

高エネルギー重イオン衝突実験による 直接光子の楕円方位角異方性の測定

(Measurement of p^0 and direct photon v_2
in $s_{NN} = 200\text{GeV}$ Au+Au collision at RHIC-PHENIX)

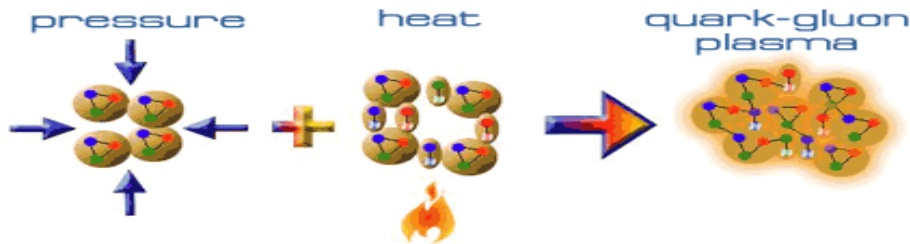
The Physical Society of Japan 61th Annual Meeting

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University of Tsukuba

27 Mar 2006

1-1. Introduction ~ probe of QGP ~

Quark Gluon Plasma



**Studying the QGP state by
Relativistic Heavy Ion Collider.**

difficulty of QGP study

1. We can not see QGP directly

2. large back ground

probe of initial state of collision

photon

Photon doesn't interact with any other hadrons
and they keep their conditions
when they are generated in final state.

1-2. Introduction ~ direct photon~

prompt photon

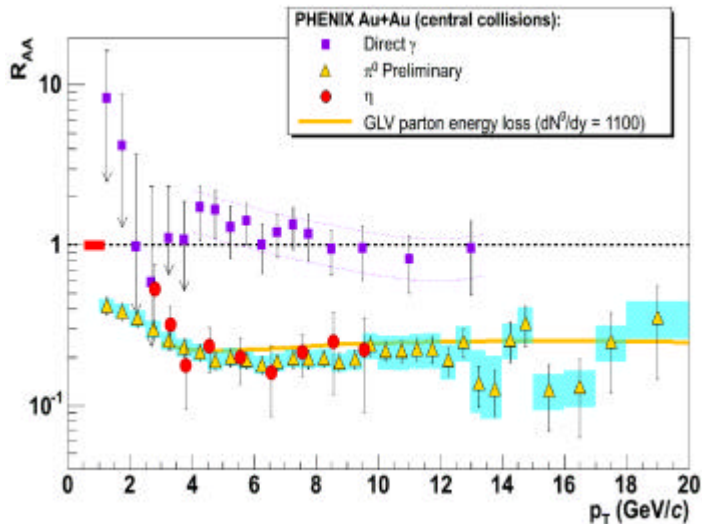
thermal photon

photon from
jet fragmentation

hadron decay

direct photon

inclusive photon



Example of direct photon analysis :
measurement of R_{AA}

$$R_{AA} = \frac{(1/N_{evt})d^2N_{AA}/dp_Td\eta}{(\langle N_{coll} \rangle / \sigma^{NN}_{inel})d^2\sigma^{NN}/dp_Td\eta}$$

We estimate the elliptic flow (v_2) of direct photon to study initial state of collisions.

2-1. Motivation ~ elliptic flow of direct photon ~

Expectation of photon v_2 at relativistic heavy ion collisions

Inclusive photon

hadron decay

Direct photon

prompt photon

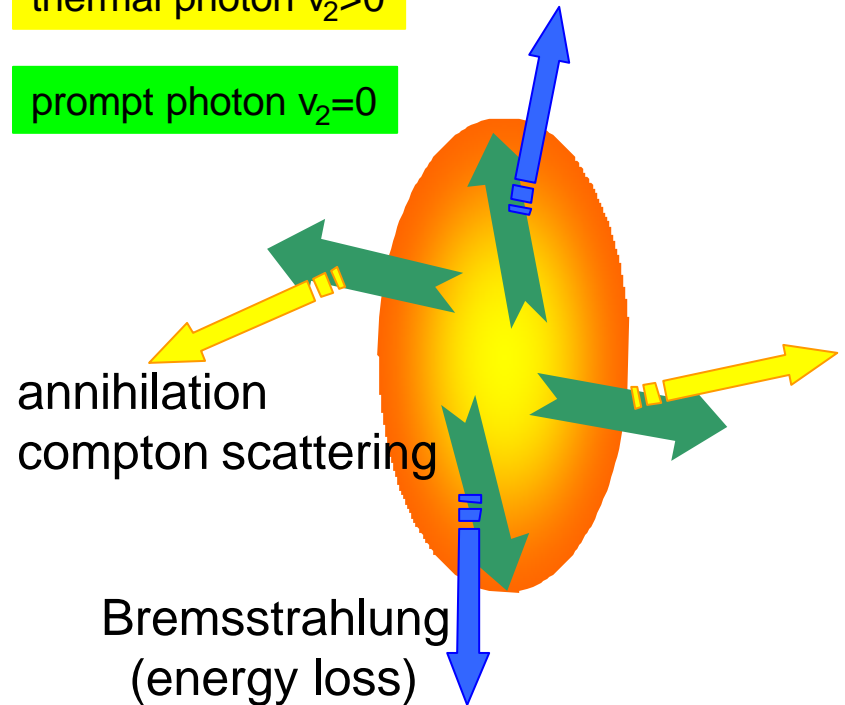
Thermal photon

photon from jet fragmentation

$$\frac{dN}{d(\phi - \Psi)} = N_0(1 + 2v_1 \cos(\phi - \Psi) + 2v_2 \cos(2(\phi - \Psi)) + \dots)$$

