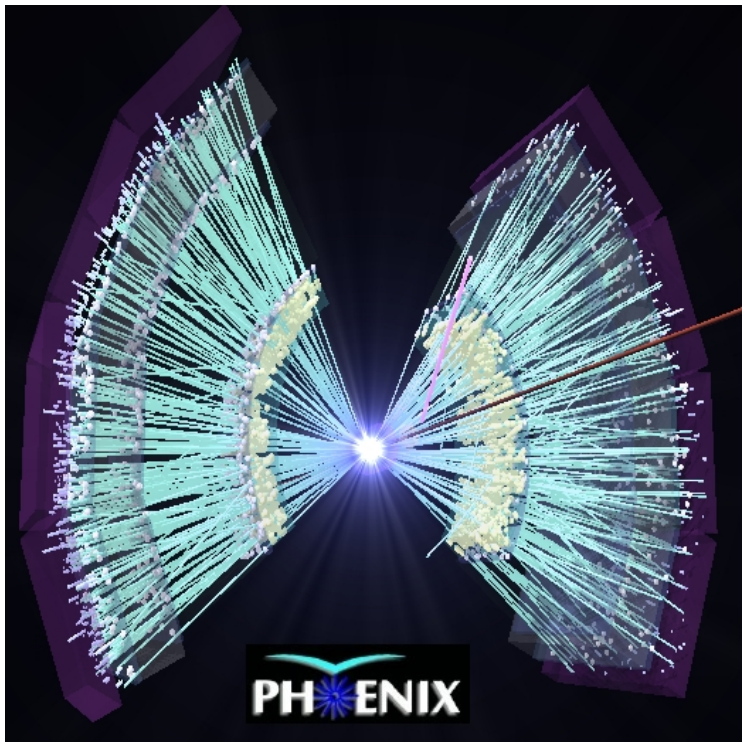
How to measure hadrons using the PHENIX Muon Arms?



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Focus Seminar

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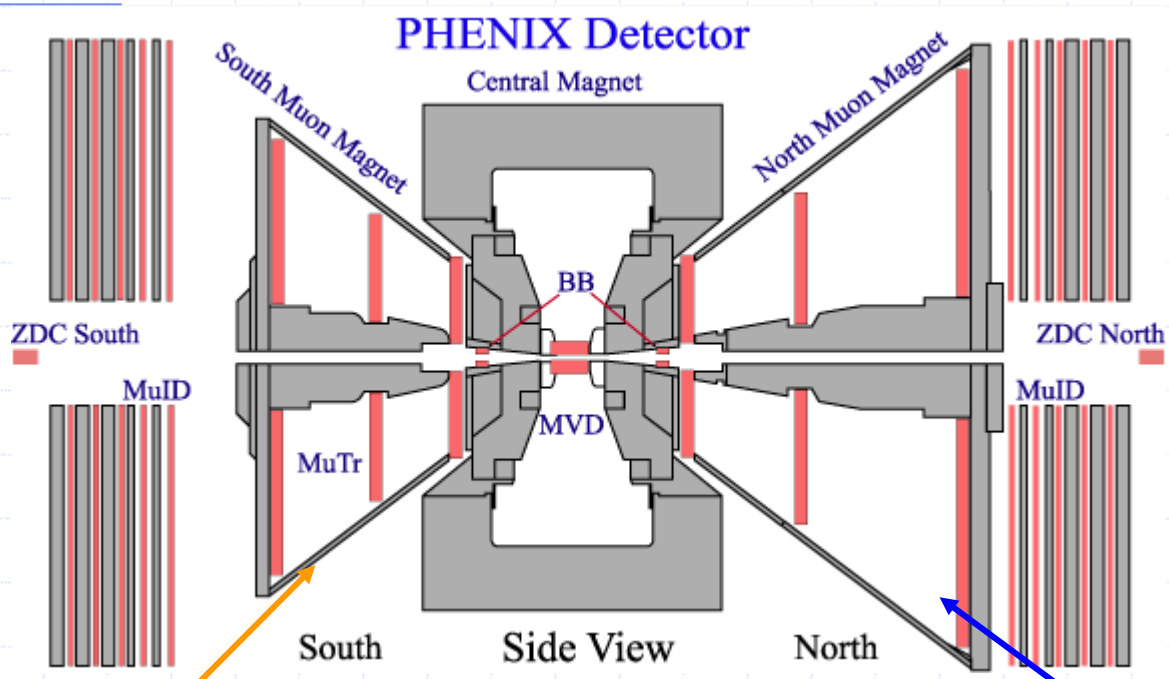
Outline

- Detector layout.
- Hadron/Muon separation.
- Cuts.
- Hadron R_{cp} measurement for d+Au.

The PHENIX Detector

deuteron → ✸ ← ***gold***



South Muon arm : $-2.2 < \eta < -1.2$

North Muon arm : $1.2 < \eta < 2.4$

PHENIX Muon Arms

- **MuTr: the tracking detector**

3 octagonal stations of cathode strip chambers in magnetic field. Measuring track momentum.

