Electron-neutrino correlations in the A =8 system

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$$W(\theta) = 1 + v/c \times a \times \cos(\theta_{e\nu})$$

interaction	a
S	- 1
V	+ 1
A	- 1/3
T	+ 1/3

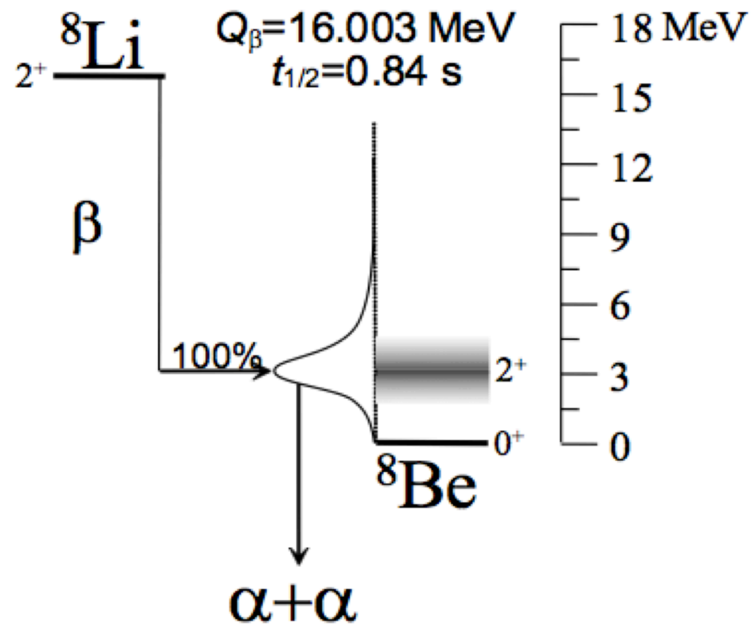


Figure 1.3: The ^{8}Li $\rightarrow$ ^{8}Be* decay scheme and subsequent α breakup.

neutrino angular distribution
β, α's parallel

- A $1 - (v/c) \cos(\Theta)$
- T $1 + (v/c) \cos(\Theta)$

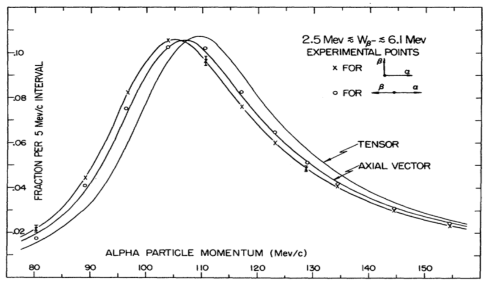


FIG. 2. Theoretical and experimental spectra as in Fig. 1 except for electrons with 2.5 Mev $\lesssim W_\beta \lesssim$ 6.1 Mev.

ation is increased by an amount

$$\Delta p_\alpha = \tfrac{1}{2}\,(p_\beta - p_{\bar{\nu}} \cos\theta_{\bar{\nu}\alpha}), \qquad (1)$$

where p_β and $p_{\bar{\nu}}$ are the absolute magnitudes of the electron and antineutrino momenta. The theoretically predicted angular correlation for antineutrino and alpha particle is, for $\cos\theta_{\beta\alpha}=-1$,

$$W(\theta_{\bar{\nu}\alpha}) = 1 \pm \frac{v}{c}\cos\theta_{\bar{\nu}\alpha}, \qquad (2)$$

where the plus sign holds for A or S and the minus sign for T or V.[2,3] When the antineutrino momenta are averaged over all angles, with the angular correlation given by Eq. (2), and average magnitudes inserted for the electron and antineutrino momenta, the spectrum of the observed alpha particles in the antiparallel configuration will be shifted upwards on the average by

$$\langle \Delta p_\alpha \rangle = \tfrac{1}{2}\langle p_\beta \rangle \pm \tfrac{1}{6}\langle p_{\bar{\nu}} \rangle \quad , \qquad (3)$$

where the plus sign holds for T or V and the minus sign for A or S. Since the measurements described in the preceding Letter[1] set upper limits for S and V, we are here interested in distinguishing A from T. To calculate $\langle p_\beta \rangle$ and $\langle p_{\bar{\nu}} \rangle$ we have assumed that the spectra of electron and antineutrino momenta in coincidence with alpha particles of energy E_α are given by the usual Fermi expression with an end-point energy $W_0=(16.6-2E_\alpha)$ Mev.

The crosses in Fig. 1 give the experimental alpha-particle momentum spectrum for the perpendicular configuration, with a smooth curve drawn through the points. The other two curves in Fig. 1 are constructed from this smooth curve with the aid of Eq. (3), for electrons of total energy $W_\beta \gtrsim 6.1$ Mev. A small correction has been made for the beta counter pulse height resolution which was ~15% at 6.1 Mev. It is evident that the open circles, which give the measured spectrum for the antiparallel configuration, agree well with the axial vector prediction.

