A high-energy direct reaction study of ^{21}C

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Collaboration: LPC-Caen, RIKEN Nishina Center, Tokyo Institute of Technology, Seoul National University, Technische Universität Darmstadt, Tohoku University, Rikkyo University, Kyoto University, GANIL, GSI, University of York, IPN-Orsay.

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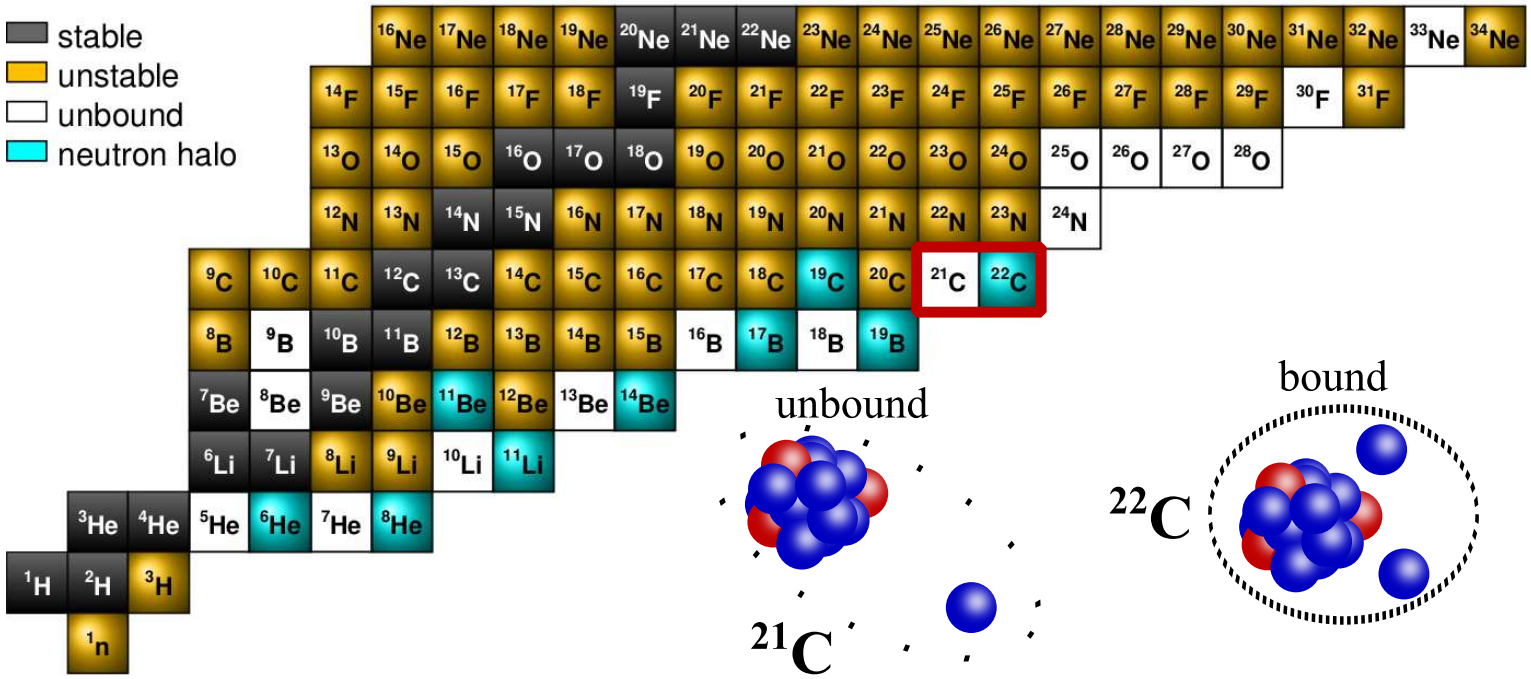
Two neutron halo



