

A wide-angle photograph of the interior of the ACTAR TPC detector at TRIUMF. The detector is a large, circular, cylindrical structure with a complex internal structure of metal plates and support beams. The lighting is dim, with some bright spots from overhead lights. The text "ACTAR TPC : Achievements and campaign @ TRIUMF" is overlaid in the center in a large, bold, black font.

**ACTAR TPC :
Achievements
and campaign @ TRIUMF**

- ⇒ ACTAR TPC: principle
- ⇒ Achievements for 2018 – 2022
 - Resonant scattering
 - Implantation/Decay
 - Transfer reactions
 - Inelastic scattering
- ⇒ ACTAR TPC collaboration
- ⇒ ACTAR@TRIUMF: scientific project
 - Study of the unbound states in ^{21}Al
 - Resonant proton elastic scattering on ^{17}F
 - Detailed spectroscopy of ^{12}Li
- ⇒ Project timeline, Human resources & Budget sharing

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Active target: (Gaseous) detector in which the atoms of the gas are used as a target

✓ Drift region: principle

- Transparent to particles on 4 sides
- Wire field cage
- Homogeneous vertical drift electric field
- Double wire field cage: 2 mm/1 mm pitch

✓ Amplification region: principle

- Bulk Micromegas (CERN PCB workshop)
- Local gain reduction via pad polarization

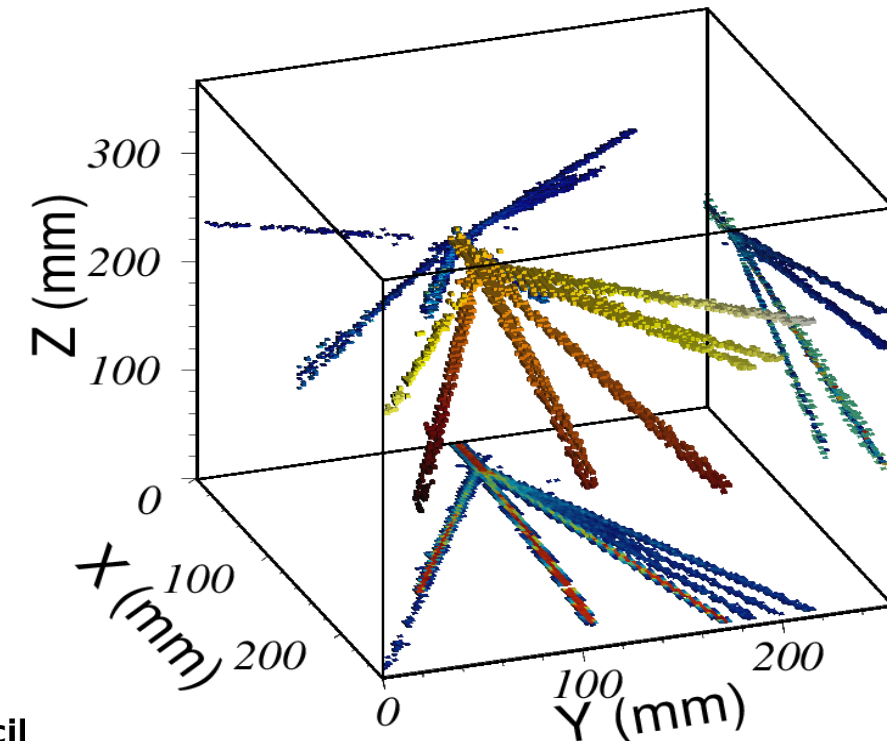
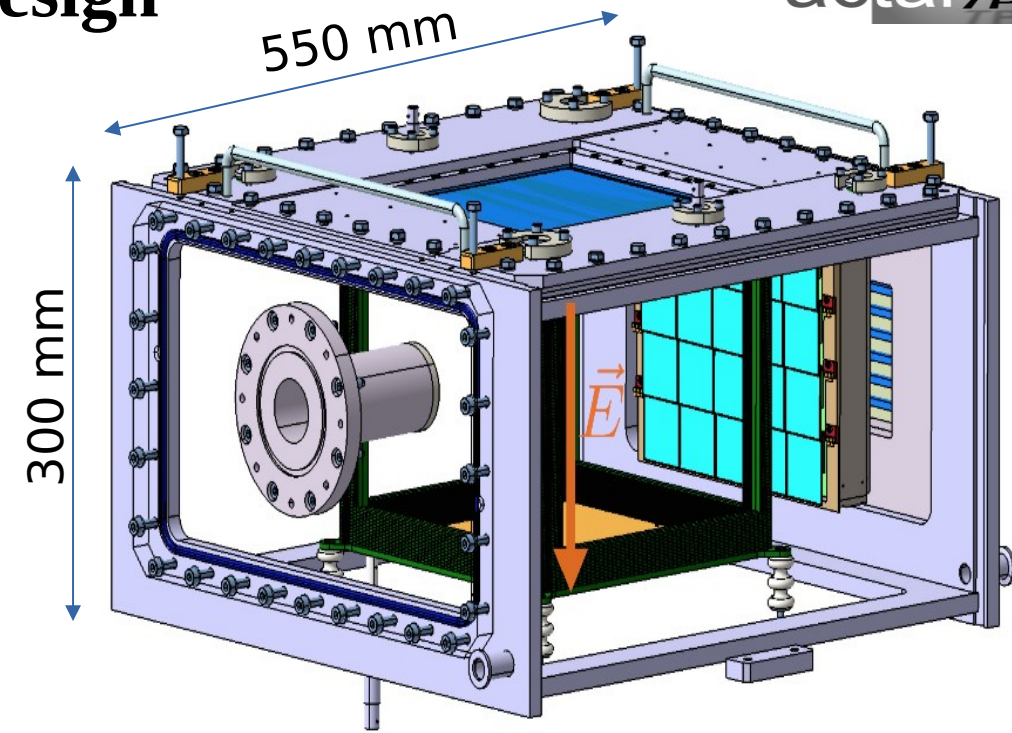
✓ Segmented pad plane

- Micromegas
- transverse multiplicity \approx electron straggling: $2 \times 2 \text{ mm}^2$ pads
- 16384 pads with very high density: challenge!
- Two solutions investigated

✓ Electronics: GET

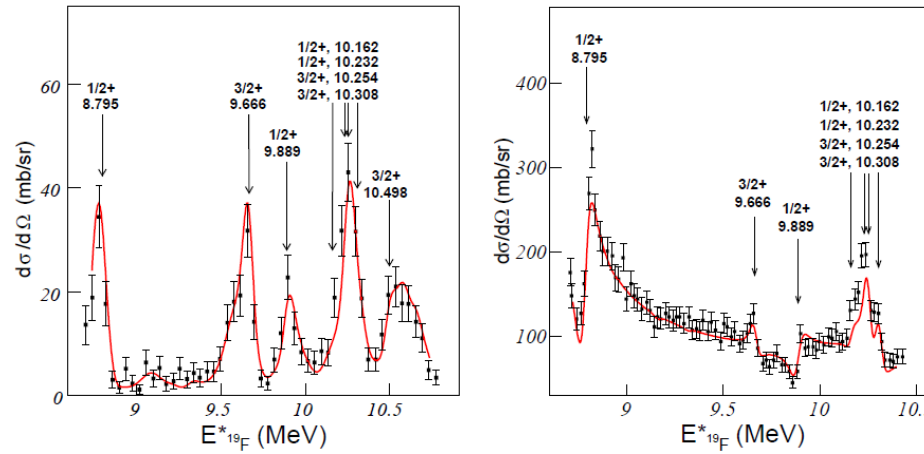
GET electronics:

- 512 samples ADC readout depth x 16384 pads
- volume sampling in 8 Mega voxel
- adjustable gain, peaking time, individual trigger: pad per pad



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⇒ T17-03 (2017): ACTAR TPC Commissioning for resonant scattering:
 $^{18}\text{O}(p,p)$ and $^{18}\text{O}(p,\alpha)$ excitation functions

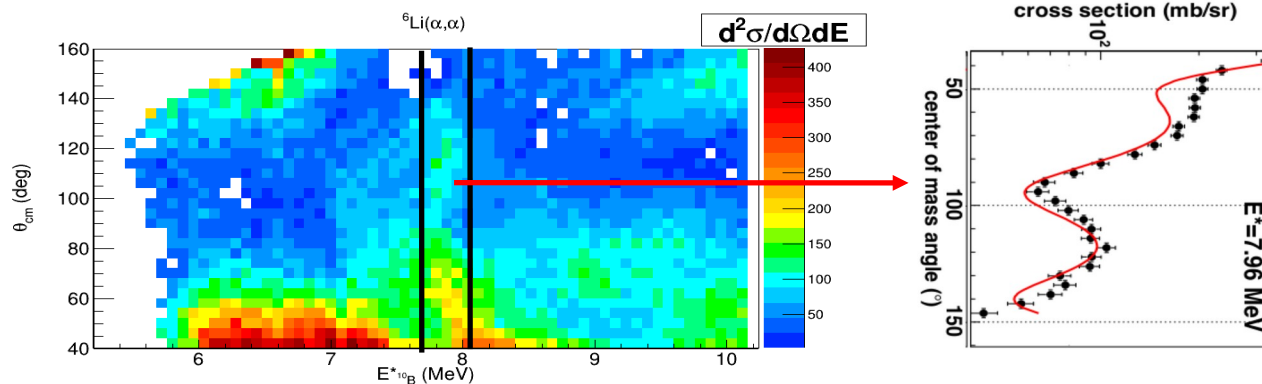


B. Mauss, PhD thesis (GANIL)

- ✓ Absolute cross section measurement
- ✓ $^{18}\text{O}(p,p)$: 38(3) keV FWHM
- ✓ $^{18}\text{O}(p,\alpha)$: 54(9) keV FWHM
 → limited by the angular straggling

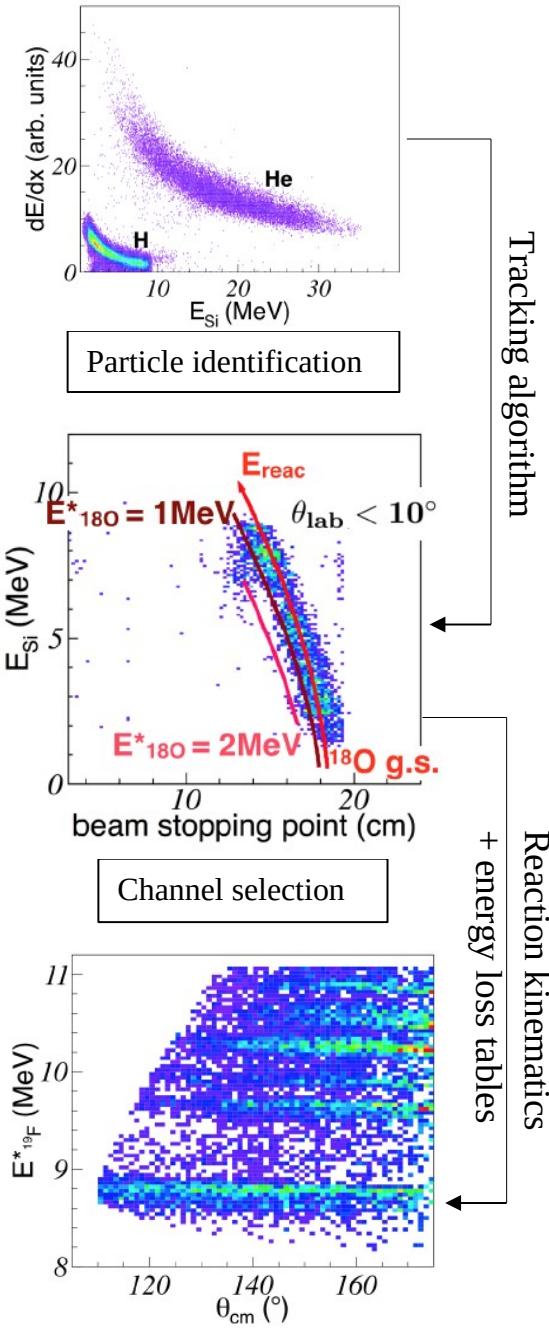
B. Mauss et al., Nucl. Instr. And Methods A 498, (2019)

⇒ LNS19-01 (2019): ACTAR TPC demonstrator @ LNS Catania:
 $^6\text{Li}(\alpha,\alpha')$ resonant reaction: search for α -cluster states in ^{10}B



3+ state @ 7.9 MeV,
 large alpha decay width

B. Mauss et al., to be published



Double differential cross section

⇒ E690 (May 2019): Proton-decay branches from high-spin isomers in ^{54}Ni and ^{53}Co

