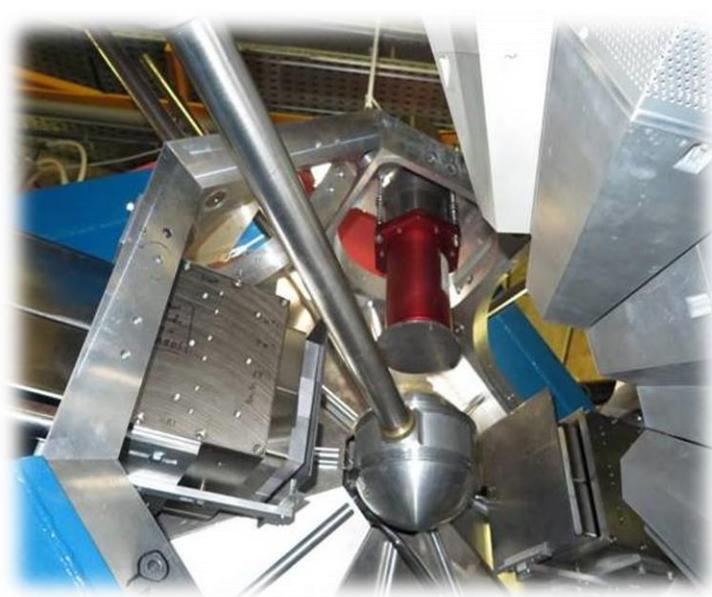




UNIVERSITÀ
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106° CONGRESSO NAZIONALE SOCIETÀ ITALIANA DI FISICA

14-18 settembre 2020

Investigation of N and C isotopes with the AGATA+PARIS+VAMOS setup

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Spokepersons: S. Leoni, B. Fornal, M. Ciemała

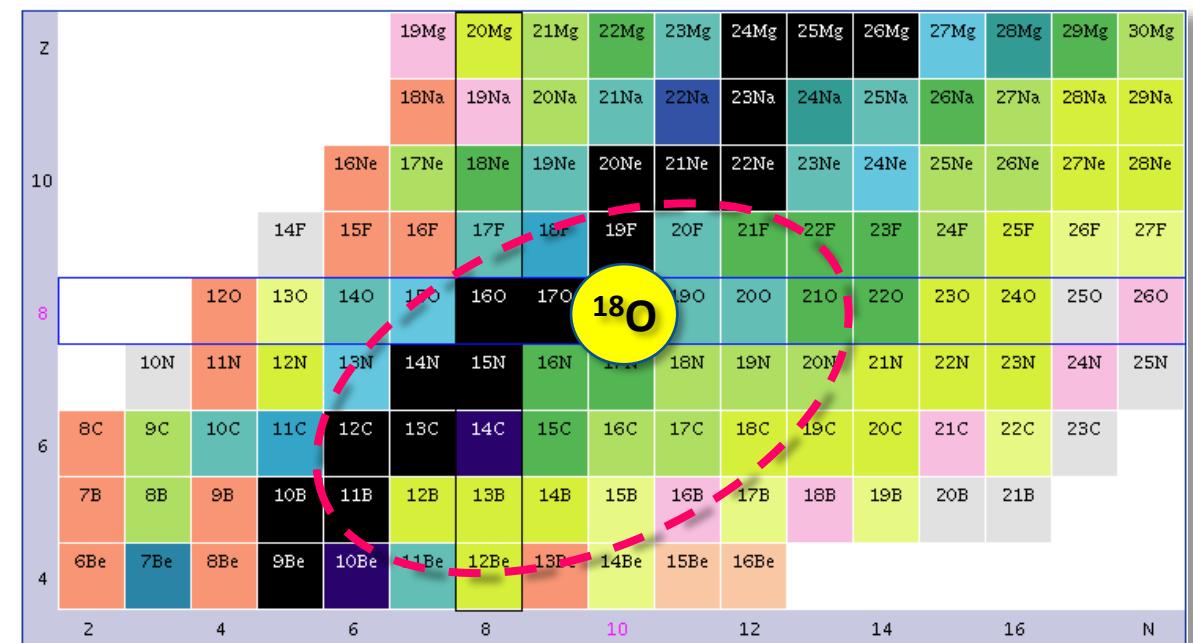
Physics case: gamma spectroscopy

Lifetime measurement of the second 2^+ state in ^{16}C and ^{20}O : a stringent test of the three body forces with the AGATA+PARIS+VAMOS setup

