



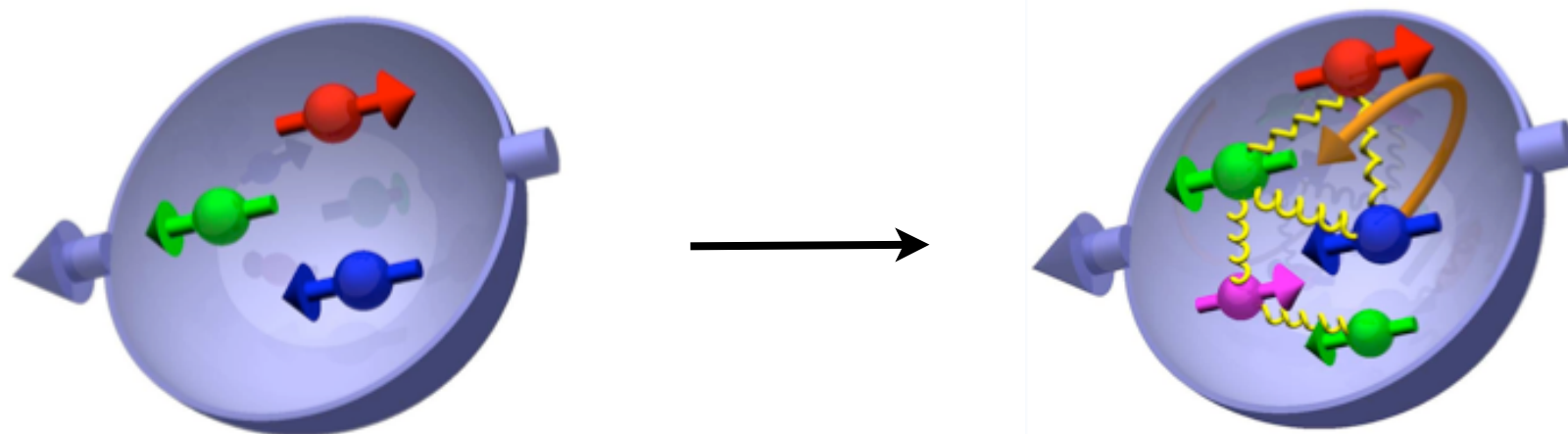
Longitudinal Spin Transfer of Λ and $\bar{\Lambda}$ in Polarized pp Collisions at $\sqrt{s}=200$ GeV

Ernst Sichtermann (LBNL), *for the STAR Collaboration*



Nucleon Spin Puzzle

The surprising *smallness* of the spin dependent part of the inclusive DIS cross section renewed the interest in and continues to force us to rethink nucleon spin structure,



Among the many open questions, what is the *role of flavor*, is there a hyperon spin puzzle?

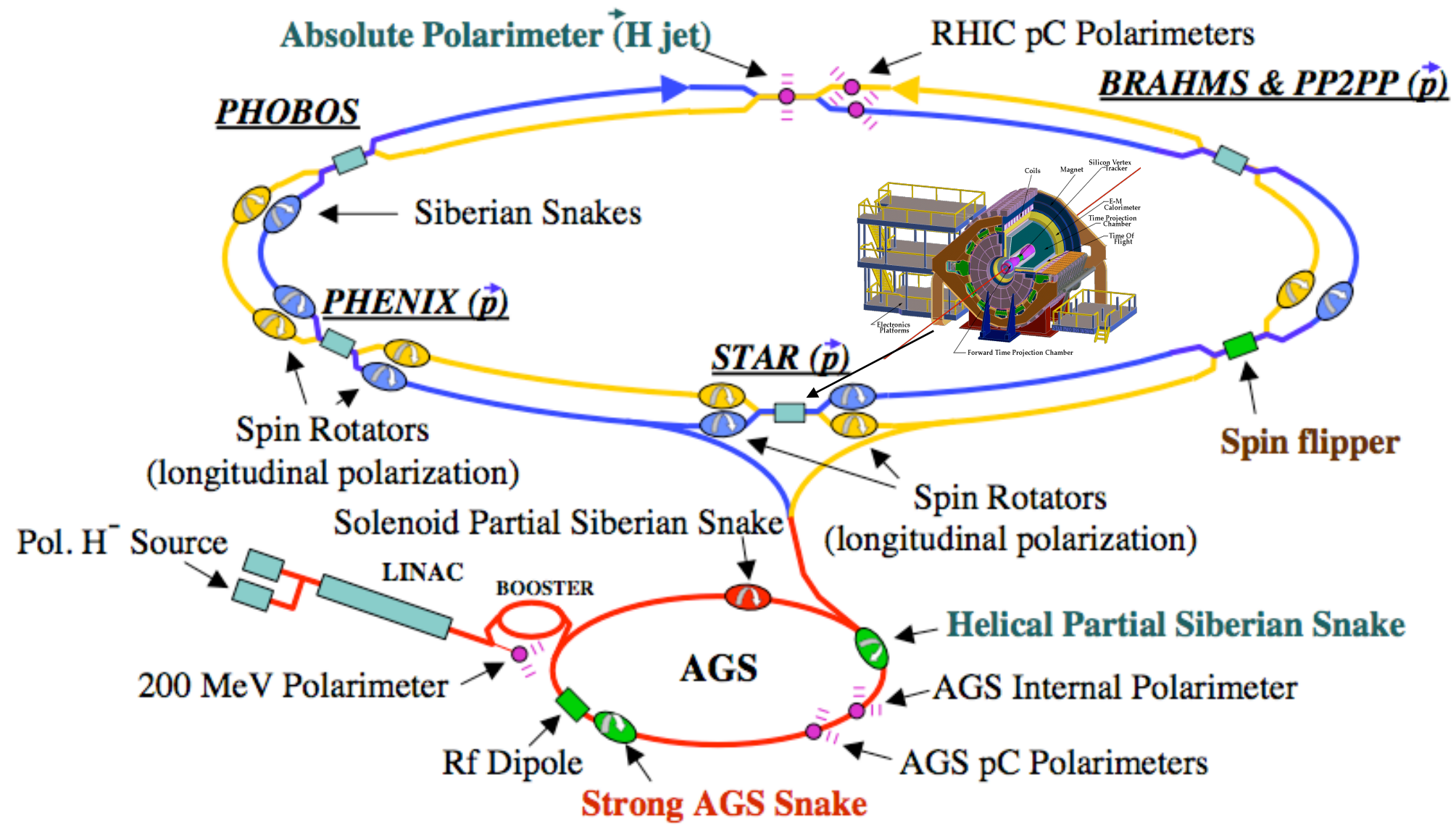
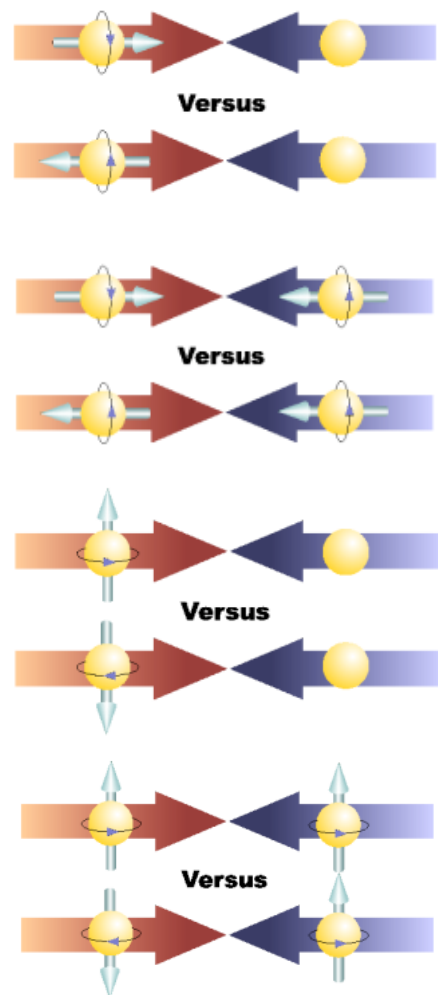
inclusive measurements, combined with hyperon decay, tell us that $\Delta s + \Delta \bar{s} < 0$

What insight(s) can hyperon polarization measurements at RHIC give?

