Towards an Active Target at SPES

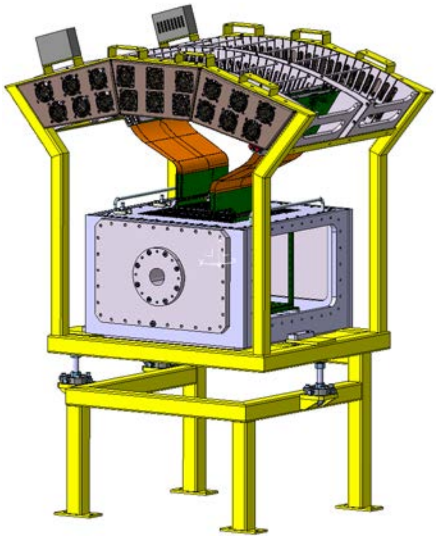
T. Marchi

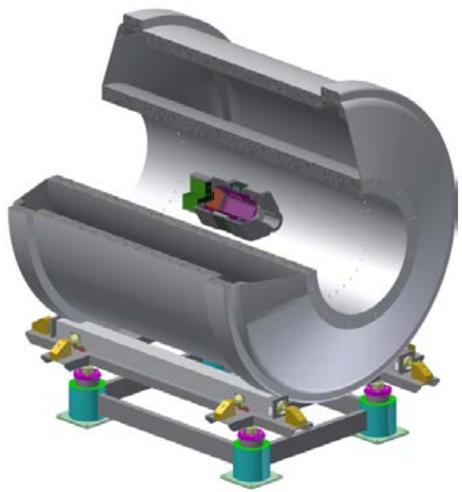
Second GDS Topical Meeting
17 Jan 2018
Santiago de Compostela, Spain

Pan-European activities, ongoing

ACTAR TPC

SpecMAT





Outline

The ATS project and the ACTAR demonstrator

LNS proposal: heavy beams

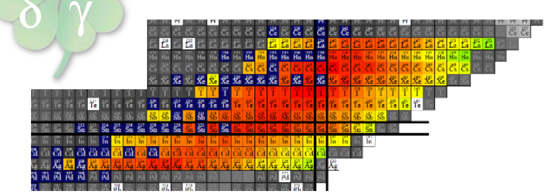
The SPES facility

Extra: GET/GES + GPUs (?)

ATS

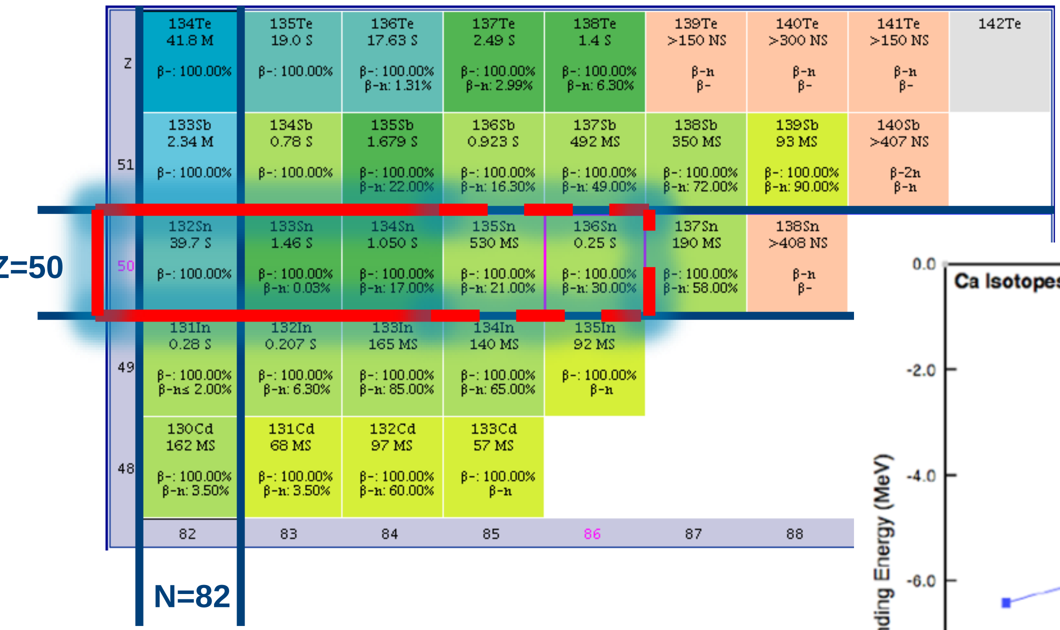
MARIE CURIE ACTIONS

MagicTin*



$f_{7/2}$ vs $p_{3/2}$ neutron orbitals, in Sn like in Ca?

MagicTin*



Expected beam intensities @ 10 AMeV		
	SPES 1st day (5 µA p beam)	SPES full power (200 µA p beam)
^{132}Sn	7.8 10^5	3.1 10^7
^{133}Sn	7.0 10^4	2.8 10^6
^{134}Sn	1.2 10^4	4.9 10^5
^{135}Sn	1.6 10^2	6.2 10^3
^{136}Sn	-	0.9 10^2

[Adapted from O. Sorlin, M.-G. Porquet, Progr Part. Nucl Phys 61 (2008) 602]

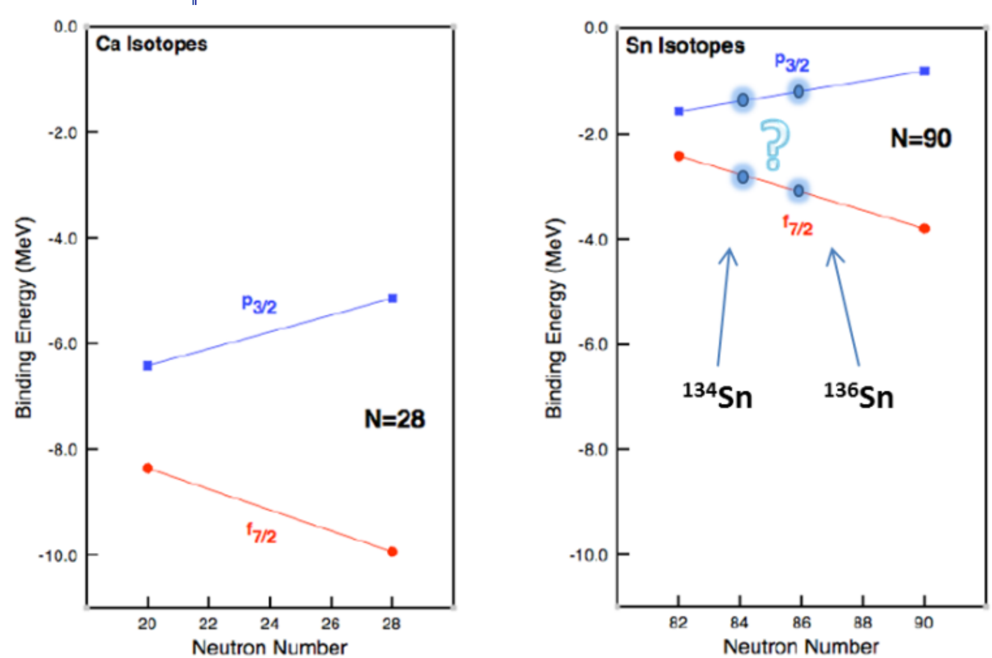
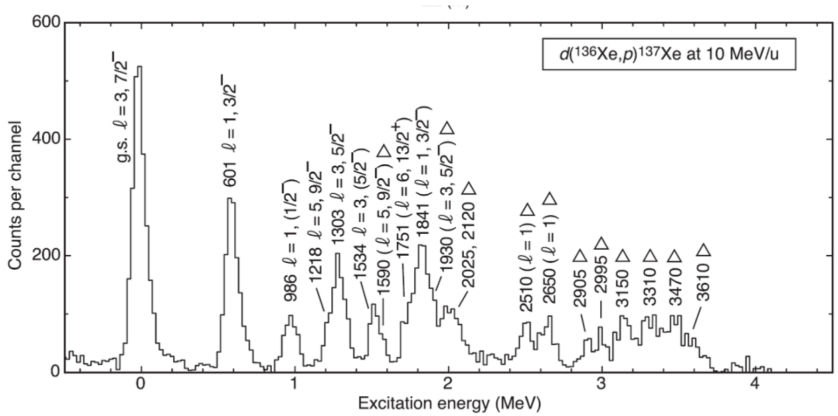


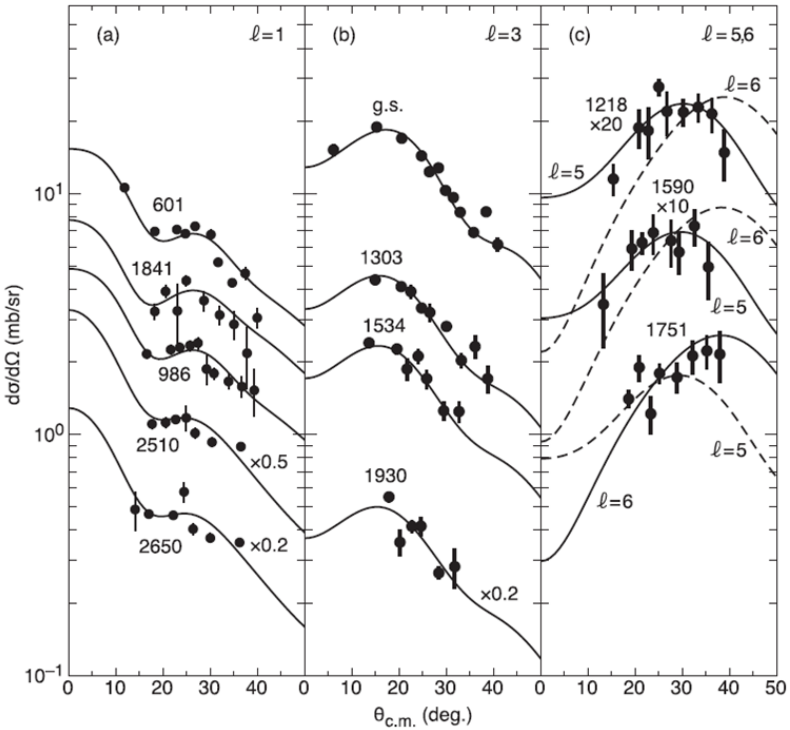
Fig.1 Analogy between f7/2 and p3/2 evolution of binding energies in the known Ca isotopes to what could be expected for the Sn isotopes approaching N=90. Figure adapted from[13].

