Nuclear Physics Institute of the Czech Academy of Sciences
public research institution

The proton and deuteron activation at NPI CAS and SPIRAL2/NFS

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EVROPSKÁ UNIE
Evropské strukturální a investiční fondy
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MINISTERSTVO ŠKOLSTVÍ, MLÁDEŽE A TĚLOVÝCHOVY

GANIL spiral2.cz
Czech Republic contribution to SPIRAL2

Center of Accelerators and Nuclear Analytical Methods (CANAM)

Activation measurements

EXFOR –database of experimental cross section data

The activation experiments are important for both basic research and nuclear data measurement and validation.

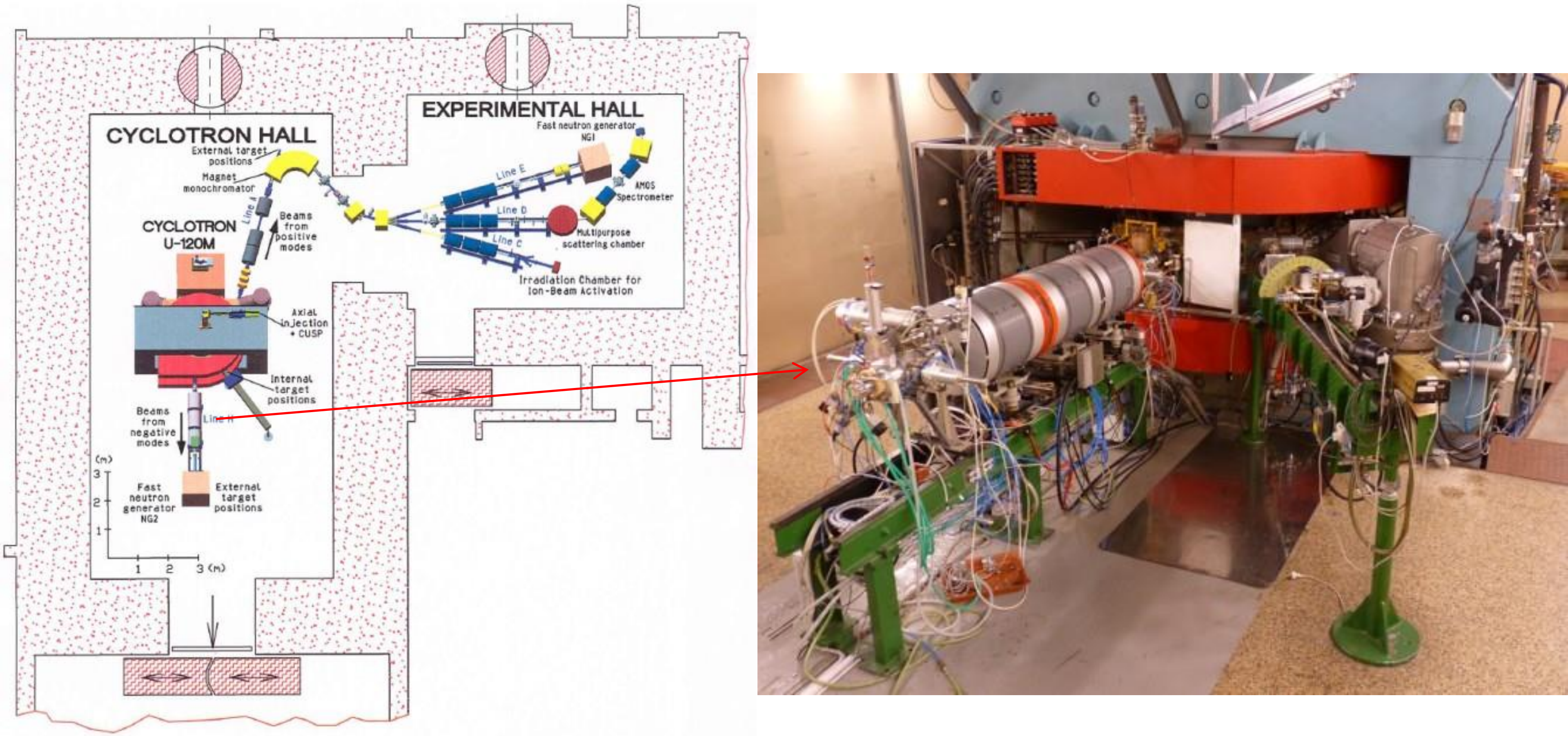
1. Evaluated data libraries (e.g. TENDL)

The future energy technology need quality activation data for different construction materials not only by neutron (ITER) but also by deuteron (IFMIF like devices) and proton for careful planning the construction, life cycle and decommission phases. The accurate knowledge of the proton activation cross section is critical for selecting the best structural materials and a number of key technologies.

2. Studies of excitation functions of charged particle-reactions are of considerable significance for testing nuclear models. The advance in the theory is important for cases that are not reachable experimentally and for better understanding the underlying physics.

3. The studies of activation by alpha particles and protons are important also for future development of medical radioisotopes.