RHIC - Polarized Proton Collider to Study Spin in QCD

Opportunities to study many facets:

$\sqrt{s} = 200 - 500 \text{ GeV}$

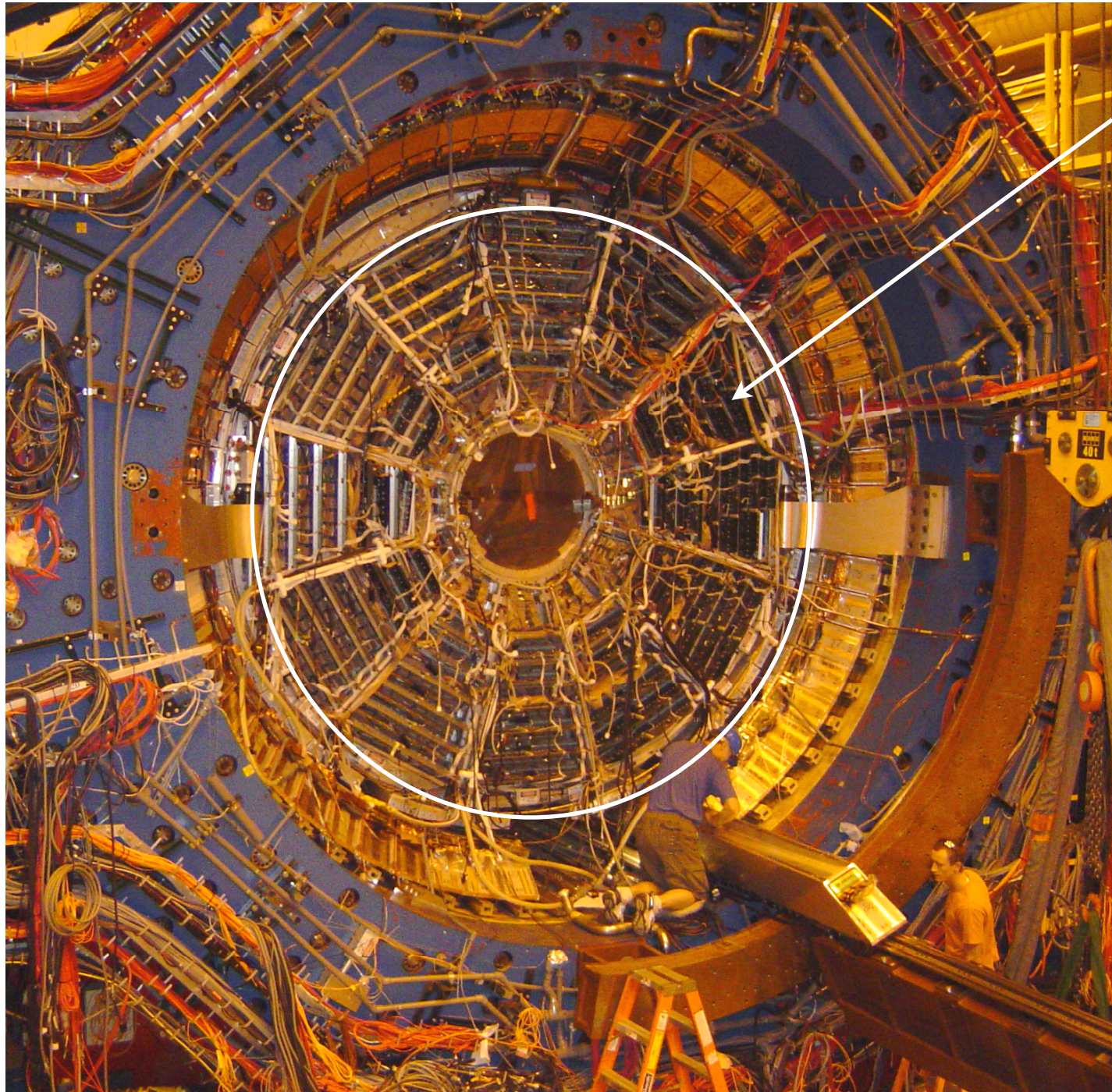


with good systematic controls, e.g.:

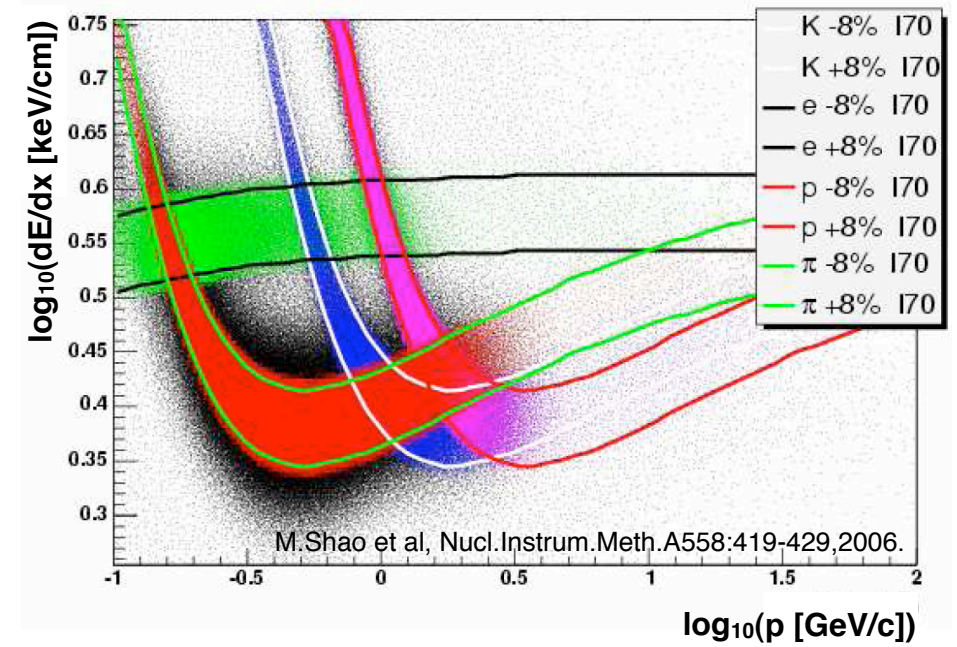


This work: $\sqrt{s} = 200 \text{ GeV}$, $\sim 2 \text{ pb}^{-1}$, $P_b \sim 50\%$ (longitudinal), collected in Y2005

