Conical emission:

p_T and system dependences of 3-particle correlation and the first result with identified protons from STAR

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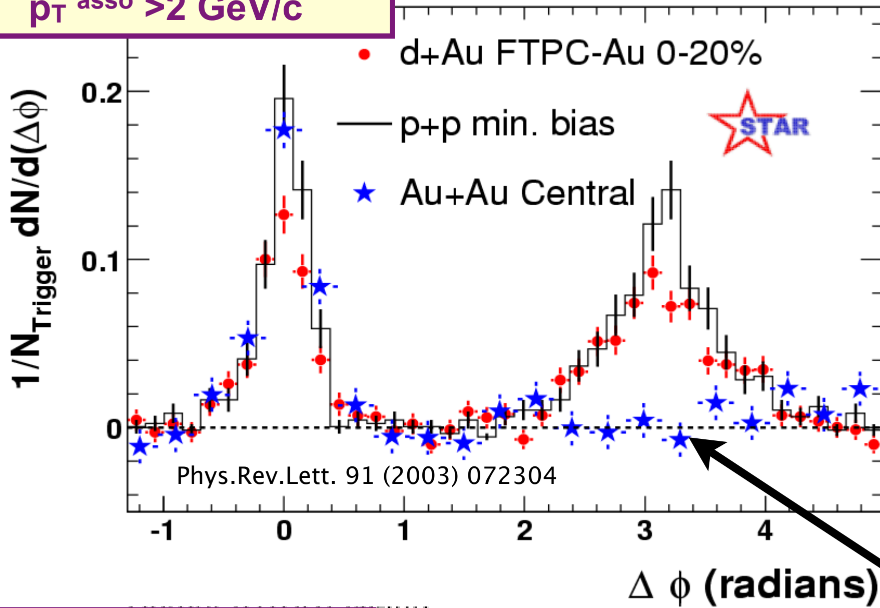
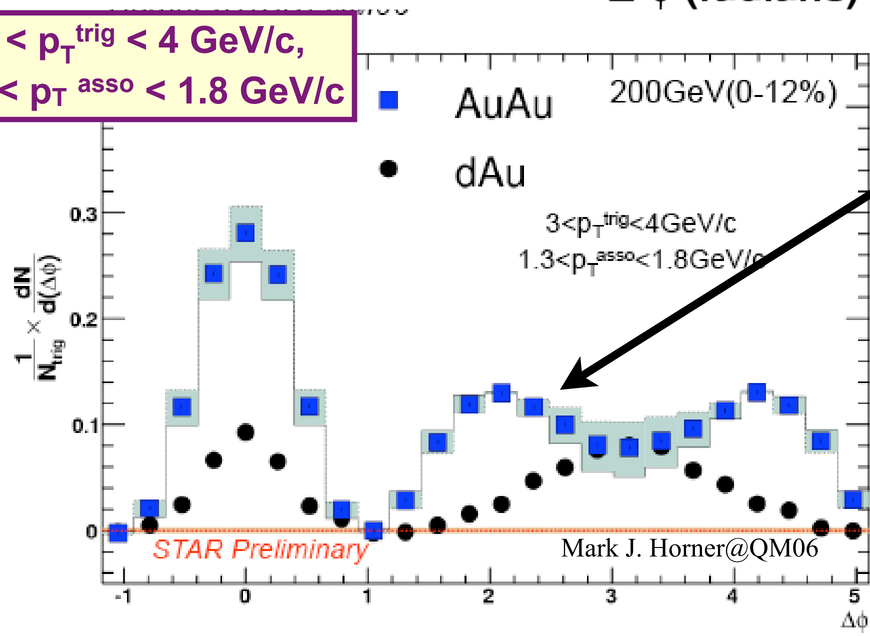
(PURDUE/SINAP)

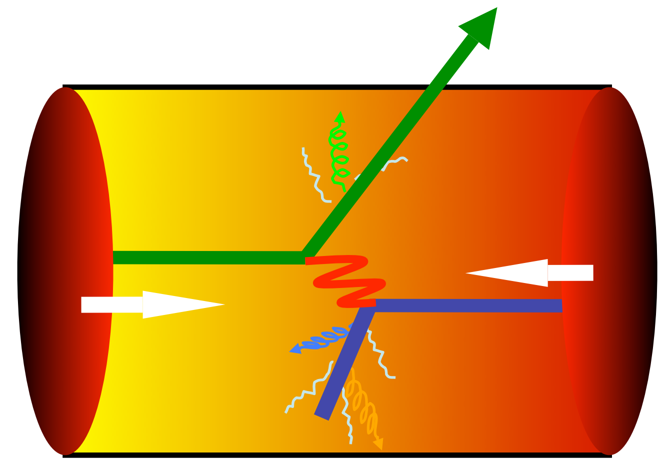
MOTIVATION

$4 < p_T^{trig} < 6$ GeV/c,
$p_T^{asso} > 2$ GeV/c



$3 < p_T^{trig} < 4$ GeV/c,
$1.3 < p_T^{asso} < 1.8$ GeV/c





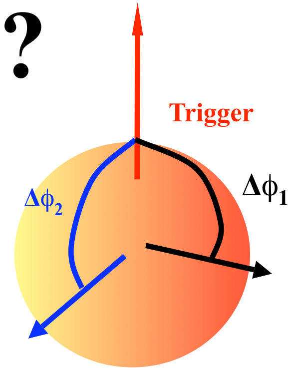
For away side in di-hadron correlation in central Au+Au collisions at RHIC:

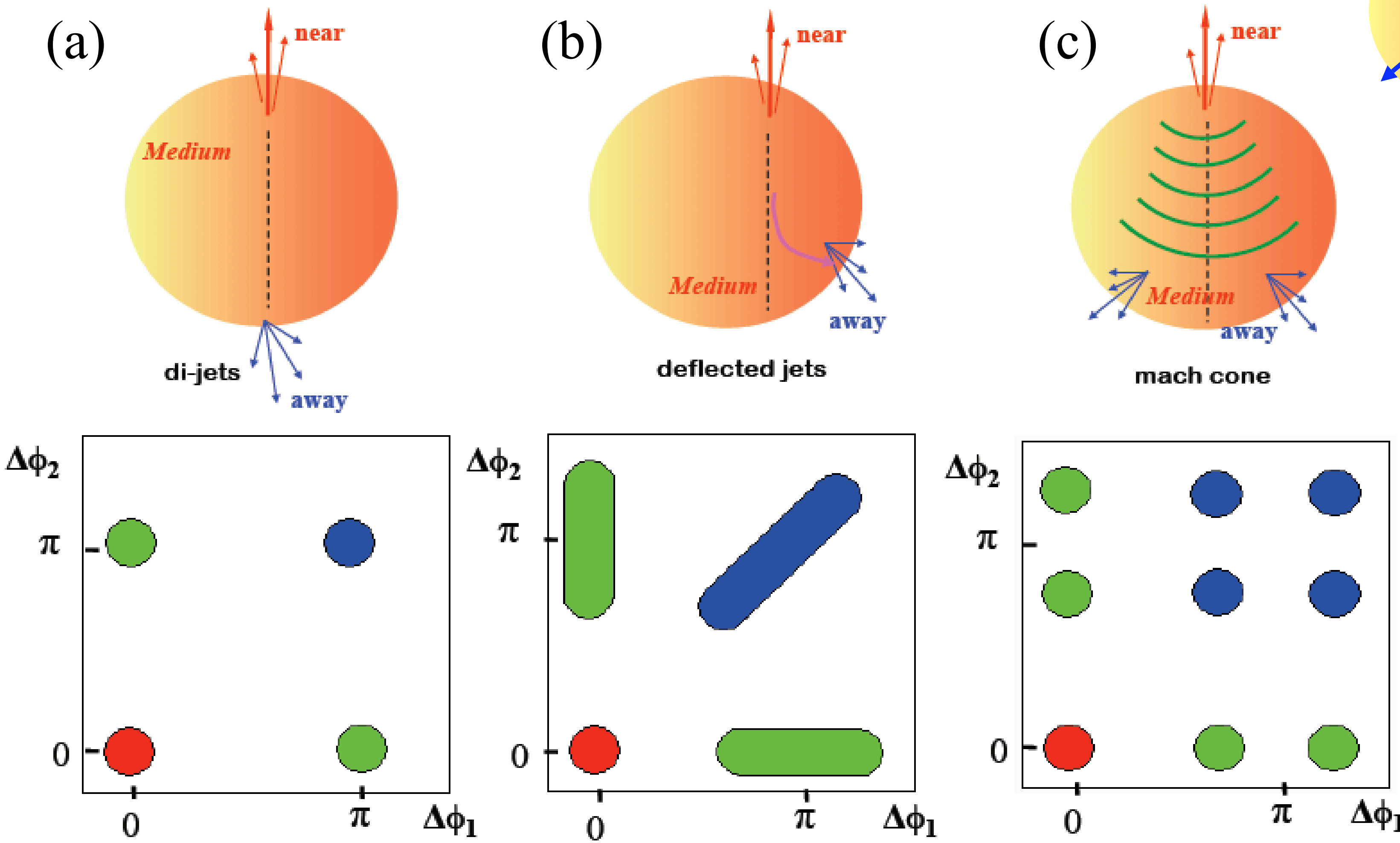
- Suppression due to jet quenching.
- Double-peak:
  - **Mach-cone** (to be discussed)
  - **Čerenkov gluon radiation** (to be discussed)
  - **Large angle gluon radiation**
    I. Vitev, PLB 630, 78 (2005)
    A. D. Polosa et al. ,PRC 75, 041901(2007)
  - **Jet deflection**
    Armesto, PRC 72, 064910 (2005)
    Charles B. Chiu et al., PRC 74, 064909 (2005)
  - ...

CONICAL EMISSION THEORIES

- **Mach-cone**:
  - Shock waves excited by a supersonic parton.
  - Can be produced in different theories:
    - **Hydrodynamics**
      - H. Stöcker et al. (Nucl.Phys.A750:121,2005)
      - J. Casalderra-Solana et. al. (J.Phys.Conf.Ser. 27:22,2005)
      - T. Renk & J. Ruppert (Phys.Rev.C73:011901,2006)
    - **Colored plasma**
      - J. Ruppert & B. Müller (Phys.Lett.B618:123,2005)
    - **AdS/CFT**
      - S. Gubser, S. Pufu, A. Yarom. (arXiv:0706.4307, 2007)
- **Čerenkov Gluon Radiation**:
  - Radiation of gluons by a superluminal parton.
    - I.M. Dremin (Nucl. Phys. A750: 233, 2006)
    - V. Koch, A. Majumder, Xin-Nian Wang (Phys. ReV. Lett. 96, 172302, 2006)
- Parton Cascade
  - G. L. Ma et. al. (Phys. Lett. B 641, 362 (2006), 647, 122, (2007))

WHY 3-PARTICLE CORRELATION?

