Search for 2γ events on DELTA

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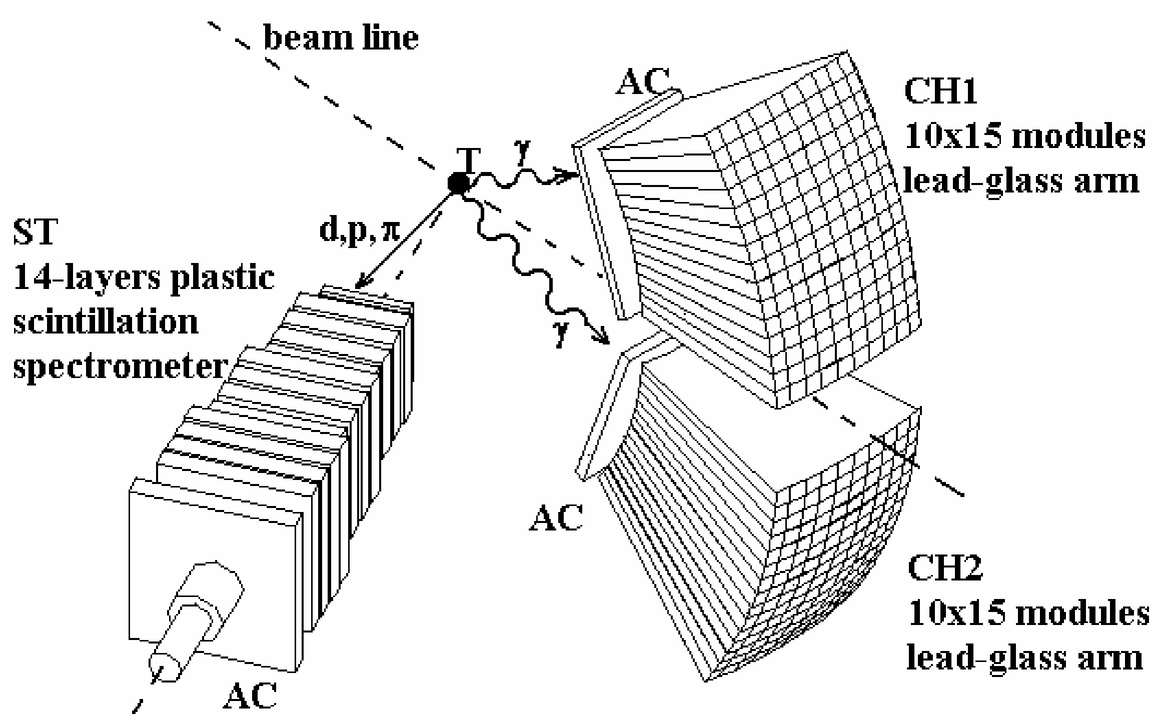
Round table discussion
JINR, Dubna, July 7 – 9, 2005

To study neutral meson production at LHE JINR NUCLOTRON, the DELTA -spectrometer has been designed and completely assembled. The setup ensures a high-resolution and high-aperture detection of π^0- and η - mesons for an energy of 100 MeV (for π^0) or 30-40 MeV (for η) and above. There is the following main unit: a 300 - channel γ,e-Cherenkov spectrometer consisting of two blocks each based on 150 lead-glass prisms.

Schematic View of DELTA Detector Positions



The spectrometer is designed to determine energies and exit angles of π^0 and η meson coming from the studied target. The used experimental method consists in detecting two energetic photons, emitted in the decay of a neutral meson (a 99% probability for π^0 and 39% for η), in an array of Cherenkov lead-glass detectors. The energies of photons emitted in the decay are of the order of $(m_0+T_{kin})/2$ increasing with increasing particle kinetic energy. The photons tend to cluster about a laboratory opening angle $\theta_{12} = 2\cdot\times\arcsin(m/E)$. This is merely due to "piling up" the spherical phase-space distribution of the photons in the decaying particle rest frame when transforming to laboratory coordinates. As the orientation of the photons in the meson rest frame is uncorrelated with the meson laboratory velocity, the observed γ-γ opening angle for a given energy of particles is greater than or equal to θ_{12}.

If θ is the laboratory opening angle between the two decay photons and E_1,E_2 are the laboratory photon energies, the mass m and total neutral meson energy E are:

$$\mathbf{m = 2 \times \sin(\theta/2) \times \sqrt{E_1 \times E_2};}$$

$$\mathbf{E = \sqrt{\frac{2m^2}{(1-\cos\theta)(1-X^2)}};} \qquad \mathbf{X = \frac{E_1 - E_2}{E_1 + E_2}}$$

where X is the asymmetry parameter of γ-quanta energies.

