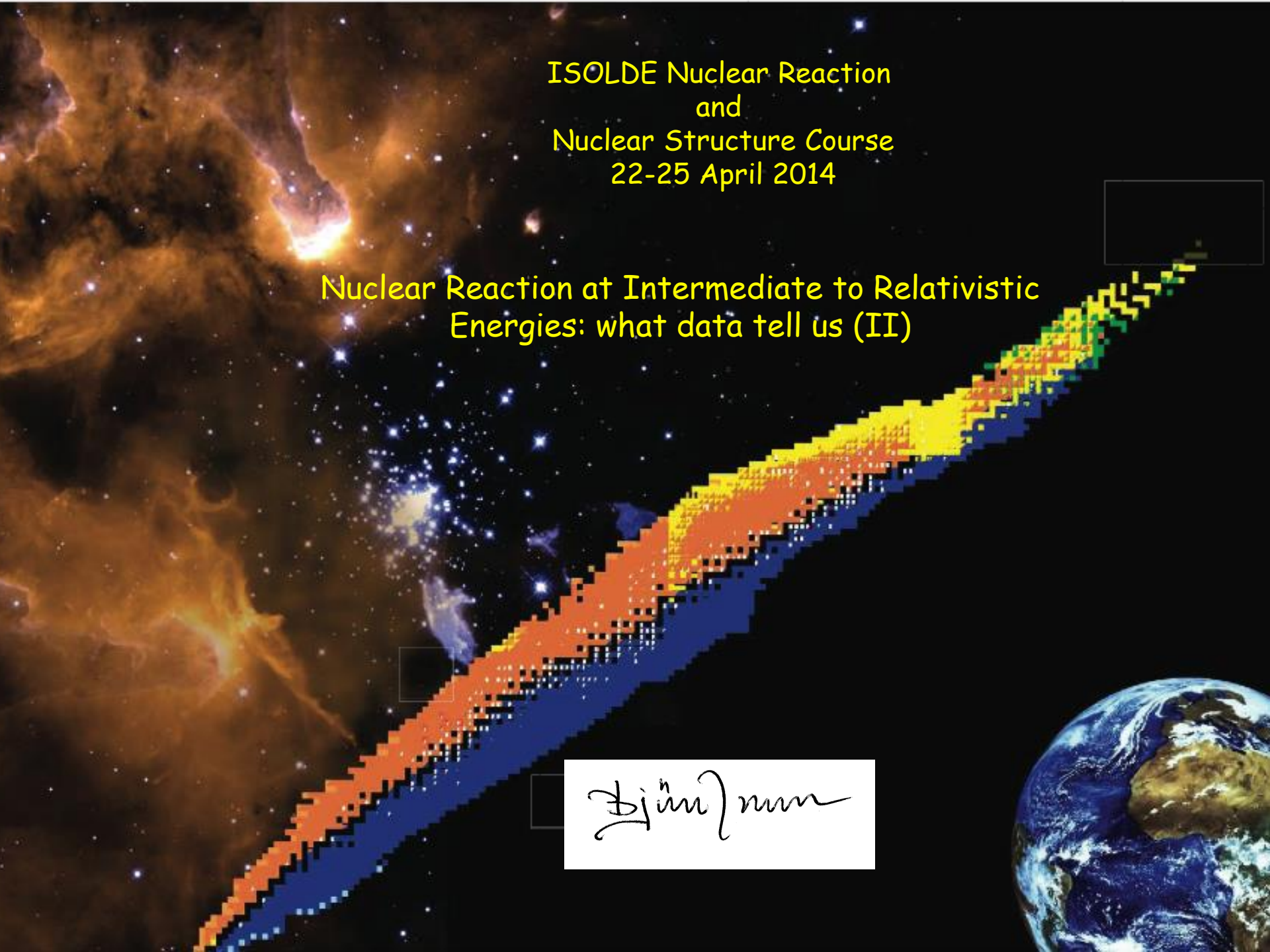
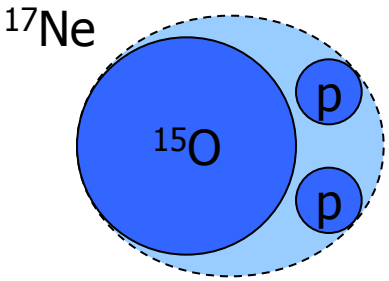
ISOLDE Nuclear Reaction
and
Nuclear Structure Course
22-25 April 2014

Nuclear Reaction at Intermediate to Relativistic Energies: what data tell us (II)

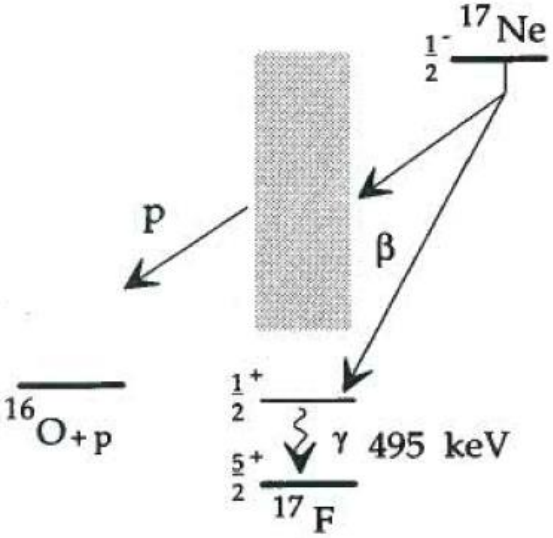


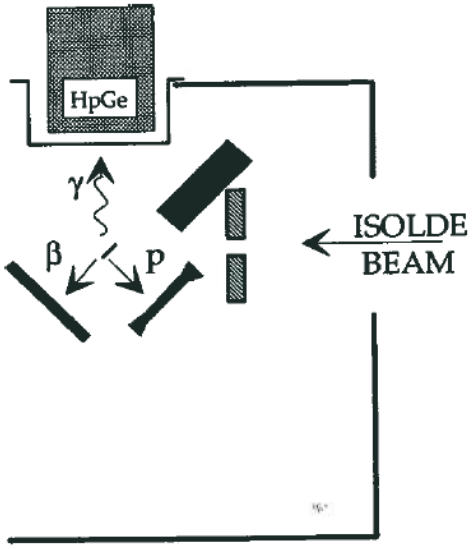
^{15}Ne unbound	^{16}Ne unbound	^{17}Ne 109.2 ms	^{18}Ne 1.67 s
	^{15}F unbound	^{16}F unbound	^{17}F 64.8 s
^{13}O 8.58 ms	^{14}O 70.59 s	^{15}O 2.03 m	

BORROMEAN



ISOLDE 1992

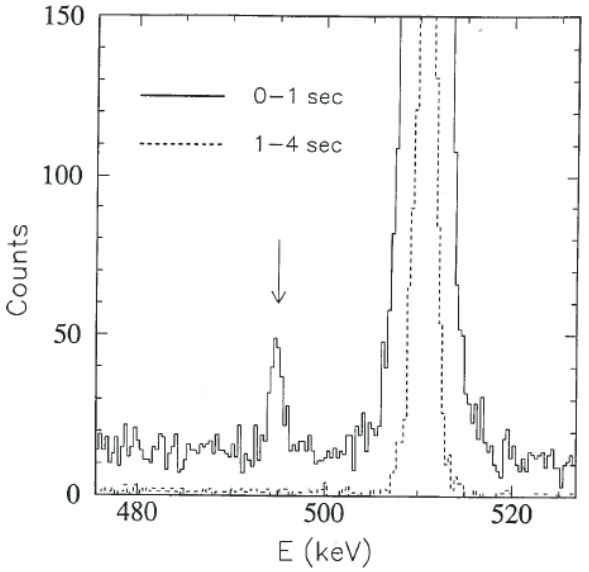




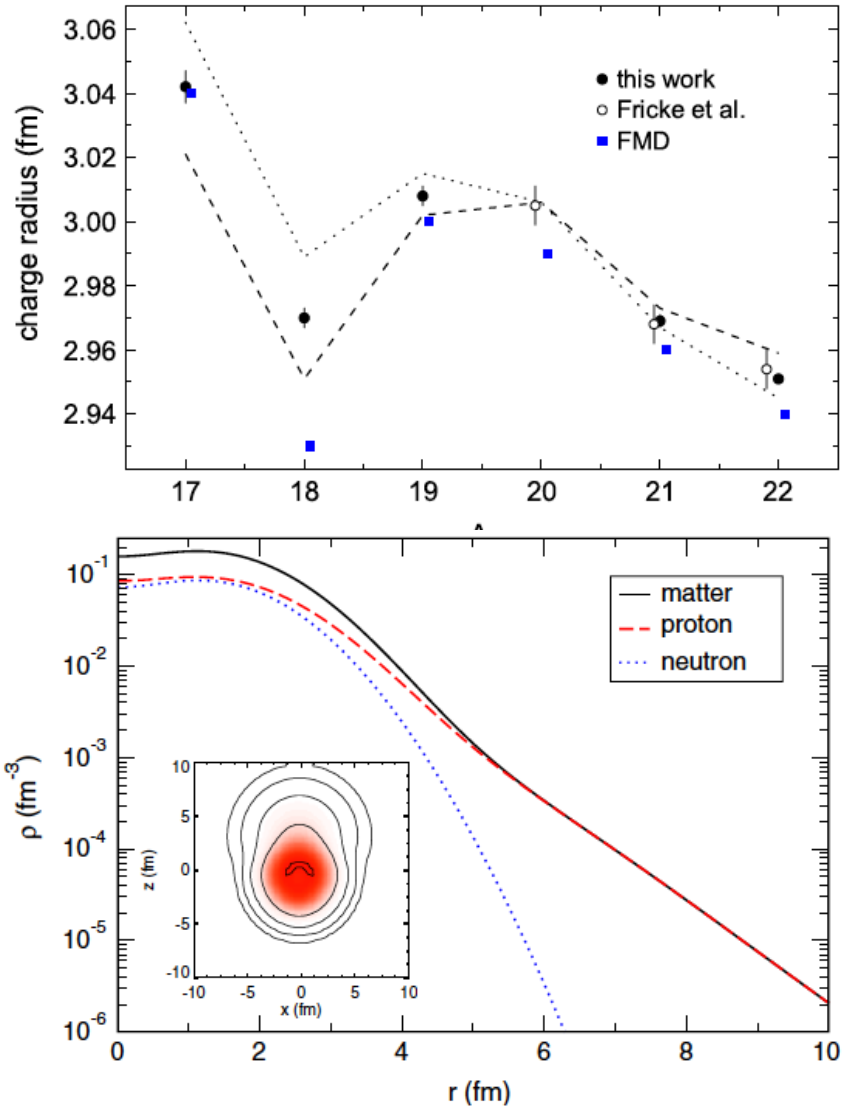
Mirror decay ^{17}N → ^{17}O

$$d = \frac{(ft)^+}{(ft)^-} - 1 = -0.55 \pm 0.09$$

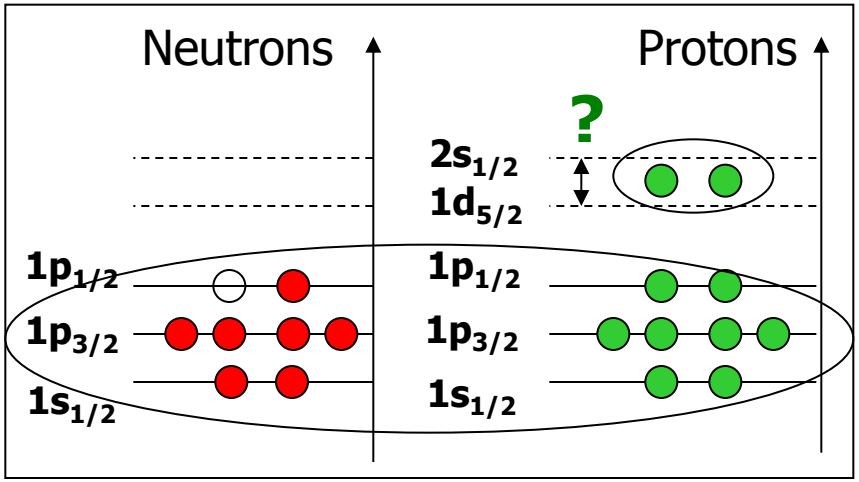
Beta-decay to the proton halo state in ^{17}F



