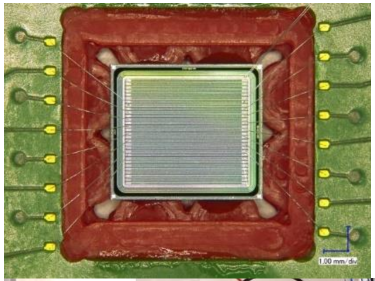
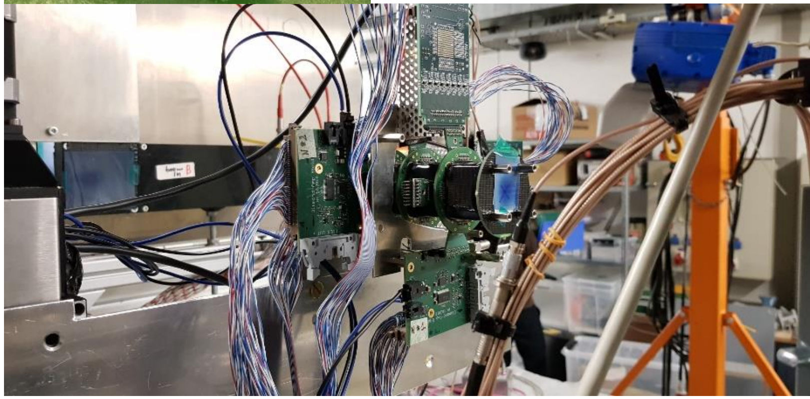
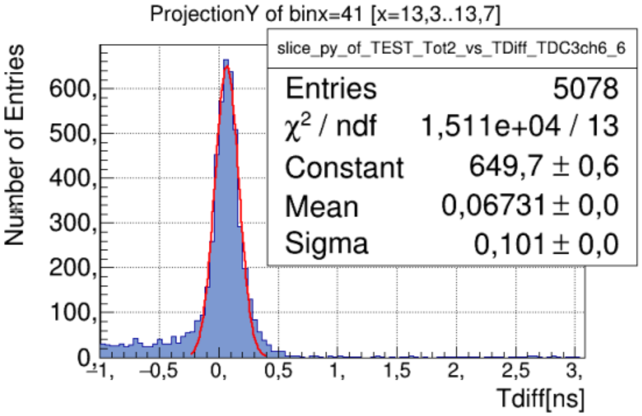
Performance of UFSD for HADES

Test on 04-10 Nov 2019

I) UFSD aka LGAD – operation principle
II) Setup Description Used in at COSY in Jülich
III) Running Conditions
IV) Selected Online Results
V) Sumary & Outlook







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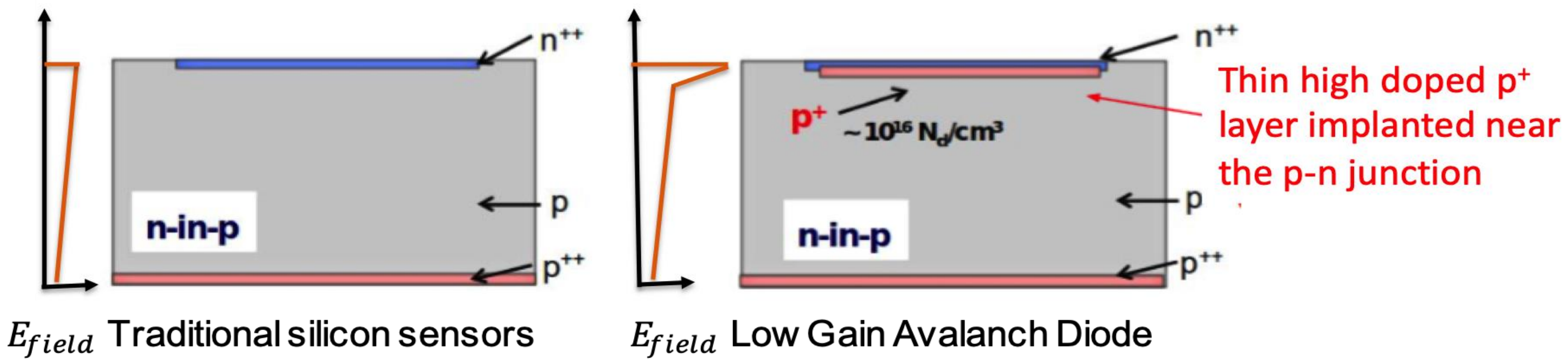
UFSD Principle of Operation

