β - ν angular correlation measurement in the decay of ^{8}Li

The 49th Winter Nuclear and Particle Physics Conference

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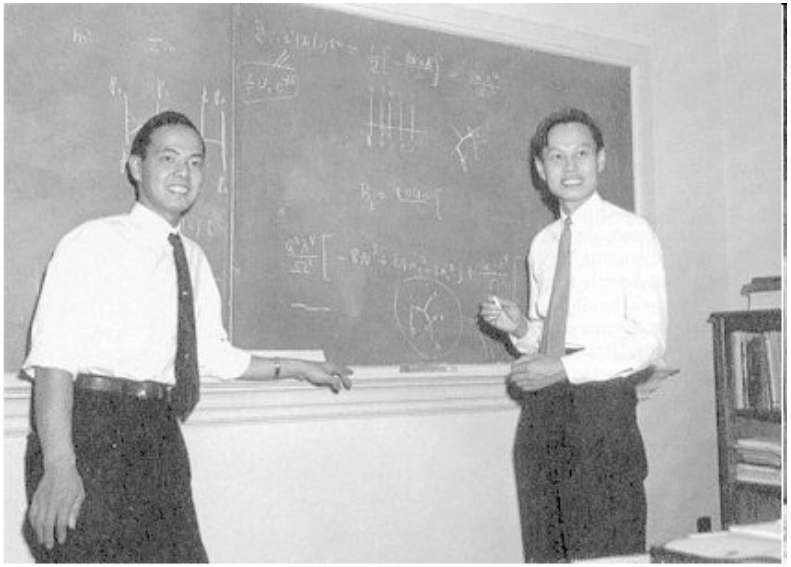
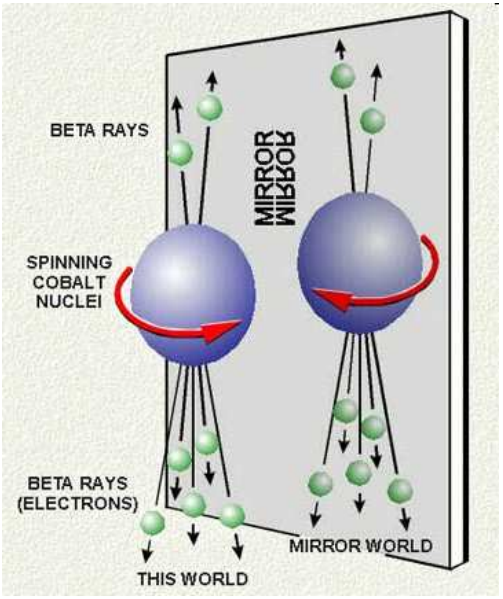
Gang Li
McGill University

Symmetry breaking



T. D. Lee C. N. Yang



Chien-Shiung Wu

1956, First symmetry broken

Beta decay in Standard model

Decay rate: $$dW = dW_o \varepsilon \left[1 + \frac{\vec{p}_e \cdot \vec{p}_\nu}{E_e E_\nu} a + \frac{m_e}{E_e} b + \frac{\vec{I}}{I} \cdot \left(\frac{\vec{p}_e}{E_e} A + \frac{\vec{p}_\nu}{E_\nu} B + \frac{\vec{p}_e \times \vec{p}_\nu}{E_e E_\nu} D \right) + \ldots \right]$$

a: β - ν correlation b: Fierz interference term

.....

$$a = |M_F|^2 \left[-|C_S|^2 + |C_V|^2 - |C_S'|^2 + |C_V'|^2 \mp 2 \frac{\alpha Z m}{p_e} mI (C_S C_V^* + C_S' C_V'^*) \right]$$
$$+ \frac{|M_{GT}|^2}{3} \left[|C_T|^2 - |C_A|^2 + |C_T'|^2 - |C_A'|^2 \pm 2 \frac{\alpha Z m}{p_e} mI (C_T C_A^* + C_T' C_A'^*) \right]$$

pure Fermi transition:

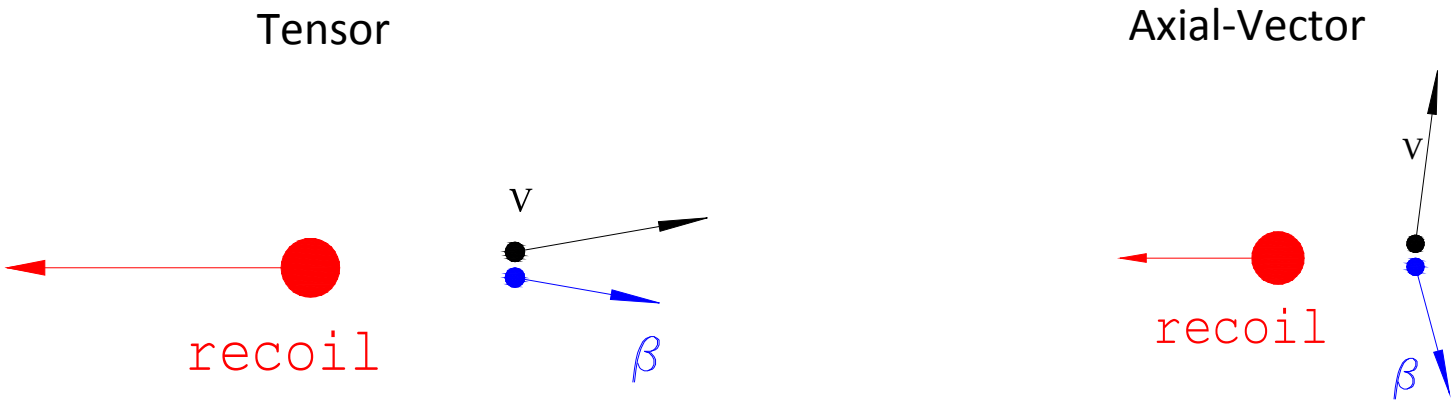
$$a_F \cong 1 - \frac{|C_S|^2 + |C'_S|^2}{C_V^2} \xrightarrow{\text{V-A only}} 1$$

