

APRENDE

TAGS Measurements: Status and Perspectives

GANIL Colloquium, Bussang, 2026

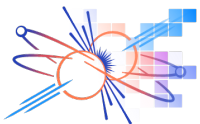


European

This project has received funding from the European Union's Horizon Europe Euratom Research and Training Programme (EURATOM) under Grant Agreement No: 101164596-APRENDE

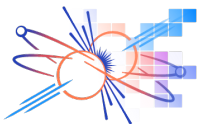


- 👁️ **Intro: What is/Why the TAGS technique ?**
- 👁️ **Total Absorption Spectrometers & Experiments**
- 👁️ **(NA)²STARS Project**
- 👁️ **(NA)²STARS First Experiment at LISE, GANIL**
- 👁️ **Conclusions & Perspectives**



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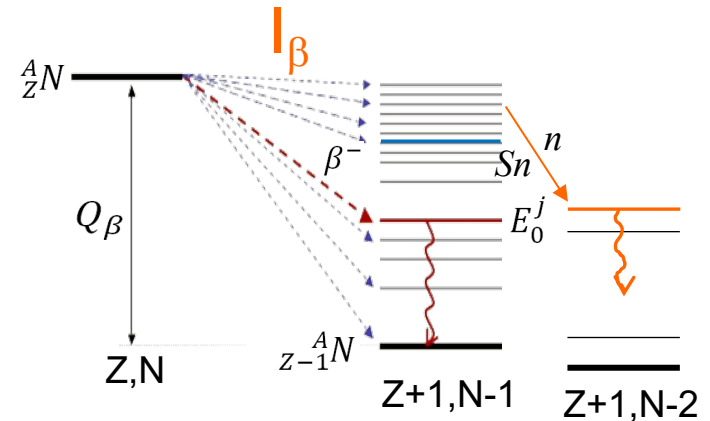
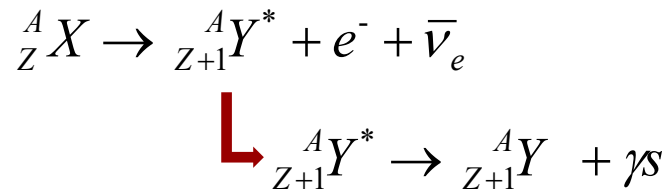
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Getting access to the β decay properties

● Gamma-ray spectroscopy:

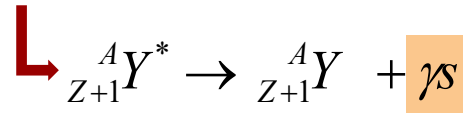
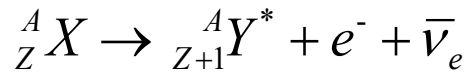


● Electron measurement:

$$S_{fp}(Z, A, p) \propto \sum_{b=1}^{N_b} I_{\beta_{fp}}^b \times S_{fp}^b \left(Z_{fp}, A_{fp}, E_{0_{fp}}^b, E \right)$$

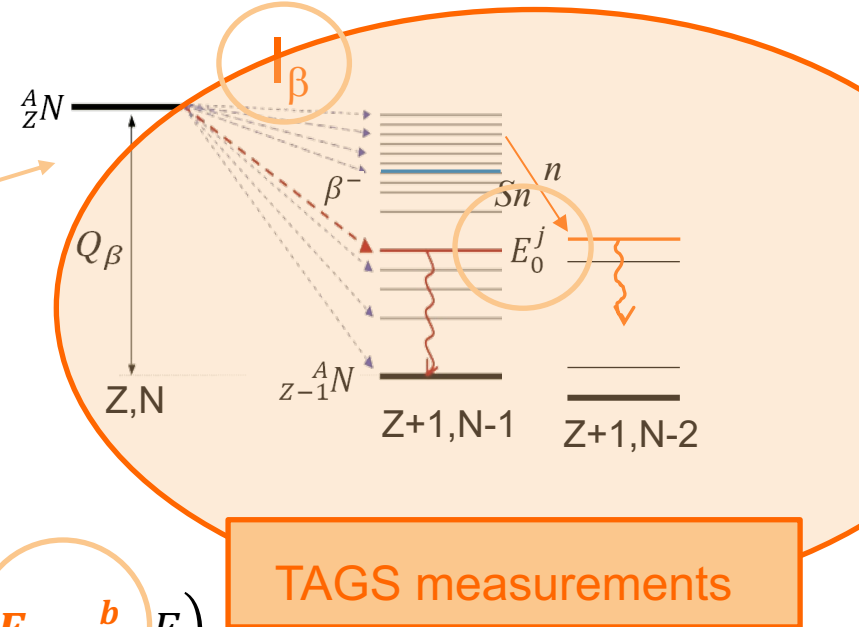
Getting access to the β decay properties

- Gamma-ray spectroscopy:



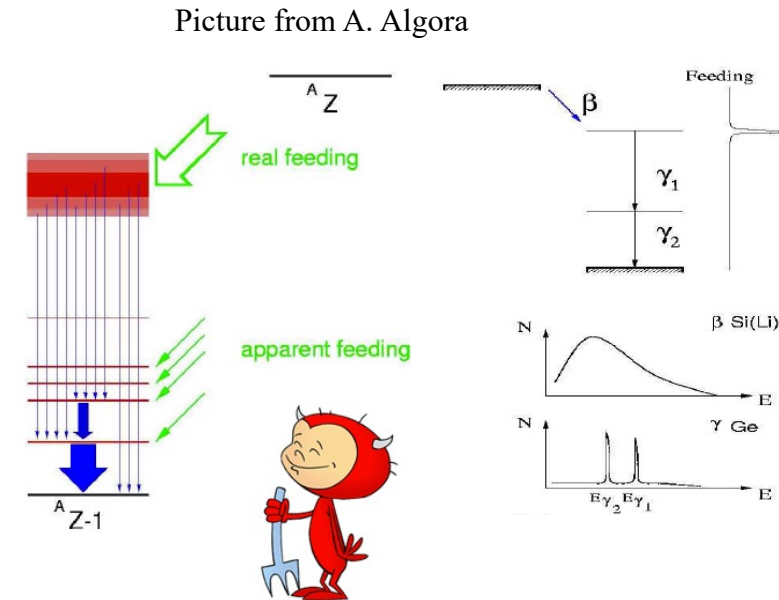
- Electron measurement:

$$S_{fp}(Z, A, p) \propto \sum_{b=1}^{N_b} I_{\beta_{fp}}^b \times S_{fp}^b(Z_{fp}, A_{fp}, E_{0_{fp}}^b, E)$$



γ Measurement Caveat

- Before the 90's, conventional detection techniques:
high resolution γ -ray spectroscopy
 - ❑ Excellent resolution but efficiency which strongly decreases at high energy
 - ❑ Danger of overlooking the existence of β -feeding into the high energy nuclear levels of daughter nuclei (especially with decay schemes with large Q-values)
- Incomplete decay schemes: overestimate of the high-energy part of the associated β spectra
- Phenomenon commonly called « pandemonium effect** » by J. C Hardy in 1977



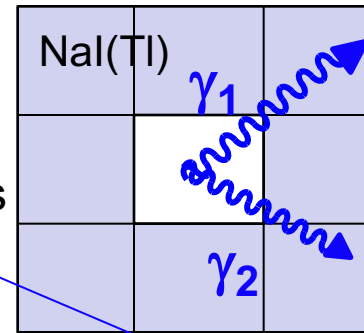
** J.C.Hardy et al., Phys. Lett. B, 71, 307 (1977)

➡ Strong potential bias in nuclear data bases and all their applications

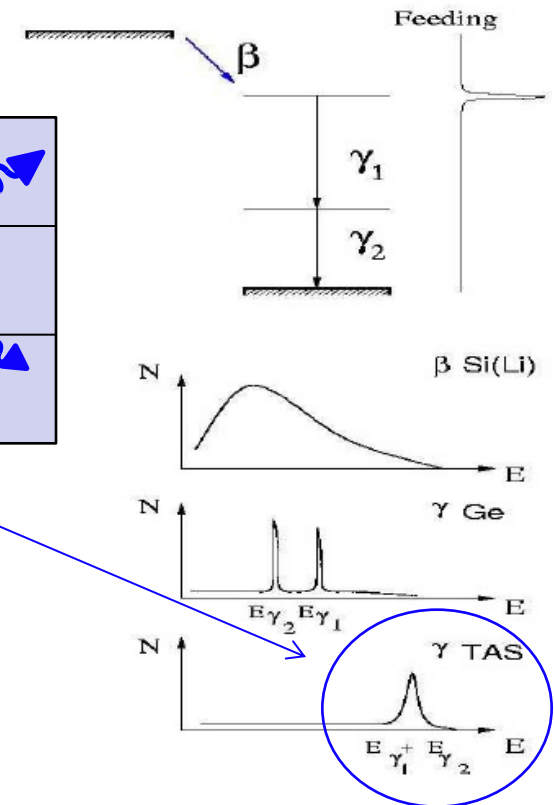
TAGS: a Solution to the Pandemonium Effect

● Total absorption γ -ray spectroscopy (TAGS)

- ❑ A TAS is a **calorimeter**
- ❑ It contains big crystals **covering 4π**
- ❑ Instead of detecting the individual gamma rays, absorbs the full gamma energy released by the gamma cascades in the β -decay process



- First TAS developed in the 70's but too small detectors to be efficient. Development of the TAGS method **efficient and systematic since the 90's** (Greenwood & al.)



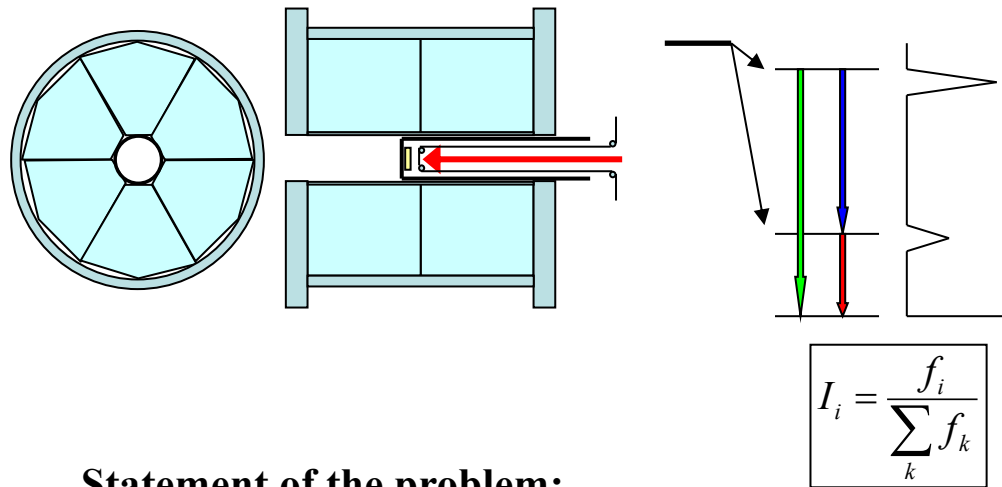
- Calculation of level energy feeding through the resolution of the inverse problem by deconvolution

- ❑ R_{ij} = matrix detector response: must be accurately known
- ❑ d_i = measured data: must be clean off contaminants
- ❑ Extract f_j the level feeding by deconvolution: solution of inverse problem must be stable

J. L. Tain & D. Cano-Ott,
 NIMA 571 (2007) 728
 NIMA 571 (2007) 719
 NIMA 430 (1999) 333
 NIMA 430 (1999) 488

Total Absorption γ -ray Spectroscopy (TAGS)

Big cristal, $4\pi \Rightarrow$ A TAS is a calorimeter !



Observable:

β -intensity $\Rightarrow$ β -strength:

An ideal TAS would give directly the β -intensity I_β which is linked with the β -strength S_β :

$$S_i = \frac{I_i}{f(Q_\beta - E_i)T_{1/2}} \quad [s^{-1}]$$

Statement of the problem:

Relation between TAS data and the β -intensity distribution:

$$d_i = \sum_j R_{ij} f_j$$



$$\mathbf{R}_j = \sum_{k=0}^{j-1} b_{jk} \mathbf{g}_{jk} \otimes \mathbf{R}_k$$

Monte Carlo
simulations
+
Nuclear statistical
model

Deconvolution (Inverse
problem) algorithms

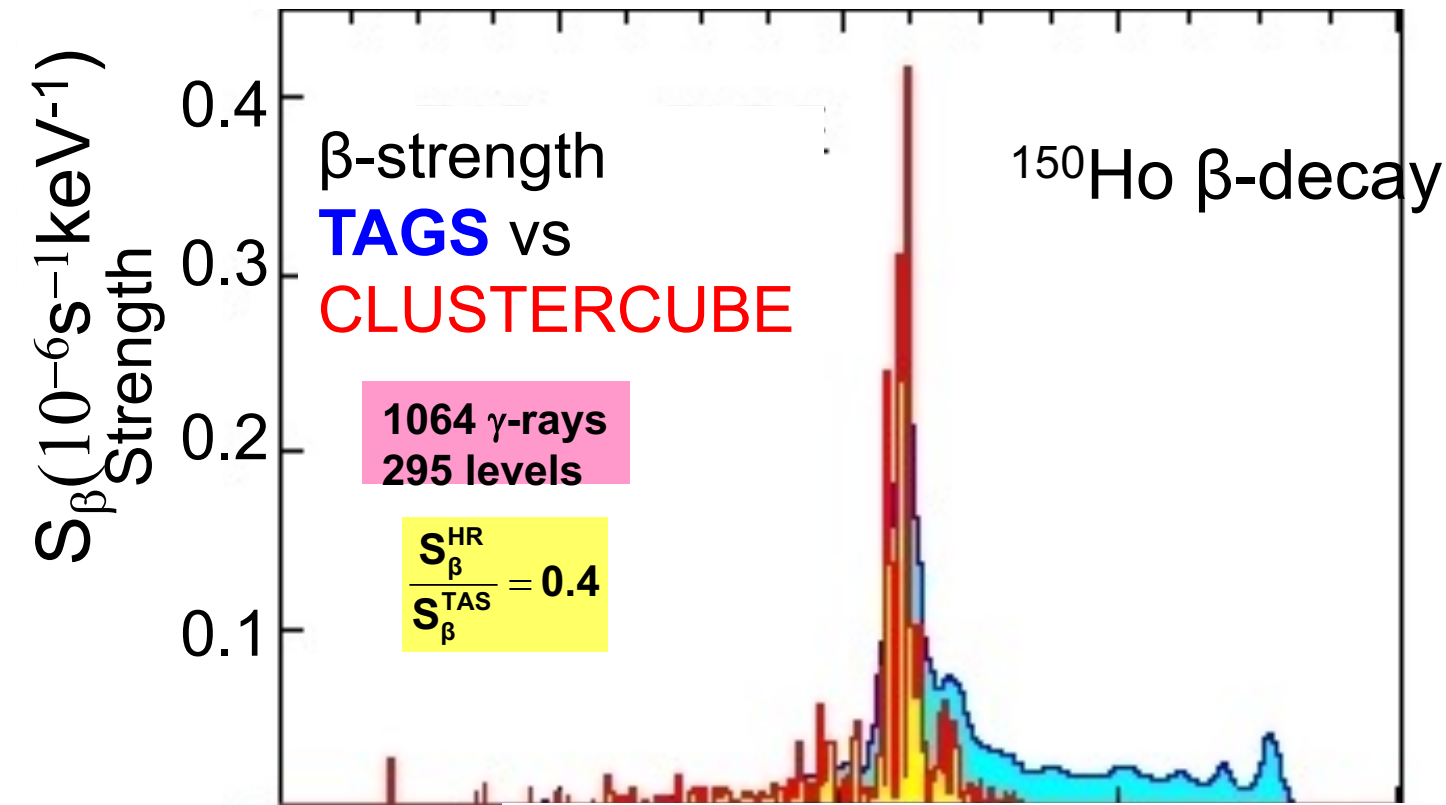
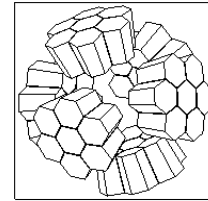
- Spectrum must be clean
- Response must be accurately known
- Solution of inverse problem must be stable (requires calorimetry)

