CENTRALITY MEASUREMENT IN THE NA50 EXPERIMENT

NA50 collaboration

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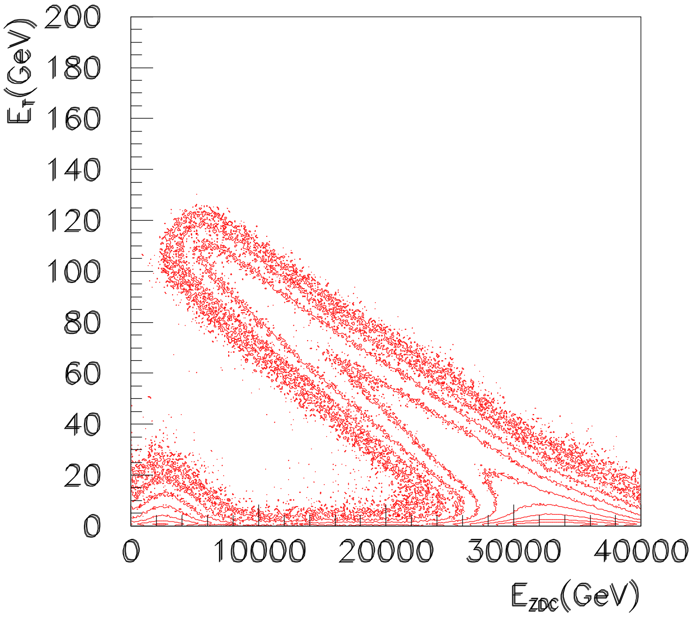
NA50 centrality detectors

- **E.m. calorimeter → neutral transverse energy E_T →** $(1.1 < \eta_{lab} < 2.3)$
- **Multiplicity detector → charged multiplicity N_{ch} →** $(1.5 < \eta_{lab} < 3.9)$
- **Zero Degree Calorimeter → forward energy E_{ZDC} →** $(\eta_{lab} > 6.3)$

⇒ Redundant system, but different variables refer to estimators of different physics quantities

⇒ Using the correlations between the different detectors it is possible to clean the events. New data selection based on the correlation between E_T and E_{ZDC}



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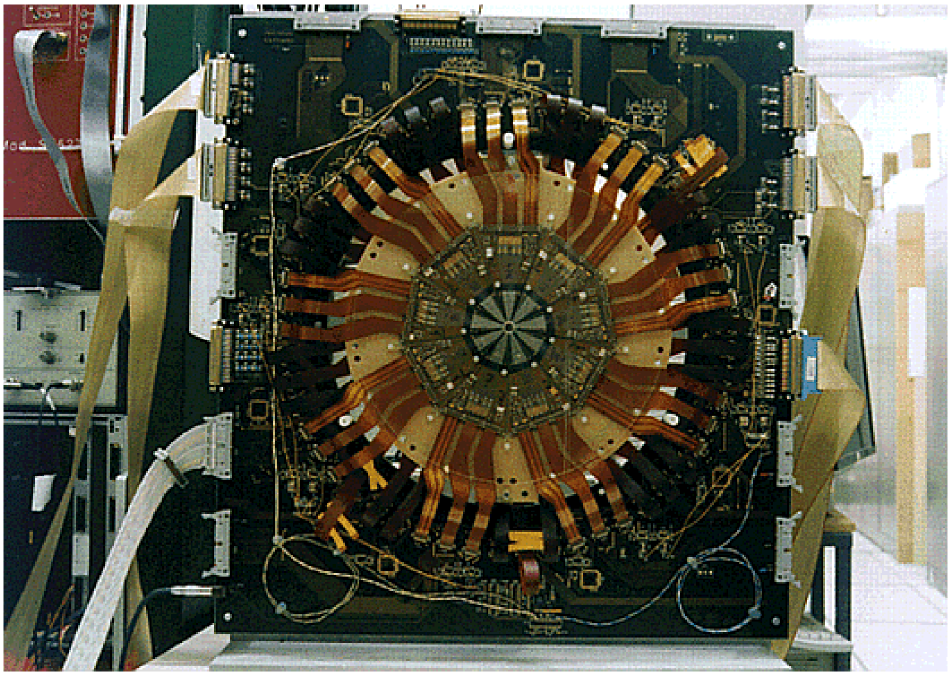
Multiplicity Detector

It consists of two silicon strip detectors organized in two discs each.

