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The role of the FMD in high p_T physics

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When the LHC begins operation in 2008 the Forward Multiplicity Detector (FMD) at ALICE will measure charged particles at forward rapidities . The measurements of the event plane of the collisions will enable studies of the properties of in medium jet modifications. In this contribution the properties and capabilities of the ALICE FMD are discussed.

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1. Introduction: High p_T physics

The evolution of heavy ion collisions is often divided into two distinct momentum regimes. Low momentum particles ('soft particles') are well described by thermal models, whereas the high momentum particles created as jets by direct interactions of the quarks can be described in the framework of pQCD ('hard particles'). To study high p_T particles, the nuclear modification factor, R_{AA} is introduced [1]:

$$R_{AA} = \frac{d^2N_{AA}/d\eta dp_T}{T_{AA}d^2\sigma_{NN}/d\eta dp_T} \quad \text{with} \quad T_{AA} = \langle N_{bin}/\sigma^{pp}_{inelastic}\rangle \tag{1.1}$$

Related to this is the ratio of central to peripheral particle emission, simply defined as:

$$R_{CP} = \frac{N_p d^2N_c/d\eta dp_T}{N_c d^2N_p/d\eta dp_T} \tag{1.2}$$

If the heavy ion collisions scale with p+p collisions the value of R_{AA} will be unity above some p_T (around 1 GeV/c) as will R_{CP}. This scaling was not found at RHIC. Figure 1 [2] shows R_{AA} from Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV measured by the BRAHMS experiment at RHIC. The figure clearly shows suppression of the nuclear modification factor as a function of p_T, an effect known as 'high p_T suppression'. Another important study of jet behaviour in medium requires a detector with full azimuthal coverage. The idea is to study the jets with respect to the event plane. A measurement of this is shown in Figure 2. The jet with the longest in-medium path (the out-of-plane jet) is widened. The study shown in Figure 2 can be done by the ALICE experiment. For this study the FMD can provide the measurement of the event plane independently of other detectors.

2. ALICE and the FMD

Figure 3 shows the ALICE [3] experiment. The heart of ALICE is the giant Time Projection Chamber. The TPC, together with other tracking detectors and detectors for particle identification, provides tracking and PID in a pseudorapidity range of $-0.9 < \eta < 0.9$. The position of the FMD [4] partially inside the TPC is shown in Figure 3. The FMD can detect charged particles in the pseudorapidity ranges $-3.4 < \eta < -1.7$ and $1.7 < \eta < 5.4$. A sketch of the FMD system is shown in Figure 4. Table 1 summarises the physical specifications of the FMD.

	Radial Coverage (cm)	Azimuthal Sectors	Radial Strips
FMD1i	4.2-17.2	20	512
FMD2i	4.2-17.2	20	512
FMD2o	15.4-28.4	40	256
FMD3i	4.2-17.2	20	512
FMD3o	15.4-28.4	40	256

Table 1: FMD segmentation and radial coverage

The FMD system consists of 5 rings each containing 10240 silicon strips for a total of 51200. There are three inner rings and two larger outer rings. Azimuthally the detector covers a full 2π with

