A Cosmic Ray Veto System for the ALPHA-g Experiment

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Outline

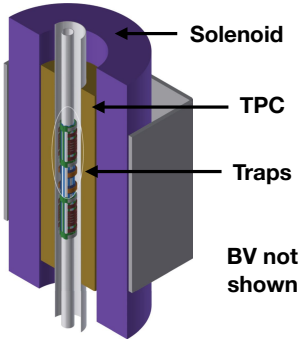
- Introduction to ALPHA-g.
- The cosmic ray background veto system.
- A first look at cosmic ray data.

ALPHA-g physics objectives

- ALPHA: Antihydrogen Laser PHysics Apparatus @ CERN.
- ALPHA-g will measure the gravitational acceleration of antihydrogen.
- The first direct test of the *Weak Equivalence Principle* using antimatter.

Figure: Dan Hanson, Pinterest

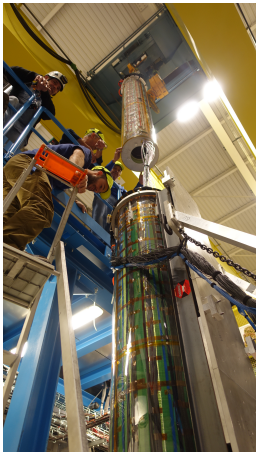
ALPHA-g apparatus



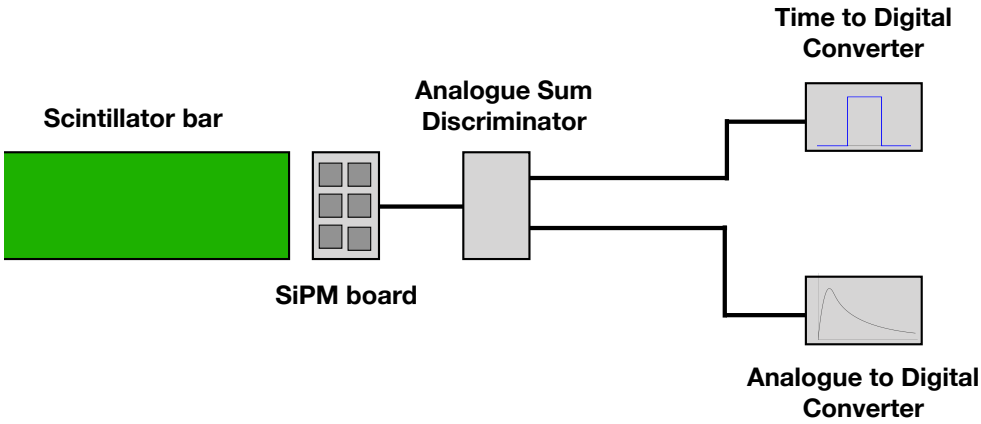
- Use magnetic traps to create and hold antihydrogen (see talk by Nathan Evetts).
- Relax vertical fields, and allow antihydrgoen to fall and annihilate.
- Track annihilation products (pions) using a *Time Projection Chamber* (TPC).
- Reconstruct annihilation positions.

Barrel Veto

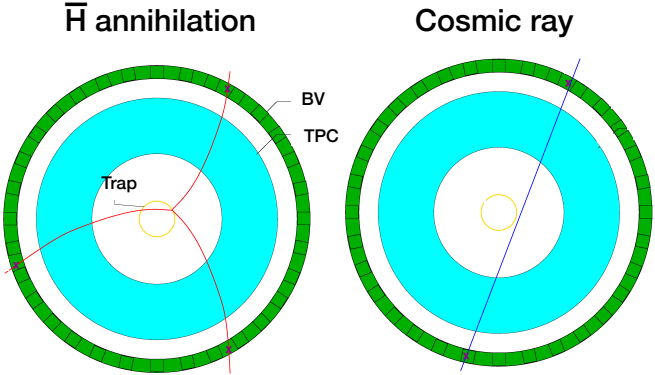
- Main background in TPC: cosmic ray muons.
- To distinguish cosmic rays, TPC surrounded by a “barrel veto” (BV).
- 64 2.6-meter bars of plastic scintillator bound together in barrel shape.



Barrel Veto readout



Background rejection principle



My project: Implement algorithm to reject cosmic ray background!