thermal photon $v_2 > 0$

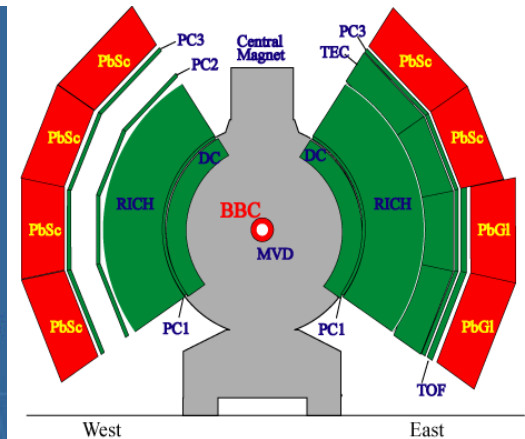
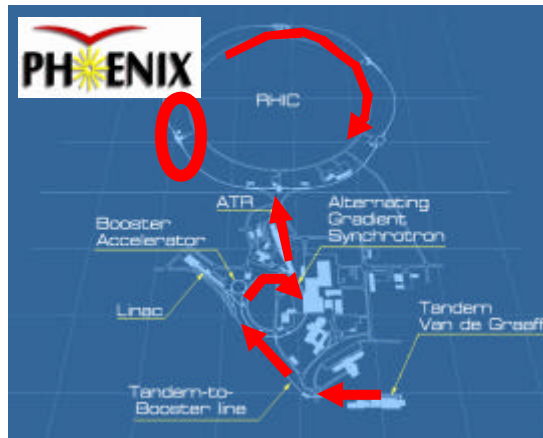
prompt photon $v_2 = 0$



2-2. RHIC-PHENIX

RHIC

The Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory is a world class scientific research facility that began operation in 2000, following 10 years of development and construction.

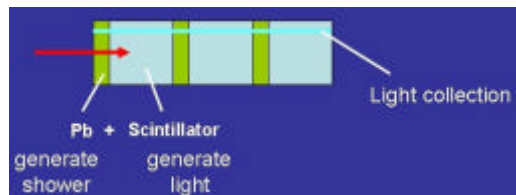
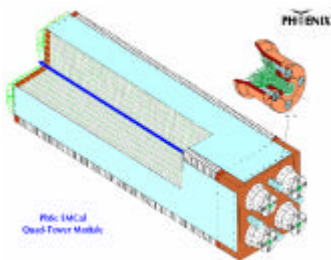


lead scintillator (PbSc)

energy resolution

$$2.1 \oplus 8.1 \% / E^{1/2} [\text{GeV}]$$

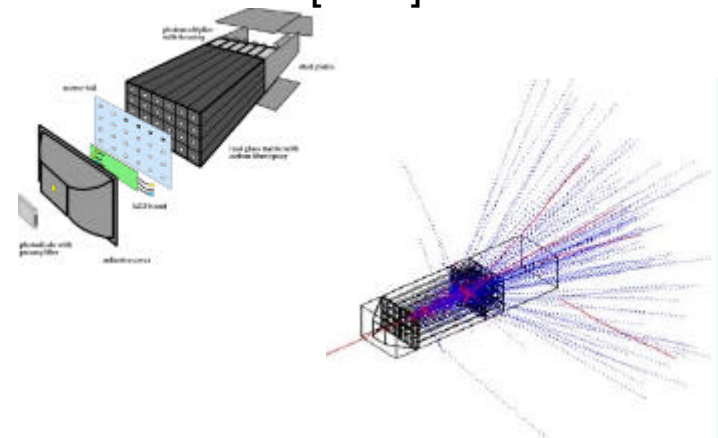
$$|\eta| < 0.375 \quad \Delta\phi = 90^\circ \times 2$$



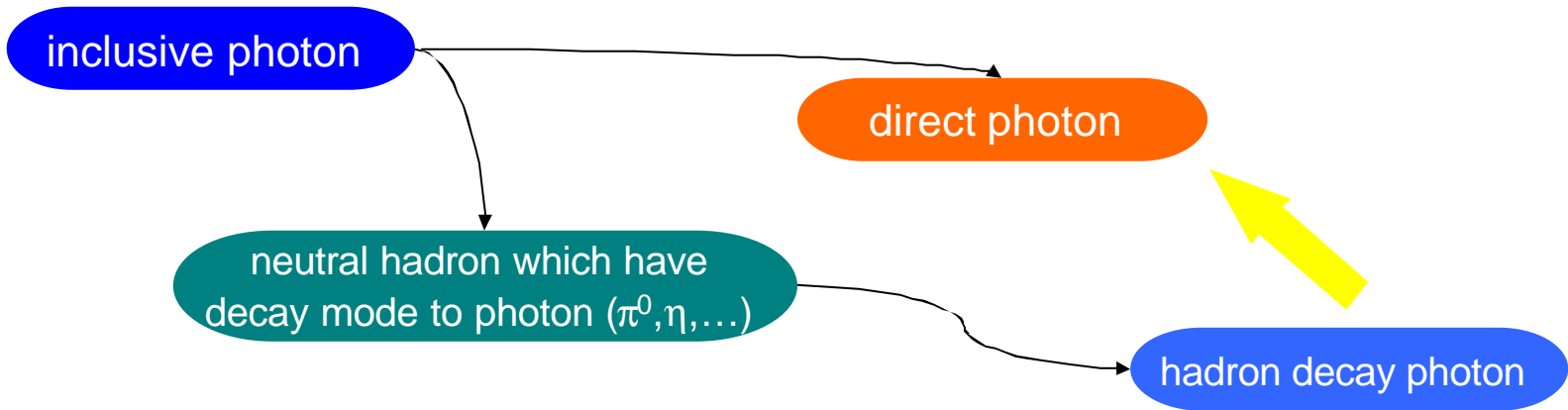
lead glass (PbGI)

energy resolution

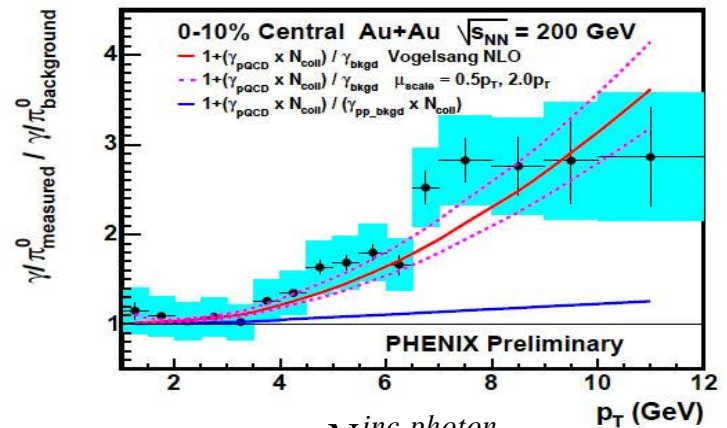
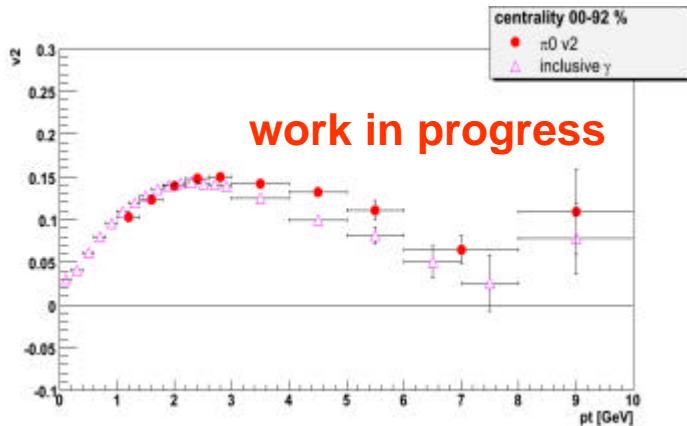
$$0.76 \oplus 5.95 \% / E^{1/2} [\text{GeV}]$$



