Results from the first AGATA-PARIS-VAMOS experiment

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S. Leoni, B. Fornal, M. Ciemala et al.,
Lifetime measurements of excited states in neutron-rich C and O isotopes PARIS (2 clusters + 2 large LaBr3), ***AGATA, VAMOS, (11-23 July 2017, E676)***

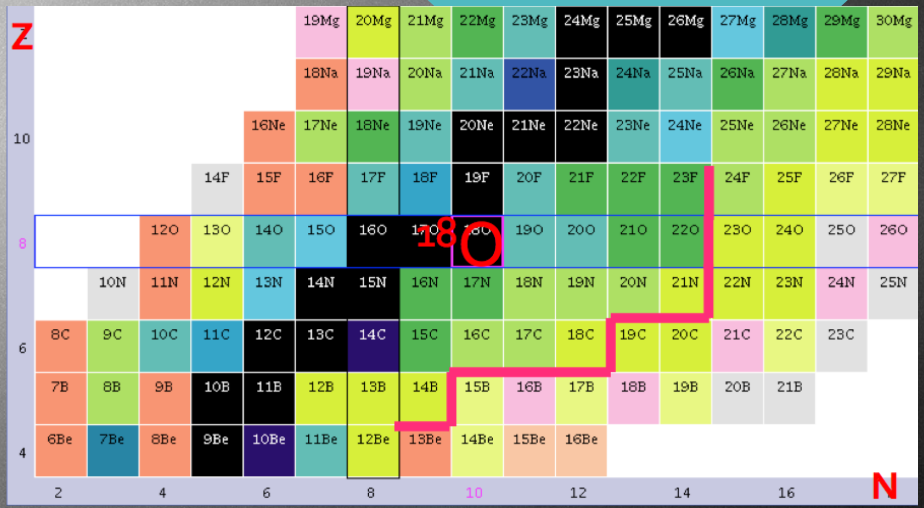
		Interactions				
Nucleus	Excited state	lifetime τ [ps] (*ab initio* NN)	lifetime τ [ps] (*ab initio* NN+ NNN)	mixing ratio δ (E2/M1) for $2^+_2 \to 2^+_1$ (*ab initio* NN)	mixing ratio δ (E2/M1) for $2^+_2 \to 2^+_1$ (*ab initio* NN+NNN)	Experiment τ [ps]
^{16}C	2^+_1	24	24			11.4(10) - 18.3(50)
	2^+_2	0.23	0.08	0.30	0.08	< 4
^{18}C	2^+_1	19.4	20			22.4(3.5)
	2^+_2	2.2	1.1	0.02	0.04	< 4.6
^{20}O	2^+_1	10,3	11,7			10.70(40)
	2^+_2	0.32	0.20	0.24	0.04	-
^{22}O	2^+_1	0.40	0.46			0.69(28)
	2^+_2	0.064	0.043	0.33	0.05	-

Main experimental goal
Measure second 2+ lifetimes for 20O and 16C with use of Doppler shift method

VAMOS++ at 45 degree
VAMOS entrance detector:
2 DC (for ions angle)
VAMOS focal plane:
DC (for Brho reconstruction),
6 rows of IC (for ΔE)
Plastic (for trigger and ToF)

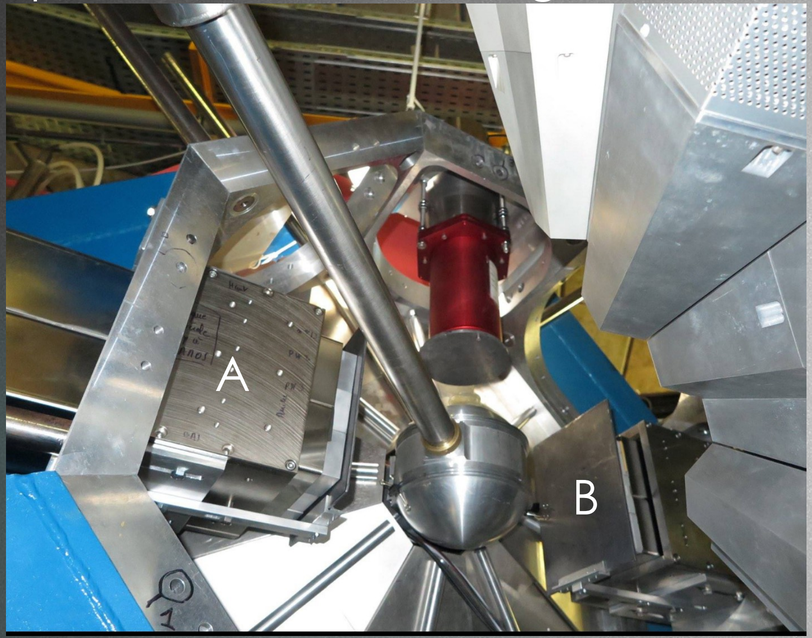
Reaction:
18O 7.0 MeV/A beam,
181Ta (4 μm thick)

AGATA:
31 crystals placed at backward angles



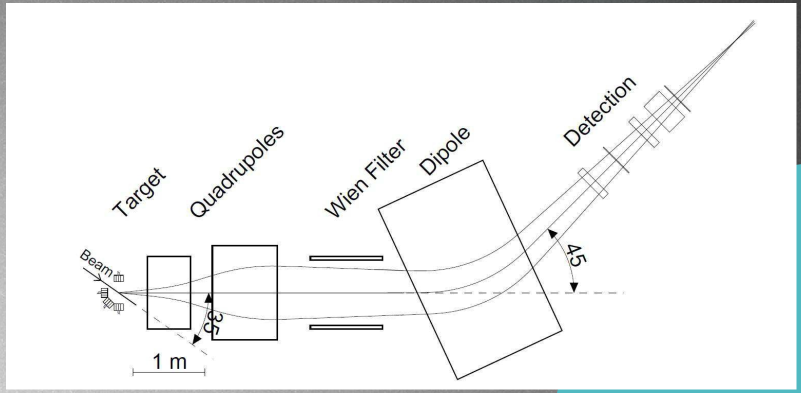
PARIS setup

1 LaBr3-NaI cluster (A) in magnetic shield
1 CeBr3-NaI cluster (B) in magnetic shield
1 big LaBr3 in magnetic shield
1 big LaBr3 without magnetic shield
All placed around 90 degree

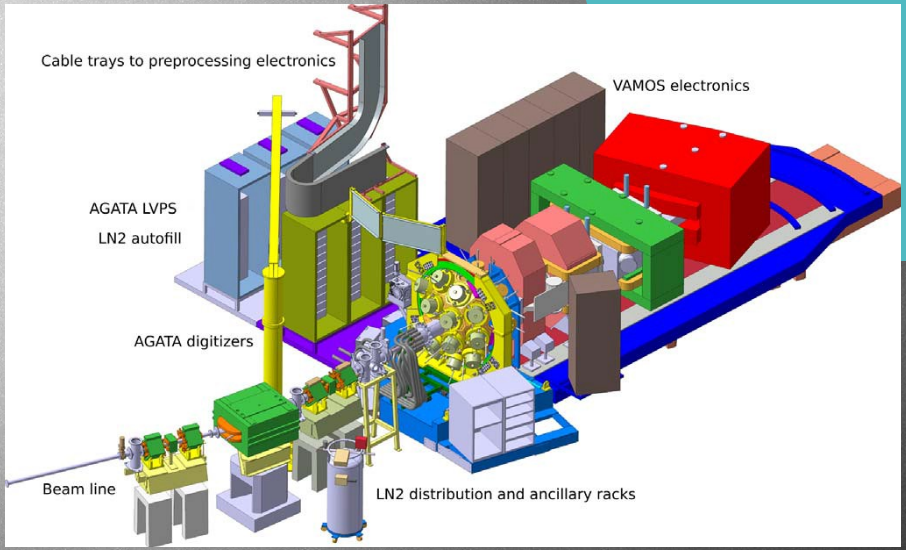


A shield for VAMOS magnetic field needed!
Designed at IPHC Strasbourg and tested in dec. 2016 at VAMOS (build of 2 mm mu-metal + 10 mm of mild steel)
Additional EXOGAM 3x2mm mu-metal plates

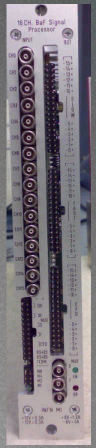
PARIS and LaBr3 shielded with 4 mm Pb in front