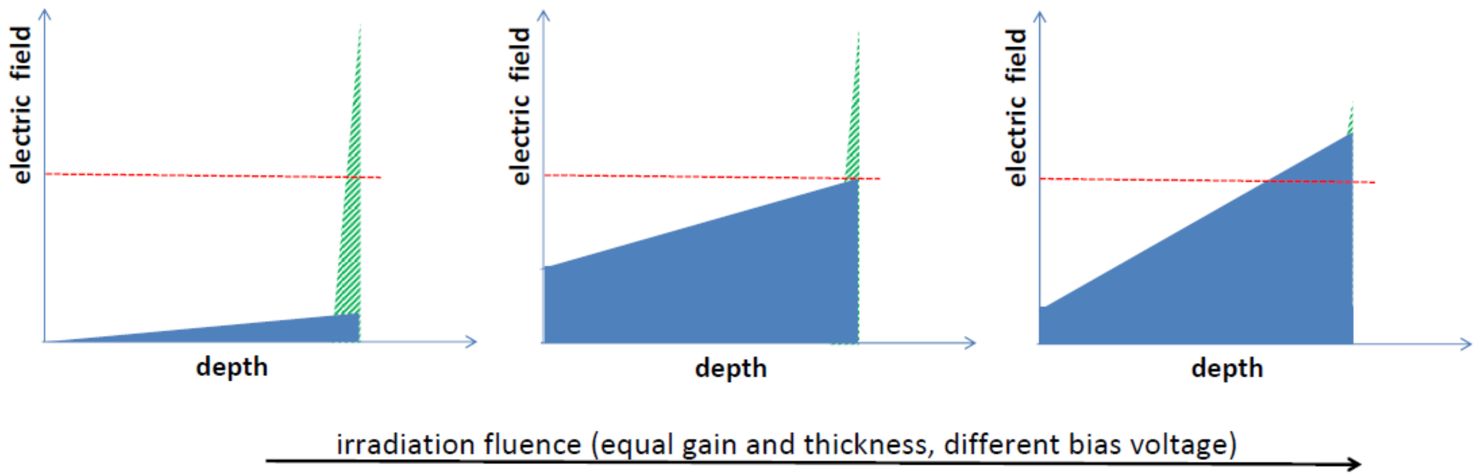
- p+ implant generates a strong electric field near the junction (~300 kV/cm)
- as doping Boron, Galion, Carbon can be used, 10**16/cm3
- amplification up to x20 due to increased electric field
- expected/demonstrated time precision: 30 ps.



Timing layers, 4D- and 5D-tracking, Cartiglia, N. INFN, Torino - Berlin 12/06/18
Design optimization of ultra-fast silicon detectors – Cartiglia, N. et al. Nucl. Instrum. Meth. A796 (2015) 141-148
First FBK production of 50 µm ultra-fast silicon detectors – V. Sola et al. Nucl. Instrum. Meth. A924 (2019)
Beam test results of a 16 ps timing system based on UFSD - Cartiglia, N. et al. Nucl.Instrum.Meth. A850 (2017) 83-88

UFSD Radiation Hardness

- At very high fluences the concentration of acceptors in the p+ implant becomes greatly reduced
- Irradiation creates acceptors in the bulk material which are used for multiplication inside the sensor
- The multiplication taking place in the bulk material shows faster induced current rise -> even better timing !
- The overall gain can be controlled by the bias voltage
- Expected time precision: 30 ps up to $6x10^{15}$ cm^{-2}

