Evolution of structures in two particle correlations in heavy ion collisions as a function of centrality and momentum

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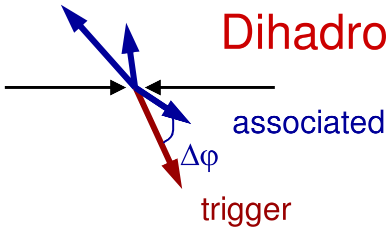
Outline

- Motivation of study: Results in two particle number correlations in 200 GeV Au+Au collisions
- Data and cuts
- Correlation measurement
- Centrality dependent evolution
- Momentum dependent evolution
- Conclusions

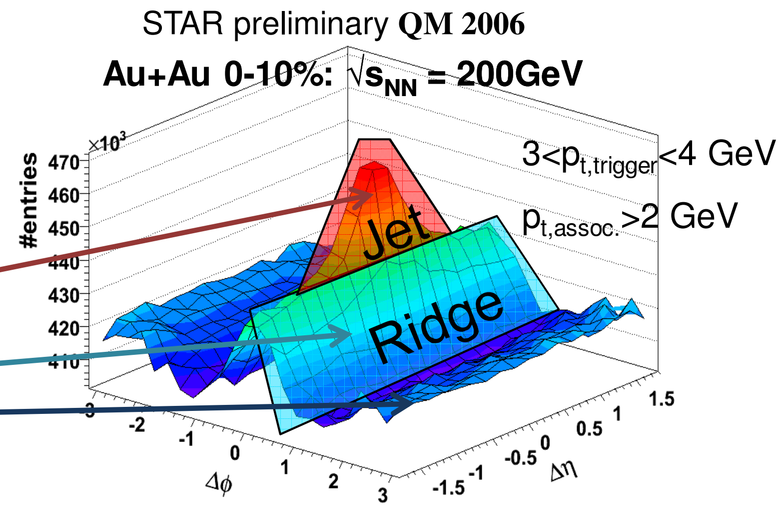
Motivation – triggered ridge

Dihadron correlations



Structures:

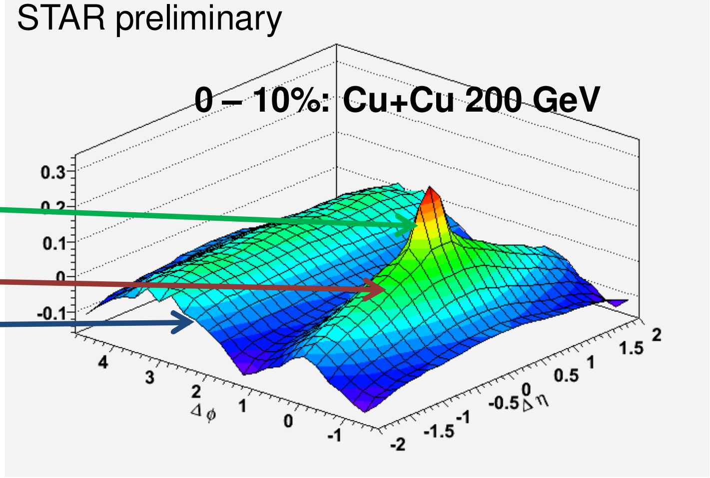
- Near side jet peak comparable to p+p
- Near side ridge structure at intermediate p_t
- Smooth away side



What do we know:(J. Putschke for STAR Collaboration, Winter Workshop in Nuclear Dynamics 08')

- Ridge yield approximately independent of $\Delta\eta$ and $p_{t,trig}$
- Ridge yield persists to highest trigger $p_t \Rightarrow$ correlated to jet production?
- Ridge only in Au+Au (not present in p+p or d+Au or peripheral Au+Au)
- Ridge p_t-spectra are 'bulk-like' and approximately independent on $p_{t,trig}$

Motivation – untriggered ridge



Structures:

- Near side "HBT, e^+e^-" peak
- Near side "ridge like" structure
- Away side structure

What do we know: (M. Daugherity for STAR Collaboration, QM 2008)

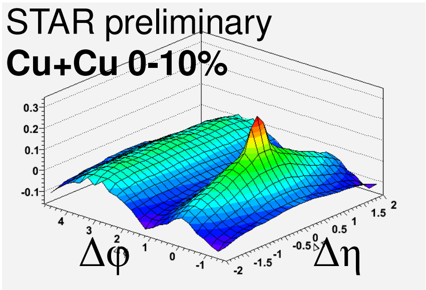
- Strong centrality variations of the same side structure
- Multiple particle production mechanisms contribute to correlation function in soft sector

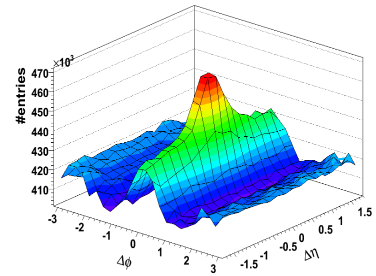
Why is it interesting:

- The same side structure is an elongated 2d Gaussian
- ~90% consists of soft particles

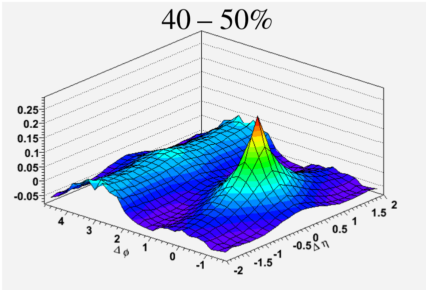
Investigations presented in this talk

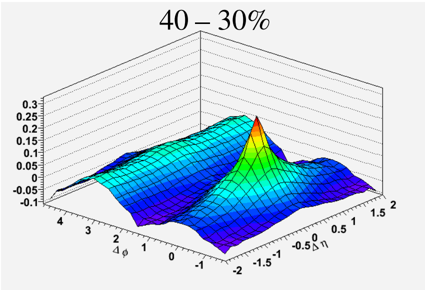
- p_t dependence: Investigate how the untriggered ridge evolves toward the triggered

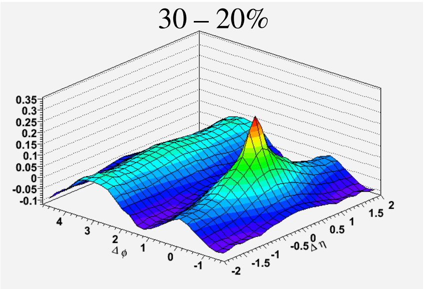


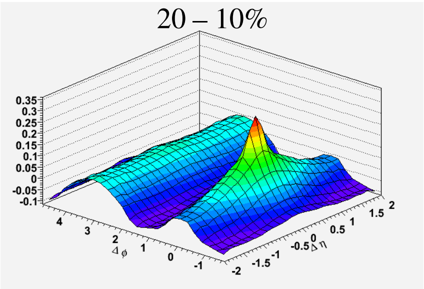


- Centrality dependence: Investigate the evolution of the untriggered ridge in 200 GeV Cu+Cu collisions



