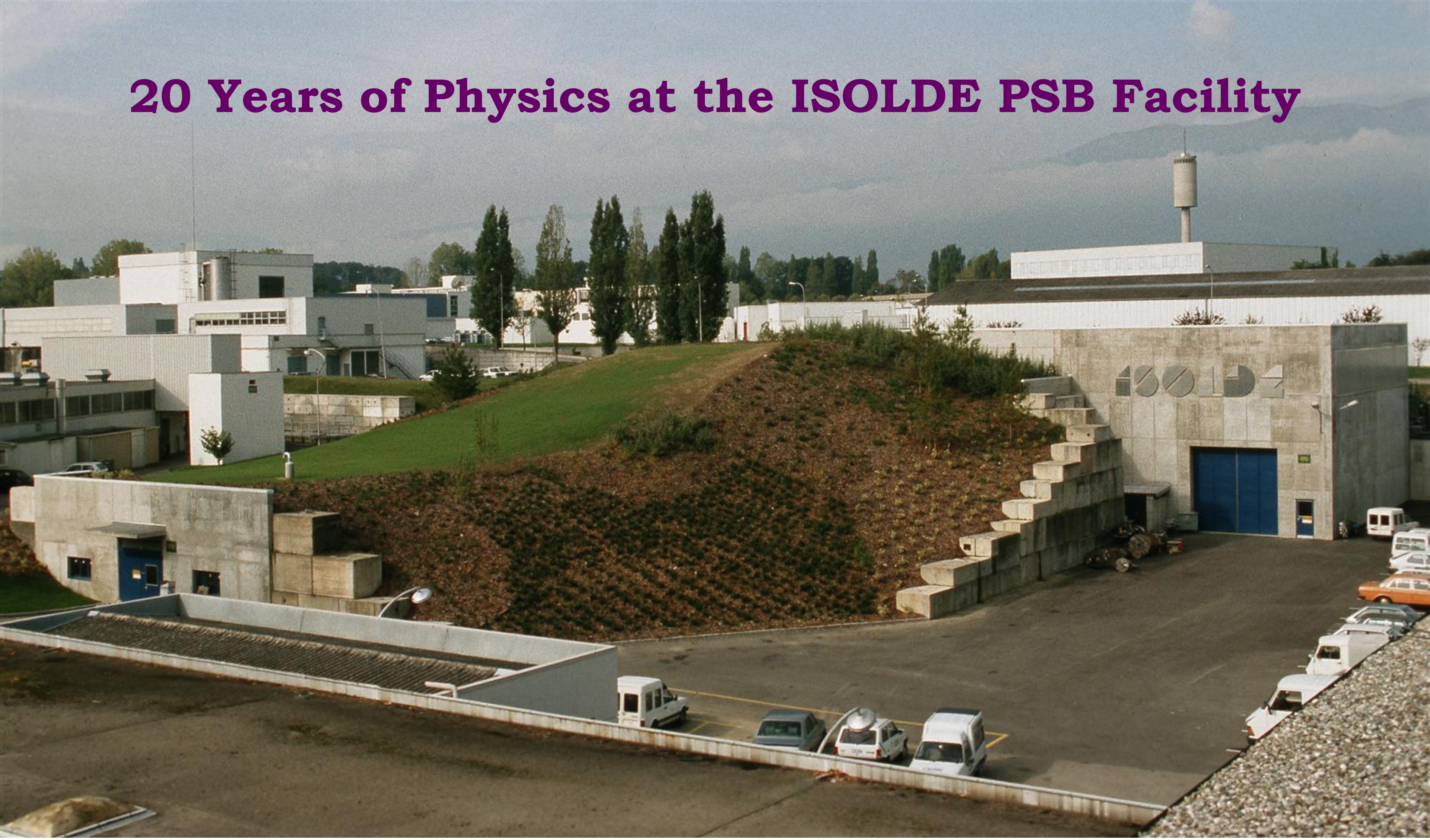
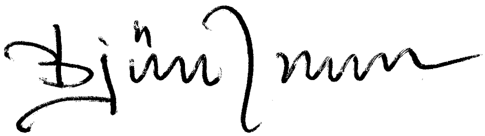
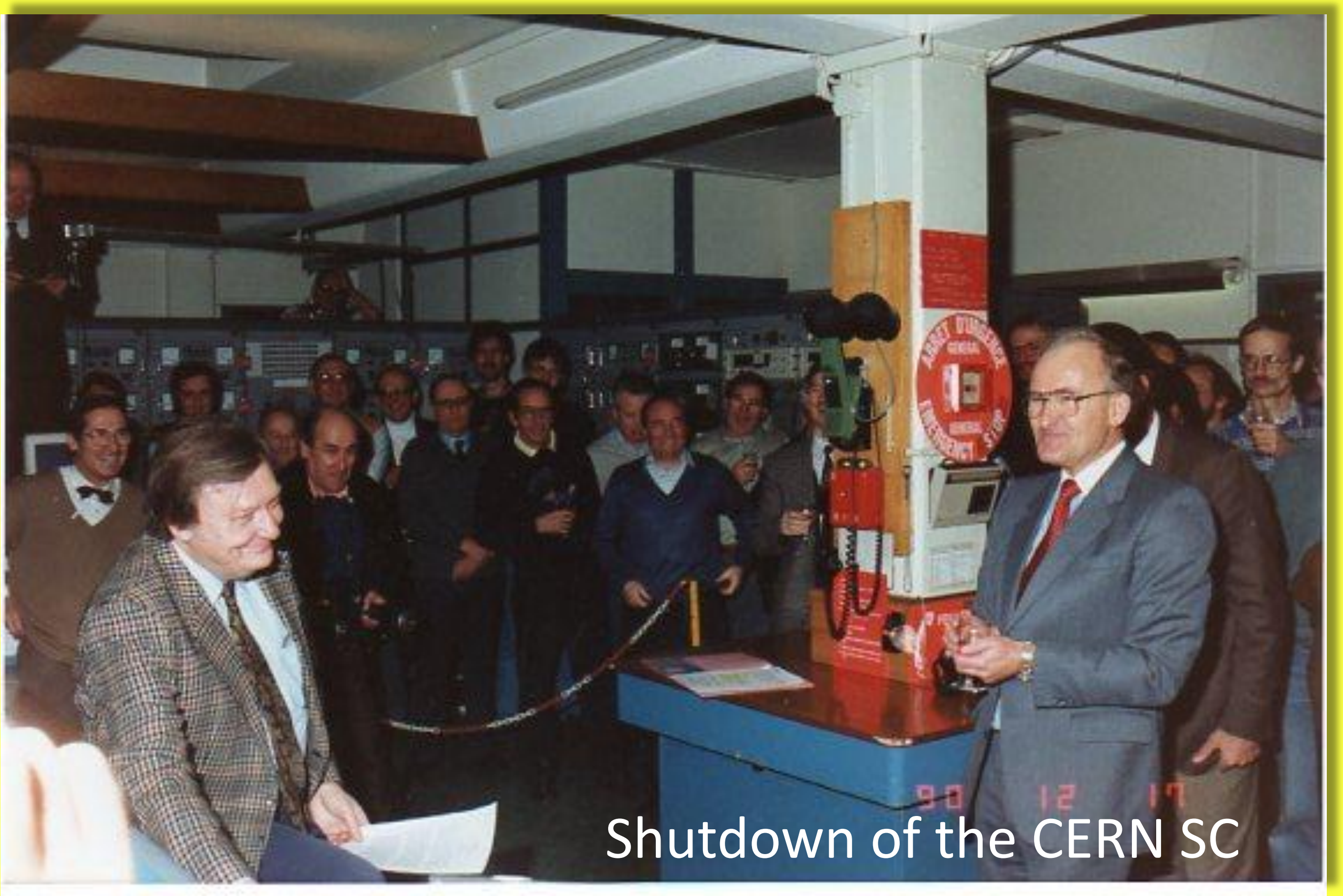
20 Years of Physics at the ISOLDE PSB Facility



ISOLDE Workshop and Users Meeting
18 December 2012



.....the end



Shutdown of the CERN SC

19 December 1990 12:00

CERN INAUGURATES ITS LATEST EXPERIMENTAL FACILITY.

Daniel Simon
1937–2011

Leading physicists from all … e to CERN on 26 May to celebrate the inauguration of CERN … ental facility, ISOLDE (Isotope Separator On-Line) at the … n Booster. A ceremony was held in the new ISOLDE experi… the participants were welcomed by Prof. C. Rubbia, Direct… N. Prof. B. Jonson, of Chalmers University in Göteborg, … physics potential of the new installation and Prof. C. De… he Institut National de Physique Nucléaire et Physique des …), stressed the importance of the ISOLDE facility for Europe… .

26 May, 1992

ISOLDE was reborn....

- **a new environment**

  Perspective for further growing and expansion

- **new technical challenges and opportunities**,

  Pulsed beam, higher energy, higher intensity

- **space to grow**

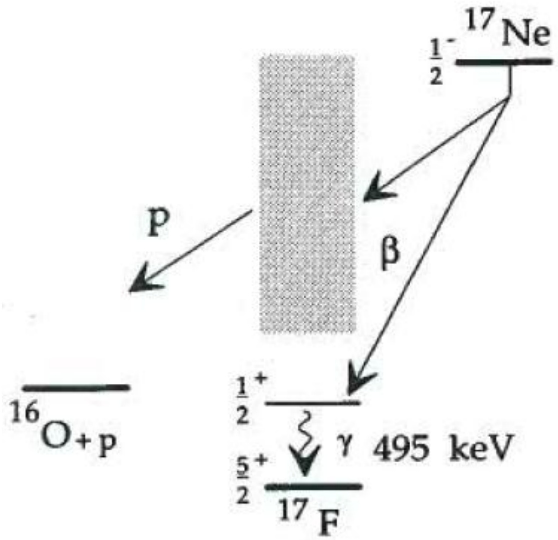
  Experiments, REX ISOLDE, HIE ISOLDE, TSR

- **new visibility**

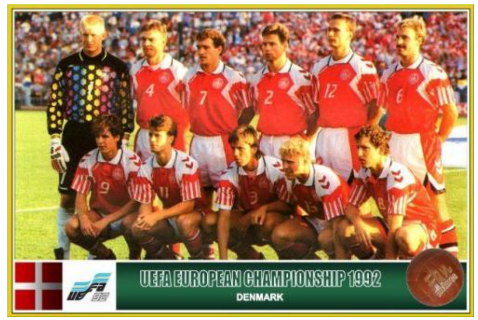
  A major CERN Facility

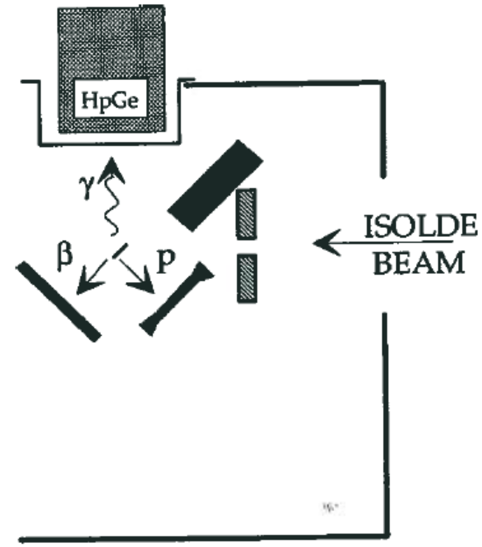
> “.....the fact that ISOLDE "survived" at CERN helped Nuclear Physics in Europe and elsewhere.” Georg Bollen, 2012

…..the beginning.

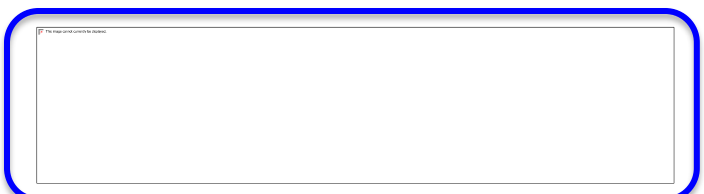


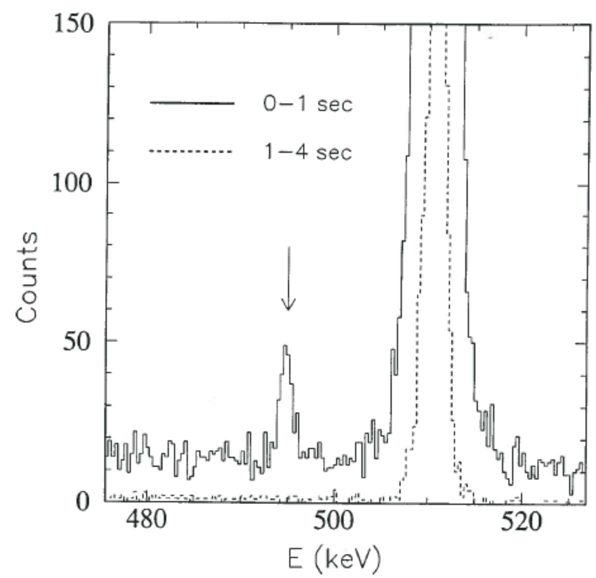
26.6.1992





Mirror decay $^{17}N \rightarrow {}^{17}O$





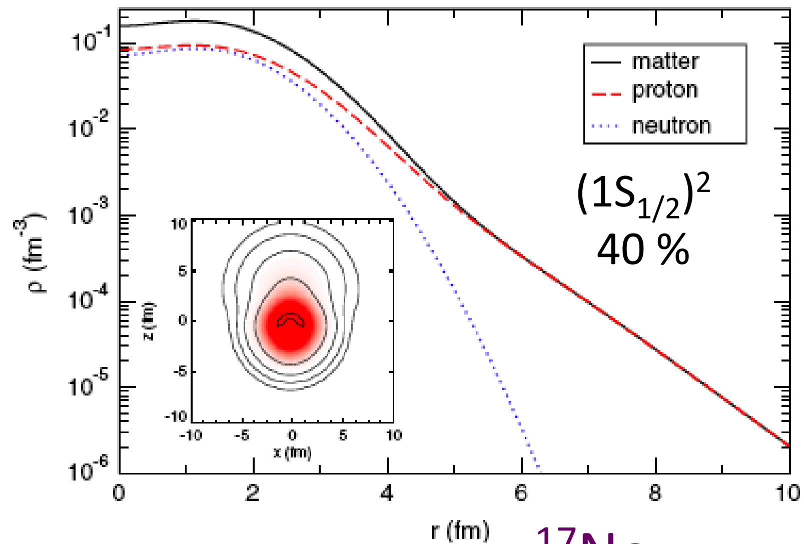
Beta-decay to the proton halo state in ^{17}Ne

M.J.G. Borge et al.,Phys. Lett. B 317 (1993) 25

$^{17\text{-}22}$Ne

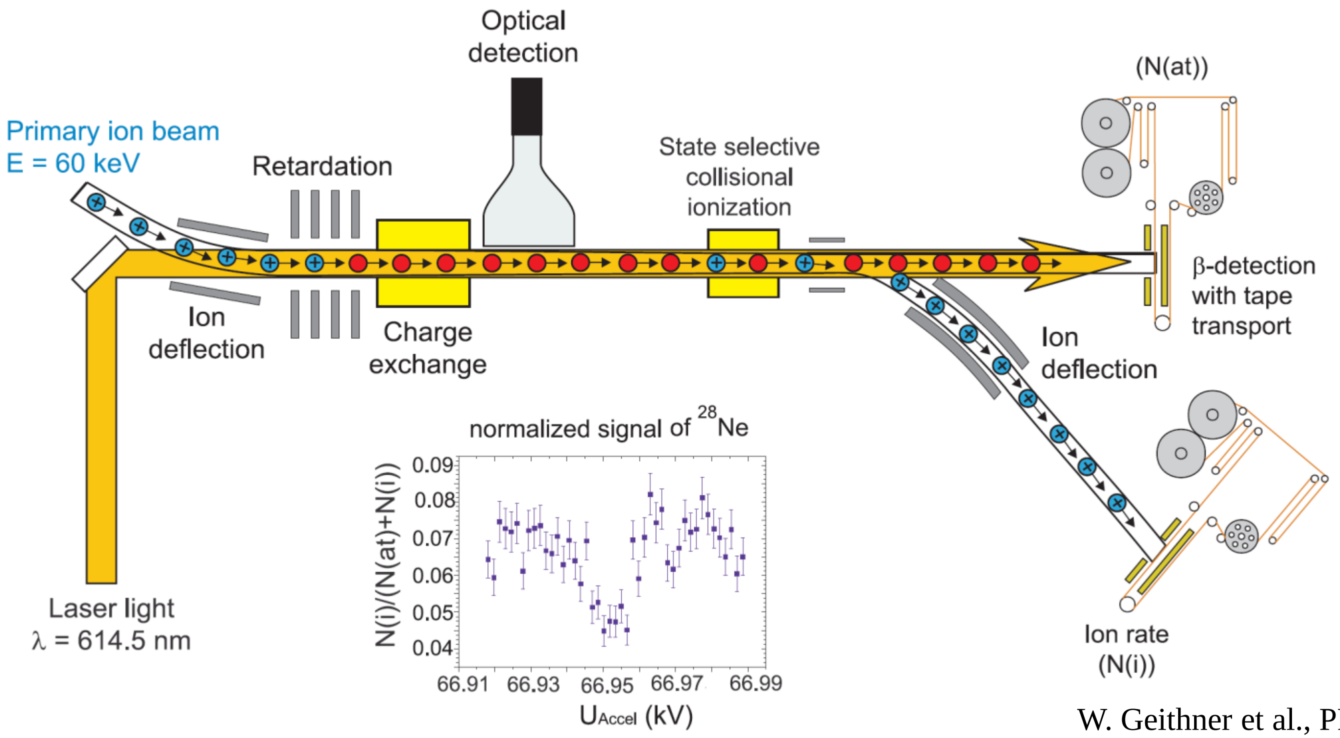
Mass :
ISOLTRAP

Charge radius:
Collinear laser spectroscopy



$(1S_{1/2})^2$
40 %

^{17}Ne



W. Geithner et al., PRL **101**, 252502 (2008)

ISC/P68
14.11.1994

PROPOSAL TO THE ISOLDE COMMITTEE

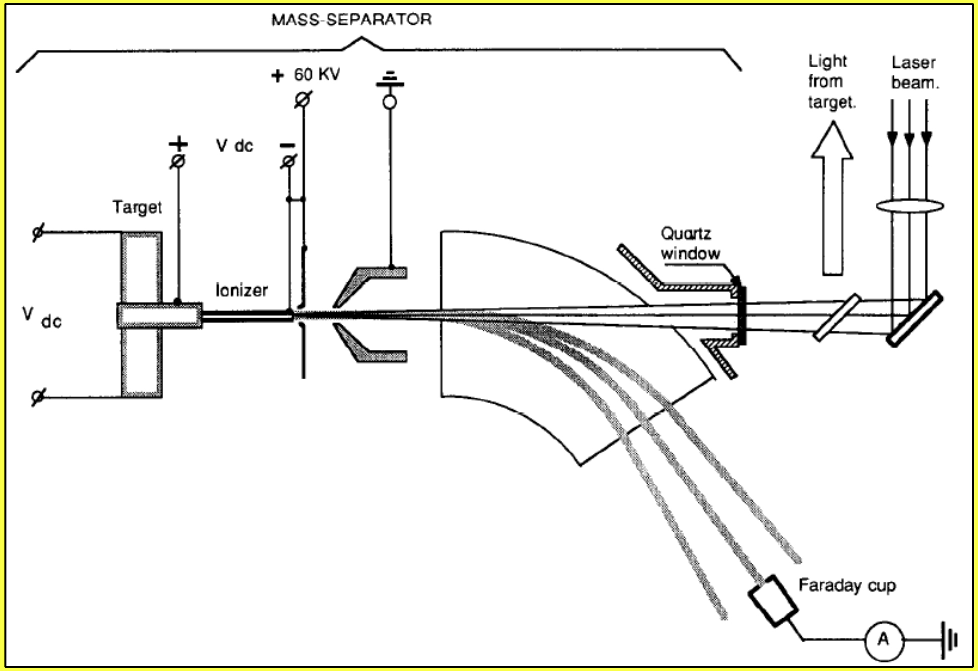
Radioactive beam EXperiments at ISOLDE:
Coulomb excitation and neutron transfer reactions of exotic nuclei