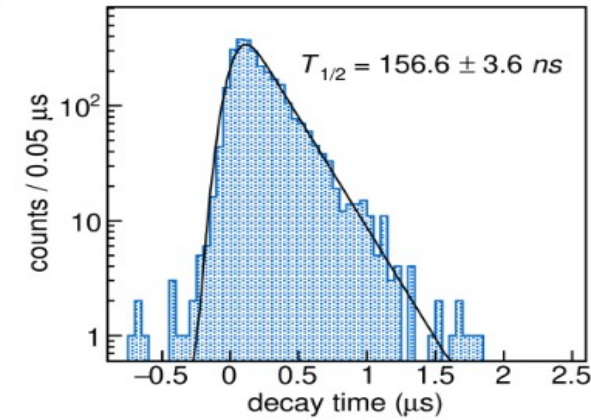
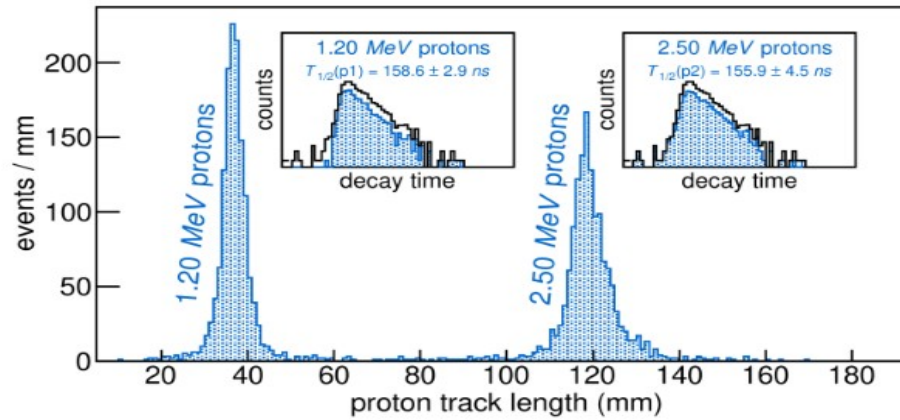
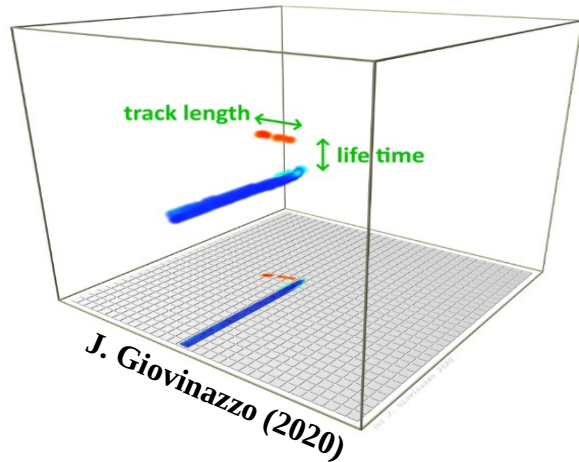
Decay of the ^{54m}Ni state:

J. Giovinazzo et al., *Nature Communications* 12, 4805 (2021)
 J. Giovinazzo et al., *Nucl. Instr. and Method A*1042, 167447 (2022)

Mirror symmetry at mass A = 54:

E4 effective charges near doubly magic ^{56}Ni :

D. Rudolph et al., *Phys. Lett. B* 830, 137144 (2022)

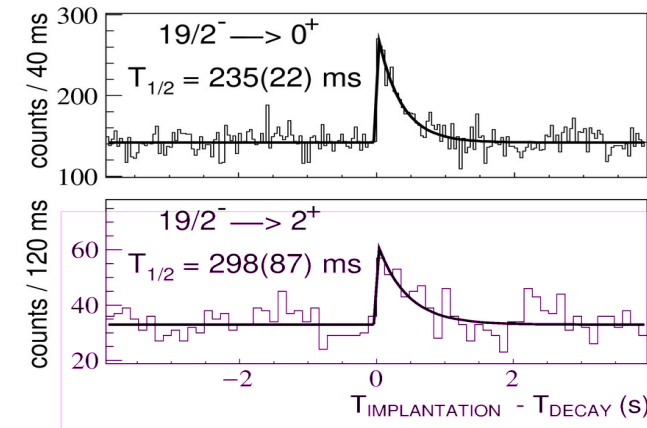
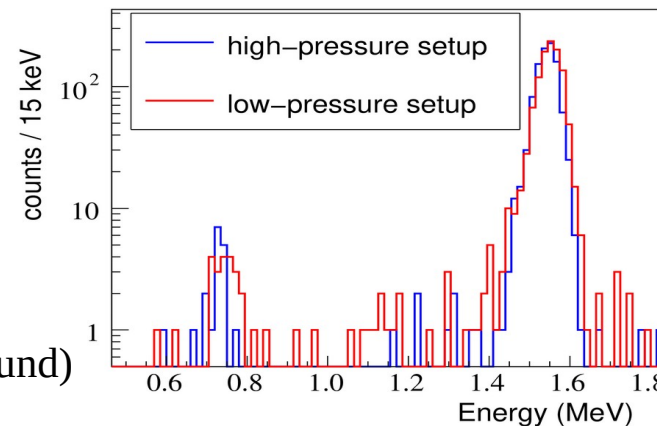


Simultaneous observation of Ni track (6 MeV/pad) and proton tracks (60 keV/pad) + Decay of $T_{1/2} = 155 \text{ ns}$ isomer : OK!

Elucidating the nature of the proton radioactivity and branching ratio of the 1st proton emitter discovered ^{53m}Co