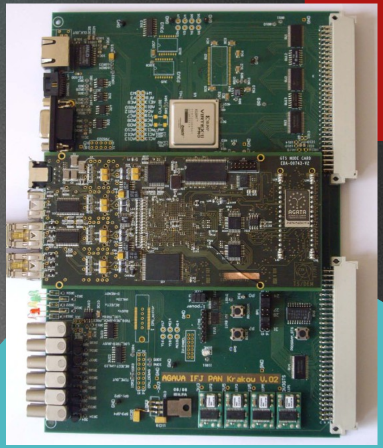
Scheme of VAMOS++



E. Clement et al. NIMA 885, 1-12 (2017)

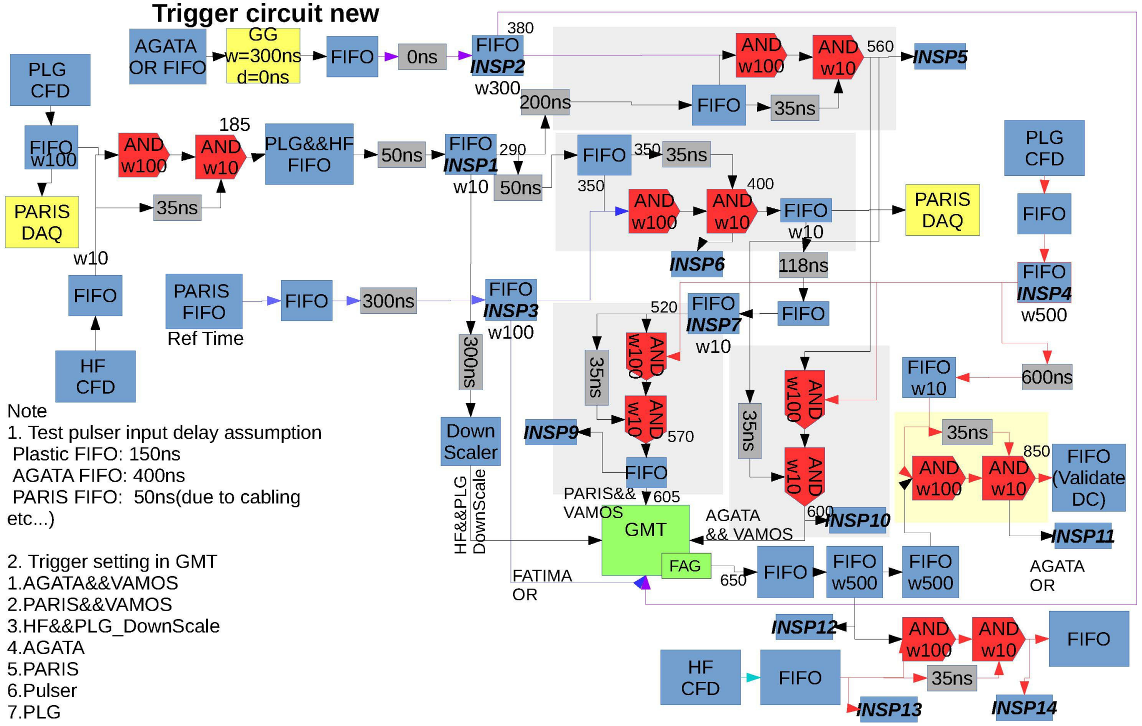


BaF/PARIS Pro



AGAVA module

Trigger circuit new

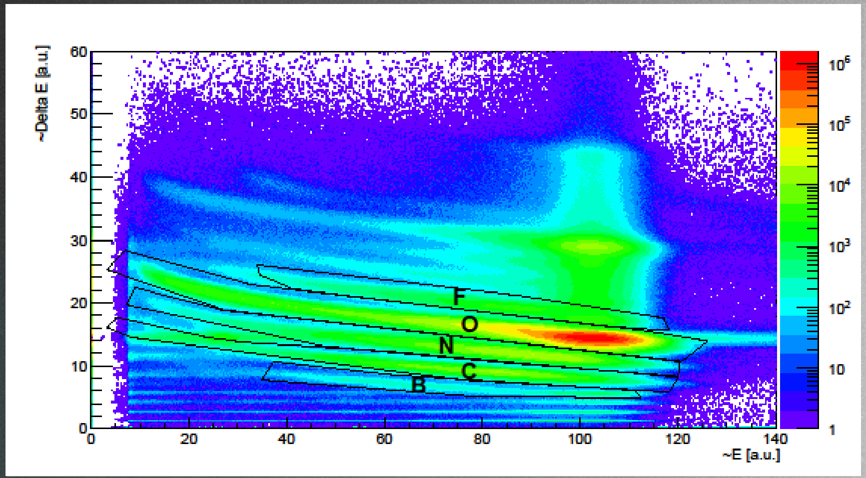


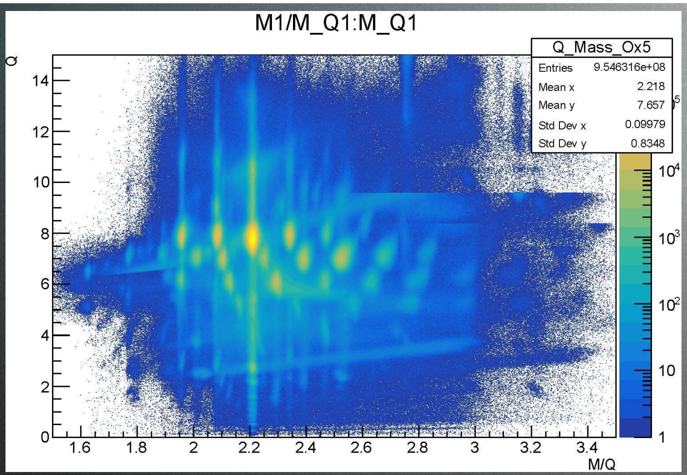
Note
1. Test pulser input delay assumption
Plastic FIFO: 150ns
AGATA FIFO: 400ns
PARIS FIFO: 50ns(due to cabling etc...)

2. Trigger setting in GMT
1.AGATA&&VAMOS
2.PARIS&&VAMOS
3.HF&&PLG_DownScale
4.AGATA
5.PARIS
6.Pulser
7.PLG

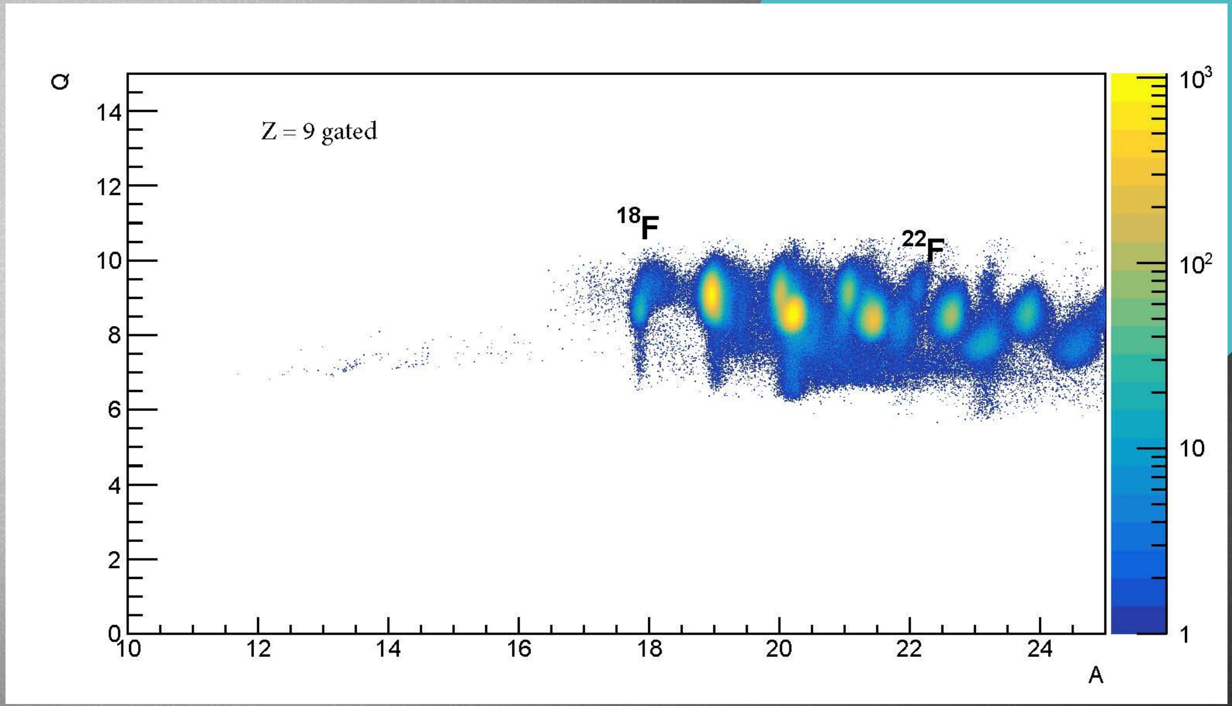
VAMOS: Z and A selections

Selections are basing on:
Delta E (IC) versus E (IC + plastic) for Z id.
A/Q is reconstructedfrom Brho (focal DC) and velocity

