KU LEUVEN

ATS

the Active Target for SPES

T. Marchi, IKS-KU Leuven

Outline

- Active Target concept
- Let’s do it! Active Targets around the World
  - ACTAR TPC and SpecMAT

- ATS: An Active Target for SPES
- The MagicTin project
  - Motivation
  - The ideal setup
  - In preparation for RiBs
  - Timeline and deliverables

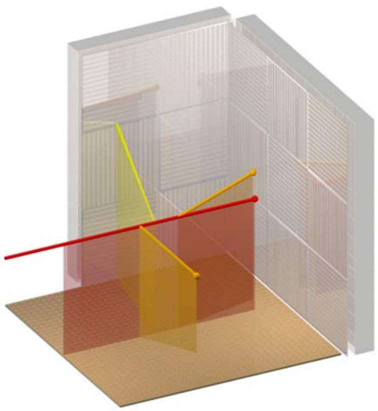
- Beyond MagicTin, physics opportunities for ATS

Active Target concept

- Gas medium is both target and detection gas
- Segmented detection plane
- Drift times recorded + charge deposition on segments (works as a ***TPC***)
- Auxiliary detectors on the sides of the chamber

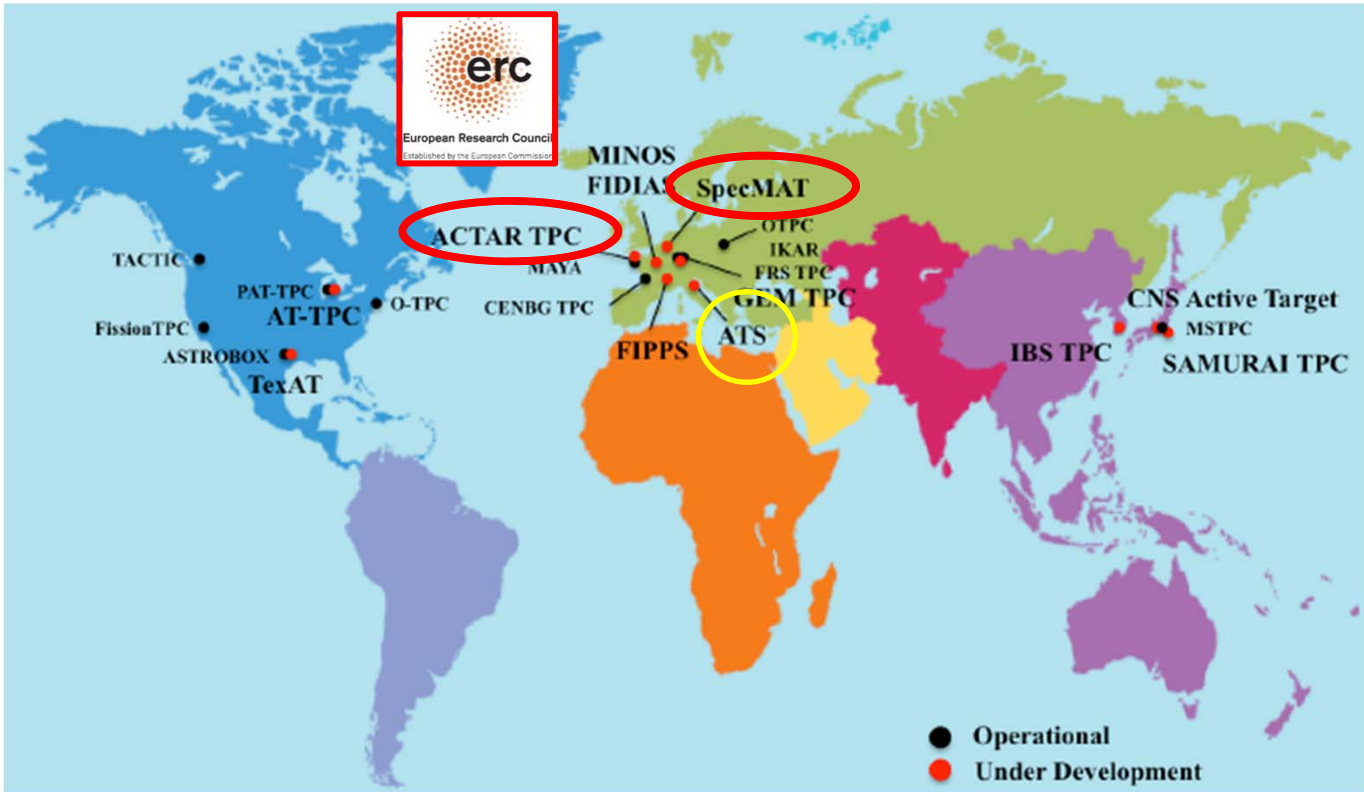
Advantages:

- <u>High efficiency and low detection thresholds</u>
- Wide angular coverage
- Interaction Vertex Reconstruction



Measure many reactions AND beam energies at the same time

Active Targets around the World



G.F. Grinyer, J. Pancin, T. Roger, EURISOL meeting 2014

Recent review about Active Target detectors:

S. Beceiro-Novo, T.Ahn, D. Bazin, W. Mittig, Prog. in Part. & Nucl. Physics (2015) 124- 165,

Active Target and TPC – ACTAR TPC

Parameter	Value	Depends upon
Dynamic range	10^3	- amplification technology - detector geometry - electronics - auxiliary detectors
Number of tracks	all tracks detected independently	- segmentation using pads - electronics
Spatial resolution	< 2 mm	- amplification technology - pad size and shape - number of channels - auxiliary detectors
Maximum beam intensity	10^6 pps	- drift velocity - operating conditions (gas type or mixture) - detector size - electronics
Timing resolution	20 ns	- drift velocity - electronics
Energy resolution (signal amplitude)	2%	- spatial resolution - operating conditions - amplification technology
Efficiency	$> 90\%$	- dynamic range - detector geometry - type of event
Counting rate for accepted events	1 kHz	- electronics - pad-to-electronics topology
Minimum half life decay events	$\approx 10\ \mu s$	- electronics
Portability		- detector design - electronics

[ACTAR TPC CDR]

- **Physics programs:**
  - **One and two nucleon transfer reactions**
  - **Rare and exotic nuclear decay (2p, β2p, …)**
  - **Inelastic scattering and giant resonances**
  - **Resonant scattering and astrophysics**
  - **Transfer-induced fission, … and more!**

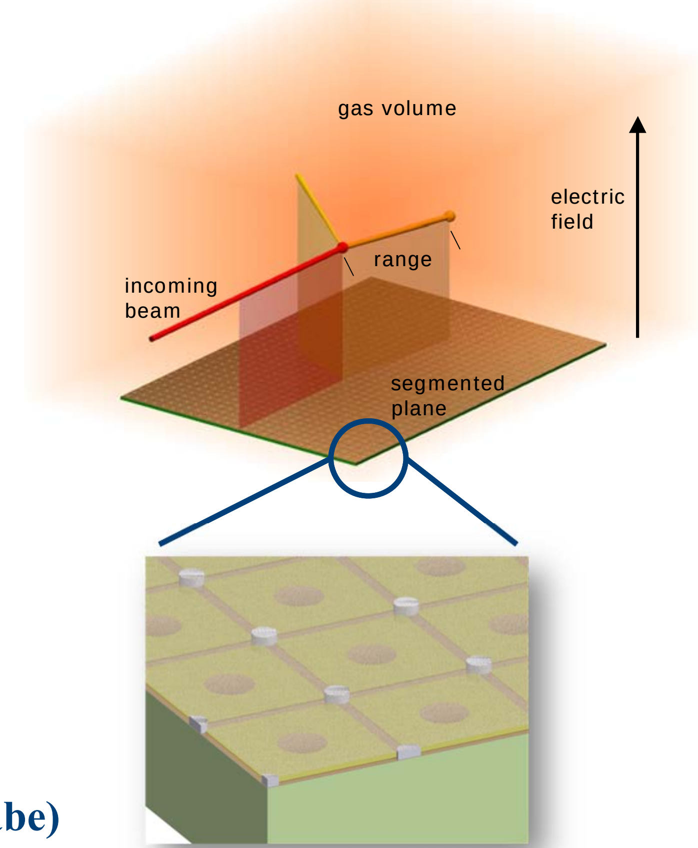
ACTAR TPC: Design

- **Drift Region**
  - **2 geometries:**
    - ✓ **square ~ 25x25 cm**
    - ✓ **rectangular ~ 12.25x25 cm (decay studies, see talk by B. Blank on 2p radioactivity)**
  - **Electric field uniformity**

- **Amplification Region**
  - **MICROMEGAS*, GEM amplifiers**
  - **Fast timing, robust, cost effective**

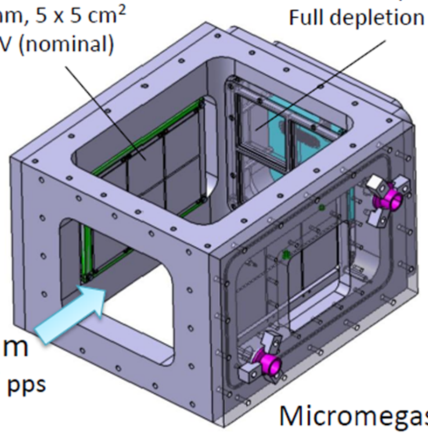
- **Segmented pad plane**
  - **Very high-density: 2x2 mm^2 (= 25 channels/cm^2)**
  - **Total of 16384 electronics channels (GET system)**
  - **Fully digitized waveforms and times for every pad**

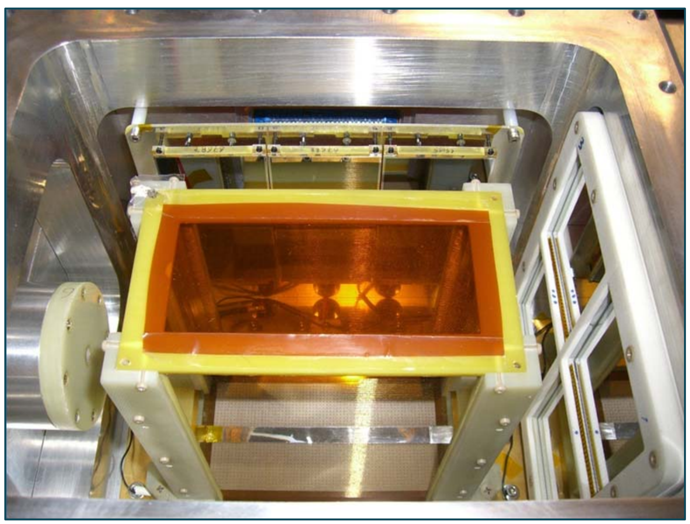
- **Auxiliary Detectors**
  - **Telescopes for escaping particles (Si+Si or Si+CsI)**
  - **LaBr$_3$ or HPGe for γ rays (SpecMAT ERC – R.Raabe)**