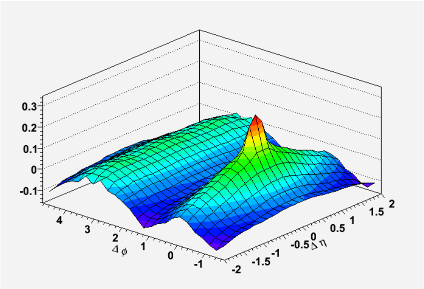






STAR preliminary
Cu+Cu 200 GeV

10 – 0%



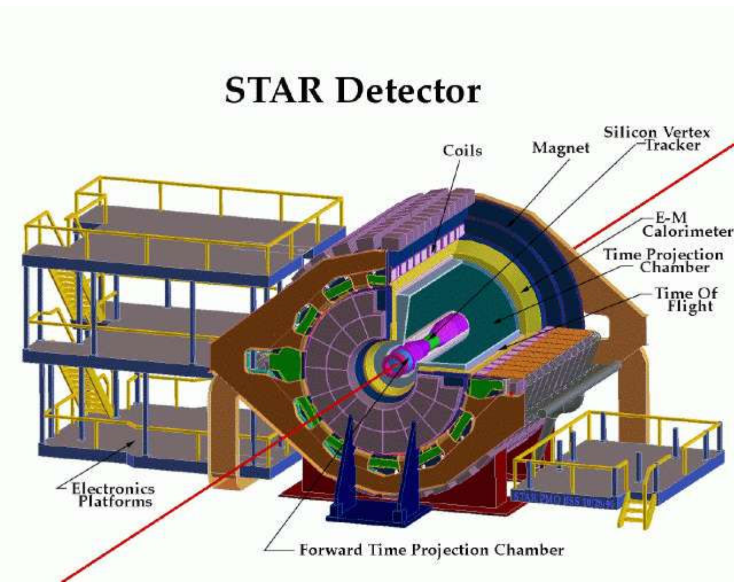
Data and cuts

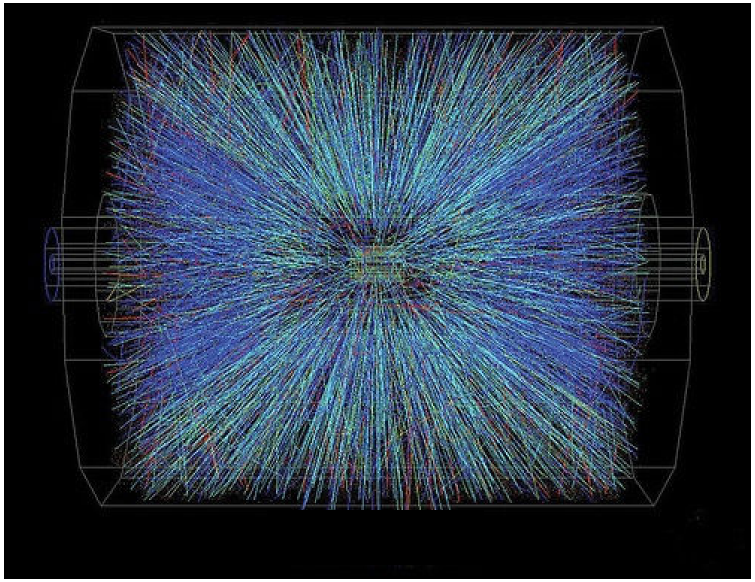
- CuCu 200 GeV; ~ 7M events were analyzed
- Track cuts for untriggered analysis

  * $0.15 \leq Pt \leq 15.45$ GeV/c

  * $|\eta| \leq 1$

- Centrality parameter: v = 2<Nbin>/<Npart>





Tracks produced in an event

Correlation measure

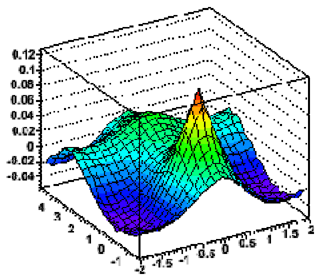
$$\frac{\Delta\rho}{\sqrt{\rho_{ref}}} = \frac{\rho_{sib} - \rho_{ref}}{\sqrt{\rho_{ref}}}$$

