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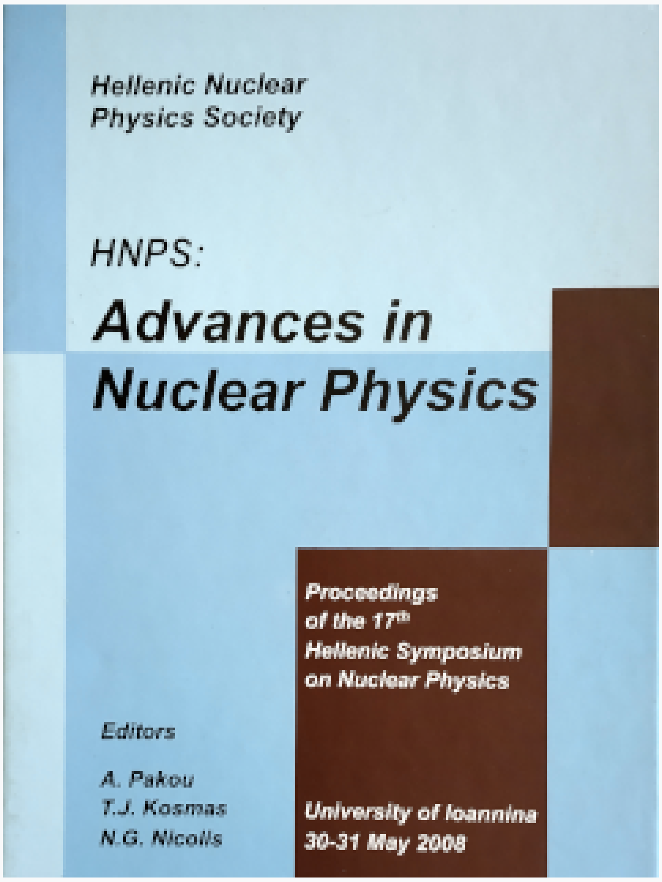

CASTOR: A Calorimeter for Forward Physics at the CMS Experiment, CERN.

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Abstract

In the search for Strange Quark Matter (SQM) and Exotic objects in Heavy Ion collisions at high energy, a new Electromagnetic plus Hadronic calorimeter, the CASTOR (Centauros And STrange Objects Research) calorimeter is now under construction. This calorimeter will operate in the experiment CMS at the LHC collider at CERN and is designed for the detection of Strange and Exotic objects at heavy ion collisions. Beam tests of two prototypes in the years 2003, 2004 and 2007 showed a good behavior of the instrument.

Key words: CASTOR, QGP, LHC

1 Introduction

Heavy Ion collisions at high energies have attracted the interest of Nuclear Physicists for the last twenty years. A new community has been formed in Physics, the Heavy Ion community, served by both Nuclear and High Energy Physicists. Fixed target experiments were performed at AGS (Brookhaven National Laboratory) up to T=16 GeV per nucleon and SPS (CERN) up to T=160 GeV/A. The projectiles used in these experiments ranged from Si to Au, on mainly heavy targets. Recently, the Relativistic Heavy ion Collider (RHIC) started operations at BNL with two colliding beams of energy 200 GeV/A each
The most powerful collider, the Large Hadron Collider, is now

under construction at CERN and is expected to be operational by the year 2007. Having a circumference of 27 Km and crossing the borders between Switzerland and France (in what used to be the LEP collider tunnel), it will accelerate protons to an energy T=7 TeV per beam, or heavy ions to the equivalent energy of 5.5 TeV/A. The scheduled time for proton to heavy ion beams is eleven months per year to one. The accelerator is expected to start operations with proton beam on September 2008.
Four experiments, ATLAS, CMS, ALICE and LHCb, will run in different crossing points of the beams. Three of these experiments will mainly run p-p beams for High Energy Physics research, while the fourth (ALICE) is dedicated in heavy ion collisions. Even so, the experiment CMS (Compact Muon Solenoid) has an active heavy ion group, which will operate during the corresponding beam time.

