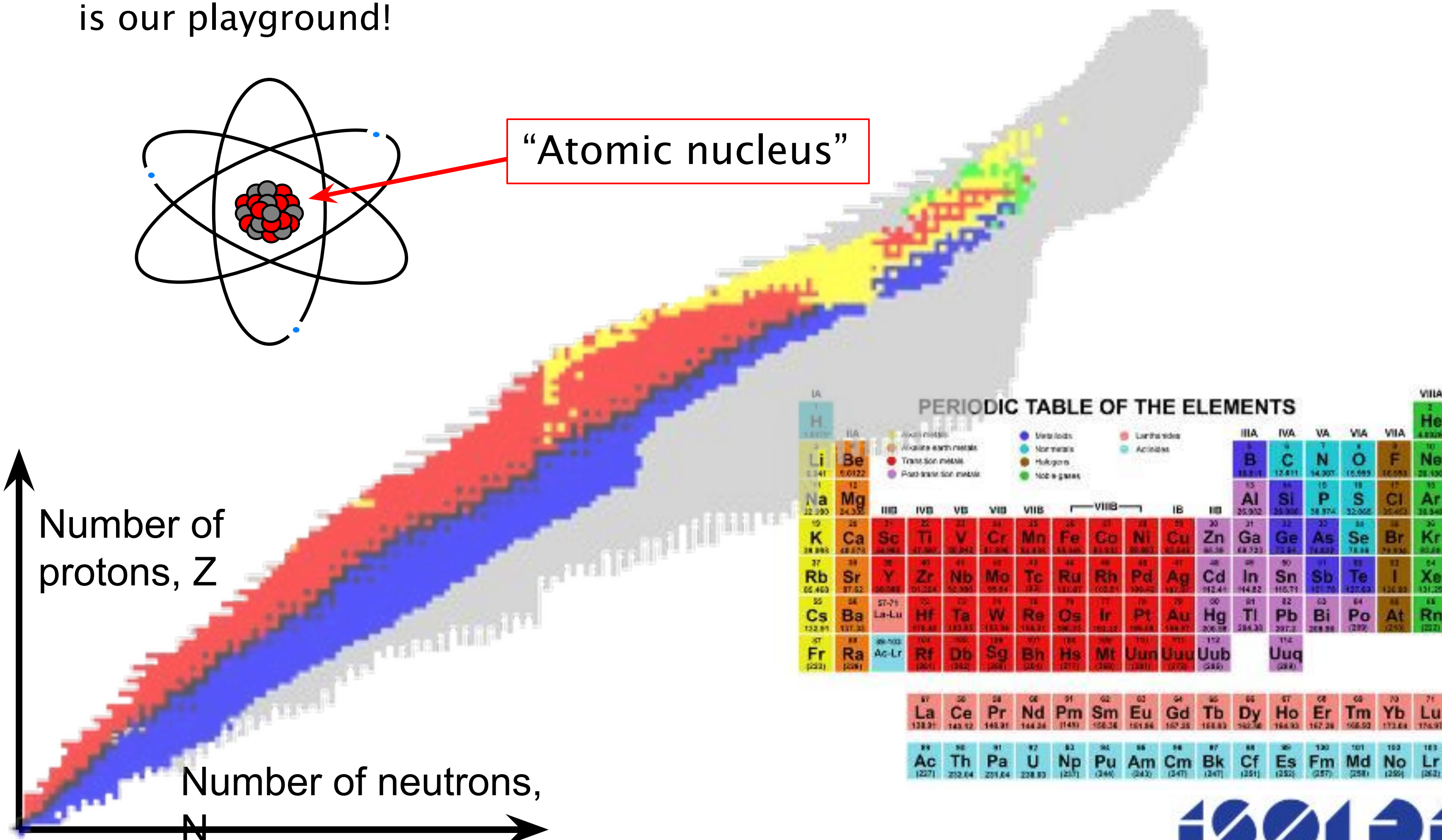
ISOLDE

CERN's Radioactive Ion Beam Facility

The nuclear playground

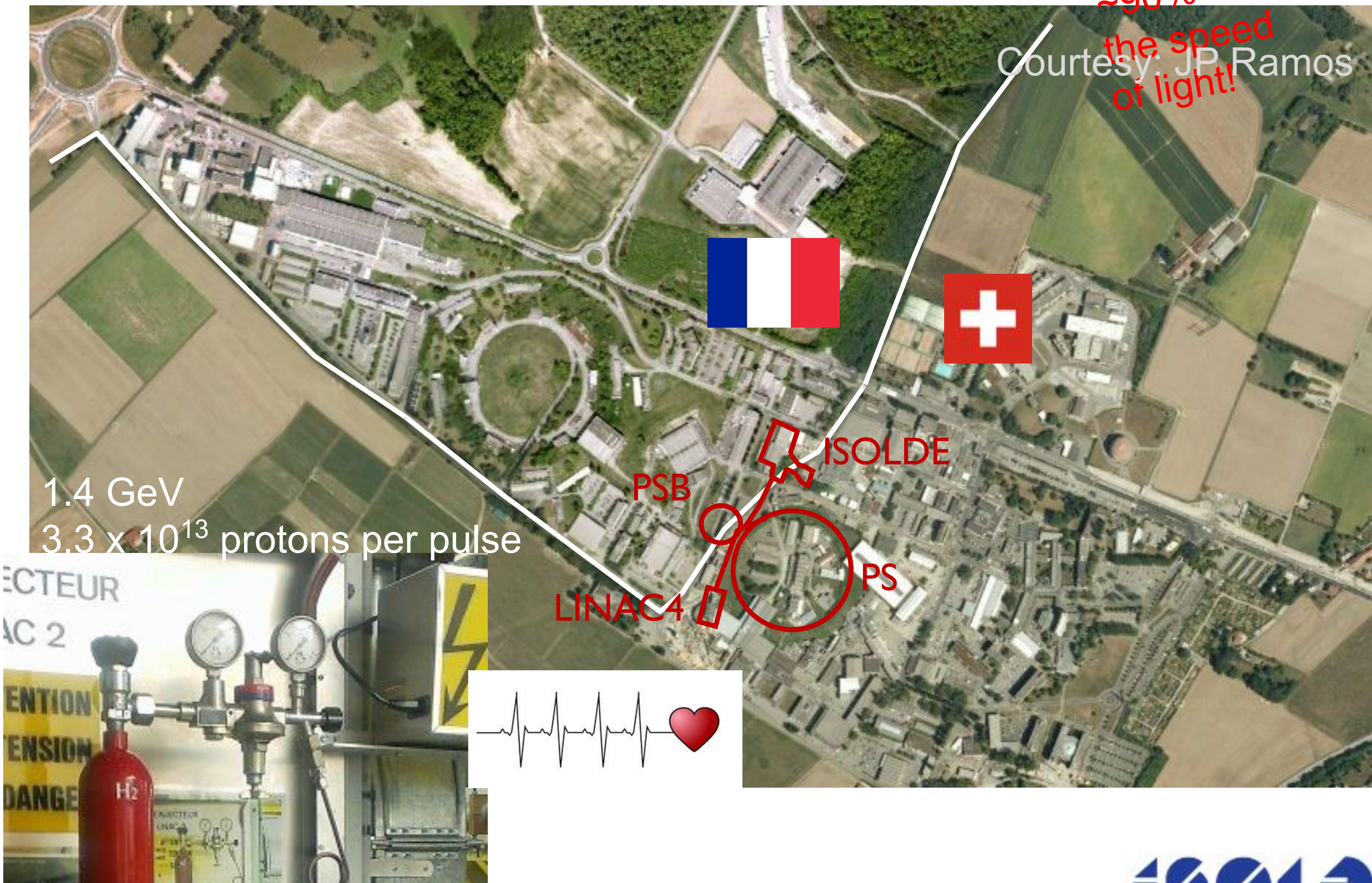
- ISOLDE is a radioactive isotope facility where the nuclear chart is our playground!