3-1. method of calculation



Ex. π^0 and inclusive photon v_2



$$v_2^{dir.photon} = \frac{R * v_2^{inc.photon} - v_2^{BG_photon}}{R - 1}$$

$$R = \frac{N^{inc.photon}}{N^{BG_photon}}$$

3-2. calculation of $\pi^0 v_2$

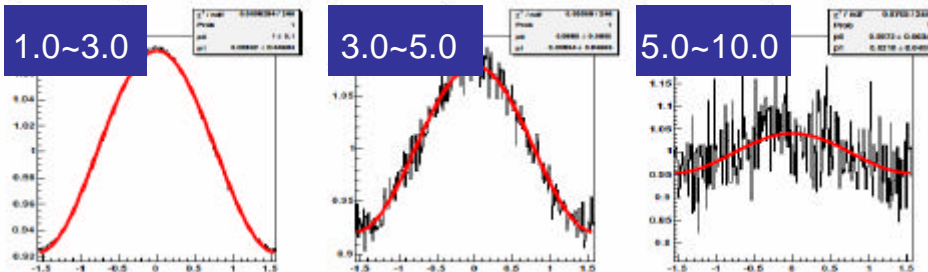
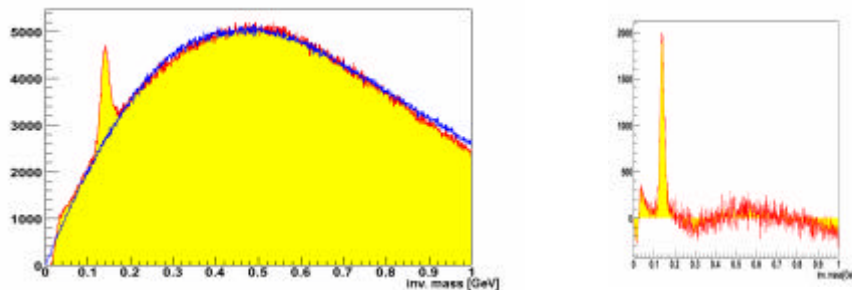
Energy cut ($E_{\text{core}} > 0.2 \text{ GeV}$)

shower shape cut ($\chi^2 < 3$)

EMCal TOF ($\text{TOF} < 1.2 \text{ ns}$)

charged veto ($\text{pc3hit} > 6.5 \text{ cm}$)

$$\text{Invariant mass} = \sqrt{2E_1E_2 \left(1 - \frac{x_1x_2 + y_1y_2 + z_1z_2}{l_1l_2}\right)}$$