- **MuID: the muon identifier**

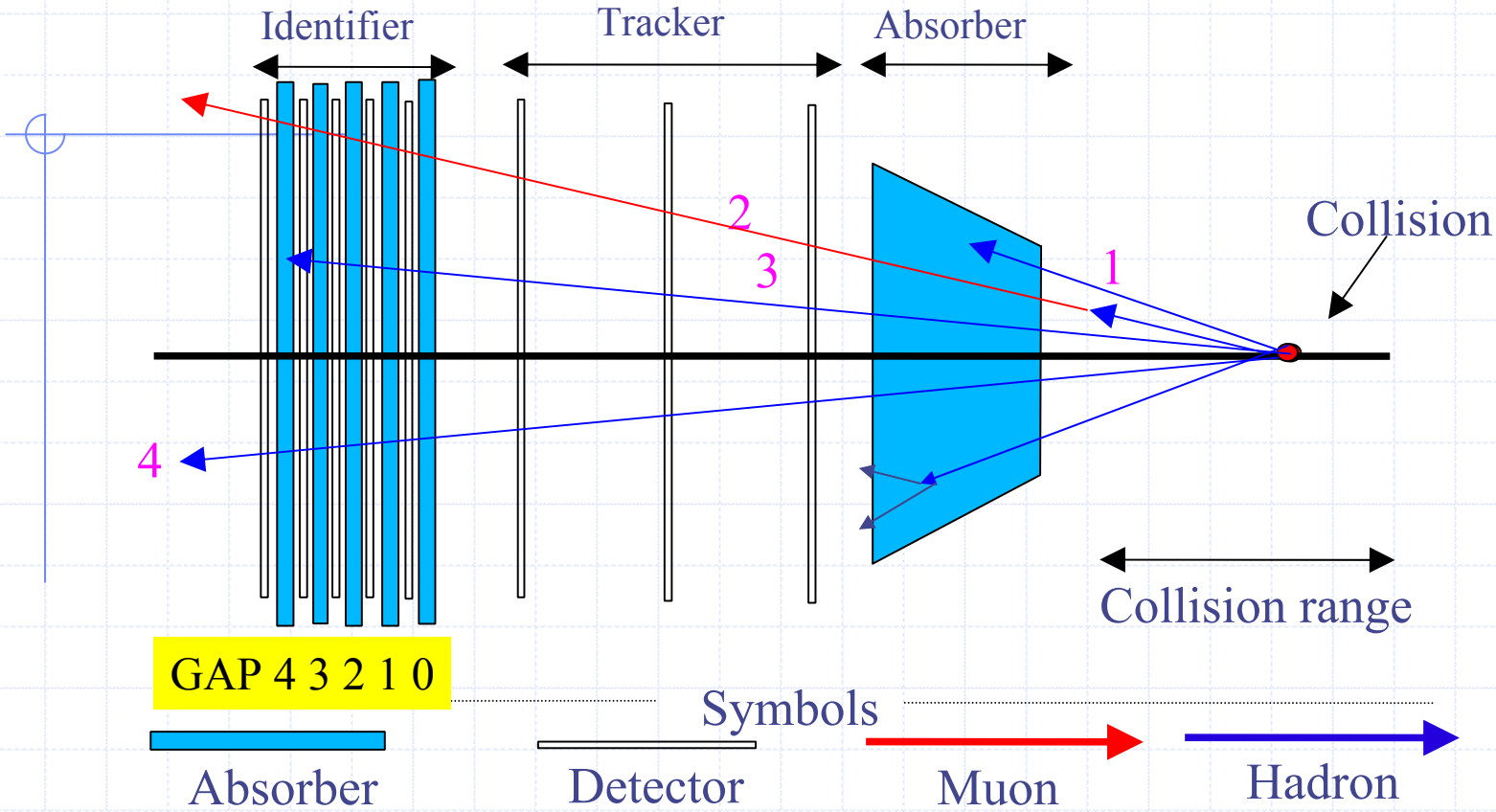
Layers of steel with h5 gaps per arm filled with planes of transversely oriented Iarocci tubes. The deeper a track hits in MuID, the more likely it is a muon.

•Most hadrons either shower and stop in absorber or decay into muons before absorber, rest are measured in MuTr.

Hadron selection

- PHENIX Muon arms can be used to detect hadrons by two methods:
  - Hadrons which penetrate partway into the MuID steel and stop, unlike muons which go all the way to the back. These are the punchthrough hadrons.
  - As light mesons (primarily pions and kaons) travel through the detector, they decay into muons. Yields of these hadron decay muons can allow us to obtain information about the parent mesons.

Major Sources of Hadronic Tracks



1 : Hadrons, interacting and absorbed (98%)
2 : Charged π/K's, "decaying" before absorber (≤1%)
3 : Hadrons, penetrating and interacting ("stopped")
4 : Hadrons, "punch-through"

Analysis Details

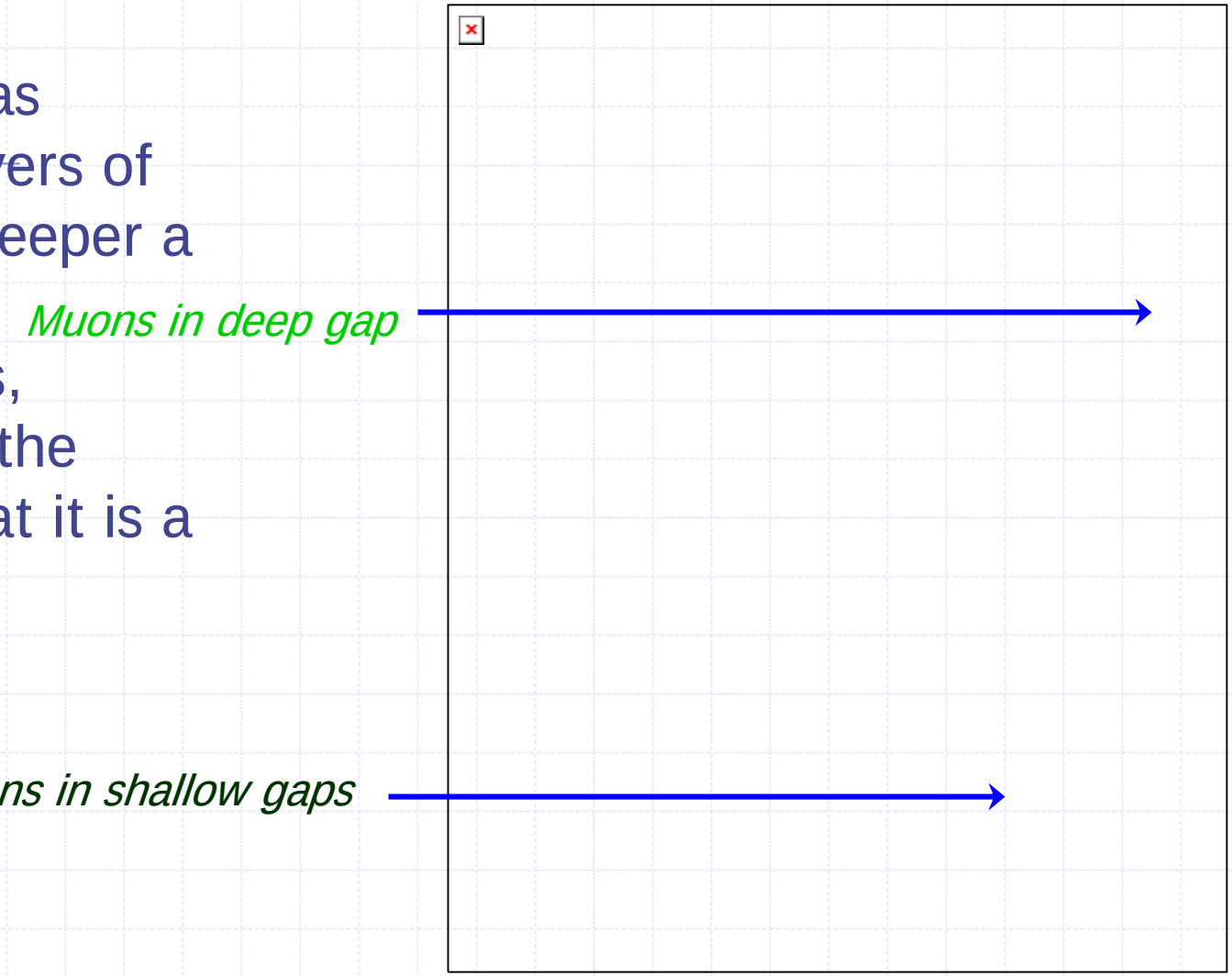
- 67 million minimum bias events and 5.8×10^9 events triggered by a track penetrating into deepest layer of the MuID.
- R_{CP}: Ratio between the central and peripheral yields scaled by the number of binary collisions, where it is assumed that peripheral is similar to pp:

$$R_{CP} = \frac{\frac{1}{N_{binary}^{central}} \left(\frac{dN}{d\eta dp_T} \right)^{central}}{\frac{1}{N_{binary}^{peripheral}} \left(\frac{dN}{d\eta dp_T} \right)^{periperal}}$$

- Advantage: a lot of detector systematics cancel.
- Disadvantage: most peripheral bin of 60-88% still corresponds to 3-4 collisions and not all nuclear effects might be eliminated.

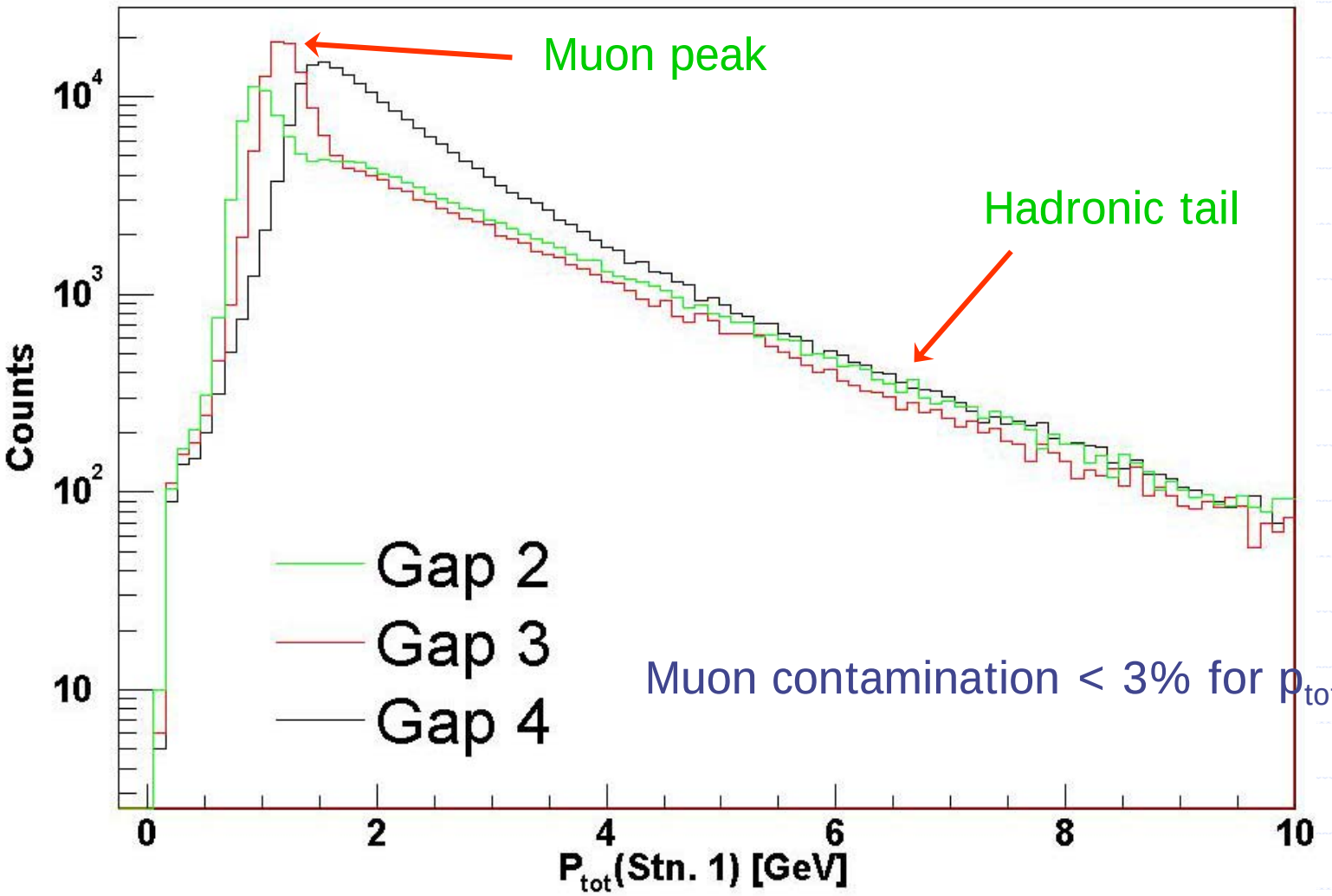
Stopped hadrons I

- MuID has several layers of steel, so deeper a particle penetrates, greater is the chance that it is a muon.



