Anti-hydrogen detection and background rejection for ALPHA-g

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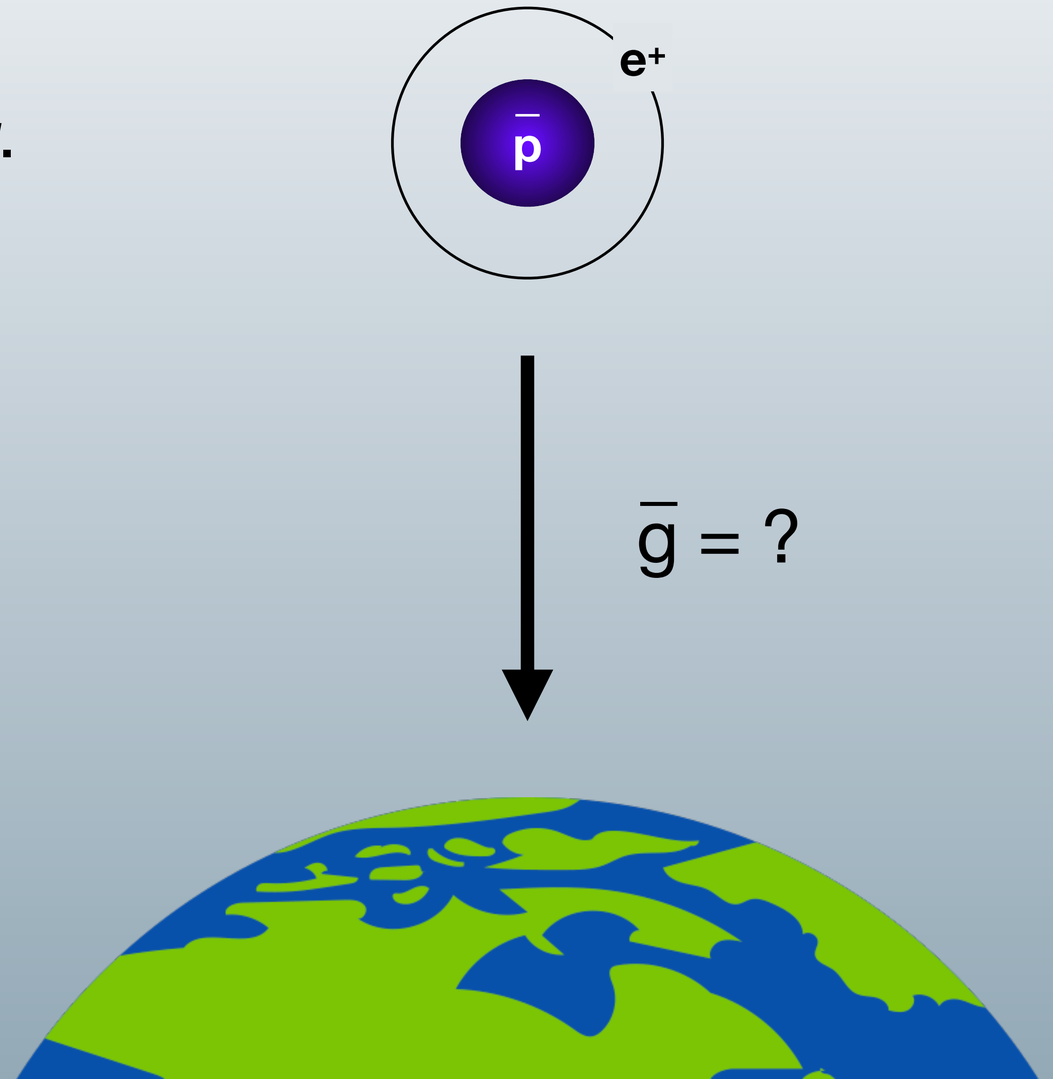
Overview

1. The ALPHA-g experiment
2. Antihydrogen detection in ALPHA-g
3. Background rejection in ALPHA-g
4. Commissioning data from 2022