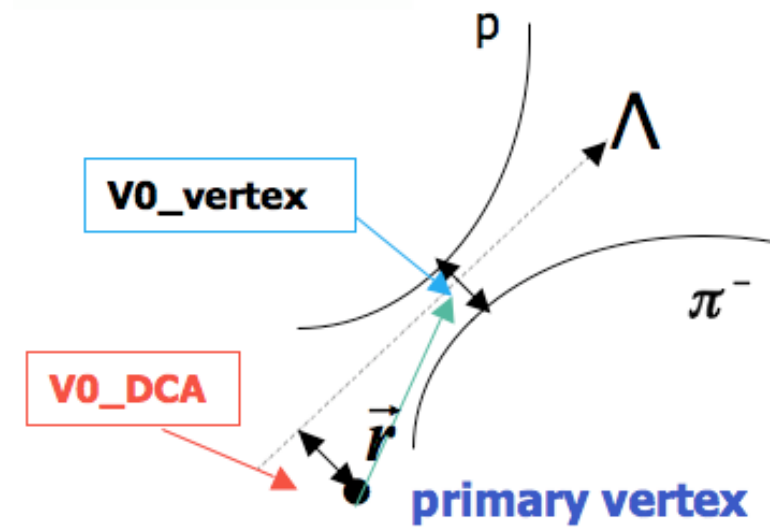
STAR - Solenoid Tracker At RHIC



Time Projection Chamber enables PID,

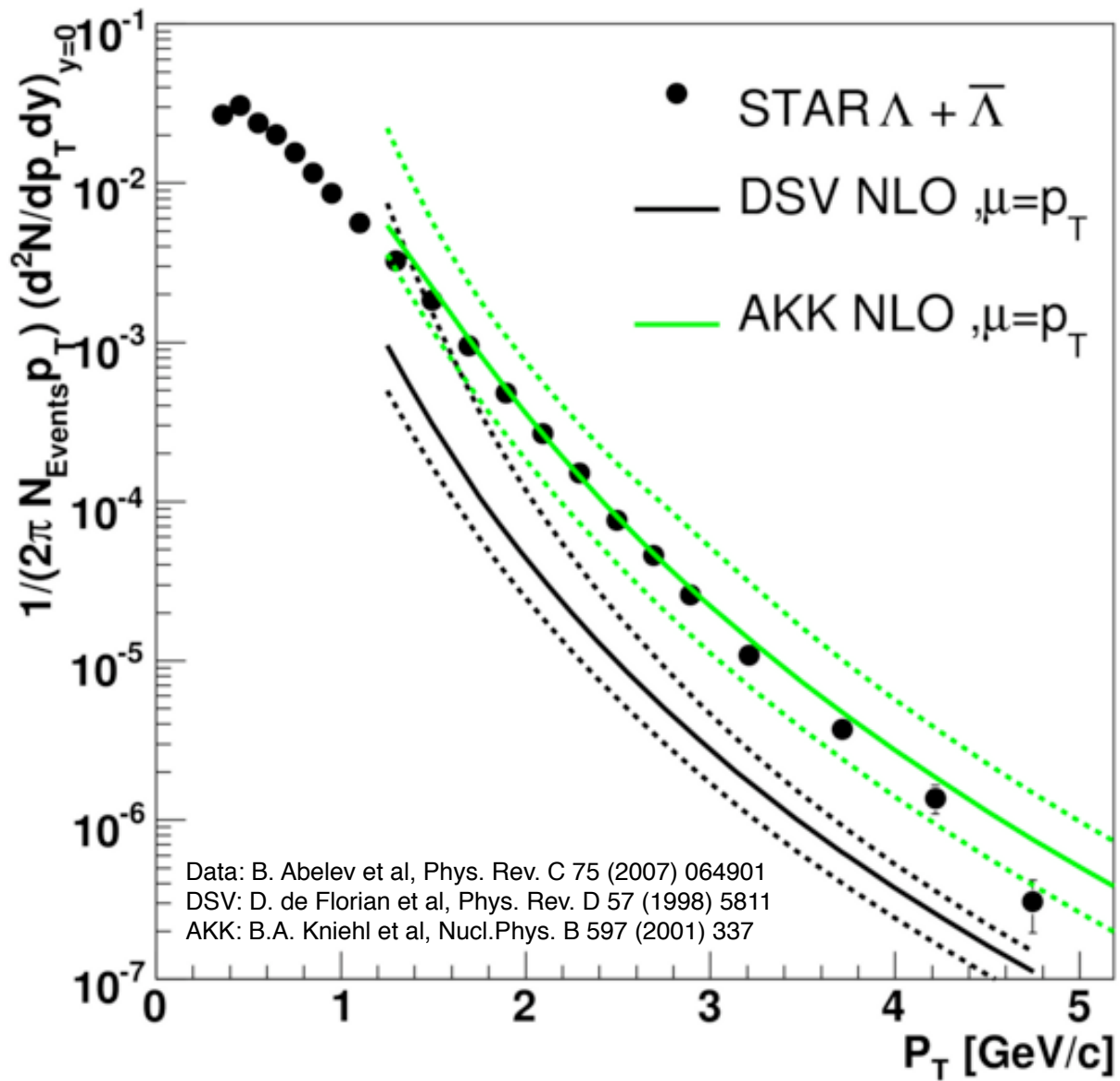


and topological reconstruction,

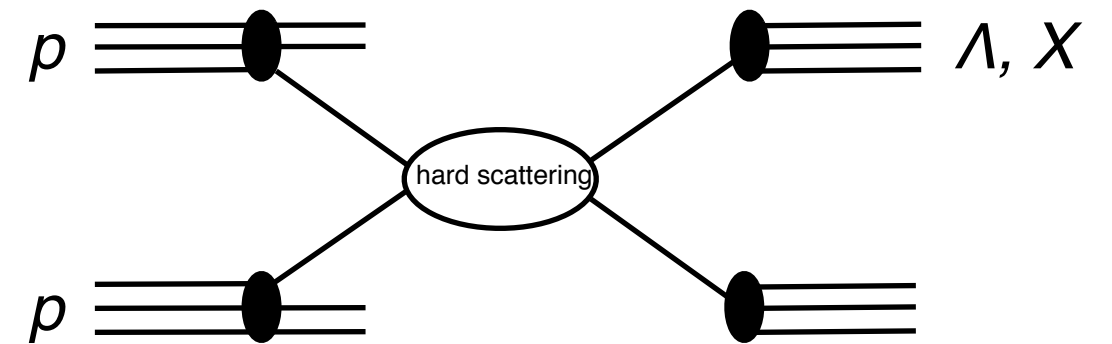


for $|\eta| \leq \sim 1.3$

Differential Cross Section



Factorized framework,



$$f, \Delta f \otimes \hat{\sigma}, \Delta \hat{\sigma} \otimes D, \Delta D$$

enables perturbative description.

Agreement of STAR data and theory, for a suitable choice of D , is a necessary condition for interpretation.

D_{LL} - Longitudinal Spin Transfer

At RHIC,

$$D_{LL}^{\Lambda} \equiv \frac{\sigma_{p^+ p \rightarrow \Lambda^+ X} - \sigma_{p^+ p \rightarrow \Lambda^- X}}{\sigma_{p^+ p \rightarrow \Lambda^+ X} + \sigma_{p^+ p \rightarrow \Lambda^- X}} = P_{\Lambda}^+$$

that is, the longitudinal polarization of the Λ for a specific beam-helicity configuration.

This polarization can be determined in the usual way,

$$\frac{dN}{d\Omega} \propto A(\cos \theta^*) (1 + \alpha P_{\Lambda} \cos \theta^*)$$

from the angular distribution of the $p + \pi$ decay mode with B.R. $\sim 64\%$.

Here,

A is the detector acceptance,

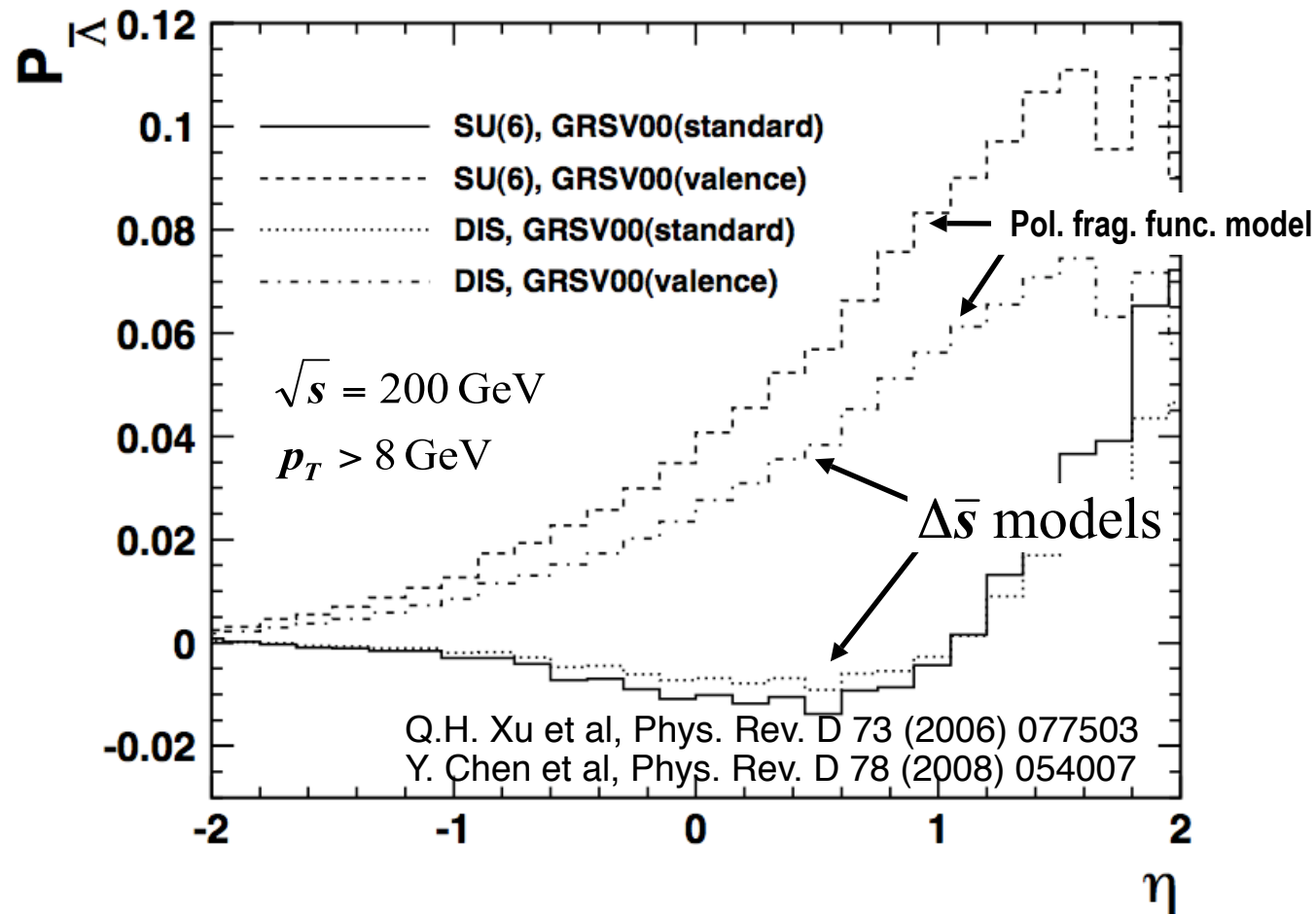
θ^* is the angle defined by the Λ momentum and the p direction in the Λ rest frame,

$\alpha = 0.642 \pm 0.013$ is the decay parameter.

