Status of the DESPEC/HISPEC Neutron Detection Working Group

D. Cano-Ott

The Neutron Detection Working Group (*)

One of the goals of this meeting is to trigger the start of the activities of the DESPEC/HISPEC Neutron Detection Working (NDW).

All kind of anouncements, documents and general information related to the group will be stored in the new NDW homepage:
http://fachp1.ciemat.es/ndespec/

There is also an electronic logbook (ELOG) available for facilitating the information exchange and keeping track of it.
https://www.agata.org/elog/nustar/

The tools are ready to be used by all of us!

(*) As it has been announced already, there is a parallel effort in creating a NUSTAR neutron detection working group. We will use for the time being the same distribution list as for DESPEC until the NUSTAR group and its activities are defined.

IMPORTANT: All people interested should please register!

NDW Participants (contact persons)

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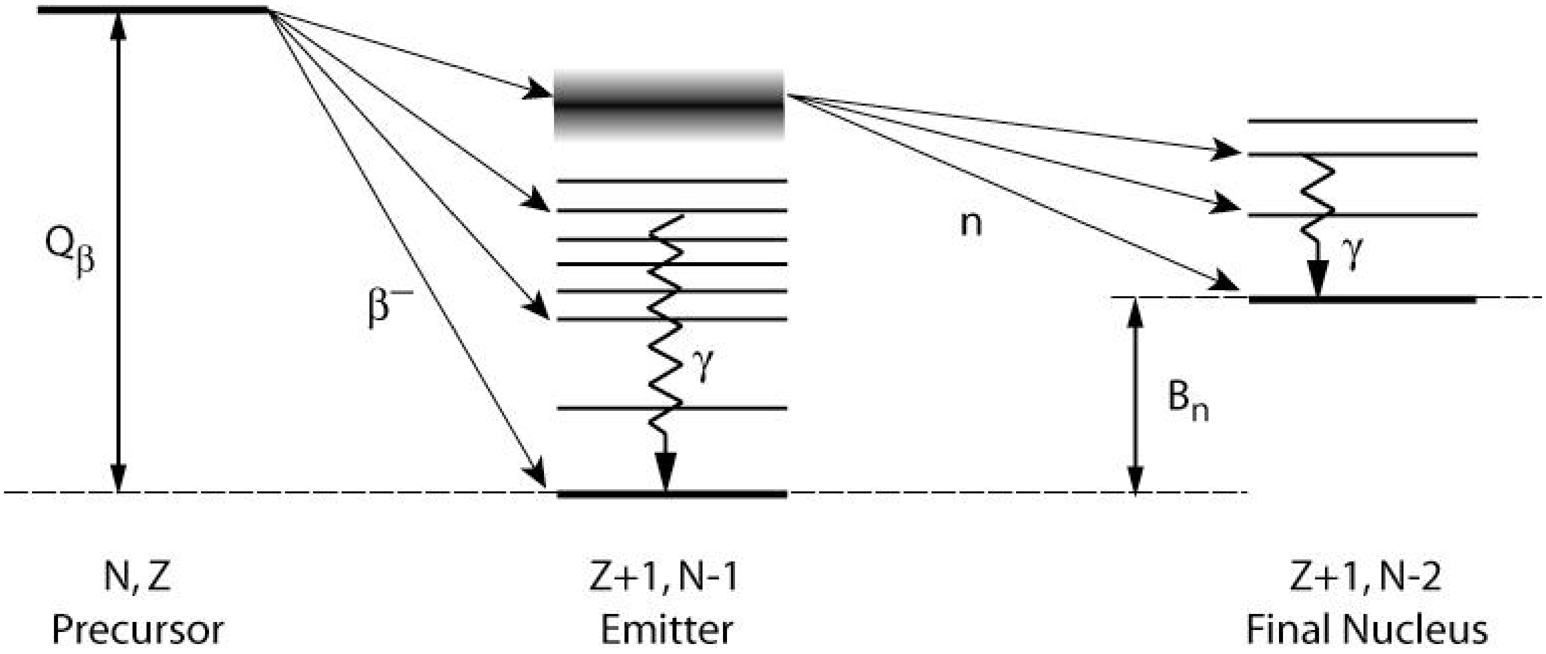
The list is clearly not complete, so please send your name and affiliation once more in case you already did.

