Neutrons For Science:

A neutron facility @ SPIRAL-2

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OUTLINE

SPIRAL-2

- NFS description
- Buildings design
- Physics case

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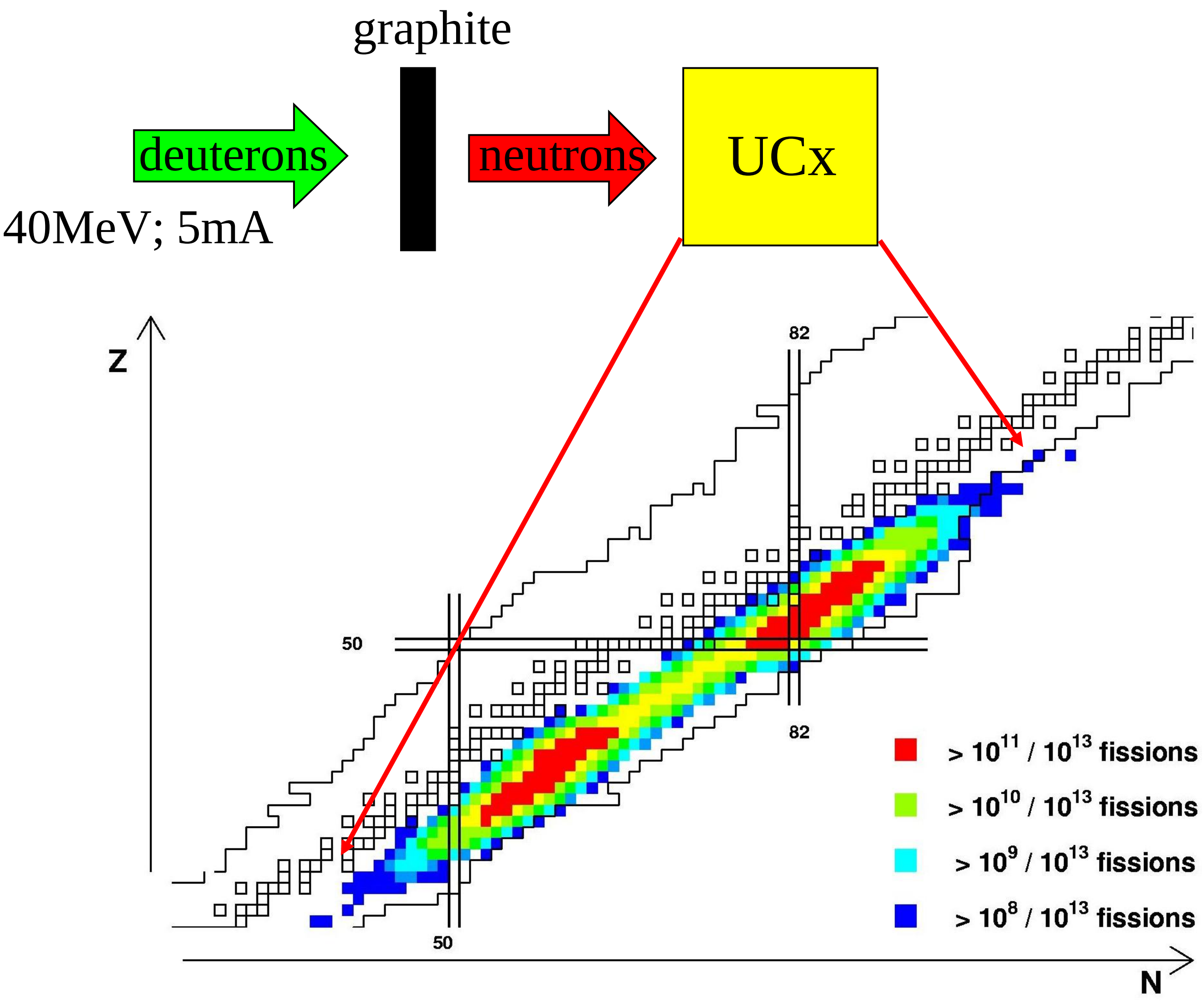
SPIRAL-2



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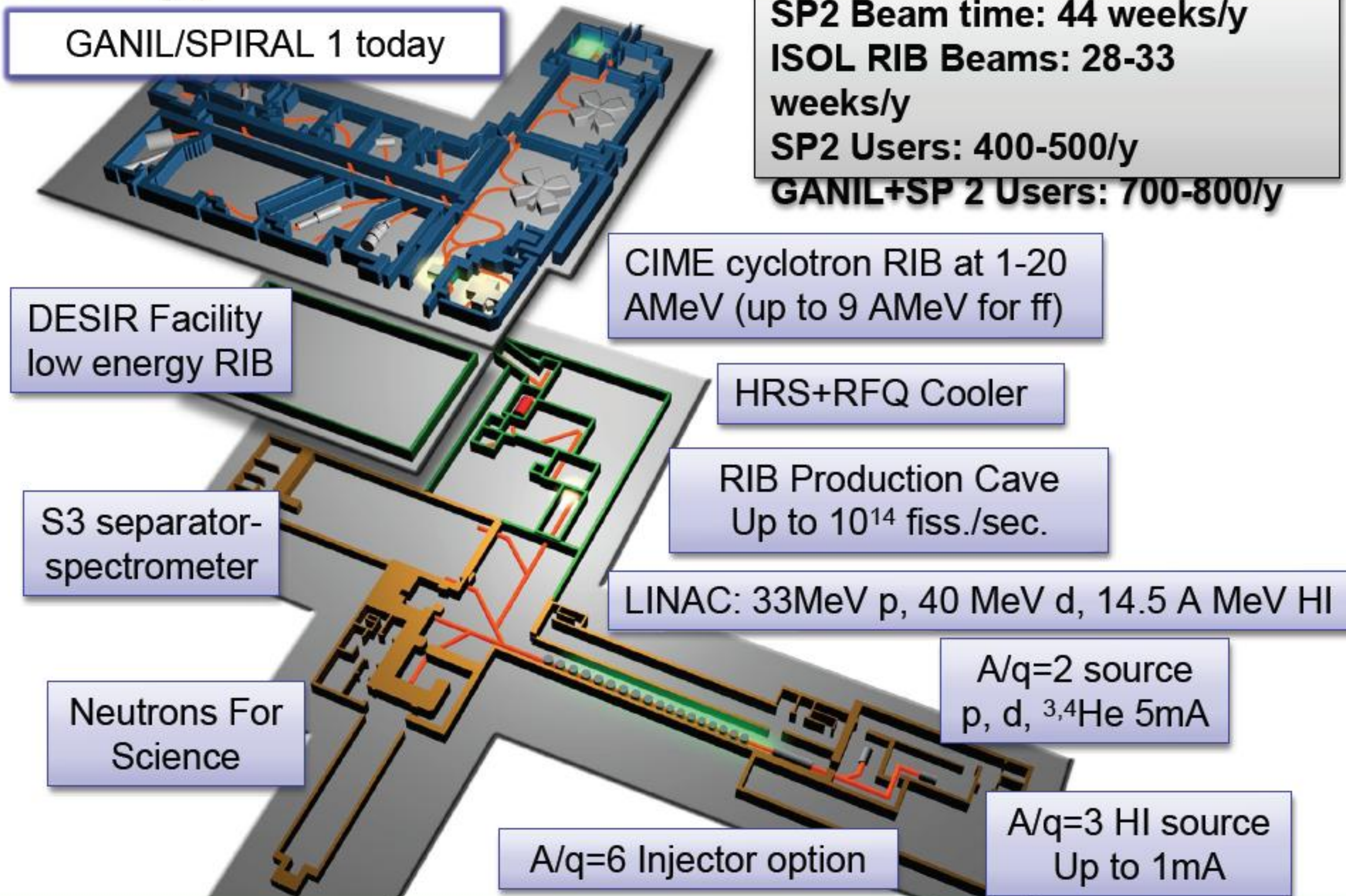
GANIL/SPIRAL1/SPIRAL2 facility layout

SP2 Beam time: 44 weeks/y
ISOL RIB Beams: 28-33 weeks/y
SP2 Users: 400-500/y
GANIL+SP 2 Users: 700-800/y



Neutrons For Science

- NFS is one of the two facilities of the LINAG Experimental Area

- Use of the LINAG's beams to produce neutrons between 1 and 40 MeV.

The NFS is composed of :

- A neutron beam in a Time-Of-Flight area
- An irradiation box (p and d induced reactions)
- An irradiation cell for interdisciplinary research at SPIRAL-2

The NFS working group study :

- Technical options
- Physics case
- Potential users (applied physic, industry…)

Scientific evaluation:

Scientific Advisory Committee of SPIRAL 2

IN2P3 Scientific council

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Neutron spectra provided at NFS

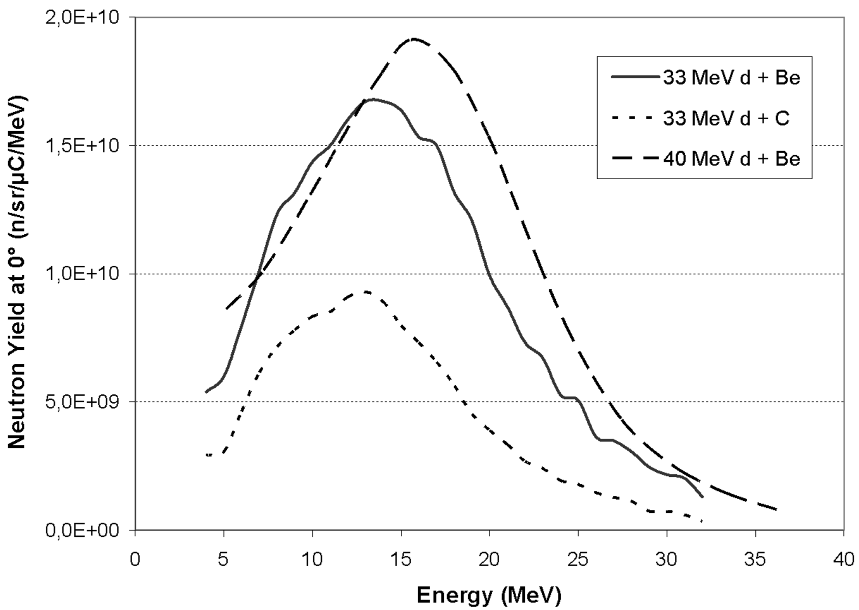
Characteristics of the beams the LINAG :

