Design of a High-Precision β-Telescope

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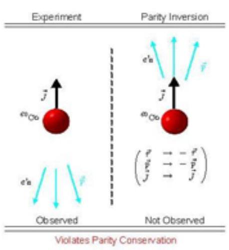
Motivation: Is Parity Violation maximal?

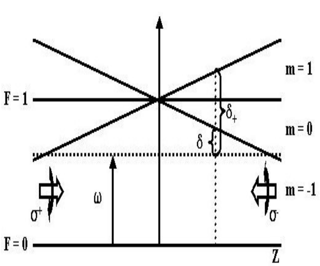


- The parity operation takes a point *(x, y, z)* and maps it to *(-x, -y, -z)*. Hence, parity takes an image and transforms it into a mirror image.
- Conservation of parity in the weak interaction was falsified in 1957 by Wu et. al.
- We are looking for right-handed weak currents, which would tell us whether or not parity violation is maximal, or just very significant.
- The Standard Model assumes maximal violation of parity; if right-handed weak currents are discovered, then we know that our theories on symmetry are incomplete.

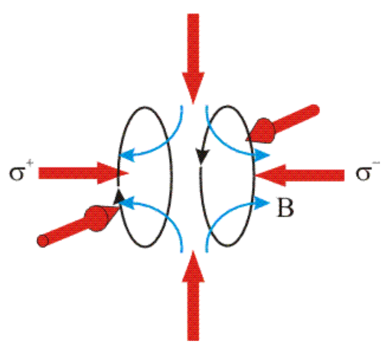
Source: 7/29/09, http://pearl1.lanl.gov/external/c-nr/atom/images/rat_p4.jpg

Trapping Neutral ^{37}K Atoms with Lasers

- We can infer the existence of weak currents by measuring the energy and momenta of the e^+ and the recoiling ^{37}Ar nucleus (which come from β^+ decay of ^{37}K) to fill in the blanks.
- ^{37}K atoms are confined within a magneto-optical trap (MOT) of circularly-polarized light, just slightly detuned below the resonant frequency.
- Energies become split according to the Zeeman effect, which separates levels by their combination of orbital and spin angular momentum.
- The splitting combined with the Doppler effect ensures that only one polarization of light gets absorbed by the ^{37}K atoms.
- ^{37}K atoms are slowed down to temperatures of hundreds of μK by the Doppler-shifted laser light, and the laser's polarization drives them back to the center as defined by the quadrupole field.



Source: 7/29/09, maincc.hufs.ac.kr/~optics/images/m2.jpg

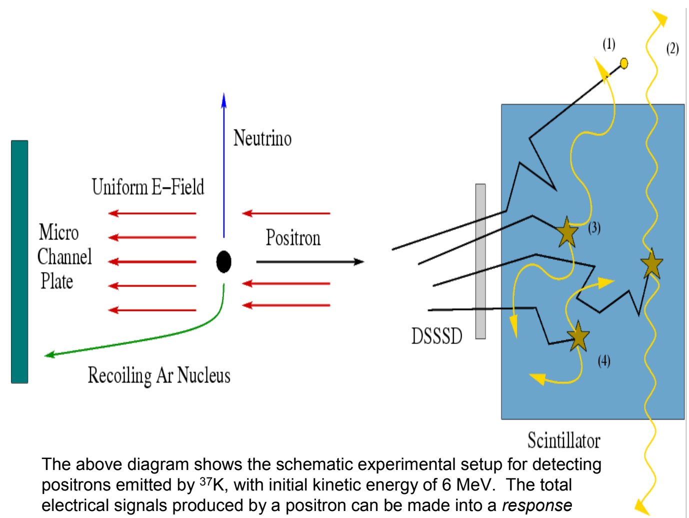


Source: 7/29/09, www.npl.co.uk/upload/img_400/MOT1.gif

References

- *Introduction to Elementary Particles,* D. J. Griffiths
- *Radiochemistry and Nuclear Chemistry,* Choppin et. al.
- *Measurement of the Neutrino Asymmetry in the β Decay of Laser-cooled, Polarized ^{37}K,* D. Melconian et. al.

Detection of Positron Momentum Towards Measuring Correlations



The above diagram shows the schematic experimental setup for detecting positrons emitted by ^{37}K, with initial kinetic energy of 6 MeV. The total electrical signals produced by a positron can be made into a *response function,* such as those at right. The numbers in parentheses above correspond to events which contribute to certain areas of the response functions at right.

GEANT 3 and Monte Carlo Simulations

- All simulations were run on GEANT 3 (**GE**ometry **AN**d **T**racking), a Monte Carlo based software package. Monoenergetic positrons were emitted in random orientations into a hemisphere containing the telescope.
- For the above data, 1,000,000 random events were generated to produce roughly 30,000 individual positron events in the scintillator.
- PHYSICA programs were used to collect the raw data and group them into response functions, which are histograms of how many positrons deposited a given quantity of kinetic energy. The bigger the peak is at 6 MeV compared to the rest of the response function, the better the β–telescope.

Status of the Experiment

- The experiment is still in its design stages, as the main vacuum chamber and the telescope remain yet to be built.
- It will take place at TRIUMF's ISAC facility in Vancouver, Canada in 2010.

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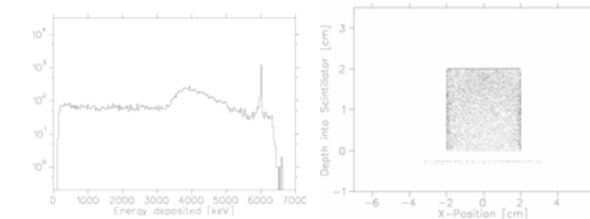
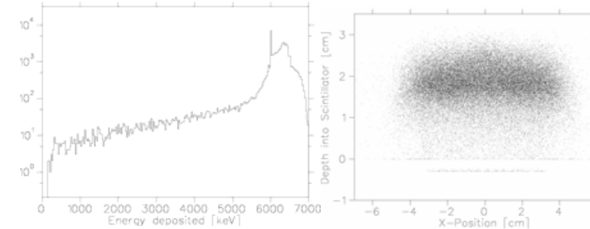
Response Functions & 2D Plots



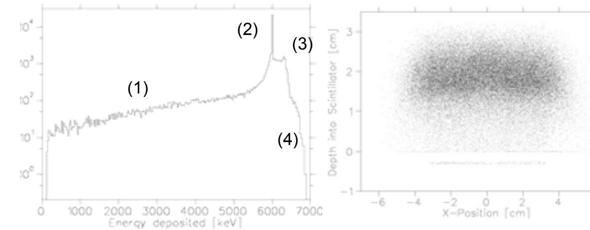
A very small scintillator; lots of escaped positrons

(Radius 2.0 cm, thickness 1.0 cm)



A very large scintillator; many annihilation events

(Radius 12 cm, thickness 100 cm)



An intermediate size, minimizing the above problems

(Radius 6.0 cm, thickness 3.2 cm)

Results & Conclusions

- After taking design considerations into account and doing thorough simulations, I decided to use the BB7 6.4 x 6.4 cm² silicon detector to be paired with a scintillator of radius 6.0 cm and thickness 3.2 cm.
- Below is a drawing of the β–telescope I designed.