Longitudinal Double-Spin Asymmetry A_{LL} for Inclusive Jet Production in Polarized Proton Collisions at $\sqrt{s}$ = 510 GeV

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For the STAR collaboration
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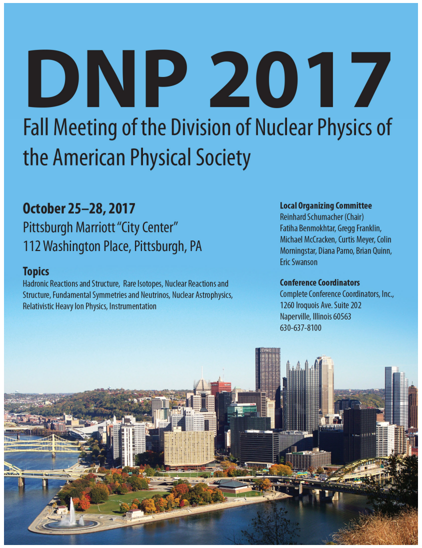


Motivation

What is the contribution of gluon polarization (ΔG) to the spin of the proton?

$$< S_p >= \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \boxed{\Delta G} + L_q + L_g$$

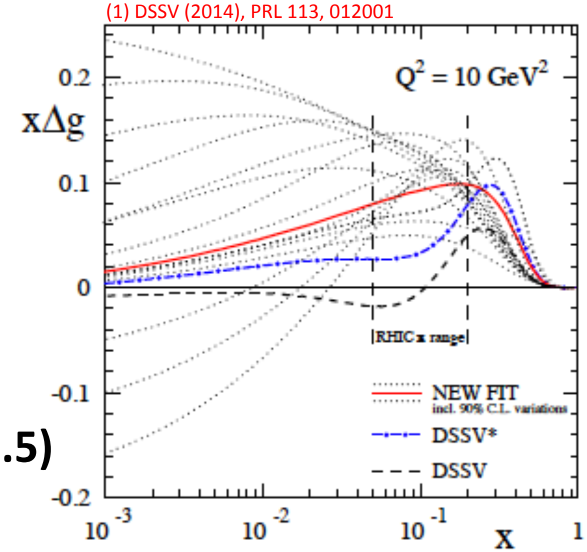
- Gluon polarization can be measured using A_{LL} of jets, within RHIC kinematic range.

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

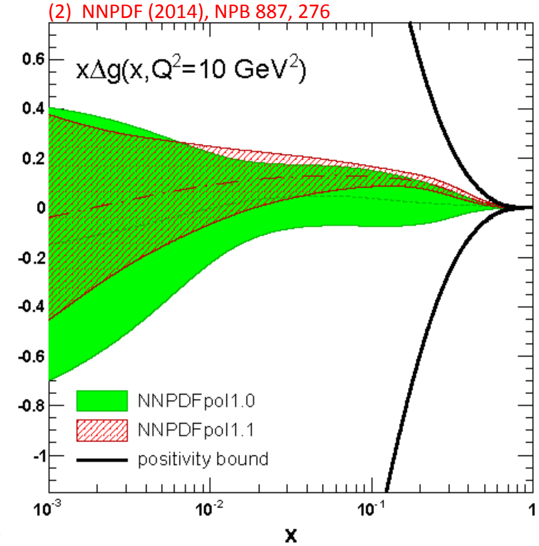
- STAR A_{LL} inclusive jet results (2009) at 200 GeV, provide the first evidence of non zero gluon polarization at x > 0.05 (Phys. Rev. Lett. 115, 092002).

DSSV[(1)] : 0.19 ± 0.06 (0.05 < x)
NNPDF[(2)]: 0.23 ± 0.07 (0.05 < x < 0.5)