- 40 MeV deuteron and 33 MeV proton
- I_{max} = 5 mA
- Pulsed beam F_0 = 88 MHz T=11 ns Burst width = 200 ps

Continuous spectrum :

E_{max} = 40 MeV , <E> = 14 MeV

thick converter (1cm)



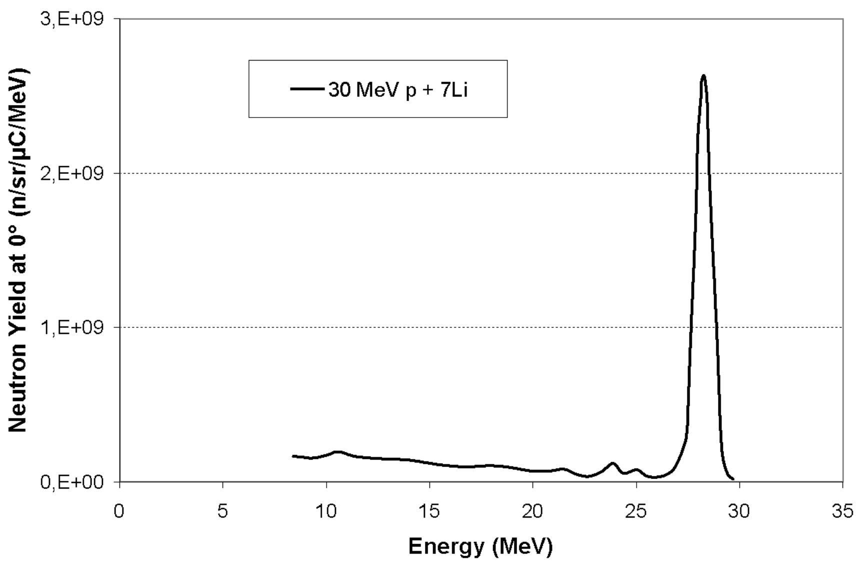
J. P. Meulders et al., Phys. Med. Biol. (1975)vol 20 n 2, p235

M. J. Saltmarsh et al., NIMA145 (1977) p81-90

Quasi-monokinetic beam :

E_n = up to 31 MeV

Thin converter (1-3 mm)



C. J. Batty et al.,NIM **68** (1969) p273-276

⇒ Similar to IFMIF spectrum

Description

Converter cave

Beam line extension

Magnet

Beam stop

Irradiation station (n, p, d)

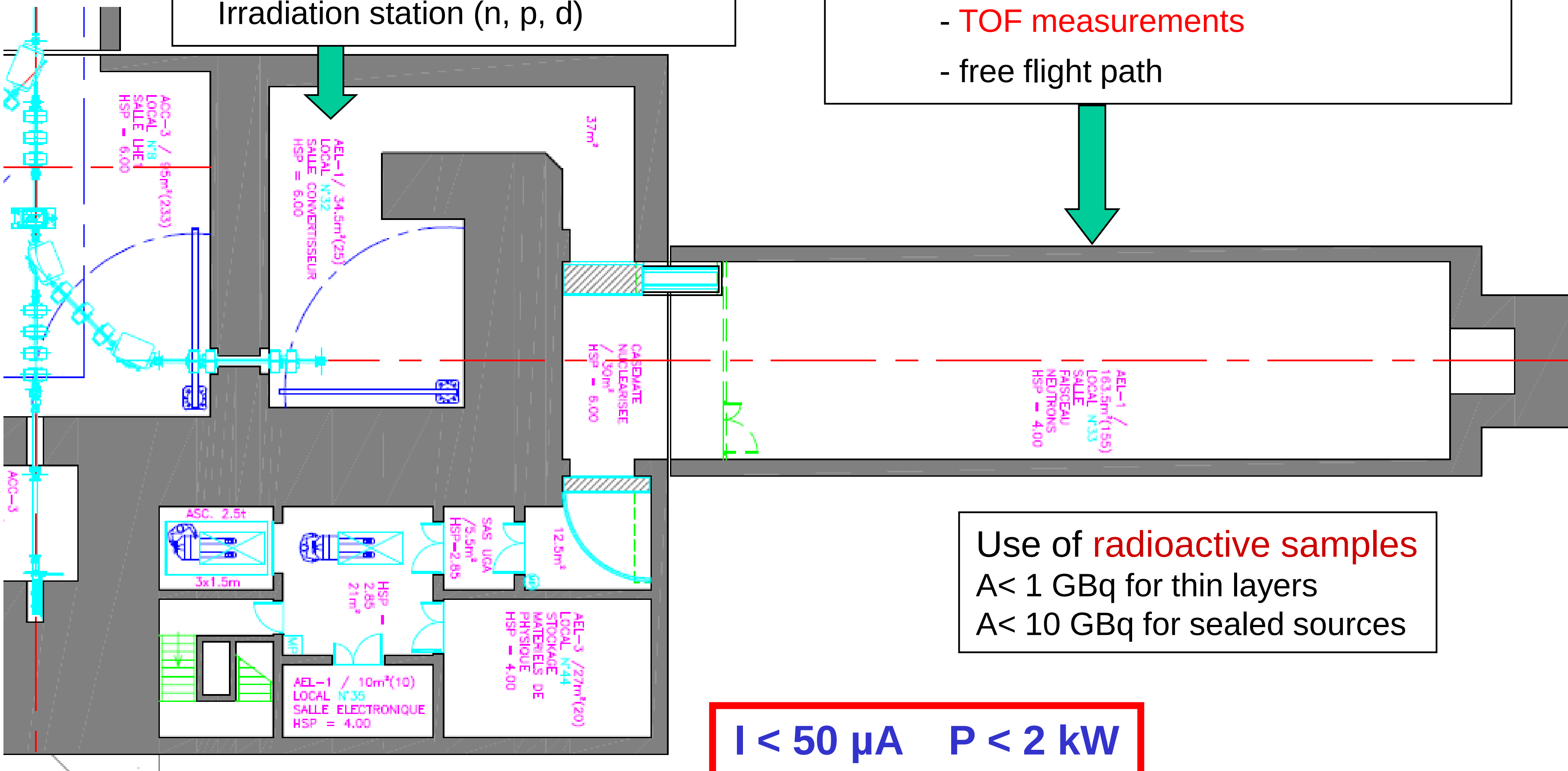
Time-of-flight area

Beam at 0°

Collimator ↔ beam quality

Size (L x l) ≃ (25m x 6m)

- TOF measurements
- free flight path



Use of radioactive samples
A< 1 GBq for thin layers
A< 10 GBq for sealed sources

I < 50 µA P < 2 kW

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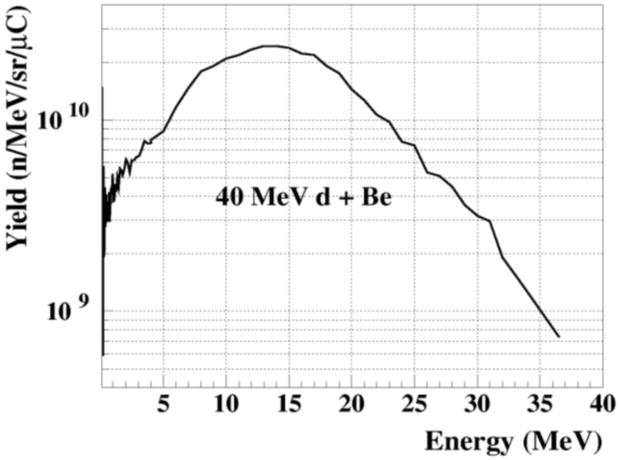
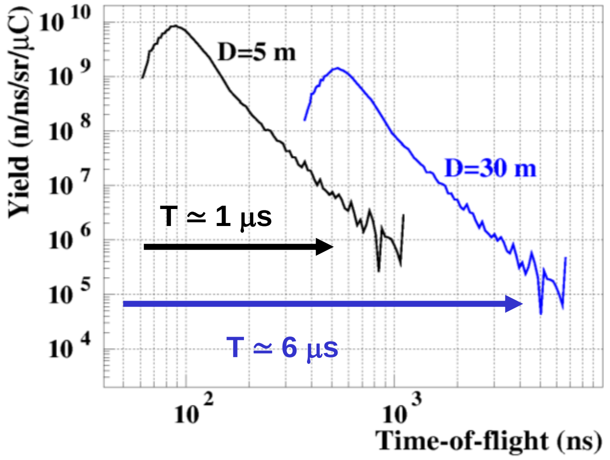
Beam characteristics

Bursts overlap :





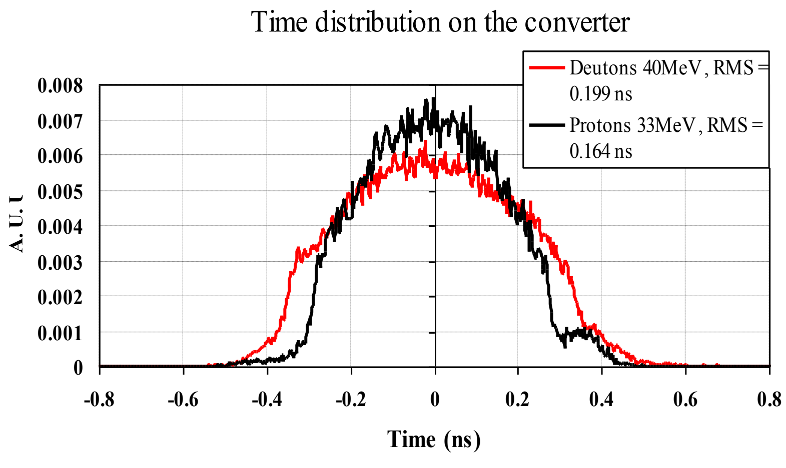
T_{LINAG} = 11 ns

Fast beam chopper

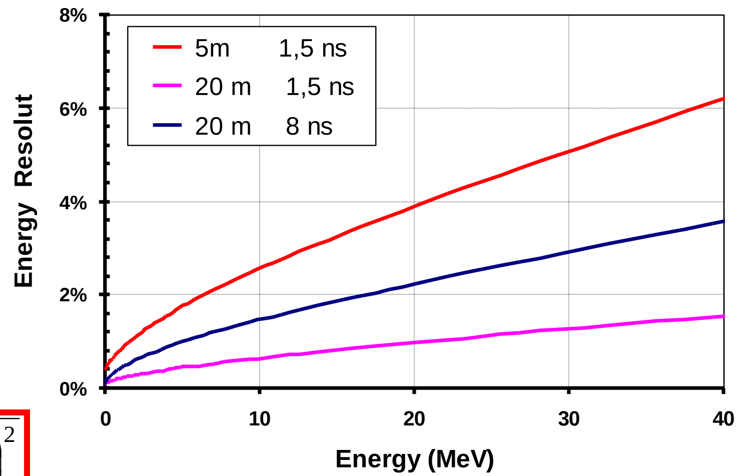
- F = F / N
- I = Imax / N

with N>100

Energy resolution :



$$\frac{\Delta E}{E} = \gamma(\gamma+1)\sqrt{\left(\frac{\Delta t}{t}\right)^2 + \left(\frac{\Delta L}{L}\right)^2}$$



