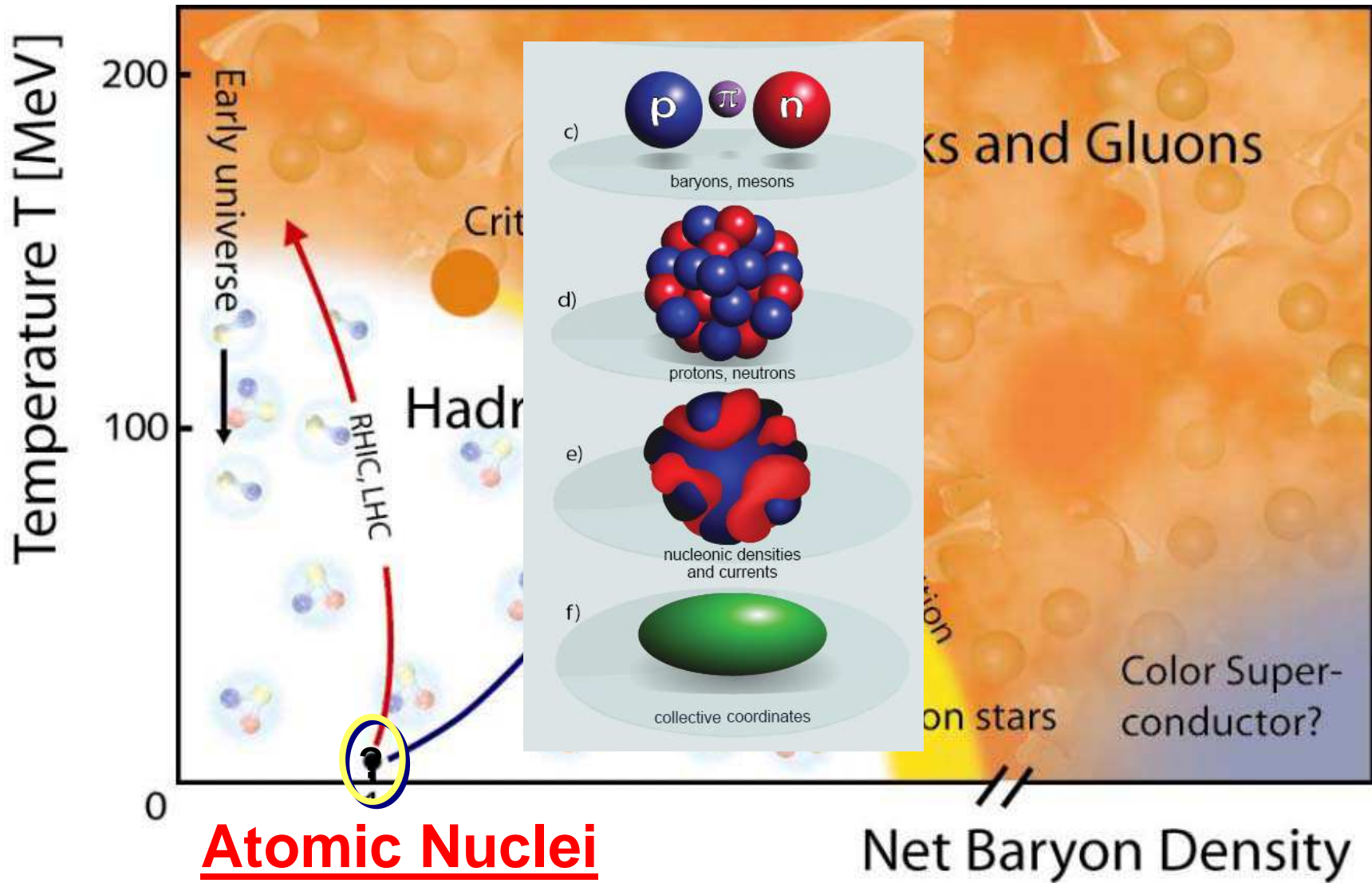


A person in a light blue jacket and dark pants is cross-country skiing on a wide, snow-covered field. The skier is in the center of the frame, moving towards the viewer. The field is marked with numerous tracks from other skiers. In the background, there are snow-covered hills and a few buildings under a clear blue sky.

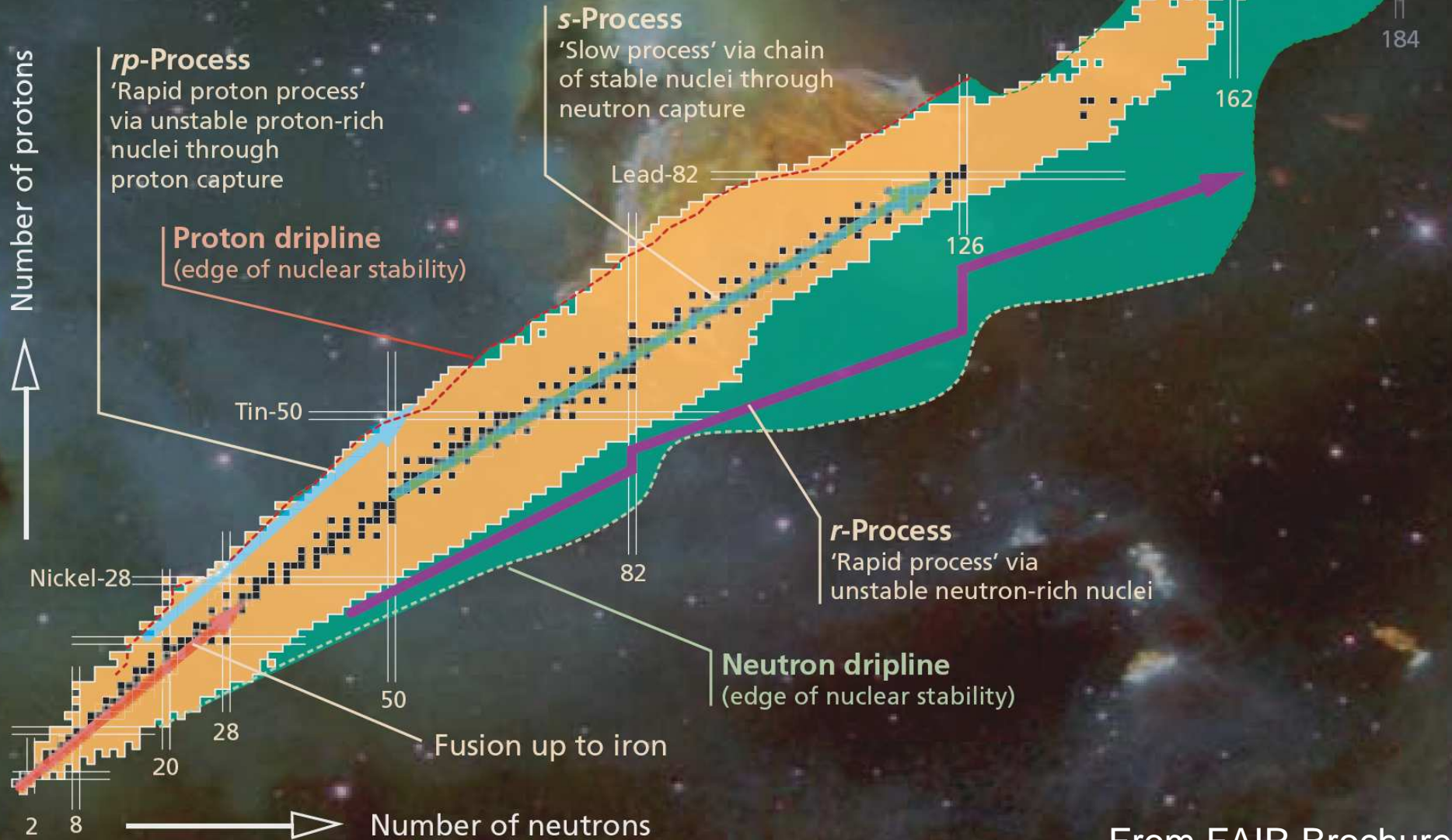
"Physics with Slow and Trapped- RI Beams -- Methods, Current Researches, and Perspectives--"