Stopped hadrons II

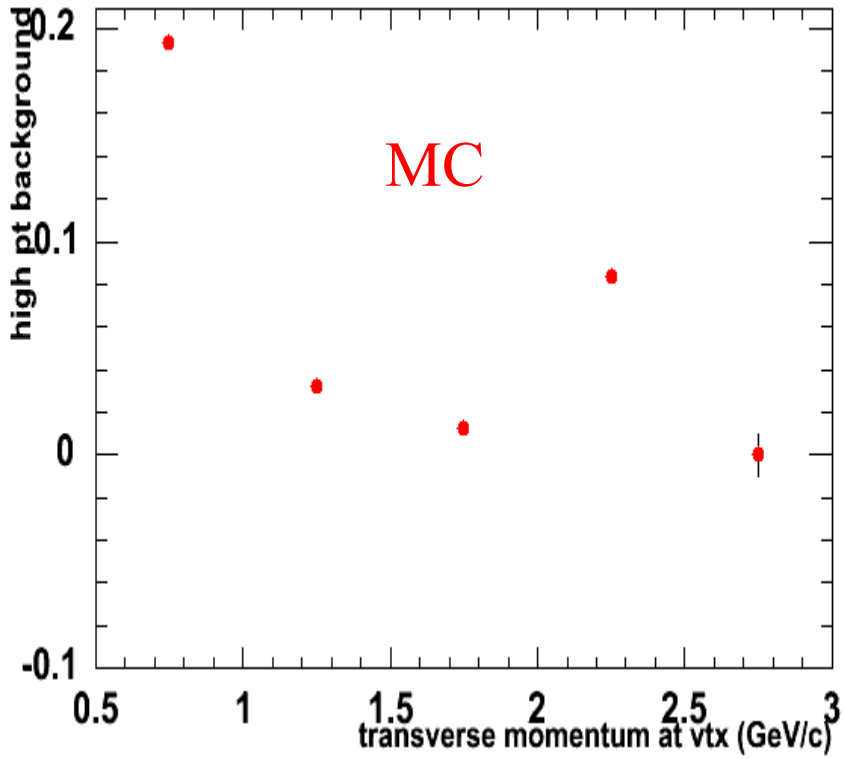
- Use shallow MuID layers to select stopped hadrons



Muon contamination < 3% for p_{tot} > 1.9 GeV

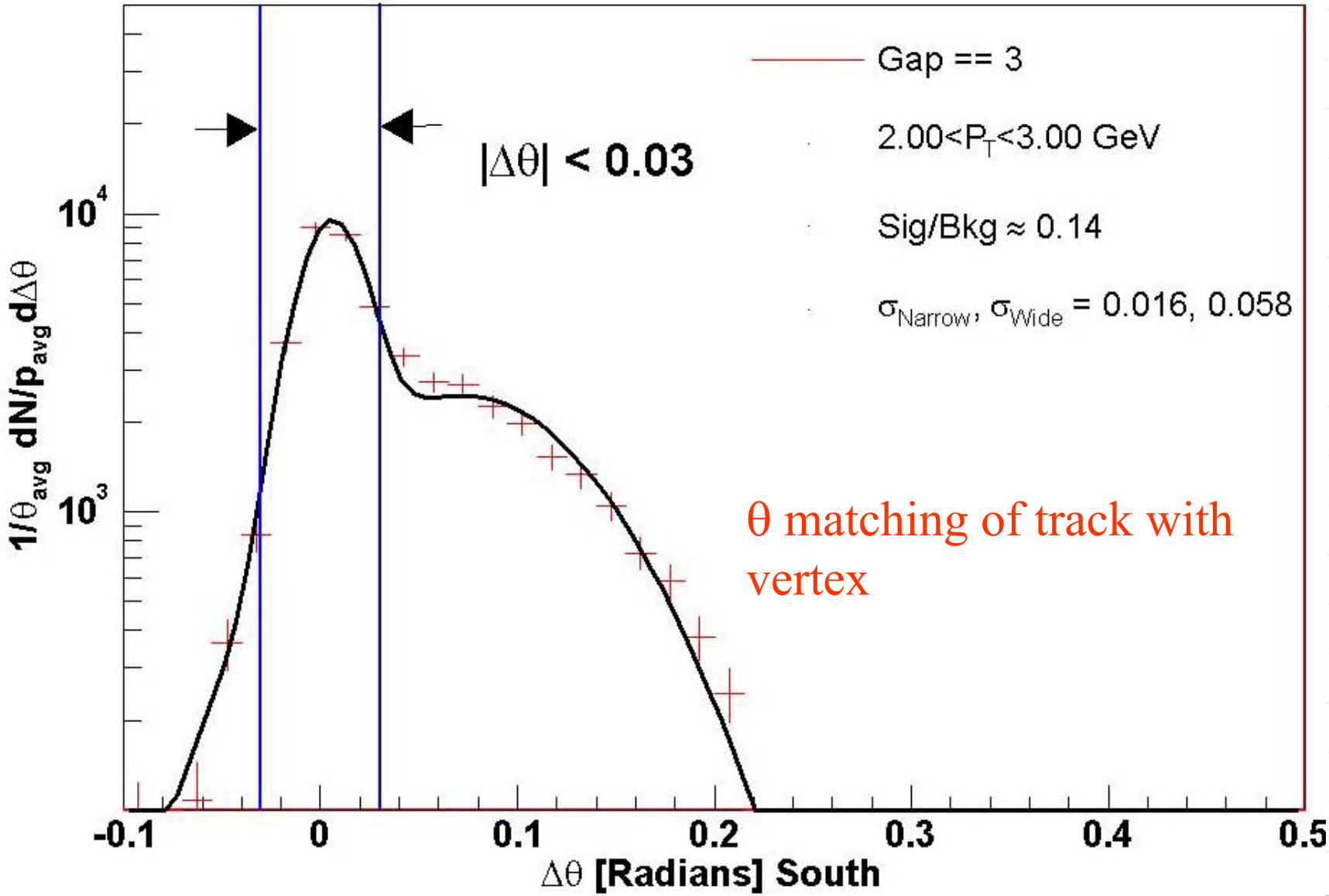
Secondary hadrons from showers

- Most hadrons in given p_T range dE/dx through absorber
- Secondary particles from hadronic showers have larger angular spread due to different momentum.
- $\Delta\theta$ cut reduces shower contamination.