(1) DSSV (2014), PRL 113, 012001



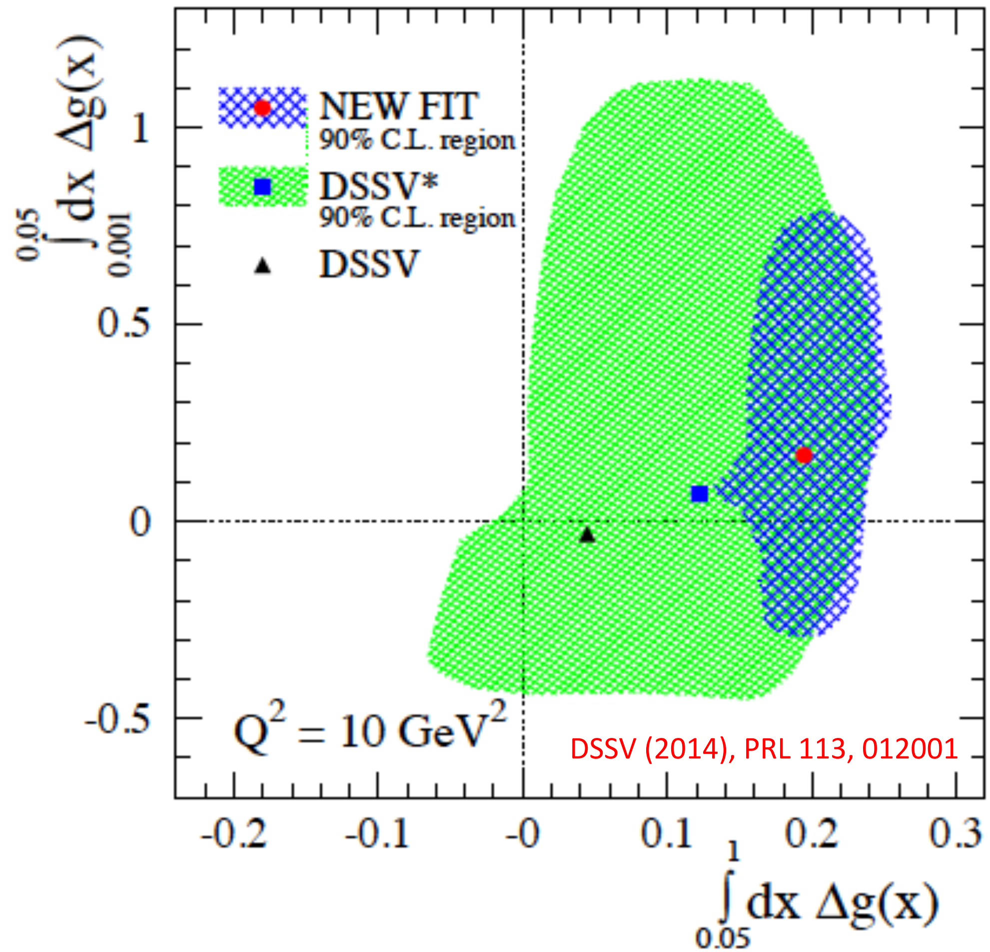
(2) NNPDF (2014), NPB 887, 276



Motivation (cont.)

- Need to increase precision in the currently sampled region to consolidate the observation of non zero gluon polarization.

- Need to extend sensitivity to lower x.

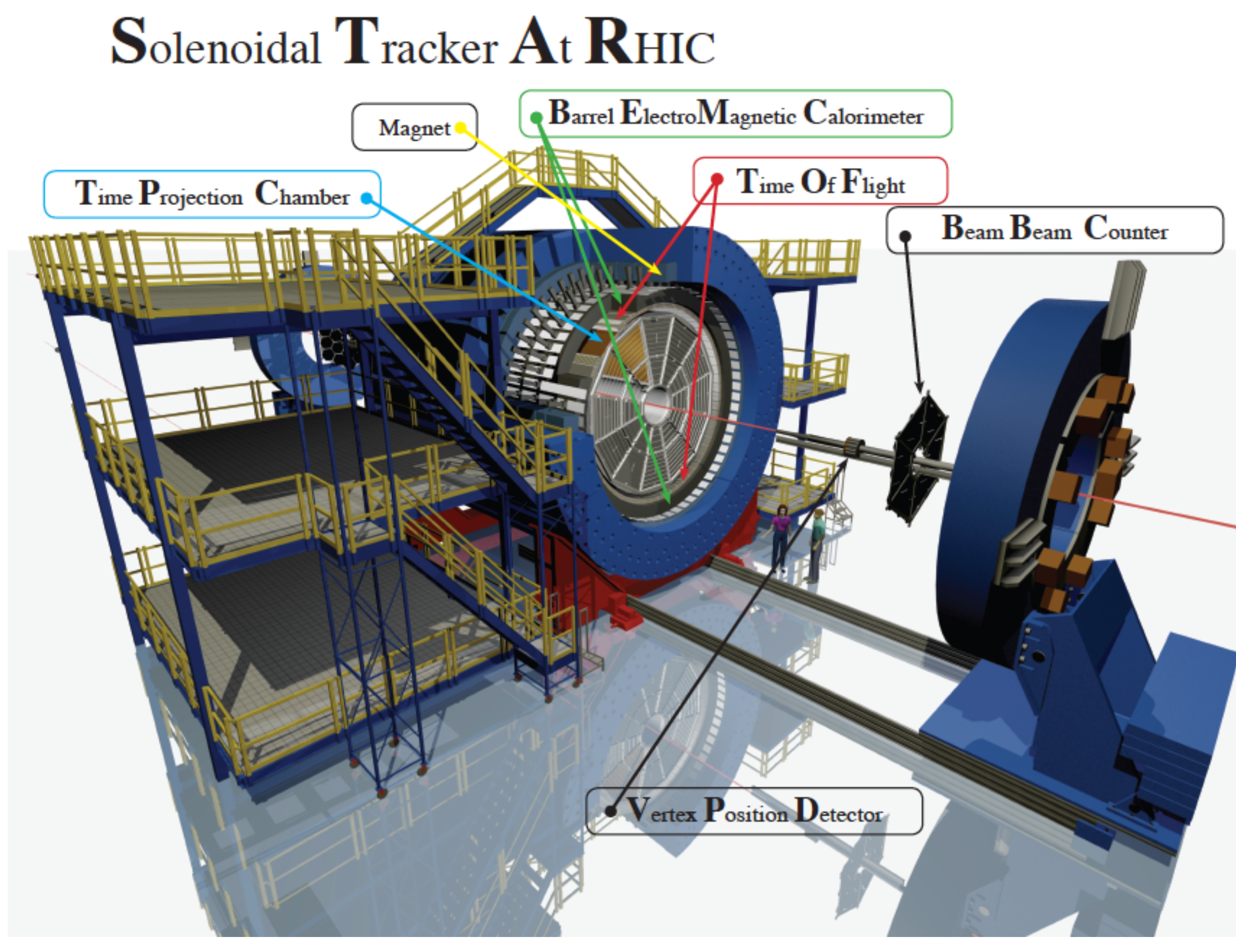


STAR Experiment

- One of the largest experiments at the Relativistic Heavy Ion Collider (RHIC).

- The main tracking device is a Time Projection Chamber (TPC) at |η| ≤ 1.3.

- Electromagnetic calorimeters (-1 ≤ η ≤ 2) are used to trigger high momentum particles and measure neutral component of jets.



