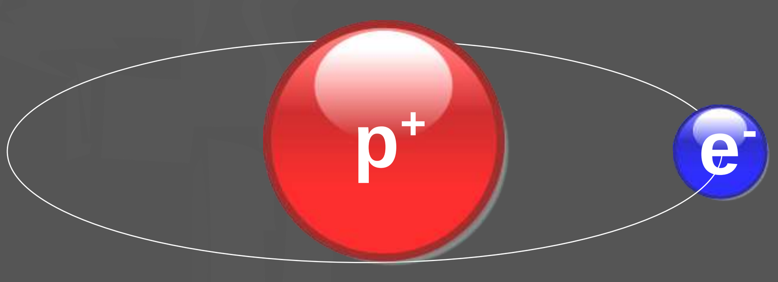
Antihydrogen identification with Silicon Vertex Detector in the ALPHA experiment

J. T. K. McKenna[1], P. Pusa[1], D. Wells[1], D. Seddon[1], J. Thornhill[1], J. Sampson[1], P. Nolan[1] and the ALPHA collaboration[2]

[1] Department of Physics, The University of Liverpool, Liverpool, L69 7ZE, United Kingdom

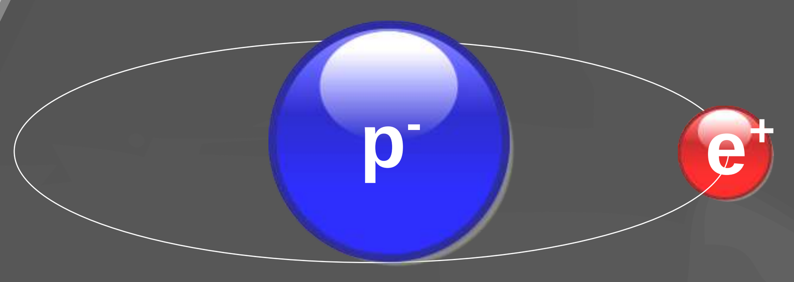
[2] CERN CH-1211, Genève 23, Switzerland

