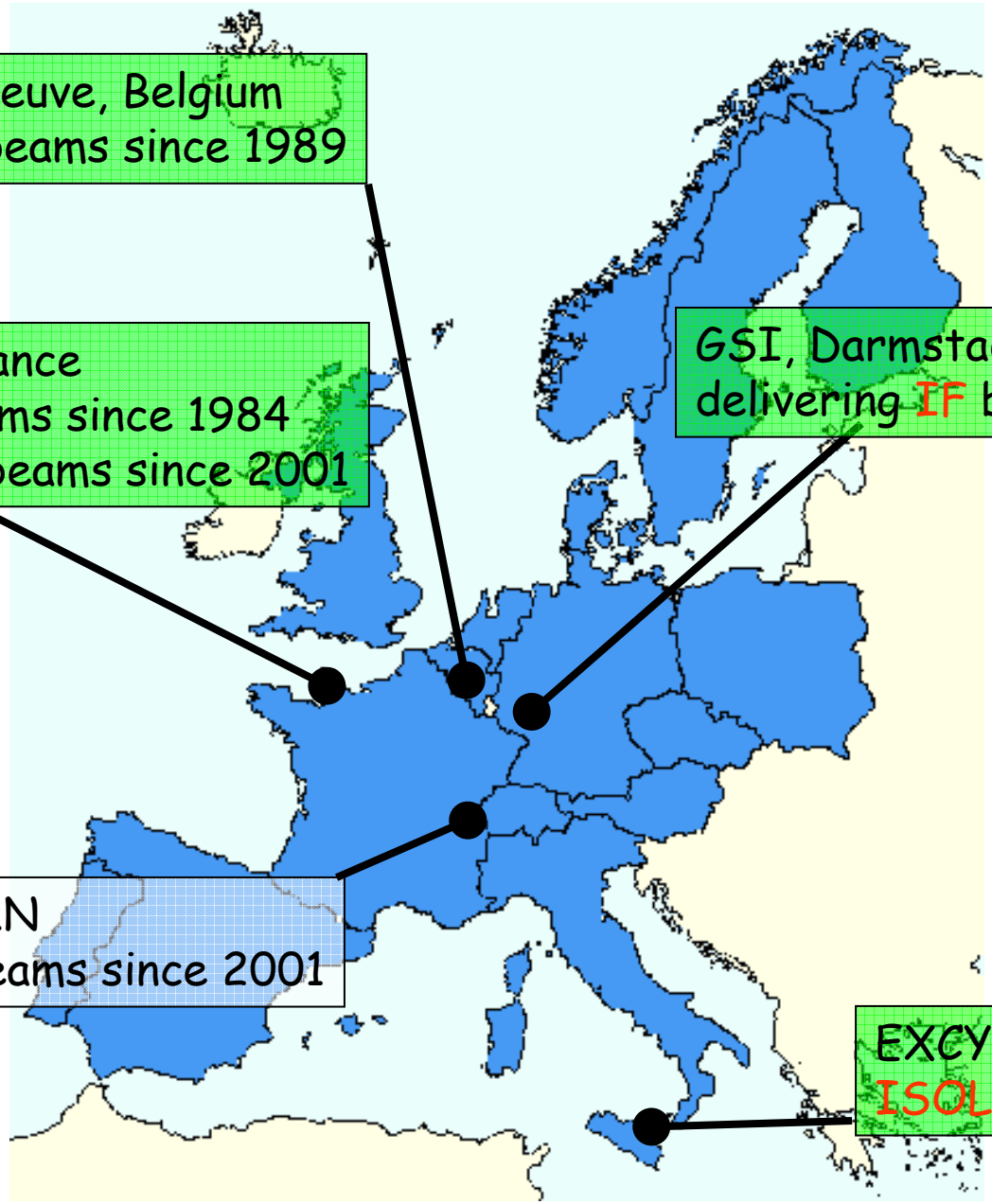
Introduction to REX-ISOLDE concept and overview of (future) European projects

Thanks to: Y. Blumenfeld, P. Butler, M. Huyse, M. Lindroos, K. Riisager, P. Van Duppen

Energetic Radioactive Beam Facilities in Europe



CRC, Louvain-la-Neuve, Belgium
delivering ISOL beams since 1989

GANIL, Caen, France
delivering IF beams since 1984
(SPIRAL) ISOL beams since 2001

GSI, Darmstadt, Germany
delivering IF beams since 1990

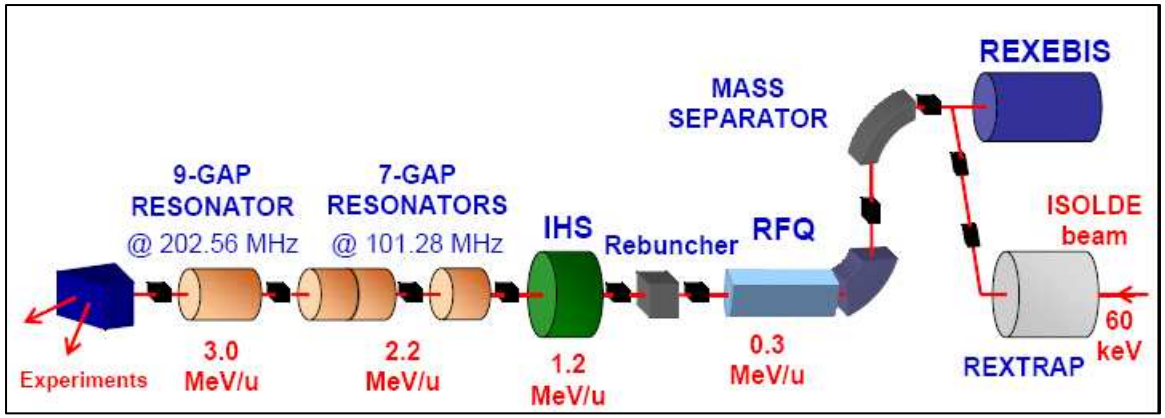
REX-ISOLDE, CERN
delivering ISOL beams since 2001

EXCYT, Catania, Italy
ISOL beams since 2006

World ISOL

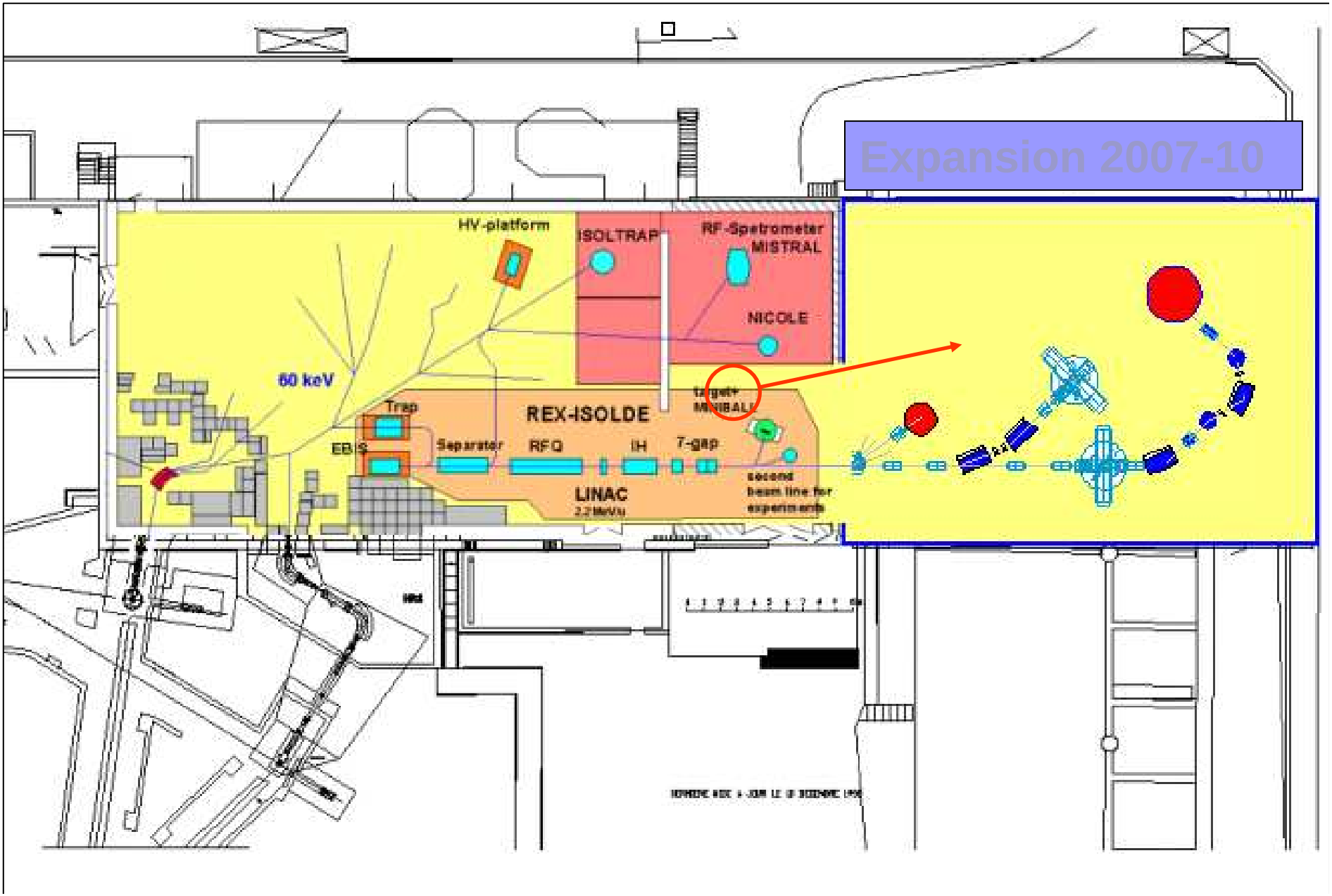
FACILITY	DRIVER	POWER	USER BEAMS ACCELERATED	ENERGY	PHYSICS REACH
LOUVAINE-LA-NEUVE (BELGIUM) 1989	30 MeV protons	6 kW	^{6}He, ^{7}Be, ^{10,11}C, ^{13}N, ^{15}O, ^{18}F, ^{18,19}Ne, ^{35}Ar	10 MeV/u cyclotron	Astrophysics, Nuclear structure
HRIBF Oak Ridge (USA) 1997	100 MeV p, d, α *(-ve ion source)*	1 kW	^{7}Be, ^{17,18}F, ^{69}As, ^{67,83}Ga, $^{75-79}$Cu, $^{80-87}$Ge, ^{84}Se, ^{92}Sr, ^{118,120,122,124}Ag, ^{129}Sb, $^{130-134}$Sn, ^{132,134,136}Te	2 - 10 MeV/u tandem	Nuclear Structure, Astrophysics
ISAC TRIUMF (CANADA) 2000	500 MeV protons	50 kW	^{8,9,11}Li, ^{11}C, ^{20,21}Na, ^{18}Ne, ^{26}Al, ^{34}Ar	4.5 MeV/u linac	Astrophysics, Condensed matter, Nuclear Structure
SPIRAL GANIL (FRANCE) 2001	100 MeV/u heavy ions	6 kW	^{6,8}He, $^{15,19-21}$O, ^{18}F, $^{17-19,23-26}$Ne, $^{33-35,44,46}$Ar, $^{74-77}$Kr	2 - 25 MeV/u cyclotron	Nuclear structure, Astrophysics
REX ISOLDE (CERN) 2001	1.4 GeV protons	3 kW	^{8,9}Li, ^{10,11}Be, $^{24-29}$Na, $^{28-32}$Mg, ^{68}Ni, $^{67-73}$Cu, ^{74,76,78,80}Zn, ^{70}Se, ^{88,92}Kr, ^{108}In, ^{108,110}Sn, ^{122,124,126}Cd, ^{138,140,142,144}Xe, ^{148}Pm, ^{153}Sm, ^{156}Eu	0.3 - 3 MeV/u linac	Nuclear structure, Condensed matter, Astrophysics

