PHENIX mid-rapidity $A_{LL}^{\pi^0}$ at $\sqrt{s} = 510$ GeV

2015/07/24

Yoon Inseok

SNU/RIKEN

Spinfest workshop @ Tokai

Contents

- Motivation:
  Expanding experimental sensitivity to Δg to lower x region.

- Introduction to RHIC spin Runs and PHENIX.

- Analysis Procedure:
  A_{LL} measurement, ΔRelative luminosity.

- Preliminary Results.

- Plan for finalization and publication.

1. Motivation

- $S_p = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L_q + L_g$

  $\Delta\Sigma = 0.366 \pm^{0.042}_{0.062}$ (PRL 101, (2008) 07200)

  → want to measure ΔG

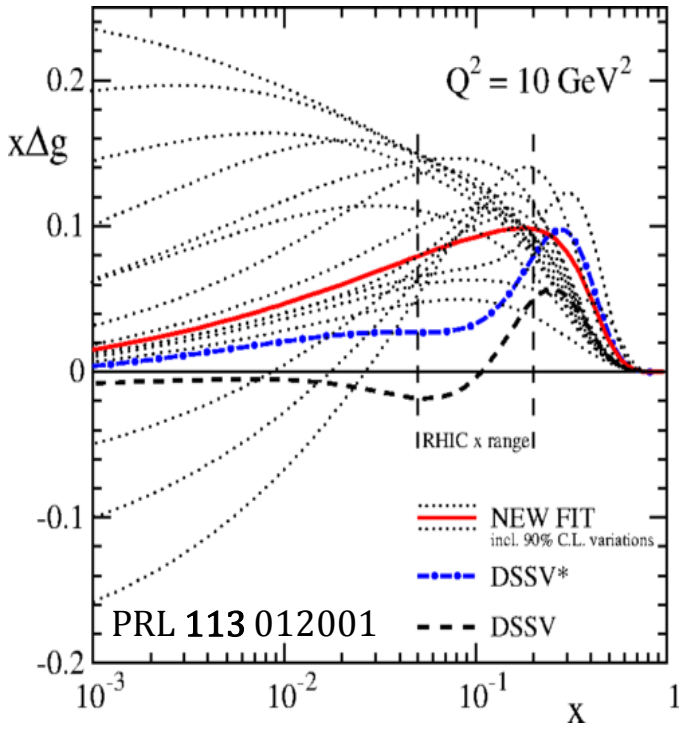
- Access to Δg via polarized PP collision and A_{LL} measurement.

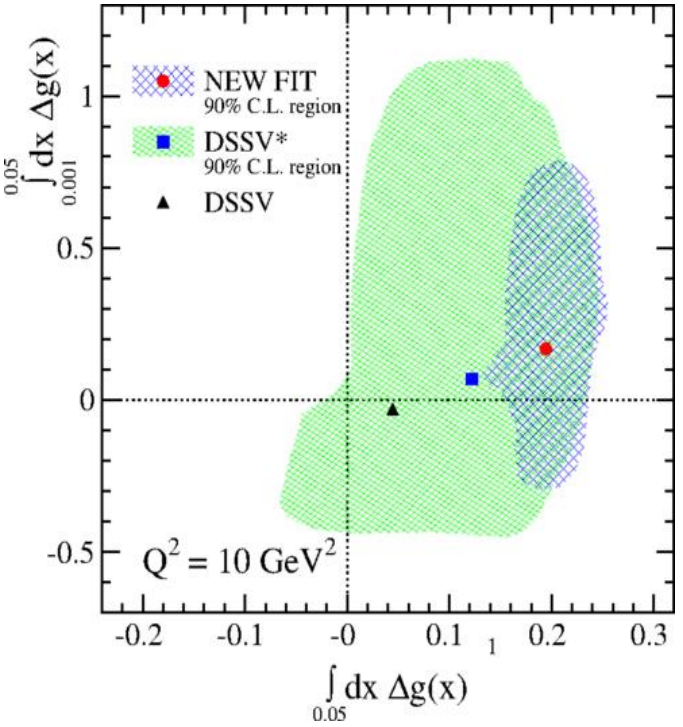
- RHIC $\sqrt{s} = 200$ GeV results

  PHENIX $A_{LL}^{\pi^0}$: 0.02<x, PRD **90** 012007

  Star A_{LL}^{Jet}: 0.05<x, PRL **100** 232003

1. Motivation





- Want to access lower x region!

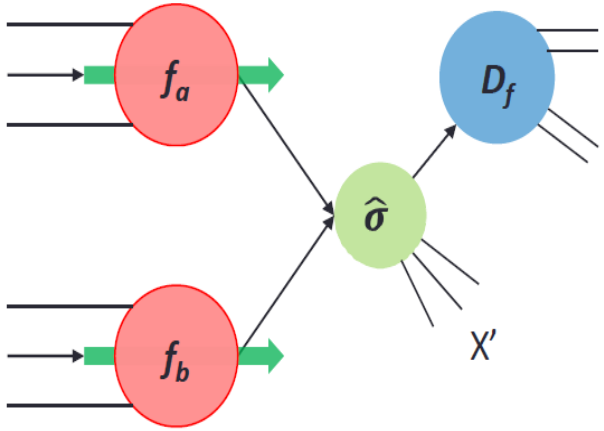
  1. mid-rapidity $A_{LL}^{\pi^0}$ $\sqrt{s} = 510$ GeV : 0.01 < x
  2. Forward-rapidity $A_{LL}^{EM\ cluster}$: 0.002<x