NIM A430 (1999) 333 NIM A571 (2007) 719
NIM A430 (1999) 488 NIM A571 (2007) 728

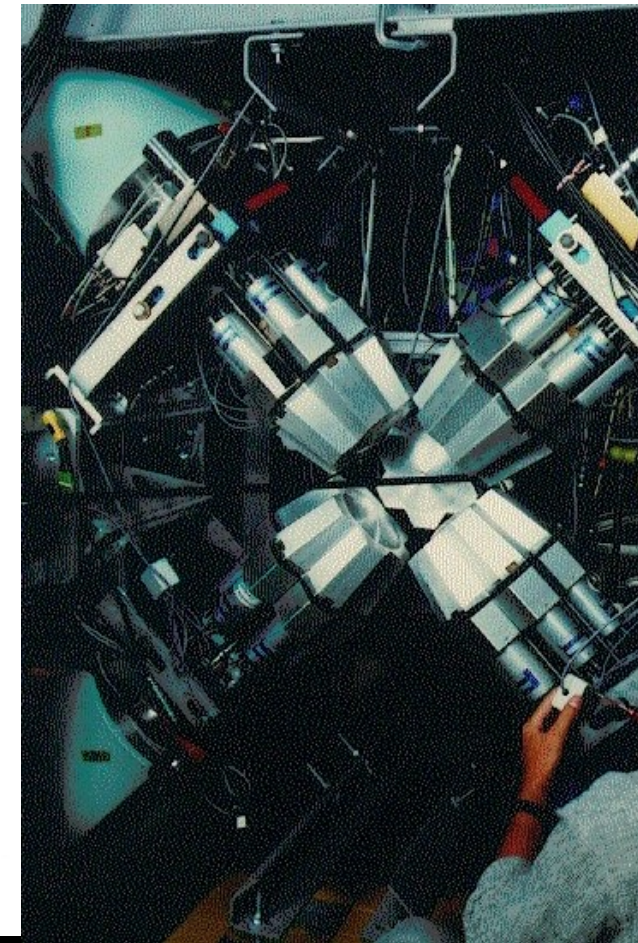
High Resolution & TAGS Complementarity

Six EUROBALL CLUSTER detectors
in close geometry

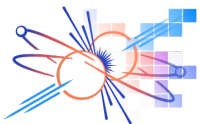
Ex[MeV]



A. Algora, B. Rubio et al PRC 50 (2002)



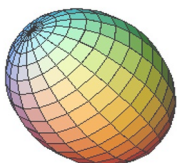
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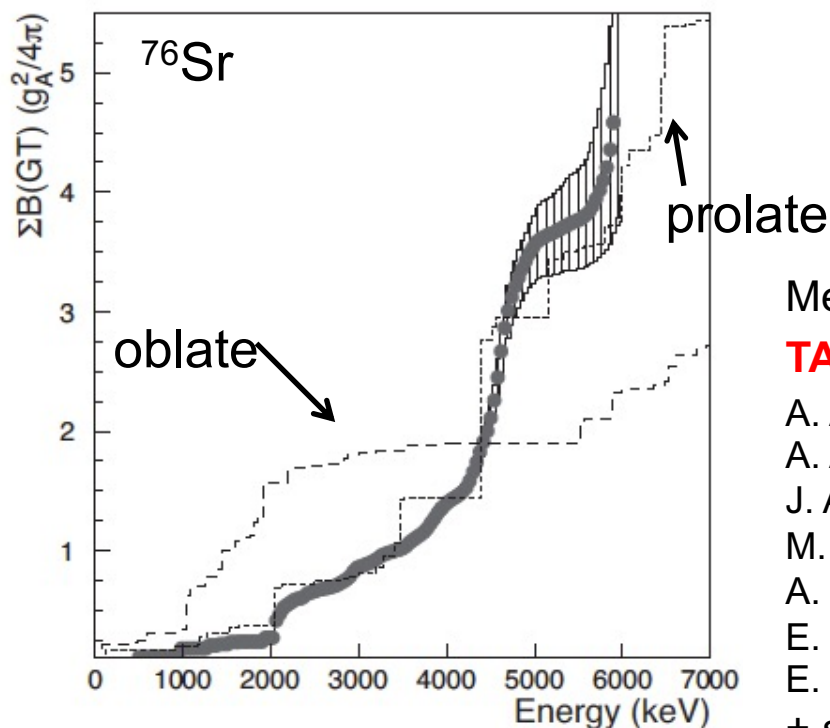
APRENDE



- Useful probe to investigate the **shape of the progenitor state** I. Hamamoto ZPA 353 (1995)
P. Sarriguren+, NPA 658 (1999)
- Comparison to theor. **QRPA calculations** with different deformations



Very prolate N=Z nucleus



Lucrecia

- ✓ NaI(Tl) single crystal
- ✓ Permanent @ ISOLDE-CE
- ✓ $\varepsilon^p=48\%$ @ $E_\gamma=5$ MeV
- ✓ $\Delta E=7\%$ @ $E_\gamma=0.66$ MeV
- ✓ Moderate n-sensitivity

B. Rubio+, JPG NPP 44 (2017)

Method **successfully employed** in many experimental
TAGS studies at ISOLDE for 20 years:

- A. Algora et al., *Eur. Phys. J. A* **57**, 85 (2021): Review of last decade
- A. Algora et al., *Phys. Lett. B* 819, 136438 (2021)
- J. A. Briz et al., *Phys. Rev. C* 92, 054326 (2015)
- M. E. Estévez Aguado et al., *Phys. Rev. C* 92, 044321 (2015)
- A. Pérez-Cerdá et al., *Phys. Rev. C* 88, 014324 (2013)
- E. Nacher et al. *Phys. Rev. Lett.* 92, 232501 (2004)
- E. Poirier et al., *Phys. Rev. C* 69, 034307 (2004)
- + several experiments in 2023: ^{186}Hg region, r-process, rp-process...

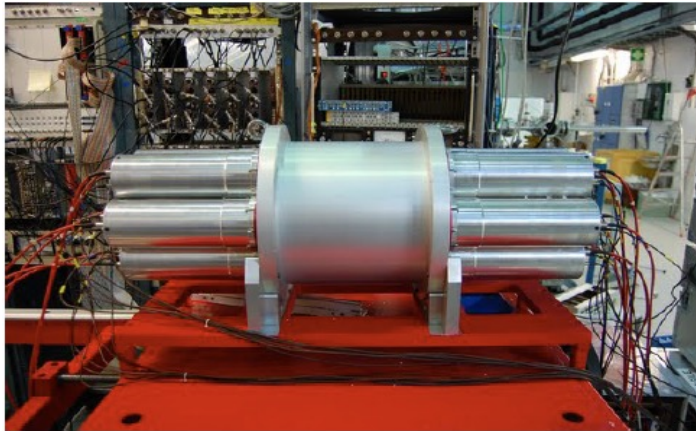
TAGS @IGISOL Jyväskylä in 2009, 2014 and 2022

● IGISOL@Jyväskylä:

- ❑ Proton induced fission ion-guide source
- ❑ Mass separator magnet
- ❑ Double Penning trap system to clean the beams

● 2 (segmented) TAS campains :

❑ ROCINANTE (IFIC Valencia/Surrey):



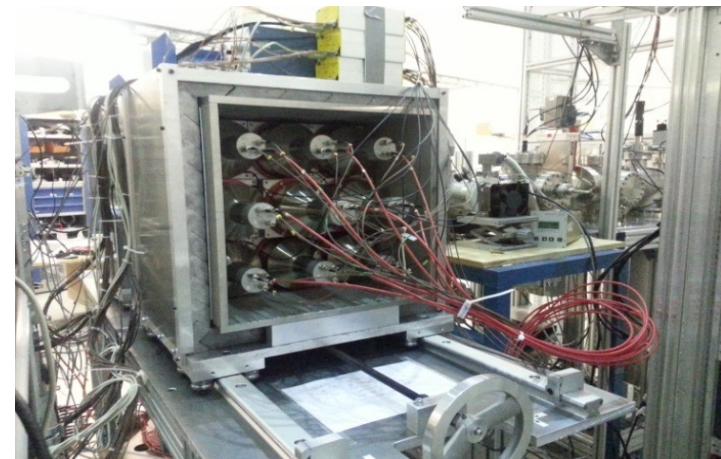
- ✓ 12 BaF₂ crystals
- ✓ Compact, γ -multiplicity
- ✓ $\varepsilon^p=40\%$ @E _{γ} =5 MeV
- ✓ $\Delta E=15\%$ @E _{γ} =0.66 MeV
- ✓ Low n-sensitivity
- ✓ Good timing $\Delta t=1$ ns
- ✓ Coupled with a Si detector for β

E. Valencia+, PRC 95 (2017)

B. Rubio, J. L. Tain, A. Algora et al.,
Proceedings of the Int. Conf. For nuclear
Data for Science and technology (ND2013)

J.L. Tain et al., NIMA 803 (2015) 36
V. Guadilla et al., submitted to NIMA (2018)

❑ DTAS (NUSTAR – DESPEC, IFIC):

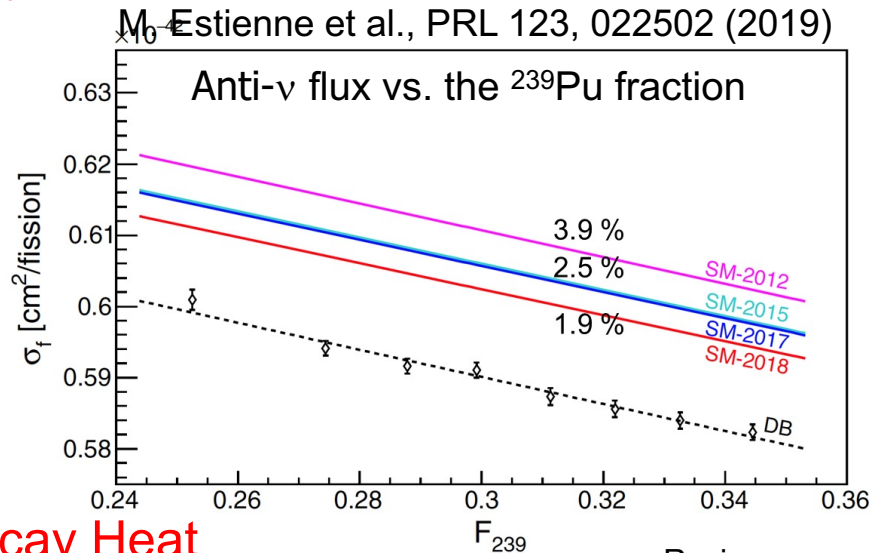


- ✓ 18 NaI(Tl) crystals of 15cm × 15cm × 25 cm
- ✓ Movable, γ -multiplicity
- ✓ $\varepsilon^p=48\%$ @E _{γ} =5 MeV
- ✓ $\Delta E=8\%$ @E _{γ} =0.66 MeV
- ✓ Moderate n-sensitivity
- ✓ Coupled with a plastic detector

J.L. Tain+, NIM A 803 (2015)

TAGS @IGISOL Jyväskylä in 2009, 2014

● Neutrino Physics

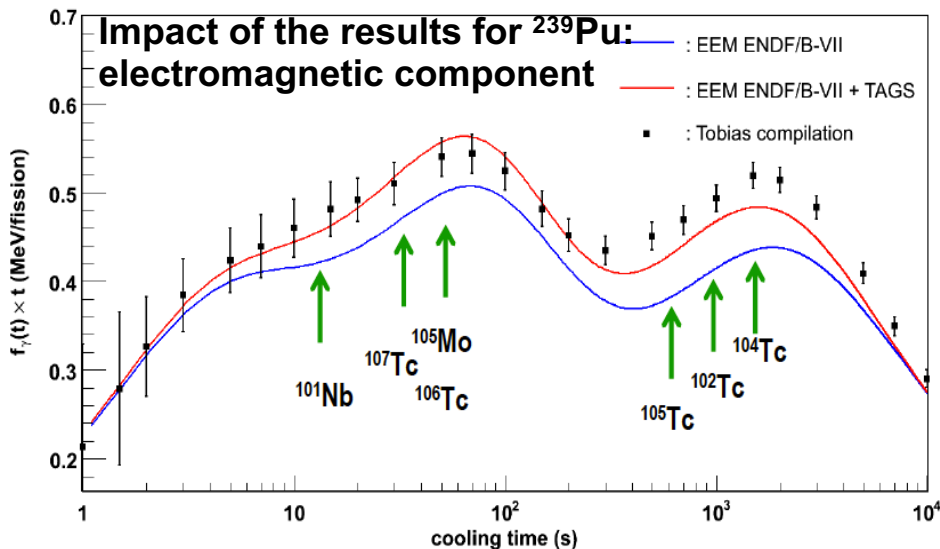


A. Algora et al. PRL 105, 202501 (2010),
M. Fallot et al. PRL 109, 202504 (2012)
D. Jordan et al. PRC 87, (2013) 044318
A.A. Zakari-Issoufou et al. PRL 115, 102503 (2015)
E. Valencia et al., PRC 95, 024320 (2017)
S. Rice et al. PRC 96 (2017) 014320
V. Guadilla et al. PRL 122, (2019) 042502
V. Guadilla et al. Phys. Rev. C 100, 044305 (2019)
V. Guadilla et al. Phys. Rev. C 106, 014306 (2022)
+ Data vs model in Daya Bay and STEREO recent papers: DB: PRL 130 (2023) 211801, PRL 129 (2022) 041801, STEREO: Nature 613 (2023) 257,

Review paper: C. Zhang, X. Qian, M. Fallot, PPNP 136 (2024) 104106

● Reactor Decay Heat

A. Nichols et al. Eur. Phys. J. A (2023) **59**: 78
Algora et al., PRL 105, 202501 (2010).

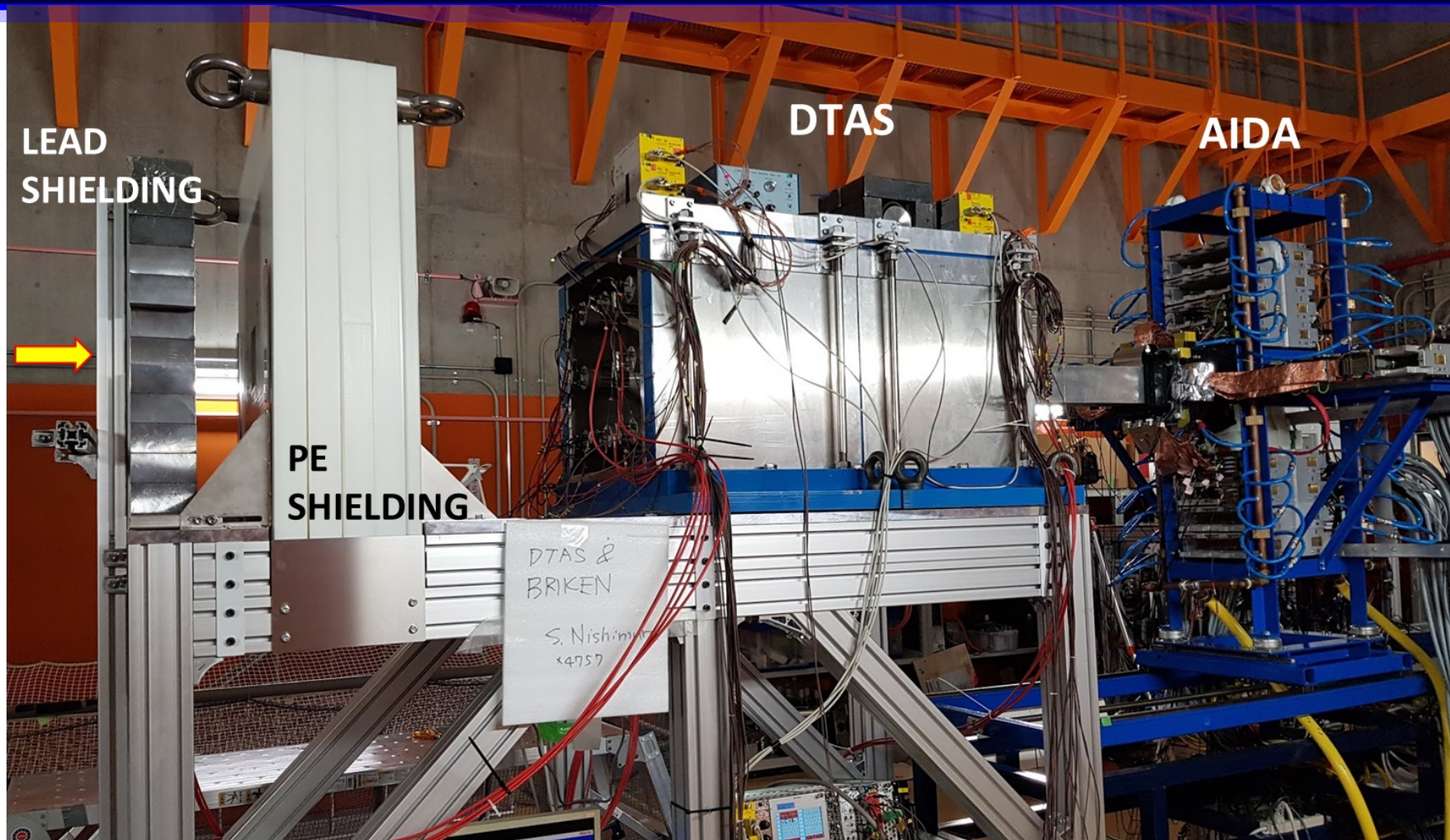


● R-process & γ/n competition above Sn

Isotope	$P_{\gamma}(\text{TAGS})$	P_n
^{87}Br	$3.50^{+0.49}_{-0.40}$	2.60(4)
^{88}Br	$1.59^{+0.27}_{-0.22}$	6.4(6)
^{94}Rb	$0.53^{+0.33}_{-0.22}$	10.18(24)
^{95}Rb	$2.92^{+0.97}_{-0.83}$	8.7(3)
^{137}I	$9.25^{+1.84}_{-2.23}$	7.14(23)

