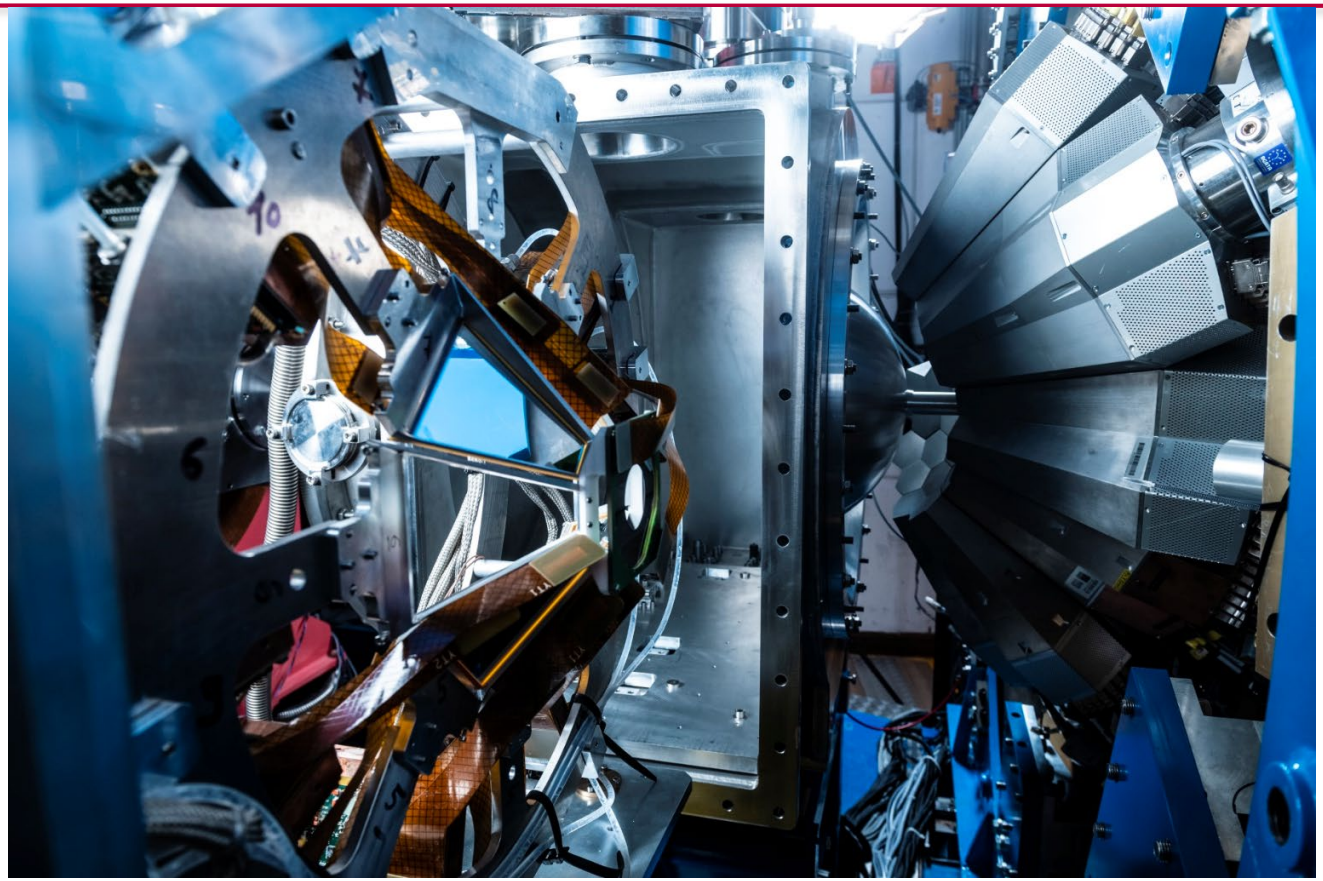
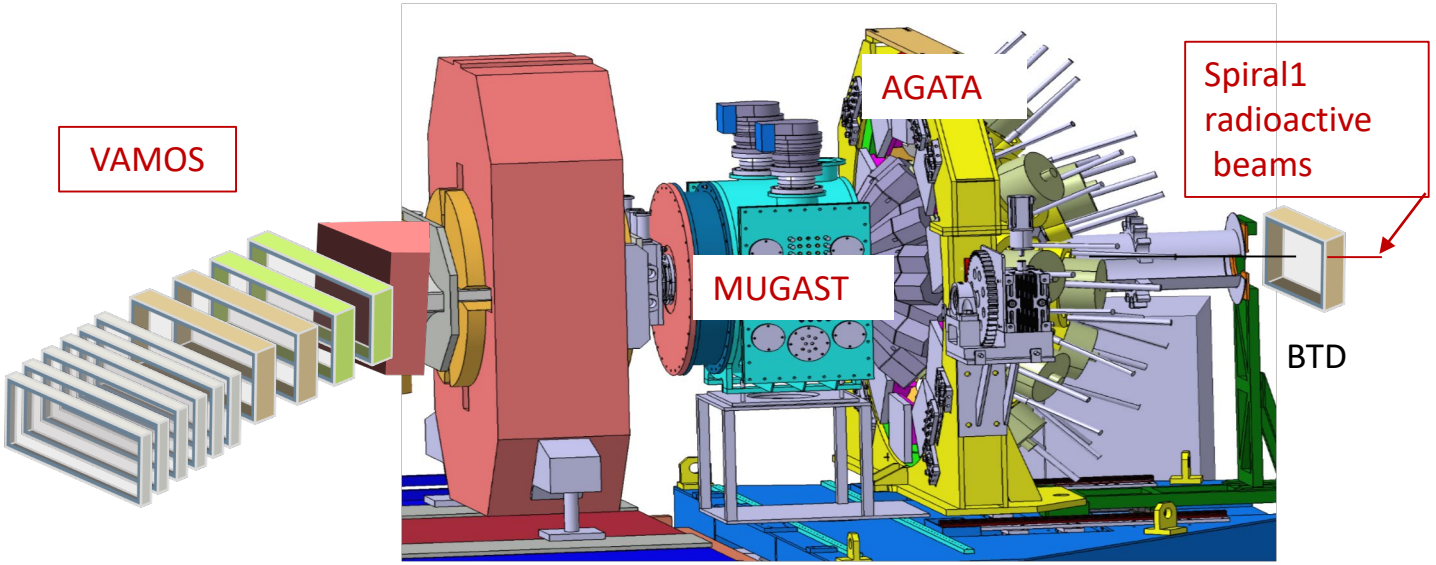
IPN
INSTITUT DE PHYSIQUE NUCLÉAIRE
ORSAY

MUGAST
Commissioning & performances



MUGAST–AGATA-VAMOS campaign 2019

An extremely complete set-up for direct reaction measurement



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

^{46}Ar(^{3}He,dγ)^{47}K to probe proton WF and study vacancies in $s_{1/2}$ and $d_{3/2}$ shells.

^{3}He cryogenic target !