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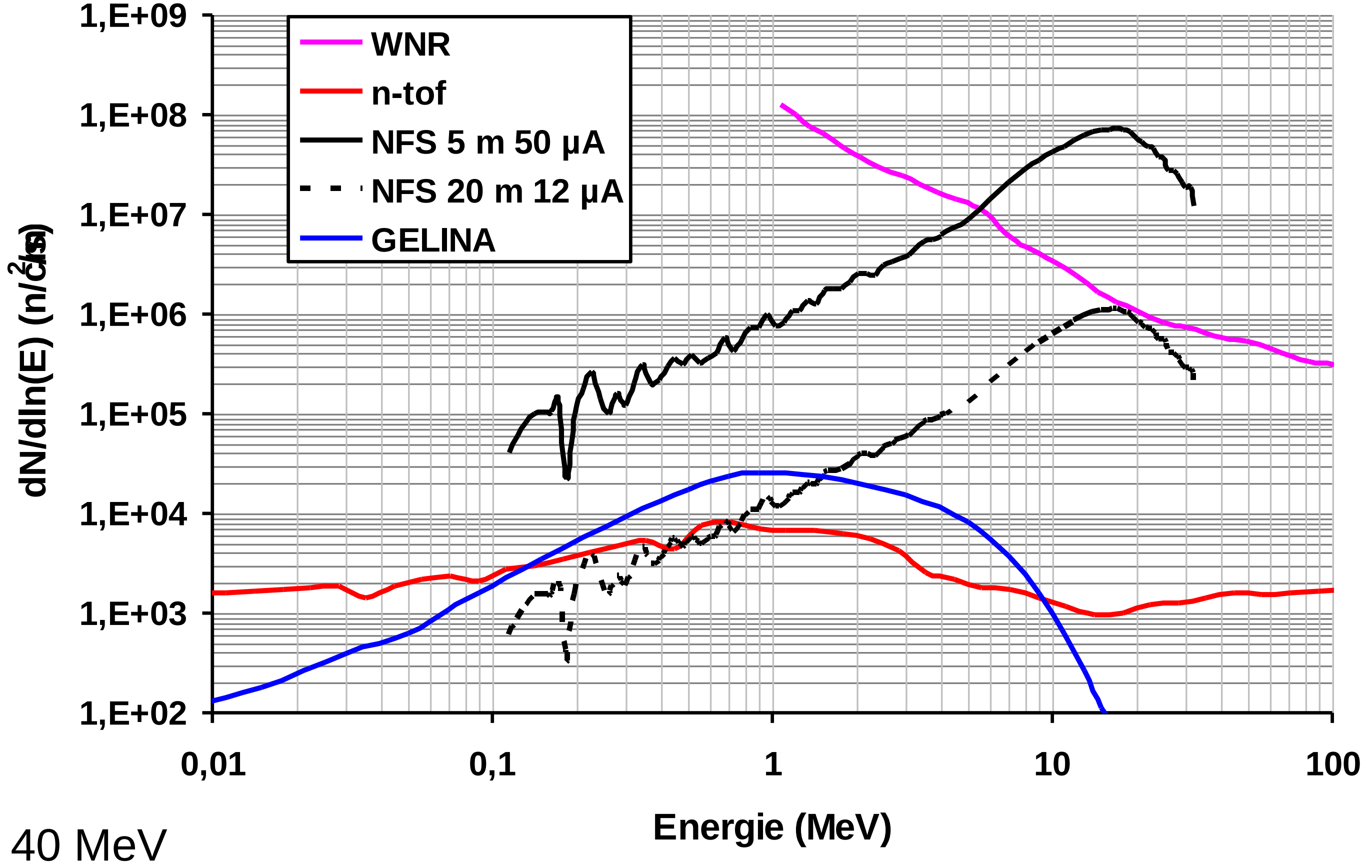
Comparison with other neutron beam facilities

WNR : Los Alamos

N-tof : CERN

GELINA : Geel



- E_n: from 1 MeV to 40 MeV
- High flux ⇒ small samples / coincident experiments
- Reduced γ flash

➡ Complementary to the existing facilities

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Buildings design

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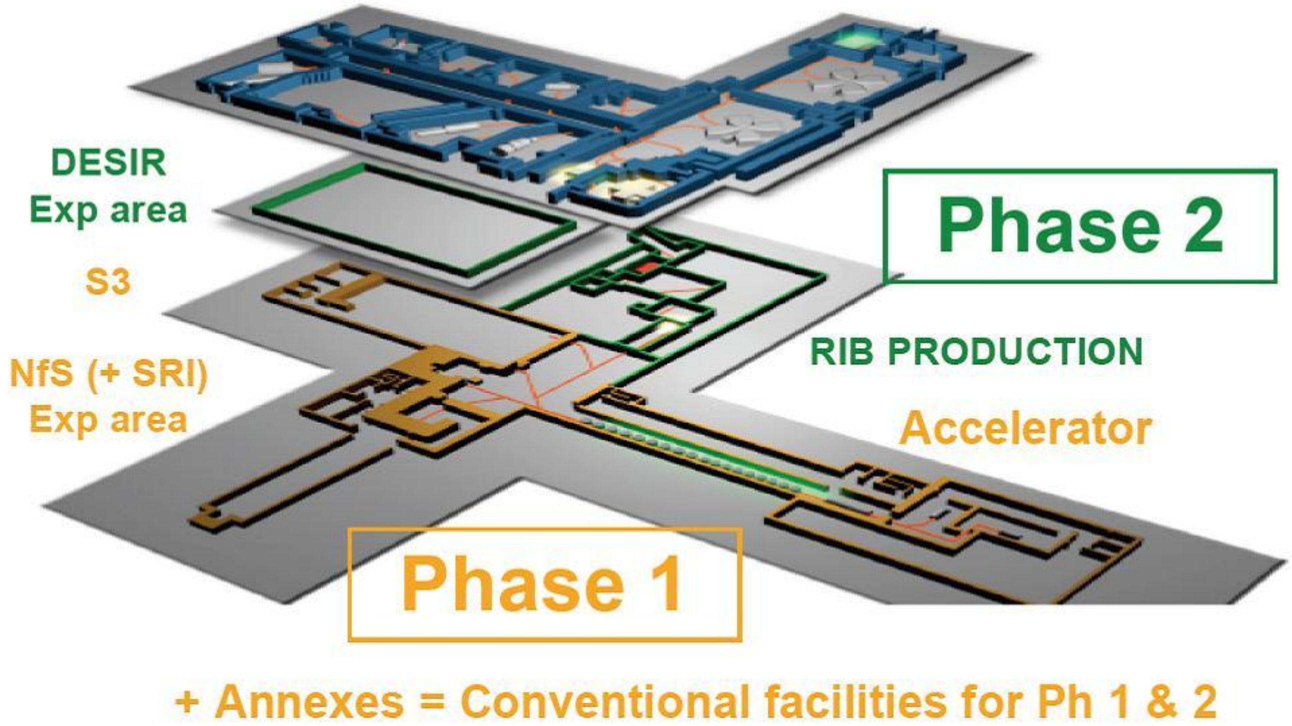
2 Phases



Milestone (M. Jacquemet, Ganil Scientific Council 6th May 2010)

February 2010 : Specifications for the contracts
March 2010 : Call for tenders
May 2010 : Responses to the Call for Tenders
July 2010 : Public inquiry
October 2010 : Permit of construction
January 2012 : Start of NFS process installation
15th October 2012 : first beam at NFS