REX post-accelerator

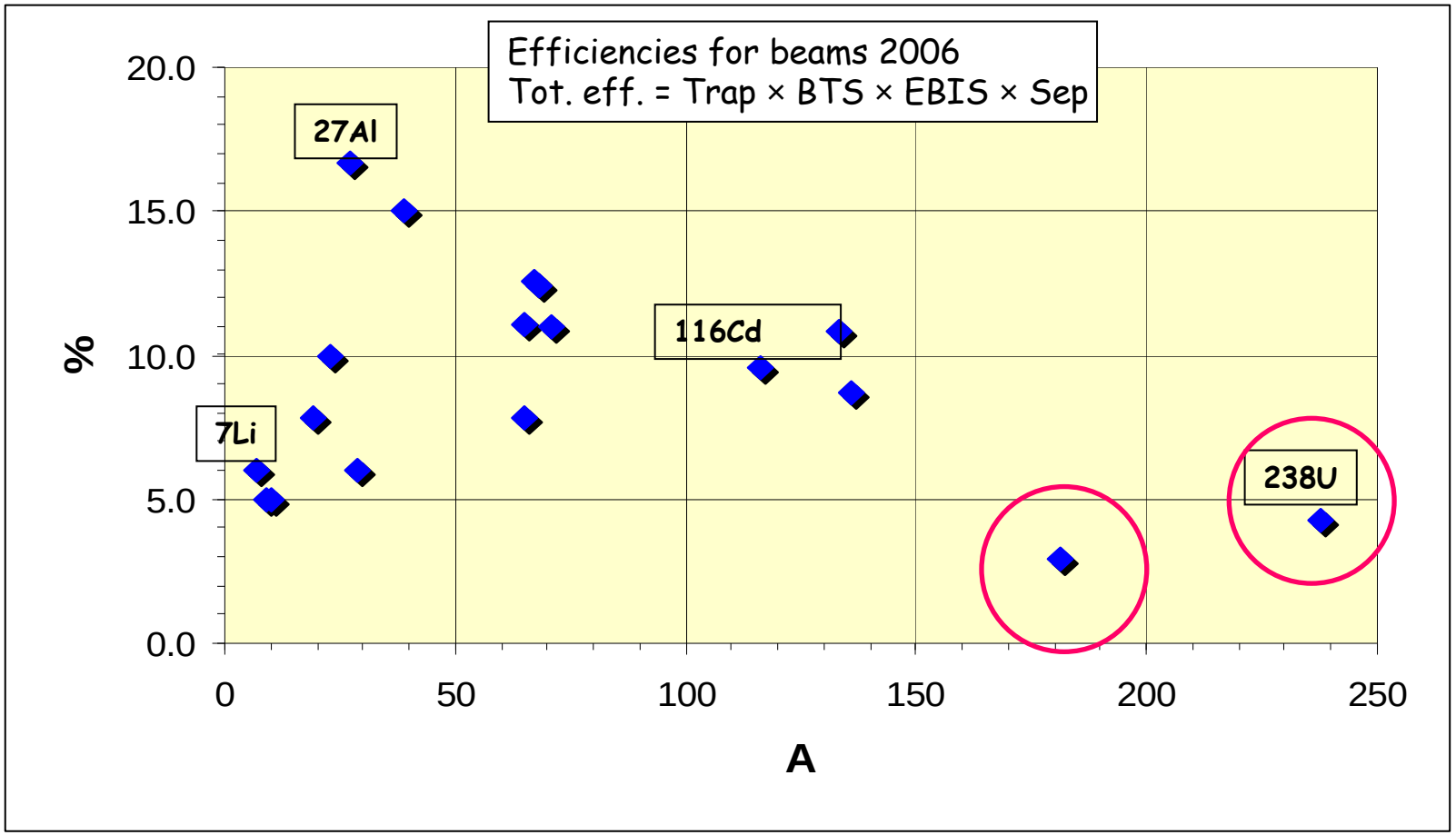


- Originally constructed by several CERN member states
  ~ 15 MCHF
- Utilises now → 50% ISOLDE running time
- REX has accelerated over 50 different RIB
- Present RIB yield from ISOLDE allows 10% of all 700 radioisotopes be used

