



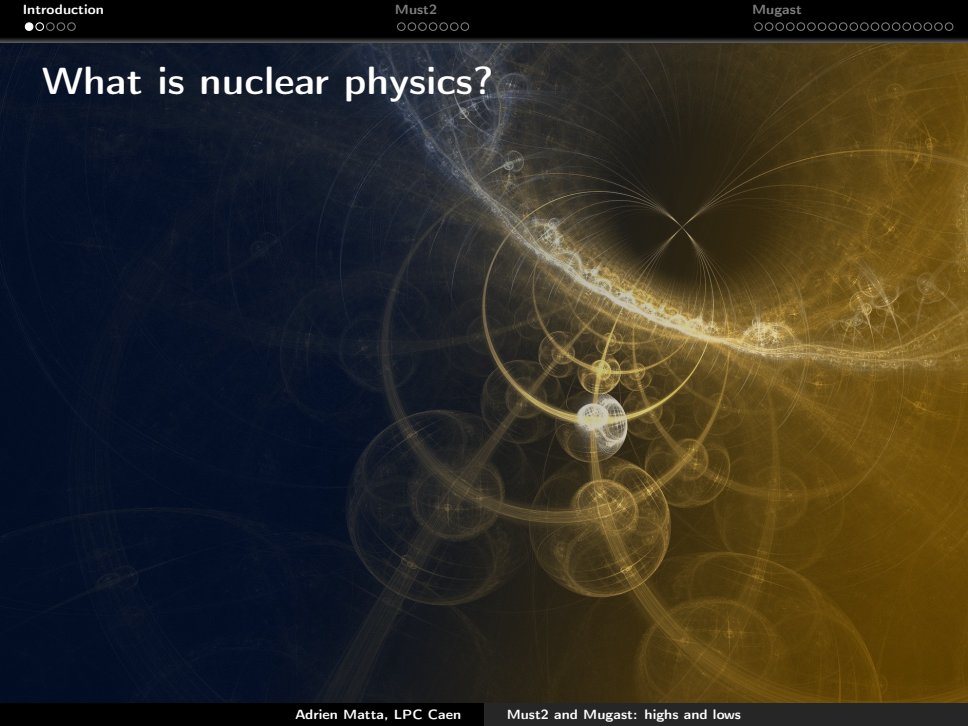
Direct reaction studies at GANIL: overview of recent MUST2 and MUGAST campaigns

Adrien Matta
MUST2 and MUGAST collaborations
Colloque GANIL, September 2021, Aurans



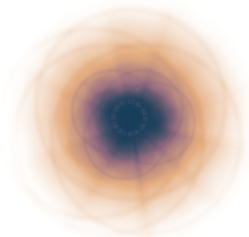
Normandie Université

What is nuclear physics?

The background of the slide is a complex, abstract visualization. It features a dark blue gradient on the left that transitions into a golden-yellow gradient on the right. Overlaid on this are numerous thin, glowing golden lines that form intricate, swirling patterns resembling particle tracks or complex mathematical curves. In the center-right of the image, there is a small, detailed globe of the Earth, which appears to be a focal point or a starting point for some of the golden tracks. The overall aesthetic is scientific and futuristic, suggesting themes of physics, cosmology, or data visualization.

What is nuclear physics?

How to predict nuclear structure?

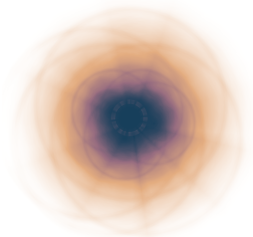


N neutrons + Z protons

- predict all eigen states
 - predict any observable: E , J^π , g , ...
- Getting the underlying W.F. right

What is nuclear physics?

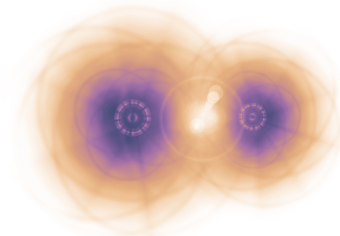
How to predict nuclear structure?



N neutrons + Z protons

- predict all eigen states
 - predict any observable: E , J^π , g , ...
- Getting the underlying W.F. right

How to predict nuclear dynamics?



Nuclei A + Nuclei B at Energy E

- predict all final states
 - predict C.S. for each one
- Getting the underlying W.F. right

Using direct reactions

Any reaction that occurs in a single-step

Using direct reactions

Any reaction that occurs (mostly) in a single-step

Using direct reactions

Any reaction that occurs (mostly) in a single-step

Selectivity

Memory of initial state



Specific state structure



Single Particle



$np-nh$



Cluster

Sensitivity

C.S. carries W.F. information



Probe $\ll \Delta\Psi \gg$

Using direct reactions

Any reaction that occurs (mostly) in a single-step

Selectivity

Memory of initial state



Specific state structure



Single Particle

$np-nh$

Cluster

Sensitivity

C.S. carries W.F. information



Probe $\ll \Delta\Psi \gg$

price to pay $\Rightarrow$ small cross section

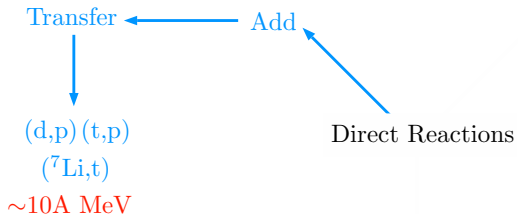
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Direct Reactions

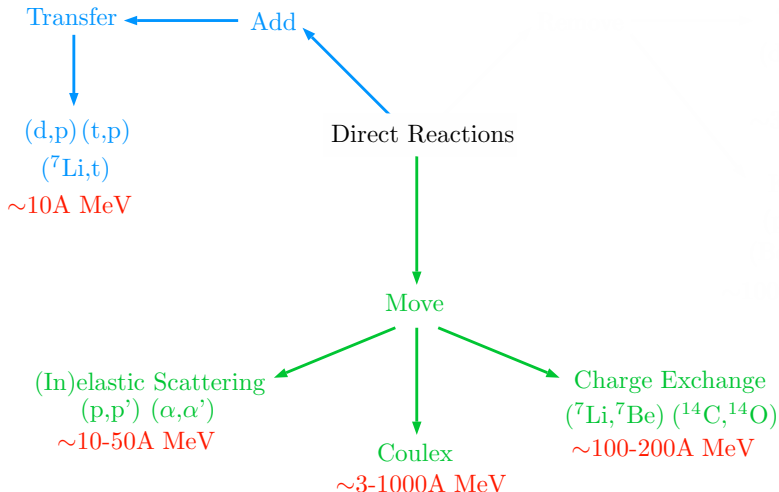
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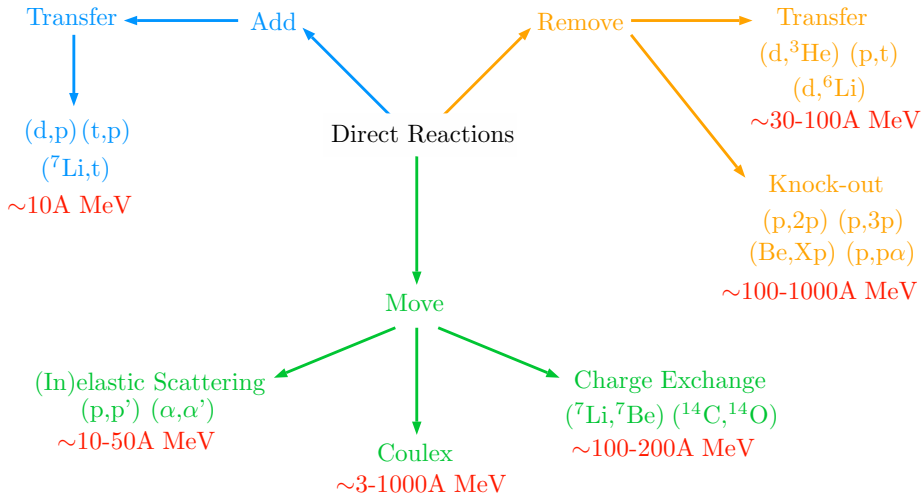
Using direct reactions

Any reaction that occurs (mostly) in a single-step



Using direct reactions

Any reaction that occurs (mostly) in a single-step



A brief history of MUST and MUST2

MUST: leading the way

Collaboration:

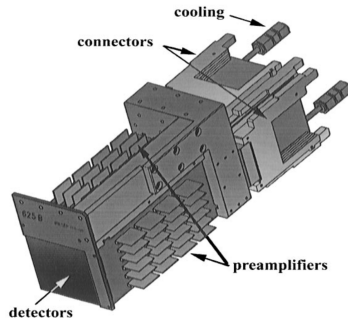
- late 1990s
- IPNO Orsay

Detection:

- Si+Si(Li)+CsI(Tl)

Electronic:

- Discrete PAC
- VXI D back end
- Multiplexe to ADC



NIM A 421,(1999) 471-491

Many PhD and articles → Great success → MUST2

A brief history of MUST and MUST2

MUST2: the workhorse

Collaboration:

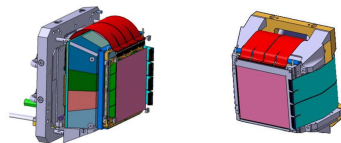
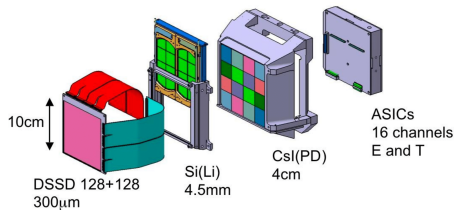
- late 2000s
- IPNOrsay / IRFU / GANIL

Detection:

- Si+Si(Li)+CsI(Tl)

Electronic:

- Integrated/Multiplex FEE
- ~4000 ch.
- VXI C back end

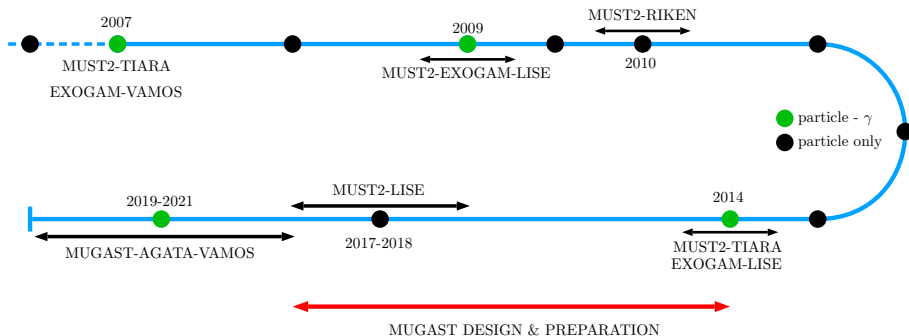


Eur. Phys. J. A25, s01, 287–288(2005)

~20 PhD and articles → Great success → How to go further?

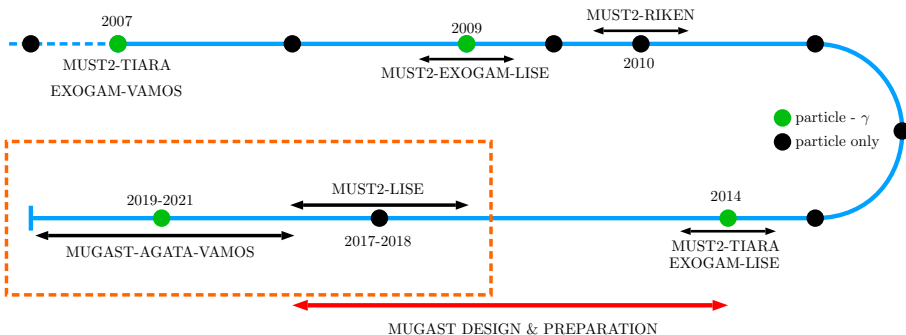
A brief history of MUST and MUST2

MUST2 campaigns time line



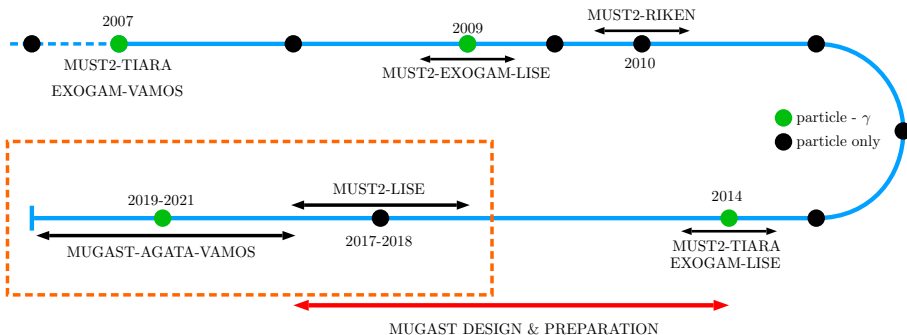
A brief history of MUST and MUST2

MUST2 campaigns time line



A brief history of MUST and MUST2

MUST2 campaigns time line

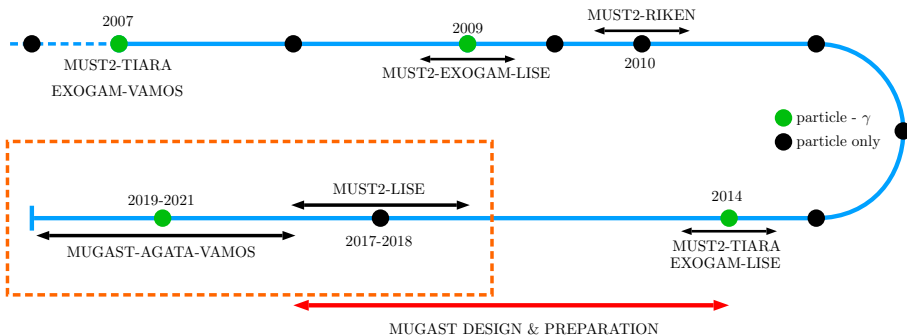


Most cited articles

- F. Flavigny *et al* Phys.Rev.Lett. 110 (2013) 12, 122503
- D. Suzuki *et al* Phys.Rev.Lett. 103 (2009) 152503
- G. Burgunder *et al* Phys.Rev.Lett. 112 (2014) 4, 042502
- S.M. Brown *et al* Phys.Rev.C 90 (2014) 5, 054324
- B. Fernandez-Dominguez *et al* Phys.Rev.C 84 (2011) 011301
- X. Mougeot *et al* Phys.Lett.B 718 (2012) 441-446

A brief history of MUST and MUST2

MUST2 campaigns time line



Article from 2014 campaigns

• B. Le Crom et al e-Print: 2104.10708 (2021)

• X. Pereira-López et al Phys.Lett.B 811 (2020) 135939

⇒ Juan LOIS-FUENTES Talks (in ~20 min)

MUST2: 2017-2018

Electronic and DAQ : Data flow and Merging

MUST2-CATS DAQ:

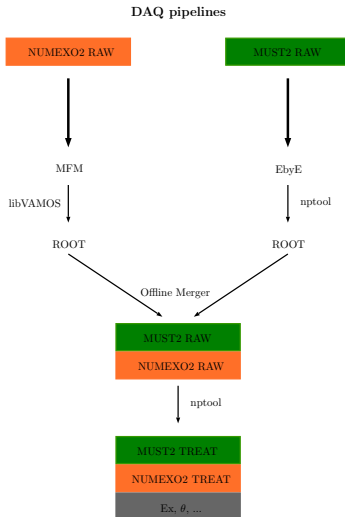
- Common dead time
- Triggered (Silicon)
- Centrum Evt. Number
- AGAVA TS

NUMEXO2 DAQ:

- Triggerless Free running
- Validated by MUST2
- GTS Tree TS

Take home messages:

- ✗ Separate DAQs (Manual S&S)
- ✗ Offline merge (TS)
- ✓ Proof of concept for MUGAST



Key people, key skills

LISE

- JC. Thomas
- O. Sorlin

CATS

- T. Roger
- P. Morfouace

MUST2

- A. Matta
- V. Alcindor

ZD-IC

- A. Lemasson
- T. Roger

CryPTa

- S. Koyama
- N. Kitamura

CAVIAR

- L. Caceres
- O. Sorlin

EXL

- V. Alcindor
- F. de Oliveira

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Plus : the larger MUST2 collab. IRFU, IJCLab, GANIL, LPC, Santiago, Surrey, ...
GANIL: E. Dessay, V. Morel, F. Saillant and their teams.