Each detector consists of $\approx$ 7000 silicon micro-strips.

Measures the angular distribution and the multiplicity of charged secondaries produced in Pb – Pb collisions.



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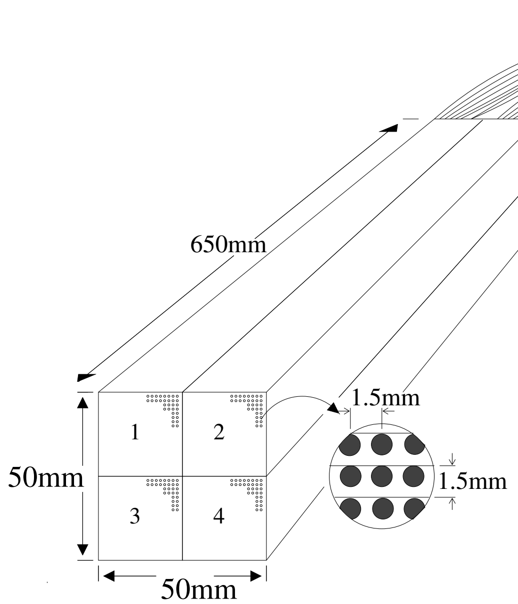
Zero Degree Calorimeter



Quartz fibers spaghetti calorimeter that exploits Cherenkov light

- Tantalum + quartz fibers
- 5*5*65 cm^3 (5.6 λ_i (Ta))
- 4 PMTs

$$E_{ZDC} = \sum_{i=1}^{4} E_{ZDC_i}$$

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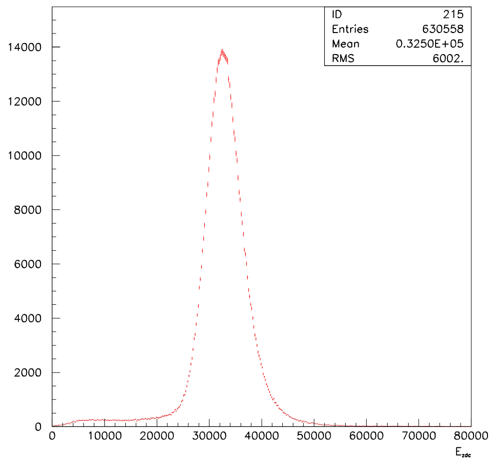
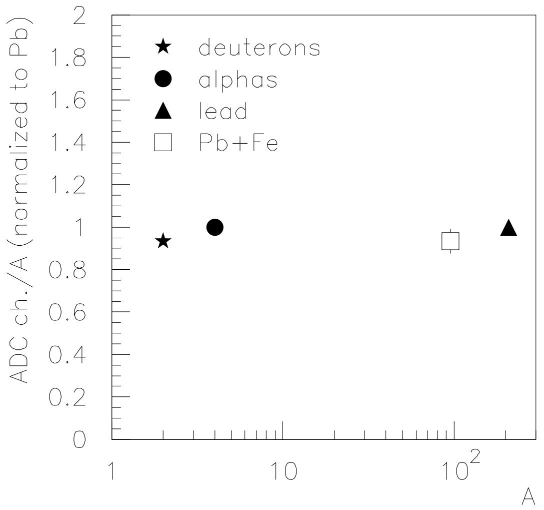
Zero Degree Calorimeter



Lead peak gives an easy calibration reference



The response of the ZDC is linear as a function of the number of spectators entering the detector

Zero Degree Calorimeter

- easy to calibrate
- during data taking period the ZDC response can be continously monitored by checking the lead peak position

- decrease of the ZDC response due to radiation damage
- problems with high intensity (5x10^7 Pb/burst):

  baseline oscillations

  high pile – up

⇒ Due to those limits, the resolution on the Lead peak is ≈ 9%

NA50 has a special MINIMUM BIAS trigger based on the E_{ZDC} measurement. This trigger fires when hadronic energy is measured in the ZDC. The low energy threshold does not cut the signal of central events