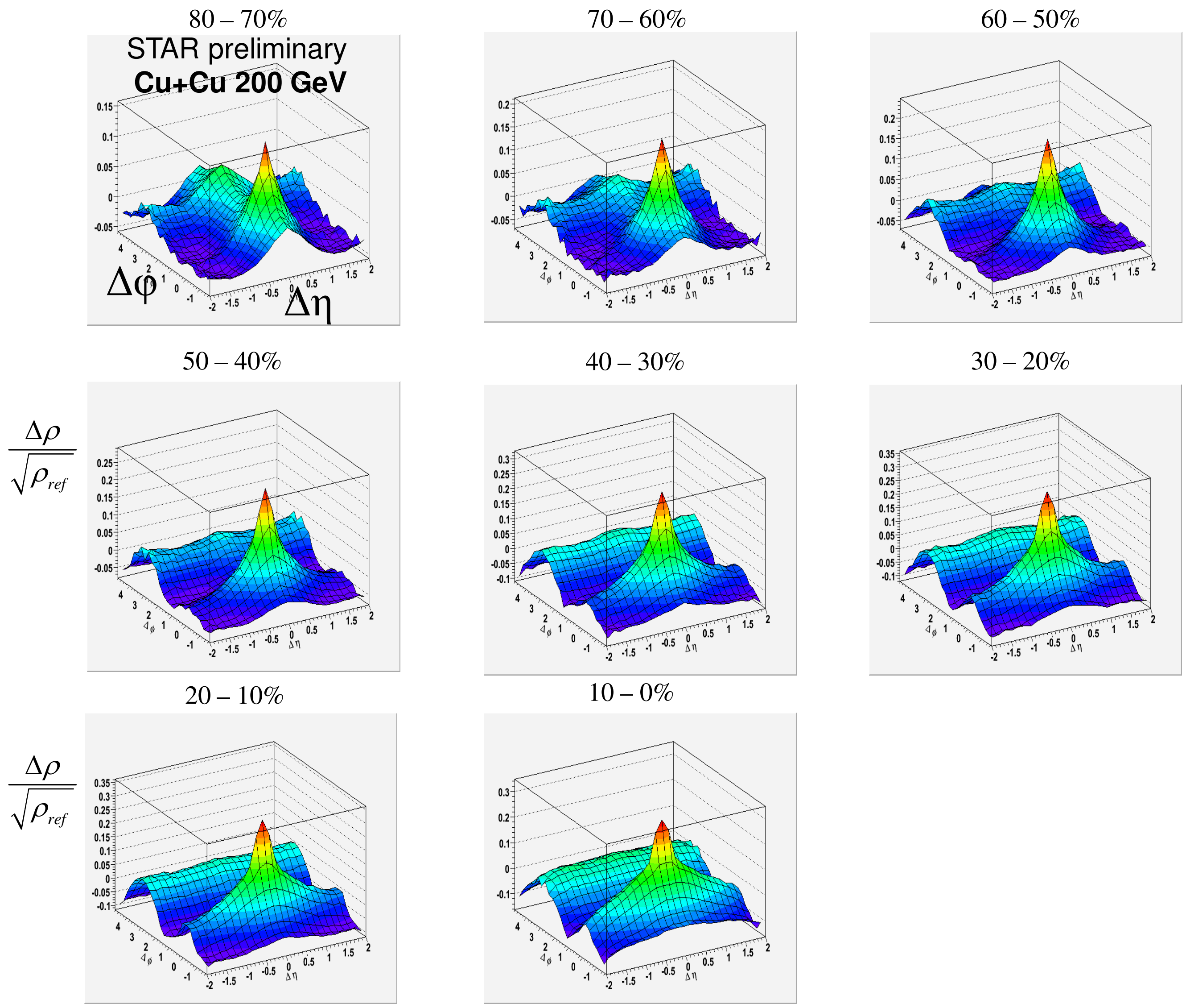
- ρ_{sib} is the pair density at a particular $(\Delta\eta,\Delta\phi)$ bin
- ρ_{ref} is the reference pair density for the same $(\Delta\eta,\Delta\phi)$ bin
  - Constructed via event mixing which forms pairs from tracks in separate events
- Each density is normalized by the respective number of events

Untriggered correlation plots – centrality evolution

proton-proton

$\frac{\Delta\rho}{\sqrt{\rho_{ref}}}$





Fit function

$$f = f_1 + f_2 + f_3 + f_4 + f_5 + f_6$$

$$f_1 = c0$$

$$f_2 = c1 * \cos\Delta\phi$$

$$f_3 = c2 * \cos 2\Delta\phi$$

$$f_4 = c3 * \exp(-0.5 * ((\Delta\eta / c4)^2 + (\Delta\phi / c5)^2))$$

$$f_5 = c6 * \exp(-0.5 * (\Delta\eta / c7)^2)$$

$$f_6 = c8 * \exp(-1 * sqrt((\Delta\eta / c9)^2 + (\Delta\phi / c10)^2))$$

f1: Offset

f2: $\cos(\Delta\phi)$ *structure*

f3: $\cos(2\Delta\phi)$ *structure*

f4: 2d Gaussian structure

f5: 1d Gaussian structure

f6: 2d exponential structure

Physics explanations

f2: "momentum conservation"

f3: "v2 like correlation"

f4: "same side ridge"

f5: "string fragmentation"

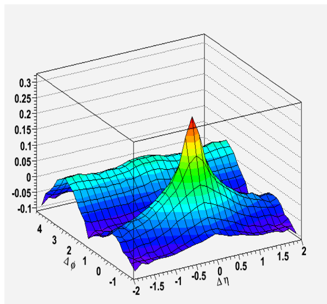
f6: "HBT, e^+e^-*"*

- Minimize chi square with respect to the measured correlation structure by adjusting the fit function parameters

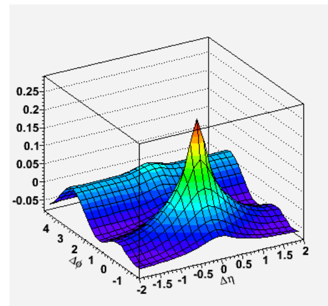
Residual and fit decomposition: 30 – 40%

STAR preliminary
Cu+Cu 200 GeV

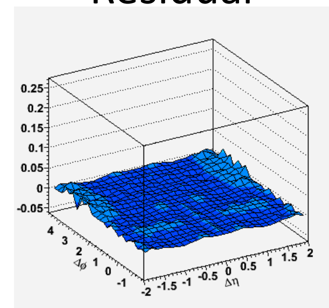
Data



Fit



Residual



χ^2/#dof ≈ 2

Decomposition

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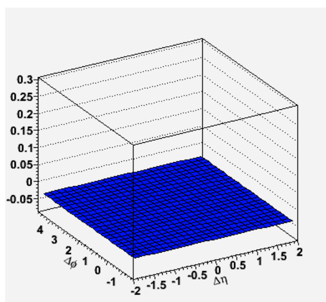
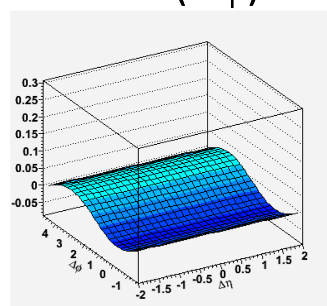
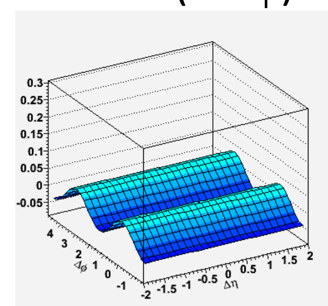
Offset



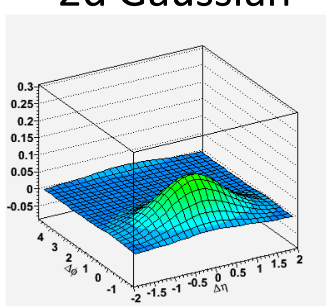
cos(Δφ)



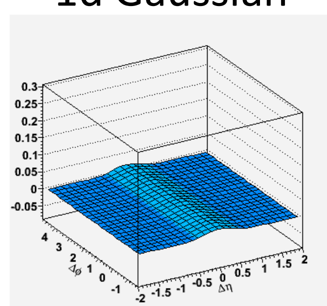
cos(2 Δφ)



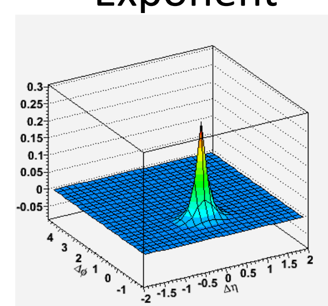
2d Gaussian



1d Gaussian



Exponent



The evolution of the near-side 2d Gaussian component

- The main focus of the centrality study is how the 2d Gaussian component varies against the centrality

- Is the change due to an altered jet-like particle production mechanism or medium response?

