Gamma decay from near-threshold states in 14C: a probe of clusterization phenomena in open quantum systems

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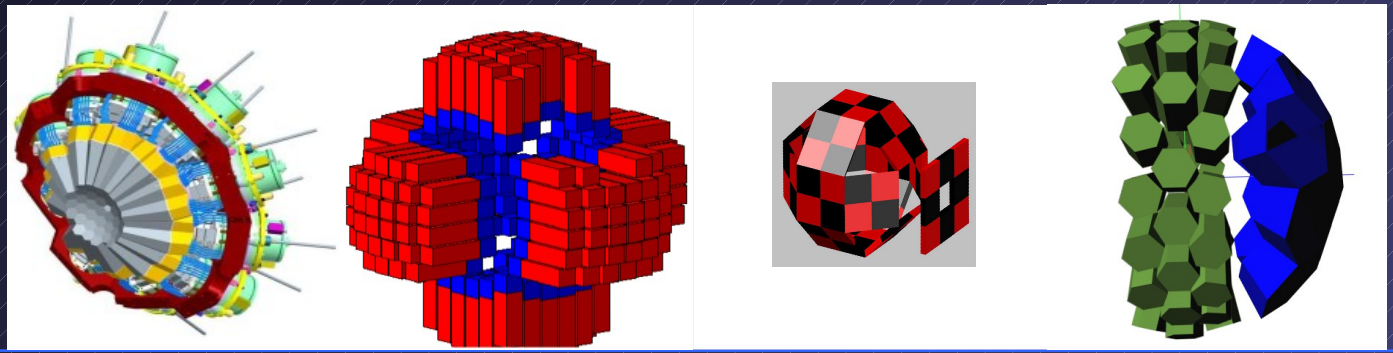
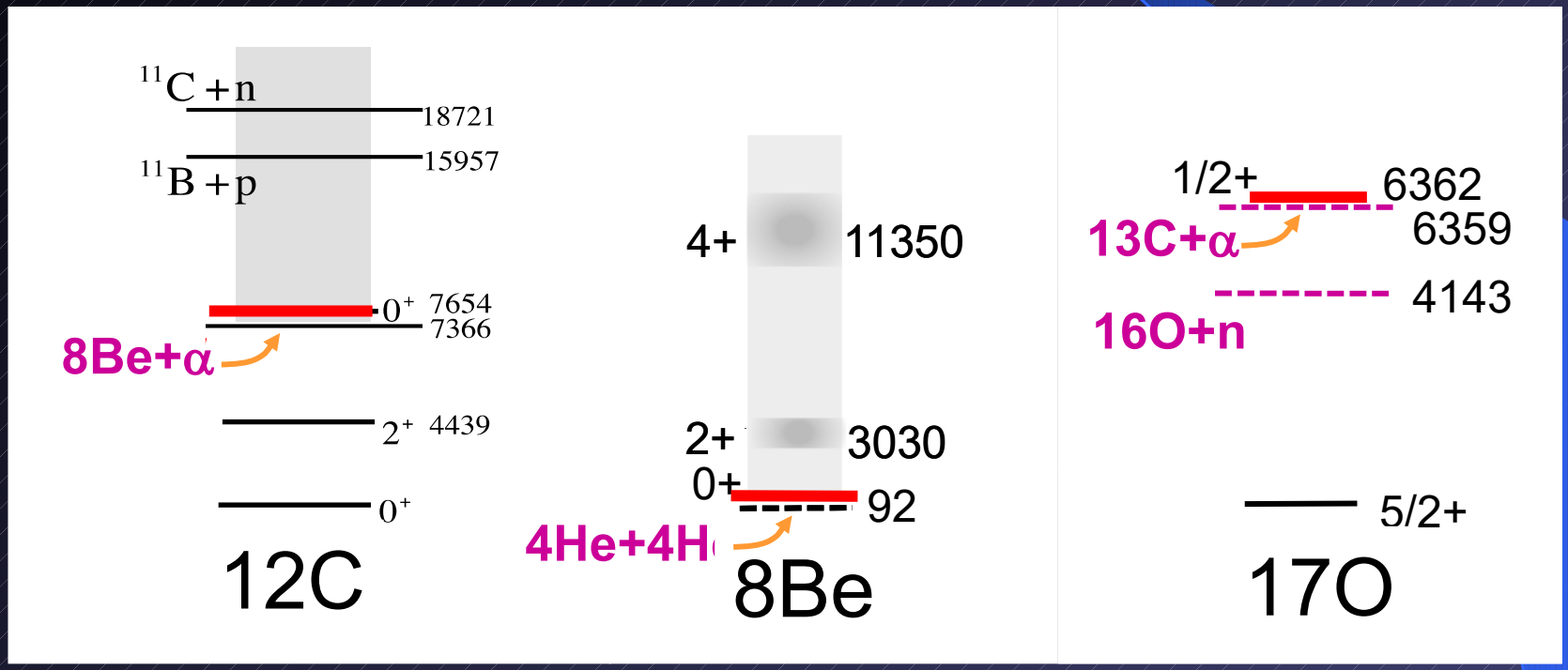
7 days approved (22 UT's)



Observation: cluster states in nuclei seem to exist around almost any cluster-decay threshold

(K. Ikeda et al., Prog. Theor. Phys. E68, 464–475 (1968)

Near-particle-threshold states in nuclei – examples:



Cluster/particle near-threshold states may be used for studying the emergence of clusterization in microscopic approaches (SHELL MODEL, ab-initio …)?

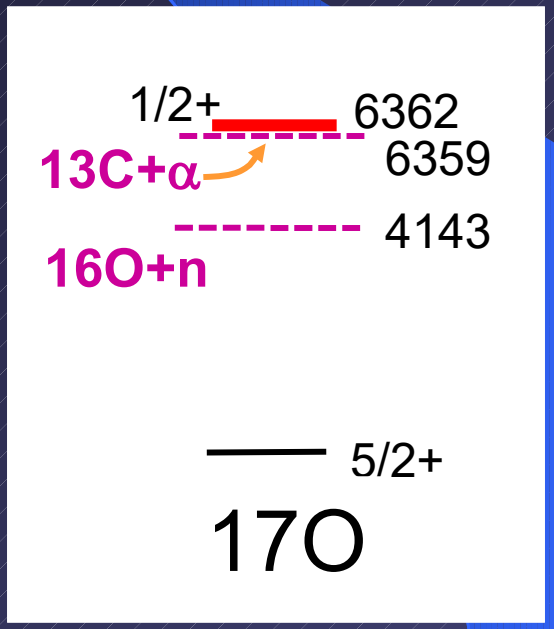
SHELL MODEL Embedded in the Continuum (SMEC)

J. Okolowicz, M. Ploszajczak, W. Nazarewicz, Fortschr. Phys. 61, 66 (2013)

NEAR EACH particle (cluster)-decay threshold a „narrow" and collective state of the same particle (cluster) character is expected !

