Positron Identification by Coincident Annihilation Photons (PICAP) system

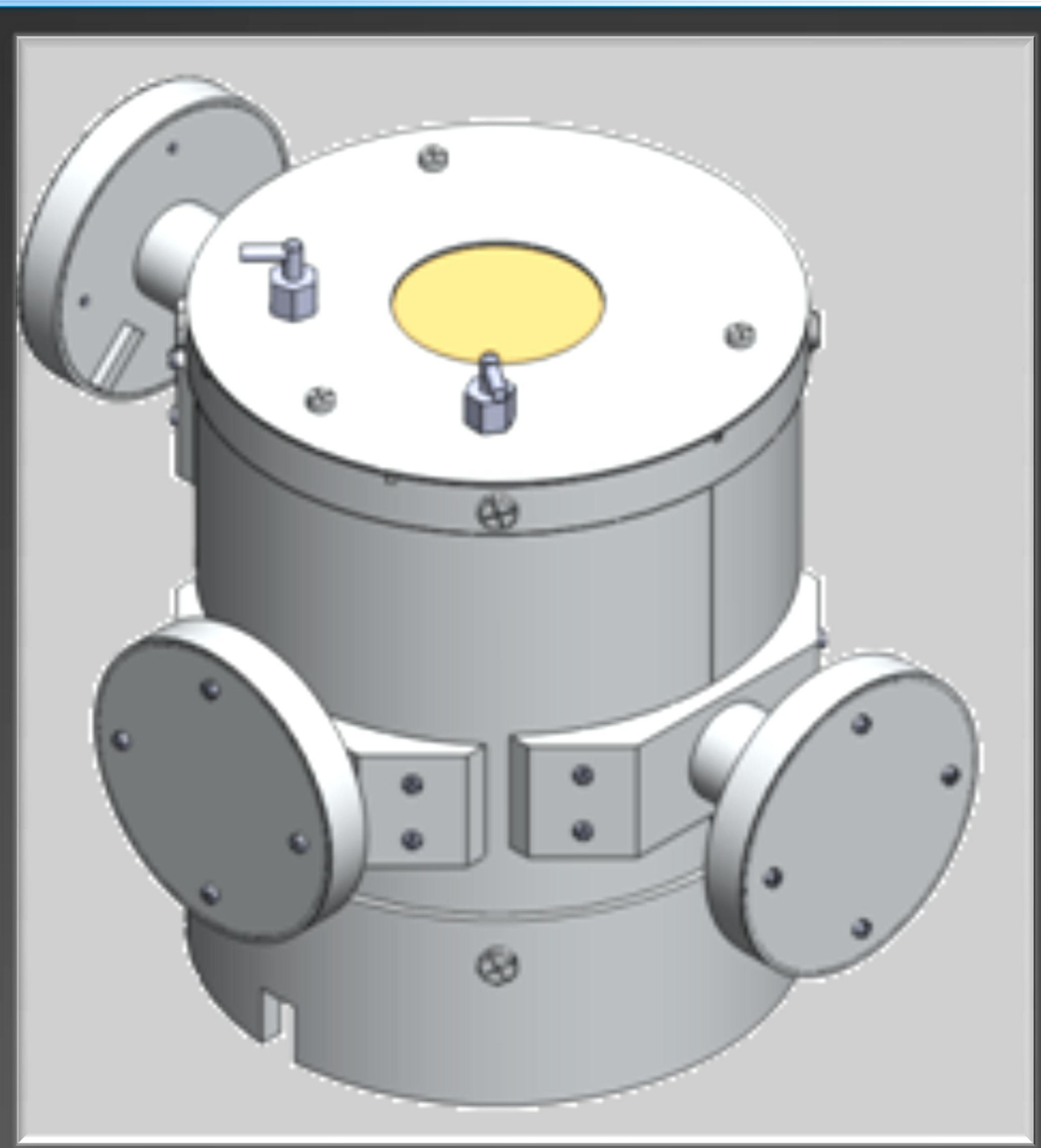
B.B. Bickford
Faculty advisors - May-Win Thein, J.J. Connell
C. Lopate D. L. Tran, Space Science Center University of New Hampshire

Background and Project Goal

- New design for detecting and distinguishing energetic positrons (anti electrons) from negatrons (ordinary electrons) in space
- Design, build, and test a proof of principle prototype telescope

Abstract

This concept is a new method for detecting moderate energy positrons and negatron in space. The current method for measuring these particles is by using a magnet spectrometer. Magnet spectrometers typically weigh greater than 10 kg, use more than 10 watts of power and require a magnet. The goal of the proposed PICAP design is to reduce these resources to provide an alternative, and more attractive space flight instrument. We estimate a flight instrument to have a weight less than 4 kg, power draw of less than 3 Watts and no magnet. As a space flight instrument this resource allotment will would make the PICAP instrument a much more desirable alternative.