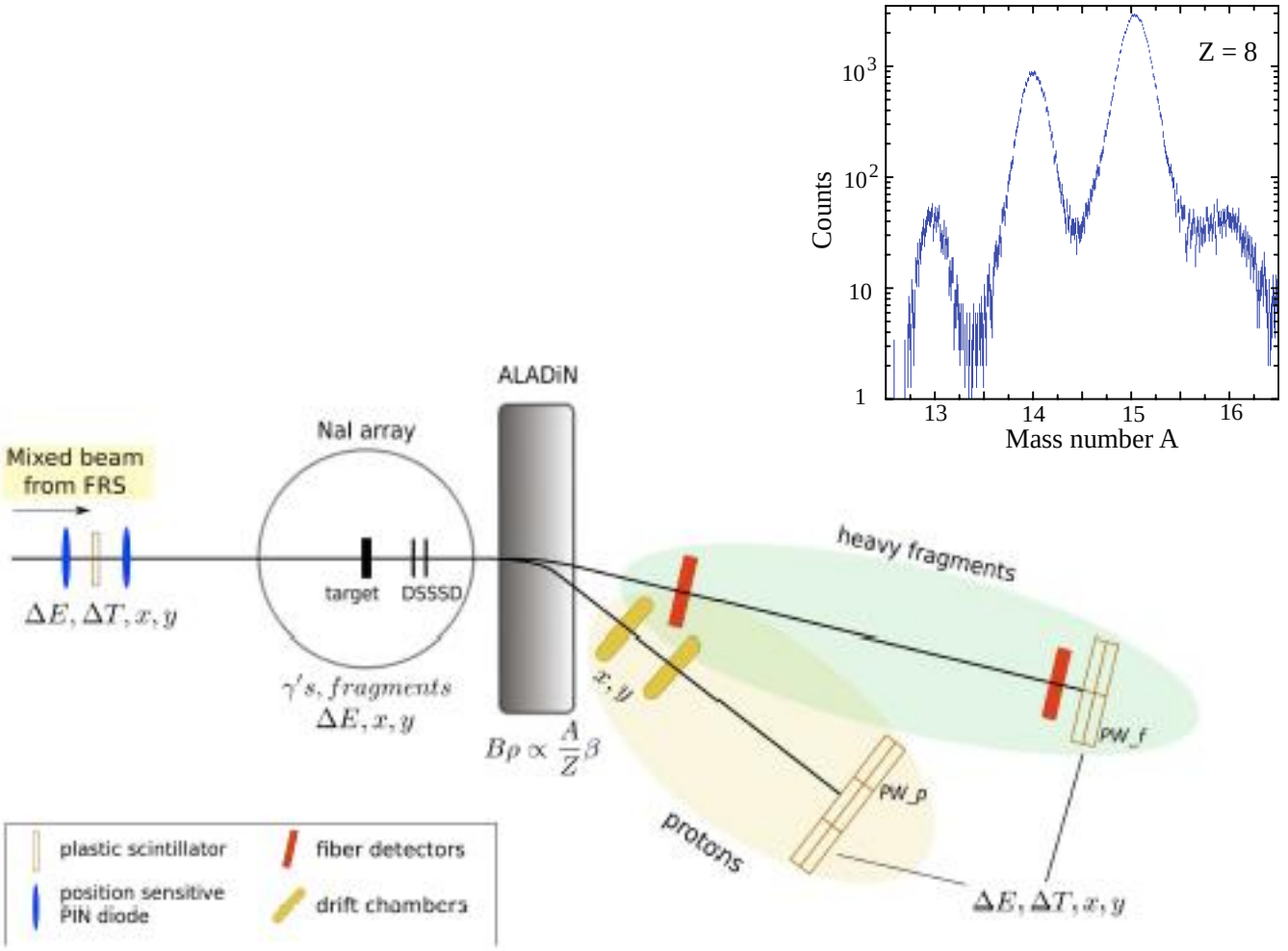
M.J.G. Borge et al.,Phys. Lett. B 317 (1993) 25

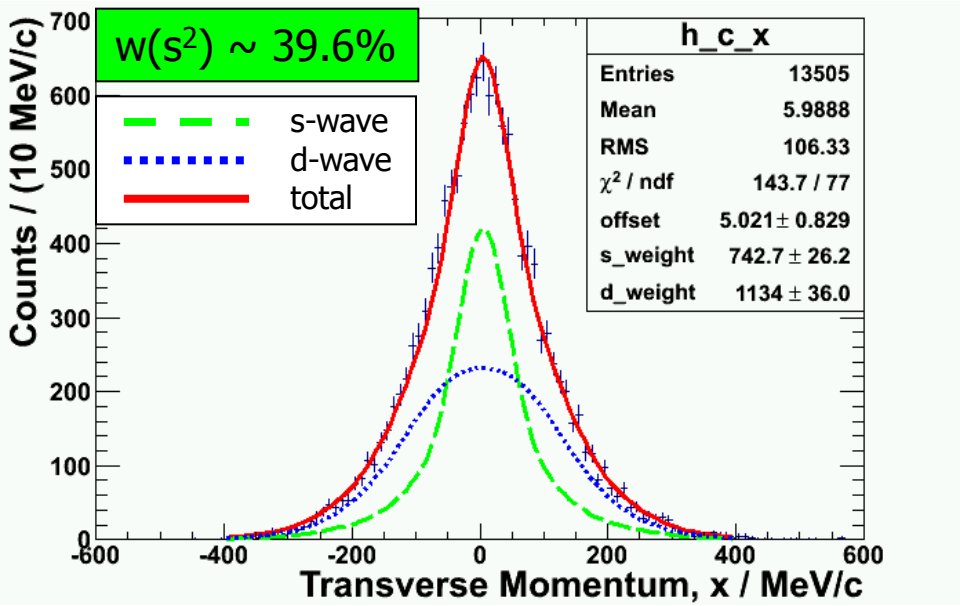


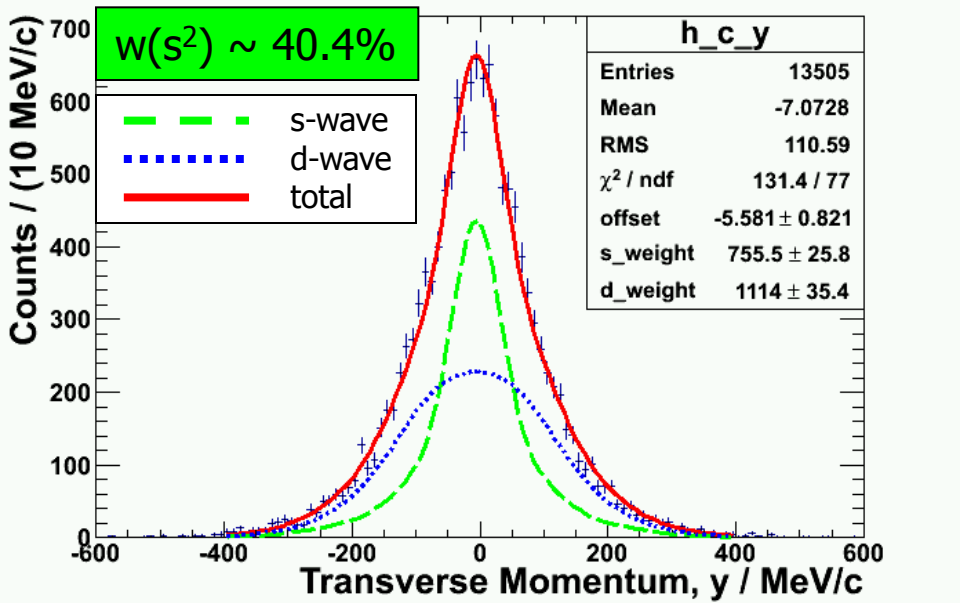
W. Geithner et al.,Phys. Rev. Lett. 101 (2008) 252502

