Proposal (expression of interest)

Test/experiment on the EJ276 and the EJ276G scintillators for a new neutron and charge particle detector.

Higher Energy CROSSTEST

Spokesperson(s): E.V. Pagano, G. Politi, P. Russotto

Participants:

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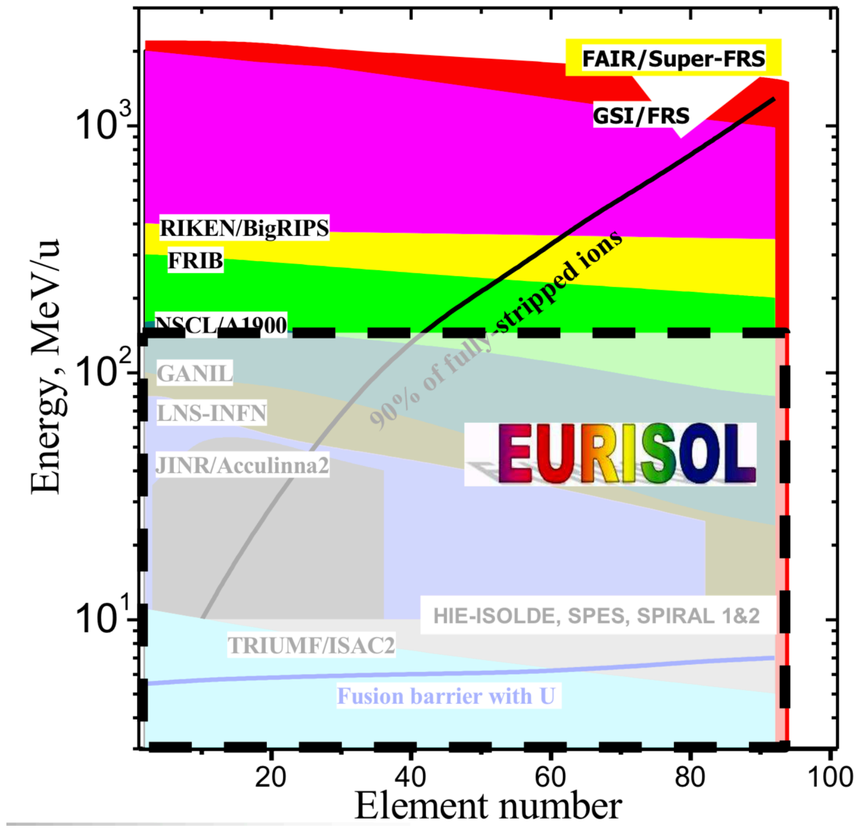
Scientific Motivations

The advent of the new facility for Radioactive Ion Beams (RIBs)
in particular for the n-rich ones

From: M. Lewitowicz EURISOL-DF 15-16 Nov 2017, Lisbon



"The RIBs are an important opportunity"

(C. Horovitz)

FAIR
Facility for Antiproton and Ion Research in Europe GmbH

FRIB

SPES
exotic beams for science

GANIL
laboratoire commun CEA/DSM
spiral2
CNRS/IN2P3

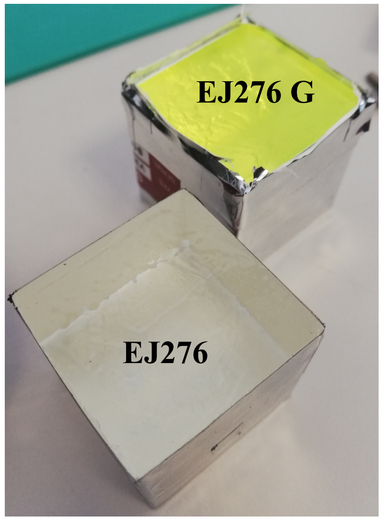
RIKEN

FRAISE@LNS

Mandatory to proper measure neutrons with high energy and angolar resolution for reaction mechanism, nuclear structure, nuclear astrophysics, energy production (etc) studies

The project

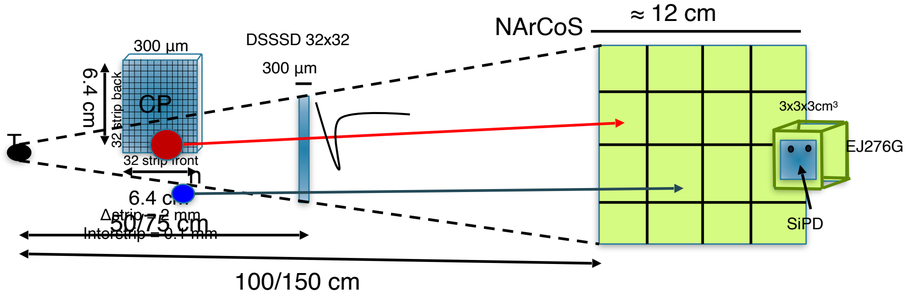
To realize a prototype of detector able to detect at the same time charged particles and neutrons with high energy and angular resolution in a stuck configuration for reaction studies and applications