CAD model of PICAP instrument

Dimensions of prototype			
Total Height	16.78 cm	Total mass	3.3 kg
Total width	22.47 cm	Total Volume	1985 cm^3

Design Constraints

- ➢ Light tight - This instrument was designed to exclude all ambient light
- ➢ Reflecting light -Teflon was used around scintillators to reflect light towards the opening face of the photo multiplier tubes
- ➢ Cross talk – Teflon and Aluminum was used around each of the scintillators to ensure light would not cross from one to another
- ➢ 7 Circuit boards and corresponding wires had to be included for the photomultiplier tubes and solid state detectors
- ➢ Purging – purge ports were required to exclude contamination
- ➢ Instrument was required to act as a faraday cage in order to exclude electromagnetic interference
- ➢ Designed with Assembly + Disassembly capabilities

Testing and Analysis

❖ Venting analysis - to ensure the change in pressure between the inside and outside of the telescope won't have adverse effects such as structural failures or separations of joined parts.
➢A ventilation area of 2.31 cm^2 is required for flight instrument

❖ Gamma ray absorption probability - calculations were performed to determine the required thickness of the scintillator based on the material
➢Thickness required for annular sections: BGO .94cm
CsI 2.3cm

❖ Thermal Analysis - was done to model the telescope with the effects of temperature due to radiation from the sun
➢Max temperature allowed 383 K (110 C°)
➢Max temperature found 331 K (58 C°)

❖ Vibration simulations - FEA software was used to find the natural frequencies of the telescope
➢Greater then 50 Hz is required for flight instrument
➢First five natural frequencies (Hz):

1277.7	1286.4	2070.6	2484.5	4055

Notes

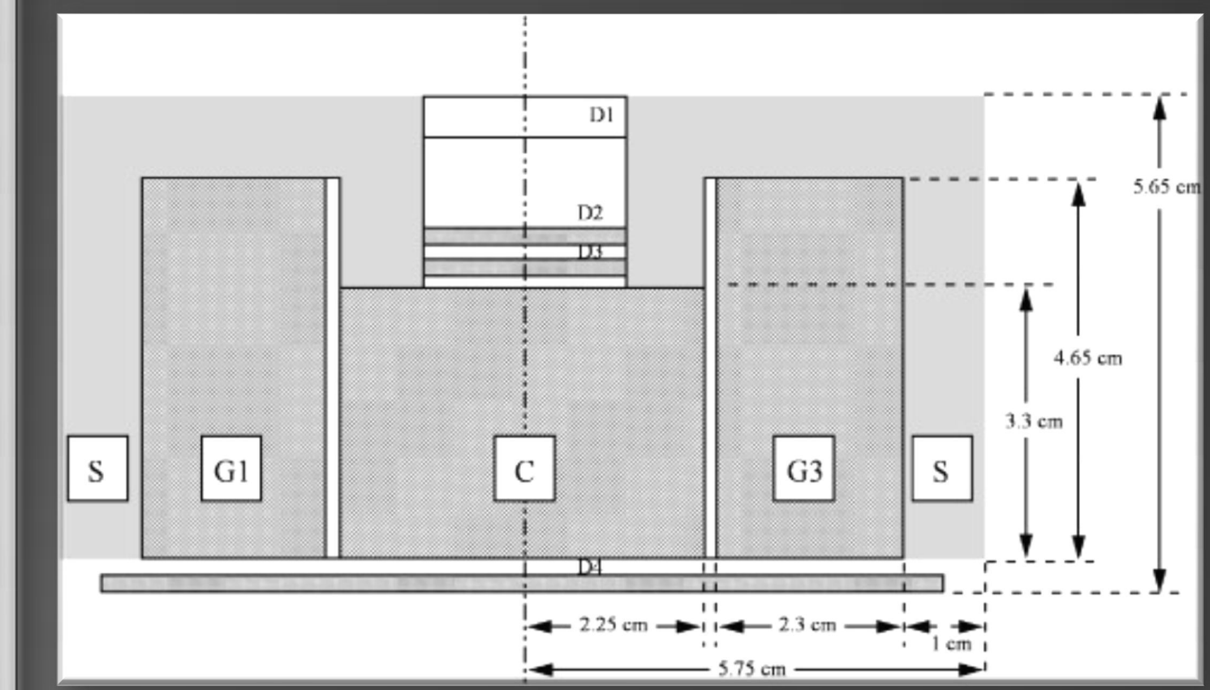
➢ 39 different fabricated parts
- designed from stock material sizes
- flight instrument will have significantly fewer but much more complex parts