LoI endorsed by SPES SAC

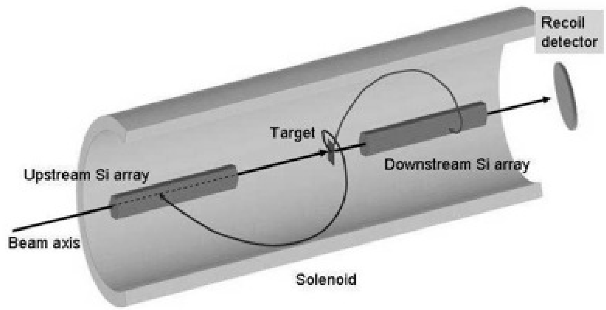
Not only exotic beams

Reference reaction: $^{136}Xe(d,p)^{137}Xe$ - inv kinem





B.P. Kay et al, PRC 84 0243325 (2011)
HELIOS @ ANL

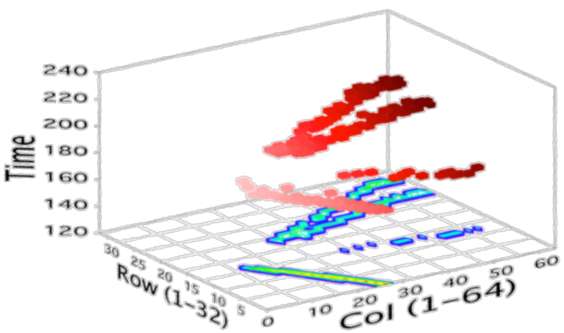


- **Possibly extend to $\theta_{cm} < 10°$**
- **Study ^{135}I via $(d,^{3}He)$**

possible at GANIL or LNS also with high intensity

ACTAR TPC Demonstrator

European Research Council
Established by the European Commission



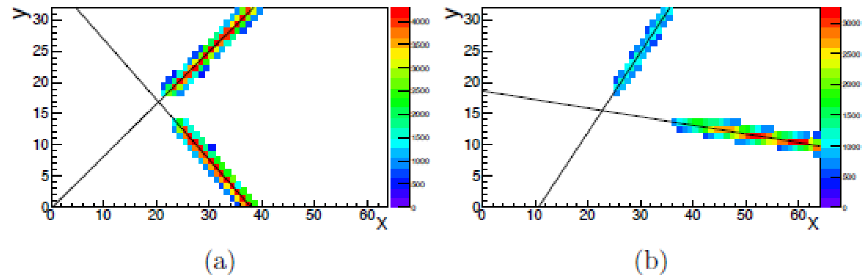
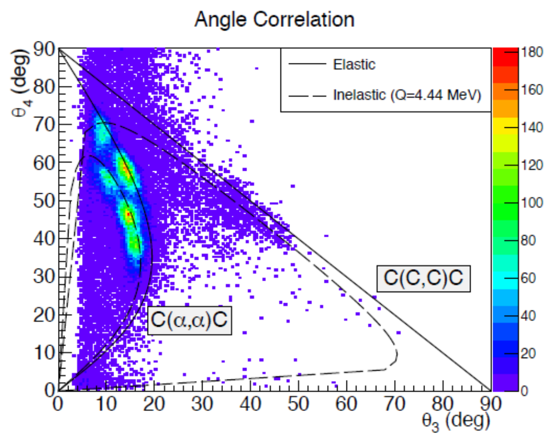
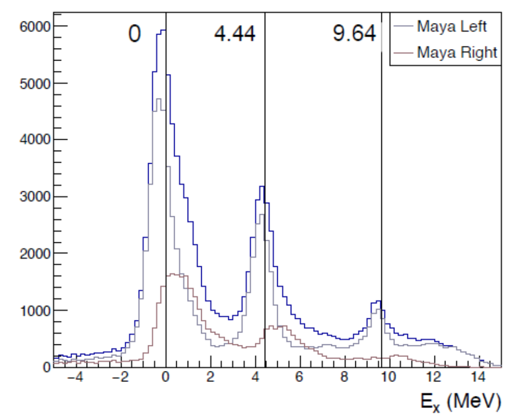
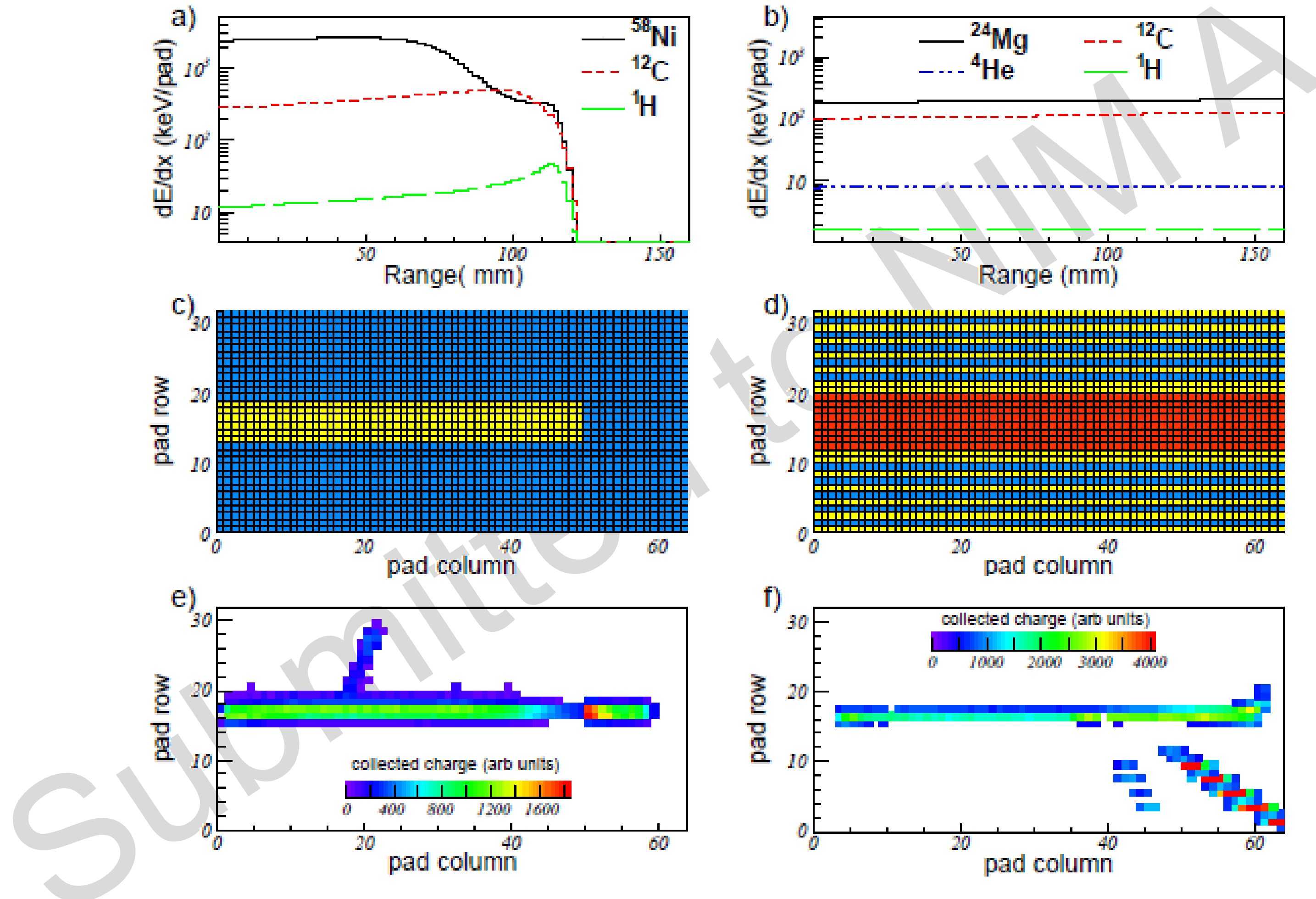


Figure 4.19: *Charge deposition on the pad plane of (a) a* $^{12}C(^{12}C,^{12}C)^{12}C$ *and (b) a* $^{12}C(\alpha,\alpha)^{12}C$ *scattering reaction.*

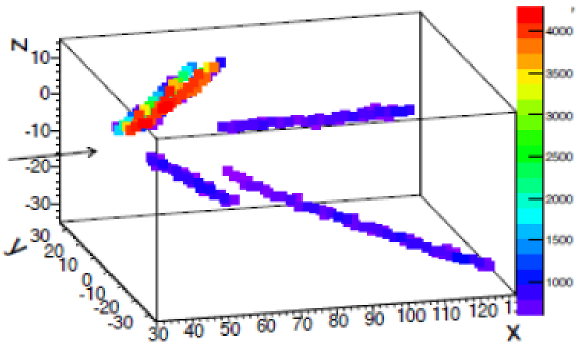


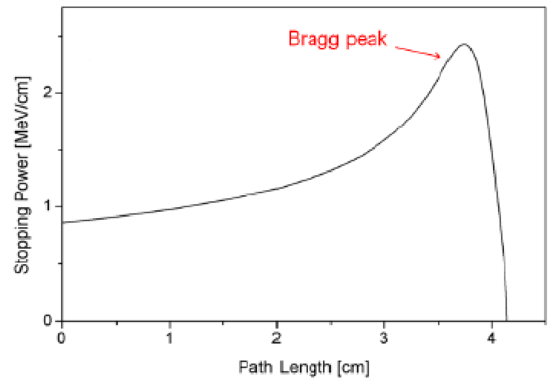


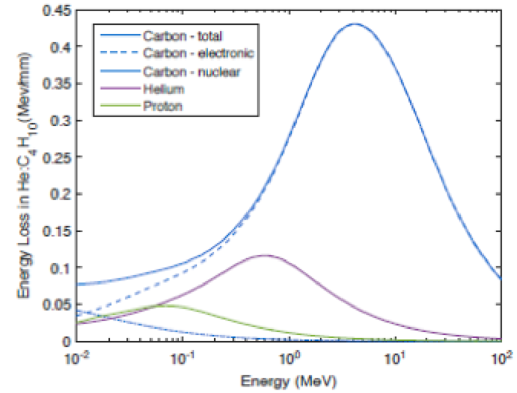
ACTAR TPC Demonstrator

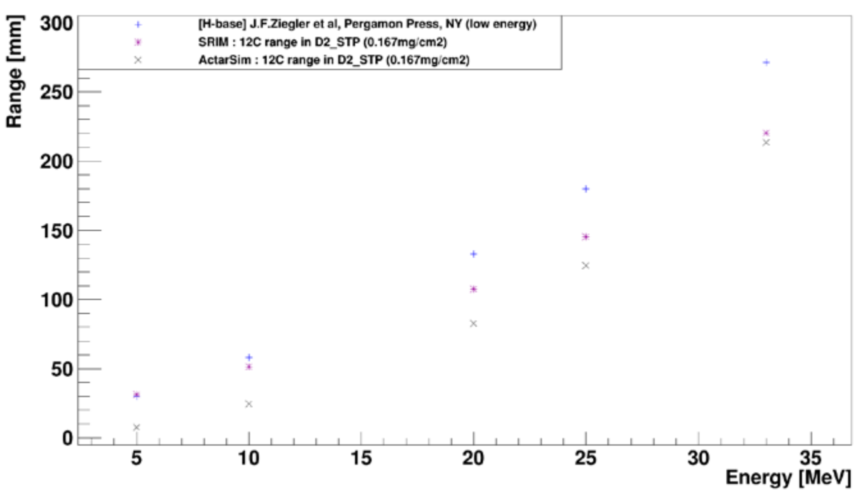


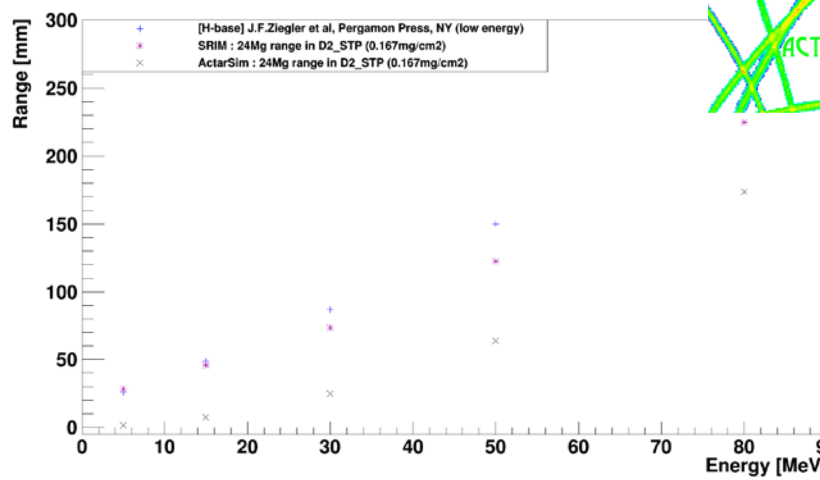
Energy loss measurement and calculation











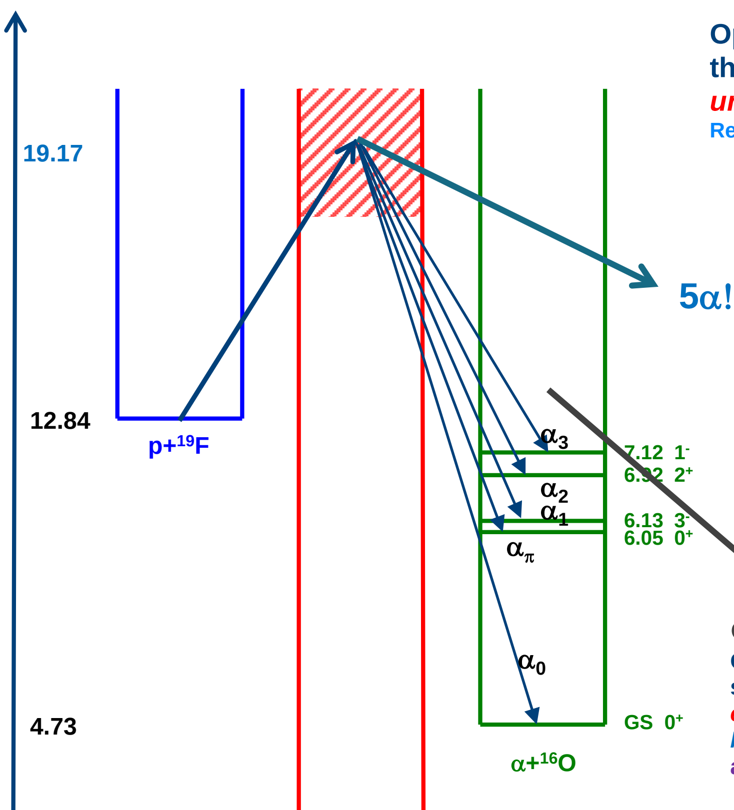
https://github.com/ActarSimGroup/Actarsim/