Juha Äystö
Department of Physics
University of Jyväskylä
Finland

Phase diagram of strongly interacting matter

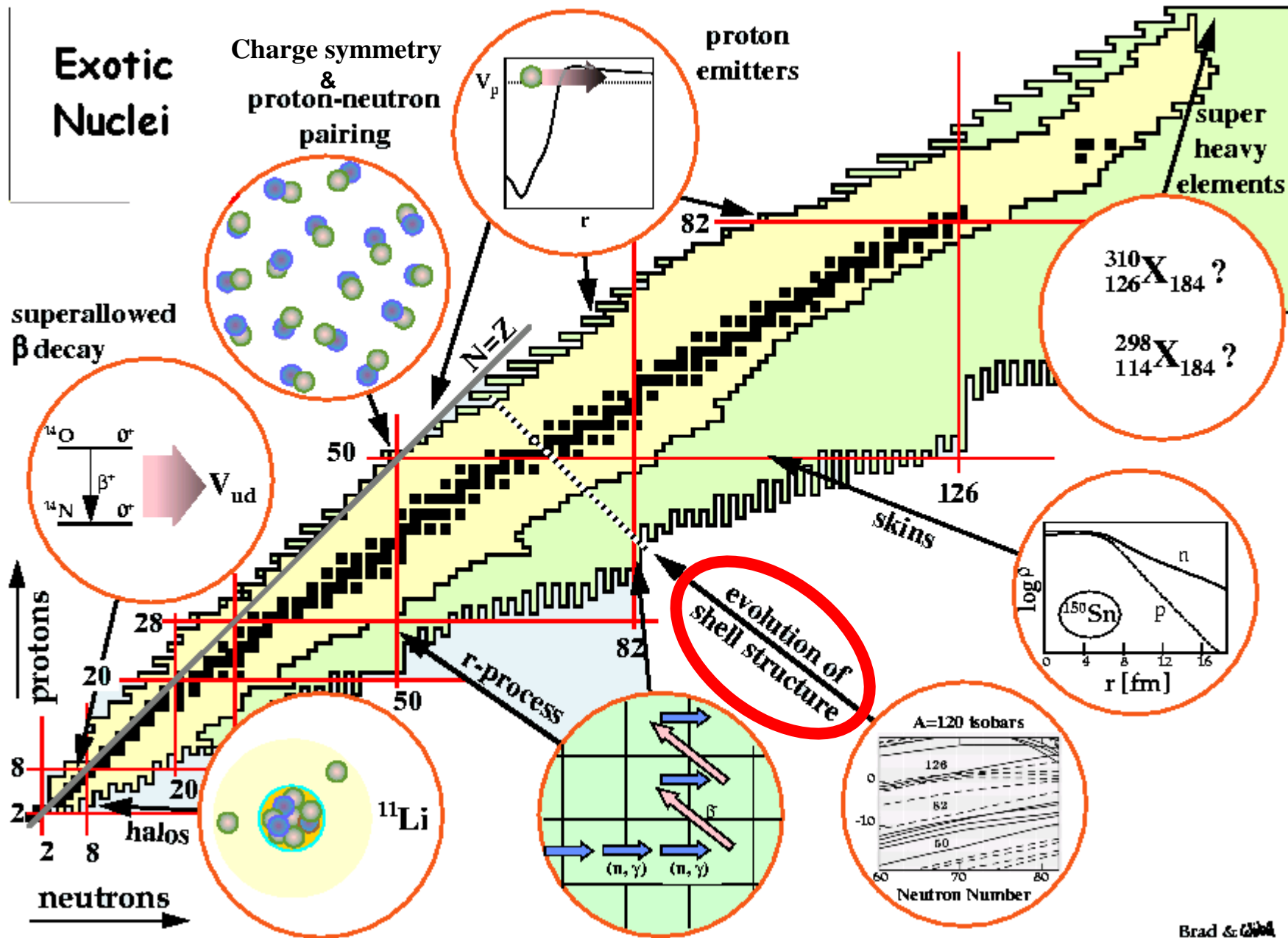


The landscape of possible nuclei

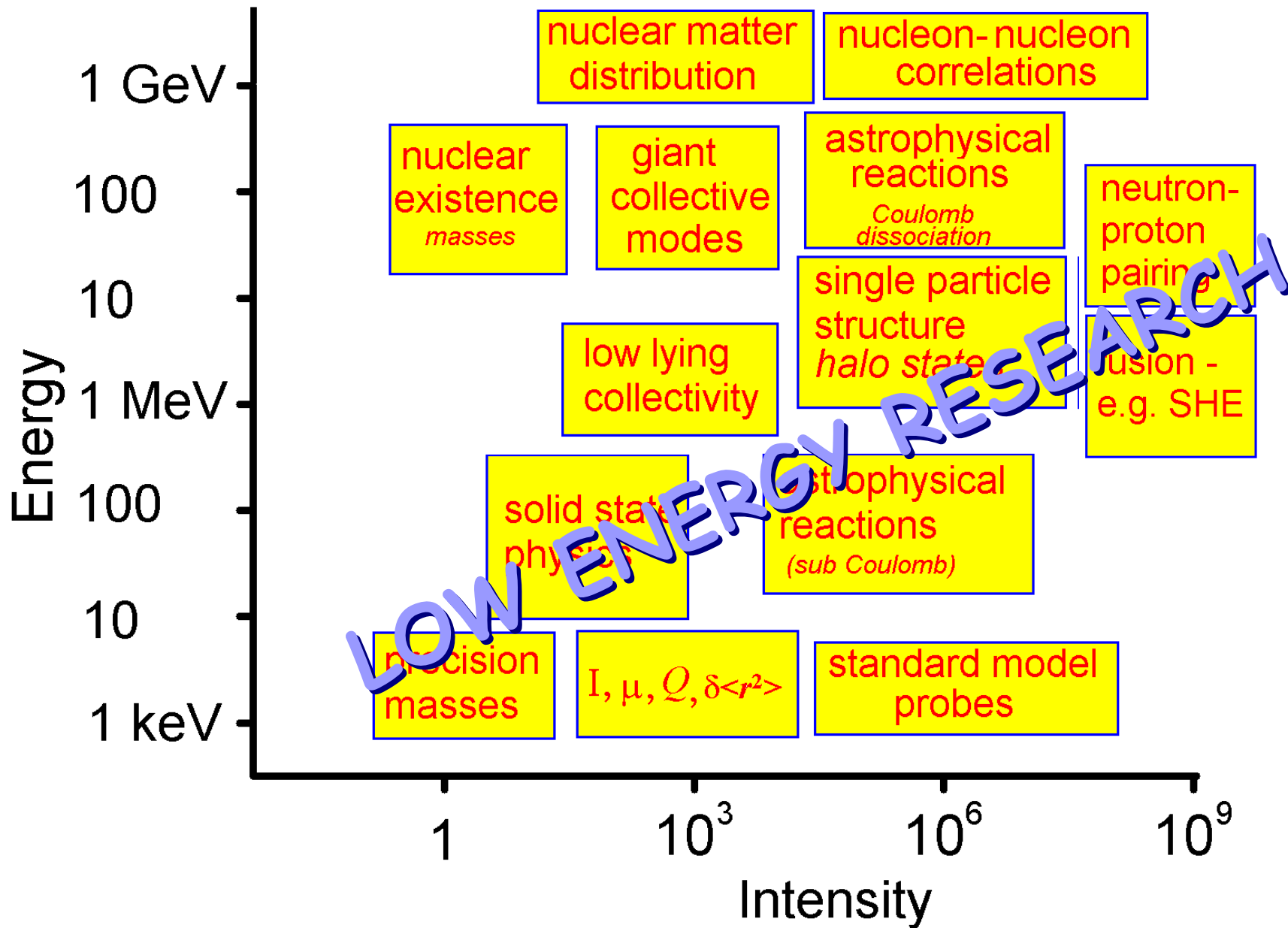


From FAIR Brochure

Exotic Nuclei



RIB Physics Reach





Methods to produce slow RI beams based on ISOL or IGISOL techniques

Thanks to: M. Lindroos + ISOLDE team, I. Moore, H. Penttilä + IGISOL team

In Flight

ISOL

heavy ions

light ions,
neutrons

driver accelerator

thin target

high-temperature thick target

fragment separator

ion source

RILIS

IGISOL

mass separator

experiment

gas
catcher
(ms)

NEW !!!