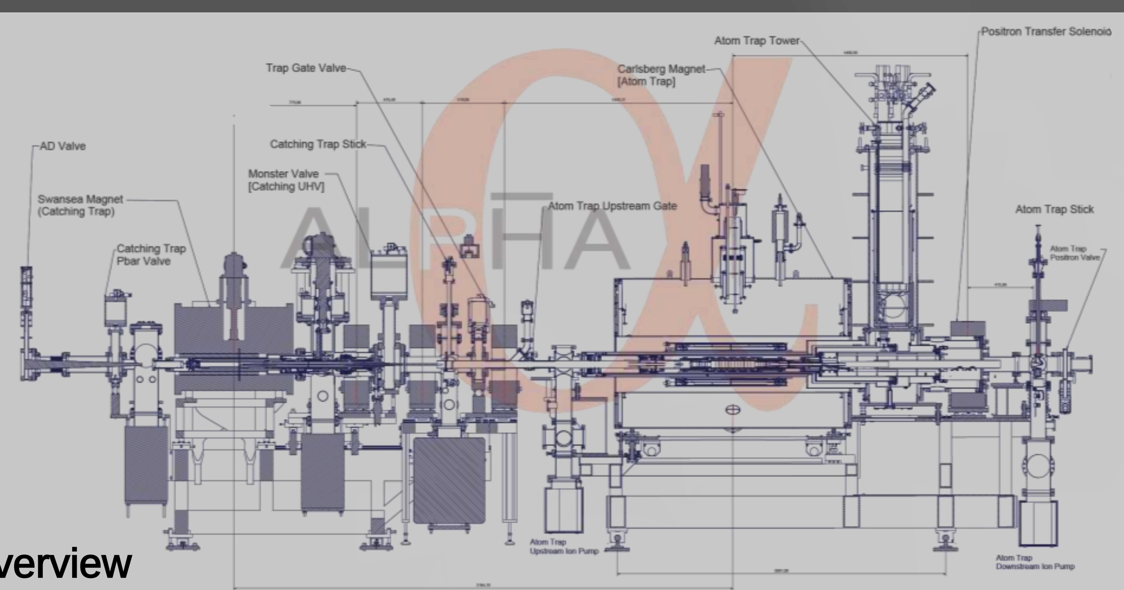
jtkm@ns.ph.liv.ac.uk



The aim of the ALPHA experiment at CERN is to trap cold atomic antihydrogen, study its properties and ultimately to perform precision comparison between the hydrogen and antihydrogen atomic spectra. Recently the collaboration has reached important milestones beginning with demonstrating the ability to trap and confine neutral cold antihydrogen [1][2], performing the first spectroscopic measurements of antihydrogen [3] and of late through demonstrations of the first application of a new technique to measure the gravitational mass of antihydrogen [4].

A Silicon Vertex Detector (SVD) is the principal diagnostic tool for antihydrogen detection [5-6]. This poster describes the role of the detector in the experiment.





Experimental Overview

The main components of the ALPHA experiment are the positron accumulator, anti-proton beam, catching trap and neutral atom trap, the later two being recently upgraded. The experiment has many diagnostic tools of which the ALPHA Silicon Vertex detector has a central role.

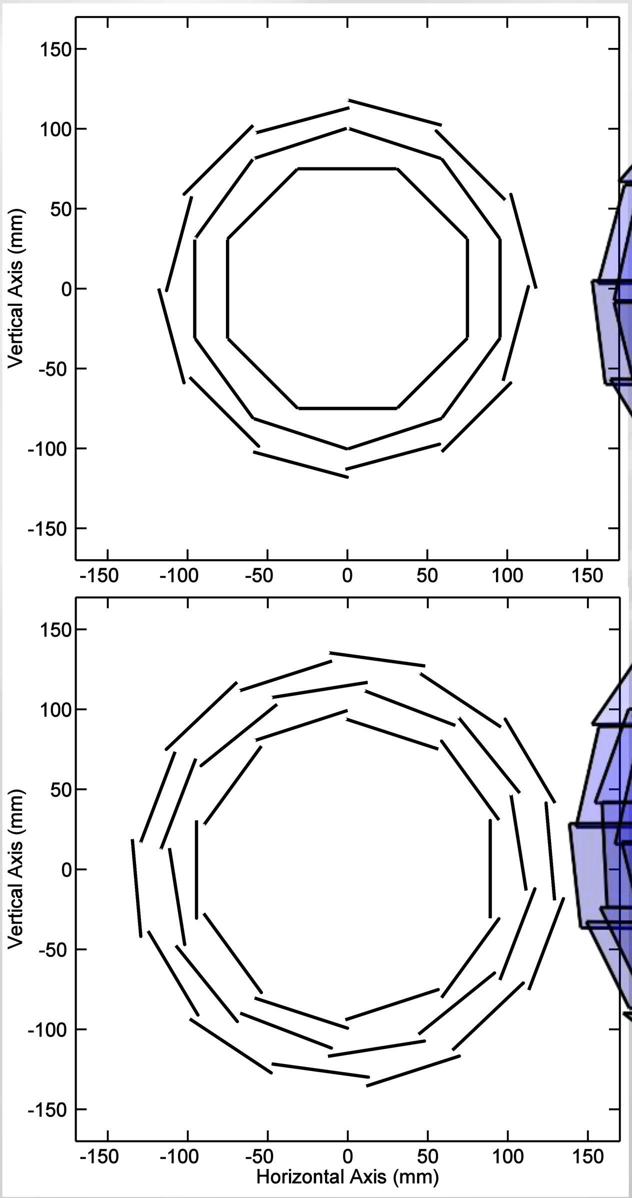
The detector is designed to surround the ALPHA neutral atom trap with the purpose of monitoring single annihilation events and collective antiproton plasma behaviour.

