Characterization of neutron detectors for nuclear technology applications

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Nuclear data for transmutation of radioactive waste (MA and LLFP)

Design, safety assessment and operation of fast reactors and ADS
Improve accuracy of nuclear data libraries.
- Neutron cross-section data (capture, fission, inelastic)
- Decay heat data, Delayed neutron data (neutron emission probabilities)

Uncertainty reduction involve development and improvement of facilities and detection techniques.

Facilities:

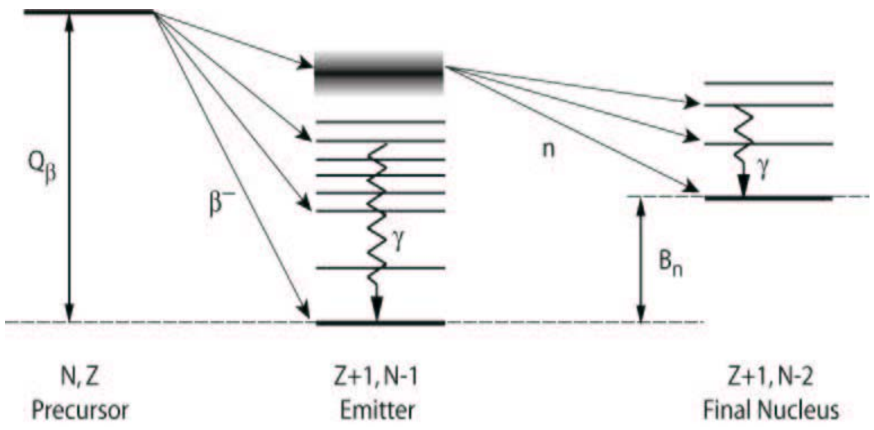
n_TOF@CERN where involved in TAC, C6D6 set-up (n capture cross-section data on Np, Pu, Bi, Pb…)
FAIR @ GSI radioactive beams available to study neutron rich nuclei

Detection and techniques:

n_TOF spectrometer
Total Absorption Gamma-ray Spectroscopy (TAGS)
New scintillation materials (LaCl3, LaBr3)
DAQ systems (flash ADC)

FAIR – DESPEC experiment (Nustar collaboration)

High Intensity secondary radioactive beams will allow to populate exotic nuclei
Nuclei produced in the fission reaction process in reactors.
Neutron rich nuclei are obtained after separation at S-FRS and implantation on a silicon detector. Beta decay properties and neutron emission probability could be studied with high accuracy.



-Delayed neutron data: absolute neutron yield, neutron energy spectra, time dependence with activity.

- High efficiency 4π moderated-based detector
- n_ToF spectrometer

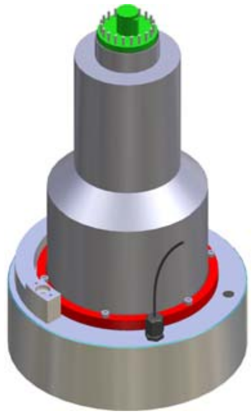
-Decay heat data: distribution of beta, gamma and neutrino energies.

- TAGS spectrometer based on inorganic scintillators

Neutron TOF spectrometer

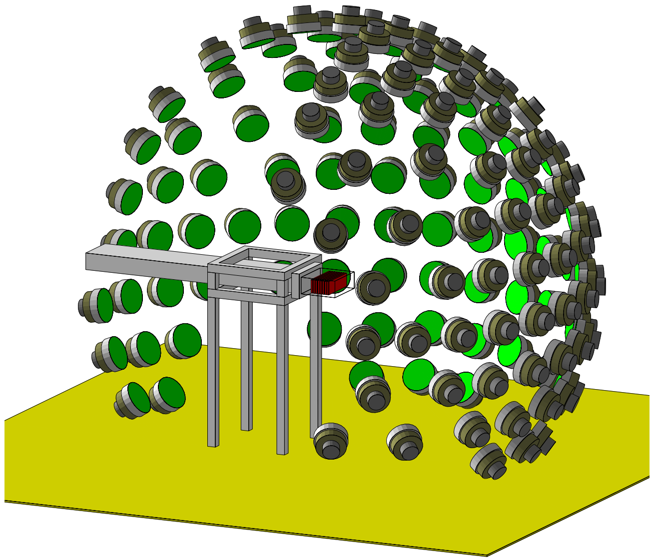
Requirements:

N-g discrimination, (reduced background)
Improved $\Delta E/E$, (thin and small detectors)
Lowest threshold, (down to 30 keVee)
high ε_n (large solid angle)
cross-talk rejection (high granularity)



Ø=20cm
L=5cm

Liquid organic scintillator cells
MonteCarlo simulations of prototype under study



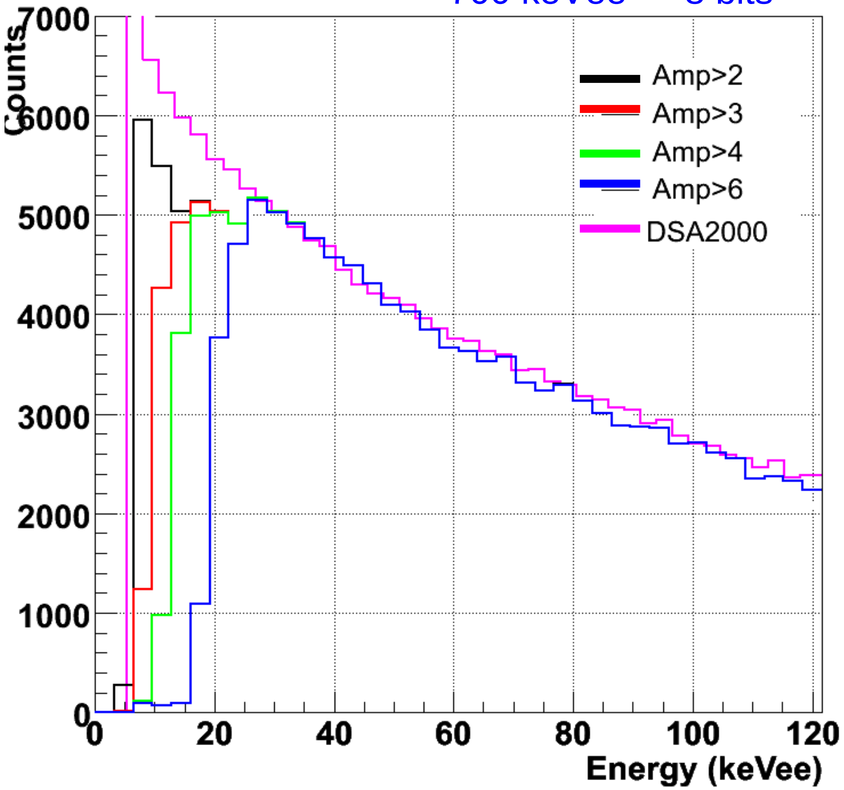
Measurements of characterization:

Light output calibration function for electrons and protons, L=f(E)
Energy resolution $\Delta L/L(\%)$ as a function of energy deposited
Absolute neutron sensitivity and detection efficiency
Comparison with MonteCarlo simulation

Performance of DAQ systems (flash ADC)