pure Gamow-Teller transition

$$a_{GT} \cong -\frac{1}{3}\left[1 - \frac{|C_T|^2 + |C'_T|^2}{C_A^2}\right] \xrightarrow{\text{V-A only}} -\frac{1}{3}$$

Required by Lorentz invariance, Beta interaction operator can only be **Scalar (S), Pseudoscalar (P), Vector (V), AxialVector (A), Tensor (T)**

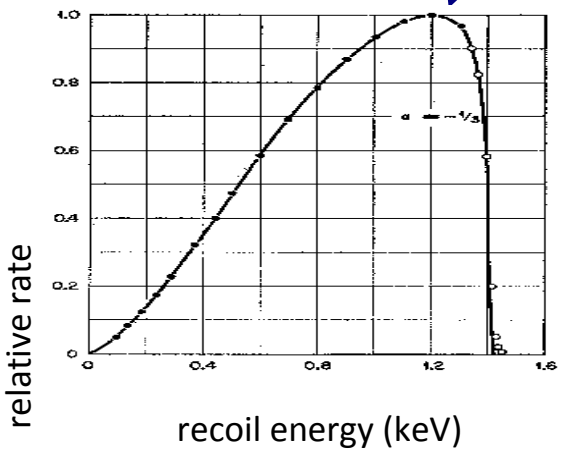
How to measure?

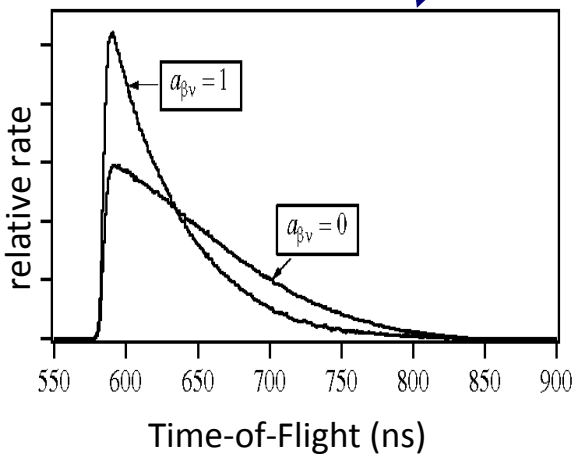


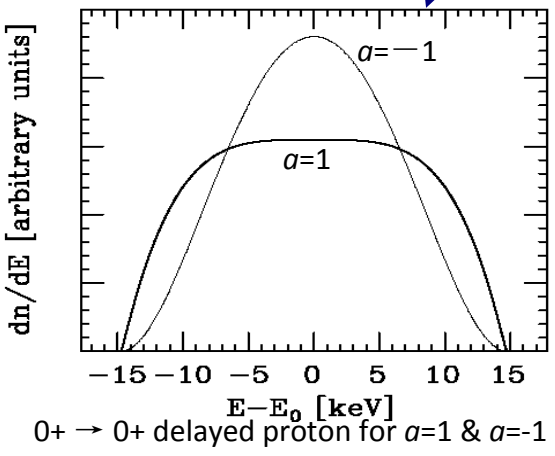
Bypass measuring neutrino, measure recoil
Difficulty: low recoiling energy, ~1 keV

How to measure?

Measure decay product energy directly	Measure TOF of recoil nucleus	Measure delayed particle emission
n, ^{19}Ne, ^{23}Ne, ^{35}Ar, ^{6}He	n, ^{6}He, ^{38M}K ^{21}Na, ^{37}K, ^{19}Ne	^{8}Li(α), ^{11}Be(γ), ^{14}O(γ) ^{18}Ne(γ),^{20}Na(α),^{32}Ar(p) ^{8}He(γ)







