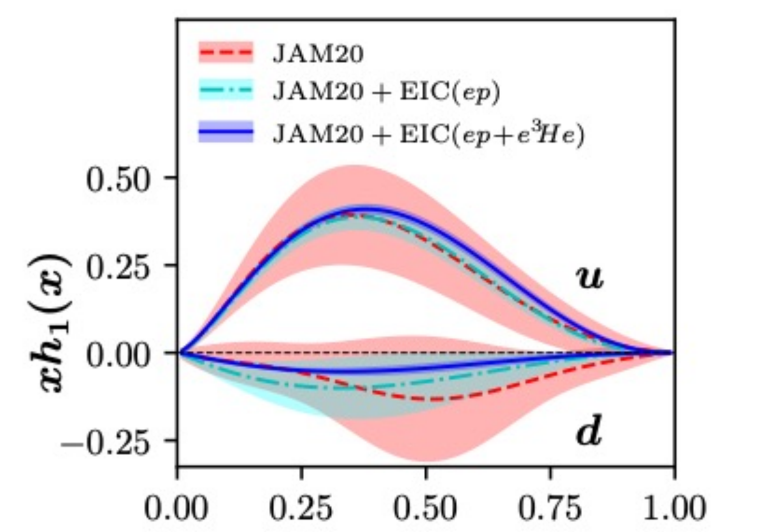
RHIC/AGS User Meeting 2023, BNL, NY

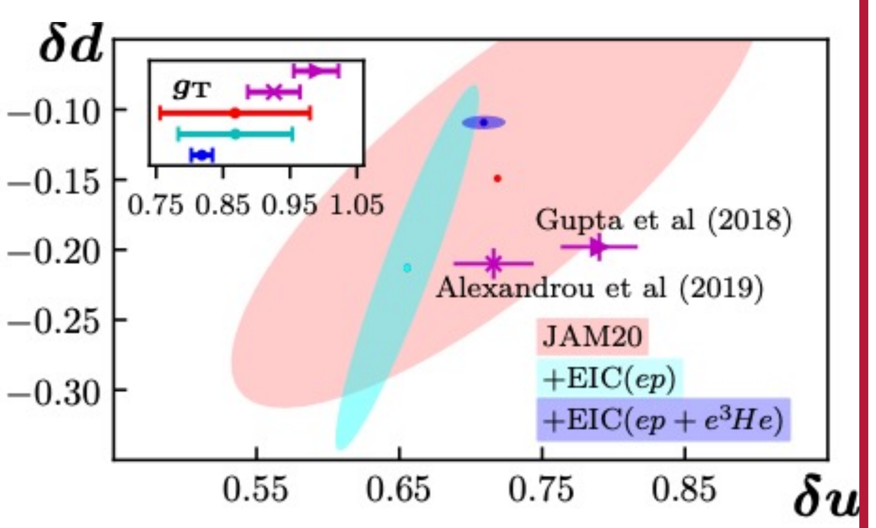
Motivation : Transversity $(h_1^q(x))$

- $h_1^q(x)$ is the leading order parton distribution function (PDF) which describes the transversely polarized partons inside a transversely polarized nucleon.
- $h_1^q(x)$ is the least known leading-order PDF due to its chiral-odd nature and is accessible only when coupled with another chiral-odd function, such as interference fragmentation function(IFF), $H_1^{\sphericalangle}(z, M^2)$, in $p^{\uparrow}p$ collisions.
- Coupling of transversity with IFF gives rise to experimentally observable azimuthally correlated asymmetry (A_{UT} (of di-pions $(\pi^+\pi^-)$ in the final state of $p^{\uparrow}p$ collisions.
- A precise measurement of $h_1^q(x)$ is necessary to measure the nucleon tensor charge (g_T) .

$$g_T = \int_0^1 dx[h_1^q(x) - h_1^{\bar{q}}(x)]$$

- Type equation here.The study of A_{UT} using the new STAR 2017 $(L_{int} = 350\, pb^{-1})$ provides a more precise measurement than the previous STAR 2011 $(L_{int} = 25\, pb^{-1})$