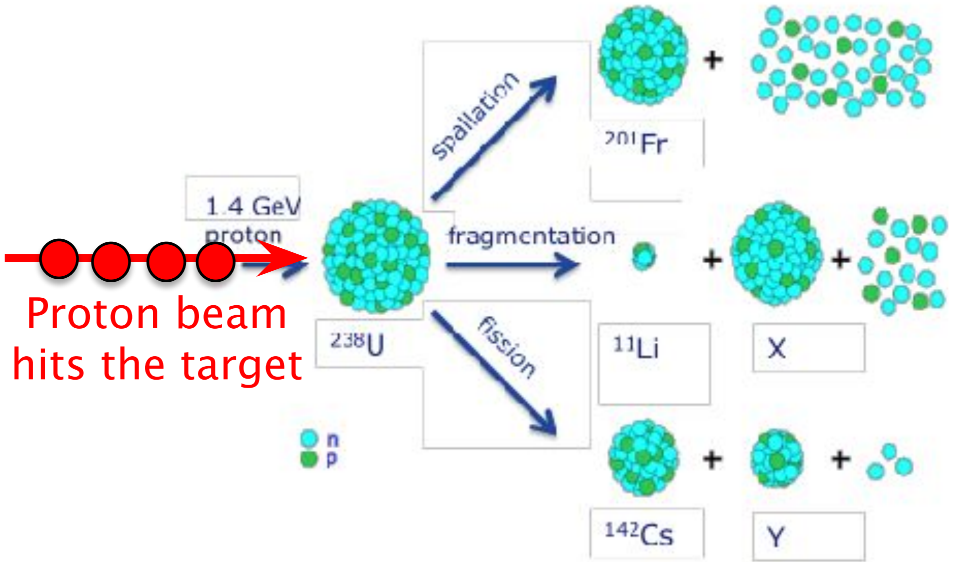
Why at CERN?

At 1.4 GeV, protons travel at ~90% of the speed of light!

ISOLDE takes more than half of CERN's protons!



Production: Modern-day alchemy

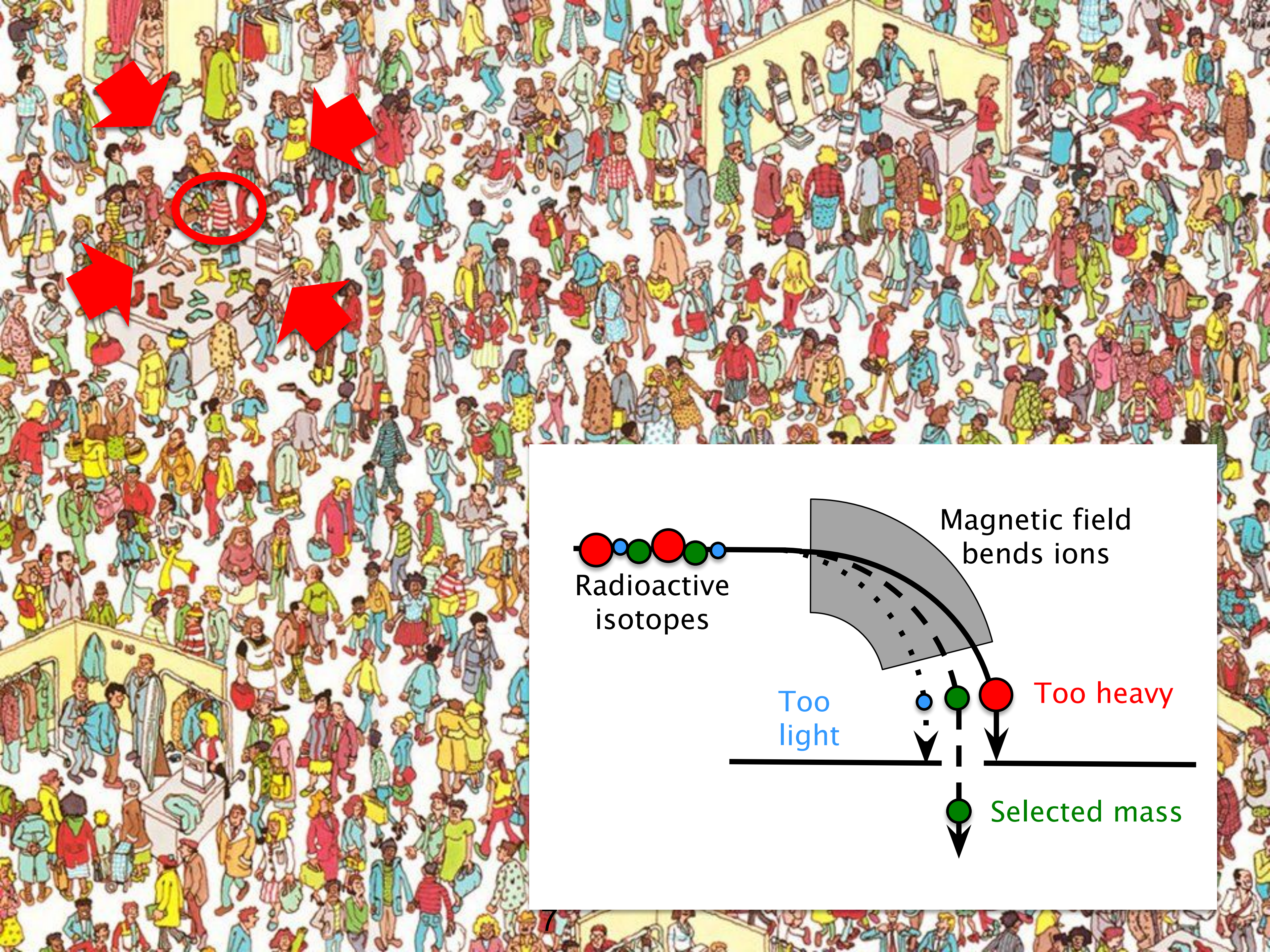


- The protons split up the heavy nucleus to produce a wide variety of nuclei **simultaneously**!
- Requirements for experiment:
  - High production
  - Pure radioactive beams: 1 kind of isotope
- Different stages of preparation
  - Production
  - Ionization
  - Separation

Gold is one of the chemical elements produced at ISOLDE, both stable as well as radioactive isotopes!

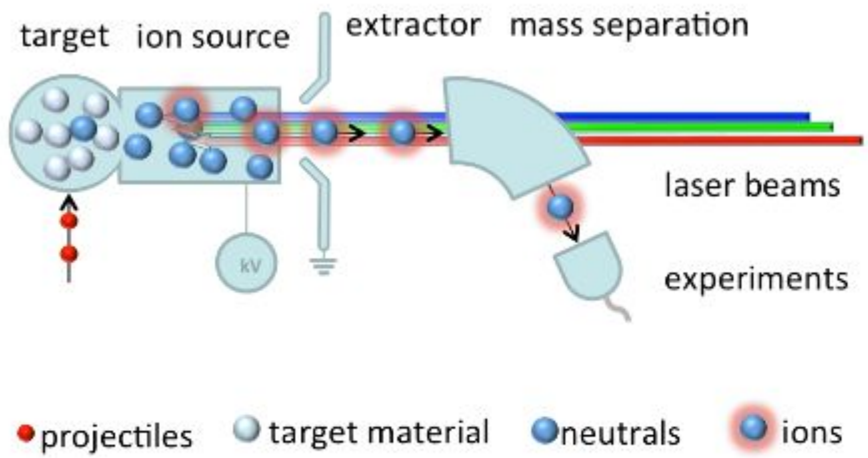
Production: Targets

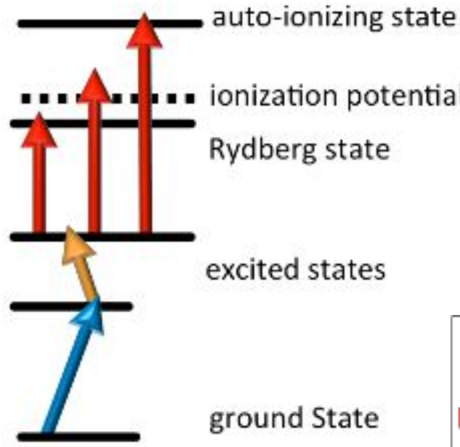
Separation: where is the ion of interest?

