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Recent beam tests of CMS MSGC Tracker Prototypes

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Abstract

The performance of the MicroStrip Gas Chamber (MSGC) prototypes, developed for the barrel Tracking Detector of the Compact Muon Solenoid (CMS) experiment at LHC, has been extensively tested over the last years. We report the results from the most recent beam tests, illustrating the standard performance of the detectors and the robustness of the MSGC technology in LHC-like beam conditions.

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1 Introduction

The MSGC technology, suitable for building large area tracking devices, has been adopted for instrumentation of the outer parts of the CMS tracking volume [1]. The performance of the CMS MSGC prototypes has been extensively tested in the past using high momentum particles at low rates compared to the LHC conditions. The main results obtained at the most recent test of this type are briefly reported here.
In order to verify the stability of the chambers in realistic LHC conditions, multiple tests with radioactive sources and two beam tests have been performed recently. We report here the beam tests dedicated to investigate the behaviour of the MSGCs exposed to high rate of mips and heavily ionizing particles produced by nuclear interactions with setup material.

2 Detector description

The realization of CMS MSGC is based on the following design and operation principles [2]:

1. coating the glass substrate of ionic bulk conductivity with electron conducting films that act as a shield against bulk instabilities and make detector operation fully insensitive to any changes of electrical properties of the glass substrate itself.
2. Providing the highest possible surface resistivity of the coating compatible with the required rate capability of 10^4/mm^2/sec, in order to avoid a high uniform tangential field between the anode and cathode and to reduce an eventual streamer development across the anode-cathode gap;
3. Passivating all critical strip edges to prevent field extraction of electrons from the cathode edges.
4. Working at the lowest possible gain, with the choice of UV free gas mixture, low noise electronics, high drift voltage, low cathode voltage and consequently narrow anode strips.

The detectors are built on a 300 μm thick, industrial DESAG 263 glass, with ionic bulk conductivity. Substrates are undercoated by Pestov glass, with a surface resistivity of 10^{15}-$10^{16}\Omega$/square. The gold strips are 10 cm long, 0.5 μm thick, and have a width of 7 μm (90 μm) for the anode (cathode); the strip pitch is 200 μm. The passivation in the readout plane was realized by using two techniques: the substrate edges are covered for 0.6 mm by a polyimide film (“standard passivation”); individual cathode edges are passivated by a 3 μm thick polyimide film, 4 μm wide across the strip (“advanced passivation”). The drift plane is made of 500 μm thick PEEK cover, closing a drift gap of 3 mm filled by 1:2 Ne-DME mixture. The active area of a MSGC module is 10x10 cm^2, with 512 anode strips.

For the MSGC prototype tests that we report here, the readout electronics consist of PREMUX chips with a shaping time close to 50 ns [3], followed by a SIROCCO FADC [1]. The chips differ from the final CMS version only by not being radiation hard and not including a deconvolution logic.

3 Standard performance of the coated detectors

Five MSGC modules were exposed to a 30 GeV/c pion beam at the CERN SPS X7 facility. Out of the five detectors, three were coated by films of Pestov glass according to the CMS baseline specifications; two other detectors were diamond-like coated. The standard passivation technique was used. The detectors were mounted on a two meter long optical bench together with four double-sided microstrip silicon detectors, used as a tracking telescope. One MSGC was installed on a movable table, to allow for uniformity studies over the whole detector surface. The typical voltage settings were $V_{cathode} = 530$ V, $V_{drift} = 3000$ V, with a gas mixture 25% Ne-75% DME. The amplitude of the signal was well described by a Landau function, Figure 6. The corresponding signal to noise ratio[2] S/N of 30 allows for a hit reconstruction efficiency of 98.5 $\pm$ 0.2% with an occupancy of 1.20 $\pm$ 0.01 hits per detector, where the errors are statistical. The average cluster size is 1.95 $\pm$ 0.01 strips.

The hit residuals are measured with respect to a track found excluding the chambers under study from the fit. The results show a standard deviation in a range of 35-45 μm for the different chambers tested. If the contribution of

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[1] Developed by LEPSI Stasbourg and available comercially from CAEN.

[2] S/N is defined as the most probable value of signal to noise ratio; N is the noise of one strip averaged on all the strips in the cluster.

the track error is unfolded from the residual distribution, the intrinsic hit resolution are measured to be 30-40 μm. The best resolution obtained is 30.5 $\pm$ 0.4 μm.

