

# Search of strangelets and “forward” physics on the collider

**A.B.Kurepin**

Institute for Nuclear Research, Russian Academy of Sciences, 117312, 60-th October Anniversary prospect, 7A, Moscow, Russia

E-mail: [kurepin@inr.ru](mailto:kurepin@inr.ru)

**Abstract.** A new stage of the collider experiments at the maximum energy of protons and nuclei at the LHC may lead to the discovery of new phenomena, as well as to confirm the effects previously observed only at very high energies in cosmic rays. A specific program of the experiments is so-called “forward” physics, i.e. the study of low-angle processes. Of the most interesting phenomena can be noted the detection in cosmic rays events called Centauro, which could be explained as the strangelets production. Centauro represent events with small multiplicity and with a strong suppression of electromagnetic component. Since the energy of the beams at the collider and kinematic parameters of the forward detectors CASTOR (CMS), TOTEM, LHCf and the ADA and ADC (ALICE) are close to the parameters and energies of abnormal events in cosmic rays, it is possible to reproduce and investigate in details these events in the laboratory.

## 1. Introduction

The “forward” physics will be one of the most important part of the experimental program at the LHC during the Run 2 in 2015 – 2018 years for proton-proton and lead-lead collisions with the ever highest energy and increased luminosity. Besides of the forward detectors existing at each of the main four installations the specialized systems CASTOR, TOTEM, LHCf will be in operation. For the ALICE the new ADA and ADC detectors are installed at very large rapidity. The main physics potential for these detectors is the measurement of the total elastic and inelastic cross sections and the study of the diffraction. The diffraction processes contribute about 25 % of all inelastic proton interactions at high energies. Because of the central barrel structure and perfect particle identification of ALICE the decay of the excited by diffraction of one or two protons could be investigated. Single proton diffraction at high energy on colliders was measured by ISR [1] and Tevatron [2]. First data on single and double proton diffraction at ALICE were obtained at three energies [3]. The advantage of the AD detectors of ALICE is the increasing of the detectors efficiency to smaller diffraction masses and the extension of the rapidity gaps for the study of central diffraction. The new experimental data on the diffraction will provide the important information on the non perturbation QCD.

However at the same time the forward detectors could be used for the search of the rare exotic phenomena observed in some cosmic rays experiments. Indeed, the energy of the LHC beams in Run 2 at  $\sqrt{s} = 13$  TeV for proton-proton collisions corresponds to  $10^{17}$  eV energy of cosmic rays. For lead-lead collisions  $\sqrt{s} = 5.27$  TeV per nucleon correspond to  $1.5 \times 10^{16}$  eV per nucleon or  $3 \times 10^{18}$  eV total heavy nucleus energy.