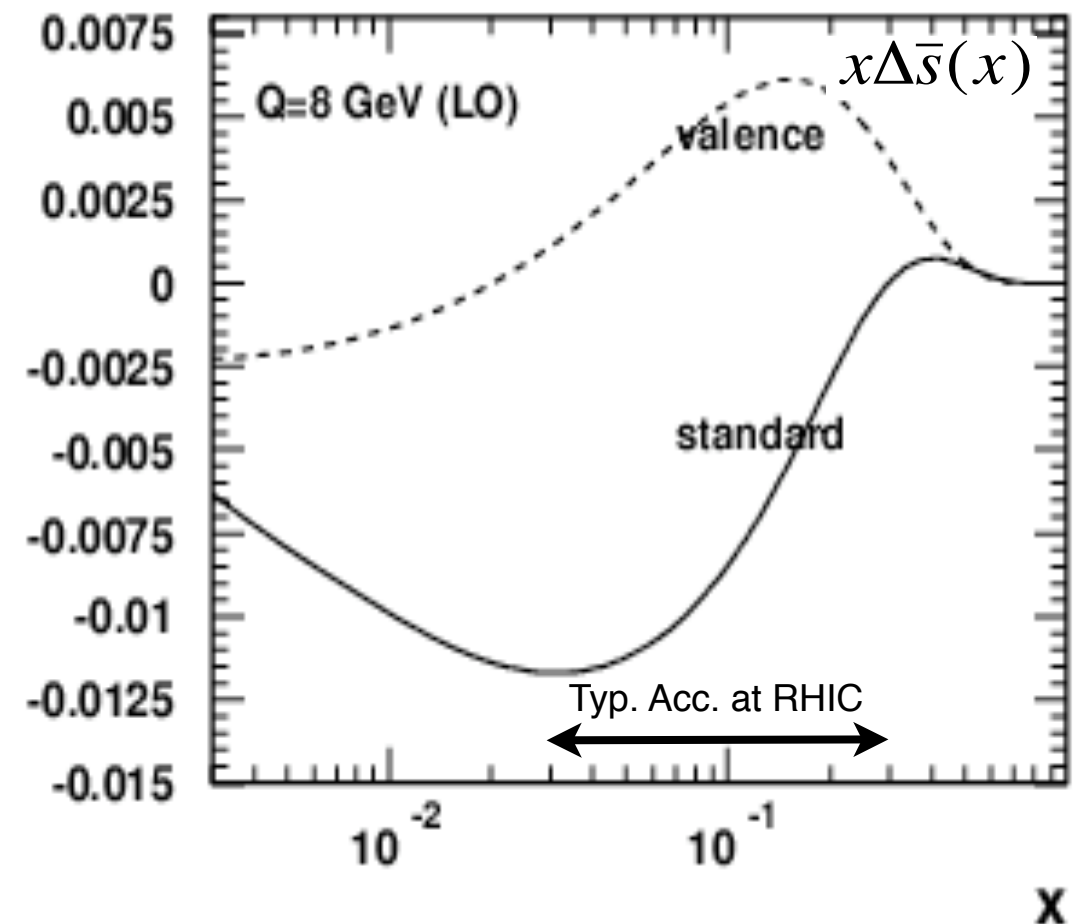
D_{LL} - Longitudinal Spin Transfer

Unlike for the differential cross section, NLO expectations do not currently exist for D_{LL} at RHIC.

Expectations at LO show sensitivity of D_{LL} for the $\bar{\Lambda}$ to the \bar{s} helicity distribution, $\Delta\bar{s}$,



GRSV00 - M. Glück et al Phys.Rev.D63 (2001) 094005



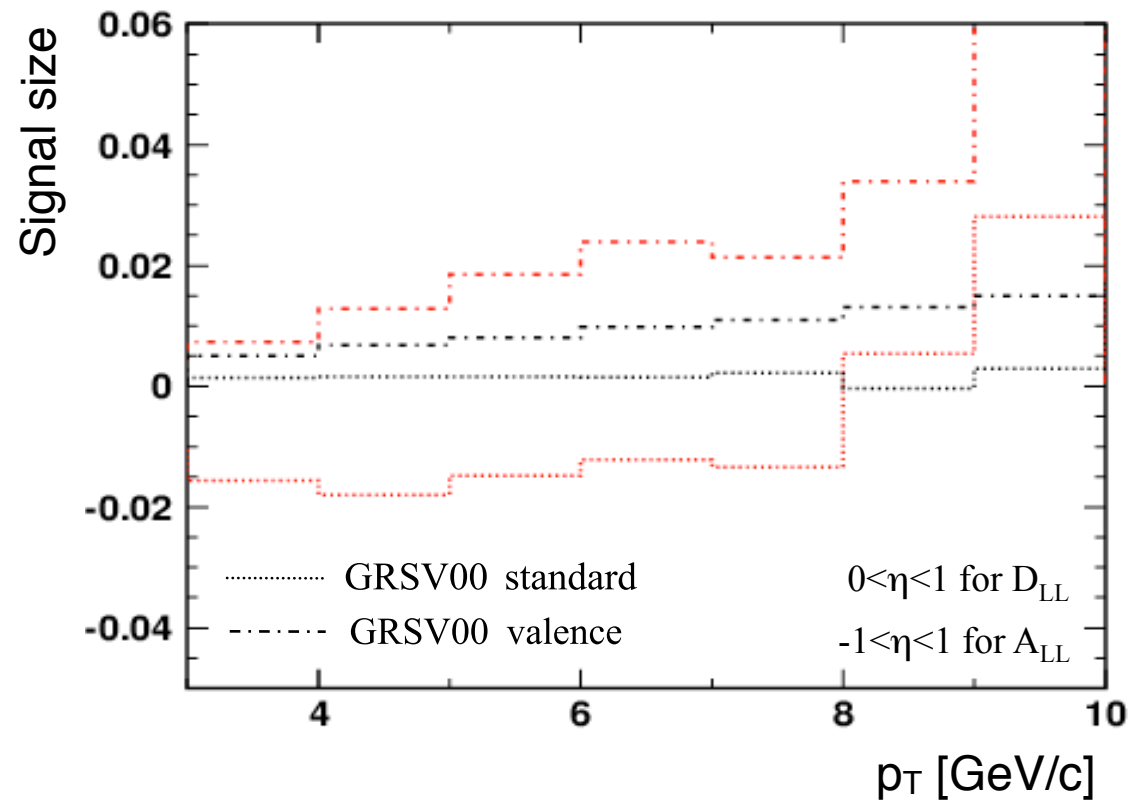
more so than to the fragmentation in this model.

The Λ D_{LL} is less sensitive to Δs , partly due to larger u and d quark fragmentation contributions.

Promising measurement: neither the role of (anti-)strange quarks nor polarized fragmentation is well known/understood - effects are potentially large enough to be observed.

Measure D_{LL} or A_{LL} ?

The same expectations versus p_T as D_{LL} and A_{LL} :



