STAR

Improving results on transverse double spin asymmetries in the CNI region at STAR

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SPIN2012

Helicity amplitudes for spin ½ ½ → ½ ½

Matrix elements

$\phi_1(s,t) = \langle ++ | M | ++ \rangle$ spin non–flip

$\phi_2(s,t) = \langle ++ | M | -- \rangle$ double spin flip

$\phi_3(s,t) = \langle +- | M | +- \rangle$ spin non–flip

$\phi_4(s,t) = \langle +- | M | -+ \rangle$ double spin flip

$\phi_5(s,t) = \langle ++ | M | +- \rangle$ single spin flip

$\phi_i(s,t) = \phi_i^{EM}(s,t) + \phi_i^{HAD}(s,t)$

$$A_{NN}(s,t)\frac{d\sigma}{dt} = \frac{4\pi}{s^2}\left\{2|\phi_5|^2 + \mathrm{Re}\left(\phi_1^*\phi_2 - \phi_3^*\phi_4\right)\right\}$$

$$A_{SS}(s,t)\frac{d\sigma}{dt} = \frac{4\pi}{s^2}\mathrm{Re}\left\{\phi_1\phi_2^* + \phi_3\phi_4^*\right\}$$

Observables: cross sections and spin asymmetries

$$\sigma_{tot} = \frac{4\pi}{s}\mathrm{Im}\{\phi_1 + \phi_3\}_{t=0} = \frac{4\pi}{s}\mathrm{Im}\,\phi_+|_{t=0}$$

$$\frac{d\sigma}{dt} = \frac{2\pi}{s^2}\left\{|\phi_1|^2 + |\phi_2|^2 + |\phi_3|^2 + |\phi_4|^2 + 4|\phi_5|^2\right\}$$

$$A_N(s,t)\frac{d\sigma}{dt} = \frac{-4\pi}{s^2}\mathrm{Im}\left\{\phi_5^*(\phi_1 + \phi_2 + \phi_3 - \phi_4)\right\}$$

$\phi_5^{HAD} \approx 0$ This experiment

ϕ_5^{EM} small in CNI

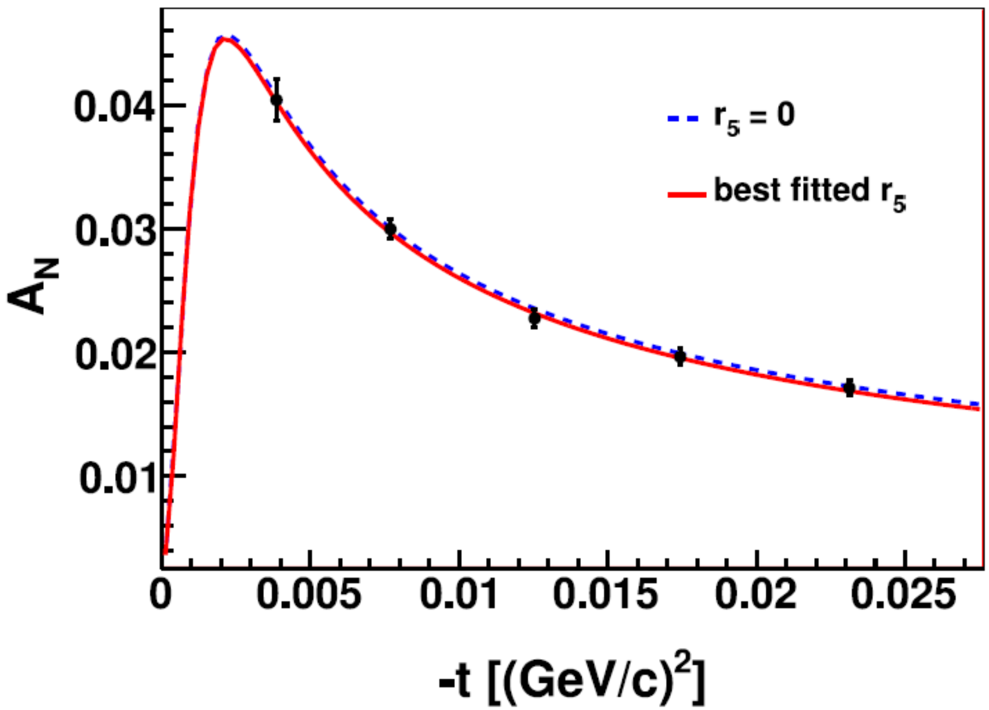
$$\frac{A_{NN} + A_{SS}}{2}\frac{d\sigma}{dt} = \frac{4\pi}{s^2}\mathrm{Re}\left\{\phi_1\phi_2^*\right\}$$

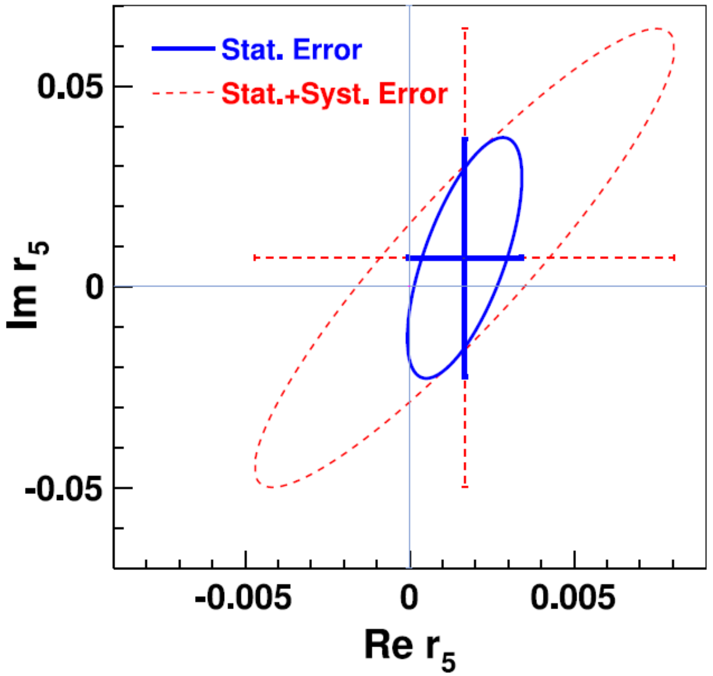
$\phi_4^{HAD} \sim t \to 0$

$A_{NN} - A_{SS} \approx 0$

Probe for ϕ_2^{HAD}

A_N and ϕ_5^{HAD}





This experiment:

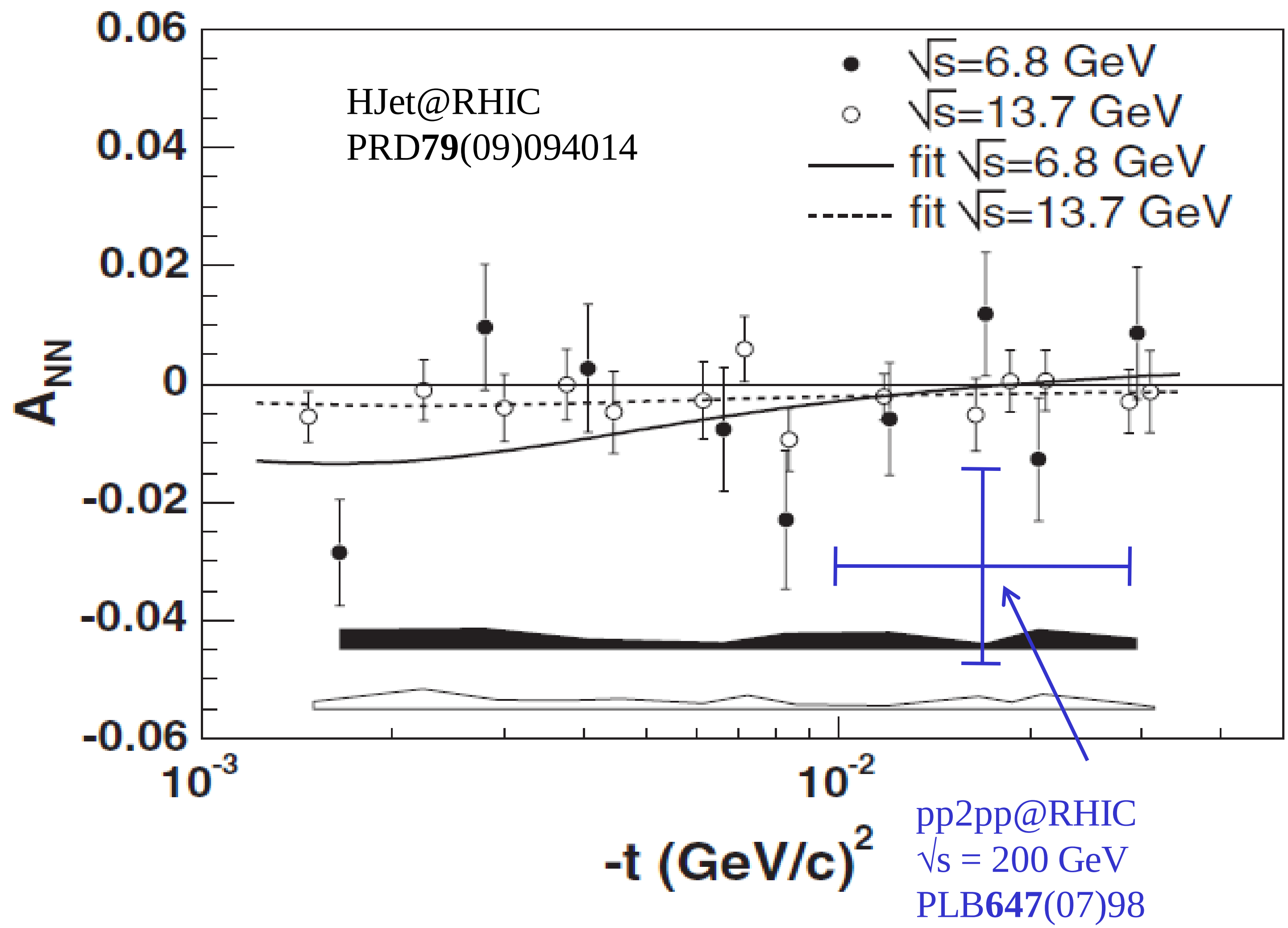
- Statistical error of 3% in each of 5 points
- Highest accuracy in extraction of r_5

$$r_5 = \frac{2m_p}{\sqrt{-t}} \frac{\phi_5^{had}}{\mathrm{Im}\left(\phi_1^{had} + \phi_3^{had}\right)}$$