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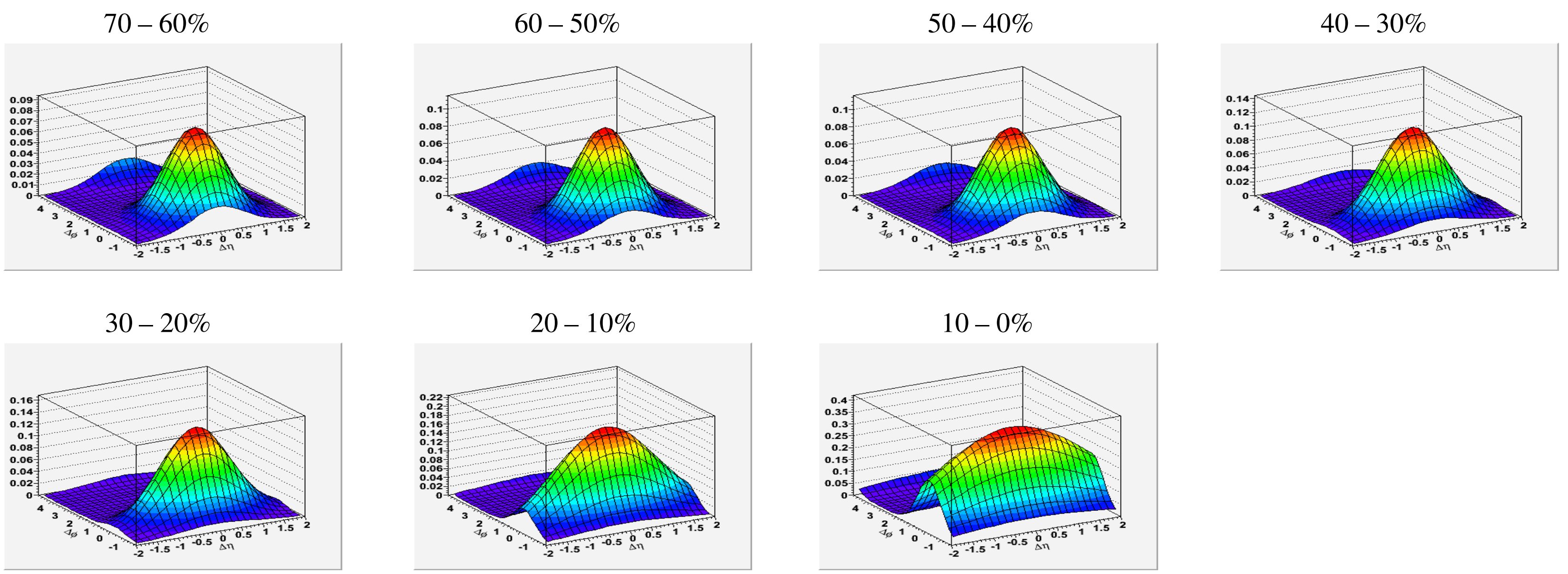
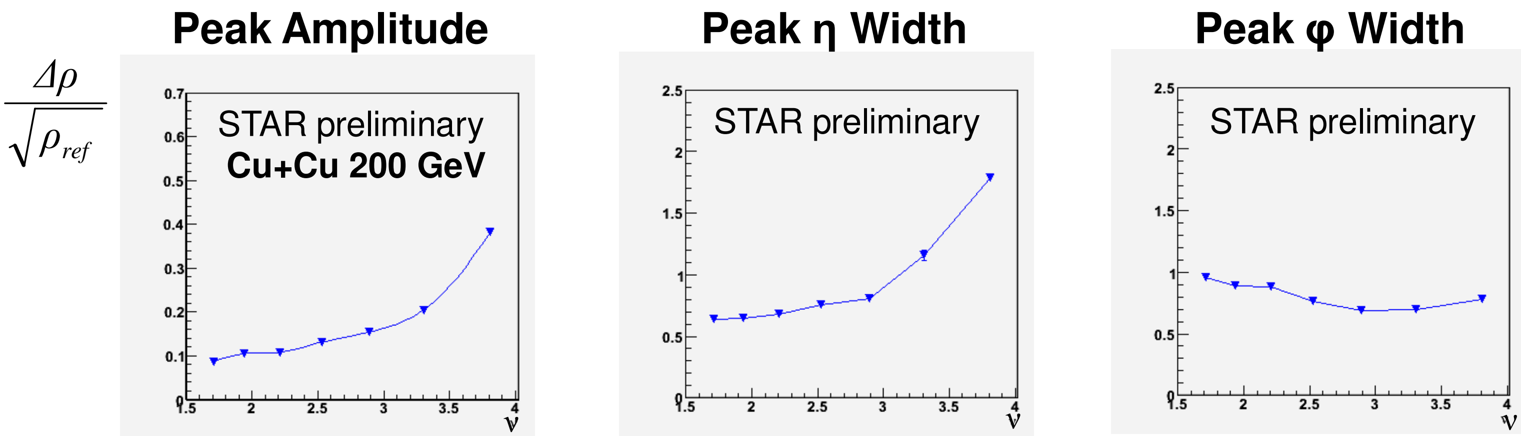
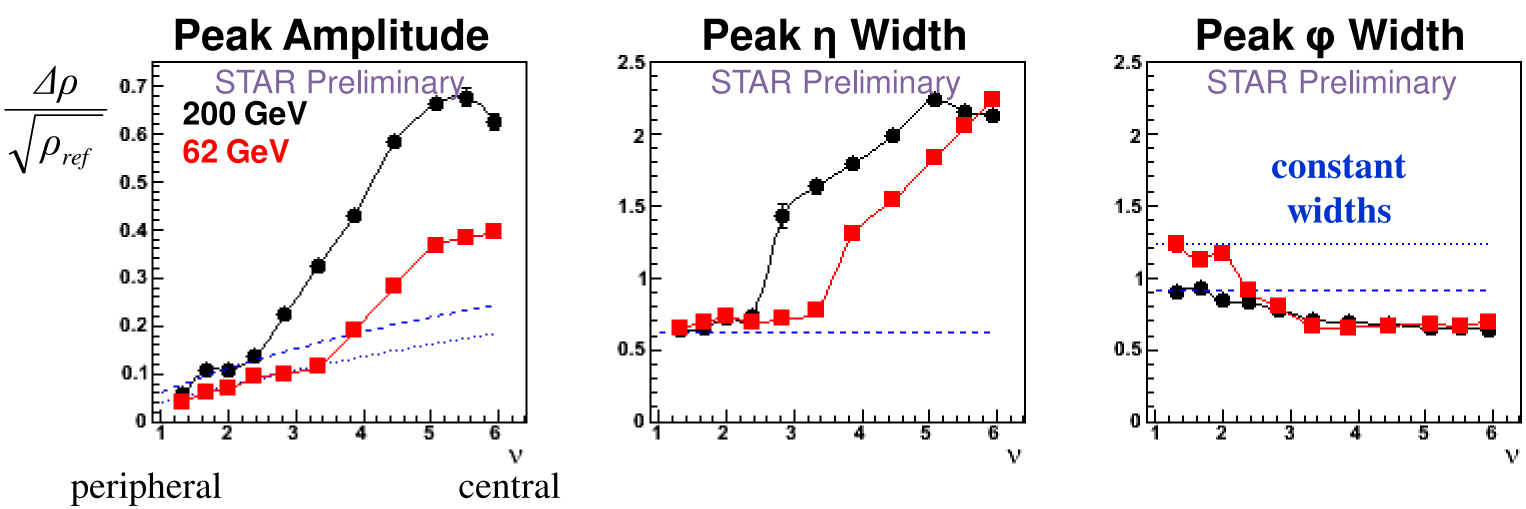
Cu+Cu 200 GeV