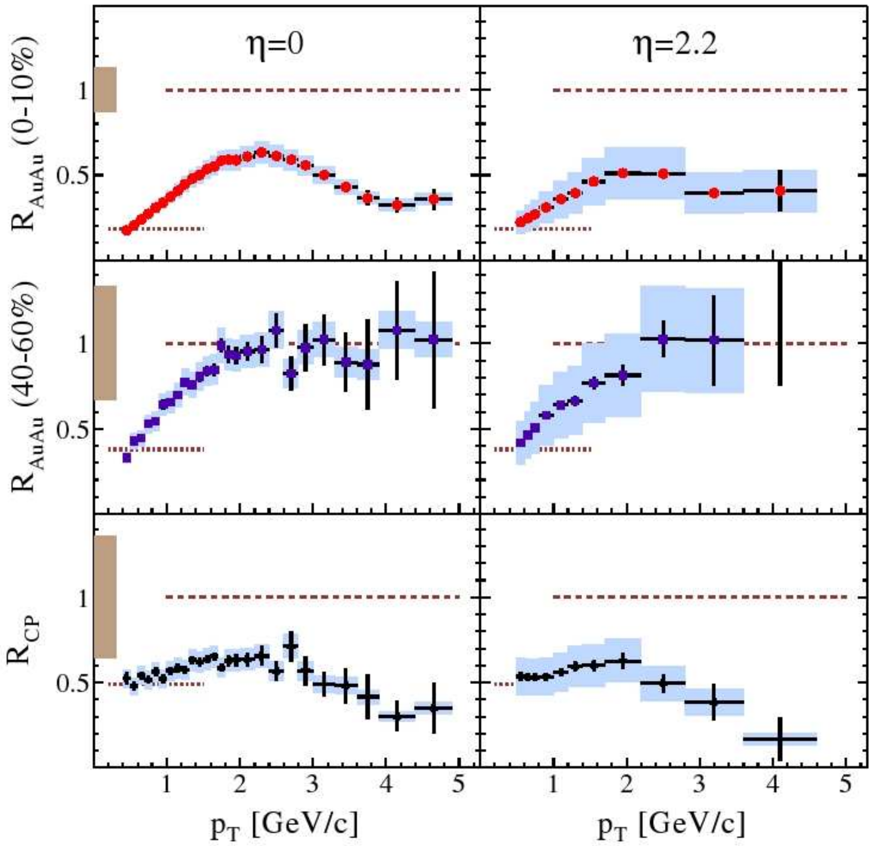

Figure 1: The nuclear modification factor measured by the BRAHMS experiment at RHIC. The lower panels show R_{CP} [2].

Ring	z(cm)	η coverage
FMD1i	320 cm	$3.68 < \eta < 5.03$
FMD2i	83.4 cm	$2.28 < \eta < 3.68$
FMD2o	75.2 cm	$1.70 < \eta < 2.29$
FMD3i	-62.8 cm	$-3.40 < \eta < -2.01$
FMD3o	-75.2 cm	$-2.29 < \eta < -1.70$

Table 2: FMD ring positions and pseudorapidity coverage.

20 sectors in the inner rings and 40 sectors in the outer rings to allow for reasonable segmentation in ϕ. The FMD strips have good signal/noise ratio: better than 20:1 for the outer rings and better than 40:1 for the inner rings. A summary of the positions and coverage of the individual FMD rings is shown in table 2.

3. Analysis

The purpose of the present study is to enable the reconstruction of data as soon as the LHC

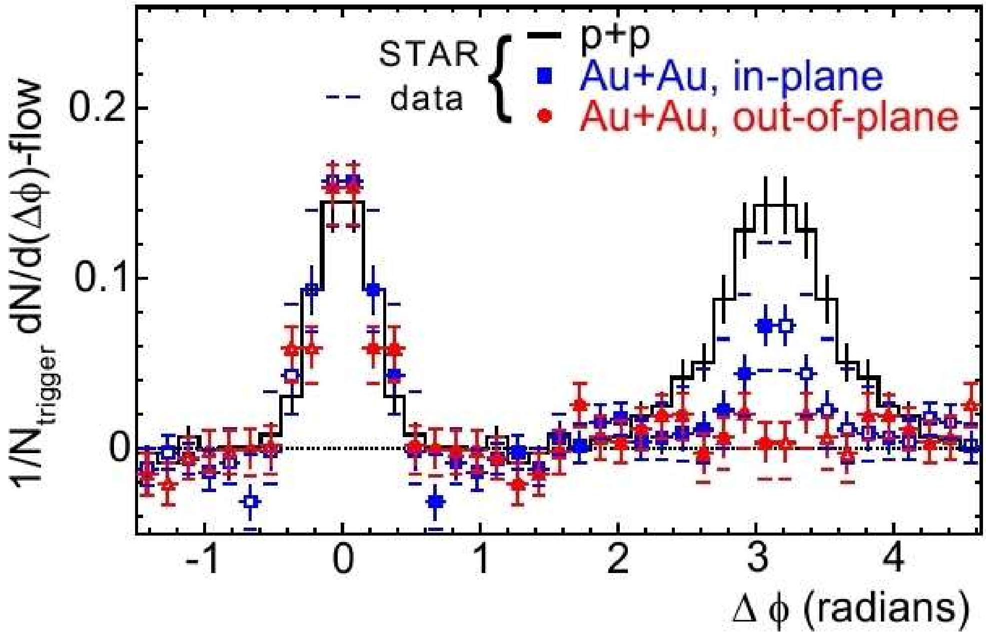

Figure 2: Suppression of the out–of–plane jet measured by the STAR experiment at RHIC.

begins operation. To facilitate this simulations are used to generate events and detector response. To generate $\sqrt{s} = 14$ TeV p+p events PYTHIA [5] is used and for generation of $\sqrt{s_{NN}} = 5.5$ TeV Pb+Pb events HIJING is used [6]. The ALICE geometry and the event generators are built into the AliROOT software package used for the simulation and analysis. To simulate flow, a separate software package has been used [7].