Cooling & trapping
Charge breeding

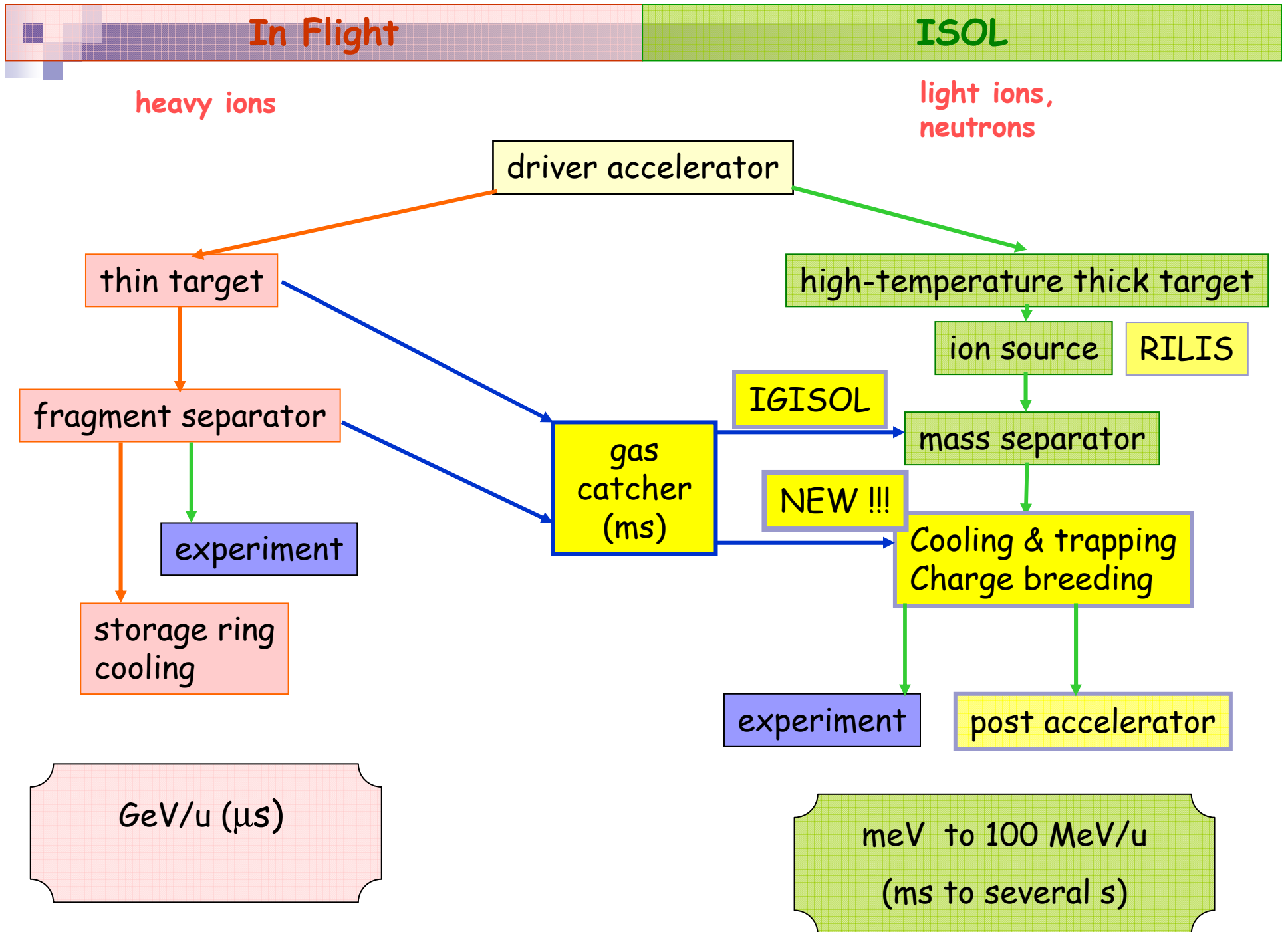
storage ring
cooling

experiment

post accelerator

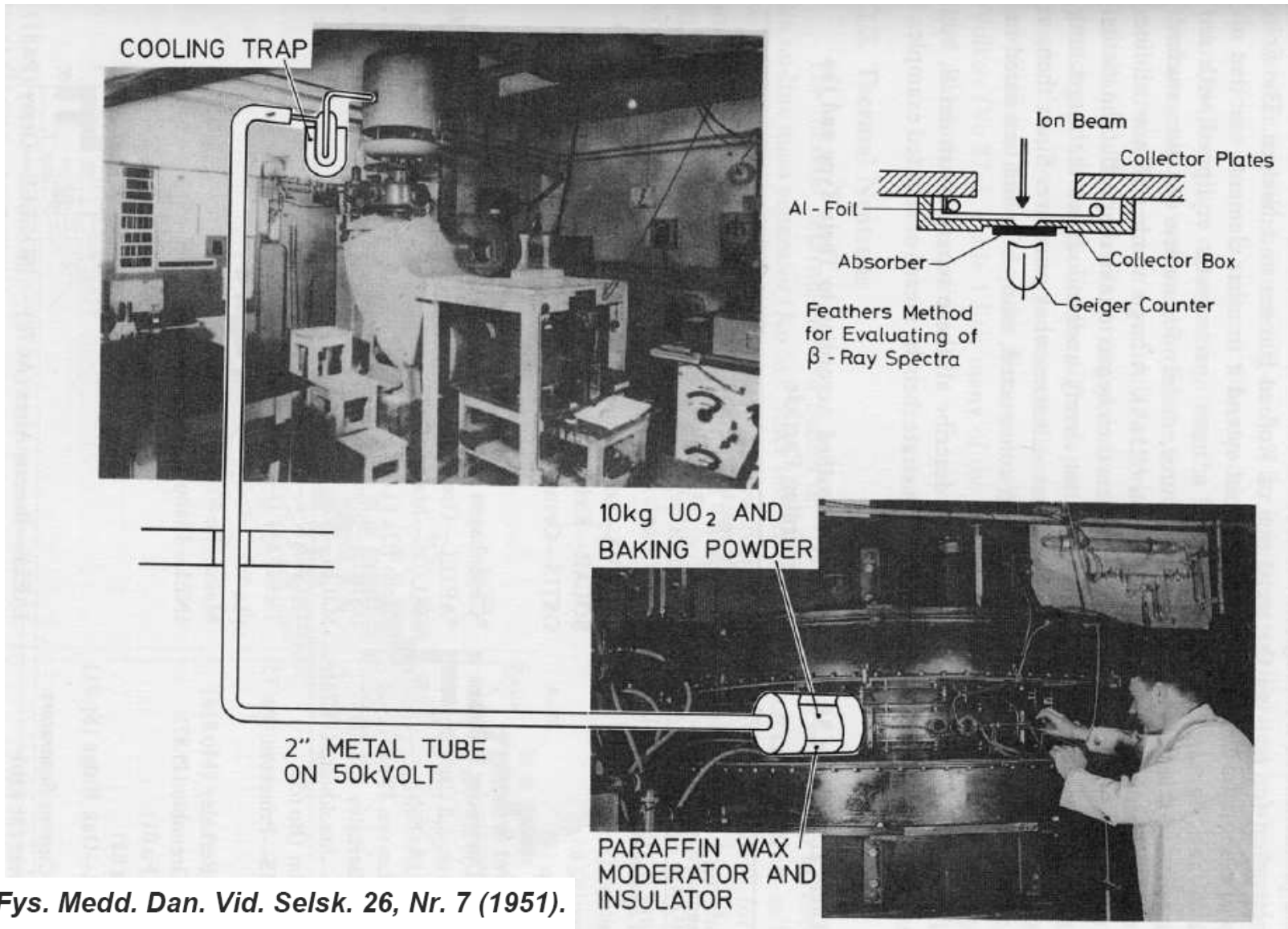
GeV/u (μ s)

meV to 100 MeV/u
(ms to several s)



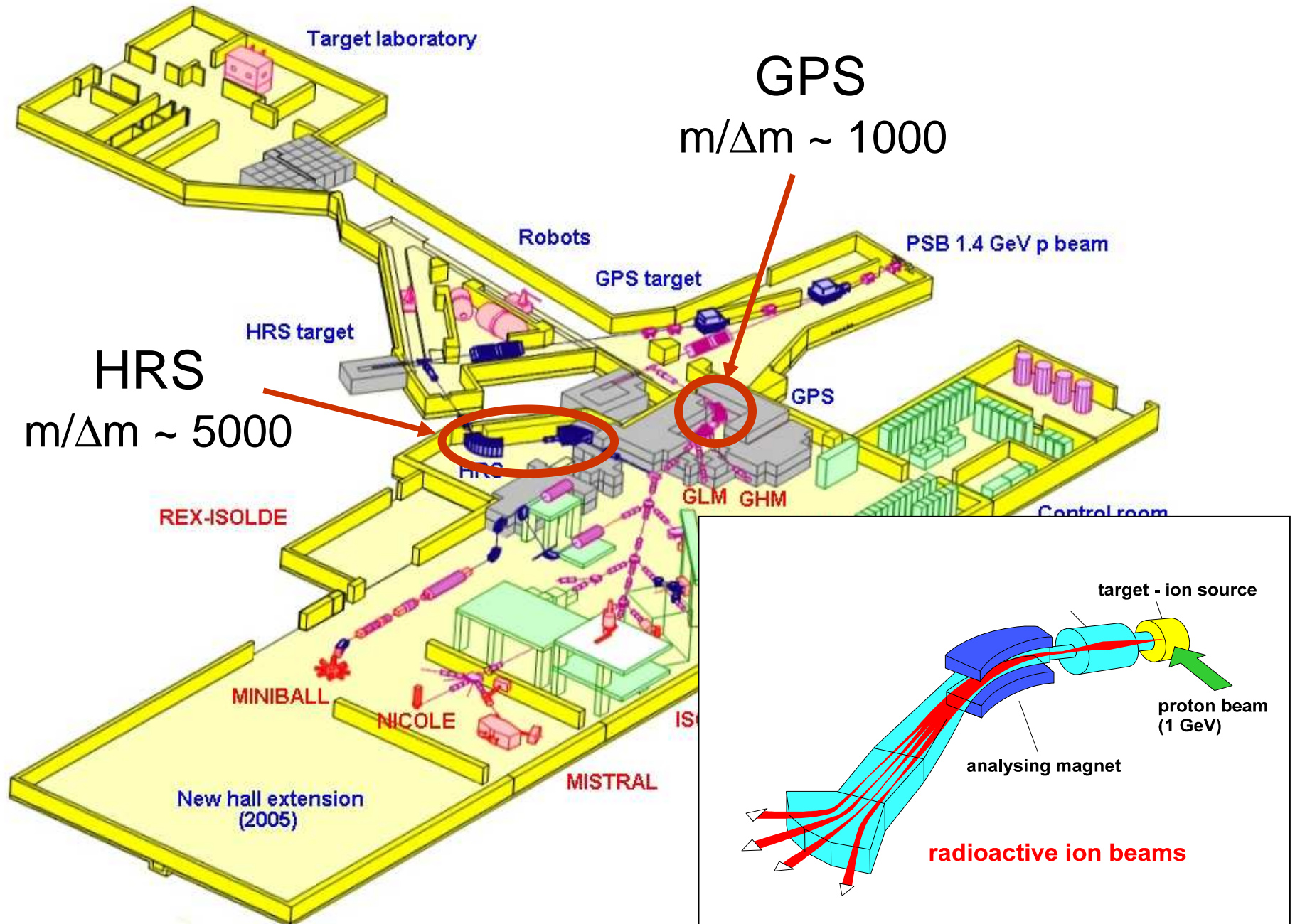
The first ISOL system operated in Copenhagen in the 1950s

"Production of n-rich Kr isotopes for ν -physics"



Mat. Fys. Medd. Dan. Vid. Selsk. 26, Nr. 7 (1951).