REX-ISOLDE layout

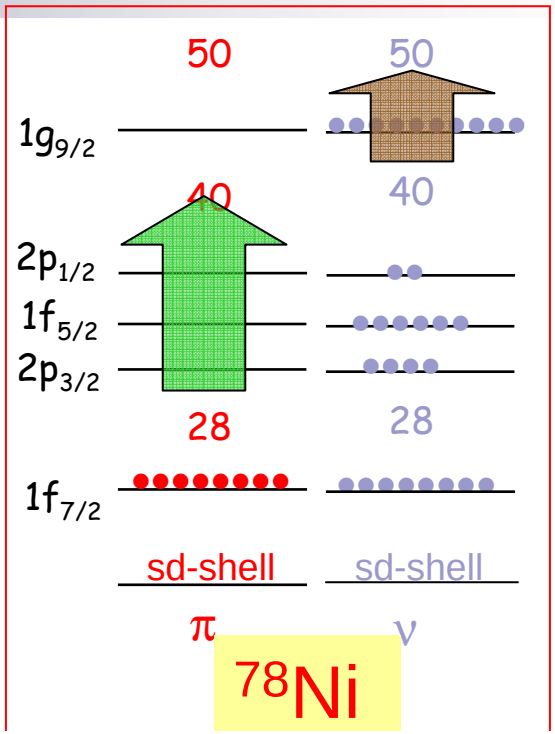


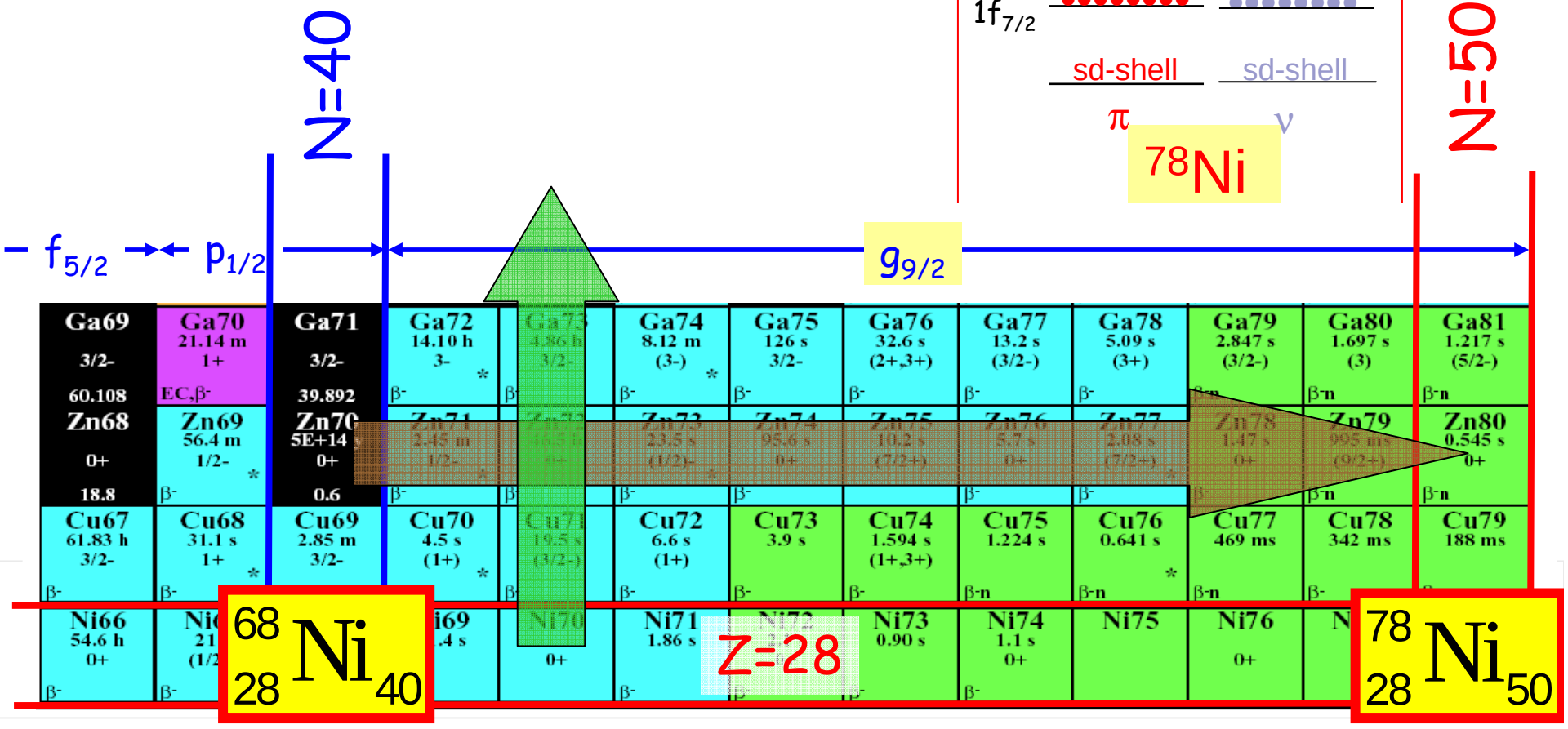
Rex efficiencies



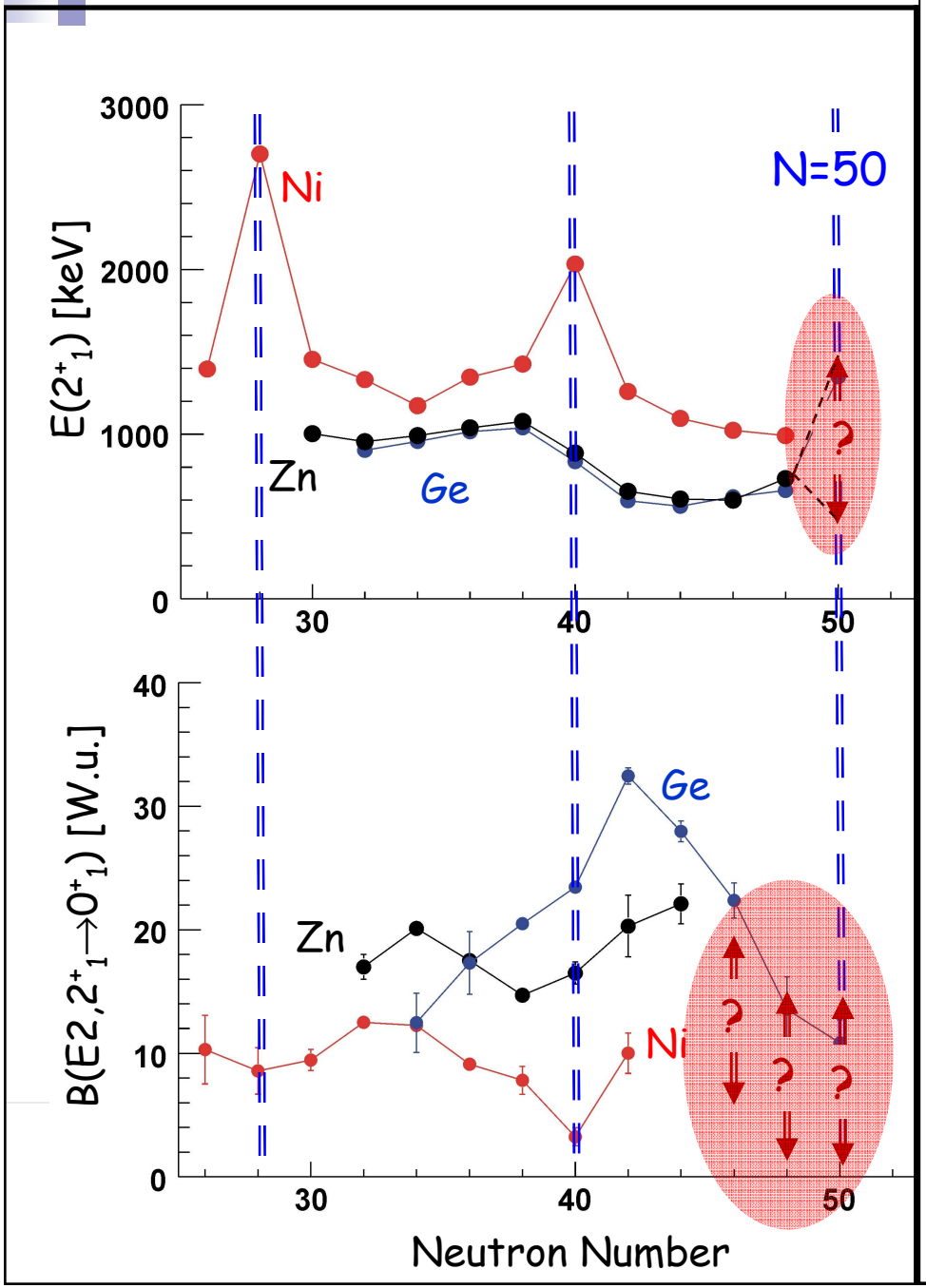
- Evolution towards ^{78}Ni along N=50
- Onset of collectivity for Z>28

Examples from ongoing programme





Ni(Z=28), Zn(30), Ge(32) isotopes



C. Mazzocchi *et al*, PLB**622** 45 (2005) - NSCL,MSU
O. Perru *et al*, PRC**96** 232501 (2006) – GANIL
E. Padilla-Rodal *et al*, PRL**70** 024301 (2004) - ORNL
O. Sorlin *et al*, PRL **88**, 2002

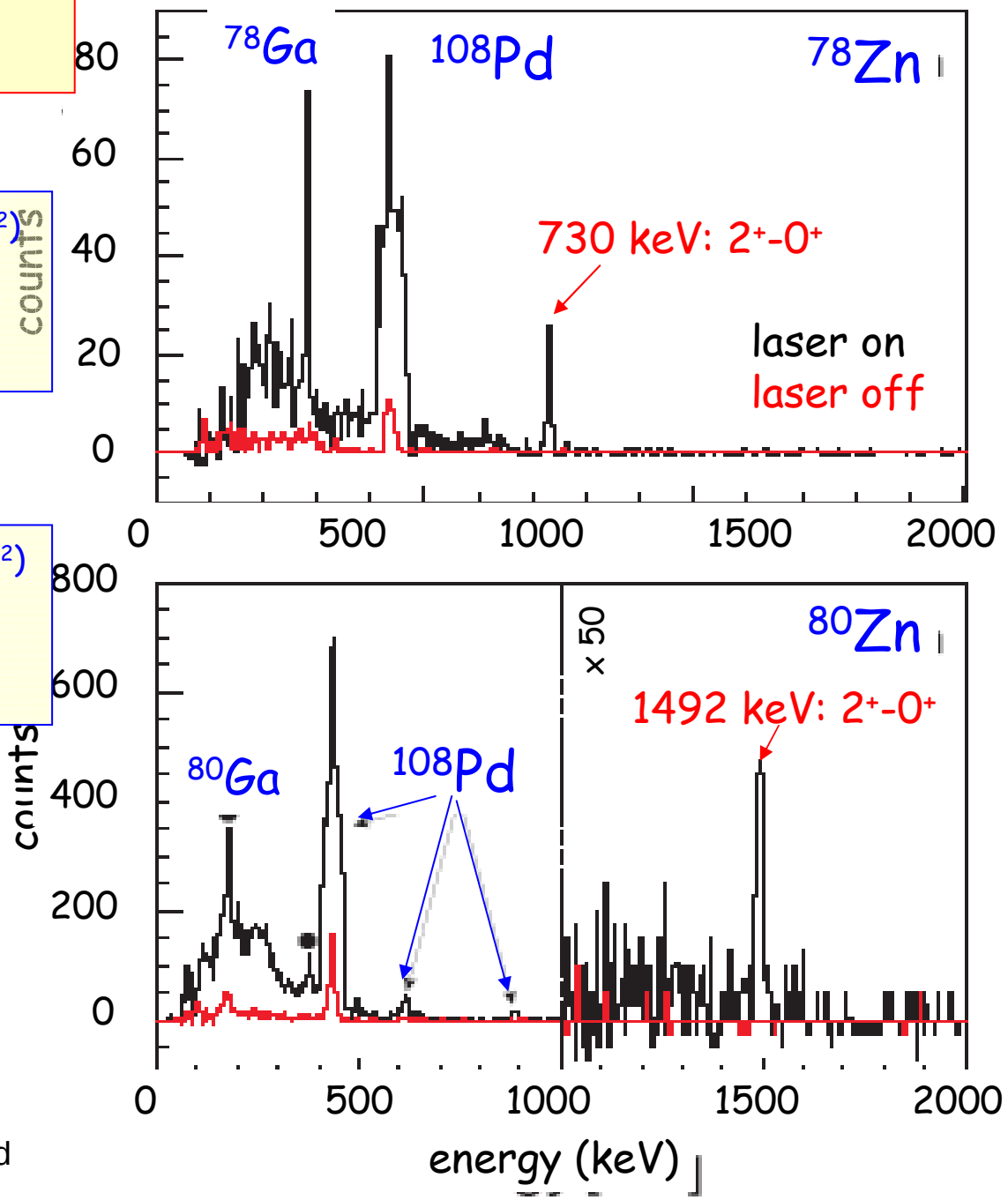
C. Mazzocchi *et al*, PLB**622** 45 (2005) - NSCL,MSU
J. Van Roosbroeck *et al*, PRC**67** 054307 (2005) - ISOLDE