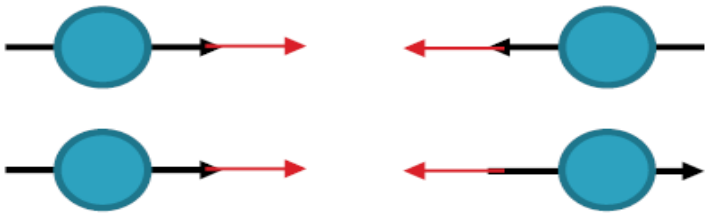
1. Motivation

- $A_{LL}{}^{h} = \frac{\sigma^{h}{}_{++} - \sigma^{h}{}_{+-}}{\sigma^{h}{}_{++} + \sigma^{h}{}_{+-}}$

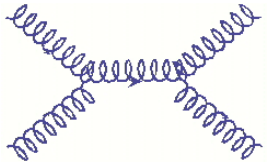
$$= \frac{\sum_{f_a, f_b, f} \Delta f_a \otimes \Delta f_b \otimes d\hat{\sigma}^{f_a f_b \to f X} \otimes D^{h}{}_{f}}{\sum_{f_a, f_b, f} f_a \otimes f_b \otimes \hat{\sigma}^{f_a f_b \to f X} \otimes D^{h}{}_{f}}$$

$$\approx A_{gg}\Delta g^2 + B_{gq}\Delta g \Delta q + C_{qq'}\Delta q \Delta q'$$



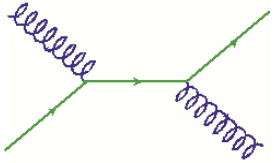


$gg \to gg$



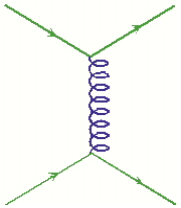
$$\propto \frac{\Delta g}{g}\frac{\Delta g}{g}$$

