Longitudinal Spin Transfer to Λ and $\overline{\Lambda}$ Hyperons Produced in Polarized Proton-Proton Collisions at $\sqrt{s}$=200 GeV

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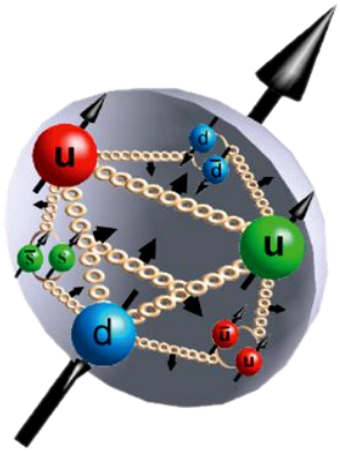
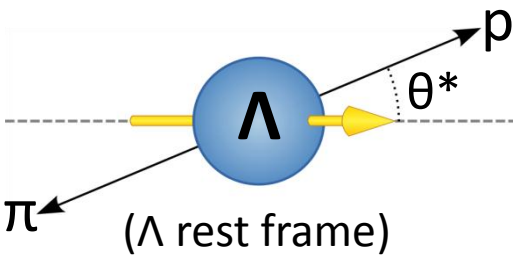


Motivation

- The quark spin contribution to the proton spin is small [1].
- Polarized fragmentation is not well understood [2].
- Polarized quark fragmentations can be studied by extracting Λ-D_{LL} from polarized proton-proton collisions at RHIC [3].

- Λ hyperon is made up of an up, down and strange quark
- At high p_T, strange quark fragmentation expected to dominate Λ production
- Weak decay parameter is externally measured



(Λ rest frame)

$$\frac{dN}{dcos\theta^*} = \frac{N_{tot}}{2} A(cos\theta^*)(1+\alpha_w P_\Lambda cos\theta^*)$$

- A(cosθ*): Acceptance function
- α_w: Weak decay parameter
- P_Λ: Λ polarization

D_{LL} : Spin Transfer

$$D_{LL} \equiv \frac{\sigma_{p^+p\to\Lambda^+X} - \sigma_{p^+p\to\Lambda^-X}}{\sigma_{p^+p\to\Lambda^+X} + \sigma_{p^+p\to\Lambda^-X}}$$

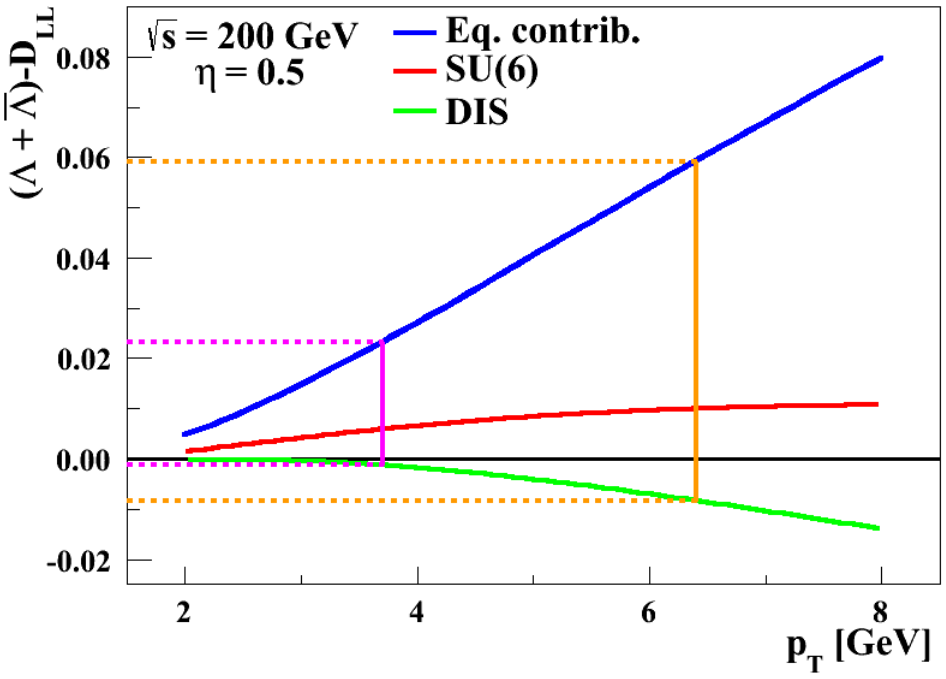
D_{LL} : Extraction Method

$$D_{LL} = \frac{1}{P_{Beam} \cdot \alpha_w \cdot \langle cos(\theta^*)\rangle} \cdot \frac{N^+ - R \cdot N^-}{N^+ + R \cdot N^-}$$

- Λ easily reconstructed at STAR via weak decay channel
- Λ polarization is determined by its self-analyzing property
- D_{LL} is expected to be sensitive to polarized fragmentation functions and polarized parton distribution functions

