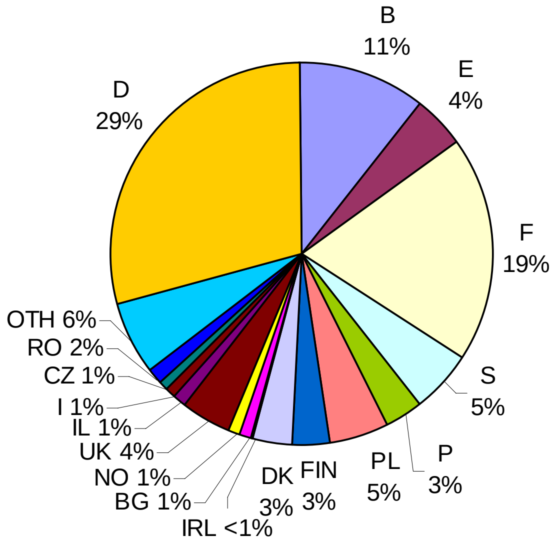
The future of ISOLDE:
accelerated radioactive beams

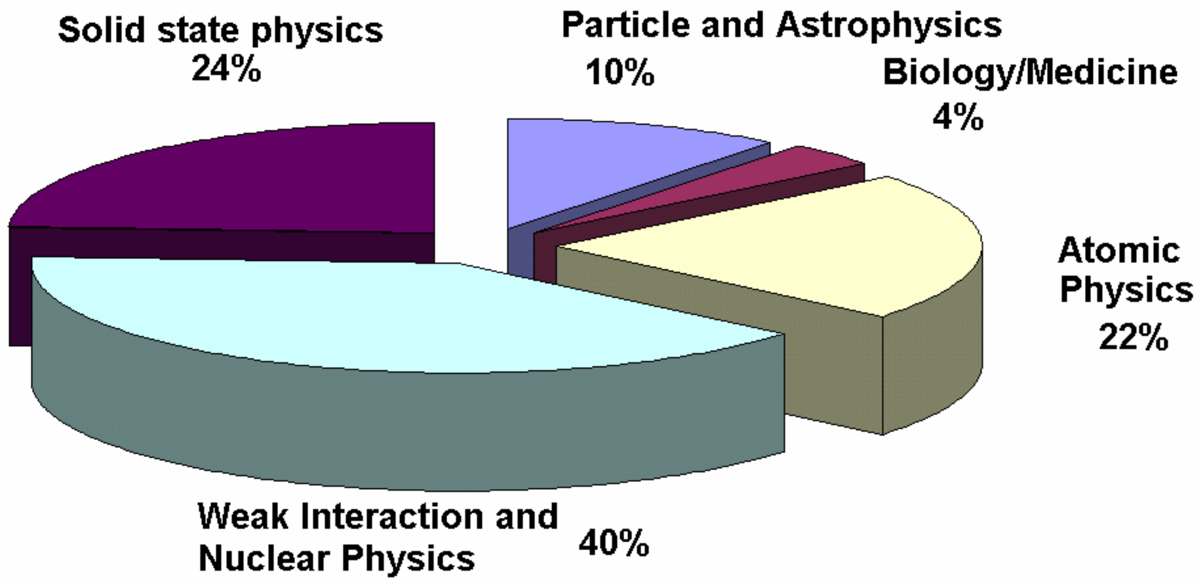
Peter Butler

1. HIE-ISOLDE
2. EURISOL

CERN NuPAC meeting 10-12 Dec 2005

Users & Science





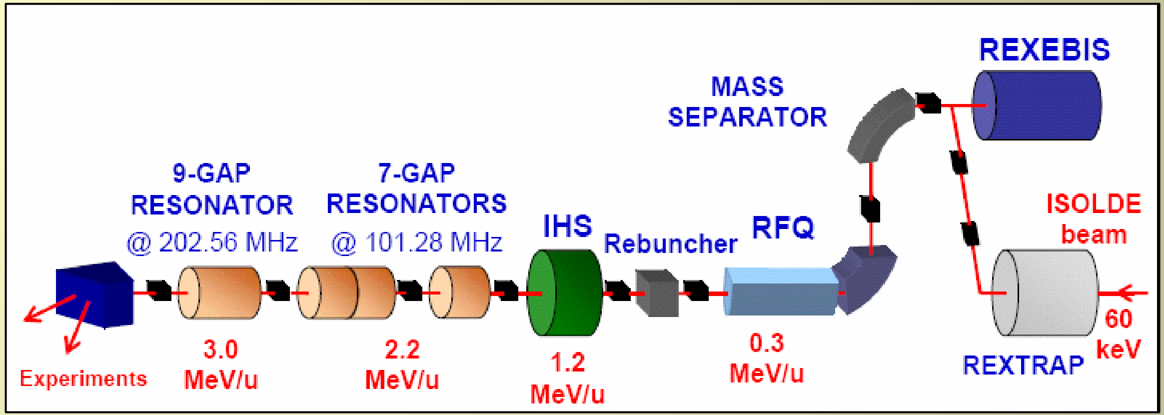
450 users (7% total CERN)

potentially 1000 users with upgrade

25 countries; 100 institutions

175 projects (4 years)

REX post-accelerator



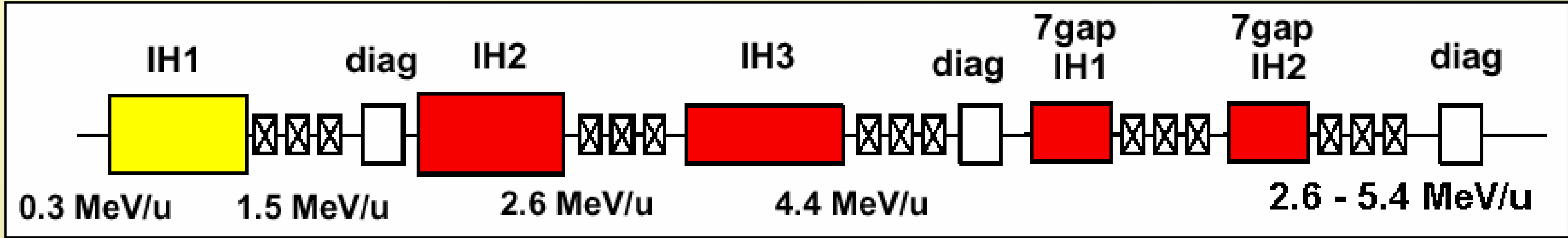
- Originally constructed by several CERN member states ~ 15 MCHF
- Utilises now → 50% ISOLDE running time
- In last three years REX has accelerated 33 different RIB
- Present RIB yield from ISOLDE allows 10% of all radioisotopes be used

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}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
ISAC1 TRIUMF (CANADA) 2000	500 MeV protons	50 kW	^{8,9,11}Li, ^{20,21}Na, ^{26}Al	1.5 MeV/u linac	Astrophysics
SPIRAL, GANIL (FRANCE) 2001	100 MeV/u heavy ions	6 kW	^{6,8}He, ^{18}F, ^{18,24,25,26}Ne, ^{44,46}Ar, ^{74,75,76,77}Kr	2 - 25 MeV/u cyclotron	Nuclear structure, Astrophysics
REX ISOLDE (CERN) 2001	1.4 GeV protons	3 kW	^{9}Li, ^{11}Be,$^{24-29}$Na, ^{28,30,32}Mg, ^{68}Ni, ^{68,69,70}Cu, ^{74,76,78}Zn, ^{70}Se, ^{88,92}Kr, ^{108}In, ^{108,110}Sn, ^{122,124,126}Cd, ^{138,140,142}Xe, ^{148}Pm, ^{153}Sm, ^{156}Eu	0.3 - 3 MeV/u linac	Nuclear structure, Condensed matter, Astrophysics

HIE-ISOLDE

Increase in REX energy from 3 to 10 MeV/u
(first step in increase to 5.4 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

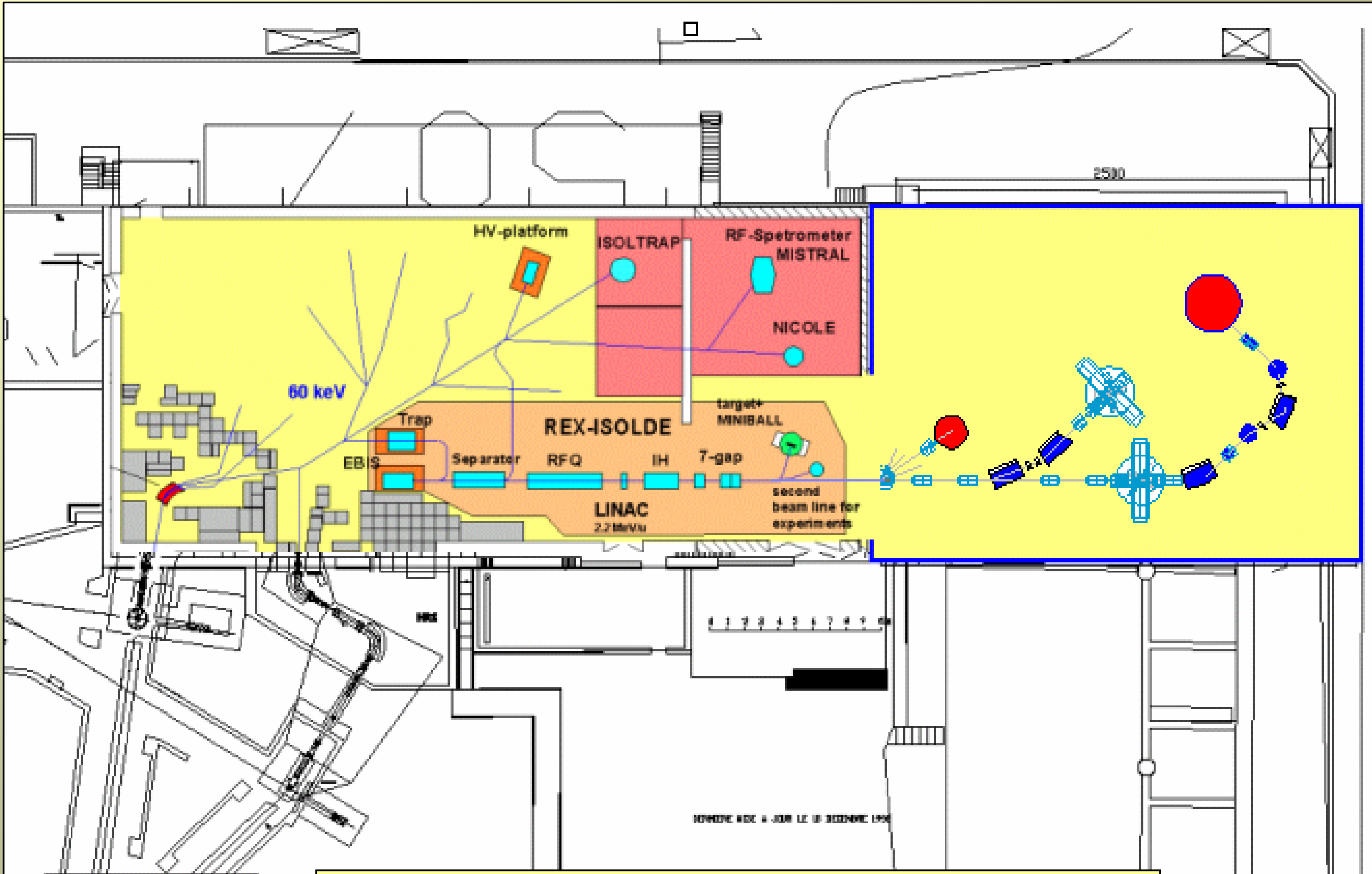
Super-HRS for isobaric separation
RILIS upgrade & LIST