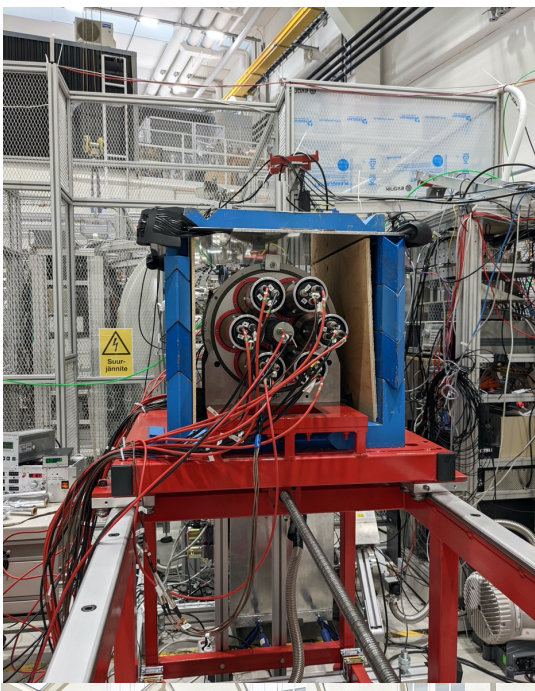
J.L. Tain et al., PRL 115, 062502 (2015)
E. Valencia et al., Phys. Rev. C 95, 024320 (2017). 13

DTAS+AIDA @ RIKEN (2019) and GSI (2022)



- 1st experiments with DTAS @ IGISOL (2014): reactor neutrino, DH, n/ γ competition
- Successfully commissioned with AIDA @ RIKEN (2019): ^{100}Sn , A. Algora+, NP1412-RIBF130
- DTAS+AIDA @ GSI (2022): n-rich nuclei in the N $\sim$ 126 region, J.L. Tain+, S505 experiment

TAGS Campaign @ Jyväskylä Sept. 2022



Proposal to the PAC of Jyväskylä

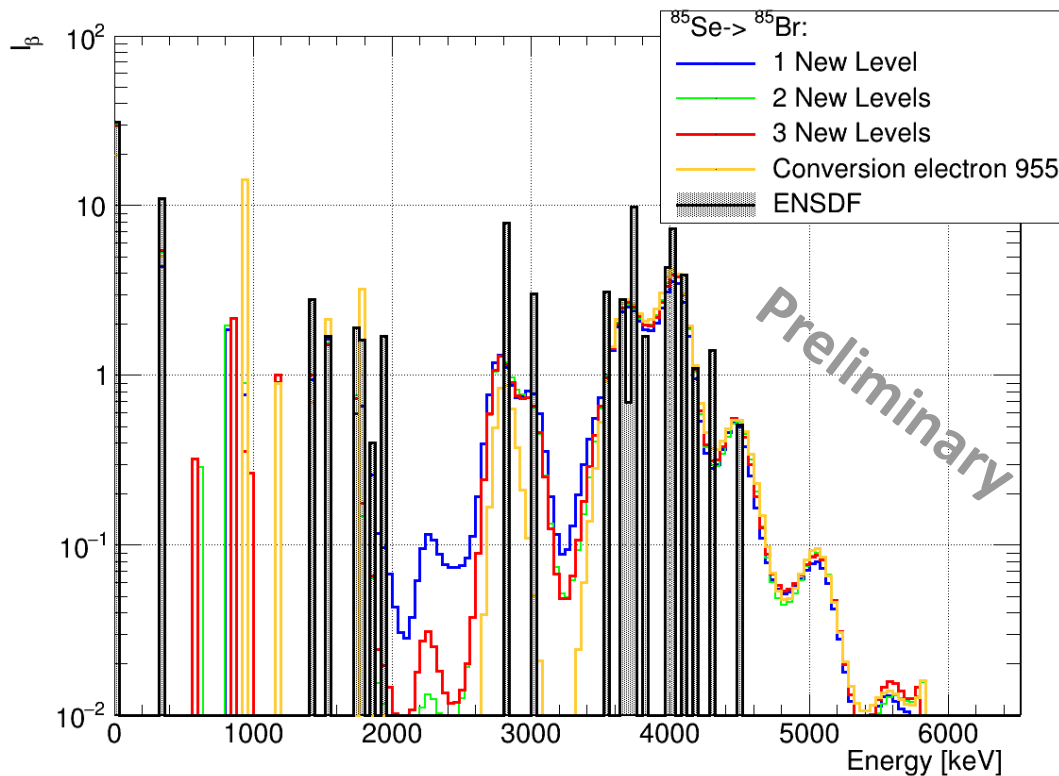
Total absorption spectroscopy measurements for the prediction of the reactor antineutrino spectra

M. Estienne, M. Fallot, V. Guadilla, L. Le Meur, A. Porta
Subatech, CNRS/IN2P3, University of Nantes, EMN, Nantes, France

A. Algora, J. L. Taín, B. Rubio, J. Agramunt, A. Montaner, S. Orrigo, C. Domingo, L. Caballero, A.
Tolosa
IFIC, CSIC-Univ. Valencia, Valencia, Spain

**Nantes-Valencia proposal,
Very successful experiment,
Rocinante Spectrometer (IFIC-
Surrey) coupled to the FASTER
DAQ by the Subatech team
17 nuclei measured with TAGS
Analysis On-going...**

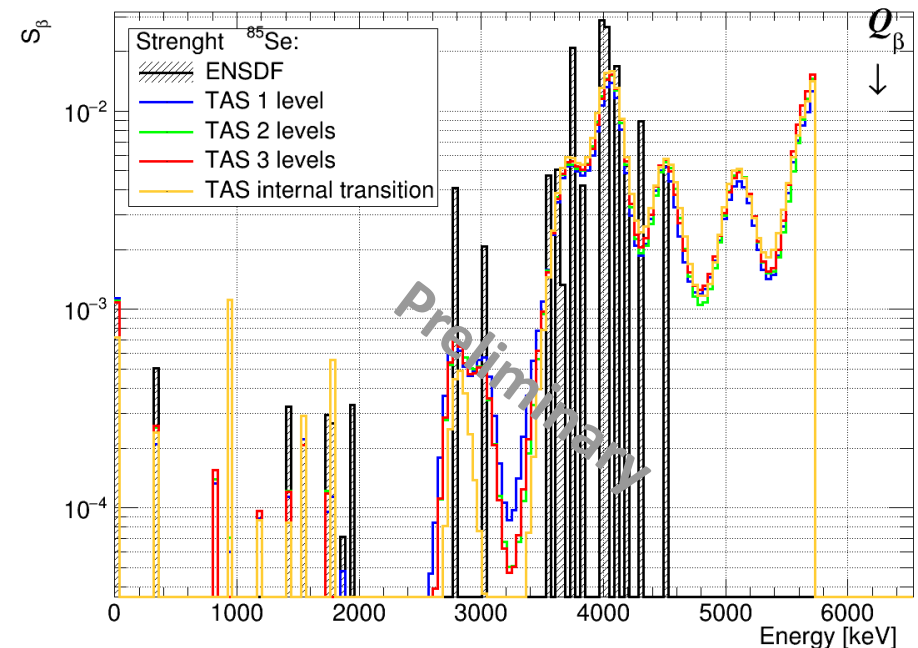
TAGS Campaign 2022: First Physics Analysis: ^{85}Se



- ⇒ Can't conclude, BaF_2 lack resolution
- ⇒ Deserves new measurements:
 - ⇒ $(\text{NA})^2\text{STARS}$?
 - ⇒ HPGe ?

Obtained β - feeding and strength:

- ^{85}Se Pandemonium case
- low energy energy scheme not well known in ENSDF



TAGS Experimental Challenges

- TAGS technique needs **some minimal knowledge on the daughter nuclei.**
- NaI crystals are very sensitive to neutrons.
- BaF₂ are less sensitive but have a poor energy resolution (but are fast).

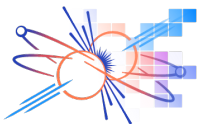
⇒ **Natural improvement of the existing TAS: combine efficiency, energy resolution, segmentation and timing !**

- Physics cases:

⇒ **Antineutrino, Decay Heat, Nuclear Structure & Astrophysics on n-rich side:** towards **shorter-lived contributors** => n-richer nuclei => large Q-values, β -n branch = n contamination and knowledge of Pn + less nuclear structure knowledge on decay daughters **efficiency, n/ γ separation through timing, better energy resolution, potential angular correlations**

⇒ **Nuclear Structure & Astrophysics on n-deficient side:** more exotic means less nuclear structure knowledge on decay daughters, large Q-values, β -delayed particle emission **efficiency, better energy resolution, potential angular correlations**

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(NA)²STARS Project

GOAL: Upgrade of the existent TAS spectrometers **DTAS** and **Rocinante** with **16 LaBr₃(Ce) modules** 2"x2"x4"

- **Large efficiency of DTAS/Rocinante + very good energy resolution and timing of LaBr₃**
 - Higher segmentation: γ - γ coincidences, angular correlations, γ -cascade multiplicity
 - n/γ discrimination through timing
- **Broad physics case:** exotic nuclei further away from stability => nuclear structure and astrophysics on the p-rich (p/γ competition $>S_p$, p-process, rp-process, SNe...) and n-rich sides (n/γ competition $>S_n$), decay heat, reactor neutrinos...

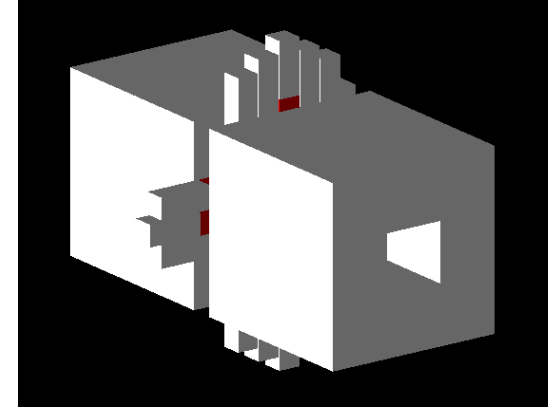
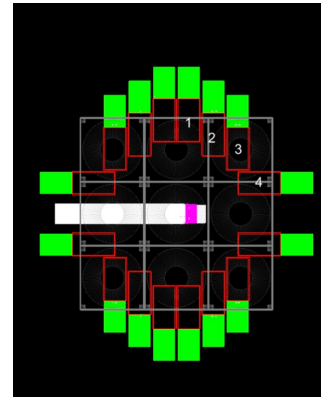
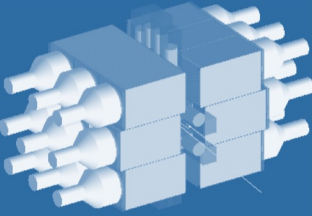


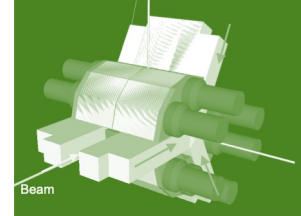
Fig. 4 : view of possible arrangement of the 16 LaBr₃:Ce (red) in the middle of the NaI crystals (grey) (courtesy A. Beloeuvre).

Neutrinos, Applications and Nuclear Astrophysics with a Segmented Total Absorption with higher Resolution Spectrometer

A combination of calorimetric and spectroscopic tools for beta decay and in-beam measurements

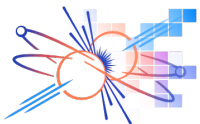


(NA)²STARS Collaboration



- SUBATECH: E. Bonnet, S. Durand, M. Estienne, M. Fallot, L. Le Floch, J. Pépin, V. Piau, A. Porta
- IFIC Valencia: A. Algora, E. Nacher, S. Orrigo, B. Rubio, J.-L. Tain
 - GANIL : J.-C. Thomas, H. Guérin, B. Rebeiro
 - CIEMAT Madrid: D. Cano-Ott
 - CSIC Madrid: T. Kurtukian Nieto
 - IP2I: C. Ducoin, N. Millard-Pinard, O. Stézowski
 - Surrey: W. Gelletly, Z. Podolyak
- U. Istanbul: E. Ganioglu Nutku, L. Şahin Yalçın, M. Yalçinkaya
 - U. Huelva: A. M. Benitez-Sanchez
 - NPI CAS: A. Cassissa, J. Mrazek, E. Simeckova

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Total Absorption Spectroscopy for Nuclear Structure and Nuclear Astrophysics

Spokespersons: M. Fallot¹, S. E. A. Orrigo², A. M. Sánchez Benítez³,

B. Rubio², A. Algora^{2,4}, J.-C. Thomas⁵, W. Gelletly⁶, B. Blank⁷, L. Acosta⁸, J. Agramunt², P. Aguilera⁹, O. Aktas⁵, G. Alcala², P. Ascher⁷, D. Atanasov⁷, B. Bastin⁵, A. Beloeuvre¹, E. Bonnet¹, S. Bouvier¹, M. J. G. Borge¹⁰, J. A. Briz¹¹, A. Cadiou¹, D. Cano Ott¹², G. de Angelis¹³, G. de France⁵, Q. Delignac⁷, F. de Oliveira Santos⁵, N. de Séréville¹⁴, C. Ducoin¹⁵, J. Dueñas³, M. Estienne¹, A. Fantina⁷, M. Flayol⁷, C. Fonseca², C. Fougères¹⁶, L. M. Fraile¹¹, H. Fujita¹⁷, Y. Fujita¹⁷, D. Galaviz¹⁸, E. Ganioglu¹⁹, F. G. Barba¹⁸, M. Gerbaux⁷, J. Giovinazzo⁷, D. Godos⁸, S. Grevy⁷, V. Guadilla²⁰, F. Gulminelli²¹, F. Hammache¹⁴, J. Mrázek²², O. Kamalou⁵, T. Kurtukian-Nieto¹⁰, I. Martel³, N. Millard-Pinard¹⁵, F. Molina²³, E. Nacher², S. Nandi¹, S. Parra², J. Pépin¹, J. Piot⁵, Z. Podolyak⁶, A. Porta¹, B. M. Rebeiro⁵, P. Regan⁶, D. Rodriguez², O. Sorlin⁵, C. Soto¹⁵, O. Stezowski¹⁵, C. Stodel⁵, J. L. Tain², O. Tengblad¹⁰, P. Teubig¹⁸, L. Trache²⁴

¹ *Subatech, Nantes, France*

² *IFIC-CSIC, Valencia, Spain*

³ *UHU, Spain*

⁴ *Atomki, Debrecen, Hungary*

⁵ *GANIL Caen, France*

⁶ *Univ. Surrey, UK*

⁷ *IP2I, Bordeaux, France*

⁸ *Instituto de Física-UNAM, Mexico*

⁹ *Univ. Padova and INFN, Italy*

¹⁰ *IEM-CSIC, Spain*

¹¹ *UCM Madrid, Spain*

¹² *CIEMAT, Spain*

¹³ *LNL-INFN, Italy*

¹⁴ *IJCLab, Orsay, France*

¹⁵ *IP2I, Lyon, France*

¹⁶ *ARGONNE, USA*

¹⁷ *RCNP Osaka, Japan*

¹⁸ *LIP-Lisboa, Portugal*

¹⁹ *Univ. Istanbul, Turkey*

²⁰ *Univ. Warsaw, Poland*

²¹ *LPCCAEN, France*

²² *NPI CAS, Czech Republic*

²³ *CCHEN, Santiago, Chile*

²⁴ *NIPNE, Romania*

Total Absorption Spectroscopy for Nuclear Structure and Nuclear Astrophysics

- 1st experiment with **STARS**
- Measure the β -decay properties of several p-rich nuclei in the Cr-Zn region of great interest for:
 - Nuclear structure: β -decay of selected $T_z = -2$ nuclei
 - To study isospin symmetry free of Pandemonium
 - Nuclear astrophysics: β -decay of ^{46}Mn and ^{48}Mn
 - To constrain reaction rates of interest for the ^{44}Ti nucleosynthesis
 - $^{45}\text{V}(p,\gamma)^{46}\text{Cr}$ and $^{47}\text{V}(p,\gamma)^{48}\text{Cr}$