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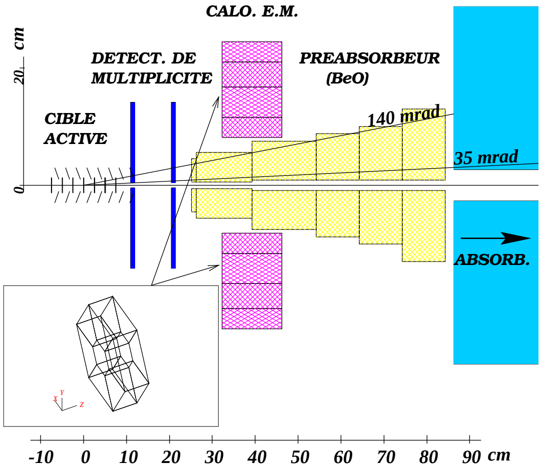
Electromagnetic Calorimeter

Scintillating fibers parallel to the beam axis embedded in lead.

14 cm long ($\sim 15X_0, 0.5\lambda_i$)

The electromagnetic calorimeter has an hexagonal geometry and it's divided into 4 crowns, each one covering $\Delta\eta = 0.34$



- **the calibration is done with electron beams of several energies (10,20,30 GeV)**
- **during the data taking period the stability is monitored by a laser**

$$E_T = \sum_j E_j sin\theta_j$$

Two corrections are applied off-line to the energy measured by the calorimeter to take into account the

- **subtarget dependence of the rapidity window**
- **charged particle contribution from a GEANT simulation**

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Electromagnetic Calorimeter

- good behaviour at high particle rate
- low pile – up
- calibration is complex
- does not cover a central rapidity window

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Resolutions

- **ZDC**

$$\frac{\sigma_{E_{ZDC}}}{E_{ZDC}} = (\frac{a}{\sqrt{E}} + b) \oplus \frac{c}{E}$$

a = 3.39 $GeV^{\frac{1}{2}}$

b = 0.062

c ∼ 1286 GeV → this term is connected with fluctuations in pedestal subtraction

- **ET**

$$\frac{\sigma_{E_T}}{E_T} \sim \frac{a}{\sqrt{E}}$$

a = 0.9 $GeV^{\frac{1}{2}}$

In the region where NA50 finds a discontinuity in $\frac{\psi}{DY}$ the resolutions of the two detectors are comparable and of the order of 10 %:

$$\frac{\sigma_{E_T}}{E_T} \sim \frac{\sigma_{E_{ZDC}}}{E_{ZDC}}$$

The size of the discontinuity in $\frac{\psi}{DY^*}$ (Minimum Bias analysis) as a function of E_T in Pb–Pb collisions is comparable with σ_{E_T}.

This is what we expect in case of a sharp transition at a certain E_T.

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NA50 results as a function of centrality

- **if only one system is considered (Pb – Pb)**

⇒ plots are presented as a function of the MEASURED variable

- **if several systems are considered (Pb – Pb, S –U)**

⇒ it's necessary to introduce other variables, like L (mean length of the path of the $(c\bar{c})$ system through nuclear matter)

for the EM calorimeter:

NA38 acceptance $(1.7 < \eta_{lab} < 4.1) \neq$ NA50 acceptance $(1.1 < \eta_{lab} < 2.3)$

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Calculation of various centrality variables as a function of measured quantities

- **The relation between the centrality variables (b,N_{part},L...) are obtained through a Glauber model.**

The nuclear density is described with a Woods – Saxon distribution

$$
\begin{aligned}
N_{part}(\vec{b}) = f(\vec{b}) &= \int d^2s (A T_A(\vec{s})[1-(1-\sigma_N T_B(\vec{b}-\vec{s}))^B] + \\
&+ B T_B(\vec{b}-\vec{s})[1-(1-\sigma_N T_A(\vec{s}))^A]
\end{aligned}
\tag{2}
$$

where A and B are the mass numbers of the colliding nuclei, $T_{A,B} = \int dz \rho_{A,B}(z,\vec{s})$ are the nuclear profile functions, σ_N is the nucleon–nucleon inelastic cross section and $\vec{s}$ is a two-dimensional vector in the transverse plane of the collision.