***Prototype detector tests: J.Pancin *et al.* NIMA 735, 532 (2014)**

ACTAR TPC Demonstrator chamber





Demonstrator runs with Bacchus Spectrometer at IPN Orsay, June/July 2015

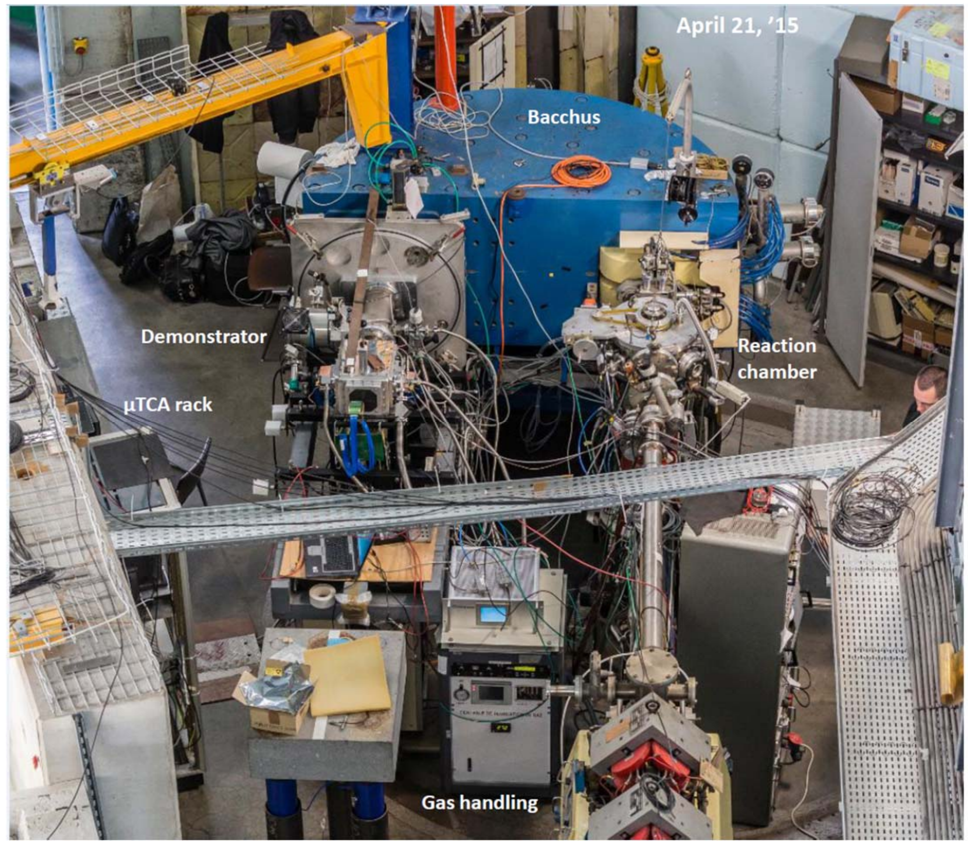
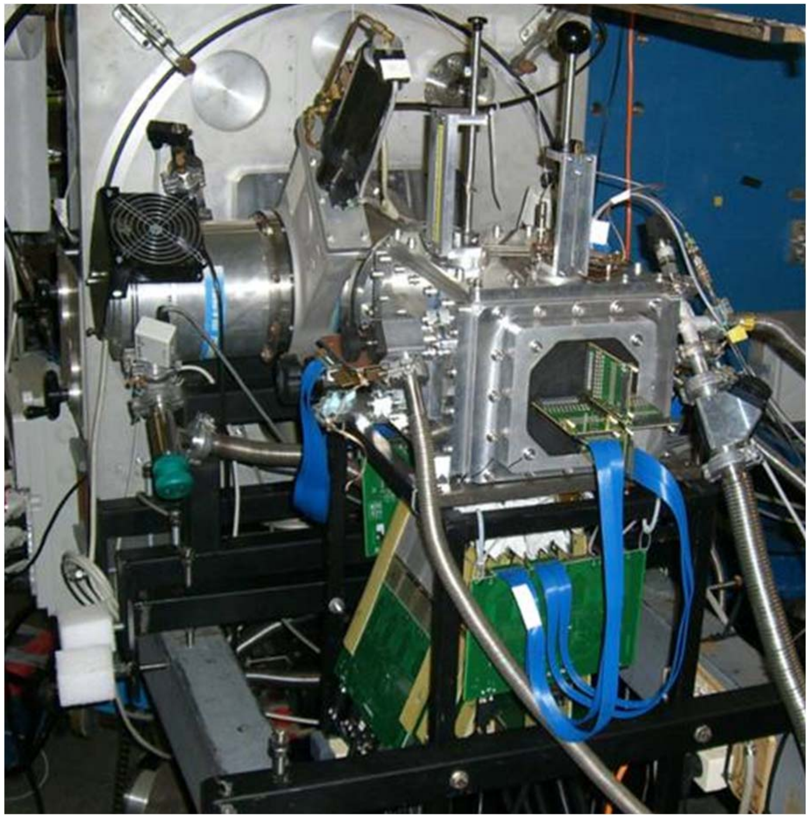
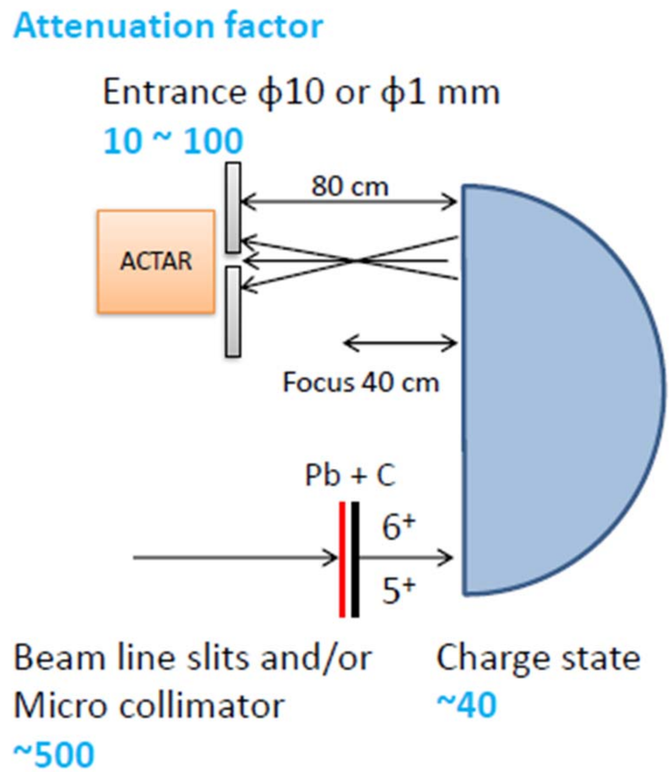


Figure and photos from D. Suzuki

ACTAR TPC Demonstrator chamber





IPNO 2015 : Goals

- **Physics : α clustering in light nuclei (D.Suzuki)**
  - Excitation of Hoyle states in ^{12}C
    - ^{12}C beam : inelastic scattering ($^{12}C+\alpha$)
  - Structure of excited states in ^{10}B
    - ^{6}Li beam : resonant alpha scattering ($^{6}Li+\alpha$)

Analysis in progress
2 Master Thesis (KU Leuven)
1 PhD (GANIL)

- **Detector : Ideal performance test**
  - Elastic scattering and transfer channels well known
  - Particle ID/resolution: protons to ^{12}C
  - Many-body final states – identify all 4 α particles?

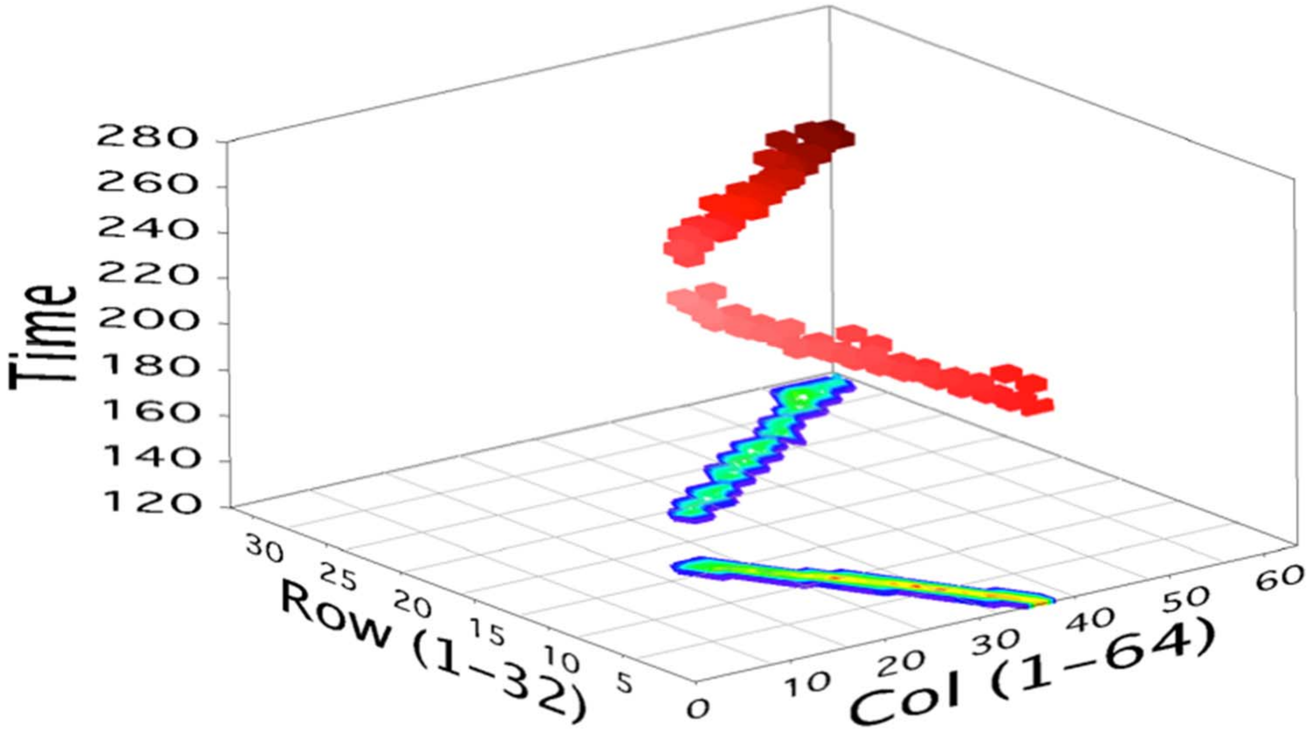
- **Electronics : A relatively complex setup**
  - 256 strips DSSD (0°) + 12 Si detectors (sides)
    - Trigger with multiplicity = 1 (in GET)
  - 2048 channels for the pads (triggered by the Si)

Are providing important feedback for the final design of ACTAR TPC and for the validation of ACTARSim code (GEANT4 simulation)