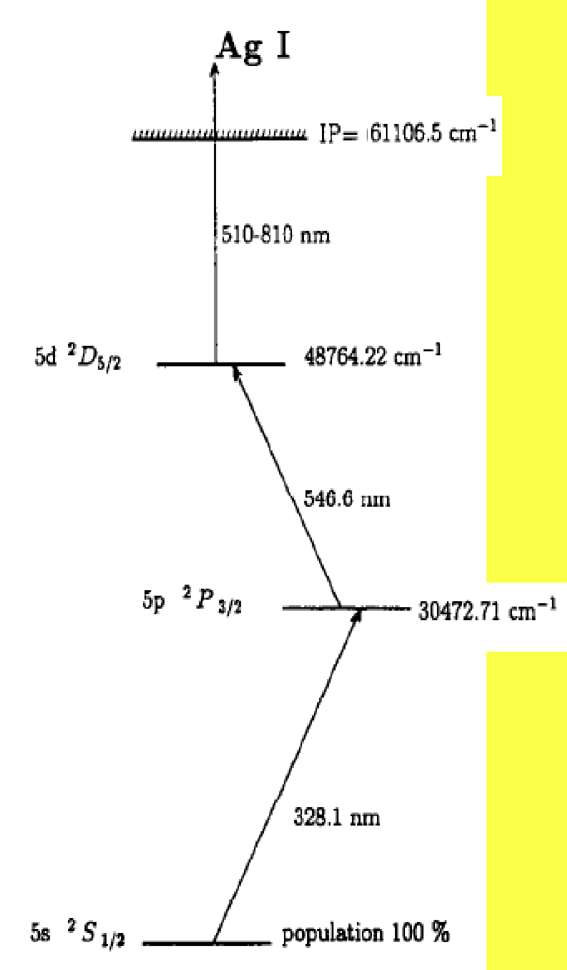
Aarhus - Brookhaven - Daresbury - Darmstadt - Dubna - Erlangen - Frankfurt - Gothenborg - Göttingen - Heidelberg - Leuven - Liverpool - Mainz - München -Paris - Saclay - Stockholm - Strasbourg - Surrey - Roskilde - Villeurbanne and CERN-ISOLDE collaboration

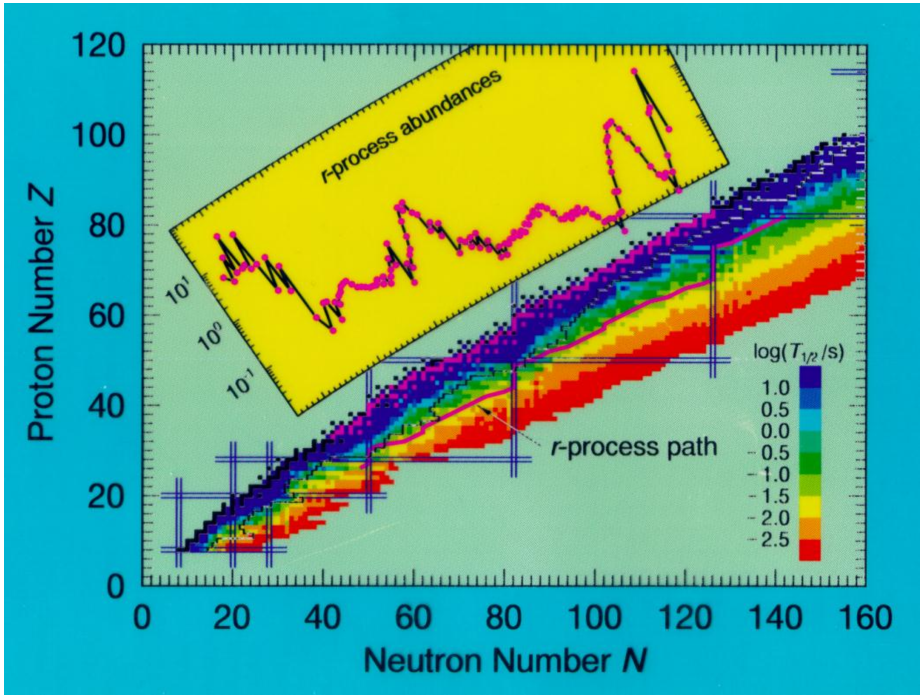
Spokesperson: Dietrich Habs

Chemically selective laser ion-source for the CERN–ISOLDE on-line mass separator facility

Mishin et al. NIM B73 (1993) 550







^{130}Cd

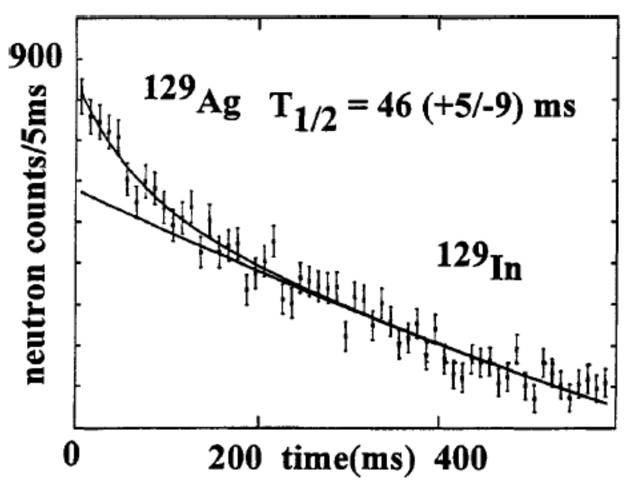
$T_{1/2}$ = 195 ms

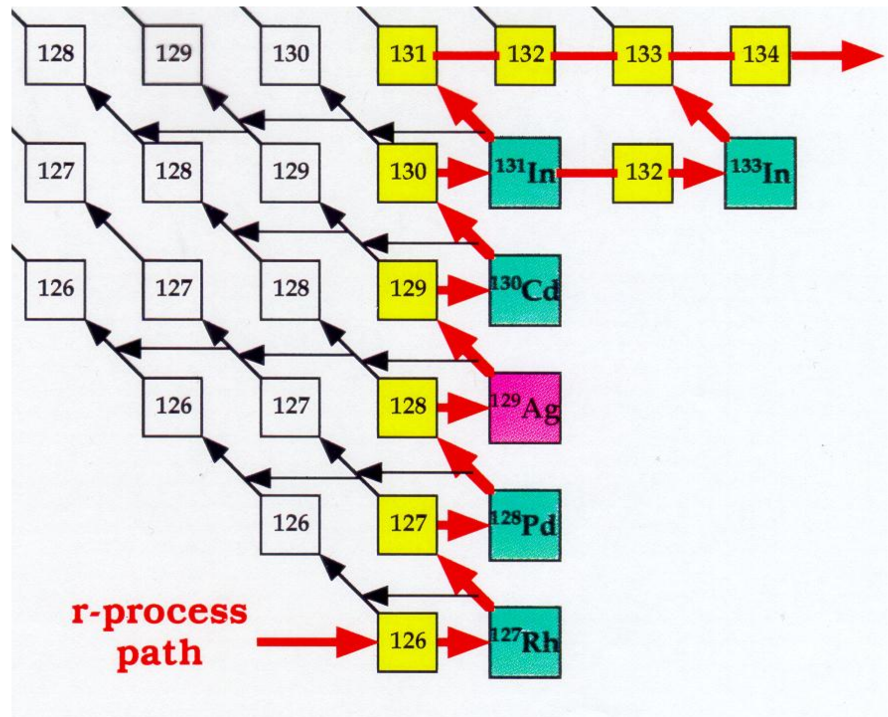
B. Pfeiffer, K.-L. Kratz, and F.-K. Thielemann, Z. Phys. A **357**, 235 (1997).

^{129}Ag

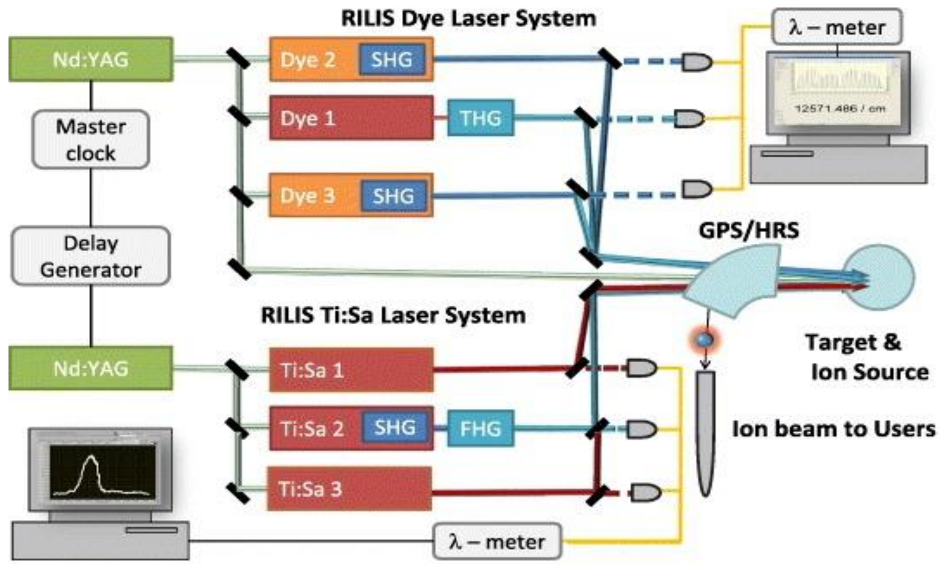
$T_{1/2}$ = 46 ms

Kratz et al., Hyperfine Interactions 129 (00) 185





RILIS Beams

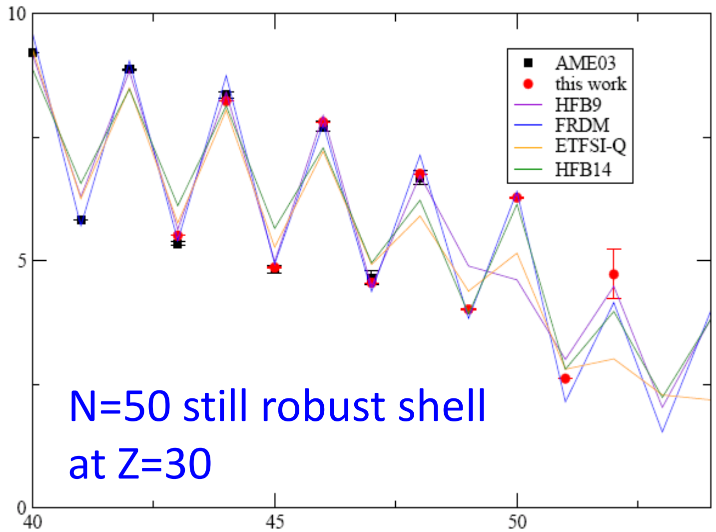


V N Fedosseev et al 2012 Phys. Scr. 85 058104

1 H																	2 He
3 Li	4 Be											5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe
55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn
87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110	111	112						

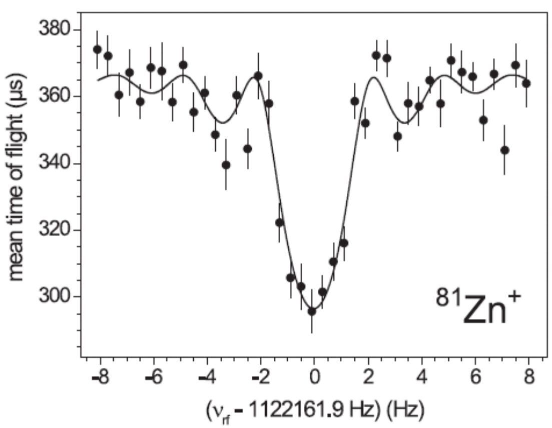
58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu
90 Th	91 Pa	92 U	93 Np	94 Pu	95 Am	96 Cm	97 Bk	98 Cf	99 Es	100 Fm	101 Md	102 No	103 Lr

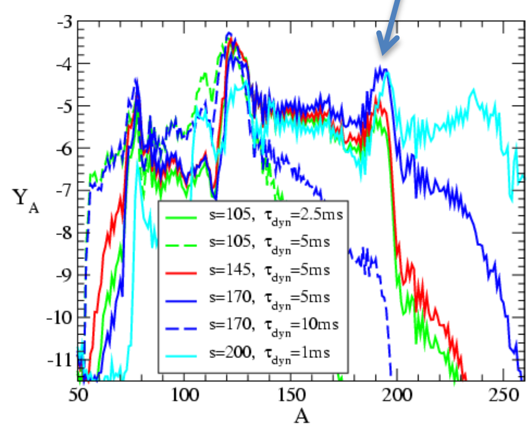
ISOLTRAP: $^{80-81}$Zn



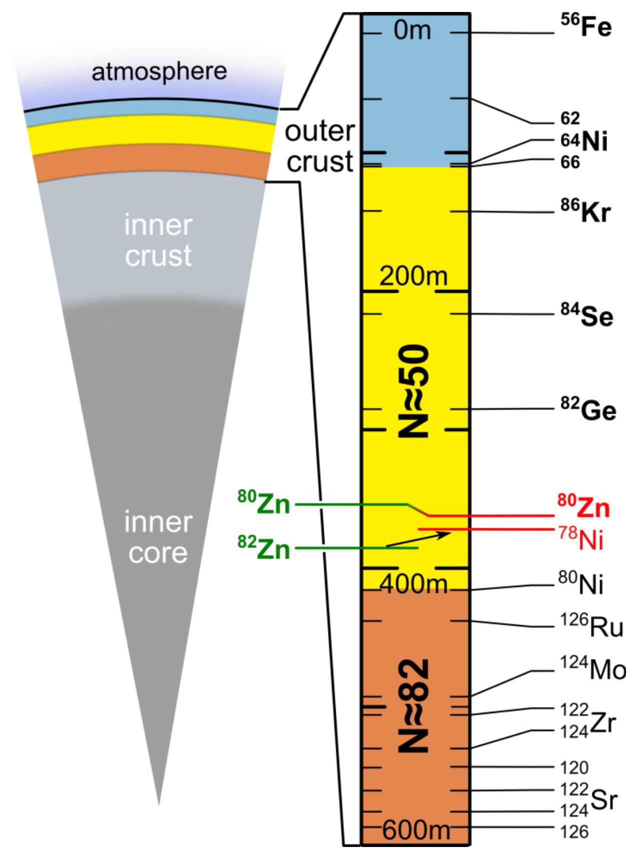
Neutron separation energy (MeV) versus N

S. Baruah et al, PRL 101 (2008) 262501



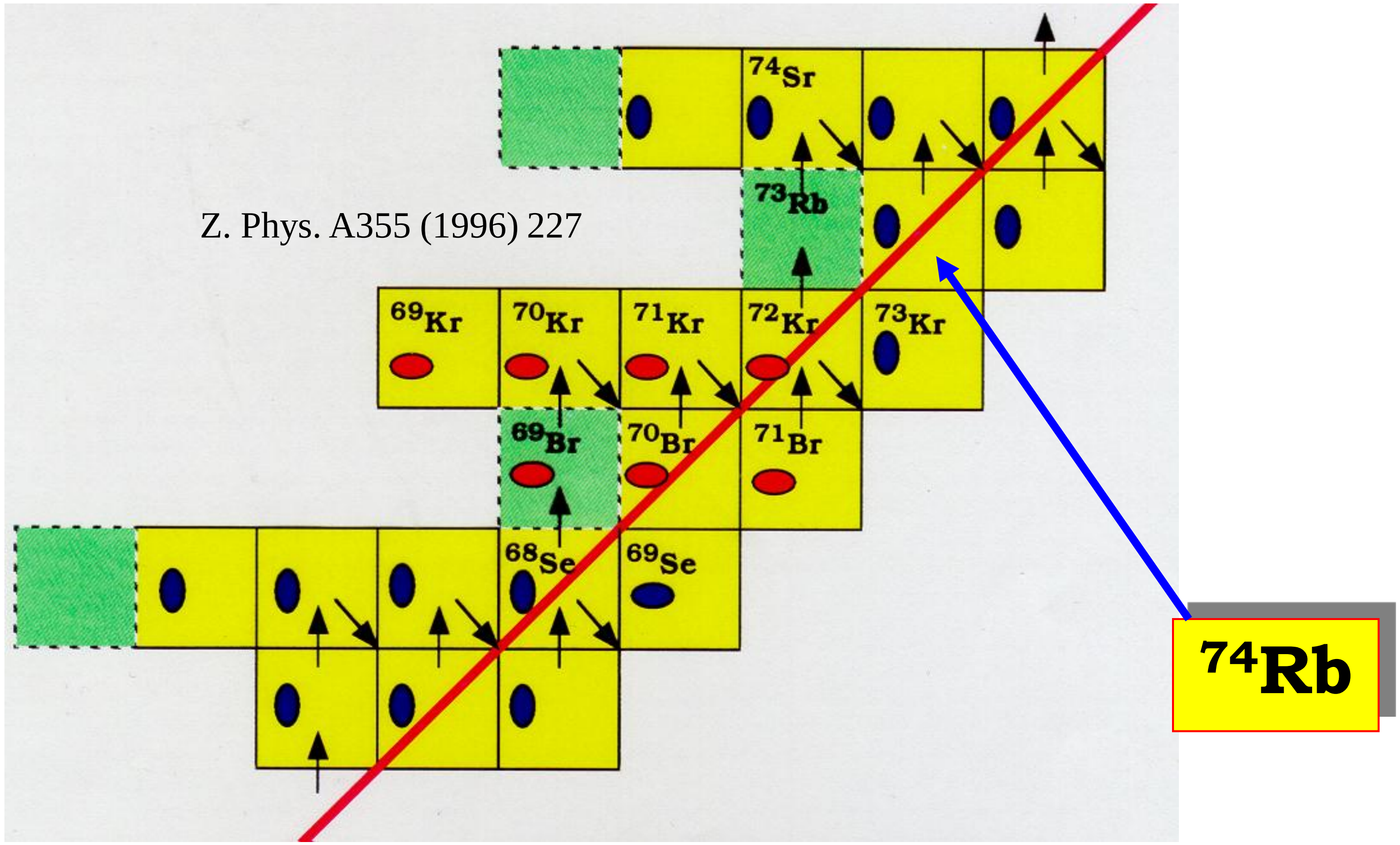


Composition of the
outer crust of a neutron star



S. Kreim and the ISOLTRAP Coll. (2011)

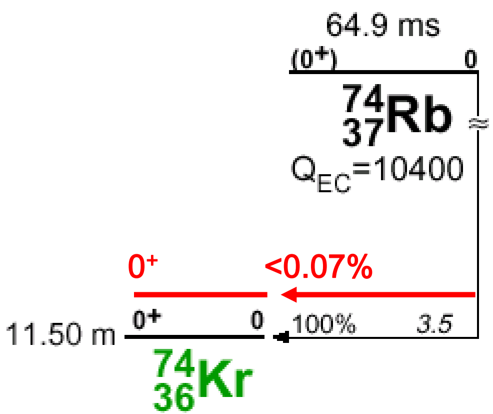
The rp -process



^{93}Nb(p,5p15n)^{74}Rb
1 GeV protons

Complete spectroscopy on Fermi β-emitter ^{74}Rb

^{93}Nb(p,5p15n)^{74}Rb

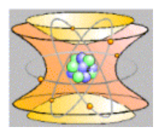


Results:

1) non-analog $0^+ \rightarrow 0^+$ transition observed
   $\rightarrow$ estimate for the Coulomb mixing
2) mass of ^{74}Rb (ISOLTRAP & MISTRAL)
3) mass of the daughter ^{74}Kr (ISOLTRAP)

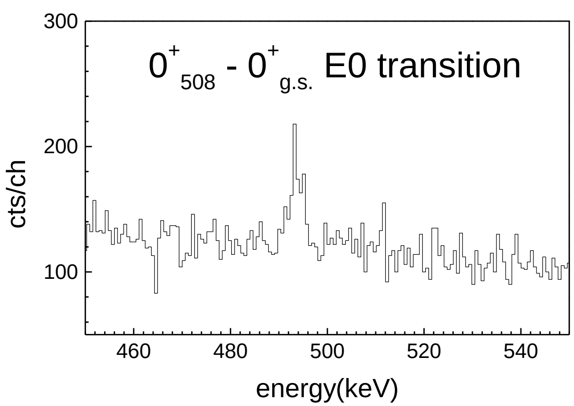
2) & 3)$\rightarrow$ Q_{EC} value

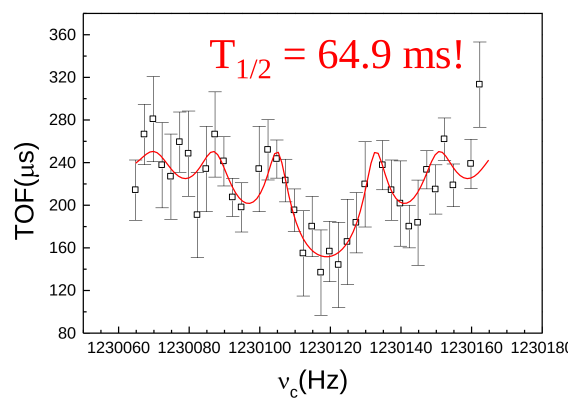
$$Ft = ft(1+\delta_R^{'})(1+\delta_{NS}-\delta_C)$$
$$= K/2G_F^2V_{ud}^2(1+\Delta_R^V)$$
$$Ft = 3073.9(8)s$$
$$V_{ud} = 0.97378(27)$$