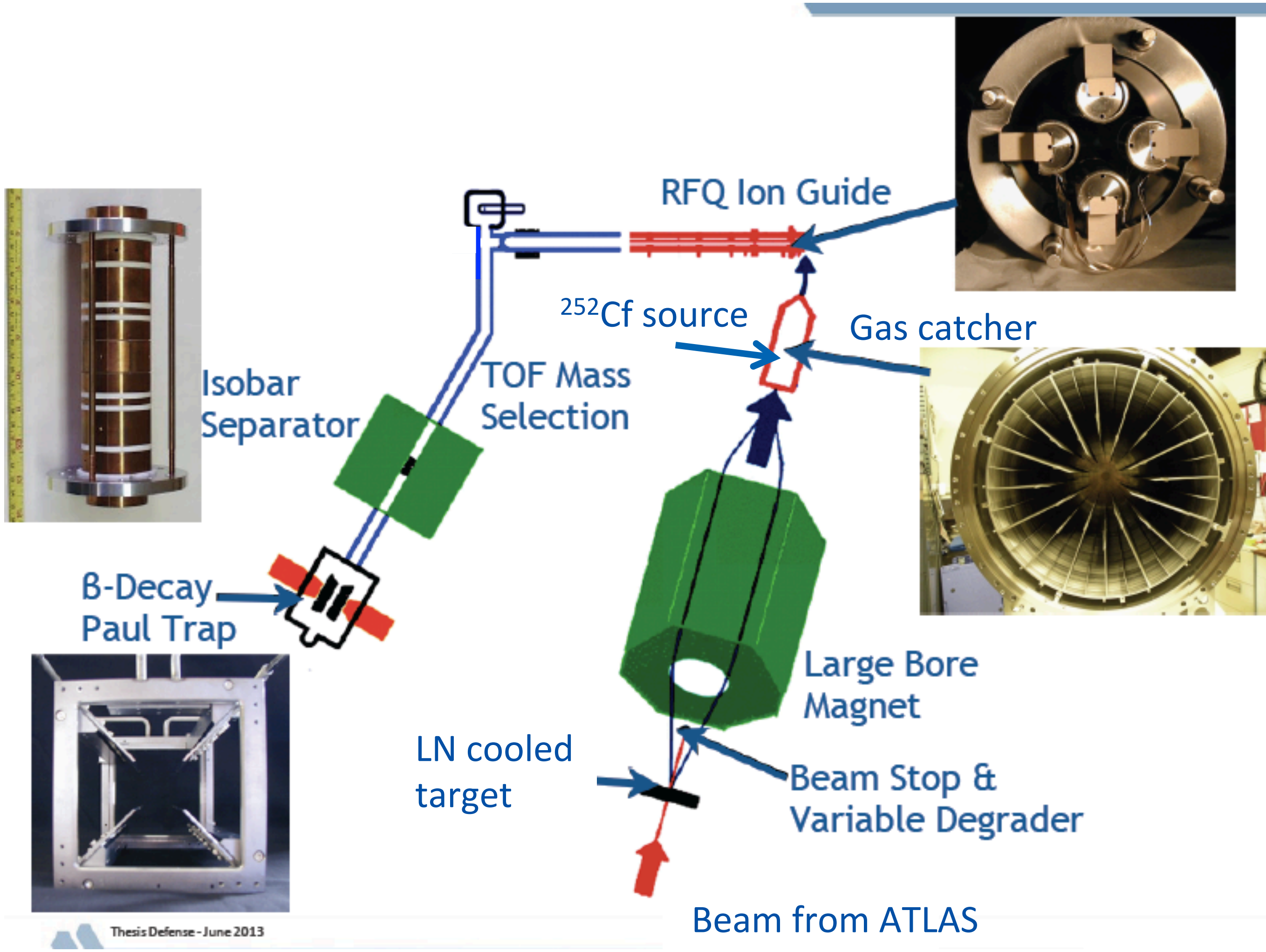
The curves in Fig. 2 are derived similarly for 2.5 Mev $\lesssim W_\beta \lesssim 6.1$ Mev. In addition to the resolution correction already mentioned, corrections have been made for high-energy electrons scattered from the collimator, as determined experimentally, and for the "tail" of small pulses always present in the pulse-height spectrum of high-energy electrons. Again, it is evident that the observed shifted spectrum agrees well with the axial vector prediction. A qualitative comparison of the results in Fig. 2 with those in Fig. 1 is instructive. A relatively large shift is expected for either A or T in the antiparallel curve of Fig. 1 since the antiparallel electron has the greater share of the decay energy and the shift is thus not very sensitive to the orientation of the low-energy antineutrino. The measurements show that the experimental arrangement was capable of measuring such a relatively large shift. On the other hand, the small shift in Fig. 2 shows the partial cancellation to be expected for the axial vector interaction between the antiparallel momentum of the low-energy electron and the average parallel component of momentum of the high-energy antineutrino.

