NEDA: DETECTING NEUTRONS IN EXPERIMENTS WITH EXOTIC NUCLEI

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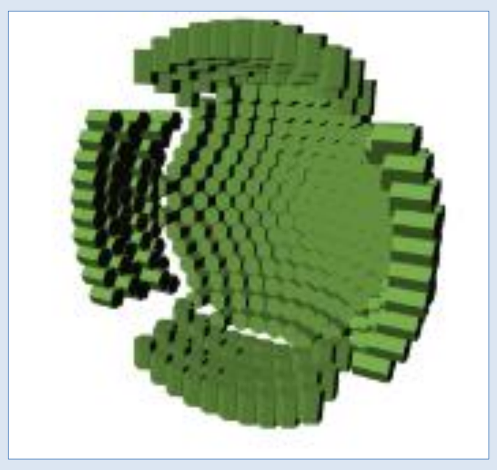
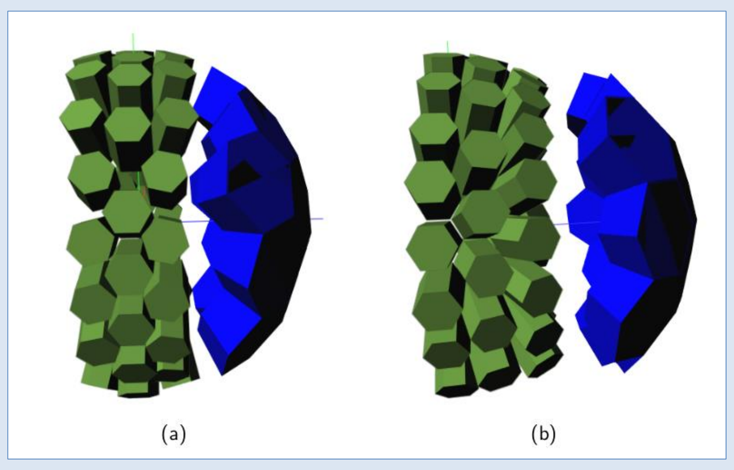
SCIENTIFICAL MOTIVATIONS

Exotic nuclei are expected to unveil new information on nuclear structure and new facilities for their production and study are being build worldwide. Production rates are however several order of magnitude smaller than the ones of stable nuclei. Consequently, the radiation detection arrays to be used in nuclear reaction experiments must be improved on the efficiency performance side. In reactions involving exotic nuclei beams, the neutron channel is very important, especially in the case of neutron rich nuclei. To increase the neutron detection efficiency, the new array NEDA was designed and is under development by an international collaboration consisting in researchers from eight European countries and more then ten institutes. With its relatively higher neutron multiplicity detection efficiency compared to the existing *Neutron Wall*, NEDA will be used in forefront experiments at European accelerator facilities such as the soon to be SPES at LNL.

THE ARRAY AND THE BASE UNIT

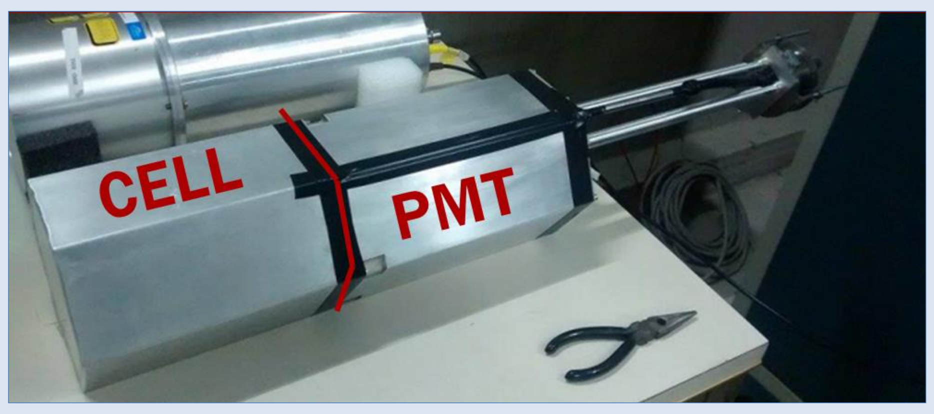




Configuration	Granlarity	Solid angle [sr]	Avr. unit vol. [liter]	Total vol. [liter]	Dist. to target [m]
NEDA 2π	331	1.87π	3.23	1065	1.0
Neutron Wall	50	$\sim 1\pi$	2.92	146	0.51
Neutron Wall+NEDA (a)	96	1.85π	3.23	294	0.51
Neutron Wall+NEDA (b)	100	1.32π	3.23	307	0.75 ; 0.51