Low energy facility (< 1 MeV/u)

Collinear Laser Spectroscopy, ISOLTRAP nuclear mass

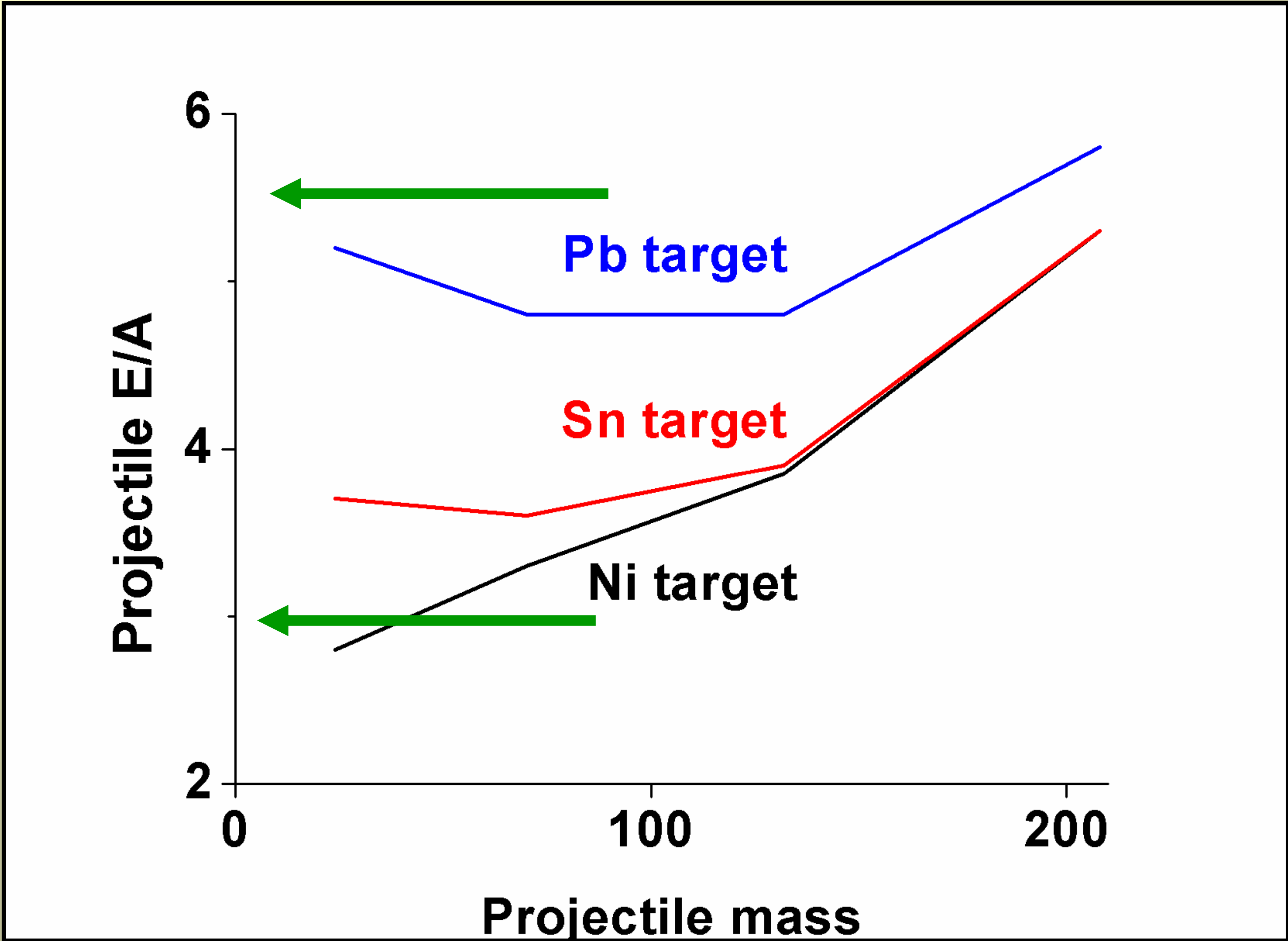
Condensed matter, Nuclear Astrophysics

Spectrometer plans

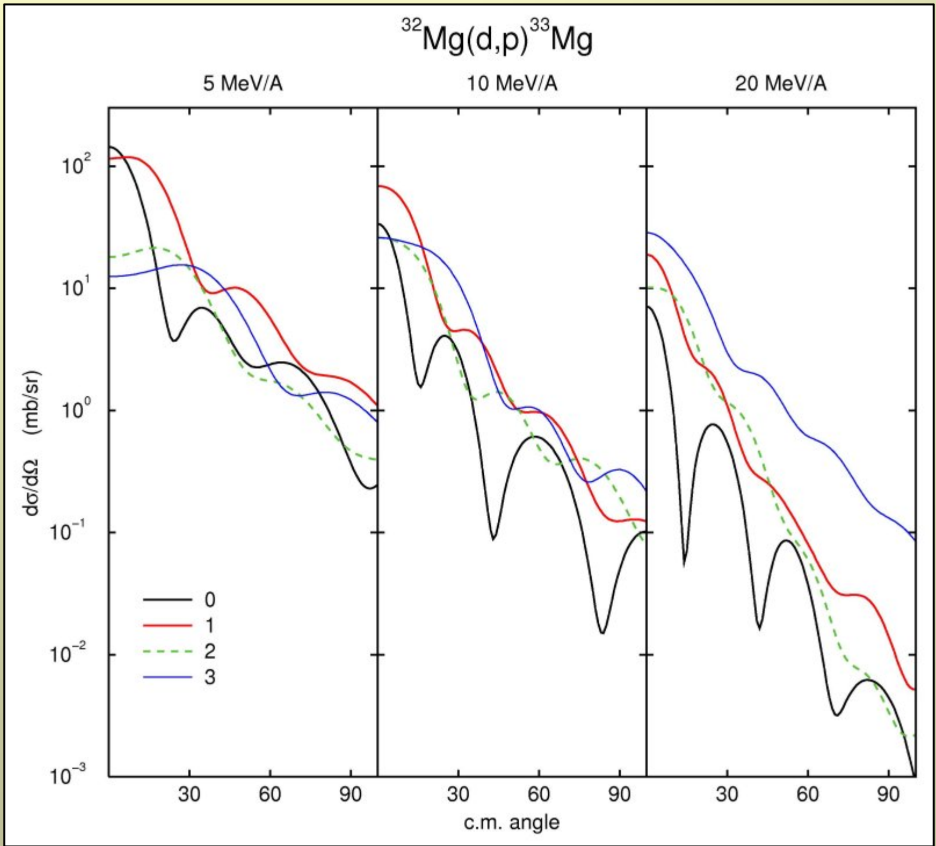


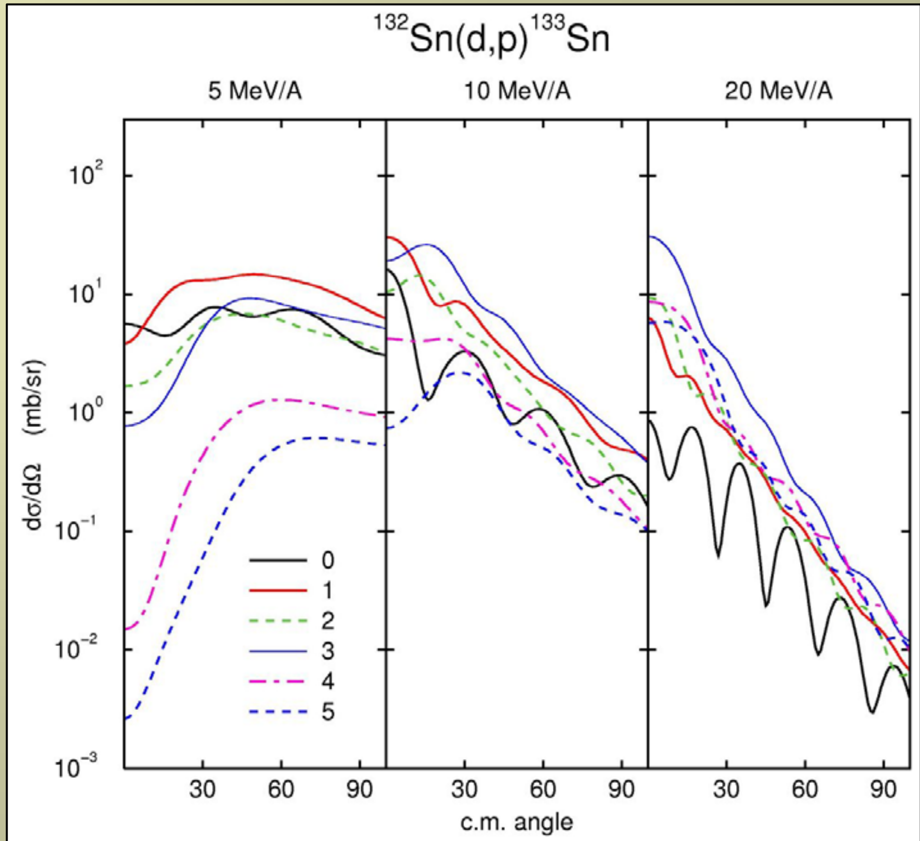
ISOLDE PH-IS and INTAG JRA

Coulomb barrier for RIB



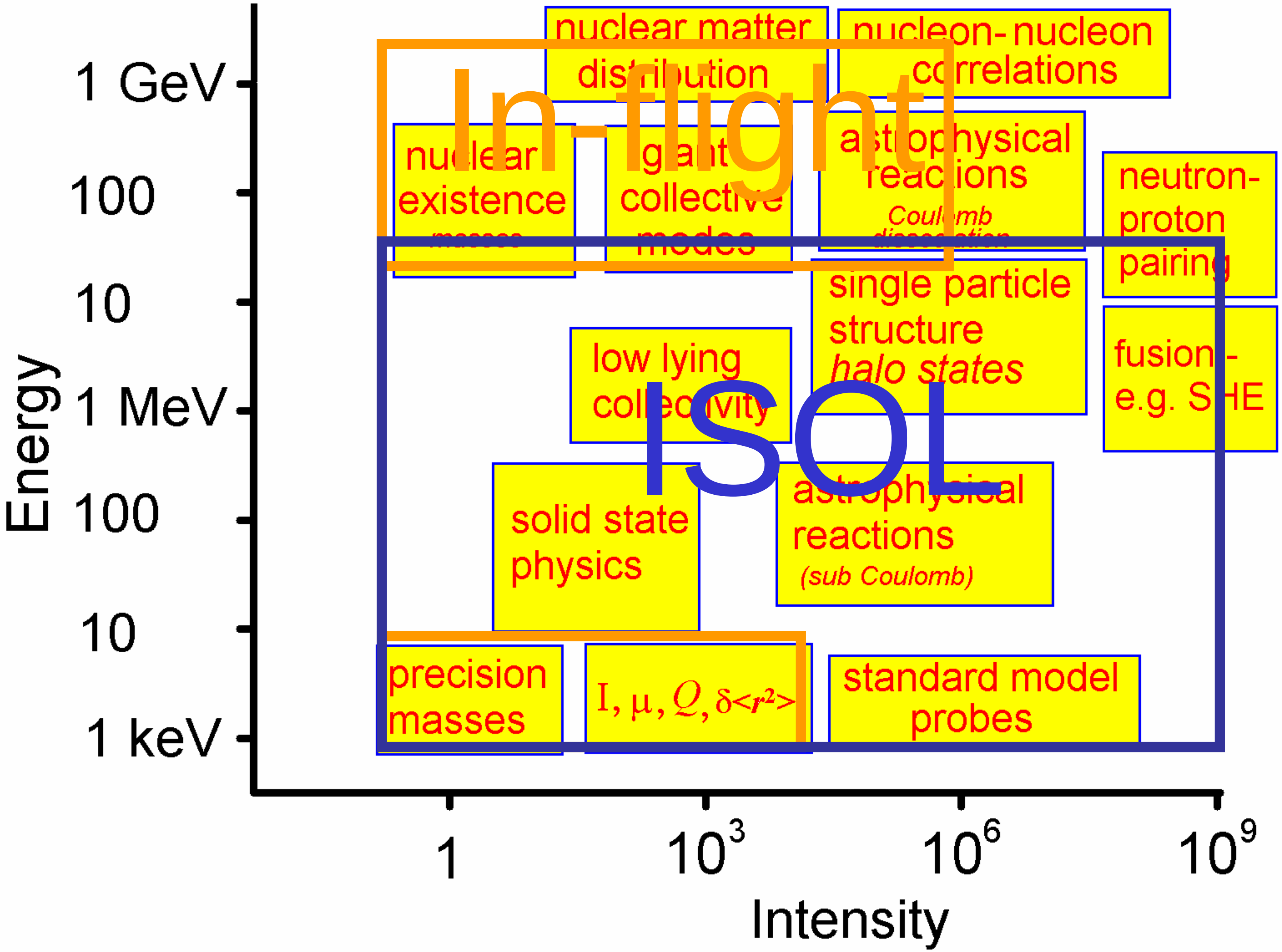
Transfer reactions at high energy





W.N. CATFORD (SURREY)

RIB Physics Reach



Time-line and costs

REX energy upgrade to 5.4 MeV/u		2008
High intensity upgrade		2010
REX energy upgrade to 10 MeV/u		2011
