High-p_t physics at the SPS

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For the CERES collaboration

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Outline

- **Results from CERN SPS experiments on nuclear modification factors R_{AA} R_{CP} and hadron spectra.**
  - **High-pt azimuthal correlations @ CERES**
    - **Experimental setup**
    - **Measurement**
    - **Results (preliminary)**
      - → **two particle correlations**
      - → **three particle correlations**
  - **Conclusion / Outlook**

Nuclear Modification factor

R_{AA} /R_{CP}

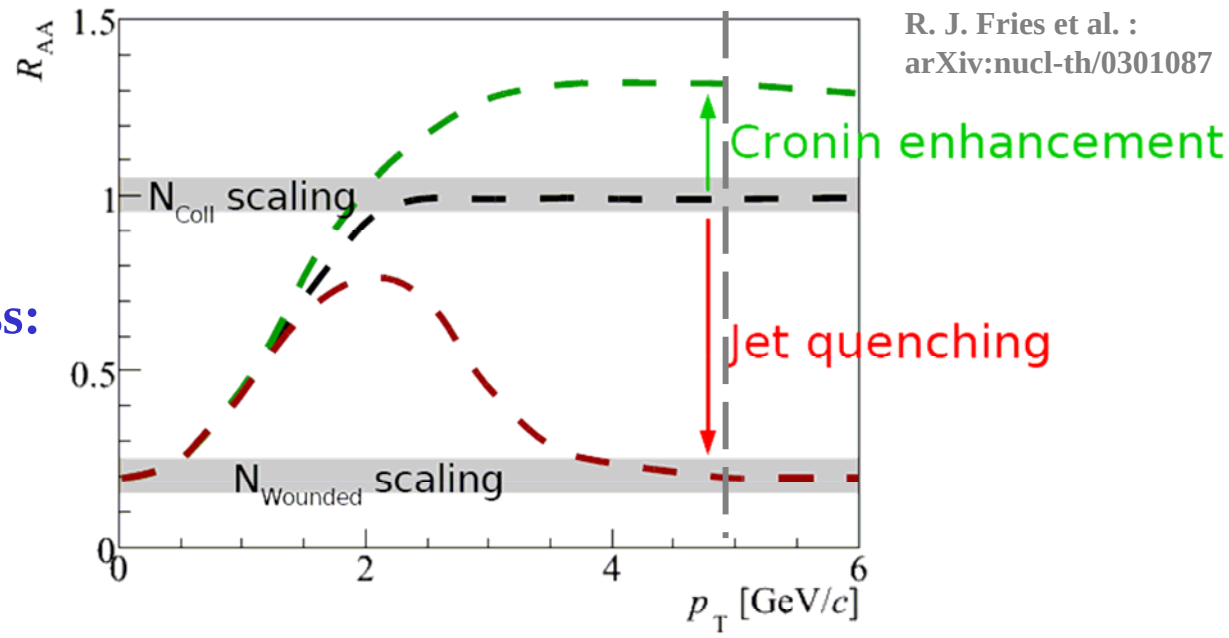
$$R_{AA} = \frac{d^2N_{AA}/dydp_t}{\langle N_{coll}\rangle \times d^2N_{pp}/dydp_t} \qquad R_{CP} = \frac{\langle N_{coll}\rangle_C \times d^2N^P_{AA}/dydp_t}{\langle N_{coll}\rangle_P \times d^2N^C_{AA}/dydp_t}$$

Initial state:
Cronin effect

Final state:
Jet quenching

Hadronisation process:
Recombination,
Fragmentation

Crossover for hadron production ≈ 5GeV/c
recombination | fragmentation

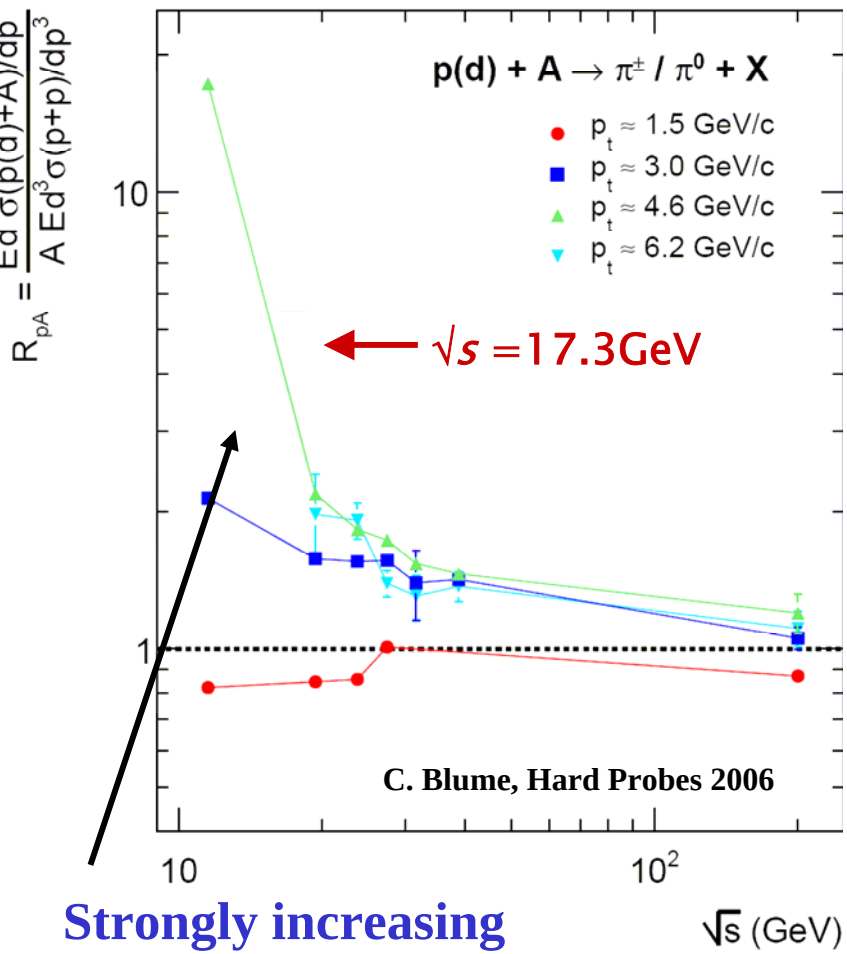


R. J. Fries et al. : arXiv:nucl-th/0301087

Are these effects reflected in SPS data?