$$N_{spect}(\vec{b}) = 208 - N_{part}(\vec{b})$$

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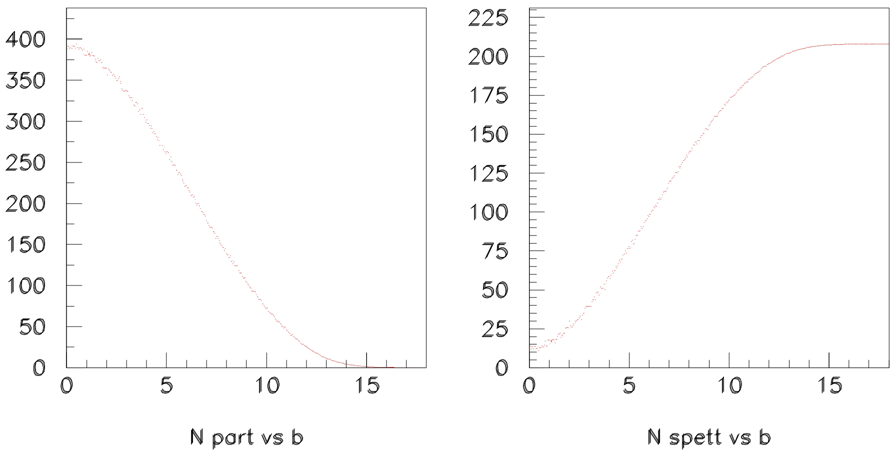

This calculation is confirmed using a nucleus – nucleus event generator such as VENUS, showing that this result is largely model – independent

$$\mathbf{L}(\vec{b}) = \frac{\mathbf{1}}{\rho} \frac{\int \mathbf{d^2 s T_A}(\vec{s})\mathbf{T_B}(\vec{b}-\vec{s})\frac{(\mathbf{A-1})\mathbf{T_A}(\vec{s})+(\mathbf{B-1})\mathbf{T_B}(\vec{b}-\vec{s})}{\mathbf{2}}}{\int \mathbf{d^2 s T_A}(\vec{s})\mathbf{T_B}(\vec{b}-\vec{s})}$$

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Calculation of various centrality variables as a function of measured quantities

- **The link between the measured quantities and b,N_{part},L is based on simple hypothesis**

$E_T = qN_{part}$

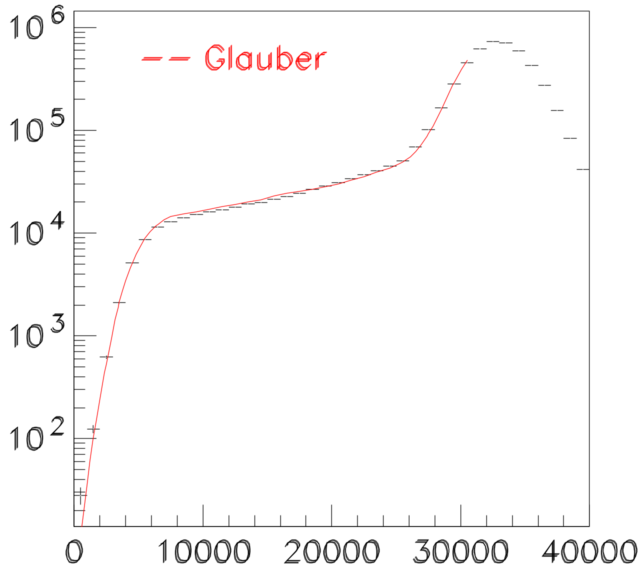
$E_{ZDC} = E_0 N_{spect} + \alpha * N_{part}$

$\Rightarrow$ **The fluctuations on E_T, E_{ZDC}, at a fixed b, are taken into account with:**

$$\sigma(E_T) = k\sqrt{E}$$

$$\sigma(E_{ZDC}) = (a\sqrt{E} + bE) \oplus c$$

$\Rightarrow$ **The free parameters have been fixed by means of a fit to the experimental data**



