ISOLDE & the HIE ISOLDE Project

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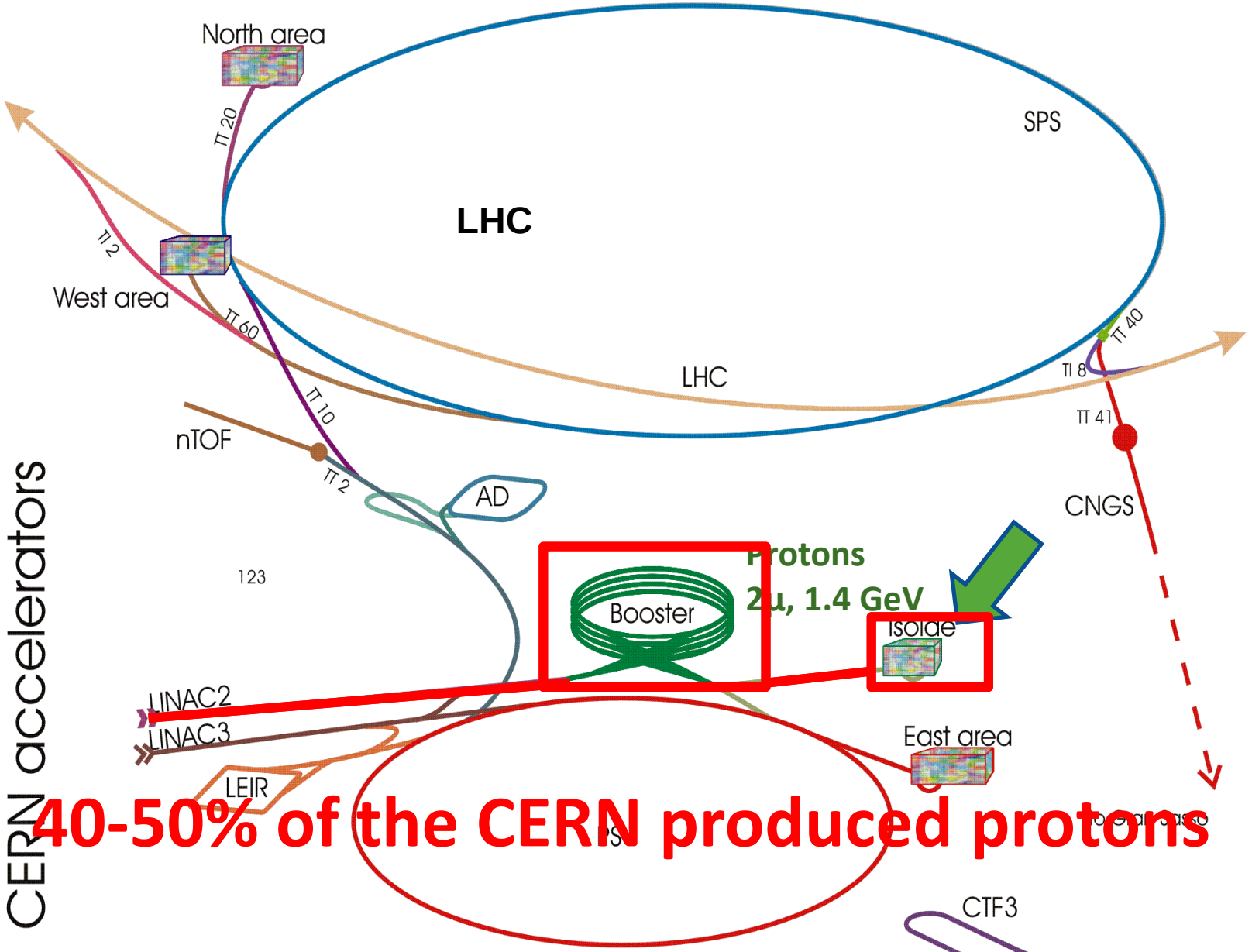
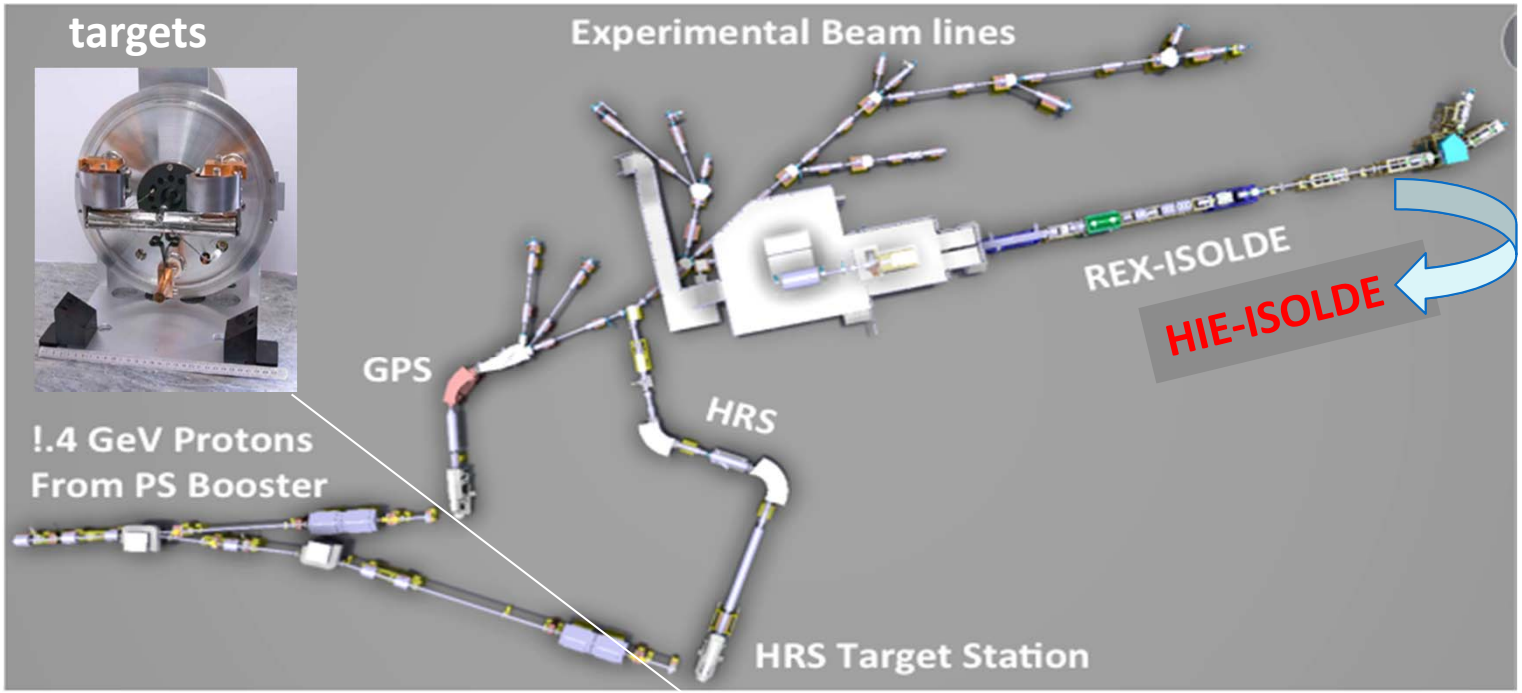
ISOLDE at CERN (since 1992)