Radionuclide production and mass separation



Optimize RIB intensity

Φ : CERN-PSB

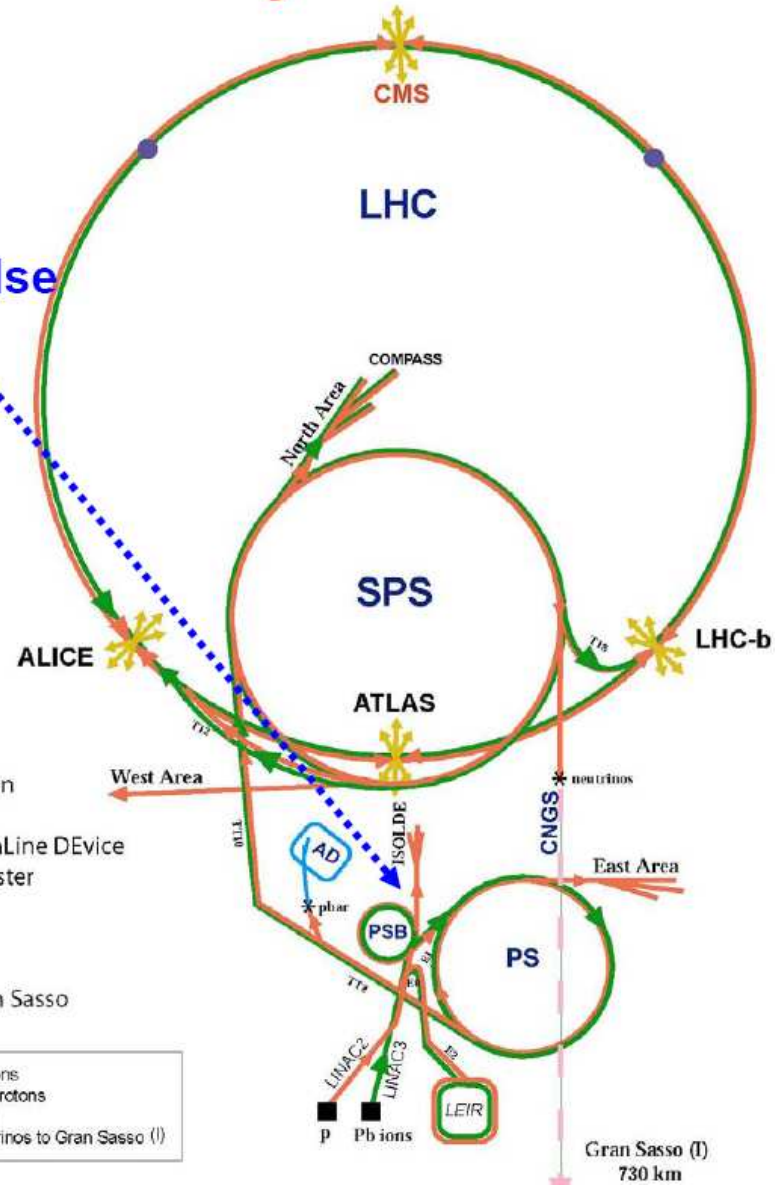
$E_p = 1.4 \text{ GeV}$

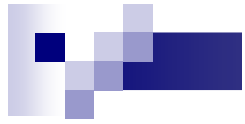
$3 \cdot 10^{13}$ protons/pulse

$I_{\text{average}} = 2.5 \mu\text{A}$

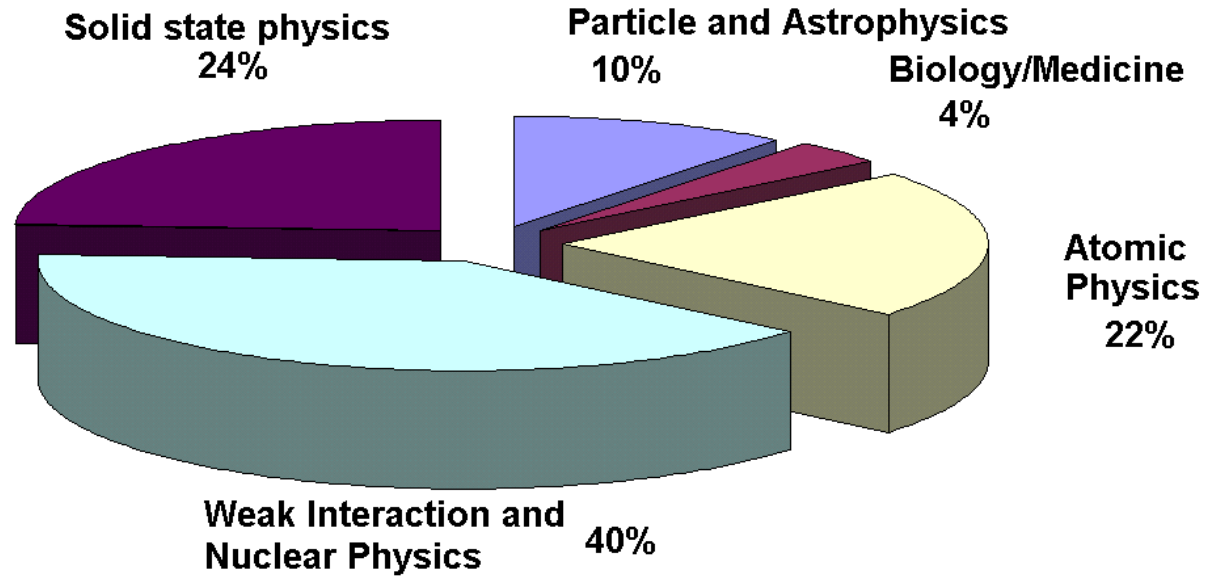
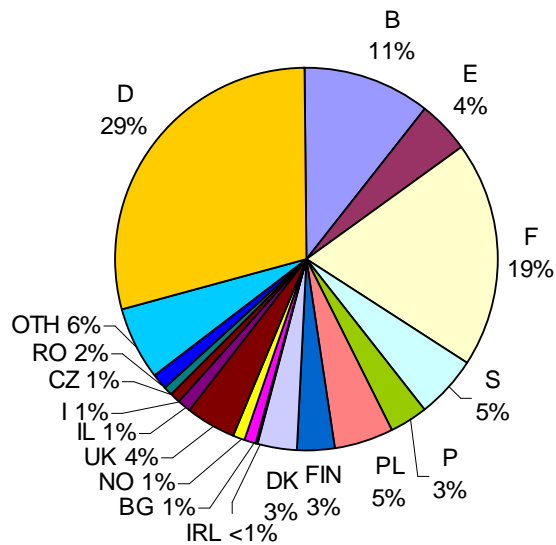
$P_{\text{average}} = 4 \text{ kW}$

LHC: Large Hadron Collider
 SPS: Super Proton Synchrotron
 AD: Antiproton Decelerator
 ISOLDE: Isotope Separator OnLine DEvice
 PSB: Proton Synchrotron Booster
 PS: Proton Synchrotron
 LINAC: LINear ACcelerator
 LEIR: Low Energy Ion Ring
 CNGS: Cern Neutrinos to Gran Sasso