K.-H. Langanke *et al*, PRC 67, 2003

➢ Coulomb excitation of even-even Zn isotopes *

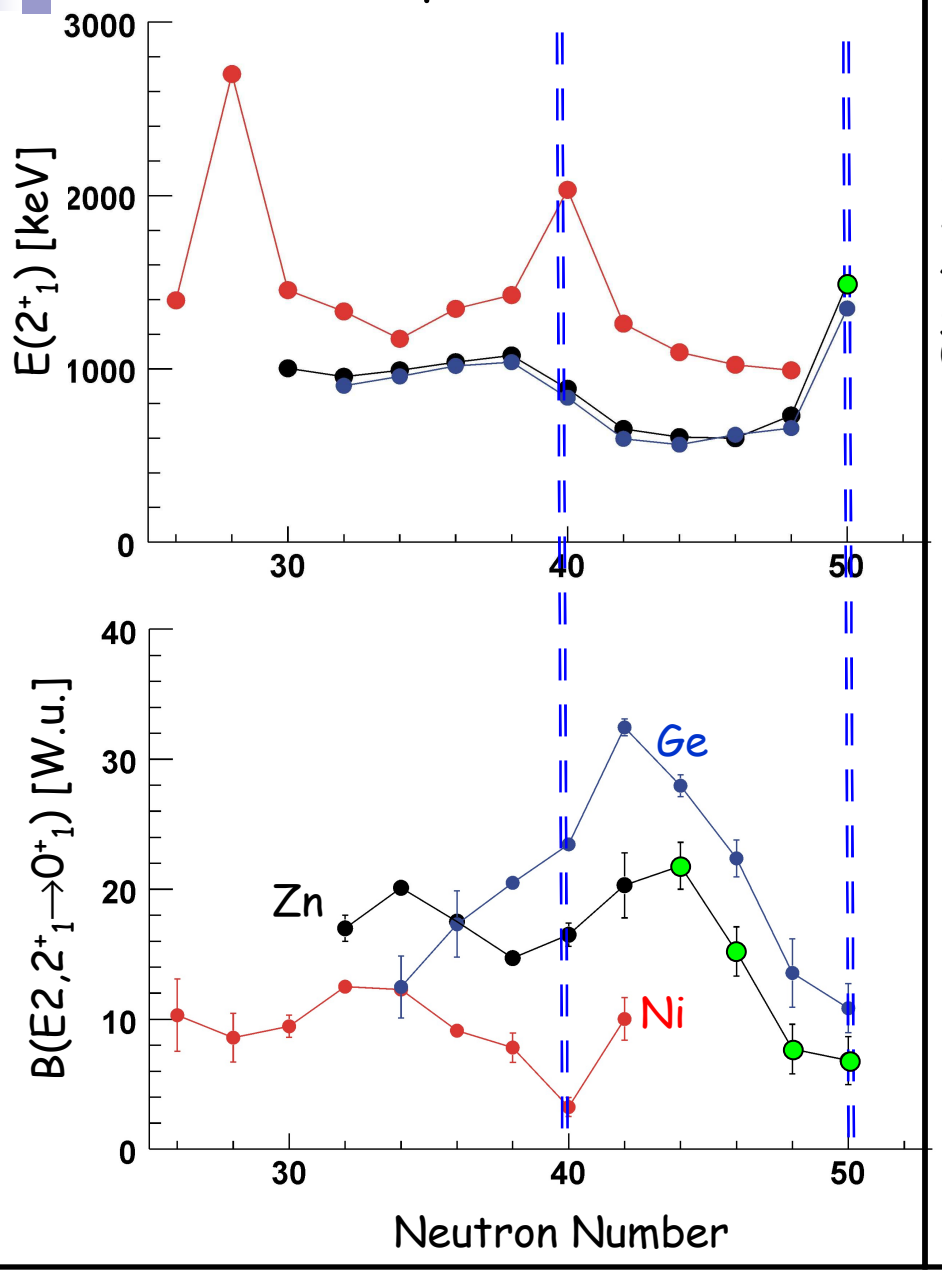
• ^{78}Zn ($T_{1/2}$=1.5 s) @ ^{108}Pd (2.0 mg/cm^2)
Energy = 2.87 MeV/u
Intensity = 4300 pps
Purity = 64 (13) %

• ^{80}Zn ($T_{1/2}$=0.5 s) @ ^{108}Pd (2.0 mg/cm^2)
Energy = 2.79 MeV/u
Intensity = 3000 pps
Purity = 43 (5) %