From the LNS proposal

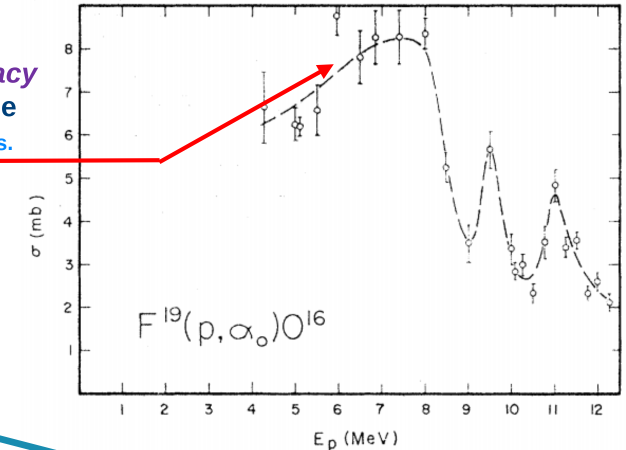
Table 1. List of the proposed projectile for the energy loss profile measurements. As an example, the pressure needed to stop the gas on the pad plane is given for the iC_4H_{10} case.

Ion	Beam Energy (MeV/u)	Gases to be measured	BTU requested	*iC4H10 pressure (mbar) typical case example*
^{7}Li	1.0 - 4.5	H_2, D_2, CH_4, iC_4H_{10}, CF_4, CO_2, He	4.5	*500*
^{9}Be	1.5 - 4.5		4.5	*500*
^{10}B	1.8 - 4.5		4.5	*500*
^{12}C	2.0 - 4.5		4.5	*250*
^{15}N	2.0 - 4.5		4.5	*250*
^{16}O	2.0 - 4.5		4.5	*250*
^{19}F	2.0 - 4.5		4.5	*250*
^{24}Mg	2.0 - 4.5		4.5	*250*
^{40}Ca	2.0 - 3.8		4.5	*250*
^{120}Sn	1.5 - 1.7		4.5	*125*
Total			45	

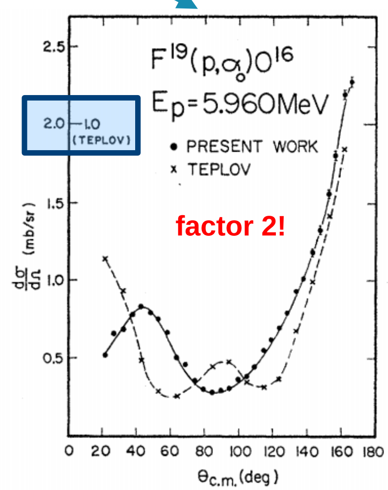
Test case 1: ^{19}F(p,a) reaction at E_p=5-7 MeV (TANDEM)

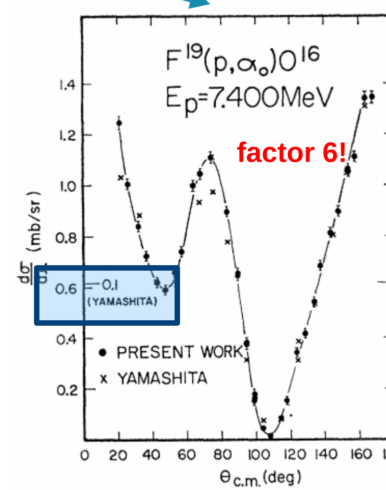


Opportunity to measure with *good accuracy* the angle-integrated *cross section* → large *uncertainties* at E_p=5-7 MeV (Warsh et al, Phys. Rev. 131 (1963) 1690)



Ambiguities in *shapes* and in the absolute *x-section scale* of angular distributions
(Warsh et al, Phys. Rev. 131 (1963) 1690)





α **feeding:**
Opportunity of studying *multi-track events* with *low background* and no ambiguities

In principle → all the α_i channels can be *separately resolved* (to be verified in the test experiment) → surely for the α_0 channel

Test case 2: ^{120}Sn(d,p) reaction at E_{Sn}= 15 AMeV (CS)

Schneid et al, Phys Rev 156 (1967) 4

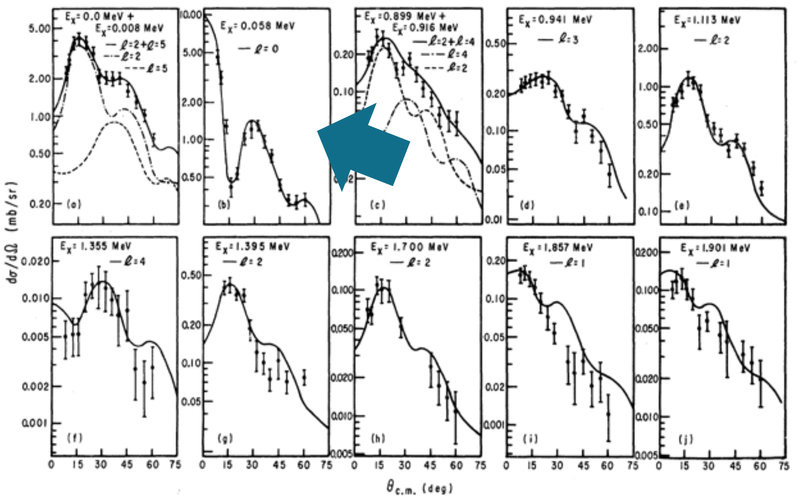
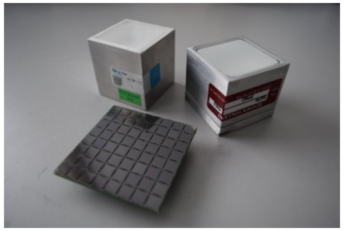


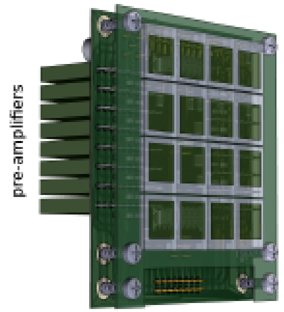
FIG. 2. Angular distributions of transitions in the ^{120}Sn$(d,p)^{121}$Sn reaction. The experimental points are given with error bars corresponding to statistics and background subtraction. The solid lines are DWBA curves fitted to the experimental data.

TABLE V. Energy levels of Sn^{121} from the (d,p) and (d,t) reactions. (See also caption for Table I.)

E^* (MeV)	(d,p) l_n	J^π	$(d\sigma/d\Omega)_{max}$ (mb/sr)	$S_{d,p}$	(d,t) E^* (MeV)	$d\sigma/d\Omega(45°)$ (mb/sr)
0	2	$\frac{3}{2}^+$	3.17	0.43	0	1.45
0.05	0	$\frac{1}{2}^+$	1.93	0.39	0.056	3.09
0.05	5	$11/2^-$	0.235	0.21	0.05	
0.93	4	$\frac{7}{2}^+$	0.276	0.19	0.90	0.381
1.12	2	$\frac{5}{2}^+$	1.03	0.065	1.11	1.47
1.40	2	$\frac{5}{2}^+$	0.477	0.029	1.37	0.802
1.71	2	$(\frac{5}{2}^+)$	0.082	0.004		
1.91	(1)	$(\frac{3}{2}^-)$	0.125	0.007		
2.06	(3)	$(\frac{7}{2}^-)$	0.047	0.005		
2.25	(2)	$(\frac{5}{2}^+)$	0.503	0.027		
2.45	(3)	$(\frac{7}{2}^-)$	0.234	0.021		
2.59	(3)	$(\frac{7}{2}^-)$	0.405	0.035		
2.69	(3)	$(\frac{7}{2}^-)$	2.24	0.185		
2.93			0.432			
3.10	(1)	$(\frac{3}{2}^-)$	2.01	0.13		
3.37	(1)	$(\frac{3}{2}^-)$	1.32	0.077		
3.51	(1)	$(\frac{3}{2}^-)$	2.44	0.15		
3.69	(1)	$(\frac{3}{2}^-)$	2.24	0.14		
3.85	(1)	$(\frac{3}{2}^-)$	0.600	0.037		
3.93	(1)	$(\frac{3}{2}^-)$	1.53	0.095		
4.16	(1)	$(\frac{3}{2}^-)$	1.14	0.073		
4.25	(1)	$(\frac{3}{2}^-)$	0.830	0.053		

Bechara et al, Phys Rev C 12 (1975) 1





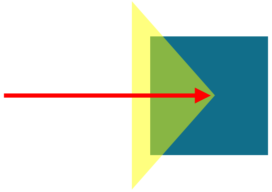


Figure 4: A schematic view of the second detection stage of OSCAR. The rear board contains two series of 8 compact charge sensitive pre-amplifiers to collect signals from 16 silicon pads welded on the front board.

D. Dell'Acquila et al, NIM A 877 (2017) 227

Auxiliary detectors:
- -Si Strip Pads (BB7)
- -OSCAR-like Si pins
- -SPECMAT CeBr3

Challenges:
- -High density of states
- -Kinematics reconstruction

Summary

Active Targets are promising tools for direct reaction studies, resonant elastic scattering experiments, clustering physics, etc.

BUT

the capabilities of measuring reactions with heavy ions need to be verified

THEREFORE

a better characterization of the ACTAR Demonstrator device is needed.

ACTAR-test aims at

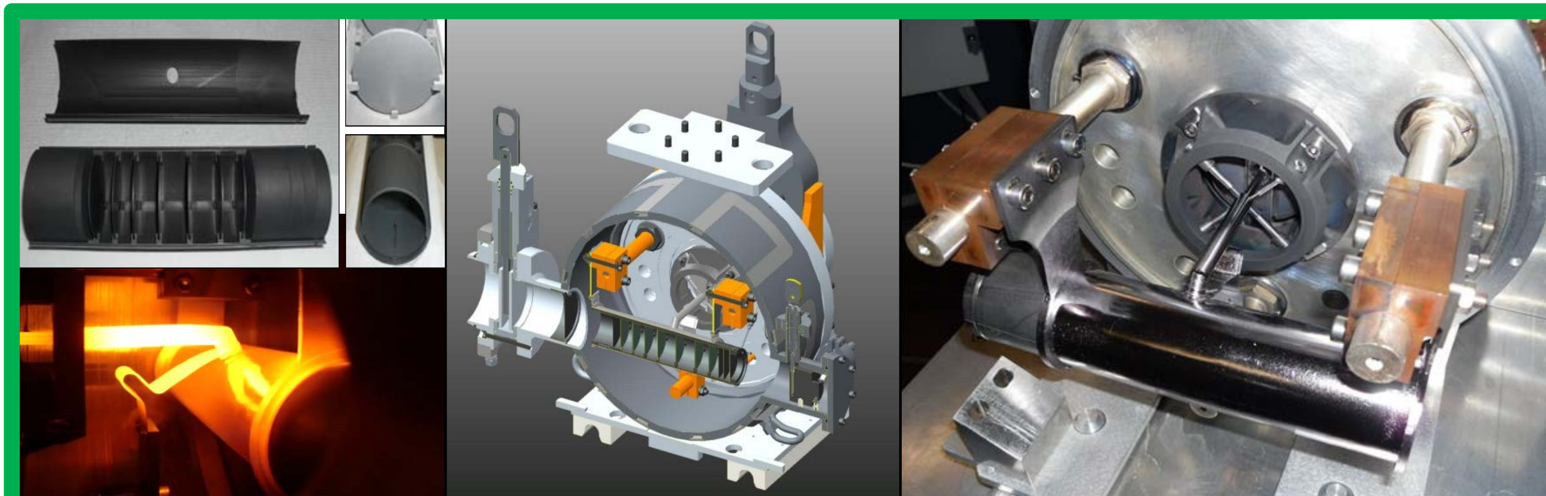
- Getting energy loss information (Shape of the Bragg Peak) to be used for Particle Identification and energy measurement and can be of more general interest [ACTAR Sim, AT-TPC].
- Using benchmark reactions to validate the techniques.

