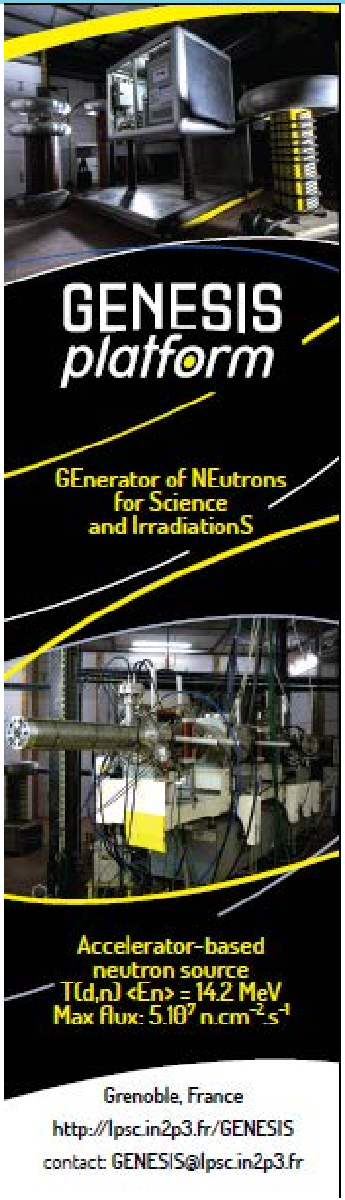
Plateforme GENESIS :

GEnerator of **NE**utrons for **S**cience and **I**rradiation**S**

A. Billebaud, B. Cheymol, M. Baylac
S. Rey, E. Labussière

Outline

- The platform : description, operation
- Science, activities
- Positionning in the landscape, visibility, networking
- Future evolution



The platform: description

➢ **GENESIS: GEnerator of NEutrons for Science and IrradiationS**

- An accelerator based fast neutron source
- Hosted at LPSC Grenoble (Laboratory of Subatomic Physics and Cosmology) since 2003
- A CNRS/IN2P3 certified platform since 2017

➢ **The accelerator: GENEPI2 (GEnerateur de NEutrons Pulsé Intense)**

- Electrostatic accelerator (250 kV)
- "2" refers to a series (GENEPI1 for MUSE exp., GENEPI-3C for GUINEVERE)
- Deuteron accelerated up to 220 keV onto a T (or D) solid target

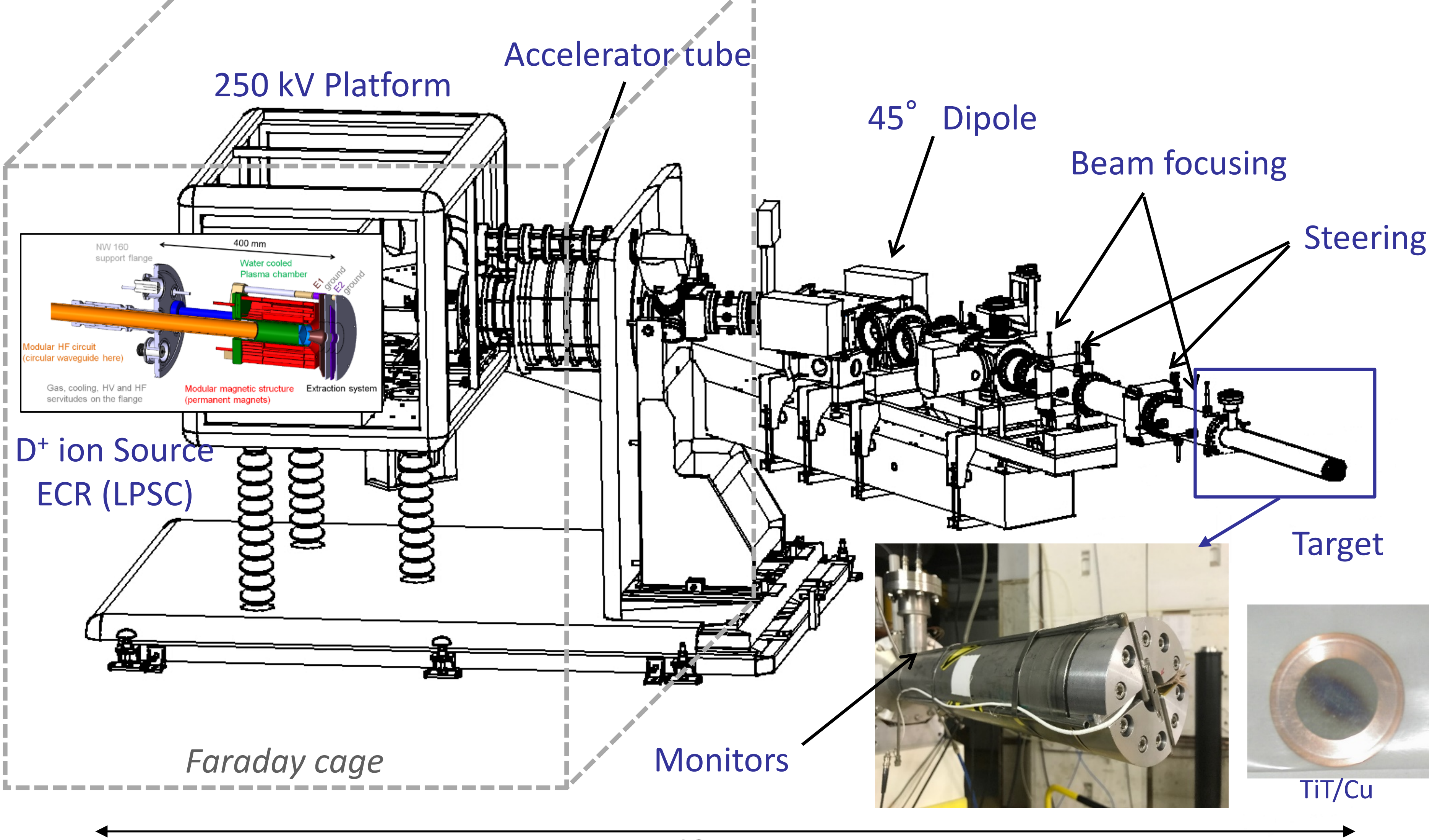
$D + T \rightarrow n + {}^{4}He$ $\quad < En > = 14.2$ MeV