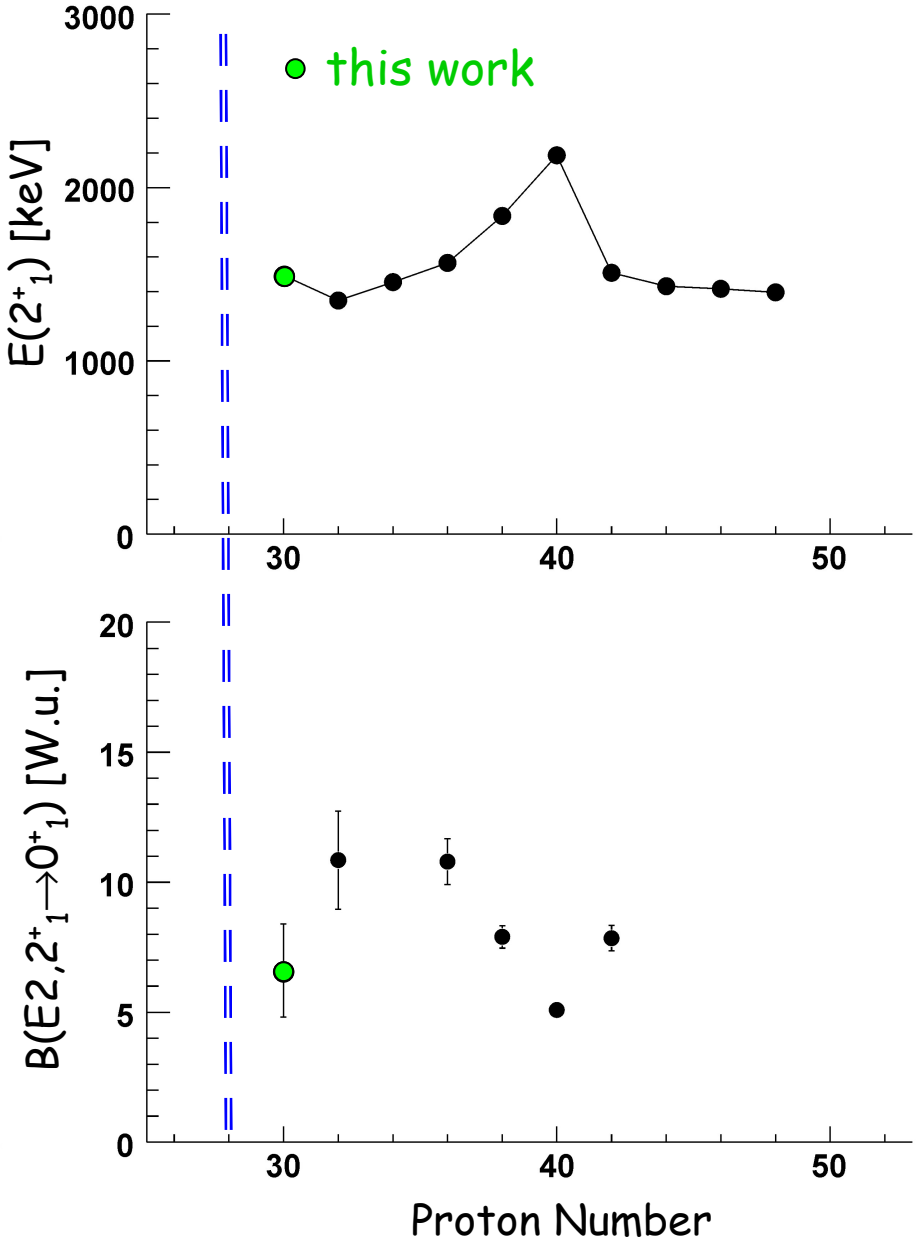


*P. Van Duppen et al., to be published

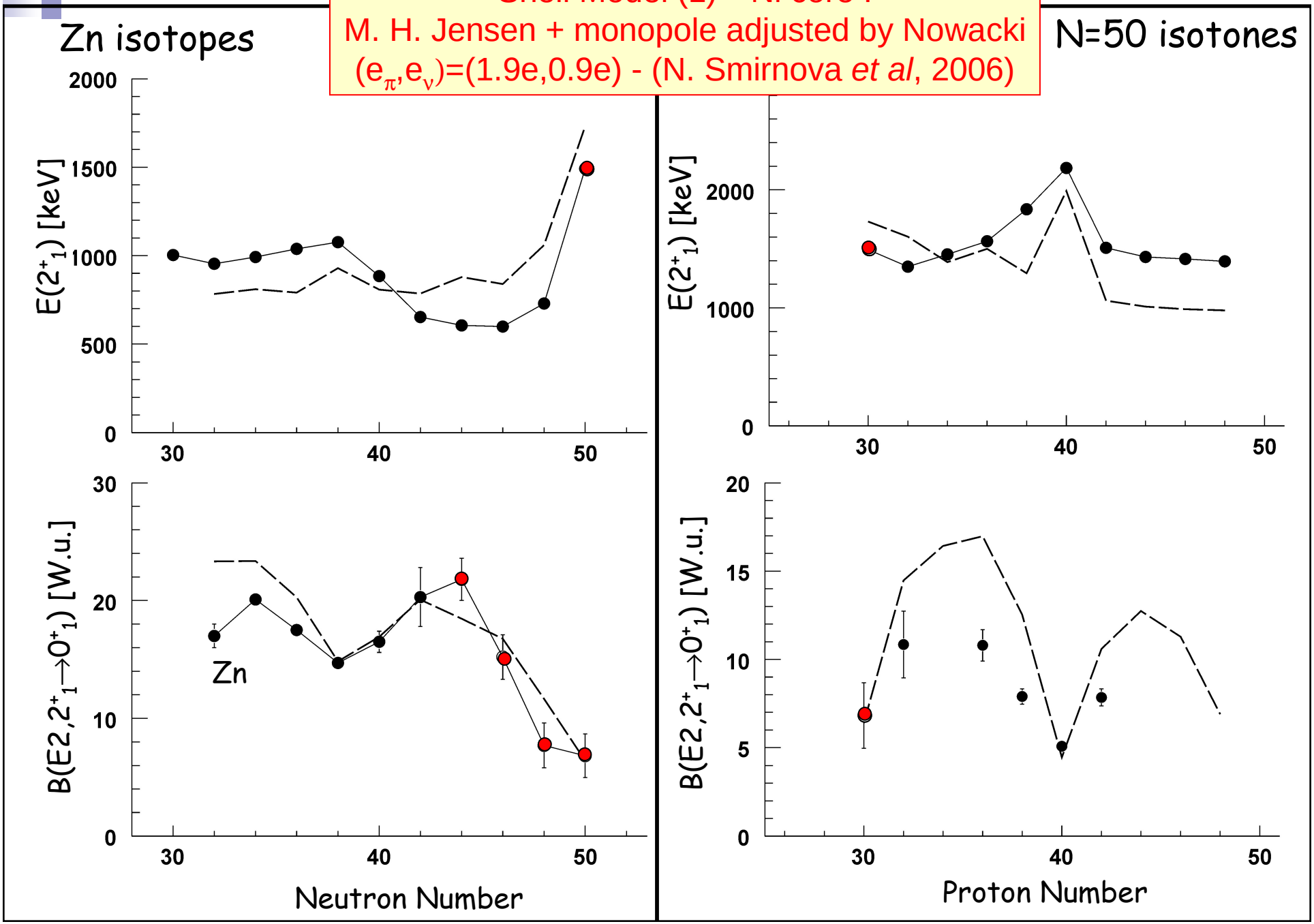
Ni,Zn,Ge isotopes



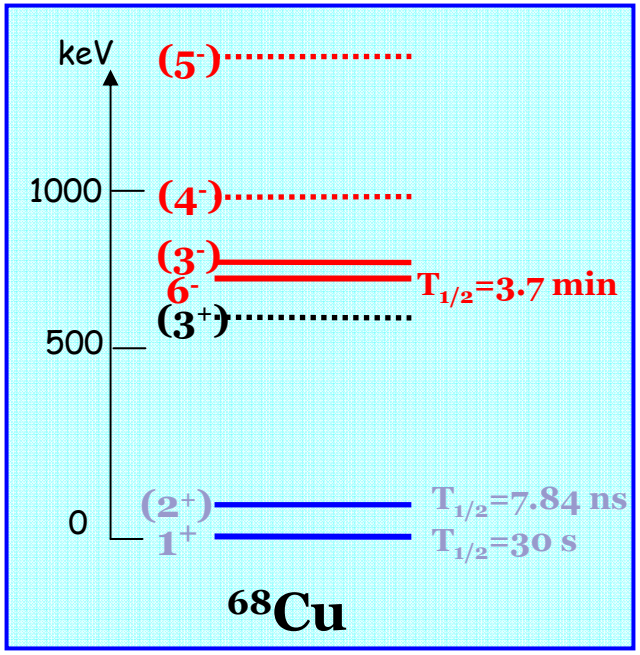
N=50 isotones

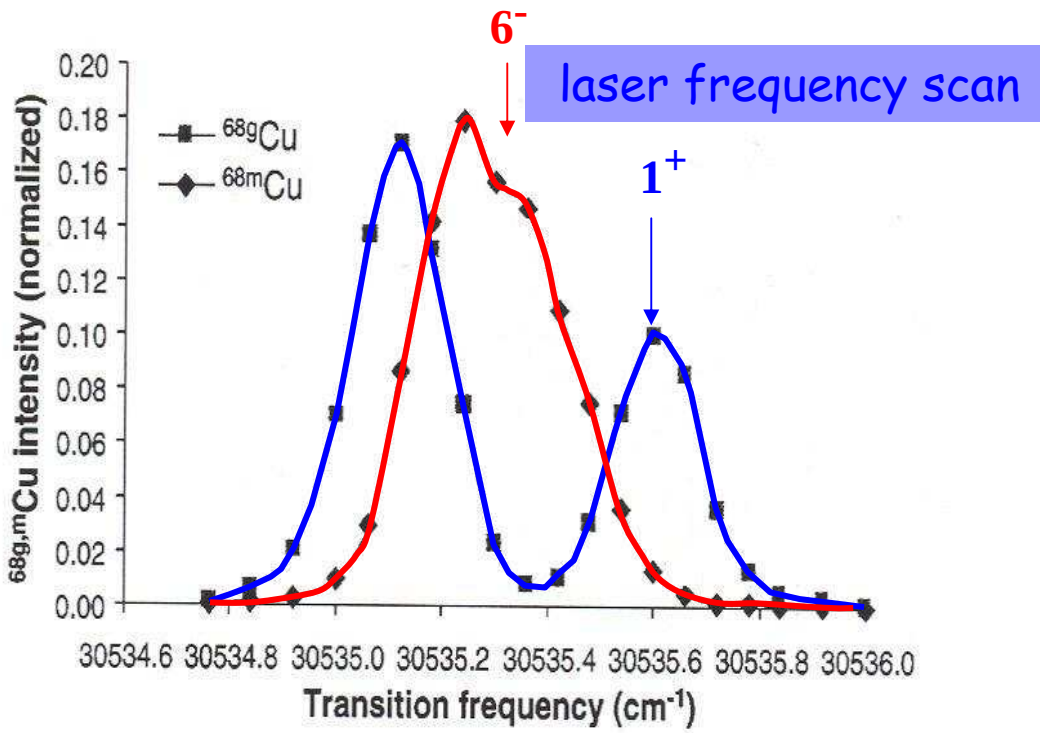


Shell Model (1) ^{56}Ni core :
M. H. Jensen + monopole adjusted by Nowacki
(e_π,e_ν)=(1.9e,0.9e) - (N. Smirnova *et al*, 2006)



New directions: production of isomeric beams,



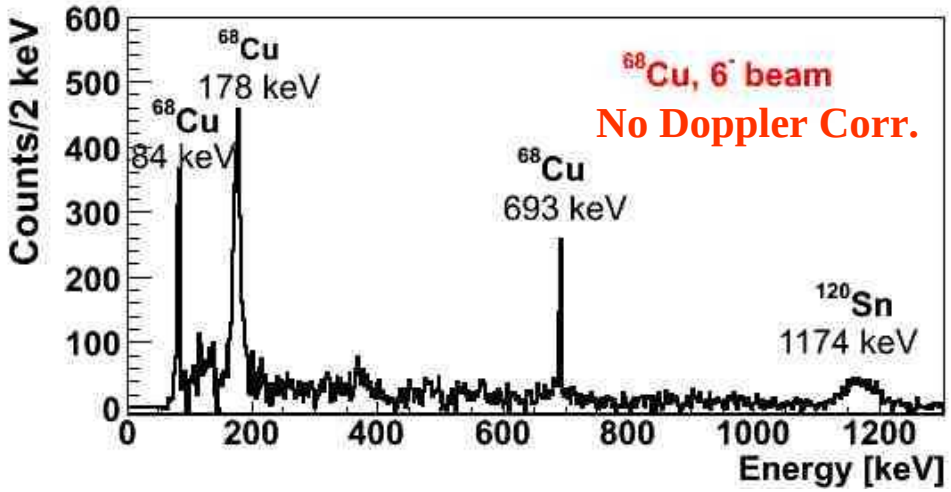


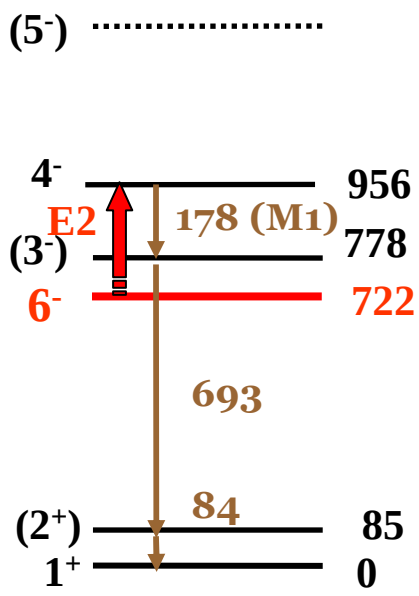
- Purified isomeric beams:
  - Laser ionization employing hyperfine splitting
  - Coulomb excitation and transfer reactions (after post-acceleration)

J. Van Roosbroeck,- PRL 92 (2004) 112501

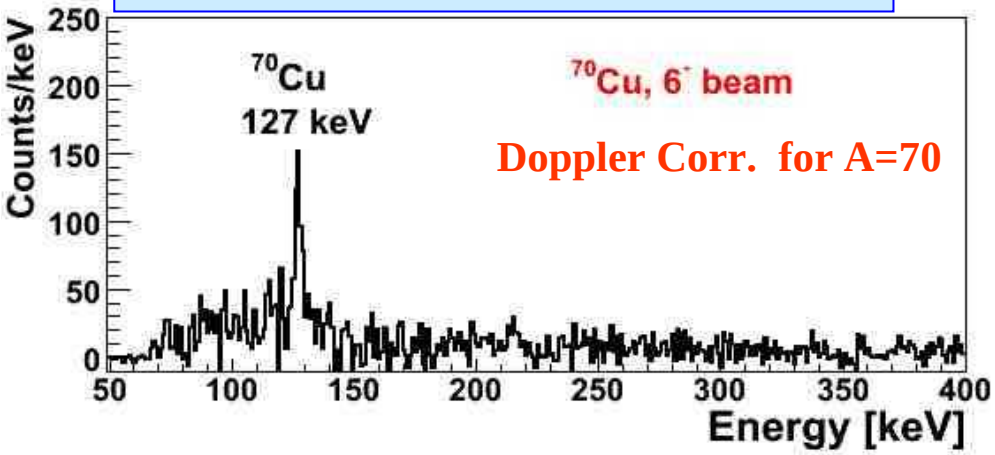
Coulomb excitation of odd-odd ^{68,70}Cu

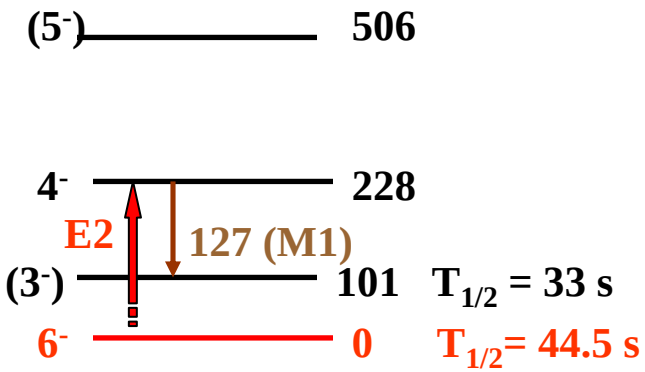
^{68,m}Cu (2.83 MeV/u) @ ^{120}Sn (2.3 mg/cm^2)
3·10^5 pps, 74% pure