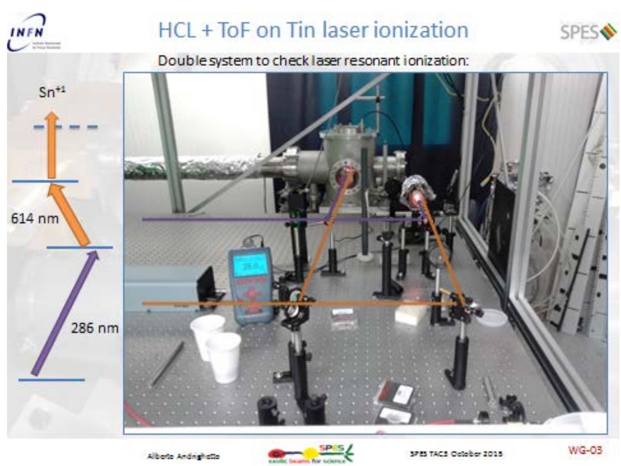
Test	Topic	Beam	Accelerator	BTU
Part 1	Energy loss measurements.	Several beams at different energies (see table 1)	Tandem	45
Part 2-a	$^{19}F(p,\alpha_0)^{16}O$ reaction	^{1}H at 5.5, 7.0, 8.0 MeV	Tandem	9
Part 2-b	$^{120}Sn(d,p)^{121}Sn$ reaction in inverse kinematics	^{120}Sn at 15 AMeV	Cyclotron	21

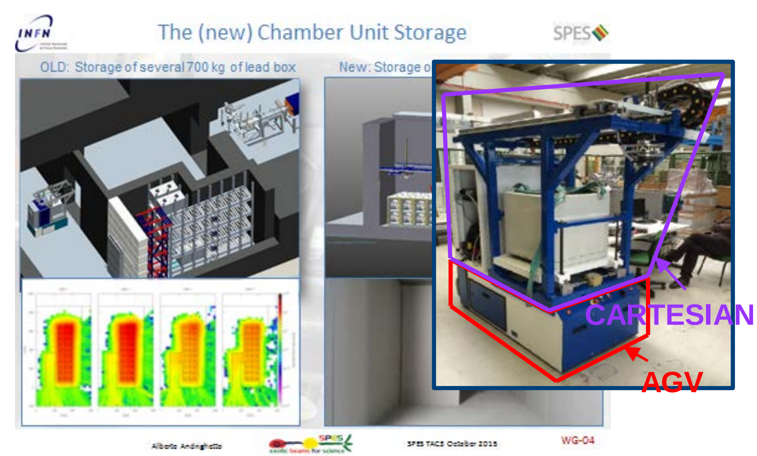
The SPES facility

RIB production: SPES-β

SPES ISOL Target:
UCx, SiC,...
10^{13} fiss./s
T ~ 2000°C
3 sources SIS, LIS, PIS
~ 8 kW power

