

Study of M4 stretched configuration decay in ^{13}C

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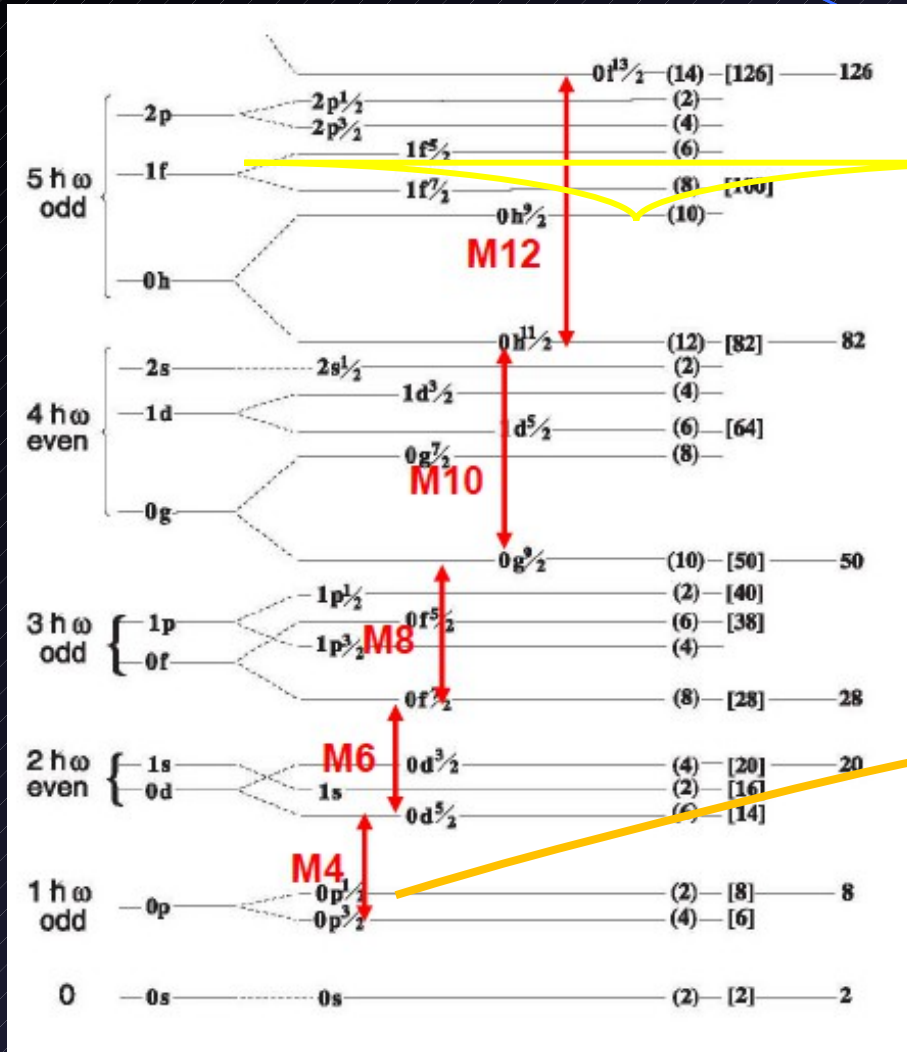
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IFJ PAN

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Magnetic Transitions to stretched states



particle-hole excitations
having the maximum total angular
momentum allowed
in a single particle excitation
to the adjacent shell

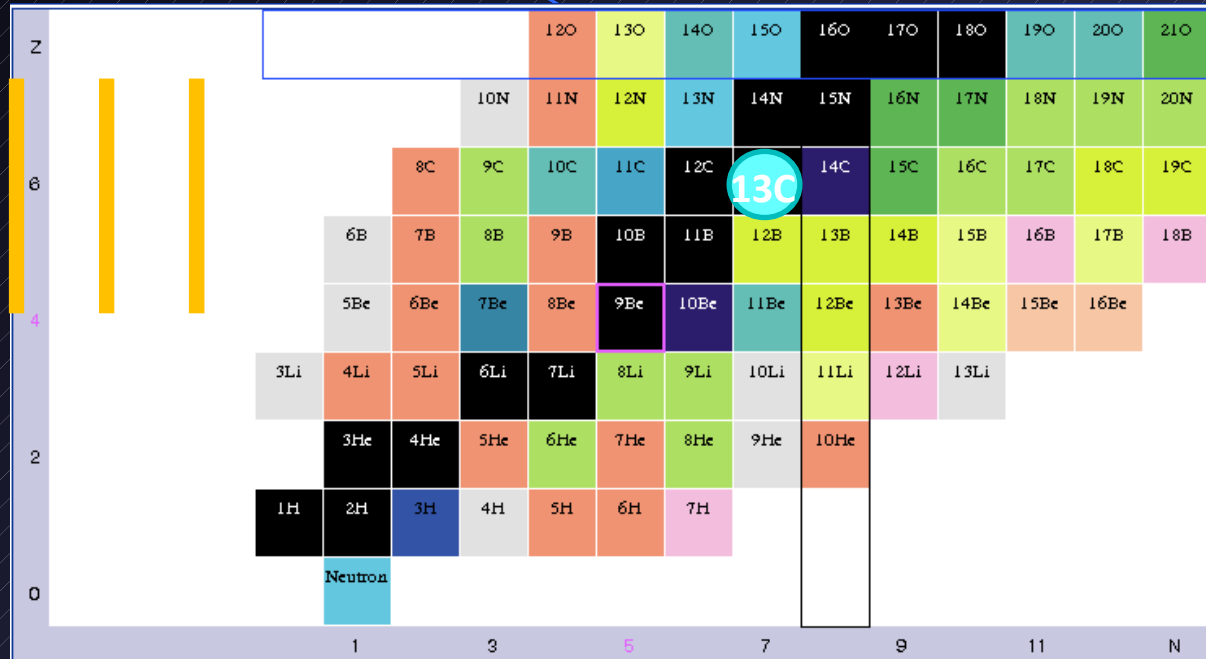
$$J_{\max} = J_p(\max, \hbar\omega) + \phi \hbar(\mu\alpha\xi, 0\hbar\omega)$$

in 1p-shell nuclei:
 $d5/2 + p3/2$

Stretched states are reached
by unnatural-parity transitions:
for 1p-shell it is M4