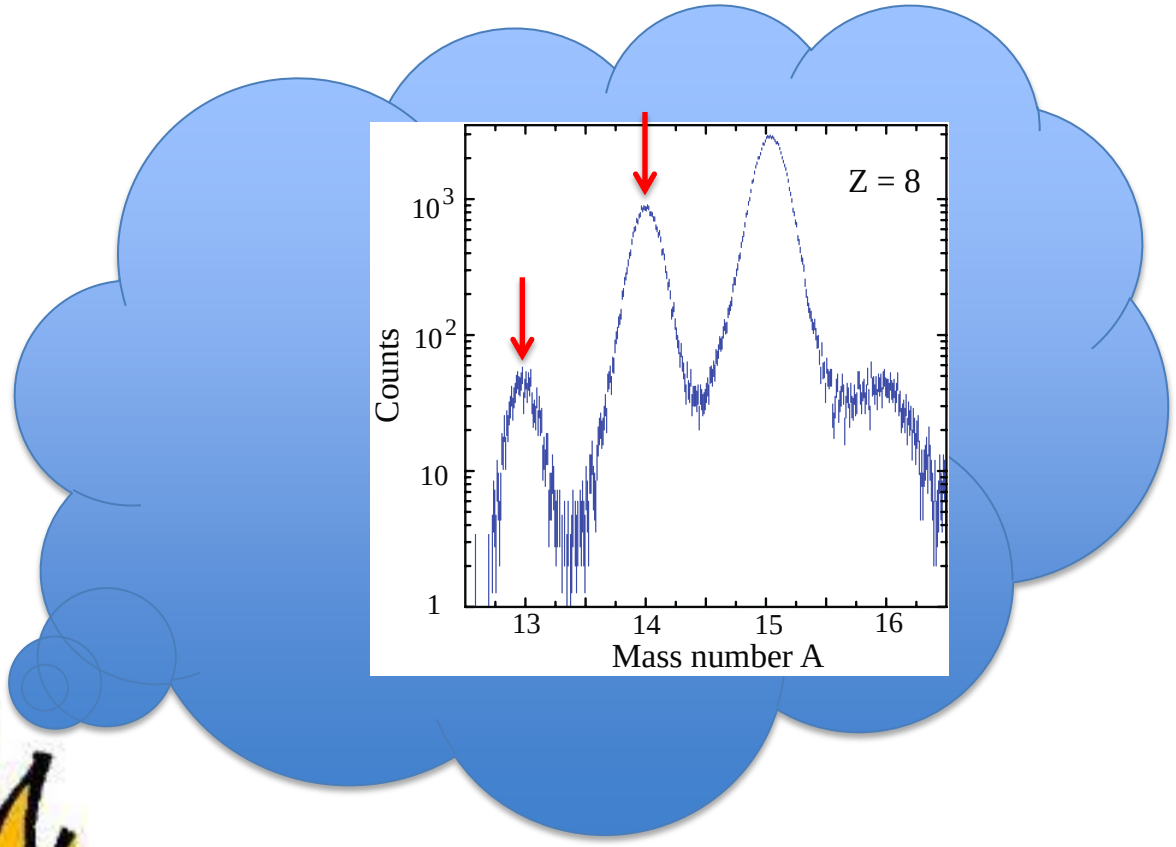


Shell model view of the ^{17}Ne ground-state

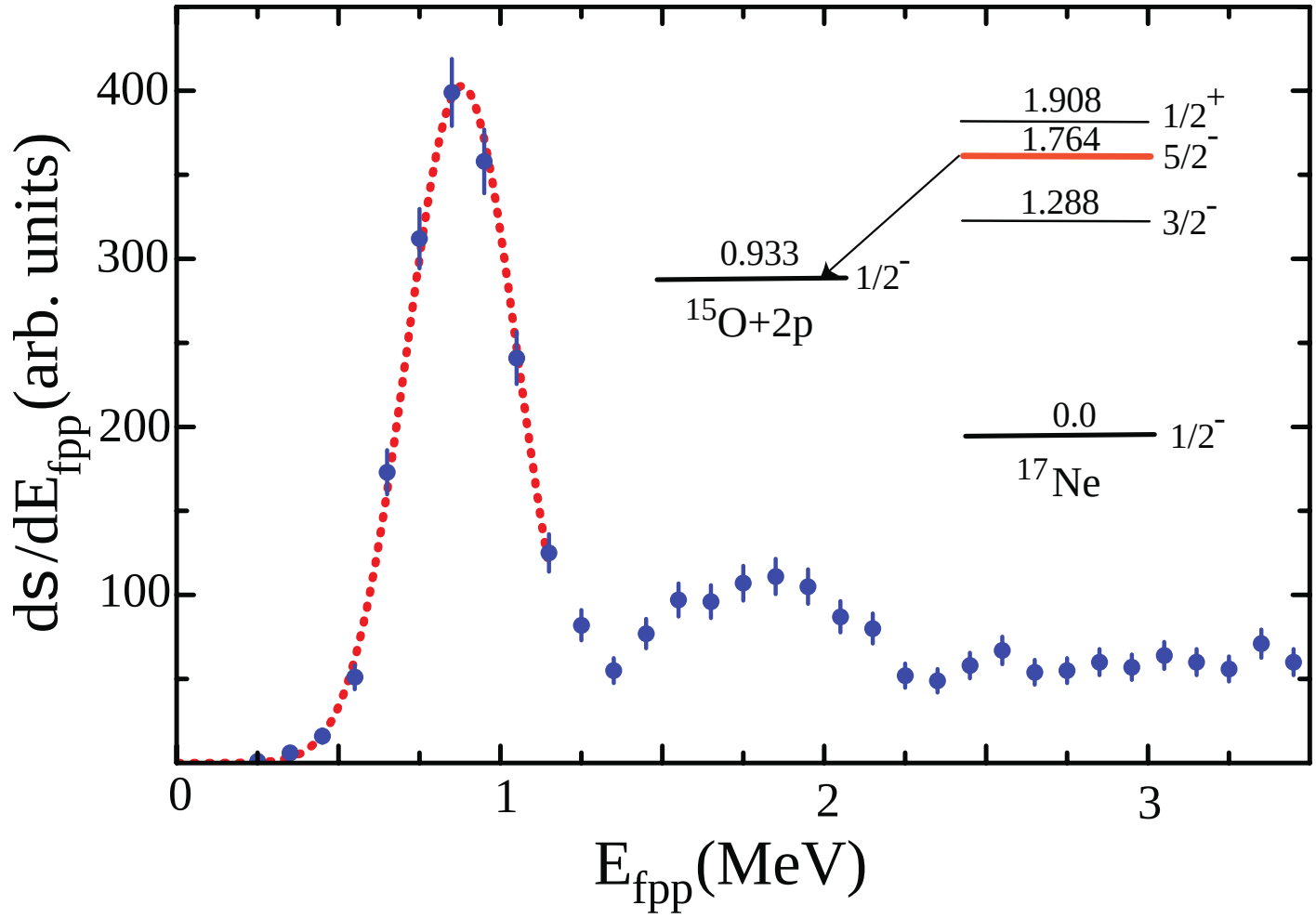

Z = 8
Counts
Mass number A
ALADiN
NaI array
Mixed beam
from FRS
target
DSSSD
$\Delta E, \Delta T, x, y$
$\gamma's, fragments$
$\Delta E, x, y$
$B\rho \propto \frac{A}{Z}\beta$
heavy fragments
protons
PW_f
PW_p
x, y
$\Delta E, \Delta T, x, y$
plastic scintillator
position sensitive
PIN diode
fiber detectors
drift chambers

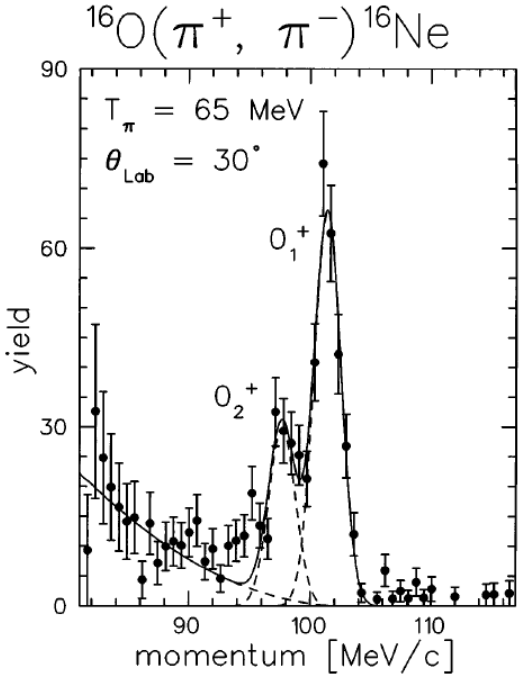

w(s²) ~ 39.6%
s-wave
d-wave
total
h_c_x
Entries 13505
Mean 5.9888
RMS 106.33
χ² / ndf 143.7 / 77
offset 5.021 ± 0.829
s_weight 742.7 ± 26.2
d_weight 1134 ± 36.0
Counts / (10 MeV/c)
Transverse Momentum, x / MeV/c


w(s²) ~ 40.4%
s-wave
d-wave
total
h_c_y
Entries 13505
Mean -7.0728
RMS 110.59
χ² / ndf 131.4 / 77
offset -5.581 ± 0.821
s_weight 755.5 ± 25.8
d_weight 1114 ± 35.4
Counts / (10 MeV/c)
Transverse Momentum, y / MeV/c



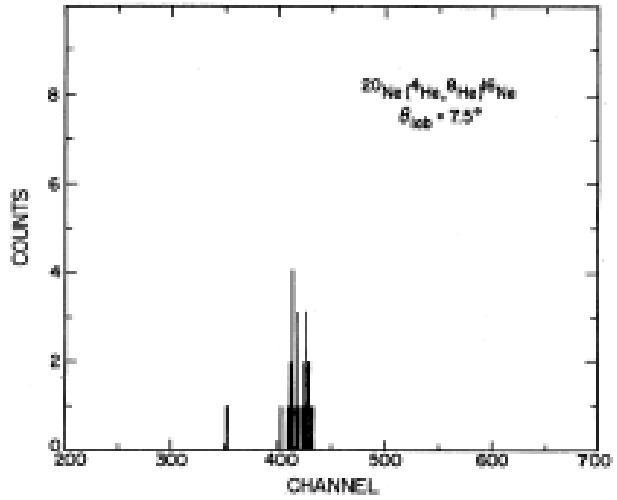
^{15}Ne	^{16}Ne	^{17}Ne
unknown	unbound	109.2 ms


400
300
200
100
0
1
2
3
ds/dE$_{fpp}$(arb. units)
E$_{fpp}$(MeV)
1.908
1/2$^+$
1.764
5/2$^-$
1.288
3/2$^-$
0.933
1/2$^-$
^{15}O+2p
0.0
1/2$^-$
^{17}Ne



K. Föhl et al.,
Phys. Rev. Lett. 79 (1997) 3849

$^{20}Ne(^4He,^8He)^{16}Ne$

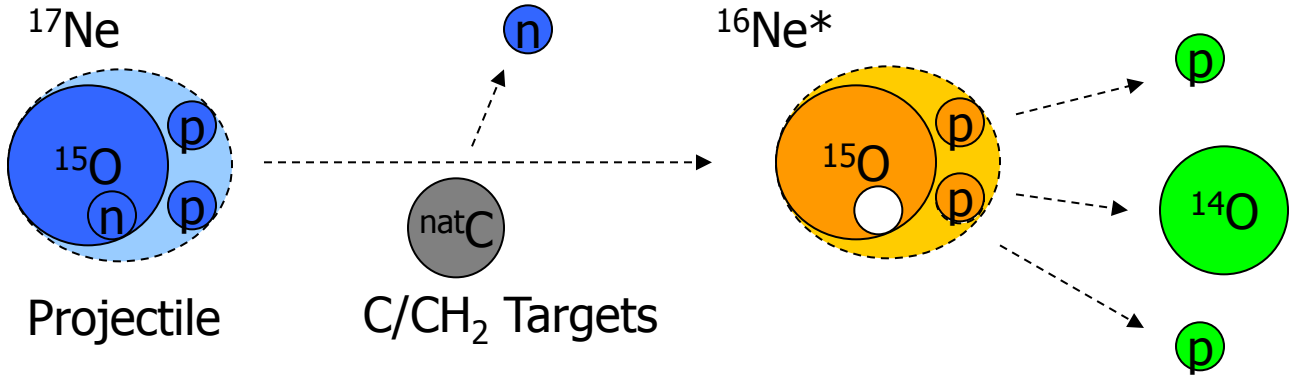


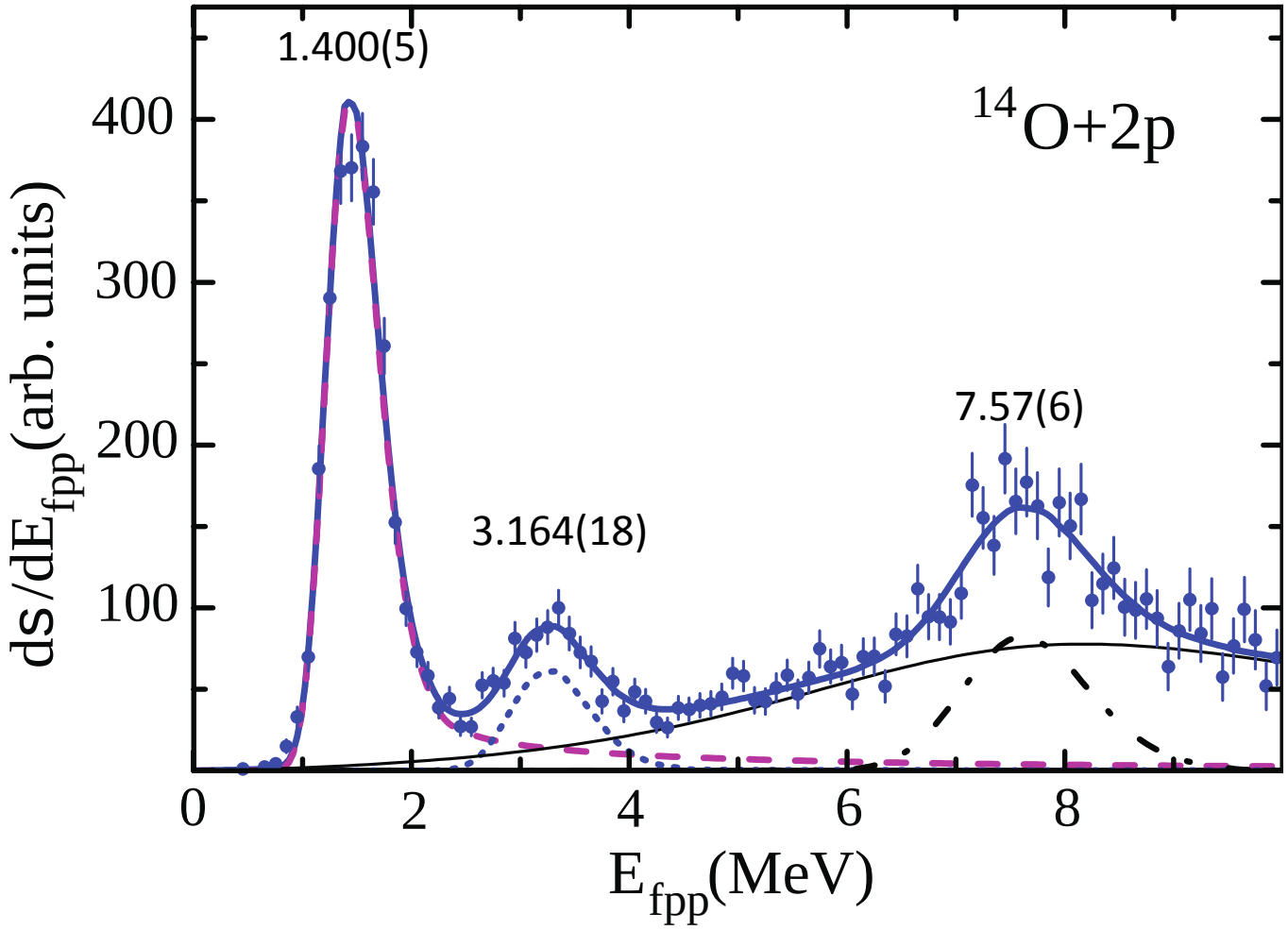
C.J. Woodward et al.,
Phys. Rev. C 27 (1983) 27

