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Section A

A fast, high-granularity silicon multiplicity detector for the NA50 experiment at CERN

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Abstract

We have designed a silicon detector to measure the angular distribution and the multiplicity of charged secondaries produced in high-energy Pb–Pb interactions. It will be used to characterize the events in the NA50 experiment. The experiment will have to function at very high rate, and the silicon detectors will have to operate in the high-radiation area close to the target.

Therefore, the detector will have to be very fast (dead time below 50 ns), radiation resistant (up to the Mrad level as dose and up to more than 10^{13} particles/cm^2 as non-ionizing damage) and of high granularity. The conditions on noise, speed and radiation hardness are comparable to the ones foreseen at the future Large Hadron Collider at CERN.

We present here the detector design, discuss some of the solutions which have been investigated and report first results on the components of the system which have been designed and produced up to now.

1. Overview of the NA50 experiment

NA50 [1] is a fixed-target experiment foreseen to begin data taking in the fall of 1994, when the new beam of 160 GeV per nucleon Pb ions will be available from the CERN SpS. The aim of NA50 is the study of nuclear matter under extreme conditions of energy density, with the ultimate goal of detecting signals of a phase transition from ordinary nuclear matter to a plasma of deconfined quarks and gluons (QGP). The experiment will look for specific signals of a phase transition, in particular in the production of muon pairs: the suppression of charmonium resonances due to Debye screening in the deconfined medium and the increase in the production of ϕ mesons linked to the approach to chemical equilibrium. The events of largest energy density will be selected by measuring the rapidity density of the charged particles produced in the interaction, while the geometry of the collision will be defined by measuring the number of spectator nucleons.

The main components of the apparatus are a high-resolution muon spectrometer with toroidal magnet, a zero-degree calorimeter, a multiplicity detector and an electromagnetic calorimeter. The target is segmented into 7 subtargets to limit the reinteractions of the secondaries, and a system of quartz Cherenkov counters allows the identification of the subtarget in which the interaction took place. Additional detectors are used for the definition of the incoming beam and the detection of pileup. To collect sufficient statistics on the production of ψ and ψ' mesons, the experiment will have to work at the maximum possible beam intensity of 10^7 beam particles/s, and with a target of 18% of an interaction length. We plan to collect $\approx 10^4$ ψ' in 100 days of running.

2. Detector specifications and assembly

The overall layout of the NA50 target region is shown in Fig. 1, including targets, target identification system and

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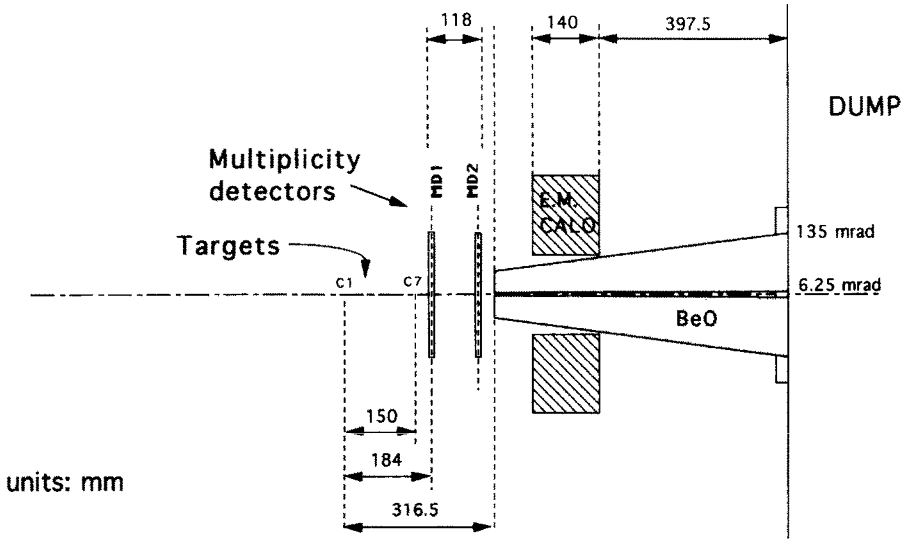

Fig. 1. Schematic view of the NA50 target region.

the multiplicity detector units. The target system has to be placed very close to the absorber in order to limit the decay background in the dimuon spectrum, and therefore the space available for the multiplicity detectors is limited to about 10 cm in the longitudinal direction.

The angular coverage of the multiplicity detector must include the muon spectrometer coverage for all targets, so it is organized in two identical units, each serving one half of the targets. Each detector unit is a disc of inner radius 4.4 mm and outer radius 86 mm, segmented both azimuthally and radially so as to have almost constant occupancy per sensitive element ($\Delta\eta \approx 0.02$, $\Delta\phi = 10^0$). The total number of independent channels is ~ 14000, which keeps the local occupancy below 30% at the highest multiplicities. Using the vertex position derived from the knowledge of the target, the detector provides a single-point measurement of the particle's angles; the size of the rapidity step is matched to the uncertainty on the angle which derives from the beam size and the multiple scattering in the target. From GEANT simulations the expected resolution on the charged multiplicity is better than 10% for central events, dominated by secondary interactions and conversions in the target.