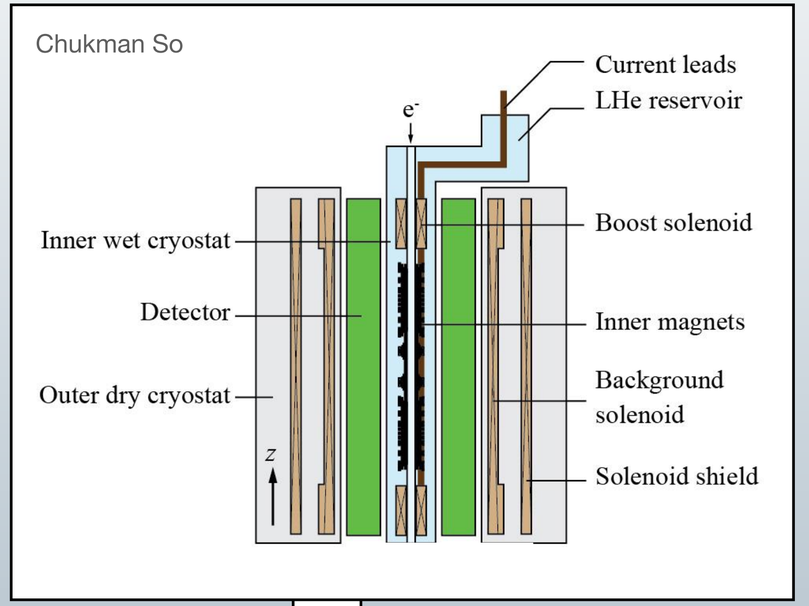
ALHPA-g Experimental Goals

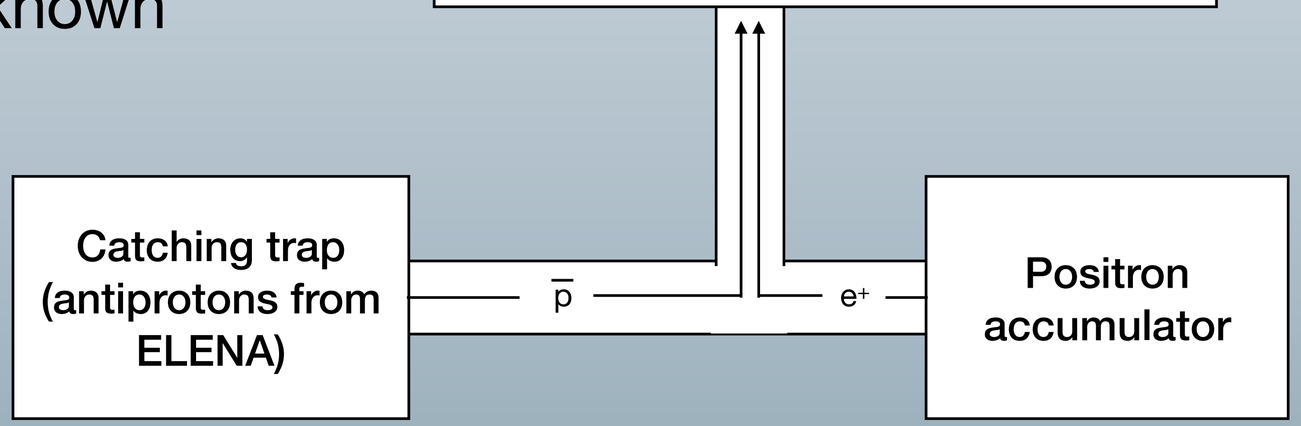
- ALPHA-g @ CERN is the first direct precision test of the ***gravitational interactions*** of ***antimatter*** with ***matter***.
- Compare gravitational constant in antimatter $\bar{g}$ with “regular” g to test Einstein’s weak equivalence principle.



ALHPA-g Apparatus

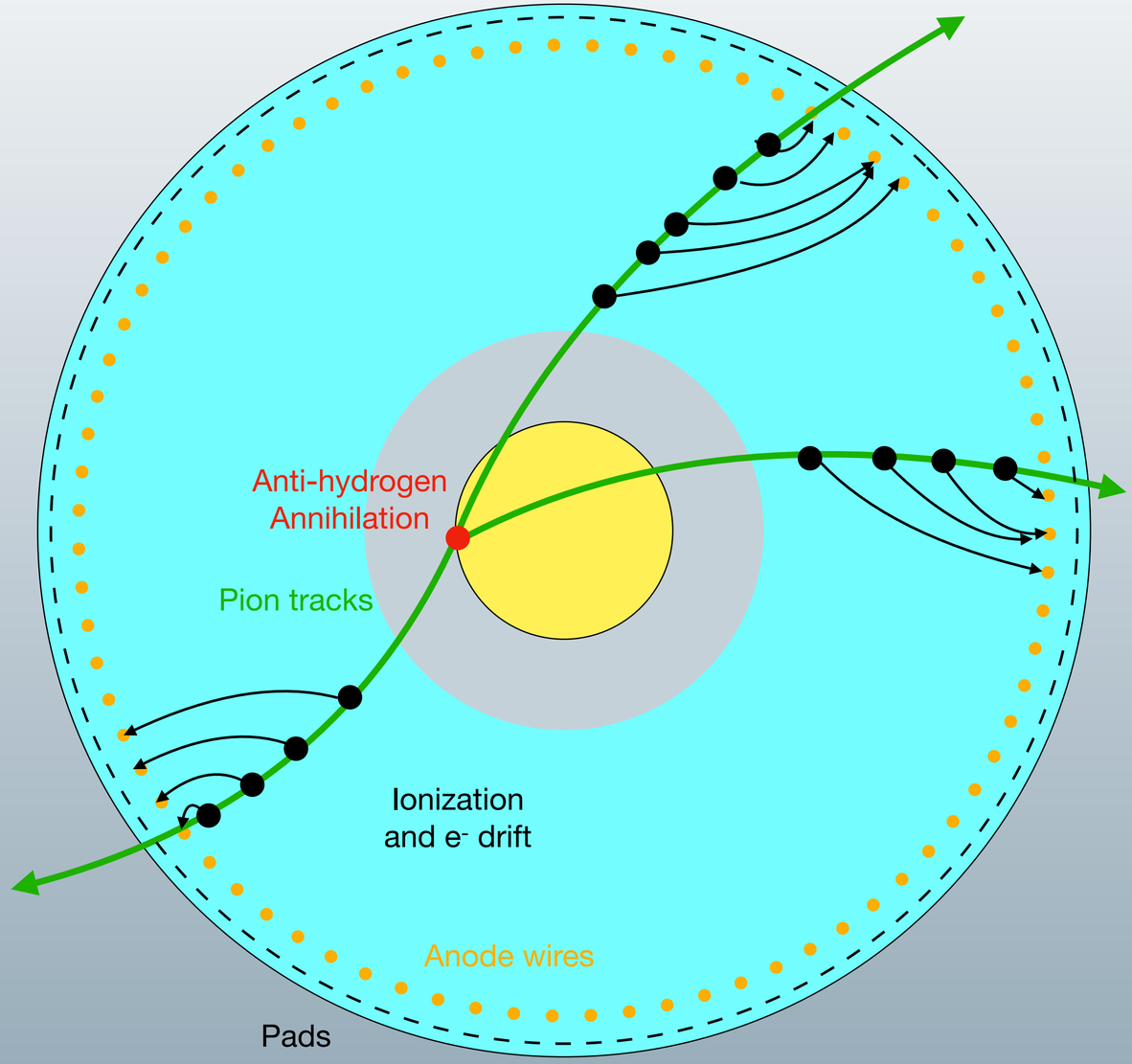
- Anti-hydrogen atoms created and trapped magnetically in ALPHA-g, then released.
- During release, gravitational force is counterbalanced by precise magnetic forces.
- When 50% of atoms go up and 50% fall down, $\bar{g}$ is properly counterbalanced!
- Magnetic fields must be very well known
  → see Adam Powell, next talk!
- Annihilation locations measured using detector.





