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SESSION SUMMARY:
ELECTRONICS, TRIGGERING AND DATA ACQUISITION*

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ABSTRACT

The session focused on the requirements for calorimetry at the SSC/LHC. Results on new readout techniques, calibration, radiation hard electronics and semiconductor devices, analog and digital front end electronics, and trigger strategies are presented.

1. Session Outline

The electronics session was focused on the needs and specifications of calorimetry for experiments at hadronic colliders (SSC: Superconducting Super Collider and LHC: Large Hadron Collider).

The topic of "Electronics, Trigger and Data Acquisitions" encompasses a broad variety of issues from front end electronics which must cope with the high radiation environment of the calorimeter region to trigger strategies which must be able to select the exceedingly few events of interest while coping with a high rate of minimum bias events.

In organizing the contributions a "down to top" approach was followed moving from the detailed description of rad-hard front end electronics to the description of trigger strategies and systems.

2. Readout and Calibration

C. de La Taille (LAL, Orsay) described a new solution for the readout of liquid ionization chamber calorimeters. The current approach for the readout of calorimeters is to locate the front-end preamplifiers on the electrodes themselves to avoid the increase in both charge transfer time and in noise due to a transmission line connecting the electrodes to the front end electronics.[1] For liquid argon calorimetry such an approach requires the use of preamplifiers able to work at 90 K. A transmission line between the

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detector and the front end electronics would exhibit many desirable advantages when compared to this solution:

- no need for cryogenic electronics, which allows the use of bipolar devices.
- no power dissipation inside the cryostat.
- easier maintenance of the front end electronics.
- preamplifiers could be located in a region with much lower radiation levels and neutron fluxes.

At fast shaping times (peaking times less than 30-40 ns) the transmission line cannot be modeled as a lumped parameter inductance and capacitance but its frequency behavior must be taken into account.

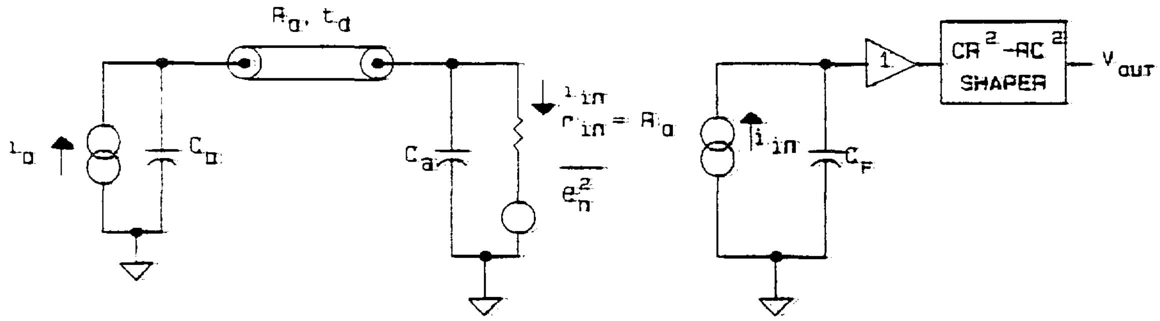

Fig. 1: Equivalent circuit for the analysis of the connection of a calorimeter tower to the preamplifier with a transmission line.

With reference to Fig. 1 a calorimeter tower, modeled as the capacitor C_D in parallel with the signal current generator, is connected with a transmission line of characteristic impedance R_0 to a charge sensitive preamplifier, modelled by its dynamic input impedance,[2] the "cold" resistance r_{in} in parallel to the preamplifier input capacitance. The controlled current generator models the integration in the preamplifier, which is followed by a $CR^2 - RC^2$ bipolar shaper (the use of a bipolar shaper is dictated by the need of avoiding the baseline shift at high rate). The preamplifier input impedance r_{in} matches the characteristic impedance R_0. The noise analysis is carried out by calculating the noise current flowing into r_{in}