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

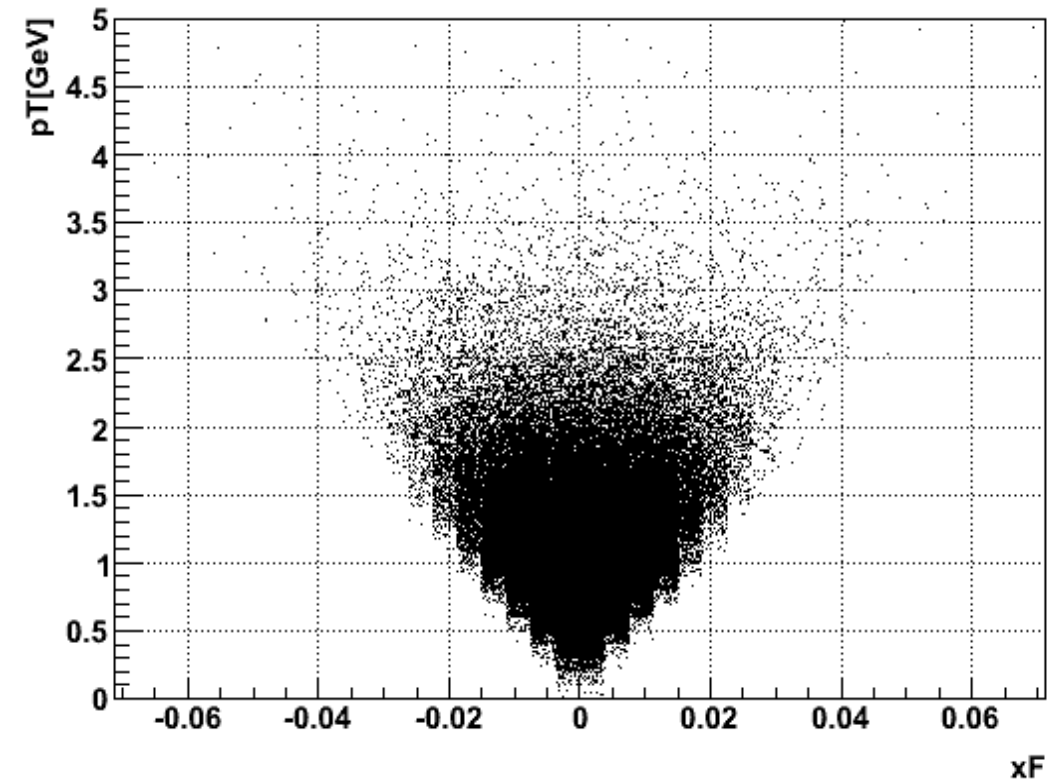
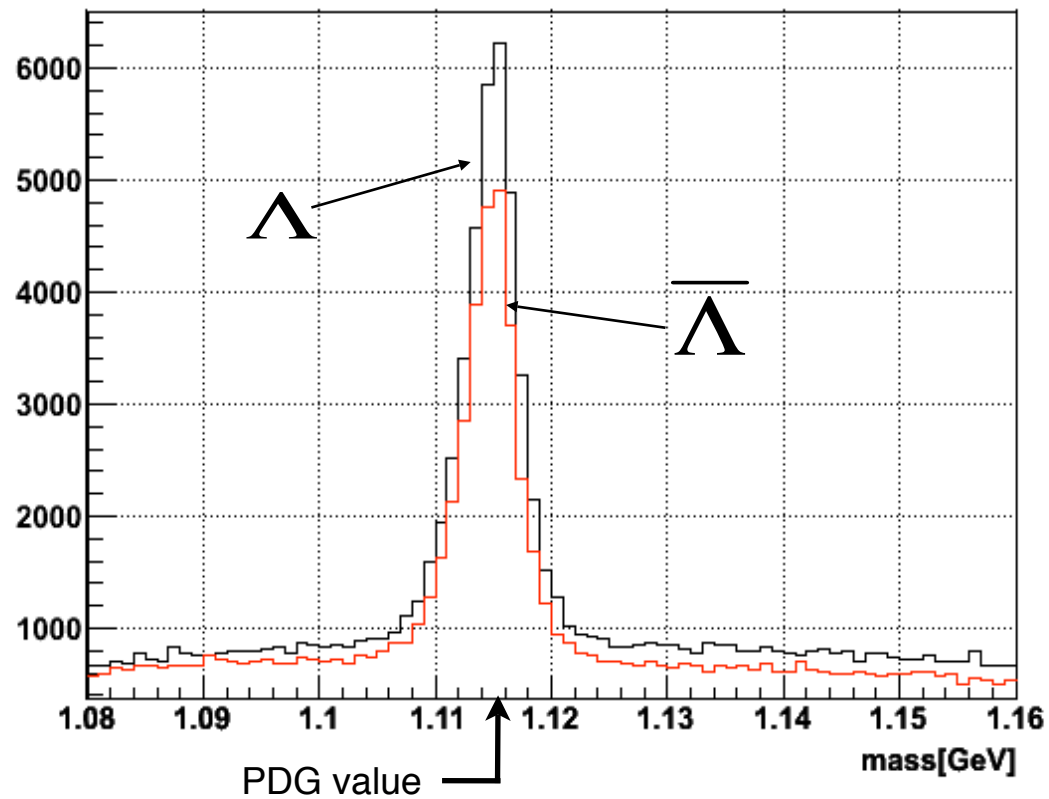
$$A_{LL} \equiv \frac{\sigma_{p^+ p^+ \rightarrow \Lambda X} - \sigma_{p^+ p^- \rightarrow \Lambda X}}{\sigma_{p^+ p^+ \rightarrow \Lambda X} + \sigma_{p^+ p^- \rightarrow \Lambda X}}$$

- + D_{LL} expected sensitivity is ~ 4 larger,
- current D_{LL} analysis requires more selections than for A_{LL} , i.e. lose some statistics,
- + D_{LL} is a single beam-spin measurement, analyzing power of the $p+\pi$ decay mode is relatively large.

Net advantage owing to the (anti-) Λ spin being carried mostly by the (anti-) s quark spin.

STAR Data - 2005

$\sim 3 \cdot 10^6$ events collected with a beam-collision trigger (minimum bias, bandwidth limited),



$\sim 30 \cdot 10^3$ Λ candidates,

$\sim 25 \cdot 10^3$ $\bar{\Lambda}$

$\langle p_T \rangle \approx 1.3$ GeV/c

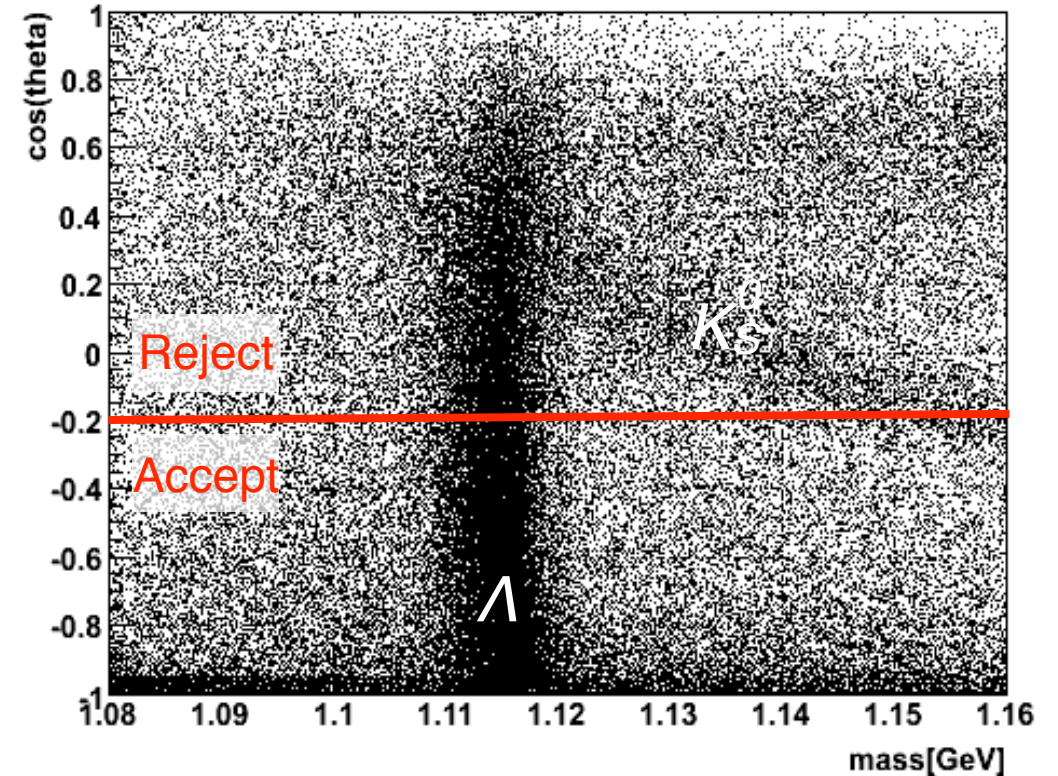
$\langle |x_F| \rangle \approx 0.008$

Analysis Features

Uses the $\Lambda \rightarrow p + \pi$ weak decay mode,

$$\frac{dN}{d\Omega} \propto A(\cos \theta^*) (1 + \alpha P_\Lambda \cos \theta^*)$$

Restrict $\cos \theta^*$ to eliminate K_S^0 background caused by misidentified π (cuts $\sim 40\%$).



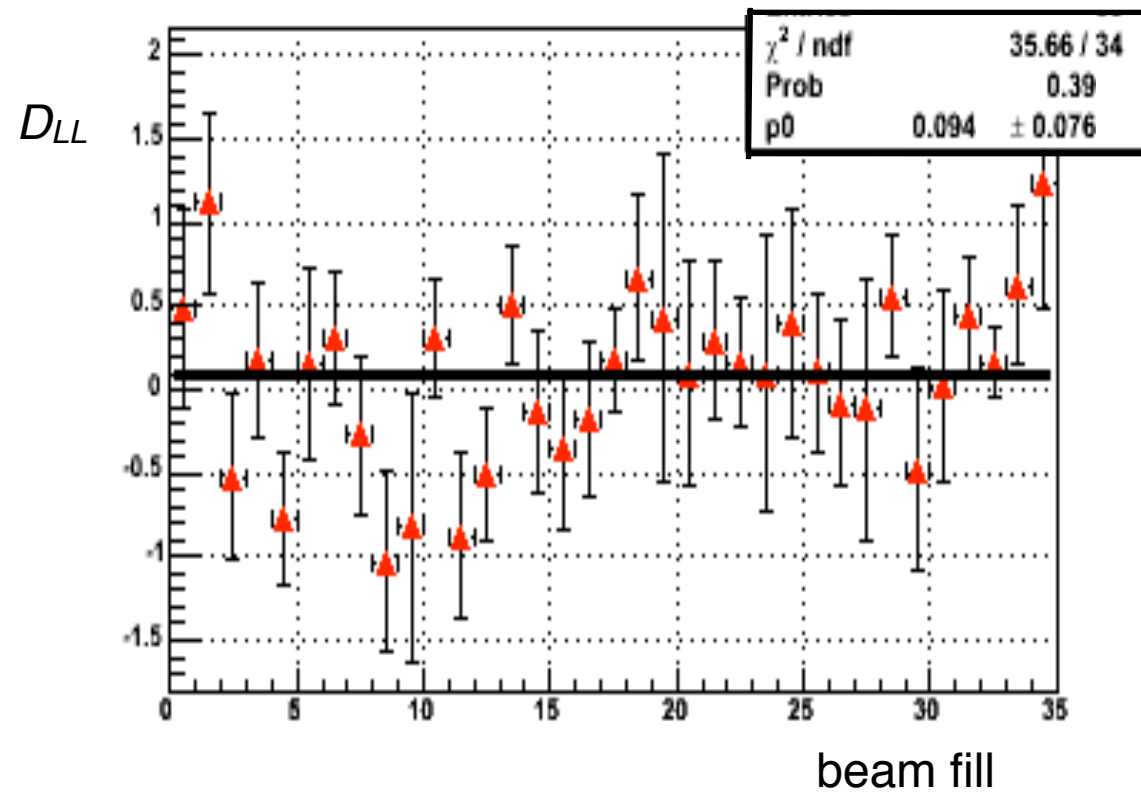
Use beam spin configurations and symmetries to (largely) cancel $A(\cos \theta^*)$ and extract,