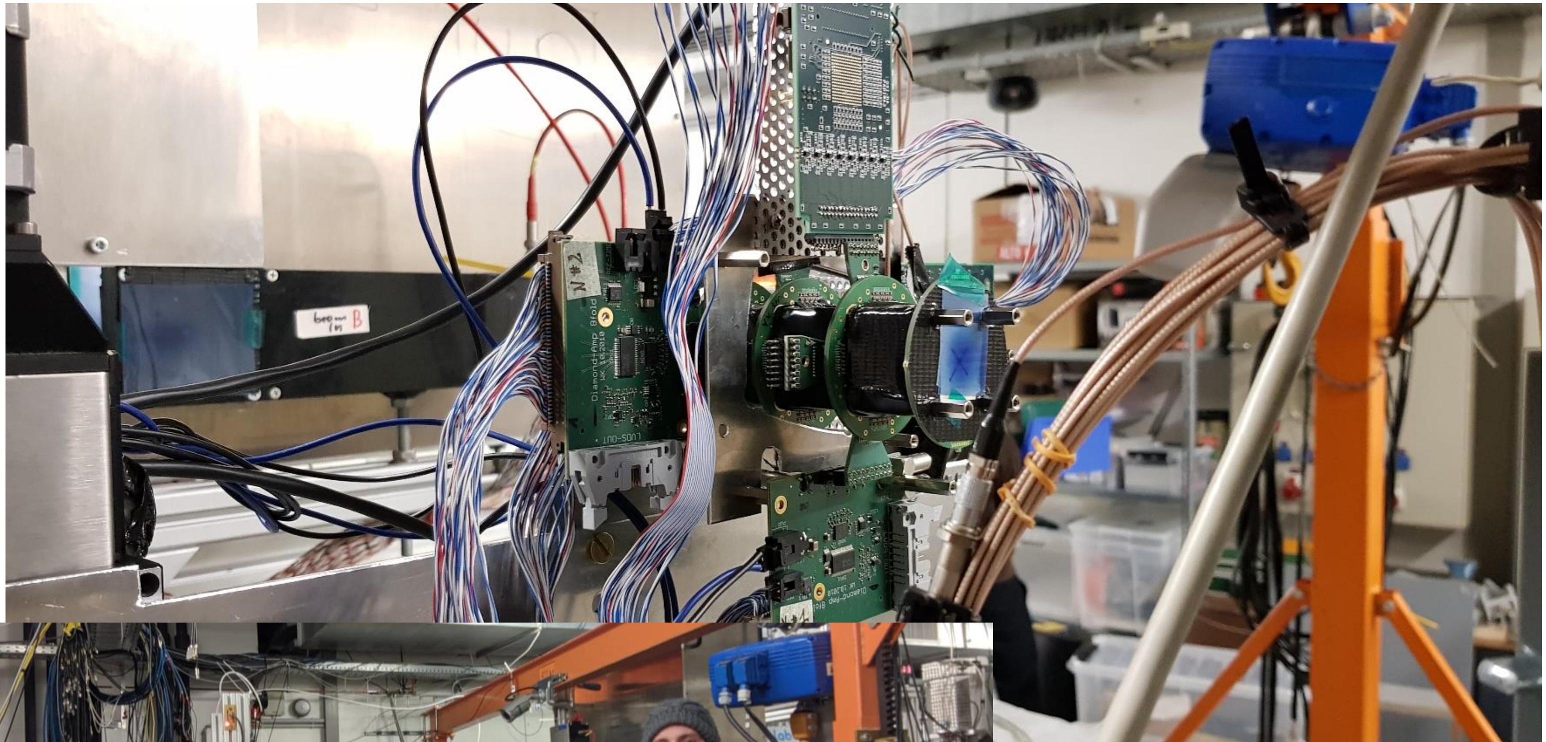


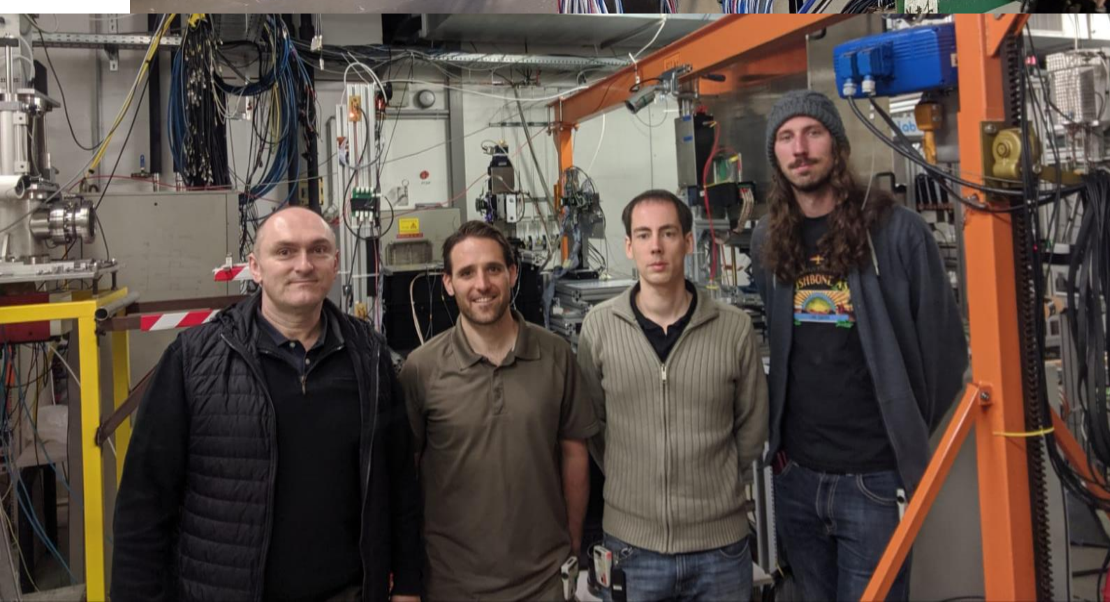
Radiation Hardness of Thin Low Gain Avalanche Detectors - Kramberger, G. et al. Nucl. Instrum. Meth. A891 (2018) 68-77