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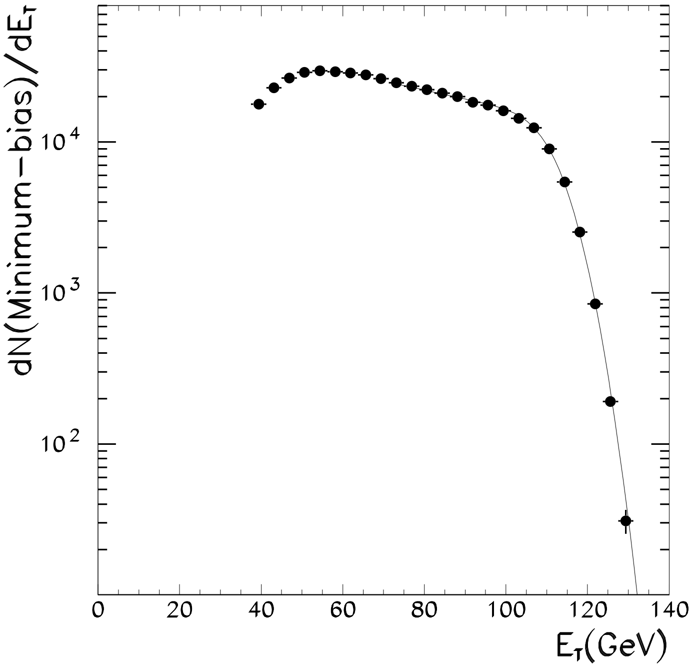

The model adopted well describes the experimental data

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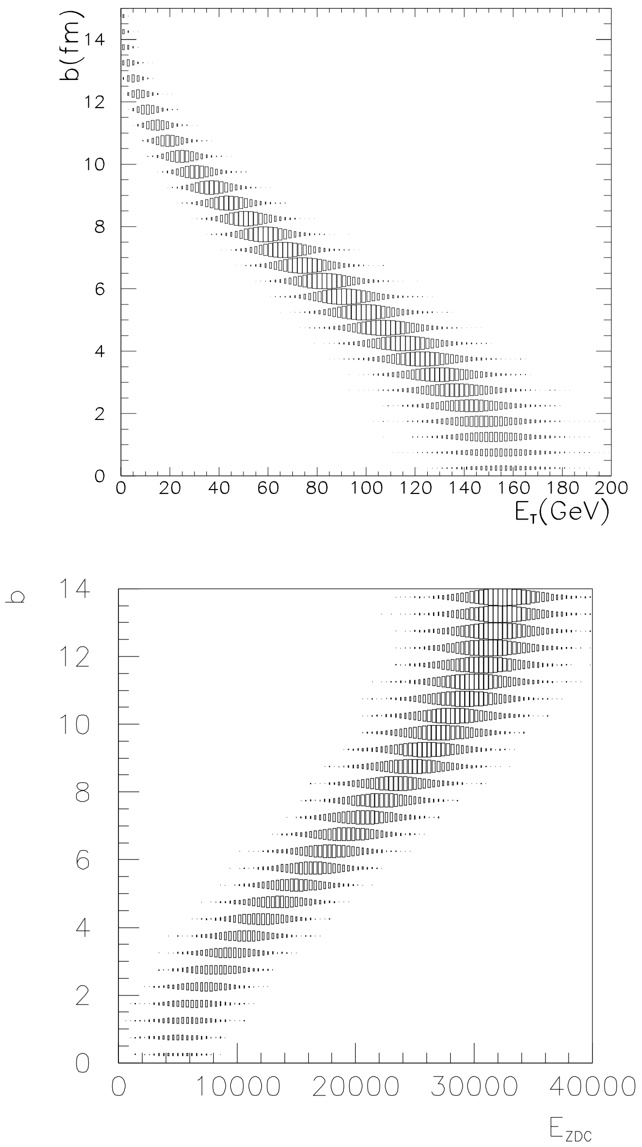
Calculation of various centrality variables as a function of measured quantities

⇒ **Combining those informations it's possible to find the correlation between the measured variables and the impact parameter, that is between the measured quantities and any othe centrality variable.**



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Work in progress

- **Study of** $\frac{dN}{d\eta} vs.\mathbf{E}_T$
- **Correlations between the 3 centrality measured quantities** E_T**,**E_{ZDC}**,Multiplicity**

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