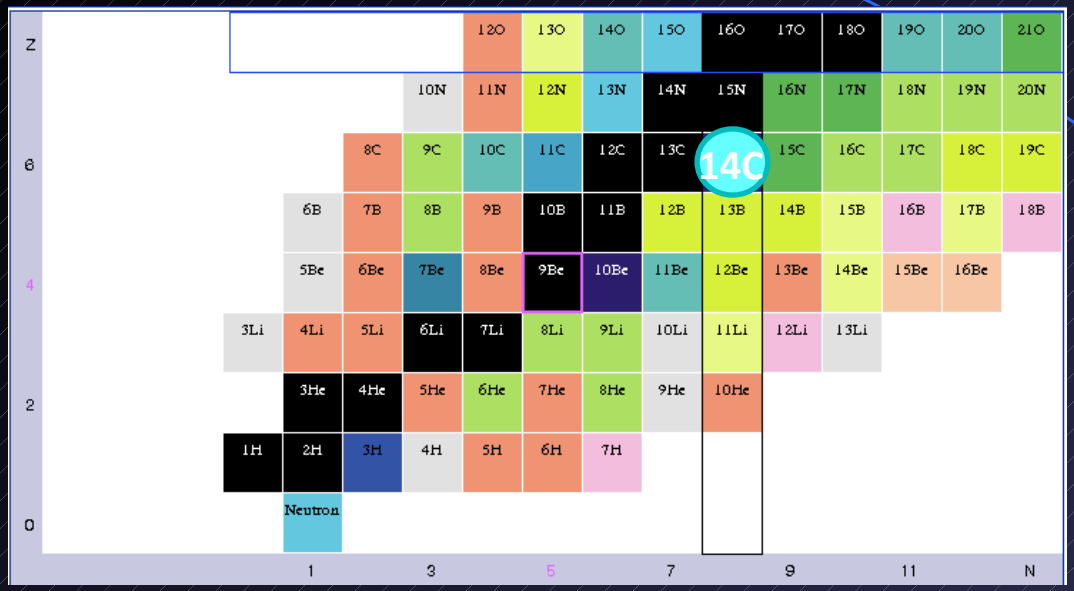
!!! CLUSTERING is a **generic near-threshold phenomenon !!!**

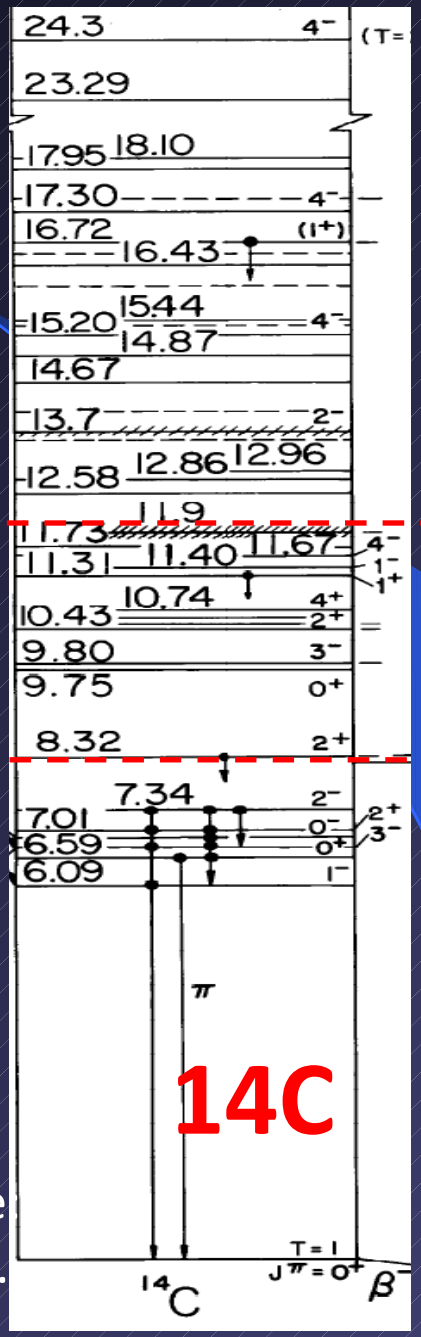
A way to check this hypothesis could be to measure **ELECTROMAGNETIC DECAY** of near-threshold states.



Important information to test ab-initio approaches …

Objective of our investigations: 14C



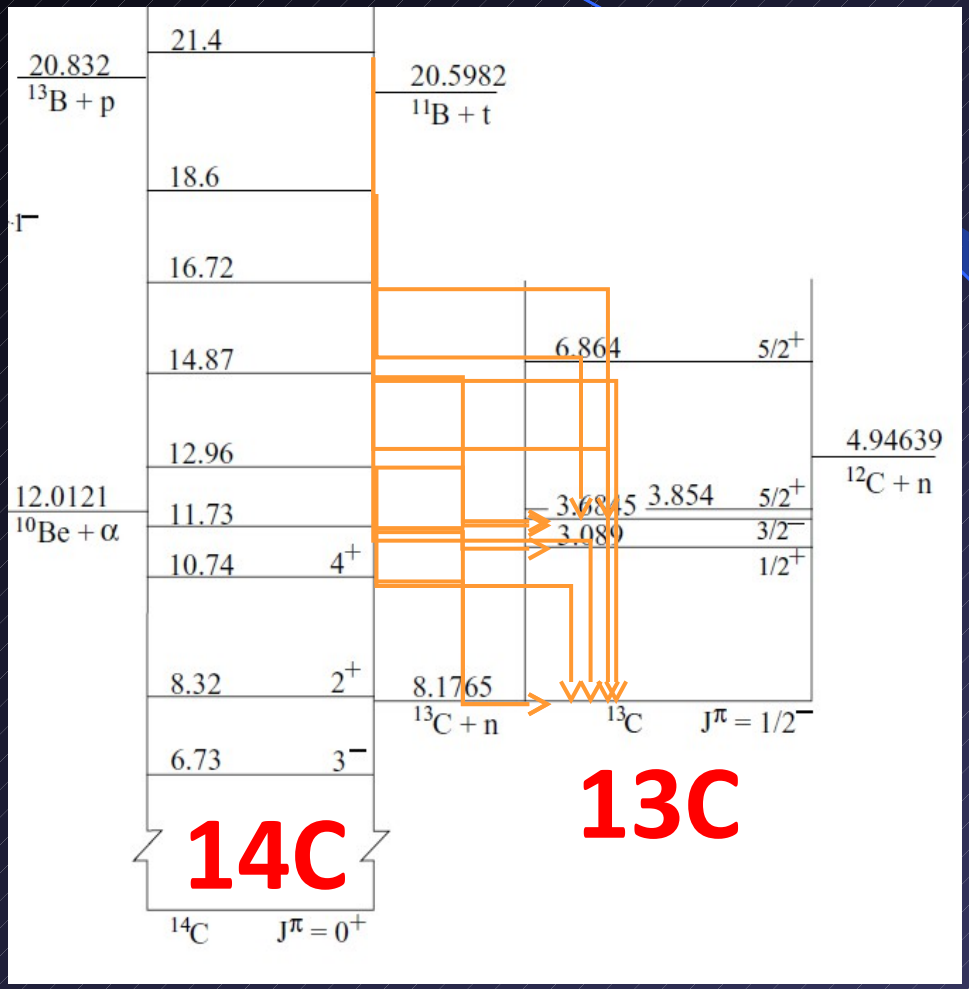


10Be + α
12.01 MeV

13C + n
8.18 MeV

14C was extensively studied in the past, for example
W. von Oertzen et al., Eur. Phys. J. A 21, 193 (2004).

