THE NEUTRONS FOR SCIENCE FACILITY AT SPIRAL-2

X. Ledoux and the NFS collaboration

CEA/DAM/DIF, F-91297, Arpajon, France
CEA/DSM/IRFU/SPhN, Saclay, France
CENBG, Gradignan, France
LPC, Caen, France
IPHC, Strasbourg, France
NPI, Řež, Czech Republic
Uppsala University, Uppsala, Sweden
KIT, Karlsruhe, Germany
GANIL, Caen, France
NIPNE, Bucharest, Romania
JRC/IRMM, Geel, Belgium
CEA/DEN, Cadarache, France
IPNO, Orsay, France
CIMAP, Caen, France
Culham Centre for Fusion Energy, United Kingdom

Physics case

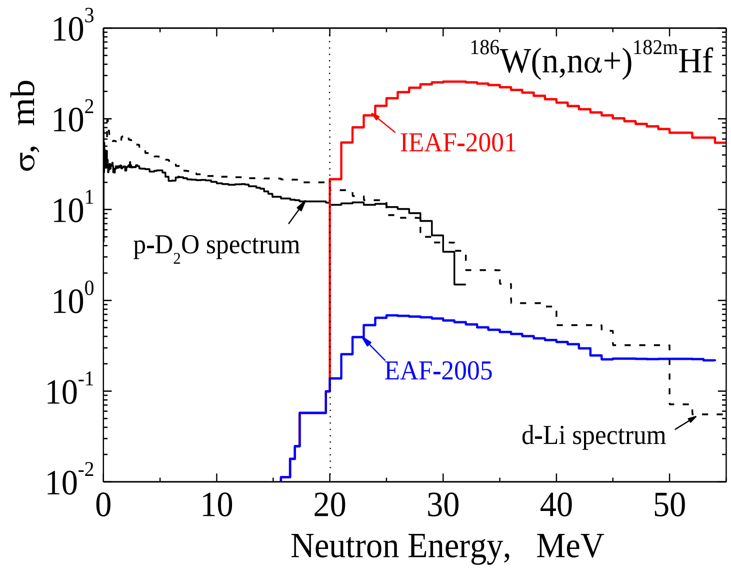
Domains where high energy neutrons play a role

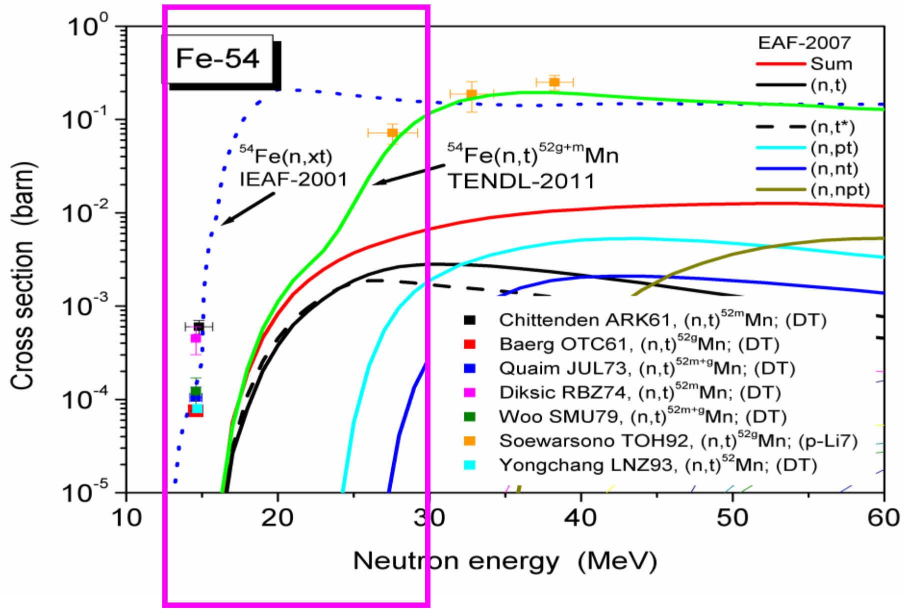
- **Fundamental physics**
  - Astrophysics
  - Production of RIB
- **Energy production**
  - New generation of reactor
  - Fusion technology
  - Accelerator Driven System
- **Nuclear medicine**
  - Radioisotopes production for medical applications → see G. DeFrance talk
  - Neutron therapy
  - Biology (cells irradiation..)
- **Development and characterization of new detectors**
- **Study of the single-event upsets**

Needs for the fusion technology

IFMIF : International Fusion Material Irradiation Facility needs neutron and deuteron induced reactions cross-section for flux monitoring and activation evaluation.

- Data scarce or not existing
- Large discrepancies between data base





IFMIF: Tritium production on iron

Evaluated data libraries and available experimental data

Material to be studied for IFMIF :

Al, Fe, Cr, Cu, Nb for cavities and beam transport elements

Be, C, O, N, Na, K, S, Ca, Fe, Cr, Ni for Li loop

Needs for the new generation of reactor

GENIV reactors and ADS need nuclear data development (evaluated data and measurements):

