Measurements of the double spin asymmetry in inclusive jet production in polarized p+p collisions at sqrt(s)= 200 GeV

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for the STAR Collaboration

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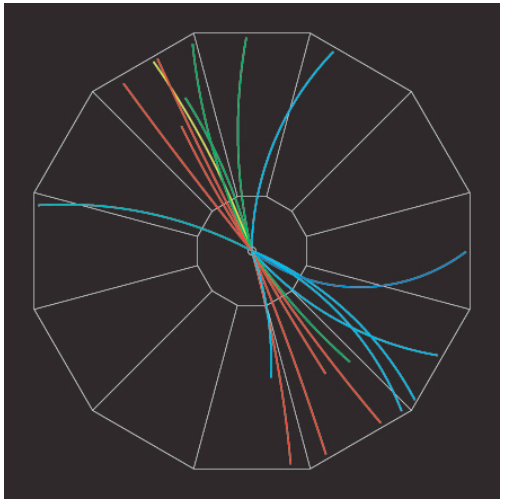
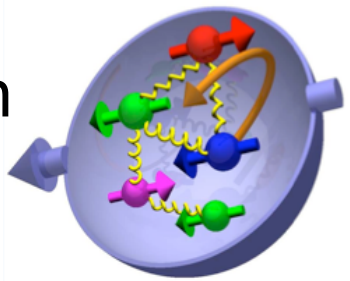


Outline:

1. Motivation
2. STAR Detector at RHIC
3. Data Selection
4. A_{LL} - (first) Preliminary Results
5. Summary and Outlook

} Today's talk

Motivation - determination of gluon polarization in the proton

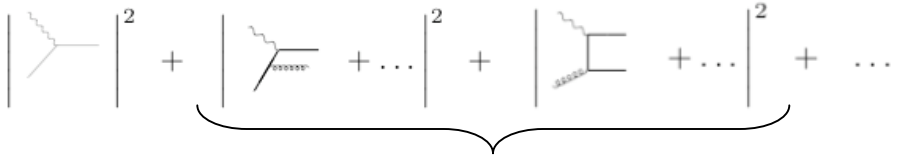


'Spin crisis' (EMC,1989)
-the quarks spins carry only a small (~10%) fraction of the proton spin

Confirmed by series of pol. Deep Inelastic Experiments (SMC, E143, Hermes …)

⟹ *Gluons? Orbital momentum?*

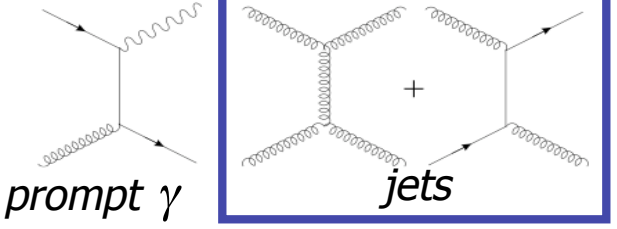
Gluon polarization - *poorly constrained* from the NLO QCD analysis of $g_1(x,Q^2)$ spin structure function in pol. DIS experiments (photons and gluons do not couple!)

$g_1 \sim$ 

LO NLO

Call for *alternative* methods to determine gluon polarization

this talk



Most promising: polarized proton-proton interactions

Inclusive jet production in pp interactions

- Cross section

$$(\Delta)\sigma \propto \sum_{\text{ab - sub-processes}} (\Delta)\text{pdf} \otimes (\Delta)\text{pdf} \otimes (\Delta)\hat{\sigma}_{ab} \quad \text{hard scattering}$$

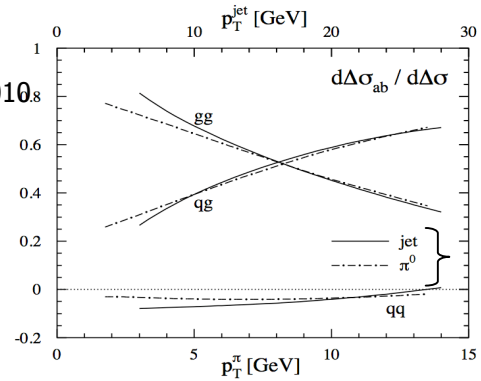
$$p_T^3 \frac{d\sigma}{dp_T d\eta} = \left| \text{p p} \to \text{a b} \to \text{F} = \gamma,\ \text{jet, pion, W, ...} + \text{X} \right|^2 + \mathcal{O}\left(\frac{\lambda}{p_T}\right)^n$$

jets - no fragmentation functions are needed (systematics!)

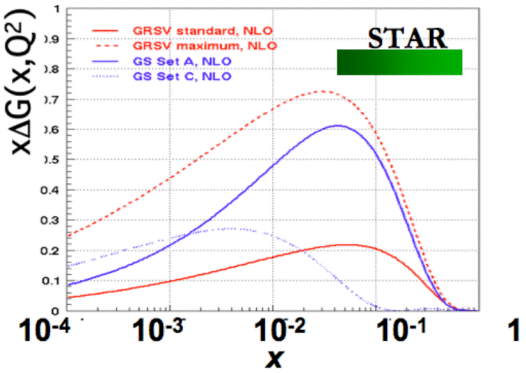
- Asymmetries $A_{LL} = \frac{\Delta\sigma}{\bar{\sigma}} = \frac{\sigma_{++} - \sigma_{+-}}{\sigma_{++} + \sigma_{+-}}$

$\Delta\sigma$ - very small (difficult to measure), measure asymmetries instead, where most of systematic effects cancel out

