Nuclear Astrophysics at Rings

Nuclear decay probability measurements at storage rings

B. Jurado, D. Denis-Petit, L. Mathieu, I. Tsekhanovich, R. Perez,
S. Czajkowski, CENBG, Bordeaux, France

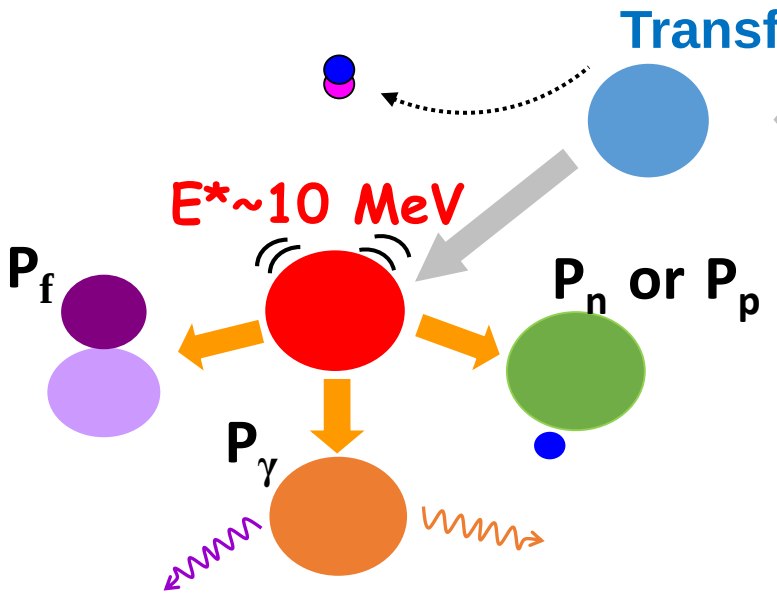
R. Reifarth, Ch. Langer, T. Heftrich, K. Goebel, University of Frankfurt, Germany

M. Grieser, MPI for Nuclear Physics, Heidelberg, Germany

P. Marini, V. Méot, O. Roig, J. Taieb, A. Chatillon CEA-DAM, Arpajon, France

L. Audouin, D. Ramos IPN-Orsay, France

The interest of transfer-induced decay probabilities



E=20-30 MeV

Decay probabilities depend on:

→Initial E*, J and π (reaction)

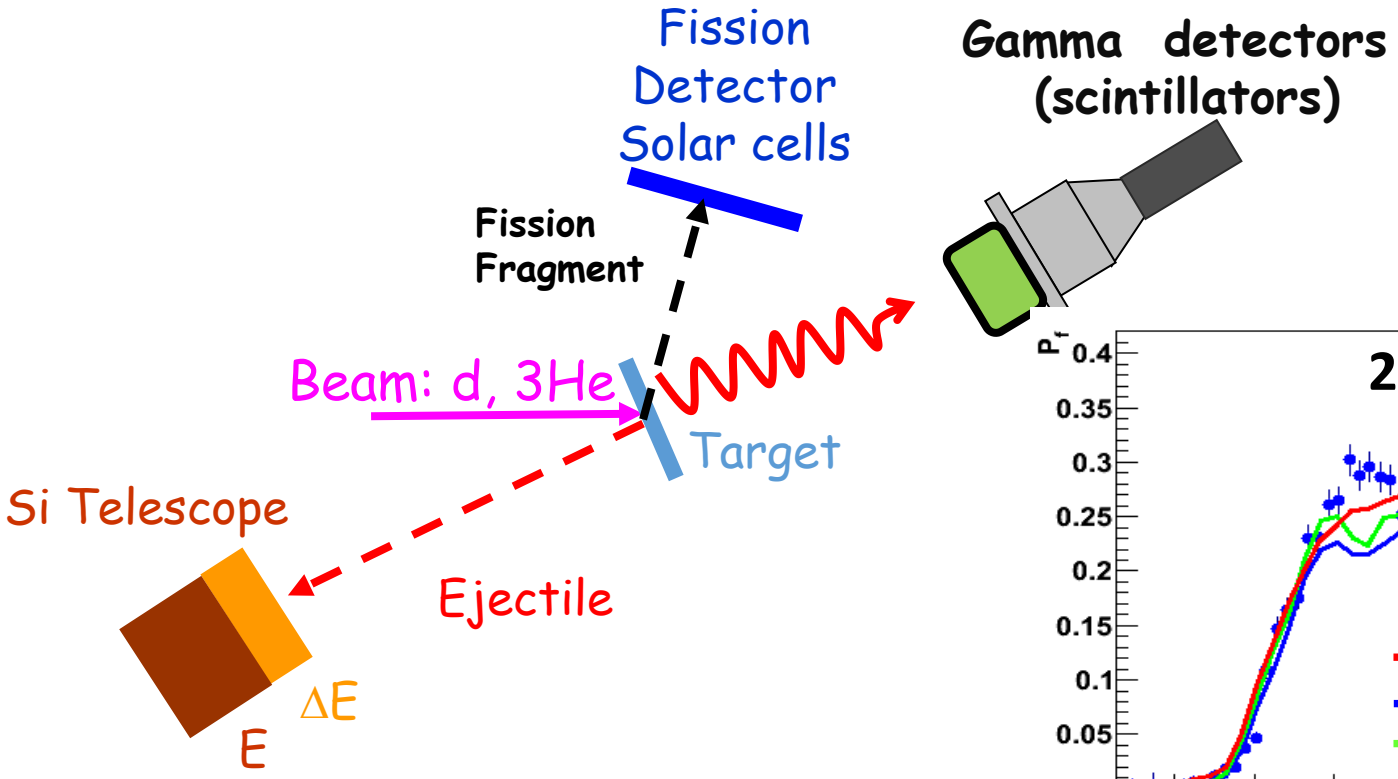
→Structure of excited nucleus: level densities, γ-ray strength functions, fission barriers…

