TRANSMUTATION STUDIES AT GANIL

FIRST

(Fission Induite par RéactionS de Transfert)

F. Rejmund et al.
CNRS/IN2P3/GANIL,CENBG,IPNO,LPSC, France
CEA/DSM/DAPNIA,DIF, France
USC, Spain, GSI, Germany, Oulu, Finland

SPIRAL2-NFS

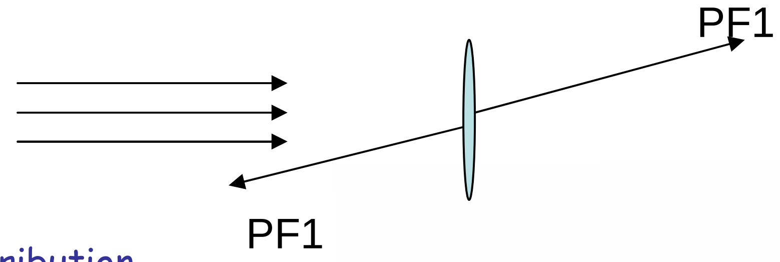
(Neutron For Science)

X. Ledoux et al. xavier.ledoux@cea.fr
CNRS/IN2P3/GANIL,CENBG,IPHC,LPC,Subatech France
CEA/DSM/DAPNIA,DIF, France
NPI, Czech Republic, Uppsala University, Sweden
IRS Karlsruhe, Germany
NIPNE, Buccarest, Romania, Manchester University, UK,
IRMM, Geel, Belgium, PNPI, Gatchina, Russia

Fission fragments from irradiation

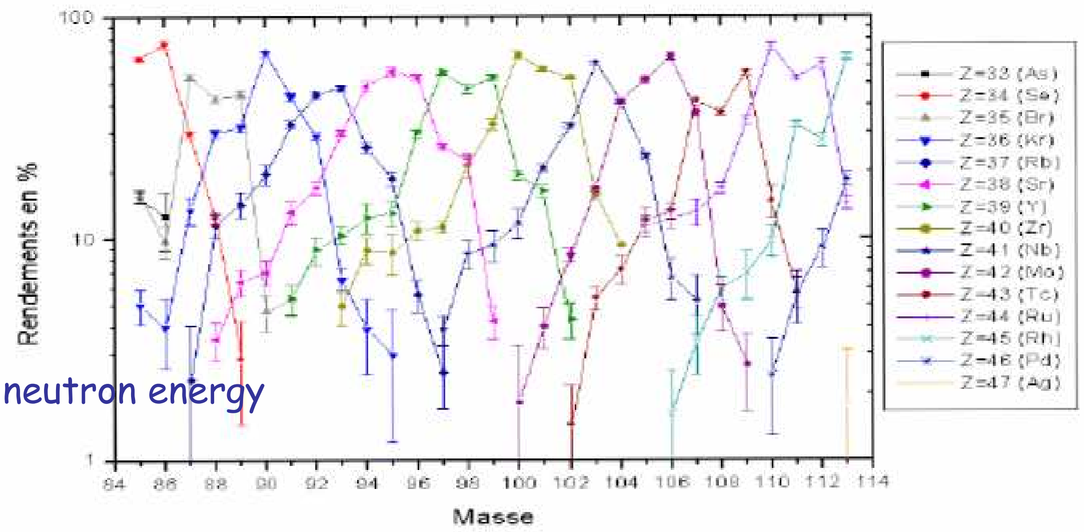
- Mass distribution

n



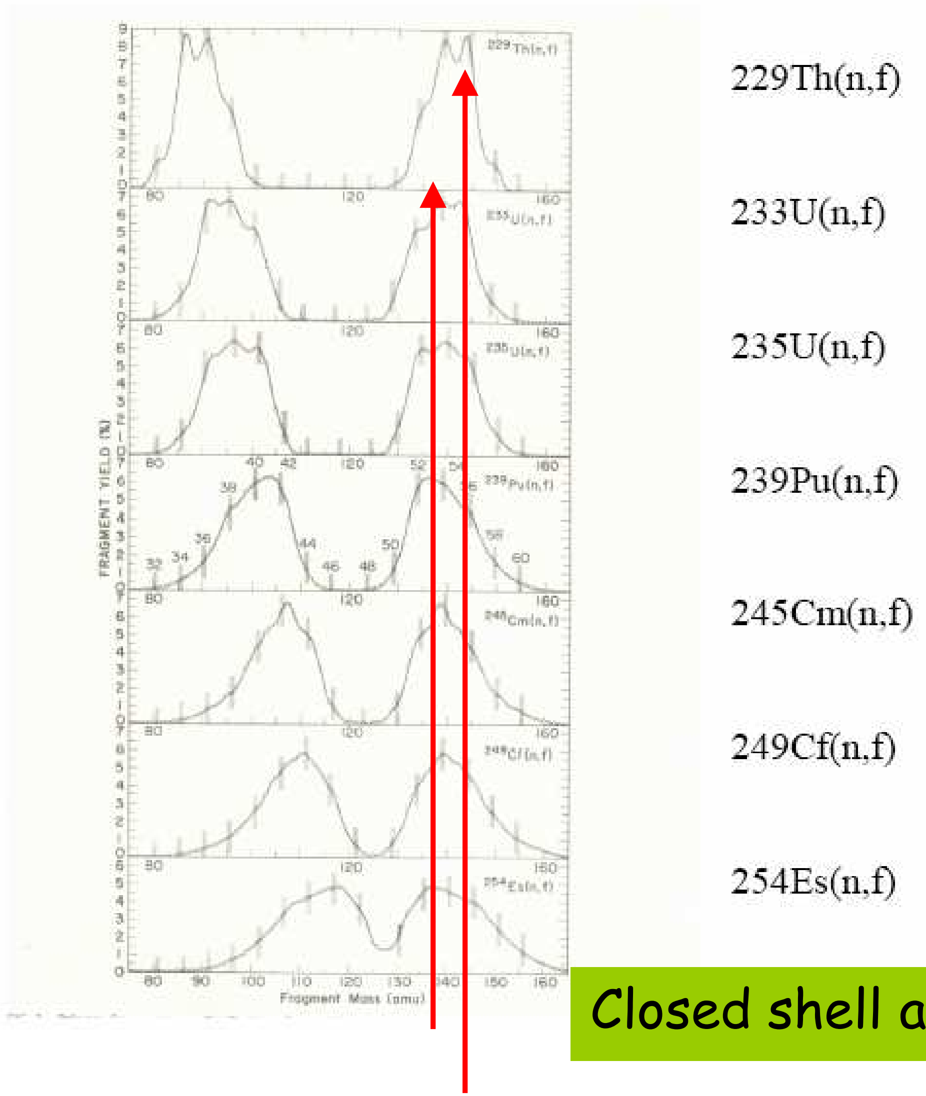
E,ToF =>M

- Isotopic distribution
  - Spectrometer
  =>light fragments
  - γ Spectroscopy
  =>branching ratio, unknown isomers



