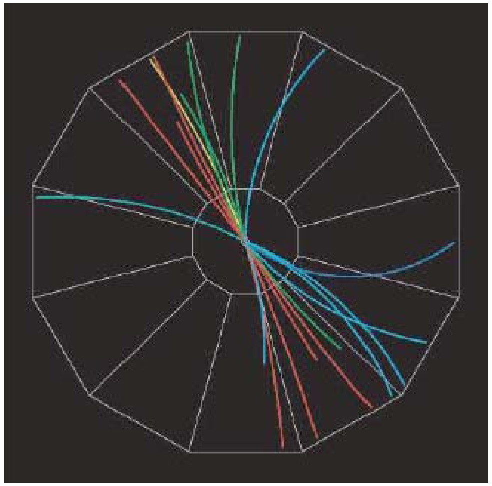


Gluon polarization and jet production at STAR

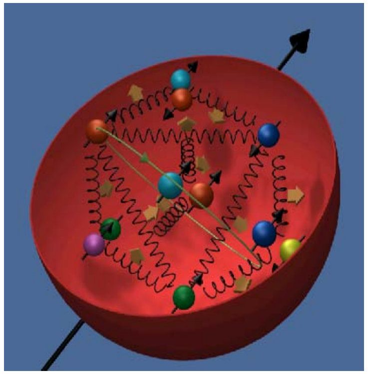
Pibero Djawotho *for the STAR Collaboration*

Texas A&M University

12 April 2011

The proton spin sum rule

$$S = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L$$



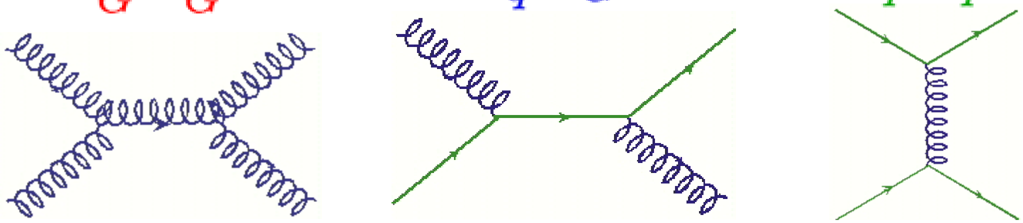
- Quark polarization $\Delta\Sigma \approx 0.3$ from polarized deep inelastic scattering
- Gluon polarization (ΔG) and orbital angular momentum (L) are poorly constrained
- A primary charge of RHIC spin physics $\Rightarrow$ map $\Delta g(x)$

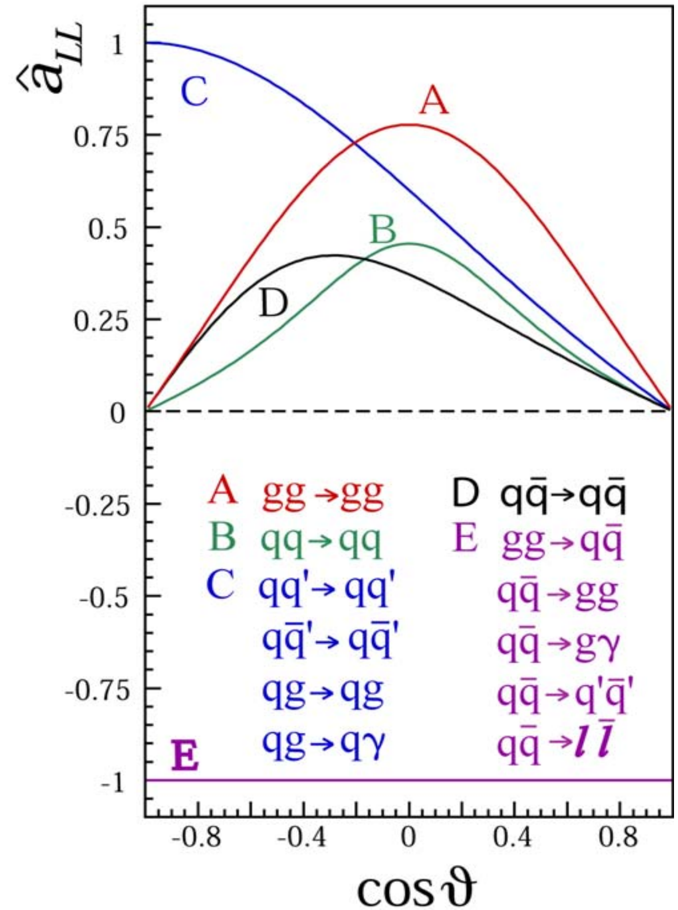
Polarized pp collisions at RHIC

$$A_{LL} = \frac{\sigma^{++} - \sigma^{+-}}{\sigma^{++} + \sigma^{+-}} \propto \frac{\Delta f_a \Delta f_b}{f_a f_b} \hat{a}_{LL}$$

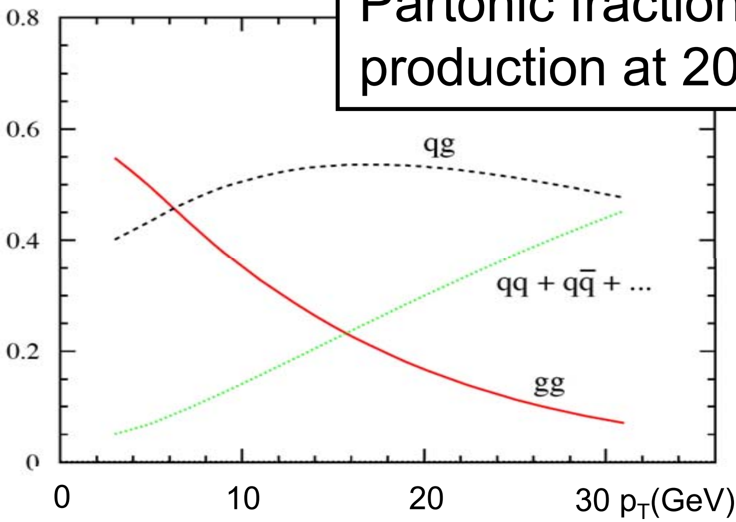
Δf: polarized parton distribution functions

$\frac{\Delta G}{G} \frac{\Delta G}{G}$ $\quad$ $\frac{\Delta q}{q} \frac{\Delta G}{G}$ $\quad$ $\frac{\Delta q}{q} \frac{\Delta q}{q}$



