

A blue hard hat is the central focus, resting on a metal beam. Below it, a pressure gauge with a white face and black markings is visible, showing a reading of approximately 4.5 bar. The background is a blurred industrial setting.

ISOLDE

CERN's Radioactive Ion Beam Facility

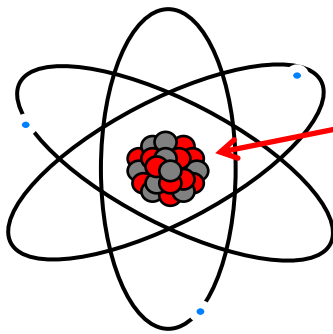
ISOLDE at CERN

- ◆ Isotope Separator OnLine Device
- ◆ 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

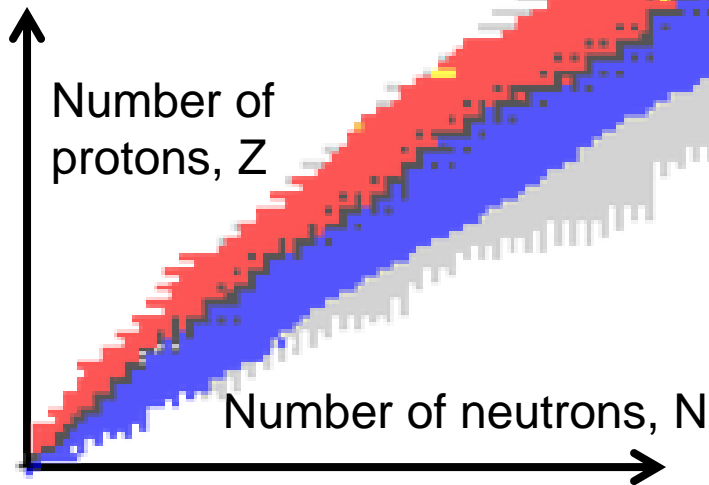


The nuclear playground

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



“Atomic nucleus”