$D + D \rightarrow n + {}^{3}He$ $\quad < En > = 2.5$ MeV

The platform: description

GENESIS platform

➢ **The GENEPI2 accelerator**



The platform: description

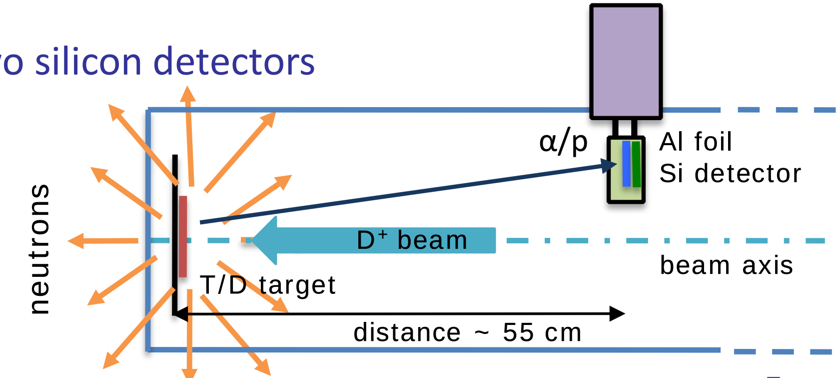
Neutron production (currently)

- Based on foil activation measurements analyzed with Ge detectors at the low activity laboratory of LPSC (LBA)

Target	<Energy>	Max. beam current	Absolute intensity	Max Flux (at 1 cm)
Tritium	14.2 MeV	~150 μA	**8×10^{9} n.s^{-1}** **6×10^{8} n.s^{-1}.sr^{-1}**	**5.10^{7} n.cm^{-2}.s^{-1}**
Deuterium	2.5 MeV		*To be determined*	

Neutron production monitoring

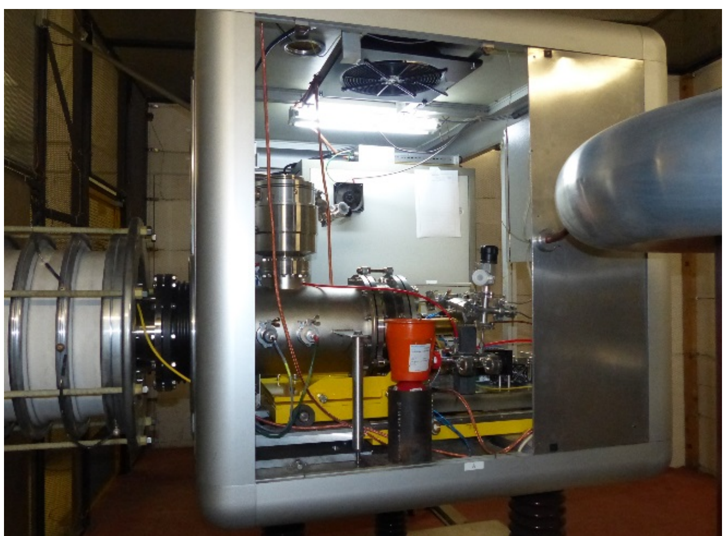
- **Target current** monitoring
- **Associated particle monitoring** thanks to two silicon detectors
  - Given solid angle (backward) ~ 10^{-5} Sr
  - Detection of alphas (d,T) ~ isotropic
  - Protons (d,D), anisotropic



The platform: the team

➢ The GENESIS team:

- Operational manager : B. CHEYMOL (IR), Accelerator and ion source pole
- Scientific coordination: A. BILLEBAUD (DR), Reactor physics group
- Client & Network support (IRT, contracts): M. BAYLAC (IR), Accelerator and ion source pole
- Pilot and vacuum expert : S. REY (IE), Accelerator and ion source pole
- Pilot and electronics engineering : E. LABUSSIERE (IE), Accelerator and ion source pole



The platform: the team

GENESIS platform

- **Regular LPSC support :**

  - **Accelerator and ion source pole:**
    - Support mécanique (AI) : T. CABANEL (AI)
    - Conception mécanique (ponctuel): P.O. Dumond (IE)

  - **Technical Services**
    - Electronics *:*
      - J. BOUVIER, (IR), Electronique Numérique, C&C (ponctuel en 2018)
      - D. TOURRES, (IE), Electronique Numérique et Analogique, C&C (ponctuel en 2018)
      - J.-P. SCORDILIS (T) Assemblage électronique (ponctuel en 2018)
    - IT:
      - G. DARGAUD (IR) Logiciel C&C
    - Mechanics :
      - J. GIRAUD, (IE) : Calculs thermiques, ponctuel
      - Atelier de fabrication
    - Health physics and security: W. REGAIRAZ (IR)

  - **Reactor Physics group**
    - O. MEPLAN (MCF) MCNP, Mesures activation – LBA
    - M. RAMDHANE (PR) Mesures activation – LBA, ponctuel

  - **Administrative and maintenance department**
    - C. BERNARD (IE), évolution infrastructures - SG
    - C. DESLORIEUX (IR), F. PETIOT (AI), contrats, commandes - Adm

Team + support
~ 3.5 - 4 FTE/year

The platform: governing model

- **IN2P3 platform since 2017, regulated by a charter**

- **Annually reviewed by a Steering Committee composed of**

  - IN2P3 representatives: Scientific deputy director(s)
  - LPSC Board representative: LPSC Director or one representative
  - UGA representative: member of PAGE pole, UGA, G-INP
  - Operation manager (**RO**): B. Cheymol (since 2018, Accelerator and ion source pole)
  - Scientific coordinator (**CoS**): A. Billebaud (since 2017, Reactor physics group)
  - Permanent guest: IN2P3 Business development officer

- **Supervising :**
  - Scientific and technical activities
  - Budget
  - Manpower