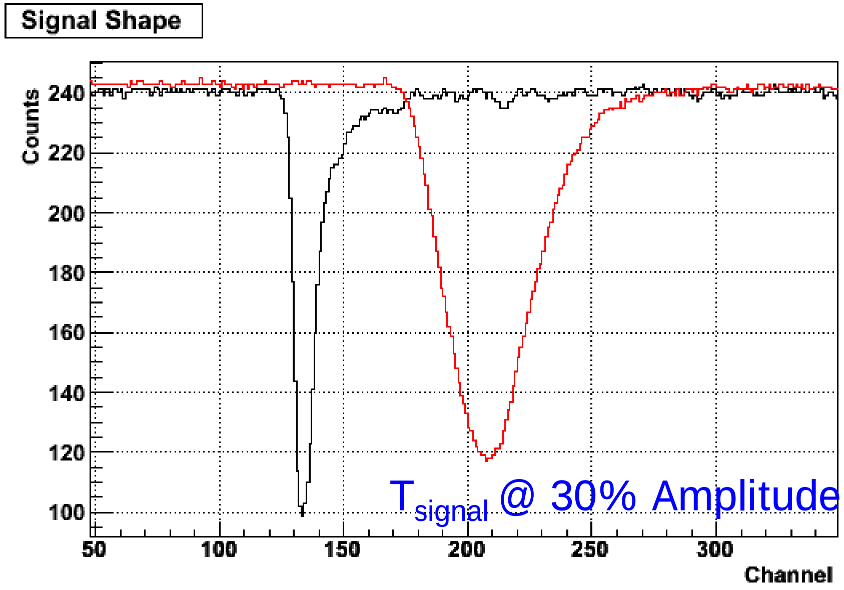
Energy Threshold

Case 12 bits 1GS/s
700 keVee --- 8 bits



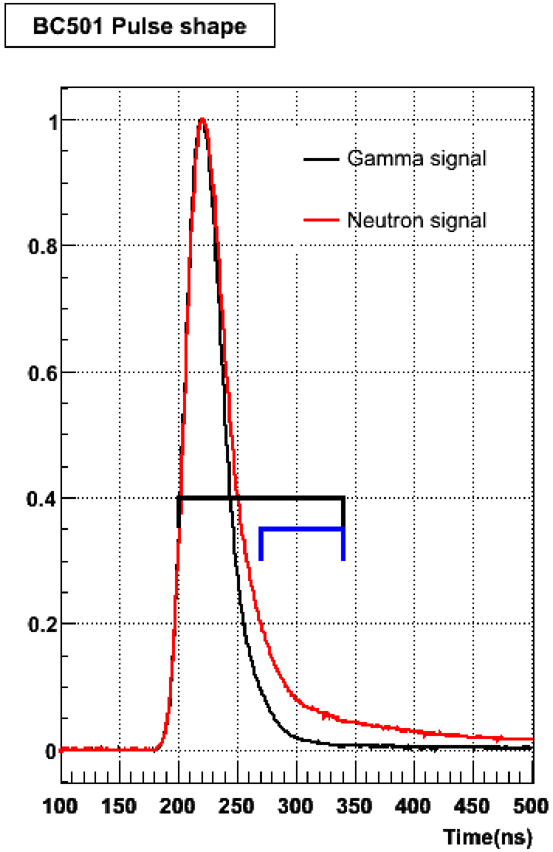
N Bits	10	12	14
E thres (keVee)	50	20	10