ACTAR TPC @ IPNO

^{12}C on $He:C_4H_{10}$

- **2-particle event**



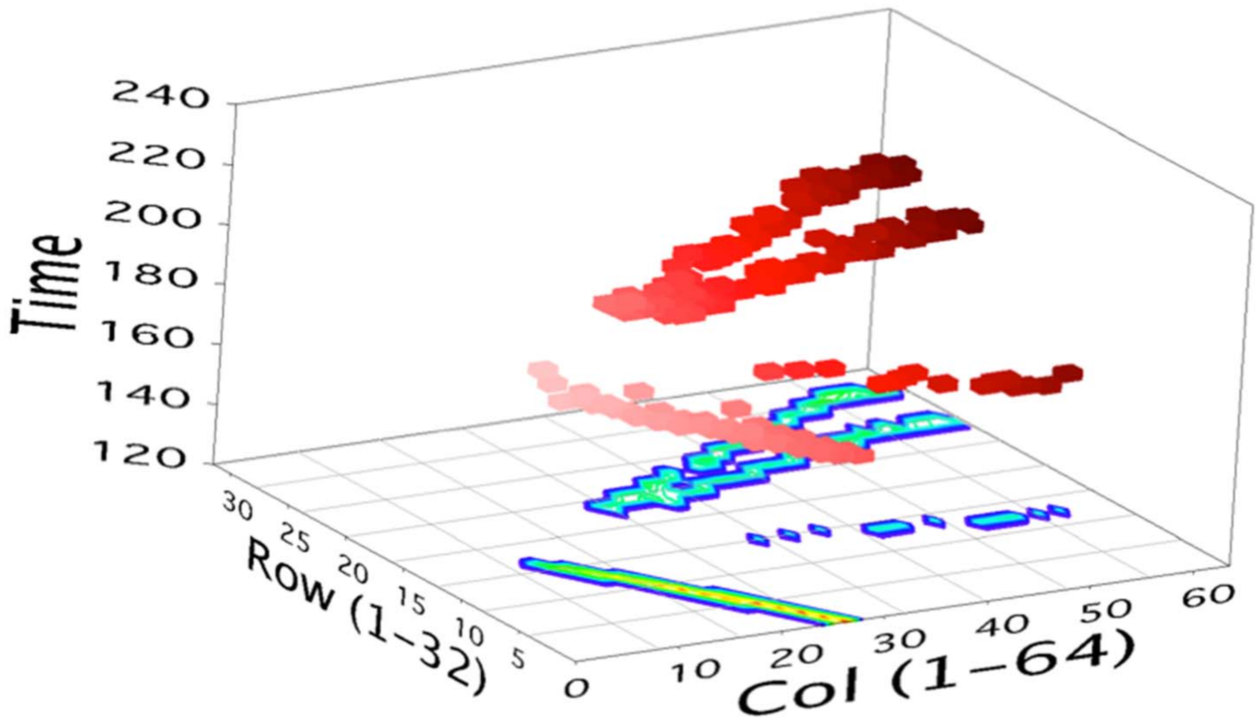
KU LEUVEN

Courtesy of G.F. Grinyer

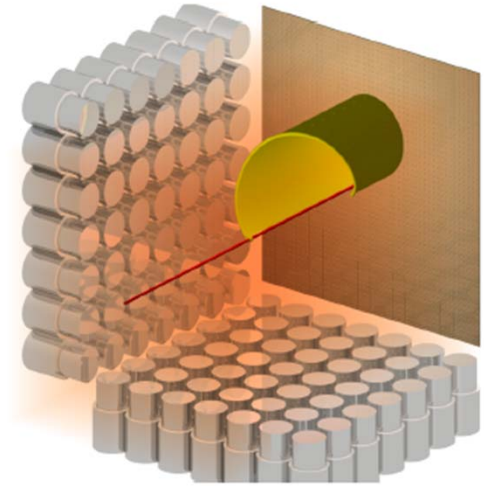
ACTAR TPC @ IPNO

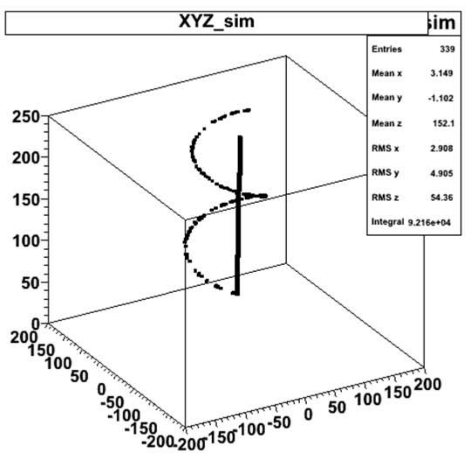
^{12}C on $He:C_4H_{10}$

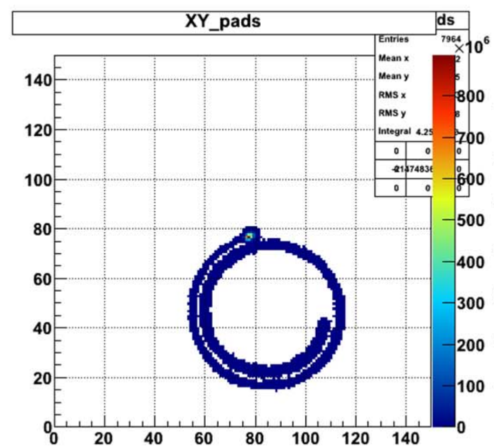
- **4-particle event**

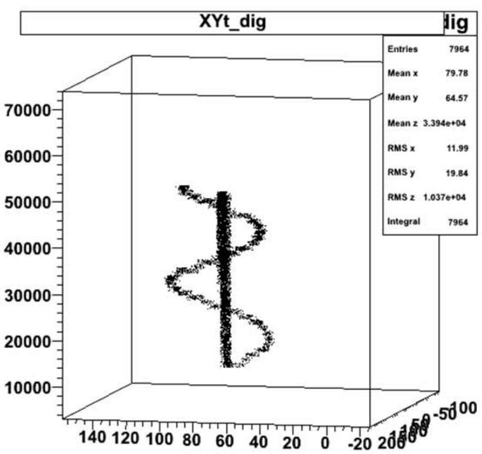


SpecMAT




XYZ_sim
Entries 339
Mean x 3.149
Mean y -1.102
Mean z 152.1
RMS x 2.908
RMS y 4.905
RMS z 54.36
Integral 9.216e+04


XY_pads

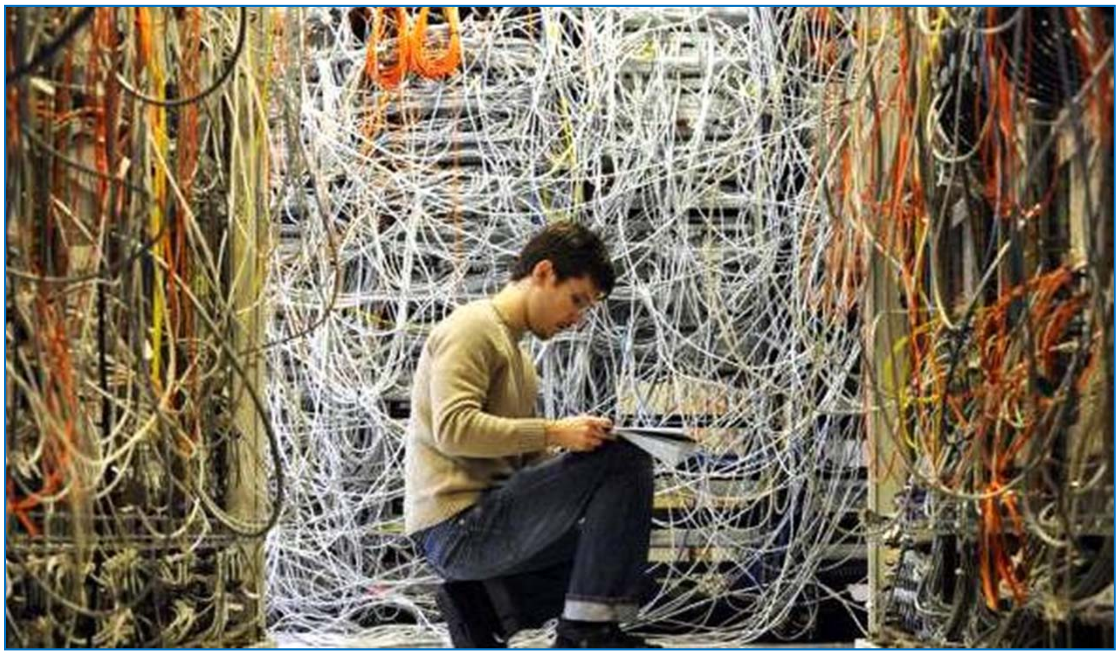

XYt_dig
Entries 7964
Mean x 79.78
Mean y 64.57
Mean z 3.394e+04
RMS x 11.99
RMS y 19.84
RMS z 1.037e+04
Integral 7964

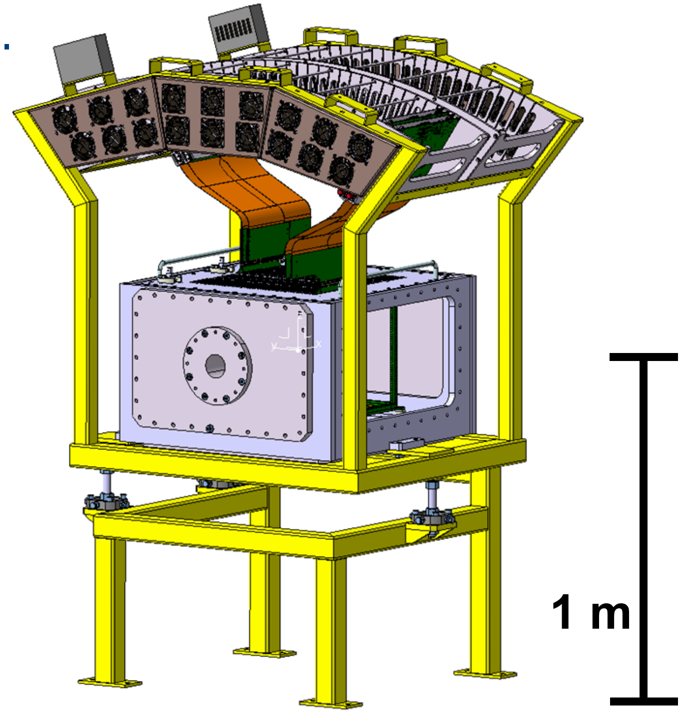
High channel numbers

- 2048 - ACTAR TPC Demonstrator, based at GANIL, Caen
- 10 024 – ATTPC Detector at NSCL, Michigan
- ~ the same for SpecMAT
- 16 284 – ACTAR TPC Detector

Concept electronics – ACTAR TPC
All 16284 ch. fit in these 2 racks

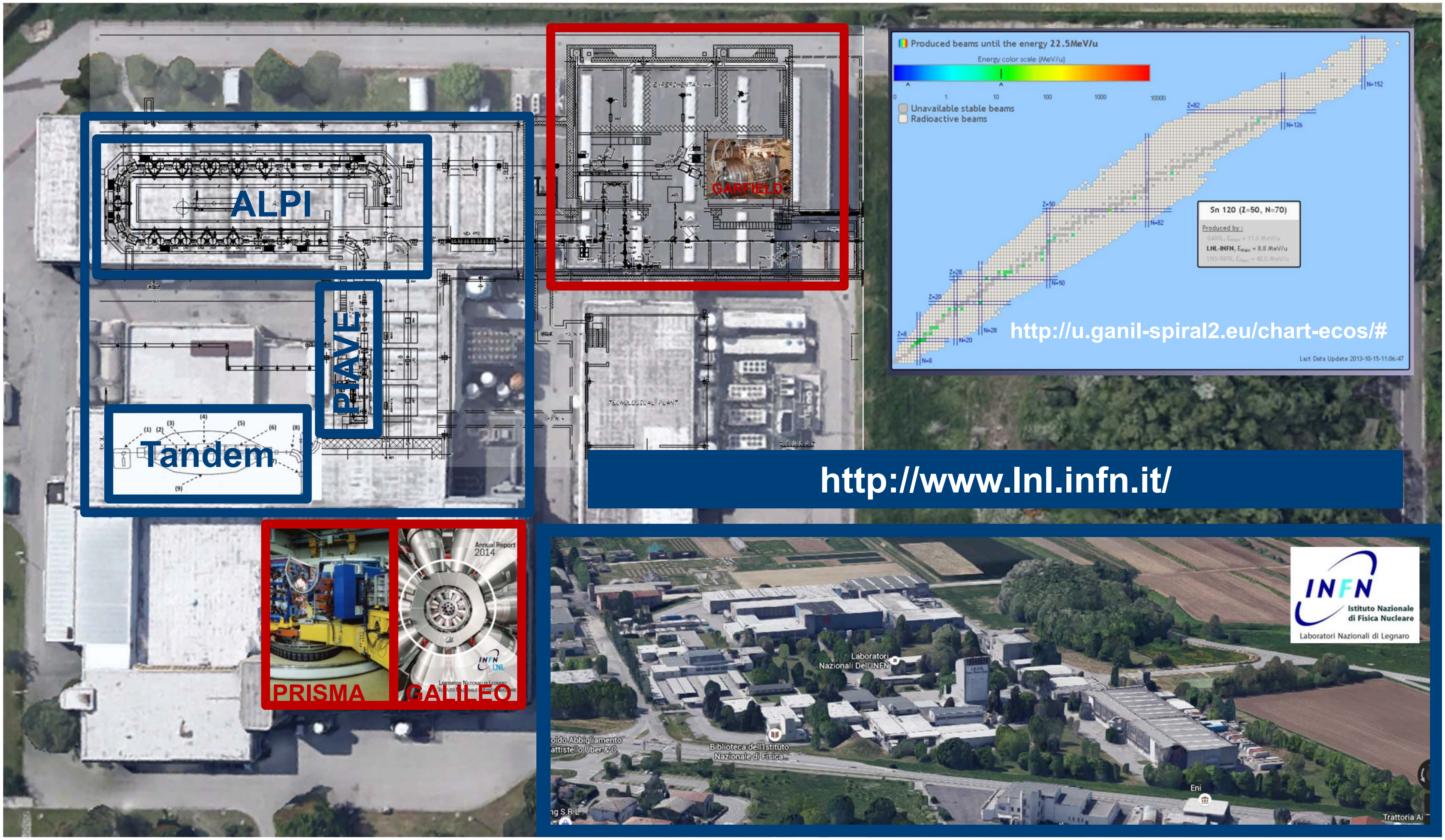
Point-to-point connections could lead to unpleasantness..