(NA)²STARS: β -decay of selected $T_z = -2$ nuclei

- During last decade we have performed a systematic study of the

β decay of proton-rich nuclei

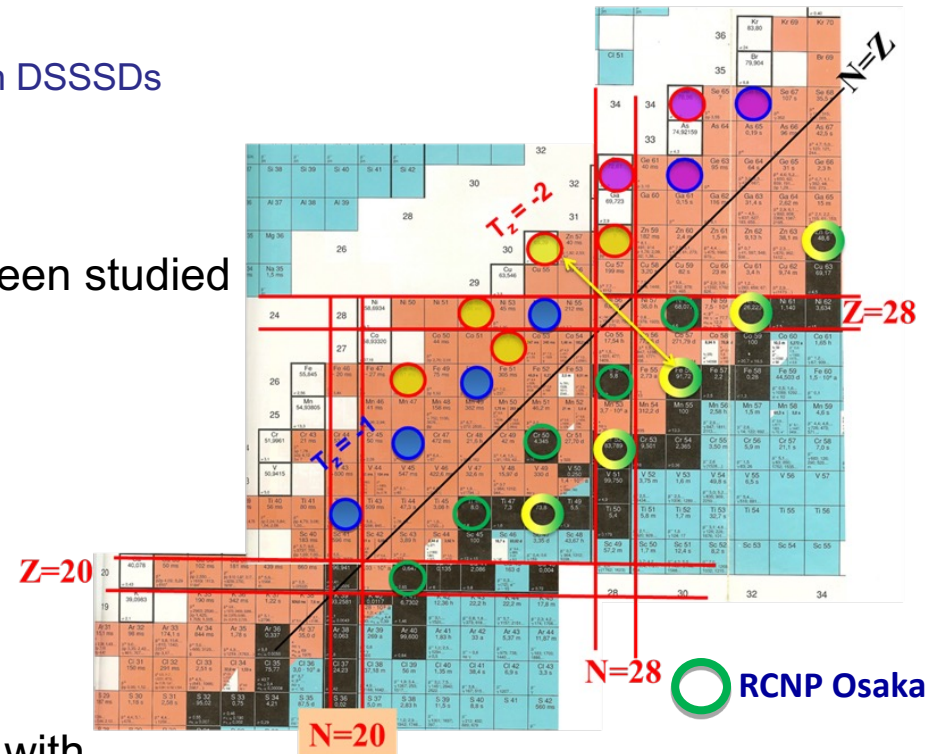
- Detection of β -particles and β -delayed protons with DSSSDs
- β -delayed γ -rays detected by HPGe arrays

- Rich spectroscopic info, many cases have been studied

- Orrigo+, PRL 112, 222501 (2014)
- Molina+, PRC 91, 014301 (2015)
- Orrigo+, PRC 93, 044336 (2016)
- Orrigo+, PRC 94, 044315 (2016)
- Kucuk, Orrigo+, EPJA 53, 134 (2017)
- Orrigo+, PRC 103, 014324 (2021)

- β -decay data is enriched by the comparison with complementary **CE reactions** on the stable mirror target

- Y. Fujita, B. Rubio, W. Gelletly, PPNP 66, 549 (2011)
- H. Fujita+, PRC 88, 054329 (2013)
- E. Ganioglu+, PRC 93, 064326 (2016)



Primary beams for RIB production:

GANIL

e556:

⁶⁴Zn @79 AMeV

e556a:

⁵⁸Ni @75 AMeV

GSi

⁵⁸Ni @680 AMeV

RIKEN

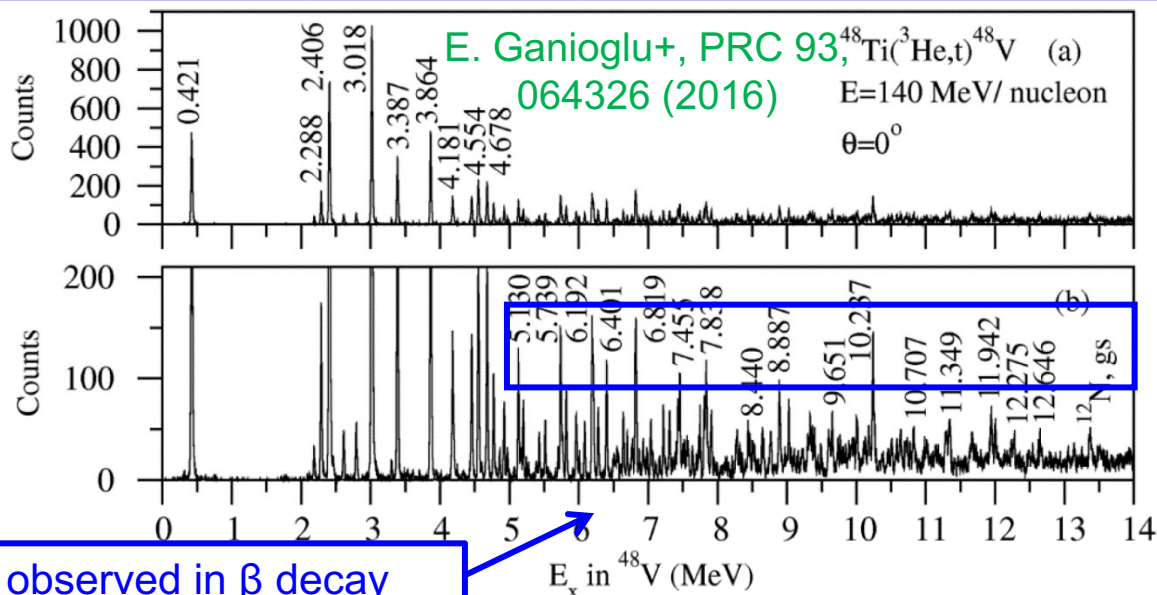
⁷⁸Kr @345 AMeV

(NA)²STARS: β -decay of selected $T_z = -2$ nuclei

- Comparing with CE data
 $\Rightarrow$ β -decay data are affected by **Pandemonium** for many of the nuclei studied

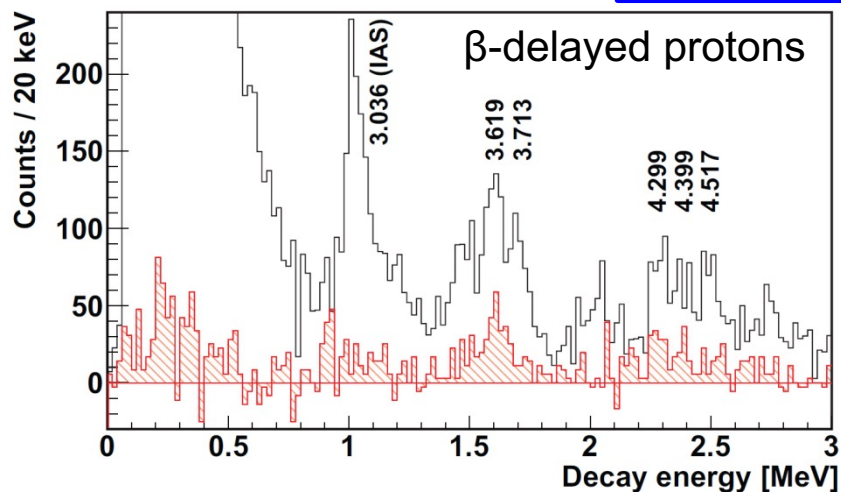
- An illustrative example:
the β decay of ^{48}Fe

- $Q_\beta = 11.2$ MeV
- Missing B(GT) at high E_x

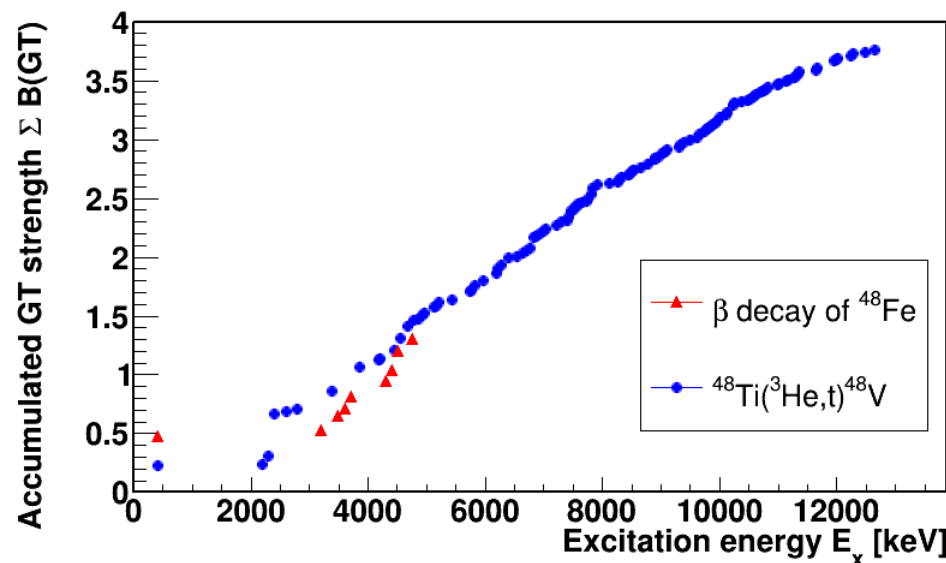


Orrigo+, PRC 93, 044336 (2016)

Not observed in β decay



γ -proton coincidences: increases x3 in TAGS!
 $\Rightarrow$ helping to fix E_x of the proton-emitting levels



(NA)²STARS: β -decay of selected $T_z=-2$ nuclei

■ We propose to measure these decays with the **Total Absorption Spectroscopy technique**

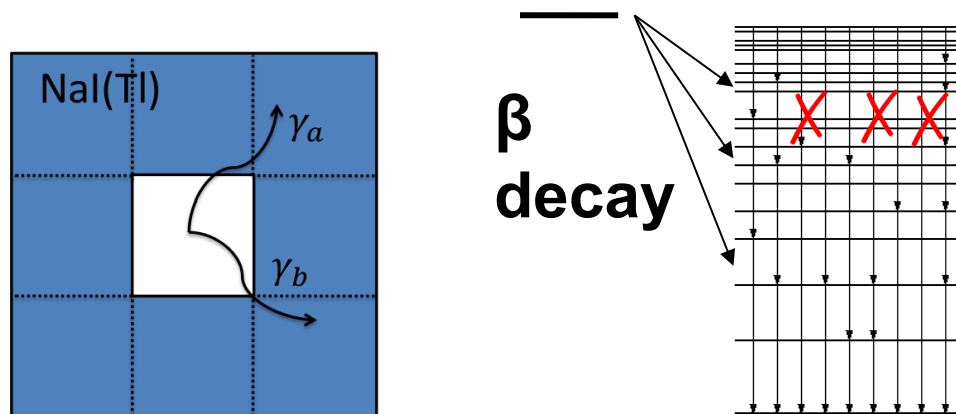
■ Improve the knowledge on the decay schemes (**Pandemonium**)

■ In some case: missing B(F) $\rightarrow$ missing γ -rays from populated levels?

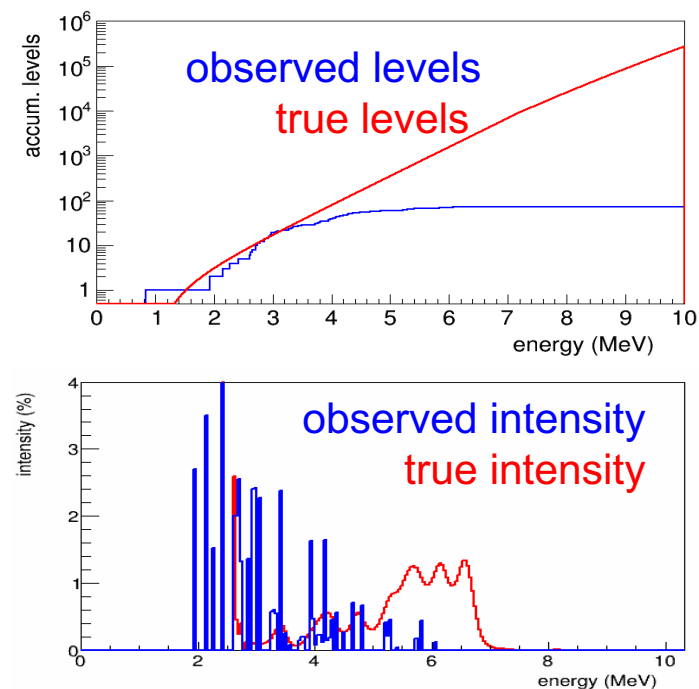
■ From CE data: missing B(GT) strength at high energy

■ Compares the TAGS technique with well-known cases for the 1st time

■ TAGS experiments done mostly at ISOL facilities



■ $T_z=-2$ cases Orrigo+, PRC 93, 044336 (2016)



^{44}Ti Nucleosynthesis: (NA)²STARS@LISE

^{44}Ti is produced in type-II supernovae and is a sensitive probe for CCSN models

TABLE 5
ORDER OF IMPORTANCE OF
REACTIONS PRODUCING
 ^{44}Ti AT $\eta = 0^a$

Reaction	Slope
$^{44}\text{Ti}(\alpha, p)^{47}\text{V}$	-0.394
$\alpha(2\alpha, \gamma)^{12}\text{C}$	+0.386
$^{45}\text{V}(p, \gamma)^{46}\text{Cr}$	-0.361
$^{40}\text{Ca}(\alpha, \gamma)^{44}\text{Ti}$	+0.137
$^{57}\text{Co}(p, n)^{57}\text{Ni}$	+0.102
$^{36}\text{Ar}(\alpha, p)^{39}\text{K}$	+0.037
$^{44}\text{Ti}(\alpha, \gamma)^{48}\text{Cr}$	-0.024
$^{12}\text{C}(\alpha, \gamma)^{16}\text{O}$	-0.017
$^{57}\text{Ni}(p, \gamma)^{58}\text{Cu}$	+0.013
$^{58}\text{Cu}(p, \gamma)^{59}\text{Zn}$	+0.011
$^{36}\text{Ar}(\alpha, \gamma)^{40}\text{Ca}$	+0.008
$^{44}\text{Ti}(p, \gamma)^{45}\text{V}$	-0.005
$^{57}\text{Co}(p, \gamma)^{58}\text{Ni}$	+0.002
$^{57}\text{Ni}(n, \gamma)^{58}\text{Cu}$	+0.002
$^{54}\text{Fe}(\alpha, n)^{57}\text{Ni}$	+0.002
$^{40}\text{Ca}(\alpha, p)^{43}\text{Sc}$	-0.002

^a Order of importance of reactions producing ^{44}Ti at $\eta = 0$ according to the slope of $X(^{44}\text{Ti})$ near the standard reaction rates.

Spectroscopy of key nuclei in astrophysics on n-deficient nuclei: constrain the cross-sections of the $^{45}\text{V}(p, \gamma)^{46}\text{Cr}$ and $^{47}\text{V}(p, \gamma)^{48}\text{Cr}$ reactions with beta-decay experiment:

Experimental approaches constraining the (p, γ) cross-section:

- TAGS technique to measure the γ -rays emitted above the p emission threshold by ^{46}Mn and ^{48}Mn : “beta-surrogate method” applied on n-rich nuclei for r-process [Tain et al. PRL 2015] ;
- Beta-Oslo method to measure the level density and γ -strength in daughter nuclei $^{46,48}\text{Cr}$ [Spyrou et al. PRL 2014]
- Take advantage of large efficiency, higher segmentation of the (NA)²STARS device and better resolution of LaBr₃ modules

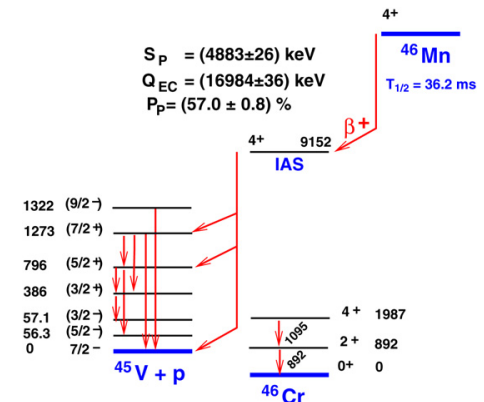
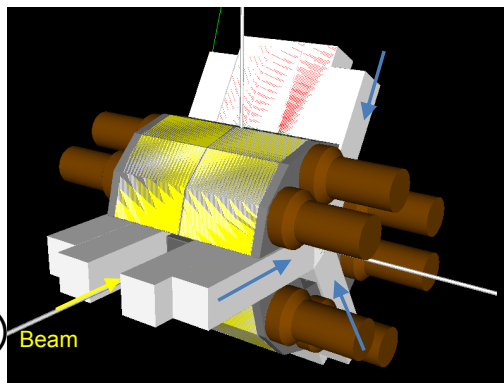
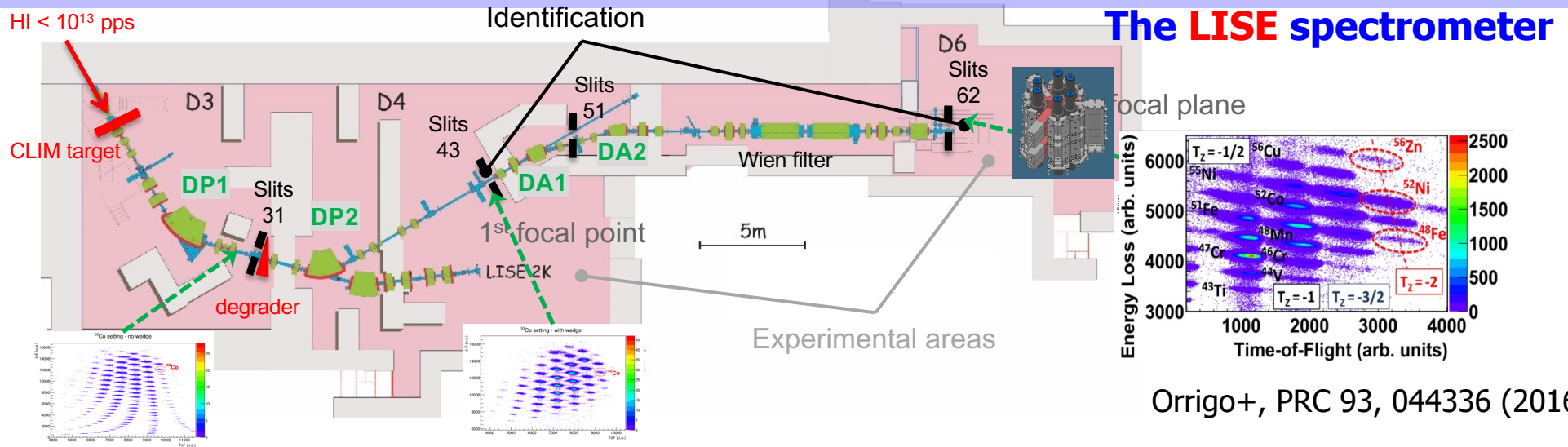


Fig. 24. Partial decay scheme for the β decay of ^{46}Mn . The decay scheme summarises the experimental results obtained in the present campaign.