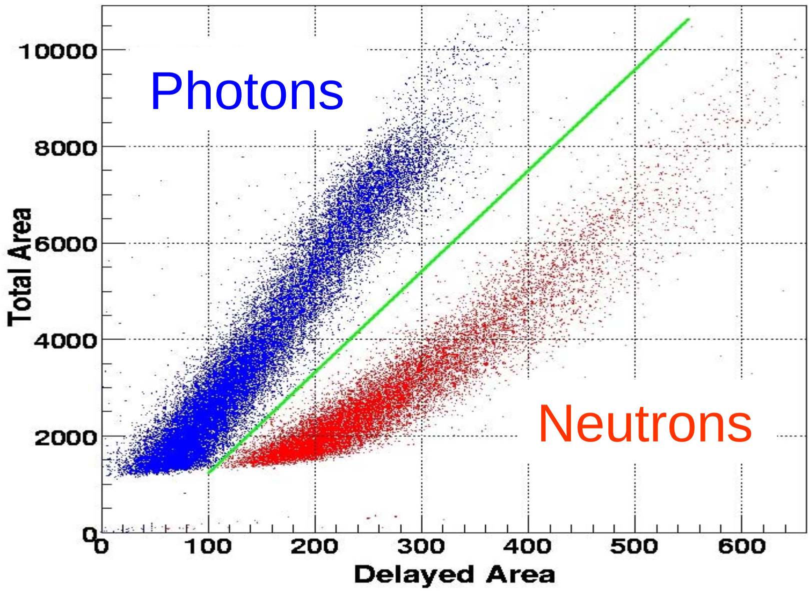
Time Resolution



		BC501A	EJ301
Signal	Sampling Rate	FWHM (ns)	FWHM (ns)
TAC	-	1.25 (7)	0.85(7)
PSA	1 GS/s	1.41 (7)	0.93 (5)

n-γ discrimination





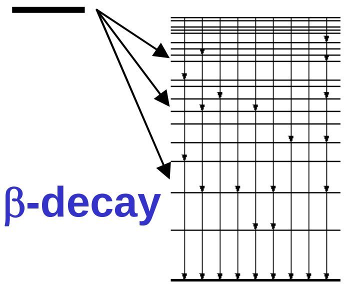
Energy (keVee)	BC501A	EJ301	N-Wall	EDEN	DEMON
80	0.75 (2)	0.78 (2)			
100	0.88 (2)	0.86 (2)	1.1	1.00 (3)	1.09
200	1.43 (2)	1.21 (3)	1.5	1.46 (3)	
300	1.76 (3)	1.41 (5)		1.72 (4)	1.73 (9)
500	2.14 (3)	1.56 (5)	1.8		

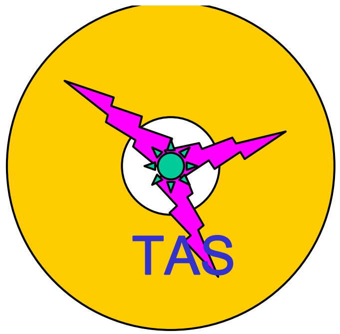
A Total Absorption Spectrometer for beta-decay measurements of neutron rich nuclei

- **Accurate measurements of beta-decay intensity distributions are important in nuclear structure studies, astrophysical applications (r-process) and nuclear technology (reactor decay heat calculations)**

- **Total Absorption Spectroscopy is the best method to measure beta strengths in β-decay (the only valid one far from stability)**

- **The main source of systematic error is contamination/background signals**





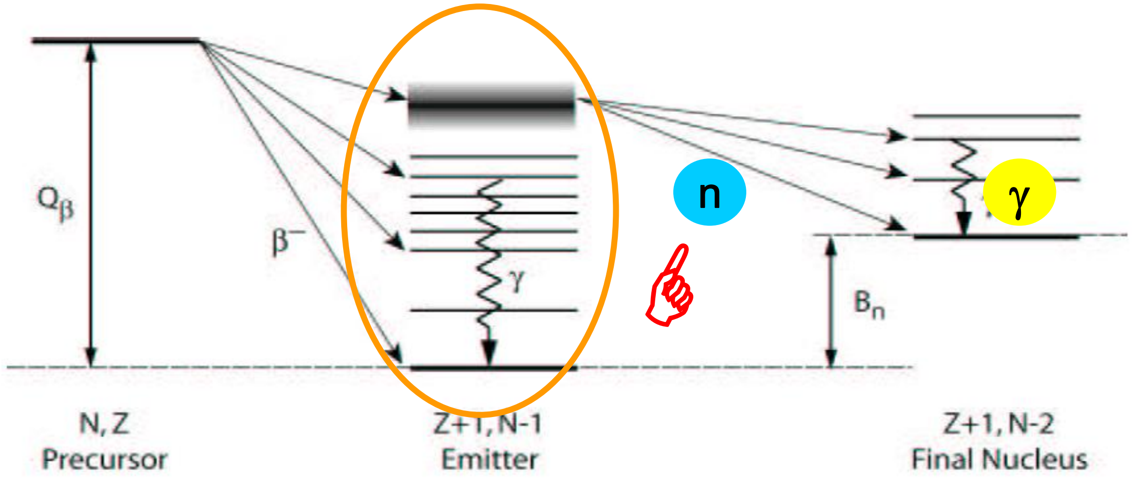
$$\mathbf{f} = \mathbf{R}^{-1} \cdot \mathbf{d}$$