NArCoS (Neutron ARray for COrrelation Studies)

- Candidate: The plastic scintillator EJ276-Green Type (ex EJ299-33) (3x3x3cm^3)
- 1 cluster: 4 consecutively cubes (stack configuration)-> 3x3x12 cm^3
- Reading the light signal: Si-PM and digitalization
- Modular, reconfigurable (in mechanic and electronic)
- Discrimination of n/γ from PSD (but also light charged particles)
- Energy measurement from ToF ($\Delta t \leq 500$ ps with $L_{ToF} \approx 1 \div 1.5$m)

  TOF measured using the RF of the CS or with an ancillary MCP (low intensity exotic beams)



One of the main problem is to manage the cross-talk among the elementary cells

State of the art of NArCoS

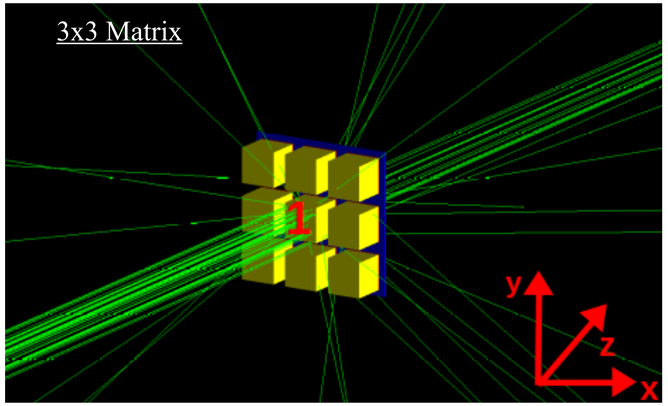
What have been learned up to now thanks also to CROSSTEST@LNL experiment

Analysis almost completed

E.V. Pagano et al., in preparation

CN facility at November 2023

The 3x3 Matrix (surface crosstalk)



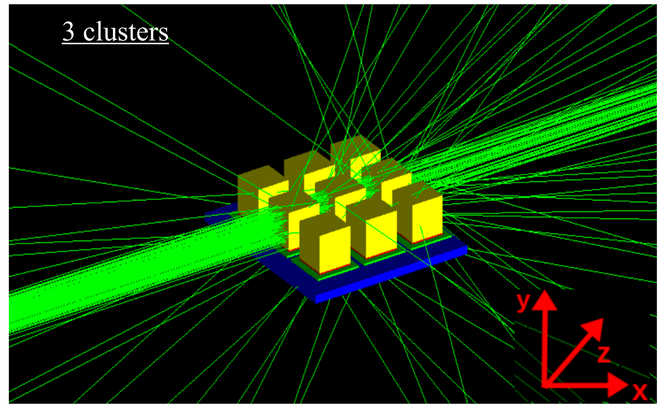
Two configurations was tested

Main reaction for neutrons

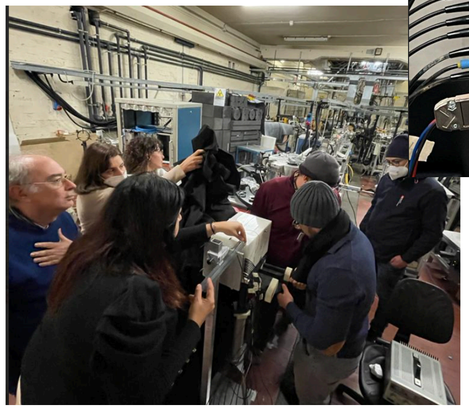
$p + {}^{7}Li \longrightarrow {}^{7}Be + n$

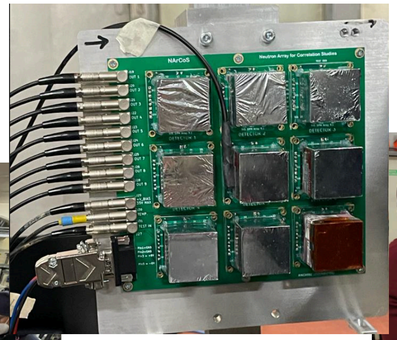
The experiment was performed at CN accelerator of INFN-LNL laboratory using a proton beam of 6 MeV on a LiF target producing a neutron beam having energy En = 4.5 MeV (neutron experimental threshold 1.5 MeV)

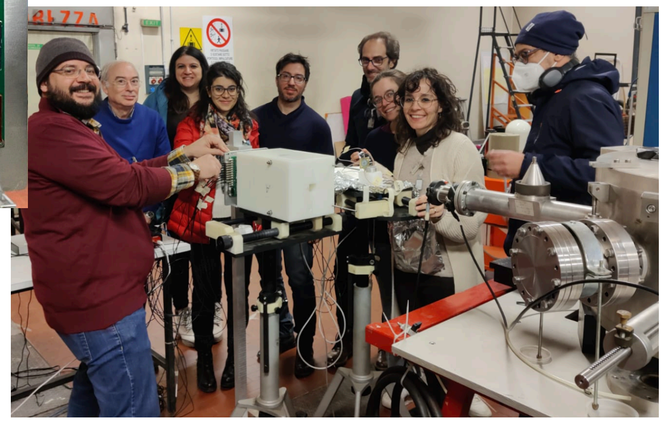
The 3 clusters (linear crosstalk)



