

CACAO

Chimie des Actinides et Cibles radioActives à Orsay

A project of laboratory for production and characterization of thin radioactive targets



Ch.O.Bacri, IPN Orsay, for the CACAO group.

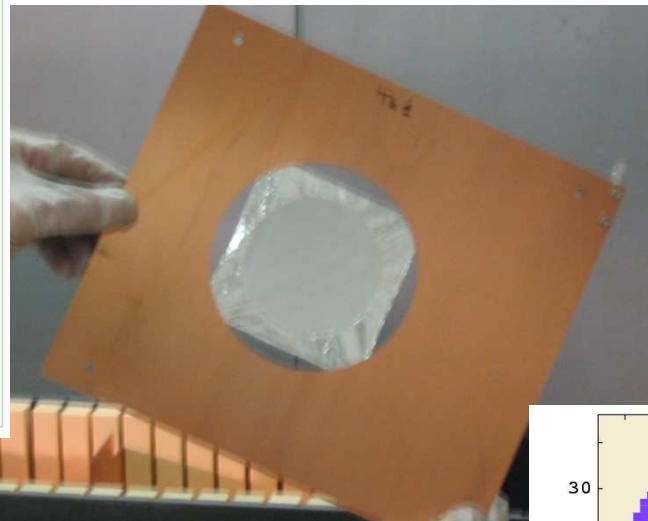
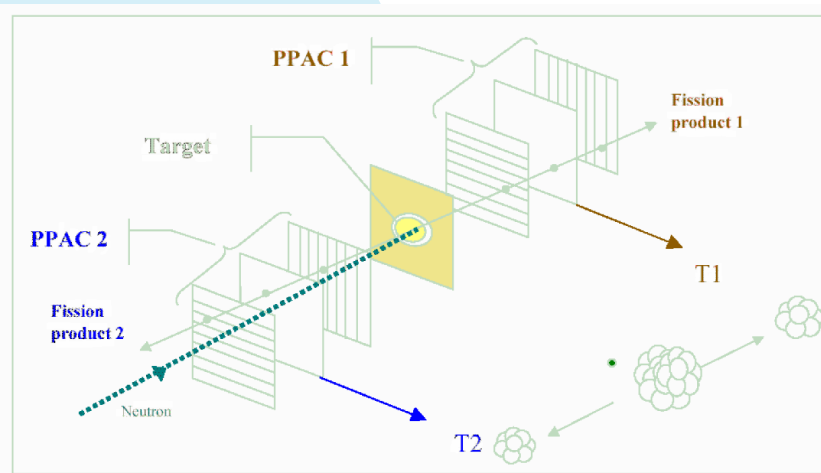
1. Motivations : IPNO's program and needs of the community
2. CACAO presentation
 - i. General overview
 - ii. Providing/production of the elements/isotopes
 - iii. Production of radioactive targets
 - iv. Target characterization
3. Conclusion

1. Motivations

IPNO's program: n-induced fission at nTOF

$^{233,234,235,238}\text{U}$, ^{232}Th , ^{237}Np , $^{241,243}\text{Am}$

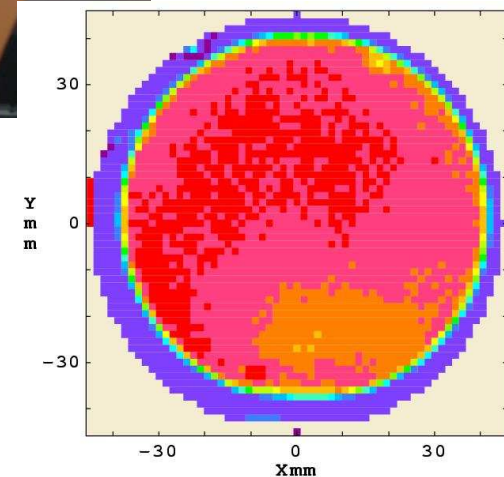
- both fission fragments should be measured \Rightarrow **THIN TARGETS**
- large n beam \Rightarrow **LARGE TARGET DIMENSIONS**
- high purity samples



^{235}U target
0.3 mg/cm²
2 μm Al backing
8 cm diameter



α cartography
3.5 mm step



1. Motivations

Needs of the community

- both fission fragments should be measured ⇒ **THIN TARGETS**
- large n beam ⇒ **LARGE DIMENSION**
- high purity samples

$^{233,234,235,238}\text{U}$, ^{232}Th , ^{237}Np , $^{241,243}\text{Am}$

Great difficulty to get radioactive targets

- loss of the knowledge for the production of thin layers on thin support
- specificity of the various laboratories (techniques, isotopes,)
 - ⇒ difficulties for the choice of the “good lab”
- recurring needs difficult to fill
- difficulty to obtain precise characterisation
- transport ...