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EXL

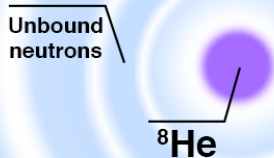
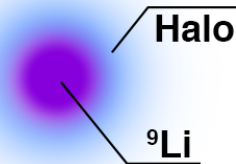
- V. Alcindor
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Plus : the larger MUST2 collab. IRFU, IJCLab, GANIL, LPC, Santiago, Surrey, ...
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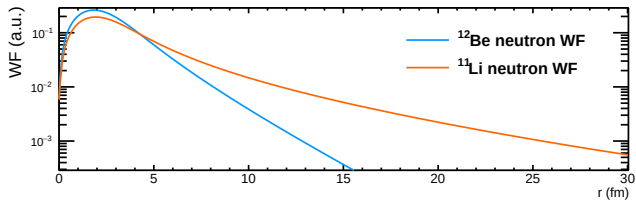
To be successful

Two persons per sub-system $\iff$ Software/Hardware/Social skills

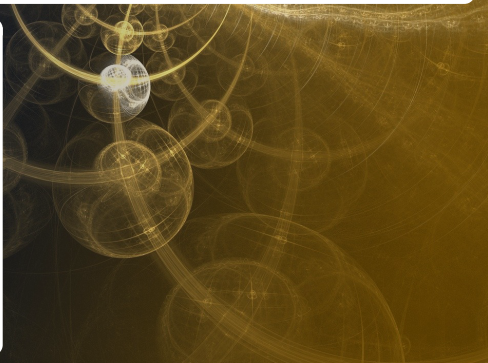
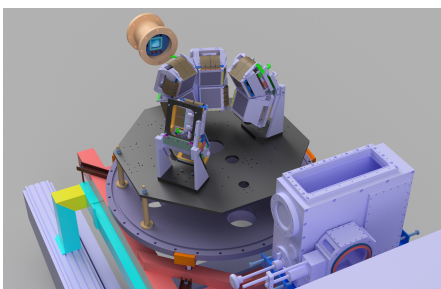
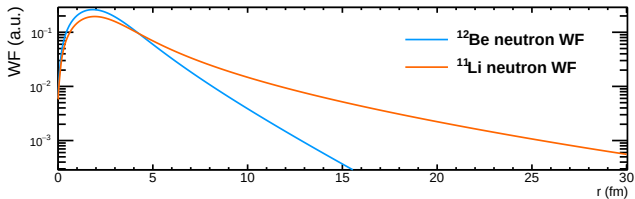
Physics: $^{10,12}\text{Be}(d, ^3\text{He})$



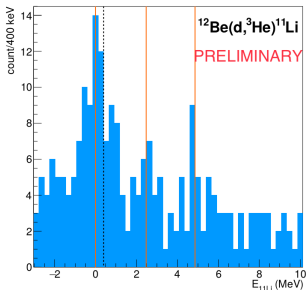
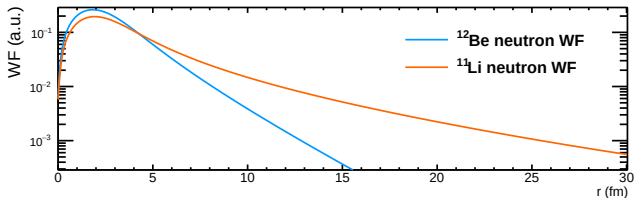
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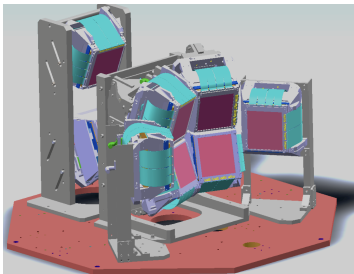


Current status

- ✗ Beam energy EbyE
 - Poor ID (Background)
 - Poor Resolution
- ✓ Indication of strong reduction

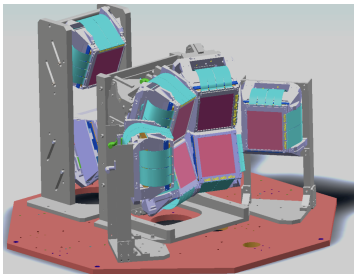
Physics: 1-2 nucleon transfer (p,t) & (p,d)

One setup, 2 exp.

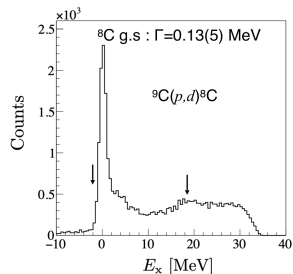


Physics: 1-2 nucleon transfer (p,t) & (p,d)

One setup, 2 exp.

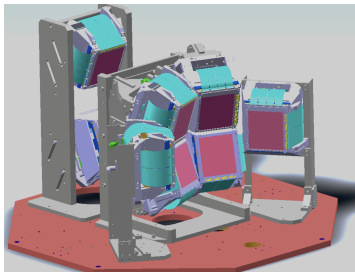


${}^9\text{C}(p,d){}^8\text{C}$

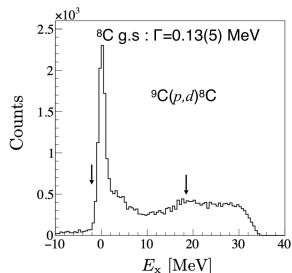


Physics: 1-2 nucleon transfer (p,t) & (p,d)

One setup, 2 exp.



${}^9\text{C}(p,d){}^8\text{C}$



Nuclear Inst. and Methods in Physics Research, A

journal homepage: www.elsevier.com/locate/nima

A liquid hydrogen target for radioactive beam experiments using the missing mass method

S. Koyama ^{a,b,*}, D. Suzuki ^c, M. Assié ^d, N. Kitamura ^e, L. Lalanne ^d, M. Niikura ^a, H. Otsu ^e, T.Y. Saito ^a, O. Sorlin ^b

^a Department of Physics, the University of Tokyo, Hongo 7-3-1, Bunkyo, Tokyo 113-0033, Japan

^b Grand Accélérateur National d'ions Lourds (GANIL), CEA-DSM-CNRS/IN2P3, Bd. Henri Becquerel, 14070 Caen, France

^c RIKEN Nishina Center, Watanabe 2-1, Wako, Saitama 351-0198, Japan

^d Université Paris-Saclay, CNRS/IN2P3, UCLab, 91191 Orsay, France

^e Center for Nuclear Study, the University of Tokyo, Hongo 7-3-1, Bunkyo, Tokyo 113-0033, Japan

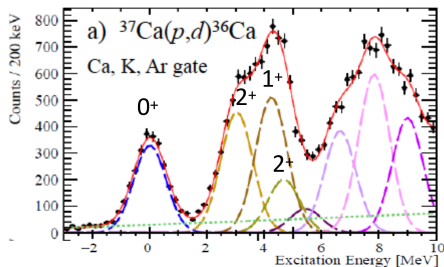
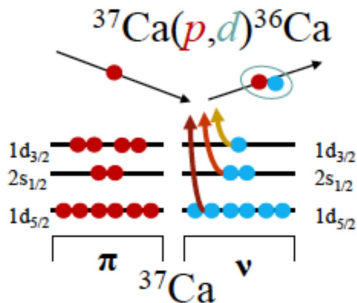


See talk by S. Koyama (~ 30 min)

- ✓ (p,d) and (p,t)
- ✓ proton drip line !
- ✓ LH2 target!