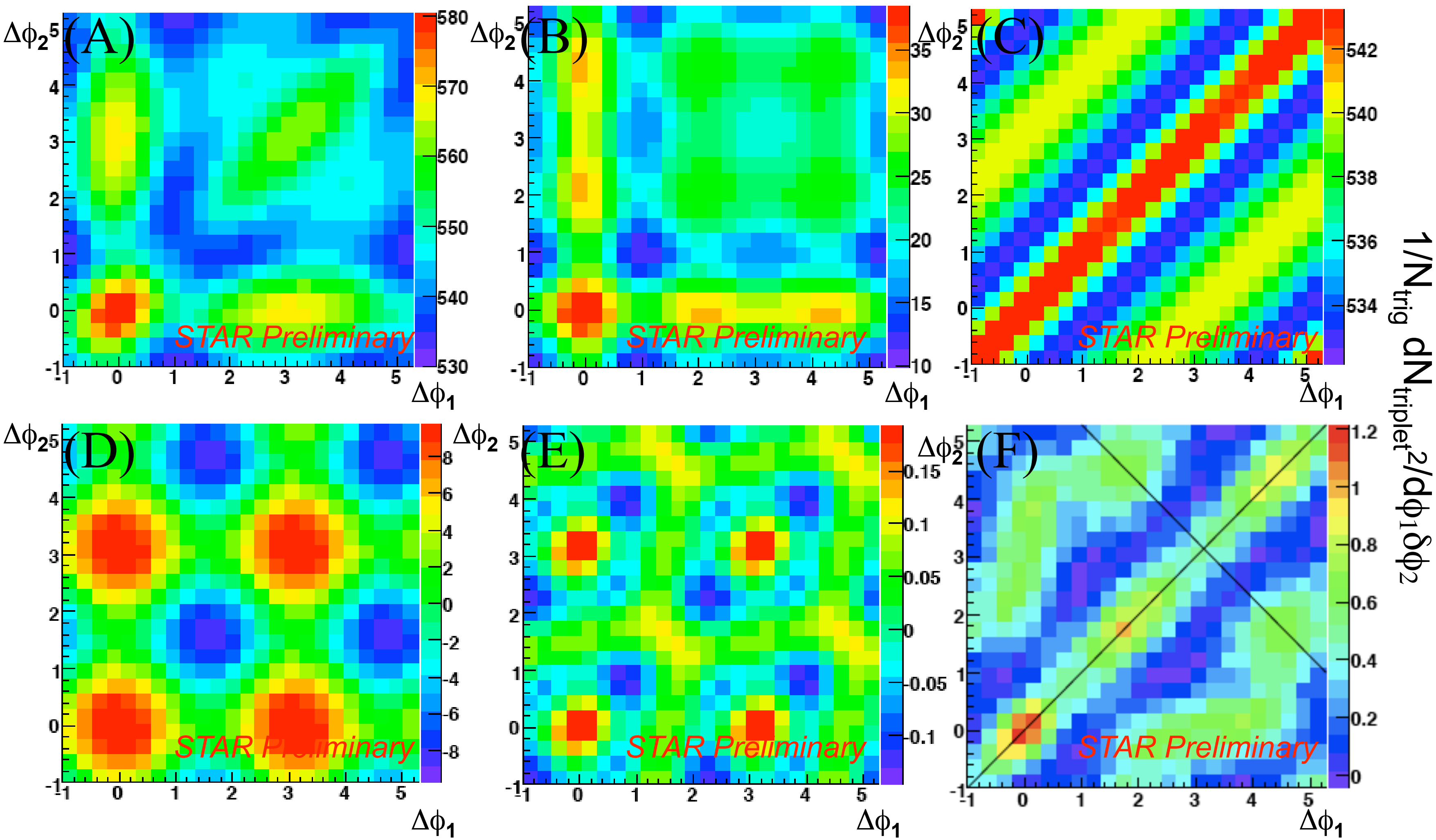




BACKGROUND SUBTRACTION

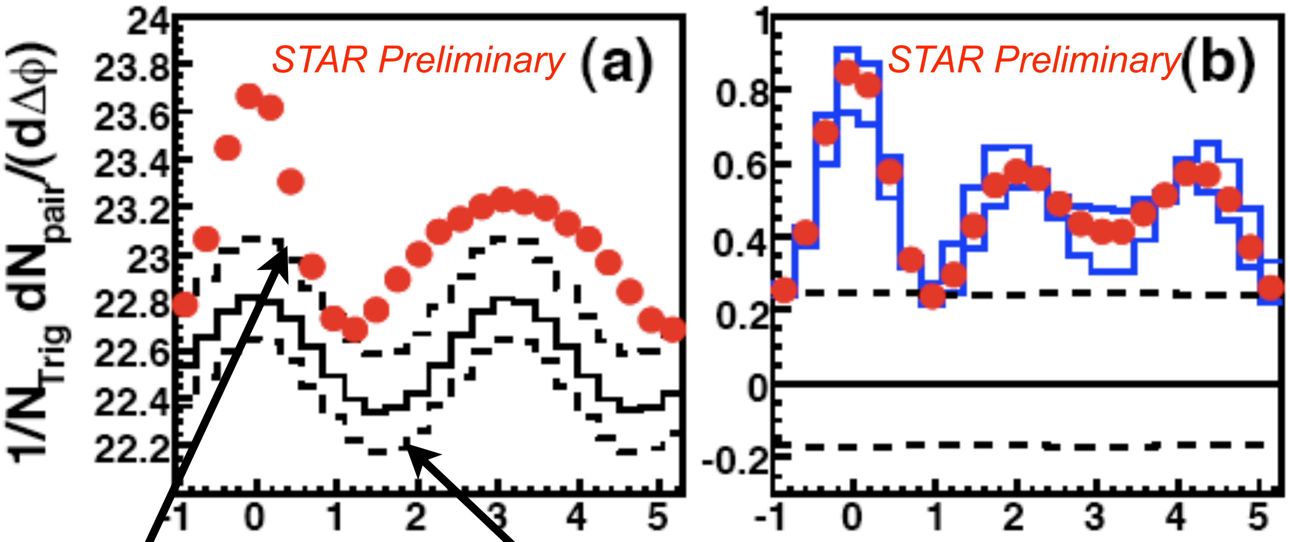
An example: Au+Au 200 GeV (0-12%),

$3 < p_T^{Trig} < 4$ GeV/c and $1 < p_T^{Asso} < 2$ GeV/c



(A): raw signal; (B): hard-soft background; (C): soft-soft background; (D): flow (v2) background; (E): flow (v4) background; (F): final signal.

SYSTEMATIC UNCERTAINTIES



A normalization factor is obtained by 3-particle ZYAM (Zero Yield At Minimum), i.e. the average of the lowest 10% data-points is required to be zero.

Systematic uncertainty from the normalization factor:

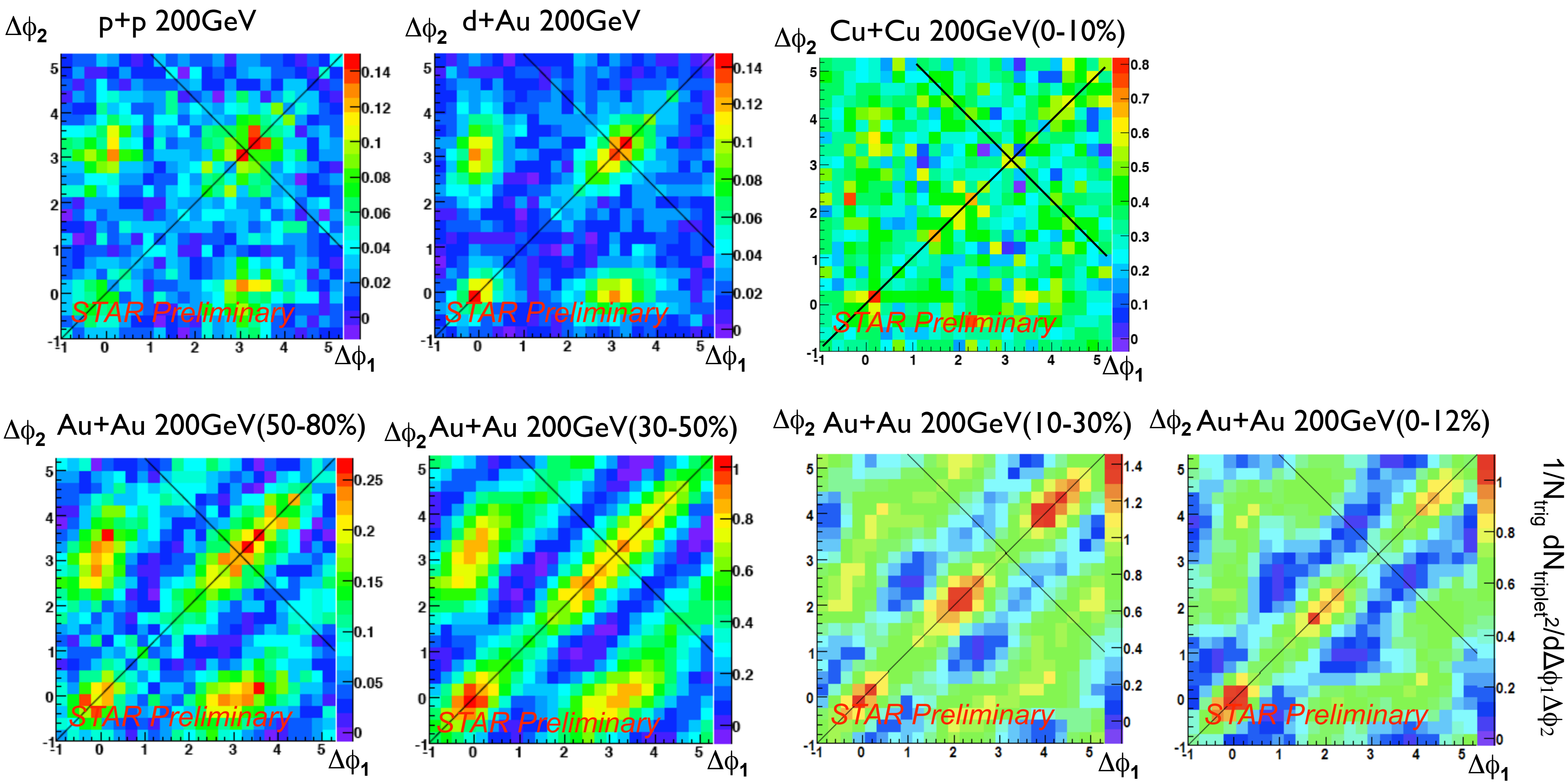
One end from 2-particle ZYAM, **the other end** from 3-particle ZYAM at only one lowest data-point.

Other systematic uncertainties:

Flow correction, multiplicity fluctuation etc.