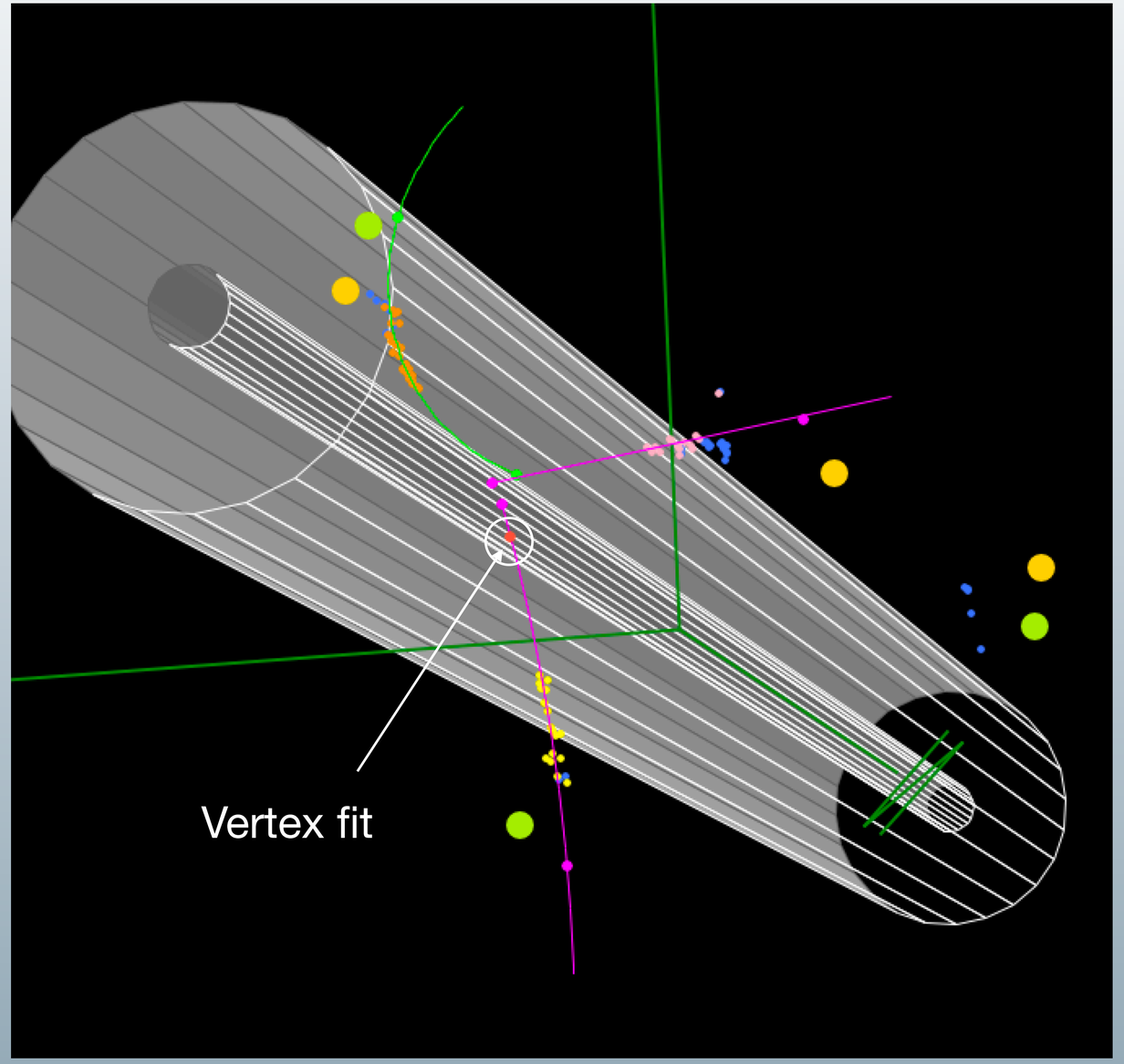
Annihilation Detection

- Pions produced in annihilations are tracked using a time projection chamber (TPC).
- Ionization electrons collected by anode wires and charge collecting pads.
- Three-dimensional position of charge depositions found using:
  → Wire position
  → Pad position
  → Drift time