Material costs		15.3 MCHF
Staff		42.5 FTE
Identified sources extra-CERN:		*4.1 MCHF*
ISOLDE collaboration	✓	
IKS Leuven BE	✓	
EPSRC UK	✓	
ISTC, EU, RU		
VR SE		

Operational costs

Existing REX operation 650 kCHF per year
(2 engineers, 3 technicians + materials)
Must be transferred to CERN May 2006

HIE-ISOLDE, *additional personnel*:

operation	3 FTE
target/front-end	2 FTE
DAQ	1 FTE
Secretariat	0.5 FTE

EU projects (2005-2009)

EURONS I^3: (2.1 MCHF)

TNA

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

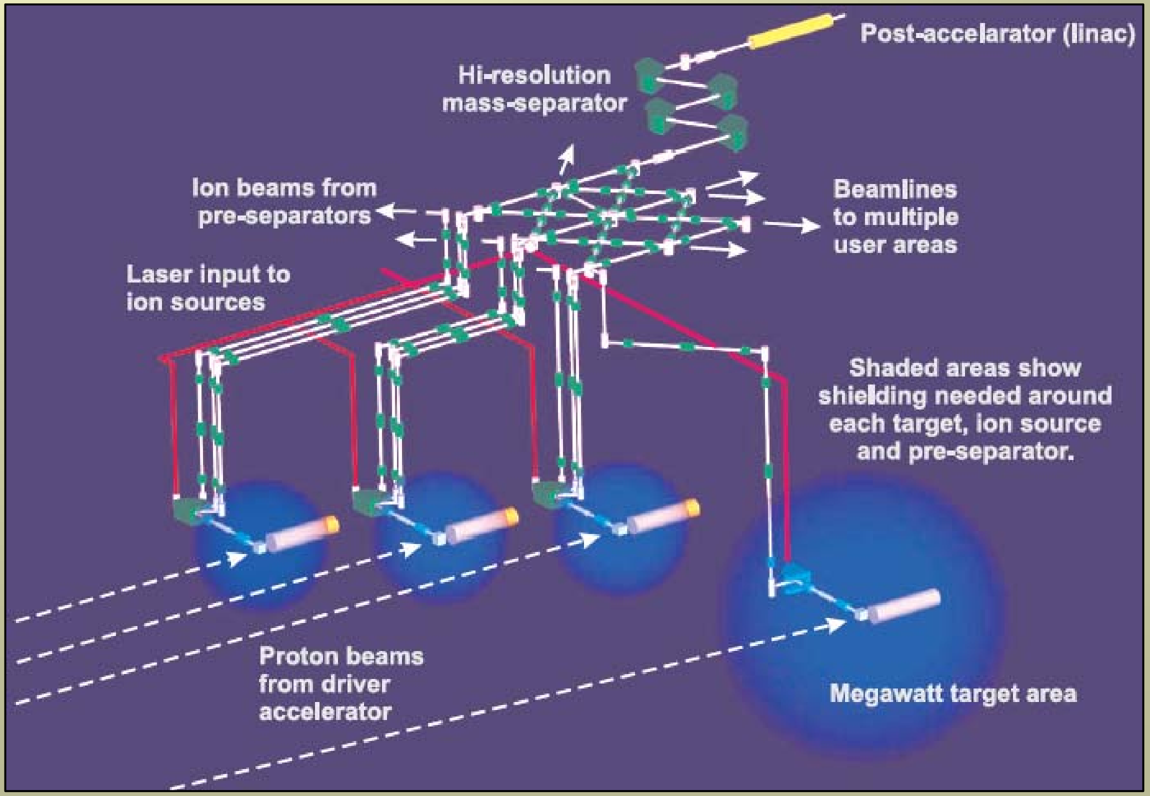
EURISOL DS: (2.8 MCHF)

