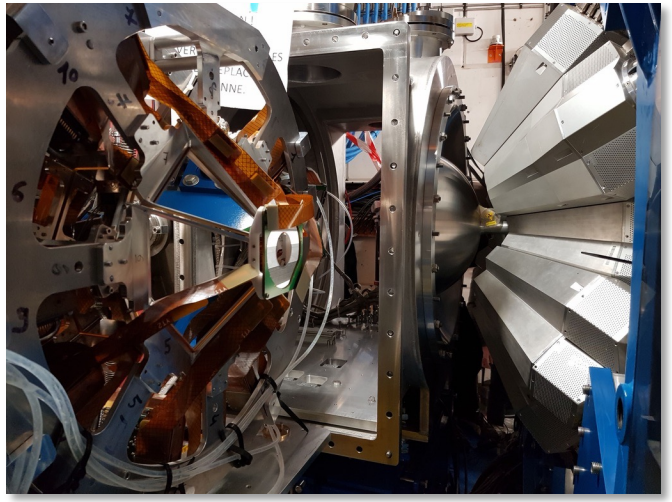
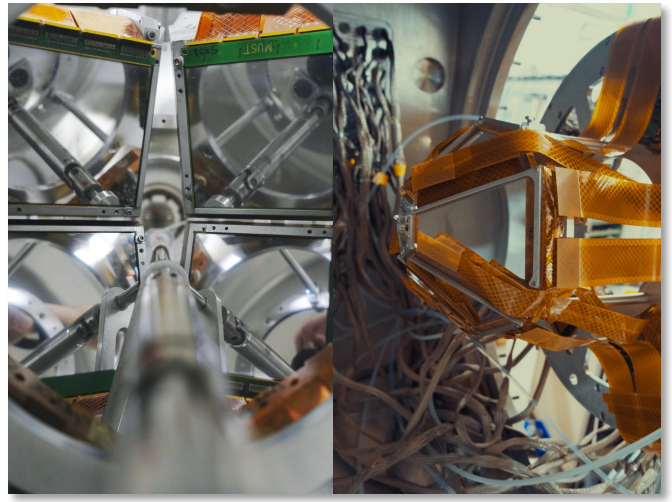
Overview and performances of the MUGAST array at GANIL

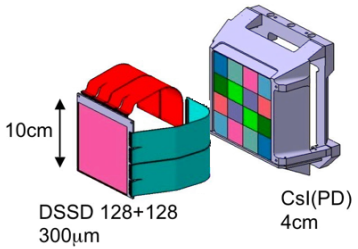




IRL NPA
Girard-Alcindor Valérian - IJCLab

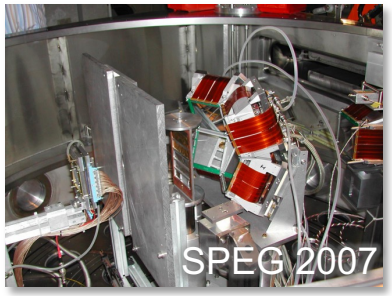
Presentation of MUST2/MUGAST

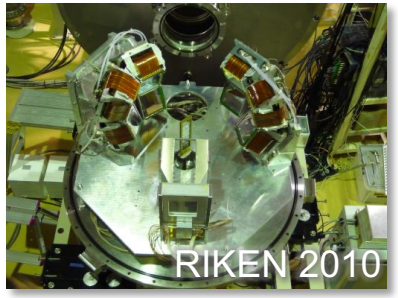
Presentation of MUST2/MUGAST

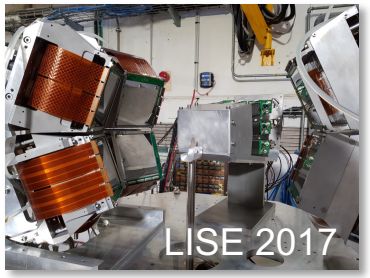


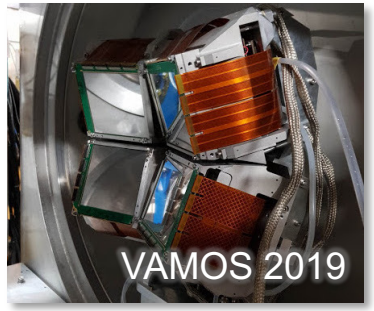
MUST2:

- 300 µm Si detector
- 4x4 CsI crystals
- Up to 8 telescopes
- In use since: 2007

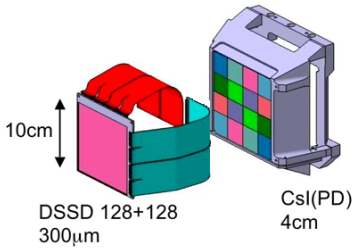






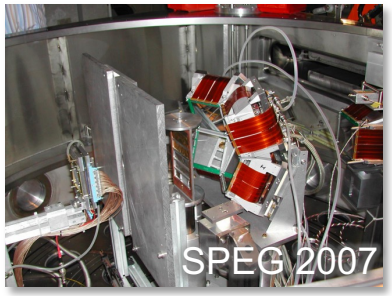


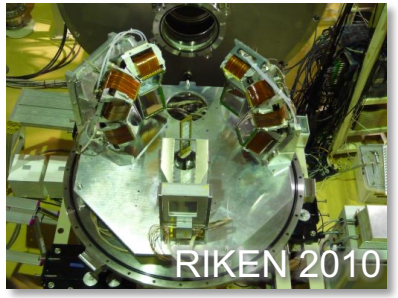
Presentation of MUST2/MUGAST

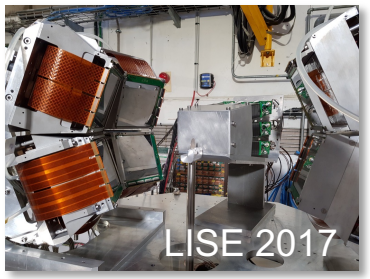


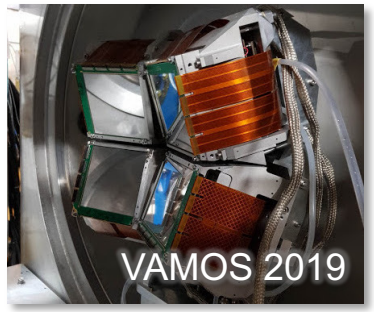
MUST2:

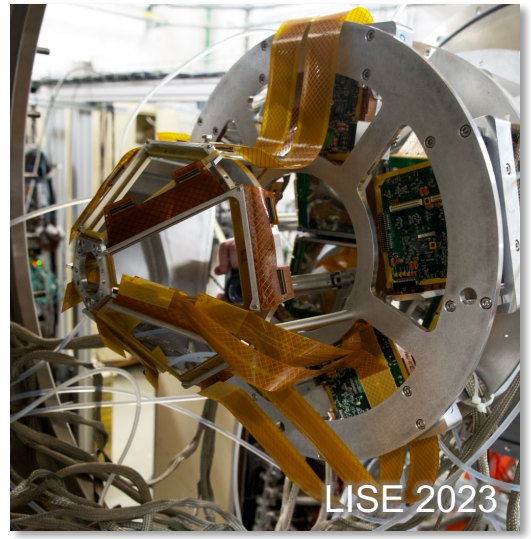
- 300 µm Si detector
- 4x4 CsI crystals
- Up to 8 telescopes
- In use since: 2007









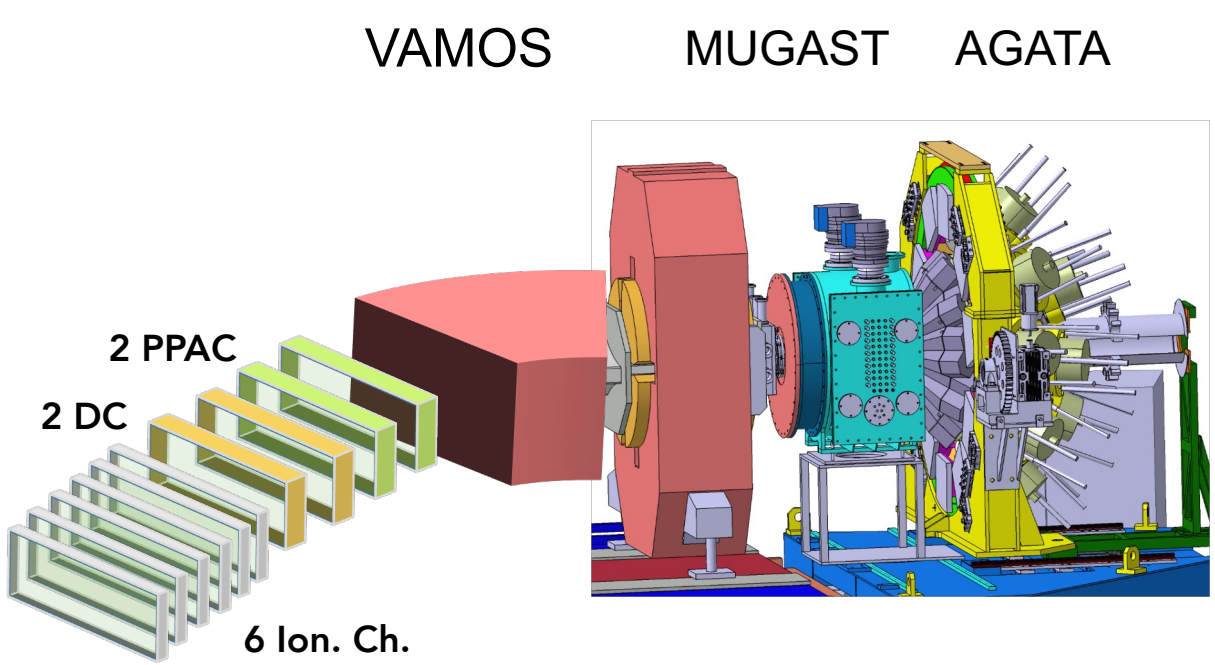


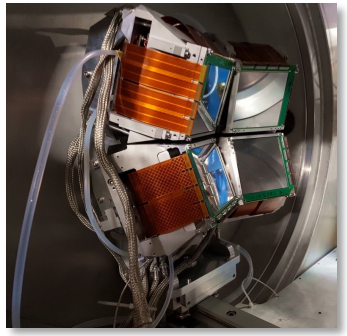
MUGAST:

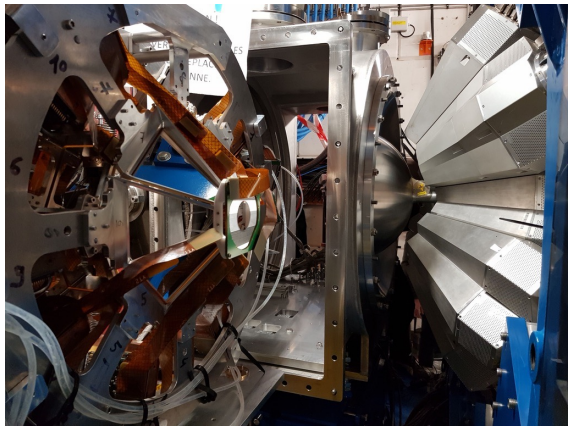
- 4 MUST2 telescopes (forward)
- 5 - 7 trapezoid-shape 500 µm DSSD (backward)
- 1 annular DSSSD (backward)
- 2 square shape 500 µm DSSD + a 1.5 mm DSSD or 1 MUST2 (90°)
- First step toward the next generation Si detector: GRIT
- In use at GANIL since: 2019 ISOL + Fragmentation beam

MUGAST/VAMOS/AGATA Campaign

MUGAST-VAMOS-AGATA: 2019 - 2021



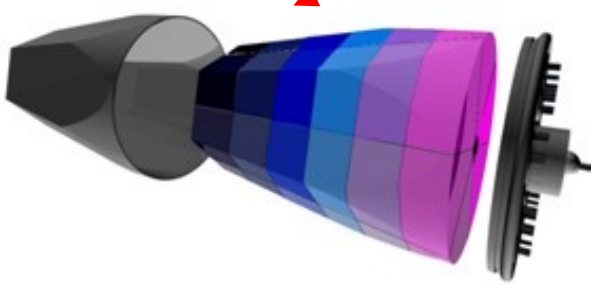


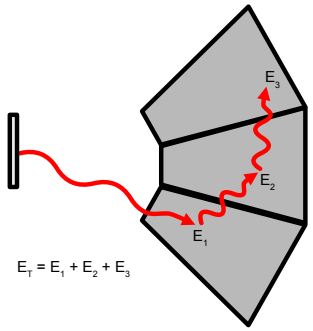


- 0º Detection: VAMOS
- AGATA Ge y-ray spectrometer
- 4 MUST2 telescopes (forward)
- 5-7 trapezoidal DSSD + 1 Annular DSSD (backward)
- 2 Square DSSD or 1 MUST2 at 90º
- Cryogenic-target compatible

- 5 experiments (2019-2021)
  - Shell-model
  - Drip-line
  - Nuclear astrophysics

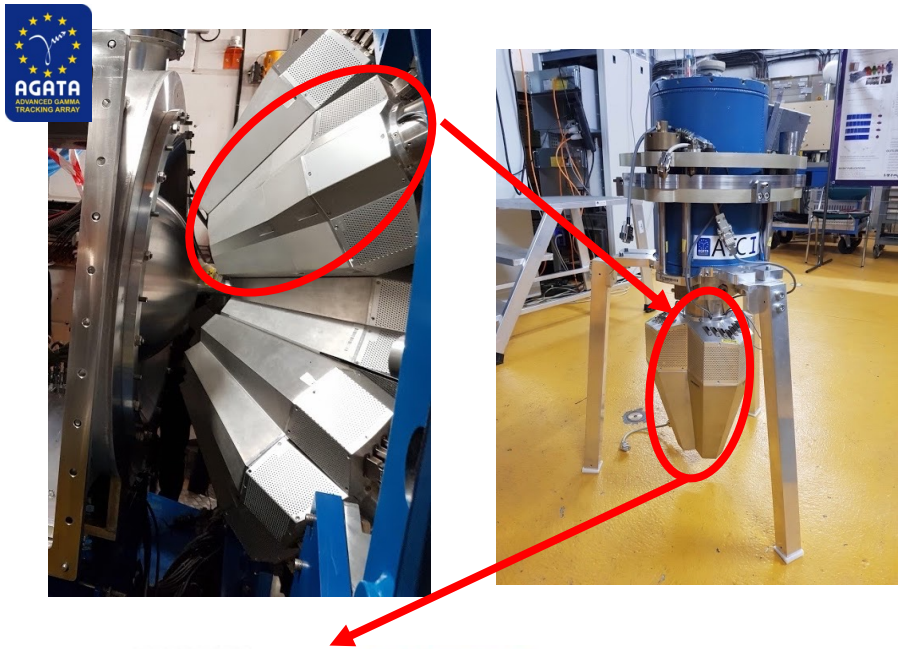
MUGAST-VAMOS-AGATA: 2019 - 2021

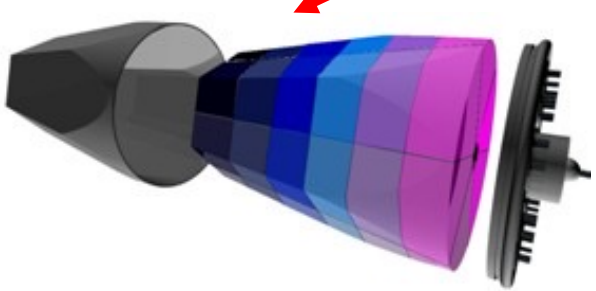


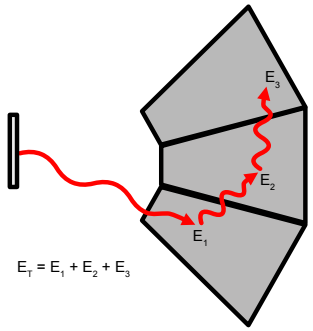


S.Akkoyun, NIM-A Volume 668, 11 March 2012, Pages 26-58

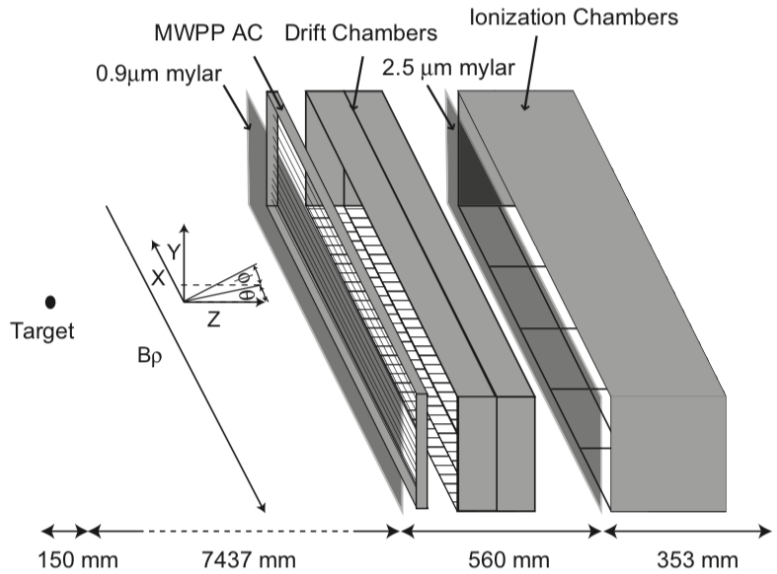
MUGAST-VAMOS-AGATA: 2019 - 2021

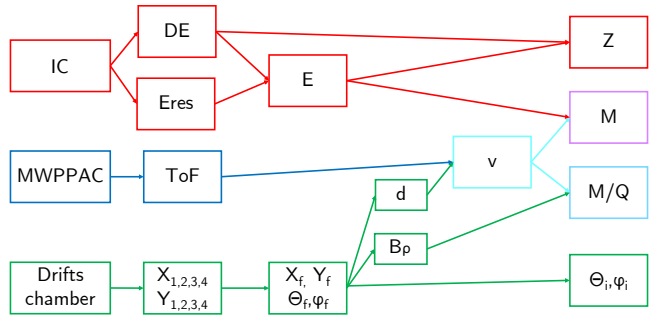




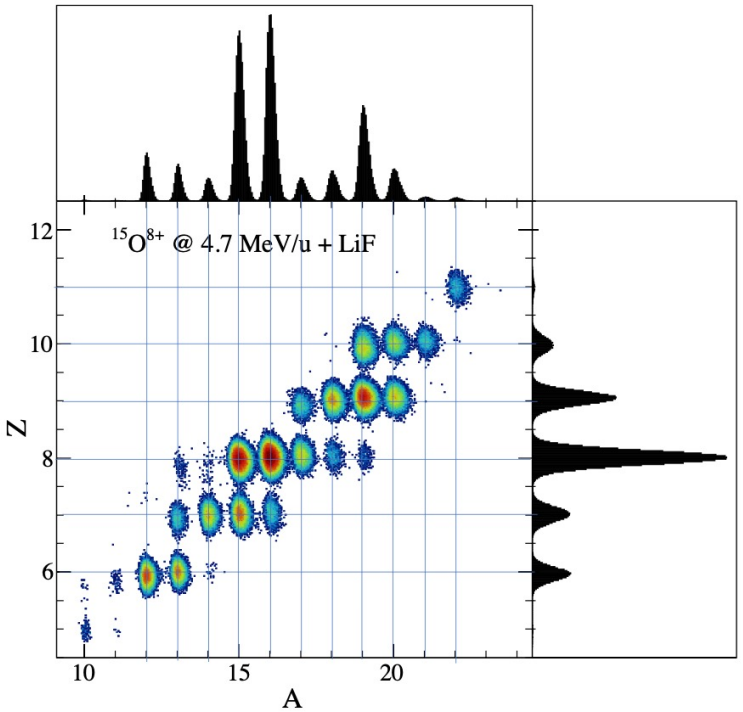


S.Akkoyun, NIM-A Volume 668, 11 March 2012, Pages 26-58



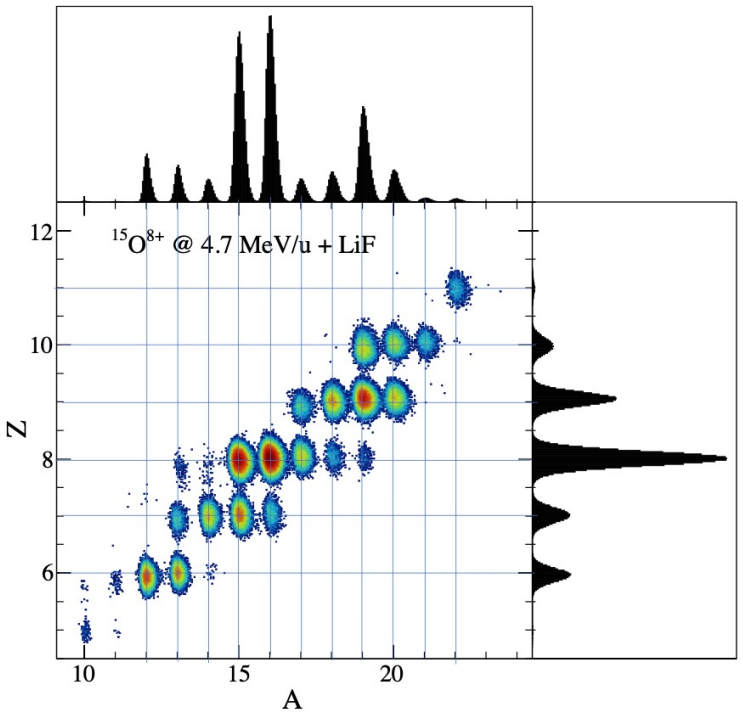


“Heavy” fragments PID in VAMOS:

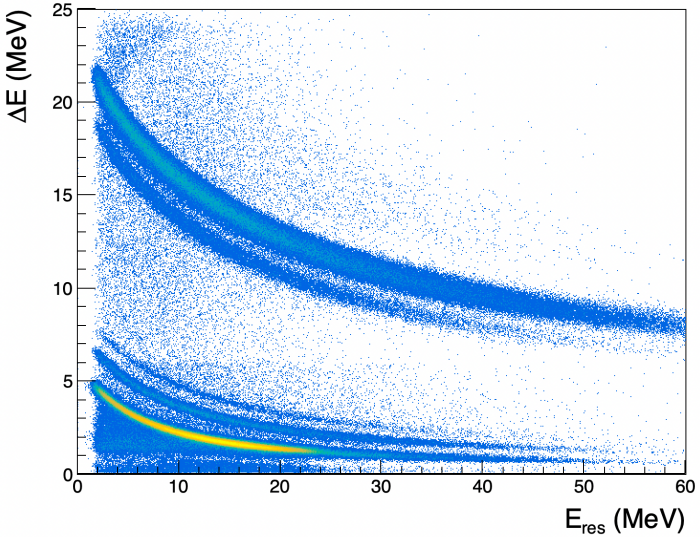


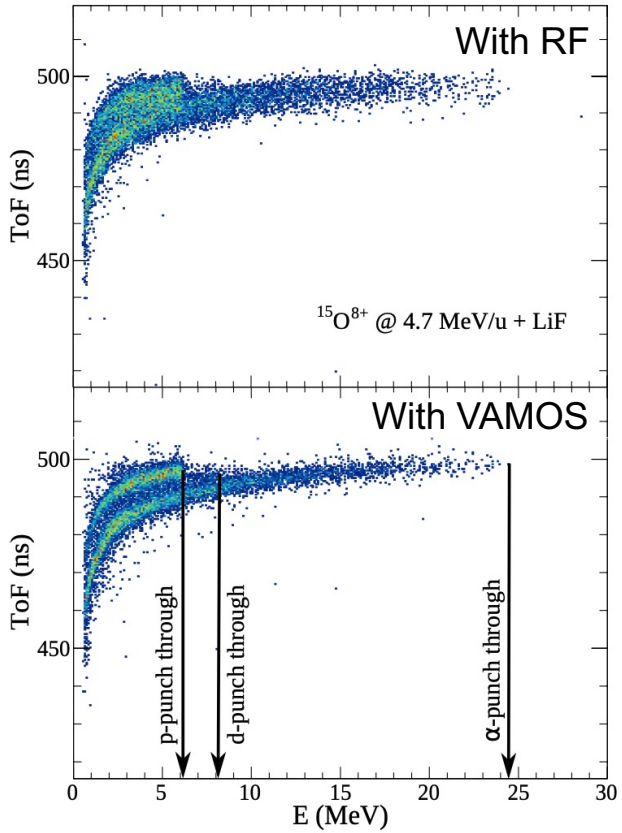
M. Assié Volume 1014, 21 October 2021, 165743

"Heavy" fragments PID in VAMOS:



Light particles PID in MUGAST:

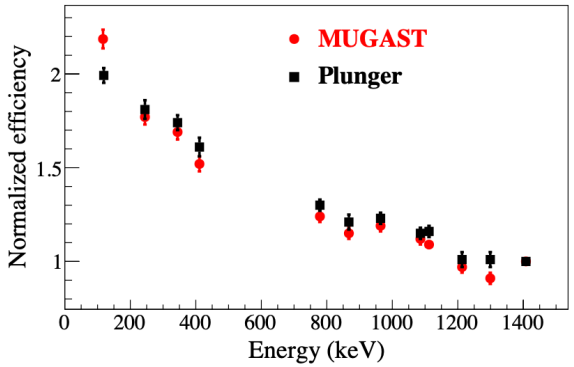




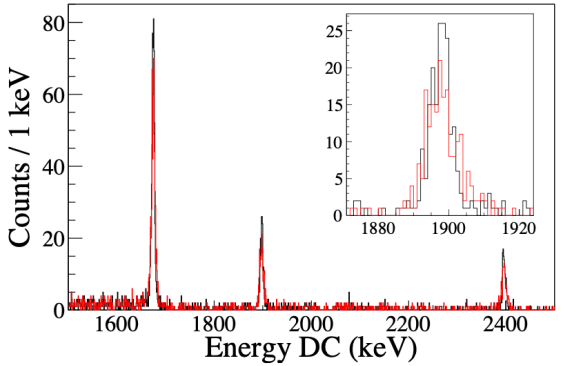
M. Assié Volume 1014, 21 October 2021, 165743

MUGAST-VAMOS-AGATA: 2019 - 2021

Efficiency MUGAST = plunger:



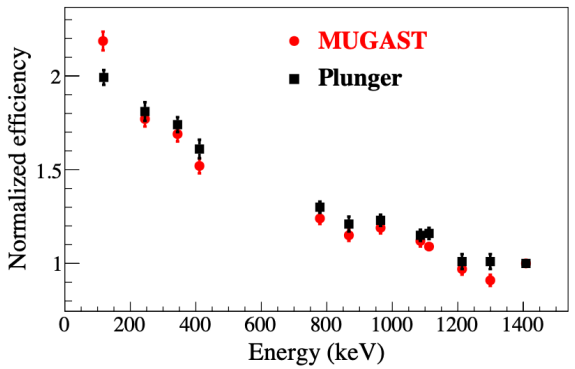
10.2 keV -> 7.1 KeV (FWHM):



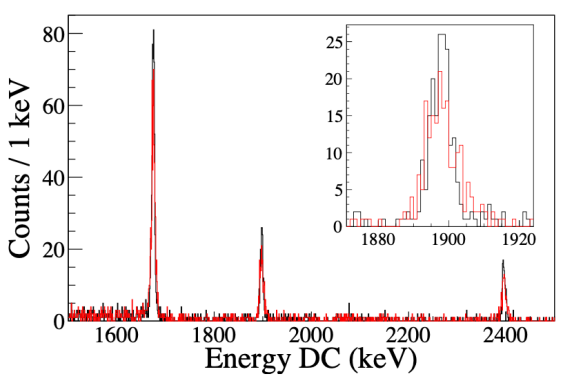
M. Assié Volume 1014, 21 October 2021, 165743

MUGAST-VAMOS-AGATA: 2019 - 2021

Efficiency MUGAST = plunger:

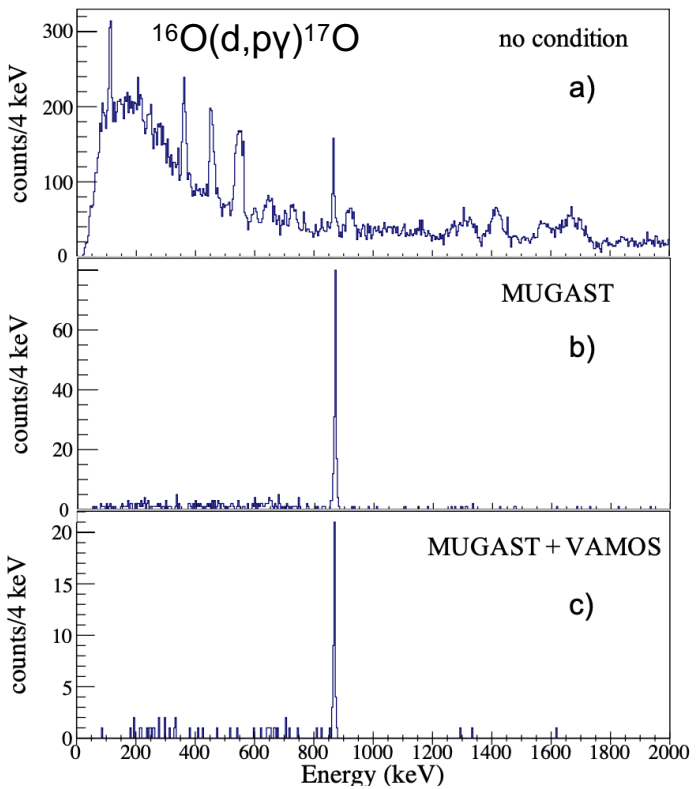


10.2 keV -> 7.1 KeV (FWHM):

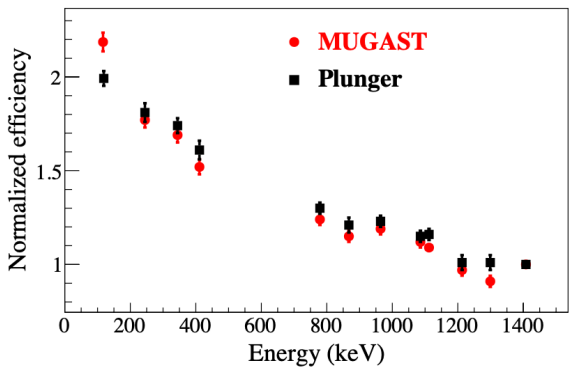


M. Assié Volume 1014, 21 October 2021, 165743

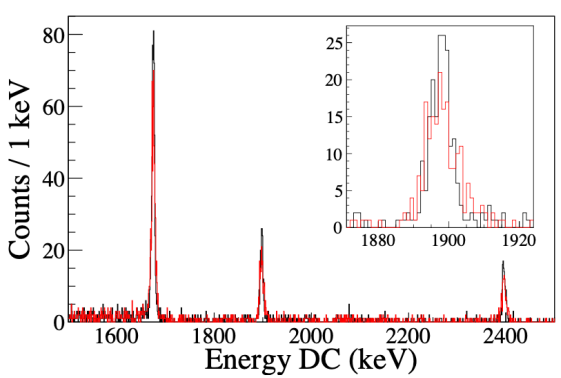
Excellent background reduction:



Efficiency MUGAST = plunger:

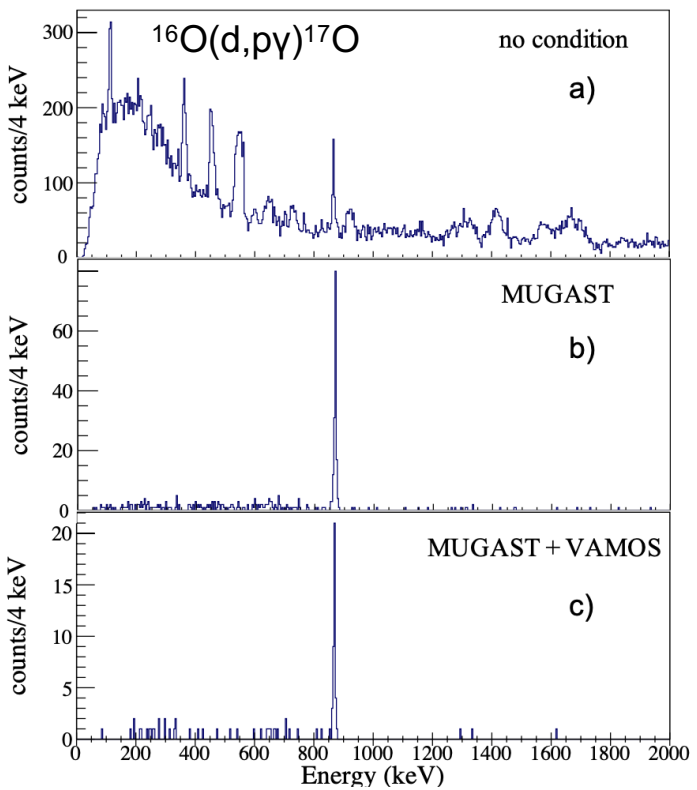


10.2 keV -> 7.1 KeV (FWHM):

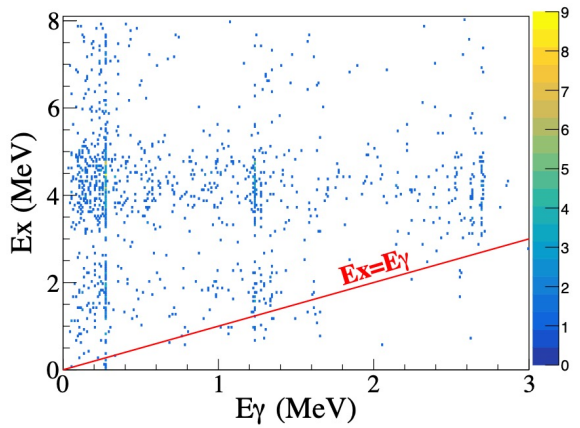


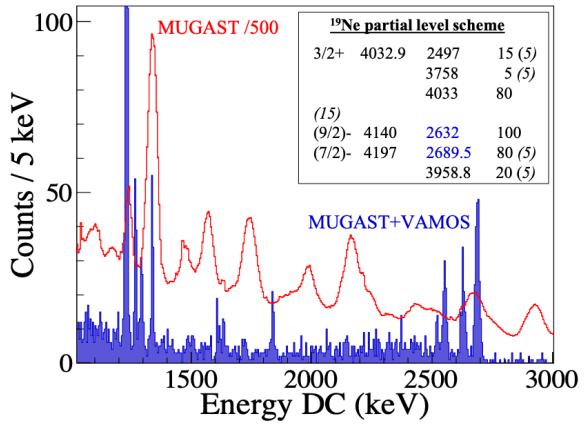
M. Assié Volume 1014, 21 October 2021, 165743

Excellent background reduction:



Missing mass + gamma spectroscopy:





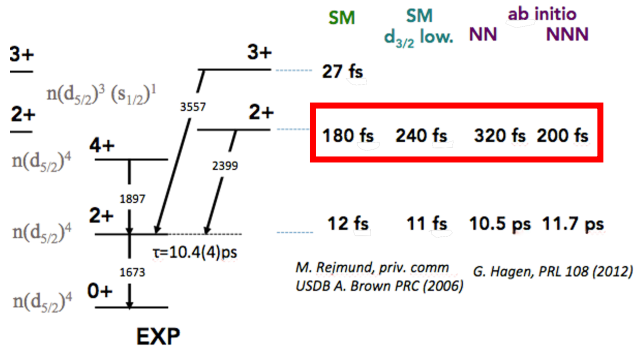
Highlights of the MUGAST/VAMOS/AGATA Campaign

E. Clément, A. Goasduf: Lifetime measurements of the 2^+_2 and 3^+_1 states in ^{20}O populated by direct nucleon transfer

Topic: Shell model
Reaction: ^{19}O(d,pγ) + DSAM
Goal:

- Constrain relative position of $s_{1/2}$ and $d_{3/2}$ in n-rich oxygen
- Probe the 3-body interaction
- Combination of DSAM + transfer to identify the entrance channel

Motivation : Oxygen drip-line anomaly explained microscopically by including three-nucleon force contribution in the nuclear interaction.
Predictions : from Shell model and ab-initio (2N and 3N forces):

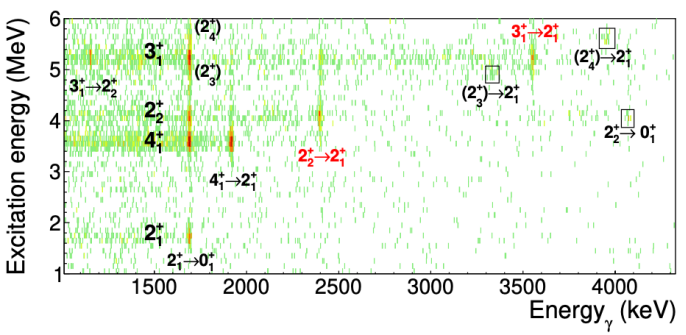


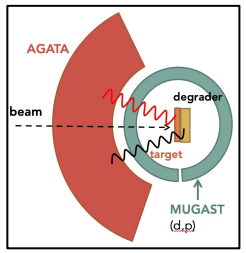
E. Clément, A. Goasduf: Lifetime measurements of the 2^+_2 and 3^+_1 states in ^{20}O populated by direct nucleon transfer

Topic: Shell model
Reaction: ^{19}O(d,pγ) + DSAM
Goal:

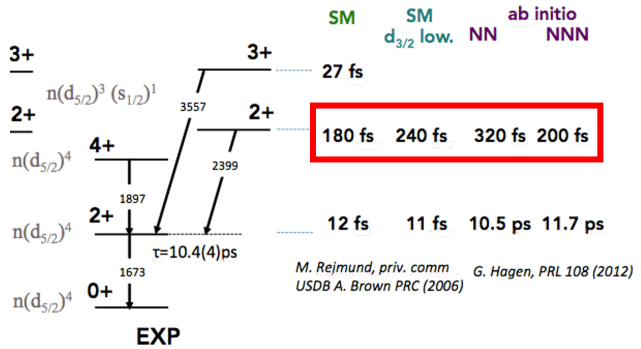
- Constrain relative position of $s_{1/2}$ and $d_{3/2}$ in n-rich oxygen
- Probe the 3-body interaction
- Combination of DSAM + transfer to identify the entrance channel

PhD : I. Zanon





Motivation : Oxygen drip-line anomaly explained microscopically by including three-nucleon force contribution in the nuclear interaction.
Predictions : from Shell model and ab-initio (2N and 3N forces):

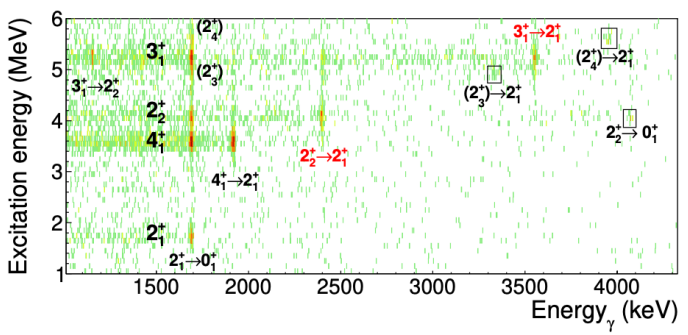


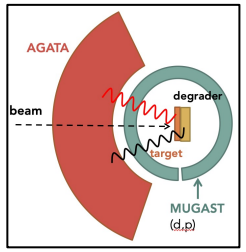
E. Clément, A. Goasduf: Lifetime measurements of the 2^+_2 and 3^+_1 states in ^{20}O populated by direct nucleon transfer

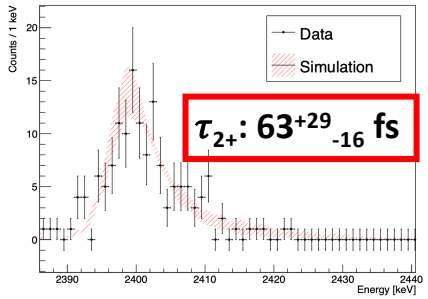
Topic: Shell model
Reaction: ^{19}O(d,pγ) + DSAM
Goal:

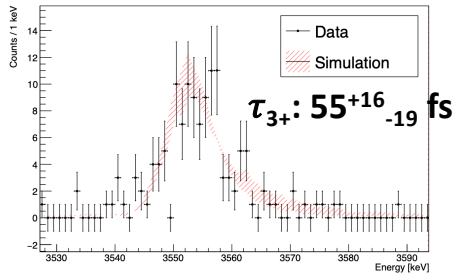
- Constrain relative position of $s_{1/2}$ and $d_{3/2}$ in n-rich oxygen
- Probe the 3-body interaction
- Combination of DSAM + transfer to identify the entrance channel

PhD : I. Zanon : Accepted in PRL 21 November 2023



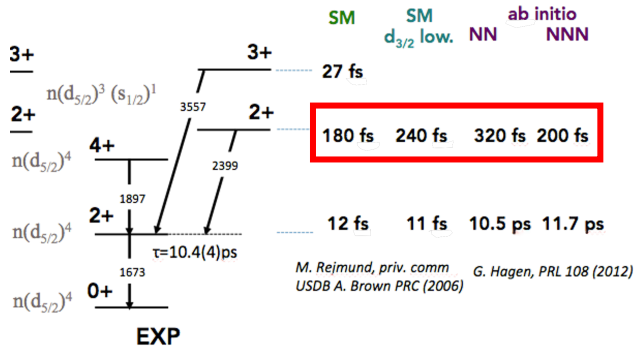






- 2^+ $t_{1/2}$ < predictions and previous measurements
- 3+ $t_{1/2}$ measured for the first time
- Strong constraints on the theoretical models
- Paves the way for similar measurements

Motivation : Oxygen drip-line anomaly explained microscopically by including three-nucleon force contribution in the nuclear interaction.
Predictions : from Shell model and ab-initio (2N and 3N forces):



C. Diget, N. De Séréville: Determining the α+^{15}O radiative capture rate

Topic: Nuclear astrophysics
Reaction: ^{15}O(^{7}Li,tγ)^{19}Ne indirect measurement

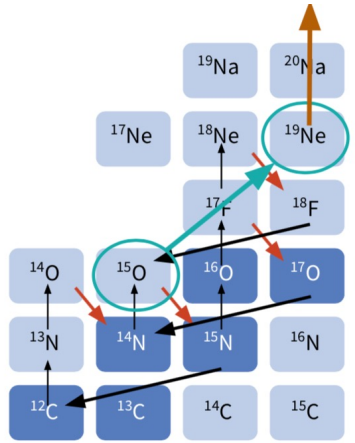
Motivations:

- Breakout to rp-process ^{15}O(α,γ)^{19}Ne and ^{18}Ne(α,p)^{21}Na
- Key beak-up route from the Hot-CNO
- Start-up of Type I X-ray burst depends upon this reaction rate
- Resonant reaction rate ^{15}O(α,γ)^{19}Ne expected to dominate through 4033 keV resonance *(to be measured in AGATA)*

Preliminary results:

- Observation of a gamma width to the alpha channel of: 4.8 μeV
- ^{15}O(α,γ)^{19}Ne reaction rate smaller than previous estimations
- The ^{18}Ne(α,p)^{21}Na must be a competitive breakout channel…

PhD : J. Sanchez Rojo



C. Diget, N. De Séréville: Determining the α+^{15}O radiative capture rate

Topic: Nuclear astrophysics
Reaction: ^{15}O(^{7}Li,tγ)^{19}Ne indirect measurement

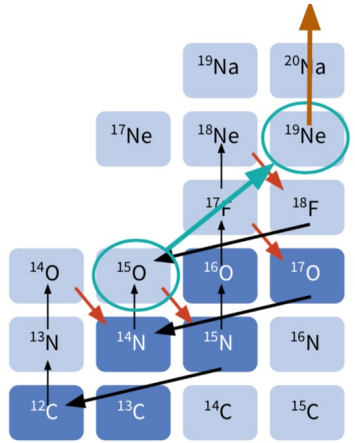
Motivations:

- Breakout to rp-process ^{15}O(α,γ)^{19}Ne and ^{18}Ne(α,p)^{21}Na
- Key beak-up route from the Hot-CNO
- Start-up of Type I X-ray burst depends upon this reaction rate
- Resonant reaction rate ^{15}O(α,γ)^{19}Ne expected to dominate through 4033 keV resonance *(to be measured in AGATA)*