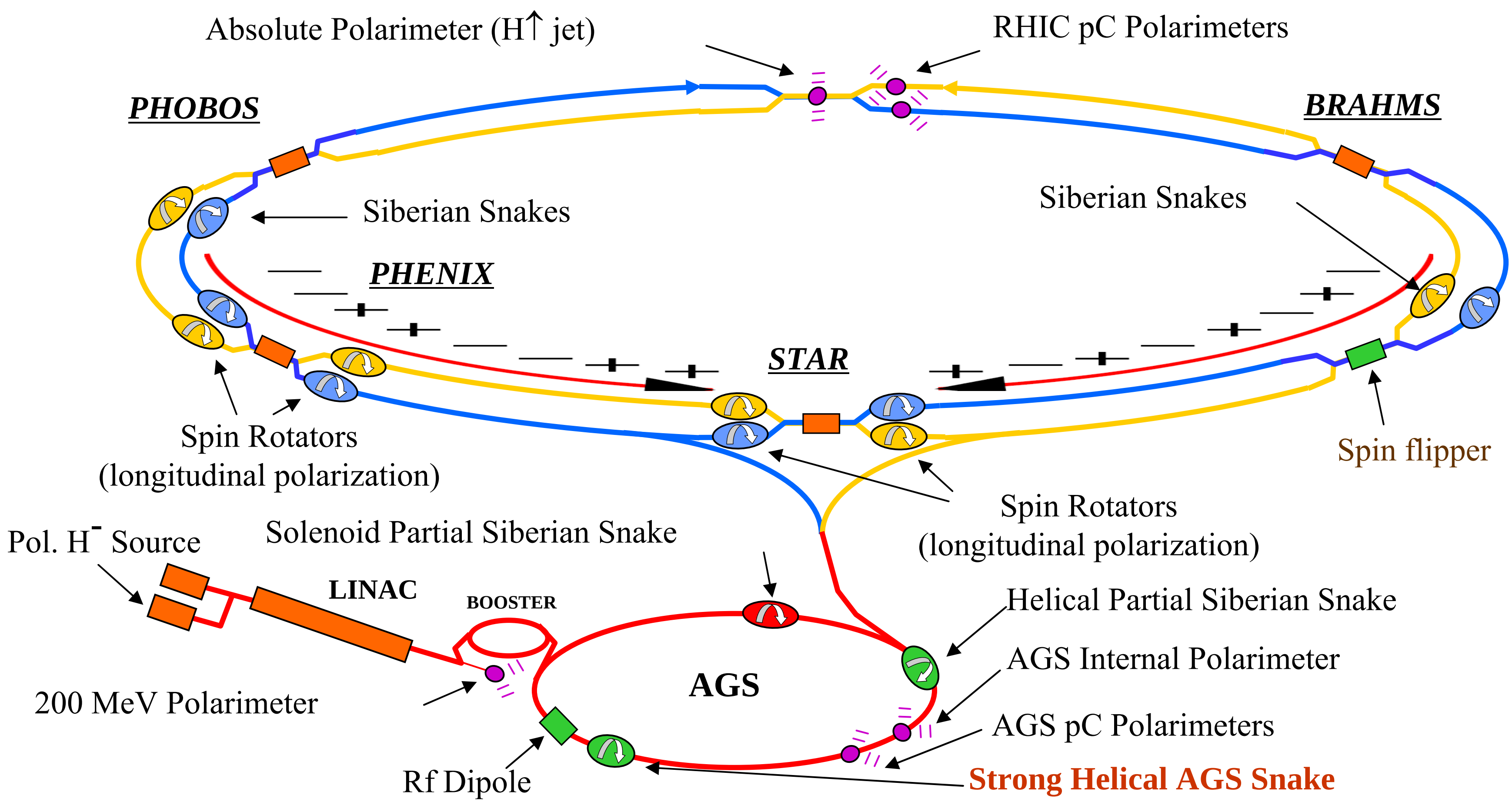


Partonic fractions in jet production at 200 GeV



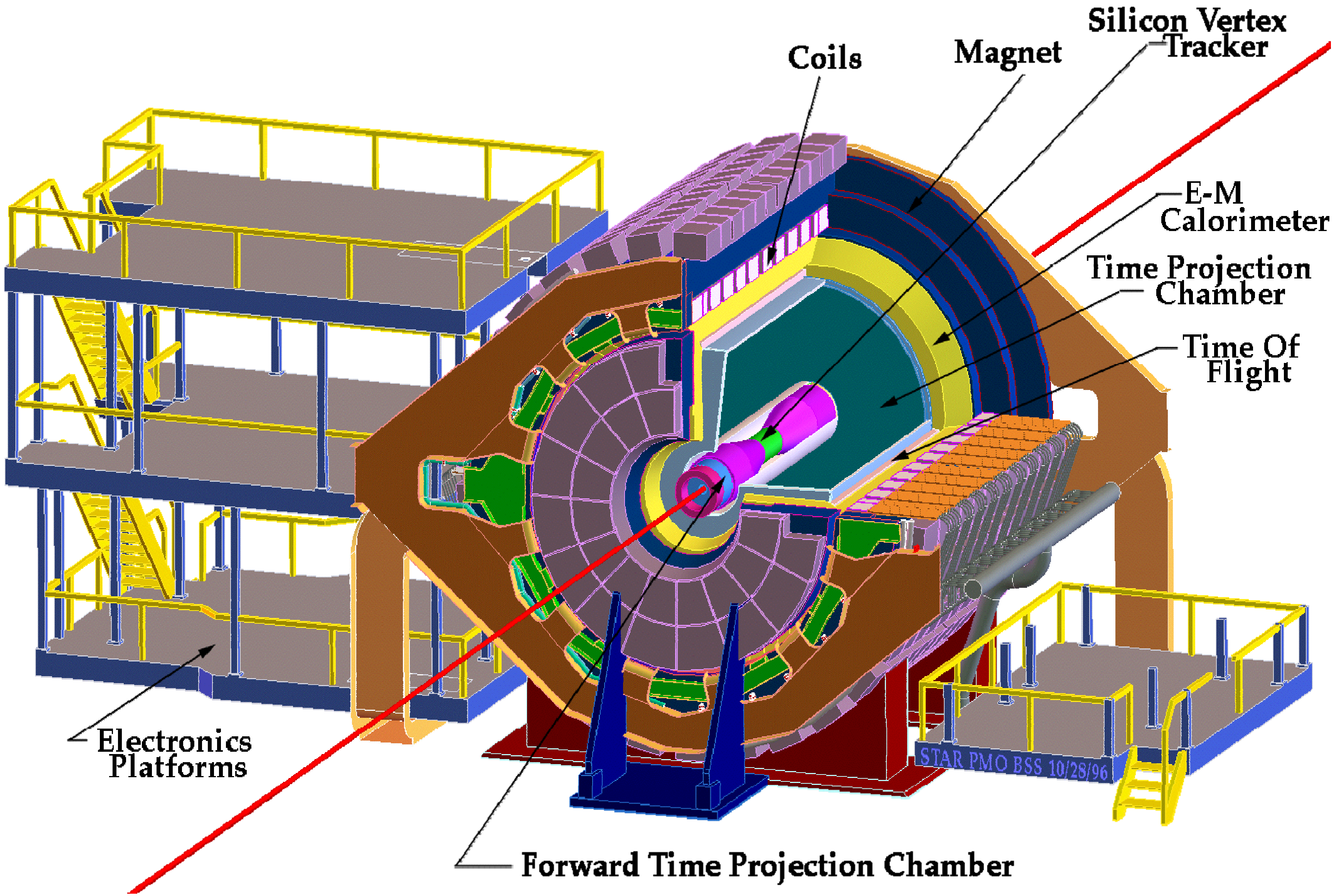
For most RHIC kinematics, ***gg*** and ***qg*** dominate, making A_{LL} for jets sensitive to **gluon polarization**.

RHIC: The World's First Polarized Hadron Collider

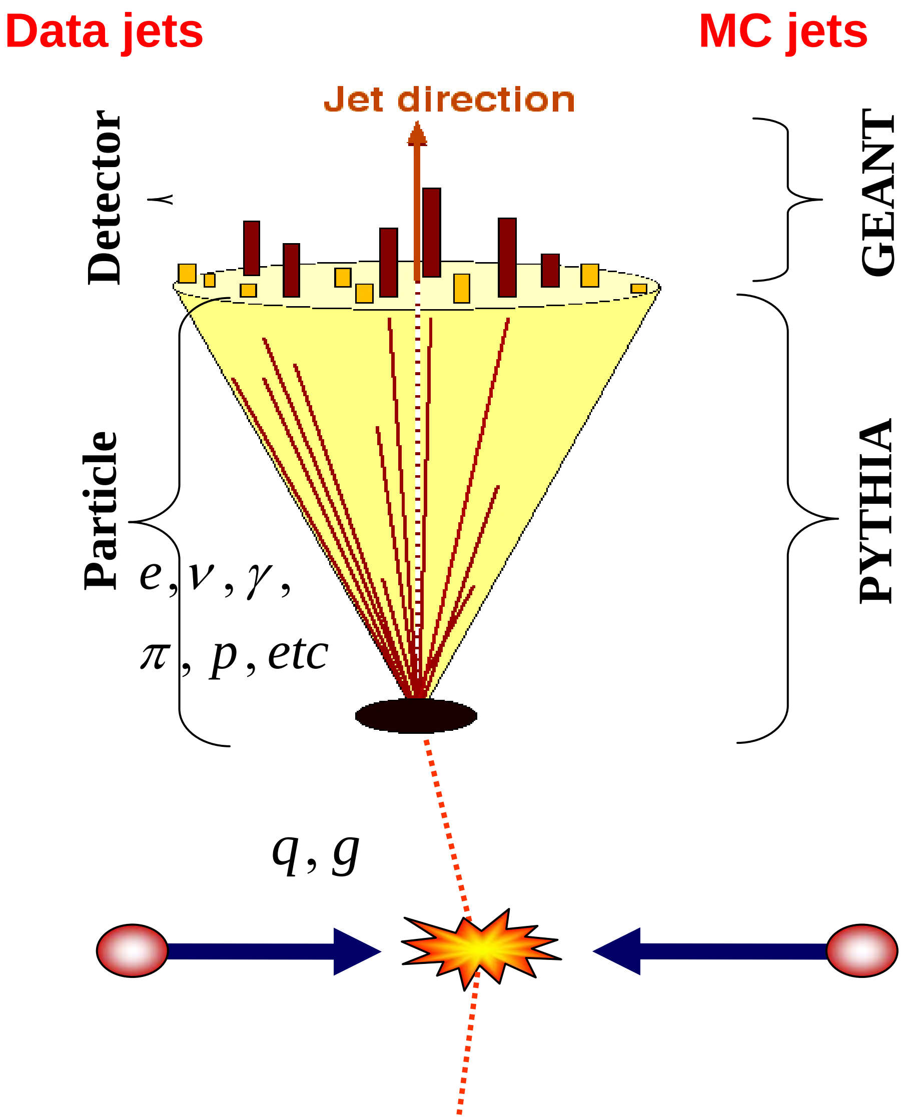


- Spin varies from rf bucket to rf bucket (9.4 MHz)
- Spin pattern changes from fill to fill
- Spin rotators provide choice of spin orientation
- Billions of spin reversals during a fill with little if any depolarization