high p_T contamination as a function of p_T at collision vertex

Comparison with Data



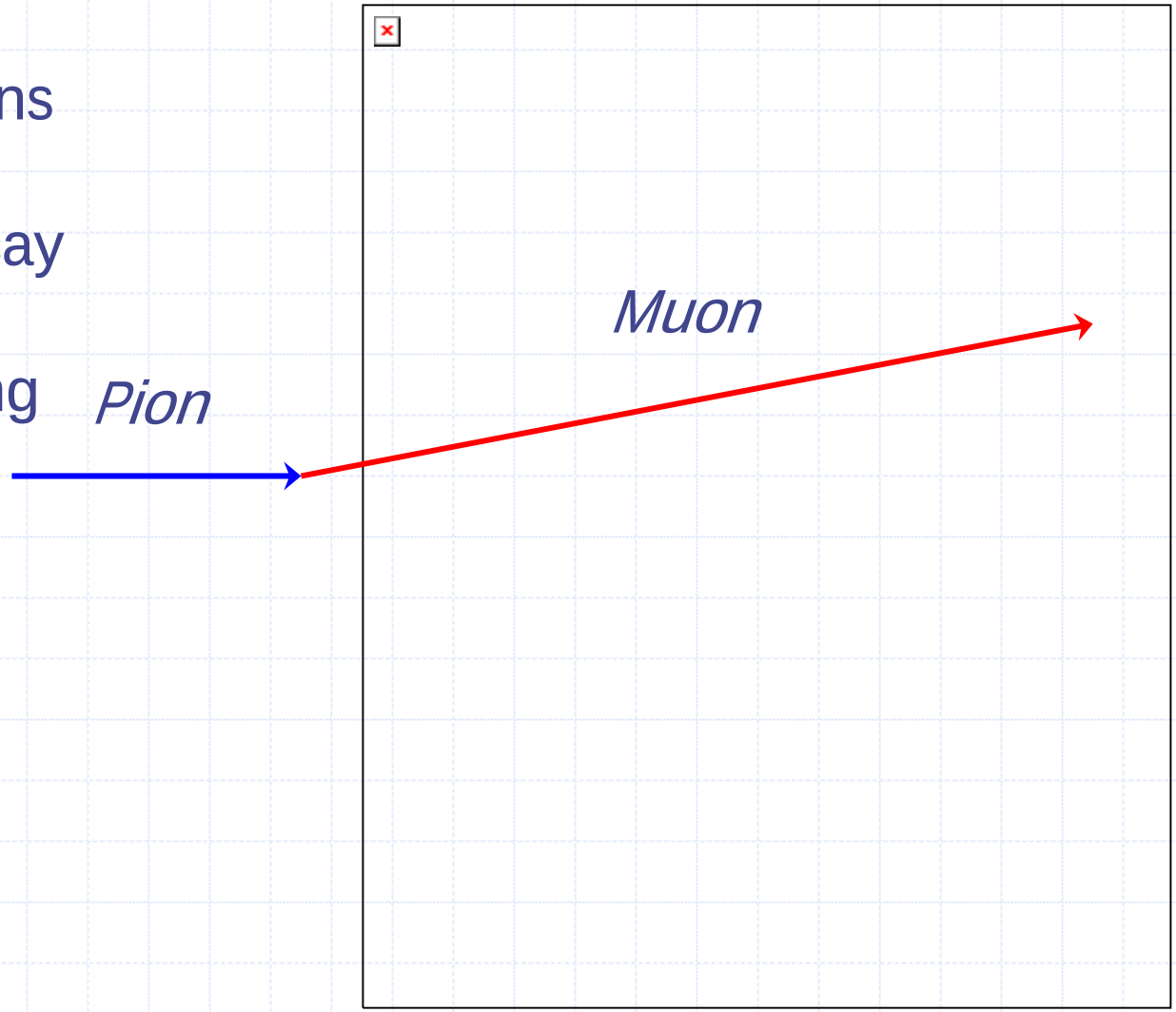
θ matching of track with vertex

Summary of stopped hadrons

- Some hadrons punch though the absorber but get stopped in the shallow MuID gaps.
- By selecting particles with $p_T > 1.9$ GeV, we are able to select the stopped hadrons.
- Additional angular cuts are used to reduce background from shower particles.

Decay Muons I

- Light hadrons like pions and kaons can decay into muons before reaching the MuID.



Decay Muons II

- The decay probability of a meson with momentum p is proportional to the distance (L) between collision vertex and absorber:

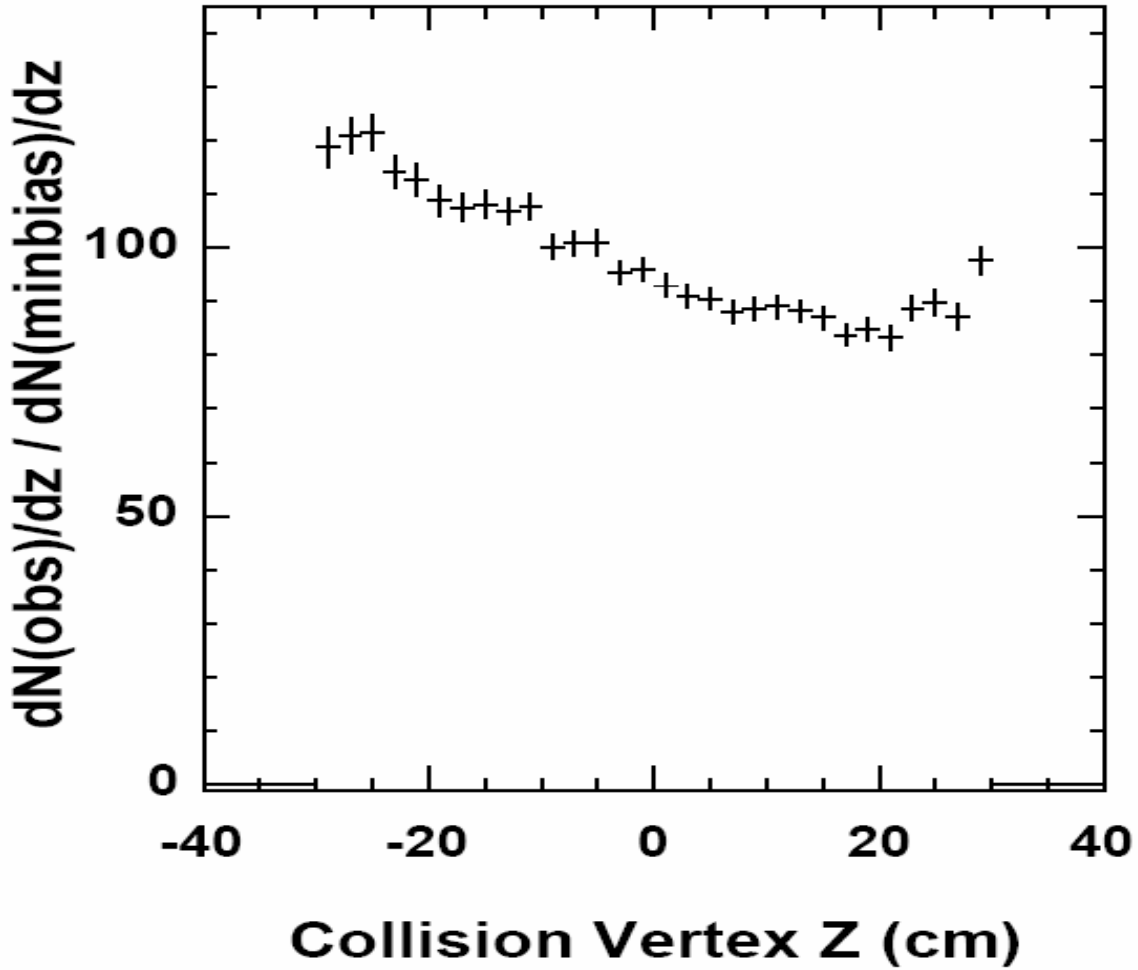
$$P_{decay}(p, L) = 1 - e^{-\frac{L \cdot m}{\tau \cdot p}}$$

- Hence by looking at the the z-vertex distribution for events with single muon candidates, we can separate the muons that come from pions/kaons from other contributions.