- L. S. The+, Astrophys. J. 504, 500 (1998)
G. Magkotsios+, ApJS 191, 66 (2010)
L.-S. The+, Astron. Astrophys. 450, 1037 (2006)
K. Hermansen, ApJ 901, 77 (2020)
S.K. Subedi+, Astr. Phys. J. 89, 5 (2020)

(NA)²STARS Experimental setup @ GANIL

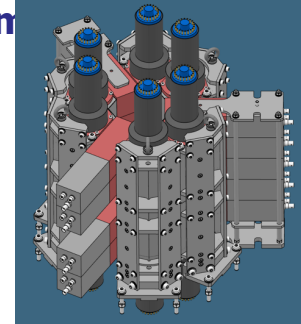
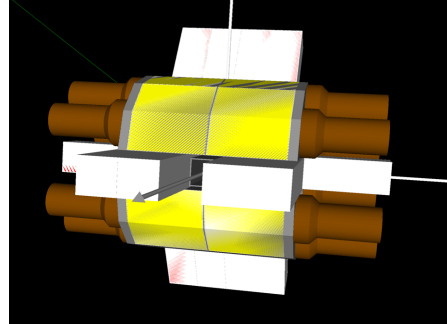


- **New DSSSD (GANIL) 1 mm-thick, 40x40 mm²**
- **Rocinante (refurbished) or DTAS + 16 LaBr₃ crystals**

Refurbished Rocinante



+ 16(17) LaBr₃ modules



+ New DSSSD1 mm-thick,



(NA)²STARS E891_23 Preparation

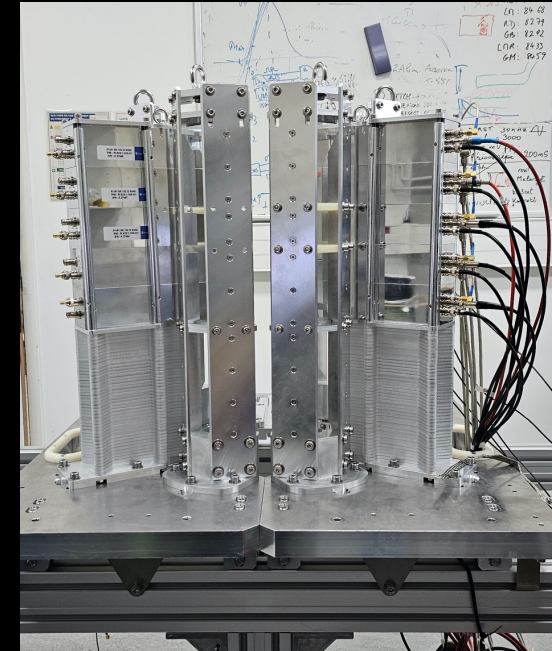
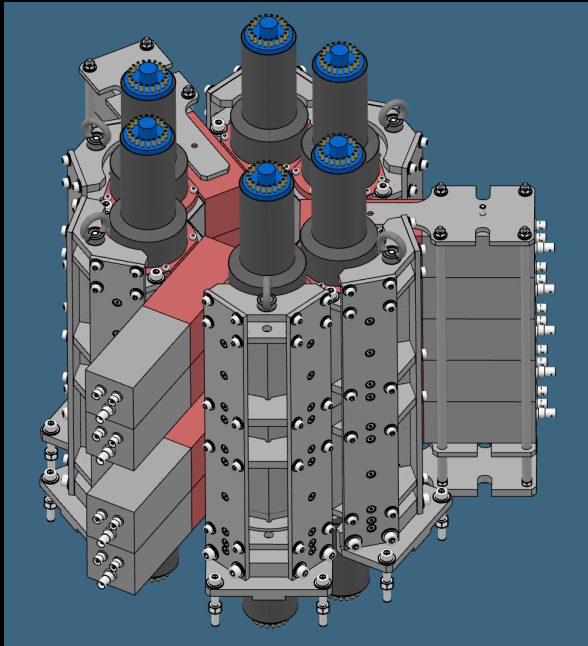
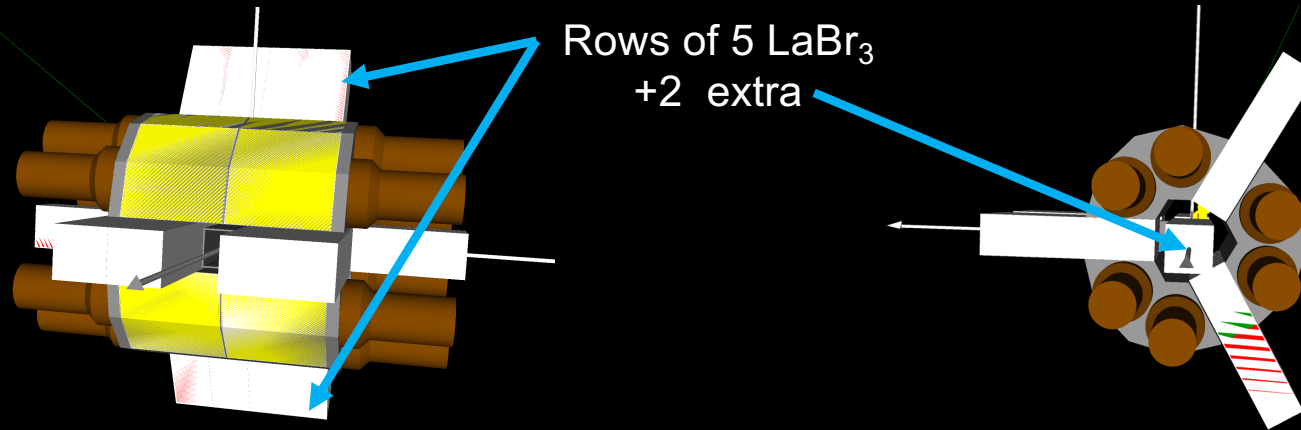


Excellent energy resolution : FWHM
~ 3 % @662 keV

- Previous individual module tests by CIEMAT and IFIC, design based on design studies performed for DESPEC TAS (DTAS)
- R&D Electronics & DAQs @ GANIL (DSSSD) and Subatech
- Mechanics: Subatech and IP2I
- Rocinante 12 BaF₂ detectors refurbished, tests @ IFIC and @ Subatech
- New tests of LaBr₃ modules @Subatech ;
- 8 internship students in SEN team in 2025 & 2026 (L3, M1, M2) on the project
- Mounting the complete set-up with all detectors and electronics @ Subatech in May
- Integration of the lower part of the supporting structure in GANIL on May 20. 2026
- **Full installation in GANIL started June 23. 2026**
- **Experiment from July 6. to 17. 2026**

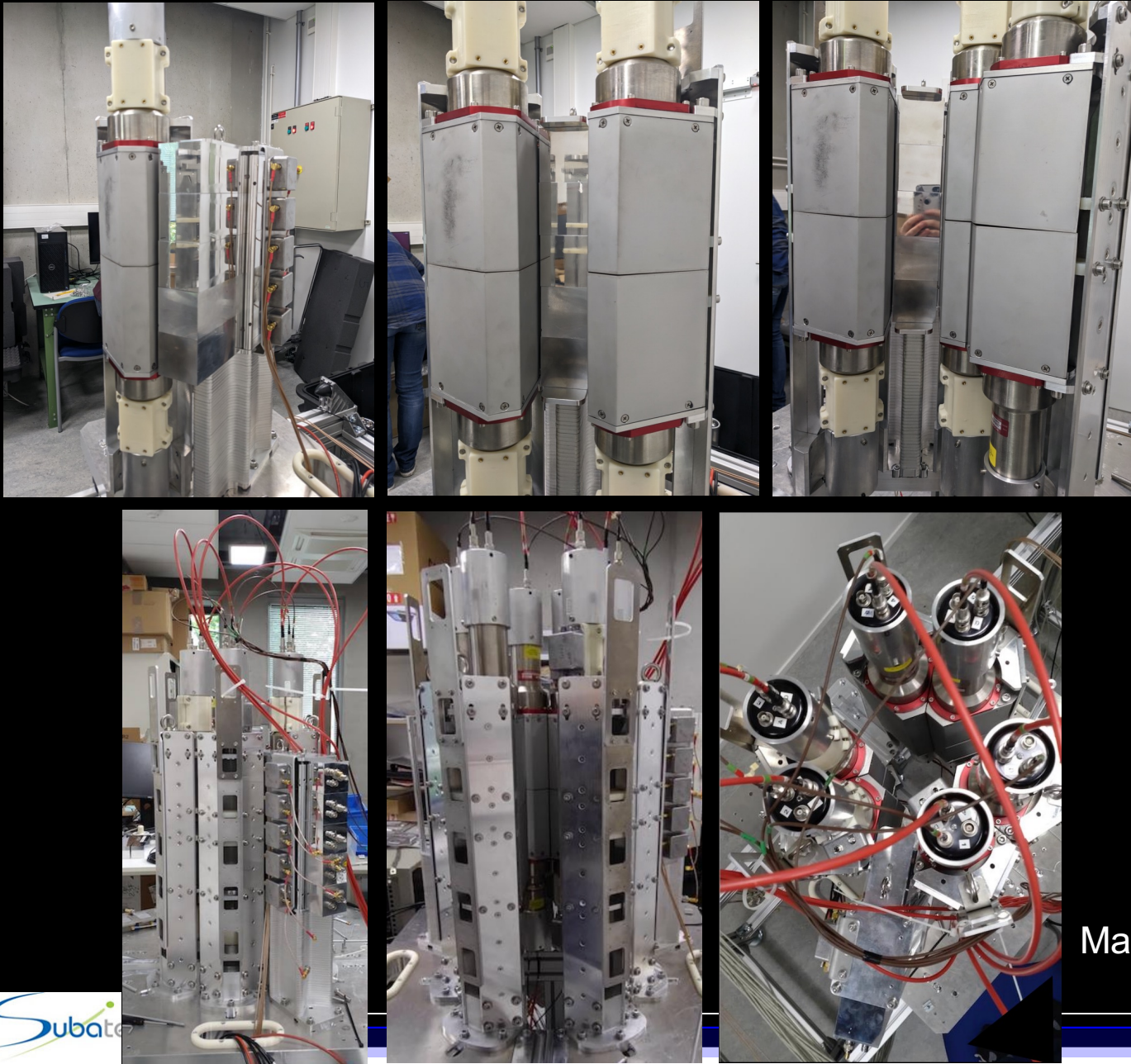
Heatwave !

(NA)²STARS “Materialization”



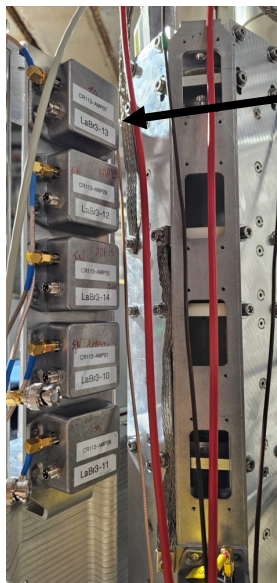
To be continued...

(NA)²STARS “Materialization”



May 2026, Subatech

(NA)²STARS E891_23 Preparation



New Preamps for LaBr₃ modules

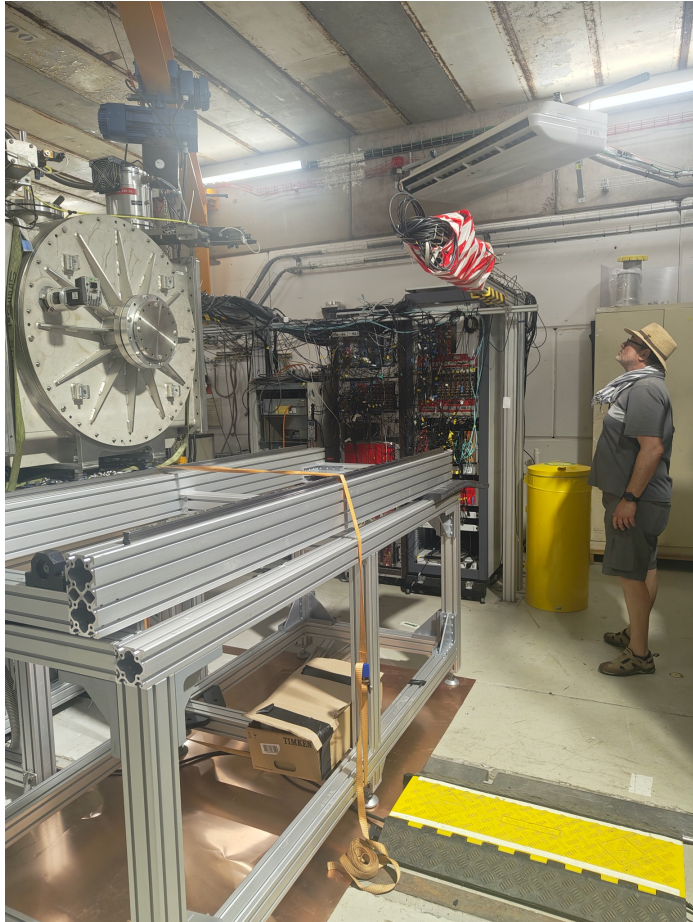
Preparing the BaF₂ detectors @ Subatech
(« re-greasing workshop », skill learnt from IFIC colleagues)

Preparing coupling of the DAQs

Mounting everything @ Subatech
(mechanics and electronics)



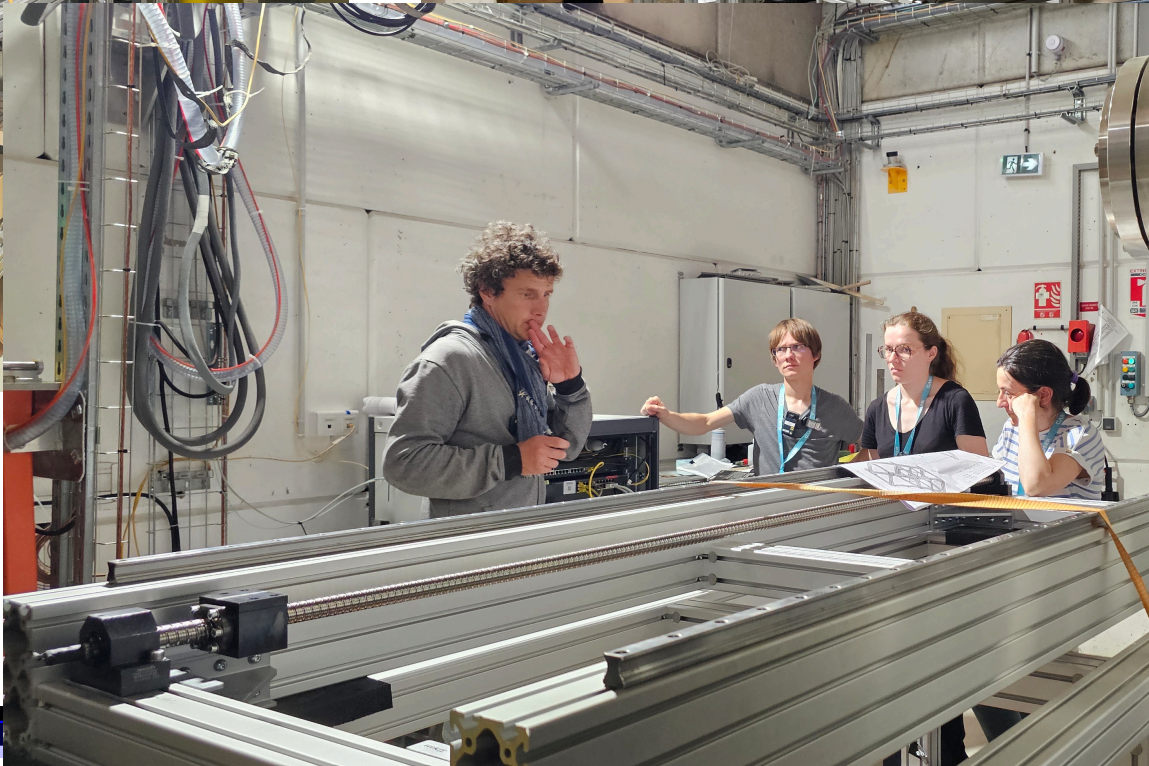
(NA)²STARS E891_23 Installation



Installation during the hottest week in June...