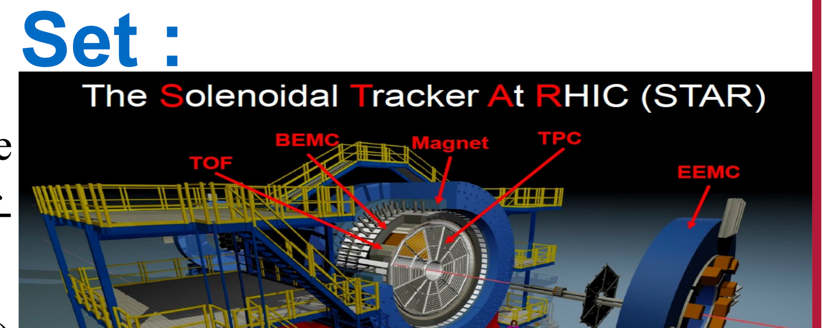




JAM Collab. (Phys.Lett.B 816 (2021) 136255)

STAR Data Set :

- **R**elativistic **H**eavy **I**on **C**ollider (**RHIC**) is capable of colliding polarized proton beams up to a center-of-mass energy, $\sqrt{s}$ = 510 GeV.
- The **STAR** (**S**olenoidal **T**racker **A**t **R**HIC) experiment, located within the RHIC ring, consists of various subsystems, including TPC, BEMC, TOF, etc.
- Particle identification in STAR primarily relies on the combination of TPC and TOF.
- STAR has a long-standing history measuring A_{UT}.
- This analysis is based on the STAR 2017 dataset, which enhances the statistical precision by a factor of 4.



Detector	Acceptance	Use
TPC	$-1<\eta<1$, $0<\phi<2\pi$	Tracking, PID
TOF	$-1<\eta<1$, $0<\phi<2\pi$	PID
BEMC	$-1<\eta<1$,$0<\phi<2\pi$	Event triggering

A_{UT} at STAR				
Year	2006	2011	2015	2017
$\sqrt{s}\,(GeV)$	200	500	200	510
$L_{int}(pb^{-1})$	~1.8	~25	~52	~350

A_{UT} Extraction :

- Reaction channel: $p^{\uparrow} + p \rightarrow h^+h^- + X$
- Di-hadron azimuthal correlation asymmetry:

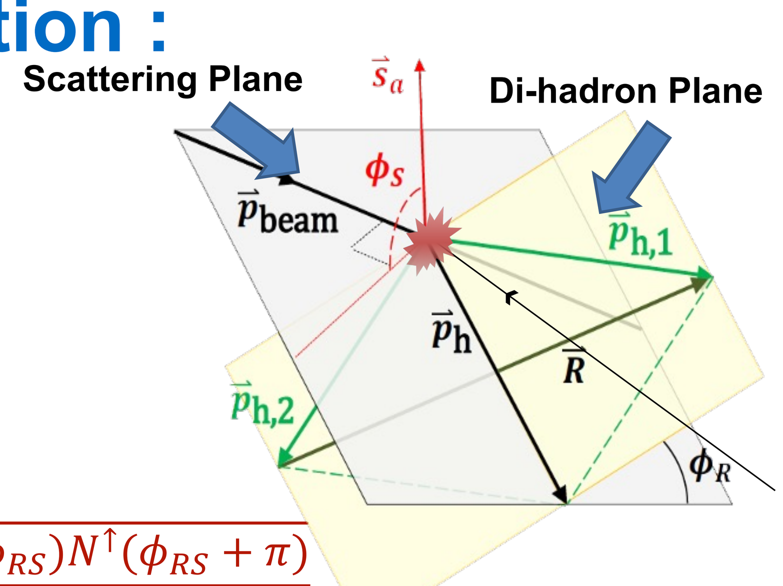
$$A_{UT} = \frac{d\sigma^{\uparrow} - d\sigma^{\downarrow}}{d\sigma^{\uparrow} + d\sigma^{\downarrow}} \propto h_1^q(x) H_1^{\sphericalangle}(z, M^2)$$