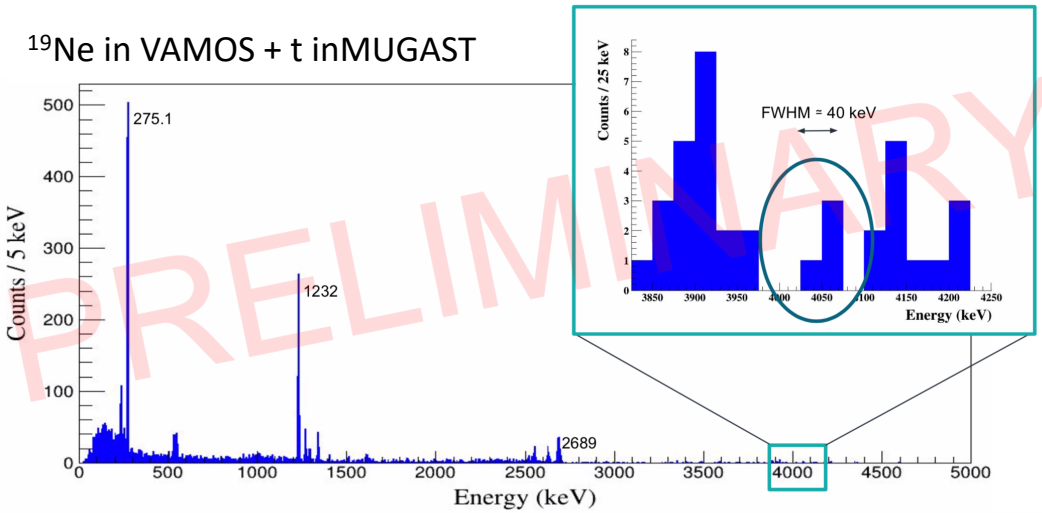
Preliminary results:

- Observation of a gamma width to the alpha channel of: 4.8 μeV
- ^{15}O(α,γ)^{19}Ne reaction rate smaller than previous estimations
- The ^{18}Ne(α,p)^{21}Na must be a competitive breakout channel…

PhD : J. Sanchez Rojo



^{19}Ne in VAMOS + t inMUGAST



C. Diget, N. De Séréville: Determining the α+^{15}O radiative capture rate

Topic: Nuclear astrophysics
Reaction: ^{15}O(^{7}Li,tγ)^{19}Ne indirect measurement

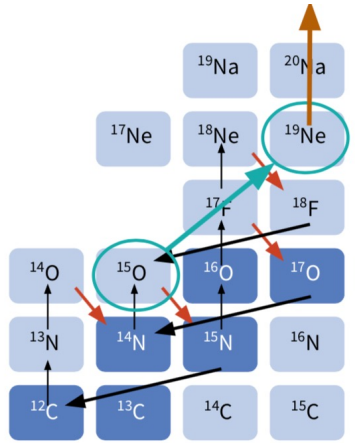
Motivations:

- Breakout to rp-process ^{15}O(α,γ)^{19}Ne and ^{18}Ne(α,p)^{21}Na
- Key beak-up route from the Hot-CNO
- Start-up of Type I X-ray burst depends upon this reaction rate
- Resonant reaction rate ^{15}O(α,γ)^{19}Ne expected to dominate through 4033 keV resonance *(to be measured in AGATA)*

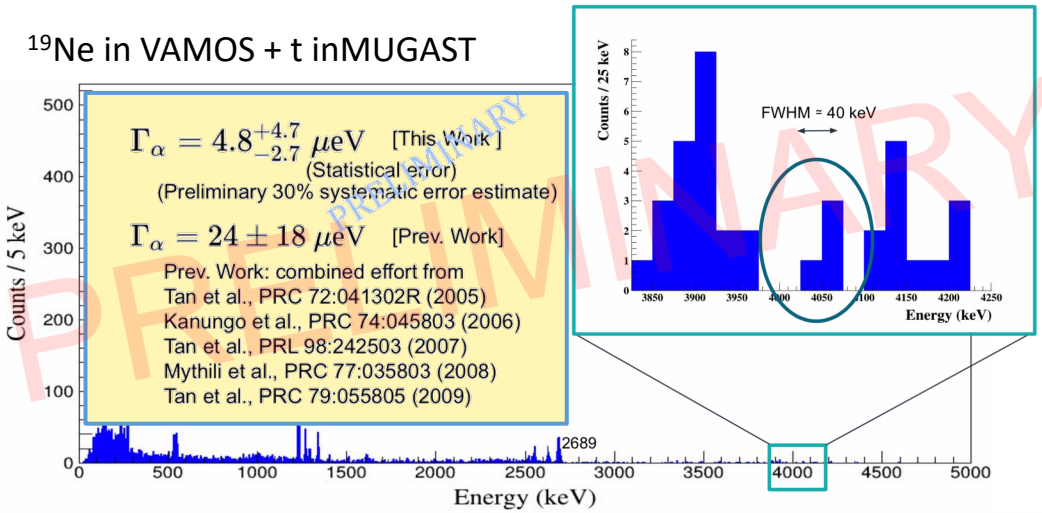
Preliminary results:

- Observation of a gamma width to the alpha channel of: 4.8 μeV
- ^{15}O(α,γ)^{19}Ne reaction rate smaller than previous estimations
- The ^{18}Ne(α,p)^{21}Na must be a competitive breakout channel…

PhD : J. Sanchez Rojo



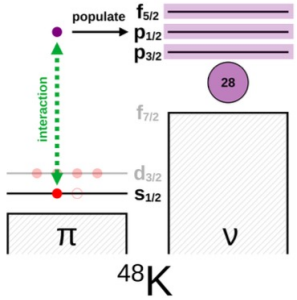
^{19}Ne in VAMOS + t inMUGAST



W. Catford, A. Matta: Proton-neutron interactions across N = 28 via ^{47}K(d,p)^{48}K and implications for the most neutron-rich phosphorus

PhD : C. Paxman

Topic: Shell model
Reaction: ^{47}K(d,p)^{48}K neutron transfer



Motivations:

- N = 34 identified as a magic number (^{54}Ca)
- Significant gap expected between p1/2 and f5/2
- Odd proton $1s_{1/2}$ interaction with odd neutron above N = 28
- $\pi(0d_{3/2})\otimes\nu(fp)$ already measured
- First experimental measurement of exotic $\pi(s_{1/2})\otimes\nu(fp)$

Preliminary results:

- Preliminary comparison with SDPF (shell model) models :
  - Fails to predict 1- ground state.
  - Measured SF consistently smaller than predicted.
- Qualitative observations suggest overestimation of N=34 gap.

W. Catford, A. Matta: Proton-neutron interactions across N = 28 via ^{47}K(d,p)^{48}K and implications for the most neutron-rich phosphorus

PhD : C. Paxman

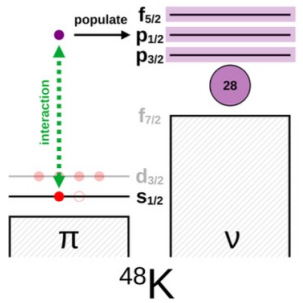
Topic: Shell model
Reaction: ^{47}K(d,p)^{48}K neutron transfer

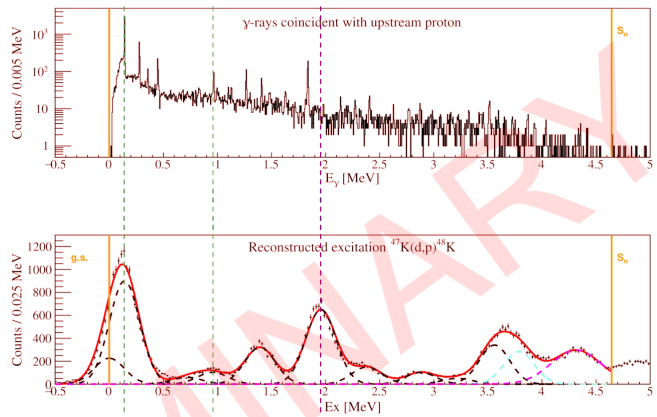
Motivations:

- N = 34 identified as a magic number (^{54}Ca)
- Significant gap expected between p1/2 and f5/2
- Odd proton $1s_{1/2}$ interaction with odd neutron above N = 28
- $\pi(0d_{3/2})\otimes\nu(fp)$ already measured
- First experimental measurement of exotic $\pi(s_{1/2})\otimes\nu(fp)$

Preliminary results:

- Preliminary comparison with SDPF (shell model) models :
  - Fails to predict 1- ground state.
  - Measured SF consistently smaller than predicted.
- Qualitative observations suggest overestimation of N=34 gap.





W. Catford, A. Matta: Proton-neutron interactions across N = 28 via ^{47}K(d,p)^{48}K and implications for the most neutron-rich phosphorus

Topic: Shell model
Reaction: ^{47}K(d,p)^{48}K neutron transfer

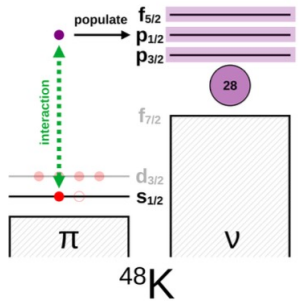
Motivations:

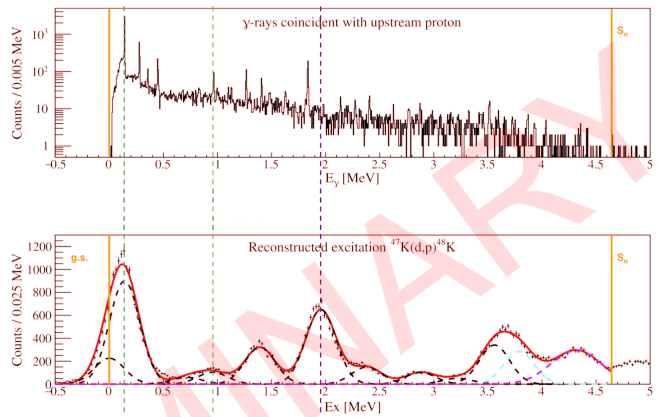
- N = 34 identified as a magic number (^{54}Ca)
- Significant gap expected between p1/2 and f5/2
- Odd proton $1s_{1/2}$ interaction with odd neutron above N = 28
- $\pi(0d_{3/2})\otimes\nu(fp)$ already measured
- First experimental measurement of exotic $\pi(s_{1/2})\otimes\nu(fp)$

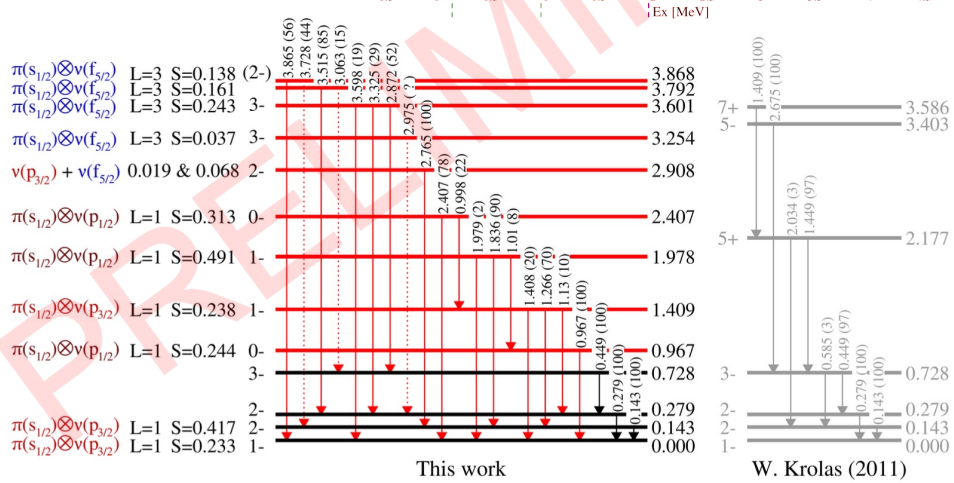
Preliminary results:

- Preliminary comparison with SDPF (shell model) models :
  - Fails to predict 1- ground state.
  - Measured SF consistently smaller than predicted.
- Qualitative observations suggest overestimation of N=34 gap.

PhD : C. Paxman



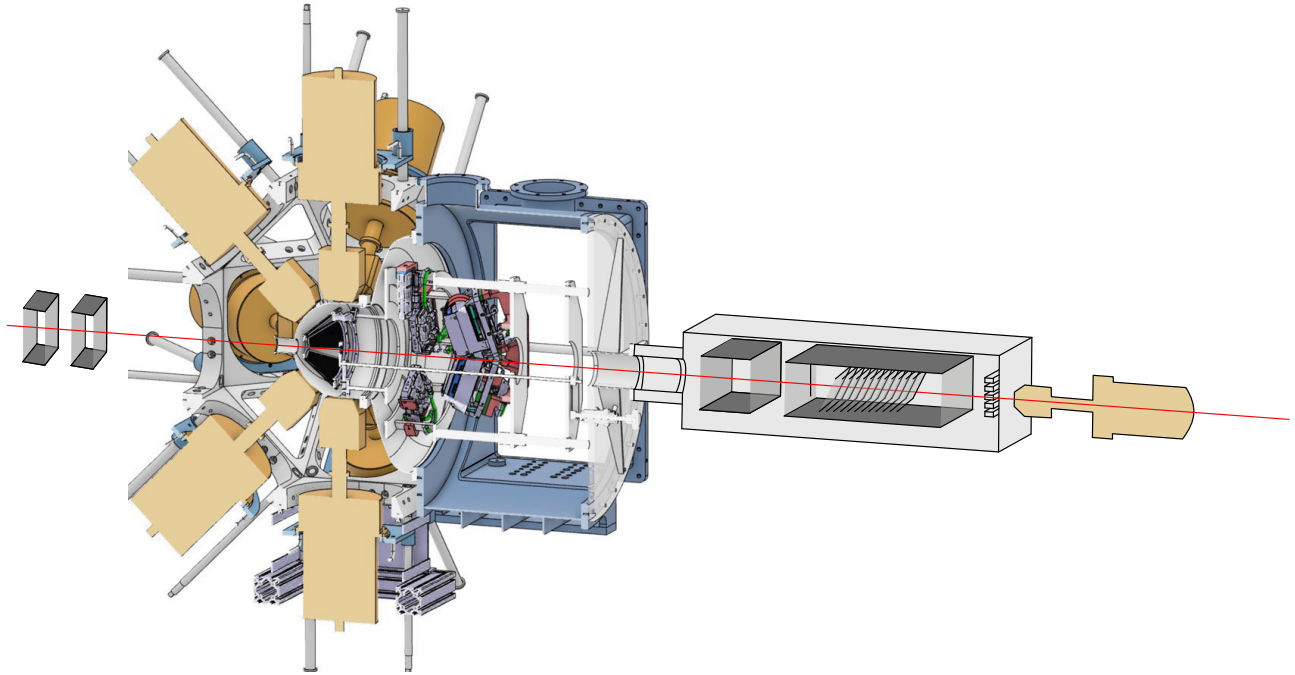




The new LISE campaign: 2023-2026?

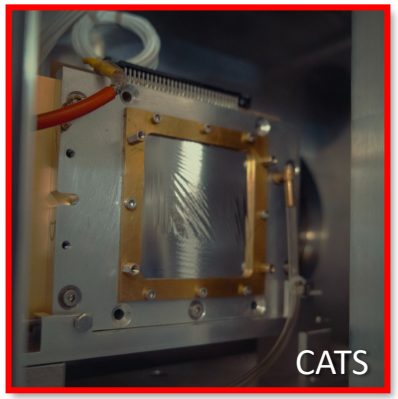
MUGAST@LISE campaign 2023-2026?

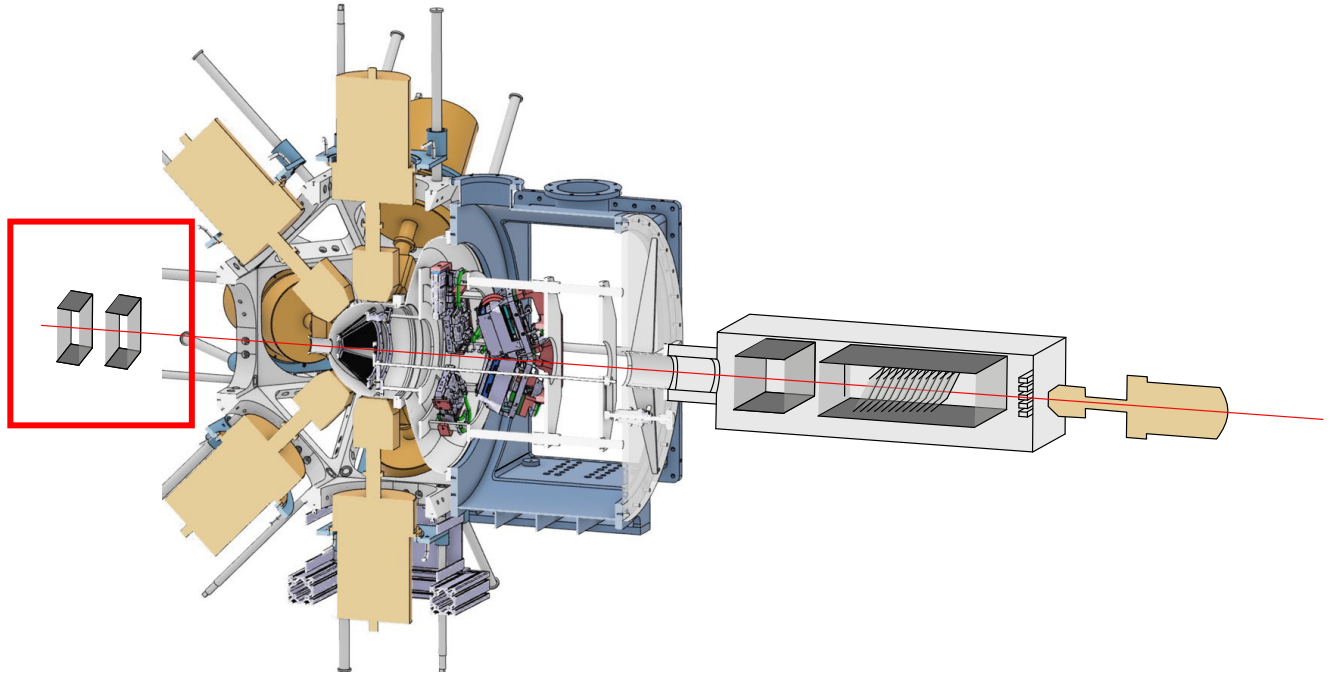
Setup:



Setup:

- CATS beam tracker

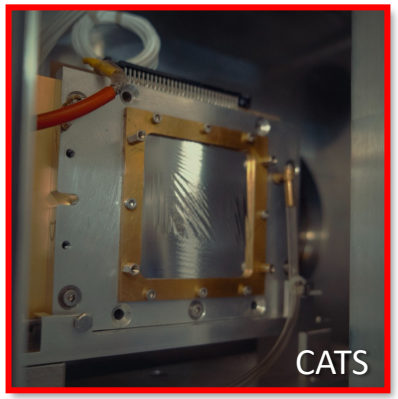




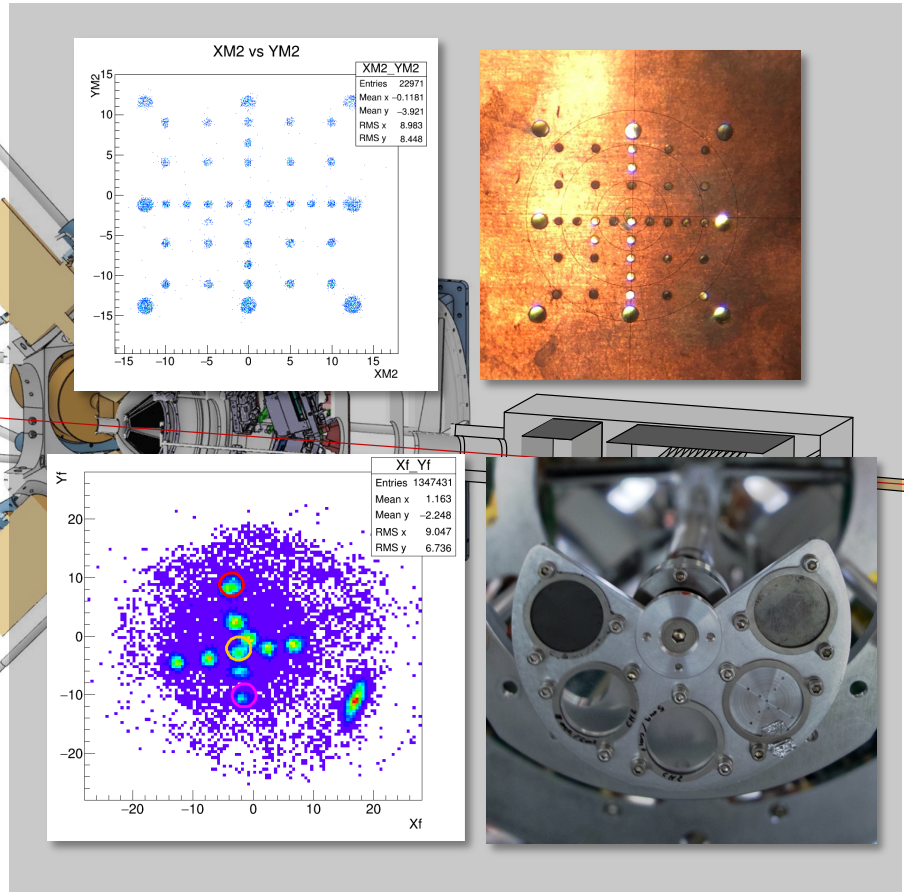
MUGAST@LISE campaign 2023-2026?

