Decay properties of beta delayed neutron emitters

JYFL Accelerator Laboratory Proposal

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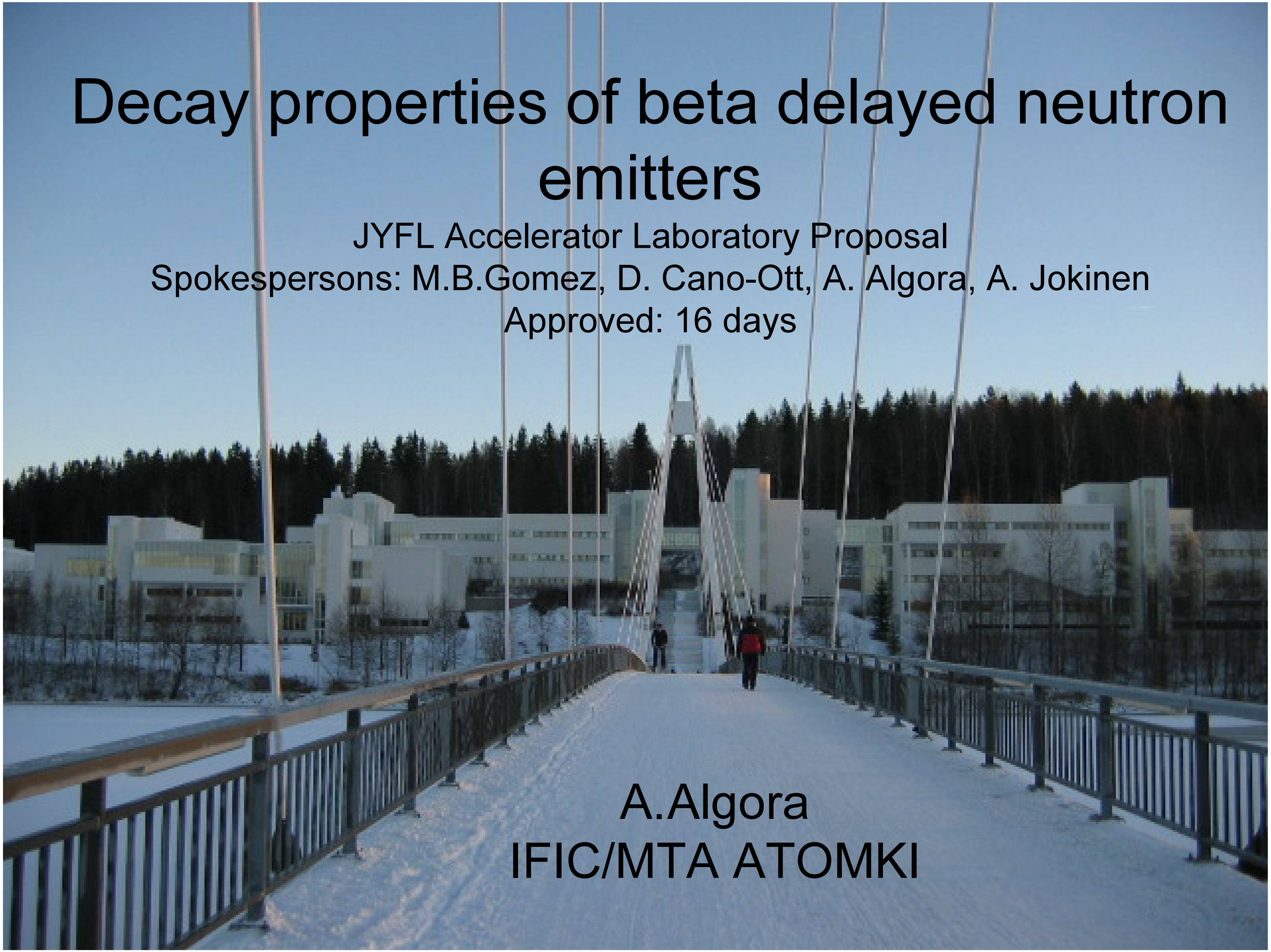
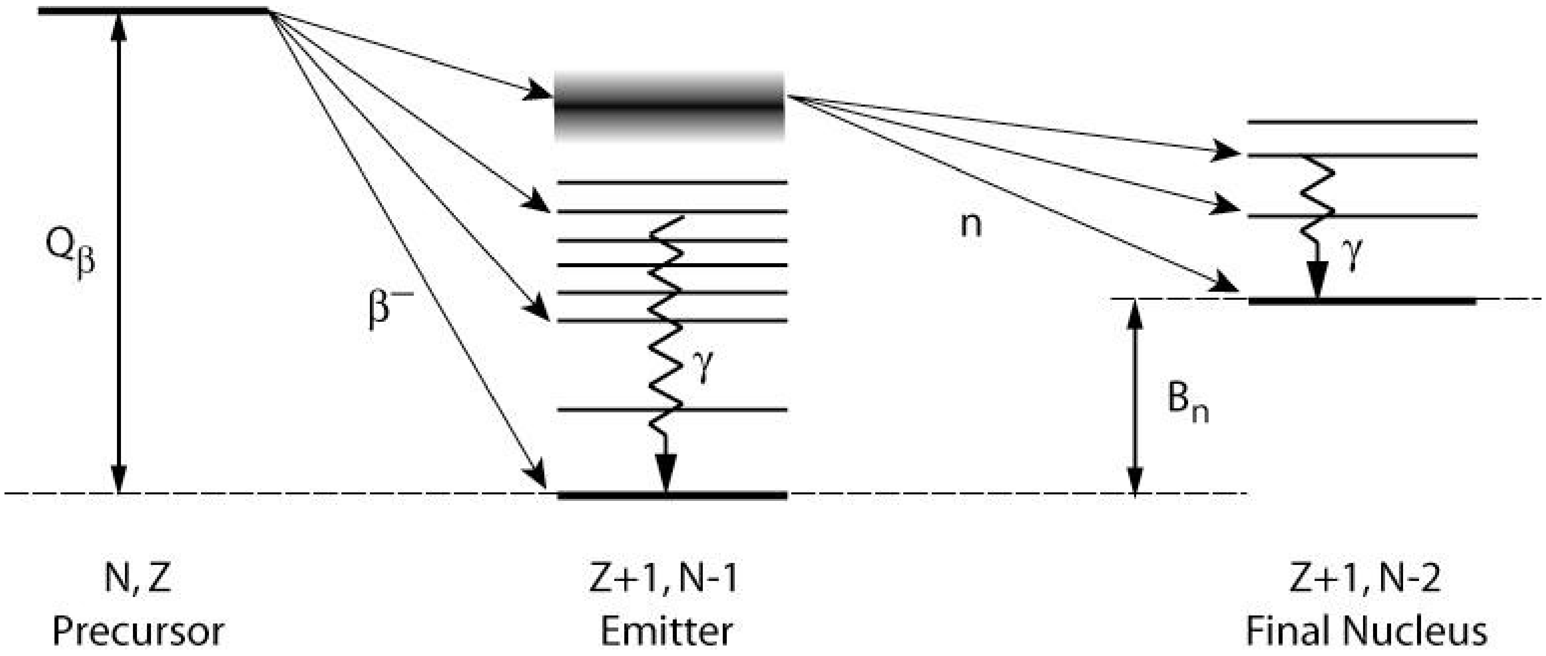
Approved: 16 days

