$A_{LL}^{\pi^{\pm}}$ at mid-rapidity in polarized p+p at $\sqrt{s}$ = 510 GeV with PHENIX

Taebong Moon
for the PHENIX Collaboration

Yonsei Univ./RIKEN

October 19th 2015

Introduction : Spin Composition of Proton

- Naive model:

  - Proton spin carried out only by valence quarks.

  - Experiments in the 1980s, showed that quarks contribute only ~30% of proton spin. → Spin Crisis!

- Current understanding:

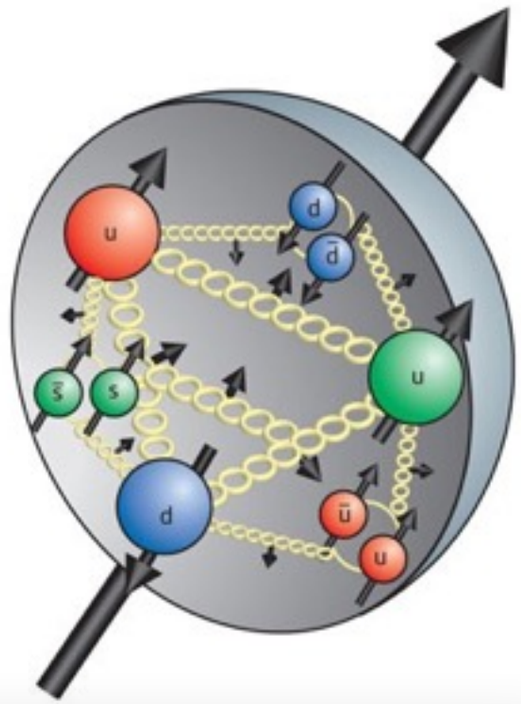
$$Proton\ Spin = \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \boxed{\Delta G} + L_{q+g}$$

- ΔG:

  - Largely unconstrained.

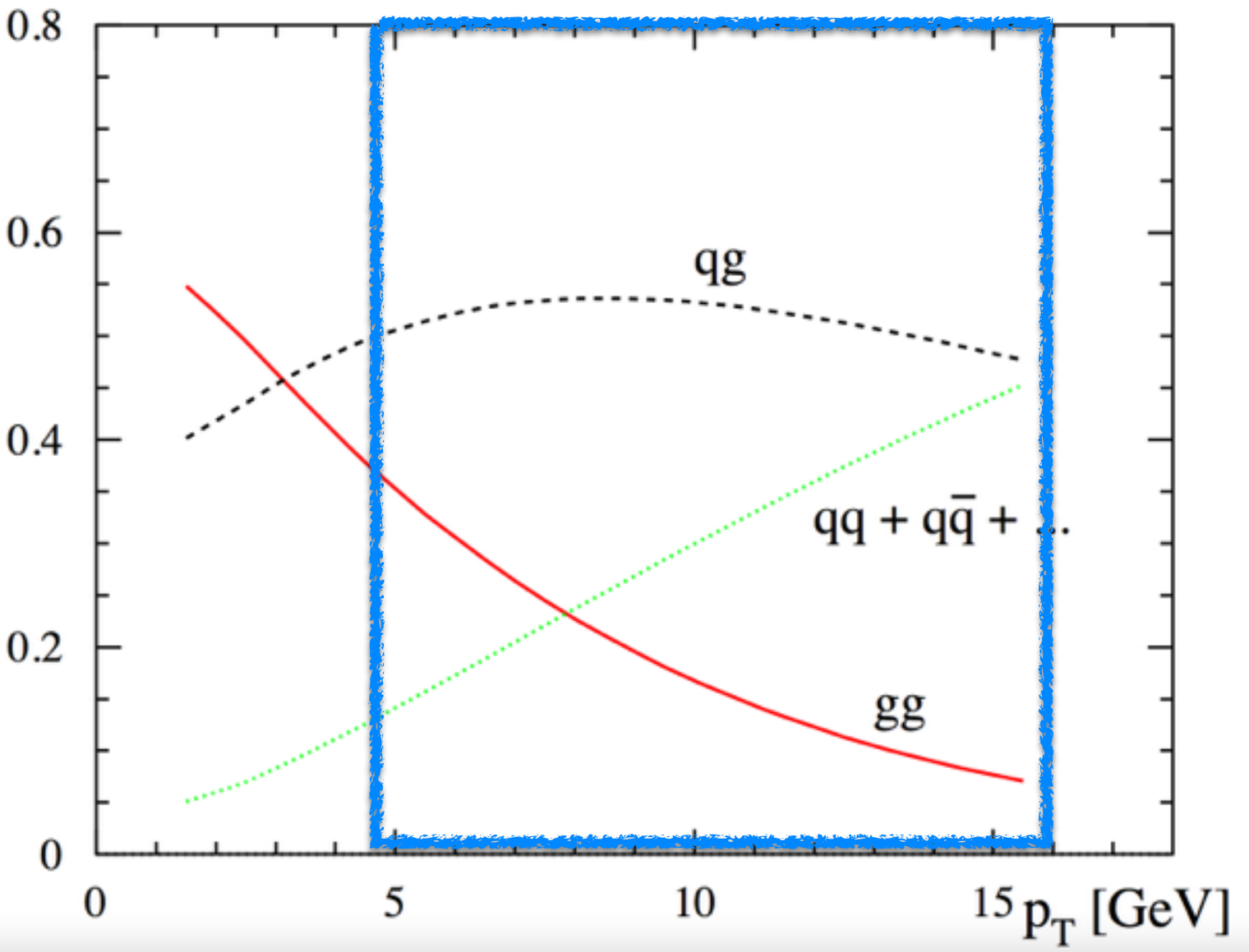
  - has been measured by various probes:

  - π^0, $\pi^{\pm}$, η, γ_{direct} and e from heavy flavor.



Introduction : "Directly" accessing ΔG via A_{LL} in p+p

$$A_{LL} = \frac{d\Delta\sigma}{d\sigma} \approx a_{gg}\Delta g\Delta g + a_{qg}\Delta q\Delta g$$



Introduction : "Directly" accessing ΔG via A_{LL} in p+p

If we also assume a favored fragmentation for π^+ and π^-,

$$D^{\pi^+}_{u,\,\bar{d}} >> D^{\pi^+}_{\bar{u},\,d,\,s,\,\bar{s}} \qquad D^{\pi^-}_{d,\,\bar{u}} >> D^{\pi^-}_{\bar{d},\,u,\,s,\,\bar{s}}$$