[1] EMC, J. Ashman et al, Nucl. Phys. B 328 (1989) 1
[2] e.g. Z.T. Liang and C. Boros, Phys.Rev.D57:4491-4494,1998
[3] Bo-Qiang Ma et al, Nucl.Phys. A703: 346-364,2002

RHIC Model Predictions



W. Vogelsang, M. Stratmann, D. de Florian, Private Communication

D. de Florian, et al., Phys. Rev. Lett. 81, 530 (1998)

Up, down, and strange quark polarizations contribute equally to D_{LL}

Based on expectations from the naïve quark model, only polarized strange quarks are allowed contribute to D_{LL}

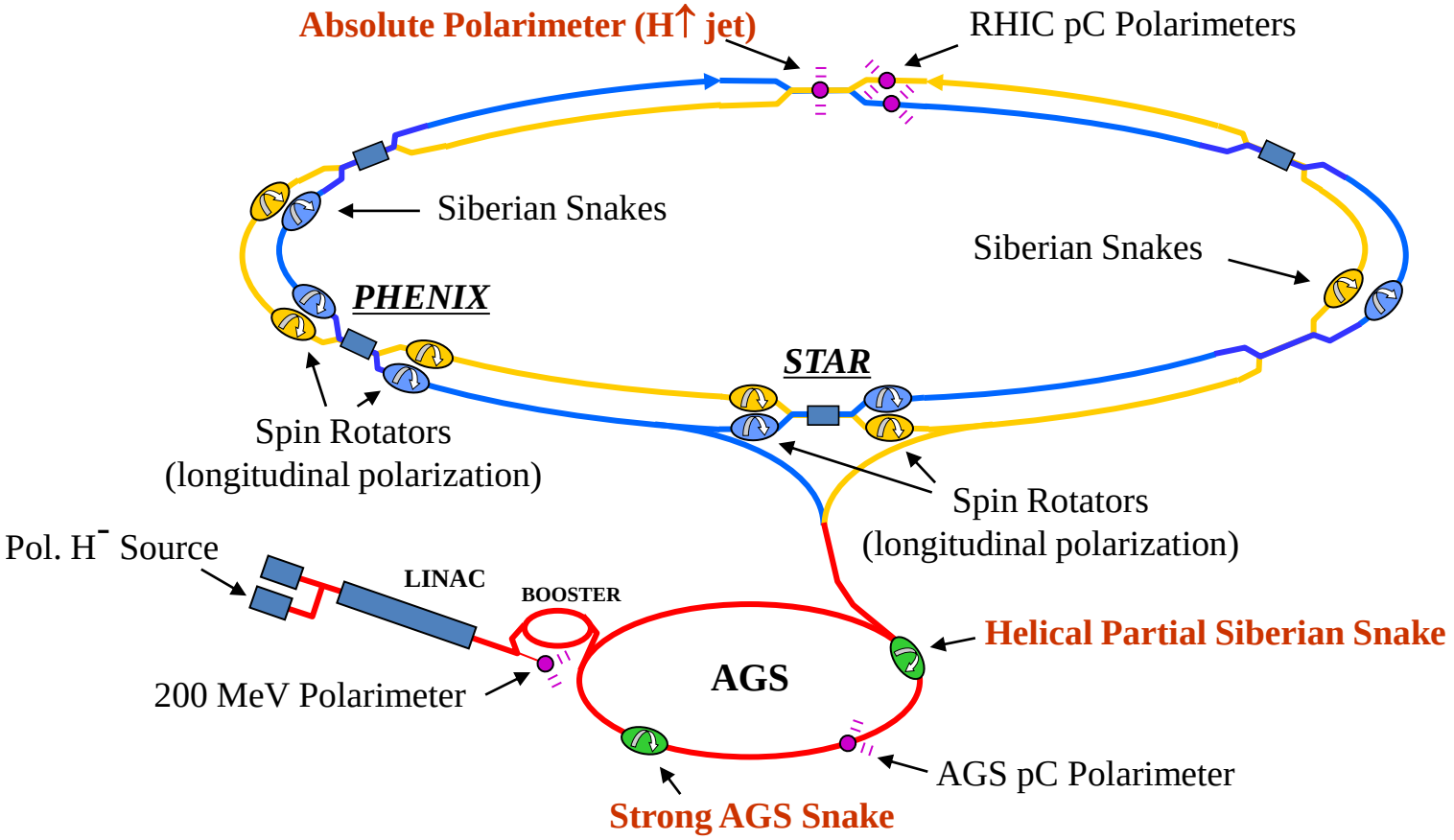
Besides polarized strange quark contribution, a DIS-like configuration expects a large negative contribution from up and down quark polarization to D_{LL}