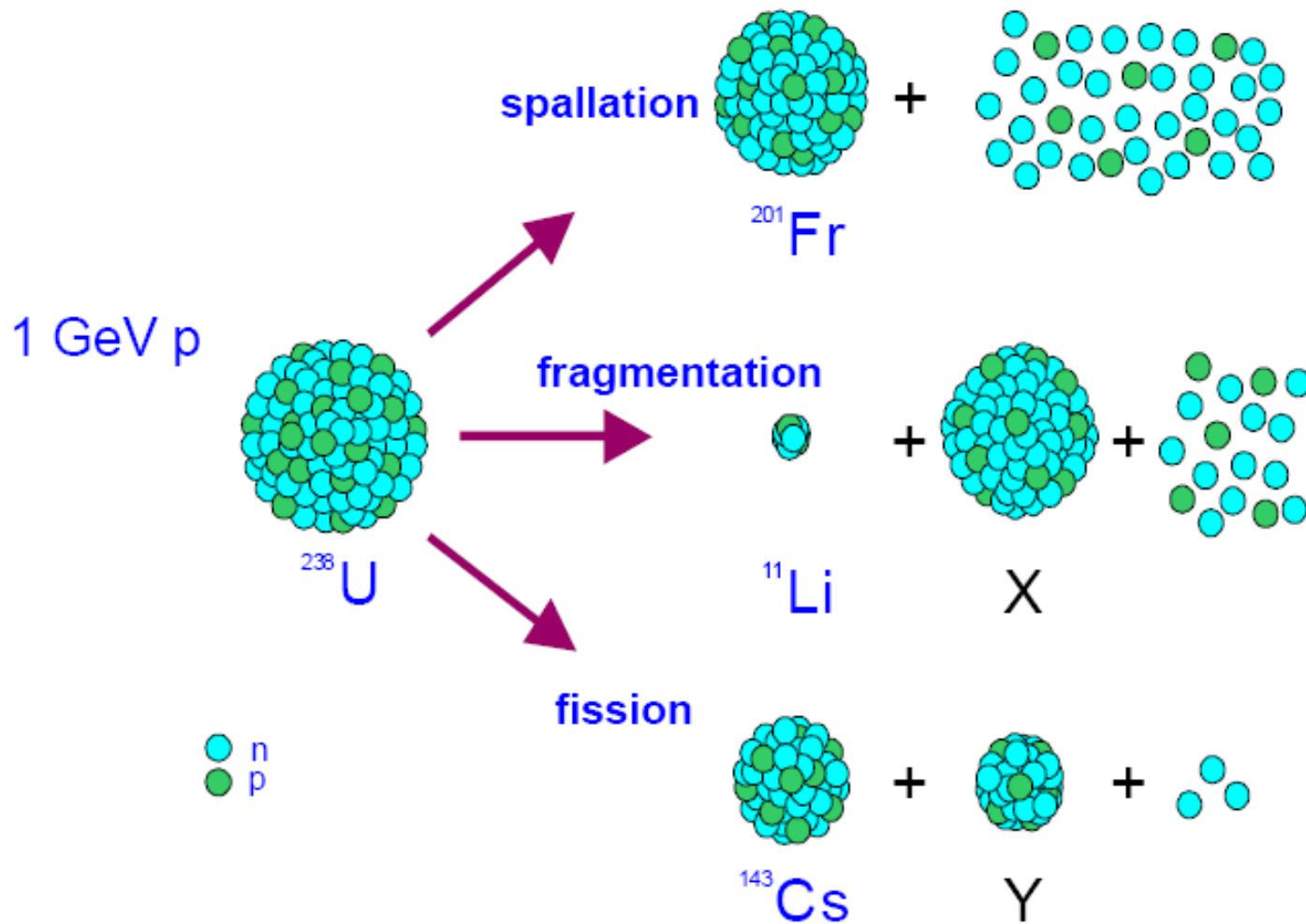


Users & Science



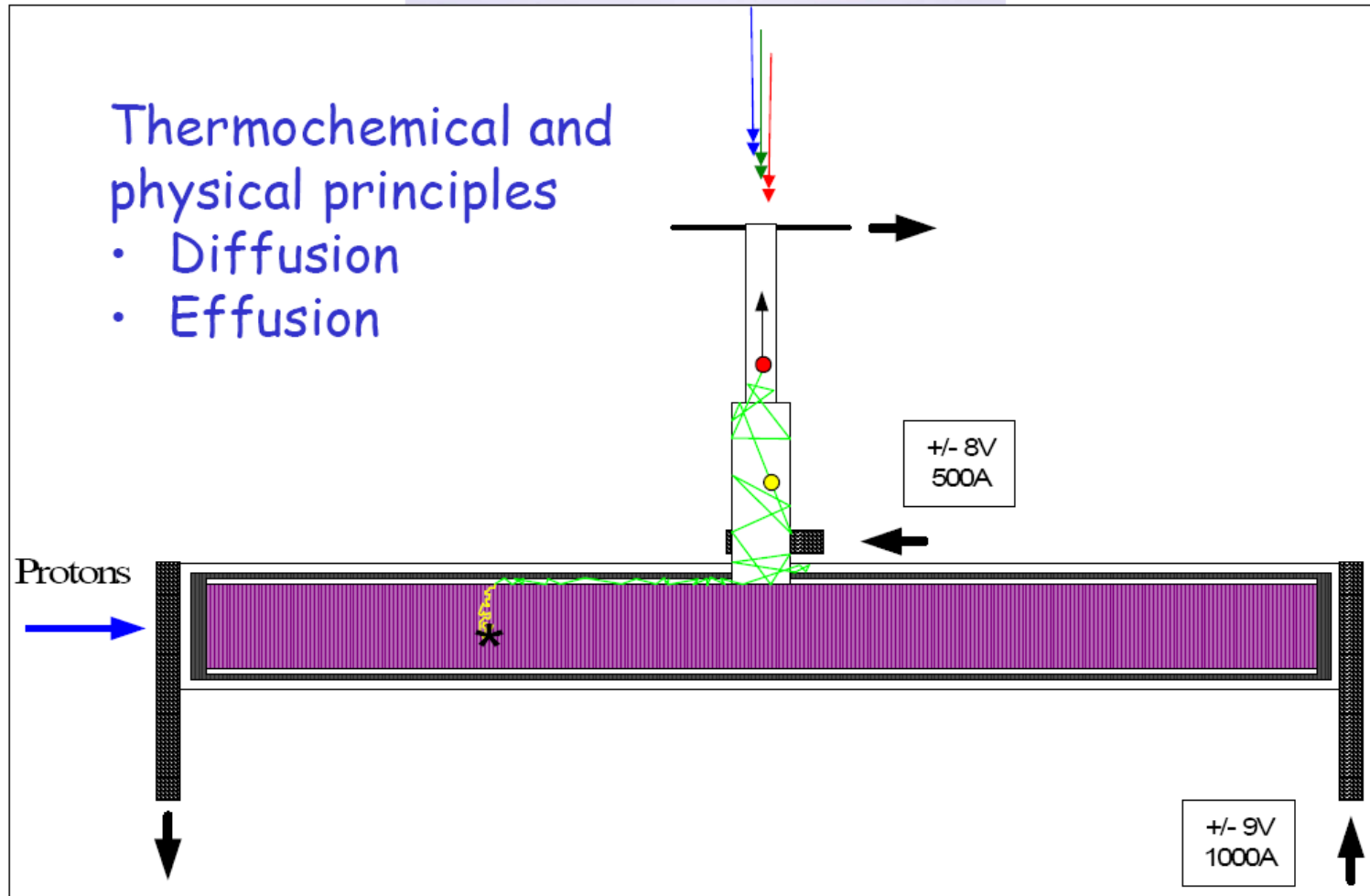
450 users (7% total CERN)
potentially 1000 users with upgrade
25 countries; 100 institutions
175 projects (4 years)

Production at ISOLDE



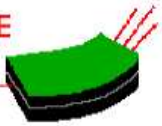


The ISOL target

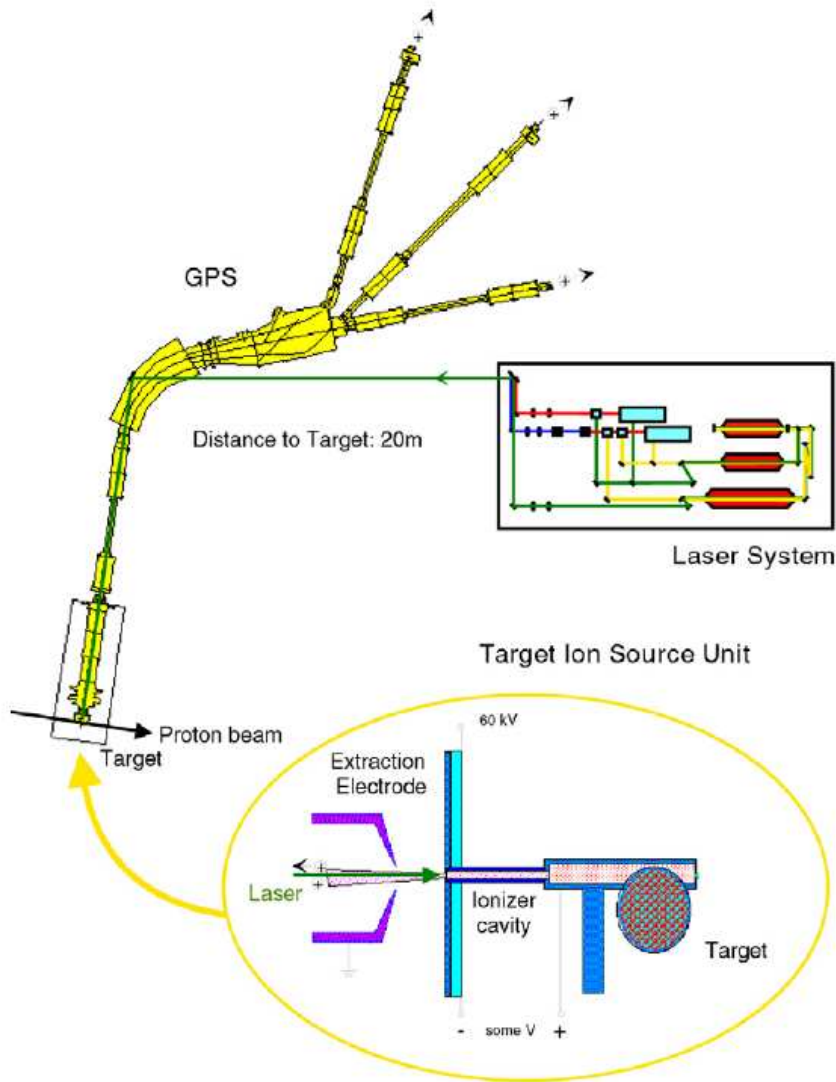


EPAC-04
Mats Lindroos

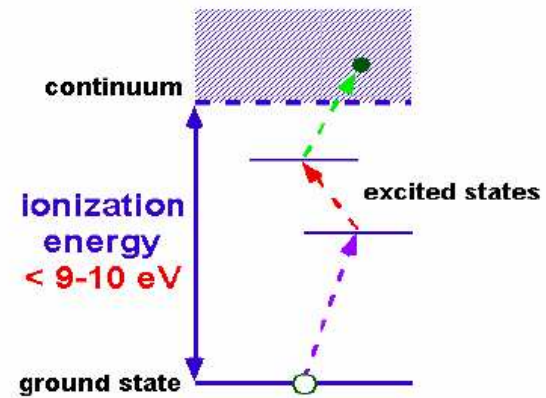
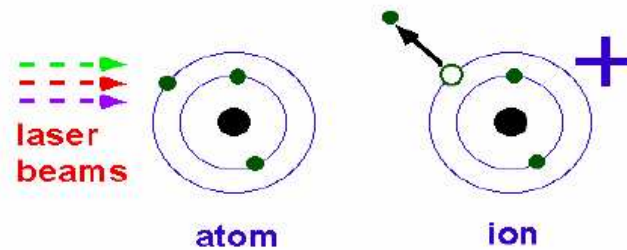
ISOL facilities



Resonance Ionization Laser Ion Source



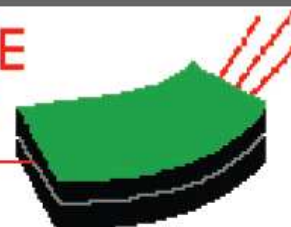
Laser Ionization



Isotope selection

- Ionisation to $q = 1+$
- Acceleration to 60 keV
- Mass selection by magnetic deflection