$$\overline{i_n^2} = \frac{\overline{e_n^2}}{|R_0 + Z|^2} \qquad (1)$$

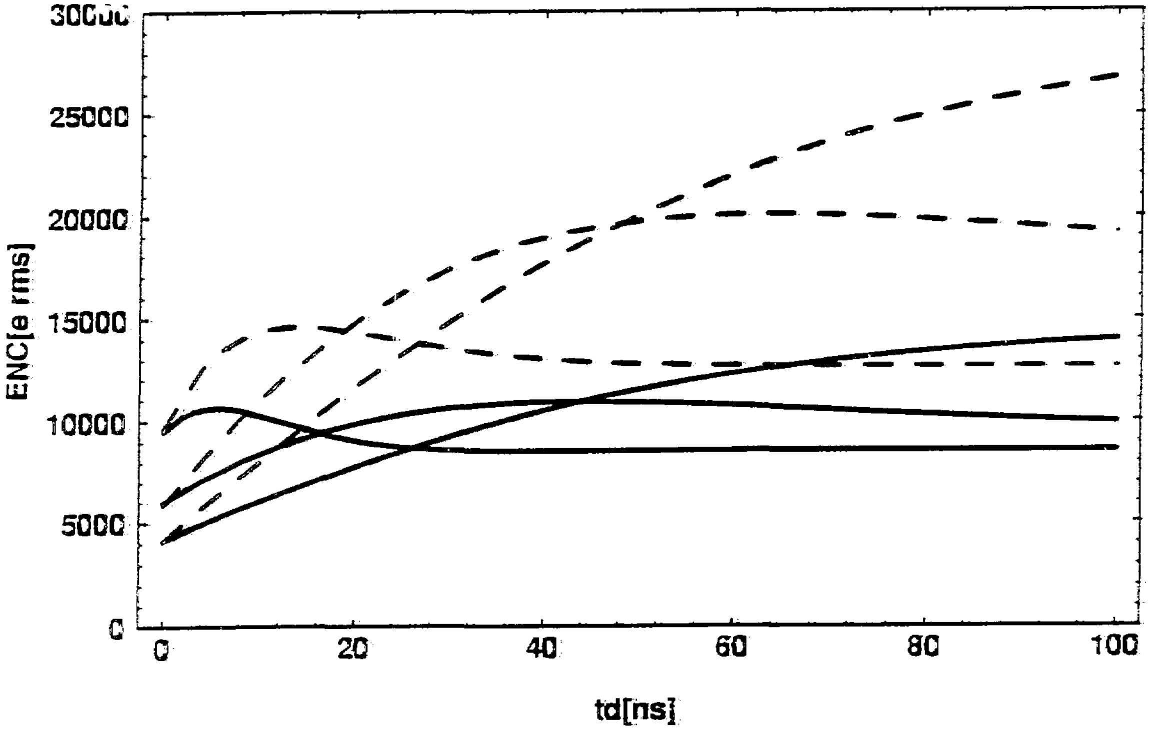

Fig. 2: Equivalent Noise Charge (ENC) versus line delay t_d for two different line impedances, 50 Ω (continuous line) and 25 Ω (dotted line) and three peaking times (20, 50 and 100 ns). The detector capacitance is C_D = 400 pF and the equivalent input noise is e_n = 0.5 nV/$\sqrt{\text{Hz}}$.

where Z is the impedance seen at the receiving end of the transmission line. Figure 2 shows a plot of the equivalent noise charge (ENC) versus line delay t_d for a detector capacitance an equivalent voltage e_n = 0.5 nV/$\sqrt{\text{Hz}}$, C_D = 400 pF, two values of line impedance, 25 and 50 Ω and for peaking times of 20, 50 and 100 ns. The point at t_d = 0 gives a comparison point with the case with no line. It is apparent that the higher the impedance, the lower ENC is. For fast shaping times (25 ns) and for R_0 = 50 Ω there is a slight reduction in noise with respect to the case with no line. A large toll in signal to noise ratio is to be paid at longer shaping times (100 ns). In this idealized case the noise quickly becomes independent of the line delay t_d, since the impedance seen at the end of the line converges to the characteristic impedance. There are some practical constraint on the cable which are to be taken into account. Given the large number of channels of the calorimeters proposed for the SSC/LHC the size of the cable must be minimized. This may cause additional attenuation and increased noise due to the skin effect of the conductors (about 0.7 Ω/m at 1 MHz for a 350 μm wide double-shielded flat cable). B. Chase (LAL, Orsay) proposed a calibration scheme for liquid argon calorimetry which avoids the problems associated with distribution of fast pulses, which is described in these proceedings.

3. Front End Preamplifier

The very first stage of front end electronics must be able to survive radiation levels of about 3×10^5 kGy (30 Mrad) and neutron fluences up to 10^{14} N/cm^2 in some part of the calorimeter (see article by A. Ferrari in these proceedings). Especially for cryogenic preamplifiers which are likely to be sealed inside the cryostat for the entire life of the detector, this poses a severe constraint on their reliability.

D. Camin (INFN, Milan) described a gallium arsenide preamplifier. The idea is to take advantage of the interesting properties of GaAs for fast, low noise applications at cryogenic temperatures. Table I gives some fundamental physical parameters of GaAs which are compared to Si, in both cases at a doping level of 10^{17} cm^{-3}, a typical value for a MESFET and JFET channel, respectively.