NEDA detector unit it's made by a cell with the shape of a uniform **hexagonal prism**, filled with a **Xilene based liquid scintillator** and coupled to a PTM by a glass window. The dimensions of the cell were established through GEANT4 Monte Carlo simulations [1]. The dimensions maximize neutron detection efficiency and minimize light attenuation and loss.

The final array configuration, chosen on the basis of performance simulations, will cover a **2 π solid angle**. In the near future the first produced detector units (~50) will be coupled with the *Neutron Wall* array.



Length	$20\,cm$
Hex. side	$8.1\,cm$
Window diam.	5"
Walls thickness	$3\,mm$
Scintillator	$BC501A$
PMT	$Hamamatsu\ R11833-100$
Voltage Divider	Hamamatsu custom made

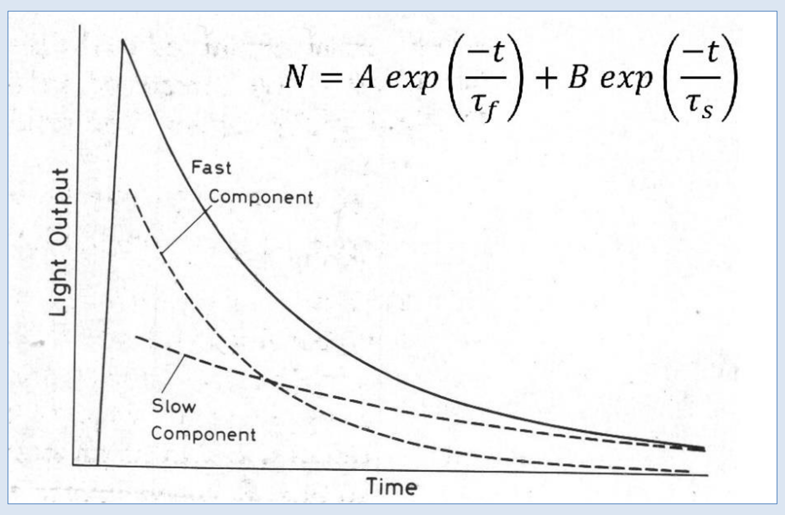
DETECTION AND DISCRIMINATION

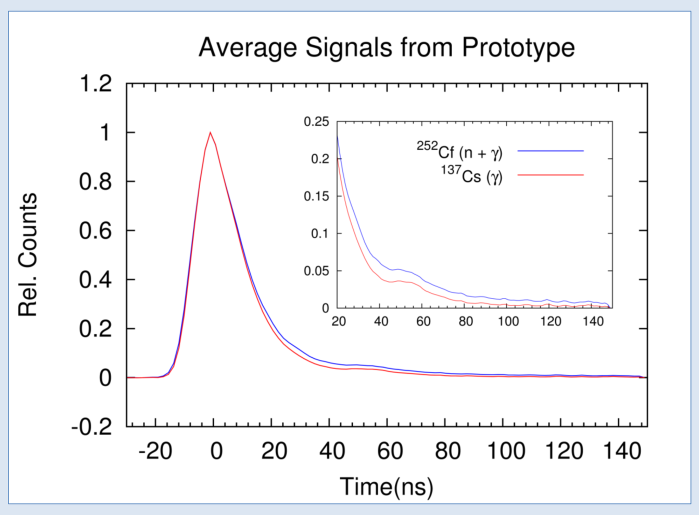
A + B → C*→ER + n + γ + l.c.p.

