JPS2017 spring, 2017/3/19

High p_T charged hadron production in ^{3}He+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV measured with PHENIX detector

RHIC-PHENIX 実験 ^{3}He+Au 衝突における 高運動量の荷電ハドロン生成量の測定

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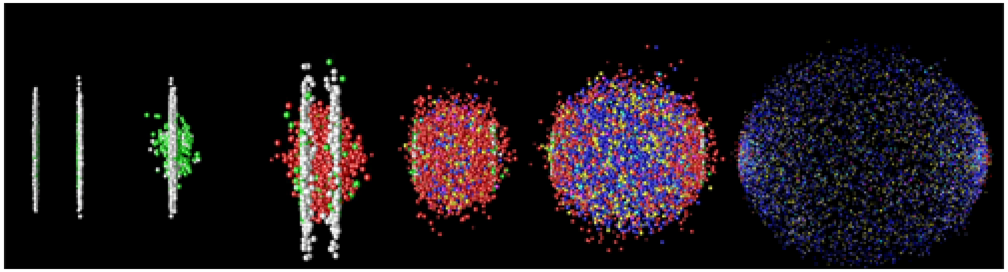
The experiment for exploring QGP

QGP(Quark Gluon Plasma)

- Matter phase realized at High temperature and high density
- Quarks and Gluons are released from the confinement within hadron by strong interaction



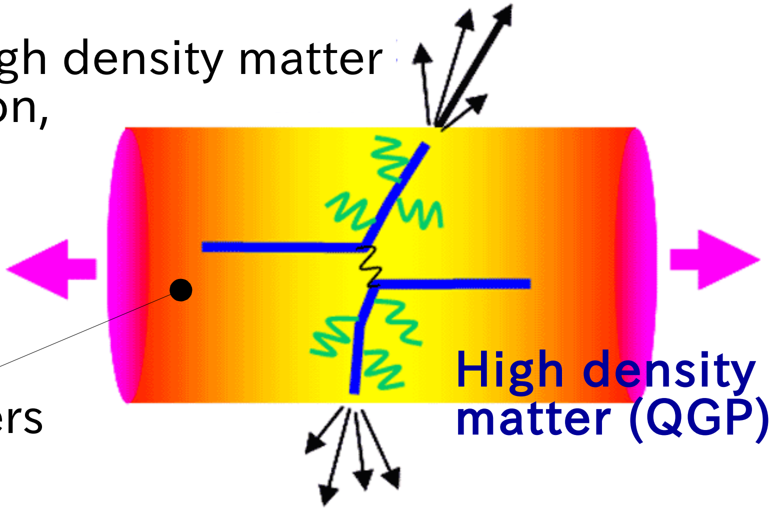
- RHIC (BNL, US)
- LHC (CERN, CH & FR)

→Heavy ion collision experiment

- Collide heavy ions that are accelerated close to the speed of light

➔A state necessary for QGP formation can be created in a wide area.

If collisions produce high density matter in the interaction region,



Momentum distribution of hadrons shifts to lower values.

R_{AA} in PHENIX experiment

<u>Nuclear modification factor R_{AA}</u>

- $R_{AA} < 1$ ··· **suppression**
- $R_{AA} = 1$ ··· p+p superposition
- $R_{AA} > 1$ ··· enhancement

$$R_{AA} = \frac{\frac{1}{N_{coll}} \cdot E\frac{d^3N_{AA}}{dp^3}}{E\frac{d^3N_{pp}}{dp^3}}$$

Number of collision scaling

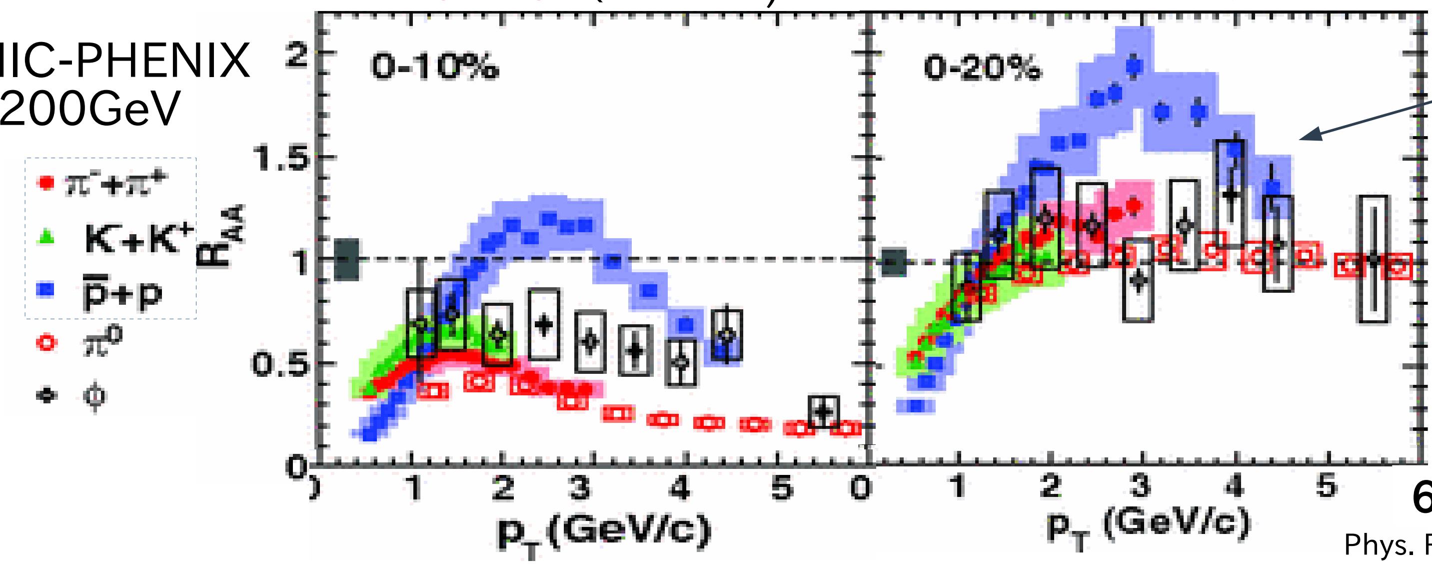
A+A collisions Invariant yields

p+p collisions invariant yields

- **High p_T hadron suppression is a evidence of QGP**

Au+Au (A=197)　　d+ Au (A=2) <u>Small system</u>

RHIC-PHENIX at 200GeV



- Enhancement at low p_T region. p > π, K (Cronin effect)

Phys. Rev. C 88, 024906 (2013)

$R_{AA} < 1$ QGP　　$R_{AA} = 1$

From the h± R_{AA} measurement up to 5 GeV/c, there is suppression at Au+Au.