- D_{LL} calculations for $(\Lambda + \bar{\Lambda})$
- Models were re-evaluated
  - $\sqrt{s}$ = 200 GeV
  - Updated fragmentation functions (NLO DSSV)
  - D_{LL} as a function of p_T
- Model spread of 0.07 at p_T = 6.5 GeV
- Potentially measurable with current data

- Additional model predictions by Q.H. Xu et al.
- D_{LL} model curves generated independently for Λ and $\bar{\Lambda}$
- Additional models generated for Λ as a function of p_T and momentum fraction z

Q.H. Xu et al., Phys. Rev. D 73, 077503 (2006)

Relativistic Heavy Ion Collider (RHIC)



Year	$\sqrt{s}$ (GeV)	$L_{recorded}$ (pb^{-1}) (long.)	Polarization (%)(blue / yellow)
2005	200	3.1	52 ± 3 / 48 ± 3
2006	200	6.5	56 ± 4 / 58 ± 3
2009	200	22	57 ± 3 / 57 ± 4

Solenoidal Tracker At RHIC (STAR)

Barrel Electromagnetic Calorimeter (BEMC)

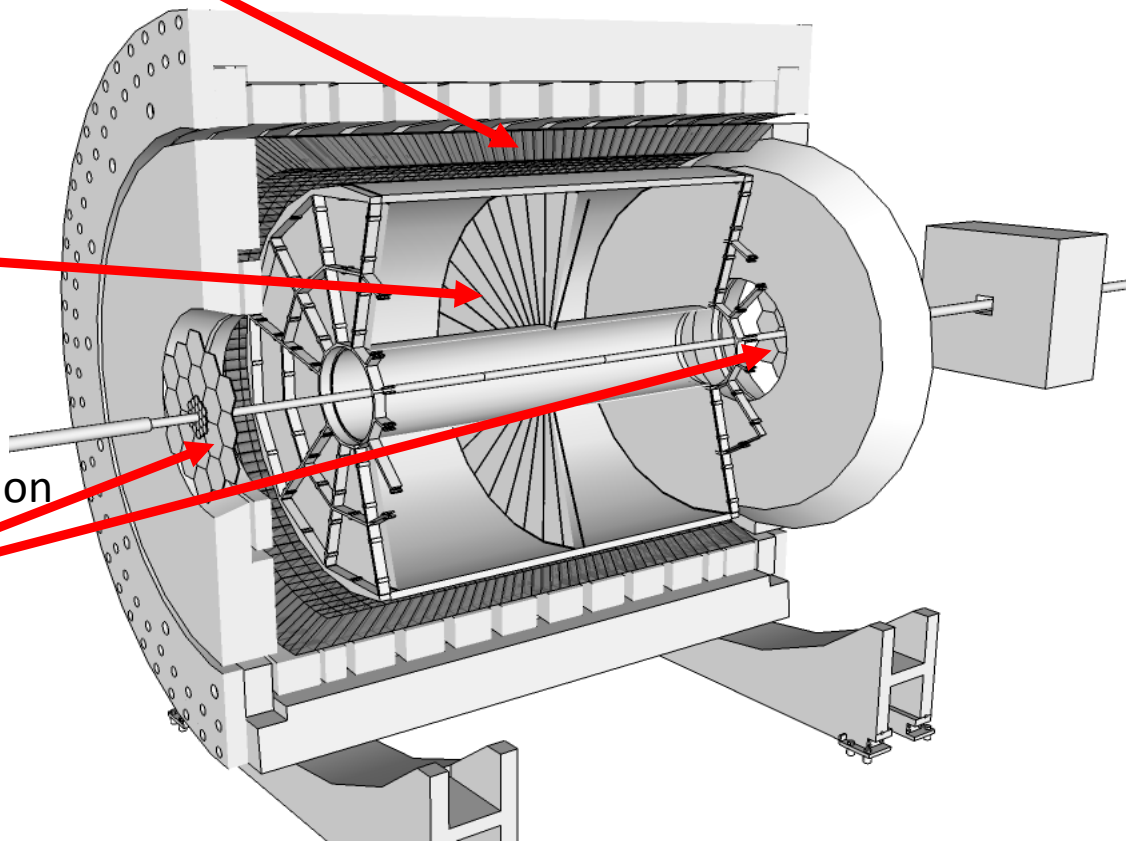
- $|\eta| < 1.0$
- Jet Patch Trigger
- Jet Reconstruction

Time Projection Chamber (TPC)