A.Algora

IFIC/MTA ATOMKI



Study of the beta decay of ^{87}Br, ^{88}Br, ^{94}Rb, ^{95}Rb and ^{137}I

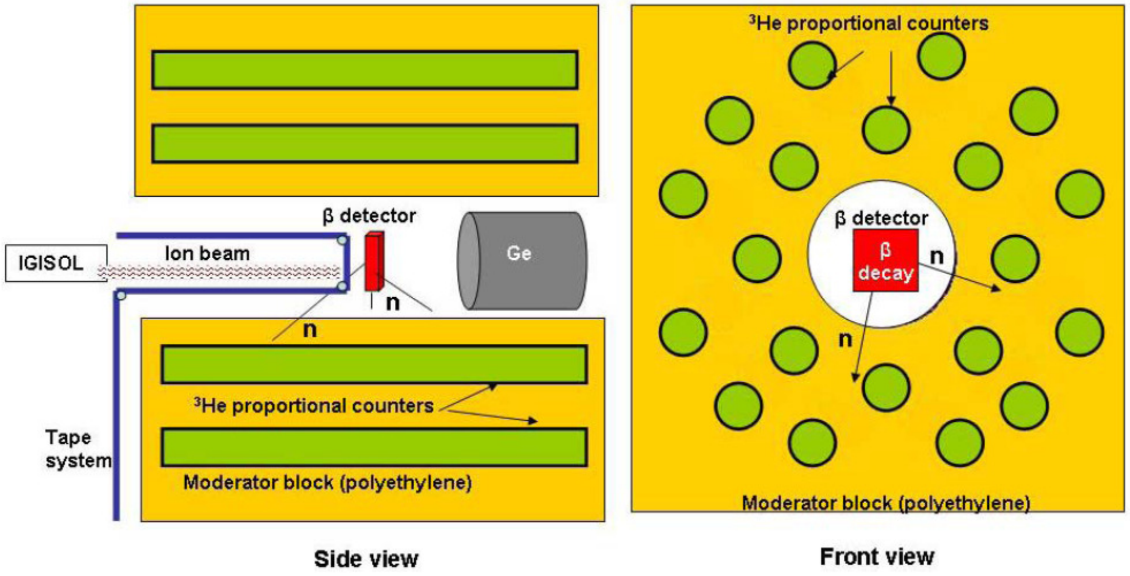


Proposed experimental techniques for the study:

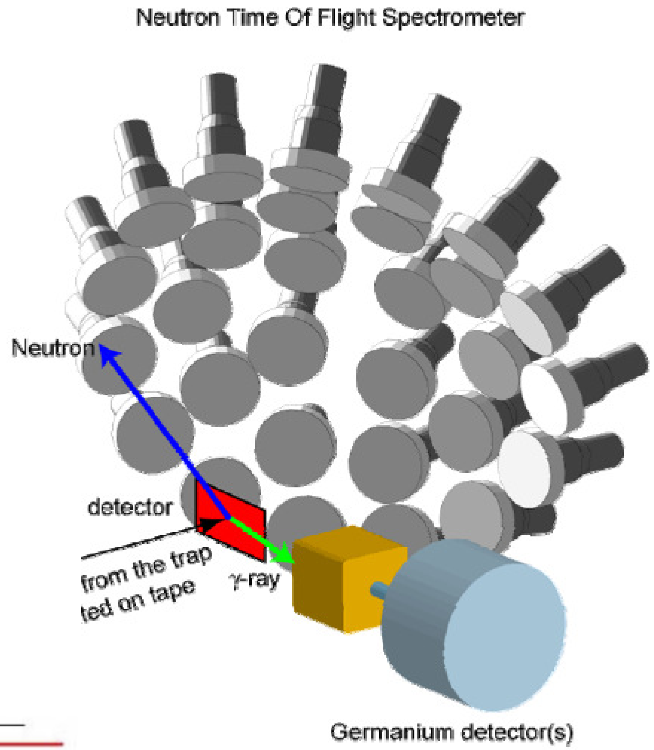
- •Total Absorption Spectrometer (TAS). β strength function measurement
- •4π neutron detector (4π). P_n measurement
- •Time of Flight neutron detector array (ToF). Neutron spectroscopy of β delayed neutrons

Study of ^{87}Br, ^{88}Br, ^{94}Rb, ^{95}Rb and ^{137}I with three techniques

Mini 4π

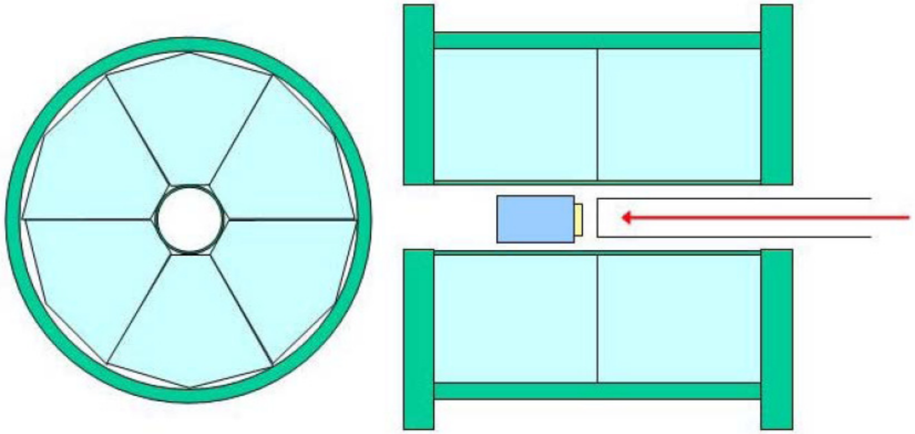


Mini TOF



Valencia-Surrey

TAS



General motivations: physics case

• Study different aspects of the decay of these nuclei and hence provide very complete information about their decay mechanism and structure, based on the **complementarity** of the proposed techniques.

• Some of the selected nuclei are rated priority “1” in our list of candidate for TAS measurements.

• Some of them are close to the path of the astrophysical r-process, the determination of the full beta strength could help to improve theoretical models used for the calculation of beta decay properties (region A~90)

• Development and testing instrumentation for the FAIR facility (DESPEC collaboration)

Some details of our cocktail of nuclei

^{87}Br, ^{88}Br and ^{137}I

Relevant for decay heat calculations in reactor technology (highest priority in the NEA/WPEC-25 list). Important contributors to the neutron emission in the 10-100 s delayed time range, for that reason they are also important from the point of view of reactor dinamics (reactivity coefficient)

^{87}Br have a rich level scheme, but there are still known inconsistencies (see NEA/WPEC-25 volume 25 comments). A comparison with TAS measurements is useful in any case (well known limitations of the high resolution techniques even using the best available Ge detectors).

^{87}Br, ^{94}Rb and ^{95}Rb.

They present low uncertainties in the previous Pn measurements and can be partially considered as "calibration" cases. TAS measurements can be relevant for these nuclei considering the large Q_β values . In any case the available information can be improved by means of the combined used of experimental techniques.