The STAR detector



Jet reconstruction in STAR

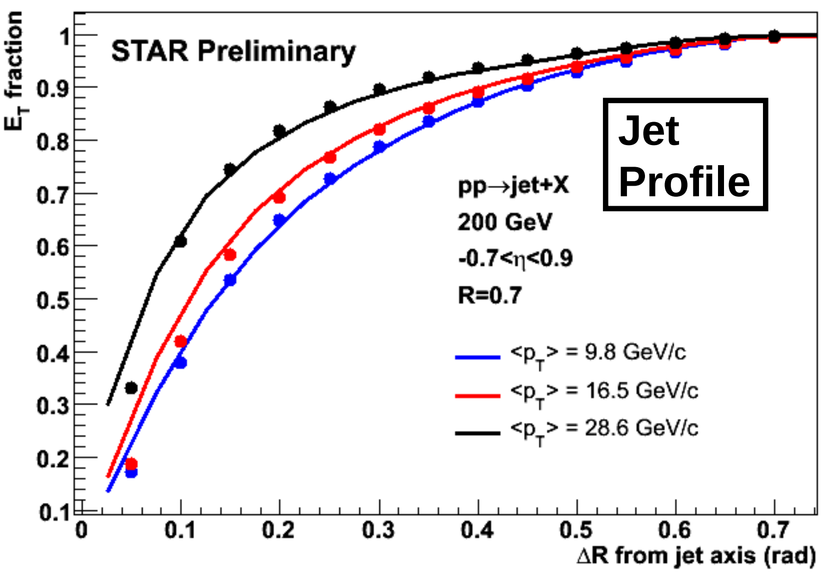


Midpoint cone algorithm

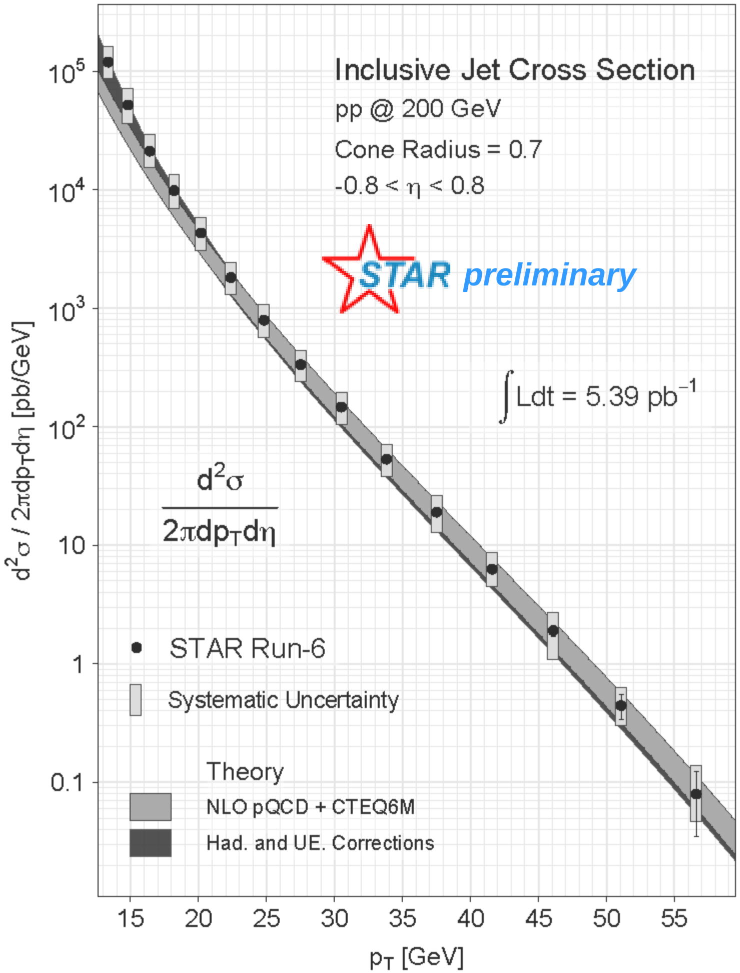
(Adapted from Tevatron II - hep-ex/0005012)

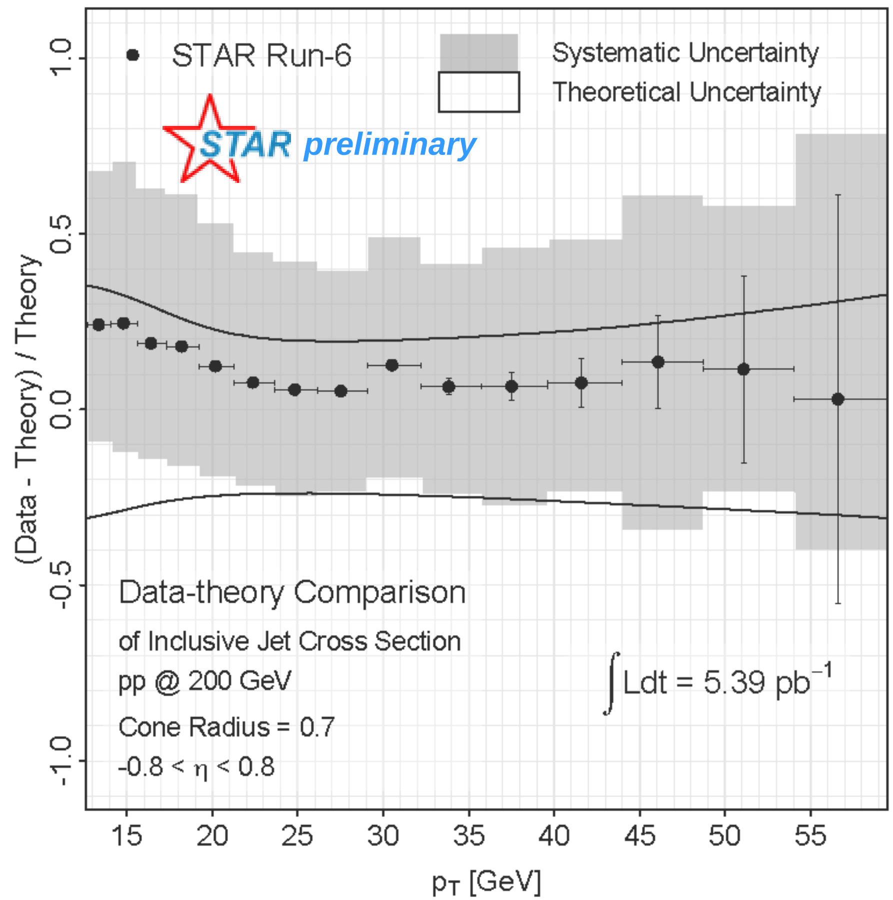
- Seed energy = 0.5 GeV
- Cone radius $R=\sqrt{\Delta\eta^2+\Delta\varphi^2} = 0.7$
- Splitting/merging fraction f=0.5