Preferentially populated by inelastic scattering of e, π and p

Objective of our investigations: ^{13}C



$0d_{3/2}$

$1s_{1/2}$

$0d_{5/2}$

$0p_{1/2}$

$0p_{3/2}$

$0s_{1/2}$

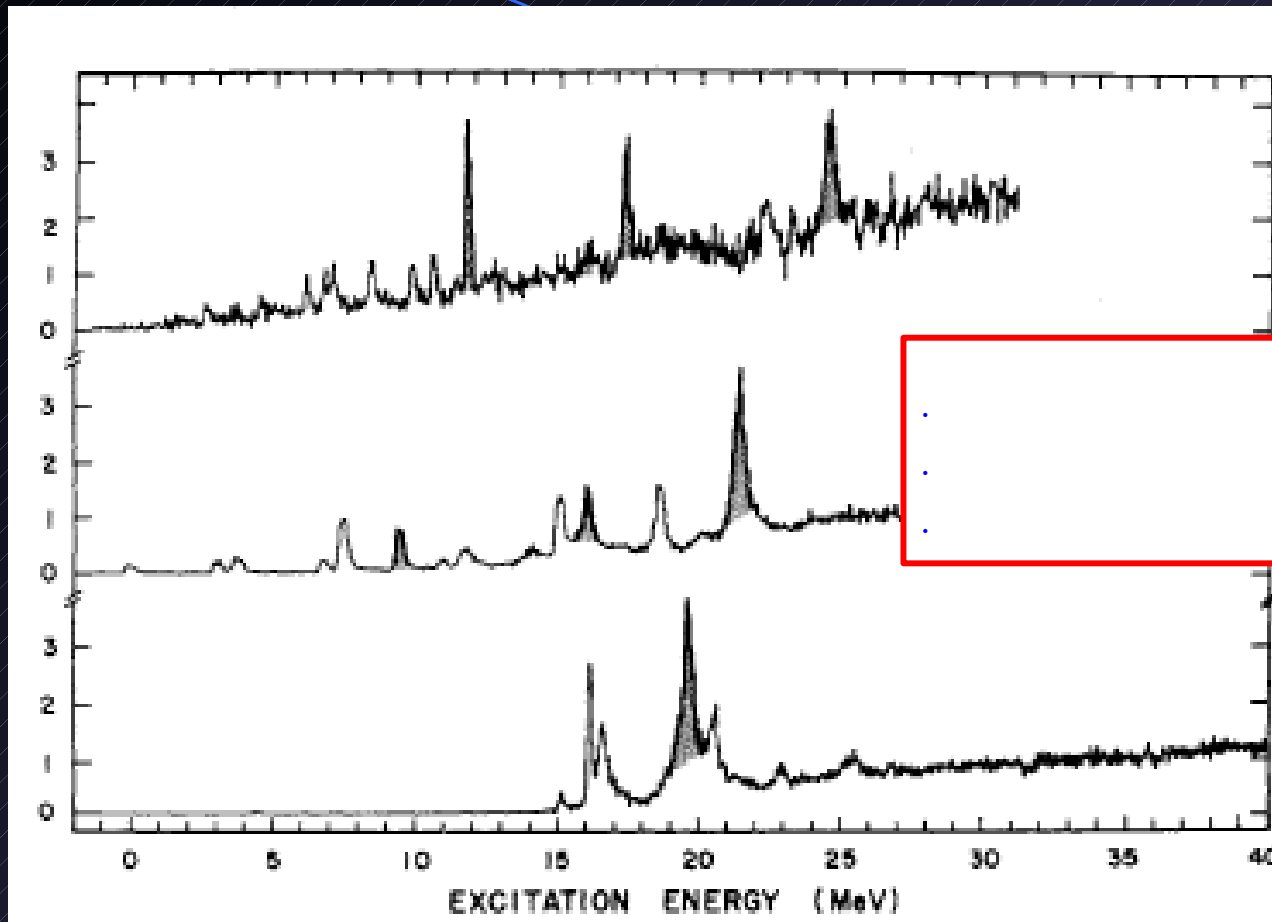
$0s_{1/2}$

$0p_{3/2} 0p_{1/2}$

$0d_{5/2} 1s_{1/2} 0d_{3/2}$

Light Nuclei: a test bench for *ab-initio* calculations

Inelastic electron scattering on ^{12}C , ^{13}C , ^{14}C

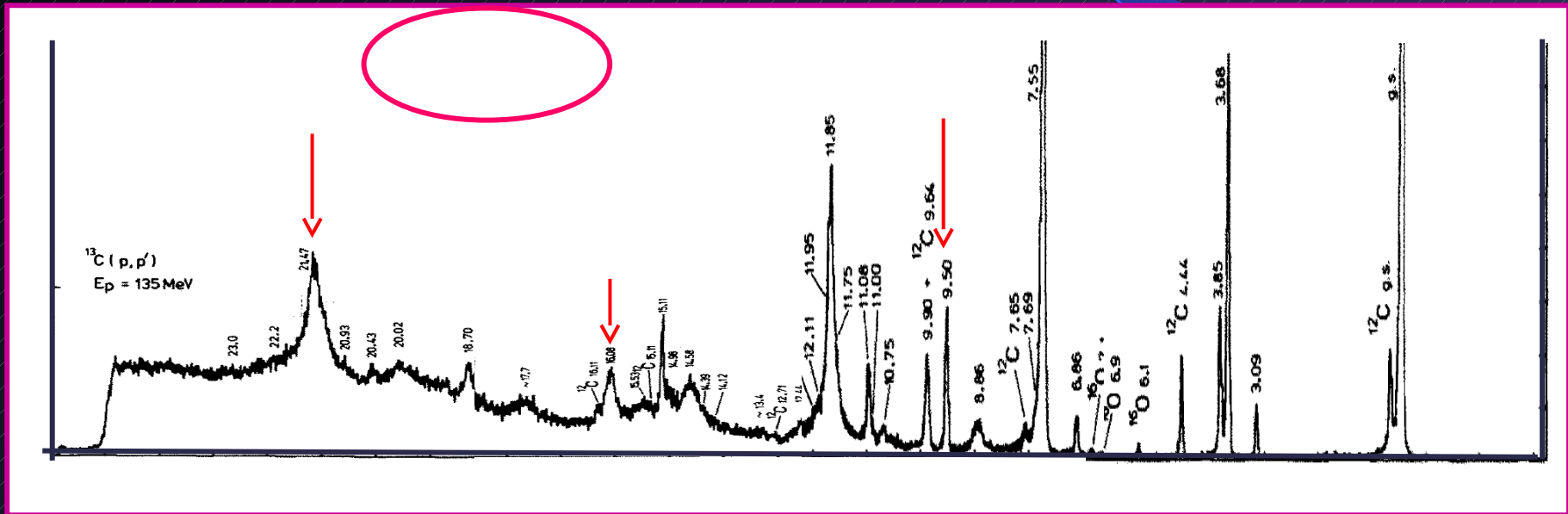


Spectra of electrons scattered through 180° —
measurements at momentum transfer close to where
M4 transitions have the maximum cross section

R.S. Hicks et al., Phys. Rev. C 34, 1161 (1986).

Inelastic proton scattering on ^{13}C

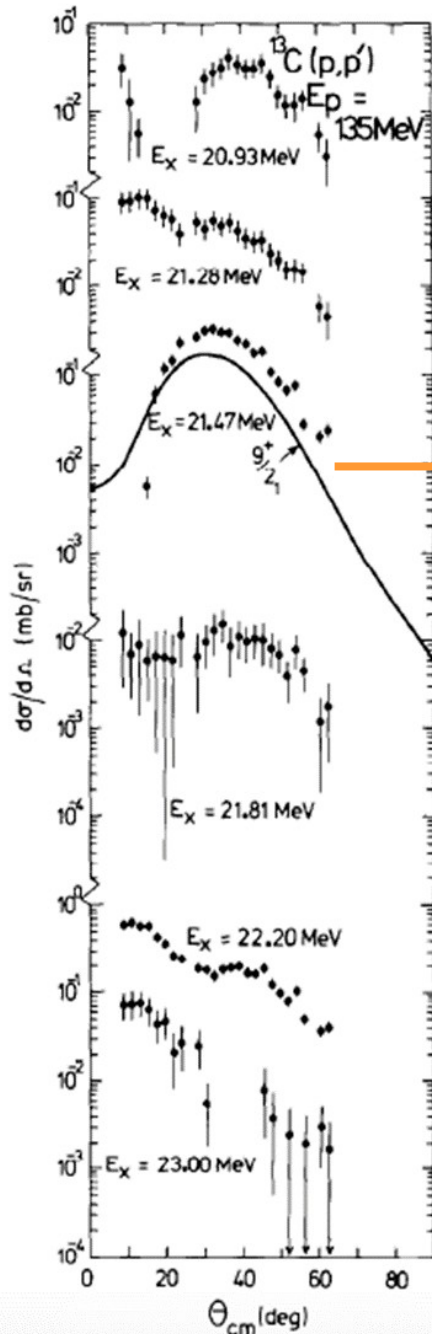
The 9.5, 16.08 and 21.47 MeV (M4) resonances are clearly visible