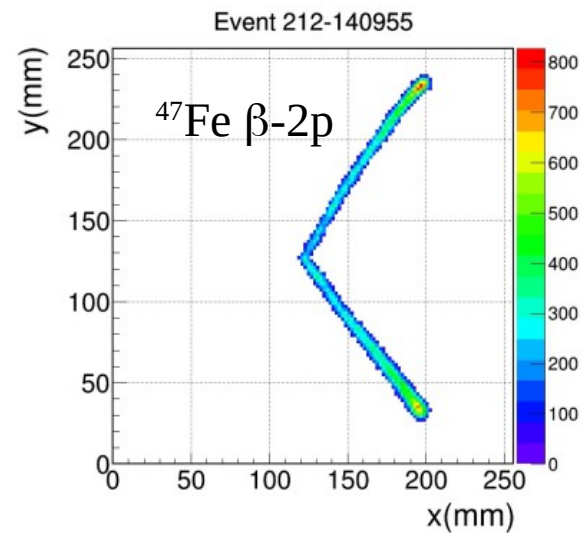
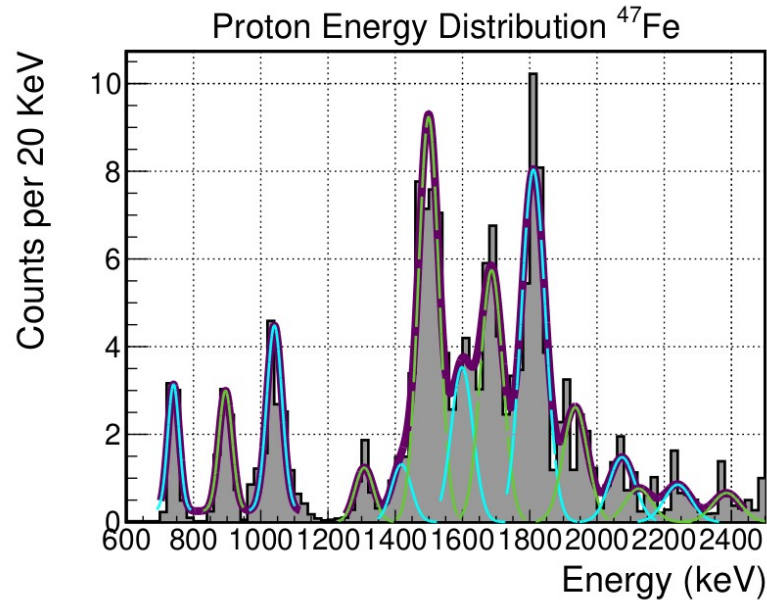
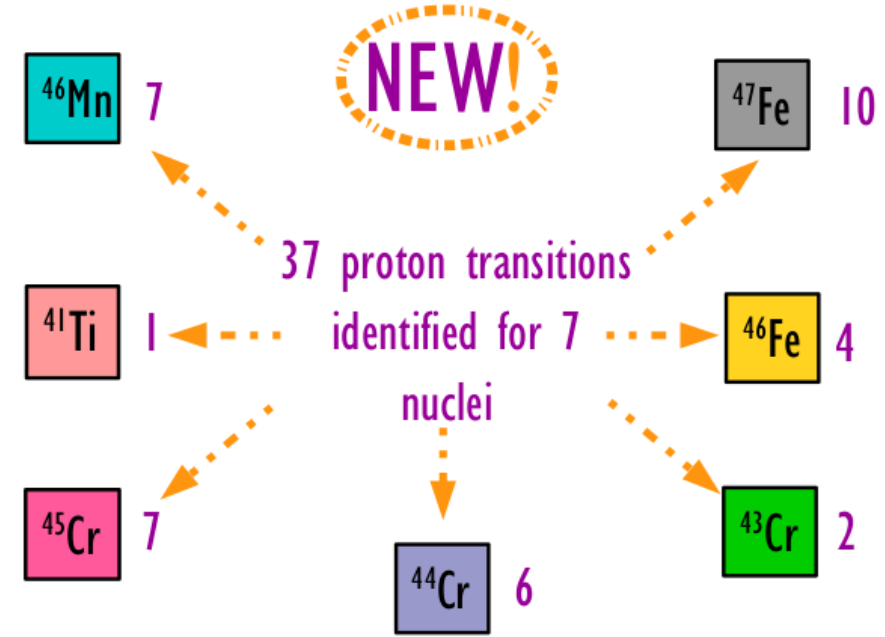
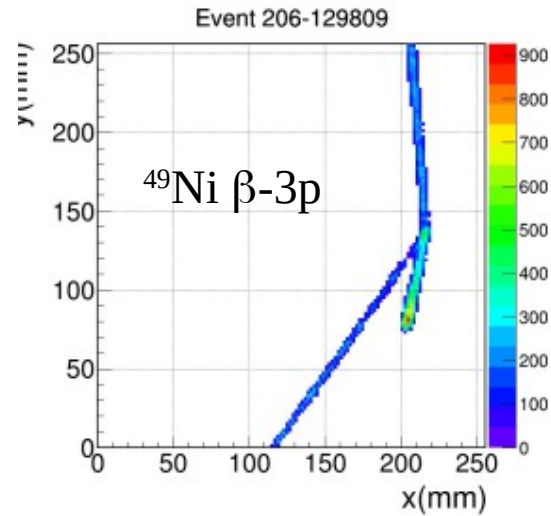
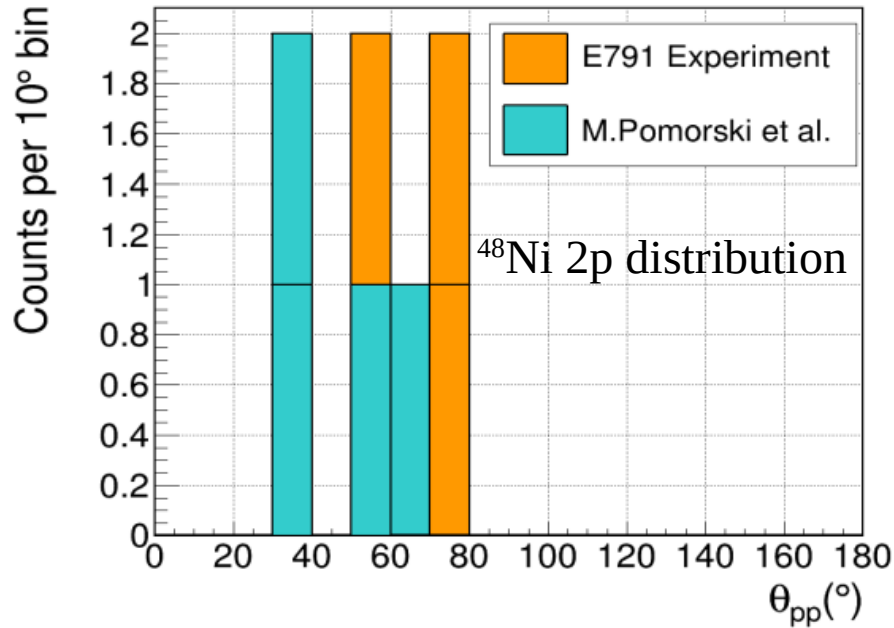
L. Sarmiento et al., *Nature Communications* 14, 5961 (2023)

Measurement of 0.025 % BR : OK (not affected by β background)