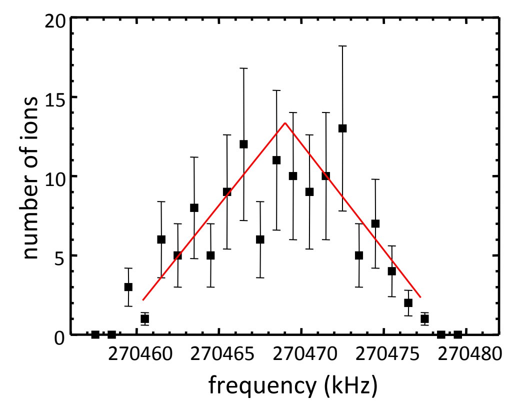


ISOLTRAP

MISTRAL







The CKM Matrix

2008-12-08

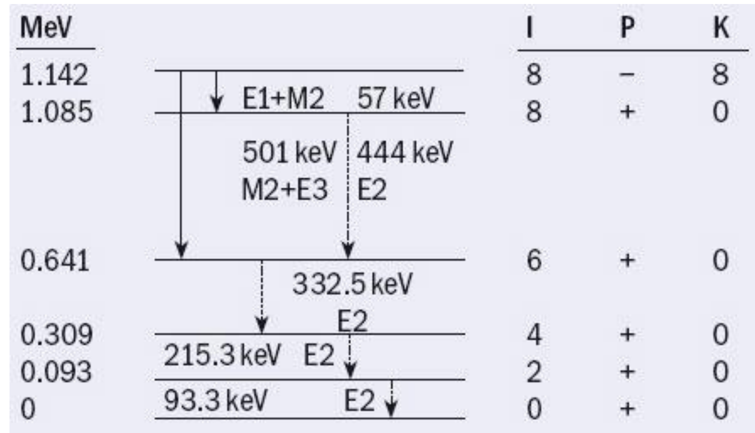
$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 0.999\,90 \pm 0.000\,60$

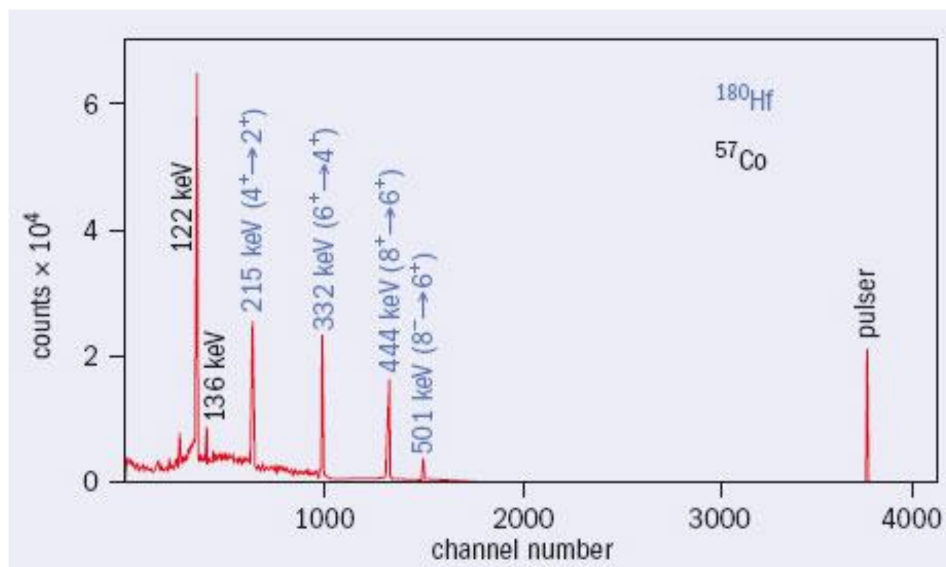
High precision frontier

parity violation in the γ decay of $^{180}Hf^{m}$

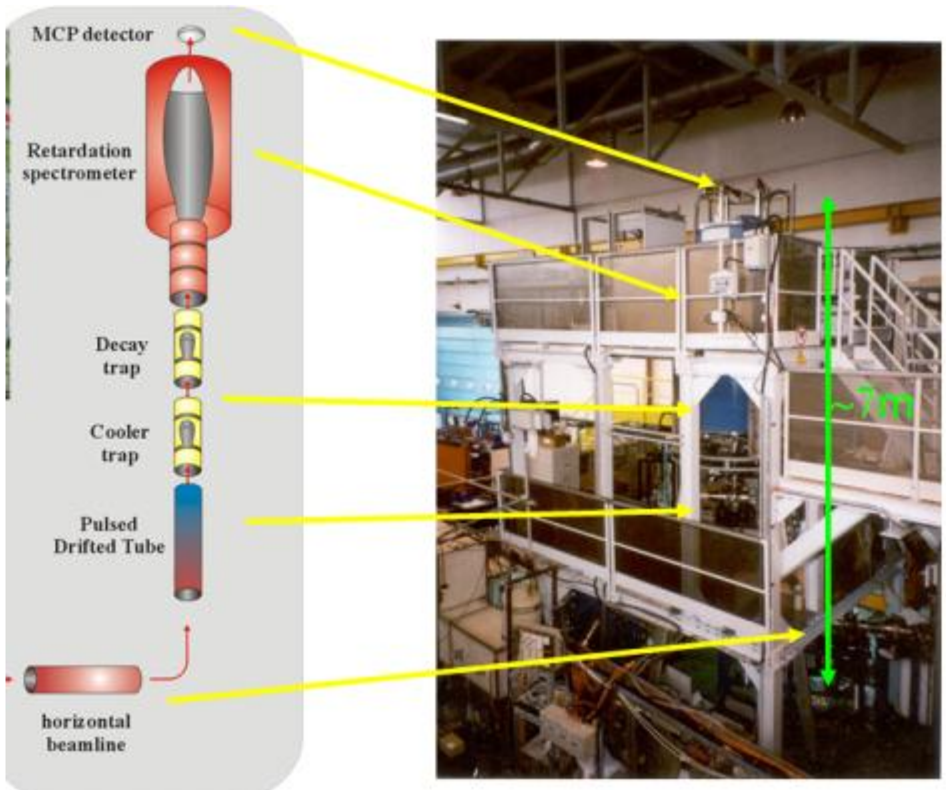
Parity violating E2/M2 mixing ratio in the 501 keV transition

NICOLE





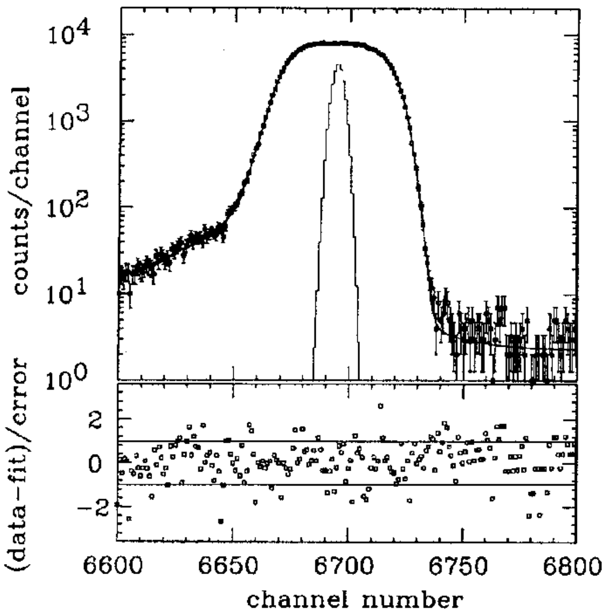
J.R. Stone et al., PRC76 (07)025502

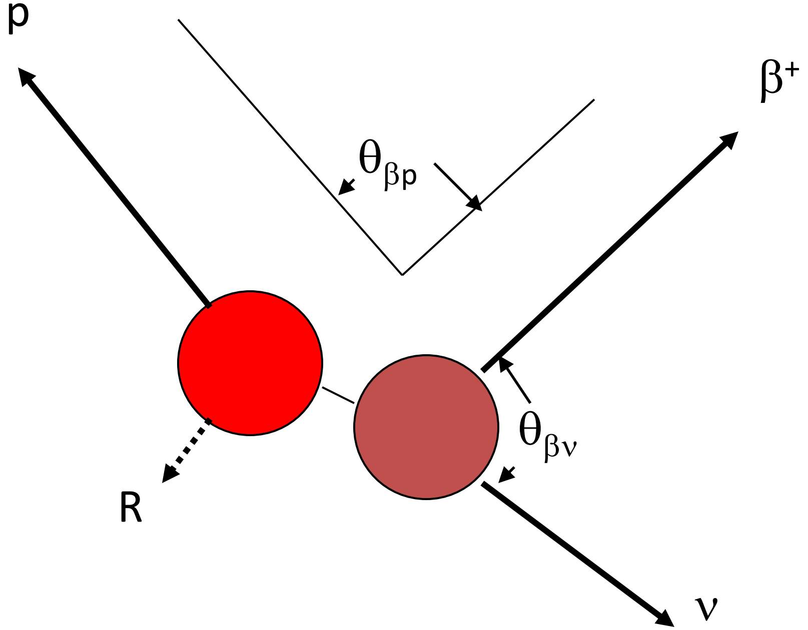

MCP detector
Retardation spectrometer
Decay trap
Cooler trap
Pulsed Drifted Tube
horizontal beamline
~7m

Positron-Neutrino Correlation in the $0^+ \rightarrow 0^+$ Beta Decay of ^{32}Ar

E. Adelberger et al.,
PRL83 (1999) 1299

p-i-n diodes at -11°





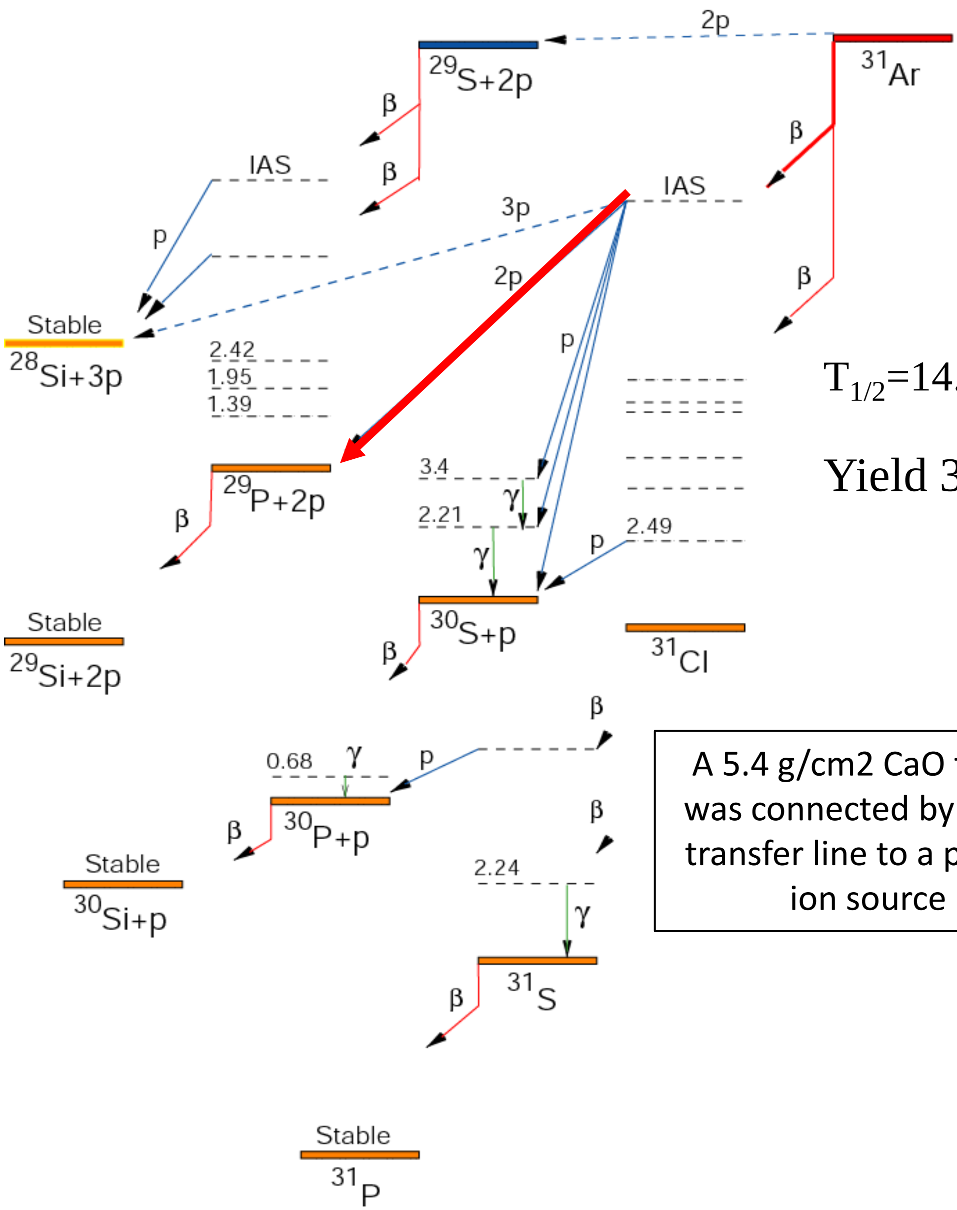
…the limit on the masses of scalar particles with gauge coupling strength, but arbitrary parity properties, is

$M_S \geq 4.1\ M_W$

eν correlation coeff.

a=0.9989(52)

The β2p decay mechanism of ^{31}Ar

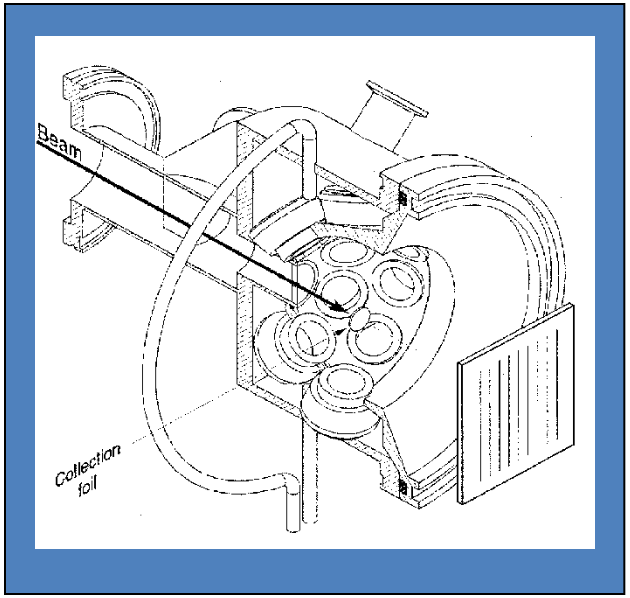


Gunvor T. Koldste

$T_{1/2}$=14.1(7) ms

Yield 3 atoms/s

A 5.4 g/cm2 CaO target was connected by a cold transfer line to a plasma ion source



H.O.U. Fynbo et al., NPA 677 (00) 38

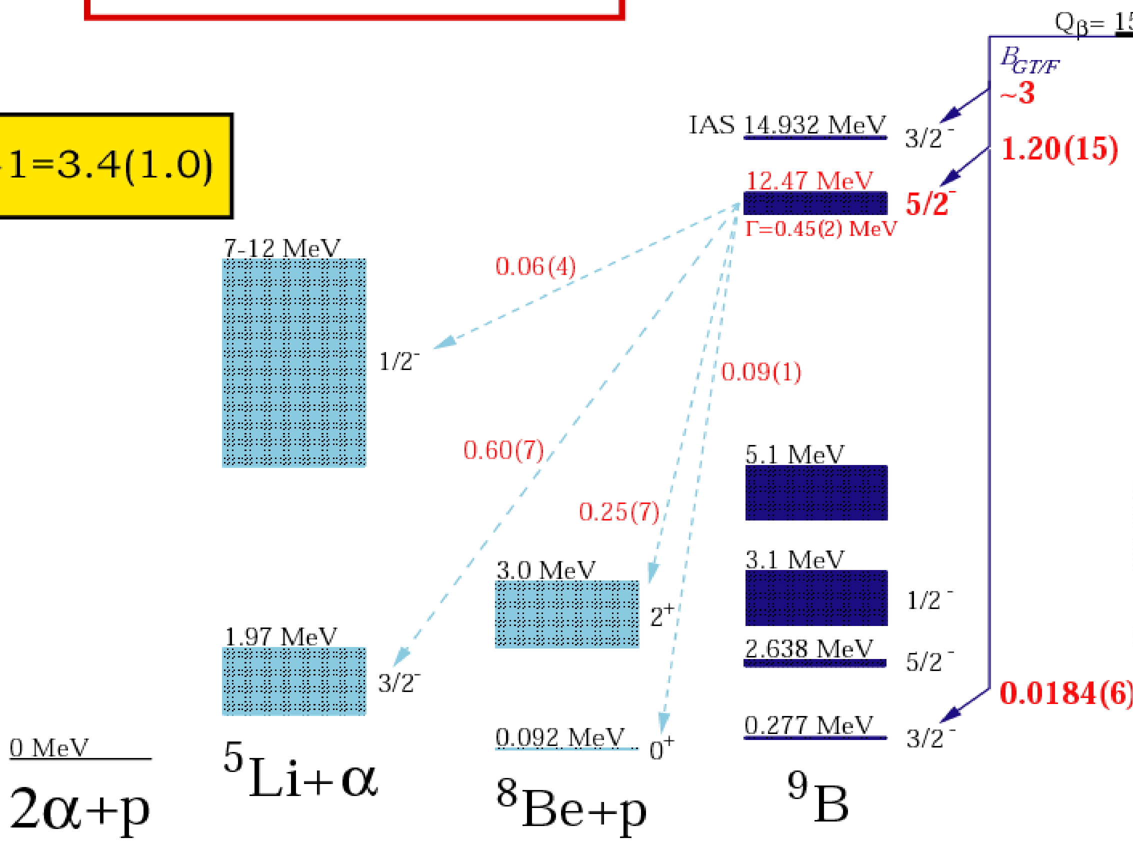
In all cases the mechanism is found to be sequential yielding information about states in ^{30}S up to 8 MeV excitation energy

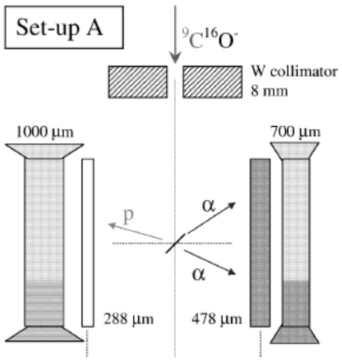
On the β-decay of ^{9}C

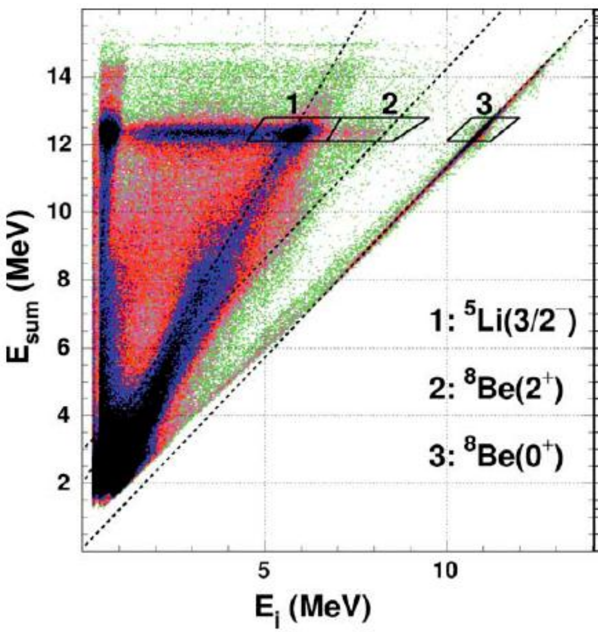
CaO target

^{9}Li : B_{GT}=5.3(1.0)