Performance of UFSD for HADES

Setup: 2 UFSD sensors, each connected to NINO and Padiwa boards

Beam: p@1.92 GeV kinetic energy from COSY

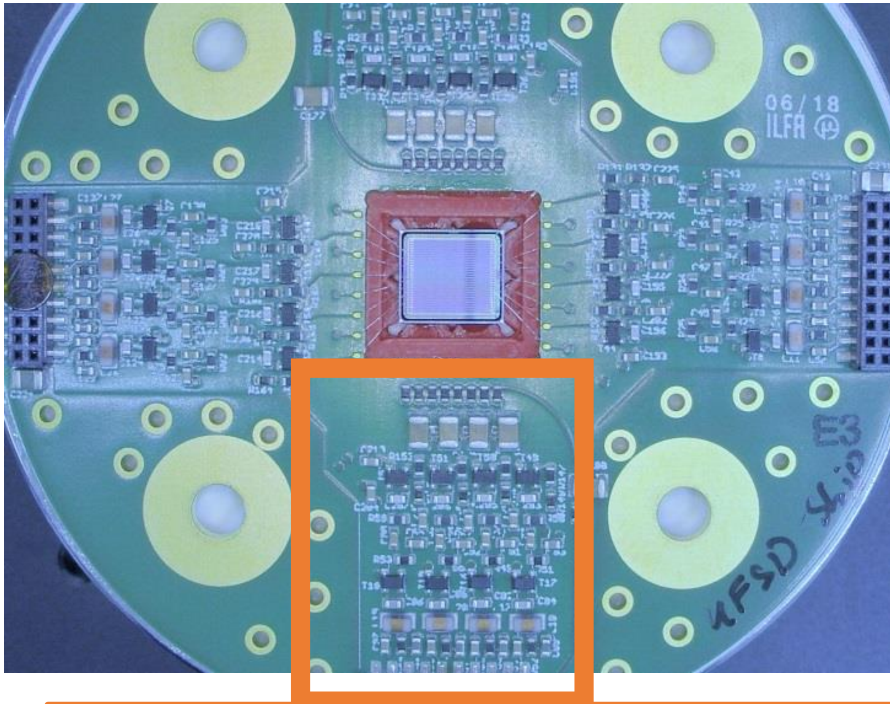


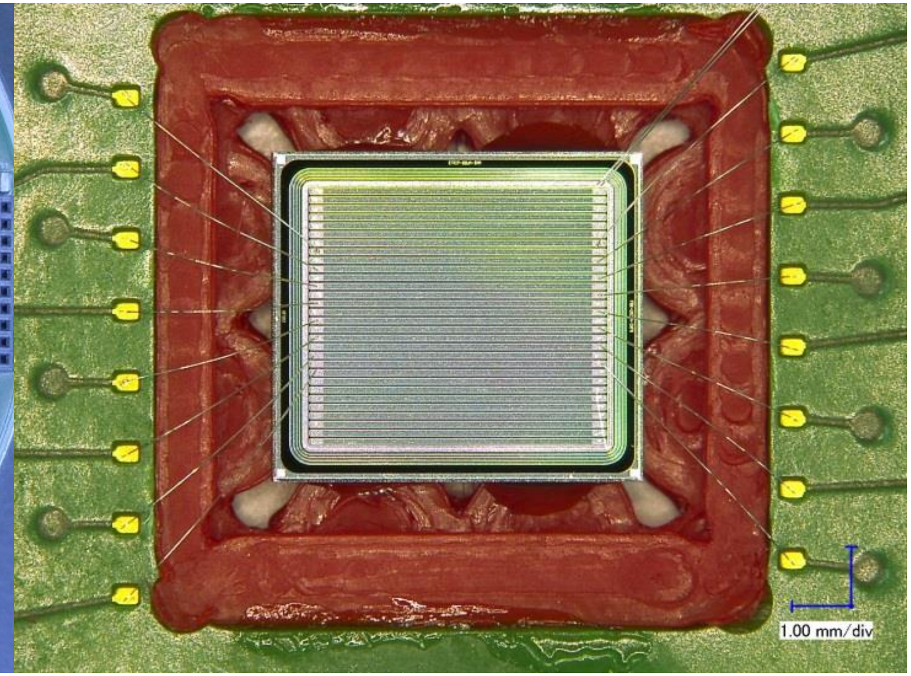


Part of the UFSD HADES team !

Performance of UFSD for HADES

Setup: Two UFSD sensors, each connected to NINO and Padiwa boards



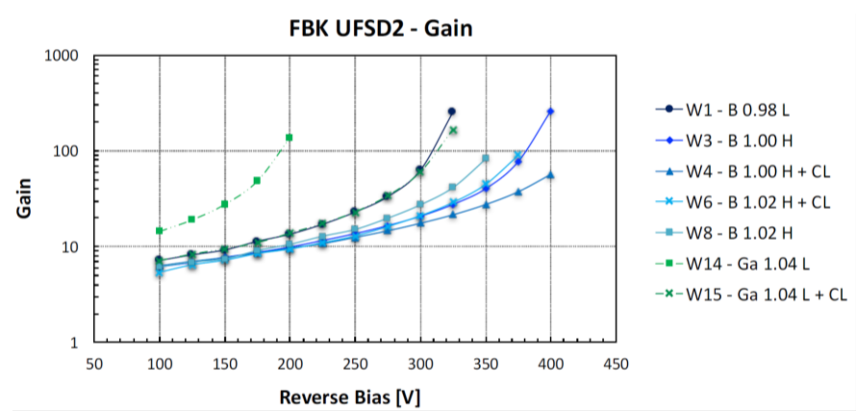


2 amplification stages close to the sensor

J. Pietraszko et al. Nucl. Instrum. Meth. A 618 (2010) 121-123

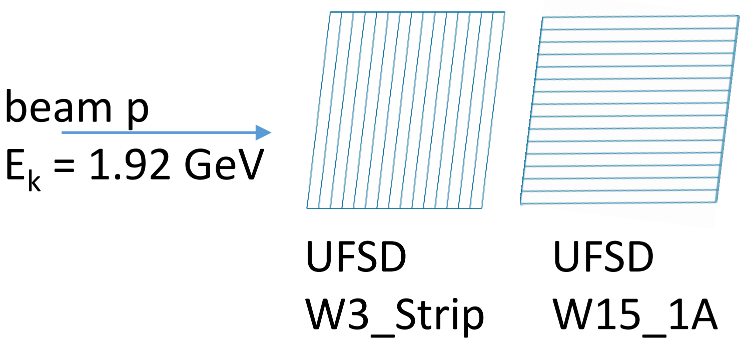
FBK UFSD detectors tested at COSY in Juelich, 5mm x 4.5 mm