Decay muons and z dependence

nucl-ex/0411054 (accepted by PRL)

- Pion and kaon decay contributions have z dependence.
- Other contributions (e.g. D mesons) are flat.



Nuclear Modification Factor: R_{AA}

- We define the nuclear modification factor as:

$$R_{AA}(p_T) = \frac{\dfrac{d^2\sigma^{AA}}{dp_T d\eta}}{\dfrac{< N_{binary} >}{\sigma_{inel}^{NN}} \dfrac{d^2\sigma^{NN}}{dp_T d\eta}}$$

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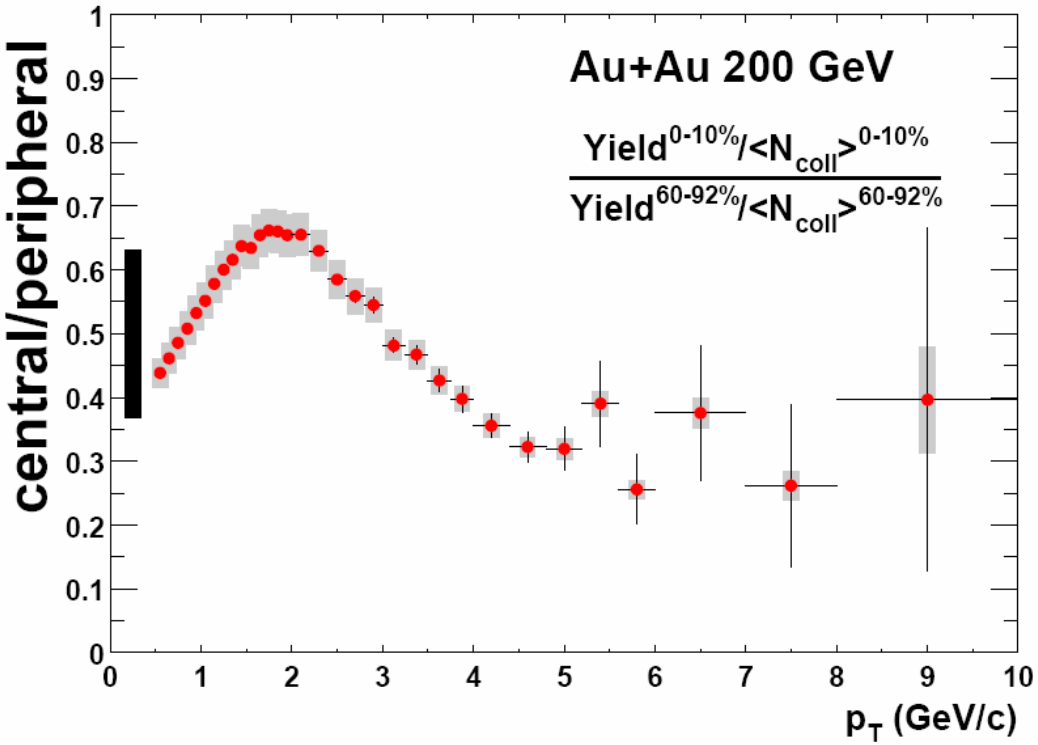
- At mid-rapidity (for pions):
  - R_{AA}<<1 for Au+Au
  - R_{dA}>1 for d+Au
- Final state interactions responsible for "jet quenching" instead of initial states.



Physics at forward rapidities

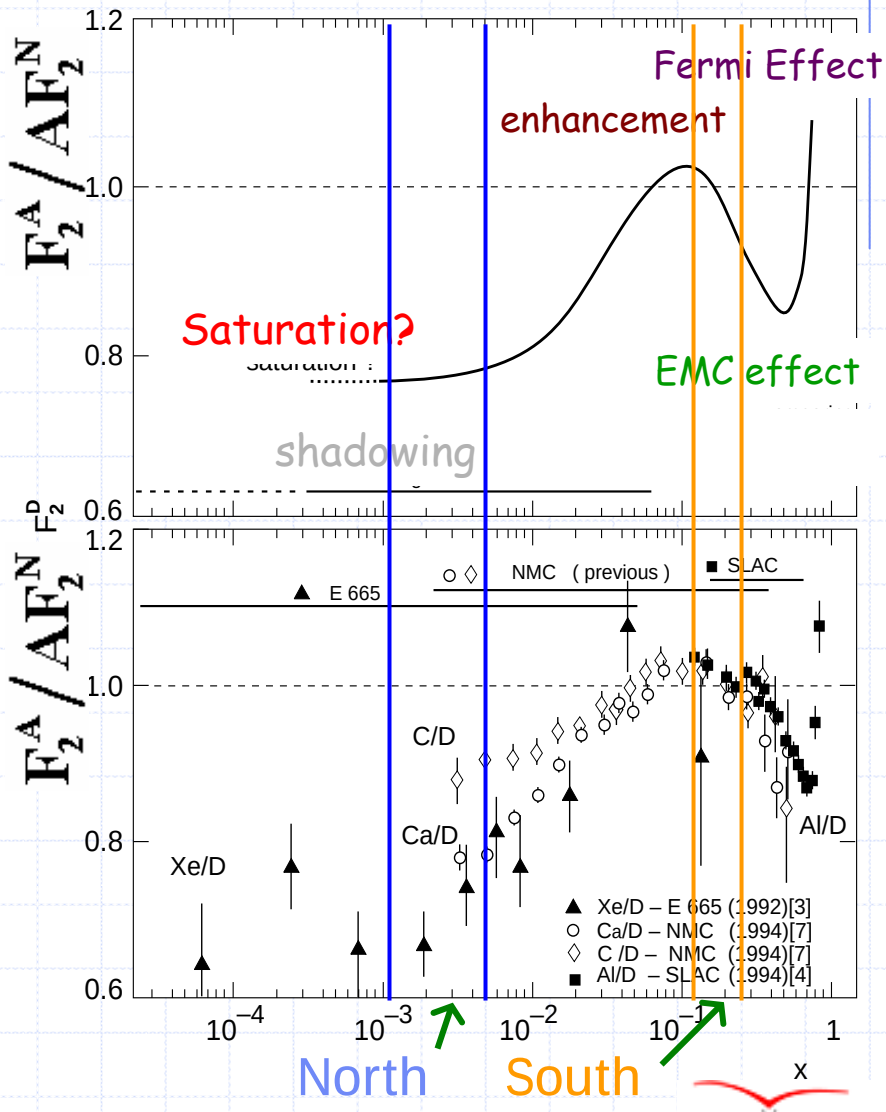
- New regime of parton physics at low-x.
- Can be reached by going to large rapidities.

