



Hyperfine Structure of Antihydrogen

ERC Advanced Grant

PI: Prof. Dr. Eberhard Widmann

A detector for in-beam measurement of the ground state hyperfine splitting of antihydrogen

Clemens Sauerzopf¹ Aaron Allan Capon¹ Martin Diermaier¹
Bernadette Kolbinger¹ Chloé Malbrunot^{1,2} Oswald Massiczek¹
Martin Simon¹ Stefan Vamosi¹ Johann Zmeskal¹ Eberhard Widmann¹

¹ *Stefan Meyer Institute for subatomic physics, Austrian Academy of Sciences*

² *Organisation Européenne pour la Recherche Nucléaire (CERN)*

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ÖAW

ÖSTERREICHISCHE
AKADEMIE DER
WISSENSCHAFTEN



DOKTORATSKOLLEG PI

$\int dk \Pi$
Particles and Interactions

FWF

Der Wissenschaftsfonds.



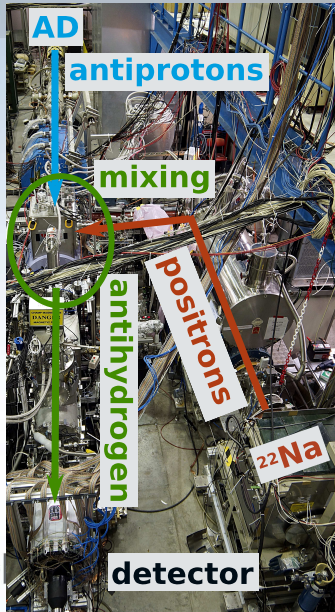
Outline

Introduction

Concept and Design

Summary and Outlook

Introduction

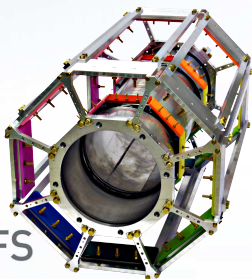
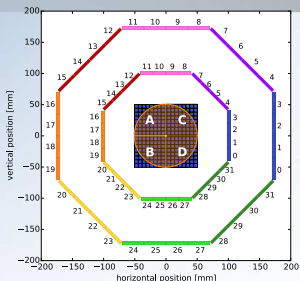


- ▶ Slow antiprotons from Antiproton Decelerator (AD) + Radio Frequency Quadrupole Decelerator (RFQD)
- ▶ Positrons from ^{22}Na source
- ▶ $\bar{\text{H}}$ is formed from p- and e+ within the CUSP trap (mixing)
- ▶ Neutral $\bar{\text{H}}$ Anti-Atoms can leave the trap
- ▶ $\bar{\text{H}}$ s reach the detector for counting

Detector requirements

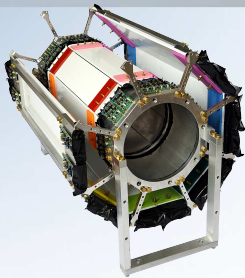
- ▶ high efficiency for annihilation detection
- ▶ good background suppression (1-2 orders of magnitude more background than signal)
- ▶ easily removable and installable
- ▶ beam diagnosis and spectroscopy
- ▶ low electronic noise pickup
- ▶ compact (limited space in experimental area)

Detector concept



- ▶ central detector unit
 - ▶ single BGO disc (10cm diameter, 5mm thick)
 - ▶ 4 H8500 multi anode PMTs (4x8x8 channels)
 - ▶ readout: Clearpulse CP80057 VME module
- ▶ 2 layered hodoscope
 - ▶ 1mm stainless steel pipe for support
 - ▶ colour coded removable panels
 - ▶ 32 scintillator bars per layer

Two layer hodoscope



- ▶ individual bars wrapped with aluminium foil
- ▶ outer wrapping: light tight white foil (3 layer composite material)
- ▶ SiPMs glued on both sides of each bar