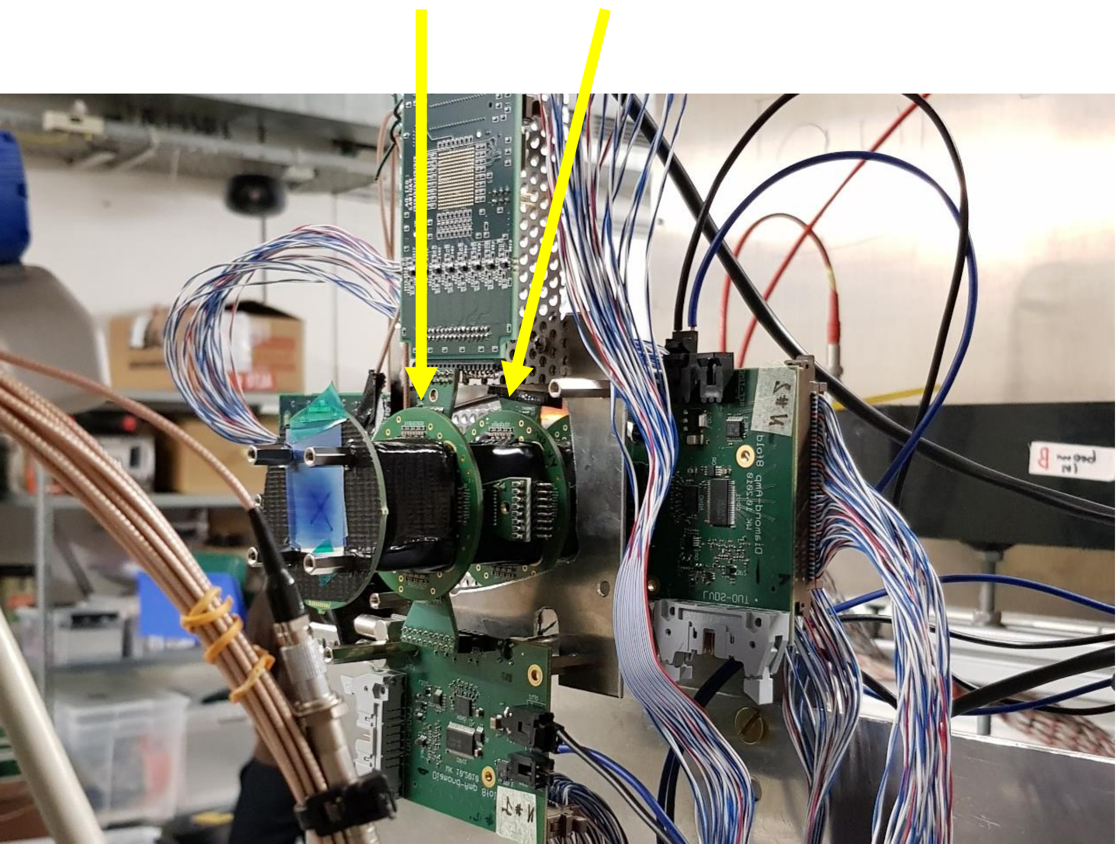
- 500 µm thickness, 50µm active sensor thickness, 5mm x 4.5 mm,
- 30 strips on each sensor, 16 connected to the FEE, 140 µm pitch
- W15_1A and W3 sensor types