Work of P. Gangnant

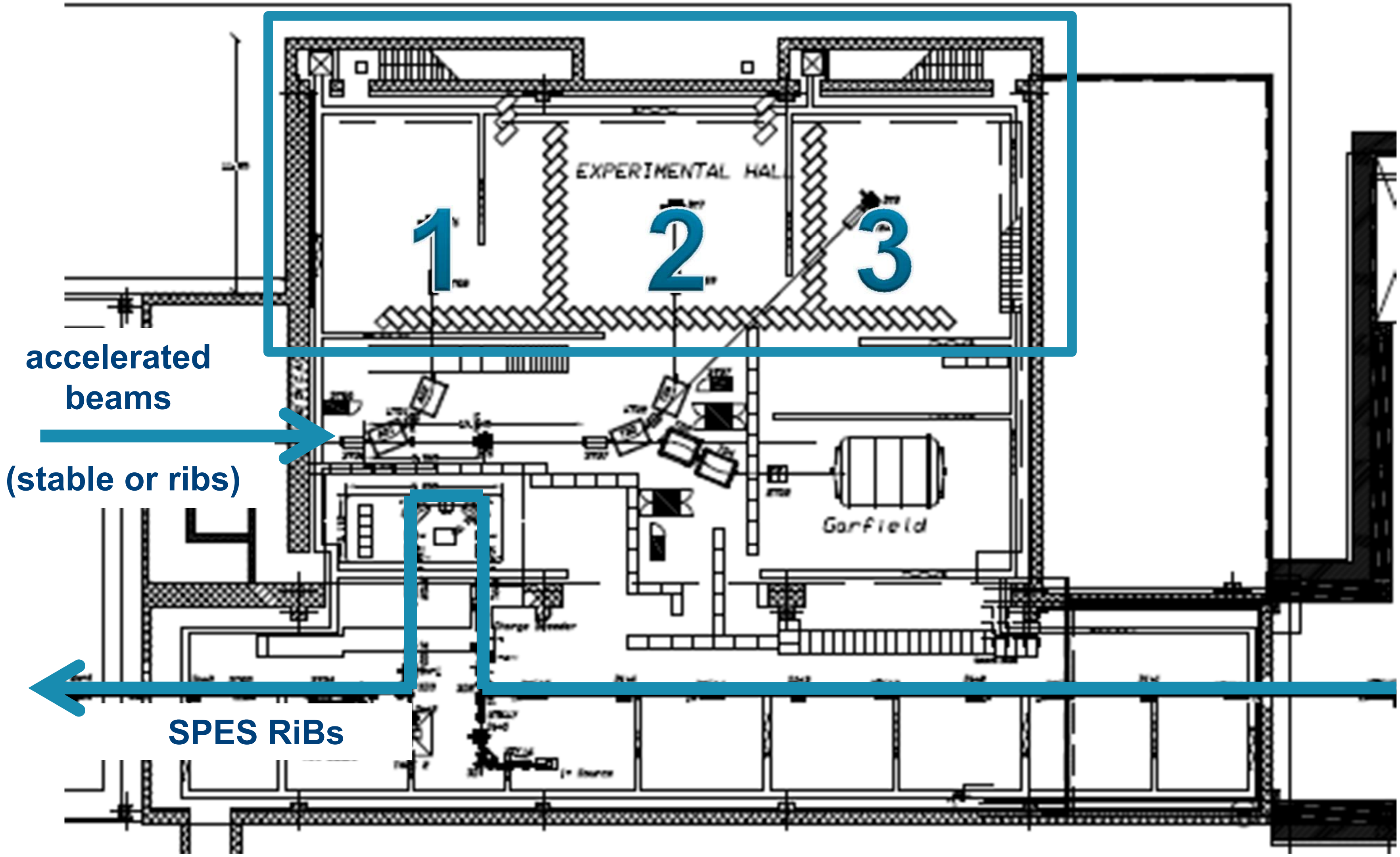
An Active Target for SPES-β



KU LEUVEN

LNL detector’s portfolio

Experimental area for an active target at SPES



KU LEUVEN

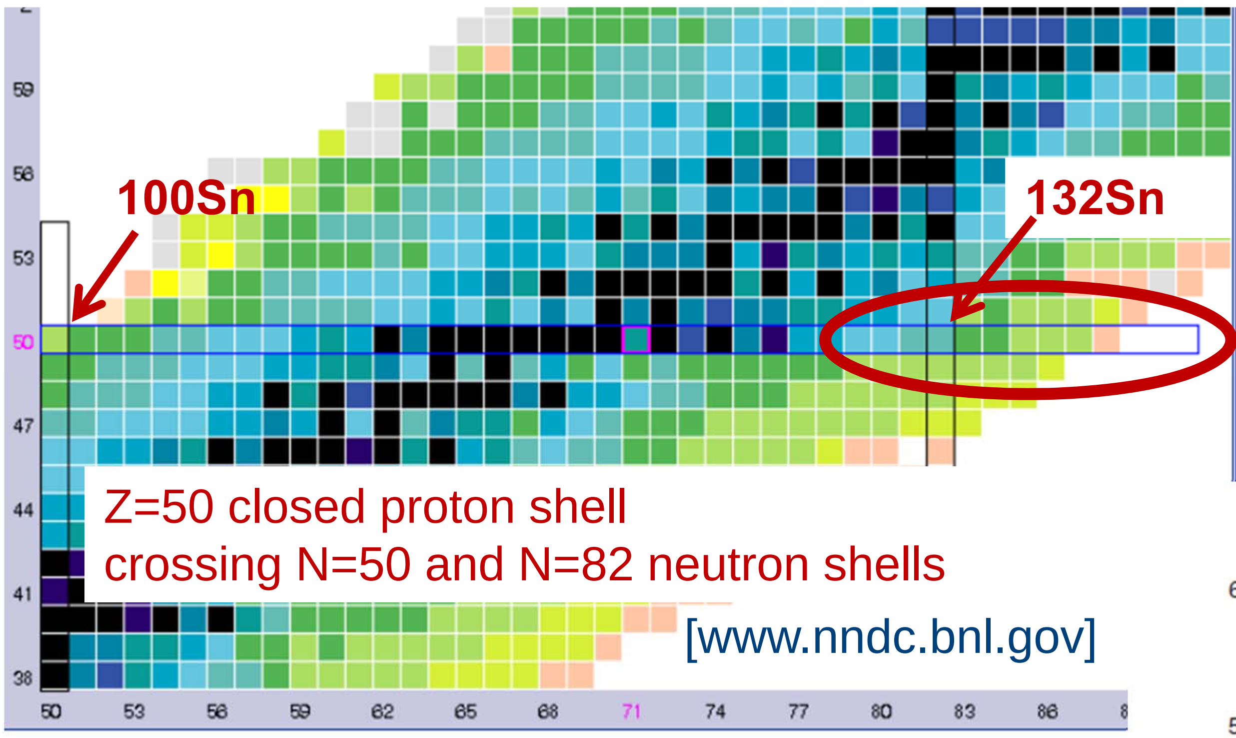
MagicTin

MARIE CURIE ACTIONS

KU LEUVEN

Shell evolution and collectivity in Tin isotopes

MagicTin



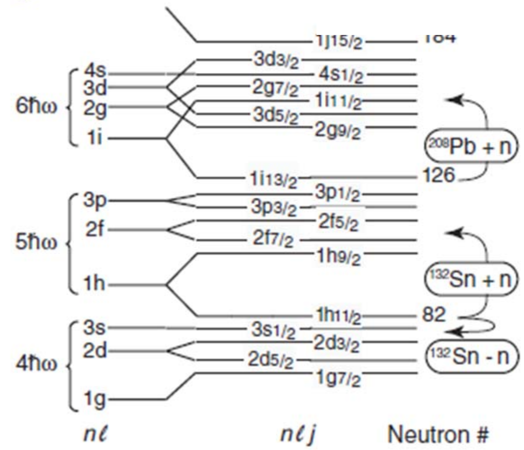
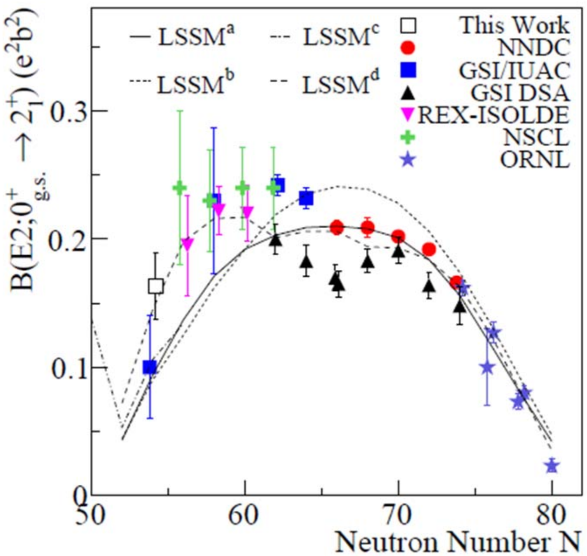


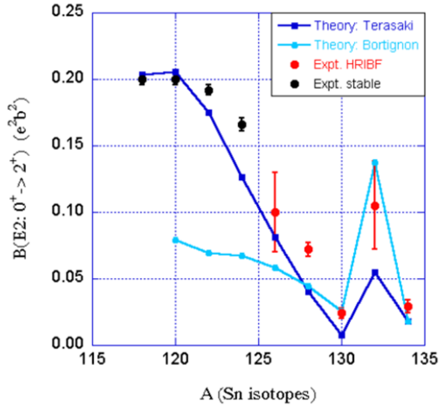
FIG. 1. Single-neutron states expected to be populated in the present one-neutron transfer study of ^{131,133}Sn and ^{209}Pb.

KU LEUVEN

Shell evolution and collectivity in Tin isotopes

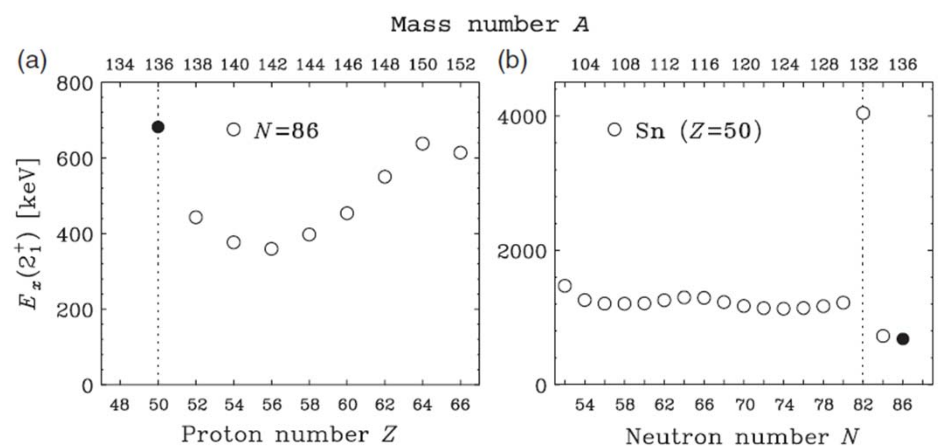


[V.M. Bader et al, PRC 88, 051301(R) (2013)]



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

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



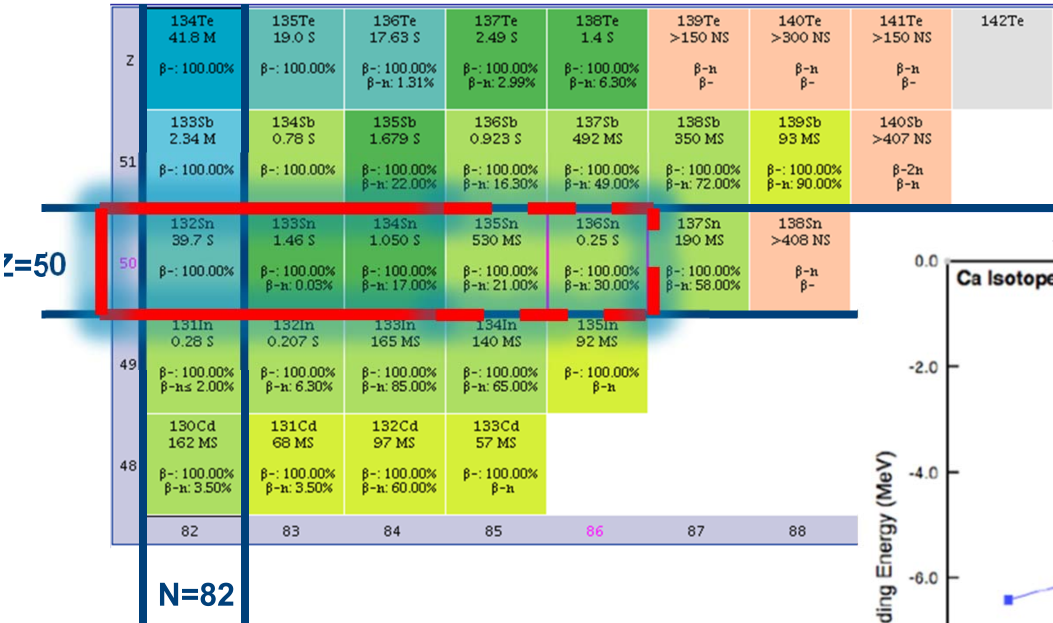
^{9}Be(^{137}Sb,^{136}Sn) @ RIKEN
DALI2 (186 NaI(Tl)~22% eff)