40-50% of the CERN produced protons

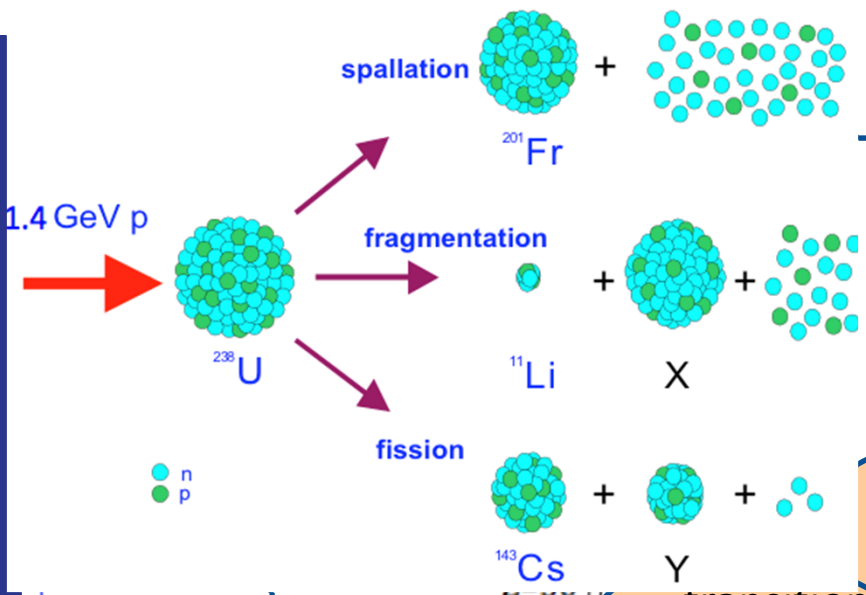
ISOLDE Facility

- ISOLDE is the CERN radioactive beam facility (operative since 1967)
- ISOLDE provides low energy (10-60 keV) and post-accelerated beams
- It is run by a collaboration of 16 countries
- **> 800 Users from 200 Institutions, 50 experiments / year**



Linac4 + PSB upgrade (2020) { intensity (2uA -> 6uA) / energy (1.4 -> 2GeV) } ≤ x 30

Research with radioactive nuclides @ ISOLDE (50 y!)



decay pattern

mass

transition probability

spin, parity

e-m moments

half-life

radius

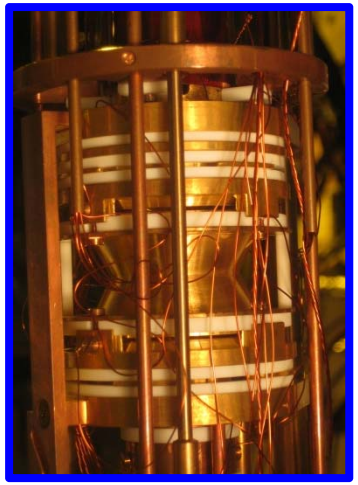
Material science and life sciences

ISOLDE today offers the largest range of nuclei of any ISOL facility worldwide

Fundamental interactions

Experimental Techniques

Traps for masses

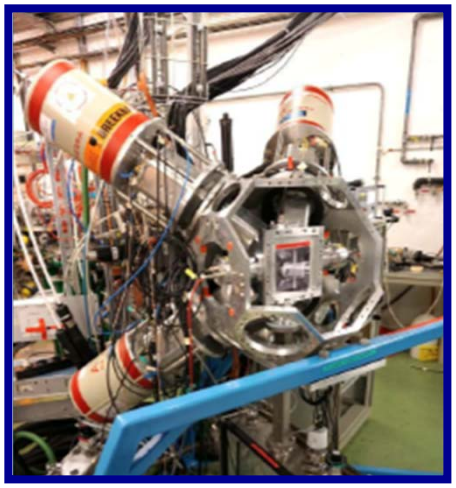


$\omega_c = qB / m$

Lasers for radii & e-m moments

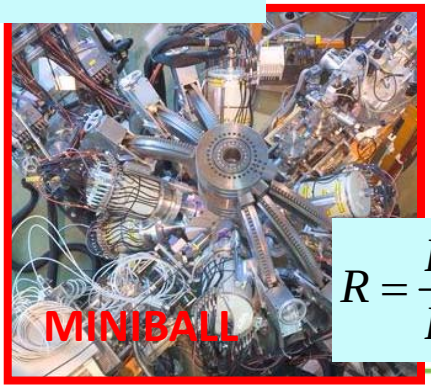
$$\delta\nu_{\mathrm{IS}}^{AA'} \propto \Delta\,|\Psi(0)|^2\;\delta\left\langle r^2\right\rangle^{AA'}$$