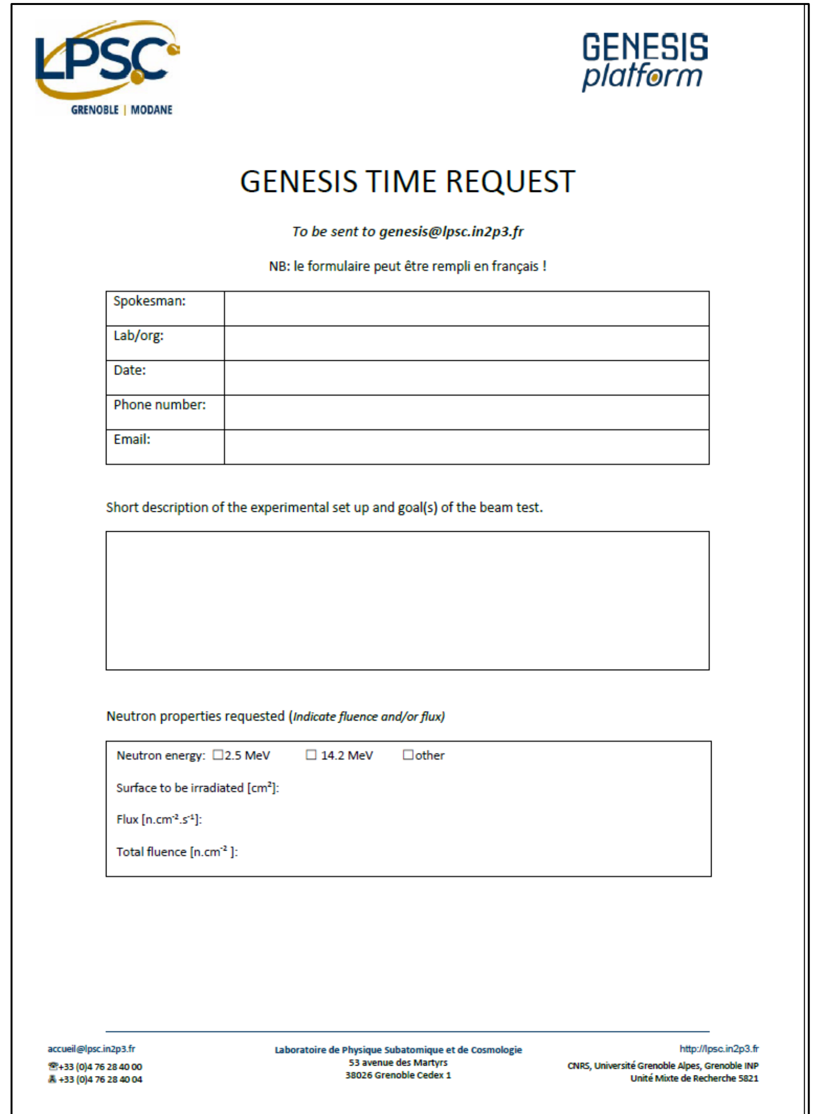
The platform: governing model

GENESIS platform

- **Platform access**
  - Up to now no competition → no PAC
  - At any time: Beam time request form →
  - Contact: GENESIS@lpsc.in2p3.fr
  - Fees :
    - IN2P3: free
    - Other academic: 100 € /h

- **Programming:**
  - Over a 6 month rolling schedule
  - One day preliminary test possible on request
  - Availability ~130 days / year
  - Priority to Science

- **Web site: http://lpsc.in2p3.fr/GENESIS**



LPSC GRENOBLE | MODANE — GENESIS platform

GENESIS TIME REQUEST

To be sent to genesis@lpsc.in2p3.fr

NB: le formulaire peut être rempli en français !

Spokesman:	
Lab/org:	
Date:	
Phone number:	
Email:	

Short description of the experimental set up and goal(s) of the beam test.

Neutron properties requested (*Indicate fluence and/or flux*)

Neutron energy: ☐2.5 MeV ☐ 14.2 MeV ☐other

Surface to be irradiated [cm^2]:

Flux [$n.cm^{-2}.s^{-1}$]:

Total fluence [$n.cm^{-2}$]:

accueil@lpsc.in2p3.fr
+33 (0)4 76 28 40 00
+33 (0)4 76 28 40 04

Laboratoire de Physique Subatomique et de Cosmologie
53 avenue des Martyrs
38026 Grenoble Cedex 1

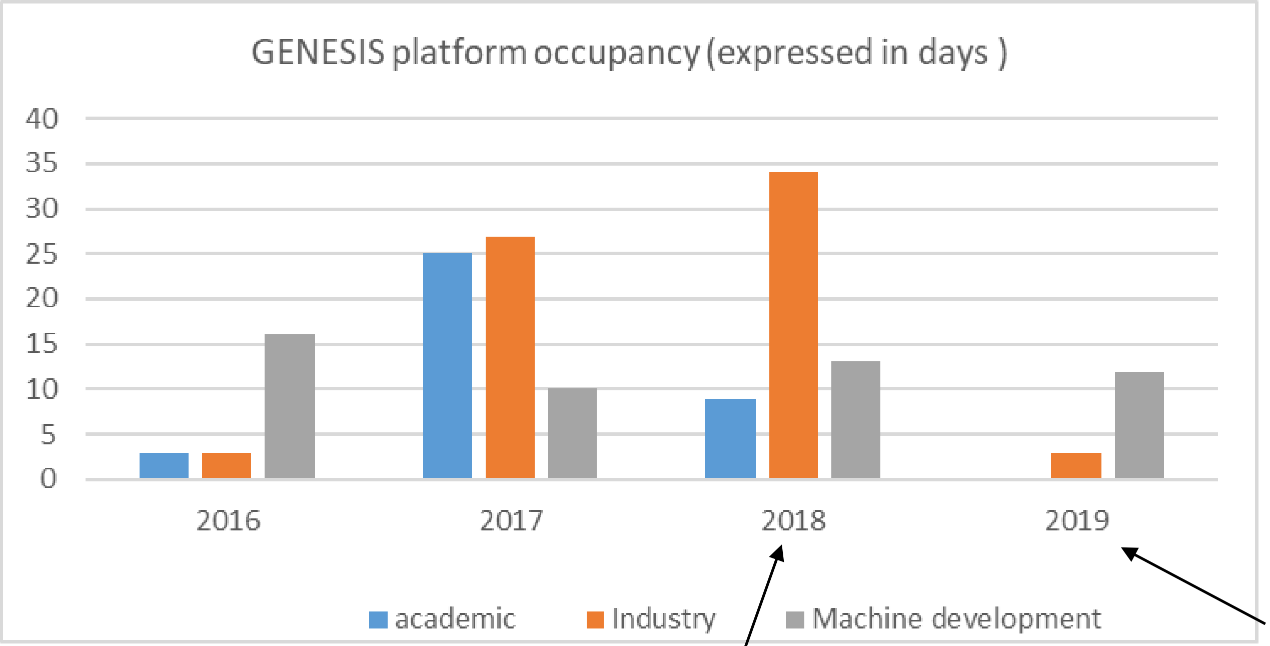
http://lpsc.in2p3.fr
CNRS, Université Grenoble Alpes, Grenoble INP
Unité Mixte de Recherche 5821