→ E791 (May 2021): Exotic decays in the region of ^{48}Ni

PhD thesis **A. Ortega Moral (LP2IB)**

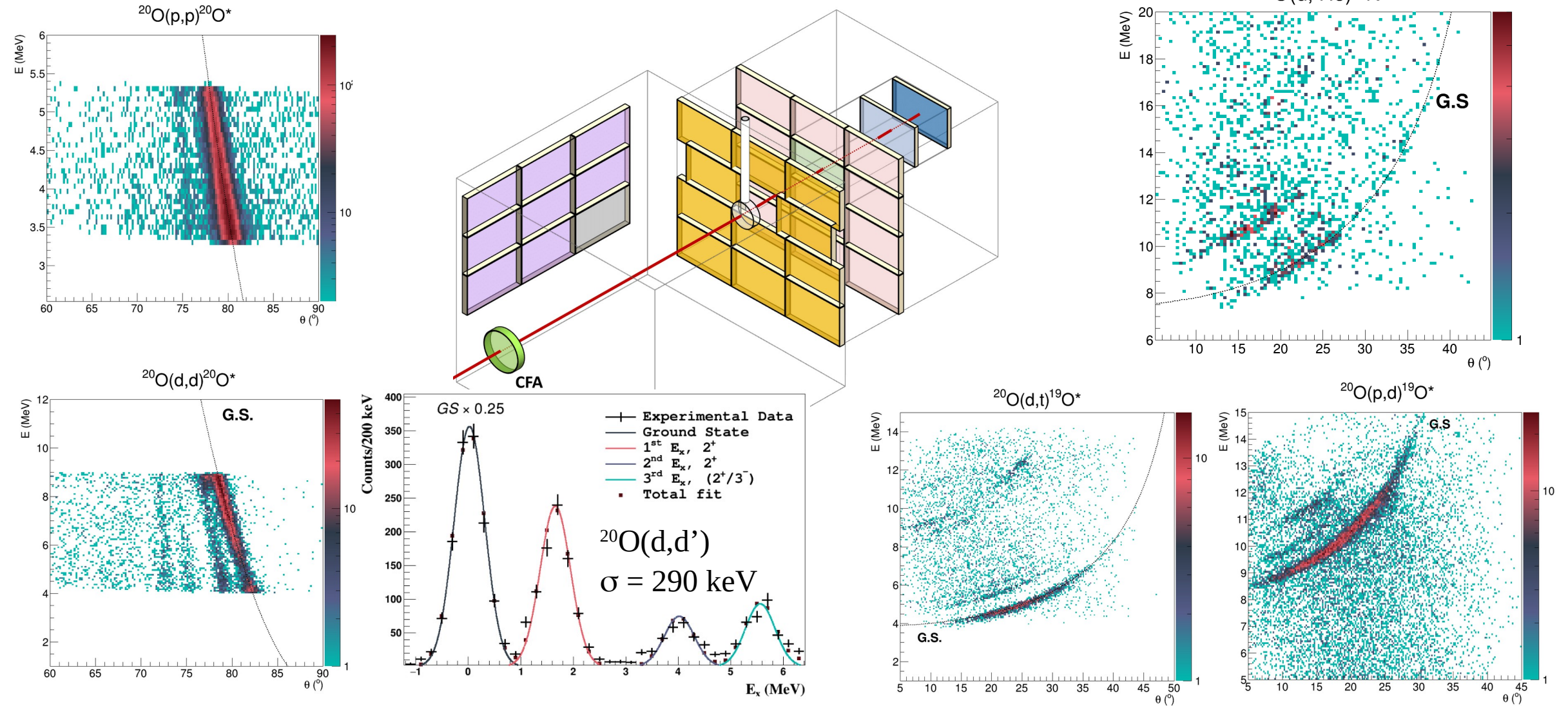


→ tracking of low energy protons & no beta background!
→ multiple particle tracking in 3D, half-life, ...

⇒ E796: Study of the $^{19}\text{N}(d, ^3\text{He})$ reaction (2020-2021-2022)

^{19}N at 30A MeV in 1 bar D_2 (90%) + iC_4H_{10} (10%) → Equivalent **11 mg/cm² CD₂ target + 5.4 mg/cm² CH₂ target**

J. Lois Fuentes PhD thesis (U. Santiago de Compostella)



Thick target, mixed proton/deuteron target, E* resolution comparable to thin target experiments

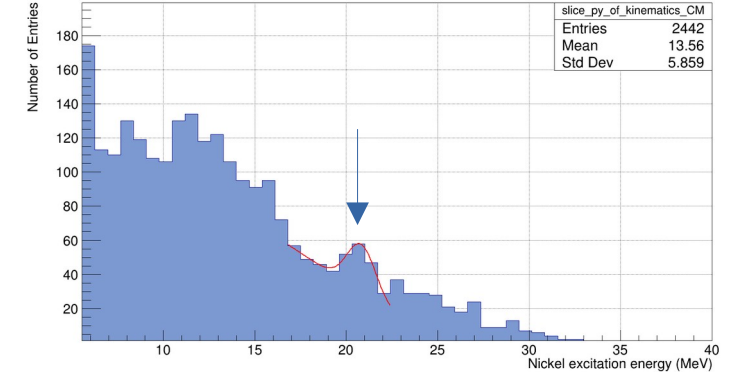
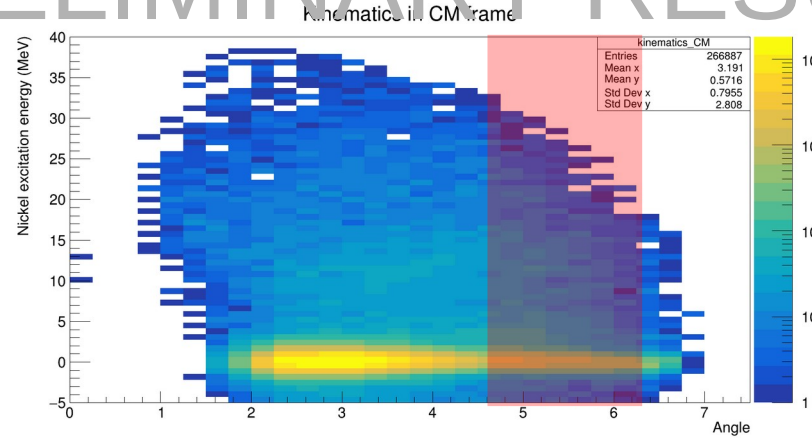
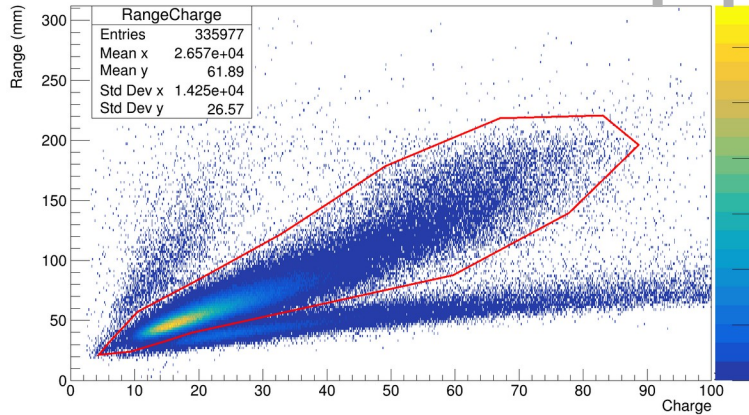
⇒ E780: Study of the $^{58,68}\text{Ni}(\alpha, \alpha')$ reaction (2019)

A. Arokia Raj PhD thesis (KU Leuven)

D. Thisse (CEA/IRFU)

→ tracking of 400 keV α particles!