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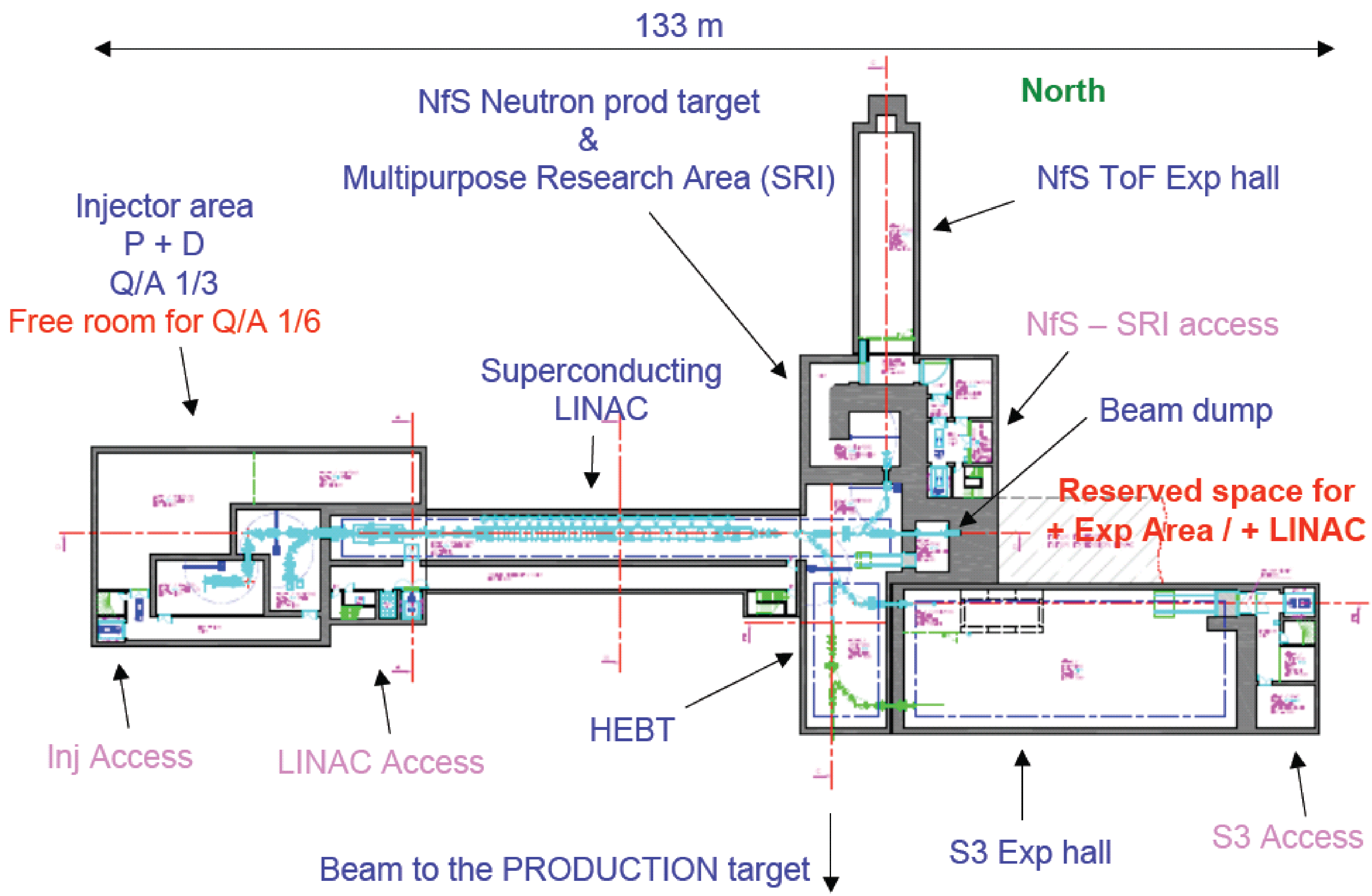
Plan : level -9,50 m



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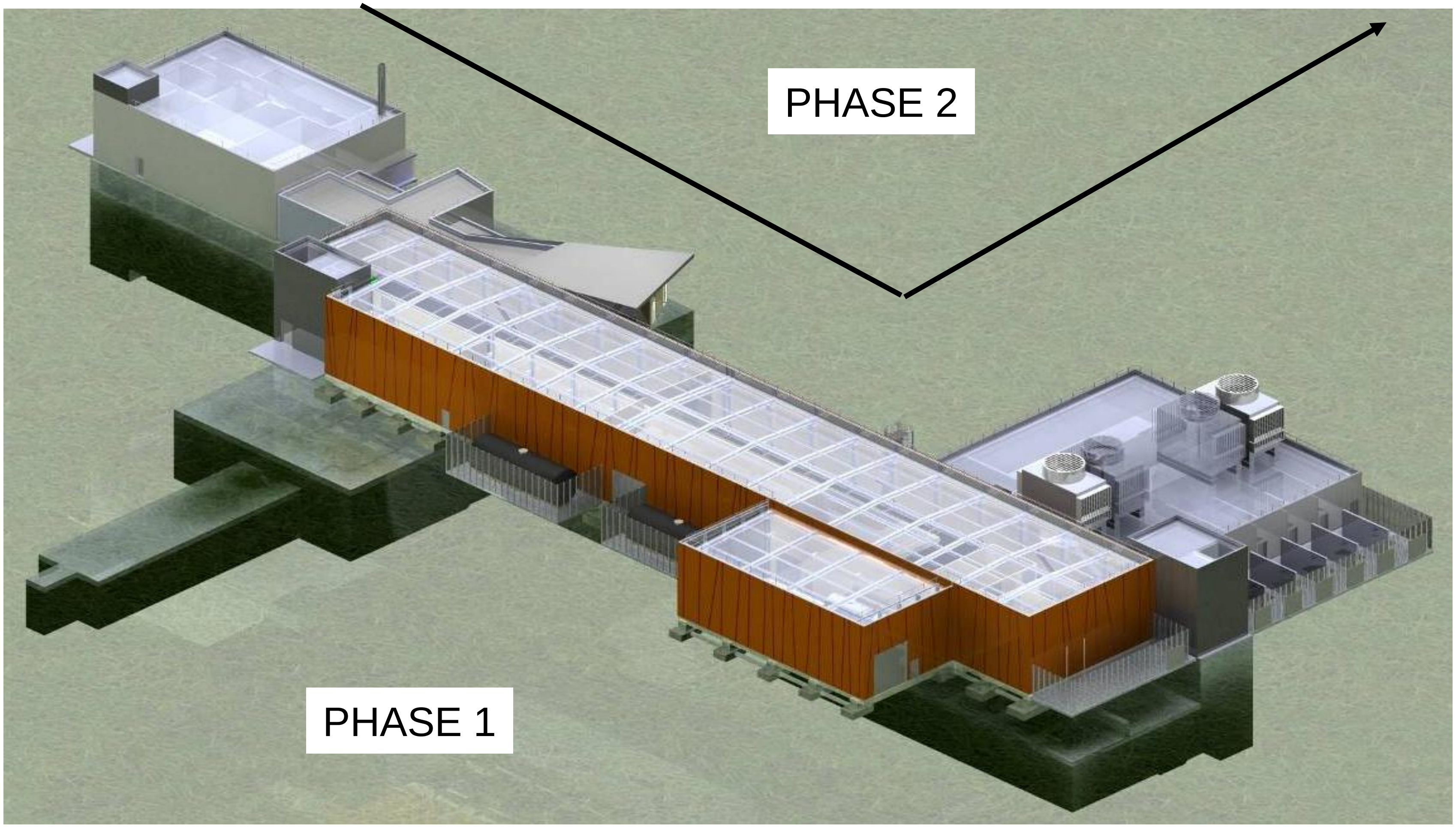

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Calculations for safety issues

Safety issues (request for the preliminary safety file)

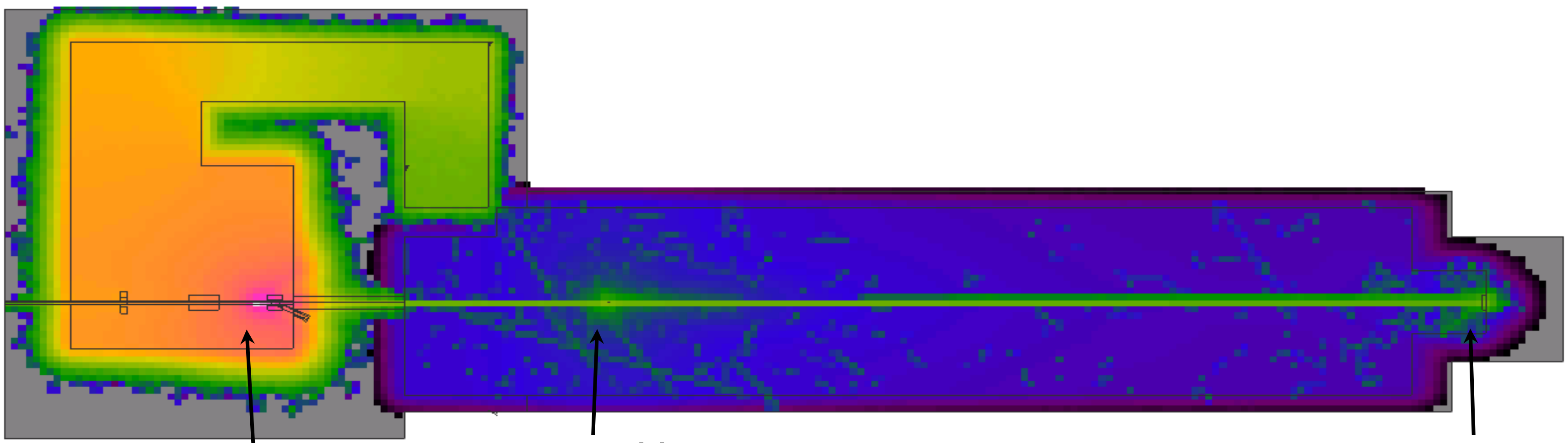
- Radioprotection → Shielding design
- Nuclear waste production → Activation

Facility performance :

- Optimization and validation of the Building Prime Contractor proposals
- Evaluation of the neutron background in the TOF hall
- Iterations on several solutions

Simulation tools :