Since the multiplicity detectors will be exposed to high,

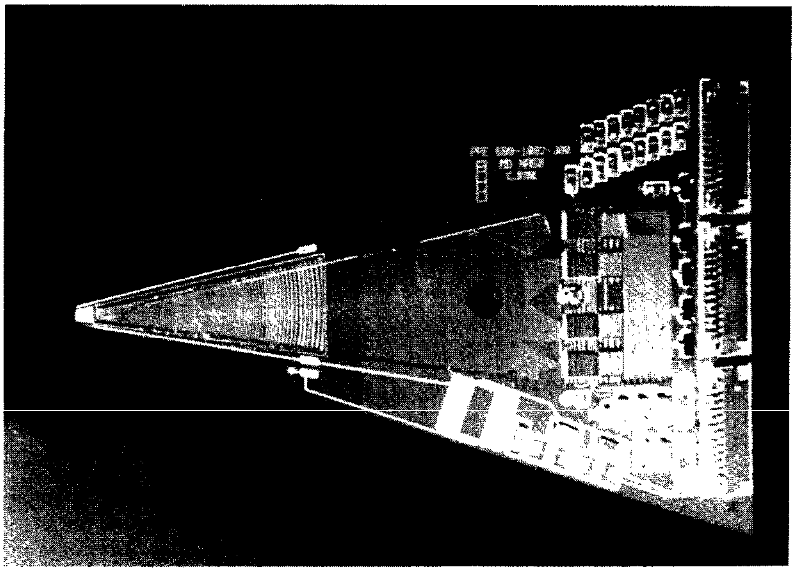

Fig. 2. Photograph of a prototype of the board for the detectors of the inner crown.

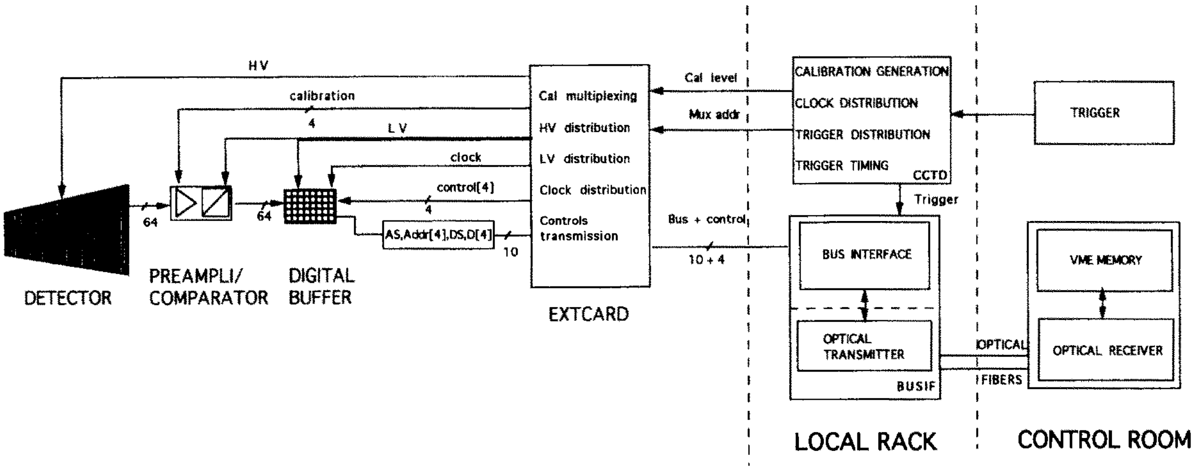

Fig. 3. Block diagram of the readout chain of the NA50 multiplicity detectors.

and non-uniform, radiation levels, reaching over 2 Mrad and more than 10^{13} particles/cm^2 at the innermost radii, each detector unit is built as a mosaic of silicon detectors, each assembled on an independent multilayer board together with its front-end electronics, so that they could be easily replaced in case of severe damage. The detectors are organized in two crowns, inner and outer, of 18 detectors, each corresponding to two units of the azimuthal segmentation. The crowns are built connecting the boards with precision pins, and finally installed in the mechanical support together with an outer multilayer circuit (EXTCARD), which provides the interconnections with the outside. The whole system can be moved vertically with a remote-controlled stepper motor. Given the foreseen radiation levels and the extremely compact assembly, we use AC-coupled detectors with integrated capacitors and polysilicon biasing resistors, made by Canberra Semiconductors. In the inner crown each detector has 256 strips, in the outer one 128. We have tested a few prototypes of the detectors, which have shown good characteristics, and exhibited no problems with the integrated coupling capacitors. We are now starting the mass testing of the final detectors. The signals are brought to the front-end electronics by means of 300 μm thick glass fanouts with 12 μm Al lines, aluminized and etched at CERN, which are overlaid on the detectors and bonded on one side to the

