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

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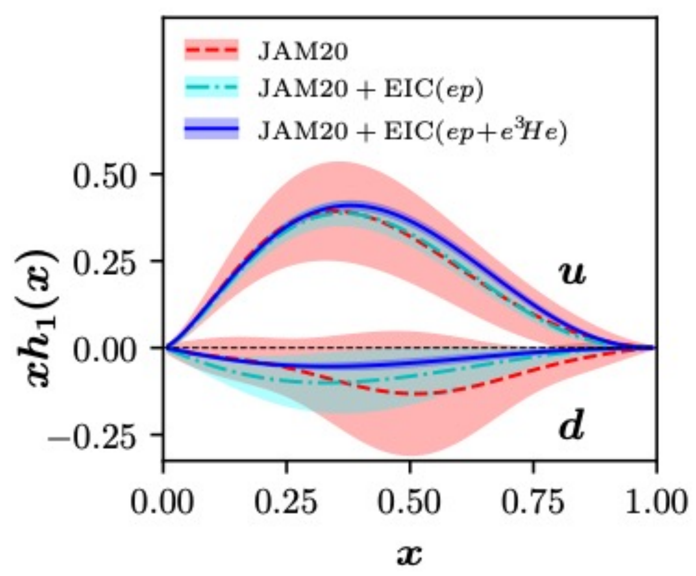
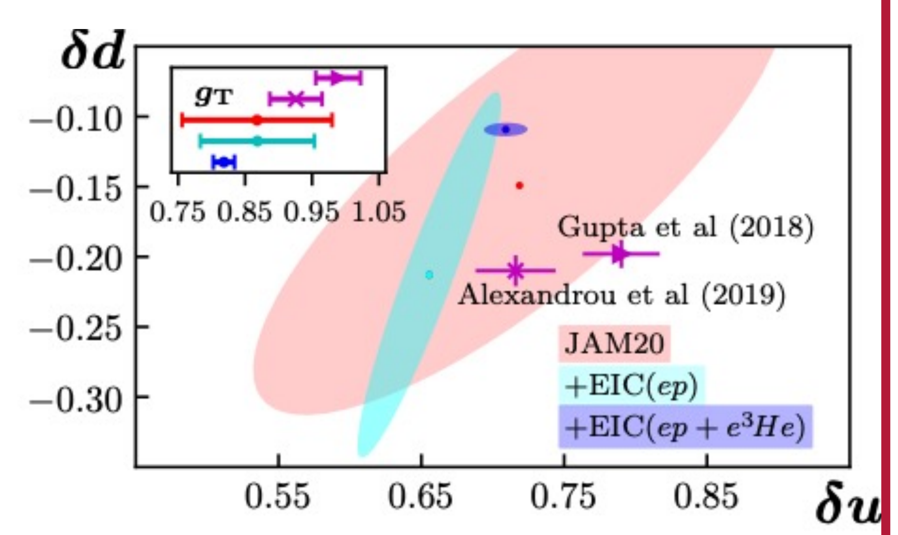
## Motivation : Transversity ($h_1^q(x)$)

- $h_1^q(x)$ is the leading order parton distribution function (PDF) which describes the transversely polarized quarks 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 ($g_T$) .

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

- 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 ($L_{int} = 25\, pb^{-1}$) results.

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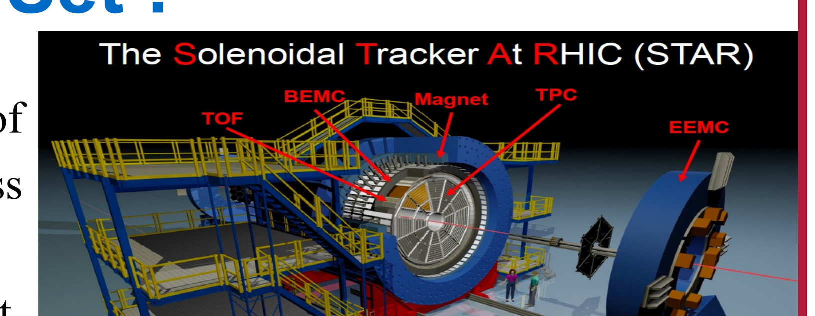
## STAR Data Set :