Motivation

- Collision system comparison of QGP formation signal

PHENIX 200 GeV	①High p_T hadron suppression	② v_2	QGP
Au+Au (2003)	○	○	○
d+Au (2008)	△ (h±, ~5GeV/c)	○ (Central collision)	△
^{3}He+Au (2014)		○ (Central collision)	?

Installed VTX in 2011 →

★ Previous PHENIX detector couldn't measure charged hadrons at high p_T region because of background contamination.

★ New detector Silicon Vertex detector (VTX) was installed in 2011, better measurement is expected at high p_T charged hadron.

Topic

★ Charged hadron production in ^{3}He+Au collisions with VTX
★ Discuss possibility of QGP formation in small system from the point of view of hadron production

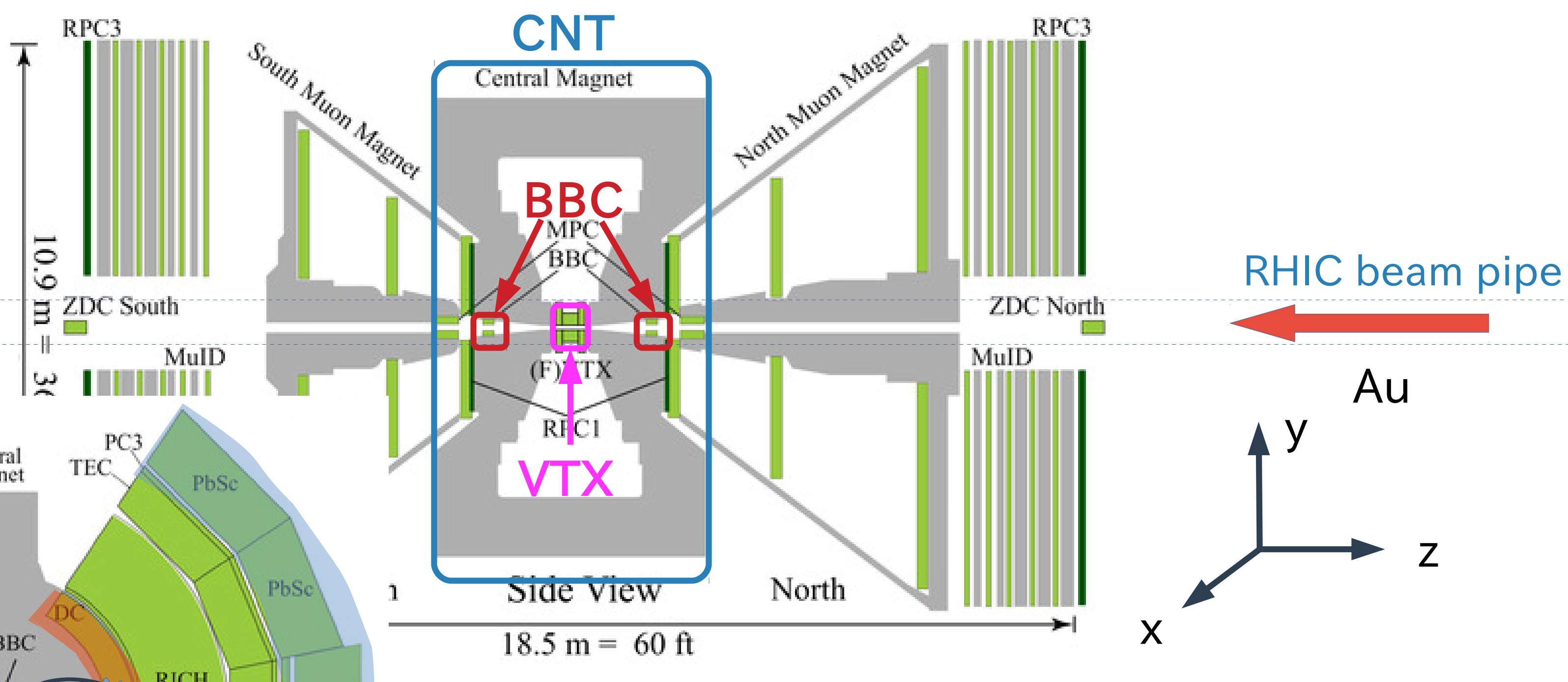
Charged hadron measurement in PHENIX

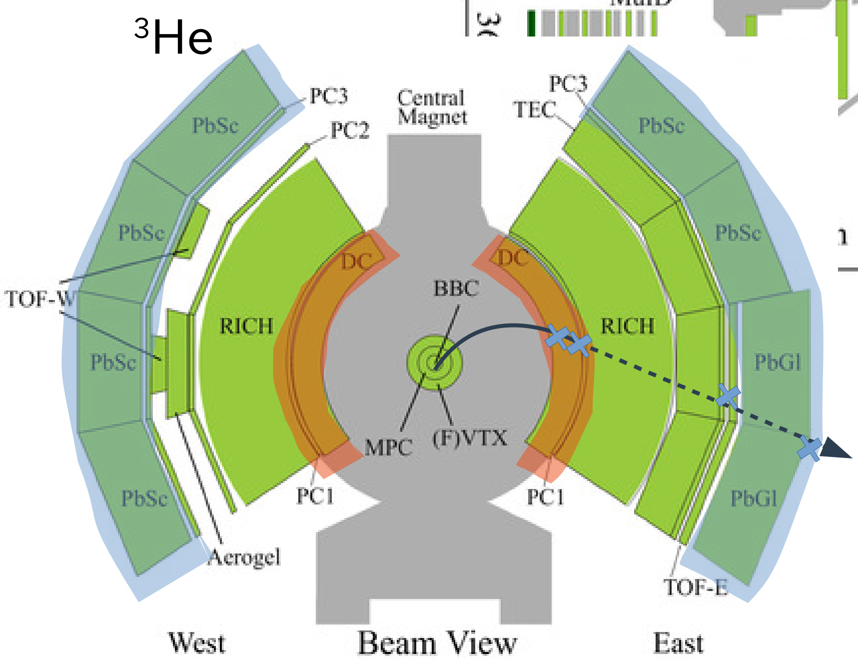
RHIC-PHENIX

^{3}He+Au collision (2014)