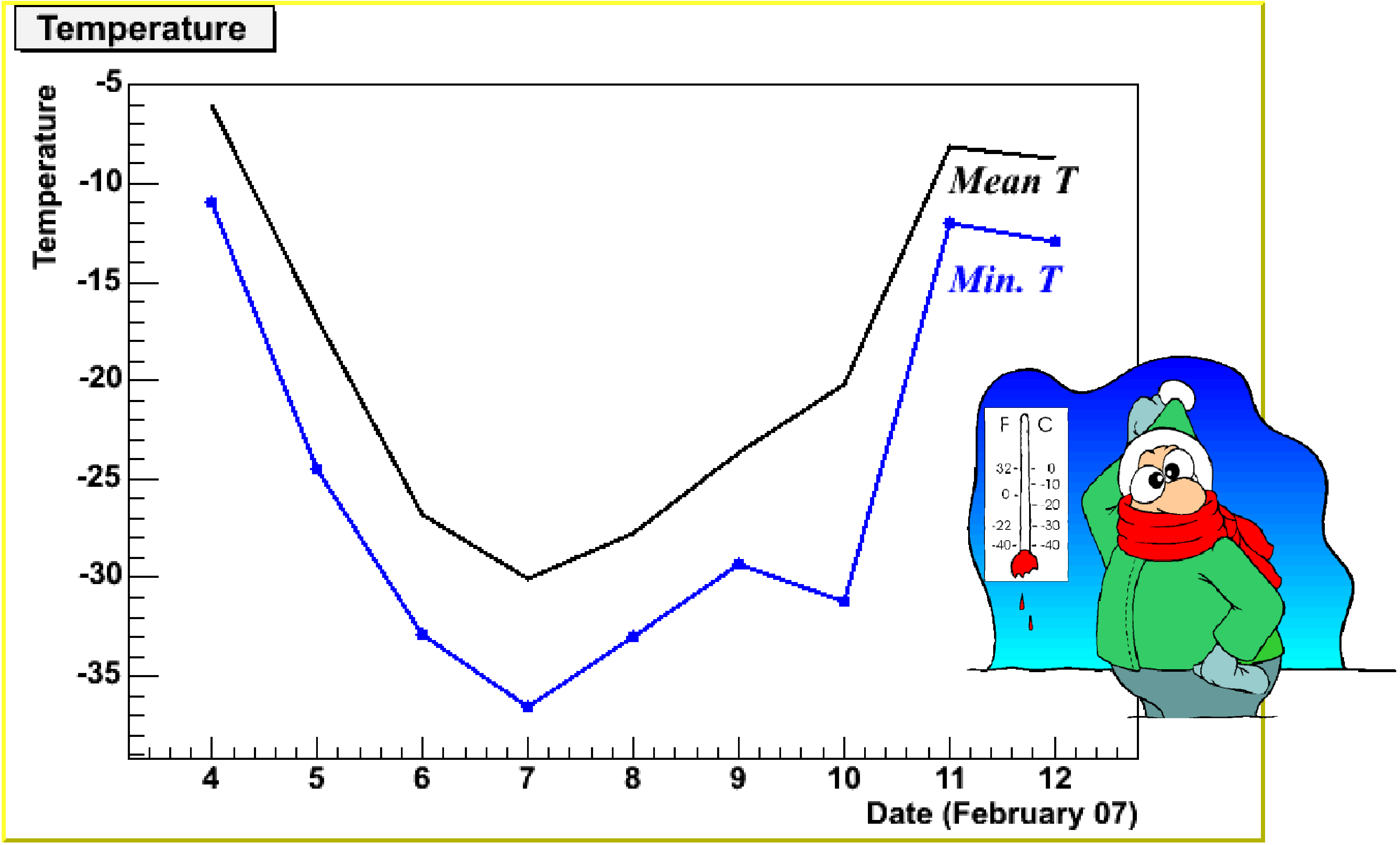
Relevant experimental details

Delayed Neutron Precursor	Half life	Q_β (MeV)	S_n (MeV)	R= $(Q_\beta - S_n)/ Q_\beta$	P_n	Daughter Nucleus	Half life
^{87}Br	55.65 s	6.85	5.5	0.195	0.0252	^{87}Kr	76.3 m
^{88}Br	16.3 s	8.96	7.05	0.213	0.0658	^{88}Kr	2.84 h
^{94}Rb	2.70 s	10.31	6.75	0.345	0.104	^{94}Sr	75.3 s
^{95}Rb	377.5 ms	9.29	4.4	0.527	0.0873	^{95}Sr	23.9 s
^{137}I	24.5 s	5.88	4.03	0.315	0.0697	^{137}Xe	3.82 m

Table 1: Relevant experimental data for the proposed nuclei (delayed neutron precursor, half live, beta decay Q_β value, neutron separation energy S_n, energy window $R=(Q_\beta-S_n)/Q_\beta$, β-n branching, daughter nucleus, half live), taken from ENSDF [4] and RIPL[5].

Why JYFL?

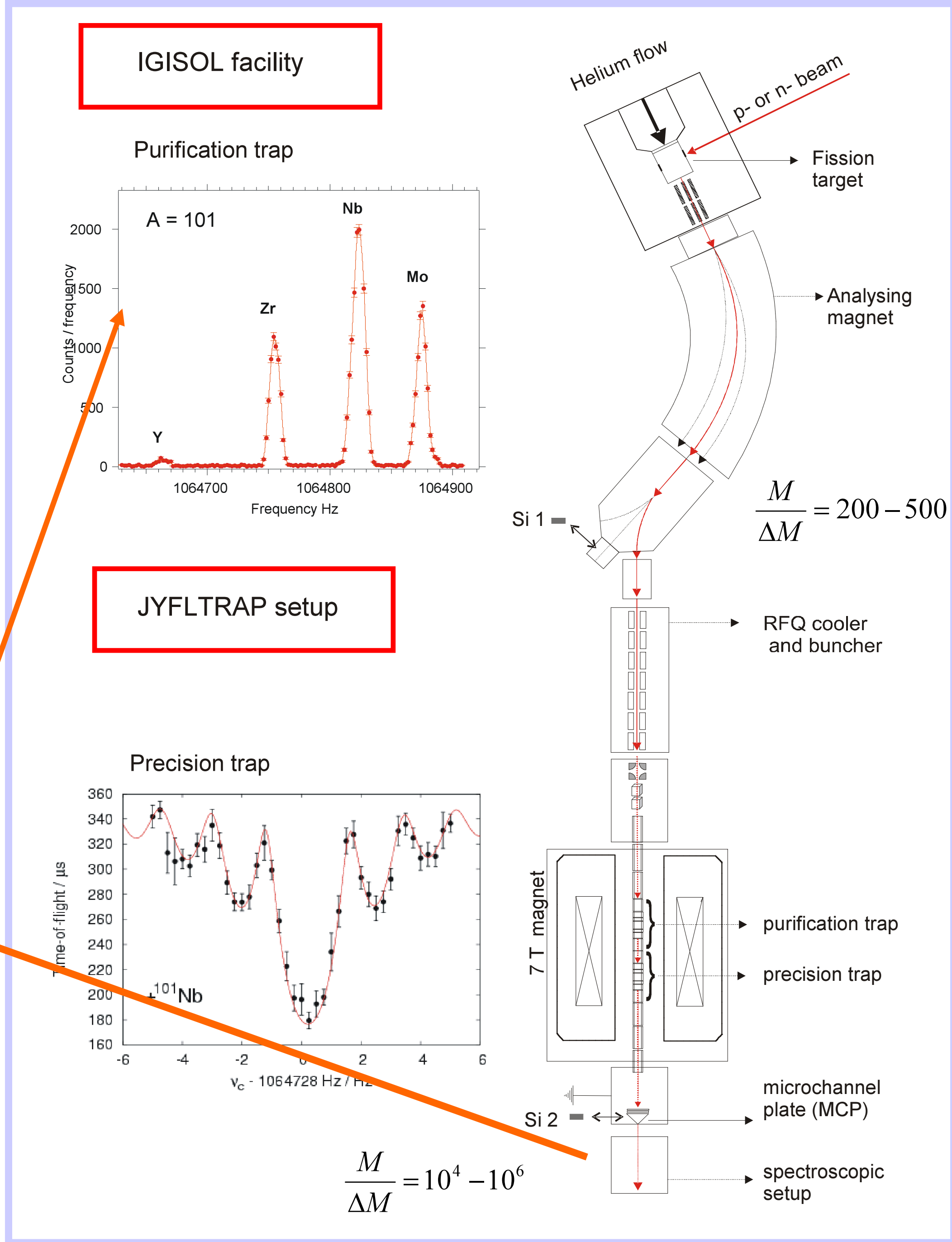
You may want to impress your friends (and or grandsons)!