Motivation

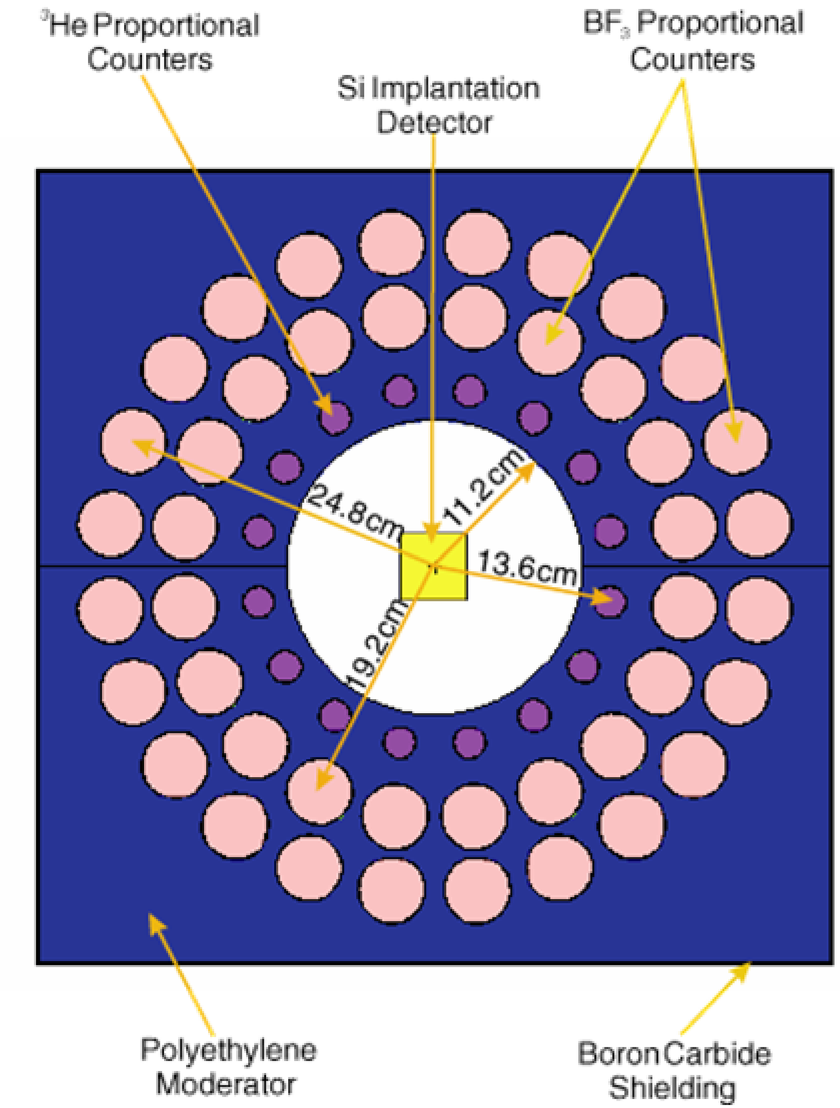


GOAL: to measure neutron emission probabilities and energies for neutron rich isotopes with relevance to basic nuclear physics and nuclear technology:

-Low production: 4π detector

-High production: TOF spectrometer (in combination with a gamma ray setup)