For Au nuclei (Going N to S)

$$x = \frac{M_T}{\sqrt{s}} e^{-y}$$

For deuterons (Going S to N)

$$x = \frac{M_T}{\sqrt{s}} e^{y}$$



R_{cp} vs η (1.5 < p_T 4.0 GeV/c)

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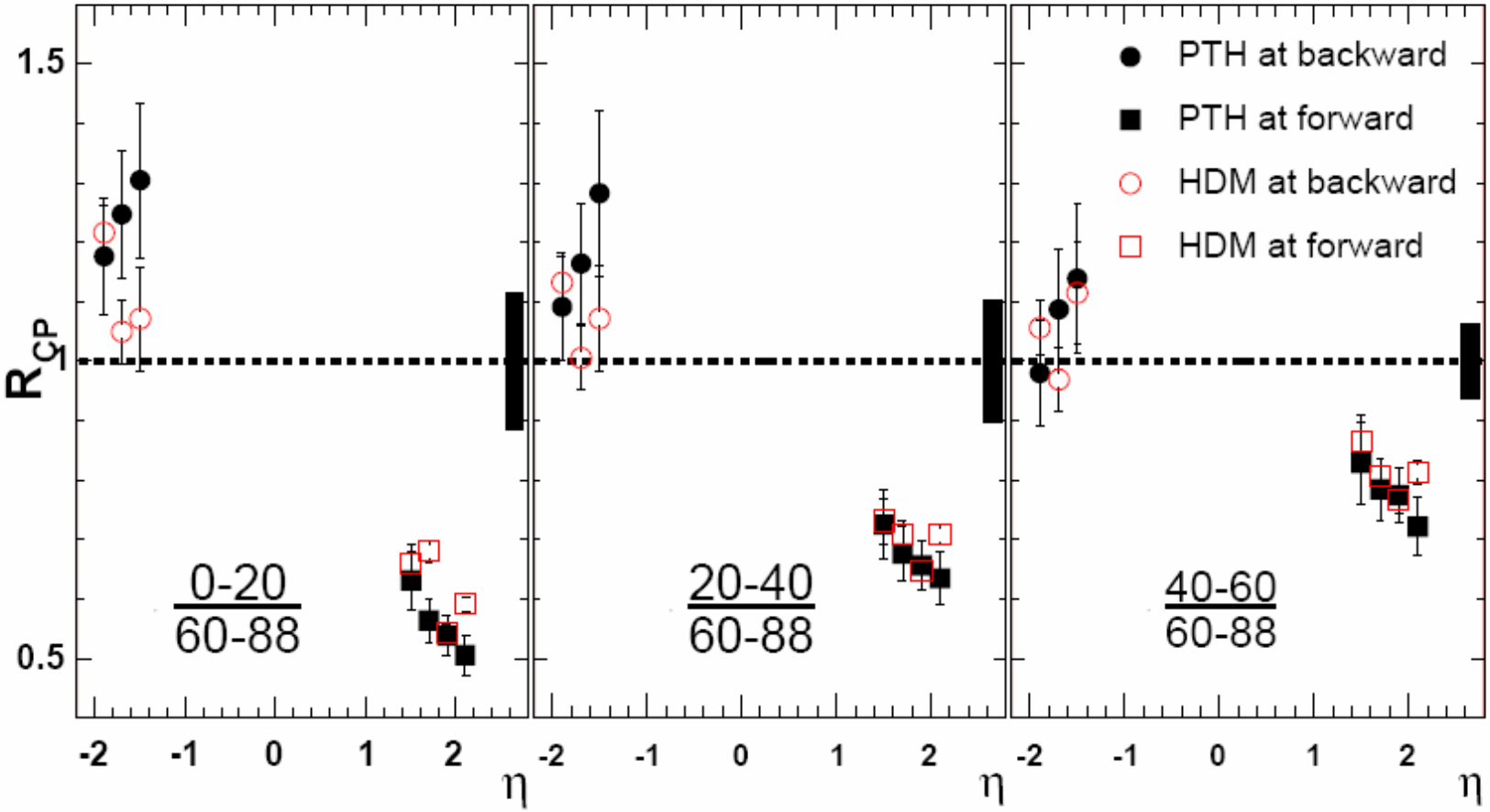
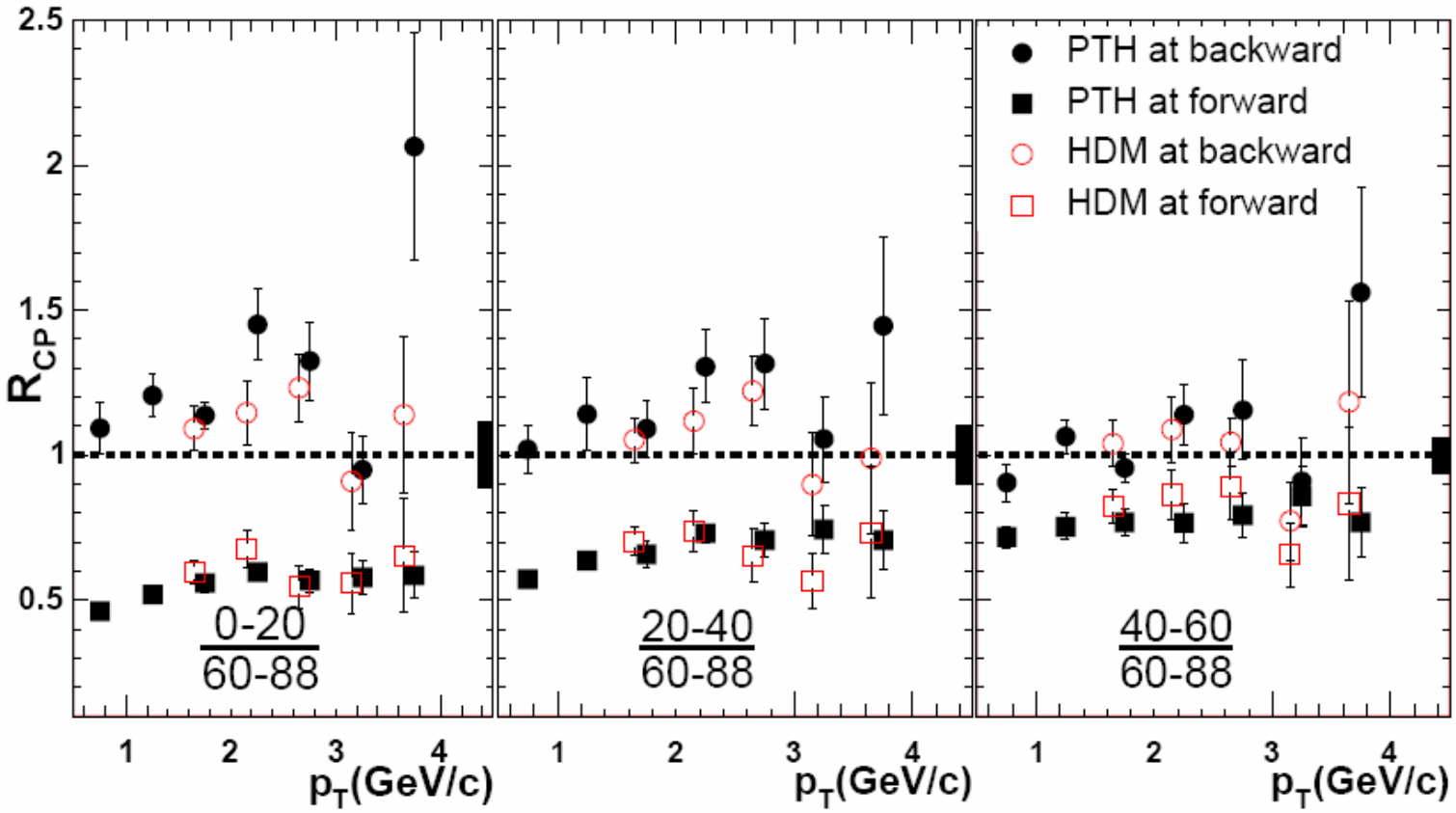