A. Gottardo INFN, M. Assié IPN)

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

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

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

C. Diget (York), N De Séréville (IPN)

UNBOUND STATES
Above barrier narrow resonances in ^{15}F

^{14}O(p,p') inelastic scattering

- Type of two-proton decay
- Gamma transition within unbound nucleus

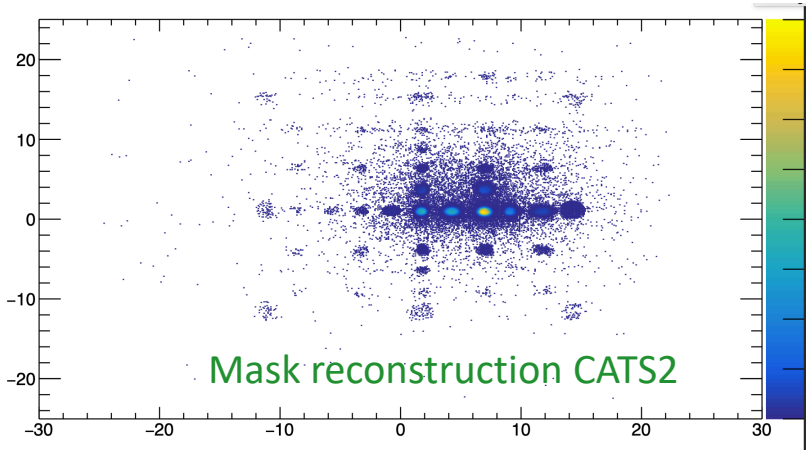
I. Stefan (IPN), F. de Oliveira (GANIL)

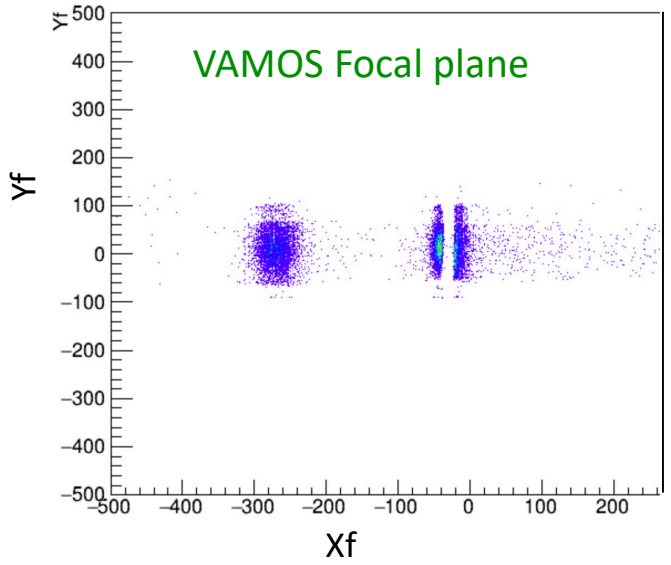
MUGAST commissioning : $^{16}O(d,p)^{17}O$ @ 6 MeV

Beam intensity : ~4 10^4 pps

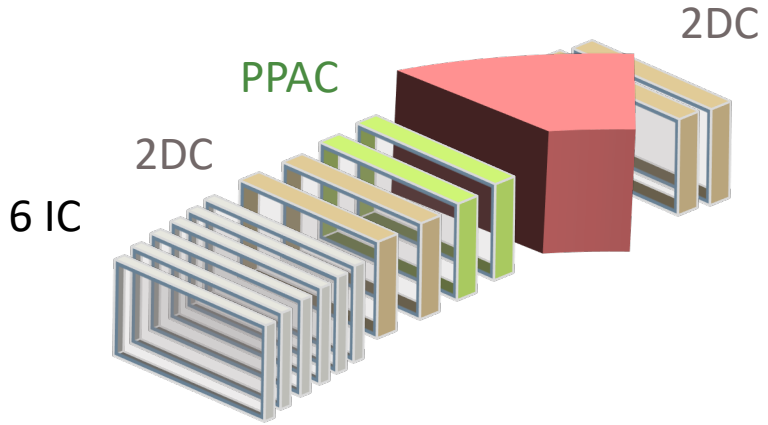
No CATS due to large straggling effect

Finger in VAMOS covering ^{16}O and partially ^{17}O





Vamos detection for commissioning



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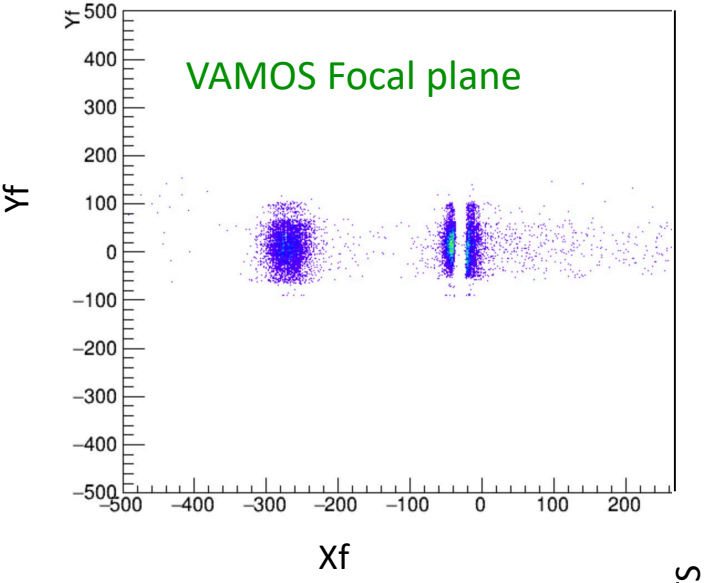
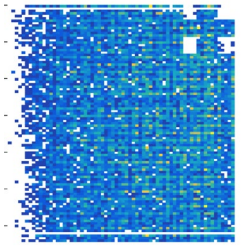
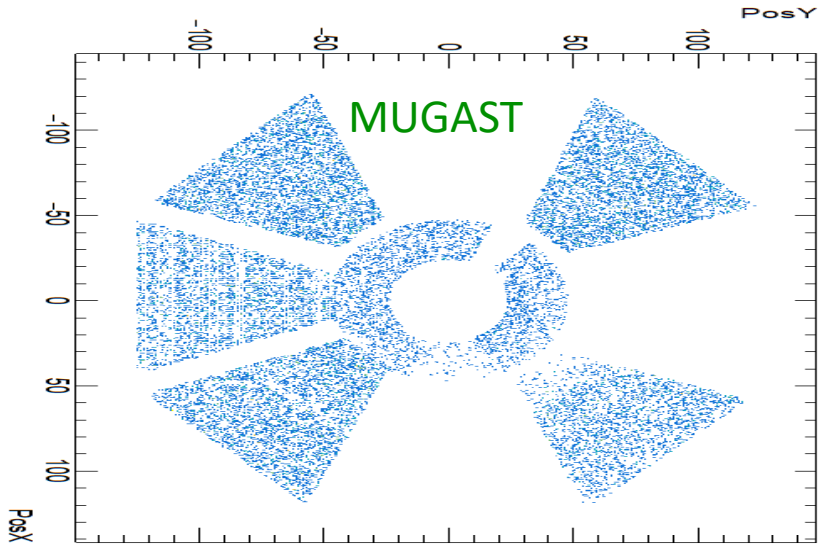
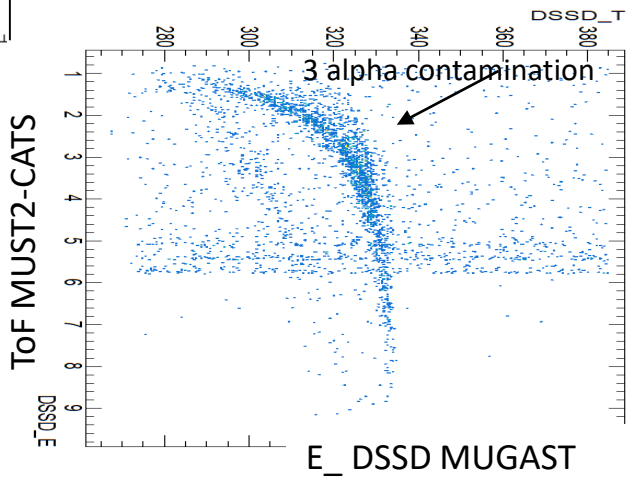
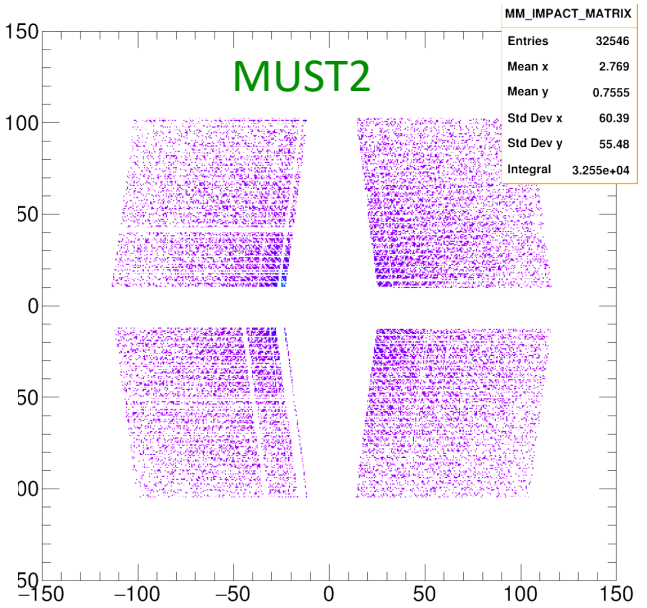