Physics: 1-2 nucleon transfer (p,t) & (p,d)

$^{37}\text{Ca}(p,d)^{36}\text{Ca}$



Phys. Rev. C 103, 055809

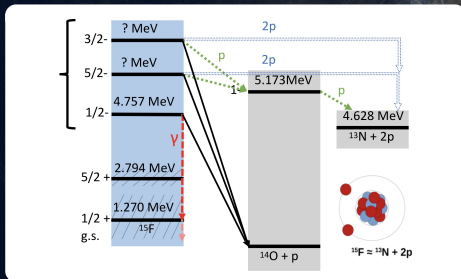
Evaluation of the $^{35}\text{K}(p,\gamma)^{36}\text{Ca}$ reaction rate using the $^{37}\text{Ca}(p,d)^{36}\text{Ca}$ transfer reaction

L. Lalanne,^{1,*} O. Sorlin,^{2,†} M. Assi,¹ F. Hammarhe,¹ N. de Sérville,¹ D. Suzuki,³ P. Flavigny,^{1,4} D. Beaumel,¹ Y. Blumenfeld,¹ B. A. Brown,⁵ F. De Oliveira,² F. Delaunay,³ S. Franchou,¹ J. Gilbelin,¹ V. Girard-Audin,² J. Guillot,¹ O. Kamalou,² N. Kitamura,⁶ S. Koyama,² V. Lapoux,² A. Lemasson,² A. Matta,⁷ B. Marm,^{4,2} P. Morfouace,^{2,9} M. Niikura,⁷ J. Panchin,² A. Poves,¹⁰ T. Roger,² T. Saito,¹¹ C. Stodel,² and J.-C. Thomas²

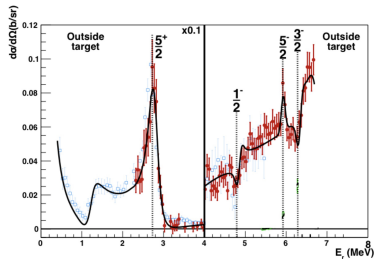
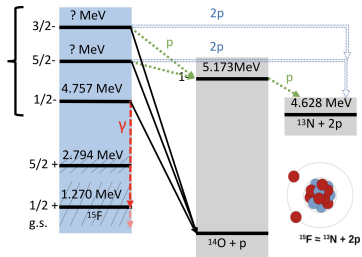
See talk by O. Sorlin (~ 10 min)

- ✓ (p,d) and (p,t)
- ✓ proton drip line!
- ✓ Massive MED

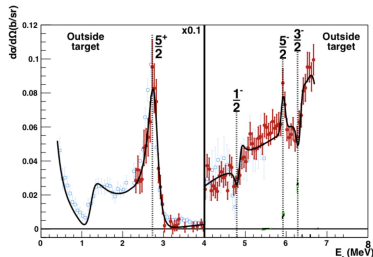
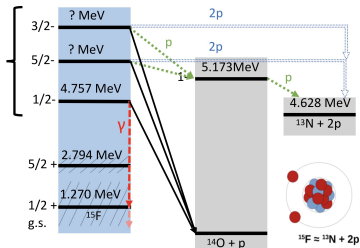
Physics: Resonant Scattering



Physics: Resonant Scattering



Physics: Resonant Scattering



EPJ manuscript No.
(will be inserted by the editor)

Probing nuclear forces beyond the nuclear drip line: The cases of ^{16}F and ^{13}F

A Tribute to Mahir Hussein

V. Girard-Alcindor^{1, *}, I. Stefan², F. de Oliveira Santos¹, O. Sorlin¹, D. Ackermann¹, P. Adley², J.C. Angélique⁵, M. Assa², D. Beunme², E. Berthoumieux¹³, Y. Blumenfeld², R. Borcea¹¹, I. Celikovic¹⁰, M. Cienala⁶, V. Chudoba⁴, G.F. D'Agata⁸, F. de Grancey¹, G. Dumitriu¹¹, F. Flavigny², B. Fornal⁶, C. Fougères¹, S. Franchoo², A. Georgiadou², J. Giovannazzo⁸, S. Grévy¹, J. Guillo², V. Guimarães³, F. Hammache², J. Kiener², L. Lalanne², V. Lapoux¹⁰, S. Leoni⁶, I. Matea², A. Matta⁵, A. Mercenne³, A. Meyer², N. Michel¹, P. Morfouace³, J. Mrázek⁴, F. Negoita⁸, M. Nilkura¹¹, D. Pantelica³, L. Perrot², C. Petrone³, M. Płoszajczak¹, C. Portal², T. Roger¹, F. Rotaru⁹, N. de Séréville², M. Stanoiu², C. Stodel³, K. Subotic⁴, D. Suzuki¹⁴, V. Tatischeff², J.C. Thomas¹, P. Ujic¹, and D. Verney²

V. Girard-Alcindor PhD

✗ Accelerator Failure :(
✓ to be continued ...

MUGAST: 2019-2021

Nuclear Inst. and Methods in Physics Research, A 1014 (2021) 165743



Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

Nuclear Inst. and Methods in Physics Research, A

journal homepage: www.elsevier.com/locate/nima



The MUGAST-AGATA-VAMOS campaign: Set-up and performances

M. Assié^{a,*}, E. Clément^b, A. Lemasson^b, D. Ramos^b, A. Raggio^c, I. Zanon^{c,d}, F. Galtarossa^a, C. Lenain^e, J. Casal^f, F. Flavigny^{a,1}, A. Matta^e, D. Mengoni^{f,g}, D. Beaumel^a, Y. Blumenfeld^a, R. Borcea^h, D. Brugnara^{c,f}, W. Catfordⁱ, F. de Oliveira^b, F. Delaunay^e, N. De Séréville^a, F. Didierjean^j, C.Aa. Diget^k, J. Dudouet^l, B. Fernández-Domínguez^m, C. Fougères^b, G. Frémont^b, V. Girard-Alcindor^{b,a,2}, A. Giret^b, A. Goasduff^c, A. Gottardo^c, J. Goupil^b, F. Hammache^a, P.R. Johnⁿ, A. Korichi^a, L. Lalanne^a, S. Leblond^b, A. Lefevre^b, F. Legruel^b, L. Ménager^b, B. Million^o, C. Nicolle^b, F. Noury^e, E. Raully^a, K. Rezyunkina^j, E. Rindel^a, J.S. Rojo^k, M. Siciliano^p, M. Stanoiu^h, I. Stefan^a, L. Vatrinet^a

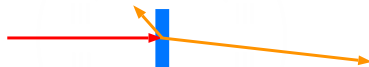


Ideal conceptual transfert experiment

Typical Setup

- Low energy beam
 - Thin target
 - Compound foil (CD_2)
 - Implanted (Ti-t)
 - Cryogenic ($^2\text{H}, ^3, ^4\text{He}$)

Conceptual design

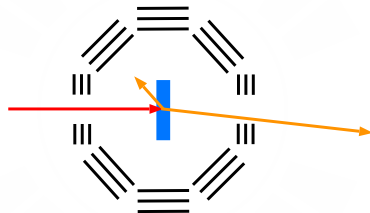


Ideal conceptual transfert experiment

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 - Cryogenic (^2H , ^3H , ^4He)
- (d,p), (d,t), (p,p), ...
 - 4π Silicon array

Conceptual design

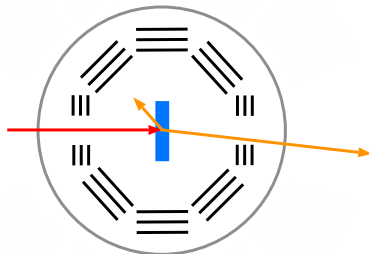


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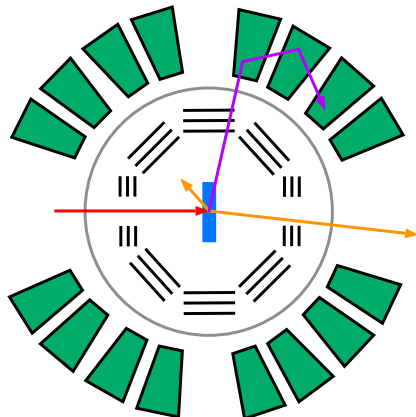


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 - Cryogenic (^2H , ^3H , ^4He)
- (d,p), (d,t), (p,p), ...
 - 4π Silicon array
- Detailed spectroscopy
 - Ge Tracking array
 - High state density
 - Good Eff.-Resolution balance

Conceptual design

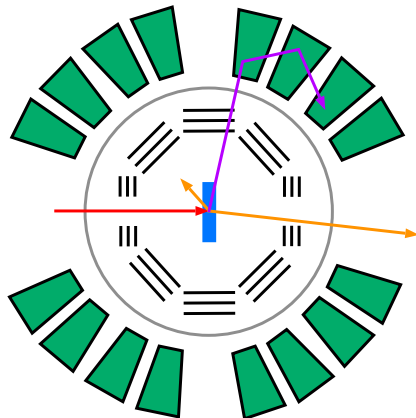


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 - Cryogenic (^2H , ^3H , ^4He)
- (d,p), (d,t), (p,p), ...
 - 4π Silicon array
- Detailed spectroscopy
 - Ge Tracking array
 - High state density
 - Good Eff.-Resolution balance
- Zero degree-detection
 - Spectrometer

Conceptual design



GRIT: next generation silicon detector

Why G.R.I.T. is GREAT ?