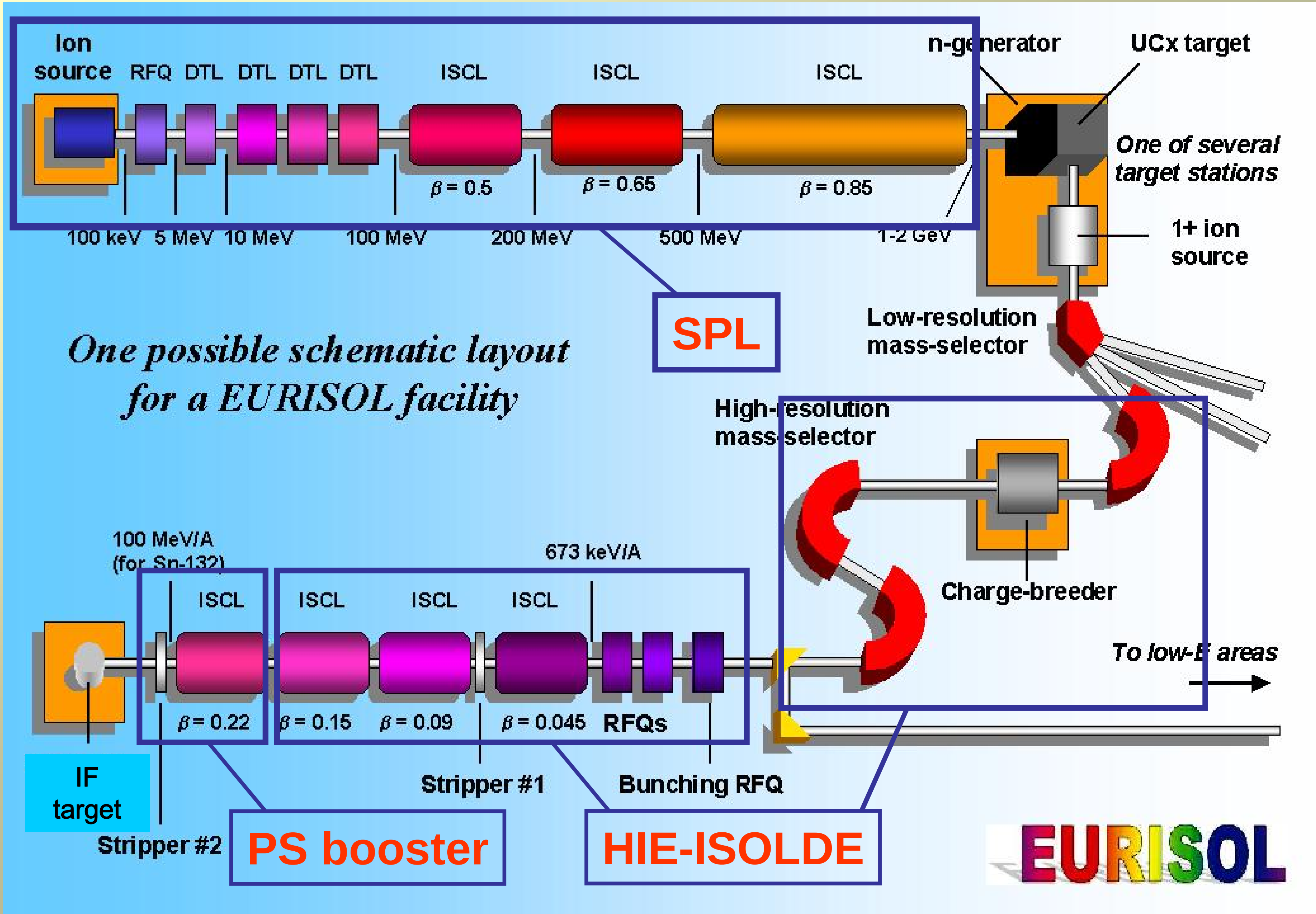
R&D in targets & β-beam

radioisotope manipulation

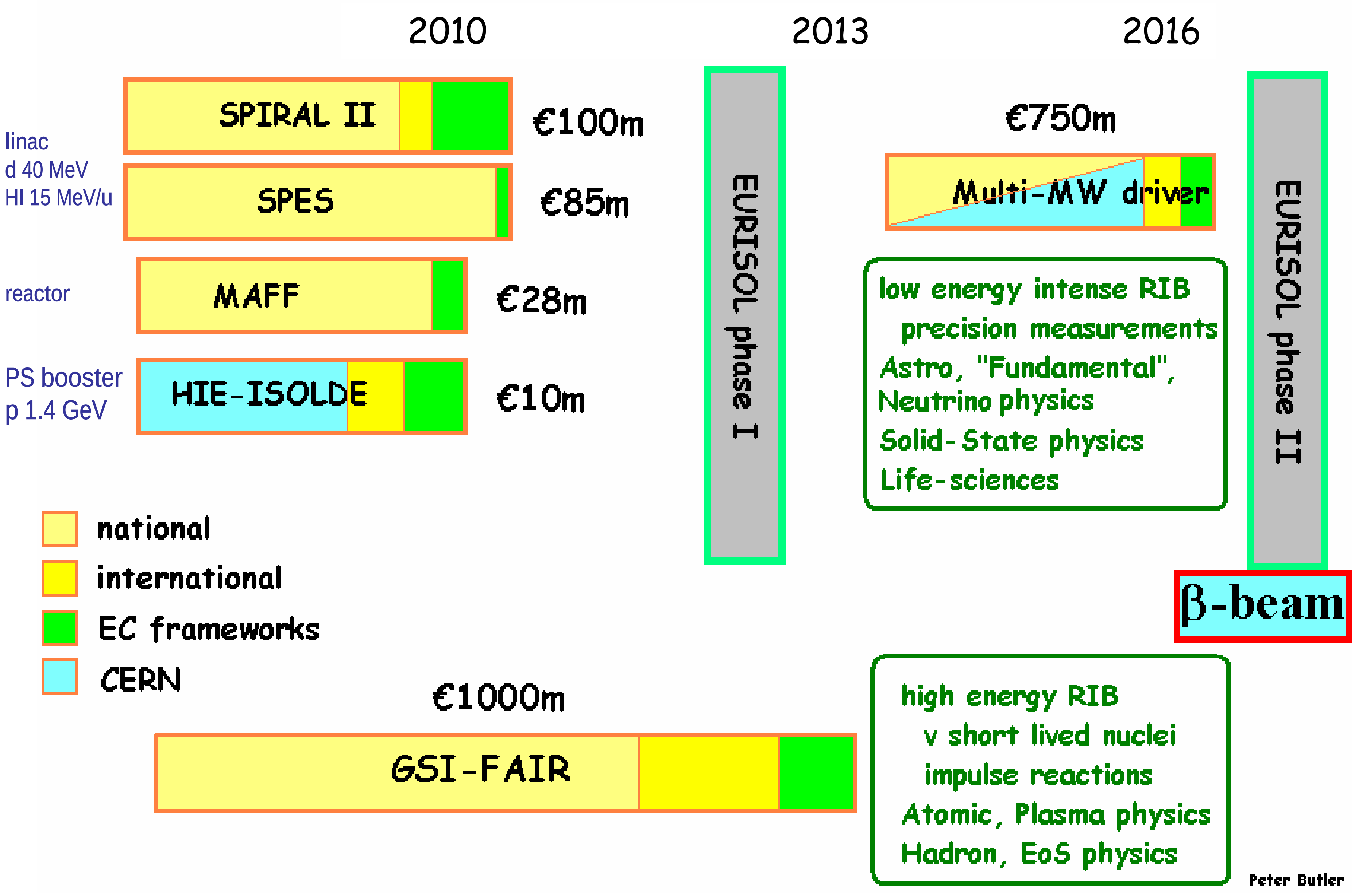
safety

100kW direct production
5 MW spallation n target
→ 100 MeV/u RIB




Ion source
RFQ
DTL
DTL
DTL
DTL
ISCL
ISCL
ISCL
n-generator
UCx target
β = 0.5
β = 0.65
β = 0.85
One of several target stations
100 keV
5 MeV
10 MeV
100 MeV
200 MeV
500 MeV
1-2 GeV
1+ ion source
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
β = 0.22
β = 0.15
β = 0.09
β = 0.045
RFQs
To low-E areas
IF target
Stripper #2
Stripper #1
Bunching RFQ
PS booster
HIE-ISOLDE
EURISOL