Jager et.al, PRD70(2004)034010



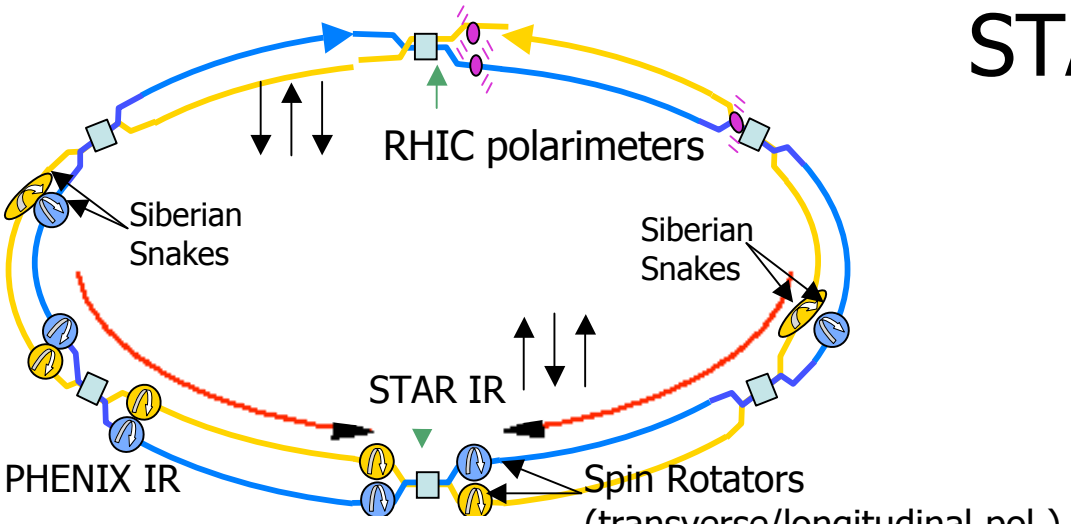
similar

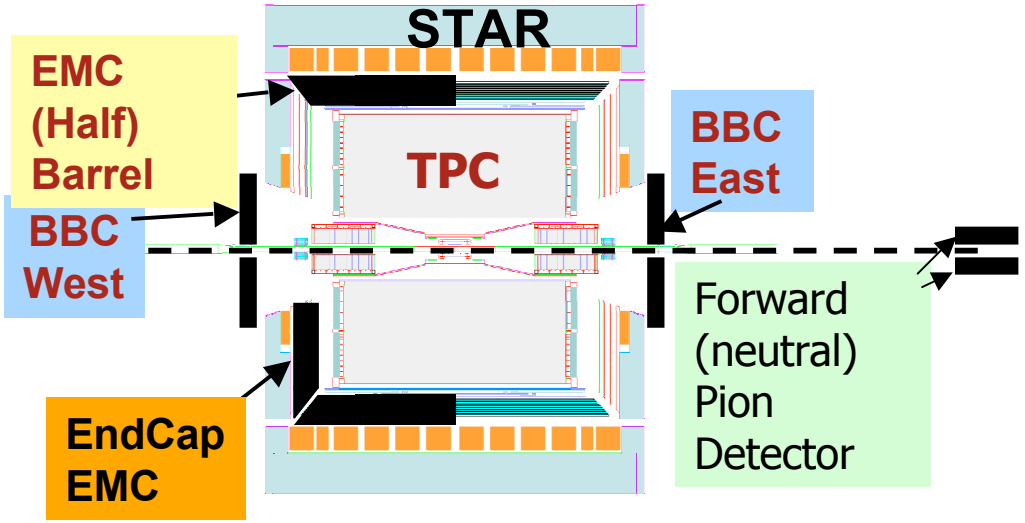


Sensitivity to the gluon polarization (no parton kinematics reconstruction)

- Convolutions "pdf × pdf × hard scattering" complicated and inversion $A_{LL} \to g(x)$ not straightforward
- At the moment emphasis is on NLO predictions of A_{LL} in terms of "model" Δg
- Future: CTEQ-style global analysis of variety of A_{LL} data (should include NLO)

STAR detector at RHIC





Solenoidal Magnet B = 0.5 T

Tracking Detectors

- Time Projection Chamber $|\eta|<1.6$
- Forward TPC $2.5<|\eta|<4.0$
- Silicon Vertex Tracker $|\eta|<1$

Trigger Detectors

- Beam-Beam Counters $3.4<|\eta|<5$
- Zero-Degree Calorimeter $|\eta|\sim6$

+ E-M Calorimeters - installation in stages to be completed before 2006

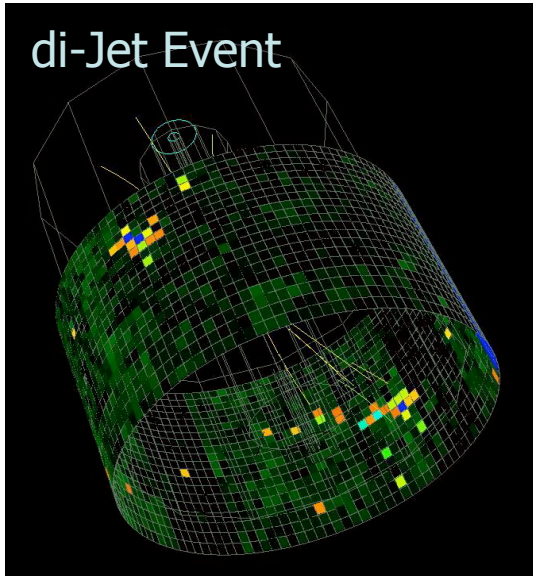
- Barrel EMC $|\eta|<1$
- Endcap EMC $1.0<\eta<2.0$
- Forward Pion Detector $3.3<|\eta|<4.1$

- STAR unique capability at RHIC for jet reconstruction (TPC+EMC)
- BBC + scaler board system for (relative) luminosity and polarization monitoring

cf. talk by B. Christie, BNL (Session ED on Wednesday)

Jet reconstruction at STAR

Jet reconstruction at STAR - via TPC p_T for charged hadrons and EMC E_T for electro-magnetic showers



1) Jets reconstruction - midpoint cone algorithm
seed energy = 0.5 GeV, cone angle R = 0.4 in $\eta-\phi$
splitting/merging fraction f=0.5

2) Trigger used in this analysis - High Tower:
E_T > 2.4 GeV deposited in one tower $(\Delta\eta \times \Delta\phi) = (0.05 \times 0.05)$
+ additional requirement of BBC coincidence.