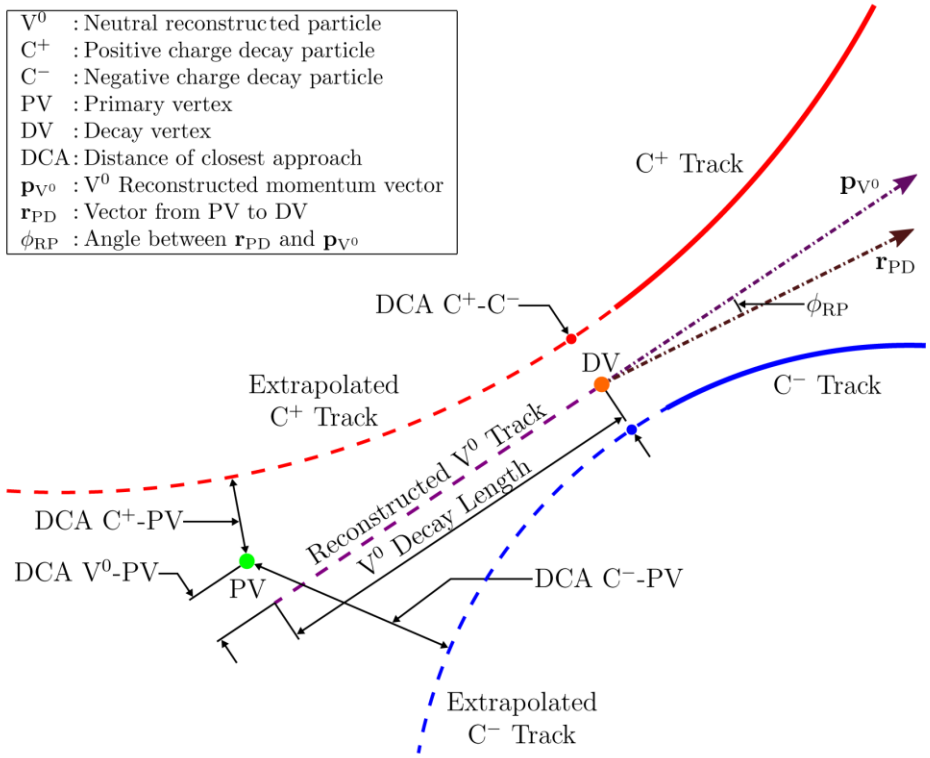
- $|\eta| < 1.4$
- Particle Identification via $\left(\frac{dE}{dx}\right)$
- Charged Particle Track Reconstruction

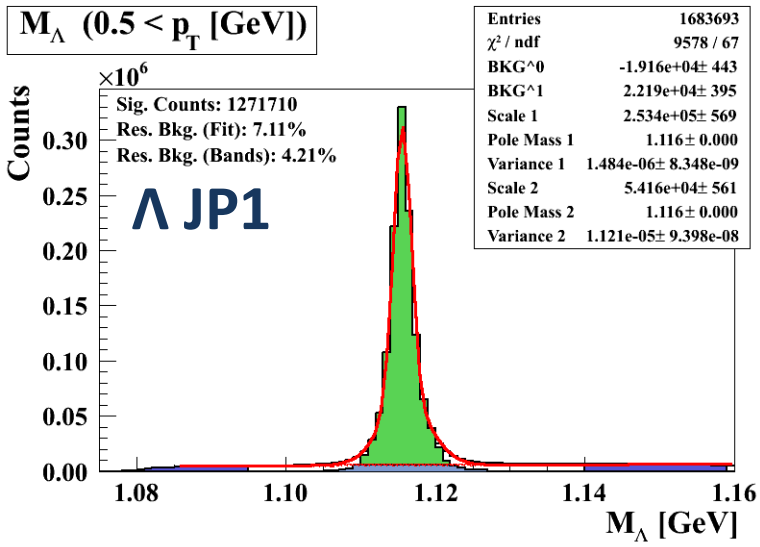
Beam-Beam Counters (BBC)

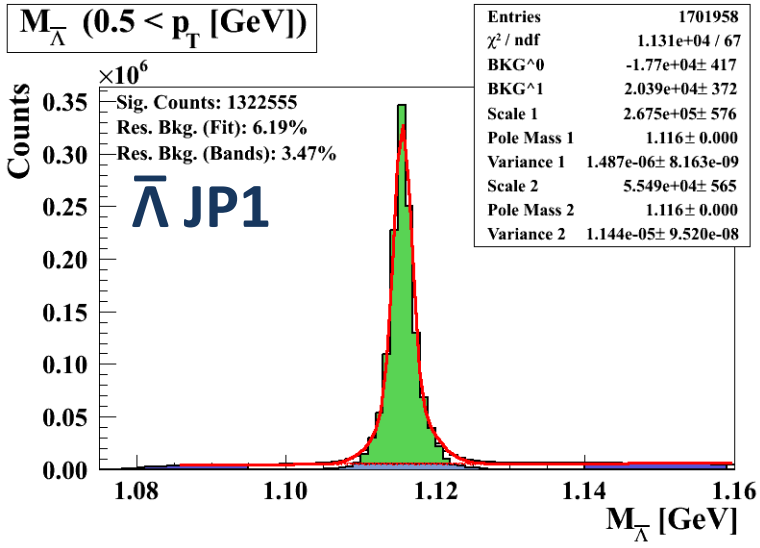
- $3.4 < |\eta| < 5.0$
- Relative Luminosity
- Local Polarimeter