Granularity: ~ 8000 strips

- High angular resolution

Resolution:

- ~ 40 keV FWHM

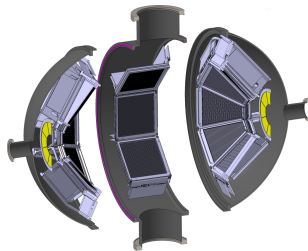
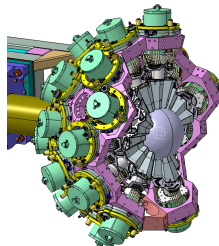
Identification: nTD, three layers

- TOF & PSA & $E-\Delta E$

Transparency:

- Minimum material for γ

AGATA-GRIT at LNL



GRIT is great, but not here yet!



MUGAST: a GRIT demonstrator

GRIT silicon (Trapezoid & Square) + MUST2 electronic

MUGAST: a GRIT demonstrator

GRIT silicon (Trapezoid & Square) + MUST2 electronic

Building the collaboration

workshop/pre-PAC in Padova, Paris, Caen (D. Mengoni, D. Beaumel, E. Clement)

AGATA-VAMOS × **GRIT dem.** × **SPIRAL1+**

IJCLab, INFN, Surrey, Santiago, GANIL

MUGAST: a GRIT demonstrator

GRIT silicon (Trapezoid & Square) + MUST2 electronic

Building the collaboration

workshop/pre-PAC in Padova, Paris, Caen (D. Mengoni, D. Beaumel, E. Clement)

AGATA-VAMOS × **GRIT dem.** × **SPIRAL1+**

IJCLab, INFN, Surrey, Santiago, GANIL

Umbrella LOI (2015) : 17 Physics Cases

- | | | | |
|-----------------------------------|-------------------------|-------------------------|-------------------------|
| • $^{56}\text{Ni}(^3\text{He},p)$ | • $^{56}\text{Ni}(d,p)$ | • $^{25}\text{Al}(d,p)$ | • $^{48}\text{Ar}(t,p)$ |
| • $^{67}\text{As}(^3\text{He},d)$ | • $^{28}\text{Mg}(d,p)$ | • $^{30}\text{P}(d,p)$ | • $^{79}\text{Se}(d,p)$ |

MUGAST: a GRIT demonstrator

GRIT silicon (Trapezoid & Square) + MUST2 electronic

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Umbrella LOI (2015) : 17 Physics Cases

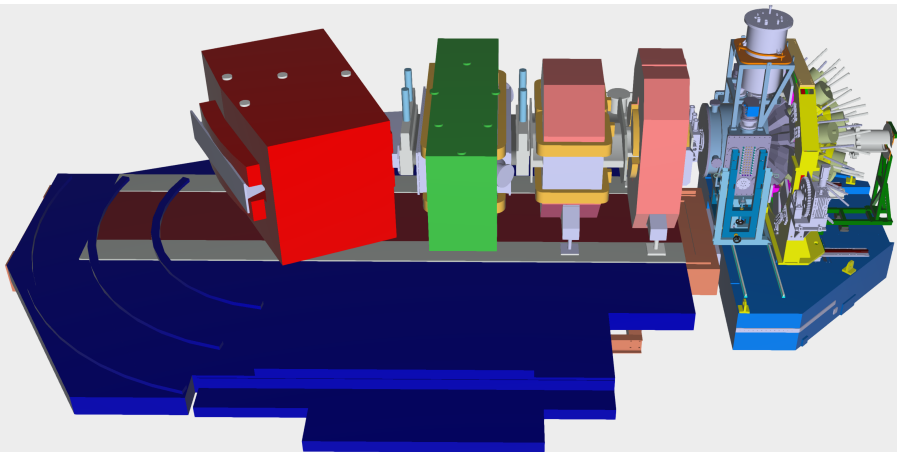
- | | | | |
|-----------------------------------|-------------------------|-------------------------|-------------------------|
| • $^{56}\text{Ni}(^3\text{He},p)$ | • $^{56}\text{Ni}(d,p)$ | • $^{25}\text{Al}(d,p)$ | • $^{48}\text{Ar}(t,p)$ |
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State of the art for particle- γ experiment

Unmatched worldwide performances and versatility!

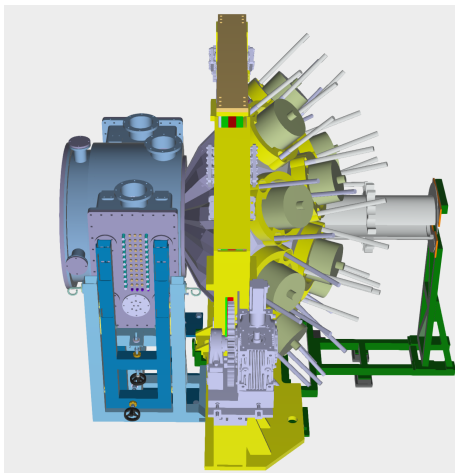
Well received by GANIL, IN2P3, IPNOrsay and LPC scientific council

Mechanical design : IJCLab / Surrey

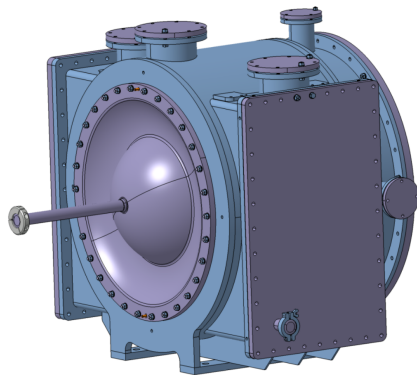
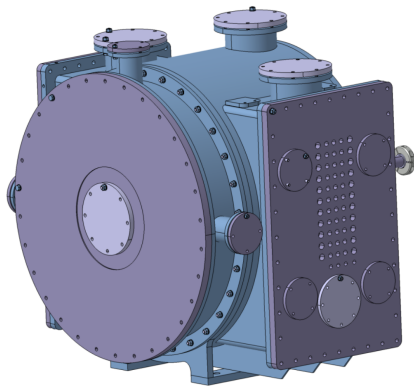


design by E. Rindel, M. Assié, F. Flavigny (IJCLab), A. Matta (Surrey)