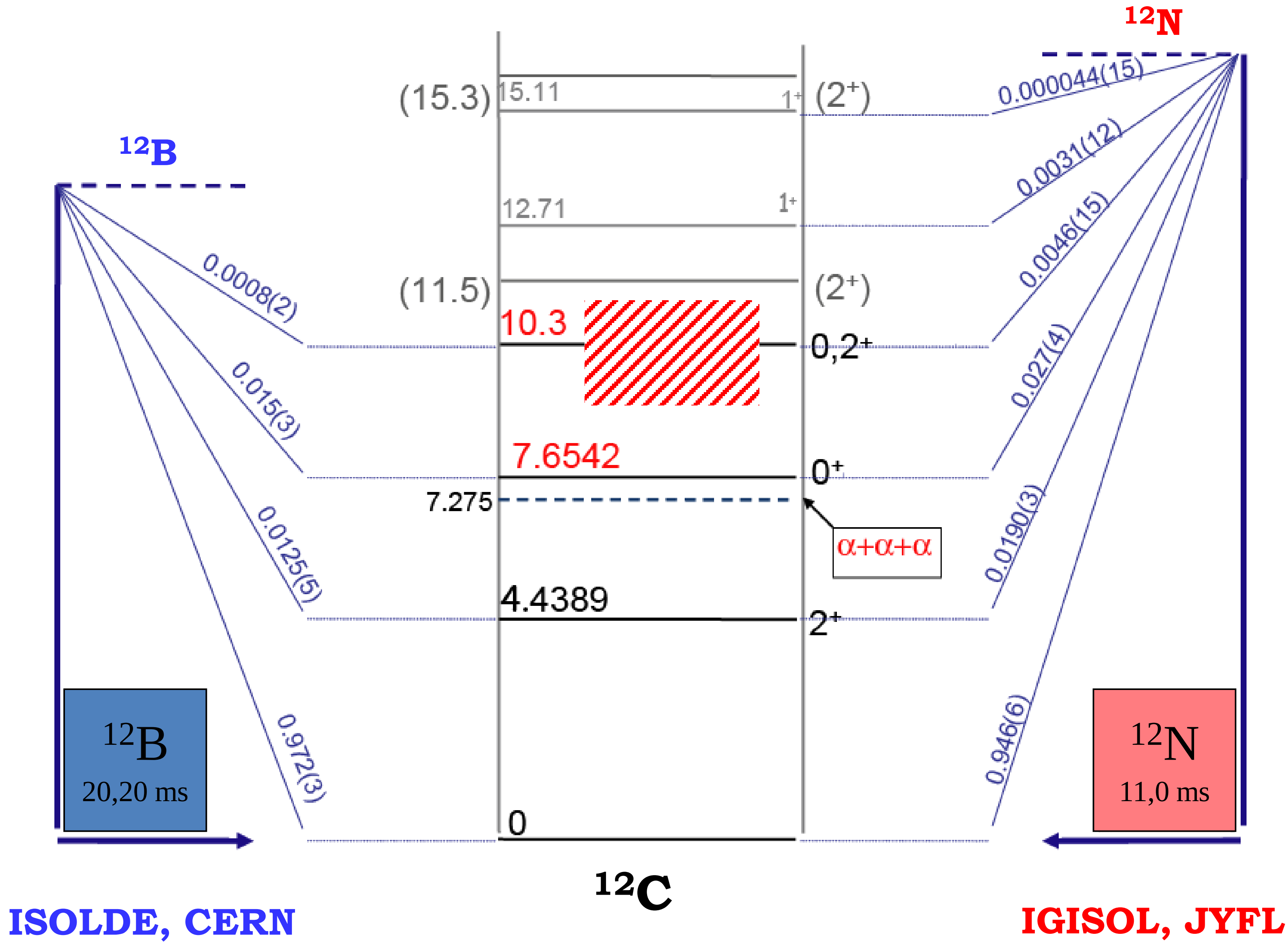
$ft^{+}/ft^{-} - 1 = 3.4(1.0)$





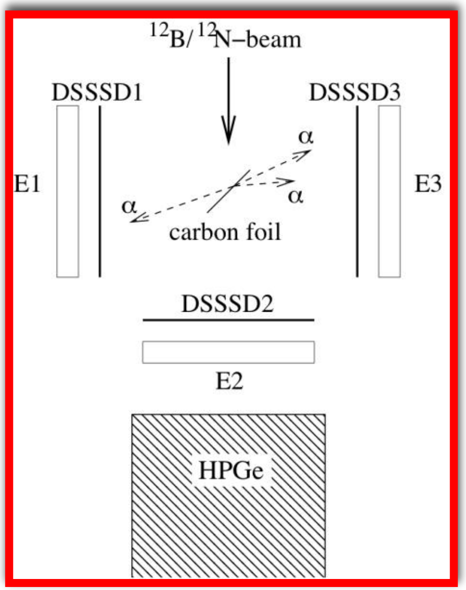


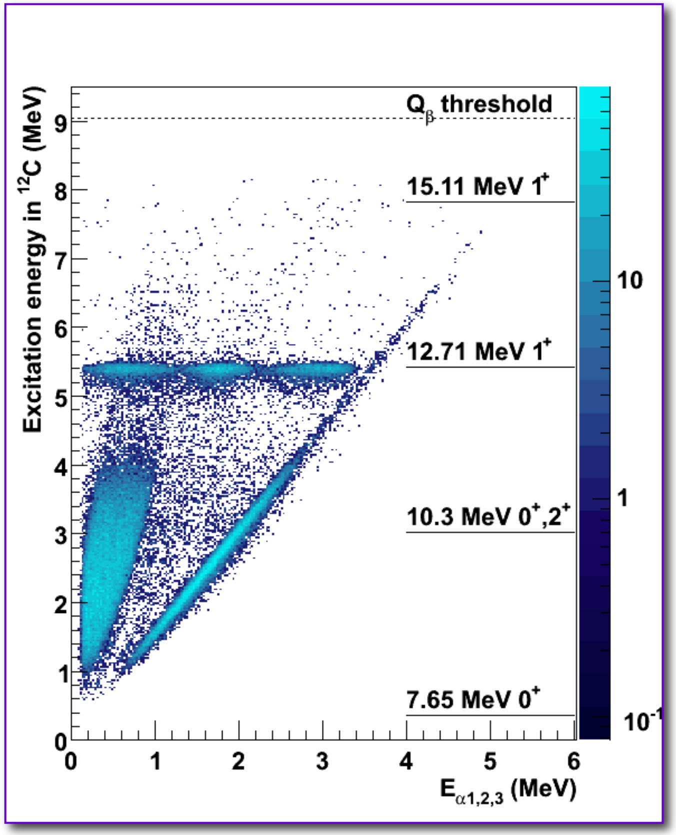
Bergmann et al., NPA 692(01) 427

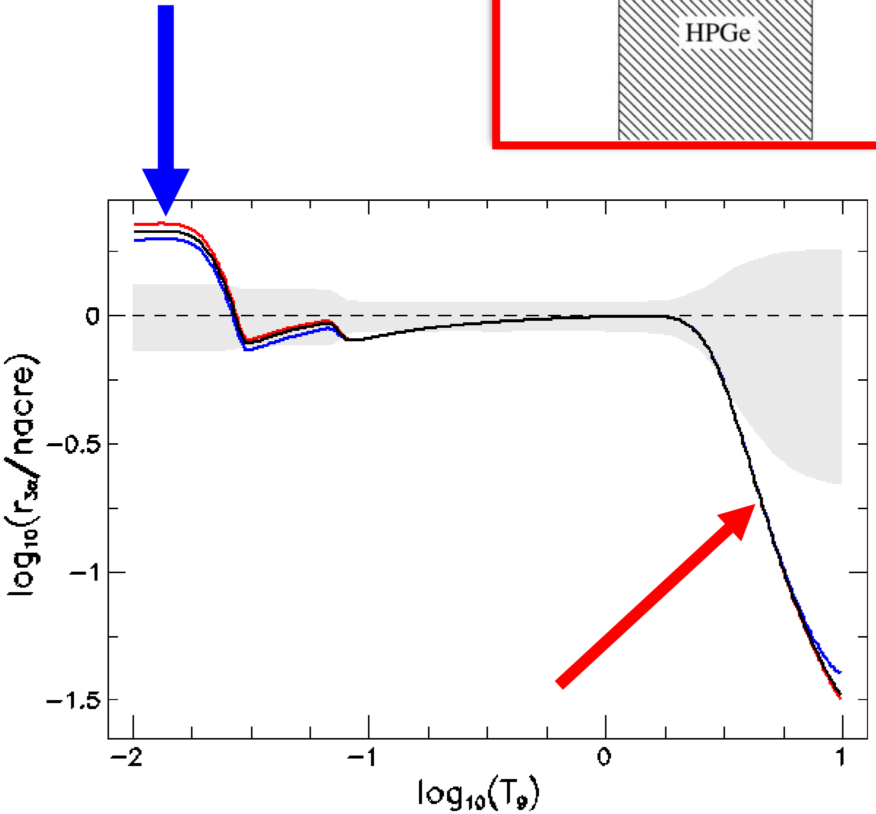


12N
12B
(15.3)
15.11
1+
(2+)
0.000044(15)
0.0031(12)
12.71
1+
0.0046(15)
0.0008(2)
(11.5)
(2+)
10.3
0,2+
0.027(4)
0.015(3)
7.6542
0+
7.275
α+α+α
0.0190(3)
0.0125(5)
4.4389
2+
12B
20,20 ms
0.972(3)
0.946(6)
12N
11,0 ms
0
12C
ISOLDE, CERN
IGISOL, JYFL

H. Fynbo et al., Nature 433 (2005) 136

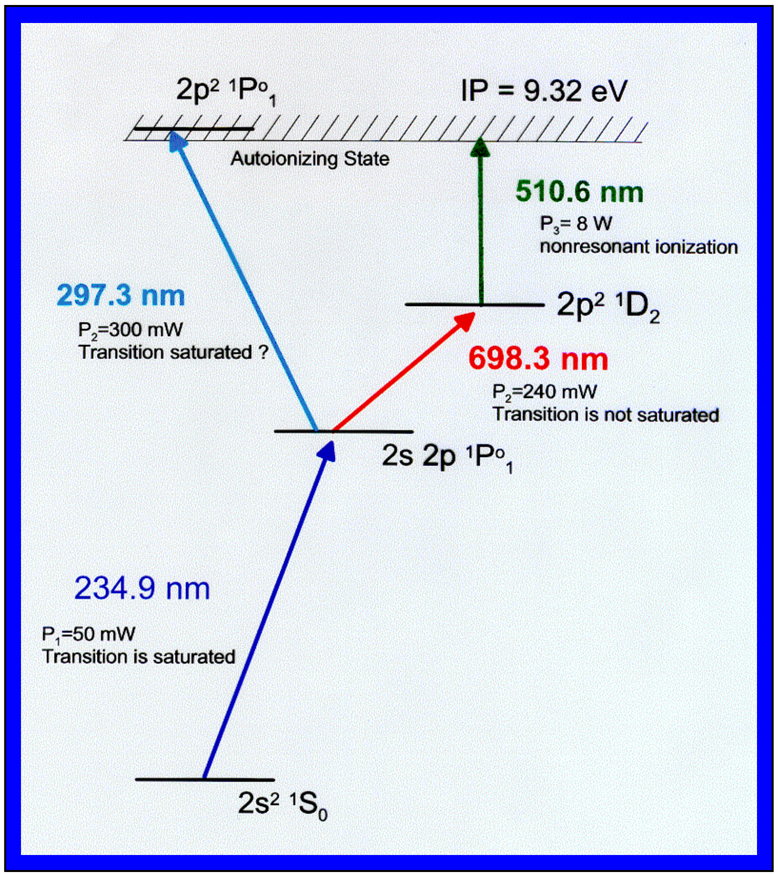


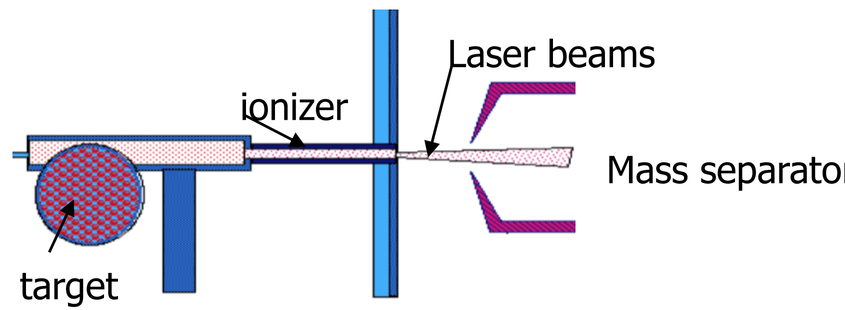




Nuclear **A**strophysics **C**ompilation
of **RE**action Rates,
C. Angulo et al.., NPA **656** (1999) 3

^{7}Be	^{8}Be	^{9}Be	^{10}Be	^{11}Be	^{12}Be	^{13}Be	^{14}Be
53 d	unbound	stable	1.6 10^{6} y	13.8 s	23.6 ms	unbound	4.35 ms





Laser Ion Source (LIS)

$$^{7}\mathbf{Be}(\mathbf{p},\gamma)^{8}\mathbf{B}$$

L.T. Baby et al., PRL 90 (03) 022501

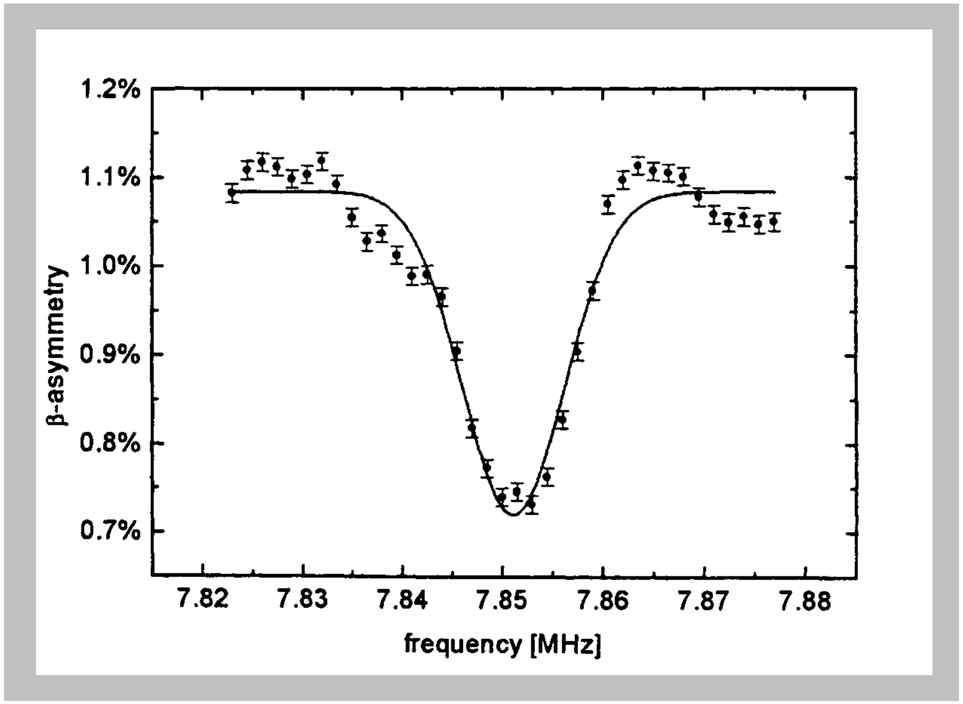
$T_{1/2}$ in different materials (C, Al, Au, Pt, kapton)

Mazzocchi et al. Act. Phys. Pol. 43 (12) 279

Magnetic Dipole Moment of ^{11}Be

β-NMR

W. Geithner et al., PRL 83 (1999) 3793

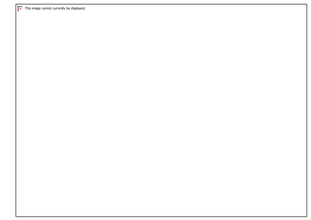


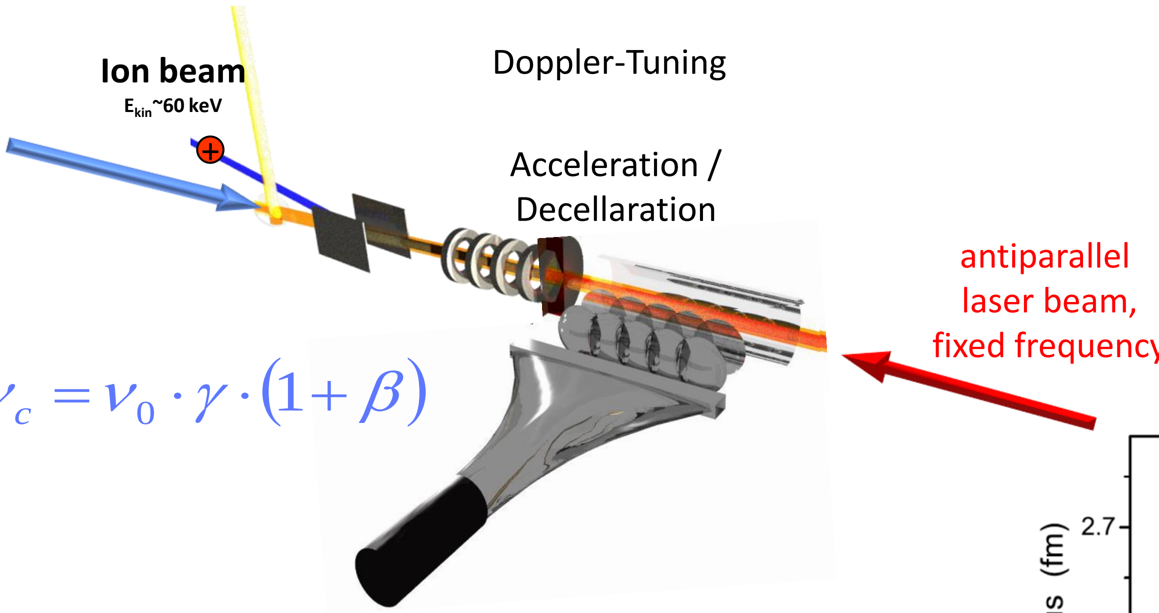
$\mu = -1.6816(8)\ \mu_N$

T. Susuki et al., Phys. Lett. B 364 (1995) 69

- •Laser ionization
- •Ion beam for optical polarization
- •Calibration with 8Li

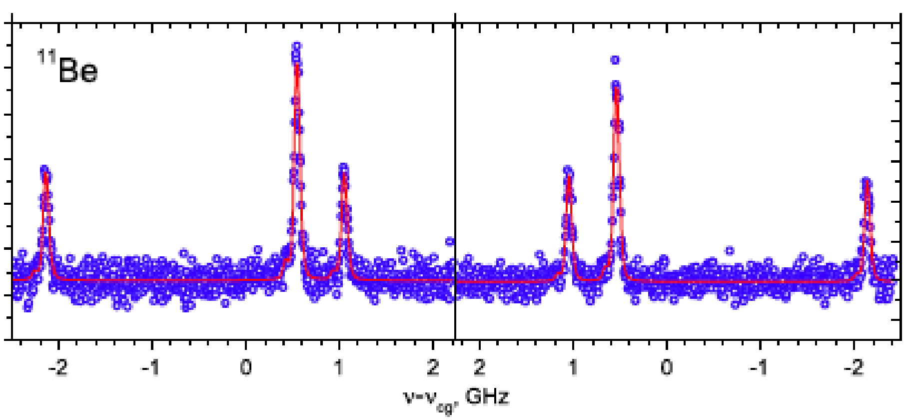
Charge Radii of ^{11,12}Be

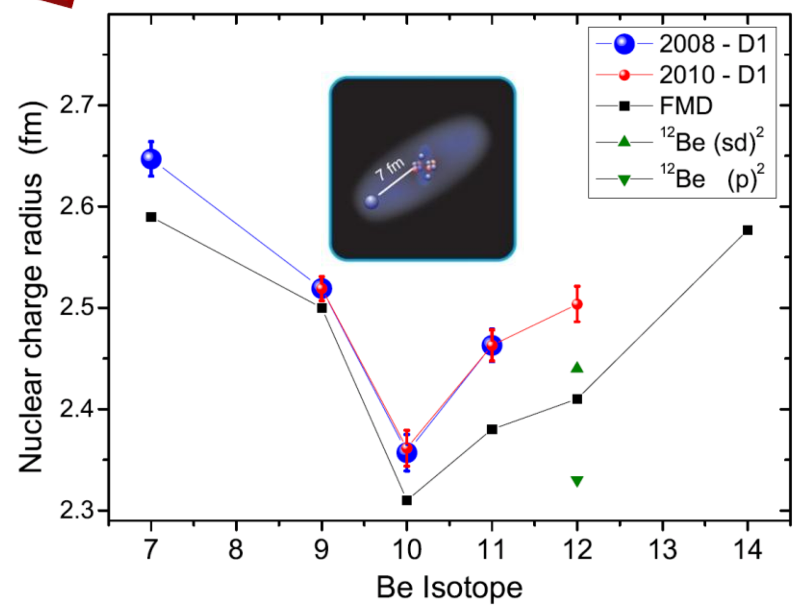




$$\nu_c = \nu_0 \cdot \gamma \cdot (1 + \beta)$$

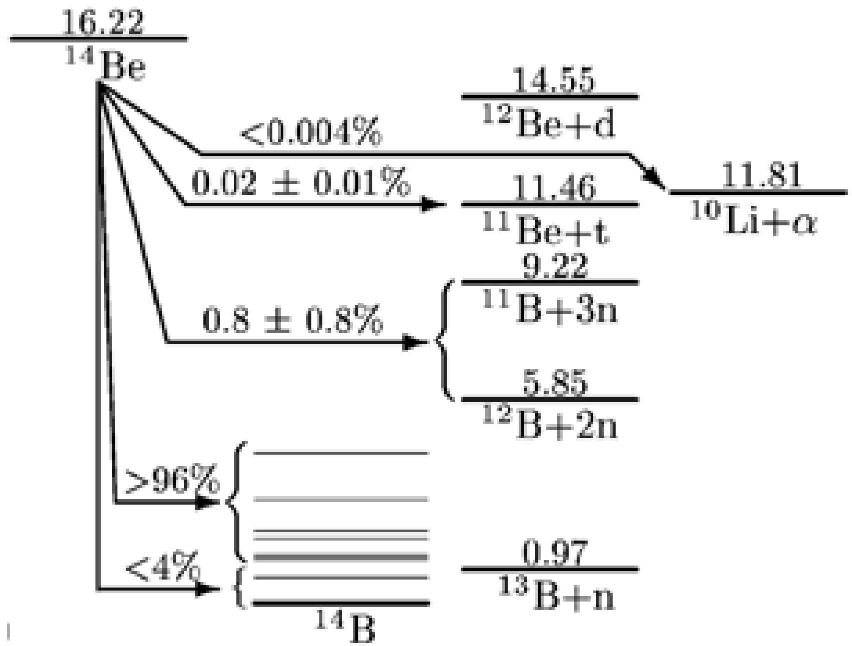
Completely (!) independent of high-voltage U