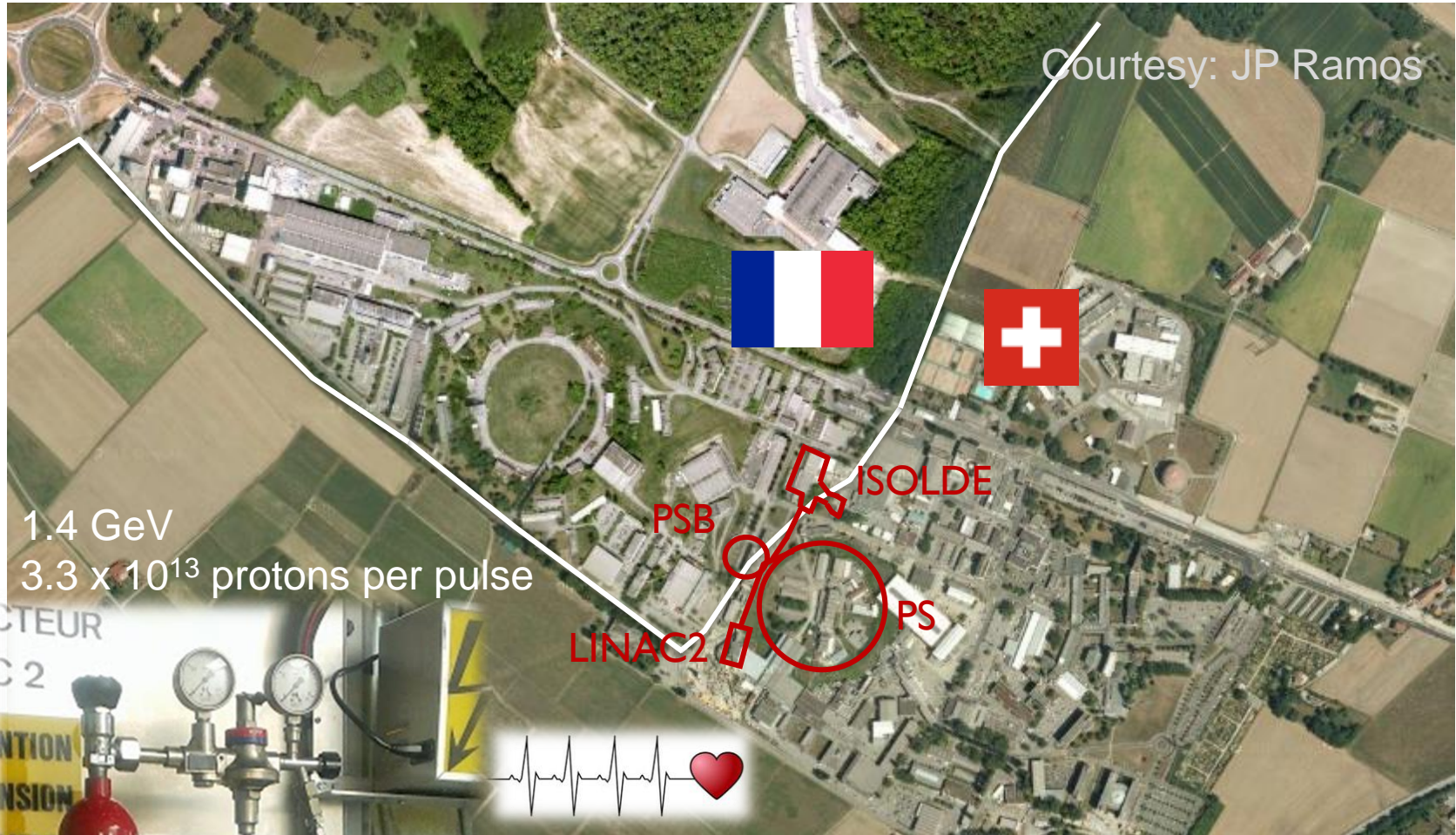


PERIODIC TABLE OF THE ELEMENTS

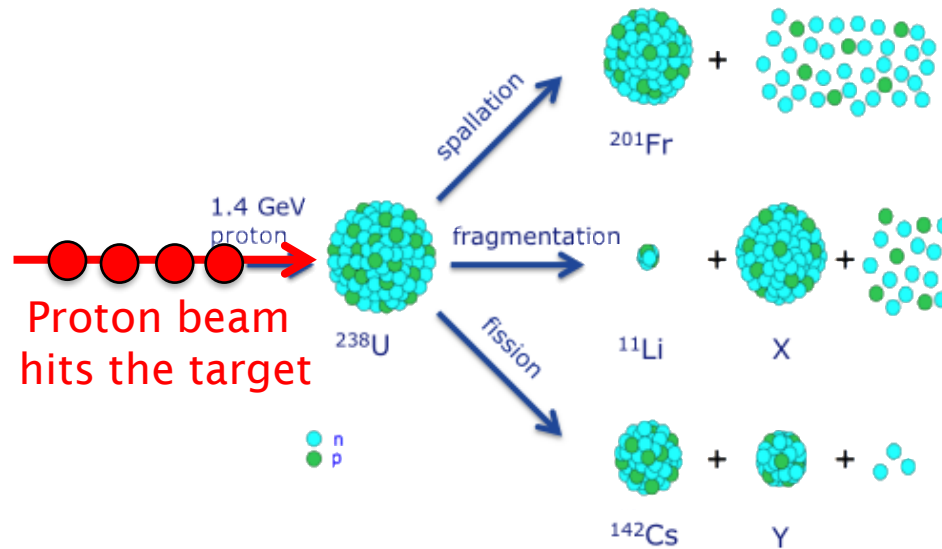
IA	IIA	IIIB	IVB	VB	VIB	VII B	VIII	IX	X	XI	XII	IIIA	IVA	VA	VIA	VIIA	VIIIA												
1 H 1.00794	2 He 4.002602	3 Li 6.941	4 Be 9.0122	5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180	11 Na 22.990	12 Mg 24.305	13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.06	17 Cl 35.453	18 Ar 39.948												
19 K 39.098	20 Ca 40.078	21 Sc 44.956	22 Ti 47.88	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.845	27 Co 58.933	28 Ni 58.693	29 Cu 63.546	30 Zn 65.38	31 Ga 69.723	32 Ge 72.63	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.80												
37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.224	41 Nb 92.906	42 Mo 95.94	43 Tc 98.906	44 Ru 101.07	45 Rh 101.07	46 Pd 106.32	47 Ag 107.868	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.757	52 Te 127.6	53 I 126.905	54 Xe 131.29												
55 Cs 132.91	56 Ba 137.33	57-71 La-Lu	72 Hf 178.49	73 Ta 180.948	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.22	78 Pt 195.084	79 Au 196.967	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po (209)	85 At (210)	86 Rn (222)												
87 Fr (223)	88 Ra (226)	89-103 Ac-Lr	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (264)	108 Hs (265)	109 Mt (266)	110 Uun (267)	111 Uuu (268)	112 Uub (269)	113 Uuq (270)	114 Uuq (271)	115 Uuq (272)	116 Uuq (273)	117 Uuq (274)	118 Uuq (276)												
89 La 138.91	90 Ce 140.12	91 Pr 140.91	92 Nd 144.24	93 Pm (145)	94 Sm 150.36	95 Eu 151.96	96 Gd 157.25	97 Tb 158.93	98 Dy 162.50	99 Ho 164.93	100 Er 167.26	101 Tm 168.93	102 Yb 173.05	103 Lu 174.967	104 La 175.053	105 Ce 177.054	106 Pr 178.055	107 Nd 179.055	108 Pm (179)	109 Sm 180.055	110 Eu 181.055	111 Gd 182.055	112 Tb 183.055	113 Dy 184.055	114 Ho 185.055	115 Er 186.055	116 Tm 187.055	117 Yb 188.055	118 Lu 189.055
89 Ac (227)	90 Th 232.038	91 Pa 231.04	92 U 238.029	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)	104 La 260.106	105 Ce 260.106	106 Pr 260.106	107 Nd 260.106	108 Pm (260)	109 Sm 260.106	110 Eu 260.106	111 Gd 260.106	112 Tb 260.106	113 Dy 260.106	114 Ho 260.106	115 Er 260.106	116 Tm 260.106	117 Yb 260.106	118 Lu 260.106

Why at CERN?

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



Production: Modern-day alchemy

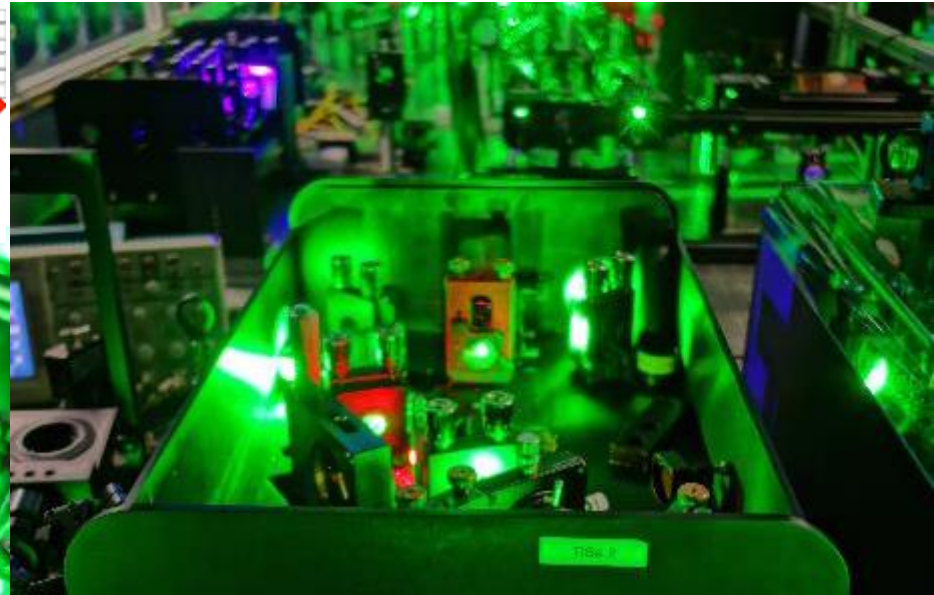
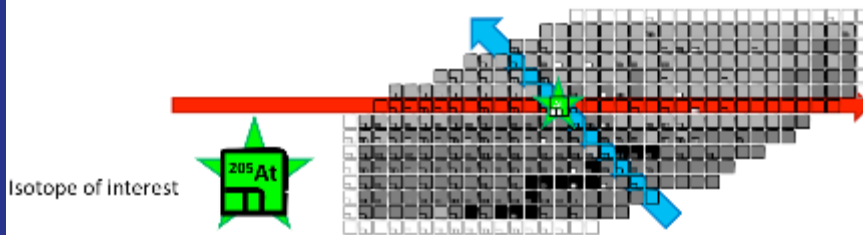
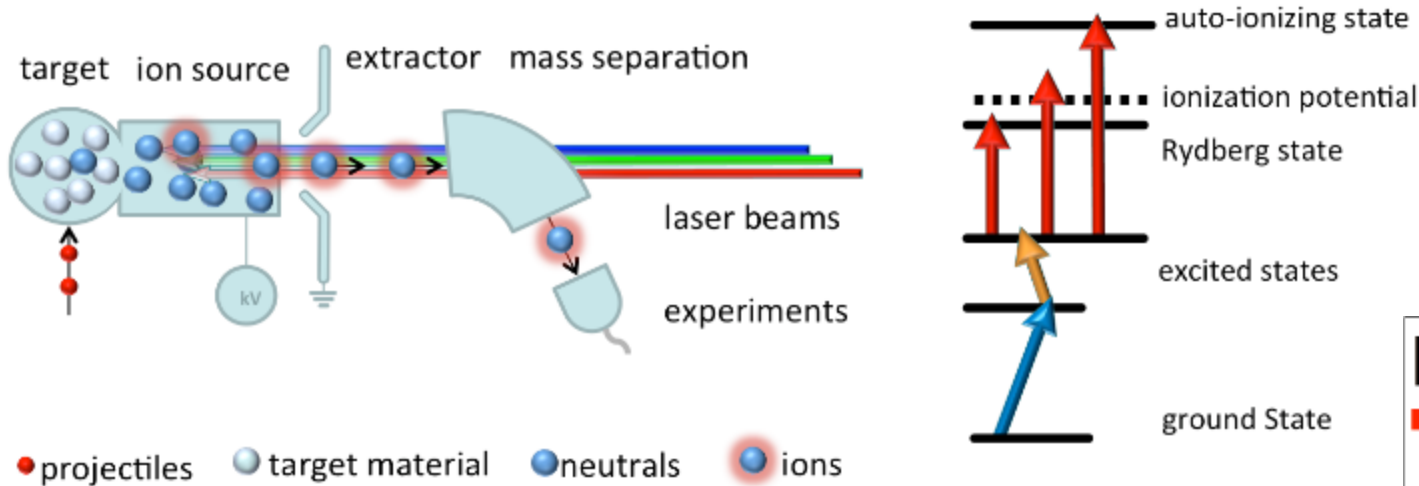