To prove the good mastering of the mechanics and the assembly procedure of the final modules for the CMS detector, we have studied the resolution and the gain uniformity near the chamber edges. A uniformity scan has been performed across and along the strips of the detector mounted on a movable frame. The resolution is uniform up to 2 mm from the chamber edge, corresponding to 10 readout strips, Figure 6. A good uniformity has been measured all over the chamber surface [4].

4 Test in a high intensity hadron beam at CERN

4.1 Experimental setup

A set of 5 MSGCs were assembled according to the CMS baseline specifications and exposed to a 3 GeV/c pion beam at the CERN PS T10 facility. The detectors were built using advanced passivation technique. One detector was assembled with the forward CMS tracker layout and read out orthogonally to the other detectors. Two additional MicroGap Chambers were used as a tracking telescope during the whole test. The seven detectors were mounted on a bench and aligned upstream with 5x5 cm^2 and 10x10 cm^2 coincidence trigger counters. Additional finger counters were located downstreams to be used for rate measurements. The probability of inelastic interaction of a pion with the setup material, producing heavily ionizing particles, was estimated to exceed 1% [5]. No dedicated trigger logic was set to detect hard interactions, but the candidate events have been observed in the data.

The voltage settings, V$_{drift} = 3500$ V and V$_{cathode} = 520$ V, were chosen keeping in mind the working conditions of the future CMS experiment. The signal to noise ratio at CMS is expected to be degraded by a factor 2.2 with respect to the beam test value, at the same voltage conditions. A S/N value of 20 allows for a hit reconstruction efficiency better than 98.5%. For this reason, the chambers were operated at S/N values of 44 or larger. A corresponding gain of 1700 was measured. The chambers were filled with 40%Ne - 60%DME gas mixture.

4.2 Results

The T10 beam spill lasted on average 0.3 s every 7.2 s, yielding a duty cycle of 5%. The beam was operated at the highest available intensity. The beam profiles seen by the detectors are well described by a Gaussian with $\sigma = 2.5$ cm in both directions. This allowed to deduce that the central 250 strips of each detector were illuminated at the maximum intensity during 155 hours. Figure 6 shows the rates recorded by a 0.5x0.5 cm^2 counter located a few milimeters off the Gaussian peak, as a function of the integrated running time. The rate measurement should be considered accurate within a factor 2 [5]. The comparison with expected LHC conditions is shown in the same figure: considering the T10 duty cycle, the beam test amounts to about 7.7 hours of continuous beam at a rate comparable or larger than the one expected at LHC at a radial distance of 100 cm from the beam pipe.

Several approaches were adopted to check the stability of the detector operation during the beam exposure. A transition to the streamer regime could be induced by extremely large energy deposition caused by heavily ionizing particles produced in nuclear interactions, and in general, by a large instantaneous rate. The apparition of destructive sparks between cathodes and anodes would cause the local melting of the gold strips and thus the shortening of the strip active length and irreversible damage in the chambers. Figure 6 shows the beam profile recorded by one of the detectors at the beginning and at the end of the run, with three intermediate stages. The binning of the plots corresponds to the strip pitch; a dead or shortened strip would reflect as an inefficiency. A visual inspection of the strips through the glass substrate has confirmed the off-line analysis [5], [6]: no damage has been detected in the MSGC. The performance of the detector has proven to be extremely stable over the whole period of data taking, in terms of collected charge, noise, S/N ratio, cluster size and hit multiplicity; a summary of the stability study is given in Figure 6 for a specific chamber.

5 Test in a high intensity hadron beam at PSI

In order to increase the total integrated rate on the chambers, a second test was performed at πM1 beam at Paul Scherrer Institute (PSI), Villigen, Switzerland. The beam was composed of pions and protons of 400 MeV/c ; proton contamination varied between 40% and 5% during time of exposure. A duty cycle of 100% allowed to gain a factor 20 in the time of exposure with respect to the T10 test. At the end of a 15 days period of data taking, the detectors had been under high voltage and exposed to high intensity beam for 161 hours.