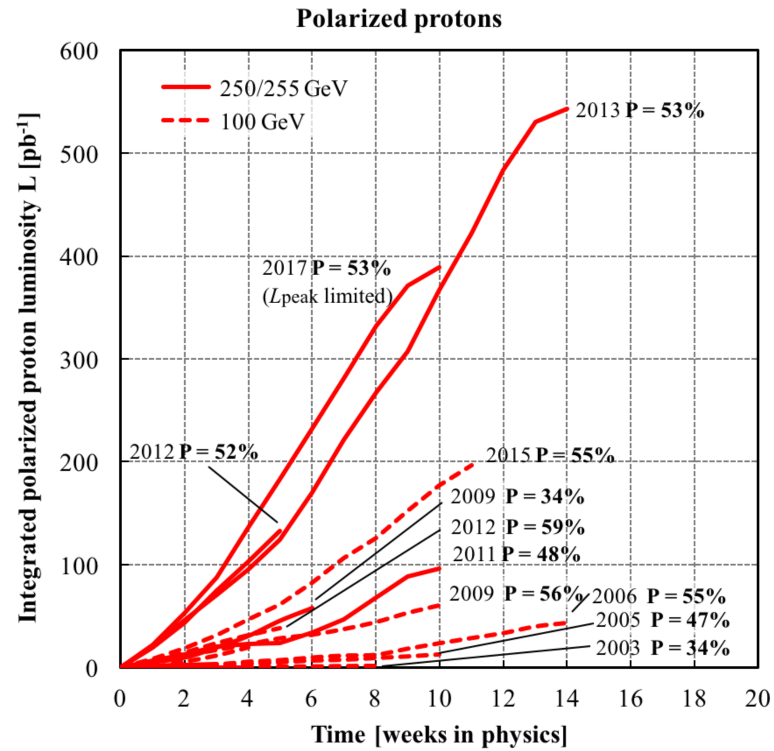
Run 2013 data

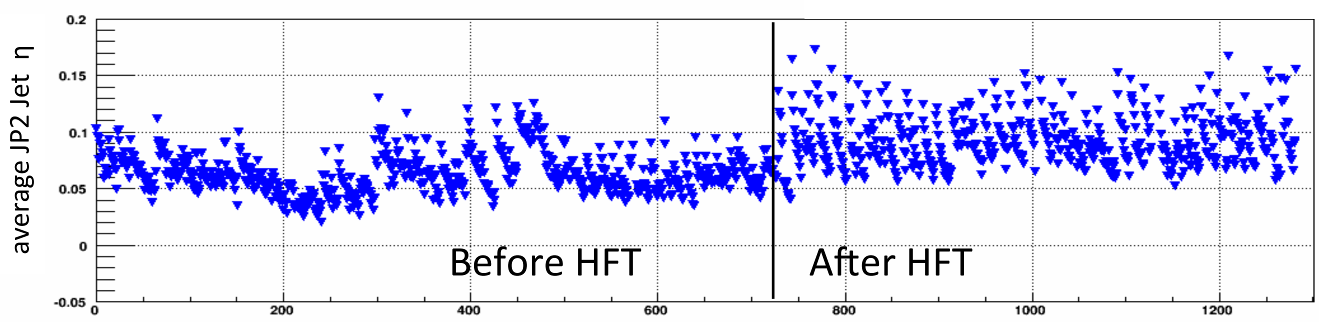
- Delivered a luminosity ~250 pb^{-1} (almost three times greater than the previous year).

- The collision energy, during 2012 and 2013, was 510 GeV. The higher energy relative to 2009 (200 GeV) provides access to lower-x gluons.

- Average beam polarization 53%.

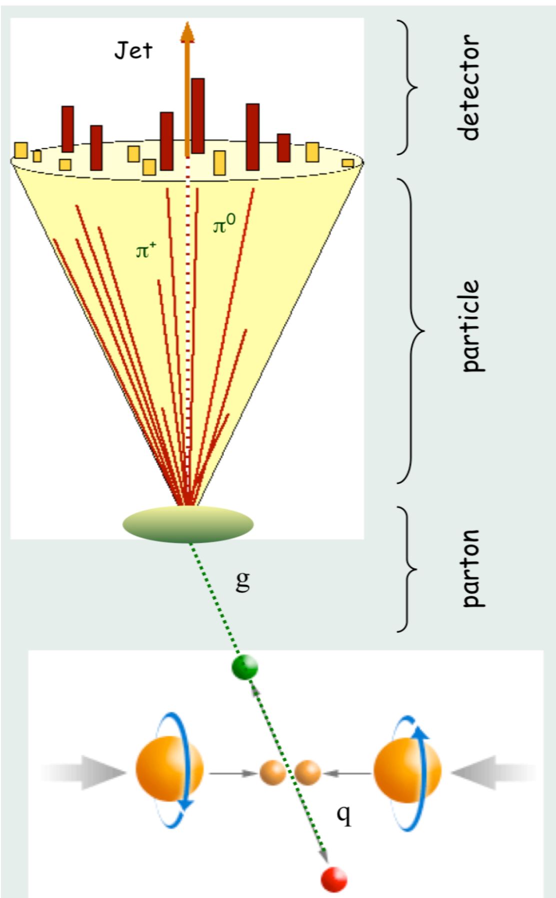
- STAR installed the Heavy Flavor Tracker (HFT) on the east side (eta < 0) in the middle of the 2013 run. The extra material affects the reconstruction of events (e.g. average η).