NPI variable energy cyclotron U120M



FNG
NPI variable energy cyclotron U120M

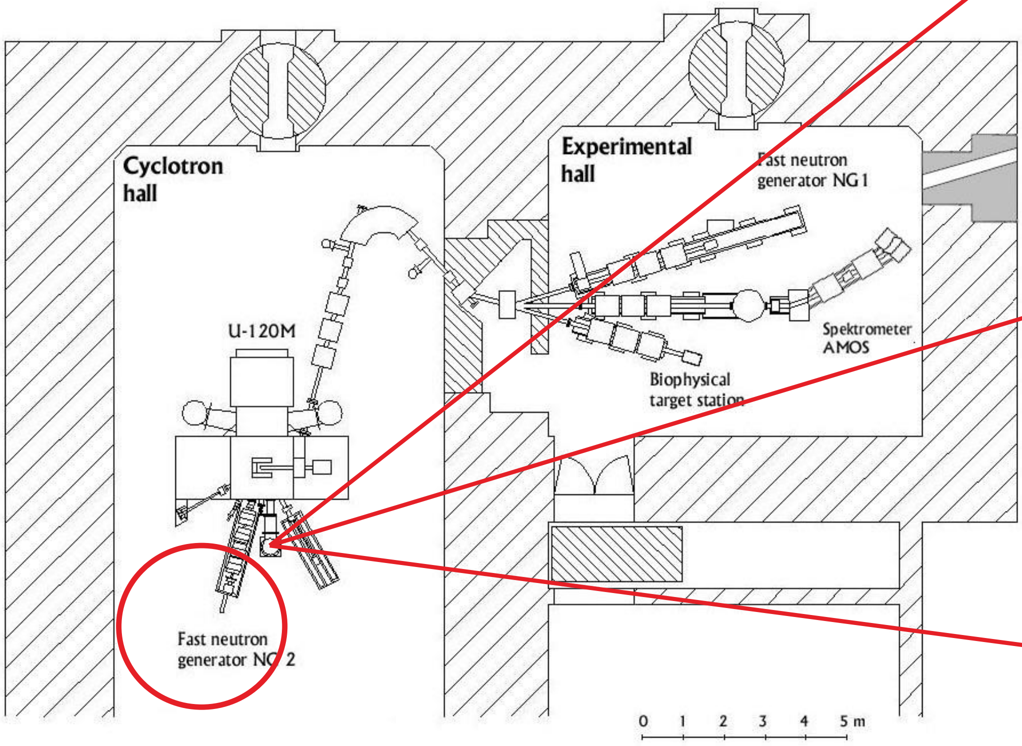
Negative ion mode: stripping foil

H^-/H^+ 6-36 MeV, up to 20μA

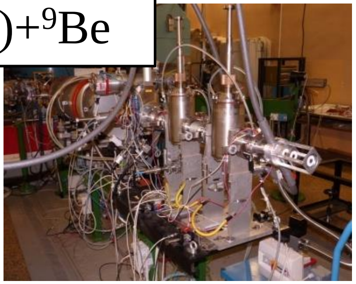
D^-/D^+ 11-20 MeV, up to 10μA

Energy uncertainty 1 %

Energy spread 1.8 %



p(18-35 MeV)+^{9}Be



Broad neutron spectrum

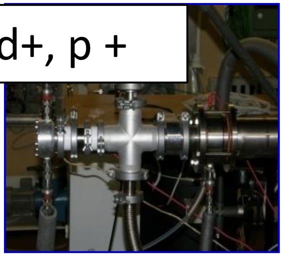
Neutron flux density up to 5×10^{11} $ncm^{-2}s^{-1}$ at the distance of 15 mm

p(6-37MeV) + ^{7}Li

Neutron flux density in the QME peak:

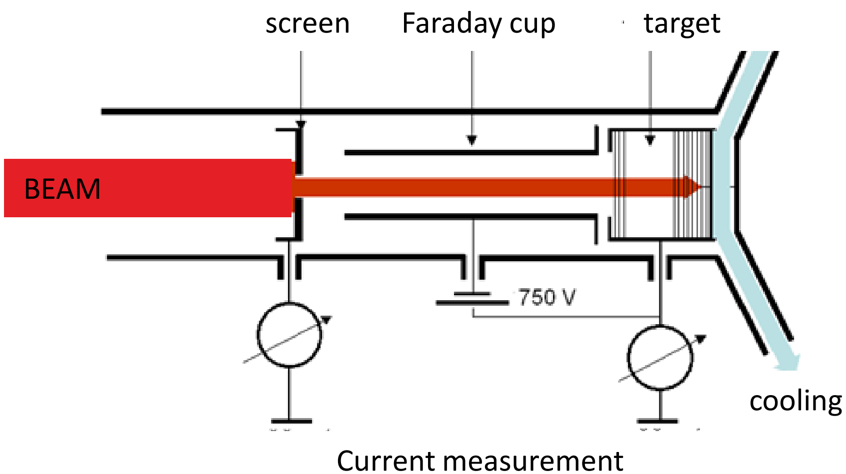
10^9 $ncm^{-2}s^{-1}$ for 8μA (p) at the distance 48 mm

d+, p +



~ 0.4 μA

Charged particle chamber



- Faraday cup
- Full beam stop

During an irradiation, the beam current was recorded with the uncertainty of 5 % in a PC keeping time synchronization with the γ-ray spectrometry device.
Energy attenuation, target density - **SRIM**

Stacked-foil technique p + Fe, Cu

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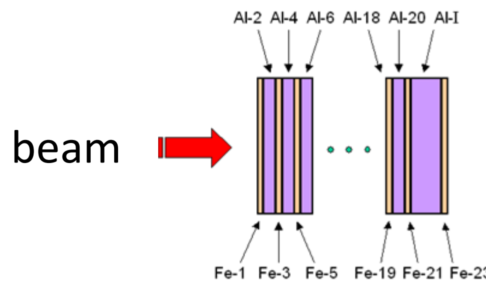
The Fe foils are interleaved by Cu foils serving as additional monitors and appropriate reduction of proton energy, as well.



Gamma-ray spectrometry

The gamma-rays from the irradiated foils were measured repeatedly by two calibrated HPGe detectors of 50 % efficiency and of FWHM 1.8 keV at 1.3 MeV.

Experimental reaction rates were calculated from the specific activities at the end of irradiation corrected to decay during irradiation using total charge and foil characteristics as well.

Activated isotopes were identified on the basis of $T_{1/2}$, γ-ray energies and intensities.

Decay data from: http://nucleardata.nuclear.lu.se/nucleardata/toi/

Natural Fe

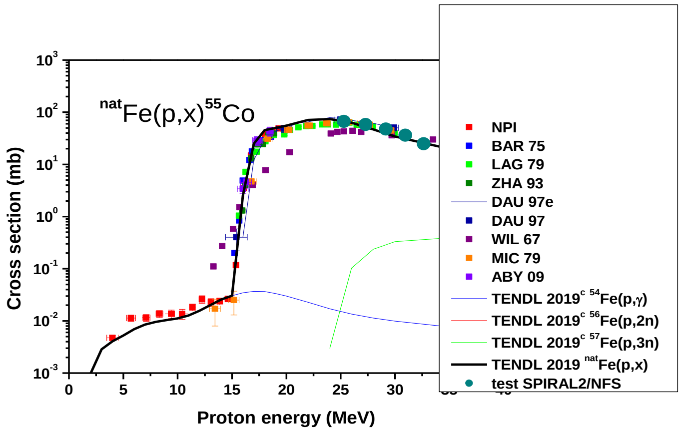
But deuteron energy is limited by 20 MeV. This fact is the main reason we want to continue our research at FNS/SPIRAL2 Ganil. Another advantage is the possibility of use pneumatic transfer system for investigation cross sections of isotopes with relatively short lives.