⇒ **Need of coordination ...**

EFNUDAT JRA3:

“Nuclear target upgrade for improved nuclear data measurements”

Topic 2: reaction targets

2. General overview of the CACAO project

Project of laboratory dedicated to radioactive thin layers

- Help to the supply in isotopes
- Possible isotope separation
- Production (radiochemistry, and/or direct implantation)
- Characterization (homogeneity, cartography, possible contaminants, ...)
- Transport



**Joint CNRS/IN2P3 – CEA National laboratory
complementary to international installations**

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Precise analysis of the needs in radioactive targets

(mainly French community)

Recurring demands (up to ~ 5 targets/year, during 10 years):

U^{233,235,238}, **Np**²³⁷, **Pu**^{239, 241}, **Am**^{241, 243}, **Cm**^{245, 248}, **Cf**^{249, 251, 252}

Punctual demands:

C¹⁴, **Na**²², **Al**²⁶, **Ti**⁴⁴, **Fe**^{59,60}, **Ni**⁶³, **Se**⁷⁹, **Kr**^{81,85}, **Zr**^{93,95}, **Cs**¹³⁵, **Nd**¹⁴⁷, **Pm**¹⁴⁷,
Sm¹⁵¹, **Eu**^{154,155}, **Gd**¹⁵³, **Tb**¹⁶⁰, **Ho**¹⁶³, **Tm**^{170,171}, **Ta**¹⁷⁹, **W**¹⁸⁵, **Tl**²⁰⁴,
Th^{230,232}, **Pa**^{231, 233}, **U**^{234,236}, **Np**²³⁶, **Pu**^{240, 242, 244},
Cm^{243, 247, 249}

- **Thickness:** some 100µg/cm² to some 100mg/cm²
- **Isotopic and chemical purity :**
 - often better than 98%
 - good knowledge of contaminants, thickness, homogeneity, ...

IPNO safety authorizations:

“already feasible”

“feasible” if authorisation
to be studied

should be difficult ...

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How to find isotopes ...

Identified isotope suppliers

- **Industry (french) :** Cerca Lea, ISOTRAK, Isotopes products, ...
- **some laboratories (IRMM, FZK, Argonne, Berkeley, ...?...)**
- **reactor irradiation → OSIRIS at Saclay**
 - $3 \cdot 10^{18} \text{ n m}^{-2} \text{ s}^{-1}$ for $E < 0,625 \text{ eV}$
 - $4.5 \cdot 10^{18} \text{ n m}^{-2} \text{ s}^{-1}$ for $E > 0.1 \text{ MeV}$
- **accelerator production**
 - ARRONAX 1 day:** $\sim 10 \text{ ng to } \mu\text{g}$ (^{22}Na , ^{26}Al , ^{44}Ti , ^{59}Fe , ^{63}Ni , ^{85}Kr , ^{95}Zr)

Isotopic separation

Safety problems

→ no available separator for radioactive isotopes in France
⇒ 3 solutions under study

- put back to the standards of an existing separator (CSNSM, Orsay)
- reorganization of an existing separator (IPNO, Orsay)
- construction of a new separator

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Producing the targets: different constraints

- not to high activity
 - need to use the target in a beam line (!)
- } ⇒ **glove boxes**
in controlled zone
- radioactive thin layers (up to $\sim 1 \text{ mg/cm}^2$, depending on isotopes)
 - ⇒ need of a support (backing)
 - ⇒ need to realize **stable thin layers**

Stable thin layers laboratory at Orsay

- with or without backing
- possibility of multilayers
- possibility of large surfaces



- **radiochemical techniques: electrodeposition and spray in a first step**

Transfer of know-how

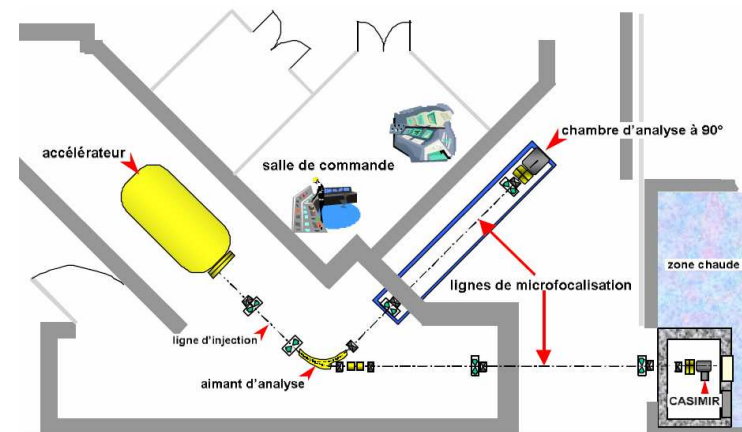
EFNUDAT → 12 months fixed term contract
Collaboration with Berkeley university (and Albany)