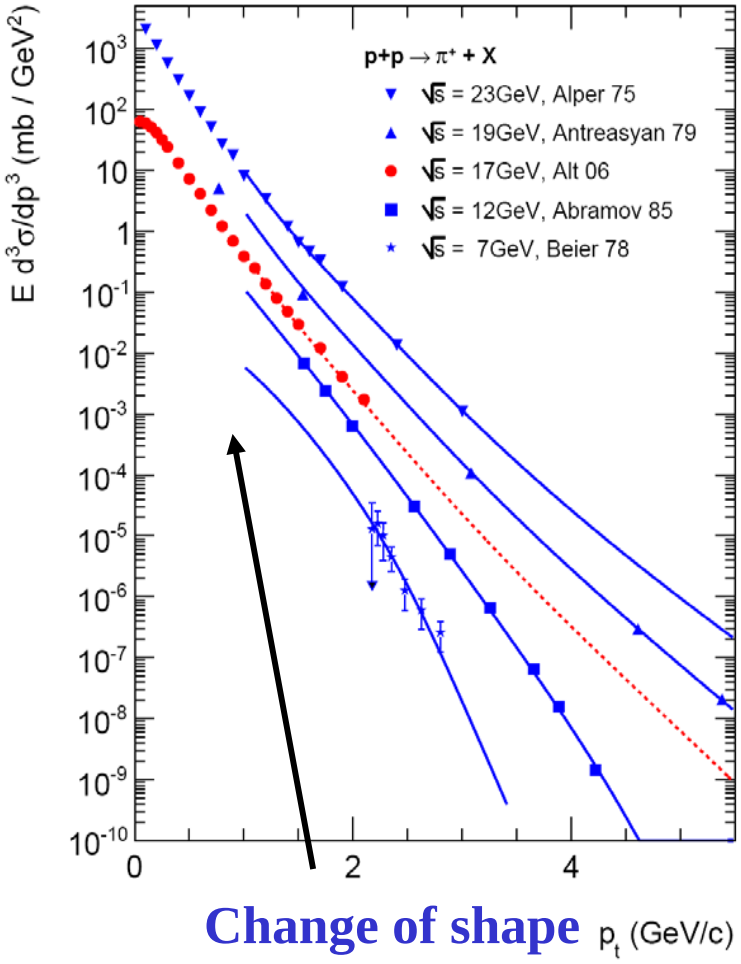
Ingredients to quantify energy loss

Cronin enhancement



Strongly increasing at SPS energies

p+p reference

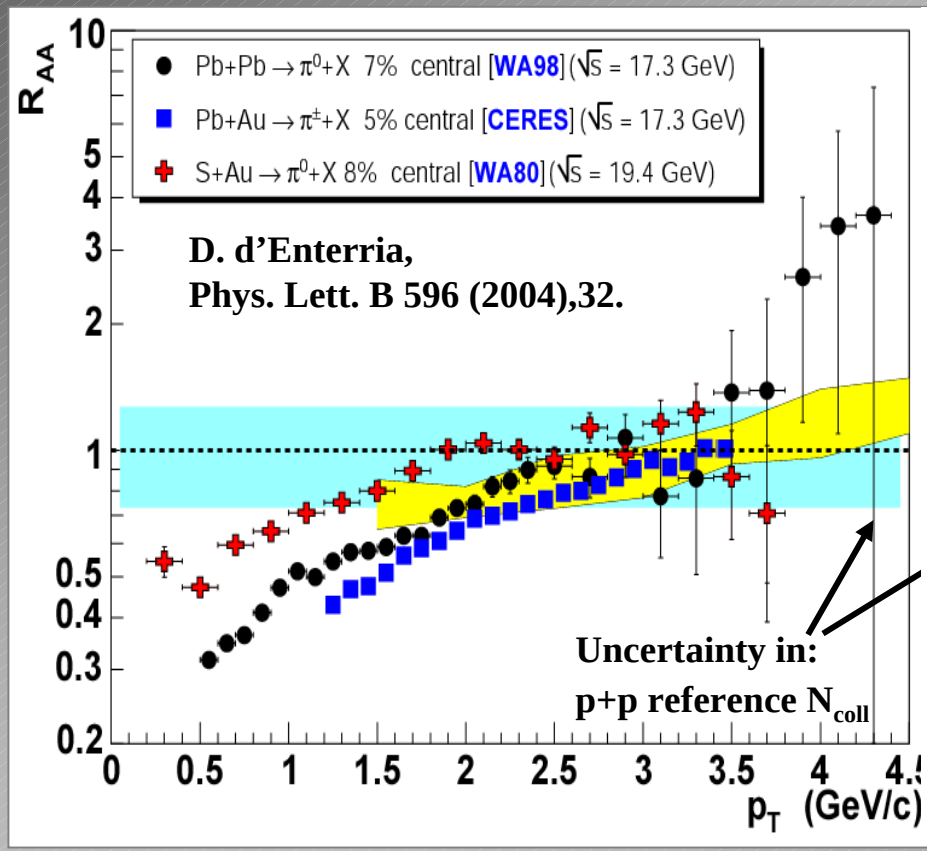


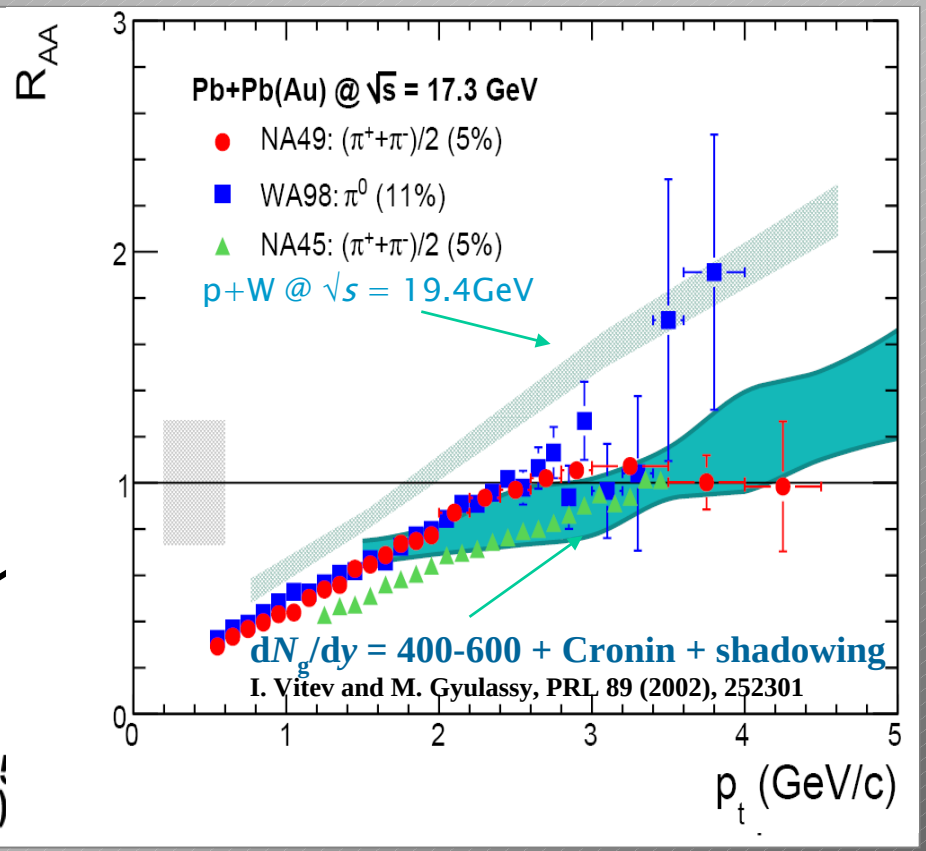
Change of shape difficult to parameterise

← few measurements →

R_{AA} for different SPS experiments

p-p reference : empirical fit to data for √s = 7- 63 GeV
(S.R.Blattnig et al. , Phys. Rev. D62 (2000) 094930)

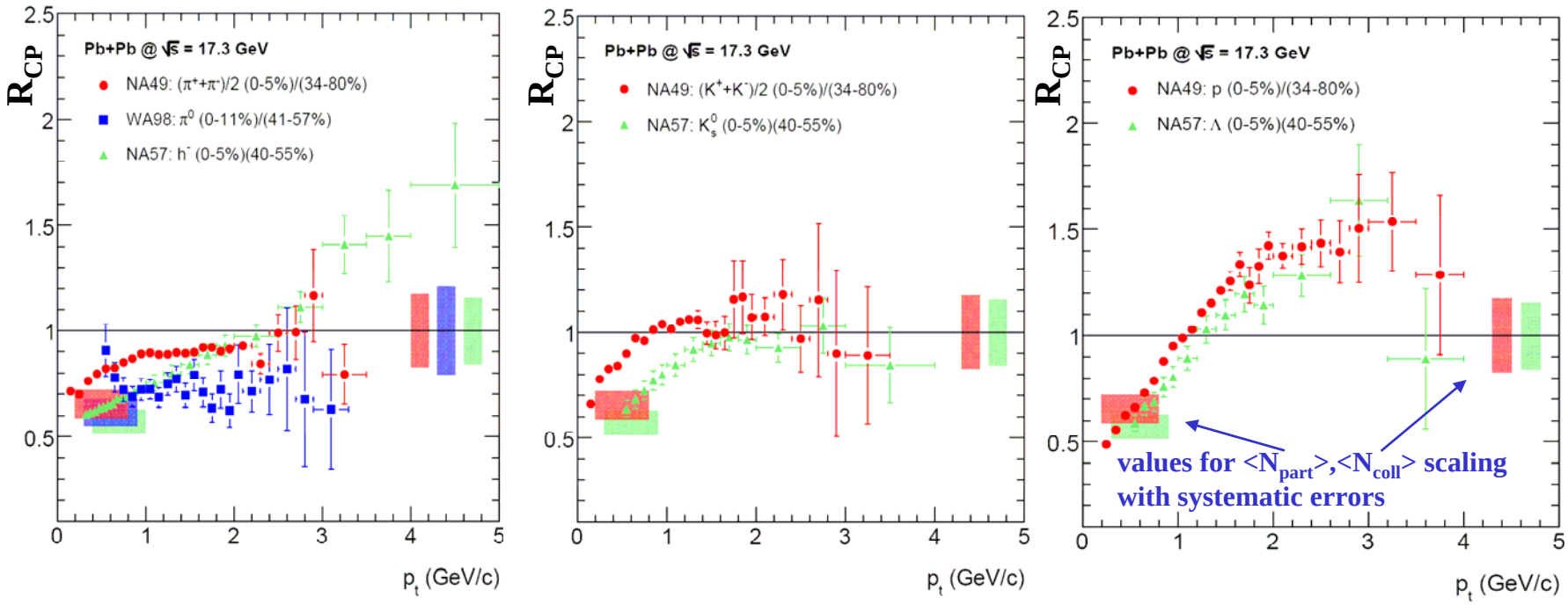




Calculations including: cronin, final state parton energy loss

R_{CP} for different SPS experiments

$\sqrt{s}$ =17.3 GeV : NA49, NA57, WA98



NA49: A. Laszlo et al., nucl-ex/0510054
WA98: Eur. Phys. J. C23 (2002), 225.
NA57: Phys. Lett. B623 (2005), 17

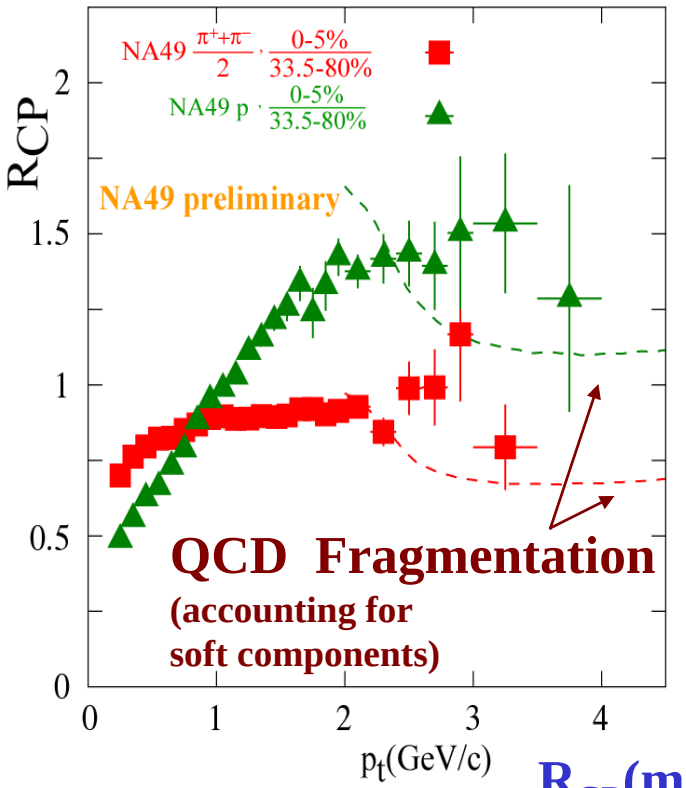
$$R_{CP}(\Lambda,p) > R_{CP}(K) > R_{CP}(\pi)$$

