Consiglio di sezione
15-05-2014

Decadimento beta di nuclei prodotti con fasci radioattivi: Attivita' GAMMA e prospettive per SPES

Menu:

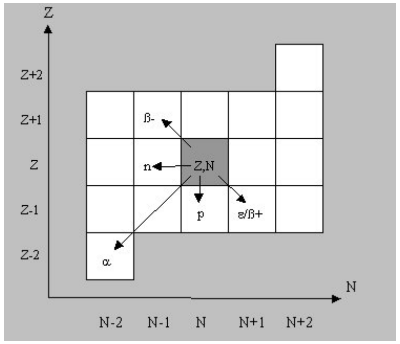
- Exotic nuclei and beta –decay studies:
  - Shell structure
  - Stellar nucleosynthesis
- Experimental techniques:
  - Fast fragmentation ➔ GSI (D) e Riken (J)
  - ISOL ➔ CERN
- Future project: tape station @ SPES-LNL

❑ Gamma collaboration in CSN III:

Universita': Angela Bracco, Franco Camera, Silvia Leoni, Fabio Crespi
INFN : G.B., Nives Blasi,, Benedicte Million, Oliver Wieland
Post-doc: A.I. Morales-Lopez, Luna Pellegri, Agnese Giaz

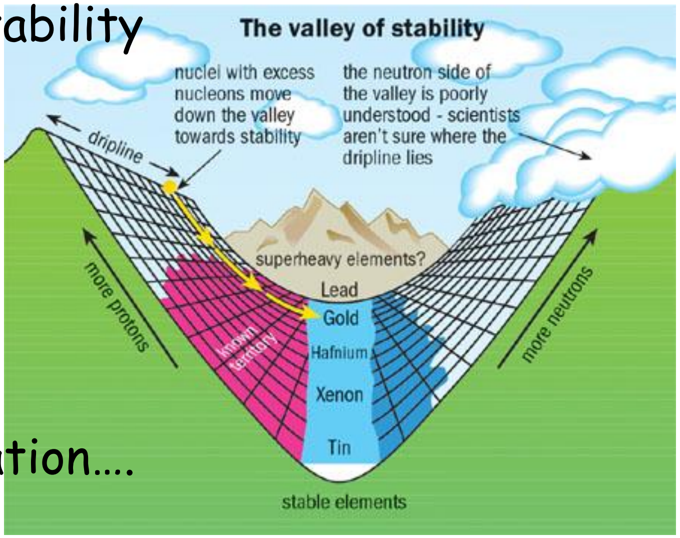
Beta decay: survey of general properties

- β^- decay is the most common type of radioactive decay
  - β^- decay
  - β^+ decay
  - Electron capture (EC)



reasons to study beta decay:

- Access to gross information on the decay, Half-life, Pn etc.
- First information on excited states far from stability
- Spin assignments owing to selection rules
- Access to non-yrast states
- Definition of shapes of daughter nuclei
- Connection to mass measurements
- Input for astrophysics and reactor heat calculation....



……many more…

Exotic nuclei exotic properties

Proximity of doubly magic ^{78}Ni N=40 sub-shell closure {HO}

Many new effects arising at small changes in nuclear configuration:
- deformations
- change in levels sequence
- collectivity
- isomerism and loss of isomerism
- monopole drift
- proton core excitations
- proton intruder isomers

…

Shell model calculations need to include a large valence space to describe all effects

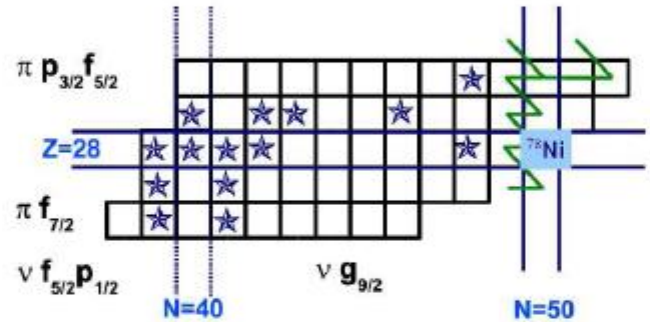
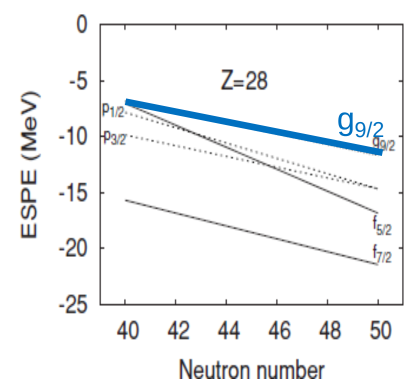