3) Data set: ~0.3 pb^{-1} (2003 and 2004) recorded luminosity
$<P_b>$ =0.3 (2003) and $<P_b>$ = 0.4 (2004)

4) Cuts on:
- |z-vertex| < 75cm (2003) and < 60cm (2004)
- charged tracks $|\eta|$ < 1.6 and p_T >0.1 GeV/c
- jets: p_T jet > 5 GeV/c , 0.2< jet η (det) <0.8
- background: E_{EMC}/E_{tot}< 0.9 (2004) and < 0.8 (2003)

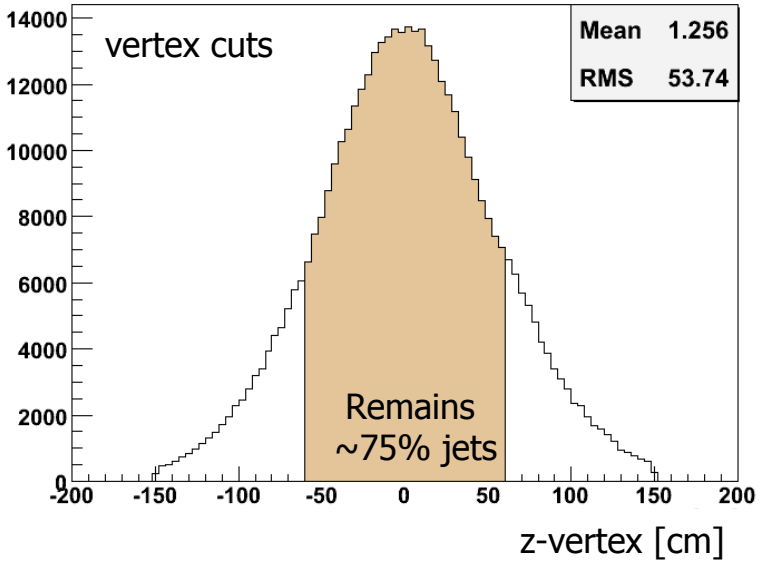
- Time Projection Chamber $|\eta|<1.6$
- Barrel EMC $0< \eta <1$
- Beam Beam Counters $3.4<|\eta|<5$

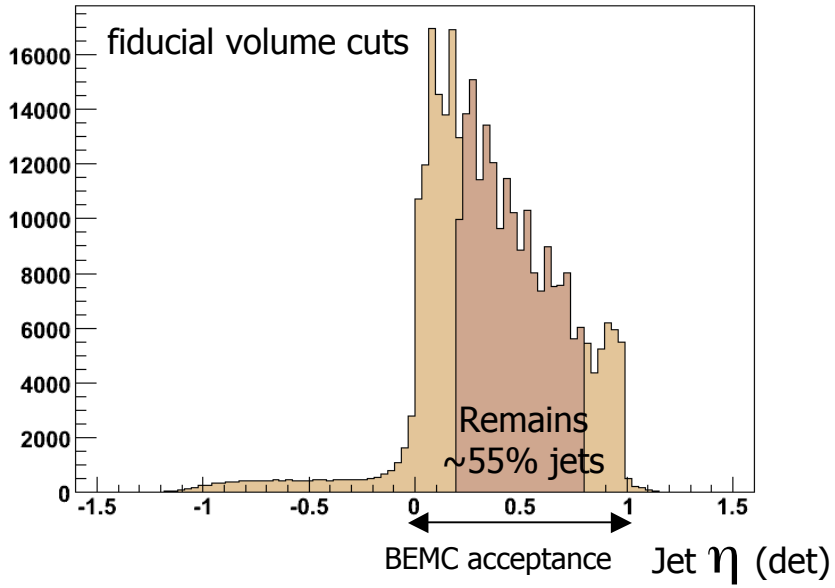
5) Final statistics (after cuts) for 5 < jet p_T < 17 GeV/c:
125k (2003) and 162k (2004) jets

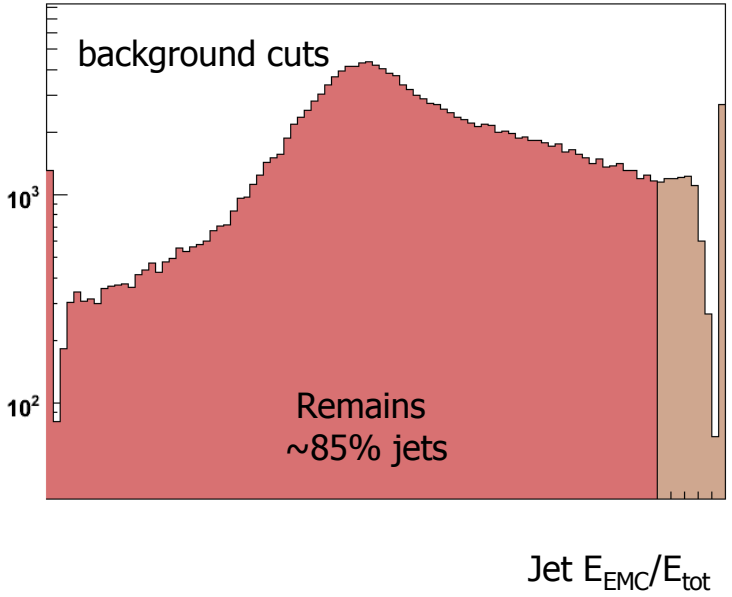
Inclusive jet cross section measurement cf. talk by M.Miller, MIT (this session)

Effect of cuts on jet statistics (e.g. 2004)

Initial sample = 1.4 M HighTower trigger events (0.4 M jets reconstructed)







Number of jets (HighTower events)
about ~35% jet survives these cuts
- 160k final (2004) statistics

Double Longitudinal Spin Asymmetry Measurements

$$A_{LL} = \frac{\sum_i A_{LL}^i w_i}{\sum_i w_i} \quad \text{where } w_i = \left(\frac{1}{\delta A_{LL}^i}\right)^2$$

$$\delta A_{LL} = \frac{1}{\sqrt{\sum_i w_i}}$$

Index i - STAR run number

$$A_{LL}(p_t) = \frac{\sum_i P_Y^i P_B^i \left(N_{\uparrow\uparrow}^i - R_i N_{\uparrow\downarrow}^i\right)}{\sum_i \left(P_Y^i P_B^i\right)^2 \left(N_{\uparrow\uparrow}^i + R_i N_{\uparrow\downarrow}^i\right)}$$