Use **PYTHIA + GEANT** to quantify detector response



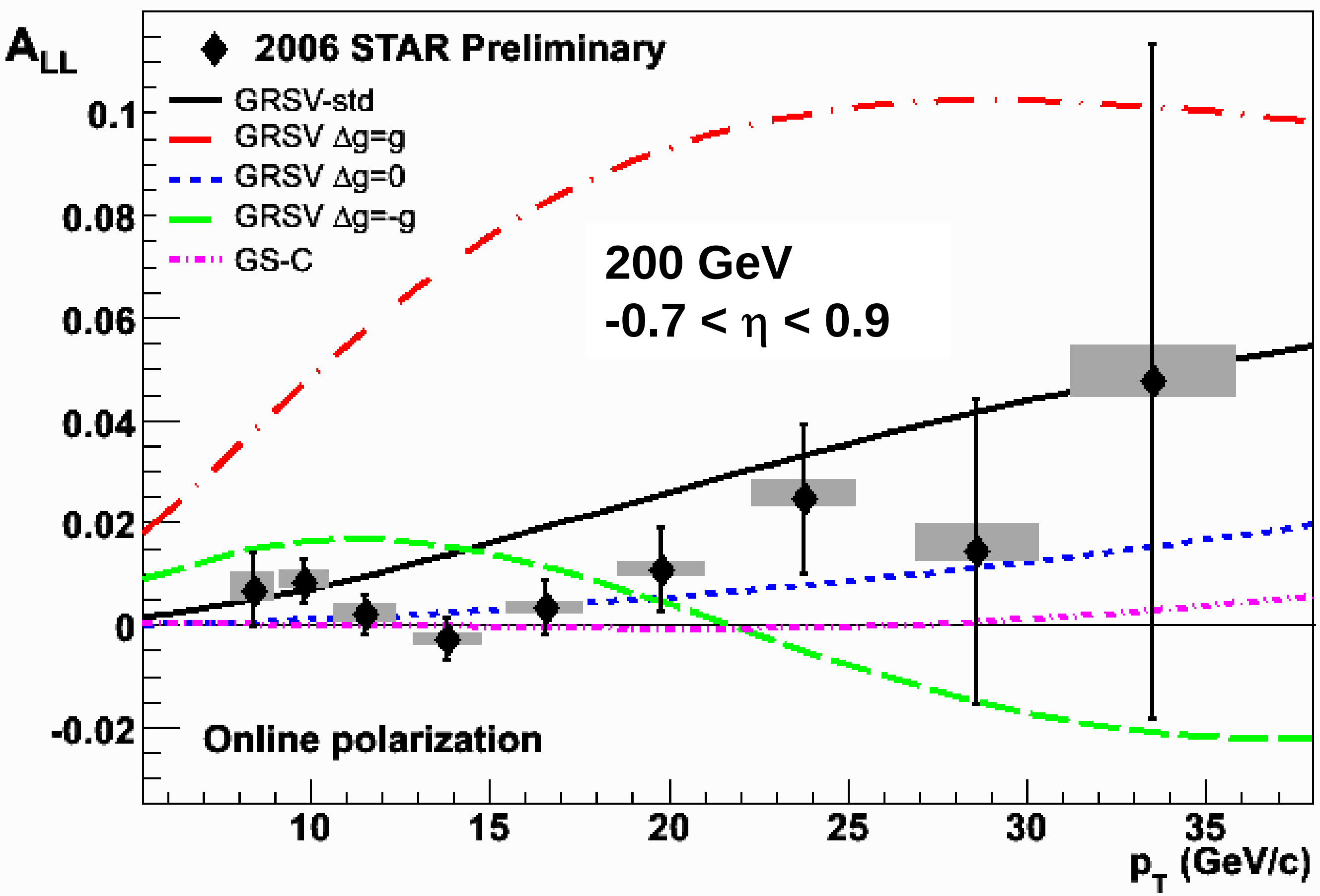
2006 inclusive jets cross section





- Data well described by NLO pQCD+Hadronization+Underlying Event
- Hadronization+Underlying event corrections significant at low jet p_T

2006 inclusive jets A_{LL}



GRSV curves with cone radius 0.7 and $-0.7 < \eta < 0.9$

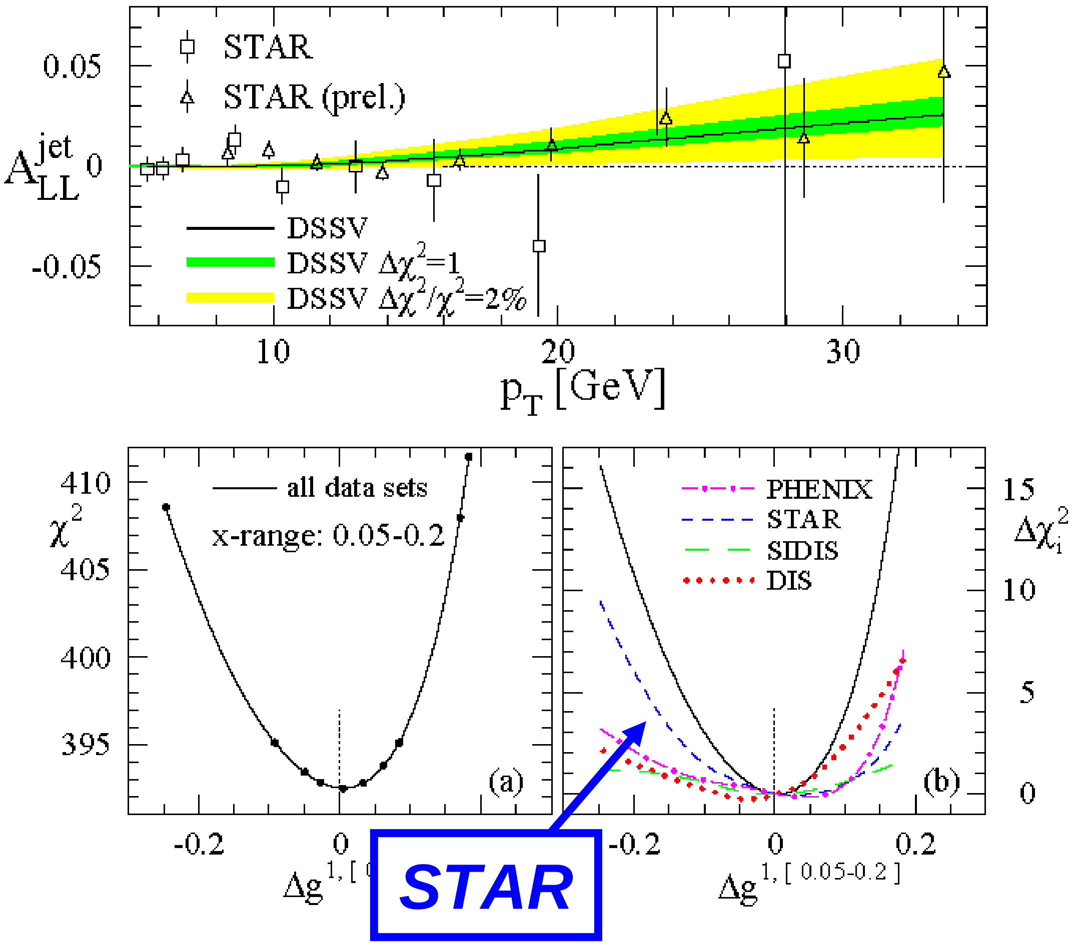
A_{LL} systematics	($\times 10^{-3}$)
Reconstruction + Trigger Bias	[-1,+3] (p_T dep)
Non-longitudinal Polarization	~ 0.03 (p_T dep)
Relative Luminosity	0.94
Backgrounds	1st bin ~ 0.5 Else ~ 0.1

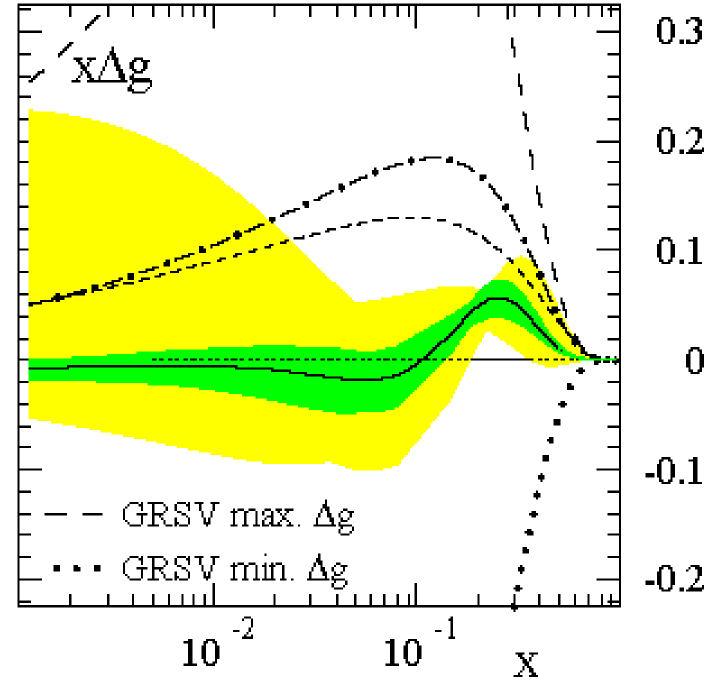
p_T systematic	±6.7%

- Sampled 4.7 pb^{-1} at 60% average beam polarization
- STAR data rule out several previous models of gluon polarization