$gq \to gq$



$$\propto \frac{\Delta q}{q}\frac{\Delta g}{g}$$

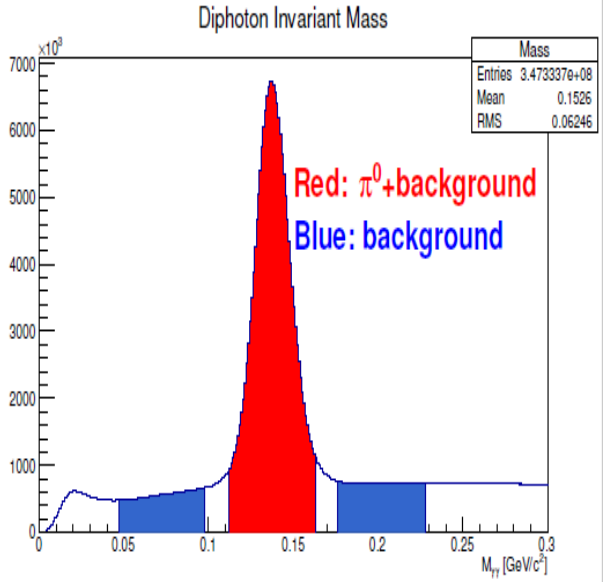
$qq \to qq$

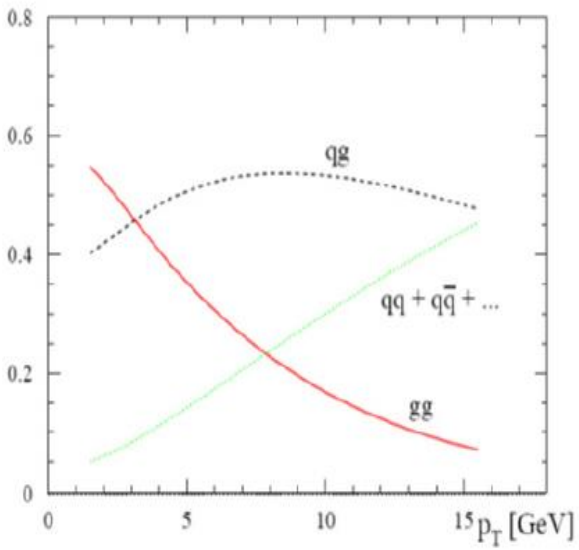


$$\propto \frac{\Delta q}{q}\frac{\Delta q}{q}$$

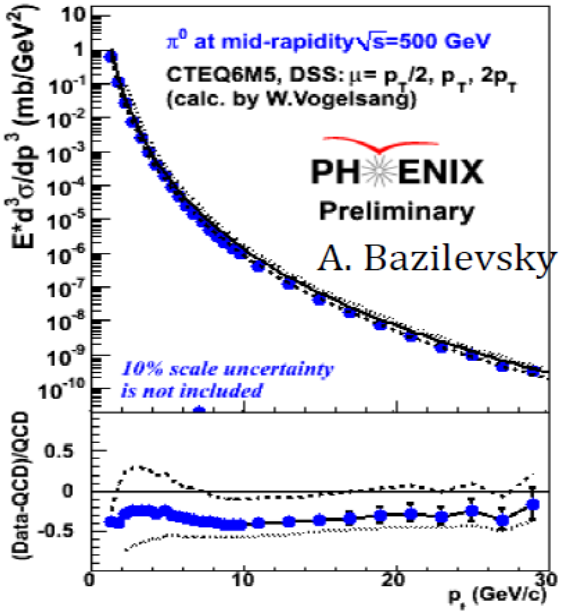
1. Motivation

- Advantage of π^0 channel:
  1. Large stat. and identifiable peak.
  2. Large fraction of π^0 from gg or gq scattering.
  3. Reasonably constrained fragmentation function.
  4. Safe to use factorization.

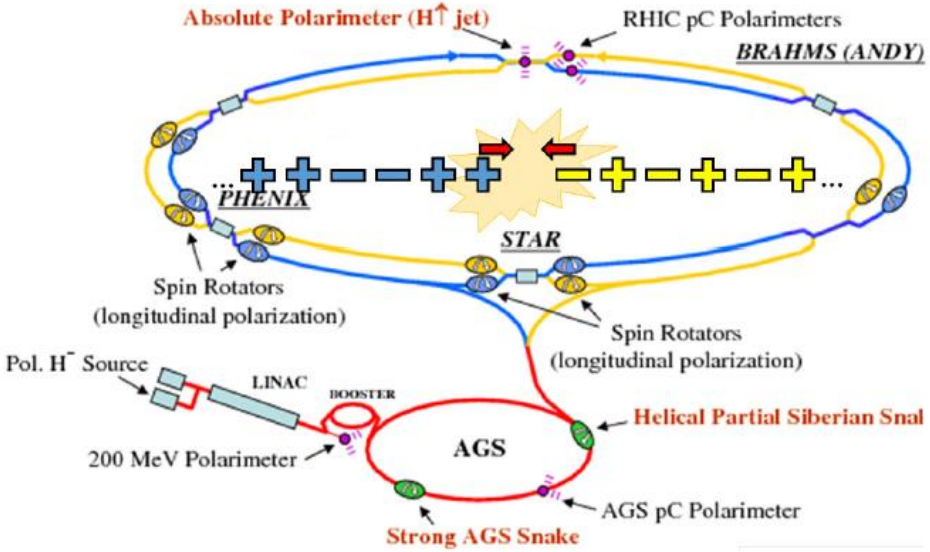




Subprocess fraction of π^0

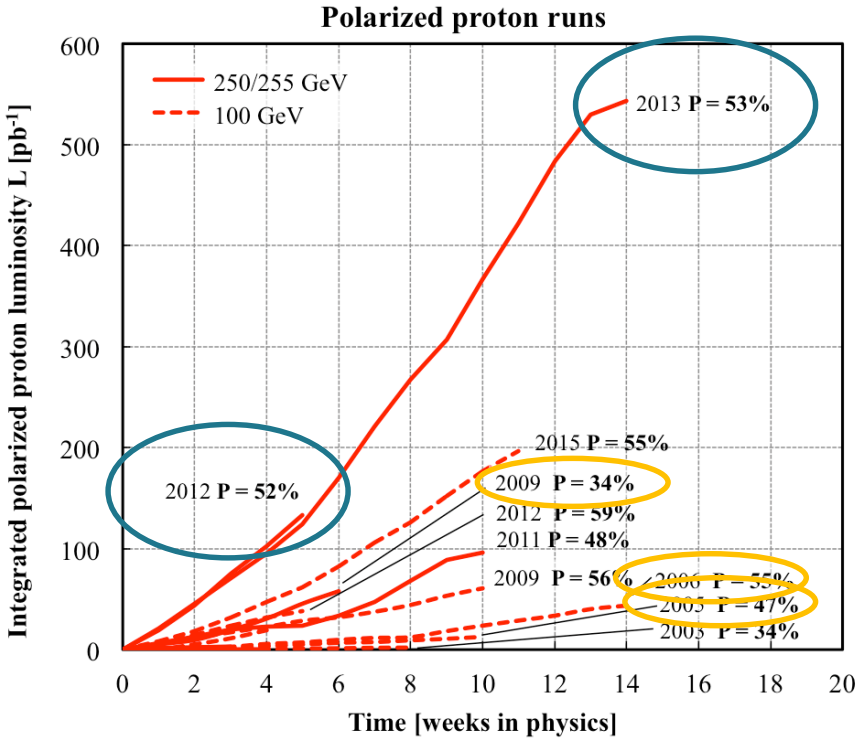


2. RHIC Spin Runs



- Polarized proton on bunch level.
  Bunch spacing: 106ns
  → Reduce syst.

- Large luminosity at $\sqrt{s} = 510$ GeV



2. PHENIX detector

- EMCal : PbSc, PbGl

  $|\eta| < 0.35, \Delta\phi = 90^0$

  measure energy, hit position and ToF.

  main γ detector.