Evolution of 2d Gaussian parameters



- Comparison to AuAu from M. Daugherity for STAR collaboration, QM 2008



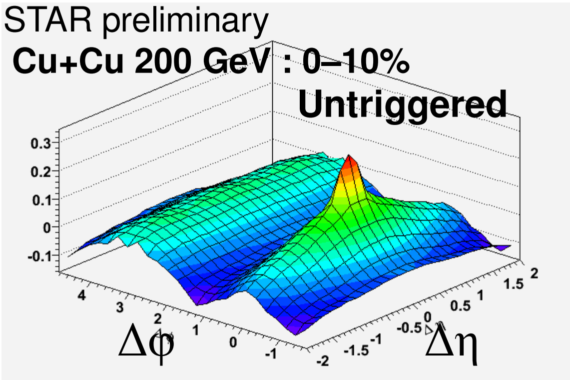
What does it reflect?

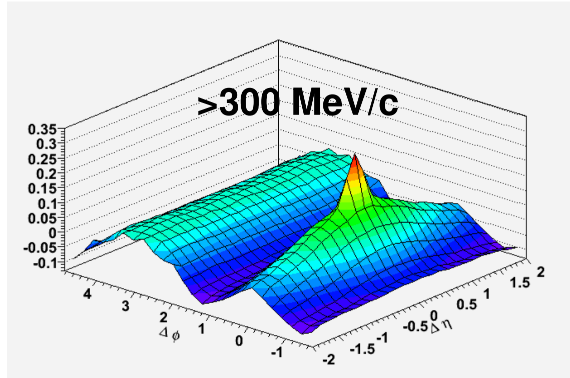
- **In peripheral:** The 2d Gaussian amplitude follows expectations from binary scaling
- **In mid central and central:** It shows large excess above the binary scaling (scaling breaks)
- Increase in $\Delta\eta$ width suggests that increase in amplitude is due to increase in long range $\Delta\eta$ correlations

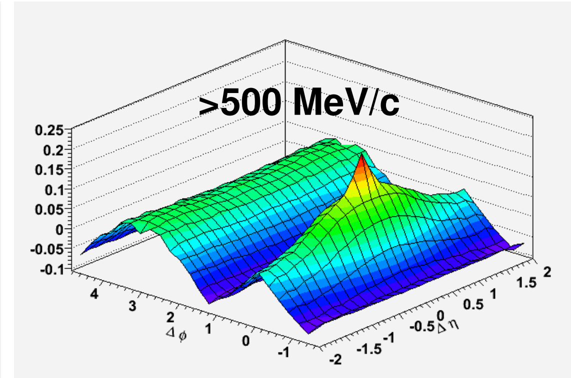
Motivates the following questions:

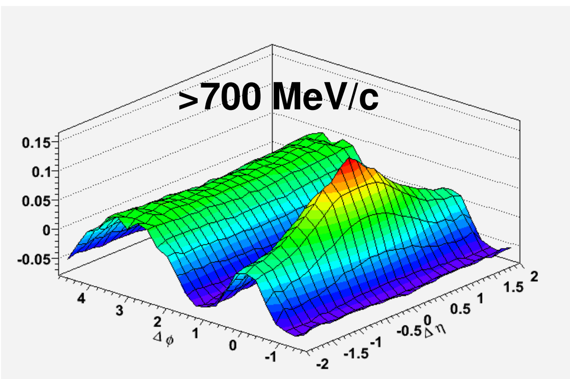
- ➢ Is the increase due to modification of (semi) hard parton fragmentation?
- ➢ Can there be other physical processes (e.g. medium response)?

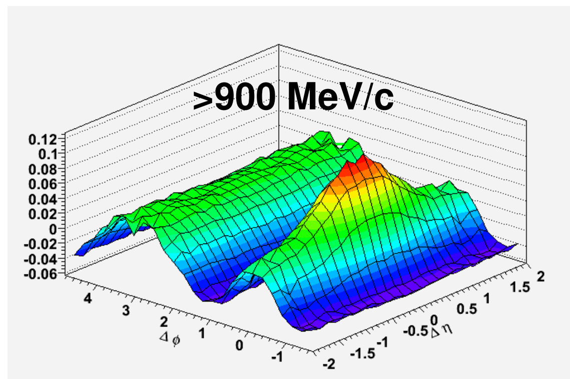
The momentum dependent evolution of the ridge