The analysis proceeds strip-by-strip. The energy deposit of each strip is evaluated and a decision must be made for each strip whether or not to accept the strip as a hit or not. An algorithm has been implemented to remove the effects of sharing where a particle deposits energy in several strips. Finally the multiplicity distribution is corrected for secondary particles, created in decays and through interactions with the detector material and support structure.

3.1 Charged Particle Multiplicity

The definition of the average charged particle multiplicity is simply $\frac{dN}{d\eta}$, the number of particles per unit of pseudorapidity per event. The reconstructed distribution of the multiplicity per event in 100.000 $\sqrt{s} = 14$ TeV p+p events is shown in Figure 5. Included in the plot is the primary $\frac{dN}{d\eta}$, picked up from PYHTIA. As can be seen the reconstruction is successful as the reconstructed points and the input distribution are identical within the statistical errors.

3.2 Event Plane and Elliptic Flow

The definitions of flow and the methods of analysing used here are based on [8]. The particle

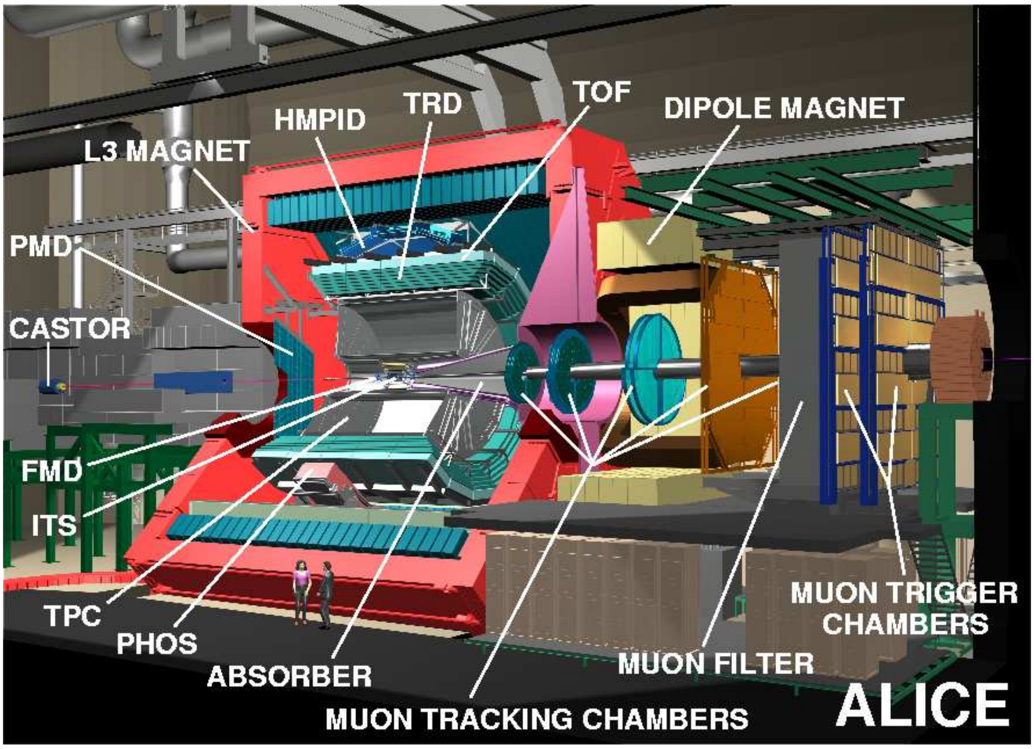

Figure 3: The ALICE experiment.

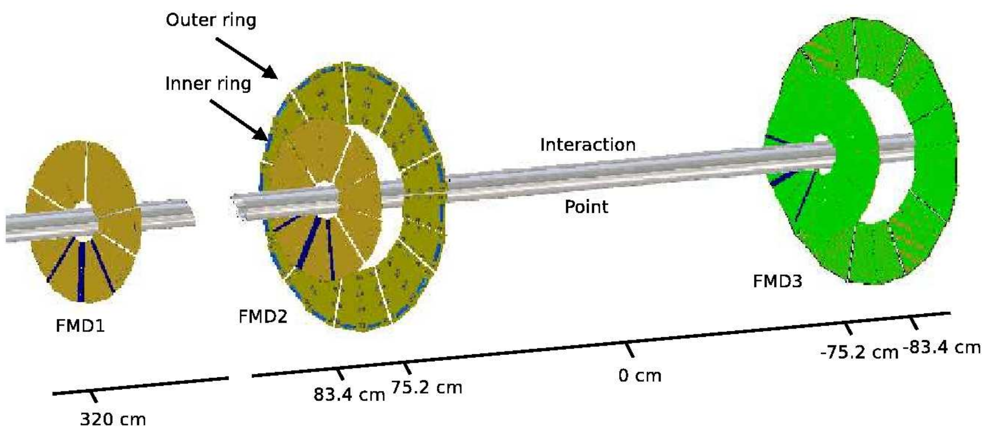

Figure 4: The Forward Multiplicity Detector. There are three inner and two outer rings. From left to right are shown FMD 1,2,3. The interaction point is midway between FMD2 and FMD3.