Model calculations can be wrong by several orders of magnitude if no data are available!!

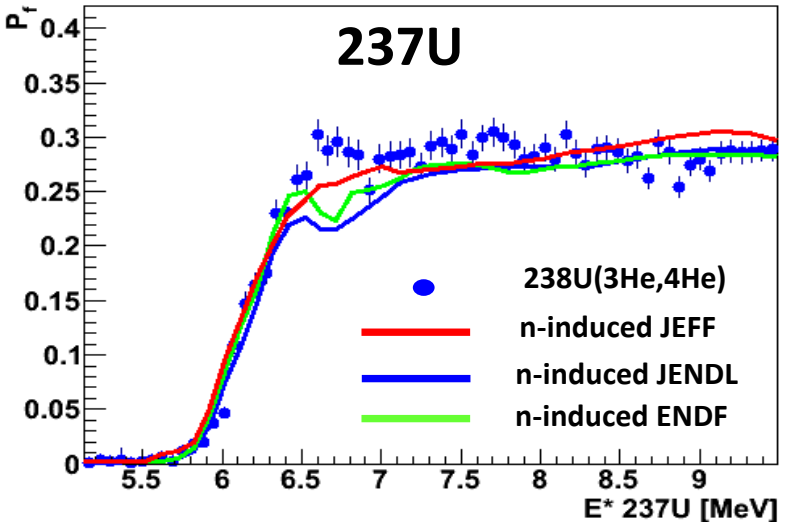
- Systematic studies with different reactions and in different regions
- Simultaneous measurement of all P to completely constrain model calculations, also useful for validating the experimental procedure since $\sum P_i=1$

Significant improvement of model predictions of n-induced cross-sections far from stability needed for e.g. understanding the origin of the elements in nuclear astrophysics!

Measurements in direct kinematics



$$P_{decay}(E^*) = \frac{N^{coin}_{ejec-decay}(E^*)}{N^{sing}_{ejec}(E^*) \cdot \varepsilon_{decay}(E^*)}$$



Transfer-induced P_f give rather direct access to n-induced fission cross sections!!