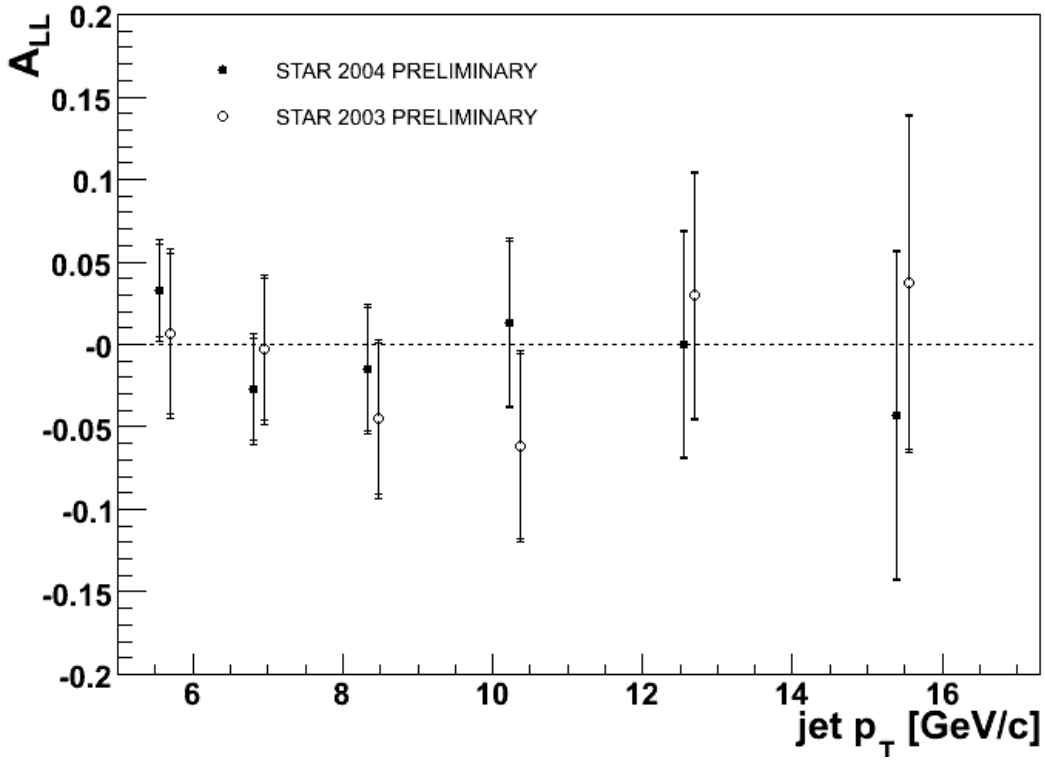
$$\delta A_{LL}(p_t) \cong \frac{1}{\sqrt{\sum_i \left(P_Y^i P_B^i\right)^2 \left(N_{\uparrow\uparrow}^i + R_i N_{\uparrow\downarrow}^i\right)}}$$

Require concurrent measurements:

- magnitude of beam polarization, $P_{1(2)}$ → RHIC polarimeter(s)
- direction of polarization vector at interaction point
- relative luminosity of bunch crossings with different spin directions: $R = \frac{L_{++}}{L_{+-}}$
- spin dependent yields of process of interest: N_i and N_{ij}

→ STAR

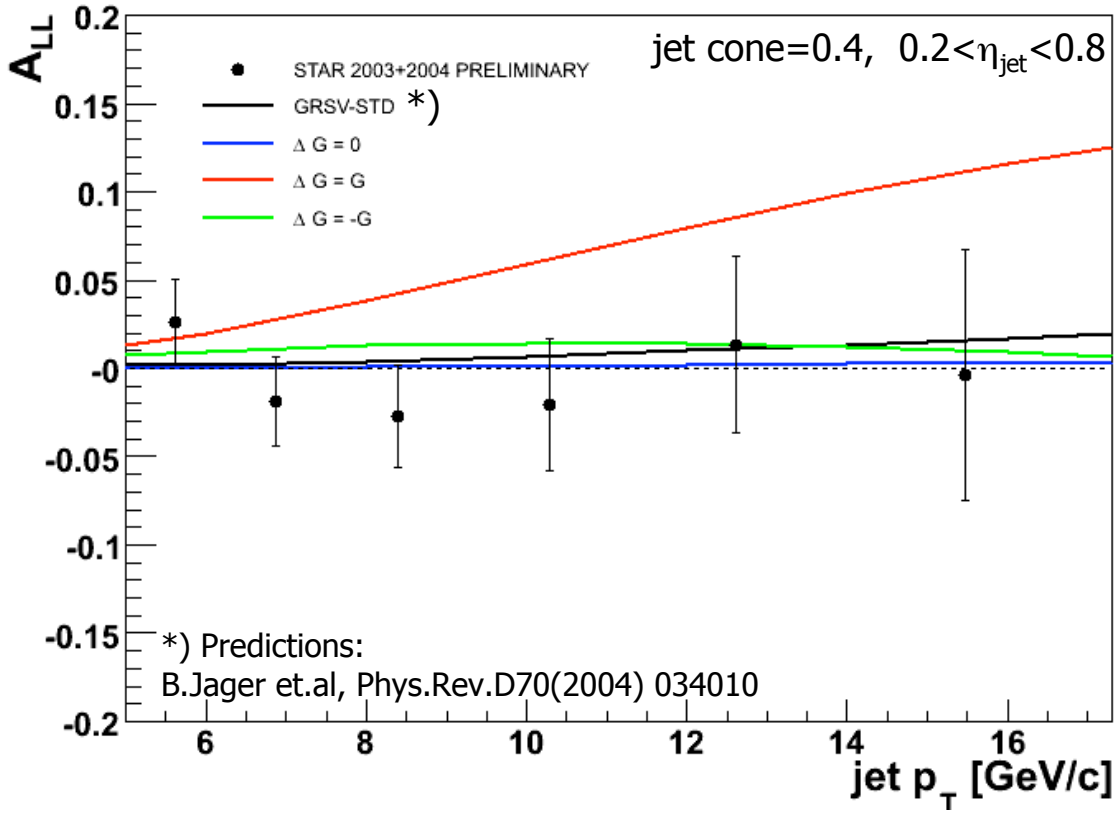
Double spin asymmetry A_{LL}(preliminary) results in inclusive jet production in p+p collisions at sqrt(s)=200GeV



- Consistent results from 2003 and 2004 analyses
- Results limited by statistical precision
- Total systematic uncertainty ~0.01 (STAR) + beam polarization (RHIC)