In this case, the two photon energies are nearly equal, X^2 is small, and the measurement of α with a good resolution can yield a good resolution for the total meson energy E.

The shoulders of the spectrometer (CH1 and CH2) are two blocks. The blocks are built up from glass prisms made of F8-type Pb-glass with PbO 45% additions (see Table 3). The number of cells in each block is 150 (10 along the horizontal line and 15 along the vertical line). Each prism is shaped as a cut pyramid 400 mm high, that is 12 rad. Lengths. Its size is (36*36) mm^2 at the bottom and (22*22) mm^2 at the top. Each cell is viewed by a 34-mm FEU-84-3 photomultiplier tube.

Table 1. F-8 and SF2 type Pb-glass main characteristics.

Type	F8 (Russia)	SF2 (USA)
%PbO	45	50.8
Radiation length, X_0, cm	3.2	2.74
Critical energy, MeV	16	15.8
Refractive index, n	1.63	1.67
Density, ρ, g/cm^3	3.6	3.85
Transmittance, (400 nm, 10 X_0)	0.96	0.8

The new principle is that glass prisms are designed as cut pyramids with a cross dimension less than the Molier radius. This allows one to use "the center of gravity" method for avalanche coordinate measurements without γ-converters and coordinate-sensitive detectors and increases the effective solid angle of the spectrometer. The main characteristics of the glass spectrometer are presented in Table 2.

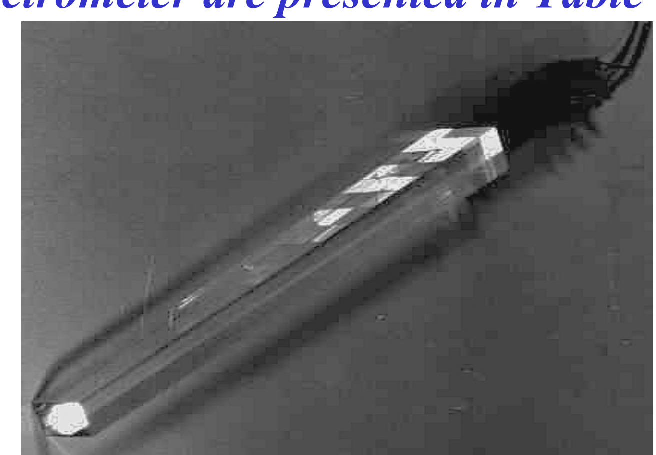


Table 2. Two-arms Pb-Glass Spectrometer

1. Number of modules:	**2 arms * 150**
2. Material:	**F8- type glass (45% PbO), light absorption <0.05%/cm**
3. Module dimensions:	**22(front)x36(end)x400 mm (12r.l.)**
4. Light yield:	$N_{ph.e.}=0.3*E_{\gamma}(MeV)$
5. γEnergy resolution (%):	$\sigma_E=1.62*(E(MeV))^{1/2}$
6. γCoordinate resolution:	$\sigma_x=\sigma_y=3$ mm (at 600 MeV)
7. Energy interval:	π^0 : 0.03 - 2 GeV η : 0.03 - 5 GeV
8. Effective accepted solid angle:	$\Delta\Omega \leq$ (8 - 12) mster (for $/X/\leq 0.3$)
9. Energy resolution (for 300 MeV π^0):	**≈(5-10) Mev (FWHM)**

The light output of the detector is the value about 0,3 photoelectrons for 1 MeV of γ-quantum input energy approximately. The approximating formula for the energy resolution for gammas looks like (numerical ratio):

$$\sigma(E)/E = 0.018 + 0.066/(E(GeV)).$$

Calibration experiment.

The work on starting up the setup in was done on a neutron beam with carbon and polyethylene targets. The detectors were preliminary calibrated using cosmic radiation particles. About 2100 coincidence events appropriate to the $np \rightarrow \pi^0 d$ reaction on the polyethylene target and about 700 events on the hydrogen target were recorded using the neutron beam with an intensity of 5×10^6 neutrons per burst and an energy 1.5 GeV. The level of random coincidence noise was of the order of 30 % of hydrogen. As an example, Fig.2 shows a spectrum of the restored values of the particle mass decaying info two gamma-quanta, with two gamma-quanta coincident in the blocks of the spectrometer. The average restored value (for 2γ events) of mass equals 130 MeV at a 15% instrument resolution.