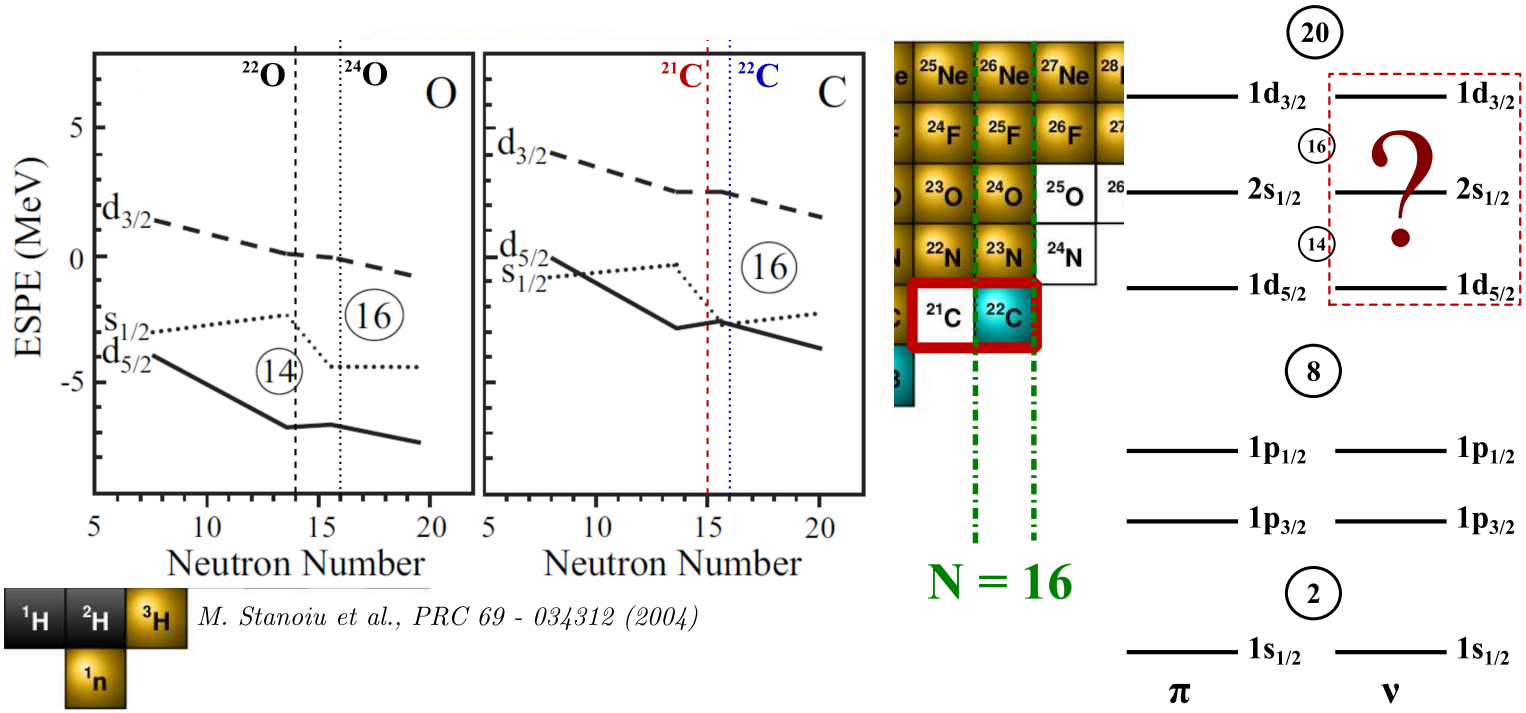
Neutron Halo

- Large spatial extension
- Very weakly bound

Borromean nuclei

- 2-body subsystems are unbound
- 3-body models require accurate C-n interaction

s-d shell evolution far from stability



M. Stanoiu et al., PRC 69 - 034312 (2004)

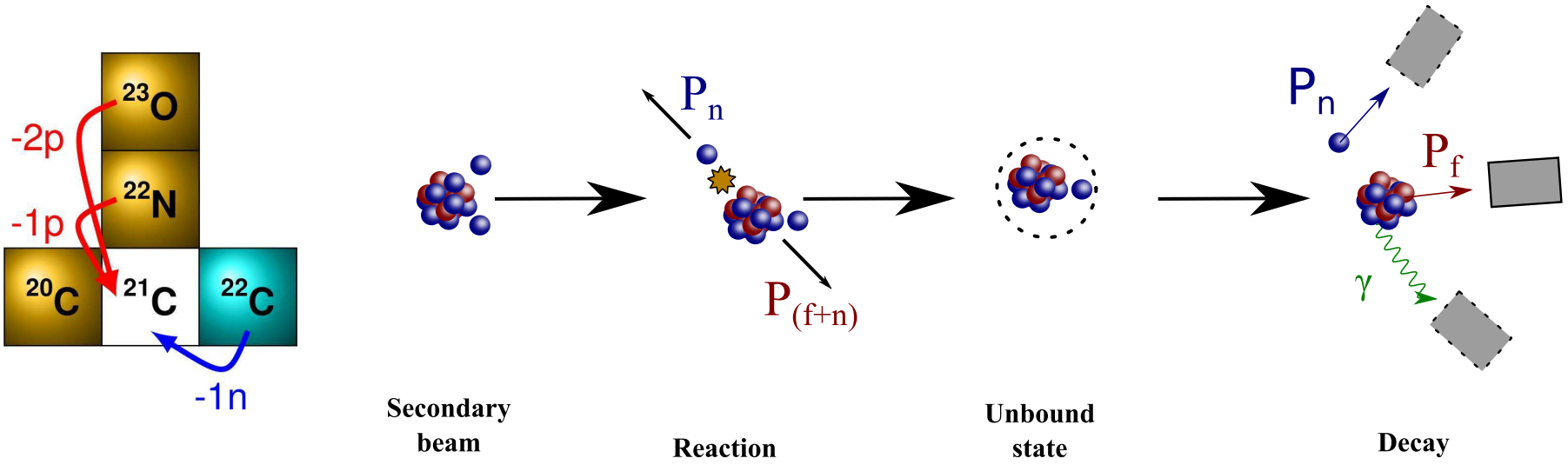
Far from stability

- New magic numbers
- Evolution of SPO

C isotopes: around N=16

- $\nu s_{1/2}$ and $\nu d_{5/2}$ ordering ?
- $\nu d_{3/2}$ location ?