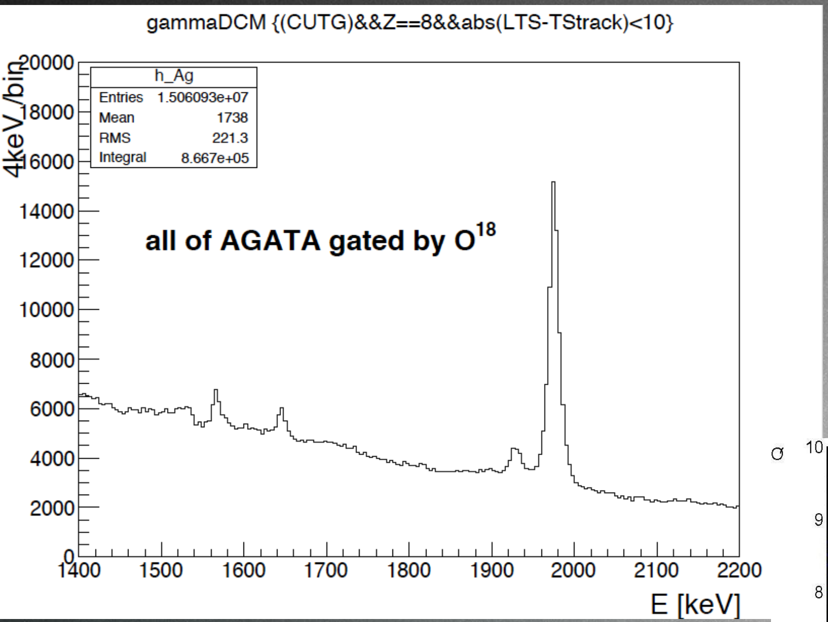


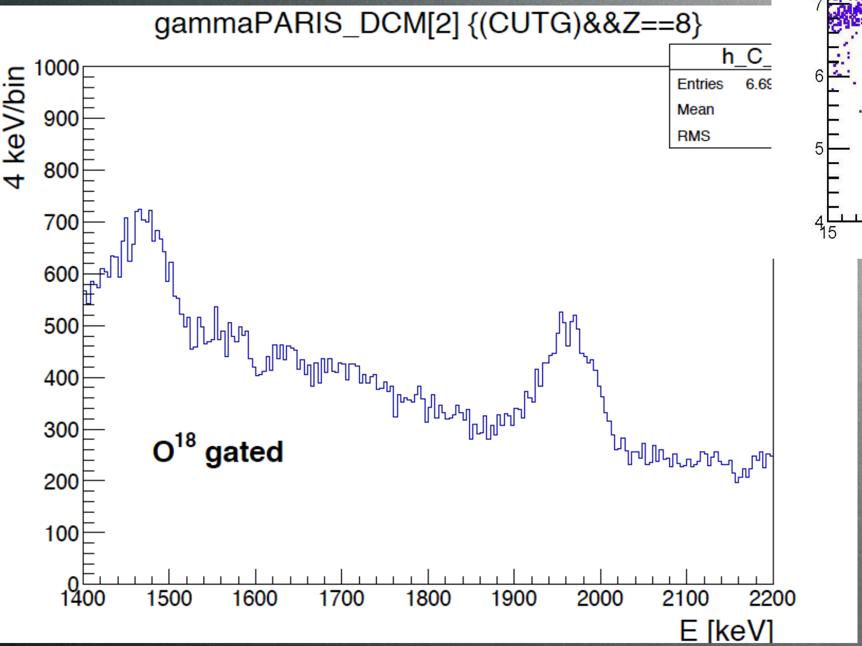


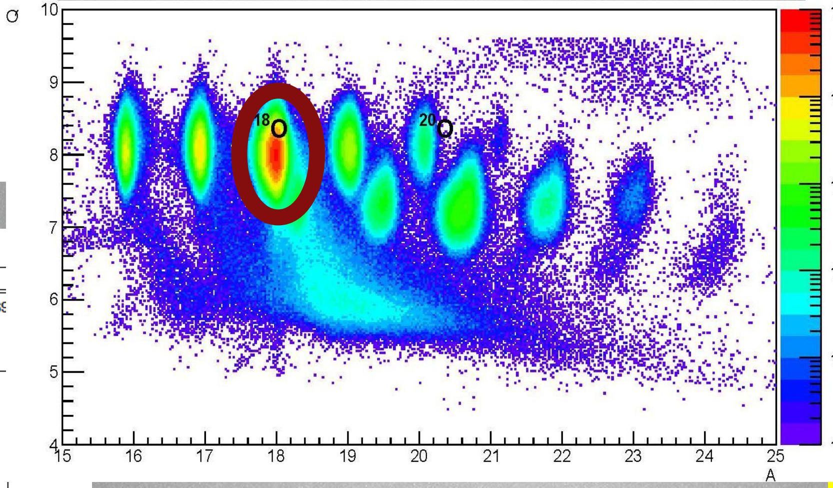
M/Q and Q with no conditions

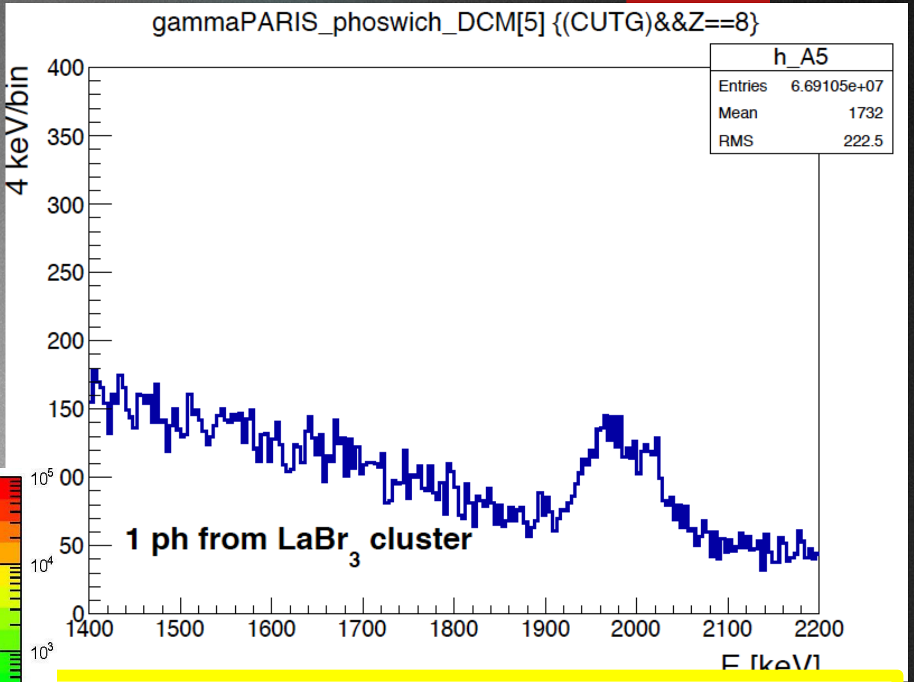


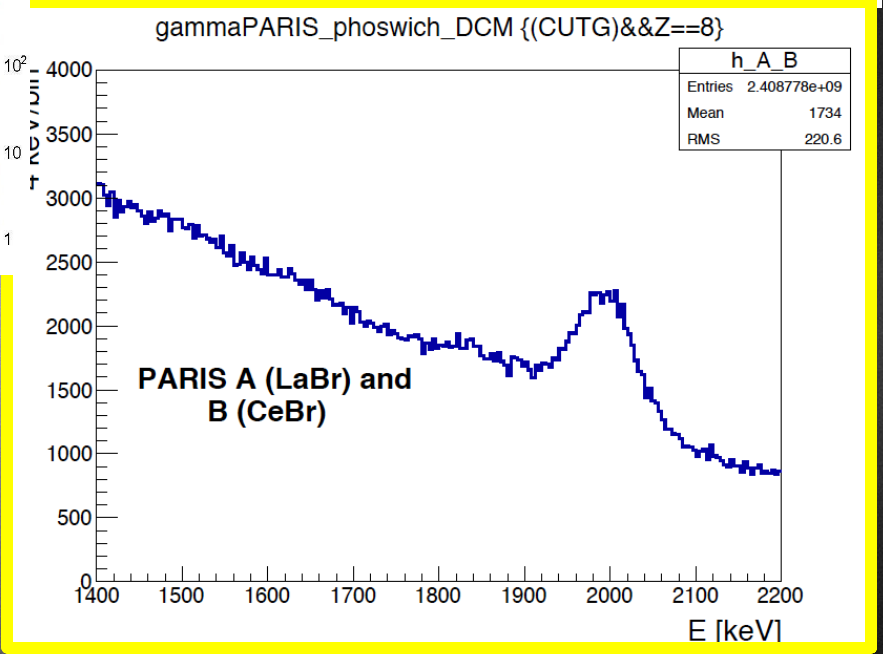
M and Q with gate on selected Z







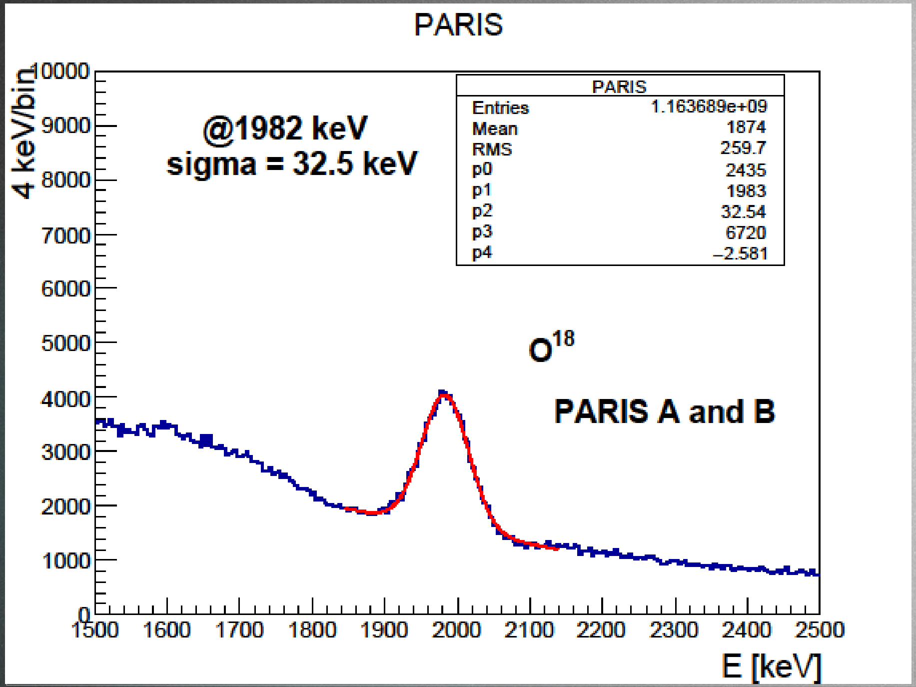


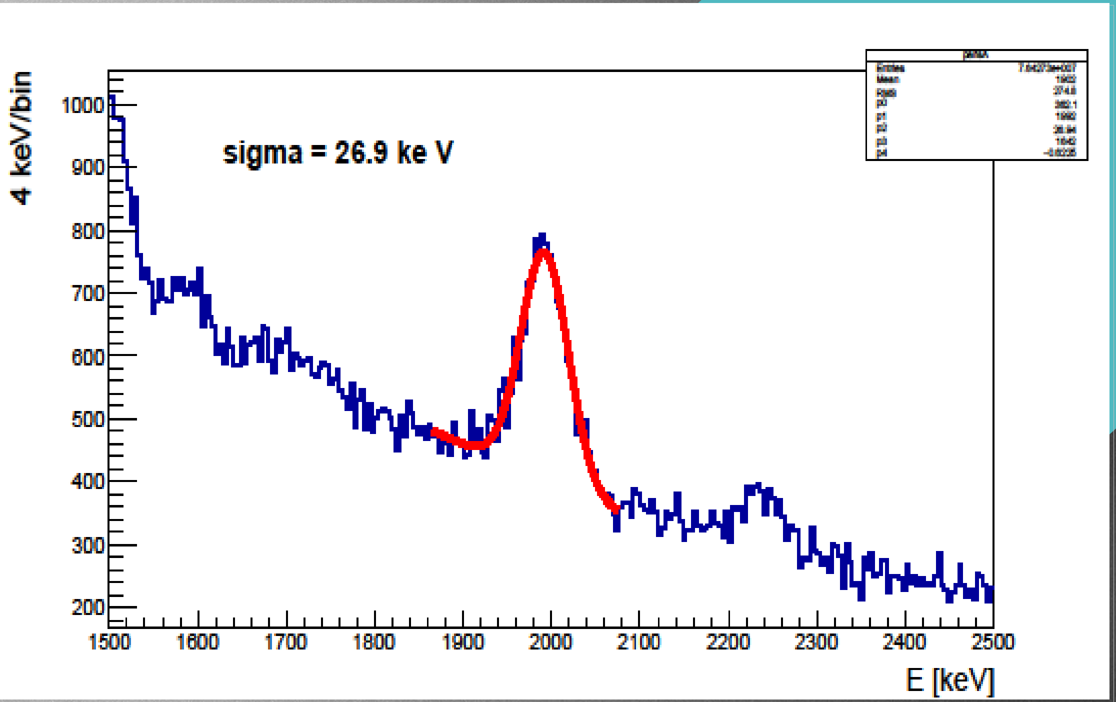


Ratio of nr of counts in peak in PARIS to nr of counts in peak in AGATA = 0.92

PARIS
FWHM/E = 5.0% (@ 662 keV)
with magnetic field switched on;
4.7% with swithed off