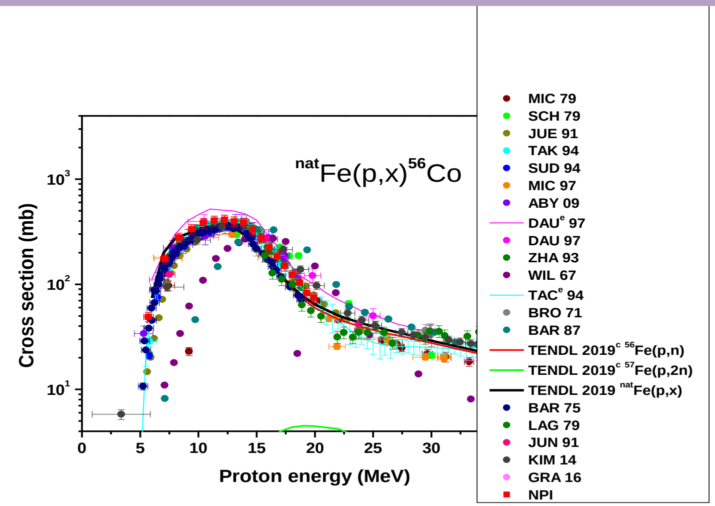
The device is currently being put into service, but unfortunately a deuteron beam current is delayed and only protons are available now. So we decided as the first experiment carry out the proton beam activation of natural iron as the continuation of experiments performed at NPI.

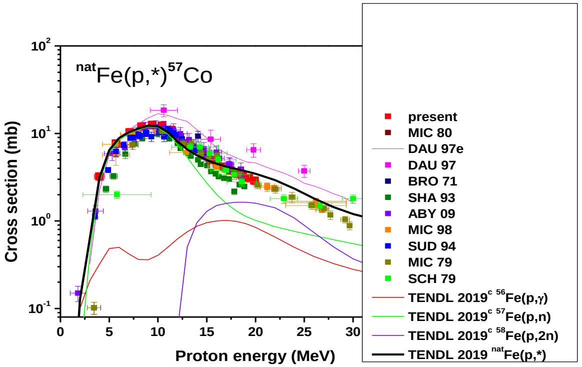
$p + {}^{nat}Fe$

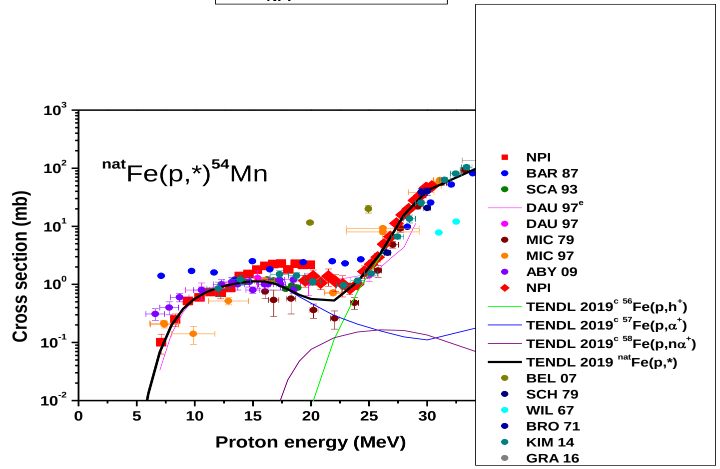
Isotope	Natural abundance (%)
^{54}Fe	5.845
^{56}Fe	91.754
^{57}Fe	2.229
^{58}Fe	0.282