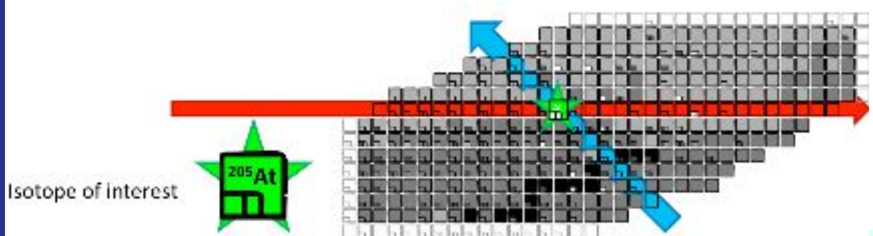

Magnetic field
bends ions
Radioactive
isotopes
Too
light
Too heavy
Selected mass

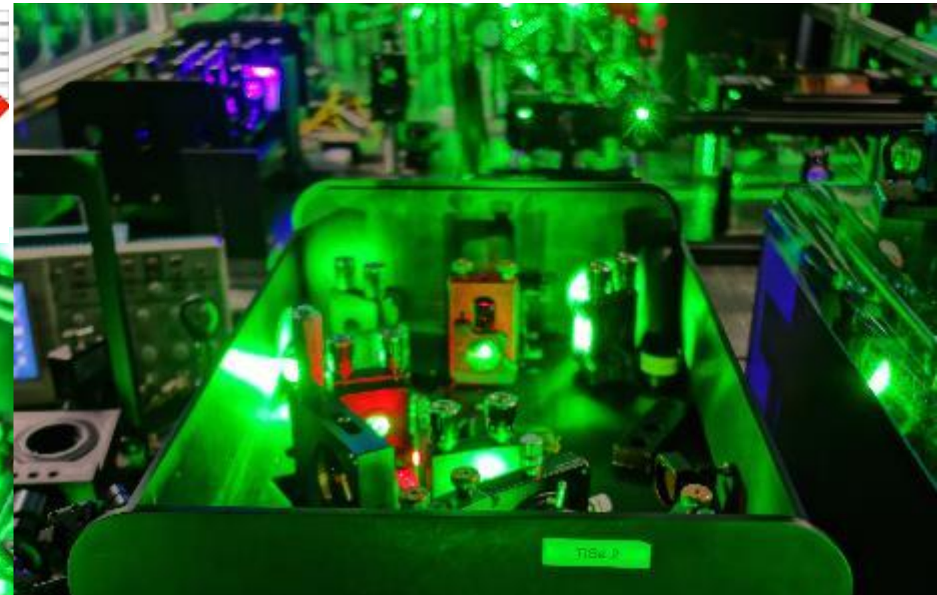
Ionization: RILIS

- Resonance Ionization Laser Ion Source
- Uses lasers to selectively ionize a particular element (isotope/isomer)