Other example of the **14C** structure studies: **neutron decay from unbound states**



P.J. Haigh et al.,
PRC 78, 014319 (2008).

14C as a TEST CASE of the properties of near-threshold states

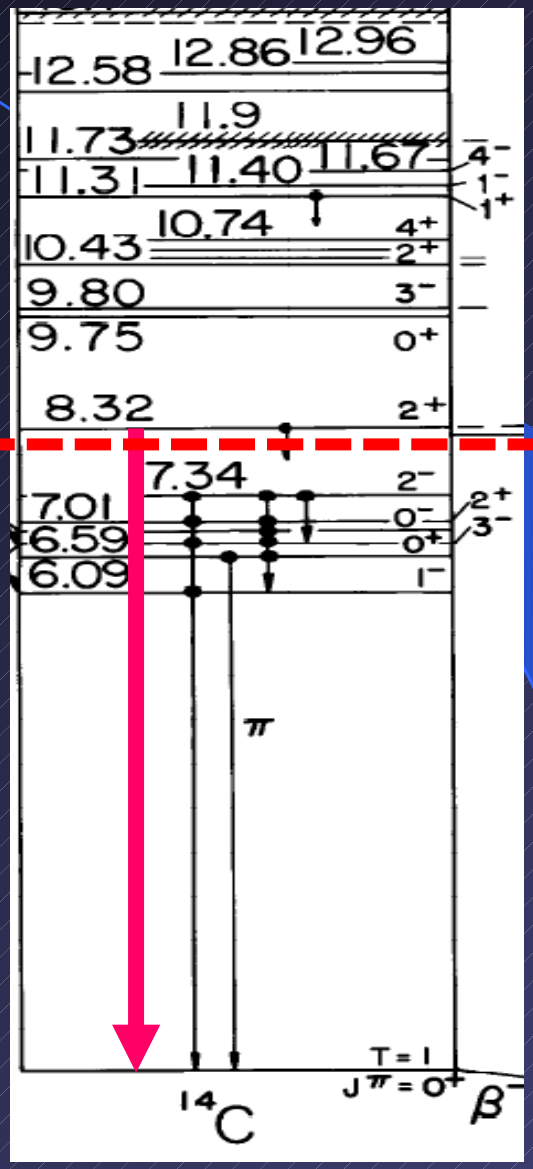
2+ state at 8318 keV

142 keV above 13C+n threshold

Γ = 3.4 keV

Standard SHELL MODEL (without coupling to the continuum)	**0.9 eV**	**2.6 10-4**
SHELL MODEL Embeded in the Continuum	**3.4 eV**	**10-3**

Continuum coupling enhances the γ-decay probability



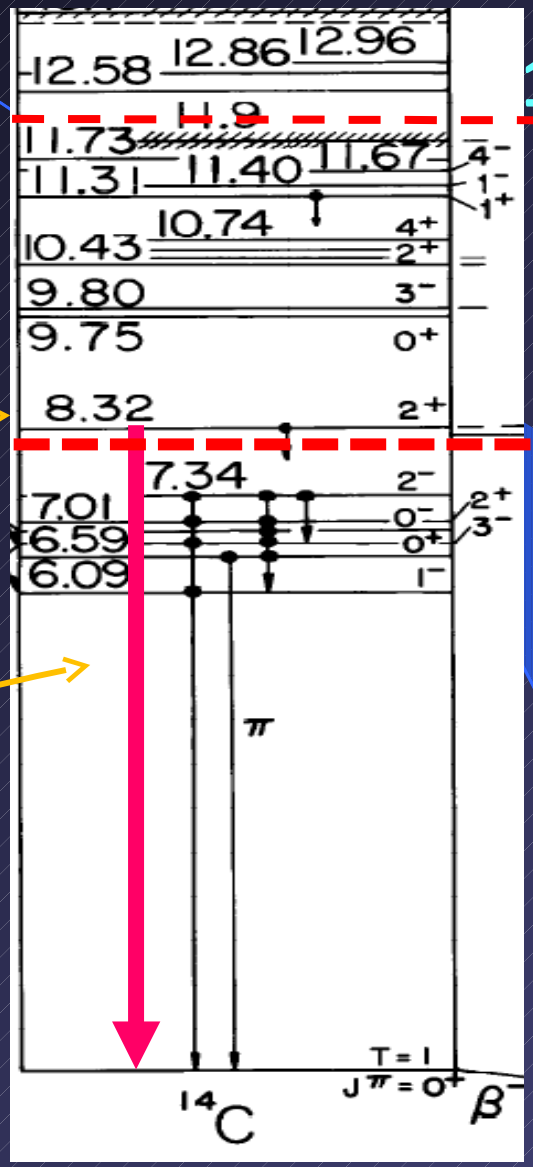
14C as a TEST CASE of the properties of near-threshold states

3 states above α threshold

Γ = 30-90 keV

6 resonances

Γ < 40 keV



10Be + α threshold 12013 keV

13C + n threshold 8176 keV

Main aim:

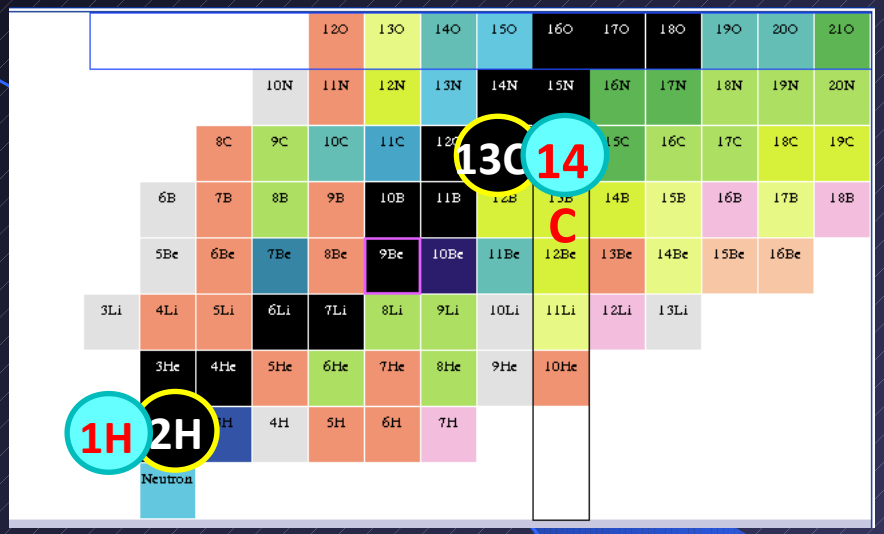
2+ state at 8318 keV, Γ = 3.4 keV

- Observation of γ-decay
- Branching ratio Γγ/Γn
- Multipolarity

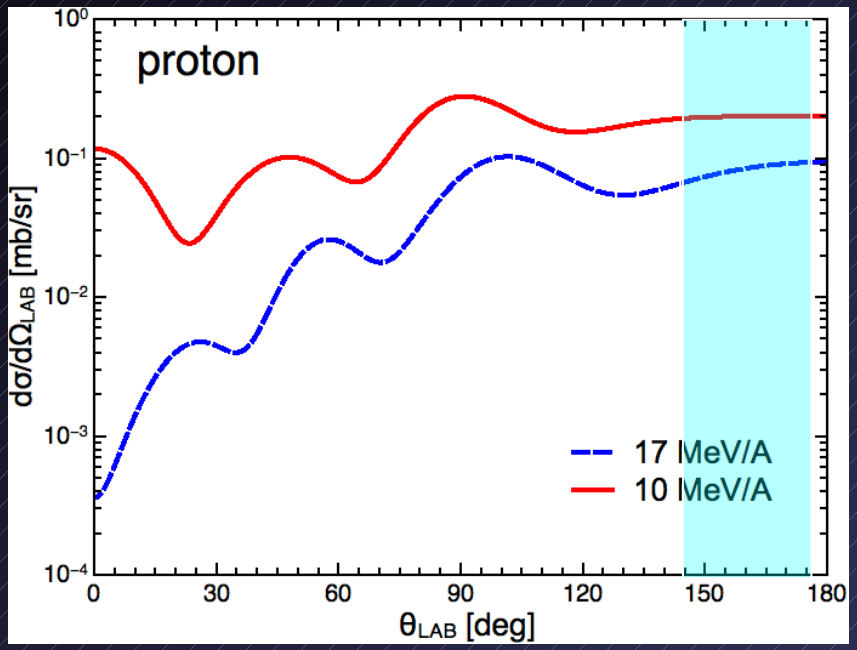
γ spectroscopy opportunity for a number of narrow resonances !!!

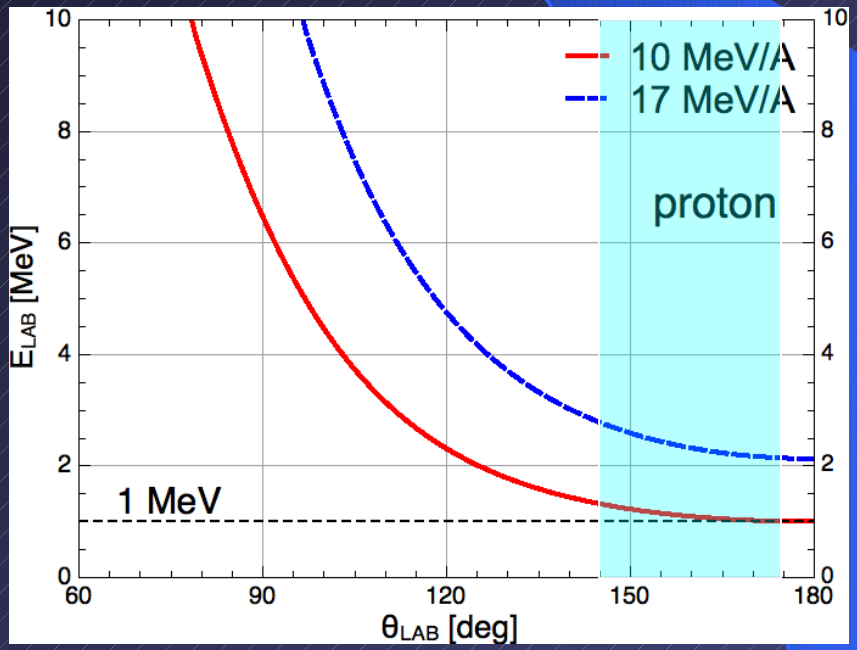
Proposed reaction and cross section evaluation

13C + d → 14C* + p



Cross section for the 2+ 8317 keV state population (FRESCO)





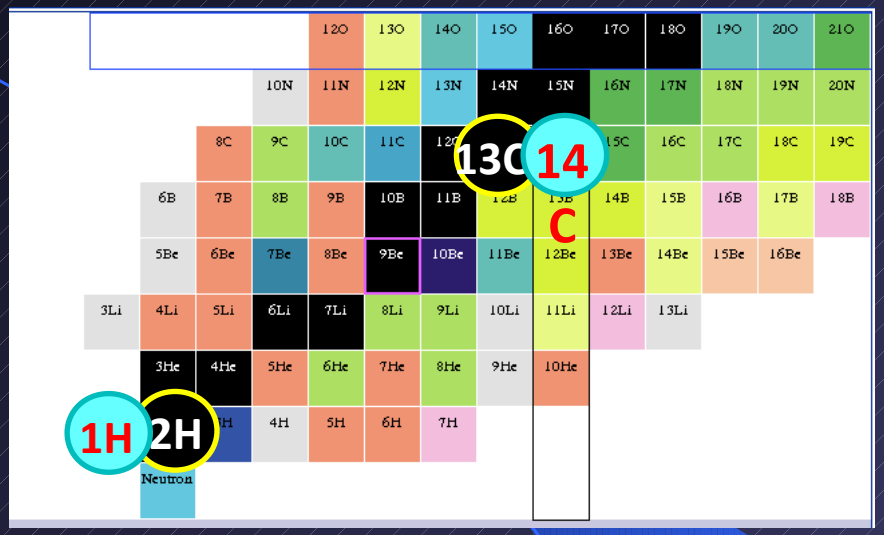
Reaction Kinematics

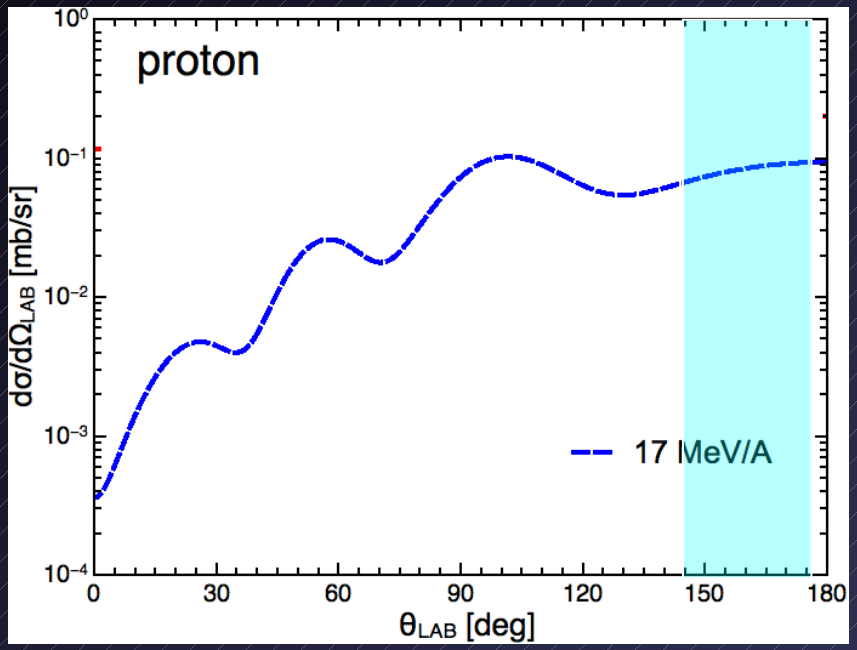
Proposed reaction and cross section evaluation

