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NA50

THE ELLIPTIC FLOW OF NEUTRAL TRANSVERSE ENERGY IN HEAVY ION INTERACTION AT SPS ENERGIES

motivation

centrality tools

method

158A GeV lead beam induced interactions

* centrality dependence of the elliptic flow
* orientation relative to the transverse plane

200A GeV sulphur beam induced interactions

conclusion

motivation

* some candidate models for the anomalous J/Ψ suppression imply «in medium» effects

* this means that macroscopic quantities, like temperature and pressure can be defined at each point of the «fire ball» : this is the so called «thermalization» of the initial state

* the thermalization causes a collective behavior of the secondaries

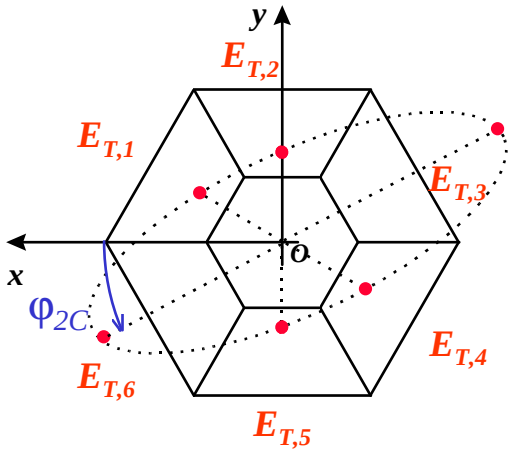
* it has been predicted(*) that an elliptic flow in the reaction plane should occur, at SPS energies, for semi central collisions of spherical nuclei

the **in plane elliptic flow** is **closely related** to the **thermalization** of the **initial state**

(*) J. Y. Ollitrault, Phys. Rev. D **46**, 229-245 (1992)

centrality tools (1)

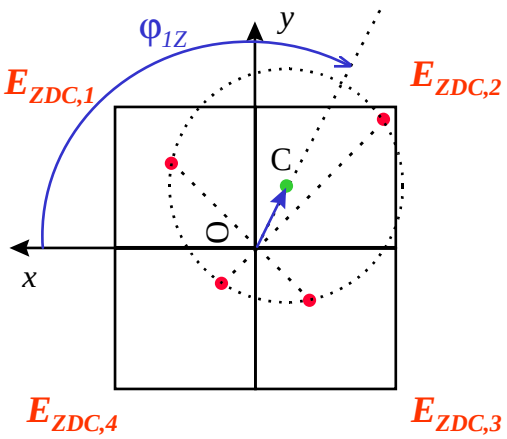
* the EM calo ⇒ **elliptic flow**



- the EM calo «sees» the elliptic flow of the neutral hadrons emitted in the pseudo - rapidity range [1.1, 2.3]

φ_{2C} is the azimutal angle of the **elliptic flow**

* the ZDC ⇒ **reaction plane**



- the ZDC «sees» the projectile fragments
- the shift of the centroid of the shower - from O to C - could originate from the **bounce of the projectile**

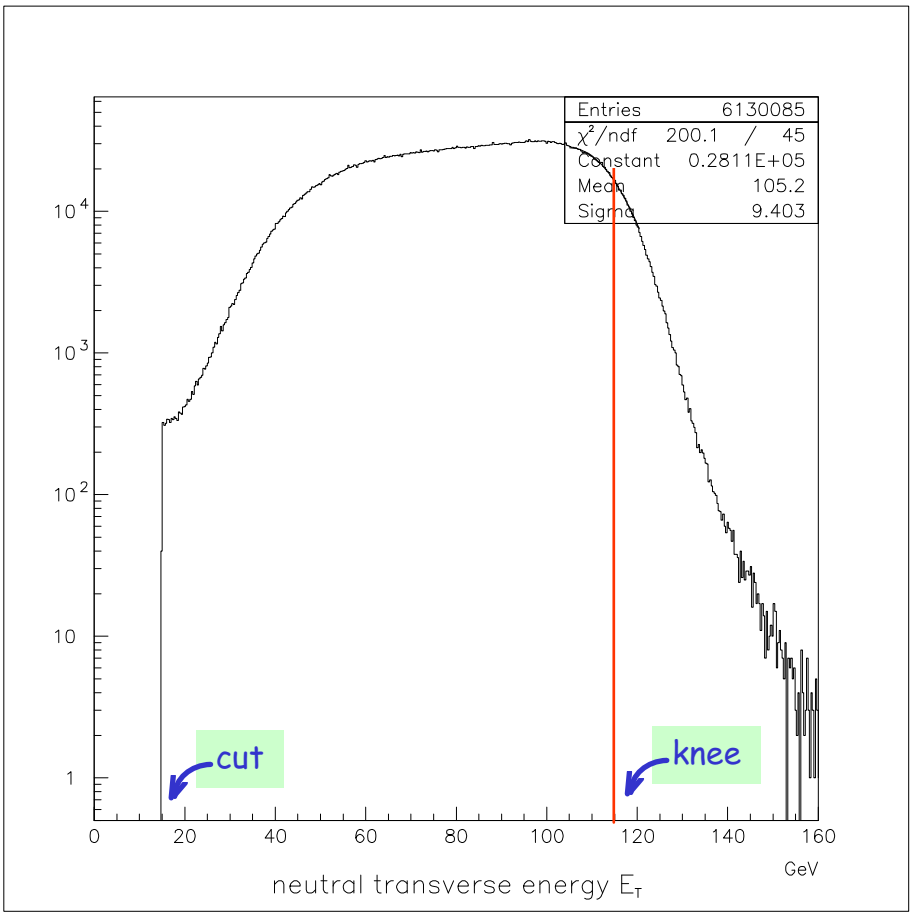
φ_{1Z} is the azimutal angle of the **reaction plane**