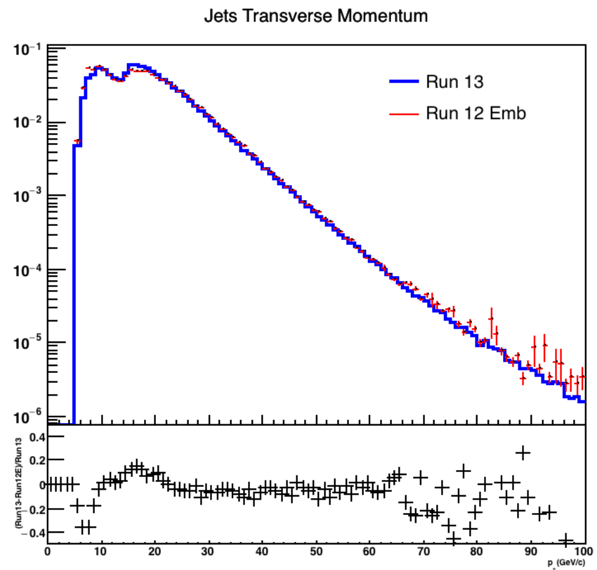




Simulation studies

- Simulations are used to quantify the detector response.

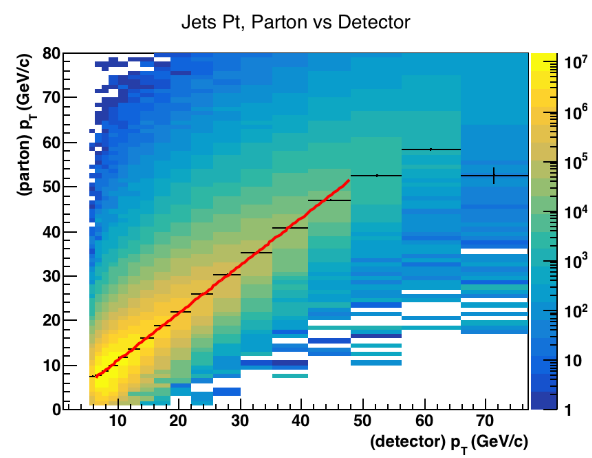


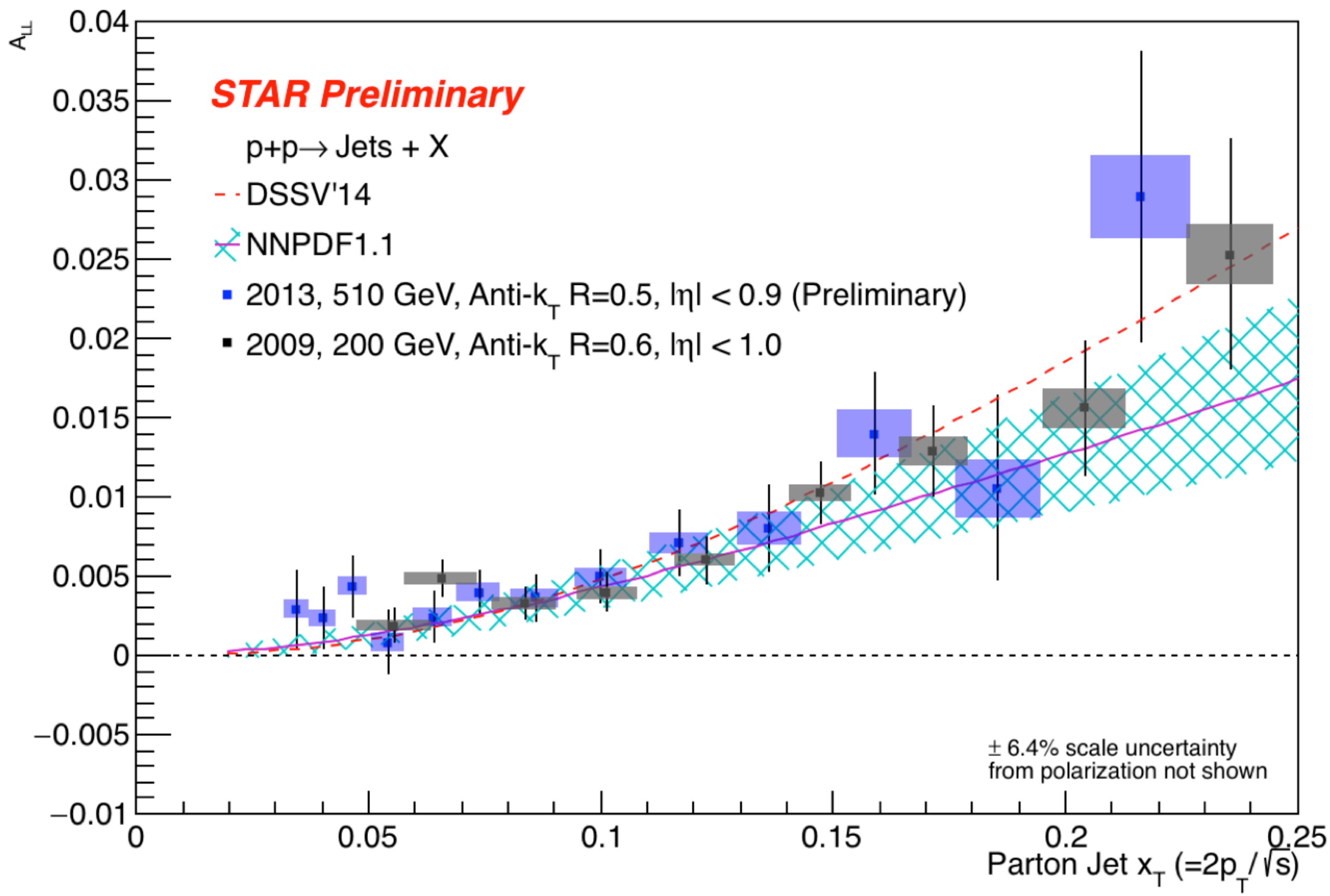


- MC for the 2012 run agrees with data for the 2013 run (before HFT).