ISOLDE
CERN

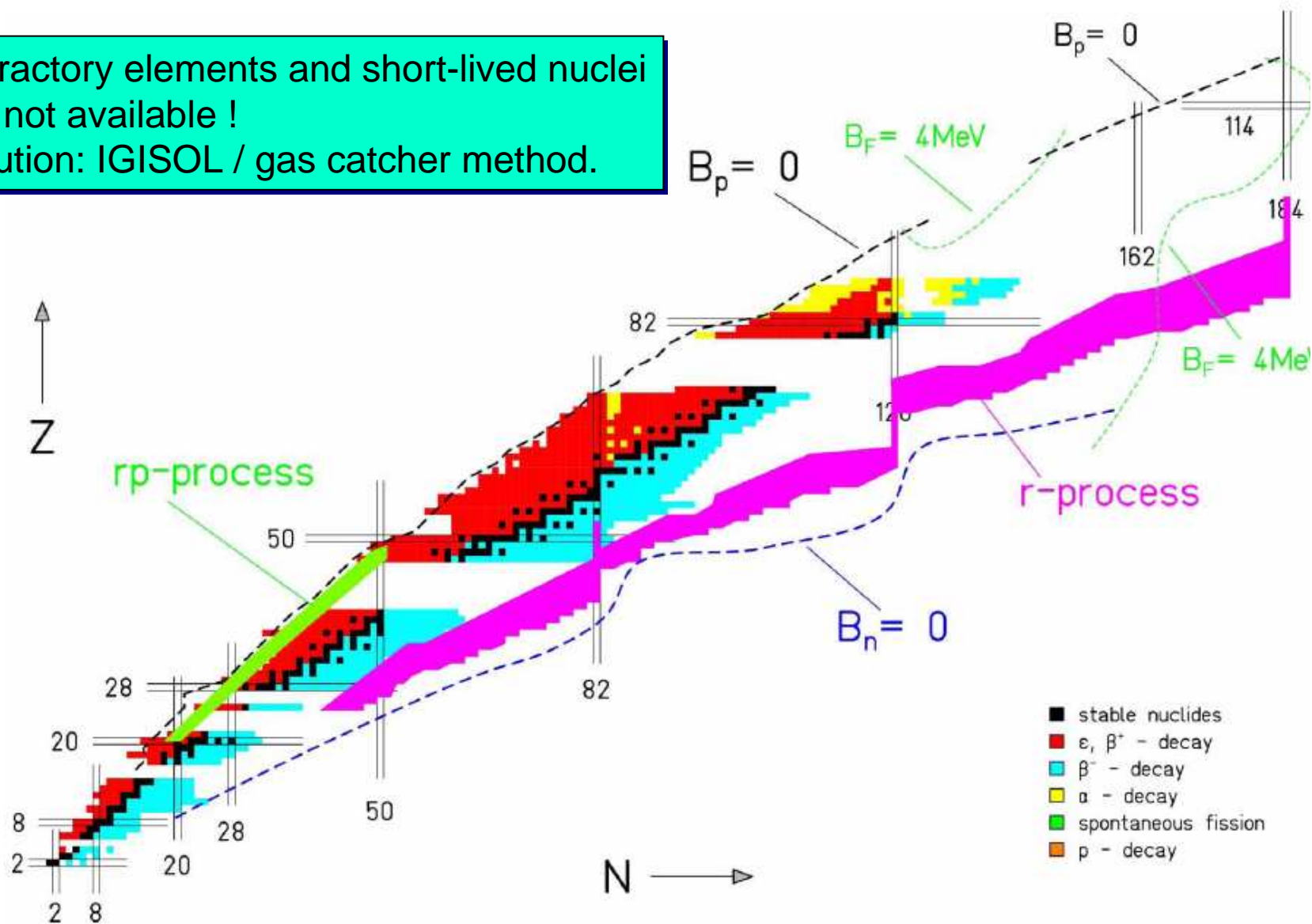


Z selection by chemically selective step

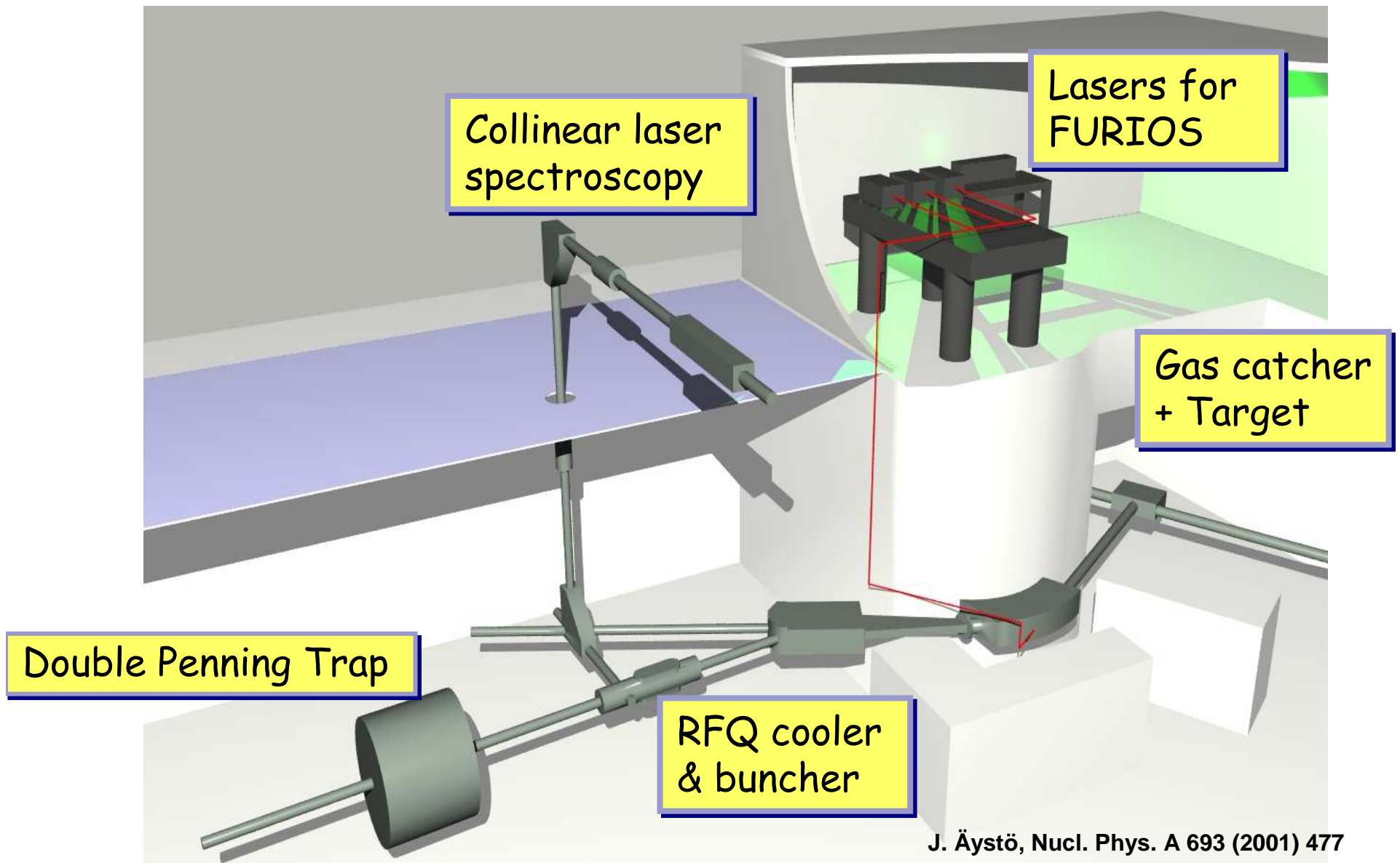


ISOLDE isotopes available for experiments

Refractory elements and short-lived nuclei are not available !
Solution: IGISOL / gas catcher method.

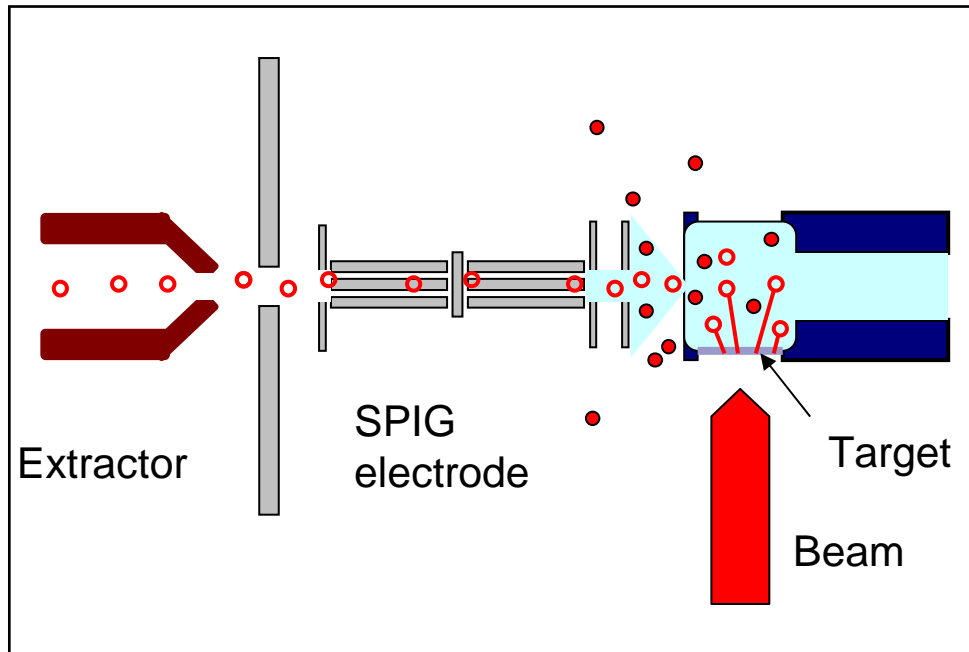


IGISOL-facility



Ion guide principle

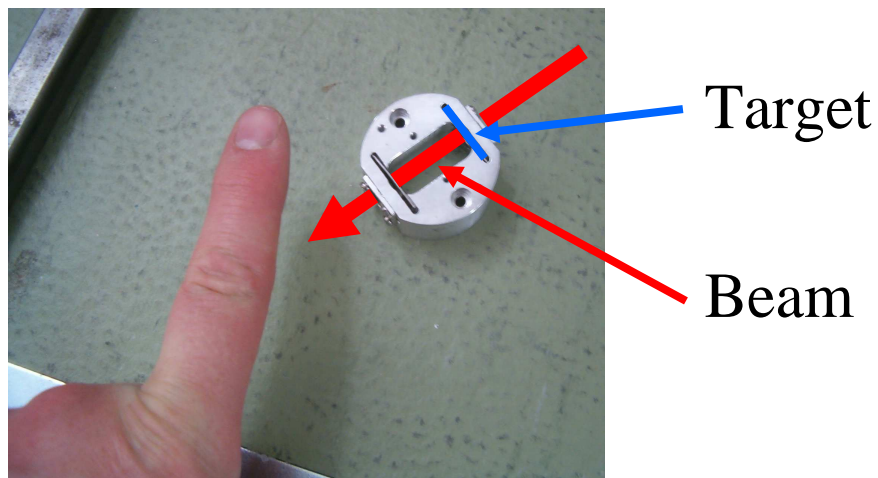
J. Äystö, Nucl. Phys. A 693 (2001) 477



Based on survival of primary ions in helium buffer gas

Charge state concentration:
(0), +1, (+2)