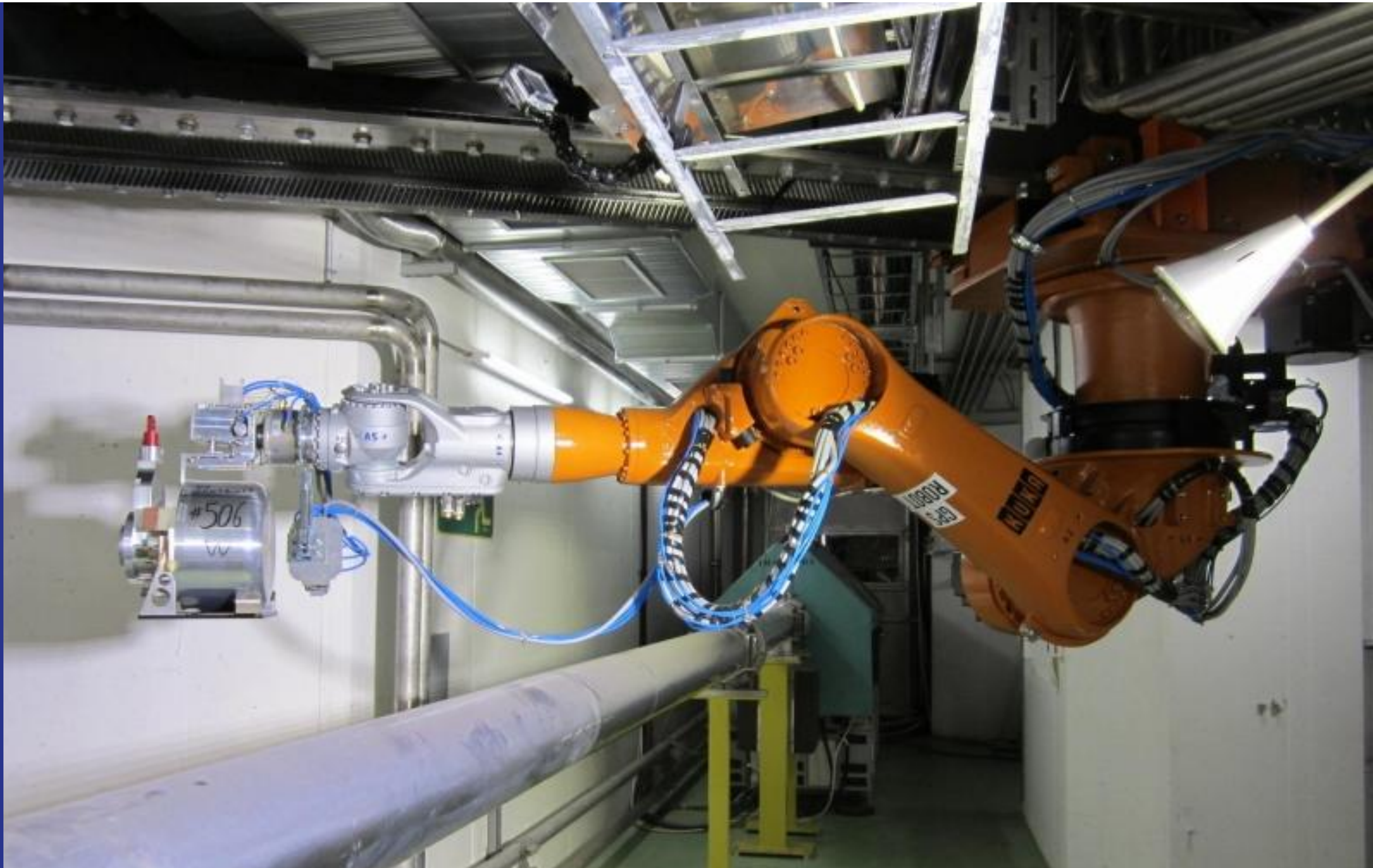






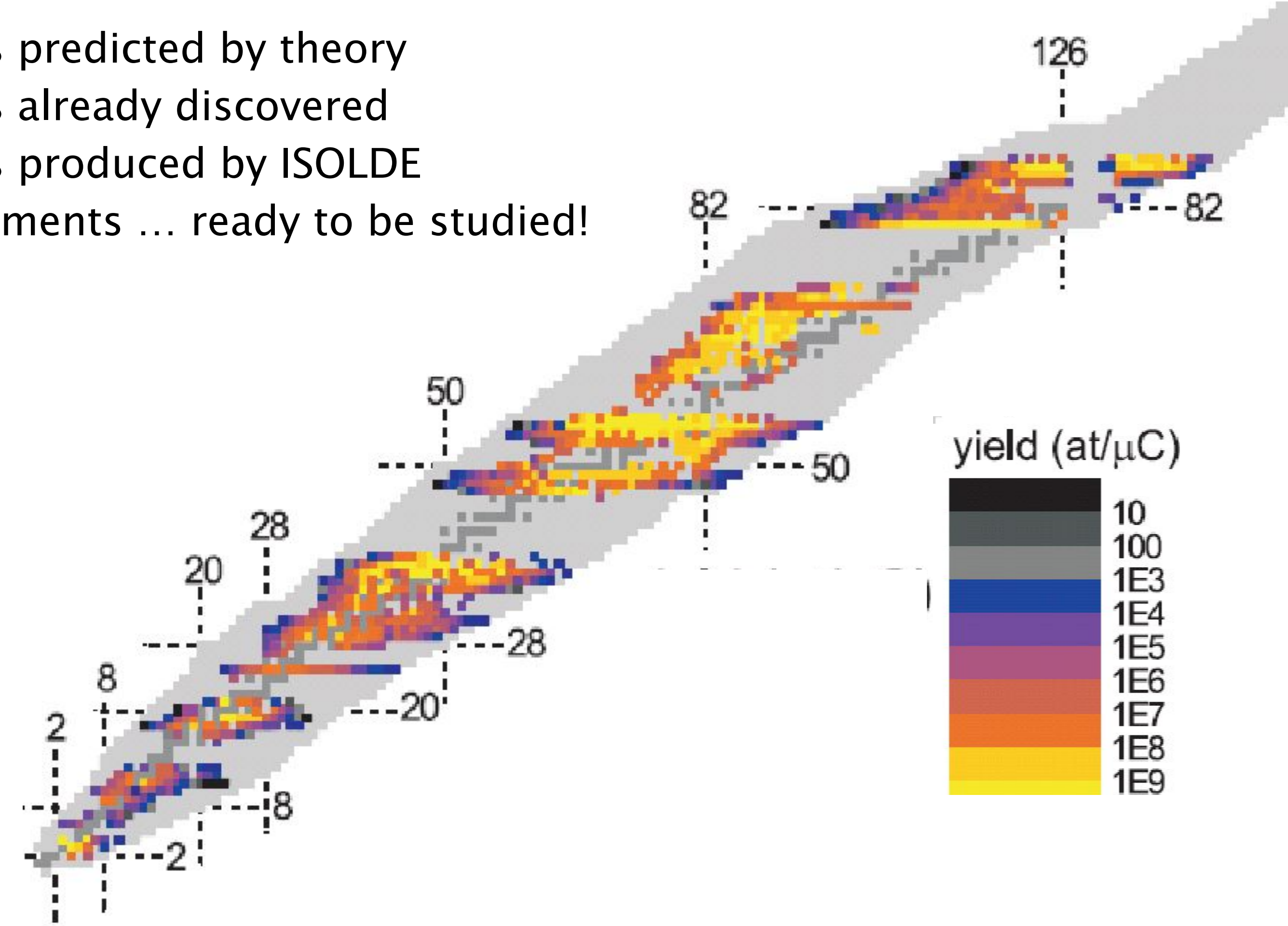


ISOLDE Robots



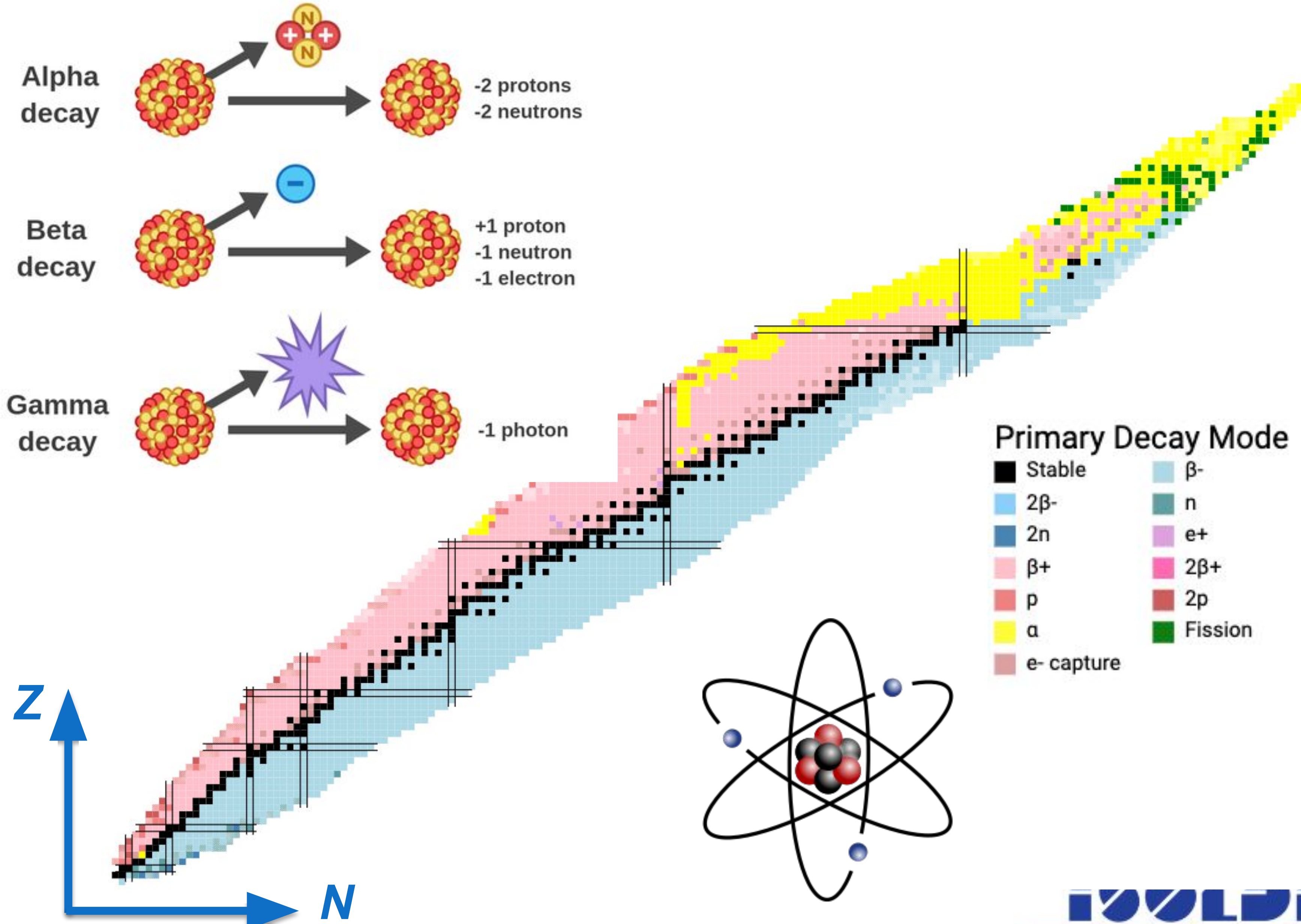
What is produced at ISOLDE?