RESULTS: SYSTEM DEPENDENCE

$(3 < p_T^{Trig} < 4$ GeV/c and $1 < p_T^{Asso} < 2$ GeV/c)



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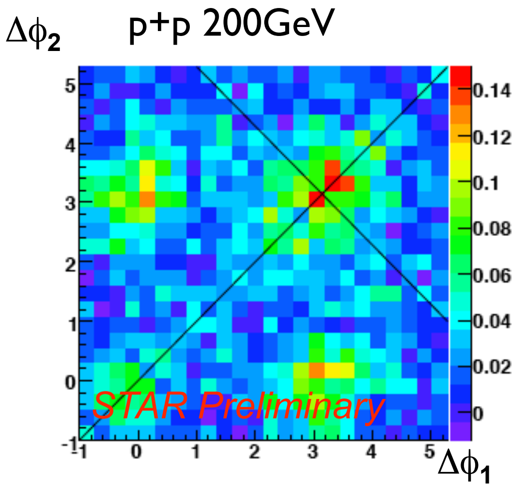
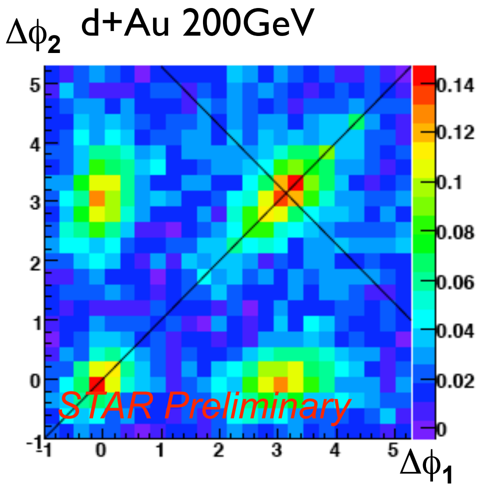
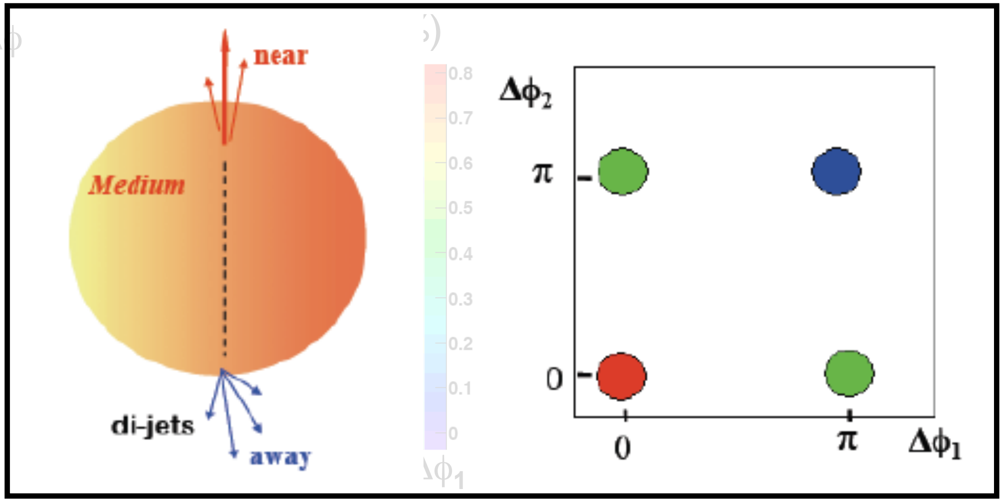
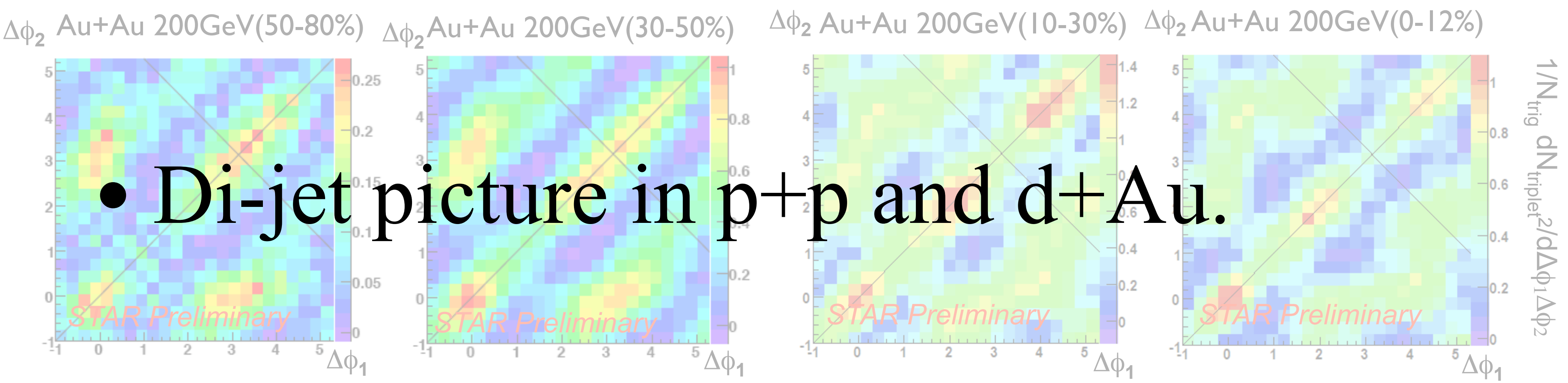
RESULTS: SYSTEM DEPENDENCE

($3 < p_T^{Trig} < 4$ GeV/c and $1 < p_T^{Asso} < 2$ GeV/c)





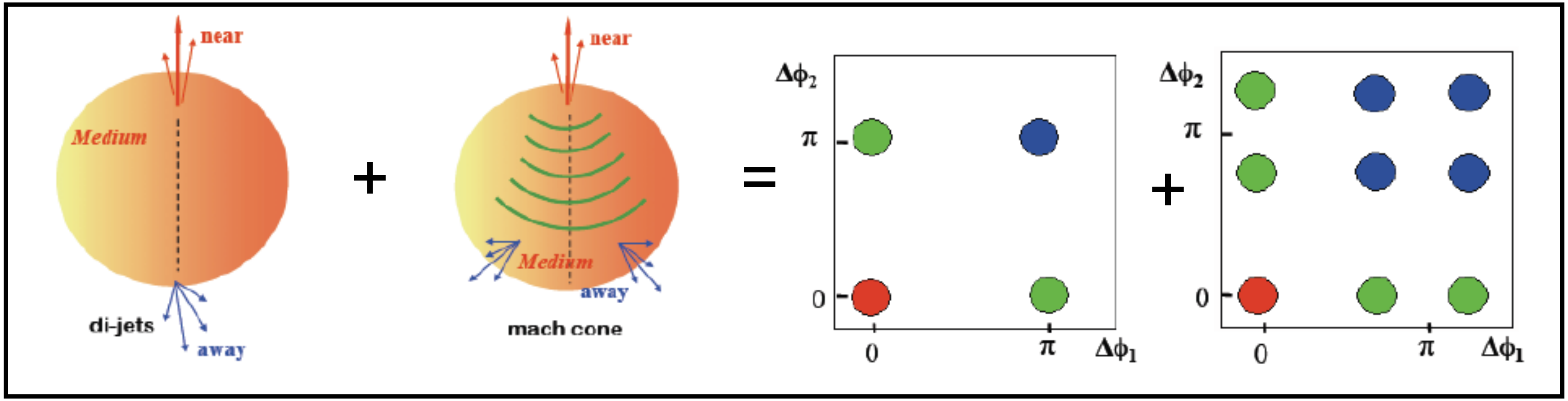


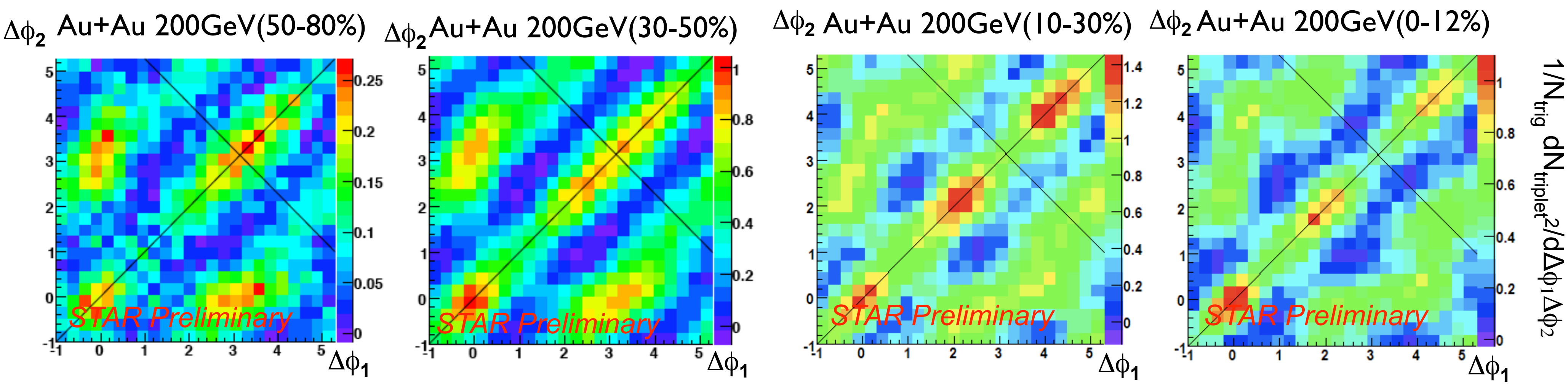


- Di-jet picture in p+p and d+Au.

RESULTS: SYSTEM DEPENDENCE

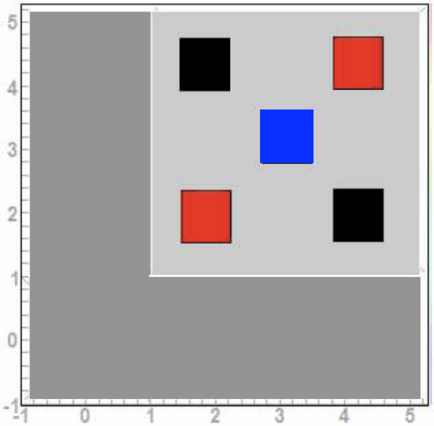
(3 < p_T^{Trig} < 4 GeV/c and 1 < p_T^{Asso} < 2 GeV/c)



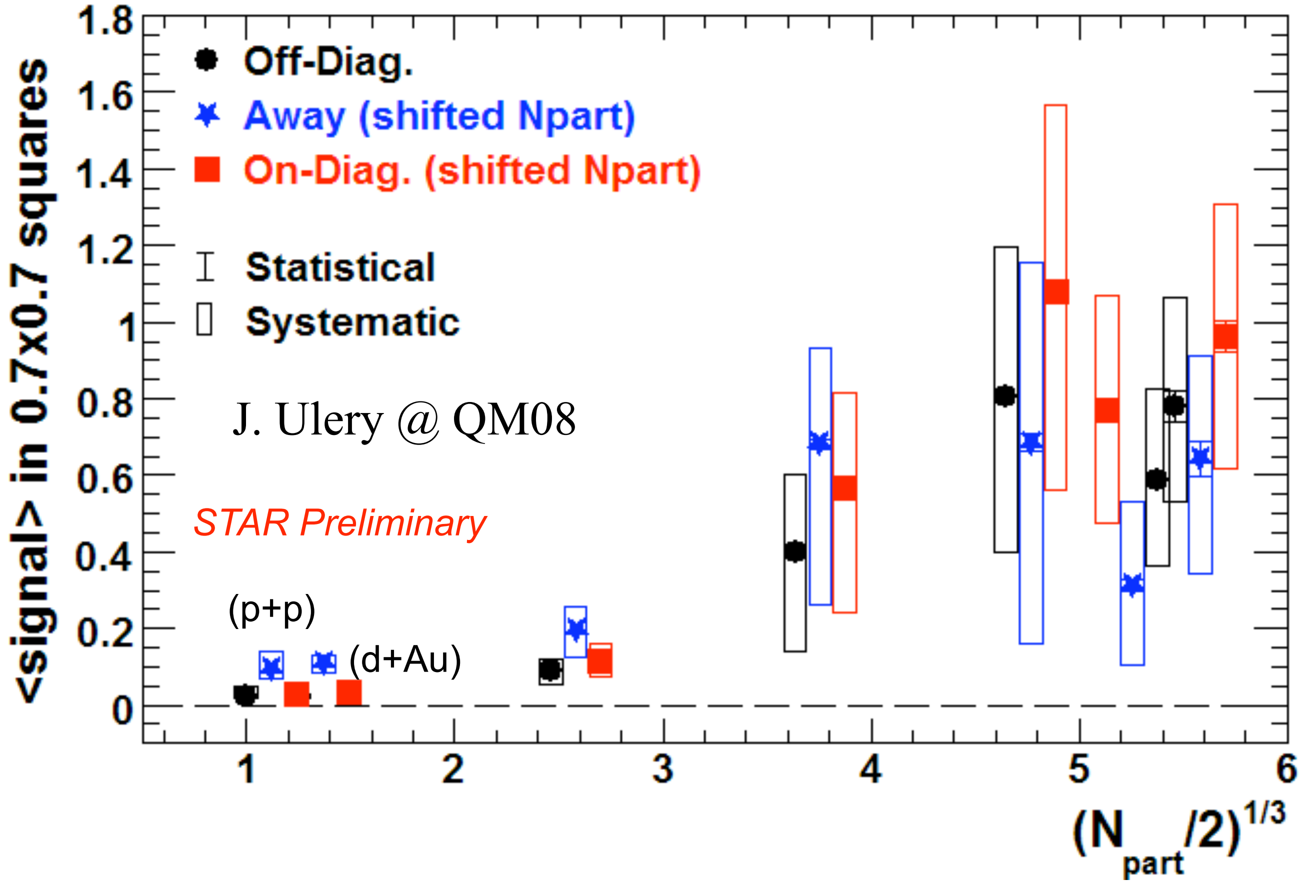


- Di-jet + conical emission in Au+Au.