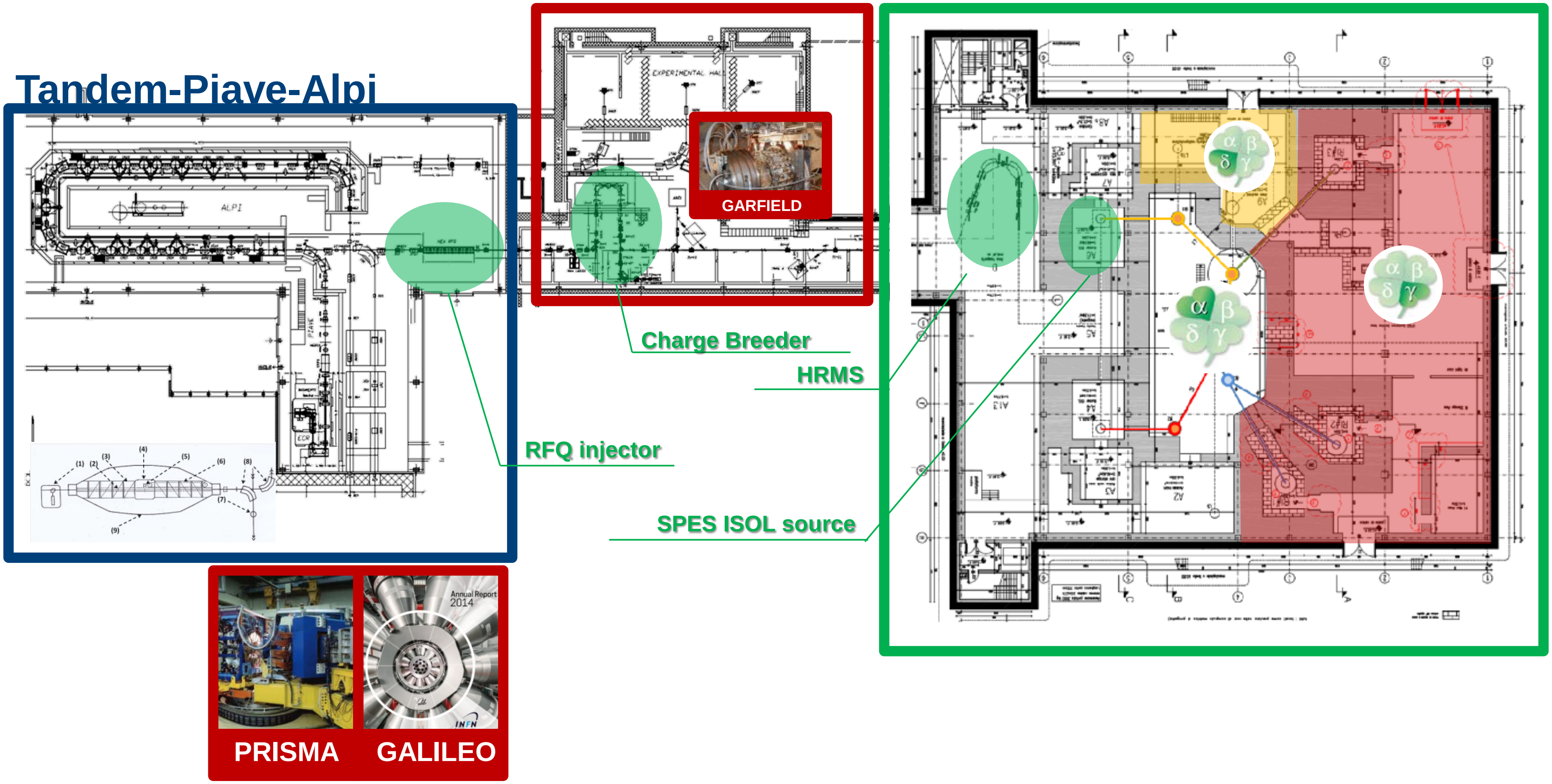




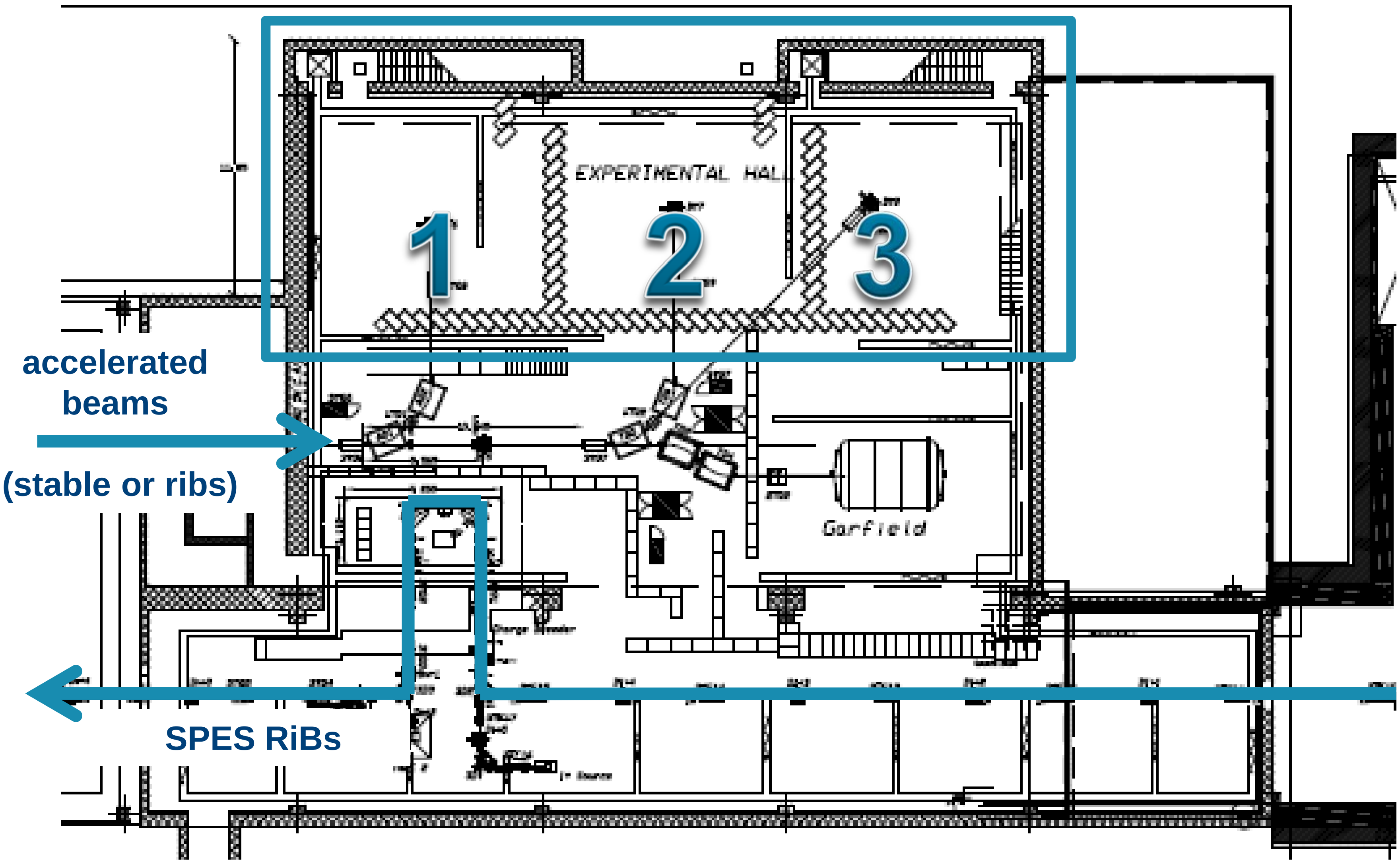


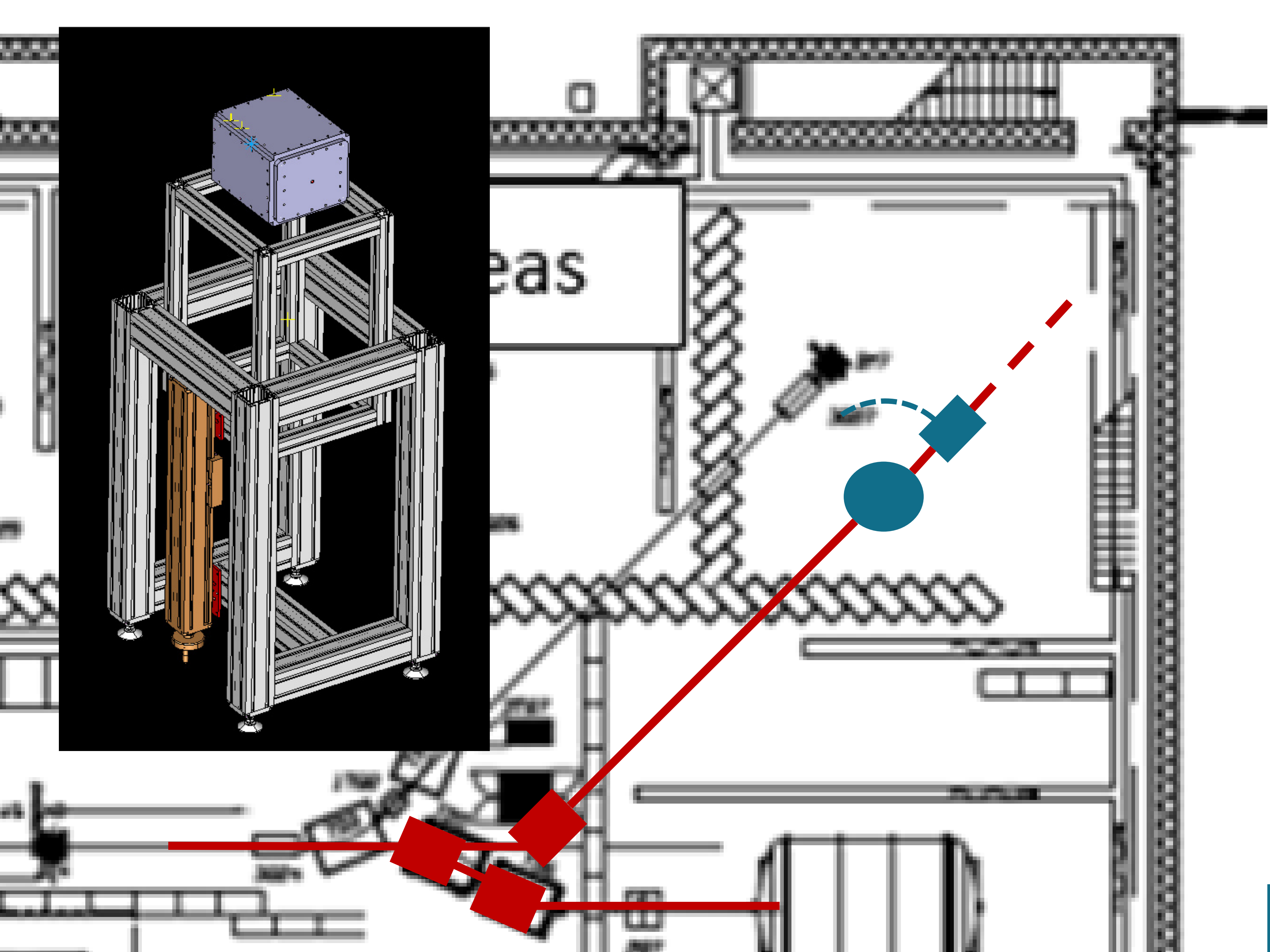
Beam test at iThemba lab. (2014): 66MeV protons, 60 μA on full scale SiC prototype at 1600 °C (FEM sim. Validation)
Former beam tests: ORNL (2007, 2010-2011) SiC, Ucx; ISOLDE(2009) UCx, IPNO (2013) UCx.
Front End and Target System: advanced nuclearization phase.
Target handling systems, <u>Heat resistance tests</u>, Nuclear Safety.

Facility layout



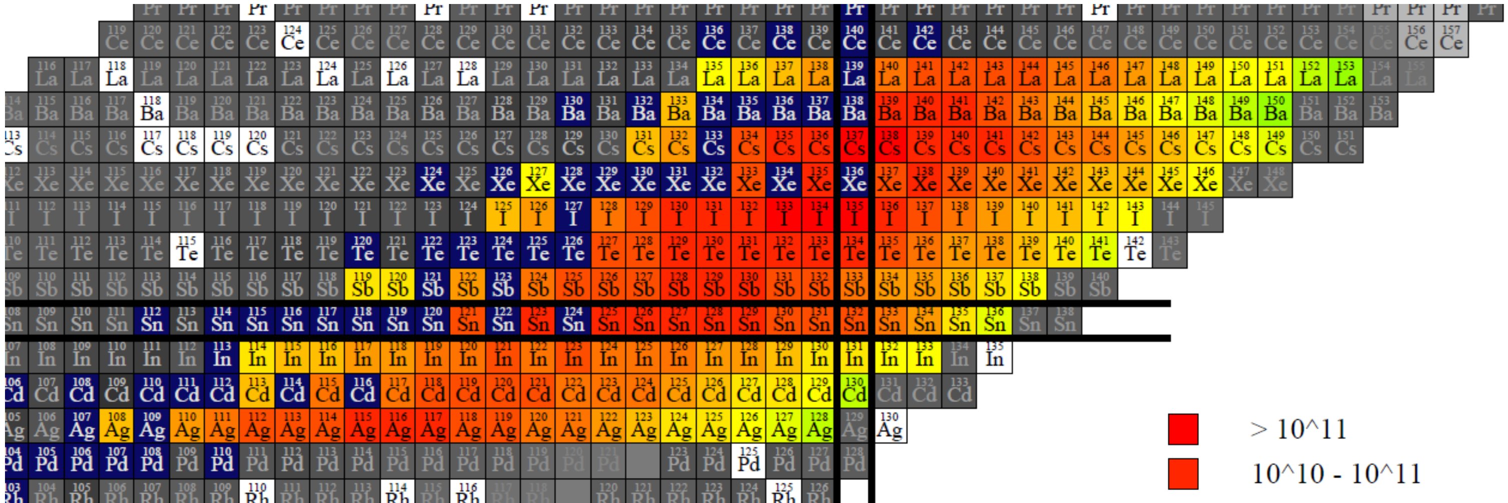
ATS: an Active Target for SPES

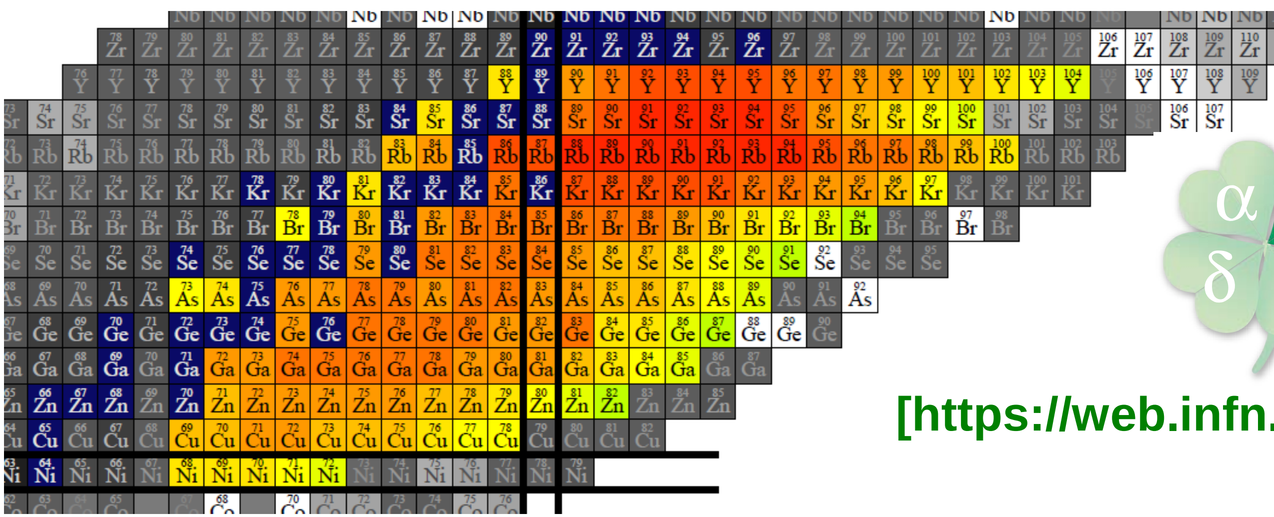


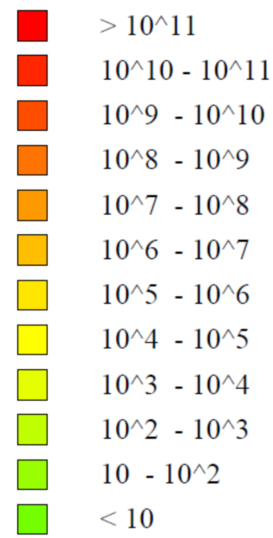





Beyond MagicTin: physics opportunities with an active target at SPES



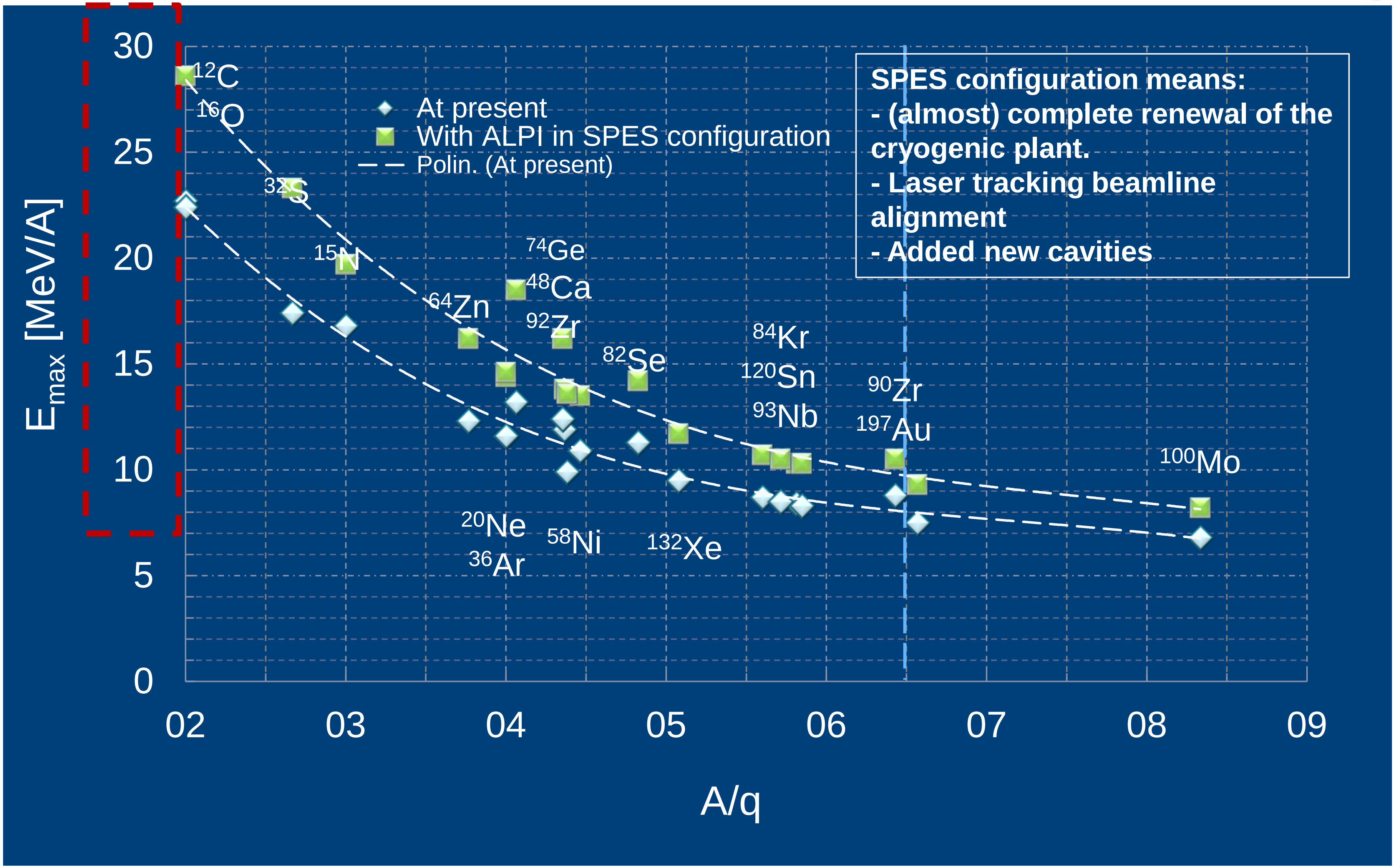




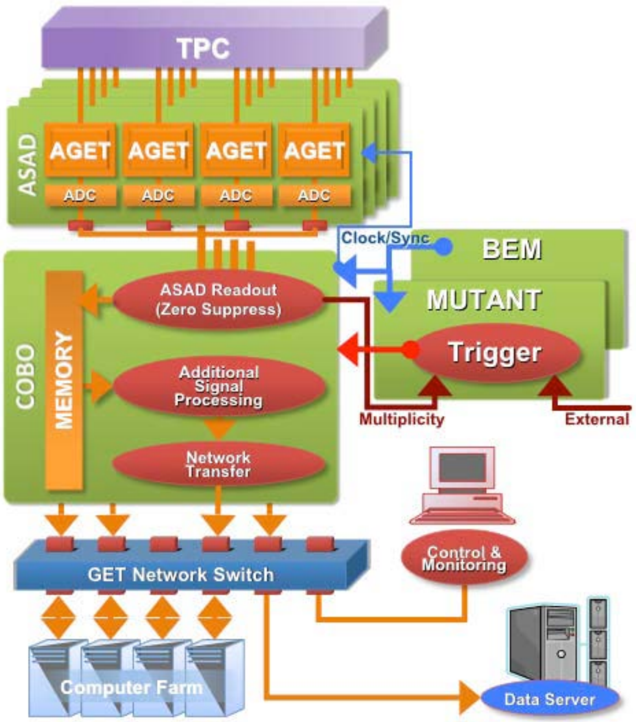
[https://web.infn.it/spes/]