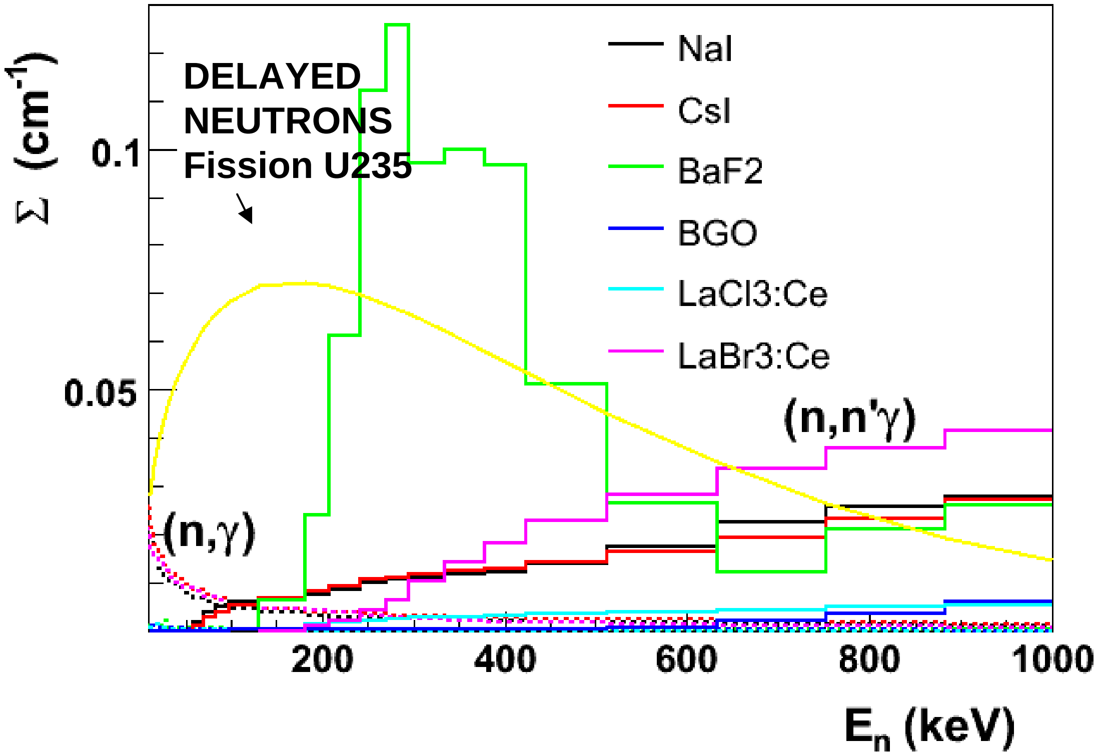
$$\mathbf{R_j} = \sum_{k=0}^{j-1} b_{jk} \mathbf{g_{jk}} \otimes \mathbf{R_k}$$

Jose L. Tain @ IFIC-Valencia

β-delayed neutron emission: scintillator neutron sensitivity

main contribution: capture and inelastic channels





Experimental tests:

- @ PTB Braunschweig
- NaI, BaF_2, CsI, $LaCl_3$, $LaBr_3$
- E_n: 25keV, 565keV, 2.5MeV, "white source"