Nucleon knock-out @ 250 AMeV



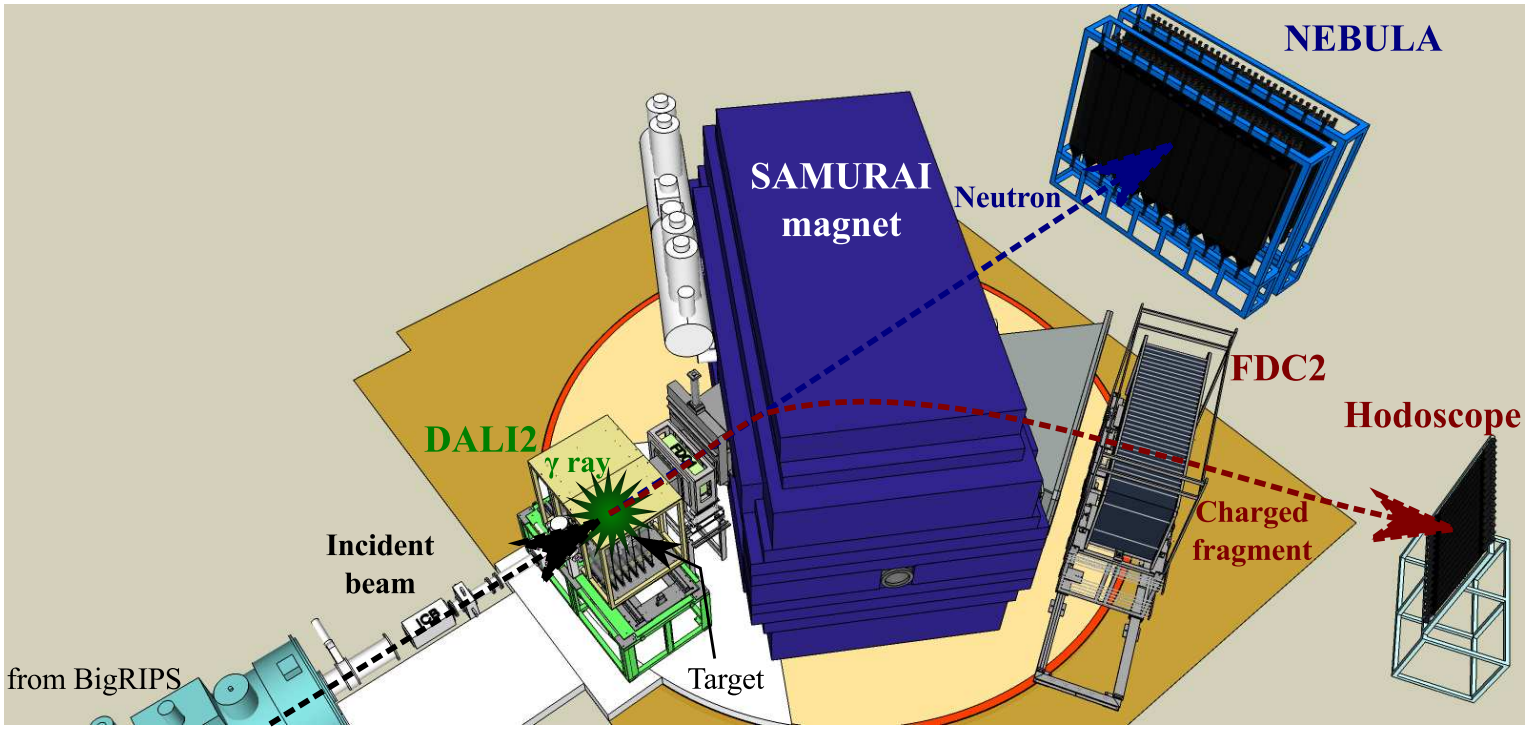
Selectivity

- $-1p, -2p$: $\Rightarrow (\nu_{nlj})_i = (\nu_{nlj})_f$
- $-1n$: $\Rightarrow (\nu_{nlj})^2 \rightarrow (\nu_{nlj})$

Invariant mass spectroscopy

- $M_{inv} = \sqrt{(E_n + E_f)^2 - (\vec{p}_n + \vec{p}_f)^2}$
- $E_{rel} = M_{inv} - (m_n + m_f)$

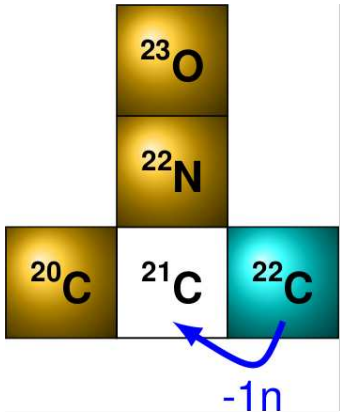
SAMURAI spectrometer



Detection setup

- Charged particle (^{20}C) $\Longrightarrow$ FDC1&2 + Hodoscope
- Neutron $\Longrightarrow$ NEBULA
- Gamma rays $\Longrightarrow$ DALI2