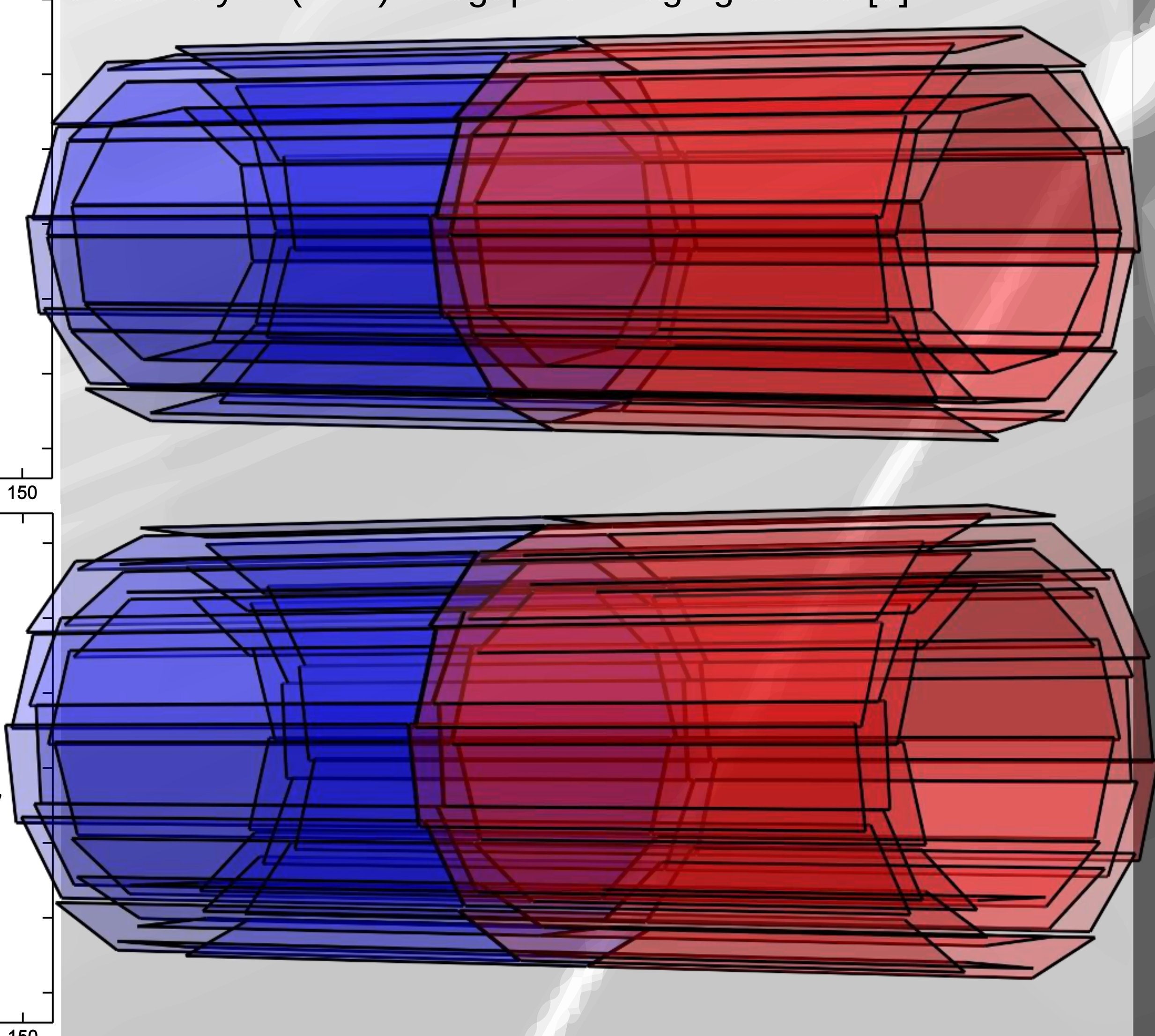
The neutral atom trap and trapping apparatus consists of nested Penning-Malmberg and Ioffe-Pritchard type traps.