Exotic nuclei are usually produced in fusion-evaporation reactions that give rise to neutrons, gamma rays and light charged particles. When struck by radiation, the scintillator emits light and due to its physical and chemical nature, the light output differs according to the kind of the radiation detected.

The light output has two components: **fluorescent light** (prompt emitted) and **phosphorescence light** (slowly emitted). [2]

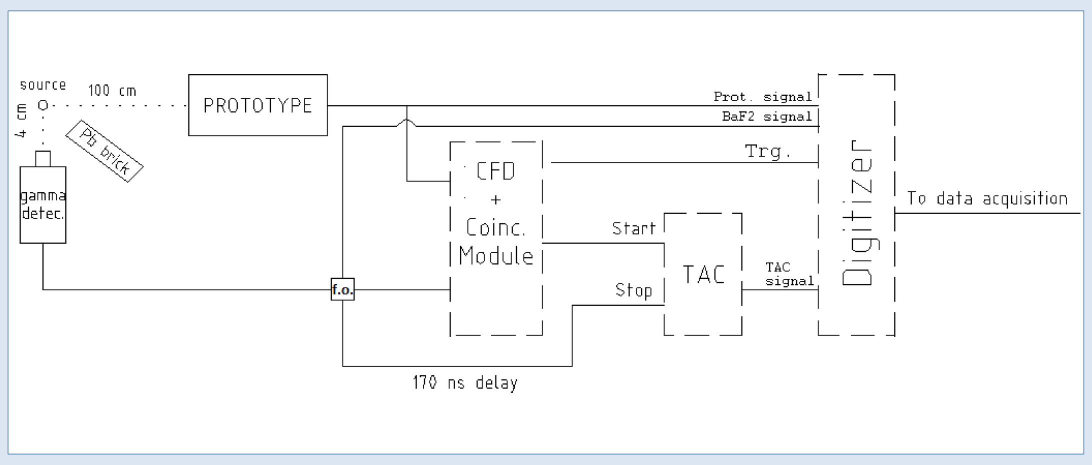
NEUTRONS	GAMMAS
INTERACION WITH PROTONS	COMPTON INTERACTION
PHOSPHORESCENT LIGH DOMINANCE	FLUORESCENT LIGH DOMINANCE
SLOWER SIGNAL DECAY	FASTER SIGNAL DECAY





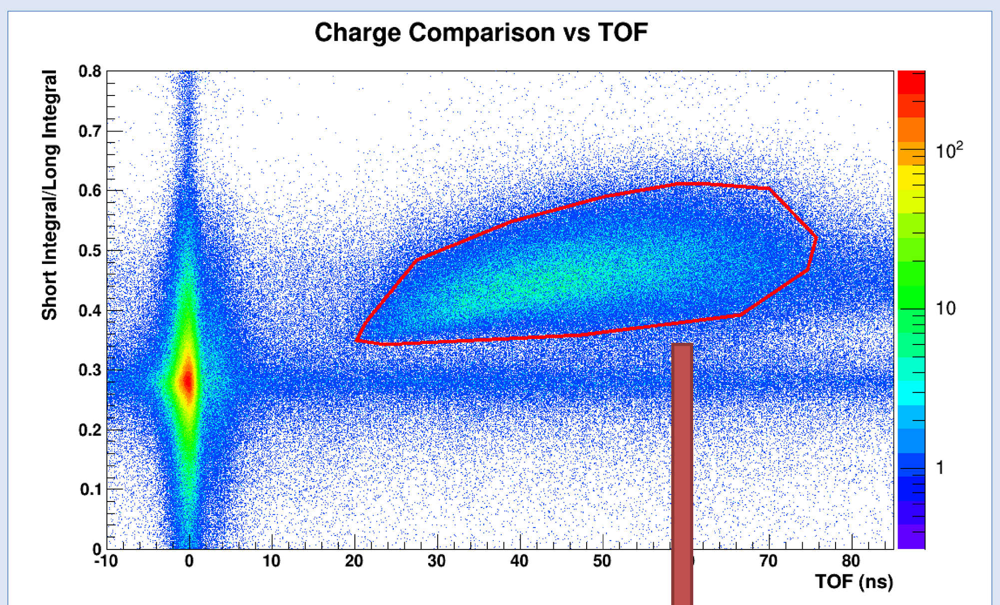
The difference between outputs lays mainly in the decay tail of the signal. This can be exploited for the discrimination between neutrons and gamma rays. Commonly used algorithms for the discrimination are the **Charge Comparison (CC)** and Integrated **Rise Time (IRT)**.