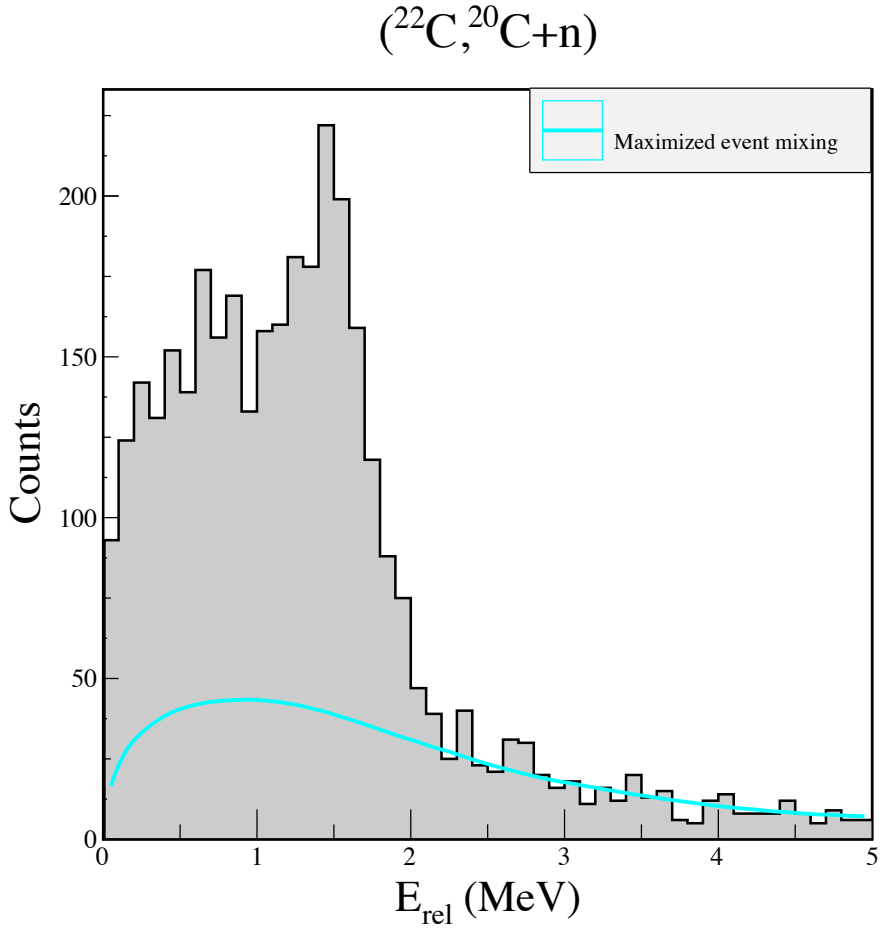
^{21}C: $-1n$ from ^{22}C



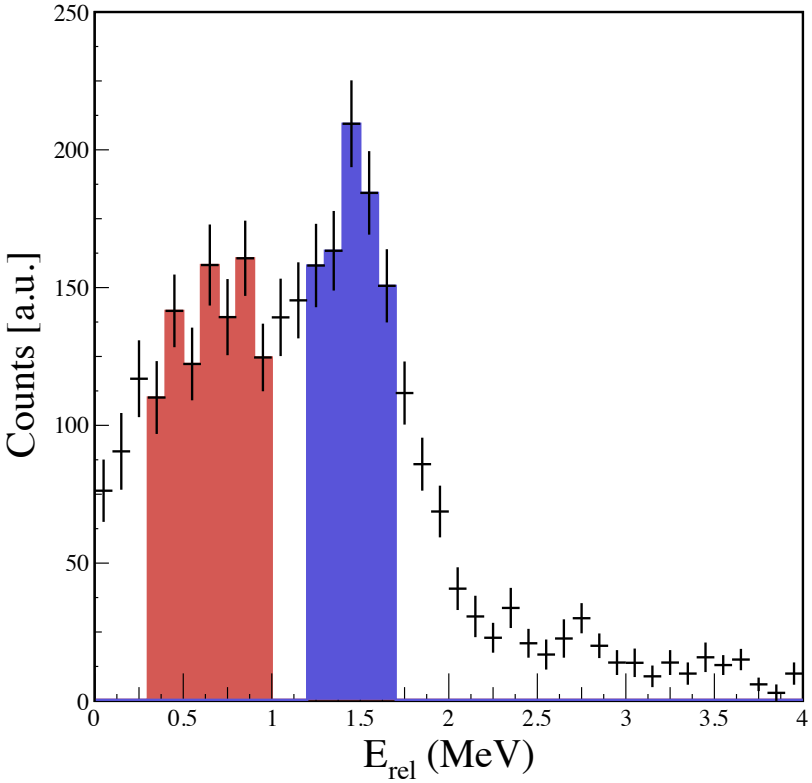
C(^{22}C,^{20}C), WBP

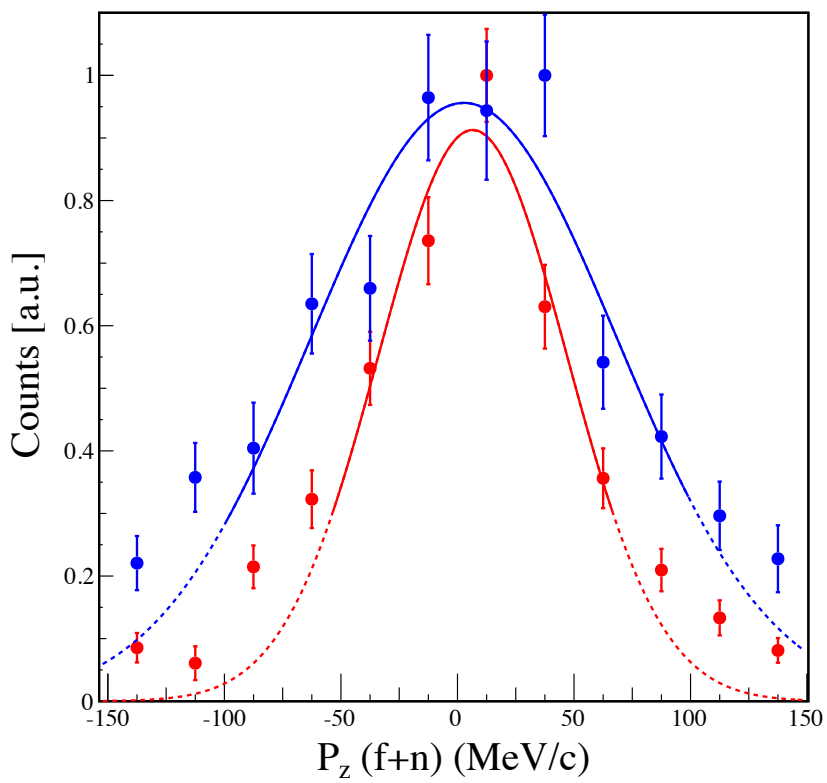
J^π	E_x	l_n	σ^{th}_{-1n}
$1/2^+$	0.0	0	137.55
$5/2^+$	1.109	2	135.87
$3/2^+$	2.191	2	9.55