SPS data consistent at high p_t within large systematic uncertainties

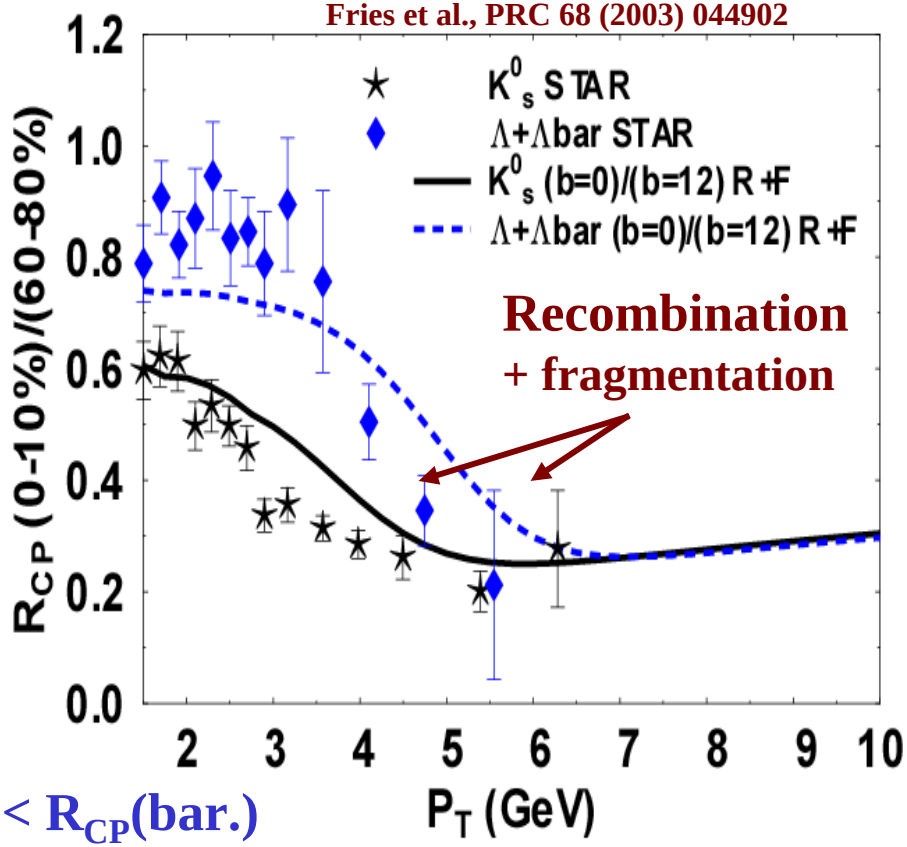
Particle Type dependence of R_{CP}

SPS ↔ RHIC

X.N. Wang, PRC 68 (2001) 064910,



Fries et al., PRC 68 (2003) 044902

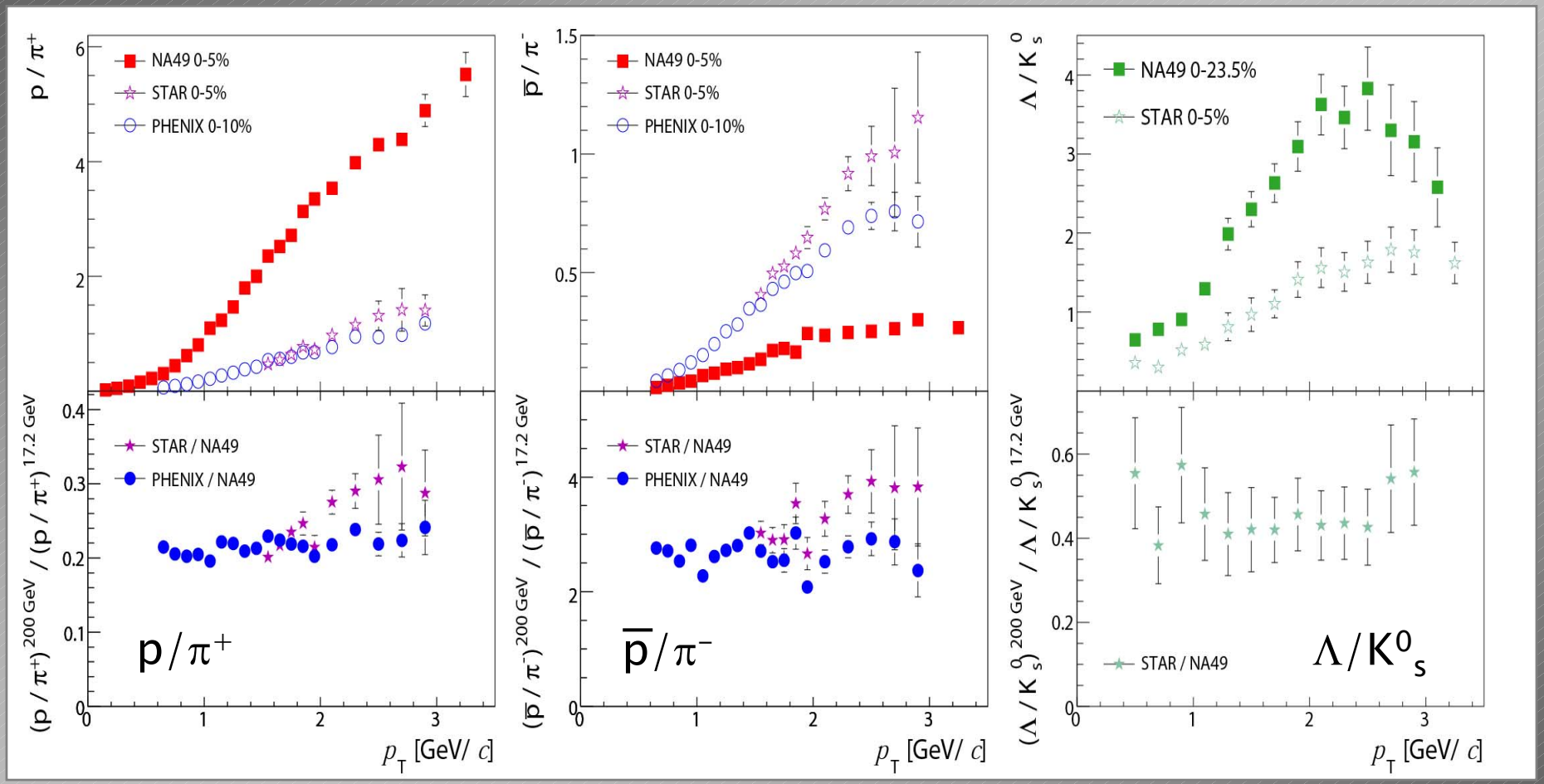


R_{CP}(mes.) < R_{CP}(bar.)

similar particle type dep. at SPS and RHIC

Hadron ratios at SPS and RHIC

Difference in ratios due to net baryon content but ....



double ratios do not depend on p_t → similar production mechanism?

Conclusion so far:

- Results from SPS experiments on R_{AA} , R_{CP} agree within systematic uncertainties

- Particle type (mass) dependence of R_{CP} at SPS similar to RHIC results

- Hadron double ratios do not depend on p_t

→Similar medium effects at SPS and RHIC ?

what can we learn from high-p_t correlations?

High-pt azimuthal correlations
@
CERES

Motivation / earlier measurements

Study of the fragmentation pattern of jets produced in hard parton-parton scatterings

Possibilities of measuring jet properties:

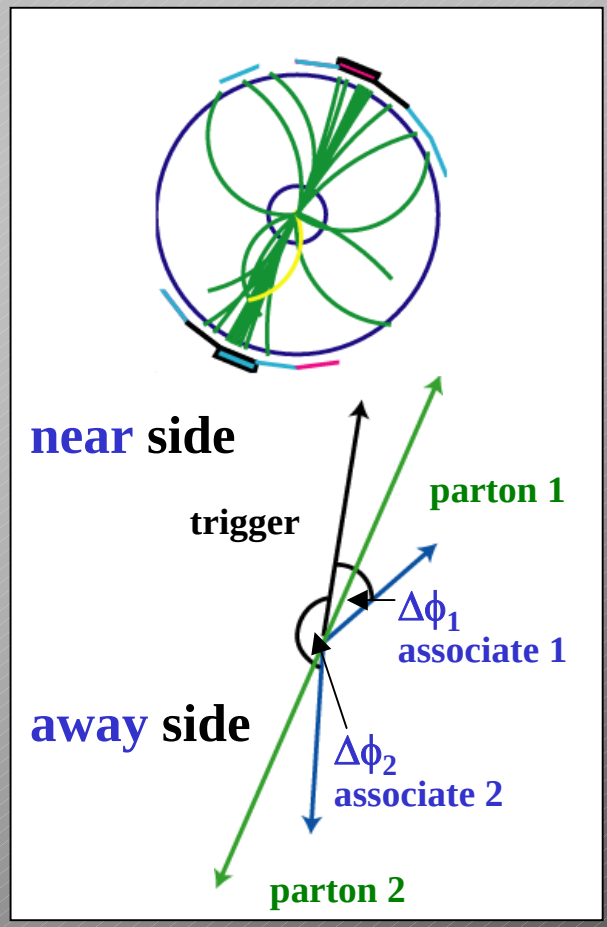
- **Full reconstruction of a single jet**

  drawback: large background in A+A collisions

- **Measuring transverse angular correlations with respect to a trigger**

  → **$\Delta\phi$ distributions : same event**
  mixed events

  → **construct correlation function**
  ratio same/mixed event distributions

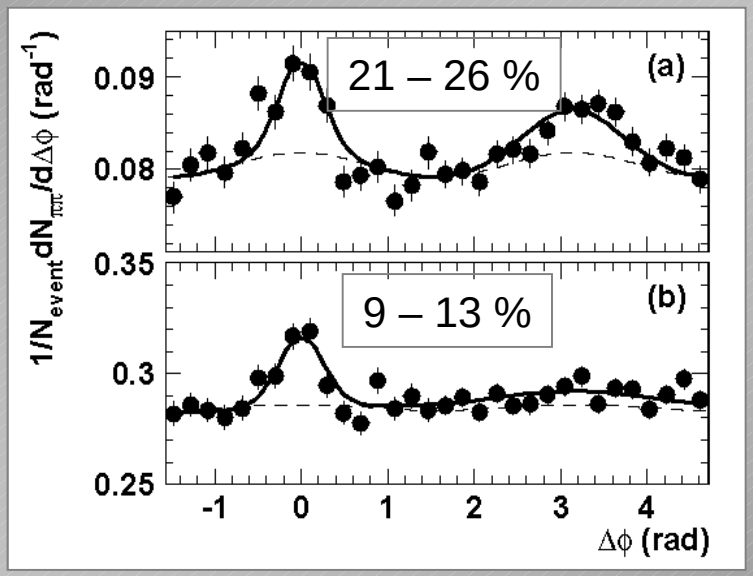


Motivation / earlier measurements

CERES:

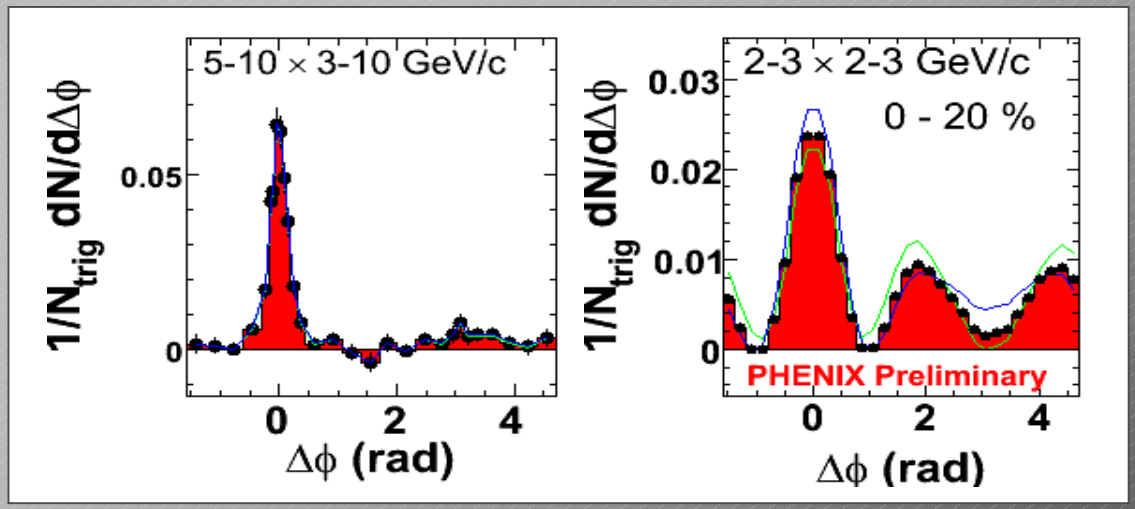
Not triggered azimuthal correlations of pions with $p_t > 1.2$ GeV/c

CERES Collaboration,
G. Agakichev, et al.
Phys. Rev. Lett. 92 (2004) 032301



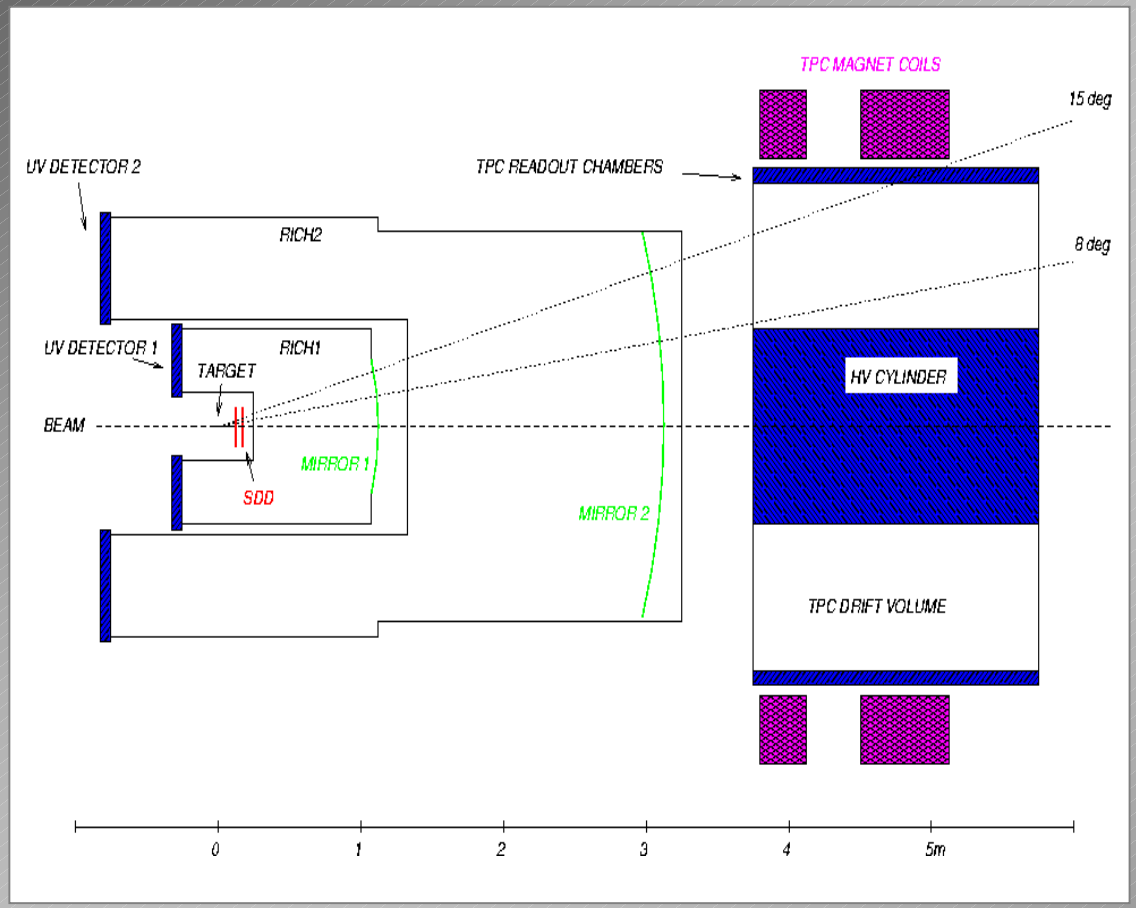
PHENIX:

-->Away side **modification** in low trigger p_t region



Detector Setup and data sets

CERES Detector



$$Pb + Au @ \sqrt{s_{NN}} = 17.2\ GeV$$

Components

- **SDD:**
  Silicon Drift Detector
- **RICH:**
  Ring Imaging Cherenkov Counters
- **TPC :**
  Time Projection Chamber
  Acceptance θ : (8-15)°
  ϕ : (0-360)°

Data sets:

- $3 \cdot 10^7$ Pb-Au events
- Centrality:
  (0-5)%, (5-10)%,(10-20)% determined by track multiplicity