Experimental Setup



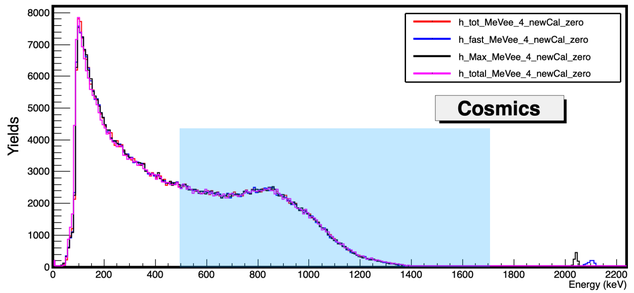




SiPM: BROADCOM AFBR-S4N66C013

Time resolution

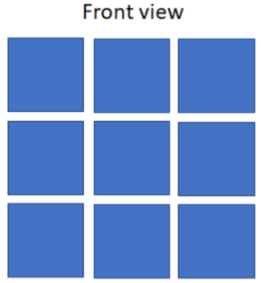
evaluated with a cosmic ray detected in coincidence between two plastic scintillators

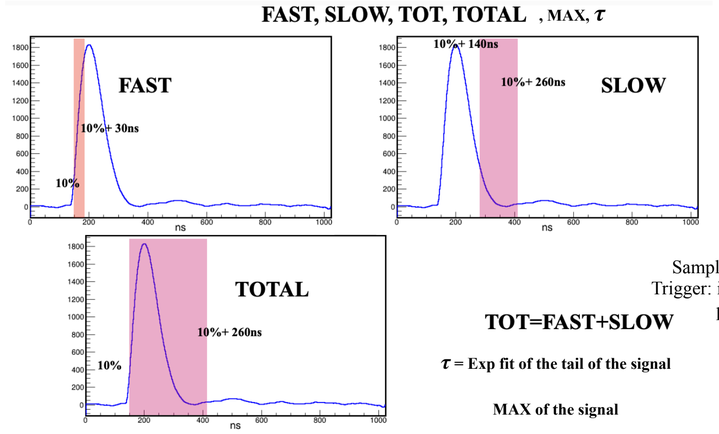


Cosmic rays

Experimental conditions:

- Multiplicity = 2;
- Contiguity of the two hit plastic detectors
- Energy difference no larger of 20%
- Energy larger than 500 keV in each one

