Modifications of high-p_T di-hadron correlations for identified triggers

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for the STAR collaboration

Outline

- Motivation: Hadronization in QGP
  - High-p_T hadrons, particle ratios, collective effects
- Implications for correlation studies
  - Flavor-dependence of jet modifications,
  - Dilution effects
- Di-hadron correlations with identified triggers
- Summary and outlook

Hadronization

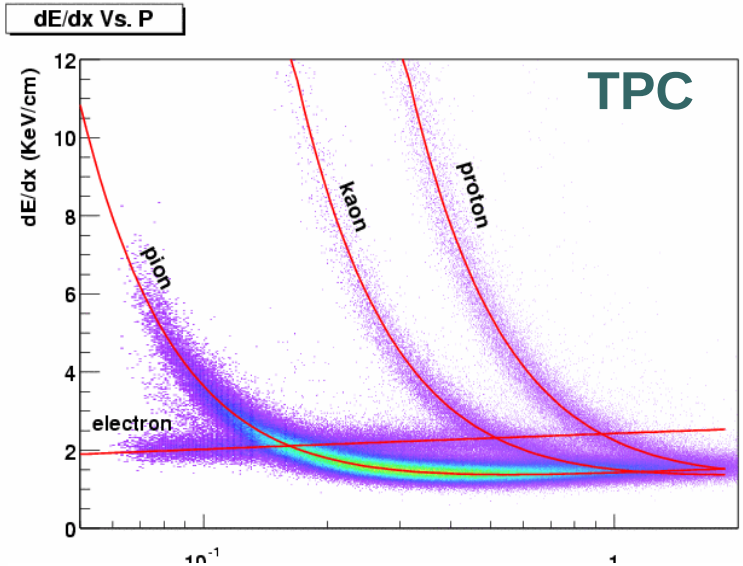
- Of many aspects of collision evolution is the least known
  - High p_T -- assume factorization holds

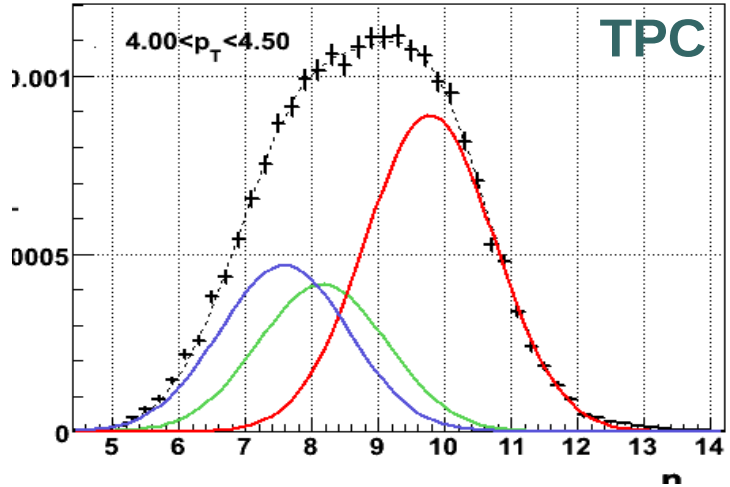
    PDF ^{x} pQCD ^{x} FF ← Seems OK

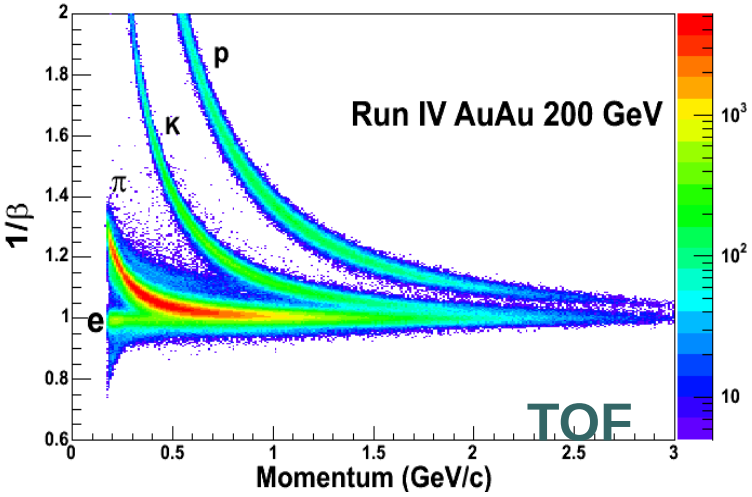
    In HI – add jet quenching on top ← Seems not OK for PID
  - Intermediate p_T -- rise of recombination
  - Soft sector ← Not part of this talk