$$A_{LL}^{\pi^+} \approx a_{gg}\Delta g\Delta g + a_{ug}\Delta u\Delta g$$

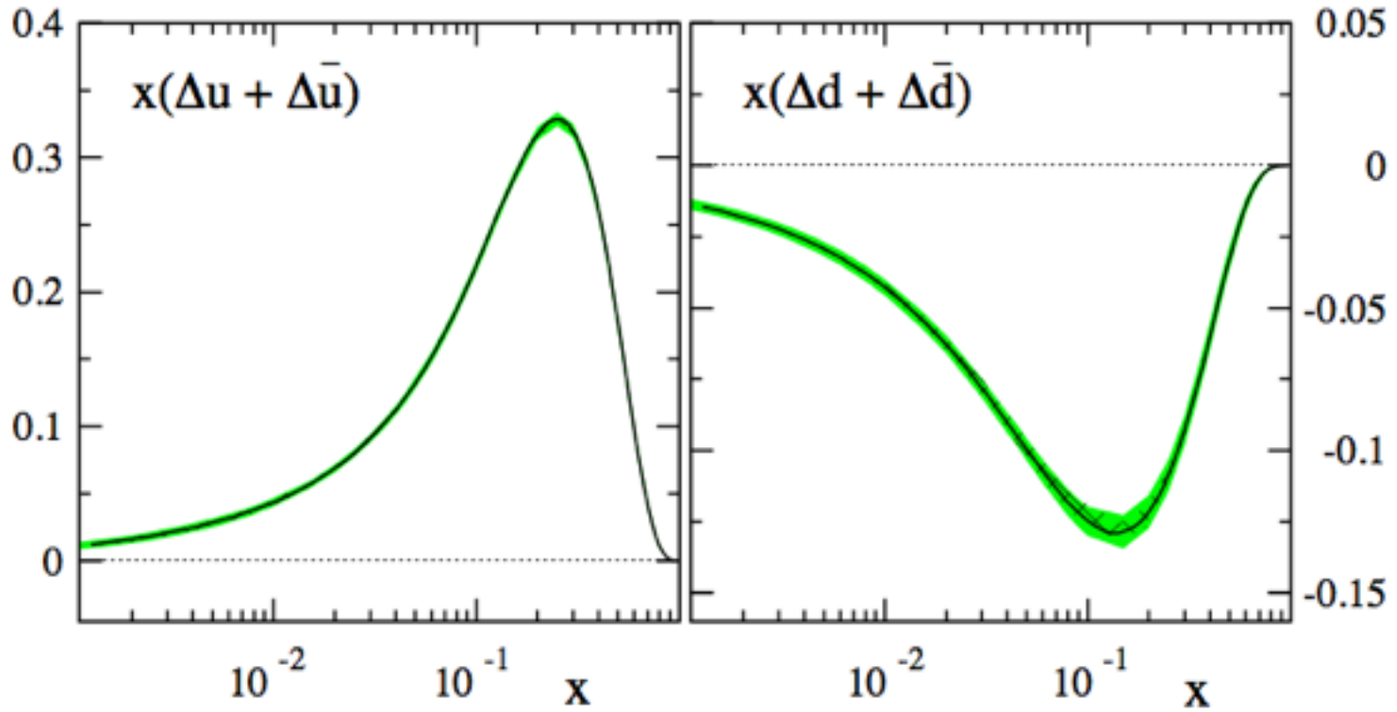
$$A_{LL}^{\pi^-} \approx a_{gg}\Delta g\Delta g + a_{dg}\Delta d\Delta g$$