=> the machines were stopped because of the heat, not a good sign for the forthcoming experiment...

(NA)²STARS E891_23 Installation



(NA)²STARS E891_23 Installation



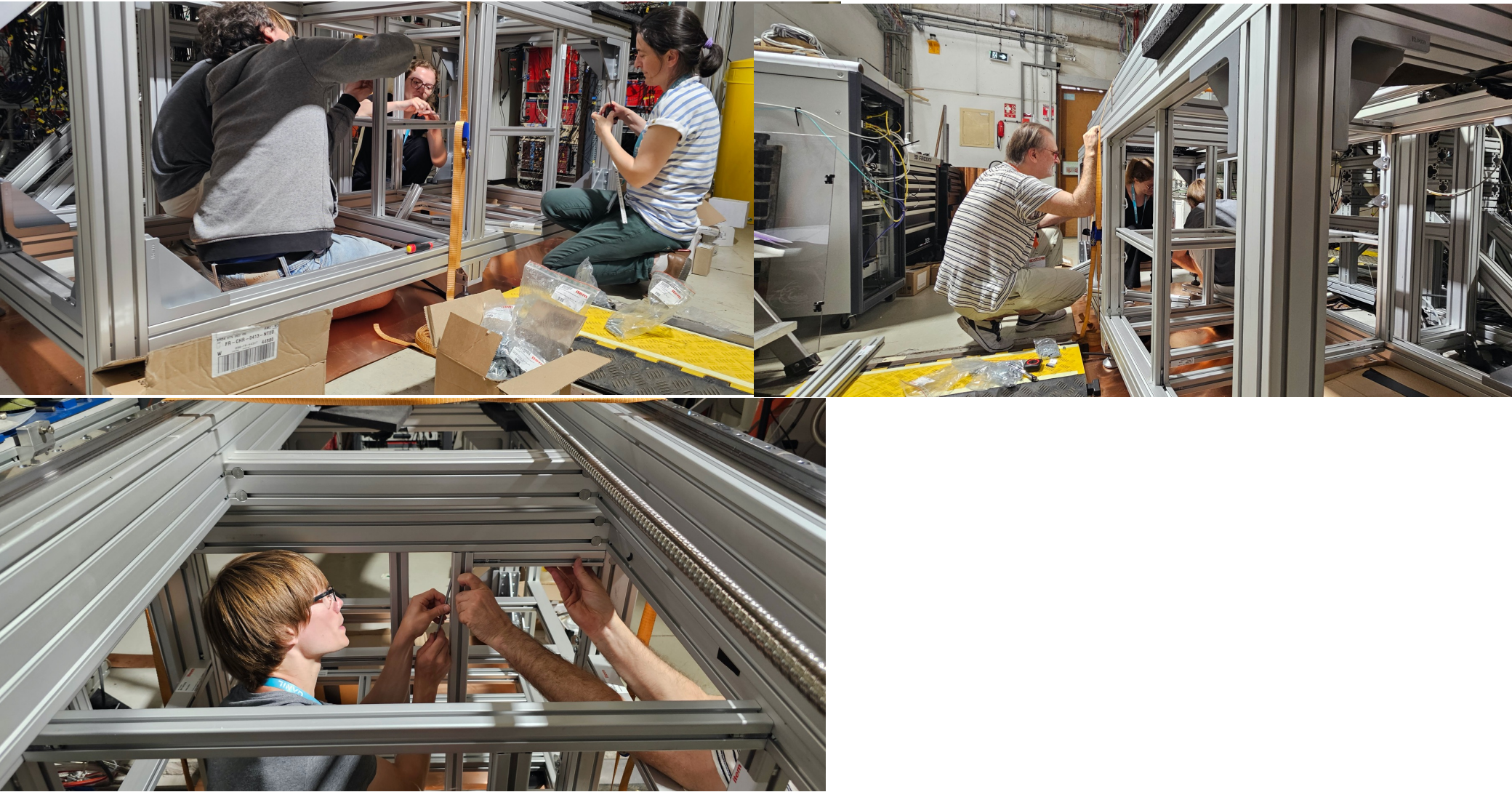
Gymnastic for the installation !

(NA)²STARS E891_23 Installation



Gymnastic for the installation !

(NA)²STARS E891_23 Installation



Gymnastic for the installation !

(NA)²STARS E891_23 Installation



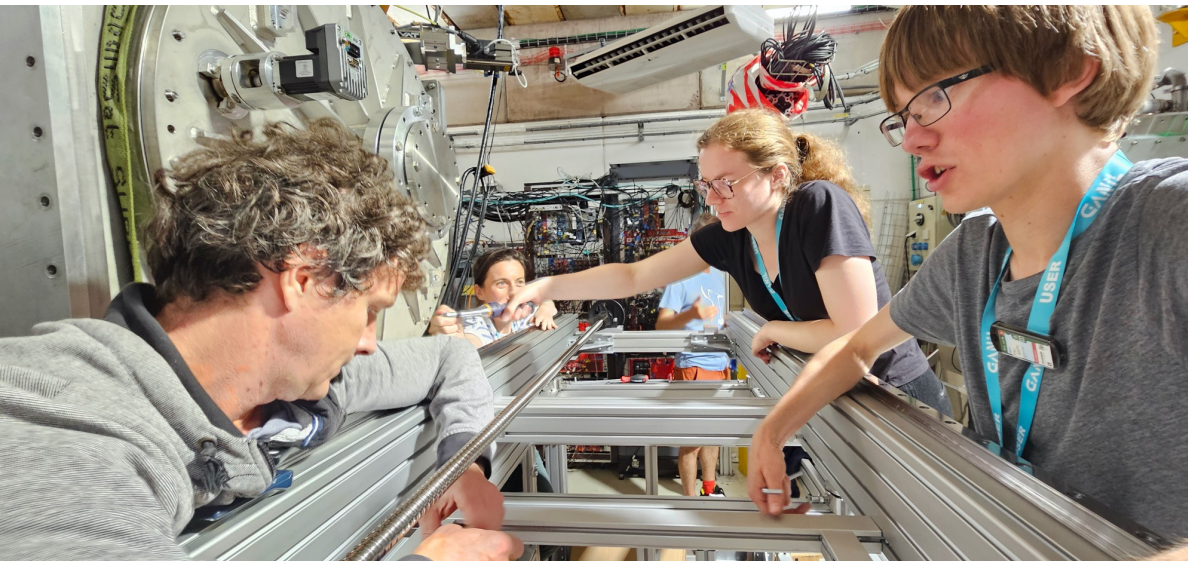
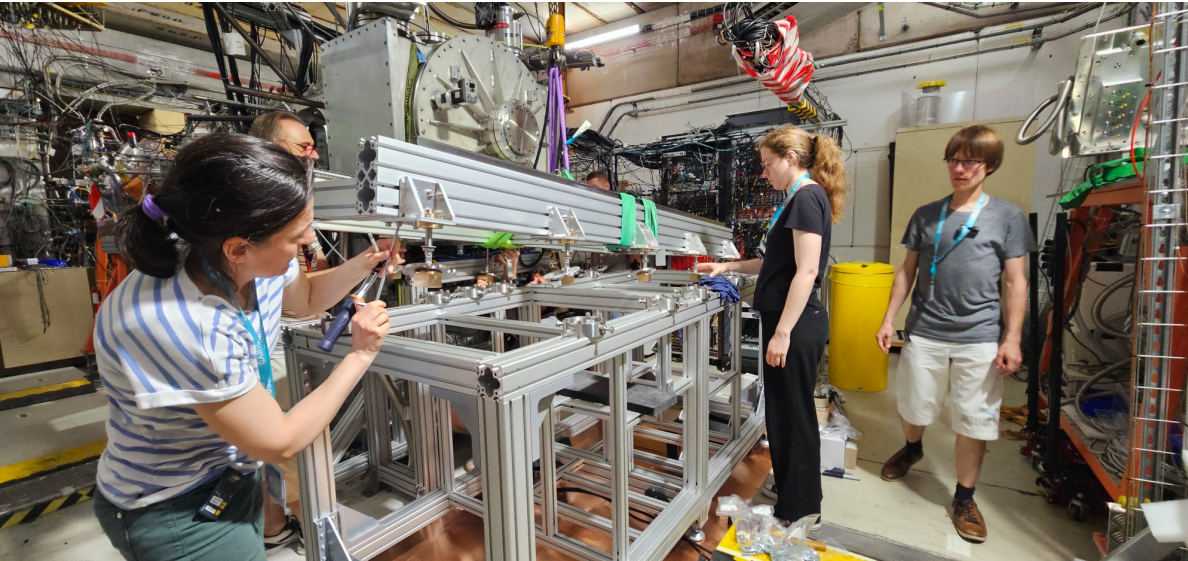
Gymnastic for the installation !

(NA)²STARS E891_23 Installation

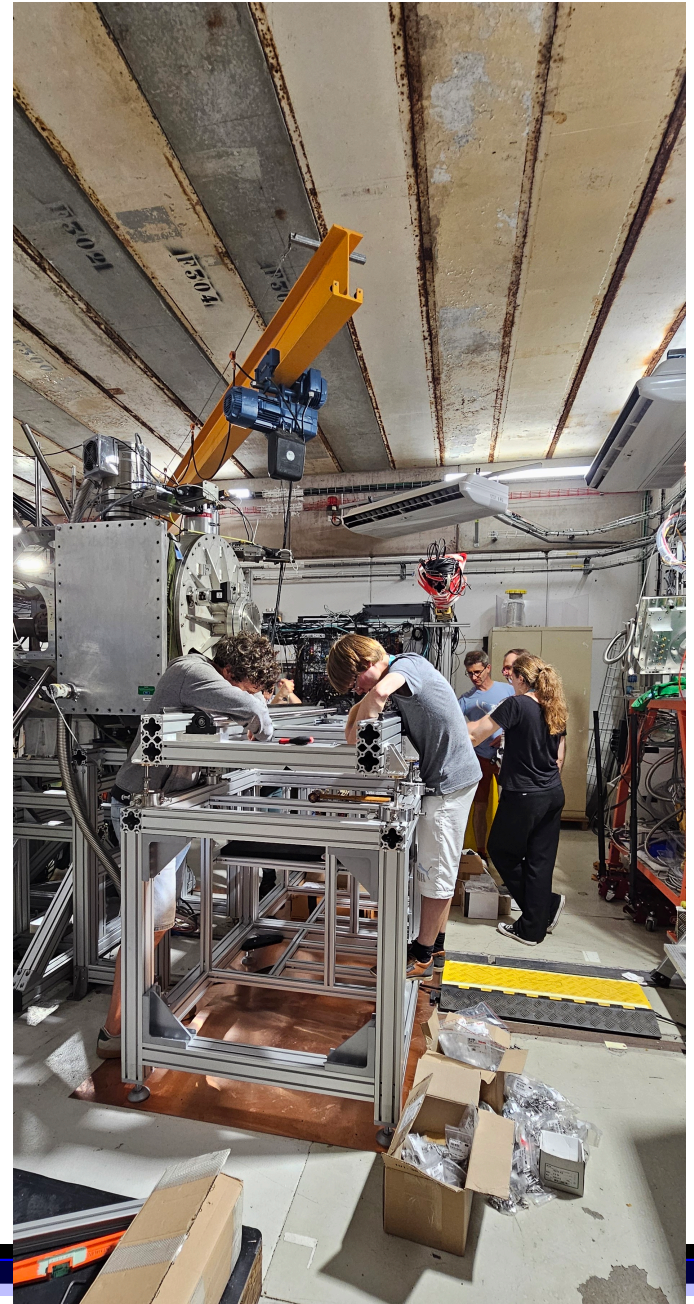


Gymnastic for the installation !

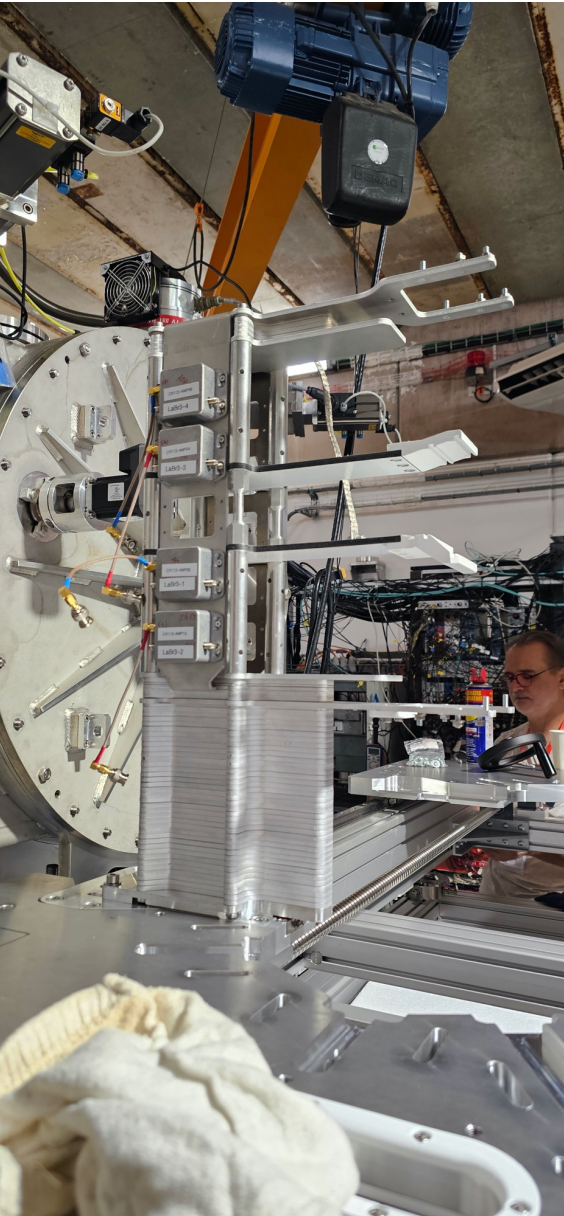
(NA)²STARS E891_23 Installation



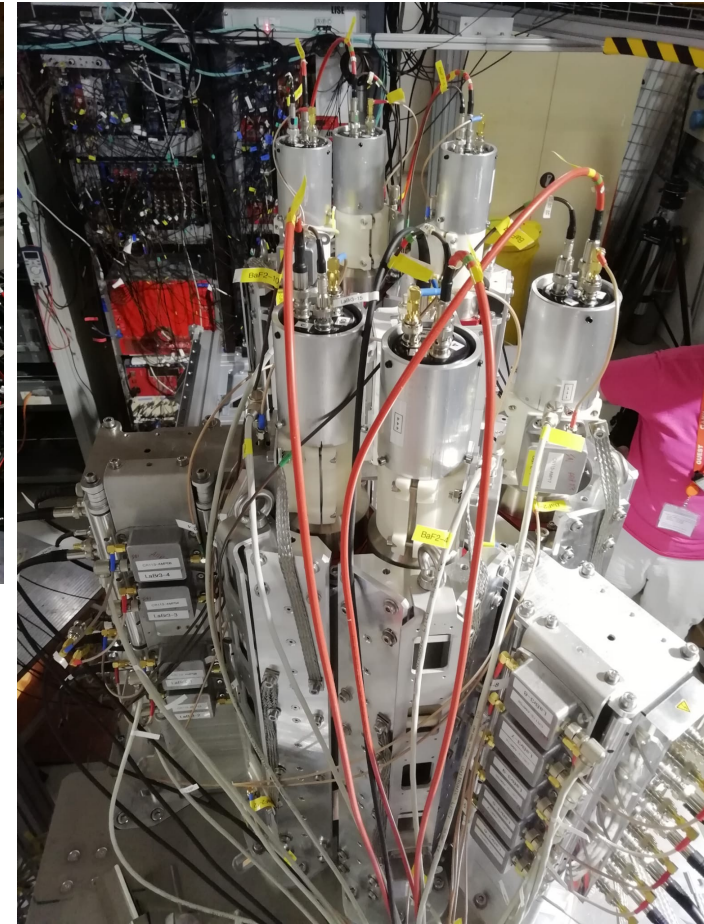
Gymnastic for the installation !