1.35 × 10^{9} events

- Event characterization
  - Centrality, Vertex point — BBC
- Track reconstruction
  - p_T, charge — CNT VTX





CNT

$|\eta| < 0.35$,

$\Delta\phi = \pi/2 \times 2$

- Drift Chamber (DC)
- Pad Chamber (PC)
- Electromagnetic Calorimeter (EMCal)

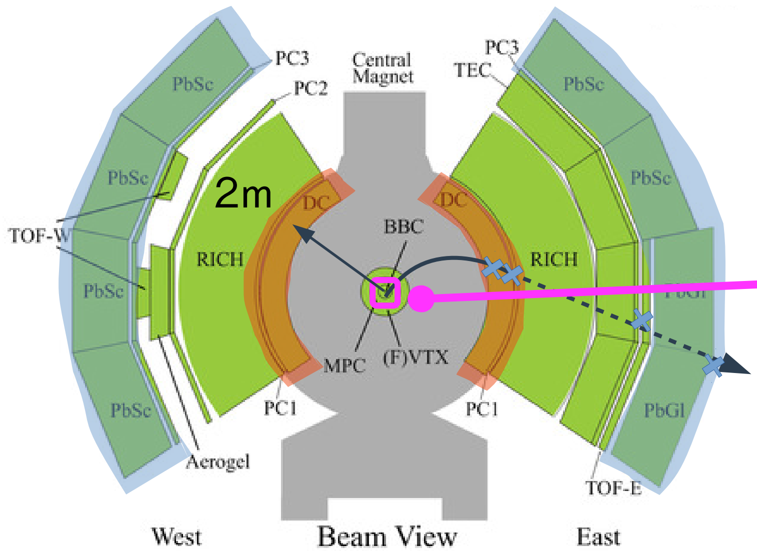
Track matching at PC3 and EMCal hits

✗ Cut fake track (background type1)

Silicon Vertex detector (VTX)

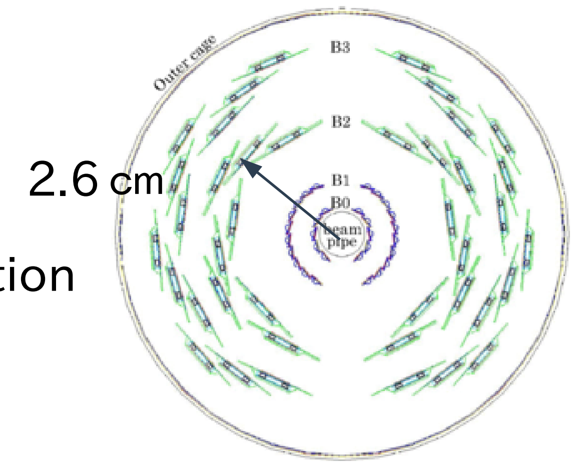
Detect charged particle around vertex position

- VTX $|\eta| < 1.2$, $\Delta\phi = 0.8\pi \times 2$



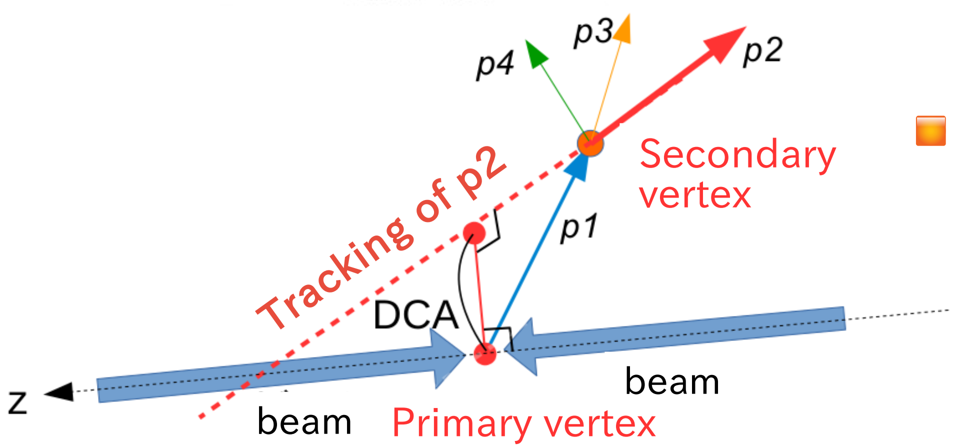
NEW !

- 4 layer Silicon detector



- determine 3D vertex position
  - → Tracking quality UP ↑
- VTX track

Track matching at VTX hits
✗ Cut fake track (background type1)