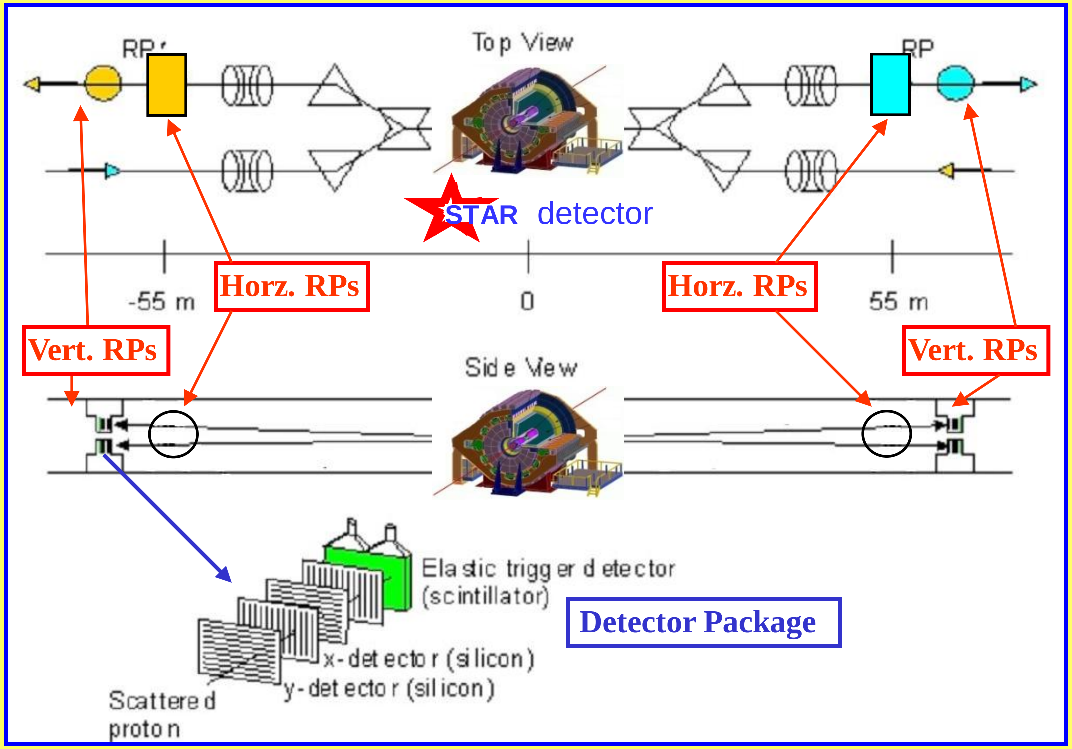
arXiv:1206.1928 [nucl-ex]
also submitted for publication

Re $r_5 = 0.0017 \pm 0.0063$
Im $r_5 = 0.007 \pm 0.057$

Previous measurements of A_{NN}

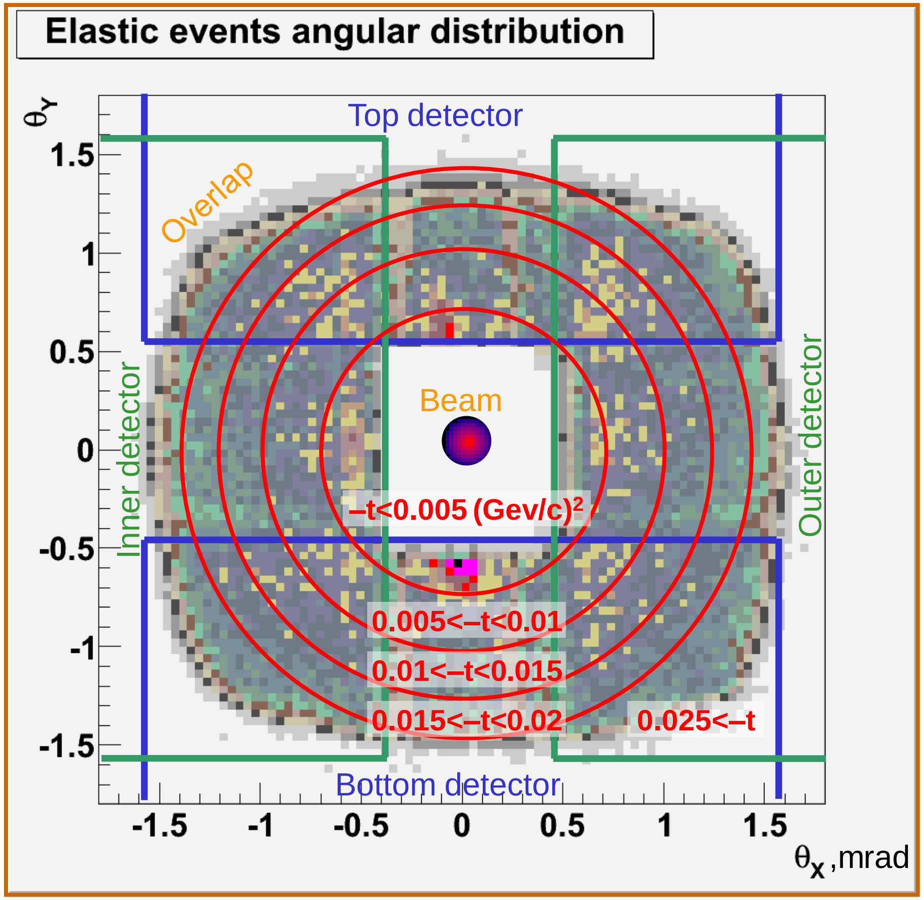


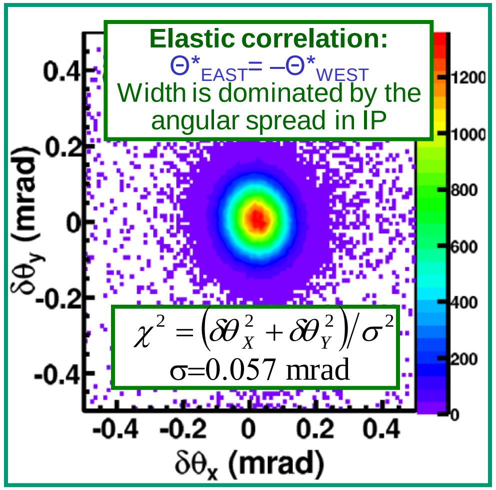
Detector layout and experimental conditions