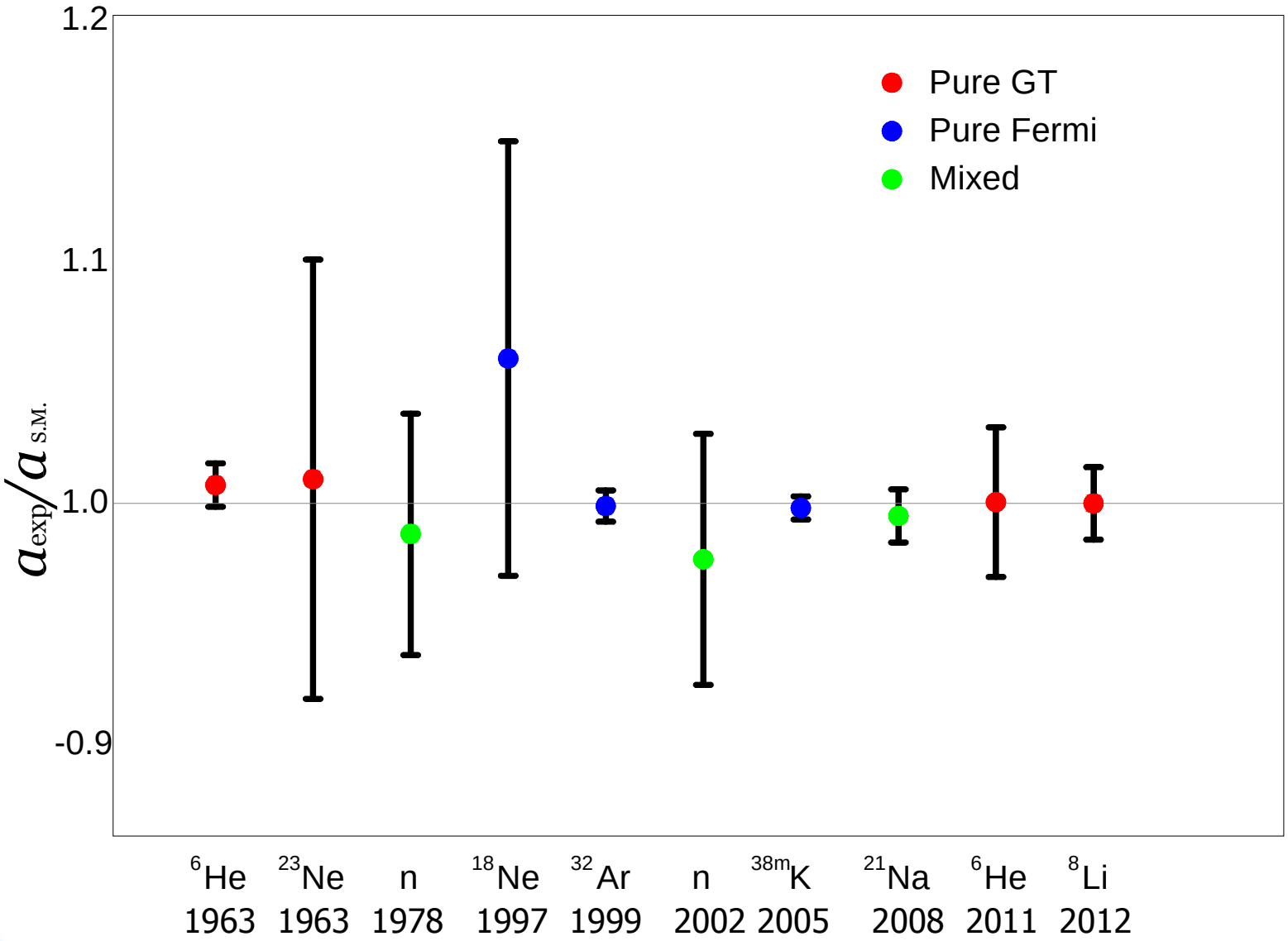
0+ → 0+ delayed proton for a=1 & a=-1

C.H. Johnson *et al*. Phys. Rev. **132**, 1149

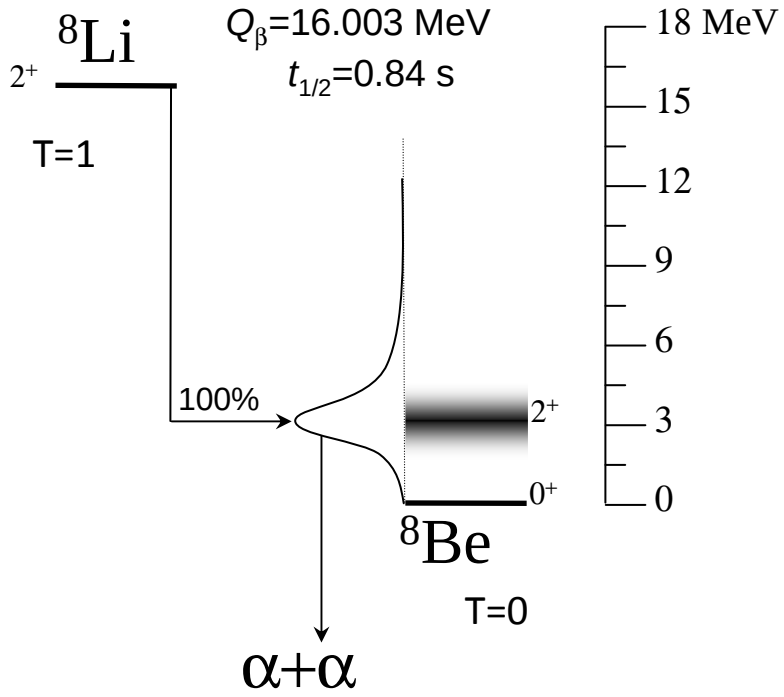
N. D. Scielzo *et al.* PRL.**93**,102501, 2004

E.G. Adelberger *et al.* PRL.**83**, 1299 (1999).