$$D_{LL}^\Lambda = \frac{1}{\alpha \cdot P_b \cdot \langle \cos \theta^* \rangle} \cdot \frac{N_\Lambda^+ - N_\Lambda^-}{N_\Lambda^+ + N_\Lambda^-}$$

in small $\cos \theta^*$ intervals. Here, $N_\Lambda^+ = N_\Lambda^{++} \cdot \frac{\mathcal{L}^{--}}{\mathcal{L}^{++}} + N_\Lambda^{+-} \cdot \frac{\mathcal{L}^{--}}{\mathcal{L}^{+-}}$ and $N_\Lambda^- = N_\Lambda^{-+} \cdot \frac{\mathcal{L}^{--}}{\mathcal{L}^{-+}} + N_\Lambda^{--}$

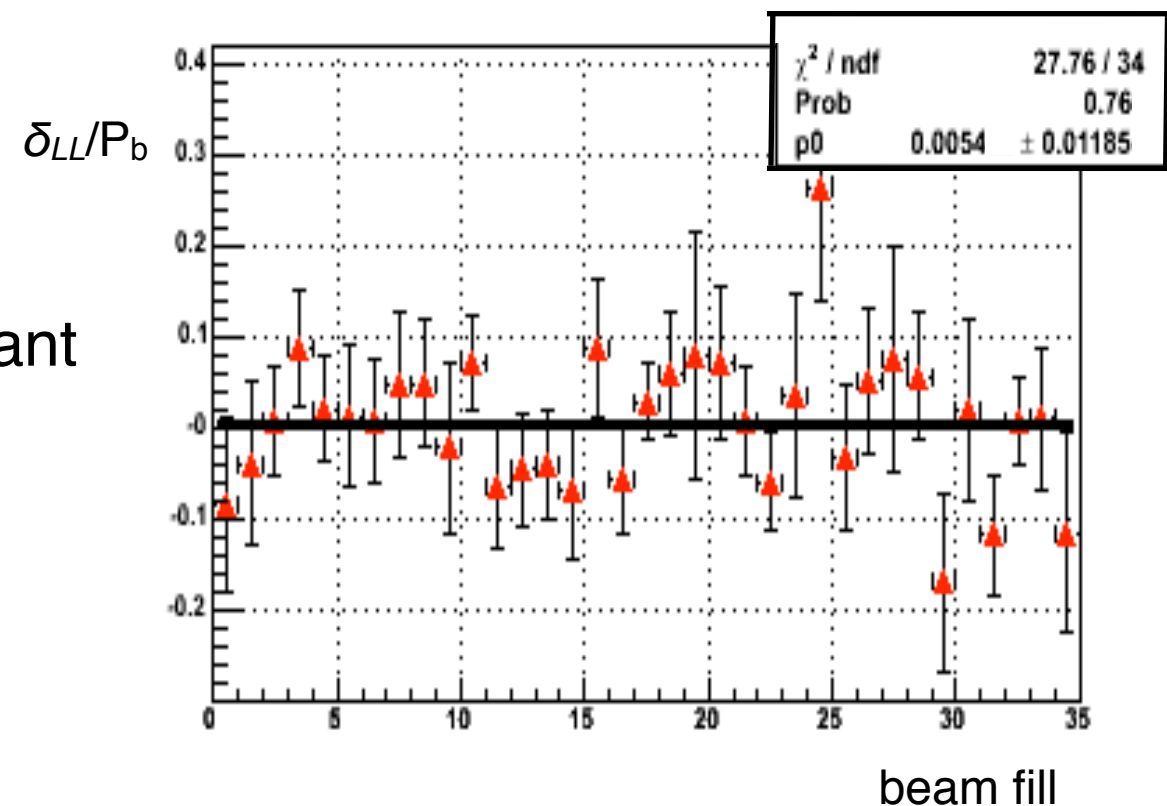
The luminosity ratios are measured at STAR and beam polarization in RHIC.

Analysis (continued)

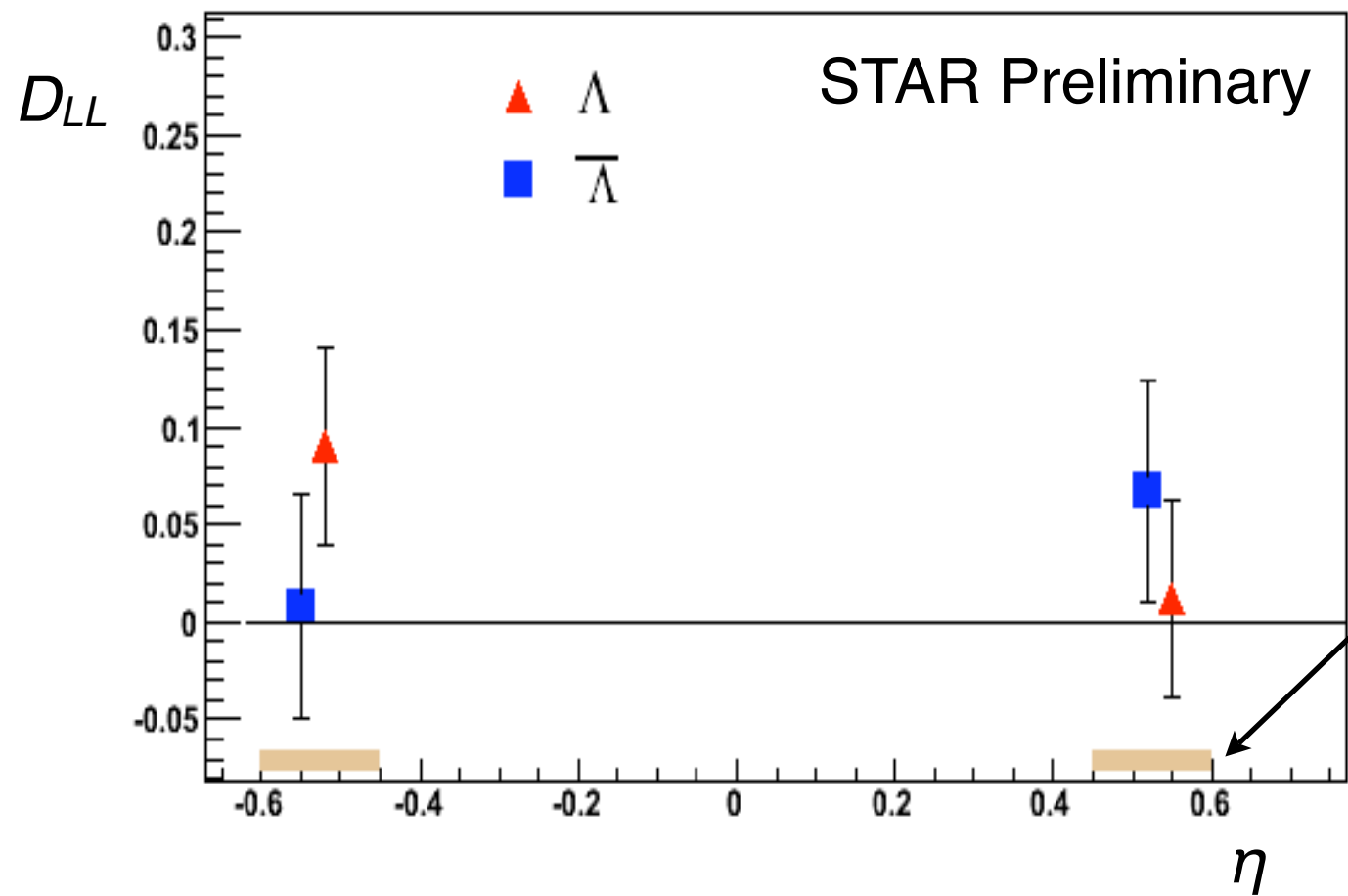


The extracted D_{LL} exhibits the expected statistical variation with time.