calculation step of $p^0 v_2$

photon ID by EMCal

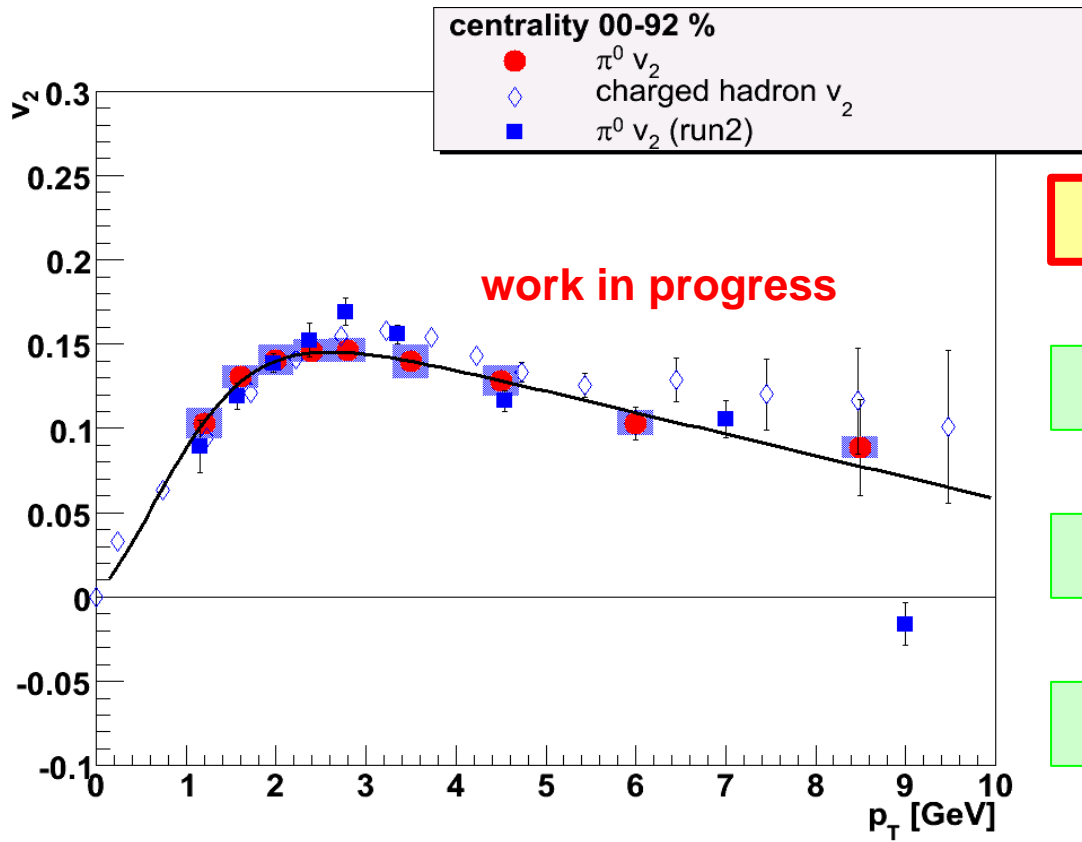
π^0 PID invariant mass

azimuthal distribution of π^0

fitting by $N_0[1+2v_2\cos\{2(\phi-\Psi)\}]$

correction by reaction plane resolution

4-1. result $\sim \pi^0 v_2 \sim$



estimate the $\pi^0 v_2$

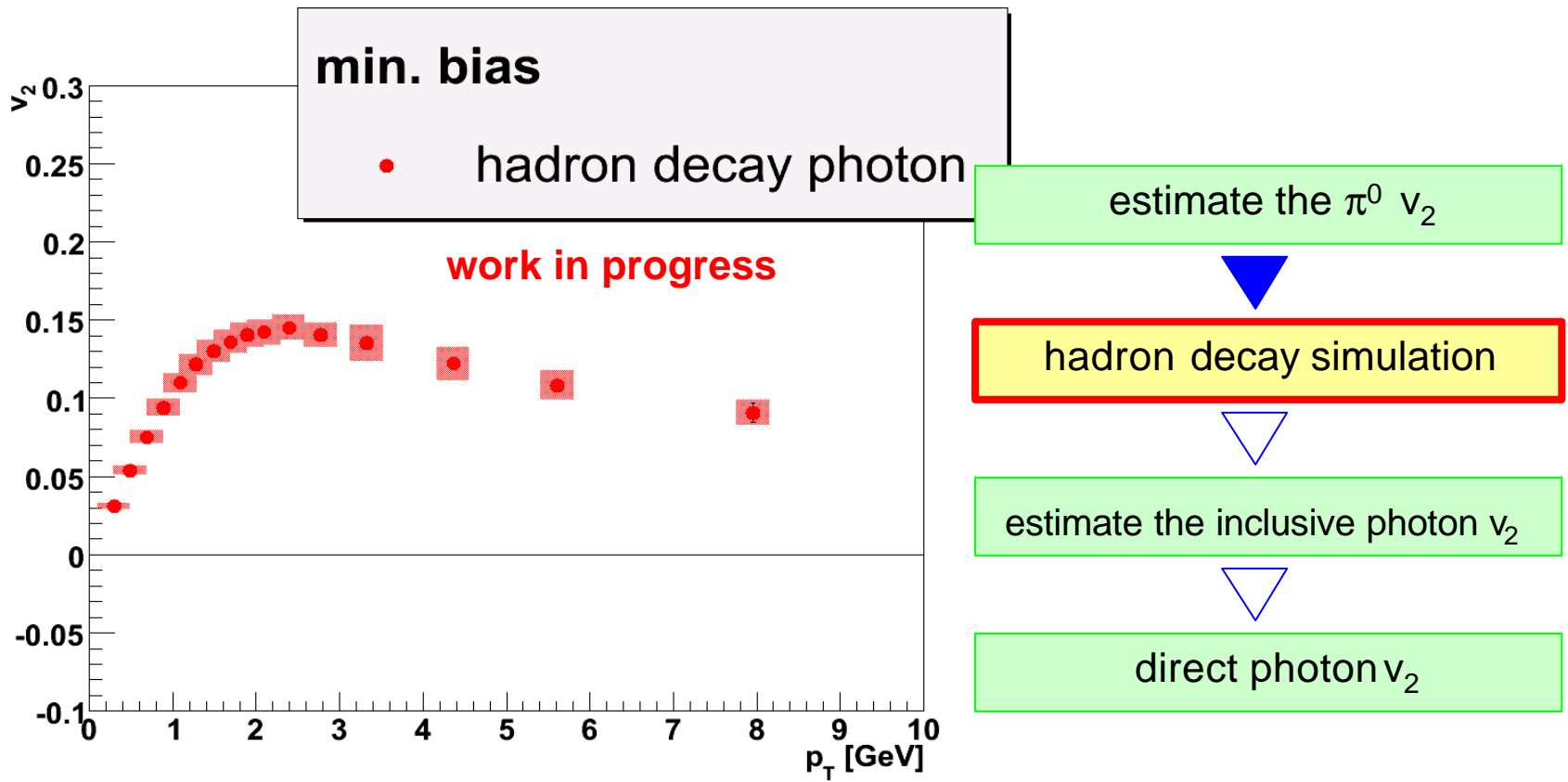
hadron decay simulation

estimate the inclusive photon v_2

direct photon v_2

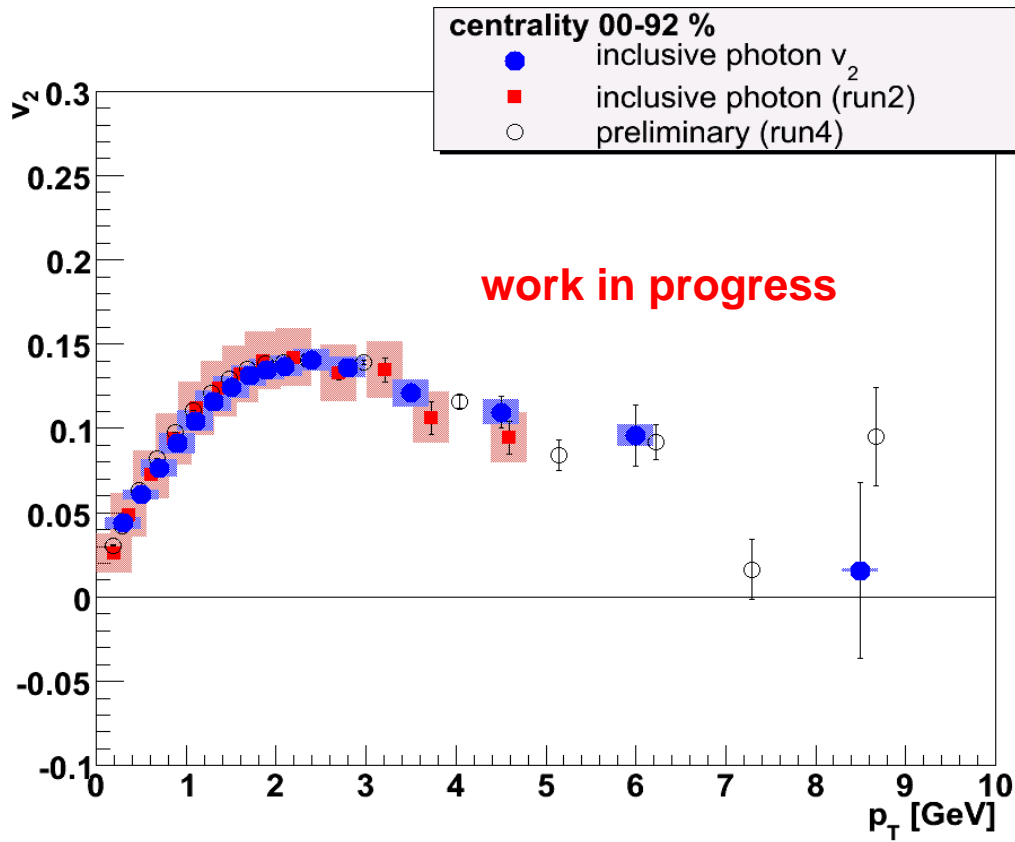
We estimate the $\pi^0 v_2$ more than 1 GeV p_T region (work in progress). This plot compared to charged hadron v_2 (PHENIX preliminary) and run 2 result.