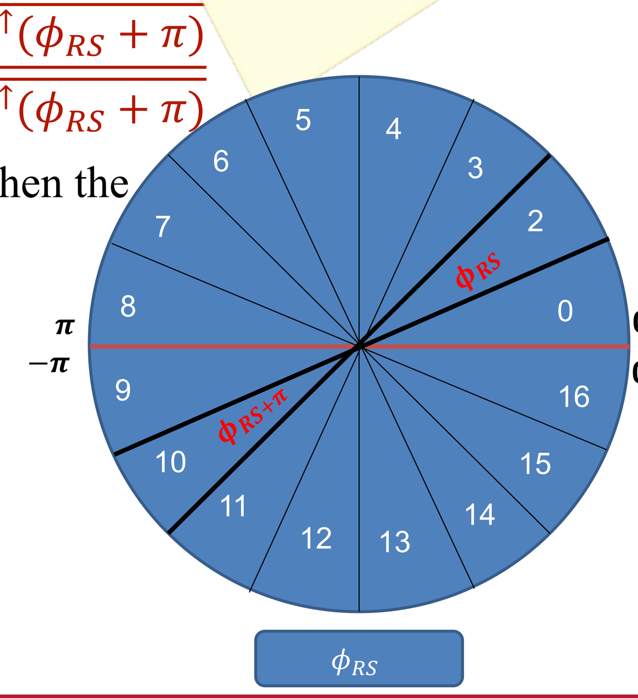
- For a symmetric detector like STAR A_{UT} can be extracted using cross-ratio formula,

$$A_{UT} \cdot sin(\phi_{RS}) = \frac{1}{P} \frac{\sqrt{N^{\uparrow}(\phi_{RS})N^{\downarrow}(\phi_{RS}+\pi)} - \sqrt{N^{\downarrow}(\phi_{RS})N^{\uparrow}(\phi_{RS}+\pi)}}{\sqrt{N^{\uparrow}(\phi_{RS})N^{\downarrow}(\phi_{RS}+\pi)} + \sqrt{N^{\downarrow}(\phi_{RS})N^{\uparrow}(\phi_{RS}+\pi)}}$$

where, $N^{\uparrow(\downarrow)}$ is the number of $\pi^+\pi^-$ in respective ϕ_{RS} bin when the beam polarization is ↑ (↓).

- This method is free from effects related to detector efficiencies and spin-dependent luminosity.