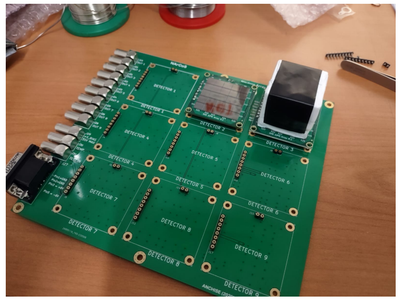




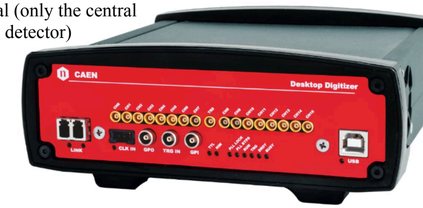
TOT=FAST+SLOW

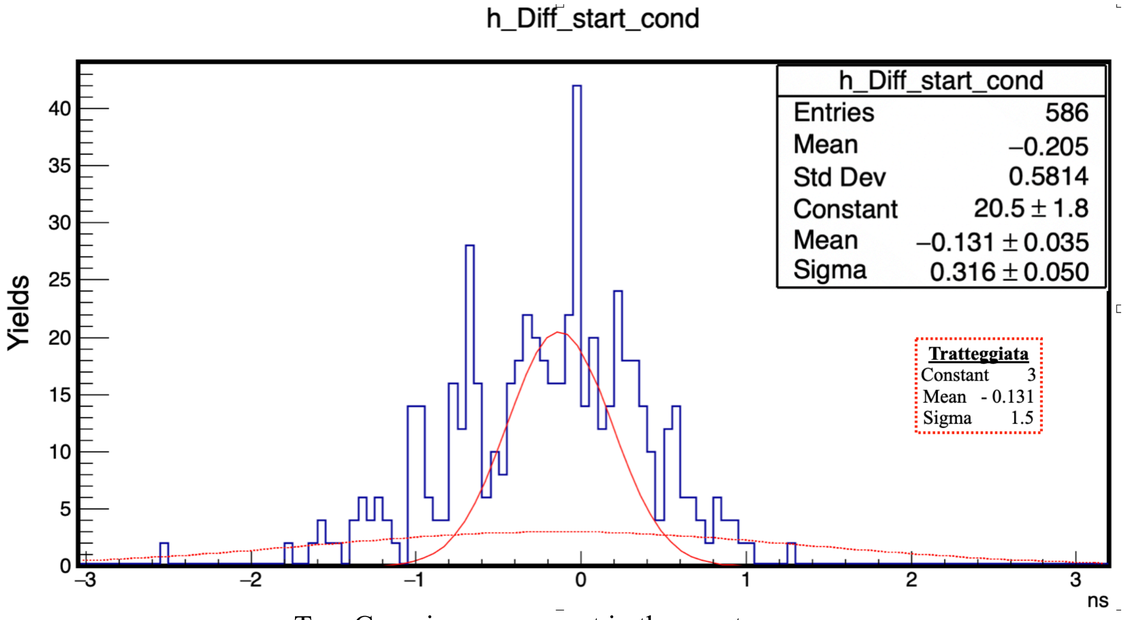
τ = Exp fit of the tail of the signal

MAX of the signal



Sampling frequency: 1 Gs/s
Trigger: internal (only the central plastic detector)





Two Gaussian component in the spectrum

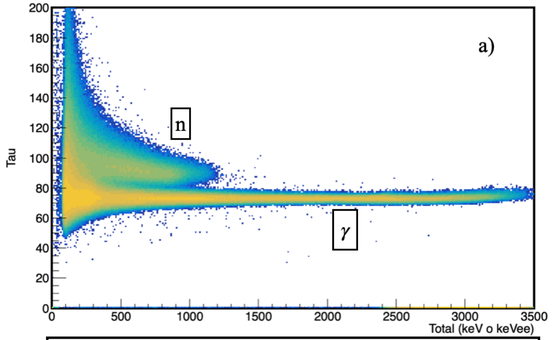
One real coincidence with a $\sigma \approx 320$ ps and another of spurious coincidence with a $\sigma \approx$ 1.5ns corresponding to about 10% of the selected events

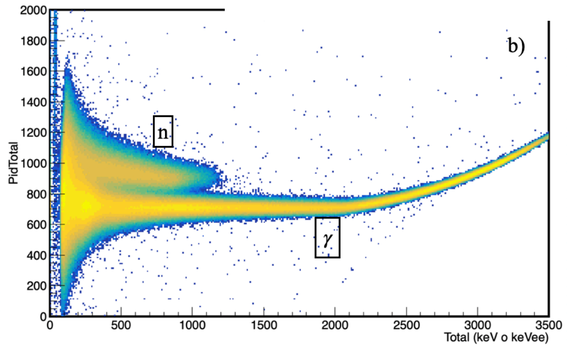
Time resolution of one single green plastic

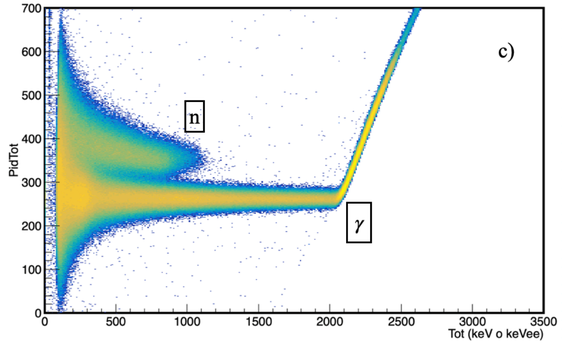
$$\sigma_{tot}^2 = 2\sigma_{green}^2 + \sigma_{el} -> \sigma_{green} = \sqrt{\frac{\sigma_{tot}^2 - \sigma_{el}^2}{2}} \approx 215\ ps$$

$$\sigma_{el} \approx 100\ ps$$

2D identification matrix







Matrici di identificazione 2D ottenute dal plastico centrale nella "schedona" posta a conf. a matrice