The charged particle plasmas are controlled by the Penning-Malmberg trap, whereas the produced cold antihydrogen atoms are confined by the Ioffe-Pritchard neutral trap. The neutral trap depth in terms of temperature is about 0.5K which means the captured antihydrogen is recorded instantly by the SVD on the trap walls annihilations above the trap depth and below only by interactions with the vacuum residual gas.

Silicon Vertex Detector Geometry

The ALPHA Silicon Vertex Detector is made of three concentric barrels of 60 (more recently upgraded to 72) silicon hybrid modules, set in two opposite halves. Each hybrid consists of two 128x256 doubled sided silicon strip detectors connected to four onboard readout ASICS. All together the detector has 30720 (36864) readout channels forming effectively 4 (4.7) megapixel imaging device [5].





The representations of the original detector geometry from ALPHA (top) and the upgraded detector (bottom) are shown, with the two identical halves rendered in blue and red respectively to distinguish them.

The larger radius of the upgraded detector is to allow for the installation of additional experimental apparatus. The solid angle of the upgraded detector has improved from 72% to 77% at the centre of the trap thanks to more staggering in the layers

The spatial reconstruction resolution for the SVD is 6mm by experimental annihilation hot spot analysis with a 64% reconstruction efficiency. The upgraded detector is expected to have a reconstruction resolution of 8.5mm and 71% reconstruction efficiency from Monte Carlo simulation, though this awaits verification.

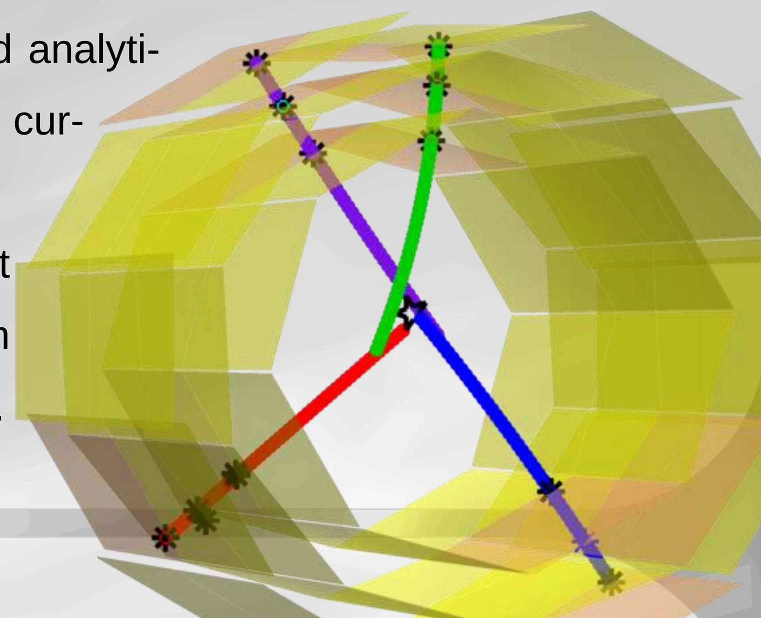
Reconstruction methodology

Upon the antiproton annihilation, on average three high energy charged pions are emitted. The pions penetrate through the apparatus depositing a small amount of energy in the silicon sensors.

These interactions are recorded, and the data is then used to reconstruct the annihilation vertex by using the track helices.