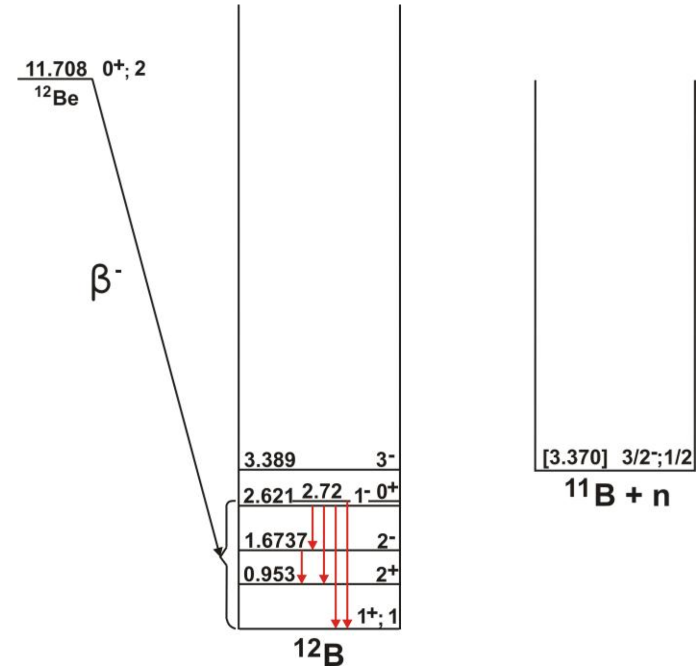




W. Nörtershäuser et al., PRL **102**, 062503 (2009)
A. Krieger et al., PRL **108**, 142501 (2012)

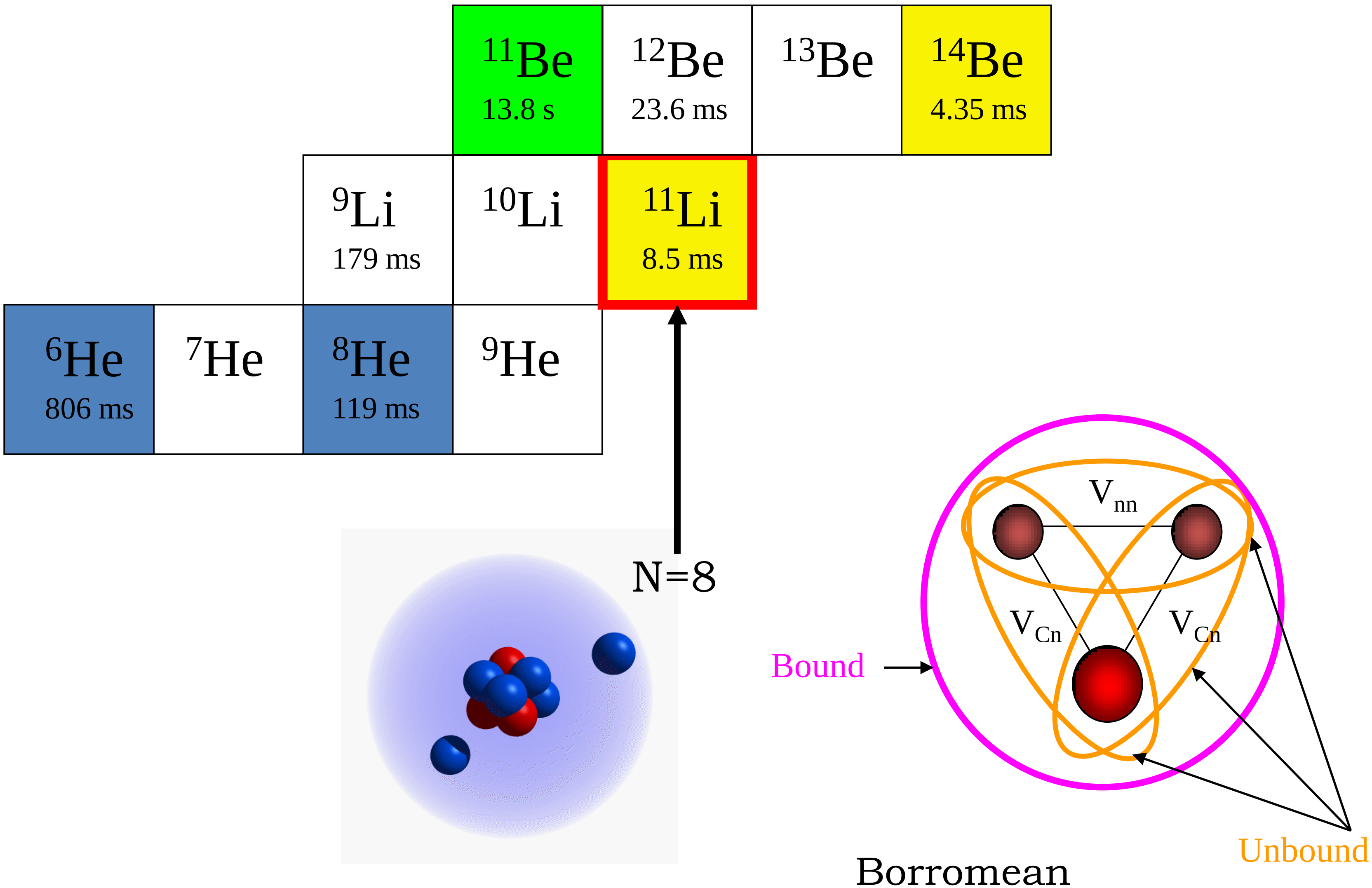
^{7}Be	^{8}Be	^{9}Be	^{10}Be	^{11}Be	^{12}Be	^{13}Be	^{14}Be
53 d	unbound	stable	1.6 10^{6} y	13.8 s	23.6 ms	unbound	4.35 ms





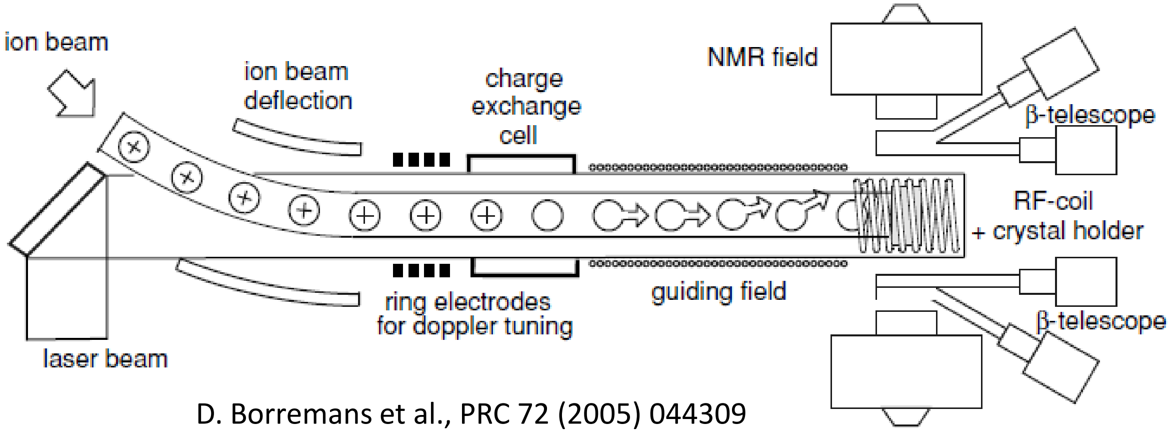
Jeppeses et al. NPA 709 (02) 119

Riisager et al. Hyperfine Int. 129 (00) 67

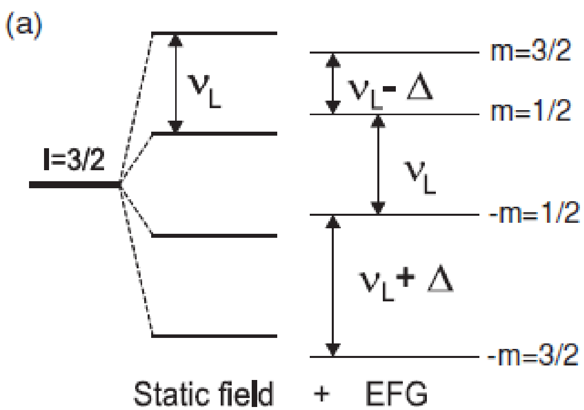


11Be 13.8 s
12Be 23.6 ms
13Be
14Be 4.35 ms
9Li 179 ms
10Li
11Li 8.5 ms
6He 806 ms
7He
8He 119 ms
9He
N=8
Vnn
VCn
VCn
Bound
Unbound
Borromean

^{6}Li	^{7}Li	^{8}Li	^{9}Li	^{10}Li	^{11}Li	^{12}Li	^{13}Li
		840 ms	179 ms	unbound	8.5 ms	unbound	unbound
			$I^{\pi}=3/2^{-}$		$I^{\pi}=3/2^{-}$		



D. Borremans et al., PRC 72 (2005) 044309



Si [LiF] → $\mu(^{11}Li) = 3.6712(3)\ \mu_N$

Zn [$LiNbO_3$] → $|Q(^{11}Li)| = 33.3(5)$ mb

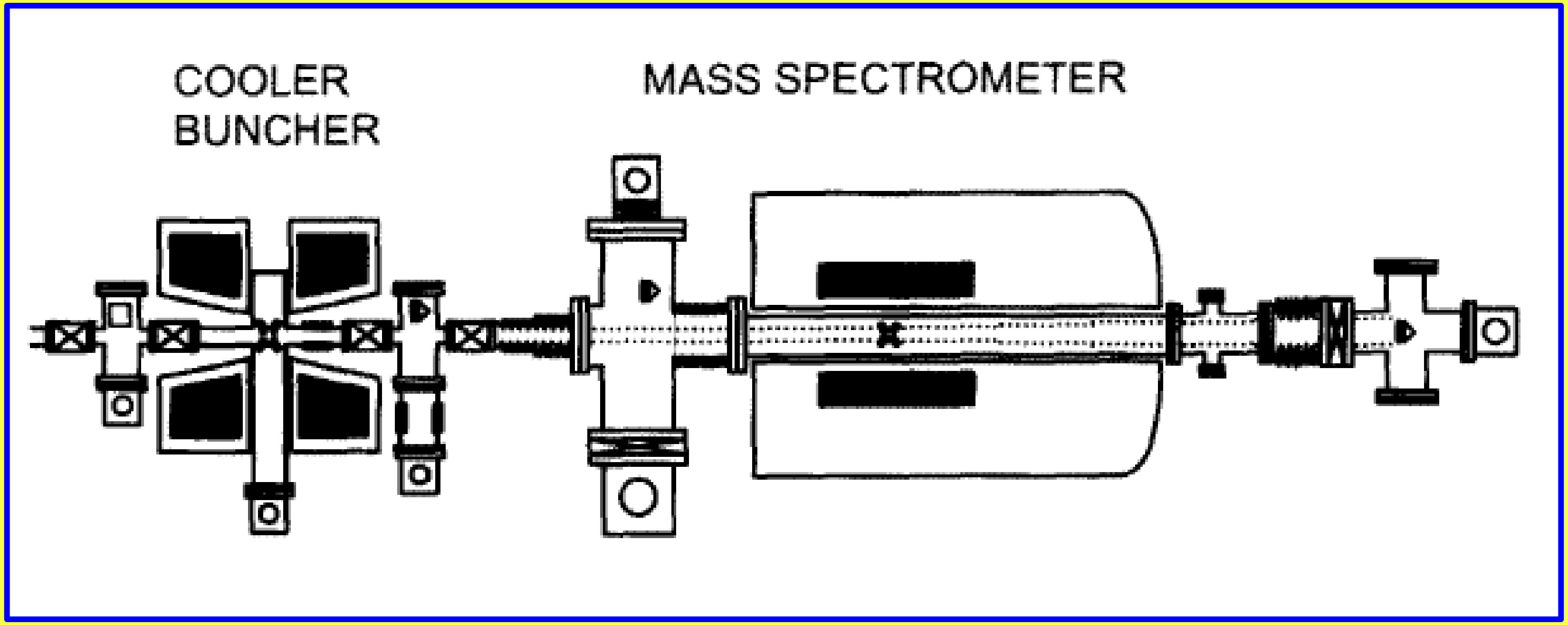
R. Neugart et al., PRL 101(2008) 132502

$|Q(^{11}Li)/Q(^{9}Li)| = 1.088(15)$

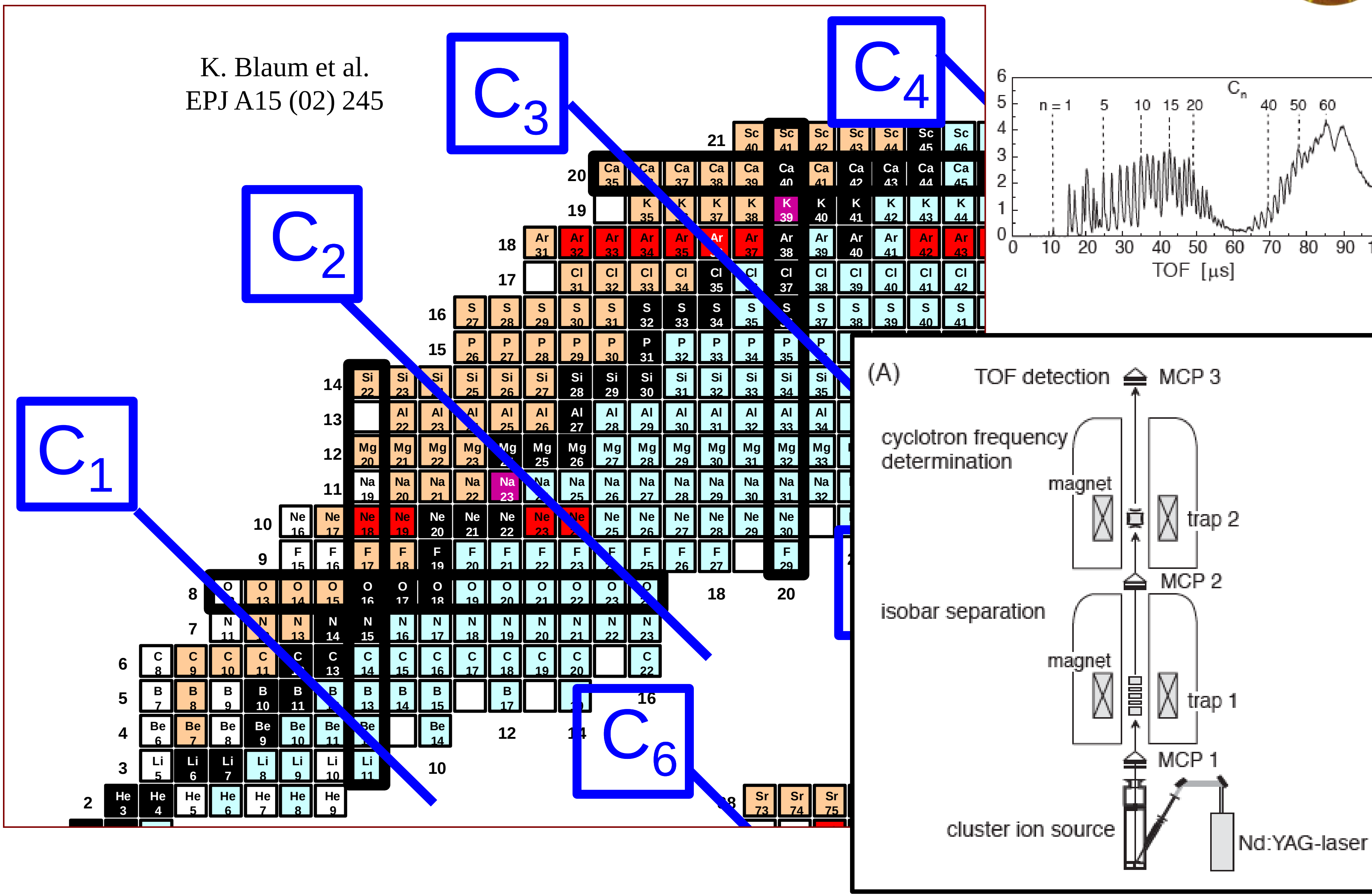
Mark Bissell

ISOLTRAP

G. Bollen et al., NIM A368 (96) 675



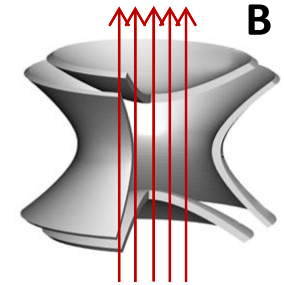
Carbon Clusters



The ISOLTRAP Spectrometer

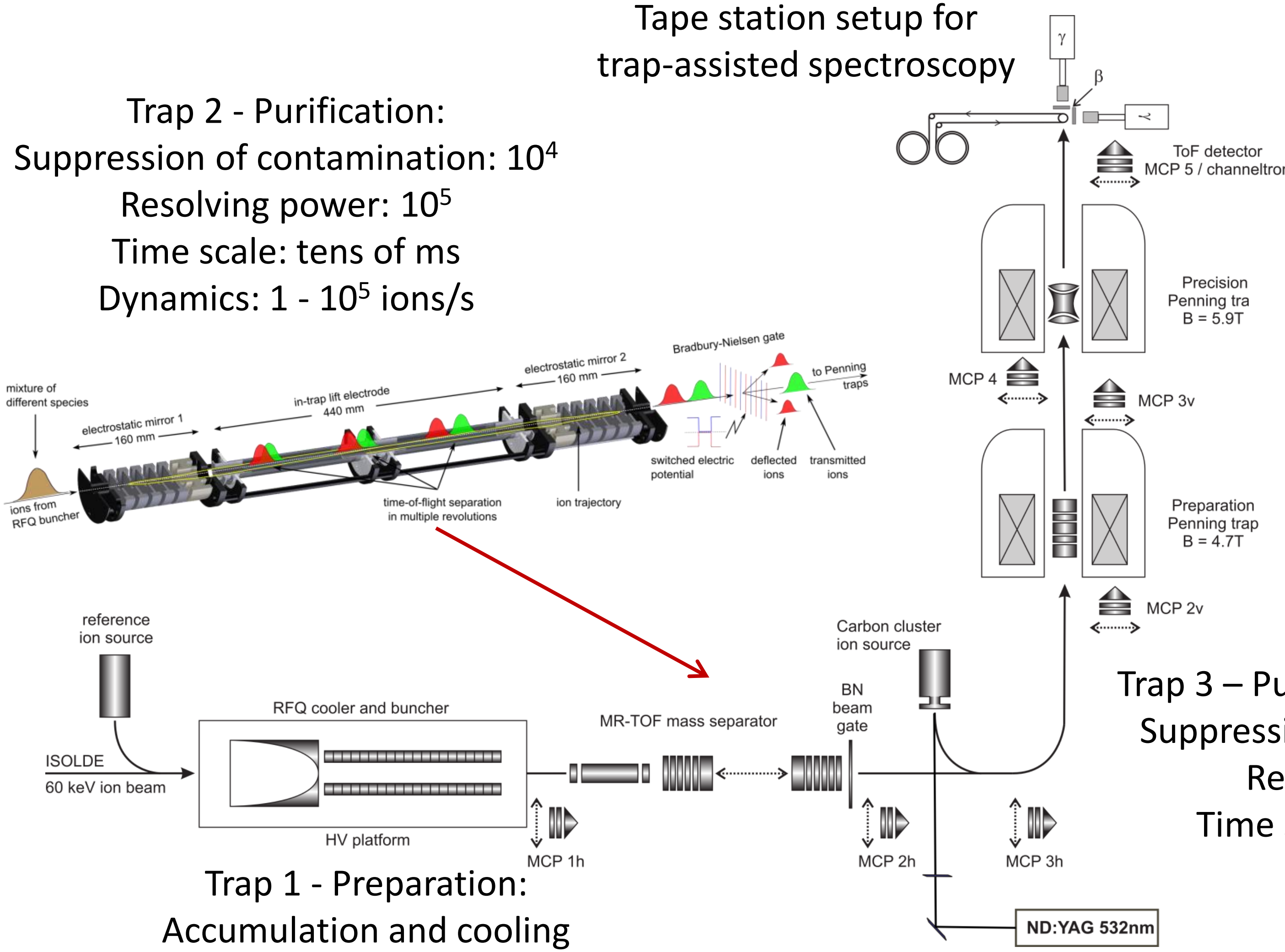
Tape station setup for
trap-assisted spectroscopy

Trap 2 - Purification:
Suppression of contamination: 10^4
Resolving power: 10^5
Time scale: tens of ms
Dynamics: 1 - 10^5 ions/s



$$\omega_c = \frac{q}{m} B$$

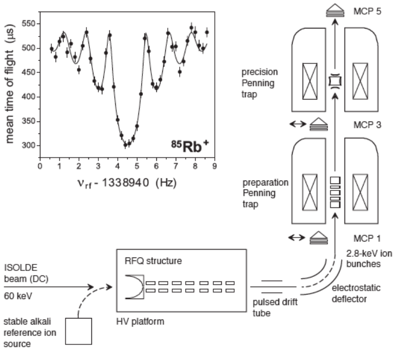
Trap 4 – Purification and measurement:
Resolving power: 10^6
Rel. uncertainty: 10^{-8}-10^{-9}