2 Heavy Ion Collisions QGP.

The main physics phenomenon under investigation at ultra relativistic heavy ion collisions is the achievement of a state of deconfined quarks and gluons, the Quark Gluon Plasma (QGP). This is a phase transition between nuclear matter state, in which quarks are confined into hadrons (Hadronic state) and a state, in which the quarks are deconfined in a volume of nuclear size. The achievement of this state depends on the baryonic density and the temperature. This process has all the characteristics of a usual phase transition: as energy is added to the system, the temperature rises. When the transition begins, the temperature stays constant until all the quarks are deconfined, and then the temperature rises again. This state will only live for about 10^{-22} s and then the hadronization follows, in which the quarks are bound in hadrons again and the system cools down to nuclear matter.
Although the phenomenology of the QGP formation and decay is very rich, the formation of Strange Quark Matter (SQM) is

thought to be a unique signature of the phase transition [1][2]. In the recombination process, a final state consisting of more than three quarks with enhanced strangeness could be formed. This state is characterized by a charge to mass ratio of the order $0.15 \leq Z/A \leq 0.5$ and a life time of 10^{-6} to 10^{-12} s. Clusters of Strange Quark Matter are usually referred to as Strangelets. These objects may come in different sizes and are the main target of our investigation. For the detection of such particles the Hadronic plus Electromagnetic calorimeter CASTOR [3] [4] is under construction and will operate as a part of the experiment CMS at the (LHC).

In the following we give a brief description of the model for the production of strangelts after heavy ion collisions at ultrareletivistic energies at LHC [5][6].

In this model, the Deconfined Quark Matter fireball is created in the baryon rich region of the projectile fragmentation and consists of u and d quarks and gluons. Gluons can decay to a quark antiquark pair but, since the baryonic number is high, the Pauli blocking prohibits the creation of $u\bar{u}$ and $d\bar{d}$ and pairs. Therefore, the first open channel for the gluon decay is the creation of a $s\bar{s}$ pair. This results in the sever suppression of pions and hence gammas (electromagnetic suppression). Then, the s antiquarks combine with the existing u and d quarks to form Kaons [$\mathrm{K}^{+}(\bar{s}u)$ and $\mathrm{K}^{0}(\bar{s}d)$] which are emitted, carrying away strange antiquarks and leaving an excess of strange quarks, resulting into a strange quark matter state (Strangeness distillation [7]). This is the Centauro fireball, which may have a lifetime of the order of 10^{-9}s. After that the system cools down by hydronization in the final state, were baryons and strangelets are emitted.

3 The CASTOR calorimeter

The CASTOR calorimeter uses Tungsten (d=19 g/cm^3) as absorber and the active material which produces the measured light, are Quartz plates (Q). Since electrons and gamma rays loose their energy faster than hadrons, the first part serves as electromagnetic calorimeter and the rest serves as Hadronic.

In the Hadronic part, the W plates have a thickness of 5 mm each, followed by a Q-plate of thickness 2 mm. When a high energy particle hits the W plate, it looses energy by creating a shower of electrons. These electrons of relativistic energy interact with the subsequent Q-plate, thus creating Cherenkov radiation. Both the W and Q plates are divided in eight octanes. Because the maximum light output of the Cherenkov radiation occurs at angle 45^0 with respect to the incoming particle, the plates, with trapezoidal shape, are inclined by 45^0 with respect to the impinging particles. Every seven W and Q plates are bunched together in a reading unit in which, the light created at this part of the calorimeter is measured by a Photomultiplier (PMT) via two air-core light guides (Fig. 1). For the electromagnetic part the W plates are 3 mm thick and the Q plates are 1.5 mm thick. There are 17 rows of reading units in the Hadronic section plus 2 in the EM section, making the total number channels 304, the number of W plates 952 and the total length 13.62 m, or 10 interaction lengths.

According to the model for strangelet production described at

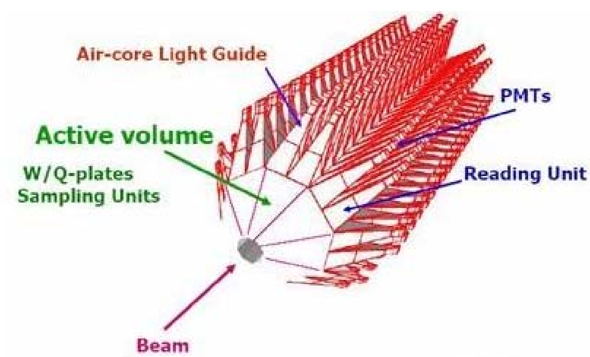

Fig. 1. The CASTOR calorimeter

Section 2, we expect the emission of these particles to come from the baryon rich region of the QGP fireball. Monte Carlo simulations of the Baryonic number distribution using two different event generators, (VENUS and HIJING) showed that the baryon rich region is contained within about two units of pseudorapitity, $5.3 \leq \eta \leq 7.3$. This range corresponds to an angular range