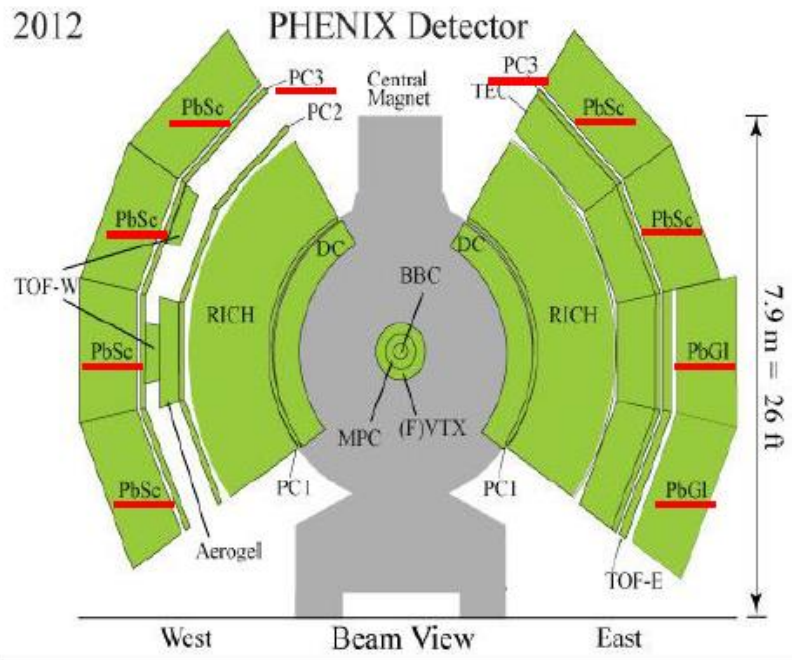
- PC3 : charged particle rejection.

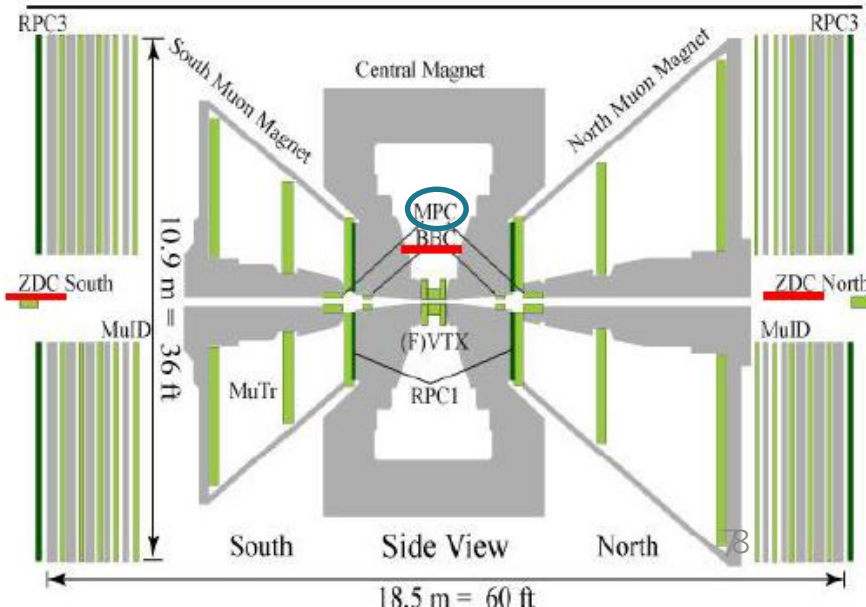
- BBC: minbias event trigger,

  vertex, event t0, luminosity

- ZDC: luminosity

* MPC: Forward-rapidity $A_{LL}^{EM\ cluster}$





3. Analysis procedure - A_{LL}

- N^{Peak} : events $0.112GeV < M_{\gamma\gamma} < 0.162GeV$ $\sim 2\sigma$

  N^{Side} : events $0.047GeV < M_{\gamma\gamma} < 0.097GeV$

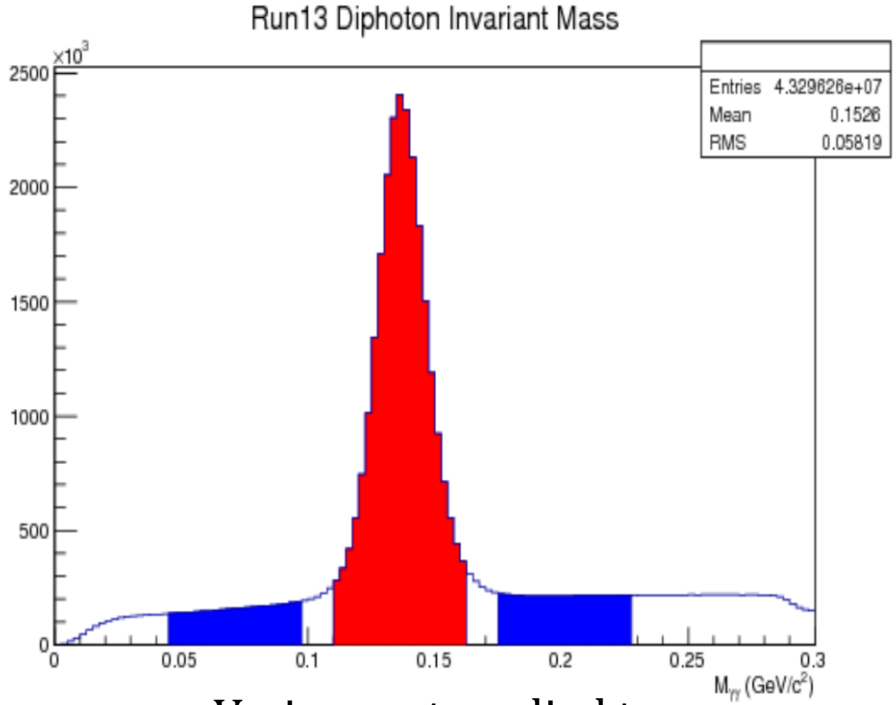
  or $0.177GeV < M_{\gamma\gamma} < 0.227GeV$