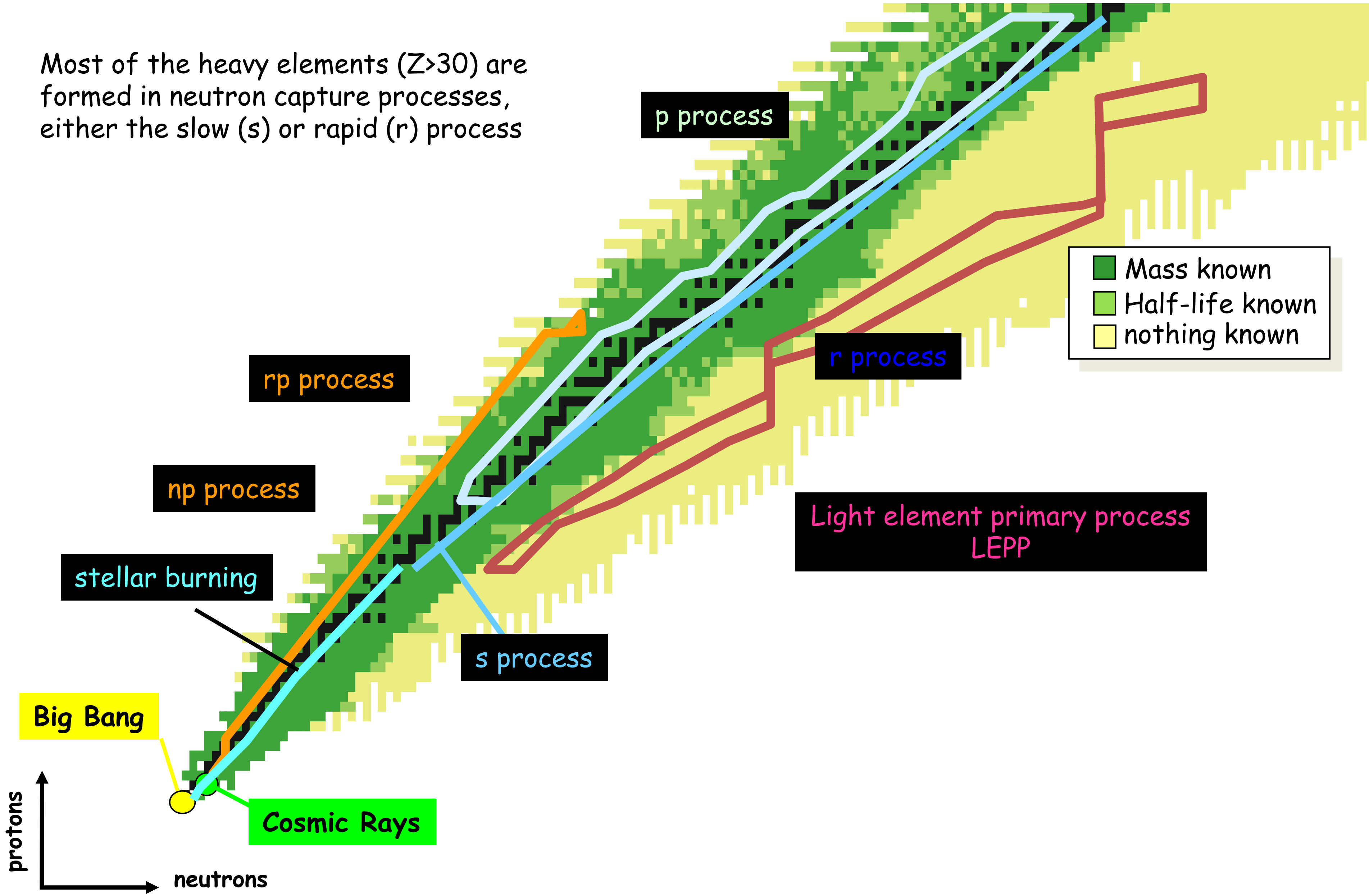
Fig. 1. Fragment of the chart of nuclei around ^{68}Ni and ^{78}Ni with selected known microsecond isomers observed using ^{86}Kr fragmentation [7, 10, 11, 30].



K.Sieja and F. Nowacki, PRC 81, 061303 R (2010)
R. Grzywacz et al., Eur. Phys. J. 25, 89 (2005).

