Measurement of Di-hadron Azimuthal Correlation Asymmetry Using pp Data at STAR

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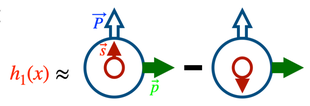
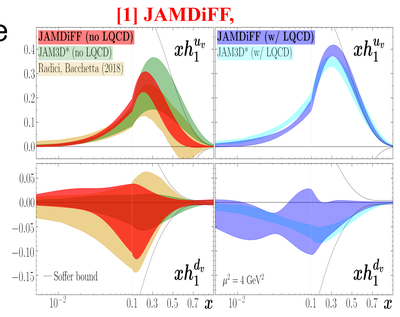
Motivation: Transversity ($h_1^q(x)$)

- At the leading twist, parton structure of hadron is described by three parton distribution functions (PDFs): unpolarized PDF($f_1(x)$), helicity PDF($g_1(x)$), and transversity PDF($h_1^q(x)$).
- $h_1^q(x)$ is the least known from the experiments due to its chiral odd nature.
- In $p^\uparrow p \to h^+h^-$ channel, the azimuthal correlation asymmetry, A_{UT}, gives rise to the sensitivity to the $h_1^q(x)$ coupled with the interference fragmentation function (IFF).
- Measurement of A_{UT} together with unpolarized cross section is required to constrain $h_1^q(x)$.
- Recent JAMDiFF $h_1^q(x)$ extraction includes STAR results: 2006[1]and 2011[2] together with the SIDIS and e^+e^-.
- The di-hadron channel offers a means of probing nucleon structure within the collinear framework and provides sensitivity to parton flavor through the selection of hadron species.

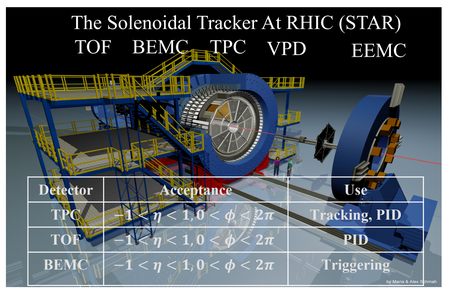




[1] STAR,Phys.Rev.Lett.115(2015) 242501
[2] STAR,Physics Letters B 780 (2018) 332–339

STAR Experiment at RHIC (STAR)

- Relativistic Heavy Ion Collider provides a unique capability of colliding polarized protons beams up to a center of mass energy, $\sqrt{s}$ = 510 GeV.
- STAR detector located at six o'clock position consists of various sub systems.
- Time Projection Chamber (TPC) is the heart of STAR detector, which provides charged particle tracking and particle identification (PID).
- Time of Flight (TOF) helps to improve the STAR PID, in conjunction with the TPC.



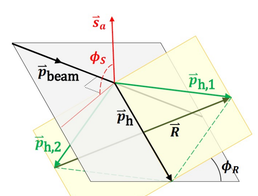
STAR PID, Nucl.Instrum.Meth.A 558 (2006) 419-429

Probing Transversity via h^+h^- Channel

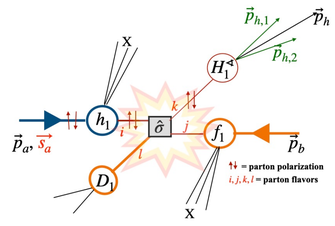
Radici et. al., Phys.Rev.D 70 (2004) 094032

- Reaction channel: $p_a^\uparrow p_b \to h^+h^- + X$
- Polarized cross section:

$d\sigma^\uparrow \propto \sin(\phi_S - \phi_R) \int dx_a dx_b f_1(x_b) h_1(x_a) \frac{d\Delta\hat{\sigma}}{d\hat{t}} H_1^\sphericalangle(z, M^2)$, where $M = h^+h^-$ invariant mass , $z = \frac{E^{h^+h^-}}{E^q}$