$^{nat}Fe(p,x)^{55}Co$, ^{56}Co, ^{57}Co and ^{54}Mn

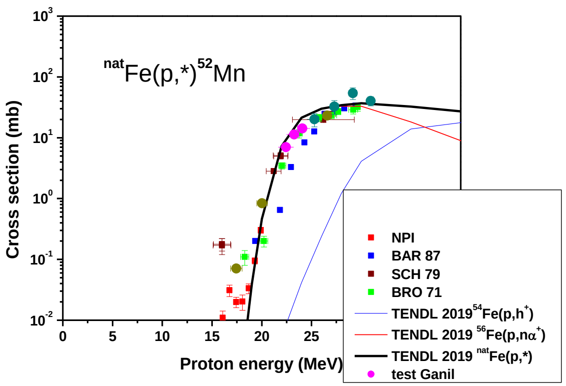


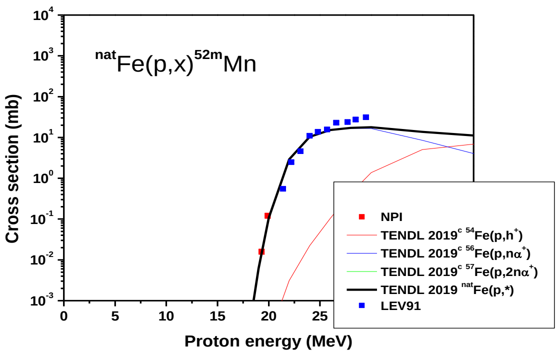


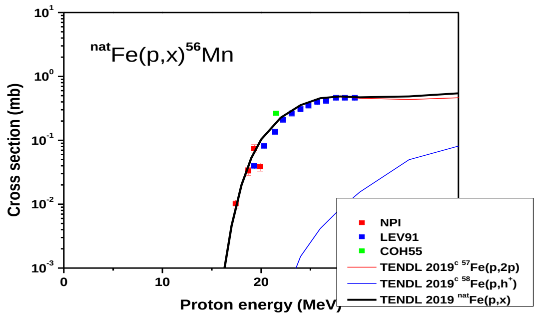


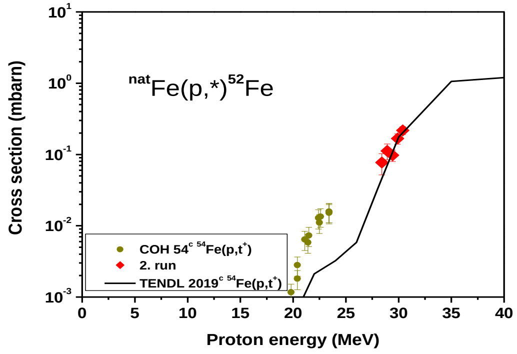


$^{nat}Fe(p,x)^{52}Mn, ^{52m}Mn, ^{56}Mn, ^{52}Fe$

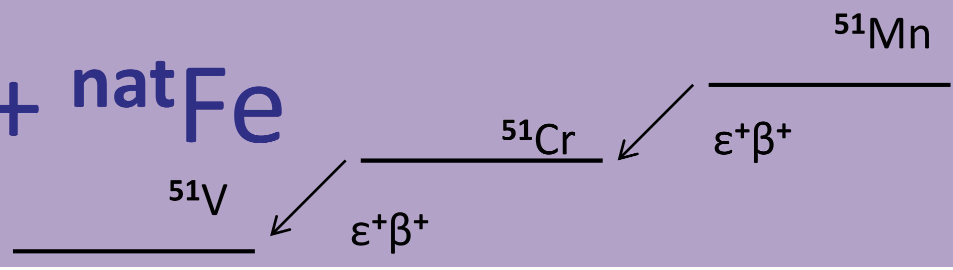








$p + {}^{nat}Fe$



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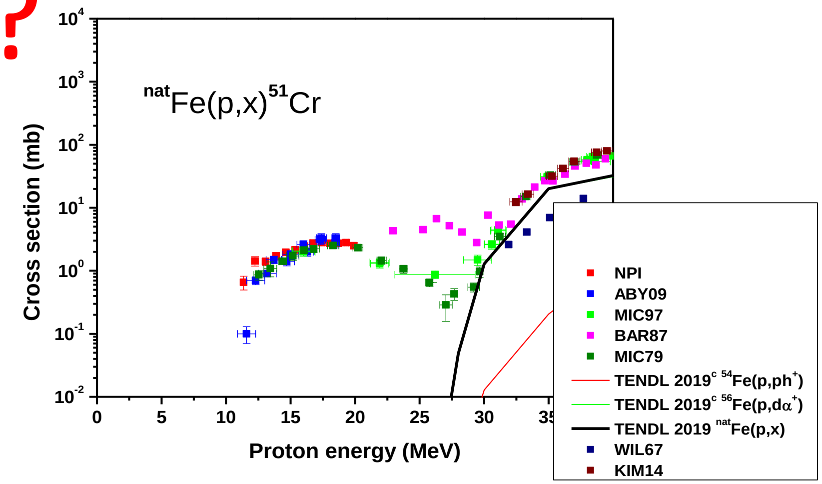
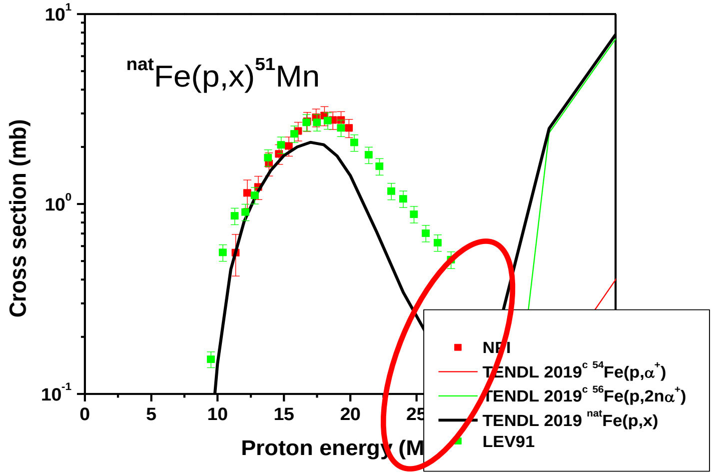




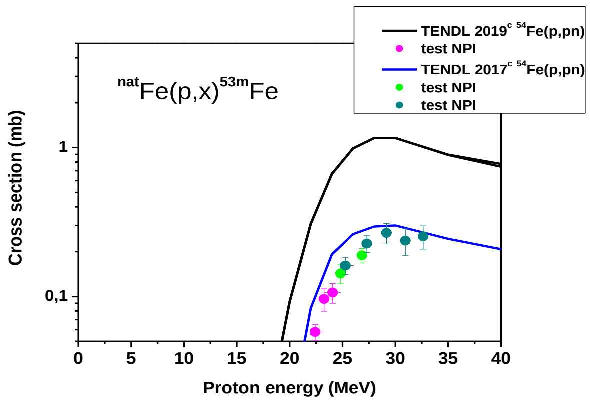
Isotope	$T_{1/2}$	E_γ (keV)	I_γ (%)
^{51}Mn	46.2 m	749.1	0.26
		1148.0	0.078
^{51}Cr	27.7025 d	320.1	10

$$A_{g(Cr)} = \frac{\lambda_{g(Cr)}}{\lambda_{g(Cr)} - \lambda_{m(Mn)}} A^0_{m(Mn)}\left(e^{-\lambda_{m(Mn)}t} - e^{-\lambda_{g(Cr)}t}\right) + A^0_{g(Cr)} e^{-\lambda_{g(Cr)}t}$$

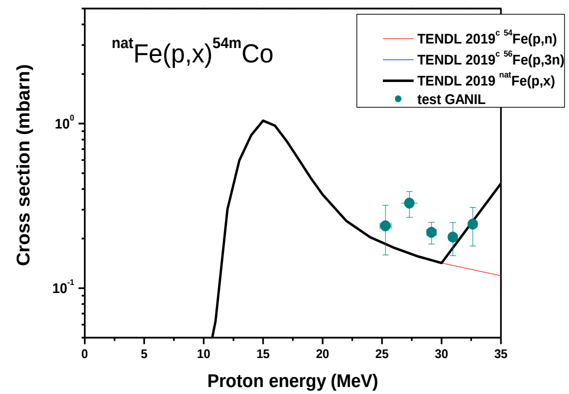
We use similar procedure to determine cross sections of the ${}^{nat}Fe(p,x){}^{58m}Co$ reaction.

$^{nat}Fe(p,x)^{53m}Fe, ^{52}Fe, ^{60m}Co, ^{51m}Mn$

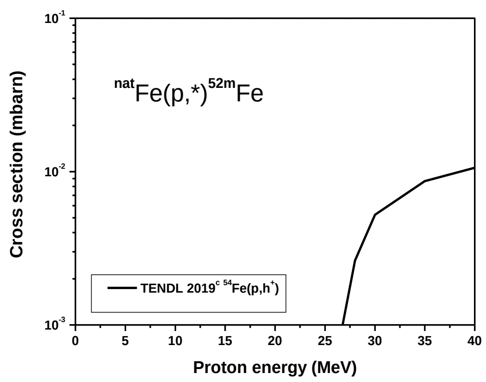
$T_{1/2}$ = 2.58 min



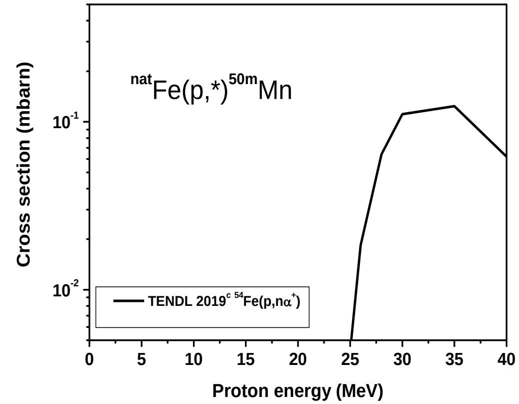
$T_{1/2}$ = 1.48 min



$T_{1/2}$ = 45.9 s



$T_{1/2}$ = 1.75 min



First experiment

PROPOSAL FOR AN EXPERIMENT

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

Spokesperson: Eva Simeckova
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GANIL Scientific Coordinator: X.Ledoux