90 deg. square

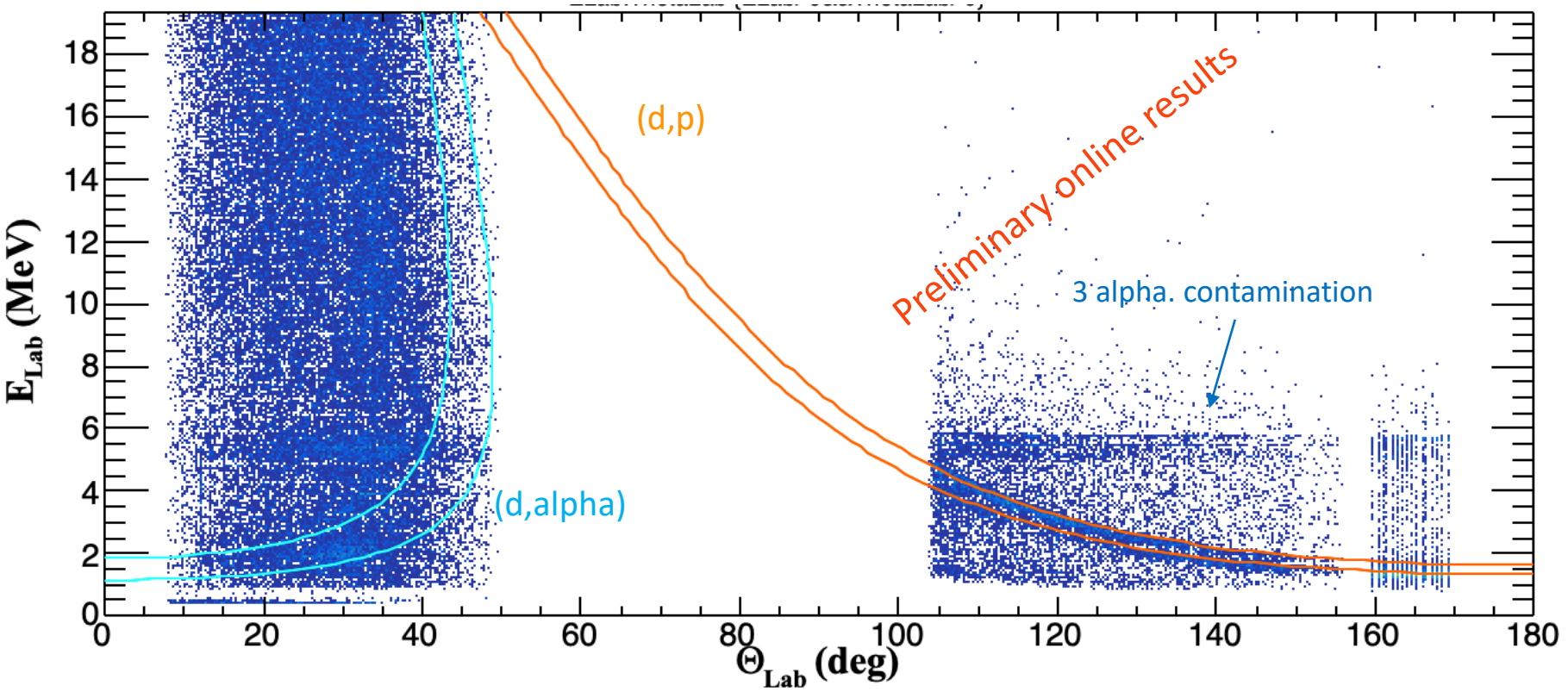






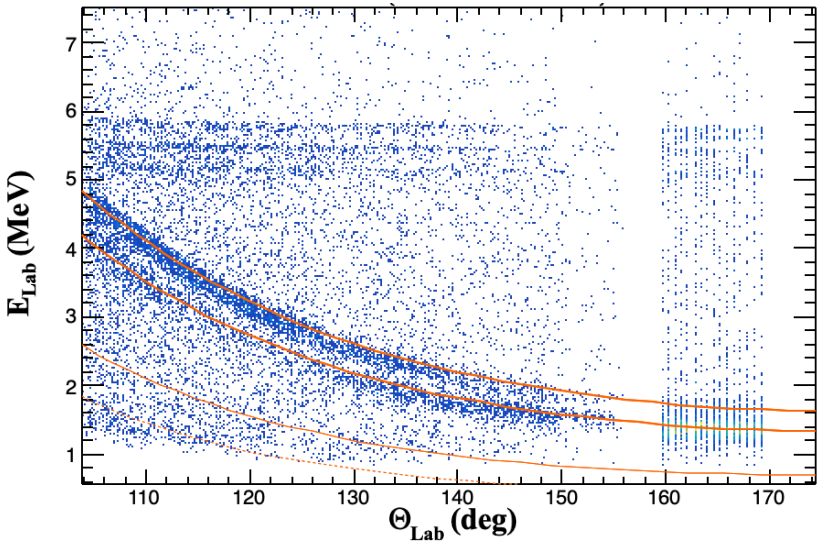
MUGAST commissioning : $^{16}O(d,p)^{17}O$