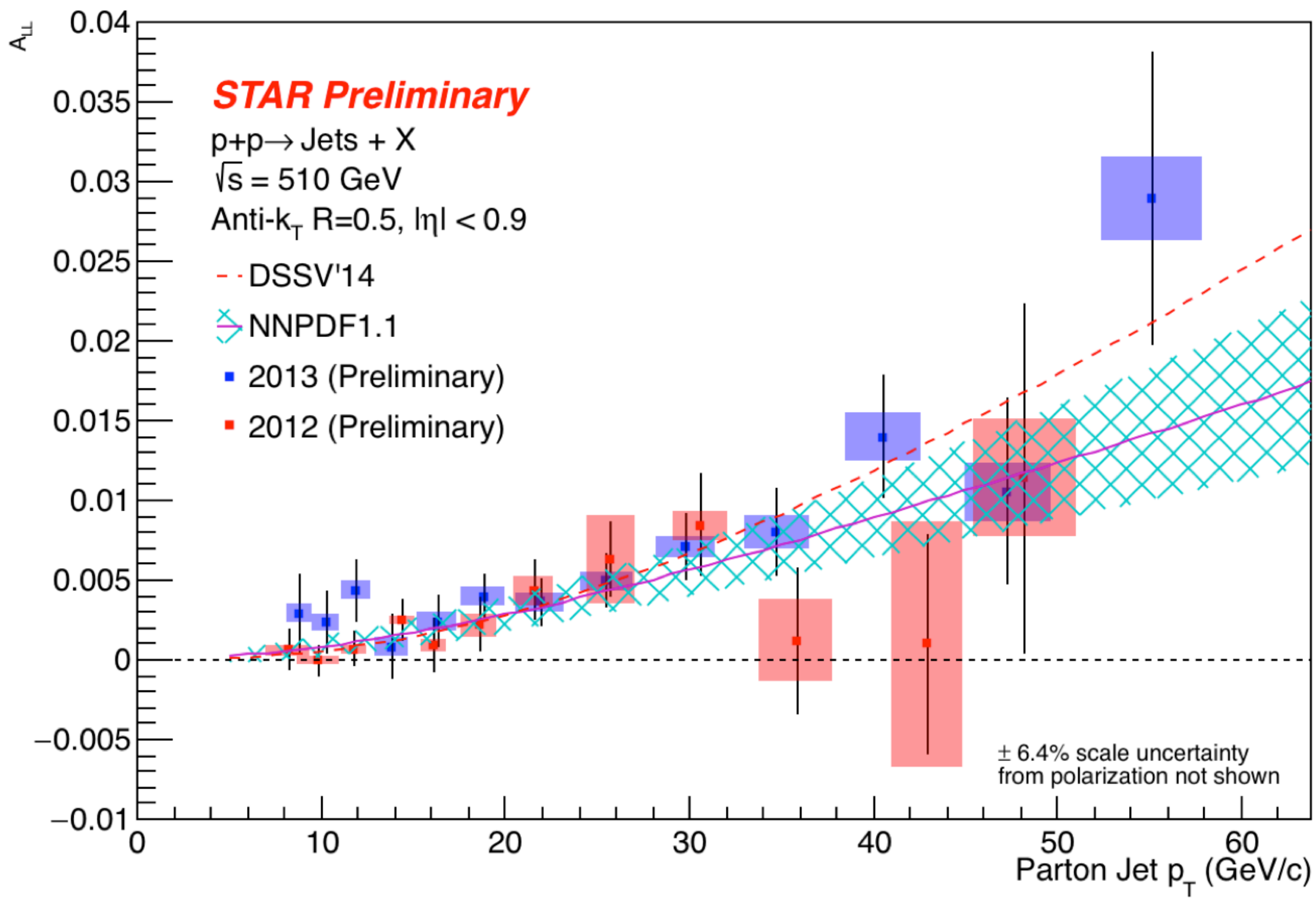
- Simulations are also used to estimate systematic uncertainties.

- Jets at the detector level are matched to jets at the parton level in simulation.





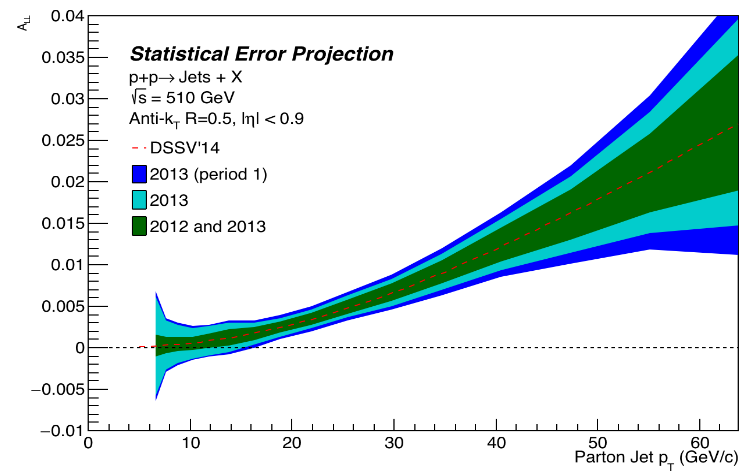
- Run 2009 (200 GeV) (Phys. Rev. Lett. 115, 092002), Run 2012 (see the next slide) and the newest Run 2013 (510 GeV) A_{LL} measurements show good agreement in x overlap region.
- The full Run 2013 (510 GeV) data sample will further constrain the gluon polarization.