A more quantitative comparison of the experimental shifts with the theoretically expected shifts may be made by correcting all shifts for their dependence on p_α and then averaging. Table I displays the average shifts, corrected to

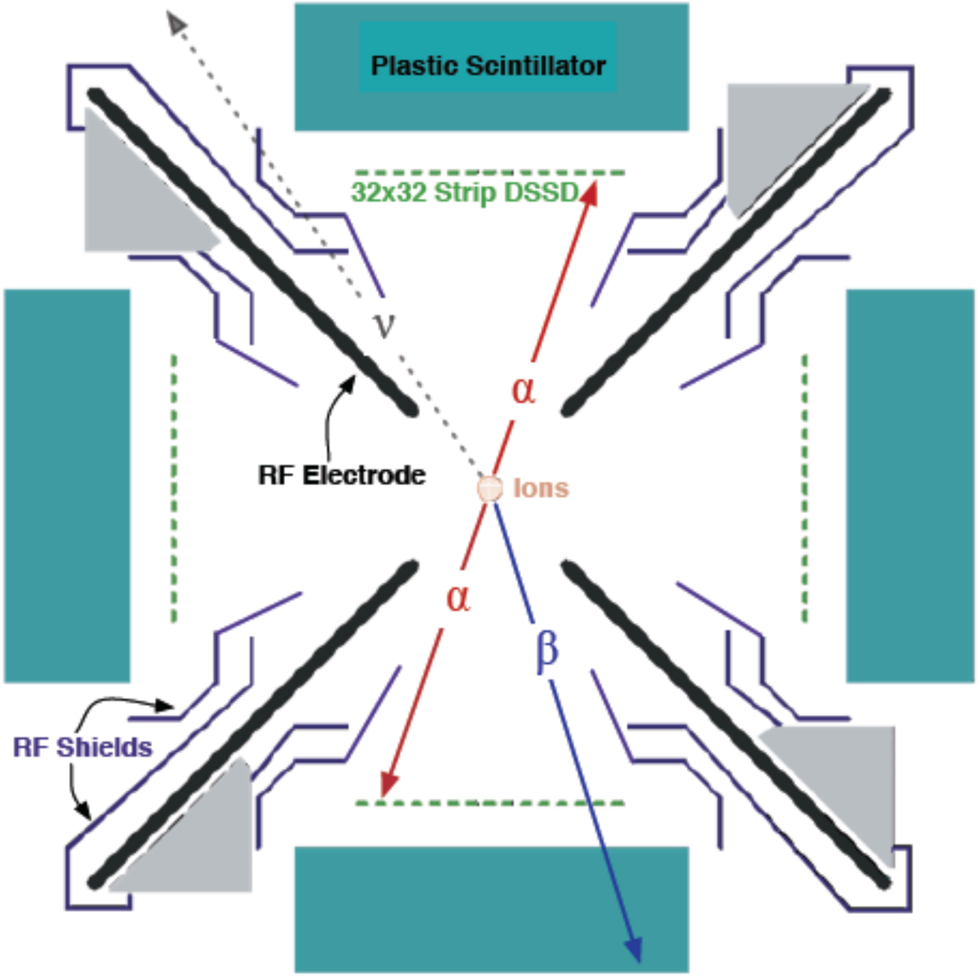
Table I. Experimental and theoretical momentum shifts (Δp_α in Mev/c) (Corrected to p_α = 100 Mev/c and averaged).

W_β	Axial vector Exp.	Axial vector Theory	Tensor Exp.	Tensor Theory
$W_\beta \gtrsim 6.1$ Mev	3.55 ± 0.16	3.41	3.63 ± 0.17	5.18
2.5 Mev $\lesssim W_\beta \lesssim$ 6.1 Mev	1.50 ± 0.08	1.51	1.60 ± 0.10	4.23
$W_\beta \gtrsim 2.5$ Mev	2.61 ± 0.17	2.40	2.71 ± 0.17	4.67

Production of ions



Experimental setup



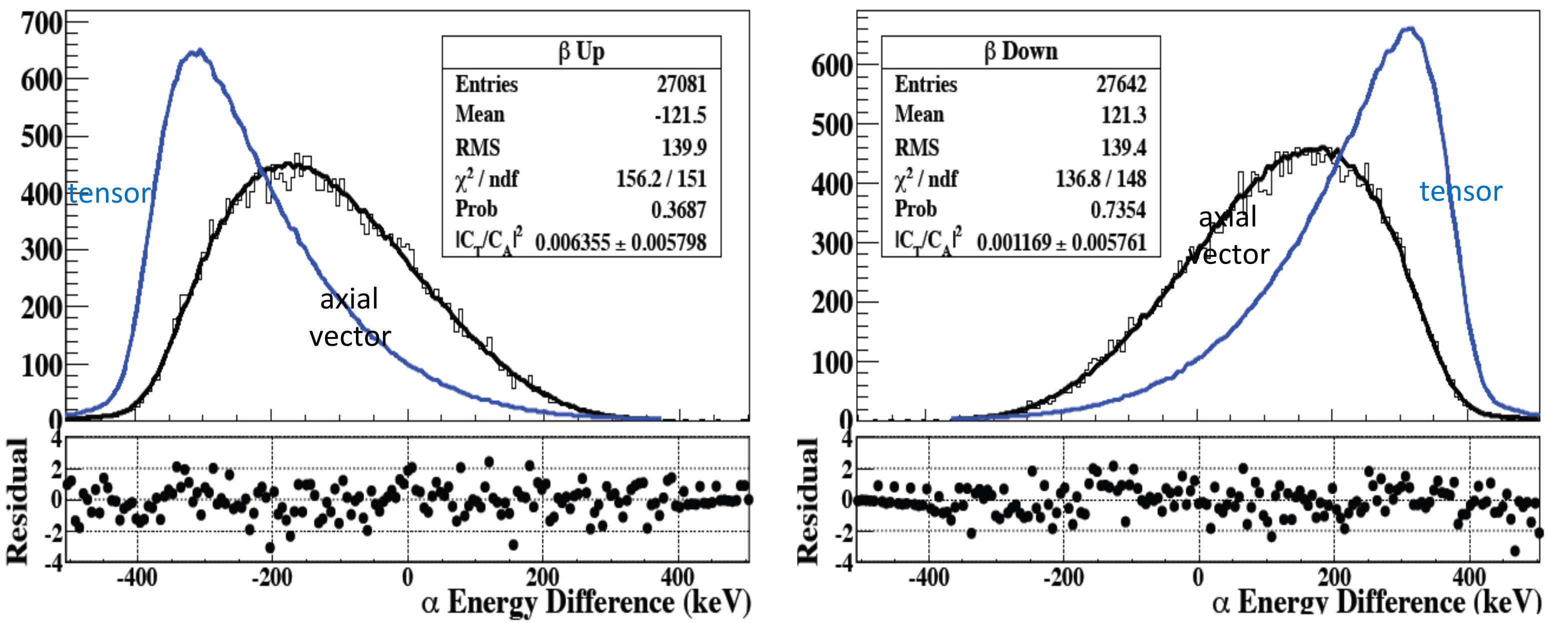
α : energies and directions (6 variables)