Big LaBr3
FWHM/E = 3.5% (@ 662 keV)
with magnetic field switched on;
3.3% with swithed off





PARIS 2 cl. LaBr3 and CeBr (2" square shape)
Doppler corrected gamma spectrum
emitted by 18O with beta = 0.1c,
sigma = 32.5 keV
FWHM/E = 3.9% (@ 1982 keV)

Big LaBr3 (Diameter 3.5"), sigma = 26.9 keV,
FWHM/E = **3.2% (@ 1982 keV)**

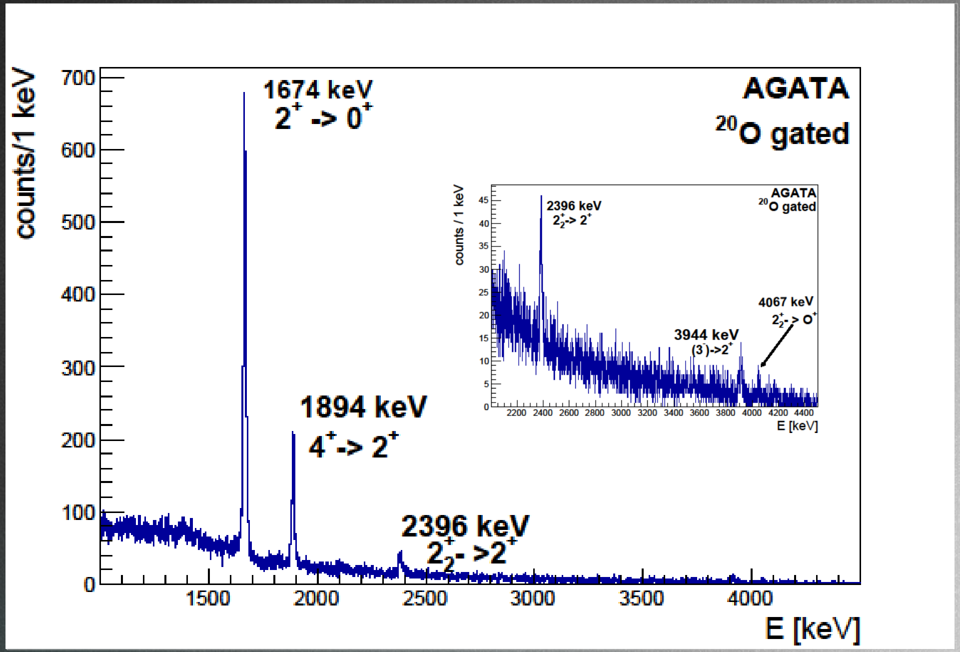
Granulation of PARIS helps in Doppler broadening correction

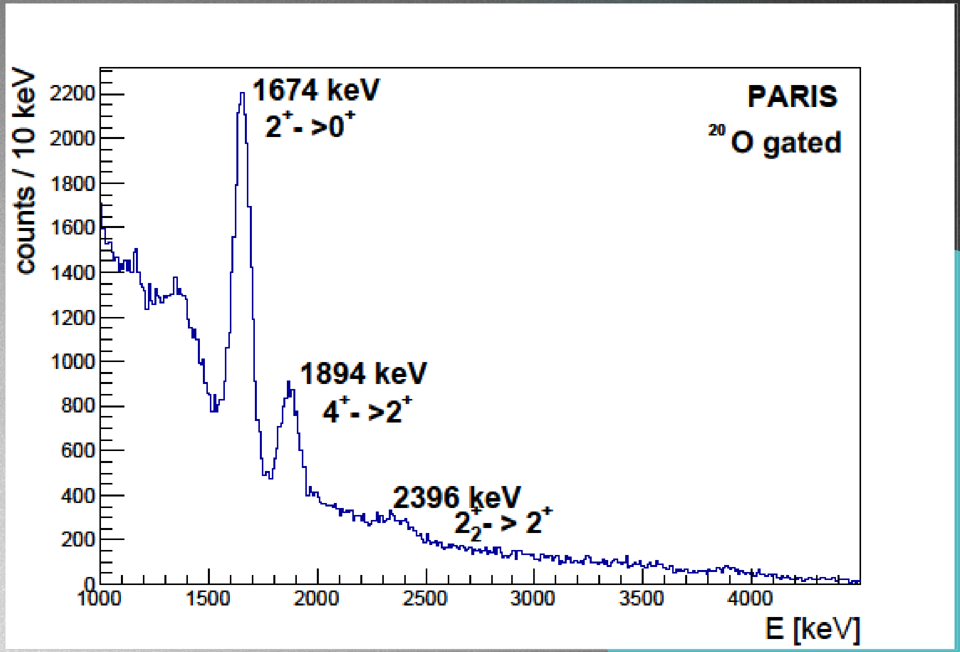
PARIS performance with 60Co, magnetic field on