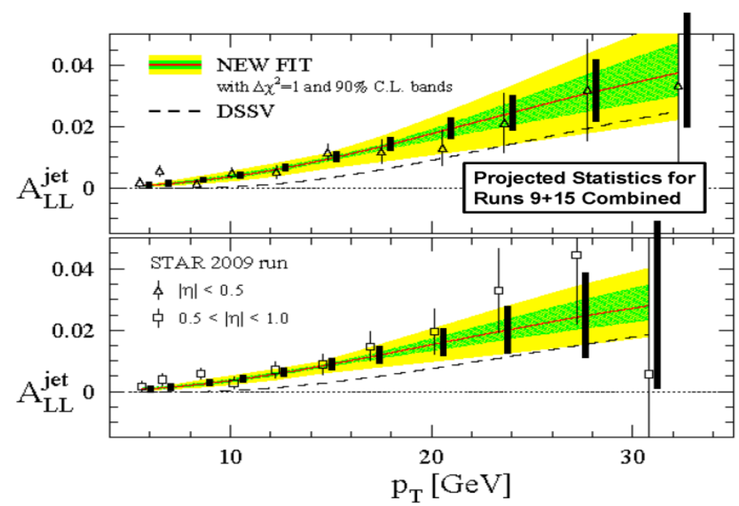


- Runs 2012 and 2013 performed measurements at √s = 510 GeV accessing lower x values.
- The inclusion of the STAR Run 2009 results to the newest global fits provides better control of the systematics (e.g. trigger and reconstruction bias), allowing to improve these errors.

Projections and summary

- Results of A_{LL} for inclusive jet production in run 2009, run 2012 and run 2013 are consistent and agree with the global fits DSSV14 and NNPDF1.1.
- Run 2013 embedding studies are ongoing and will improve the data-MC agreement of the jet quantities especially for the period after the HFT insertion, allowing its inclusion in the A_{LL} measurement.
- STAR took additional 200 GeV pp data during 2015, that will reduce uncertainties for A_{LL} at 200 GeV by a factor of ~1.6.
- These high precision measurements motivate the natural step forward to move to an Electron Ion Collider, in order to achieve lower x values.





Backup

Runs QA

All quantities studied (34):

- Vertex Z
- Bunch Crossing
- Asymmetry
- Each False Asymmetry (4)

(for Asymmetries took the ->Integral(3,15), not mean)

- Each Relative Luminosity (6)
- Each Polarization (2)
- Jets per Event, Pt, Rt, Eta, Phi, Det Eta, Underlying event
- Tracks per jet, Pt, DcaXY, Eta, Phi, DcaZ
- Tower multiplicity, Et, Energy, Eta, Phi, Adc

Procedure:

1.- Divide Period 1 in four sub-periods A, B, C, D.

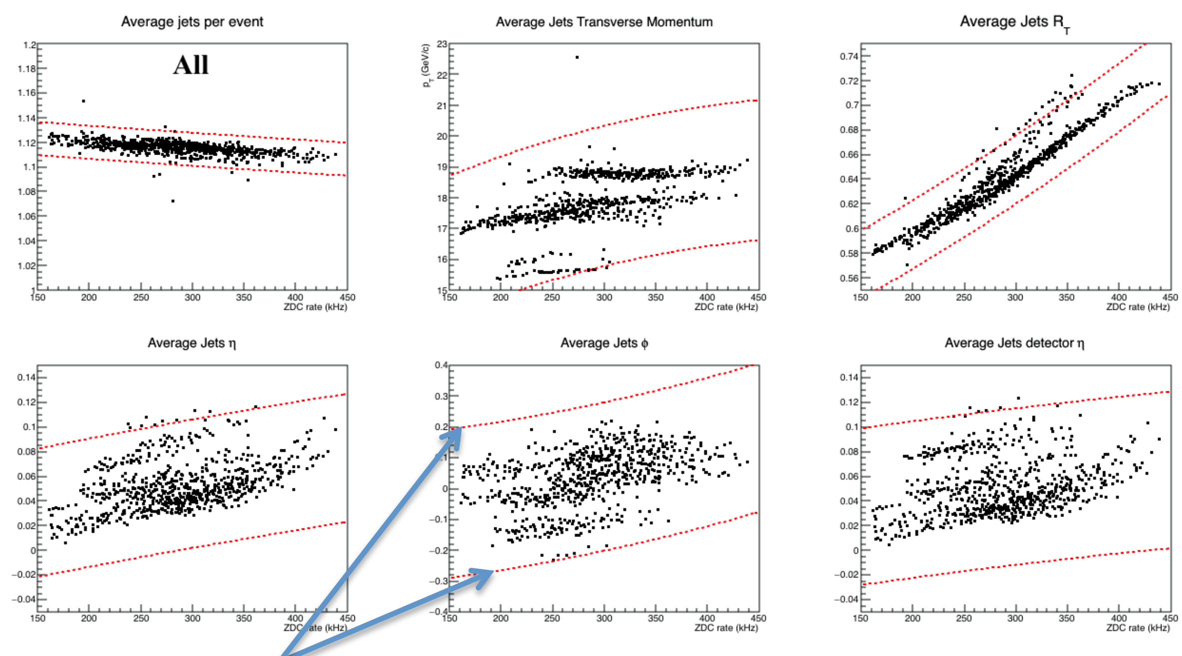
2.- Calculate the average of each quantity per run per period.

3.- Plot versus ZDC rate.

4.- Fit a 2nd order polynomial per quantity.