Versatile Decay Station: IDS



$N(t) = N_0\, e^{-t/\tau}$

Post-acceleration: for reactions studies

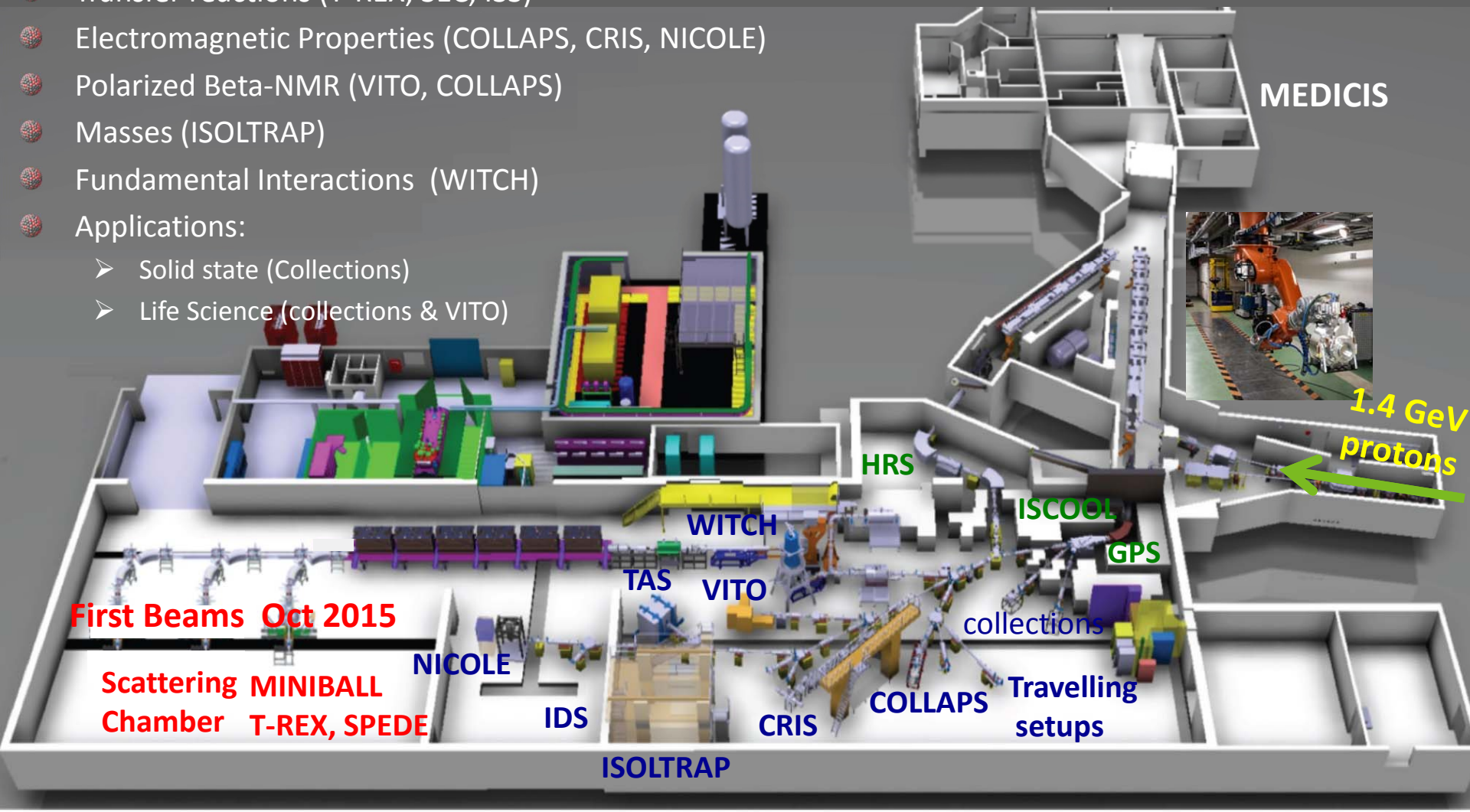


Reactions studies

Shapes

$$R = \frac{B(E2, 2_i^+ \rightarrow I^+)}{B(E2, 2_i^+ \rightarrow 0_1^+)}$$

- Decay spectroscopy (IDS, TAS,..)
- Coulomb excitation (MINIBALL+ CD + SPEDE)
- Transfer reactions (T-REX, SEC, ISS)
- Electromagnetic Properties (COLLAPS, CRIS, NICOLE)
- Polarized Beta-NMR (VITO, COLLAPS)
- Masses (ISOLTRAP)
- Fundamental Interactions (WITCH)
- Applications:
  - Solid state (Collections)
  - Life Science (collections & VITO)

