INSTITUT DE PHYSIQUE NUCLÉAIRE ORSAY

MUGAST : Results and plans

Franco Galtarossa, on behalf of the MUGAST collaboration
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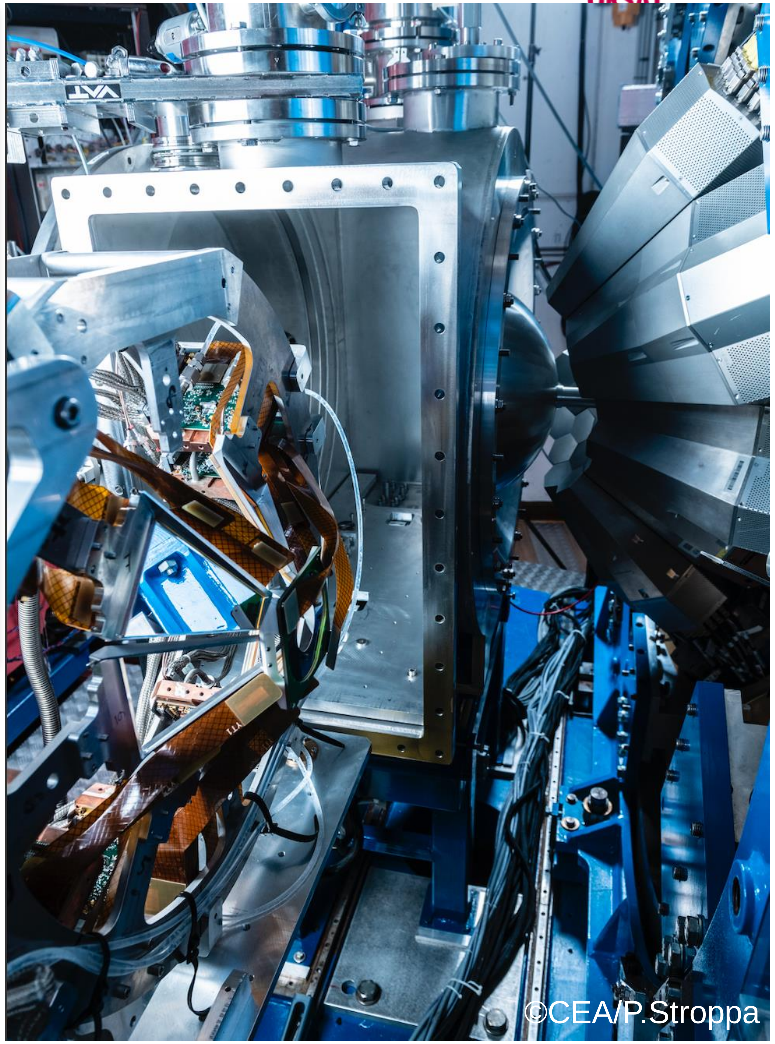


Many of the following slides are cortesy of M. Assié

MUGAST–AGATA-VAMOS set-up @ GANIL with Spiral1 beams

An extremely complete set-up for transfer reactions measurement

VAMOS

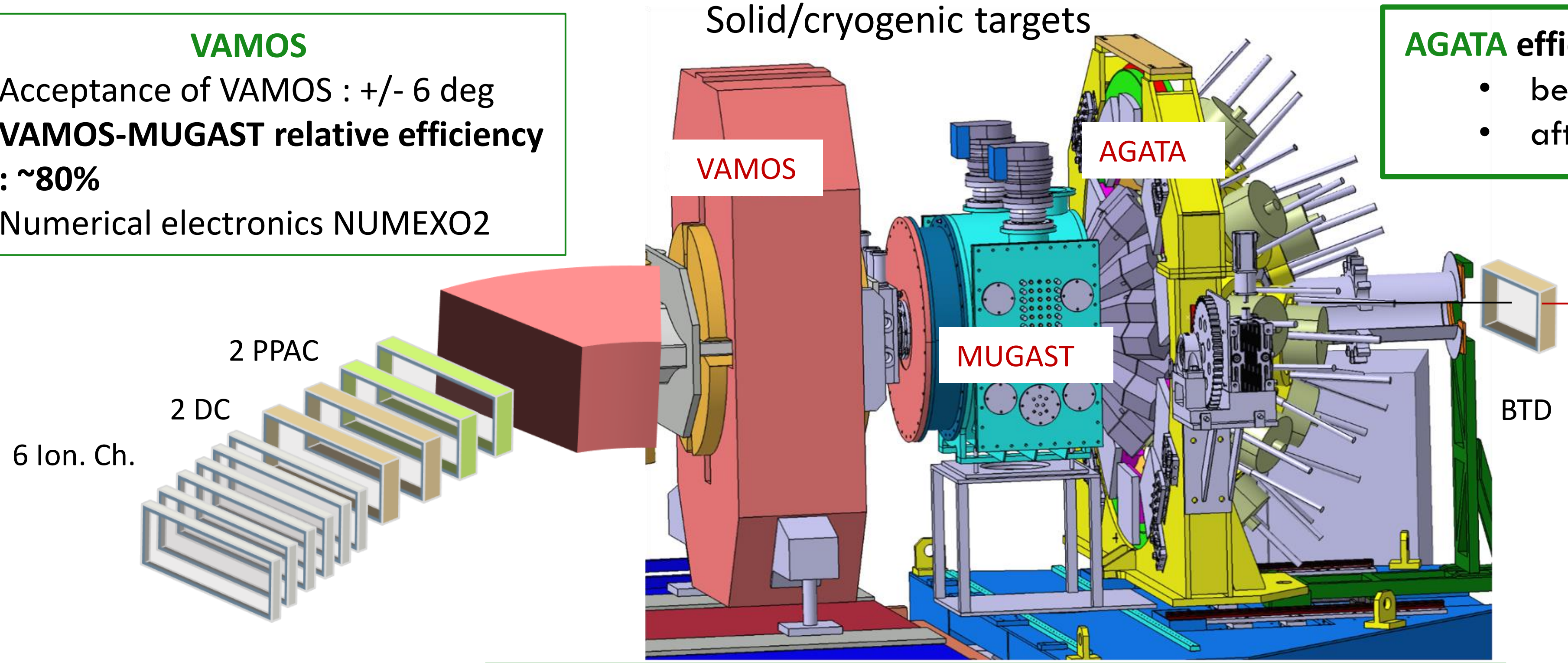
Acceptance of VAMOS : +/- 6 deg

VAMOS-MUGAST relative efficiency : ~80%

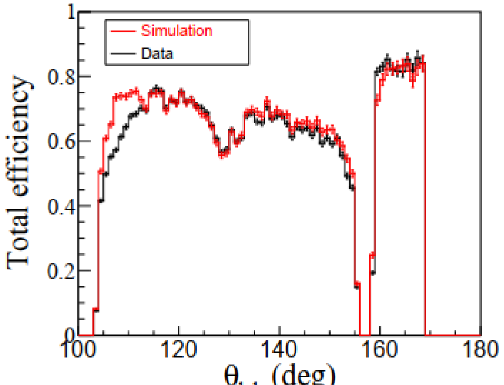
Numerical electronics NUMEXO2

AGATA efficiency (18cm) at 1 MeV:

- before add-back : 5.5%
- after add-back : ~8%



Spiral1 radioactive beams



MUGAST :

Forward : 4 MUST2 (128X+128Y) DSSD 300um + CsI

Backward : 5 in 2019 (7 in 2020) trapezoid (128X+128Y) DSSD 500um + **Annular (S1)**

90 deg : square (128X+128Y) DSSD 500um

Granularity : 0.4 deg

~ 3000 channels all read by MUST2 integrated electronics

MUGAST–AGATA-VAMOS-Spiral1 campaigns : an overview

2019

UNBOUND STATES

Above barrier narrow resonances in ^{15}F

I. Stefan (IPN), F. de Oliveira (GANIL)

^{14}O(p,p') with few 10^5 pps

NUCLEAR ASTROPHY.