β^+ : direction (2 variables)

$E^1_\alpha + E^2_\alpha$ → ^{8}Be*

$E^1_\alpha - E^2_\alpha$ → A v. T info

Improvements: 10× statistics
Finer segmentation on DSSD
Thinner dead layer on DSSD



Analysis nearly complete… will be tightest limits on tensor interaction from nuclear decay (1st improvement in 50 years!)

$$|C_T/C_A|^2 = 0.0018 \pm 0.0036_{stat} \pm 0.0041_{syst}$$

$$a_{\beta\nu} = -0.3321 \pm 0.0036$$

preliminary

$$d\sigma/dE/d\omega_e/d\omega_\nu=F(E)\times(g_1\pm g_2\pm g_3\pm g_{10}\pm g_{12}\pm g_{13}\pm g_{14})$$

for A use + for T use –

$$g_1=1-\tfrac{2}{3}(E_0/M)(1+d+b)+\tfrac{2}{3}E/M(5+2b)-m^2/3ME(2+d+b)$$

$$g_2= (-\tfrac{1}{3}+\tfrac{2}{3}E_0/M(1+d+b)-4/3E/M((3+b))\beta\cos(e,\nu)$$

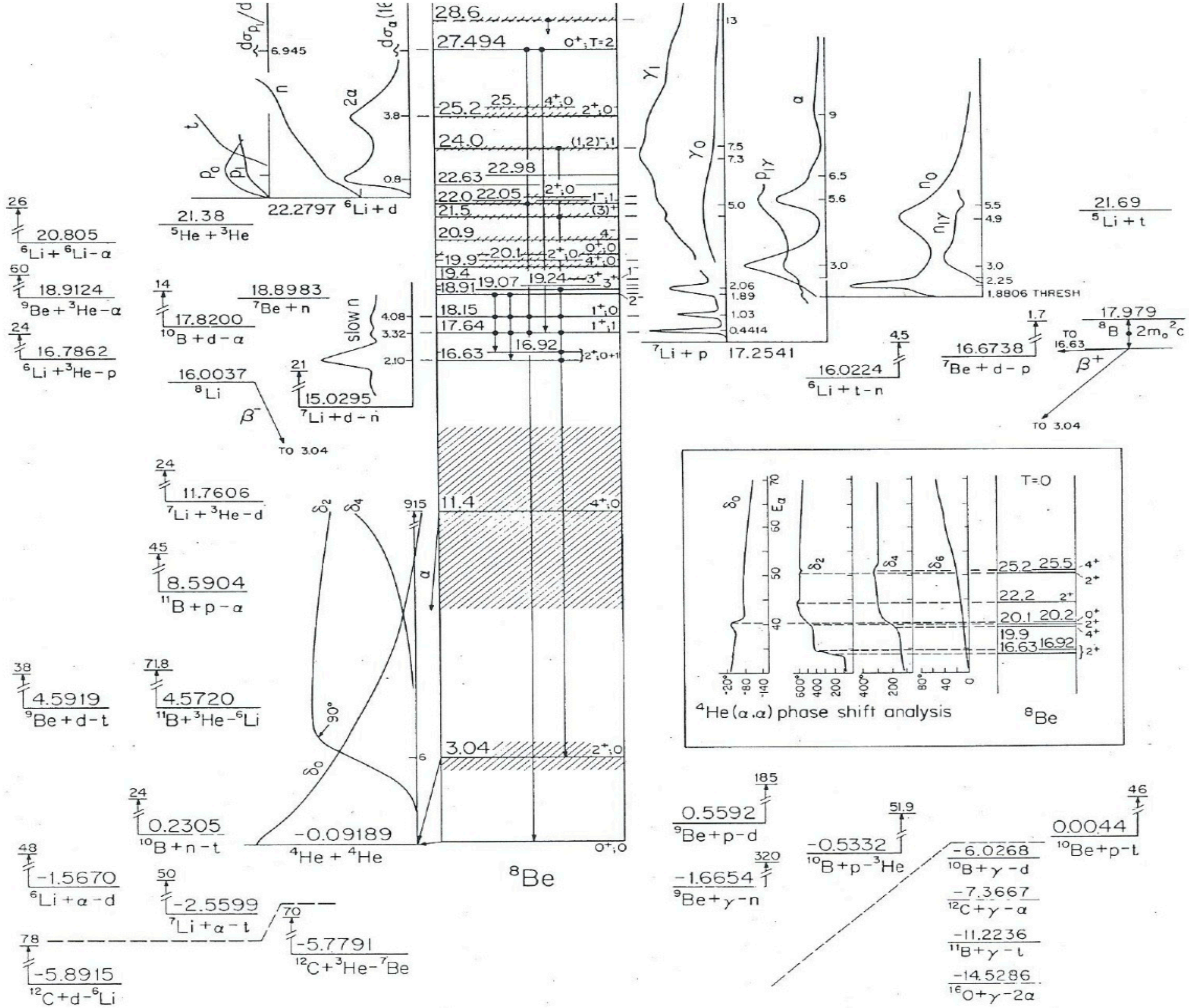
$$g_3=\beta^2E/M(\cos^2(e,\nu)-\tfrac{1}{3})$$