- $A^{Peak(Side)}{}_{LL} = \frac{\sigma_{++}-\sigma_{+-}}{\sigma_{++}+\sigma_{+-}}$

$$= \frac{1}{P_B P_Y} \frac{\frac{N_{++}^{peak(side)}}{L_{++}} - \frac{N_{+-}^{peak(side)}}{L_{+-}}}{\frac{N_{++}^{peak(side)}}{L_{++}} + \frac{N_{+-}^{peak(side)}}{L_{+-}}}$$

$$= \frac{1}{P_B P_Y} \frac{N^{Peak(Side)}{}_{++} - R N^{Peak(Side)}{}_{+-}}{N^{Peak(Side)}{}_{++} + R N^{Peak(Side)}{}_{+-}}$$

Where $R = \frac{\sum BBC_{++}}{\sum BBC_{+-}}$



Various cut applied to reduce background

3. Analysis procedure - A_{LL}

- To correct asymmetry from background,

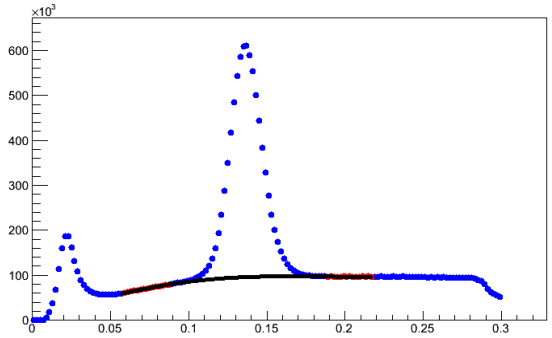
  $A_{LL}^{\pi^0} = \frac{A_{LL}^{Peak} - r A_{LL}^{Side.}}{1 - r}$

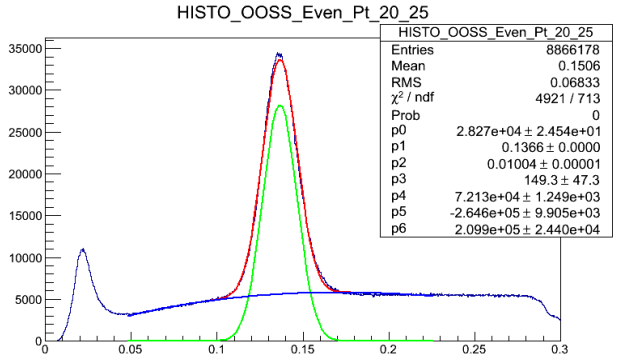
  r = background fraction under π^0 peak.

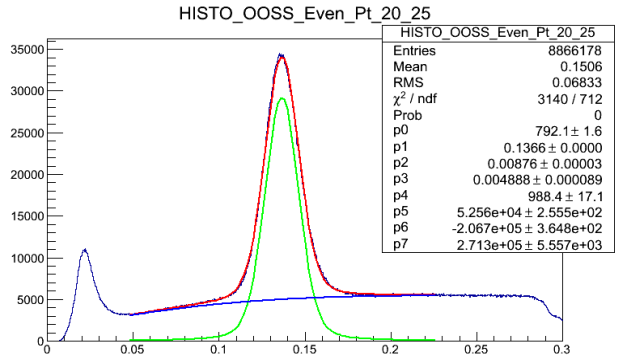
- To estimate r, GPR, Gaus+Pol3 or Voigt+Pol3 fitting.

  GPR: best estimator ∵ no assumption of functional form.

  To be conservative, small discrepancy of r from fittings → syst.







3. Analysis procedure – ΔRelative luminosity

- Relative luminosity, $R = \frac{\sum BBC_{++}}{\sum BBC_{+-}}$:

  underlying syst. source of all A_{LL} measurement

  cf) $A_{LL} = \frac{1}{P_B P_Y} \frac{N_{++} - RN_{+-}}{N_{++} + RN_{+-}}$

- To measure relative luminosity precisely,
  1. High stat.
  2. Low background.
  3. Same acceptance of detector is being used.
  4. No helicity dependence, i.e. zero A_{LL}.

  Condition 1, 2, 3 are trivial, but condition 4 is not easy.