Fast gas flow required to prevent neutralisation



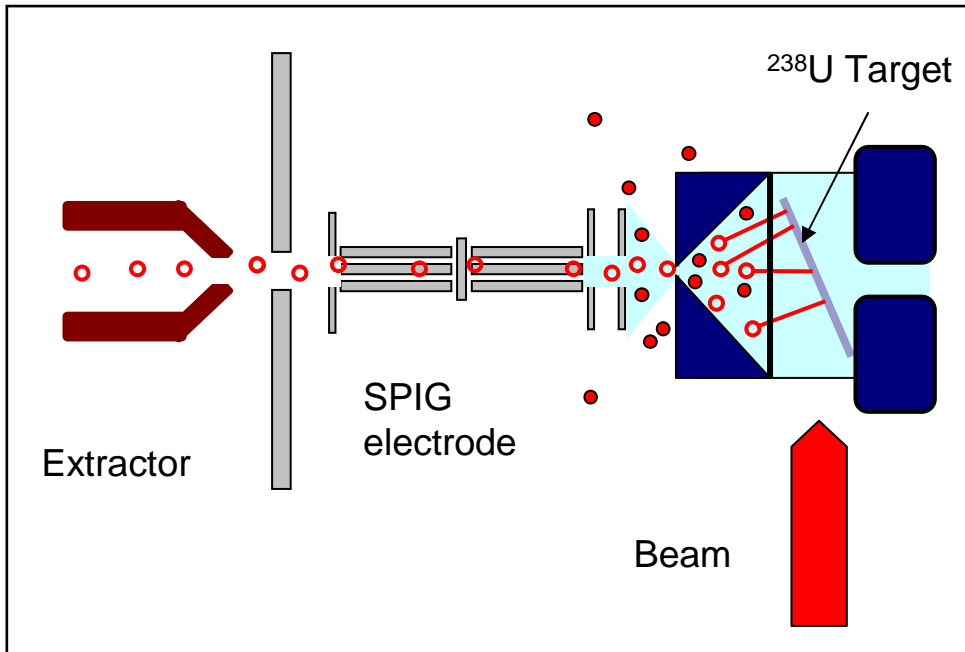
Produces ions of any element

All ions are primary ions from reaction

Delay time (a) few milliseconds

Efficiency: 0.1 to 10 %

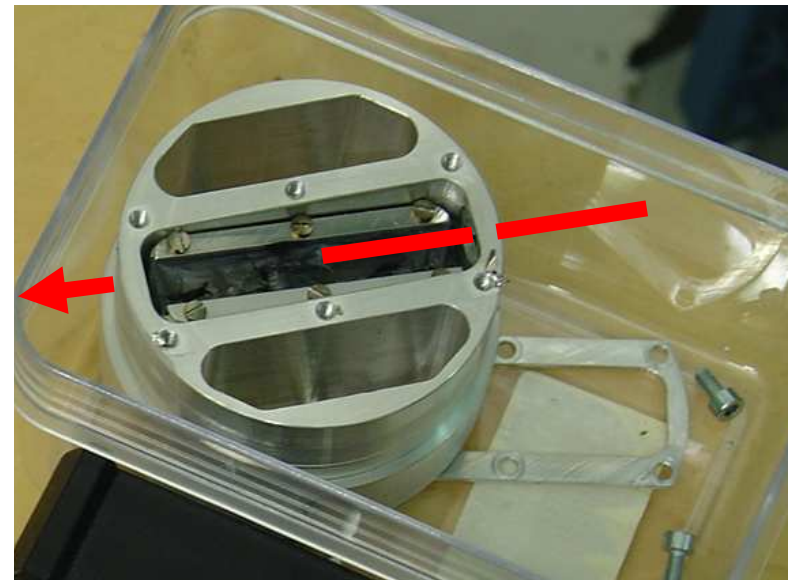
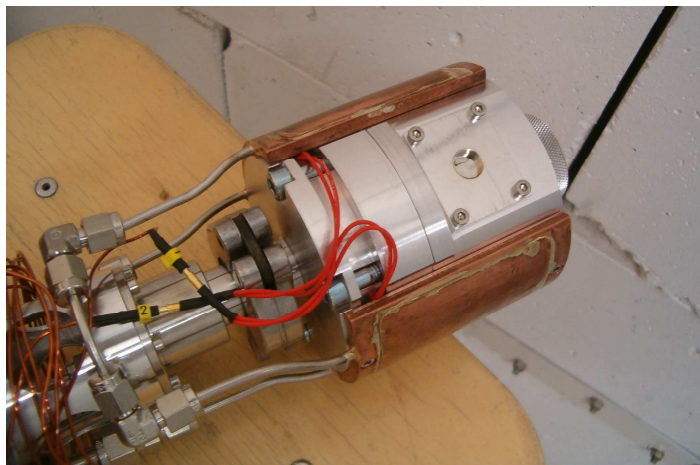
Fission ion guide



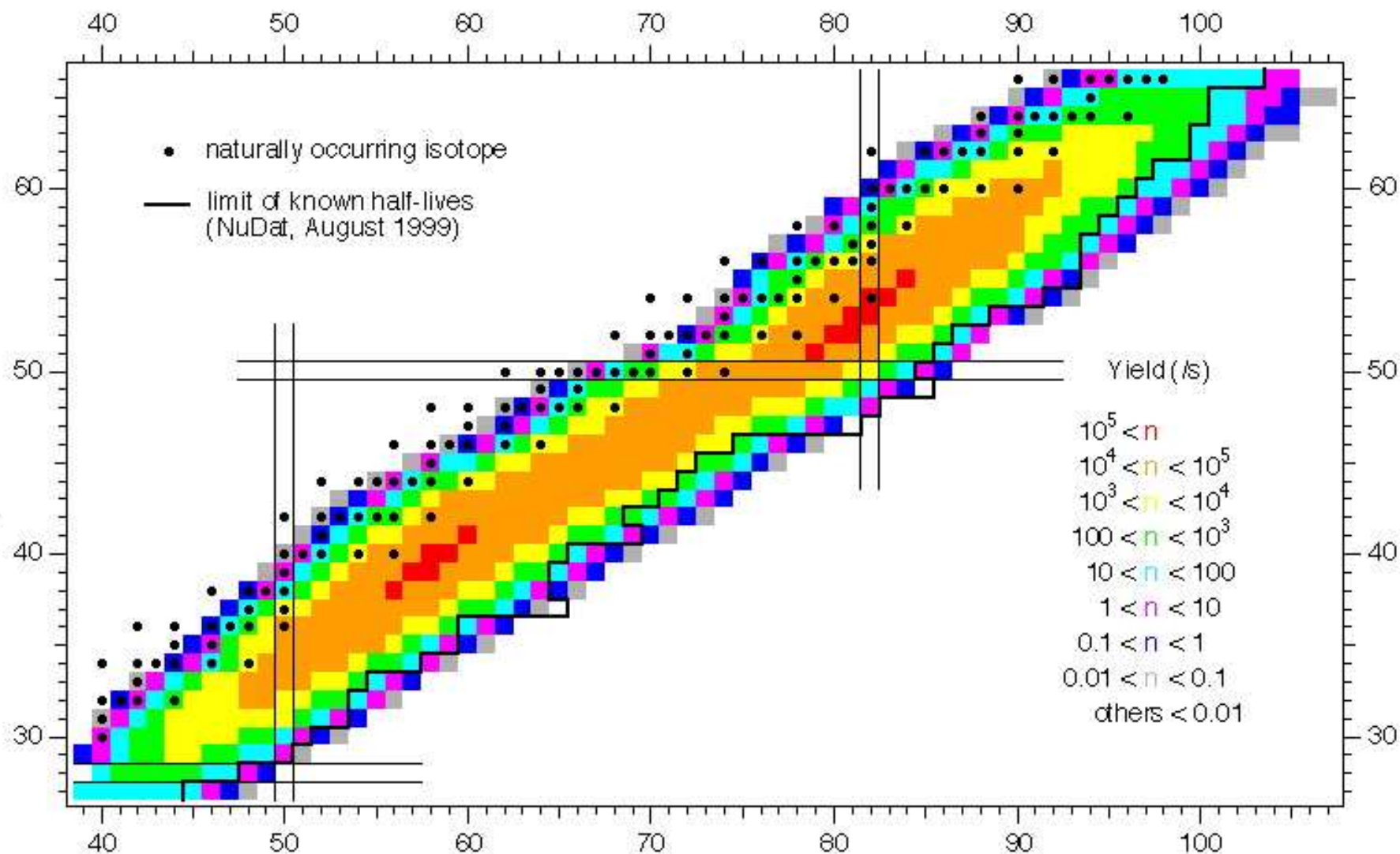
Ion neutralisation rate related to free electron density \rightarrow
two separated gas volumes

Tilted target to increase the effective thickness

Production rates: 10^5 ions/s per isobar



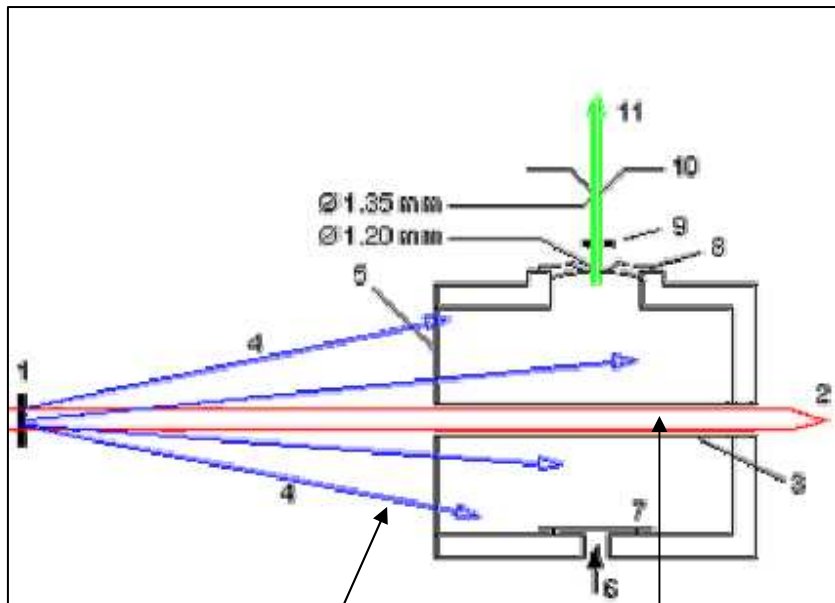
$^{238}\text{U}(p,f)$ -reaction @ 30 MeV and 10-50 μA



Yields from theoretical cross sections, V. Rubchenya, Phys. Rev. C75 (2007) 054601