CENTRALITY DEPENDENCE of average yield from different regions



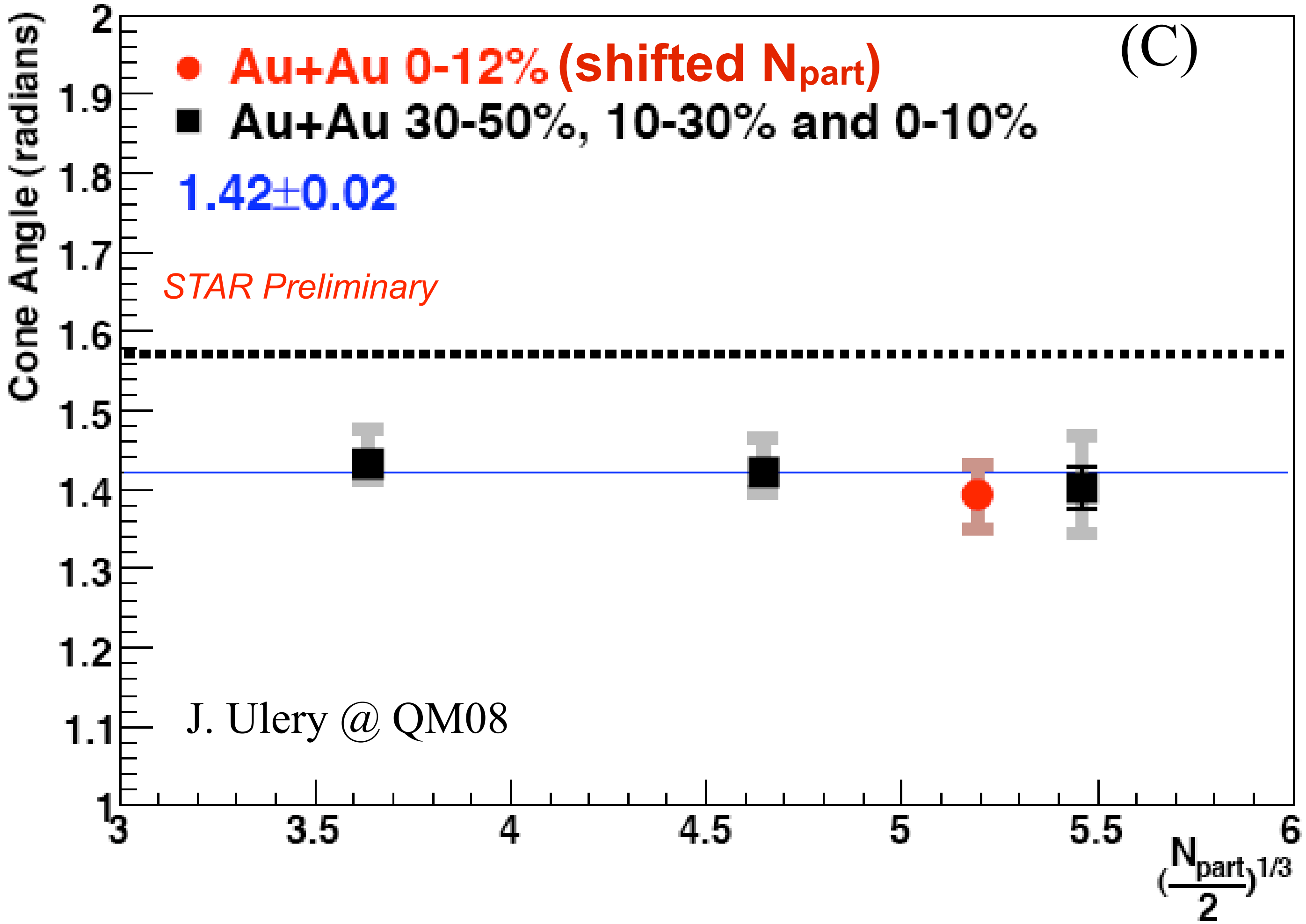
($3 < p_T^{Trig} < 4$ GeV/c and $1 < p_T^{Asso} < 2$ GeV/c)



- the system size dependences of average yield in 0.7x0.7 squares centered on the different regions.

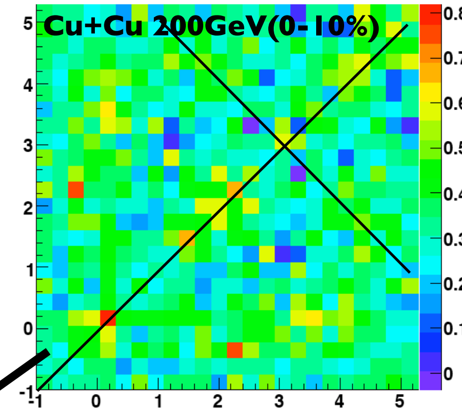
CENTRALITY DEPENDENCE of emission angle

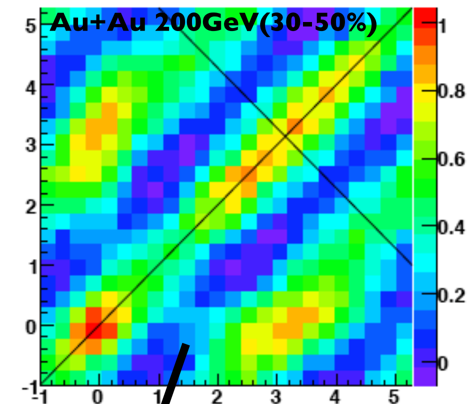
($3 < p_T^{Trig} < 4$ GeV/c and $1 < p_T^{Asso} < 2$ GeV/c)



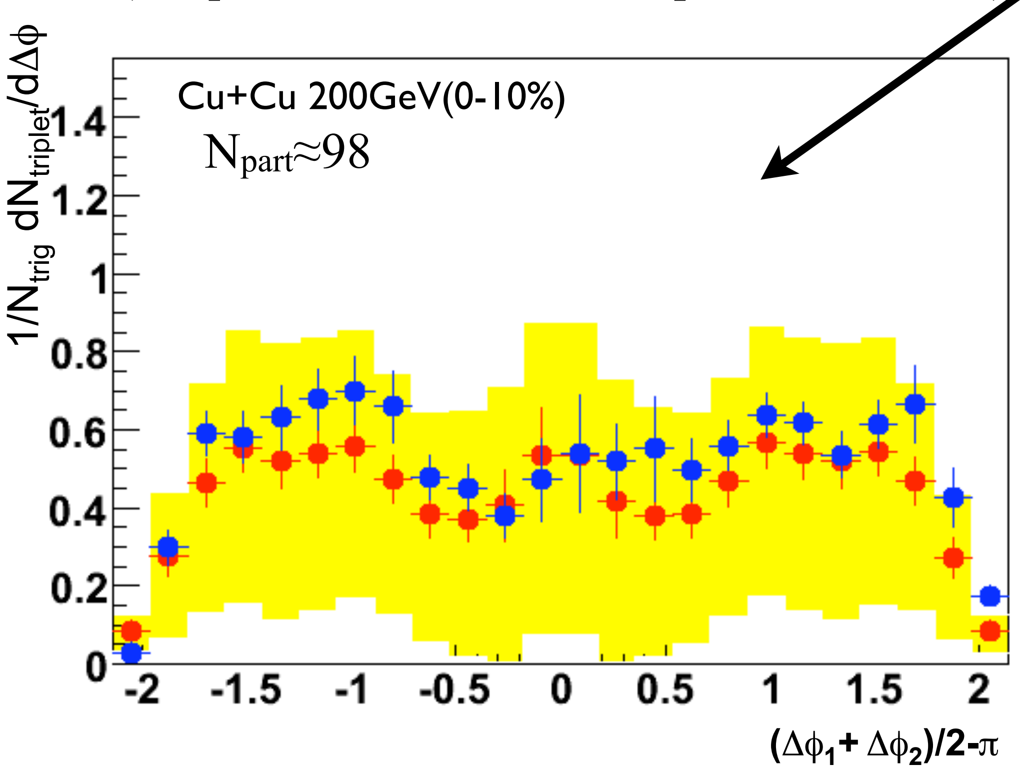
- constant dependence of cone angle on system size.

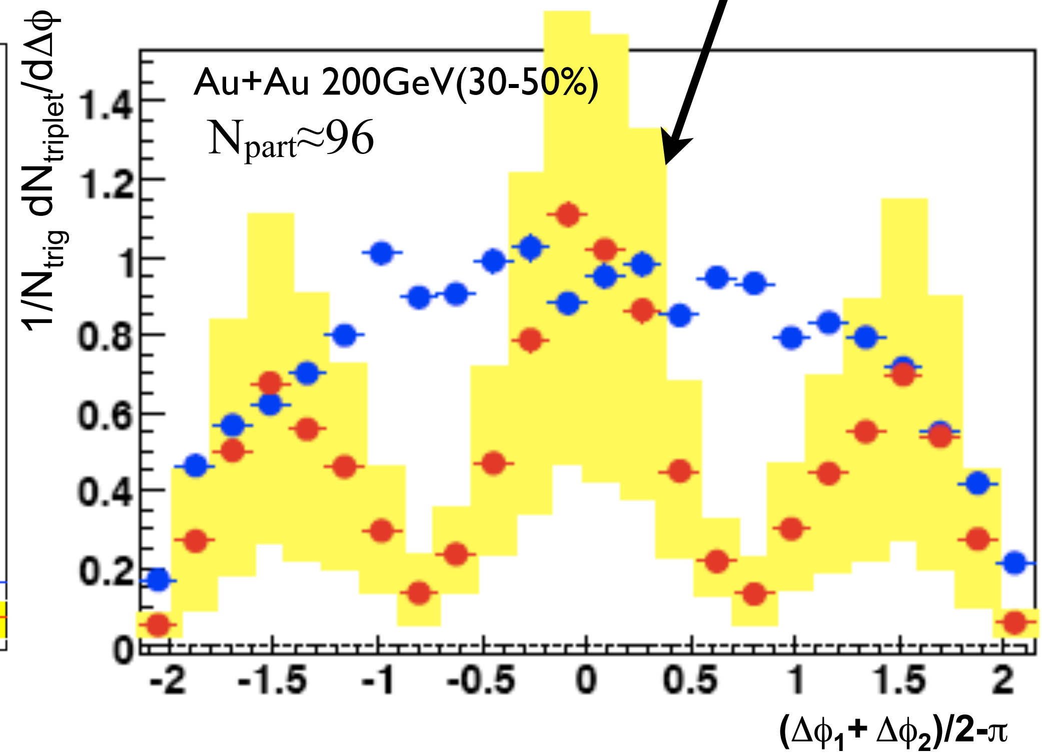
Cu+Cu vs Au+Au





($3 < p_T^{Trig} < 4$ GeV/c and $1 < p_T^{Asso} < 2$ GeV/c)