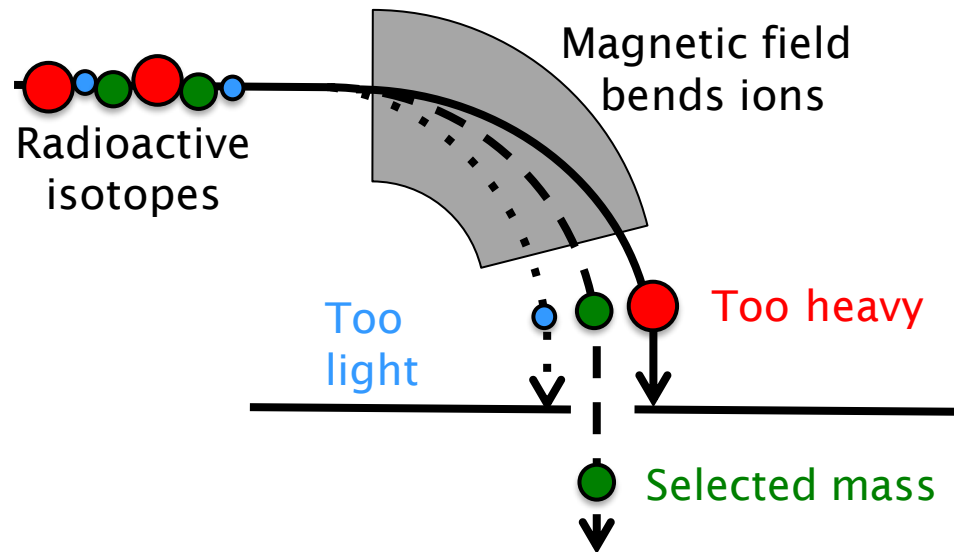
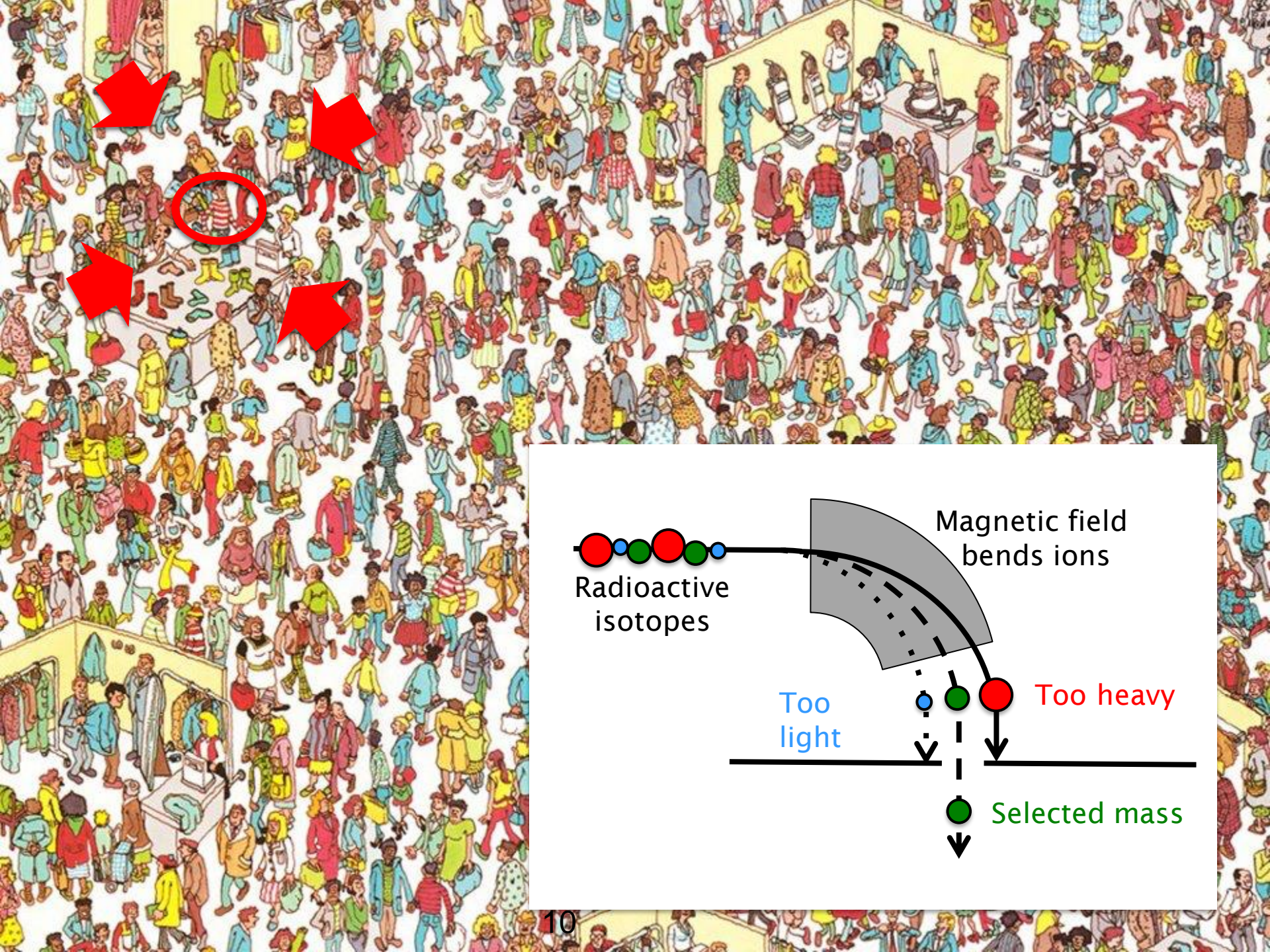
- ◆ The protons split up the heavy nucleus to produce a wide variety of nuclei **simultaneously!**
- ◆ Requirements for experiment:
 - ◆ High production
 - ◆ Pure radioactive beams: 1 kind of isotope
- ◆ Different stages of preparation
 - ◆ Production
 - ◆ Ionization
 - ◆ Separation

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

Ionization: RILIS

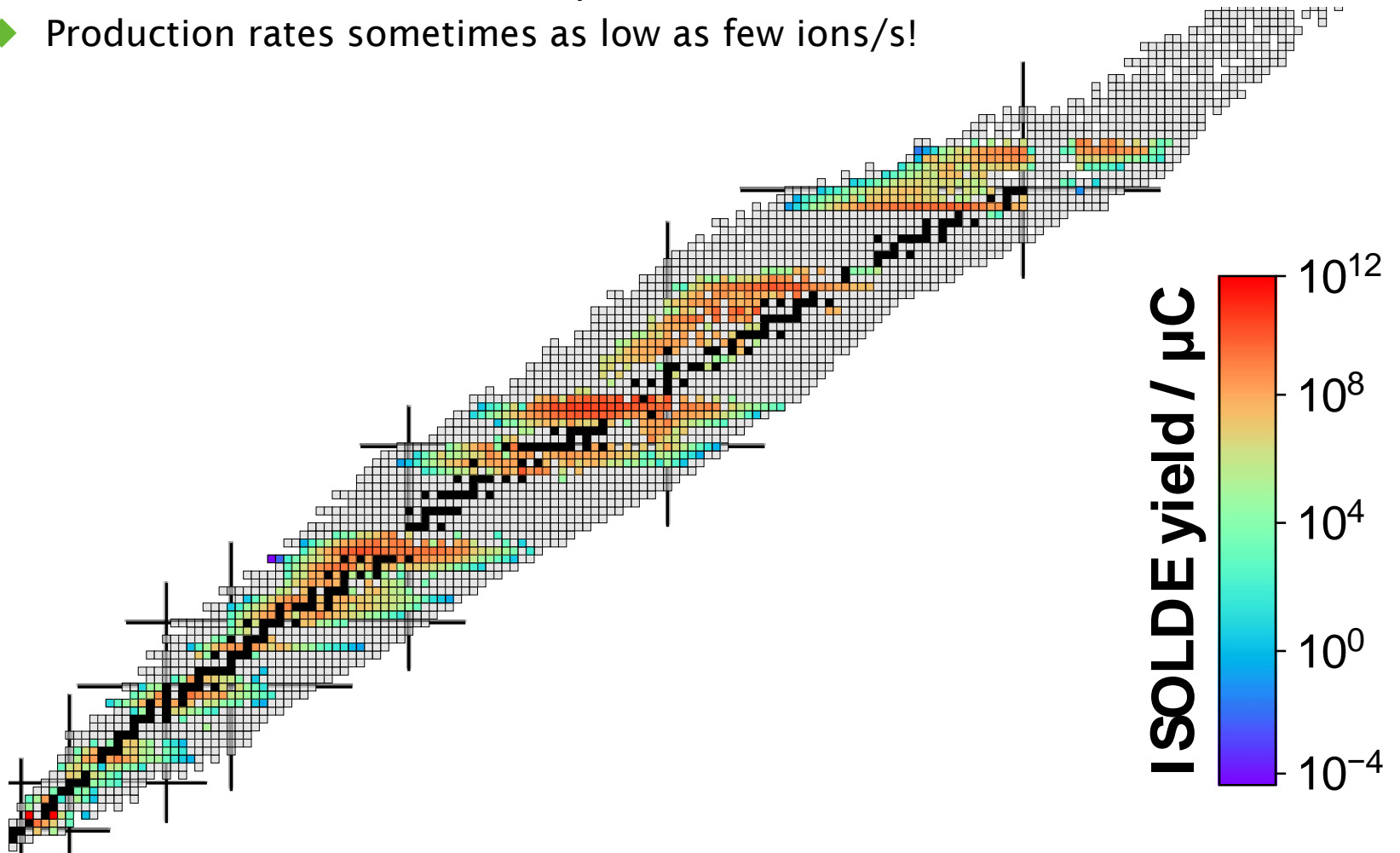
- ◆ Resonance Ionization Laser Ion Source
- ◆ Uses lasers to selectively ionize a particular element (isotope/isomer)