4π Detector



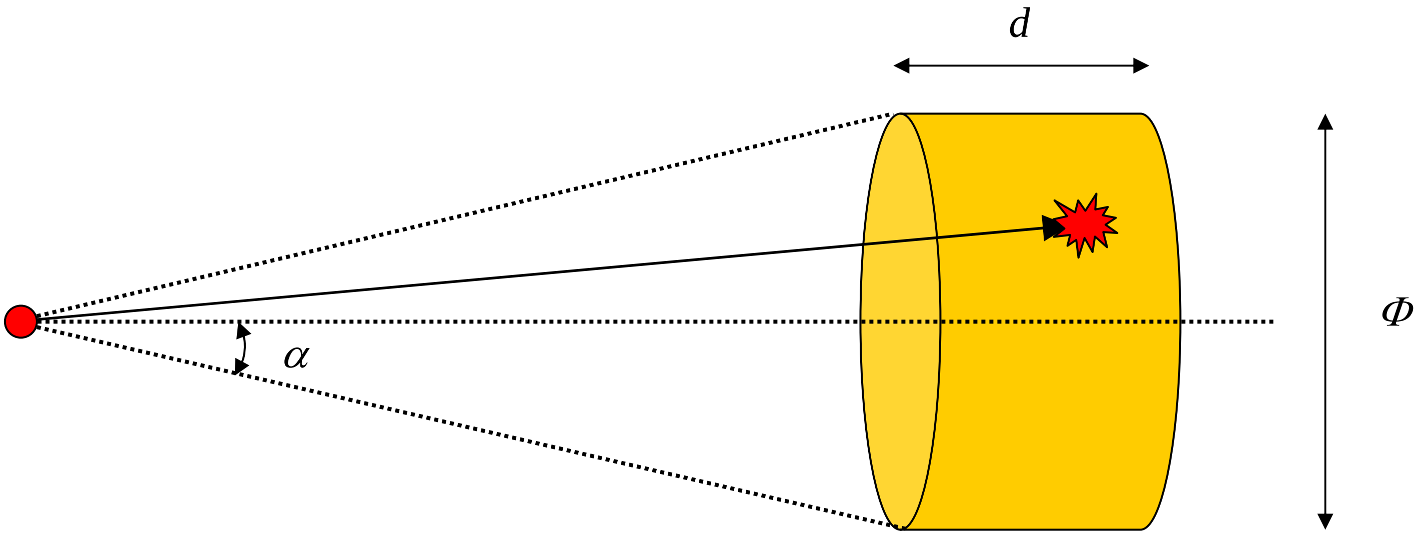
The device proposed for FAIR is nearly identical to the already existing NERO detector [1].

Detection system based on the "long counter principle": neutrons with energies over a broad range (eV – MeV) are moderated and detected with an efficiency "nearly" independent on the initial neutron energy. IDEAL neutron counter.

Additional possibilities are the energy reconstruction by an alternative design and after applying deconvolution techniques.

[1] Hendryk Schatz schatz@nscl.msu.edu
Pictures taken from