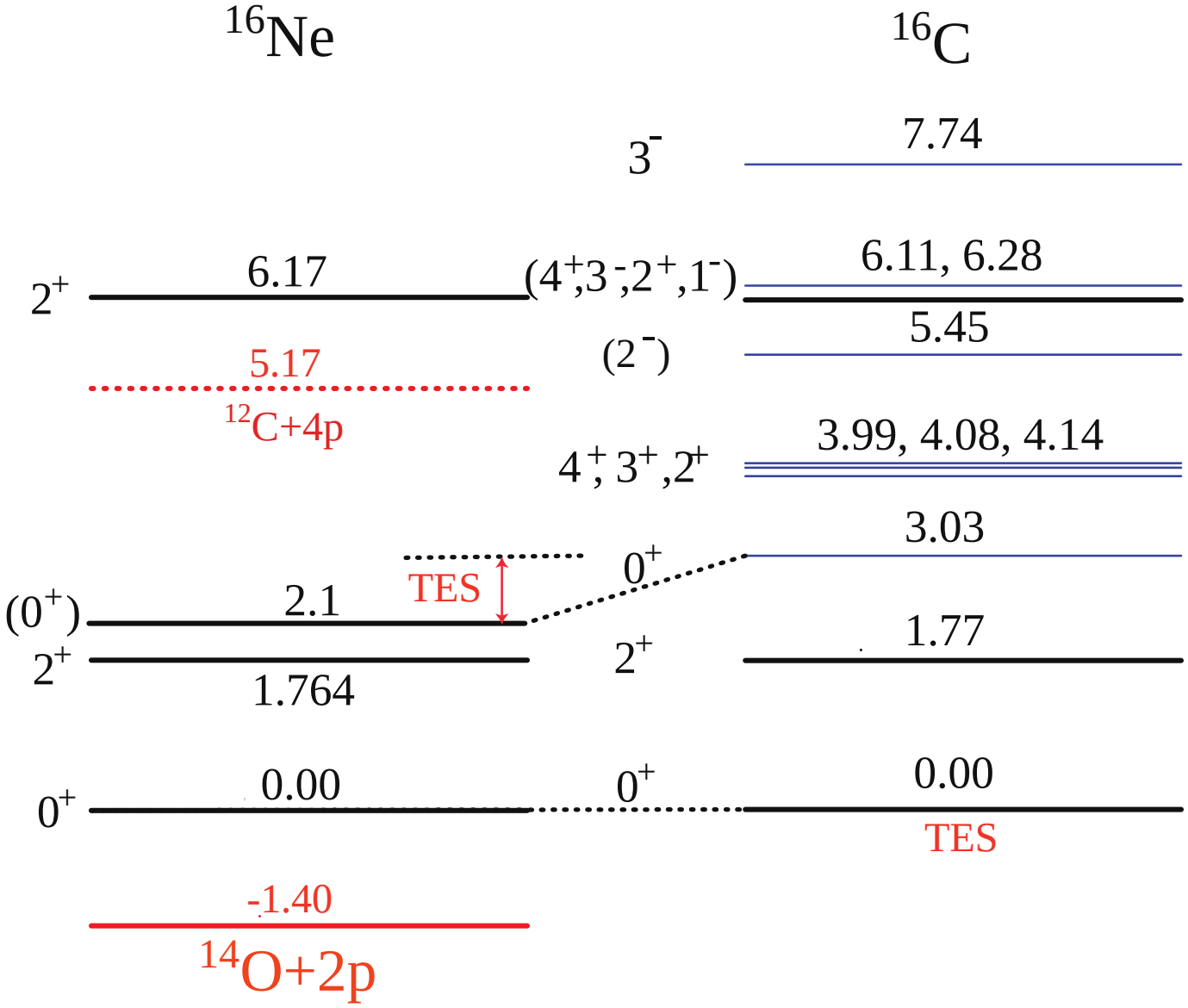
$I^\pi = 0^+$		$I^\pi = (0^+, 2^+)$		$I^\pi = (2^+)$	
E_r	Γ	E_r	Γ	E_r	Γ
1.33(8)	0.2(1)	3.02(11)	–	–	–
1.466(45)	–	–	–	–	–
1.399(24)	0.11(4)	–	–	–	–
–	–	3.5(2)	–	–	–
1.35(8)	–	3.2(2)	0.2(2)	7.6(2)	$0.8(^{+4}_{-8})$

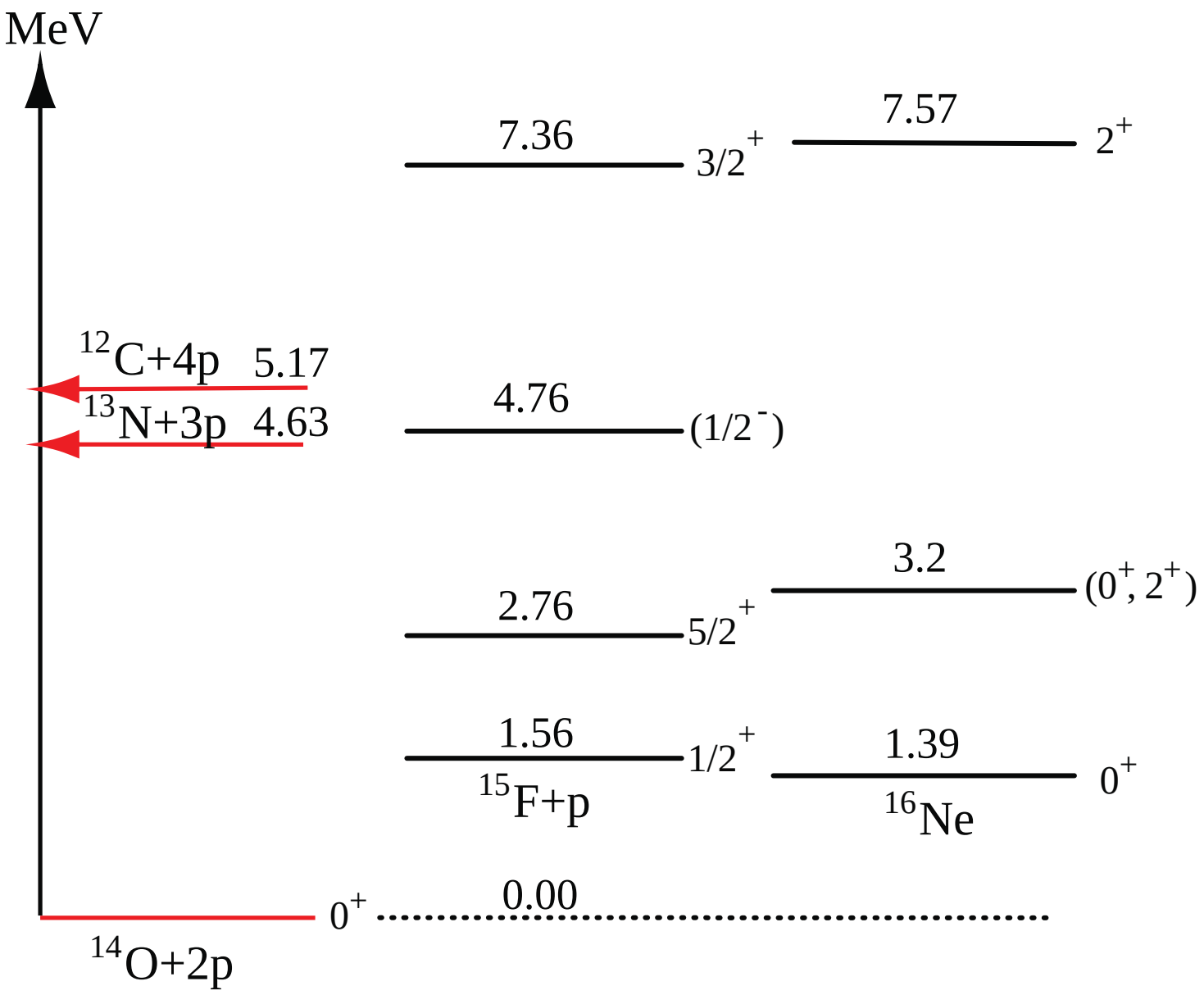
I.Mukha et al.,
Phys. Rev. C 79 (2009) 061301®

One-neutron Knockout

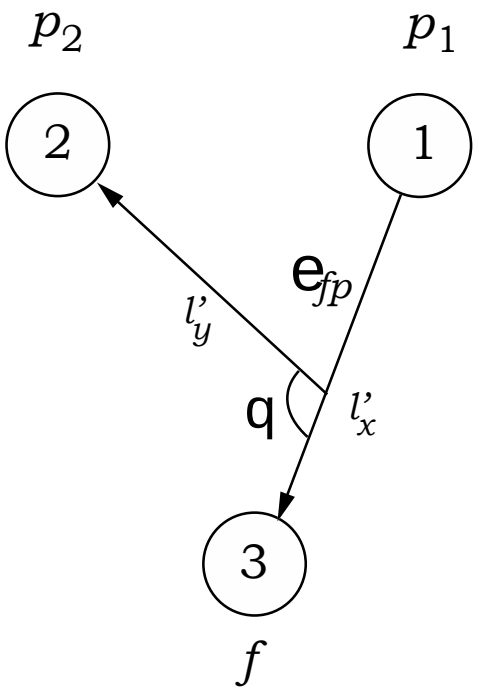


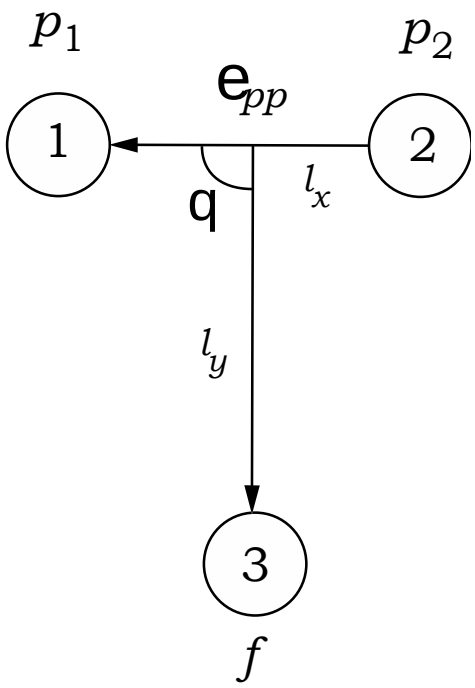

1.400(5)
3.164(18)
7.57(6)
^{14}O+2p
ds/dE$_{fpp}$(arb. units)
E$_{fpp}$(MeV)
0
2
4
6
8
100
200
300
400


16Ne
16C
7.74
3-
6.11, 6.28
(4+,3-,2+,1-)
6.17
2+
5.45
(2-)
5.17
12C+4p
3.99, 4.08, 4.14
4+,3+,2+
3.03
0+
TES
2.1
(0+)
1.77
2+
2+
1.764
0.00
0+
0+
0.00
TES
-1.40
14O+2p


MeV
7.36
3/2+
7.57
2+
12C+4p 5.17
13N+3p 4.63
4.76
(1/2-)
3.2
(0+, 2+)
2.76
5/2+
1.56
1/2+
15F+p
1.39
0+
16Ne
0+
0.00
14O+2p

Jacobi coordinates





Y-system

$$\mathbf{p}_{fp} = \left(\frac{\mathbf{p}_f}{m_f} - \frac{\mathbf{p}_1}{m_p} \right) \frac{m_f m_p}{m_f + m_p}$$

$$\mathbf{p}_{pfp} = \left(\frac{\mathbf{p}_2}{m_p} - \frac{\mathbf{p}_f + \mathbf{p}_1}{m_f + m_p} \right) \frac{m_p (m_f + m_p)}{m_f + 2m_p}$$