distributions can be written as the Fourier expansion:

$$E\frac{d^3N}{d^3p} = \frac{1}{2\pi}\frac{d^2N}{p_T dp_T dy}(1+\sum_{n=1}^{\infty} 2v_n \cos(n(\phi-\Psi_r))) \tag{3.1}$$

The components, $v_n = < \cos(n(\phi-\Psi_r)) >$ of this expansion characterise the flow. v_1 is the direct flow and v_2 is the elliptical flow. The experimentally observed reaction plane, the event plane, Ψ_r

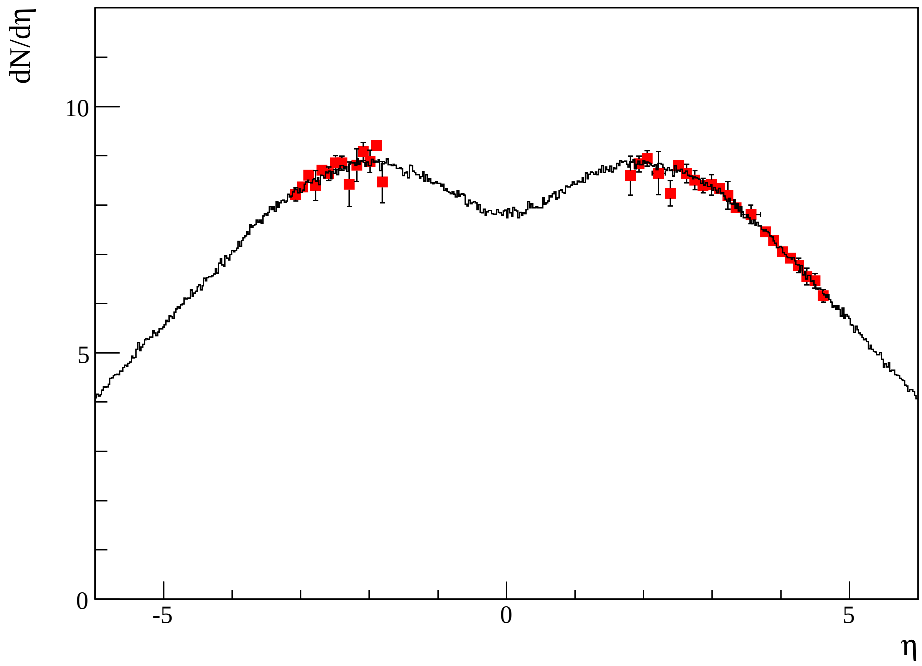

Figure 5: Reconstructed data (red points) plotted on top of the PYTHIA input function. The precision is good, as the data match the input within statistical errors.

is defined as:

$$\Psi_n = \frac{1}{n}\arctan\left(\frac{\sum_i w_i \sin(n\phi_i)}{\sum_i w_i \cos(n\phi_i)}\right) \tag{3.2}$$

With these equations the event plane and the flow can be measured. There is an ambiguity in this as the event plane to be used to calculate the v_n should be calculated from particles not used for the calculation of the coefficients themselves or else autocorrelations might occur. This defines one of the roles of the FMD in ALICE; namely to provide the detectors at midrapidity with the event plane angle. On the other hand the to calculate the v_n in the FMD a way to avoid autocorrelations is to use an event plane angle calculated by another detector in ALICE.

In the following the effects of these autocorrelations have been ignored altogether. Figure 6 shows the reconstructed second order event plane from 1000 Pb+Pb events. The event plane angle has been reconstructed from a simulation where it was set to zero. The mean of the distribution was found to be $\psi_2 = 0.033 \pm 0.12$, consistent with this.

Figure 7 shows the reconstructed v_2 from 1000 Pb+Pb events. In the simulation v_2 was set to 0.05 and the result resembles this. A gaussian fit to the distribution gives $v_2 = 0.045 \pm 0.01$ which is in agreement with the value set in the simulations.