- Limitations due to target activity, neutron energy

Mass distribution of fission fragments



- Stabilisation of heavy fragment when changing mass of the fissioning nucleus

-Two fission modes (spherical and deformed)

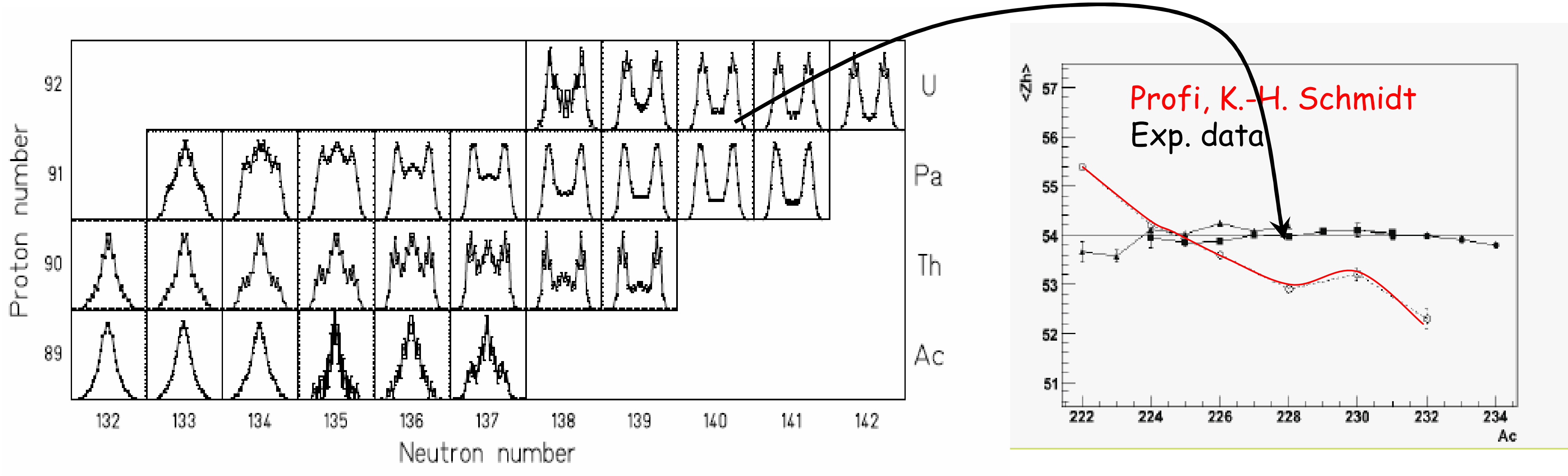
N~ 88 deformed shell

N=82 spherical shell

Closed shell at N=86,88,90 ?? Still under debate!!

GSI data in inverse kinematics

Wide systematcis on element yields for U fragmentation products



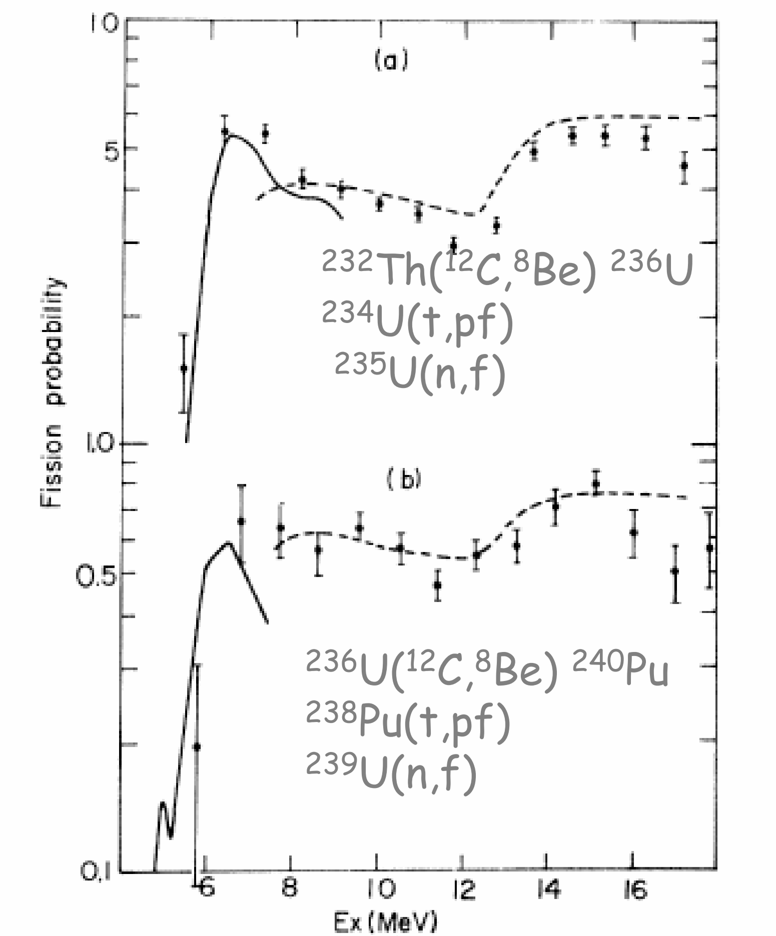
$A_f = Z_f + N_f$
Average charge constant
=>Influence of moving neutron shell
=>Existence of proton closed shell ?

Necessity to get isotopic yields in heavy FF!!