Mechanical design : IJCLab / Surrey



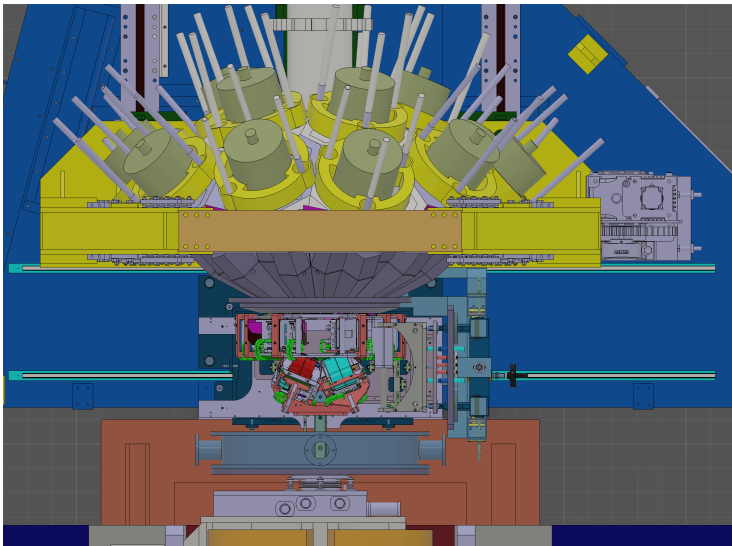
Mechanical design : IJCLab / Surrey



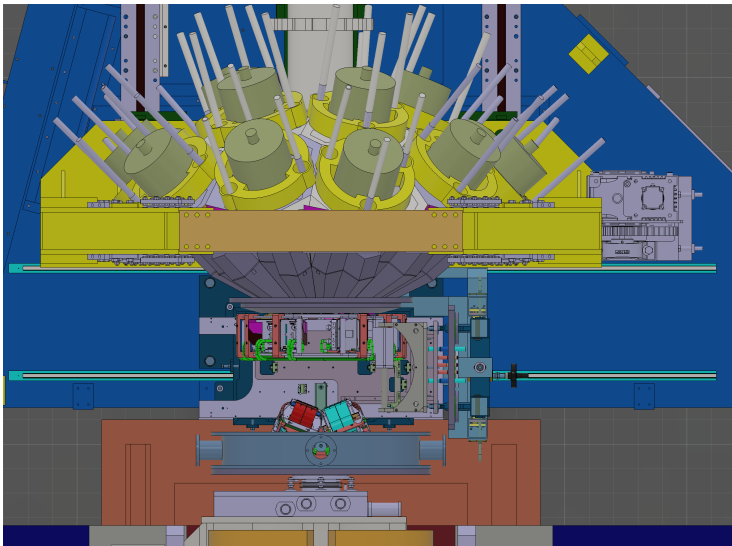
Mechanical design : Opening sequence



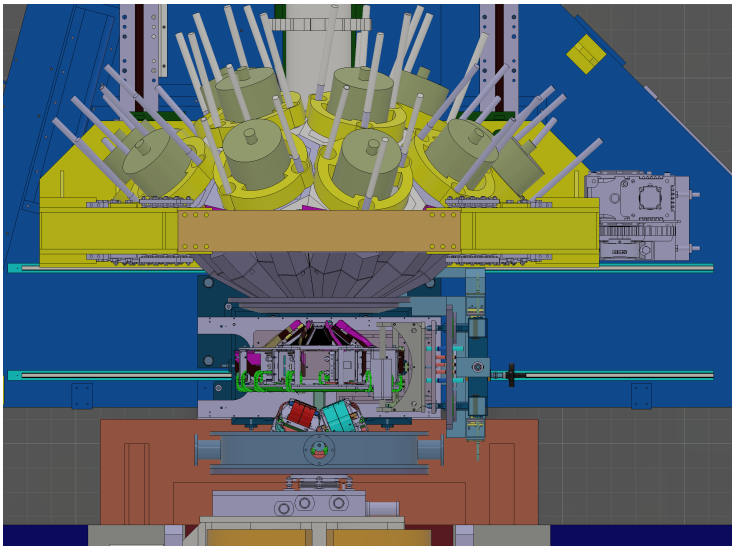
Mechanical design : Opening sequence



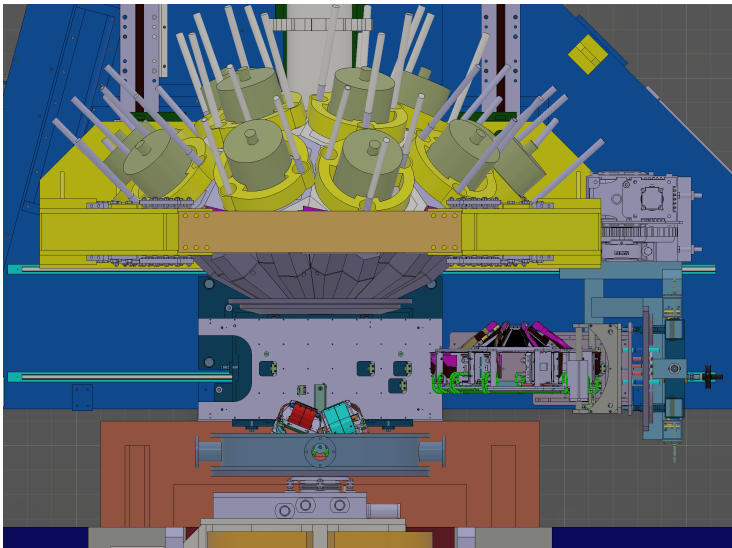
Mechanical design : Opening sequence



Mechanical design : Opening sequence



Mechanical design : Opening sequence



Mechanical design : Opening sequence



Mechanical design : Detection

Backward Angle

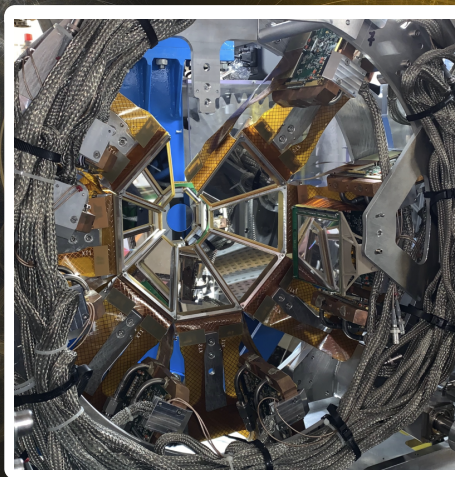
- 7 nTD Trapezoid
- 1 S1 annular

90 deg

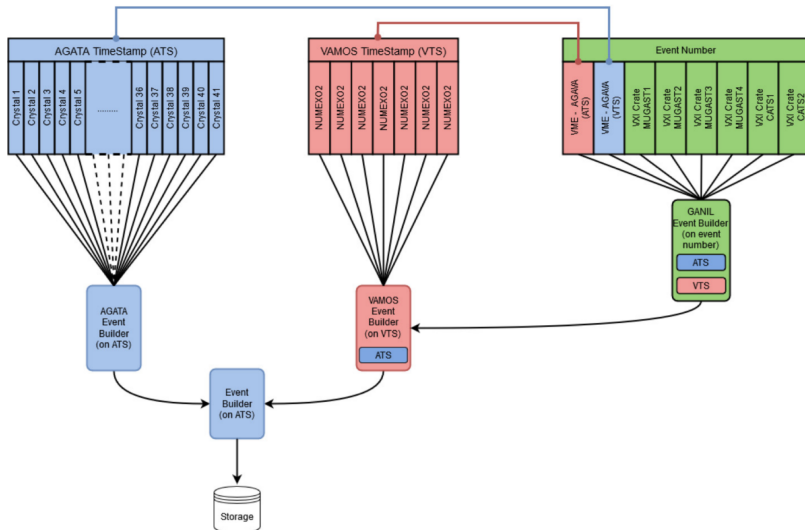
- 1 MUST2 DSSD
- 9 MUST2 Elec. Block

Forward Angle

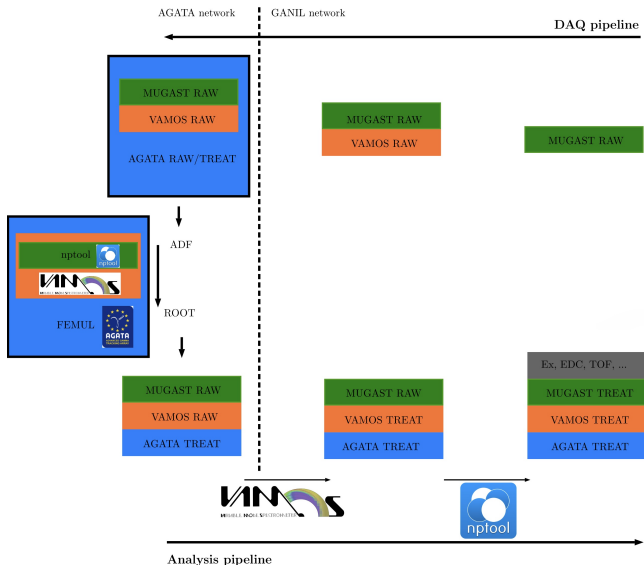
- 1 MUST2 DSSD (90deg)
- 4 MUST2 Telescope



Electronic and DAQ : Coupling and merging



Electronic and DAQ : Data flow



Software, Env, and Algorithm development

COMPUTING $\Rightarrow$ E. Clement, A. Lemasson

FEMUL/VAMOS integration $\Rightarrow$ J. Dudouet, O. Stezowski, A. Lemasson

MUGAST Analysis & Simulation $\Rightarrow$ A. Matta, F. Flavigny, V. Girard-Alcindor

VAMOS-MUGAST ToF Enhancement $\Rightarrow$ D. Ramos

Online Monitoring $\Rightarrow$ D. Ramos, A. Lemasson, J. Dudouet, F. Flavigny, A. Matta

FSC (MUST2 Slow Control) $\Rightarrow$ V. Girard-Alcindor, A. Matta

HVM (High-Voltage Control & Monitoring) $\Rightarrow$ V. Girard-Alcindor, A. Matta

ELOG integration $\Rightarrow$ V. Girard-Alcindor, A. Matta

Key people, Key skills

Project management: M. Assié (IJCLab)

AGATA

- E. Clement
- J. Dudouet

CATS

- T. Roger
- S. Herlant

MUGAST

- M. Assié
- A. Matta

VAMOS

- A. Lemasson
- D. Ramos

MUST2

- V. Alcindor
- F. Flavigny

SPIRAL1

- P. Delahaye
- B. Jacquot

HeCTOR

- F. Galtarosa
- D. Brugnara

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Plus : the larger AGATA/MUGAST/VAMOS

GANIL: A. Giret, L. Menager, J. Goupil, E. Dessay, F. Saillant and their teams.