Determining the α+^{15}O radiative capture rate

C. Diget (York), N De Séréville (IPN)

^{15}O(^{7}Li,tγ)^{19}Ne with $4{\cdot}10^7$ pps

SHELL MODEL

Is there a problem with protons in N=28 nucleus ^{46}Ar ?

A. Gottardo INFN, M. Assié IPN)

^{46}Ar(^{3}He,dγ)^{47}K with $4{\cdot}10^4$ pps

2020

SHELL MODEL

Lifetime measurements of 2_2^+ and 3_1^+ of ^{20}O by direct nucleon transfer

E. Clément (GANIL), A. Goasduff (INFN)

^{19}O(d,pγ) + DSAM with $4{\cdot}10^5$ pps

2021

SHELL MODEL

Proton-neutron interactions across the N = 28 shell closure via ^{47}K(d,p)^{48}K

W. Catford (Surrey), A. Matta (LPC)

^{47}K(d,pγ)^{48}K with $5{\cdot}10^5$ pps

COMMON FEATURES

- SPIRAL 1 radioactive beams from ~ 5 to ~10 MeV/u and intensity between few 10^4 and 10^8 pps.
- Direct transfer reactions such as (d,p), (^{3}He,d), (^{7}Li,t)…
- γ-particle coincidence.

Determining the α+^{15}O radiative capture rate

NUCLEAR ASTROPHYSICS

Determining the α+^{15}O radiative capture rate

C. Diget (York), N De Séréville (IPN)

PhD : J. Sanchez Rojo

^{15}O(^{7}Li,tγ)^{19}Ne indirect measurement

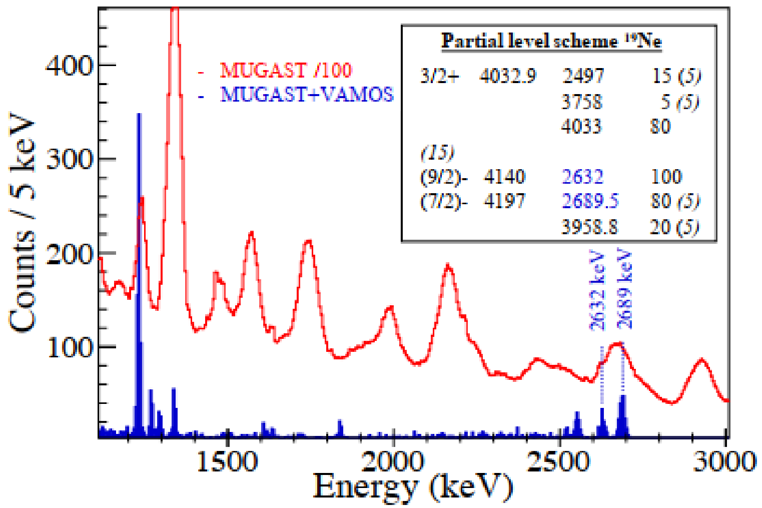
GOAL:

Important reaction for breakout from Hot-CNO cycle to rp-process in Type I X-ray bursts

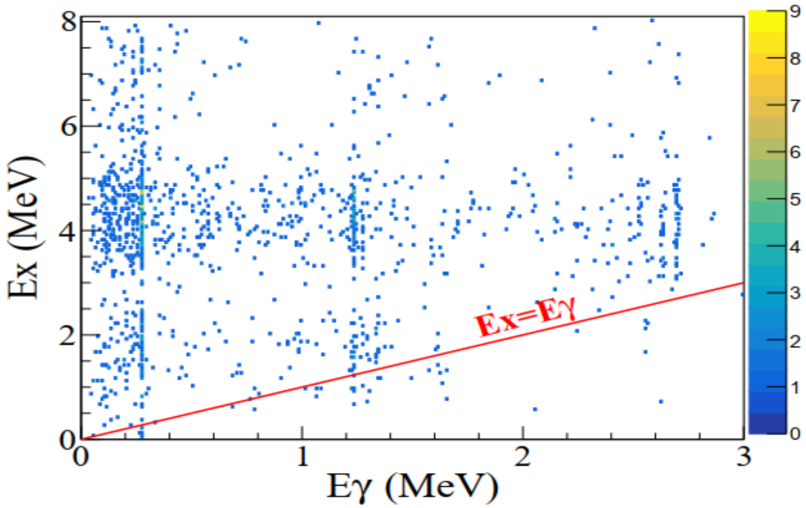
SPECIFICITIES:

- ➟ High intensity beam : up to 10^8 pps
  - No beam tracking
  - PId by reconstructing trajectories in VAMOS (new!)
- ➟ High energy gammas (~4 MeV)
- ➟ Triple coincidences: background free