Why JYFL?

But seriously: the main reasons are the chemical insensitivity (ion guide technique), high purity by means of purification of the beam using the JYFLTRAP and acceptable yields!

Isobar spectrum of A=101 fission products measured at spectroscopy setup



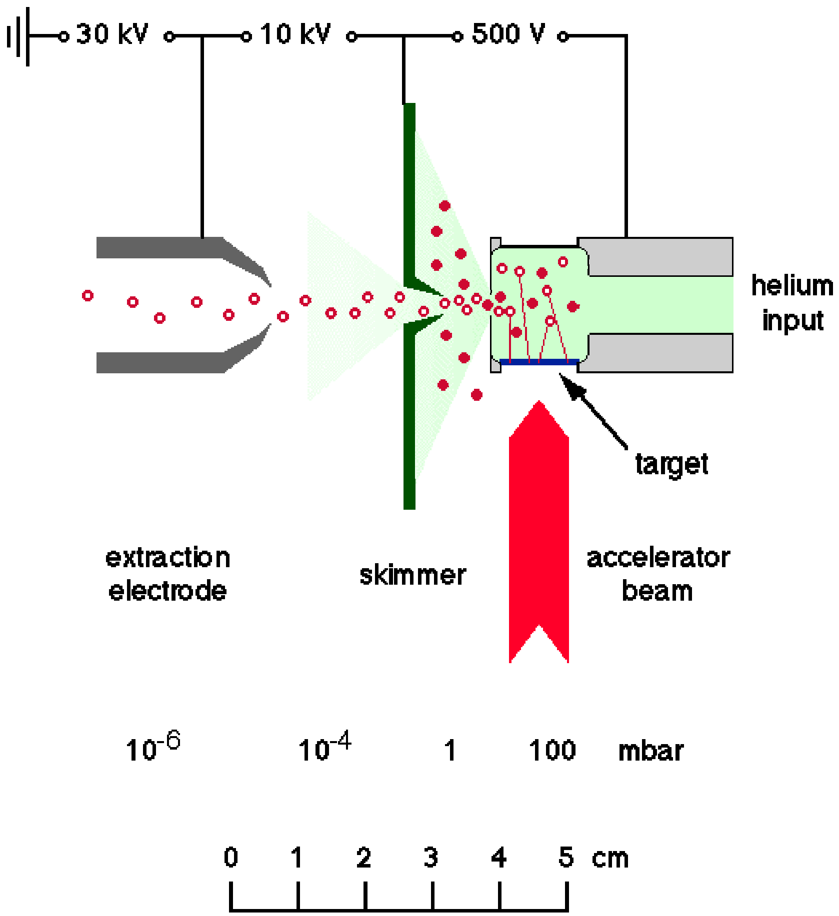
ISOLDE(CERN)

GPS $\frac{M}{\Delta M} = 2400$

HRS $\frac{M}{\Delta M} = 5000$

The ion guide technique

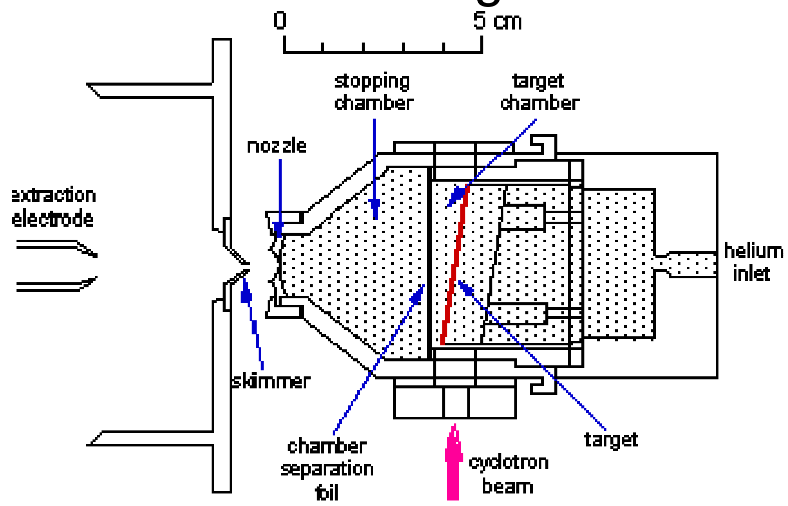
Generic ion guide



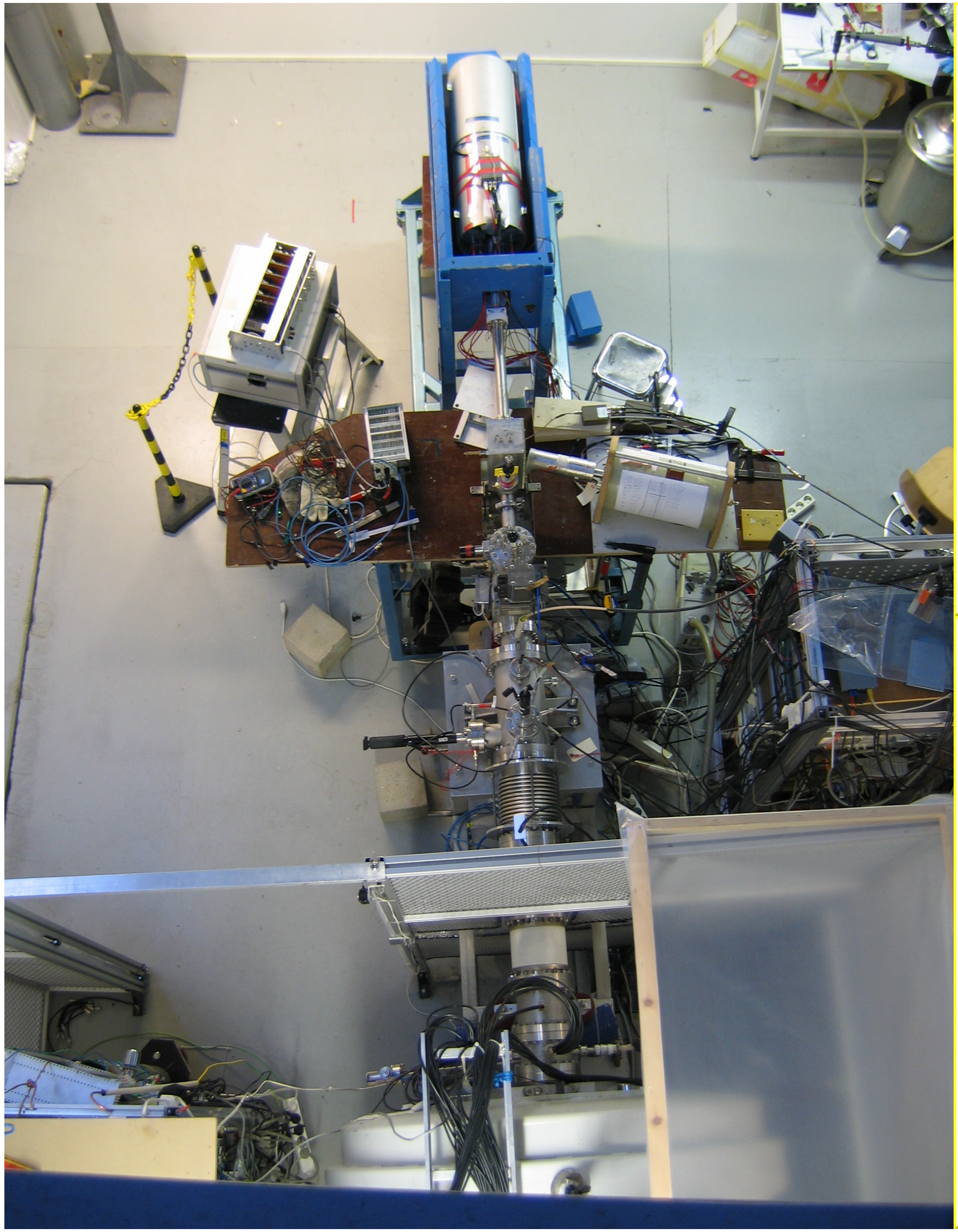
Generic ion guide: the nuclear reaction products are stopped in a gas and are transported through a differential pumping system into the accelerator stage of the mass separator.