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Target characterisation

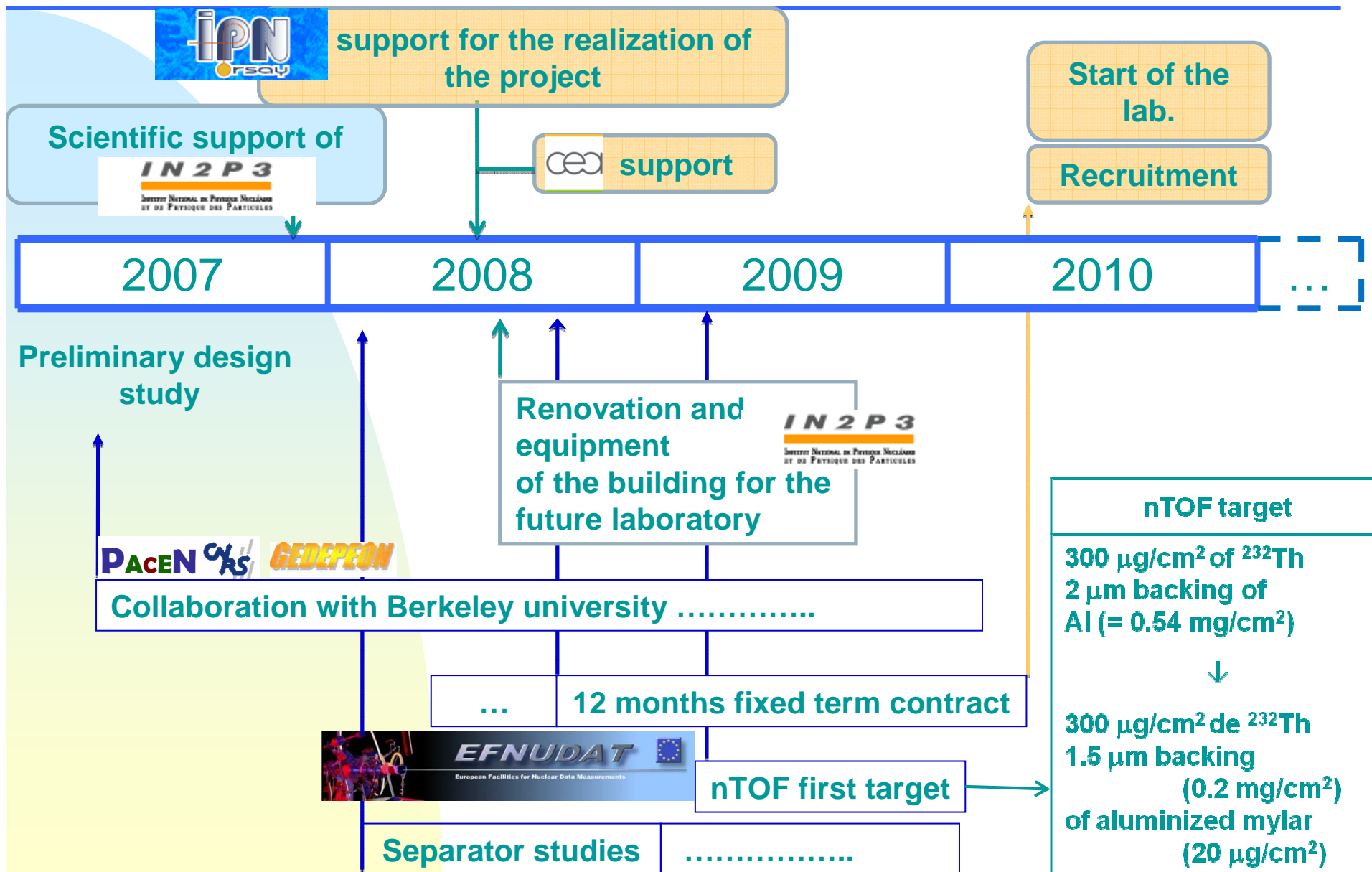
- **cartography / homogeneity:**
 - β, α autoradiography, RBS, α spectroscopy
- **chemical and isotopic purity:**
 - Nuclear Reaction Analysis (NRA), Particle Induced X-Ray Emission (PIXE), neutronic activation
- **Collaboration with the “Laboratoire National Henri Becquerel” (LNHB)**
 - ✓ laboratory of metrology (CEA Saclay)
 - ⇒ knowledge to transmit (quality, precision, ...)
 - ✓ β and γ spectrometry
 - ✓ autoradiography possible
- **« Laboratoire Pierre Süe » (LPS)**
 - Van de Graaf ; V_{\max} : 3,75 MV
 - H^+ , $^2H^+$, $^3He^+$ et $^4He^+$
 - X, γ , and charged particles detectors