$0.08^0 \leq \theta \leq 0.57^0$. CASTOR will be placed at a distance 14.4 m from the interaction point and will cover the pseudorapidity range of $5.3 \leq \eta \leq 6.5$

4 CASTOR beam tests

Successive beam tests were performed for different CASTOR prototypes to test the performance of the system under electron and hadron beams, in the years 2003, 2004 and 2007. The results of the early beam tests are described elsewhere [8]. All beam tests were performed at the accelerator SPS at CERN, by utilizing electron beams of energy from T=20 to 220 GeV and pion beams of energy from from T=50 to T=180 GeV.
For the year 2007 beam test, a full length octane was built, consisting of 17 reading units in the Hadronic part and 2 in the Electromagnetic part (the 1/8 of fig. 1), coupled to 38 Hamamatsu PMTs.
Since at SPS the electron beam is a secondary beam of low inten-

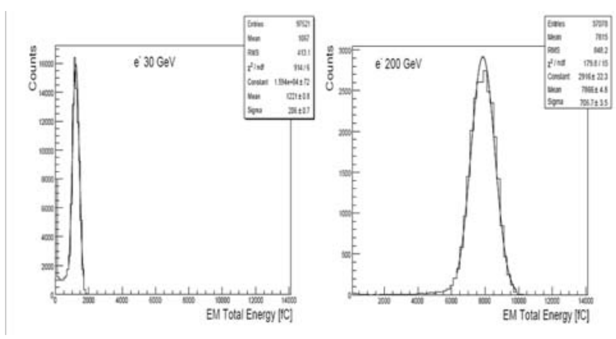

Fig. 2. Energy spectrum of 30 (left) and 200 GeV (right) electrons.

sity (10^3 e/s), the beam was directed directly to the calorimeter. To extract the total energy signal for the electrons, the light output from the PMTs of the two EM reading units was summed, while in the case of pions, the sum was extended in all 19 reading units. Fig. 2 shows total energy spectra for electrons energy T=30 and 200 GeV. The peak shape is Gaussian and the overall resolution is good . This performance is conserved over all the energy range investigated. The linearity of the light output is also good, as shown in fig 3, together with the dependence of the resolution on the energy.

In the hadron side, fig 4 shows total energy spectra for pions at

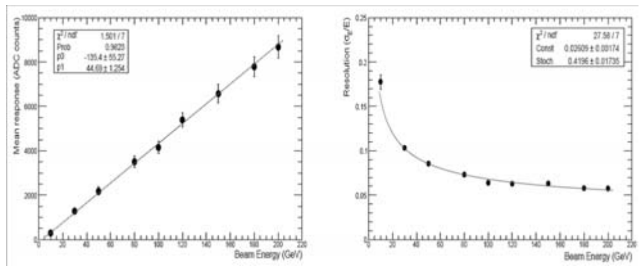

Fig. 3. Energy dependence of the signal (light output) and resolution of electrons.

50, 80, 100 and 180 GeV. The pion peak is fitted by a convoluted of Landau and Gaussian distributions.

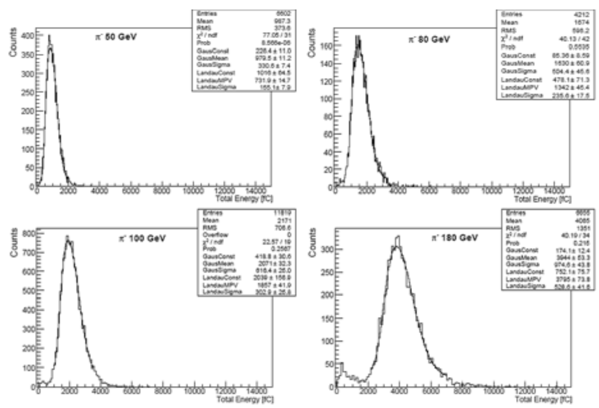

Fig. 4. Total enerfy spectra for pions at various energies.

5 Summary

Beam tests for different components of the CASTOR calorimeter showed that the instrument stands up to its specifications, as far as the amount of light produced and the performance of the measurements are concerned. Monte Carlo simulations for identification of heavy strangelets are under way and the results are very promising. Another challenge under investigation is the radiation hardness of the components used, in the environment of p-p collisions at very forward angles. A final beam test is scheduled for summer of 2008, followed by the installation phase.

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