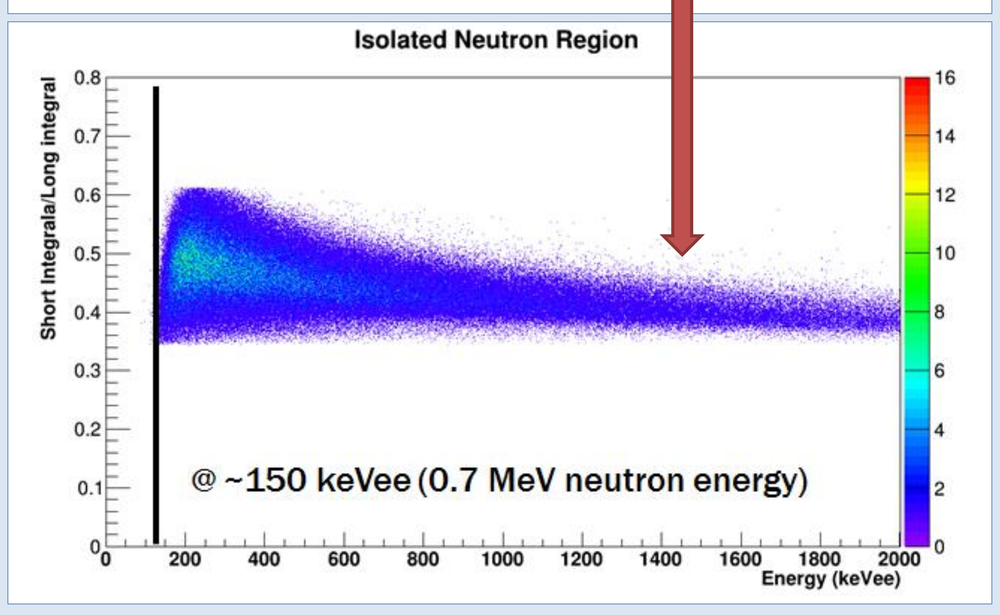
EXPERIMENTAL SETUP



Signals from a **252Cf (n,γ) source** were digitized and analysed offline via software. Data from a commercially available **5"x 5" cell neutron detector** coupled to the same PMT for the prototype were collected for comparison [3].