Hodoscope:

outer layer

inner layer

SiPM electronics

BGO detector

H beam

double sided readout

350 mm

606 mm

Materials and Design

- ▶ scintillator material: EJ-200 (distributor: G-Tech)
- ▶ 32 inner bars: $300 \times 30 \times 5 \text{ mm}^3$
- ▶ 32 outer bars: $450 \times 35 \times 5 \text{ mm}^3$
- ▶ light guides reducing scintillator surface down to $10 \times 5 \text{ mm}^2$
- ▶ plastic spacers for support and stability



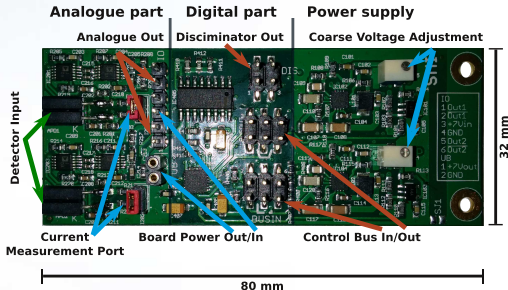
Readout

- ▶ 256 SiPMs: KETEK PM3350TS ($3 \times 3 \text{ mm}^2$ active area, $50 \times 50 \mu\text{m}^2$ micropixel size)
- ▶ two SiPMs in serial connection per side of each bar
- ▶ novel readout electronics providing - Intelligent Frontend Electronics for Silicon photo detectors (IFES)



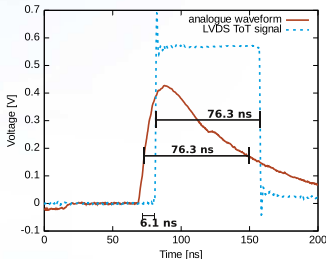
IFES part 1/2

- ▶ differential SiPM readout, allowing 50cm cable length without disturbing the leading edge, with 10m signal still detectable
- ▶ differential, balanced analogue output
- ▶ LVDS discriminator output
- ▶ LVDS control bus (SPI, controlled via an Arduino), remote control of bias voltage ($<90V$) and discriminator threshold

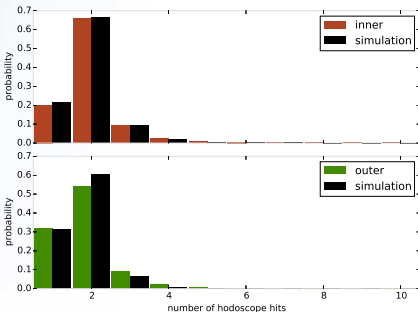
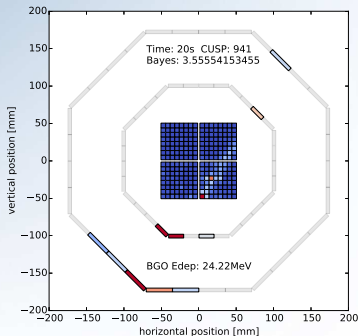


IFES part 2/2

- ▶ time over threshold discriminator output
- ▶ Differential amplifier with 2.2 GHz -3dB bandwidth, slew rate 13 kV/ μ s, noise: 2.7 nV/ $\sqrt{\text{Hz}}$ (AD8351)
- ▶ Bias supply: boost converter LT3482
- ▶ 12 bit DAC for remote control (MAX5135)



Performance during beamtime 2015



- ▶ data in good agreement with Geant4 simulations
- ▶ timing performance not fully optimised \Rightarrow further optimisations at SMI


Summary

- ▶ A detector for antihydrogen annihilations was developed.
- ▶ Key features are: compact design, easily transportable, two layers, and two-sided readout for each scintillator.
- ▶ New all-in-one SiPM electronics including bias supply, time over threshold discriminator and analogue amplifier were developed.
- ▶ Detector data is consistent with Geant4 simulation.

Outlook



- ▶ detector refurbishment in process (light tightness)
 - ▶ new improved IFES modules developed (16 channels per module, sturdier connectors)
 - ▶ timing improvement by new wrapping. Preliminary timing < 600 ps FWHM.
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- ▶ preparation for beamtime 2016 (April)



Thank you for your attention!