- **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 |

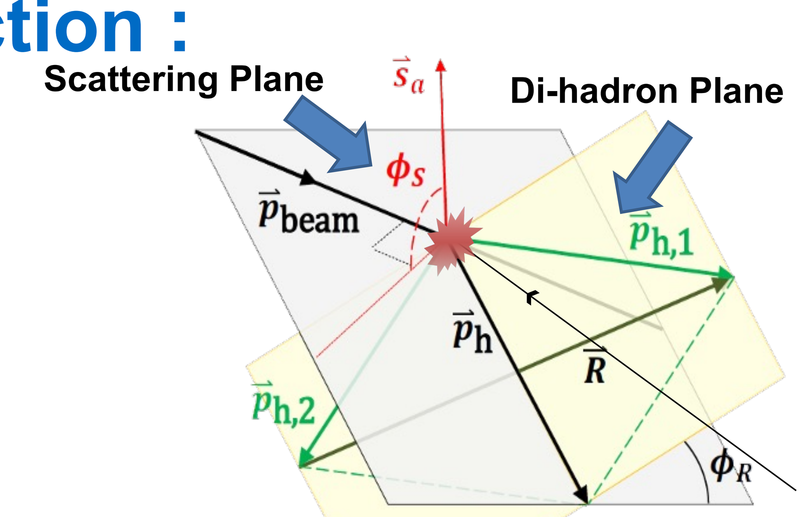
$A_{UT}$ at STAR

| 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:

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

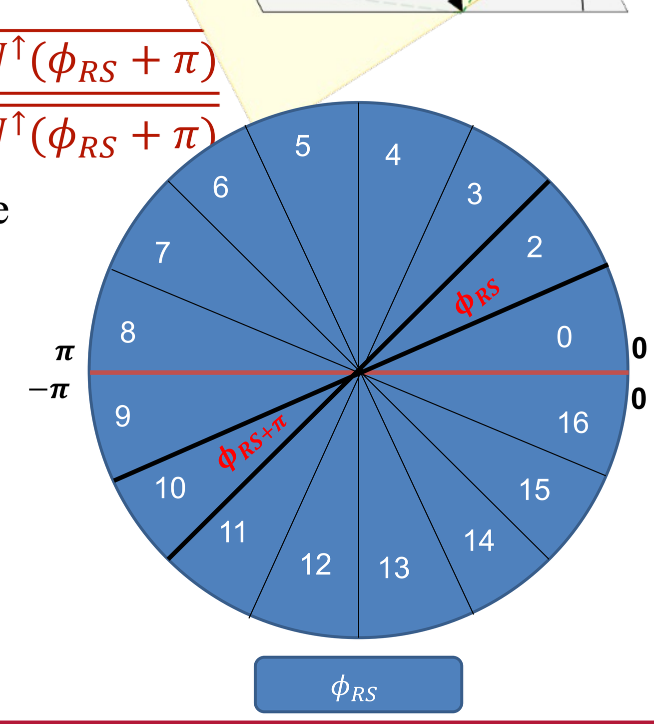



- For a symmetric detector like STAR $A_{UT}$ can be extracted using cross-ratio formula,

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

where, $N^{\uparrow(\downarrow)}$ is the number of $\pi^+\pi^-$ in respective $\phi_{RS}$ (angle between scattering and di-hadron plane) bin when the beam polarization is ↑ (↓).