http://www.nscl.msu.edu/tech/devices/nero/tech.html

Time of Flight Neutron Spectrometer for DESPEC



In a time of flight measurement the neutron energy is obtained from: $E_n = \left(721.977\frac{L}{t}\right)^2$
where E_n is expressed in eV, L in cm and t in ns.

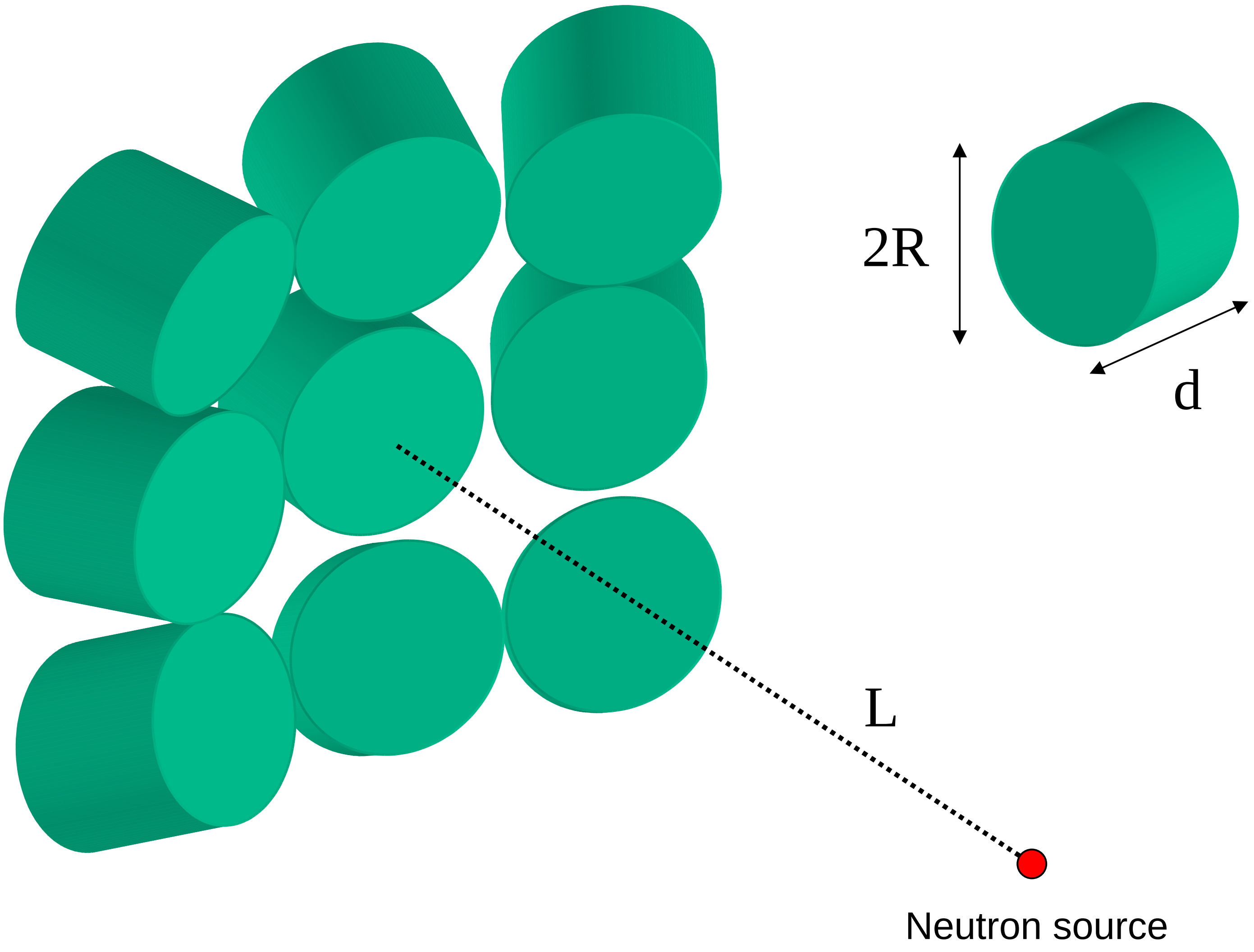
If the angle α and the diameter Φ are small, the flight path L can be approximated $L \approx R + \frac{d}{2}$ and the uncertainties in the reconstructed energy to the uncertainty associated to the flight path $\sigma_L = \frac{d}{\sqrt{12}}$ and to the "intrinsic" time resolution of the detection system.