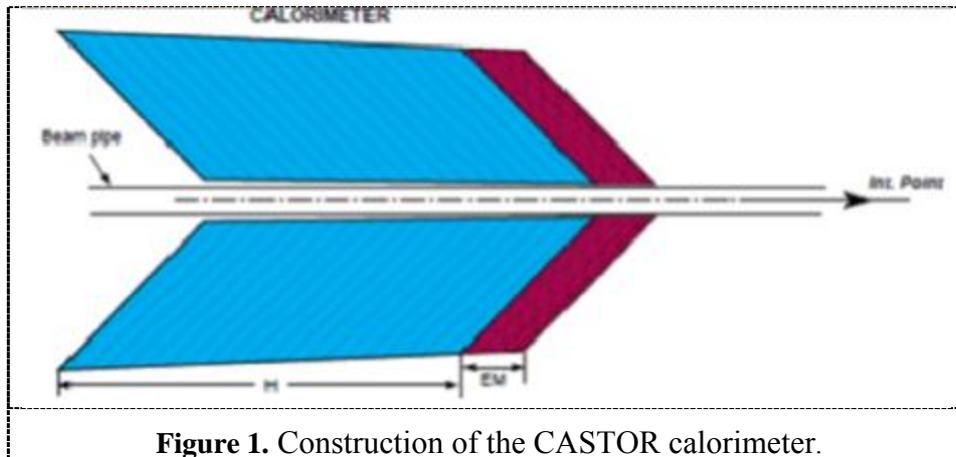


The most interesting unusual cosmic rays events are called Centauros, observed in the emulsion chamber experiments at Mt. Chacaltaya and in the Pamir at energies above  $10^{15}$  eV. These events have abnormal ratio of hadrons to photons yield. Centauros exhibit relatively small multiplicity and strong suppression of the electromagnetic component [4]. Also some hadron rich events are accompanied by a strongly penetrating component [5,6] or long living cascades with many maxima in the transition curve [7,8]. Some new results by re measurement of Centauros were published [9]. Several models have been proposed by assumption that the Centauros events are the results of nucleus-nucleus collisions with formation of a quark-gluon plasma.

Due to high baryochemical potential the creation of  $u-\bar{u}$  and  $d-\bar{d}$  quarks are blocked by Pauli principle and the fragmentation of gluons is going to  $s-\bar{s}$  pairs. Therefore the production of pions is suppressed as well as gamma from neutral pions decay [10, 11]. Then strangelets are formed via a mechanism of strangeness distillation and could be identified as the strongly penetrating particles in forward direction with large rapidity [12]. Simulations based on this model predicted the mass of strangelets up to several hundreds of GeV and large transverse momentum due to the large mass [13]. The signature for observation of Centauro events or strangelets in heavy ion collisions at LHC with the forward detectors could be small multiplicities, predominance of detected hadrons compared to gamma and large transverse momenta. At high energy, compared to the energy of cosmic rays, there was only one attempt for the search of strangelets on the collider RHIC at  $\sqrt{s} = 200$  GeV in gold-gold collisions by the STAR experiment [14]. Assuming that the strangelets have nearly straight trajectory in the magnetic field due to a small charge to mass ratio, the search was made to find a large energy deposition with a narrow transverse shower profile in the Zero degree calorimeter. No candidates were observed and an upper limit was obtained of the order  $10^{-5}$  to  $10^{-6}$ , depending on the possible strangelets mass. In the next chapters two proposed experiments for the search of strangelets at LHC are considered.

## 2. Search of strangelets by the CASTOR calorimeter.

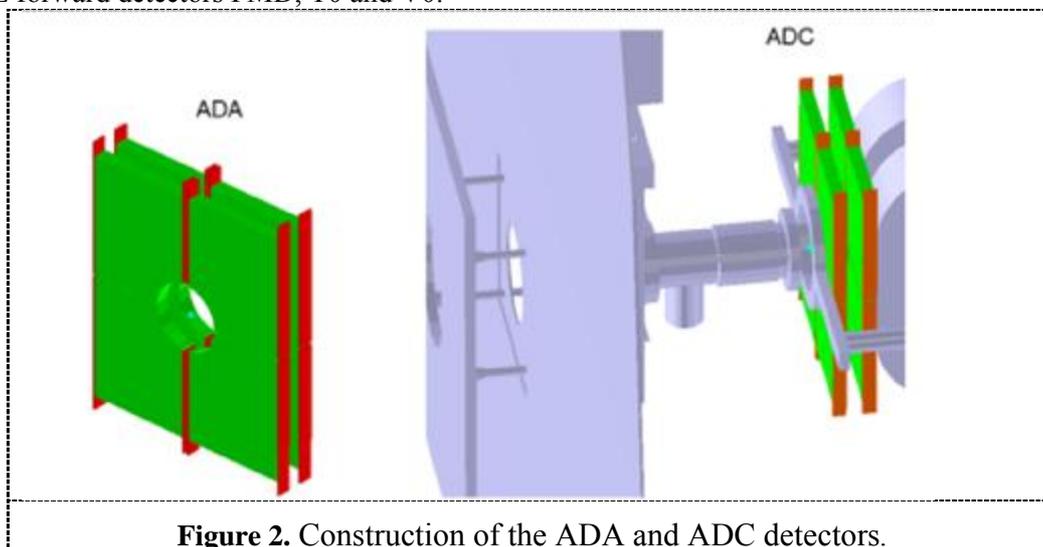
The CASTOR calorimeter was constructed especially for the search of Centauros like events or strangelets in the heavy ion collisions at the LHC. Firstly it was proposed to be installed at the Point 2 of the ALICE [12], but afterwards it was positioned about 14 m from the Point 3 of the CMS [15]. The CASTOR calorimeter consists of 80 tungsten and quartz layers placed symmetric around the beam pipe and tilted at 45 degrees to the beam axes ( Fig.1 ). CASTOR is azimuthally segmented into 16 semi octants and divided longitudinally into 18 sections. It covers the pseudorapidity interval  $5.2 < \eta < 6.6$ . The photo multipliers with the air light guides were calibrated by electron, pion and muon beams. First 8 sections ( $\sim 14.7 X_0$ ) comprise the electromagnetic calorimeter and the remaining 72 ( $\sim 9.47 \lambda_i$ ) the hadronic calorimeter. The structure of the CASTOR calorimeter permits to search for the events with unusual ratio of electromagnetic to hadron emission. The longitudinal transition curve can display the long living cascade with many maxima structure like it was observed in some of Centauro cosmic ray events. The alignment effects seen in some events could be detected due to the azimuthally segmentation. The additional multiplicity information could be obtained from the TOTEM – T2 tracker placed in front of CASTOR.