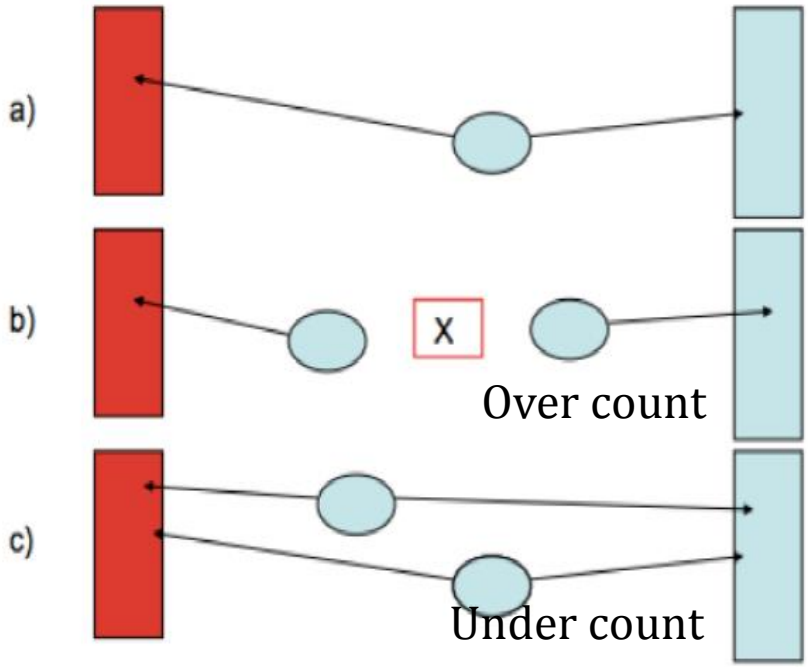
- Need to measure A_{LL} of luminosity detector.

3. Analysis procedure – ΔRelative luminosity

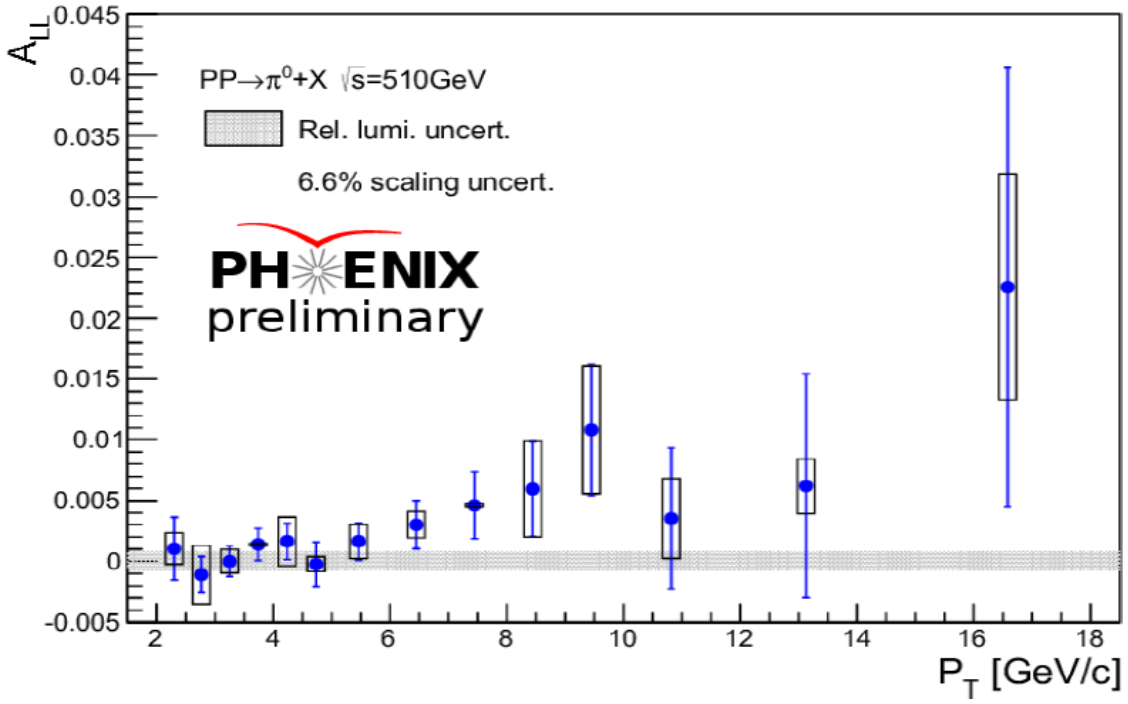
- To measure A_{LL} of luminosity detector, $A_{LL}^{ZDC/BBC}$ is measured.

- Luminosity miscounted
  : piled collisions, single sided collisions, or vertex width and resolution
  fully corrected to obtained $A_{LL}^{ZDC/BBC}$.