J. Benlliure et al, EPJA 13(2002)

Multi-nucleon transfer reaction

•Good definition of the fissioning system



Cheifetz et al,,1981

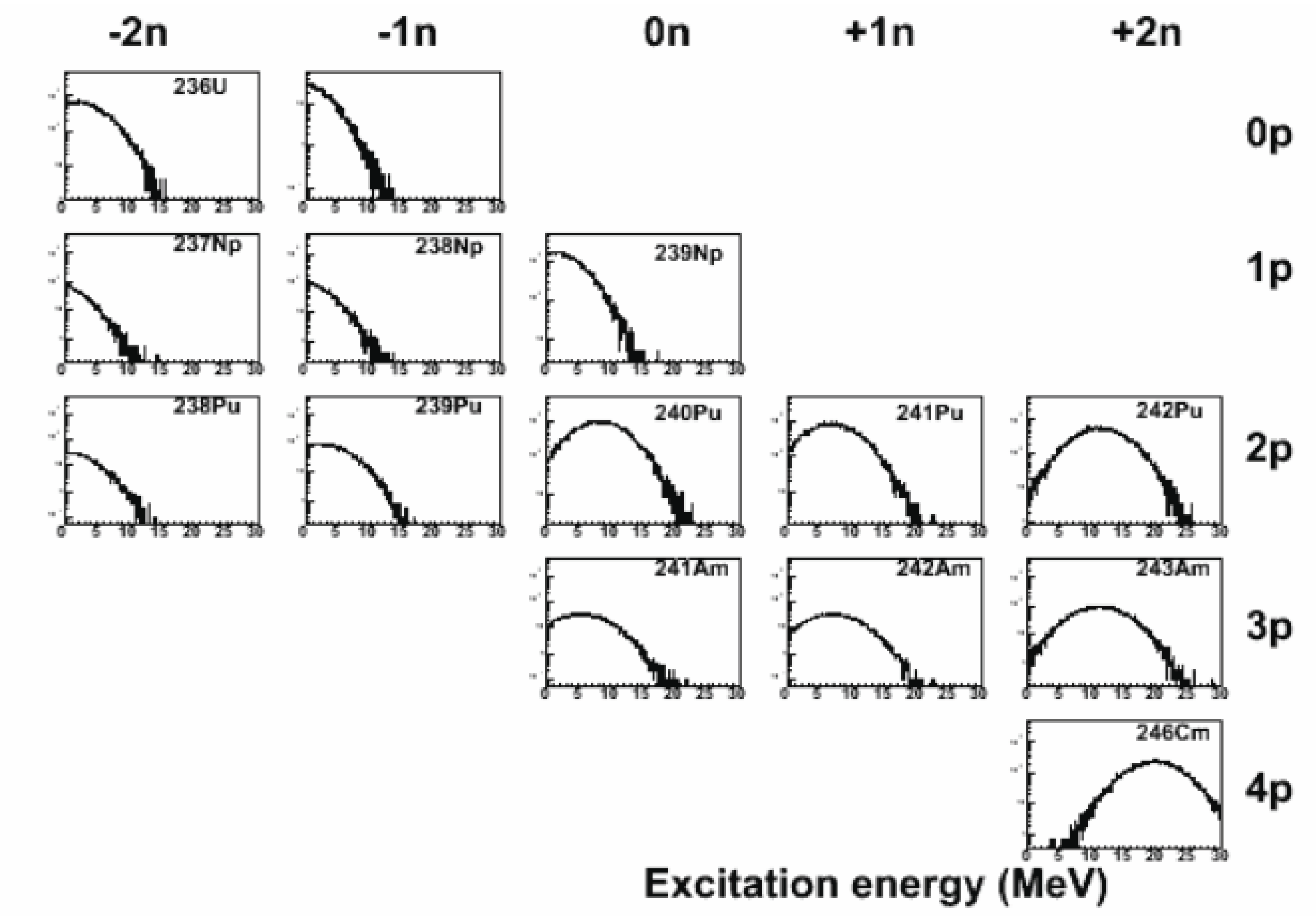
•Large range of transfer Channels

$^{238}U+^{12}C$

Eje	Rec	Q(MeV)	σ(mb)
^{13}C	^{237}U	-1.2	23
^{14}C	^{236}U	1.8	8
^{11}B	^{239}Np	-10	25
^{12}B	^{238}Np	-13	5
^{13}B	^{237}Np	-14	0.8
^{10}Be	^{240}Pu	-15	10
^{9}Be	^{241}Pu	-17	5
^{8}Be	^{242}Pu	-12	5
^{11}Be	^{239}Pu	-21	0.8
^{7}Li	^{243}Am	-26	0.5
^{6}Li	^{244}Am	-19	3
^{4}He	^{246}Cm	-17	3
^{6}He	^{244}Cm	-24	0.5

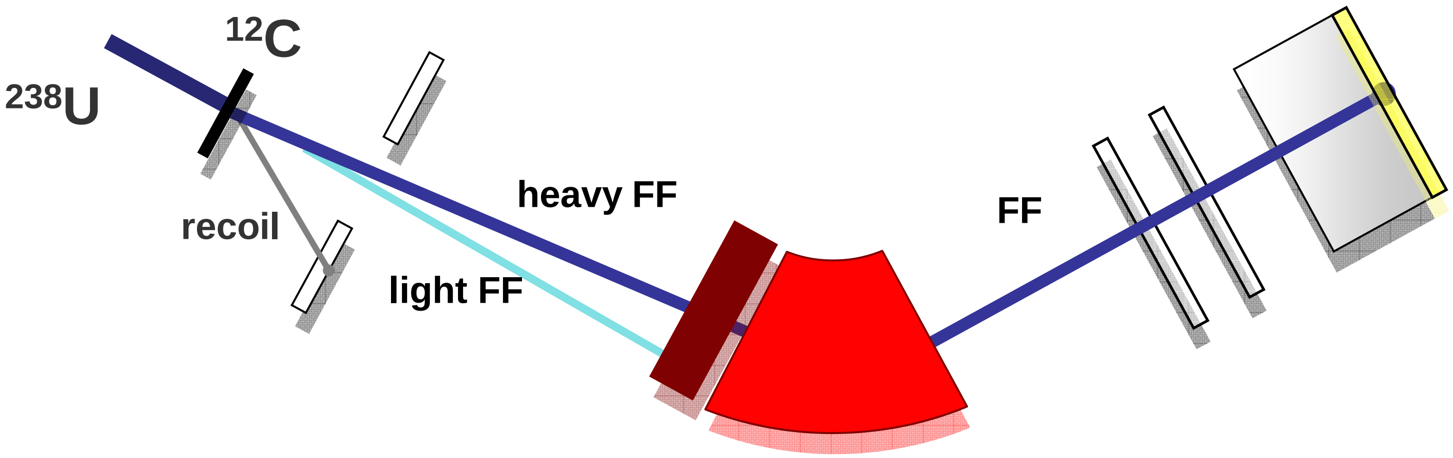
Transfer-induced fission reactions: wide range of fissioning systems

- Neutron-rich actinides : ^{238}U beam, ^{12}C Target
- Energy range 0-40 MeV



Multinucleon induced fission in inverse kinematics@GANIL

-Inverse kinematics (high Z resolution)
-Isotopic identification (spectrometer)
-Wide range of actinides
Precise measure of the excitation energy (particle detection)