➢ 7 Photomultiplier tubes (PMT) and corresponding dynode circuit boards
➢ 4 Solid-State detectors
➢ Materials; Aluminum, Teflon, BGO, PVT, Delrin, Brass foil
➢ Space flight instrument will be fabricated with magnesium rather than aluminum, this is expected to drop the total weight by roughly 1 kg

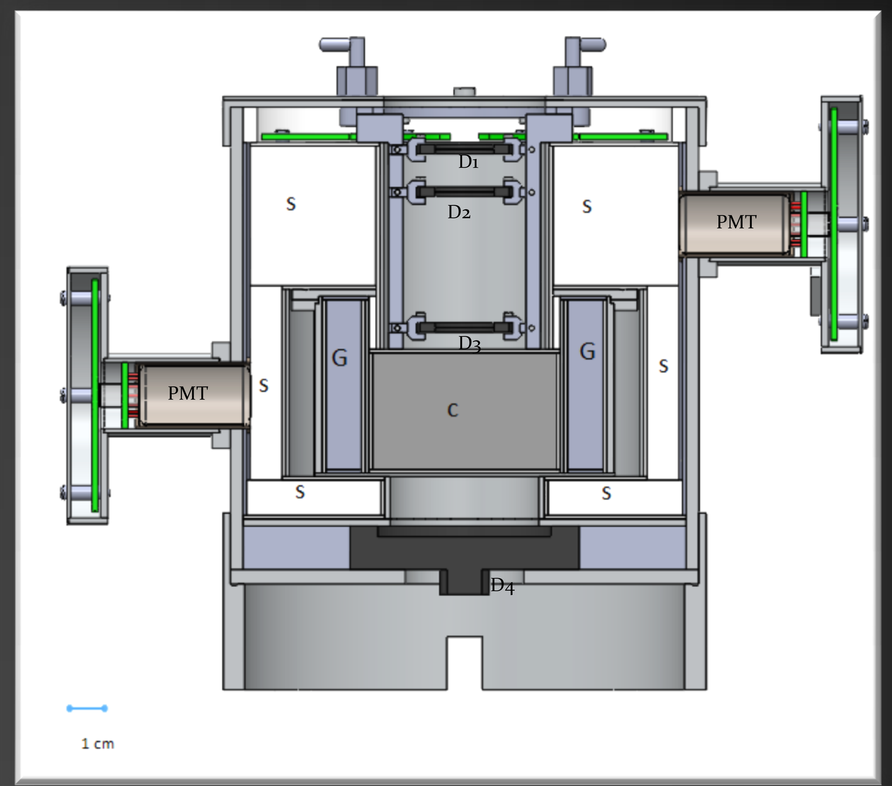
Methods

The PICAP instrument works by first using the dE/dx method versus residual energy technique to identify incoming particles. Positrons within the appropriate energy range will annihilate in the scintillation material and produce coincidental 511 keV photons. These annihilation photons are then detected by two of the four surrounding annular sections of crystal scintillators. Unwanted particle data, particles not entering through top window, will be identified by using scintillation material all around the instrument along with a large solid state detector at the bottom of the device.

