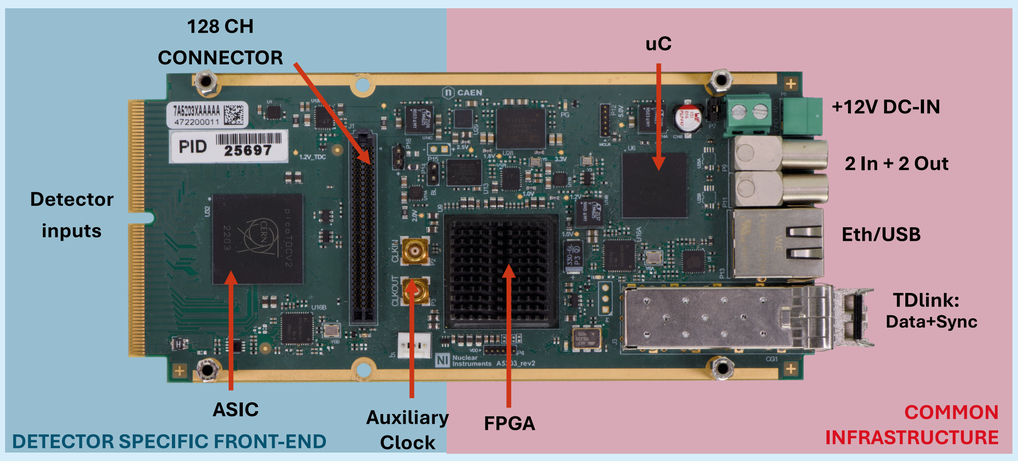
Picosecond timing performances of the FERS time unit

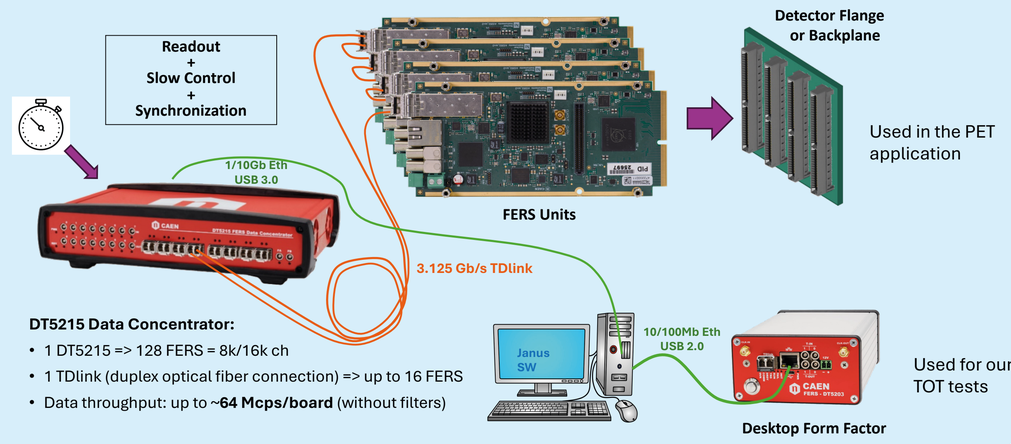
F. Giordano[1*], C. Maggio[1], T. Williams[2]

TWEPP 2024, 30th September – 4th Oct 2024, Glasgow - Scotland (UK)

High-precision time measurements are the latest trend for experiments and PET applications. Compactness, scalability and applicability to thousands of channels is required for the readout electronics. CAEN A5203 board, part of a synchronizable and distributable Front-End Readout System (FERS), integrates the CERN picoTDC ASIC on a small unit for high-resolution time measurements of ToA and ToT. This poster presents the performance of the A5203 unit, in terms of time resolution, walk correction, background reduction and signal amplitude reconstruction. The results of its application to the Picotech PET system are also included.