Setup:

- CATS beam tracker



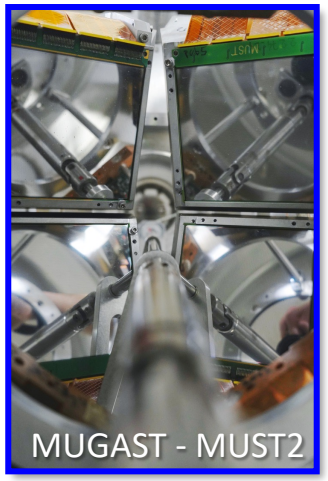
Mask on CATS:

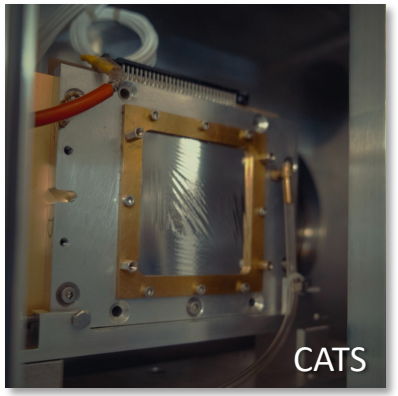


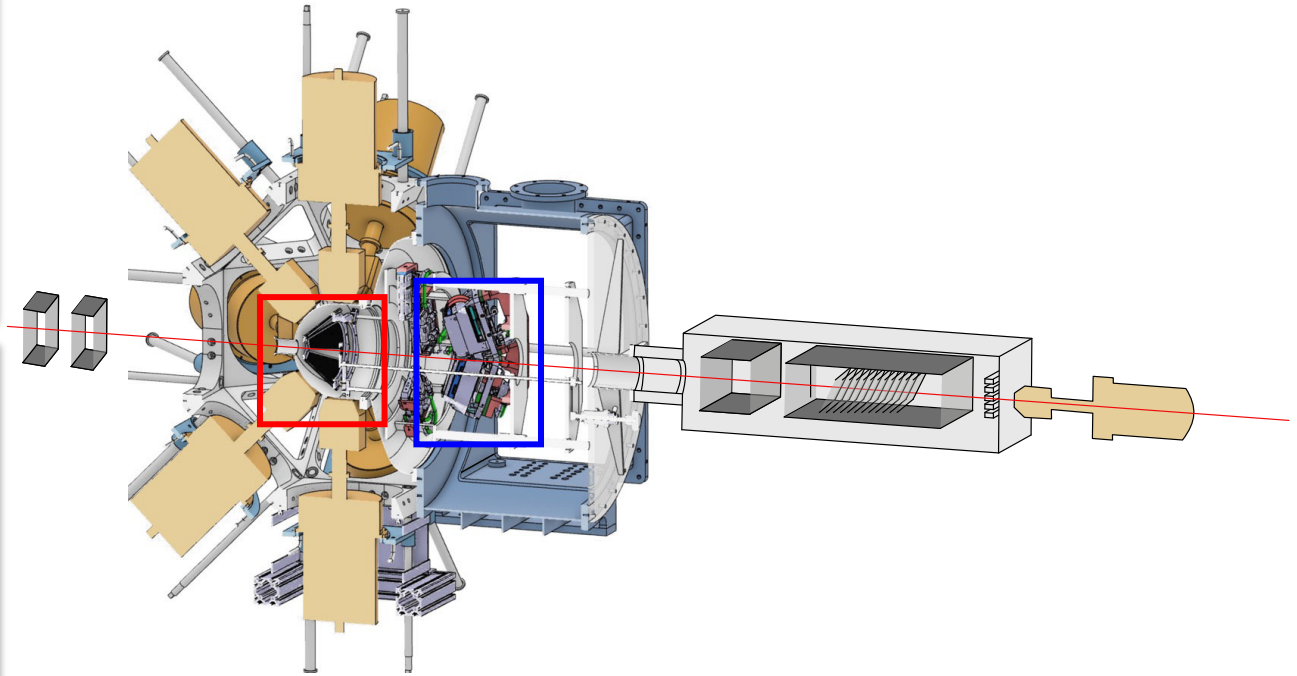
MUGAST@LISE campaign 2023-2026?

Setup:

- CATS beam tracker
- 5 trapezoidal DSSD (backward)
- 4 MUST2 telescopes (forward)
  - 300 um DSSSD
  - CsI crystals



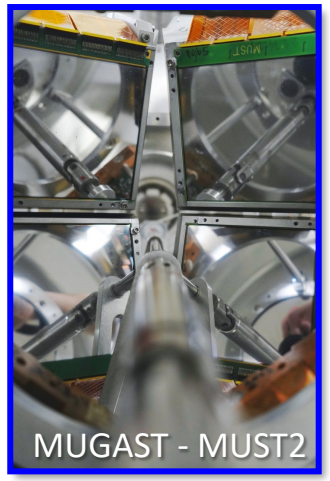


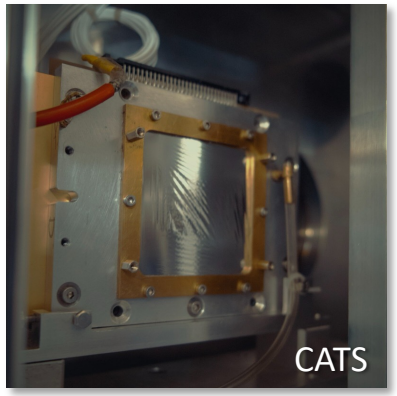


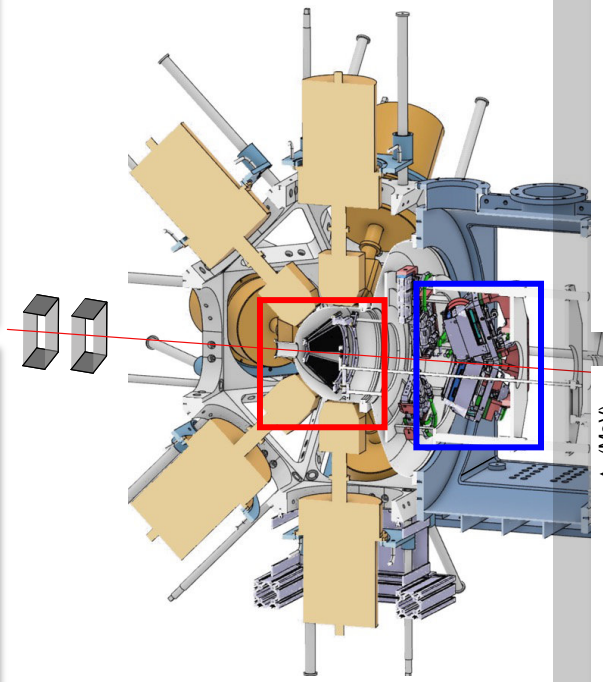
MUGAST@LISE campaign 2023-2026?

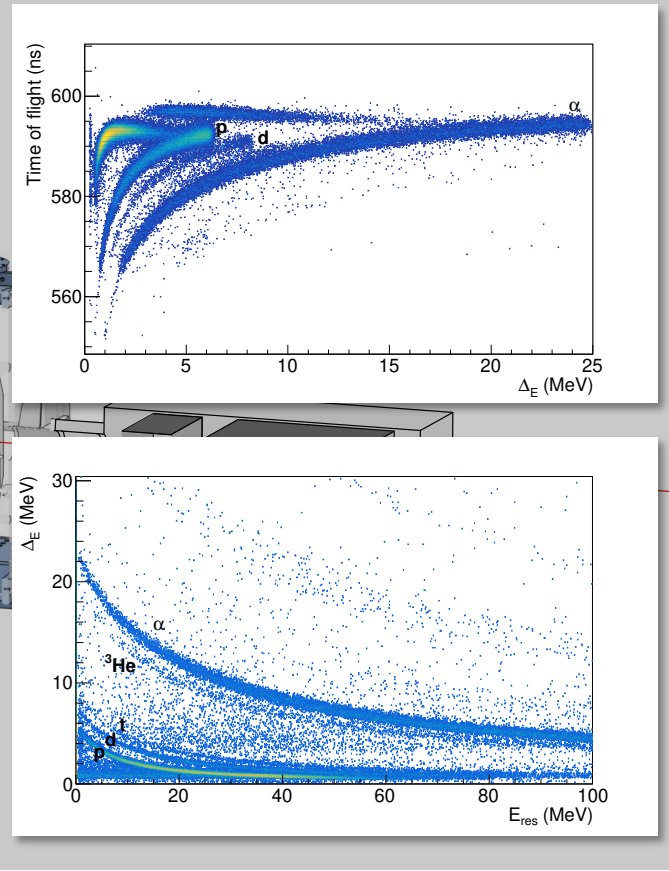
Setup:

- CATS beam tracker
- 5 trapezoidal DSSD (backward)
- 4 MUST2 telescopes (forward)
  - 300 um DSSSD
  - CsI crystals





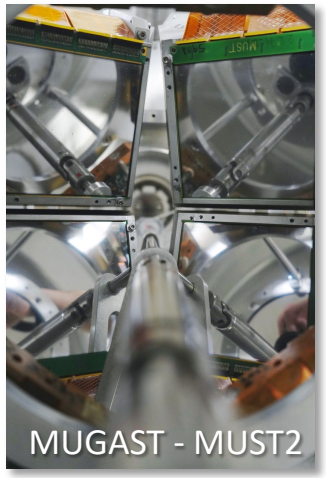


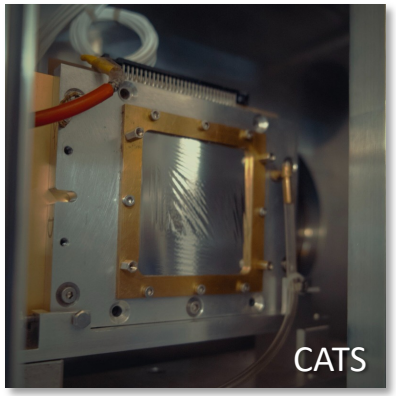


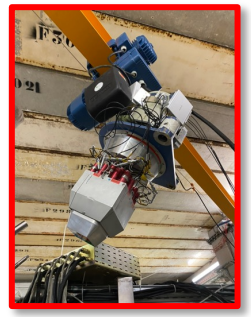
MUGAST@LISE campaign 2023-2026?

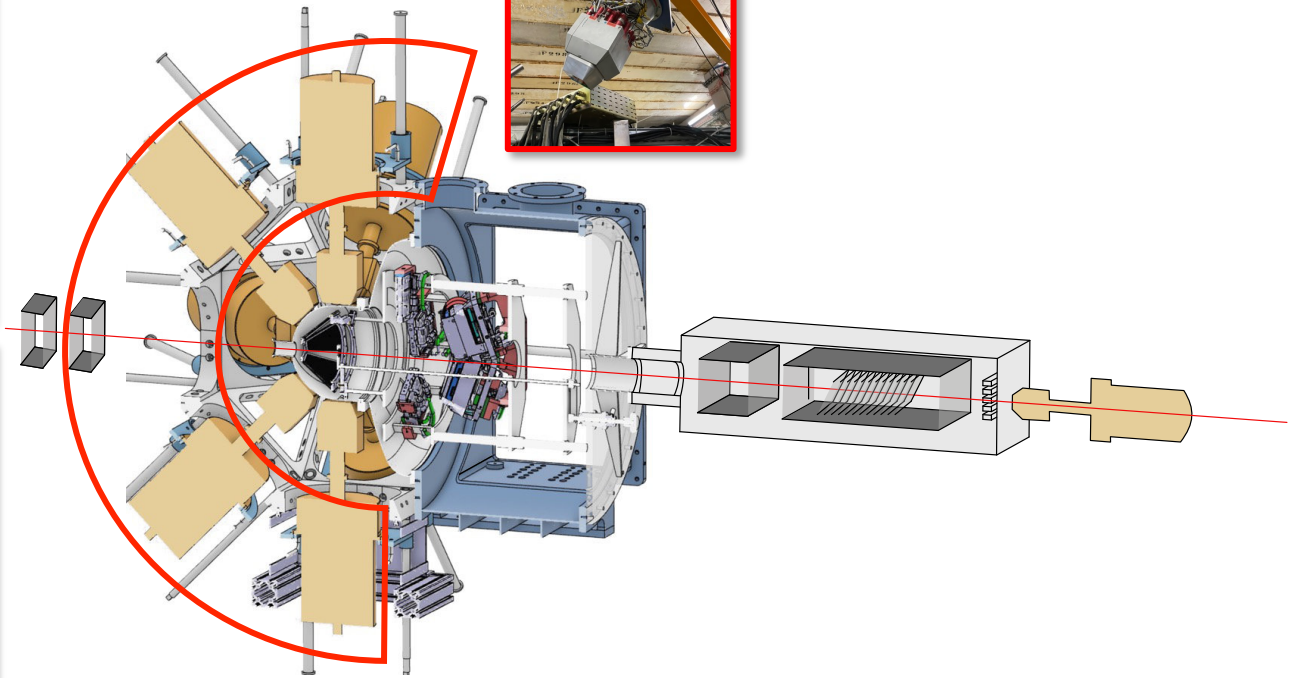
Setup:

- CATS beam tracker
- 5 trapezoidal DSSD (backward)
- 4 MUST2 telescopes (forward)
  - 300 um DSSSD
  - CsI crystals
- Exogam Ge y-ray spectrometer





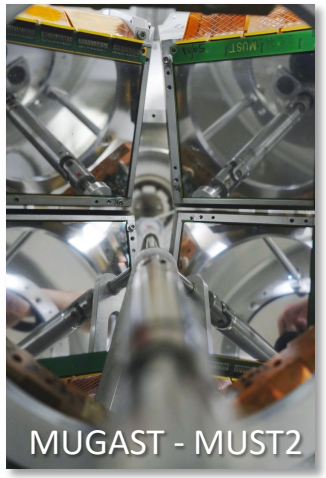


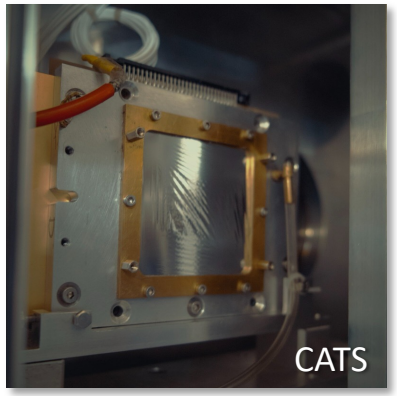


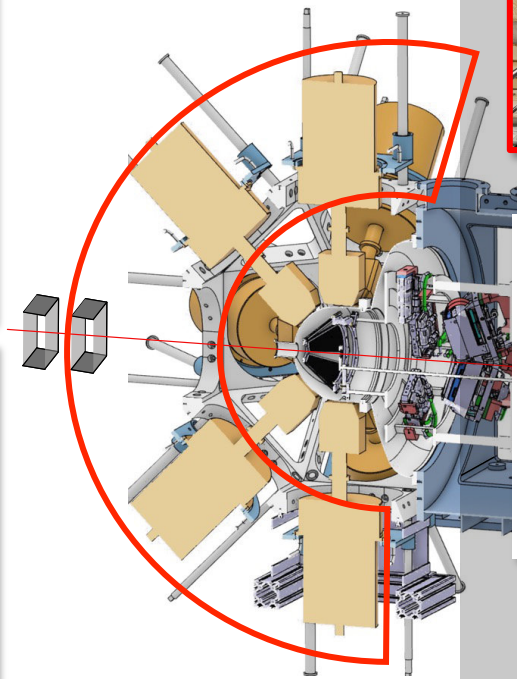
MUGAST@LISE campaign 2023-2026?

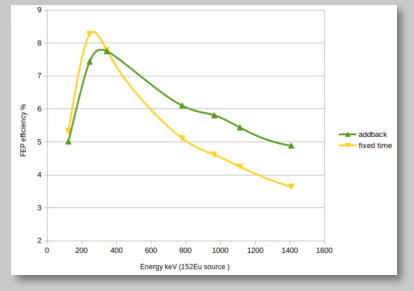
Setup:

- CATS beam tracker
- 5 trapezoidal DSSD (backward)
- 4 MUST2 telescopes (forward)
  - 300 um DSSSD
  - CsI crystals
- Exogam Ge y-ray spectrometer

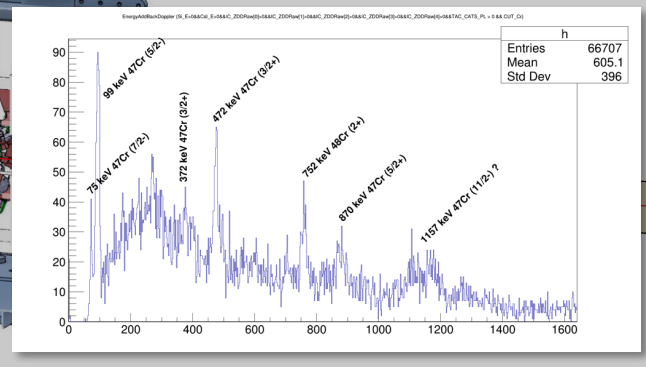








Courtesy of Ozgë Aktas

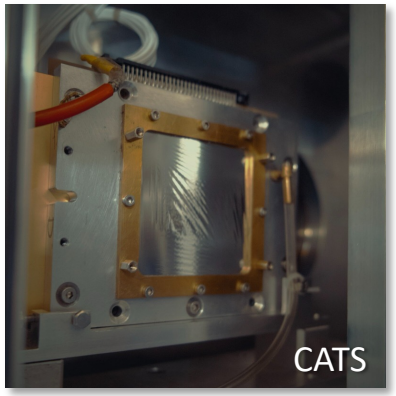


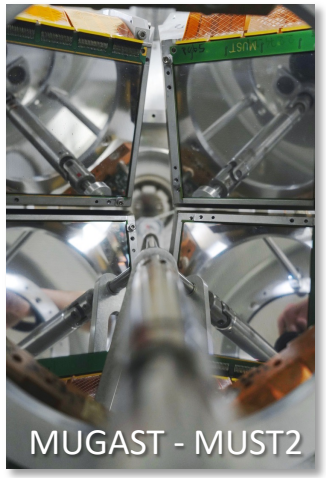
Example of online add-back doppler corrected spectra

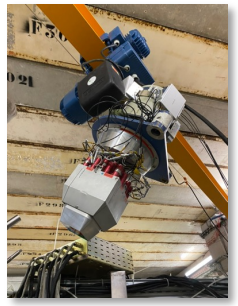
MUGAST@LISE campaign 2023-2026?

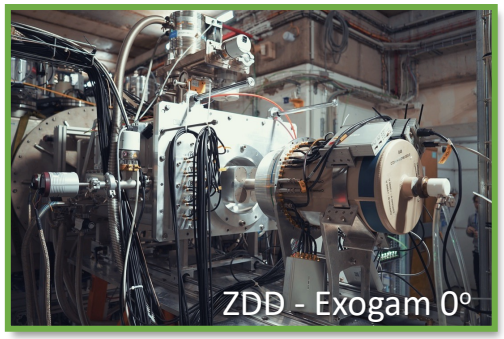
Setup:

- CATS beam tracker
- 5 trapezoidal DSSD (backward)
- 4 MUST2 telescopes (forward)
  - 300 um DSSSD
  - CsI crystals
- Exogam Ge y-ray spectrometer
- 0° Detection: ZDD from LISE
  - Drift chamber (DC)
  - Ionization chamber (IC)
  - Plastic detector
  - Exogam





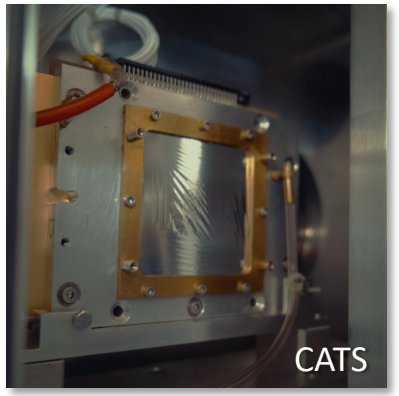




MUGAST@LISE campaign 2023-2026?

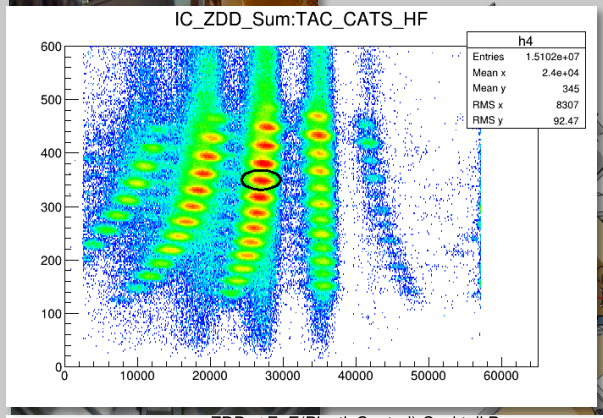
Setup:

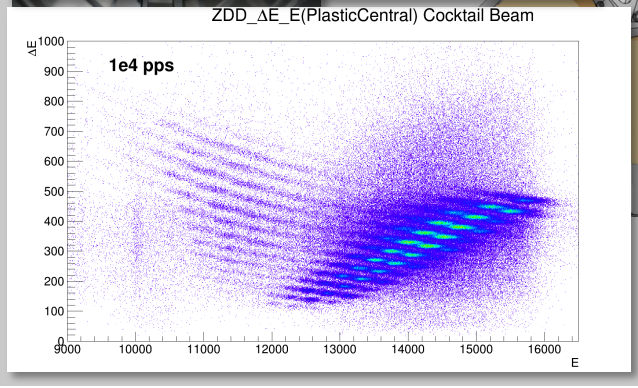
- CATS beam tracker
- 5 trapezoidal DSSD (backward)
- 4 MUST2 telescopes (forward)
  - 300 um DSSSD
  - CsI crystals
- Exogam Ge γ-ray spectrometer
- 0° Detection: ZDD from LISE
  - Drift chamber (DC)
  - Ionization chamber (IC)
  - Plastic detector
  - Exogam

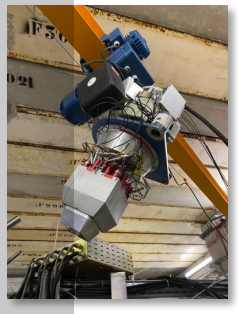


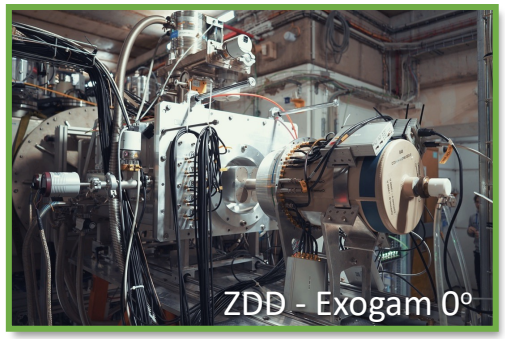
Damage to the central plastic

- No ΔE-E
- identification ΔE-ToF









Preliminary results of the first two experiments

Two-nucleon transfer: $^{48}Cr(p,^{3}He)^{46}V$

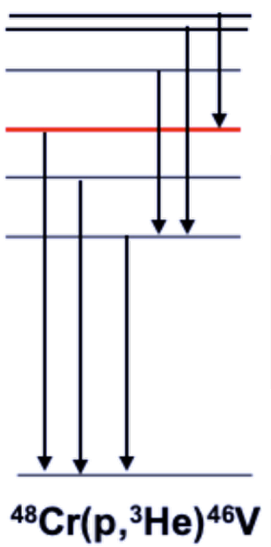
M. Assié (IJCLab) PhD: Hugo Jacob (IJCLab)

- Beam : ^{48}Cr at 30 MeV/u, 3×10^{5} pps, 90% purity
- Target : CH_2 5 mg/cm^2
- Reaction studied : $^{48}Cr(p,^{3}He)^{46}V$
- Topic: Influence of deformation on neutron-proton pairing

Two-nucleon transfer: $^{48}Cr(p,^{3}He)^{46}V$

M. Assié (IJCLab) PhD: Hugo Jacob (IJCLab)

- Beam : ^{48}Cr at 30 MeV/u, 3×10^{5} pps, 90% purity
- Target : CH_2 5 mg/cm^2
- Reaction studied : $^{48}Cr(p,^{3}He)^{46}V$
- Topic: Influence of deformation on neutron-proton pairing



Isoscalar
Deuteron-like
993 keV, J=1+ T = 0

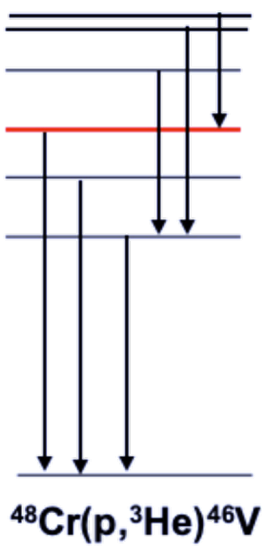
Isovector
0 keV, J=0+ T=1

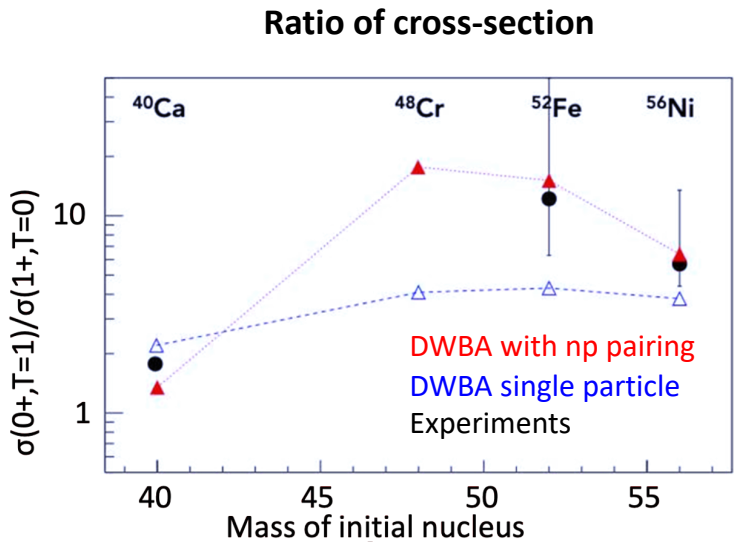
Lee J. et al. Ayyad Y. Phys. Rev. C, 2017.
Chong Qi and Ramon Wyss, Physica Scripta, 2015.