signature of a partnership agreement
in progress



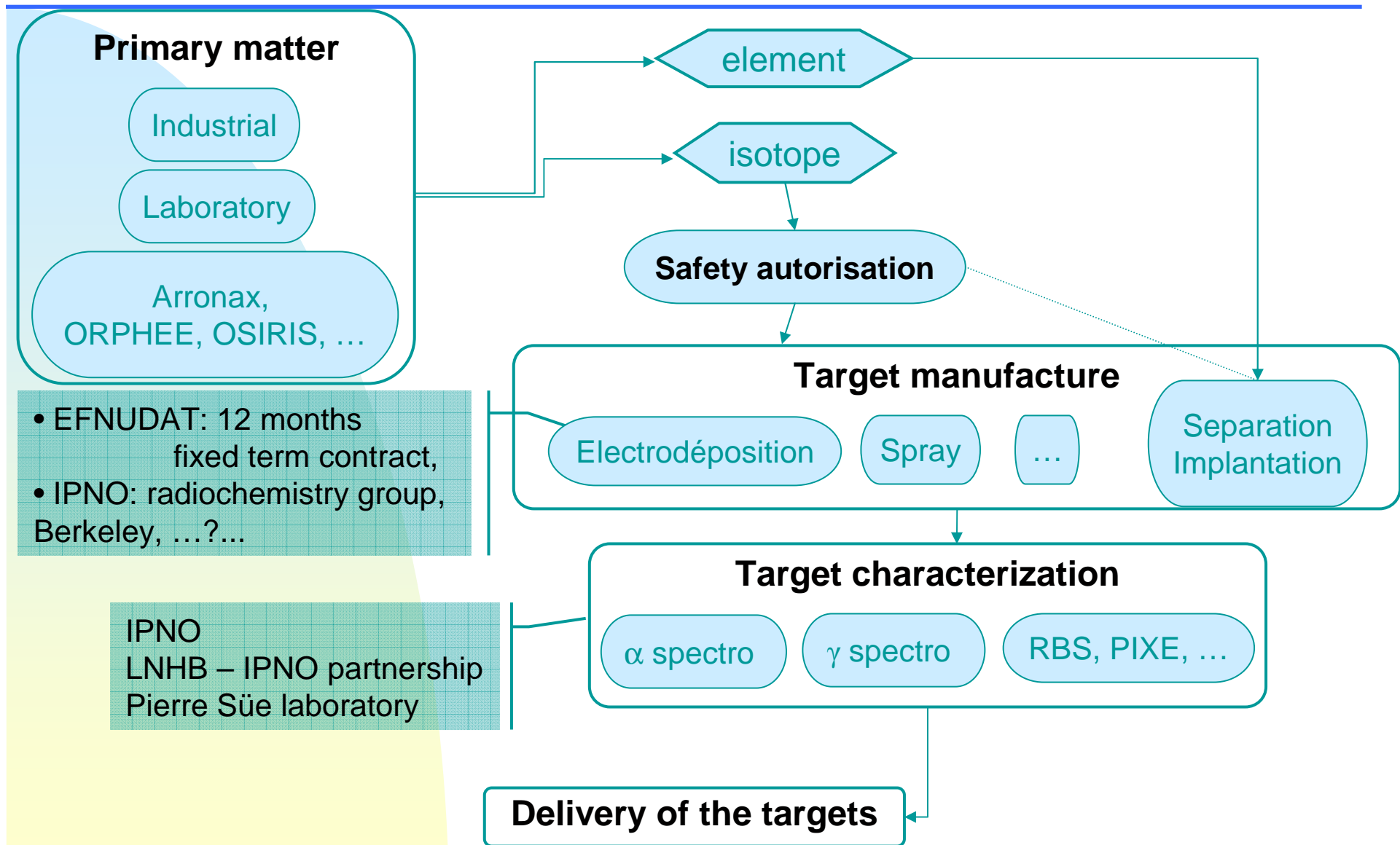
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Status and planning



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General overview of the project