What is produced at ISOLDE?

- ◆ More than 1500 isotopes of 74 different chemical elements
- ◆ Half-lives from 1 ms and 10^{12} years
- ◆ Production rates sometimes as low as few ions/s!



Research with radioactive beams

Astrophysics

Search for beyond
Standard model
physics

Nuclear physics
and
atomic physics

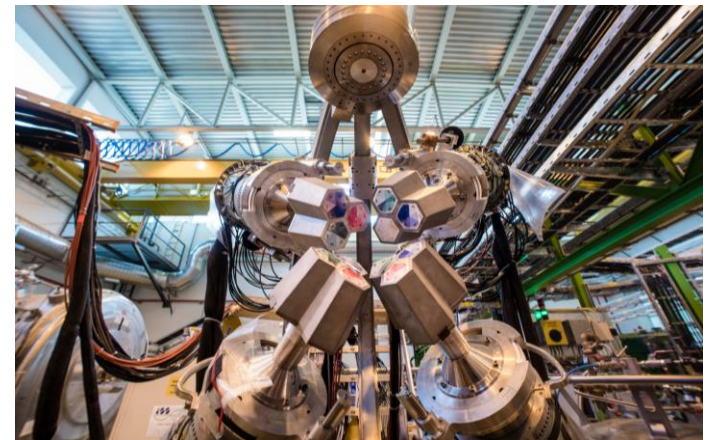
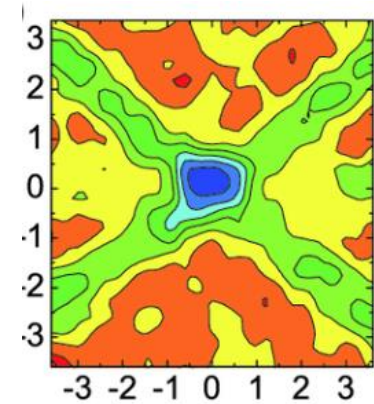
Material science

Life sciences and
biophysics

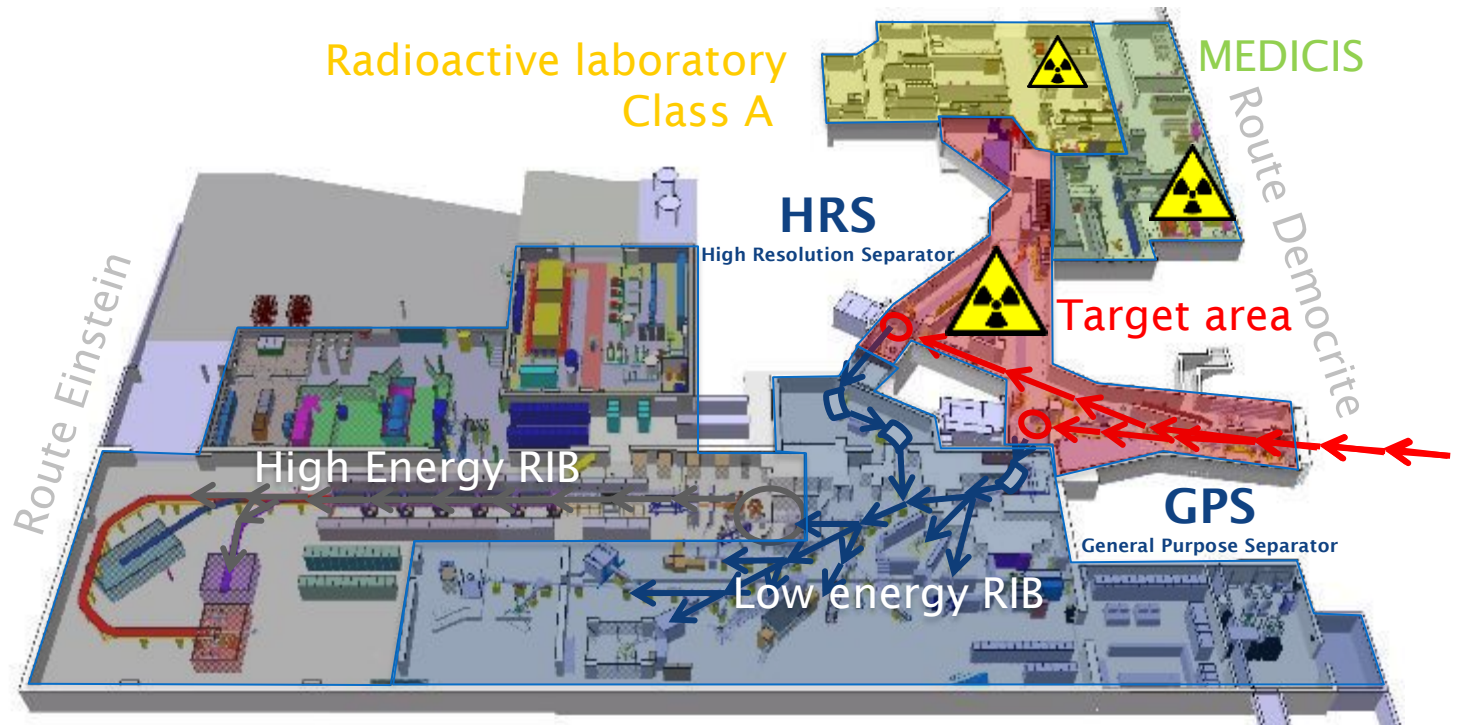
Radioisotopes for
medical
applications

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?