Introduction : "Directly" accessing ΔG via A_{LL} in p+p

$$a_{qg} > 0$$

$$\Delta u > 0$$

$$\Delta d < 0$$

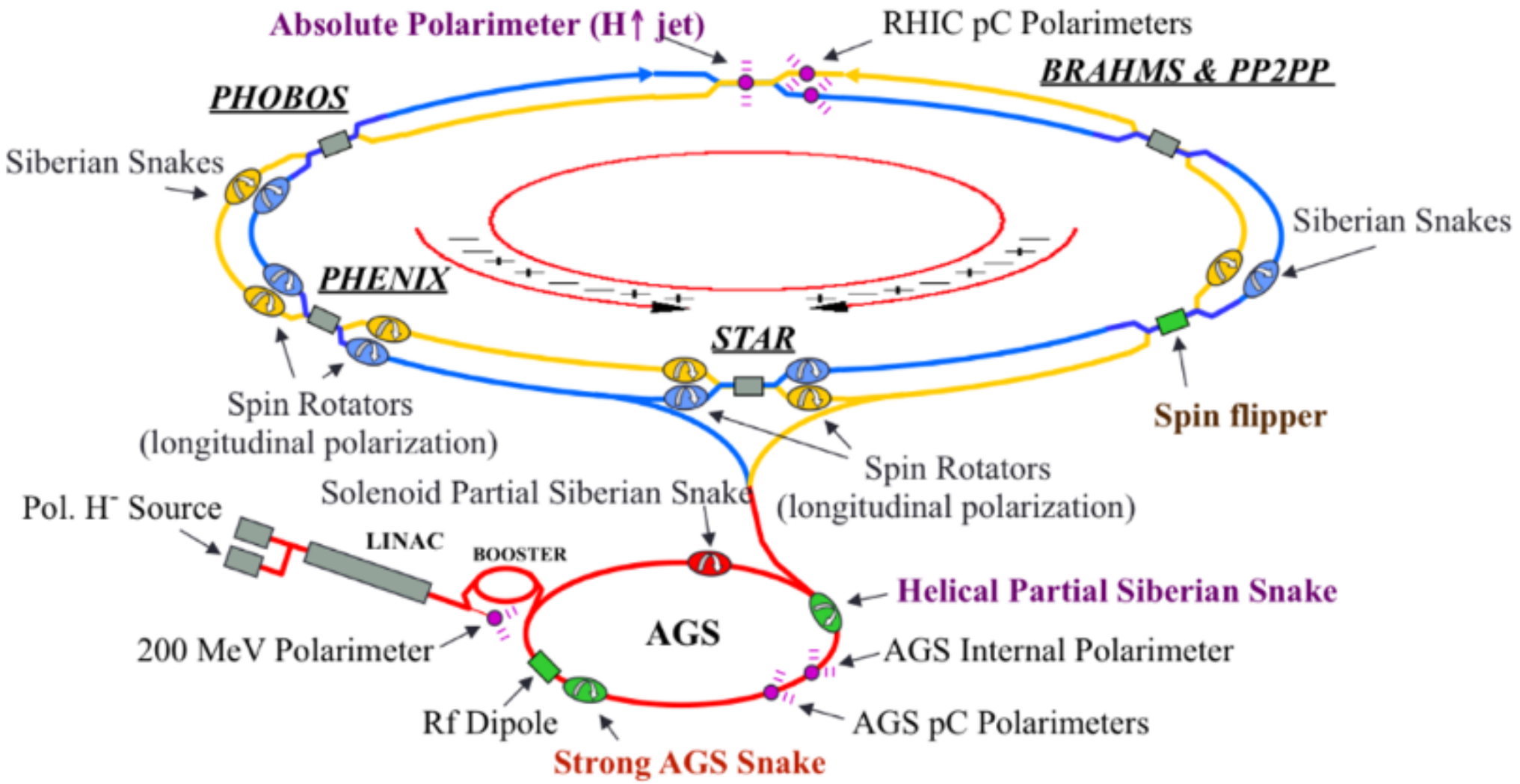


$$A_{LL}^{\pi^+} \approx a_{gg}\Delta g\Delta g + a_{ug}\Delta u\Delta g$$

$$A_{LL}^{\pi^-} \approx a_{gg}\Delta g\Delta g + a_{dg}\Delta d\Delta g$$

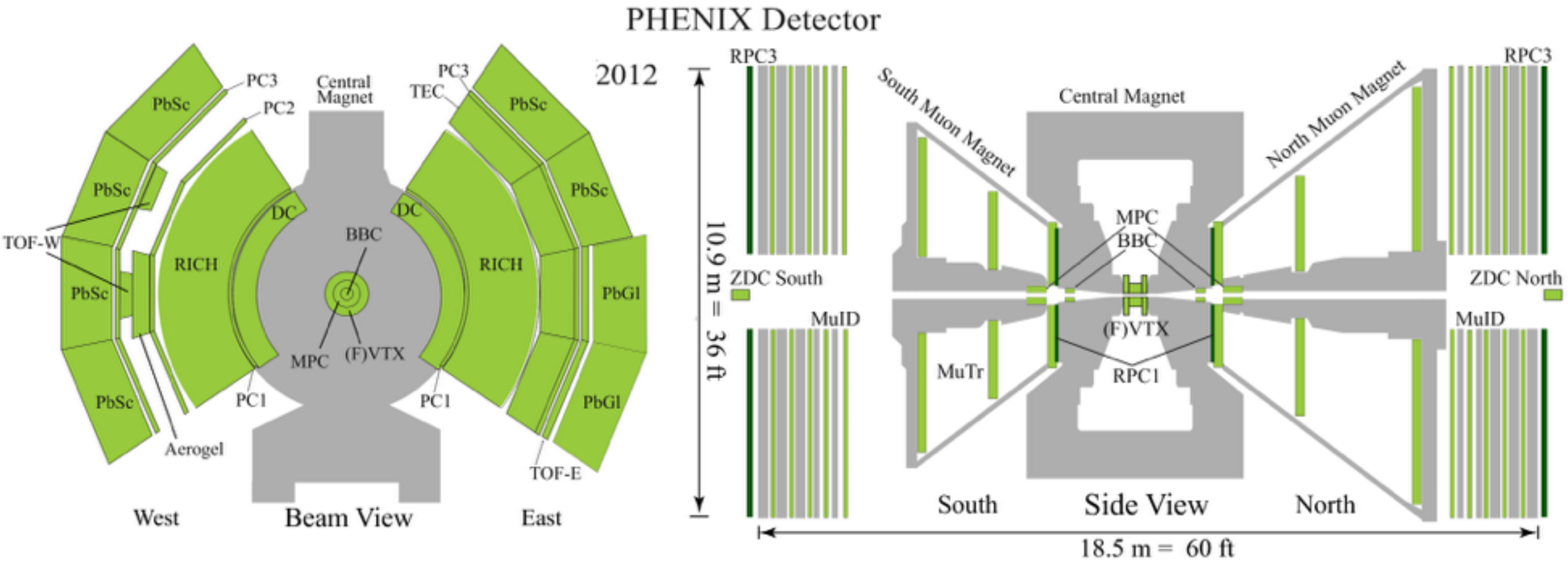
$$\Delta g > 0 \rightarrow A_{LL}^{\pi^+} > A_{LL}^{\pi^-}$$ and vice versa

RHIC



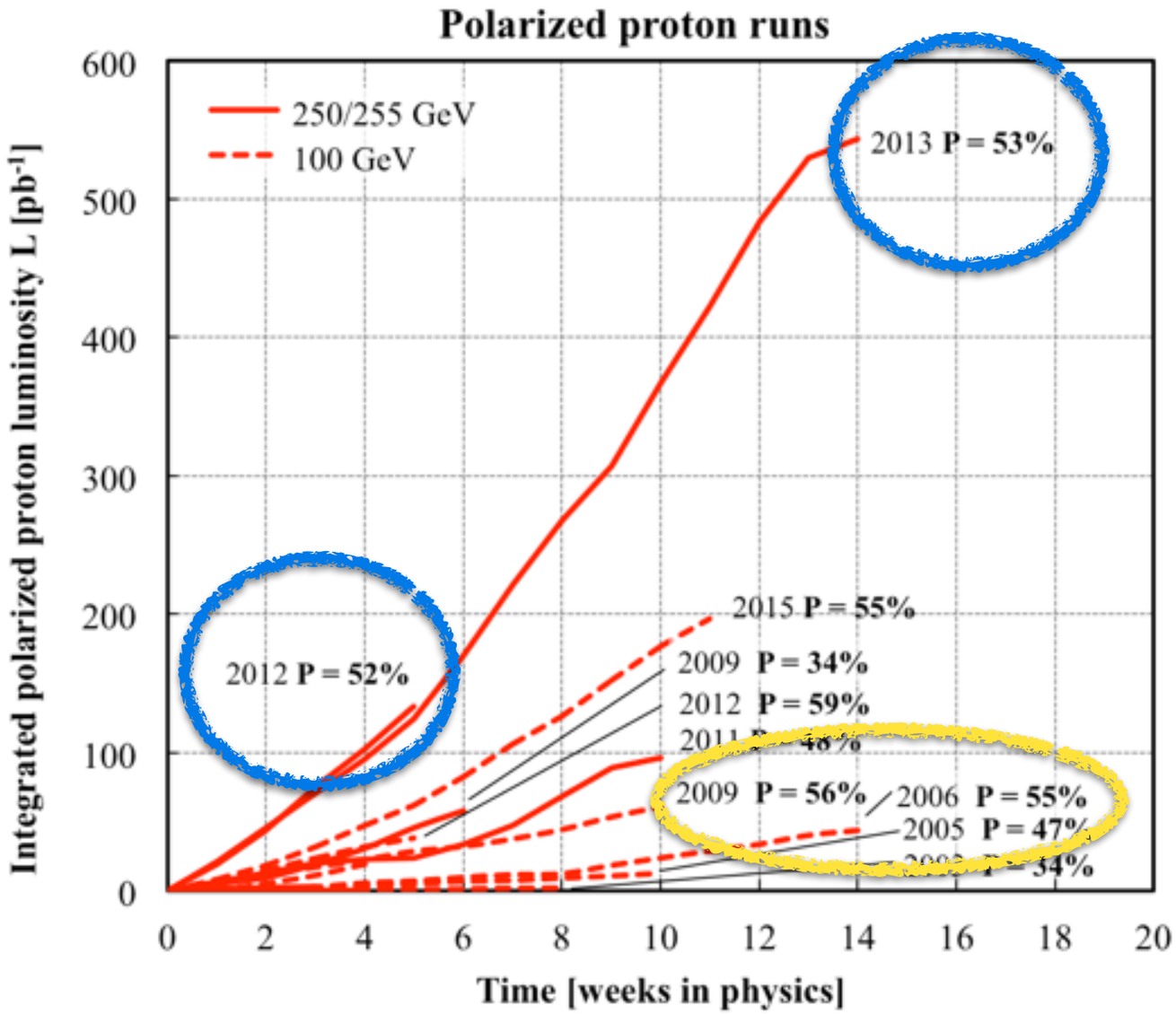
- World FIRST polarized p+p collider
  - Up to $\sqrt{s}$ = 510 GeV
  - Integrated luminosity 150 pb^{-1}, polarization ~ 56% at $\sqrt{s}$ = 510 GeV (2013)
  - Longitudinal or transverse polarization

PHENIX



- Tracking
  - VTX, DC and PC
- Luminosity
  - BBC and ZDC
- PID
  - RICH and EMCal
- Acceptance
  - $|\eta|<0.35$, $\Delta\phi = 2 \times \pi/2$

