Pulse-shape discrimination in NE213 liquid scintillator detectors

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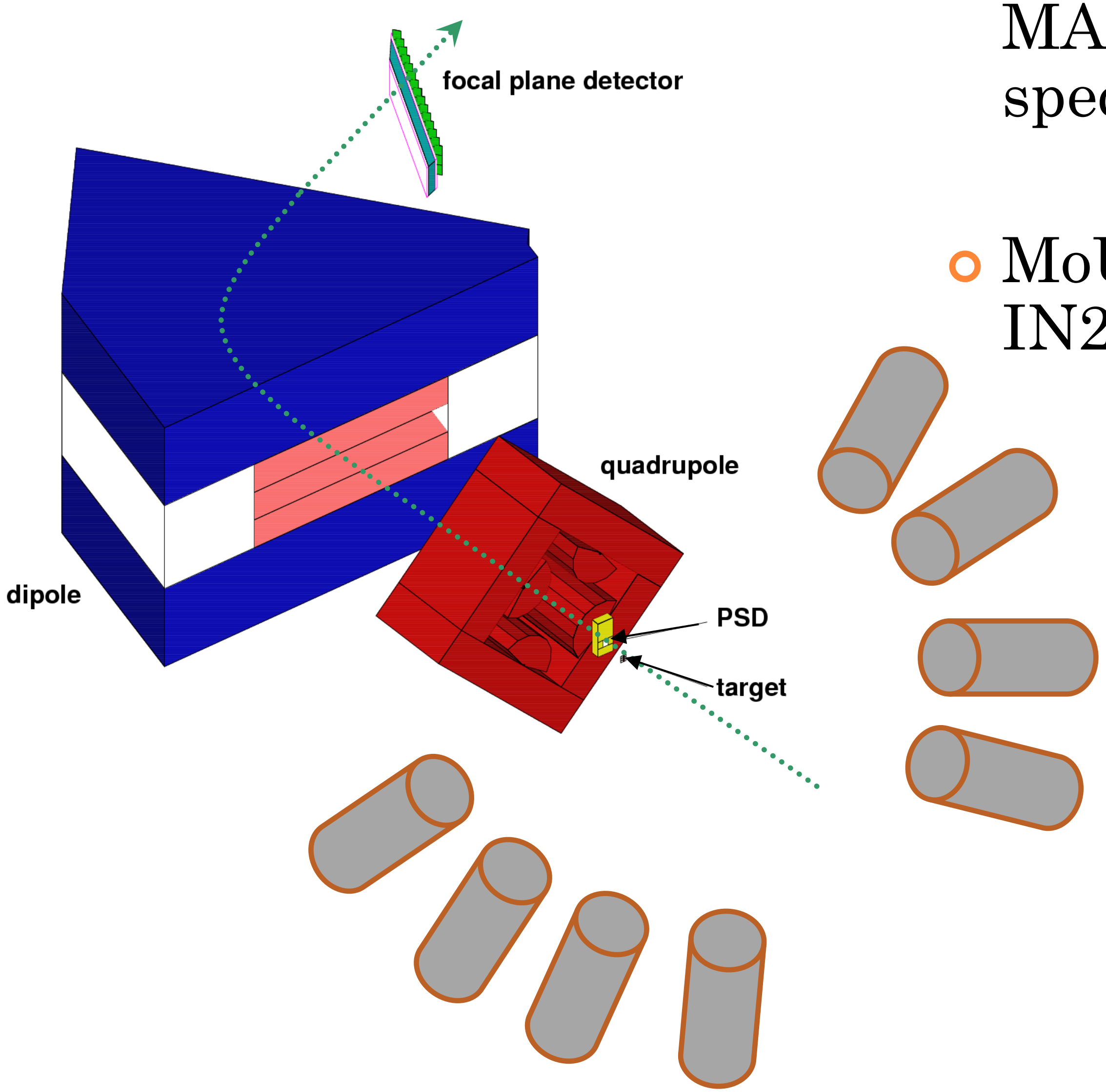
- Neutron-gamma discrimination in liquid scintillators
- Techniques based on the properties of most of the scintillator materials that exhibits a light pulse-shape characteristic of the ionizing radiation
- Wide dynamic range and low threshold → High neutron detection efficiency