The intrinsic efficiency of a detector depends on the geometry (thickness) and composition (elastic cross sections). The table shows the main characteristics of two standard neutron detector materials:

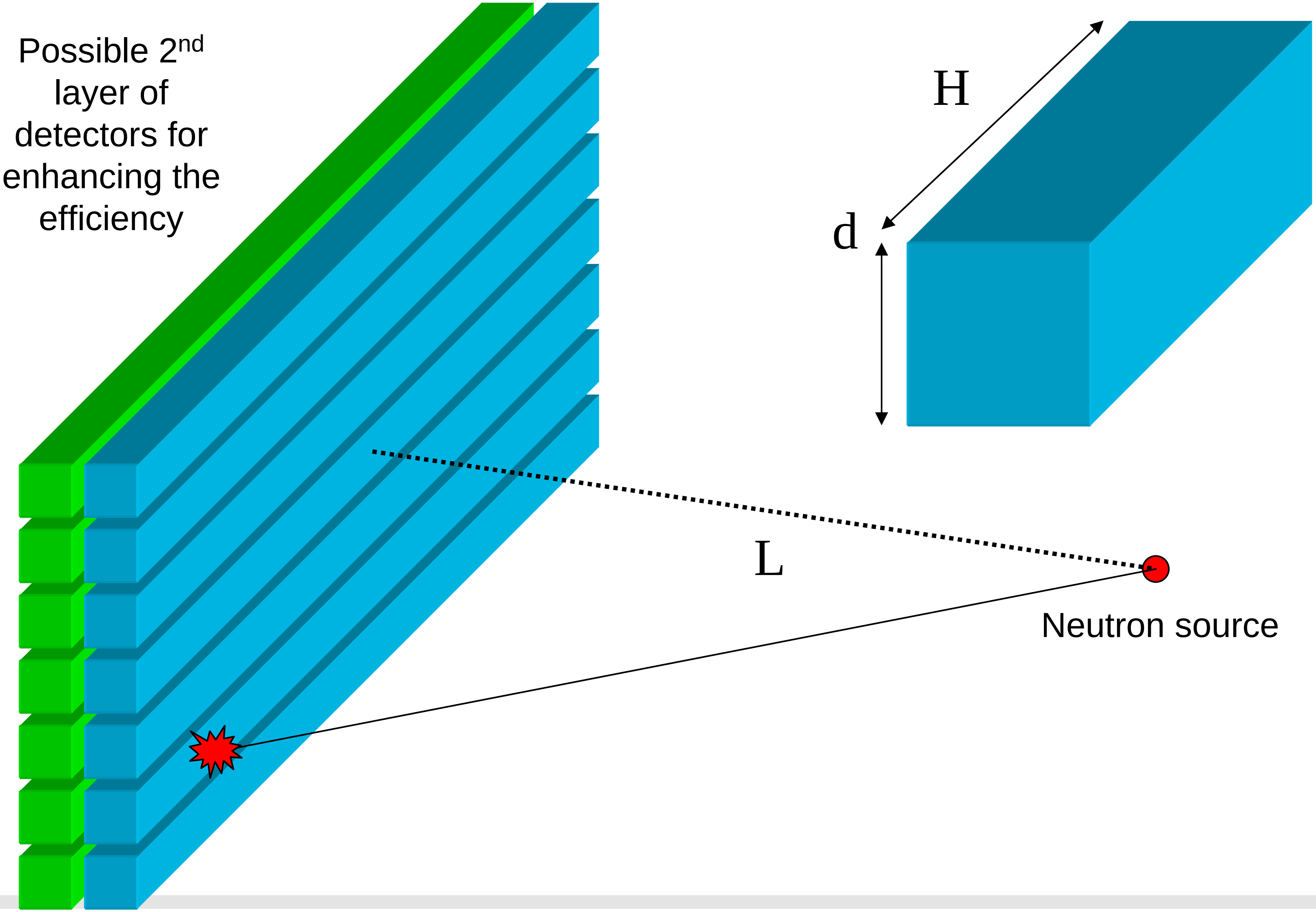
Liquid Scintillator (BC501/NE213)		Plastic Scintillator (BC400/NE102)	
ρ_H (atoms/cm^3)	$4.82\cdot10^{22}$	ρ_H (atoms/cm^3)	$5.23\cdot10^{22}$
$<\sigma_{elatstic}>$ at 1 MeV in barns	4.2	$<\sigma_{elatstic}>$ at 1 MeV in barns	4.2
Mean free path λ (cm)	4.95	Mean free path λ (cm)	4.55