Indiana University Cyclotron Facility
Magnetic Spectrograph

(p,p') on ^{13}C

Differential cross sections
measured for states
around 21 MeV in excitation

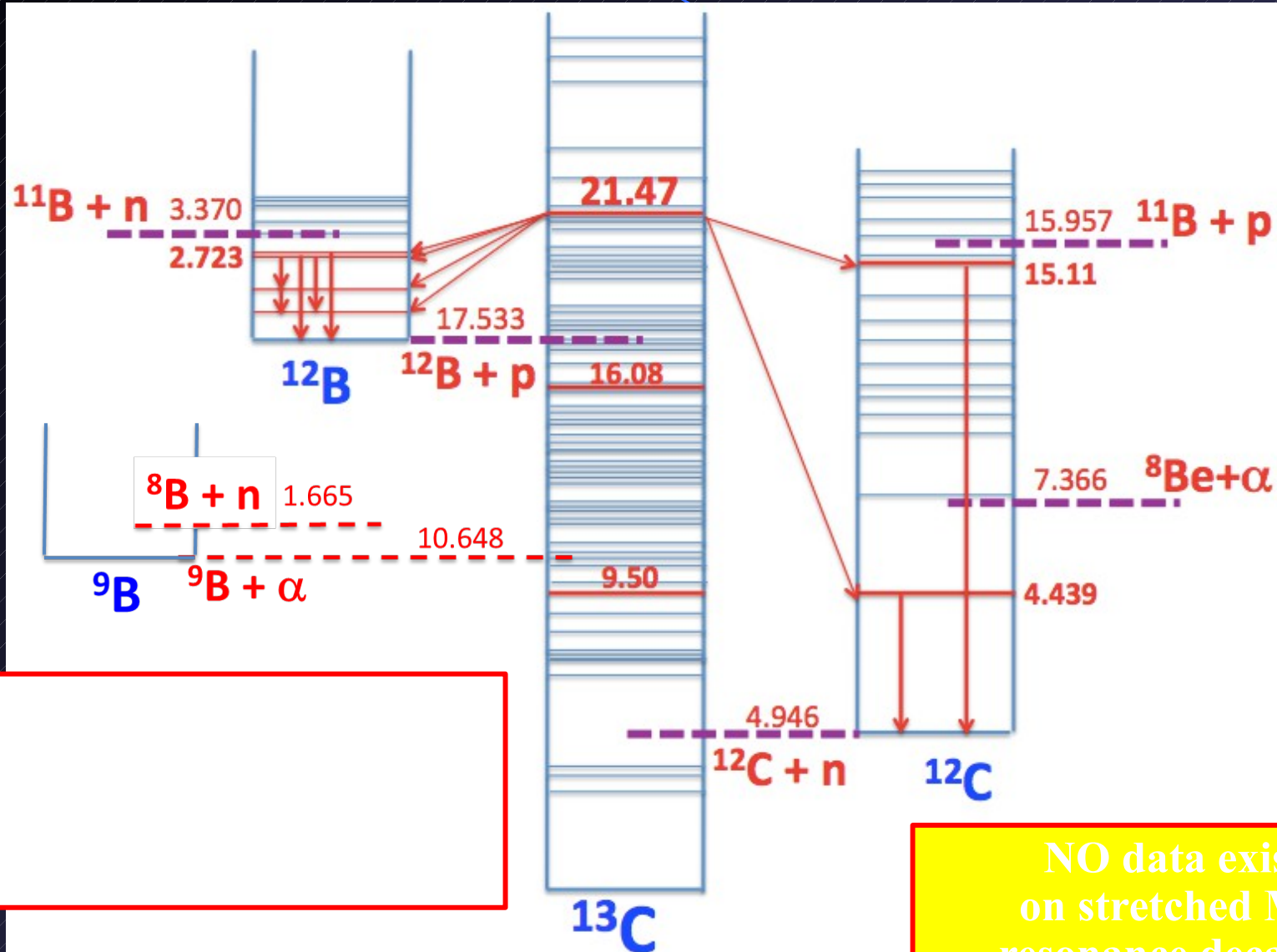


The M4 resonance at 21.47 MeV
is peaked at 35°

Very fortunate angular position
for our experimental setup !

Aim of the experiment:

To identify decay from the 21.47 MeV resonance in ^{13}C for future comparisons with *ab-initio* and *particle-core coupling* models



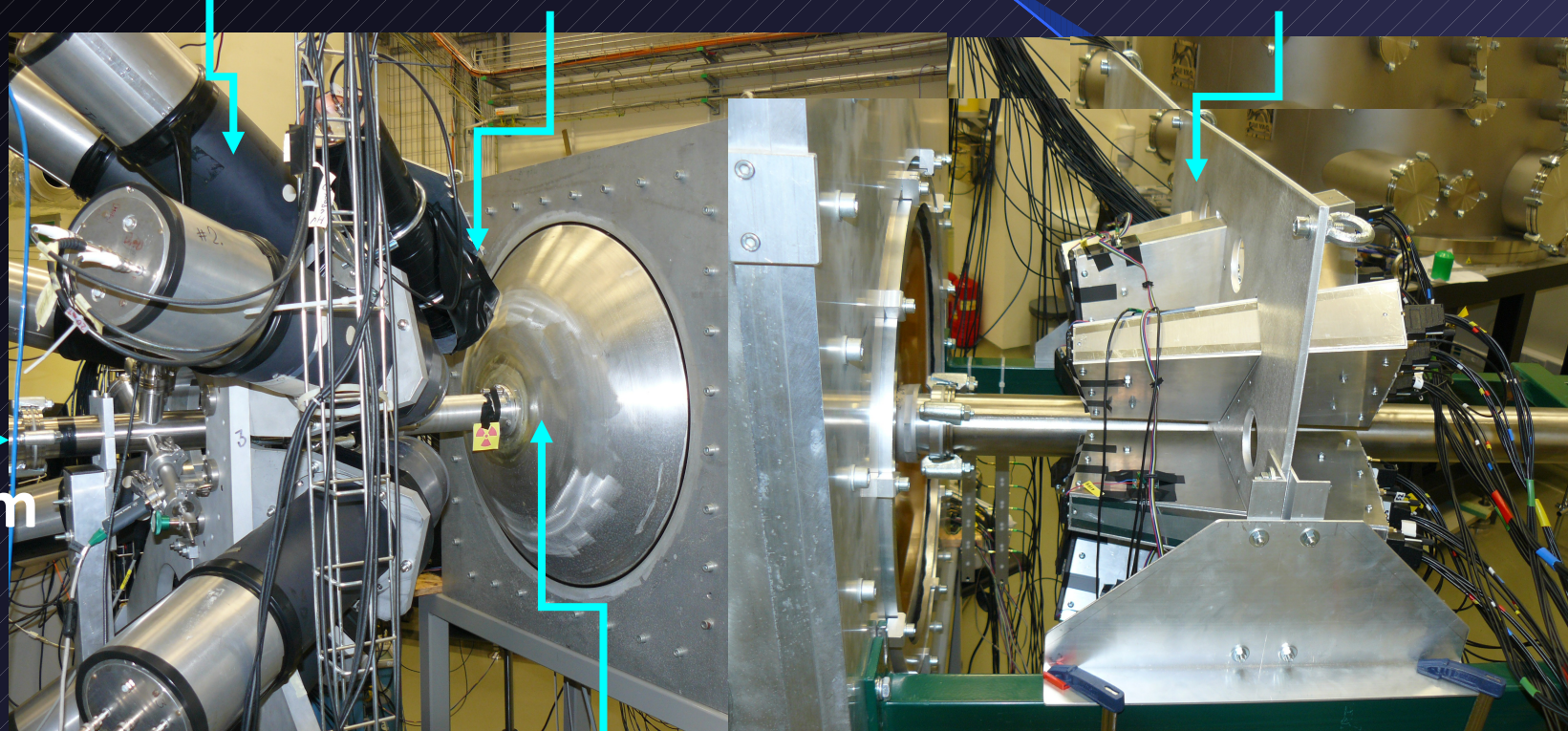
NO data exist
on stretched M4
resonance decay !!