Identification of fission fragments in VAMOS

$$A = \frac{2E}{v^2}$$

$$B\rho = f\,(x, y, \theta, \varphi)$$

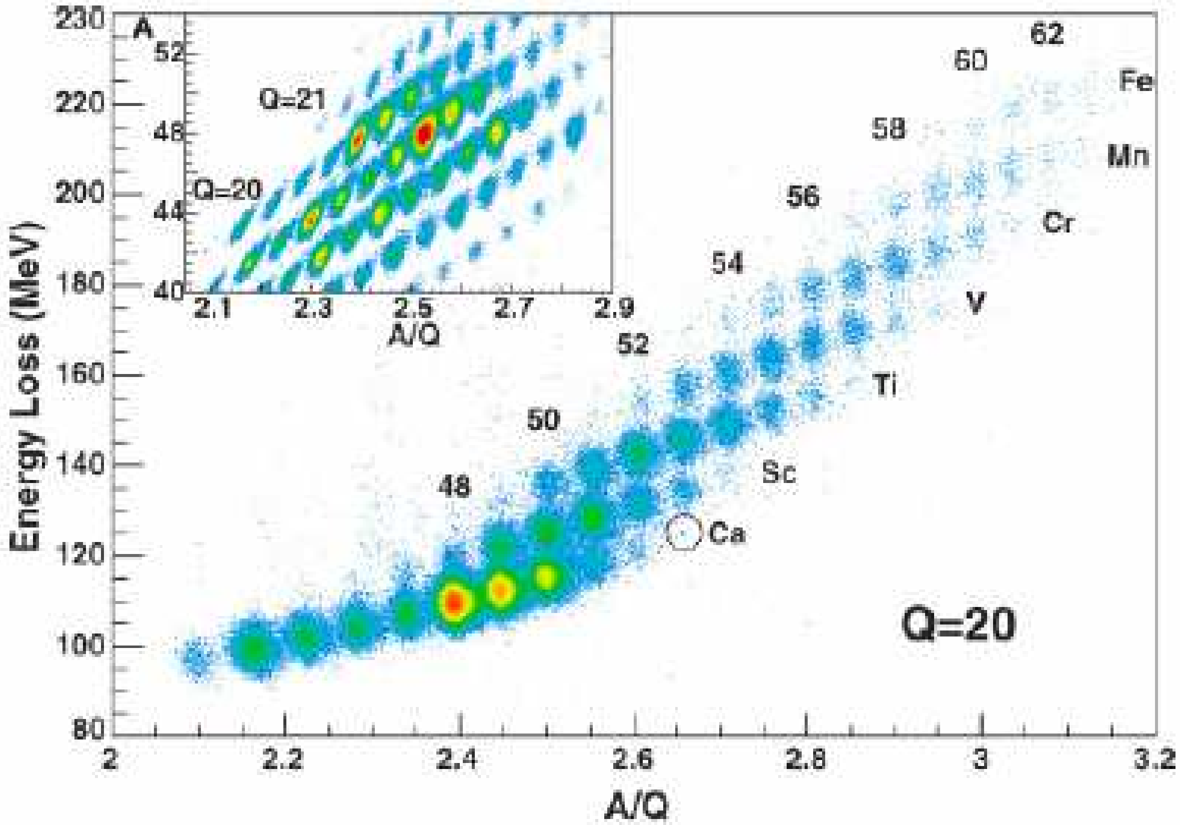
$$B\rho = \frac{A}{Q} v$$

X,Y, θ,φ

ToF
E
ΔE

$$\Delta E \propto \frac{Z^2}{v^2}$$

^{238}U+^{48}Ca



M. Rejmund et al. PRC76(2007)

CENTRE NATIONAL
DE LA RECHERCHE
SCIENTIFIQUE

FIRST
Expected results

EURATOM

GEDEPEON

- Complete isotopic distribution of fission fragments (heavy and light) as a function of excitation energy
- For a ten of actinides
- Fission probability over a range from 0 to 25 MeV with resolution ~1 MeV

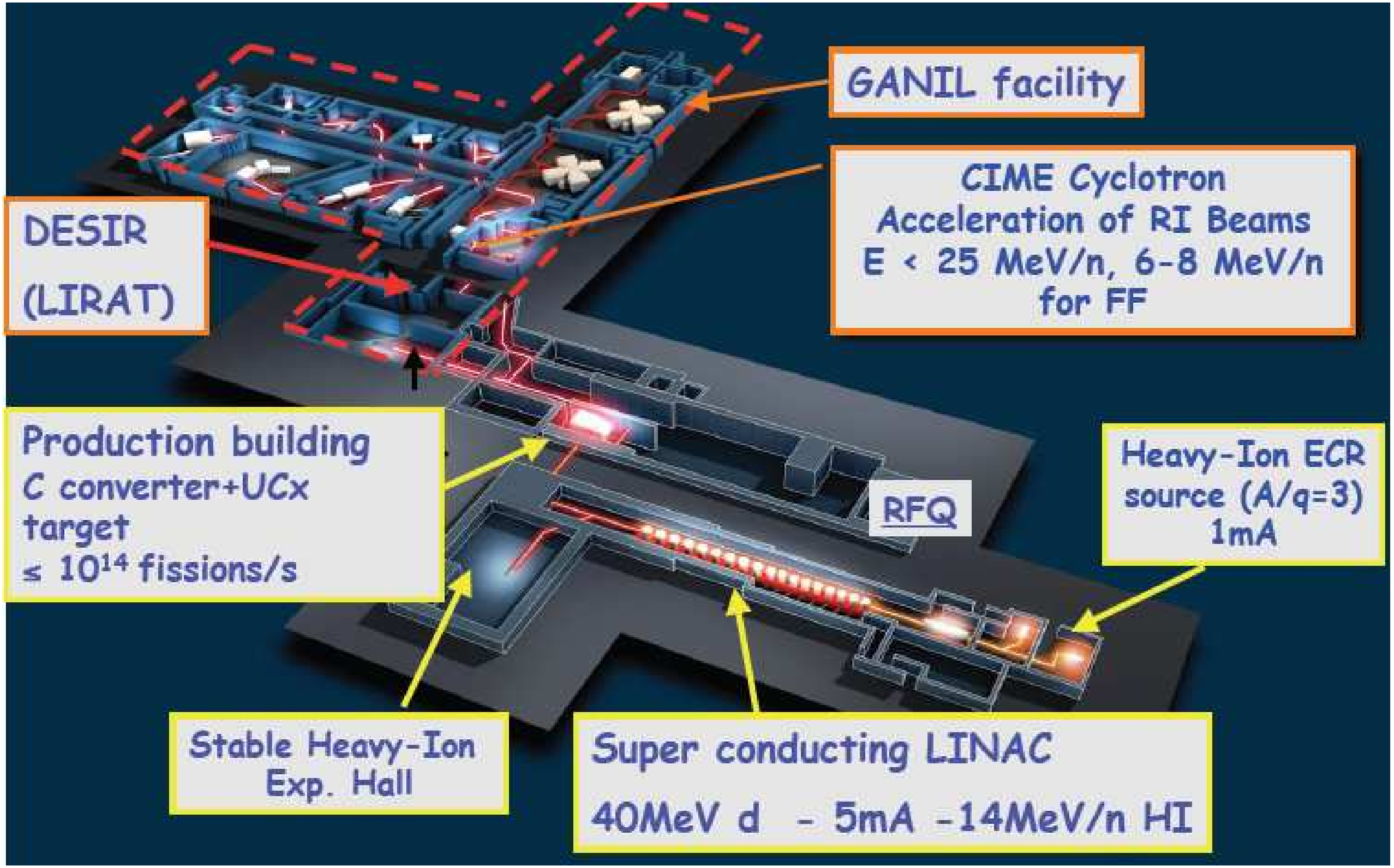
Applications:

When minor actinides are not minor anymore…

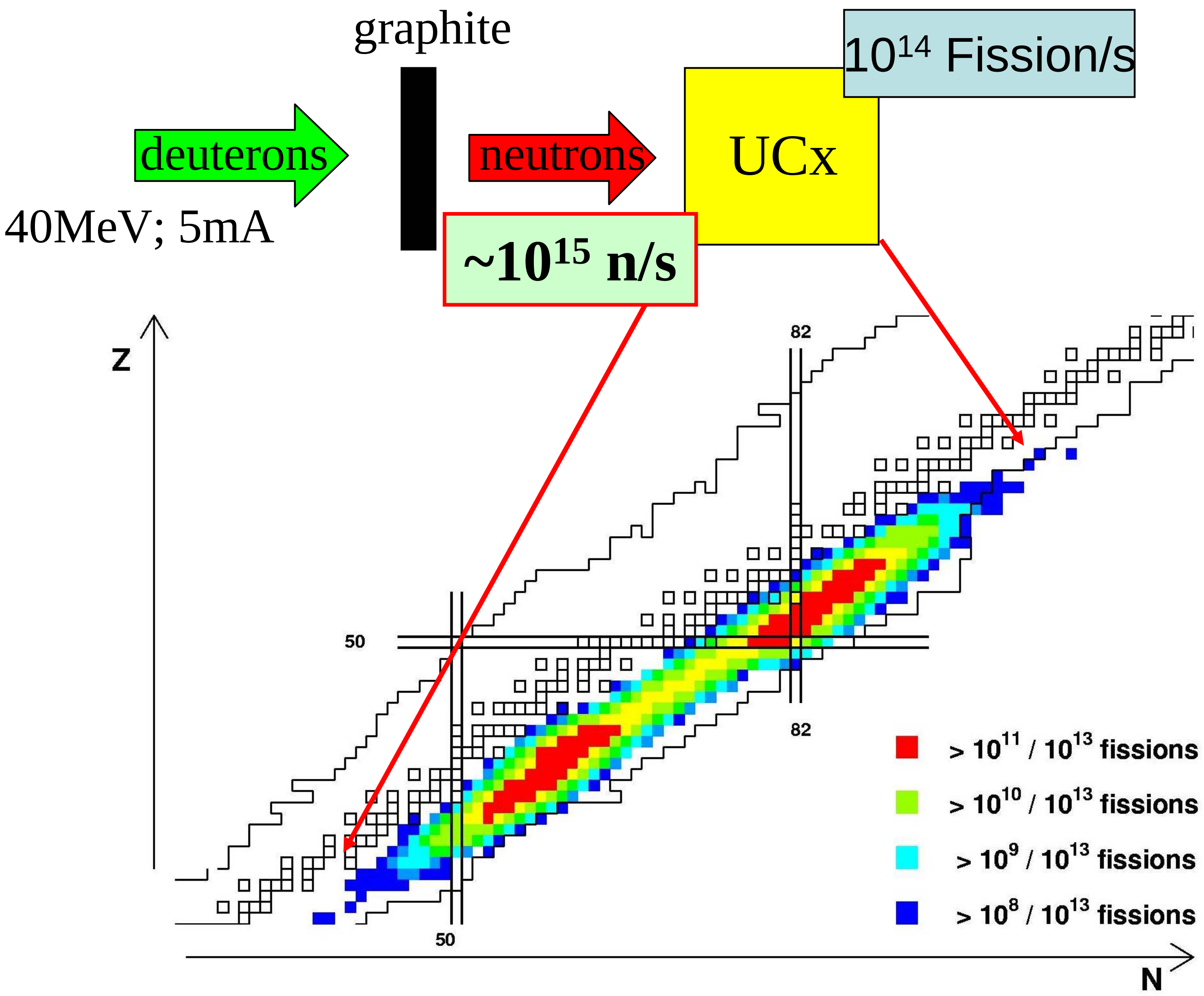
- Dissipated heat in the used fuel
- Estimation of poisoning isotopes (high n capture)
- Estimation of delayed neutrons
- A. Nichols, head of Nuclear Data Section of IAEA: "*Evaluation of isotopic yields of FF has been abandoned, due to a lack of convergence between scarce data and models*"
- Improvement of uncertainty

Experience April 2008

SPIRAL 2 : Radioactive Beam facility

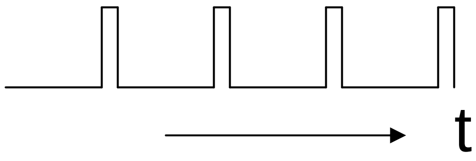


Neutron For Science @ SPIRAL2



NFS : neutron spectrum

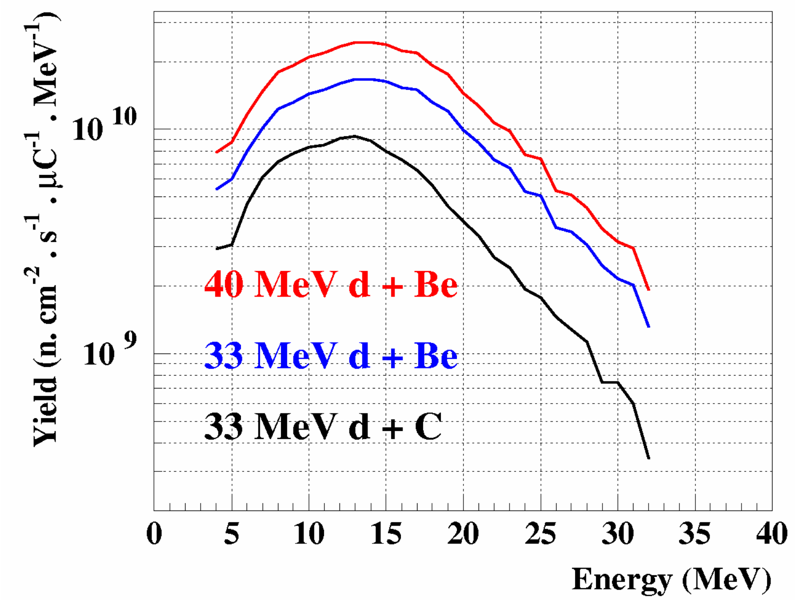
LINAG: I = 5mA E= 40 MeV
F= 88 MHz T= 11ns Largeur=200ps