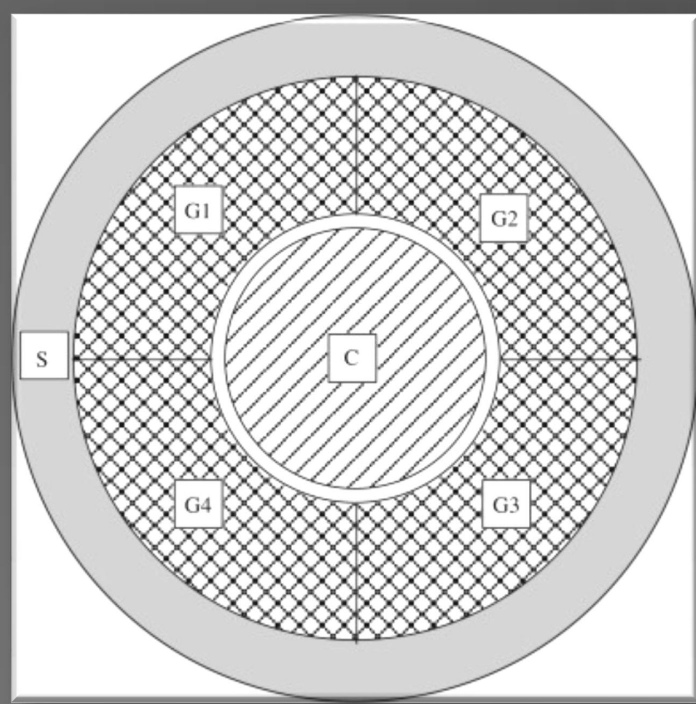
Instrument Concept and Design



Side cross section view of concept design

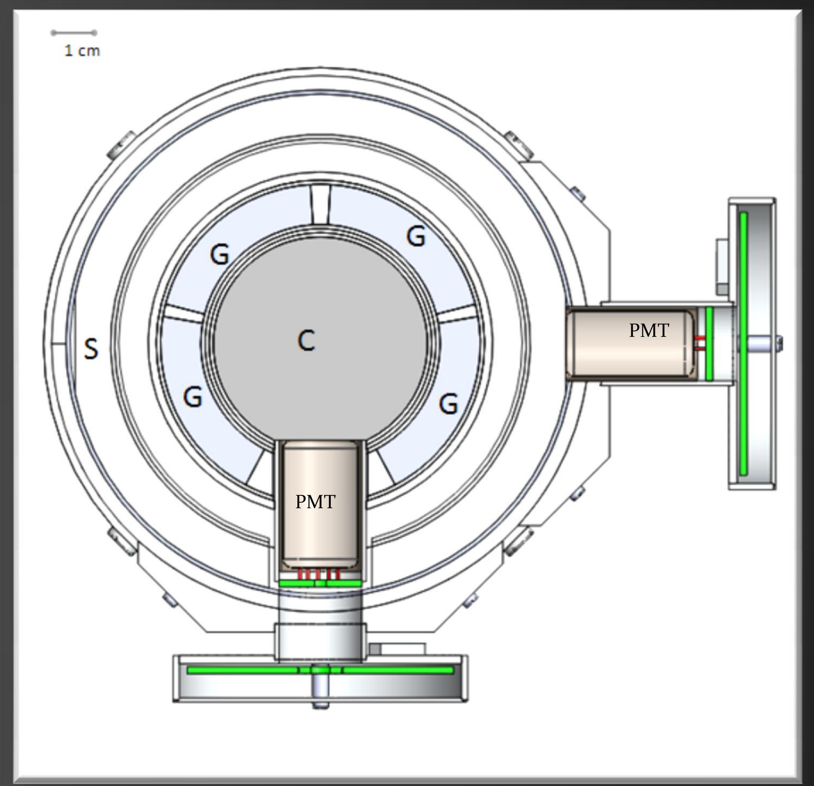


Side cross section view of Mechanical design



C- Center scintillation material (PTV)
G- Heavy scintillation material (BGO)
D- Solid state detectors
S- Plastic scintillation material (PTV)

Top cross section view of concept design



Top cross section view of Mechanical design

Future plans

•Finish fabrications
•Test at the Idaho State cyclotron, and Mass General Hospital proton beam

References

Connell, J., J. Kalainoff, and C. Lopate. "Design Concept and Modeling of a New Positron Identification by Coincident Annihilation Photons (PICAP) System." *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* 593.3 (2008): 431-39. Print.