**Figure 1.** Construction of the CASTOR calorimeter.

### 3. The use of the ADA –ADC detectors of ALICE for the search of exotic events

The important contribution for the “forward” physics at the LHC could be obtained by the new detector system ADA - ADC of ALICE. The two scintillator hodoscopes are installed at the distance 17 m from IP 2 at the A – side and 19.5 m at the C – side of ALICE ( Fig.2 ). They cover the pseudorapidity intervals  $4.8 < \eta < 6.3$  and  $- 7.0 < \eta < 5$  at A and C sides correspondently. The kinematics of these detectors is close to that of the Centauro events in pseudorapidity and in transverse momentum. Each of the AD detectors consists of 4 scintillators arranged around the beam pipe. Wave shifter bars are glued on the side of each scintillator. Optical fibers bundles collect the light from the wave shifters and transmit to the PMTs. The centrality information will be provided by the Central Barrel detectors. Strangelets with large rapidity and high transverse momentum will give a large amplitude signal in one of the scintillators of the AD detector and small multiplicity measured in other AD scintillators and in other ALICE forward detectors FMD, T0 and V0.



**Figure 2.** Construction of the ADA and ADC detectors.

### 4. Conclusion

The forward detectors CASTOR and AD will provide a possibility for the search of exotic events during Run 2 at the LHC. This will complement the diffraction physics program and could solve the nature of Centauro events observed in the cosmic rays experiments.

### References

- [1] Armitage J C M et al. 1982 Nucl. Phys. B194 365

- [2] Affolder T et al. 2001 Phys. Rev. Lett. 87 141802
- [3] ALICE Collaboration 2013 Eur. Phys. J. C73 2456
- [4] Lattes C M G, Fugimoto Y and Hasegawa S 1980 Phys. Rep. 65 151
- [5] Hasegawa S and Tamada M 1996 Nucl. Phys. B474 225
- [6] Barsadzei L T et al. 1992 Nucl. Phys. B370 365
- [7] Arisawa T et al. 1994 Nucl. Phys. B424 241
- [8] Buja Z et al. 1981 Proc. 17th ICRC, Paris Vol. 11 104
- [9] Ohsawa A, Shibuya E and Tamada M 2006 J. Phys. G: Nucl. Part. Phys. 32 2333
- [10] Panagiotou A D et al. 1992 Phys. Rev. D45 3134
- [11] Gladysz-Dziadus E and Wlodarczyk Z 1997 J. Phys. G: Nucl. Part. Phys. 23 2057
- [12] Angelis A L S et al. 1999 arXiv:hep-ph/99082210
- [13] Angelis A L S et al. 2004 Phys. At. Nucl. 67 396
- [14] Abelev B I et al. 2007 arXiv:nucl-ex/0511047
- [15] Norbeck E et al. 2007 CMS CR 2007/013