⇒ **centrality dependence of the elliptic flow**
⇒ **search for a correlation between φ_{1Z} and φ_{2C}**

centrality tools (2)

EM transverse energy

* any trigger (dimuons + min. bias)
* cut : $E_T > 15$ GeV
* «knee» of the E_T distribution $\Leftrightarrow$ central interactions
* $E_T \propto M \quad \Leftrightarrow E_T$ scaled = M scaled
* scaled multiplicity : $m = \dfrac{E_T}{E_{Tknee}} = \dfrac{M}{M_{\max}}$



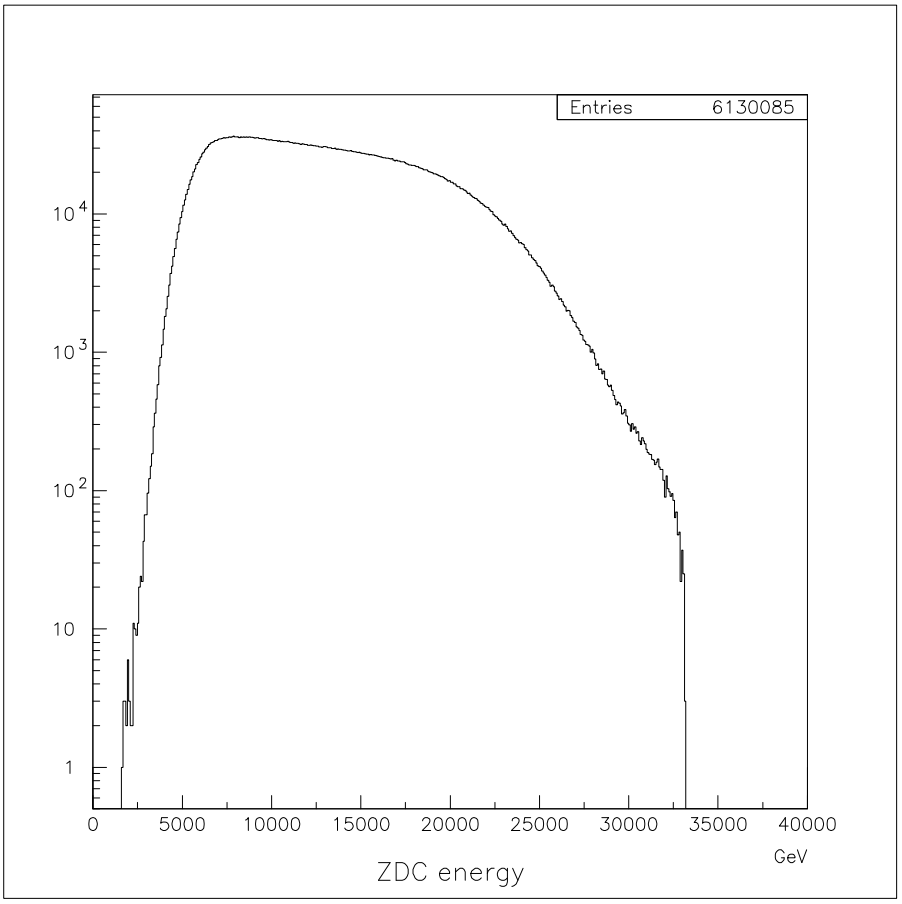
centrality tools (3)