- $\Delta A_{LL}(syst.Rel.Lumi)$
  $\sim 50\%$ $\Delta A_{LL}(stat.)$ of richest P_T bin

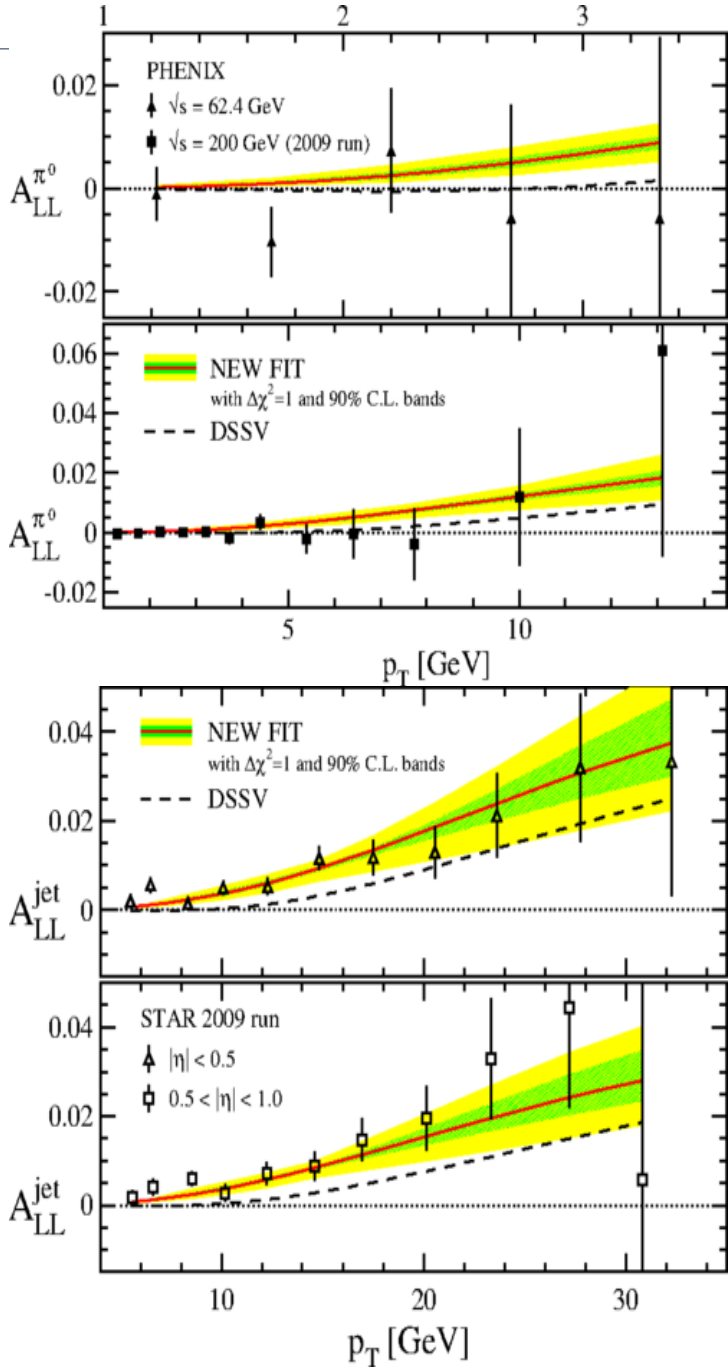


4. Preliminary Results

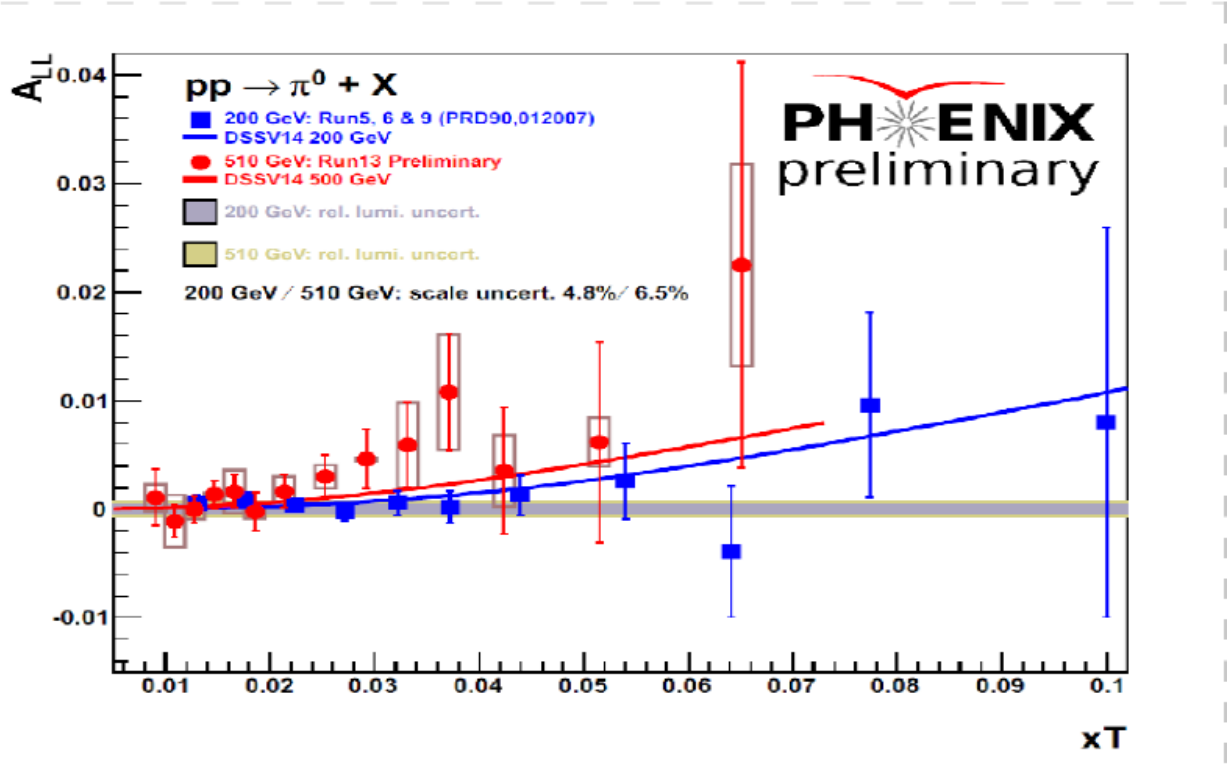


- Non-zero asymmetry is measured.