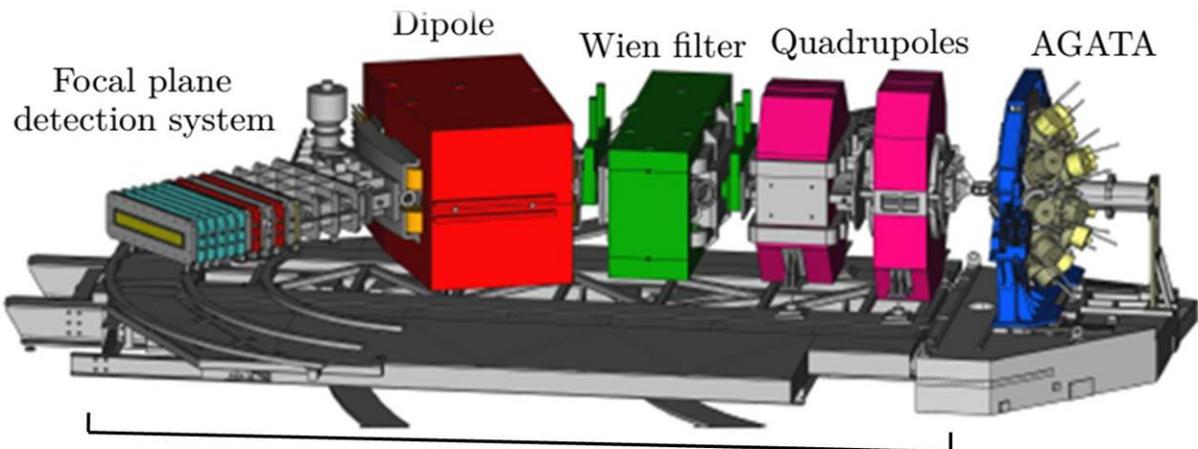
- Spectroscopy of n-rich B, C, O, N, F nuclei by deep-inelastic reactions
- Limited spectroscopic information in this region of mass
 - Key systems in astrophysics processes, especially in nucleosynthesis

Experiment Performed
in GANIL (France)
July 2017 (13 days)

^{18}O (7 MeV/A) on ^{181}Ta (6 mg/cm²)

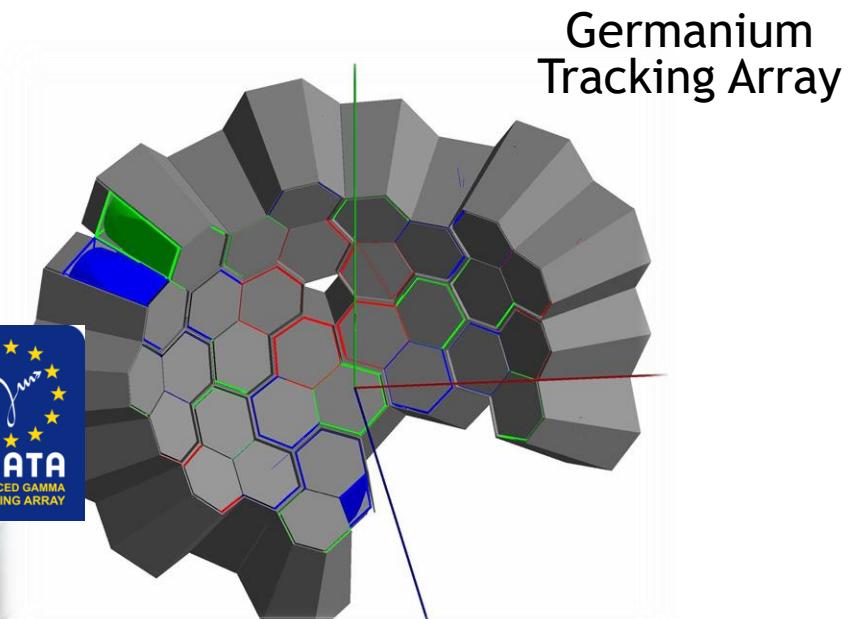
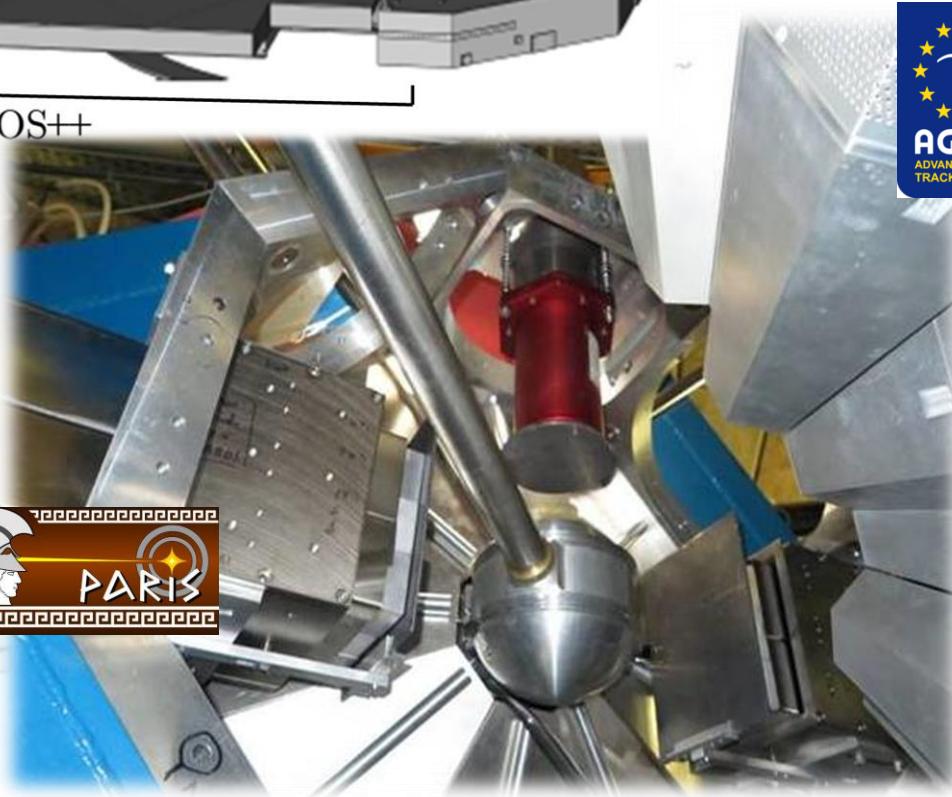