Two letters of intent for SPES endorsed by the SAC:
B. Fernandez Dominguez et al, Direct Reactions with exotic nuclei in the r-process using an active target
R. Raabe, T. Marchi et al, Shell Structure in the vicinity of ^{132}Sn with an active target

Reacceleration using ALPI



GET/GES and GPUs



TPC = 16k ch

ASAD = 4*AGET + ADC
256 ch →

64 x (average) 300 Mbit/s
LVDS standard

NEW DATA CONCENTRATOR/TRANSLATOR

4 x (average) 10 Gbit/s TCP over
Optical link
-commercial standard and hw-

Opt-link 10 Gb/it/s
Opt-link 10 Gb/it/s
Opt-link 10 Gb/it/s
Opt-link 10 Gb/it/s

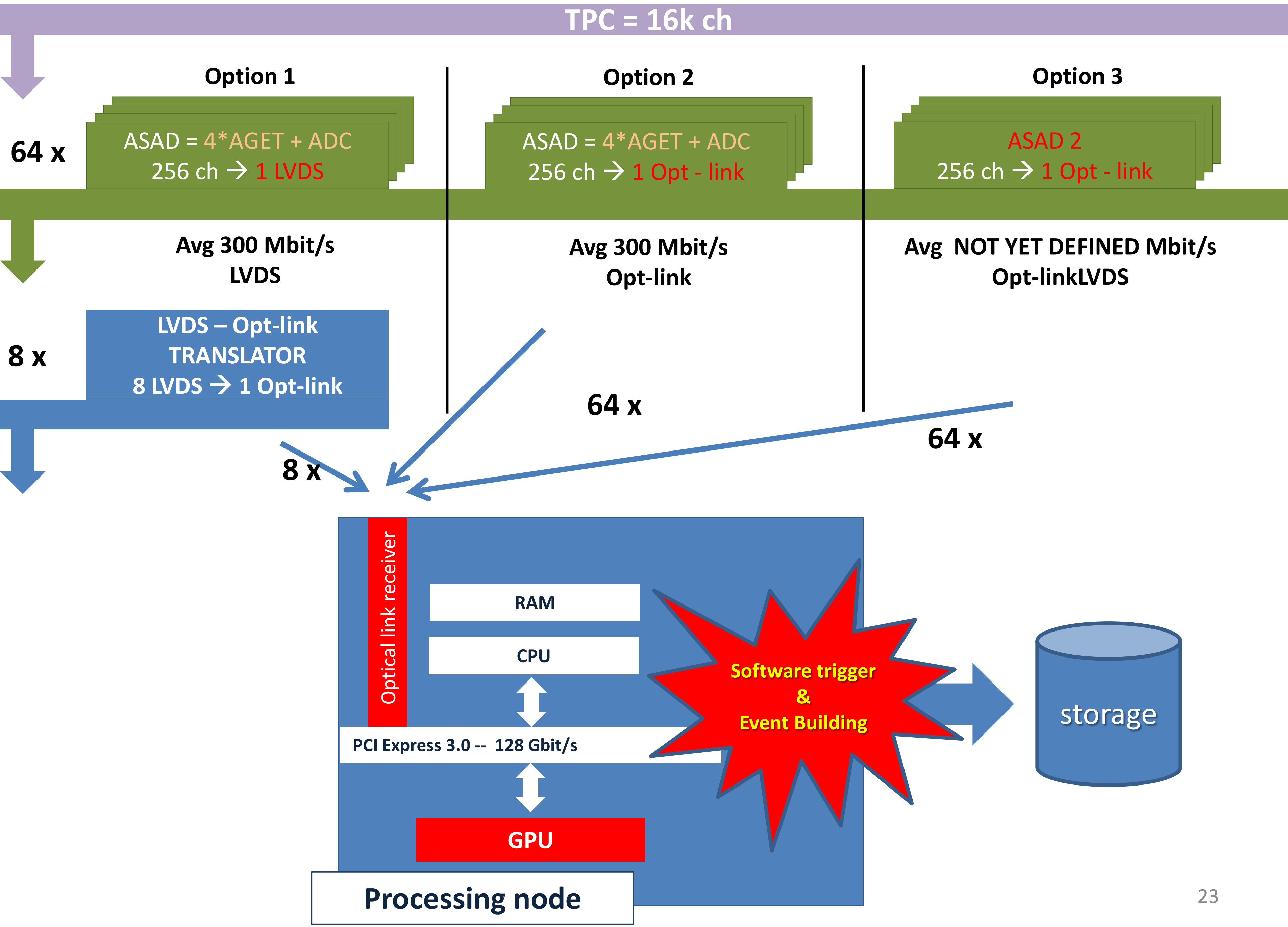
RAM

CPU – seq processing

PCI Express 128 Gbit/s (?)

GPU – parallel processing

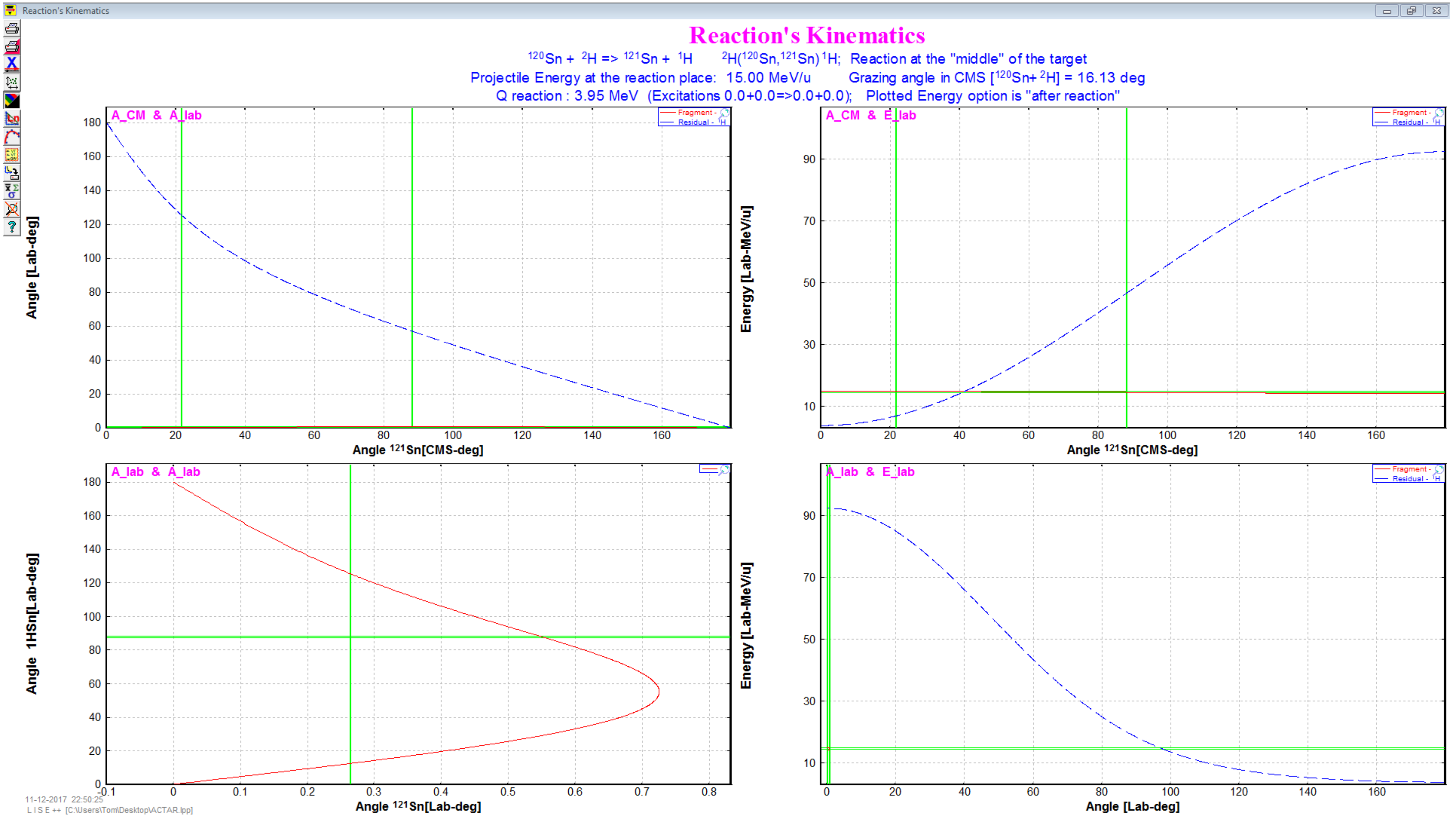
Processing node


TPC = 16k ch
Option 1
Option 2
Option 3
64 x
ASAD = 4*AGET + ADC
256 ch → 1 LVDS
ASAD = 4*AGET + ADC
256 ch → 1 Opt - link
ASAD 2
256 ch → 1 Opt - link
Avg 300 Mbit/s
LVDS
Avg 300 Mbit/s
Opt-link
Avg NOT YET DEFINED Mbit/s
Opt-linkLVDS
8 x
LVDS – Opt-link
TRANSLATOR
8 LVDS → 1 Opt-link
64 x
64 x
8 x
Optical link receiver
RAM
CPU
PCI Express 3.0 -- 128 Gbit/s
GPU
Software trigger
&
Event Building
storage
Processing node

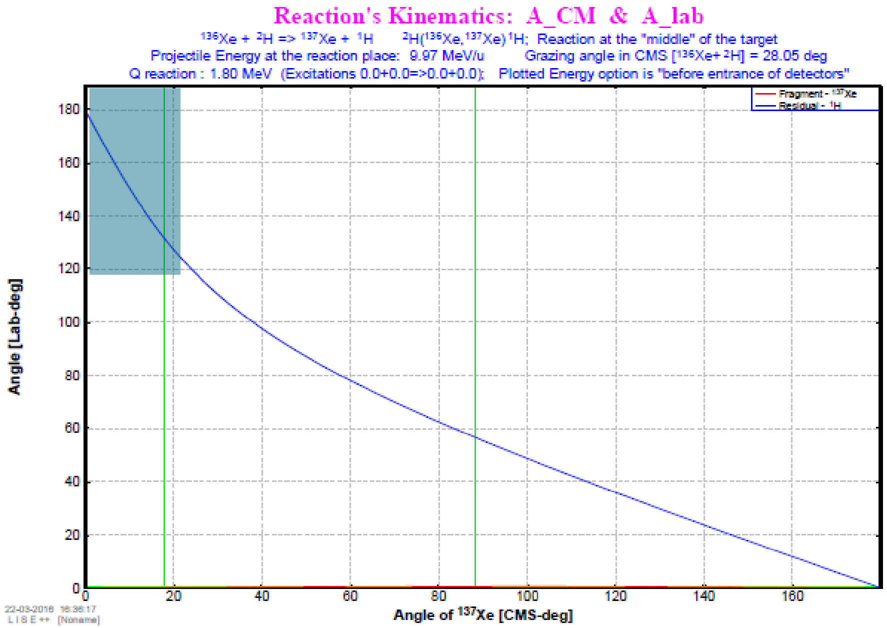
Thank you!