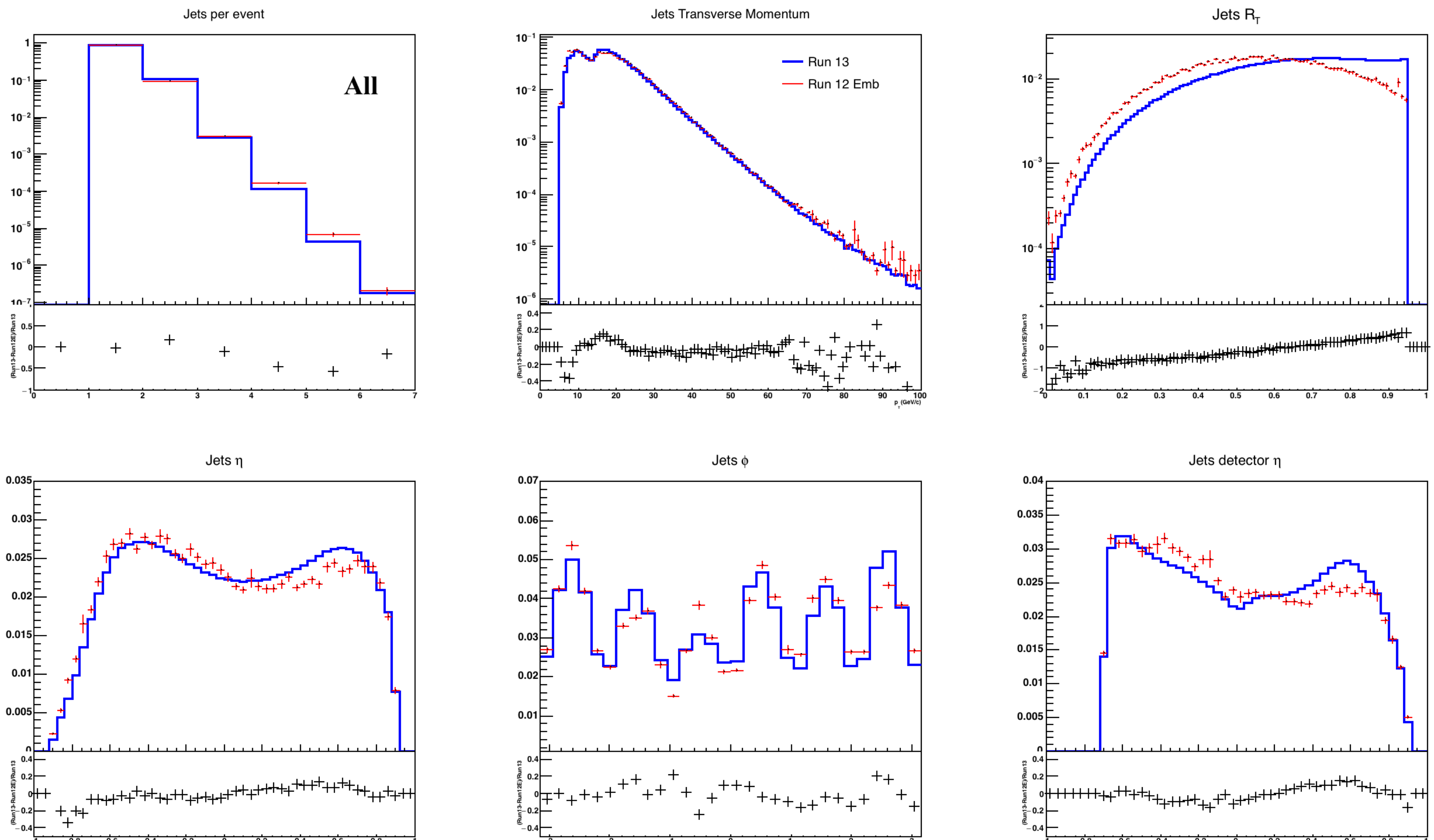
5.- Calculate RMS of sample respect to the pol2 fit.

6.- Runs outside 3*RMS per quantity, are removed.