Table 1. Main Physical Parameters of GaAs

		GaAs	Si
Electron mobility (cm^2/Vsec)	300 K 77 K 4 K	5000 10000 3000	800 3000 nd
Electric field at peak velocity (V/μm)		0.7	3
Ionization energy of dopants (meV)		6	50
Energy bandgap (eV)		1.4	1.1

The high electron mobility and low electric field for carrier peak velocity make it possible to obtain high transconductance to input capacitance ratios at low power dissipation. This is a parameter of prime importance in charge-sensitive preamplifiers as it is related to the product of the charge sensitivity times the speed for a given detector capacitance.[3] In addition, the low ionization energy of dopant impurities prevents carrier freeze-out at cryogenic temperatures.

Regarding noise, the 1/f component is dominant at room temperature but it decreases by about two orders of magnitude when cooled to 77 K. Therefore its contribution to the total ENC is very much reduced at cryogenic temperatures particularly at short shaping times. A high value of transconductance can be reached at low bias voltage and current. For this reason a low white noise level can be obtained keeping the power dissipation low.

With this idea in mind, different versions of charge-sensitive preamplifiers based on GaAs MESFETs have been developed in Milan and tested in the prototype of the Accordion LAr calorimeter in the frame of the RD3 collaboration at CERN. The performance of the most recent preamplifier version used in the test of the calorimeter at 20 ns peaking time bipolar shaping are given in Table 2.

Table 2. GaAs Preamplifier at t_p = 20 ns

ENC @ C_D = 400 pF	13700 rms el. (54 MeV)
Matching capacitance	80 pF
Input resistance @ C_F = 33 pF	less than 9 Ω
Dynamic range	165 GeV
Power dissipation	54 mW

The circuit diagram is shown in Fig. 3.

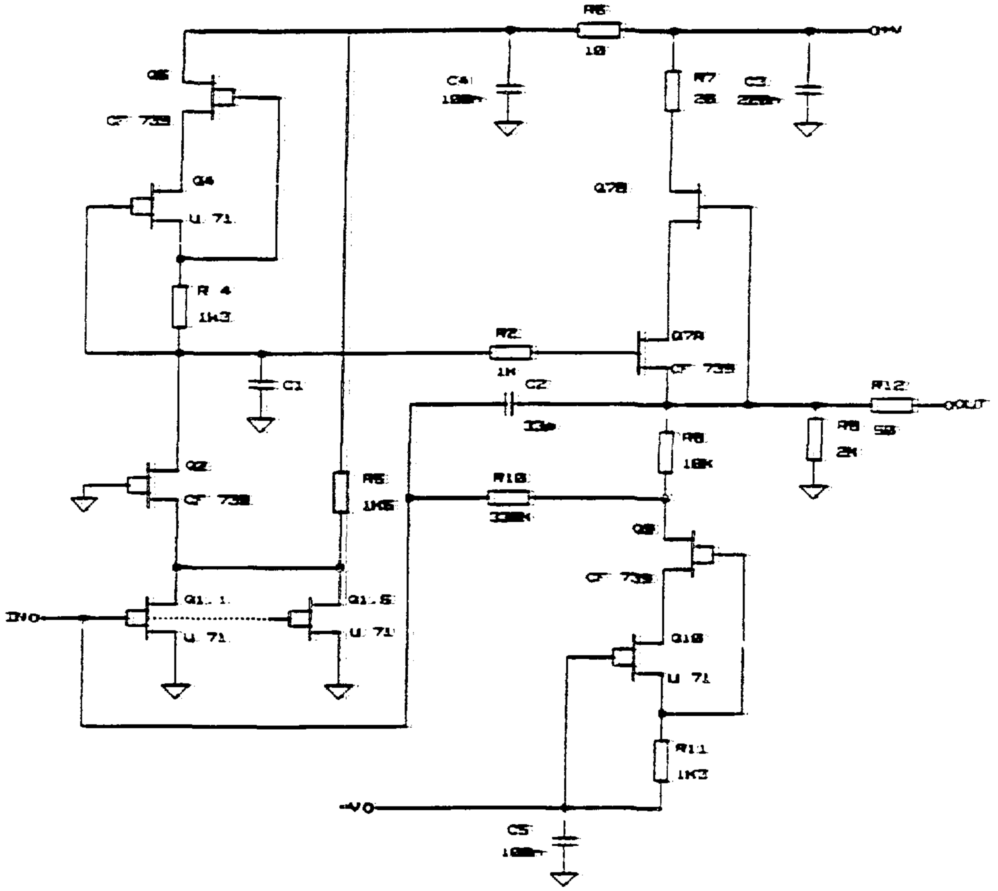

Fig. 3: Schematic diagram of the GaAs charge preamplifier used for the test of the accordion calorimeter at t_p = 20 ns.