PRELIMINARY RESULTS

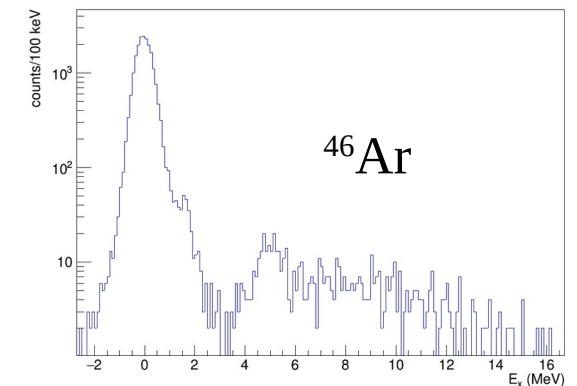
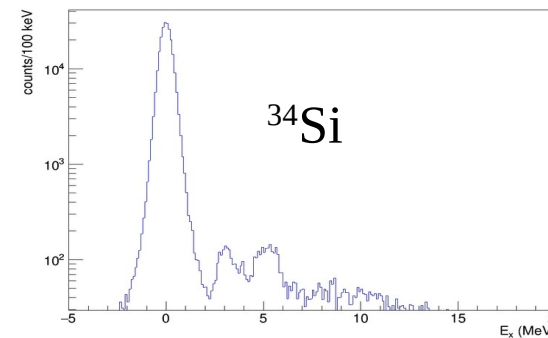
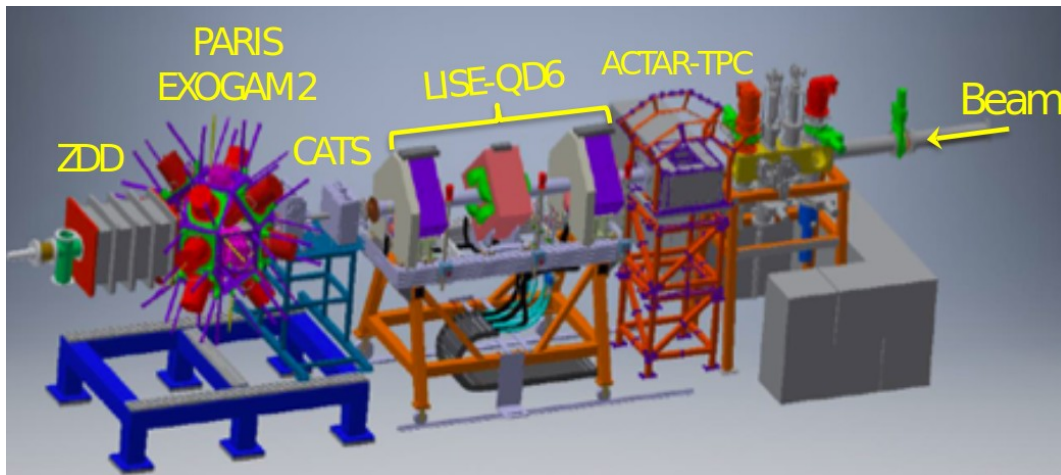


⇒ E823: Coulomb excitation and inelastic proton scattering of neutron-rich Si isotopes between N=20 and N=28 (2022)

Q. Delignac PhD thesis (LP2IB)

A. Cassisa PhD thesis (UJF CAS)

→ “Brochette mode”: 2 experiments in one!



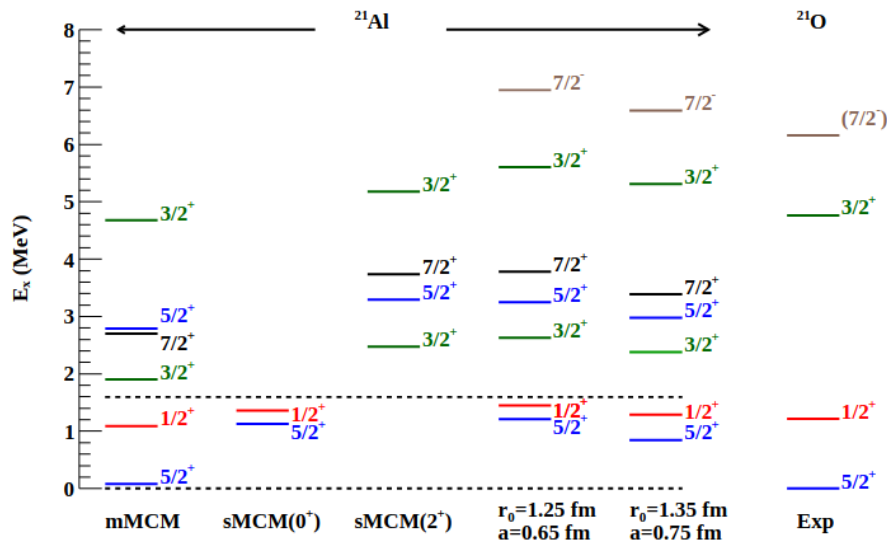
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- ⇒ 10 institutions represented
- ⇒ About 30 members
- ⇒ 4 PhD defended + 3 PhD ongoing
- ⇒ Guided by a collaboration agreement: decisions taken by majority vote (includes TRIUMF campaign)

Institution	Country	Representative
GANIL	France	T.Roger (PI)
CENBG	France	J.Giovinazzo
LNL	Italy	T.Marchi
KUL	Belgium	R.Raabe
USC	Spain	B.Fernandez-Dominguez
RIKEN	Japan	D.Suzuki
U. Regina	Canada	G.F.Grinyer
UHU	Spain	Á.M. Sánchez Benítez
IJCLab	France	Y. Blumenfeld
IRFU	France	M. Vandebrouck

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⇒ S2008 : Study of the unbound states in ^{21}Al using an active target (B.F.D, O. Tengblad, T.R.)
 → Experiment approved in 2022 (expires on Dec. 2025) – **21 BTU = 7 days**



⇒ Only experimental information on ^{21}Al : $T_{1/2} < 13$ ns
 → Theoretical predictions in disagreement

⇒ Mirror nuclei ^{21}O
 → Largest known TES predicted (according to sMCM)

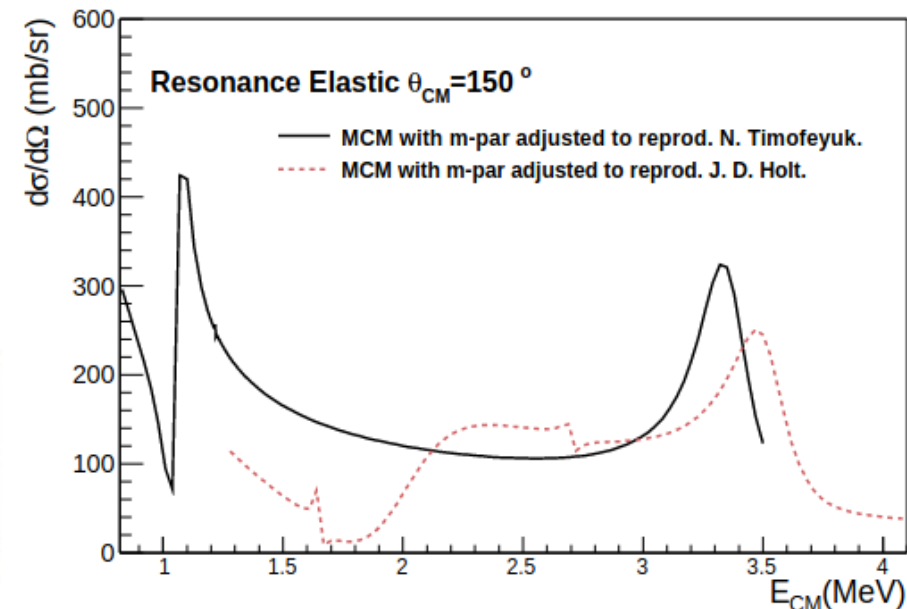
⇒ Nuclei located at the N=8 gap and just below the Z=14 gap
 → Is the modification of the Z=14 gap due to combined action of the central component and the tensor part of the effective nucleon-nucleon (NN) like on the neutron rich side?