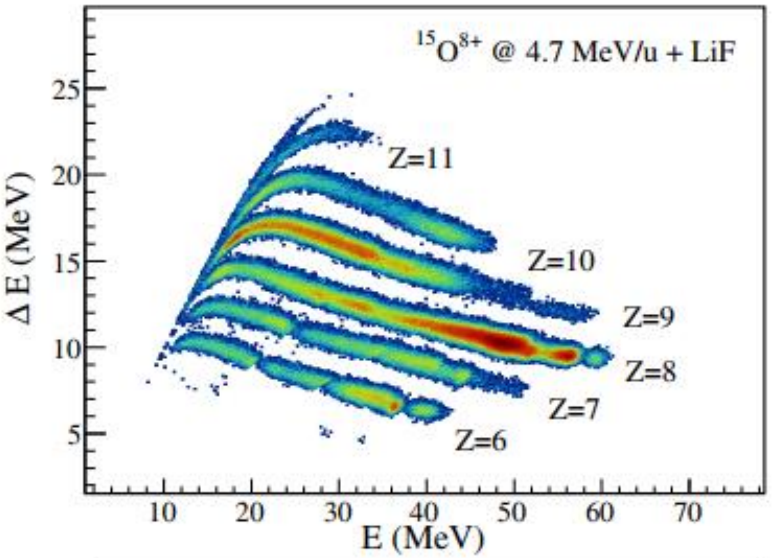
Gamma spectrum in triple coincidence

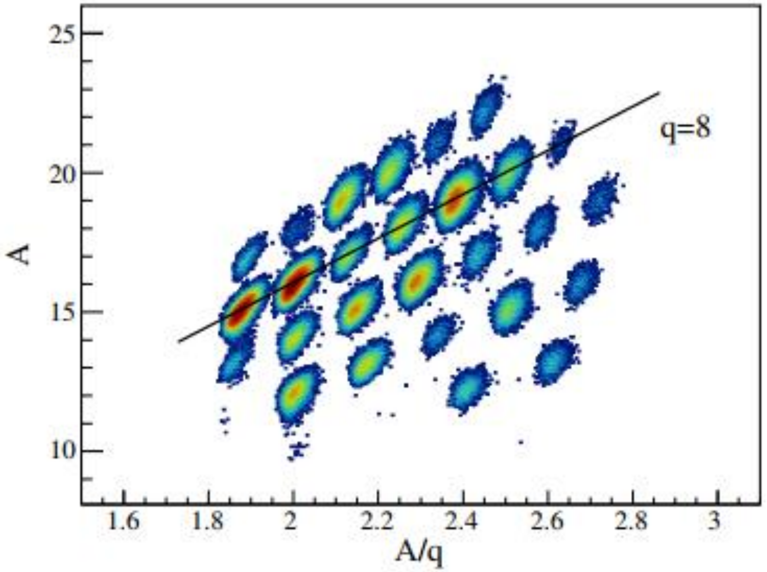


--> Very clean spectrum : almost no background



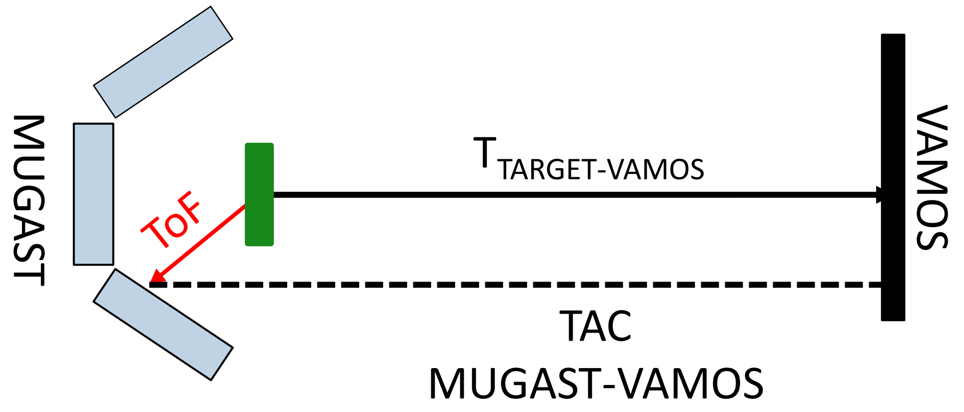
VAMOS identification

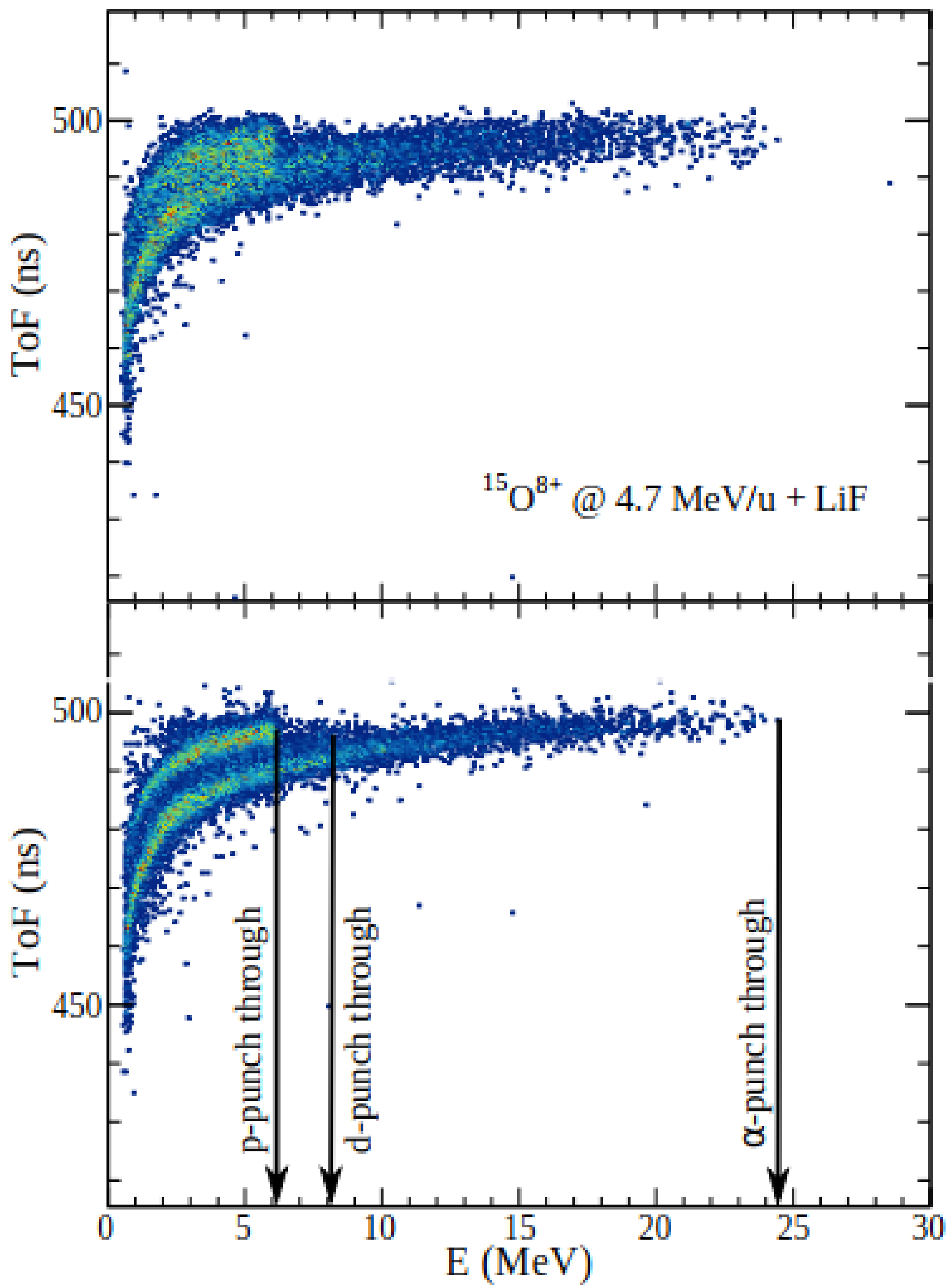




The particle identification turns out to be difficult if the time signal of the RF is used (resolution ~3 ns).
It can be improved measuring the ToF of the light particles from the target to MUGAST as:

$$ToF = T_{TARGET\text{-}VAMOS} - T_{MUGAST\text{-}VAMOS}$$





The time $T_{TARGET\text{-}VAMOS}$ is deduced from the measured Brho and event-by-event reconstructed trajectory of the ions in the spectrometer.
The final ToF resolution is around 1.4 ns.

Is there a problem with protons in N=28 ^{46}Ar ?

SHELL MODEL

Is there a problem with protons in N=28 nucleus ^{46}Ar ?

A. Gottardo (INFN), M. Assié (IPN)

PhD : D. Brugnara

^{46}Ar(^{3}He,dγ)^{47}K proton transfer

GOAL:

Probe proton WF and study vacancies in $s_{1/2}$ and $d_{3/2}$ shells.

SPECIFICITIES:

First experiment with ^{3}He cryogenic target

Beam issues :

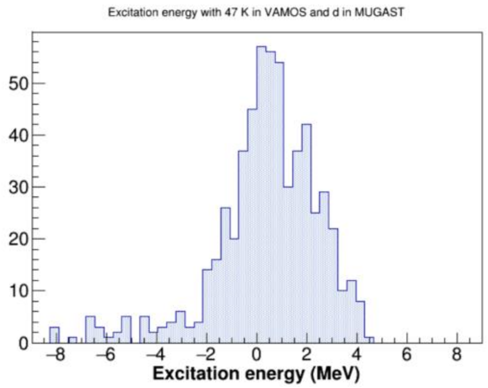
statistics is 1/3 of the expected one

- **Excellent theory for neutrons WF** confirming N=28 shell closure in ^{46}Ar

  Large discrepancy in measured B(E2) at N=28: problem with the proton E2 contribution?