Experimental setup (at GANIL, France)



Magnetic
Spectrometer

Large Volume
Scintillator Array



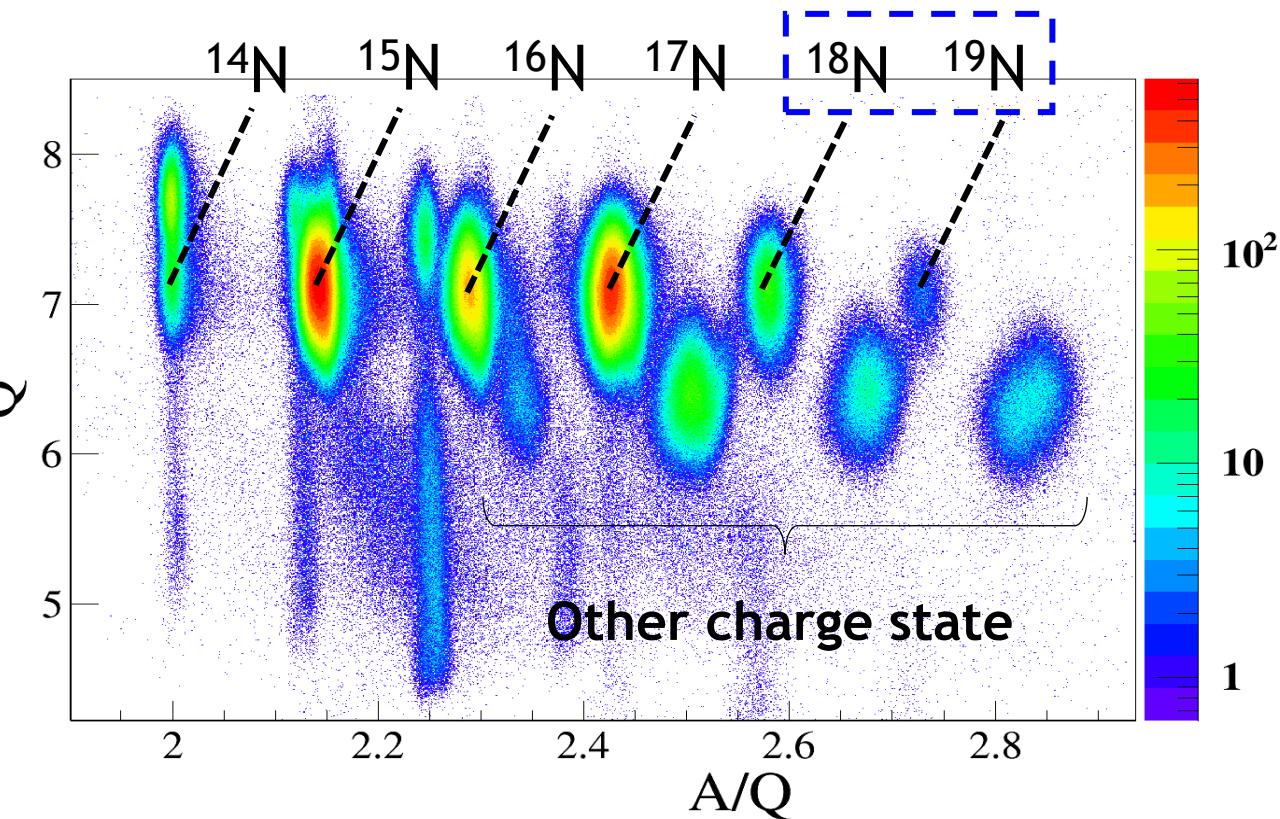
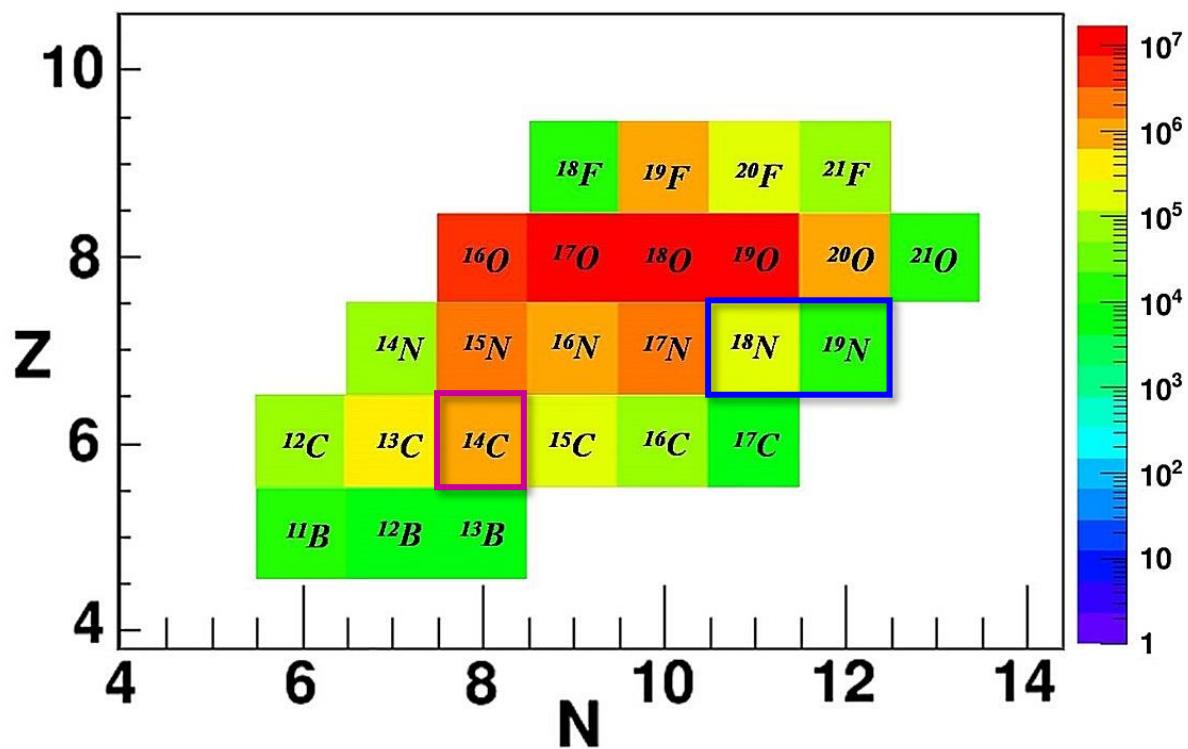
^{18}O (7 MeV/A) on ^{181}Ta (6 mg/cm²)