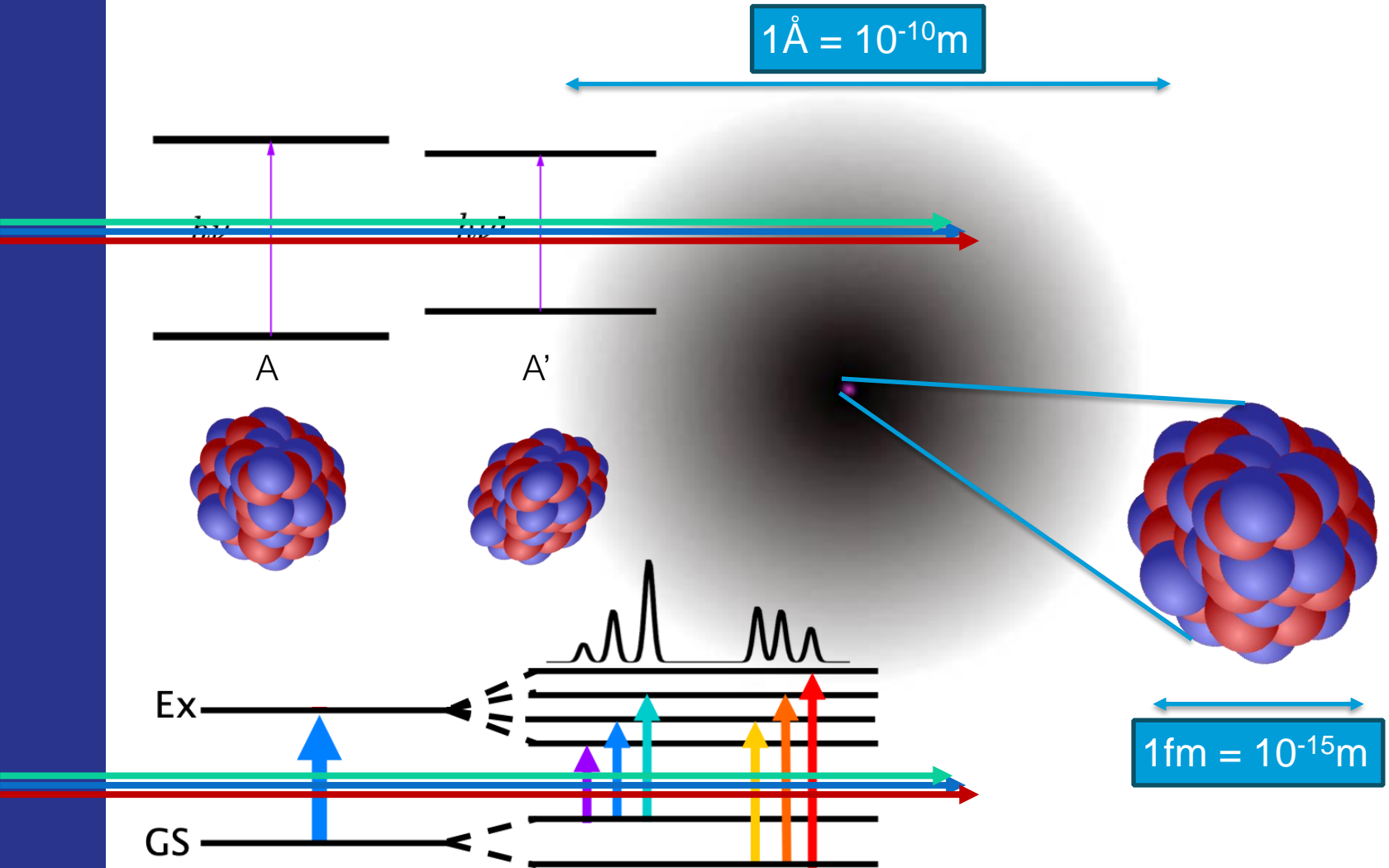


The ISOLDE facility

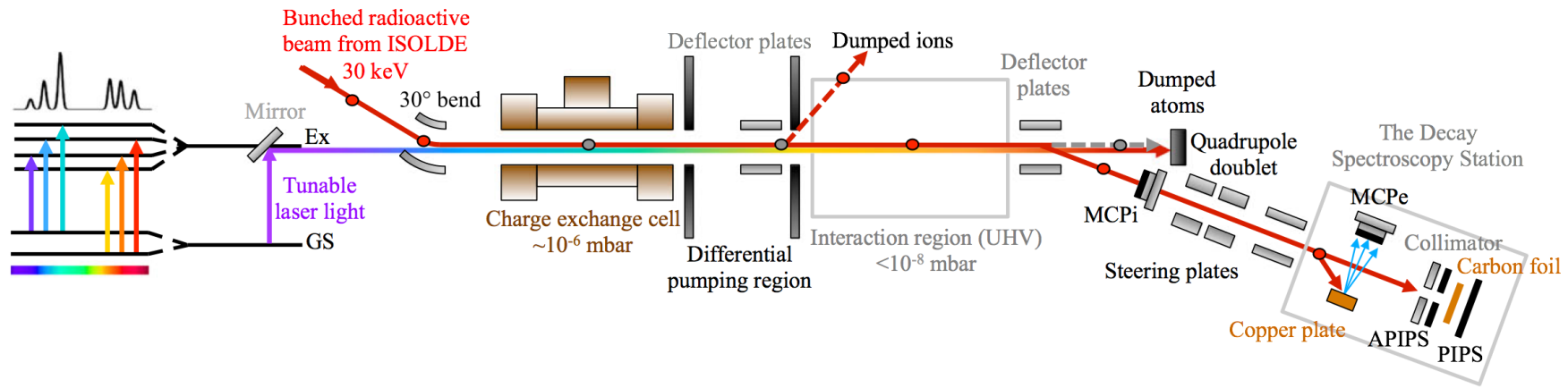


- Protons (1.4 GeV)
- Low energy RIBs (up to 60 keV)
- High energy RIBs (up to 10 MeV/u)

CRIS



CRIS



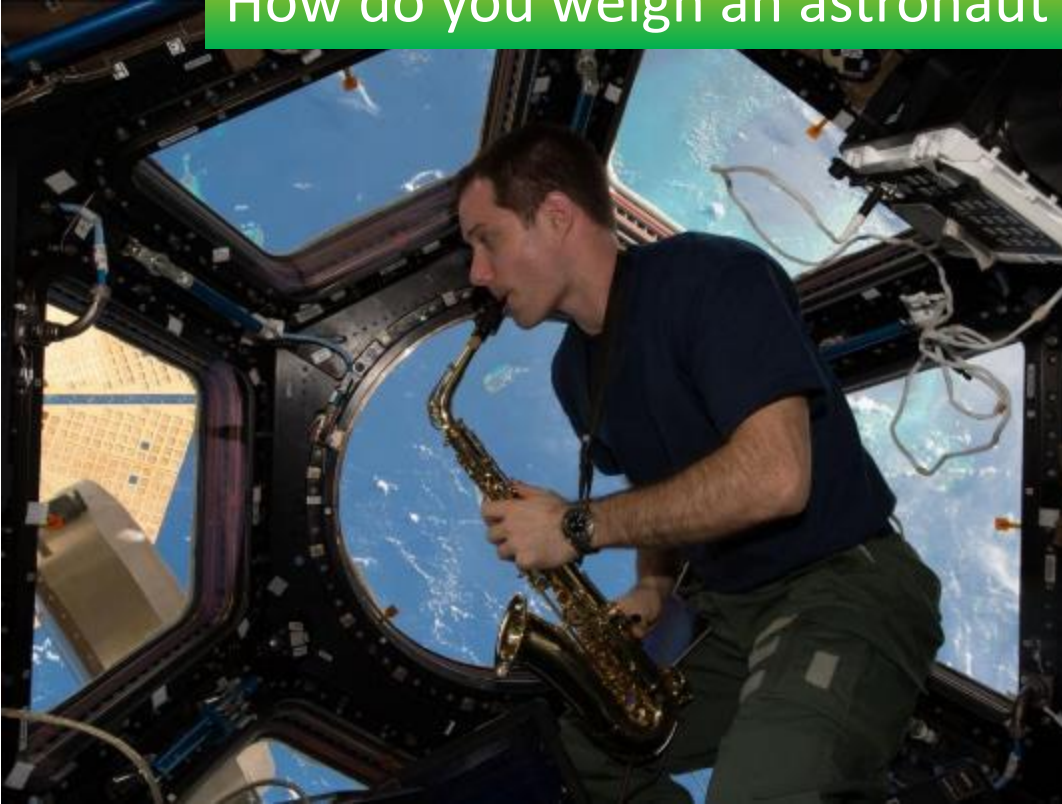
ISOLTRAP

How do you measure flour for a cake?