Sources of systematic uncertainties: background contribution, trigger bias, relative luminosity, residual (non-longitudinal) asymmetries, bunch to bunch systematic variations (random pattern analysis) + beam polarization

Double spin asymmetry A_{LL}(preliminary) results in inclusive jet production in p+p collisions at sqrt(s)=200GeV



Results limited by statistical precision

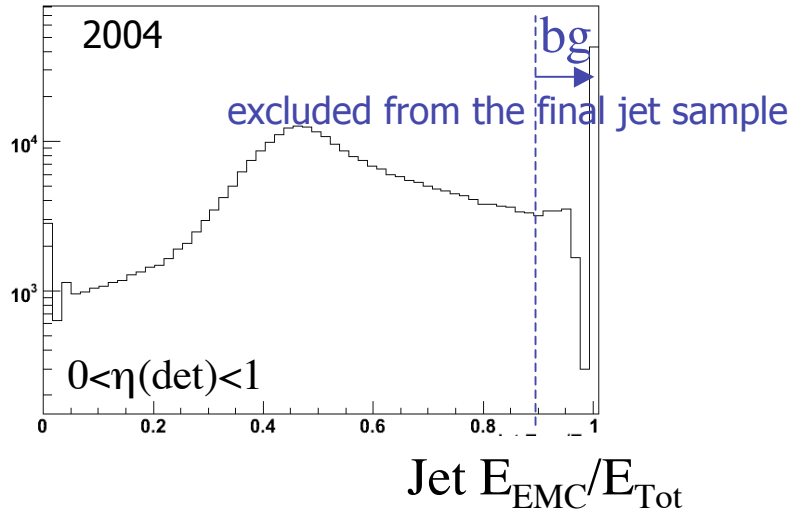
Total systematic uncertainty ~0.01 (STAR) + beam pol. (RHIC)

A_{LL} systematics - a closer look

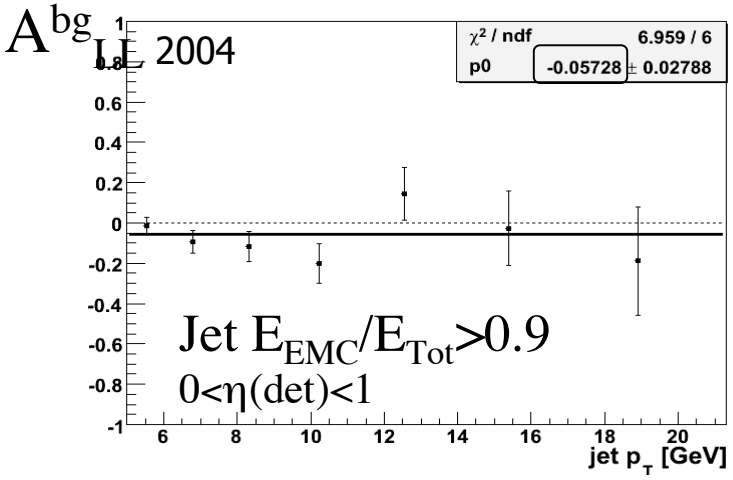
- Jet background contribution
  (= 'jets' with no TPC tracks, only e-m energy)

- can cause a bias in the measurement of A_{LL}

$$A_{LL}^{meas}(p_T) = \frac{A_{LL}(p_T) + f_{bg}(p_T) \times A_{LL}^{bg}(p_T)}{1 + f_{bg}(p_T)}$$



We estimated (i) the background spectrum and background fraction f_{bg} in the final (after all cuts, including Jet E_{EMC}/E_{tot} <0.9 cut) jet sample and (ii) extracted background asymmetry A^{bg}_{LL}