Thank you

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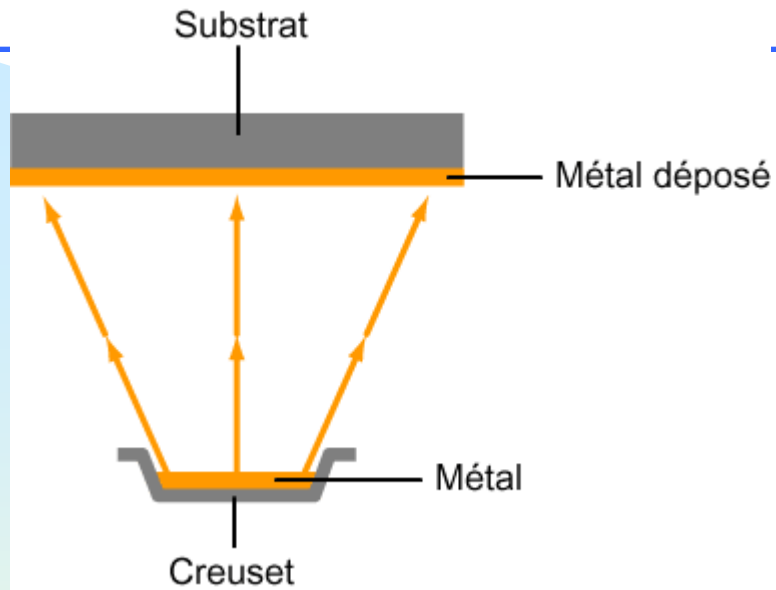
Laboratoire de Physique Subatomique et de Cosmologie (IN2P3/LPSC)

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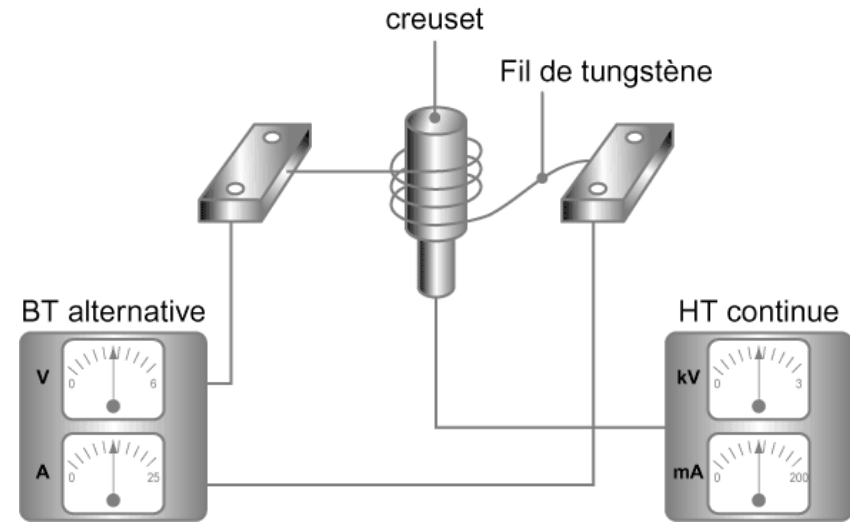
Laboratoire National Henri Becquerel (CEA/DRT/LNHB)

