Revised Version CERN-CMS-CR-2005-006

Acta Phys. Hung. A 19/1 (2004) 000–000

HEAVY ION PHYSICS

Hadronic physics with the CMS experiment

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Received 31 March 2005

Abstract. The capabilities of the CMS detector are shown and its Heavy Ion program is outlined.

Keywords: CMS, nucleus-nuleus, quarkonia, jets
PACS: 25.75.-q

arXiv:hep-ph/0504259 v2 28 Apr 2005

1. Introduction

Experiments observing nucleus-nucleus collisions have been studying hot nuclear matter for several decades at ultra-relativistic energies. With a long history (BNL AGS, CERN SPS, BNL RHIC) the next step is again at CERN with the Large Hadron Collider (LHC).

The field has recently brought exciting results, such as anomalous suppression of heavy mesons at the SPS [1, 2], the suppression of high p_T jets [3, 4, 5] and the disappearance of back-to-back high p_T hadron correlations at RHIC [6], ultimately leading to the observation of a new kind of strongly interacting matter.

In the coming LHC era the higher available energy (5.5 TeV per nucleon pair for A+A) will provide a wider kinematic range and higher cross-sections for rare probes. Familiar as well as new observables will be available: enhancement of particles with high p_T; the "temperature"-indicators J/ψ, ψ' and Υ family; medium effects on jets, such as their shape and fragmentation; dijets, the newly available jet-γ, jet-Z^0 correlations; the centrality dependence of these effects.

2. Heavy ion experiments at LHC

The LHC is being built in the LEP tunnel. It will provide collisions for four experiments, three of them which have a specific heavy ion program. One of them is the Compact Muon Solenoid (CMS) detector which has good acceptance, spa-

1219-7580/04/ $ 20.00
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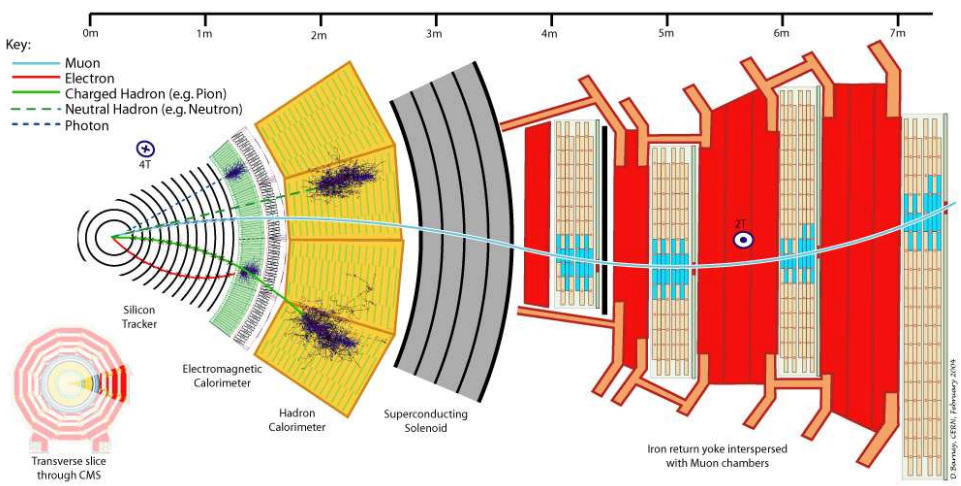

Fig. 1. Slice through CMS showing particles incident on the different sub-detectors.

tial and momentum resolution, and is able to clearly observe rare signals. CMS is somewhat complementary to the other heavy ion experiments. While ALICE has particle identification capability at moderate p_T, CMS is good at observing higher p_T particles, especially muons, and jets.

The CMS Heavy Ion component is an integral part of the physics program of the experiment with both a detailed A+A and p+A program [7].

3. The CMS detector

The detection of charged and neutral particles, leptons and hadrons is achieved using several detector components: namely the silicon tracker, electromagnetic and hadronic calorimeters, muon chambers (Fig. 1).

The silicon tracker includes pixels and strips, it has geometric coverage for $|\eta| < 2.5$. There are about 10 million microstrips and 40 million pixels with a size of $100 \times 150 \mu m^2$. The pixel part consists of three barrel and two forward layers on each side. The occupancy of the pixels is expected to be at the few percent level for a multiplicity of $dN/d\eta = 5000$, even for the innermost layer at a radius of 4.5 cm. The strip part consists of ten barrel and nine forward layers on each side, some of which are single-, others are double-sided. The silicon tracker has excellent reconstruction performance for $p_T > 1$ GeV/c. For lower p_T the reconstruction capabilities are limited by the high magnetic field and effects of the material in the detector.