- **AGATA** (10 TC+ 1 DC=32 crystals)
31 crystals working
- **PARIS-Demonstrator** @ 23 cm
2 Clusters + 2 Large volume LaBr₃
- **VAMOS++** @ 45°

Reaction products

^{18}O (7 MeV/A) on ^{181}Ta (6 mg/cm²)

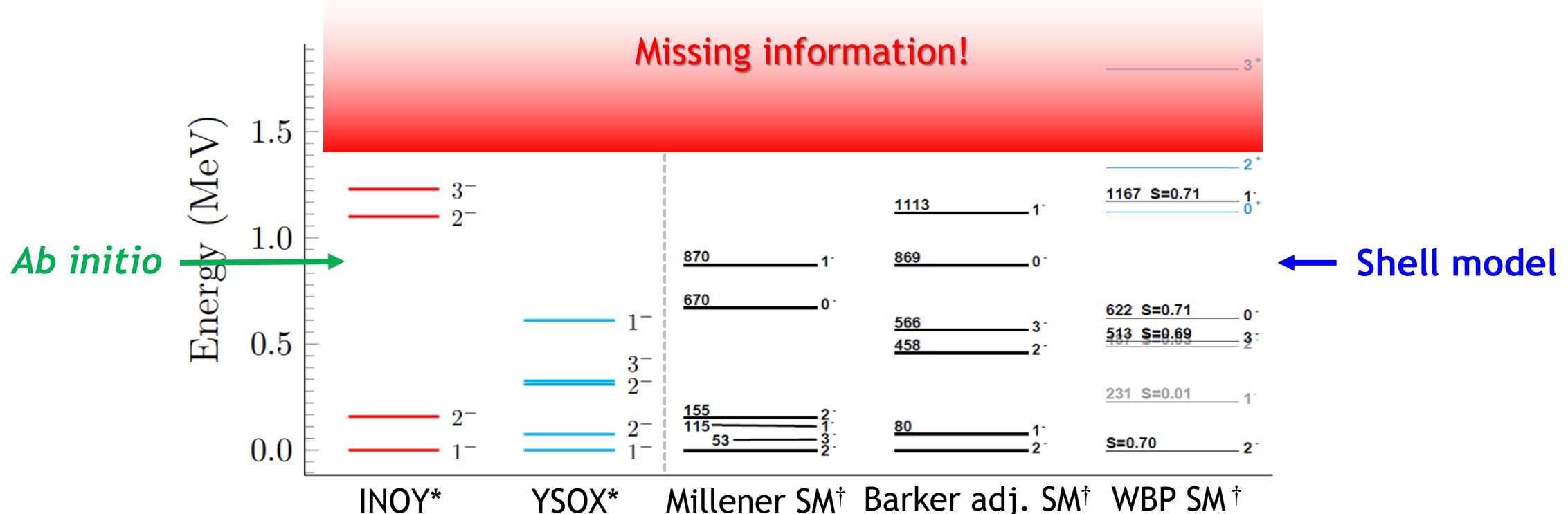
Reaction products (**deep-inelastic reaction**): main focus on $^{18,19}\text{N}$ and ^{14}C isotopes



Need for **high-precision spectroscopy** to extend and verify very old information quoted in the database

^{18}N : key system in supernovae

- Part of the flow path as a **seed nucleus** to r-process element production in Type II supernovae
- Likely produced in the **supernova environment** by $^{17}\text{N}(\text{n}, \gamma)^{18}\text{N}$ reactions
- **^{18}N spectroscopy almost missing in literature**
- **Real challenge to theoretical models (both shell model and *ab initio* calculations)**