MAGNEX + EDEN

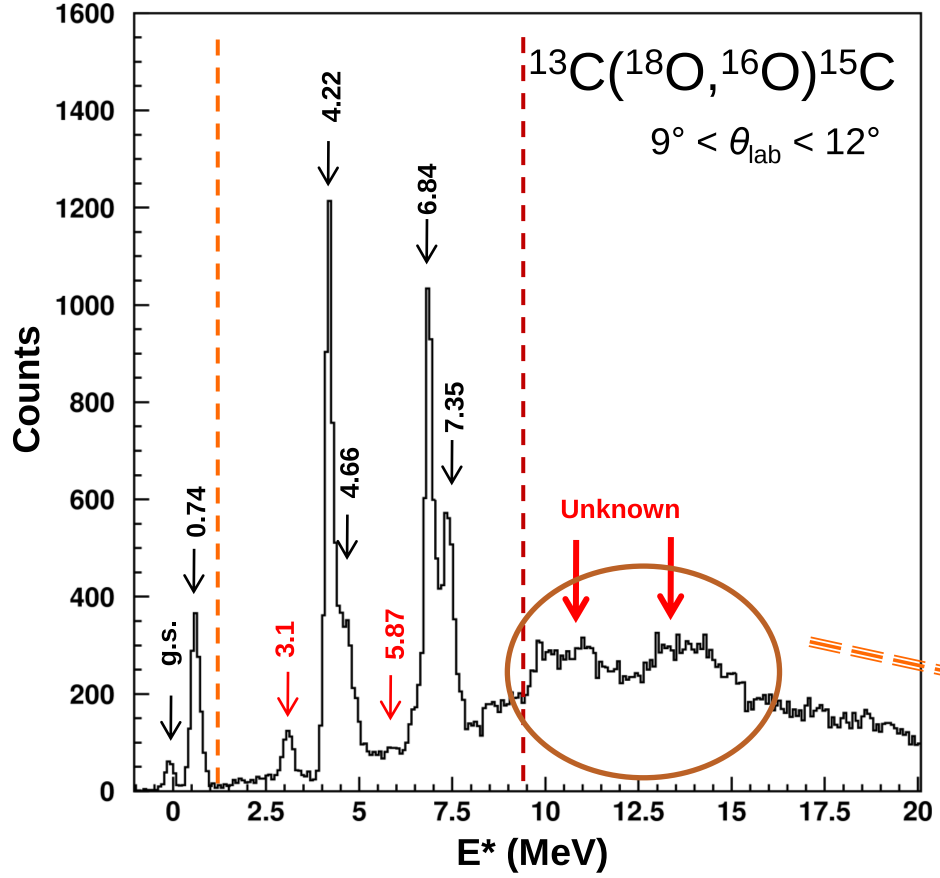


- In 2010 the EDEN neutron detector array was transferred at LNS to be coupled with the MAGNEX magnetic spectrometer.
- MoU between INFN and IN2P3-IPNO

MAGNEX to measure high resolution energy spectra for well identified reaction products
EDEN to study the decaying neutrons emitted by the observed resonances with good efficiency and energy resolution

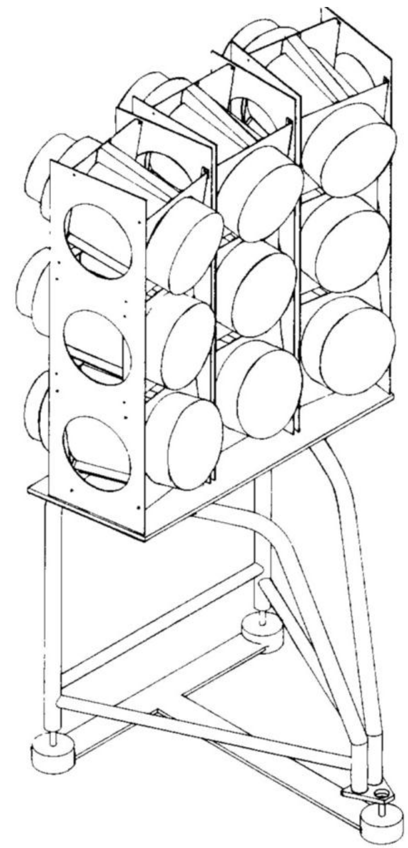
Unique facility to study the resonant states of neutron rich nuclei (low separation energy)