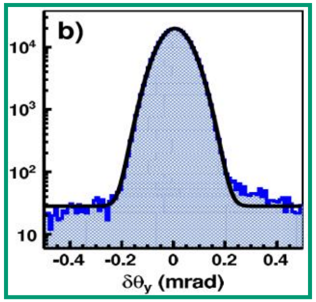


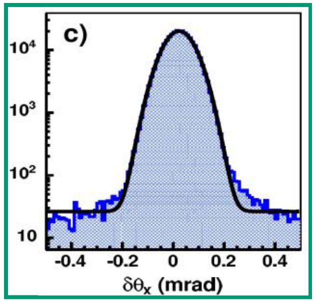
- ✓ Roman Pots integrated with STAR detector – closest proximity to the beam.
- ✓ CNI region – $0.003 < -t < 0.03$.
- ✓ Ideal beam optics: $\beta^* = 21$m and parllel to point focusing – terms other than L_{EFF} in the transport matrix were very small.
- ✓ High transverse polarization of both beams ~60%.
- ✓ Excellent detector performance – nearly 100% efficiency and only 5 dead/noisy strips per ~14000 active strips.

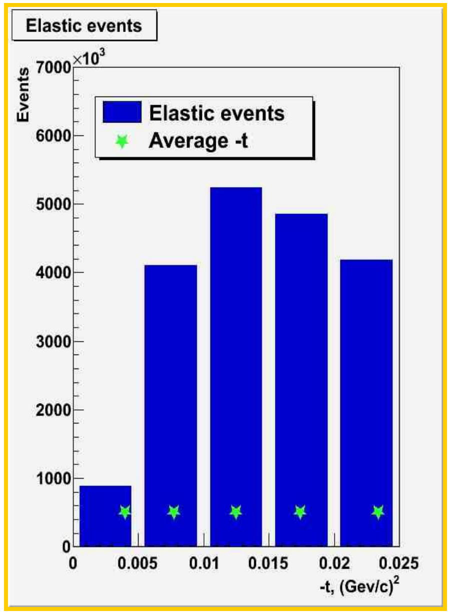
Elastic events, acceptance and –t ranges











- ✓ 2π acceptance in φ.
- ✓ Exactly the same sample of elastic events as for A_N studies

- ✓ $2{\cdot}10^7$ elastic events with background <1%.
- ✓5 (–*t*) ranges up to 0.03 $(GeV/c)^2$

Polarized cross-sections and spin parameters

Cross-section azimutual angular dependence for transversely polarized beams:

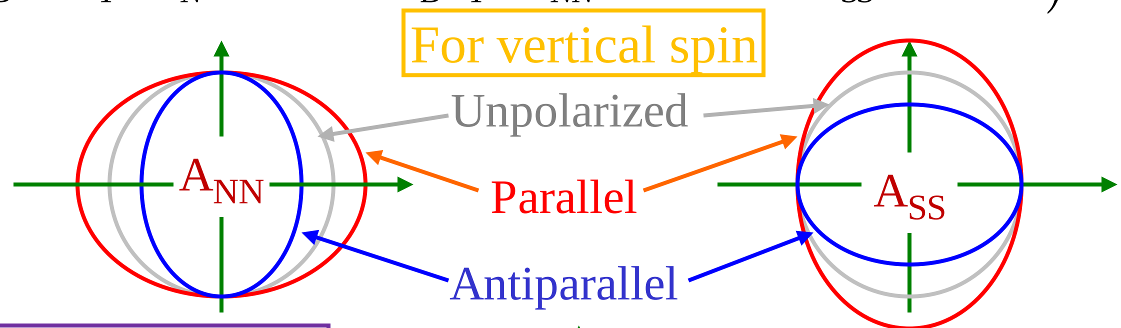
$$\sigma = \sigma_0 \left[1 + A_N (\vec{P}_B + \vec{P}_Y) \cdot \vec{n} + A_{NN} (\vec{P}_B \cdot \vec{n})(\vec{P}_Y \cdot \vec{n}) + A_{SS} (\vec{P}_B \cdot \vec{s})(\vec{P}_Y \cdot \vec{s}) \right]$$

$\vec{n}$ - vector normal to the scattering plane

$\vec{P}_B ; \vec{P}_Y$ - polarizations of the two beams

$\vec{s} = \dfrac{\vec{n} \times \vec{p}}{|\vec{n} \times \vec{p}|}$ - is the vector in the scattering plane, normal to the initial momentum

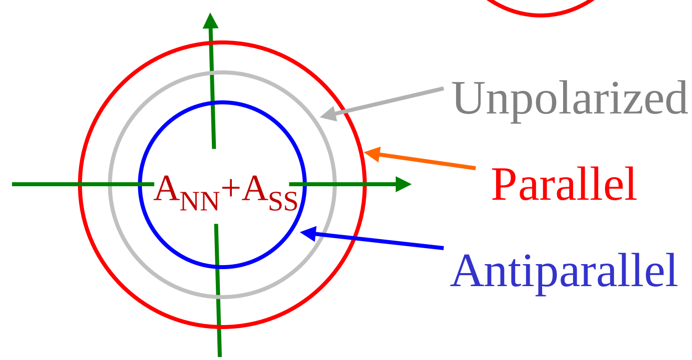
$$2\pi \frac{d^2\sigma}{dt\,d\varphi} = \frac{d\sigma}{dt} \cdot \left(1 + (P_B + P_Y) A_N \cos\varphi + P_B P_Y (A_{NN} \cos^2\varphi + A_{SS} \sin^2\varphi) \right)$$