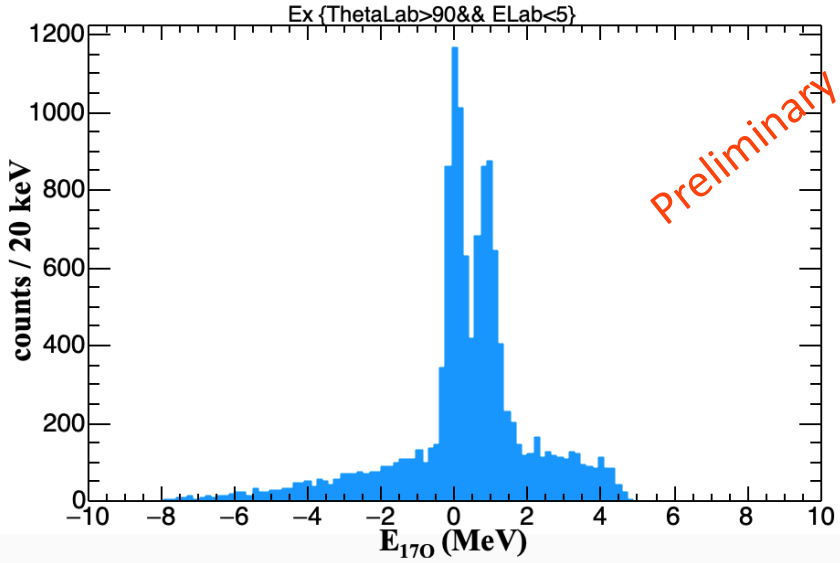
Full kinematic lines for ^{16}O on CD_2



MUGAST commissioning : $^{16}O(d,p)^{17}O$

Kinematic lines for $^{16}O(d,p)$



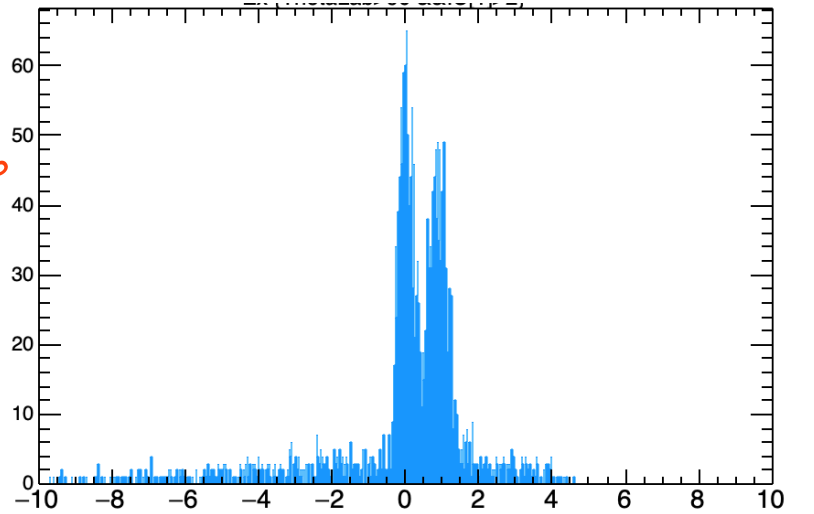


Preliminary online results

Energy resolution :

- from fit of 2 peaks : ~500 keV
- from simulation with CD_2 1mg/cm^2 : 500 keV

Condition on VAMOS IC



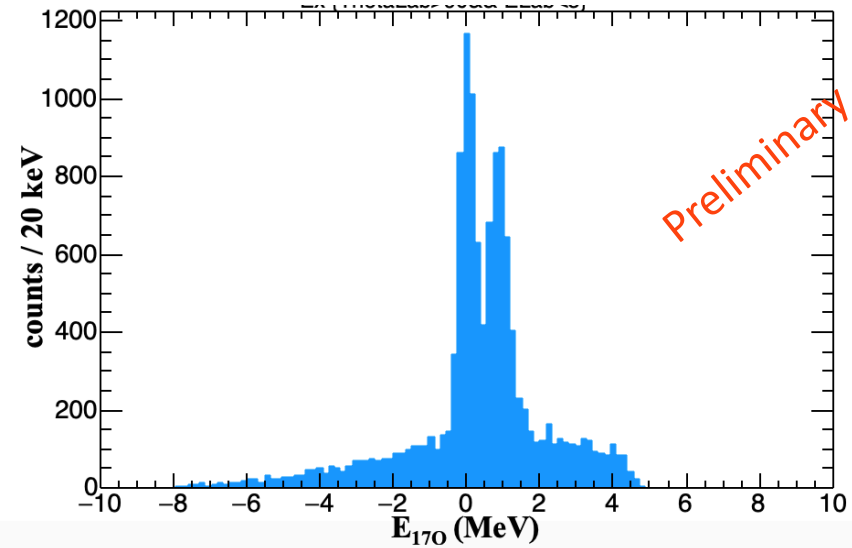
VAMOS-MUGAST relative efficiency : ~60%

- a lot of pile-up event
- large effect of straggling in the DC at the entrance of VAMOS

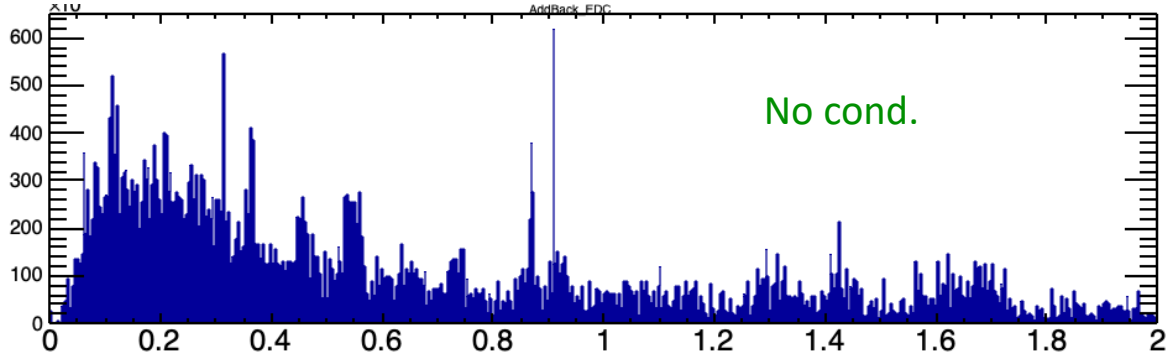
MUGAST commissioning : $^{16}O(d,p)^{17}O$

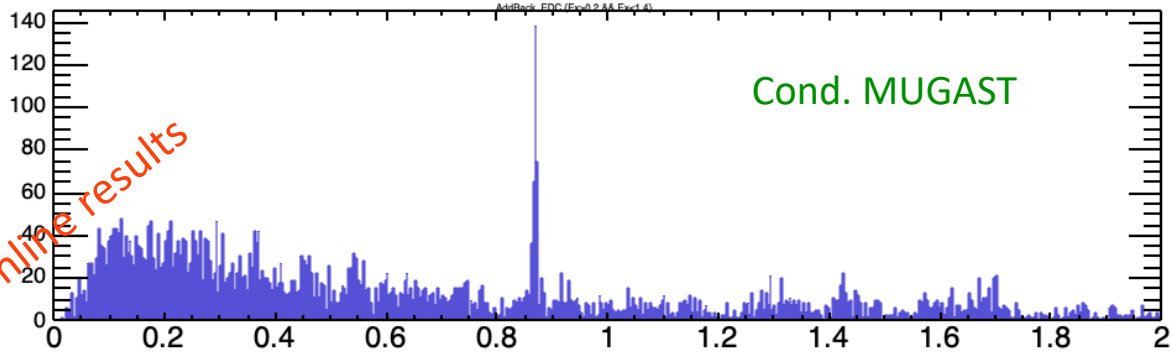
Relative efficiency MUGAST-AGATA:

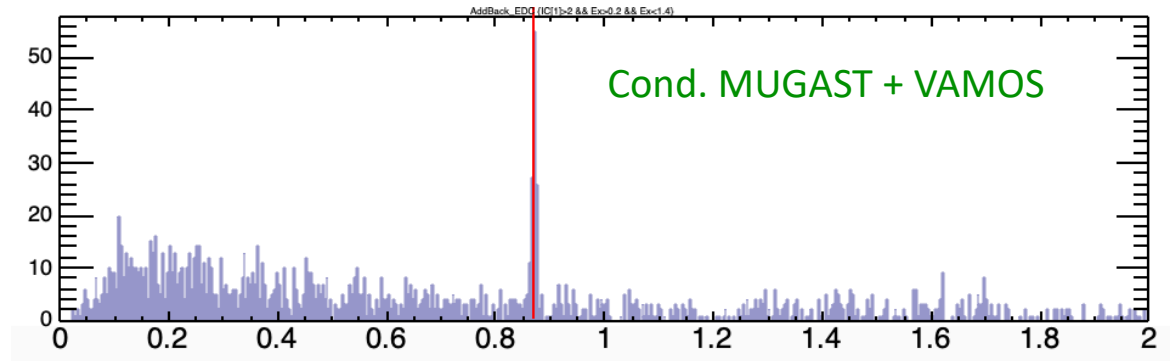
- before add-back : 5.5%
- after add-back : ~8%



Preliminary online results







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

Spokespersons : C. Diget, N. De Séréville

Method: Indirect measurement of alpha capture rate through alpha stripping ^{15}O(^{7}Li,tγ)^{19}Ne

- Spiral1 beam of ^{15}O at 4.7 MeV/u and 2 10^{7} pps with 1.25 mg/cm^{2} LiF target
- Triple coincidence measurement of ^{15}O(^{7}Li,tγ)^{19}Ne : t (MUGAST)+ γ (AGATA) + ^{19}Ne (VAMOS)
- Mirror reaction ^{15}N(^{7}Li,tγ)^{19}F at same energy and few 10^{8}pps

► Explosive burning on neutron star surface :
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 cycle and in the right conditions lead to rp-process
- start-up of Type I X-ray burst on the surface of a neutron star depends critically 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)*

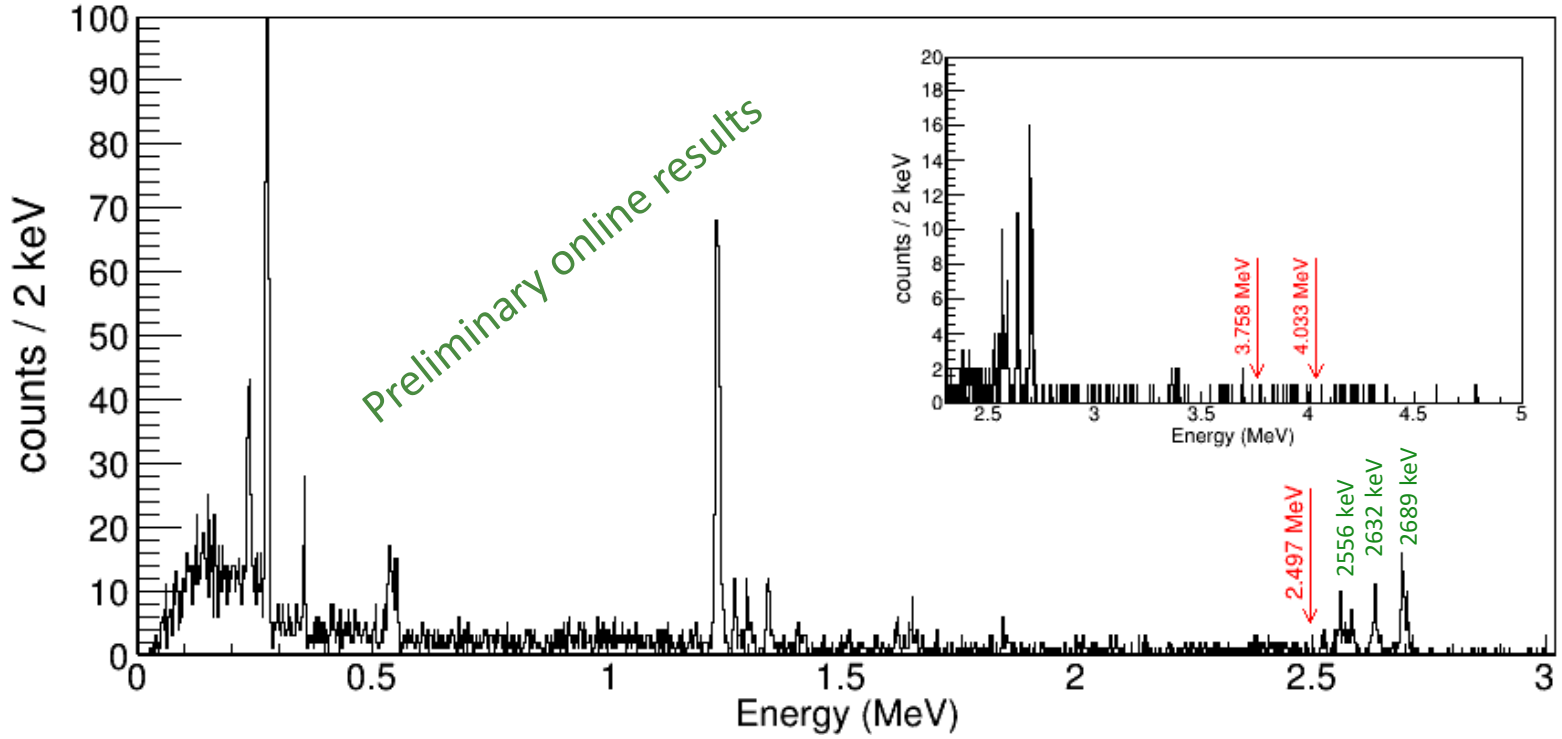
► Previous measurements :

- $\Gamma_{tot} = \Gamma_\gamma \propto 1/\tau$ with $\tau = 7.9(15)$ fs from: γ-ray Doppler-shift lineshape
  Tan et al., PRC 72:041302(R) (2005)
  Kanungo et al., PRC 74:045803 (2006)
  Mythili et al., PRC 77:035803 (2008)
- $B_\alpha = 2.9(21) \cdot 10^{-4}$ from: $^{19}\mathrm{F}(^{3}\mathrm{He}, \mathrm{t})^{19}\mathrm{Ne}^{*}(\alpha)^{15}\mathrm{O}$
  Difficult: 8 t-α on 35 b.gr.
  $\Gamma_\alpha = B_\alpha \cdot \Gamma_{tot} = 24(18)\ \mu$eV
  Tan et al., PRL, 98:242503 (2007)
  Tan et al., PRC, 79:055805 (2009)