⇒ Proton resonant scattering to probe proton states
 ⇒ ACTAR TPC to disentangle elastic v.s. inelastic channels (probes core excitations in ^{21}Al)

⇒ ^{20}Mg beam @ 2A and 6A MeV – min. I expected: 1000 pps

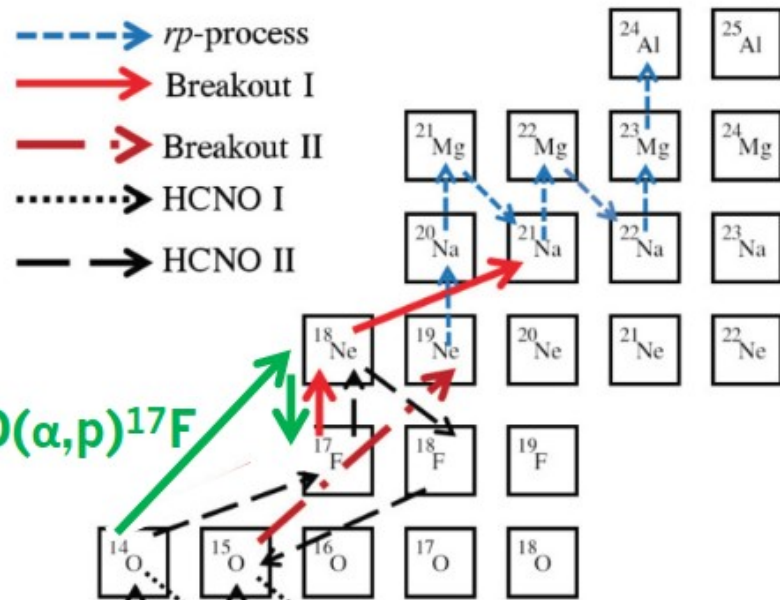
Beam not yet available at GANIL (and predicted with much lower intensity)

Radioactive Beam	Intensity (pps)	
	Low Energy Beamline	Post accelerated (on target)
20Mg	1.5E+03	1.4E+01



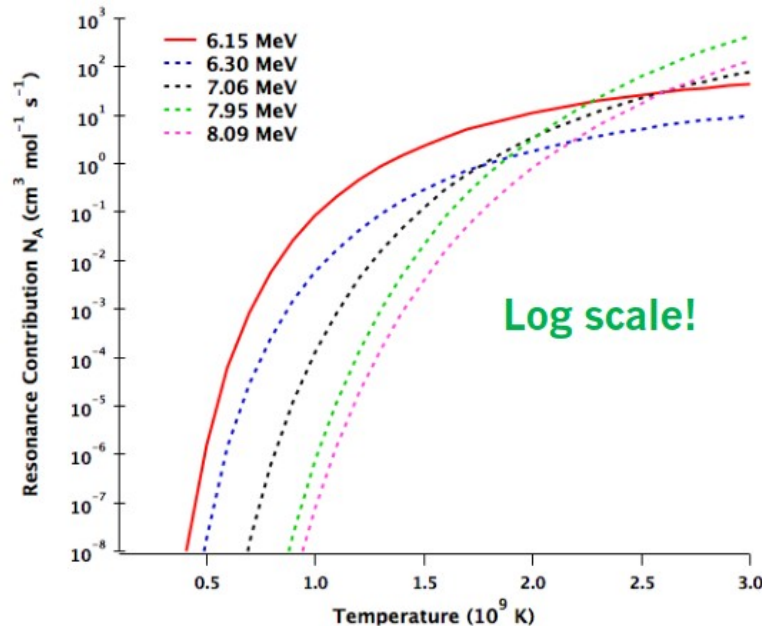
⇒ S2029 : Resonant proton elastic scattering on ^{17}F (G.F.G., T.R.)

→ Experiment approved in 2022 (expires on Dec. 2025) – **16 BTU = 5 days**



- ⇒ $^{14}\text{O}(\alpha,p)$ is one of the two break-out pathways from the HCNO cycle
- ⇒ This reaction is dominated by the 6.15 MeV (1^-) resonance in ^{18}Ne
- ⇒ The 1^- state is known to decay by single proton, but 2p and α channels are opened
- ⇒ Γ_{2p} has been experimentally measured (indirectly) to be $\sim 27\%$, but theoretical estimates are about 10000 times smaller!
- ⇒ Γ_{α} has never been measured.

- ⇒ $^{17}\text{F}+p$ resonant scattering to populate 6.15 MeV state in ^{18}Ne
- ⇒ $^{17}\text{F}^{9+}$ beam @ 4.5A MeV in $\text{H}_2(95\%)+\text{iC}_4\text{H}_{10}(5\%)$ @ 700 mbar, $I > 5000$ pps



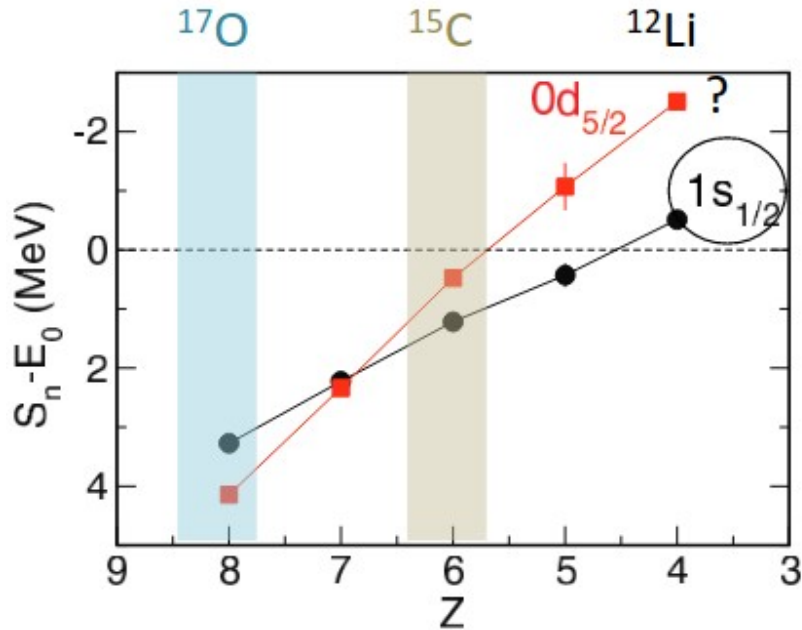
Γ_{2p}/Γ_{tot} (%)	2p yield (counts/day)
< 27.0	$< 7 \times 10^4$
0.03 to 0.11	70 to 280
0.001 to 0.006	2 to 14

Radioactive Beam	Intensity (pps)		Max Energy (MeV/nucleon)
	Low Energy Beamline	Post accelerated (on target)	
17F	1.70E+04	2.00E+03	3.5