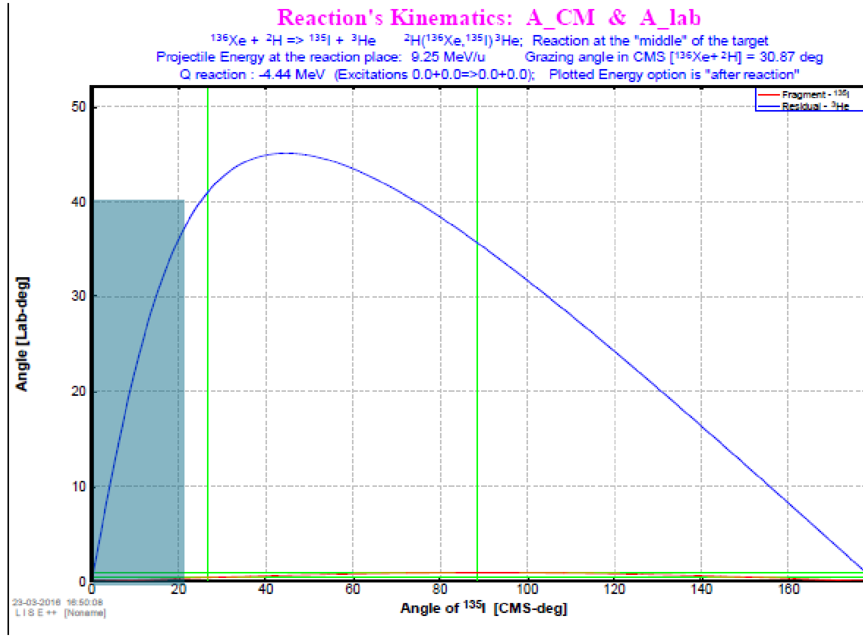
http://pro.ganil-spiral2.eu/laboratory/detectors/actartpc

	iC_4H_{10}			H_2			CH_4			CF_4			CO_2			D_2		
BEAM	E/A	PRESSURE	x Bragg Peak	E/A	PRESSURE	x Bragg Peak	E/A	PRESSURE	x Bragg Peak	E/A	PRESSURE	x Bragg Peak	E/A	PRESSURE	x Bragg Peak	E/A	PRESSURE	x Bragg Peak
p	3.5 MeV	550 mbar	7.3 cm	3.5 MeV	1000 mbar	/	3.5 MeV	1000 mbar	/	3.5 MeV	550 mbar	7.2 cm	3.5 MeV	1000 mbar	7.3 cm	3.5 MeV	1000 mbar	/
d	1.8 MeV/A	350 mbar	7.3 cm	1.8 MeV/A	1000 mbar	/	1.8 MeV/A	1000 mbar	9.05 cm	1.8 MeV/A	350 mbar	7.8 cm	1.8 MeV/A	650 mbar	7.5 m	1.8 MeV/A	1000 mbar	/
^{4}He																		
^{7}Li	1 MeV/A	70 mbar	6.2 cm	1 MeV/A	1000 mbar	4.6 cm	1 MeV/A	250 mbar	5.09 cm	1 MeV/A	70 mbar	7.9 cm	1 MeV/A	125 mbar	7.7 cm	1 MeV/A	800 mbar	7.1 cm
^{9}Be	1.3 MeV/A	100 mbar	4.09 cm	1.3 MeV/A	1000 mbar	6.5 cm	1.3 MeV/A	270 mbar	6.09 cm	1.3 MeV/A	100 mbar	5.4 cm	1.3 MeV/A	150 mbar	7.3 cm	1.3 MeV/A	900 mbar	7.9 cm
^{10}B	1.5 MeV/A	70 mbar	7.6 cm	1.5 MeV/A	1000 mbar	6.1 cm	1.5 MeV/A	250 mbar	6.4 cm	1.5 MeV/A	80 mbar	7.2 cm	1.5 MeV/A	150 mbar	7.4 cm	1.5 MeV/A	900 mbar	7.4 cm
^{12}C	1.8 MeV/A	100 mbar	5.4 cm	1.8 MeV/A	1000 mbar	7.3 cm	1.8 MeV/A	270 mbar	7.5 cm	1.8 MeV/A	100 mbar	6.3 cm	1.8 MeV/A	200 mbar	5.1 cm	1.8 MeV/A	1000 mbar	8.4 cm
^{15}N	1.8 MeV/A	100 mbar	5.4 cm	1.8 MeV/A	1000 mbar	7.3 cm	1.8 MeV/A	270 mbar	7.5 cm	1.8 MeV/A	100 mbar	6.3 cm	1.8 MeV/A	200 mbar	5.1 cm	1.8 MeV/A	1000 mbar	8.3 cm
^{16}O	2 MeV/A	100 mbar	5.5 cm	2 MeV/A	1000 mbar	8.6 cm	2 MeV/A	270 mbar	7.7 cm	2 MeV/A	100 mbar	6.5 cm	2 MeV/A	200 mbar	5.3 cm	2 MeV/A	1000 mbar	8.6 cm
^{19}F	1.8 MeV/A	80 mbar	6.7 cm	1.8 MeV/A	1000 mbar	6.9 cm	1.8 MeV/A	270 mbar	6.2 cm	1.8 MeV/A	100 mbar	5.3 cm	1.8 MeV/A	150 mbar	7.2 cm	1.8 MeV/A	1000 mbar	6.9 cm
^{24}Mg	2 MeV/A	80 mbar	6.8 cm	2 MeV/A	1000 mbar	7.09 cm	2 MeV/A	250 mbar	7.2 cm	2 MeV/A	100 mbar	5.6 cm	2 MeV/A	125 mbar	5.8 cm	2 MeV/A	1000 mbar	7.1 cm
^{40}Ca	2 MeV/A	80 mbar	5.6 cm	2 MeV/A	1000 mbar	5.8 cm	2 MeV/A	225 mbar	7.2 cm	2 MeV/A	80 mbar	6.9 cm	2 MeV/A	150 mbar	6.2 cm	2 MeV/A	900 mbar	7.1 cm
^{120}Sn	1.3 MeV/A	100 mbar	5.1 cm	1.3 MeV/A	1000 mbar	7.4 cm	1.3 MeV/A	270 mbar	7.1 cm	1.3 MeV/A	100 mbar	6.9 cm	1.3 MeV/A	170 mbar	7.3 cm	1.3 MeV/A	1000 mbar	7.8 cm


Reaction's Kinematics
Reaction's Kinematics
120Sn + 2H => 121Sn + 1H   2H(120Sn,121Sn)1H; Reaction at the "middle" of the target
Projectile Energy at the reaction place: 15.00 MeV/u   Grazing angle in CMS [120Sn+2H] = 16.13 deg
Q reaction : 3.95 MeV (Excitations 0.0+0.0=>0.0+0.0); Plotted Energy option is "after reaction"
A_CM & A_lab
Angle [Lab-deg]
Angle 121Sn[CMS-deg]
A_CM & E_lab
Energy [Lab-MeV/u]
Angle 121Sn[CMS-deg]
A_lab & A_lab
Angle 1HSn[Lab-deg]
Angle 121Sn[Lab-deg]
A_lab & E_lab
Energy [Lab-MeV/u]
Angle [Lab-deg]
Fragment -
Residual -
11-12-2017 22:50:25
L I S E ++ [C:\Users\Tom\Desktop\ACTAR.lpp]

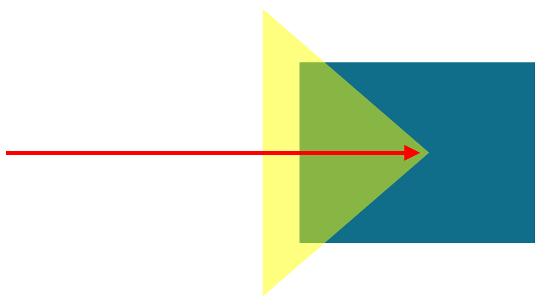
Does kinematics help?

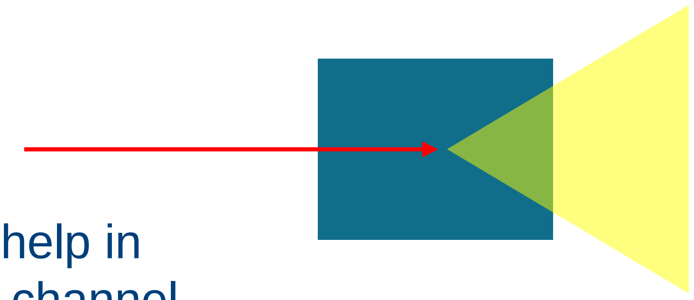




^{136}Xe(d,p)^{137}Xe - inv kinem

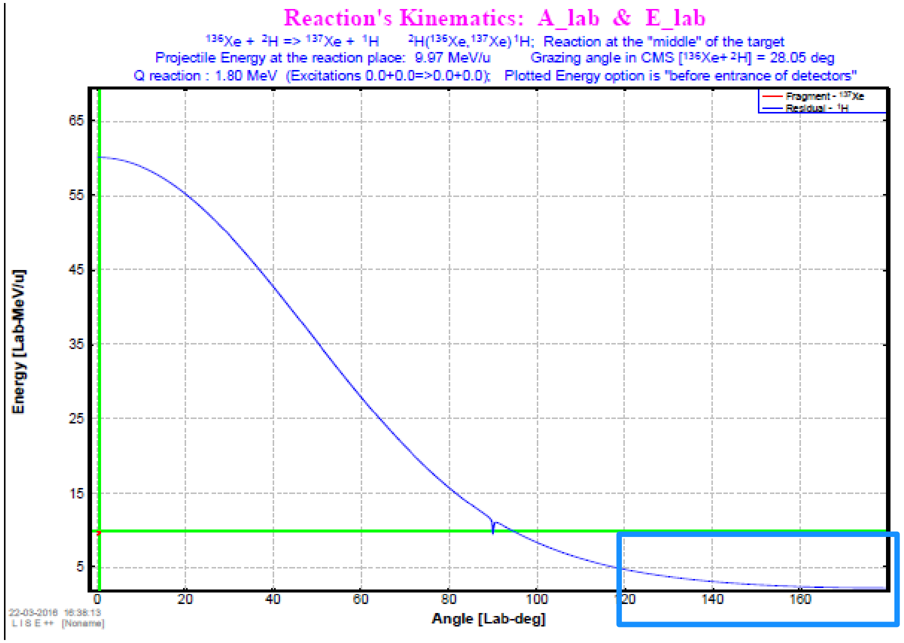
^{136}Xe(d,^{3}He)^{135}Ie - inv kinem

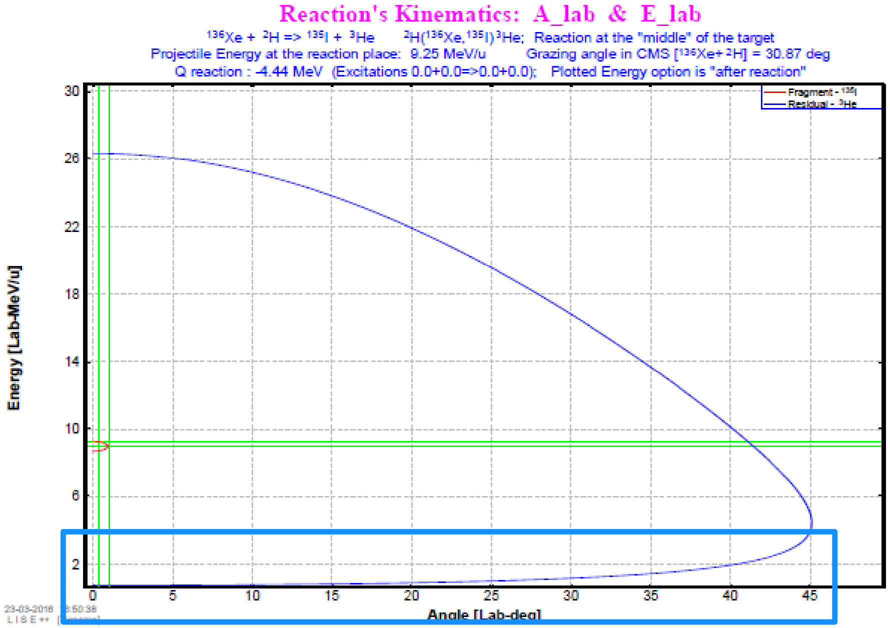




Kinematics seems to help in selecting the reaction channel

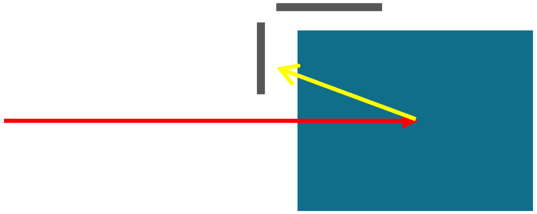
Or not?