$$\varepsilon_{fp} = E_{fp}/E_{fpp}$$

T-system

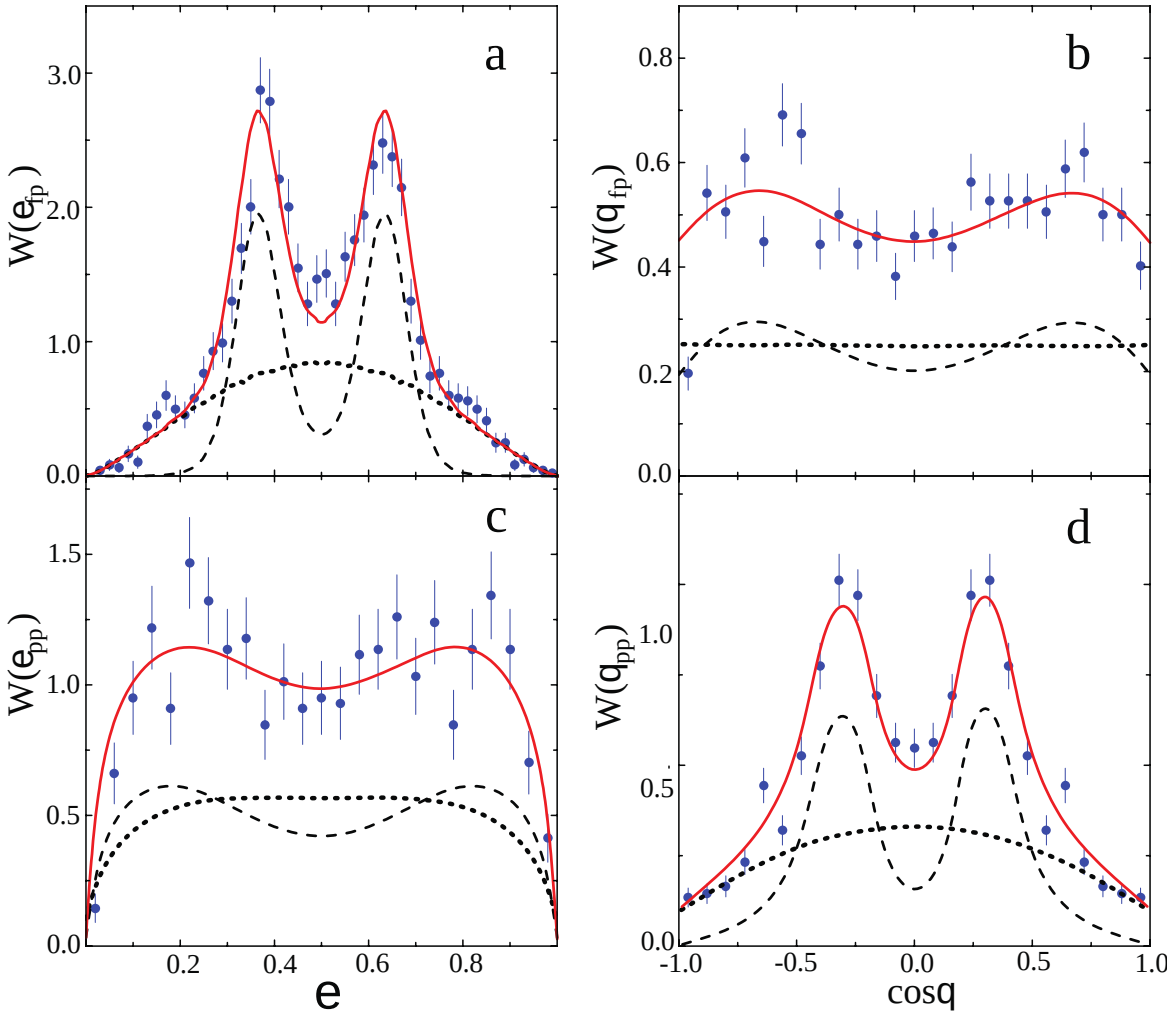
$$\mathbf{p}_{pp} = \frac{1}{2} (\mathbf{p}_1 - \mathbf{p}_2)$$

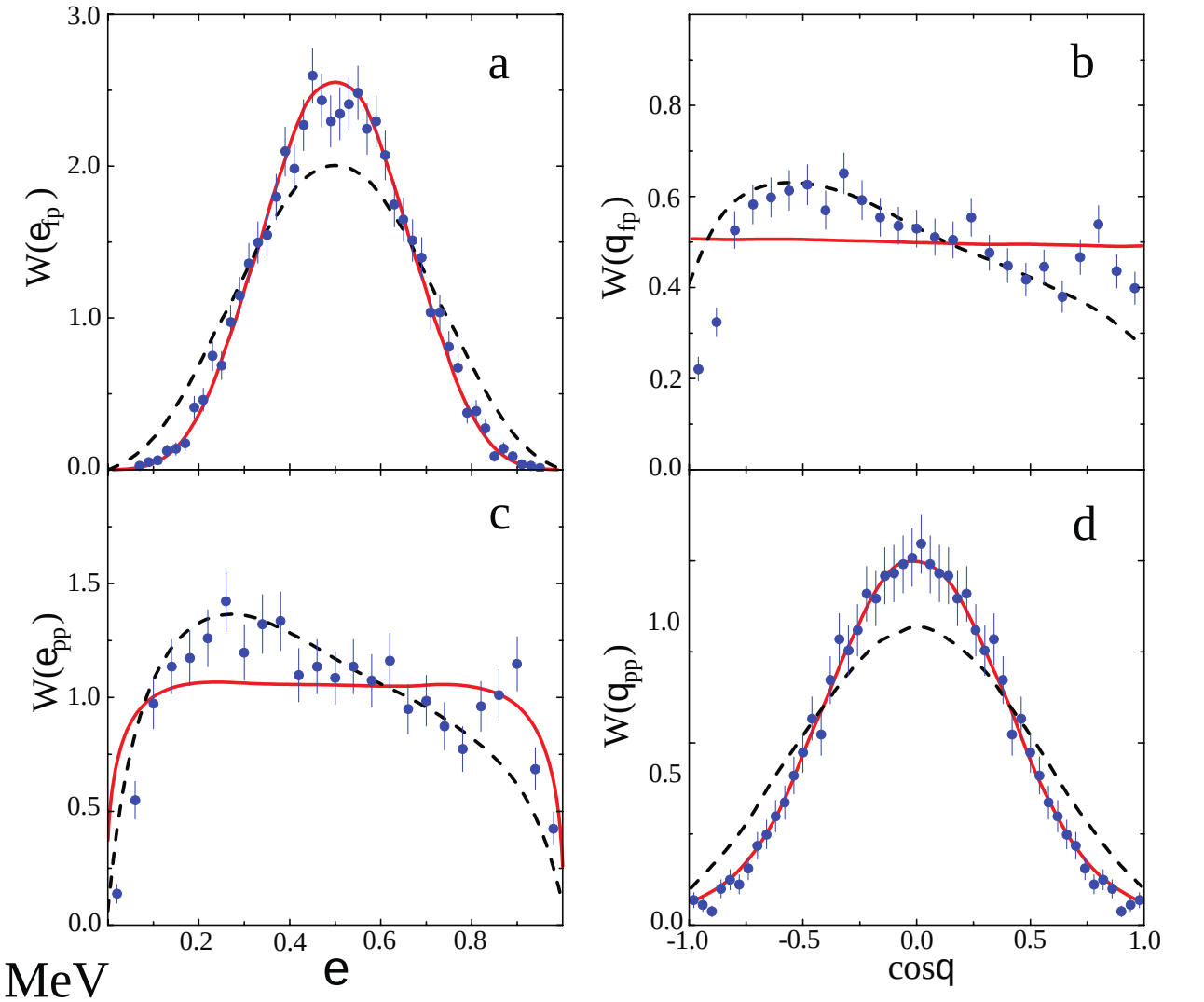
$$\mathbf{p}_{fpp} = \left(\frac{\mathbf{p}_f}{m_f} - \frac{\mathbf{p}_1 + \mathbf{p}_2}{2m_p} \right) \frac{2m_f m_p}{m_f + 2m_p}$$