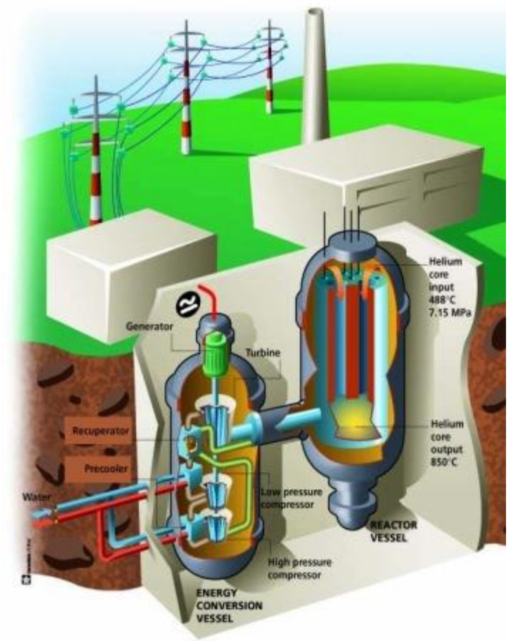
- **Fast neutron**
- **Transmutation and target design in ADS**
- **High burn-up systems.**
- **Structural materials and coolants**

→

Cross sections (fission, capture, scattering)
Fission neutron spectra, Nu-bar
Gamma source term, Spent fuel inventories,
Decay heat, and dose rates

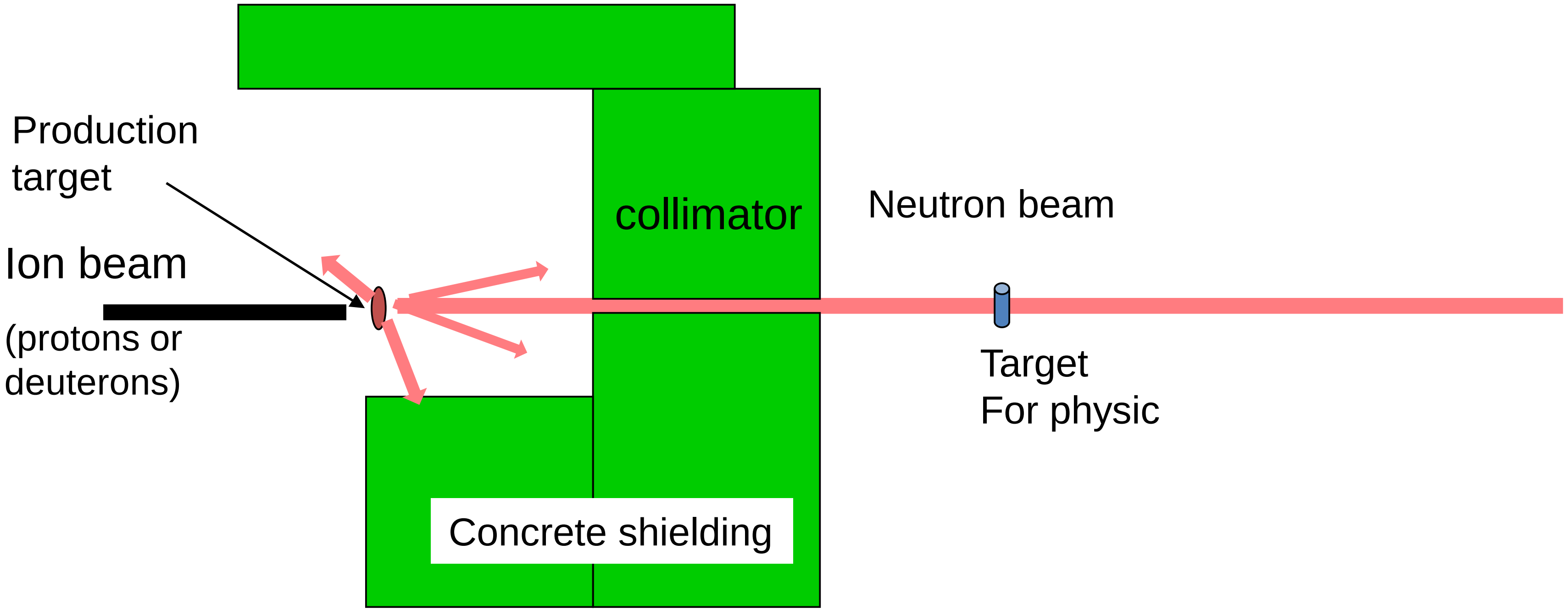
A High Priority Request List (Short list) :

- fission cross sections of ^{234}U, ^{237}Np, $^{238,240\text{-}242}$Pu, ^{241,242m,243}Am, $^{242\text{-}246}$Cm
- fission nu-bar of ^{238,240}Pu, ^{241}Am and ^{244}Cm
- capture of ^{235,238}U, ^{237}Np, $^{238\text{-}242}$Pu, ^{241,242m,243}Am, ^{244}Cm
- inelastic scattering of ^{238}U, ^{239,240,242}Pu, ^{241,243}Am, C, O, Na, ^{56}Fe, Pb, Bi, ^{90}Zr
- neutron removal of ^{10}B, C, O, Na, Si, Fe, Ni, Pb
- elastic scattering of ^{238}U, C, ^{15}N, O, ^{52}Cr, ^{56}Fe, Pb



And
- Prompt neutrons and gamma fission spectra
- Delayed neutrons and gamma yield