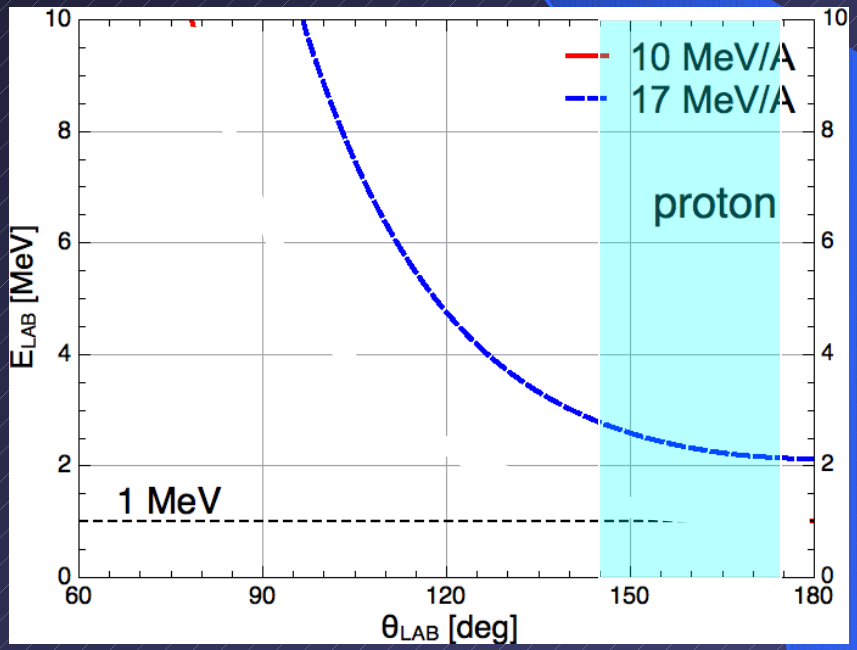
$^{13}C + d \rightarrow {}^{14}C^{*} + p$

17 MeV/A

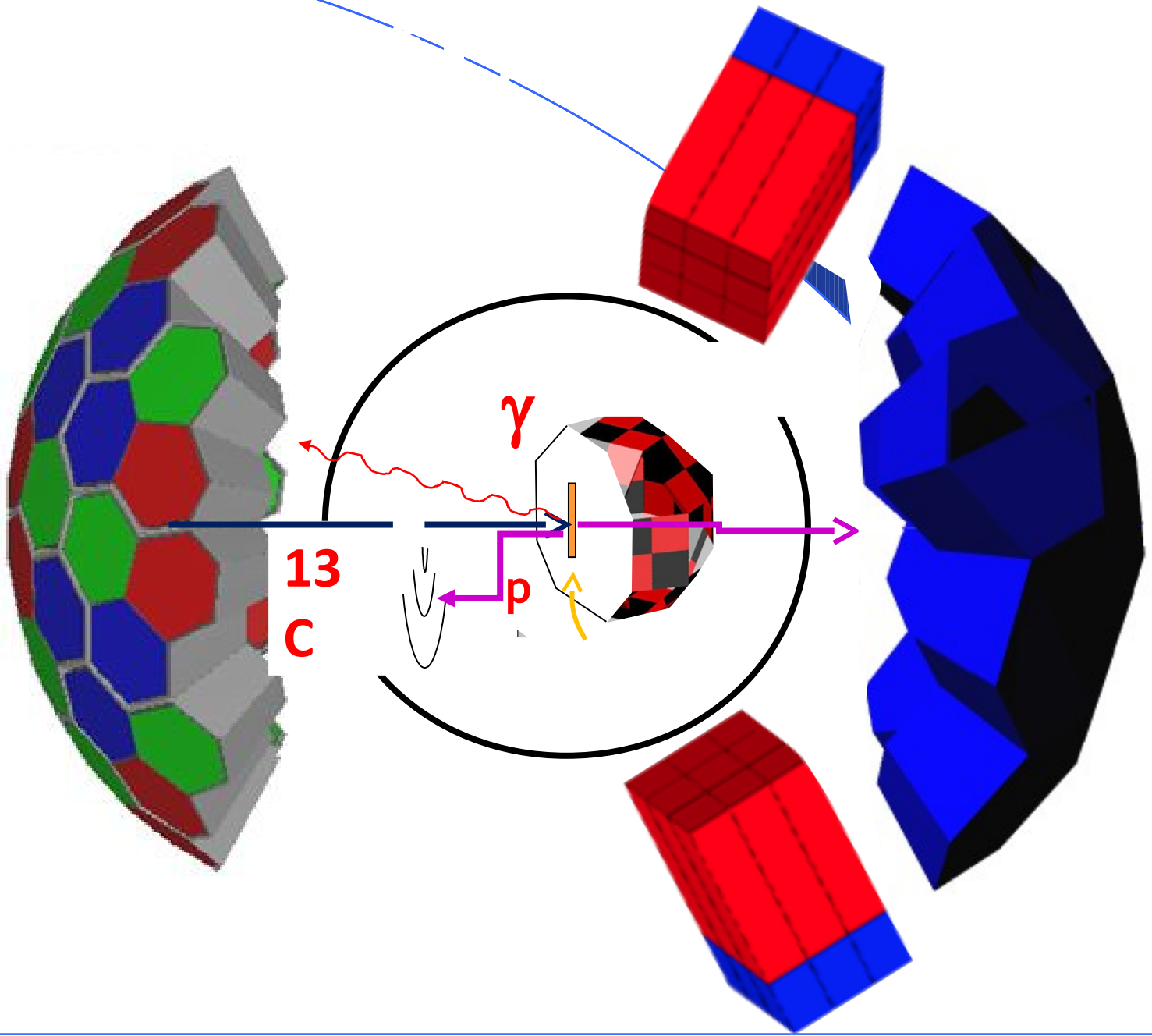
Cross section for the 2+ 8317 keV state population (FRESCO)