<http://ipnweb.in2p3.fr/~pacs/pacs/cacao/cacao.html>

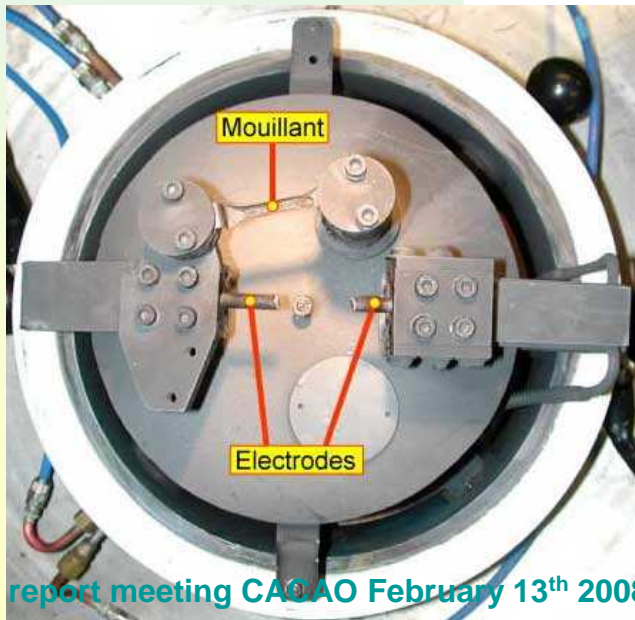
Joule effect evaporation



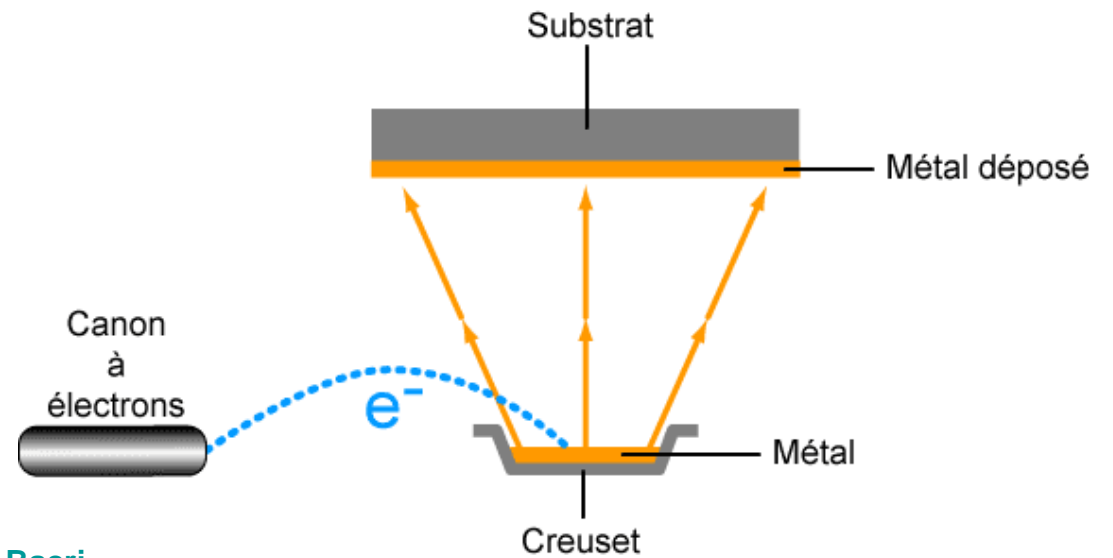
electronic bombardement



Electrical arc



Canon with electron



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Les programmes européens

EFNUDAT: European Facilities for Nuclear DATA measurements

I3 du FP6 - (CENBG, IPNO, JRC/IRMM, IKI, FZK, FZR, PTB, UU-TSL, CEA, CERN, NPI)