Hyperon Reconstruction







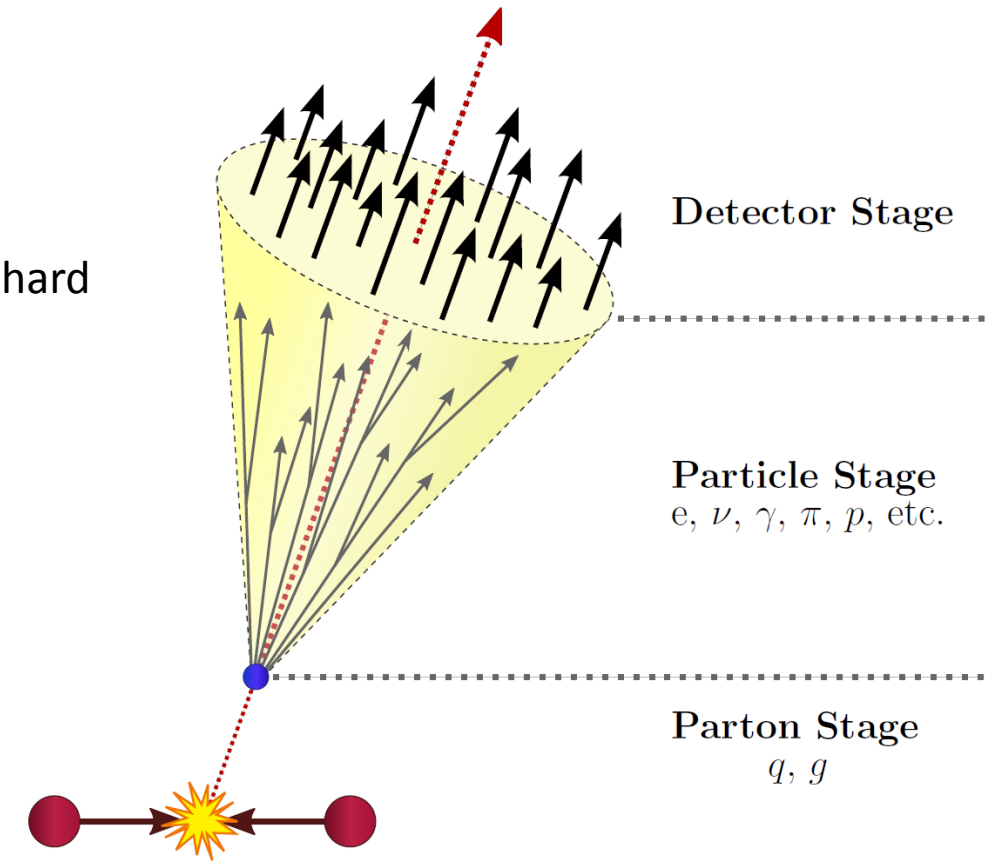
- Hyperon observables:
  - DCA C^+-C^- , DCA V^0-PV
  - DCA π-PV , DCA p-PV
  - Decay Length
  - ϕ_{RP}
- Standard STAR cuts:
  - $|n\sigma_{p(\pi)}| < 3$

- Observables tuned per p_T interval remove bulk of combinatorial background

Jet Reconstruction

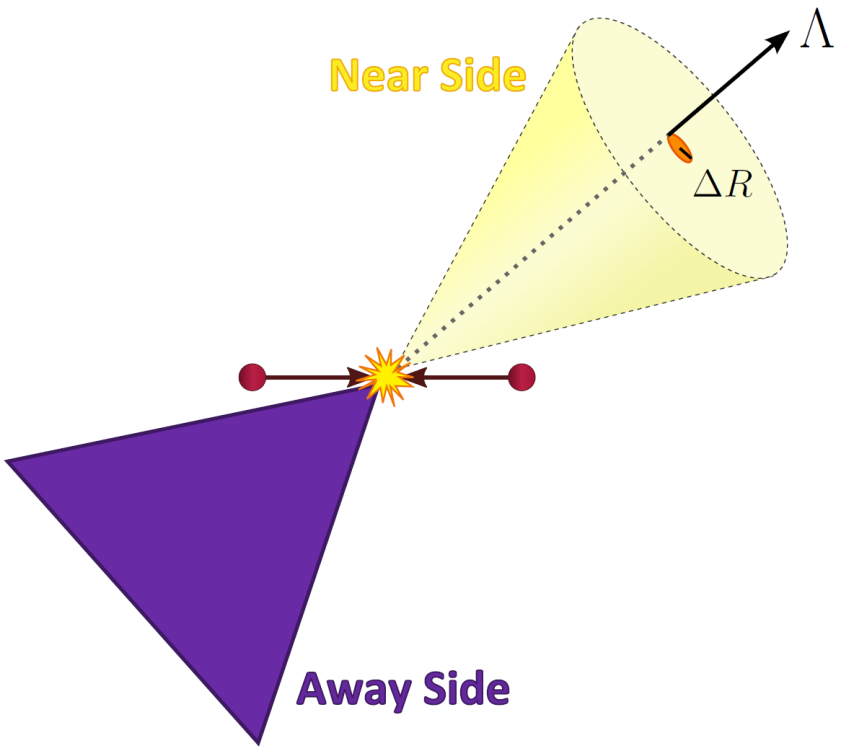
(Identical to 2009 Jet A_{LL} Analysis)