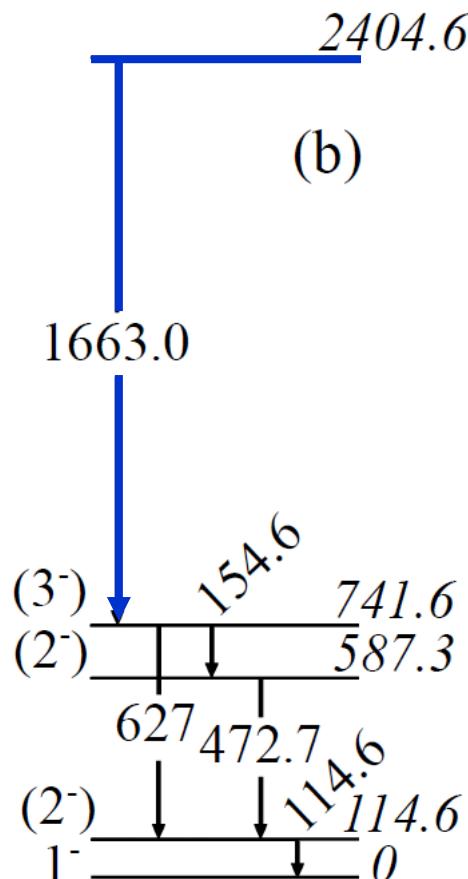
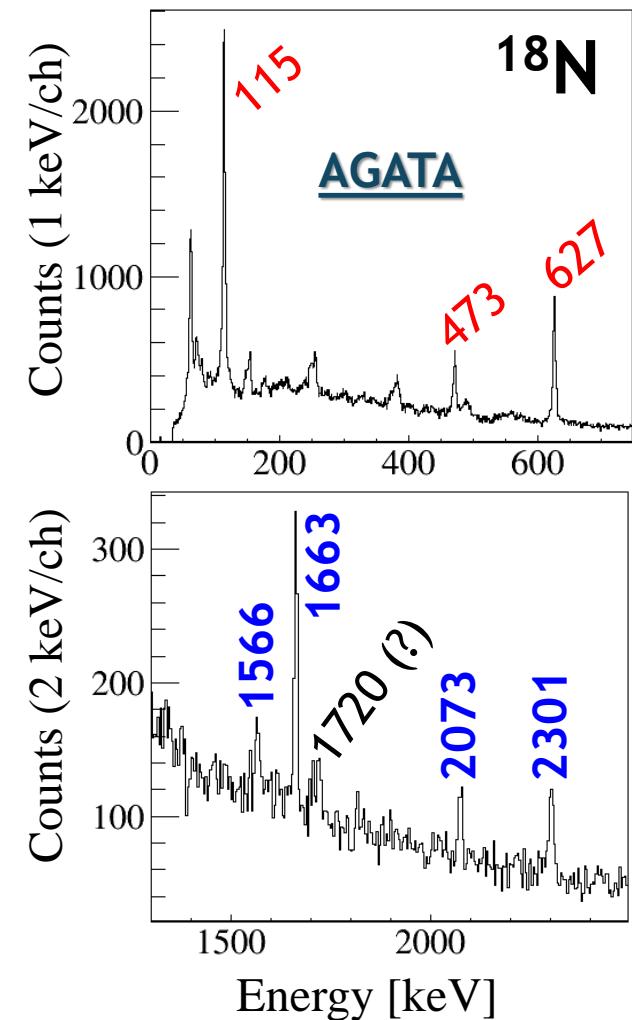


*A. Saxena and P.C. Srivastava, arXiv:1902.01712v4 (2019)

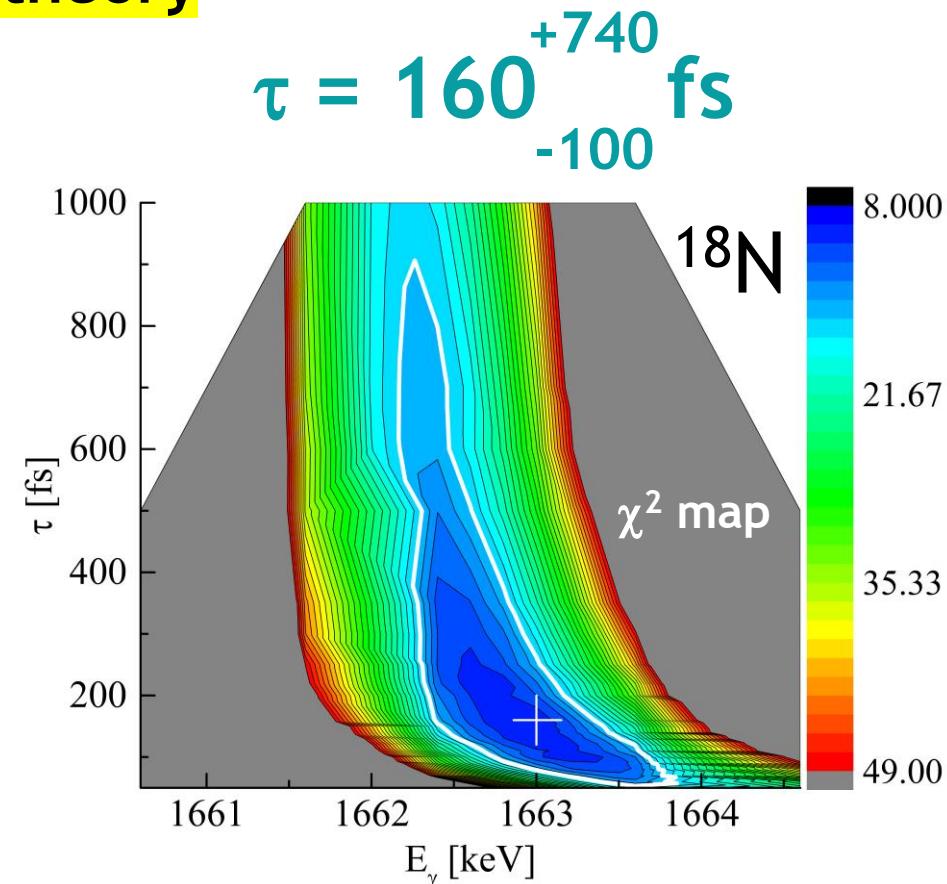
[†]A. Matta et al., CERN-INTC-2013-012/INTC-P-377 (2013)