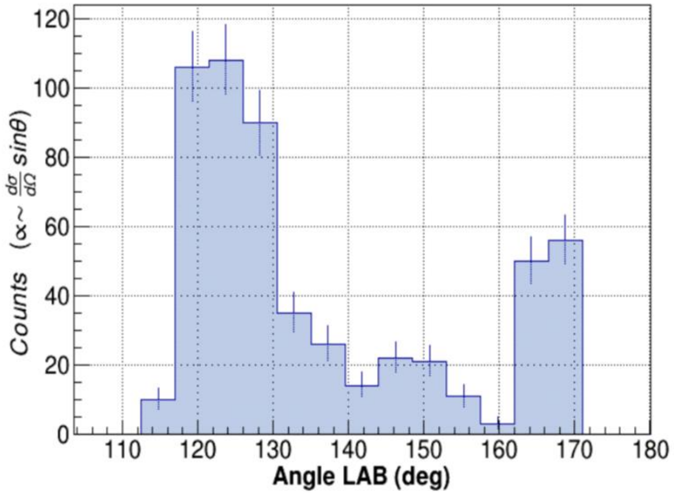
- **Proton shell structure at N=28 :**

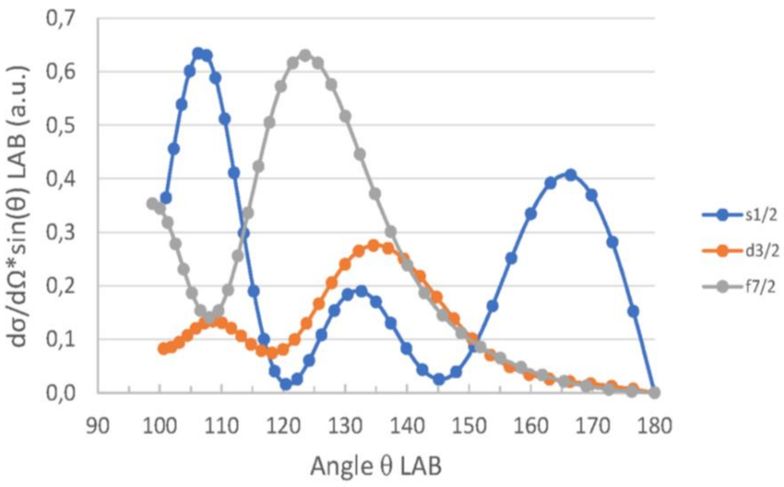
Measuring πs1/2 depletion in ^{46}Ar --> indication on possible change in the $\pi s_{1/2}$- $\pi d_{3/2}$



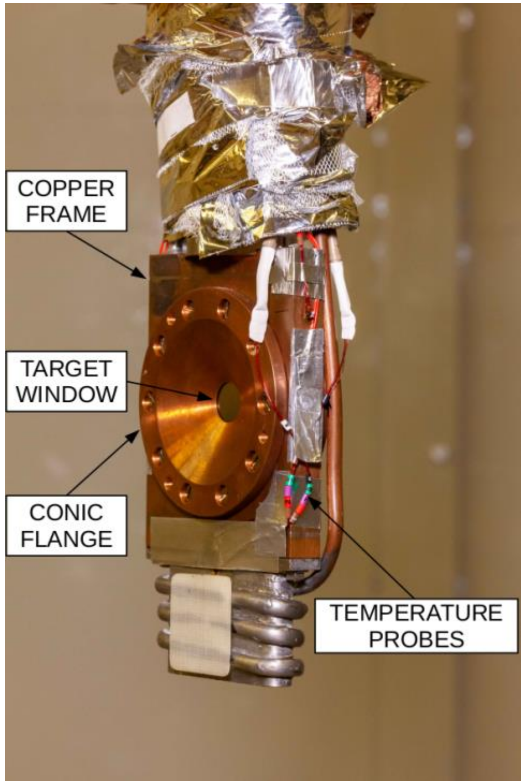
Spiral1 beam intentisity 2x higher than predicted
BUT 1/3 of the statistics obtained due to beam issues

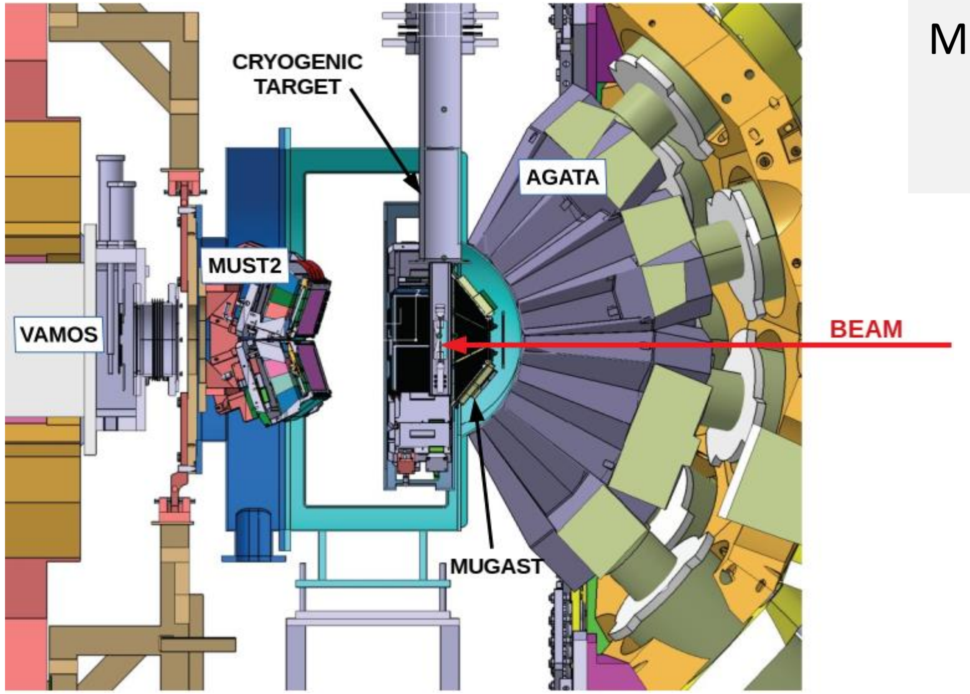
Preliminary angular distribution of deuterons (without efficiency correction) compared to theoretical ones