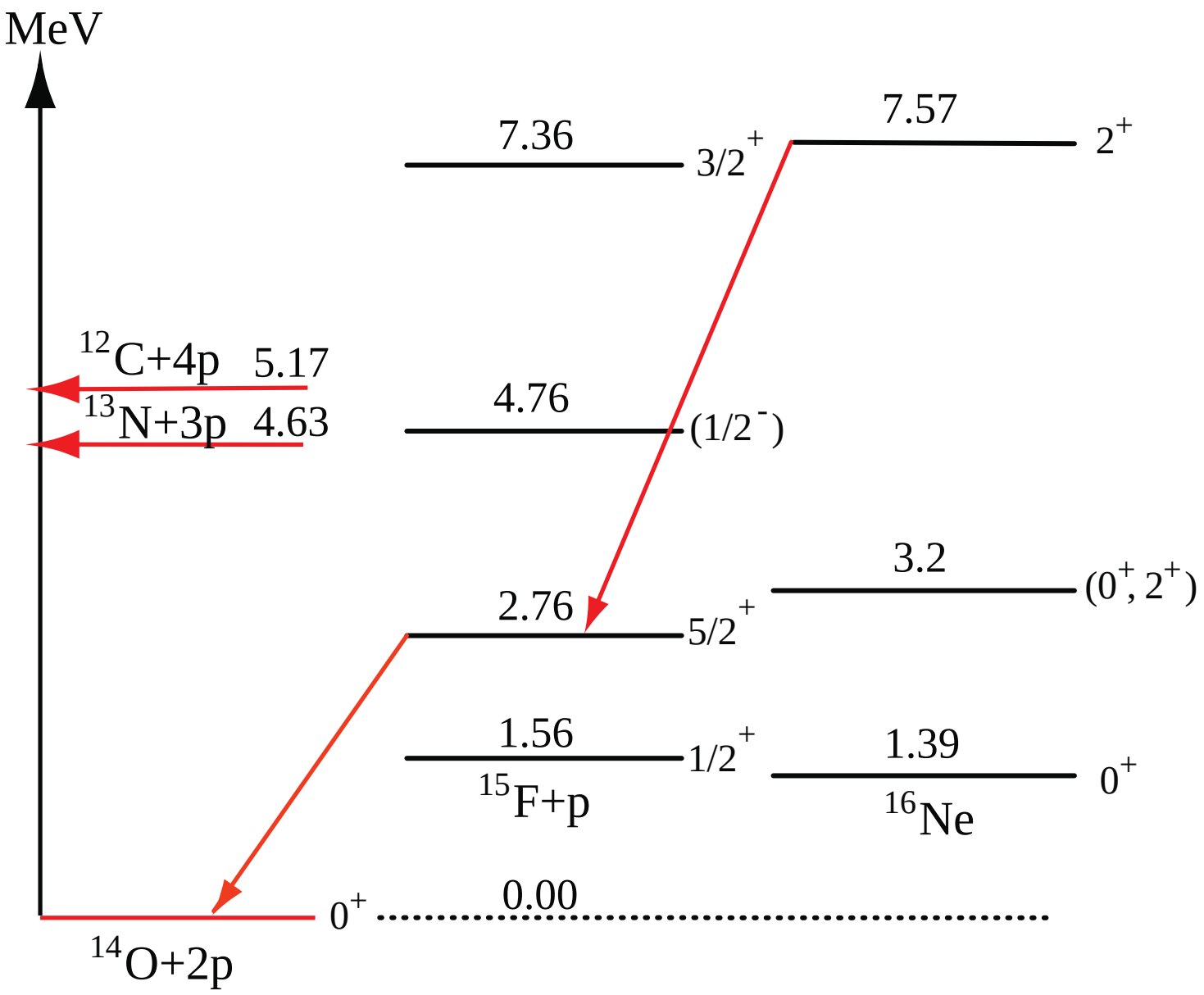
$$\varepsilon_{pp} = E_{pp}/E_{fpp}$$

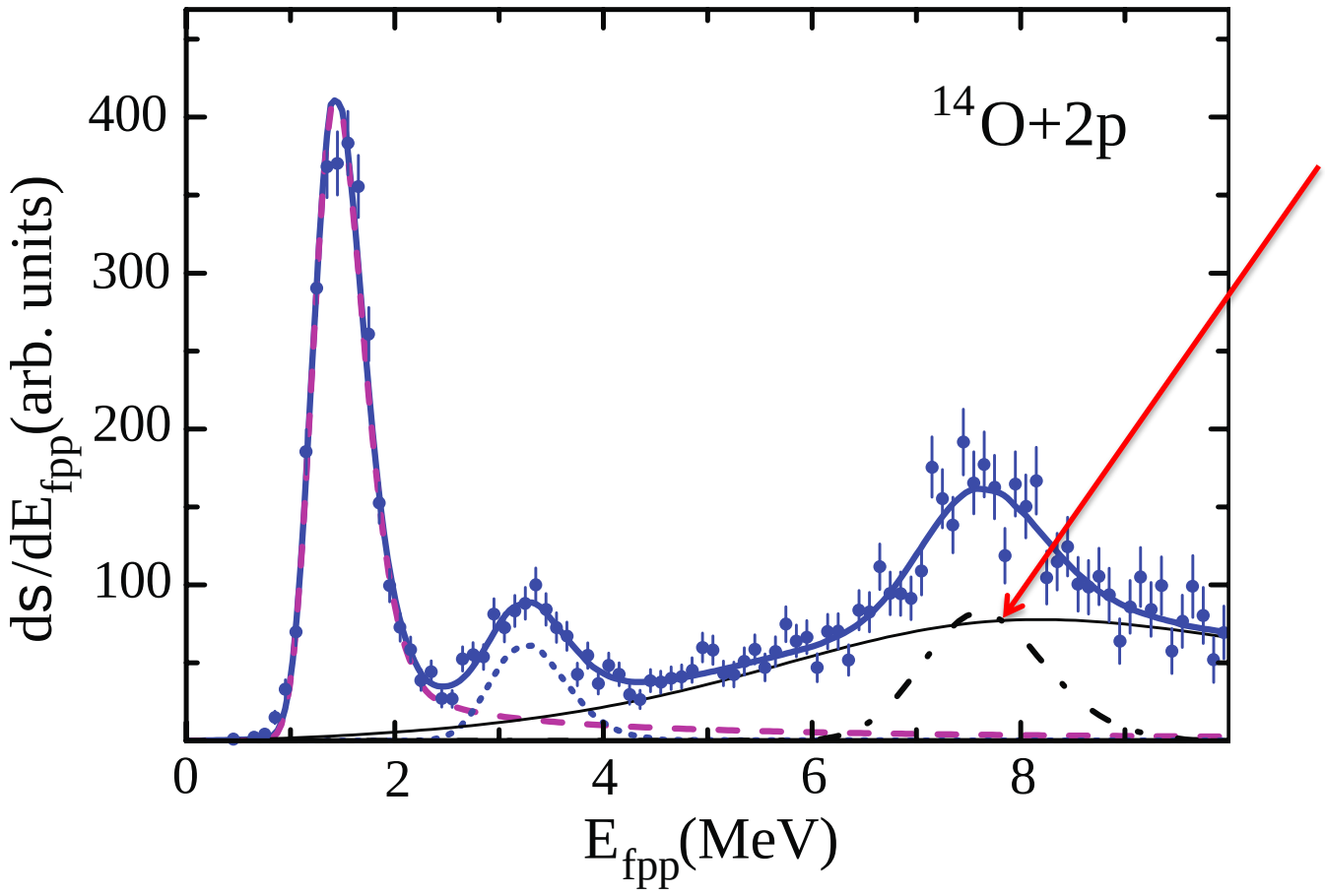
$$m_f >> 2m_p$$

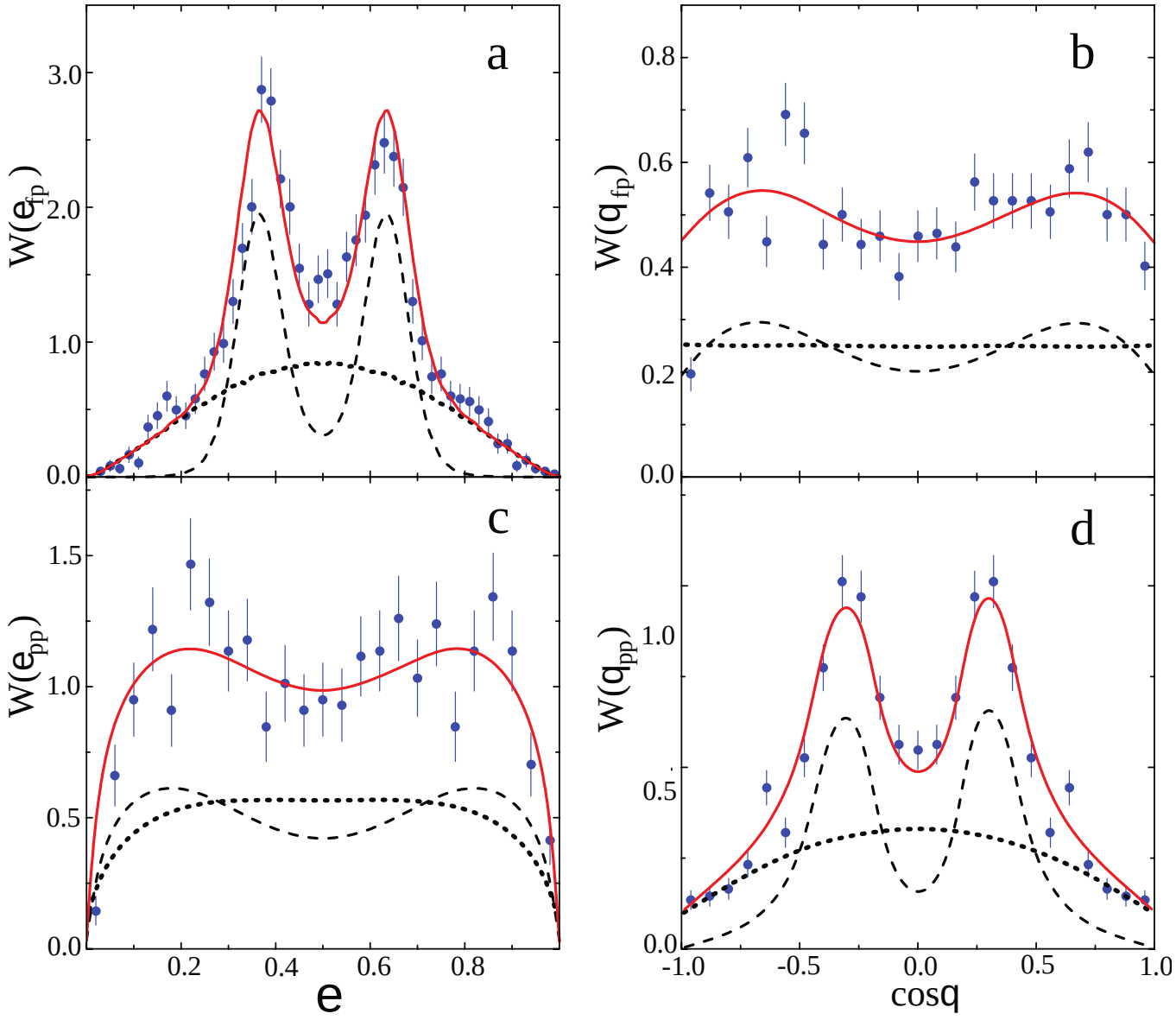
$$\cos\theta_{fp} \approx \frac{2\epsilon_{pp} - 1}{2\sqrt{\epsilon_{fp}(1-\epsilon_{fp})}}$$

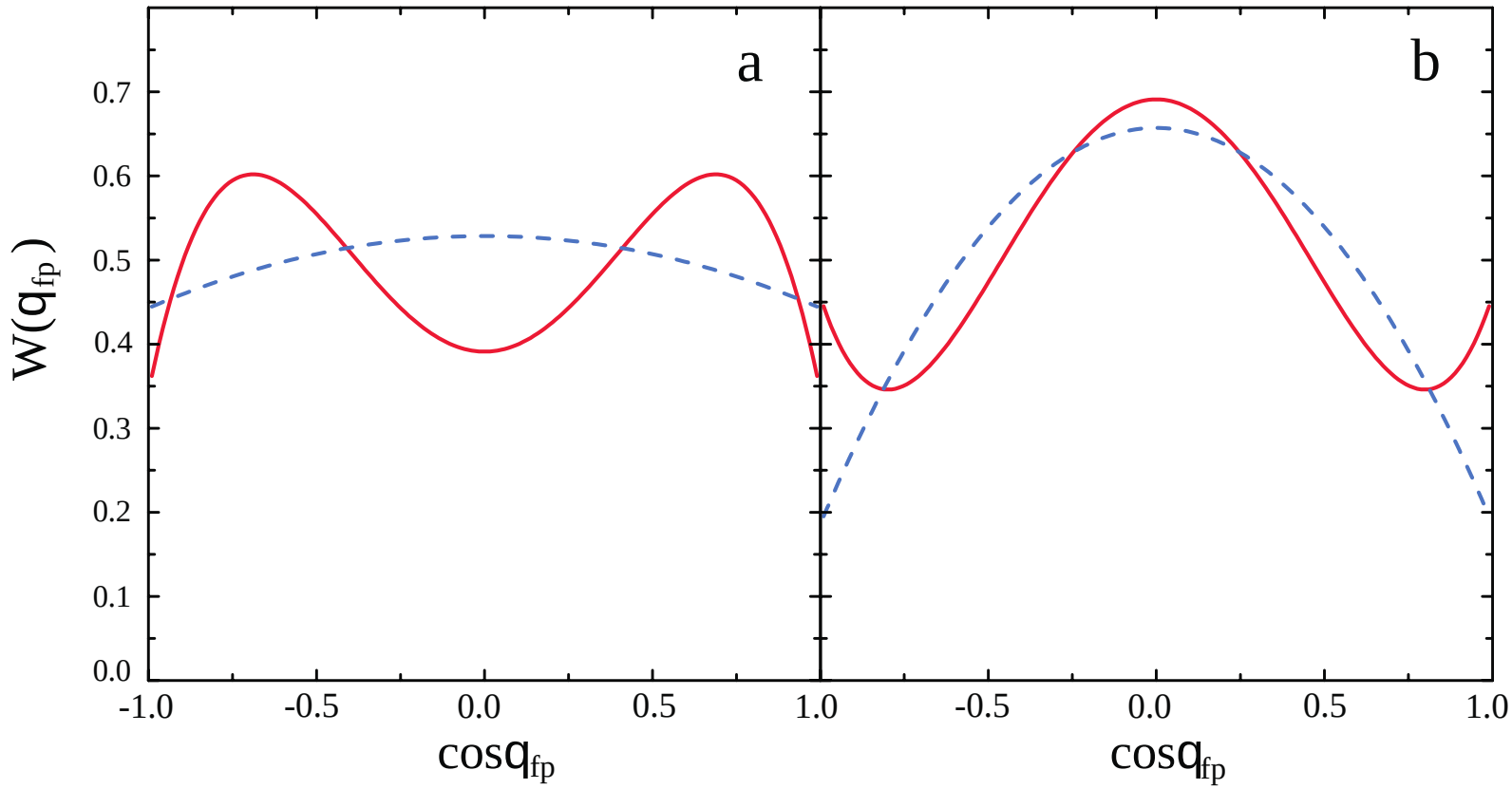



a
b
c
d
W(e_fp)
W(q_fp)
W(e_pp)
W(q_pp)
e
cosq
MeV
1.56
1/2+
15F+p
1.39
0+
16Ne
0+
0.00
14O+2p

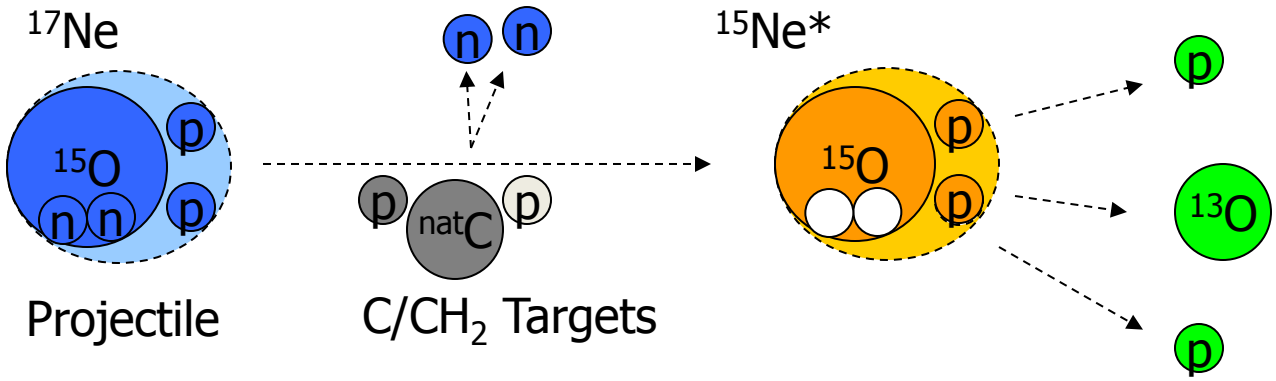

MeV
7.36
3/2+
7.57
2+
12C+4p 5.17
13N+3p 4.63
4.76
(1/2-)
3.2
(0+, 2+)
2.76
5/2+
1.56
1/2+
15F+p
1.39
0+
16Ne
0+
0.00
14O+2p