Both detector types have a very similar macroscopic cross $\Sigma=1/\lambda$ section for neutrons.

(I) Granular Neutron Array (NE213)

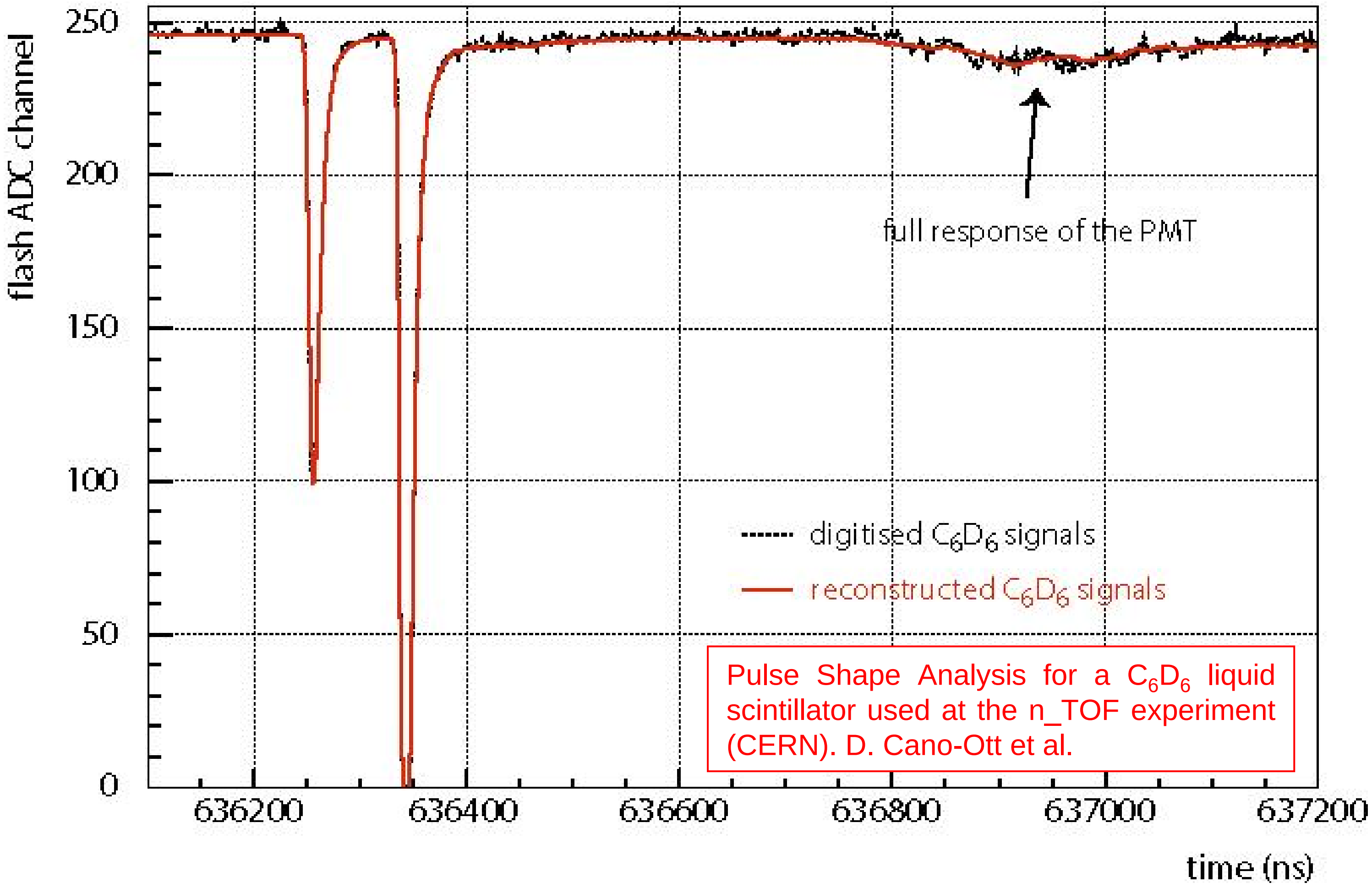


(II) Position Sensitive Neutron Array (NE213)



Possible 2nd layer of detectors for enhancing the efficiency

DAQ electronics



Pulse Shape Analysis for a C_6D_6 liquid scintillator used at the n_TOF experiment (CERN). D. Cano-Ott et al.

The basic question to answer will be “analogue or digital?”

Proposal for a Working Plan

1.) Create two sub-working groups for the neutron TOF spectrometer and the 4π detector respectively

The activities of each group should run in parallel and there should be an intense cross talk. The ELOG should be used for facilitating the information exchange!

2.) Re-analyse the whole project starting from the ideas written in the TP

New physics cases or new interests?
Define the neutron energy range to be covered.
Define how the experiments will be carried out.
Identify the best suited neutron detection mechanisms: (n,n), (n,α), (n,γ)…
Identify the best suited materials for the detectors (liquid scintillators, plastic scintillators, gaseous detectors) taking into account the experimental needs (n/γ discrimination?) and costs.
Identify alternative possible geometries for the detection setups, taking into account the combined used with other detectors (implantation, Ge).
Define the electronics: analogue or <u>digital</u>.

3.) Perform Monte Carlo simulations for the design phase

Decide which codes are best suited: GEANT4 for the TOF spectrometer and MCNP(X) for the 4π detector?

Assess the efficiency and energy resolution (if any) of the possible setups

Identify and simulate the sources of background: time correlated gamma rays, uncorrelated events, ambient background…

Define the optimal geometries.

Cross talk with other setups: implantation, but also others like Ge-array

Agree on the optimal final design of the detection setups.

4.) Design, build and perform test measurements with prototypes

TOF spectrometer: a few modules

4π detector: mini detector

Build the prototypes.

Measure in simple experimental conditions at some existing facilities: well studied cases, simple geometry, clean experimental conditions.

5.) Perform complete MC simulations of the test experiments and analyse the results

Validate the Monte Carlo simulations with the results from the test measurements.
Produce Monte Carlo data similar to the data format that will be produced by the DESPEC DAQ.
Develop analysis software and reconstruction algorithms based first on the MC and later on the on the Experimental data.

6.) Help in the design and test of the DAQ electronics and software

Depending on the final decision (analogue or digital), different approaches will be necessary. For digital processing: pulse shape analysis and fast data reduction techniques.

7.) Define the final design of the detection setups

8.) Build the detectors

Links to other Working Groups

1.) Implantation setup

Determine the effect of the implantation setup on the response of the neutron detectors: degradation of the TOF resolution, degradation of the neutron energy resolution, sources of background

Collaborate in the design for avoiding future incompatibilities between the implantation setup and the detectors. Geometric design and material composition (isotopic!!!) is needed.