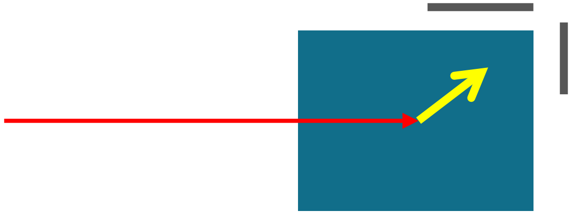


^{136}Xe(d,p)^{137}Xe - inv kinem

^{136}Xe(d,^{3}He)^{135}Ie - inv kinem



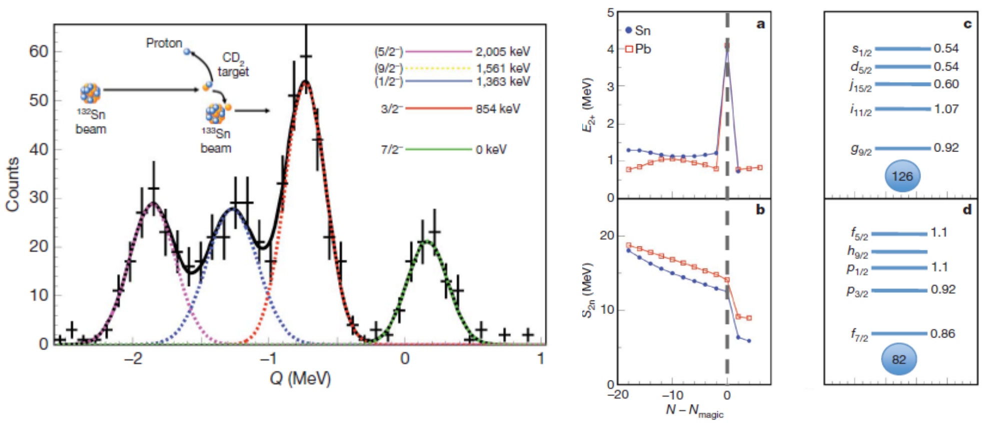
Tradeoff:
Range vs good tracking



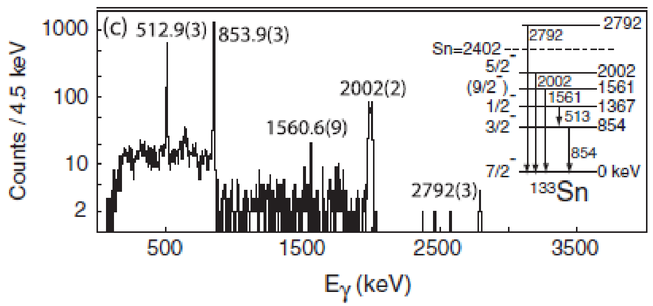
Getting more details - transfer reactions

MagicTin*

- **Probe single particle properties determining spectroscopic factors**
- **Extend towards more neutron-rich region (+1n)**



[K.L. Jones et al, Nature 465 (2010) 454]



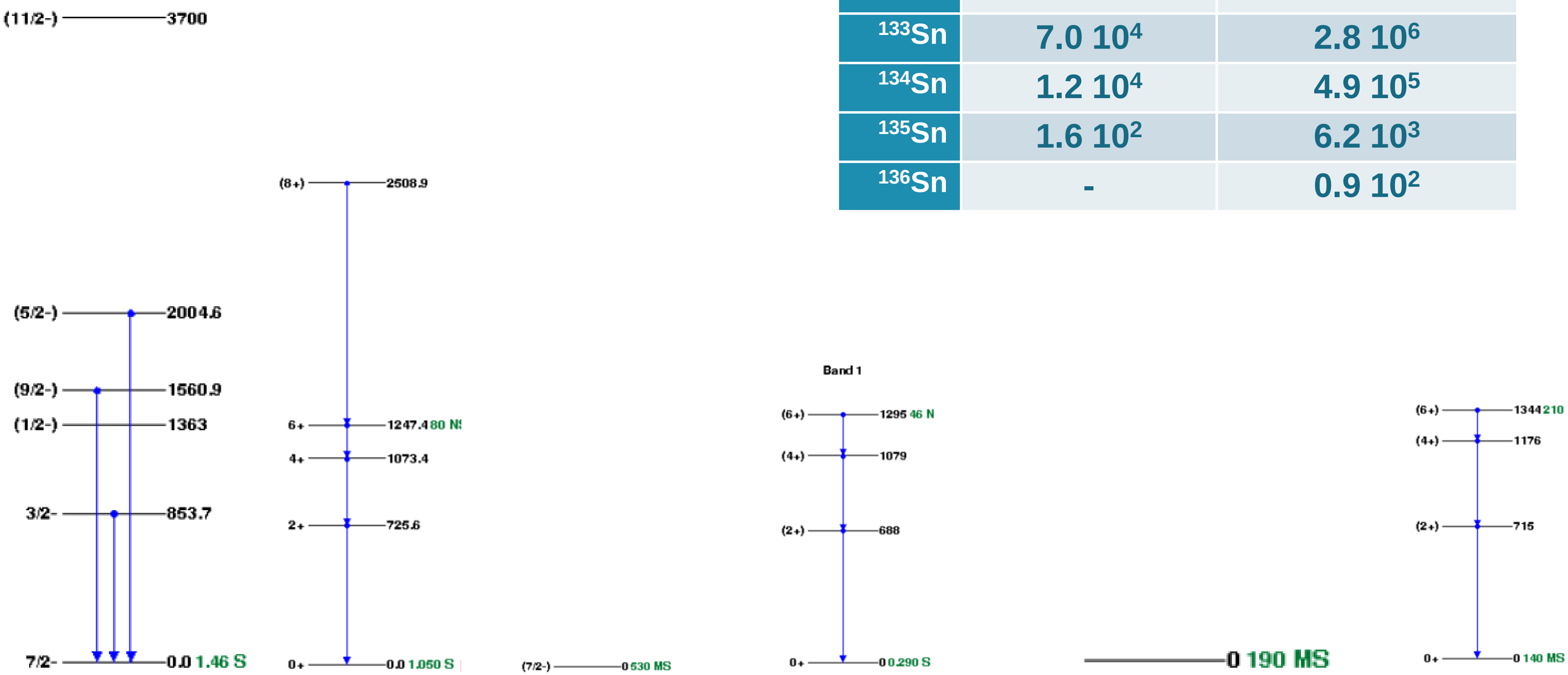
[J.M. Allmond et al, PRL 112, 172701 (2014)]

Evidences of ^{132}Sn double magicity
Resolution ~ 300 keV

High resolution spectroscopy for ^{131}Sn ^{133}Sn using (^{9}Be, ^{8}Be) transfer reactions

Beyond ^{132}Sn

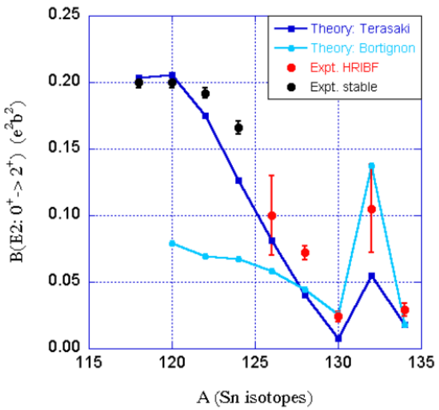
Expected beam intensities @ 10 AMeV		
	SPES 1st day (5 μA p beam)	SPES full power (200 μA p beam)
^{132}Sn	$7.8\ 10^{5}$	$3.1\ 10^{7}$
^{133}Sn	$7.0\ 10^{4}$	$2.8\ 10^{6}$
^{134}Sn	$1.2\ 10^{4}$	$4.9\ 10^{5}$
^{135}Sn	$1.6\ 10^{2}$	$6.2\ 10^{3}$
^{136}Sn	-	$0.9\ 10^{2}$



^{133}Sn	^{134}Sn	^{135}Sn	^{136}Sn	^{137}Sn	^{138}Sn
d(^{132}Sn,^{133}Sn)p	d(^{133}Sn,^{134}Sn)p	d(^{134}Sn,^{135}Sn)p	d(^{135}Sn,^{136}Sn)p	d(^{136}Sn,^{137}Sn)p	d(^{137}Sn,^{138}Sn)p
Q = 177 keV	Q_{gs} = 1.4 MeV	Q = 47 keV	Q = 1.1 MeV	Q = -264 keV	Q = 0.9 MeV

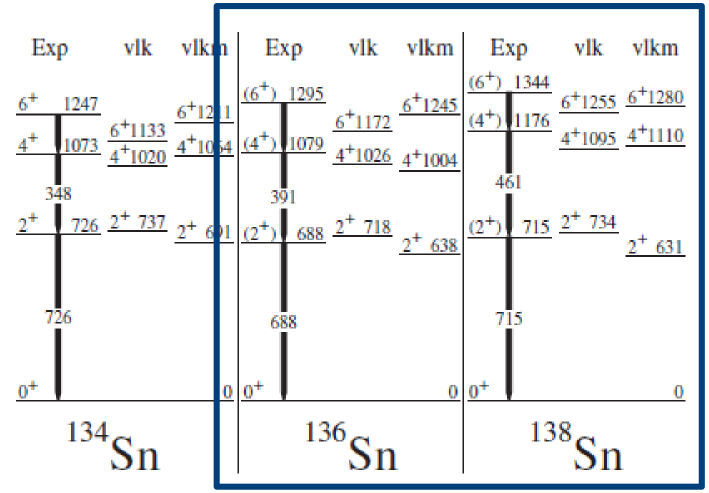
[ENSDF 2016]

Shell evolution and collectivity in Tin isotopes



[R.L. Varner et al, EPJA 25 (2005) 391]

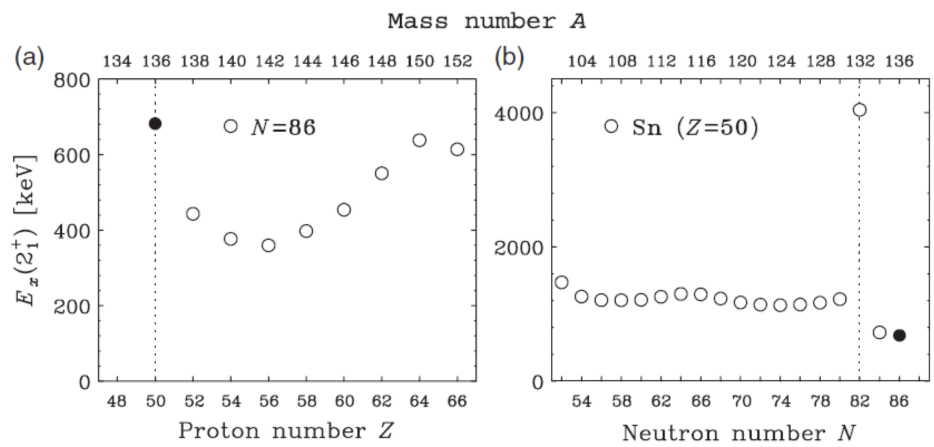
^{132,134}Sn Coulex @ HRIBF
9000 ions/s
150 BaF_2 (~30% eff)



[G. Simpson et al, Phys Rev Lett 113 (2014) 132502]

RIBF ^{238}U
345 MeV/u

^{9}Be(^{137}Sb,^{136}Sn) @ RIKEN
DALI2 (186 NaI(Tl)~22% eff)



[He Wang et al, PTEP 023D02 (2014)]