Neutron beam production



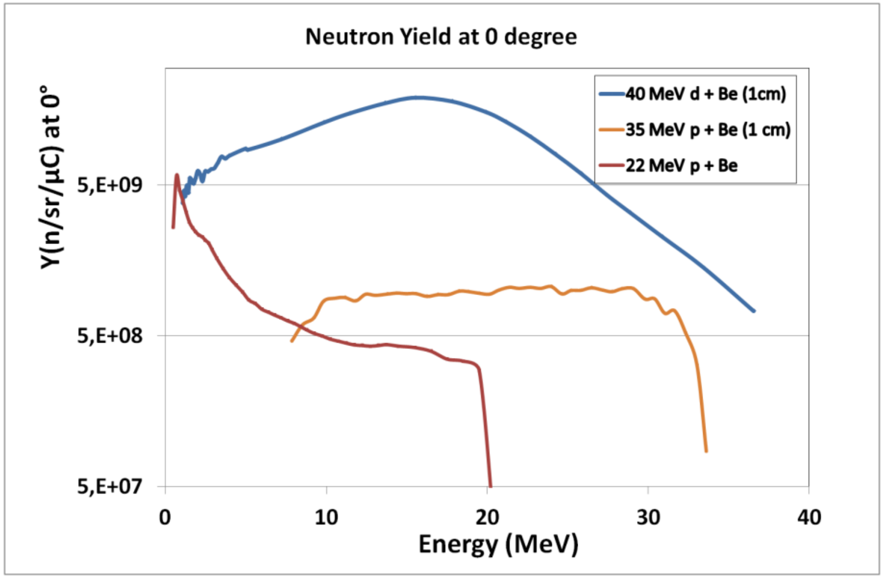
The neutron yield and energy distribution depend on:

- The used nuclear reaction
- The beam energy
- The beam intensity

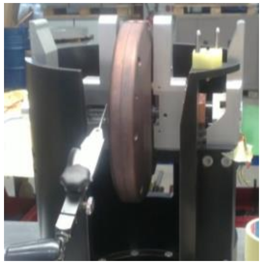
Neutron spectra provided at NFS

Continuous spectrum

40 MeV d+ Be (6 mm)

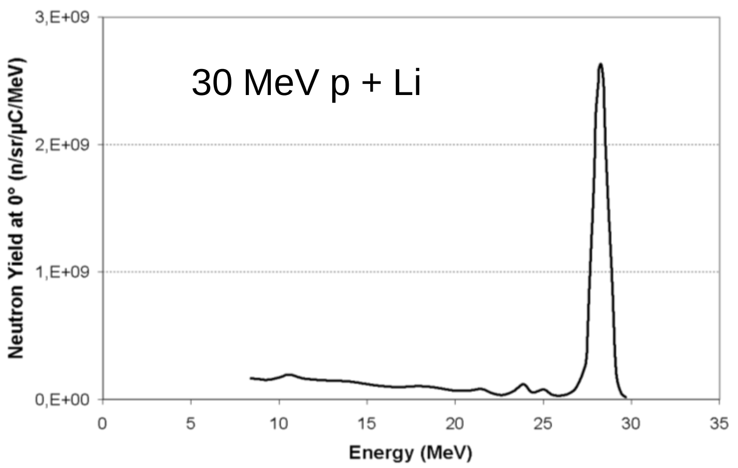


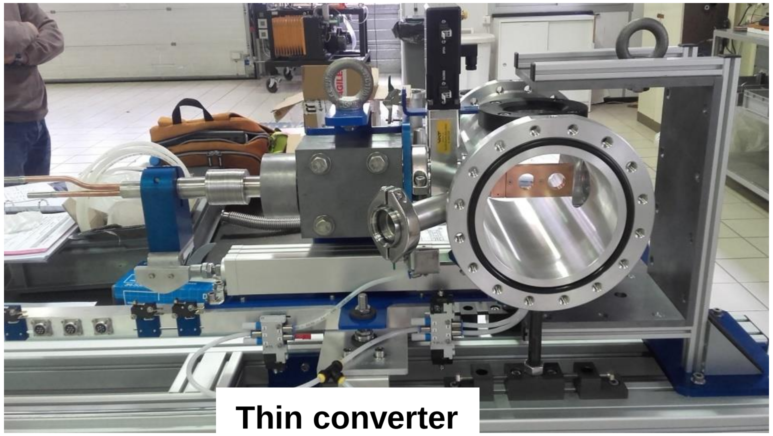
Rotating thick converter



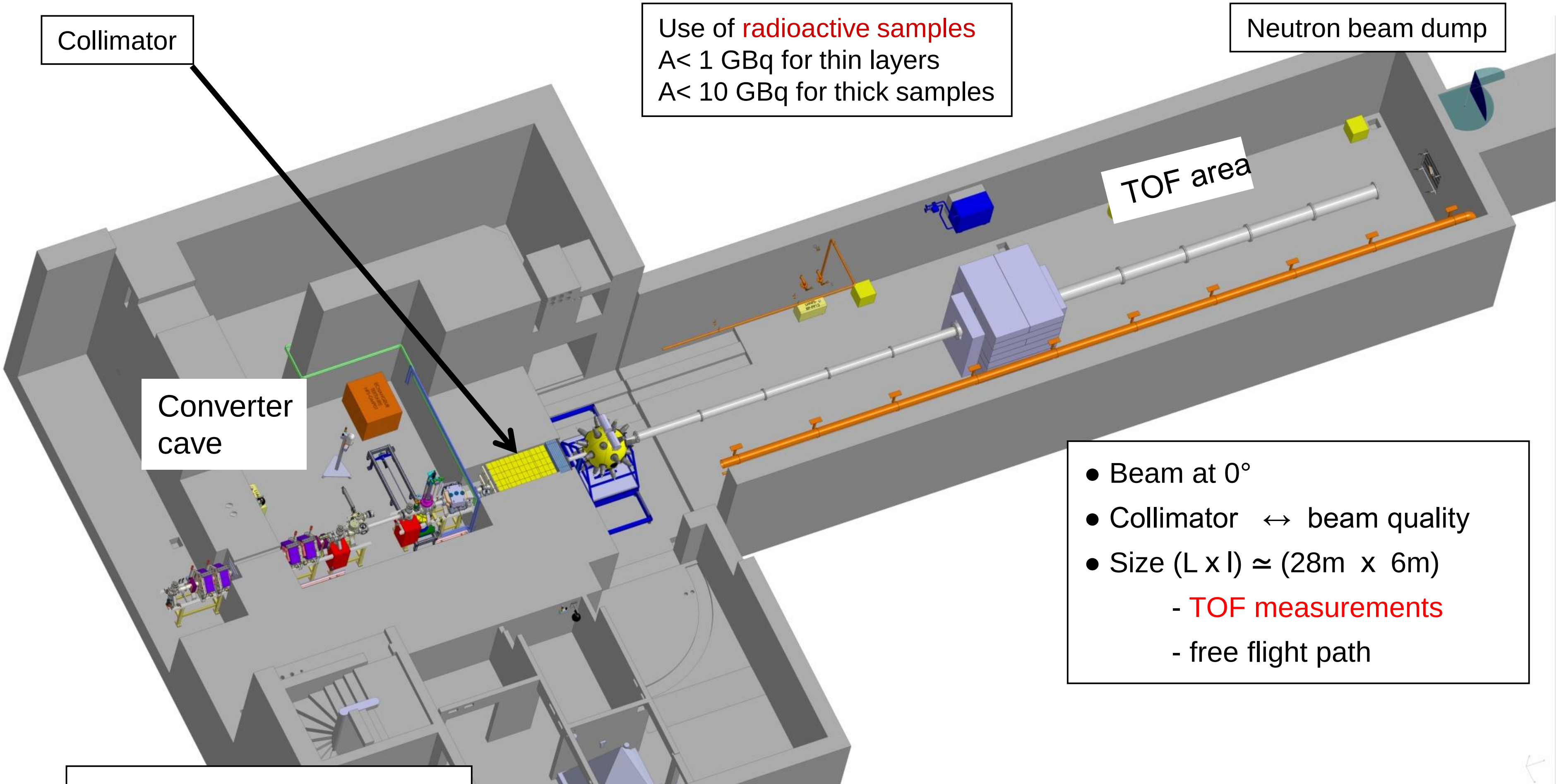
Quasi-mono-energetic spectrum