The electromagnetic calorimeter is very compact: its lead tungstate crystals have high density, small Moliére radius and short radiation length. It includes barrel and endcap parts covering $|\eta| < 3$ with a granularity of $2 \times 2 cm^2$, the resolution

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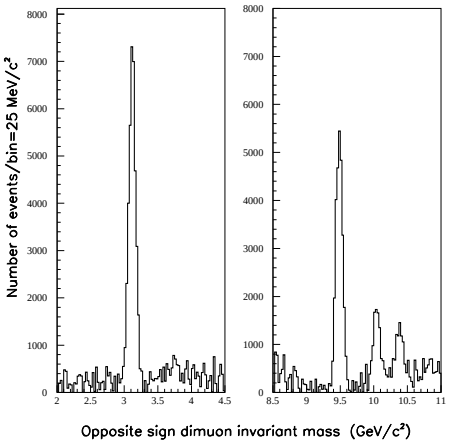

Fig. 4. Mass spectrum of opposite sign dimouns after background subtraction, with clear signs of J/ψ and the Υ family.

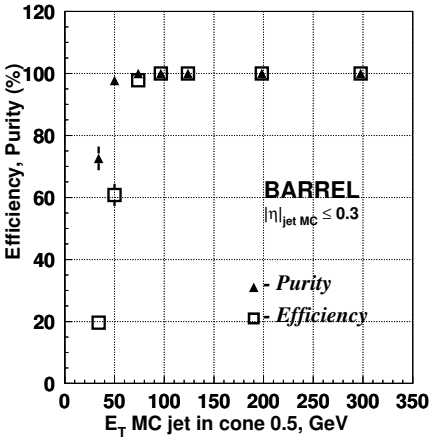

Fig. 5. Reconstruction efficiency and purity of jets in the barrel.

4. Physics studies

4.1. Soft

The tracking of charged particles using the silicon tracker is efficient and results in low fake rates for $p_T > 1$ GeV/c (Fig. 2). An efficiency of 80% at $dN/dy = 5000$ is expected even for tracks in jets. The relative resolution of p_T is about 1% for tracks in the 1-30 GeV/c range. In order to achieve these results a rethinking of the reconstruction algorithms and tuning of their parameters was necessary.

One of the first results of the heavy ion program could be the measurement of charged particle multiplicity using the silicon pixels alone (Fig. 3).

Using the electromagnetic and hadronic calorimeters, azimuthal asymmetry and flow effects can be studied.

4.2. High p_T

The extraction of the quarkonia signal is possible via the decay to $\mu^+\mu^-$: the CMS detector is well suited for detection of muons up to 2.5 in pseudorapidity. The mass resolution of dimuons in the Υ region is 50 MeV/c^2 (Fig. 4) [8], as compared to about 100 MeV/c^2 in ALICE. The background comes from $\pi/K \to \mu$ decay and via $c\overline{c}$ or $b\overline{b}$ production.

One of the strong points of the CMS Heavy Ion program is the detection of high energy jets, using calorimetry [9] and also tracking. Special jet finding algorithms

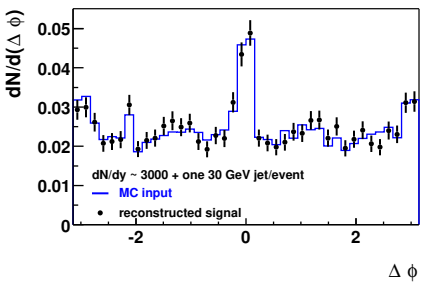

Fig. 6. Azimuthal correlation of a 30 GeV/event jet on a $dN/dy \sim 3000$ background: simulated and reconstructed signal.

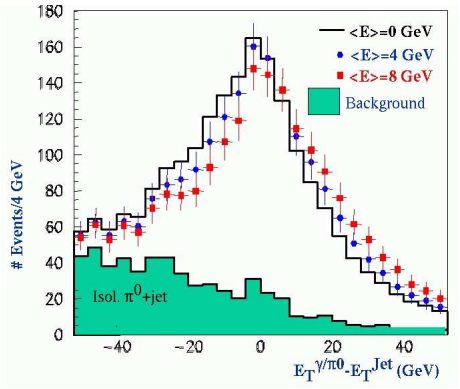

Fig. 7. Distribution of energy difference between the jet and its photon partner at several average energy loss values.

have been developed which are able to work in the high background of a central A+A collision (subtraction of background, contribution from tracks, counting energy in a cone). High purity and reconstruction efficiency can be reached for jets with $E_T > 50$ GeV (Fig. 5). Good linearity is seen with a jet energy resolution of 16% at 100 GeV.

Correlation of jets can be studied as well: good angular resolution is expected (Fig. 6).

Due to the higher available energy, the correlation of the jet with a weakly interacting partner can be observed: jet-γ and jet-Z^0 (Fig. 7). This way the energy loss and partonic propagation effects of the individual jets through dense matter can be directly measured and compared to predictions: the back-to-back photon or Z^0 should give the unaffected p_T of the jet at the point of its initial production.

5. Summary

The CMS Heavy Ion group is a growing international collaboration with an exciting physics program. Topics to be studied include particle multiplicities, spectra and correlations, with an extensive high p_T program looking at quarkonia, medium effects on jets and jet correlations.

Acknowledgment

The author wishes to thank to the Hungarian Scientific Research Fund (T 048898).

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