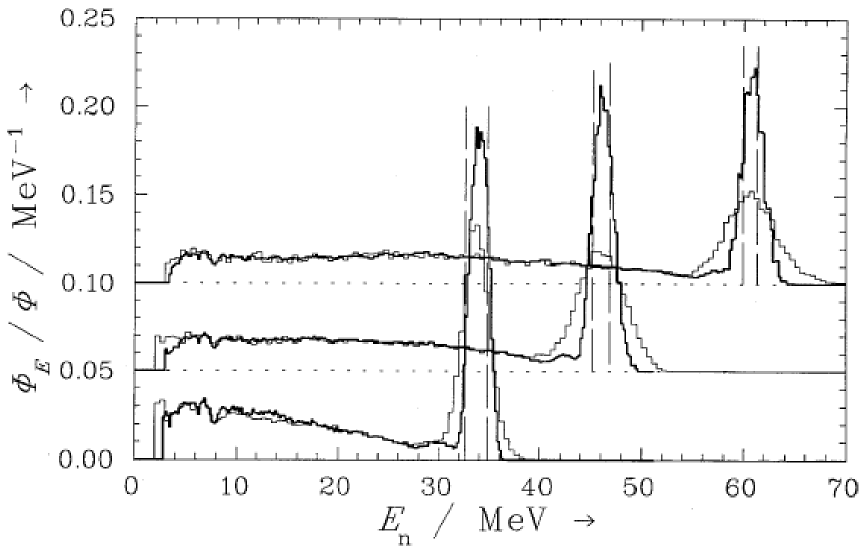


- d +C,Be

White spectrum
d beam stops in converter

7Li(p,n)7Be
monoenergetic spectrum
thin Li target=>need for clearing magnet



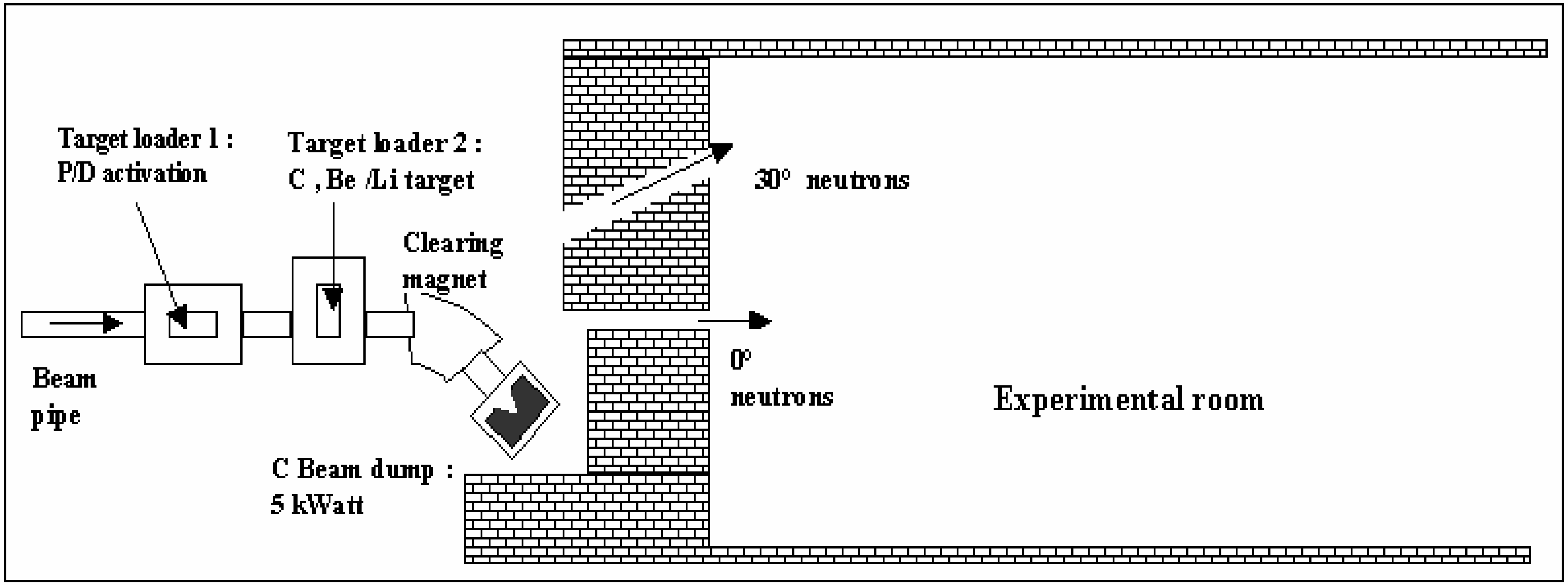


Neutron For Science facility

Burst selector
Buncher
Converter
Clearing magnet

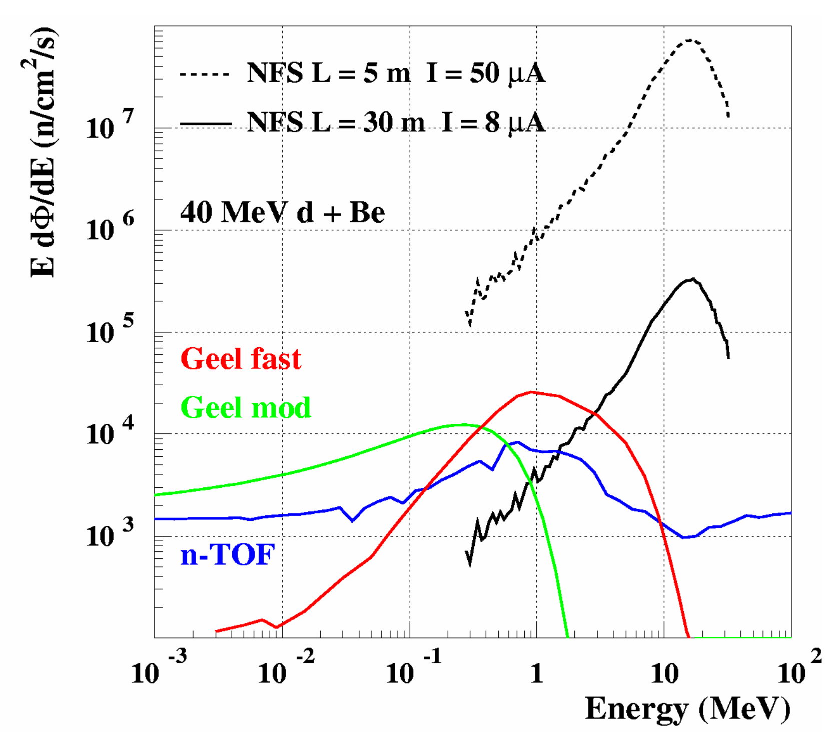
Collimator
5m

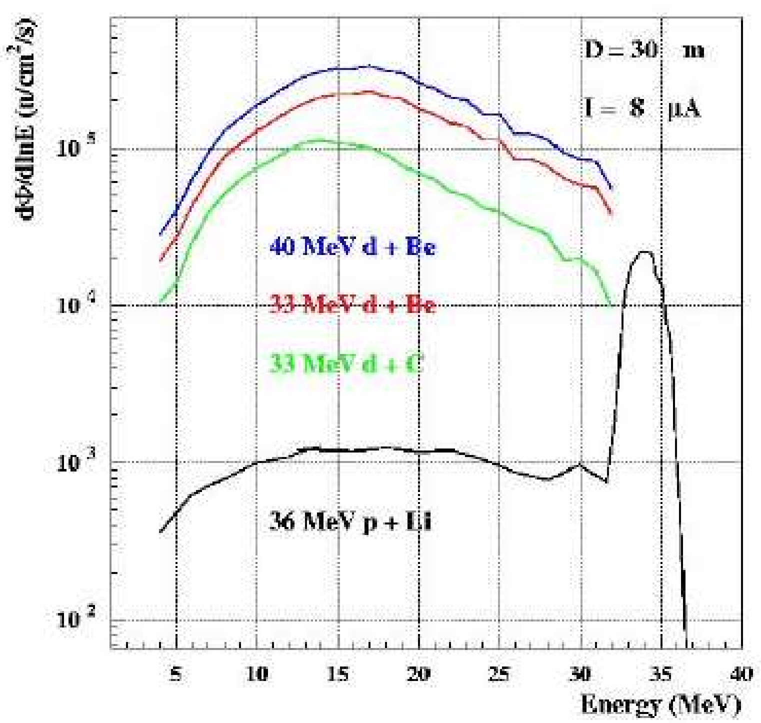
Experimental area
5 to 30m for ToF



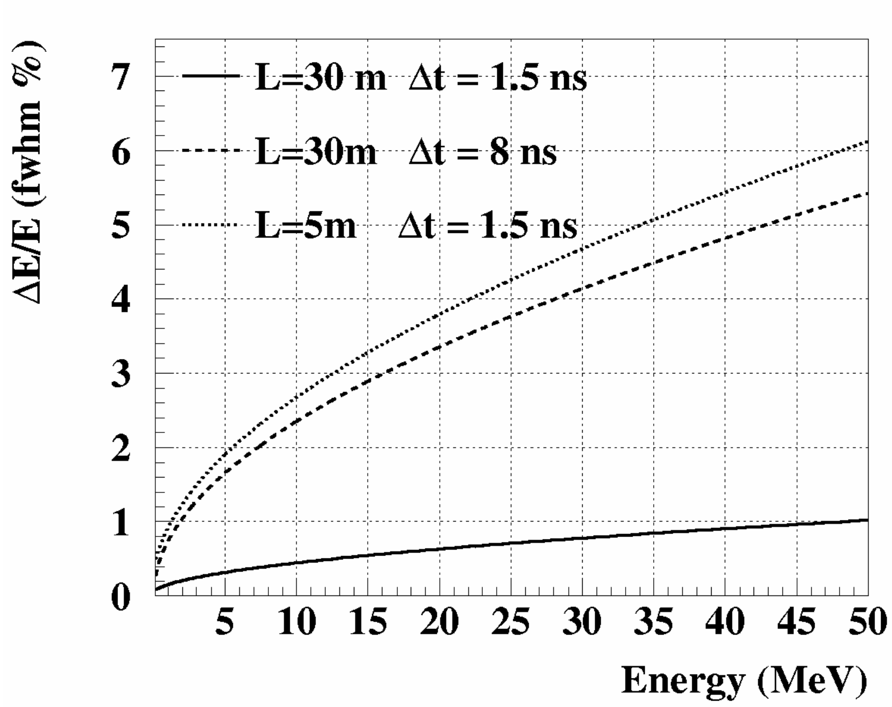
Beam repetition rate

- Disentangle slowest neutron from burst n and faster neutron from burst n+1