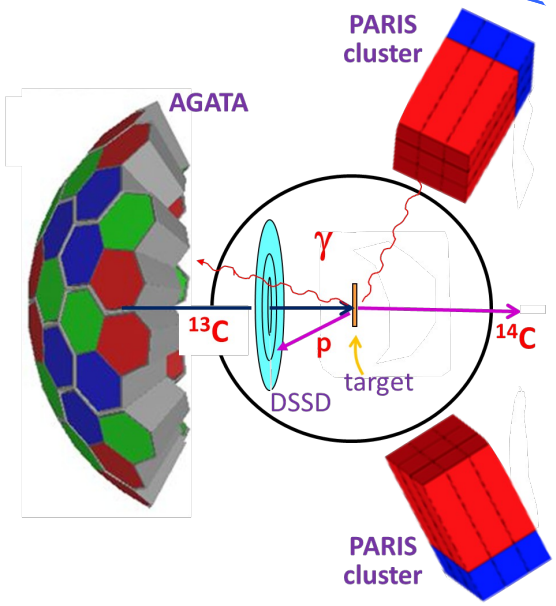


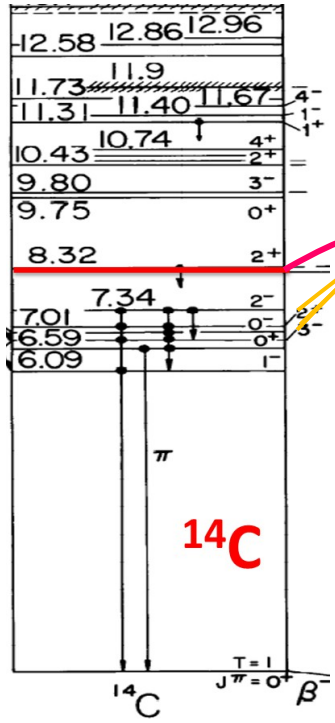


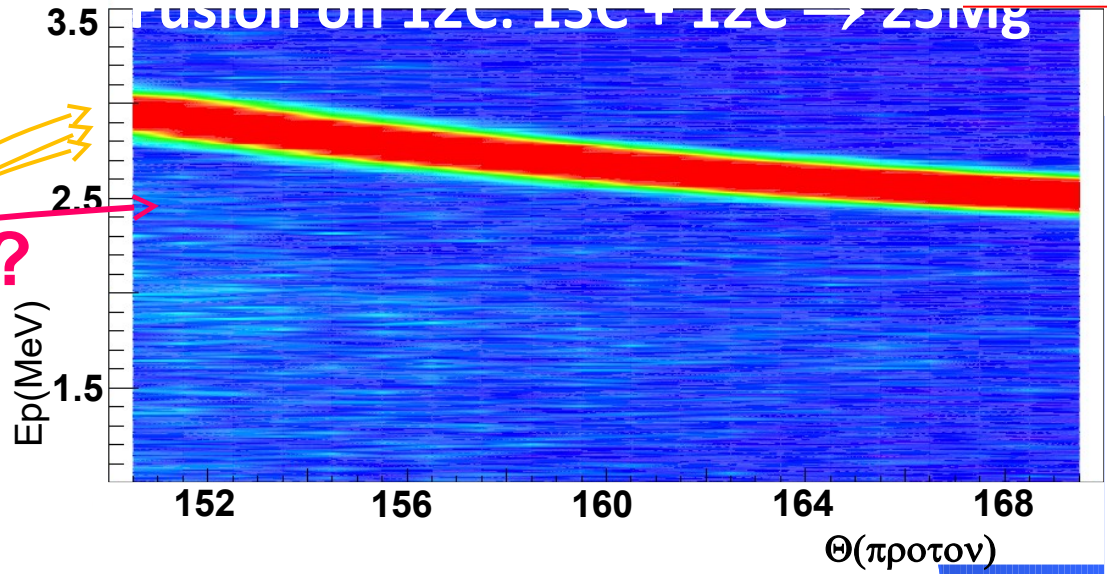


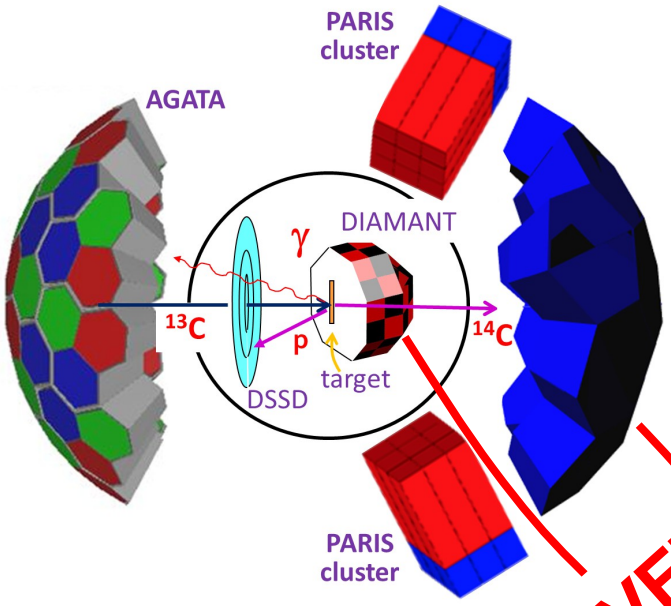
Reaction Kinematics


γ
13
C
p

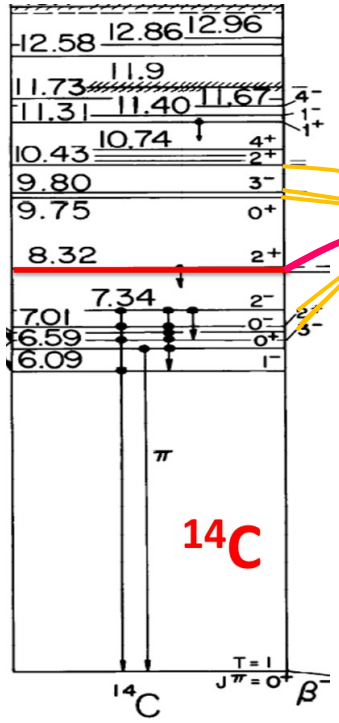

PARIS
cluster
AGATA
γ
^{13}C
^{14}C
p
target
DSSD
PARIS
cluster


12.58
12.86
12.96
11.9
11.73
11.67
11.31
11.40
10.74
10.43
9.80
9.75
8.32
7.34
7.01
6.59
6.09
^{14}C
T = 1
$J^\pi = 0^+$
β^-


?
3.5
2.5
1.5
Ep(MeV)
152
156
160
164
168
Θ(προτον)