Note) Not all statistics included.



4. Preliminary Results



- $A_{LL}^{\pi^0}$ at $\sqrt{s} = 510$ GeV approaches two times smaller $x_T (= \frac{2P_T}{\sqrt{s}})$

  → Significant contribution on global analysis is expected.

5. Plans for finalization and publication

- In preliminary result,
  only Run13 and single triggered (ERT 4x4c) data was used
  → In final result, Run12 510 GeV and every Run13 data have been used.
  Significant of statistical gain has been achieved.

- With more detail correction of luminosity miscounted by vertex cut,
  $\Delta A_{LL}(syst.Rel.Lumi)$ has been reduced much.

- Cross check between two analyzers has been done.

- Now preparing publication is ongoing.

6. Summary

- Measurement of $A_{LL}^{\pi^0}$ is good tool to constrain Δg.

- To expand experimental sensitivity to lower x region,
  measurement at higher energy, or at forward region have been planned.

- Preliminary result of mid-rapidity $A_{LL}^{\pi^0}$ at $\sqrt{s} = 510$ GeV has been released.
  Non-zero asymmetry is observed.
  Two times smaller x_T.

- Final result is ready.
  Full statistics analysis.
  Reduced syst. from Rel. Lumi by detail correction of luminosity miscount by vertex cut.
  Cross check.

- Pushing for publication!

Back Up

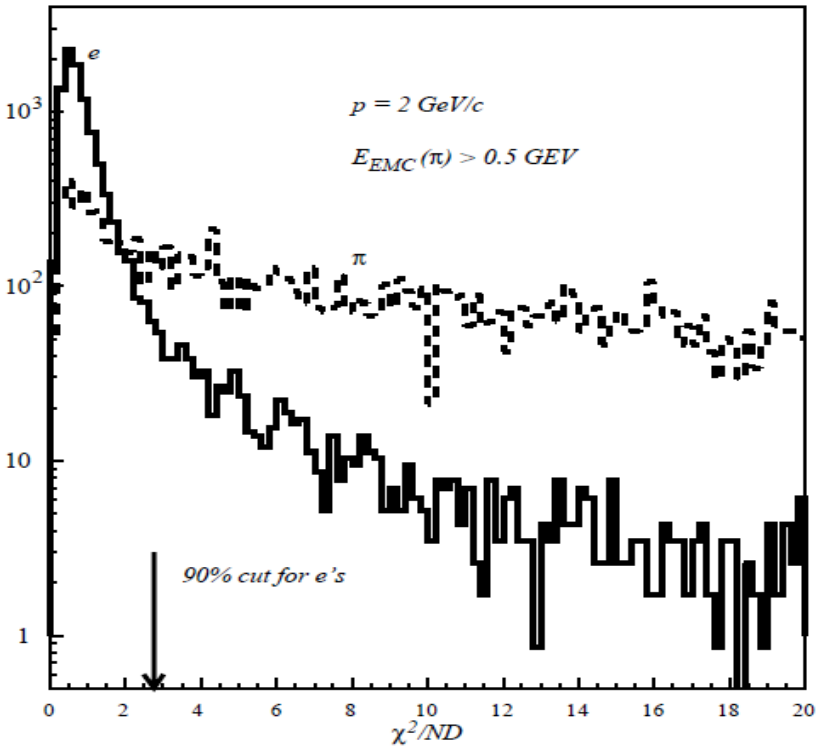
Shower shape Cuts

- To reduce background from hadronic event.

- Compare measured shower shape with shower of electron beam by calculating
$\chi^2 = \sum_i (E_i{}^{elec} - E_i{}^{meas})^2 / \sigma_i{}^2$

- Conventional 2% cut is applied.
(= Level of killing 2% of real EM)

χ^2 distribution of e^-, π



ToF Cuts

- -15ns<ToF<15ns for PbSc, -10ns<ToF<10ns for PbGl.

- To reduce background from ghost cluster.

- Ghost cluster : cluster from previous bunch crossing.
  Cluster in EMCal can remain up to 3 bunch crossing.
  → Source of background.

- Ghost cluster can make different background for different spin patterns.
  → Systematic difference of A_{LL} of different spin pattern has been observed.

- Ghost cluster can't associate BBC T0 and wider ToF distribution.
  Thus ghost cluster can be rejected by ToF cuts.

- Pattern separated analysis has been done.

Charge Veto Cuts

- To reject charged hadrons.

- (a) : photons that convert outside of the magnetic field prior to the EMCal, and have very small θ_{cv}

  (b) : charged hadrons that bend in the magnetic field, and so have moderate sized θ_{cv}.

  (c) : photons that do not convert, and are randomly associated with a different particle's PC3 hit.