$p + {}^{7}Li \rightarrow n + {}^{7}Be$ Q= -1.64 MeV





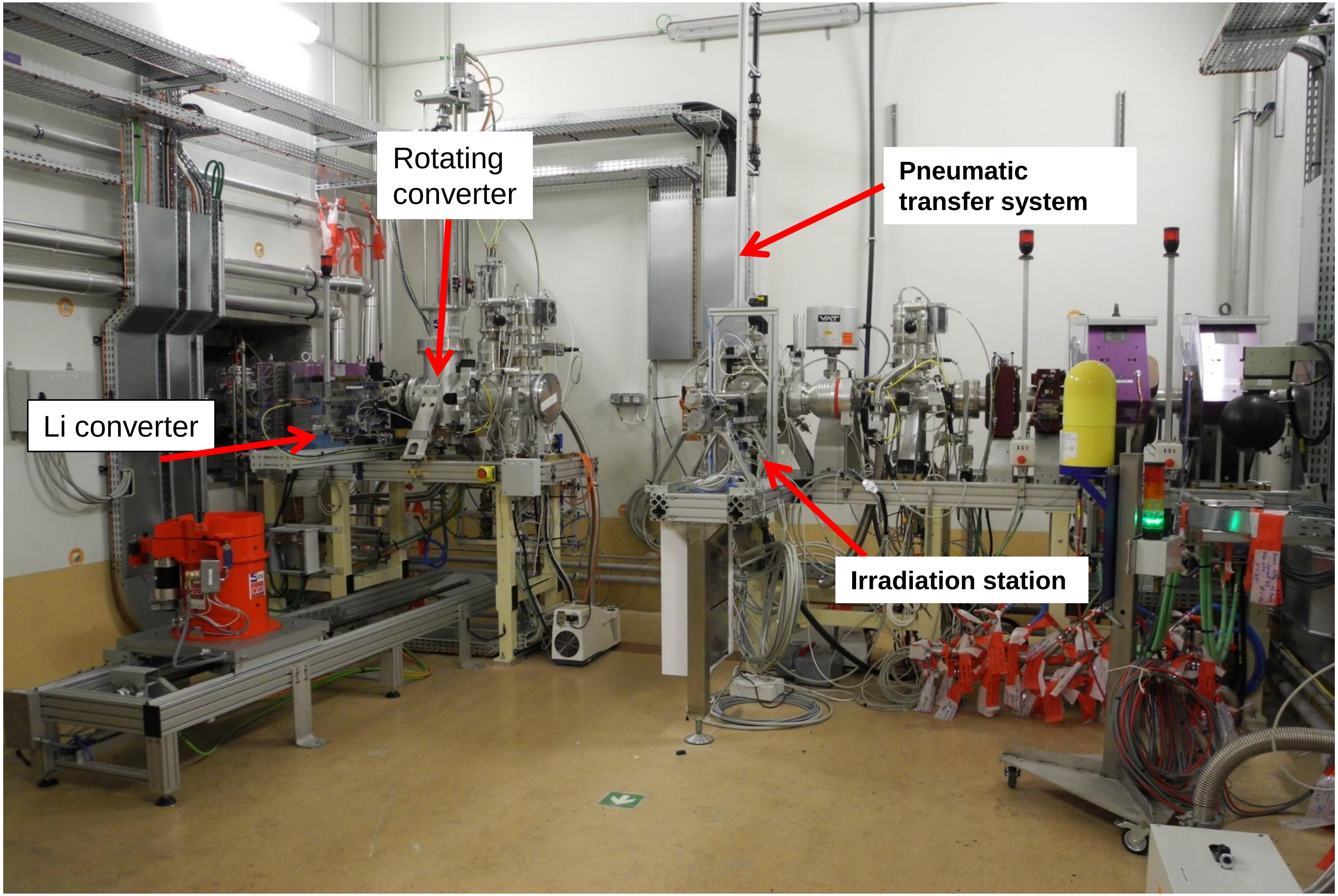
NFS layout



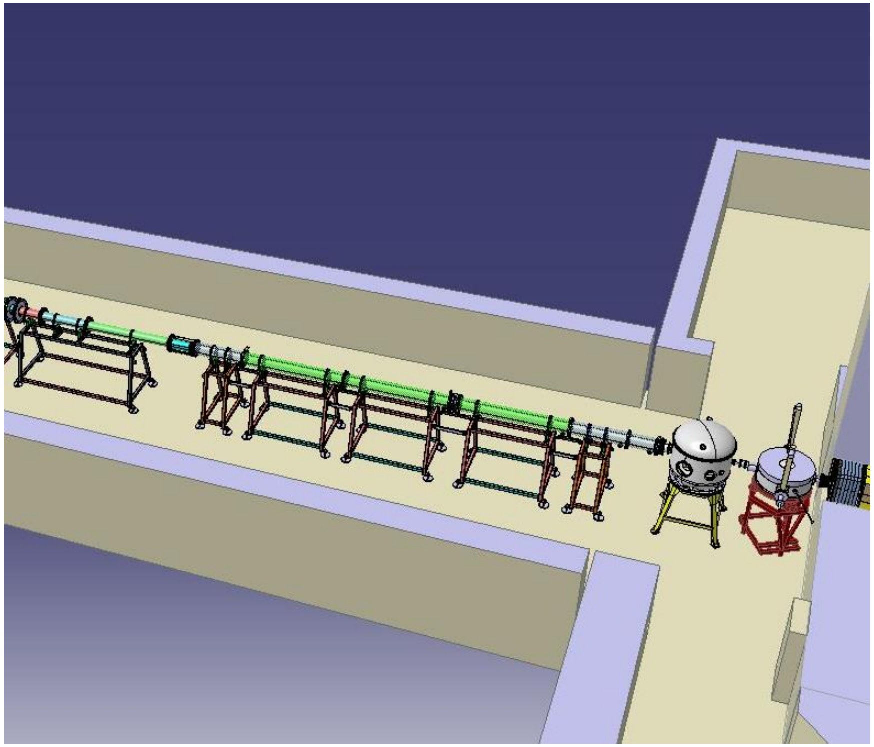
- Beam at 0°
- Collimator ↔ beam quality
- Size (L x l) ≃ (28m x 6m)
  - TOF measurements
  - free flight path

- Beam line extension
- Converter
- Magnet and beam dump
- Irradiation station (n, p, d)