ISOLTRAP

How do you weigh an astronaut in space?

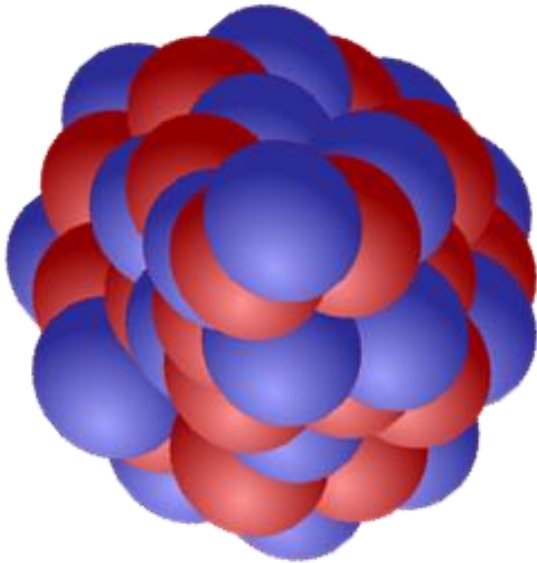


$$\sum F = ma$$

If gravity is not the force to use anymore, then you can use tension!

ISOLTRAP

How do you weigh an atom?



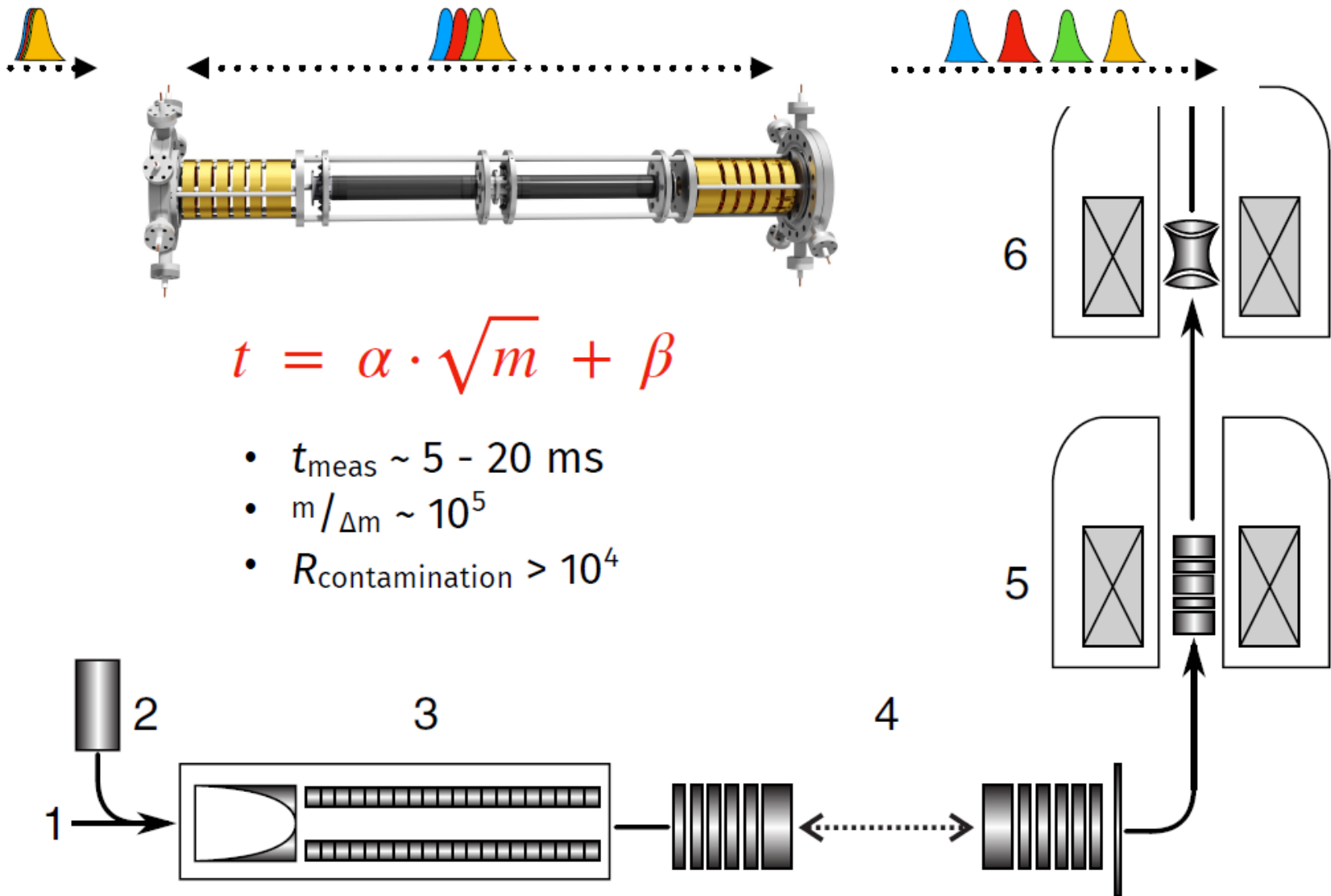
$$\sum F = ma$$

If gravity and tension won't work, then you must search for something else!

$$E = \frac{1}{2}mv^2$$

Electromagnetic
forces

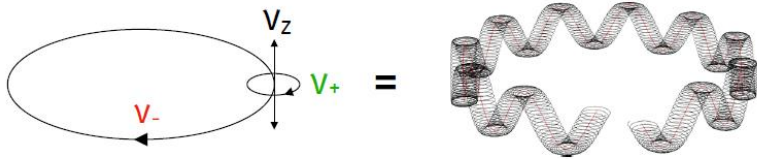
ISOLTRAP



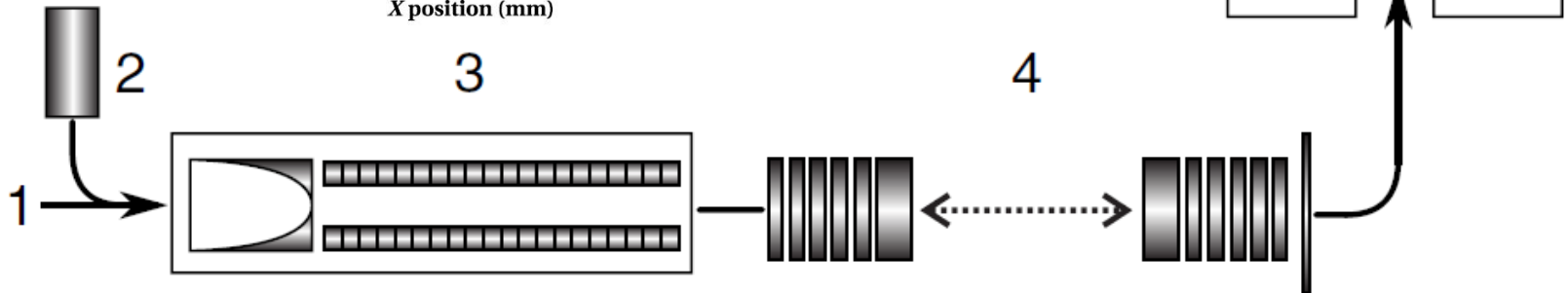
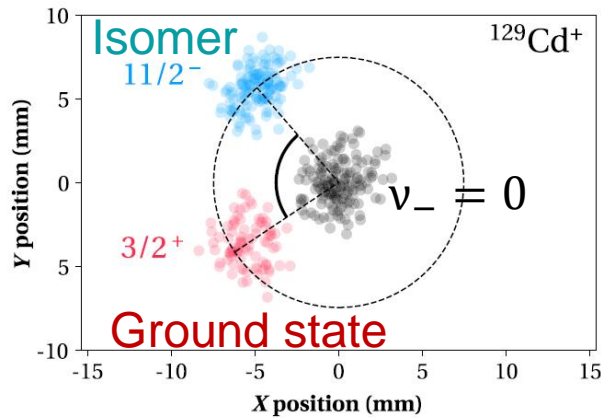
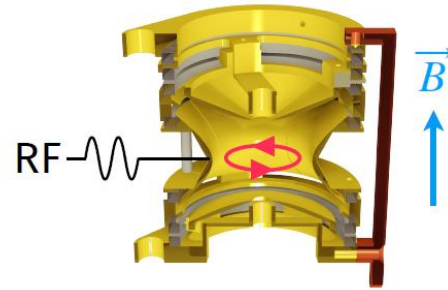
$$t = \alpha \cdot \sqrt{m} + \beta$$