4-2. result ~ hadron (π^0 or η) decay photon $v_2 \simeq$



This plot shows the hadron (π^0 or η) decay photon from π^0 or Kaon v_2 .
Input of π^0 decay photon is fitting function of $\pi^0 v_2$.
Input of η decay photon is Kaon v_2 (PHENIX preliminary).

4-3. result ~ inclusive photon v_2 ~



estimate the $\pi^0 v_2$

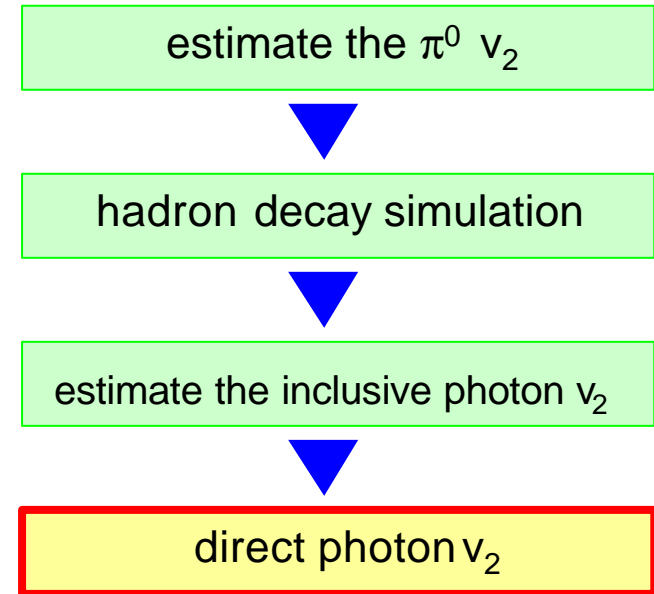
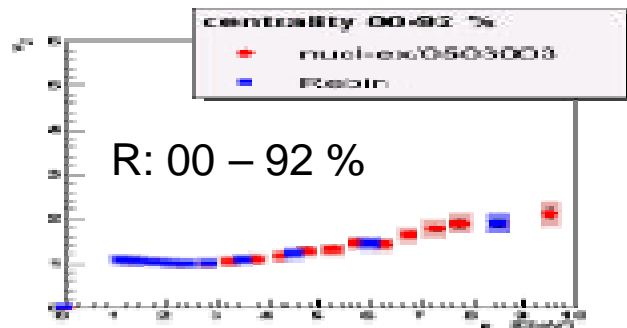
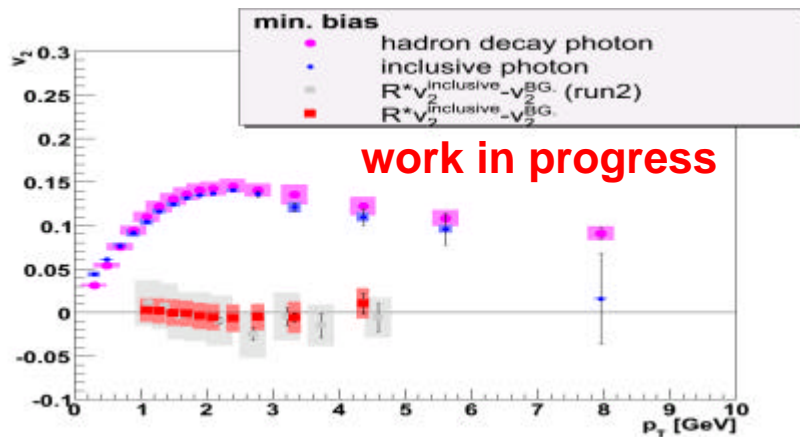
hadron decay simulation

estimate the inclusive photon v_2

direct photon v_2

We calculate the inclusive photon and compared to results of previous analysis.