NFS: The converter room

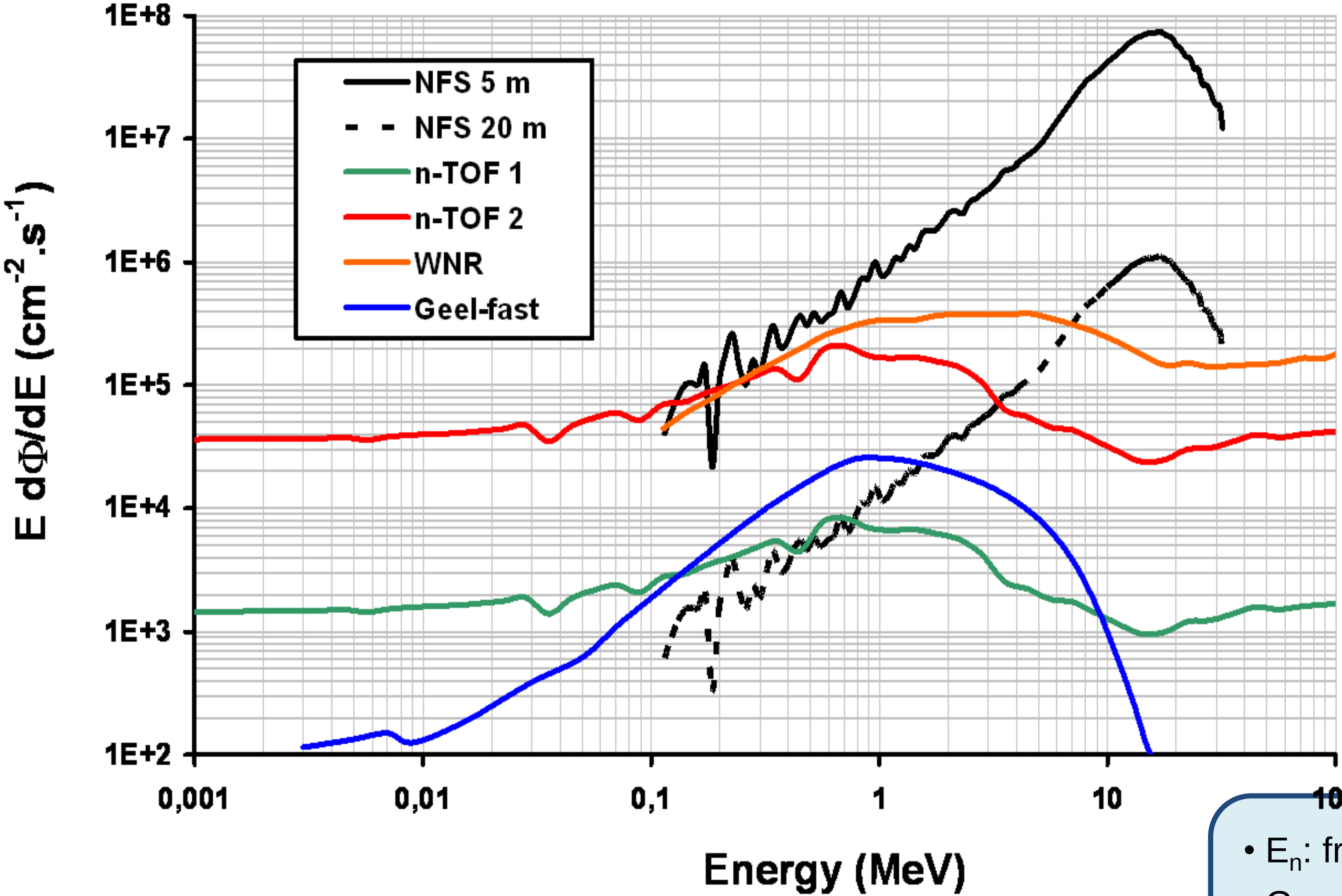


The TOF area



Installation of several experimental set-ups
Along the beam line

Comparison with other Neutron TOF facilities



NFS : 40 MeV d + Be

WNR : Los Alamos

n-TOF 2 : CERN

n-TOF 1 : CERN

GELINA : Geel

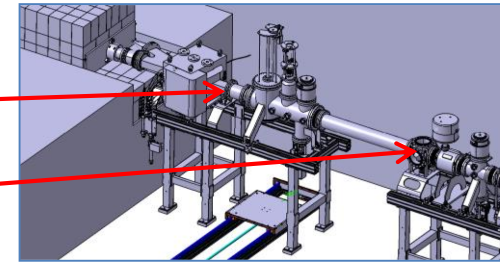
- E_n: from 0,1 MeV to 40 MeV
- Good energy resolution
- Reduced γ flash
- Low instantaneous flux

Complementary to the existing facilities

Measurement by activation technique

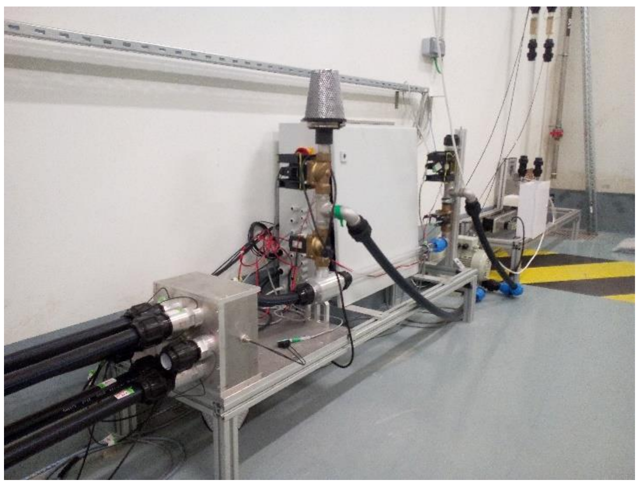
1- Irradiation of a sample in the converter room :

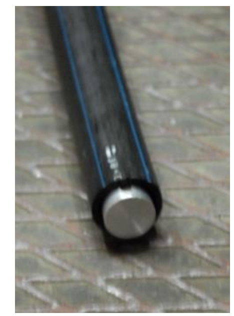
- with neutrons (in air)
- with ions (in the irradiation station)