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

Spokespersons : C. Diget, N. De Séréville

Gamma spectrum in triple coincidence: ^{19}Ne in VAMOS + MUGAST



9/2+	2794.7	2556.4	100
3/2+	4032.9	2497	15 *5*
		3758	5 *5*
		4033	80 *15*
(9/2)-	4140	2632	100
(7/2)-	4197.1	2689.5	80 *5*
		3958.8	20 *5*
7/2+	4379.1	1584.4	15 *4*
		4140.8	85 *4*

NNDC-ENSDF

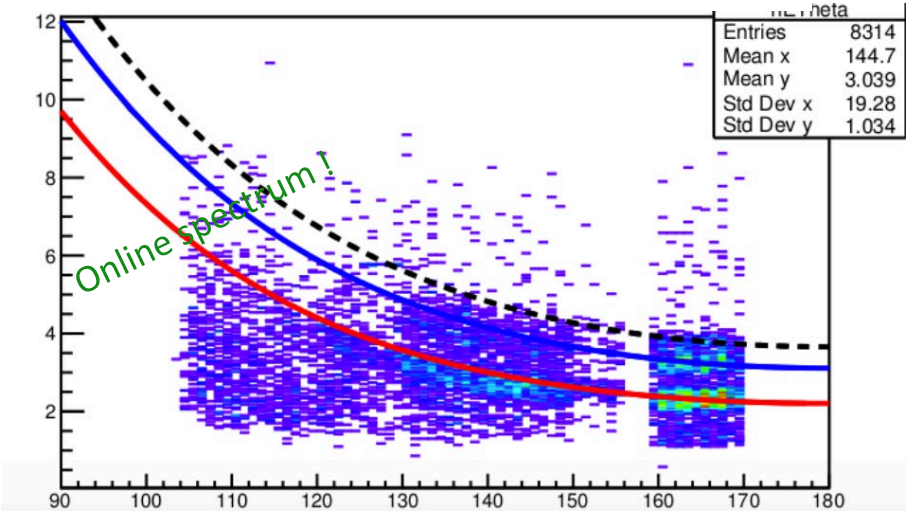
Partial level scheme ^{19}Ne

--> Very clean spectrum : almost no background !

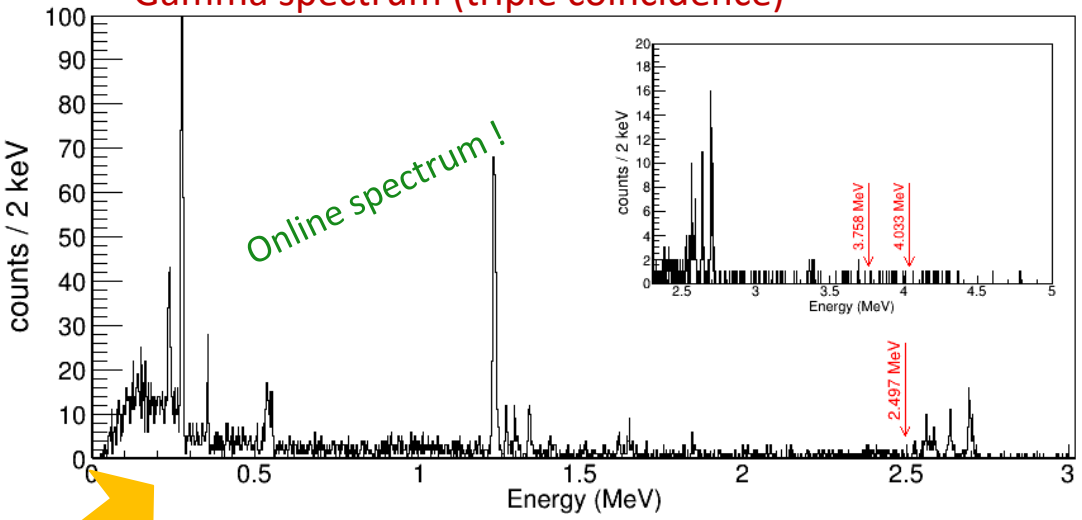
Nuclear astrophysics : Determining the α+^{15}O radiative capture rate

Spokespersons : C. Diget, N. De Séréville

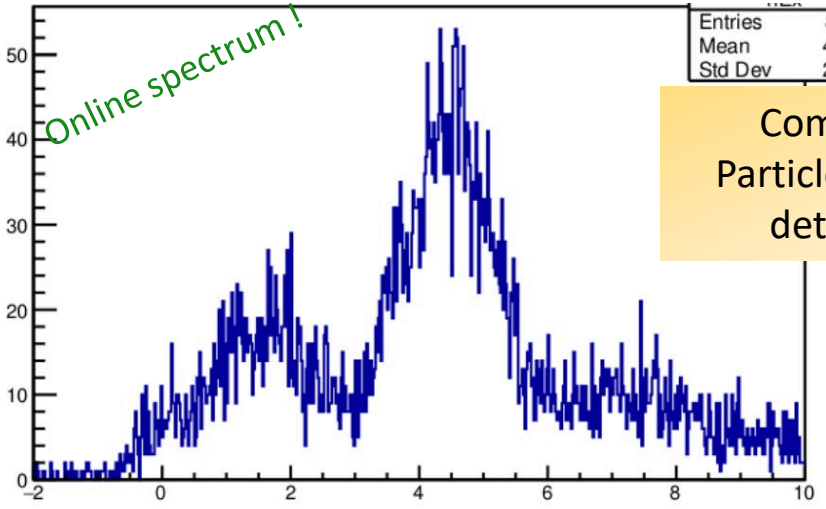
Kinematical lines (^{19}Ne cond. VAMOS)



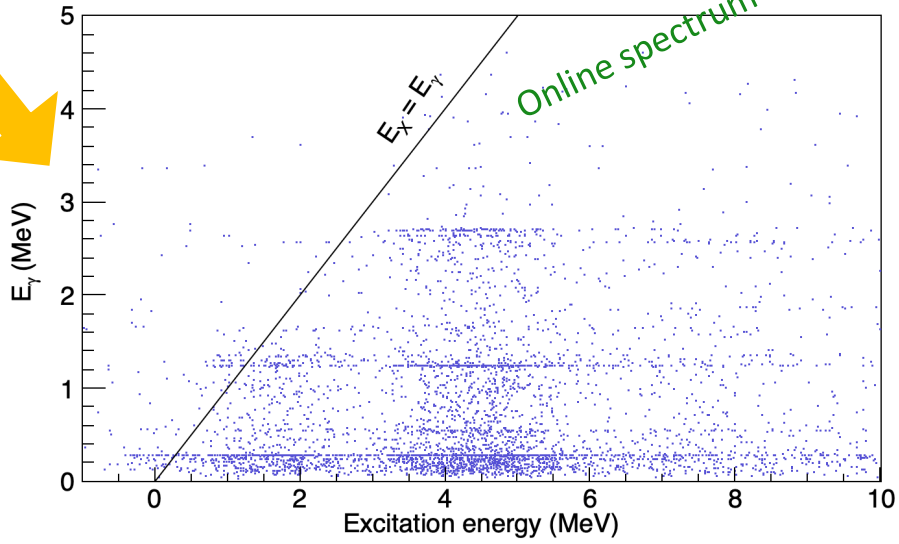
Gamma spectrum (triple coincidence)



Excitation energy (^{19}Ne cond. VAMOS)