ZDC energy

* any trigger (dimuons + min. bias)
* provides the energy of the projectile fragments

⇒ energy released in the interaction :

$$E_{beam} - E_{ZDC}$$



method (1)

for one given event
(EM calo for instance)

* six data $E_{T,k}$

$\Downarrow$

* Fourier series expansion (rectangular coordinates)

$$\frac{dE_T}{d\varphi} = \frac{E_{T(event)}}{2\pi}\left(1 + a_1\cos\varphi + b_1\sin\varphi + a_2\cos 2\varphi + b_2\sin 2\varphi + b_3\sin 3\varphi\right)$$

transverse energy of the given event

directed anisotropy

$$\begin{cases} \tilde{V}_1^2 = \dfrac{a_1^2 + b_1^2}{4} \\ \varphi_1 = \tan^{-1}\left(\dfrac{b_1}{a_1}\right) \end{cases}$$

elliptic anisotropy

$$\begin{cases} \tilde{V}_2^2 = \dfrac{a_2^2 + b_2^2}{4} \\ \varphi_2 = \dfrac{1}{2}\tan^{-1}\left(\dfrac{b_2}{a_2}\right) \end{cases}$$

pure statistical fluctuation (for symmetric systems)

$\Uparrow$

* Fourier series expansion (polar coordinates)

$$\frac{dE_T}{d\varphi} = \frac{E_{T(event)}}{2\pi}\left(1 + 2\tilde{V}_1\cos(\varphi - \varphi_1) + 2\tilde{V}_2\cos 2(\varphi - \varphi_2) + \cdots\right)$$

* measured : anisotropy = (intrinsic) flow + statistical fluctuation

method (2)

to remove the statistical fluctuations

for a sample of events of same given scaled multiplicity m

* plot the distributions of a_i and b_i
* then get the measured anisotropy

$$\langle \tilde{V}_i^{\,2} \rangle = \frac{\langle a_i^2 \rangle + \langle b_i^2 \rangle}{4}$$

- ♥ a_i and b_i have centered (gaussian) distributions
- ♠ the $\langle a_i^2 \rangle$ and $\langle b_i^2 \rangle$ are the variances
- ♦ the flow and the statistical fluctuations are independent

* given a m bin

$$\langle \tilde{V}_i^{\,2} \rangle = V_i^{\,2} + \frac{k_i}{m}$$

measured anisotropy — **flow** — **measurement** of the statistical fluctuations

- ♣ there is no flow in central collisions (for spherical nuclei) :

$$V_i\big|_{m=1} = 0$$

* for each m bin, the **flow** of i^{th} order is

$$V_i^{\,2} = \langle \tilde{V}_i^{\,2} \rangle - \frac{k_i}{m}$$

method (3)

a useful variable : R_i ($i = 1$ or 2)

* given m

$$R_i = \frac{\langle a_i^2 \rangle + \langle b_i^2 \rangle}{2\langle b_3^2 \rangle}$$

* meaning

$$R_i = K \cdot m \langle \tilde{V}_i^2 \rangle$$

* related to the flow of i^{th} order

$$R_i = K \cdot m V_i^2 + C_i$$

* the first term
  - is greater or equal to zero
  - cancels for $m \to 0$ and for $m = 1$ $\quad V_i\big|_{m=1} = 0$
  - is always zero in absence of flow

* clear indication for the existence of a flow :
  one needs only to compare with a horizontal line