Experimental Setup

HECTOR

4 LaBr₃ + 2 PARIS clusters

KRATTA



beam

Target

June 2016

PREPARATORY TEST – June 2017 (3 hours)

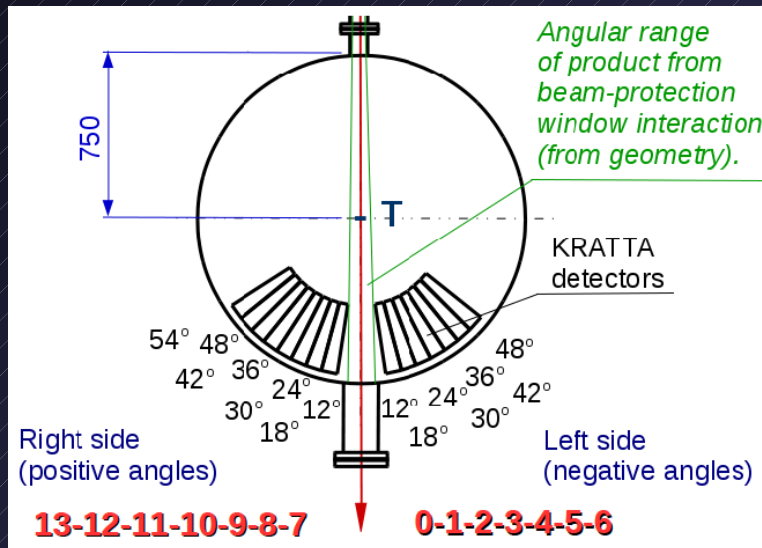
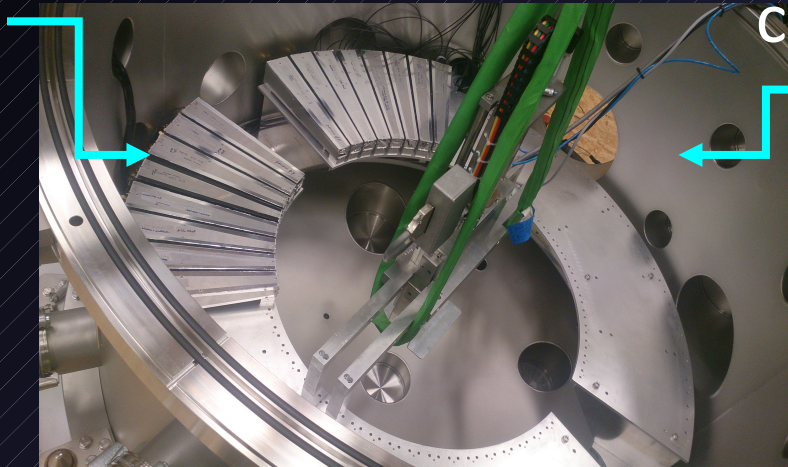
Population of 21.47 MeV resonance in ^{13}C

KRATTA

Scattering
chamber

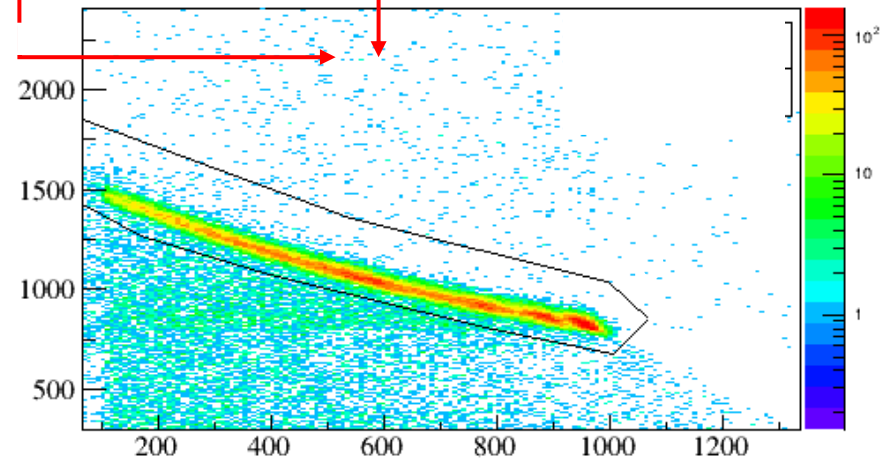
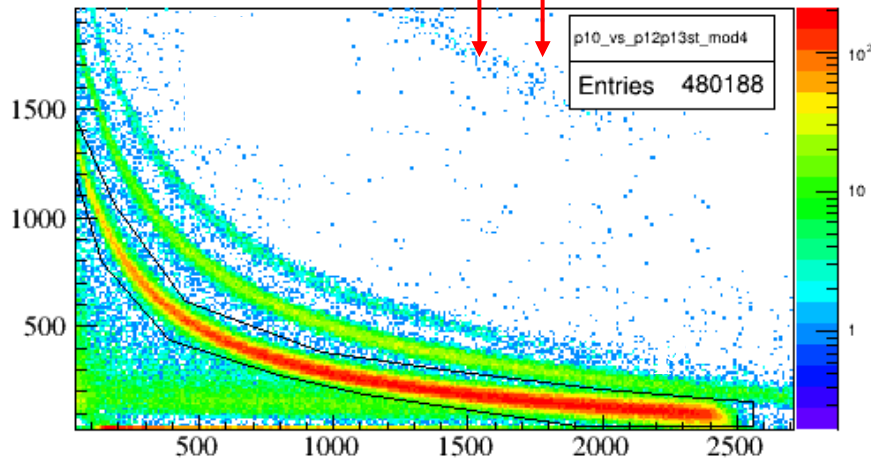
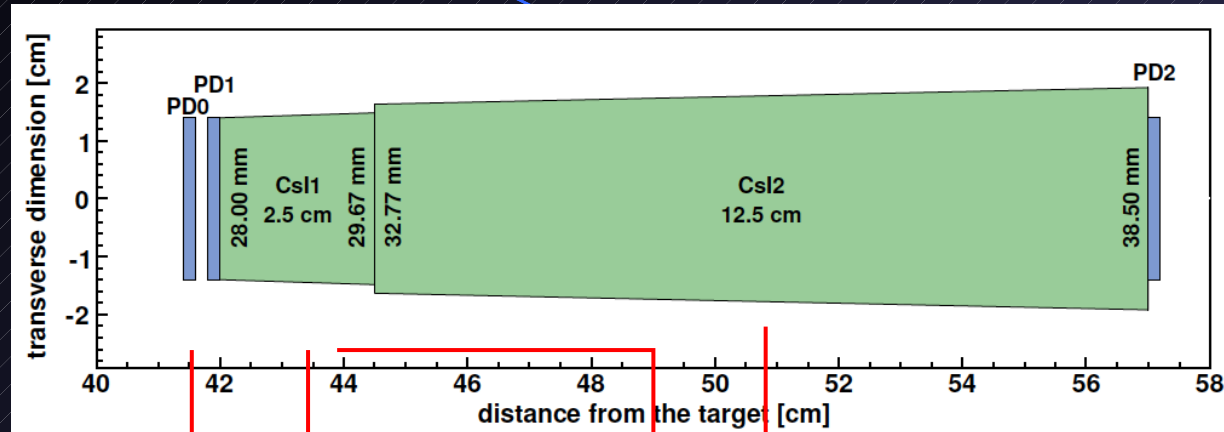
Target

$^{12}\text{C} - ^{13}\text{C}$: 50%-50%
160 mg/cm² (700 μm)
 $\rightarrow = 3 \chi\mu$