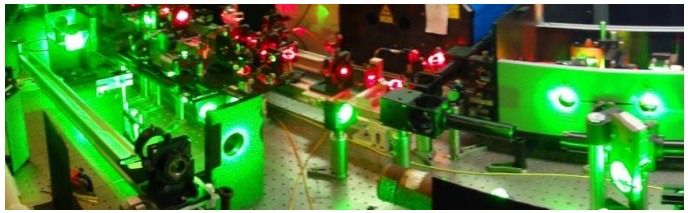


Post-accelerated Exps (5.5 MeV/u), Low Energy (10-60kV) Exps, Machine elements

Highlights from ISOLDE

RILIS: Ionisation potential of Astatine

S. Rothe et al, **Nature Communications** 4 (2013), 1835



Least abundant element on Earth
Series of Rydberg states
IP = 9,31751 (8) eV

REX-ISOLDE + MINIBALL : Octupole deformation in 220Rn and 224Ra

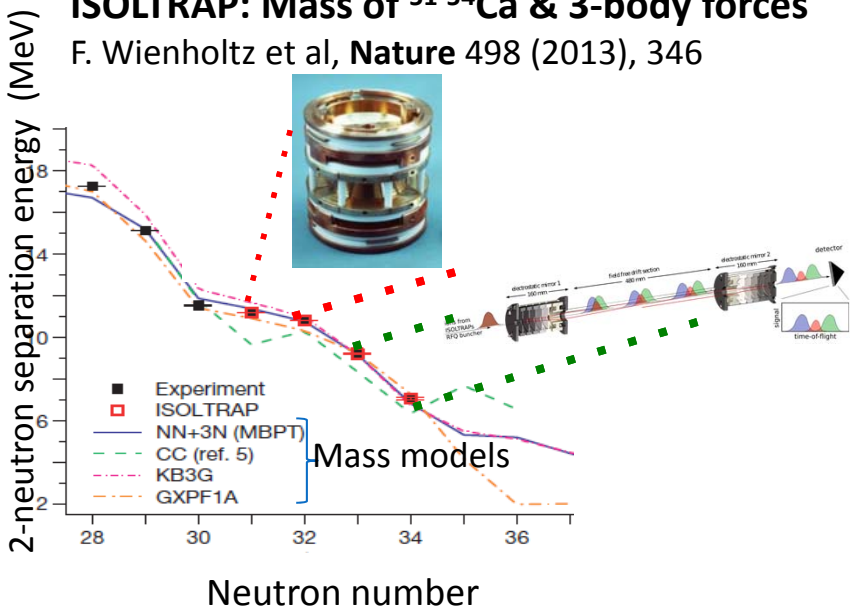
L.P. Gaffney et al, **Nature** 497 (2013) 199

Candidates for searches for permanent EDMs:

- Radiums-223 and 225 promising

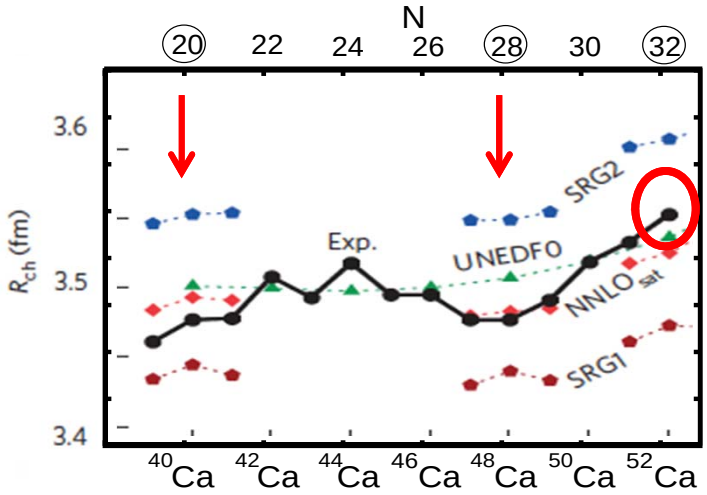
ISOLTRAP: Mass of $^{51-54}$Ca & 3-body forces