- $t_{\text{meas}} \sim 5 - 20 \text{ ms}$
- $m/\Delta m \sim 10^5$
- $R_{\text{contamination}} > 10^4$

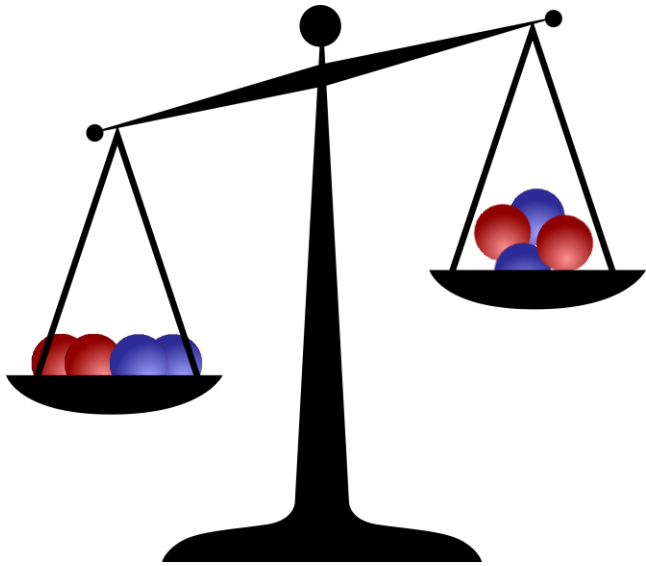
ISOLTRAP



$$V_C = V_- + V_+ = \frac{B \cdot q}{2\pi \cdot m}$$



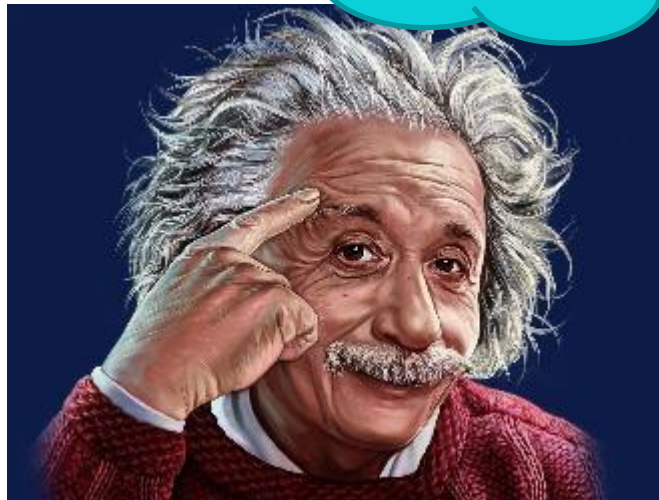
ISOLTRAP



Binding energy

$$BE = m_A - \sum_N m_n - Z \sum m_p$$

$$E = mc^2$$

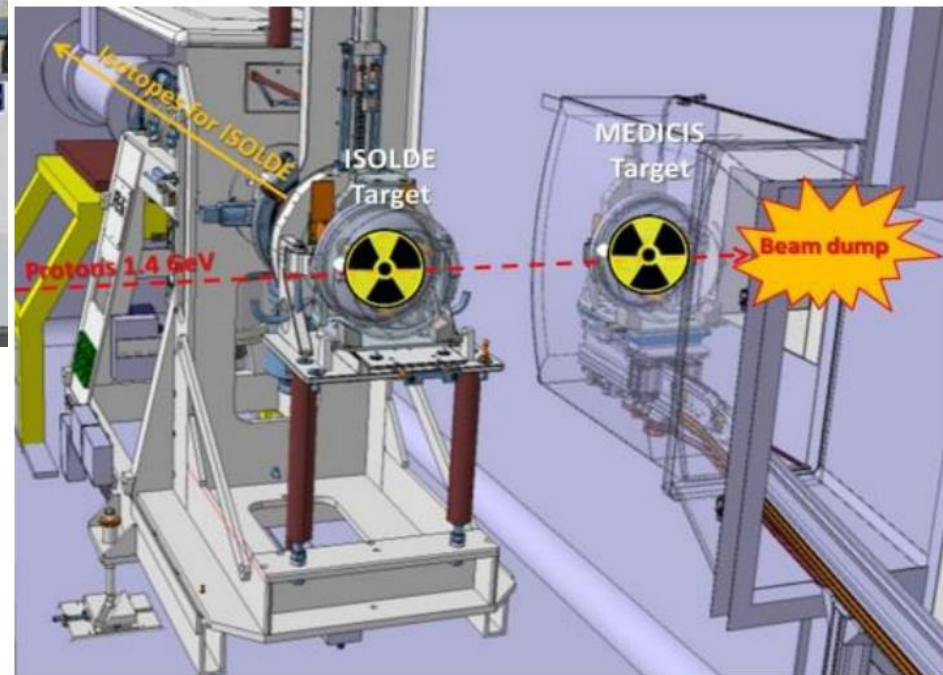


Daily life at ISOLDE

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

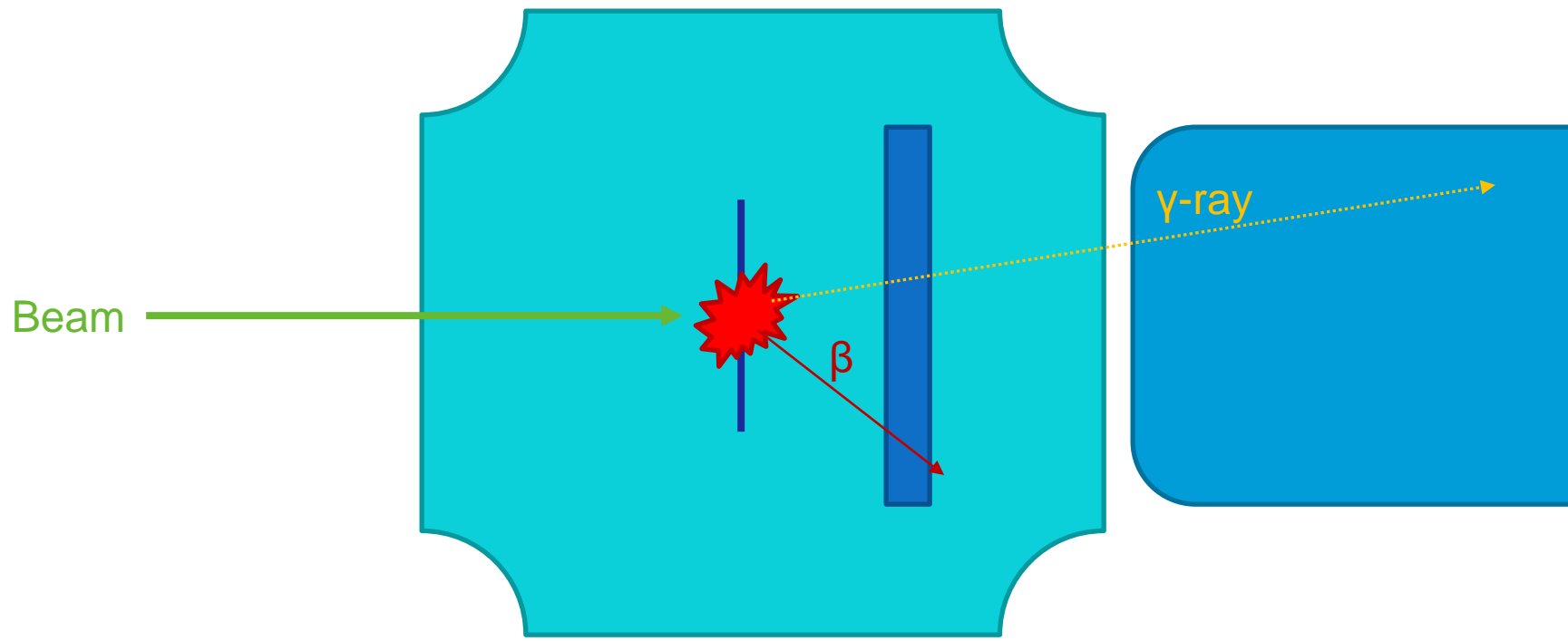


MEDICIS: recycling protons for society

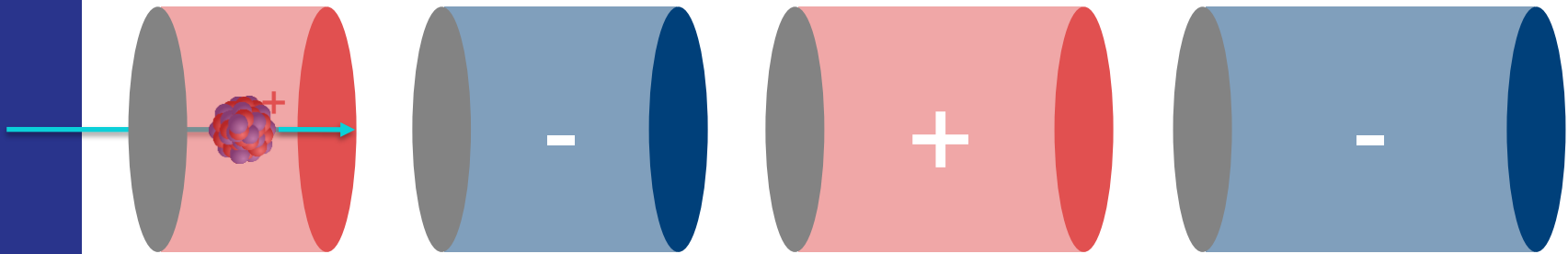


- ◆ Production of non-conventional radioisotopes for medical research