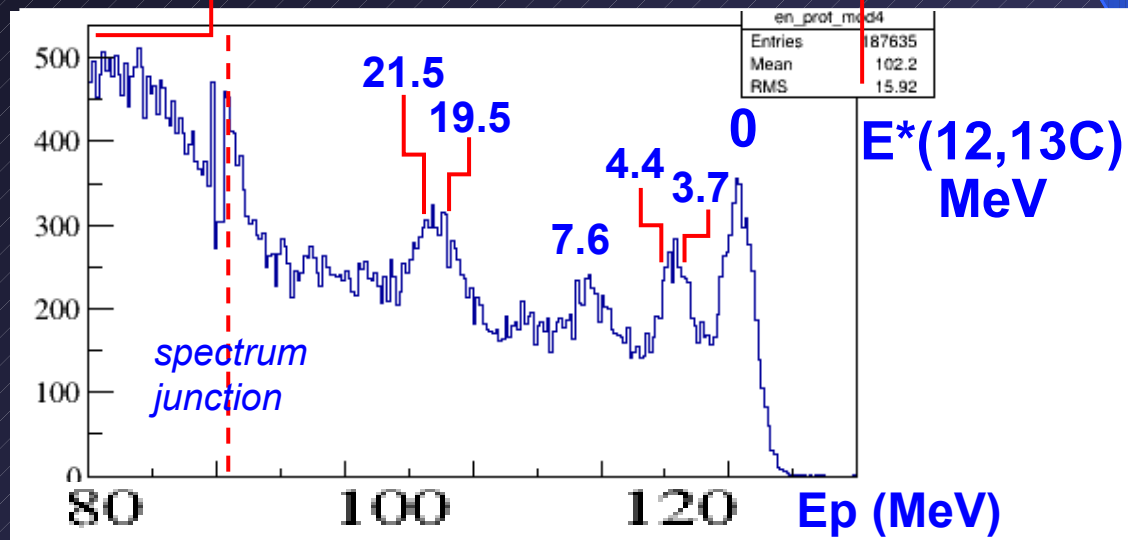
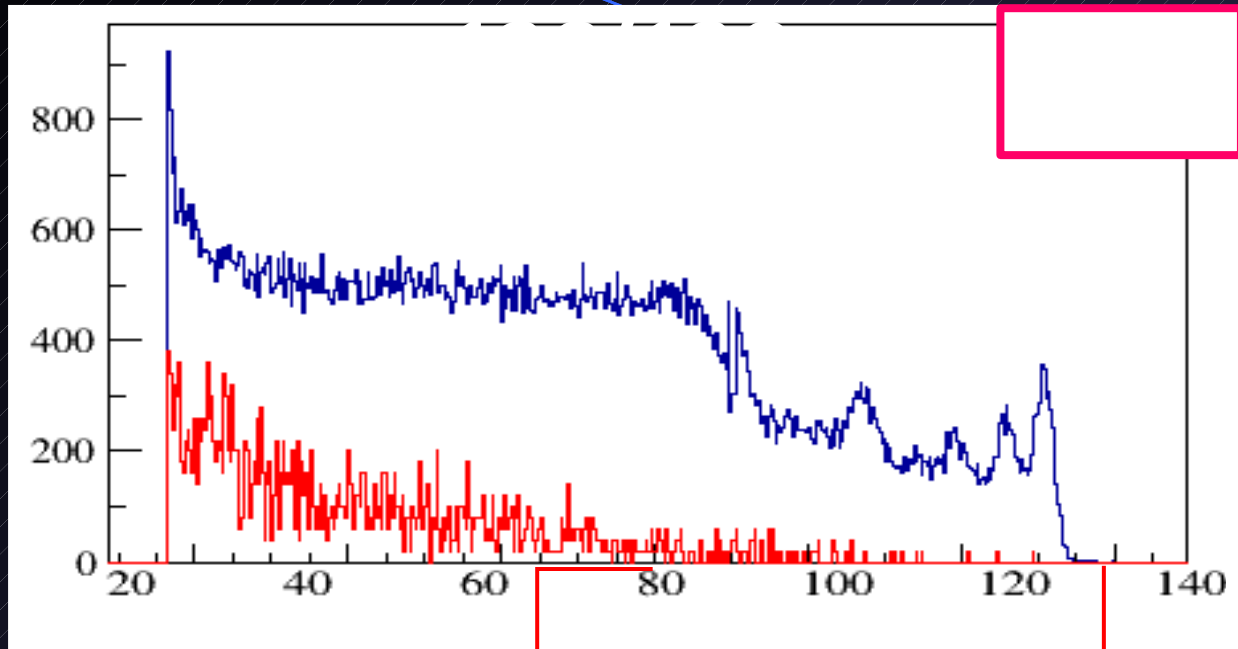


p (130 MeV, $I_{\text{target}} = 0.3 \text{ nA}$) + $^{12}\text{C}/^{13}\text{C}$