^{15}C ENERGY SPECTRUM



---- S_n = 1.2 MeV

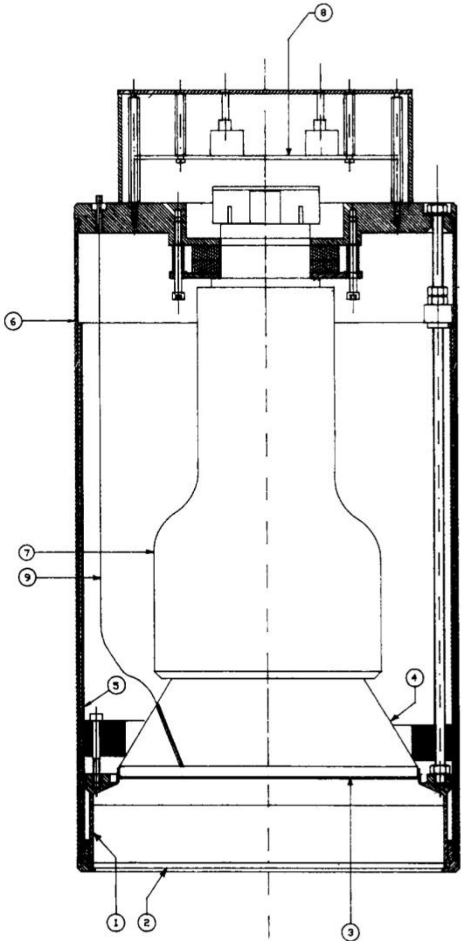
---- S_{2n} = 9.4 MeV



MAGNEX spectrum

The EDEN neutron multidetector

H. Laurent et al., NIM A326 (1993) 417-525



❖ 40 liquid scintillator detectors (NE213)

❖The cells are cylindrical, 5 cm thick with 20 cm diameter

❖ Possibility of n - γ discrimination by pulse shape analysis

❖ Energy measurement by TOF with Time resolution of 0.9 ns

❖ Typical energy resolution at a 1.7 m distance from the target: 60 keV for 850 keV neutrons and 500 keV for 6 MeV neutrons

❖ Intrinsic efficiency ~ 50% for 1 MeV and 30% for 6 MeV neutrons

❖ Mechanical assembly easily configurable for different experimental requirements

❖Old CAMAC electronics (QDC, GDG, CFD)