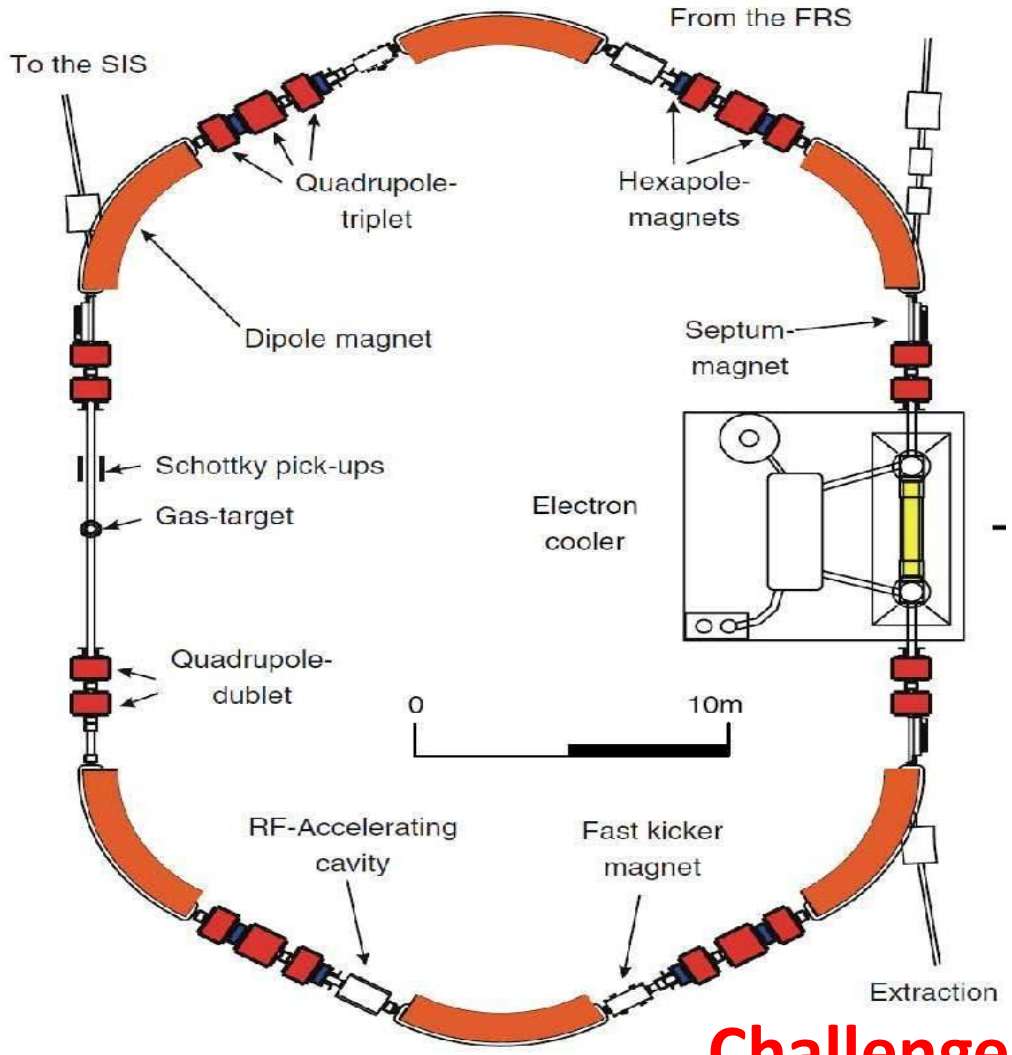
Limits:

- **Unavailability of targets (radioactive samples)**
- **Target contaminants and backing**
- **P_γ : discrimination of γ's from fission fragments**
- **P_n: measurement of low-energy neutrons and neutron efficiency**

SOLUTION: Measurements in inverse kinematics at storage rings!