2.) Ge Array

Guarantee the satisfactory use of the combined neutron and gamma ray detection setups: minimise the backgrounds and the cross talk. Geometric design and material composition is needed.

3.) Monte Carlo Simulation (or DESPEC/HISPEC representative inside the NUSTAR collaboration)

Participate in the definition of conventions and protocols for the geometries, materials, outputs…

Preserve the compatibility between different codes (geometries) for facilitiating the future upgrades.

4.) DAQ

Participate in the defintion of the electronics, data processing and data structures (correlations).

Distribution of TASK (and time schedule?)

Re-analyse the whole project starting from the ideas written in the TP.

New physics cases or new interests? Define the neutron energy range to be covered. Define how the experiments will be carried out. Identify the best suited neutron detection mechanisms: (n,n), (n,α), (n,γ)…Identify the best suited materials for the detectors (liquid scintillators, plastic scintillators, gaseous detectors) taking into account the experimental needs (n/γ discrimination?) and costs. Identify alternative possible geometries for the detection setups, taking into account the combined used with other detectors (implantation, Ge). Define the electronics: analogue or digital.

ALL PARTICIPANTS

Perform Monte Carlo simulations for the design phase

	TOF	4π detector
Decide which codes are best suited: GEANT4 for the TOF spectrometer and MCNP(X) for the 4p detector?	All participants	
Simulate the efficiency of the possible setups.	CIEMAT, IFIC, UPC, Uppsala, Sevilla	CIEMAT, IFIC, UPC
Identify and simulate the sources of background: time correlated gamma rays, uncorrelated events, ambient background…		
Define the optimal geometries.	CIEMAT, Debrecen, IFIC, LNL (Andres), Uppsala, Edinburgh (Tom)…	
Cross talk with other setups: implantation, but also others like Ge-array.		
Agree on the optimal final design of the detection setups.	All participants	

Design, build and perform test measurements with prototypes

	TOF	4π detector
Define the geometry of the prototype.	All participants	
Build the prototypes.	CIEMAT, LNL, UPC, Uppsala	St. Petersburg? IFIC, CIEMAT, UPC
Perform test measurements in simple experimental conditions: well studied cases, simple geometry, optimal signal to noise ratio.	CIEMAT, LNL, Uppsala, IFIC, UPC, GSI,	

Perform complete MC simulations of the test experiments and analyse the results

	TOF	**4π detector**
Validate the Monte Carlo simulations with the results from the test measurements.	All participants	
Produce Monte Carlo data similar to the data format that will be produced by the DESPEC DAQ.	CIEMAT,	
Develop analysis software and reconstruction algorithms based first on the MC and later on the on the Experimental data.	CIEMAT,	

Help in the design and test of the DAQ electronics and software

	TOF	**4π detector**
Definition of the DAQ electronics.	All participants	
Develop digital electronics.	Strassbourg (Patrice Medina), Daresbury	
Develop pulse shape analysis software and reconstruction algorithms.	CIEMAT, Uppsala + external coll.	

Define the final design of the detection setups

Build the detectors

Parameters for the nominal setups

NE213 Array

Number of detectors	**30**	
Detector radius	12	**cm**
Detector thickness d	10	**cm**
L	70	**cm**
Time Resolution	2	**ns**
$\varepsilon_{geometric}$	22.04%	

Neutron energy (eV)	**TOF (ns)**	ε_{total}	**ΔE/E (%)**
1.00E+05	171.23	22.0%	18.90%
2.00E+05	121.08	21.8%	19.69%
1.00E+06	54.15	19.1%	25.07%
2.00E+06	38.29	16.8%	30.50%
1.00E+07	17.12	8.4%	57.80%
2.00E+07	12.11	4.7%	79.71%
Energy thresholds NOT included (for 100 and 200 keV)			

Position Sensitive NE213 Array

Number of detectors	10	
Detector length	100	**cm**
Detector thickness	10	**cm**
L	70	**cm**
Spatial Resolution	10	**cm**
Time resolution	2	**ns**
$\varepsilon_{geometric}$	23.42%	

Neutron energy (eV)	**TOF (ns)**	ε_{total}	**ΔE/E (%)**
1.00E+05	171.23	23.4%	18.90%
2.00E+05	121.08	23.1%	19.69%
1.00E+06	54.15	20.3%	25.07%
2.00E+06	38.29	17.9%	30.50%
1.00E+07	17.12	9.0%	57.80%
2.00E+07	12.11	5.0%	79.71%
Energy thresholds NOT included (for 100 and 200 keV)			