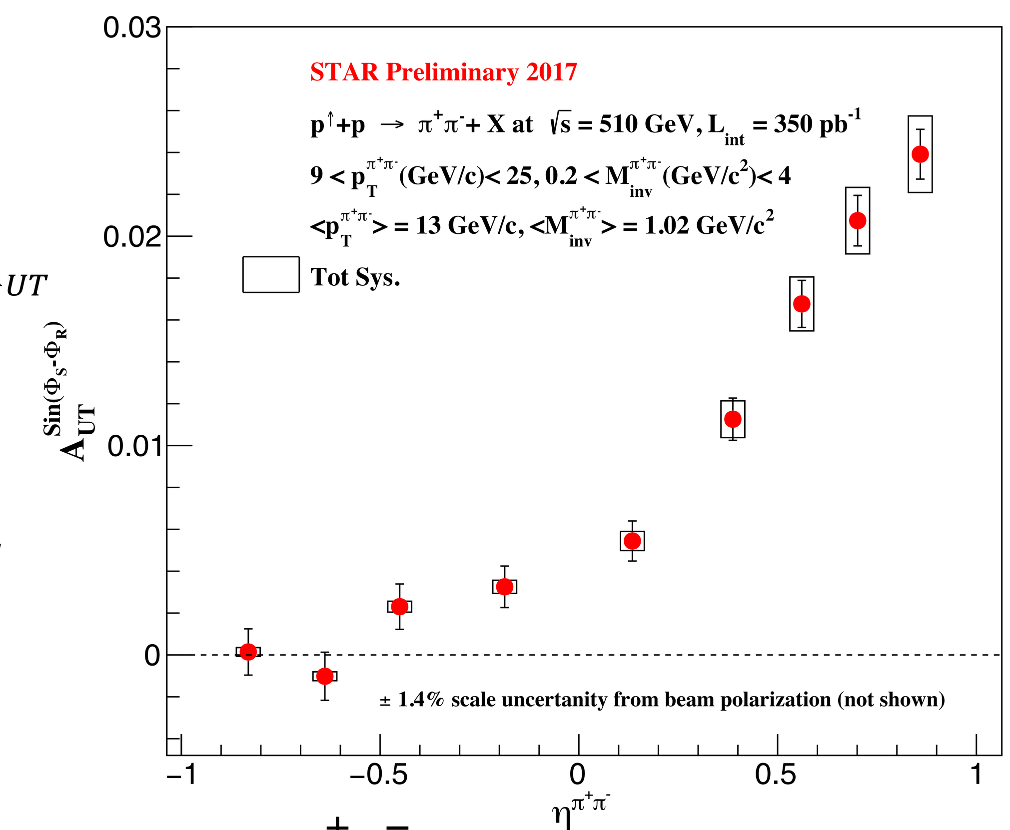
Summary and Outlook :

- STAR's new result from the 2017 data set precisely measures the di-pion azimuthal correlation asymmetry A_{UT} at $\sqrt{s}$ = 510 GeV.
- A_{UT} is larger for $\eta^{\pi^+\pi^-} > 0$ due to higher x (where $h_1^q(x)$ is sizable) whereas A_{UT} is smaller in $\eta^{\pi^+\pi^-} < 0$ due to low-x.
- Interference between the different $\pi^+\pi^-$ production channels causes a strong A_{UT} signal around ρ meson mass (~ 0.8 GeV/c^2).
- A_{UT} signal increases linearly with $p_T^{\pi^+\pi^-}$.
- This result, together with precise unpolarized di-pion cross-section measurement, will help improve our current understanding of transversity.
- Results of this analysis will help in probing transversity at much higher Q^2 than SIDIS and test the universality of the mechanism which produces azimuthal correlations amongst SIDIS, e^+e^-, and $p^{\uparrow}p$ collisions.

Results :