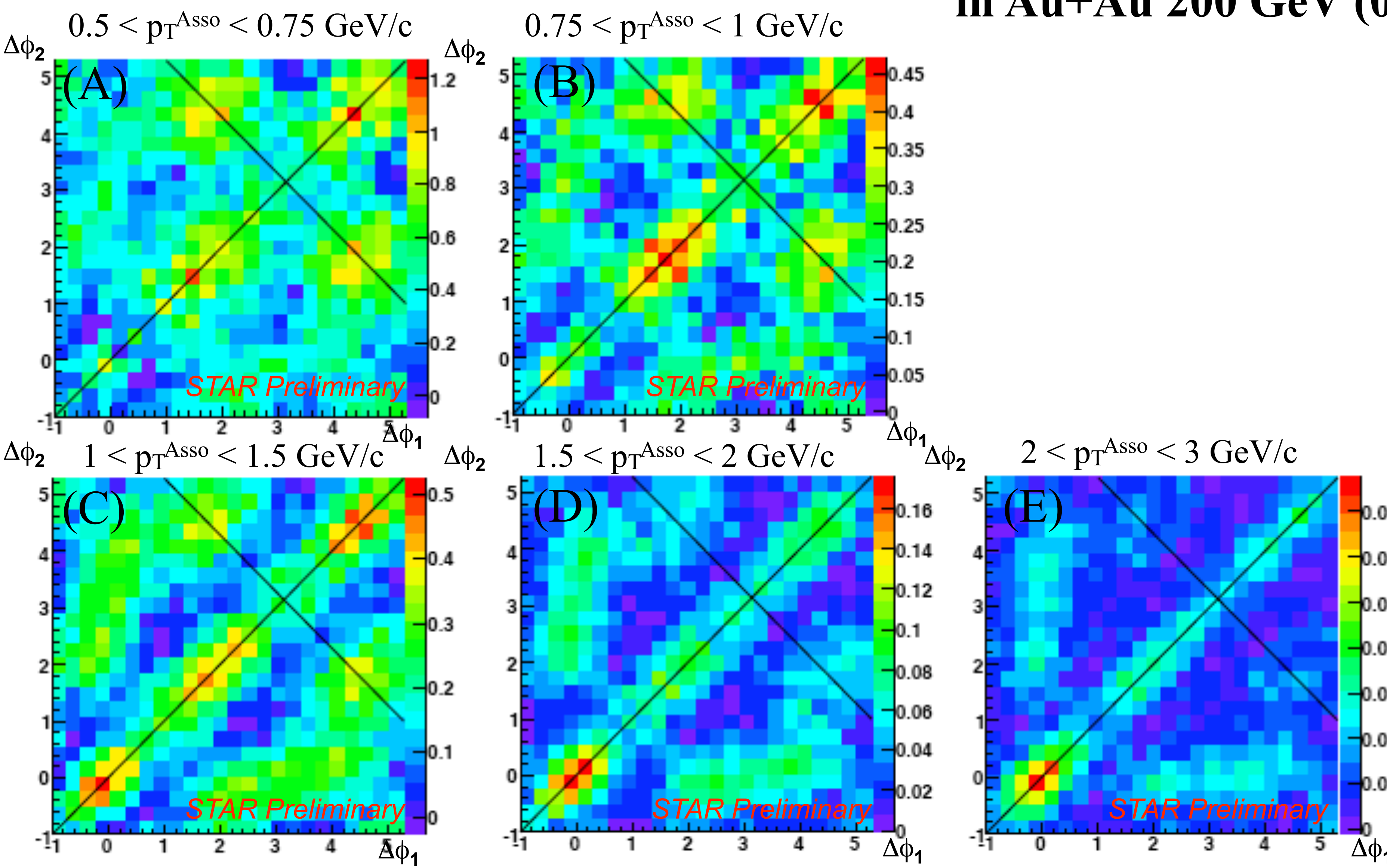
the off-diagonal projection

the diagonal projection

There seems to be some difference between Cu+Cu and Au+Au, which needs more further studies.

(2) p_T^{asso} DEPENDENCE

—— with $3 < p_T^{Trig} < 4$ GeV/c in Au+Au 200 GeV (0-12%)



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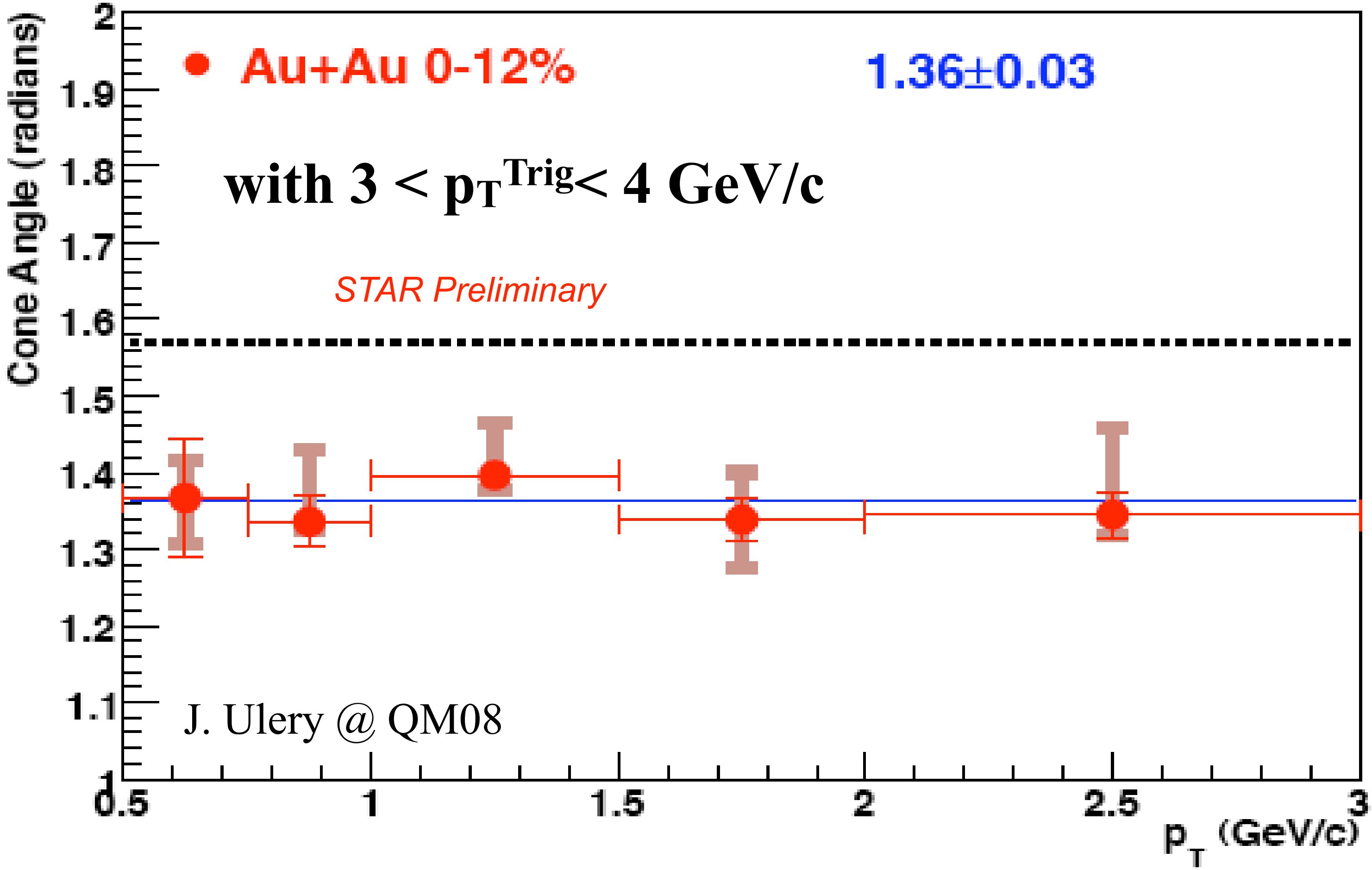
p_T^{Asso} DEPENDENCE of emission angle

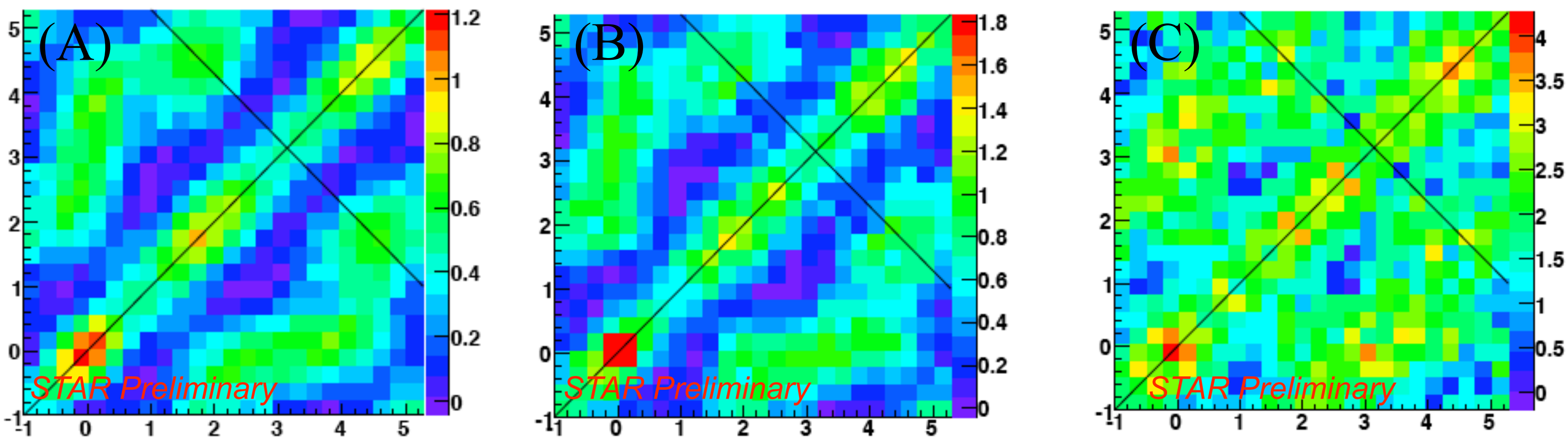


- p_T^{Asso}-independent cone angle, consistent the prediction of Mach-cone, and inconsistent with that of Čerenkov.