Our approach

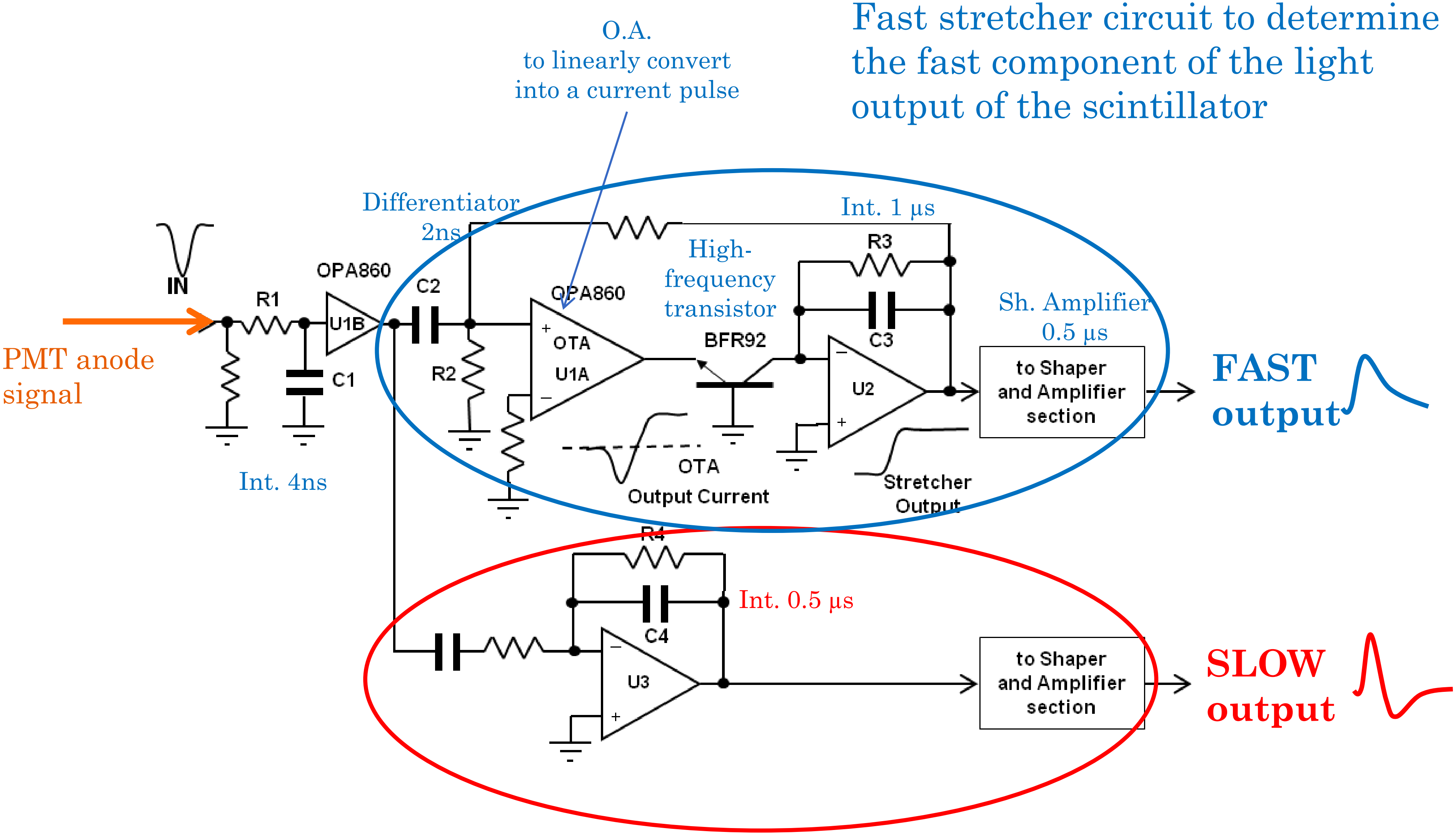
Modified BaFPro - **INFN-Milano**

Originally studied and developed for processing signals of BaF_2 and $LaBr_3$

C. Boiano, et al., IEEE Trans. on Nucl. Science NS53 (2006) 444.