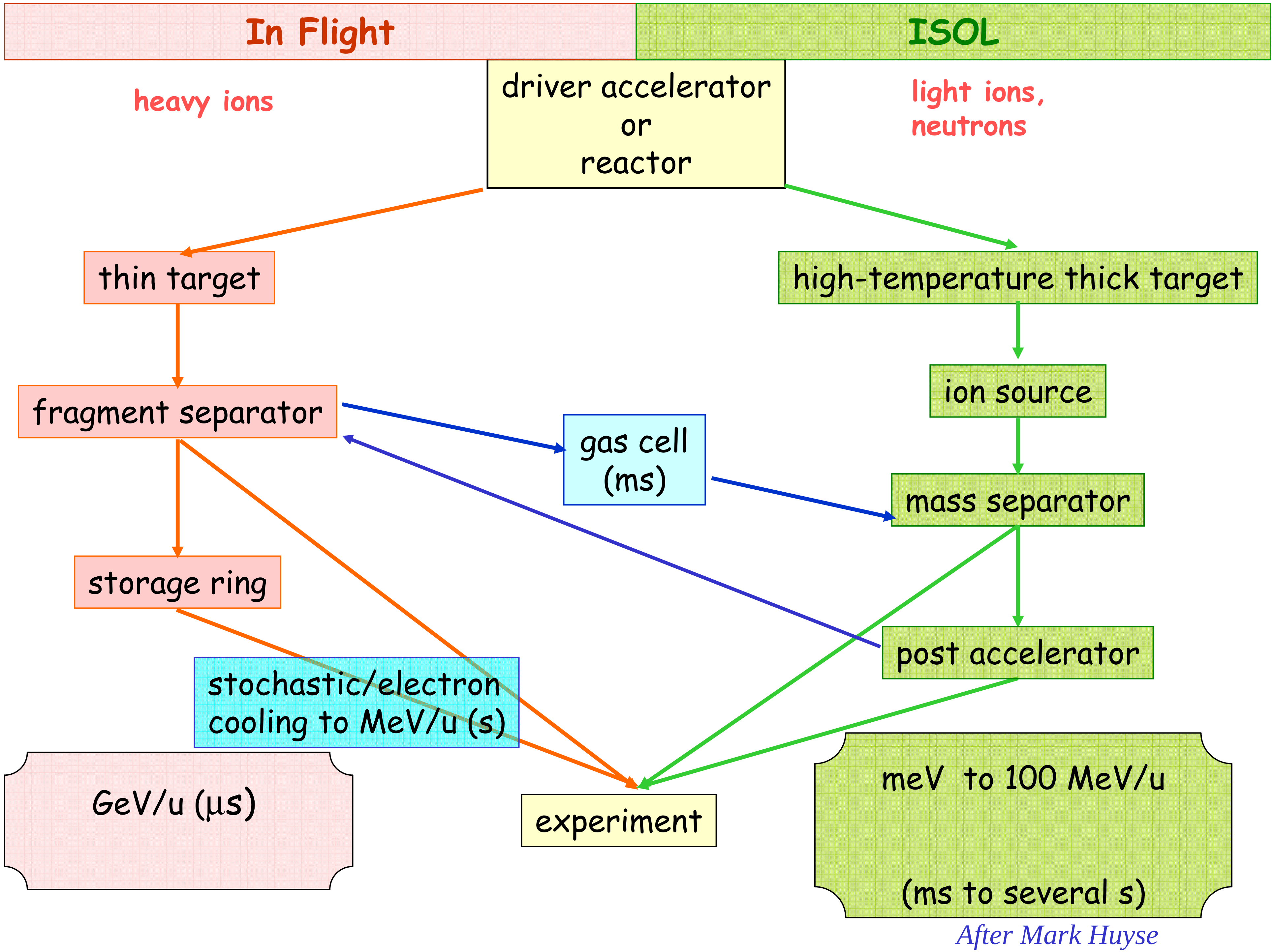
European Roadmap for RIB facilities



FINIS

Europe 2nd Generation ISOL

FACILITY	DRIVER	POWER	ENERGY
HIE- ISOLDE CERN	PS booster p, 1.4 GeV, 10 µA	10 KW	0.8 - 10 MeV/u linac
SPIRAL-II GANIL	linac deuterons 40 MeV heavy ions 15 MeV/u	200 kW (secondary target)	2 – 25 MeV/u cyclotron
MAFF Munich	reactor	10^{14} n/cm^2.sec	7 MeV/u linac
SPES Legnaro	linac p,d, … 100MeV	200 kW (secondary target)	10 MeV/u linac


In Flight
ISOL
heavy ions
driver accelerator
or
reactor
light ions,
neutrons
thin target
high-temperature thick target
ion source
fragment separator
gas cell
(ms)
mass separator
storage ring
post accelerator
stochastic/electron
cooling to MeV/u (s)
GeV/u (µs)
experiment
meV to 100 MeV/u
(ms to several s)
After Mark Huyse

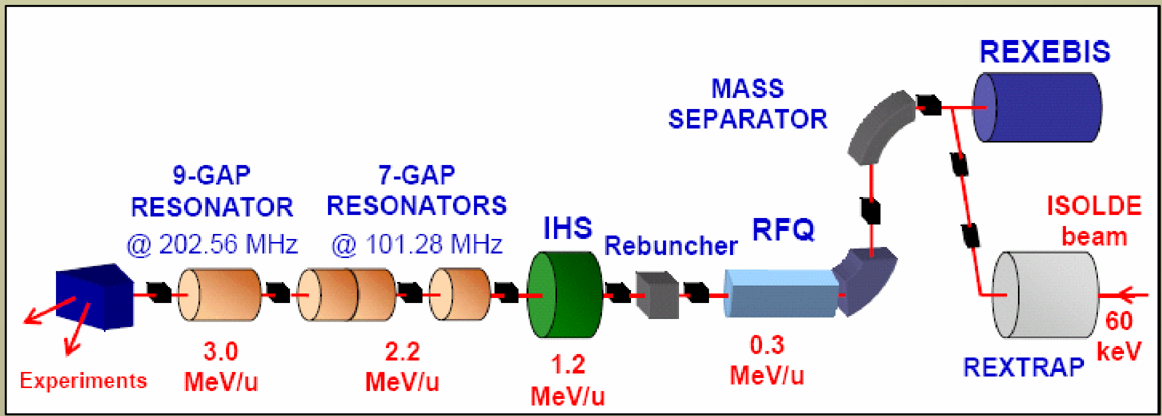
Unique Experimental Facility

Repertoire: 850 radionuclides from 70 elements

Availability: 350 shifts of radioactive beam /year
(2 primary targets & mass separators)

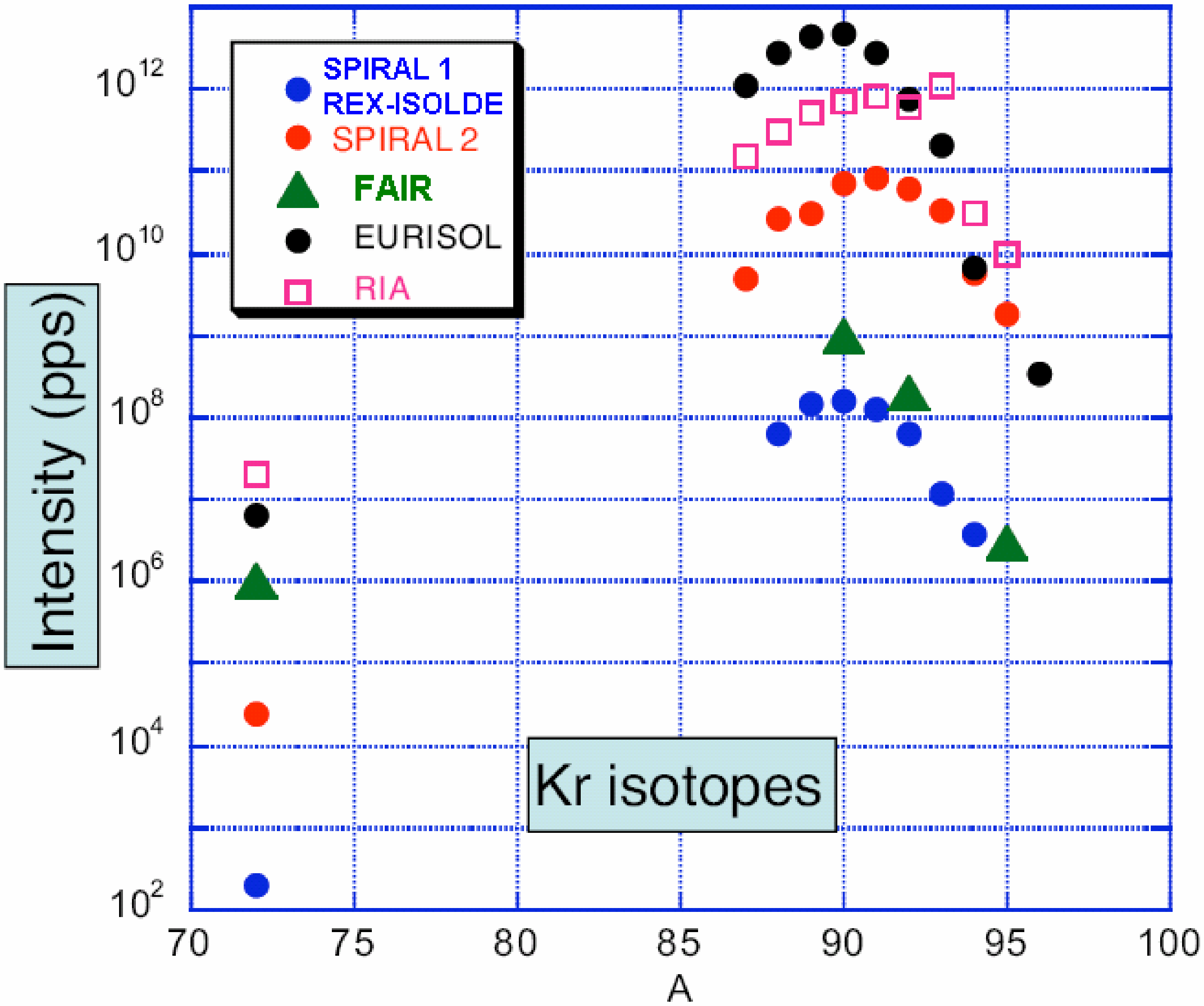
Selectivity: target/ion source expertise, RILIS,
mass separation