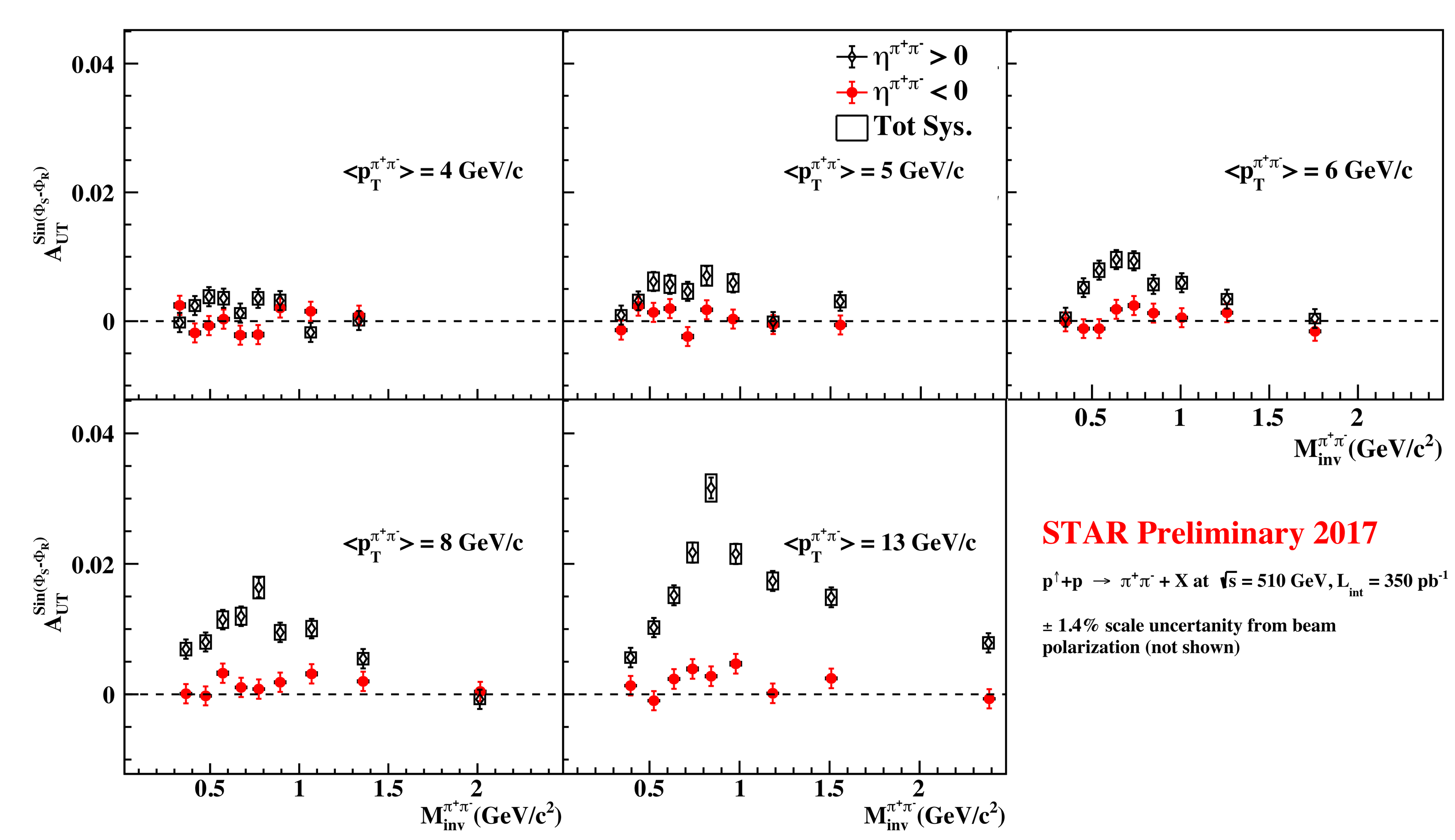
A_{UT} as function of $\eta^{\pi^+\pi^-}$

- $\eta^{\pi^+\pi^-} > 0$ probes higher x, valence region, where $h_1^q(x)$ is sizable, hence A_{UT} is large.
- $\eta^{\pi^+\pi^-} < 0$ probes lower x from backward propagating transversely polarized particles resulting lower A_{UT} signal.