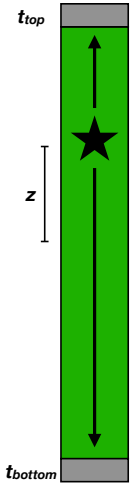
Finding z from BV time

$$t_{bottom} = t_0 + (L/2 + z)/v$$

$$t_{top} = t_0 + (L/2 - z)/v$$

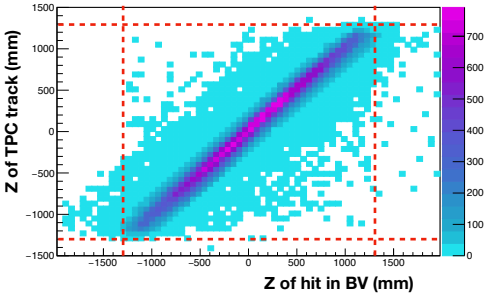
$$\implies z = \frac{v}{2}(t_{bottom} - t_{top})$$

L = bar length, v = speed of light in bar



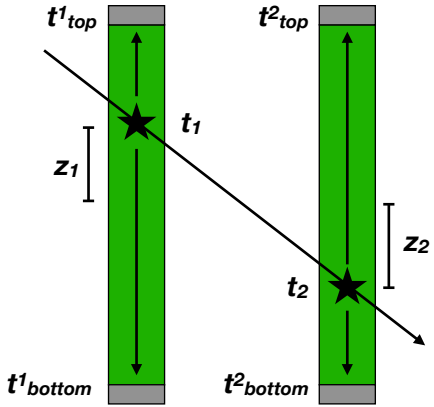
Matching BV and TPC data

- Extrapolate TPC tracks into the BV $\longrightarrow$ intersection point (z, ϕ).
- Calculate z and ϕ of BV hit.
- Match each BV hit to the geometrically closest TPC track.



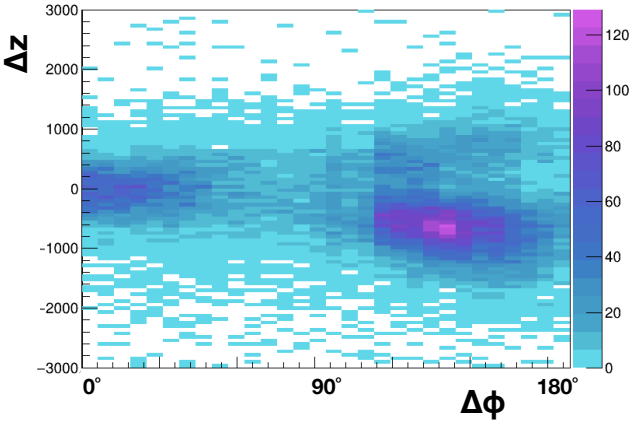
Calculating time of flight

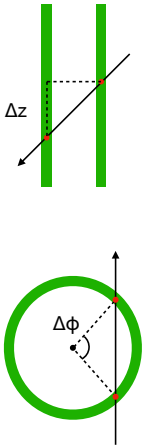
$$TOF = t_2 - t_1$$
$$= \frac{t^2_{bottom} + t^2_{top}}{2} - \frac{t^1_{bottom} + t^1_{top}}{2}$$



Pairs of BV hits

Next I looked at every combination of two BV hits.





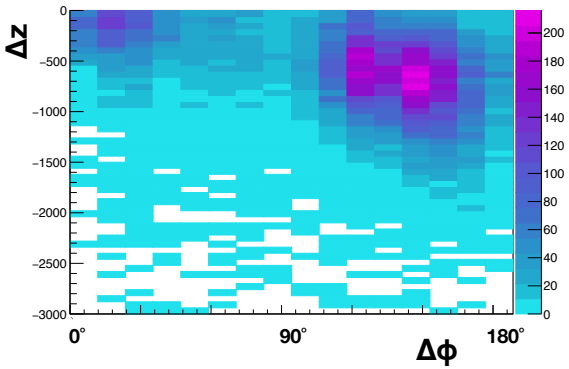
Calculating expected hit geometry

$$\text{Rate} \sim \boxed{\text{Cosmic ray flux}} \times \boxed{\text{Detector efficiency}} \rightarrow \boxed{\Delta\phi, \Delta z}$$

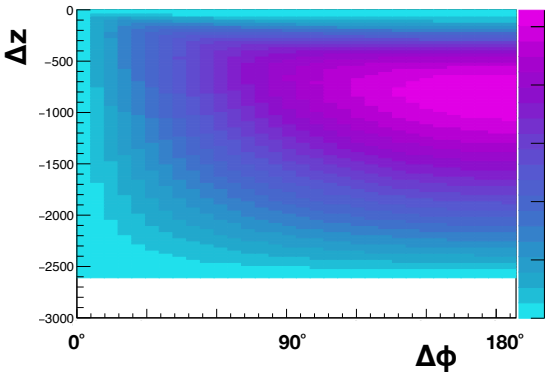
~ $\cos^2(\theta)$
Uniform in x, ϕ

Data vs prediction

Data



Prediction



Summary and outlook

Summary:

- Barrel veto detector used to reject cosmic ray background in ALPHA-g.
- Analysis of cosmic ray data is ongoing.
- Barrel veto system appears to be working as expected.

Future goals:

- Apply this analysis to simulation, and to $\overline{H}$ data once it is taken.
- Develop an algorithm to distinguish cosmic ray background from $\overline{H}$ events.