Azimuthal angles in h^+h^- channel



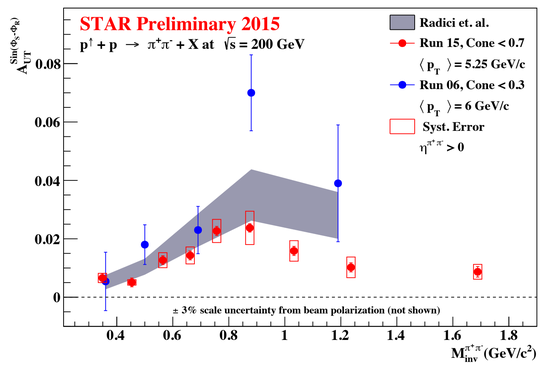
Detailed mechanism for the h^+h^- channel

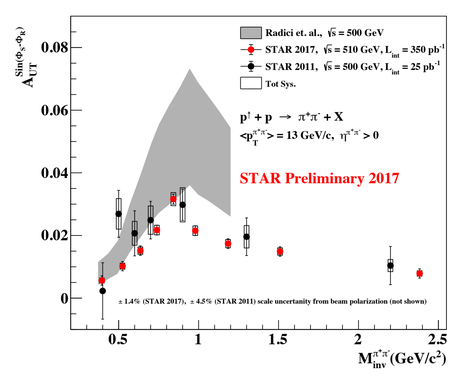
- f_1= unpolarized PDF, $H_1^\sphericalangle$ = Interference fragmentation function (IFF), $d\hat{\sigma}$ = perturbatively calculable hard scattering cross section.
- Jet reconstruction is not required while preserving collinearity.
- Access to quark polarization $\sim \vec{s}_a \cdot \vec{R} \times \vec{p}_h$, where $\vec{R} = \frac{1}{2}(\vec{p}_{h_1} - \vec{p}_{h_2})$, $\vec{p}_h = \vec{p}_{h_1} + \vec{p}_{h_2}$
- The coupling of $h_1^q(x)$ and IFF results in the azimuthal correlation asymmetry,

$$A_{UT} \propto \sum_{i,j,k,l} \frac{f_1^{j/b}(x_b)\, h_1^{i/a}(x_a)\, H_1^{\sphericalangle h_1 h_2/k}(z_h, M_h^2)}{f_1^{j/b}(x_b)\, f_1^{i/a}(x_a)\, D_1^{h_1 h_2/l}(z_h, M_h^2)}$$

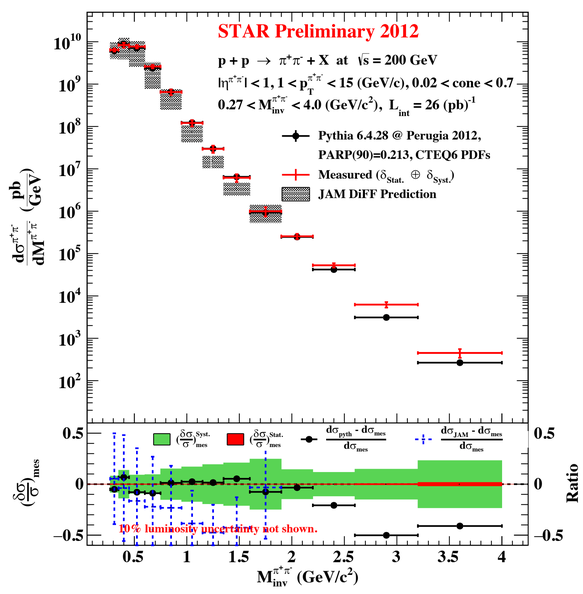
- The extraction of D_1 requires the measurement of the unpolarized di-hadron cross section ($d\sigma_{UU}$).
- $d\sigma_{UU}$ provides access to the gluon FF, allowing model-independent extraction of $h_1^q(x)$.