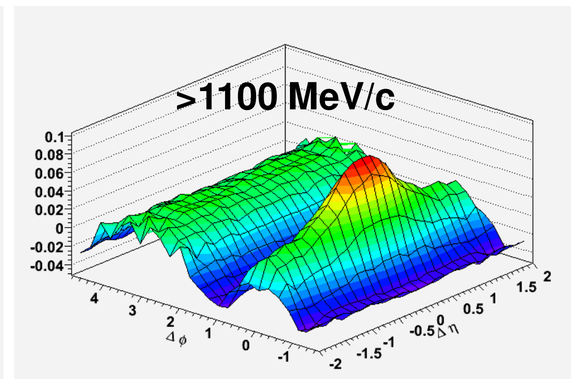


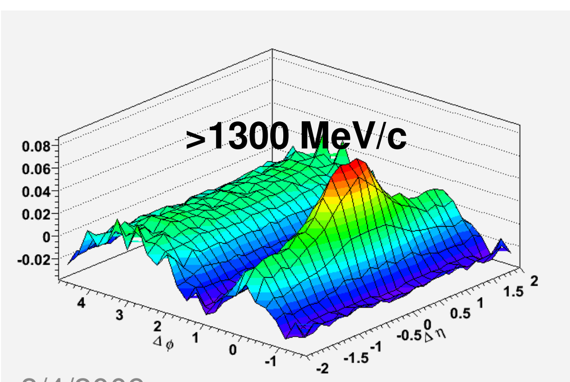


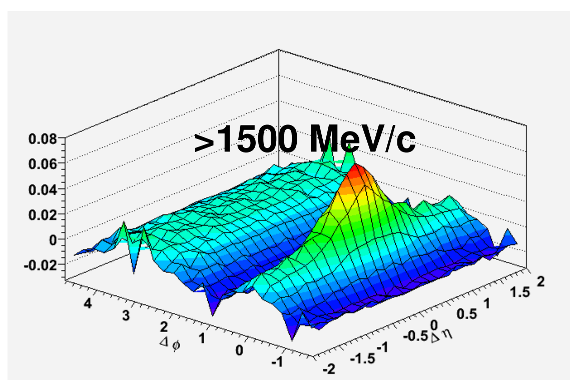


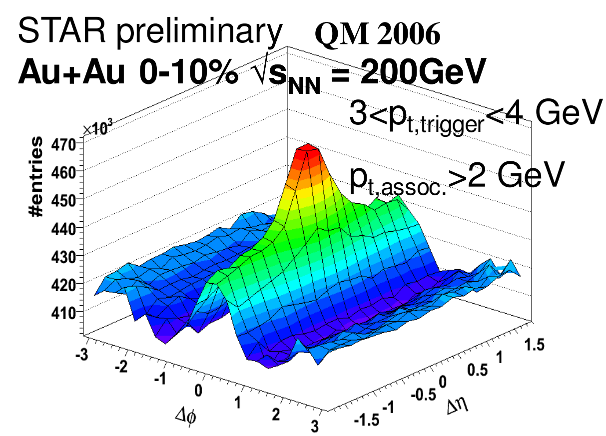












Interpretation of the preliminary results

- The loss of (0,0) spike at high p_t. i.e.: HBT and e^+e^- disappear (low p_t phenomena)

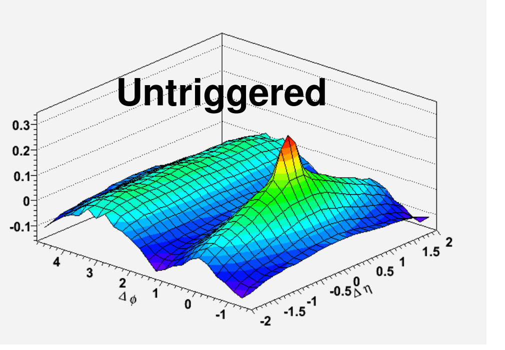
- The wide same side structure flattens out and decreases in amplitude

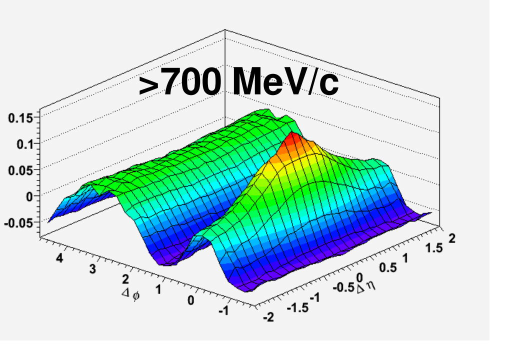
- At high p_t: Emergence of a new peak at (0,0); is it the jet?

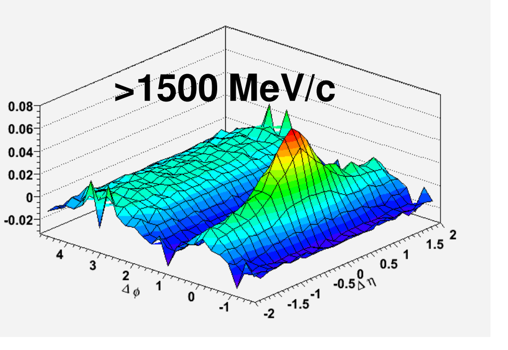
- A smooth transition is observed from untriggered to triggered ridge

- Does it suggest soft and hard ridges have same physical origin?

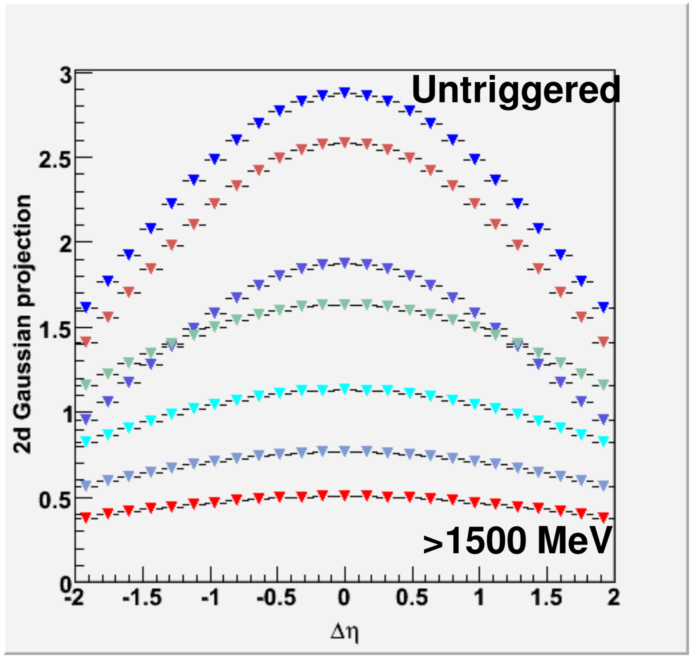
- Ridge: Transition from a wide 2d Gaussian to a flat structure in $\Delta\eta$?