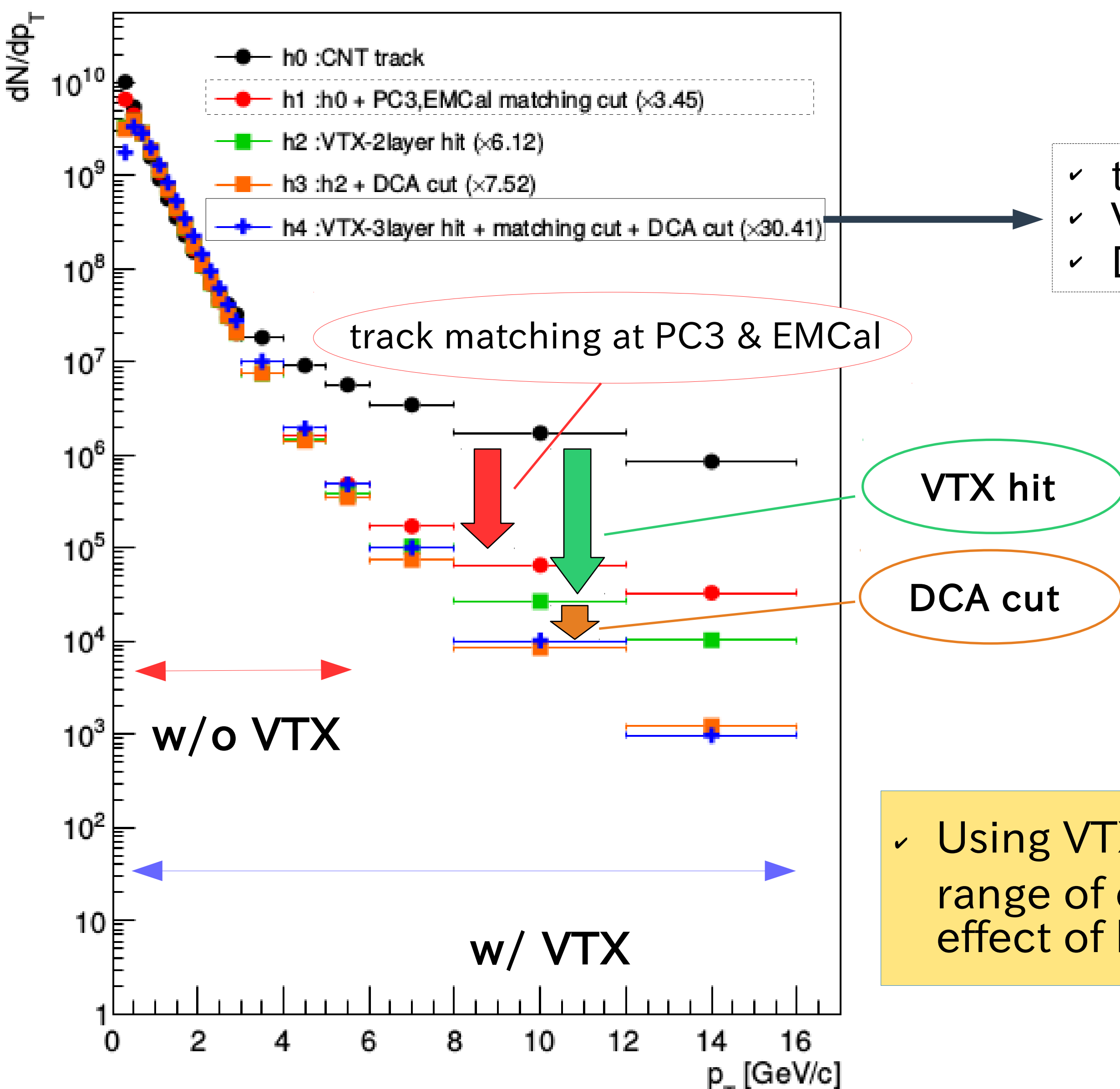
- Distance of Closest Approach (DCA)
  - → Closest distance between Primary vertex and tracking

Select tracks which have small DCA
✗ Cut secondary particle (background type2)

✔ **VTX is used for the purpose of background reduction at high p_T.**

The effect of background reduction from comparison of p_T spectra at various cut condition

- dN/dp_T (MB 0-88%, $|\eta| < 0.35$, charged hadron)



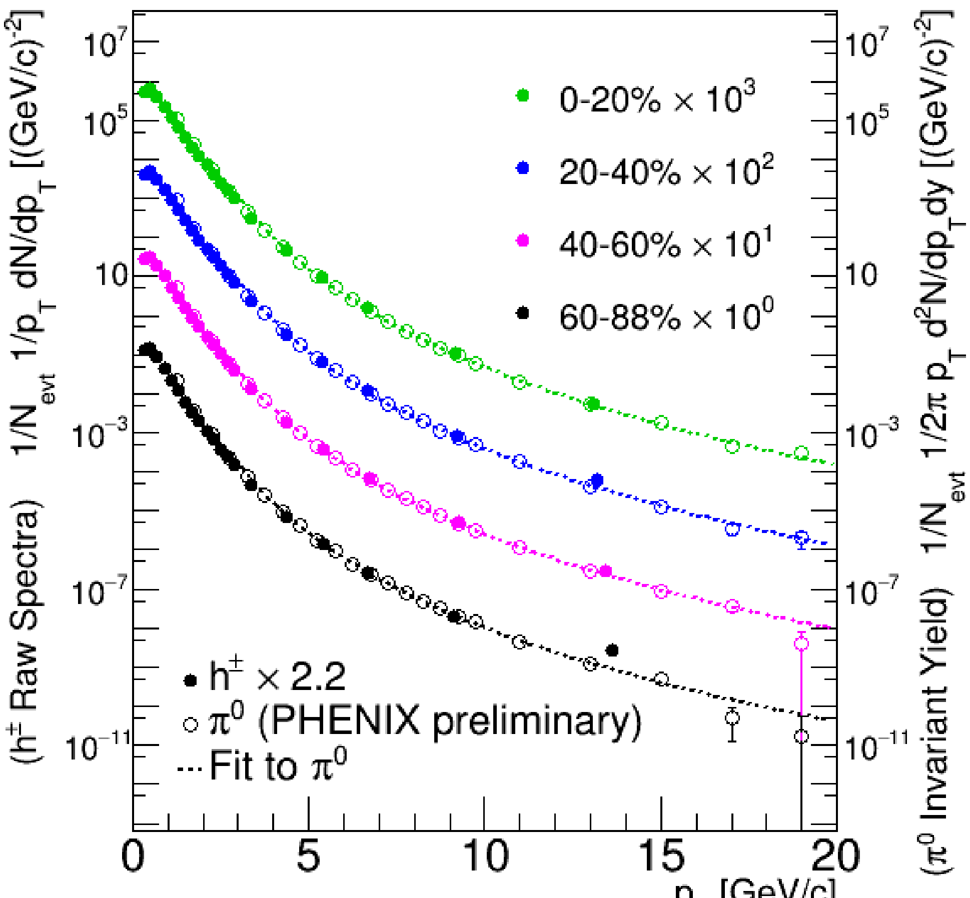
- ✓ track matching at PC3 & EMCal
- ✓ VTX 3 layer hits
- ✓ DCA cut

- ✓ Using VTX can extend measurable p_T range of charged hadron because of the effect of back ground reduction at high p_T.