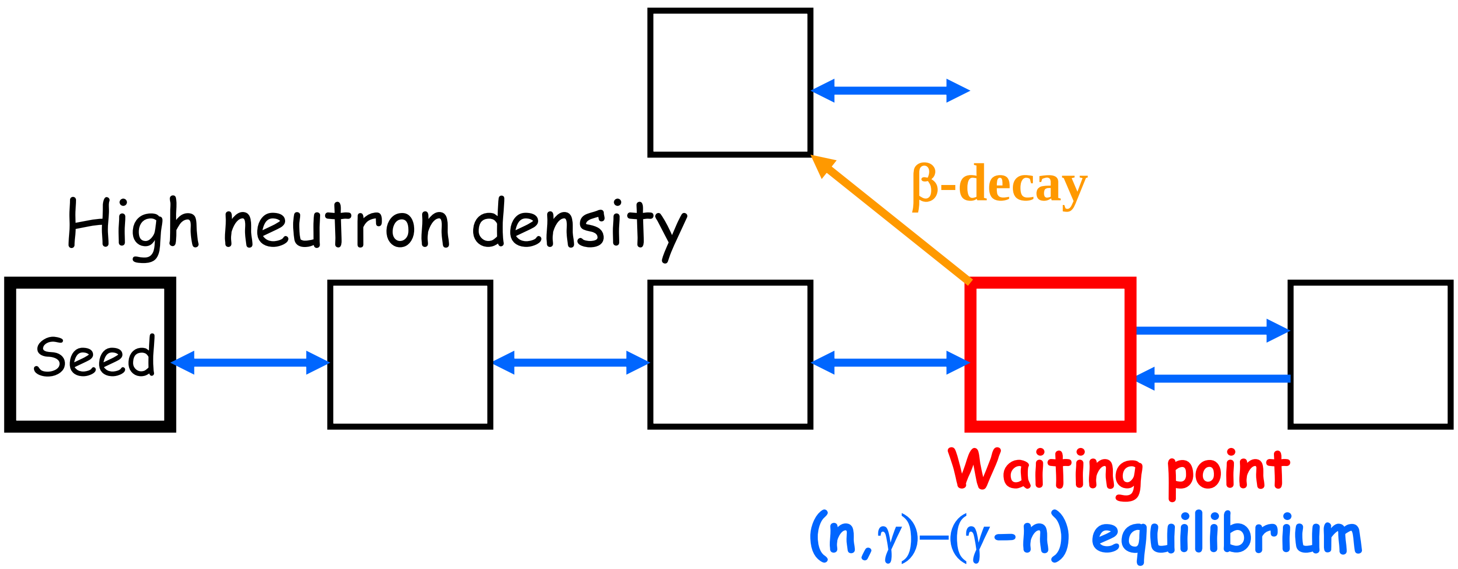
Nucleosynthesis

Most of the heavy elements (Z>30) are formed in neutron capture processes, either the slow (s) or rapid (r) process



R-process basics

Element formation beyond iron involving rapid neutron capture and radioactive decay



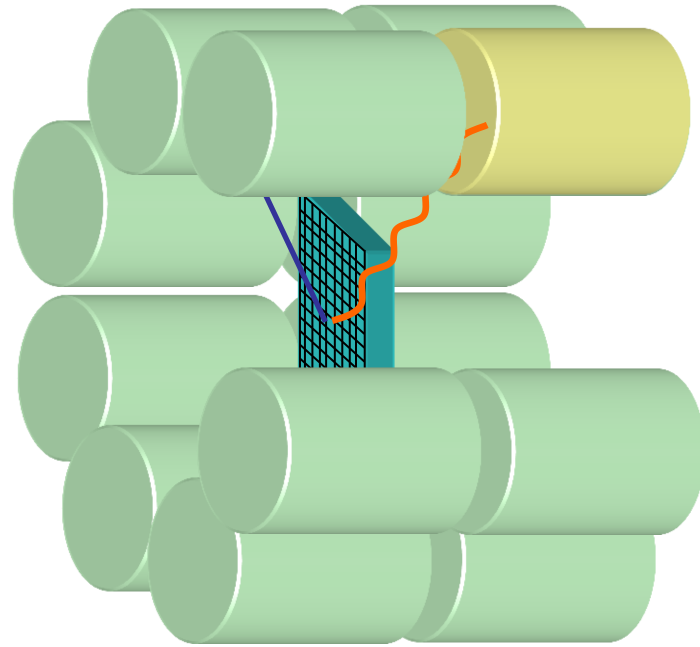
- **β-decay half-lives (progenitor abundances, process speed)**
- **β-delayed n-emission branchings (final abundances)**
- n-capture rates (Smoothing progenitor abundances during freezeout)

Beta spectroscopy: experimental technique

Mother ^{148}Cs

β^- $T_{1/2}$= 146 ms

^{148}Ba **Daughter**



Basic principle:

- Detect Mother nucleus implantation
- Correlate succeeding beta emission
  - ➔ measure HALF-LIFE ($T_{1/2}$)
  - ➔ measure delayed GAMMA EMISSION, spectroscopy of daughter nucleus