The platform: financial model

- **Incomes**
  - IN2P3 basic support (~15 k€/year)
  - Research network : IRT Nanoelec
  - Commercial activity (contracts)
  - Projects
  - Transnational access European projects (ARIEL, RADNEXT)
- **Expenses**
  - Accelerator maintenance (vacuum, electronics,…)
  - Platform maintenance (access system, radioprotection equipment,…)
  - Neutron monitoring system (detectors, electronics, DAQ)
  - TiT, TiD targets (new ones and part-exchange, SODERN company)
  - Temporary manpower contracts (pilots)

➔ Positive balance since 2016 (platform self-financed, excluding labor costs of permanent staff), enable improvement plan and temporary staff employment

- **Fast neutrons for Science and Irradiations**
  - Academic research, public laboratories
  - Commercial activity, private companies
  - Mainly in the fields of physics and microelectronics



Heavy works (shut-down)

6 months only

Science, activities

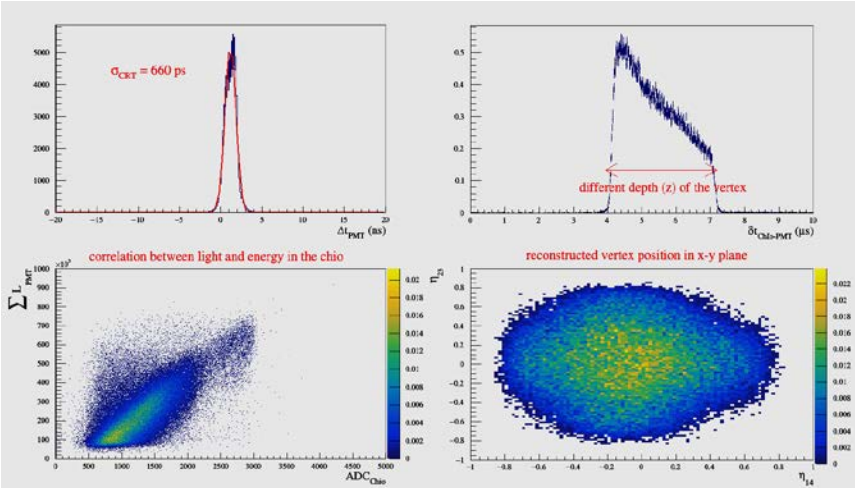
- **Users (2016-2019)**

Origin	IN2P3	Other CNRS	Other Academic	Private	Intern at.	Total
Nb users	3	1	2	7	2	15
Nb of days/y (average)	5	6	2	30	4	47

- **Neutrons for Science**
  - *As incident particles for nuclear reactions (Cross section validation, LPSC)*
  - For testing detectors devoted to neutron induced reaction (SCALP, STEFF)
  - For fast neutron detector testing (MIMAC Fast-n, Monodiam, …)
  - For detector characterization in fast neutron field (Candelle TLD dosimeters, CEA)
- **Neutrons for Irradiations**
  - Micro-Electronic applications
    - Study of Single Event Effects in integrated circuits under irradiation (SEE studies) (microelectronics academic research)
    - Industry applications : test of electronic components (SEE studies, fault injection)

➢ Test of detectors or set-ups for neutron induced reaction measurements

- **SCALP (LPC Caen)**: from GENESIS to NFS
  - Design of a detector dedicated to $^{16}O(n, \alpha)^{13}C$ cross section measurement (=> 20 MeV) : NEA « High Priority Request List »
  - SCALP = scintillating ionization chamber $CF_4 + CO_2$ surrounded by 4 PM for alpha detection: charges + light as a function of E_n (tof)
  - Final measurement foreseen at NFS@SPIRAL2 (5m tof), first test done @GENESIS in June 2018 ($^{19}F(n, \alpha)^{16}N$), next test @n_ELBE (FZDR, D)



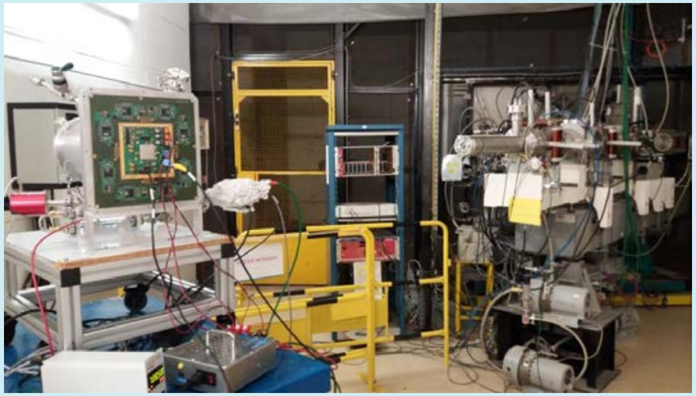
Science, activities

GENESIS platform

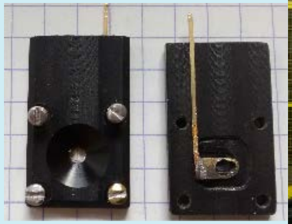
➢ Test of fast neutron detectors

Calibration of a prototype of **spherical proportional counter** developped by LSM