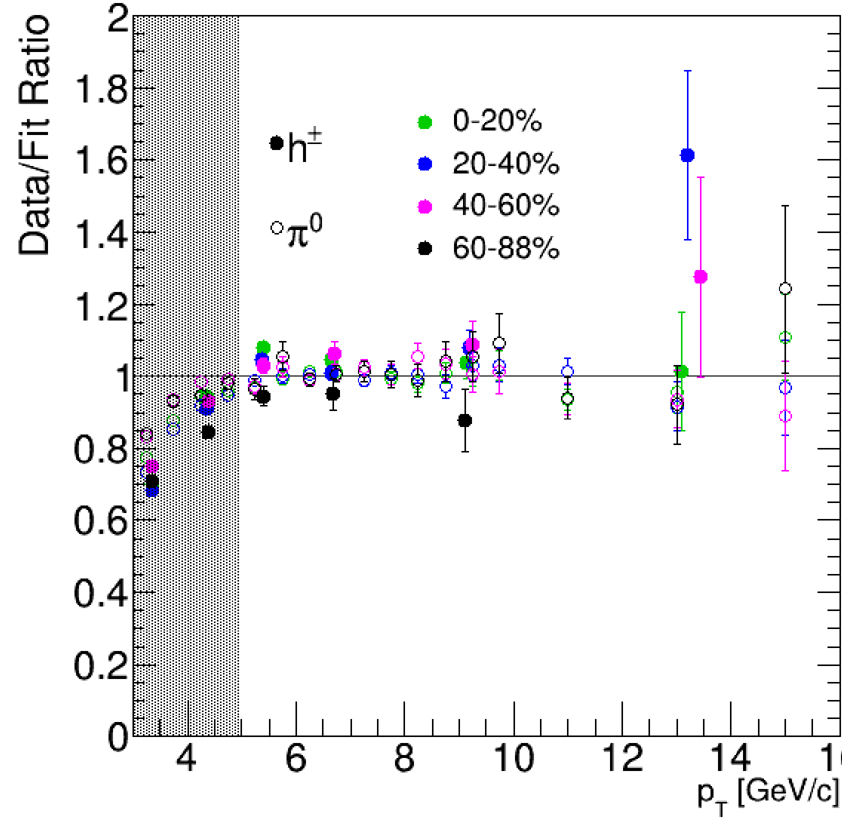
$h^{\pm}$ raw p_T spectra at each centralities

For $h^{\pm}$, detector acceptance and efficiency have not corrected yet. ➡ Assuming that the corrections don't depend on centrality, the relative charge of the spectra between centralities can be compared with other corrected spectra.

- ✓ $h^{\pm}$ raw spectra are compared with π^0 invariant yield. ($h^{\pm}$ are scaled by an arbitary value)



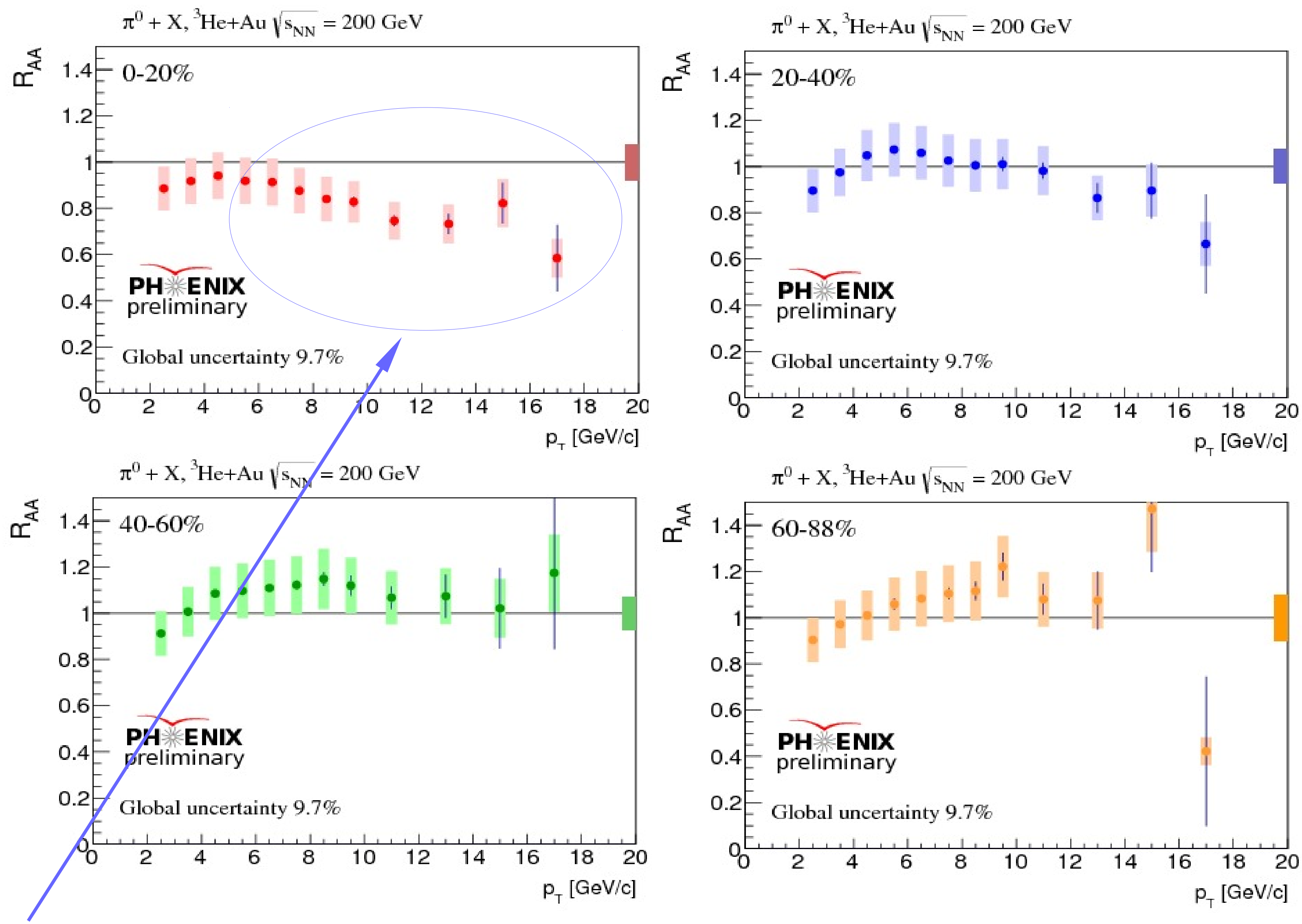
Fit function : "$a \times p_T^{\,b}$" for each centralities
(a and b are free parameters)



Have good match at 5~9 GeV/c

- ✗ π^0 and $h^{\pm}$ seem to have similar shape of p_T spectra in this p_T range

π^0 R_{AA} at ^{3}He+Au



In ^{3}He+Au π^0 R_{AA}, suppression at high p_T is observed in central collision.
→ will expect that charged hadron results have same p_T dependence.