Current Status ($\pi^+\pi^-$)





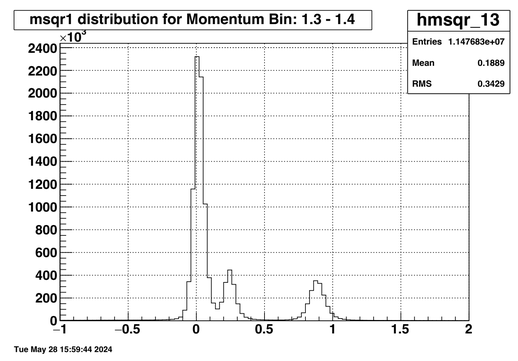
- STAR has released preliminary results on $\pi^+\pi^-$ asymmetry using Run 2015 and 2017 at 200 GeV and 510 GeV, respectively. These measurements significantly improve the statistical and systematic precision over previously published results.
- The observed resonance peak at $M_\rho \sim 0.8\ \text{GeV}/c^2$ for $\eta > 0$ is due to the interference between $\pi^+\pi^-$ from relative s and p wave channels, consistent with theory (Radici.et.al., private communication).
- Systematic uncertainties are greatly reduced by the inclusion of TOF for the PID together with TPC in Run 2017, while 2015 result is based on TPC PID only.

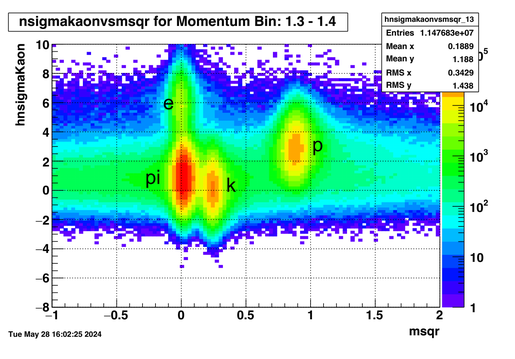


[3] STAR,Phys.Rev.Lett.115(2015) 242501

- Unpolarized $\pi^+\pi^-$ cross section is measured which shows good agreement with PYTHIA cross section and theory prediction[3].

Current Status (K^+K^-) and Projections

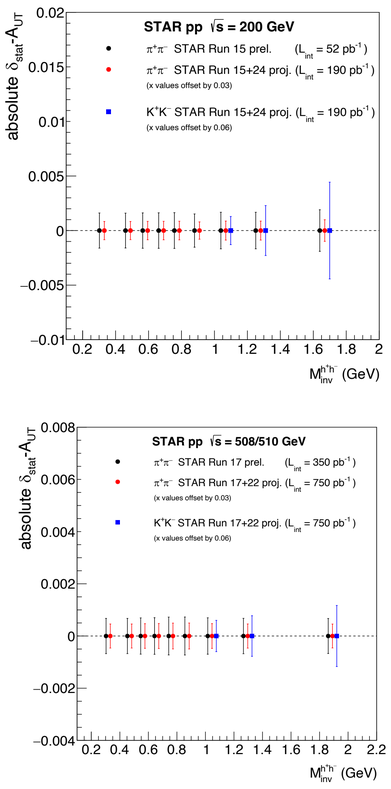




- Data Set: p+p collisions at $\sqrt{s}$ = 200 GeV from Run 2015 , Polarization: 58%, Trigger: Jet Patch.
- TOF and TPC PID will be used for the Kaon identification. PID analysis is in progress.
- Asymmetry calculation will be done in different mass, p_T and η bins.

Projections

- Precision measurement of $\pi^+\pi^-$ A_{UT}
  - Statistical uncertainty will be improved by more than 50%.
- First measurement of K^+K^- A_{UT}
  - The K^+K^- A_{UT} probes the strange quark transversity.
- All projections are purely statistical based on the run 2015 data at $\sqrt{s}$ = 200 GeV and run 2017 data at $\sqrt{s}$ = 510 GeV.



Summary and Outlook

- The $\pi^+\pi^-$ azimuthal correlation asymmetry has been measured. Large forward signal is observed, with a resonance peak at $M_\rho \sim 0.8\ \text{GeV}/c^2$, consistent with theory and previous STAR results.
- Statistical precision of new 2015 and 2017 results is significantly improved.
- Systematic uncertainty is assigned from PID and Trigger bias.
- K^+K^- analysis of both asymmetry and cross section will be performed with Run 15 data set at $\sqrt{s}$ = 200 GeV, corresponding to $L_{int} \sim 52$ pb^{-1} for asymmetry and Run 12 data set at $\sqrt{s}$ = 200 GeV, corresponding to $L_{int} \sim 14$ pb^{-1} for cross section.
- PID will be done based on both TPC and ToF information.