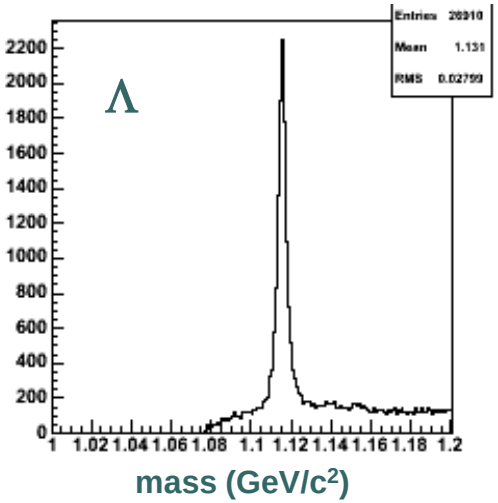
    "Statistical" hadronization + Hydro

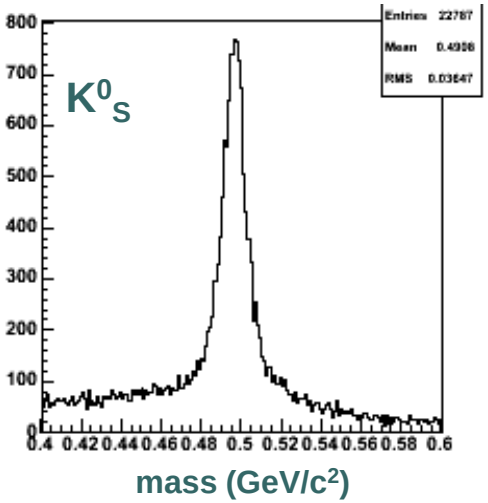
Particle identification in STAR





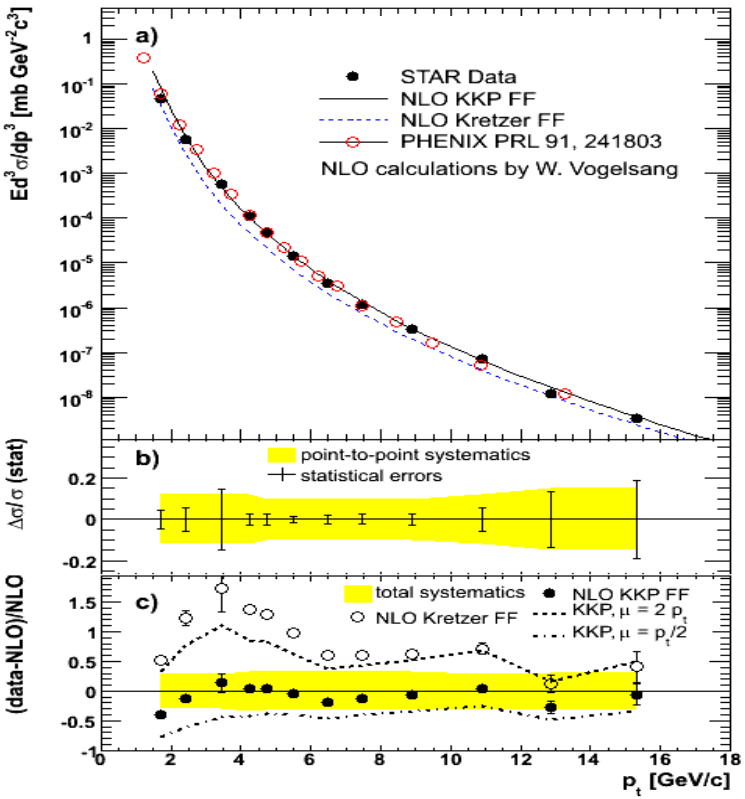


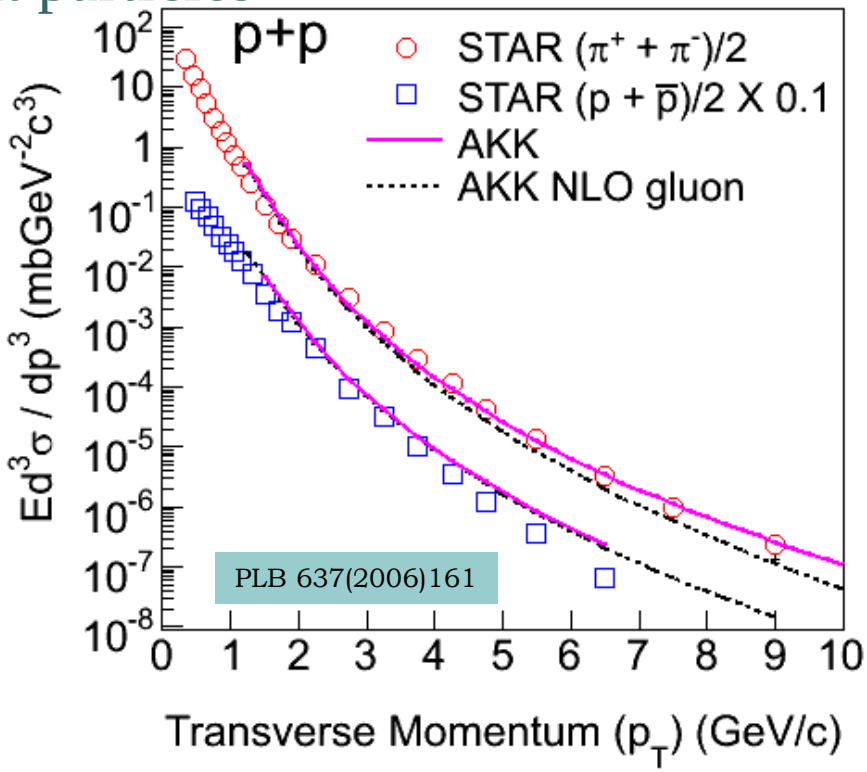




High p_T

pp Reference – success of pQCD description depends on FF details –different for different particles

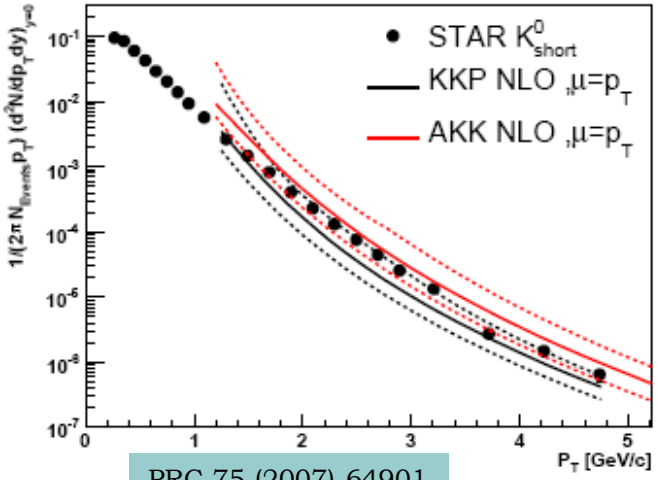




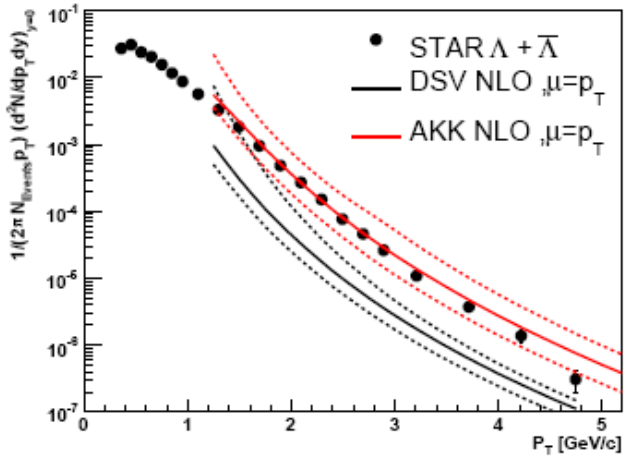
AKK:(Albino-Kniehl-Kramer)NP B725,181(2005)

pQCD for the strange sector

mid-rapidity

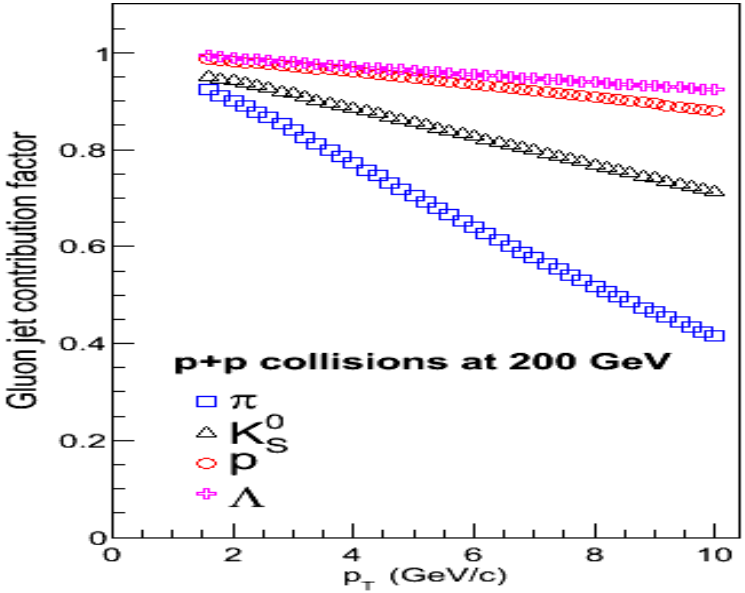


PRC 75 (2007) 64901



The full set of STAR identified spectra results in pp collisions is best described by AKK FF

Gluon vs quark contributions



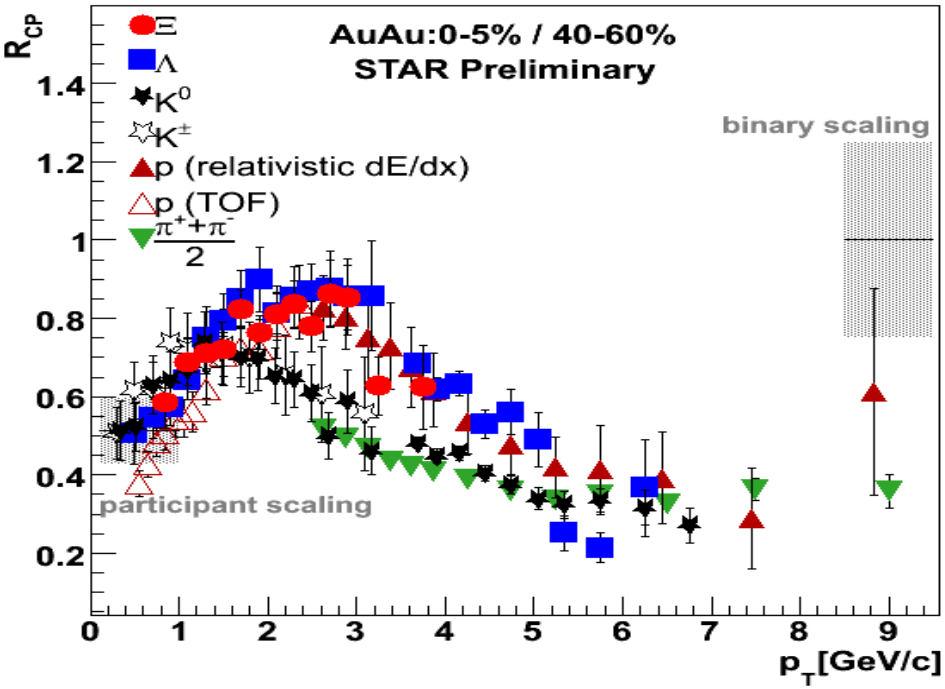
KKP (Kniehl-Kramer-Potter): NPB 582 (200)

AKK (Albino-Kniehl-Kramer): NPB 734, 50 (2006)

DSV (DeFlorian-Stratmann-Vogelsang): PRD57, 58111 (1998)

QGP hadronization - R_{aa}

- From not-so-recent results:
  - Systematic of PID R_{CP}



PRL 97 (2006) 152301
PRL 92 (2004) 52302

- High-p_T:

  similar suppression level
  q vs. *g* energy loss??