Heavy-ion storage rings

The Experimental Storage Ring (ESR) at GSI

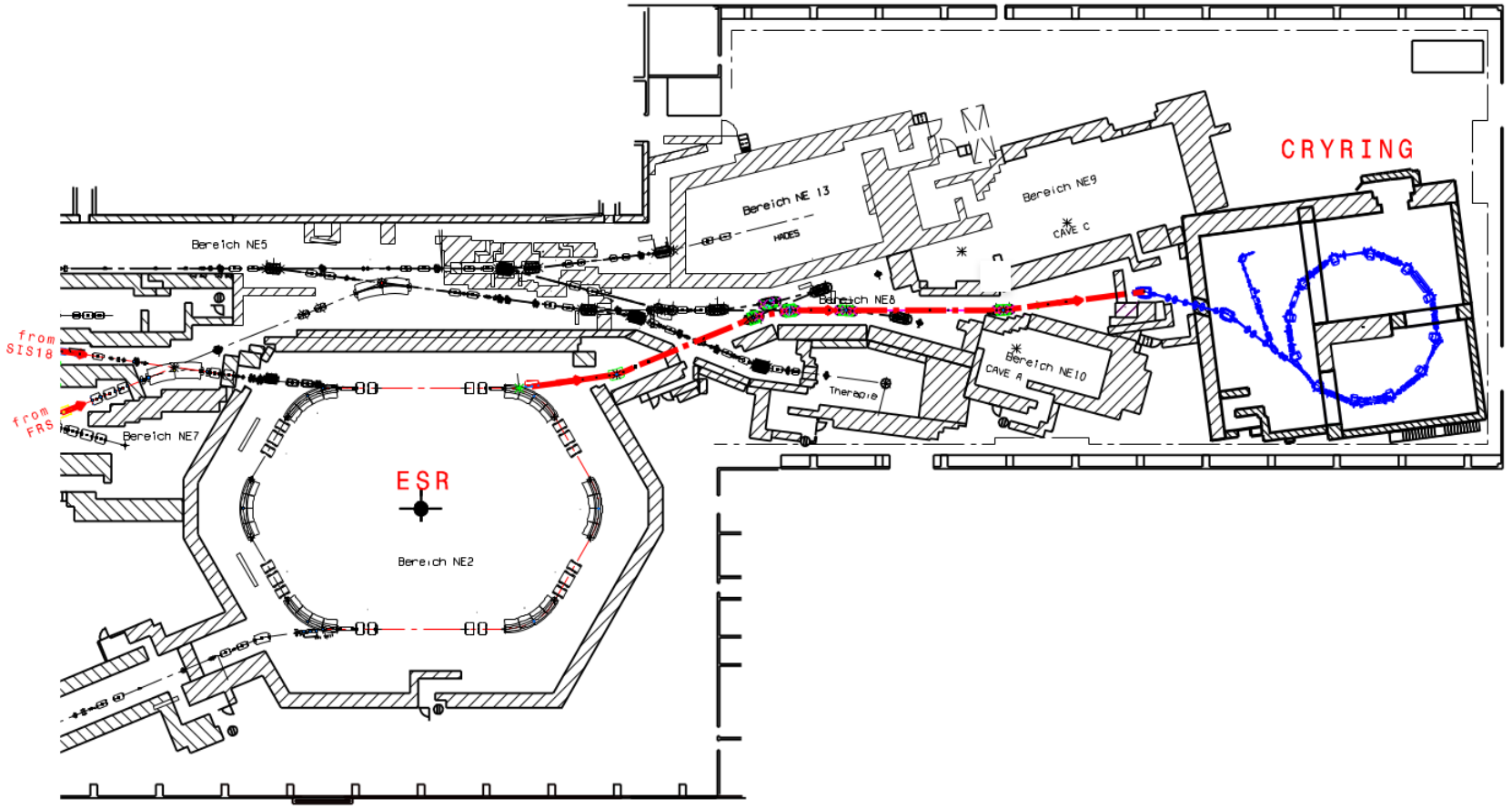


- Slow down of the beam to ~ 10 A MeV
- Beam cooling → Excellent beam-energy resolution of few hundreds keV at 10 A MeV, beam size 1 mm
- Radioactive nuclei $T_{1/2}$~1s
- In-ring gas-jet targets (H_2, D_2, 3He, 4He) with $10^{14}/cm^2$. Effective target thickness increased by ~10^6 due to revolution frequency
- Pure beams, pure targets (no contaminants, no backing)
- Pure isomeric beams

Challenge: Detectors in Ultra-High Vacuum (10^{-11} mbar)!