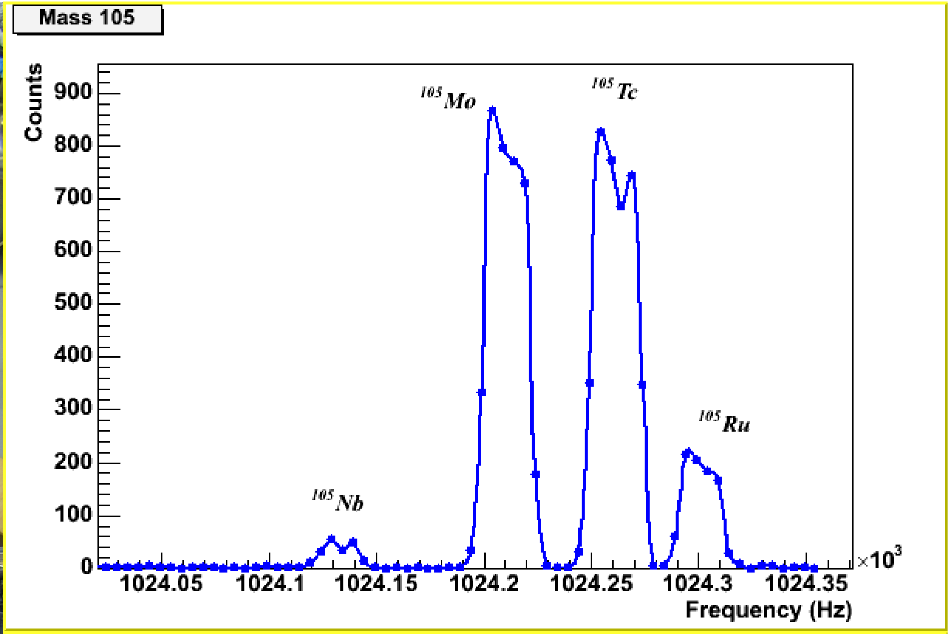
The process is fast enough for the ions to survive as single charged ions. The system is chemically insensitive and very fast (sub-ms).