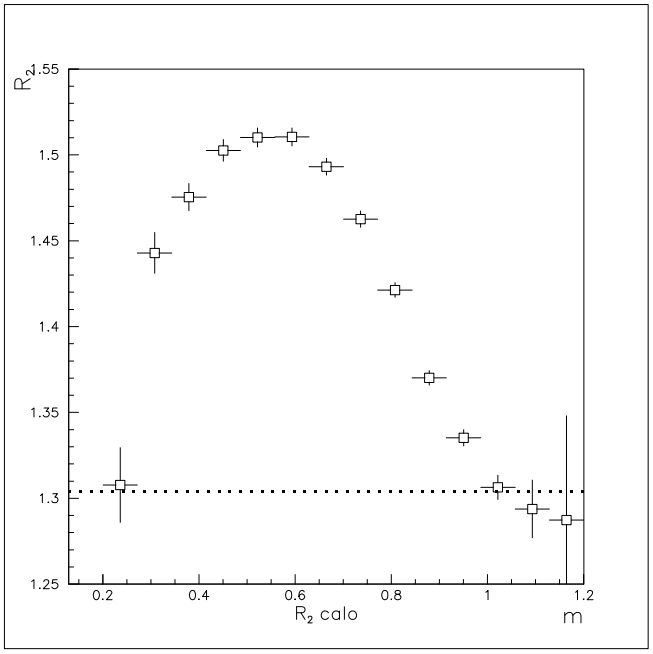
* allows comparison between different systems

158A GeV lead beam (1)
(Pb-Pb '96 data)

centrality dependence of the elliptic flow

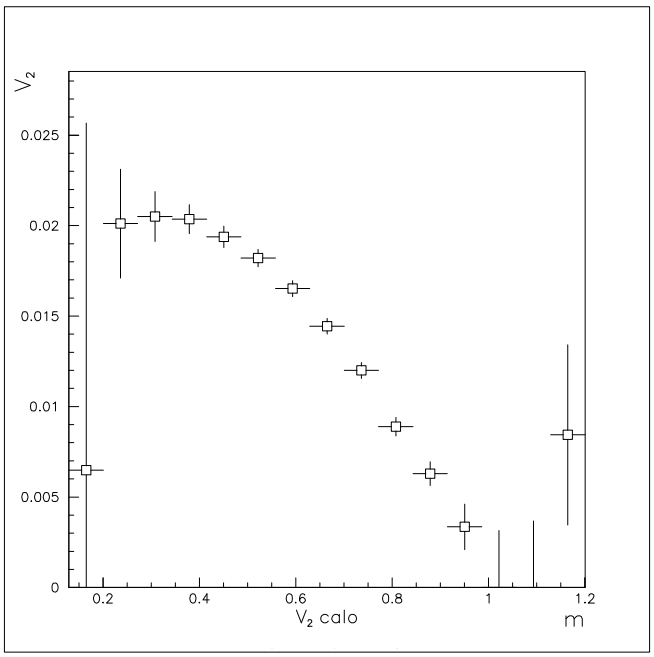
* neutral transverse energy, pseudo rapidity : [1.1, 2.3]