Key people, Key skills

Project management: M. Assié (IJCLab)

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MUGAST

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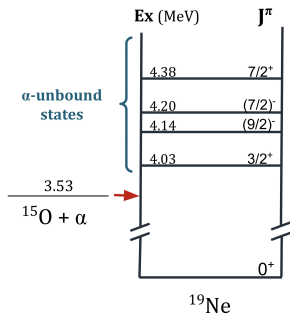
GANIL: A. Giret, L. Menager, J. Goupil, E. Dessay, F. Saillant and their teams.

To be successful

Two persons per sub-system $\iff$ Software/Hardware/Social skills

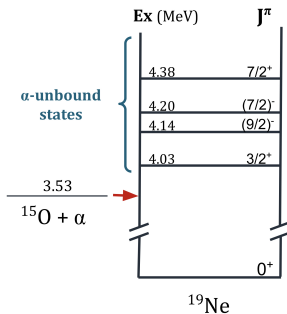
Physics: $^{15}\text{O}(^7\text{Li},t)(\text{York/IJCLab})$

Atrophysical states

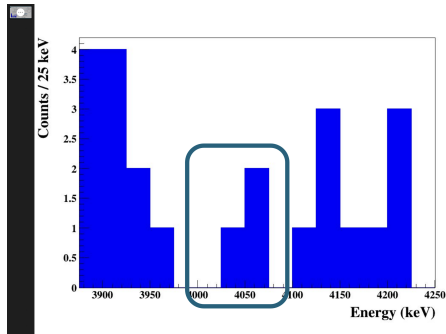


Physics: $^{15}\text{O}(^7\text{Li},t)(\text{York/IJCLab})$

Atrophysical states

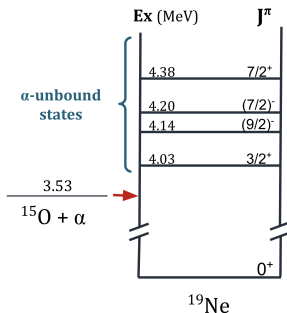


AGATA-VAMOS-MUGAST coic.

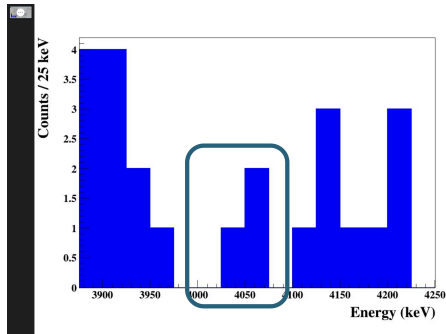


Physics: $^{15}\text{O}(^7\text{Li}, t)(\text{York/IJCLab})$

Atrophysical states



AGATA-VAMOS-MUGAST coic.



An implantation Diamond detector as a beam monitor for an intense radioactive ion beam

J S Rojo¹, C Aa Diget¹, N de Séréville², M Assié², A Lemasson³, D Ramos³, A Lohstroh⁴ and C Reardon¹

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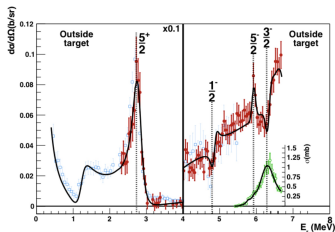
[Journal of Physics: Conference Series, Volume 1643, 27th International Nuclear Physics Conference \(INPC2019\) 29 July - 2 August 2019, Glasgow, UK](#)

Citation J S Rojo et al 2020 *J. Phys.: Conf. Ser.* **1643** 012040

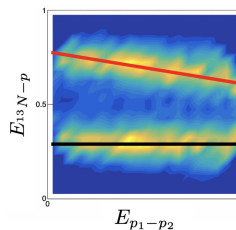
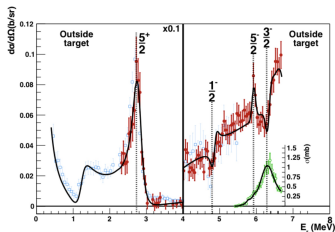
See talk by J.S. Rojo (Tuesday)

- ✓ Indirect α Capture
- ✓ X-Ray bursts implication
- ✓ triple coinc.!

Physics: $^{14}\text{O}(p,p)^{15}\text{F} \rightarrow ^{13}\text{Ne} + 2p$ (GANIL/IJCLab)



Physics: $^{14}\text{O}(p,p)^{15}\text{F} \rightarrow ^{13}\text{Ne} + 2p$ (GANIL/IJCLab)

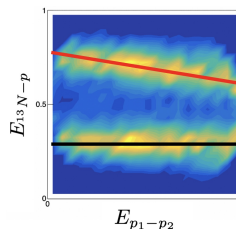
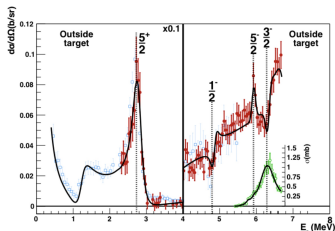


Sequential emission of
2 protons

First proton

Second proton

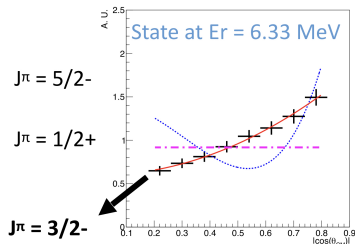
Physics: $^{14}\text{O}(p,p)^{15}\text{F} \rightarrow ^{13}\text{Ne} + 2p$ (GANIL/IJCLab)



Sequential emission of
2 protons

First proton

Second proton



V. Girard-Alcindor PhD

✓ Beam was there :D

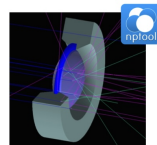
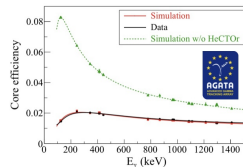
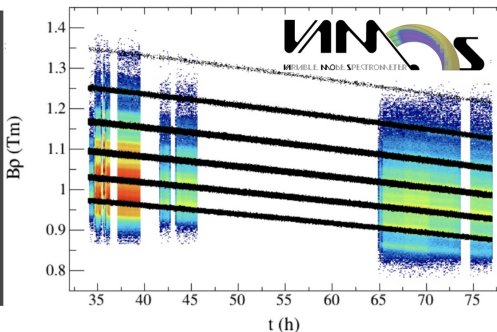
✓ Paper in preparation

Physics: $^{46}\text{Ar}(^3\text{He},d)$ (INFN/IJCLab)

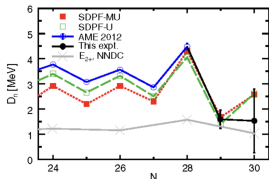
HeCTOR: the ^3He Cryogenic Target of Orsay
for direct nuclear reactions with radioactive ion beams

Accepted
NIM-A

F. Galtarossa^{a,1}, M. Pierens^a, M. Assié^a, V. Delpech^a, F. Galet^a, H. Sagnac^a, D. Brugnara^b, D. Ramos^c, D. Beaumel^a, P. Blache^a, M. Chabot^a, F. Chatelet^a, E. Clément^c, F. Flavigny^d, A. Giret^c, A. Gottardo^c, J. Goupil^c, A. Lemasson^c, A. Matta^d, L. Ménager^c, D. Mengoni^b, E. Rindel^a

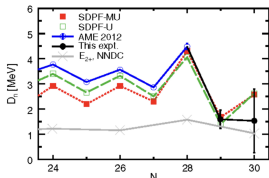


Physics: $^{46}\text{Ar}(^3\text{He},d)$ (INFN/IJCLab)