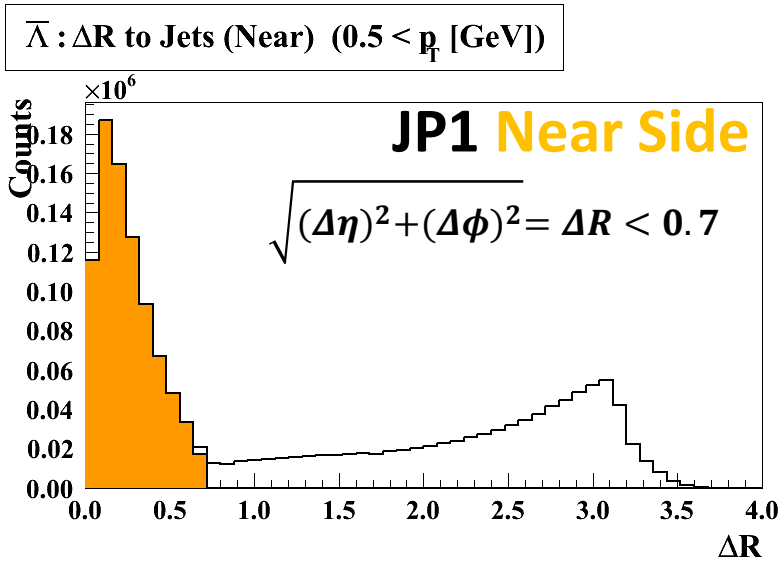
- STAR cannot directly trigger on Λs
- STAR triggers on electromagnetic energy deposited on the BEMC
- Triggering on high p_T jets allows to study hard scattering events
- Only jet-events are used
  - Standard STAR jet reconstruction
  - Midpoint cone algorithm
    - Cone radius R = 0.7 rad
    - Jet p_T > 3.5 GeV
    - Seed E_T = 0.5 GeV
    - Split Fraction = 0.5
  - Jet Cuts
    - $-0.7 < \eta_{det} < 0.9$
    - $0.01 < NEF < 0.95$

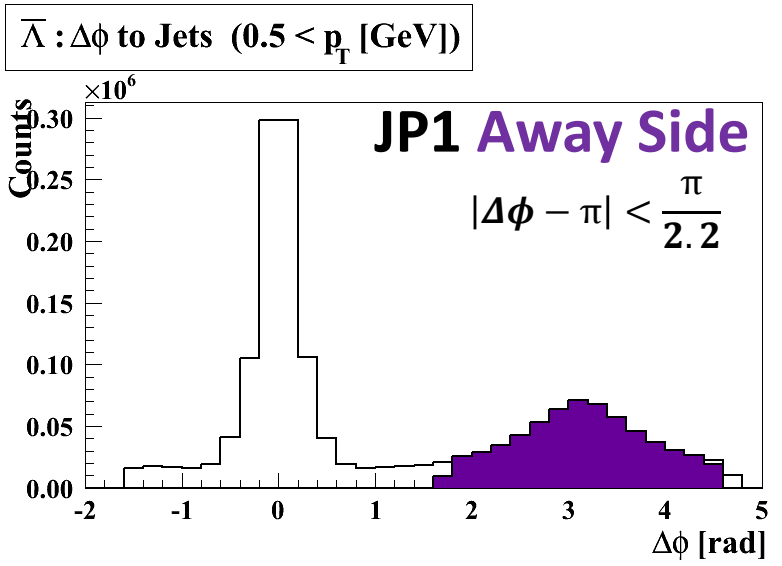


G. C. Blazey et al, arXiv:hep-ex/0005012v2 (2000)

Hyperon-Jet Association







- Jet matched to triggered jet patch
- Near-side: Λ resides within jet cone
- Away-Side: Λ resides Δϕ = π from jet cone
- Away side has similar precision as near side

$$\Delta\phi = \phi_{\Lambda} - \phi_{jet} \qquad \Delta\eta = \eta_{\Lambda} - \eta_{jet}$$