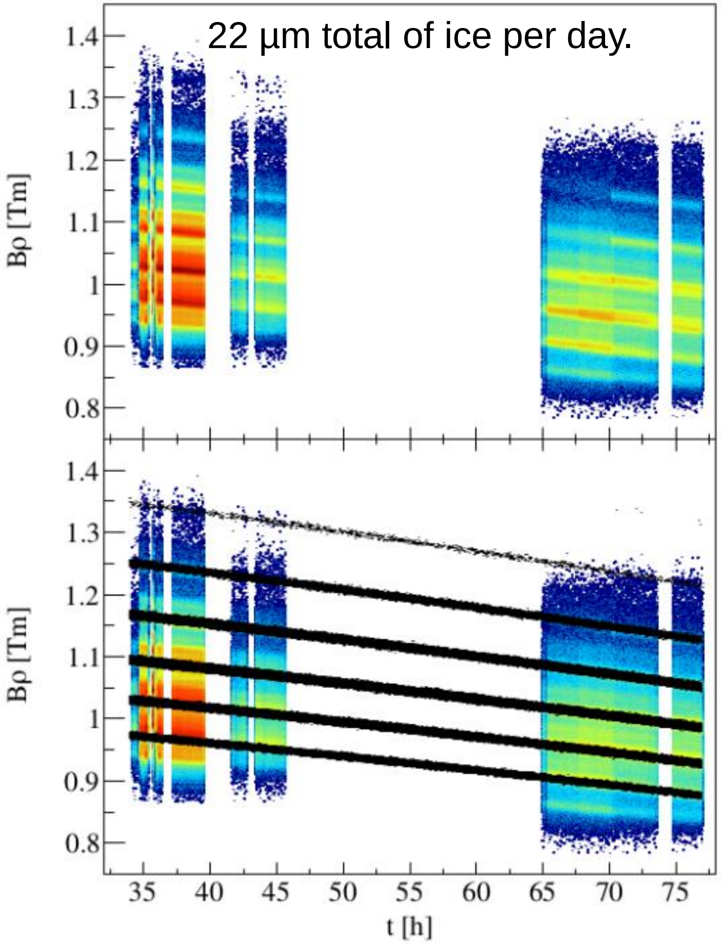


The cryogenic ^{3}He target

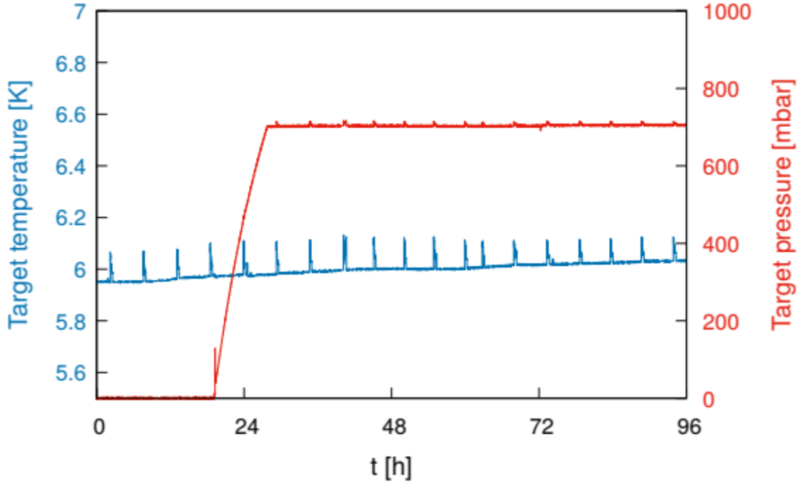




Monitoring of target with VAMOS :
- Target pressure & temperature stable
- Ice formation on the target with time



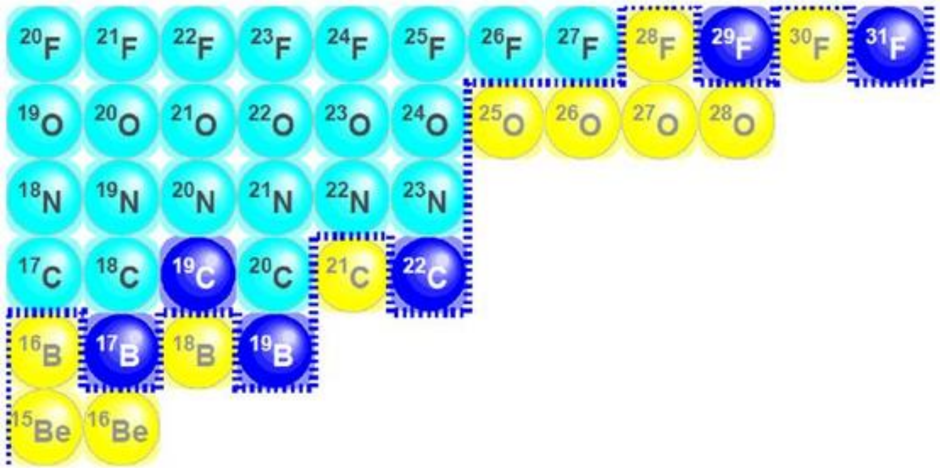
- Ø 16 mm
- Opening angle: 130 deg.
- Havar windows: 3.8um
- T ~ 6-7 K. / P up to 1 bar
- Equivalent thickness 2 mg/cm^2
- ^{3}He recycling
- LHe open circuit



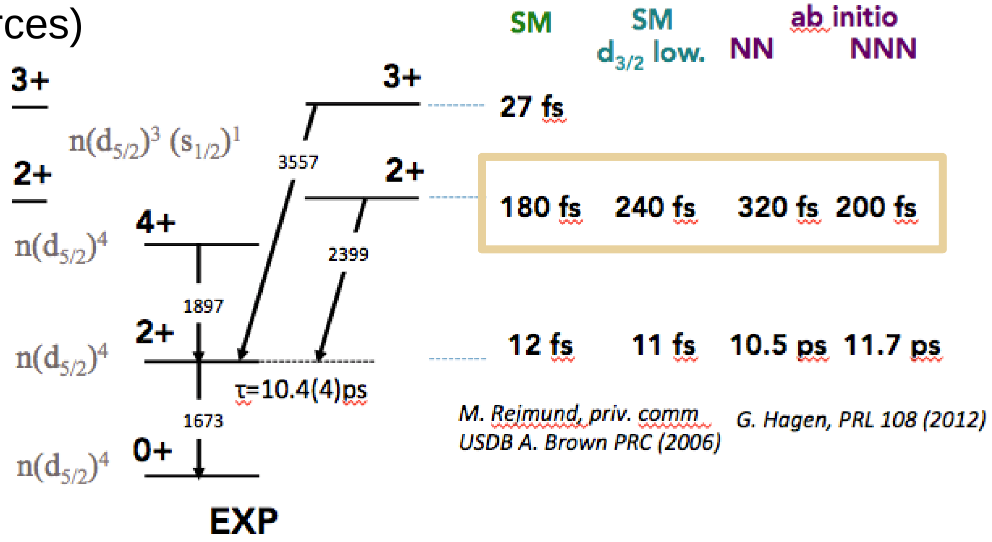
M. Pierens, V. Delpech,
F. Galet, H. Saugnac (IJCLab)
A. Giret & J. Goupil (GANIL)

Experiment SP: E. Clément (GANIL), A. Goasduff (INFN) / PhD : I. Zanon (INFN)

Motivation : Oxygen drip-line anomaly explained microscopically by including three-nucleon force contribution in the nuclear interaction.



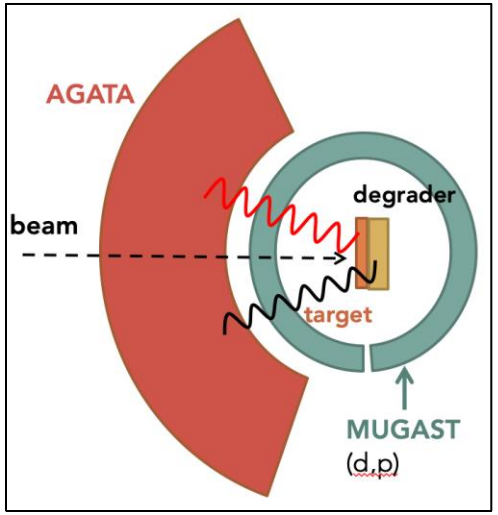
Predictions : from Shell model and ab-initio (2N and 3N forces)

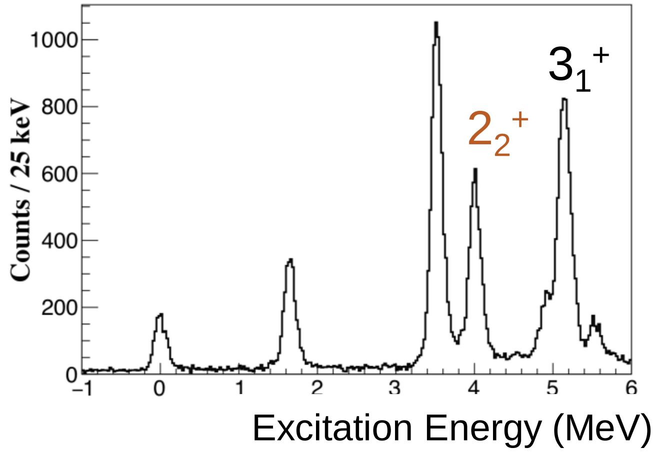


Method : Exclusive lifetime measurement in the femto-sec. scale (DSAM) using $^{19}O(d,p)^{20}O$