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

KU LEUVEN

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

MagicTin*



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

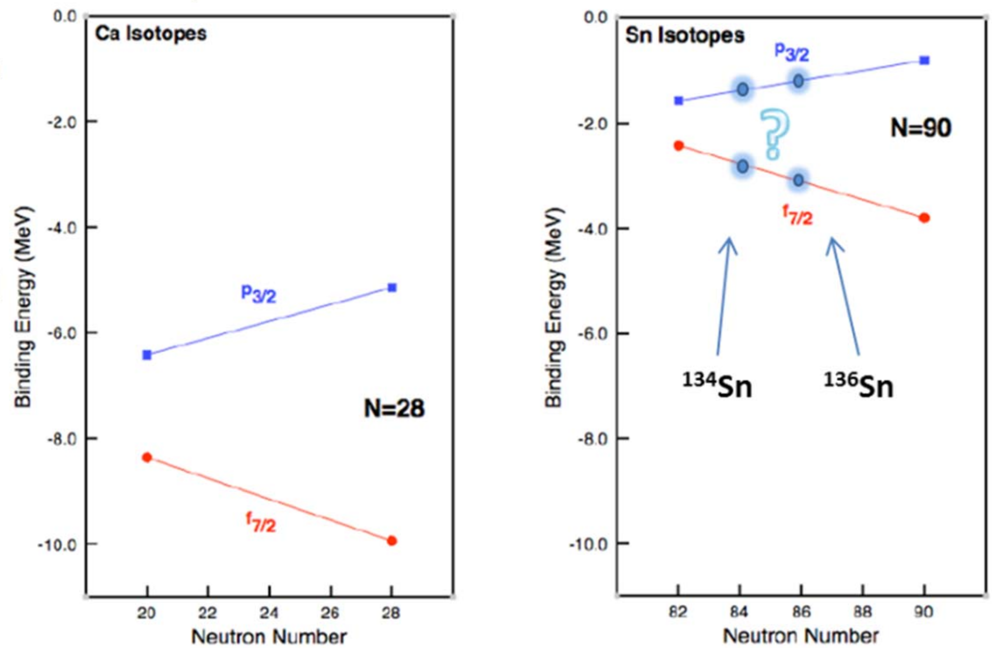
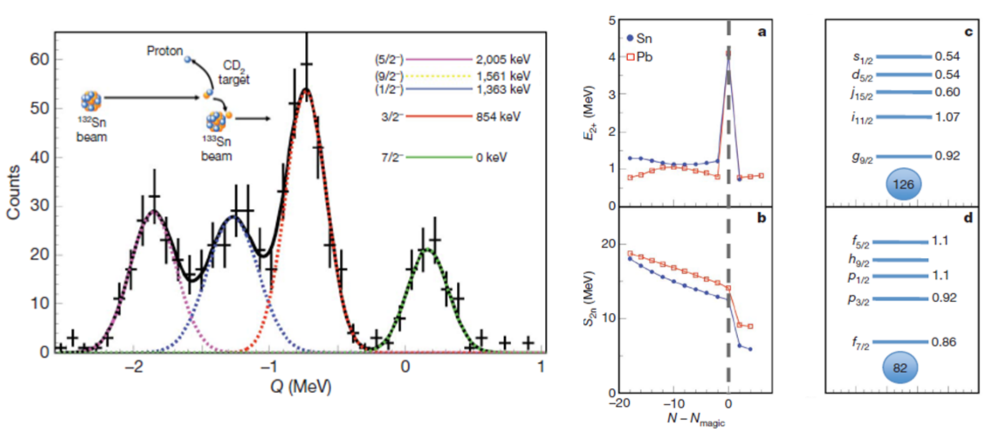


Fig.1 Analogy between f7/2 and p3/2 evolution of binding energies in the known Ca isotopes to what could be expected for the Sn isotopes approaching N=90. Figure adapted from[13].

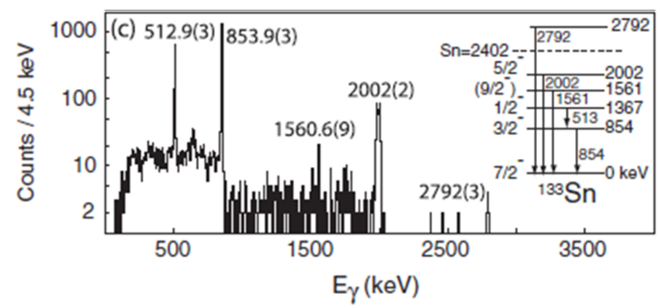
Getting more details - transfer reactions

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

KU LEUVEN

Possible setup and beams

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

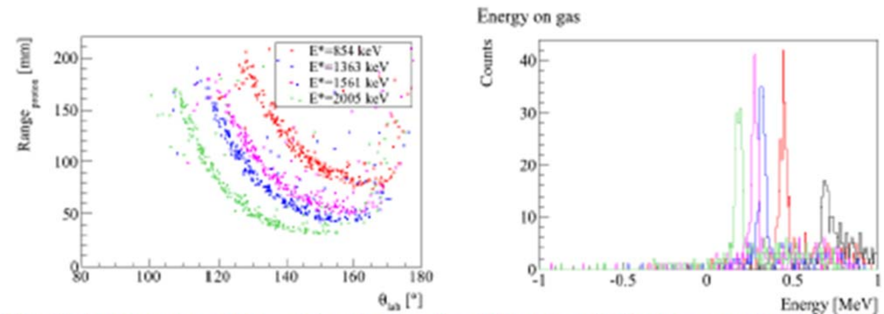


Fig. 5: Reconstructed kinematics plot for the different excited states populated in ^{133}Sn for protons stopped in the gas at a pressure of 400 mbar. Note that the majority of protons populating the ground state escape the gas and the resolution is thus slightly degraded.

Stopped in gas: ~ 110 keV FWHM res

ACTAR + Si wall

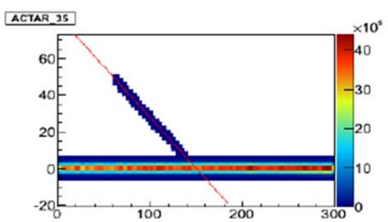
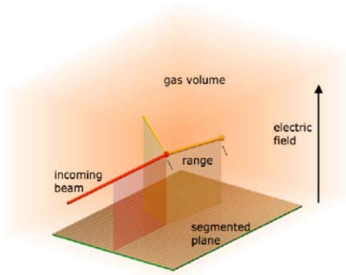


Fig. 4: Sample digitized trace for a ^{132}Sn(d,p) reaction with 2x2mm^2 sized pads. The red line corresponds to the fitted trajectory used for determining the range of the proton.



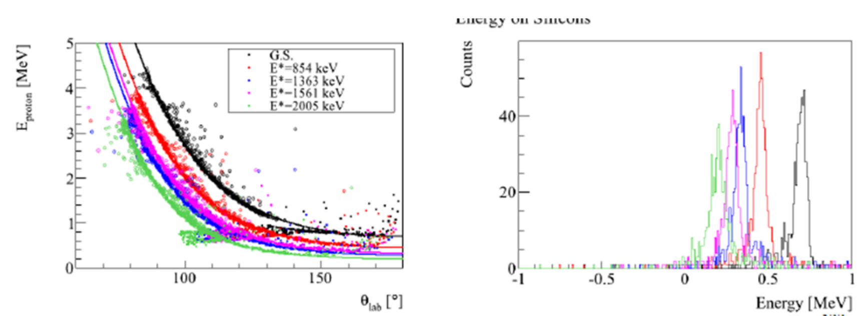


Fig. 6: Reconstructed kinematics plot for the different excited states populated in ^{133}Sn for protons stopped in the Si detectors (open circles) and stopped in the gas (closed circles).

^{132}Sn(d,p)^{133}Sn @ 5 AMeV
400 mbar D_2

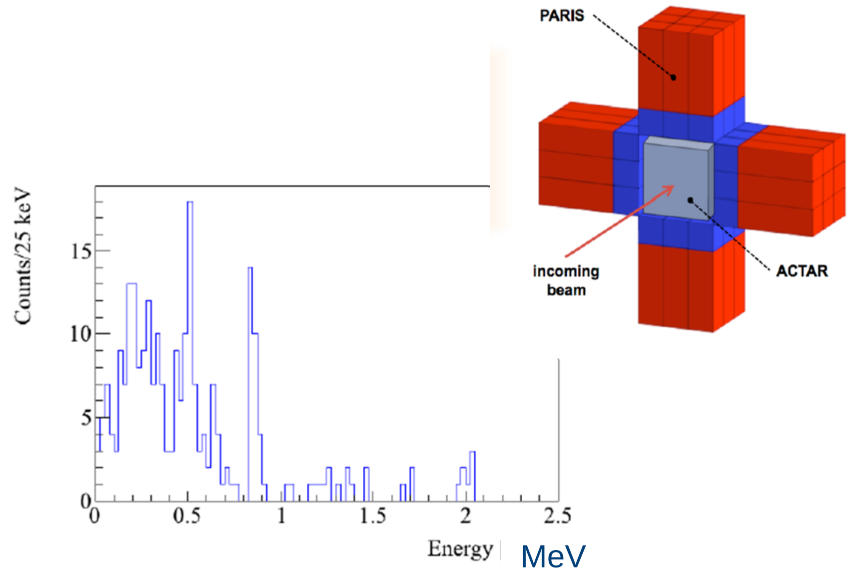
Gas-Si (ΔE-E): ~ 90 keV FWHM res

[D..Perez-Loureiro and G.F.Grinyer, ACTARsim Report (2013)]

Improving resolution with gamma-ray detectors

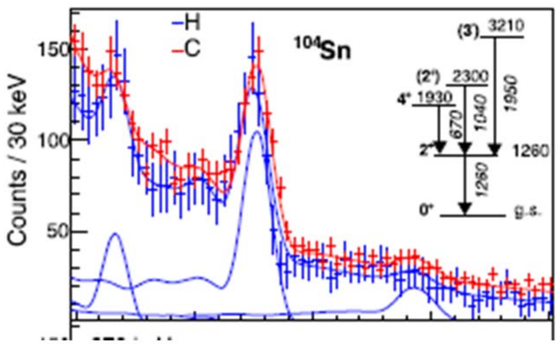
- γ-rays in PARIS-like detectors
from population of 854, 1363, 2005 keV states in ^{133}Sn

- Statistics corresponding to 2 days of beam time at 10^3 pps (total cross section 10 mb, photopeak eff 17%)



Issue: might reduce global efficiency

Further steps… (p,p')



[A. Corsi et al, PLB 743 (2015) 451]

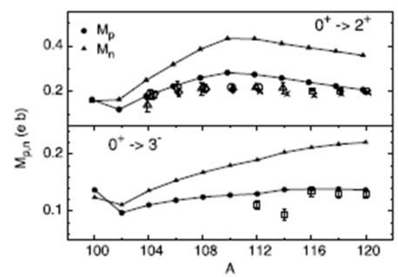
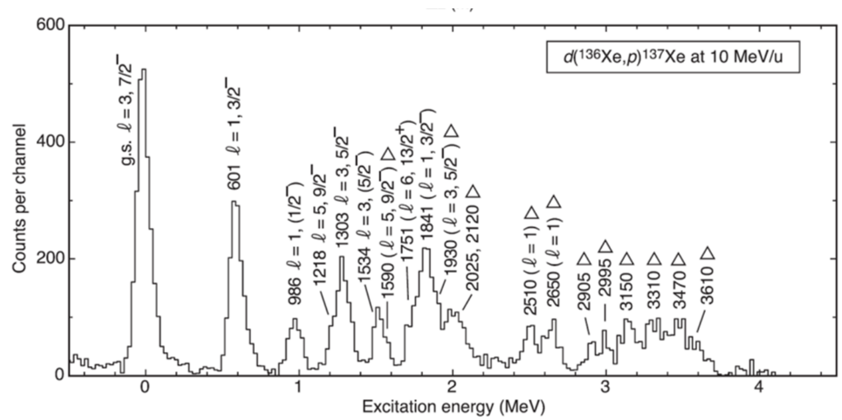


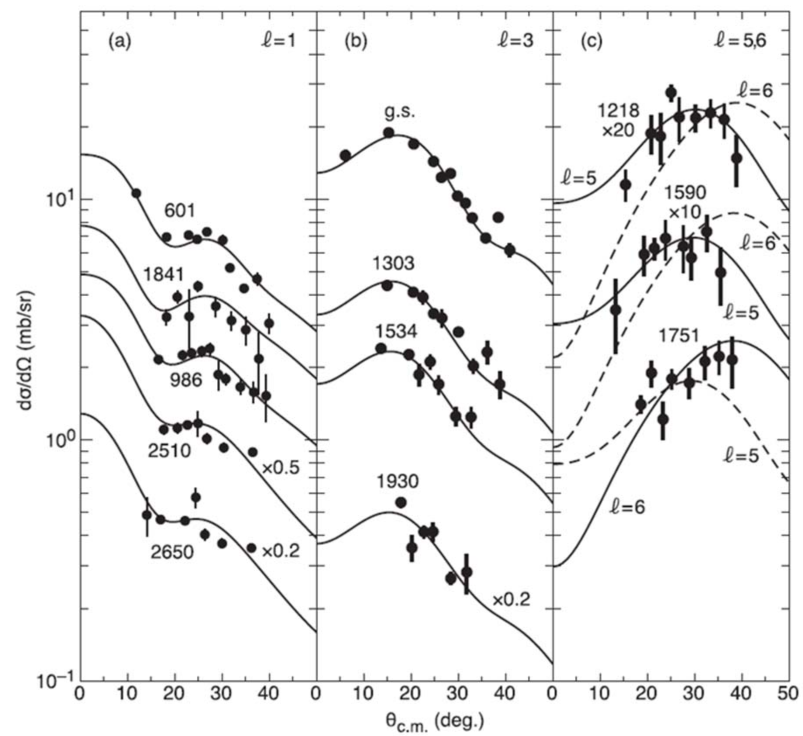
Fig. 4. M_p (•) and M_n (▲) from QRPA calculations with the Gogny D1M interaction compared to experimental M_p (▽: RIKEN [14], ○: NSCL [9,13], ×: GSI Doppler Shift Attenuation Method [34], △: GSI Coulomb excitation [6,10–12], ◇: ISOLDE [7,8], □: NNDC [28]). Top: 2^+_1. Bottom: 3^-_1. Experimental M_n values are taken from the literature [22].