f_{bg}<0.05

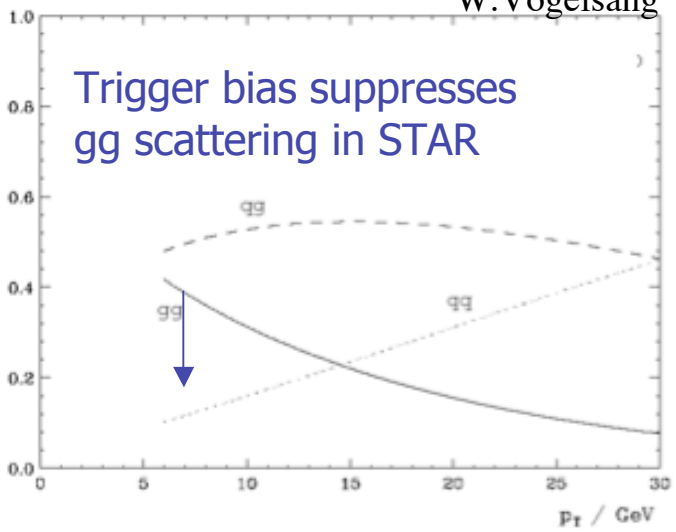
A^{bg}_{LL} ~ -0.06 ± 0.03

$\delta_{sys,bg} A_{LL} < 0.003$

A_{LL} systematics - a closer look

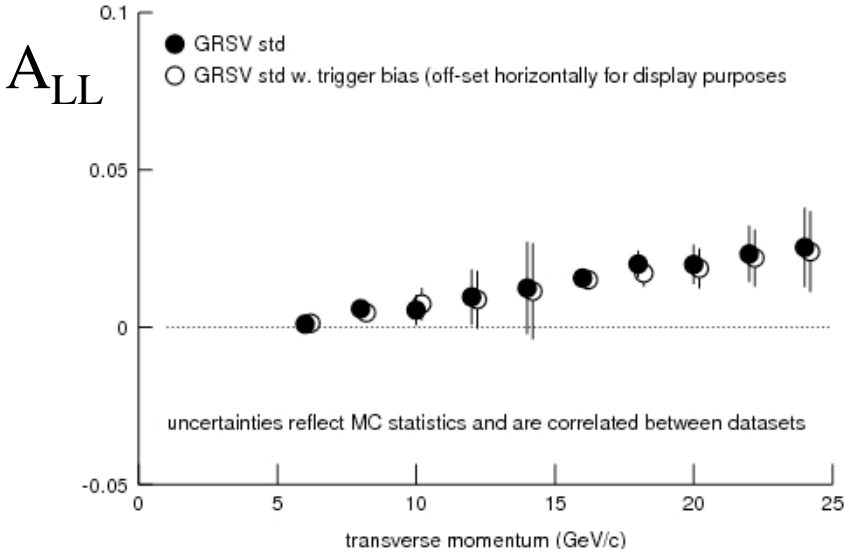
- Trigger bias

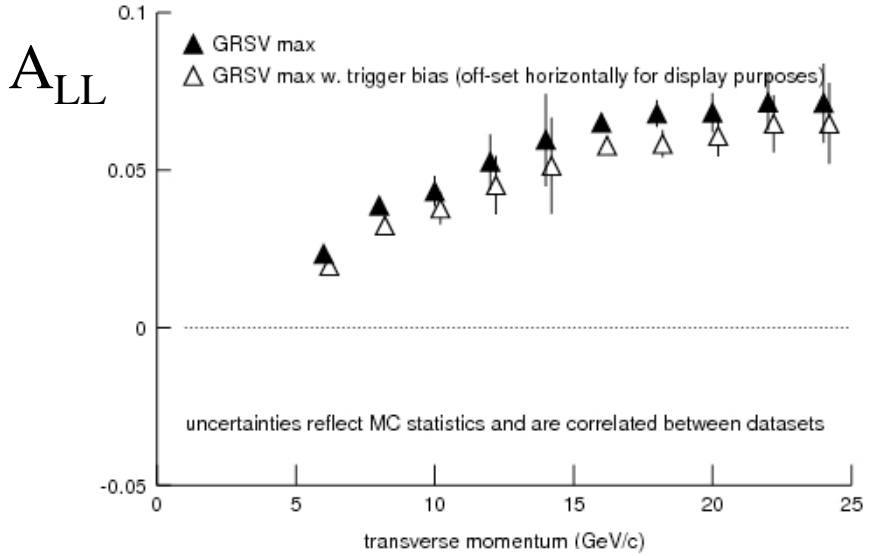
W.Vogelsang



High Tower trigger *($E_T > 2.4$ GeV deposited in one tower)* selects on e-m energy deposits and may thus distort the partonic sub-process contributions in inclusive jet production.

Possible size of this effect was estimated from MonteCarlo (Pythia+GEANT) simulations of the trigger response, and from various polarized parton distribution functions such as GRSV-std and -max.

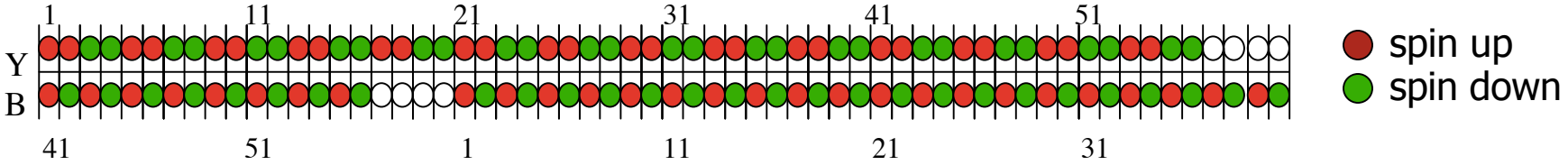




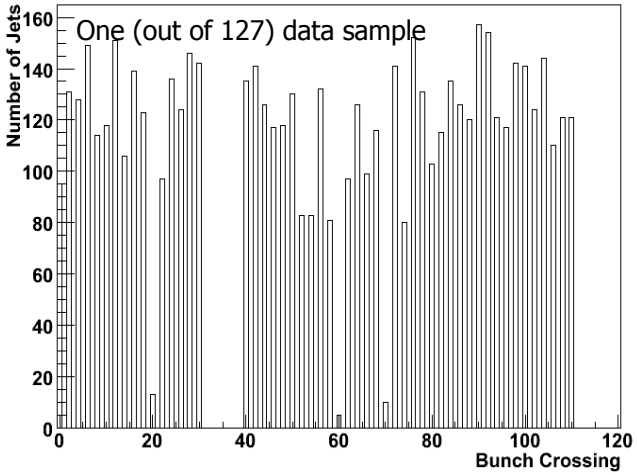
$$|A_{LL}(\text{with bias}) - A_{LL}(\text{no bias})| < 0.007$$

Systematic Study for A_{LL} - Random Fill Pattern Analysis

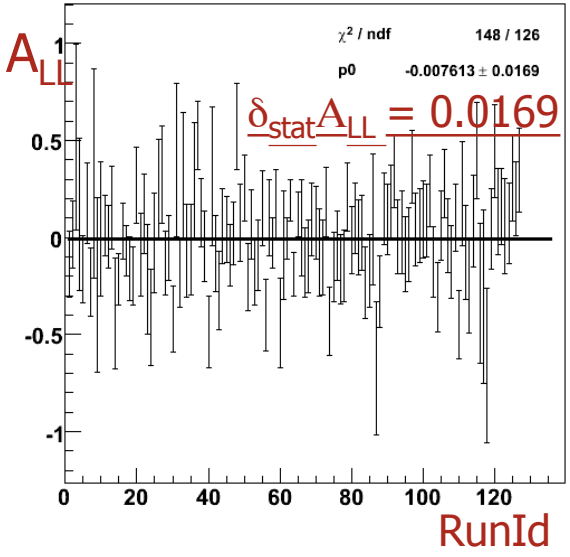
- Method: take true fill pattern (56 bunches in 2004) and mix assignment of spin up and down bunches (red and green points) to the bunch crossing number