Postacceleration: **REX** TRAP+EBIS+LINAC

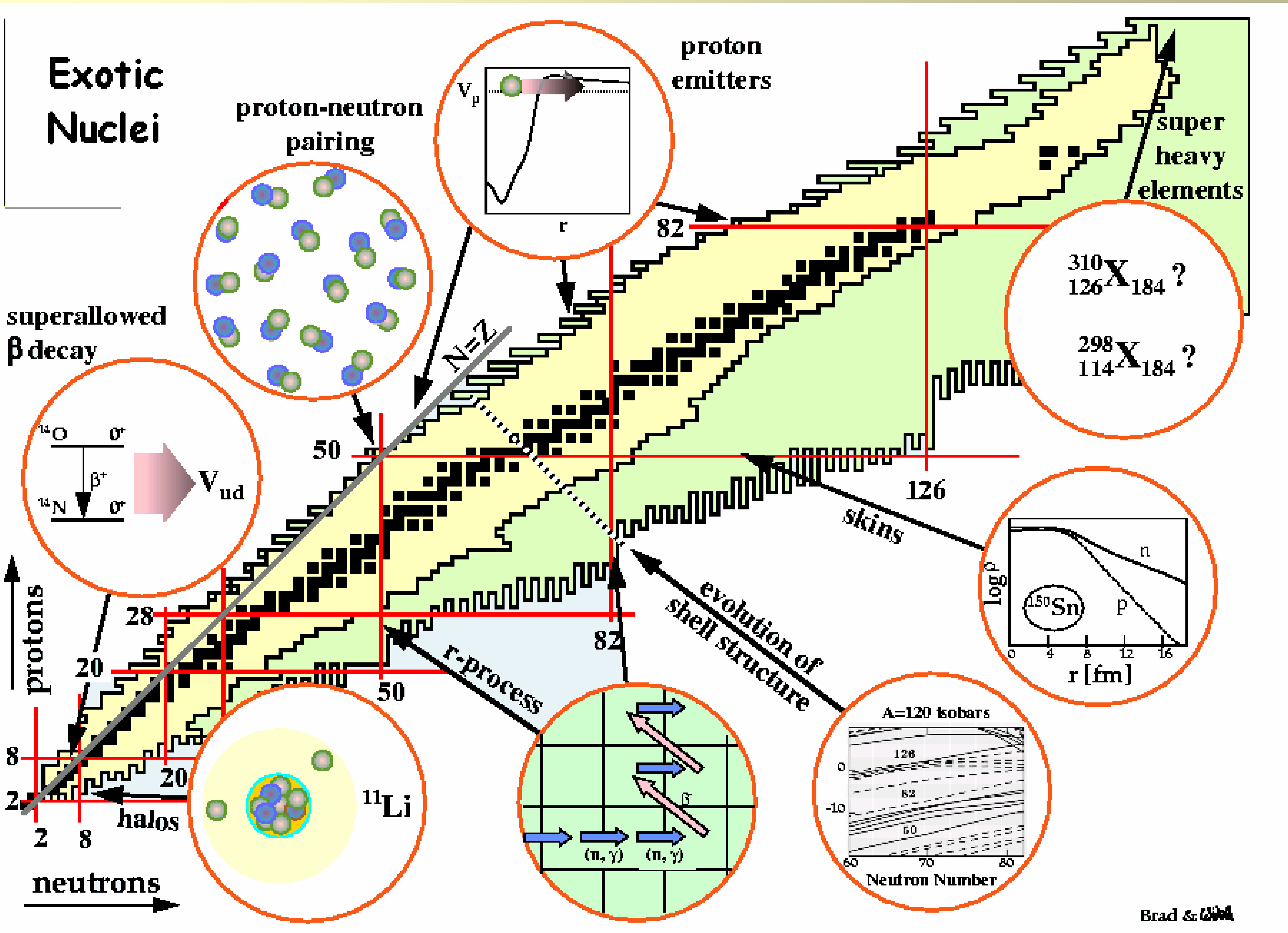


World machines

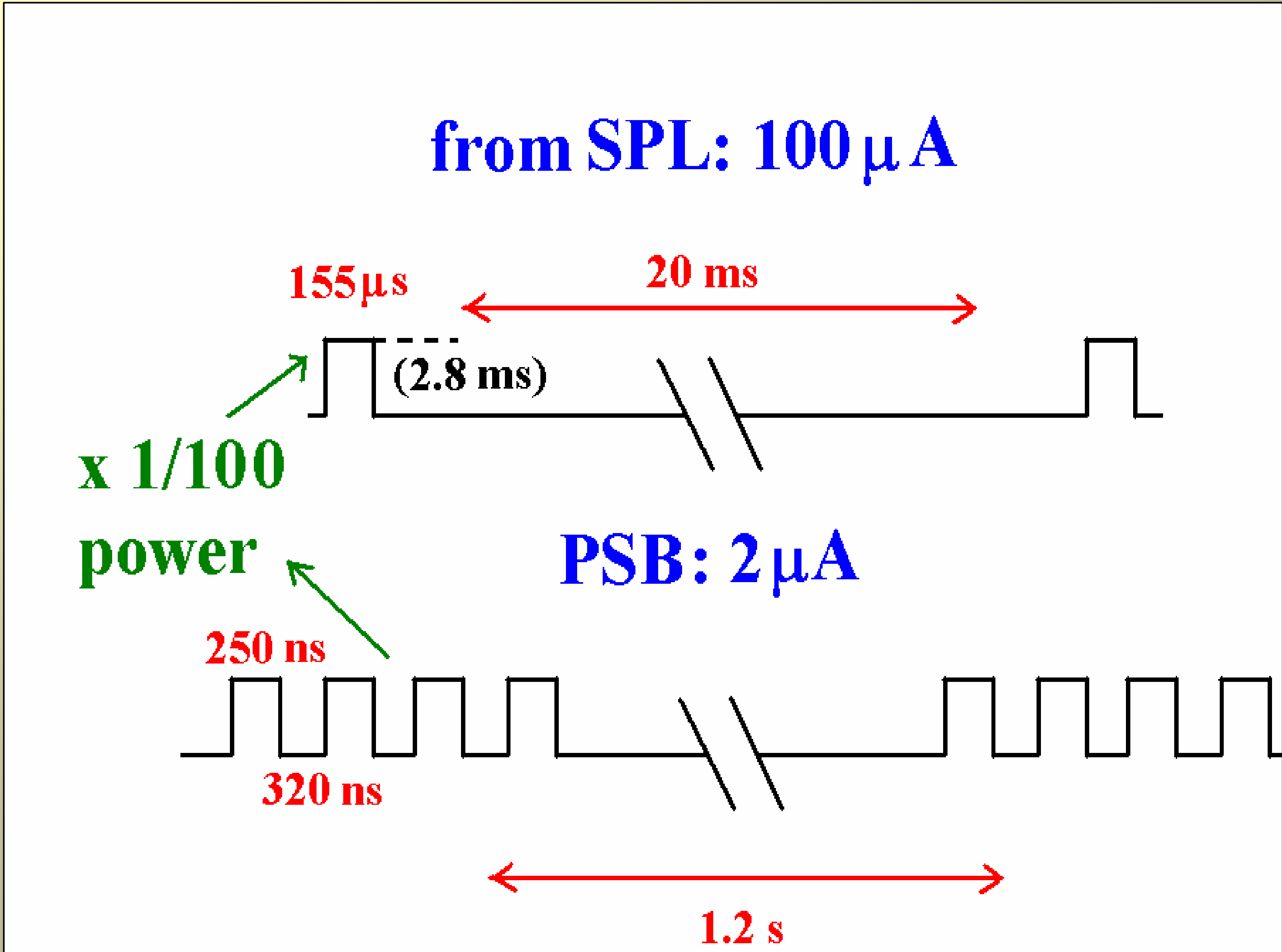
Location	Driver	Post-accelerator	Fragment separator	Type of facility
GSI –FAIR	synchrotron, heavy ions: 1.5 A GeV	-	'Super-FRS'	In-Flight
EURISOL	protons, 1 GeV, 1-5 MW	CW Linac, up to 100 A MeV	-	ISOL
USA: RIA Rare Isotope Accelerator	900 MeV protons heavy ions: 400 A MeV, 100 kW	Linac up to 8–15 A 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



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


Exotic Nuclei
proton-neutron pairing
proton emitters
super heavy elements
superallowed β decay
N=Z
82
50
28
20
8
2
126
skins
evolution of shell structure
r-process
halos
protons
neutrons
^{11}Li
V_{ud}
$^{310}_{126}X_{184}$?
$^{298}_{114}X_{184}$?
log ρ
^{150}Sn
r [fm]
A=120 isobars
Neutron Number
(n, γ)
Brad &