 - ◆ 80-90% of the proton beam goes through the ISOLDE target unaffected
 - ◆ Use these (free!) protons to create more radioisotopes

ISOLDE Decay Station IDS



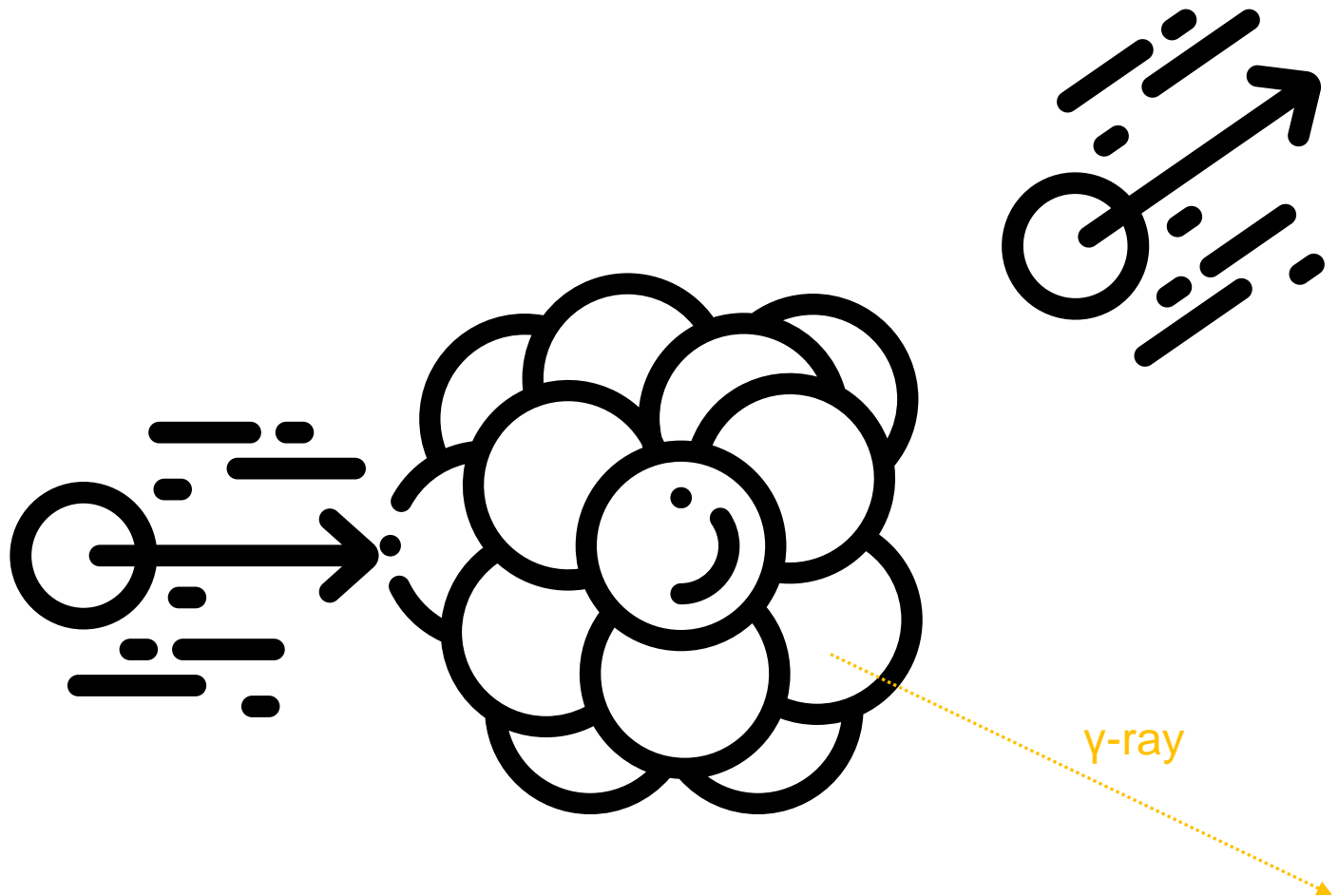
DTL



The polarity of the electrode is then switched while the ion is inside.

It would like falling into a lift, and when you reach the bottom of the lift, the lift has brought you back to the top so that you may fall again further!

Nuclear reactions



Merci! Bedankt! Thank you!



Sarina Geldhof



Thomas Elias Cocolios



Maxime Mougeot

ISOLDE

<https://isolde.cern>

MEDICIS

<https://medicis.cern>

And some behind the scenes!