Test of **MIMAC FASTn** (LPSC): directional spectrometer for fast neutrons developped by LPSC : recoil 4He analyzis (elastic scattering)



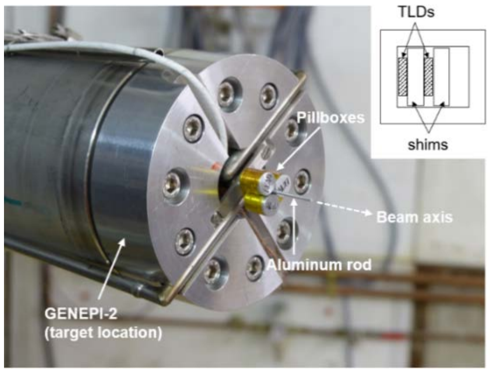
Test of **diamond detectors** for neutron detection (Monodiam, LPSC)



➢ Detector characterization in fast neutron field

- CANDELLE (CEA/DEN):

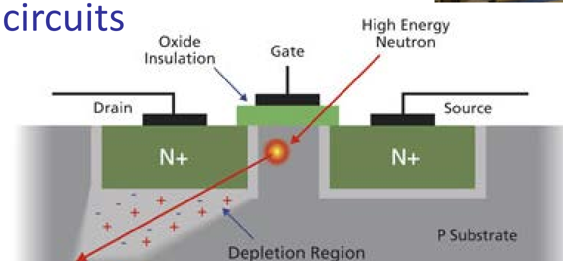
- Calibration of TLD dosimeters in a fast neutrons field (D(d,n) source)



Used to measure gamma heating in low power reactors (mixed gamma-neutron field)

Objective: to reduce the uncertainties of the doses measurements for calculation scheme validation

- **Micro-Electronics (TIMA-CNRS Grenoble, ONERA Toulouse, Université de Madrid)**
  - 14 MeV neutrons mimic high energy hadron effects (for space applications)
  - Study of Single Event Effects of integrated circuits (SEE-SEU)