Combining Particle/gamma detection

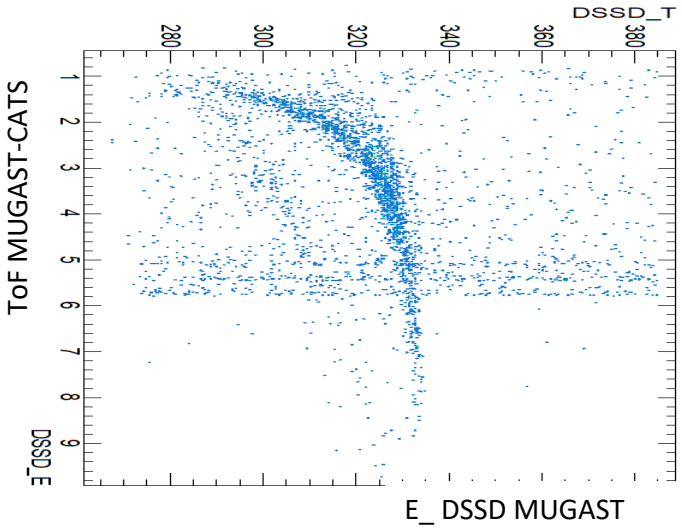


Nuclear astrophysics : Determining the α+^{15}O radiative capture rate

Charged particle identification : work in progress

For low intensity beam (< few 10^5pps) ,
BTD devices are used for ToF and normalisation

ToF with CATS (0.5ns resolution)

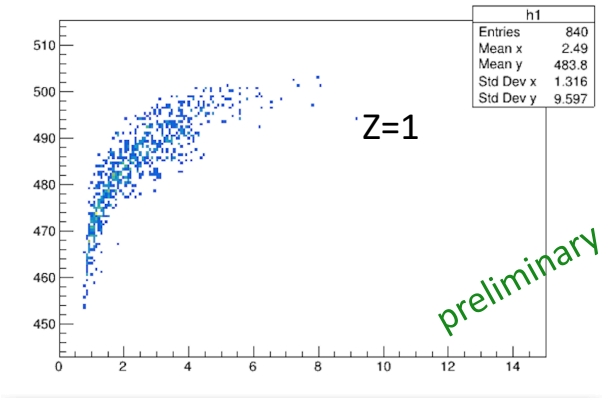


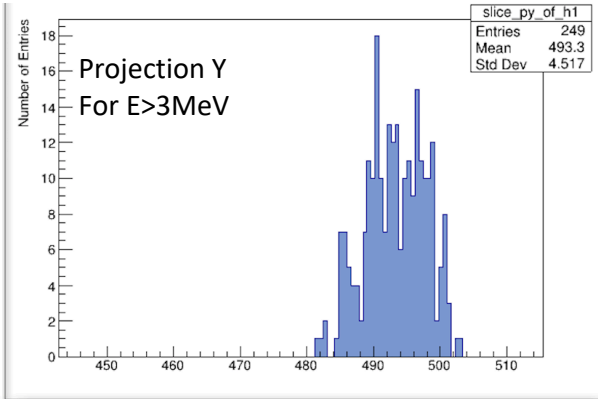
Courtesy of D. Ramos (GANIL)

For higher beam intensity

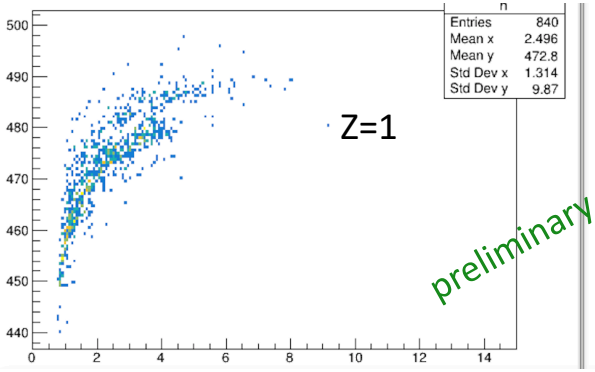
ToF with RF (3 ns resolution)

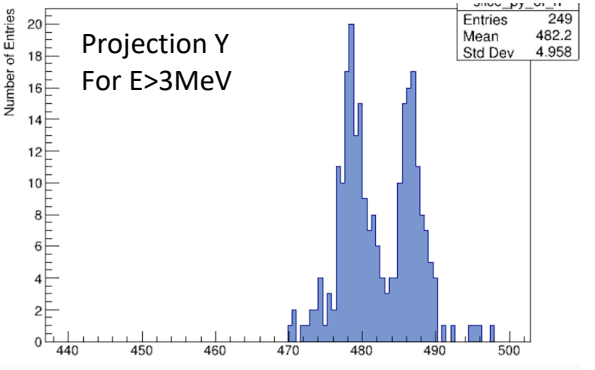
courtesy of Diego Ramos (GANIL)





ToF with VAMOS reconstructing trajectories of heavy residues in VAMOS



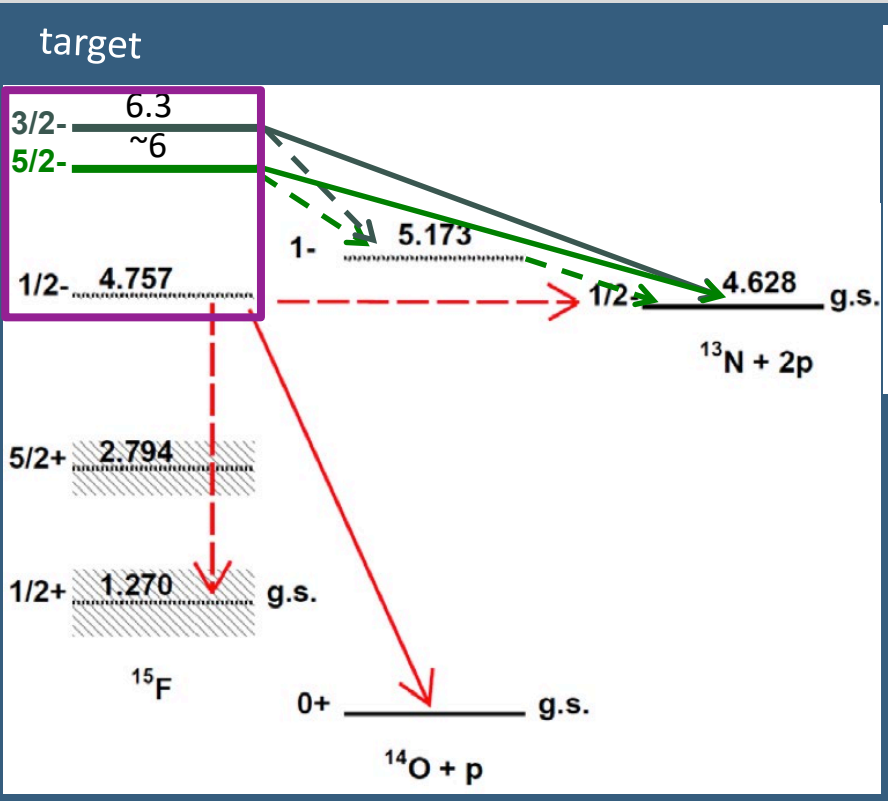


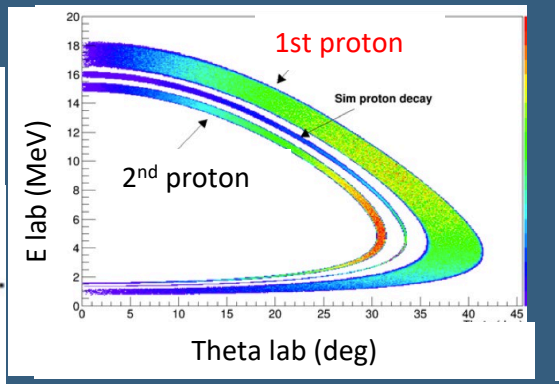
Unbound states : Above barrier narrow resonances in ^{15}F