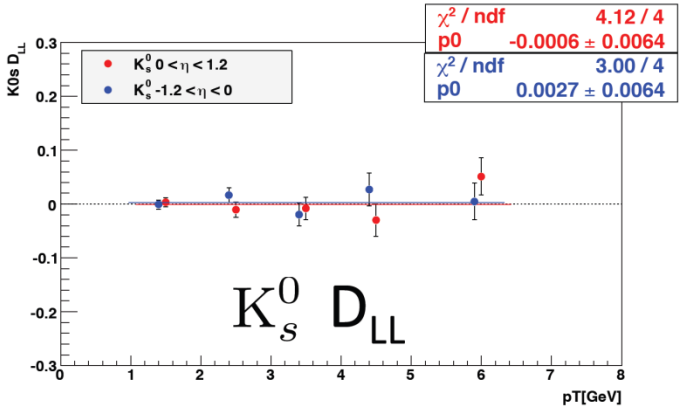
Systematics

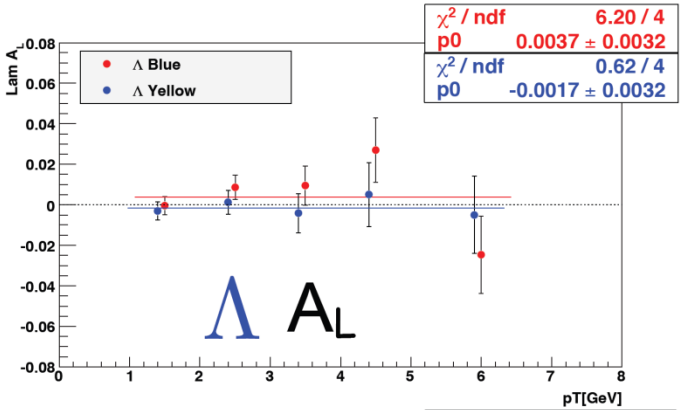
Systematic Checks

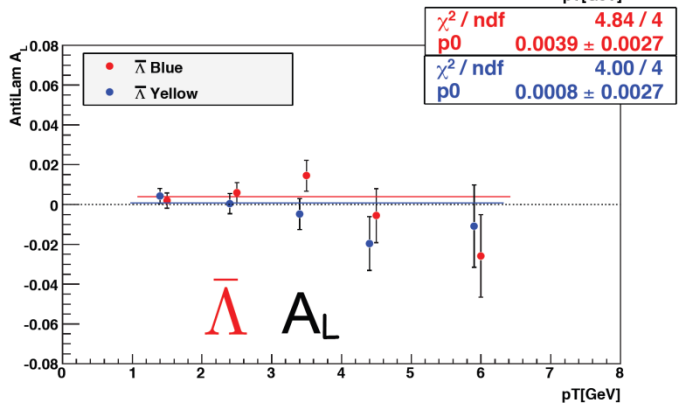
- Null measurement of spin-less K_s^0-D_{LL}
- Null measurements of A_L, $A_{l.s}$, $A_{u.s}$

Systematic Contributions

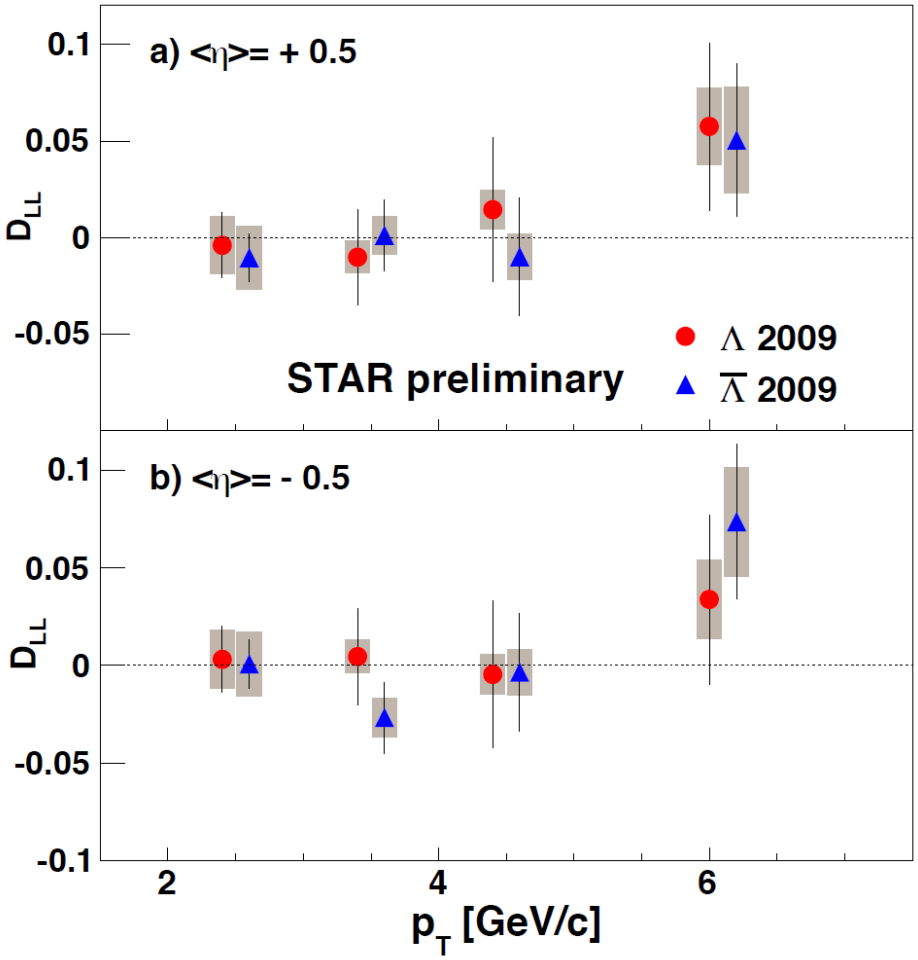
- 4.7% Beam polarization
- 2.0% Weak decay parameter, α_w
- 1.9% Residual transverse polarization
- 5×10^{-3} Relative luminosity
- $< 6 \times 10^{-3}$ Residual background
- 0.013 (smallest p_T interval) Pileup
- 0.027 (largest p_T interval) Trigger bias