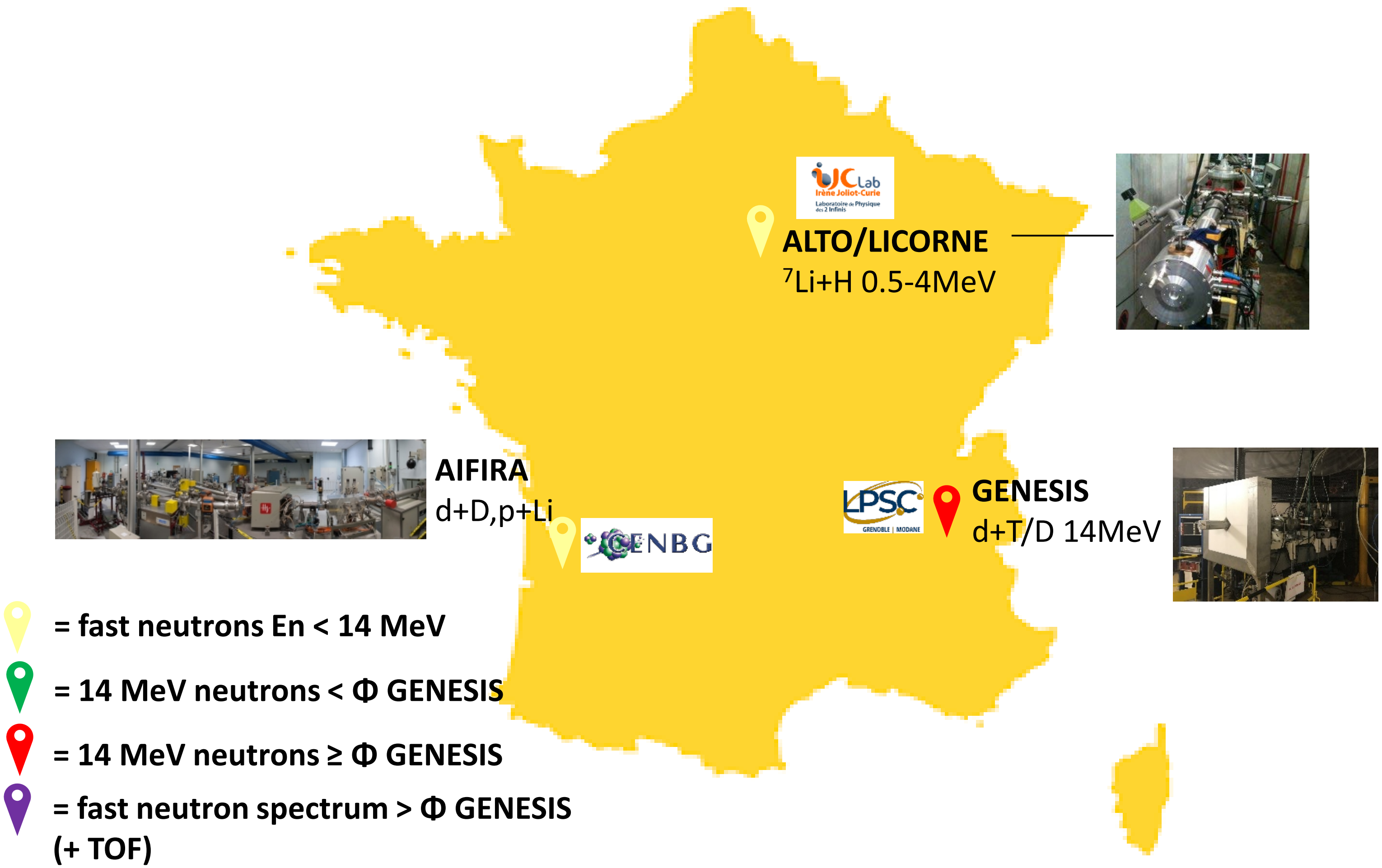


➢ Some publications:

- G. Lehaut, M. Bourgeot, B. Galhaut, D. Goupillière, M. Henri, F.R. Lecolley, X. Ledoux, J. Lory, L. Manduci, N. Marie, J. Perronnel and Ch. Vandamme, **SCALP: a detector for (n,α) cross-section measurements**, ANIMMA conference, 17-21 juin 2019, Portoroz, Slovénie, EPJ Web of Conferences 225, 01001 (2020).
- - M. Le Guillou, A. Billebaud, A. Gruel, G. Kessedjian, O. Méplan, C. Destouches, P. Blaise, **The CANDELLE experiment for characterization of neutron sensitivity of LiF TLDs**, IEEE Transactions on Nuclear Science, (2018) Vol 65, Issue 9, 2426.
- - Pabo Ramos, Vanessa Vargas, M. Baylac, F. Villa, S. Rey et al., **Evaluating the SEE sensitivity of a 45nm SOI Multi-core Processor due to 14 MeV Neutrons,** IEEE Transactions on Nuclear Science, Institute of Electrical and Electronics Engineers, 2016, 63 (4), pp.2193 - 2200.
- - J.A. Clemente, F.J. Franco, F. Villa, M. Baylac, P. Ramos et al., **Single Events in a COTS Soft-Error Free SRAM at Low Bias Voltage Induced by 15-MeV Neutrons**, IEEE Transactions on Nuclear Science, Institute of Electrical and Electronics Engineers, 2016, 63 (4), pp.2072 - 2079. 〈10.1109/TNS.2016.2522819〉
- - J.A. Clemente, F.J. Franco, F. Villa, M. Baylac, S. Rey et al., **Statistical Anomalies of Bitflips in SRAMs to Discriminate SBUs From MCUs**, IEEE Transactions on Nuclear Science, Institute of Electrical and Electronics Engineers, 2016, 63 (4), pp.2087 - 2094.
- - J.A. Clemente, G. Hubert, F. Franco, F. Villa, M. Baylac et al., **Sensitivity Characterization of a COTS 90-nm SRAM at Ultra Low Bias Voltage,** IEEE Transactions on Nuclear Science, Institute of Electrical and Electronics Engineers, 2017, PP (99), <10.1109/TNS.2017.2682984>
- - M. Cecchetto et al., **Impact of thermal and intermediate energy neutrons on SRAM SEE rates in the LHC accelerator**, to be published in RADECS2017 proceedings.

GENESIS platform

- **Fast neutron facilities in France:**



Positionning, networking and visibility

- **Fast neutron facilities in France:**

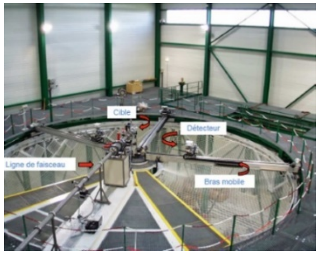
4 MV & 7 MV NENUPHAR
d+T/D
d+D/Be 4-25MeV

ALTO/LICORNE
^{7}Li+H 0.5-4MeV

AIFIRA
d+D,p+Li

GENESIS
d+T/D 14MeV

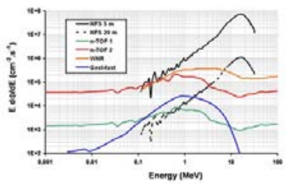
AMANDE
d+T/D 14MeV



- (yellow pin) **= fast neutrons En < 14 MeV**
- (green pin) **= 14 MeV neutrons < Φ GENESIS**
- (red pin) **= 14 MeV neutrons ≥ Φ GENESIS**
- (purple pin) **= fast neutron spectrum > Φ GENESIS (+ TOF)**