N. Kobayashi et al., PRC 86, 054604 (2012)



^{21}C:$-1n$, Momentum distribution





$FWHM \approx 95\ MeV/c \quad < \quad FWHM \approx 155\ MeV/c$

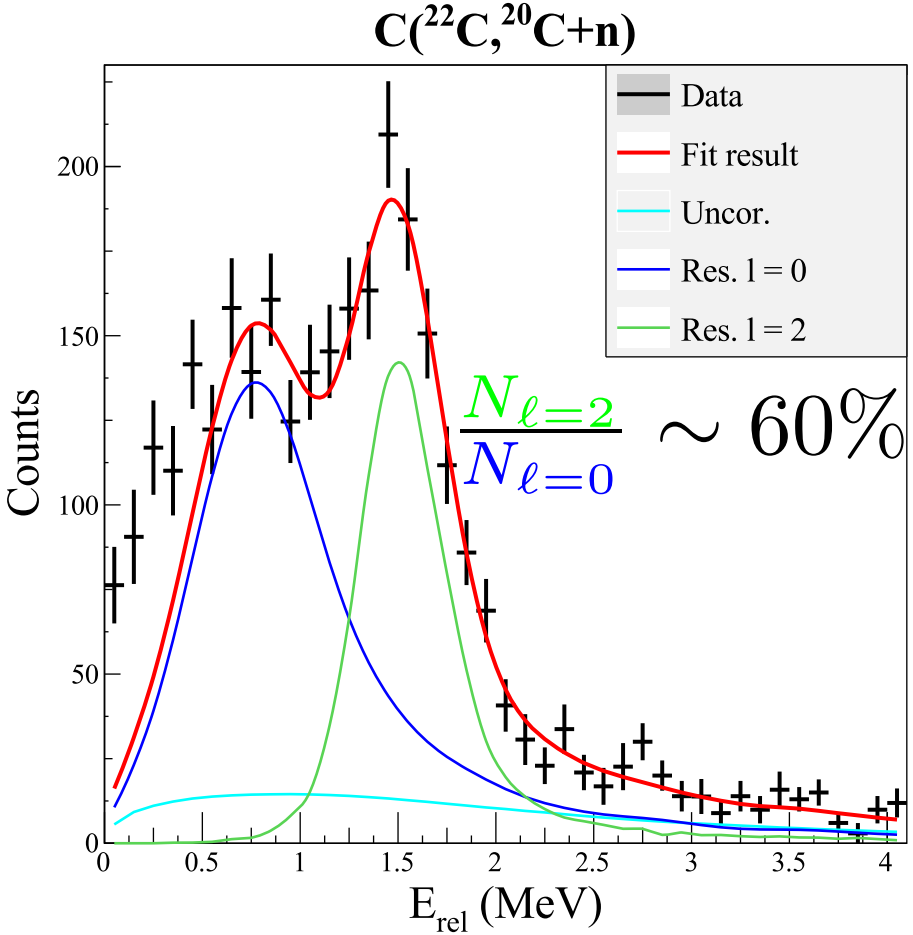
Observation

$\ell_n < \ell_n$

Conclusion

$\ell_n = 0 \quad \& \quad \ell_n = 2$

^{21}C: $-1n$, interpretation

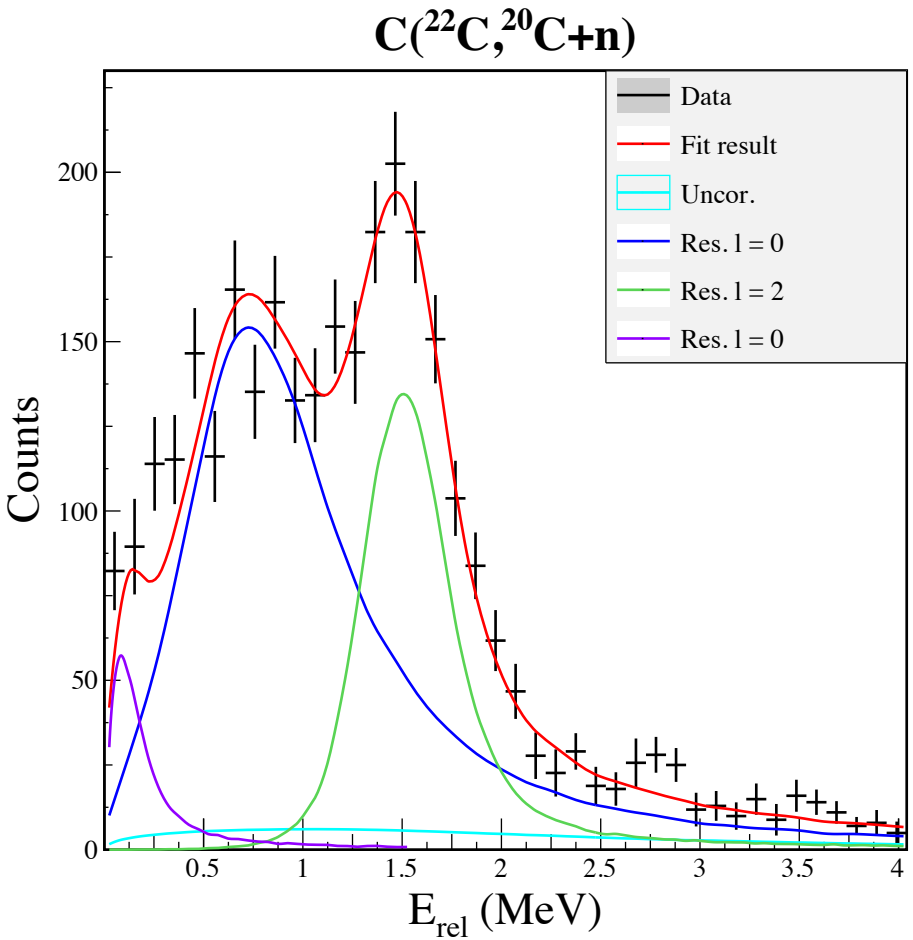


Fit results

ℓ	E_r (MeV)	Γ (MeV)
0	0.80 ± 0.18	0.90 ± 0.90
2	1.49 ± 0.09	$0.2\ ^{+0.9}_{-0.2}$