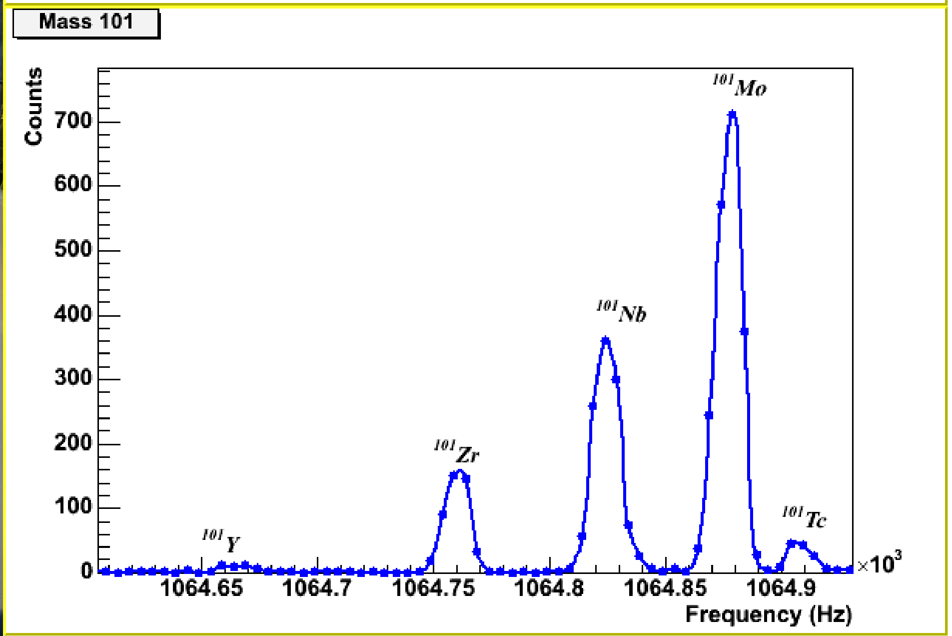
Fission ion guide



The problem of the contaminants



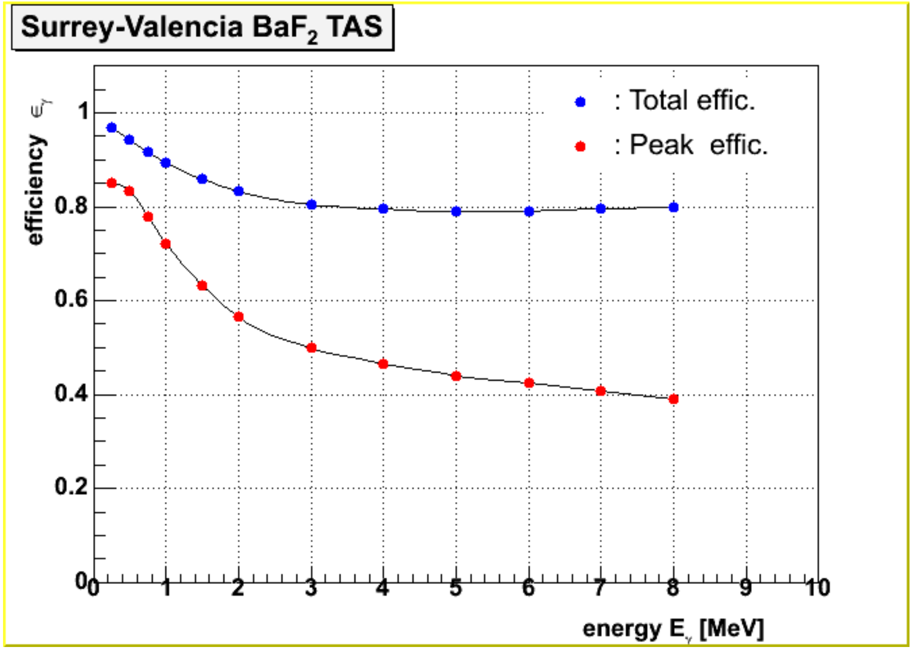


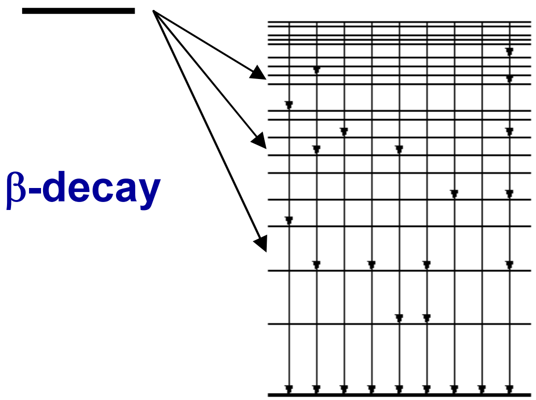


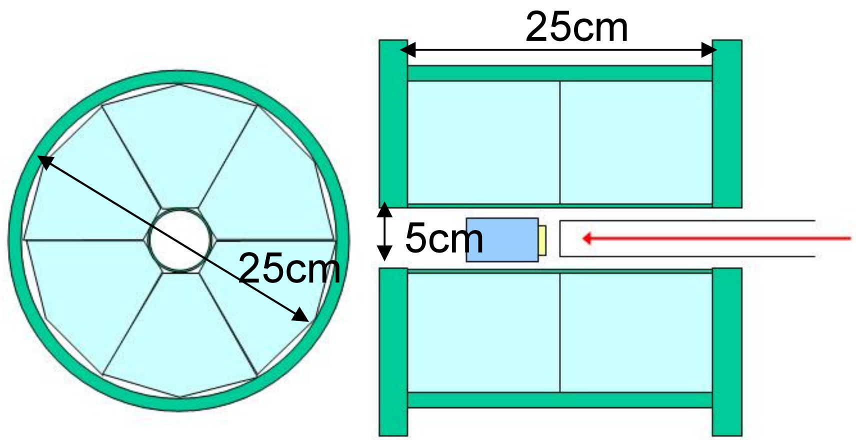
The new Surrey-Valencia TAS

Segmegted TAS!

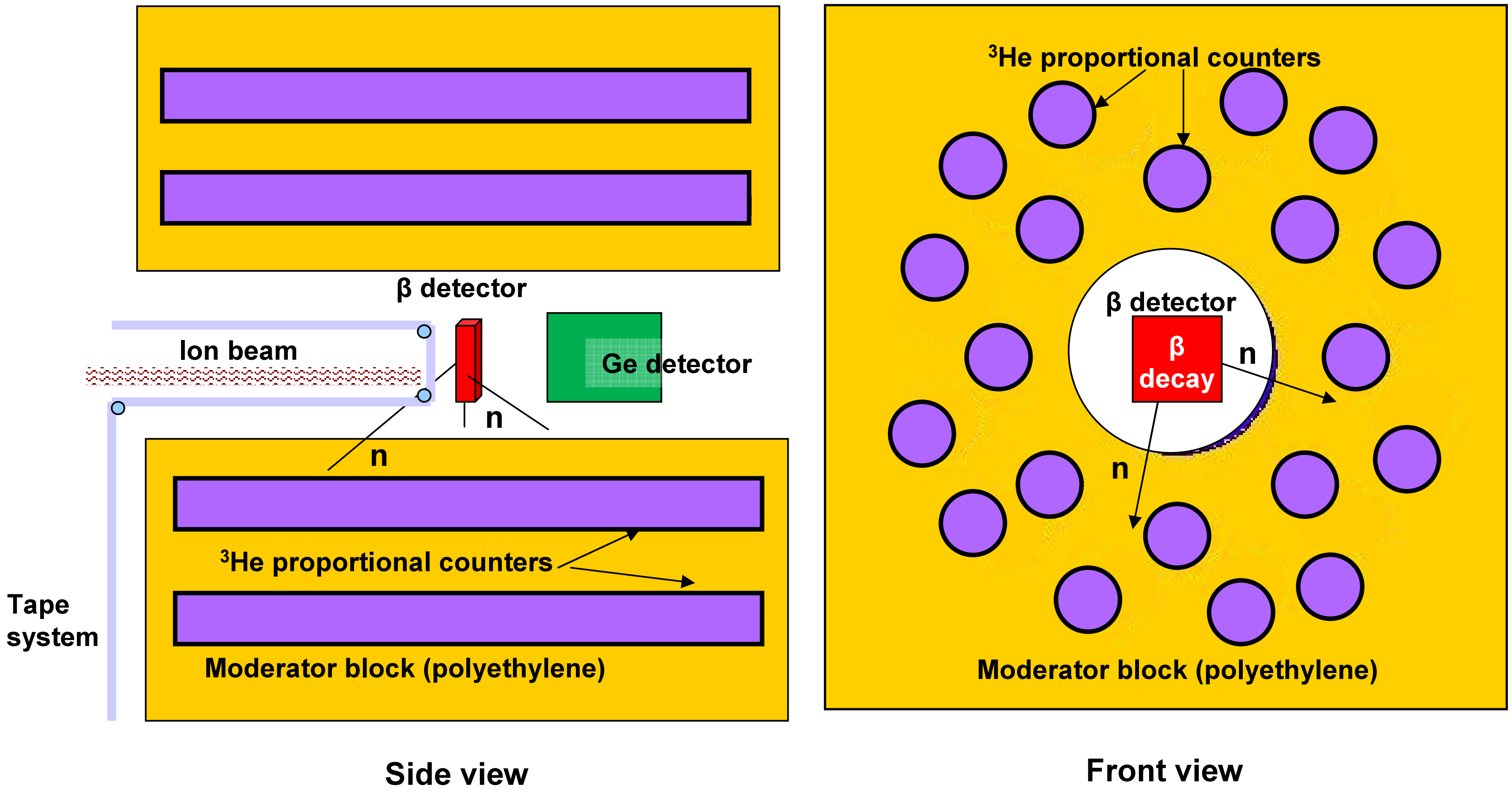
- **12 BaF_2 crystals**
- **Dimensions: ∅25cm×L25cm (5cm hole)**
- **Information on cascade multiplicity**
- **Studies have been performed in order to reduce the effect of the neutron induced background**
- **Work has been done in order to exploit the internal α-contamination of the crystals to stabilize the gain of the dete**







The 4π neutron detector setup



“Mini” version of the planned detector for DESPEC

The 4π detector efficiency

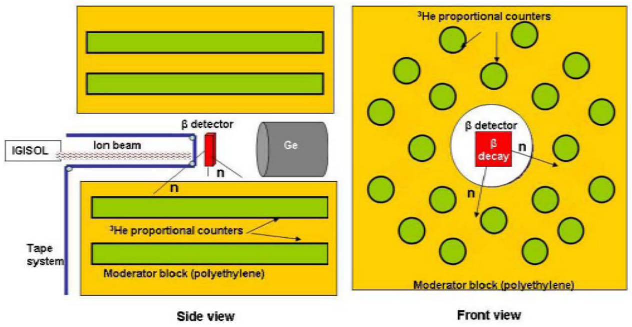
The efficiency of the 4π neutron detector has been calculated by Monte Carlo simulations with MCNP.