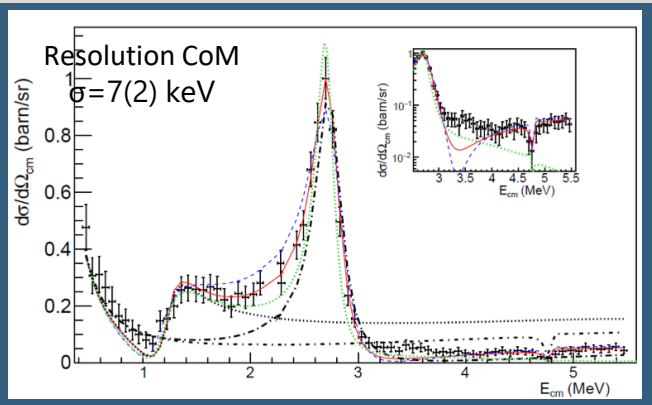
I Stefan (IPN), F. De Oliveira (GANIL)

Method: Resonant elastic scattering & inelastic scattering with thick target technique : ^{14}O(p,p$^{(\prime)}$)

- Spiral1 beam of ^{14}O at 7.6 MeV/u and few 10^5 pps with thick CH_2 target (105 um)
- Coincidence measurement : p-p (MUGAST)+ eventual γ (AGATA) + ^{13}N (VAMOS)
- ToF : Beam tracking detector (CATS)
- VAMOS : ^{14}O and ^{13}N (after 2p decay) / finger remove direct ^{14}O beam / counting rate few 10^5 pps







→ **New negative parity states** (5/2-) to be observed`

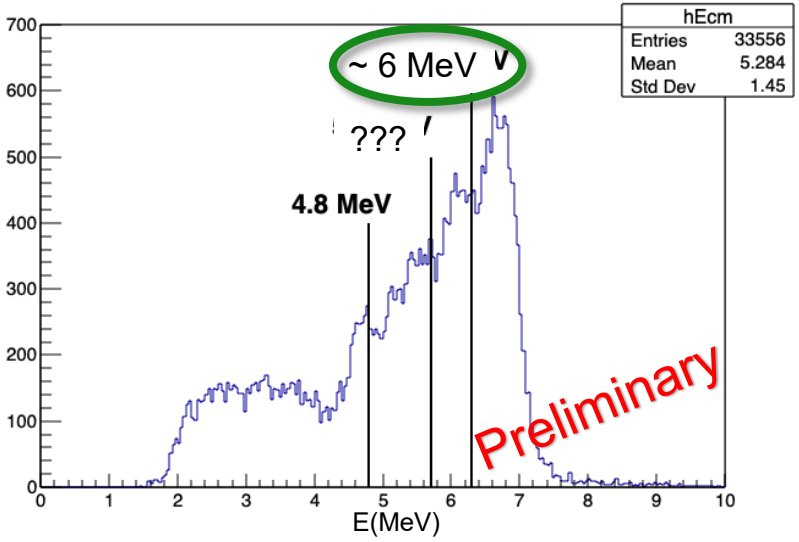
→ **Two-proton decay** of negative parity states (3/2-, 5/2-) : sequential or simultaneous ?

→ **Gamma transition within an unbound nucleus** (EX ~4 MeV)

Unbound states : Above barrier narrow resonances in ^{15}F : First preliminary results

I Stefan (IPN), F. De Oliveira (GANIL)
courtesy of Valérian Alcindor (IPN/GANIL)

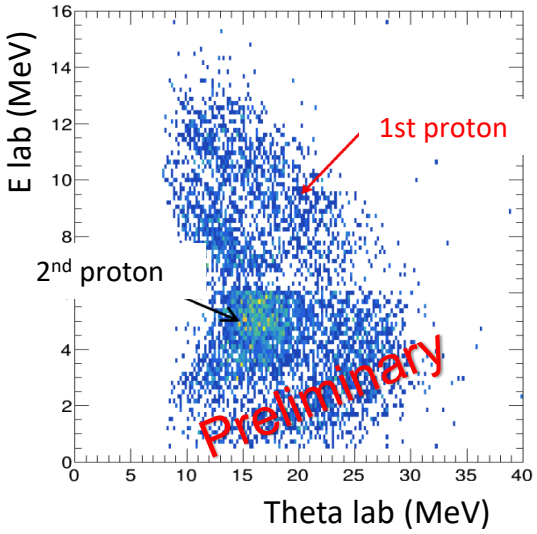
Excitation function



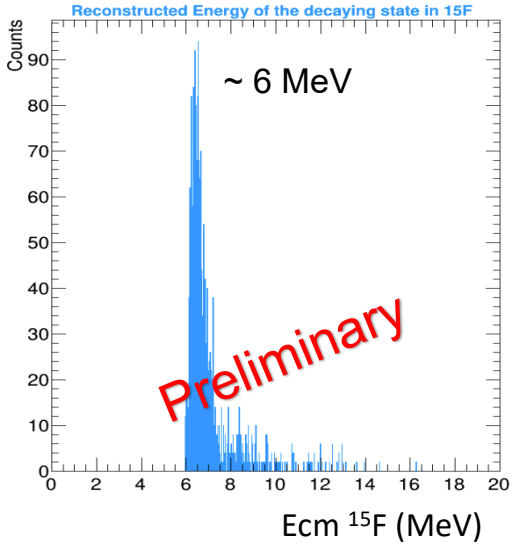
State that decrease by emitting two proton sequentially at the expected energy of ~ 6 MeV

J	E (MeV)	Γ (keV)	Ex (MeV)
1/2-	4.8	35.1	3.5
3/2-	**~ 6**	**29.2**	**5.0**
3/2+	6.9	106.8	5.6

Two-proton in coinc. ^{13}N



Reconstructed E* of decaying ^{15}F



Conclusion

2019 MUGAST-AGATA-VAMOS campaign at GANIL :

- transfer experiments to study nuclear structure and nuclear astrophysics
  - -> proton shell evolution
  - -> study of unbound states decay properties
  - -> nuclear astrophysics : alpha capture rate

- set-up very well adapted to study transfer reaction (stripping & pick-up)
  - High gamma efficiency, 50 to 80% efficiency for particles (backward/forward)
  - Triple coincidences --> very low-background
  - Correlator techniques implemented (two-proton decay)
  - High & low beam intensity (from Spiral1 beams) with VAMOS
  - Special targets can be integrated ^{3}He cryogenic target, tritium target under study

2020 MUGAST-AGATA-VAMOS campaign at GANIL :

- **improvement of particle efficiency up to 85%**
- transfer reaction + DSAM measurement already accepted by the PAC
  (spokesperson : E. Clément, A. Goasduff)