Collaboration : Participant names, institutions, and indicate students (S), and post-doctoral fellows (PDF):

NPI CAS: M.Stefanik (PDF), J.Mrazek, D.Thomas (S), O.Lebeda, M.Majerle, P.Alexa, G.Thiamova

GANIL: X.Ledoux, F.Oliveira, B.Bastin, J.Grinyer

KIT: U. Fischer, A. Klix

IFIN-HH: M.Avrigeanu, V.Avrigeanu

SPIRAL2-CZ

The system for irradiation by charged particles for NFS/SPIRAL2 was built within a program SPIRAL2-CZ that is a framework of a Czech participation in GANIL/SPIRAL2.

The irradiation chamber was developed, constructed and tested in NPI and installed in GANIL/SPIRAL2 - NFS

PTS - **Pneumatic Transfer System** - developed and built in **KIT Karlsruhe** - modified in NPI CAS transports the sample (with a mid-step) to the HPGe detector, where it is put into a desired position

GANIL/SPIRAL2- Linac

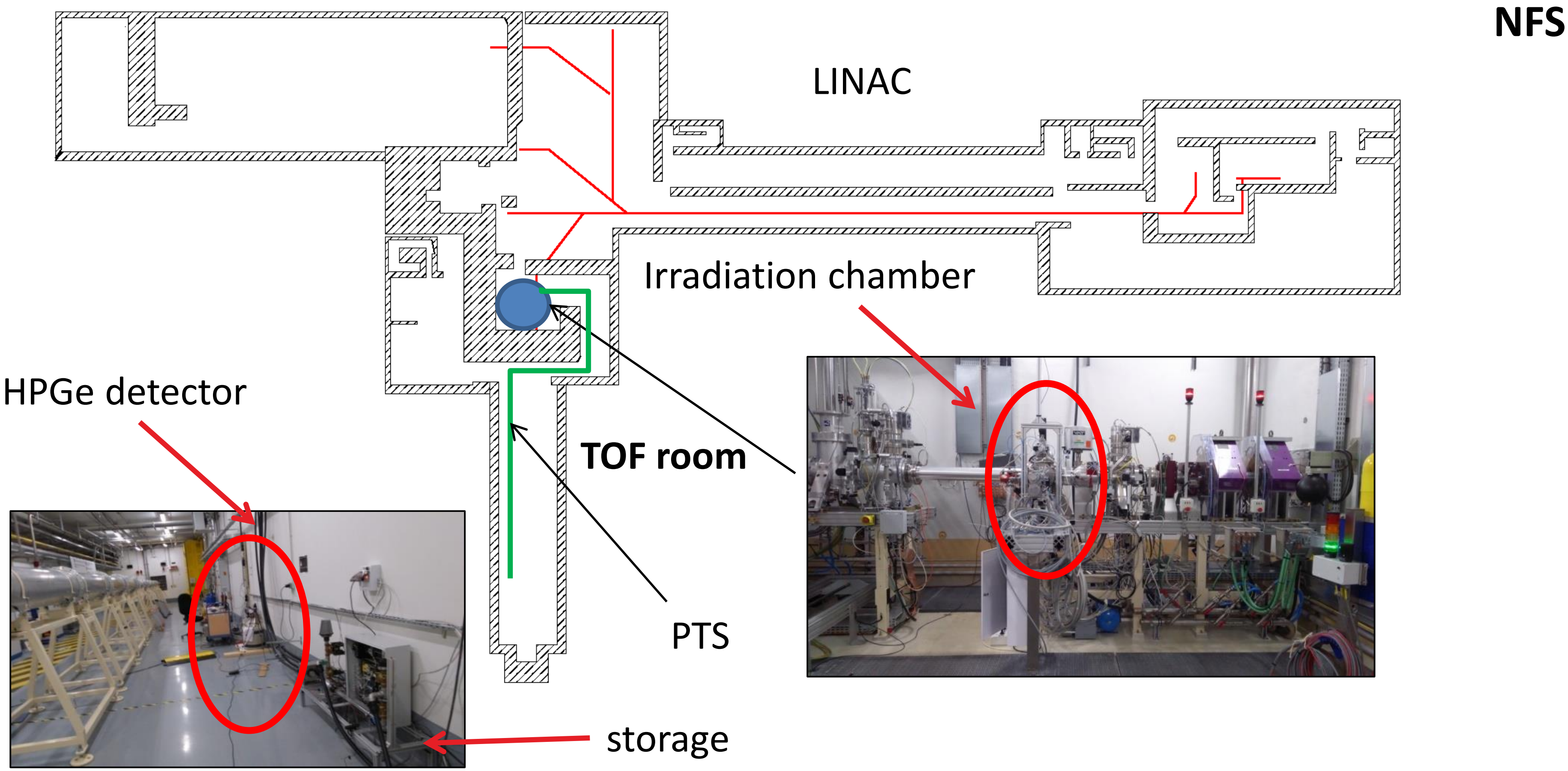
LINAC accelerator of GANIL/SPIRAL2

protons 0.75-33 MeV (50 µA)
deuterons 1.5-40 MeV (50 µA)

Charged particle activation

- stacked-foils technique
- **single foil technique**
- Faraday cup; reaction chamber cooled by glycoethylen
- **Pneumatic Transfer System**
- HPGe detectors – off line