4. Conclusions

High p_T physics is an important topic of study at LHC. The ALICE experiment will be able to do these studies at midrapidity. To do detailed studies of the in-medium modifications of jets the

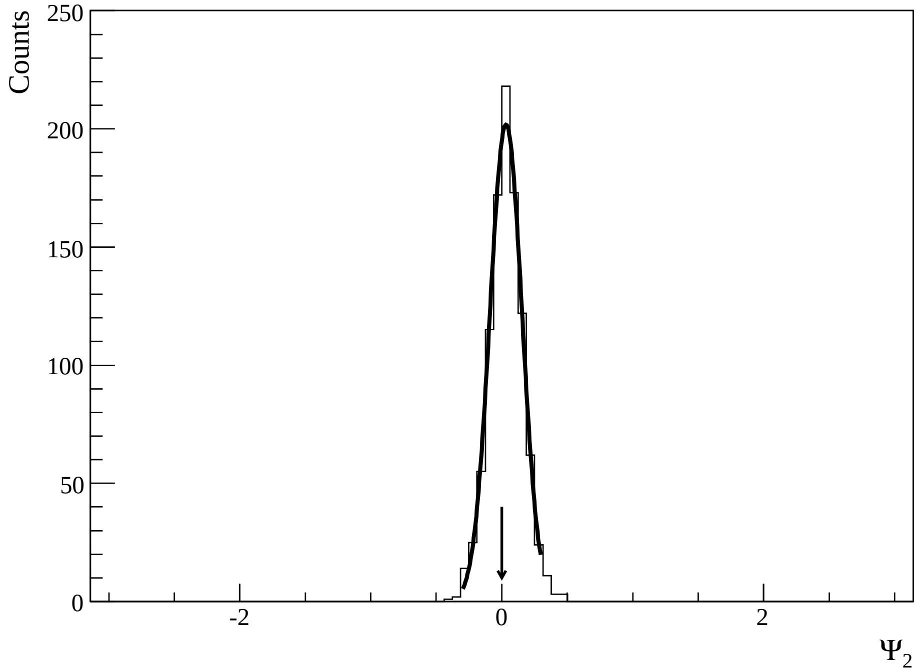

Figure 6: The reconstructed event plane angle distribution fitted with a gaussian. The arrow indicates the value set in the simulation.

FMD provides an independent precision measurement of the event plane. Furthermore the FMD provides measurements of the charged particle multiplicity and the flow in Heavy Ion Collisions.

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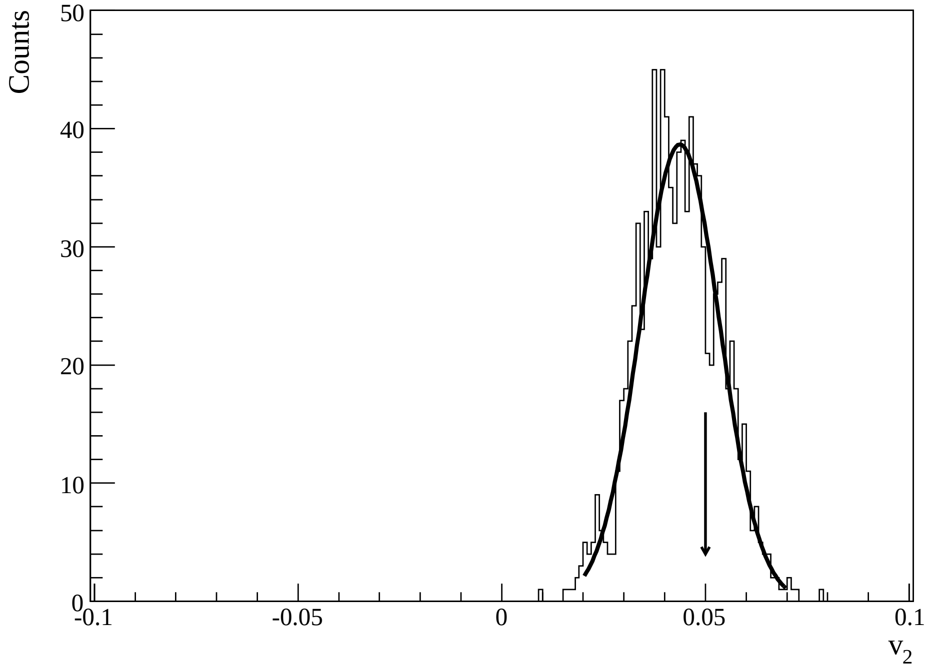

Figure 7: The reconstructed values of v_2 fitted with a gaussian. The arrow indicates the value set in the simulation.