- ✓ cos 2φ dependence for $A_{NN} - A_{SS}$
- ✓ NO angular dependence for $A_{NN} + A_{SS}$

Just cross-section difference

- ✓ Cannot use square root formula
- ✓ Must use external normalization



Normalization

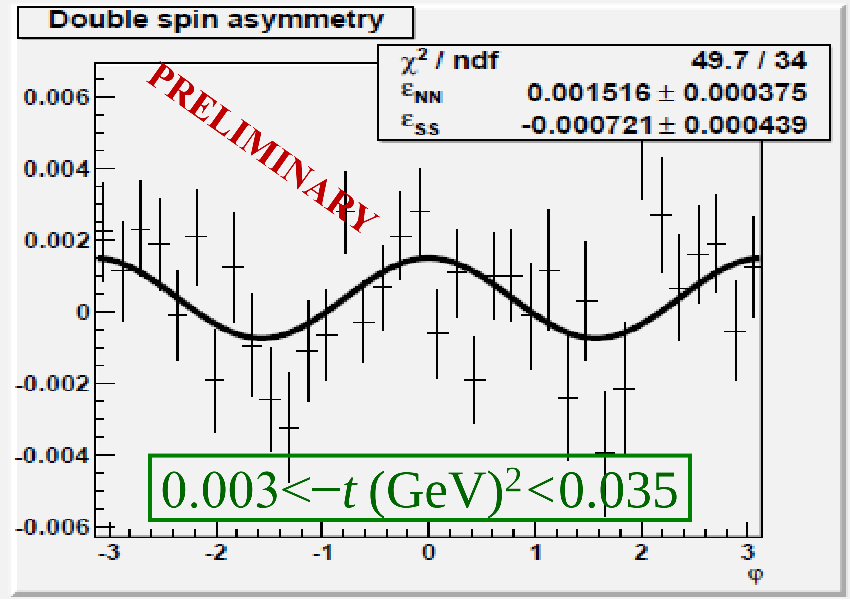
- Normalization is based on "inelastic" event counts assuming their negligible polarization dependence, yet this needs to be proved
- Normalized counts: $K^{+/-} = N^{+/-}/L^{+/-}$, $N^{+/-}$ -- elastic event counts for a certain spin combination, $L^{+/-}$ -- normalization factor
- Cannot use square root formula – have to rely on normalized counts $K^{+/-}$

$$\varepsilon_{NN}(\varphi) = P_B P_Y (A_{NN}\cos^2\varphi + A_{SS}\sin^2\varphi) =$$

$$= \frac{(K^{++}(\varphi) + K^{--}(\varphi)) - (K^{+-}(\varphi) + K^{-+}(\varphi))}{(K^{++}(\varphi) + K^{--}(\varphi)) + (K^{+-}(\varphi) + K^{-+}(\varphi))}$$

- Study of several independent STAR subsystems, all having nearly or fully 2π acceptance for forward particles in both directions (East and West)
  - BBC – beam-beam counters
  - VPD – vertex position detector
  - ZDC – zero degree calorimeter
  - In addition WCM – RHIC wall current intensity monitor

First preliminary results



- Based on BBC and VPD normalizing counts.
- The values are of the order 10^{-3}.
- Large normalization uncertainty 0.25%.
- Needed much better analysis of the normalization possibilities.

For further normalization studies use INDEPENDENT ratios instead of $L^{+/-}$:

$N = N^{++} + N^{--} + N^{-+} + N^{+-}$ – total counts of the normalizing subsystem

$R_2 = (N^{++} + N^{--})/N$ – fraction of parallel spin interactions (double spin)

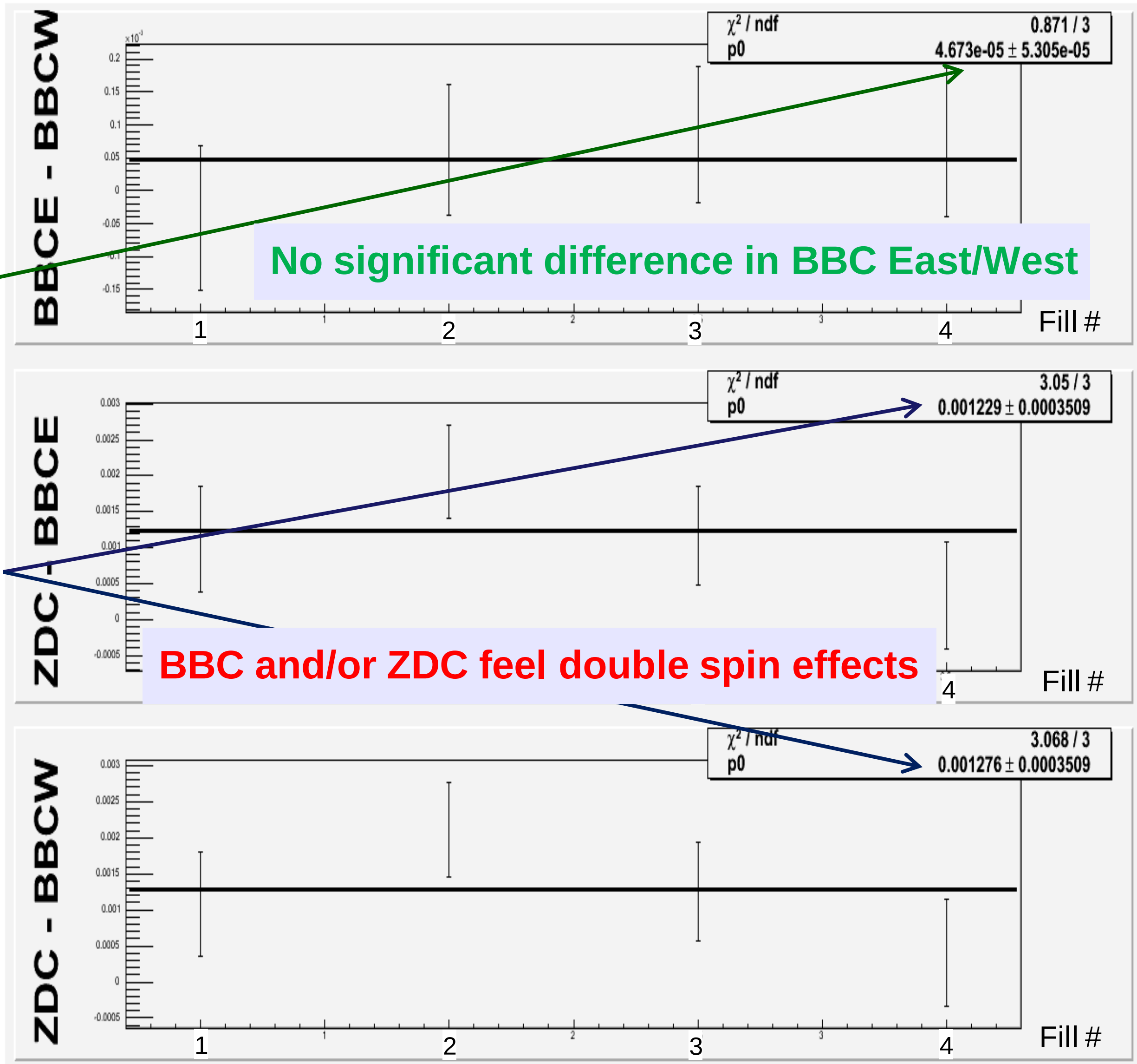
$R_B = (N^{++} + N^{+-})/N$ – fraction of interactions with spin UP in Blue beam