^{18}N : new spectroscopic information

Very difficult comparison with theory



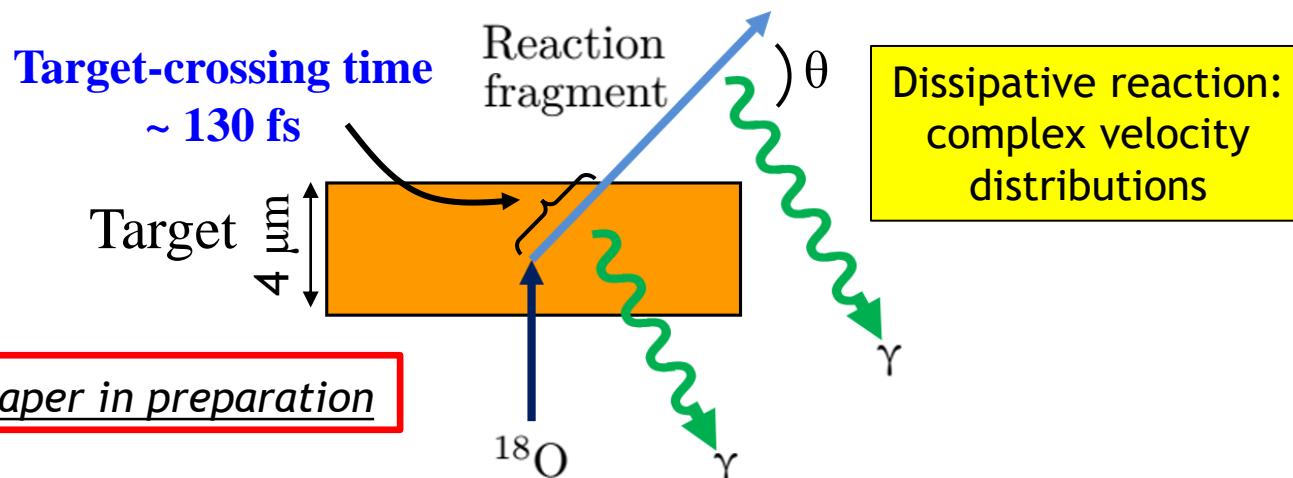
Publication on "Il Nuovo Cimento C" coming in few days



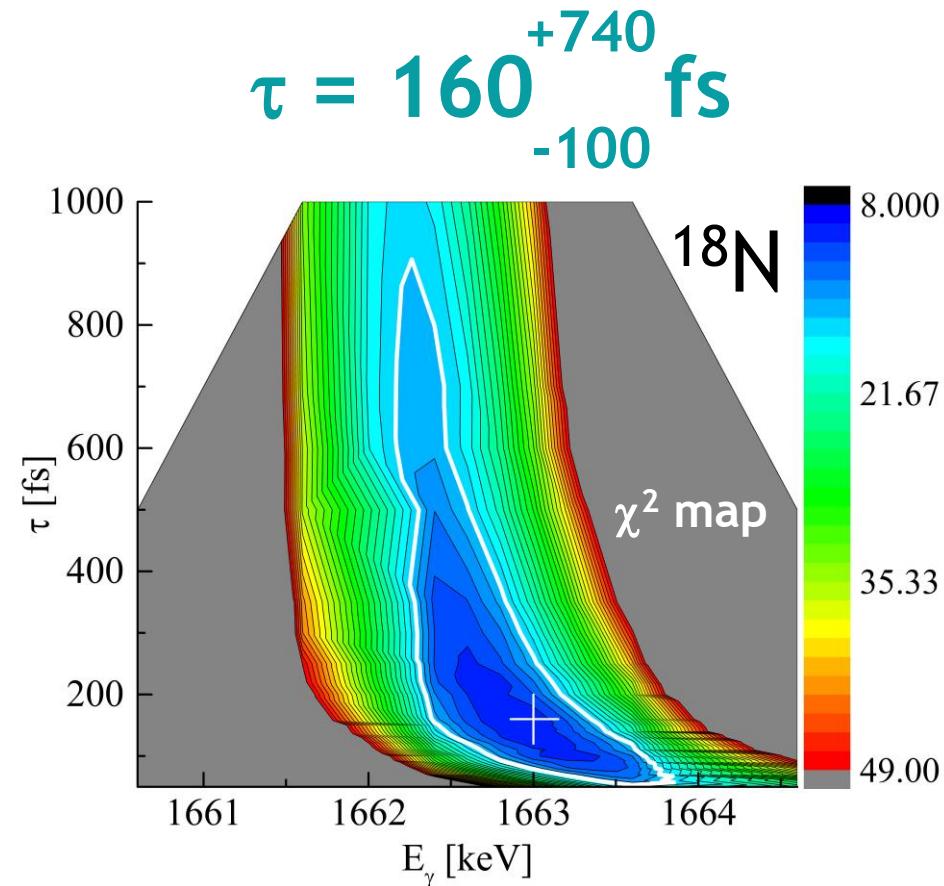
$$E_\gamma = 1663.0(8) \text{ keV}$$

Application of a **novel DSAM implementation** to access **tens-to-hundreds femtoseconds** nuclear state lifetimes with **low-energy binary heavy-ion reactions** and state-of-the-art tracking arrays (AGATA)