4-4. result ~ subtract the hadron decay ~



$$v_2^{sub.} = Rv_2^{inc.} - v_2^{BG.}$$

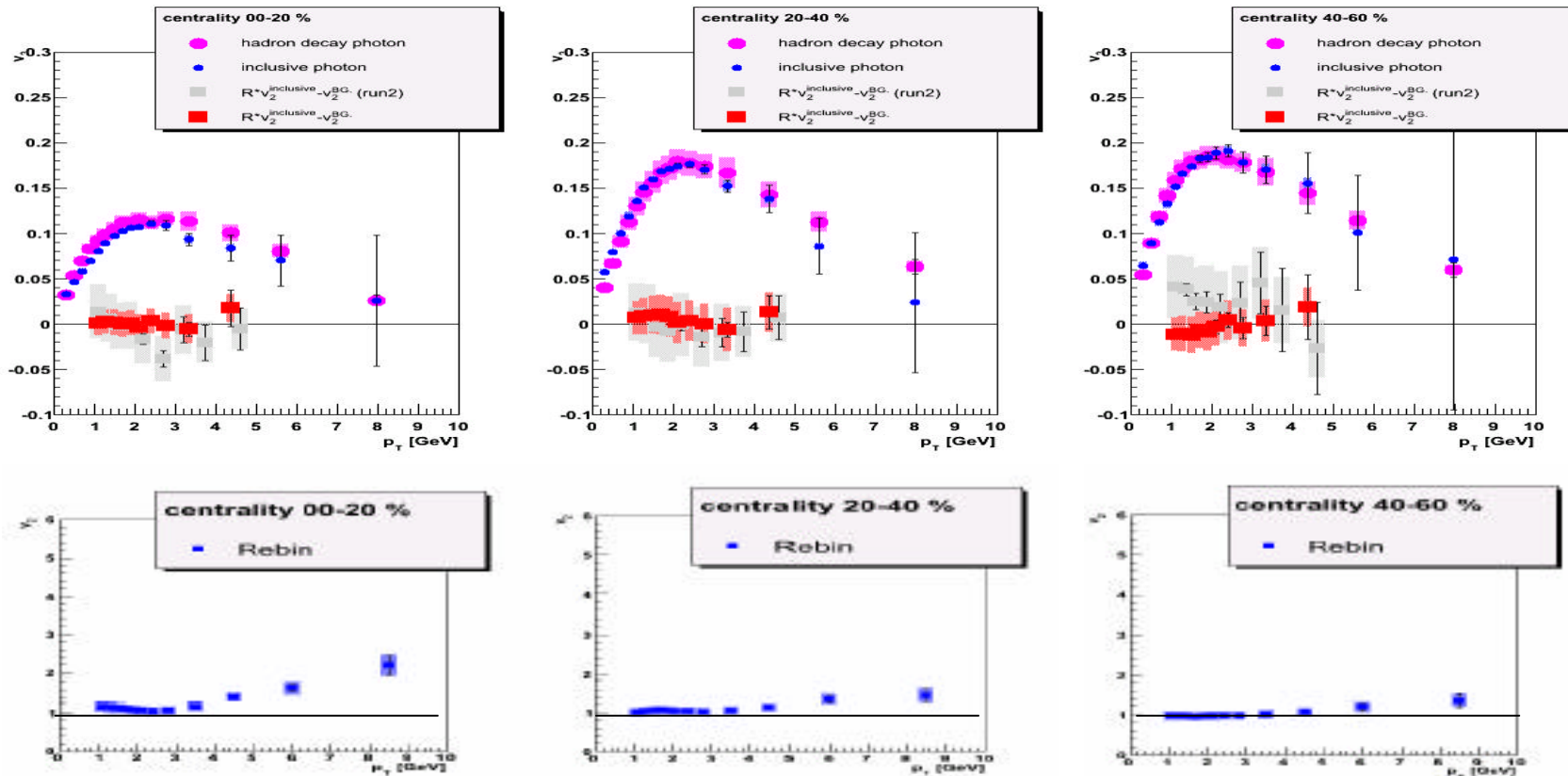
$$R = \frac{N^{inc. \text{ photon}}}{N^{BG. \text{ photon}}}$$

$$\Delta v_2^{sub.} = \sqrt{(v_2^{inc.} \Delta R)^2 + (R \Delta v_2^{inc.})^2 + (\Delta v_2^{BG.})^2}$$

This plot shows v_2 of subtracted the hadron decay photon from inclusive photon.

4-5. result ~ centrality dependence ~

work in progress



These plots show centrality dependence of subtracted photon v_2 .

5. summary and to do list

summary

- + We estimate v_2 of π^0 , inclusive photon, and subtracted photon to study initial state of relativistic heavy ion collisions and QGP.
- + We used Au+Au collisions data set in $s_{NN} = 200\text{GeV}$ at RHIC-PHENIX.
- + Compared to results of previous analysis.
- + We show the subtract photon at less than 5 GeV p_T region, and these results are still work in progress.

to do

- + need to more study about systematical error.
- + study of v_2 calculation methods
- + estimate the direct photon v_2 from inclusive photon and hadron decay photon.
- + prepare to show result at more large p_T range.

Ex. Back up

Ex. Introduction (generation of photon)

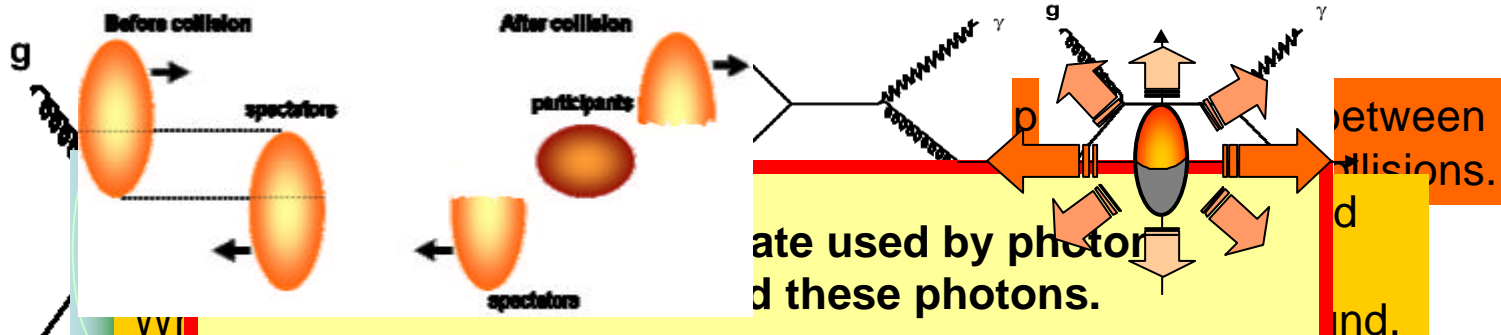
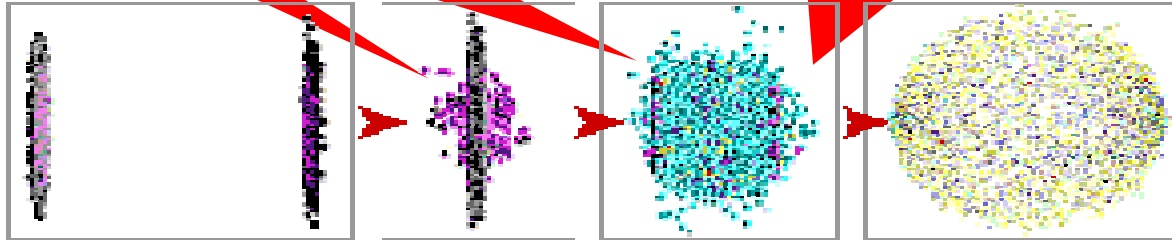
Typical generation of photon at heavy ion collisions