$$g_{10}=-\tfrac{1}{2}\beta^2E/M(1+d+b)(\cos^2(e,\alpha)-\tfrac{1}{3})$$

$$g_{12}=-\beta(1-\tfrac{1}{2}(1+d+b)E_0/M+(3+b)E/M)(\cos(e,\alpha)\cos(\alpha,\nu)-\tfrac{1}{3}\cos(e,\nu)$$

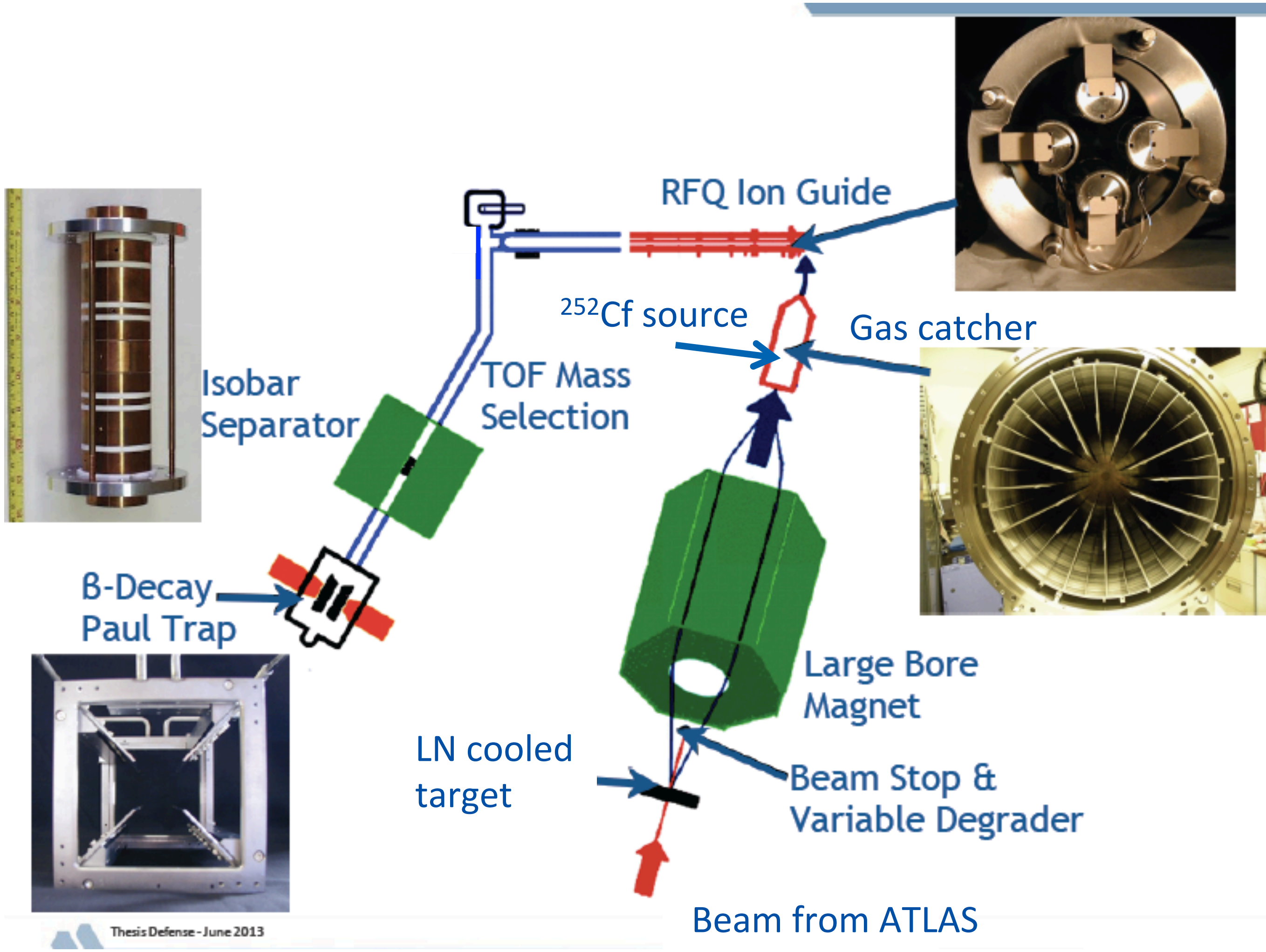
$$g_{13}=\beta^2E/M(\cos(e,\alpha)\cos(\alpha,\nu)-\tfrac{1}{3}\cos(e,\nu))\cos(e,\nu)$$