DSSV – First Global Analysis with Polarized Jets

de Florian *et al.*, PRL **101** (2008) 072001



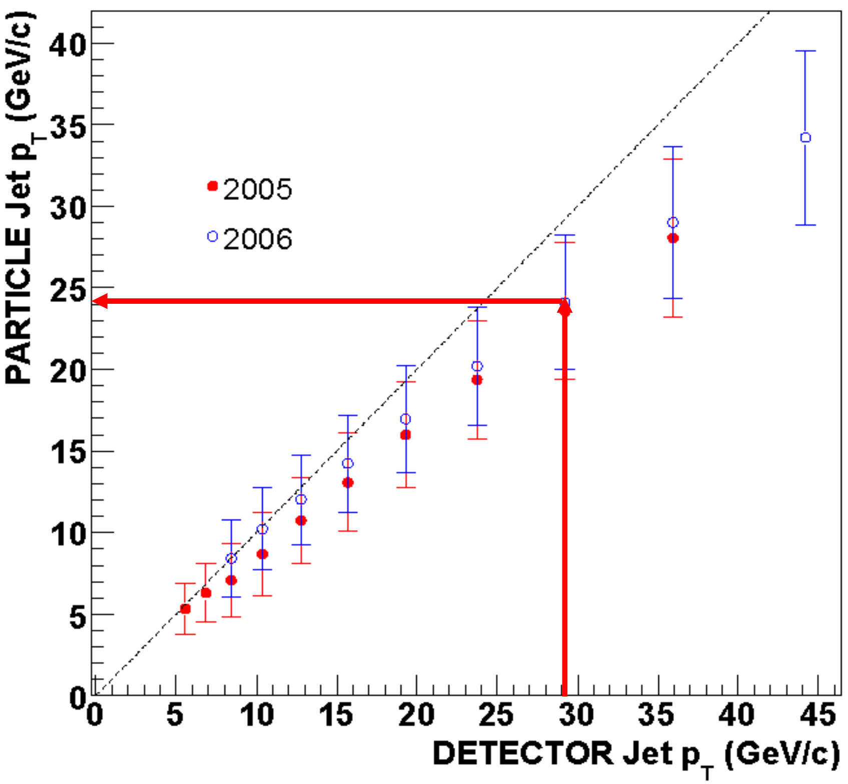


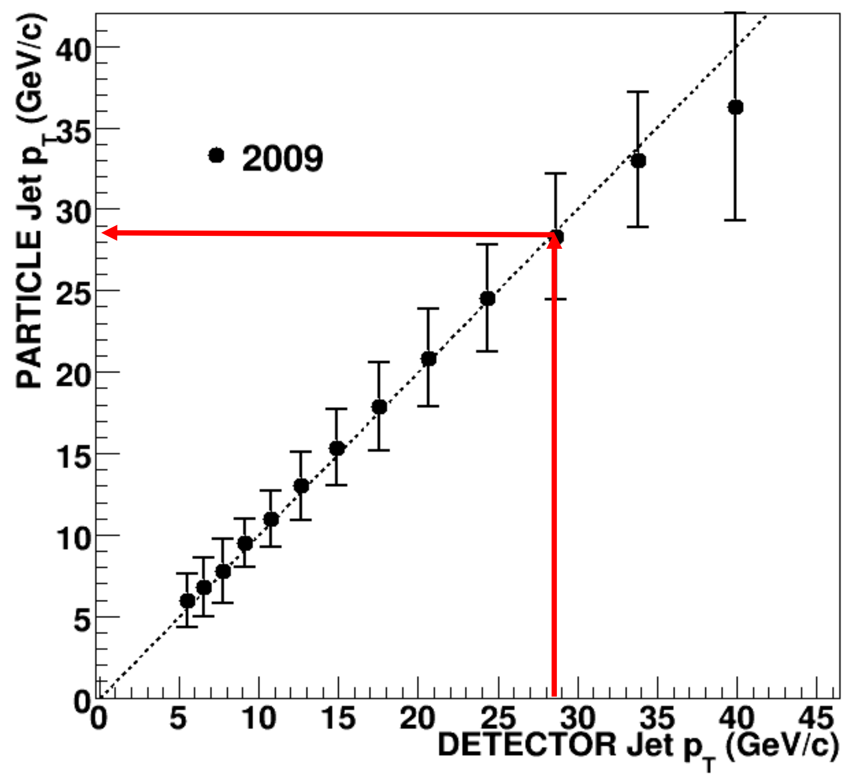
- The first global NLO analysis to include inclusive DIS, SIDIS, and RHIC pp data on an equal footing
- Finds a node in the gluon distribution near x ~ 0.1, but with the opposite phase from GS-C

2009 upgrades

- 2009 jet patch trigger upgrades
  - Overlapping jet patches and lower E_T threshold improve efficiency and reduce trigger bias
    - Net increase of 37% in jet acceptance
  - Remove beam-beam counter trigger requirement:
    - Trigger more efficiently at high jet p_T
    - Measure non-collision background
  - Increased trigger rate enabled by DAQ1000
- Improvements in jet reconstruction
  - Subtract 100% of track momentum from struck tower energy (2009) instead of MIP (2006)
  - Overall jet energy resolution improved from 23% to 18%
- Sampled 20 pb^{-1} at 58% average beam polarization

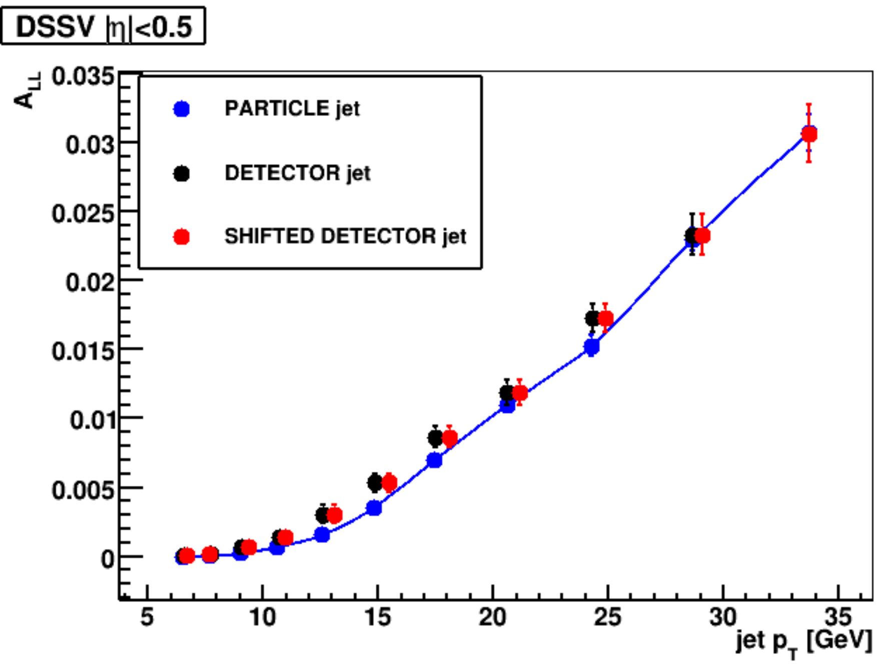
From detector to particle jets

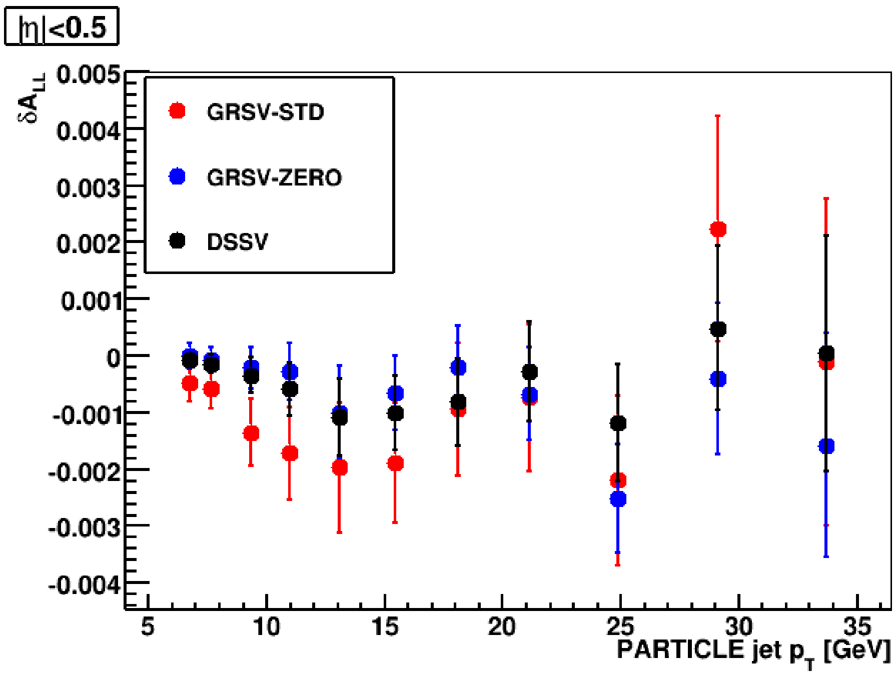




- 2009 hadronic subtraction scheme:
  - Smaller mean and RMS p_T shift
  - Better jet p_T resolution
- Dominant uncertainties in jet energy scale arise from calorimeter calibration and response to neutral hadrons
  - Jet p_T uncertainties are highly correlated