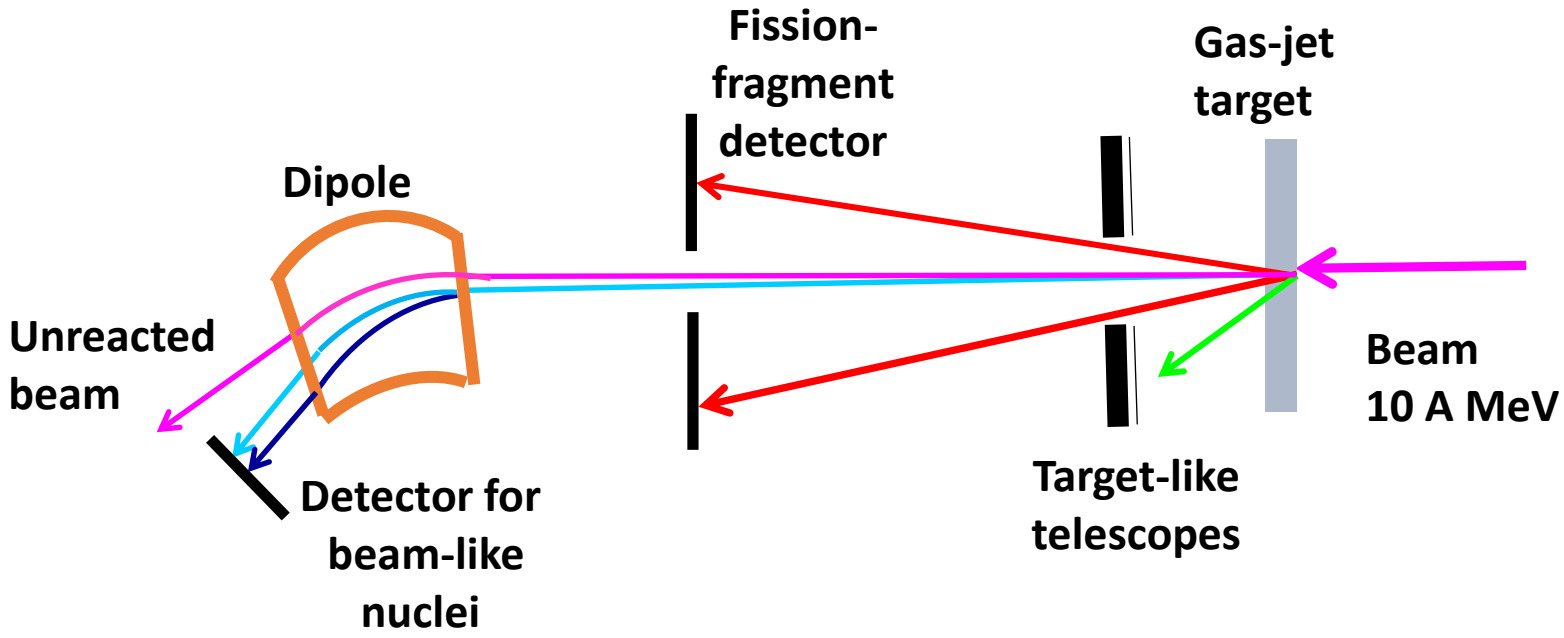
Possible since a few years!

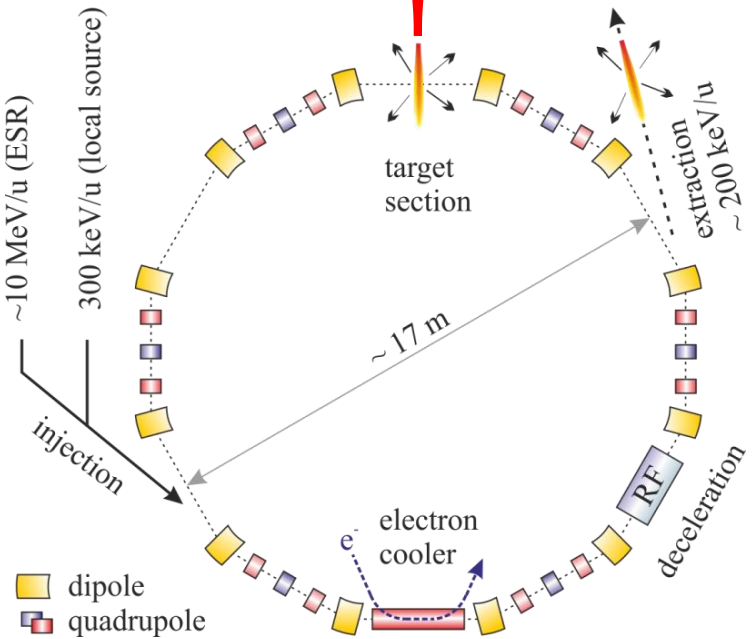
CRYRING@ESR



- **The ESR can be used to slow down and cool the beam, while the CRYRING is used for measurements, no time lost in beam preparation, UNIQUE!**
- **CRYRING is well adapted for energies of 10 A MeV for $^{238}U^{92+}$**