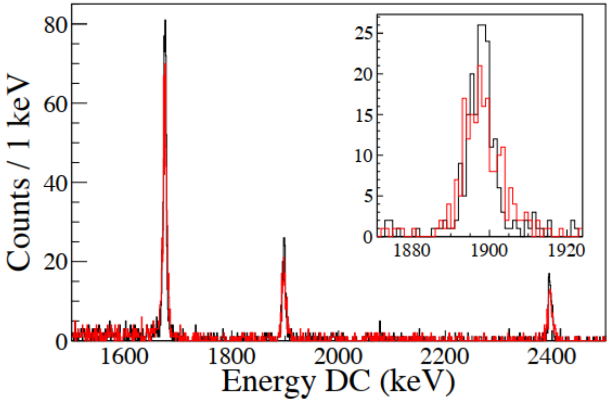
First time in inverse kinematics !

- ★ Triple coincidences in high-resolution mode
- ★ Control entry point through transfer reaction



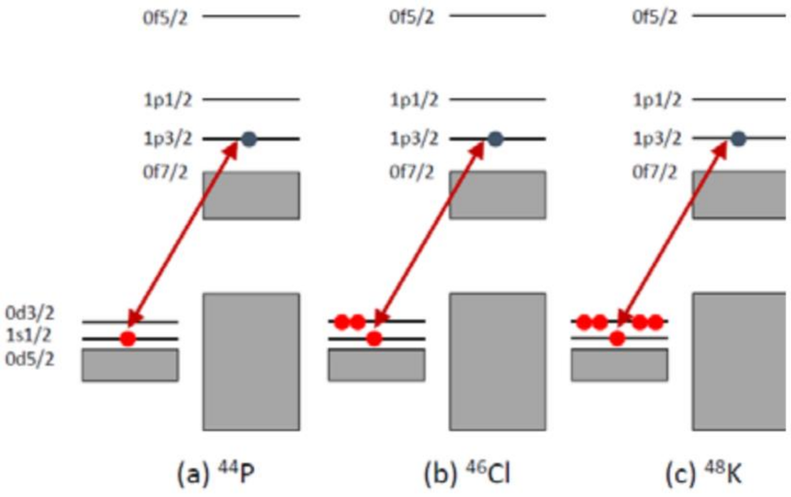


The measurement of angle and energy of the light ejectile allows to **refine the Doppler correction** and increase the precision on the extracted lifetimes.
In this case the resolution is improved from ~10 keV to ~ 7 keV.

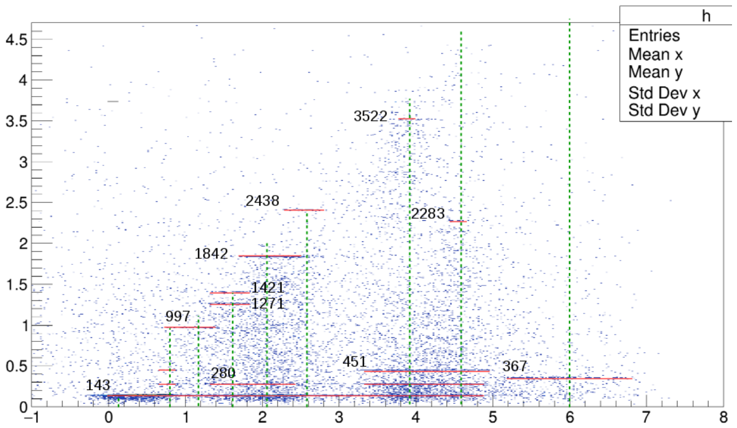


Proton-neutron interactions across N=28 via ^{47}K(d,p)^{48}K

Experiment SP: W. Catford (Surrey), A. Matta (LPC Caen) / PhD : C. Paxman (Surrey)

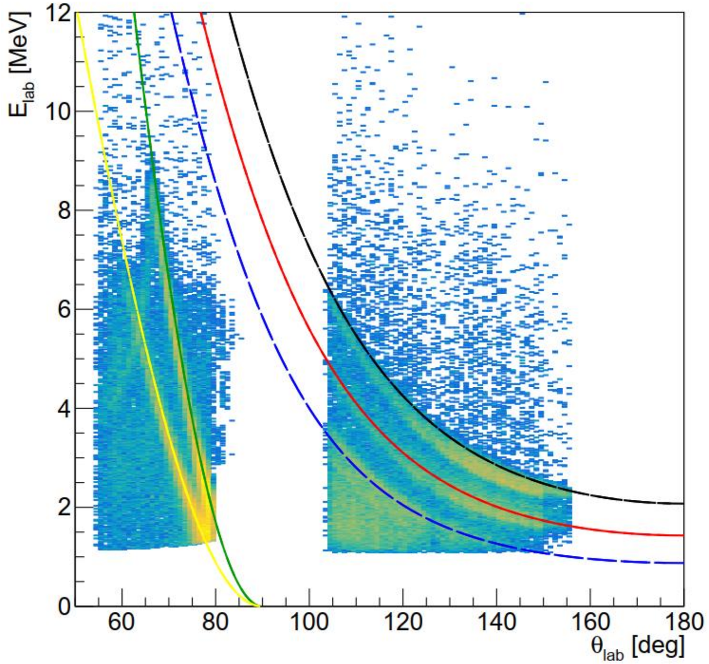


- Odd proton $1s_{1/2}$ interaction with odd neutron above N=28
- Spectroscopy of N=29 nuclei towards ^{44}P

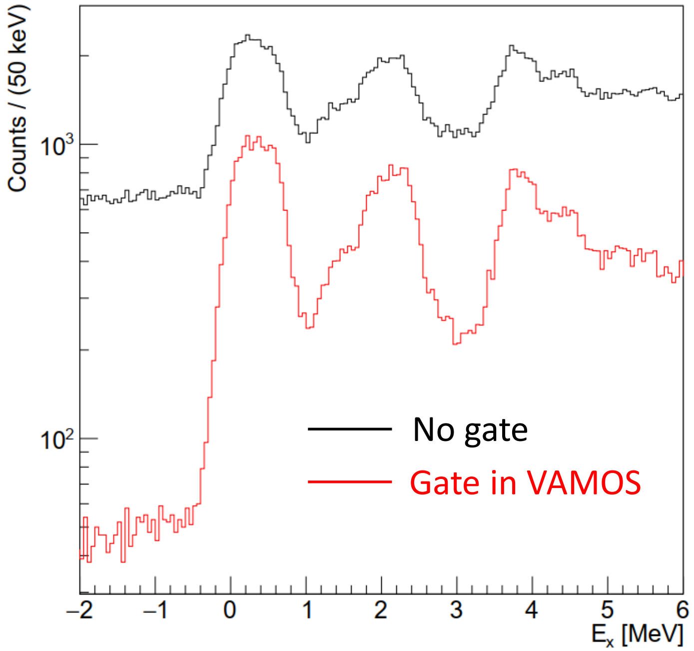


The (d,p) channel is normally quite clean at backward angles. VAMOS was used in «reduced mode», asking only a coincidence with its focal plane detector, to remove background from fusion-evaporation.