A set of four MSGC Pestov coated chambers were mounted on an optical bench: 3 of them had undergone the T10 test, and the fourth had been previously used for ageing tests. Three additional diamond-coated chambers were made available and read out orthogonally to the other detectors, in order to provide a tracking telescope. The detectors were equipped with picoamperometers, used to monitor the beam induced current and to check for the onset of a possible streamer regime. The chambers were operated at the standard CMS working voltages determined at the T10 test, $\mathrm{V}_{cathode} = 540$ V, $\mathrm{V}_{drift} = 3500$ V. The increase of the cathode voltage with respect to the standard CMS working point determined at the T10 test is adjusted in order to have locally (at PSI) the same gain as at CERN/T10. The variation of gain is due the difference in atmospheric pressure, and to the lower pion energy at PSI which yields 30% less ionization. The gain uniformity in time was checked by splitting a run (40 min) into 12 different periods, Figure 6: no visible fluctuation was observed.

Two 1x1 cm^2 scintillator counters were installed in front of the chambers to allow for a rate measurement, and displaced by 2 and 4 cm respectively with respect to the beam axis. The rate recorded by the two counters corresponds to 10 kHz/mm^2. The complementary information on the actual particle rates was provided by monitoring the beam induced current in the detectors. The chambers were operating on beam induced currents larger than 400 nA. At a radius of 60 cm in the CMS experiment, a current of 400 nA is expected to be induced by a mip flux of 5 kHz/mm^2 distributed uniformly over the detector surface [1]. During the 161 hours of operation at the high intensity beam, the chambers were exposed to a rate higher than the LHC rate at the innermost layer of the MSGC tracker.

To investigate further the operational stability of the detectors, one chamber was ramped to higher voltages. The cathode voltage was being increased by 10 V every 3 hours. The transition to the streamer regime has been observed only at $\mathrm{V}_c = 620$ V and $\mathrm{V}_d = 3700$ V, 100 V above the LHC working point; about 100 streamers were observed during two hours of operation. After the study, the detector was brought to the regular working voltage, and continued to operate normally.

The search of the strip loss has been performed by an offline analysis similar to the one applied in the previous test [6] and by visual inspection. Strip damage has been detected in the chamber that has been brought to the unstable regime, 100 V above the LHC working point. Out of the 100 streamers observed online, not all of them has been destructive: 50 “mouse bites” on the strips have been visually spotted. The loss of 3 strips is reported for the remaining detectors; these strips belonging to the first chamber on the bench, exposed to the huge background produced by the beam hitting the collimators. No indication of sparking activity has been detected in the neighborouhoud of these strips; the loss is due to further hardening of the detectors.

The additional post-run verification of the stability of performance is provided by comparing the values of the gain of the chambers, measured before and after the test [7]. No deviation from the initial value was observed.

6 Conclusions

The MSGC technology allows to build large area tracking detectors that meet the CMS requirements in terms of resolution, signal to noise ratio, efficiency, uniformity and rate capability. A set of CMS MSGCs has been exposed to a high rate of mips during two beam test periods. The integrated rate amounts to about 170 LHC equivalent hours at the innermost layer of the CMS MSGC tracker. No spark-induced damage has been observed in the chambers operated at the CMS working point. The performance of the detector is proven to be extremely stable. The results confirm that the CMS MSGCs are well suited for operation in hostile LHC environment.

References

[1] The CMS Collaboration, The Compact Muon Solenoid - Technical Proposal, CERN/LHCC 94-38.

[2] F. Angelini et al., Operation of MSGCs with gold strips built on surface treated thin glasses, NIM A382 (1996) 461.

[3] L. Jones, Premux 128 Specifications, version 2.1, RAL note 1994.

[4] E. Manola-Poggioli et al., Performance of a Prototype of the Microstrip gas chambers for the CMS experiment at LHC, submitted to the proceedings of the Frontier Detector for Frontier Physics Conference, Isola d’Elba, 25-31.05.1997. The ps version can be found in http://wwwcn.cern.ch/ manola

[5] A. Caner et al., Test of a CMS MSGC Tracker Prototype in a High Intensity Hadron Beam, submitted to the proceedings of the Frontier Detector for Frontier Physics Conference, Isola d’Elba, 25-31.05.1997.

[6] The analysis results can be found in http://edms.cern.ch/cms-tk.

[7] M. Bozzo, CMS meeting with LHC referees, CMS Document 1997-151.