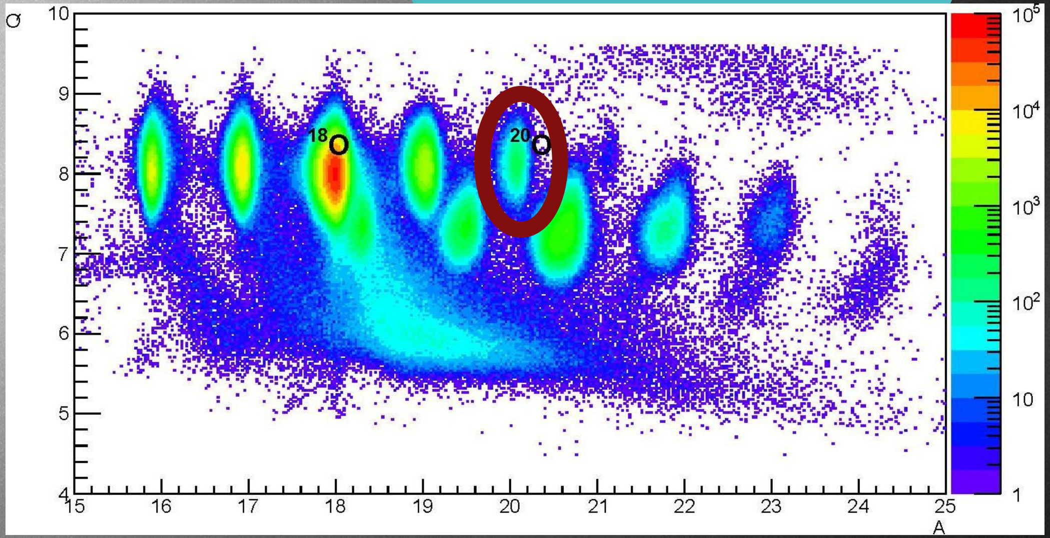
After removing 3 worst LaBr - all of them are old types

1	3.643687	5.092639	4.52078	6.461945
2	4.556489	8.33547	3.838807	5.412377
3	4.536139	7.087935	3.496675	5.900171
4			4.368846	6.171717
5	3.308528	6.356404	3.725846	5.554212
6	4.9068	6.583658	3.497768	6.568201
7			4.509137	5.492337
8			3.901281	5.969133
9	4.235209	5.744096	4.362971	5.633507

20O spectra (ion of interest)

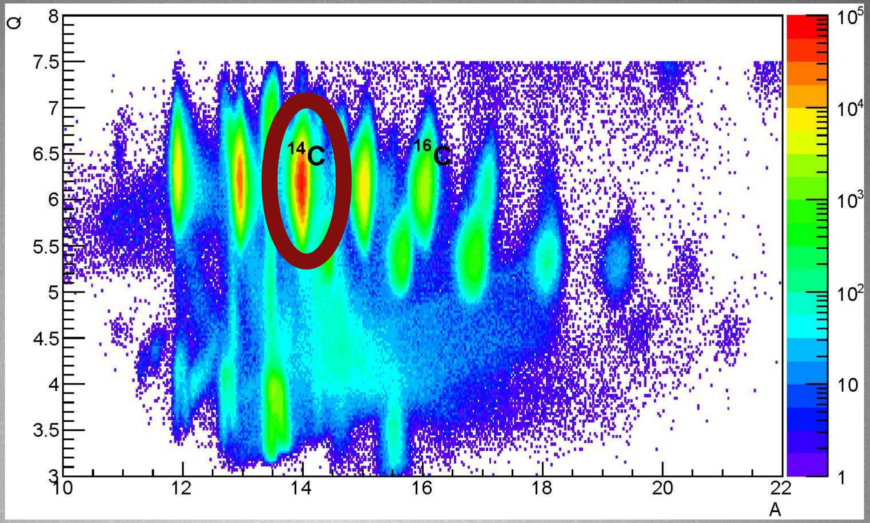




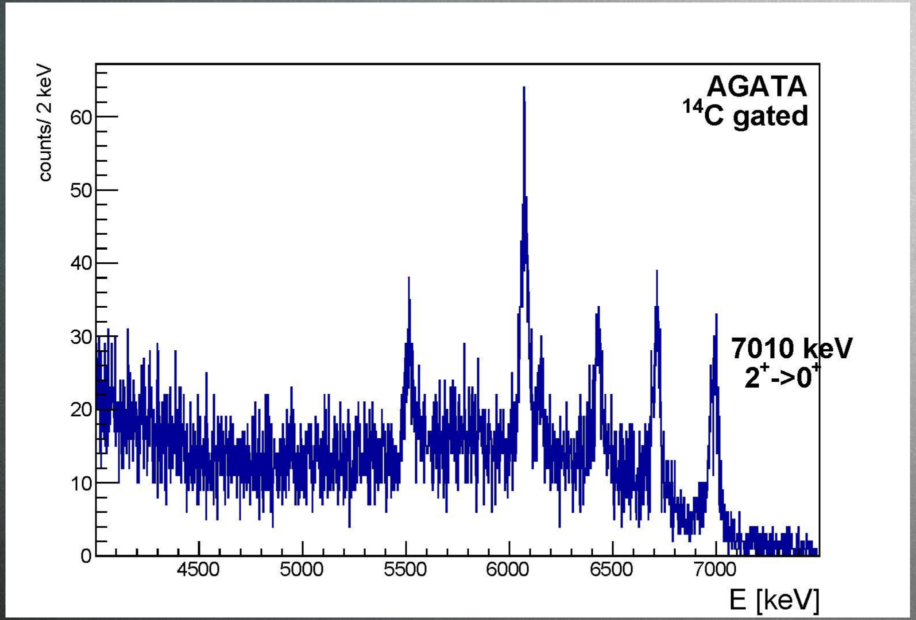


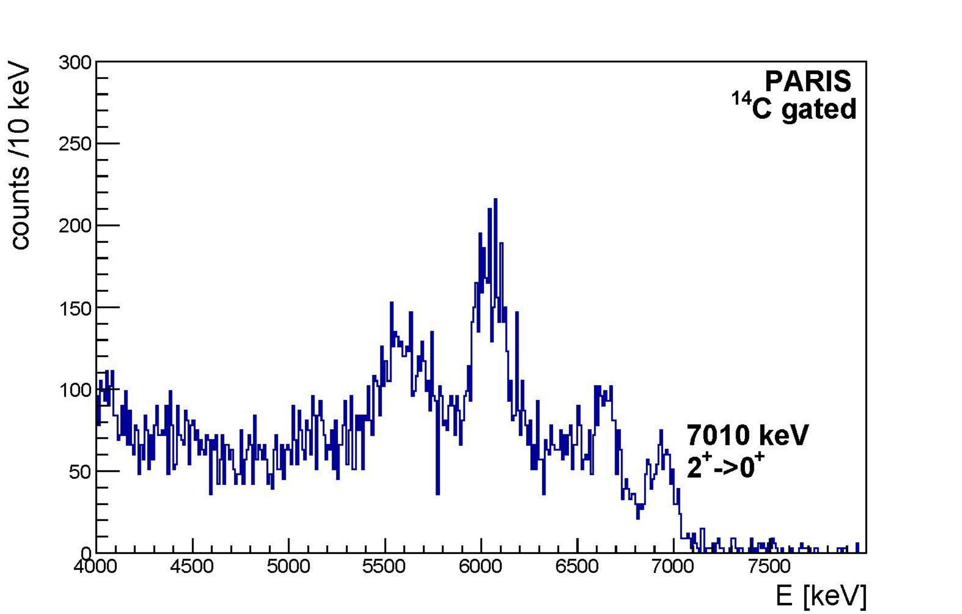
Gamma-rays measured by PARIS in coincidence with AGATA, will be used for determining gamma decay branching ratios for most populated C, N and O isotopes.
Moreover, PARIS data will be used for measuring the gamma-ray angular distributions, providing the data point for theta angle around 90 degrees.