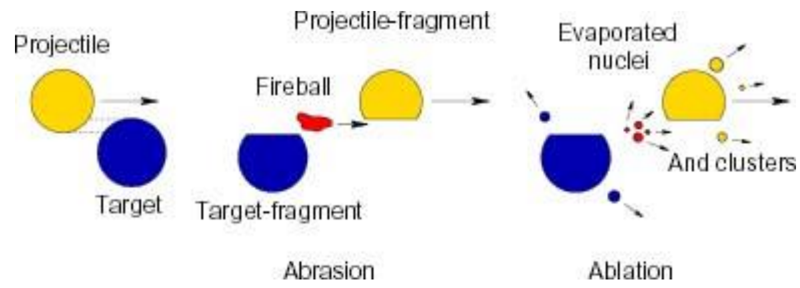
2 ways to produce exotic nuclei ➔
2 different techniques to study beta spectroscopy

A) **IN-FLIGHT**:Stack of Si stripped detectors for implant/beta det.
B) **ISOL**:Tape system + Plastic/Si

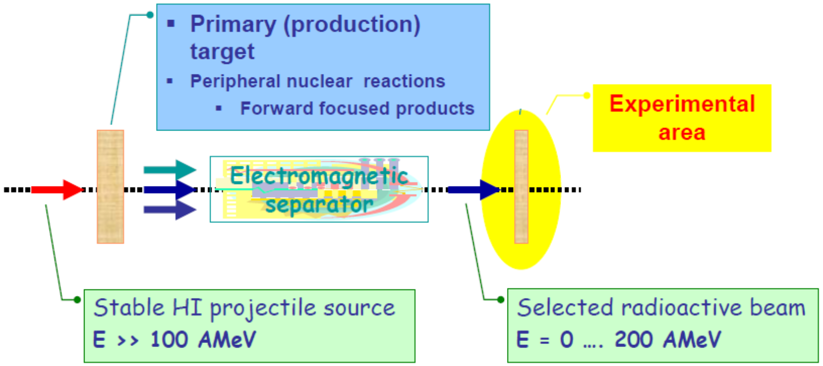
Both surrounded by HPGe + additional detectors (LaBr3, Neutron det.)

IN-FLIGHT fragmentation reactions

Fragmentation reactions:
Fragmentation of heavy ion beams
(up to ^{238}U) using thin targets



- ✓ Cocktail beam ➔ many nuclei at once
- ✓ both short-living (ms) and long living (100s) nuclei
- ✓ Get information already with few particles
- ✘ Low production rates (μb-> fb)
- ✘ Need to run at low rate to distinguish contributions from each nucleus