Control-measurement with the more abundant and spin-less K_S^0 shows no evidence for experiment systematics larger than ~ 0.01 .



Results I



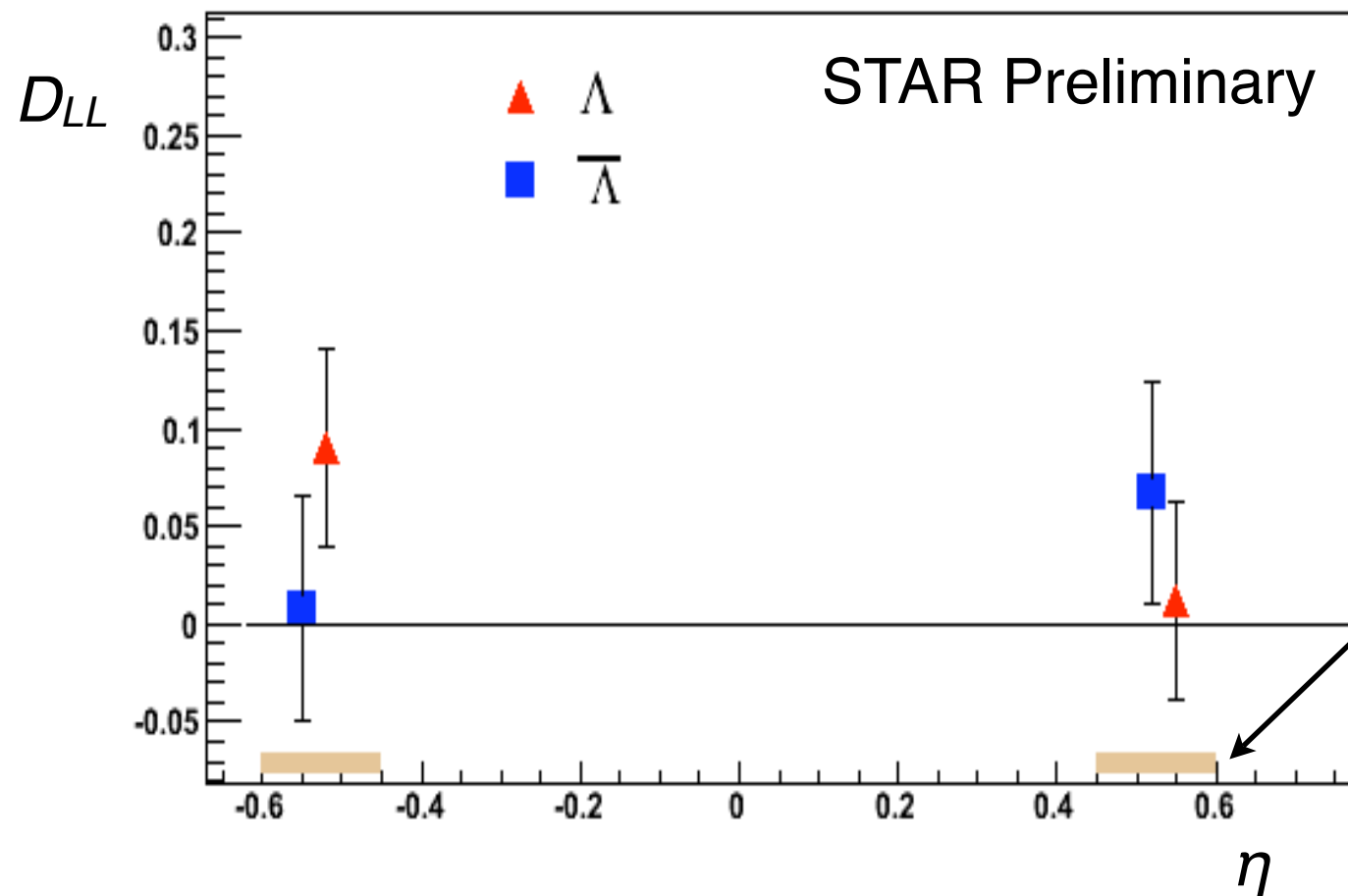
First D_{LL} from RHIC,

Statistics limited,

Systematics under control,

$\langle p_T \rangle \approx 1.3$ GeV/c, $\langle |x_{F1}| \rangle \approx 0.008$

Results I



First D_{LL} from RHIC,

Statistics limited,

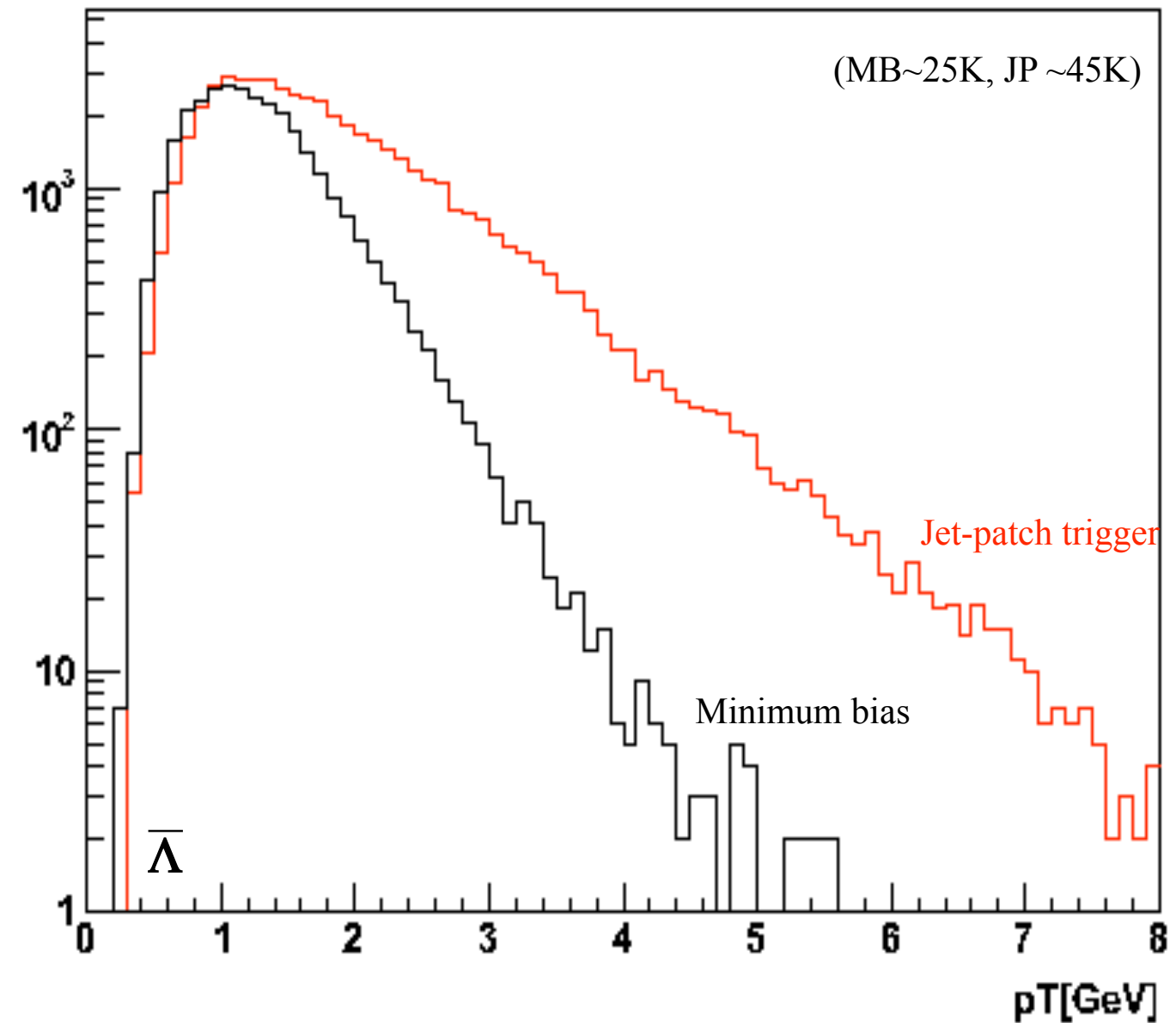
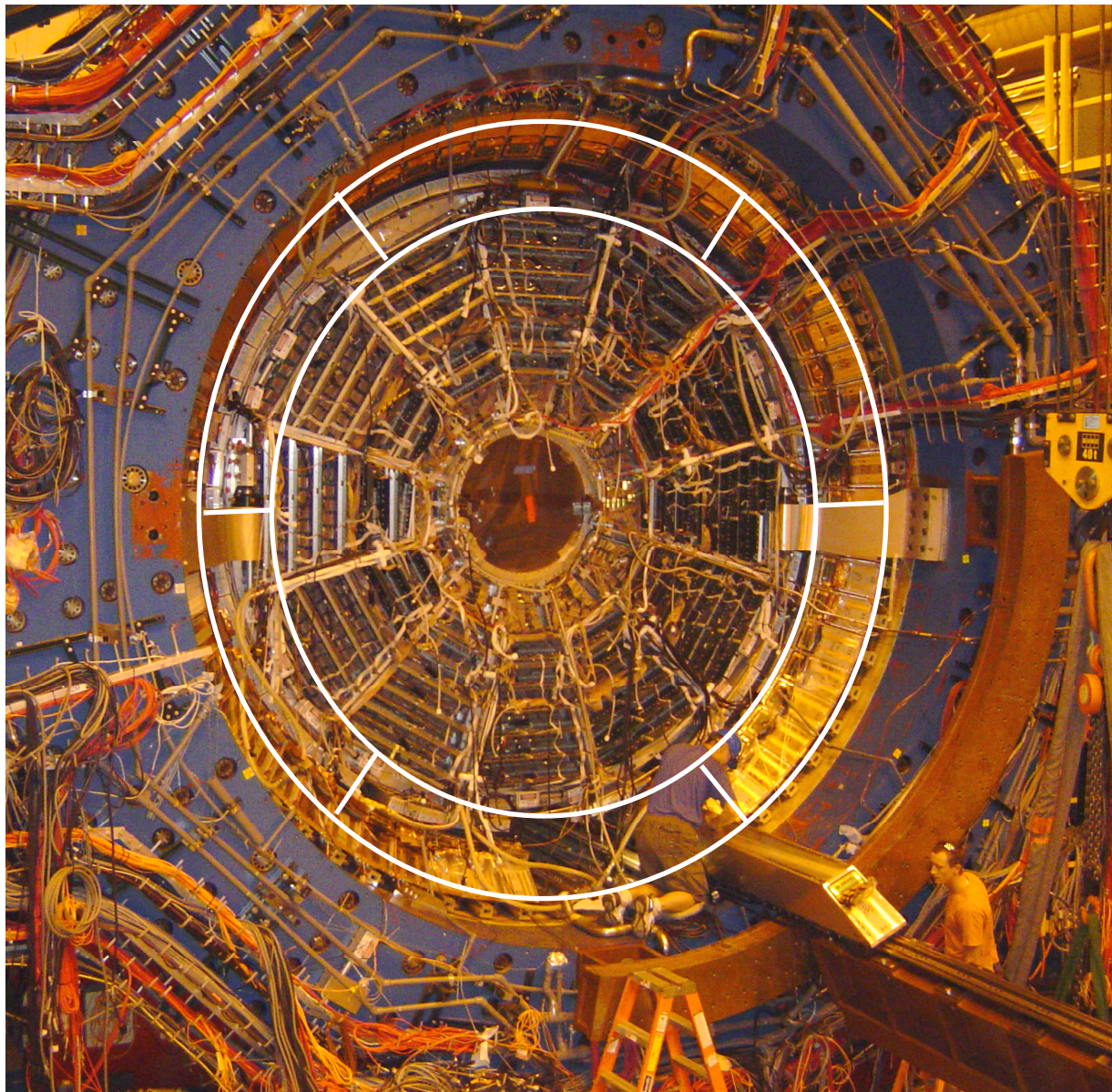
Systematics under control,