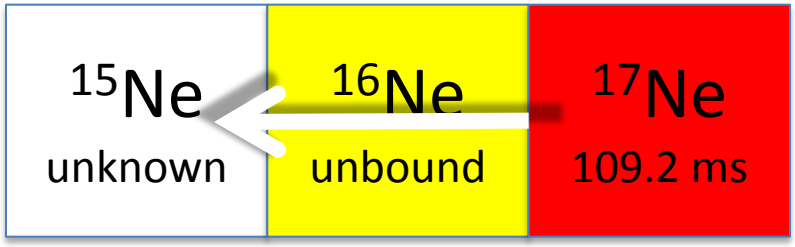

^{14}O+2p
ds/dE$_{fpp}$(arb. units)
E$_{fpp}$(MeV)
0
2
4
6
8
100
200
300
400

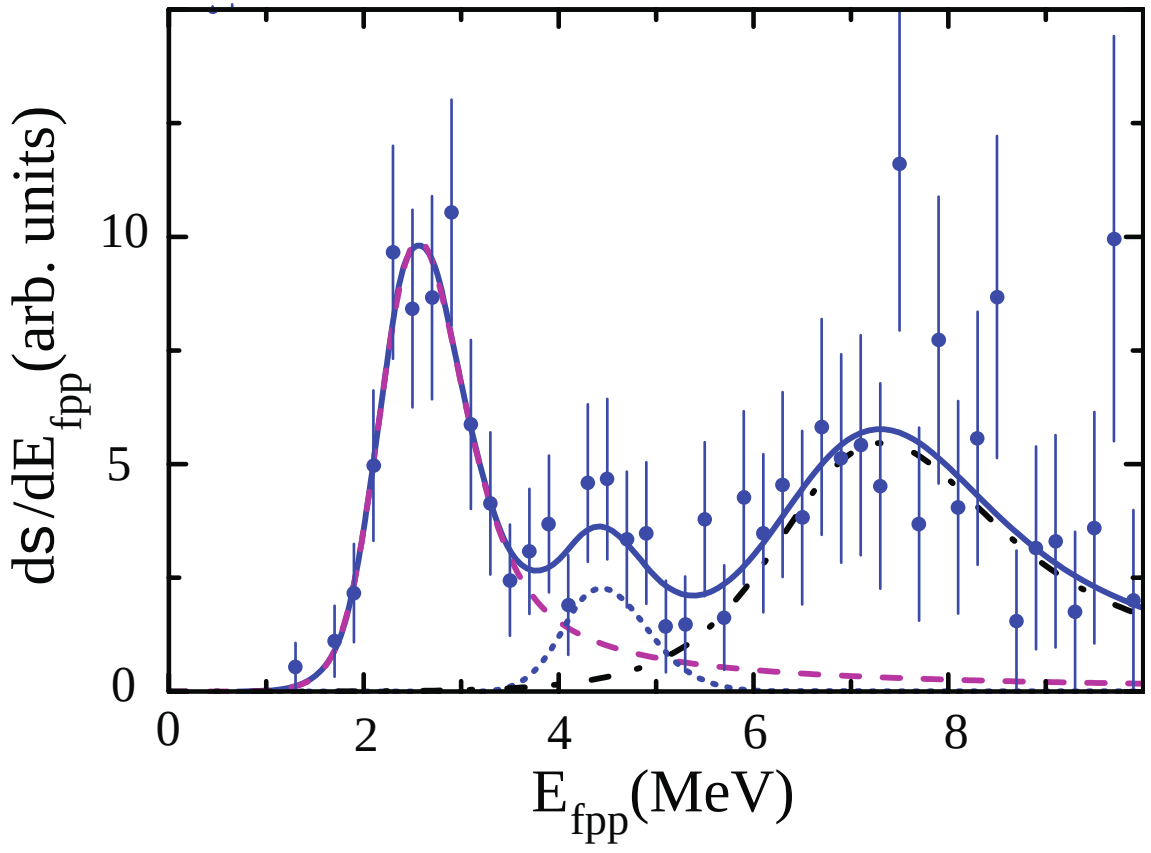

a
b
c
d
W(e_fp)
W(q_fp)
W(e_pp)
W(q_pp)
e
cosq
0.0
1.0
2.0
3.0
0.2
0.4
0.6
0.8
0.5
1.5
-1.0
-0.5
0.5
1.0


a
b
W(q_fp)
cosq_fp
cosq_fp
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
-1.0
-0.5
0.0
0.5
1.0
-0.5
0.0
0.5
1.0

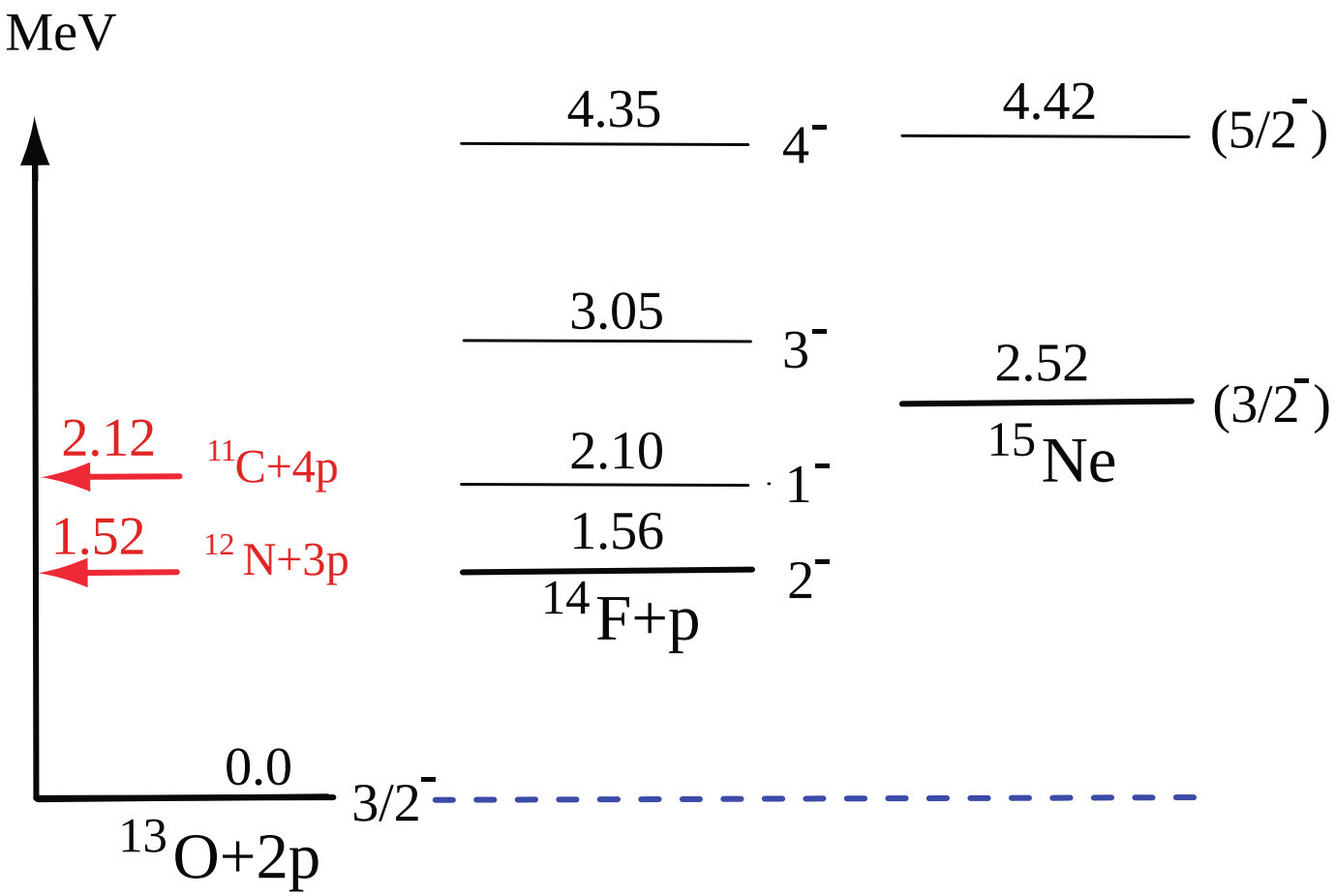
Two-neutron Knockout

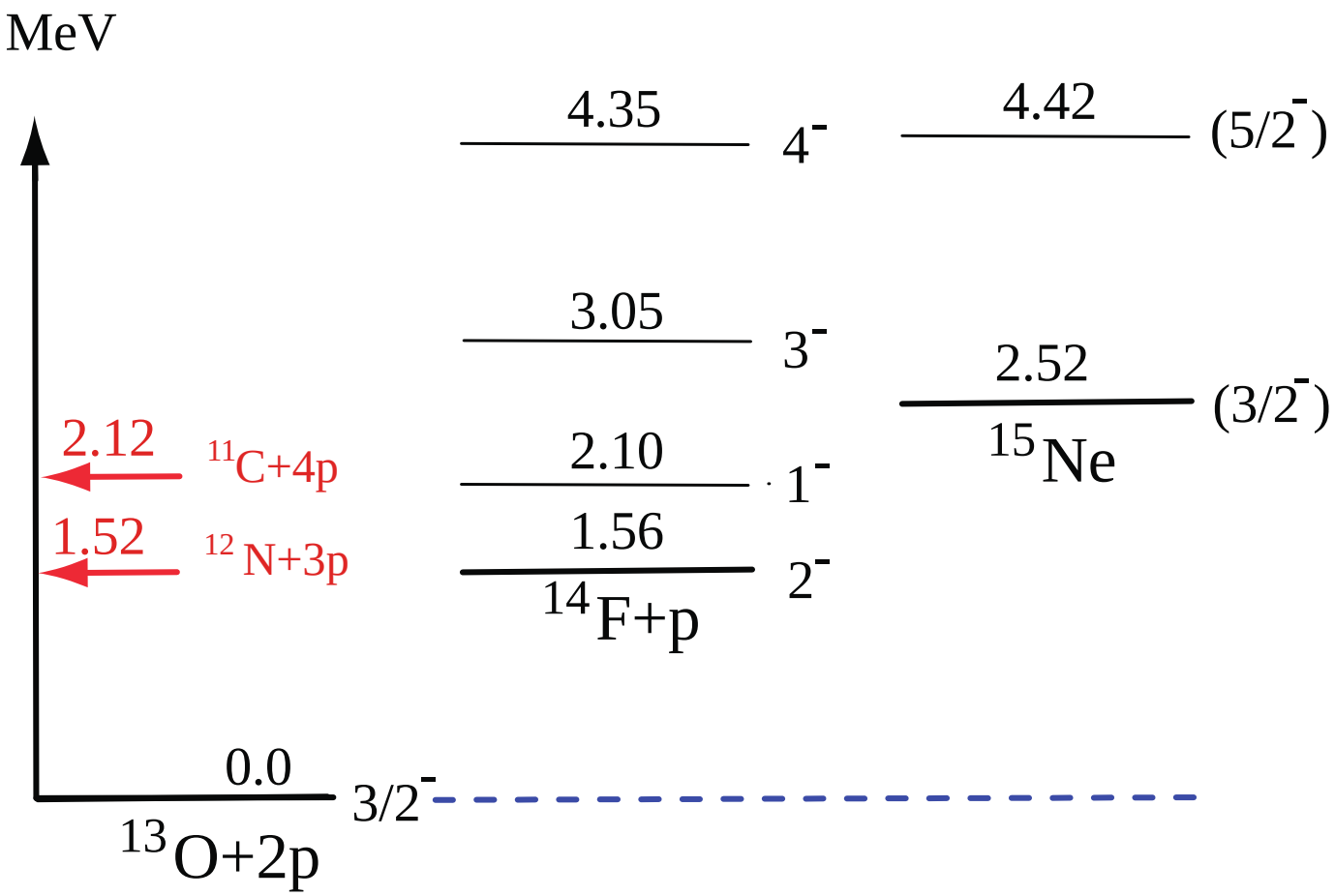


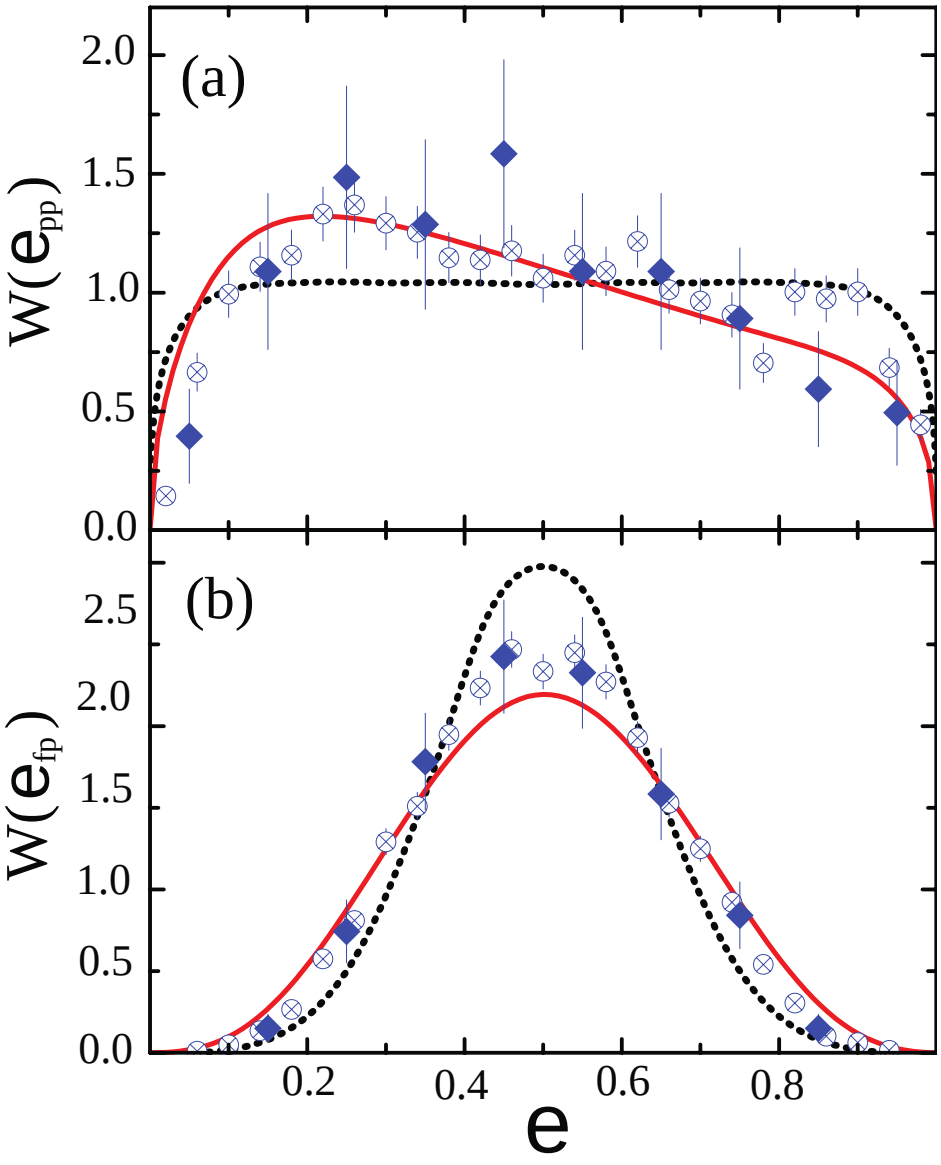




^{15}Ne	^{16}Ne	^{17}Ne
unbound	unbound	109.2 ms


MeV
4.35
4^-
4.42
(5/2^-)
3.05
3^-
2.52
(3/2^-)
15Ne
2.12
11C+4p
2.10
1^-
1.52
12N+3p
1.56
2^-
14F+p
0.0
3/2^-
13O+2p