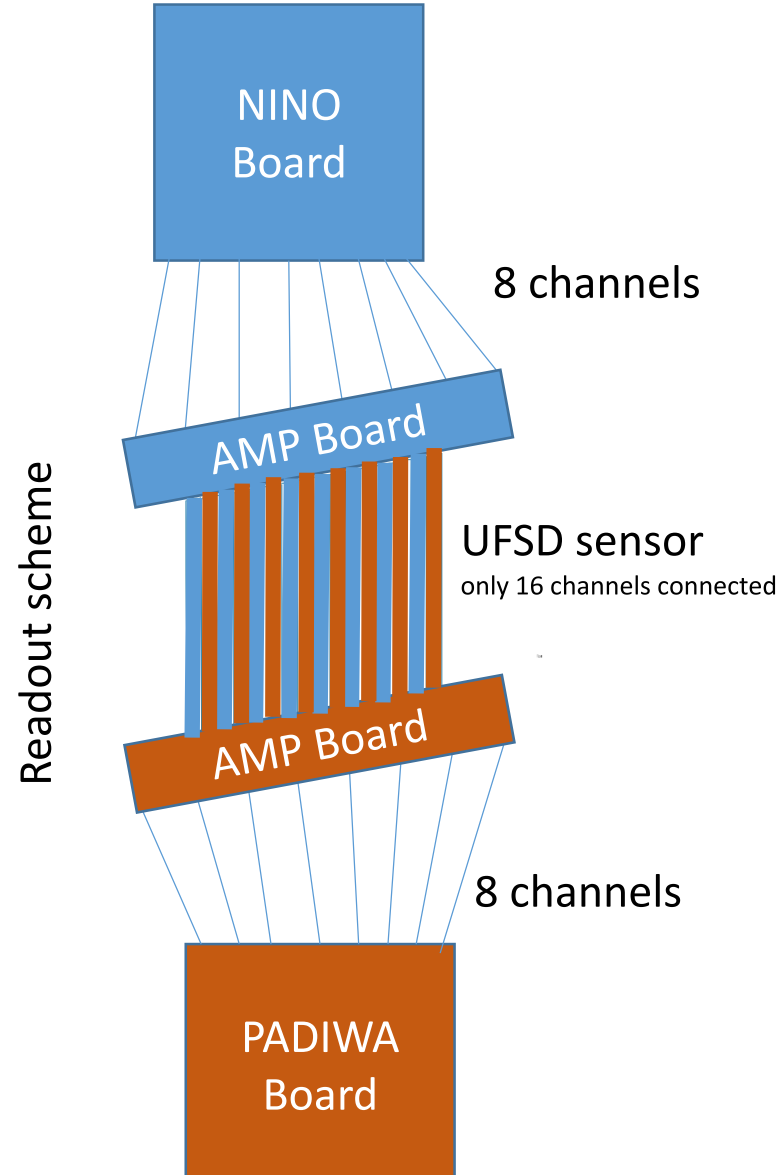


Performance of UFSD for HADES

Setup: Two UFSD sensors, each connected to NINO and Padiwa boards



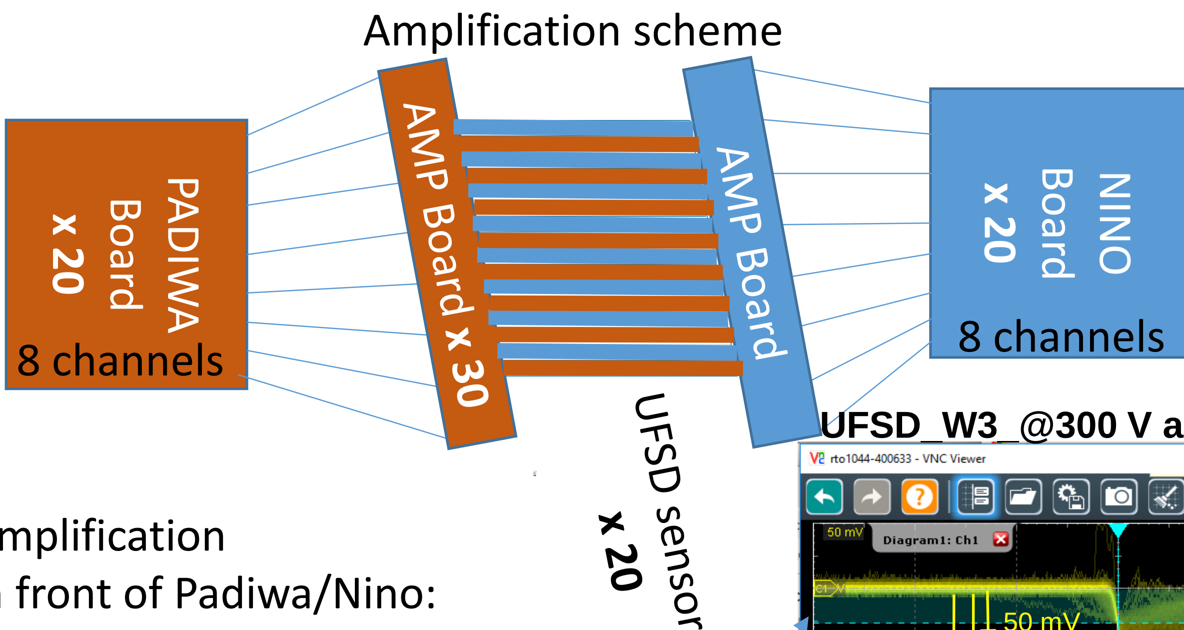




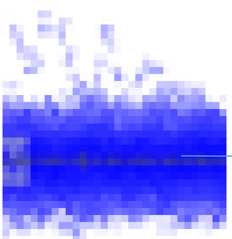
Parallel test of both Amp/Discriminator boards