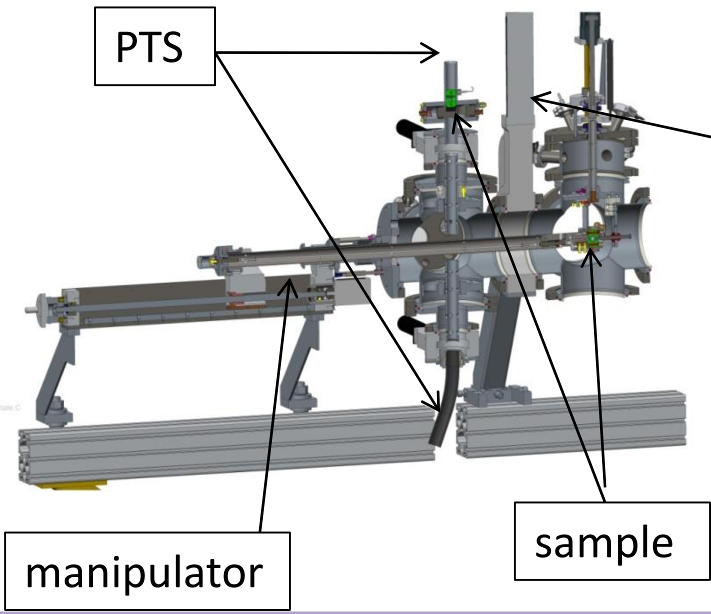
SPIRAL2/NFS

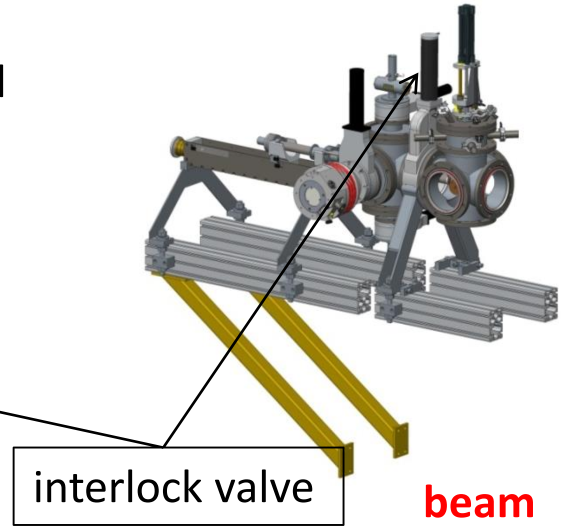

NFS
LINAC
Irradiation chamber
HPGe detector
TOF room
PTS
storage

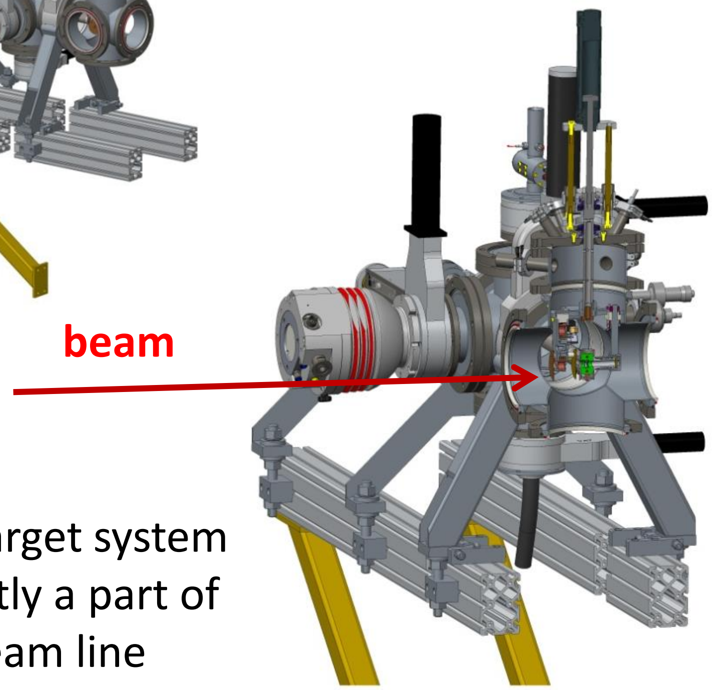
Irradiation chamber

The IC is an airlock system composed of two vacuum chambers separated by interlock valve.