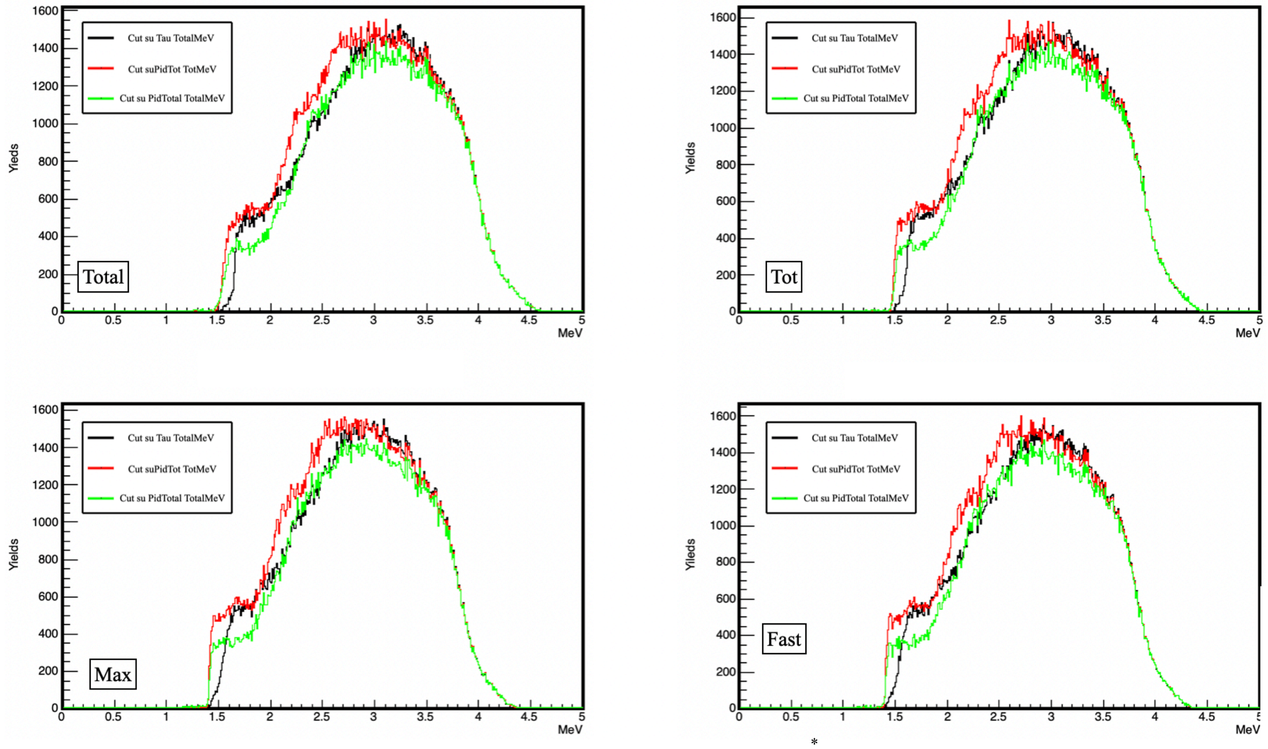
a) Tau Vs del Total (keV)
b) PidTotal VS Total (keV)
c) PidTot Vs Tot (keV)

Tau: fit esponenziale nella parte decrescente del segnale
PidTotal: Slow/Total*
PidTot: Slow/Tot*

Central plastic

Three different 2D identification matrix was analyzed in order to study the detector performances

Neutron spectra



$$L_{out} = aE_{dep} - b[q - e^{-cE_{dep}}]$$

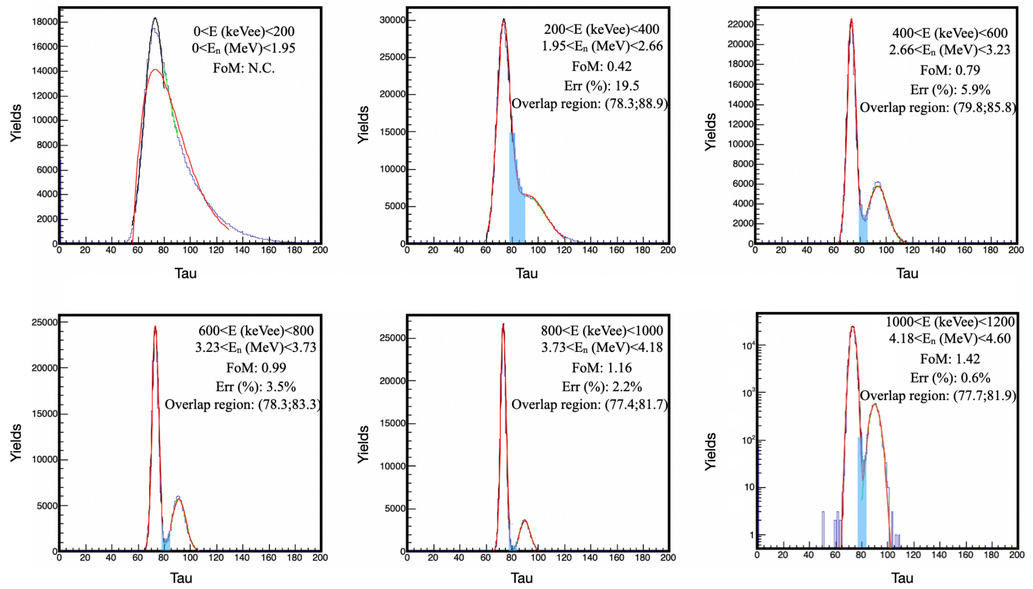
a = 0.8 MeVee*MeV^{-1}
b = 0.39MeVee
c = 0.22 MeV
L_{out} in MeVee
E_{dep} in MeV