Performance of UFSD for HADES

Amplifications at individual stages

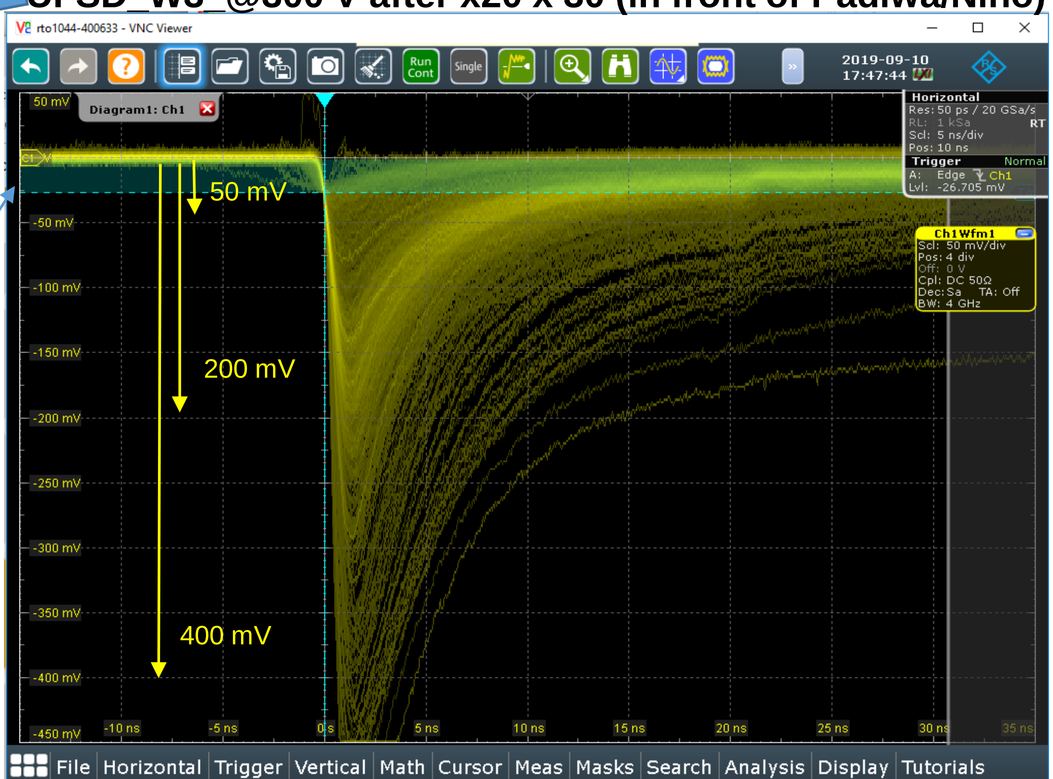


Amplification
in front of Padiwa/Nino:
x20(UFSD) x 30(AMP board)



Noise thresholds:
NINO 0x5000 ~5mV
Padiwa ~10mV

UFSD_W3_@300 V after x20 x 30 (in front of Padiwa/Nino)



The best performance at thresholds at 5mV !

Performance of UFSD for HADES

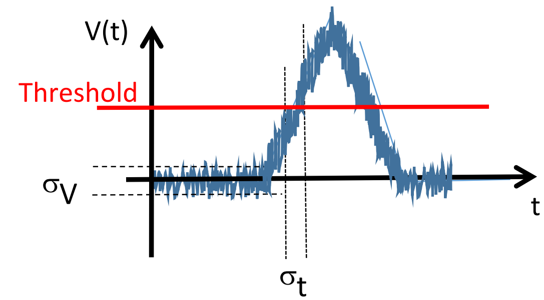
Best performance at thresholds at 5mV !

Time Walk **jitter** **TDC precision**

$$\sigma_t^2 = \left(\left[\frac{V_{th}}{S/t_r}\right]_{RMS}\right)^2 + \left(\frac{N}{S/t_r}\right)^2 + \left(\frac{TDC_{bin}}{\sqrt{12}}\right)^2$$

where S is the signal amplitude, t_r the signal rise time, N the noise, and V_{th} is the comparator threshold used to set the time of arrival of the particle ($V_{th} \sim 10{*}N$).

Jitter

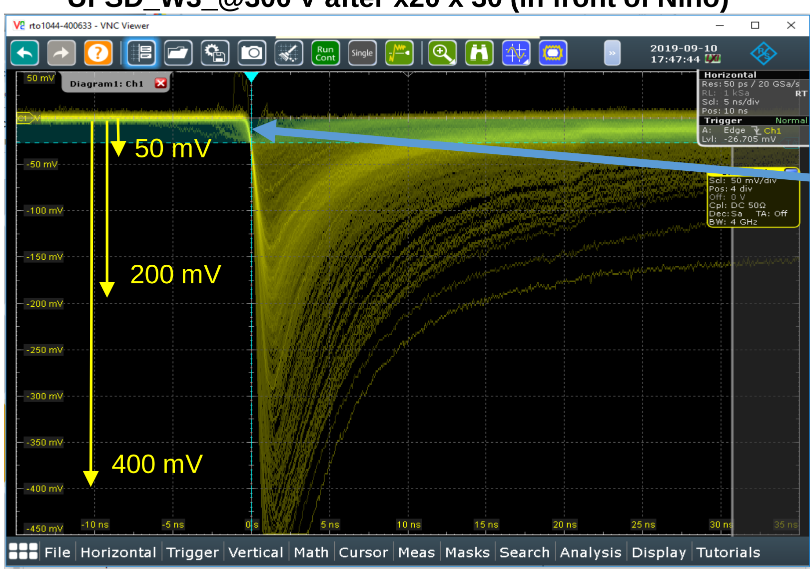


N. Cartiglia, et al., Design optimization of ultra-fast silicon detectors, NIMA 796 (2015)141–148

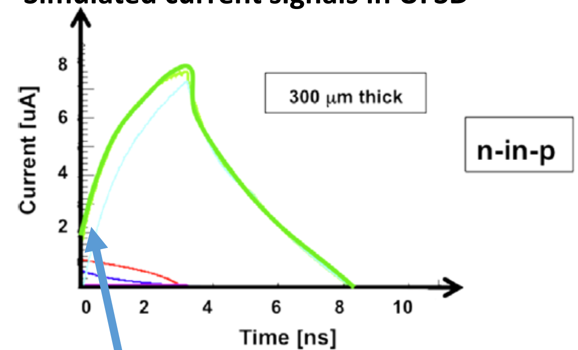
The most important parameters for good time precision:

- Short rise time
- Low noise

UFSD_W3_@300 V after x20 x 30 (in front of Nino)