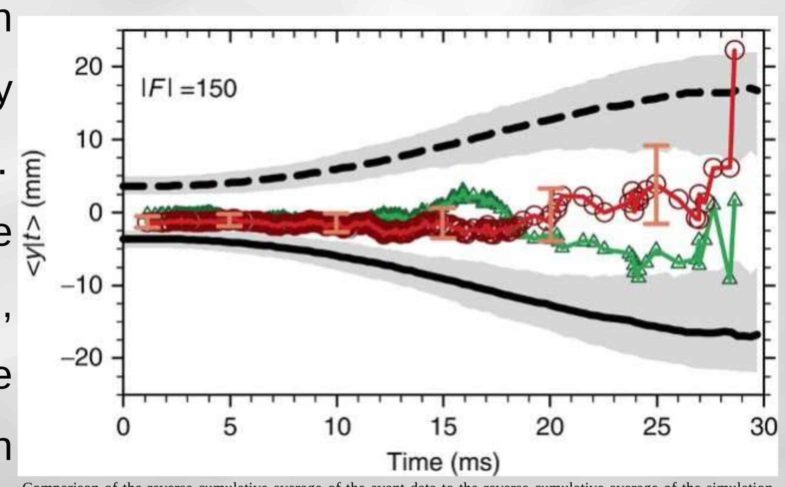
The detector is also sensitive to cosmic events, these have different characteristics from annihilation events and can be removed analytically. Cosmic rate of annihilation mimicking events is currently suppressed to a level of 47mHz.

Shown inset is an example of a reconstructed event with four vertices, effective detector area is shown in yellow with activated silicon modules shown in orange.



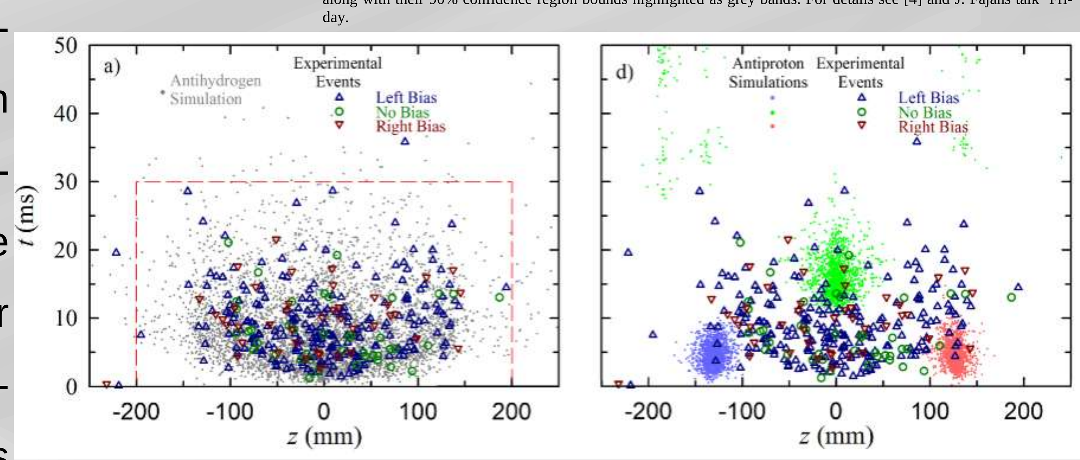
Position sensitivity

Sensitivity to single annihilation events and position sensitivity of the detector have led to the possibility of making several measurements on anti-hydrogen. Sensitivity to single annihilation events proved to be invaluable during the trapping of antihydrogen [1-2], and analysing further measurements including the first microwave spectroscopy of antihydrogen in 2012 [3] as presented by M. Hayden.



Comparison of the reverse cumulative average of the event data to the reverse cumulative average of the simulation data. The red-circle line is the reverse cumulative average y annihilation positions of the event data, the green-triangle line is the reverse cumulative average of the x annihilation positions of the event data.
For comparison, the black line, and black dashed line represent simulated data for F=150 and F=-150 respectively, along with their 90% confidence region bounds highlighted as grey bands. For details see [4] and J. Fajans talk Friday.