World Status



Why ^{8}Li a promising candidate?



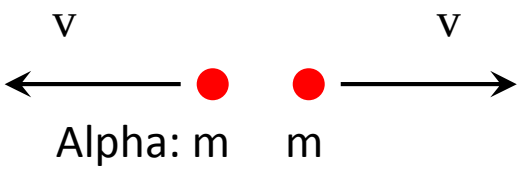
Advantages:

- proper life-time: 0.8 s
- almost pure GT decay
- large *Q*-value: 16MeV
- small nuclear mass:
  →10keV recoil
- Break up to two α's

$$^{8}Be^{*} \rightarrow \alpha + \alpha$$

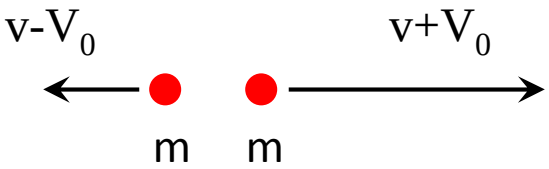
^{8}Be center of mass frame

^{8}Be mass = 2m



Lab frame

$$E_{Be} = mV_0^{\,2}$$



$$E_{\alpha 1} - E_{\alpha 2} = 2mvV_0$$

(Be)10keV →($\Delta\alpha$)400keV

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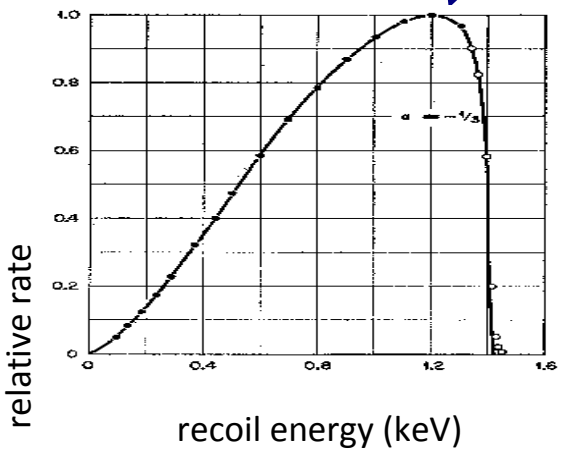
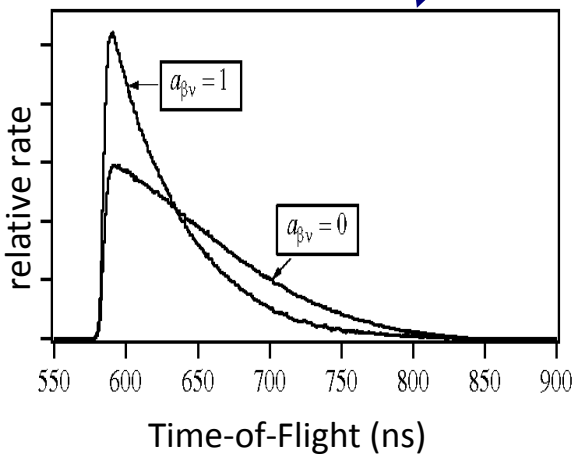
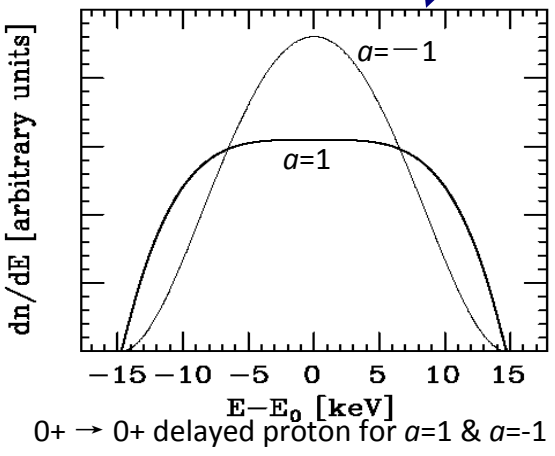
n, ^{19}Ne, ^{23}Ne, ^{35}Ar, ^{6}He	n, ^{6}He, ^{38M}K ^{21}Na, ^{37}K, ^{19}Ne	^{8}Li(α), ^{11}Be(γ), ^{14}O(γ) ^{18}Ne(γ),^{20}Na(α),^{32}Ar(p) ^{8}He(γ)