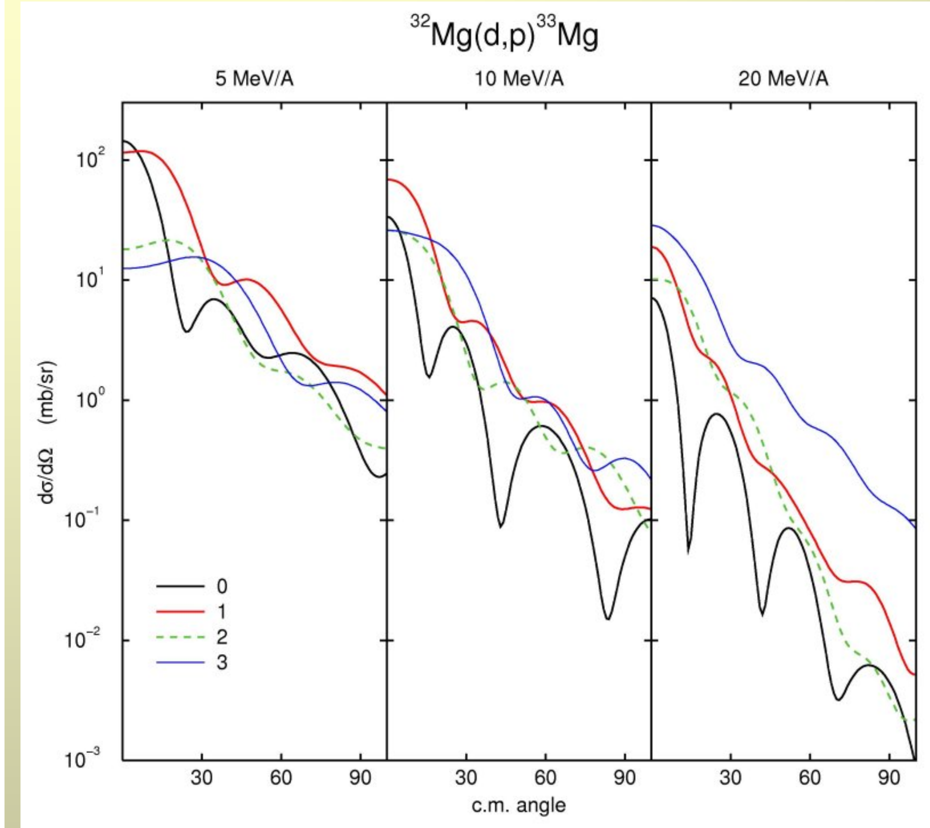
SPL versus PS Booster

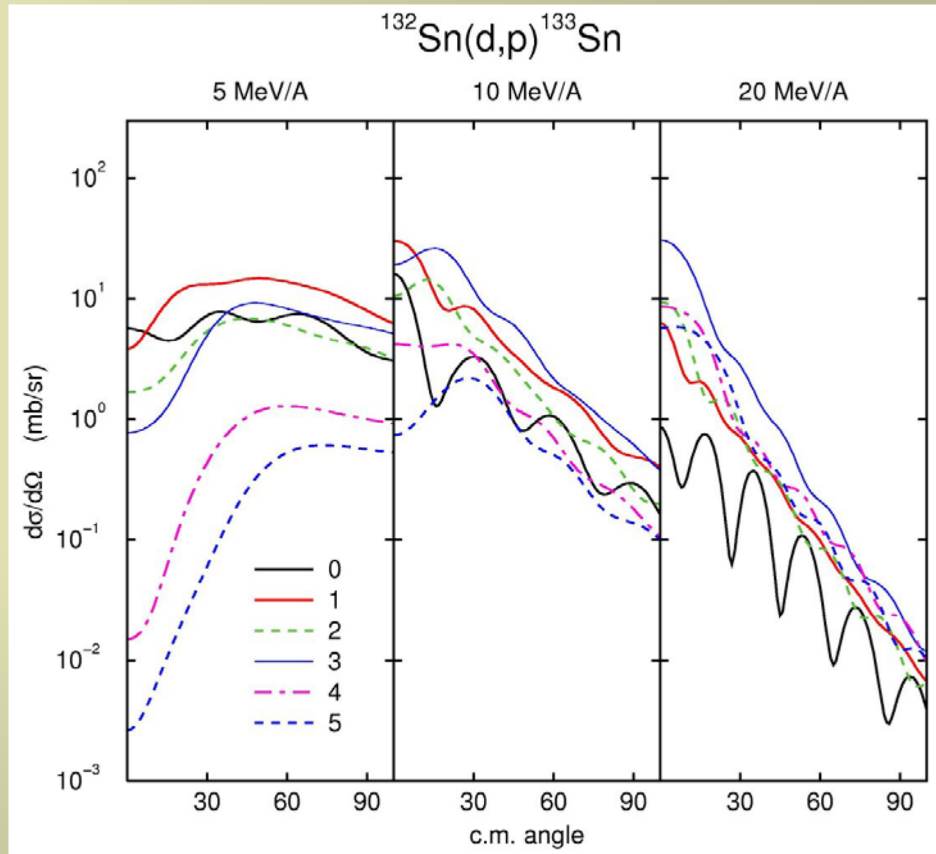


Costs

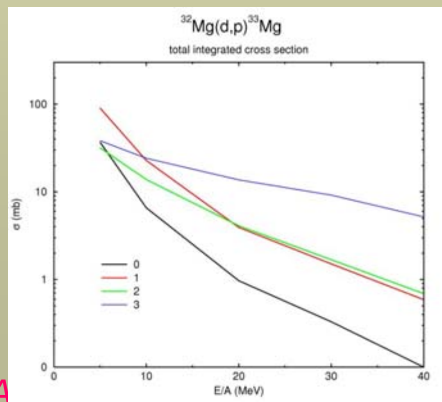
Task No	Task name	Cost	
		Material (kCHF)	*Staff (FTE)*
1	REX upgrade 5.5 MeV/u	2950	8.6
2	REX upgrade 10 MeV/u	3000	7.8
3	REX TRAP and EBIS upgrades	255	0.5
4	REX ECR chargebreeder	750	1.9
5	RFQ cooler	275	0.9
6	High charge state beam line	400	0.9
7	New HRS	1000	1.6
8	Targetry for linac 4 proton beam	3130	9.5
9	RILIS upgrade	880	1.2
10	Ti:Saphire lasers	400	0.6
11	TS infrastructure improvements	700	1.5
12	AT/VAC consolidations	1550	1.5
13	ISOLDE physics group		6
	Total:	15290	42.5

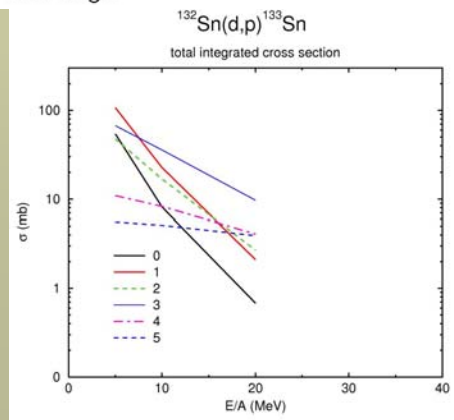
How does the differential cross section vary with beam energy ?





and the total cross section ?





TIARA

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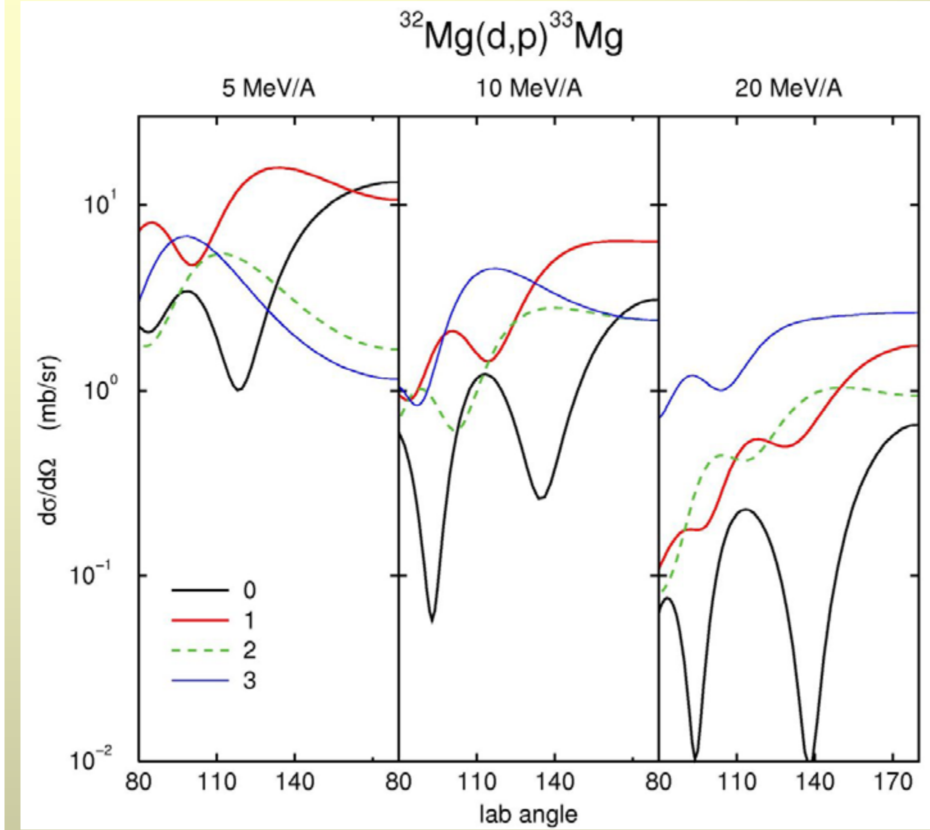

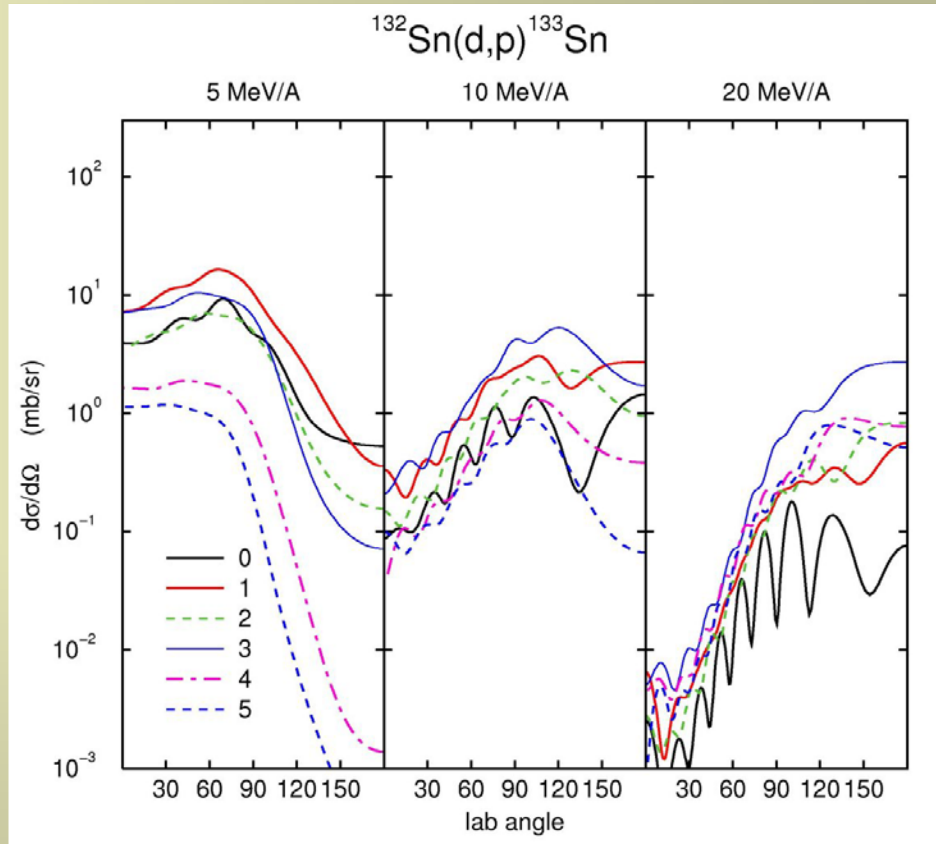

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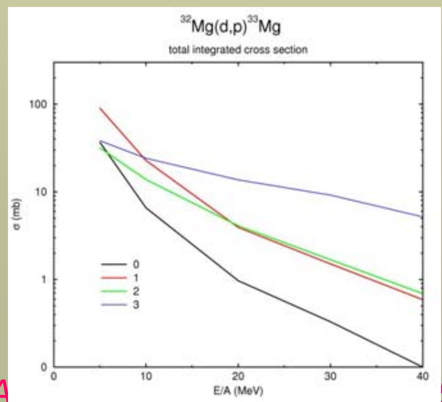