Annihilation Reconstruction

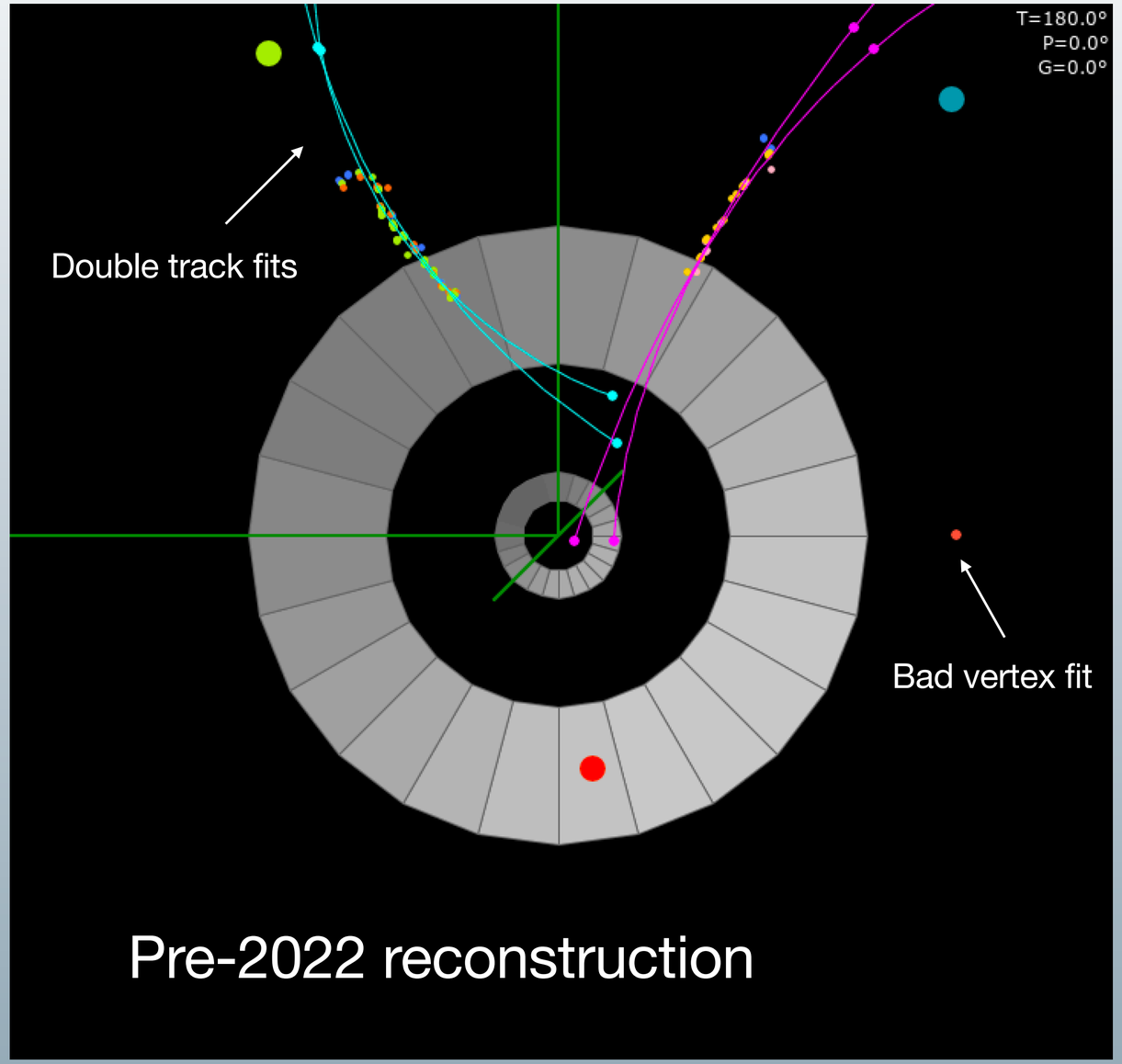
- Wire signals are deconvoluted to find e- arrival times.
- Wire signals are matched to pad signals and “time-projected” to generate ***spacepoints***.
- Spacepoints are grouped together by proximity into ***tracks***.
- Tracks are fit with ***helices***.
- Helix intersection is fit to find a ***vertex***.