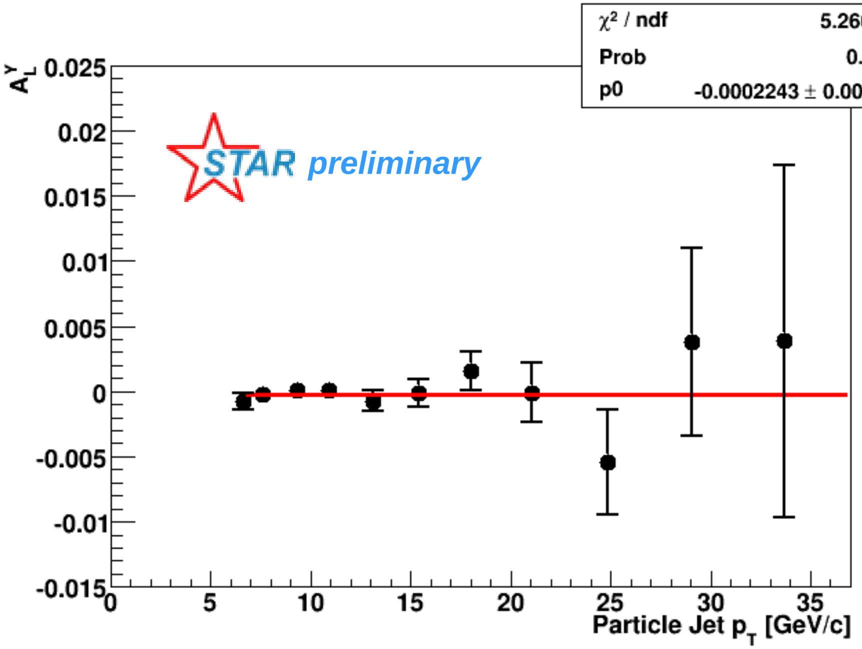
Trigger and reconstruction bias

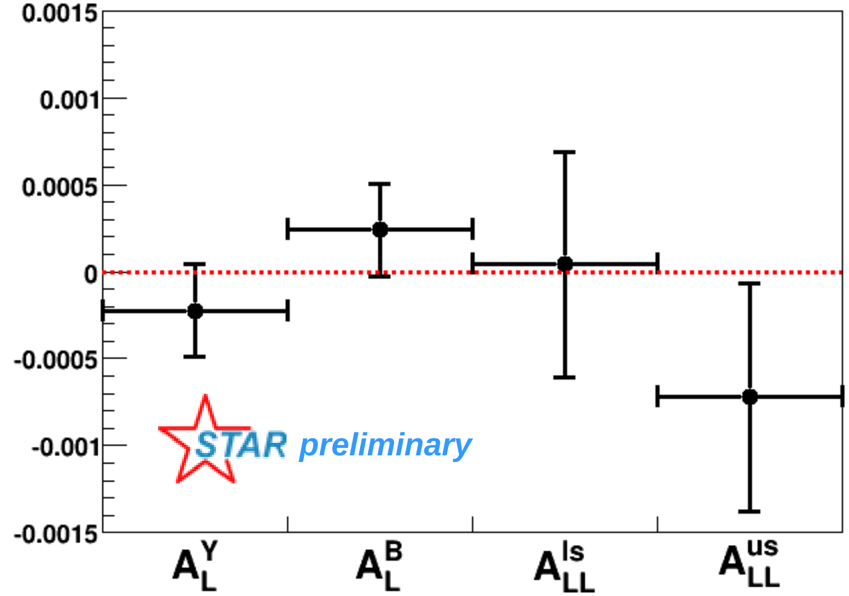




1. Calculate PYTHIA A_{LL} at PARTICLE jet p_T
2. Calculate GEANT A_{LL} at DETECTOR jet p_T
3. Move GEANT A_{LL} from DETECTOR jet p_T to appropriate PARTICLE jet p_T
4. Calculate δA_{LL}=(PYTHIA-GEANT) A_{LL} $\Rightarrow$ trigger and reconstruction bias

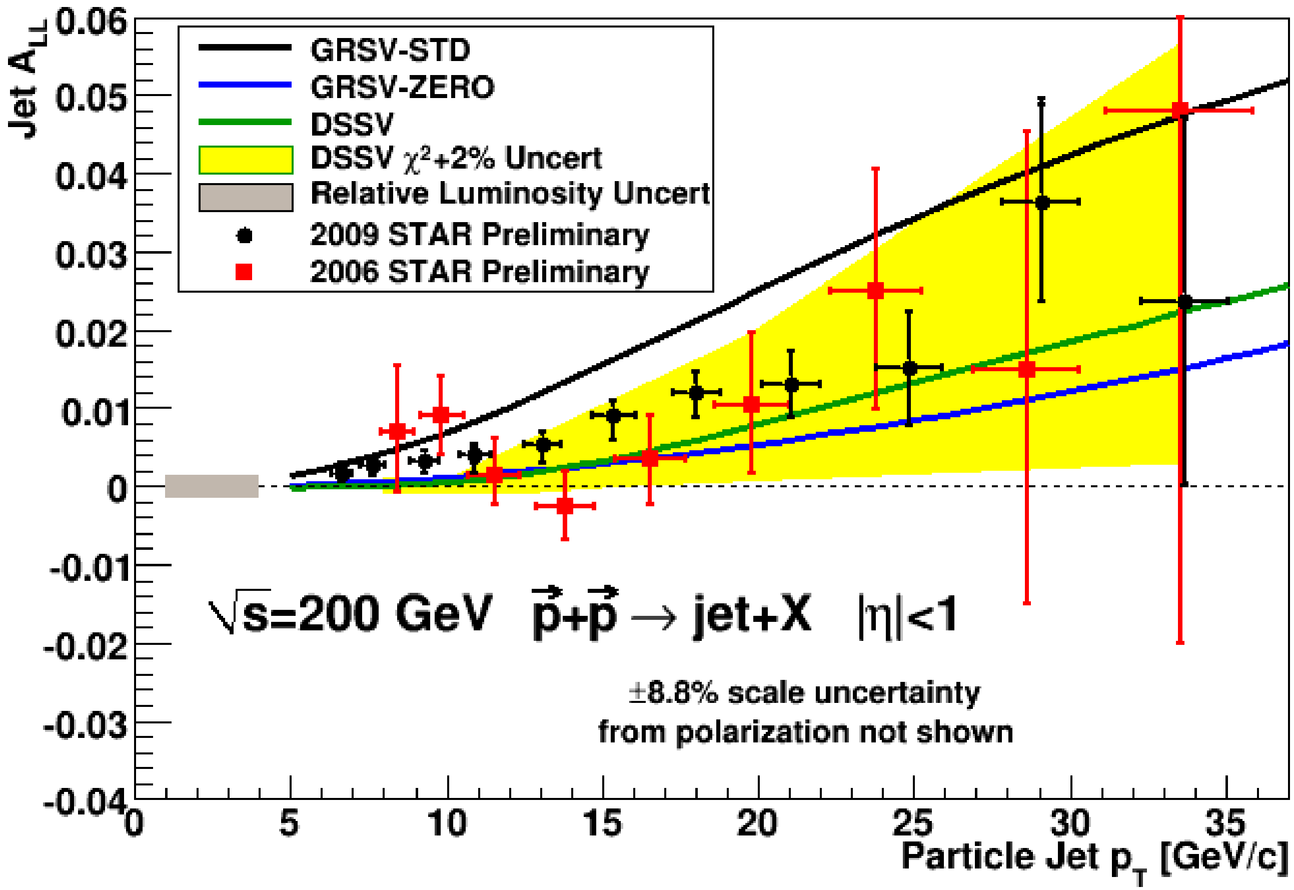
Relative luminosities





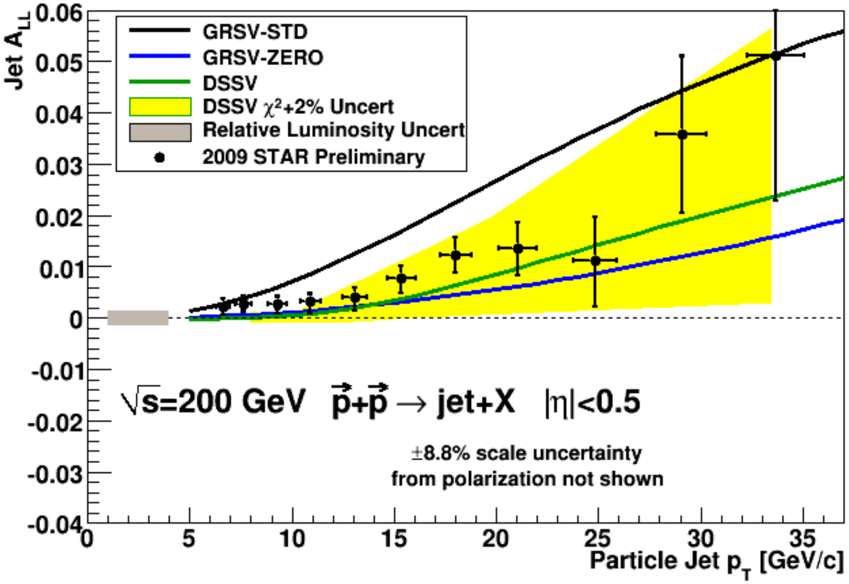
- Relative luminosities are calculated using the beam-beam counters (BBC)
- Relative luminosity systematic from comparisons of BBC and zero-degree calorimeter (ZDC) rates
- Preliminary estimated systematic for A_{LL} (±0.0015) very conservative
- False asymmetries from jet data are consistent with zero