Kinematics



Ex distribution



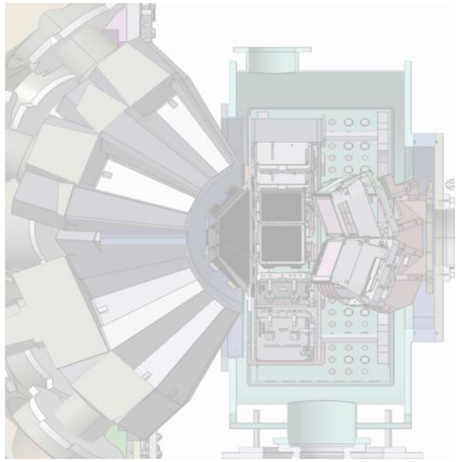
- ➢ E_x vs E_γ and γ-γ matrices could produced -> level scheme of ^{48}K extended
- ➢ Elastic scattering could be measured close to 90°

Experiment finished today!

Beyond 2021 : MUGAST on LISE

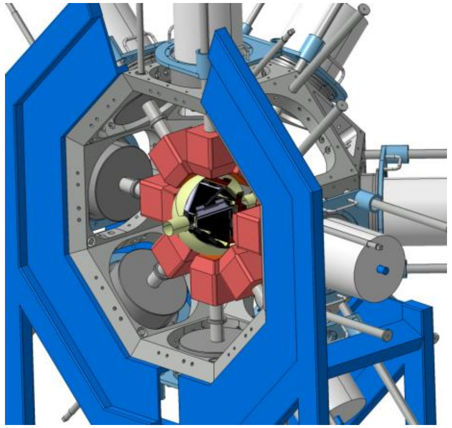
2019	2020	2021	2022	2023	2024	2025
MUGAST-AGATA-VAMOS			MUGAST on LISE		GRIT	

New Spiral1 beam
VAMOS-AGATA
12-14 DSSD
specific targets
PId : ToF

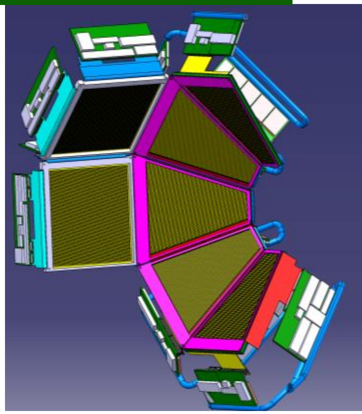


+ EXOGAM, PARIS, neutrons

4-5 telescopes (2 layers)
spherical config.
Close config.
(85 mm)



SPES - AGATA
PSA digital elec.
~10 DSSD (2 layers)

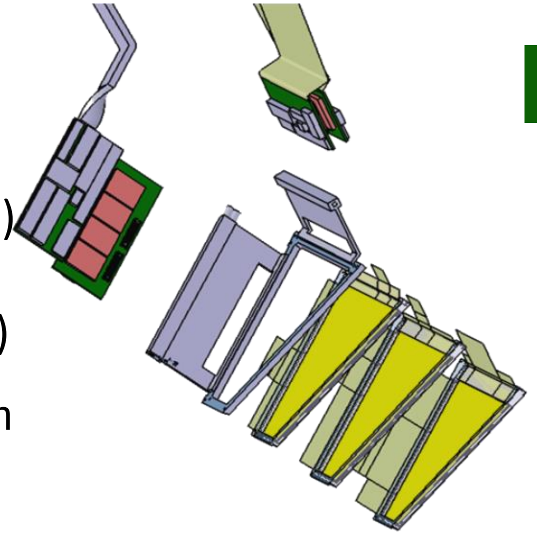


LISE well suited for beam energies ~ 20-50 MeV/u
→ pick-up reaction, inelastic scatt.

Proposed topics for MUGAST on LISE in 2022-23:

- np pairing in N=Z nuclei above the sd shell: ^{48}Cr(p,^{3}Heγ)^{46}V (approved, SP: M. Assié and A. Macchiavelli)
- Proton-stripping transfer near ^{56}Ni: ^{55}Co(^{3}He,d)^{56}Ni
- 1N transfer to investigate single-particle structure :^{11}Be(d,p), ^{68}Ni(d,p) and (d,t)
- …

GRIT design and specificities



DETECTORS

- High efficiency for particles
- High granularity (strip pitch < 0.8 mm)
- Forward ring : 8 trapezoid (3 layers: 0.5+1.5+1.5mm)
- Backward ring : 8 trapezoid (2 layers: 0.5+1.5mm)
- 90 deg : square detectors (2 to 3 layers: 0.5+1.5 mm)

Layers of Silicon

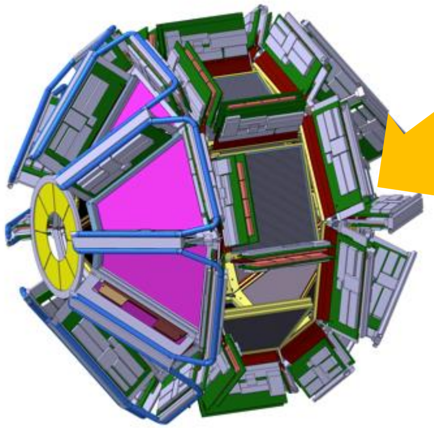
- 500 um DSSD pitch < 0.8 mm
- 1.5 mm DSSD pitch ~5mm

ELECTRONICS

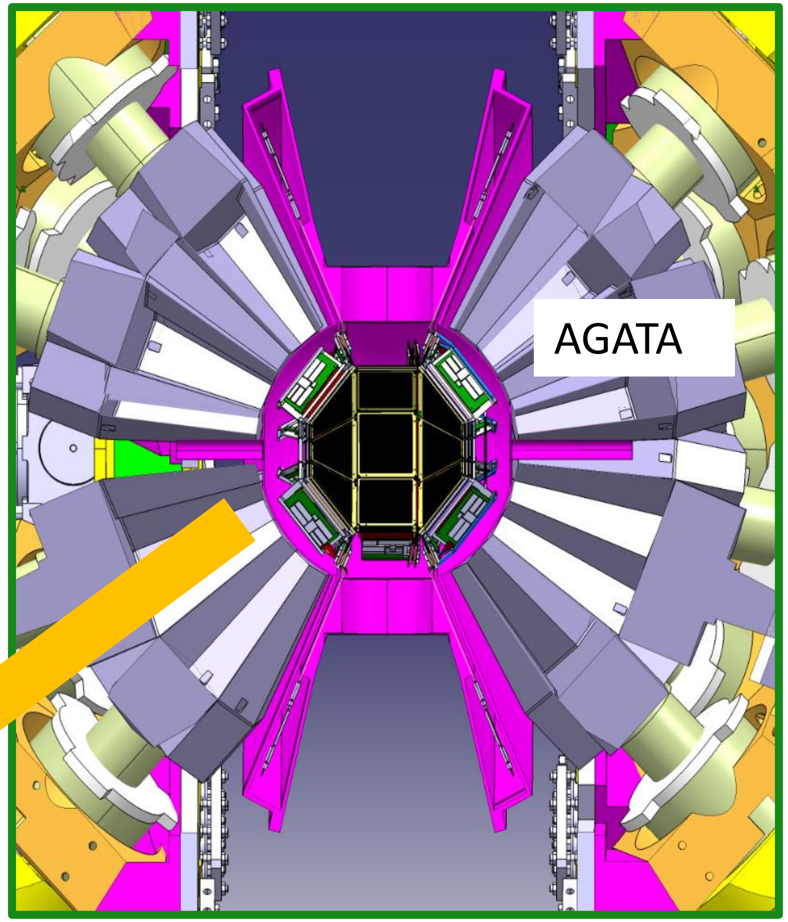
- Large dynamical range
- PID using Pulse Shape Analysis techniques
- New Integrated electronics designed by IJCLab, LPC Caen, INFN