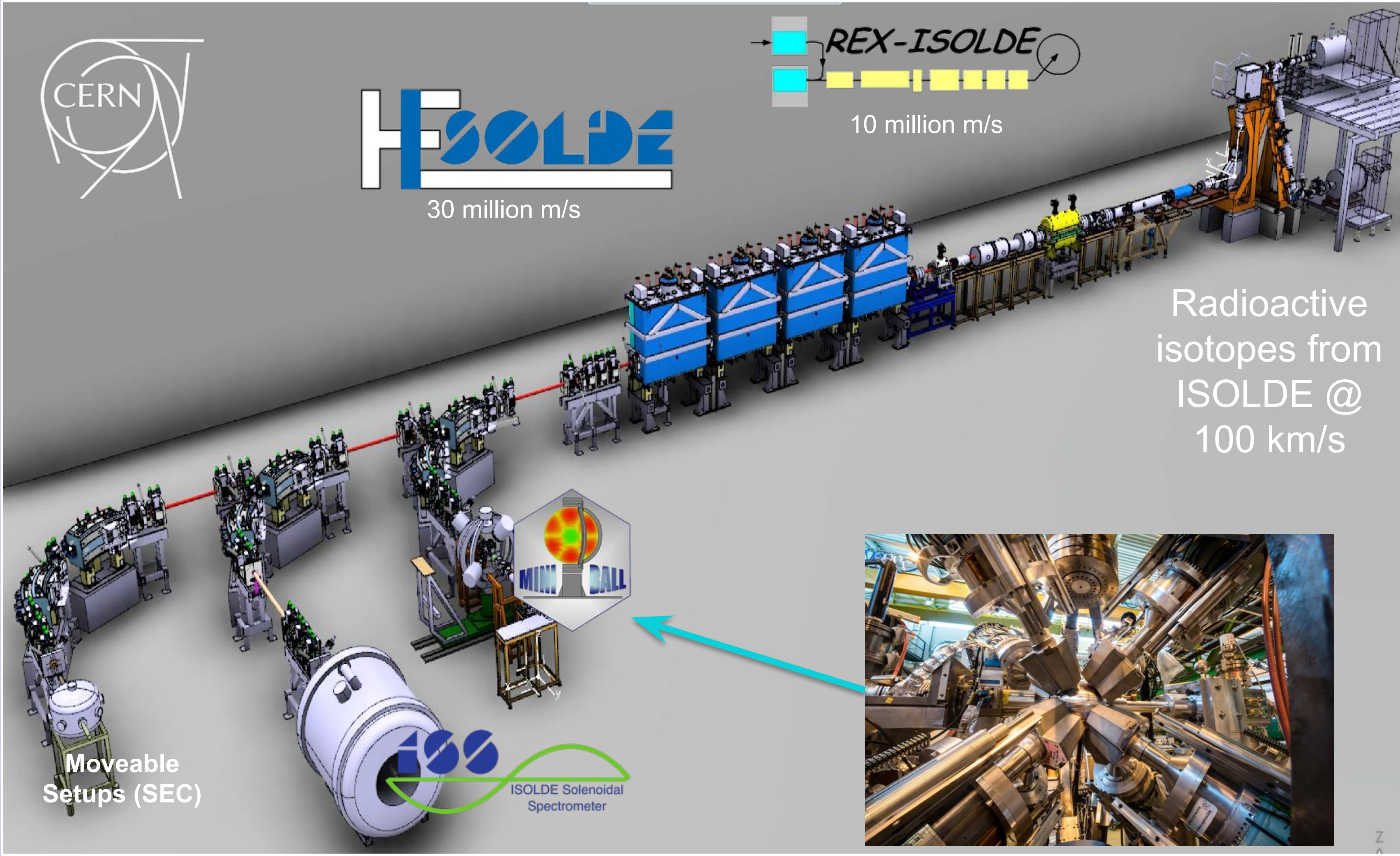
- ~6000 isotopes predicted by theory
- ~3000 isotopes already discovered
- ~1500 isotopes produced by ISOLDE
- 74 different elements … ready to be studied!



- ISOLDE can produce isotopes that live between 1 ms and 10^{12} years
- Production rates range from < a few per hour to >10^9 a second

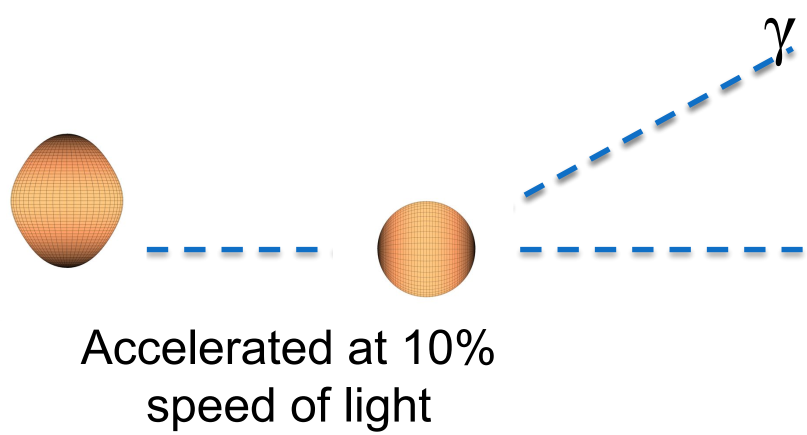
Radioactive decay

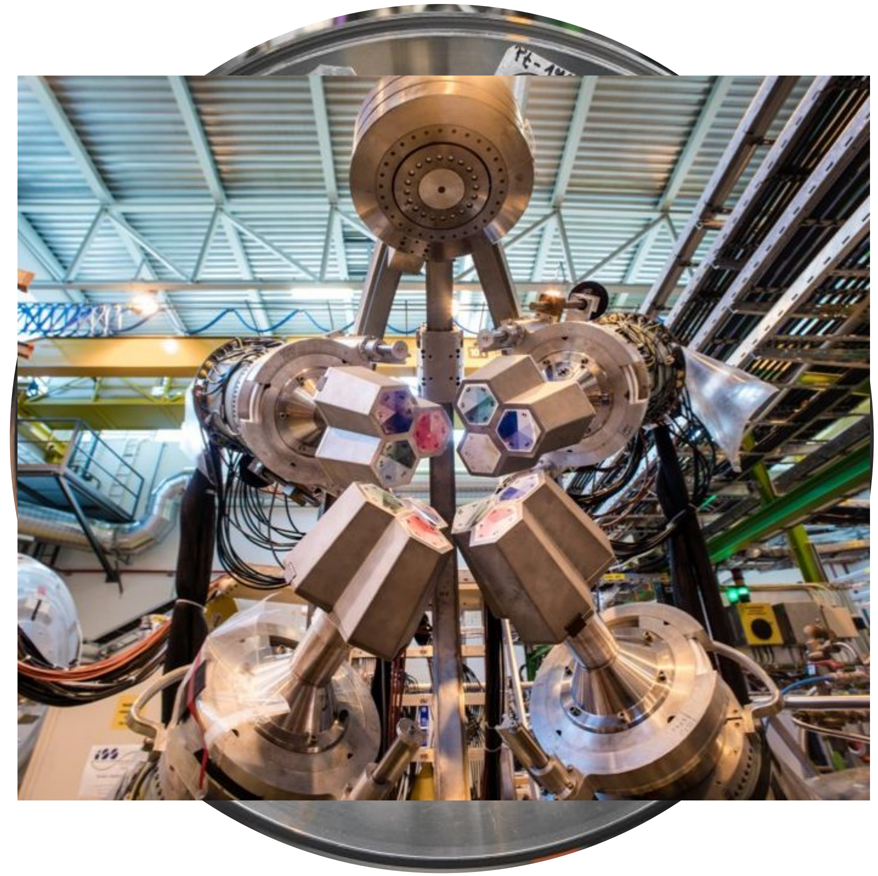



CERN
HIE ISOLDE
30 million m/s
REX-ISOLDE
10 million m/s
Radioactive isotopes from ISOLDE @ 100 km/s
MINI BALL
Moveable Setups (SEC)
ISS
ISOLDE Solenoidal Spectrometer