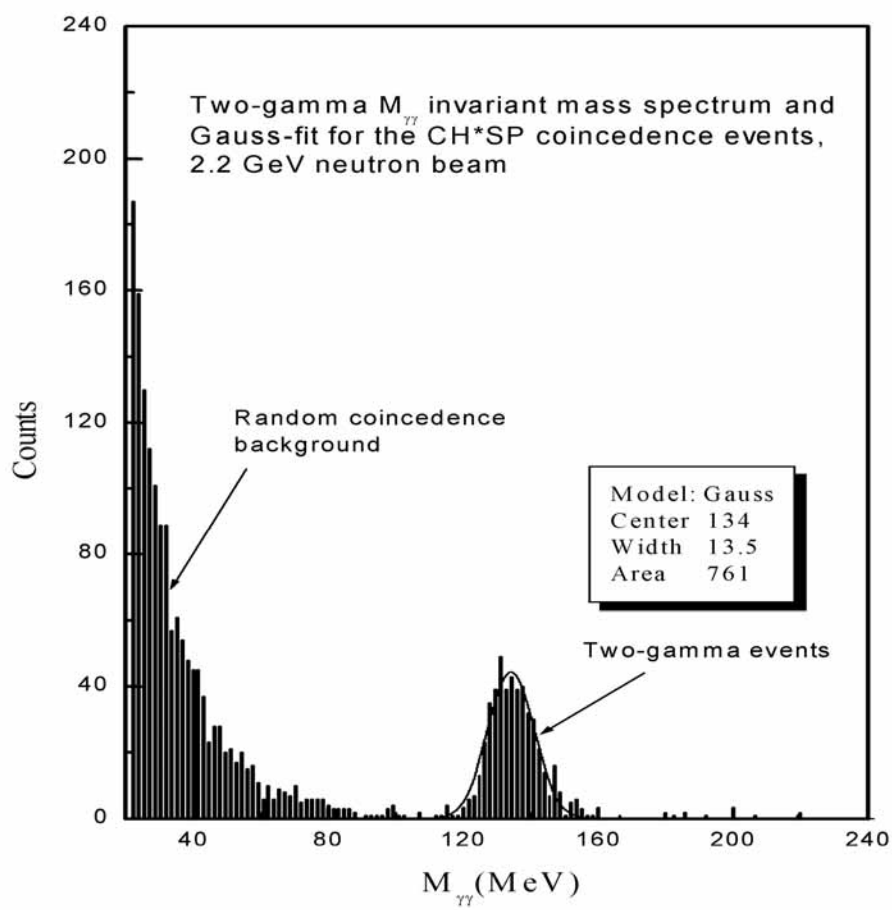
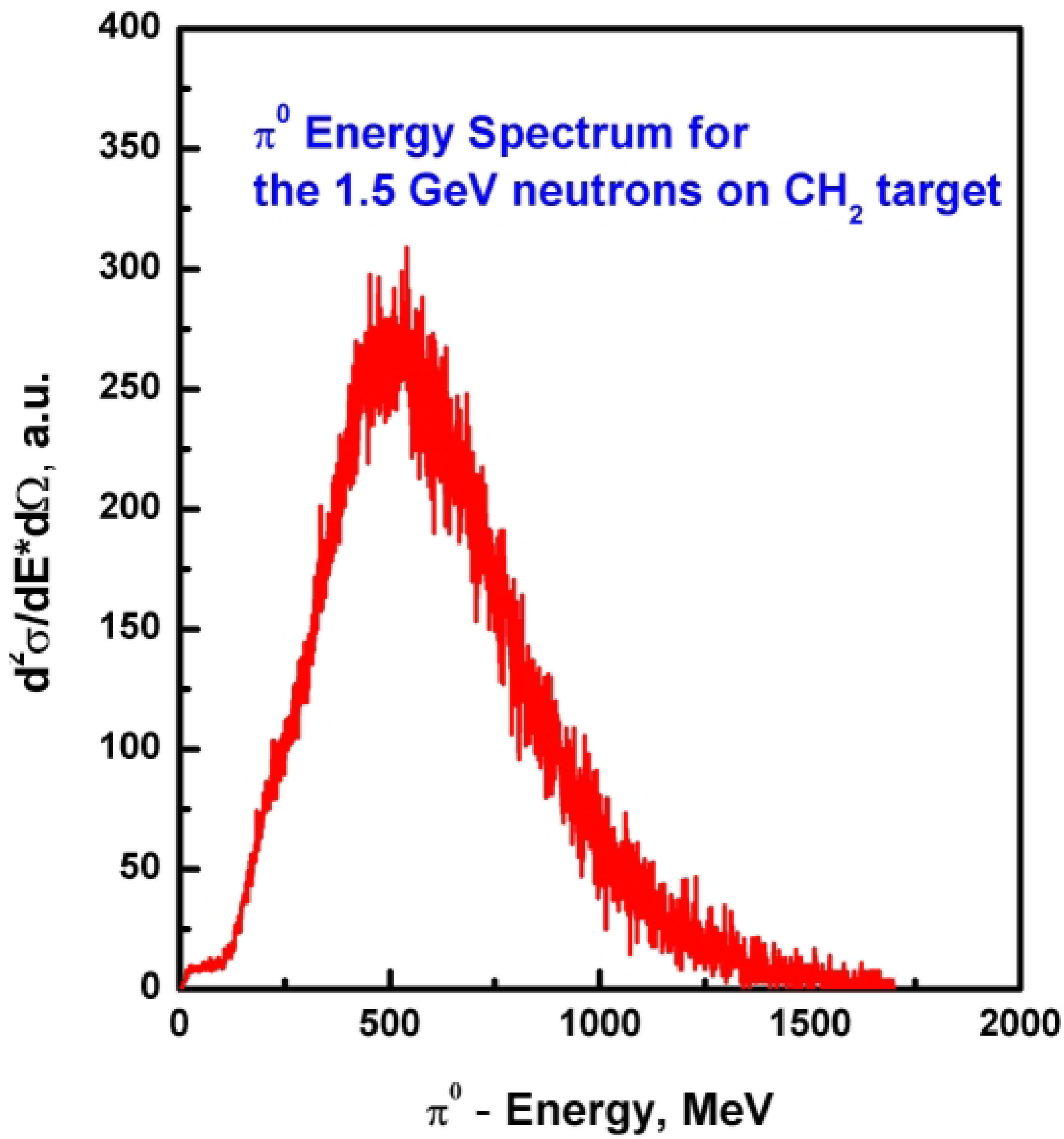
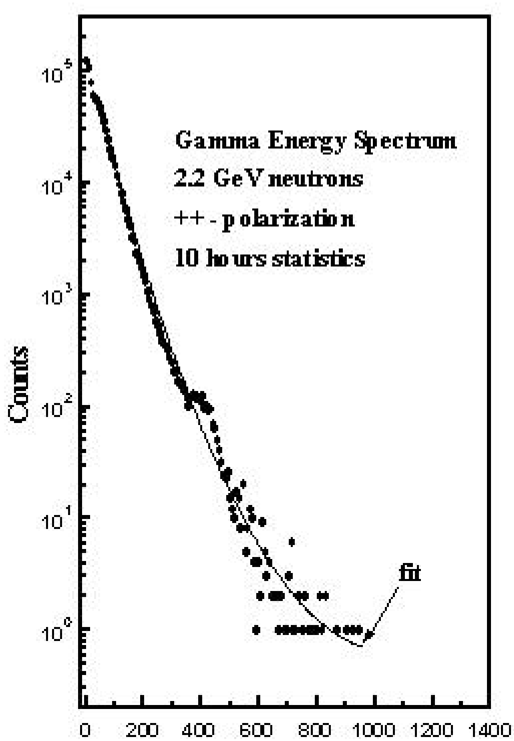