R_2



m

V_2



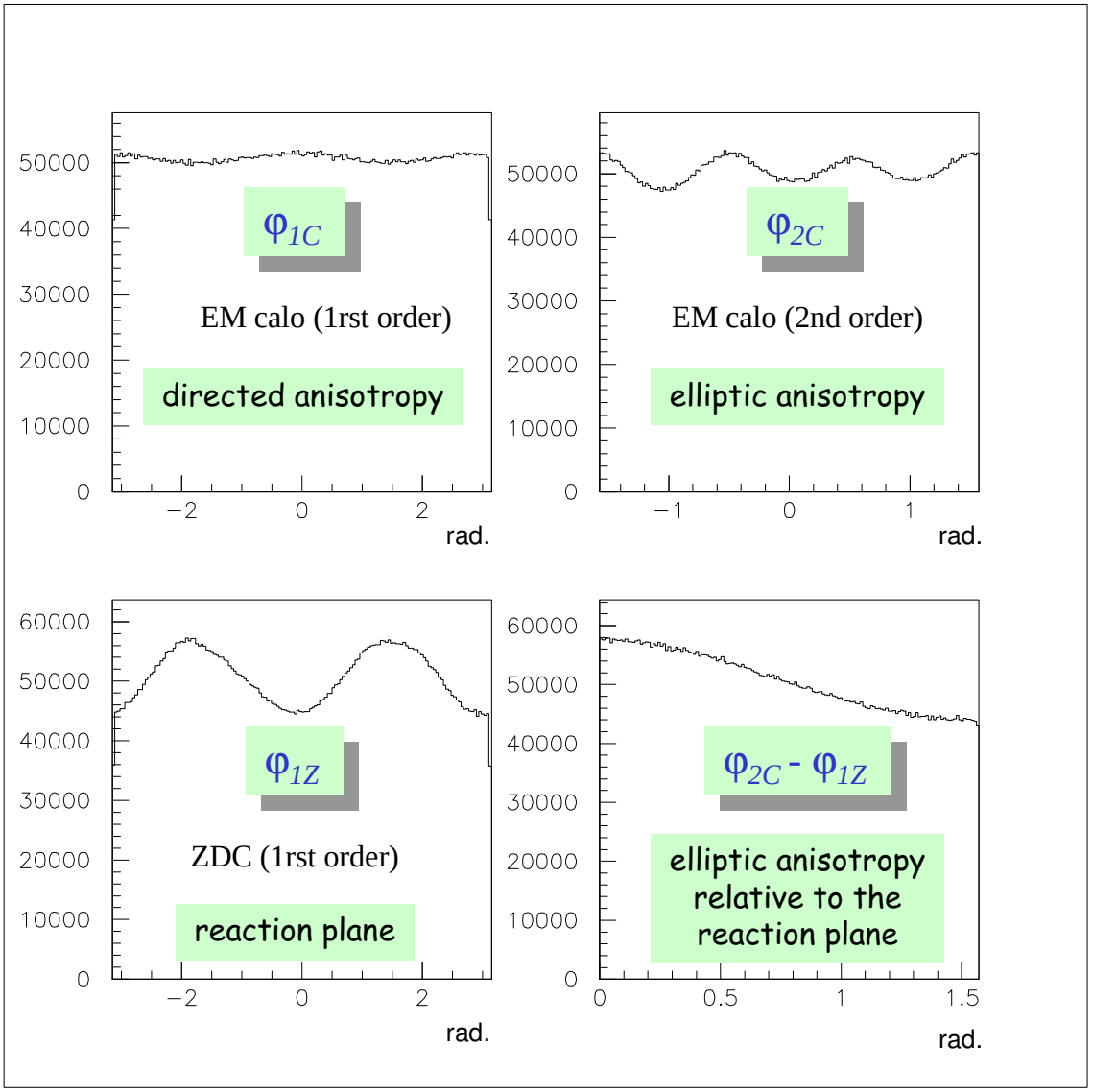
m

158A GeV lead beam (2)
(Pb-Pb '96 data)

orientation relative to the transverse plane (1)

* distributions of the measured azimuthal angles

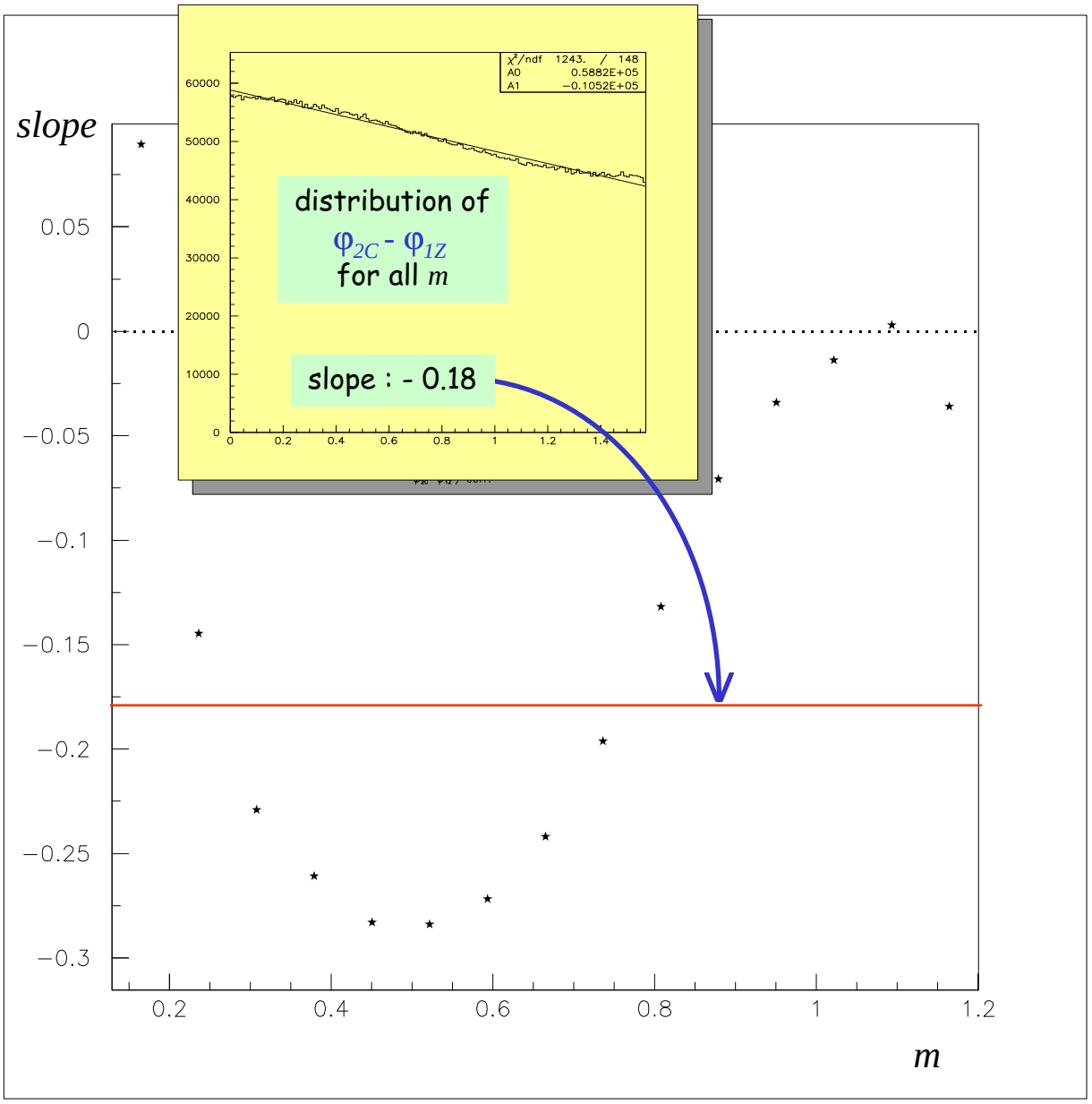
⇒ note that the oscillations of the distributions characterize the resolution of the method («cut-off» of high order harmonics)