Two-nucleon transfer: $^{48}Cr(p,^{3}He)^{46}V$

M. Assié (IJCLab) PhD: Hugo Jacob (IJCLab)

- Beam : ^{48}Cr at 30 MeV/u, 3×10^{5} pps, 90% purity
- Target : CH_2 5 mg/cm^2
- Reaction studied : $^{48}Cr(p,^{3}He)^{46}V$
- Topic: Influence of deformation on neutron-proton pairing



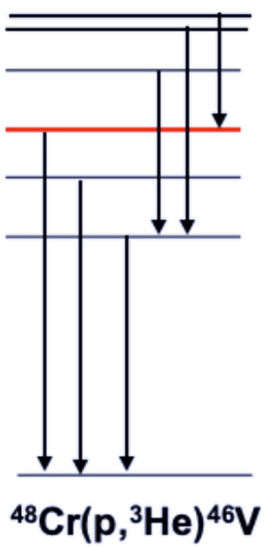


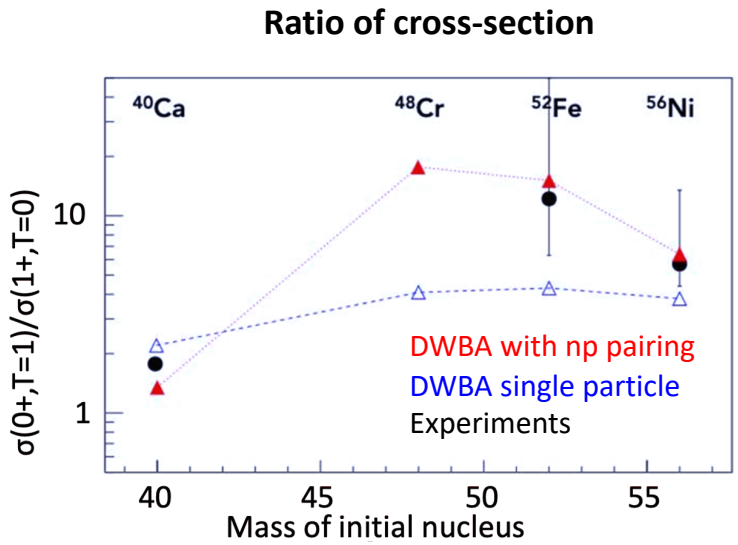
Lee J. et al. Ayyad Y. Phys. Rev. C, 2017.
Chong Qi and Ramon Wyss, Physica Scripta, 2015.

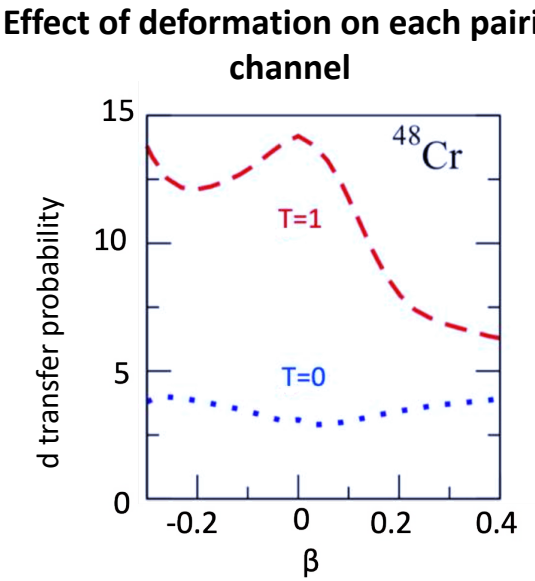
Two-nucleon transfer: $^{48}Cr(p,^{3}He)^{46}V$

M. Assié (IJCLab) PhD: Hugo Jacob (IJCLab)

- Beam : ^{48}Cr at 30 MeV/u, 3×10^{5} pps, 90% purity
- Target : CH_2 5 mg/cm^2
- Reaction studied : $^{48}Cr(p,^{3}He)^{46}V$
- Topic: Influence of deformation on neutron-proton pairing





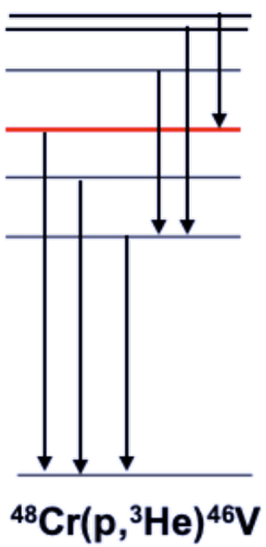


Lee J. et al. Ayyad Y. Phys. Rev. C, 2017.
Chong Qi and Ramon Wyss, Physica Scripta, 2015.

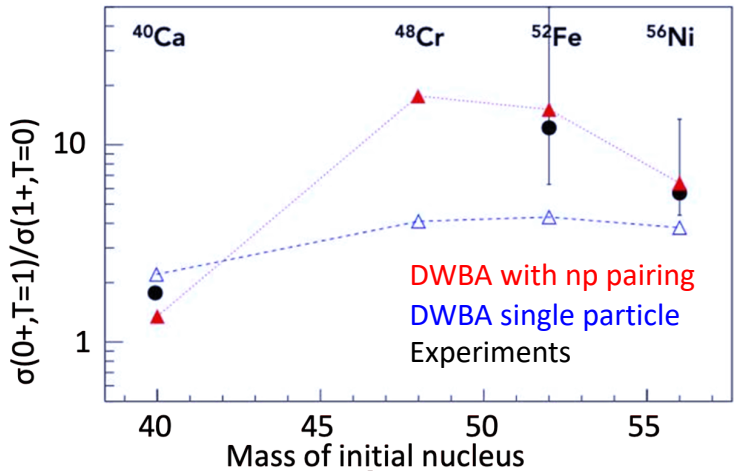
Two-nucleon transfer: $^{48}Cr(p,^{3}He)^{46}V$

M. Assié (IJCLab) PhD: Hugo Jacob (IJCLab)

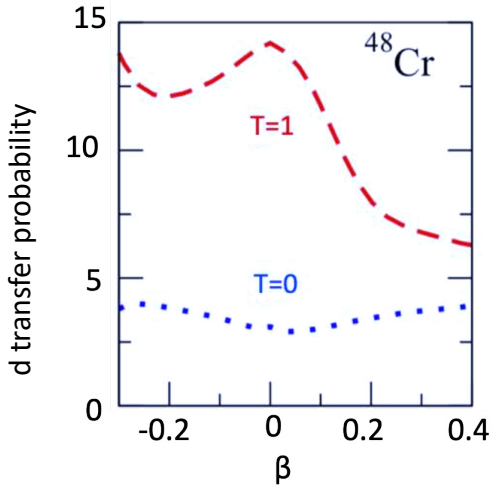
- Beam : ^{48}Cr at 30 MeV/u, 3×10^{5} pps, 90% purity
- Target : CH_2 5 mg/cm^2
- Reaction studied : $^{48}Cr(p,^{3}He)^{46}V$
- Topic: Influence of deformation on neutron-proton pairing



Ratio of cross-section



Effect of deformation on each pairing channel

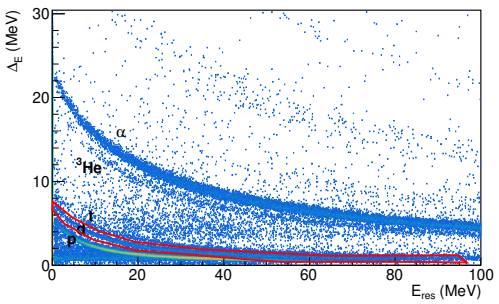


- $^{48}Cr(p,^{3}He)^{46}V$ channel currently under analysis by Hugo… More to come soon!

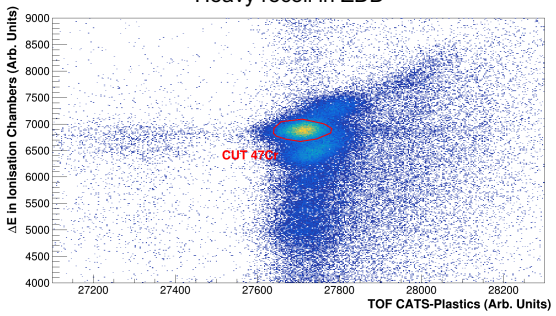
Lee J. et al. Ayyad Y. Phys. Rev. C, 2017.
Chong Qi and Ramon Wyss, Physica Scripta, 2015.

$^{48}Cr(p,d)^{47}Cr$ online analysis:

Light particle in MUGAST

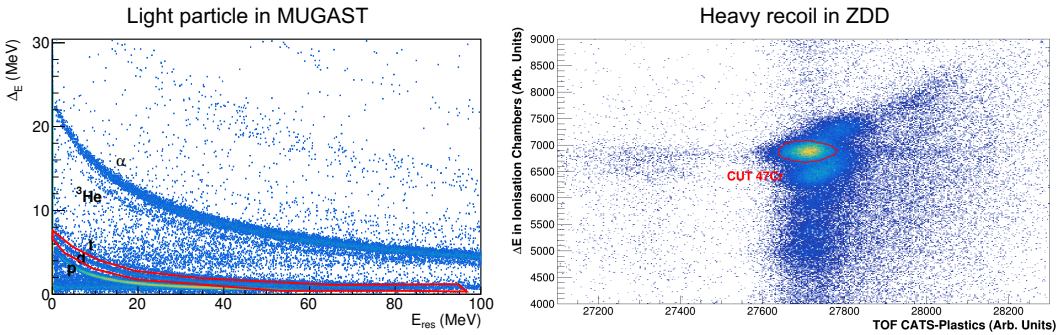


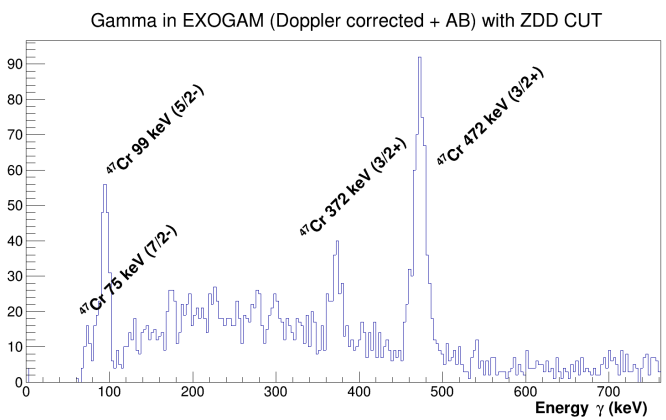
Heavy recoil in ZDD



Courtesy of H. Jacob

$^{48}Cr(p,d)^{47}Cr$ online analysis:

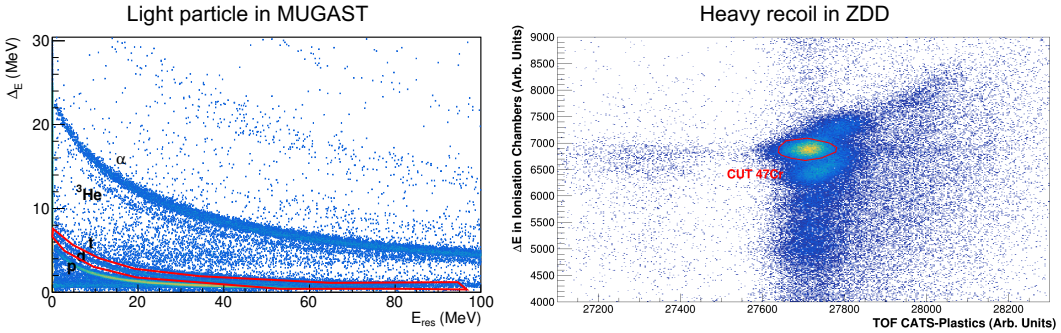


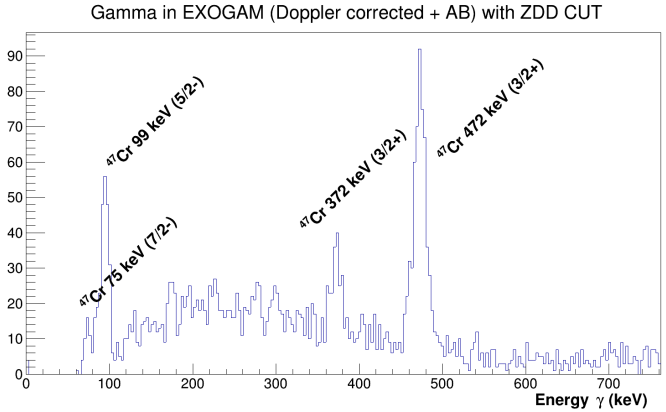


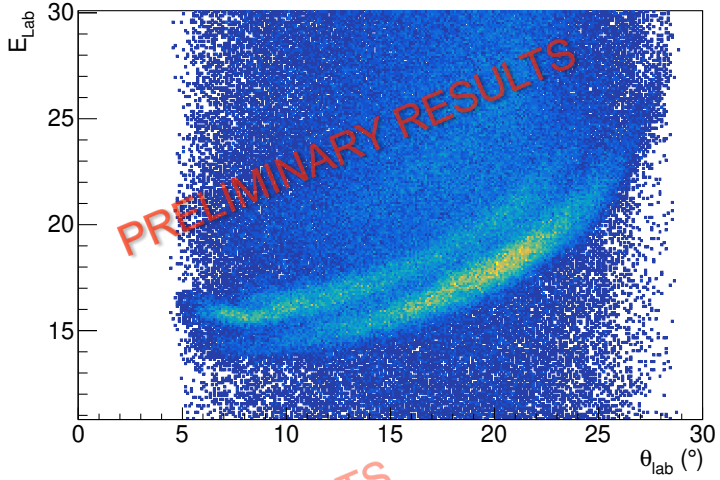
Courtesy of H. Jacob

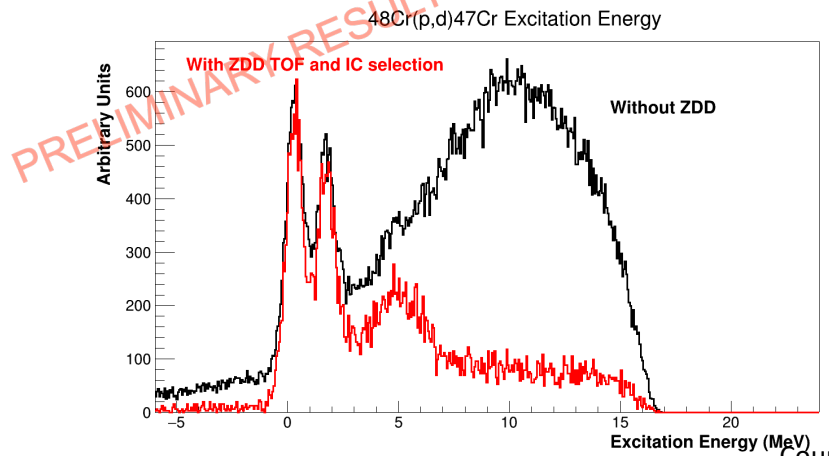
MUGAST@LISE: Online performances

$^{48}Cr(p,d)^{47}Cr$ online analysis:









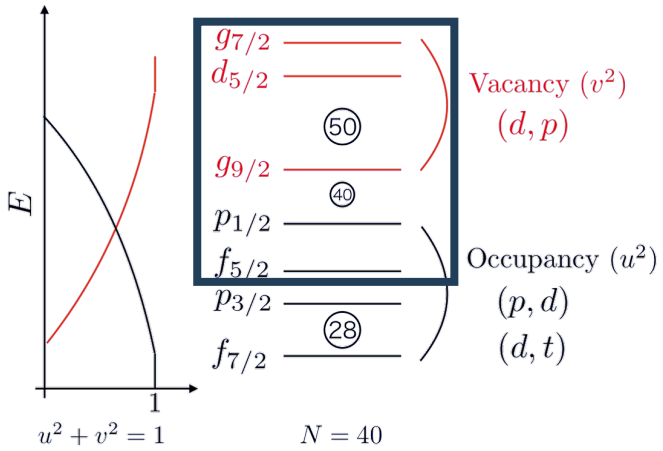
Courtesy of H. Jacob

Study of ^{68}Ni by +1n and -1n transfer

S. Koyama (GANIL), O. Sorlin (GANIL):

- Beam : ^{68}Ni at 18 MeV/u and 40 MeV/u, 10^5 pps, 80% purity
- Target : CH_2 5 mg/cm^2 and CD_2 0.5 mg/cm^2
- Reaction studied : ^{68}Ni(p, d)^{67}Ni, ^{68}Ni(d, p)^{69}Ni
- Phenomenon studied : SO splitting and N=40/50 shell gap

Neutron Fermi surface at N=40



^{68}Ni: 40ν + 28π

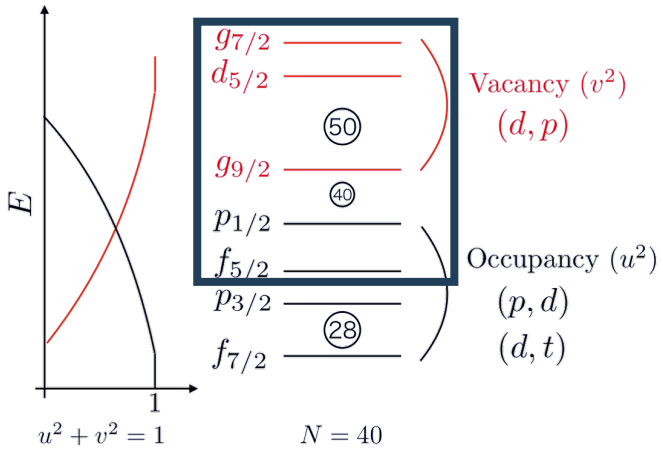
O. Sorlin, F. de Oliveira Santos, and J.P. Ebran. 2020
O Sorlin and M-G Porquet. Physica Scripta, 2013

Study of ^{68}Ni by +1n and -1n transfer

S. Koyama (GANIL), O. Sorlin (GANIL):

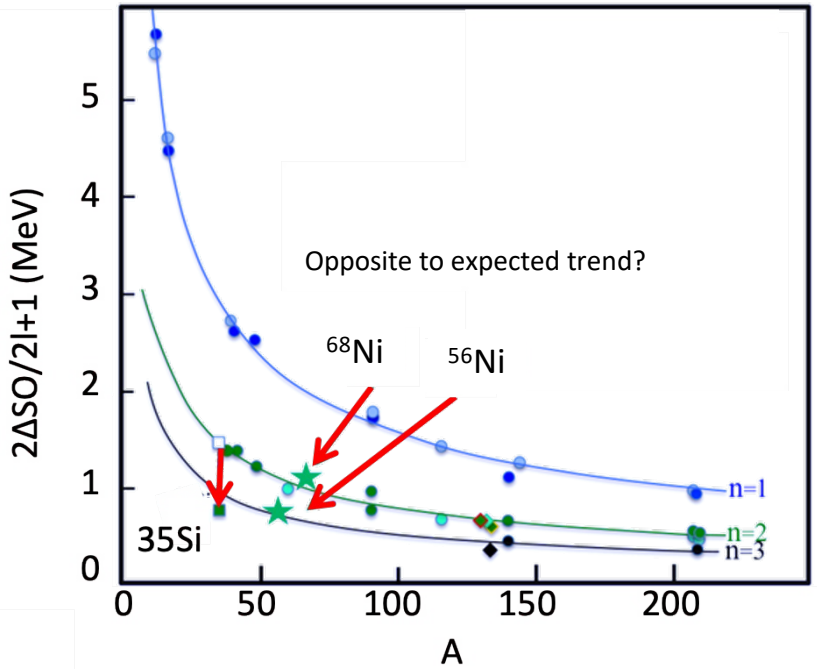
- Beam : ^{68}Ni at 18 MeV/u and 40 MeV/u, 10^5 pps, 80% purity
- Target : CH_2 5 mg/cm^2 and CD_2 0.5 mg/cm^2
- Reaction studied : ^{68}Ni(p, d)^{67}Ni, ^{68}Ni(d, p)^{69}Ni
- Phenomenon studied : SO splitting and N=40/50 shell gap