Getting ready for RIBs: MT implementation

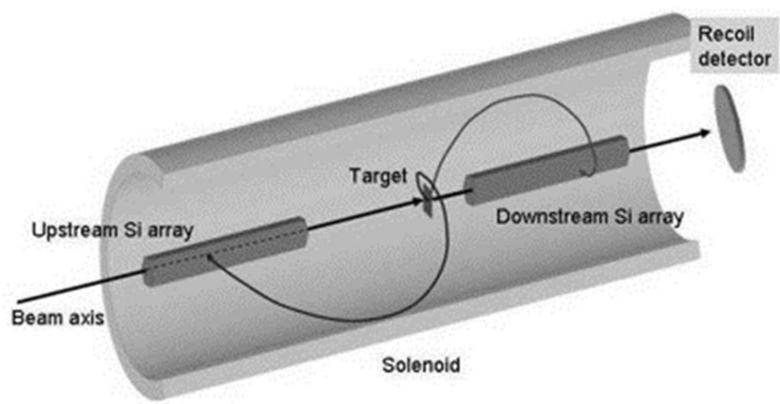
MagicTin

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





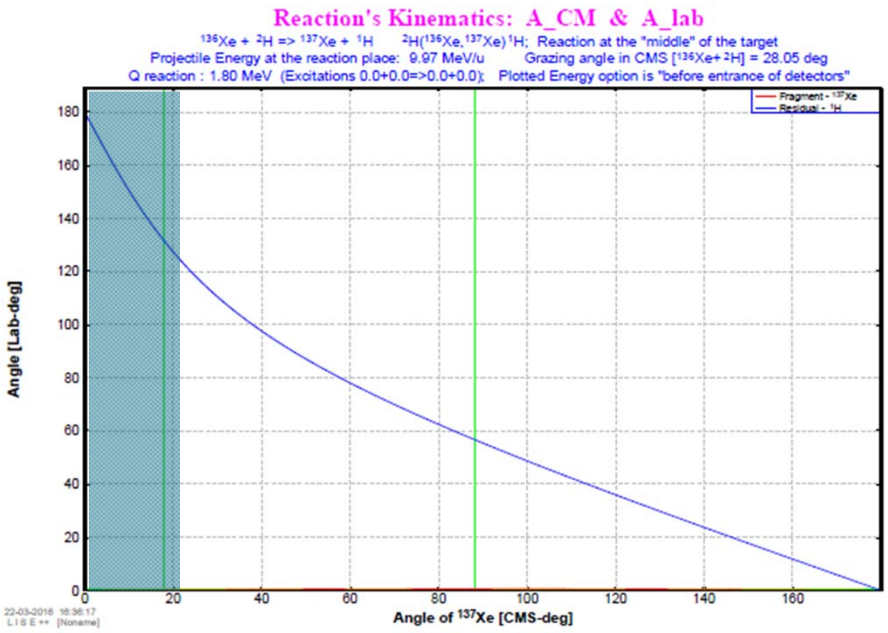
B.P. Kay et al, PRC 84 0243325 (2011)
HELIOS @ ANL

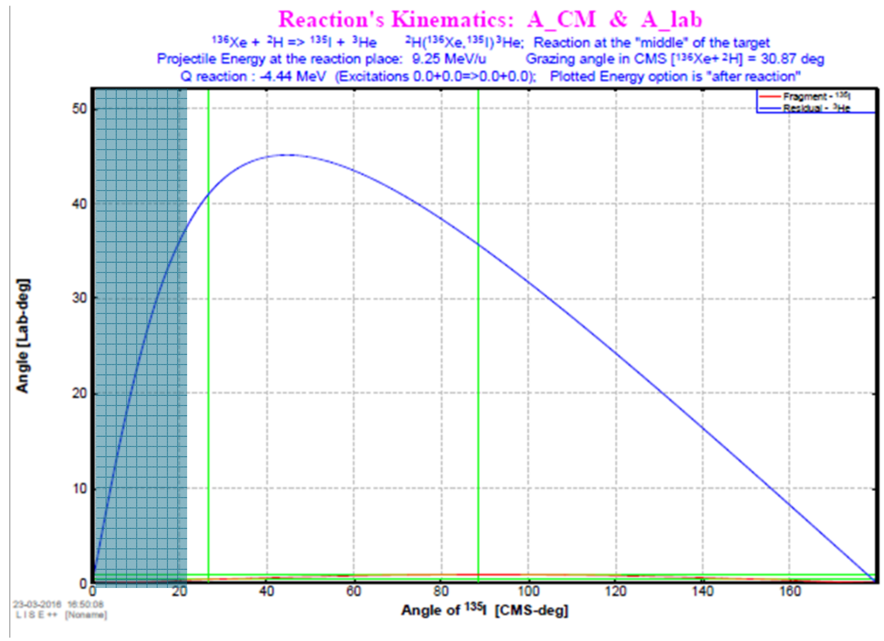


KU LEUVEN

Does kinematics help?

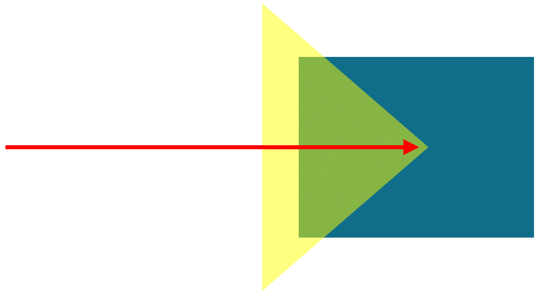
MagicTin*

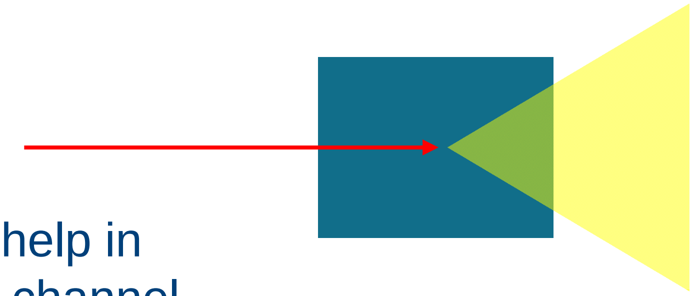




^{136}Xe(d,p)^{137}Xe - inv kinem

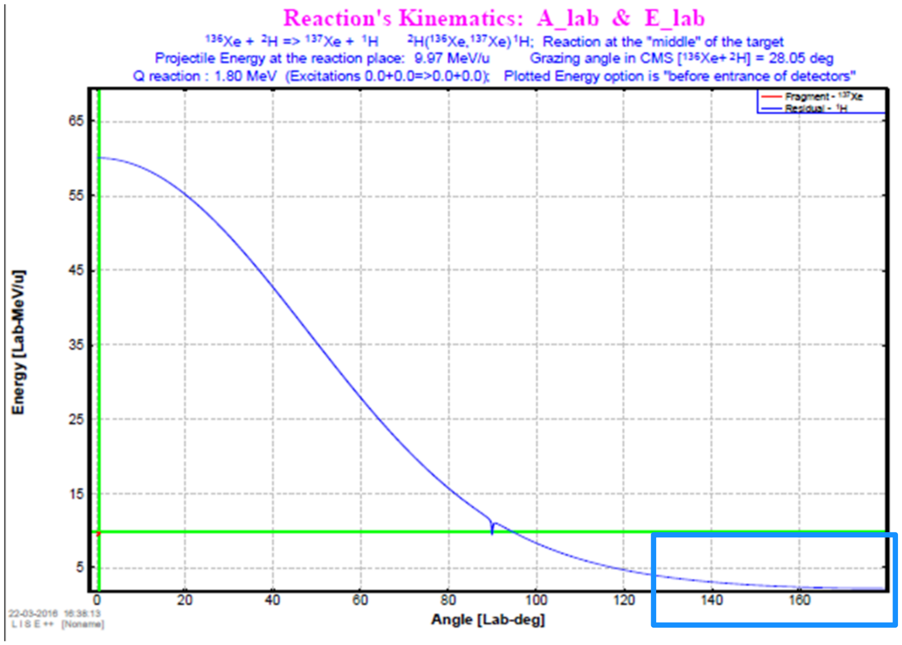
^{136}Xe(d,^{3}He)^{135}Ie - inv kinem

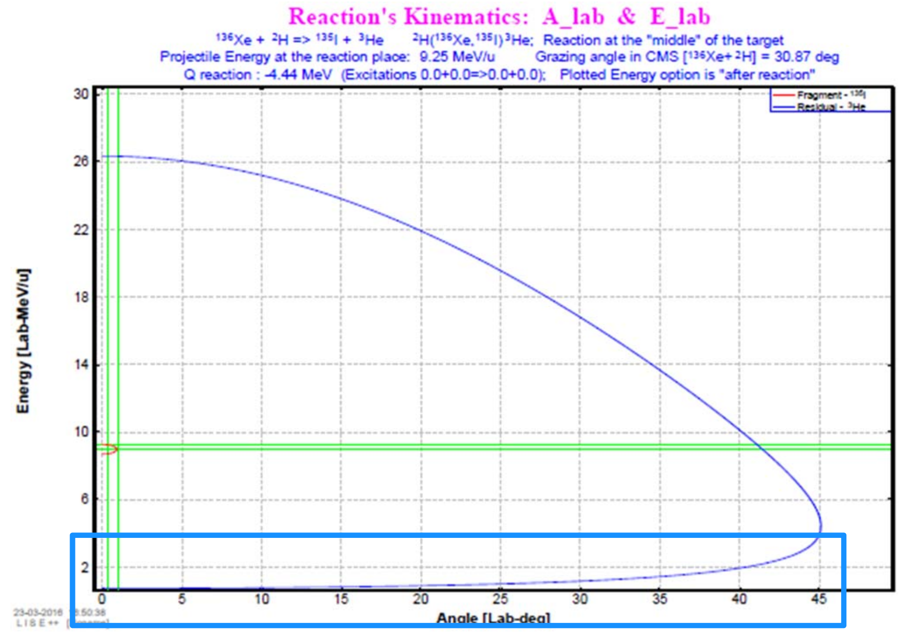




Kinematics seems to help in selecting the reaction channel

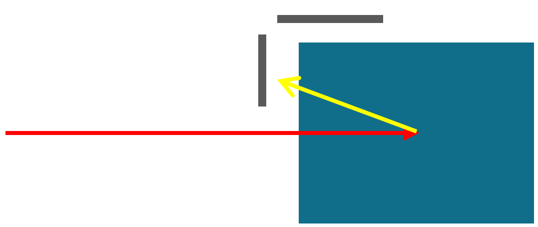
Or not?