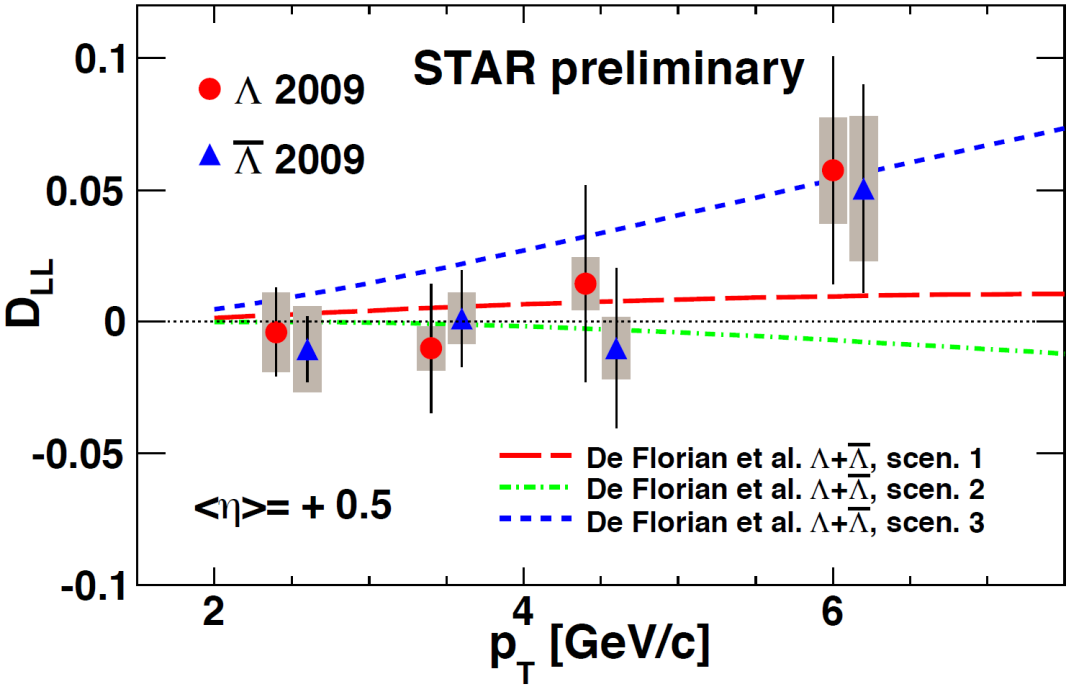


Preliminary 2009 Near-Side D_{LL} Results



- Data provides no significant difference between Λ and $\overline{\Lambda}$ D_{LL}
- Additional sample of away-side Λ's with similar precision

Comparison to Vogelsang's Model



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Based on expectations from the naïve quark model, only polarized strange quarks are allowed contribute to D_{LL}

Besides polarized strange quark contribution, a DIS-like configuration expects a large negative contribution from up and down quark polarization to D_{LL}

- 2009 data improved by a factor of 5(4) in precision for Λ($\overline{\Lambda}$) D_{LL} compared to 2005 published results
- 2009 D_{LL} extends in Λ p_T up to ~6. 5 GeV
- Data does not yet discriminate between model expectations
- Λ and $\overline{\Lambda}$ D_{LL} consistent with model curves
- D_{LL} model calculations for (Λ + $\overline{\Lambda}$)

Summary & Outlook

- Preliminary 2009 D_{LL} results are presented
- D_{LL} extends in Λ p_T up to ~6. 5 GeV
- Cross Checks & Systematics:
  - Cross Checks and null tests performed and passed with expected results
  - Complete assessment of systematic uncertainties
- Finalizing 2009 D_{LL} results for publication currently in progress
- Away-side sample will complement the near-side D_{LL} analysis with similar precision