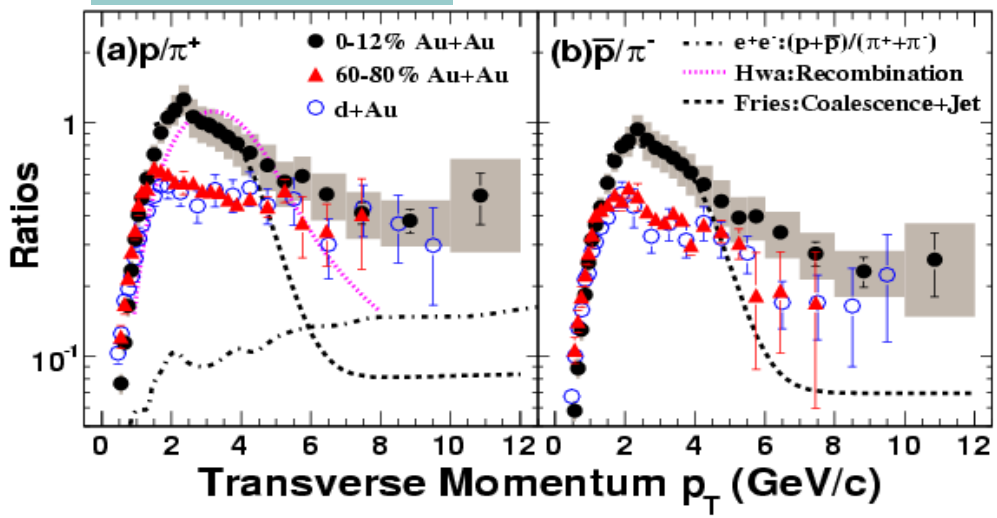
- Intermediate-p_T:
  $R_{CP}^{(meson)} < R_{CP}^{(baryon)}$

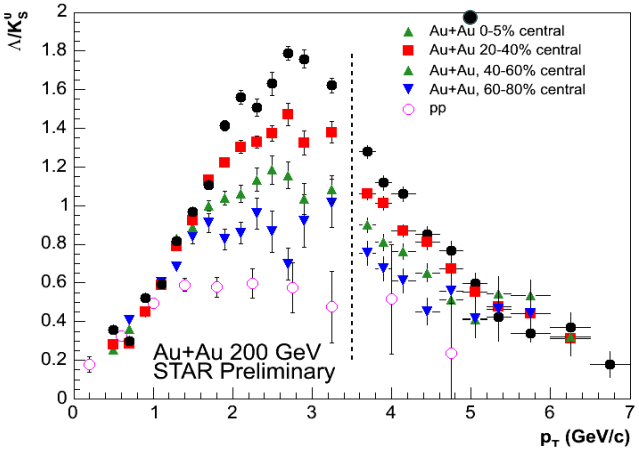
Recombination/coalescence?

QGP hadronization – B/M

- From not-so-recent results:
  - Systematic of baryon to meson ratios

PRL 97 (2006) 152301



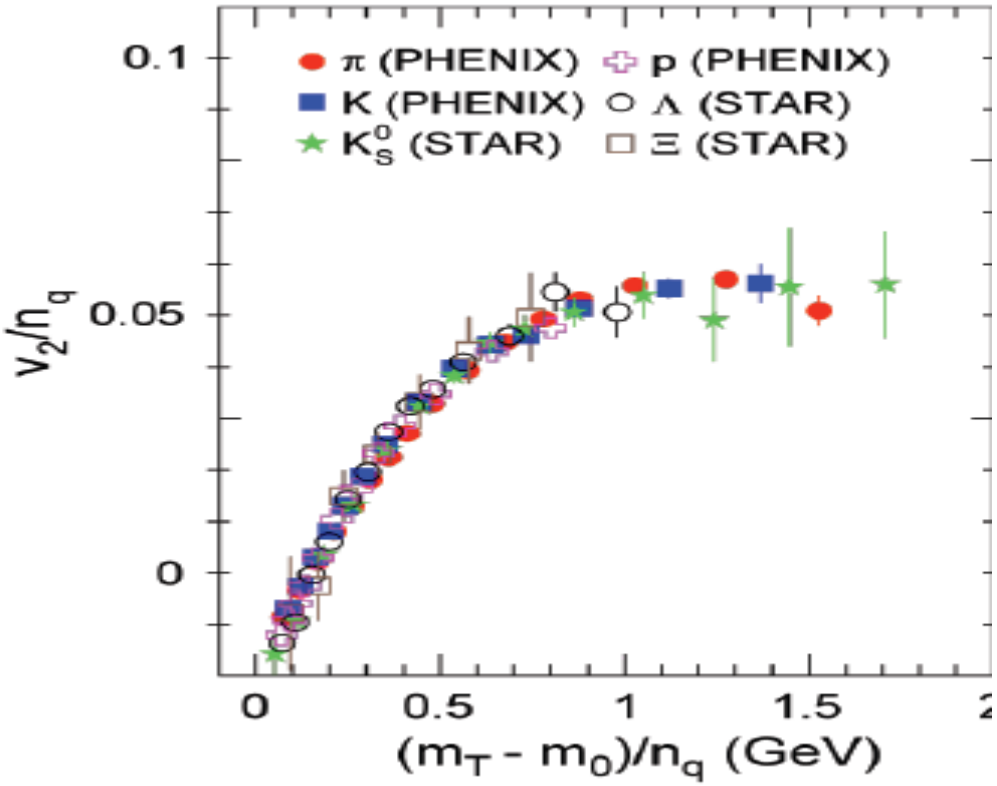


- High-p_T: back to pQCD values?
- Intermediate-p_T: baryon enhancement by factor of 2-3

Recombination/coalescence?

QGP hadronization – v_2

- From not-so-recent results:
  - Systematic of v_2 measurements

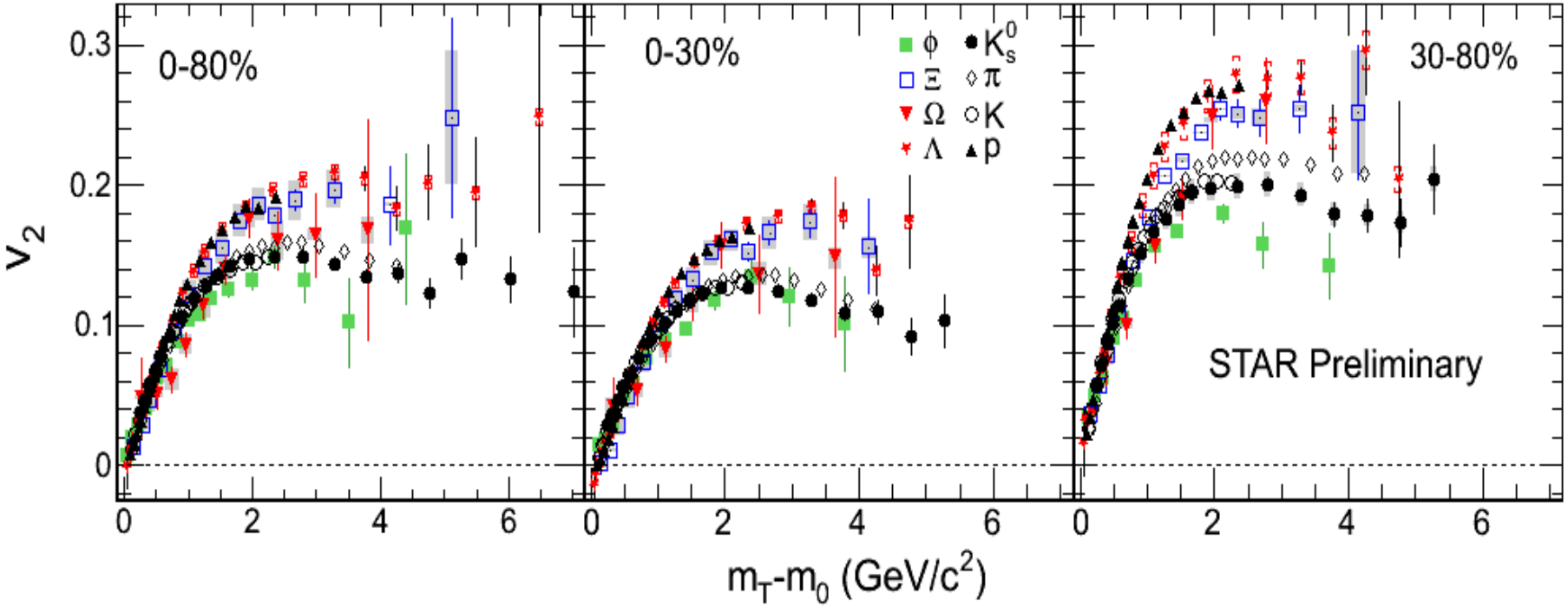


- All (measured) hadrons flow
- Low p_T - mass ordering (hydro)
- Intermediate p_T – NCQ scaling

Recombination/coalescence!