QGP signal in small system?

Summary and Outlook

- Charged hadron production is measured in $^{3}He+Au$ collisions
  - ★ New track selection method with VTX
    → VTX is expected to improve background contamination at higher p_T
- Spectra comparison between $h^{\pm}$ and π^{0} in $^{3}He+Au$ collisions
  - ★ They have similar shape with small centrality dependence
- π^{0} R_{AA} in $^{3}He+Au$ collisions
  - ★ High p_T suppression is observed at 0-20 % centrality

    → will expect that charged hadron results are similar

    → A hint of QGP formation at small systems at RHIC energy
- Outlook
  - ★ Calculate invariant yields and R_{AA} by applying acceptance and efficiency correction for $h^{\pm}$ results

Back up

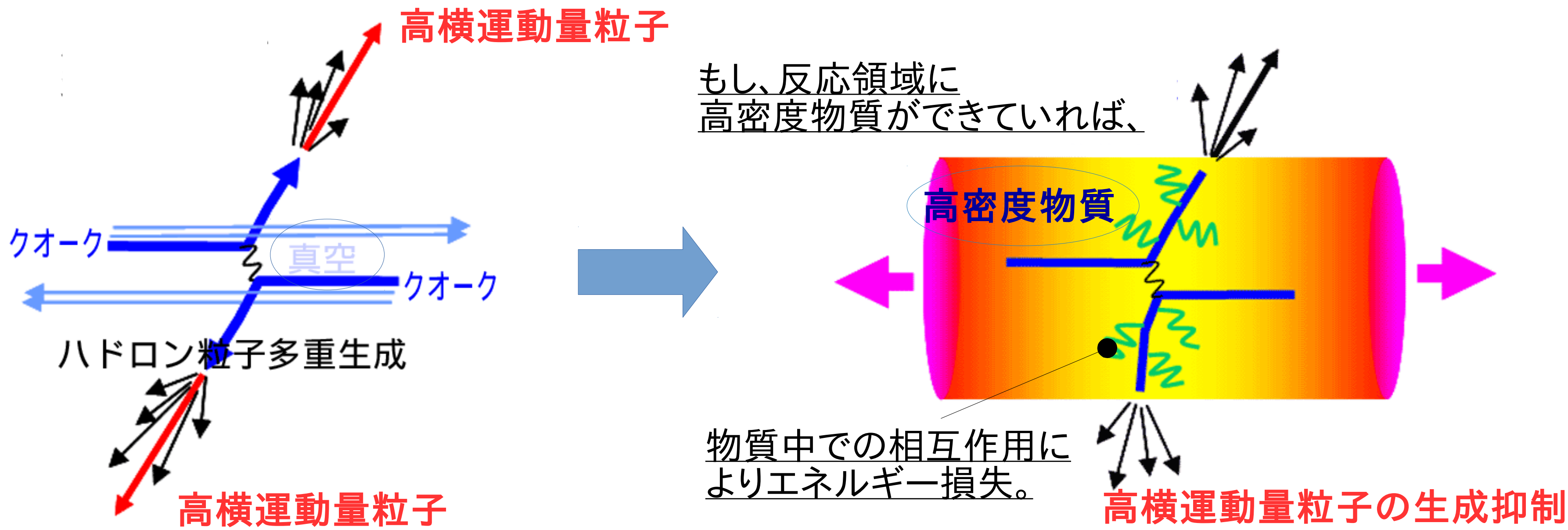
QGP probe ①high p_T hadron suppression

高横運動量粒子の生成過程：**ジェット**

$$p_T = \sqrt{p_x^2 + p_y^2}$$

- パートン同士の衝突・散乱によって生成

クォークやグルーオン



原子核効果比 R_{AA}

- $R_{AA} < 1$ … **抑制**
- $R_{AA} = 1$ … 核子+核子衝突の重ね合わせ
- $R_{AA} > 1$ … 増加

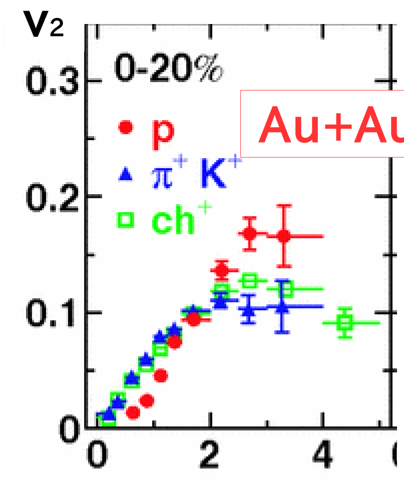
$$R_{AA} = \frac{\frac{1}{N_{coll}} \cdot E\frac{d^3 N_{AA}}{dp^3}}{E\frac{d^3 N_{pp}}{dp^3}}$$