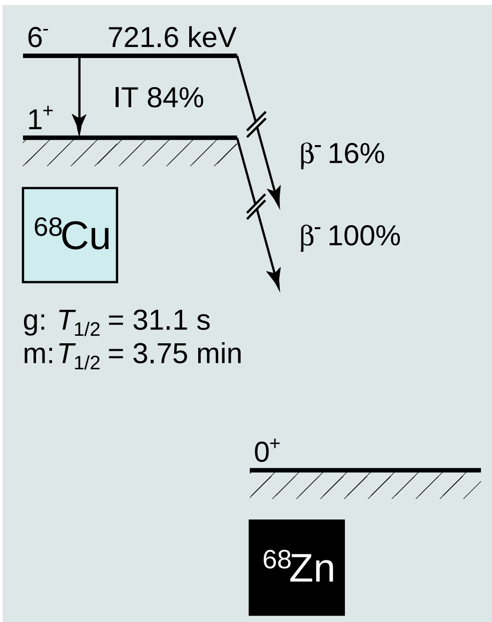
Trap 3 – Purification and preparation:
Suppression of contamination: 10^4
Resolving power: 10^5
Time scale: hundreds of ms

Trap 1 - Preparation:
Accumulation and cooling
→ few-ion bunches

M. Mukherjee *et al.*, Eur. Phys. J A **35**, 1 (2008) -- R. N. Wolf *et al.*, IJMS **313**, 8 (2012) -- M Kowalska et al., NIM A **89**, 102 (2012)



Isomers in ^{68}Cu

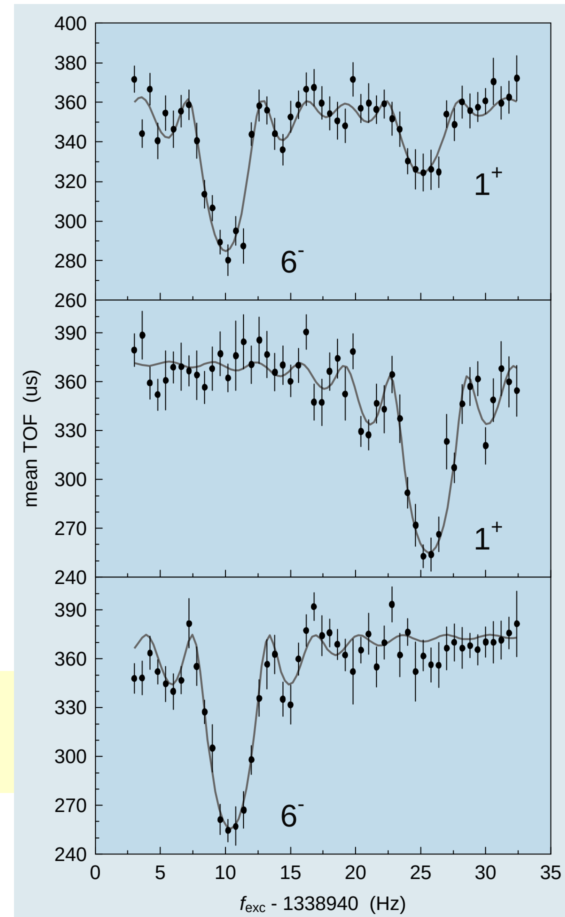


K. Blaum *et al*., Europhys. Lett. 67, 586 (2004)

as produced by ISOLDE

isolation of the 1^+ ground state

isolation of the 6^- isomeric state



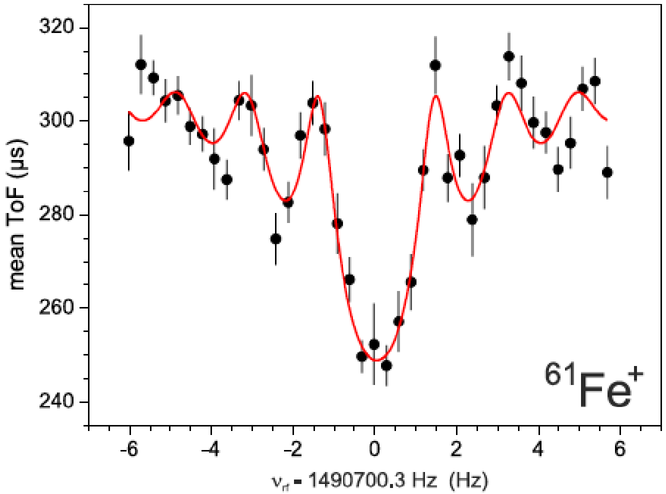
Resolving power of excitation: $R \approx 10^7$

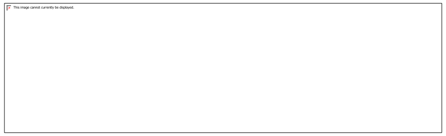
$\Rightarrow$ Population inversion of nuclear states

$\Rightarrow$ Preparation of an isomerically pure beam

Recoil-ion trapping for precision mass measurements

A. Herlert et al. Eur. Phys. J. A 48 (12) 97

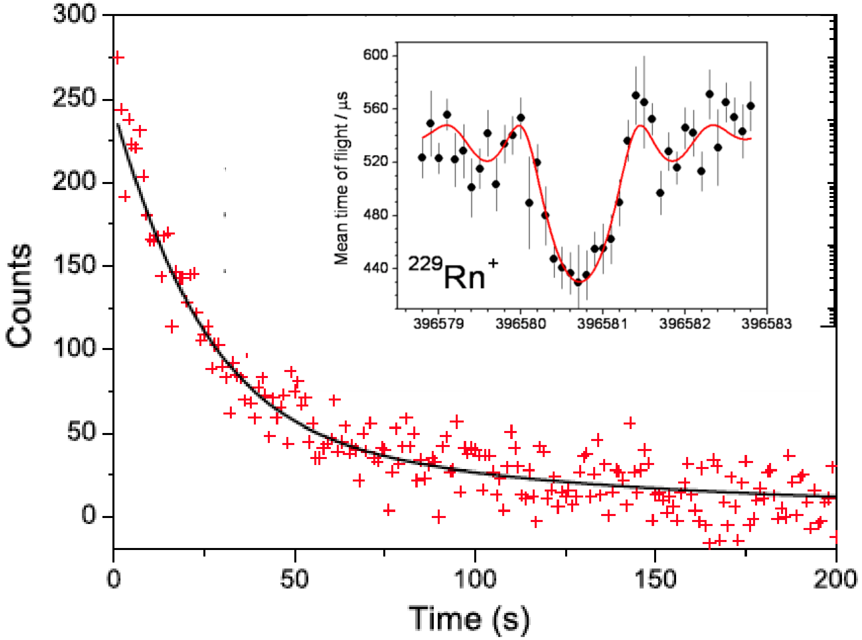


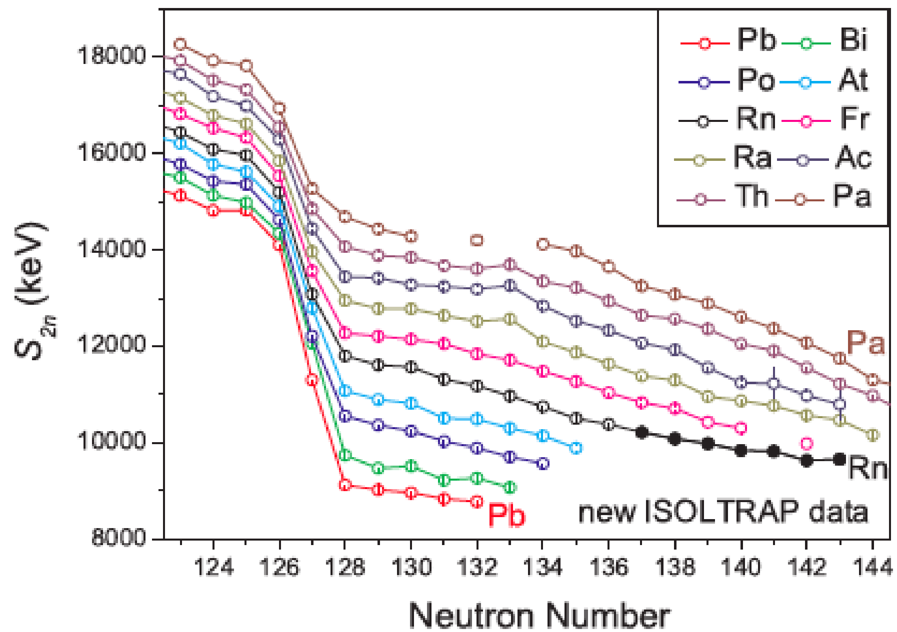


Nuclide	Q_{exp} (keV)	Q_{lit} (keV) [32]	Max. recoil energy (eV)
^{61}Mn	7178(4)	7370(230)	518
^{62}Mn	10697(4)	10860(220)	1086
^{63}Mn	8750(7)	9190(310)	729

Discovery of ^{229}Rn

D. Neidherr et al. PRL 102 (09) 112501





26.08.2008, 4:24 am

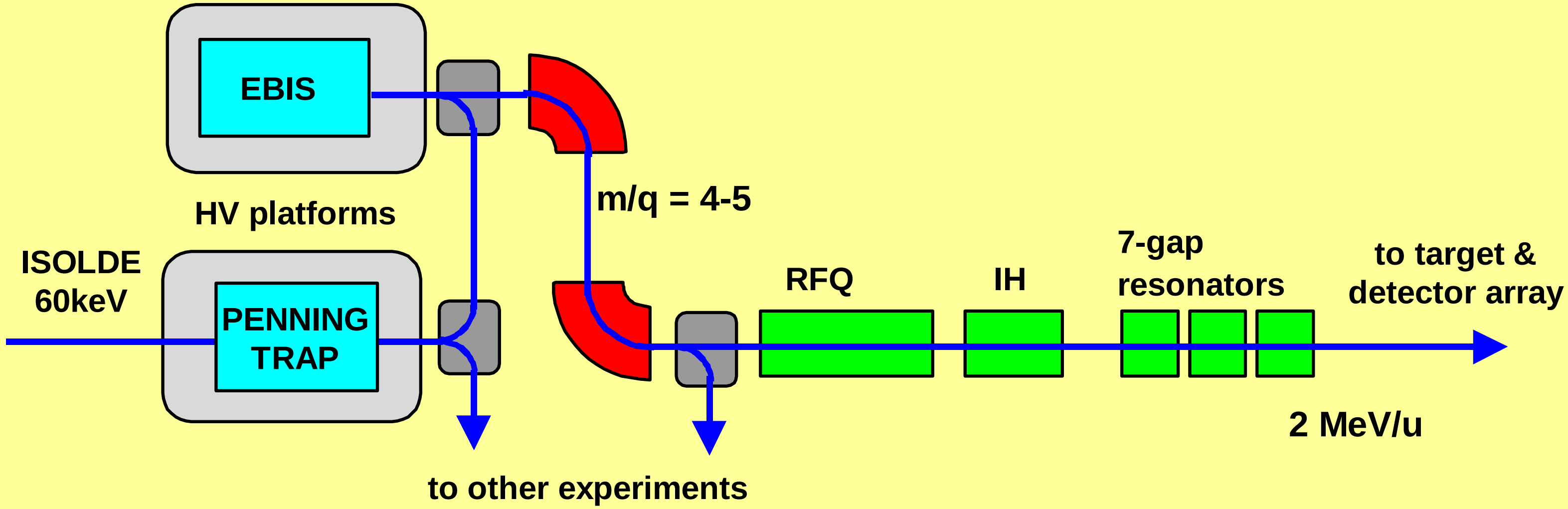
WELT (24.03.2009):
Physicists from an international collaboration discovered with the ISOLTRAP experiment at ISOLDE/CERN a new isotope of the element radon. It is made of 86 protons and 143 **neurons** and is now the 3176th known isotope in the chart of nuclides.

/o=CERN/ou=First Administrative Group/cn=Recipients/cn=tnilsson

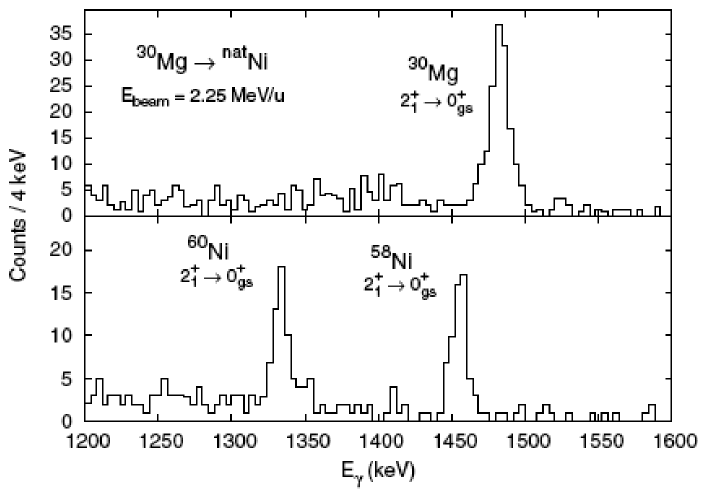
From: owner-isolde@listbox.cern.ch on behalf of Thomas Nilsson
Sent: 31 October 2001 00:24
To: ISOLDE - Information List; E-MAIL LIST FOR THE REX EXPERIMENT
Subject: Post-accelerated radioactive beams in REX-ISOLDE

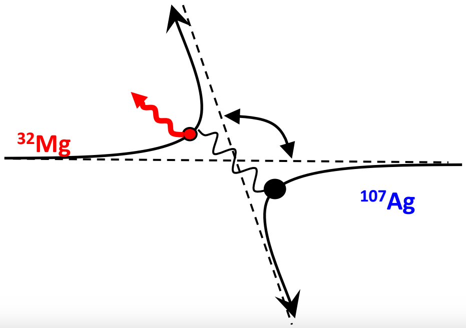
Tonight, the first radioactive beam was successfully post-accelerated at REX-ISOLDE. A beam of 26Na (T1/2 = 1.07 s) from the ISOLDE High Resolution Separator was accelerated to 2 MeV/u (using only two out of three 7-gap resonators) and delivered to the reaction target of a nuclear spectroscopy set-up, including one MINIBALL unit and detectors for charged particles. All systems for beam cooling, charge breeding and post acceleration behaves according to expectation. This important step will be immediately followed by further commissioning, beam characterization and data taking.

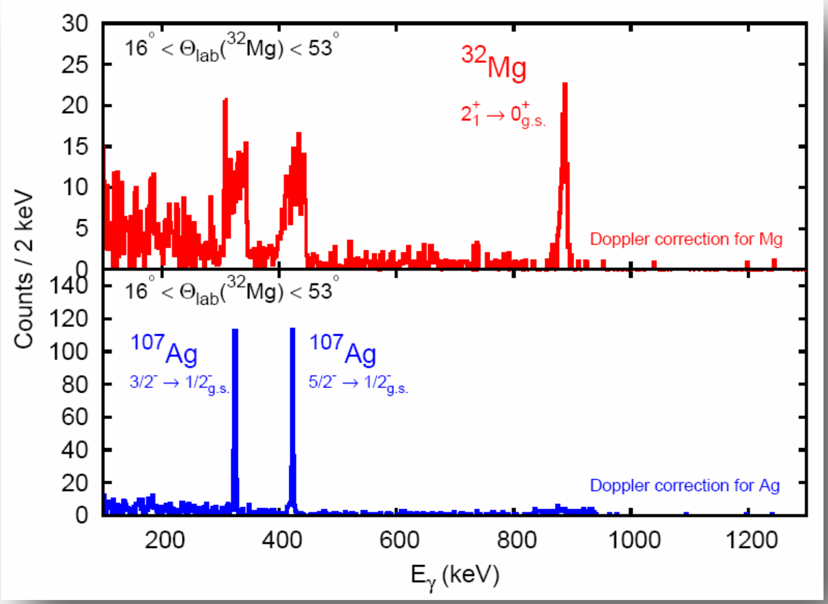
The REX-ISOLDE team

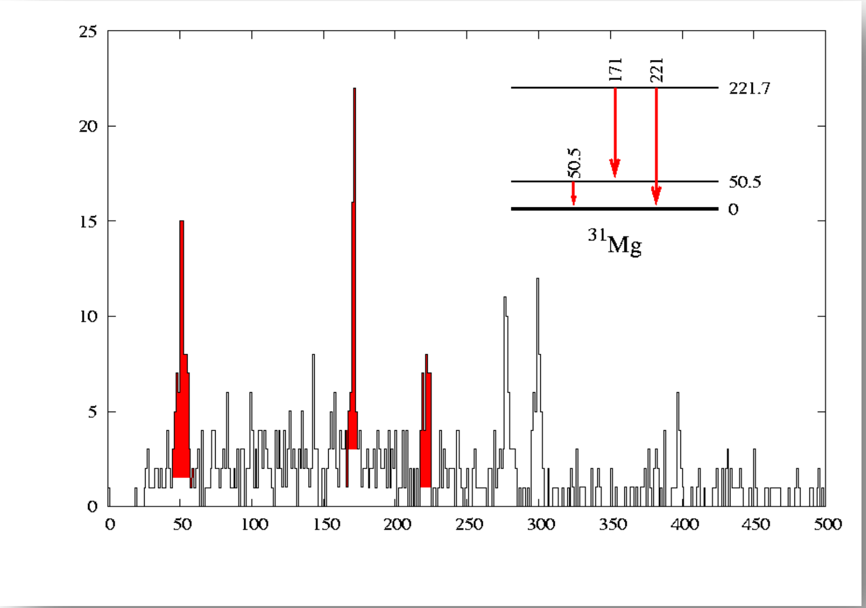


O. Niedermaier et al. PRL 94(05) 172501

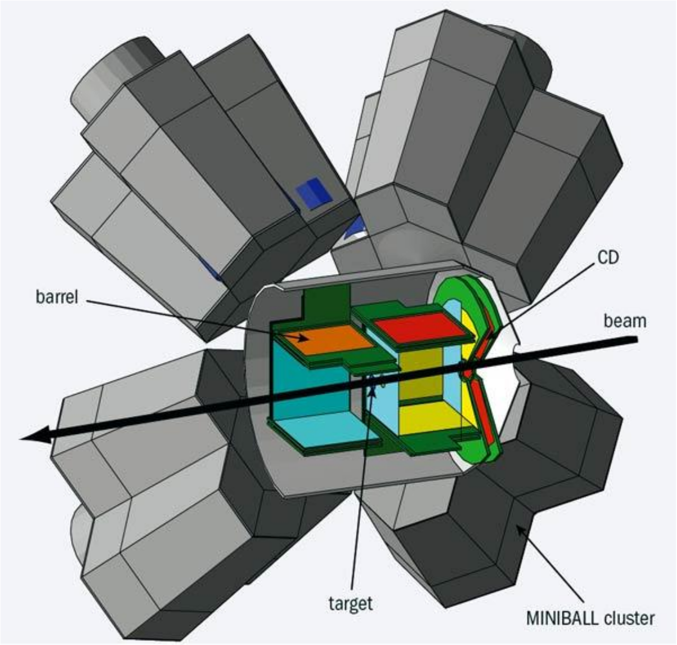






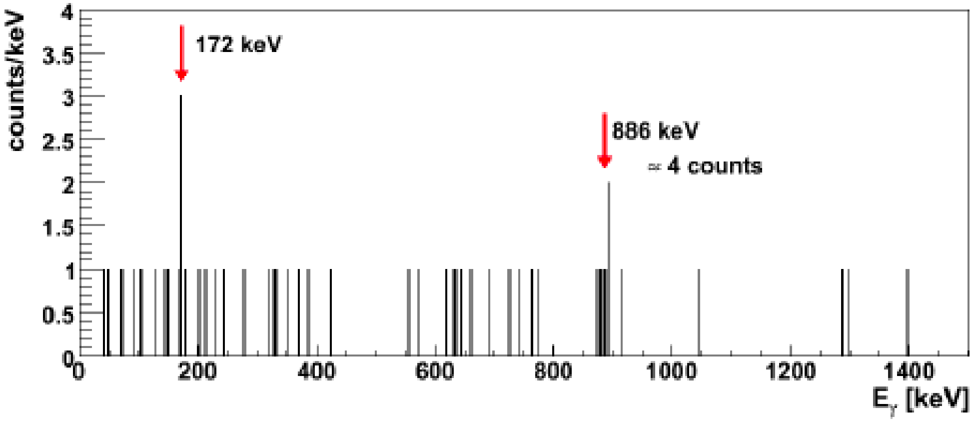


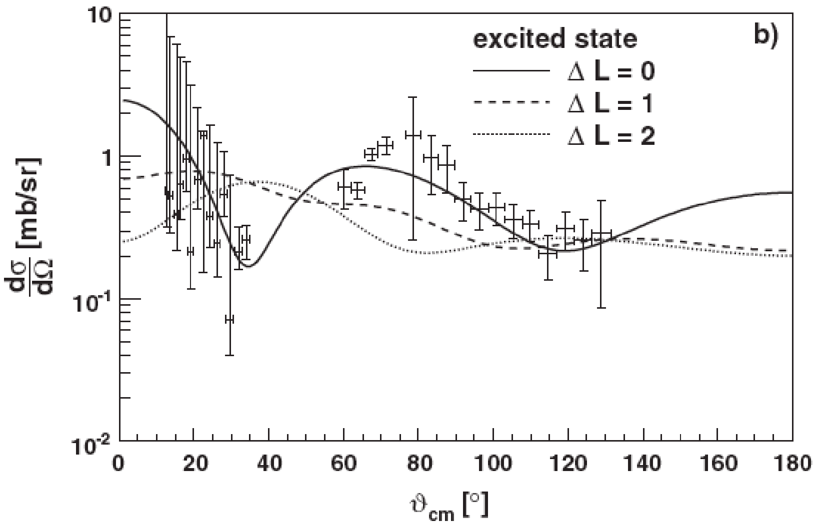
Shape Coexistence in ^{32}Mg –
2n Transfer Reaction in Inverse Kinematics:
$t(^{30}Mg,p)^{32}Mg$