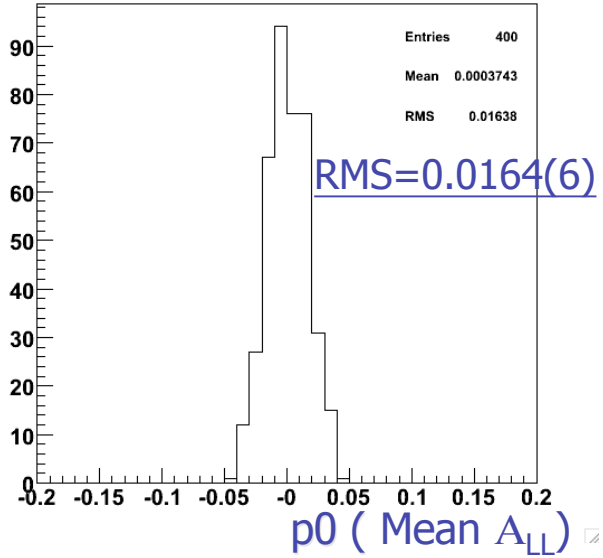


- Input



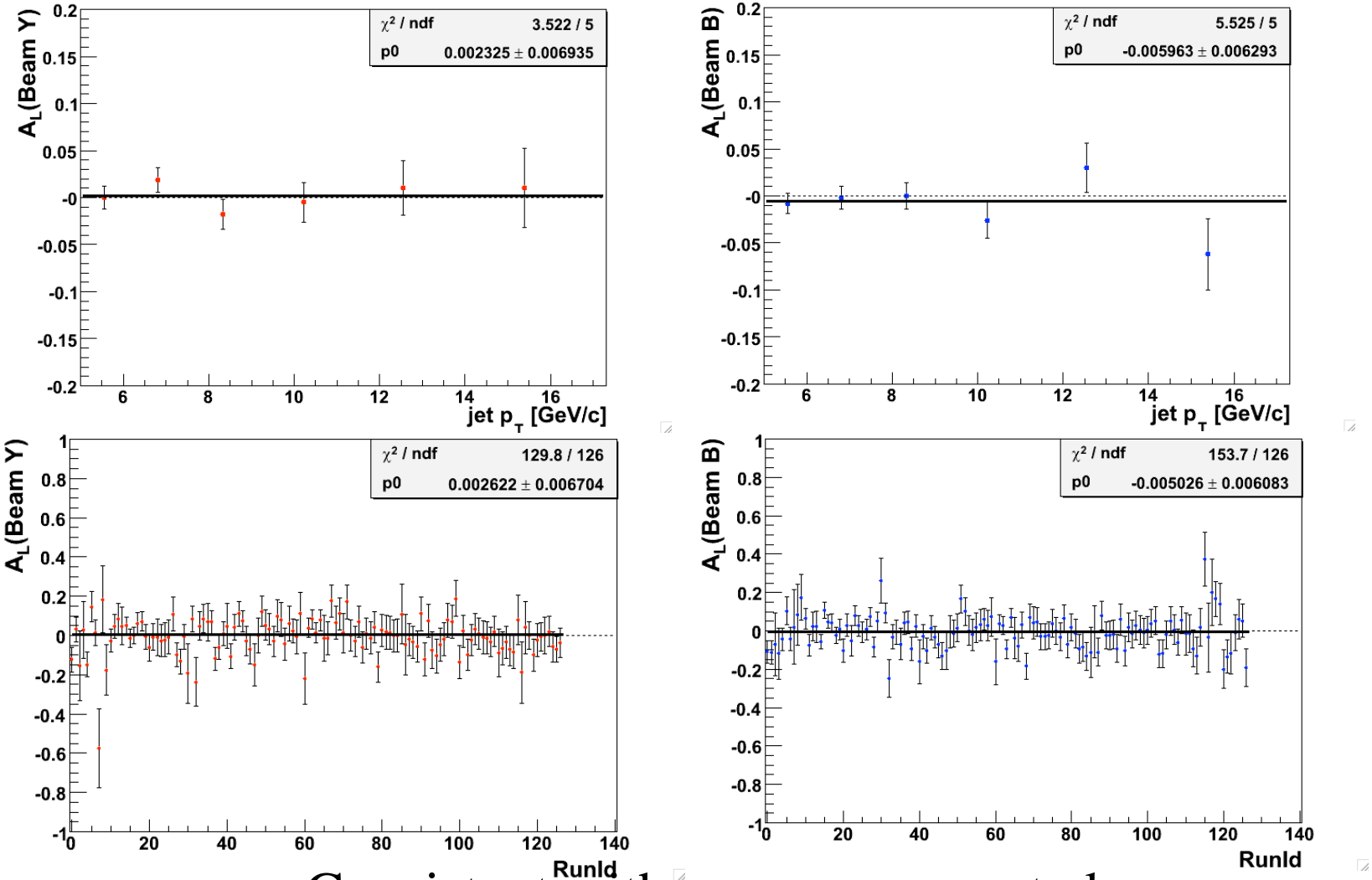
- Result for: one random fill pattern and 400 random fill patterns





The RMS is consistent with A_{LL} statistical uncertainties indicating that bunch to bunch and fill to fill systematic uncertainties are negligible

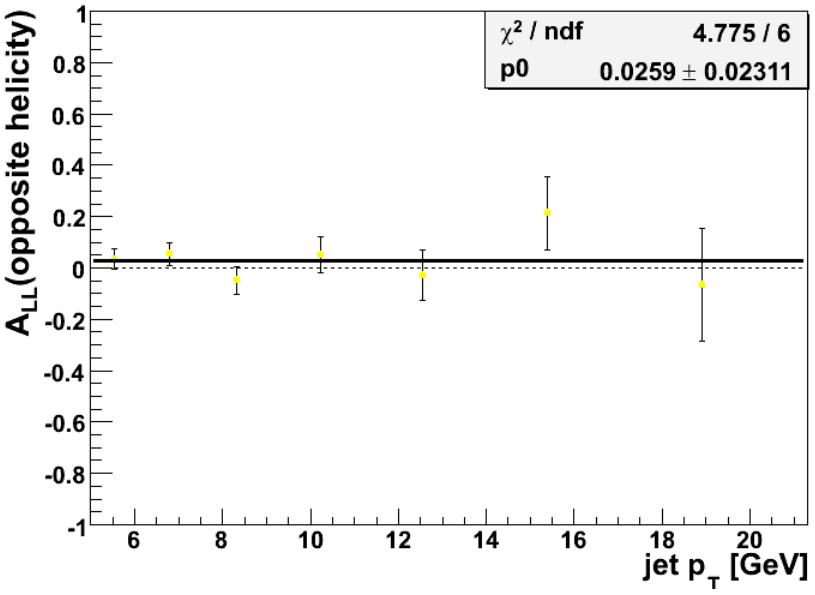
Cross checks - e.g. (2004) parity violating asymmetries