F. Wienholtz et al, **Nature** 498 (2013), 346

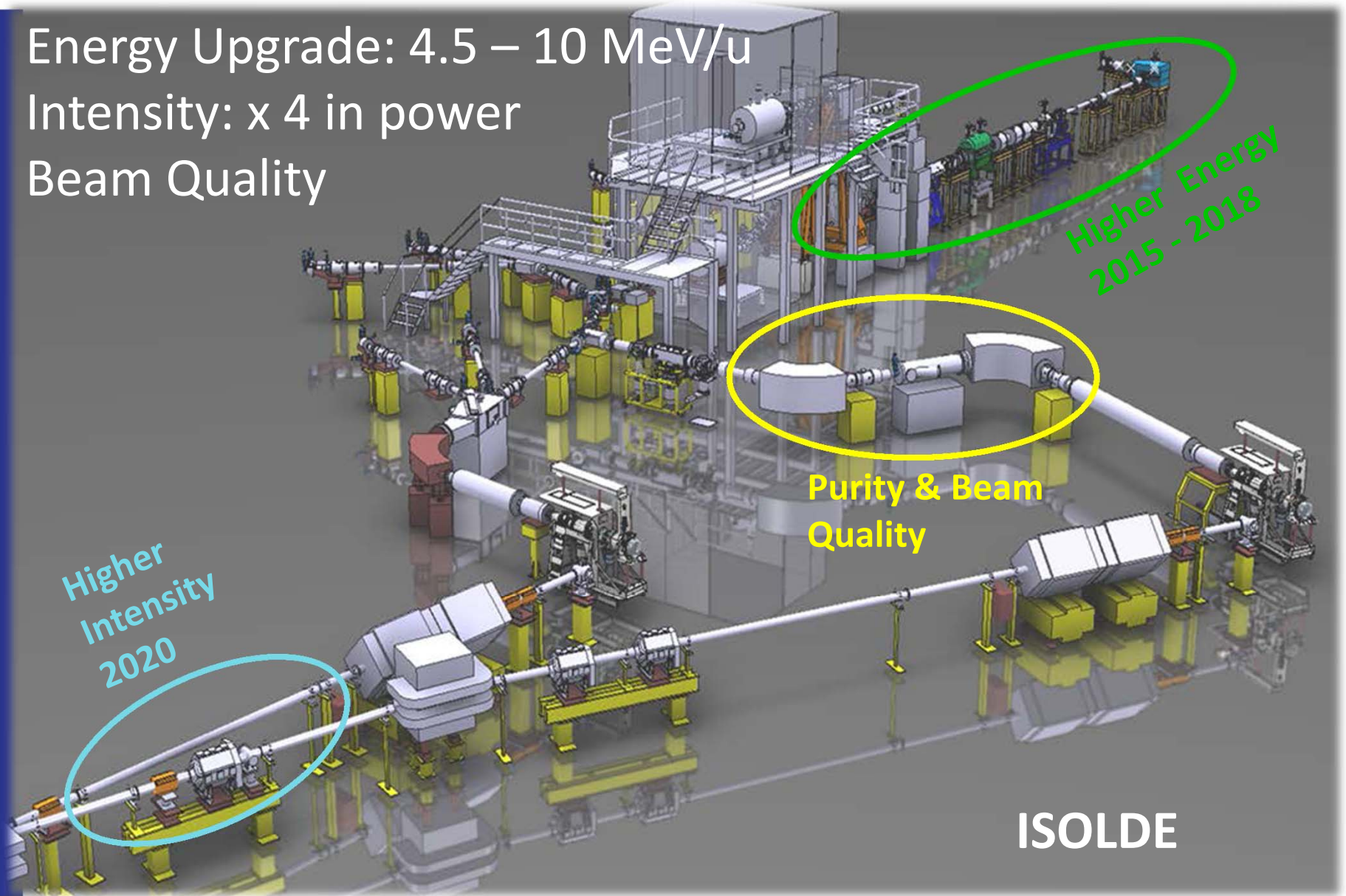


COLLAPS: Radii of $^{40-52}$Ca

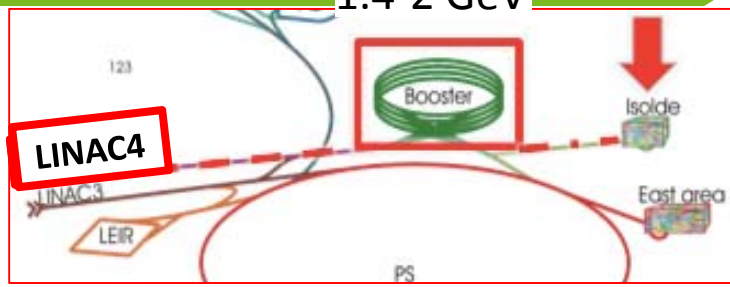
R. Garcia-Fdez et al, **Nature Phys** Feb 2016, 594



The HIE-ISOLDE project (2010 -)

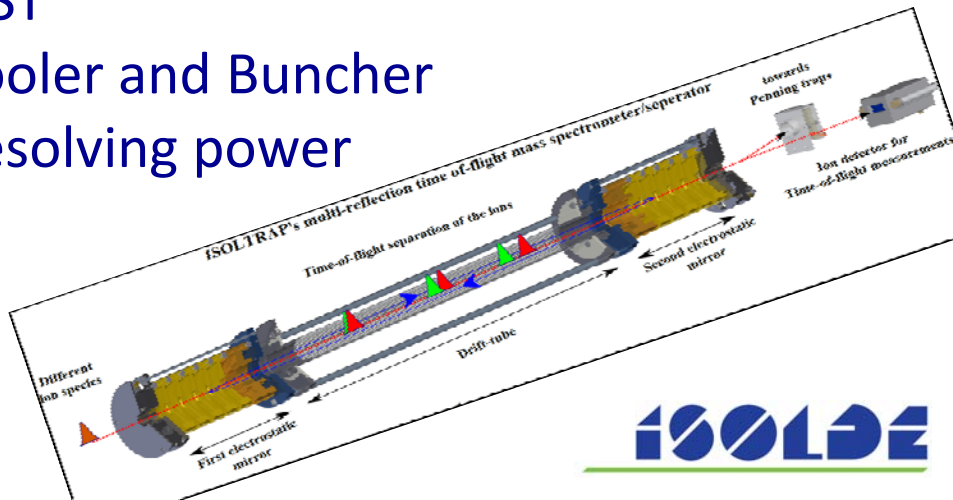


HIE-ISOLDE (2010-)