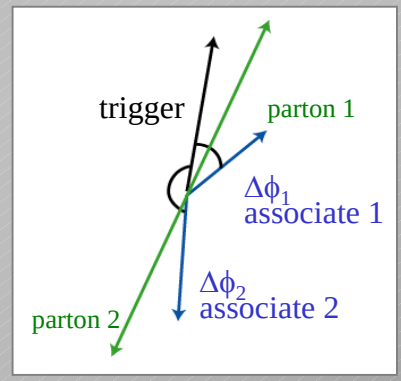
Measurement

Construction of the correlation function

$$C(\Delta\phi) = \frac{S_{norm}(\Delta\phi)}{B_{norm}(\Delta\phi)}$$

$$\Delta\phi = \phi_{trigger} - \phi_{associate}$$

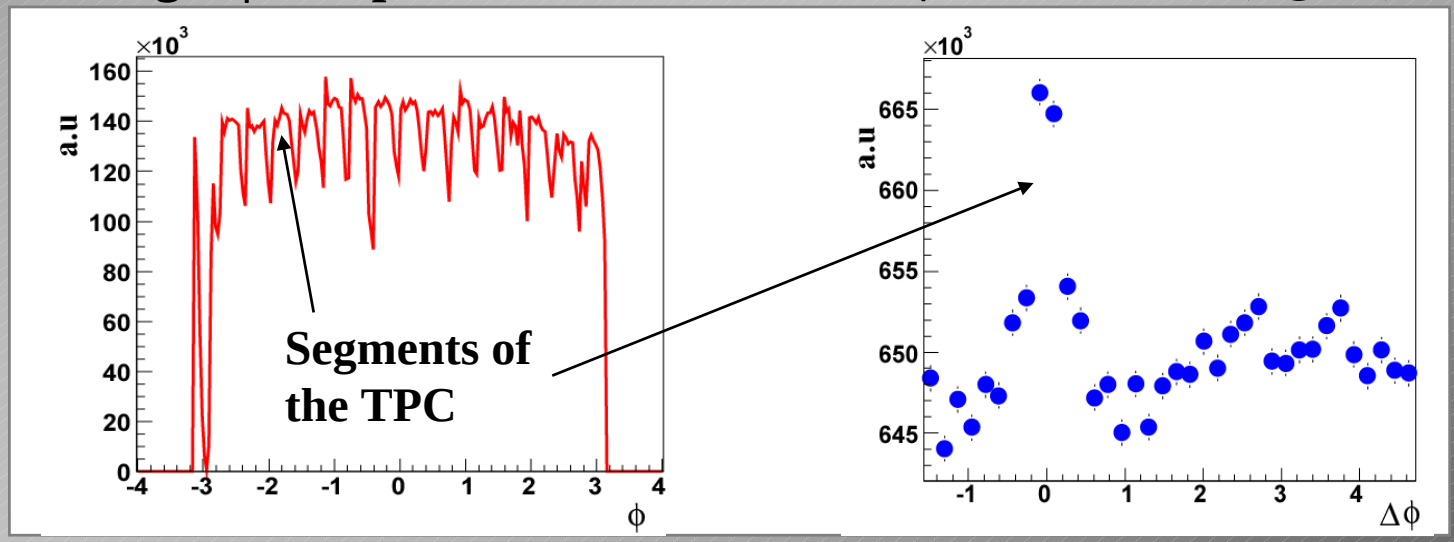
p_t : (2.5-4.0) GeV/c (1.0-2.5) GeV/c



Infulence of acceptance effects

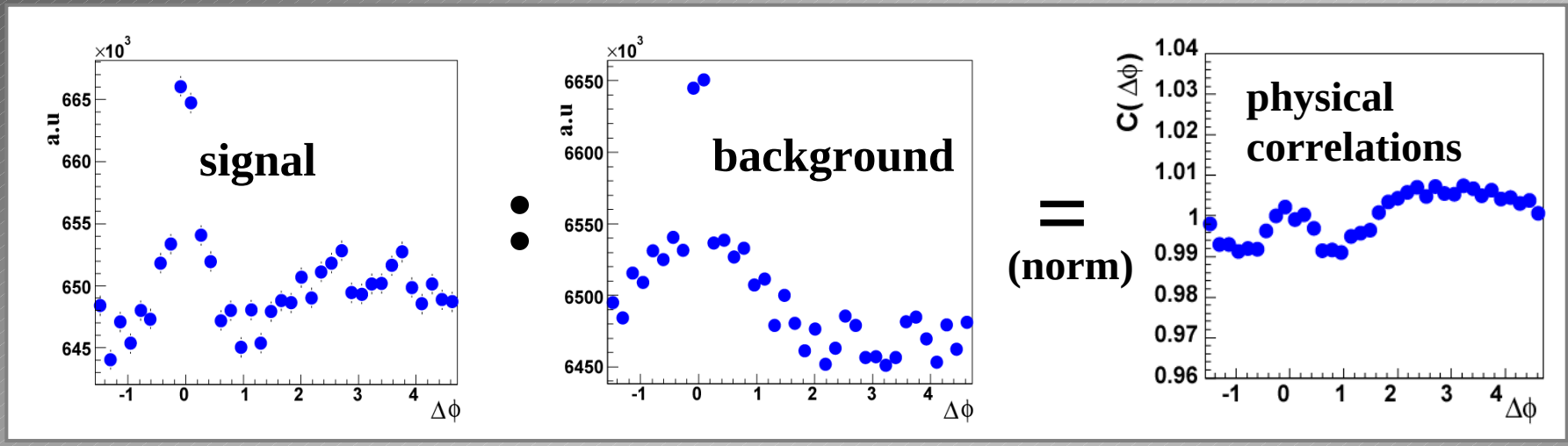
single ϕ acceptance

$\Delta\phi$ distribution (signal)



Measurement

(signal/background) →removal of acceptance effects



Significant flow contribution to Δϕ correlations

Two source model : flow + jet contribution to C(Δϕ)

$$C(\Delta\phi) = b_0(1 + 2 < v_2^A v_2^B > \cos(2\Delta\phi)) + J(\Delta\phi)$$

$v_2^A v_2^B$ **: elliptic flow in trigger (A) and associate (B) p_t range determined with CERES reaction-plane analysis**

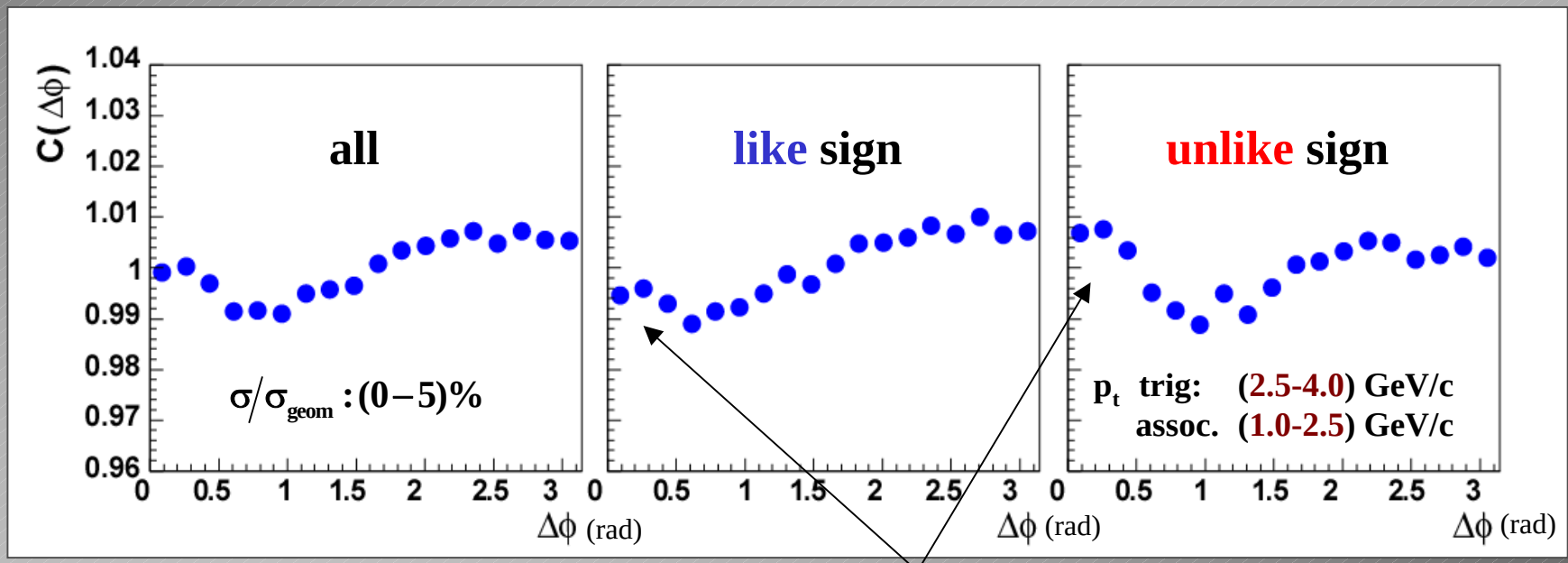
Results

Quality cuts on tracks and pairs:

→Min. number of fitted hits on tracks in TPC: 12

→Two track separation cut $\Delta\Theta_{min}$ = 0.01 (rad)

Measurement for pairs of like/unlike sign charge



CERES preliminary

Indication of charge correlations in the fragmentation process

Measurement

Removing flow contribution

$$C(\Delta\phi) = b_0(1 + 2 < v_2^A v_2^B > \cos(2\Delta\phi)) + J(\Delta\phi)$$

ZYAM (Zero Yield At Minimum) $J(\Delta\phi_{min}) = 0$ **:**

→ **Adjust flow contribution to** $C(\Delta\phi)$ **to extract** b_0

→ **Subtract flow from** $C(\Delta\phi)$ **to get Jet correlations**

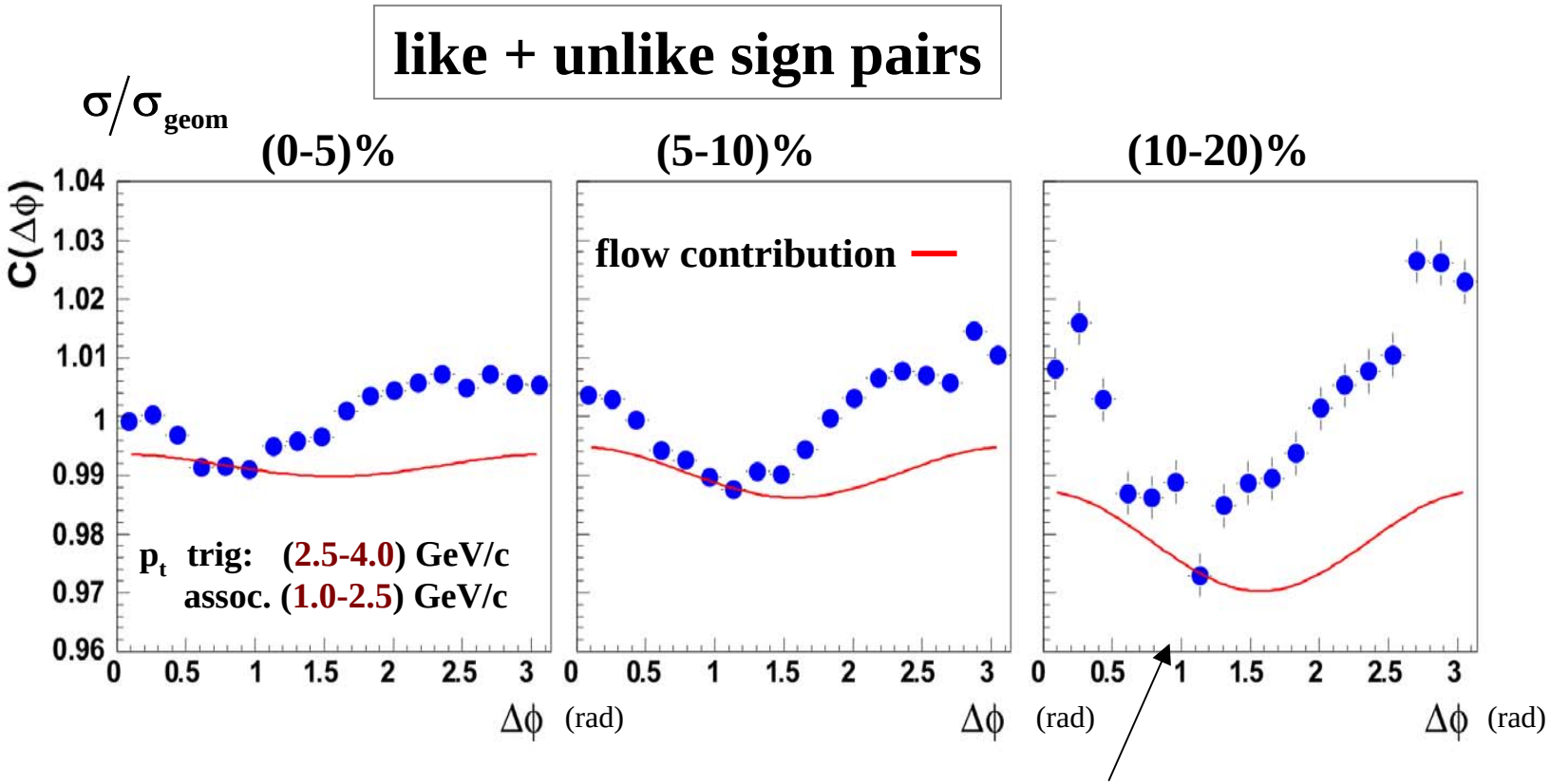
Conditional yield:

Jet associated particles per trigger

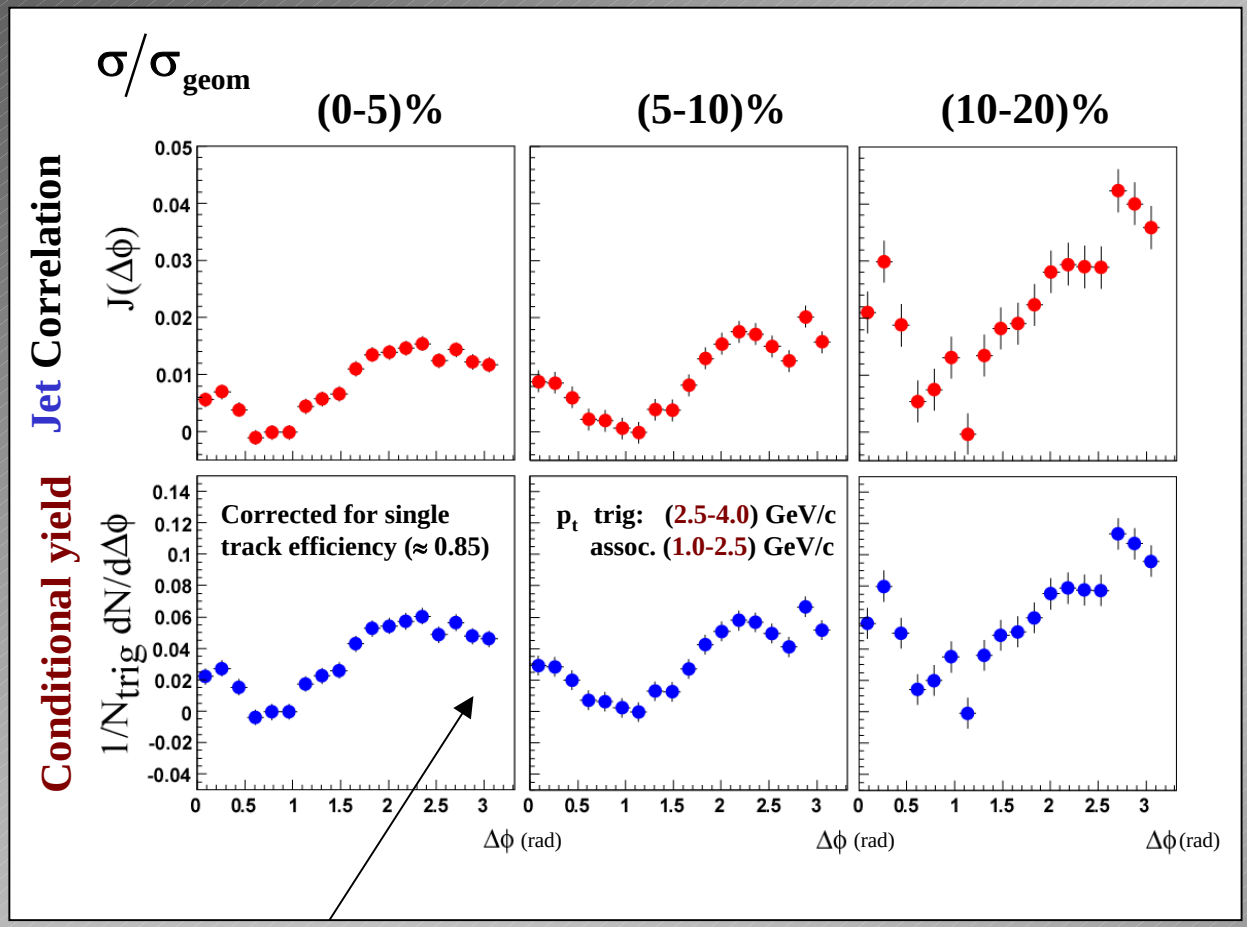
$$\frac{1}{N_{trig}}\frac{dN}{d\Delta\phi} = \frac{J(\Delta\phi)}{\int C(\Delta\phi')d(\Delta\phi')} \cdot \frac{N^{AB}}{N^{A}}$$