核子間衝突数でスケール

A+A 衝突の不変生成量

p+p 衝突の不変生成量

v_2 in small system

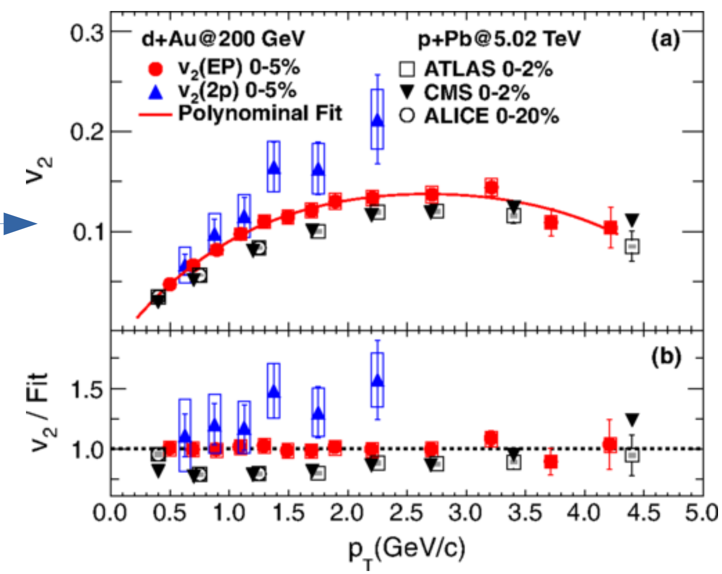


Au+Au 衝突

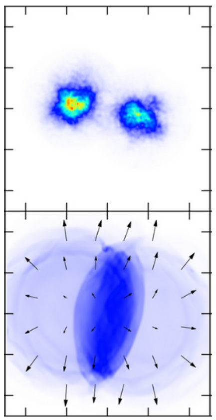
p_T 依存性
が類似

小さい衝突系

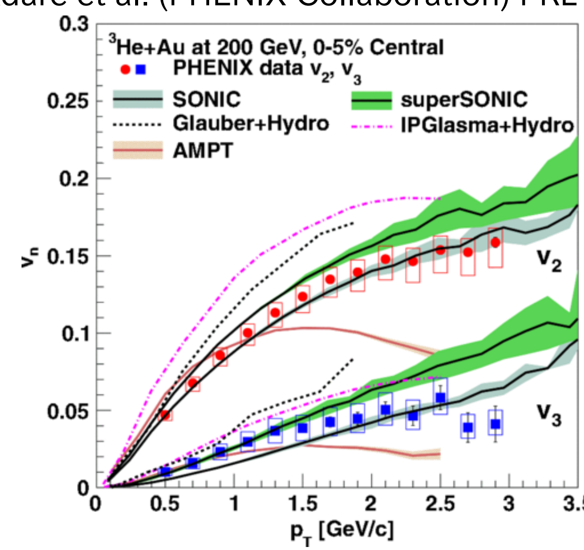
A. Adare et al. (PHENIX Collaboration) PRL 114,192301(2015)



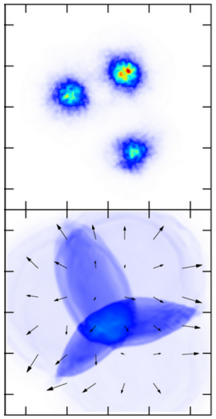
d+Au 衝突



A. Adare et al. (PHENIX Collaboration) PRL 115,142301(2015)



^{3}He+Au 衝突



- Au+Au 中心衝突と似た v_2 の横運動量依存性が d+Au 中心衝突でも確かめられた。
- d+Au より大きな衝突系として ^{3}He+Au 中心衝突でも v_2 が測定される。

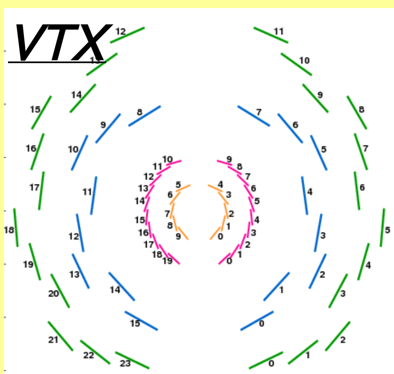
→ 流体計算モデルの予想とよく合っている。

Vertex selection

- 3 types of vertex

PRECISE ･･･ 3D reconstruction by VTX Standalone tracks
SEED ･･･ Z direction by VTX & BeamCenter (mean vertex X-Y)
BBCZ ･･･ Z direction by BBC & BeamCenter (mean vertex X-Y)

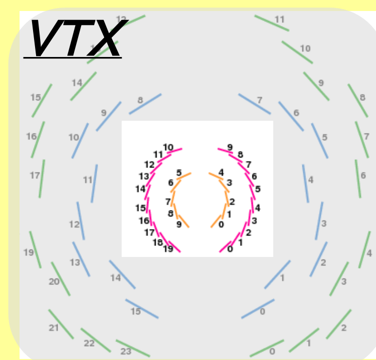
PRECISE



3~4 clusters are needed for 3D vertex reconstruction.

If not

SEED

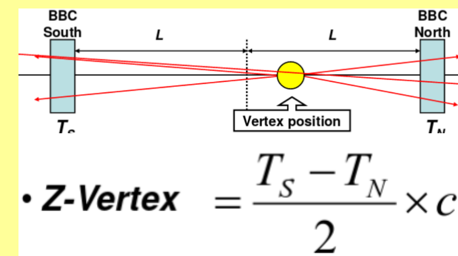


Use only B0 & B1 clusters. Decide only vertex z-position.

X-Y is defined by BeamCenter.

If not

BBCZ

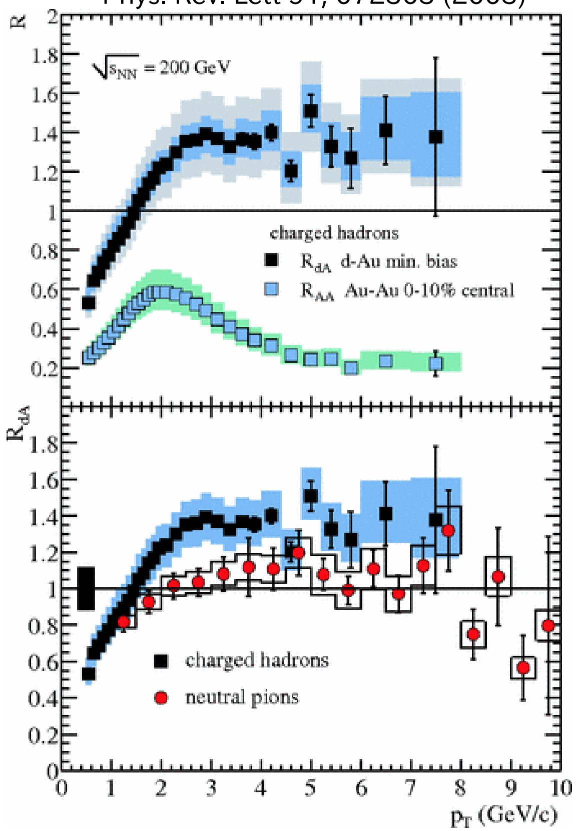


Use forward-backward timing difference. (resolution |Δz| ~3cm at pp)