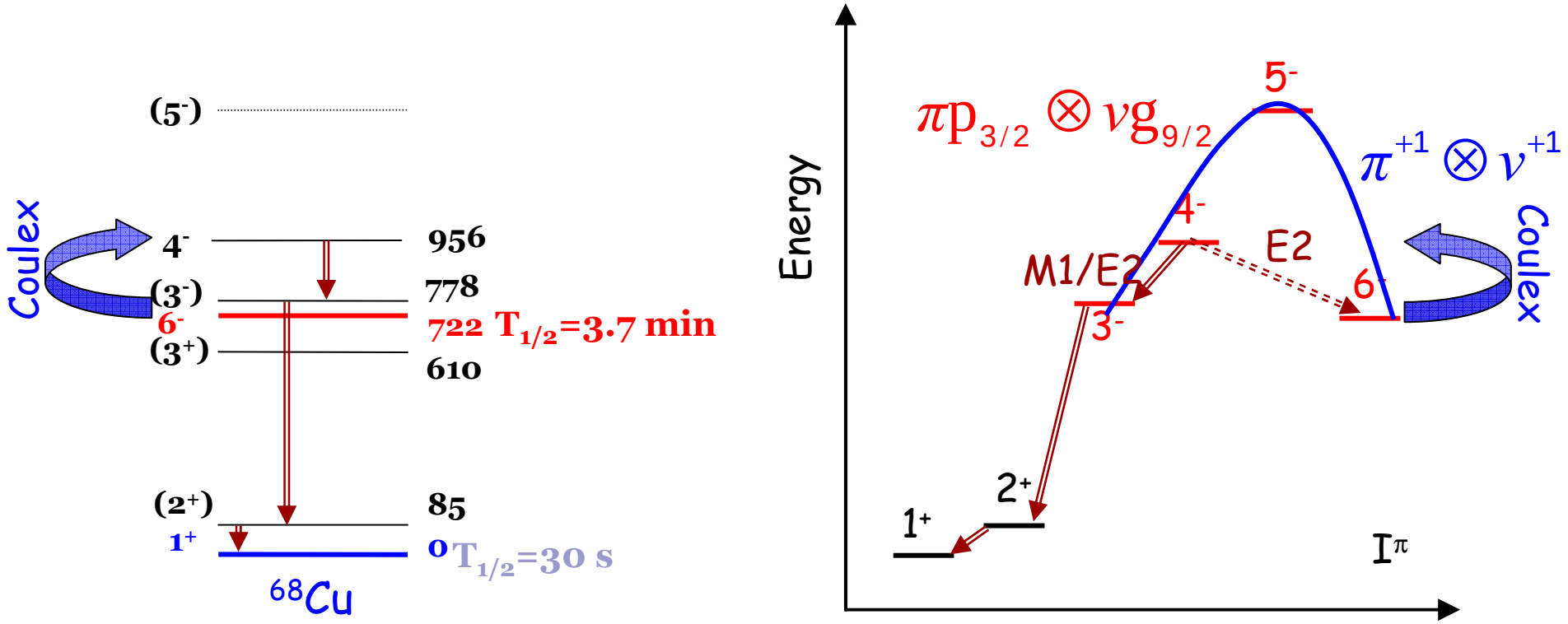
^{70}Cu (2.83 MeV/u) @ ^{120}Sn (2.3 mg/cm^2)





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

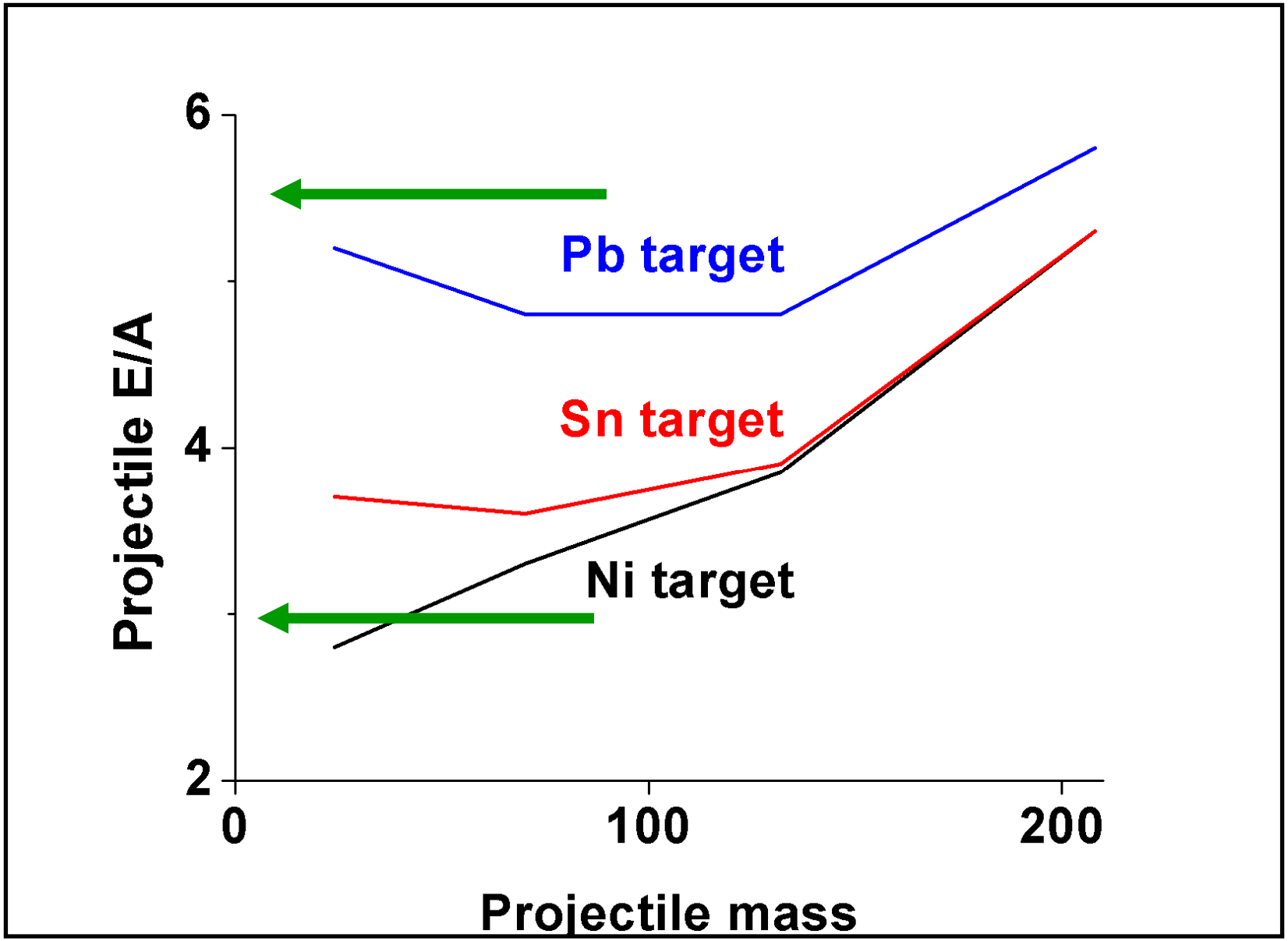
Induced instantaneous depopulation of a nuclear isomer



- Population via Coulex (E2)
- Decay through faster M1 transition
- "Paar" parabola (I(I+1) dep.): E2 excitation over the parabola's maximum

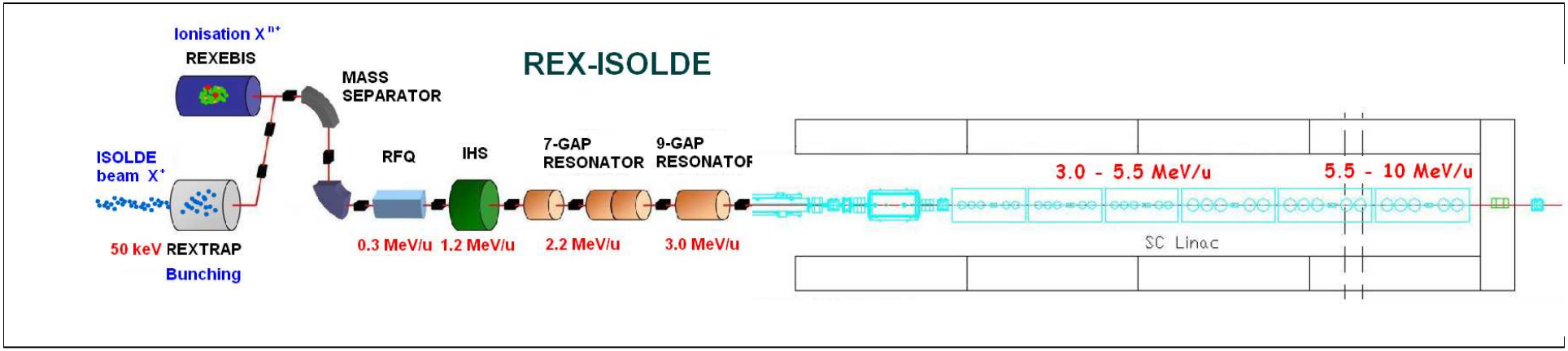
- Energy is "released" and half life of the isotope is changed
- Mechanism present in other odd-odd nuclei (e.g. $^{108,110}Ag$) ?
- Interest for nucleosynthesis processes?