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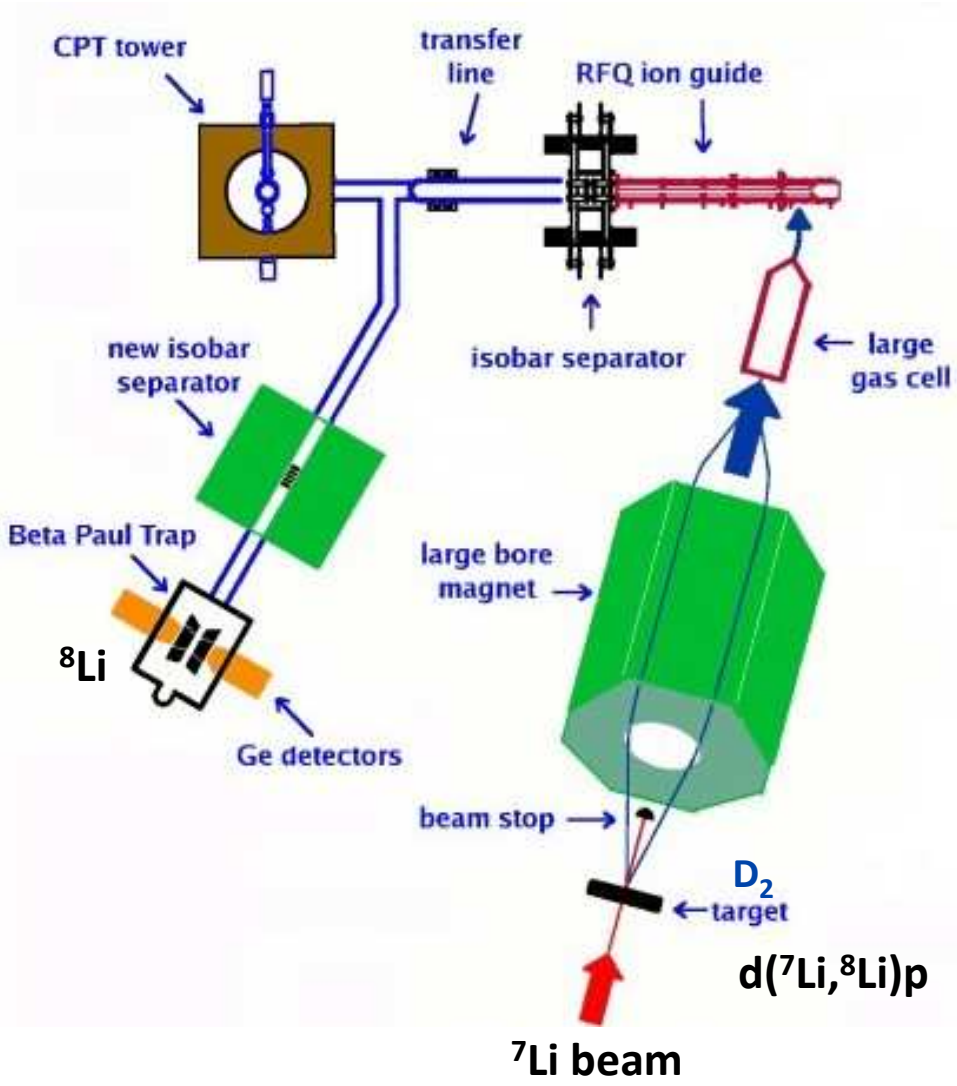
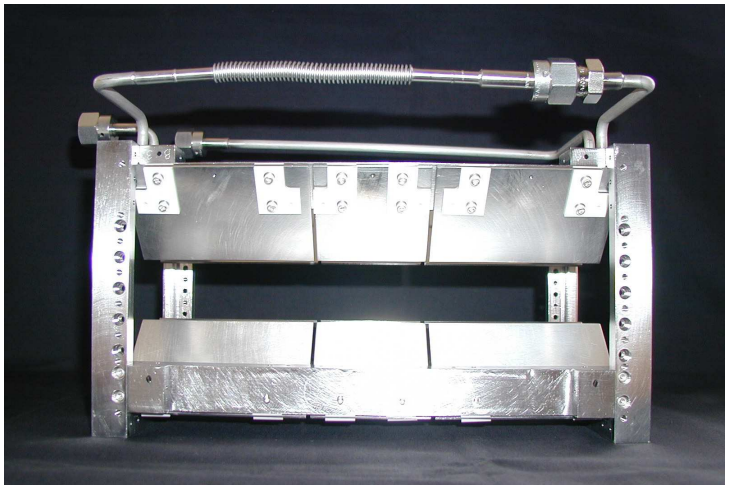
CPT and BPT(Beta decay Paul Trap) system

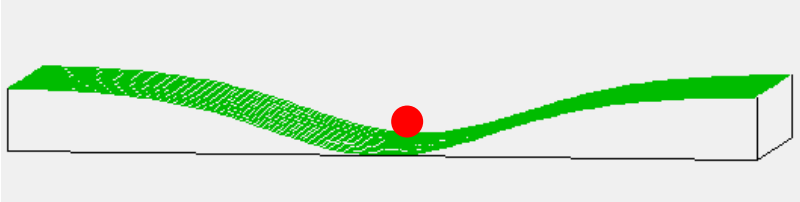


Beta-decay Paul-Trap

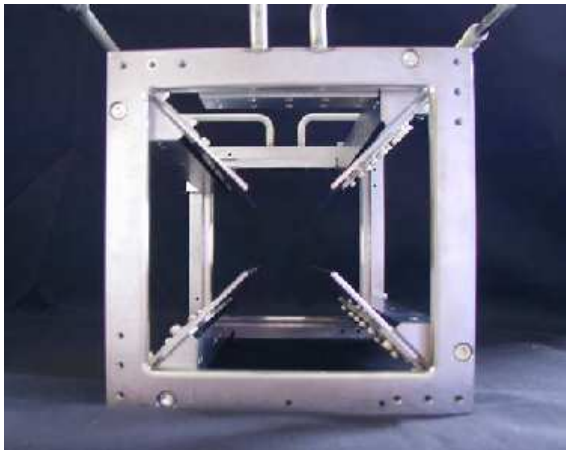
- Axial Direction (DC potential)