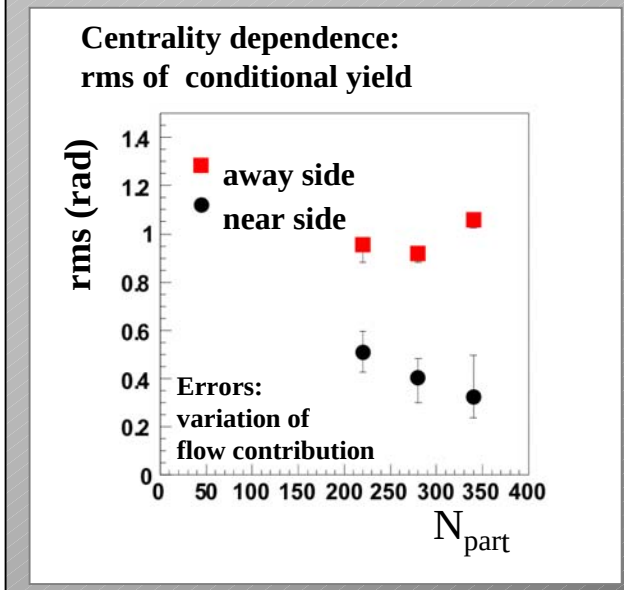
Results : flow contribution

Flow contribution : stronger for the more peripheral Centrality bins



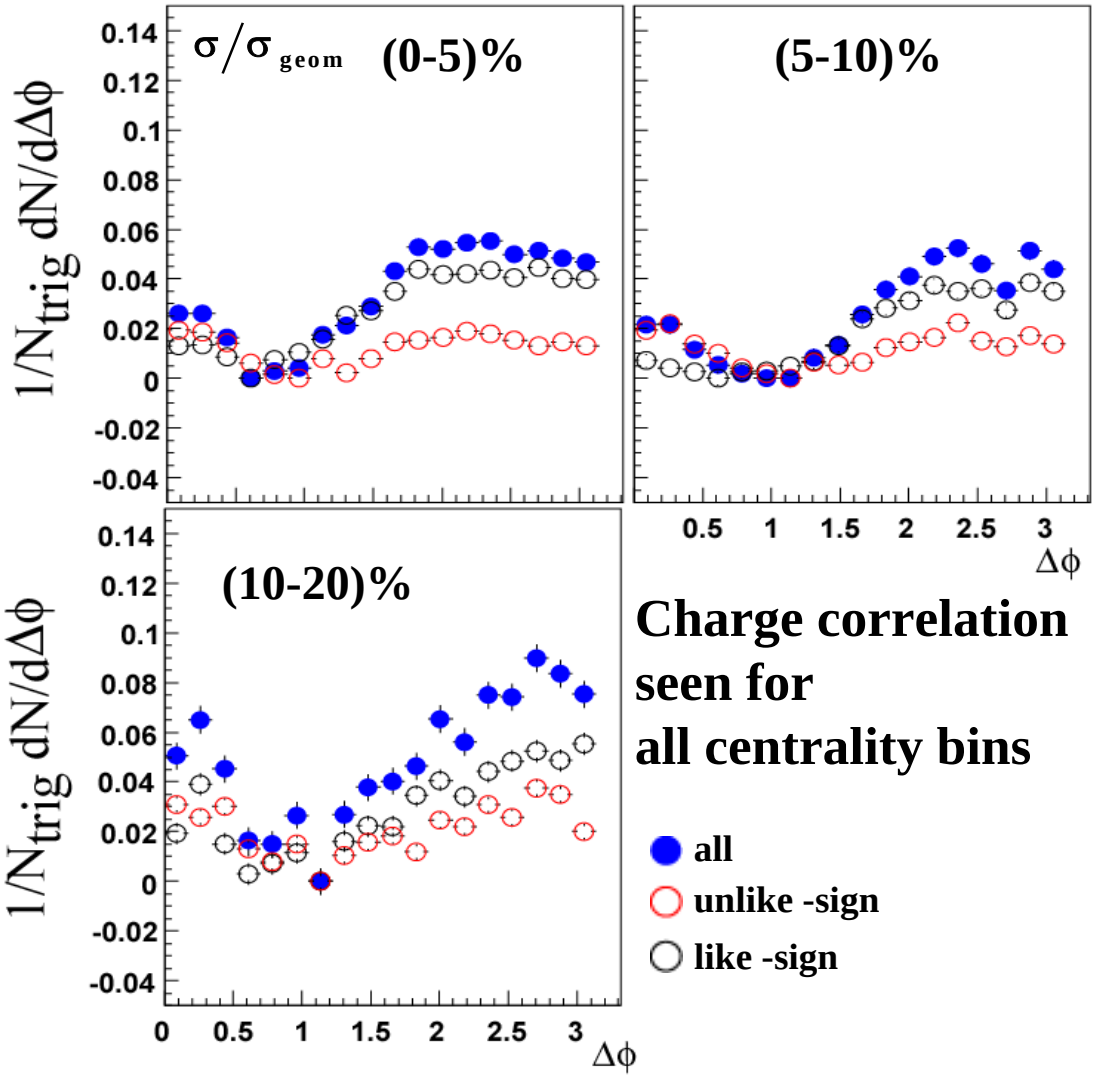
Results: conditional yield





Non-gaussian shape on the away side

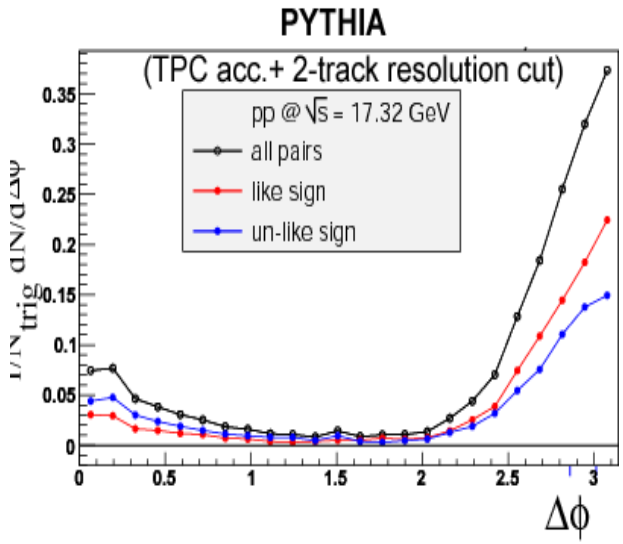
Results : charge ordering



Charge correlation seen for all centrality bins

- **all**
- **unlike -sign**
- **like -sign**

Charge correlation also visible in p+p simulations



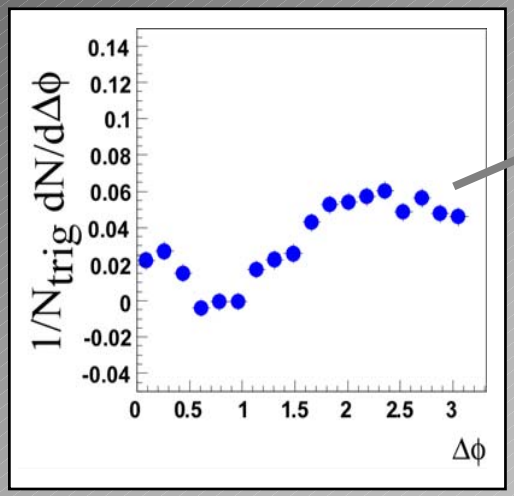
Outlook on 3-particle correlations

Investigating the structure on the away side

Preliminary

3 particle correlations

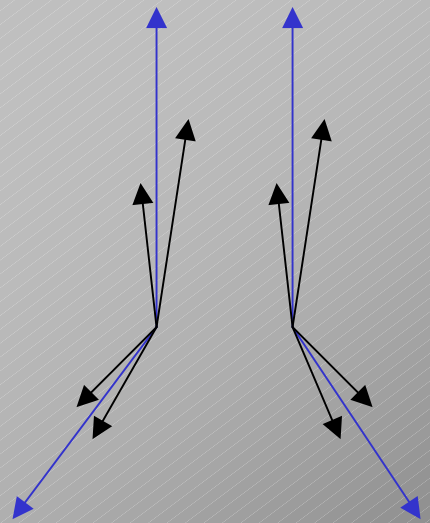
Impact of jet topologies on the 2 particle correlation function



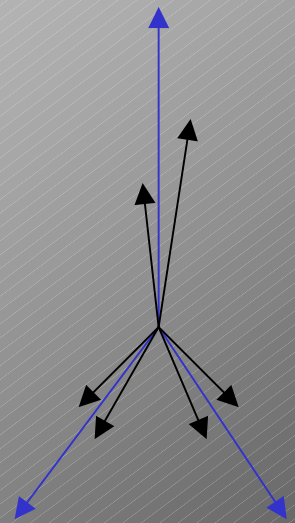
Preliminary

Non gaussian shape on the away side

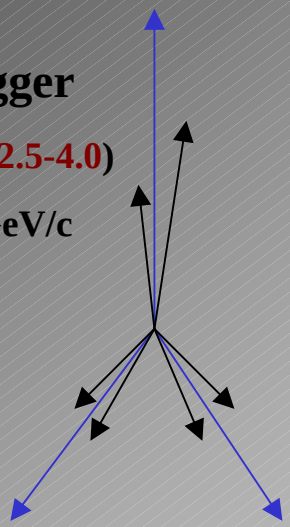
Event by event Deflection of jets



Cone like structure in one event



3 particle correlation function

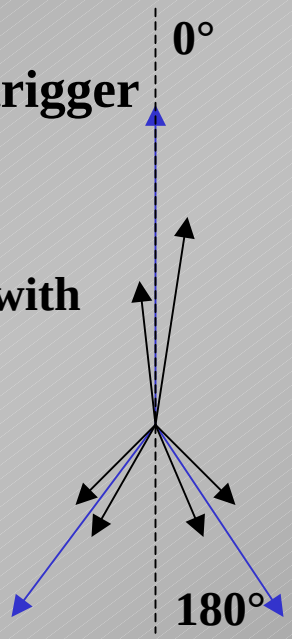


$$C(\Delta\phi) = \frac{S_{norm}(\Delta\phi)}{B_{norm}(\Delta\phi)} \qquad \Delta\phi = \phi_{associate1} - \phi_{associate2}$$

p_t : (1.0-2.5) GeV/c

S: trigger and accociates from the same event

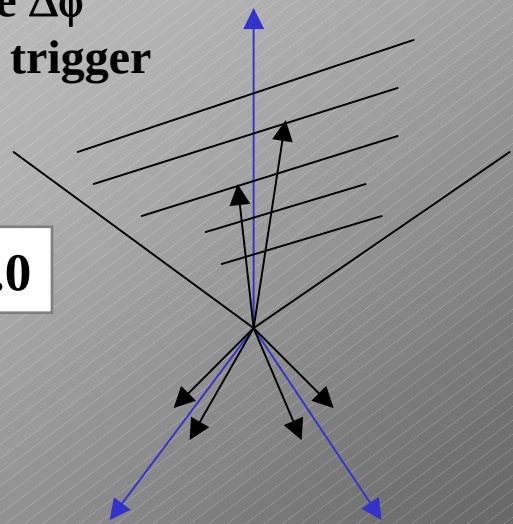
B: trigger, accociate1, associate2 from different events