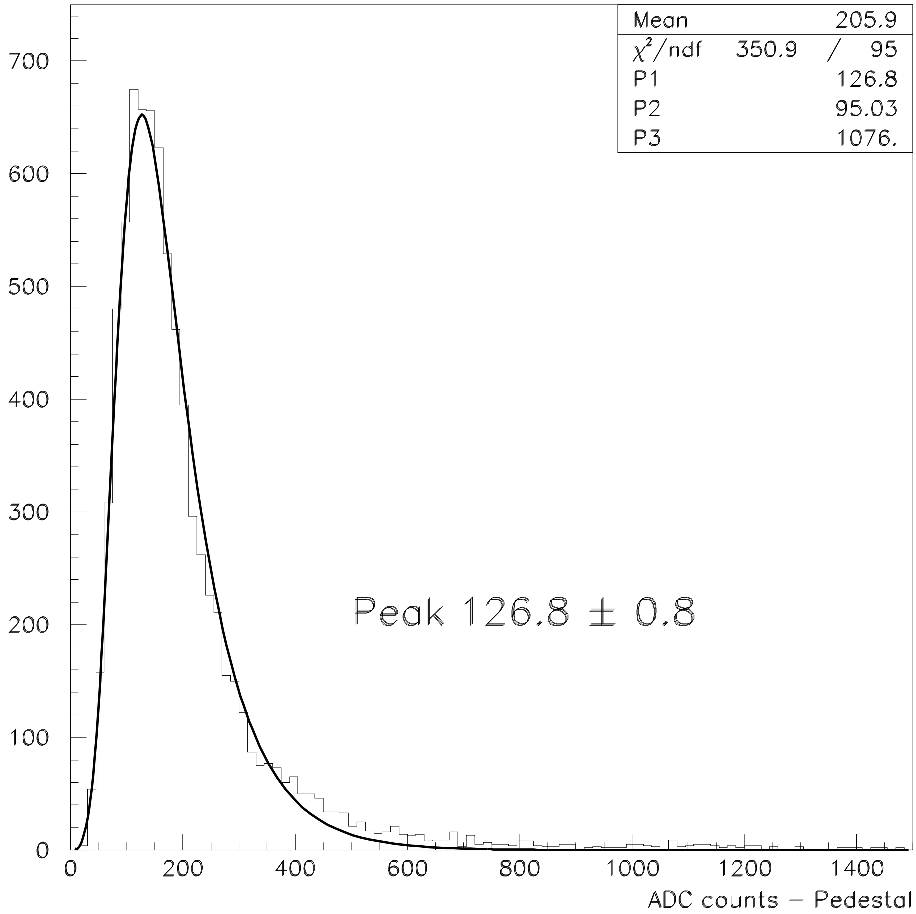

Figure 1: Cluster charge at $V_{cathode} = 530$ V , $V_{drift} = 3000$ V, 25% Ne - 75% DME gas mixture.

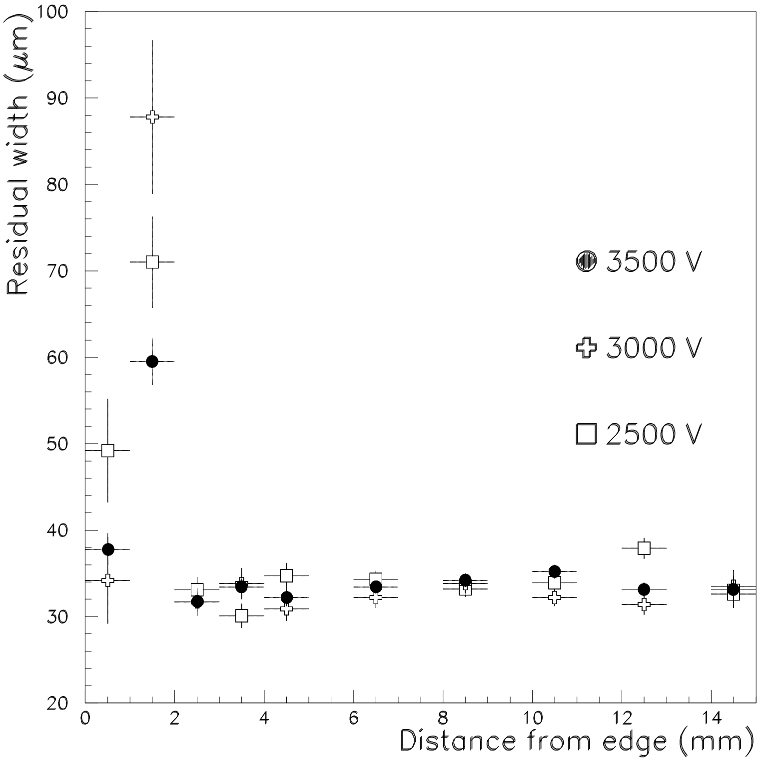

Figure 2: Standard deviation of the residual distribution as a function of the distance from the chamber edge, at $V_{cathode} = 540$ V, 25%Ne - 75%DME gas mixture, for different conditions of the drift voltage.