prompt photon

thermal photon

photon from jet fragmentation

hadron decay

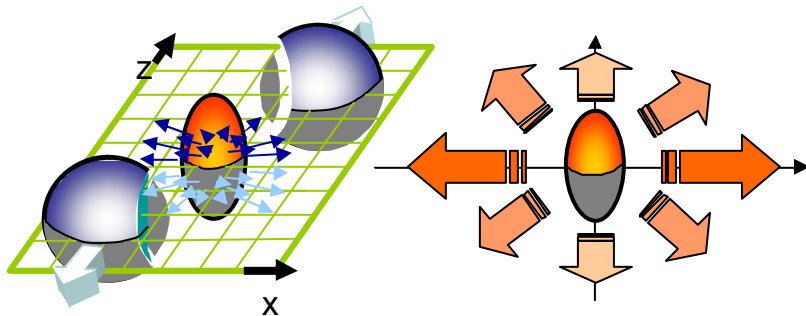


Photons from thermal equilibrium state.
 These photon have thermal information of initial state.
 And, these photons are important of studying expansion process about hottest matter.

Ex. Introduction ~ elliptic flow ~

直接光子の楕円方位角異方性を測る

楕円方位角異方性 (v_2)



衝突初期の反応関与部の幾何学的異方性が
粒子の運動量空間における異方性に反映される

粒子の生成過程を探る上で重要な情報源

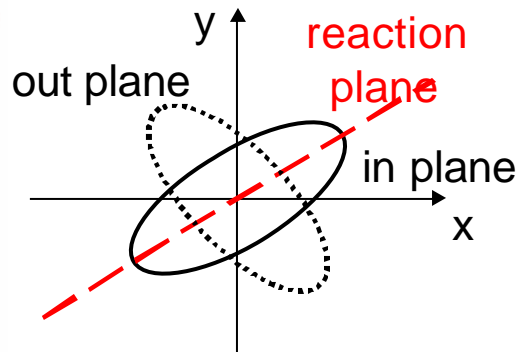
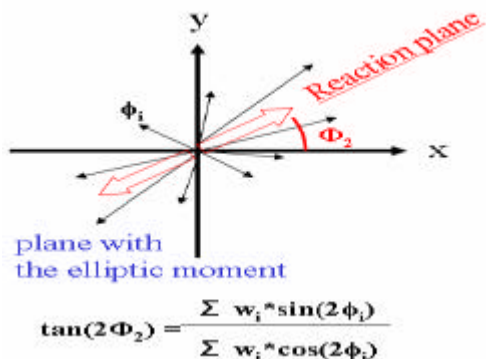
$$\frac{dN}{d(\phi - \Psi)} = N_0(1 + 2v_1 \cos(\phi - \Psi) + 2v_2 \cos(2(\phi - \Psi)) + \dots)$$

ϕ : 発生粒子の方位角

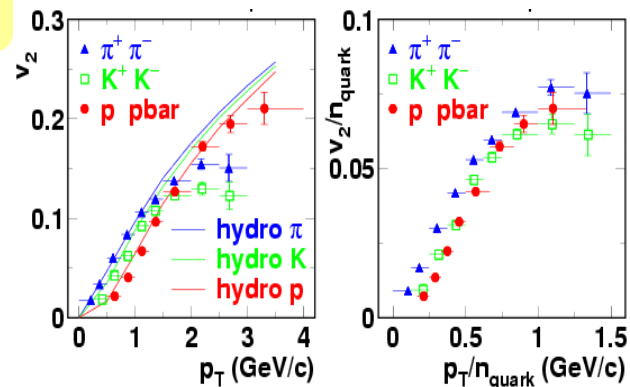
Ψ : reaction planeの方位角

反応平面法(reaction plane)

ビーム軸方向とインパクトパラメータ方向が張る平面



例 : 荷電ハドロン v_2



Ex. systematic error propagate

direct photon
systematic error

hadron decay
photon error

pi0 PID
eta contamination
reaction plane determination

inclusive
photon error

calculation method difference
reaction plane determination

$R = N(\text{inc.}) / N(\text{BG.})$
error

from PPG042

there are same
component



they have to remove
when error propagate of
direct photon

centrality [%]	systematic error from reaction plane determination [%]	centrality [%]	systematic error from reaction plane determination [%]
00-10	20.60970	10-20	5.11321
20-30	3.94074	30-40	3.75969
40-50	4.05684	50-60	4.60628
60-70	22.52510		
00-20	13.4326	20-40	3.8683
40-60	4.25345	00-92	4.5