Simple nuclear reactions

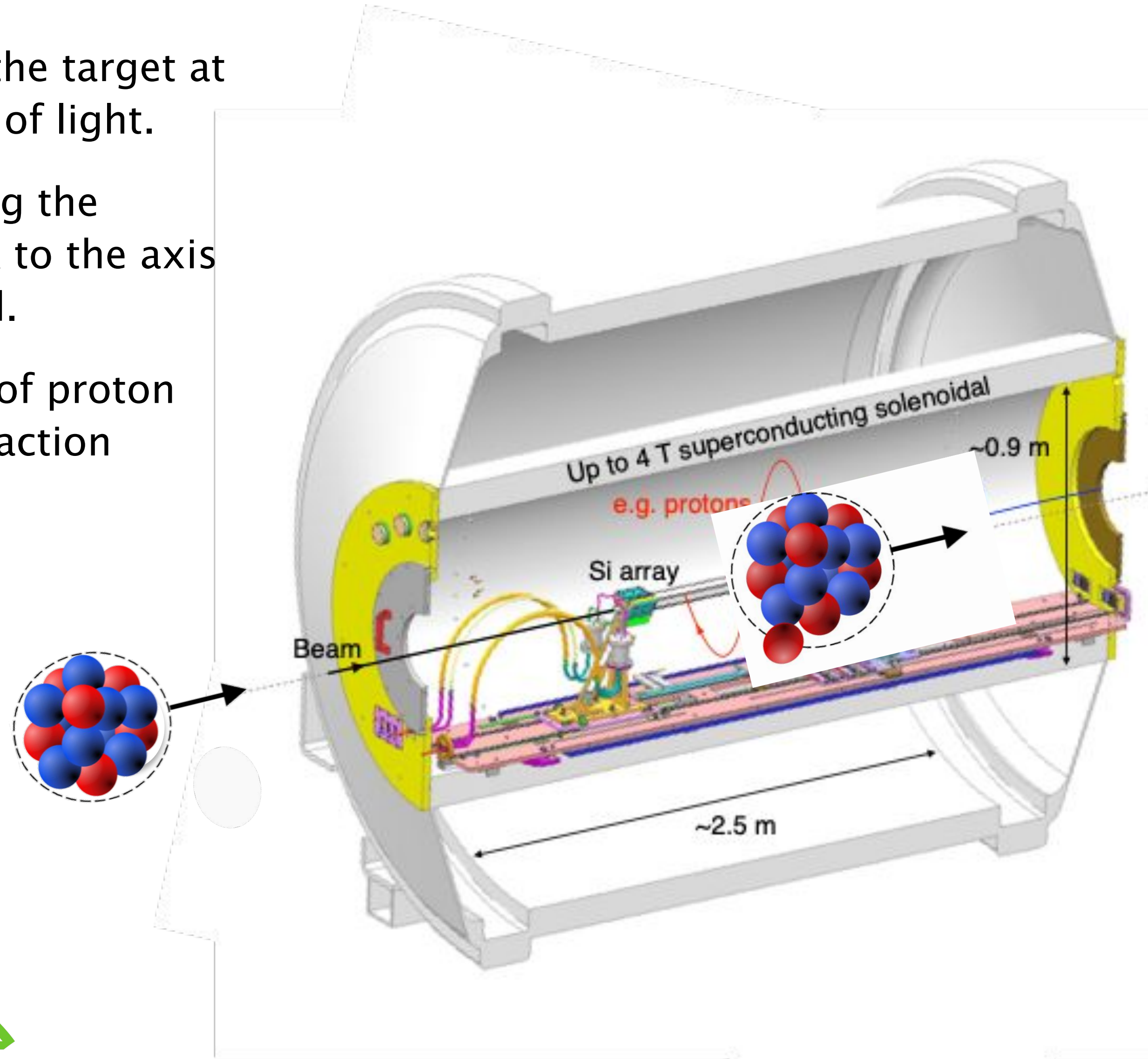
- Scattering reactions can be used to determine the shape of nuclei.
  - Just like **Rutherford scattering**!
  - But the nucleus can get excited and gain angular momentum.





How does ISS work?

- Radioactive ion hits the target at 10-15% of the speed of light.
- Proton emitted during the reaction is bent back to the axis by the magnetic field.
- Energy and position of proton let's you "see" the reaction happen.



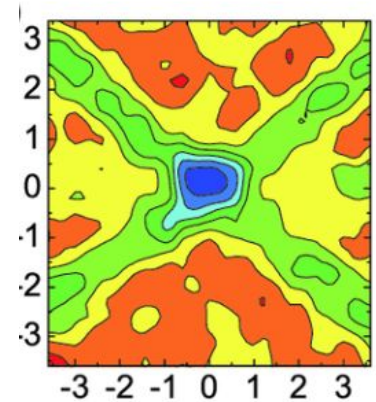
ISOLDE Solenoidal Spectrometer

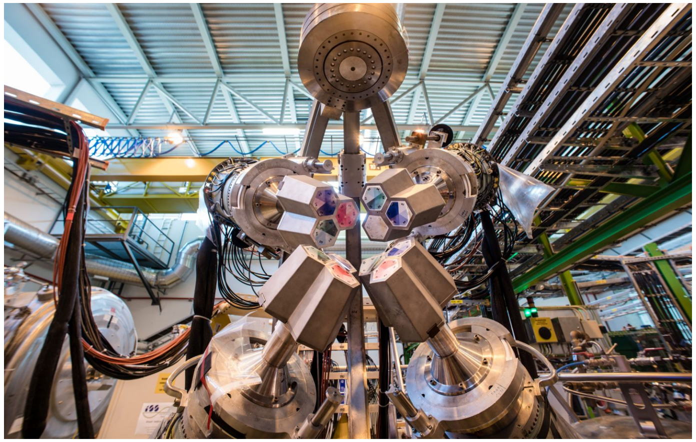
Empty slide

Recycling an MRI magnet

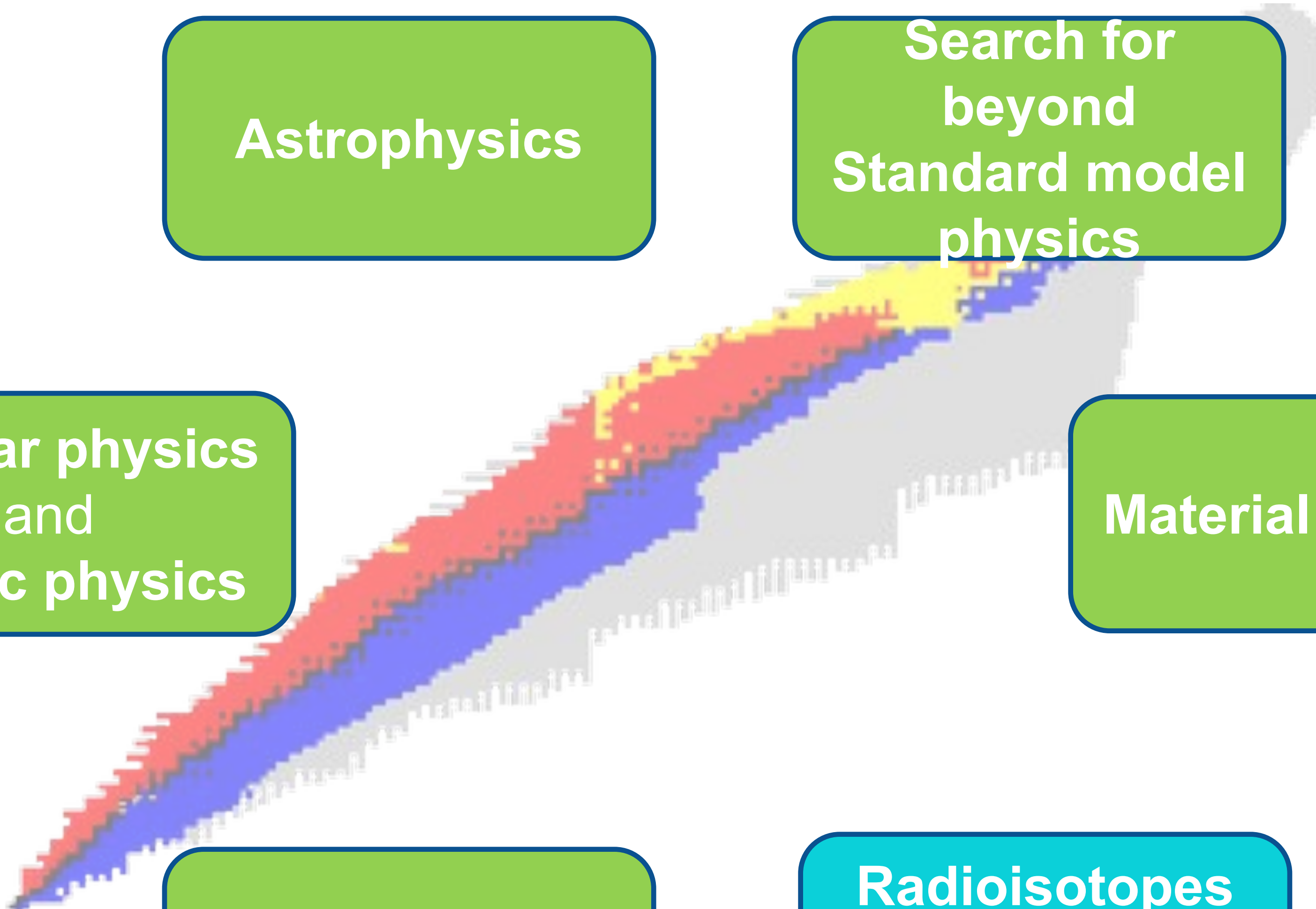
Research with radioactive beams

- How much do nuclei weigh? How big are they? What shape do they have?
- How and where in the universe are chemical elements produced?
- Why can protons and neutrons be bound together in many 1000 combinations? What are the limits of nuclear existence?
- How can we use the unique properties of radioactive nuclei for diagnosing and treating cancer?
- What's the location of impurities in crystals and biological samples?