TOF ANALISIS

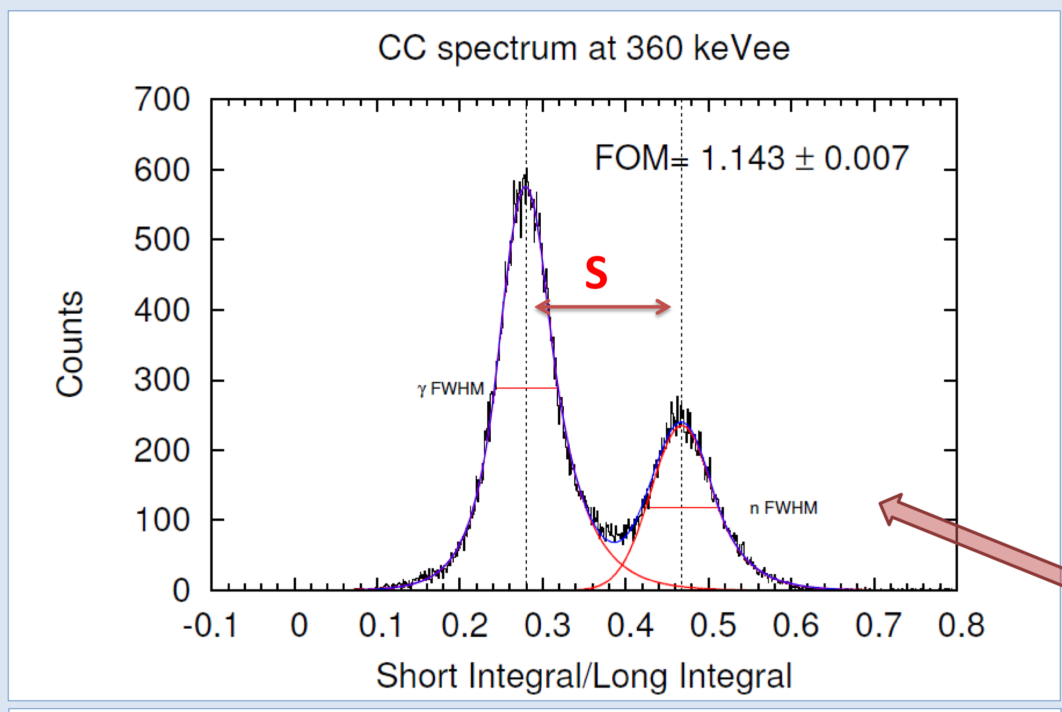


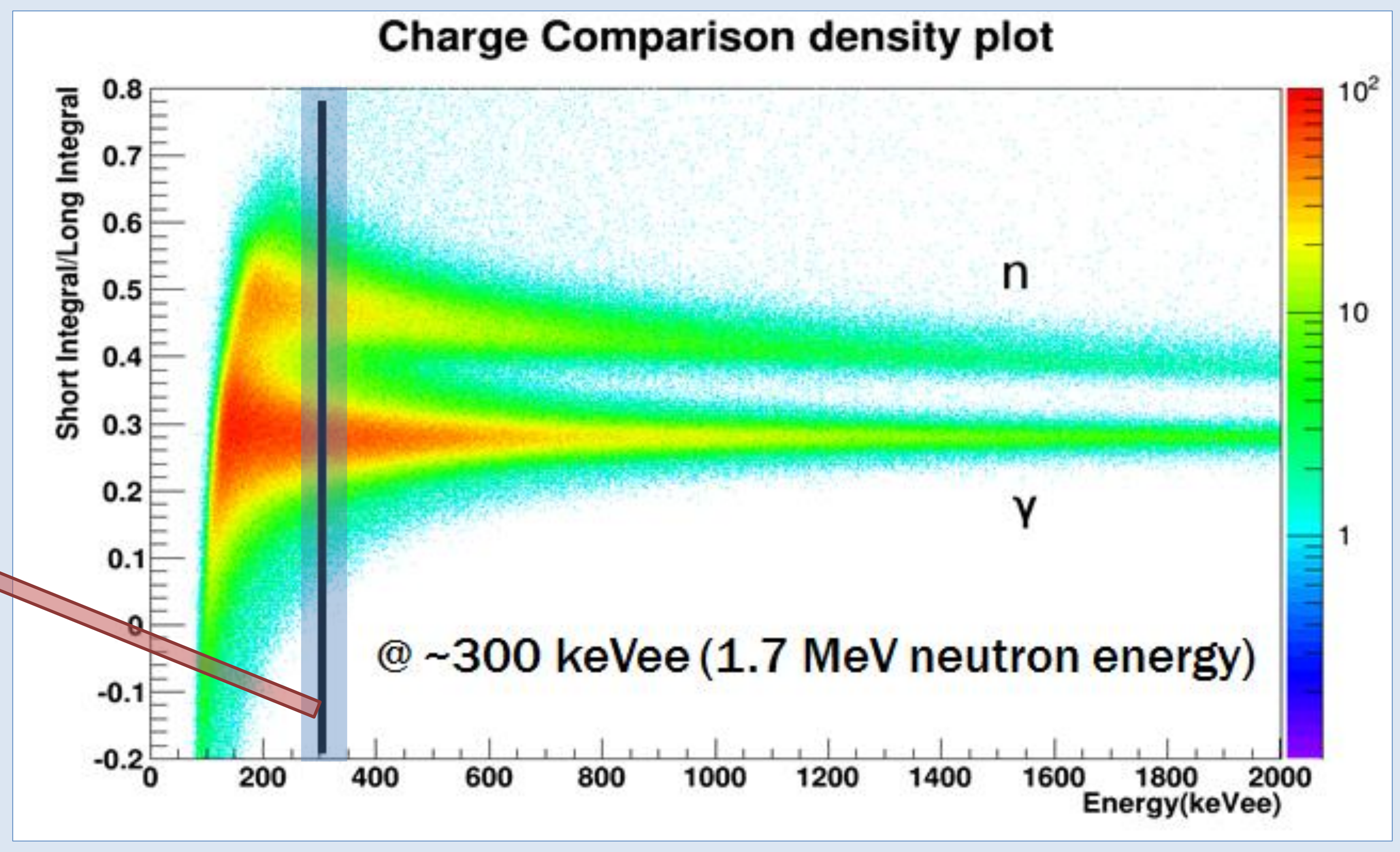


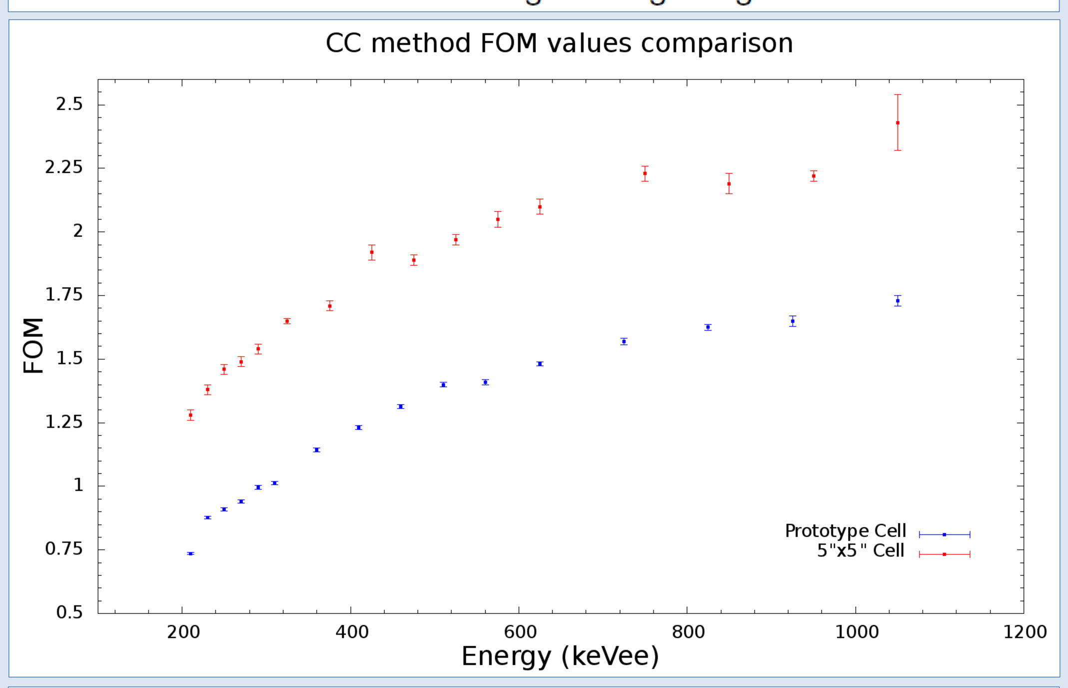
Time of Flight (TOF) measurements were also used as a further discrimination method. **The TOF vs. CC density plot shows two well separated clusters for neutrons and gammas**. A gate on neutron events can thus be selected. This leads to the **lowering of the discrimination threshold in energy at 150 keVee (0.7 MeV), that is the energy of interest for experiments that involve NEDA.**