Coulomb barrier for RIB



HIE-ISOLDE at CERN

Increase in REX energy from 3 to 10 MeV/u (first step in increase to 5.5 MeV/u)



Increase proton intensity 2 → 6 μA (LINAC4, PSB upgrade) - target and front-end upgrade

RFQ cooler, REX-TRAP, REX-EBIS
REX-ECR upgrades

Super-HRS for isobaric separation
RILIS upgrade & LIST

EU projects (2005-2009)

EURONS I^3: (2.1 MCHF)

TNA

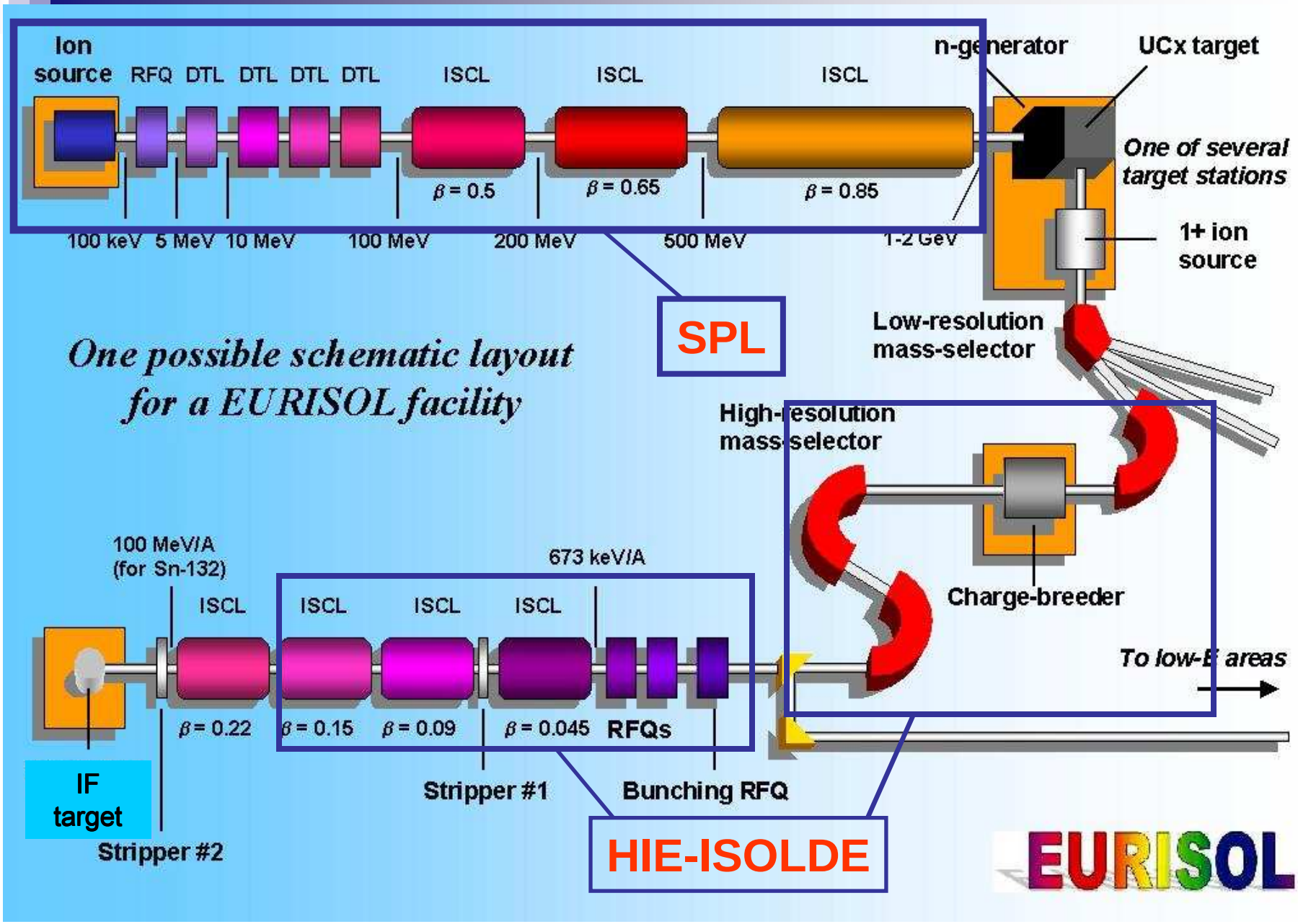
JRA's: INTAG, CHARGE BREEDER,
LASER, SAFERIB, (TRAPSPEC)

EURISOL DS: (2.8 MCHF)

R&D in targets & β-beam

radioisotope manipulation

safety

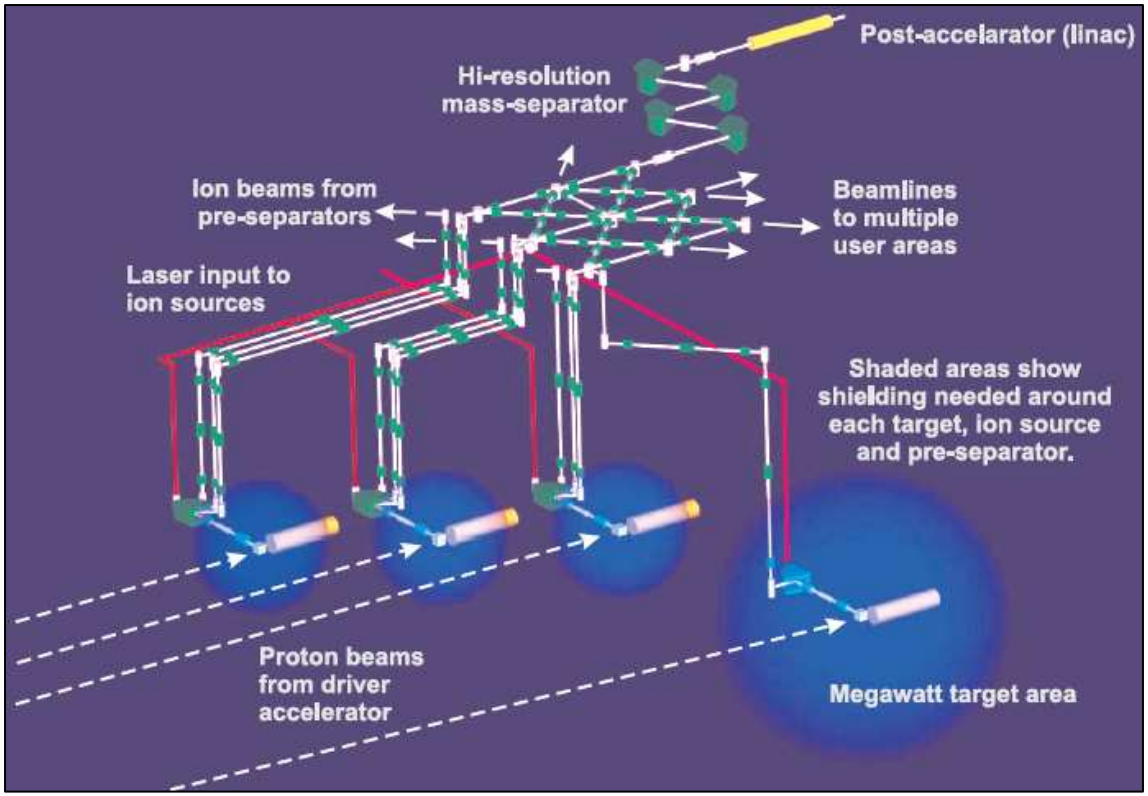

Ion source
RFQ
DTL
DTL
DTL
DTL
ISCL
ISCL
ISCL
n-generator
UCx target
One of several target stations
1+ ion source
β = 0.5
β = 0.65
β = 0.85
100 keV
5 MeV
10 MeV
100 MeV
200 MeV
500 MeV
1-2 GeV
SPL
Low-resolution mass-selector
One possible schematic layout for a EURISOL facility
High-resolution mass-selector
Charge-breeder
100 MeV/A (for Sn-132)
673 keV/A
ISCL
ISCL
ISCL
ISCL
To low-E areas
β = 0.22
β = 0.15
β = 0.09
β = 0.045
RFQs
IF target
Stripper #1
Bunching RFQ
Stripper #2
HIE-ISOLDE
EURISOL