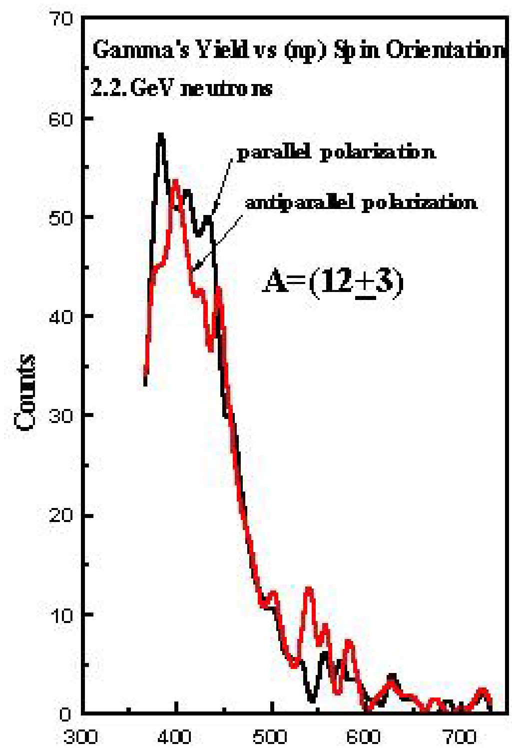
Fig.2. Reconstructed invariant mass spectrum of pions. The solid lines are the result of right peak Gaussian fitting.