14C spectra



Ratio od nr of counts in peak in PARIS to nr of counts in peak in AGATA = 1.5, @7010 keV





Sensitivity of the method – test case 18O

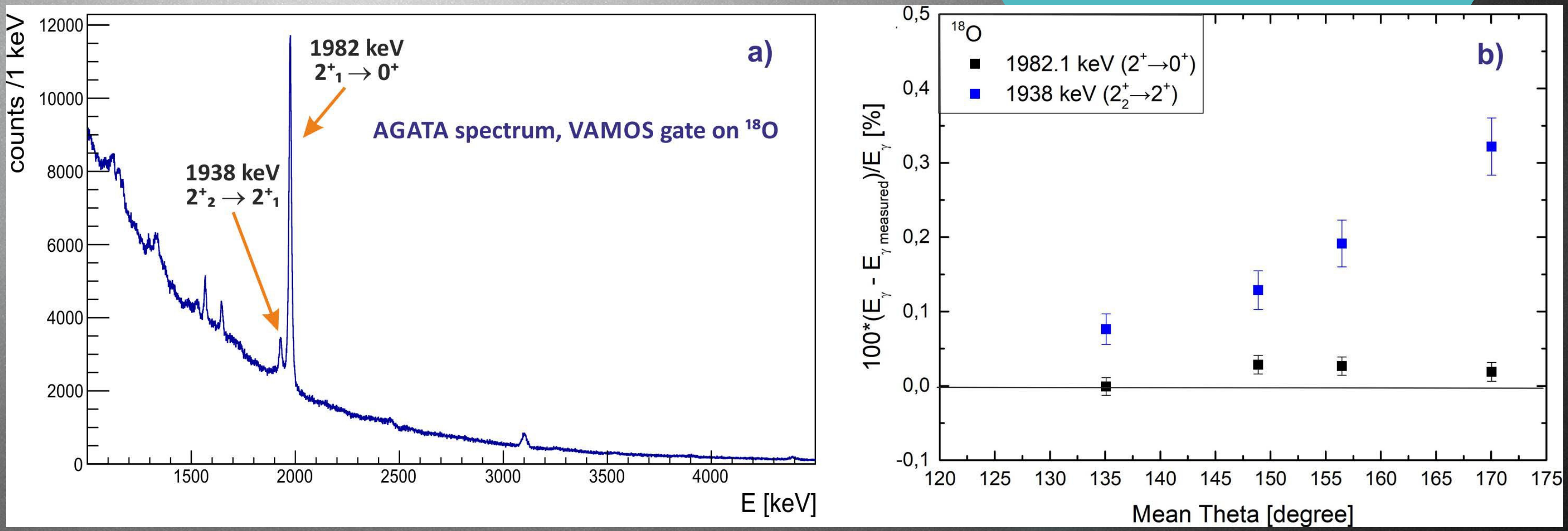
18O:

i) 1982.1 keV gamma-ray from the decay of the 2+1 state with known lifetime of 2.80 ps

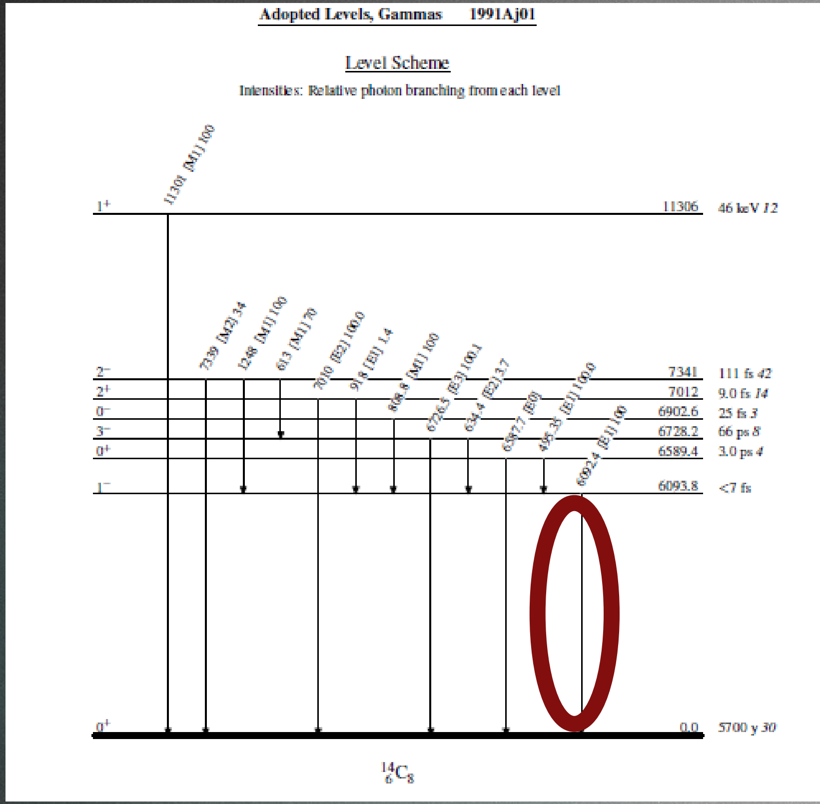
ii) the 1938 keV from the 2+2 state, with lifetime 26.5 fs

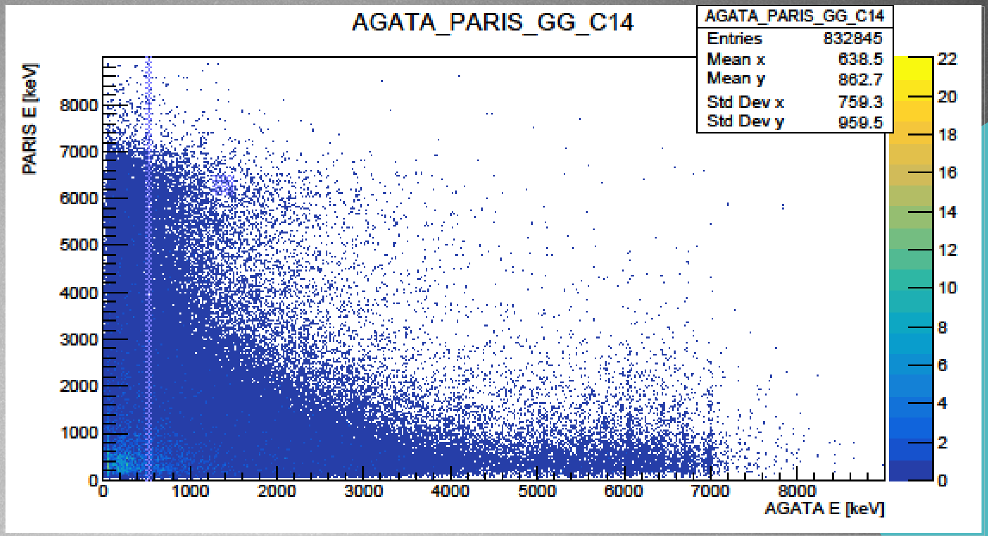
AGATA detectors was divided into 4 groups, with average theta angles: 135°, 149°, 156° and 170°. Energy of centroid for the lines, at each angle was obtained.

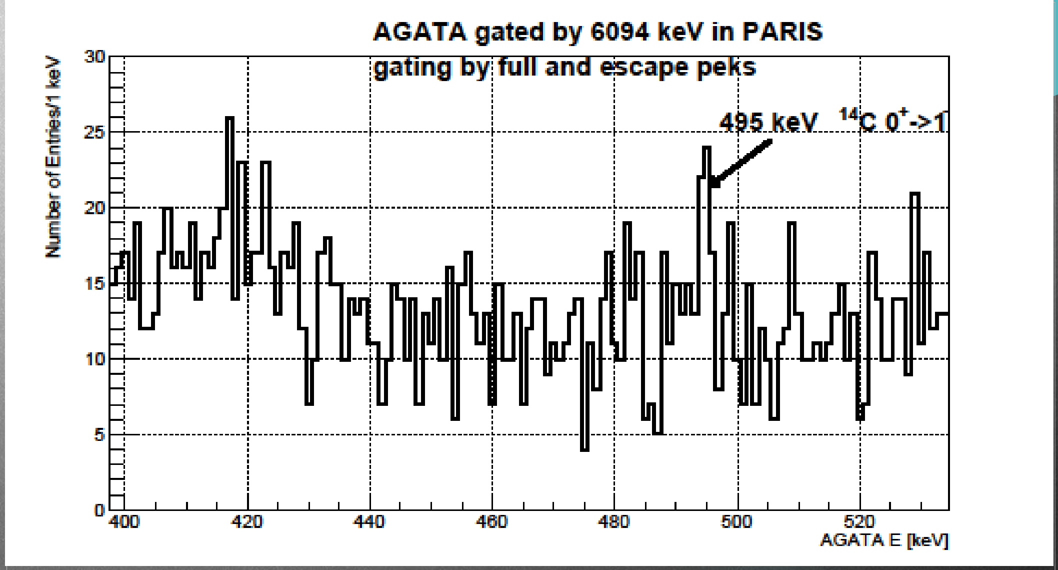
Then we look at the relative energy difference between these centroids and the nominal energy (taken from literature).