Novel DSAM implementation based on Monte Carlo Simulation for dissipative reactions



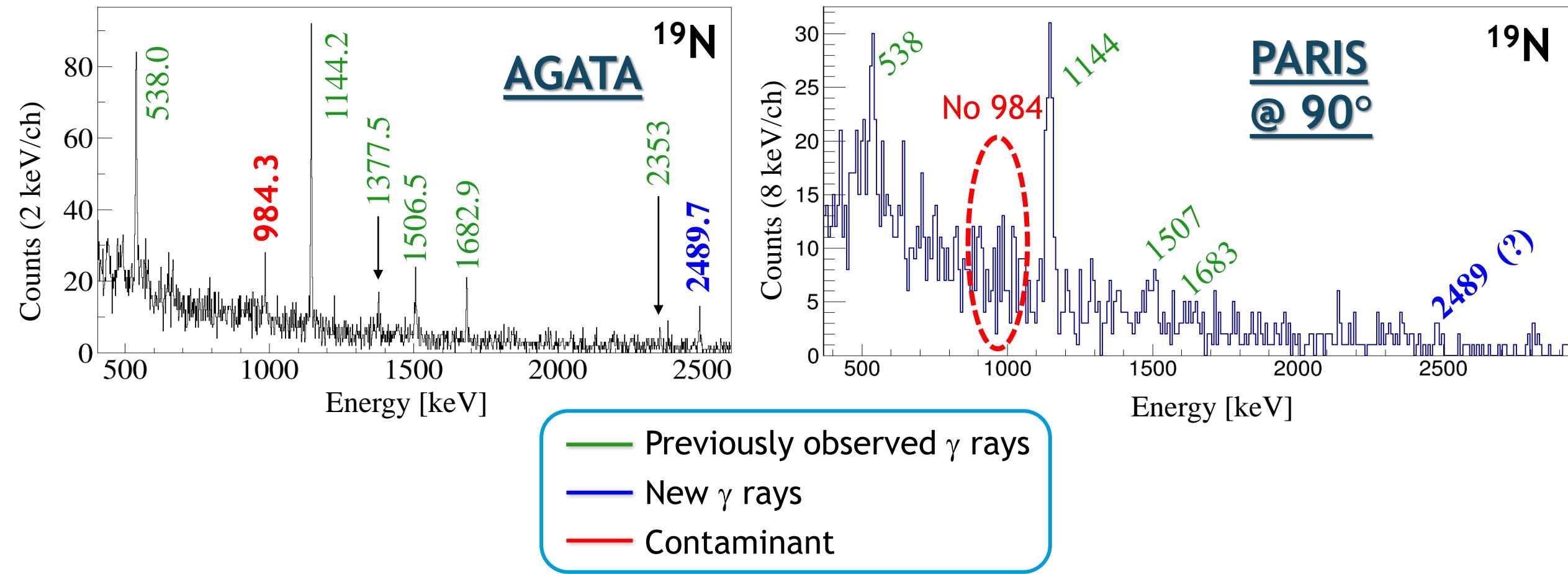
1. Simulation of the reaction and decay mechanisms inside the target (production, slowing down, velocity distribution at emission point and γ decay with fixed lifetime)
2. Simulation of AGATA response (tracking, Doppler correction and experimental resolution and counting rates)
3. Comparison with experimental data
2D χ^2 maps (E_γ and τ) are produced to extract the optimum lifetime



$$E_\gamma = 1663.0(8) \text{ keV}$$

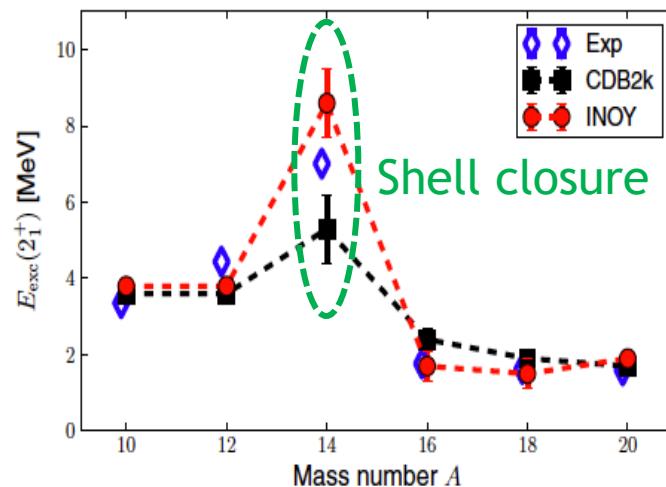
New gamma-ray line at 2489.7 keV

The 984-keV line is a **contaminant** of the ^{180}W partner at 902 keV, not smeared out after Doppler correction