C. Boiano, et al., IEEE Trans. on Nucl. Science Conf. Rec.N30 (2008) 2068.

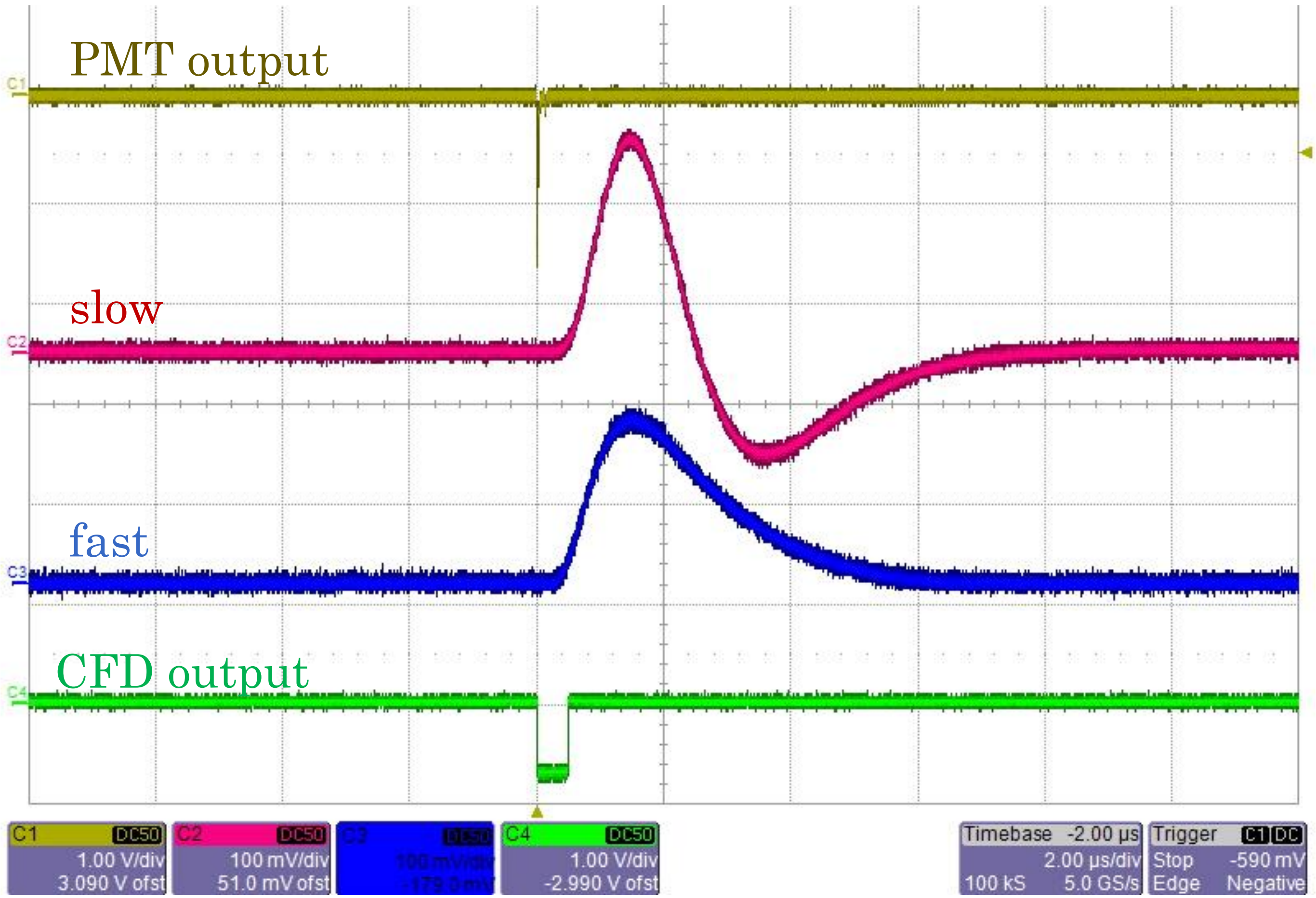
16-channels NIM module producing two Gaussian signals whose amplitudes are proportional to the fast component of the light and to the total energy deposited into the scintillator.