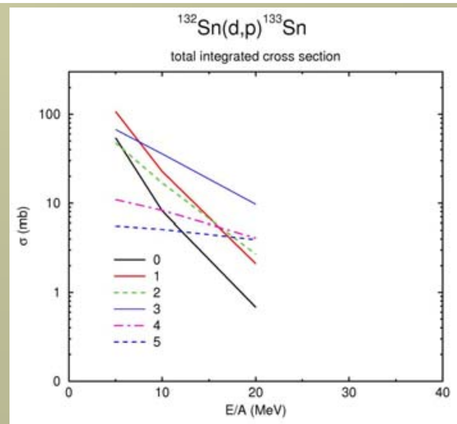

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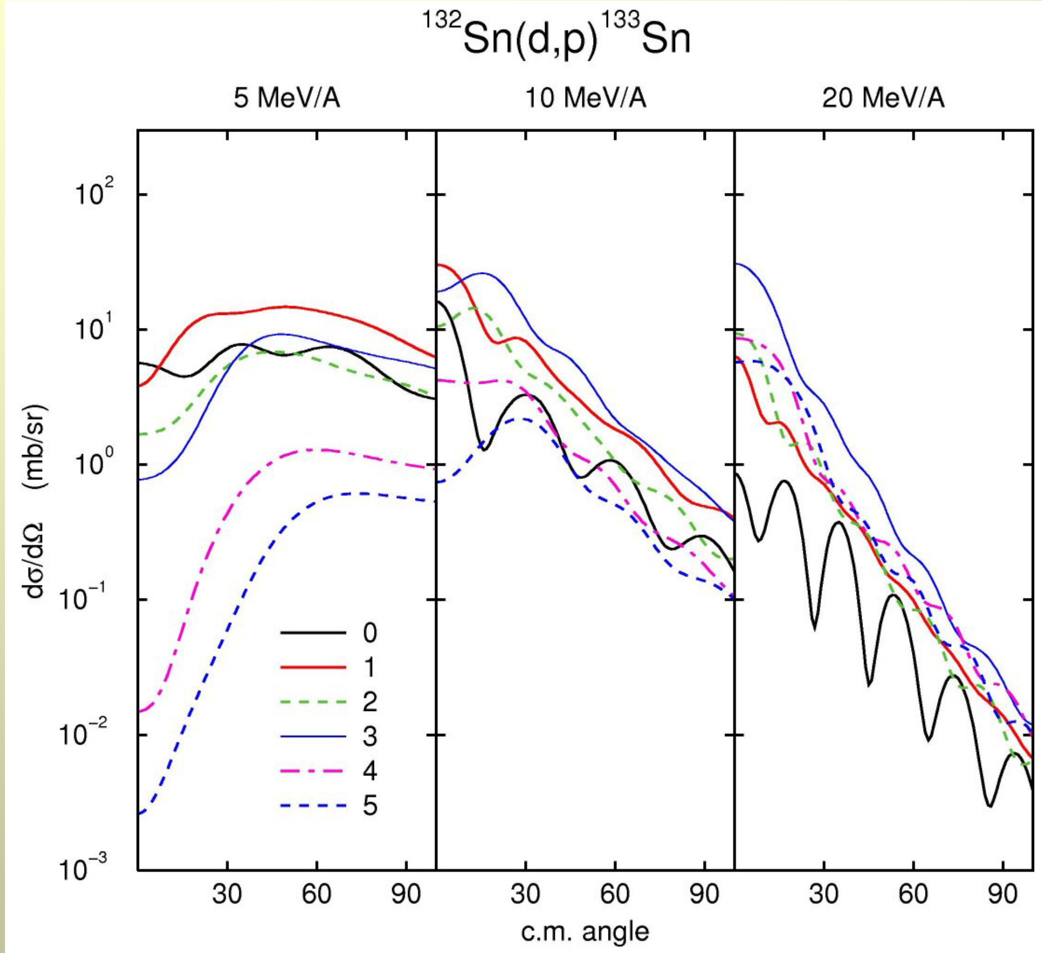

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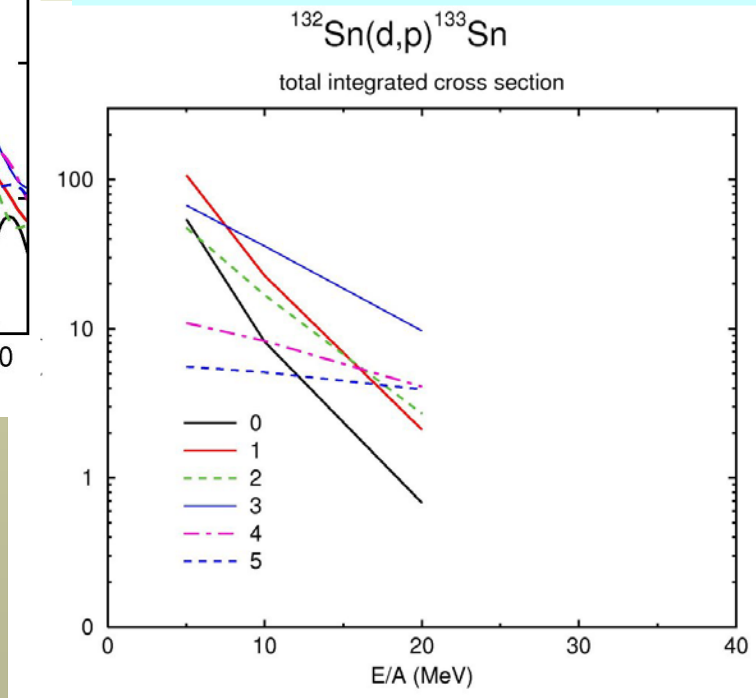

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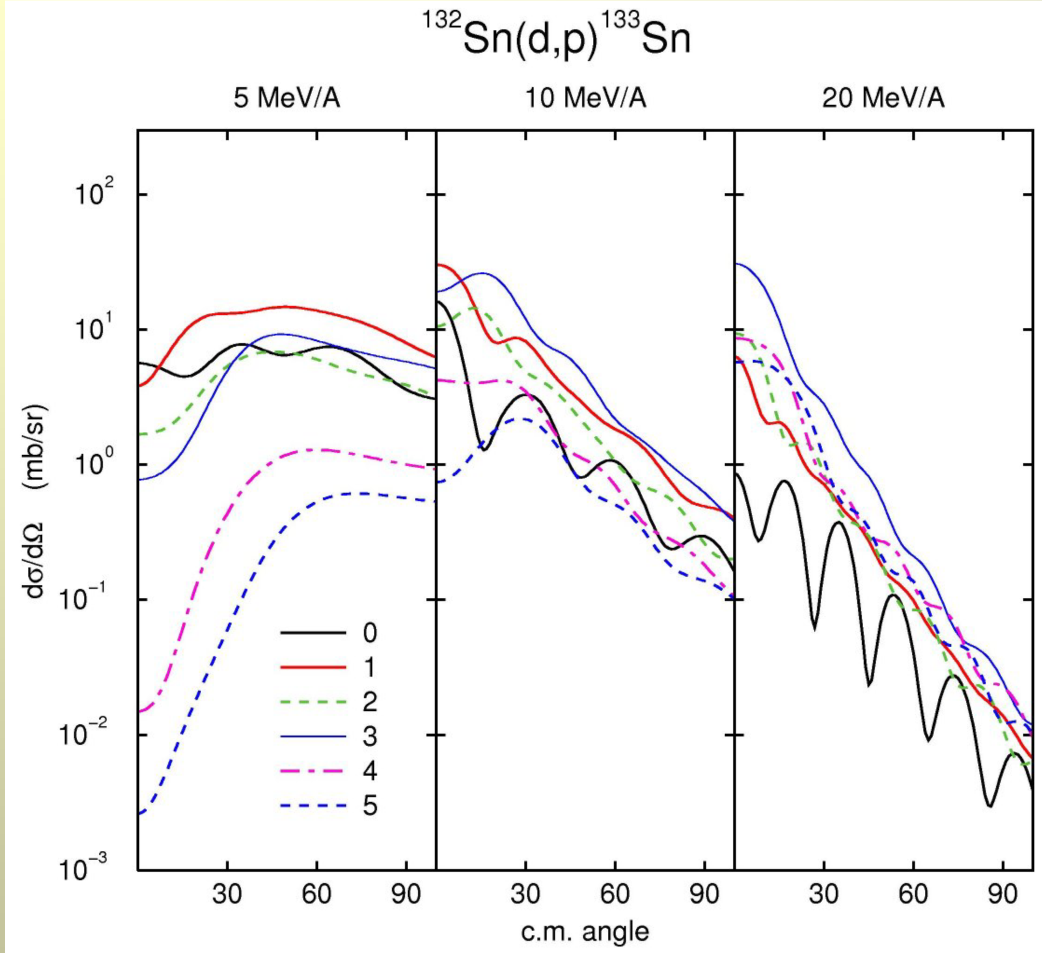

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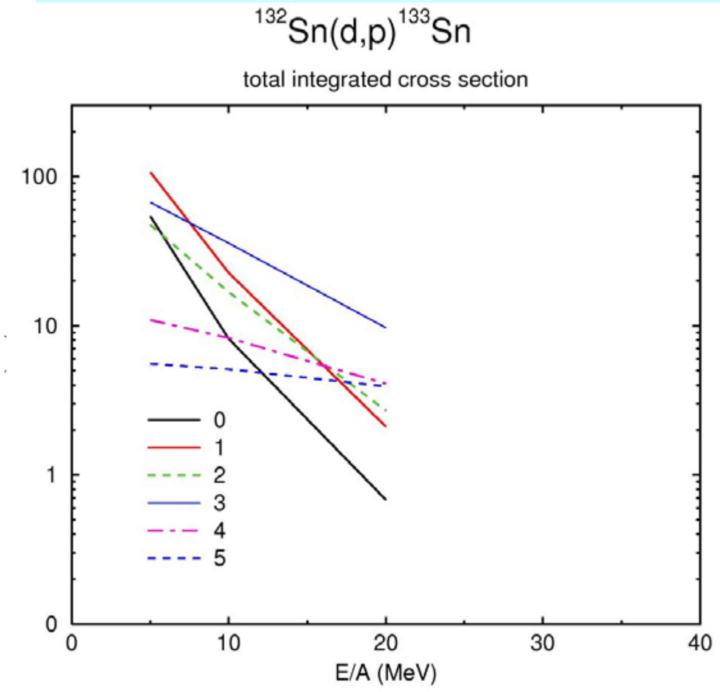

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