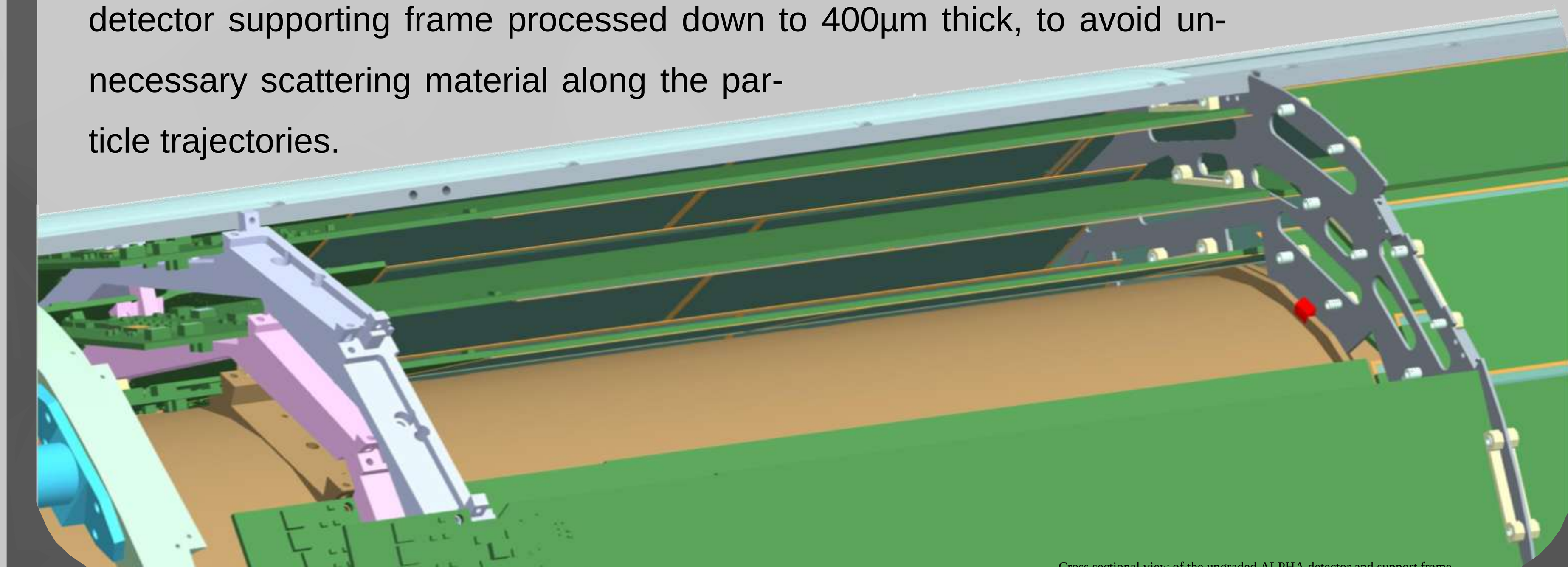
The position sensitivity of the detector was also vitally important in verification that neutral-antihydrogen was trapped in the neutral trap rather than mirror trapped anti-protons [6]. The position sensitivity of the detector was also used to study the gravitational effect on antihydrogen with the demonstration of a new method of measuring inertial mass which will be presented in detail on by J. Fajans on Friday.



Plots showing space and time locations of the annihilations from trapping events (triangles and circles), and the annihilation coordinates predicted by the antihydrogen (small gray dots on left) and anti-protons (colour coded dots on right). The colours correspond to an electric bias places across the trap of the experiment during trapping

Structure, support structure and cooling

The ALPHA Silicon Vertex Detector operates in atmospheric pressure at a temperature of about 15°C. The cooling is provided by vortex tube provided with dried, filtered air. The operating reverse bias voltage of the fully depleted silicon sensors kept at 65V. The mount is constructed to be as lightweight as possible, by using aluminium alloy in the inner bore of the detector supporting frame processed down to 400µm thick, to avoid unnecessary scattering material along the particle trajectories.



Cross sectional view of the upgraded ALPHA detector and support frame

References

[1] G. B. Andresen et al, Nature, 468, 673 (2010)
[2] G. B. Andresen et al, Nature Physics, 7, 558 (2011)
[3] C. Amole et al, Nature, 483, 439 (2012)
[4] A. E. Charman et al, Nature Communications, 4, 1785 (2013)
[5] G. B. Andresen et al, JINST, 7, C01051 (2012)
[6] C. Amole et al, New Journal of Physics, 14, 105010 (2012)