Positionning, networking and visibility

- **Fast neutron facilities in France:**



GANIL spiral2 laboratoire commun CEA/DRF CNRS/IN2P3

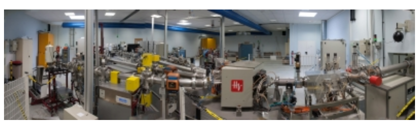
NFS

4 MV & 7 MV NENUPHAR
d+T/D
d+D/Be 4-25MeV

cea

IJCLab Irène Joliot-Curie

ALTO/LICORNE
^{7}Li+H 0.5-4MeV



AIFIRA
d+D,p+Li

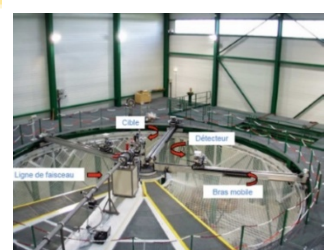
CENBG

LPSC GRENOBLE | MODANE

GENESIS
d+T/D 14MeV

IRSN INSTITUT DE RADIOPROTECTION ET DE SÛRETÉ NUCLÉAIRE

AMANDE
d+T/D 14MeV



- **= fast neutrons En < 14 MeV**
- **= 14 MeV neutrons < Φ GENESIS**
- **= 14 MeV neutrons ≥ Φ GENESIS**
- **= fast neutron spectrum > Φ GENESIS (+ TOF)**

Positionning, networking and visibility

- (Some) Fast neutron facilities in Europe:

= fast neutrons En < 14 MeV

= 14 MeV neutrons < Φ GENESIS

= 14 MeV neutrons ≥ Φ GENESIS

= fast neutron spectrum > Φ GENESIS (+ TOF)

Positionning in the landscape

GENESIS platform

➢ **Monoenergetic 14 MeV neutrons**

Machine	Institute	Reaction	Intensity n/s/sr
FNG	ENEA (I)	d+T	8.10^9
(NESSA)	*Uppsala Univ.*	*d+T*	*3.10^9*
GENESIS	LPSC	d+T	6.10^8
4 MV	CEA/DAM	d+T	$1.7.10^7$
AMANDE	IRSN	d+T	$2.8.10^6$

Positionning, networking and visibility

➢ Visibility

- Part of the **transnational access ARIEL** project (EURATOM): **nuclear data community**
- Part of the European training network **RADSAGA** managed by CERN and applying to the **RADNEXT** project (follow up) for a **transnational access** : **microelectronics community**
- Present at the "**Journées scientifiques du neutron**" organized by IRSN in 2018, 2020
- Contacts with GDR SciNEE and MI2B

➢ Networking

- NUPIA (Nuclear Physics Innovation) network of the ENSAR2 (European Nuclear Science and Applications Research) program
- Part of the Platform of Advanced Characterization- Grenoble (PAC-G) with ILL ESRF and CEA (in the frame of IRT Nanoelec)

➔ Regular communications (RADECS, UCANS conferences,…)

Future evolution: users

➢ Former users

- LPCC: SCALP 2021 ?
- Microelectronics research: TIMA + ONERA
- Irradiations : Private companies

➢ Possible new academic users (contacts)

- ONERA (other team): albedo effect measurements with different materials with a Bonner sphere
- CEA-LLB/CNRS: test of moderators for cold neutrons
- IM2NP (Univ Marseille) : test of neutron detectors SiC (diamonds)
- Via **ARIEL and RADNEXT TNA projects**

➢ New possible users under study

- First stage test for NFS (GANIL/SPIRAL2) users ?
- Fusion and biology communities

Future evolution: the platform

GRENOBLE | MODANE

GENESIS platform

Scientific improvements

- Objective: **better knowledge of the platform neutron production:**
  - n monitor upgrade,
  - characterization of the neutron field,
  - study of n production rate of tritiated target as a function of beam charge

Technical improvements

- Objective: **availability and flux increase** by a factor 10
  - new target design with improved cooling (update of the safety file),
  - increase of the capability of tritiated effluent storage
- Objective: **beam characterization**:
  - development and design of online diagnostics (4D emittancemeter, …)

Future evolution

➢ Medium term evolution

- ICS (Integrated Control System) Upgrade (techno > 10 years)
- R&D for pulsed beam production (interest for NFS users)
- R&D for future improvement of GENEPI-3C (connected or not with MYRRHA project)
- Study of versatility between « irrad » specifications and « physics » specifications

As a conclusion: SWOT analysis

Strengths

- Easy access (no PAC)
- Good availability (130 d/year)
- Unique 14 MeV-neutron intense source

Weaknesses

- Need for temporary manpower
- Lack of mechanical assembly manpower

Opportunities

- Context of **lack of neutron facilities**
- Nuclear physics community before going on TOF facilities: context of NFS starting up
- Increase needs for **spatial activities** and high reliability applications

Threats

- Increase weight of administrative work (contracts, budget management) for LPSC

Thank you !