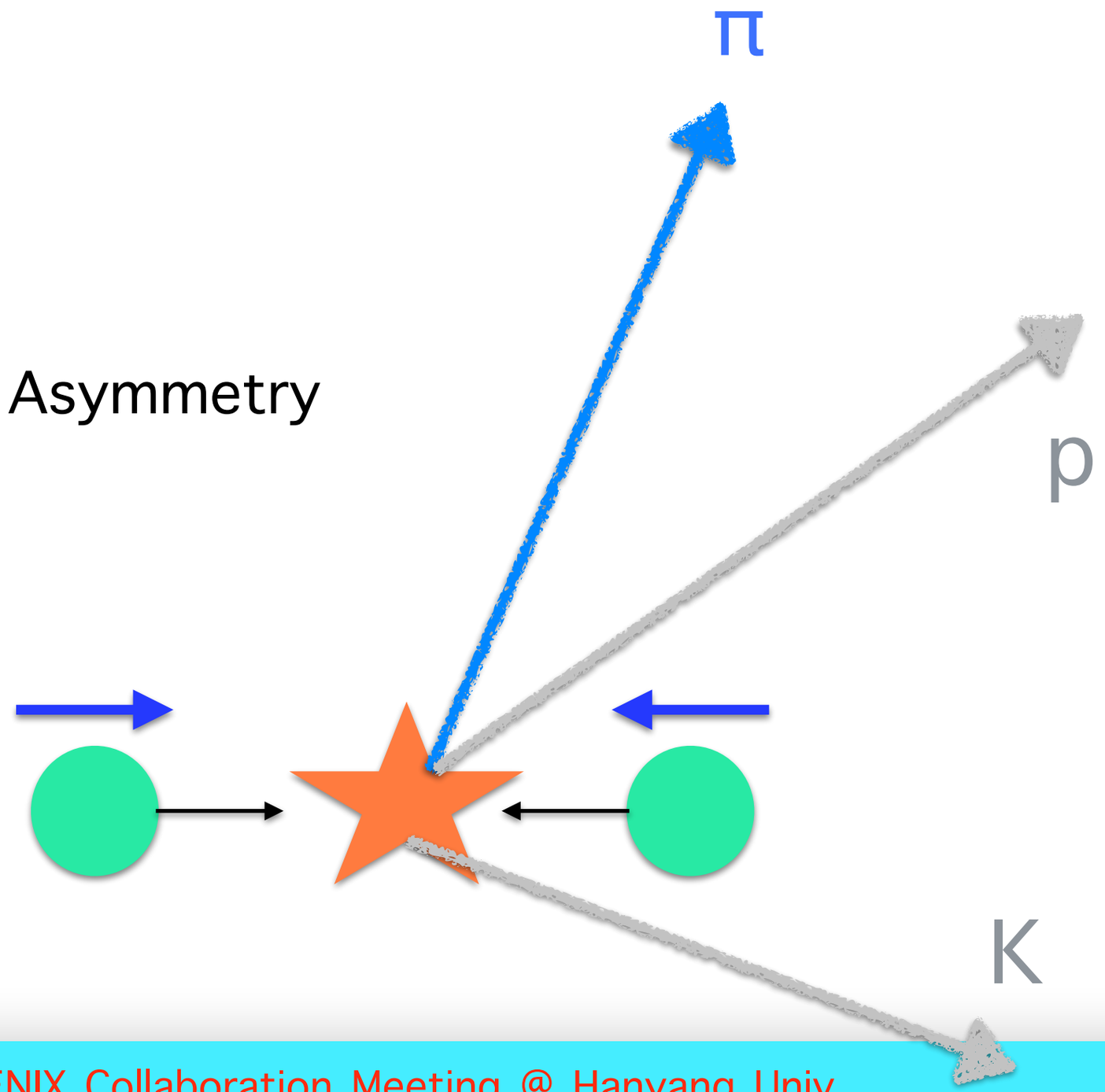
Datasets



- 20(2012) and 108(2013) pb^{-1} polarized p+p data available.
- In 2013 dataset, charged pion analysis with ~ 4G events analysed.
- Triggering : “EMCal” and “EMCal RICH” Triggers used.

Analysis procedure

1. Data selection
2. Event cut
3. Particle ID
4. Measurement of Asymmetry



(1) Data selection

- Data sample: Run13 510 GeV pp ERT
- 1008 physics runs available in AnaTrain
- 782 runs passed QA and analyzed
- ERT triggers analysed:
  - ERTLL1_4x4a&BBCLL1(noVtx)
  - ERT_4x4b
  - ERT_4x4c&BBCLL1(noVtx)
  - ERTLL1_E&BBCLL1(narrow)

(1) Data selection

- At this moment I analyzed 782 runs passed by Inseok.

1. DAQ time > 10 minutes
2. Live time > 0.5
3. Only runs in the spin database
4. Polarization on both beams > 10%
5. GL1p and Starscaler agreement
   - 0.998 < GL1p scaler counts / Star scaler counts < 1.002
   - Chi2 of constant fitting on the ratio above < $2.5X10^3$

(2) Event cuts

- Event cut:
  - |BBCZ| < 30cm
  - ERTLL1_4x4a&BBCLL1(noVtx)
  - ERT_4x4b
  - ERT_4x4c&BBCLL1(noVtx)
  - ERTLL1_E&BBCLL1(narrow)

(3) $\pi^{\pm}$ ID - Background sources

- $e^{\pm}$ from the collision vertex and beam pipe conversions

  - primary $e^{\pm}/\pi^{\pm}$ and $\mu^{\pm}/\pi^{\pm}$ production ratios < 10^{-3} [ANA311]

  - emce/mom < 0.9 & EM shower shape cut < 0.2

- Fake track & $\pi^{\pm}$ from hadron shower at pole tips

  - DC track quality = 31 or 63, and |DC zed| < 75 cm

- Charged hadron: K (>16.5GeV) and p (>29GeV)