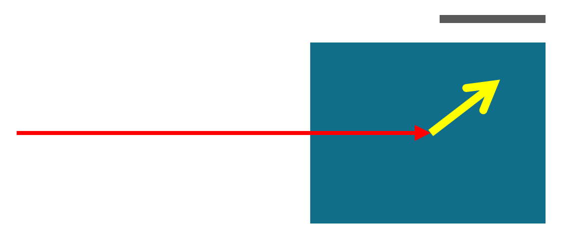


^{136}Xe(d,p)^{137}Xe - inv kinem

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



Tradeoff:
Range vs good
tracking



Using heavy ion beams - simulations

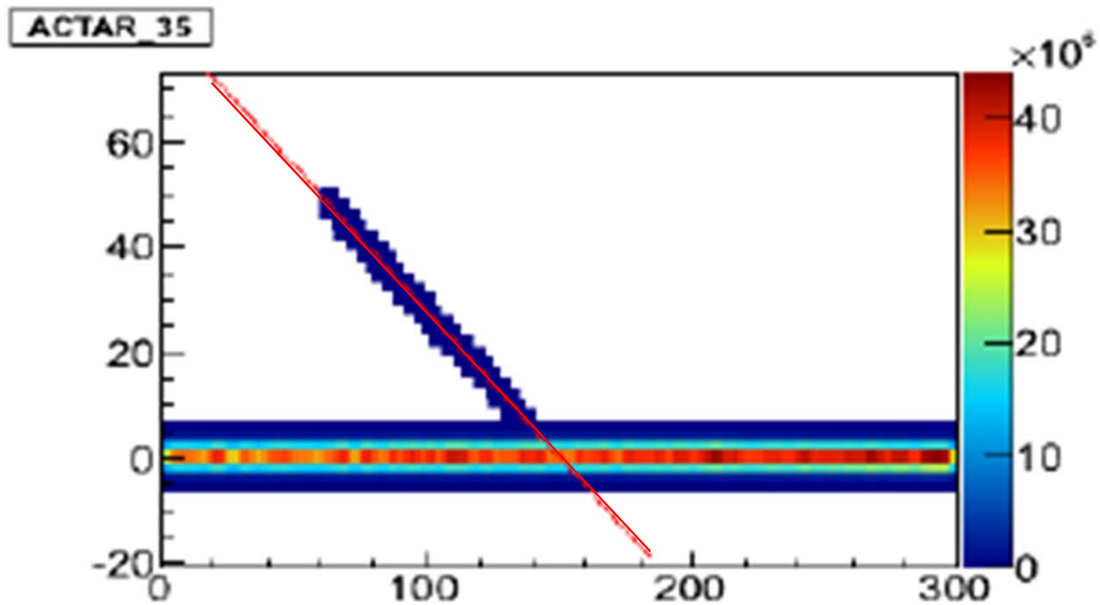


Fig. 4: Sample digitized trace for a ^{152}Sn(d,p) reaction with 2x2mm^2 sized pads. The red line corresponds to the fitted trajectory used for determining the range of the proton.

Beam Shielding

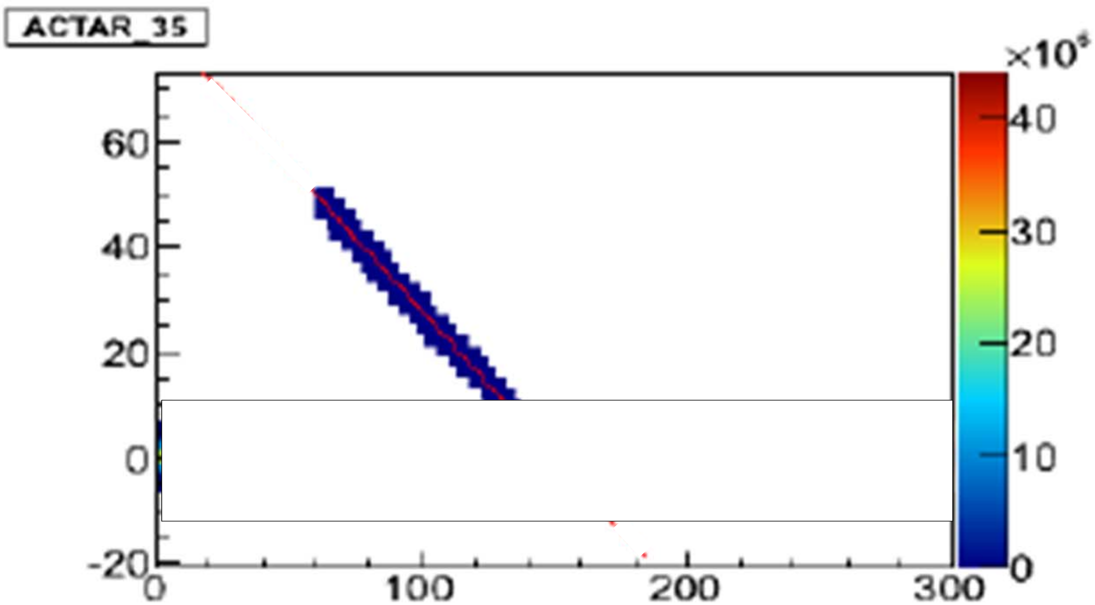


Fig. 4: Sample digitized trace for a ^{152}Sn(d,p) reaction with 2x2mm^2 sized pads. The red line corresponds to the fitted trajectory used for determining the range of the proton.

Tracking

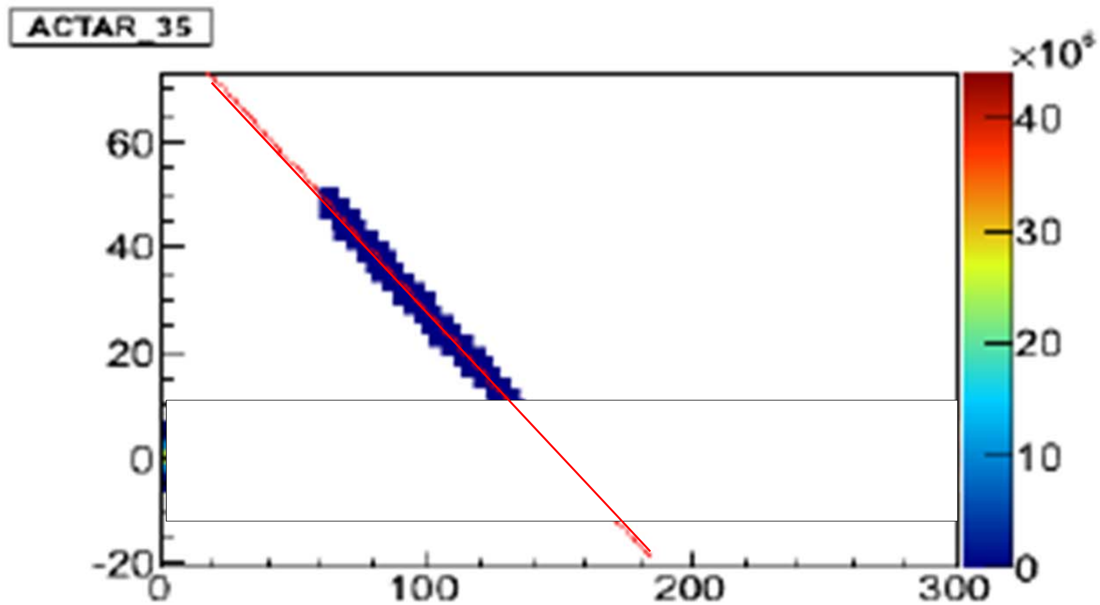


Fig. 4: Sample digitized trace for a ^{152}Sn(d,p) reaction with 2x2mm^2 sized pads. The red line corresponds to the fitted trajectory used for determining the range of the proton.

Tracking

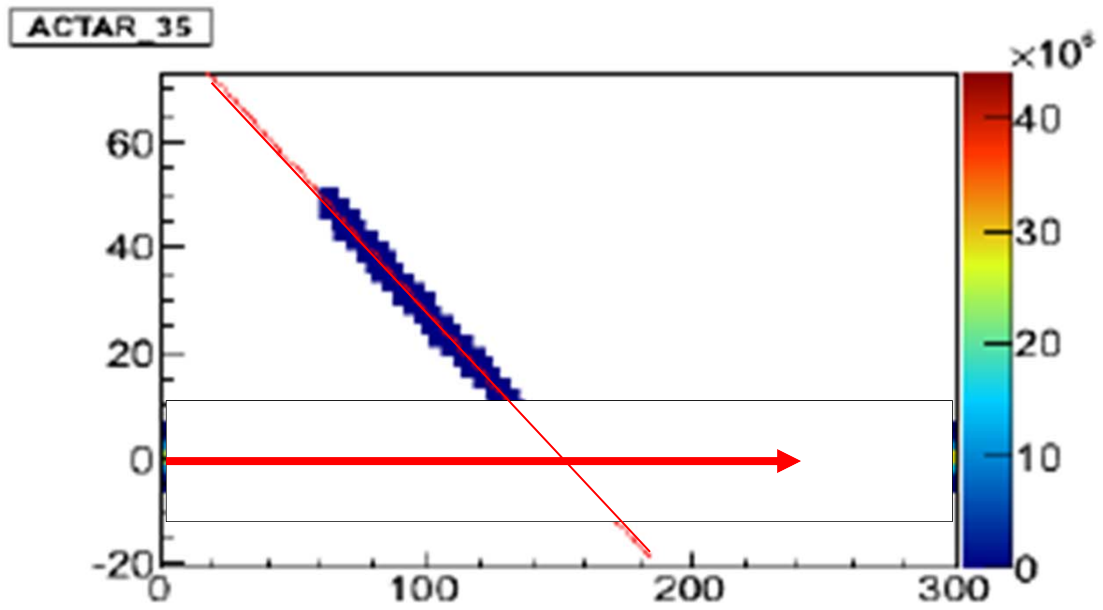
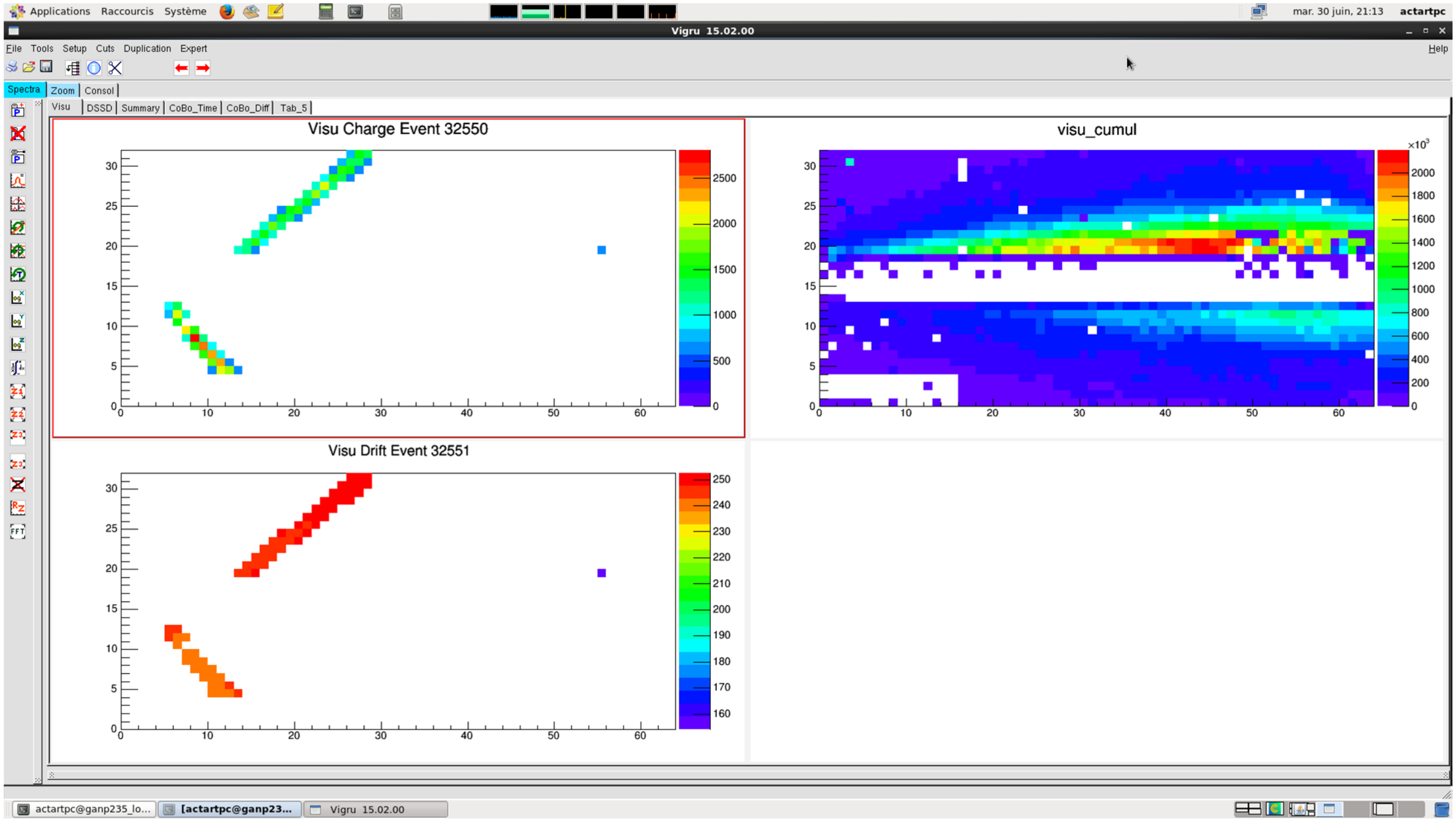
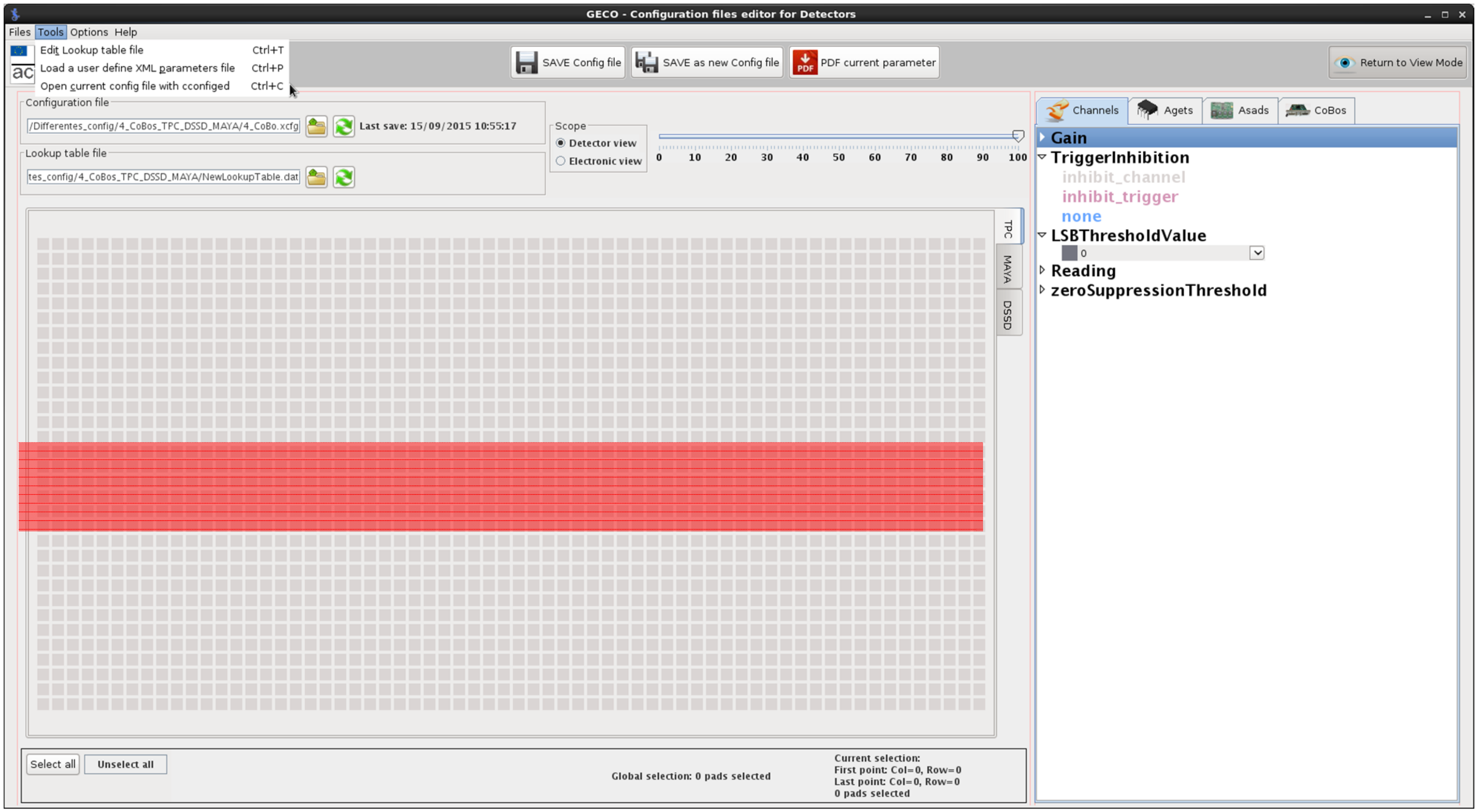