$$g_{14}=\tfrac{1}{2}(E-E_0)(1+d+b)(\cos^2(\alpha,\nu)-\tfrac{1}{3})$$

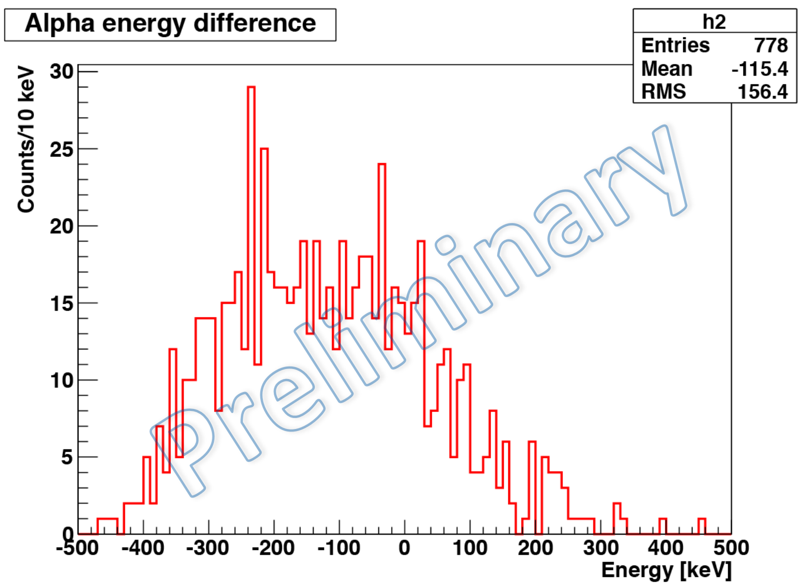


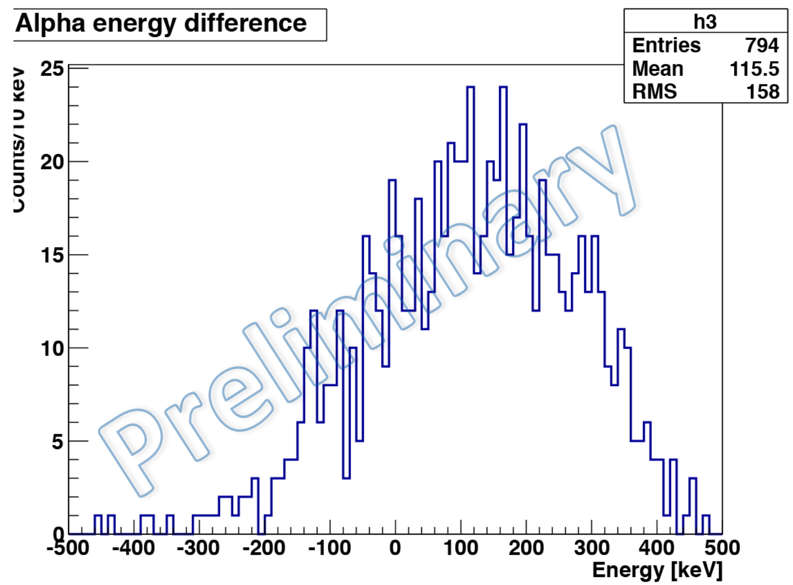
28.6
27.494
0+;T=2
25.2
25.
4+;0
2+;0
24.0
(1,2)-;1
22.63
22.98
22.0
22.05
2+;0
1-;1
21.5
(3)+
20.9
4-
20.1
0+;0
2+;0
4+;0
19.9
19.4
18.91
19.07
19.24
3+
18.15
1+;0
17.64
1+;1
16.63
16.92
2+;0+1
11.4
4+;0
3.04
2+;0
0+;0
8Be
22.2797 6Li+d
21.38
5He+3He
20.805
6Li+6Li-α
18.9124
9Be+3He-α
16.7862
6Li+3He-p
17.8200
10B+d-α
18.8983
7Be+n
16.0037
8Li
15.0295
7Li+d-n
TO 3.04
11.7606
7Li+3He-d
8.5904
11B+p-α
4.5919
9Be+d-t
4.5720
11B+3He-6Li
0.2305
10B+n-t
-0.09189
4He+4He
-1.5670
6Li+α-d
-2.5599
7Li+α-t
-5.7791
12C+3He-7Be
-5.8915
12C+d-6Li
7Li+p 17.2541
1.8806 THRESH
16.0224
6Li+t-n
16.6738
7Be+d-p
17.979
8B
2m0c2
21.69
5Li+t
TO 3.04
0.5592
9Be+p-d
-1.6654
9Be+γ-n
-0.5332
10B+p-3He
0.0044
10Be+p-t
-6.0268
10B+γ-d
-7.3667
12C+γ-α
-11.2236
11B+γ-t
-14.5286
16O+γ-2α
T=0
25.2 25.5
22.2
20.1 20.2
19.9
16.63 16.92
4He(α,α) phase shift analysis
8Be