Neutron Fermi surface at N=40



^{68}Ni: 40ν + 28π

2p, 1f and 1g SO splitting



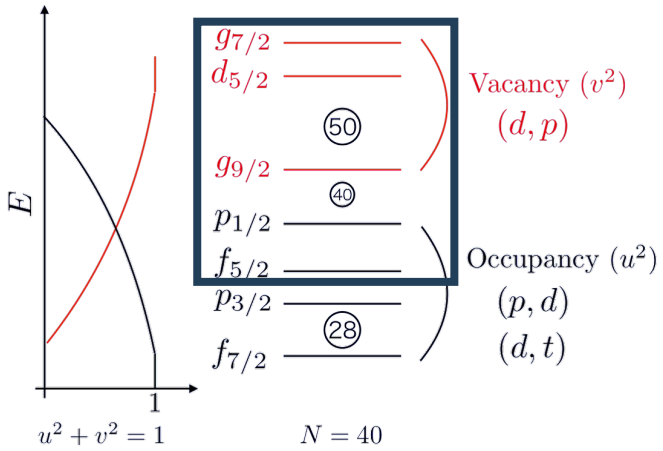
O. Sorlin, F. de Oliveira Santos, and J.P. Ebran. 2020
O Sorlin and M-G Porquet. Physica Scripta, 2013

Study of ^{68}Ni by +1n and -1n transfer

S. Koyama (GANIL), O. Sorlin (GANIL):

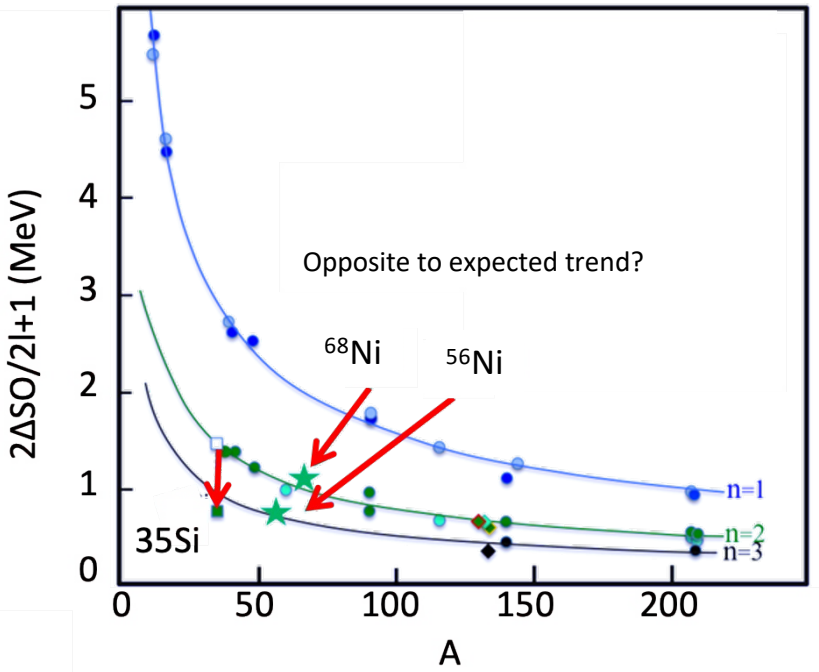
- Beam : ^{68}Ni at 18 MeV/u and 40 MeV/u, 10^5 pps, 80% purity
- Target : CH_2 5 mg/cm^2 and CD_2 0.5 mg/cm^2
- Reaction studied : ^{68}Ni(p, d)^{67}Ni, ^{68}Ni(d, p)^{69}Ni
- Phenomenon studied : SO splitting and N=40/50 shell gap

Neutron Fermi surface at N=40

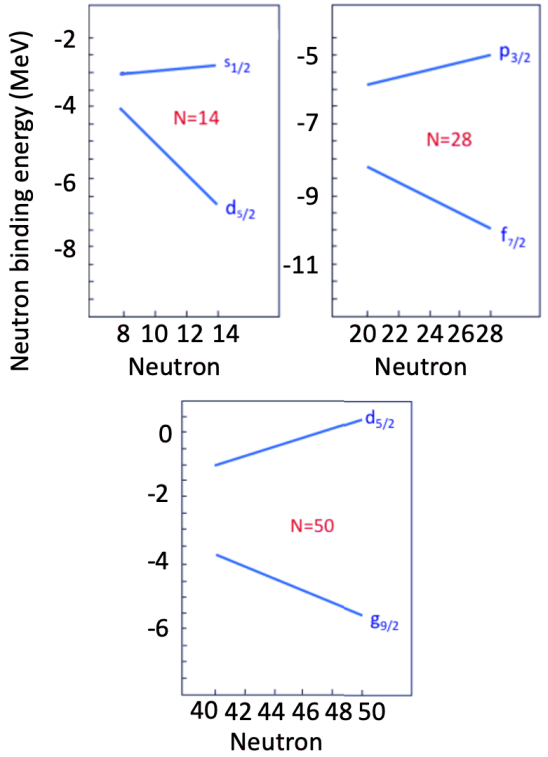


^{68}Ni: 40ν + 28π

2p, 1f and 1g SO splitting



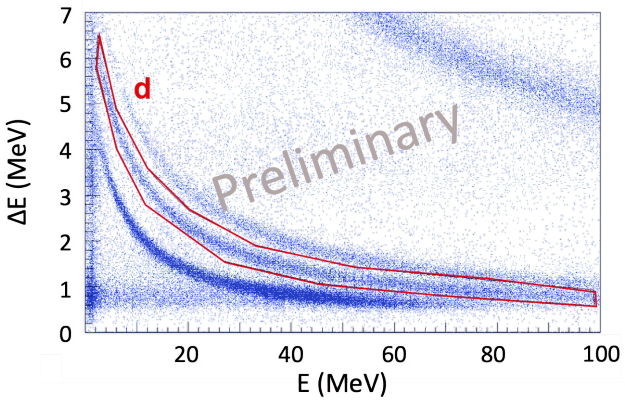
$g_{9/2}$-$d_{5/2}$ spacing at N=40

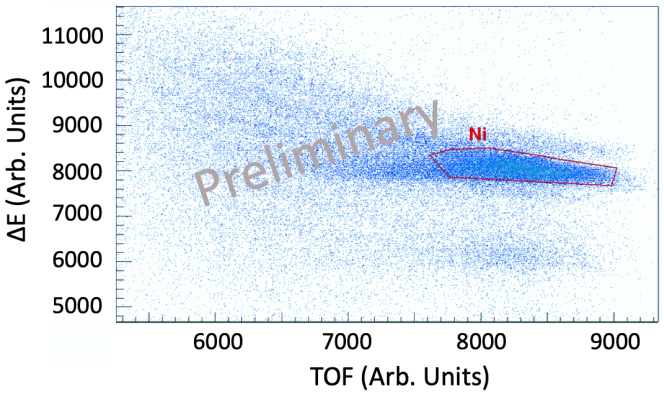


O. Sorlin, F. de Oliveira Santos, and J.P. Ebran. 2020
O Sorlin and M-G Porquet. Physica Scripta, 2013

Study of ^{68}Ni by +1n and -1n transfer

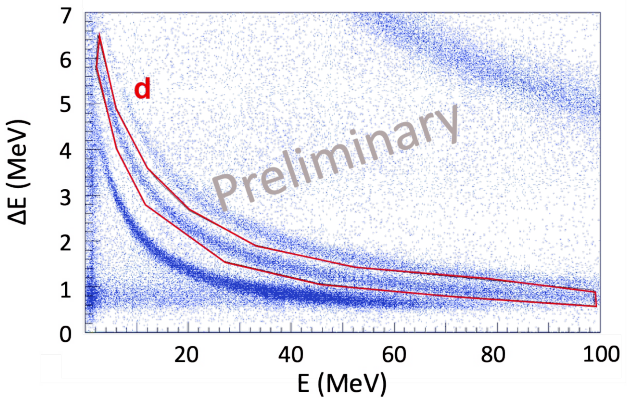
^{68}Ni(p,d)^{67}Ni online analysis:

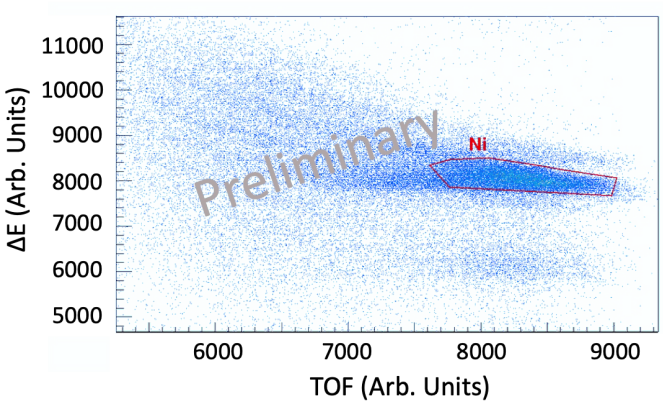


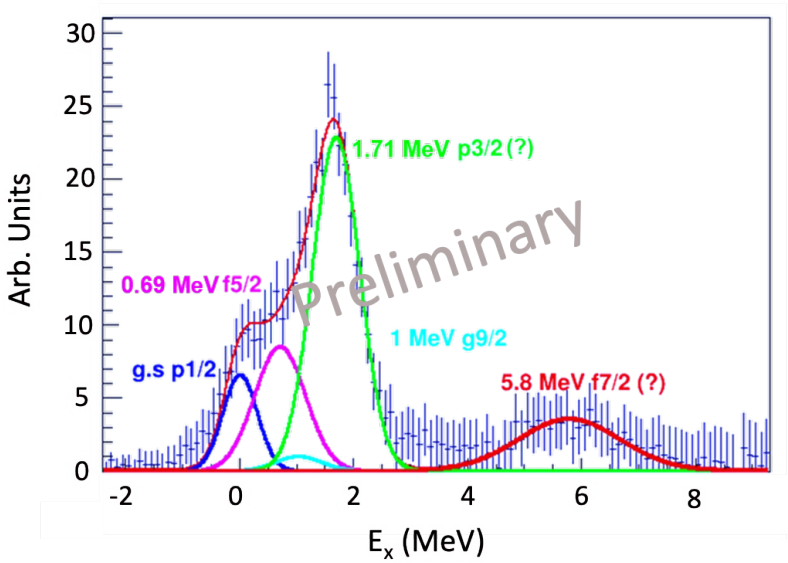


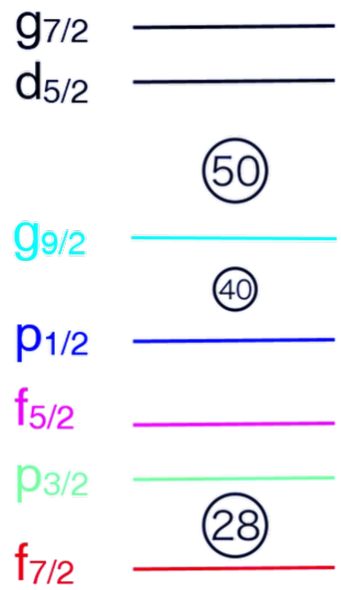
Study of ^{68}Ni by +1n and -1n transfer

^{68}Ni(p,d)^{67}Ni online analysis:





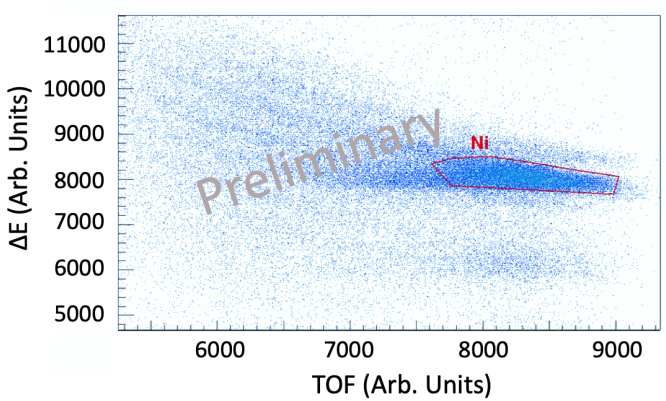




- $f_{5/2} - f_{7/2}$ SO splitting
- $p_{1/2} - p_{3/2}$ SO splitting
- Partial filling of the $g_{9/2}$ orbital

Study of ^{68}Ni by +1n and -1n transfer

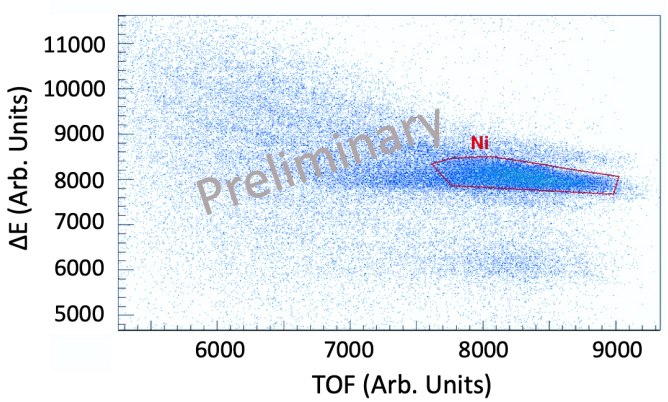
^{68}Ni(d,p)^{69}Ni online analysis:



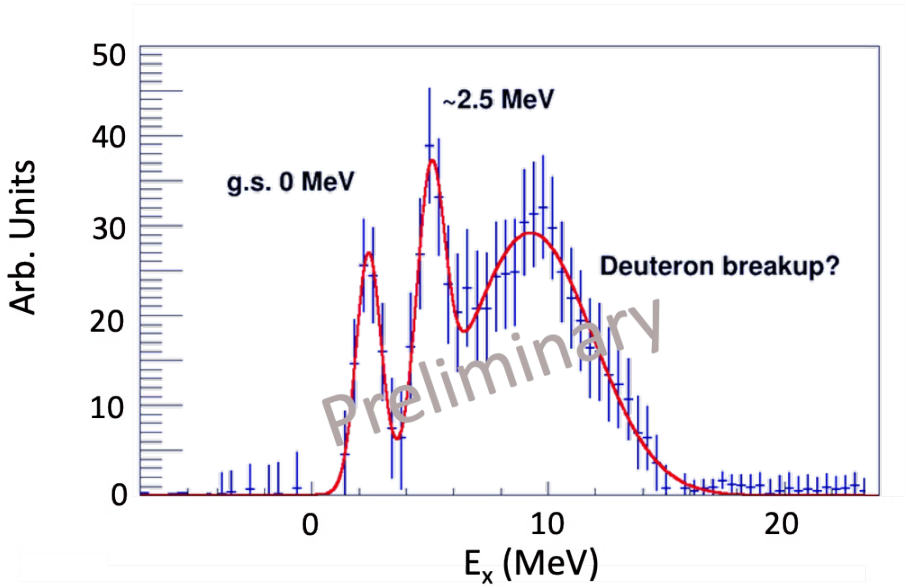
- No selection in MUGAST yet
- Selection of Ni isotopes in ZDD

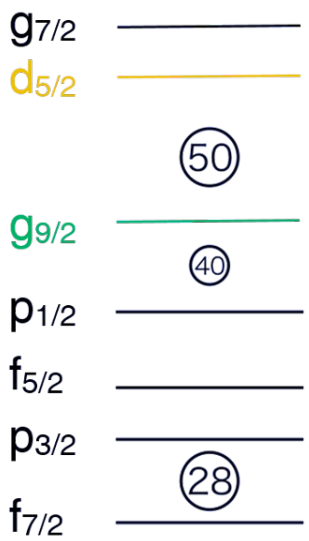
Study of ^{68}Ni by +1n and -1n transfer

^{68}Ni(d,p)^{69}Ni online analysis:



- No selection in MUGAST yet
- Selection of Ni isotopes in ZDD





- $g_{9/2} - d_{5/2}$ spacing
- $g_{9/2} - g_{7/2}$ SO splitting ?
- Only two visible states? Similar to previous experiments…

What's next?

MUGAST@LISE: Upcoming experiments

F. Galtarossa: (To be scheduled end of April 2024)

Evolution of the neutron $1d_{3/2}$-$1d_{5/2}$ spin-orbit splitting in N = 19 isotones and Fermi surface in ^{34}Si

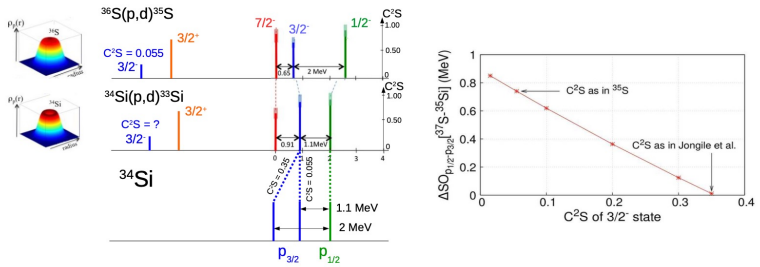


FIG. 3: Pictorial representation (left) and graphic (right) of the predicted variation of the difference between the $\nu p_{1/2}$-$\nu p_{3/2}$ SO splitting in ^{37}S and in ^{35}Si as a function of the C^{2}S of the $3/2^-$ state at 1.981 MeV in ^{33}Si.

F. Galtarossa: (To be scheduled end of April 2024)

Evolution of the neutron $1d_{3/2}$-$1d_{5/2}$ spin-orbit splitting in N = 19 isotones and Fermi surface in ^{34}Si

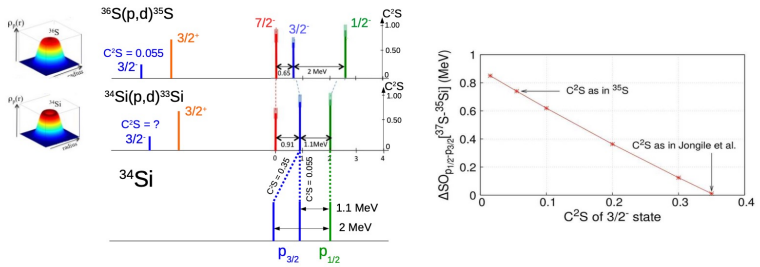
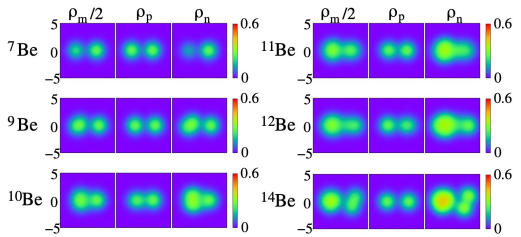


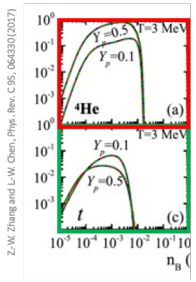
FIG. 3: Pictorial representation (left) and graphic (right) of the predicted variation of the difference between the $\nu p_{1/2}$-$\nu p_{3/2}$ SO splitting in ^{37}S and in ^{35}Si as a function of the C^2S of the $3/2^-$ state at 1.981 MeV in ^{33}Si.

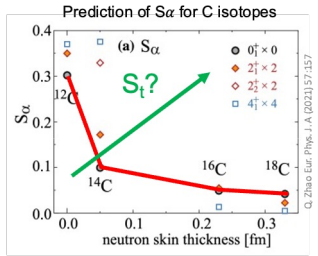
V. Girard-Alcindor, D. Beaumel: (To be scheduled end of June 2024)

Cluster structure of the ground state of light exotic nuclei beyond alpha-clustering



Clustering in Be isotopes





Expected triton clustering in neutron rich isotopes

MUGAST@LISE: Upcoming experiments

F. Galtarossa: (To be scheduled end of April 2024)

Evolution of the neutron $1d_{3/2}$-$1d_{5/2}$ spin-orbit splitting in N = 19 isotones and Fermi surface in ^{34}Si

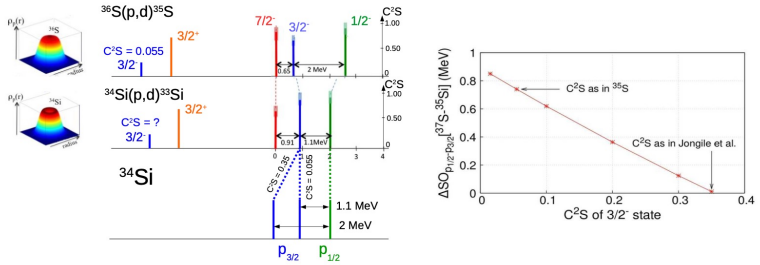


FIG. 3: Pictorial representation (left) and graphic (right) of the predicted variation of the difference between the $\nu p_{1/2}$-$\nu p_{3/2}$ SO splitting in ^{37}S and in ^{35}Si as a function of the C^2S of the $3/2^-$ state at 1.981 MeV in ^{33}Si.

C. Diget, N. De Séreville: (To be scheduled in 2025)

Determining the thermonuclear ^{18}Ne(α,p)^{21}Na reaction rate by measurement of the ^{7}Li(^{18}Ne,t)^{22}Mg(p)^{21}Na reaction

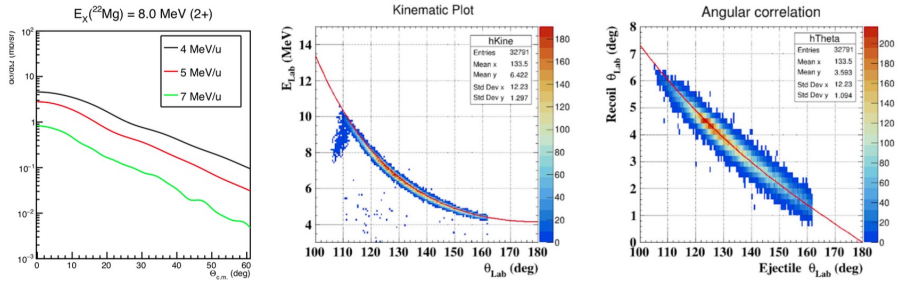
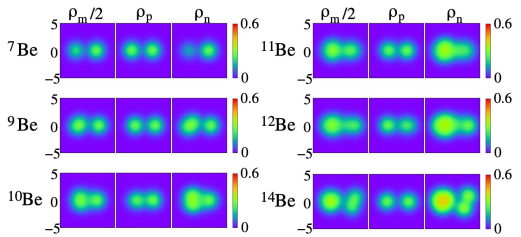


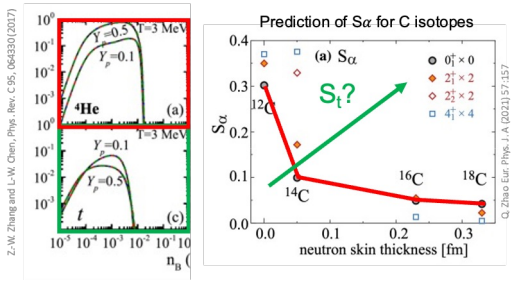
Figure 1: Differential cross section for 2+ state with $C^2S = 1$ (left); triton kinematics for ^{22}Mg resonance (middle); and heavy-ion (^{22}Mg) angle against triton angle (right).