Orientation of angles with respect to the trigger

cut on associate $\Delta\phi$ with respect to trigger

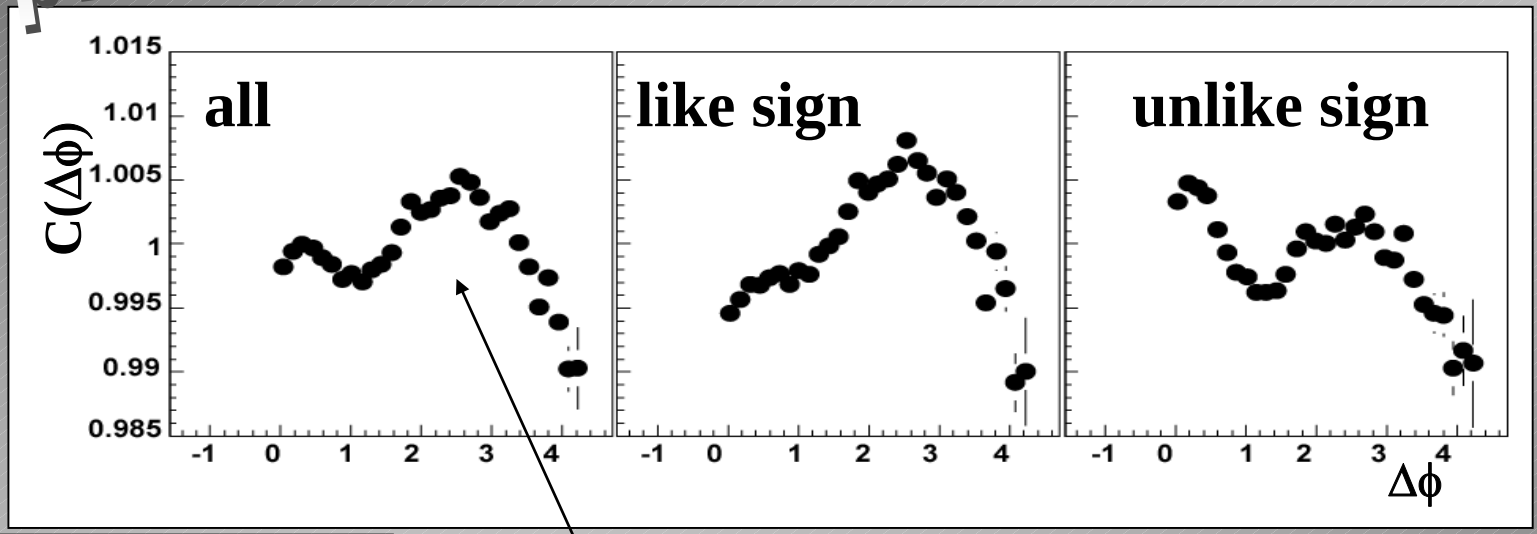
$\Delta\phi_{trig<->ass} > 1.0$

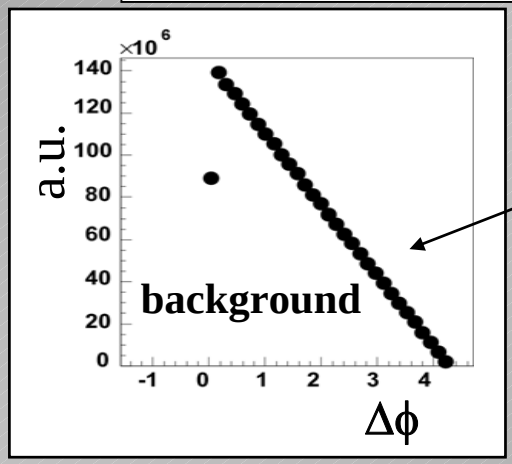


3 particle correlations

very preliminary

Pure correlation function !!!
No flow subtraction , No normalisation





correlations on top of a steeply falling background
(due to orientation of angles with respect to the trigger)

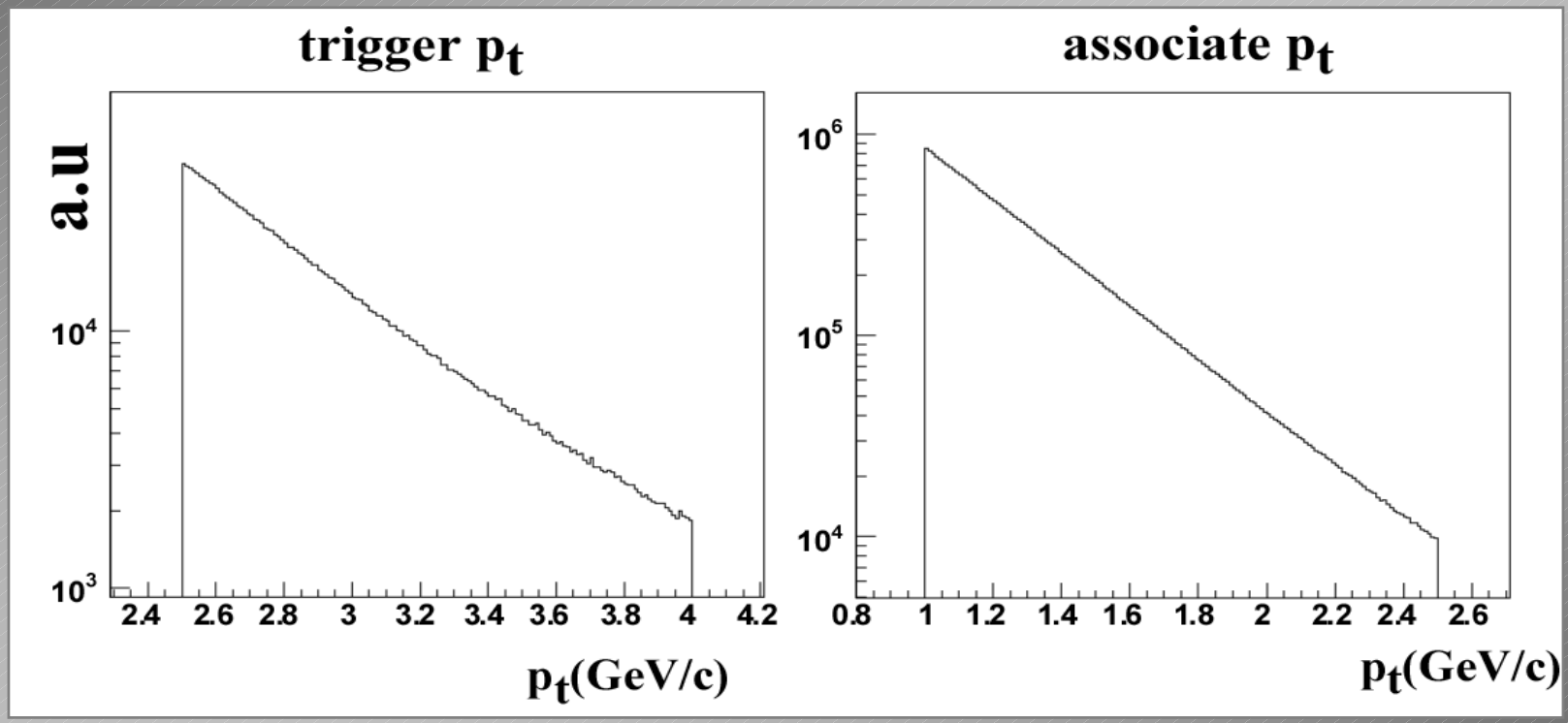
Conclusion from preliminary CERES results

- Indication of **charge ordering** in the fragmentation process
- **Deviation from gaussian shape** on the away side
- 3-particle correlations might **resolve the structure on the away side**

Thanks for your attention

Backup

Uncorrected trigger- and associate p_t- distribution



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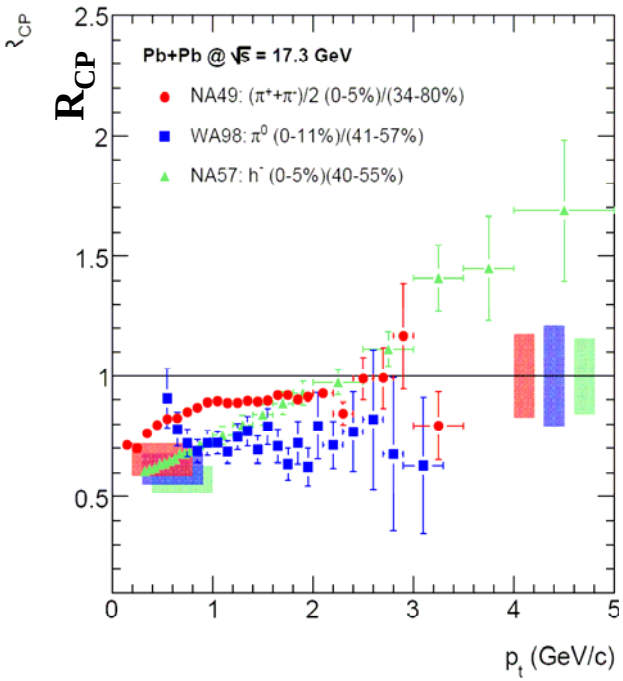

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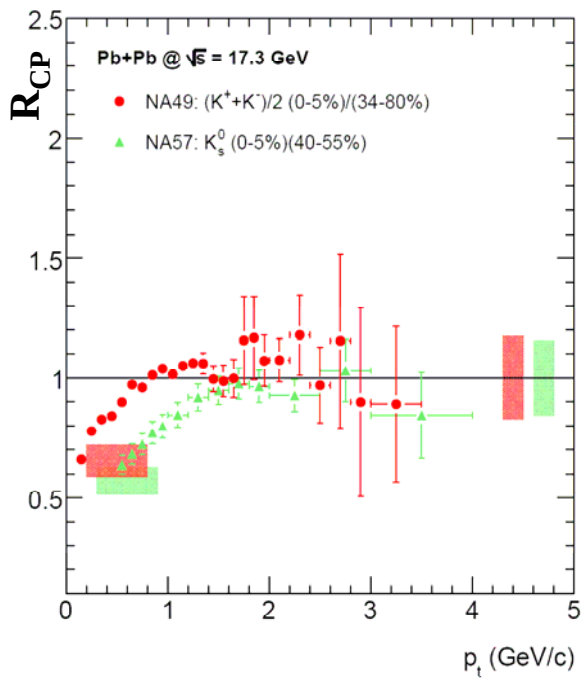

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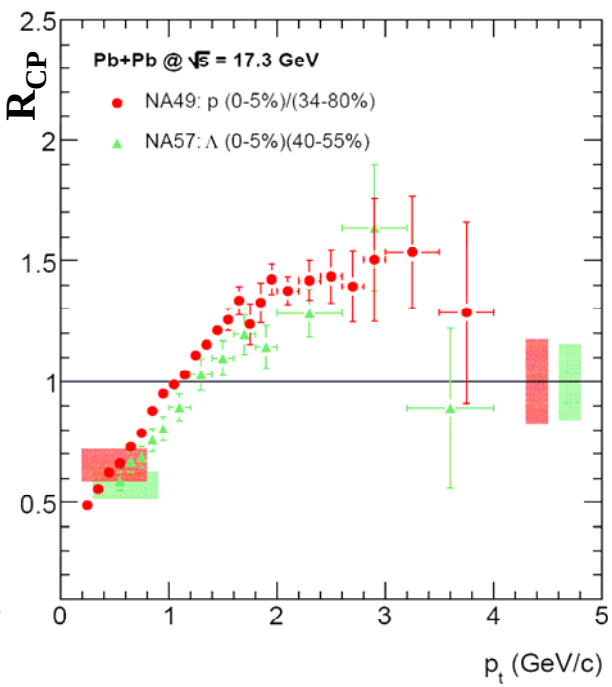

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