J^π	E_x	l_n	σ^{th}_{-1n}
$1/2^+$	0.0	0	137.55
$5/2^+$	1.109	2	135.87
$3/2^+$	2.191	2	9.55

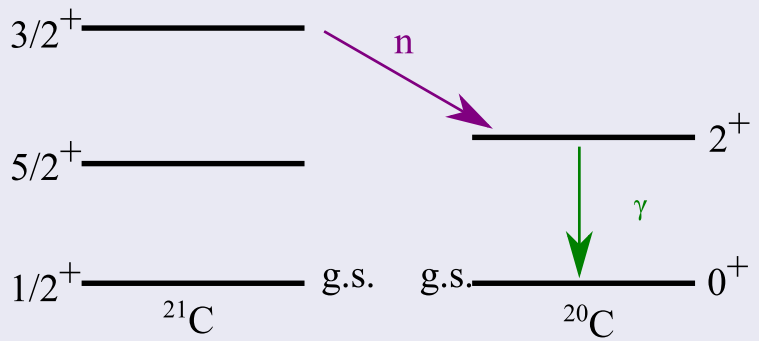
^{21}C: $-1n$, low energy discrepancy



Fit results

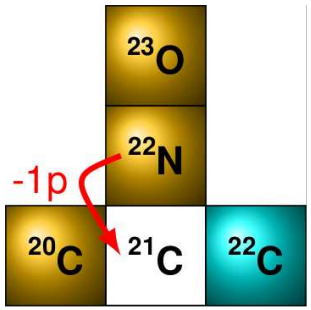
ℓ	E_r (MeV)	Γ (MeV)
0	0.80 ± 0.18	0.90 ± 0.9
2	1.49 ± 0.09	$0.20\ ^{+0.9}_{-0.2}$
(0)	< 0.2	–