- Suppression forward and enhancement backward

R_{cp} vs p_T at forward & backward rapidity

nucl-ex/0411054 (accepted by PRL)



- R_{CP} rather independent of p_T

Summary of hadron measurement

- Get MWG nanodsts.
- Make basic track quality cuts (χ^2, nhits).
- Select particles in shallow gaps (2 & 3) with p > 1.9 GeV to get stopped hadrons.
- Look at z-vertex distributions to get decay muons from hadrons.
- Calculate R_{cp}

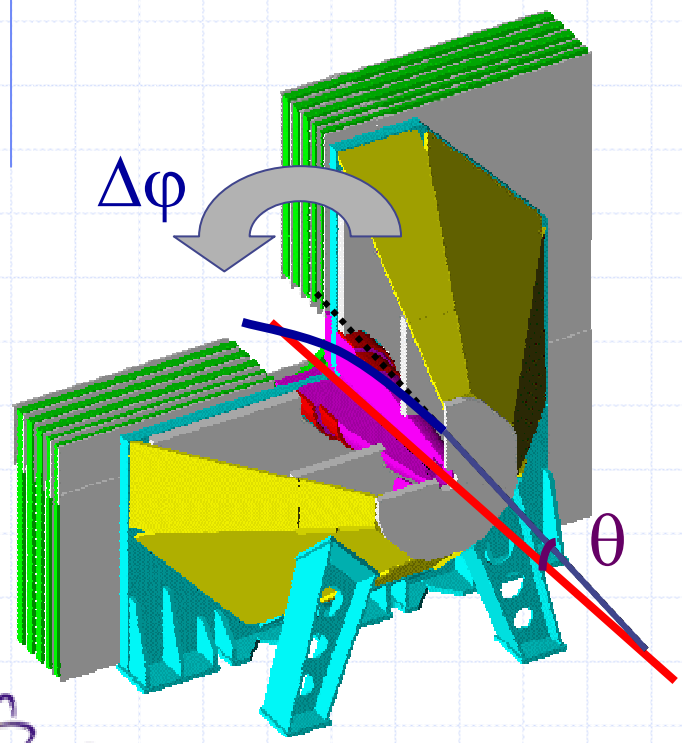
Measure charged particle tracks

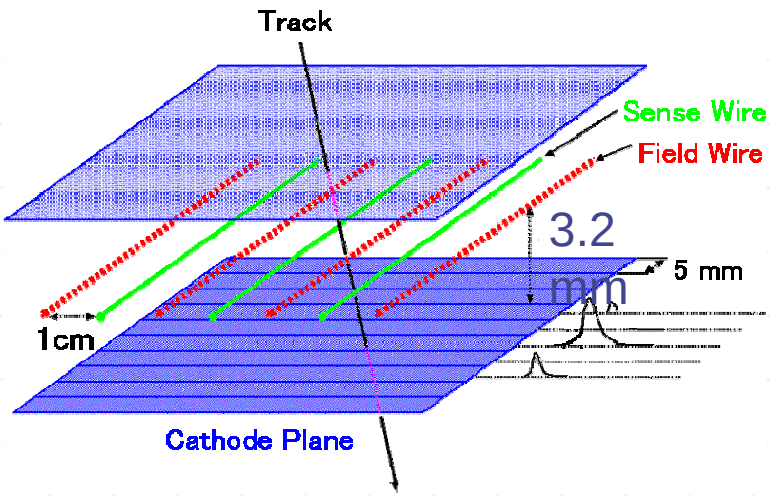
Charged particle bend

$\Delta\varphi$ (~P_L)

$\Delta\varphi$ & θ: particle momentum

Particles passing through a gap
- Ionization in the gas
- Strips collect induced signal





More detail: vi-nham's run4 mutr focus talk