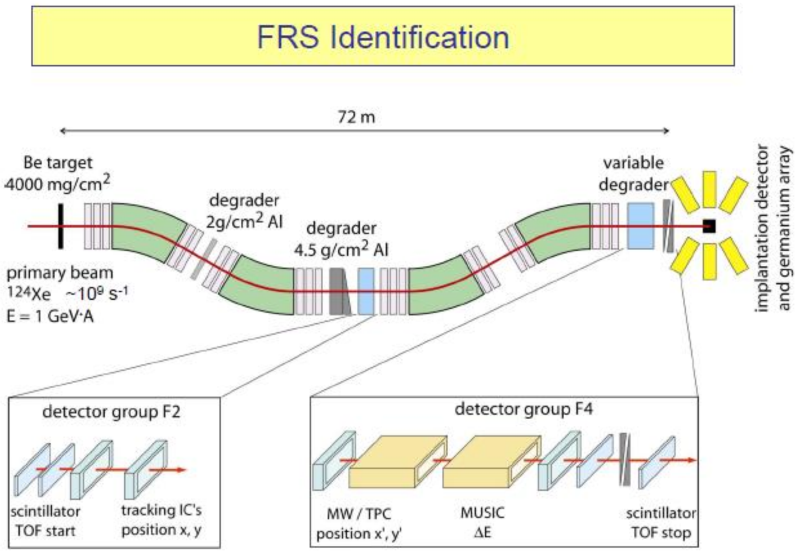


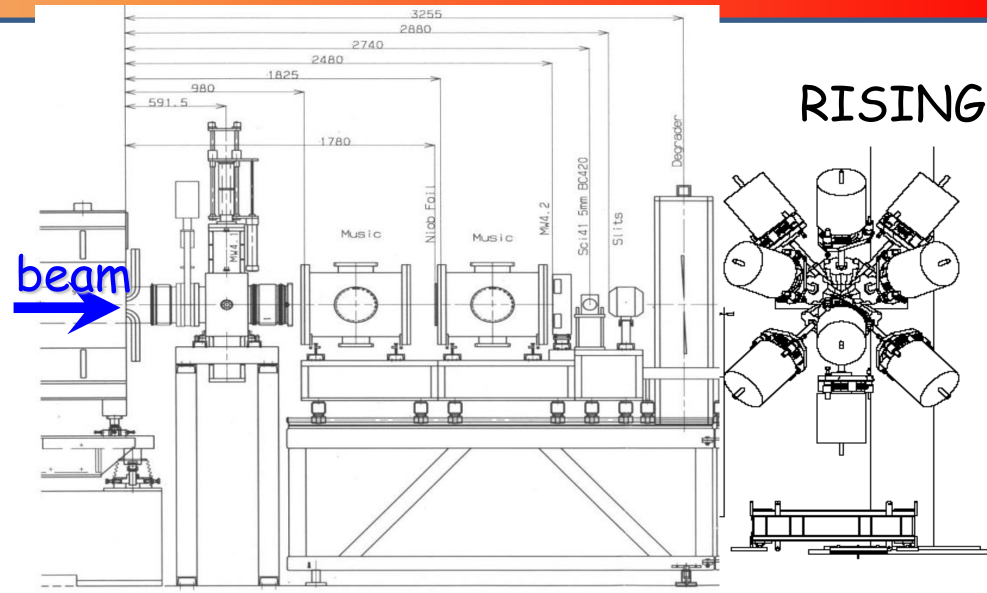
* Active, position sensitive, pixelated stopper to correlate implanted ions (mother) with β-decay (daughter).
➔ stack of several DSSSD to ensure implantation and detect electrons

Typical Trigger conditions
Implantation: Signal coming from separator
Decay: OR signal coming from Si detectors

γ rays are usually acquired as SLAVE

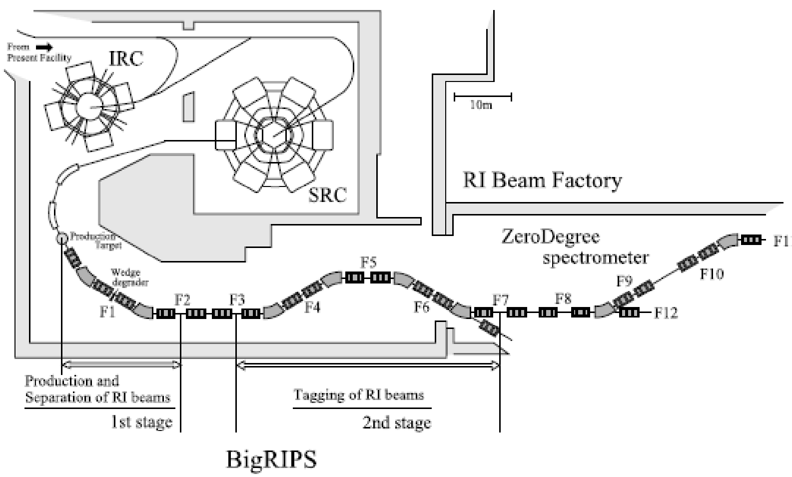
Fragmentation facilities



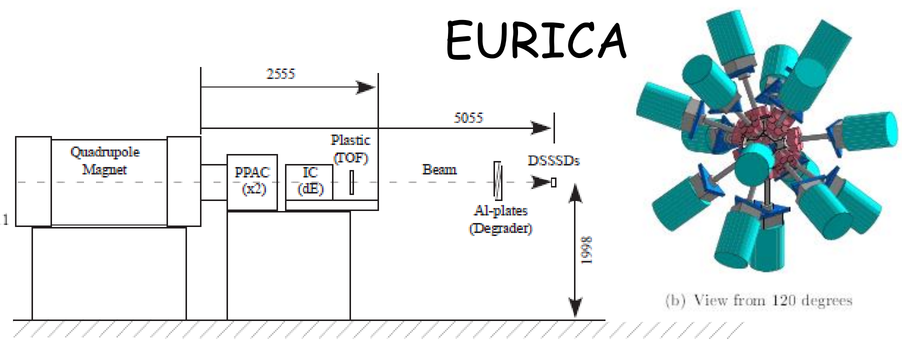


RISING

GSI (Darmstadt- Germany)