$R_Y = (N^{++} + N^{-+})/N$ – fraction of interactions with spin UP in Yellow beam

R_2 is most important: $\delta\varepsilon_{NN} \approx 2\delta R_2$, while R_B and R_Y contribute negligibly to the systematic uncertainty in ε_{NN}

Difference in ratio R_2, 4 fills of this exp.

- Of the four systems under study BBC and ZDC were chosen as most reliable
- BBC East is the same as BBC West at least to the level 10^{-5}.
- DS difference between BBC and ZDC ~10^{-3} for 4 fills of our run with transverse polarization
- Checked for fake polarization pattern – DS averages out
- Also checked for 15 longitudinal runs: $2 \cdot 10^{-4}$.
- Systematic uncertainty ~$2 \cdot 10^{-3}$ in raw double spin asymmetry: too bad.



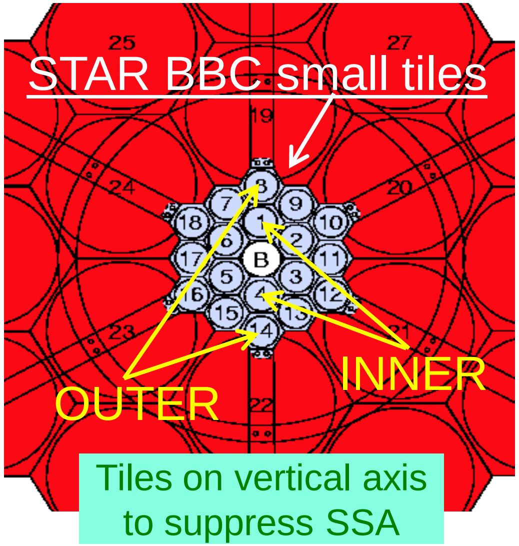
Probing various physics with BBC

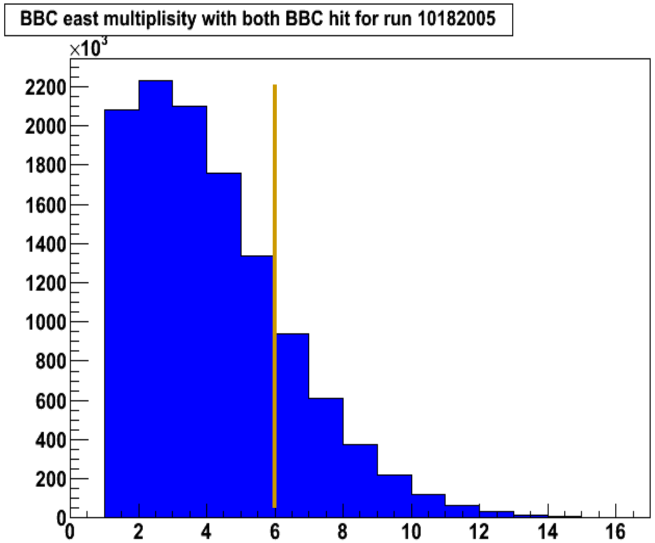
- Have access to single BBC tiles and coincidence of East and West BBC arms in any combinations.
- Choose several different physics processes, which give the same normalization.
- Double spin asymmetry for two different processes could be the same only if it is zero.
- Counts analyzed and corresponding physics:

  Leading particle at small angle in East/West:
  - **BBCIE** = (exactly 1 hit in INNER EAST tiles) & (at least 1 hit in WEST arm)
  - **BBCIW** = (exactly 1 hit in INNER WEST tiles) & (at least 1 hit in EAST arm)

  Leading particle at twice this angle in E/W:
  - **BBCOE/W =** (exactly 1 hit in OUTER E/W tiles) & (at least 1 hit in opposite arm)

  Large forward multiplicity:
  - **BBCXE/W** = (BBC E/W > 5 hits) & (at least 1 hit in opposite arm)