PARIS
cluster
AGATA
DIAMANT
γ
^{13}C
^{14}C
p
target
DSSD
PARIS
cluster

VETO


12.58
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^{14}C
T = 1
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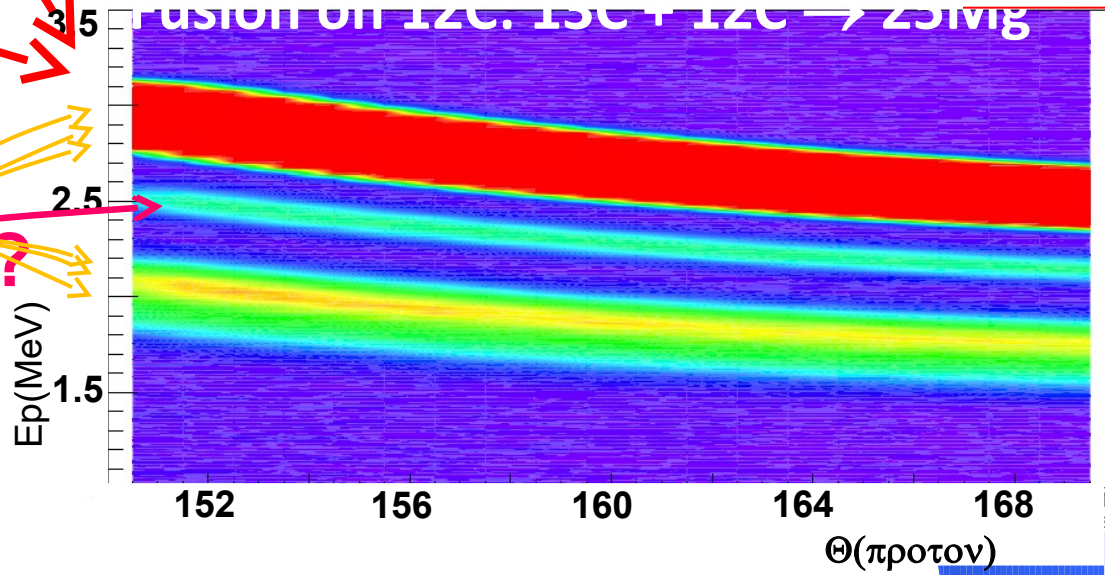
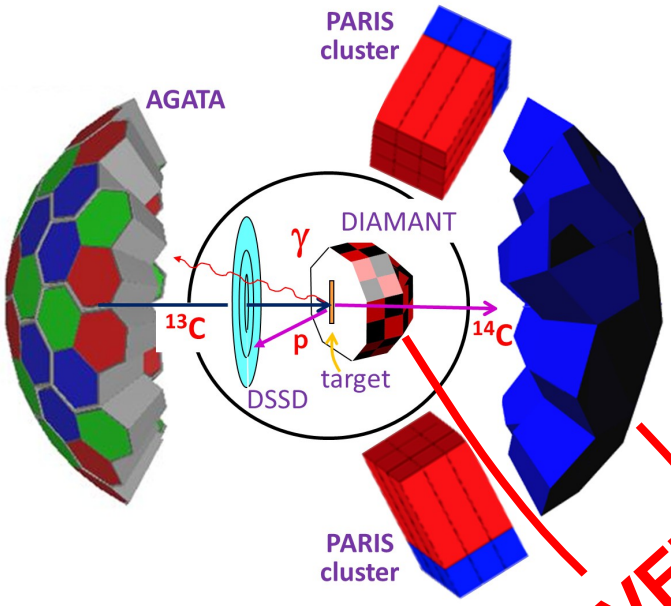
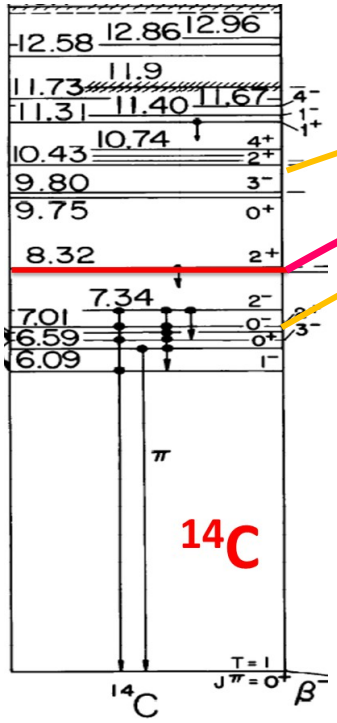
β^-


3.5
2.5
1.5
Ep(MeV)
152
156
160
164
168
Θ(προτον)


PARIS
cluster
AGATA
DIAMANT
γ
^{13}C
^{14}C
p
target
DSSD
PARIS
cluster

VETO


12.58
12.86
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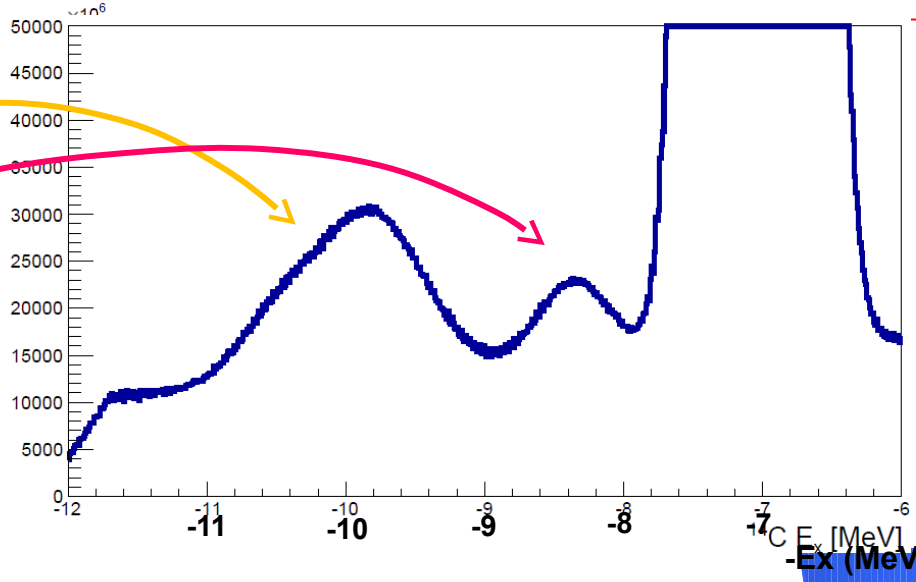
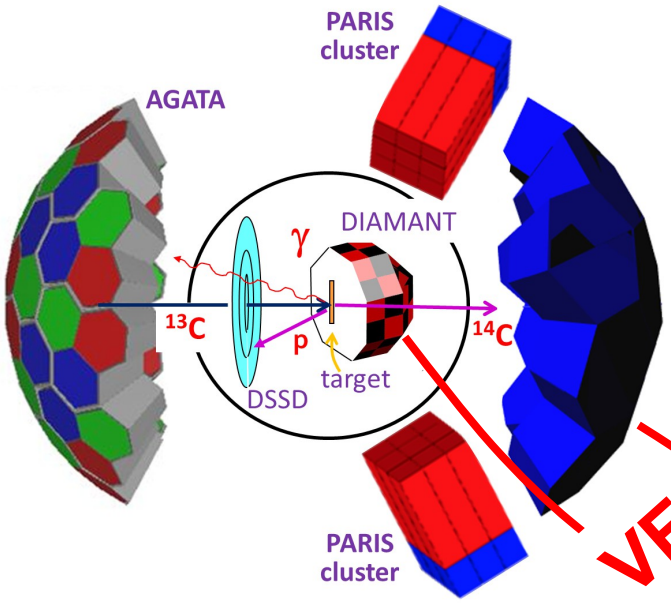
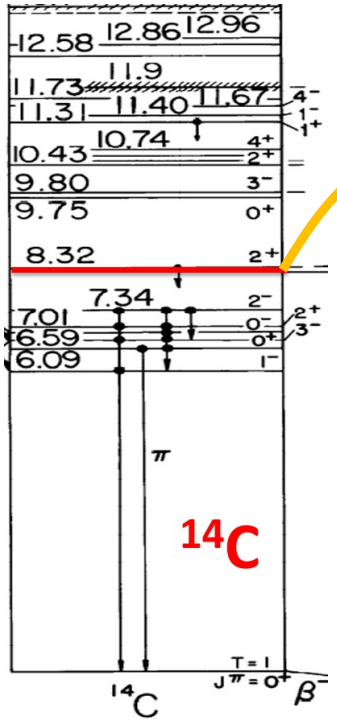
8.32
7.34
7.01
6.59
6.09
^{14}C
T = 1
$J^{\pi} = 0^+$
β^-