- un JRA (Joint Research Activity) consacré à la préparation de cibles radioactives (IPNO, JRC/IRMM, FZK et FZR, pour les couches minces)

Thin actinide targets optimized for high intensity primary beams

Lettre d'intention au FP7 – (ILL, Ganil, IPNO, LPSC, Munich, IRMM)

- Etude et développement de techniques de fabrication de cibles radioactives supportant de hauts flux, de hautes températures, ...

ERAWAST:

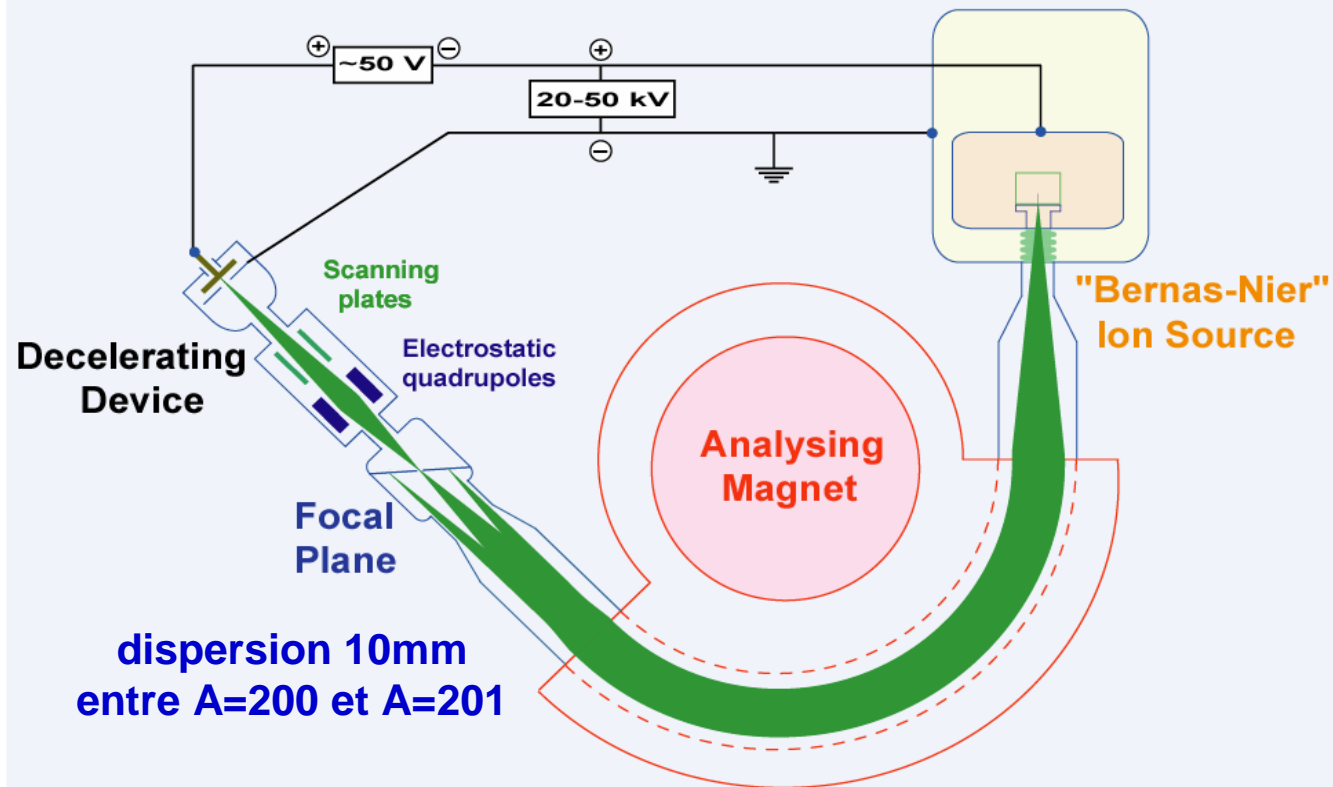
Exotic Radionuclides from Accelerator WASTE for Science and Technology