Fast stretcher circuit to determine the fast component of the light output of the scintillator

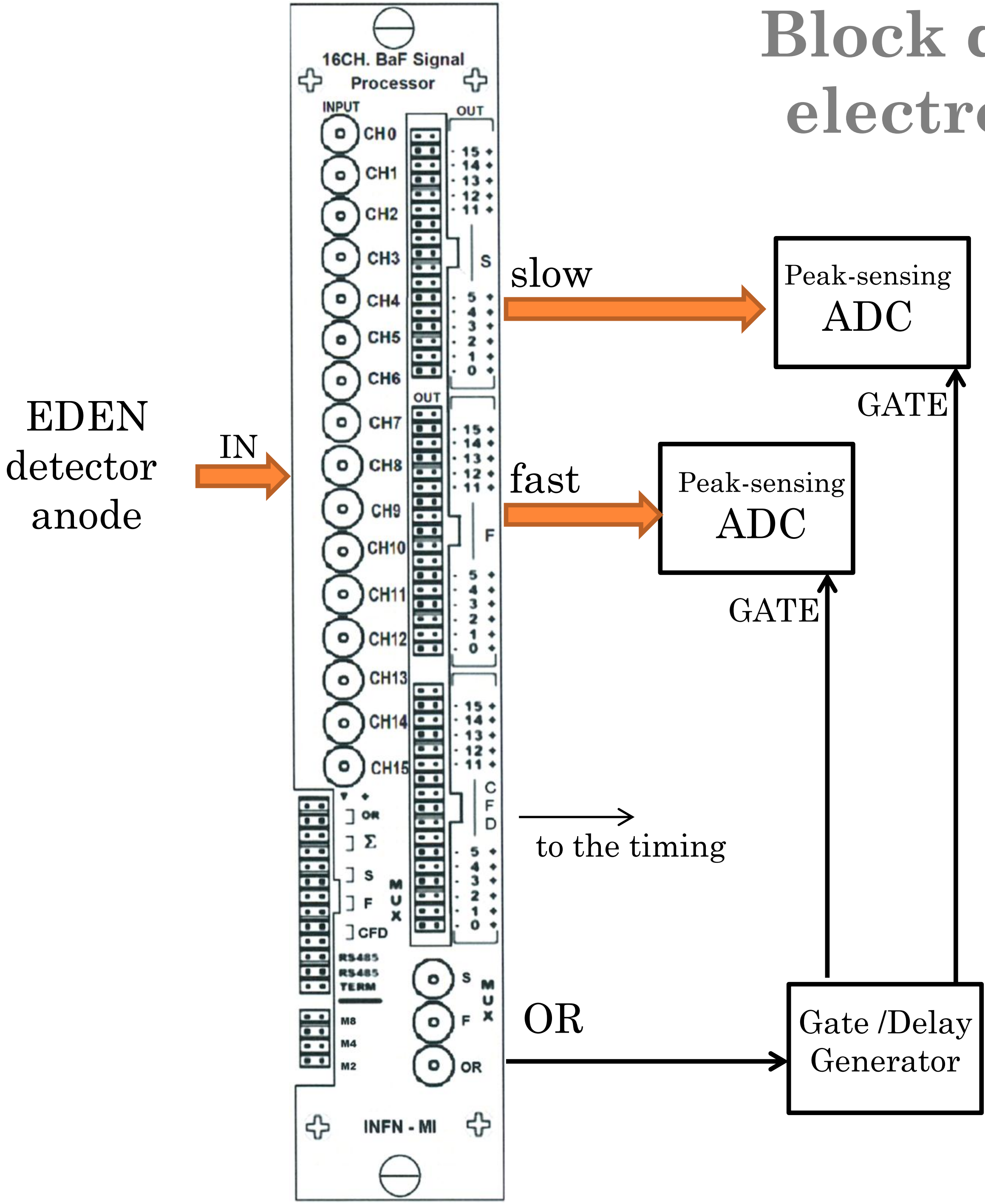


Integration section
providing the total energy

Typical pulse shapes



Block diagram of the electronics for PSD



Dynamic range

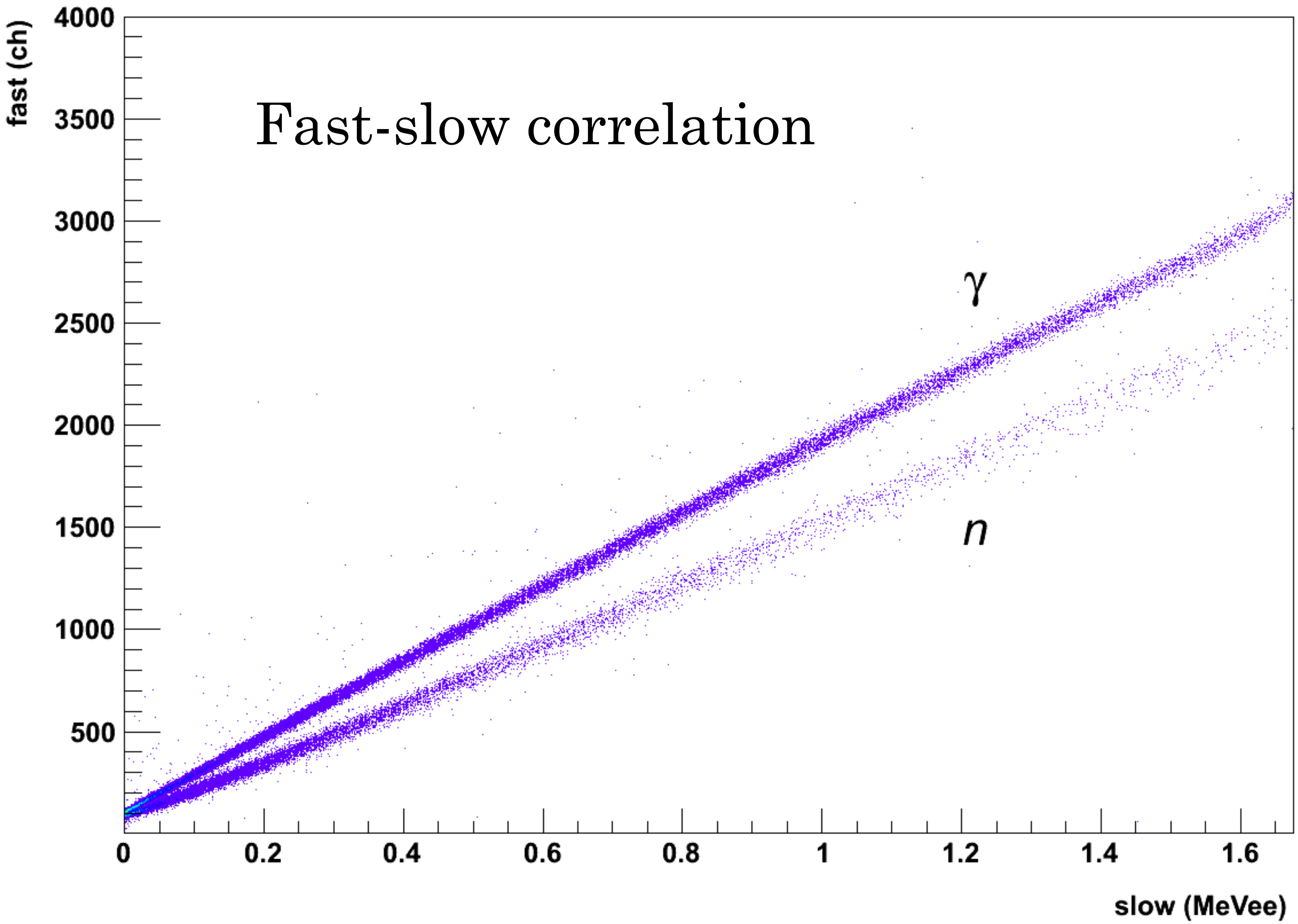
- Wide dynamic range necessary to increase the neutron detection efficiency
- Extension of the max working amplitude from 2 V to 4 V and the introduction of 4 ns integration before the stretcher
- Dynamic range 200-1 (4 V - 20 mV)