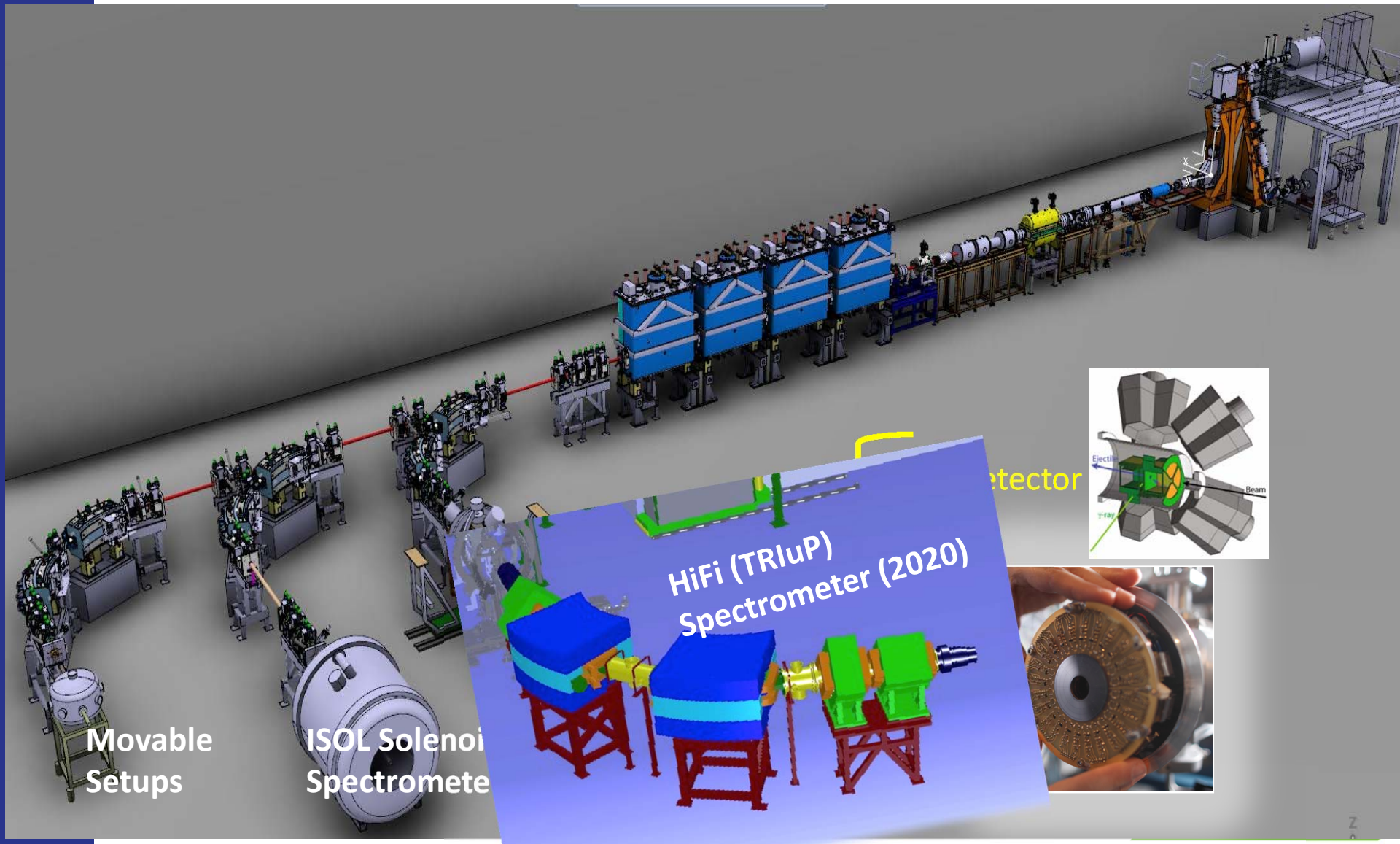


- **Energy (2015-) up to 10 MeV/u**
  - **Phase 3 : Astrophys Domain**
- **Intensity from Injectors (2020)**
  - ✓Linac 4 ($5x10^{13}$ – $1x10^{14}$)(2020)

  Production increases linearly with injector intensity ⇔ Factor 3
  - ✓PSBooster to 2 GeV(2024)
    - – Increase x 2 – x 5 in fragmentation cross reactions
    - – Increase x 6 - x 10 for spallation cross section
- **Beam Purity:**
  - ✓New Target Materials & LIST
  - ✓ISCOOL: DS of new RFQ Cooler and Buncher
  - ✓HRS: DS for higher mass resolving power
  - ✓EBIS: DS for EBIS upgrade
  - ✓General purpose MR-ToF



HIE-ISOLDE Phase 2 (2017-2018)



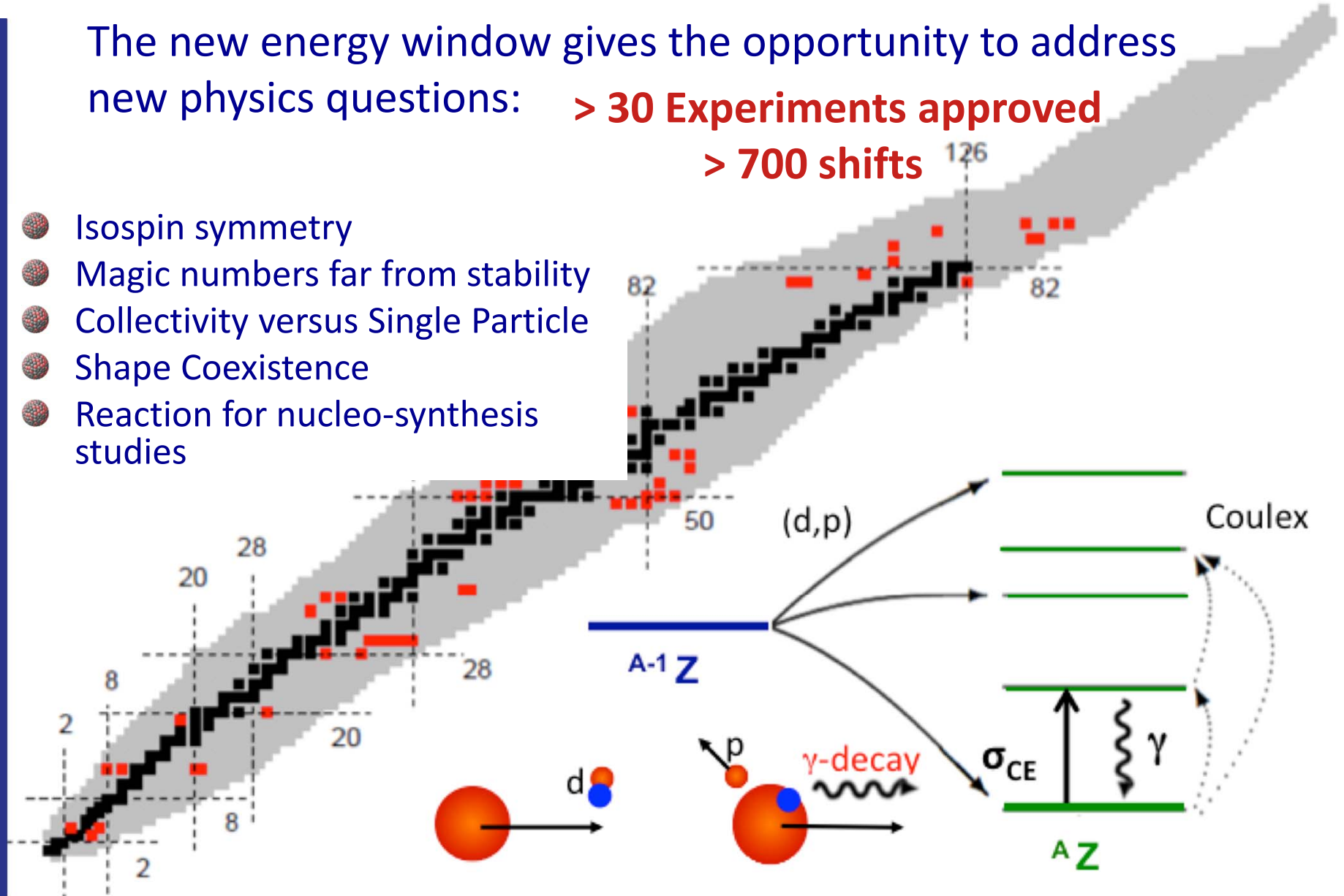
Physics at HIE-ISOLDE

The new energy window gives the opportunity to address new physics questions:

> 30 Experiments approved

> 700 shifts

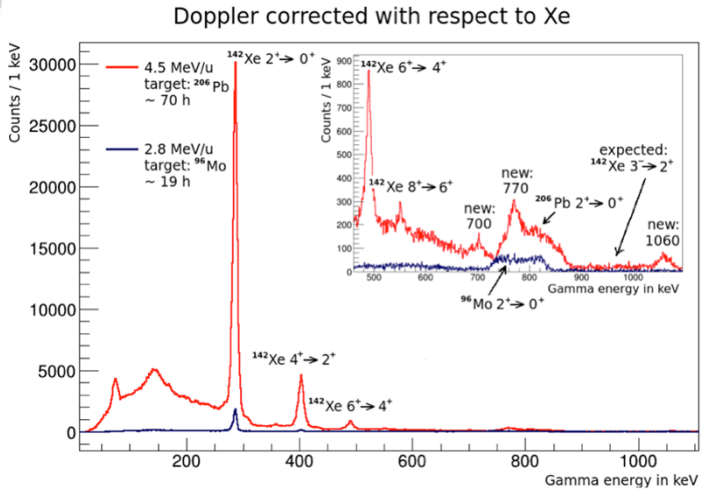
- Isospin symmetry
- Magic numbers far from stability
- Collectivity versus Single Particle
- Shape Coexistence
- Reaction for nucleo-synthesis studies



Radioactive beams @ 5.5 MeV/u

- HIE-ISOLDE producing physics: beams @ 4.3 MeV/u in 2015 and 5.5 MeV/u in 2016.
- Coulomb excitation of ^{74,76,78}Zn (4.3 MeV/u), ^{110}Sn(4.5 MeV/u), ^{142}Xe(4.5 MeV/u), ^{132}Sn(5.5 MeV/u)
- **Transfer reaction with ^{9}Li beam (6.8 MeV/u)**

MINIBALL



Summary

- ISOLDE is in continuous transformation to stay at the forefront of nuclear physics research
- ISOLDE produces low energy and post-accelerated radioactive beams
- Plenty of challenging physics!
- Many new devices and groups have been attracted by the increase of energy of the post-accelerated beams.
- **HIE-ISOLDE stage 1 in operation with energies of 5.5 MeV/u for A/Q = 4.3 ⇔ Higher energies for lower A/Q**
- In Jan 24th 2017 the third cryomodule will be connected → 7.5 MeV/u for A/q = 4.3
  - ➢ 10 MeV/u will be reached for 2018 Campaign.

FUTURE: On-going Projects

HIE-ISOLDE

- Phase 3: Exchange of existing normal conducting cavities by SC ones allowing for deceleration on beams: 0.5-10 MeV/u ⇔ Astrophysics
- The intensity upgrade by new Linac4 and the 2 GeV of PSB
  Expected improvement of isotope production up to a factor of 30

Storage Ring @ ISOLDE

- The combination of HIE-ISOLDE + storage ring, unique worldwide, will reinforce program in Atomic Physics, Reaction and nucleosynthesis studies
- External beam line to exploit the ISOLDE Solenoidal Spectrometer (ISS) at maximum.

Coordination with other present and future ISOL-Facilities in Europe via EURISOL-DF

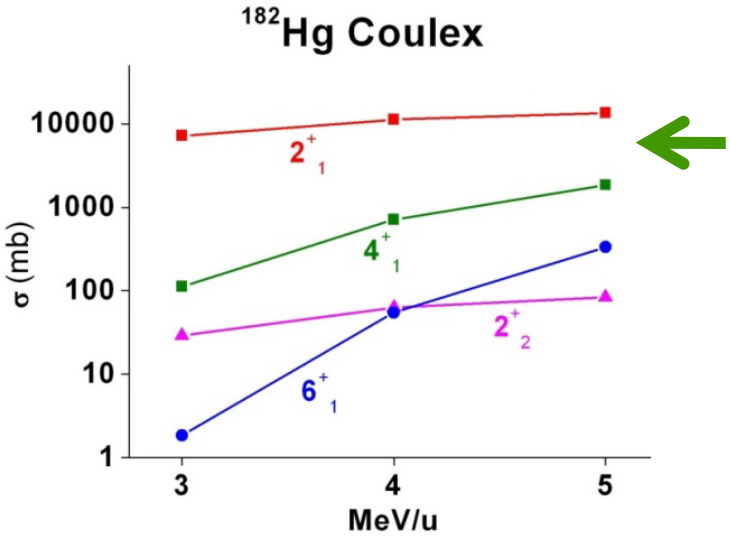
Thanks for your attention !