*Lawrence et al. NIM A 759 (2014) 16-22

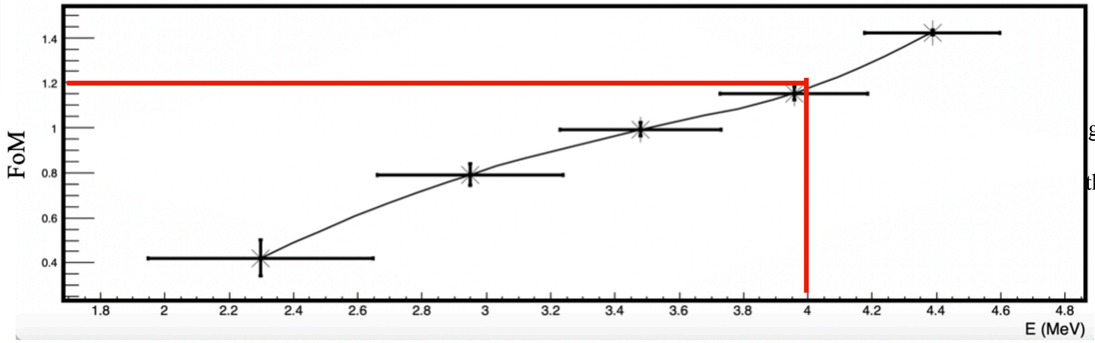
Reasonable neutron energy spectra (neutron beam maximum energy 4.5MeV), robust energy calibration as a function of the variable, robust neutron selection as a function of the three 2D identification matrix, about 1.5 MeV of neutron energy threshold

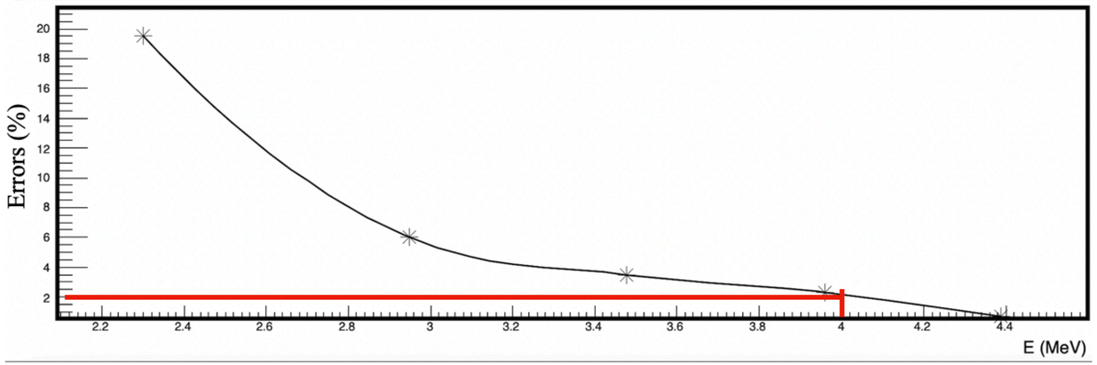
Very close results for the others 2D Identification Matrix

FoM and Errors estimations



Tau Vs Total 2D identification matrix

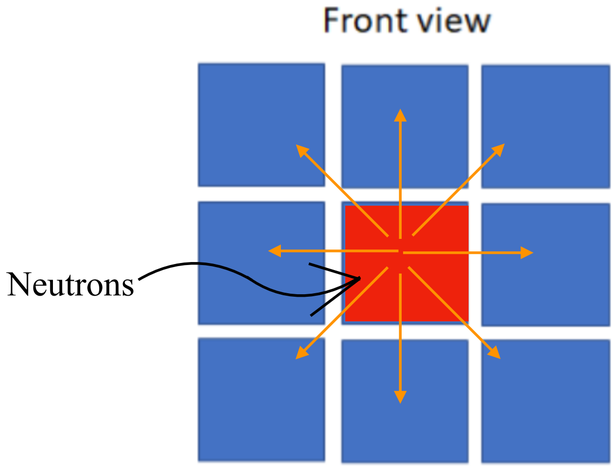




At about 4 MeV of neuters we obtain a value of 1.2 of FoM generally considered as "good". At this value the corrispondi errors in the neutron identification is about 2%

Crosstalk Measurement for 4.5 MeV of neutrons

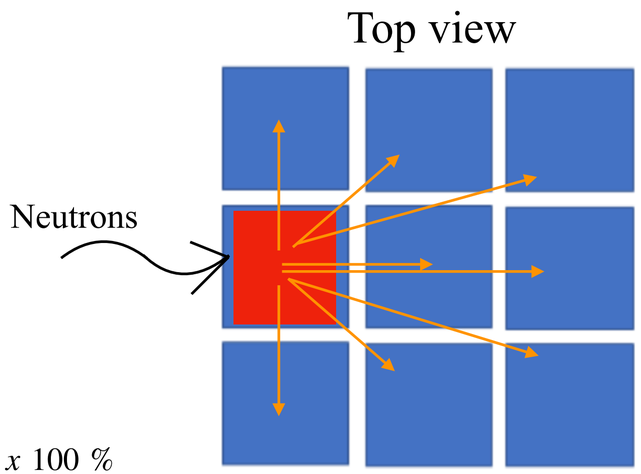
Matrix configuration (surface crosstalk)