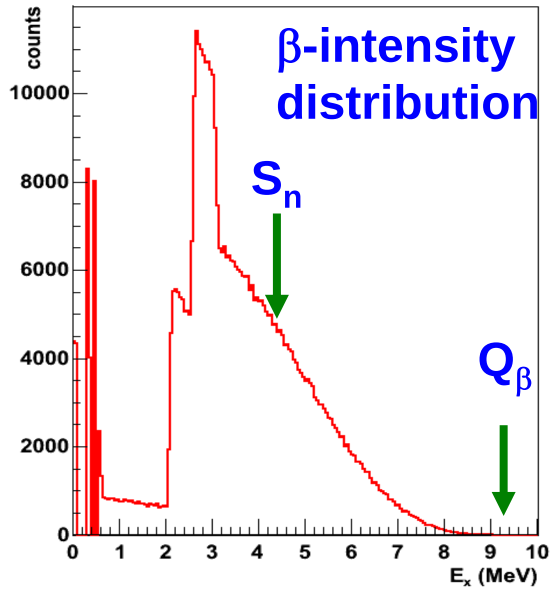
^{147}Cs β-decay

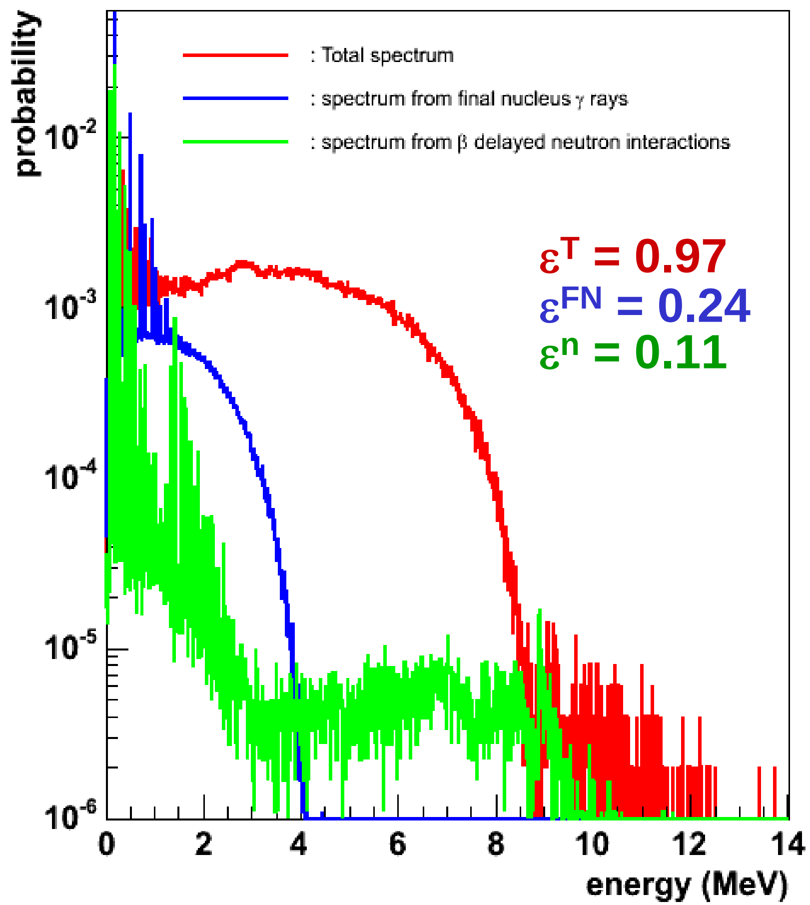
$T_{1/2}$= 0.235 s ; J^{π}= $3/2^{+}$; Q_{β} = 9.2 MeV
^{147}Ba S_n= 4.45 MeV ; P_n= 27.5 %