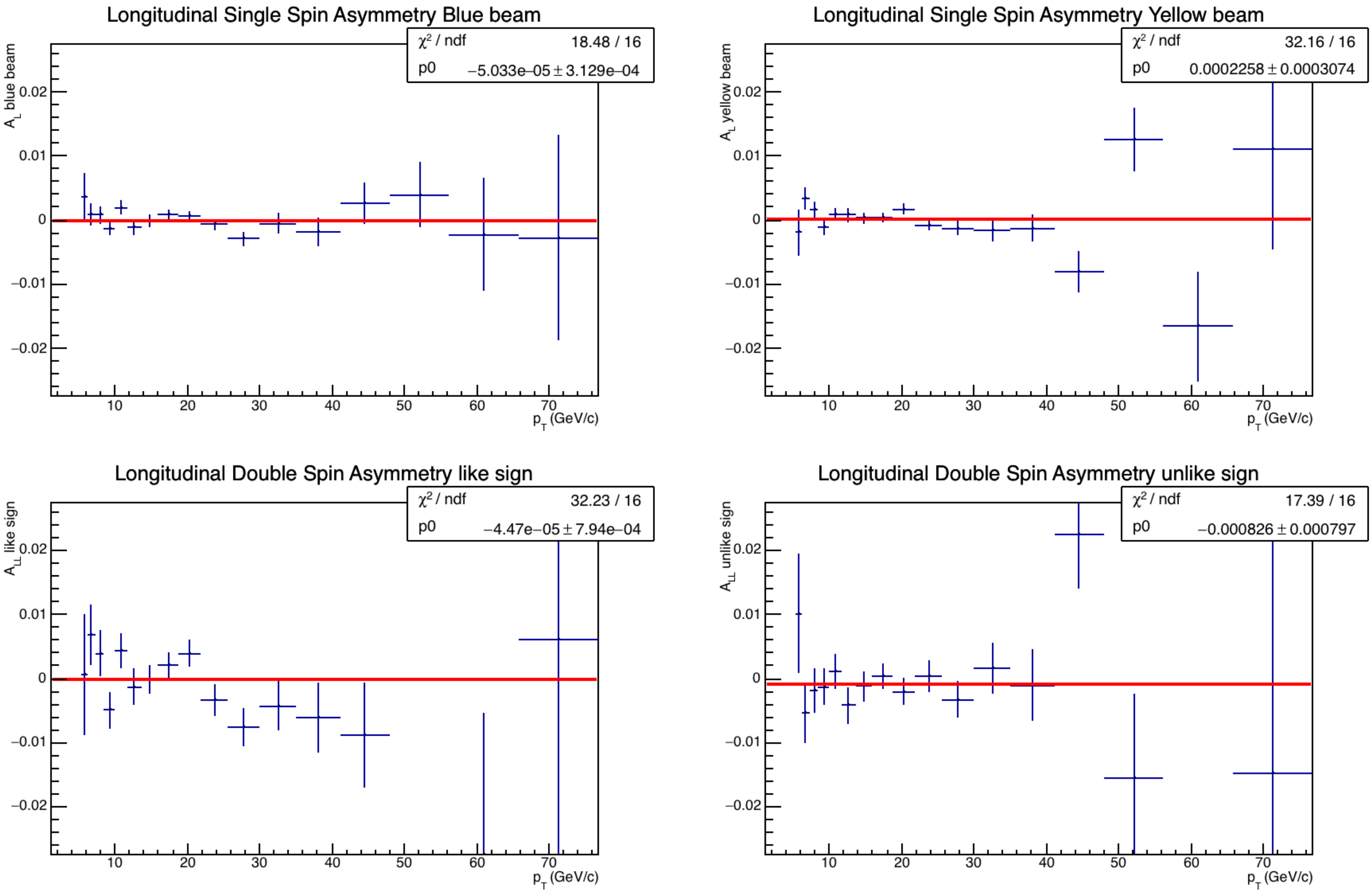


Showing all period 1.The RMS lines match each sub-period.

Comparison of data and simulation



False asymetries



Jet Energy Scale systematic

1. P_T shift: is the statistical error of each bin obtained for the ProfileX of the p_T shift (appendix).
2. BEMC track:

$$p_{T,avg} * \sqrt{((1-R_T)*trk\_p)^2 + ((1-R_T)*(NH - trk\_eff * trk\_dep) * BEMC\_trk * BEMC\_unc / trk\_eff)^2}$$

Trk_p = Track momentum uncertainty as 1%

NH = Scale up for neutral hadrons 1.1628

Trk_eff= Track efficiency 55%

Trk_depTrack deposition in projected tower 50%

BEMC_trk = BEMC resp to track 30%

BEMC_unc = BEMC resp to track uncertainty 9%.

3. BEMC neutral:

$$p_{T,avg} * R_T \sqrt{(gain)^2 + (eff\_unc)^2}$$

gain= 8% (5% run 13 + 3% Run12 emb)

Eff_unc= 1%

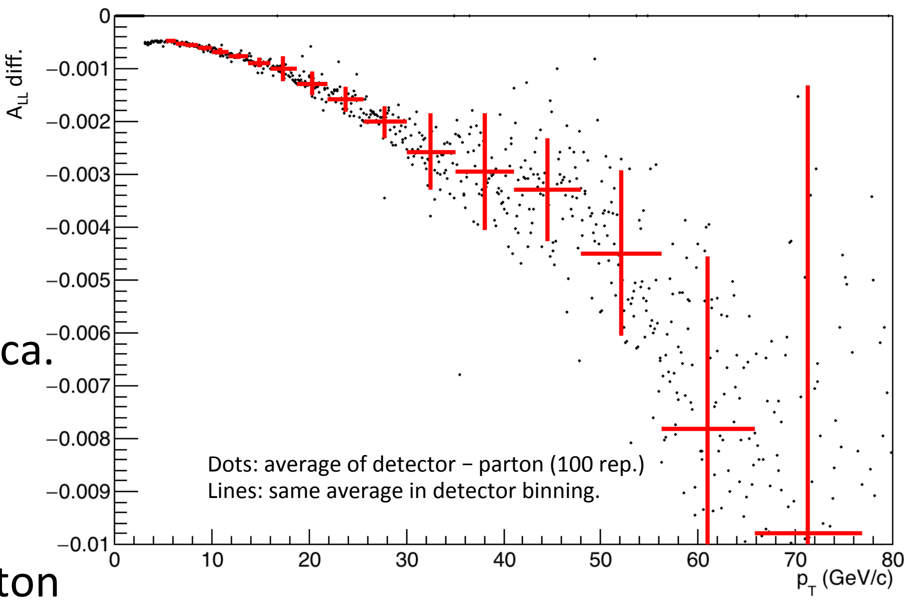
4. 7% track loss: sqrt ((pt-pt7%)^2 + 0.01^2)
5. UE shift: difference between Profile of UE in data and UE in simulation.
6. Pt tune: extrapolate Zilong results to my pt bins. Tune13 = (Pt13/Pt12) *Tune12

A_{LL} systematic uncertainty

1.- Relative luminosity systematic: 5.6E-4.

2.- UE systematic: 1E-4.

3.- Trigger Bias:
   -Use NNPDF1.1 100 replicas.
   -Take the diff Detector – Parton for each replica.
   -The Mean is the A_{LL} correction.
   -The RMS is the systematic.



4.- The RMS of NNPDF1.1 best fit Detector – Parton
   is the systematics.

5.- Track 7% loss:
   -Take the average of 100 rep. nominal and 7% loss.
   -The difference of Detector Nominal − Detector 7% loss is the systematic.

Final systematic, add everything in quadrature