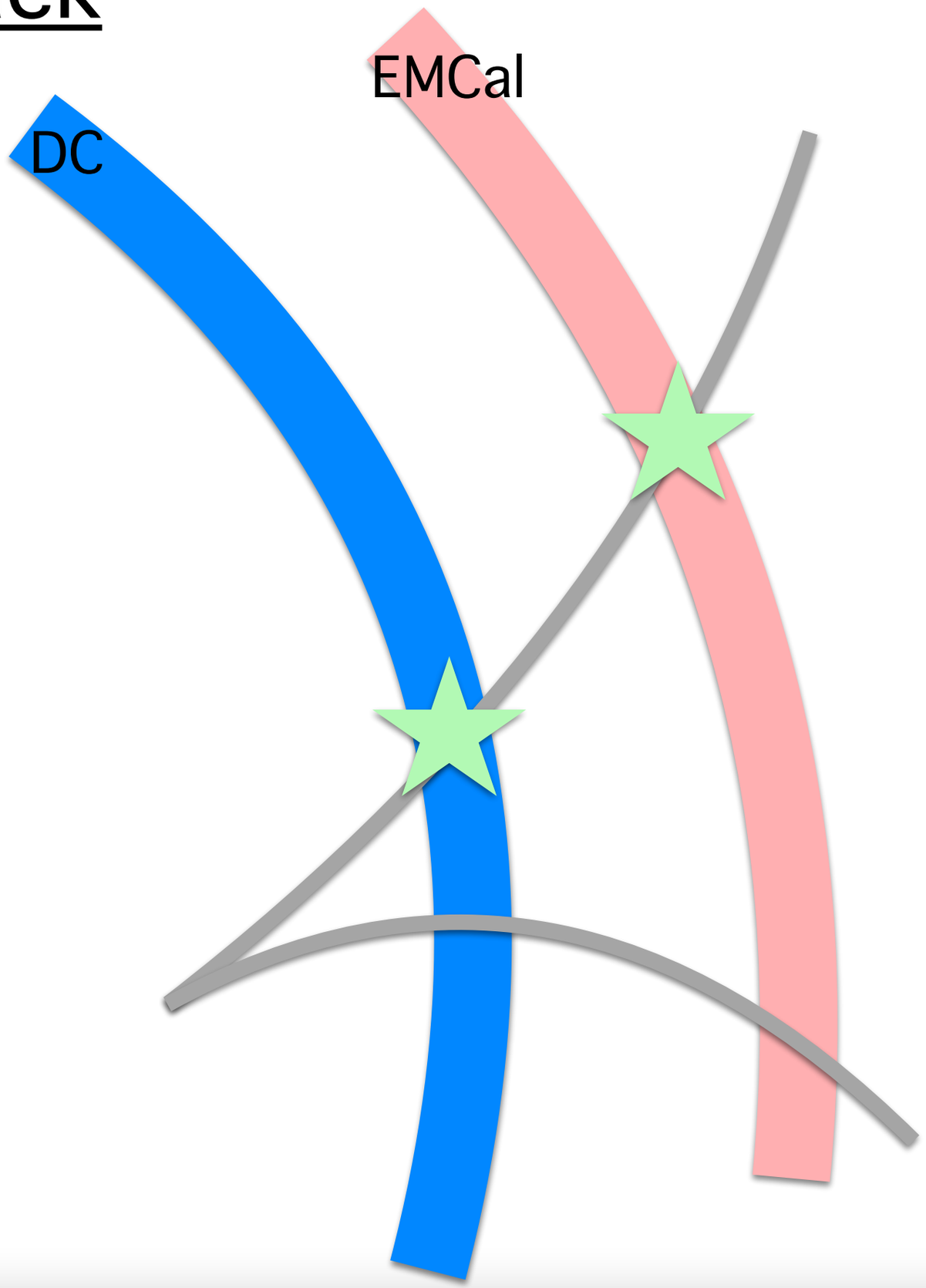
  - RICH PMT hit (N1) > 0

- "Fake" high pT backgrounds by decay-in-flight and photon conversion

  - require large energy deposition in EMCal -> pT dependent emce

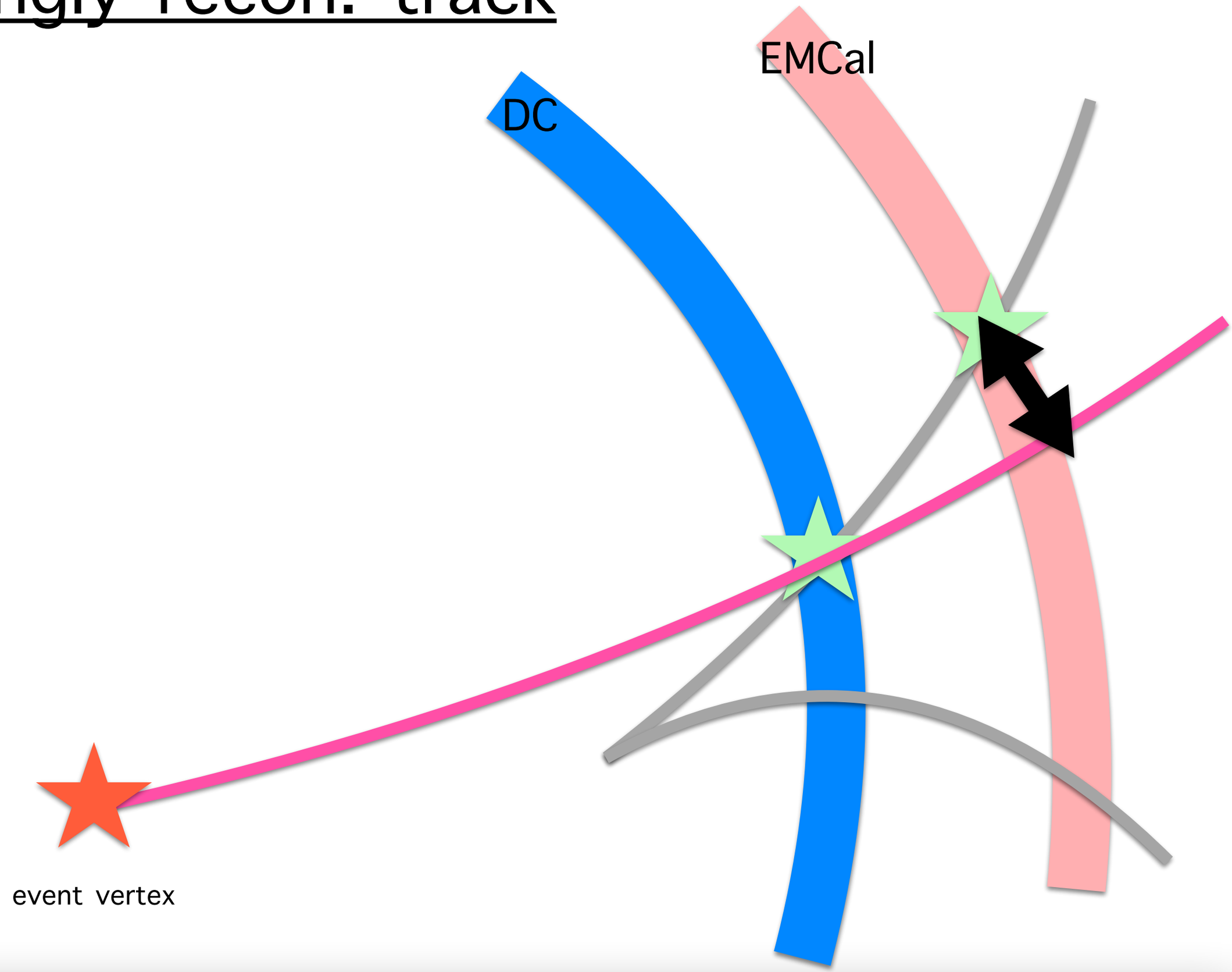
  - EMCal and PC3 matching cuts

Wrongly recon. track



event vertex

Wrongly recon. track



(3) $\pi^{\pm}$ ID - Background sources

- Track cuts:

  - RICH n1 > 0

  - emce/mom < 0.9

  - emce > 0.3 + 0.15pT

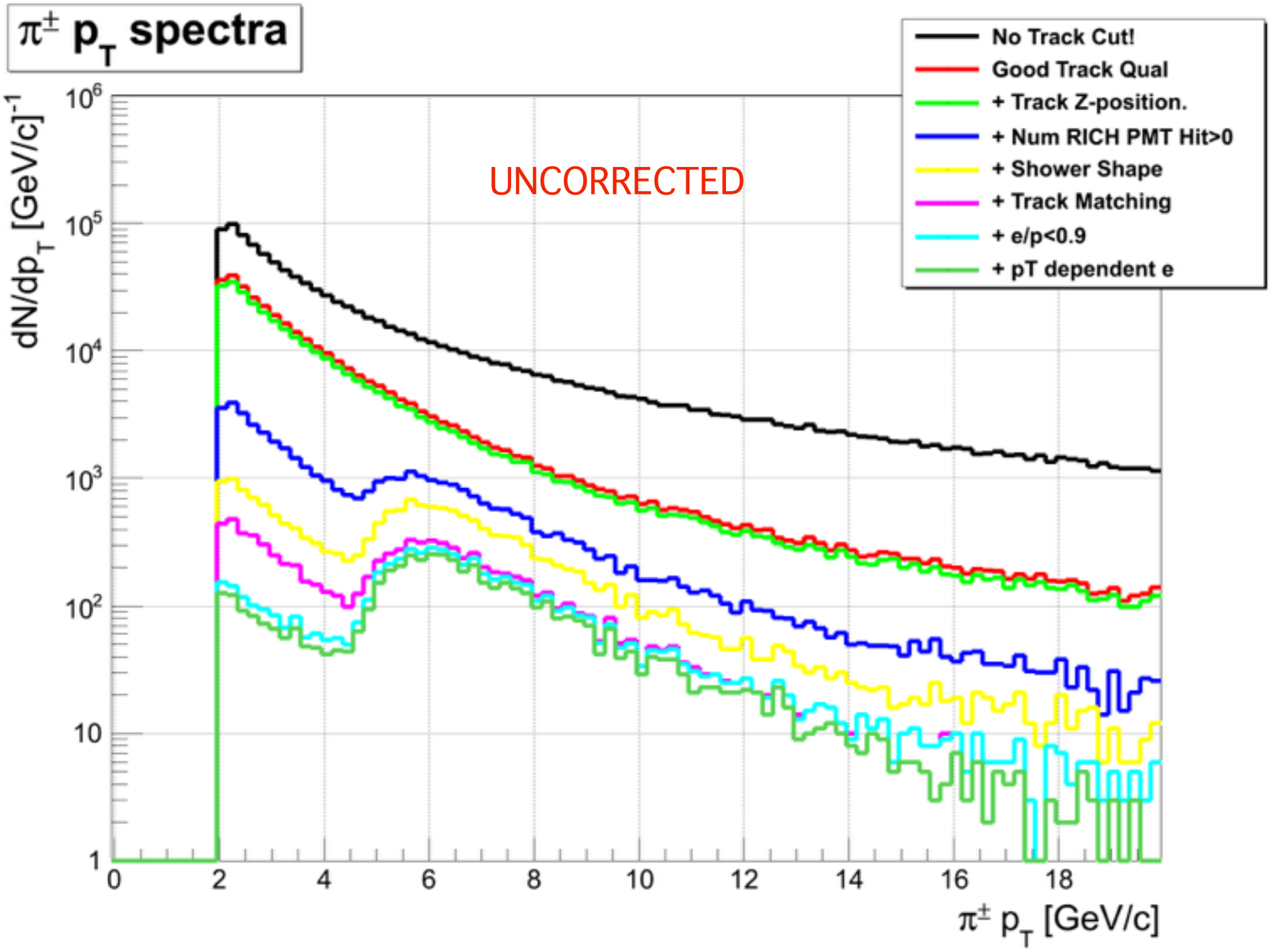
  - prob < 0.2

  - DC track quality = 31 || 63

  - |DC track zed| < 75cm (Sookhyun applied ±70 cm cut)

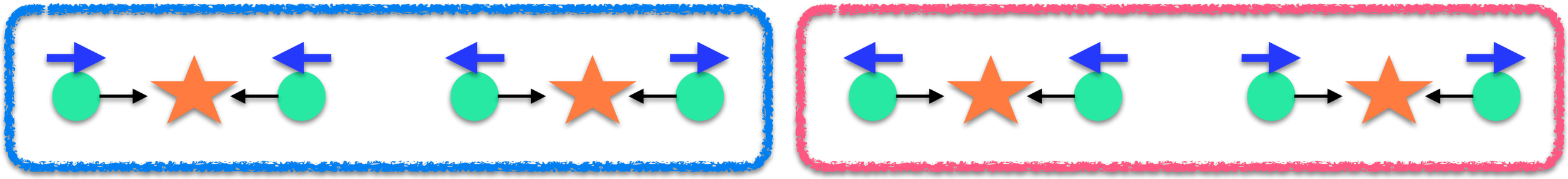
  - 3 sigma PC3 and EMcal matching cuts

Particle ID (one data sample)



- $\pi^{\pm}$ turn on at above 4.7 GeV (threshold p for producing Cerenkov light).