PARIS-AGATA $\gamma\gamma$ matrix for 14C ions



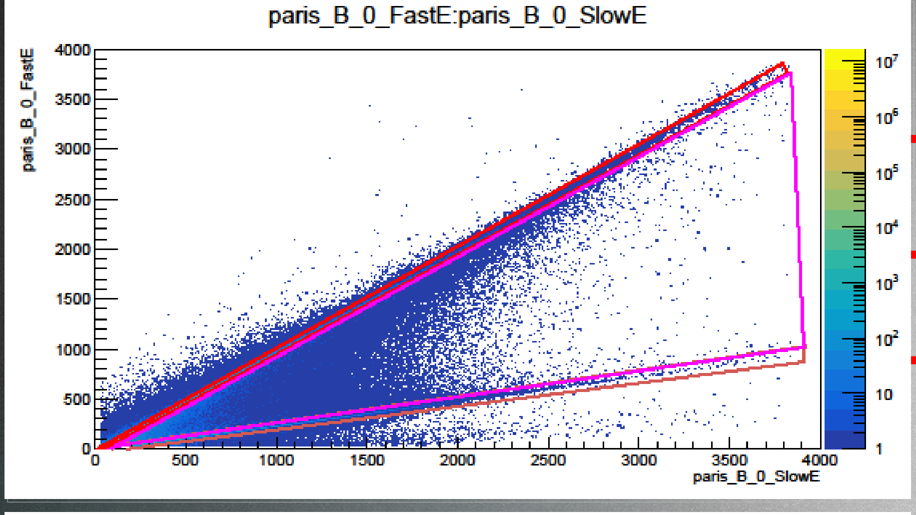


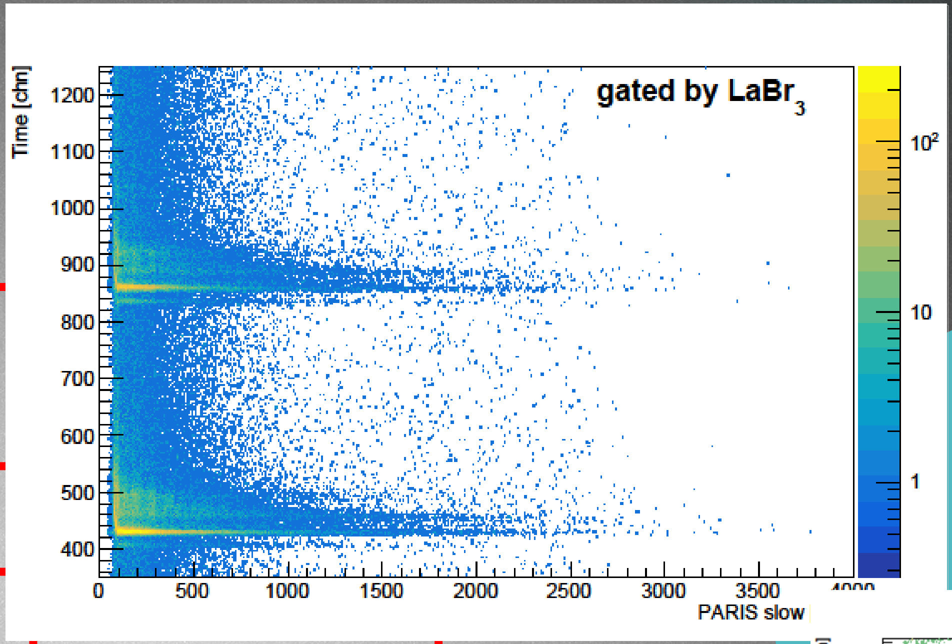


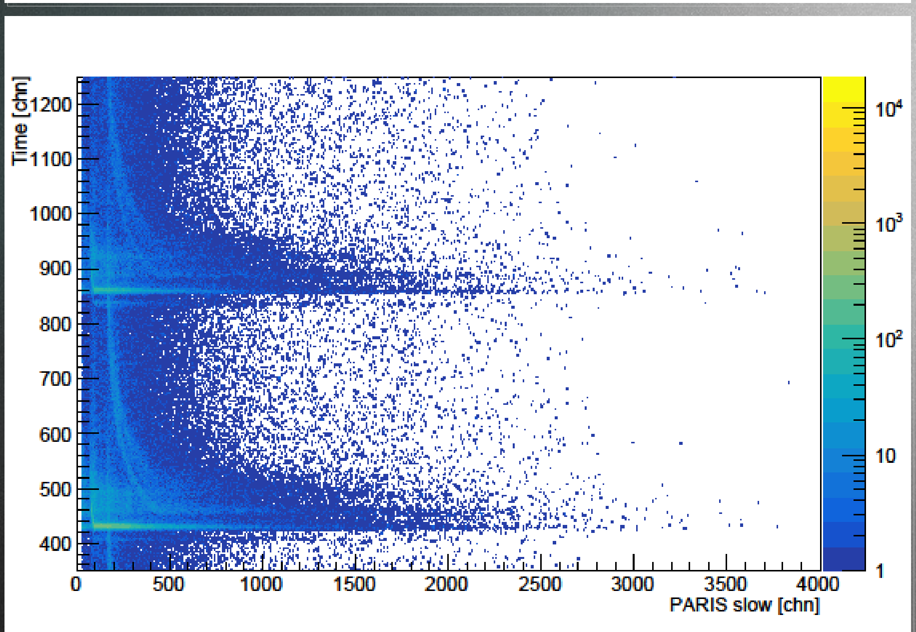
Possibility of use PARIS for gating on high energy gamma-rays (6.09 MeV) and look in AGATA for coinciding ones.

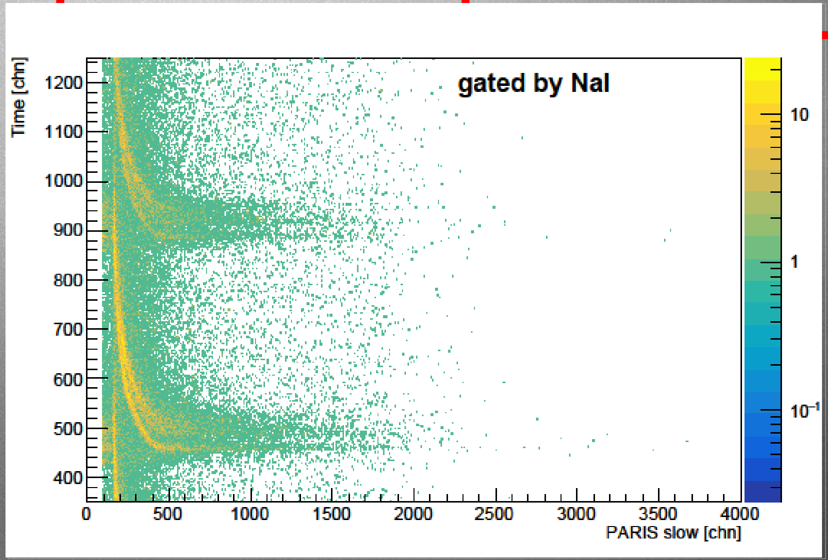
PARIS time information

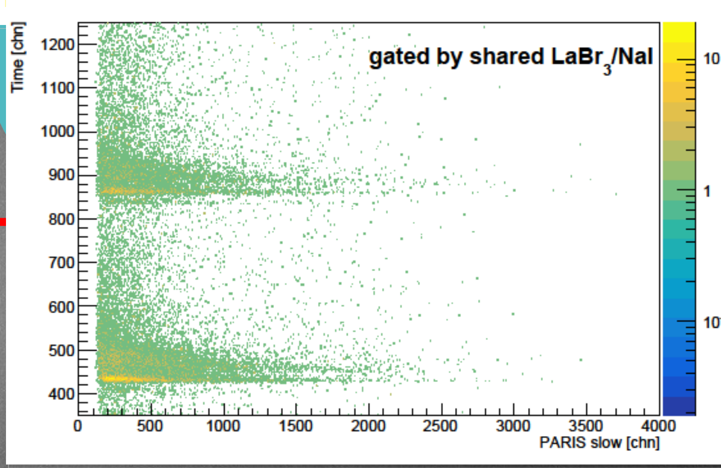
PARIS time (RF start, PARIS stop)