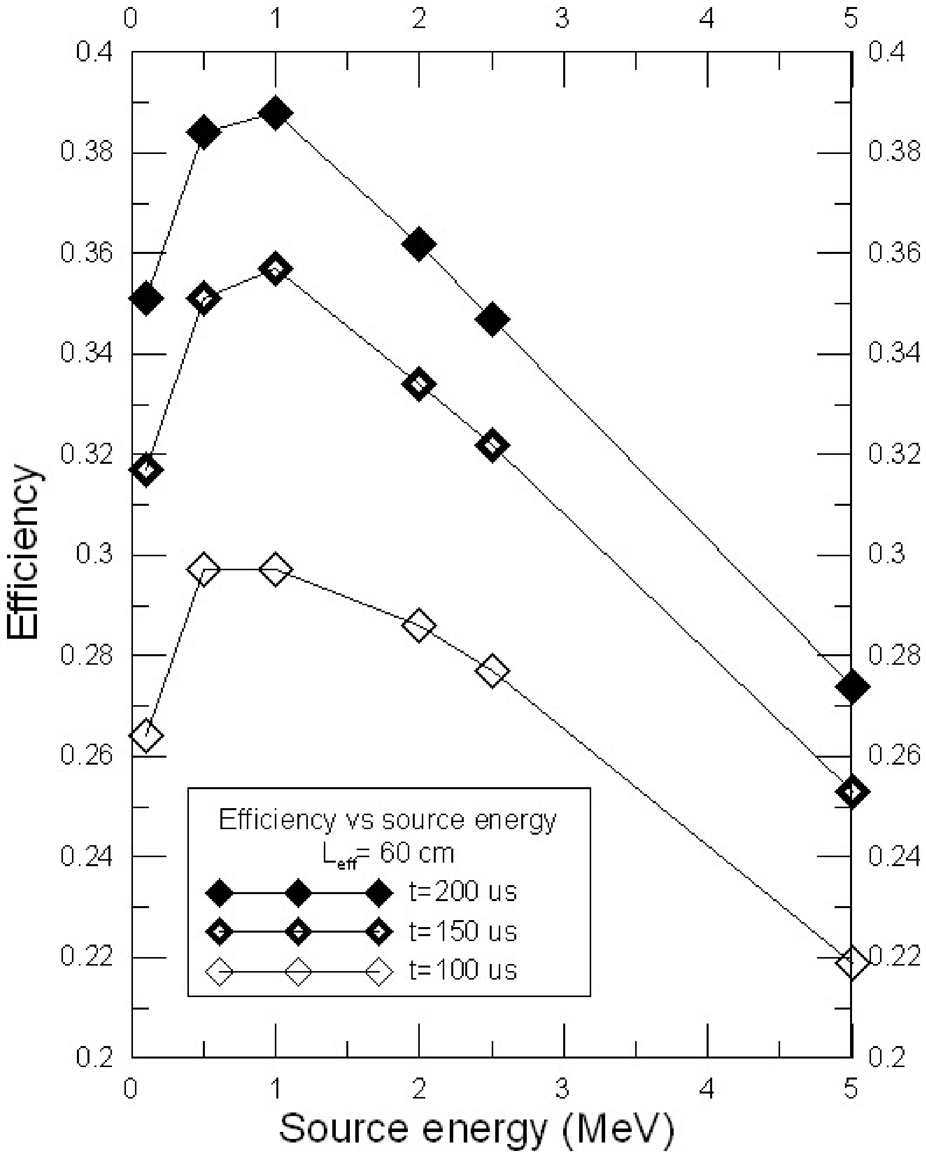
Polyethylene block 42x80x42 cm^3

^{3}He Tubes:

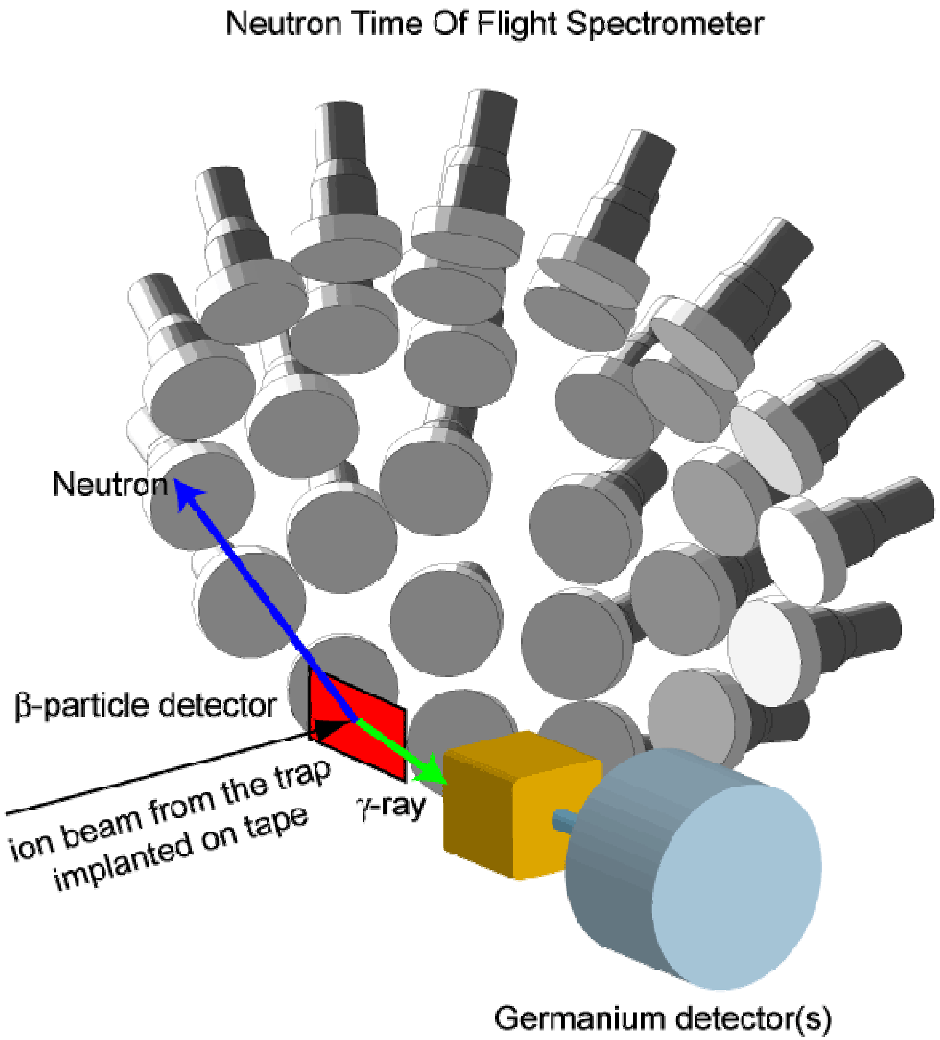
- 60 cm effective length
- 70 cm total length
- 2.54 cm diameter
- 15200 torr

Ring A: 8 counters R_A=10.5cm
Ring B: 12 counters R_B=16.7 cm





The ToF Spectrometer



NE213/BC501A

Flight path: ~75cm distance from the implantation position
$\Delta\Omega/\Omega$ ~13%

The calibration of the complete spectrometer will be made in-place with on-line and off-line neutron sources.

Coincident β-n and β-γ-n events (for the most intense transitions).

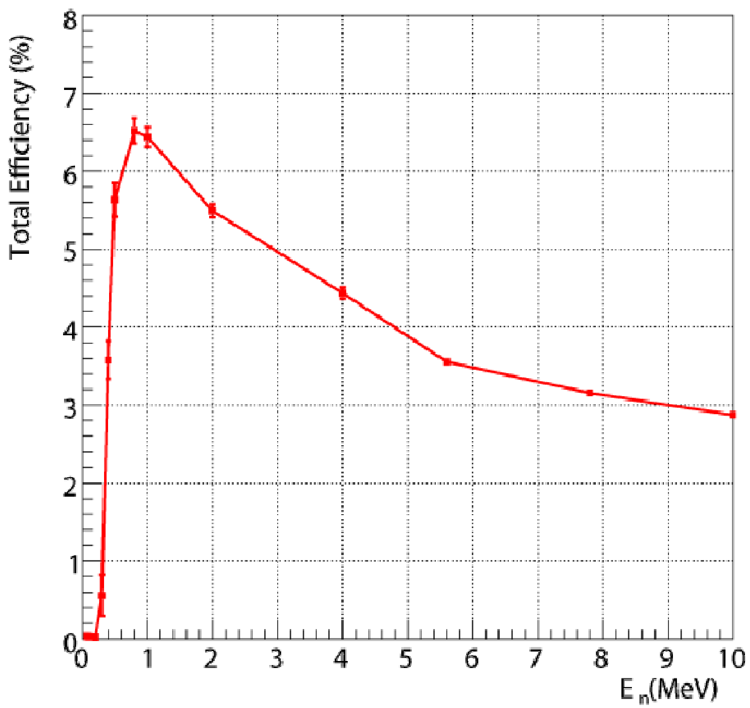
Start signal: plastic β-detector
Stop signal: liquid scintillator.