Only the central plastic scintillator was in trigger

Neutrons in other plastics in the same event (with multiplicity equal to 2) are crosstalk (or background)

Cluster configuration (linear crosstalk)



Crosstalk probability: $\frac{number\ of\ neutrons\ not\ in\ trigger}{number\ of\ neutron\ in\ trigger\ (central)}\ x\ 100\ \%$

$P\,(\%) = prob\,(\%) \pm Er_{ass}\,(\%) = (0.117 \pm 0.008)\ \%$

$P\,(\%) \approx 0.1\ \%$

$P\,(\%) = prob\,(\%) \pm Er_{ass}\,(\%) = (0.163 \pm 0.005)\ \%$

$P\,(\%) \approx 0.2\ \%$

Comparison with simulate value (GEANT4)

Conf.	Measured crosstalk Probability	Measured Error	Measured Error (%)	GEANT4 crosstalk Probability	GEANT4 error	GEANT4 error (%)	Difference
MATRIX	0,117	0,008	7	0,45	0,06	13	0,333
CLUSTER	0,163	0,005	3	1,37	0,07	5	1,207

Crosstalk Measurement for 4.5 MeV of neutrons

The preliminary results obtained so far are encouraging: a very good and linear energy calibration of several variable acquired was obtained, good separation between neutron and gamma with a FoM of 1.2 at 4 MeV of neutrons with three different 2D identification matrices, a neutron threshold of 1.5 MeV, a gamma threshold of 70 keV and a time resolution of 320 ps was achieved for 2 plastic scintillators and the electronics (assumable 220 ps for one scintillator and the electronics).

The crosstalk valute at 4.5 MeV of neutrons was measured for the matrix configuration is about P(%) = 0.1% and for the cluster configuration is about P(%) = 0.2%.

Thees values are really encouraging because are below the expected one from the MC based simulation (GEANT4 and MCMPX) or the matrix configuration is about P(%) = 0.5% and for the cluster configuration is about P(%) = 1.4%.

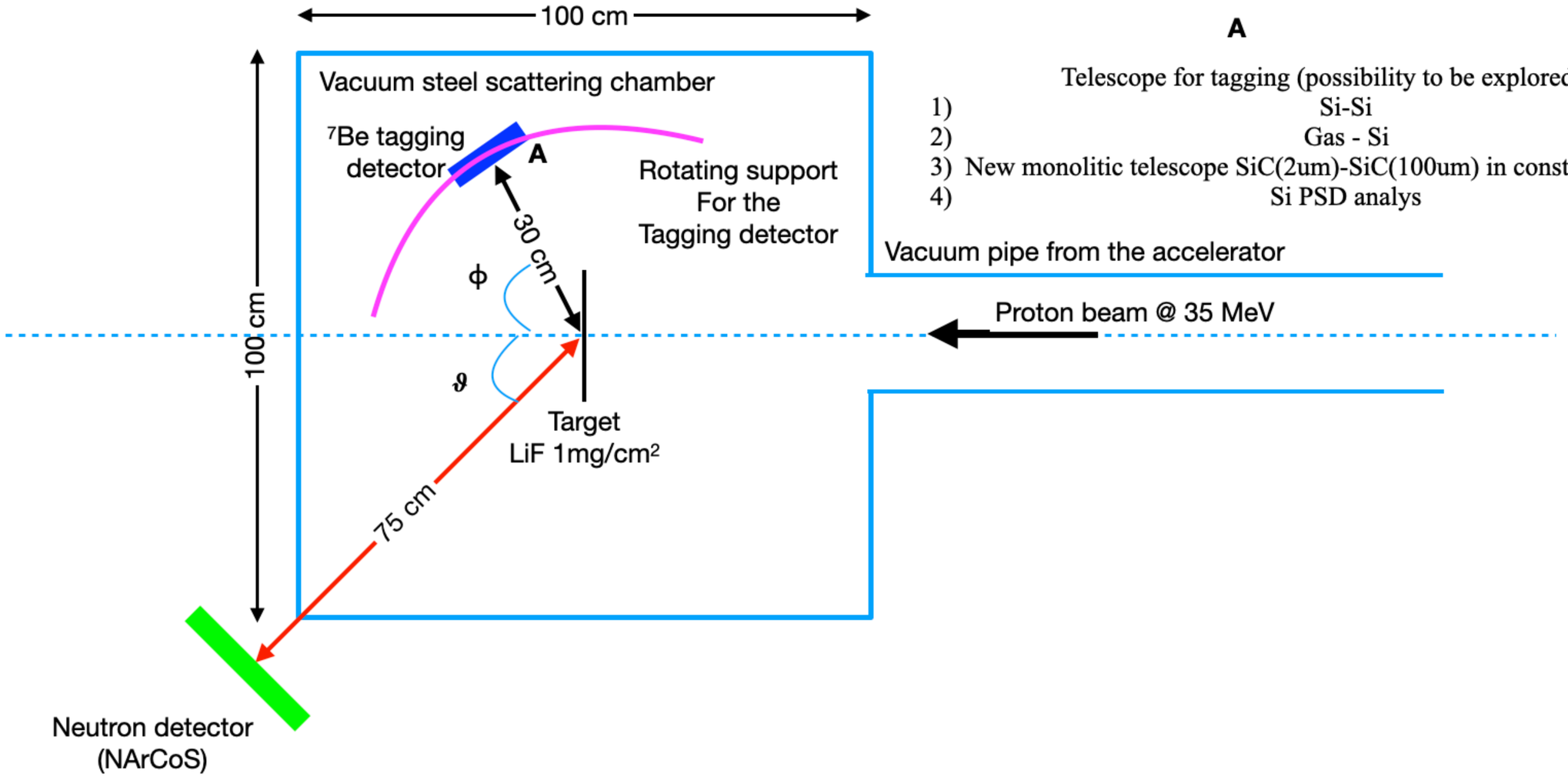
What we ask for ?