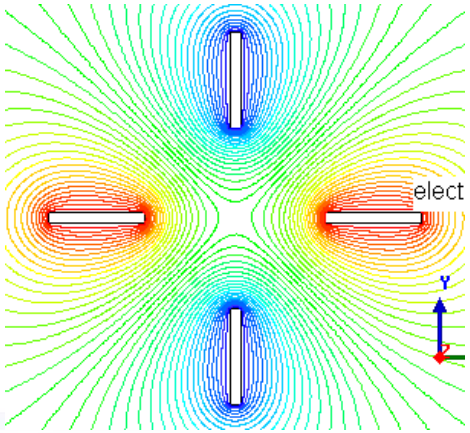
DC (V): 60 -50 60



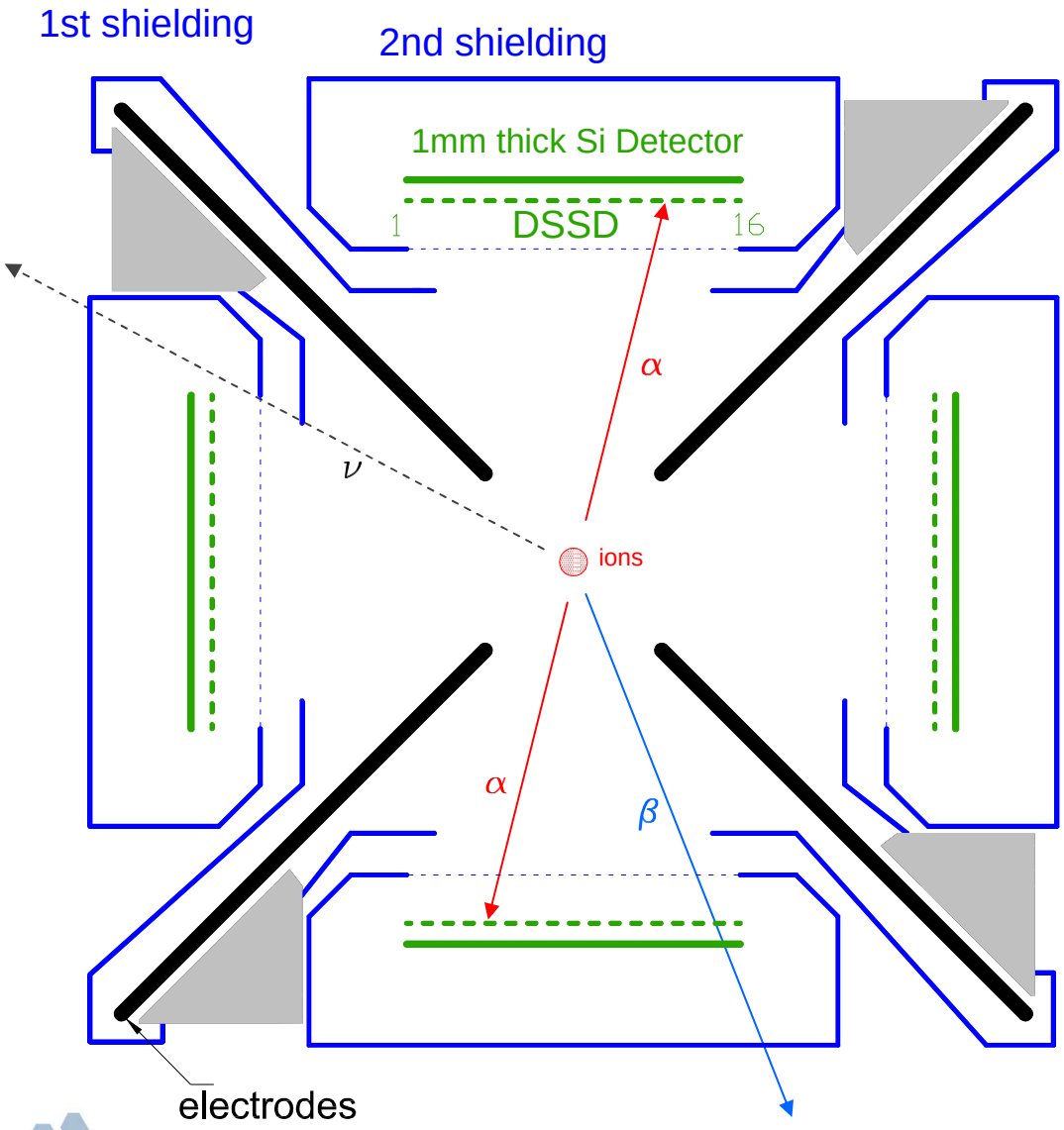
- Radial Direction (PseudoPotential Well)



RF: 850 $V_{p\text{-}p}$, 2 MHz



Detector



Measure full decay kinematics:

Eight degrees of freedom:

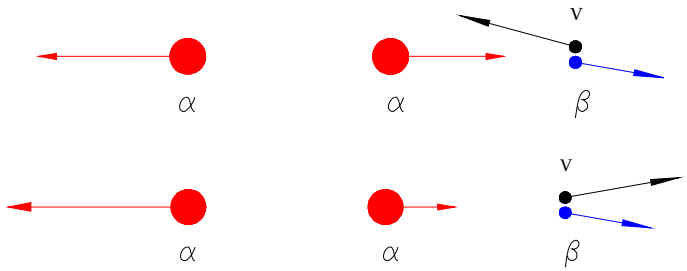
$4 \times 3 - 4 = 8$

4×3 : momentum $\alpha, \alpha, \beta, \nu$

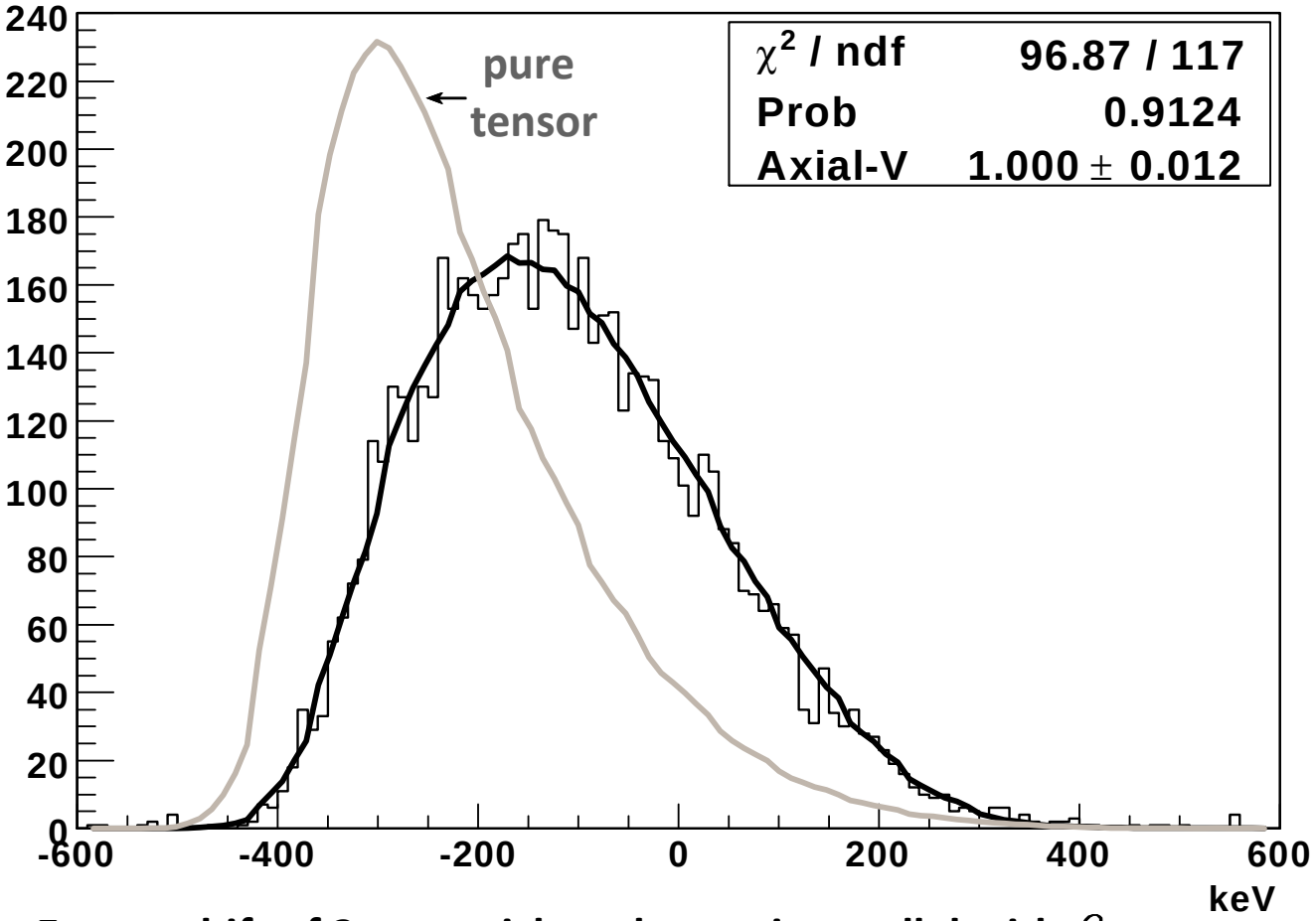
−4: E, p conservation

Measure: α, α and direction of β.