My Reconstruction Contributions

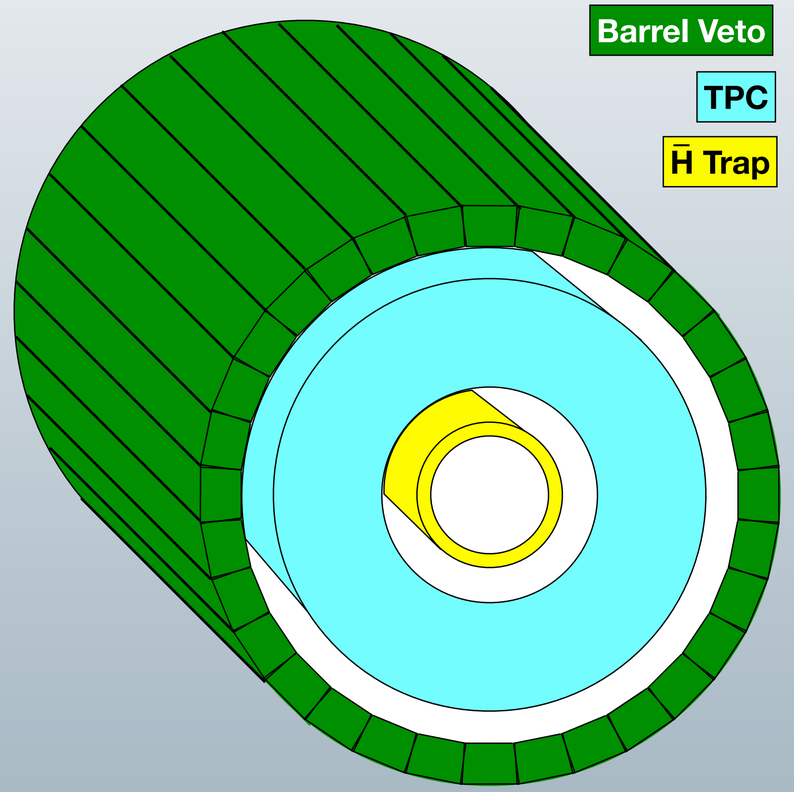
- **Track finding**: New algorithm
- **Track fitting**: Bug fixes and tuning
- **Vertex fitting**: Increased reliance on best 2-3 tracks

- **Results**: Vertex Z resolution improved from 80 mm → <40 mm, further improved by others



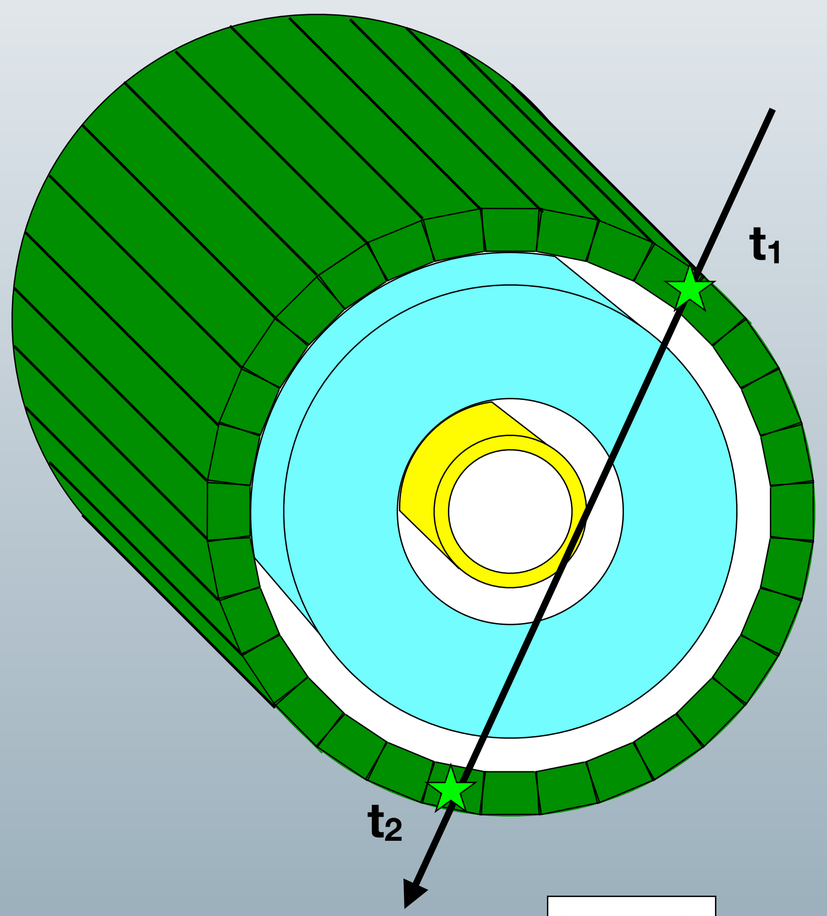
Barrel Veto (BV) Detector

- After 4 hours of trapping, ~100 anti-atoms trapped.
- Cosmic rays produce a background of 70 Hz.
- Anti-atom release ~20 seconds
  → 1400 background events!
- Barrel Veto = a second detector enclosing the TPC.
- 64 bars of plastic scintillator.
- Scintillation light collected at both ends by SiPMs.