Example of the π^0 energy spectrum



For the first time, the energy spectra of a single gamma-quantum with the polarized proton target and polarized neutrons beam were measured, in an dependence from initial polarization direction of nucleons, with at 2.2. GeV neutron beam energy and 8^0 average gammas angle. The preliminary results have shown availability of effect (relative difference of an exit at different directions of mutual polarization) at gamma-quantum energies close 400 MeV, at a level 12 % at a statistical exactitude of measurements ±3%. For the analysis of detected effect the further measurements are planned. On Fig.3, as an example, the spectrum a gamma quantum at parallel orientation of spins and 2,2 GeV neutron energy is shown. A total number of events in a spectrum is about $4{,}7\times 10^5$ for 10 hours of measurements. It is clearly visible an amplification of an gamma – quantum exit at 400 MeV gamma energies. The relative difference of an exit, after statistic normalization (in %), is shown on Fig 3.

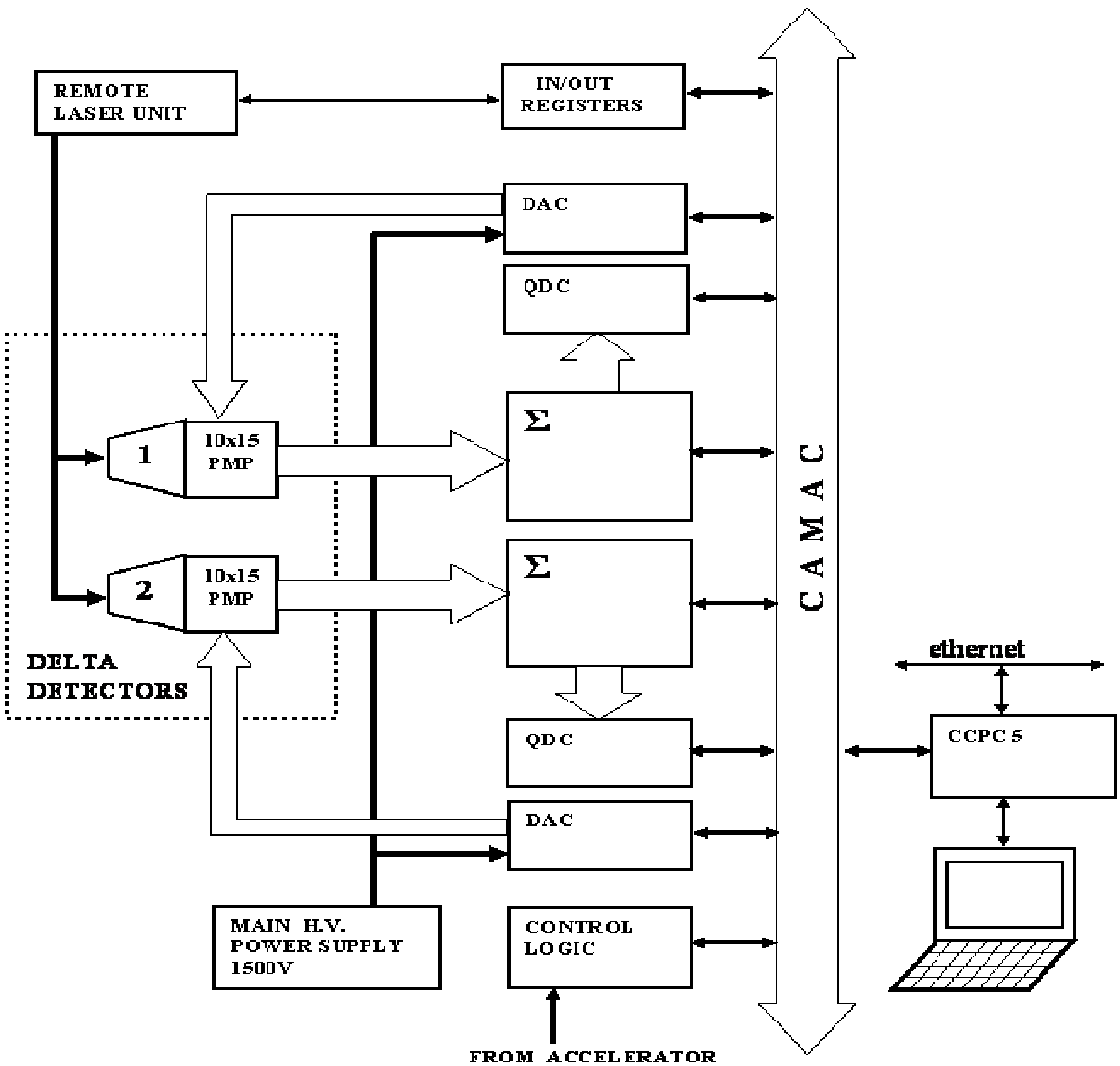




Data acquisition electronics

http://www.fu.sav.sk/nph/projects/Calib/

The same configuration of CAMAC electronic modules is used for calibration process as for measurement. The principle block diagram is on the following picture:



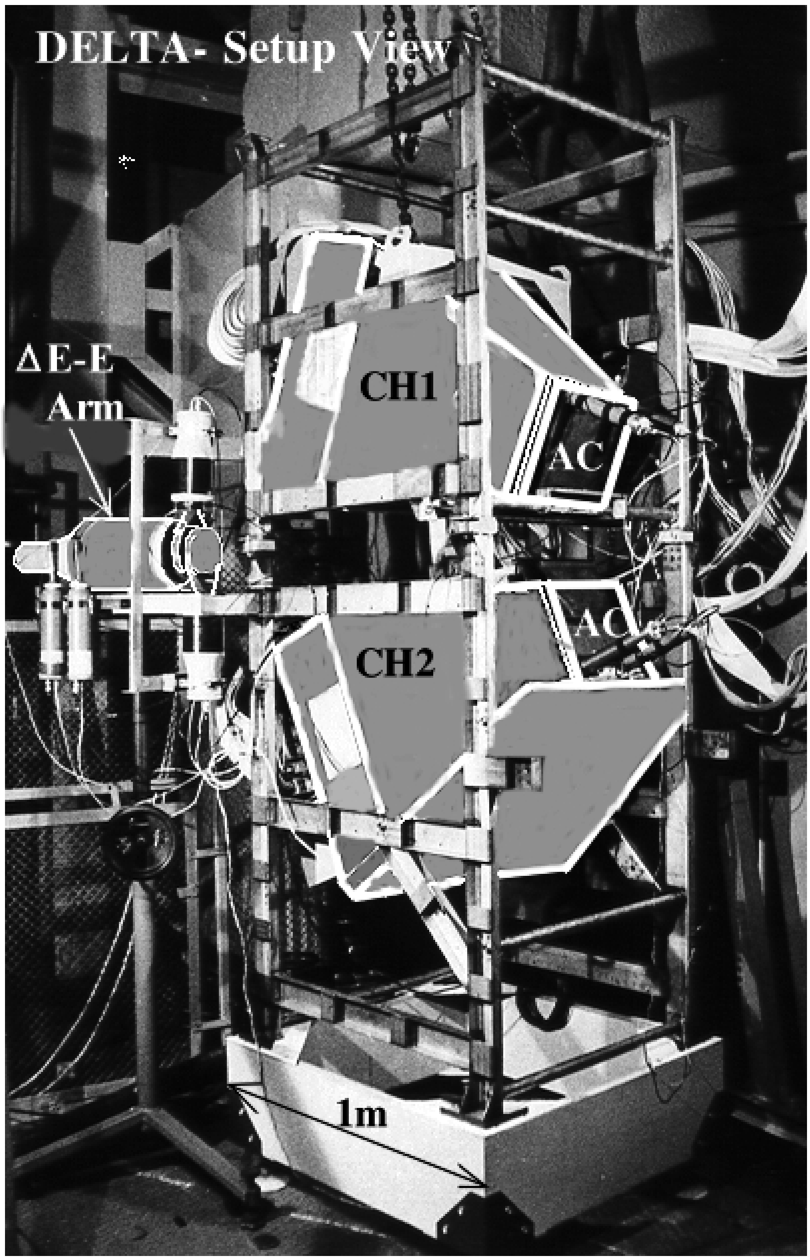
The data acquisition is organized by the intelligent CAMAC crate controller of type CCPC5 containing PC compatible computer. The whole data acquisition system consists of 4 CAMAC crates (EUR4100) organized in a branch. The crate 0 is controlled by the CCPC5 and contains branch driver. The other crates are connected via standard branch (EUR 4600) using the crate controller of type A1. The functional user modules placed in crates are described in brief in Appendices.

The pulses from PMP are led to analogue Summators. They are organized such that they allow to work with whole rows or columns summed or with pulses from individual PMP on the output. The control program switches the summators to the desired mode. The pulses from summators are led to QDC.