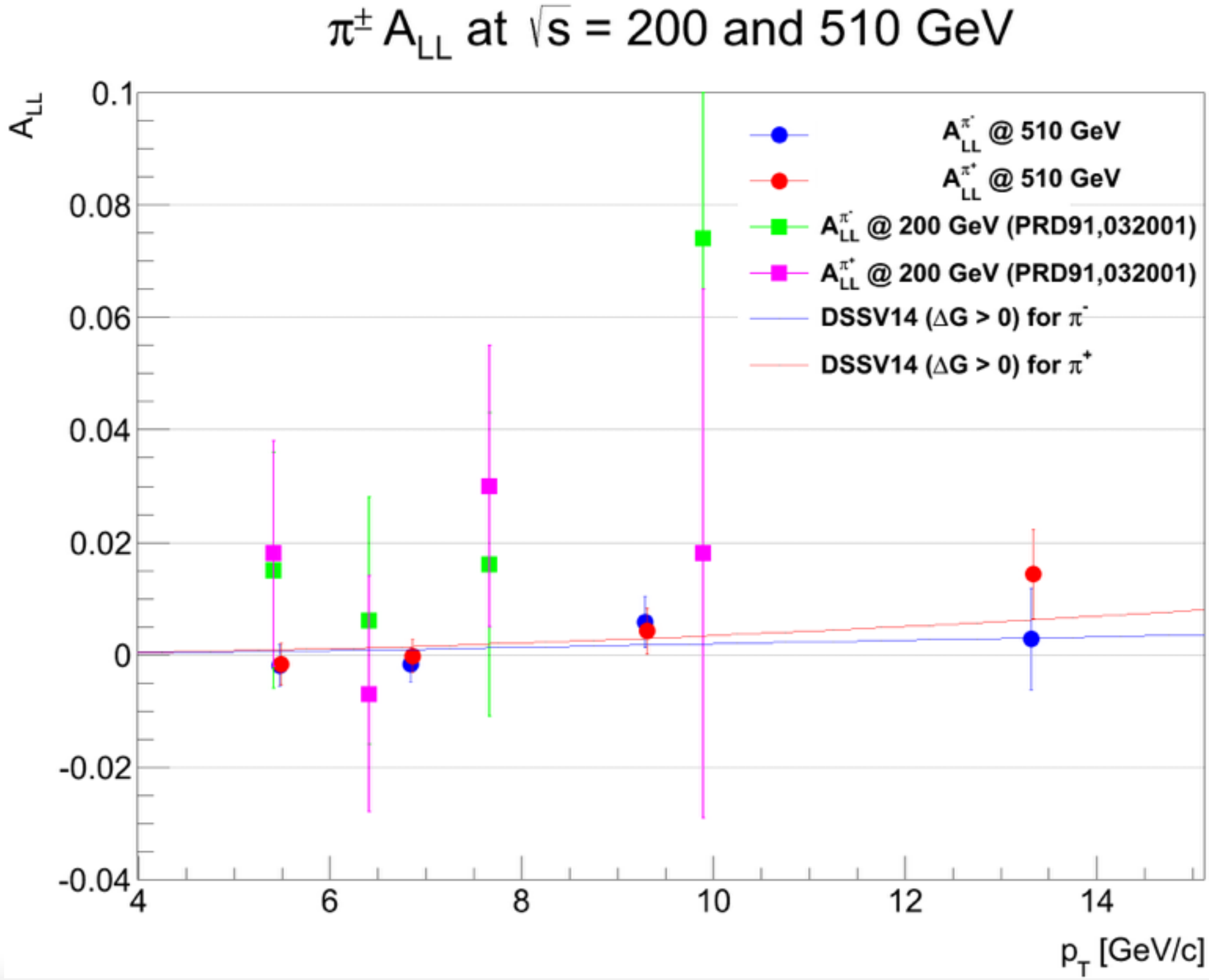
Measuring A_{LL} in experiment



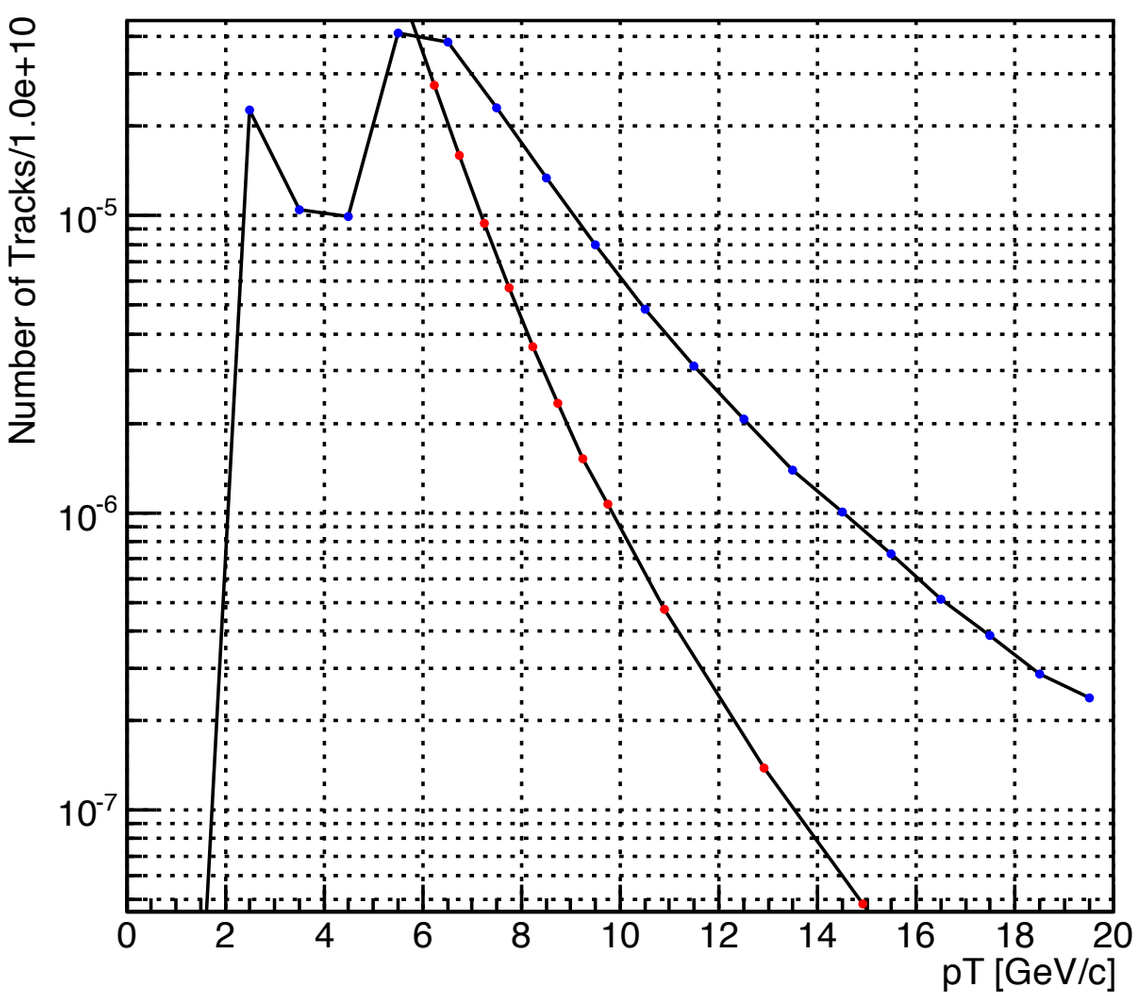
$$A_{LL}^{\pi} = \frac{d\Delta\sigma}{d\sigma} = \frac{1}{|P_B P_Y|} \frac{N_{++} - R N_{+-}}{N_{++} + R N_{+-}}$$