FERS Architecture



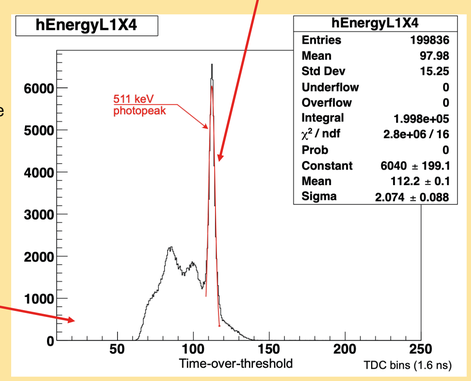


ProVision PET Scanner

ProVision PET Scanner is specialized in imaging aggressive prostate cancer at an early-stage, it is high precision compact machine with reduced dose exposure constituted of two planar detectors that are placed on either side of the lying patient.

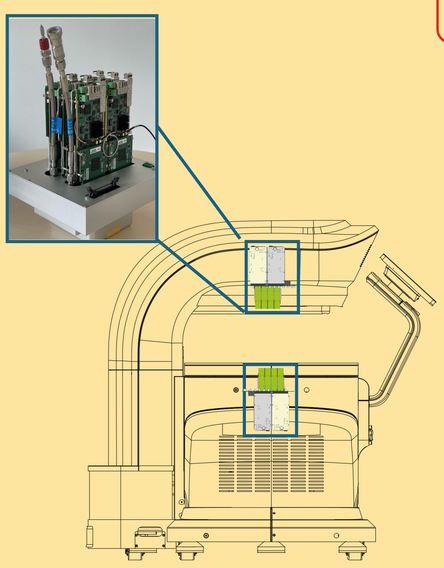
- 2x768 SiPM channels
- 2x6 A5203Bs (128 ch TDC)
- 1 DT5215 Concentrator
- Precise timing and TOT measurement
- High throughput – almost zero deadtime
- ToT cut for Dark Count and noise suppression
- Coincidence Time Resolution 170ps

Amplitude reconstruction

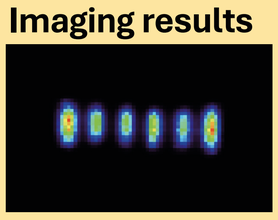


hEnergyL1X4	
Entries	199836
Mean	97.98
Std Dev	15.25
Underflow	0
Overflow	0
Integral	1.998e+05
χ^2 / ndf	2.8e+06 / 16
Prob	0
Constant	6040 ± 199.1
Mean	112.2 ± 0.1
Sigma	2.074 ± 0.088

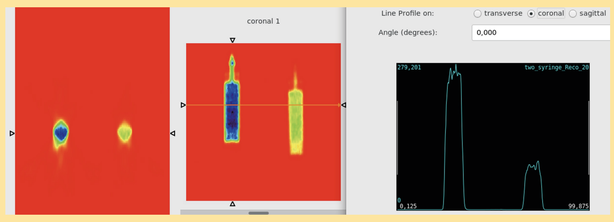
'Empty' region thanks to TOT filter



Imaging results



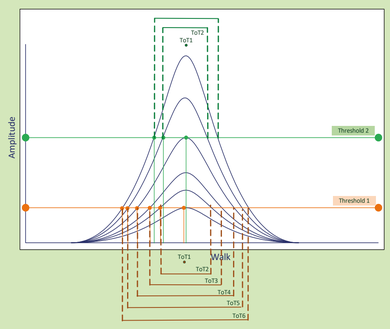
4mm thick Sodium disks separated by 4mm gaps



Transverse view, coronal view and line profile of 2 syringes filled with FDG radiotracer, with activities at 3:1 ratio

A5203 Time Measurements

Pros	Cons
• high timing resolution (~ 5 ps), high channel density, almost no dead time • provides ToA and ToT in one word	• ToA affected by walk effect • No energy information (PHA) acquired -> need for a separate ADC readout chain



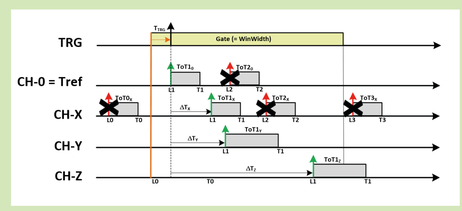
-> ToT-Based Analysis: Walk correction and PHA

- **ToT** can be used **to correct for time walk** => no need of Constant Fraction Discriminator in hardware
- **ToT** can be used **to reconstruct pulse amplitude**: ToT – PHA curve is not linear => need calibration (pulse shape dependent)
- **FPGA ToT filter**: rejects pulses if **ToT < LowCut** or **ToT > HighCut** (remove noise, DCR, saturation…)