ΔR_2 for different physics in BBC

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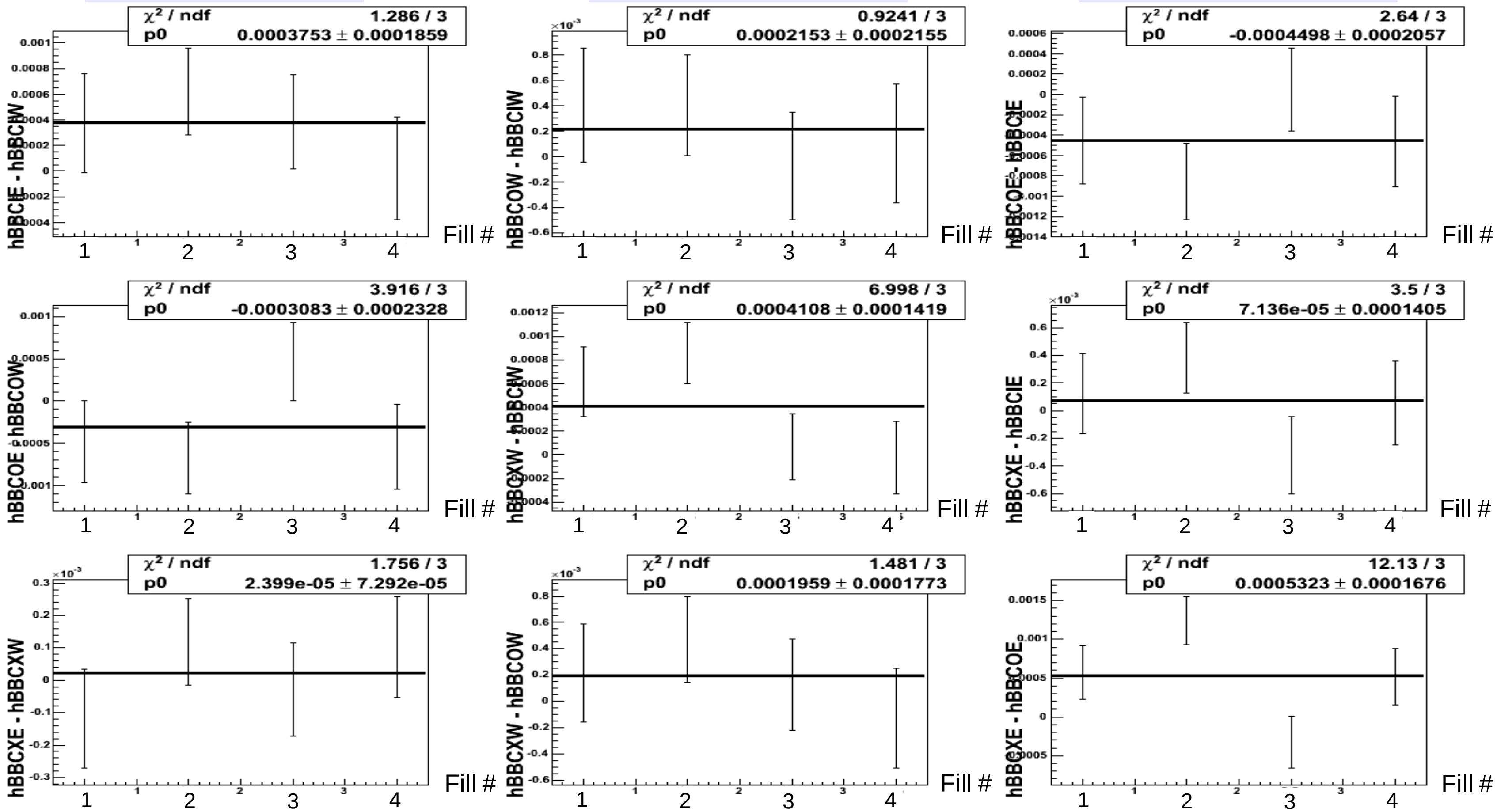
East / West	I / O / X West	I / O / X East