V. Girard-Alcindor, D. Beaumel: (To be scheduled end of June 2024)

Cluster structure of the ground state of light exotic nuclei beyond alpha-clustering



Clustering in Be isotopes



Expected triton clustering in neutron rich isotopes

MUGAST@LISE: Upcoming experiments

F. Galtarossa: (To be scheduled end of April 2024)

Evolution of the neutron $1d_{3/2}$-$1d_{5/2}$ spin-orbit splitting in N = 19 isotones and Fermi surface in ^{34}Si

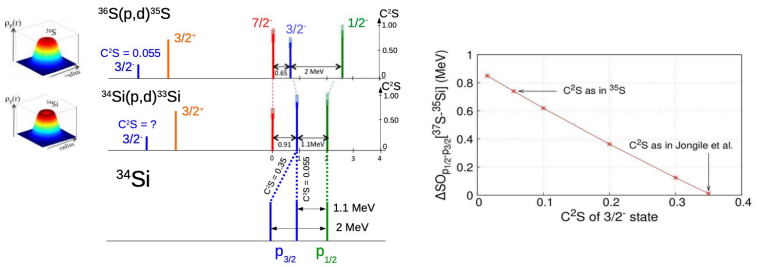


FIG. 3: Pictorial representation (left) and graphic (right) of the predicted variation of the difference between the $\nu p_{1/2}$-$\nu p_{3/2}$ SO splitting in ^{37}S and in ^{35}Si as a function of the C^{2}S of the $3/2^-$ state at 1.981 MeV in ^{33}Si.

C. Diget, N. De Séreville: (To be scheduled in 2025)

Determining the thermonuclear ^{18}Ne(α,p)^{21}Na reaction rate by measurement of the ^{7}Li(^{18}Ne,t)^{22}Mg(p)^{21}Na reaction

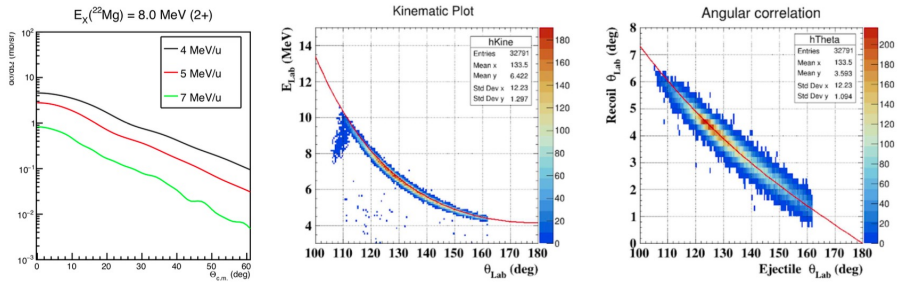
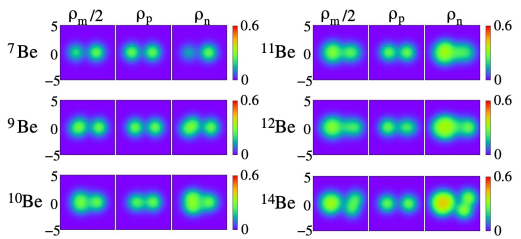


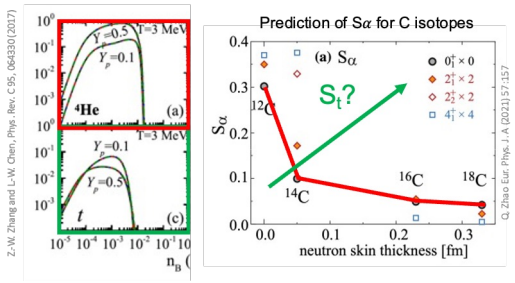
Figure 1: Differential cross section for 2+ state with $C^2S = 1$ (left); triton kinematics for ^{22}Mg resonance (middle); and heavy-ion (^{22}Mg) angle against triton angle (right).

V. Girard-Alcindor, D. Beaumel: (To be scheduled end of June 2024)

Cluster structure of the ground state of light exotic nuclei beyond alpha-clustering



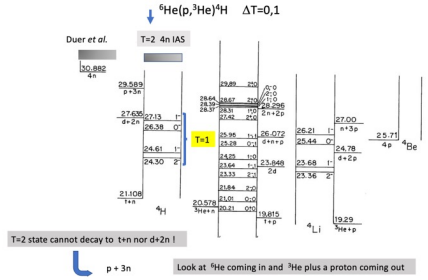
Clustering in Be isotopes

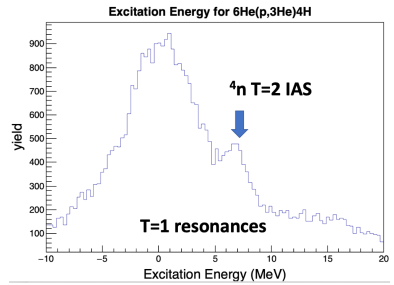


Expected triton clustering in neutron rich isotopes

A. Machiavelli, M. Assié: (To be scheduled in 2025)

The tetra-neutron Isobaric Analog State in ^{4}H : The case for the ^{6}He(p,^{3}He) reaction

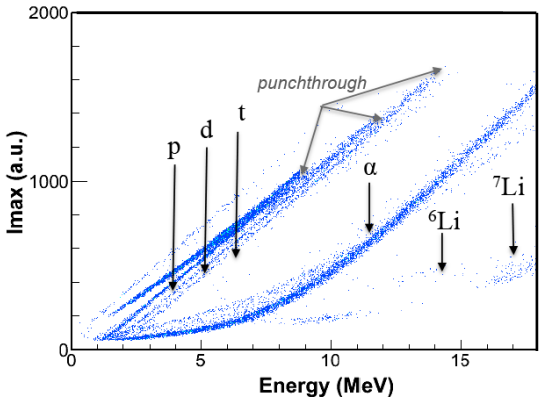


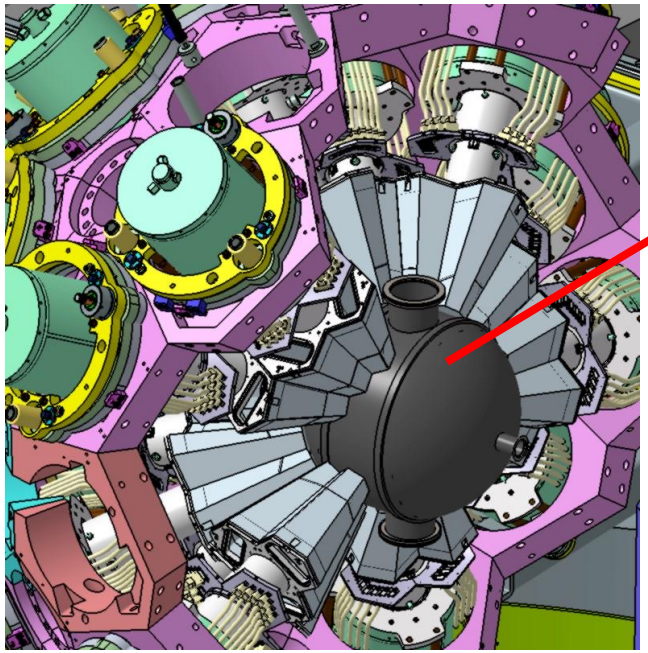


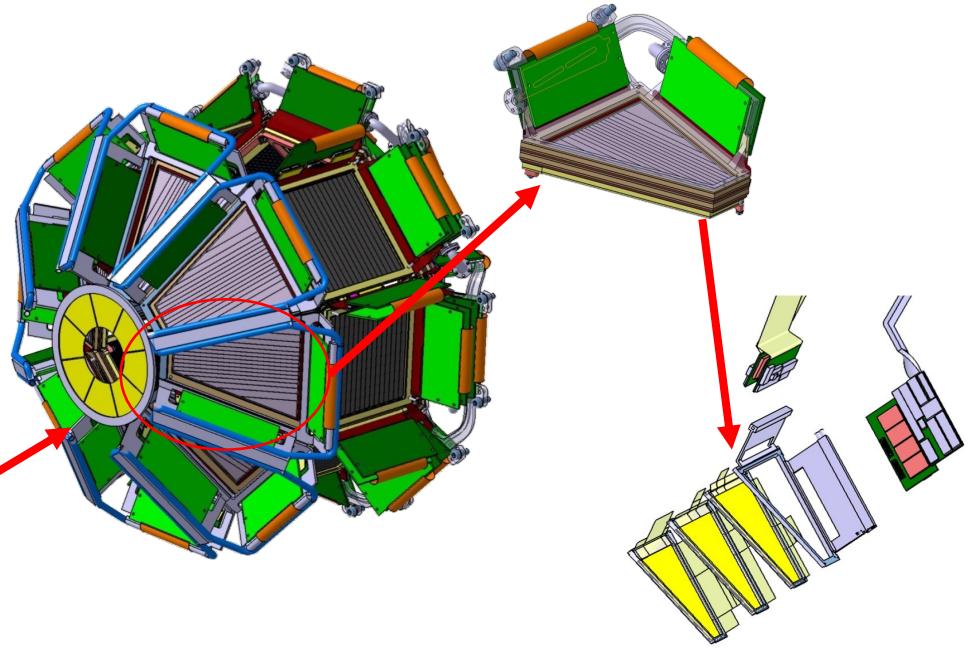
GRIT
2026/27-?

GRIT: **G**ranularity, **R**esolution, **I**dentification and **T**ransparency

- ~4π silicon detector
- Coupled to AGATA
- Missing mass
- With PSA identification







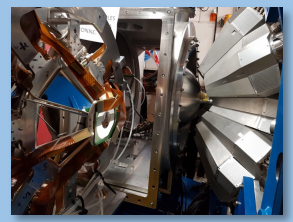
Integration challenge:

- GRIT is inside the 450 mm sphere of AGATA
  - 90 electronics card
  - 24 silicon detectors
- To be ready in 2026/27

Conclusion

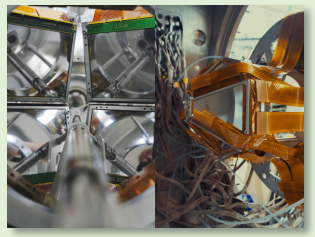
Combination of light-particle + gamma-ray + Residue detection:

- Measuring all the particles is very powerful
- Opens up many new possibilities (high precision DSAM…)
- Can study a broad range of topics (shell-model, astrophysics, drip-line…)
- Can lead to nearly background free missing mass and gamma spectroscopy studies
- MUGAST is a first step toward the new generation of highly segmented silicon arrays
- More is coming : 4+ experiments in GANIL
- GRIT@SPES after 2026/2027
- Are similar device developed for GRET(I)NA? FAUST? Others?



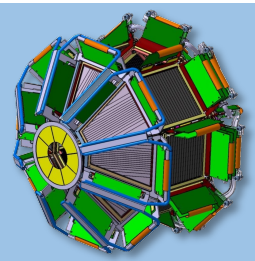
MUGAST/VAMOS/AGATA

2019-2021



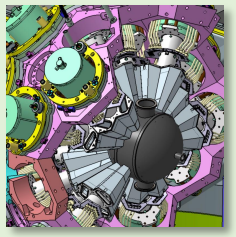
MUGAST@LISE

2023-2026?



GRIT/AGATA@SPES?

2027?-2030?



Depends on AGATA

after 2030?

Thank you for your attention!

Collaboration:

IJCLab Orsay: M. Assié, D. Beaumel, Y. Blumenfeld, N. De Séréville, V.Girard-Alcindor, J. Guillot, F. Hammache, H. Jacob, A.Korichi, L. Lalanne, I. Stefan

INFN-Padova, LNL: D. Brugnara, J.Casal, F. Galtarossa, A Goasduff, A. Gottardo, D. Mengoni, D. Testov

INFN-Legnaro: A. Raggio, A. Montanera Piza, I. Zanon

INFN-Milano: S.Leoni, B.Million

GANIL: E. Clément, A. Lemasson, D. Ramos, M. Rejmund, O. Sorlin, F. de Oliveira, C.Fougères, G. De France, B. Bastin, S. Leblond

LPC Caen: F. Delaunay, J.Dudouet, F. Flavigny, C.Lenain, A.Matta, F.Noury, N.Orr

IRFU-CEA-Saclay: M.Siciliano

IPHC Strabourg: K. Rezynkina, G. Duchêne, F. Didierjean

University of York: C. Diget, A. Laird, J.S. Rojo

University of Surrey: W. Catford, G. Lotay, C. Paxman

HHNIPNE Magurele: R.Borcea, F. Rotaru, M.Stanoiu

University of Santiago: B. Fernandez-Dominguez

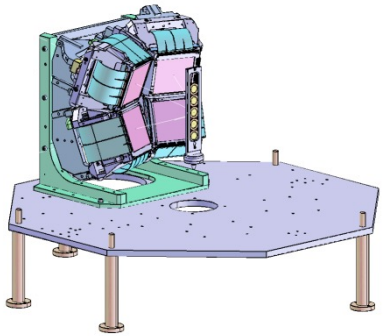
University of Valencia: A. Gadea

BACKUP SLIDES

Brief (recent) history of MUGAST at GANIL

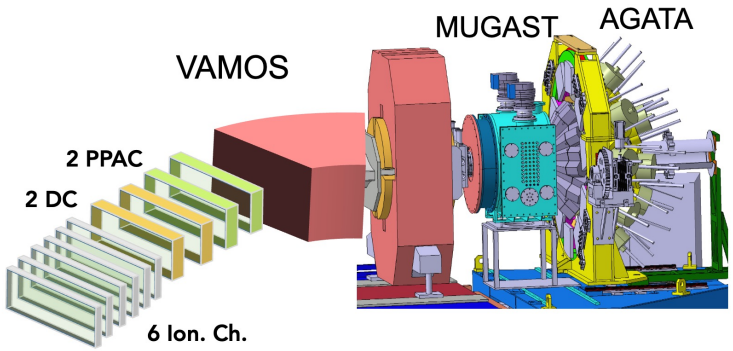
Last LISE (fragmentation) campaign:

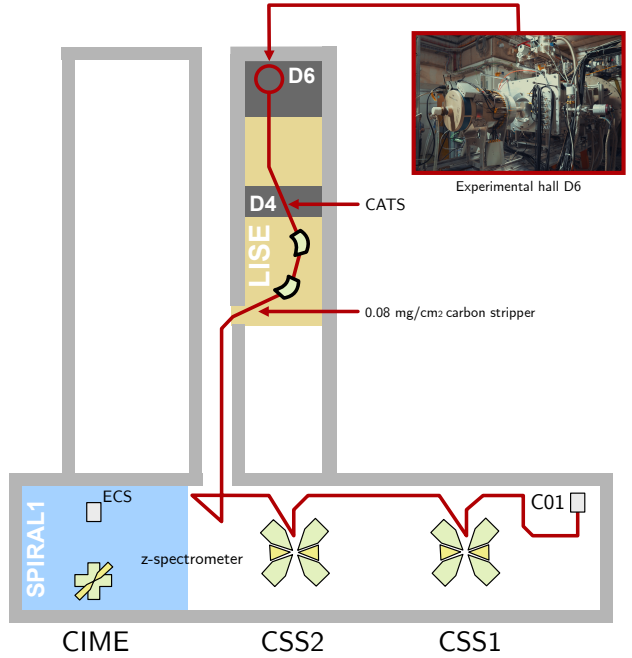
- MUST2@LISE:
  - MUST2 + ZDD
  - 4 experiments (2017-2018)
  - 5 publications



ISOL campaign:

- MUGAST/VAMOS/AGATA:
  - 5 experiments (2019-2021)
  - 3 Publications
  - More to come!
  - See talk of:
    - Irene Zanon
    - Charlie Paxman

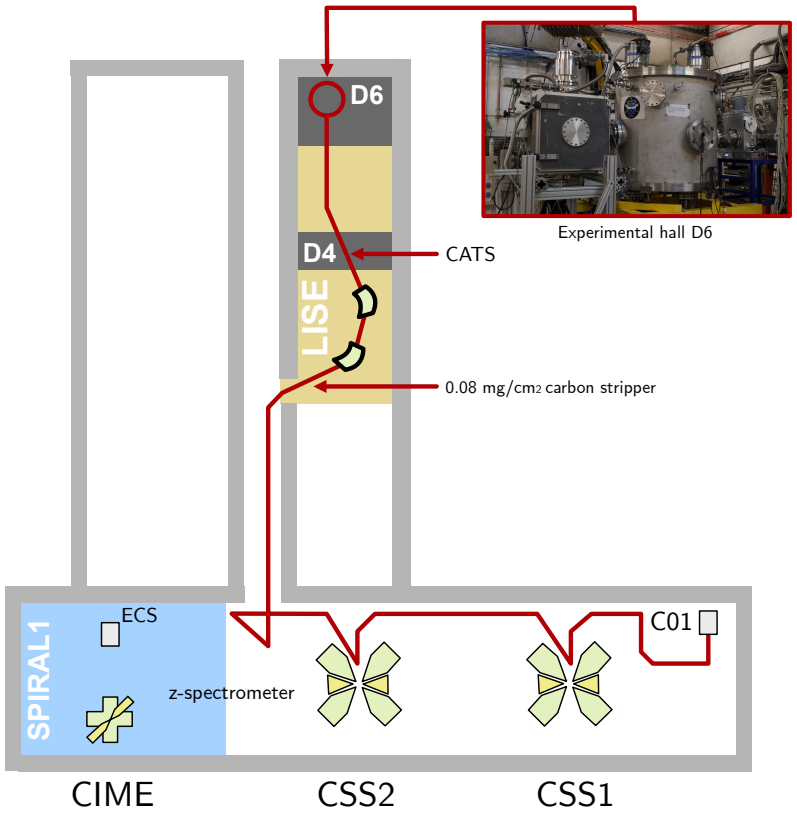


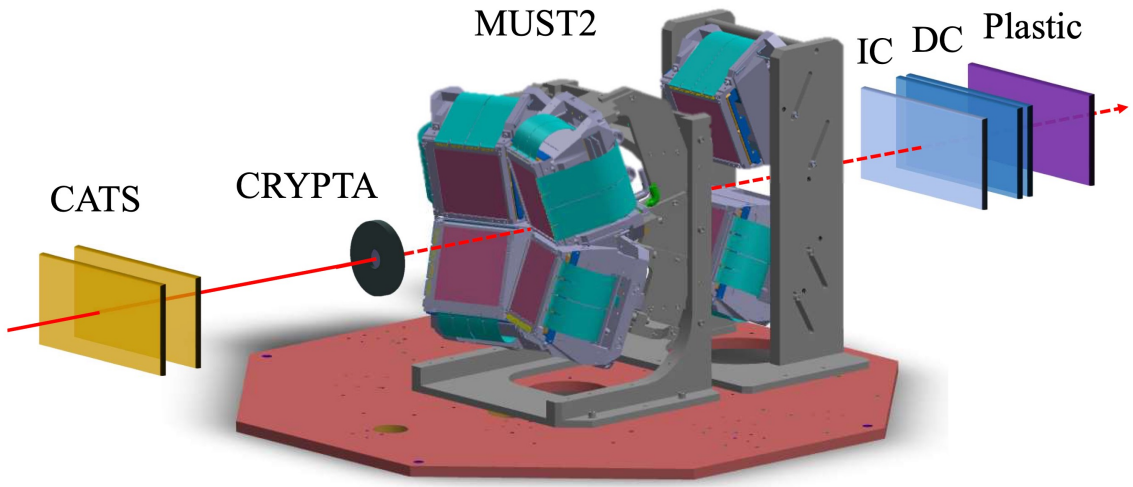


New LISE campaign:

- MUGAST + ZDD + Exogam
- 6+ experiments:
  - 2 performed (2023)
  - 4 scheduled (2024-2025)
  - Currently open to GANIL PAC!