MECHANICS

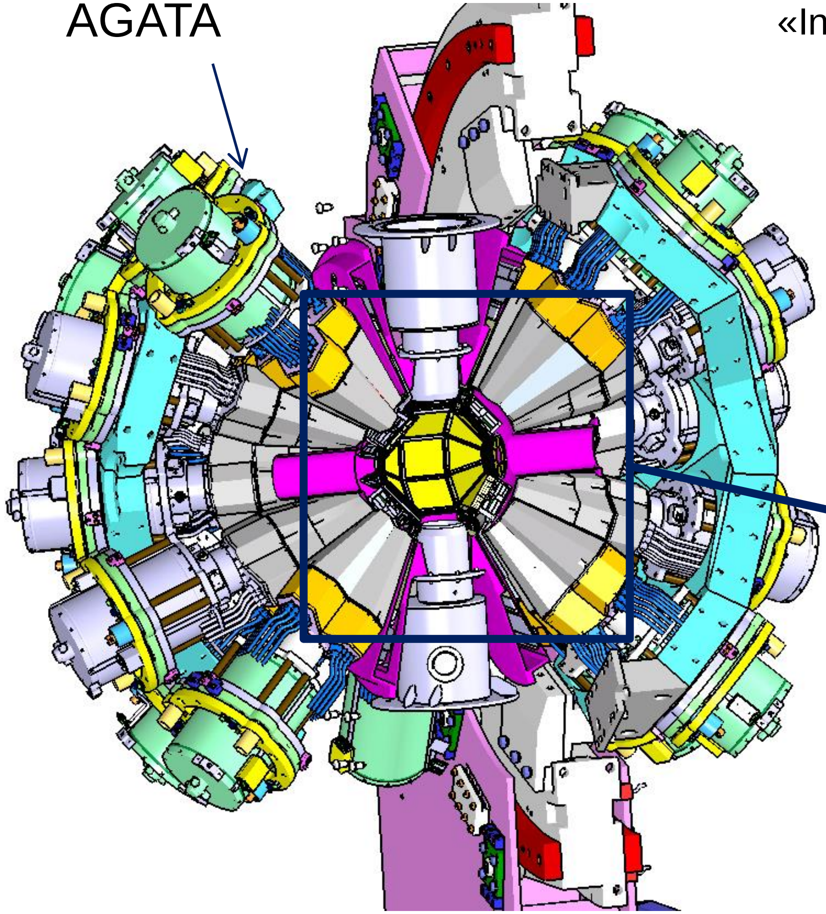
- Integration into AGATA (radius=23 cm)
- transparency to gamma
- high compactness
- Special targets : cryogenic, tritium, windowless

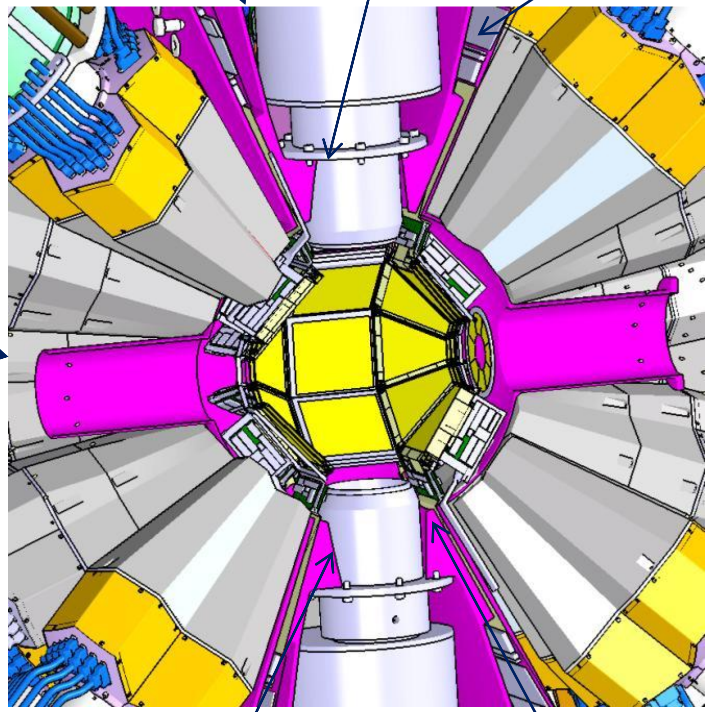


GRIT

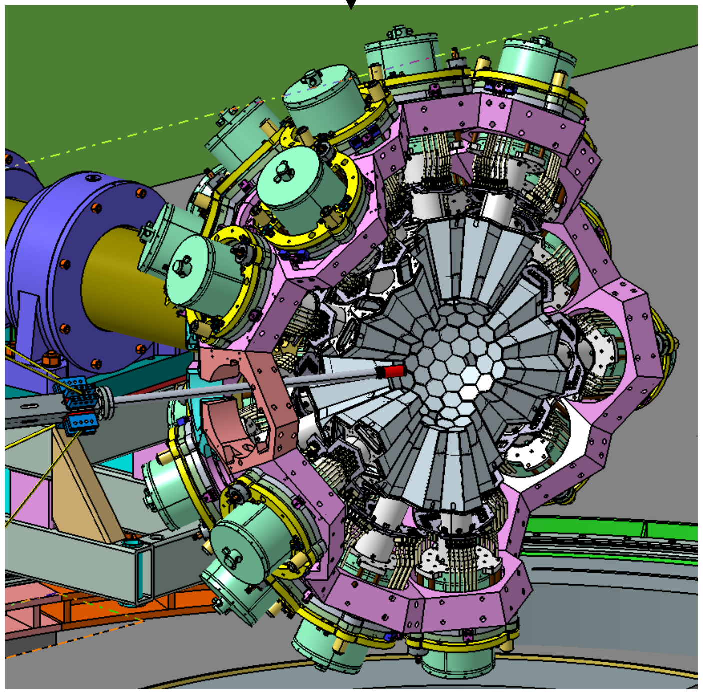


AGATA + GRIT in 2012-2025





This chamber is no longer compatible with this configuration of AGATA



A new spherical chamber is being designed at IJCLab.

Conclusions

- The **MUGAST-AGATA-VAMOS campaign** at GANIL has successfully been completed. A commissioning + 5 experiments were performed, employing re-accelerated SPIRAL 1 beams (^{14}O, ^{15}O, ^{19}O, ^{46}Ar, ^{47}K) with intensities **from $5 \cdot 10^4$ to about 10^8 pps** and energies around **10 MeV/u**.

- The **triple coincidence** particle-γ-beamlike recoil allows to perform high-resolution exclusive measurements with strong **reduction of the background** and high control on the different physical observables.

- A campaign **MUGAST on LISE** is foreseen for 2022-2023, with possible coupling to EXOGAM, PARIS or neutron detectors like NEDA.

- With GRIT the **full solid angle** will be covered and particle identification performed via **pulse-shape analysis**.

- GRIT would ideally be employed with SPES beams, coupled with AGATA and a 0-degree detector (magnetic spectrometer?). First experiments with GRIT may be foreseen starting from 2024.

MUGAST collaboration

IJCLab: M. Assié, D. Beaumel, Y. Blumenfeld, N. de Séréville, F. Galtarossa, J. Guillot, F. Hammache , S. Harrouz, L. Lalanne, I. Stefan

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University of Santiago: B. Fernandez-Dominguez

University of Valencia: A. Gadea