The ENC as a function of peaking time for two different shapers is given in Fig. 4.

Preliminary measurements of radiation damage have been done on hybrids using commercial MESFETs. The results have shown a 5% increase in noise after 10^{14} N/cm^{2}, and a 7% decrease in transconductance after 10^{7} rad of a ^{60}Co source.[4]

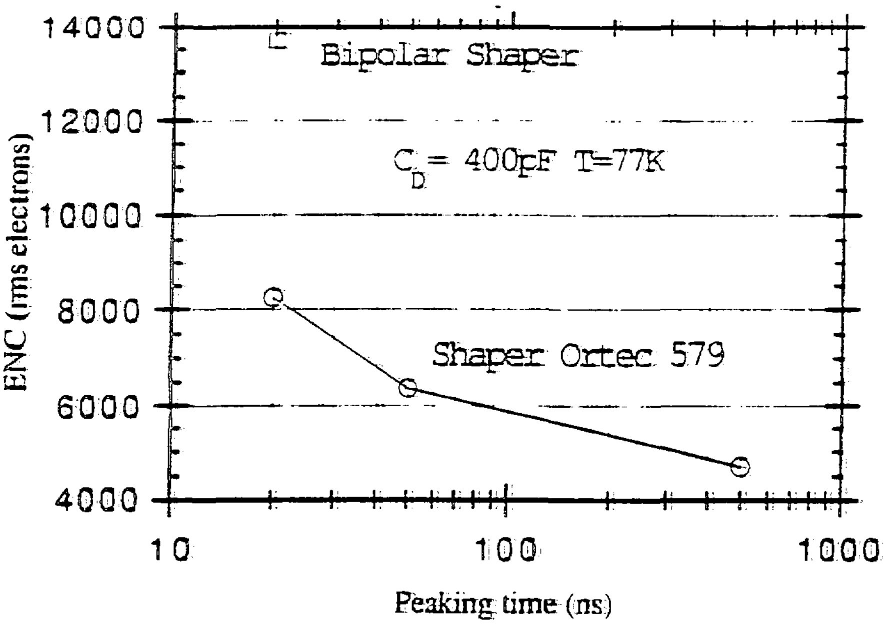

Fig. 4: ENC as a function of peaking time for two different shapers

As for the future, the Milan group intends to realize a monolithic version of a GaAs charge preamplifier in a rad-hard process. The semi-insulating characteristic of GaAs substrates make the problem of device isolation simpler. So far, a charge preamplifier based on a monolithic array of MESFETs have been successfully tested.

D. DiBitonto (University of Alabama) presented a monolithic preamplifier based on a transimpedance configuration. The circuit was built in a GaAs rad-hard technology with a radiation hardness of more than 100 GGy (1 Grad) and 10^{16} N/cm^{2} for 5% variation of static parameters as measured by the manufacturer. Data on radiation hardness with respect to noise are being measured. The circuit is described in a separate article in these proceedings.

4. Front End Electronics

M. Levi (LBL) described the proposed front-end electronics system for the scintillating tile calorimeter of the SDC (Solenoidal Detector Collaboration) experiment at the SSC.

The key component of the system is a sixteen channel analog waveform sampler with 256 cells per channel able to operate at the 60 MHz sampling rate synchronized with the SSC clock. Analog information is stored on capacitors and a double set of switches allows simultaneous read and write of information. An ancillary circuit, the address list processor manages the various lists of available storage cells, pending level 1, level 2 and pending readout for a number of SCAs. The system is described in these proceedings. Given the complexity and sophistication of the trigger procedures necessary at SSC/LHC a second line of though advocates digital font end electronics and trigger system.[5]

N. Yamdagni (University of Stockholm) described a digital front end system (Front End Readout Microsystem: Fermi) and trigger level 1 and 2. Figure 5 shows a block diagram of the system. The key requirements are summarized in Table 3.