  - Energy threshold (100 keV)
  - Burst selector
    - (1 burst/100 for 5m (T=1us); 1 burst/600 for 30m)
  - Intensity decreases with distance and selection





Energy resolution



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

Δt : Full time resolution :

$$\Delta t = \sqrt{(\Delta t_d)^2 + (\Delta t_b)^2}$$

Δt_d ≃ 1 ns scintillator

≃ 8 ns HPGe

Δt_b ≃ 1 ns

... resolution

L=30m and slow detector (Ge)

L=5m and slow detector

} DE/E ~ 5%

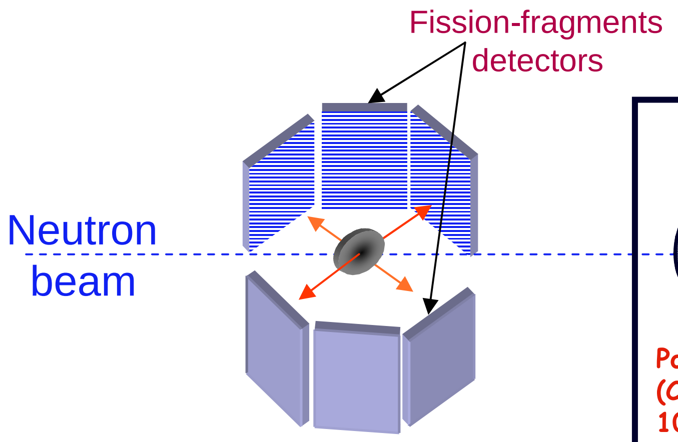
Buncher to insure the time resolution of the beam