In-beam test

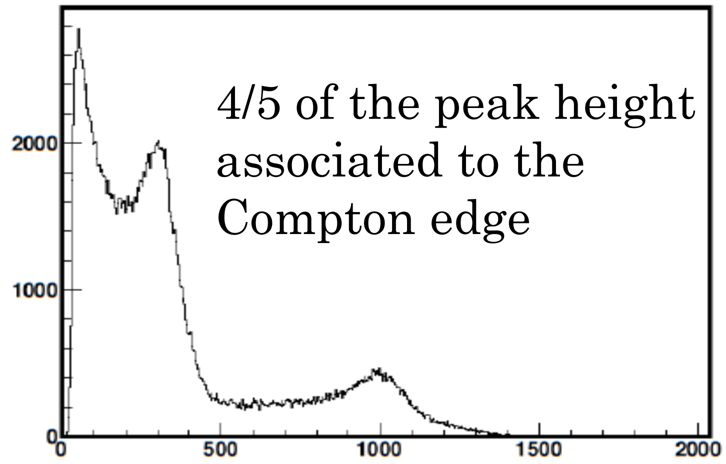
$^{12}C(^{18}O\ ,^{17}O\ n)\ ^{12}C$ at 84 MeV

EDEN at 1.9m–2.4m from the target

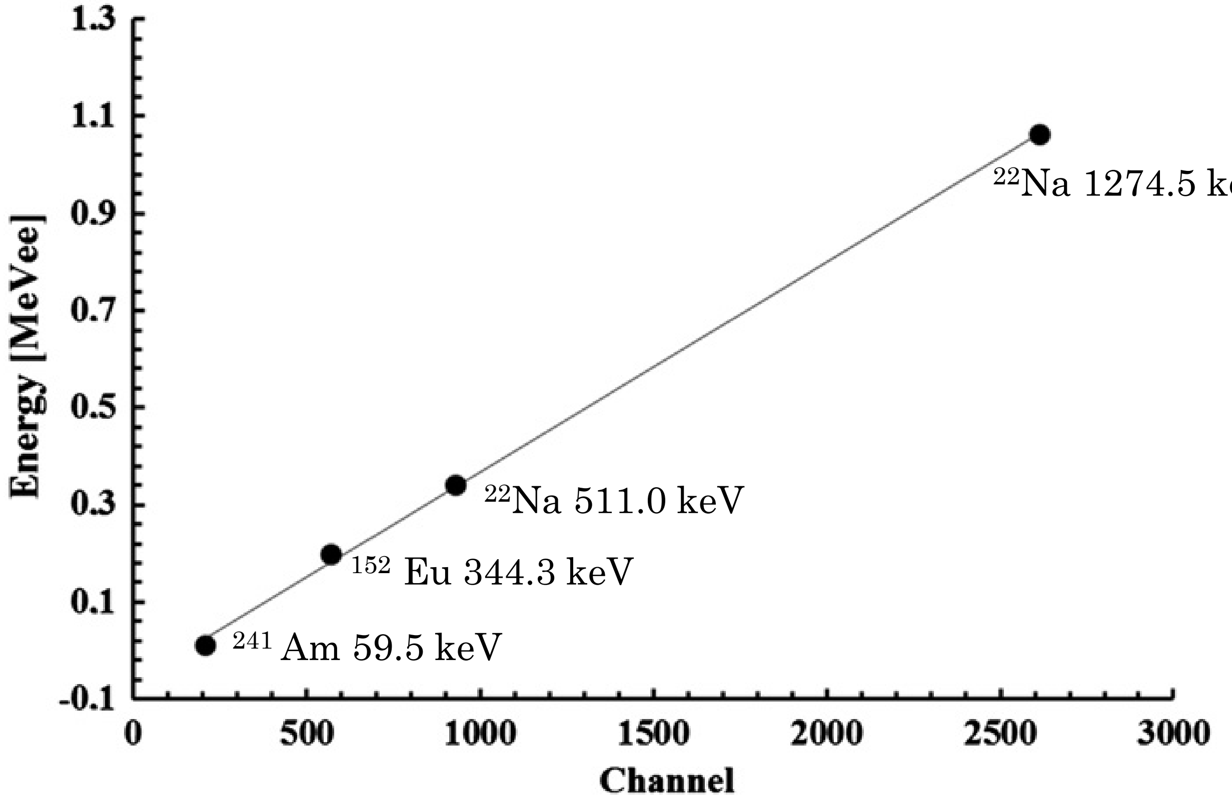
-59°<θ<-71° and +103°<θ<+146°



Gamma-source calibration



4/5 of the peak height associated to the Compton edge



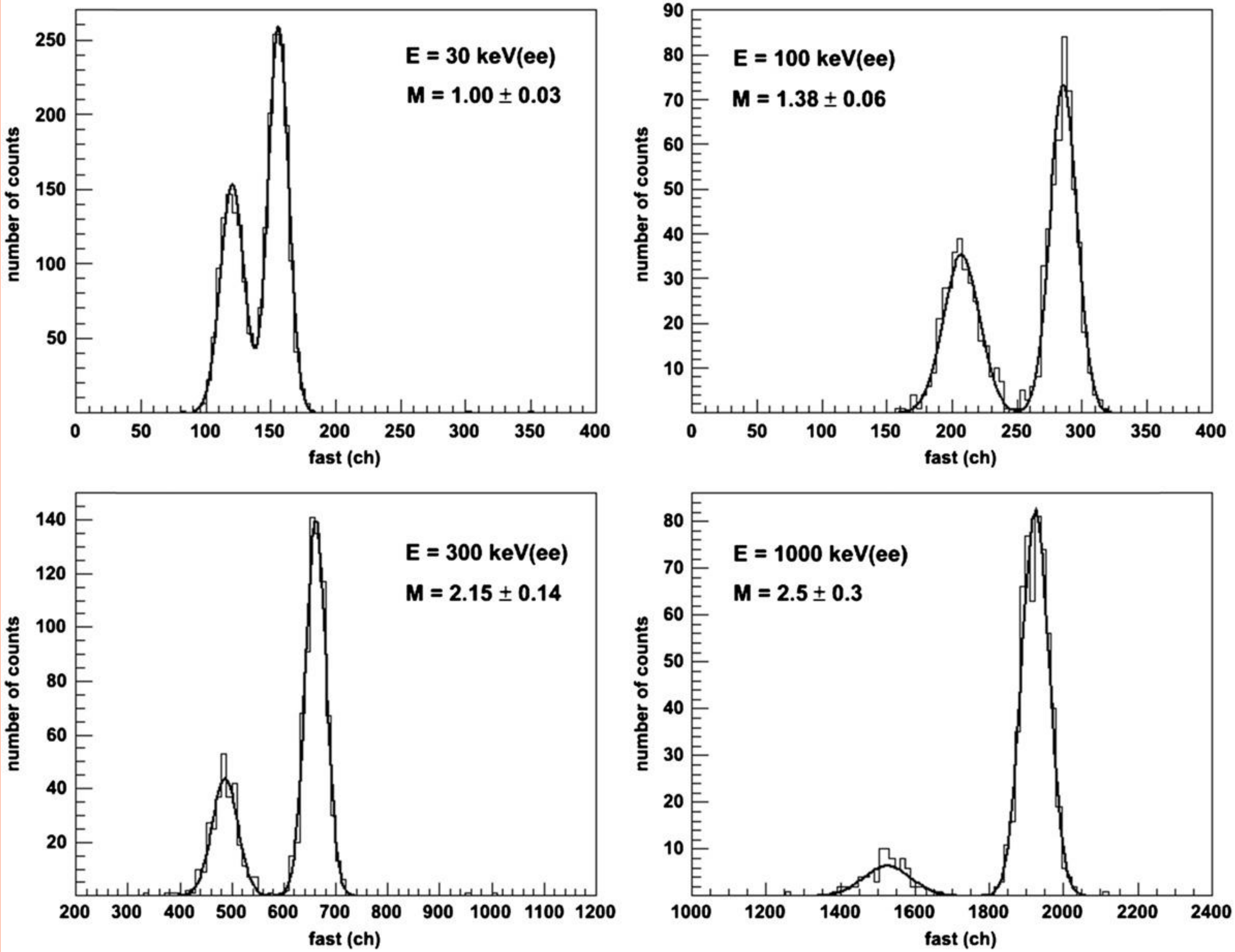
20 keV accuracy

DISCRIMINATION SPECTRA

Figure of merit:

$$M = \frac{\Delta P}{W_1 + W_2}$$

M. Cavallaro, et al., NIM A 700 (2013) 65-69



Comparison with the old electronics

Energy (keVee)	Interval width (keVee)	M M. Cavallaro et al. (2013)	M H. Laurent et al. (1993)
30	5	1.00 ± 0.03	-
100	5	1.38 ± 0.06	1.00 ± 0.03
200	10	1.92 ± 0.08	1.46 ± 0.03
300	20	2.15 ± 0.14	1.72 ± 0.04
1000	50	2.5 ± 0.3	2.12 ± 0.05

- The maximum of the PMT signal is captured, event by event. There the information of n-γ discrimination is more evident
- The use of gate signals of fixed width is avoided. The influence of time walk and jitter is minimized (compared to charge-integration method).

Collaboration

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Thank you