Hypothesis



$E_r\,(3/2^+) = E_r\,(^{20}C + n) + E_\gamma$

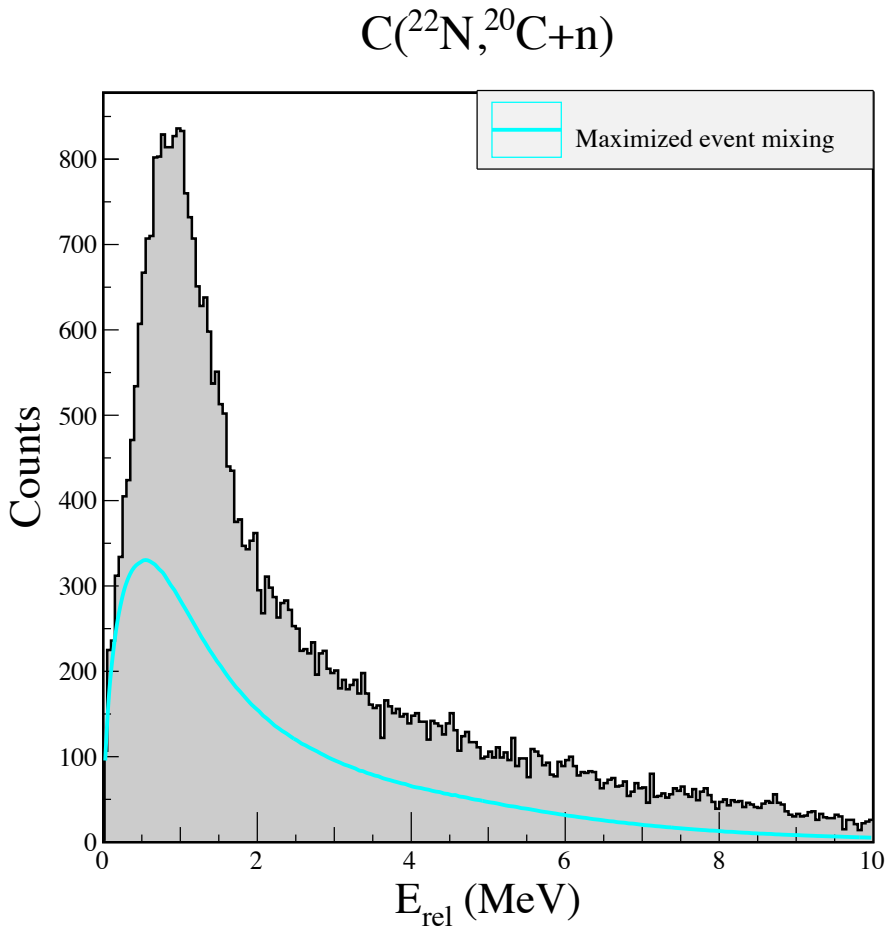
^{21}C: $-1p$ from ^{22}N



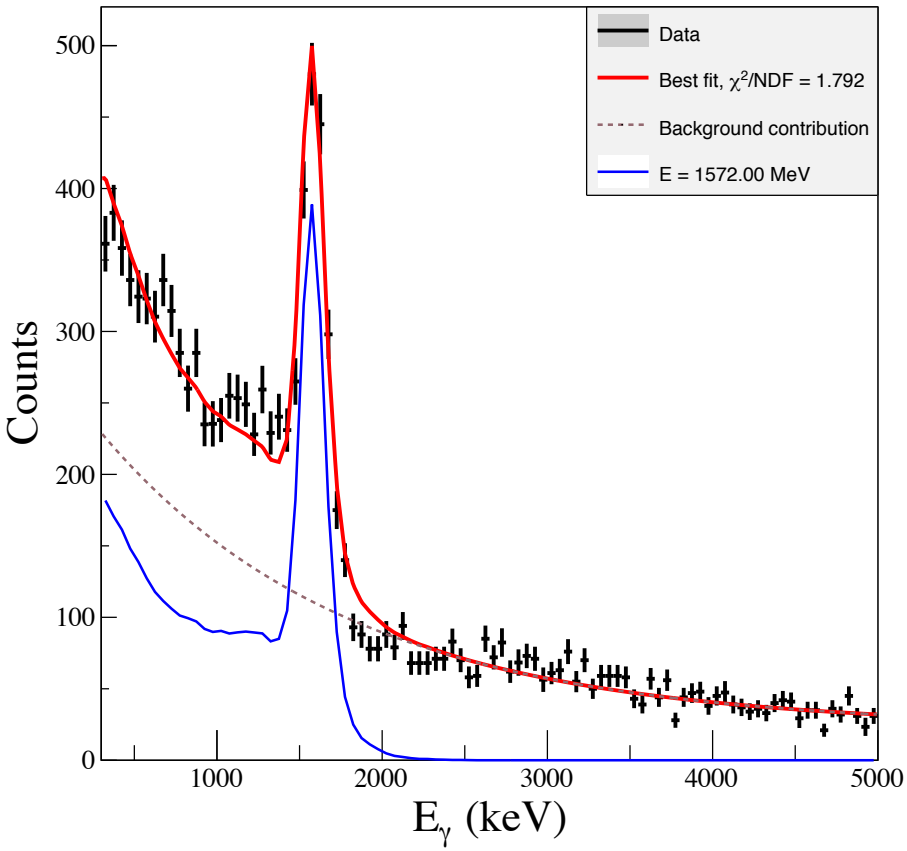
^{22}N: $\pi(1p_{1/2})^1 \otimes \nu(2s_{1/2})^1$
$\Longrightarrow$ Expecting $1/2^+$ in ^{21}C

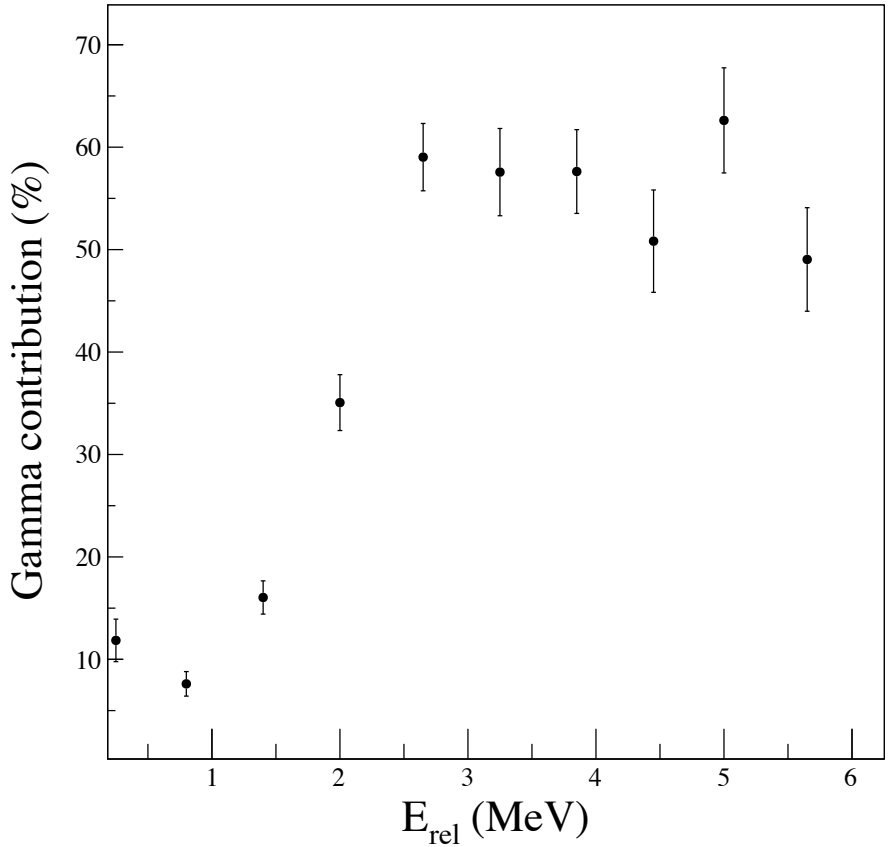
J^π	E_x	l_n
$1/2^+$	0.0	0
$5/2^+$	1.109	2
$3/2^+$	2.191	2