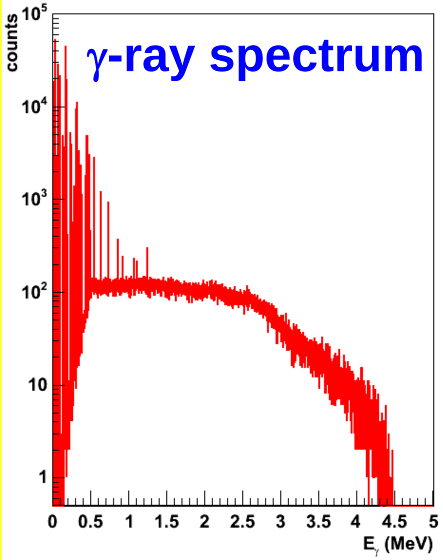
Geant4 Monte Carlo simulation

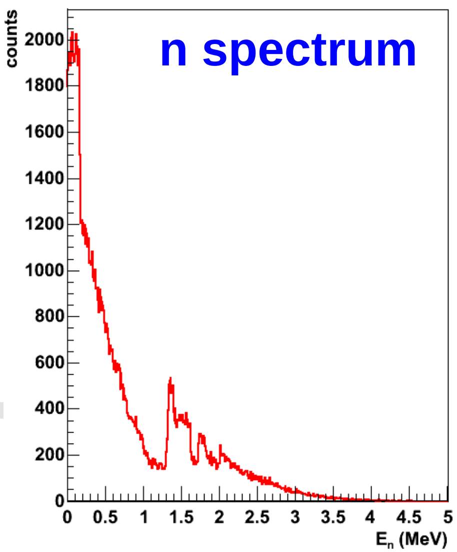
(D. Jordan MSc Thesis, U. Valencia)

- ☞ **n detection probability: ~ 50%**
- ☞ **discrimination through timing (5-10ns window)**





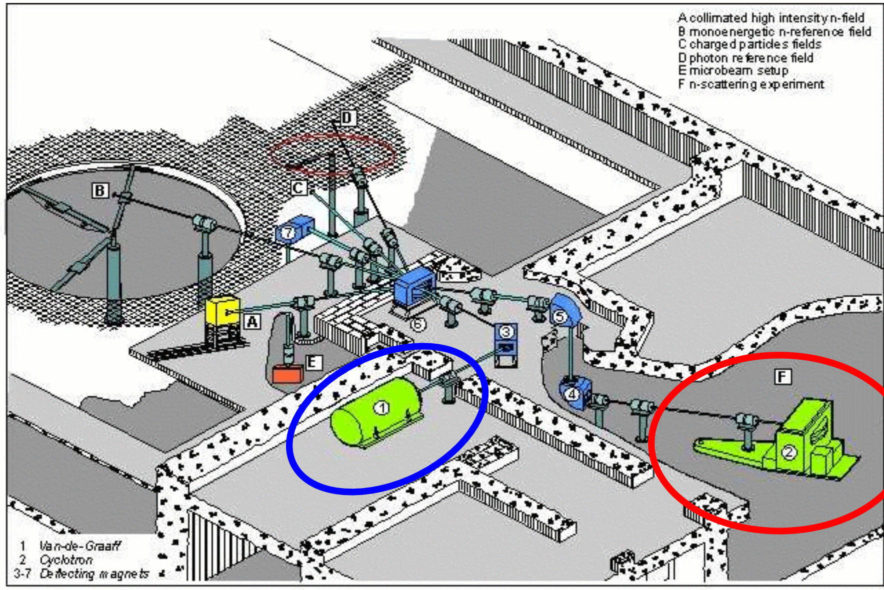




Transnational Access to the EFNUDAT facilities program: PTB Institute

Production of mono-energetic neutron reference fields
High intensity white neutrons beams

Flux and Beam Time with Cyclotron
Liquid scintillators:
D(d,n) reaction @ En=8, 10, 12, 14 MeV
Fluence of 120-160 n cm^{-2} s^{-1} @ 12 m
4 shift (8h each) for 2 detectors



Flux and Beam Time with Van de Graaf
Inorganic scintillators:
Li(p,n) reaction @ En=24, 565 keV
T(p,n) reaction @ En=2.5 MeV
White source
6 shifts (48h total) 4 detectors

Allocated in spring 2008