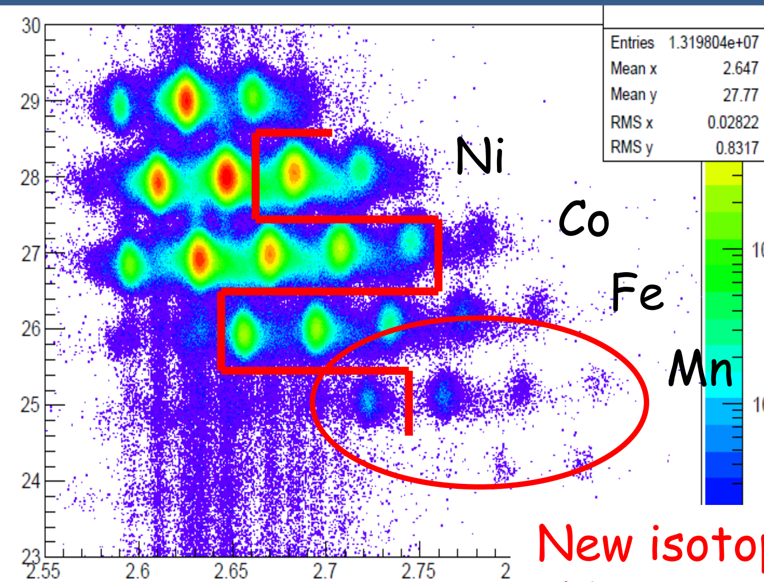
EURICA



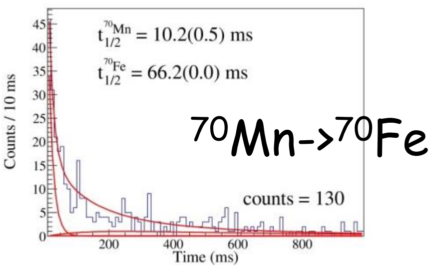
RIKEN (Wako-shi, Japan)

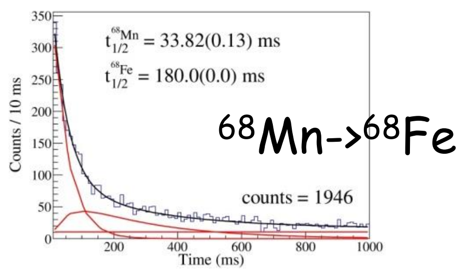
Fragmentation facilities: results from a recent exp. @ RIKEN

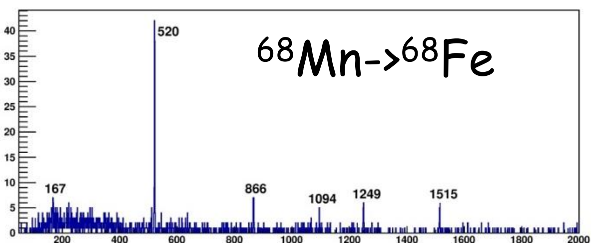
- New half-lives
- Delayed spectroscopy:
  - Transitions measured for first time
  - Extension of level schemes

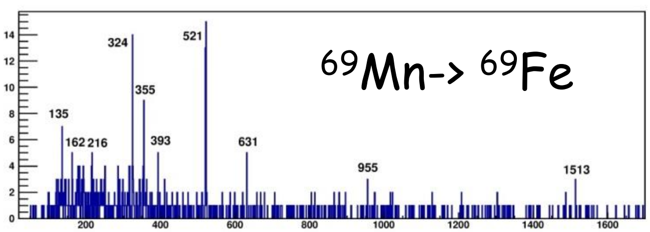


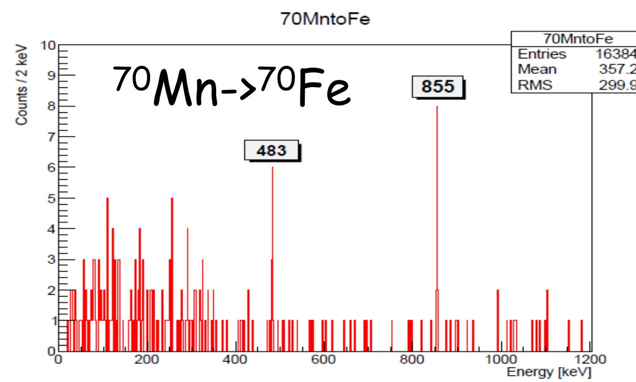
New isotopes:
No previous info available







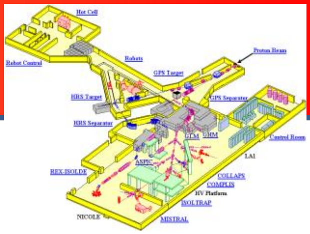




^{70}Mn : 130 Implant-beta events

$^{68-70}$Mn $T_{1/2}$ measured
Tranisitions in $^{68-69-70}$Fe seen

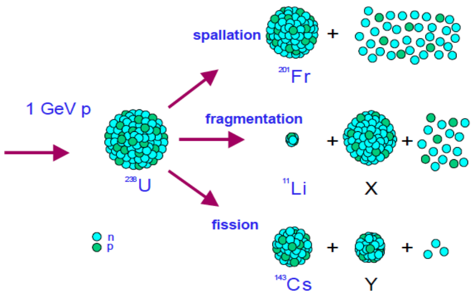
ISOL (Isotopic Separation On-Line) method