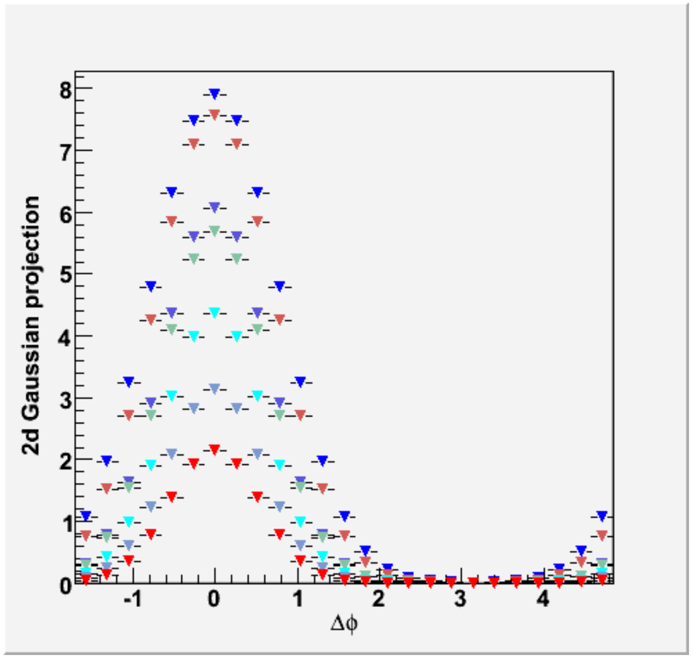






The variation of the 2d Gaussian projections





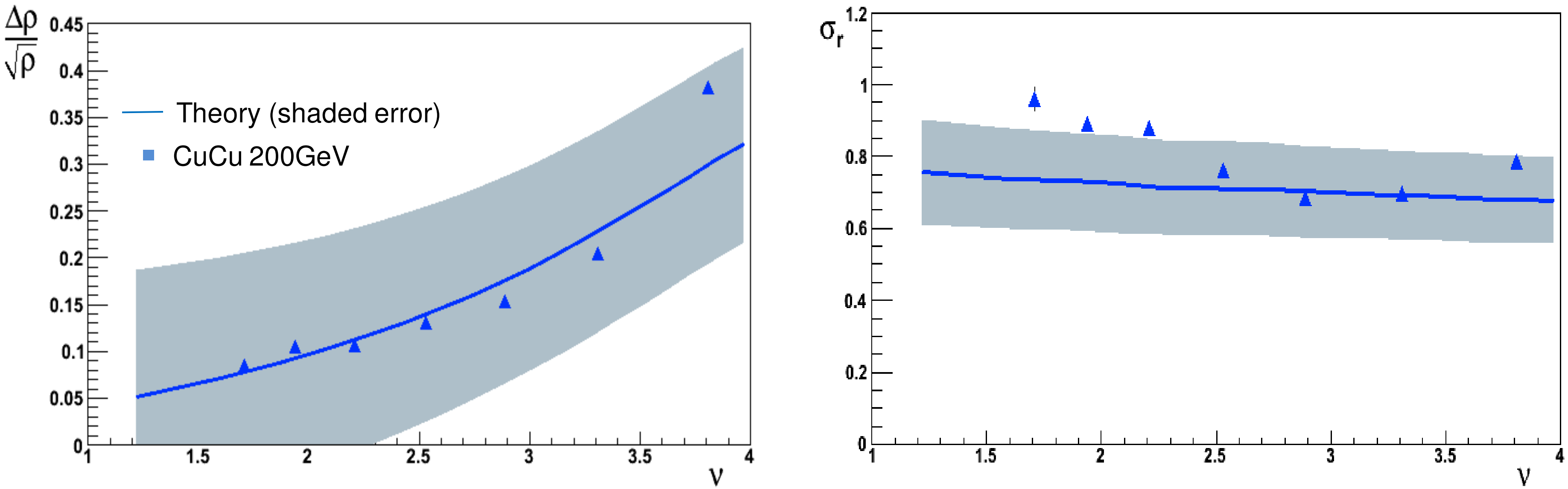
- The expected "jet" like behavior from the 2d Gaussian fit component is supported by the Δφ width reduction

- The Δη width variation is deviating from "jet" like behavior

- **In Δη: Apparent shape change**, Should we introduce another fit component? (e.g. a structure that is flat in Δη and Gaussian in Δφ at the same side)

Comparison to theory (centrality dependence)

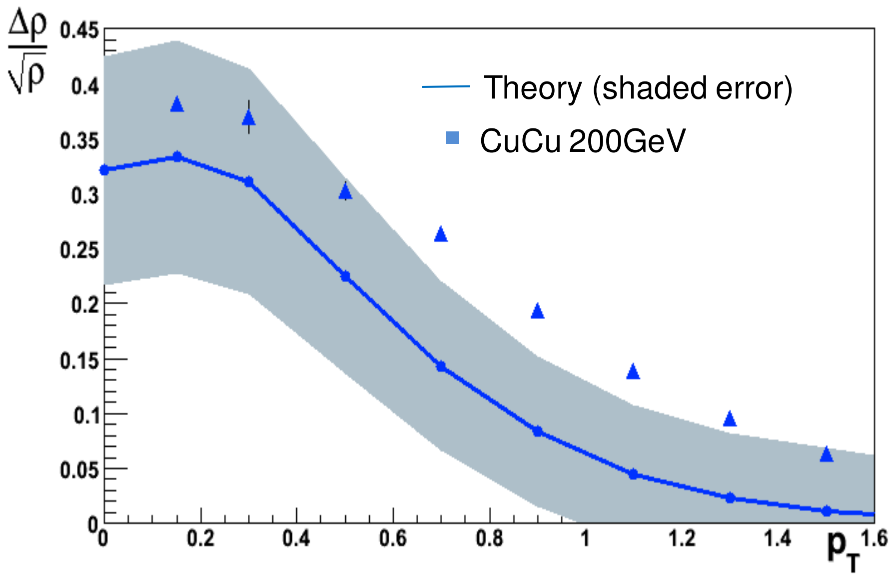
- Hypothesis: Increase in amplitude is due to soft physics
- Compare to theory based on CGC flux tubes and radial (blast wave) flow (Gavin, McLerran, Moschelli, arXiv:0806.4718)