Fig. 4: Sample digitized trace for a ^{152}Sn(d,p) reaction with 2x2mm^2 sized pads. The red line corresponds to the fitted trajectory used for determining the range of the proton.

2 or more particle events

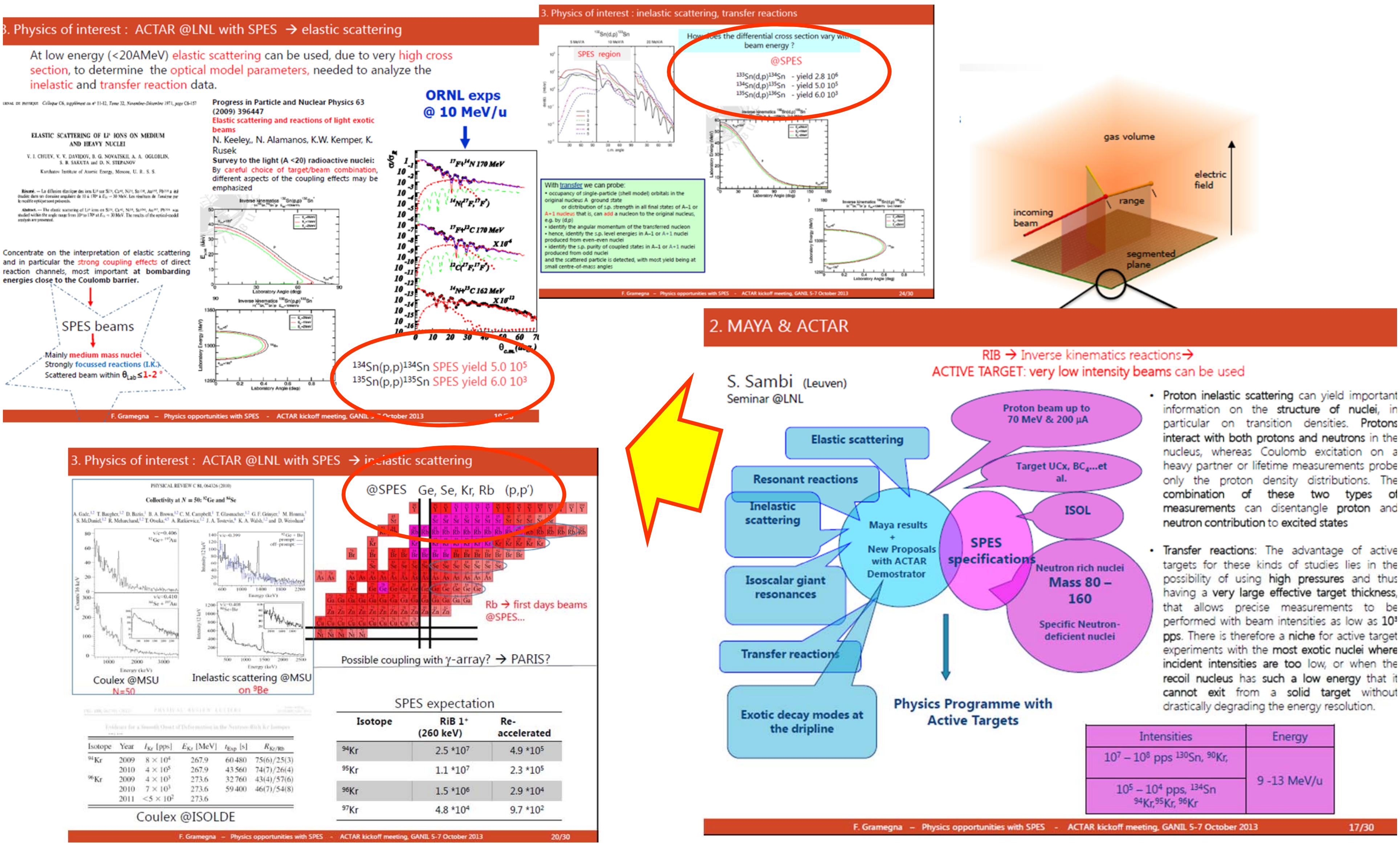


Looking for a smart solution



KU LEUVEN

Beyond MagicTin: physics opportunities with an active target at SPES

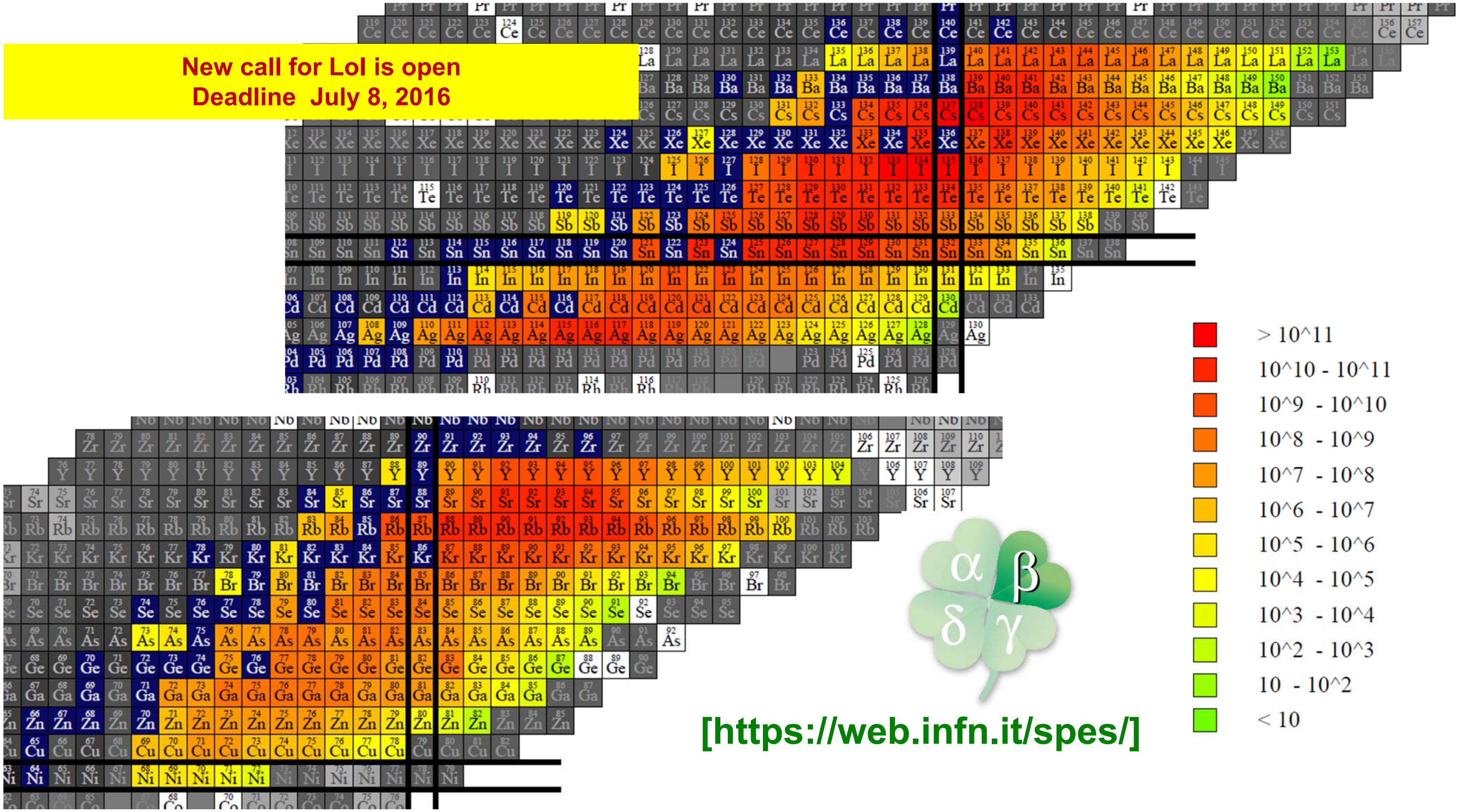


KU LEUVEN

[F. Gramegna, ACTAR TPC Kickoff meeting 2013]

Beyond MagicTin: physics opportunities with an active target at SPES

New call for LoI is open
Deadline July 8, 2016



[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

ENSAR2 Network Activity: Gas Detection Systems

W.P. Leader: G.F. Grynier (GANIL)
Deputy Leader: F. Gramegna (LNL)

Task 1: … gather together the GDS community …

4 topical meetings

Task 2: GDS in strong and non-uniform magnetic fields

Task 3: Novel detection systems for high-intensity and heavy beams

Task 4: Rare gas target handling and recycling systems

Task 5: Auxiliary detectors

Thank you!