(NA)²STARS E891_23 Installation

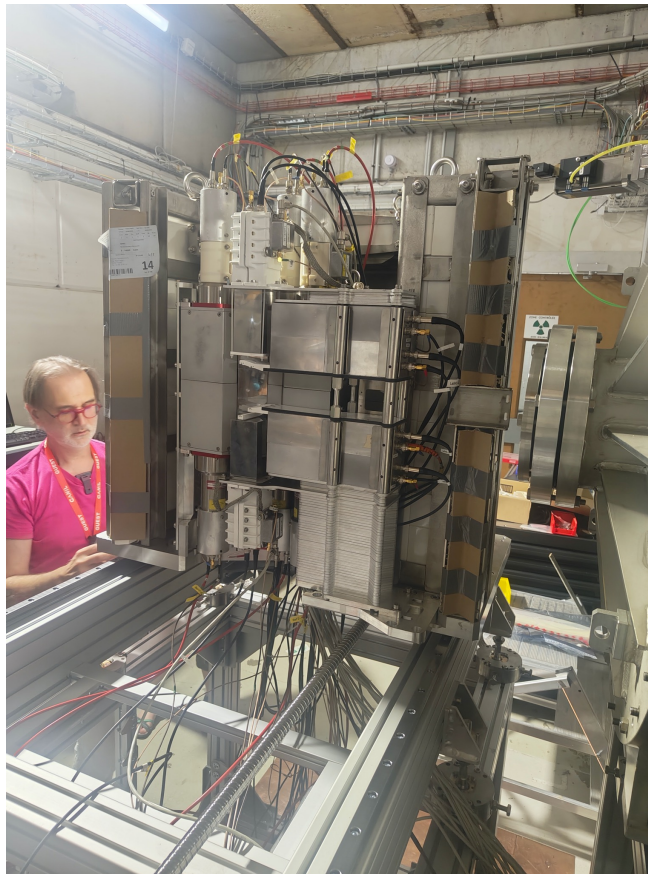
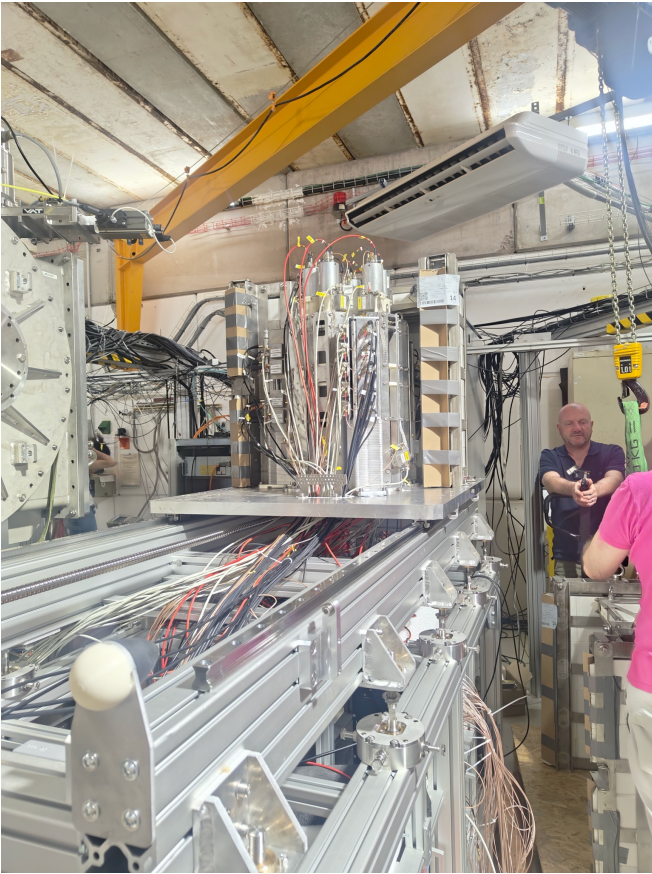


Detector fully
mounted without the
shielding



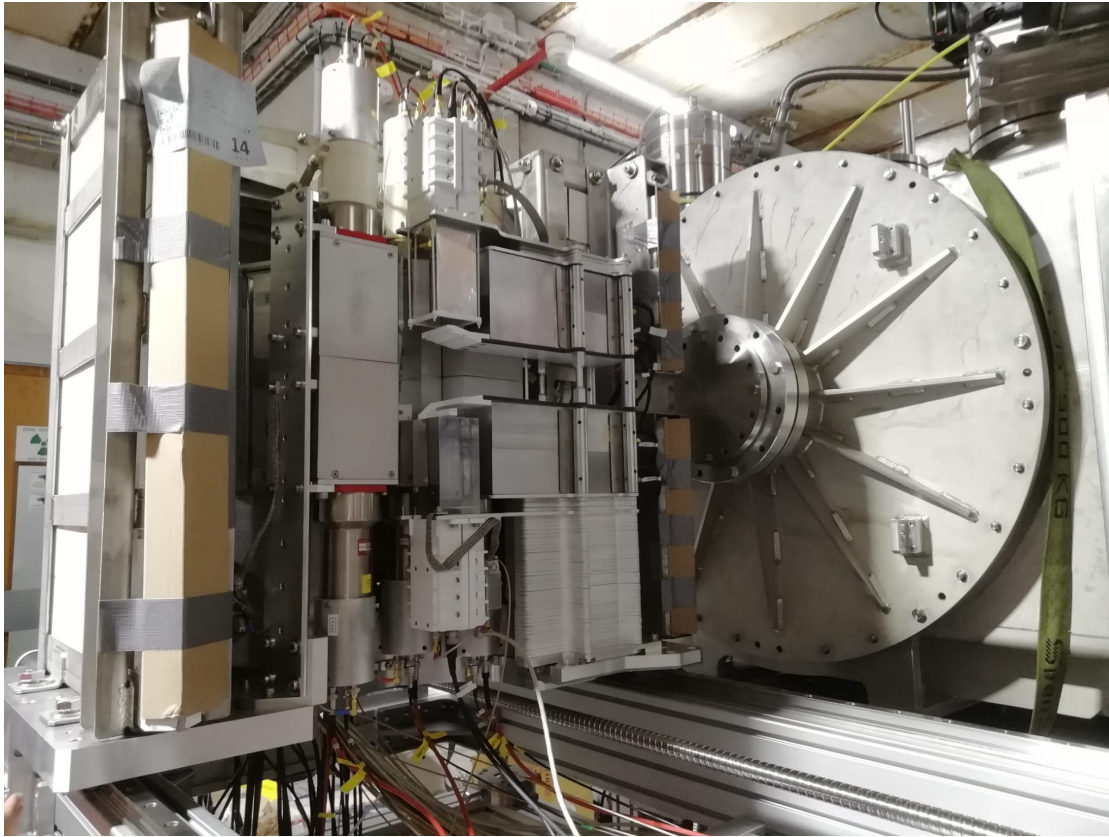
Central support

(NA)²STARS E891_23 Installation

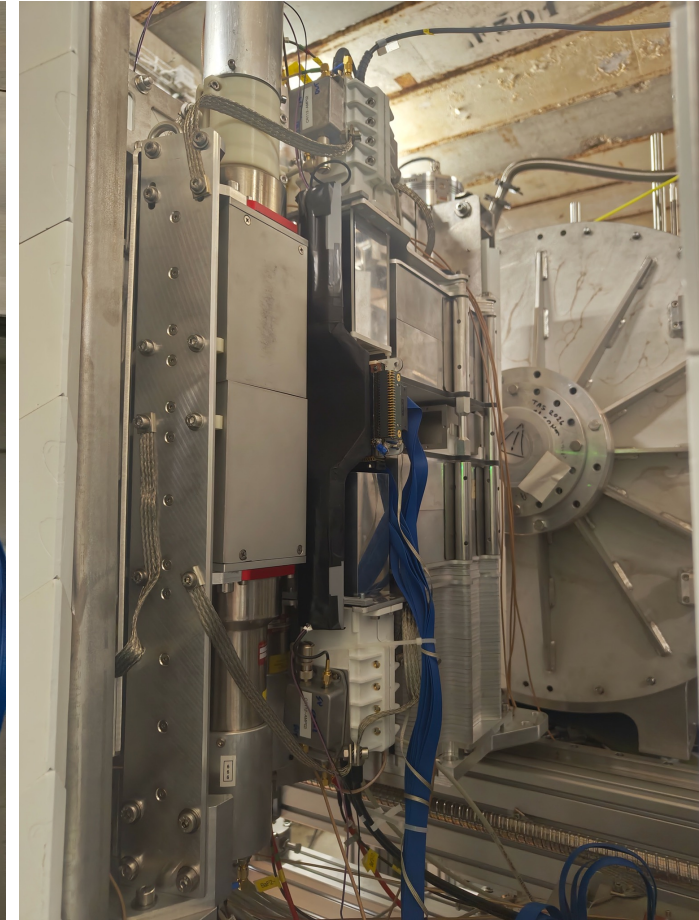
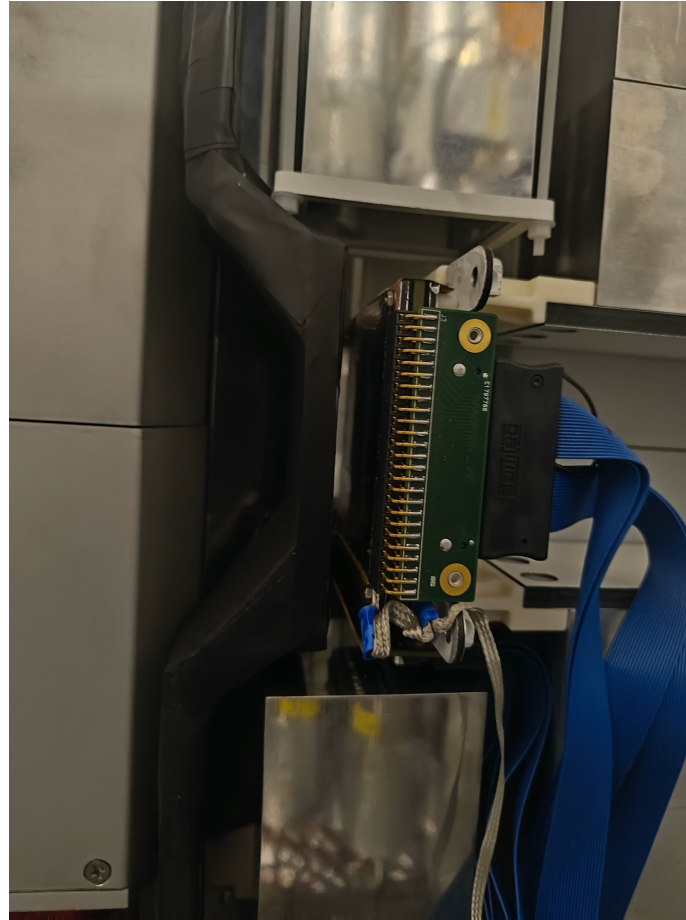
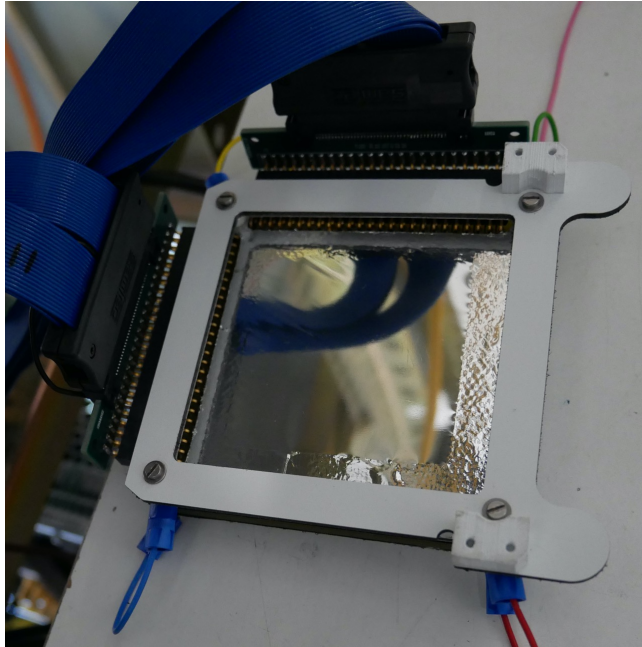


Shielding mounted, then alignment by GANIL geometrics

(NA)²STARS E891_23 Installation



(NA)²STARS E891_23 Installation



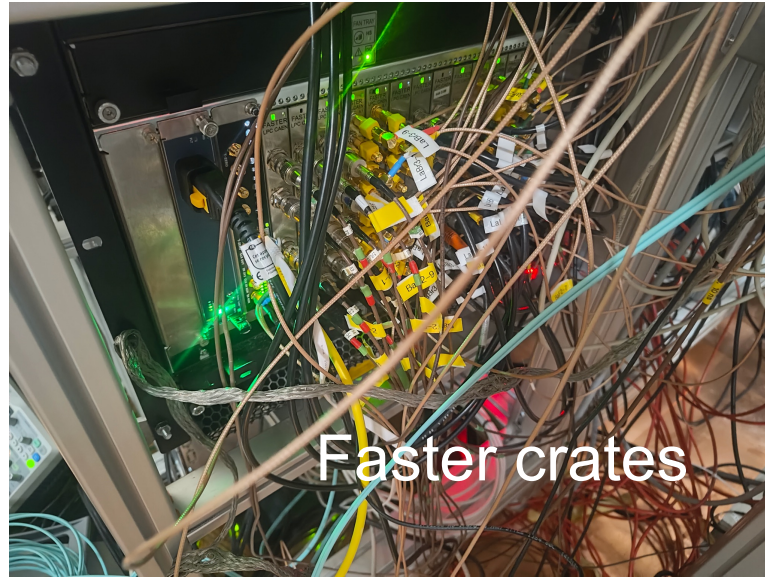
- New LISE DSSSD **GANIL**
- Plastic detector successfully made by GANIL at the last minute !!! (the ones ordered from Luxium still haven't arrived...)

(NA)²STARS E891_23 Installation

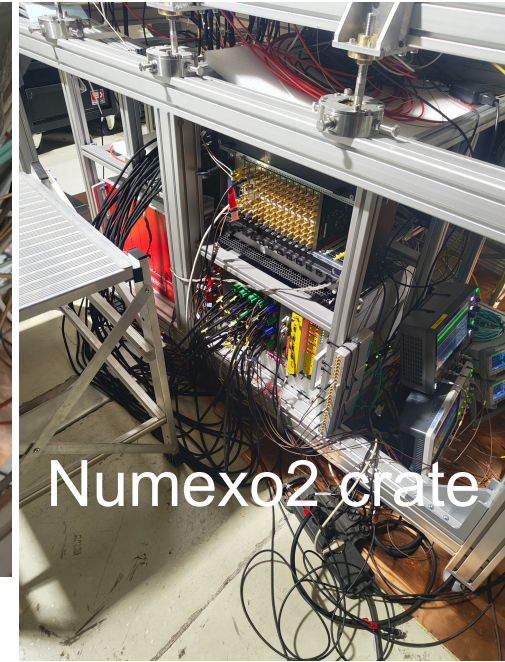
Master box



Faster crates



Numexo2 crate

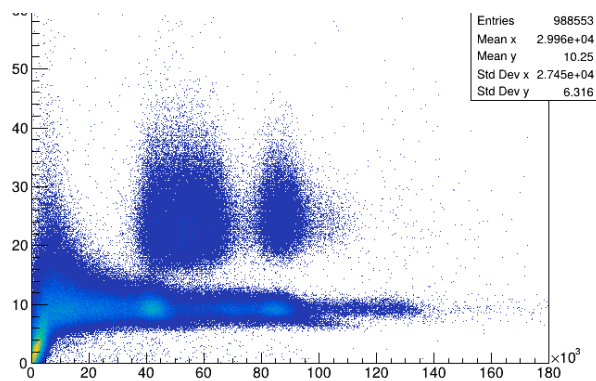


Cabling attempts

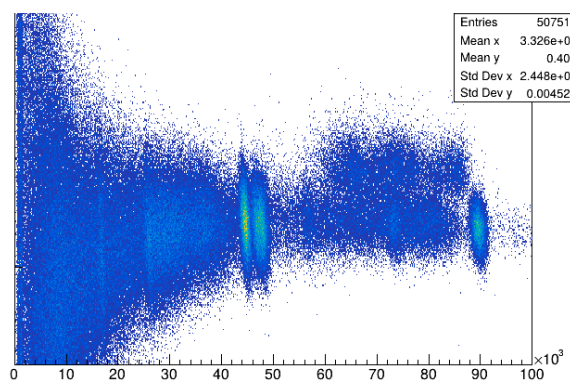


- Despite hard work and huge efforts from all sides, the NUMEXO2 (DSSSD) and FASTER DAQs could not be coupled online
- But they were coupled offline, with a pulser
- Preliminary x-checks in July were promising
- ⇒ on-going work, definite answer soon
- ⇒ Improvement for the future