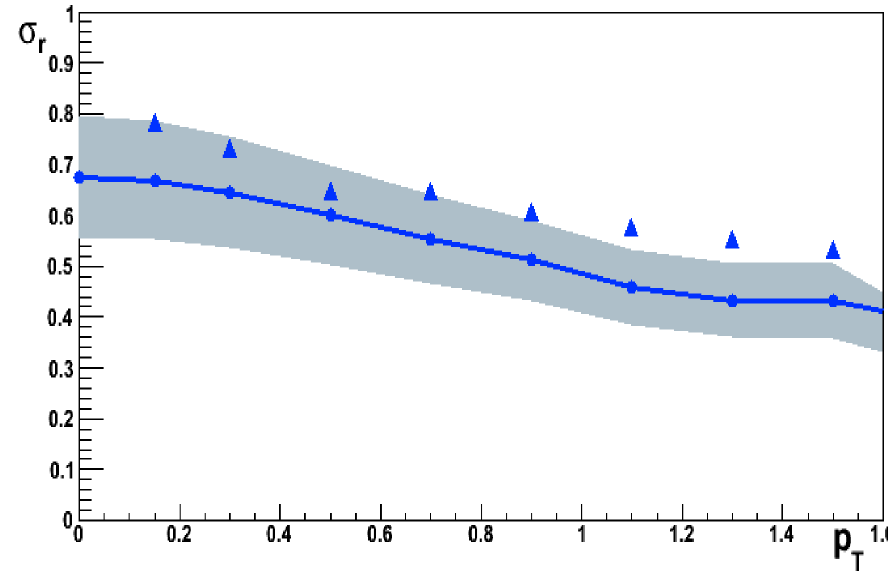


- Alternative medium response theories:

Momentum kick: C.-Y. Wong, PRC 76 (2007)
Recombination: R. Hwa *et.al,* PRC 72 (2007)
Plasma instability: A. Majumder *et.al,* PRL 99 (2007)
Longitudinal flow: N. Armestro *et.al,* PRL 93 (2004)

Comparison to theory (p_t dependence)





- The theory reproduces the data trends
- Theory only takes in to account bulk particle correlations. Slight enhancement in data over theory at high p_t might be due to jet contributions to the correlation function
- Both soft and hard ridges might have the same physics (Flux tubes and radial flow)
- The theory does not predict the $\Delta\eta$ width behavior

Summary and Outlook

- Summary
  - Increase in untriggered near side 2d Gaussian amplitude beyond binary scaling and broadening along $\Delta\eta$, both as a function of centrality, indicate new physical processes in heavy-ion collisions
  - The smooth evolution of the untriggered near-side 2d Gaussian structure towards the p_t-triggered suggests a common physical origin
  - A CGC model, assuming strong radial flow describes the amplitude and $\Delta\varphi$ width behavior of the 2d Gaussian

- Outlook
  - The two component fit (flat ridge + Gaussian jet) will be tested to fit the same side structure smoothly as a function of the momentum cut
  - Efficiency correction for tracking will be carried out
  - The proper extracted fit parameter uncertainties will be calculated

Extra slides

Justification of physics structures

Motivated by the observations made in p+p 200GeV collisions
arXiv:hep-ph/0506172v1

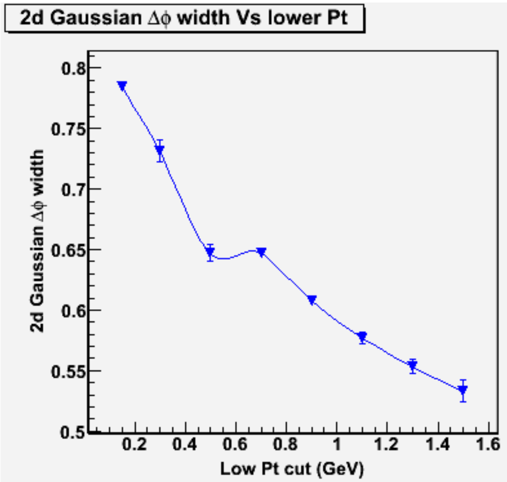
- The soft particles (pT < 0.5 GeV/c) exhibit the expected longitudinal string fragmentation and HBT/e+e- correlation structures

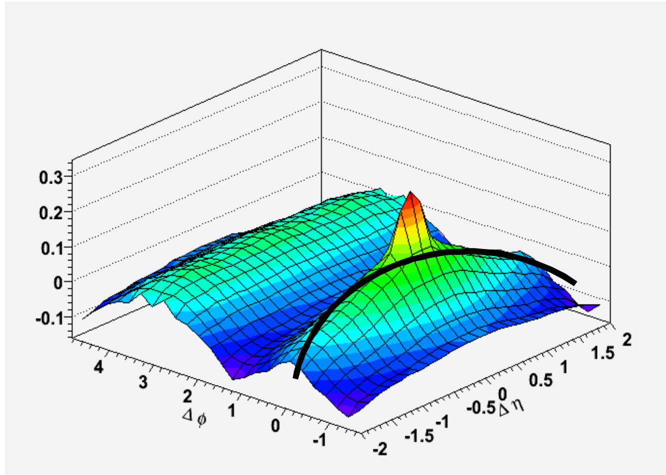
- The hard particles (pT > 0.5 GeV/c) exhibit a 2d Gaussian structure on the near side and a -cos(phi) structure on the away side

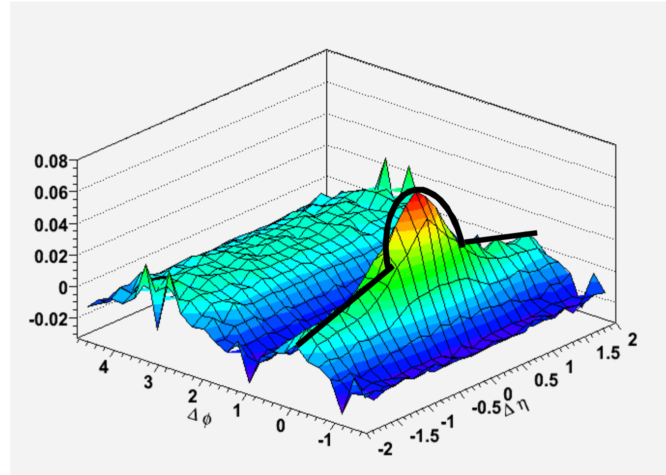
- The latter are attributed to Jet fragmentation and away side momentum conservation respectively

- The amplitude of cos(2phi) term is included to represent the v2 like azimuthal particle correlations

Introduction of a new fit component







- We will expand the fit to allow for a structure that is flat in Δη and Gaussian in Δφ at the same side

- The quality of the fits will be compared

- Do we obtain a better description with a ridge + jet composition?