NCQ scaling - Update

High precision identified hadron *v2* results from high statistics 200 GeV Au+Au



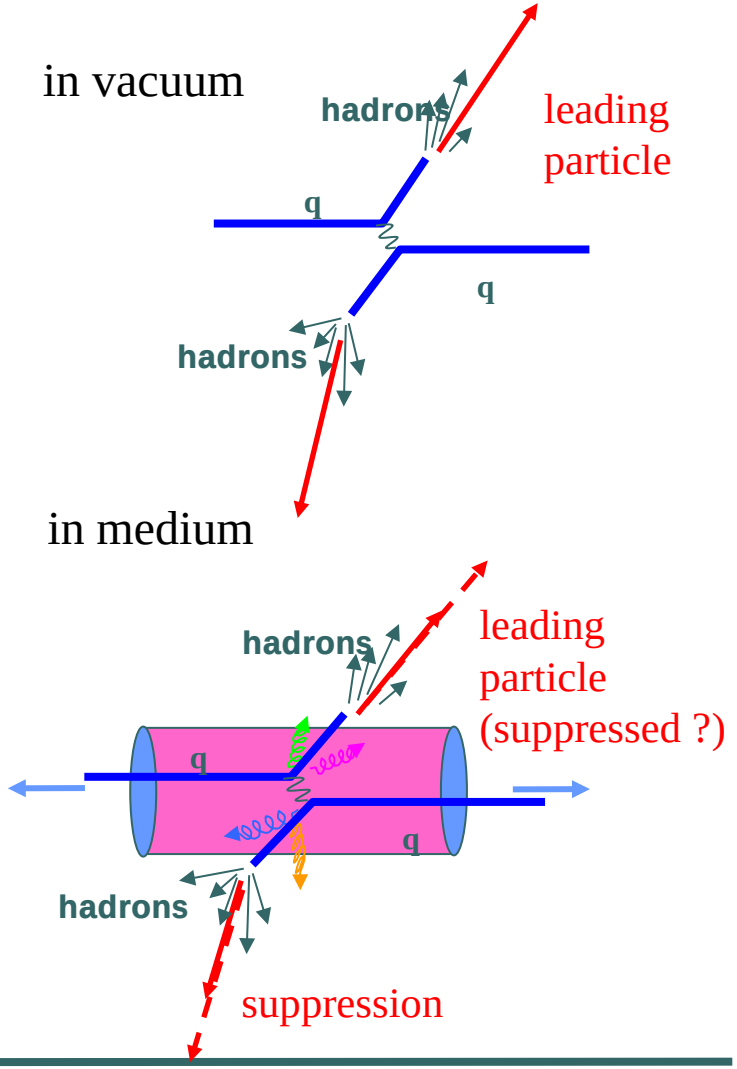
- Central data: baryon-meson splitting, NCQ scaling (to ~10% level)
- Peripheral data: break-down of scaling features for multi-strange hadrons
- Even high p_T – anisotropy related to jet attenuation (also – in R_{AA})

Part 2: Jet-like correlations

- From not-so-recent results:

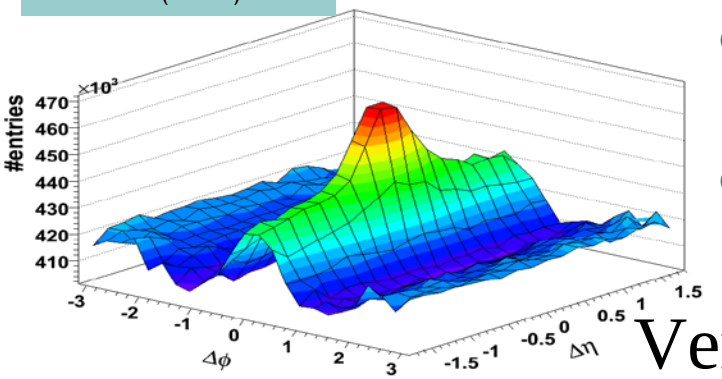
  The overall picture:

  - High-p_T hadron suppression (factor of 5 in central events)
  - Suppression/modifications of away-side azimuthal correlations
  - Both due to final state effects: jet-quenching



Jet-like Correlations: Ridge

PLB 704 (2011) 467



From not-so-recent results:

- Discovered first in Au+Au collisions at RHIC
- Extends to acceptance boundary and to the highest trigger p_T measured
- Production mechanisms for jet and ridge differ

Very recent results:

- Ridge discovery at LHC in pp
- Ridge in pPb, dAu

The ridge open question:

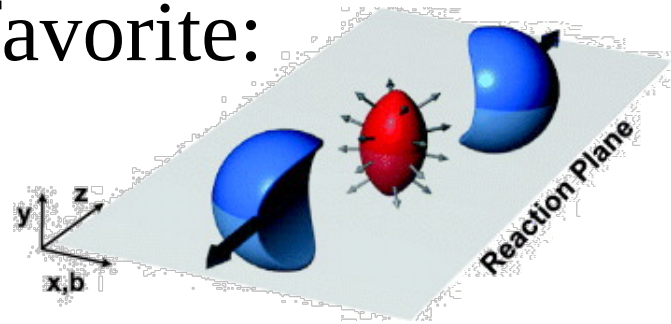
manifestation of the jet quenching or coincidental nuisance?

PID results would help determine the formation mechanism

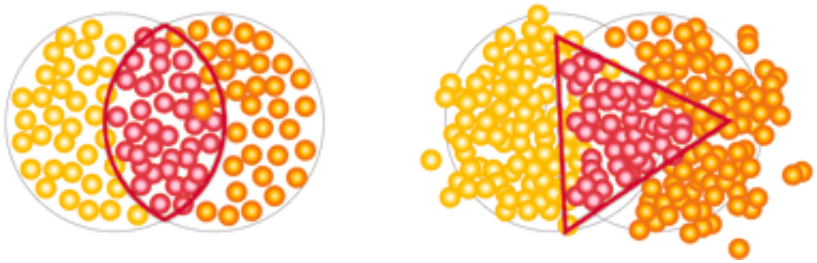
Ridge formation?

- Multiple Models
  - Radiation + Jet Quenching
  - Radiation + Longitudinal Flow
  - Phantom Jet
  - Turbulent Color Fields
  - Momentum Kick
  - Medium Heating and Parton Recombination
  - ...

Recent favorite:



- Hydro:
  Initial State **Anisotropy** → Final State

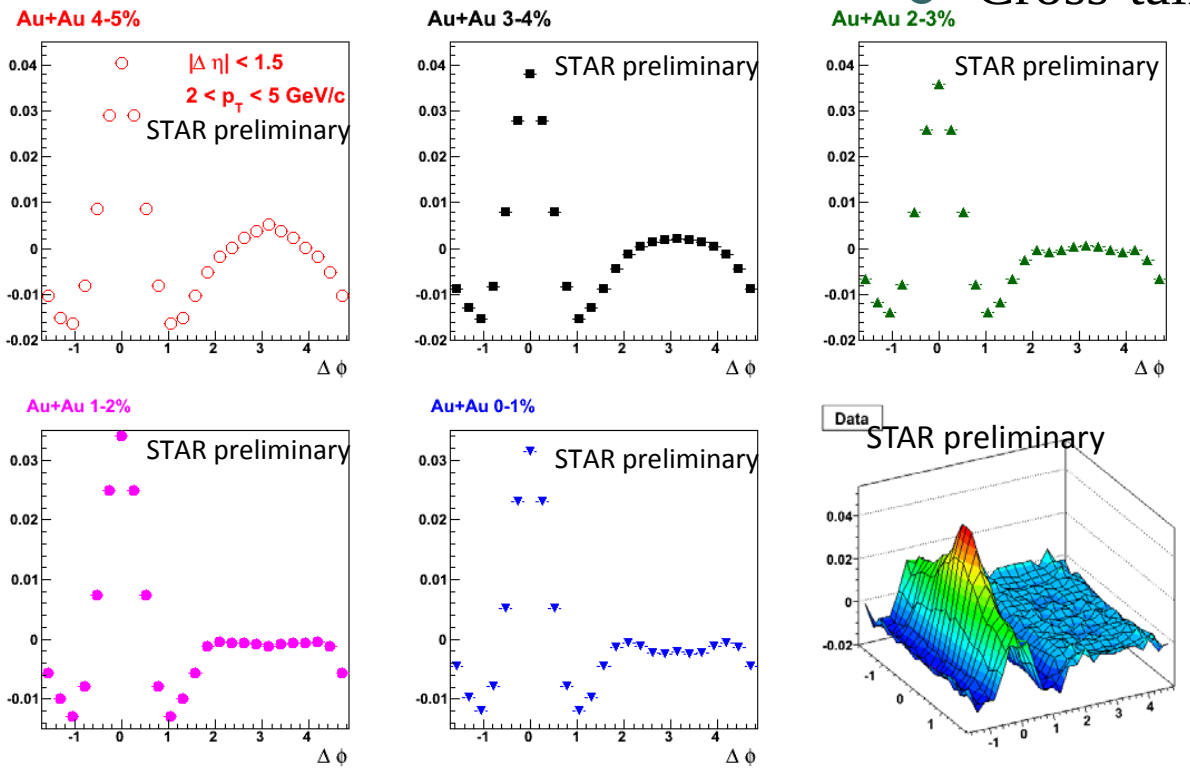


- **Ridge**: **the odd harmonics?**

Ridge in Ultra-central Collisions

Motivation for "v_n fit"

- Cross-talk between data and theory:
  - Extra-central collisions
  - Transport model predictions



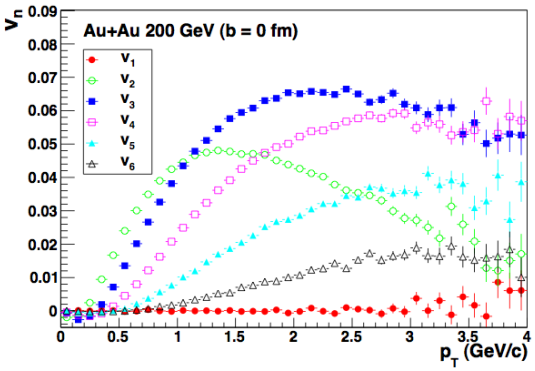
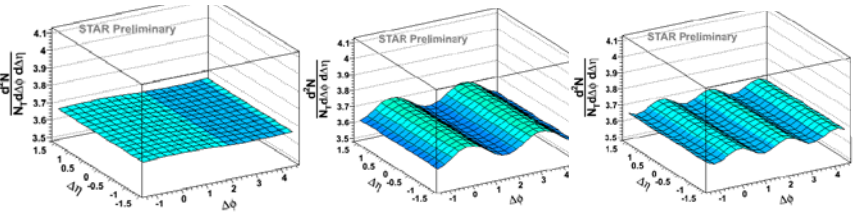


FIG. 2: (Color online) Azimuthal anisotropies of hadron spectra $v_n(p_T)$ $(n = 1 - 6)$ in central $(b = 0)$ $Au + Au$ collisions at $\sqrt{s} = 200$ GeV from AMPT model calculation.

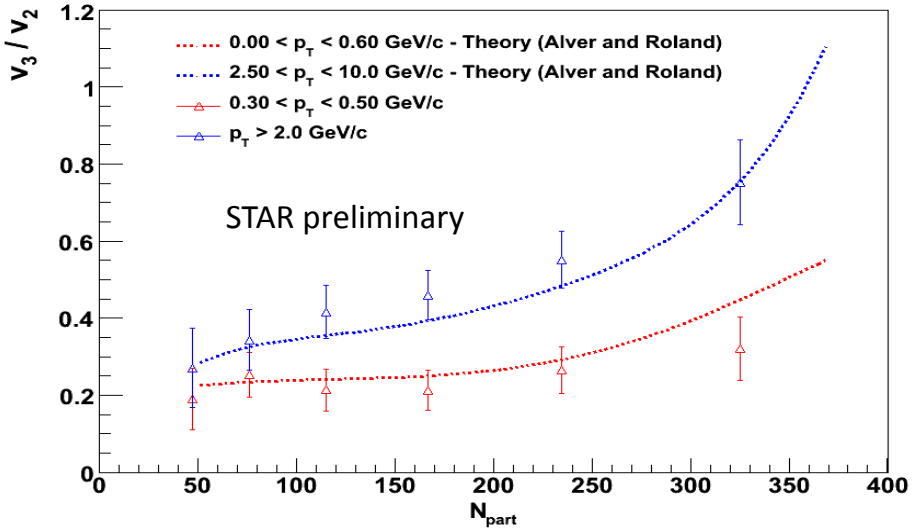
Long Range Correlation – Fourier fits

cos(Δϕ) cos(2Δϕ) cos(3Δϕ)



+…

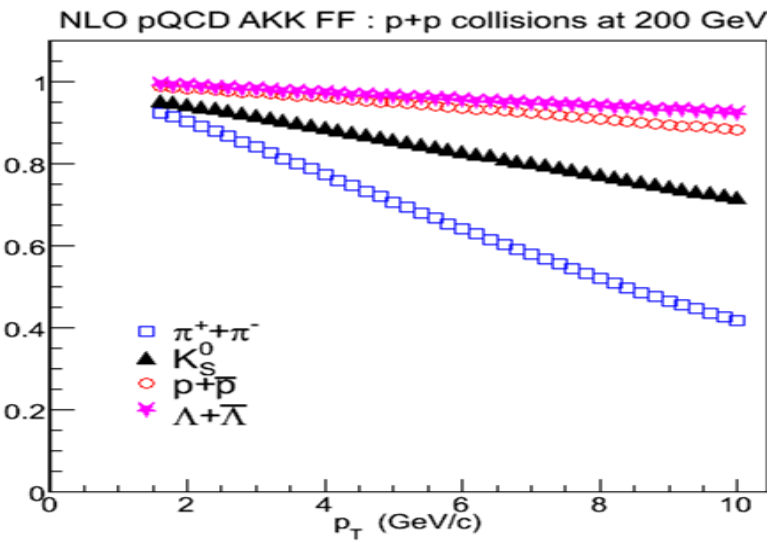
- Comparison with flow:



Alver and Roland, *PRC 81, 054905 (2010)*

- Long range correlations near- and away from the trigger are tested via Fourier decomposition
- Could be simultaneously described via higher order v_n terms
- v_n fit results are consistent with flow expectations

Implications for PID correlations

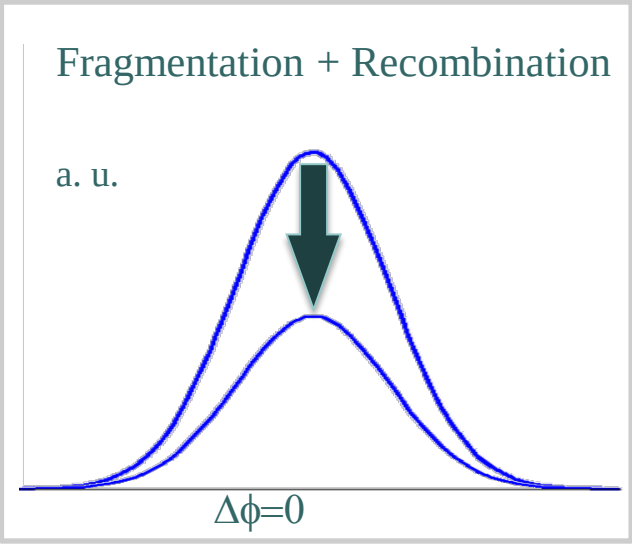


From Recombination perspective:

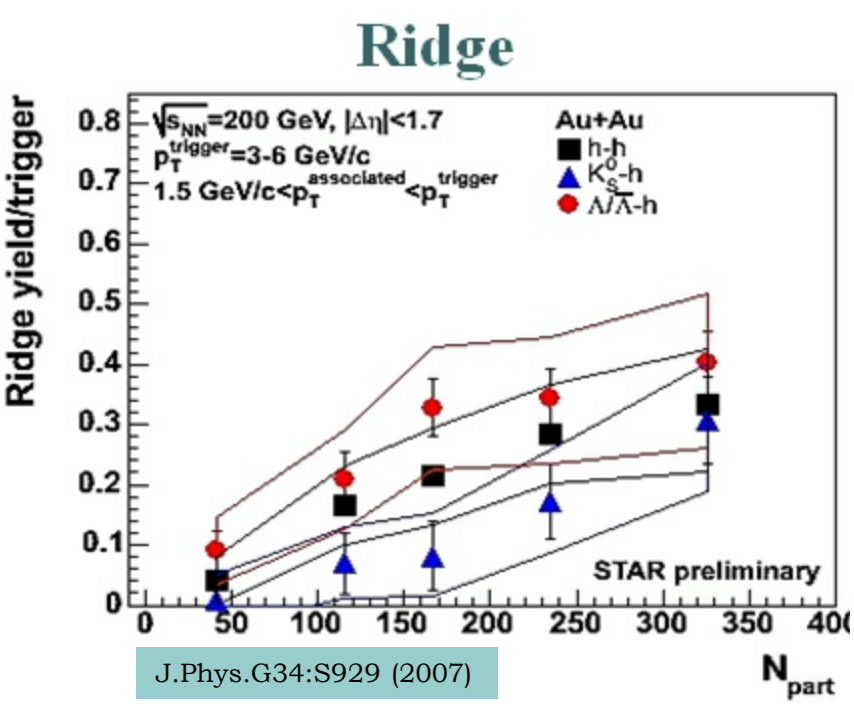
- More fake triggers for baryons →
- Trigger dilution effects

From E-loss perspective:

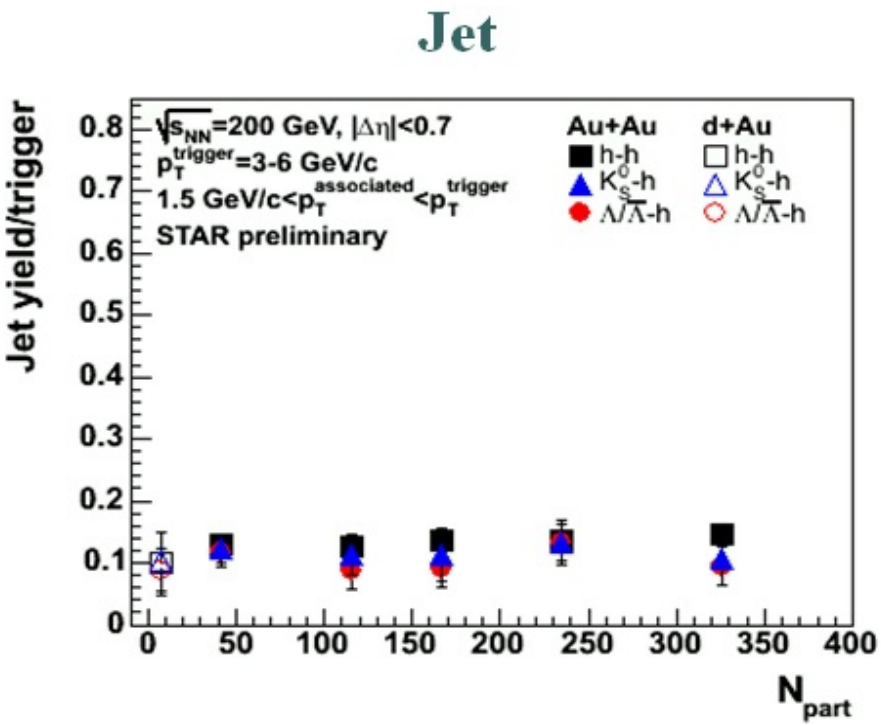
- Baryon triggers bias toward more gluons →
- Larger energy loss/modifications for baryon triggers



Early PID studies



J.Phys.G34:S929 (2007)



- Jet-cone yield

  Independent of particle specie; agrees with dAu data

  Surface bias?

- Ridge yield

  Increases with multiplicity; higher for baryons– NCQ?

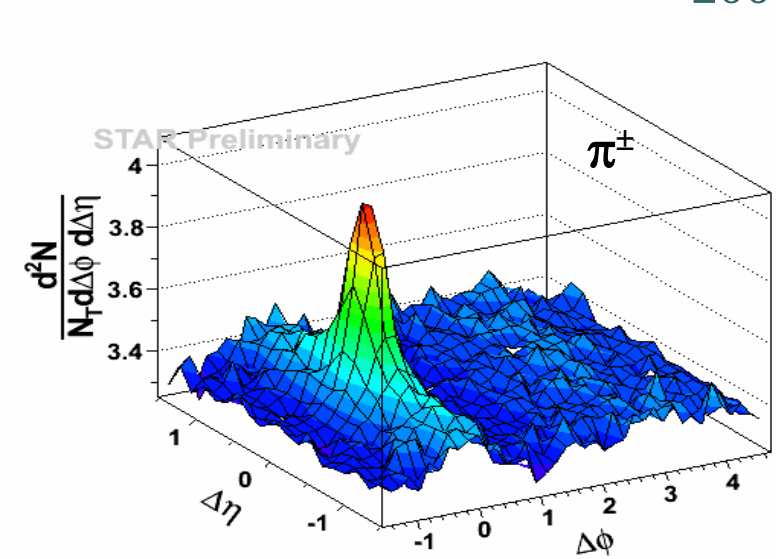
  Seems good for the flow

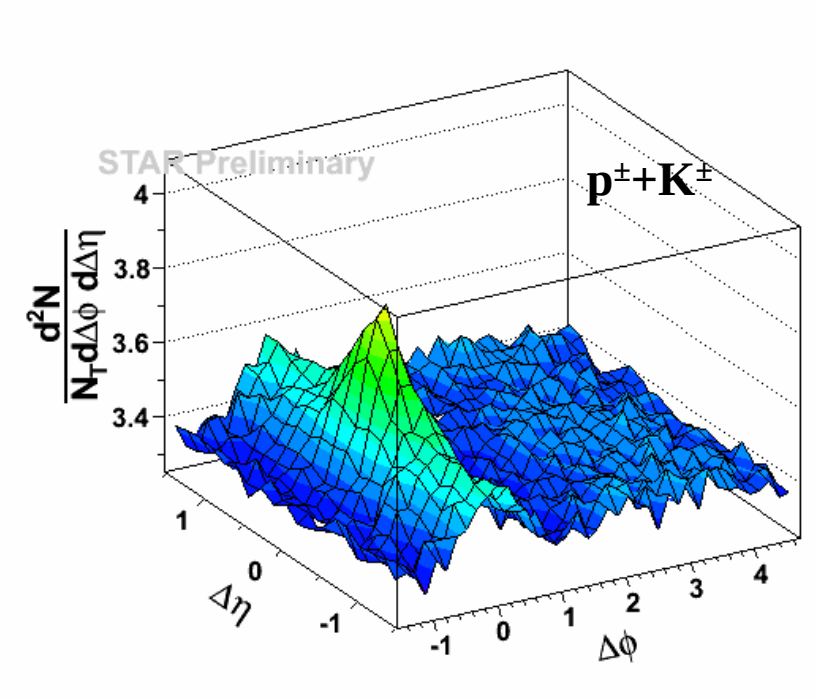
New PID correlations

New data:

200 GeV Au+Au Central (run 10) -- 150M events

GeV d+Au MinBias (run 8) – 46M events



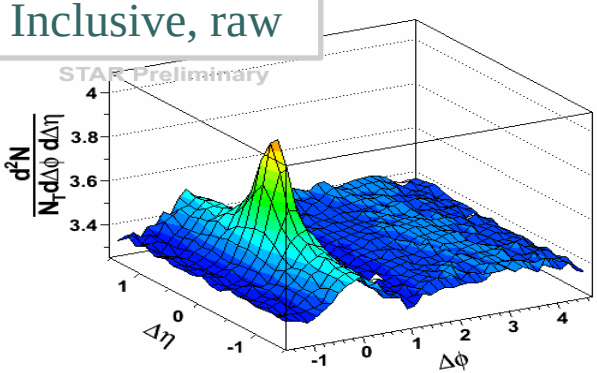


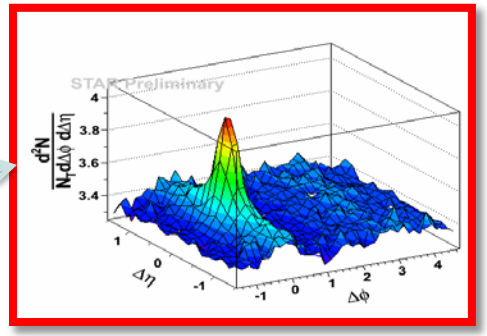
New analysis:

- dEd/x based PID
- Statistical separation
- 2D fits

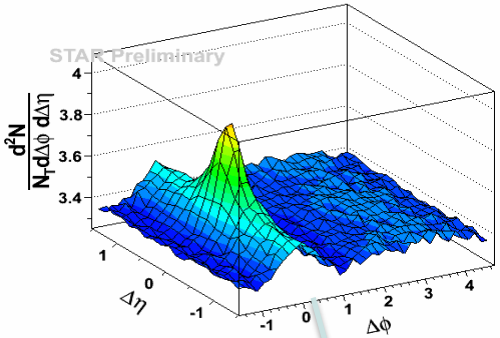
Statistical Separation

Inclusive, raw



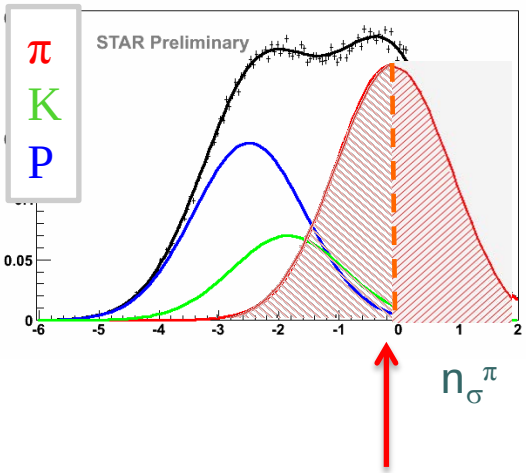


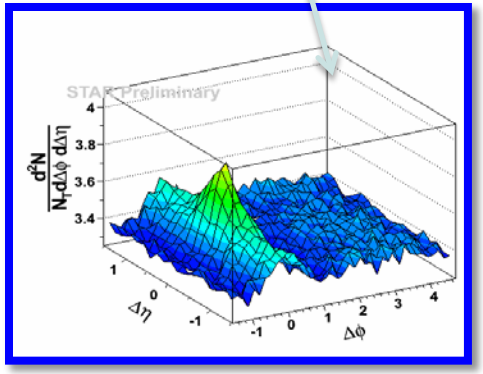
$n_\sigma^\pi > 0$.
97% purity
pion sample



$n_\sigma^\pi < 0$,
pion-depleted sample

$n_\sigma^\pi = (dE/dx - \pi \text{ prediction}) / \text{resolution}$

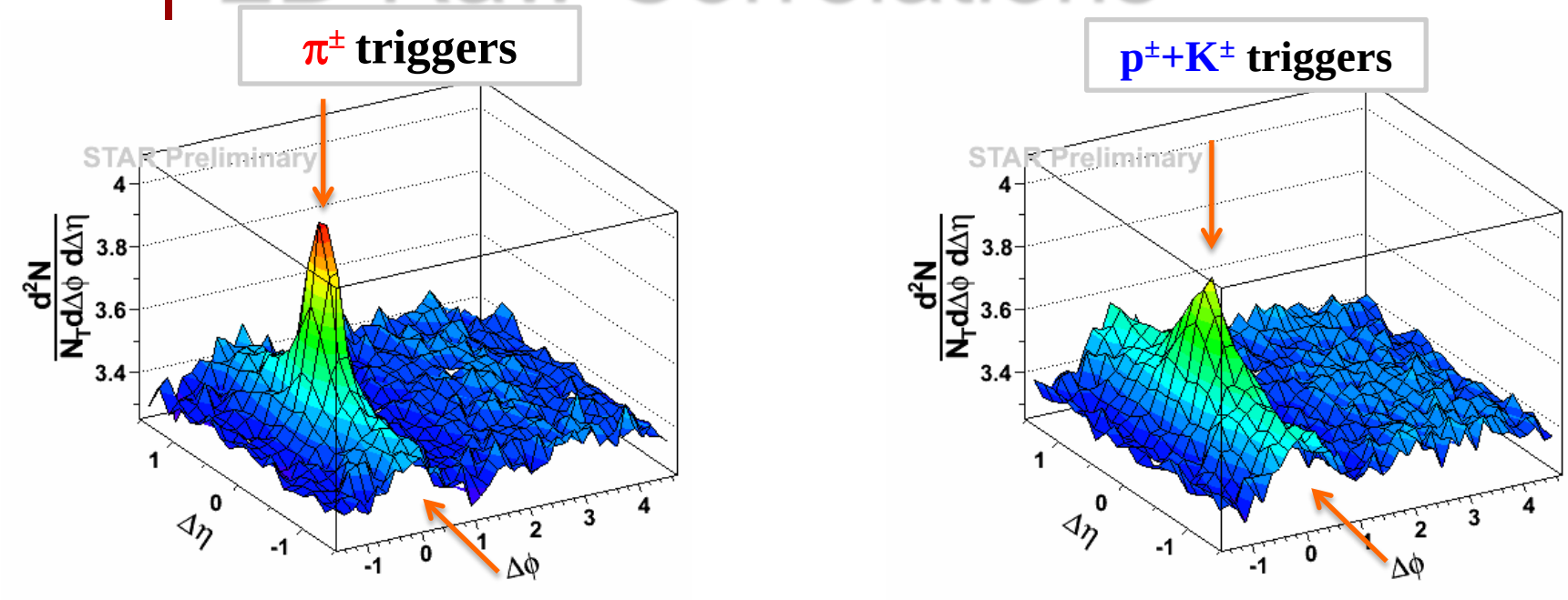




$n_\sigma^\pi < 0$, cleaned
p+K sample

0-10% central
$4 < p_T^{trig} < 5$ GeV/c
$1.5 < p_T^{assc} < 4$ GeV/c

2D Raw Correlations



- Visible differences in the raw* data!

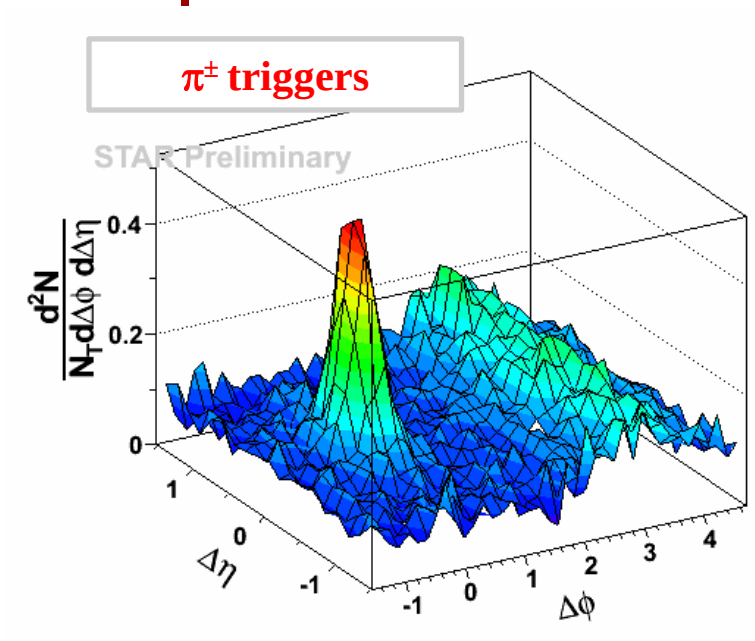
* Efficiency and acceptance effects are corrected

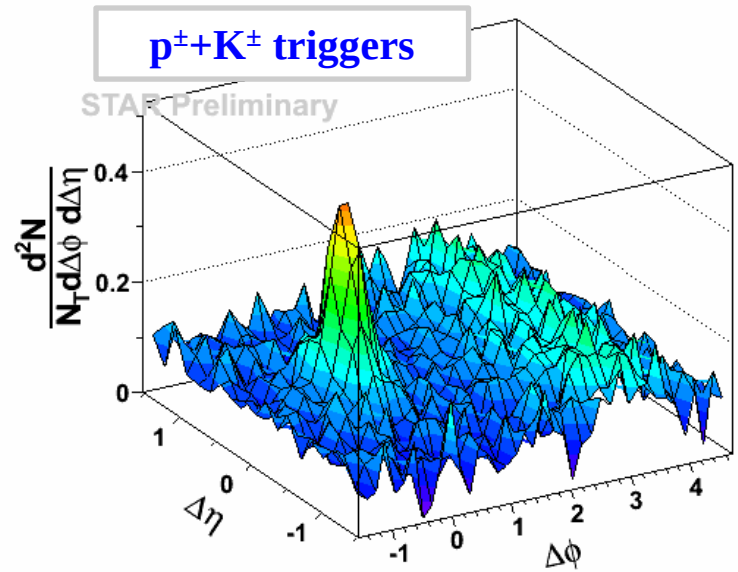
π triggers: large cone, small ridge

p+K triggers: small cone, large ridge

eLoss? Flow? Dilution? --Need d+Au reference!