2- Transfer of the sample to the TOF room for activity measurement

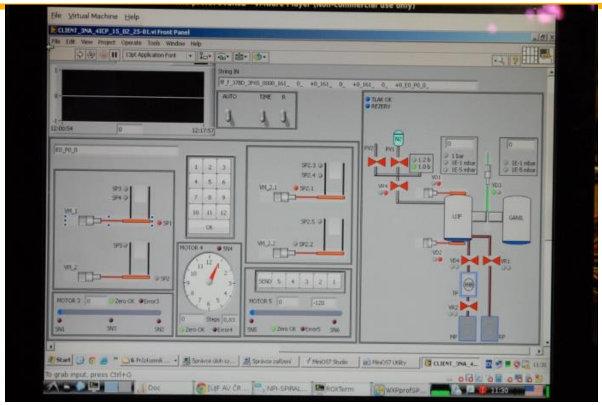
Pneumatic transfer system

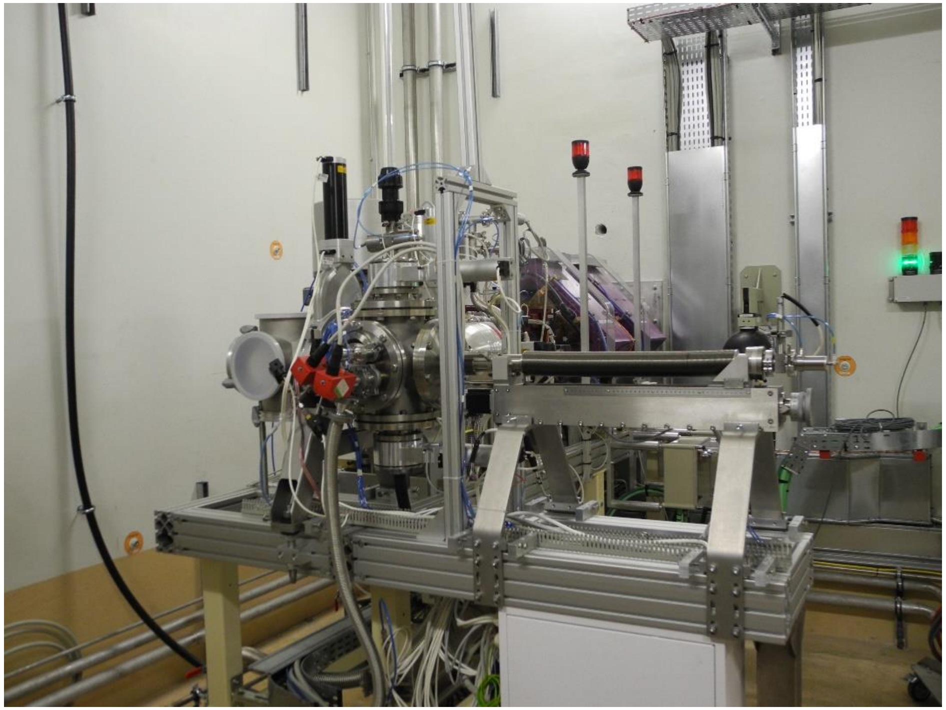




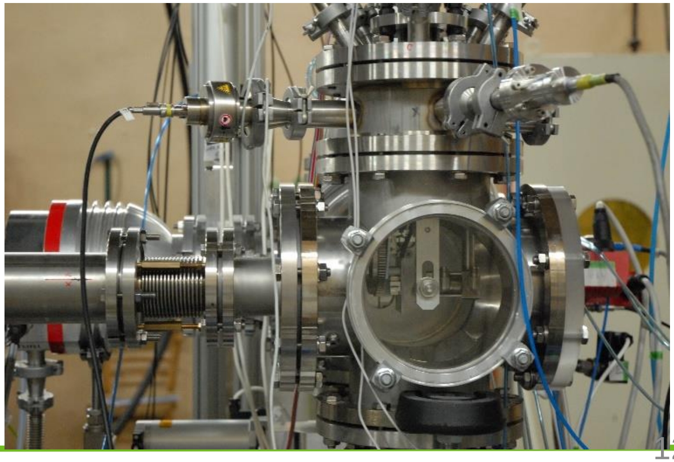
- System connected to the irradiation station.
- Sample removal time of irradiation station ≈ 40s
- Sample transfer time < 5 s

The irradiation station





NPI Řež



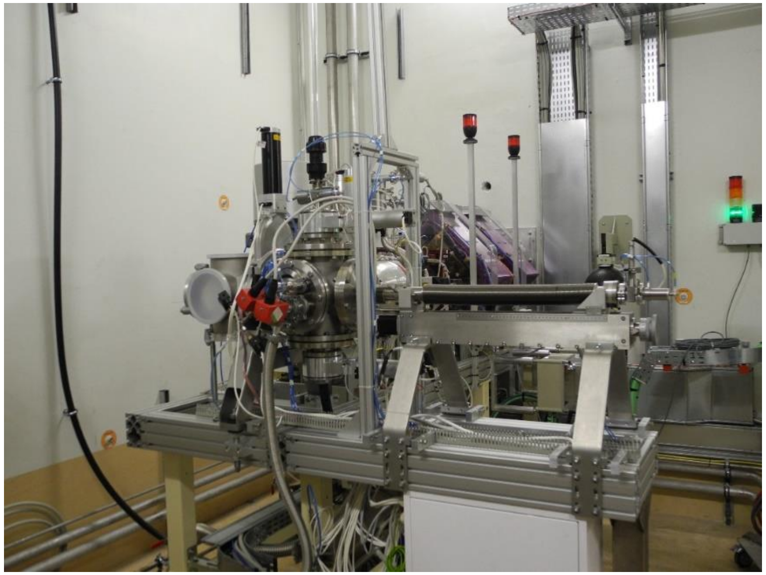
- For irradiation of samples only by ions
- Vacuum chamber + lock for vacuum samples
- Connection to the sample transfer system
- Integration with the NFS process

E714: Excitation functions of short-lived isotopes in proton-induced reactions on ^{nat}Fe

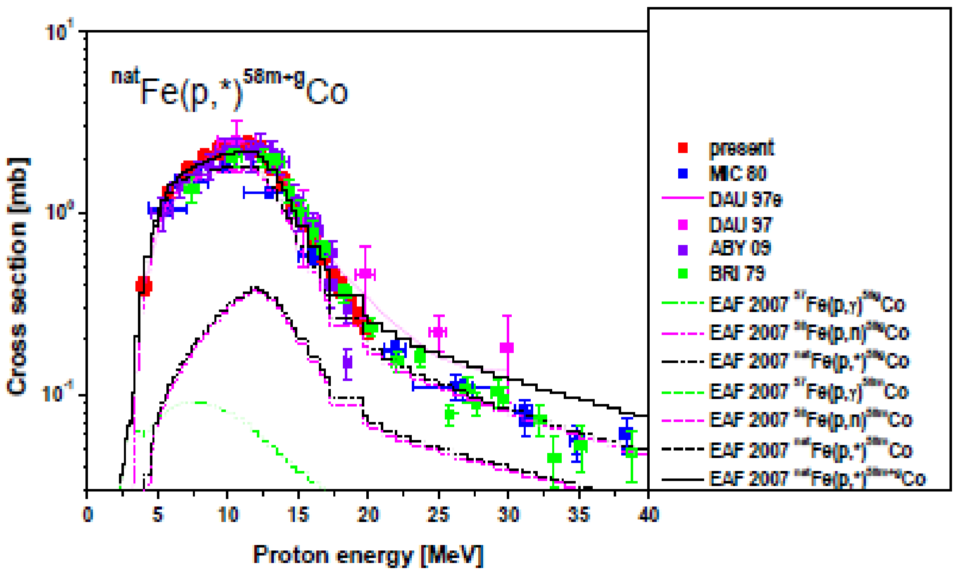
Spokesperson : E. Simeckova, NPI, Rez

Measurement of reaction cross-sections by activation technique :