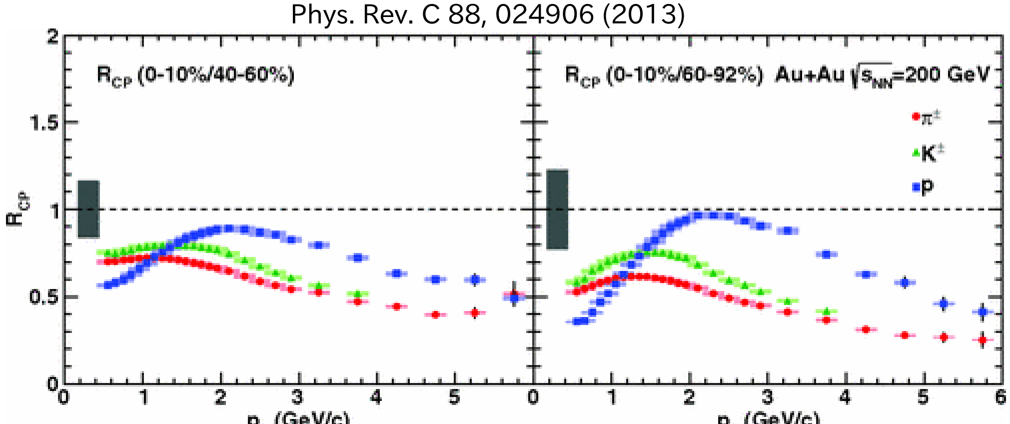
X-Y is defined by BeamCenter.

R_{AA} reference

Phys. Rev. Lett 91, 072303 (2003)



Phys. Rev. C 88, 024906 (2013)



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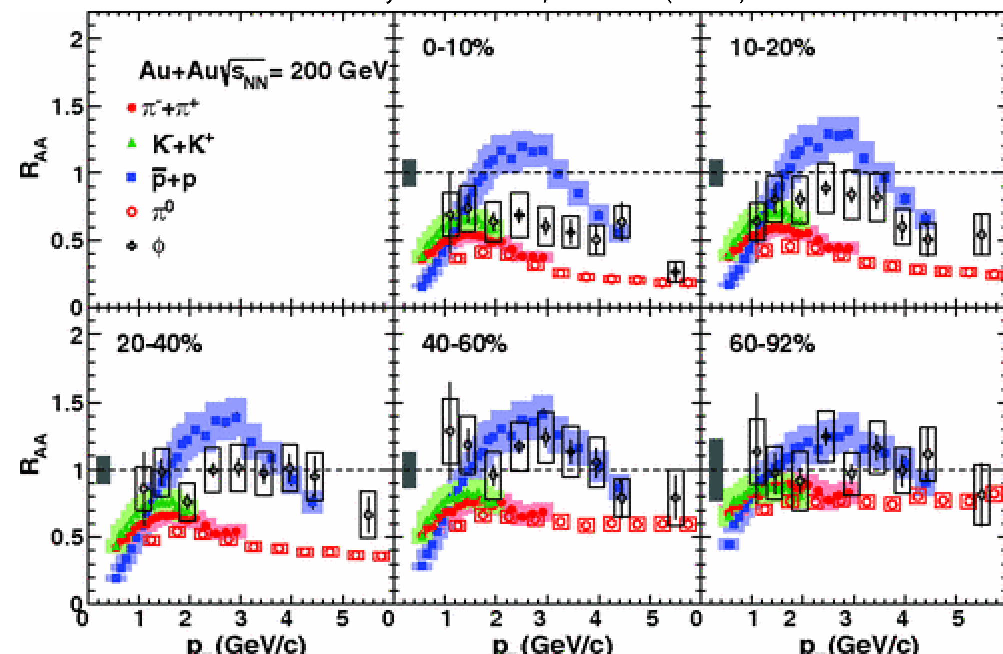

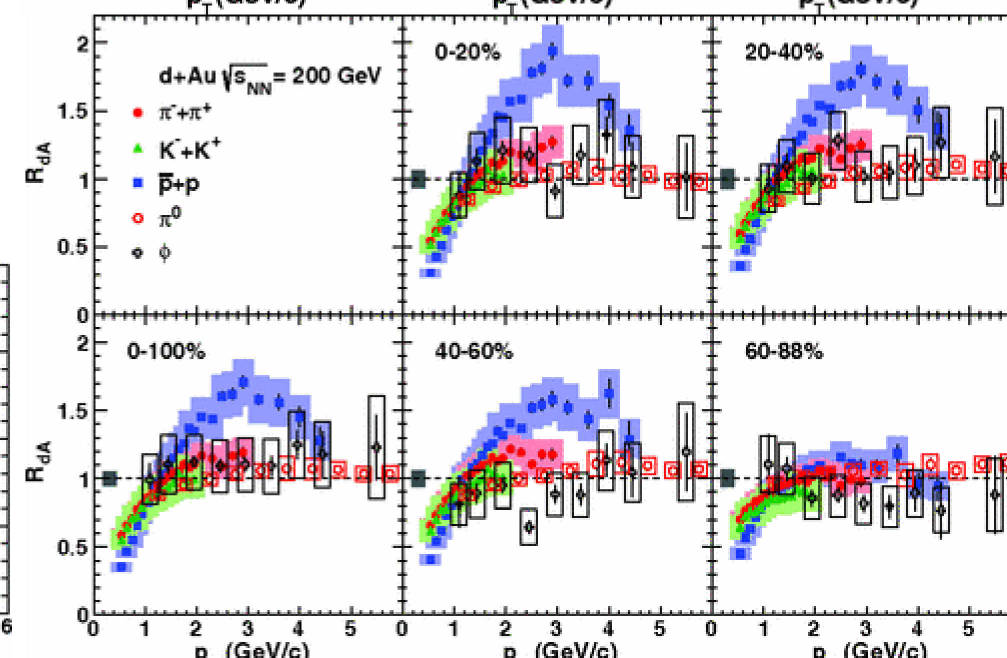

^{3}He+Au π^0 production