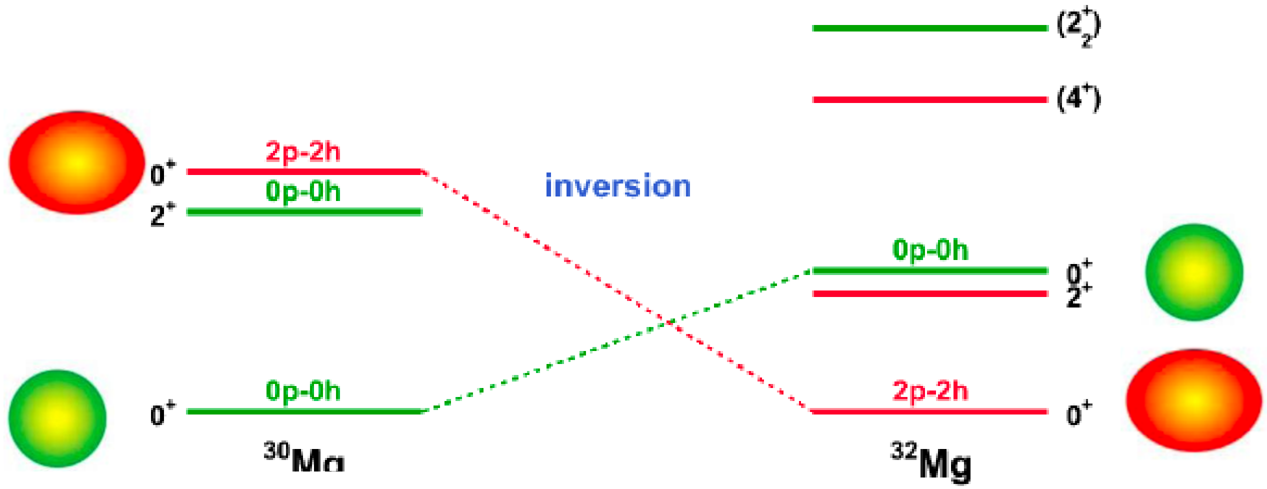


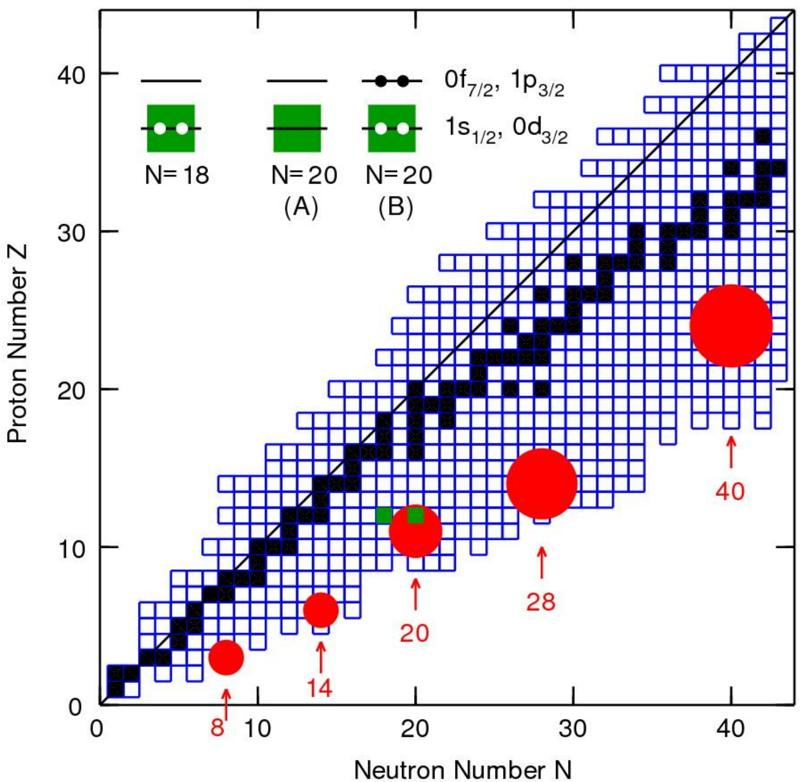
T-REX
MINIBALL

K.Wimmer *et al.* PRL 105(2010)252501





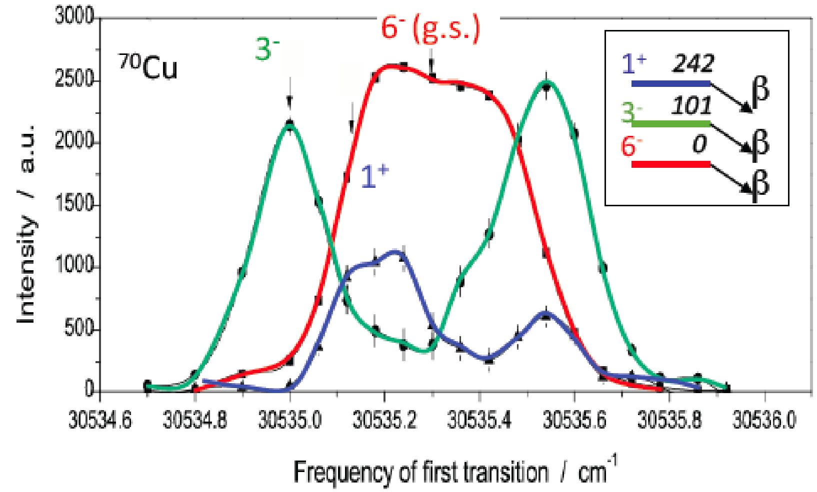




….archipelago of islands where the shell model magic numbers are broken…

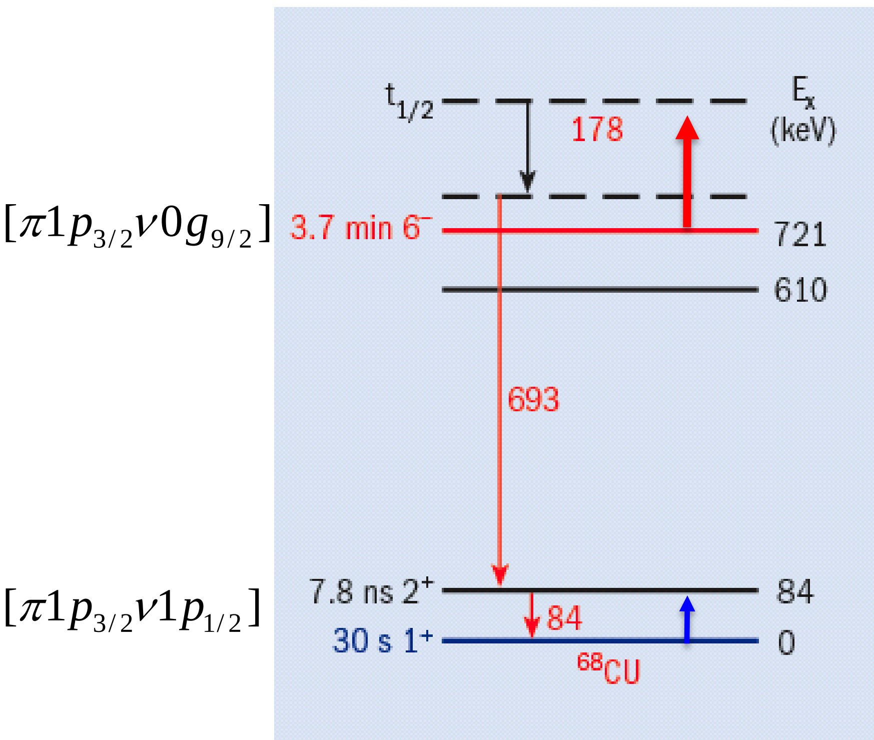
[B. Alex Brown, Physics 3, 104 (2010)]

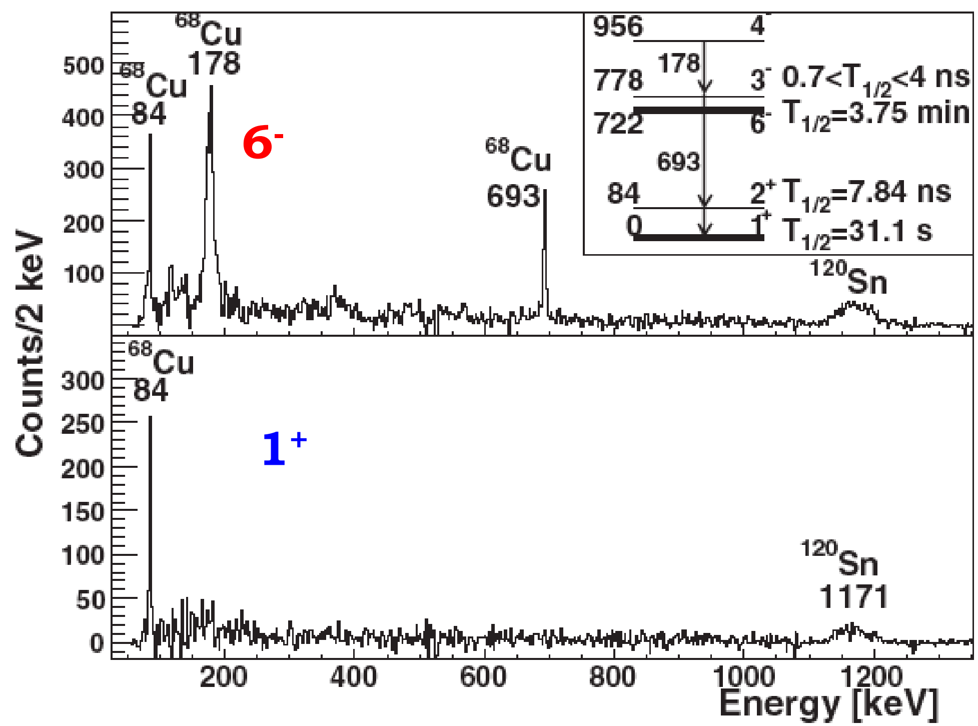
Isomeric Radioactive Beams



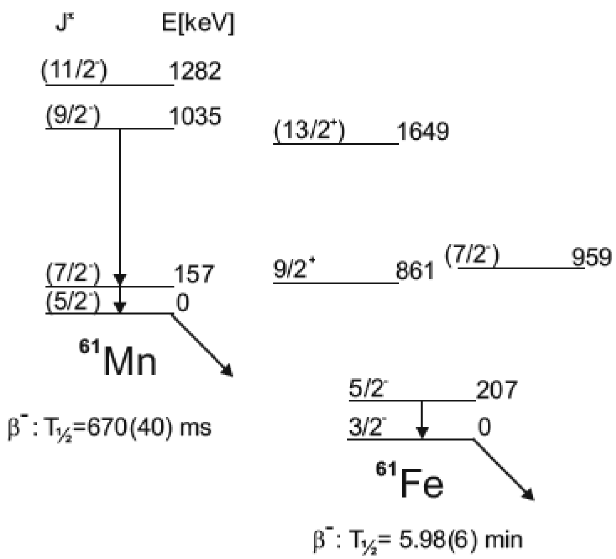
Stefanescu et al.,
Phys.Rev.Lett. 98, 122701 (2007)

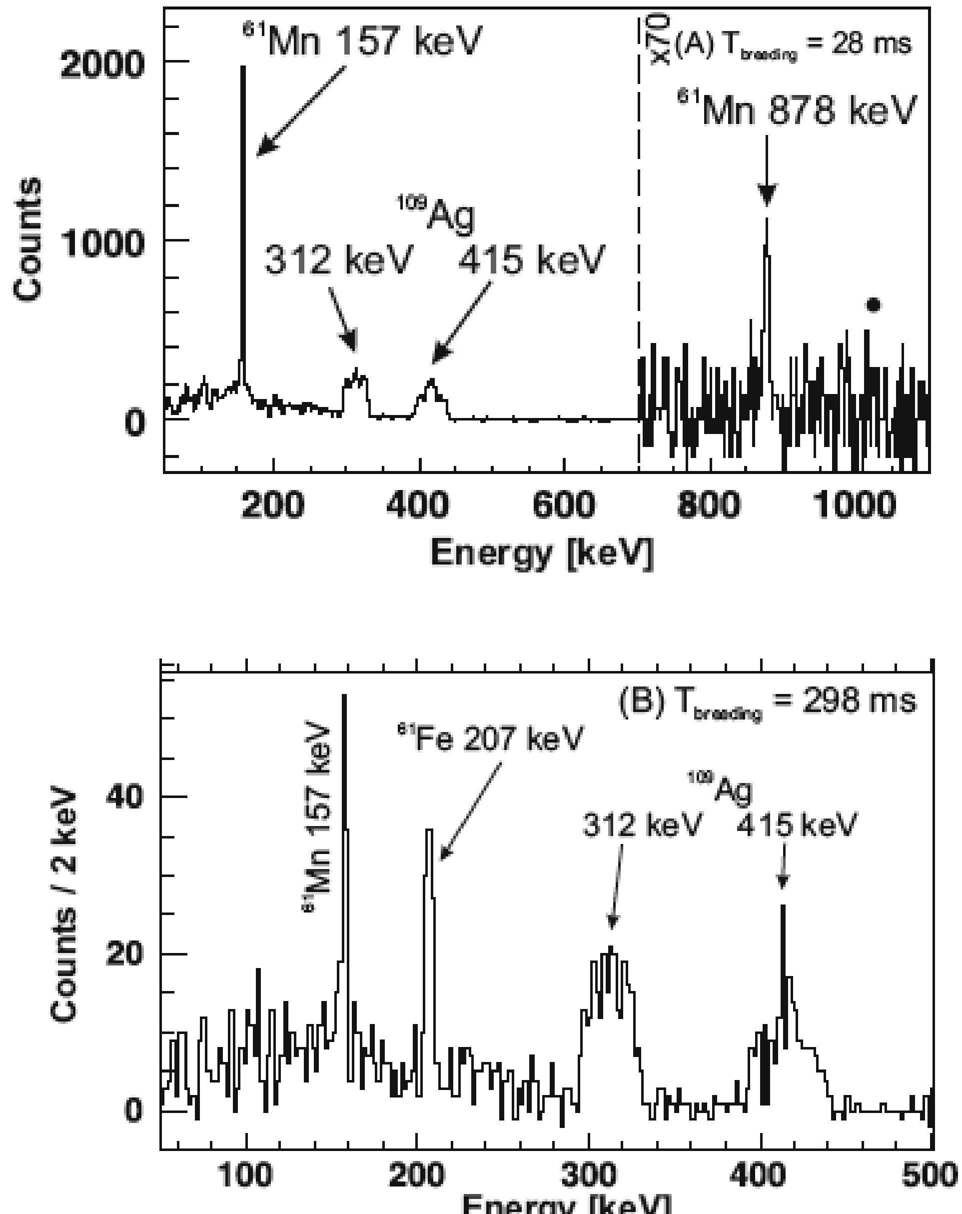
Laser-> Maximize different isomers





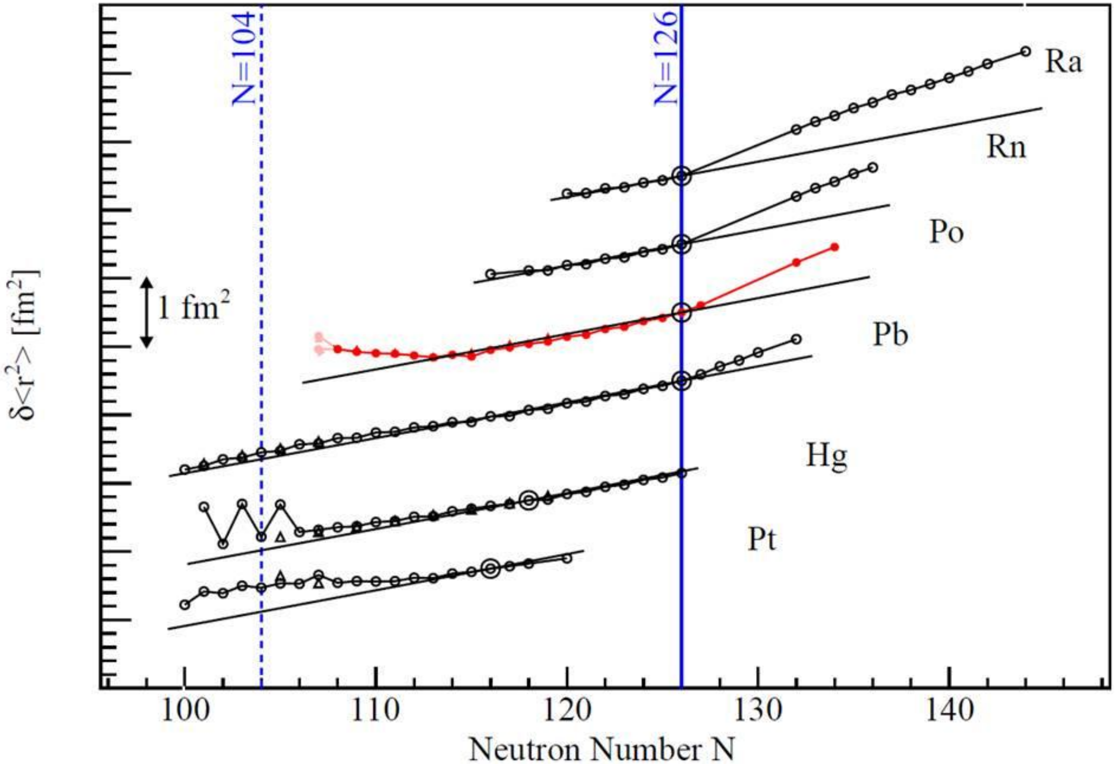
In-trap decay of ^{61}Mn and Coulomb excitation of ^{61}Mn/^{61}Fe

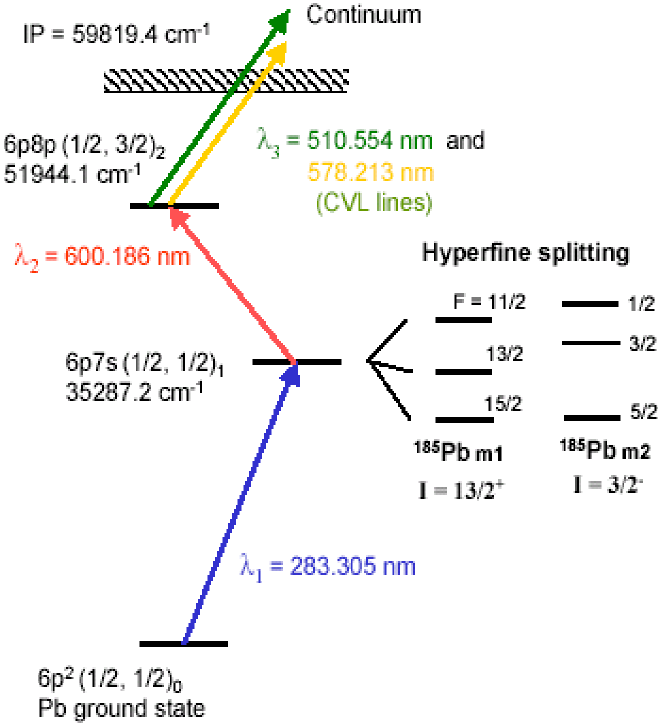




J. Van de Walle et al. Eur. Phys. J. A 42 (09) 401

Charge Radii



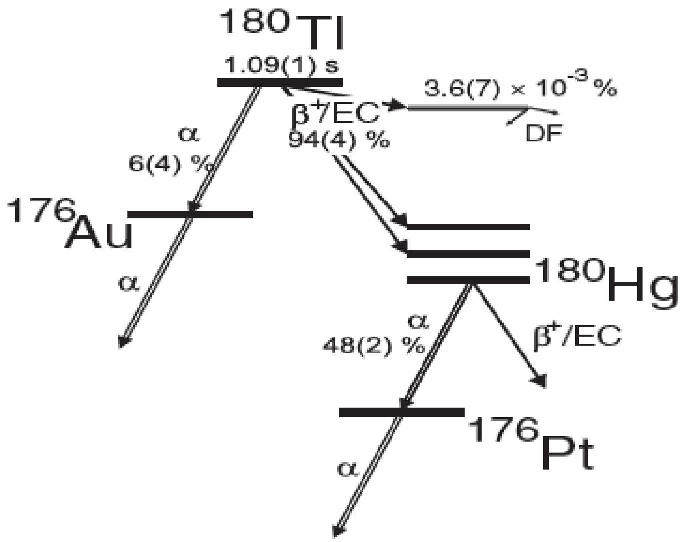


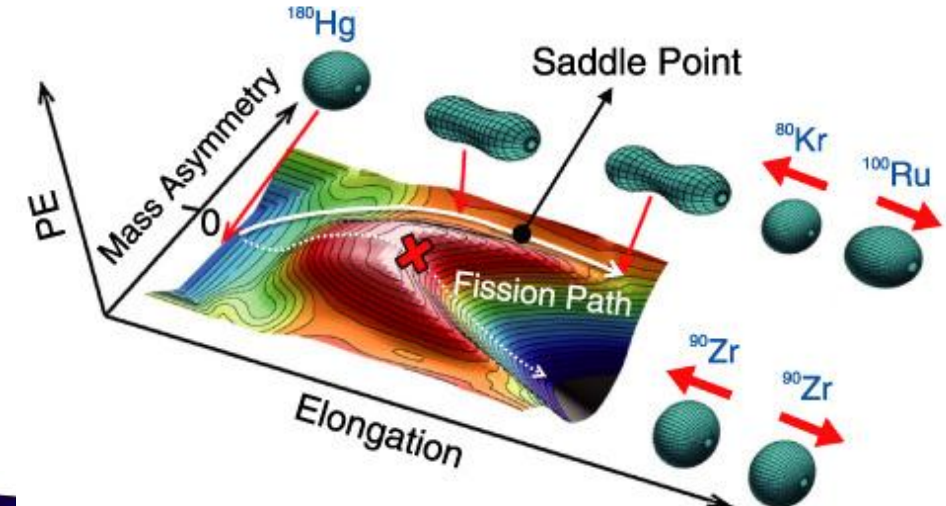
^{182}Pb (2005)