reaction plane determination

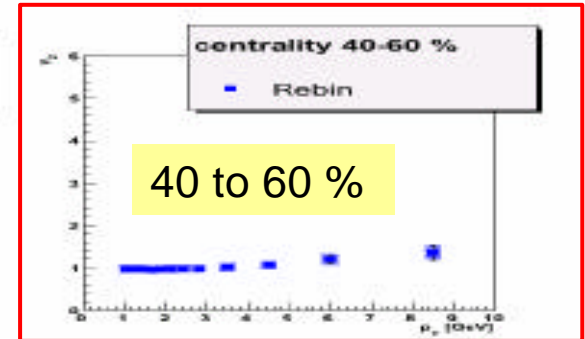
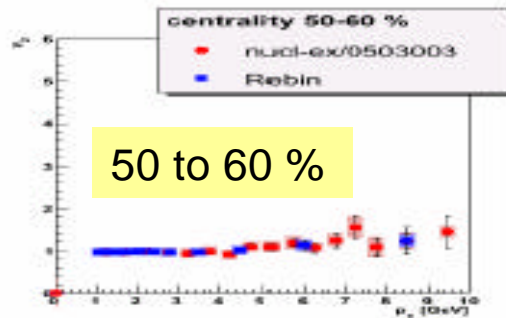
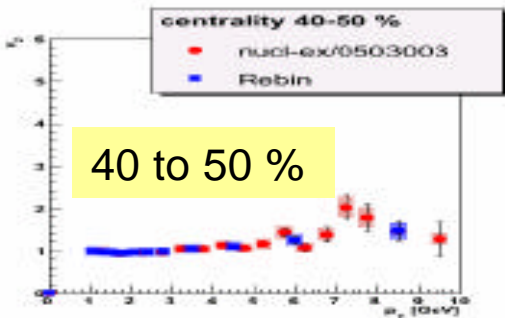
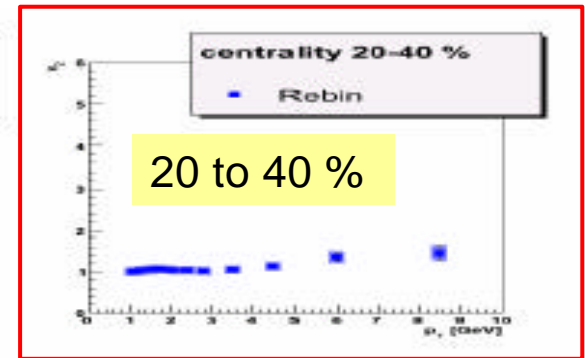
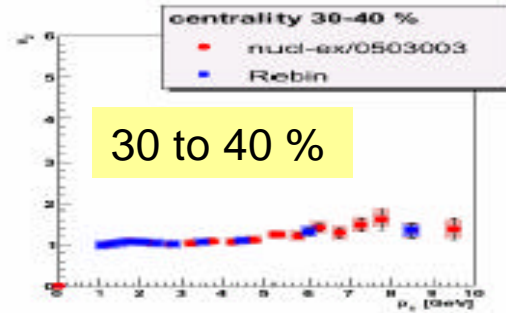
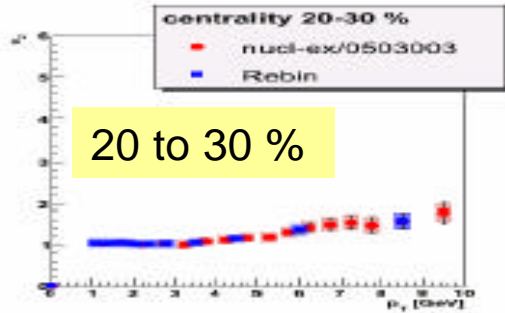
centrality [%]	systematical error from π^0 PID in high p_T [%]
00~20	6.54137
20~40	7.66519
40~60	5.72981
00~92	5.61786

π^0 PID

centrality [%]	systematical error from calculation method of inclusive photon in high p_T [%]
00~20	5.36431
20~40	4.16751
40~60	3.72115
00~92	4.91141

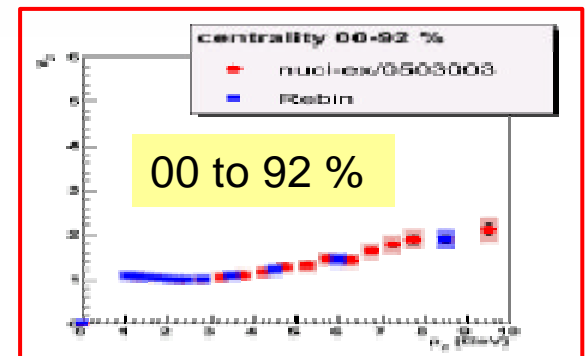
calculation method of
inclusive photon

Ex. R



$$R = \frac{N_{\text{inclusive}}}{N_{\text{background}}}$$

$$R_{\text{rebin}}^{\text{syserr}} = \frac{\frac{1}{R_1^{\text{staerr}}} R_1^{\text{syserr}} + \frac{1}{R_2^{\text{staerr}}} R_2^{\text{syserr}}}{\frac{1}{R_1^{\text{staerr}}} + \frac{1}{R_2^{\text{staerr}}}}$$



Ex. systematical error propagate

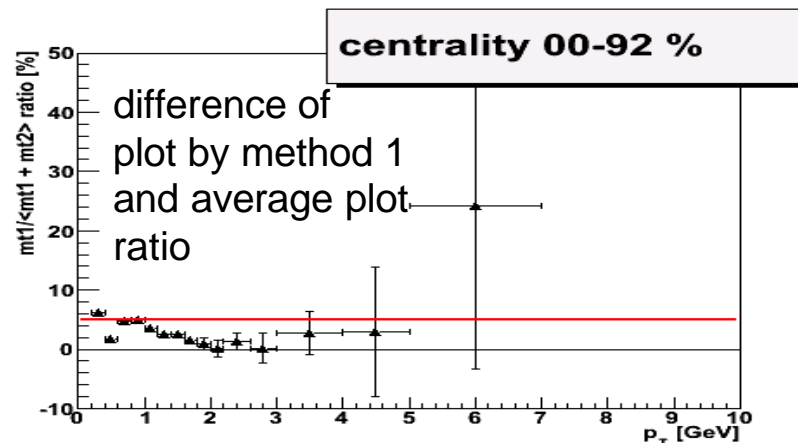
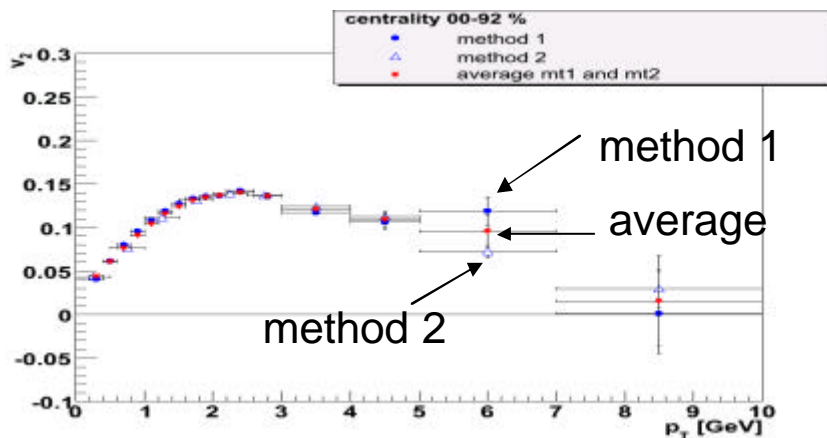
hadron decay
photon error



inclusive
photon error



$R=N(\text{inc.})/N(\text{BG.})$
error



As systematic error of inclusive photon, I have estimated error from calculation method difference and reaction plane determination. The error from photon PID have not estimated yet.

Please refer to my analysis note for calculation method.