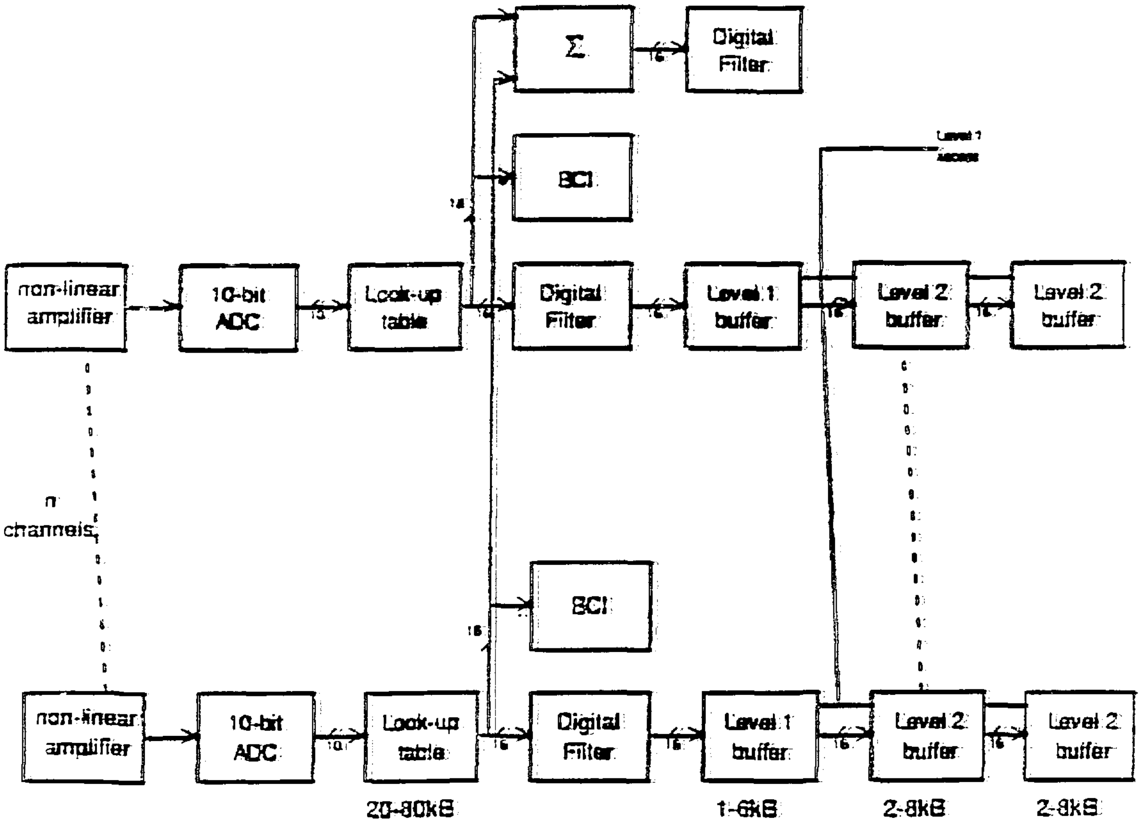

Fig. 5: Block diagram of the proposed Front End Readout Microsystem (FERMI).

Table 3: FERMI Data Acquisition Requirements (DA)

1.	Multiple (probably 9) parallel data channels
2.	15 ns/sample
3.	15 bit dynamic range, compressed to 10 bits by a nonlinear amplifier, then expanded to 15 bits by a look-up table after digitization
4.	Digital filtering of signals
5.	Sum output for first level trigger
6.	Event recognition
7.	On module level 1 and level 2 data storage
8.	No data loss for fixed level 1 processing time
9.	Low power consumption
10.	Fault tolerance

Particularly interesting in calorimetry is the idea of using a non-linear front-end stage which may allow handling of the wide dynamic range (from about 50 MeV noise level up to events in the few TeV range) with only one electronic channel instead of a split-range system as for example proposed in SDC.

5. Miscellaneous Devices and Circuits

W. Wallraff (RWTH, Aachen) reported on radiation damage tests and GaAs diodes. After 100 Mrad irradiation with 3 MeV electrons the reverse leakage current at -100 V bias increased from 100 nA to 450 nA and the pulse height from alpha particles decreased to about 50%. Neutron damage studies are under way.

J. M. Seixas (CERN) presented a novel technique for electron identification in a lead-scintillating fiber calorimeter based on the different time width of electron and pion signals. This technique is capable of providing a very fast trigger (response time about 50 ns) for electrons. The technique is described in detail in these proceedings.

L. Knudsen (CERN) described a small tungsten calorimeter built for beam monitoring purposes at CERN which makes use of advanced digital signal processing techniques.

6. Acknowledgements

The author wishes to thank all the participants in the session (too numerous to mention) for the friendly discussions which made the session most interesting and informative. A special thanks goes to the organizers of the conference and in particular to the chairman, A. Ereditato.

7. References

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