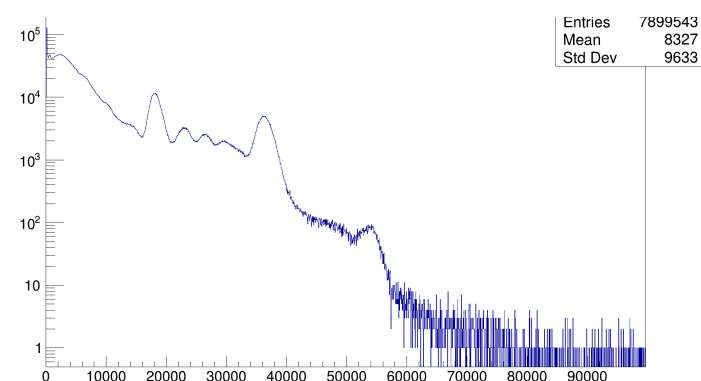
(NA)²STARS E891_23 Datataking



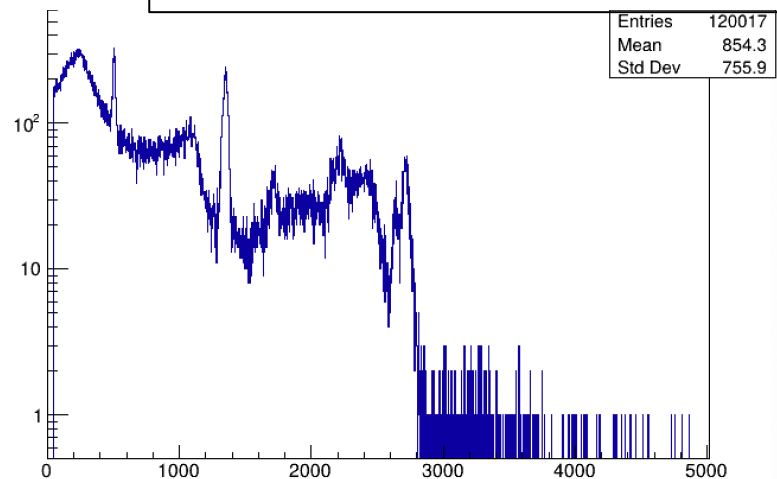
BaF₂ and LaBr₃ α/γ discrimination during ²⁴Na source run



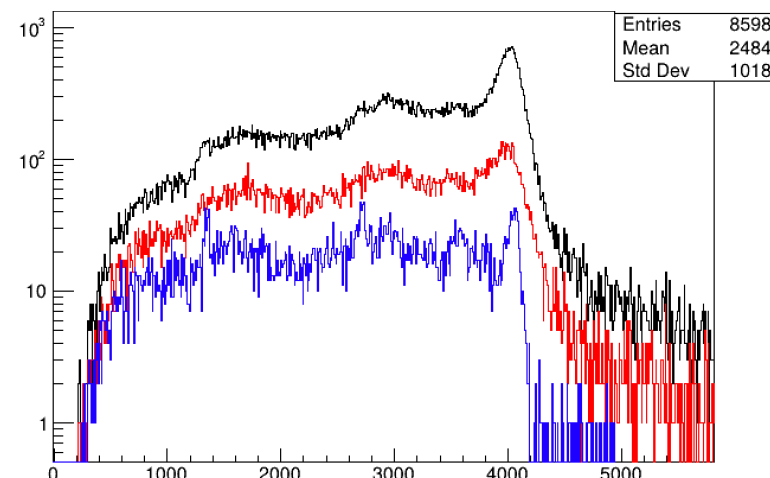
²⁴Na source: BaF₂ #12



Calibration sources: ¹³⁷Cs, ⁶⁰Co, ²⁰⁷Bi, ²²Na, ¹⁵²Eu, ¹³³Ba, AmBe and a « home made » ²⁴Na at NFS



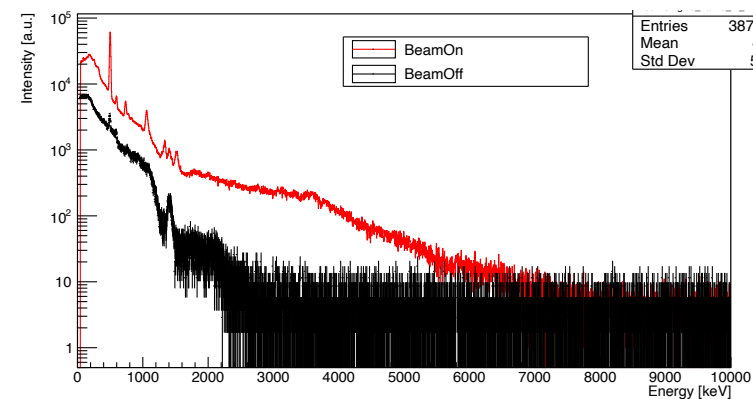
²⁴Na source: « single » sum of all LaBr₃



²⁴Na source: TAS sums (1 run)

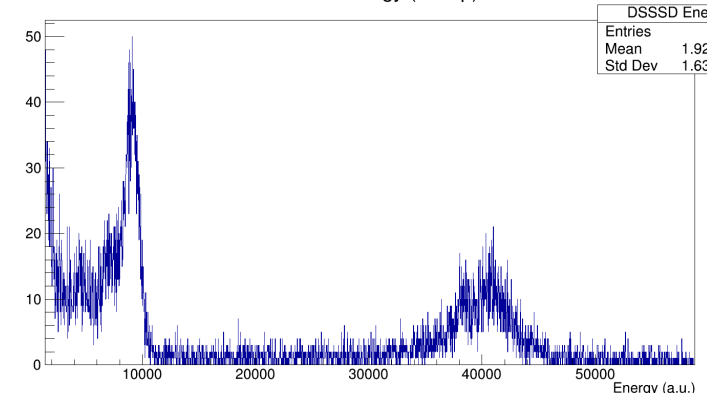
(NA)²STARS E891_23 Datataking

- Primary beam: ⁵⁸Ni @ 74.5 MeV/u, went up to 4μA
- Target: 197.1 μm ^{nat}Ni + 10 mg/cm² C stripper @ 0°
- Wedge shaped degrader: 109.5 μm Be
- Wien filter 2600kV/m
- Si det 143 μm, air ~40cm, Al extraction window 50 μm



Online example: 3 days of beam time
Multiplicity > 2, sum of LaBr₃ only
In black same with beam Off

DSSSD Energy (1 strip)



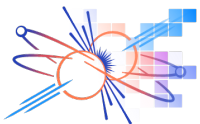
Online DSSSD 1 strip spectrum

⇒ After ~one week without beam (most probably because of the heat), we got full intensity until the end
😊😊😊😊

⇒ 300pps total implantations in the DSSSD
16.7UT of physics over 24UT of physics allocated

⇒ **Successful first TAGS experiment @ GANIL !!!**

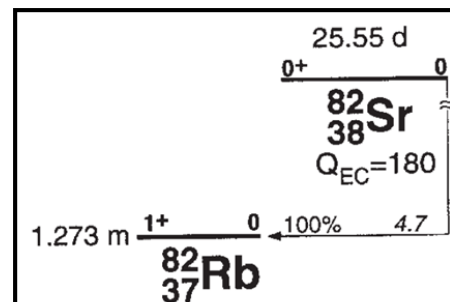
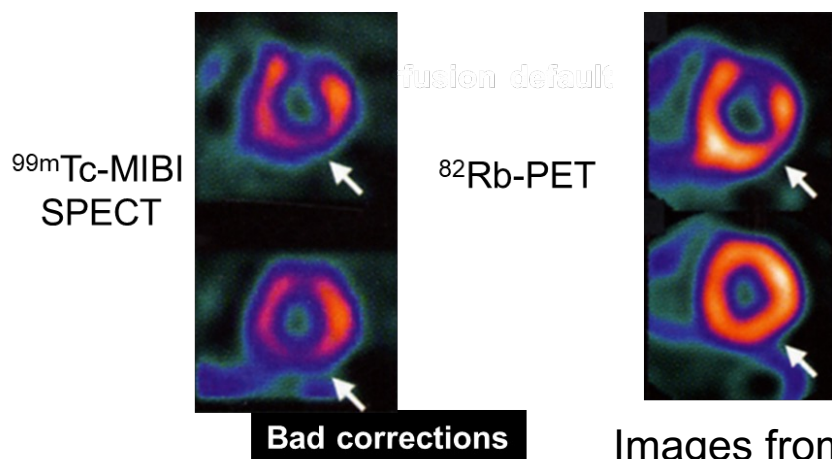
- 👁️ Intro: What is/Why the TAGS technique ?
- 👁️ Total Absorption Spectrometers & Experiments
- 👁️ (NA)²STARS Project
- 👁️ (NA)²STARS First Experiment at LISE, GANIL
- 👁️ **Conclusions & Perspectives**



(NA)²STARS still on-going

B. Rebeiro's **TAS-PROBE** project funded by NEXT Talent Junior Position in Nantes:
physics motivations: super-allowed decays + **health**:

- Generator systems allows to provide short lived isotopes at the hospital on-demand
- An example the ⁸²Sr/⁸²Rb generator for cardiology: Rubidium-82 enables the measurement of blood flow and thus the diagnosis of coronary artery disease with greater specificity than currently used techniques:



- ⇒ ⁸²Rb: relatively complex and well-defined decay scheme, ENSDF: Q_β 4.4 MeV, 34 EC/β⁺, 88 γ: good first case for (NA)²STARS
- ⇒ Other samples to be measured before unmounting in December

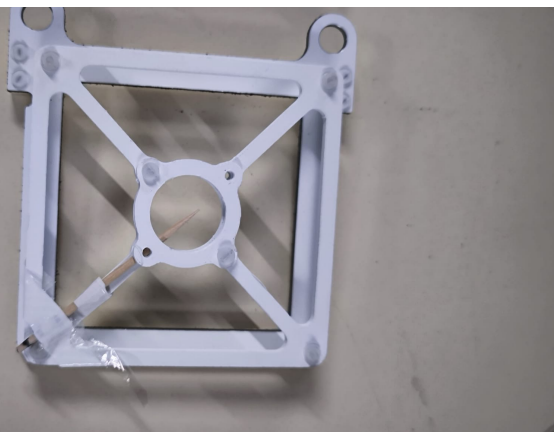


(NA)²STARS still on-going



Huge involvement of the GANIL SPR + a lot of help from GANIL collaborators

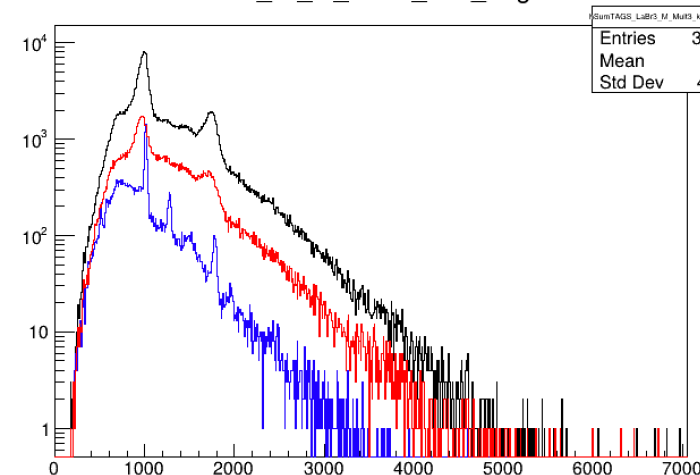
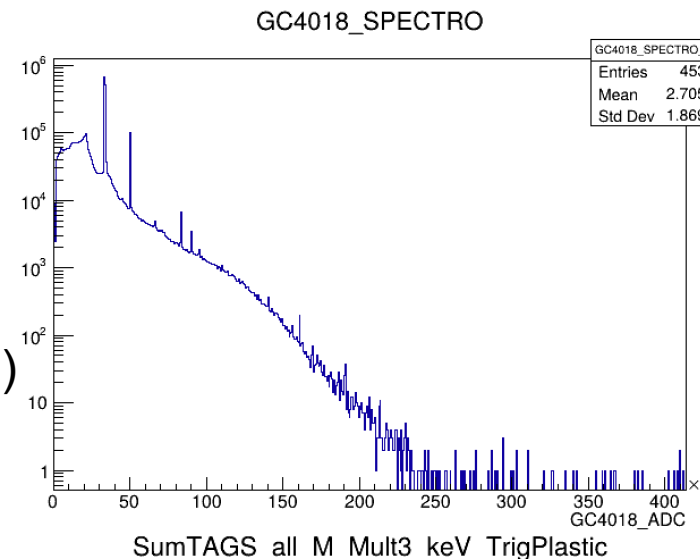
(NA)²STARS still on-going



Each new measurement deserves on top of TAGS:

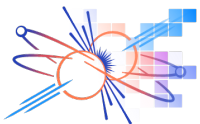
- Calibrations,
- Background runs,
- Ge measurement@IBE,

Several times (contaminants)



17th LaBr₃ brought on purpose by CSIC Madrid team, filling the beam hole

- 👁 Intro: What is/Why the TAGS technique ?
- 👁 Total Absorption Spectrometers & Experiments
- 👁 (NA)²STARS Project
- 👁 (NA)²STARS First Experiment at LISE, GANIL
- 👁 Conclusions & Perspectives



The (NA)²STARS perspectives

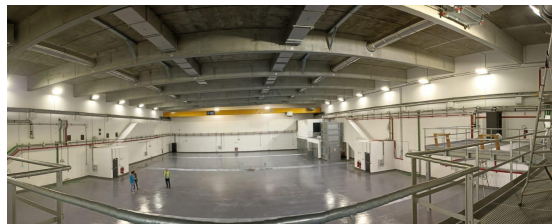
- Accepted (NA)²STARS proposal @ Jyväskylä motivated by neutrino physics, nuclear astrophysics, decay heat..., spokespersons: M. Estienne, A. Porta, A. Algora. ~Autumn 2027
- New Proposals on LISE & NFS in preparation
- 3 Lols for experiments @ LISE
- 11 Lol for experiments @ DESIR
- Start to work on mechanical support and decay station for (NA)²STARS@ DESIR in 2027



● ● ● Setups used

• PIPERADE:	13 experiments	• LRC:	1 experiment
• LASAGN:	11 experiments	• TETRA:	1 experiment
• DDS:	11 experiments	• PARIS:	1 experiment
• (NA) ² STARS:	11 experiments	• ASGARD:	1 experiment
• MLLTRAP:	4 experiments	• MORA:	1 experiment
• S3-LEB:	4 experiments	• gSPEC:	1 experiment
• COeCO:	4 experiments	• ARGOS:	1 experiment
• SiCube:	4 experiments	• MOT:	1 experiment
• MR-ToF-MS:	3 experiments		
• SEASON:	3 experiments		
• TORTILA:	2 experiments		
• HINA:	2 experiments		

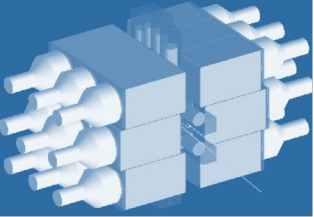
- some experiments ask for 1 isotope, others for up to 35!
- up to 300 UTs for a single experiment
- in total 345 different isotopes requested



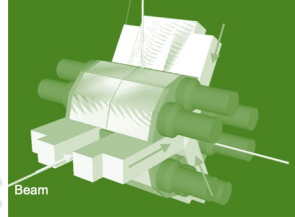
Bertram Blank's slide @ the DESIR workshop, 18-20 march 26

Conclusions

- TAGS experiments are complementary to high-resolution γ -ray spectroscopy
- Particularly well adapted to measure high energy γ -rays and B(GT) avoiding the Pandemonium effect
- The TAGS collaboration in Europe has a large physics program spanning both n-rich and n-deficient nuclei, performed presently at IGISOL Jyväskylä, ISOLDE Cern, GSI, Riken and GANIL
- The (NA)²STARS project will allow studying more exotic nuclei with the TAGS technique
- Part of this program will be performed at GANIL in the future: starting @ LISE in early 2026, then LISE + DESIR
- The First TAGS experiment @ LISE with (NA)²STARS is **a success**, despite challenging (heatwave + beam ; DAQ coupling, commissioning...) but we met the challenge !!!
⇒ PhDs of Lena Le Floch (⁴⁴Ti) and Meenakshi Pillai (health)



THANK YOU



E891 Experiment + TAS-PROBE collaborations @ GANIL:

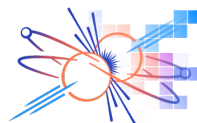
- SUBATECH: E. Bonnet, S. Bouvier, M. Chabrun, S. Durand, M. Estienne, M. Fallot, L. Le Floch, V. Piau, A. Porta, B. Rebeiro, J.-S. Stutzmann, and Mechanical and Electronical workshops
- IFIC Valencia: G. Alcala, A. Algora, C. Lupi Casale, E. Nacher, R. Naqvi, S. Orrigo, D. Rodriguez, B. Rubio, J.-L. Tain
- GANIL : C. Berteloite, L. Canete, F. De Oliveira, H. Guérin, X. Ledoux, B. Rebeiro, J.-C. Thomas – and support from the SPR and GTA teams
- USTHB, Alger: N. Adimi
- UC Madrid: J.A. Briz-Monago
- CIEMAT Madrid: D. Cano-Ott
- CSIC Madrid: M. J. Borge, T. Kurtukian Nieto, D. Godos, J.F. Gonzales Limenes, P. Ortega, O. Tengblad
- IP2I: C. Ducoin, N. Millard-Pinard, O. Stézowski, L. Zago
- Surrey: W. Gelletly, Z. Podolyak
- U. Istanbul: E. Ganioglu Nutku, L. Şahin Yalçın, M. Yalçinkaya
- U. Huelva: A. M. Benitez-Sanchez, L. Acosta
- NPI CAS: A. Cassissa, J. Mrazek, E. Simeckova
- Atomki: G. Kiss, S.R. Kovacs
- ARRONAX Production Team and N. Audouin, F. Haddad, N. Michel, Th. Sounalet



NUCLÉAIRE
& PARTICULES



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APRENDE



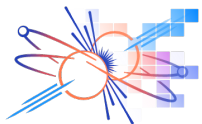
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