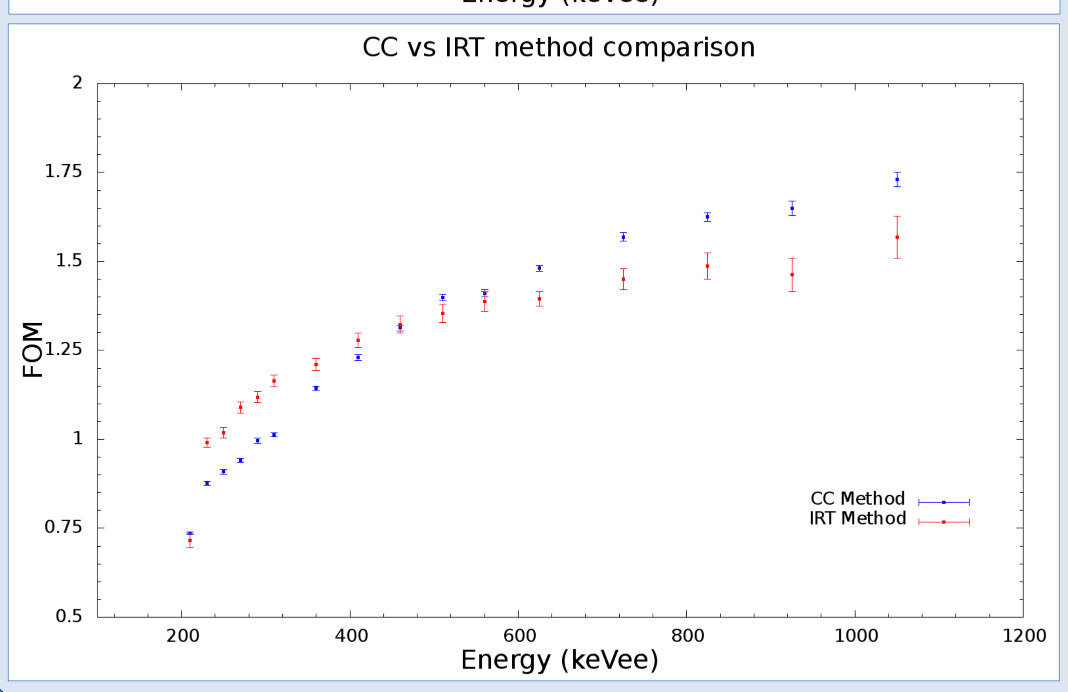
n- γ DISCRIMINATION ANALISIS

The CC method consist in the **evaluation of the ratio between the charge of the slow part of the pulse and its total charge**. The CC ratio vs. energy (total charge) density plot shows two **branches that are well separated from ~300 keVee (1.7 MeV), thus setting an energy threshold in the discrimination resolving power**.









As a quantitative parameter for discrimination quality, the **Figure of Merit (FOM)** was chosen and evaluated at various energies for both the prototype and the standard 5"x5" cell.

$$FOM = \frac{S}{FWHMn + FWHM\gamma}$$

The 5"x 5" cell performances on n- γ discrimination are better by a factor of 2. This could be caused by differences in the geometry of the two detector. **Better results for the prototype could be achieved by more highly performing electronics for data sampling.**

A similar analysis was performed using the IRT method which consist in **evaluating the time taken from the integrated pulse to reach a certain top value**. FOM values were compared to the ones obtained using the CC method showing that **the data trends are identical and overall the values from the two methods are comparable, thus the analysis is consistent.**

Overall the detector showed a good discrimination power for the chosen shape. This shape grants the best geometrical and intrinsic efficiency for the whole apparatus.

WHAT'S NEXT?

- New tests with the newly assembled detectors with neutron beam at *Laboratorio dell'Acceleratore Tandem* in Naples
- Implementation of Neural Network algorithms for a better discrimination resolution at lower energies

[1] G. Jaworski et al., Nucl. Instr. Meth. A673 (2012) 64. [2] G.F.Knoll, Radiation detection and measurement. [3] X. Luo et al., Nucl. Instr. Meth. A 767 (2014) 83.