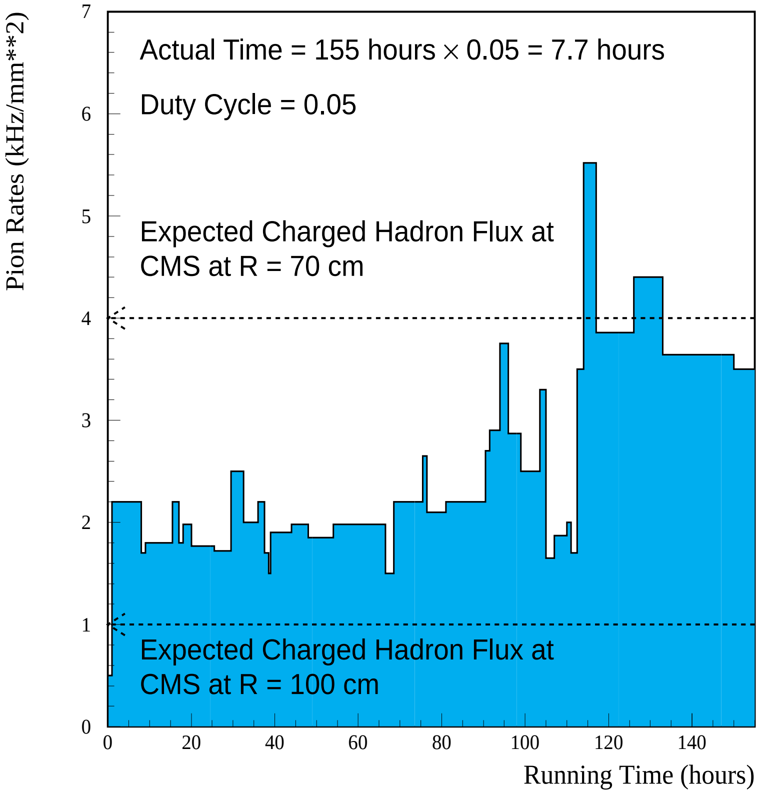

Figure 3: Average particle rates measured by a 0.5x0.5 cm^2 counter set close to the region of maximum beam intensity as a function of the integrated running time.

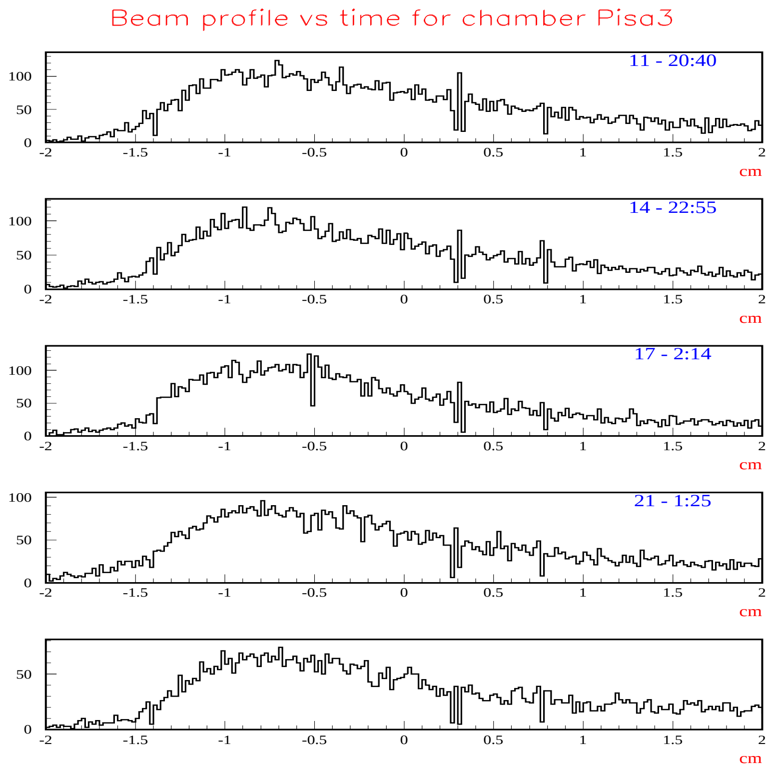

Figure 4: Beam profile seen by a MSGC detector from the beginning (1st plot) to the end (last plot) of the test. No inefficient nor dead strip can be detected.