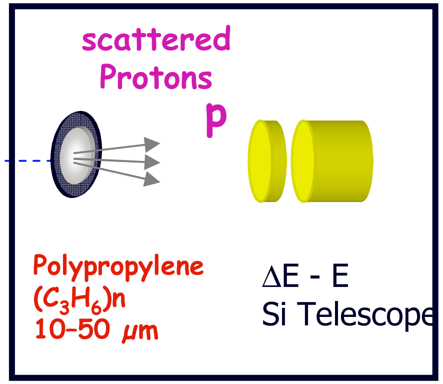
Scientific programme at NFS

Neutron-induced Minor Actinides fission-fragment yields in the 1-20 MeV energy range

CENBG Bordeaux

Experimental technique





Flux montoring

Thin targets are needed (~150μg/cm²)
both fission fragments can exit the sample

-targets:

^{235}U, ^{237}Np, ^{241,243}Am, $^{?}$Cm

Intense neutron flux

Kinetic energy and mass of each fragment

Pulsed beam, neutron TOF

Fragment masses : double-energy measurement
Fragment Z:

- Bragg spectrometer (Manchester)
- X detectors

E_n(MeV)	Fission rate(s^{-1}) NFS at 5m	Fission rate(s^{-1}) N-TOFCERN at 20m
1	0.18	-
5	0.37	$8.24\ 10^{-3}$
10	1.42	$4.74\ 10^{-3}$
20	1.36	$2.33\ 10^{-3}$

Scientific programme at NFS

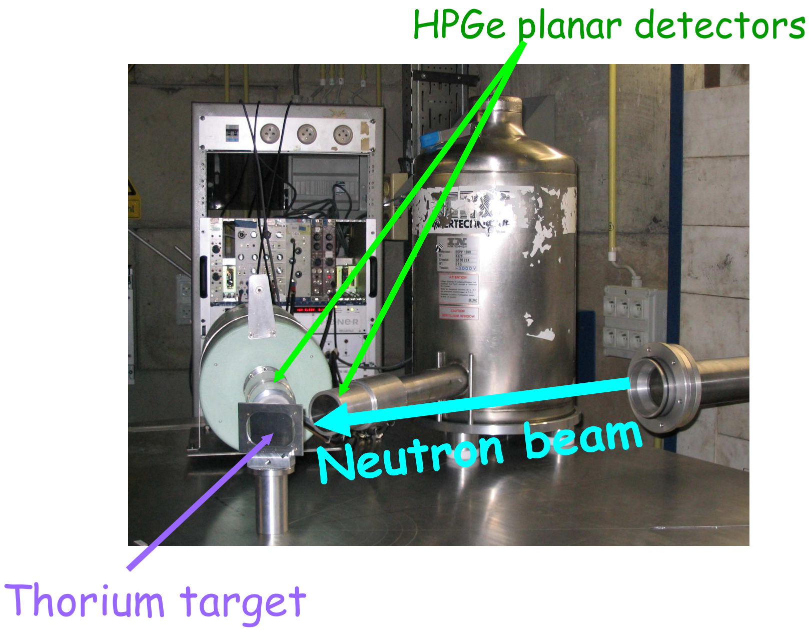
Measurement of (n,n'γ) et (n,xnγ) cross-sections

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 and Digital electronics

Gamma detection



Advantages of NFS :

-mono energetic or white spectrum

- Reduced gamma flash

- $E_{Gelina} < E_{NFS} < E_{Louvain\text{-}la\text{-}Neuve}$

-Cleaner beam due to a low repetition rate

Next measurement : radioactive sample

Scientific programme at NFS

- Neutron activation measurement — IRS Karlsruhe
  - Scarce data above 14 MeV
  - Use mono energetic and white spectrum
  - Proton and deuteron activation
- N, xn — CEA/DIF Bruyères le Chatel
- ….
- FP7 150k€ for
  - » collaboration meetings
  - » Post-doc fellowship (target, collimator)
  - » Study & developpement of prototypes
- First neutron beam on the horizon 2012
- Integrated in the next EFNUDAT network ??

Neutrons For Science (NFS) at SPIRAL-2

X. Ledoux[1)], M. Avrigeanu[10)], V. Avrigeanu[10)], M. Aïche[2)], G. Ban[3)], G. Barreau[2)], P. Baumann[4)], P. Bem[5)], V. Blideanu[6)], J. Blomgren[7)] , S. Czajkowski[2)], P. Dessagne[4)], D. Doré[6)] , E. Dupont[6)], T. Ethvignot[1)], M. Fallot[13)],U. Fischer[8)], L. Giot[13)],F. Gunsing[6)], B. Jacquot[9)], B. Jurado[2)], M. Kerveno[4)], F. R. Lecolley[3)], J. L. Lecouey [3)],N. Marie-Noury, F. Negoita[10)], S. Oberstedt[11)], M. Petrascu[10)], A.J.M. Plompen[11)], F. Rejmund[9)], D. Ridikas[6)], G. Rudolf[4)], O. Shcherbakov[12)], S.P. Simakov[8)], J. Taïeb[1], I. Tsekhanovitch[14], G. Smith[14]

1) Service de Physique Nucléaire, CEA/DIF, BP 12, 91980 Bruyères-le-Châtel Cedex, France

2) Centre d'Etudes Nucléaires de Bordeaux-Gradignan, 33175 Gradignan, France

3) Laboratoire de Physique Corpusculaire, ISMRa et Université de Caen, CNRS/IN2P3,France

4) Institut Pluridisciplinaire Hubert Curien, Strasbourg, France

5) Nuclear Physics Institute, 25068 Řež, Czech Republic

6) Centre d'Etudes Nucléaires de Saclay, DSM/DAPNIA, France

7) Department of Neutron Research, Uppsala University, Uppsala, Sweden

8) Forschungszentrum Karlsruhe, Institute for Reactor Safety, Karlsruhe, Germany

9) GANIL, CEA/CNRS, Caen, France

10) NIPNE, Bucharest, Romania

11) Institute for Reference Materials and Measurements, Geel, Belgium

12) PNPI, Gatchina, Russia

13) Laboratoire de physique subatomique et des technologies associées, Nantes, France

14)University of Manchester, UK

Isotopic Yields of Fission Fragments from Transfer-Induced Fission

F. Rejmund, M. Caamaño, X. Derkx, C. Golabek, J. Frankland, M. Morjean, A. Navin, M. Rejmund	GANIL, France
M. Aïche, G. Barreau, S. Czajkowski, B. Jurado	CENBG, France
K.-H. Schmidt, A. Kelic,	GSI, Germany
C. Shmitt	IPNL, France
G. Simpson	LPSC,France
J. Benlliure, E. Casarejos,	USC, Spain
L. Audouin, C.-O. Bacri, L. Tassan-Got,	IPNO, France
T. Enqvist,	CUPP, Finland
D. Doré, S. Panebianco, D. Ridikas	CEA SPhN
L. Gaudefroy, J. Taieb	CEA DIF