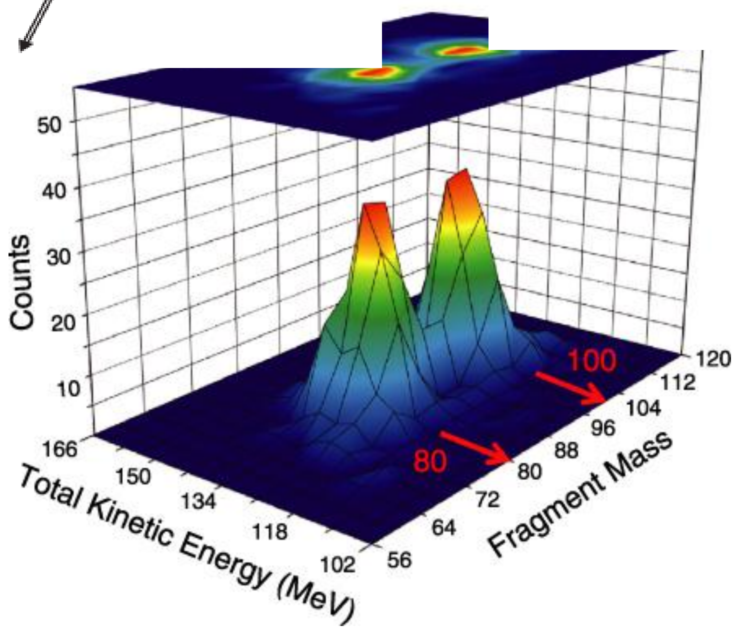
0.9 s cycling time -> 5 μA protons

H. De Witte et al. PRL 98 (07) 112502
T.E. Cocolios et al., PRL 106 (2011) 052503M. M.D.
Seliverstov et al., EPJ A41(2009) 315H. De

β-delayed fission



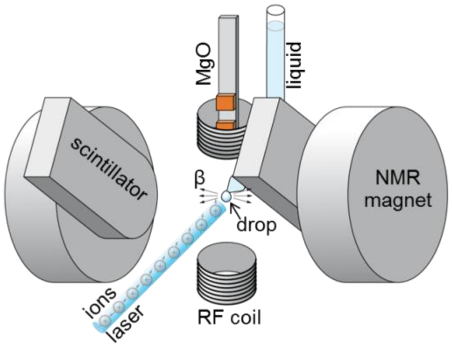




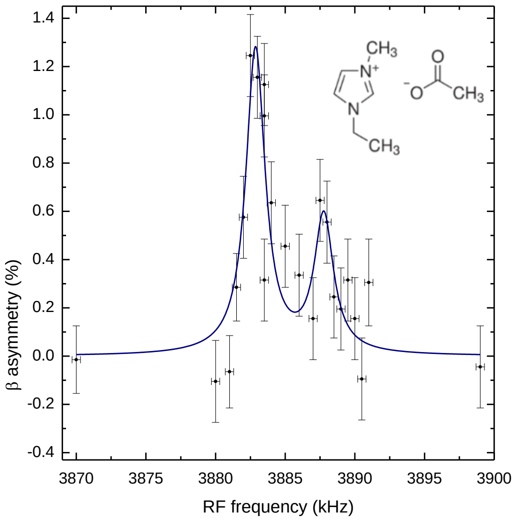
Solid State Physics

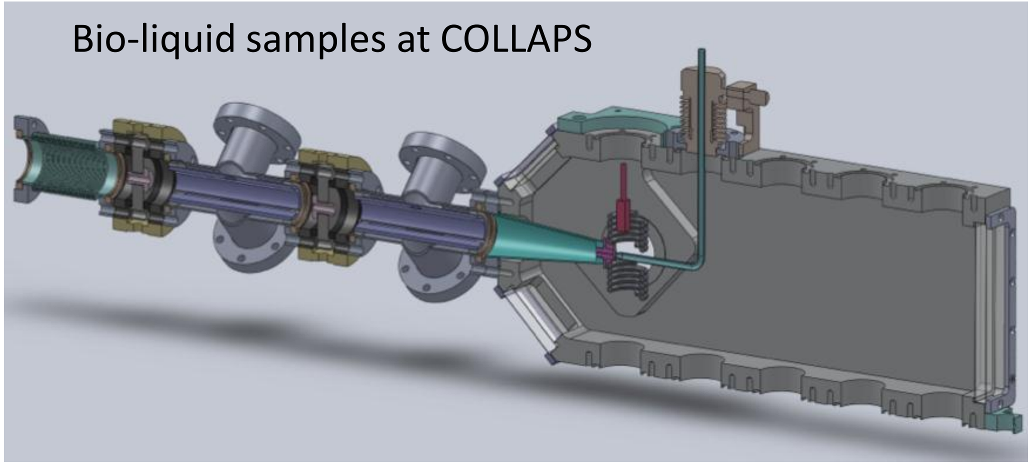
- Detect nuclear radiation to quantify impurities:
- Radiotracer diffusion
- Decay particles transmit information with atomic resolution:
- Emission Channeling (EC)
- Perturbed Angular Correlation (PAC)
- Mössbauer Spectroscopy (MS)
- Beta Nuclear Magnetic Resonance (beta-NMR)

-Identify spectroscopic signals via isotope half life:
- Deep Level Transient Spectroscopy (DLTS)
- Hall effect
- Photoluminescence (PL)

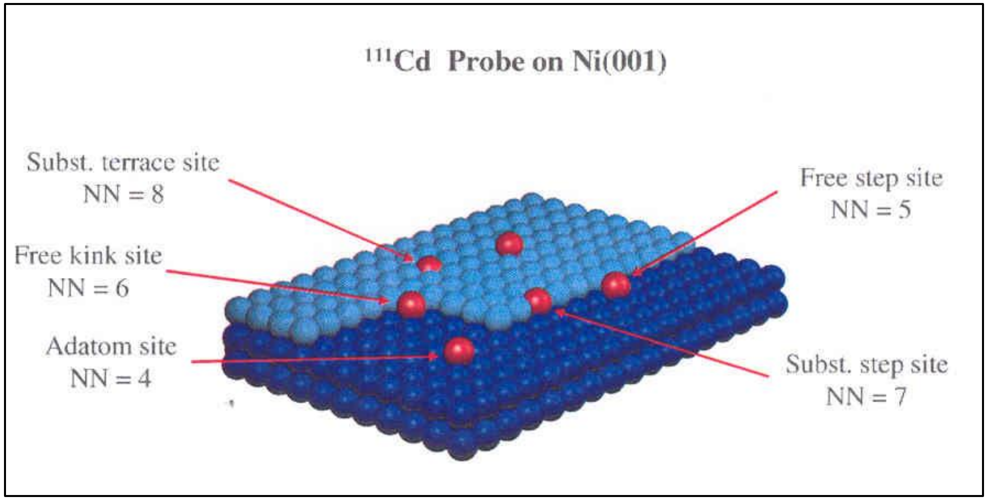


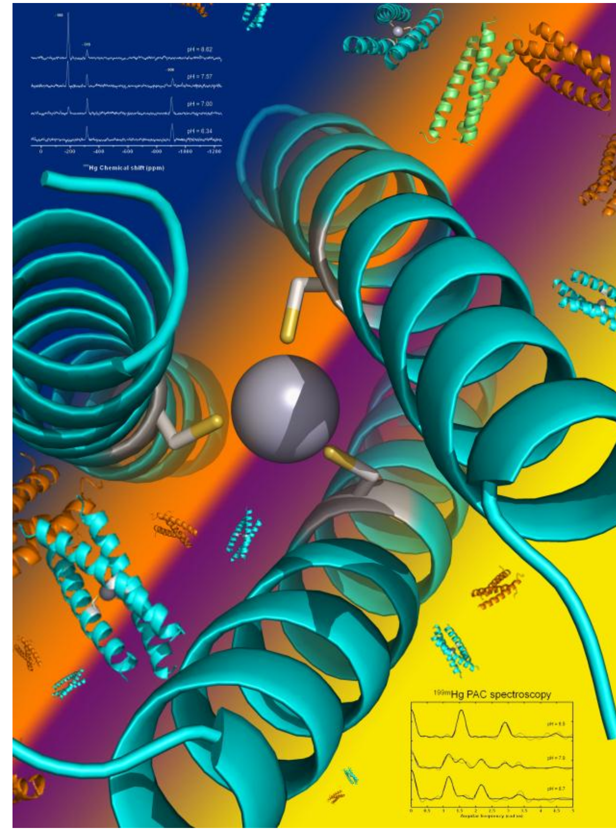
Mark Bissell





Monika Stachura and Alexander Gottberg



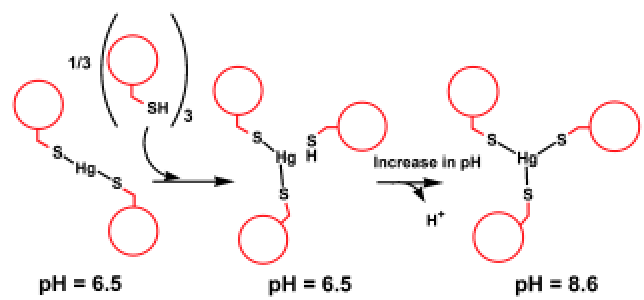


$$N_A = \frac{V_{mol}}{V_o}.$$

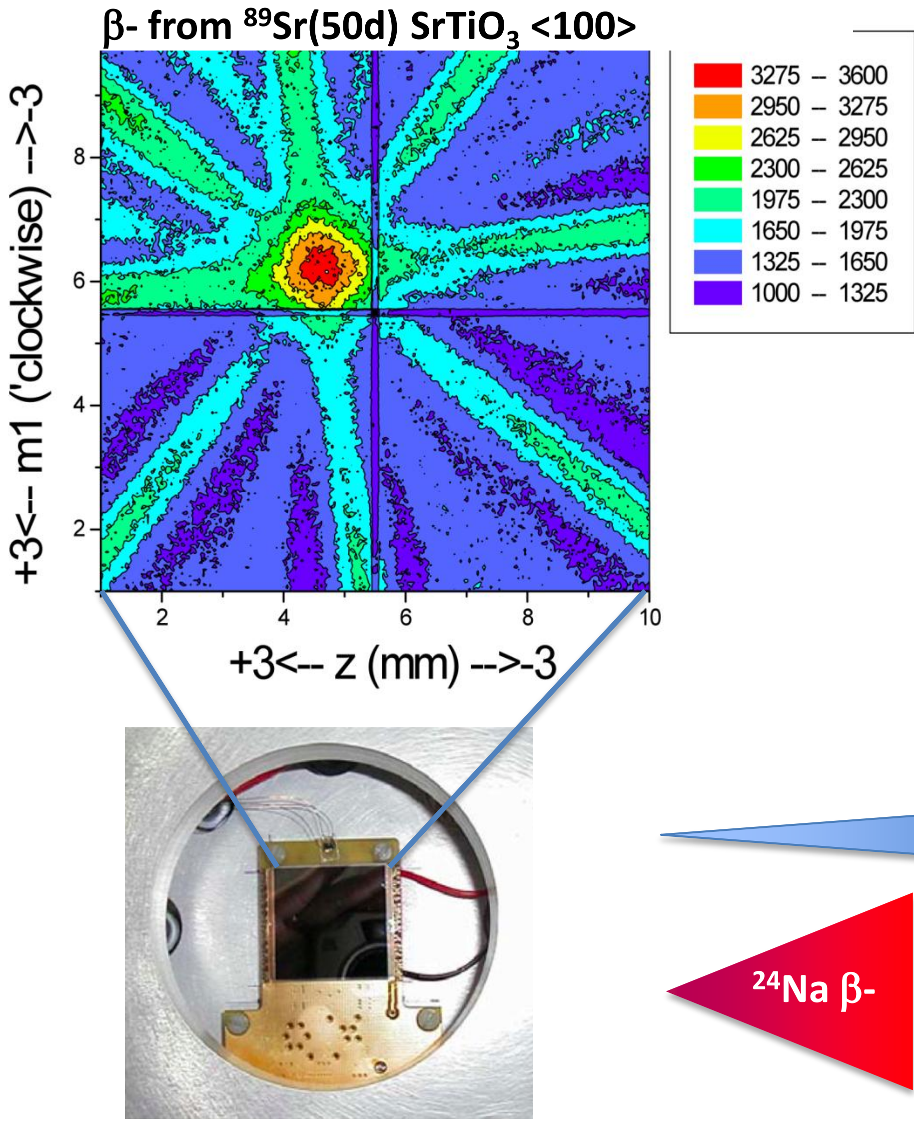
$$N_A = \frac{V_{mol}}{(a^3/n)},$$

$$N_A = \frac{M_{Si}}{m}\frac{V}{(a^3/8)},$$

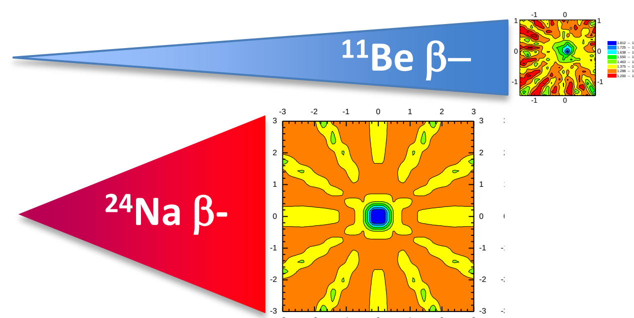
Scientific American
295, 102 – 109 (2006)

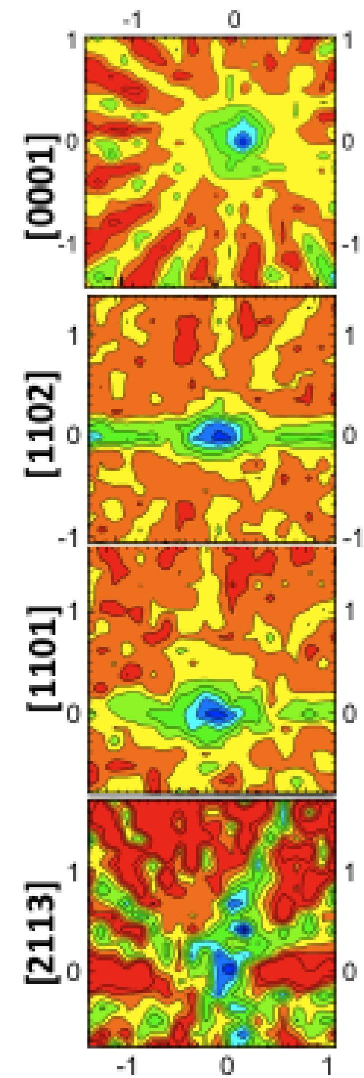


On-line emission channelling



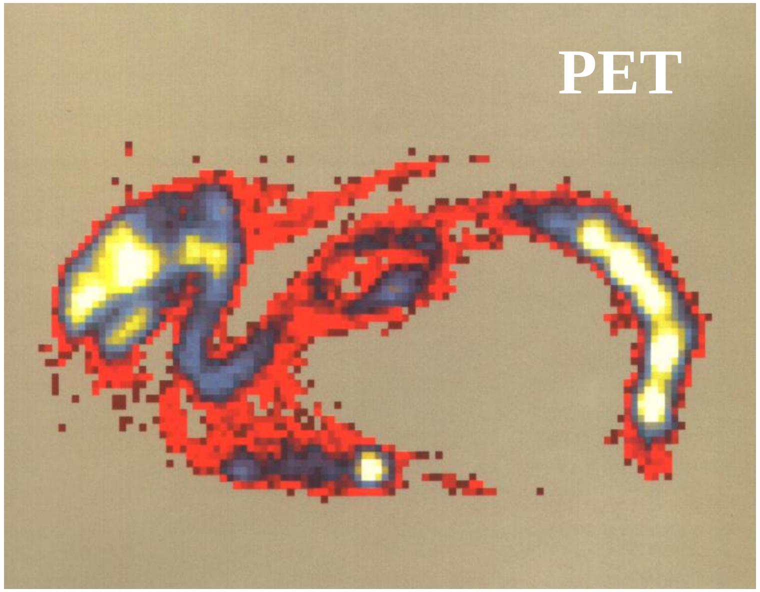
2012
first ever done β^-
EC patterns
using ^{11}Be(14 s)
in GaN

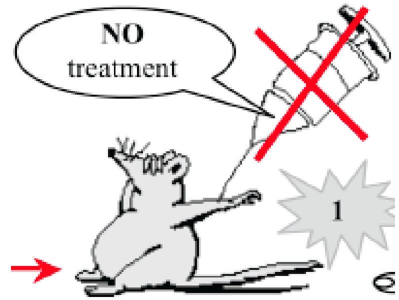


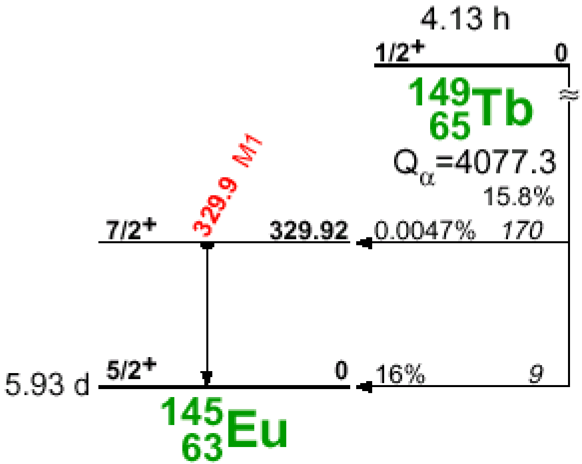


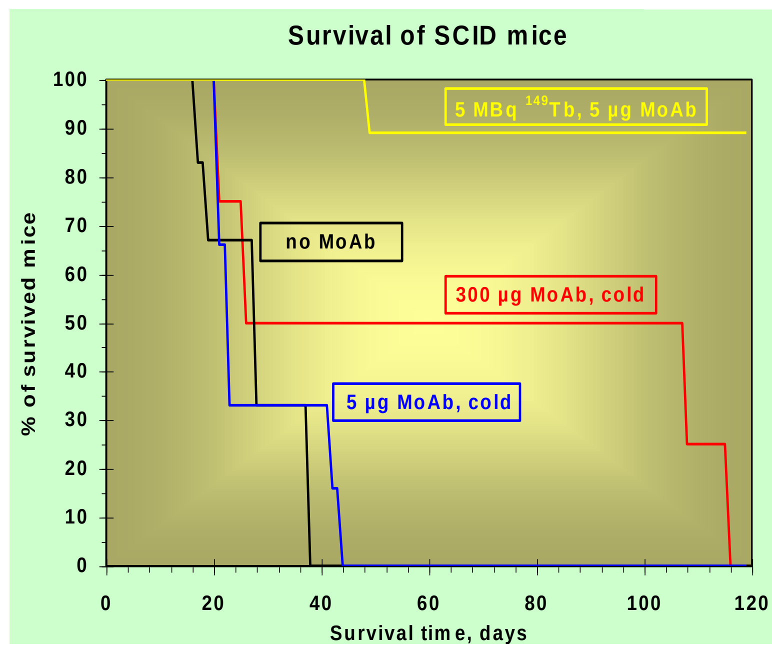
^{142}Sm (ε, $T_{1/2}$ = 72m) $\Rightarrow$
^{142}Pm (β_{+}, $T_{1/2}$ = 40s)

Targeted alpha therapy in vivo: direct evidence for single cancer cell kill using ^{149}Tb-rituximab









CERN-MEDICIS

T. Stora

MINUTES OF THE 174th MEETING OF THE RESEARCH BOARD HELD ON THURSDAY, 1 DECEMBER 2005

of the AB and PH departments [4]. **A more complete report should be prepared by the AB department in consultation with the ISOLDE collaboration, and with input from the TS, PH and AT departments, in time for a decision to be taken at the Research Board meeting of 8 June 2006.**

ISOLDE