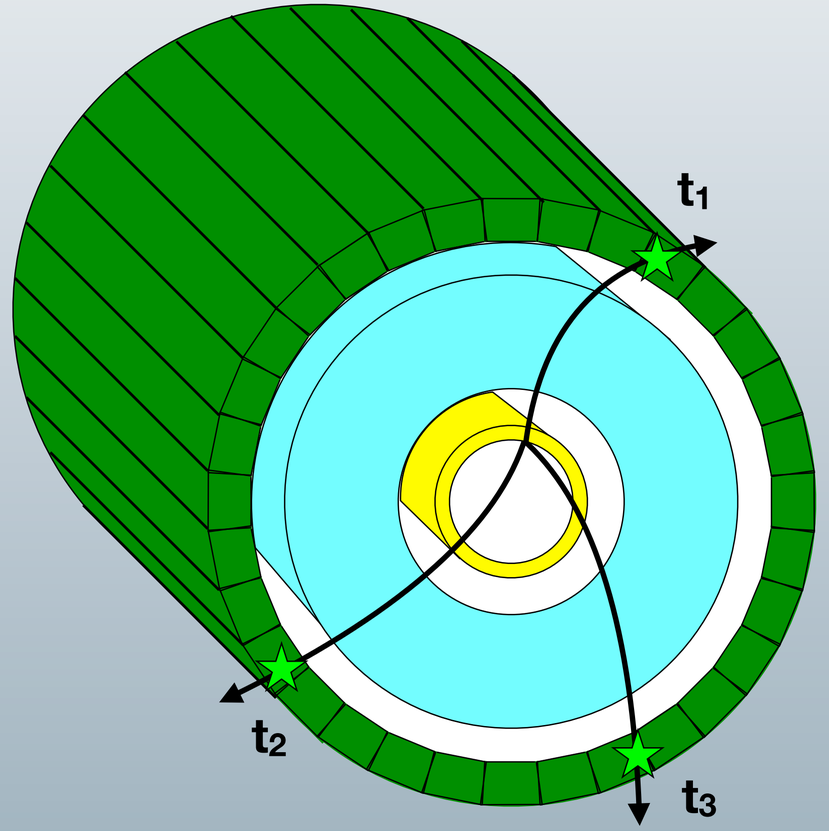
Time-of-Flight Background Rejection

Case 1: Cosmic ray



$t_1 << t_2$

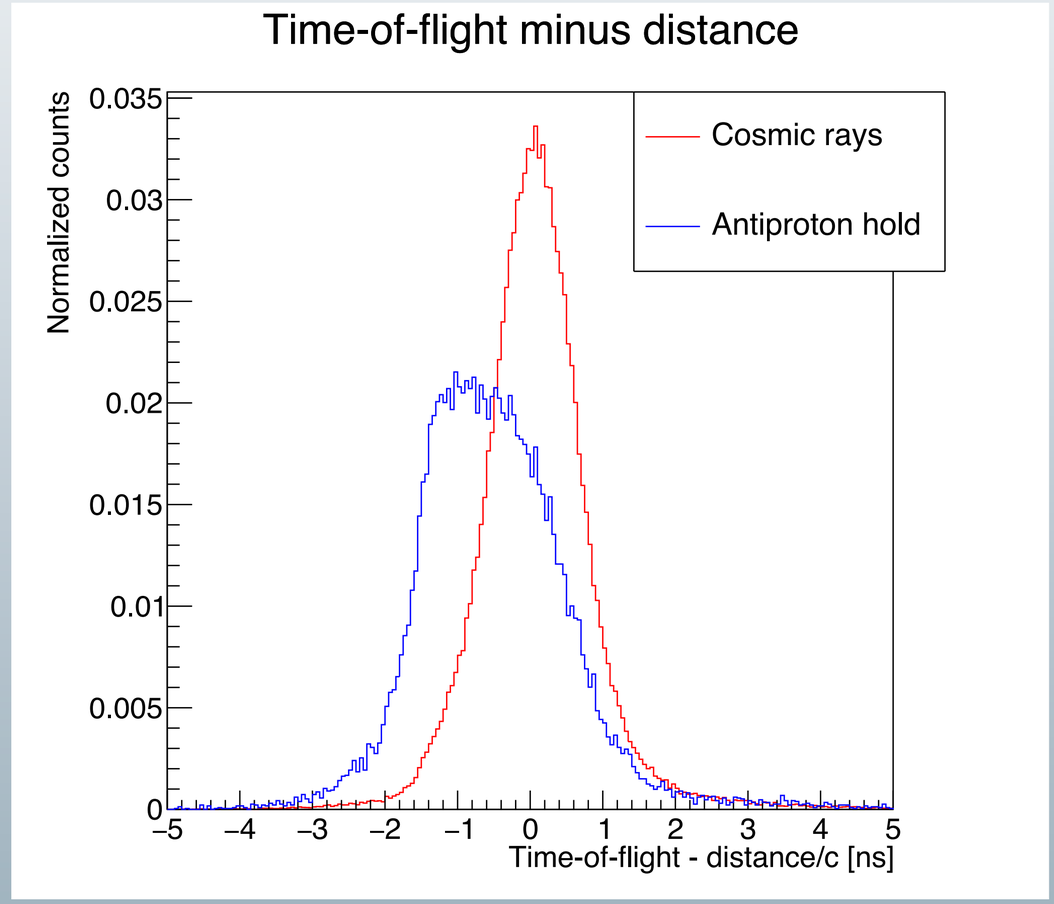
Case 2: $\bar{H}$ annihilation



$t_1 \sim t_2 \sim t_3$

Time-of-Flight – Ongoing!