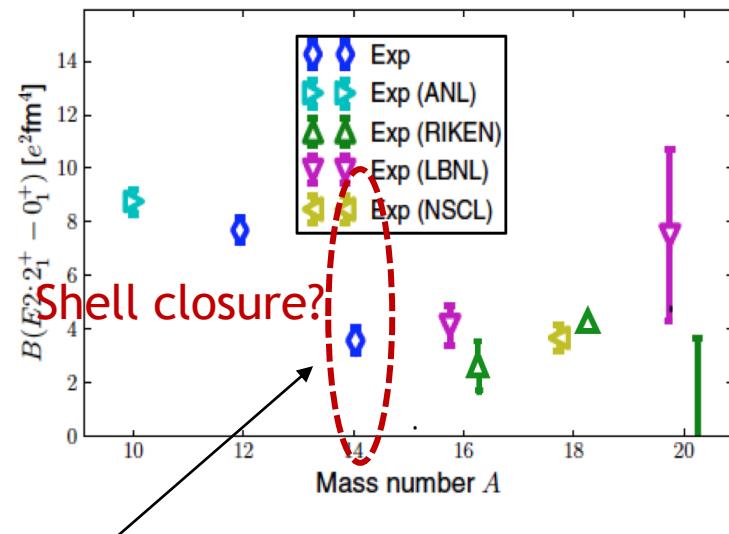


Only magic nucleus of the carbon isotopic chain:
particularly attractive from the theory point of view
→ *test bench for ab initio calculations*

Energies first 2^+



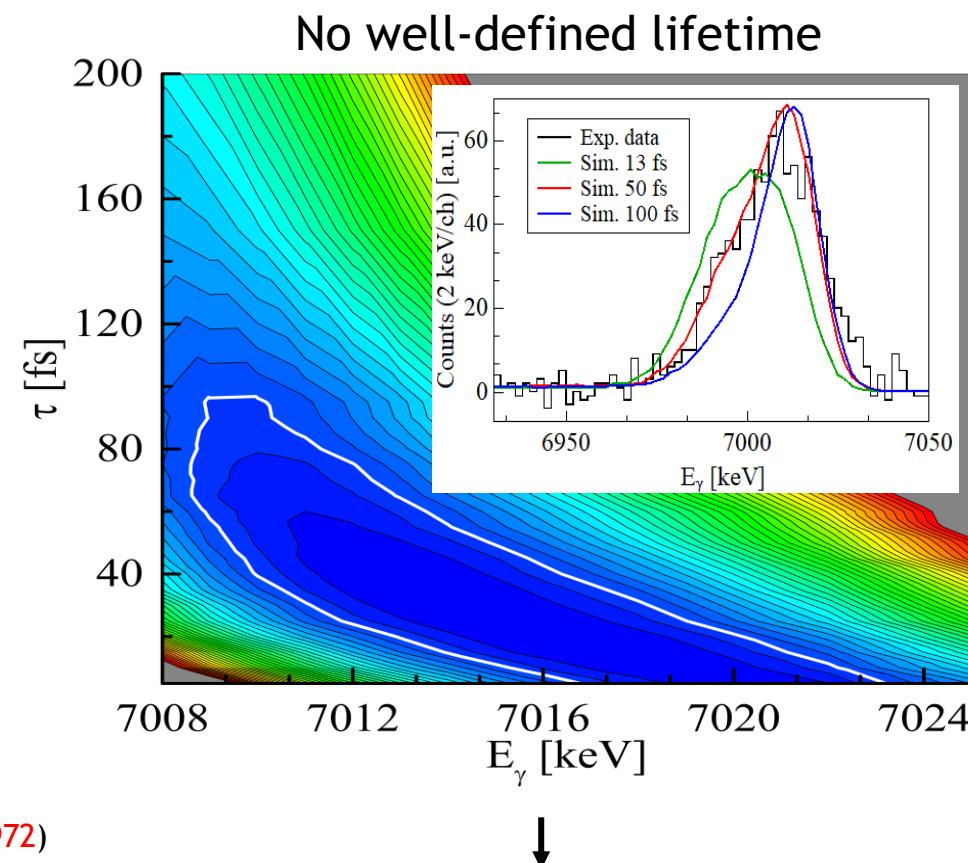
B(E2) first 2^+



Very old value reported in literature - Anomalous trend

H. Crannell *et al.*, Kakuriken Kenkyu Hokoku: Int. Conf. on Nuclear Structure Studies 5, 375 (1972)

Thermal neutron capture experiment on ^{13}C
realised at ILL (Grenoble) at the end of August



Need for a very precise
energy measurement:
 E_{γ} (literature): $7010 \pm 4 \text{ keV}$

Conclusions

Application of a novel technique to access **tens-to-hundreds femtoseconds** nuclear state lifetimes with **low-energy binary heavy-ion reactions** and state-of-the-art tracking arrays (AGATA)

- Extended spectroscopic data of ^{18}N and ^{19}N
- Successful application of the novel lifetime measurement technique to the ^{18}N new state
- Investigation of ^{14}C to measure the lifetime of the first 2^+ state (anomalous trend)
- Application of the lifetime measurement technique to the case of ^{17}N in the future



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VAMOS+AGATA+PARIS
collaboration
e676 experiment @GANIL