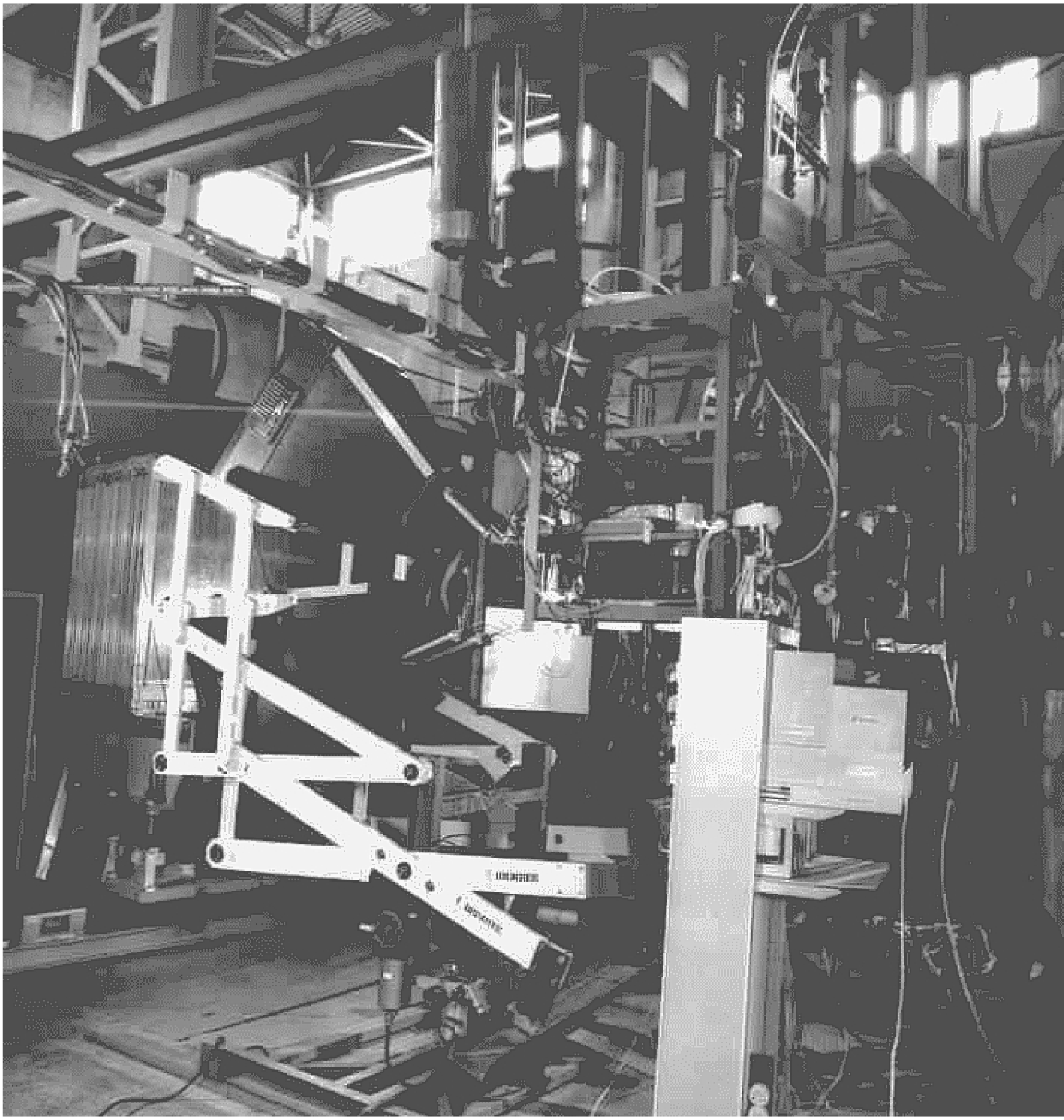
The work of acquisition subsystem is triggered by the signals from laser and from the accelerator. These signals are processed in logical modules and led to CAMAC input or output register.

The data from QDC are used for computing the correction codes for DACs which set up the high voltage. The role of this is to set the optimal working mode for photomultipliers and ensure the maximum stability during the experiments.

A general view of DELTA installation for use at the polarized proton target in 205 LHE hall.



A general view of DELTA installation for use at the external beam in 205 LHE hall.