Most sensitive observable:
2 α's Energy difference



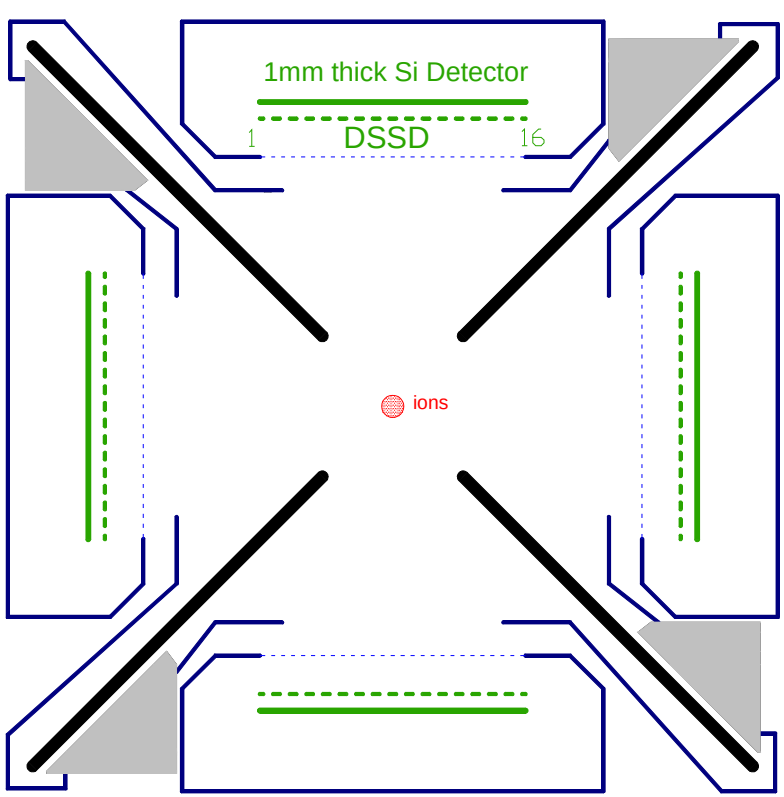
First result

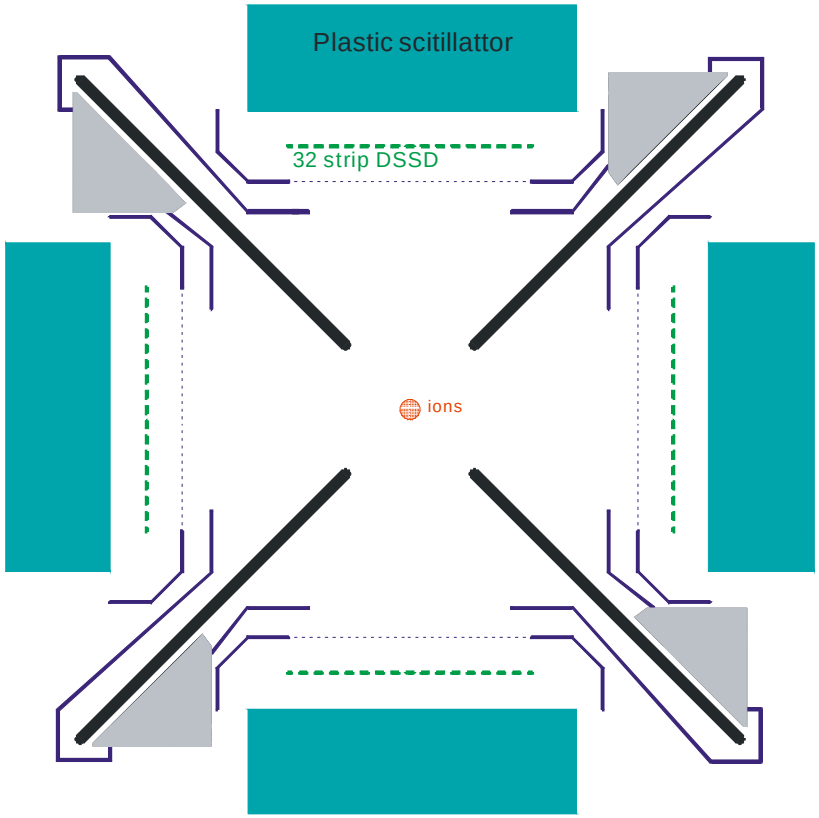


Energy shift of 2 α particles when α is parallel with β.
1% statistical uncertainty and 1% systematic uncertainty dominated by Energy Calibration.

$$a_{\beta\nu} = -0.3333 \pm (0.0031)_{\text{stat}} \pm (0.0033)_{\text{syst}}$$

upgrade: Detector





- **DSSD upgrade:**
  - **16x16 strip → 32x32 strip: better angular resolution**
  - **thickness 0.3 mm→ 1.0mm: record β direction in DSSD**
  - **deadlayer: 0.6 μ m → 0.1 μ m: better energy calibration**
- **Plastic scintillator detector to record β energy**

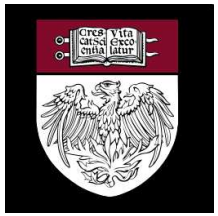
Collaborator

F. Buchinger, J.E. Crawford, S. Gulick, J.K.P. Lee, G.Li

R. Segel, D. Lascar

N.D. Scielzo

G. Savard, J. Clark, A.F. Levand, B.Z. Zabransky
P. Wilt, J.P. Greene, T. Sun, A. Chaudhuri, C. Deibel
M. Alcorta, P. Bertone, D. Seweryniak



M. Sternberg, J. Van Schelt
S. Caldwell

K.S. Sharma
J. Fallis

R. Yee

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