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



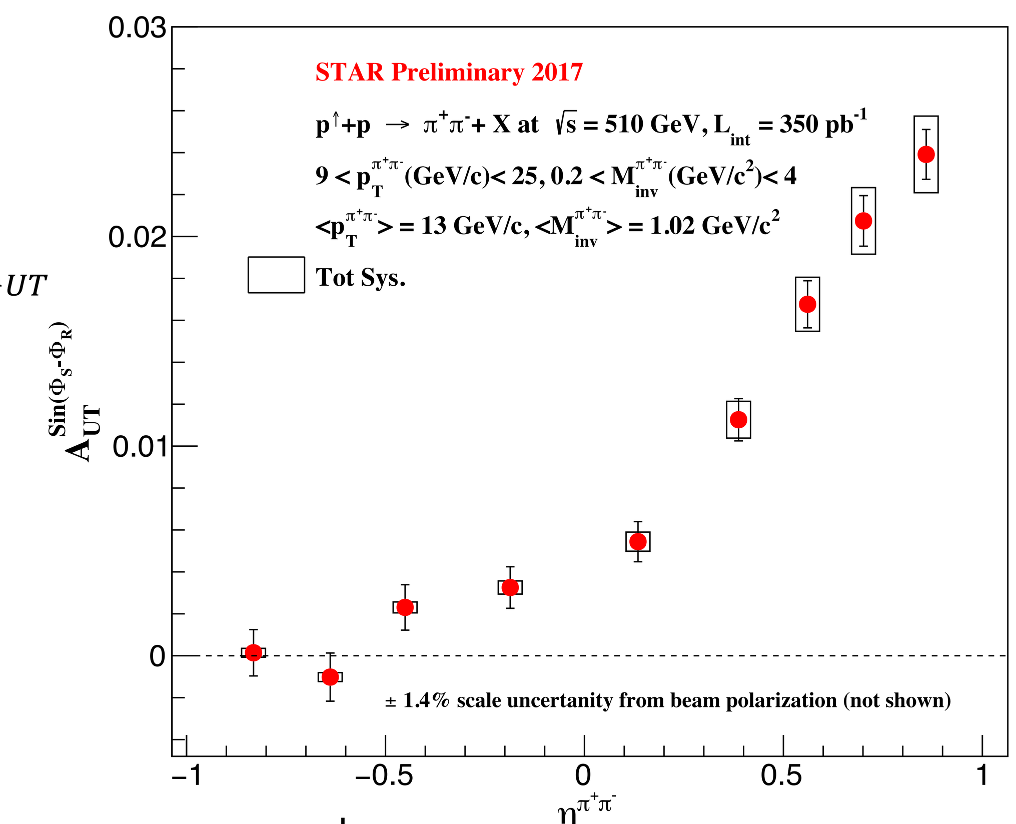

## Summary and Outlook :

- 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 $\rho$ 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 :

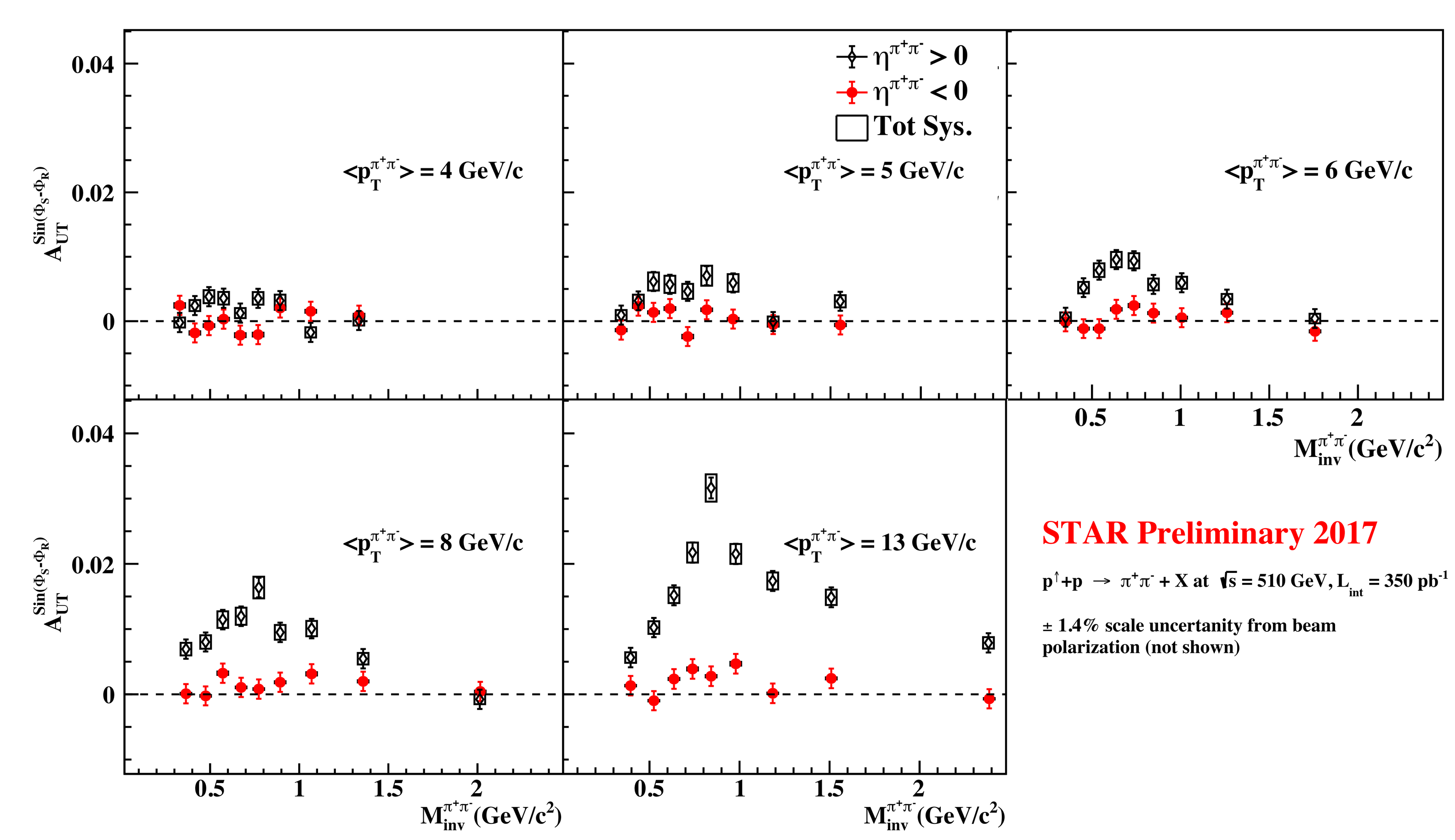
### $A_{UT}$ as function of $\eta^{\pi^+\pi^-}$

- $\eta^{\pi^+\pi^-} > 0$ 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.