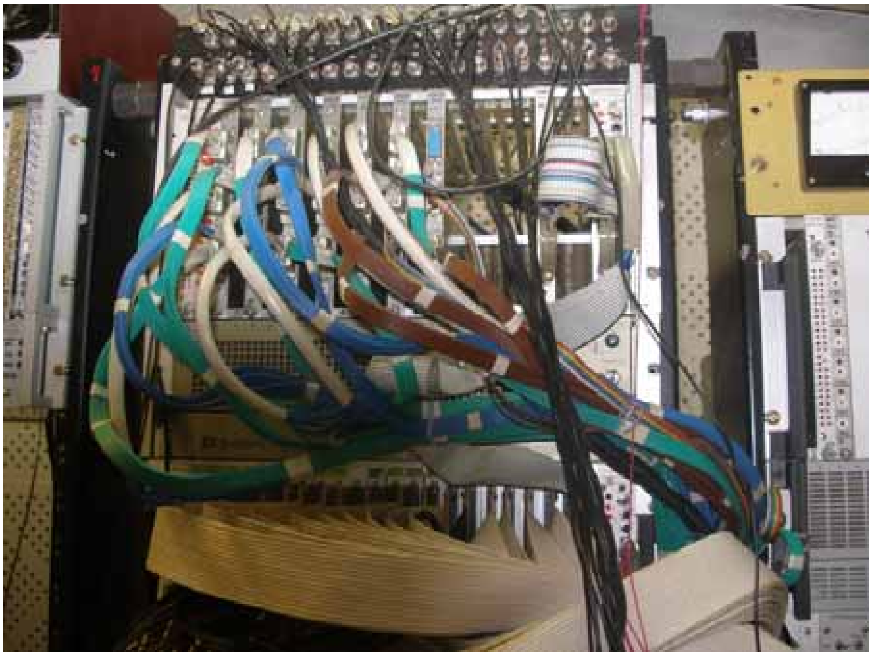
DELTA mechanical frame for use at external nuclear NUCLOTRON beams

DELTA control room electronics

DELTA Lazer calibration design

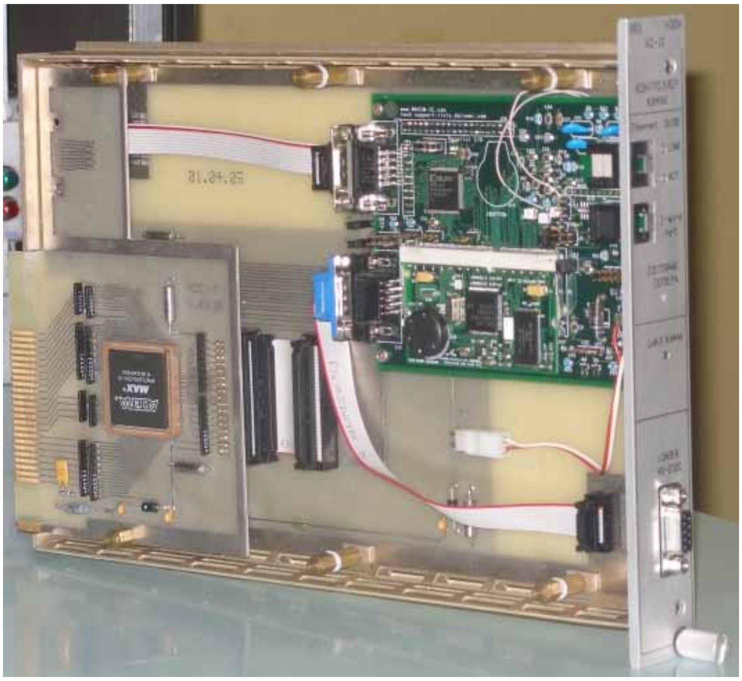
DELTA electronics examples

DELTA HV control Crate



DELTA QDC Crate

DELTA new electronics designs



KC-10 Ethernet CAMAC Controller

- **Full CAMAC Bus Control**
- **Ethernet 10/100 Base – T**
- **TCP/IPv4, TCP/IPv6**
- **Telnet, FTP, HTTP**
- **100 KB/sec**
- **TINI OS**
- **JAVA Language**
- **CAMAC 2M module**

16 – channel fast QDC

- **16 inputs, 50Ω, 0 to –2 V**
- **512 pC, 10 bits + 1bit**
- **30 nsec – 500 nsec gate**
- **700 nsec convers. Time**
- **CAMAC 1M module**

The estimate of expenditures under the design
For nearest future

The name of expenditures	cost	1 y.	2 y.	3 y.
The direct expenditures on the design NUCLOTRON hours DAQ and COMPUTING Work-shop hours		36		
Total direct expenditures				