- data for IFMIF facility design
- improvement of reaction model
- Irradiation station + pneumatic transfer system
- proton at 33 and 25 MeV



Goal: measure the ^{58m}Co and ^{58g}Co alimentation

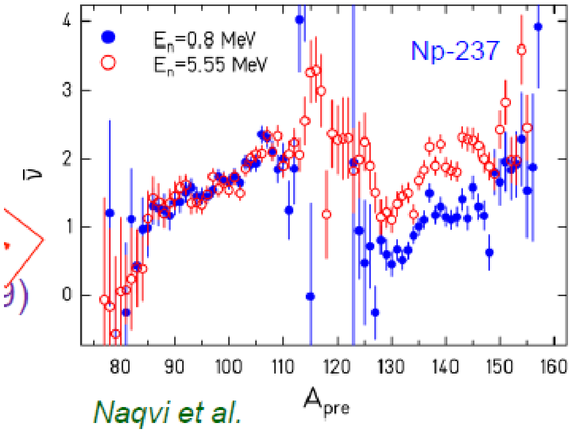


Other short-lived isotopes measured:

- ^{53m}Fe (2.58)
- ^{53}Fe (8.51)
- ^{54m}Co (1.48 min)
- ^{50m}Mn (1.75 min)
- ^{52m}Fe (45.9 s)

Neutron induced fission

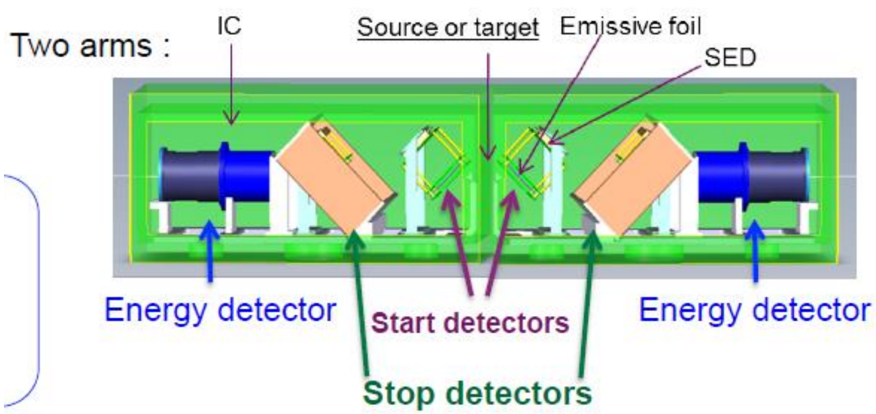
- Need of data for fast neutron essentially for minor actinides **(ADS, GEN IV reactors)**
  - Cross-section measurements
  - Neutron, gamma multiplicity and spectra
  - Fragment yields -> residual heat in the reactors



- Study of the fission process
  - fission fragment mass and charge distributions
  - ff kinetic energy (deformation energy, scission conf)
  - neutron multiplicity (deformation energy)
  - Need of data below the 2nd chance fission and beyond

Maximal activity
1 GBq for thin sample
10 GBq for thick target

- Experimental set-ups
  - Fission chambers, active targets
  - MEDLEY, FALSTAFF



- Advantage of NFS
  - High flux
  - Energy resolution
  - Use of actinide samples

PAC 2016

- 10 experiences submitted to the PAC of 9th and 10th of June 2016 -> 7 accepted
- For the first call :
  - no deuterons beam
  - no burst selector → limitation on realizable experiments

	NUM	Title	Spokesperson
Reaction model	E712	Measurement of (n,xn) reaction cross sections on U238	G. Bélier, CEA-DAM
	E721	LIONS - Light-Ion Production Studies with Medley at the NFS facility	A.V. Prokofiev, Uppsala University
Fission	E713	Prompt fission neutron spectra measurement in neutron induced fission reactions	B. Laurent, CEA-DAM
Fusion		Excitation functions of short-lived isotopes in proton induced reactions on ^{nat}Fe	E. Simeckova, NPI, Rez
Radionuclei for medical applications	E717	Measurements of the excitation function for the production of possible candidates for targeted alpha therapy at SPIRAL2	G. de France, Ganil
Astrophysic	E719	Precise direct measurements of the $^{28}Si(p,\gamma)^{29}P$ and $^{29}Si(p,\gamma)^{30}P$ reaction rates to understand the origin of presolar nova grains	B. Bastin, Ganil
Instrumentation	E720	Measurement of the absolute neutron detection efficiency of FAZIA telescopes	E. Bonnet, Ganil

Summary

- NFS will be a very powerful tool for applied and fundamental physics
- Main characteristics
  - 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
  - Measurements by activation reactions (n, p, d)
- The commissioning will start as soon as the LINAC will deliver beam
- Very fruitful collaboration with the NPI Rez for many years:
  - The irradiation station
  - The pneumatic transfer system
  - The study of high power target for ^{211}At production

Fruitful collaboration