158A GeV lead beam (3)
(Pb-Pb '96)

orientation relative to the transverse plane (2)

* centrality dependence of the $\varphi_{2C} - \varphi_{1Z}$ distribution
* rough estimate : **slope** of the line obtained from a **linear fit**



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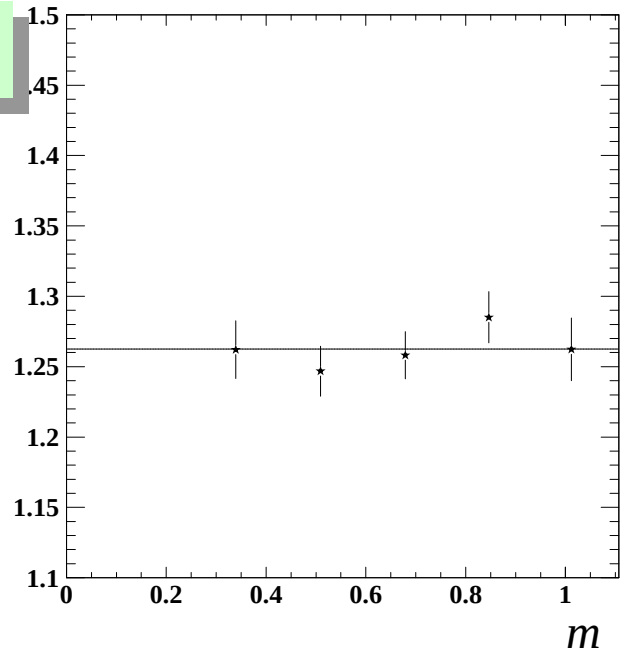
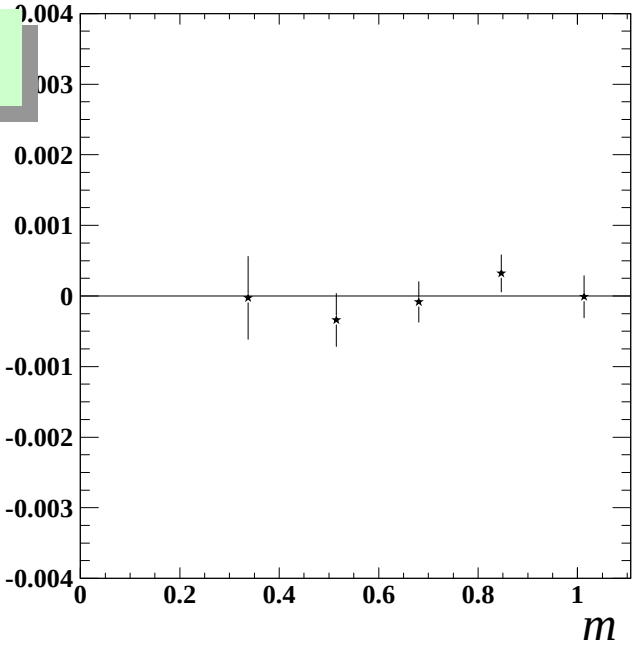
200A GeV sulphur beam (1)
(S-S '91)*