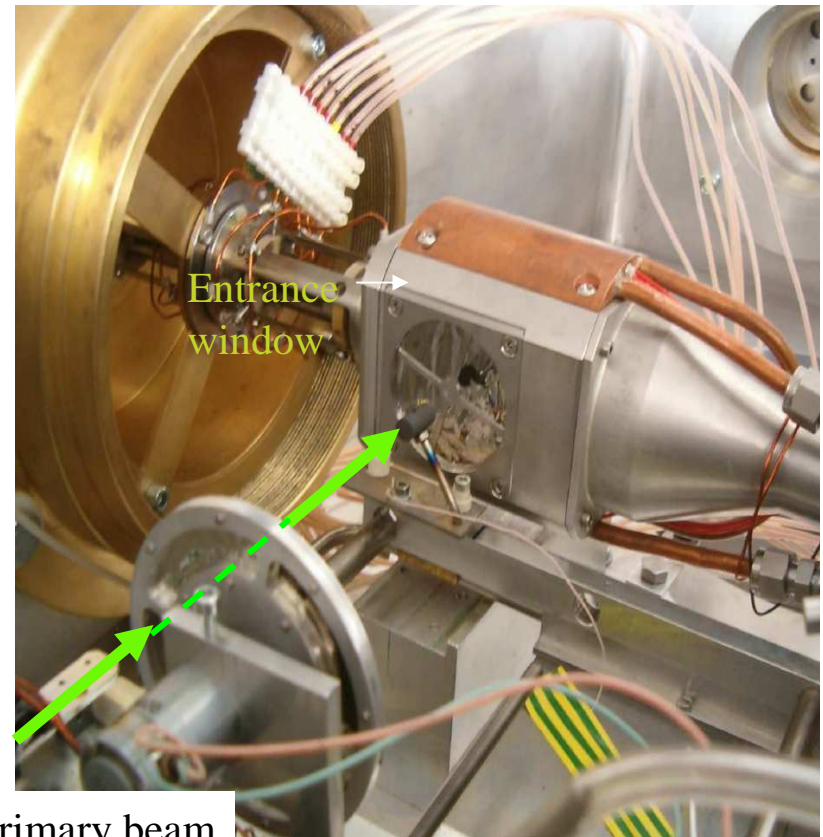
Ion Guide for Heavy Ion induced reactions

"Shadow method to remove
Primary beam"
→ Reduce "plasma effect"



Recoil ions

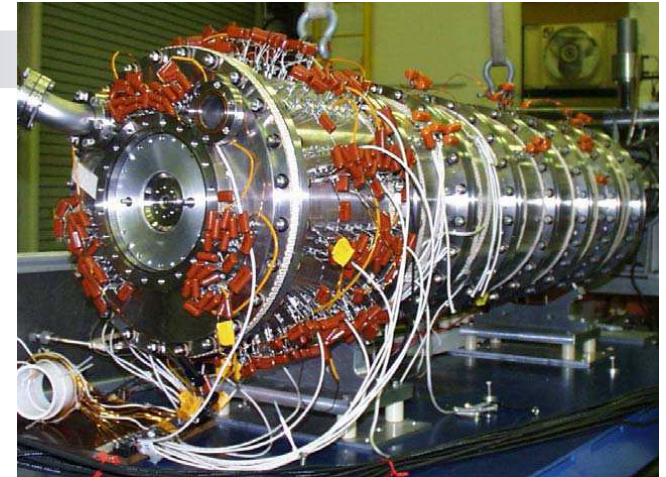
Primary beam



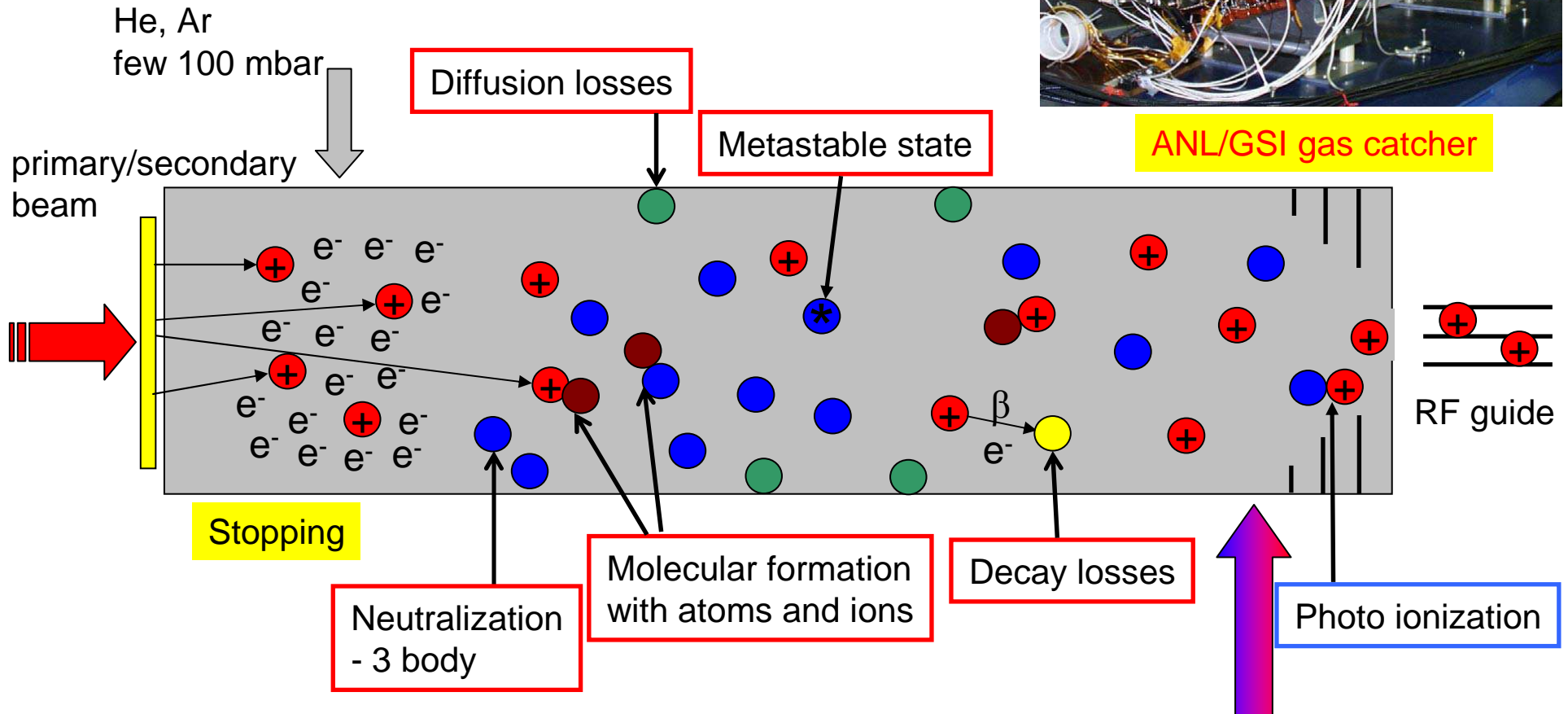
Primary beam

Gas catcher principle*

- High density gases to stop energetic particles
- High ionization potential of noble gas atoms prevents charge exchange between ions and buffer gas atoms – long survival



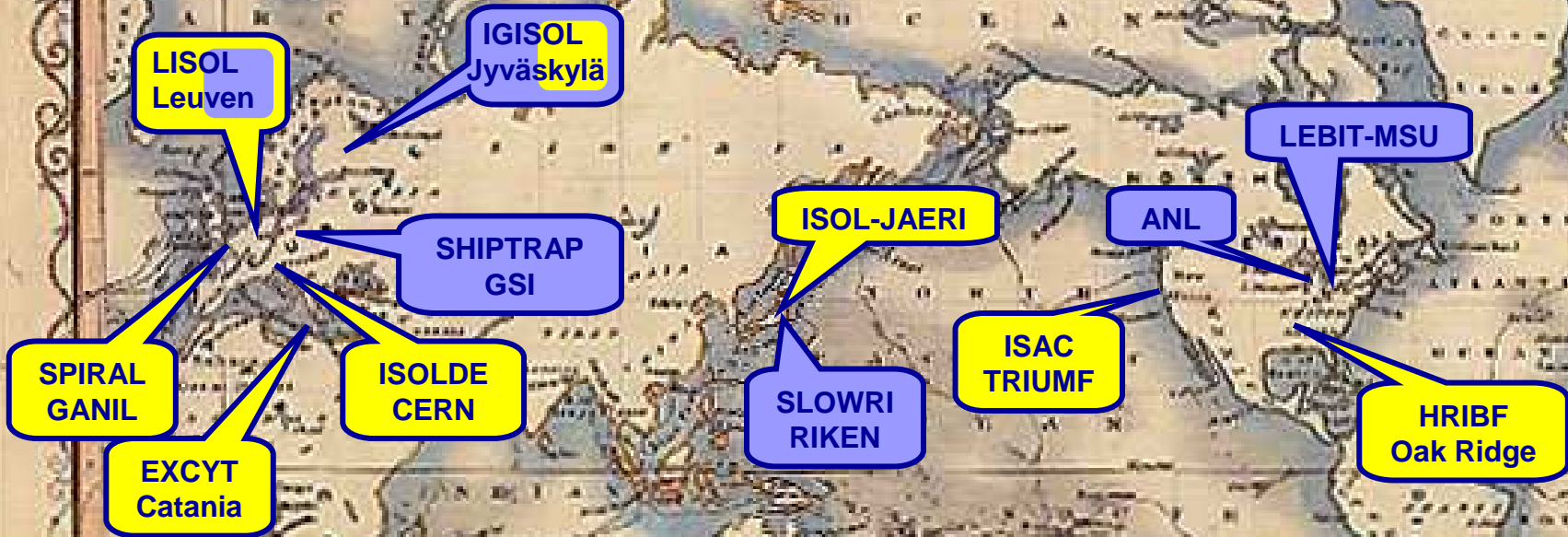
ANL/GSI gas catcher



DC electrical fields for guidance, RF carpets, funnels and walls incorporated and laser ionization

(* Possible solution for SLOWRI at RIKEN and NUSTAR at FAIR)

THE WORLD
of
ISOL facilities



+ IGISOLs at Sendai and Warsaw

Thick target ISOL

IGISOL / gas catcher