Decay-probability measurements at CRYRING

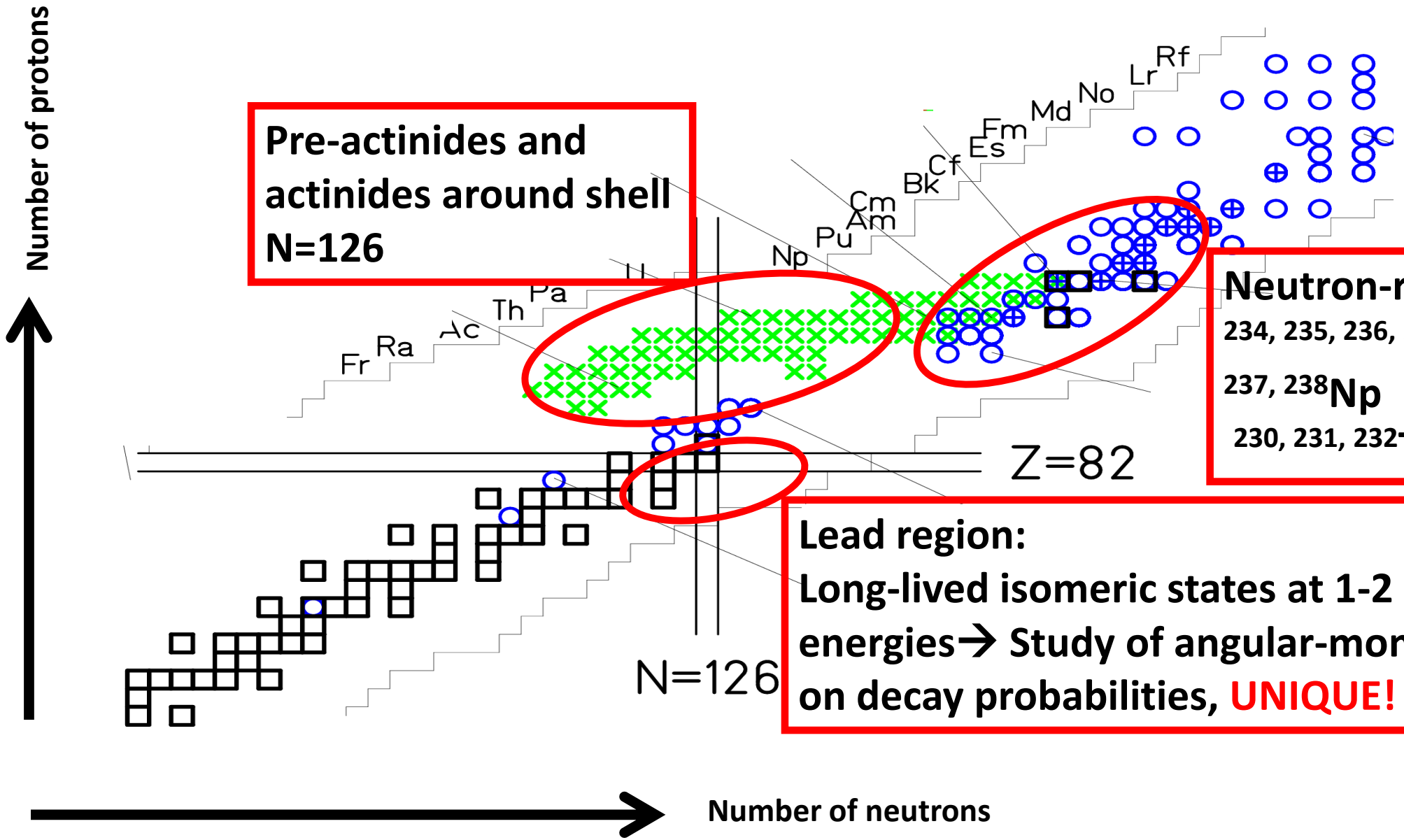




Results of feasibility studies:

- **Decay probabilities for ALL open channels can be measured simultaneously with much higher efficiencies than in direct kinematics!**
- **E* steps of ±200 keV!**
- **Set-up can be built in 2-3 years**
- **Searching for funding!**

GSI/FAIR Beams of interest



FAIR (ESR@CRYRING) offers unique possibilities for precission measurements of transfer-induced decay probabilities with which we can significantly improve model predictions of neutron-induced cross sections for astrophysics and applications in nuclear technology!