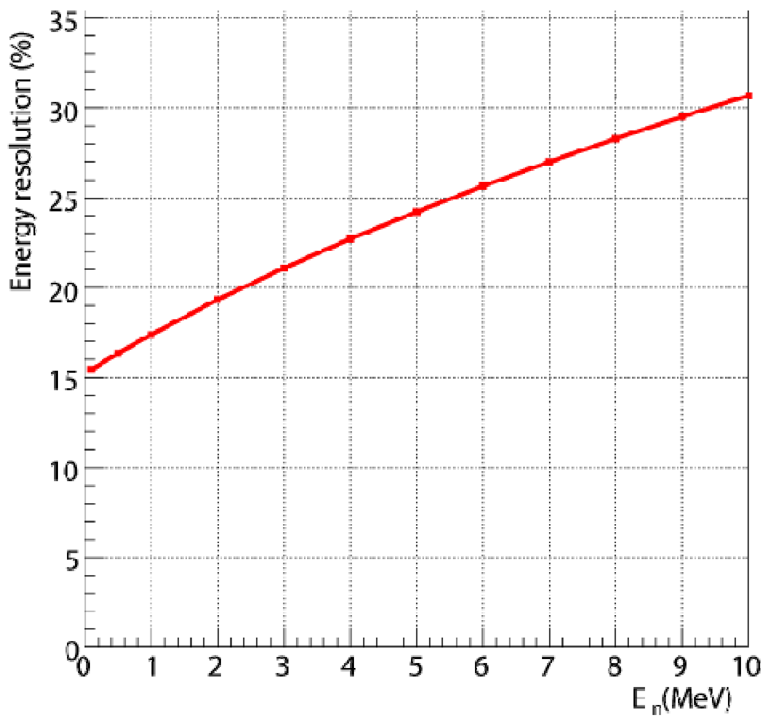
The γ-ray background in the neutron detectors will be rejected by time of flight (for prompt coincident gammas) and by pulse shape discrimination.

The TOF array efficiency

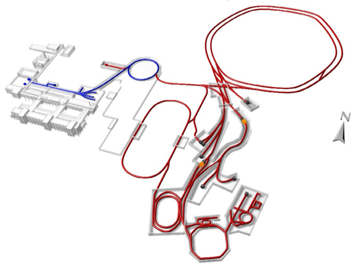
The total neutron detection efficiency of the setup has been computed by Monte Carlo simulation with the GEANT4 code: 6.6% at 1 MeV to 2.9% at 10 MeV.
One reference cell will be calibrated in with calibrated neutron beams at PTB-Braunschweig (Spring 2009)

Δt ~ 1ns, which corresponds to an energy resolution the spectrometer of16% at 1 MeV and 30% at 10 MeV.



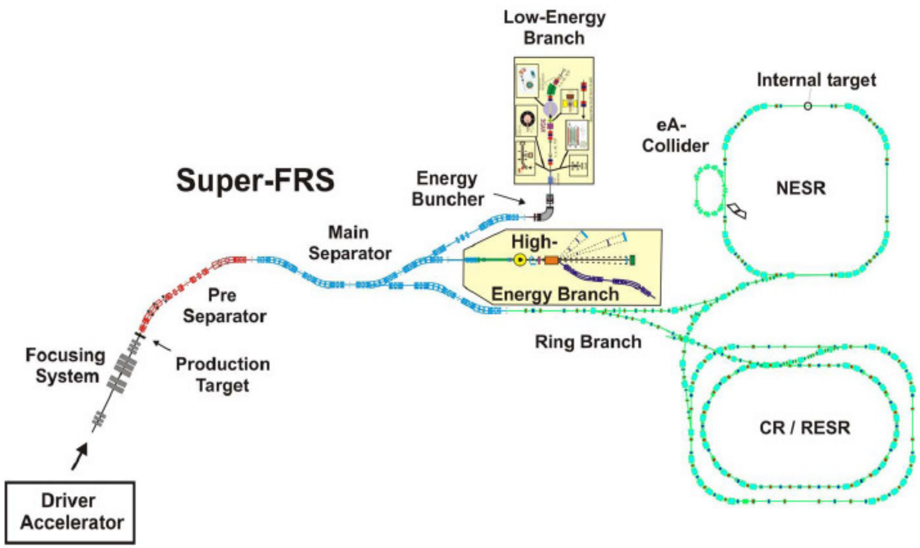


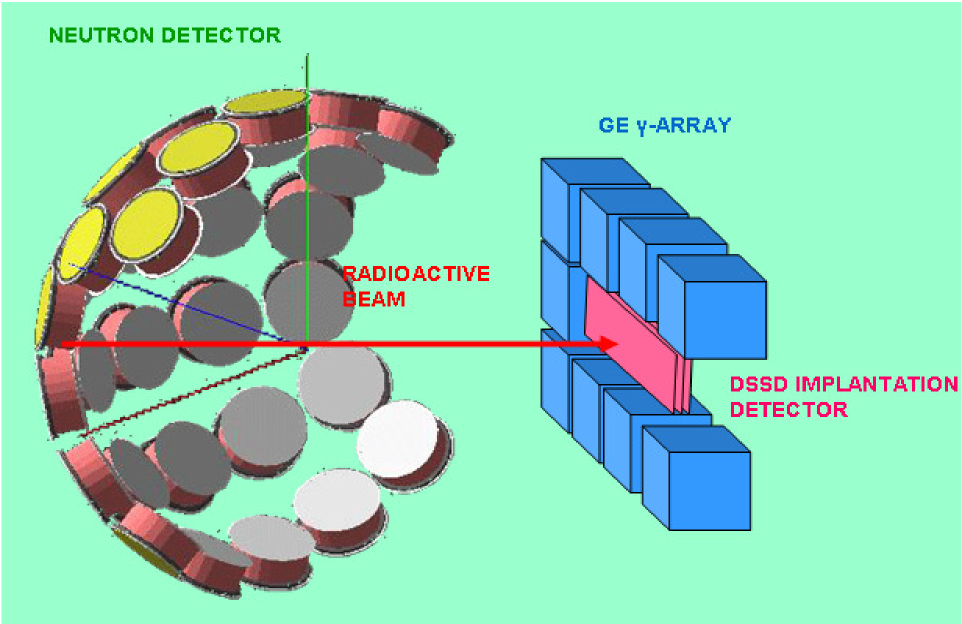
Testing prototypes for FAIR



The groups of IFIC (CSIC-Univ. Valencia), CIEMAT, and UPC of Barcelona are heavily involved in the development of instrumentation for the future facilities of FAIR. They have a leading role in the development of gamma and neutron detectors for the experiment DESPEC (DEcay SPECtroscopy).

The experience in the fore coming experiments will be important from this point of view also.





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THANK YOU

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