N. Kobayashi et al., PRC 86, 054604



^{21}C: $-1p$, gamma rays in coincidence





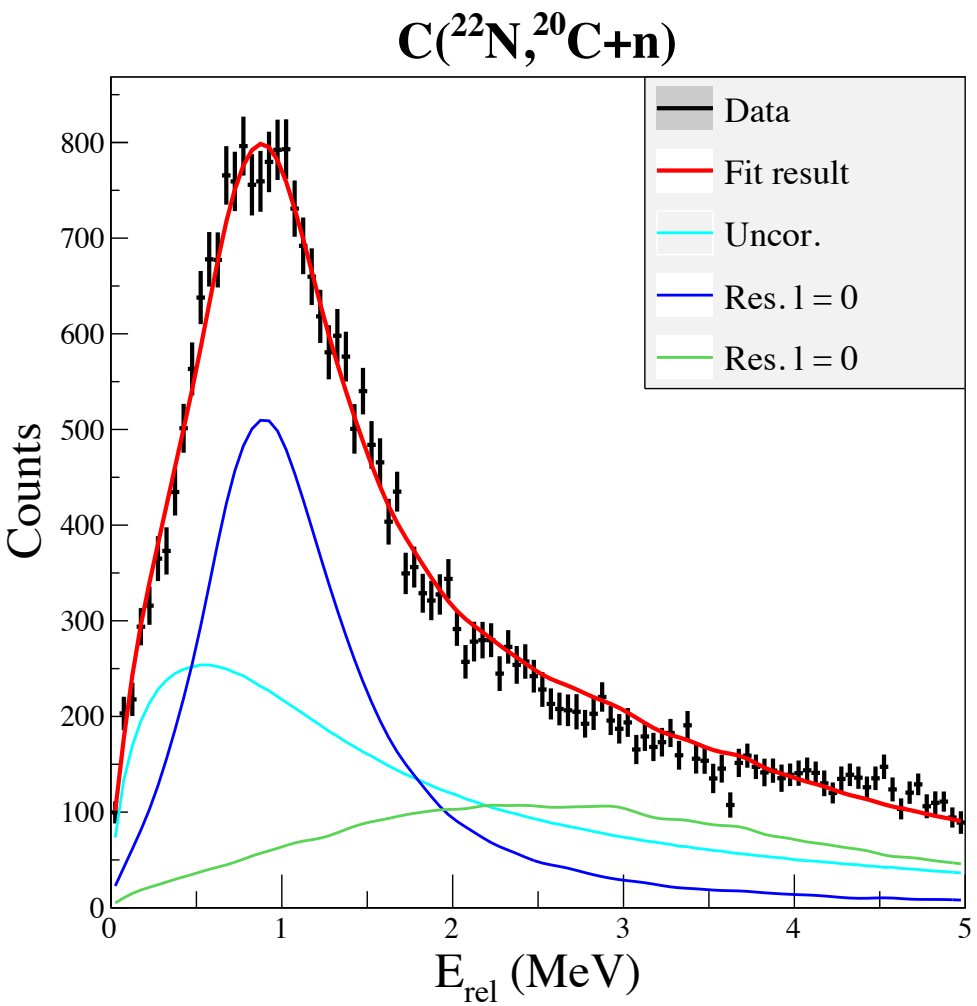
Minimization: $E_\gamma = 1578 \pm 30$ keV

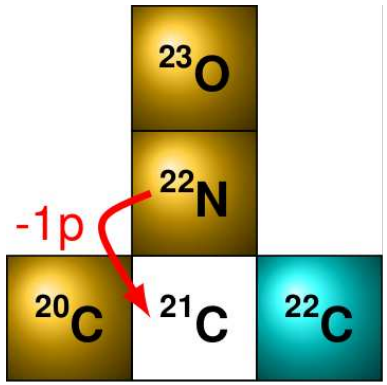
Compatible with: $E_\gamma = 1614 \pm 11$ keV

Z. Elekes, PRC 79, 011302

Strength correlated with $E_{rel} > 2MeV$

^{21}C: $-1p$, interpretation





Fit results

ℓ	E_r (MeV)	Γ (MeV)
0	0.94 ± 0.11	0.80 ± 0.5
0	3.3 ± 0.5	4.1 ± 3.0

Conclusions

^{22}N - 1p

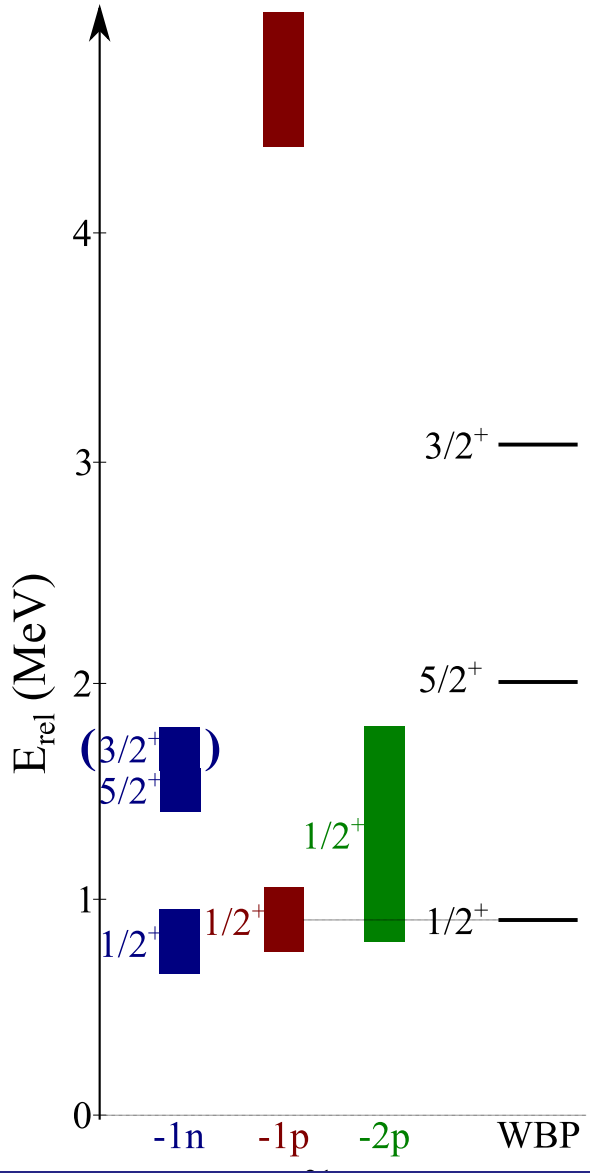
- $J^\pi = 1/2^+$: $E_r = 0.94 \pm 0.11$ MeV.
- High lying level(s): $E_r \approx 5$ MeV.

^{22}C - 1n

- $J^\pi = 1/2^+$: $E_r = 0.80 \pm 0.18$ MeV.
- $J^\pi = 5/2^+$: $E_r = 1.49 \pm 0.09$ MeV.

$$\Longrightarrow 1/2^+ \text{ below } 5/2^+.$$

- Strenght at low energy: $3/2^+$?
  $E_r \in [1.6; 1.8]$MeV.



SAMURAI collaboration

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