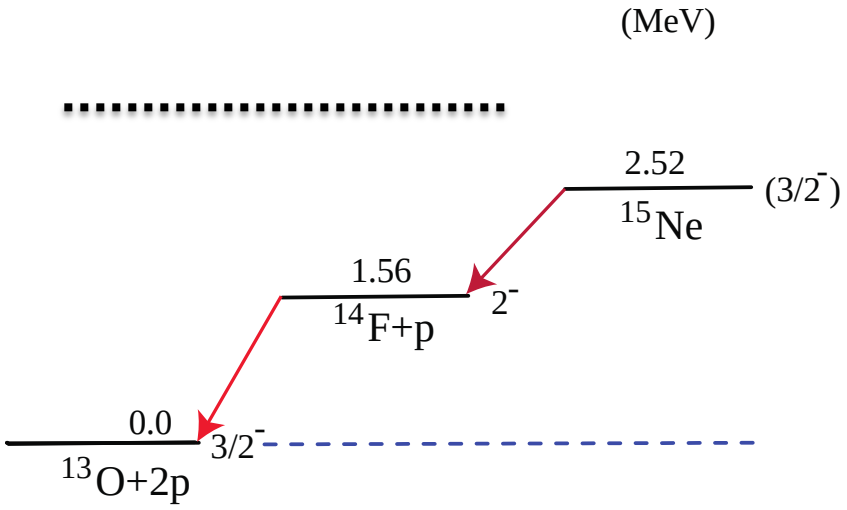

MeV
4.35
4^-
4.42
(5/2^-)
3.05
3^-
2.52
(3/2^-)
15Ne
2.12
11C+4p
2.10
1^-
1.52
12N+3p
1.56
2^-
14F+p
0.0
3/2^-
13O+2p



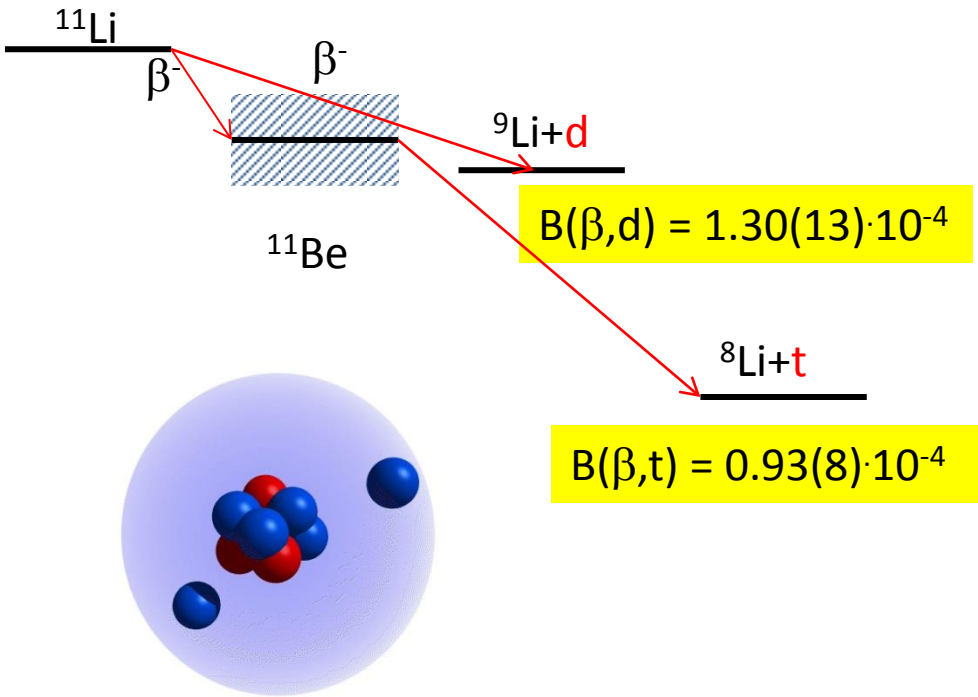
L. Grigorenko et al.,
Phys. Rev. Lett. 101 (2008) 252502

◆ ^{15}Ne

⊗ ^{16}Ne



Beta-delayed tritons and deuterons

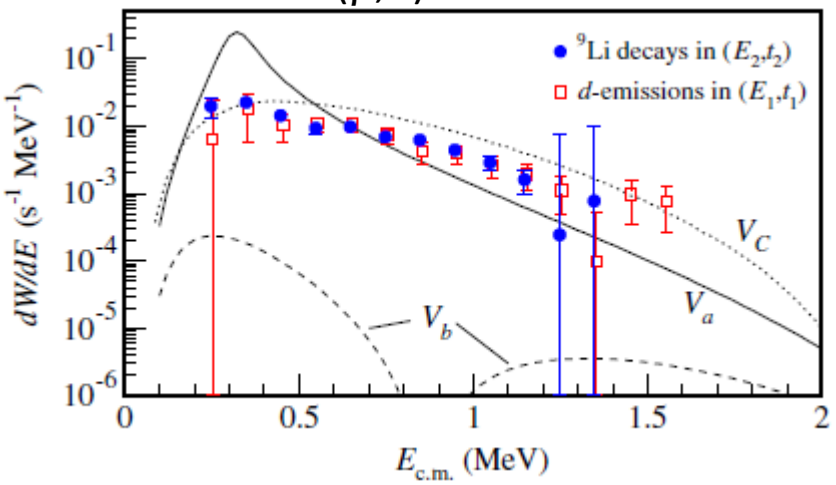


B(β,d) = 1.30(13)·10^{-4}

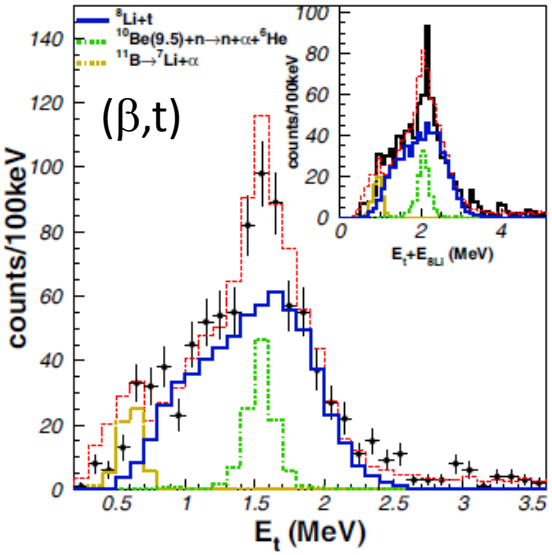
B(β,t) = 0.93(8)·10^{-4}

$Q_{\beta d}$= 3.004 - S_{2n} MeV

(β,d)

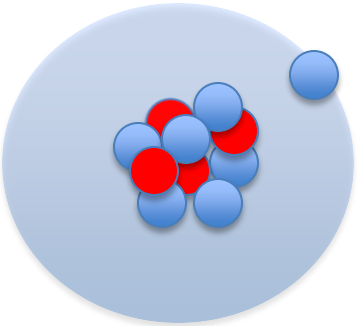


R. Raabe *et al.*, PRL 101 (2008) 212501

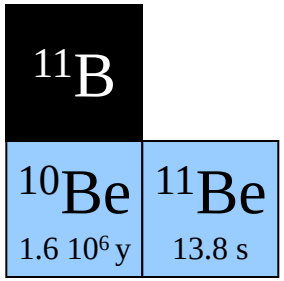


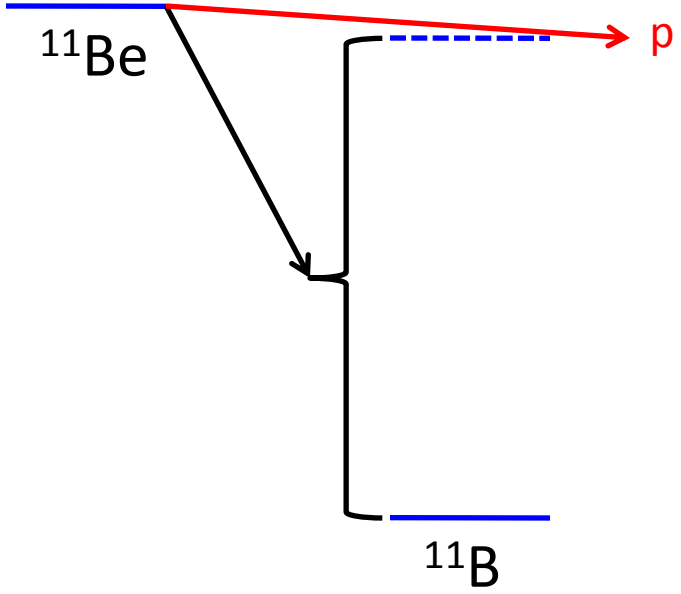
M. Madurga *et al.*, Eur. Phys. J. A42 (2009) 415

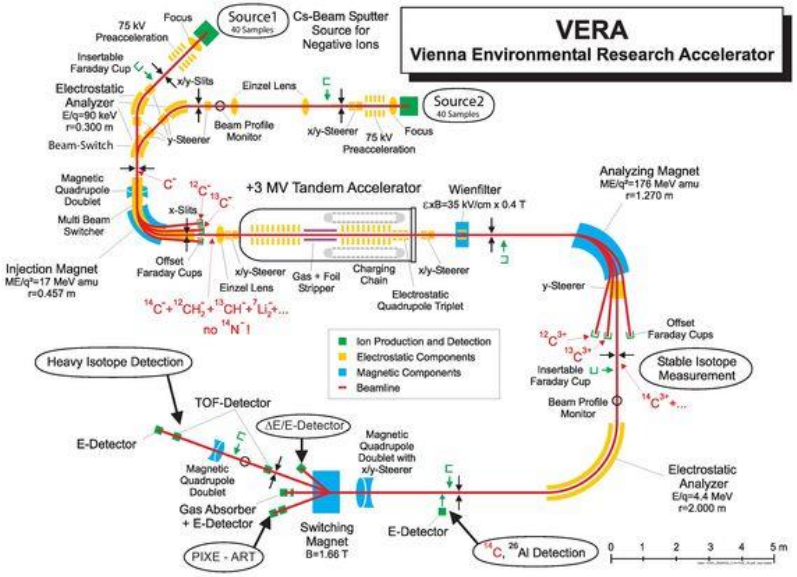
$$Q_{bp} = 0.782 - S_n\ MeV = 0.2807(3)\ MeV$$



^{10}Be







^{11}Be(β$^-$p)=8.4(6)·10^{-6}

This is Man's wonderful ability:
to be able to grasp the inner essence of phenomena,
not what they appear to be, but what they mean,
and the reality we see with our eyes
is a symbol only of something higher.

Ty detta är det herrliga hos menskan
att hon kan fatta tingens inre väsen,
ej hvad de synas, men hvad de betyda;
och verkligheten, hvart vårt öga ser,
den är symbolen endast af ett högre.

Esaias Tegnér,
Magisterpromotionen i Lund
1820