MUST2@LISE: 2009, 2014, 2017 - 2018





- 4 - 8 MUST2 telescopes
- y-ray detectors:
  - CsI
  - LaBr3
  - 4 EXOGAM
- 0º Detection (MUST2 or DC/IC)
- Cryogenic target compatible

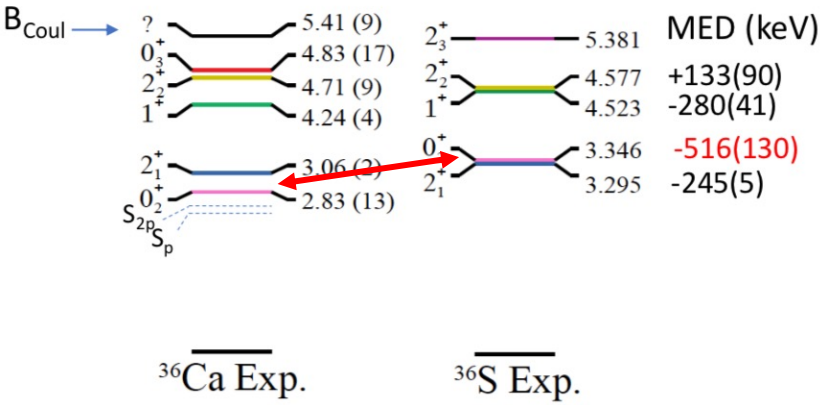
- Broad range of topics:
  - Shell model
  - Drip-line
  - Clustering

O. Sorlin, D. Suzuki, M. Assié: Colossal mirror energy difference between ^{36}Ca and ^{36}S evidenced through transfer reactions

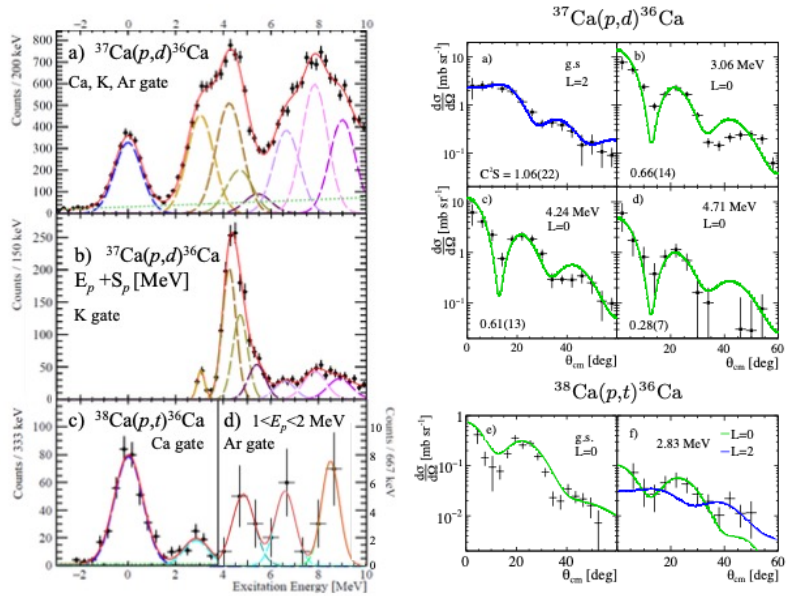
Topic: Shell model
Reaction: ^{37}Ca(p,d)^{36}Ca and ^{38}Ca(p,t)^{36}Ca
Goal: Study of MED between ^{36}Ca and ^{36}S
Specificities: Use of LH2 target (*S. Koyama et al., NIM A 1010,165477 (2021)*)

Motivations:

- Colossal MED (-700 keV) predicted between 0^+_1 and 0^+_2 states in ^{36}S - ^{36}Ca
- Explained by the very different configuration between the spherical ground state and the intruder 0^+_2 state - *Valiente-Dobon et al., PRC 98 (2018)*



PhD : L. Lalanne

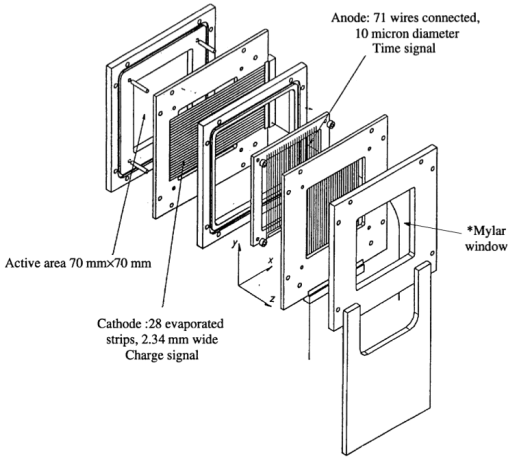


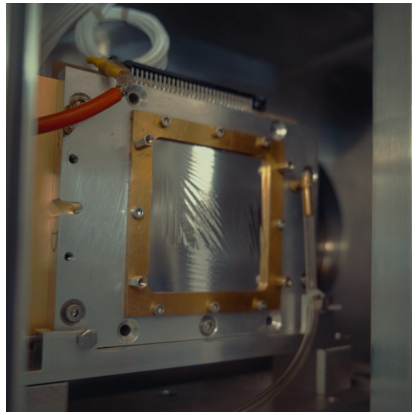
- -500 keV MED for the 0^+_2 the **largest** one ever observed
- -250 keV MED for the 2+ and 1+ states.
- 1st time evidence of MED breaking in shape coexistence

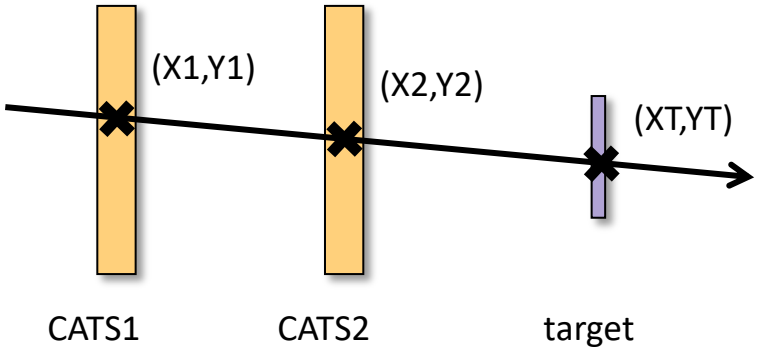
L. Lalanne et al., PRL 129 122501 (2022)

Beam tracking

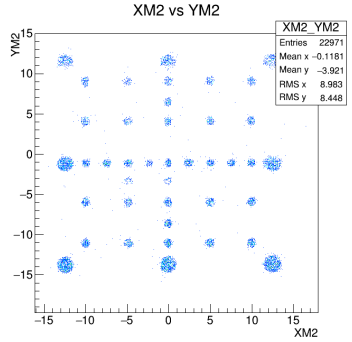
Beam tracking: CATS

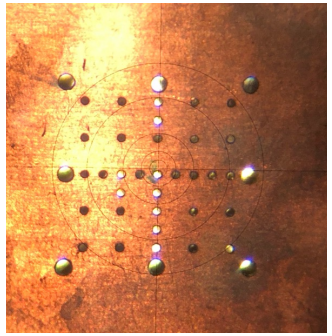


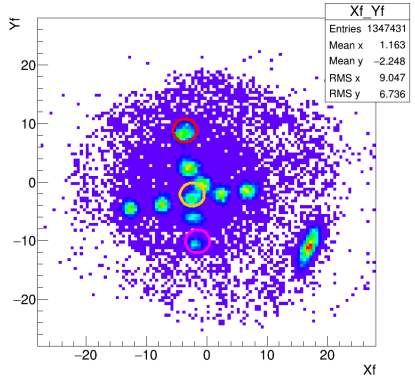


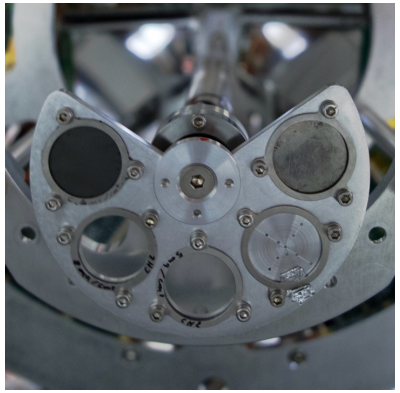


Mask on CATS:



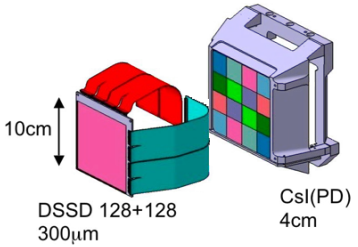


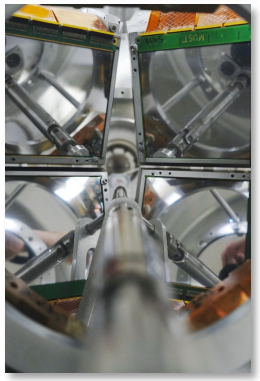


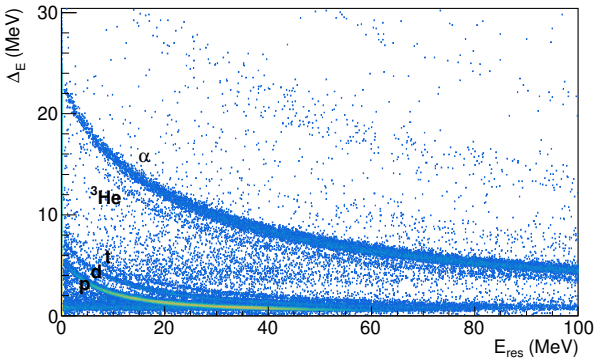


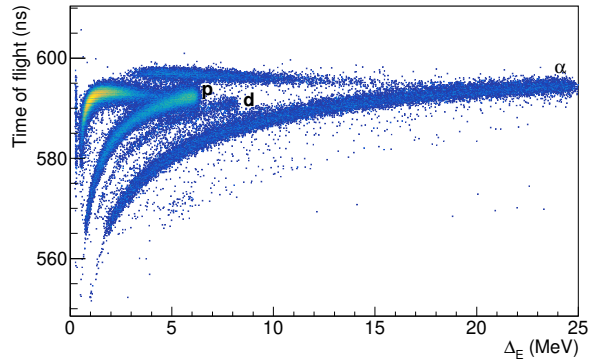
Particle identification

ΔE-E / tof identification in MUGAST:

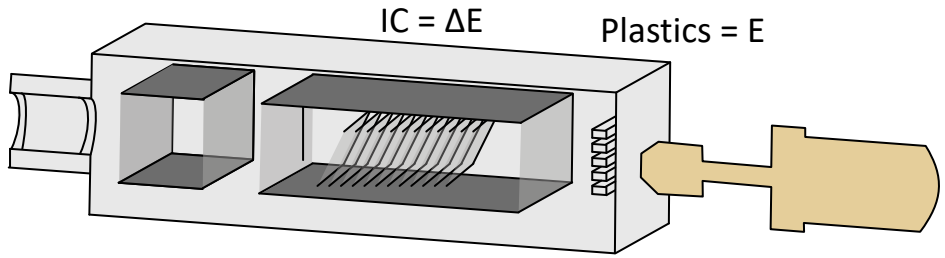


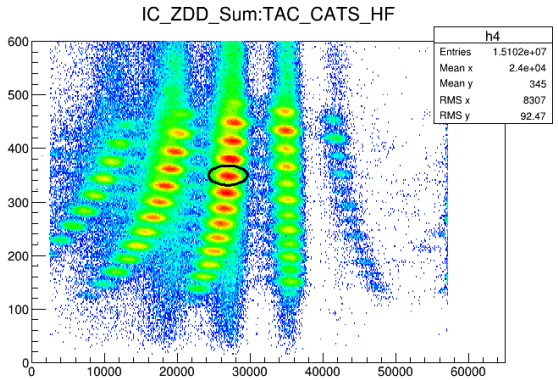


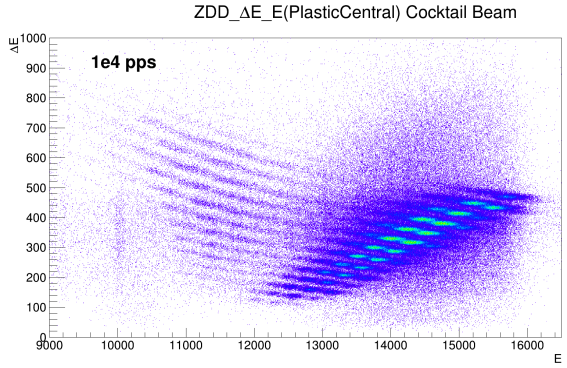




ΔE-E + ToF identification in the ZDD:



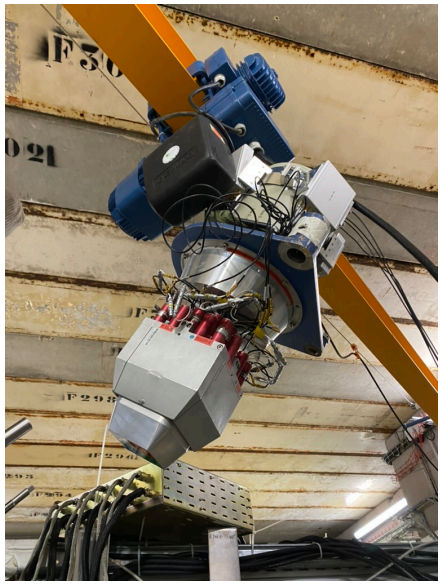




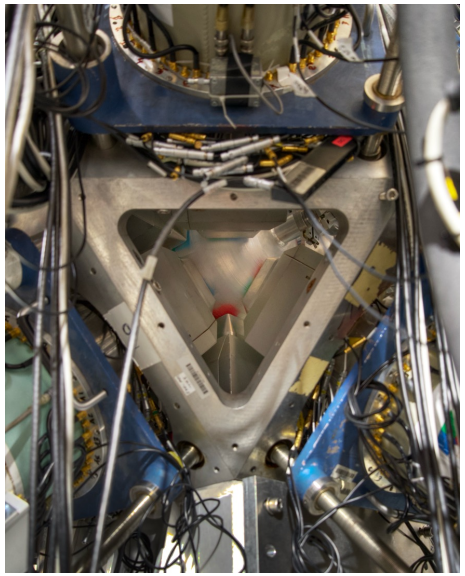
Damage to the central plastic due to direct beam -> bad ΔE-E:
-> identification ΔE - ToF CATS_HF (or CATS-Plastic)

Gamma spectroscopy

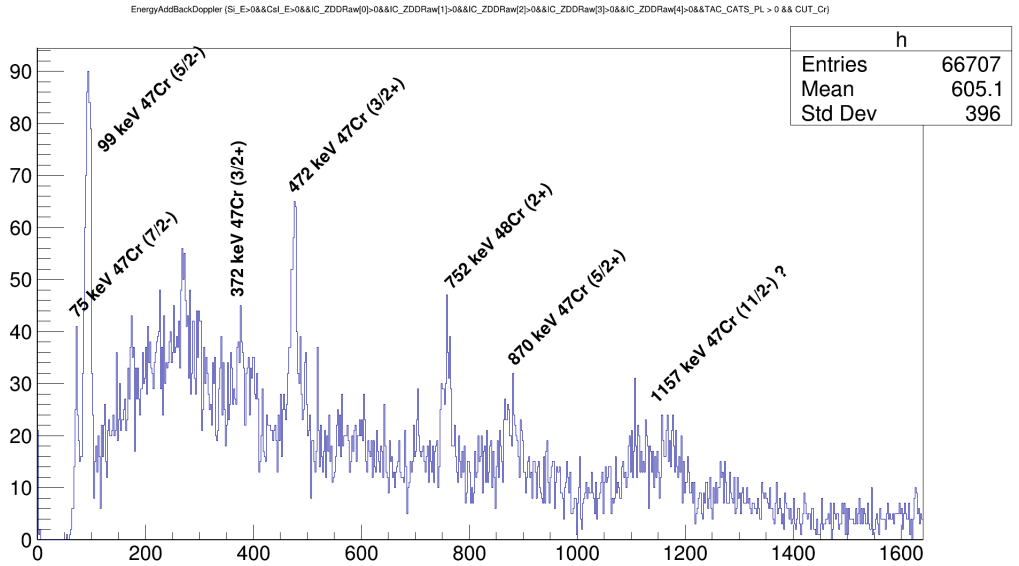
Exogam:



Exogam cluster before mounting



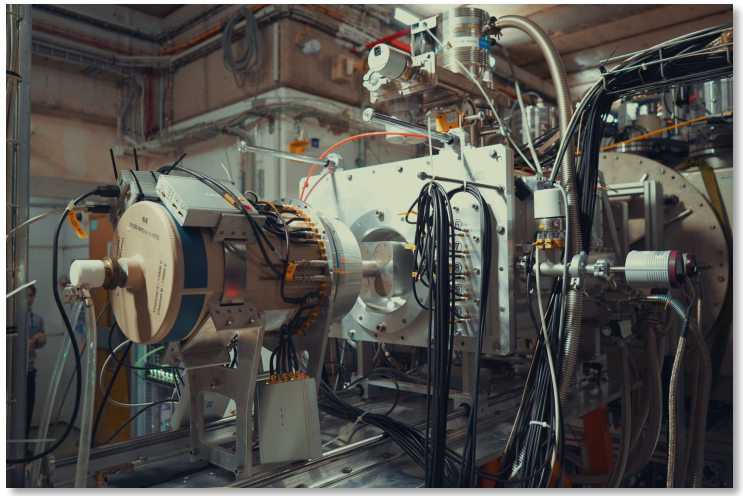
Exogam clusters around the trapezoids



Example of online add-back doppler corrected spectra

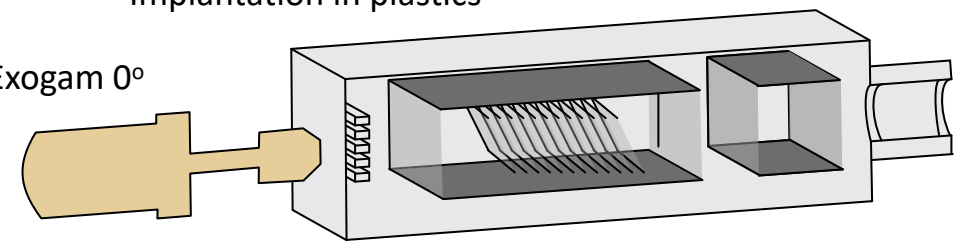
Decay station

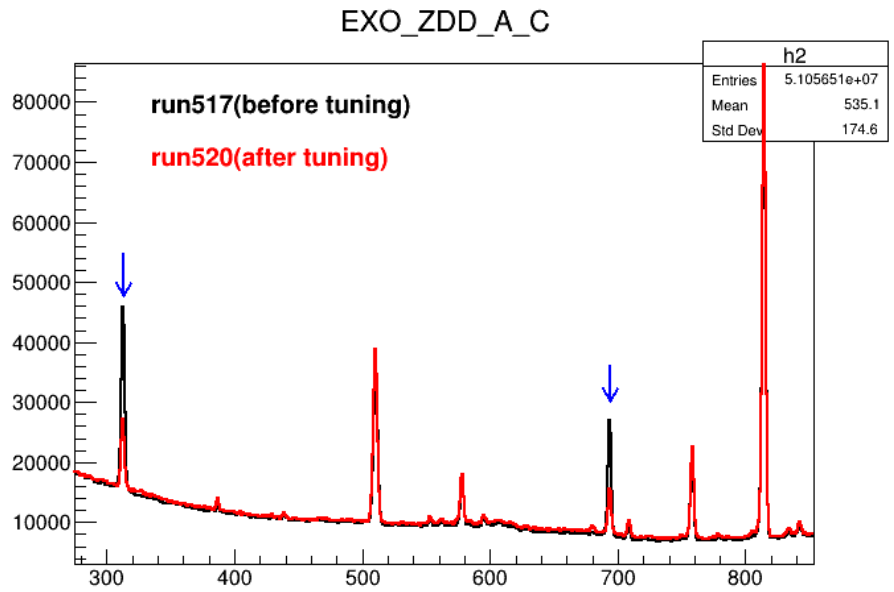
Isomer identification: ZDD Exogam



Implantation in plastics

Exogam 0°

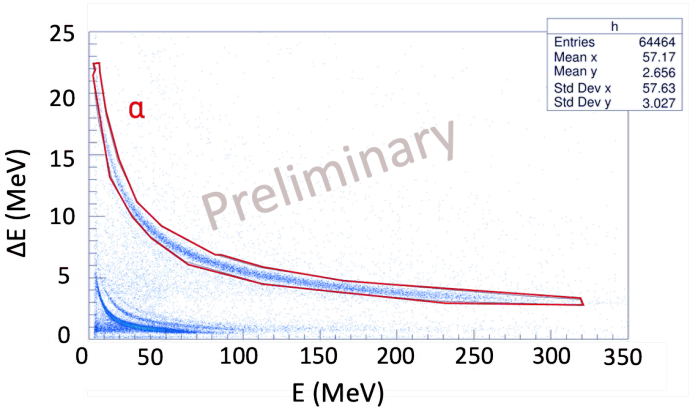


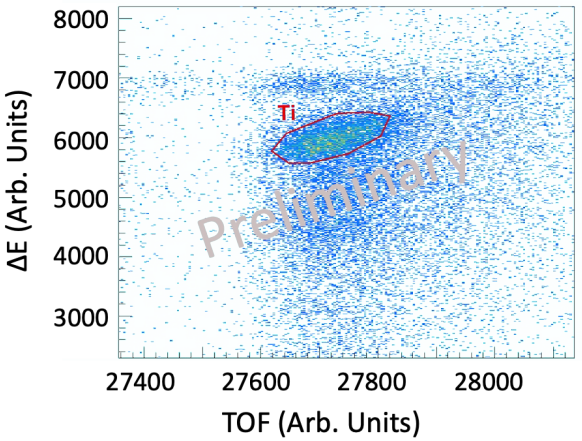


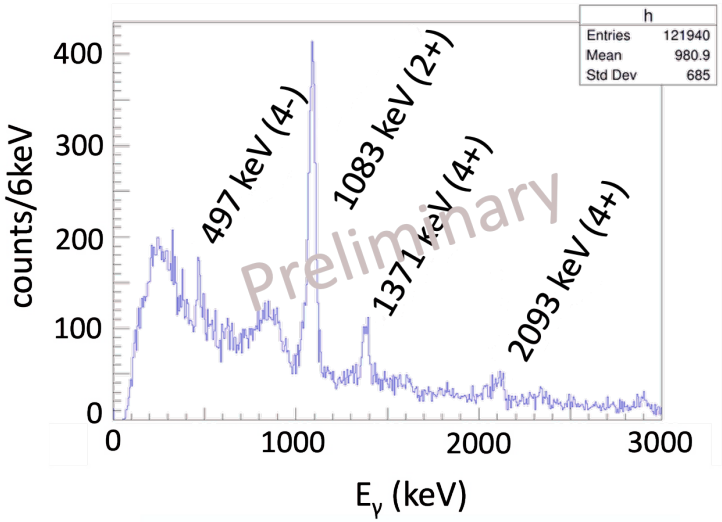
- Beginning of beam time, large contamination from ^{67}Ni isomer
- Contamination estimated thanks to the decay station
- Help diagnose and reduce the contamination !
- The decay station is also of interest for reaction induces by isomers
  - To estimate their production
  - To subtract the “isomer-induced” background

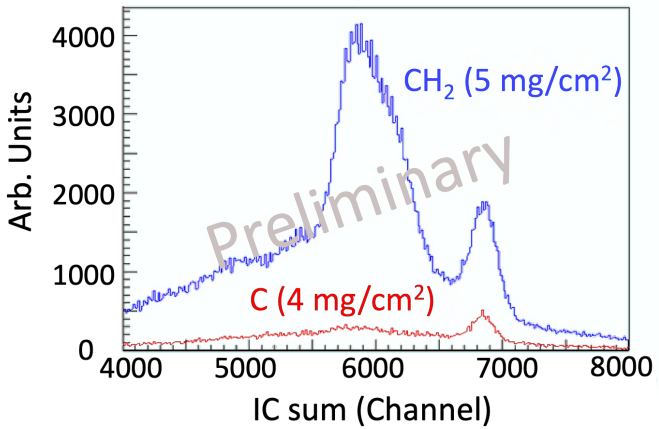
MUGAST@LISE: Online performances

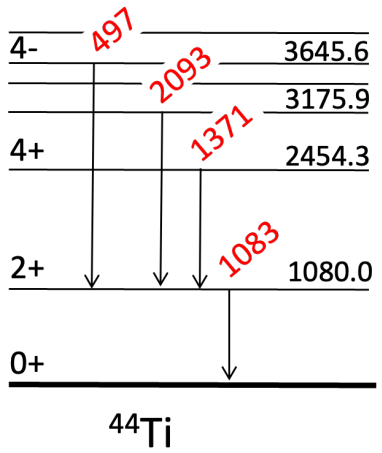
^{48}Cr(p,^{4}He)^{44}Ti online analysis:











Seemingly large ^{48}Cr(p,^{4}He)^{44}Ti cross-section
Not visible in the Carbon background!
To be investigated…

Courtesy of L. Dienis