* 81085 events
* neutral transverse energy in the pseudo-rapidity range [1.1, 2.8]

R_2



V_2^2

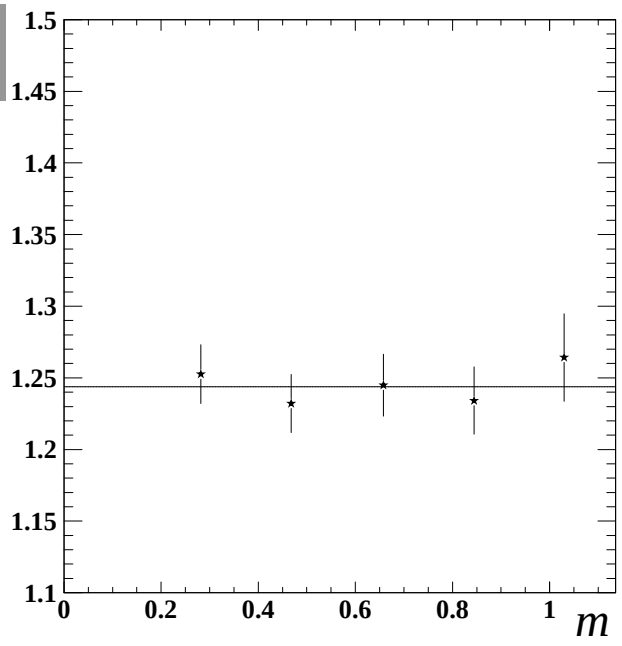


*Isabelle Chevrot, phD thesis, Clermont-Ferrand (Nov. '98)

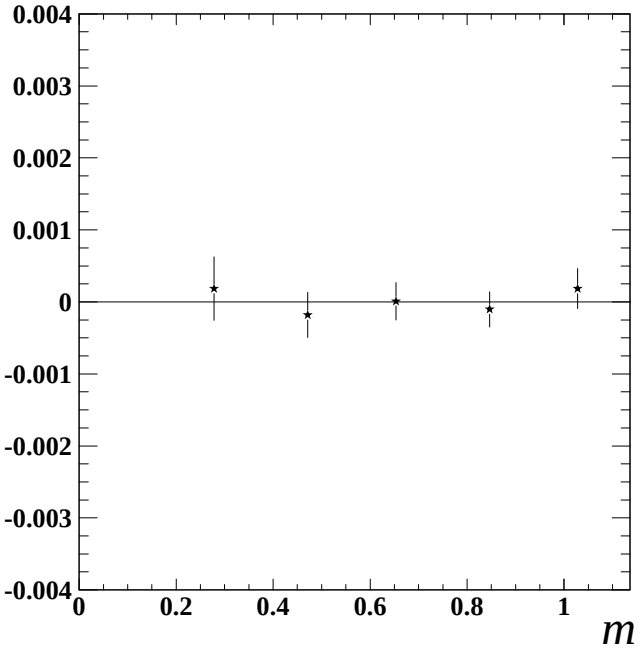
200A GeV sulphur beam (2)
(S-Cu '91)*

* 56615 events
* neutral transverse energy in the pseudo-rapidity range [1.1, 2.8]

R_2



V_2^2



*Isabelle Chevrot, phD thesis, Clermont-Ferrand (Nov. '98)

conclusion

✓ **the in plane elliptic flow is a signal of the thermalization of the initial state**

✓ **from the 158A GeV lead beam ('96 data)**

Pb - Pb interactions

there is an elliptic flow of neutral transverse energy in the pseudo-rapidity range [1.1, 2.3]

* shape of centrality dependance
* oriented " in (the reaction) plane "

} as predicted for a **thermalized medium**

* 5 to 6 times lower than predicted

✓ **from the 200A GeV sulphur beam ('91 data)**

S - S (and S - Cu) interactions

* **no elliptic flow** of neutral transverse energy in the pseudo-rapidity range [1.1, 2.8] can be seen in the data