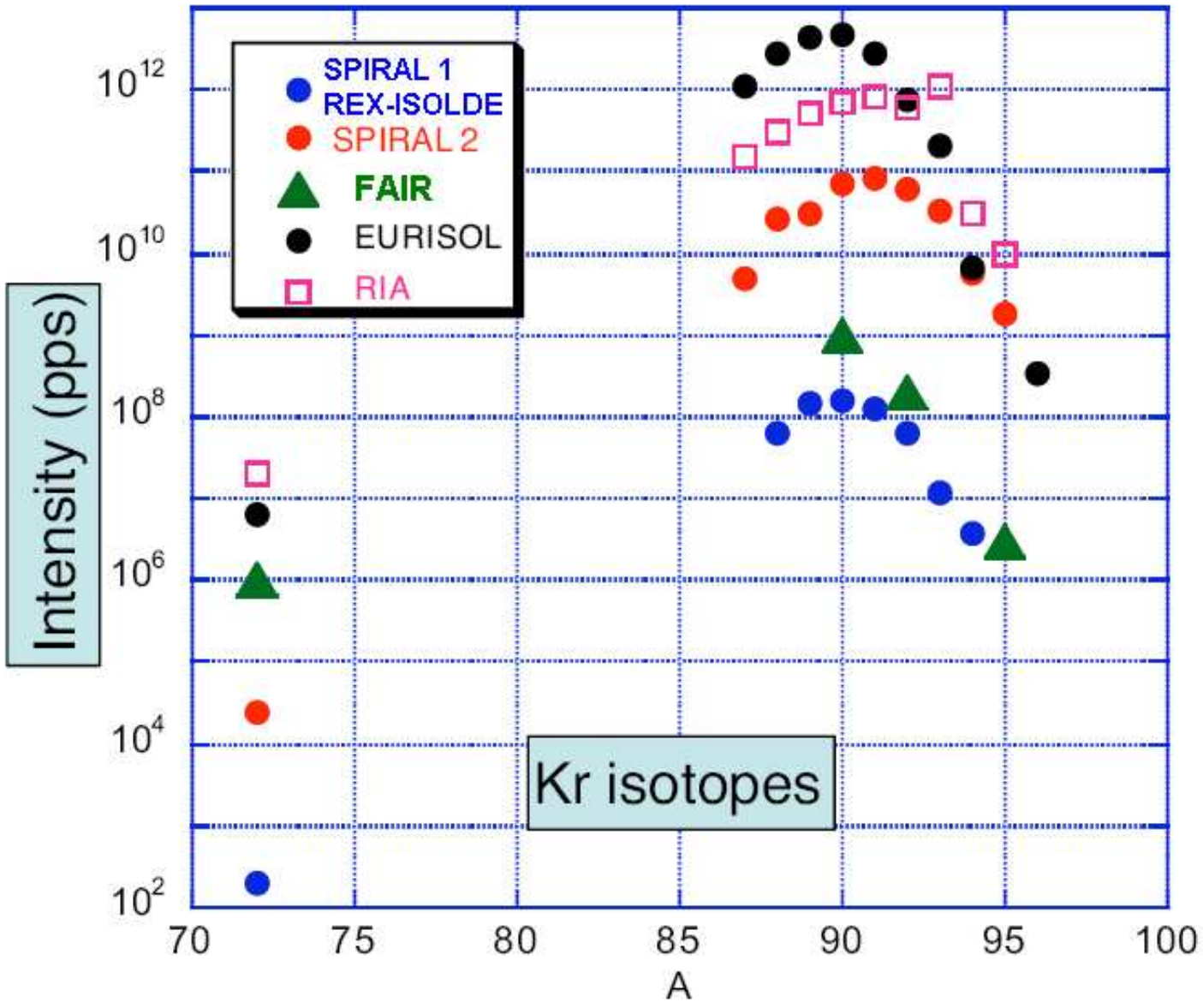
EURISOL

100kW direct production

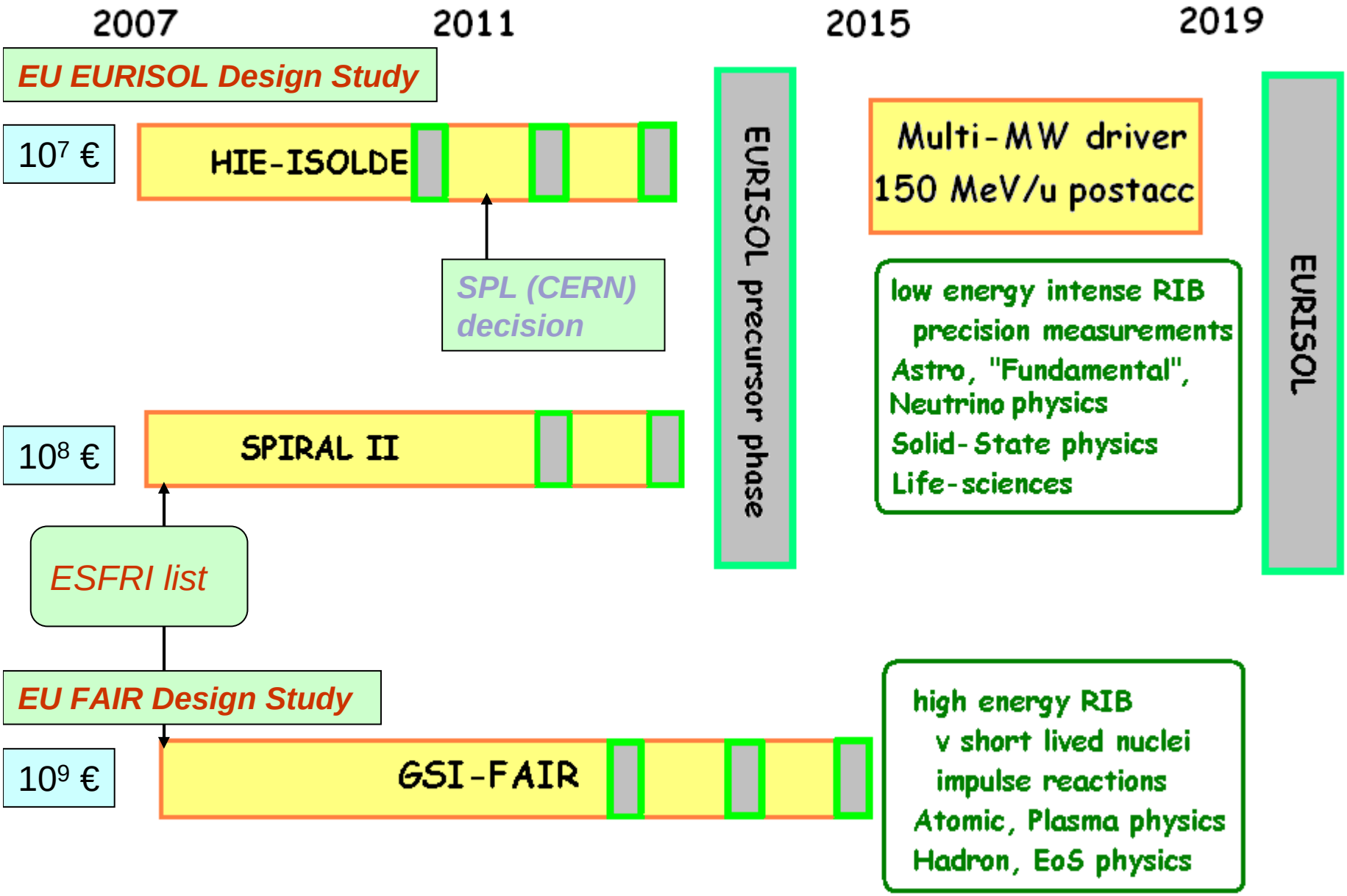
5 MW spallation n target

→ 100 MeV/u RIB



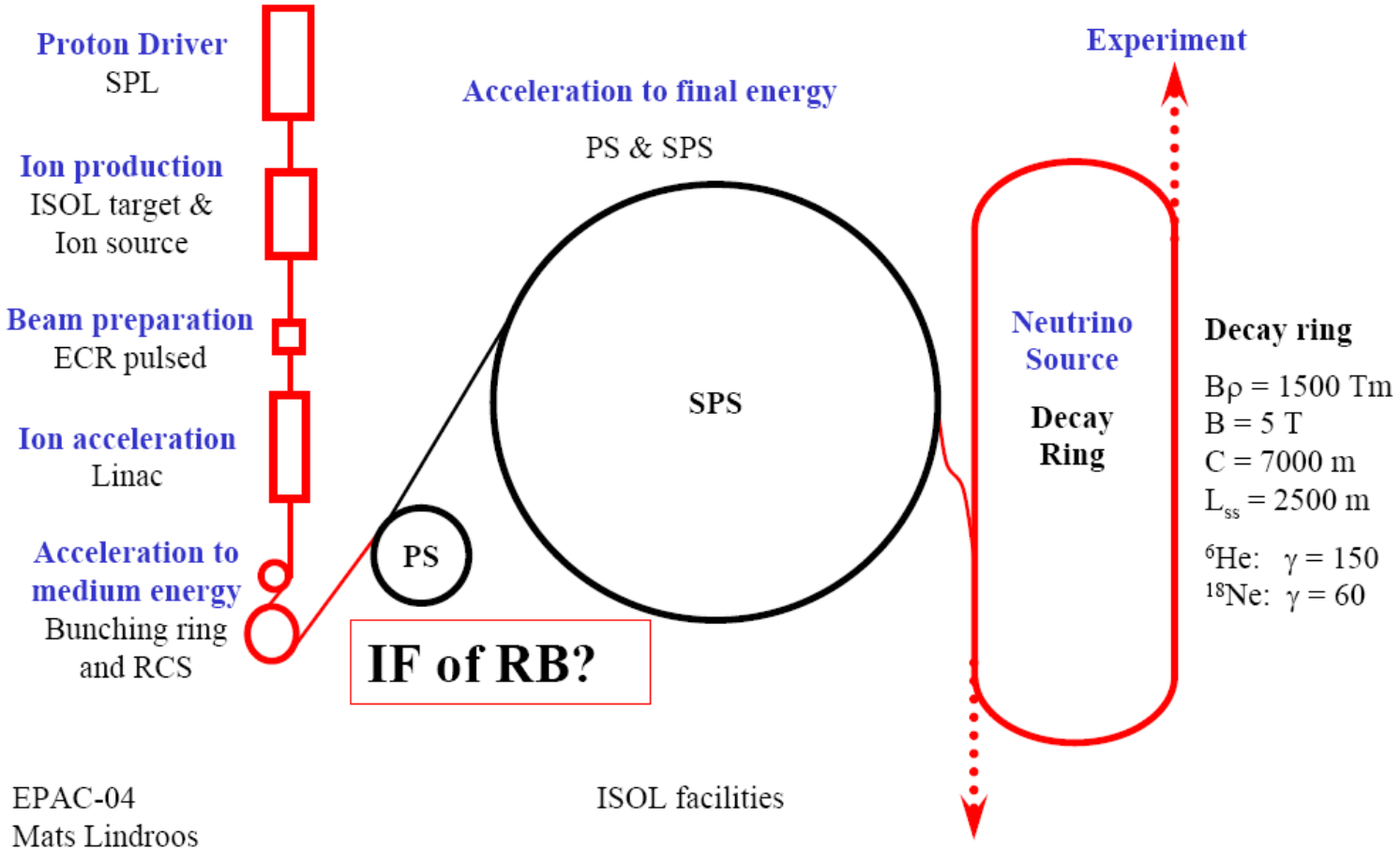

SPIRAL 1
REX-ISOLDE
SPIRAL 2
FAIR
EURISOL
RIA
Intensity (pps)
10^{12}
10^{10}
10^{8}
10^{6}
10^{4}
10^{2}
Kr isotopes
70
75
80
85
90
95
100
A

European Roadmap for RIB facilities



The beta-beam, see Poster MOPLT007

AIM: provide beams of electron (anti) neutrinos by decay of beta active ions.



World machines

Location	Driver	Post-accelerator	Fragment separator	Type of facility
GSI –FAIR	synchrotron, heavy ions: 1.5 A GeV	-	'Super-FRS'	In-Flight
EURISOL	protons, 1 GeV, 1-5 MW	CW Linac, up to 100 A MeV	-	ISOL
USA: RIA Rare Isotope Accelerator	900 MeV protons heavy ions: 400 A MeV, 100 kW	Linac up to 8–15 A MeV	4-dipole Separator	ISOL, In-Flight
JAPAN: RIKEN RIB Factory	Ring-cyclotrons up to 400 AMeV (light ions) up to 150 A MeV (heavy ions)	-	3 fragment Separators storage & cooler rings	In-Flight