2D Correlation – d+Au



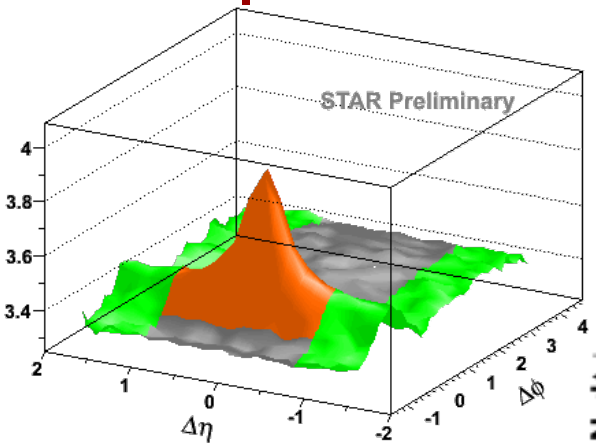


- No appreciable ridge*

*these are minimum bias events

- Cone is **similar** in d+Au
  - Detailed comparison – next…

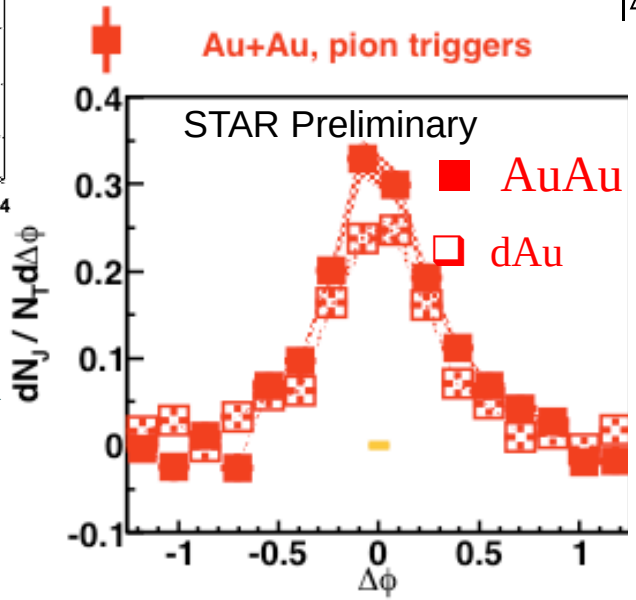
“Pure cone” extraction

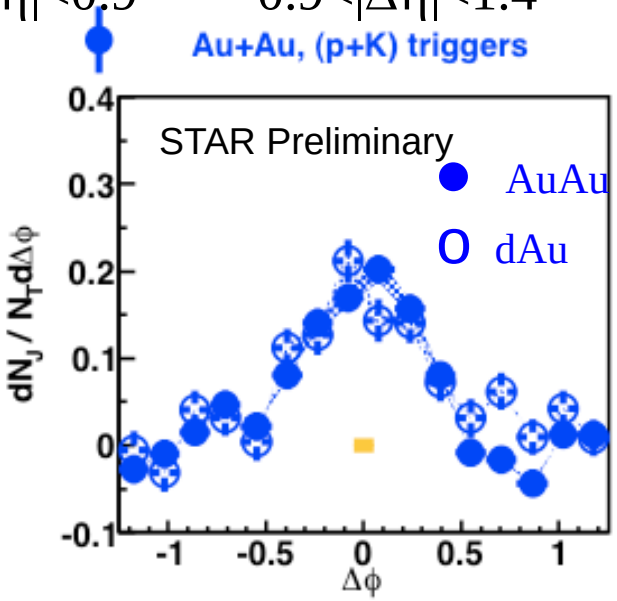


200 GeV Au+Au 10% central
200 GeV d+Au MinBias

Pure cone = Short range – Long range

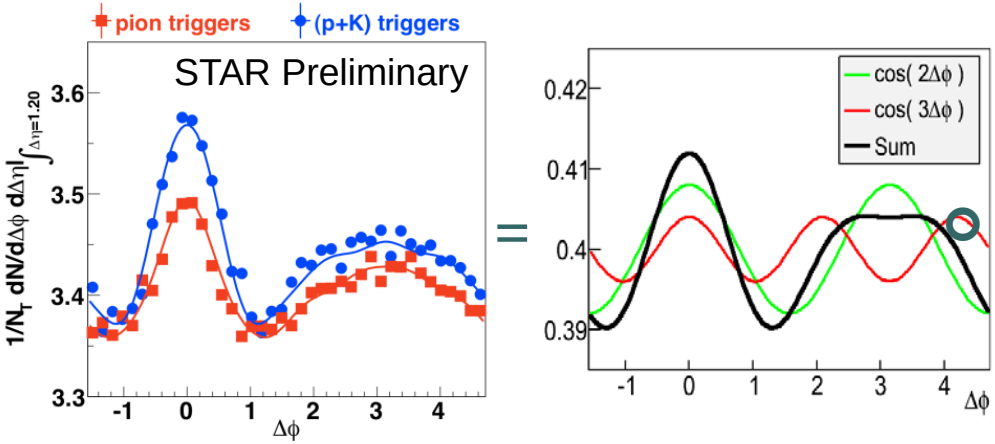
$|\Delta\eta|<0.9$ $0.9<|\Delta\eta|<1.4$





- Expectations from Reco – dilution for **p+K**
- Data – similar near side yields for **p+K**, enhancement for **π**
- Offsetting effects?

V_n fits for Ridge



200 GeV Au+Au 10% central

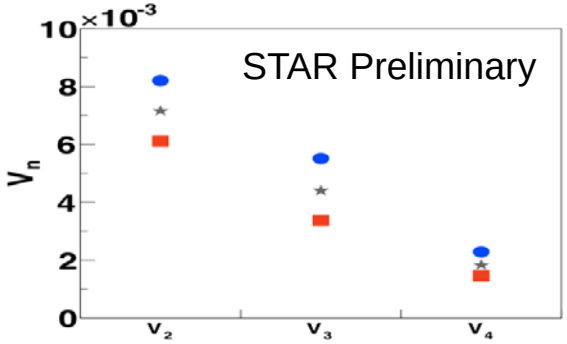
- Expectation:

  If Reco dominates the particle production, all harmonics should scale with NCQ

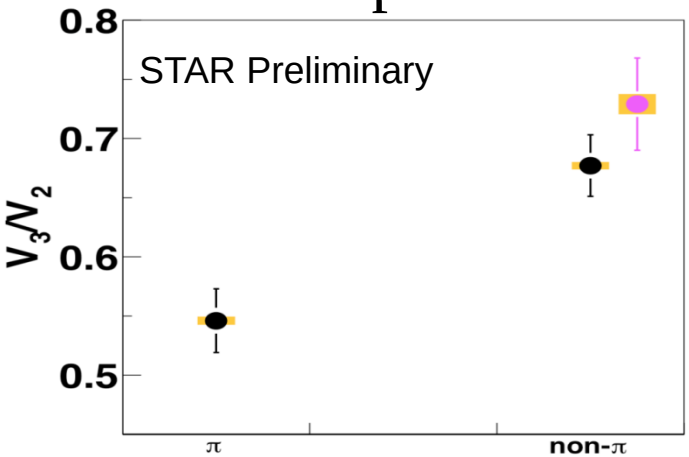
- Data:

  Fourier decomposition yields significant values for harmonics up to fourth order

V_n Coefficients



Double-ratio removes $h^{\pm}$ uncertainties



Summary

- Hadronization in QGP remains under-explored territory
- Multiple open questions from di-hadron correlations
  - Similarity of jet-cone yields for dAu and central AuAu data
  - Trigger dilution vs. in-cone radiation
  - Origins of ridge – “Could be flow.” or “Could it be flow?”
  - Observed scaling behavior constrains models
- Outlook
  - The data available should now allow to tackle the hadronization questions.