- MCNPX Particle transport
- CINDER Evolution code



Source (1)
d+ Be and p+^{7}Li

Source (4)
^{238}U sample

Source (5)
Interaction of the neutrons in the beam dump

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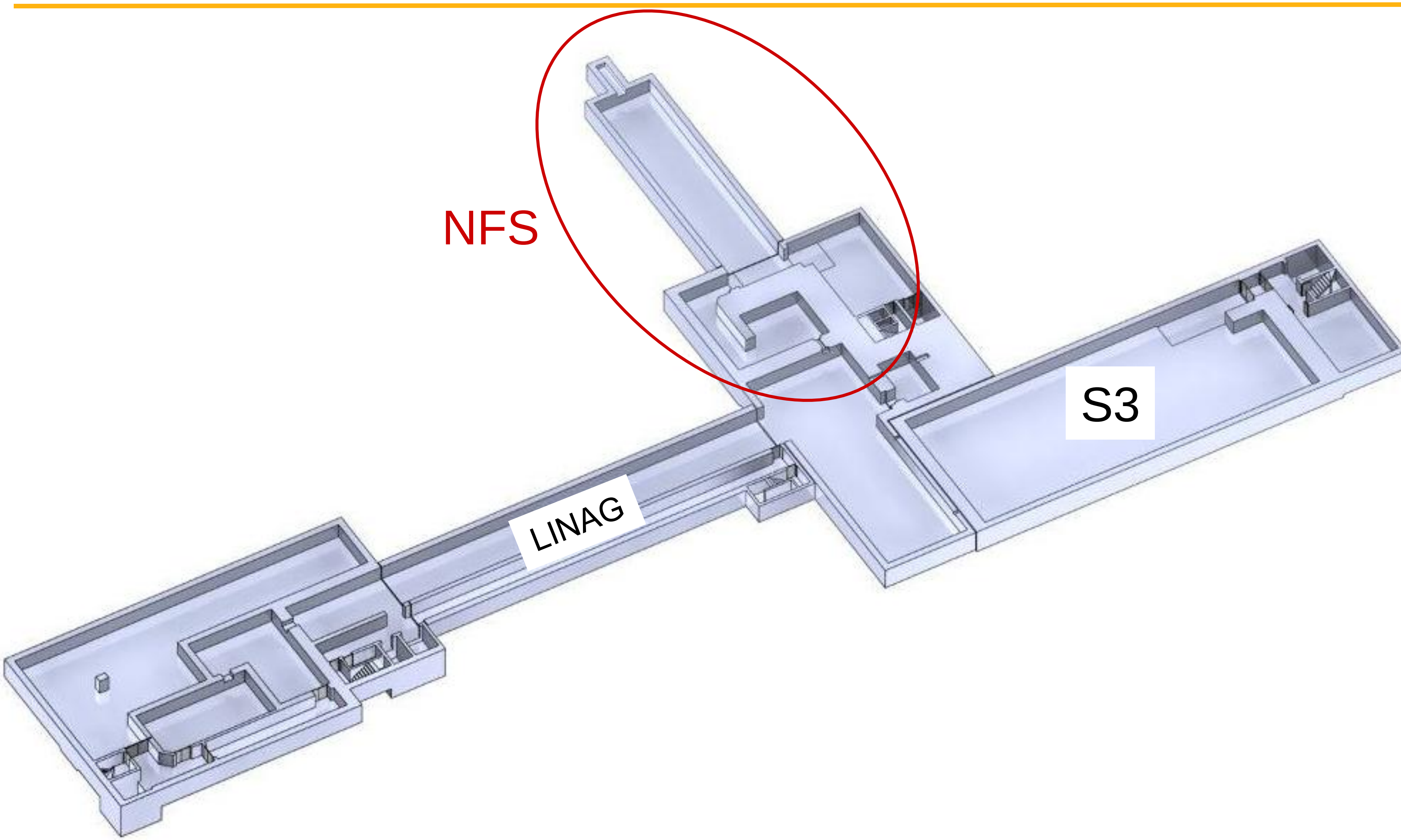
SPIRAL2 Phase 1 Building



Level -9,5 m

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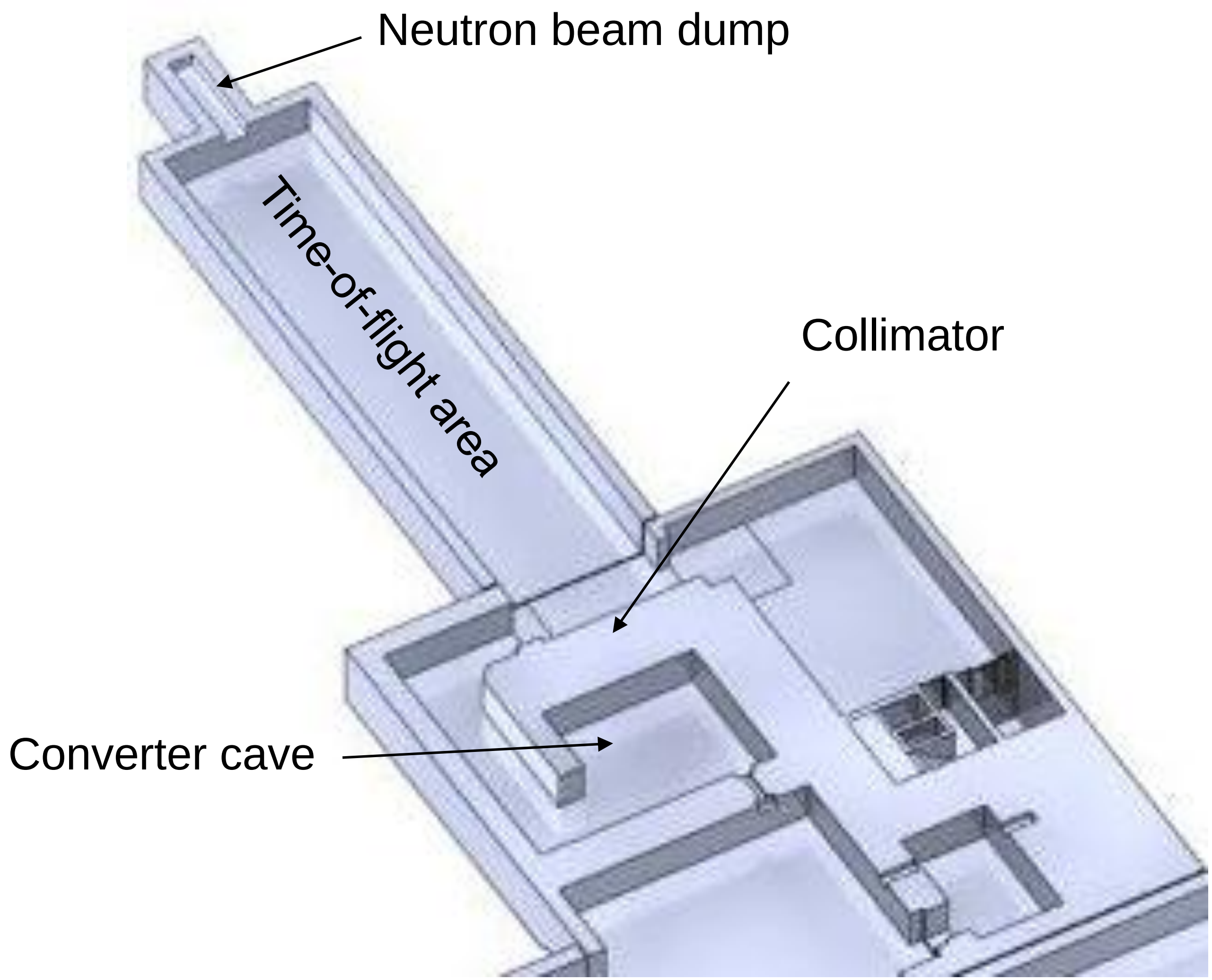
NFS facility



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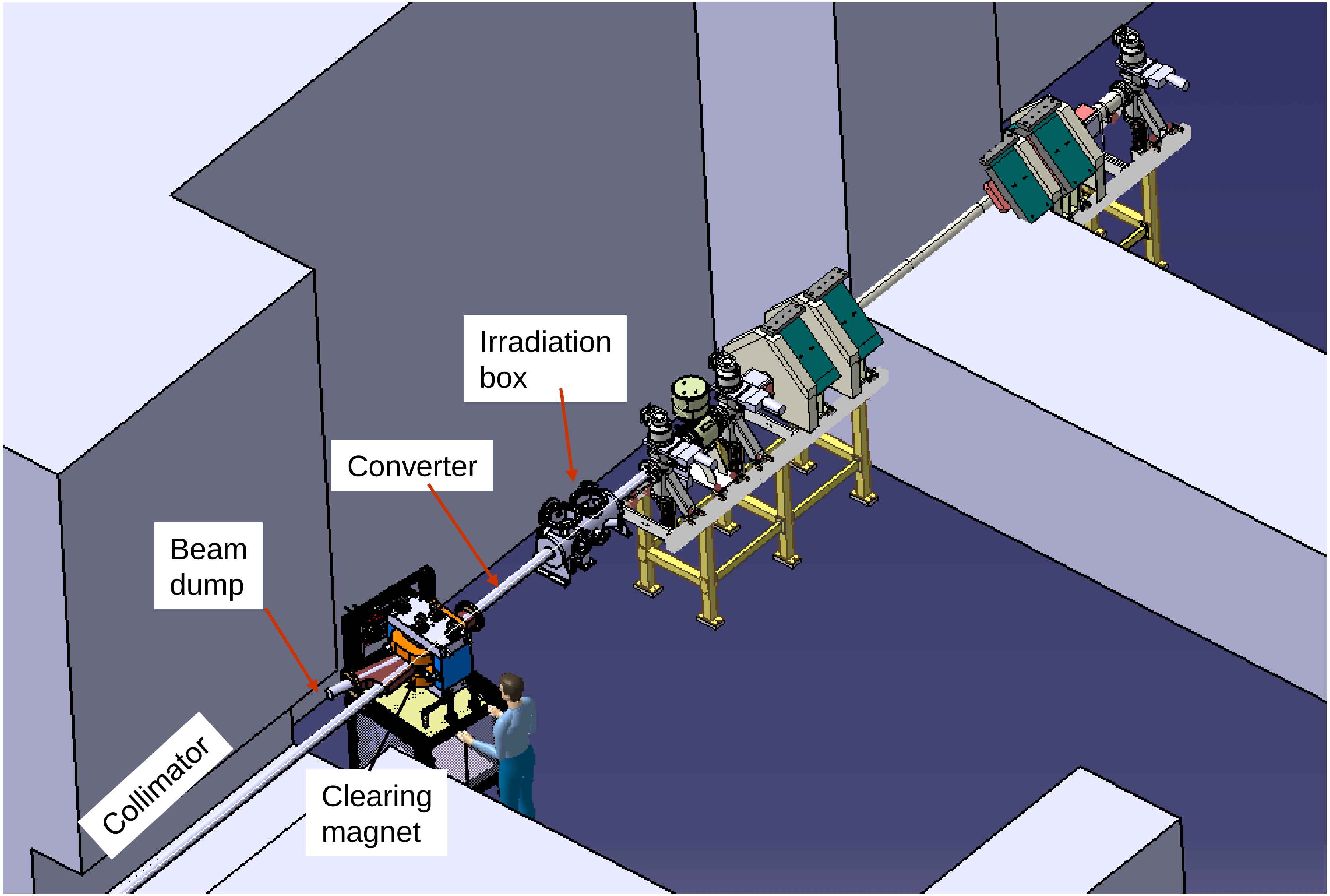
Technical components