KRATTA Triple Telescope

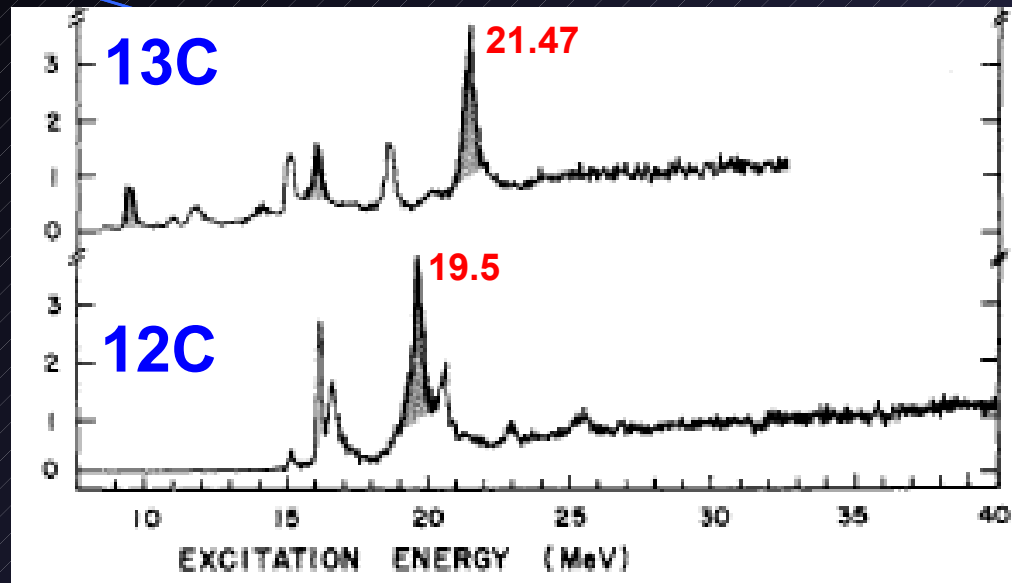


p (130 MeV, $I_{\text{target}} = 0.3 \text{ nA}$) +

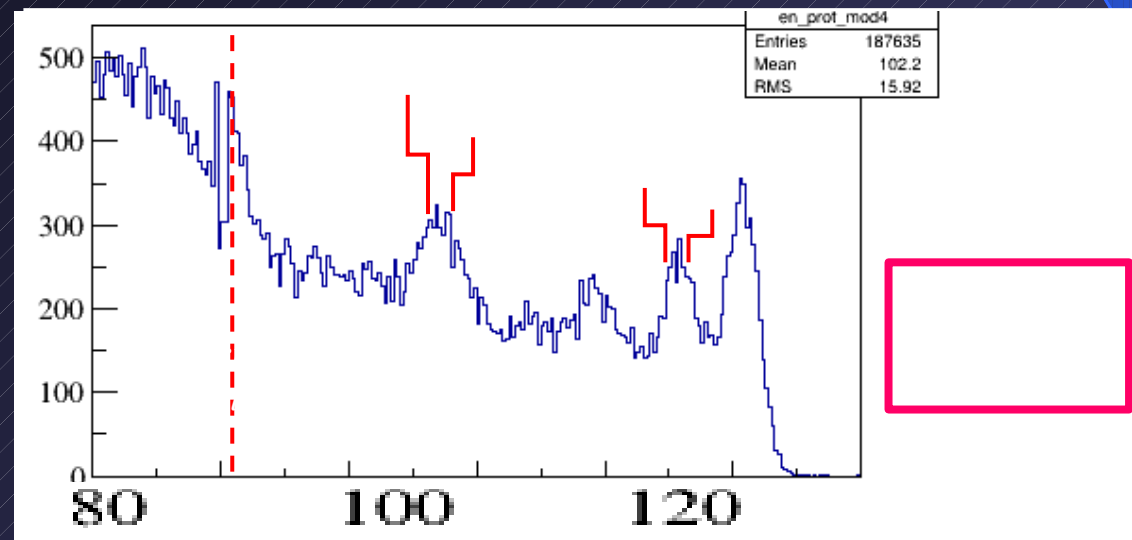


Analysis performed by I. Ciepal and J. Lukasik

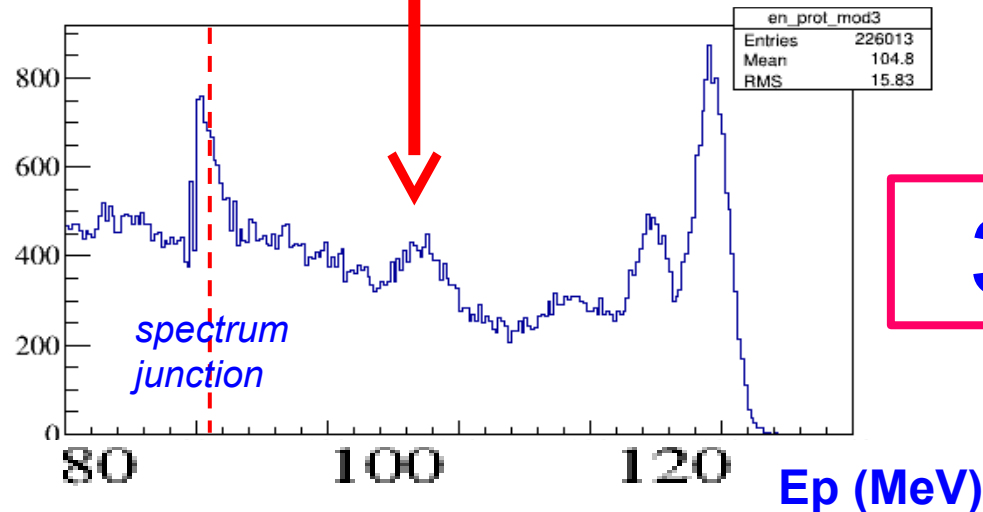
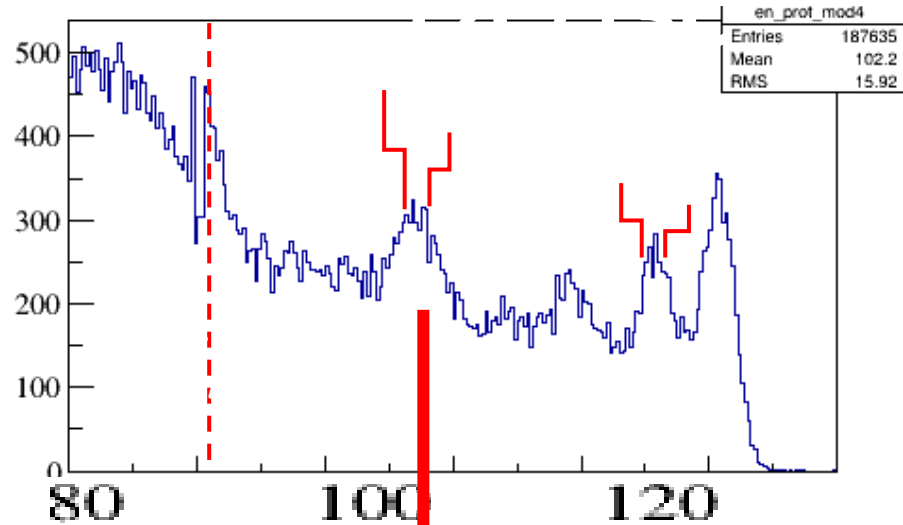
$e +$
 $^{12}\text{C}/^{13}\text{C}$



$p +$
 $^{12}\text{C}/^{13}\text{C}$



p (130 MeV, $I_{\text{target}} = 0.3 \text{ nA}$) +



30°

COUNT RATES ESTIMATES based on the TEST

γ -decay after p, n decay from M4 resonance of ^{13}C at 21.47 MeV

^{13}C target: 160 mg/cm²; beam energy : 130 MeV

proton beam current (on target): 0.3 nA

→ 1000 counts in 1 KRATTA module for the 21.47 MeV resonance in 3 hours

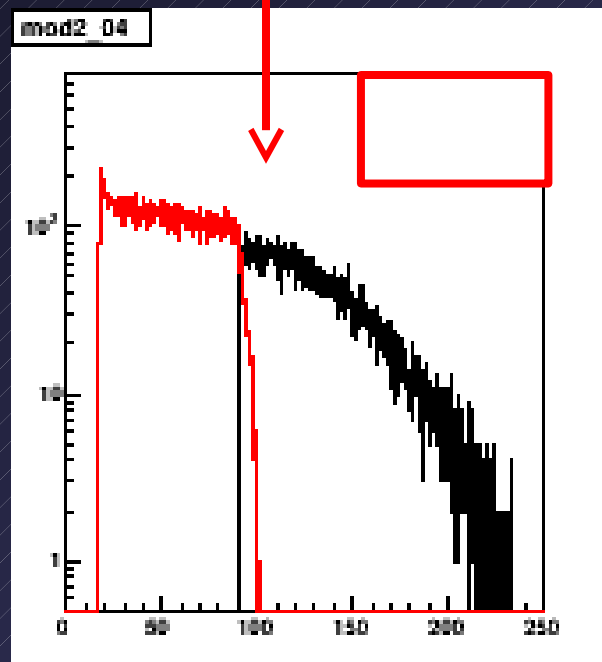
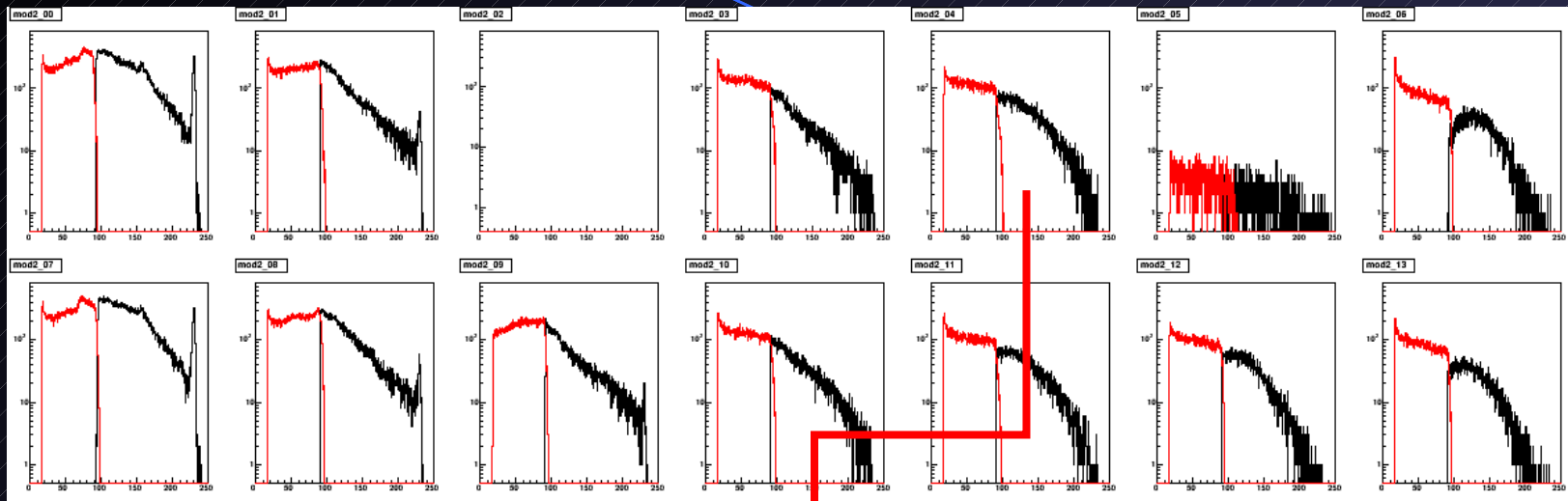
	4 MeV γ -ray	15 MeV γ -ray
p or n branching (to ^{12}C / ^{12}B states)	5 %	1 %
KRATTA coverage around 30°	0.08 sr	0.08 sr
ϵ (4 LaBr ₃)	1.5 %	0.5 %
ϵ (2 PARIS Clusters)	3.0 %	1.5 %

9 (left) + 9 (right)
KRATTA Telescopes

2 weeks are equivalent
to 160 hours (20 shifts)

N.B. : by reducing the dead time of KRATTA
(for example by using only detectors around 30°)
a factor ≥ 10 can be gained