$\langle p_T \rangle \approx 1.3$ GeV/c, $\langle |x_{Fl}| \rangle \approx 0.008$

Need better precision and higher p_T

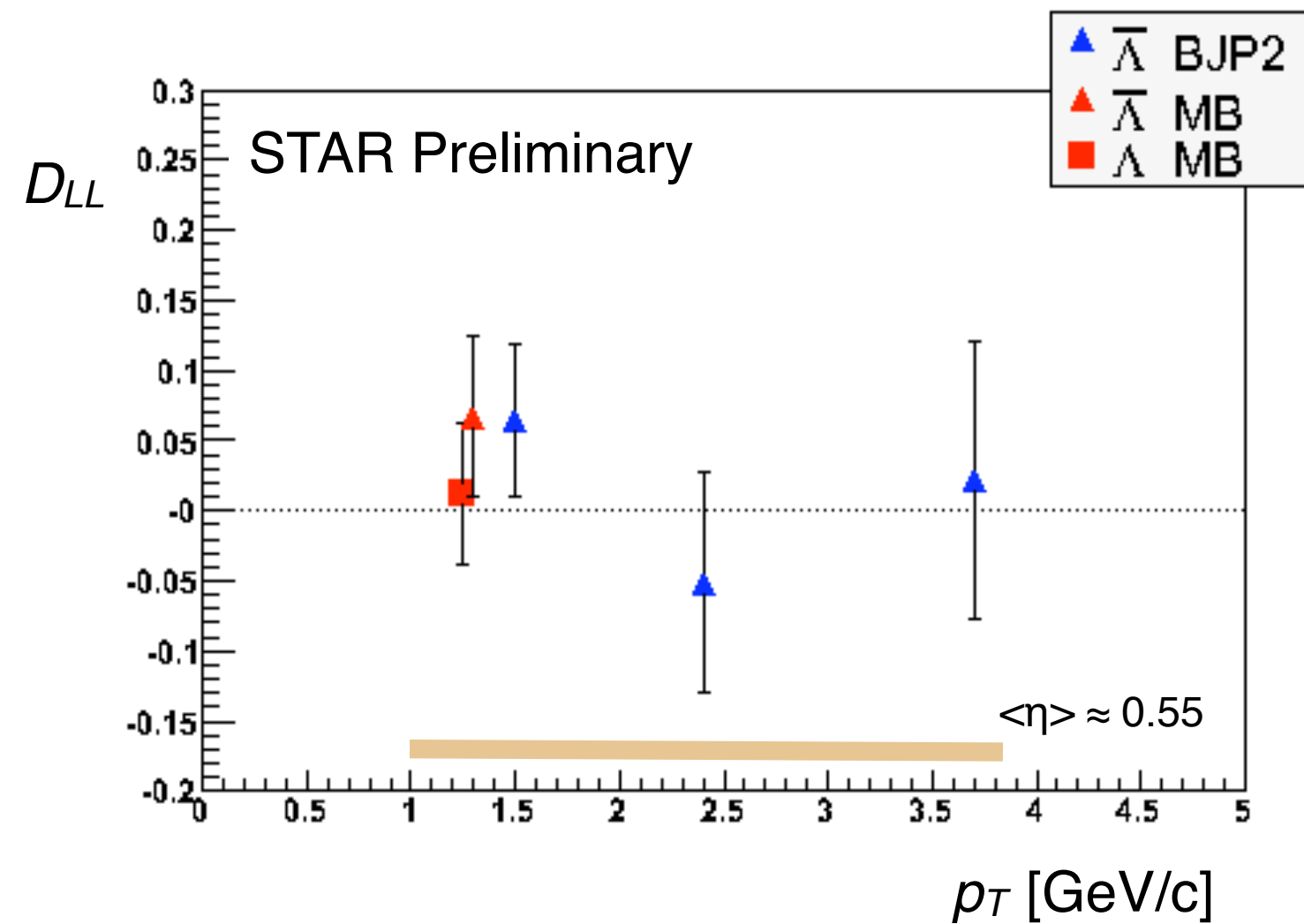
STAR Triggered Data - 2005

STAR was triggered on energy deposits in jet-patches of the Barrel E.M. Calorimeter,



Although this is not a “Hyperon Trigger”, it did record a (biased) sample of Λ and $\bar{\Lambda}$ candidates with considerably higher p_T ; focus on $\bar{\Lambda}$ here.

Results II



Systematic Uncertainty Estimates:

5% RHIC measurement of P_b ,
2% residual transverse pol. at STAR,
2% decay parameter α ,
< 0.01 relative luminosity measmnt,
< 4% event pile-up in TPC,
< 5% background,
<15% trigger bias (MC simulation).

Summary and Outlook

- Perturbative QCD consistent with $\Lambda+\bar{\Lambda}$ yield observed in p+p coll. at $\sqrt{s} = 200$ GeV,
- $\bar{\Lambda} D_{LL}$ sensitive to $\Delta\bar{s}$ and polarized fragmentation - $\sim 3\%$ effects,
- STAR has performed first proof-of-principle measurements of Λ and $\bar{\Lambda} D_{LL}$ at RHIC; reached $\sim 10\%$ precision up to 4 GeV/c transverse momentum
- Observations are consistent with small strange quark polarization, but do not (yet) discriminate between GRSV-standard and -valence small,
- Ongoing analysis including a trigger on the anti-proton daughter; $\sim 7\%$ precision at 4 GeV/c,
- Eagerly anticipate polarized $p+p$ operations at RHIC with further improved L and P_b ,