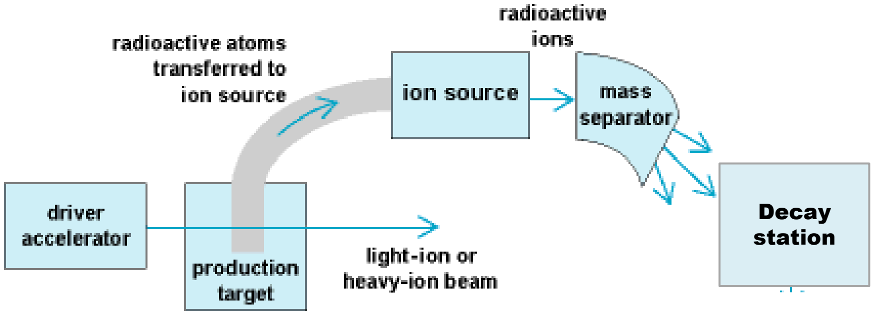


ISOLDE@CERN

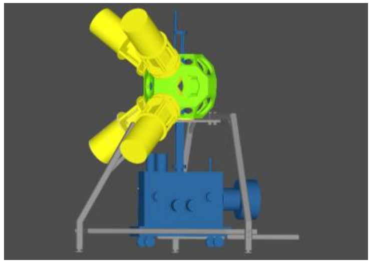
spallation/fission/fragmentation on thick targets, followed by chemical/physical processes to extract desired nuclei

- ✓ high cross sections ➔ high rates
- ✓ Nearly mono-isotopical beams
- ✘ Not all nuclei can be successfully extracted
- ✘ long-living nuclei (> 100ms) owing to intermediate processes of effusion and diffusion

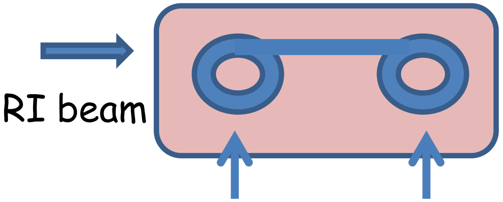




(a)



TAPE Station systems

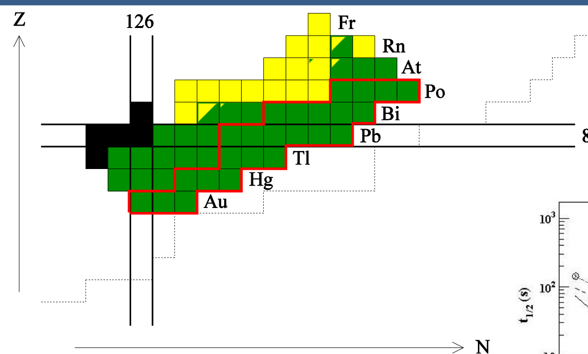


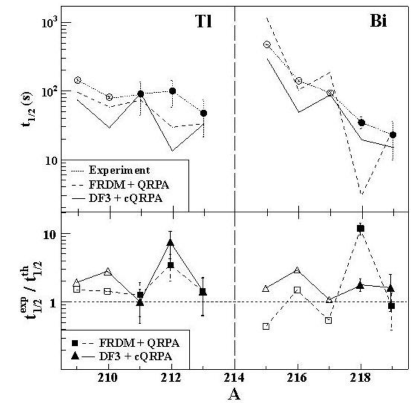
Each "point" is a measuring point and can be equipped with egs. Ge detectors and Plastic or Si detectors for β particles
Trigger given by implantation signal and β signal
Long-living activity is removed by moving away the tape

Beta decay spectroscopy in Milano

- Recent past: RISING @GSI
  "Spectroscopy of n-rich Pb nuclei",
  G.Benzoni et al.

G.Benzoni et al., PLB 715 (2012) 293
A.I.Morales et al., PRC 89 (2014) 014324
+ conf. proceedings



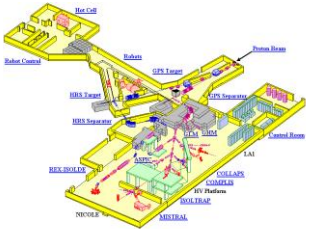


- Present:
  * EURICA campaign @ RIKEN
  "Structural changes btw N=40 and N=50 next to Ni isotopes",
  G.Benzoni et al.
  ➔ under analysis. ARIS2014 -Tokyo,

Existence of octupole static/dynamic deformations is a long standing quest attracting much attention

* ISOLDE @CERN
"Study of octupole deformation in n-rich Ba isotopes populated via β decay",
G.Benzoni et al.