KRATTA Calibration - Ti Target



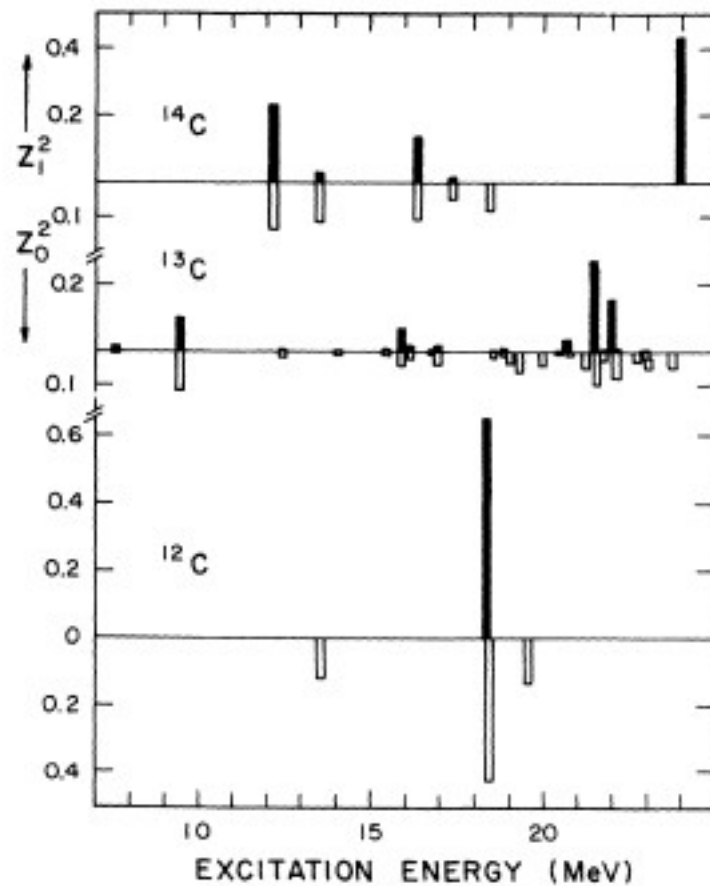


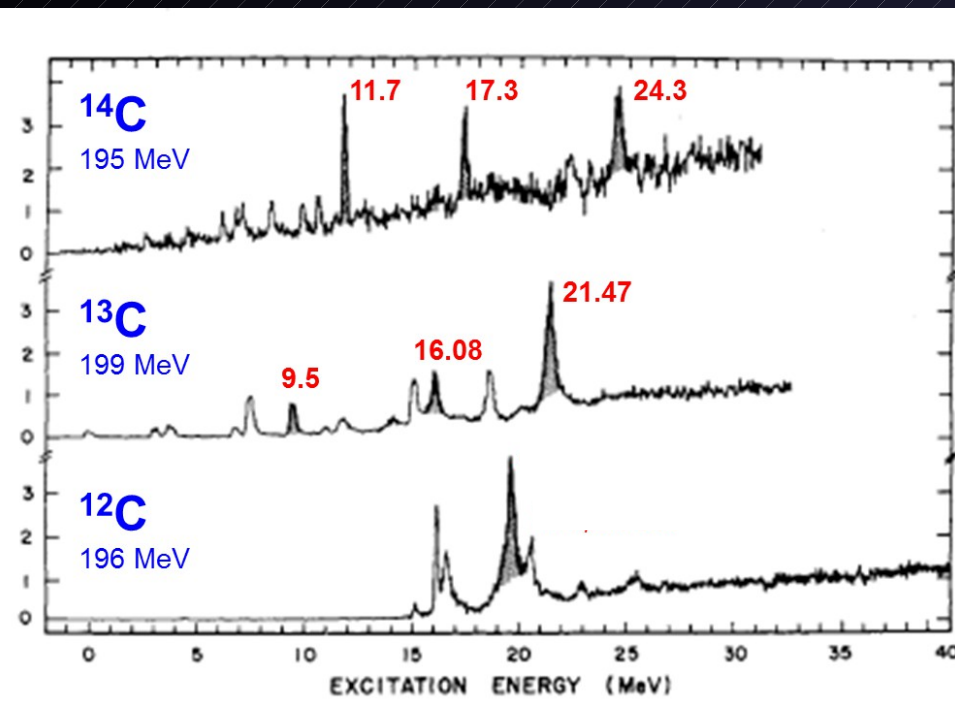
FIG. 2. Squared shell model transition amplitudes obtained for $M4$ excitations in carbon isotopes. Isovector amplitudes are represented by solid bars and read upward. Isoscalar amplitudes are represented by open bars and read downward.

TABLE I. A tabulation of excitation energies and (e, e') and (p, p') cross sections for known unnatural-parity states of expected stretched configurations. The experimental uncertainties on σ_{exp} are typically $\pm 15\%$ except for $^{28}\text{Si}(e, e')$, where it is larger.

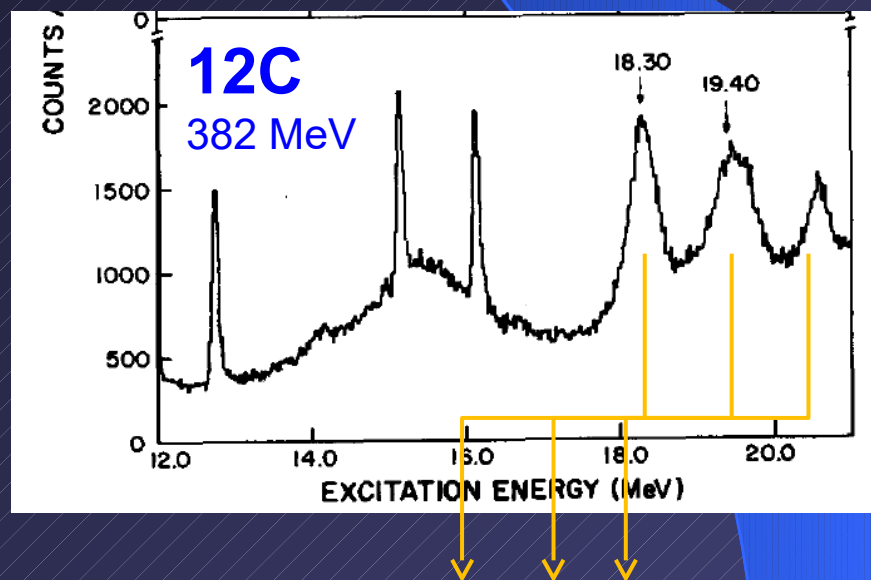
Nucleus	E_{exp} (MeV)	E_{th} (MeV)	$\sigma_{\text{exp}}/\sigma_{\text{th}}$ (e, e')	(p, p')
$^{12}\text{C}(d_{5/2}p_{3/2}^{-1})4^{-}$	19.5	17.6 ^b	0.27 ^f	
$^{16}\text{O}(d_{5/2}p_{3/2}^{-1})4^{-}$	18.9	17.7 ^b	0.45 ^g	0.32 ^m
$^{24}\text{Mg}(f_{7/2}d_{5/2}^{-5})6^{-}$	15.14	17.6 ^c	0.27 ^h	0.30 ⁿ
$^{28}\text{Si}(f_{7/2}d_{5/2}^{-1})6^{-}$	14.36	16.9 ^c	0.59 ⁱ	0.29 ⁿ
$^{58}\text{Ni}(g_{9/2}f_{7/2}^{-1})8^{-}$	10.30 ^a	10.4 ^d	0.30 ^j	
$^{208}\text{Pb}(\pi i_{13/2}h_{11/2}^{-1})12^{-}$	7.06	7.18 ^e	0.56 ^k	0.20 ^o
$^{208}\text{Pb}(\nu j_{15/2}i_{13/2}^{-1})12^{-}$	6.42	6.49 ^e	0.54 ^k	0.80 ^o
$^{208}\text{Pb}(\nu i_{15/2}i_{13/2}^{-1})14^{-}$	6.75	6.49 ^e	0.56 ^l	0.46 ^o