Parameters for 140 cm TOF distance

NE213 Array

Number of detectors	**30**	
Detector radius	12	**cm**
Detector thickness d	10	**cm**
L	**140**	**cm**
Time Resolution	2	**ns**
$\varepsilon_{geometric}$	5.51%	

Neutron energy (eV)	TOF (ns)	ε_{total}	$\Delta E/E$ (%)
1.00E+05	331.05	5.5%	9.78%
2.00E+05	234.09	5.4%	10.18%
1.00E+06	104.69	4.8%	12.97%
2.00E+06	74.02	4.2%	15.77%
1.00E+07	33.10	2.1%	29.90%
2.00E+07	23.41	1.2%	41.23%
Energy thresholds NOT included (for 100 and 200 keV)			

Position Sensitive NE213 Array

Number of detectors	10	
Detector length	100	**cm**
Detector thickness	10	**cm**
L	**140**	**cm**
Spatial Resolution	10	**cm**
Time resolution	2	**ns**
$\varepsilon_{geometric}$	10.97%	

Neutron energy (eV)	TOF (ns)	ε_{total}	$\Delta E/E$ (%)
1.00E+05	331.05	10.9%	9.78%
2.00E+05	234.09	10.8%	10.18%
1.00E+06	104.69	9.5%	12.97%
2.00E+06	74.02	8.4%	15.77%
1.00E+07	33.10	4.2%	29.90%
2.00E+07	23.41	2.3%	41.23%
Energy thresholds NOT included (for 100 and 200 keV)			

Parameters for half thick detectors

NE213 Array

Number of detectors	30	
Detector radius	12	cm
Detector thickness d	5	cm
L	70	cm
Time Resolution	2	ns
$\varepsilon_{geometric}$	22.04%	

Neutron energy (eV)	TOF (ns)	ε_{total}	$\Delta E/E$ (%)
1.00E+05	165.52	21.1%	10.95%
2.00E+05	117.04	19.5%	12.33%
1.00E+06	52.34	14.0%	20.25%
2.00E+06	37.01	11.3%	27.07%
1.00E+07	16.55	4.7%	57.56%
2.00E+07	11.70	2.5%	80.86%
Energy thresholds NOT included (for 100 and 200 keV)			

Position Sensitive NE213 Array

Number of detectors	20	
Detector length	100	cm
Detector thickness	5	cm
L	70	cm
Spatial Resolution	10	cm
Time resolution	2	ns
$\varepsilon_{geometric}$	23.42%	

Neutron energy (eV)	TOF (ns)	ε_{total}	$\Delta E/E$ (%)
1.00E+05	165.52	22.4%	10.95%
2.00E+05	117.04	20.7%	12.33%
1.00E+06	52.34	14.9%	20.25%
2.00E+06	37.01	12.1%	27.07%
1.00E+07	16.55	5.0%	57.56%
2.00E+07	11.70	2.7%	80.86%
Energy thresholds NOT included (for 100 and 200 keV)			

Effect of the intrinsic time resolution

NE213 Array

Number of detectors	30	
Detector radius	12	cm
Detector thickness d	10	cm
L	70	cm
Time Resolution	1	ns
$\varepsilon_{geometric}$	22.04%	

Neutron energy (eV)	TOF (ns)	ε_{total}	ΔE/E (%)
1.00E+05	171.23	22.0%	18.30%
2.00E+05	121.08	21.8%	18.50%
1.00E+06	54.15	19.1%	20.06%
2.00E+06	38.29	16.8%	21.86%
1.00E+07	17.12	8.4%	32.87%
2.00E+07	12.11	4.7%	42.83%
Energy thresholds NOT included (for 100 and 200 keV)			

Position Sensitive NE213 Array

Number of detectors	10	
Detector length	100	cm
Detector thickness	10	cm
L	70	cm
Spatial Resolution	10	cm
Time resolution	1	ns
$\varepsilon_{geometric}$	23.42%	

Neutron energy (eV)	TOF (ns)	ε_{total}	ΔE/E (%)
1.00E+05	171.23	23.4%	18.30%
2.00E+05	121.08	23.1%	18.50%
1.00E+06	54.15	20.3%	20.06%
2.00E+06	38.29	17.9%	21.86%
1.00E+07	17.12	9.0%	32.87%
2.00E+07	12.11	5.0%	42.83%
Energy thresholds NOT included (for 100 and 200 keV)			