50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
-12
-11
-10
-9
-8
-7
-6
^{14}C Ex [MeV]
-Ex (MeV)


PARIS
cluster
AGATA
DIAMANT
γ
^{13}C
^{14}C
p
target
DSSD
PARIS
cluster

VETO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11.31
11.40
10.43
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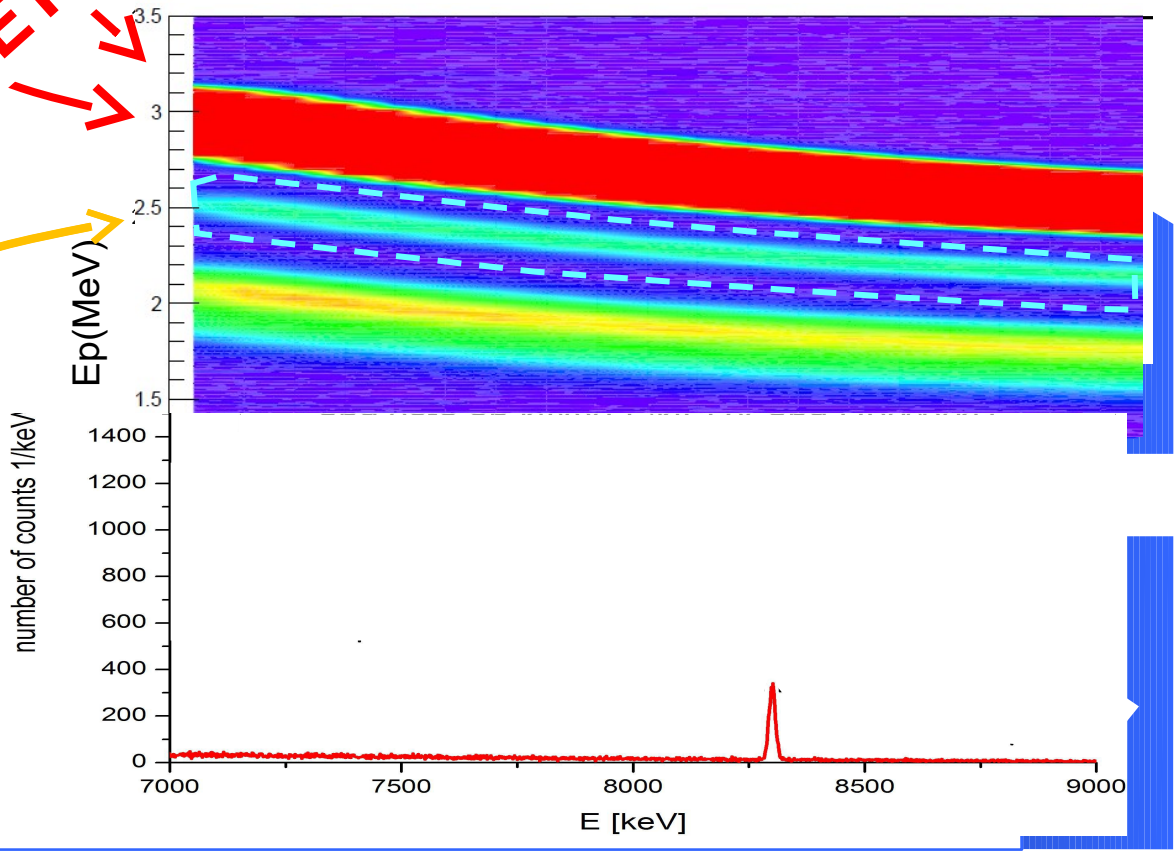
9.80
9.75
8.32
7.34
7.01
6.59
6.09
^{14}C
T = 1
$J^{\pi} = 0^+$
β⁻


Ep(MeV)
number of counts 1/keV
E [keV]

COUNT RATES ESTIMATES

γ-decay of unbound narrow states in 14C

CD2 target: 1.5 mg/cm2
13C Beam Energy : 221 MeV, 17 MeV/A
13C Beam Current: 3 pnA

	22+→0+ Γγ = 3.4 keV
Eγ [MeV]	8.32
σ [mb]	0.1
γ-Branching	10-3
Ɛ(AGATA@13 cm) CLOSE	3 %
Ɛ(PARIS -2 Clusters)	2.5 %
p counts/s	210
(p–γ) counts/s AGATA	0.006
(p–γ) counts/s PARIS	0.005
(p–γ) counts AGATA 10 DAYS	**5500**
(p–γ) counts PARIS 10 DAYS	**4550**

Sufficient statistic to estimate

- *γ-decay*
- *γ-branching*
- *E/M character*

Possibility of γ–γ coincidences between bound states and higher lying narrow resonances

COUNT RATES ESTIMATES

γ-decay of unbound narrow states in 14C

CD2 target: 1.5 mg/cm2
13C Beam Energy : 221 MeV, 17 MeV/A
13C Beam Current: 3 pnA

	22+→0+ Γγ = 3.4 keV	32-→22+ Γγ < 30 keV
Eγ [MeV]	8.32	5
σ [mb]	0.1	0.1
γ-Branching	10-3	5 10-4
Ɛ(AGATA@13 cm) CLOSE	3 %	4.2 %
Ɛ(PARIS -2 Clusters)	2.5 %	3.2 %
p counts/s	210	210
(p–γ) counts/s AGATA	0.006	0.004
(p–γ) counts/s PARIS	0.005	0.0034
(p–γ) counts AGATA 10 DAYS	**5500**	**3800**
(p–γ) counts PARIS 10 DAYS	**4550**	**2900**

Sufficient statistic to estimate

- *γ-decay*
- *γ-branching*
- *E/M character*

Possibility of γ–γ coincidences between bound states and higher lying narrow resonances