1. Sample received/send system and manipulator that transfers a sample to/from the beam target system

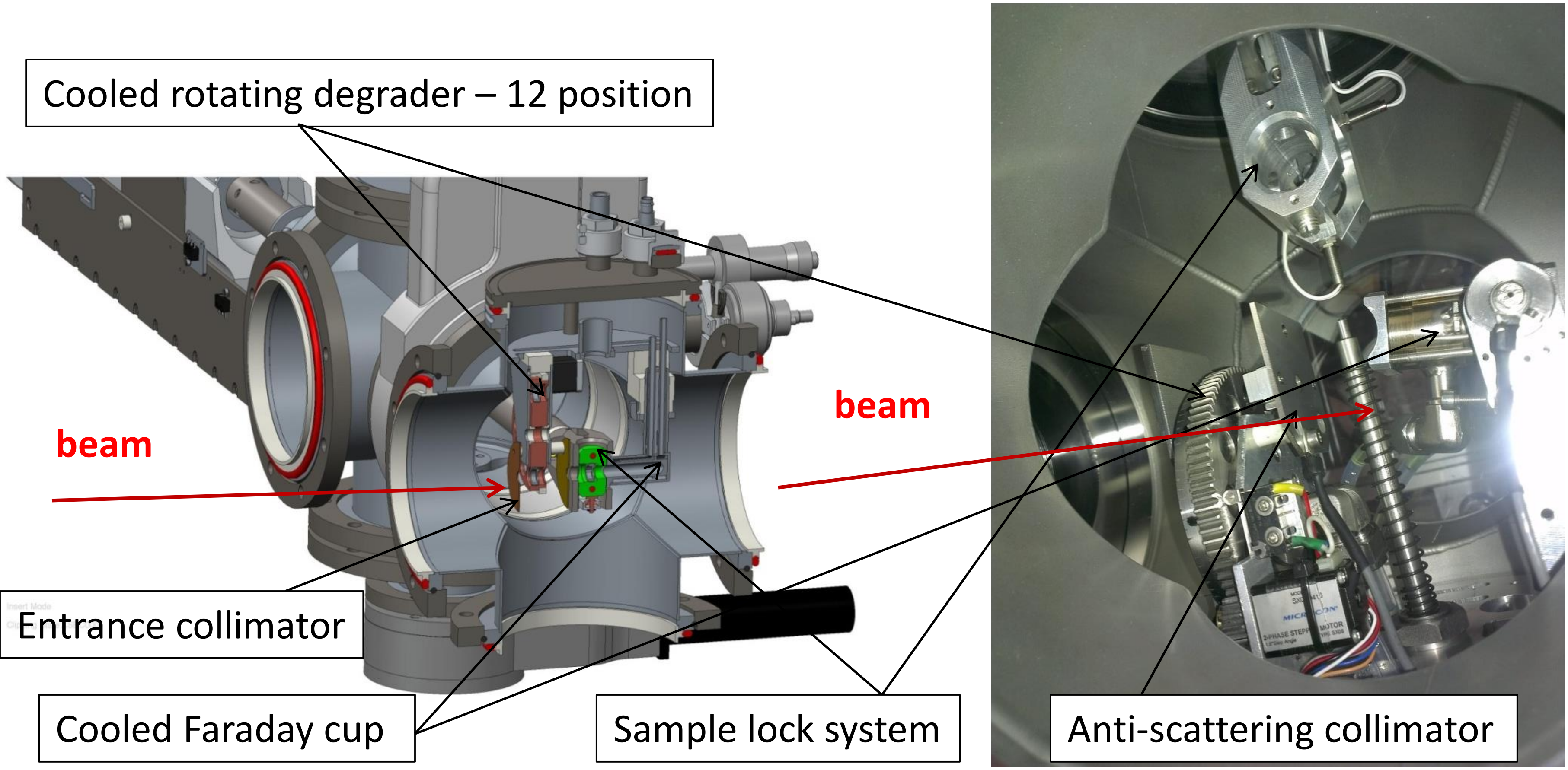






2. Beam-target system permanently a part of the NFS beam line

The beam-target system



Pneumatic transfer system

PTS enables to transfer the irradiated samples between IC, HPGe detector or sample storage

Distance IC- HPGe – 60 m
Delivering time – 42 s

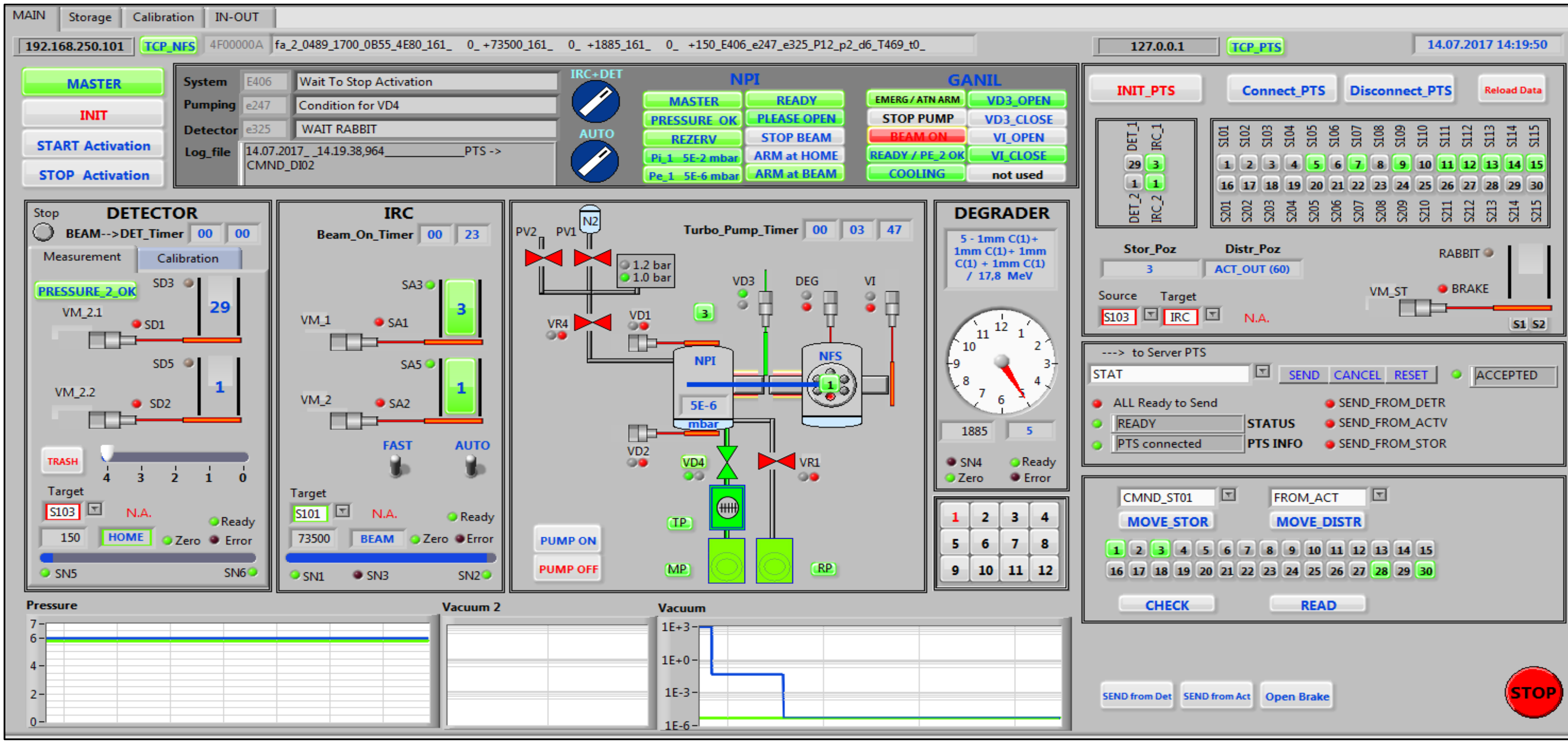
HPGe detector system – allows to put sample to the desired position