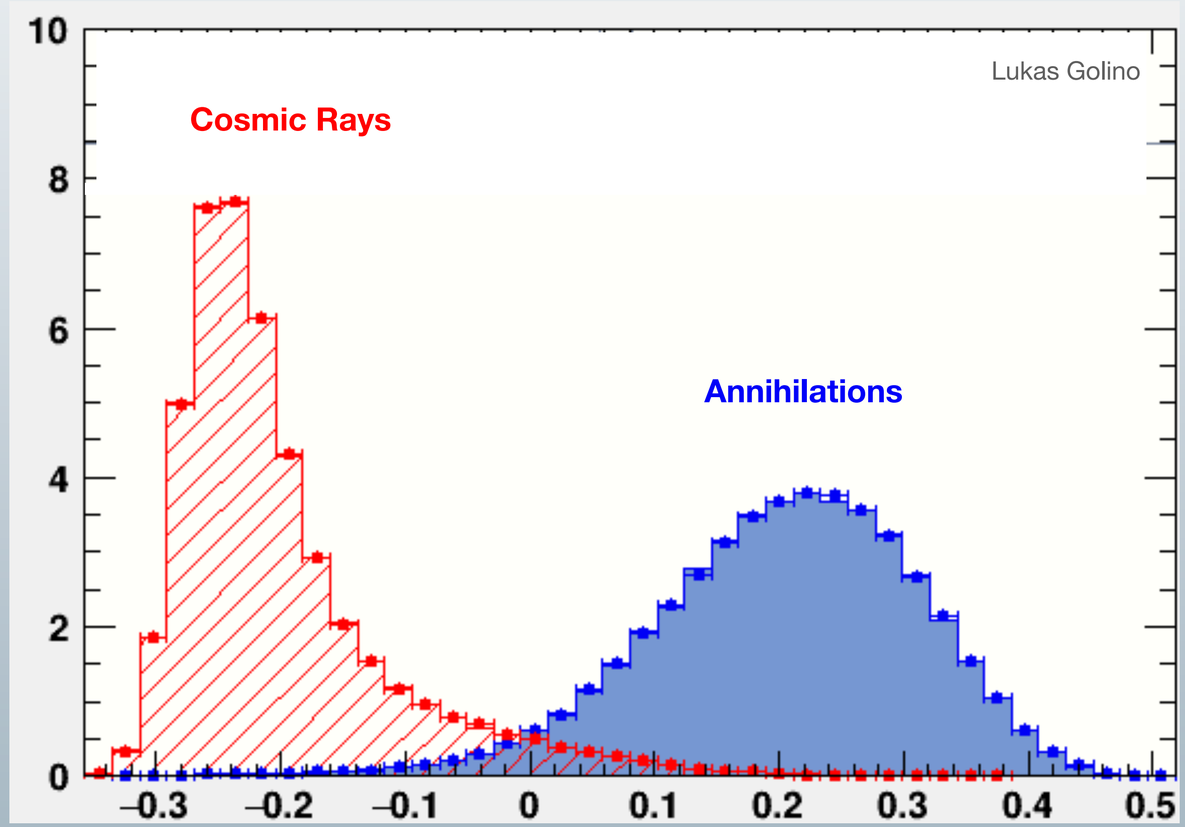
- Time-of-flight based background rejection requires <200 ps time resolution.
- This was achieved in a small-scale test setup but not yet in the BV.
- Work ongoing to calibrate and quantify some huge time corrections:
  → Each channel has a characteristic delay (~5 ns).
  → “Time walk” correction for pulse amplitude (~5 ns).