(3) p_T^{Trig} DEPENDENCE

with $1 < p_T^{Asso} < 2$ GeV/c

$3 < p_T^{Trig} < 4$ GeV/c $\quad$ $4 < p_T^{Trig} < 6$ GeV/c $\quad$ $6 < p_T^{Trig} < 10$ GeV/c



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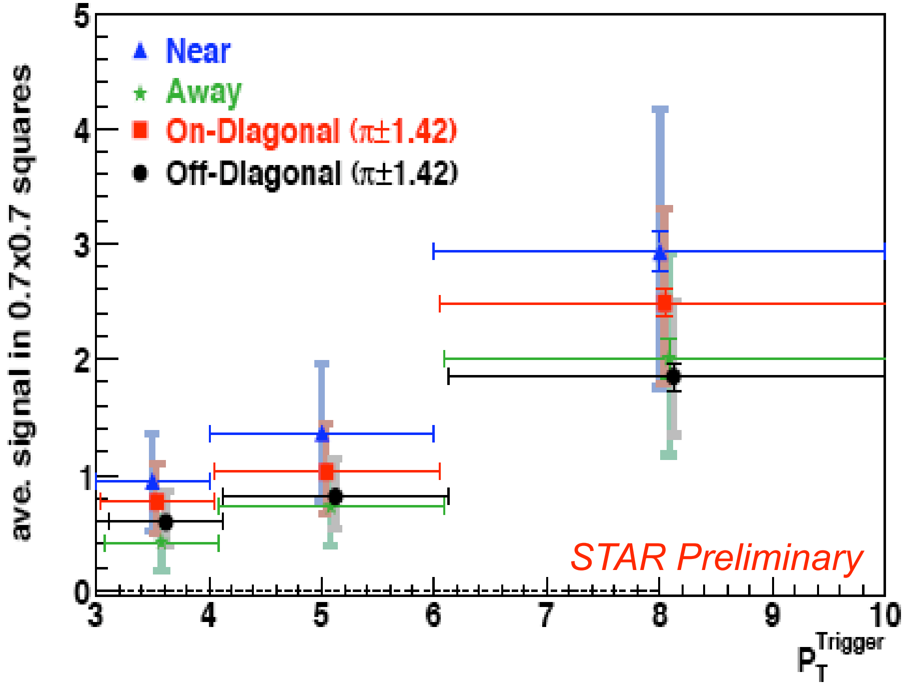
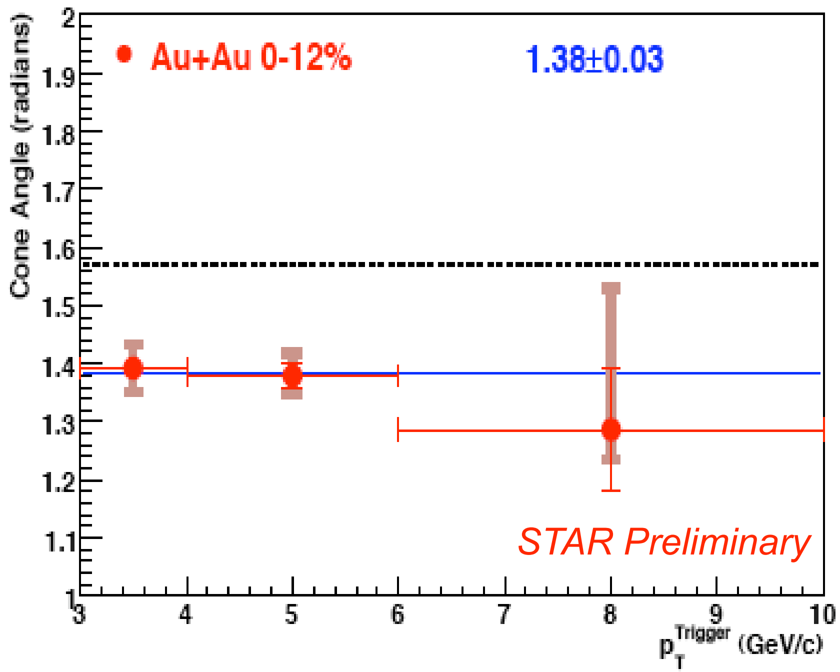
- Three-particle correlations with trigger particles of $3 < p_T^{Trig} < 4$ (A), $4 < p_T^{Trig} < 6$ (B) and $6 < p_T^{Trig} < 10$ (C) and associated particles of $1 < p_T^{Asso} < 2$ GeV/c for Au+Au collisions (0-12%) at $\sqrt{s_{NN}} = 200$ GeV/c;

p_T^{Trig} DEPENDENCES of average yield from different regions and emmision angle

with $1 < p_T^{Asso} < 2$ GeV/c





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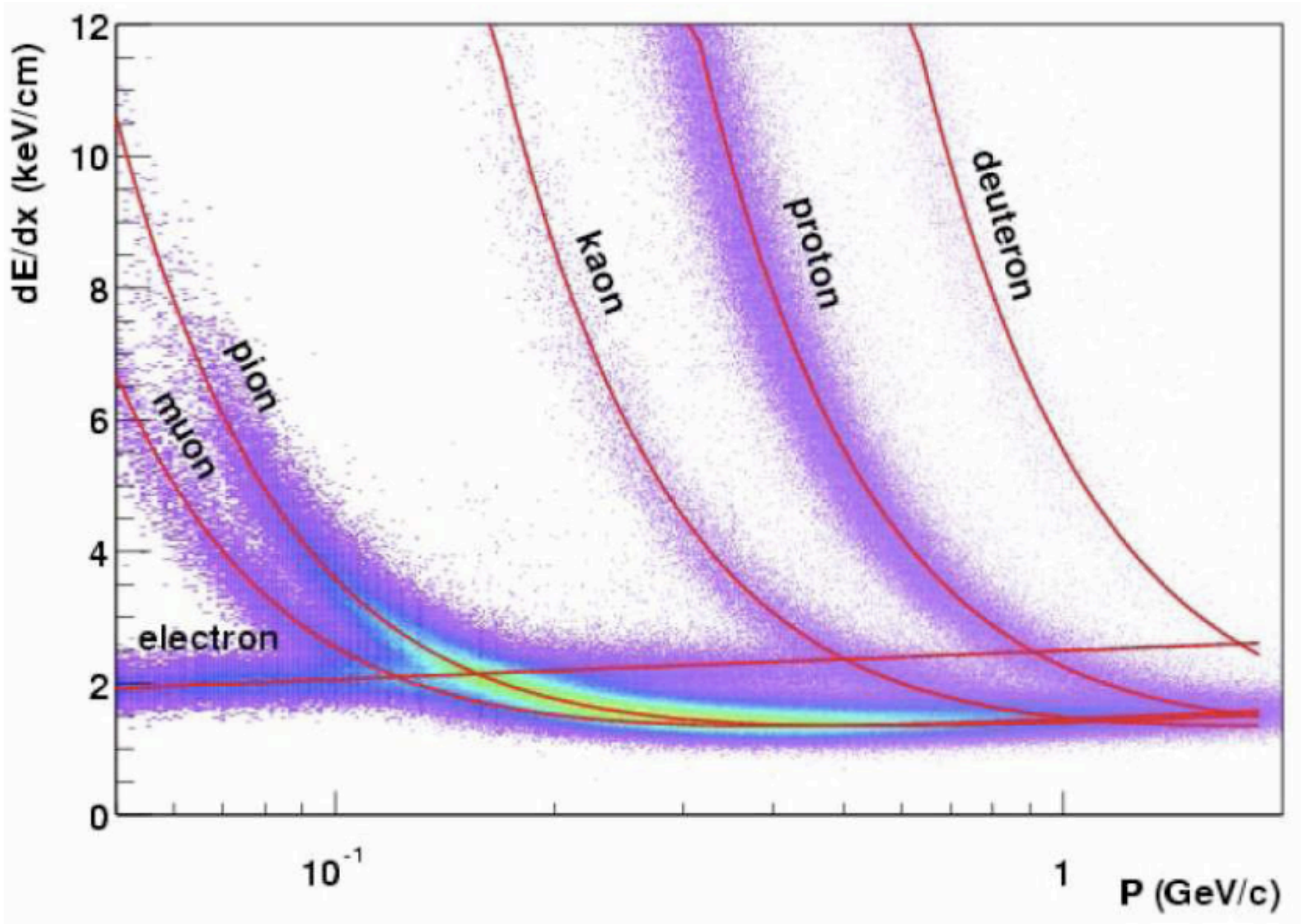
- the average yield in 0.7x0.7 squares centered on different regions and cone angle as a funcfion of p_T^{Trig} respectively.