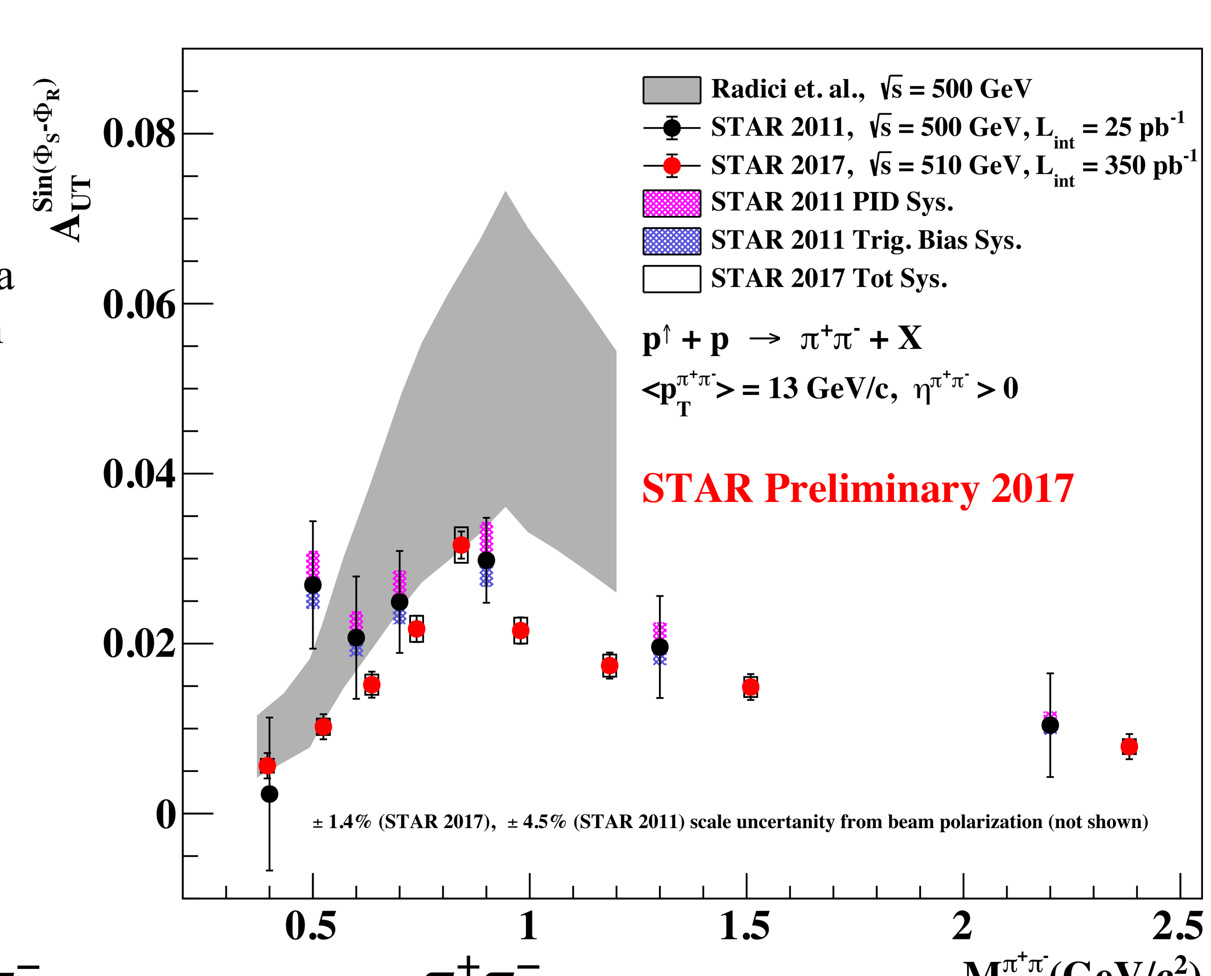

### $A_{UT}$ as function of $M_{inv}^{\pi^+\pi^-}$ in different $p_T^{\pi^+\pi^-}$ bins

- The enhancement of $A_{UT}$ signal around the $\rho$ 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 dataset 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 $\rho$ mass region.