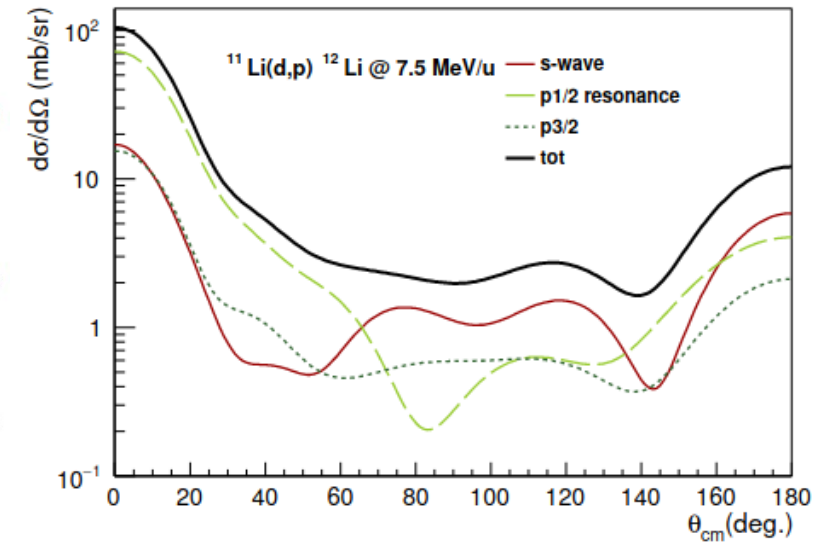
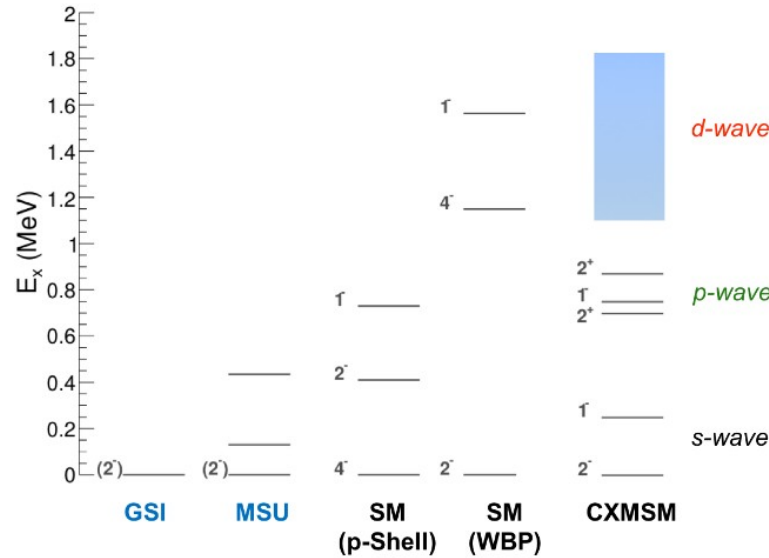
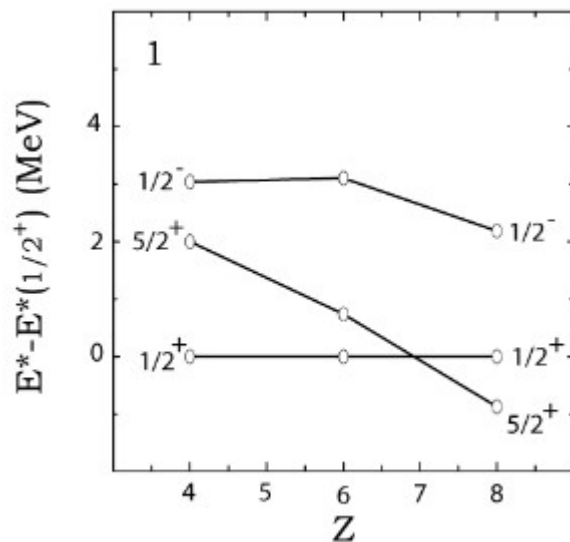
Though listed in the GANIL available beams, ^{17}F could not be delivered (E750 experiment accepted, programmed, but not performed – 2018)
+ Not possible at GANIL: Quoted intensity & energy are too low

⇒ S2384 : Detailed spectroscopy of ^{12}Li (B.F.D., W. Catford, T.R.)

→ Experiment unofficially accepted @ last TRIUMF EEC meeting – 24 BTU = 8 days



- ⇒ Neutron $2s_{1/2}$ orbital is going down in energy in the N=9 isotones
- ⇒ Trend confirmed with $l=0$ ground state found for ^{12}Li
- ⇒ Simultaneously, neutron $1p_{1/2}$ is going down in energy. Could even go below $1d_{5/2}$ in ^{12}Li



- ⇒ $^{11}\text{Li}(d,p)$ in order to locate the p- and d- wave resonances in ^{12}Li and deduce the nature of the low-lying states in ^{12}Li
- ⇒ ^{11}Li beam @ 7.5A MeV, $I > 2000$ pps

^{11}Li beam is out of reach in GANIL ($T_{1/2} = 8.75$ ms)

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TASK	2024				2025			
	T1	T2	T3	T4	T1	T2	T3	T4
Campaign GANIL	X X X	X X X						
Memorandum of Understanding		X X X X	X X X X					
Preparation & Shipping to TRIUMF			X X	X X				
Mounting at TRIUMF					X X X			
TRIUMF Campaign						X X X X	X X X X	
Return to GANIL							X X X	X

Before leaving

- A. Administrative work
(MoU, shipping, customs, ...): 4 mFTE (GANIL + USC + U.Regina + TRIUMF)
- B. Packing (send to TRIUMF): 1 mFTE (GANIL + USC)
- C. Acquisition & Electronics portability: 1 mFTE (GANIL - GTA)

On site

- D. Mounting at TRIUMF: 1.5 mFTE (GANIL + U.Regina + USC)
- E. Running exp: > 8 mFTE (All)
- F. Packing (return to GANIL): 1 mFTE (GANIL + U.Regina + TRIUMF)

TOTAL: 16.5 mFTE

Resources from partner labs:

- ⇒ GANIL: 0.8 senior + 1.3 eng. + 0.5 tech. = 2.6 FTE → A. B. C. D. E. F.
- ⇒ USC: 0.9 senior + 0.5 tech. + 2.2 students = 3.6 FTE → A. B. D. E. F.
- ⇒ U.Regina: 1 senior + 2 students = 3.0 mFTE → A. D. E. F.
- ⇒ TRIUMF: 1 senior + 1 tech. = 2.0 mFTE → A. D. E. F.
- ⇒ Collaboration: senior + students = 2.0 mFTE → E.

Item	Amount (k€)	Laboratory in charge
Shipping detector to TRIUMF	70=21-35*-14	GANIL - U. Regina - IGFAE-USC
New gas recycling system	40*	GANIL
New array of silicon detectors	40*	IGFAE-USC
Electronics : preamplifiers	5*	GANIL-IGFAE-USC
Thick GEMS	4*	IGFAE-USC
Gaz Bottles : H ₂ , D ₂ , C ₄ H ₁₀	10=5+5*	GANIL - U. Regina
Additional computer for DAQ	10*	IGFAE-USC
Operational costs	5	TRIUMF
TOTAL	184	

* Investment already done, or financing secured

+ Budget mission GANIL 200€/day, 5 mFTE = 30 k€

+ Plane tickets = 5 k€