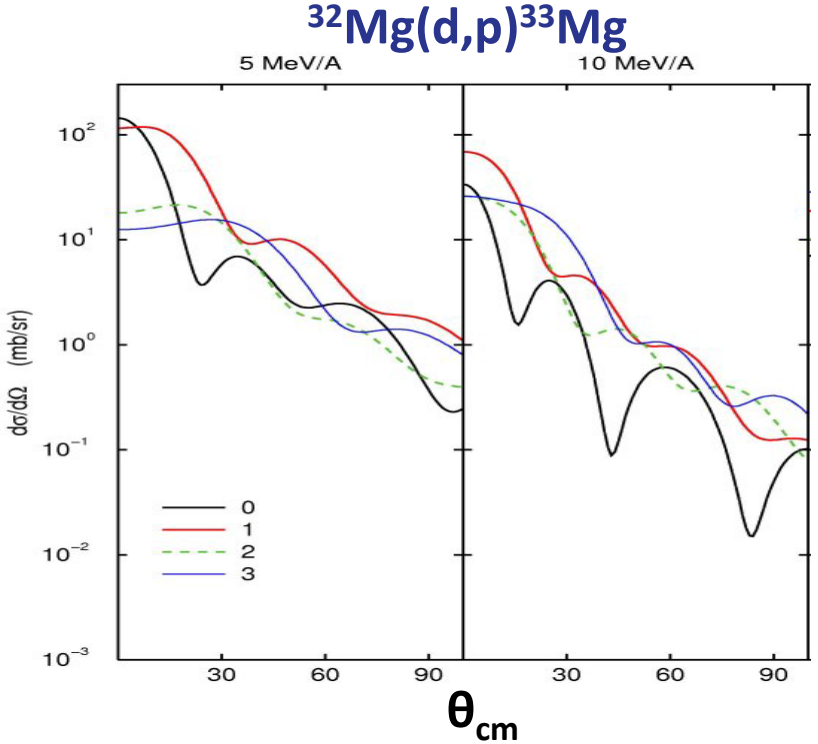
Advantages of HIE-ISOLDE

Design study: Intensity & Beam quality & Efficiency

Phase 1&2: Energy upgrade to 5.5 MeV /A → 10 MeV /A

Phase 3: Continuous beams from 0.8 MeV – 10 MeV/A





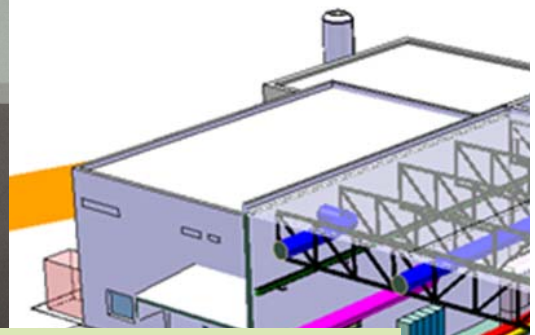
- Access to a wealth of spectroscopic information
- From the absolutes intensities of $4^+/2^+$ (multistep coulex)

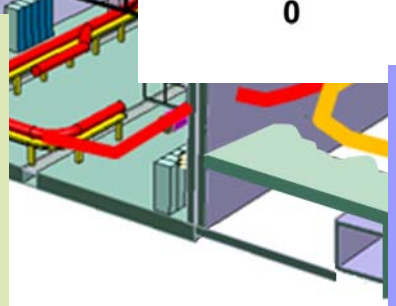
⇒Access to the sign of deformation

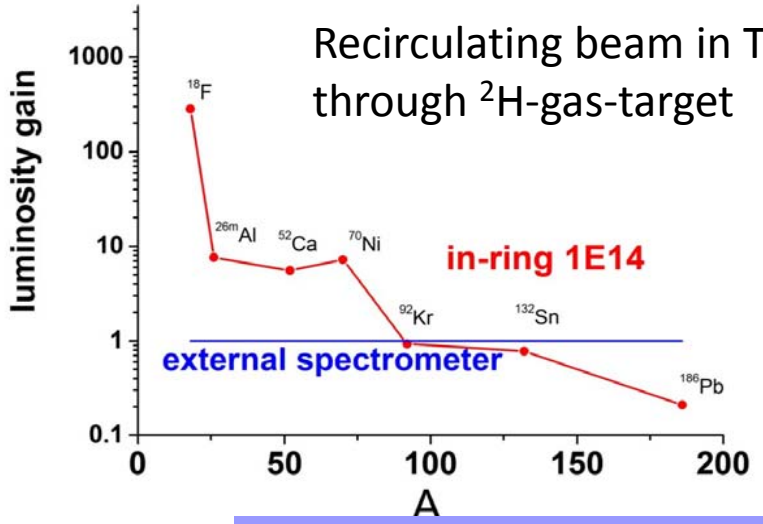
- Single particle information through the spectroscopic factors
- High energy needed to learn about the "l" transfer

The TSR in a nutshell

Grieser EPJ 2012







Recirculating beam in TSR through ^{2}H-gas-target

Advantages

With respect to in-flight storage rings

- Higher intensity
- Shorter cooling time

With respect to "direct" beams

- Less background (target container, beam dump)
- Improved resolution (smaller beam size, reduced energy straggling in target)
- CW beam
- Luminosity increase for light beams

Initiative of
Max Planck Instit

Physics programme

Astrophysics

- Capture, transfer reactions
- ^{7}Be half life

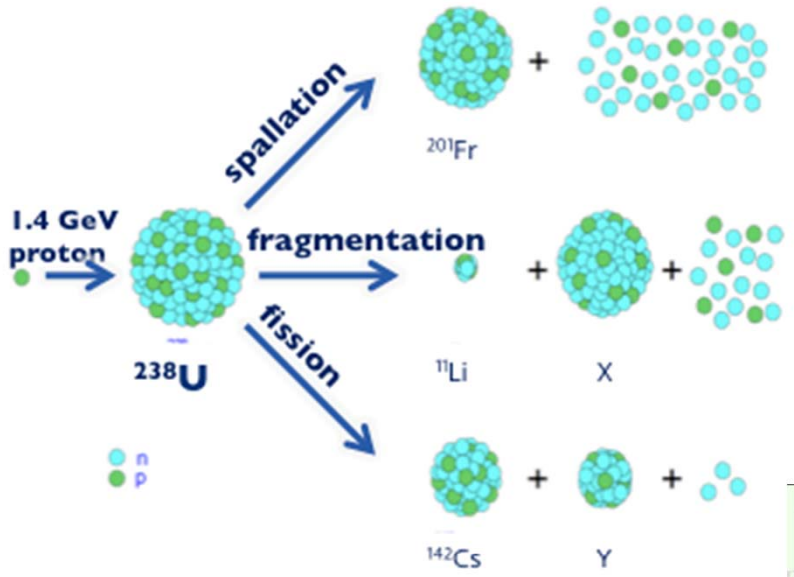
Atomic physics

- Effects on half lives
- Di-electronic recombination

Nuclear physics

- Nuclear reactions
- Isomeric states
- Laser spectroscopy

Production Mechanism



$$Y = I \times \sigma \underbrace{\varepsilon_{rel}\ \varepsilon_{ion}}_{10^{-3} - 10^{-8}}\ \underbrace{\varepsilon_{sep}\ \varepsilon_{transp}}_{5 - 90\ \%}$$