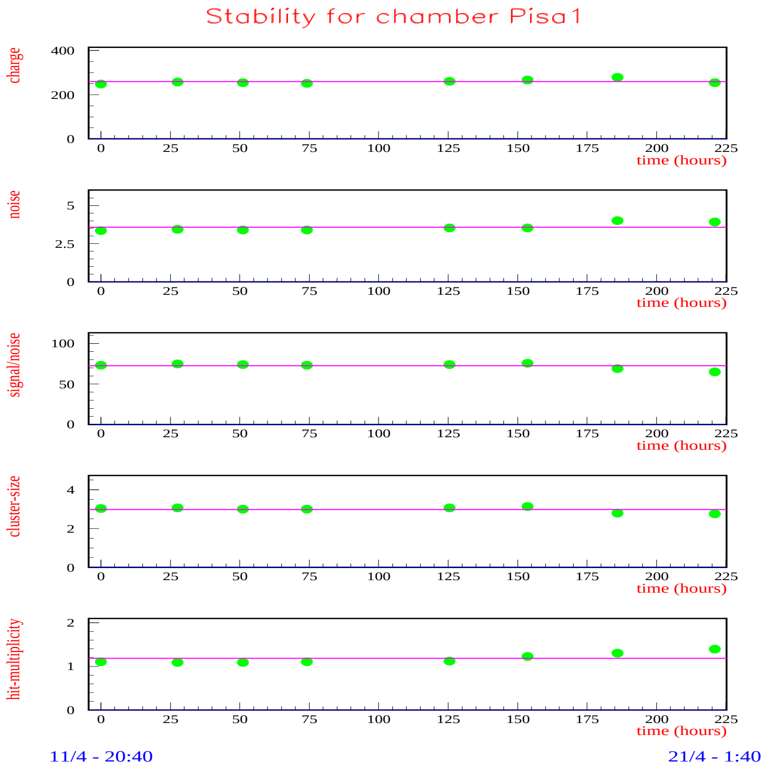

Figure 5: Stability study for a MSGC chamber. All variables are plotted for 225 hours of running time (T10).

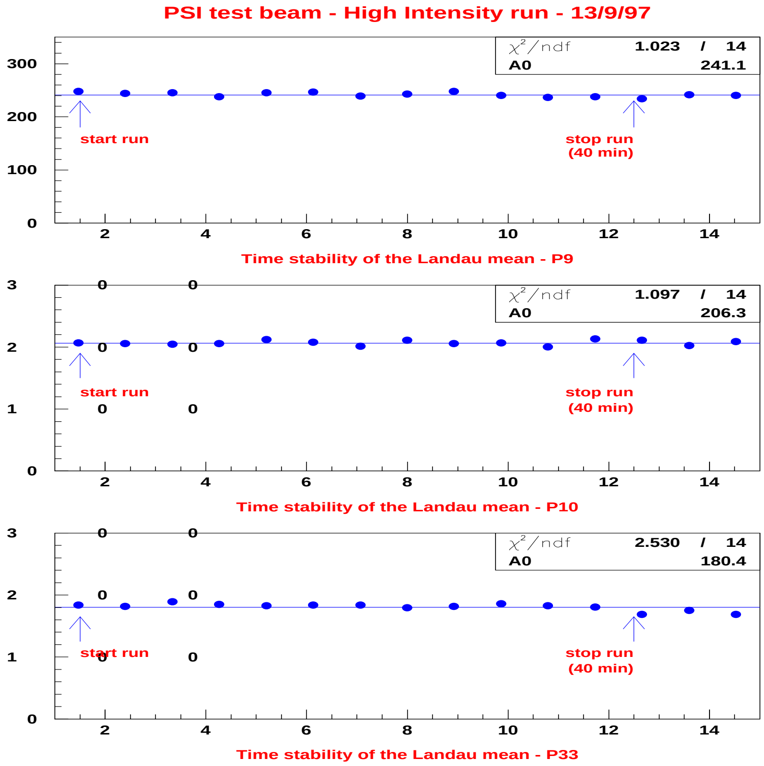

Figure 6: Cluster charge recorded at 12 different periods during a high intensity run, for 3 MSGC prototypes (PSI).