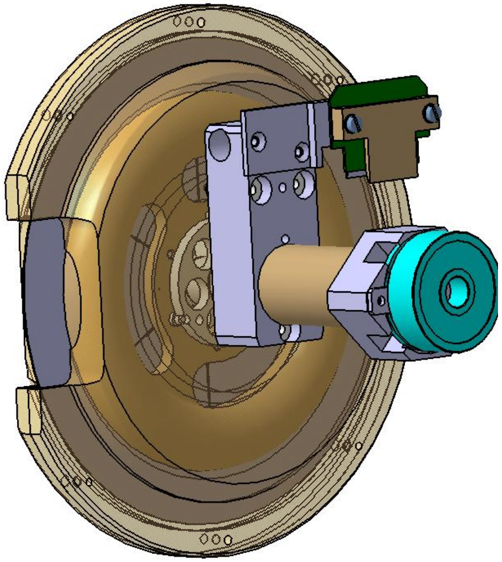


Converter

Thick target for neutron production
Be and C, 10 mm thick, 2 kW

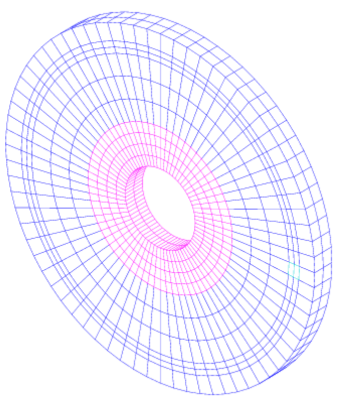
Strategy : Adaptation of the CLIM target

1. Thermal calculations (CEA/IRfU)
2. Radioprotection calculations
3. Copy or new design

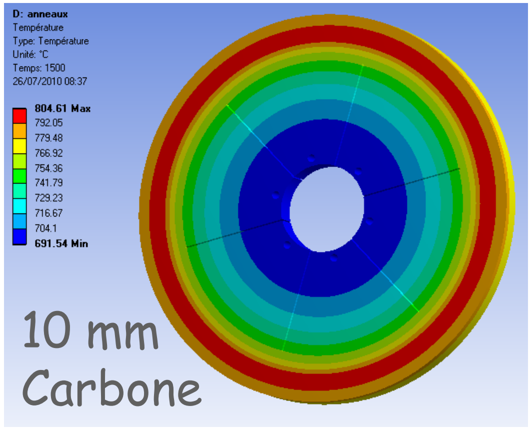


Preliminary results

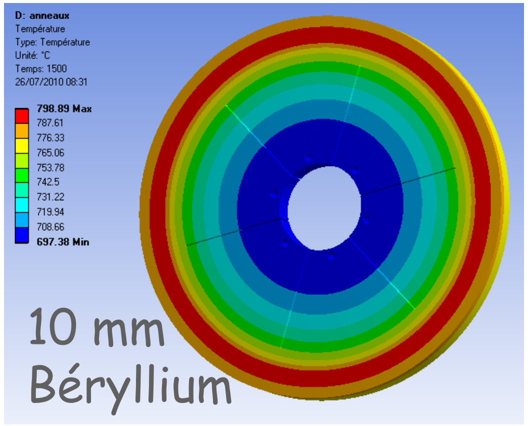
1. Fixed target : T_{max} = 4250°C
2. Rotating target $T_{max} \approx$ 800°C



Convertisseur Roue SPIRAL2 : Source 2000 W



T°max. = 804°C



T°max. = 798°C

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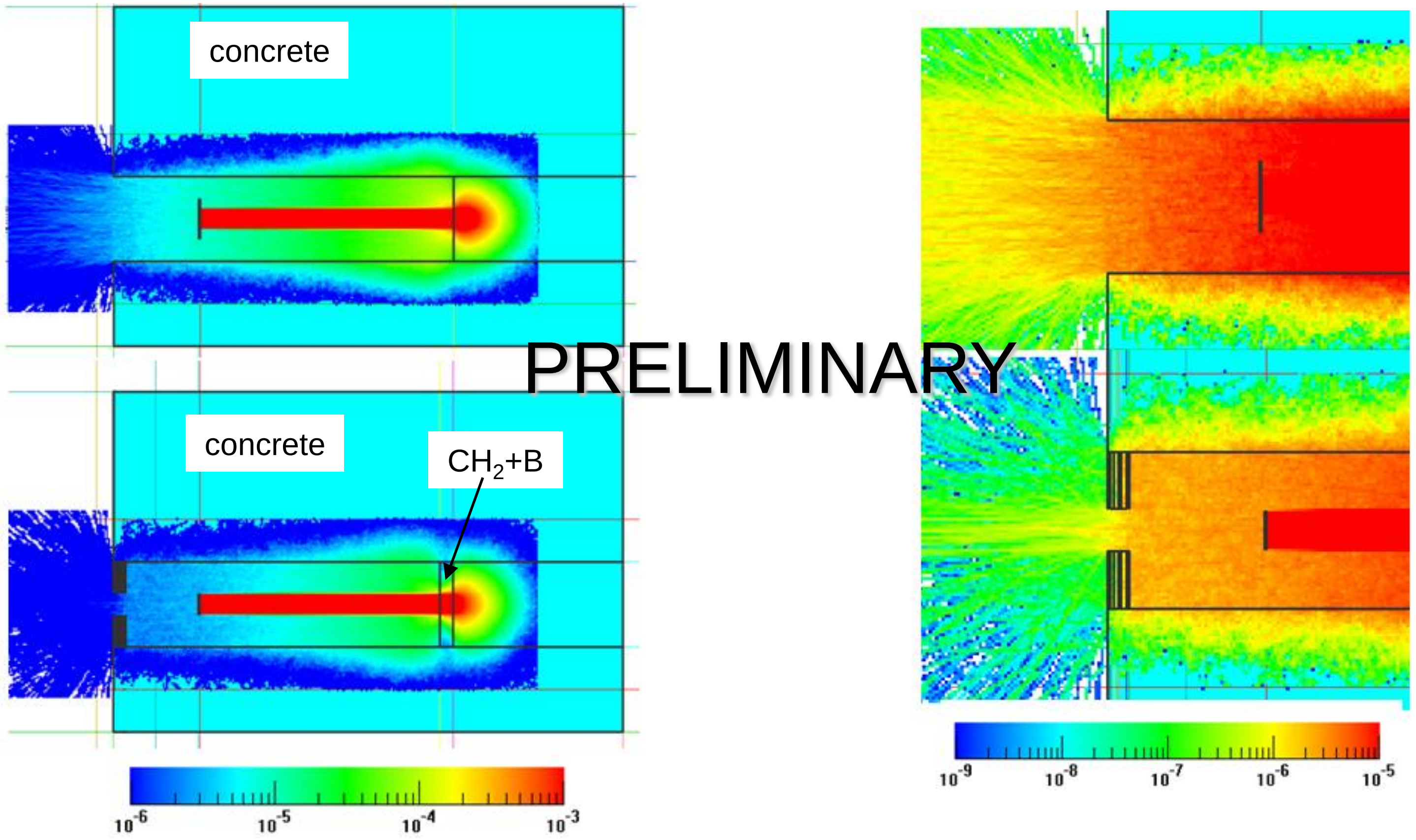
Beam dump

Goal : minimize neutron back-scattering to the TOF area



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Physics case

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General Physics Case

Reactions induced by fast neutrons are of first importance in the following topics :

- Fission reactors of new generation
- Fusion technology
- Studies related to hybrid reactors (ADS)
- Validation of codes
- Nuclear medicine
- Development and characterization of new detectors
- Irradiation of chips and electronics structures

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Letters of Intents for Day-One experiments at NFS

The SPIRAL-2 Scientific Advisory Committee requests LOI for potential first experiments

Submitted in 2009 :

- LoI_12 : Fragment angular distributions in neutron-induced fission of actinide nuclei, *L. Tassan-Got et al.*
- LoI_13 : Study of pre-equilibrium process in (n,xn) reaction, *X. Ledoux et al.*
- LoI_14 : Comparison between activation and prompt spectroscopy as means of (n,xn) cross section measurements, *M. Kerveno et al.*
- LoI_15 : Fission fragment distributions and neutron multiplicities, *D. Doré et al.*
- LoI_16 : Proton and deuteron induced activation reactions, *P. Bem et al.*

New LoIs (June 2010):

- LoI_19 : Use of the STEFF spectrometer at NFS, *G. Smith et al.*
- LoI_20 : Direct measurement of (n,xn) reaction cross sections on ^{239}Pu, *G. Bélier et al.*
- LoI_21 : Light-ion production studies with Medley, *S. Pomp et al.*
- LoI_22 : Fission fragment angular distribution and fission cross section measurements relative to elastic *np* scattering with Medley, *S. Pomp et al.*

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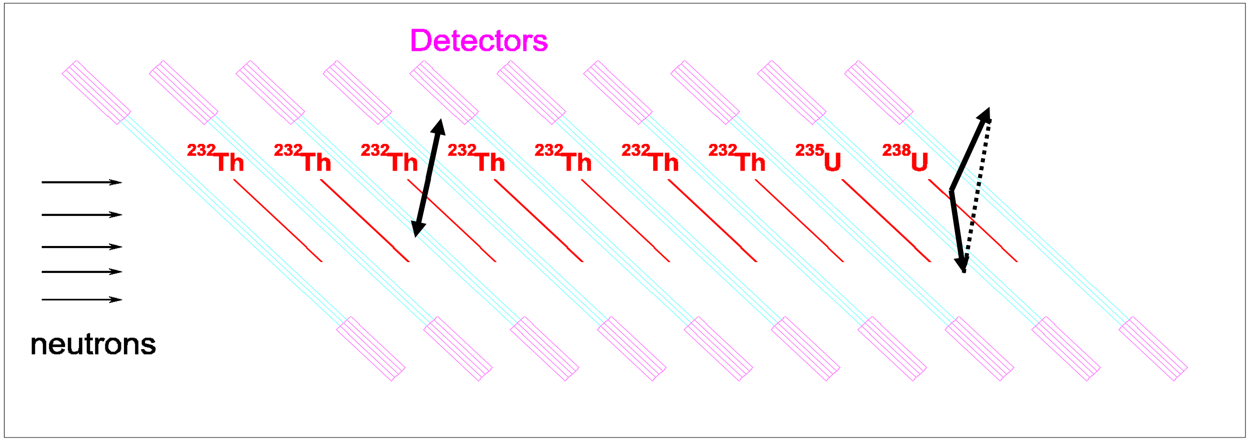
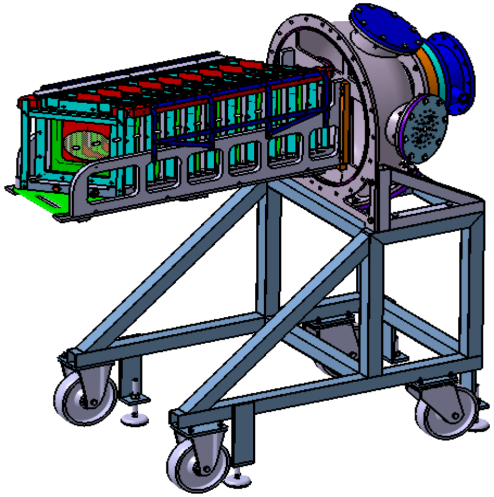
LOI 12 :Fission cross-section and anisotropy measurement at NFS