Rabbit with foil to be irradiated

The correct orientation is ensured by two magnets

Sample storage

The control system

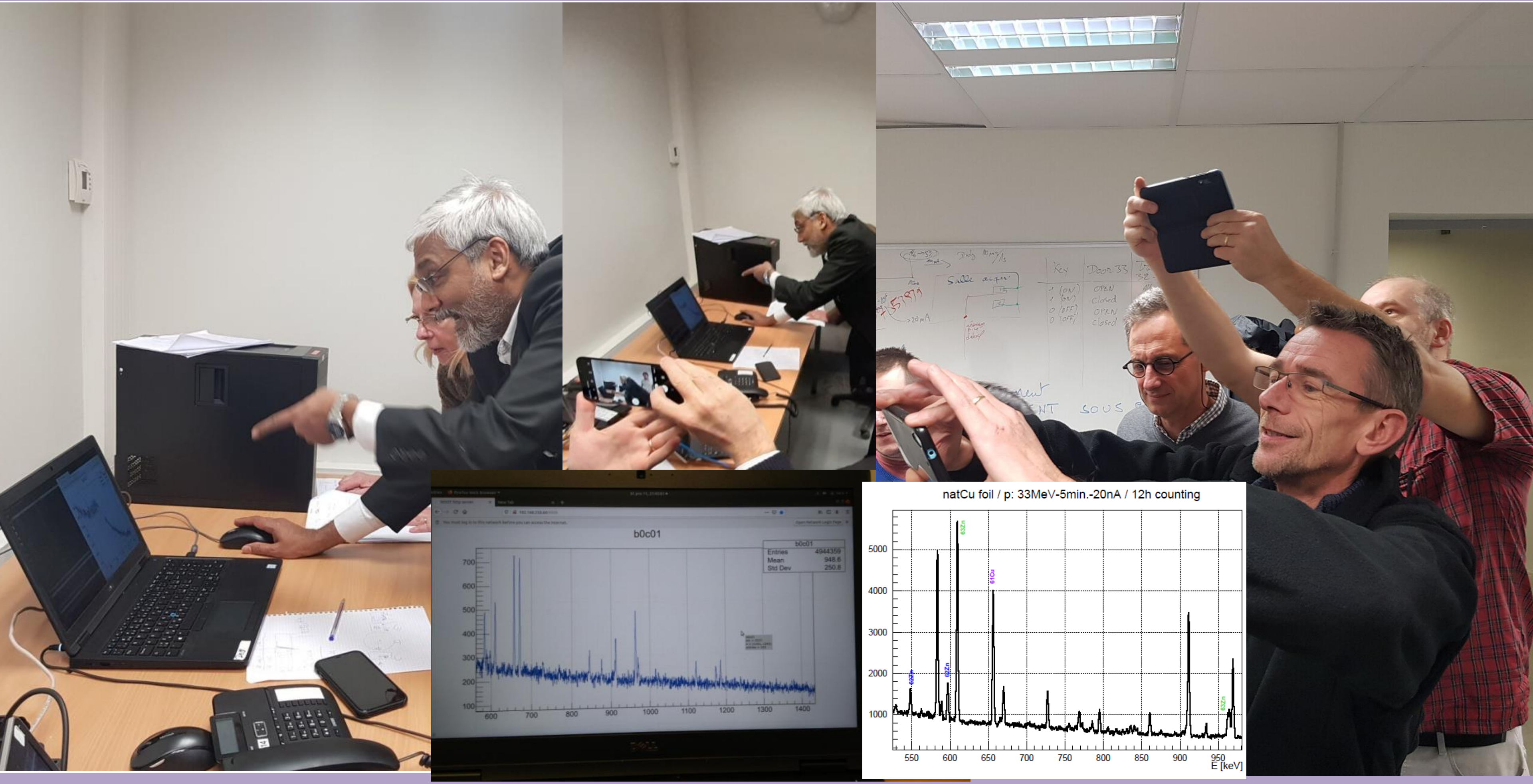


It is based on the IPC-DAS and Nanotec microprocessors with communication by RS486 and Ethernet. The control application is programmed in LabView.

Transport the IC from NPI to Ganil

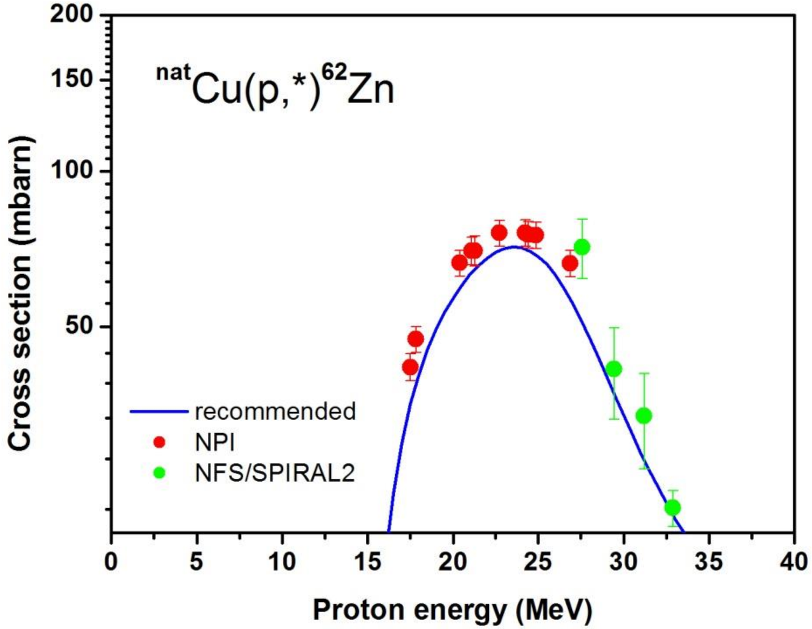
Installation IC at Ganil

Test experiment – the first spectrum

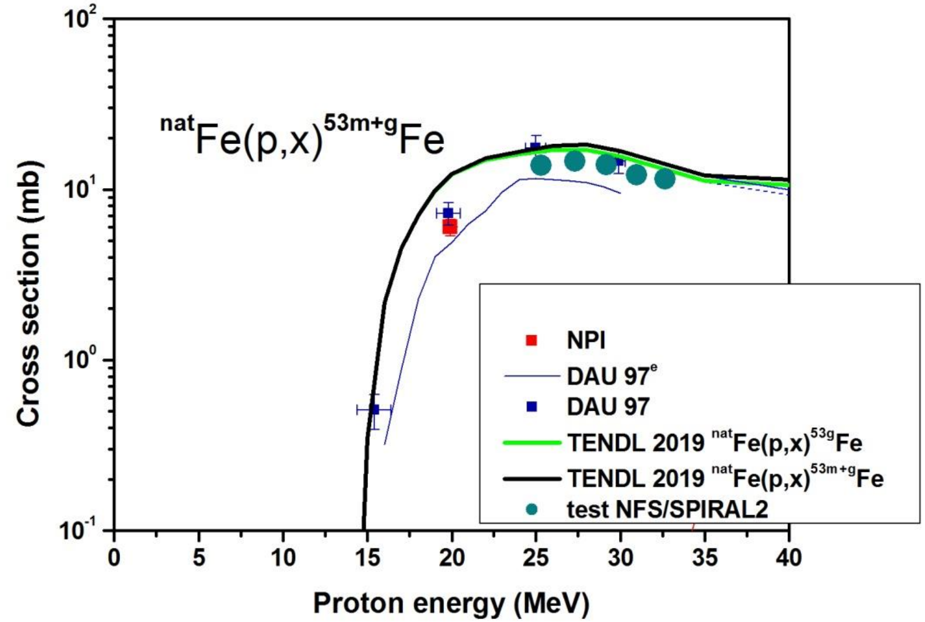


Conclusion

$T_{1/2}$ = 9.186 h



$T_{1/2}$ = 8.51 m



The results show satisfactory agreement with previous data and ability to study production cross sections of short-lived isotopes.

Thank you for your attention.

www.canam.ujf.cas.cz

www.spiral2.cz

First experiment