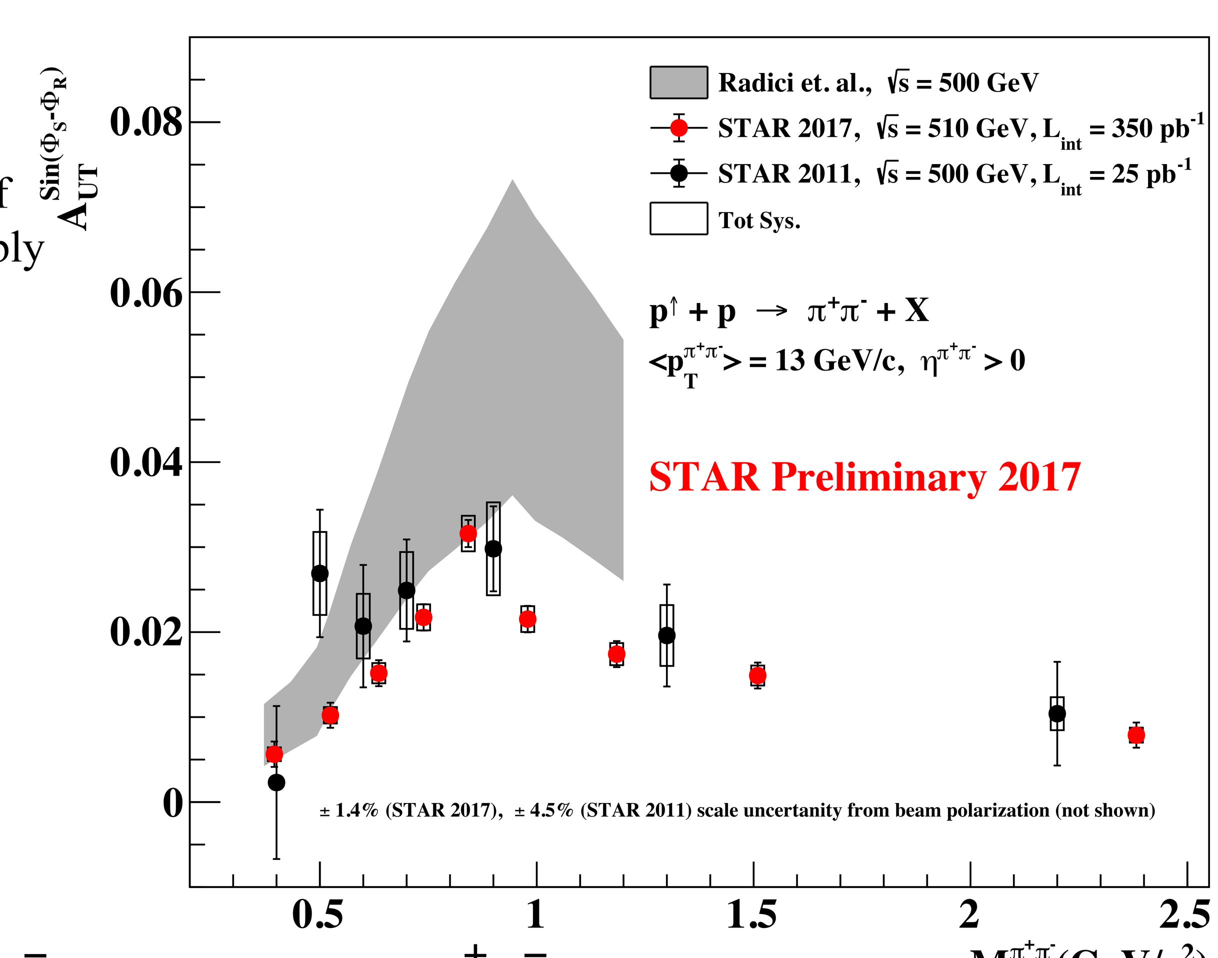
A_{UT} as function of $M_{inv}^{\pi^+\pi^-}$ in different $p_T^{\pi^+\pi^-}$ bins.

- The enhancement of A_{UT} signal around the ρ meson mass (~0.8 GeV/c^2) is due to the interference between the different $\pi^+\pi^-$ production channel.
- The A_{UT} signal increases with increasing $p_T^{\pi^+\pi^-}$.



A_{UT} as function of $M_{inv}^{\pi^+\pi^-}$ for highest $p_T^{\pi^+\pi^-}$ bin and $\eta^{\pi^+\pi^-} > 0$:

- STAR's latest measurement of A_{UT} from 2017 exhibits a notably higher level of precision and is consistent with previous STAR measurement and theory prediction from SIDIS, e^+e^- data.



A_{UT} as function of $p_T^{\pi^+\pi^-}$ in different $M_{inv}^{\pi^+\pi^-}$ bins.

- A_{UT} increases linearly with $p_T^{\pi^+\pi^-}$.
- Stronger rise in A_{UT} around ρ mass region.