- High precision anisotropy measurement of the fragments emitted in neutron induced fission of actinide
- Cross-section measurement of highly radioactive actinide
- Fission fragment angular distribution is an ingredient in the measurement of the fission cross section
- Angular distribution gives information on the spin properties of the fissionning nucleus
- The angular distributions are not well known above 10 MeV





NFS Flux and resolution ⇨ scan of threshold and second chance fission

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LOI 15 : Fission fragment distributions and neutron multiplicities

Experiment at NFS

Continuous neutron spectra (d+Be) → excitation energy scan

Counting rate

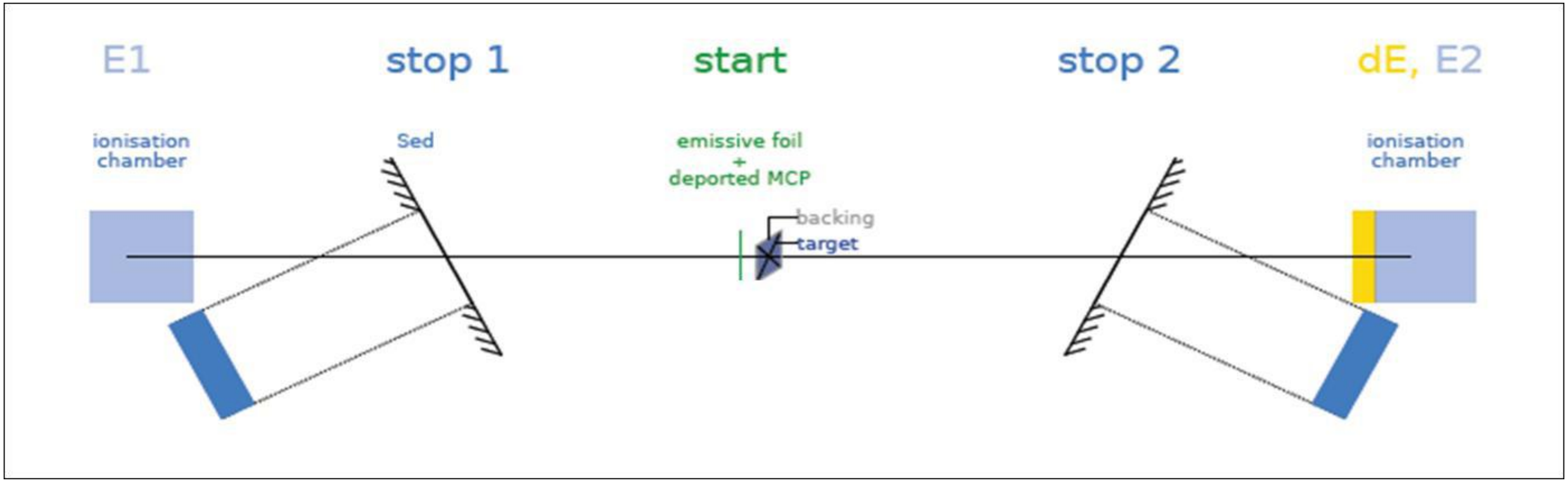
Experimental challenge :

Identification of both fragments in A and Z :

2v,2E method → primary and final fragment masses → neutron multiplicities

SED, Silicon junction or ionization chamber, X spectroscopy …..

Sample (thin layer) ⇨ CACAO



Preliminary design

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LOI 14 : Comparison between activation and prompt spectroscopy as means of (n,xn) cross section measurements,

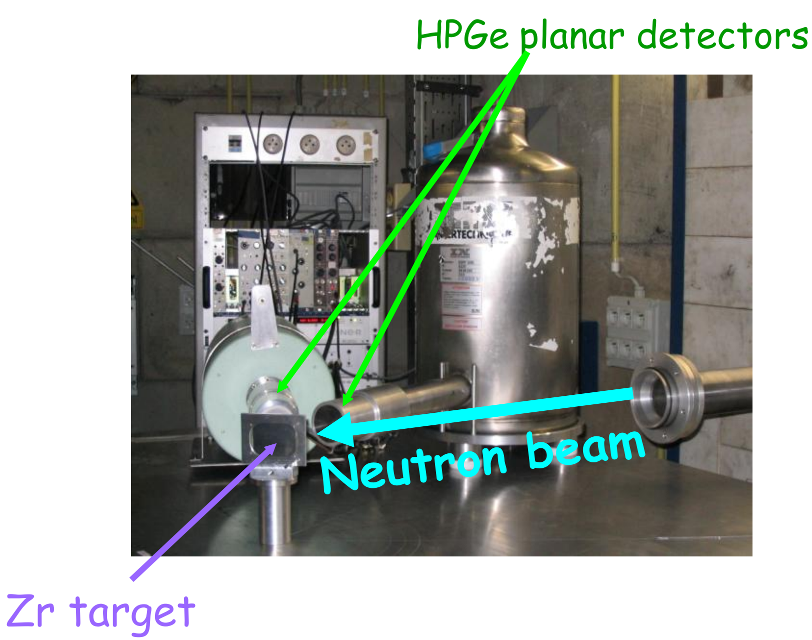
IPHC Strasbourg

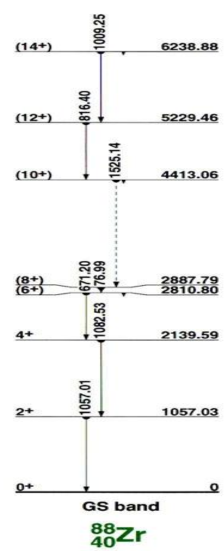
Method:

- Detection of the γ-rays stemming from the decay of excited states of nuclei created by the (n,xn) reaction.
- Pulsed neutron beam
- HPGe detectors

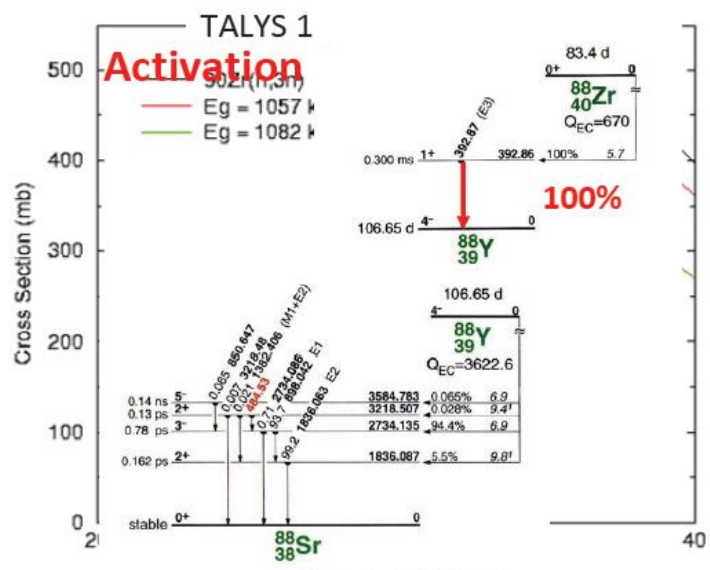
$^{90}Zr(n,3n)\,^{88}Zr$ measured at the same time by activation and prompt spectroscopy

Gamma detection





Prompt



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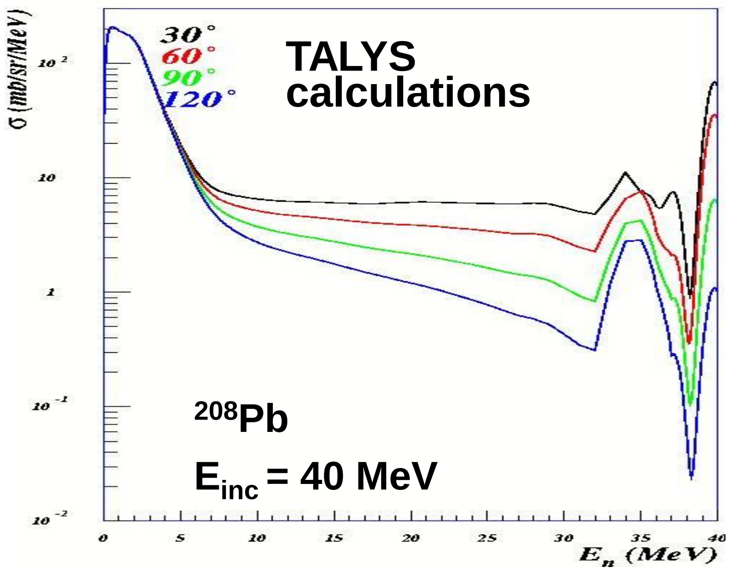
LOI 13 : Study of pre-equilibrium process in (n,xn) reaction

Measurement of (n,xn) double differential cross section in coincidence with neutron multiplicity.

Validation of pre-equilibrium models



Method :

- measurement of energy and angle of one neutron
- count of the (x-1) neutrons emitted simultaneously.