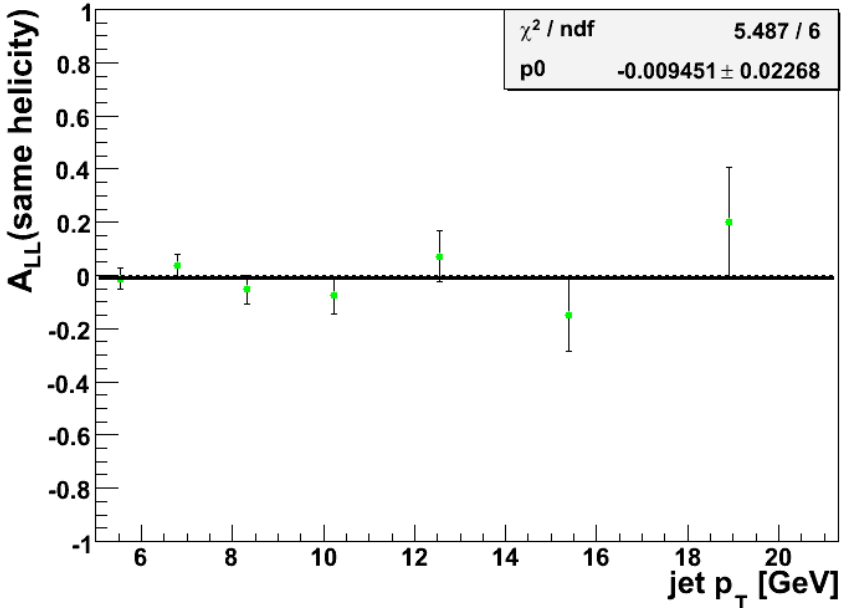


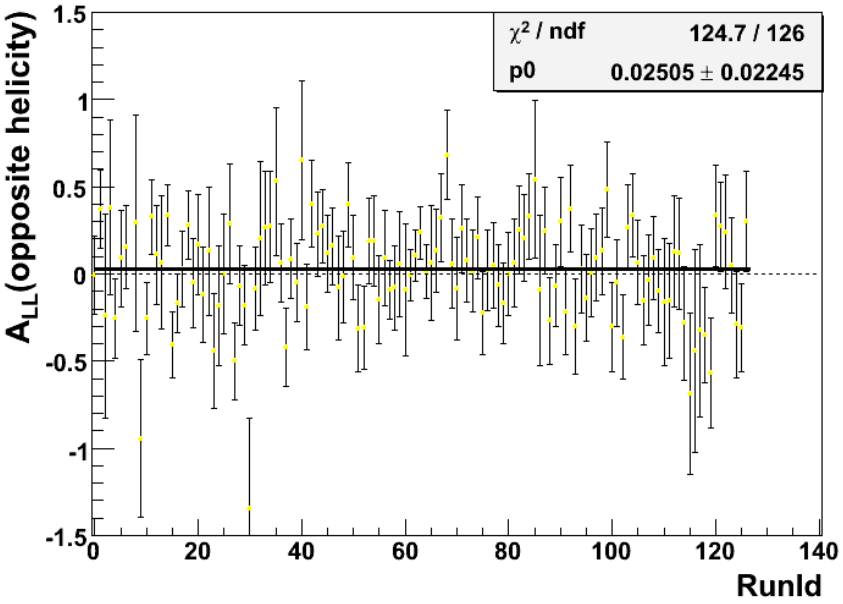
Consistent with zero - as expected

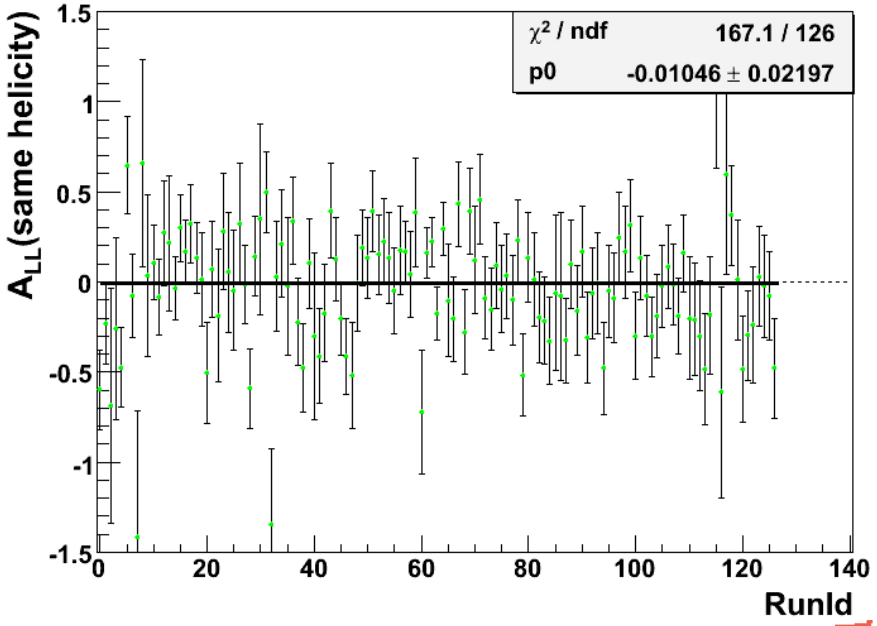
All other asymmetries were found consistent with zero

Cross checks - e.g. (2004) cont'd









Summary and Outlook

- We presented the first (preliminary) results for the measurement of double spin asymmetry A_{LL} in inclusive jet production in polarized proton-proton collisions at sqrt(s)= 200 GeV over the measured jet p_T range 5-17 GeV .
- The data was collected during 2 weeks in 2003 (first physics pp run at RHIC with longitudinally polarized beams) and 2 weeks in 2004 (commissioning run) with average beam polarizations of about 30% in 2003 and 40% in 2004.
- The asymmetry A_{LL} is consistent with evaluations based on DIS over the measured kinematic range of jet $5 < p_T < 17$ GeV/c.
- The results for A_{LL} are limited by statistical uncertainties of about 0.015 and currently do not distinguish between the different scenarios for gluon polarization in the proton allowed by polarized DIS data.

Prospects for Run5

- STAR collected ~10 times more statistics (the first long pp run) with higher beam polarization (better source) than in 2003 and 2004.
- STAR will be able to distinguish between the most extreme scenarios for gluon polarization in the proton.