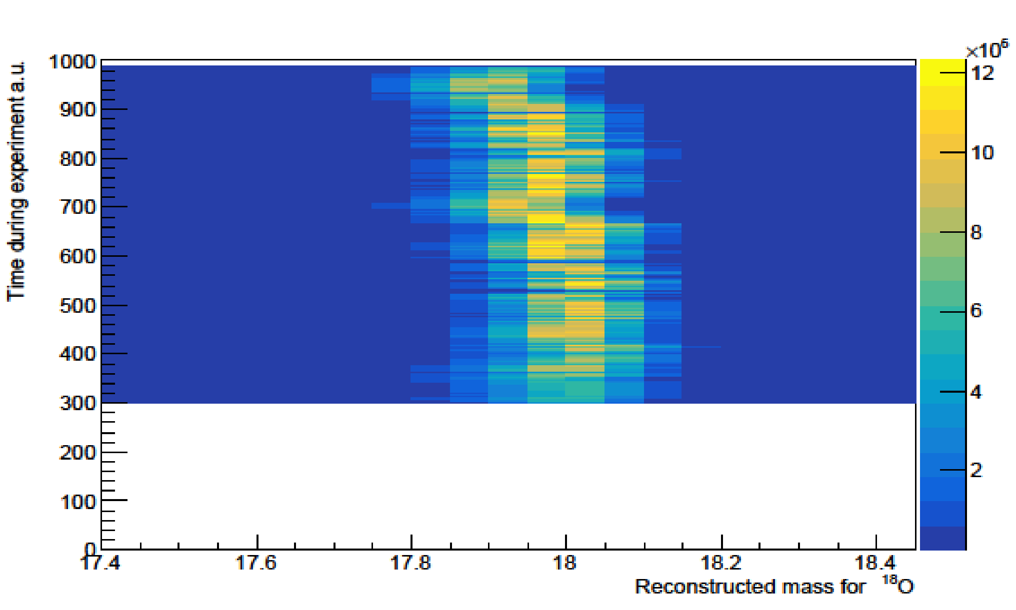


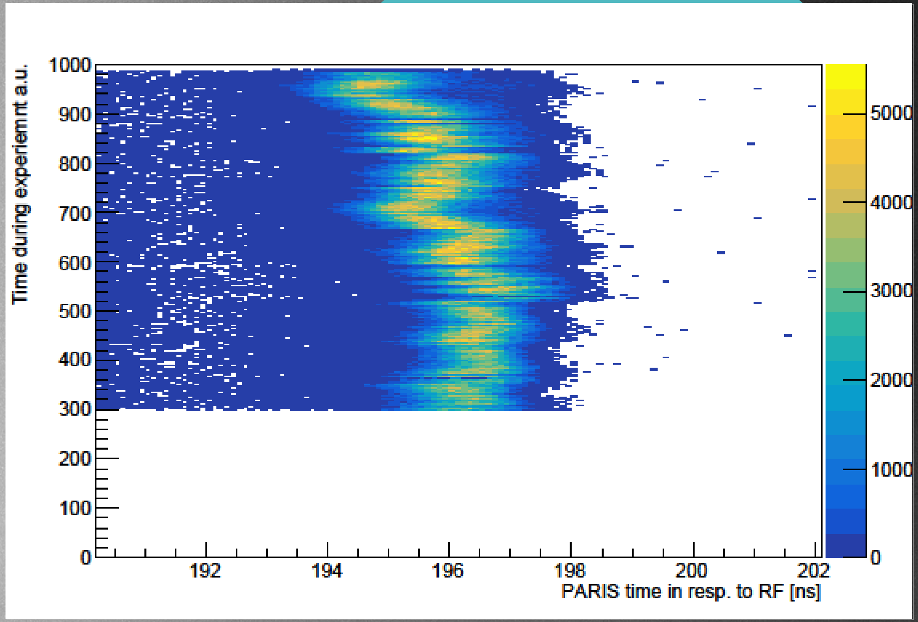


Need to use Tcuts for time gates for NaI part

PARIS timing – correction to velocity

We measure V by path in spectrometer and time between RF and Plastic at the end of focal plane.



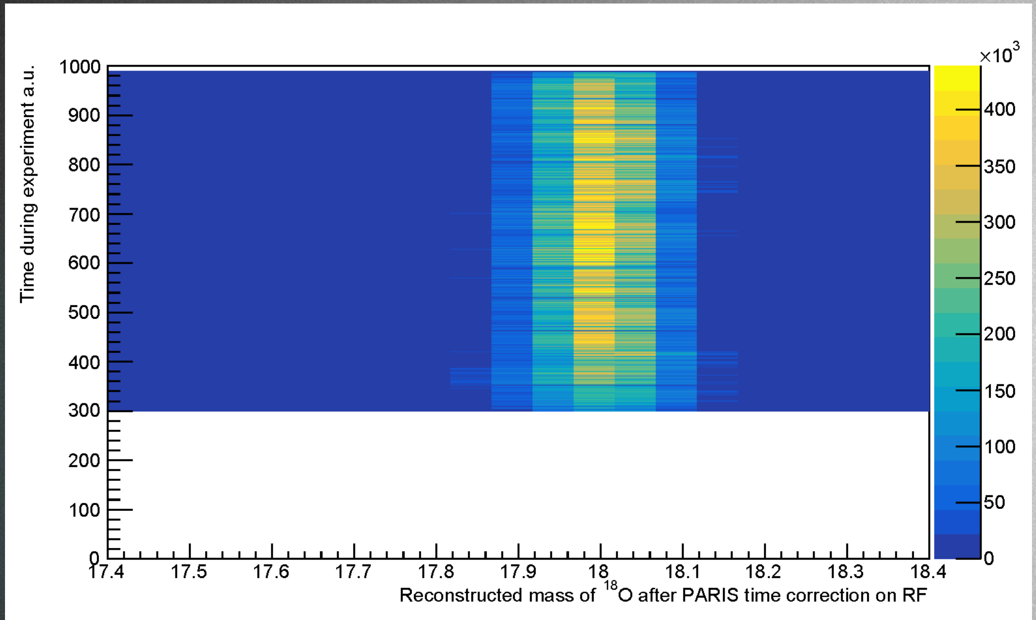


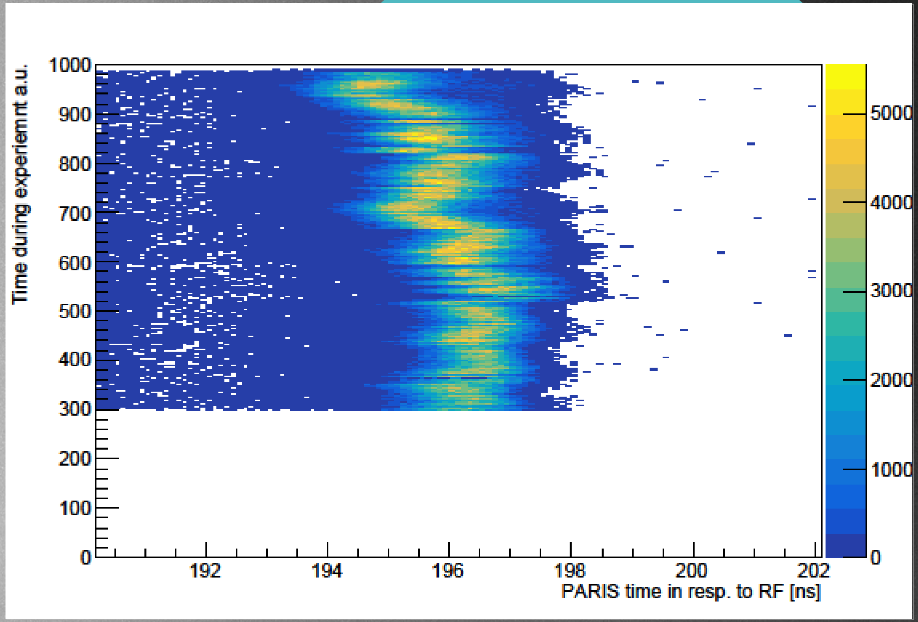
But RF signal is not stable in time in respect to beam on target – best observable is Mass (calculated from Brho and V)

We are using PARIS (LaBr part) vs. RF timing to correct RF fluctiations (up to 2 ns, epsecially at the end of exp.)

PARIS timing – correction to velocity

We measure V by: measure path in spectrometer and time between RF and Plastic at the end of focal plane.





Thanks to PARIS timing we recovered good A reconstruction/stability (it means also good V)!

We are using (mean) PARIS vs. RF timing to correct RF fluctiations (up to 2 ns, epsecially at the end of exp.)

Further improvements before final result

- AGATA (re)calibration and data replay
- AGATA check of the neutron damage corrections and crtoss-talk matrices
- AGATA tuning to get good data with not performing well detector(s)
- AGATA stability check during the experiment
- VAMOS focal plance DC (re)calibration which will provide better Brho reconstruction (and better separation on ID plot and path in the spectrometer)
- VAMOS timing properties tuning (timing of the plastic adjustements)
- PARIS tune all of phoswiches aligment during time of experiment

Conclusions

- We collected enought statistic for case of 20O to perform lifetime analysis
- LaBr3 and also CeBr+NaI phoswich is a viable solution for the elements of the PARIS calorimeter, also in terms of its meeting the requirements for energy and timing resolution.
- **It is shown possibility of PARIS to be used for gating on high Energy gamma-ray transitions as well as good PARIS timing properties are very usefull.**
- **Data analysis of GANIL experiment is in progress!**

Acknowledgements

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