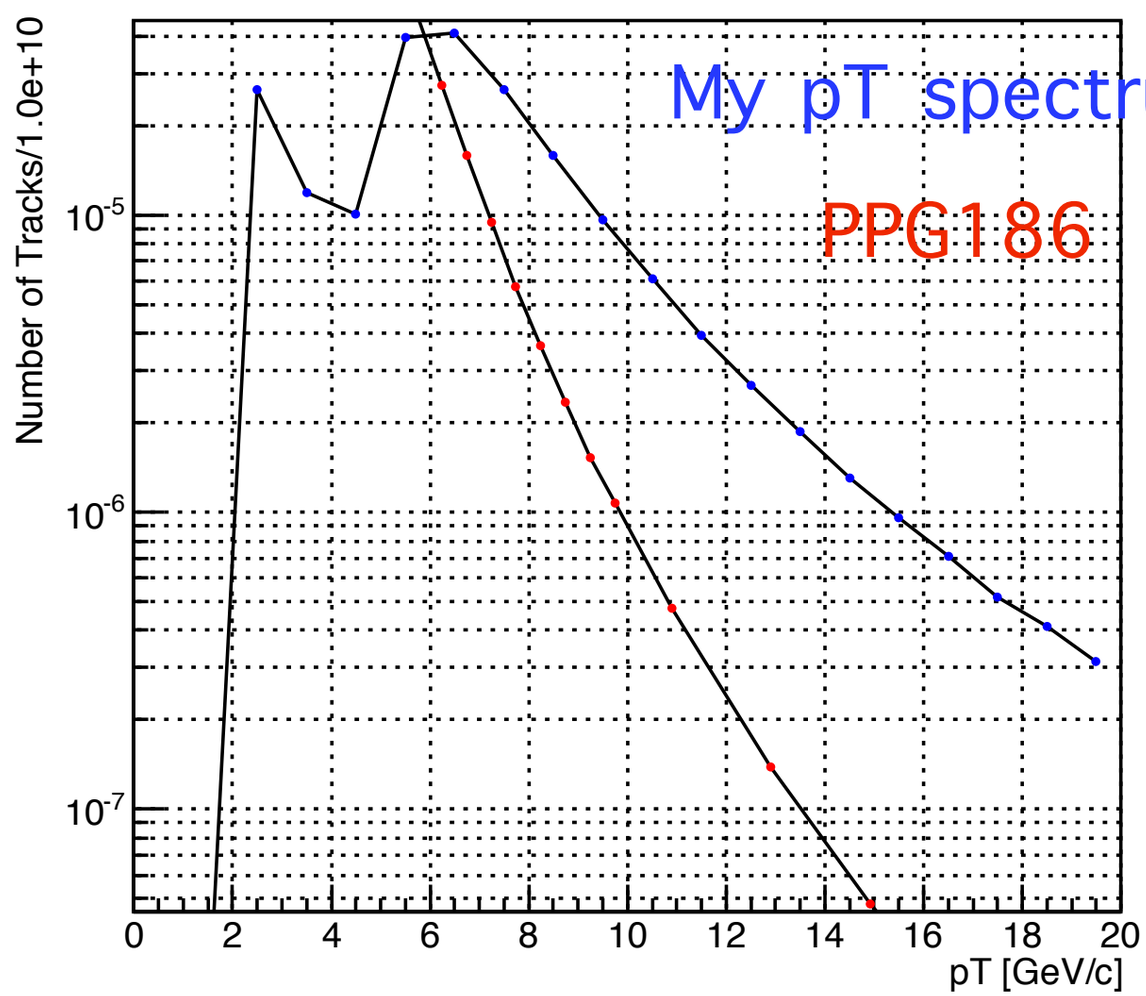
$$R = \frac{L_{++}}{L_{+-}}$$

A_{LL}


$\pi^{\pm}$ A_{LL} at $\sqrt{s}$ = 200 and 510 GeV
A_{LL}
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
4
6
8
10
12
14
p_T [GeV/c]
$A_{LL}^{\pi^-}$ @ 510 GeV
$A_{LL}^{\pi^+}$ @ 510 GeV
$A_{LL}^{\pi^-}$ @ 200 GeV (PRD91,032001)
$A_{LL}^{\pi^+}$ @ 200 GeV (PRD91,032001)
DSSV14 ($\Delta G > 0$) for π^-
DSSV14 ($\Delta G > 0$) for π^+

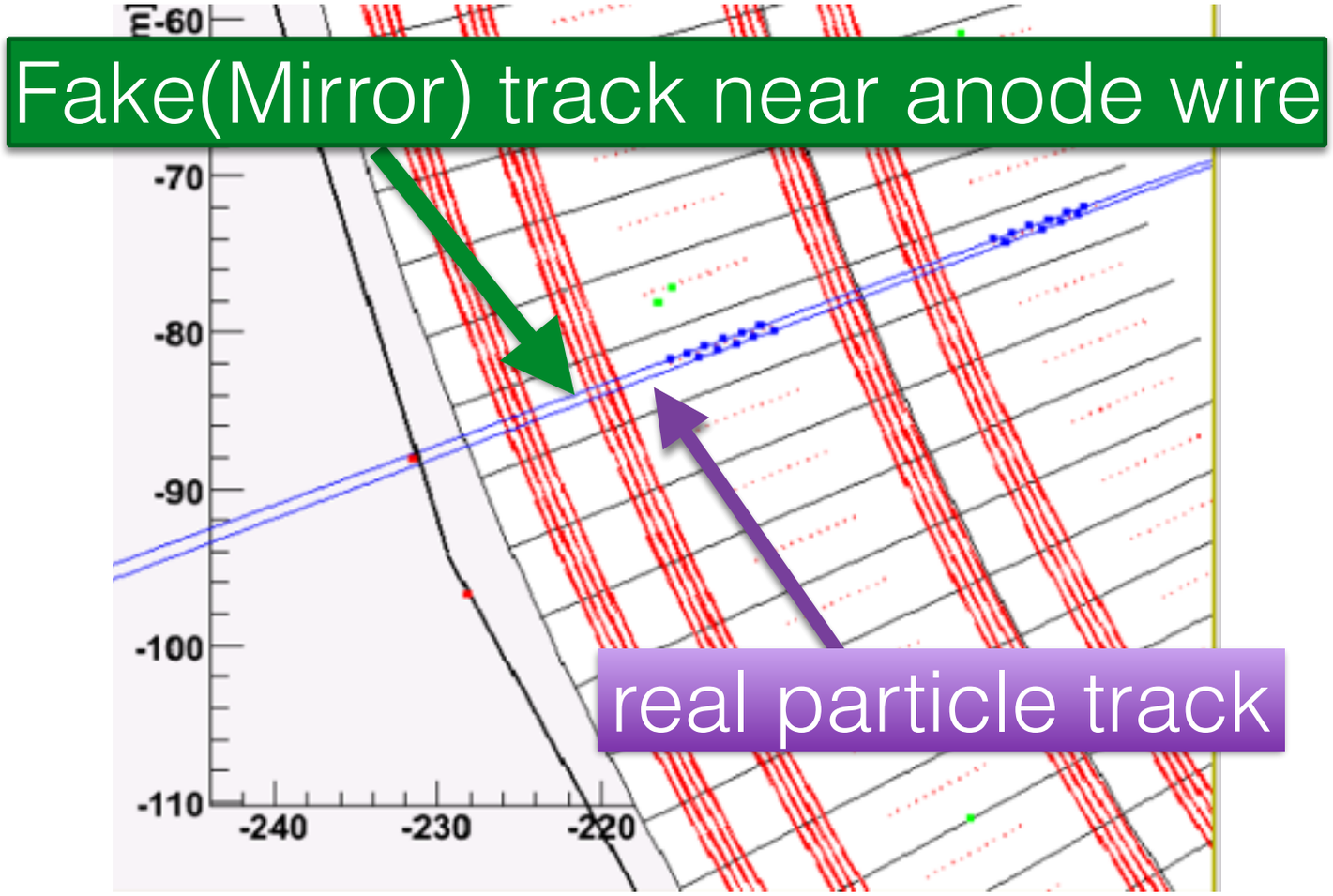
High pT background





- My *Uncorrected pT spectra scaled by 1.0e+10 for comparison with PPG186(Pi0 ana).
- There are still remaining backgrounds.
  - decayed particle/photon conversion
  - fake tracks due to left right ambiguity [should be rejected track near anode wire]

Anode wire region



- High pT particle going through near anode wire region.
- Due to left right ambiguity one more (fake) track might be reconstructed.

- Therefore, this region btw anode and back wires should be masked.

Summary

- Sensitive to the sign and magnitude of ΔG.
- Charged pion analysis with 510 GeV dataset is ongoing.
- Especially working on high pT background rejection.

Outlook

- The key is to remove high pT backgrounds as much as possible.
- With improved statistics, expected to contribute to constrain ΔG.
- To cross-check the sign of ΔG with higher C.L., the dataset in 2012 will be analyzed as well.

Thanks!!

Introduction : "Directly" accessing ΔG via A_{LL} in p+p

$$A_{LL} = \frac{d\Delta\sigma}{d\sigma} = \sum_{f=q,g} \frac{\Delta f_1}{f_1} \otimes \frac{\Delta f_2}{f_2} \otimes \hat{a}_{LL} \otimes \text{(Fragmentation Functions)}$$