Research with radioactive beams



Astrophysics

Search for beyond Standard model physics

Nuclear physics and atomic physics

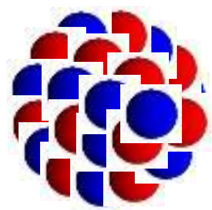
Material science

Life sciences and biophysics

Radioisotopes for medical applications

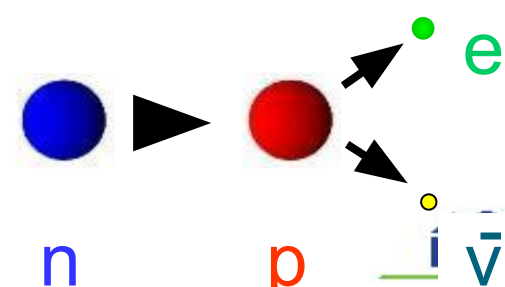
The rich physics in an atomic nucleus

- **Coulomb force** repels protons



- **Strong interaction** ("nuclear force") causes **binding** between nucleons (= attractive).

- **Weak interaction** causes β-decay



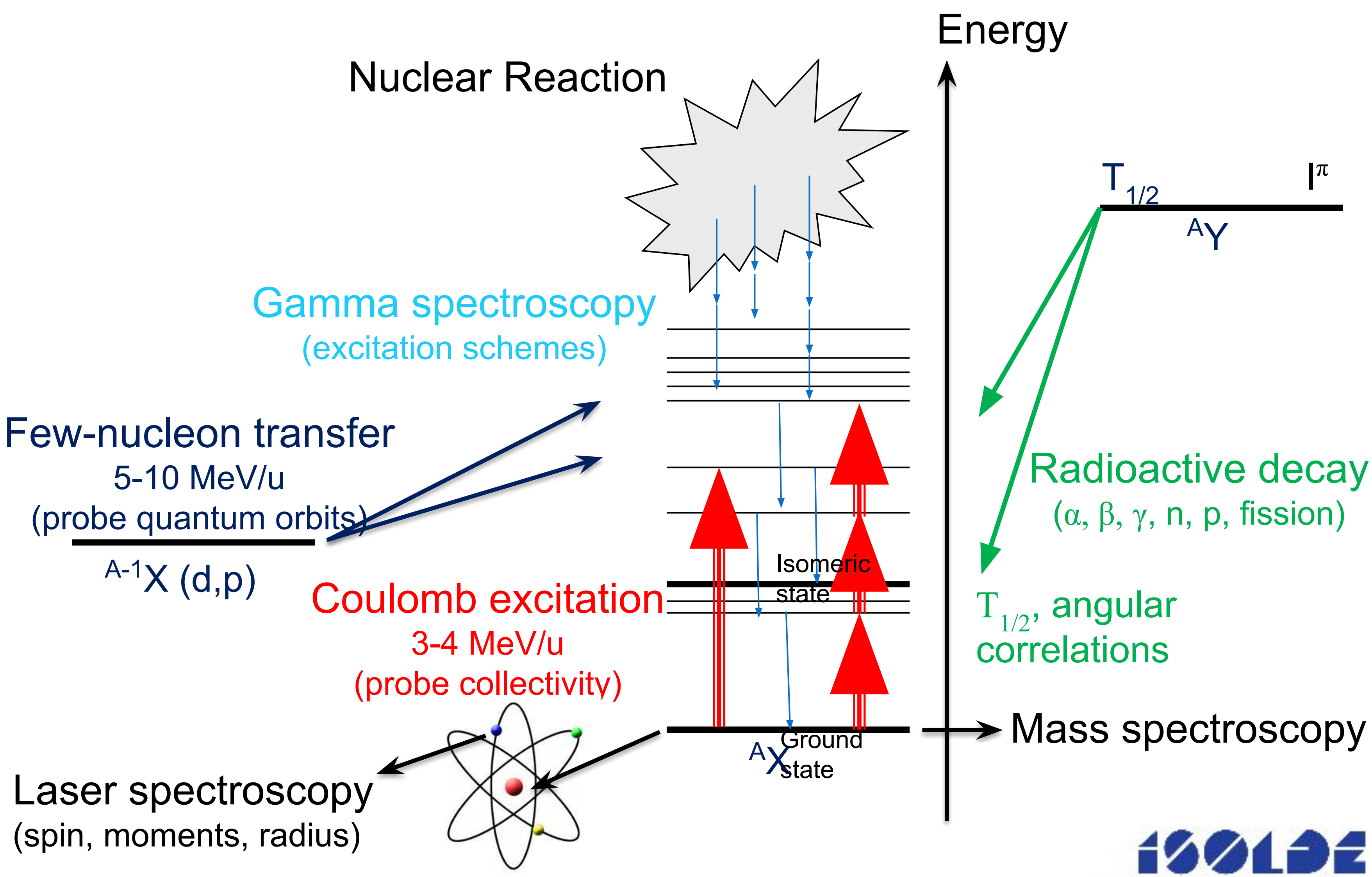
The rich physics in an atomic nucleus

- The atomic nucleus consists of a few 100 nucleons (protons and neutrons)
  - Too few to apply statistical methods to describe its properties
  - Too much to allow for ‘ab-initio’ calculations starting from the ‘nucleon-nucleon interaction’ between individual nucleons

- the ‘nuclear’ force between protons and neutrons is not a ‘fundamental’ force
  - Use ‘empirical’ or ‘effective’ nucleon-nucleon interactions
  - Recent progress: interaction derived from QCD via chiral effective field theory

- Use experimental data to test predictive power of nuclear models when going to ‘extremes’…