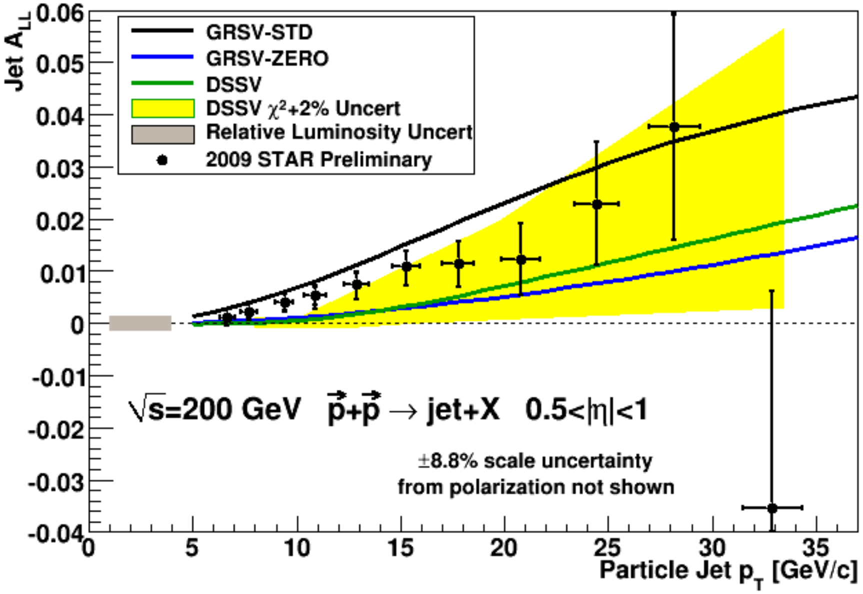
2006 vs 2009



- 2009 STAR data is a factor of 3 (high-p_T) to >4 (low-p_T) more precise than 2006 STAR data
- Results fall between predictions from DSSV and GRSV-STD
- Precision sufficient to merit finer binning in pseudorapidity

2009 inclusive jets A_{LL}





- A_{LL} separated into two pseudorapidity ranges
- Models predict a ~20% reduction in A_{LL} from $|\eta|<0.5$ to $0.5<|\eta|<1$
- A_{LL} falls between the predictions from DSSV and GRSV-STD

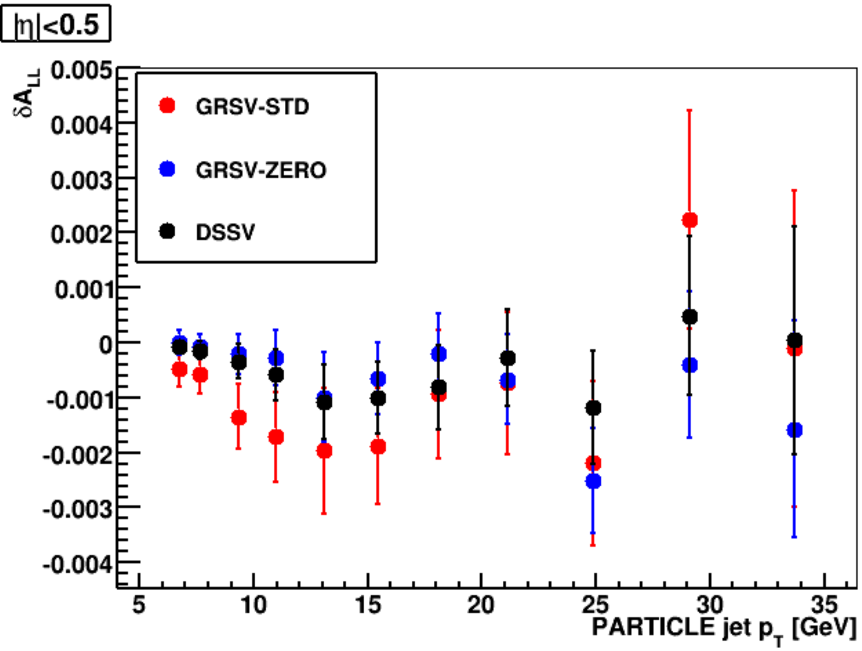
Summary

- STAR inclusive jets cross section from 2006 is in good agreement with NLO pQCD calculations when hadronization and underlying event effects are included
- STAR inclusive jets A_{LL} from 2006 provide significant constraints on gluon polarization in NLO global analyses
- 2009 STAR inclusive jets A_{LL} is factor of 3 (high-p_T) to >4 (low-p_T) more precise than 2006 results; will lead to a significant further reduction in uncertainties for gluon polarization
- A_{LL} for inclusive jets falls between DSSV and GRSV-STD predictions

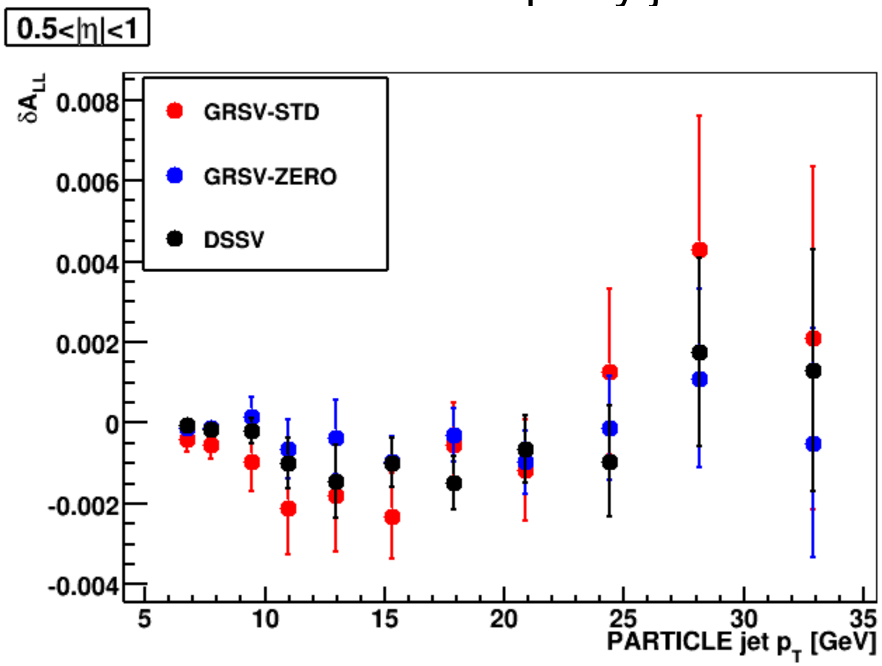
BACKUP

Trigger and reconstruction bias

Midrapidity jets

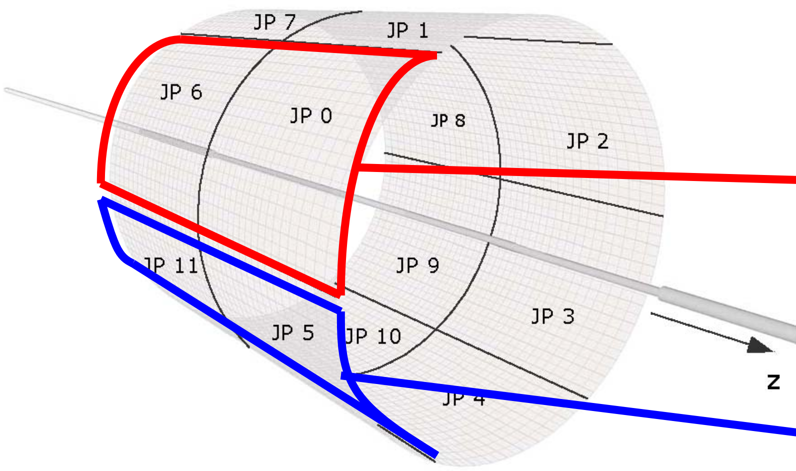


Forward rapidity jets

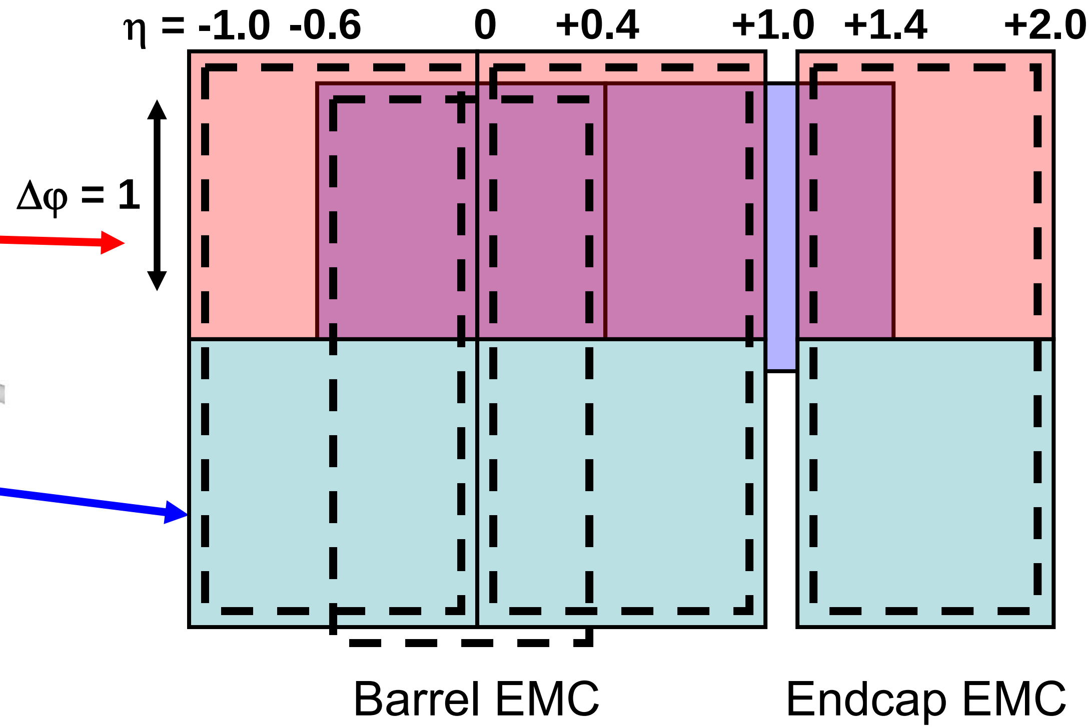


Uncertainty on A_{LL} is larger of maximum/minimum δA_{LL} for 3 models (GRSV-STD, GRSV-ZERO, DSSV) and positive/negative statistical error bar