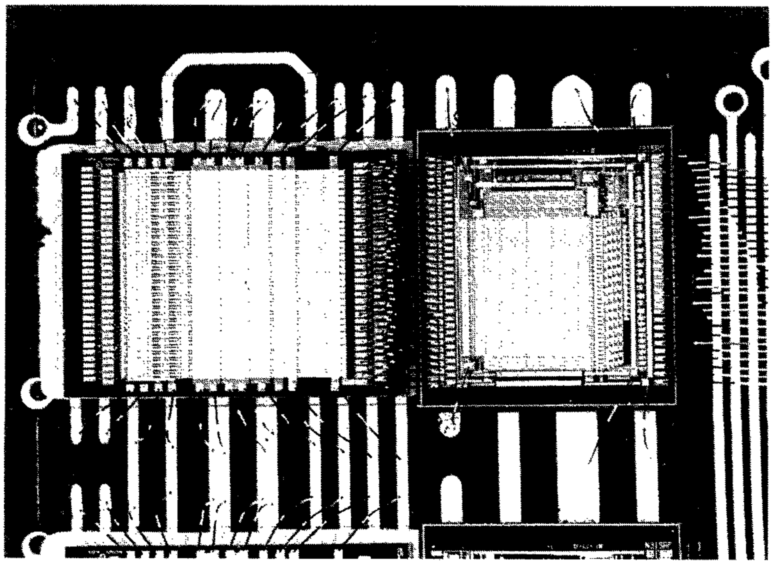

Fig. 4. Photograph of the two readout chips, FABRIC and CDP, assembled together on the detector board.

electronics and on the other to the detector elements. A photograph of a prototype board for the inner crown, in which are visible the detector, the glass fanout and the four pairs of readout chips serving 256 channels, is shown in Fig. 2.

3. Front-end electronics and readout chain

Since only the on/off information from the strips will be used, we have chosen a binary readout scheme, in which the signals are immediately discriminated and only the digital information is stored for transmission. A block diagram of the MD readout chain is shown in Fig. 3.

The first VLSI chip, FABRIC [3], bonded directly to the glass fanouts, preamplifies, shapes and discriminates the signals, and is bonded to the second one, CDP [2], which is a clock driven digital buffer, working at 50 MHz and providing the storage of the information for the duration of the trigger latency of about 1 μs. The data are then stored for the whole burst (up to 5000 events) on memories in a local rack (BUSIF modules) and finally transferred to the counting room on optical links. A VME module (CCTD) provides the clocks, the calibration signals and the proper synchronization of the trigger signals. The VLSI chips must have narrow channel pitch (50 μm) to limit the length of the fanouts, low-power consumption, so that local cooling could be avoided, and be radiation resistant. They were realized as full-custom 64-channel chips, FABRIC in bipolar (Tektronix) and CDP in rad-hard CMOS (Honeywell) technology. Both chips provide test-mode operation, allowing full test and calibration of the system: the FABRIC allows pulsing all channel inputs through individual 53 fF integrated capacitors, each connected to one of four calibration lines, while the CDP allows writing into the buffer through the address lines. The maximum foreseen rates of 10^7 beam particles/s and 2×10^6 interactions/s, coupled with the high occupancy, make dead time and time resolution of primary importance for the front-end electronics. We fixed as design goals 50 ns for the dead time, based on the maximum the experiment can tolerate as loss of events for pileup protection [1], and 8 ns for the walk, to avoid losses in the digital buffer. In addition, we required that the channel to channel variation of gain and threshold values would not deteriorate significantly the system performance as compared to the single channel one.

At this time, the FABRIC chip has been tested in its final form, and the CDP in a non-rad-hard version produced by HP. We have performed a detailed test of both chips assemblying them on specially designed boards, and developed an automatic test setup which allows a rapid check of the functionality of the bare chips for selection before assembly, using custom probe cards. Fig. 4 shows a picture of the two chips, FABRIC and CDP, assembled together on the detector board. The CDP prototype has proven [2] to be fully adequate for our purposes, since it can operate up to more than 80 MHz, with a power consumption below 1 mW per channel, and it leaves the additional freedom to choose whether to sample the input signal in level sensing mode (which will be the configuration most probably used in NA50) or in edge sensing mode. The tests for the FABRIC chip are described elsewere [3], so here we will just recall the main results, to show that the chips perform better than required essentially for all parameters of interest:

Equivalent noise charge (electrons): 476 + 63 C_{in} [fC].
Walk of discr. out for input signals 2 fC to 8 fC: 5 ns.
Dead time for two 4fC signals: 42 ns.
Gain: 100 mV/fC.
Gain uniformity: 5% (σ).
Threshold uniformity: 2.4% (σ).
Uniformity of the calibration capacitors: 0.6% (σ).
Power consumption: 1.3 mW/channel.

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