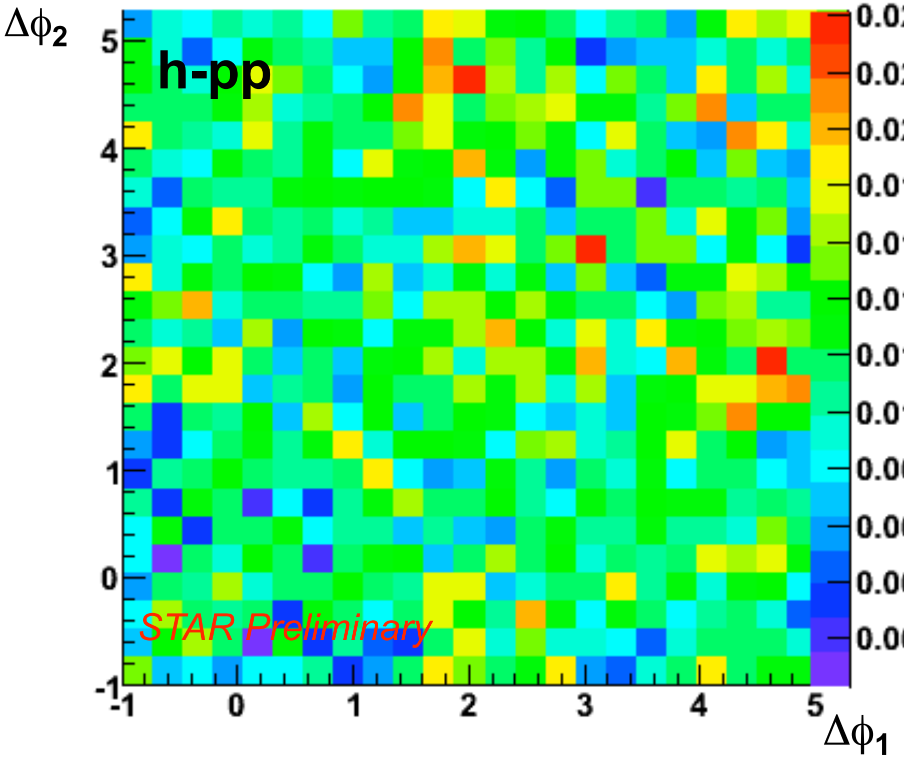
PARTICLE IDENTIFICATION

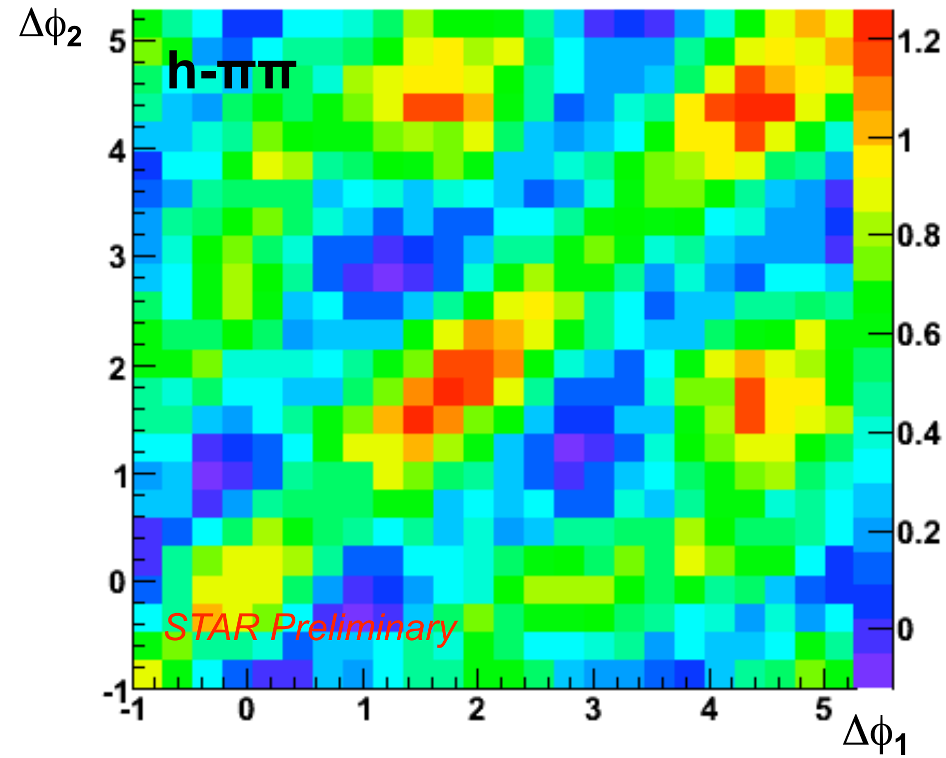
—— for PID 3-particle correlation



PID 3-PARTICLE CORRELATIONS

—— h-pp and h-ππ

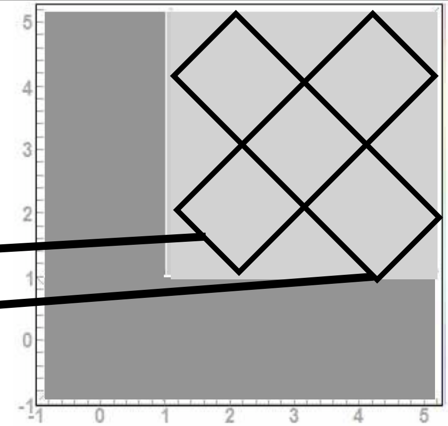




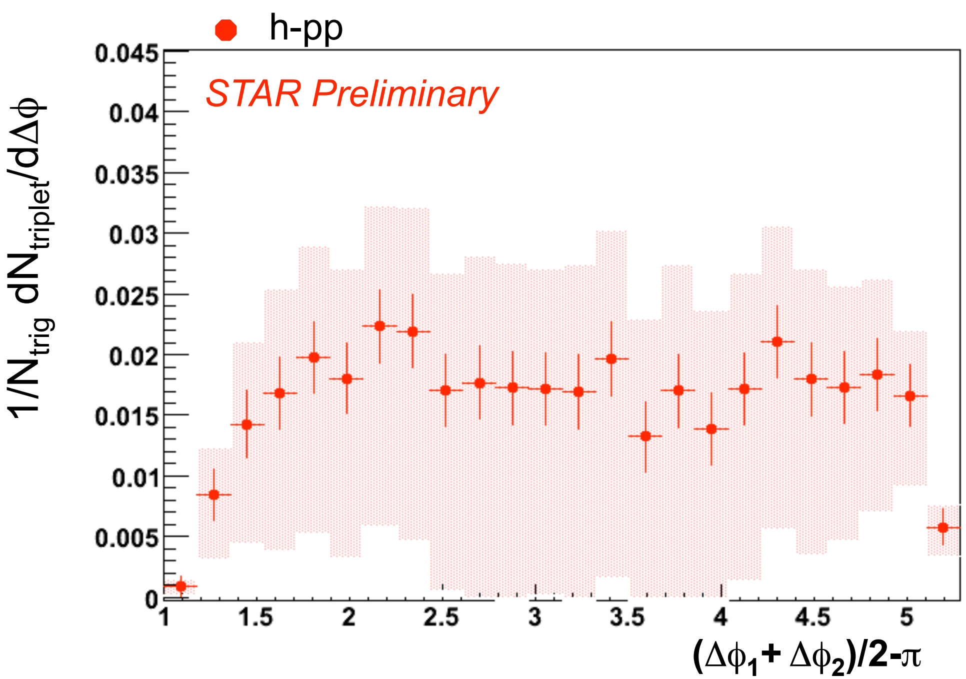
- $2.5 < p_T^{Trig} < 10$ GeV/c and $0.7 < p_T^{asso} < 1.4$ GeV/c in Au+Au collisions (0-12%) at $\sqrt{s_{NN}}$ =200GeV.
- More statics needed.

PID 3-PARTICLE CORRELATIONS

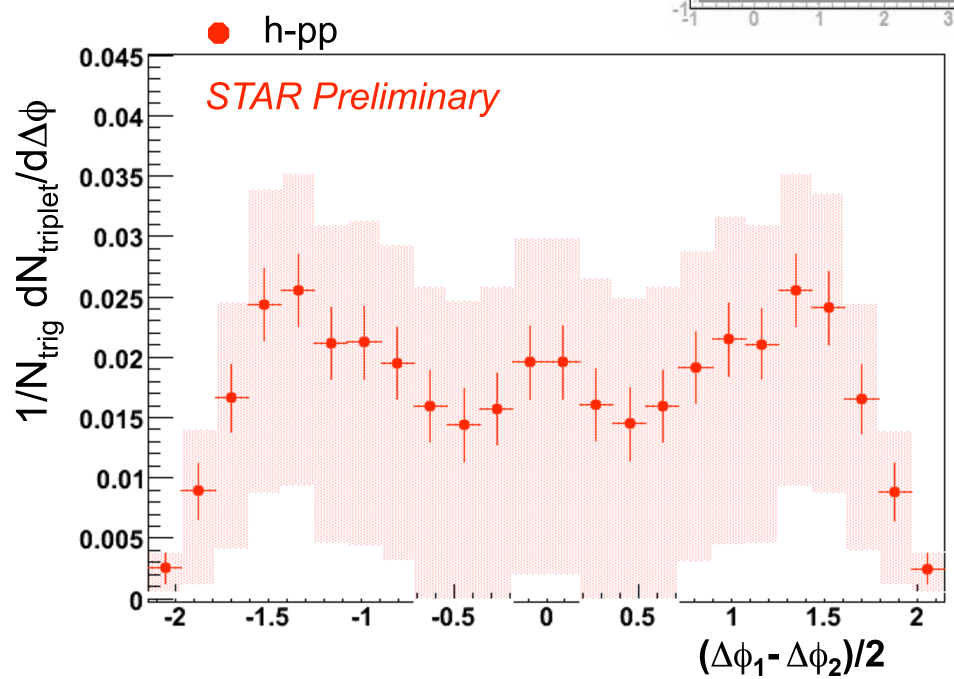
— diagonal and off-diagonal projections



diagonal:

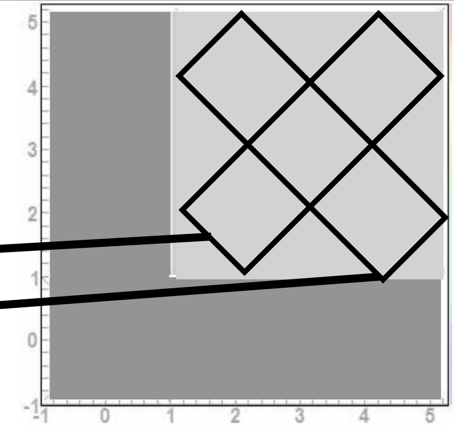


off-diagonal:



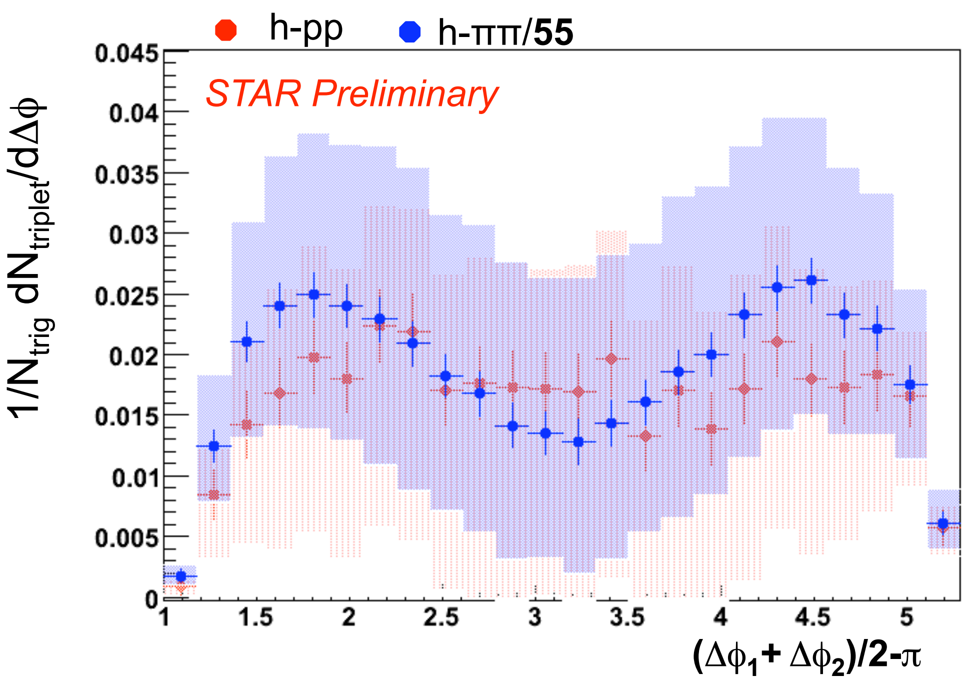
the diagonal and off-diagonal projections of ‘h-pp’

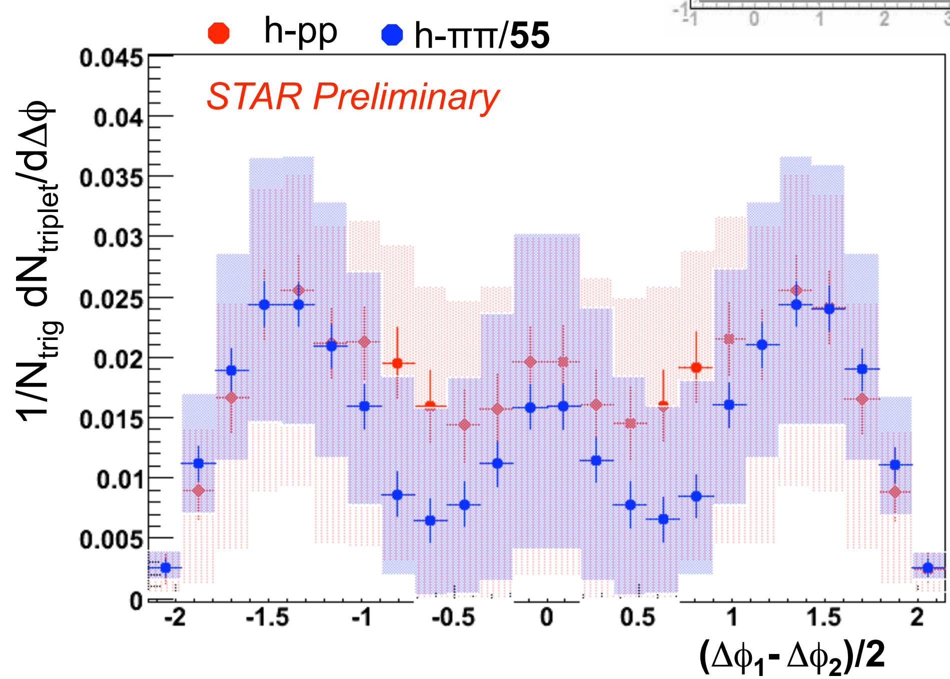
PID 3-PARTICLE CORRELATIONS



— diagonal and off-diagonal projections

diagonal: **off-diagonal:**





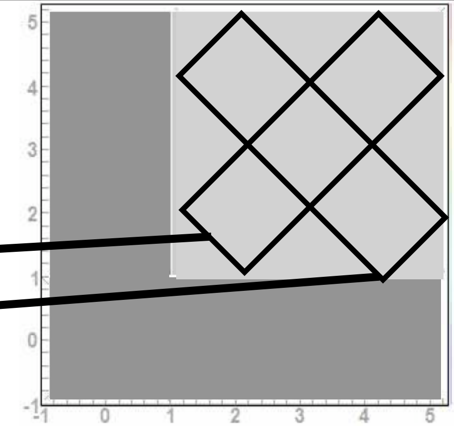
the diagonal and off-diagonal projections of 'h-pp'

the diagonal and off-diagonal projections of 'h-ππ' (scaled by **1/55**)