Experiments to probe nuclear structure



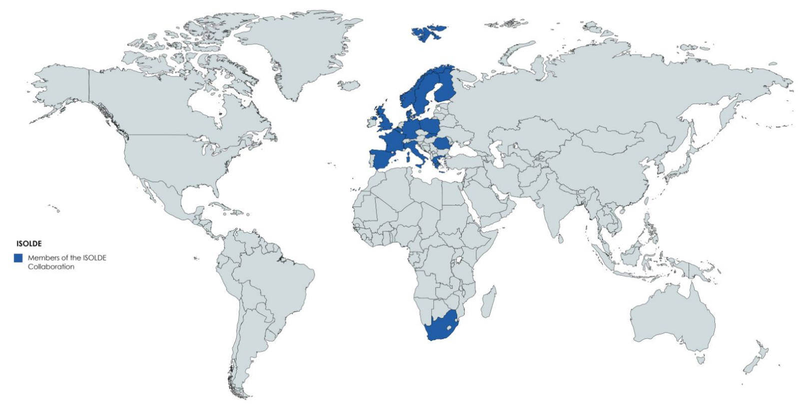
ISOLDE at CERN

- Isotope Separator OnLine Device

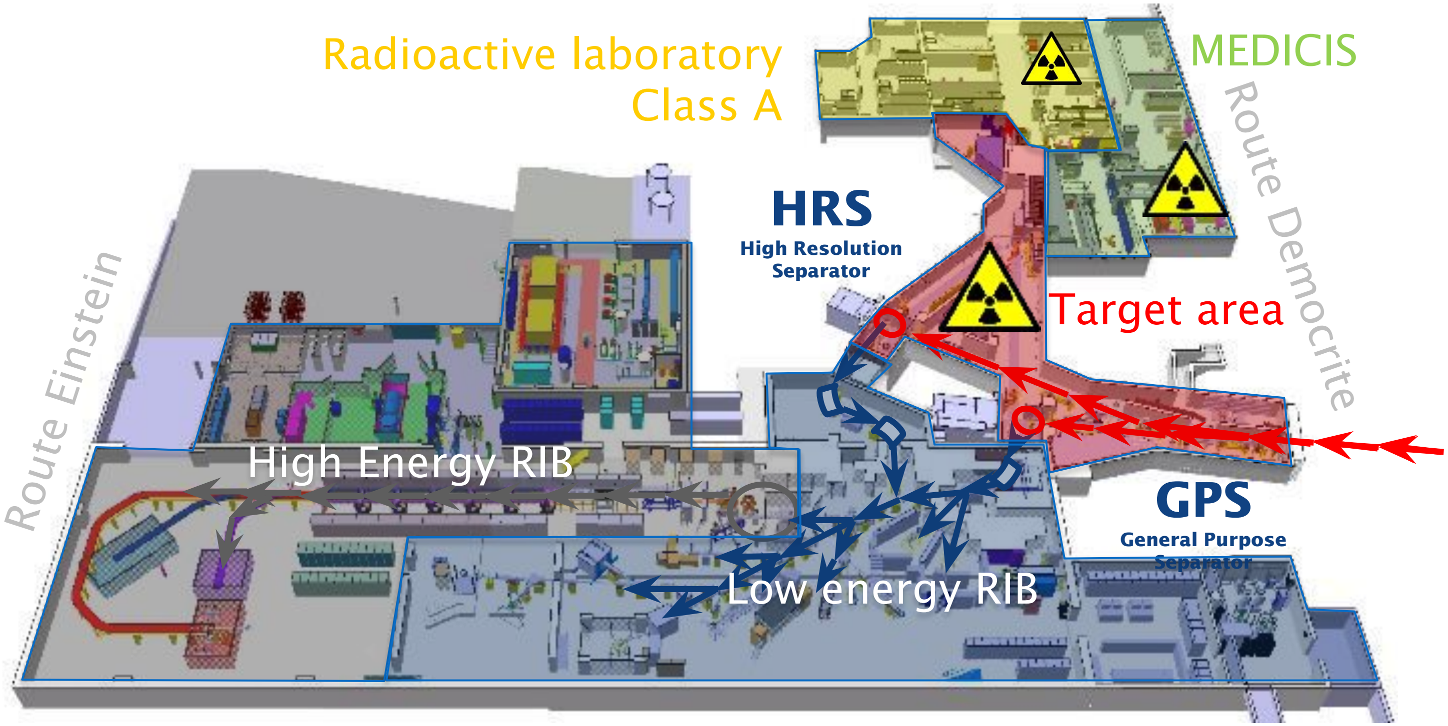
- Approved by the CERN council in 1964, first beams in 1967
  - Initially used 600 MeV protons from SC
  - Then used 1.0 GeV (later 1.4 GeV) protons from the PSB

- A small facility with a big impact!
  - ~0.1% of the CERN budget
  - ~7% of the CERN scientists
  - ~50% of the CERN protons

- Run by international collaboration
  - CERN, BE, DE, DK, FI, FR, GR, IT, NO, PL, RO, SK, ZA, ES, SE, UK
  - ~50 staff/students/fellows
  - ~1500 users



The ISOLDE facility

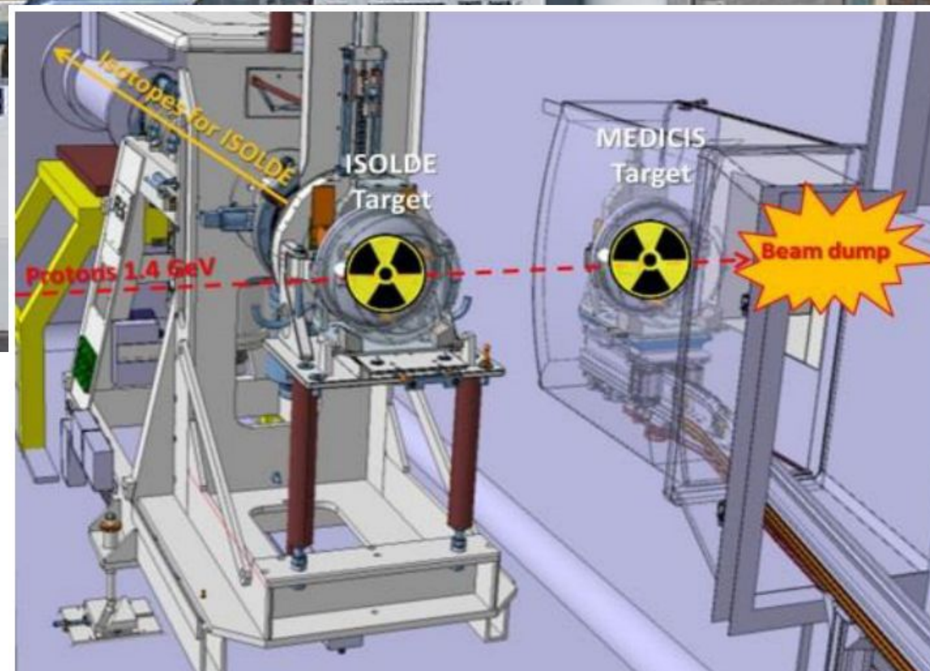


Protons (1.4 GeV)
Low energy RIBs (up to 60 keV)
High energy RIBs (up to 10 MeV/u)

Daily life at ISOLDE

1. Propose experiment for board of experts
2. Experiment gets scheduled
   - Winter: shutdown
   - April – November: beam times
   - ~8 months/year, 24/7
4. Prepare set-up
5. Do experiment
   - ~1 week continuously
6. Analysis, discussion, publication, conferences

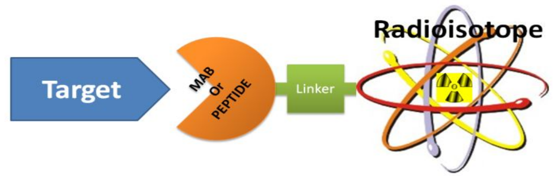
MEDICIS: recycling protons for society



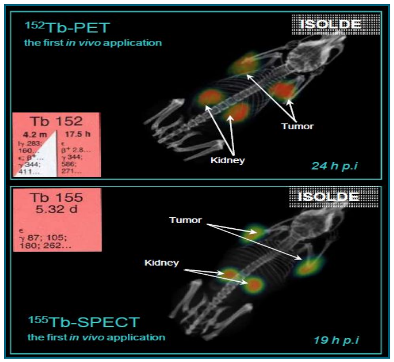
- Production of non-conventional radioisotopes for medical research
  - 80-90% of the proton beam goes through the ISOLDE target unaffected
  - Use these (free!) protons to

Theranostics

DiagNOSTICS



THERApy



β^+-emissions

PET E(γ) = 511 keV

γ-emissions

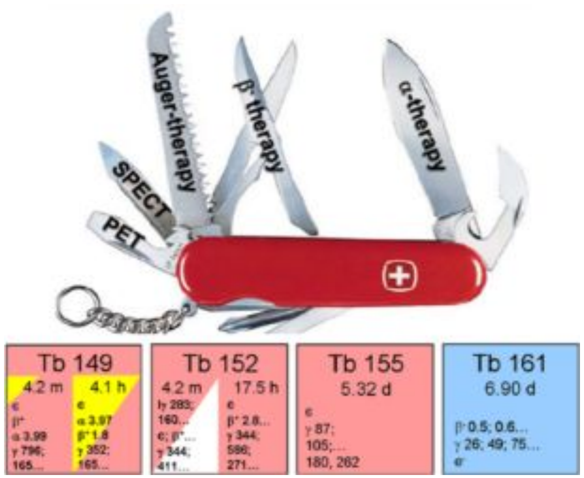
SPECT
100keV<E(γ)<200keV

α-emitter

High LET, short distance in human tissue

β-emitter

Low LET, long distance in human tissue



Medical isotope production