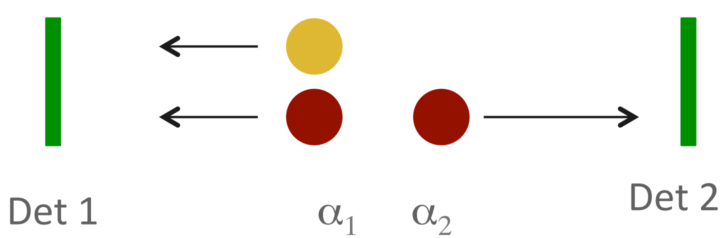
Production of ions

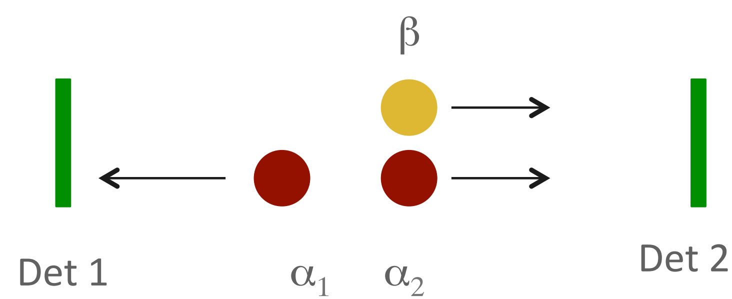


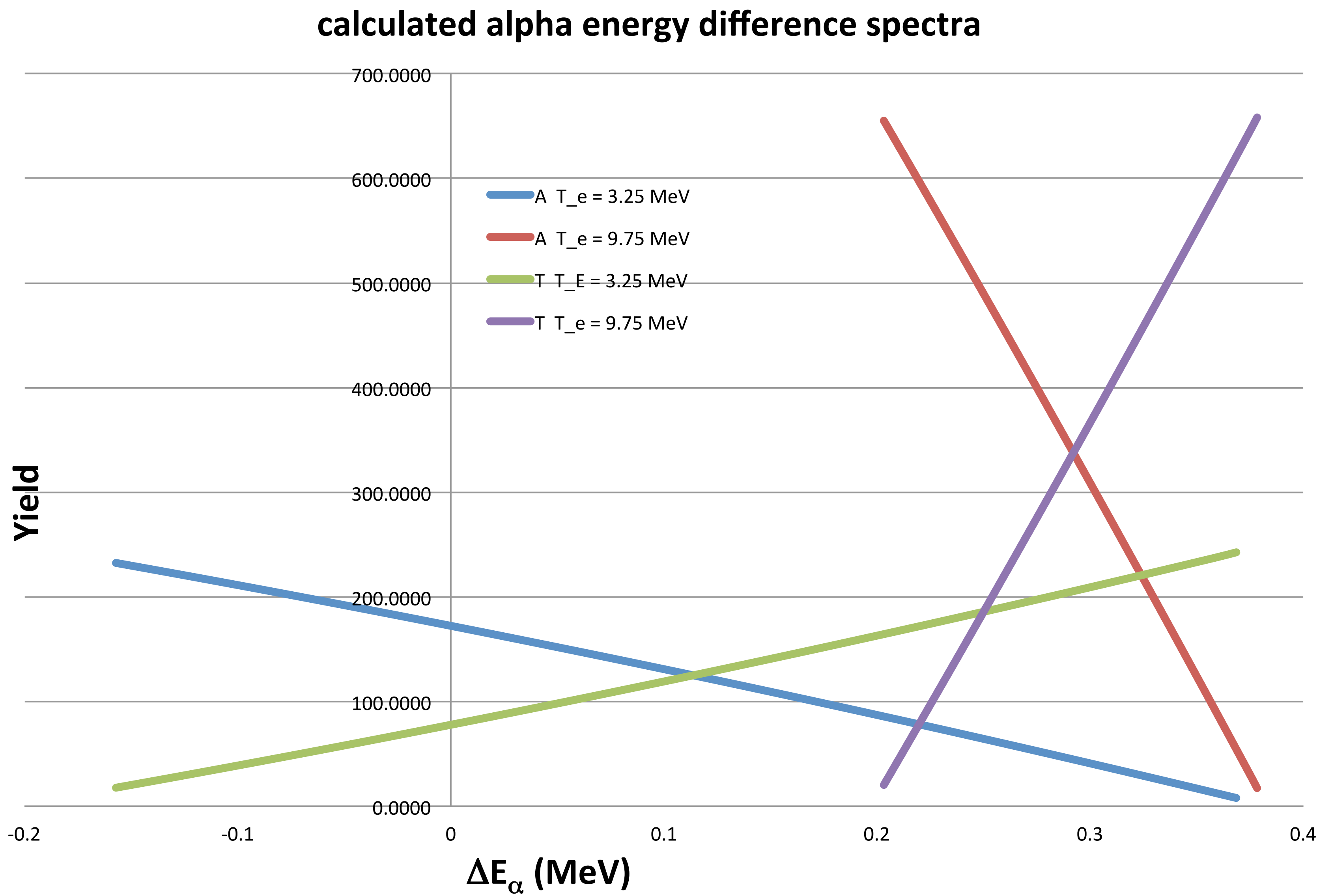
Beta-neutrino correlation studies in ^{8}B