Experimental set-up :

NE213 detectors

CARMEN detector

Already existing and validated

Beam request:

Quasi-monkinetic beam

Pulsed

Well collimated

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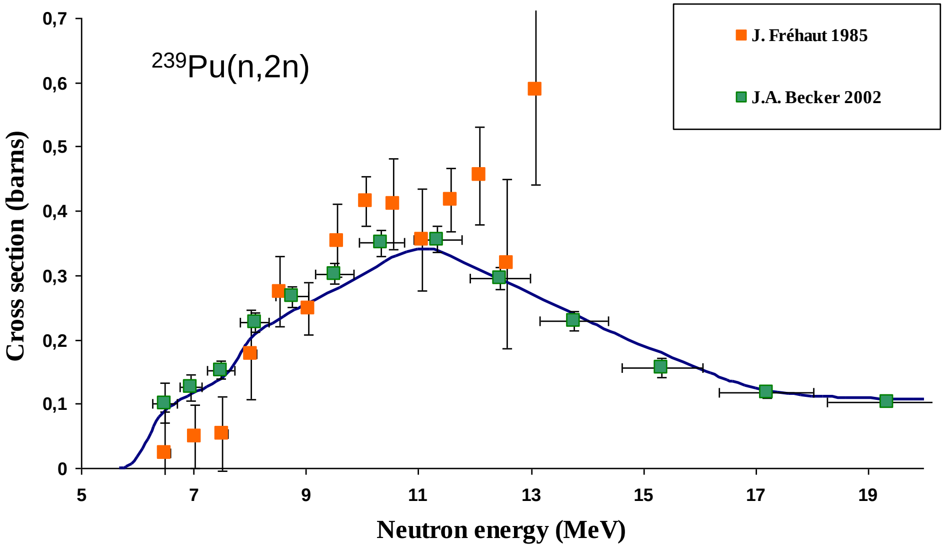
LoI_20 : Direct measurement of (n,xn) reaction cross sections on ^{239}Pu



Passive target
→ **Fission to be subtracted**
→ **High uncertainties**

Indirect measurement (n,xnγ) with GEANIE/WNR
→ **Model dependent**

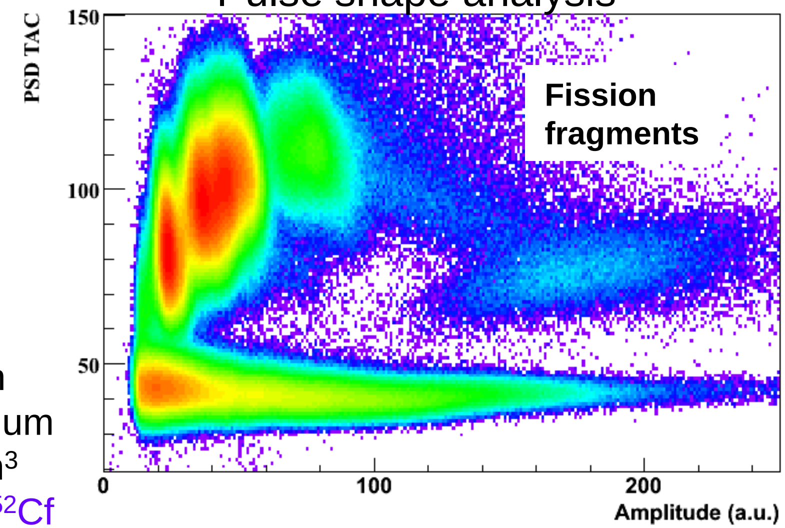
First direct measurement of n,xn reactions thanks to:

- A neutron ball : **CARMEN,**
- a highly efficient active target → fission veto

Scintillator + photodiode

Tests with natural thorium 10 mg/cm^3 + 7 Bq de ^{252}Cf

Pulse shape analysis



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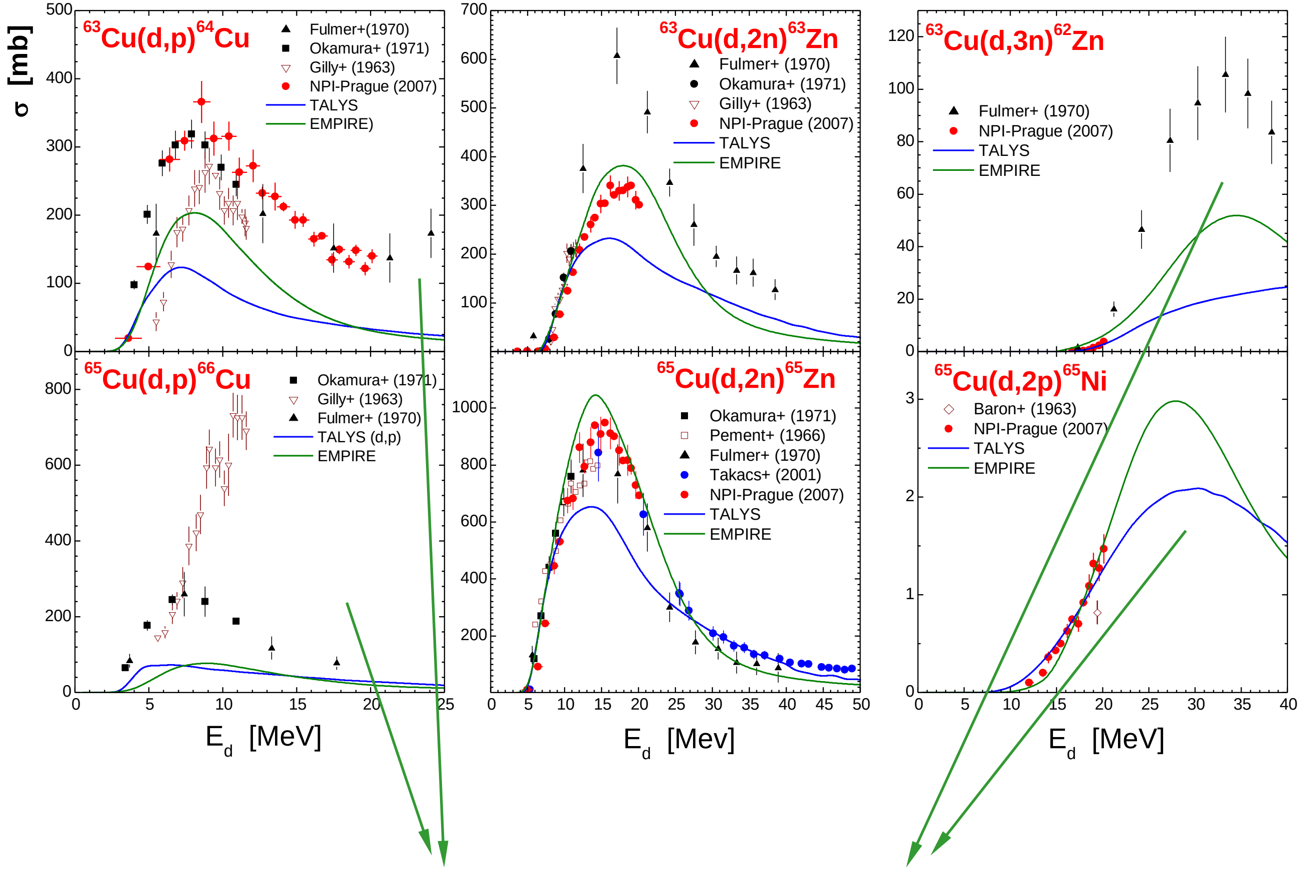
LOI 16 : Proton and deuteron induced activation reactions

- Measurement by activation technique
- Interest for fusion technology : IFMIF
- 20 < Ed < 40MeV



Need of data to distinguish between model predictions at 20<E_d<40 MeV

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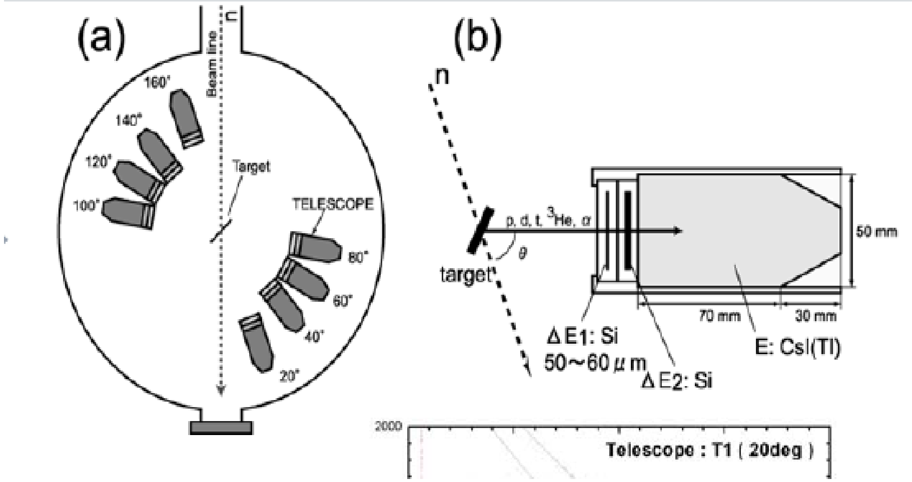
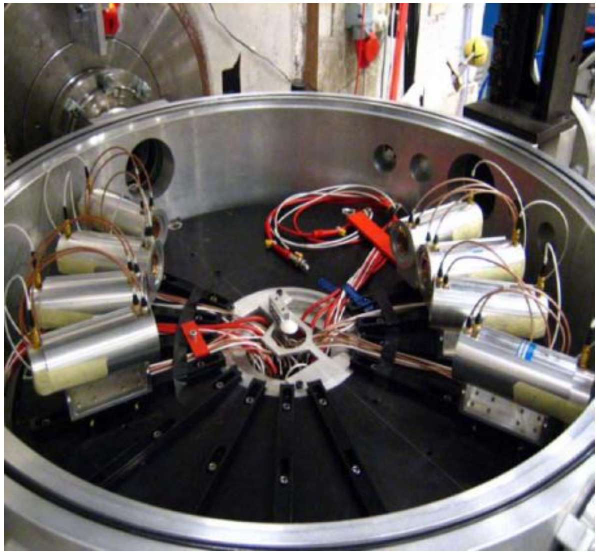
LoI_21 : Light-ion production studies with Medley

– Motivations :
  - Cancer therapy and dosimetry H, C, O, Ca, ...
  - Radiation effects in microelectronicsSi, O, ...
  - Energy applications (GenIV, Fusion, IFMIF …)
    - Construction material: Fe, …
    - Fuel: U, Th, …
    - Coolant: Pb, Bi, Na



– Medley set-up
  - ddxdata for *X(n,lightions)*
  - Move to NFS
  - Upgrade (New digital acquisition DAQ, new Si1)



– Medley can also be used for :
  - Neutron spectra measurements
  - σ, dσ/dΩ for X(n,fission) measurement (LOI 22)

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Summary

NFS will be a very powerful tool for physic with neutrons

Technical issues :

- White and quasi-monokinetic spectra in the 1-40 MeV range
- Neutron beams with high flux and good energy resolution
- Complementary to the existing n-tof facilities
- Irradiation stations for activation measurements (n, p, d)

Physics case :

- Fundamental and applied research
- Fission and fusion technology
- Material studies ….

First experiment in 2012

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