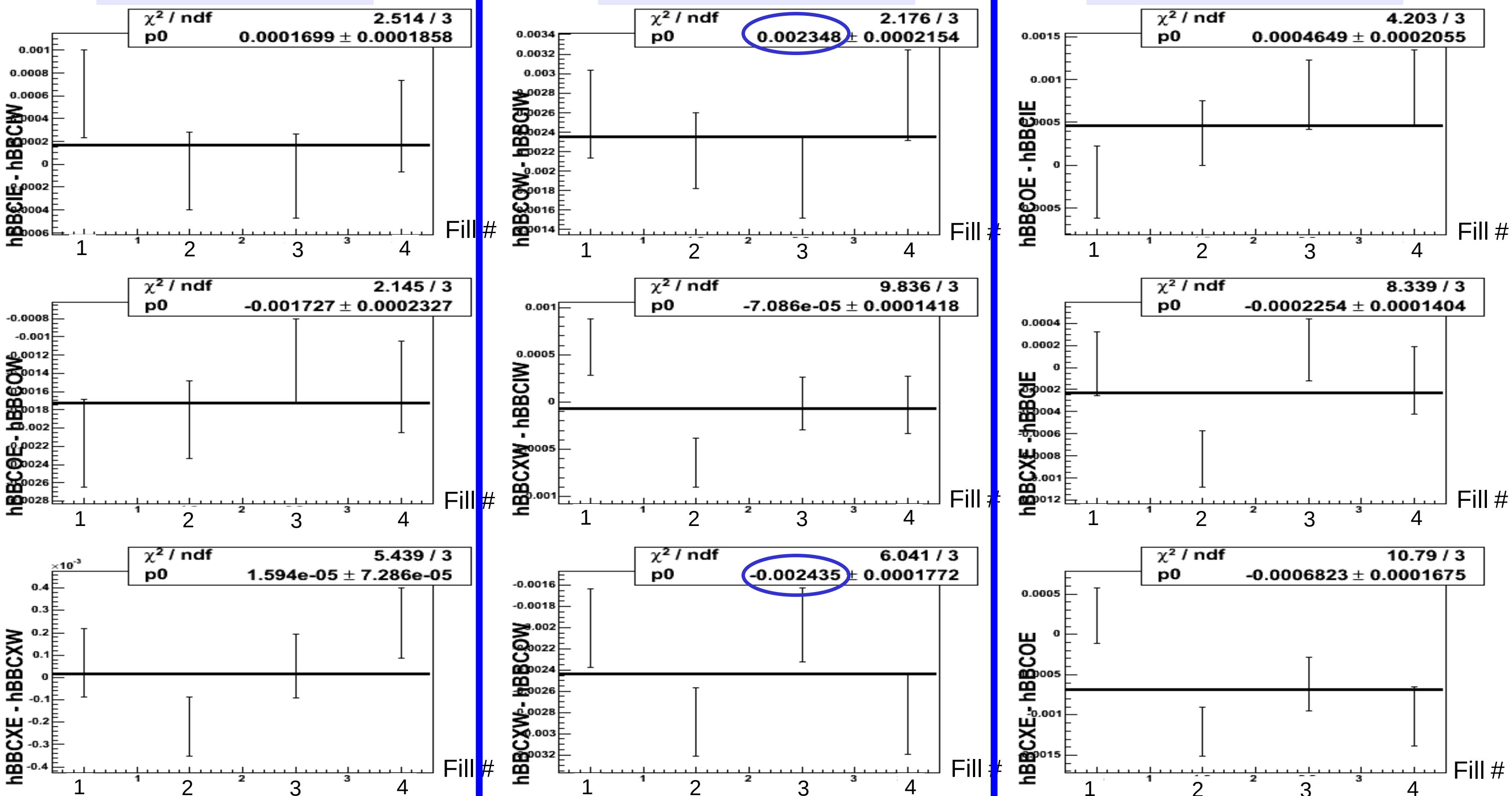


All shifts below 5*10^{-4} => small or no DS effects in BBC

Choose BBC coincidence for normalization and use I/O/X for uncertainties

Check ΔR_B for physics channels in BBC

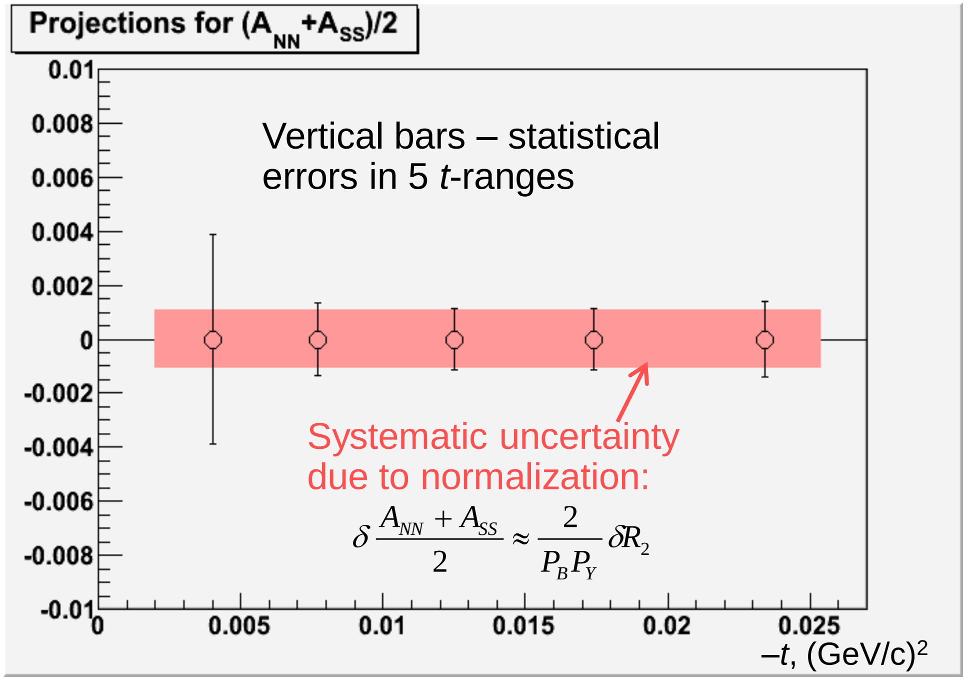
East / West | I / O / X West | I / O / X East



Maximum difference for West arm (~2*10^{-3}) – Blue beam fragmentation direction. Similar conclusion for Yellow single spin fraction ΔR_Y.

Projections and conclusions

- Very clean data set of ~20 million *pp*-elastic events is taken with Roman Pots integrated into the STAR detector for low *t* studies and both single and double spin asymmetries are being extracted with unprecedented accuracy in 5 *t*-ranges at √s=200 GeV.
- Careful study of several STAR subsystems for extracting of normalization counts showed that BBC is nearly free of double spin effects and can be used for normalization.
- Analysis of 3 processes in BBC with sensitivity to various physics allows to estimate the uncertainty in R_2 normalization ratio at the level of $2 \cdot 10^{-4}$.



- Uncertainties of R_B and R_Y are 5 times larger but their contributions to the systematic error are strongly suppressed.
- Need even more checks prior to release of the final result
- Further plans include data taking at √s=500 GeV and measurements of A_{LL}.