The obvious ^{12}C case is complex

(e,e') scattering



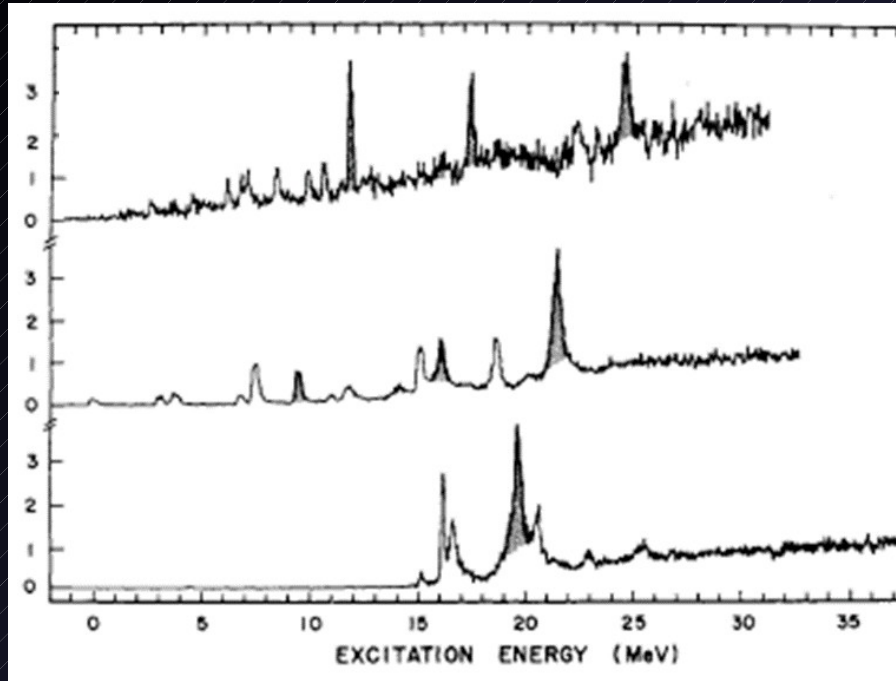
(p,p') scattering on ^{12}C



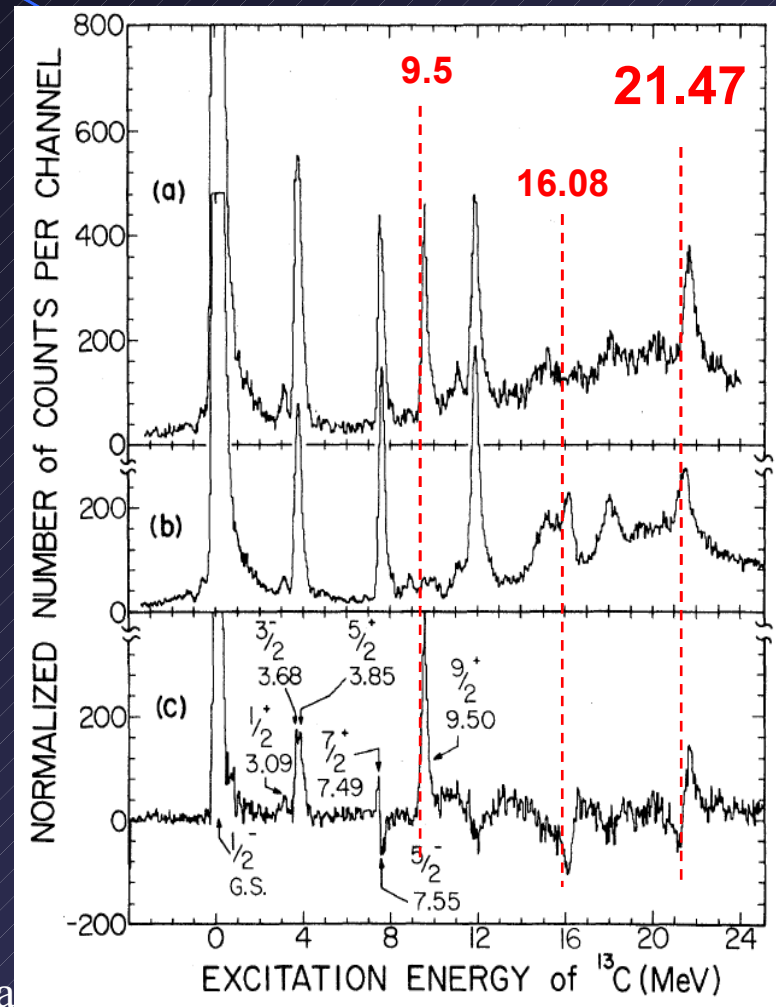
strong 2- components

Our choice is ^{13}C

(e,e') scattering



(π,π') σχαττερινηγ ον ^{13}X



π^+

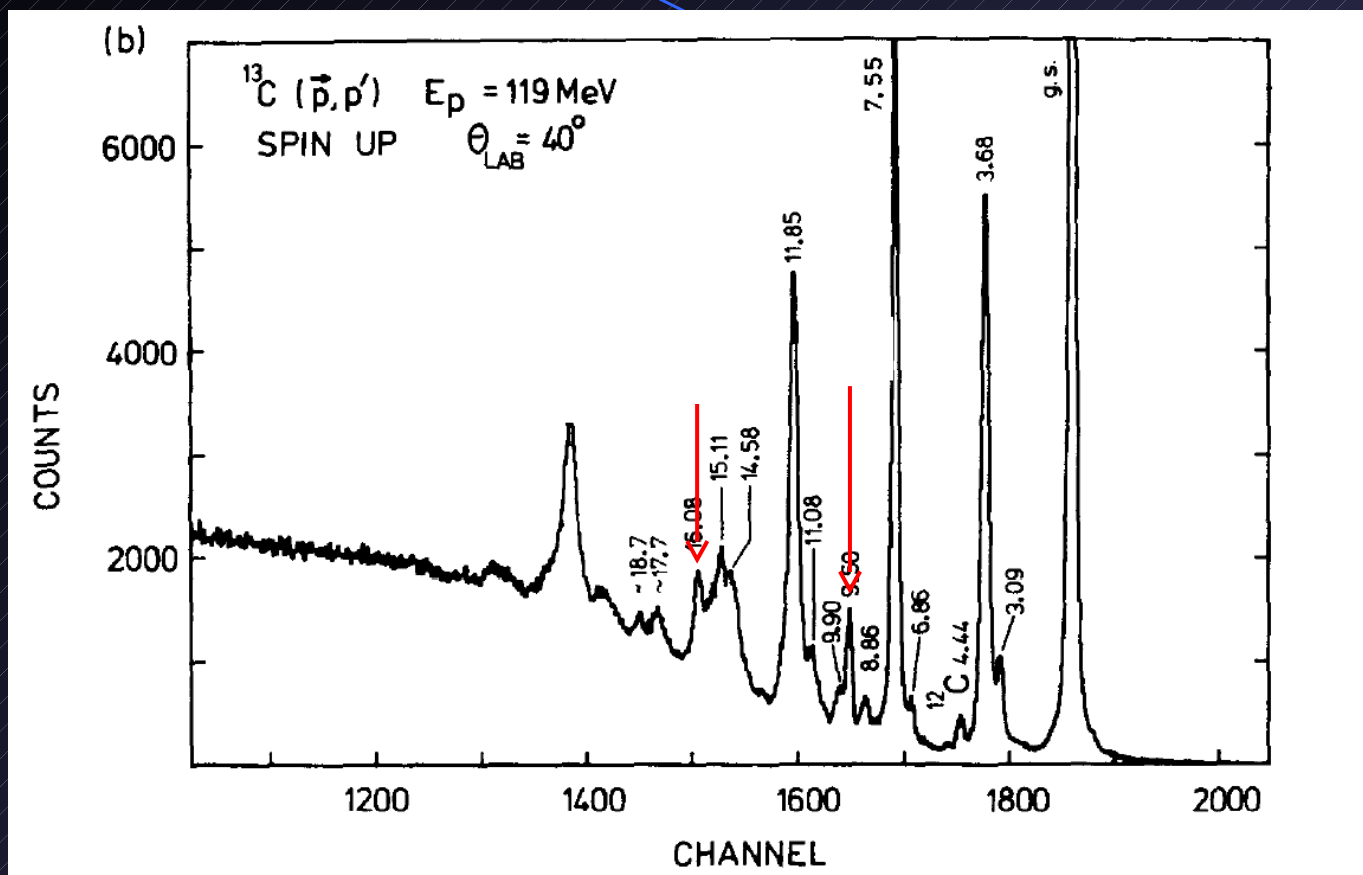
π^-

$\pi^+ - \pi^-$

from (π,π') scattering:

- **9.5 MeV** is $9/2^+$: pure n excitation
- **16.08 MeV** is $7/2^+$: mainly p excitation
- **21.47 MeV** is $(7/2^+, 9/2^+)$ p and n excitations

Inelastic scattering of polarized protons on ^{13}C



Indiana University Cyclotron Facility
Ge Detector Telescope
(0.17 msr solid angle)