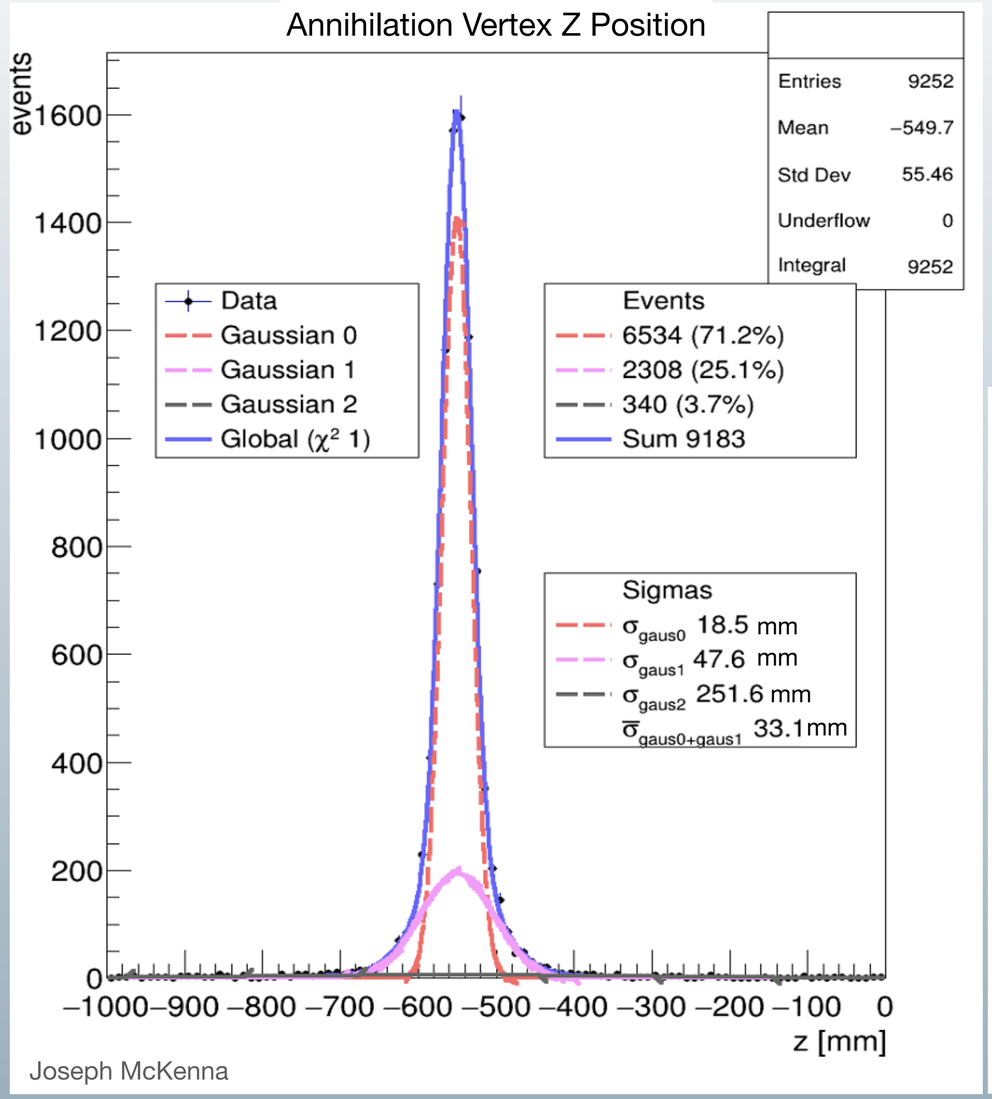
Current Background Rejection

Two methods currently in use:

1. A cut based on BV event topology.
   - Group hits on adjacent bars into clusters.
   - Events with <=3 clusters → background
   - Events with >=4 clusters → signal
2. Machine learning!



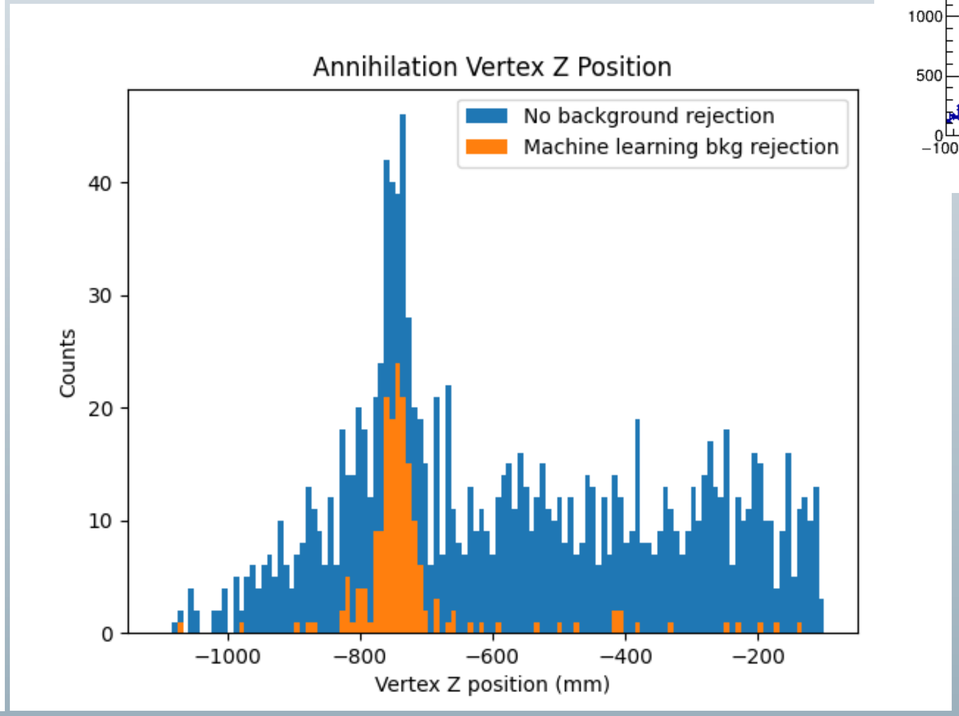
Antimatter Signal in ALPHA-g

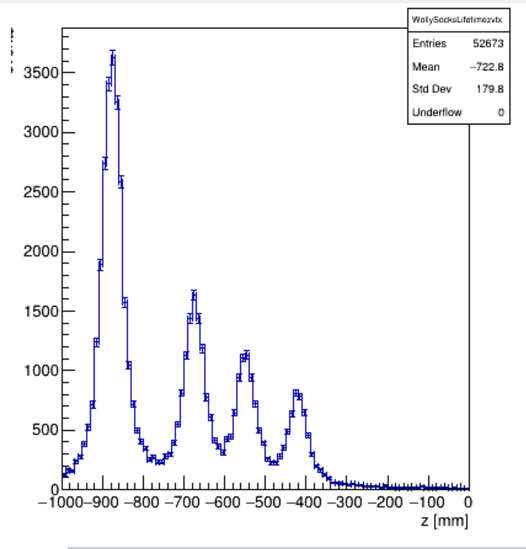


Joseph McKenna

Antiprotons held in one location ←

Antiprotons held in four locations! →





Commissioning antihydrogen release ←

Outlook

- First ALPHA-g run completed 2022.
- Our detectors were able to determine annihilation positions with greater precision than necessary for the first gravity measurement!
- Background rejection based on BV event topology worked well
  → room for improvement with time-of-flight

- Thank you for listening!