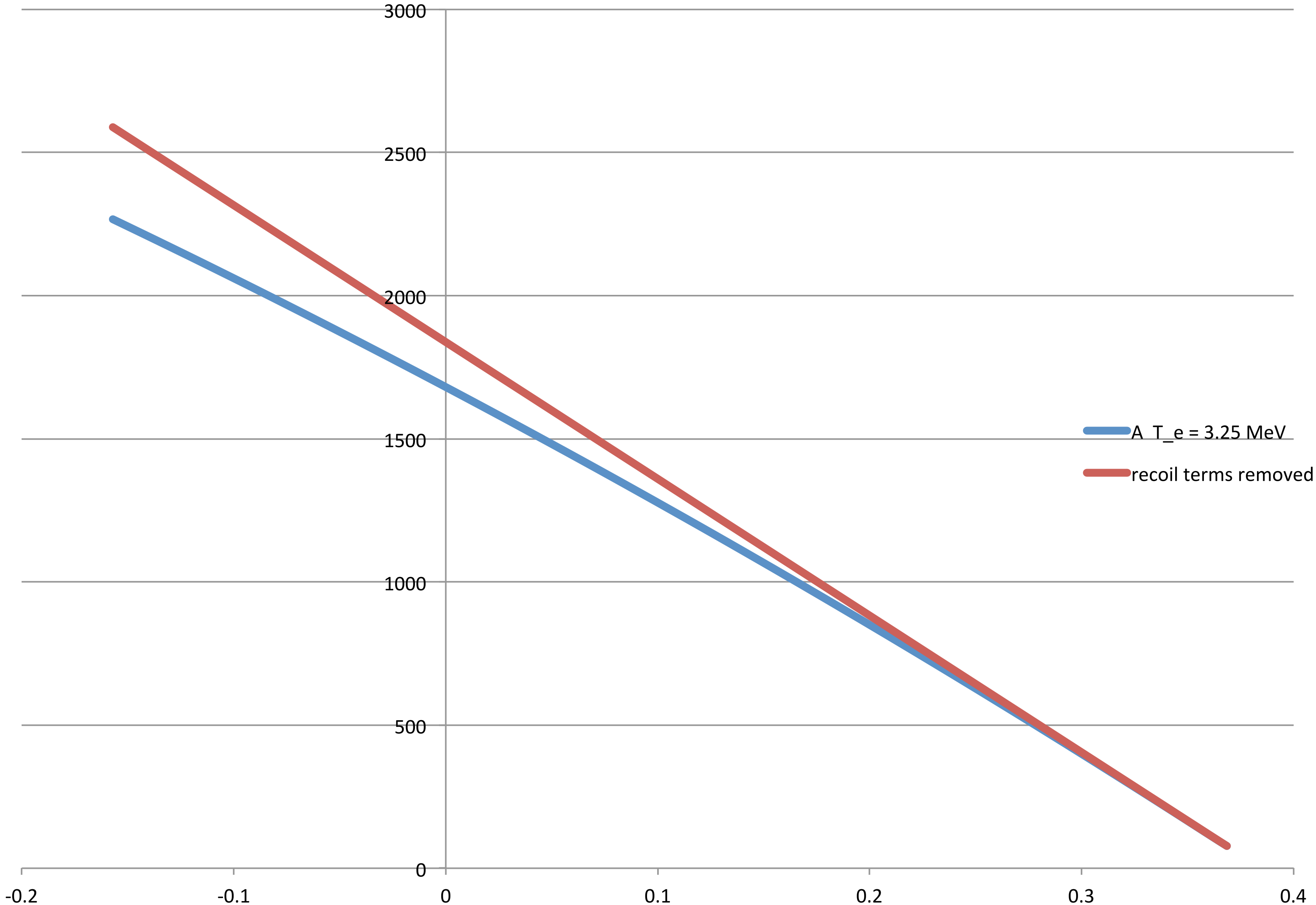









calculated alpha energy difference spectra
Yield
700.0000
600.0000
500.0000
400.0000
300.0000
200.0000
100.0000
0.0000
-0.2
-0.1
0
0.1
0.2
0.3
0.4
ΔE_α (MeV)
A T_e = 3.25 MeV
A T_e = 9.75 MeV
T T_E = 3.25 MeV
T T_e = 9.75 MeV



3000
2500
2000
1500
1000
500
0
-0.2
-0.1
0
0.1
0.2
0.3
0.4
A T_e = 3.25 MeV
recoil terms removed

outlook

- Complete analysis of 8Li data
- measure 8B (e,ν) correlation scheduled late June, 2014
- Improve DSSD calibrations using 20Na
- Install new electron-energy detectors
- High statistics 8Li measurement - early 2015

This work was performed by

- *Guy Savard* Has led ion trapping program from the beginning.
- *Jason Clark* Everything is always ready when needed.
- *Nick Scielzo* Initiated correlation measurements. Developed analysis codes.
- *Gang Li* Got DSSD's working in trap. First 8Li data.
- *Matt Sternberg* Extensive 8Li data. Improved upper limit on T.
- *Adrian Perez-Galvan* Leading 8B measurements
- Many other students, post docs, staff members and faculty who have participated in the ion trapping program