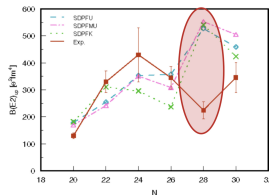


Z. Meisel et al. PRL 114, 022501 (2015)

Physics: $^{46}\text{Ar}(^3\text{He},d)$ (INFN/IJCLab)

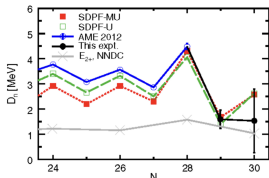


Z. Meisel et al. PRL 114, 022501 (2015)

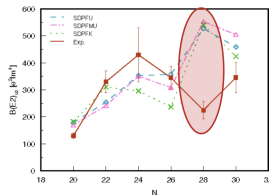


S. Calinescu et al., PRC 93, 044333

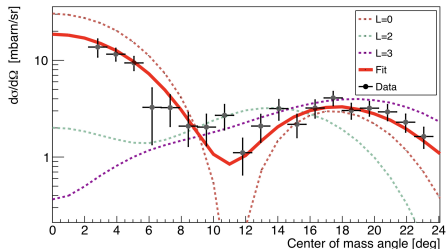
Physics: $^{46}\text{Ar}(^3\text{He},d)$ (INFN/IJCLab)



Z. Meisel et al. PRL 114, 022501 (2015)



S. Calinescu et al., PRC 93, 044333

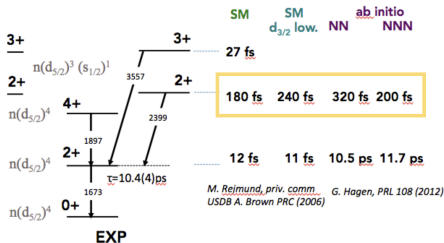


see talk by D. Brugnara (~ 45 min)

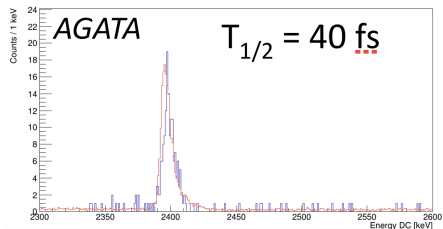
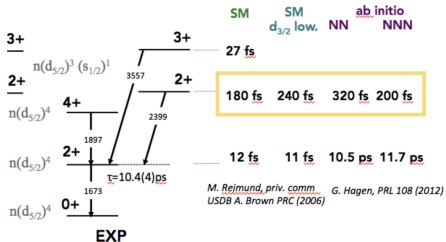
✗ Accelerator Failure :(

✓ ^3He target !

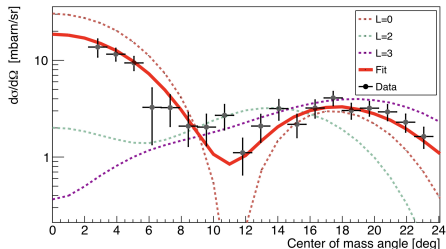
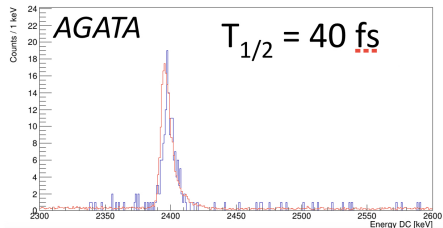
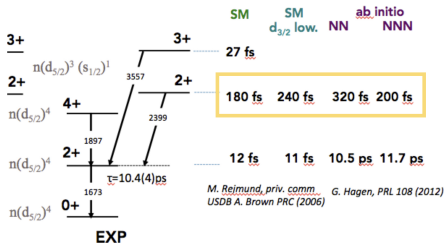
Physics: $^{19}\text{O}(\text{d},\text{p})$ DSAM (GANIL/INFN)



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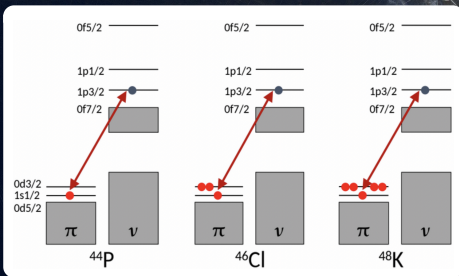
Physics: $^{19}\text{O}(\text{d},\text{p})$ DSAM (GANIL/INFN)



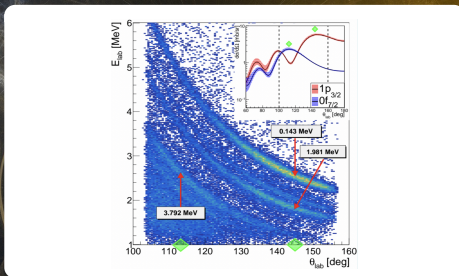
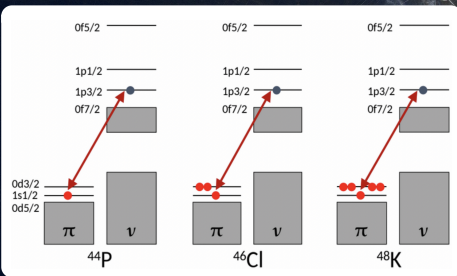
see talk by I. Zanon (yesterday)

- ✓ Novel DSAMxTransf.
- ✓ Lead the way to more!
- ✓ Beautiful analysis

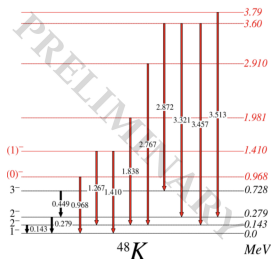
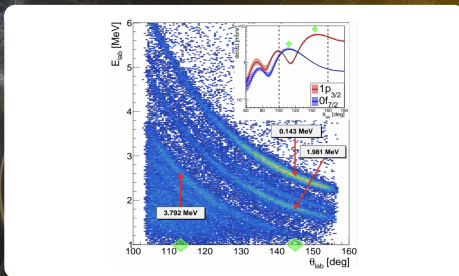
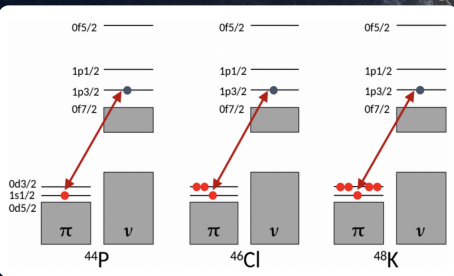
Physics: $^{47}\text{K}(\text{d},\text{p})$ (Surrey, LPC Caen)



Physics: $^{47}\text{K}(\text{d},\text{p})$ (Surrey, LPC Caen)



Physics: $^{47}\text{K}(\text{d},\text{p})$ (Surrey, LPC Caen)



see talk by C. Paxman (~ 60 min)

- ✓ SPIRAL1+ Beam !
- ✓ 6 new states!
- ✓ 9 new transitions!

Conclusion

MUST2

- ✓ $^{10,12}\text{Be}(d, ^3\text{He})$
- ✓ $^9\text{C}(p,d)(p,t) \rightarrow \text{S. Koyama}$
- ✓ $^{37}\text{Ca}(p,d)(p,t) \rightarrow \text{O. Sorlin}$
- ✓ $^{14}\text{O}(p,p)$

MUGAST

- ✓ $^{14}\text{O}(p,p)$
- ✓ $^{15}\text{O}(^6\text{Li}, t) \rightarrow \text{J.S. Rojo}$
- ✓ $^{46}\text{Ar}(^3\text{He}, d) \rightarrow \text{D. Brugnara}$
- ✓ $^{19}\text{O}(d,p) \rightarrow \text{I. Zannon}$
- ✓ $^{47}\text{K}(d,p) \rightarrow \text{C. Paxman}$

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- ✓ $^{47}\text{K}(d,p) \rightarrow \text{C. Paxman}$

Take home message: Golden age of nuclear physics

- Many opportunities for travelling detector!
- ⇒ limited competition between physicists and collaborations
- ⇒ **fierce competition between installations**



NEXT GENERATION SILICON DETECTOR



Thank you !

and visit : grit.in2p3.fr to know more!