Soutenu par ESF – 10 pays – 18 institutions – piloté par PSI

- Récupérer les « déchets » produits par les accélérateurs (sources de spallation, cages de Faraday, ...), pour en extraire des isotopes « exotiques »

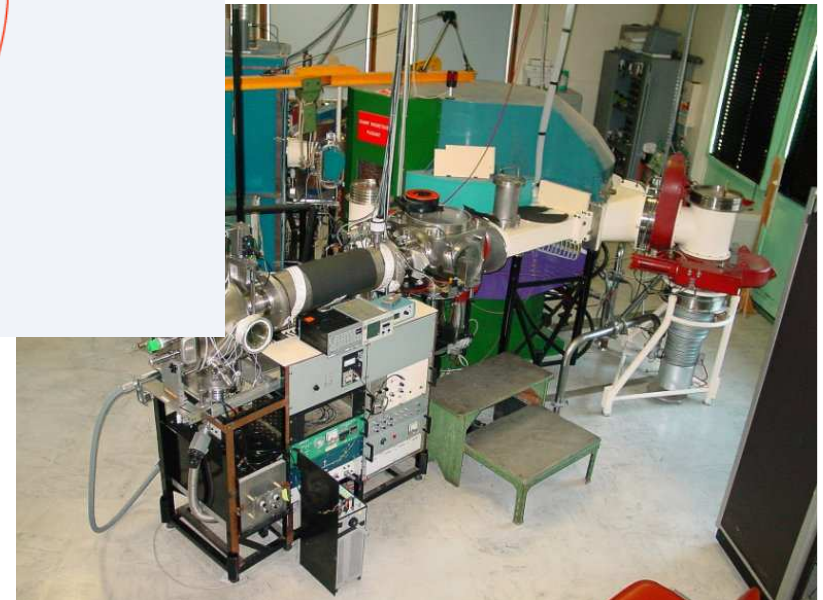
CACAO Séparateur magnétique

Remise aux normes ou fabrication



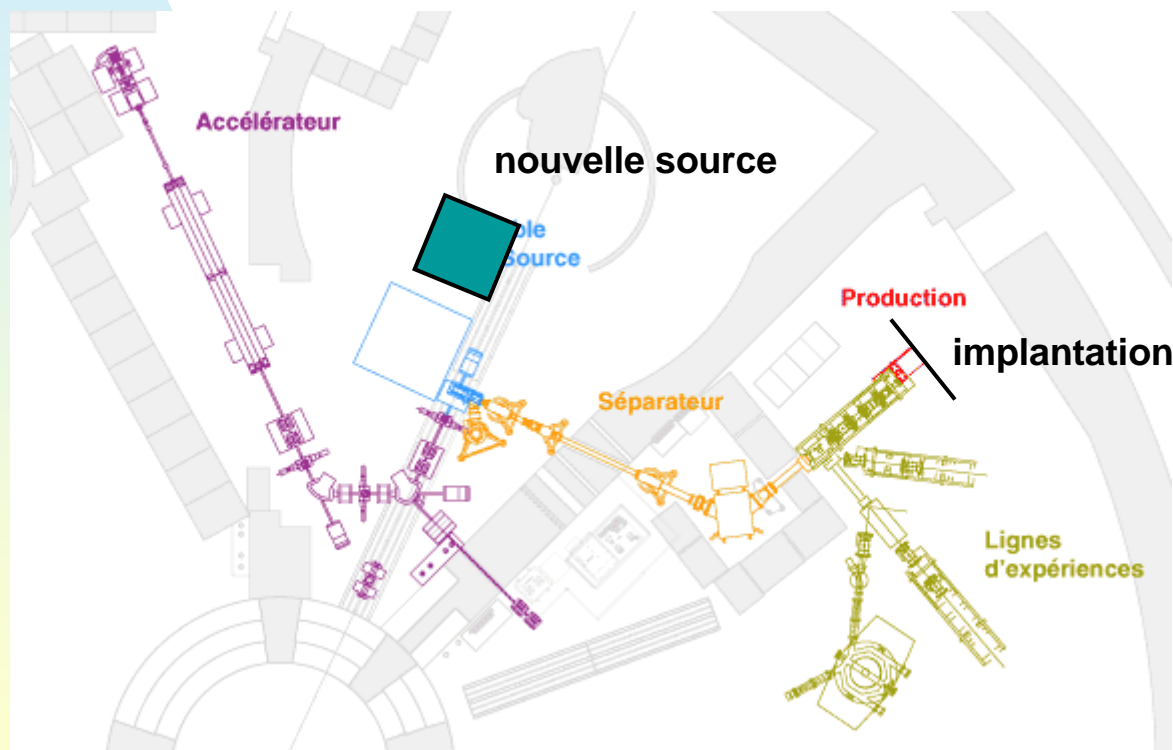
Sidonie
au CSNSM

Remise aux normes: ~ 500 k€
Construction d'un nouveau « Sidonie »:
~1,3 M€



CACAO: Séparateur magnétique Réaménagement du séparateur d' Alto

Cycle de fonctionnement prévu pour l'ensemble cible-source:
Fonctionnement: 3 semaines
Arrêt pour changement de la cible: 1 semaine



Faisabilité
à étudier ...

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Manufacturing of the targets: different constraints

- not too high activity ie activity manipulable
 - need to use the target in a beam line (!)
- } ⇒ **glove boxes**
in controlled zone
- radioactive thin layers (up to $\sim 1 \text{ mg/cm}^2$, depending on isotopes)
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	Φ max	e max
Joule effect evaporation	80 cm ²	0,025 à 10 μm
Electrical arc	108 cm ²	0,025 μm à 10 μm
Electronic bombardment	20 cm ²	0,1 μm à quelques μm
Canon with electrons	900 cm ²	0,025 μm à 10 μm
Chemical solution	108 cm ²	0.1 μm à quelques mm

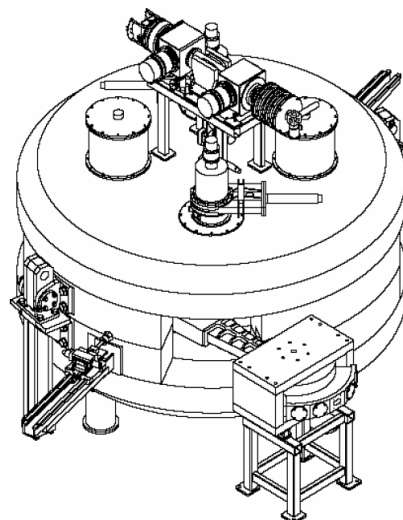
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Fabrication des cibles: les accélérateurs (II)

ARRONAX à Subatech (Nantes)

Accélérateur pour la Recherche en Radiochimie et en Oncologie
à Nantes-Atlantique

	Énergie MeV	Intensité μA
H-	70 - 30	350
HH+	35	50
D-	35 - 15	50
He++	70	35



Diamètre 4 mètres
1,5 Tesla
ECR

	Nb atomes
^{22}Na	$2 \cdot 10^{15}$
^{26}Al	$3 \cdot 10^{14}$ $7 \cdot 10^{15}$
^{44}Ti	10^{16}
^{59}Fe	$3 \cdot 10^{15}$ 10^{16}
^{63}Ni	10^{15}
^{85}Kr	10^{14}
^{95}Zr	$2 \cdot 10^{15}$ 10^{15}

Conception, Production et Utilisation
de radioisotopes
pour la recherche en médecine nucléaire.

Irradiation: 1j;
 $50\mu\text{A}$ de p ou $35\mu\text{A}$ d' α
Cible: 5mm, $\Phi=1\text{cm}$