2009 jet patch trigger upgrades



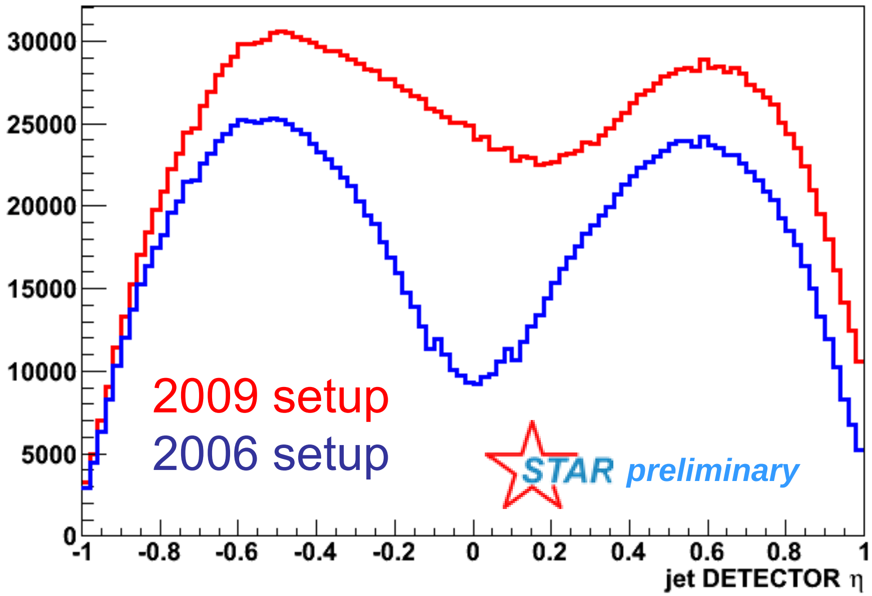
Tai Sakuma, Thesis MIT (2010)

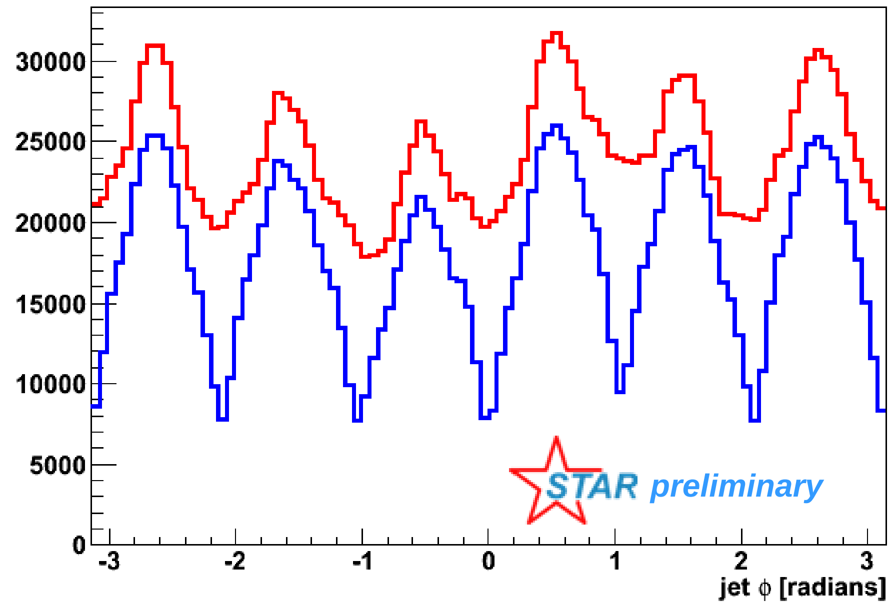


- Overlapping jet patches and lower E_T threshold increase efficiency and reduce trigger bias in η:
  - JP1 (~5.4 GeV, prescaled) ~130M events on tape
  - JP2 (~7.3 GeV) ~84M events on tape
  - Compare to Run 6: JP (~8.5 GeV) ~4.2M events on tape
- Adjacent jet patches (AJP):
  - Require 2 neighboring jet patches in φ above JP0 threshold (~3.5 GeV)
  - Capture jets that would deposit only half their energy in each jet patch ⇒ soften gaps in φ

2009 jet patch trigger upgrades

Two analyses of the same 2009 data subset:



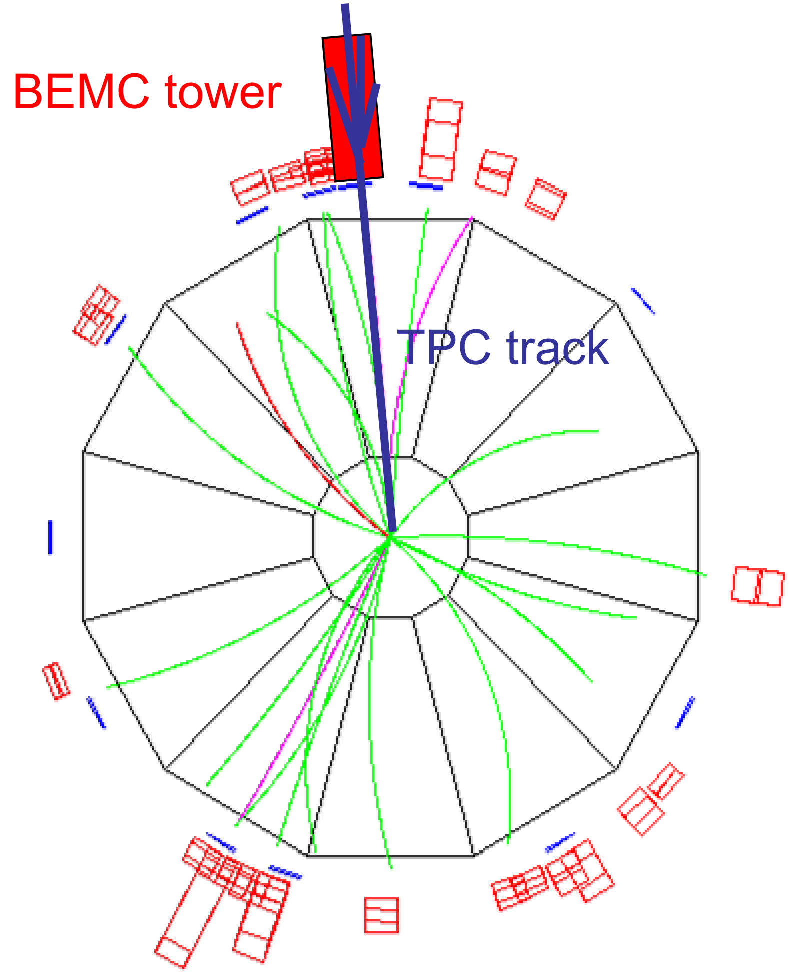


- Overlapping jet patches in η
- Collisions at different z-vertex locations provide an even more uniform acceptance for particle jet η

- Two adjacent jet patches in φ at half nominal jet patch E_T threshold combined to fill in φ gaps
- Gaps in φ softened

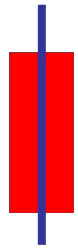
37% increase in jet acceptance due to improvements in jet patch trigger

Improvements in jet reconstruction

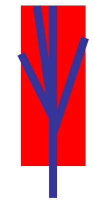


- EMCs are ~1 strong interaction length thick
- Many charged hadrons deposit Minimum Ionizing Particle (MIP) ~250 MeV
- Others shower and may deposit sizeable fraction when passing through

Improvements in jet reconstruction



- 2006 treatment: Subtract MIP from EMC tower when charge track passes through
- Allows to see EM energy emitted very close to charge track
- Makes reconstruction susceptible to fluctuations in charge hadron showering
- Major contribution when jet energies are larger at detector level than particle level



- 2009 treatment: Subtract total charged track momentum from EMC tower when passing through
- Reduces ability to see EM energy emitted close to charge track
- Significantly reduces response to fluctuations from charge hadron showering
- Reduces average difference between jet energies at the detector and particle level

Improves overall jet energy resolution 23% to ~18%

A_{LL} vs run number