The possibility of an extension of crosstalk measurement at higher Energy

What is our proposal/suggestion for the LNL?

A laboratory facility in order to have tagged neutrons in a range of energy of about 20 < En < 33 MeV

example of experimental setup



A

Telescope for tagging (possibility to be explored) :

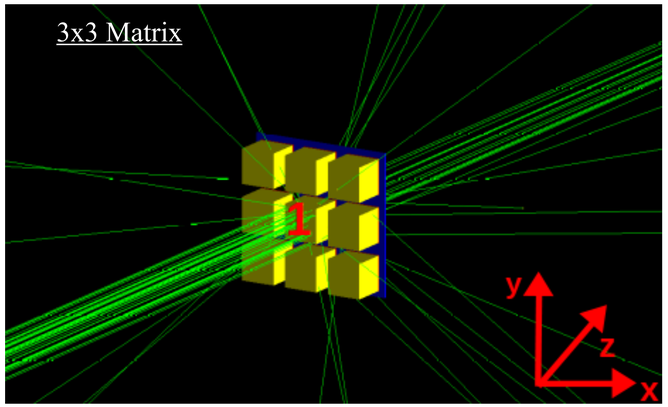
1) Si-Si
2) Gas - Si
3) New monolitic telescope SiC(2um)-SiC(100um) in construction at LNS
4) Si PSD analys

An example of case of interest for us

The possibility of an extension of crosstalk measurement at higher Energy

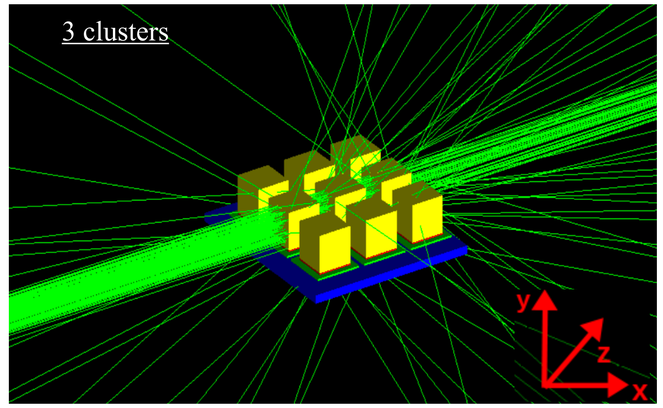
beamline 0°, proton beam at 35 MeV on a target of LiF (1mg/cm^2) @ new cyclotron at LNL at 200 enA of beam intensity

The 3x3 Matrix (surface crosstalk)



We could test once more the two configurations for the surface and linear crosstalk (at higher neutron energy) and also measure the ^{7}Be and the neutron in coincidence. It could make it possible to measure the neutron detection efficiency

The 3 clusters (linear crosstalk)



Four neutron energies as a function of the angle:

Neutron Detection angle	Neutron energy (MeV)	^{7}Be energy (MeV)	Cross Section* (mb/sr)	Expected Crosstalk events/h
5°	33	0	132.6	222
45°	30	0.5	122.0	204
85°	25	7	101.5	170
130°	20	12**	80.8	135

Neutron Detection angle	Neutron energy (MeV)	^{7}Be energy (MeV)	Cross Section* (mb/sr)	Expected Crosstalk events/h
5°	33	0	132.6	444
45°	30	0.5	122.0	408
85°	25	7	101.5	340
130°	20	12**	80.8	270

** Suitable for neutron efficiency measurements

*value from LISE++ software

Summary

Thanks to tests @ LNS and in particular to CROSSTEST @LNL experiment we increased our knowledge, in particular, obtaining detailed and crucial information about the cross-talk problem in order to validate the simulations and consequently, advancing with the construction of the correlator.

Now we need to measure at higher neutron energies and the new LNL Cyclotron should be a good opportunity.

Our expression of interest is related in the construction of a new laboratory facility at LNL able to have a beam of tagged neutron in a range between 20 and 30 MeV, also useful, more generally, for nuclear studies and applications

Thanks for the attentions