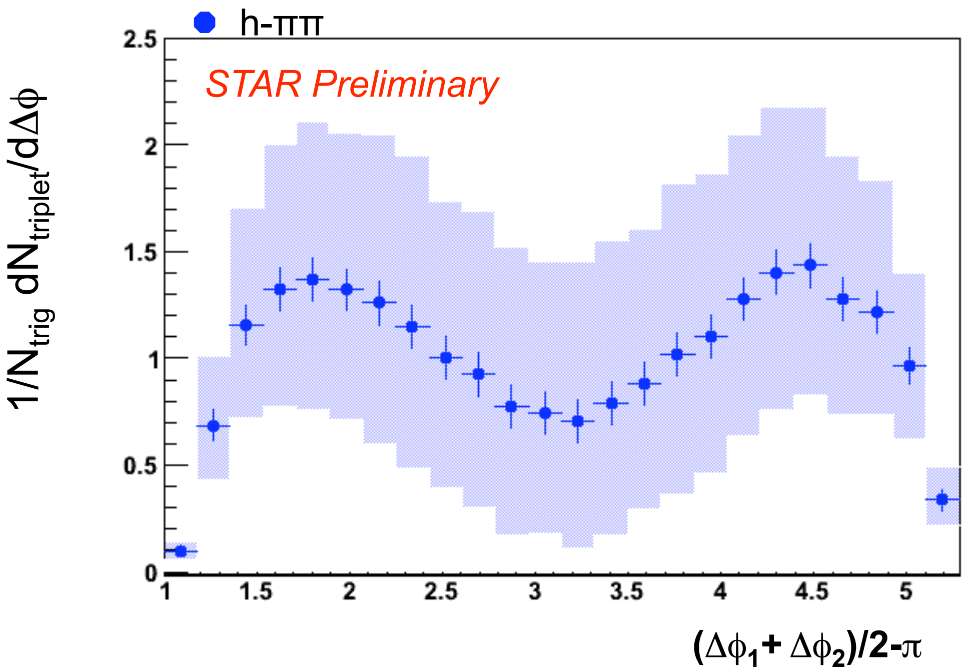
➡Needs more statistics.

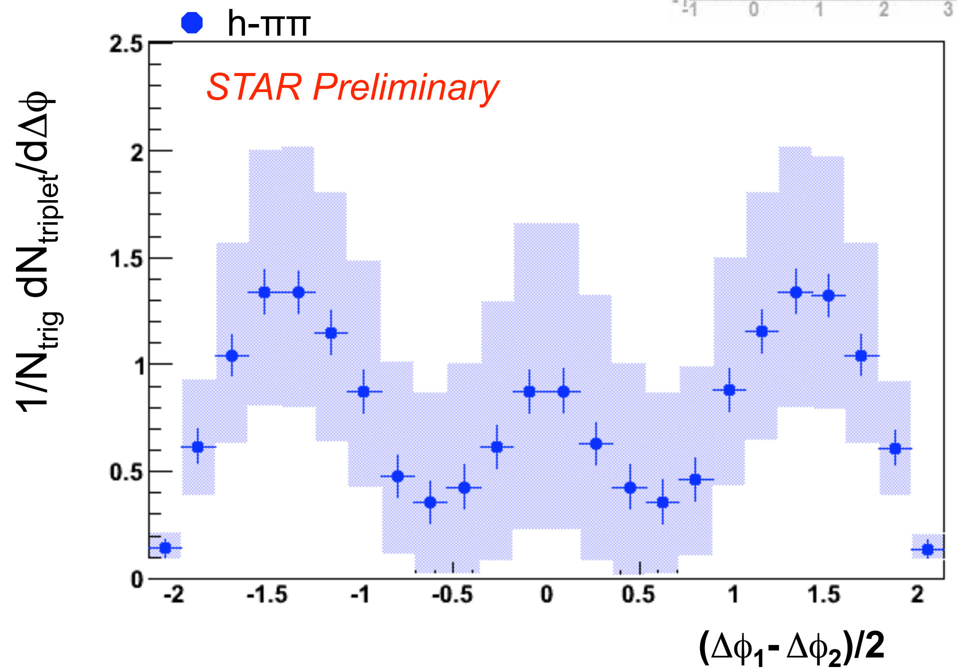
PID 3-PARTICLE CORRELATIONS

— diagonal and off-diagonal projections



diagonal: **off-diagonal:**

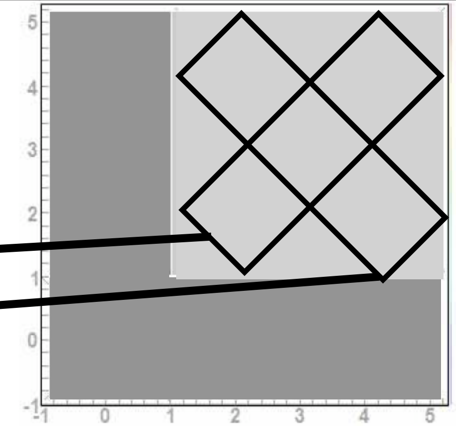




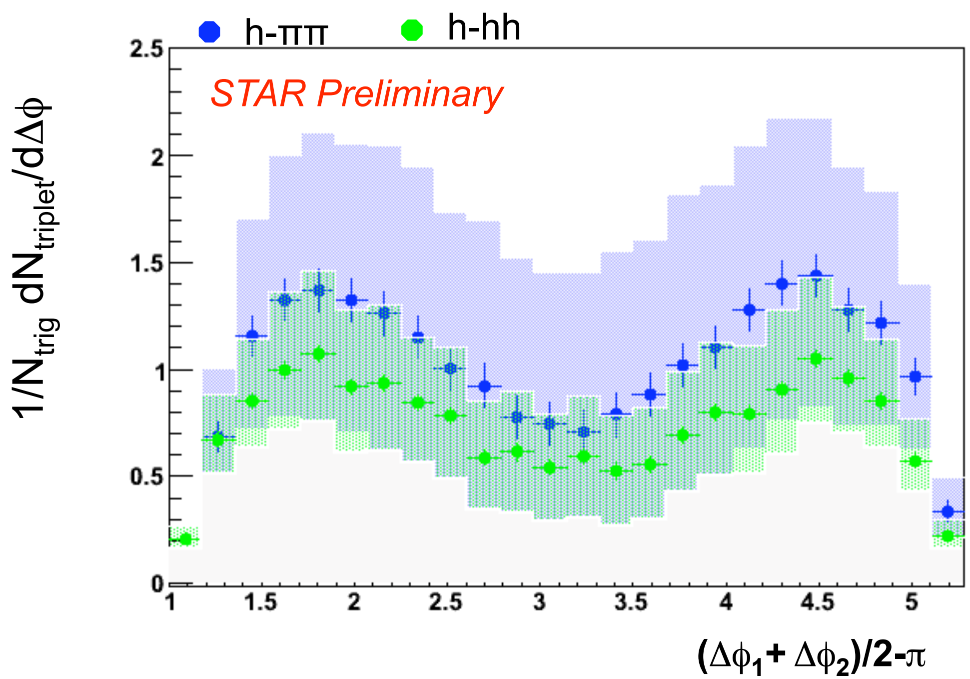
the diagonal and off-diagonal projections of ' h-$\pi\pi$' ($2.5 < p_T^{Trig} < 10$ GeV/c and $0.7 < p_T^{Asso} < 1.4$ GeV/c)

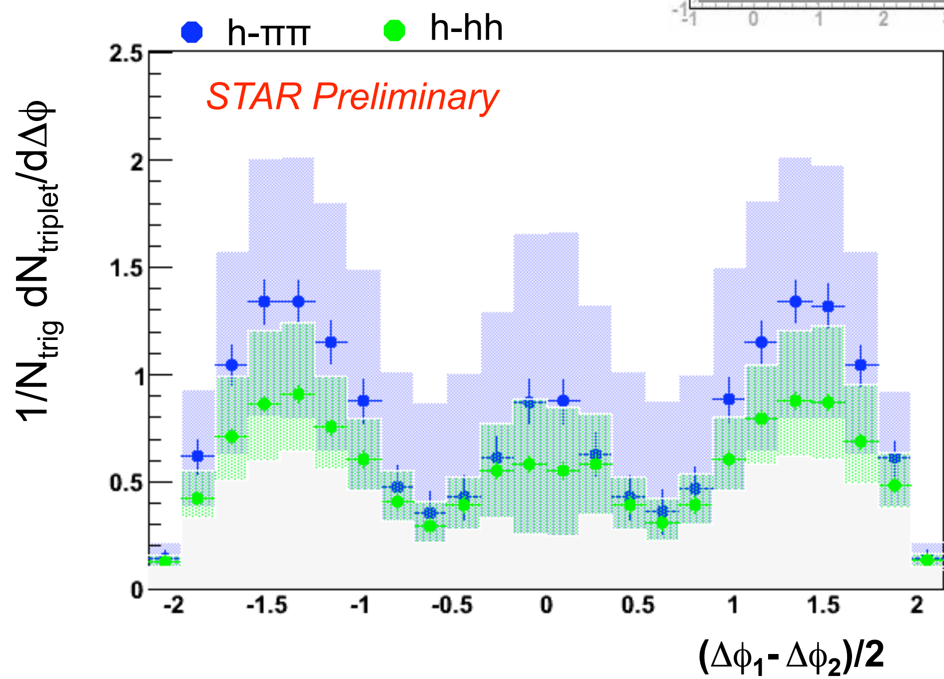
PID 3-PARTICLE CORRELATIONS

—— diagonal and off-diagonal projections



diagonal: off-diagonal:





- the diagonal and off-diagonal projections of ‘ h-ππ’ ($2.5 < p_T^{Trig} < 10$ GeV/c and $0.7 < p_T^{Asso} < 1.4$ GeV/c)
- the diagonal and off-diagonal projections of ‘h-hh’ ($3 < p_T^{Trig} < 4$ GeV/c and $0.75 < p_T^{Asso} < 1.0$ GeV/c + $1.0 < p_T^{Asso} < 1.5$ GeV/c)

CONCLUSIONS

(1) A systematic study of three-particle correlation vs system (size), p_T^{Asso}, and $p_T^{Trig.}$

(2) p_T^{Asso}-independent cone angle consistent with Mach-cone emission, inconsistent with Čerenkov radiation.

(3) New data from Cu+Cu, and identified 'h-pp' and 'h-ππ' in central Au+Au.

(4) No significant difference observed between 'h-pp' and 'h-ππ' in shape within systematic error.