To run 7-12 August



Strong octupole correlations **show up due to interaction of orbitals with ΔJ=ΔI=3**
Two predicted regions for octupole def. are around Ba and Th-Ra
Possibility of having dynamic and static correlations ➔ Theoretical models do not agree on onset of static deformations

Beta decay spectroscopy in Milano

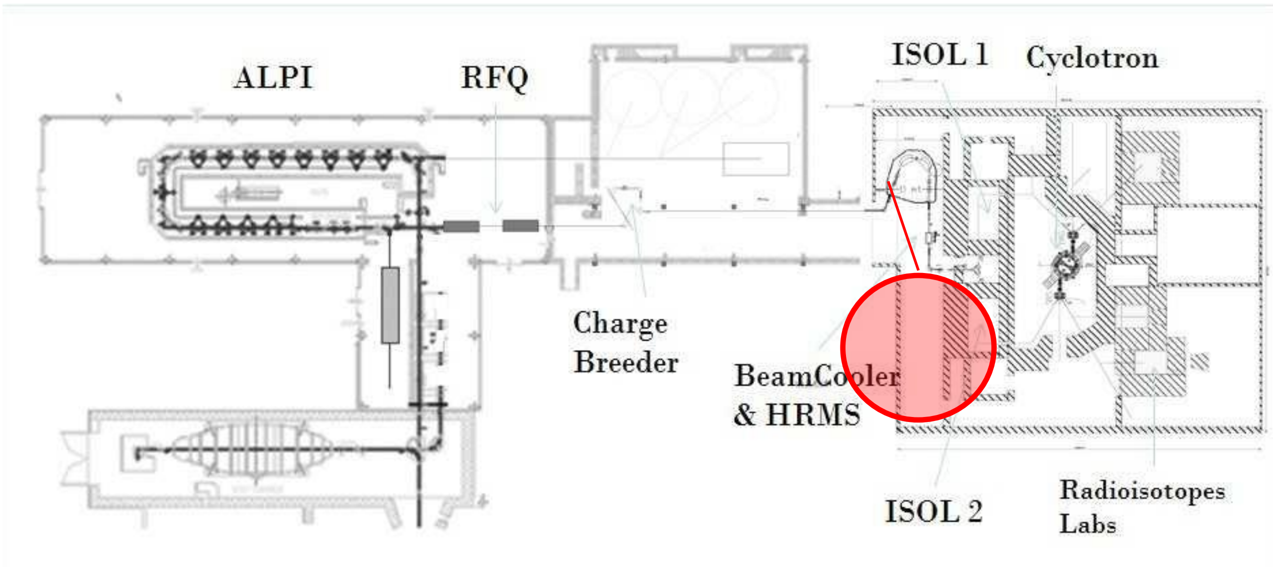
- Future: SPES (Selective Production of Exotic Species) @ LNL

"A Letter of Intent for Beta-Decay Spectroscopy at SPES", G.Benzoni et al.

Construction of a decay station (tape system) @ LNL to use beams of SPES

high performance cyclotron with high output current (~0.7 mA) and high energy (up to 70 MeV), together with the related infrastructure for the accelerator and experimental stations.

The beams will be dedicated to the nuclear physics facility producing neutron-rich ions by collisions of protons onto a UCx target



Beta counting station is being developed together with HRIBF (Oak Ridge, USA), Bordeaux (France), ISOLDE (CERN)

Timeline:
Cyclotron installation 2015
First beams available 2016

- Moving tape system
- Plastic detectors surrounding measuring point
- HPGe detectors (GALILEO-Clover), neutron detectors (NEDA),
- LaBr3 detectors: - fast timing for half-lives meas.
  - total absorption spectrometer

Conclusions

Beta decay studies in exotic nuclei:

- A good tool to access first info on nuclei
- Strong correlation with nuclear astrophysics (nucleosynthesis)
- Can be applied to nuclei produced both with IN-FLIGHT and ISOL methods

- ❑ Gamma spectroscopy group in Milano has a **lively program** to study beta decays with both techniques
- ❑ Recently published analysis on n-rich Tl-Pb-Bi
- ❑ Current analysis of nuclei around doubly-magic ^{78}Ni
- ❑ Scheduled exp. @ CERN on $^{150-152}$Ba

➢ Future: construction and setup of a **tape decay station** @ SPES,LNL