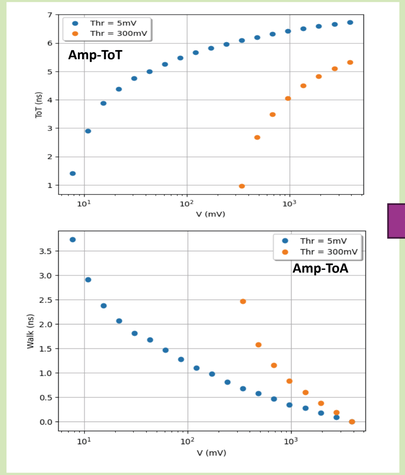
Performance Measurements

Common Start Acquisition: start on Ch0 with fixed amplitude, stop on Ch1 and Ch2 (dual threshold) with variable amplitude (max = 3.85 V). Delay = 13 ns

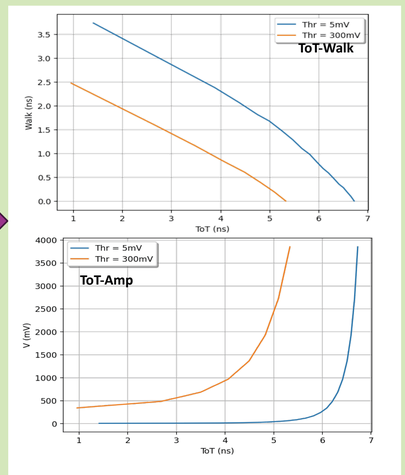
1. Sweep: acquire **ToT** and **ΔT (ToA)** at different amplitudes (from 0 to 54 dB, 3 dB step)
2. Fit points and build **ToT-Walk (ToA)** and **ToT-Ampl** curves
3. Use curves to **correct Walk** from ToT (replace CFD)
4. Use curves to **get Amplitude** from ToT (make ADC from TDC)



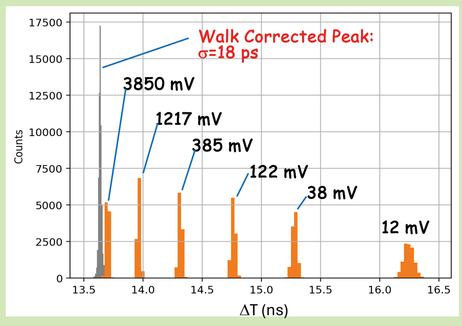
ToT calibration curves (double threshold)



Curve Fit

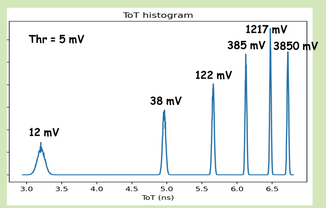


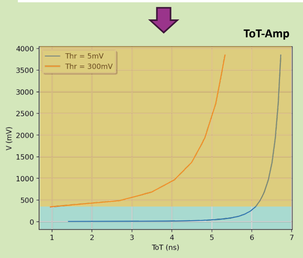
Walk Correction



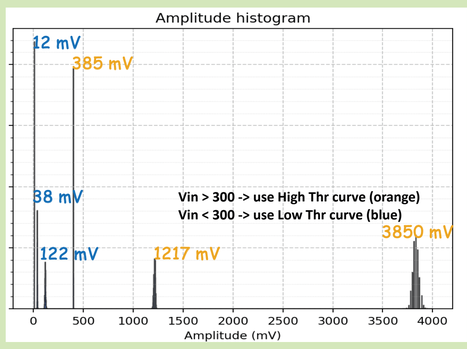
- Pulses at 6 different amplitudes over a 50 dB dynamic range
- ~2 ns spread on ΔT (ToA) caused by the walk effect:
  6 separate peaks !!
  ➔ timing resolution compromized
- ΔT corrected by ToT using a 5th order polynomial fit of the **ToT-Walk** points taken at threshold = 5 mV
- Corrected ΔT histogram presents one single peak:

18 ps RMS over 50 dB dynamic range





Amplitude Reconstruction



[*] f.giordano@caen.it
[1] CAEN S.p.A. – Italy
[2] Picotech - France