Simulated current signals in UFSD



The highest slope is at the very beginning of the signal

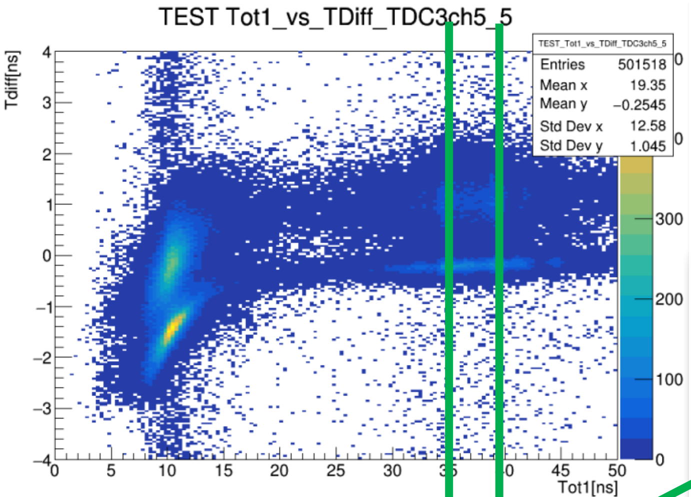
→ Best timing at very low thresholds, as close as possible to the noise

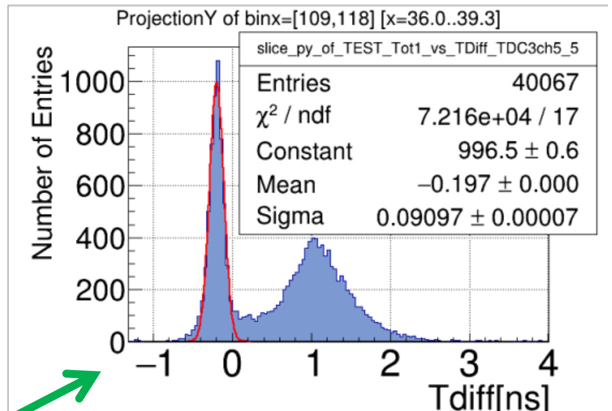
→ This we see in the test data

Performance of UFSD for HADES

Best performance at 5mV threshold – consequences

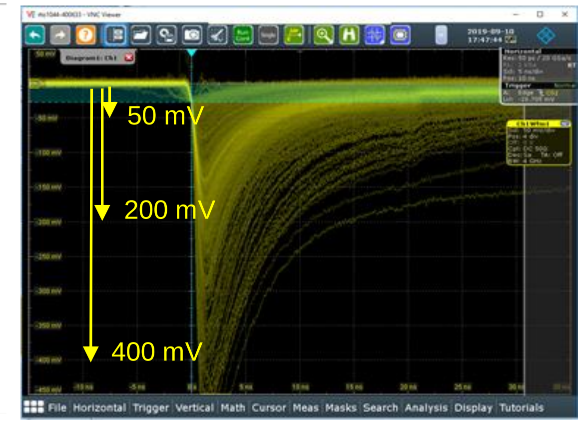
→ a huge number of signals with very low amplitude (ToT)





UFSD_W3_@300 V

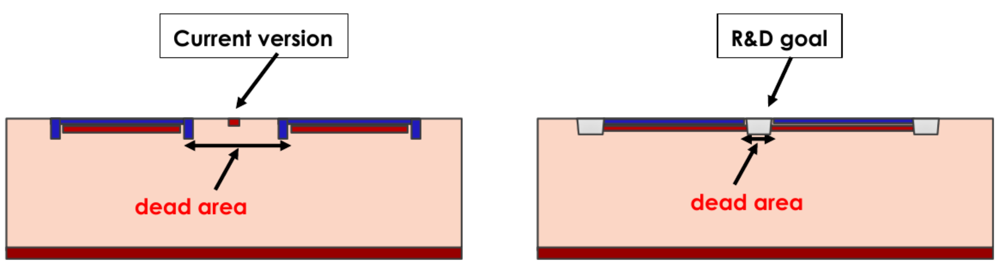
after x20 x 30 (in front of Nino)



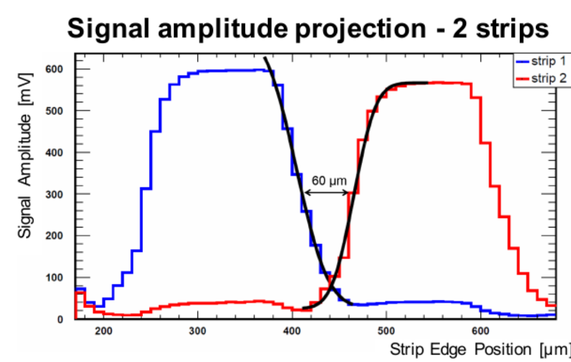
Result: 90ps / 1.4 = 64ps

The origin of signals with an amplitude close to 5mV

1. Crosstalk is Sensor, Amplifiers and in Discriminator
2. “Dead area” between strips of the detector, low amplitude signals
   - Current gap: 50 μm→fill factor of 75 %.
   - Goal: <10 μm→ fill factor of 95 %.



Nicolo Cartiglia, *4D-Tracking*, Berlin 2018



Performance of UFSD for HADES

Running conditions

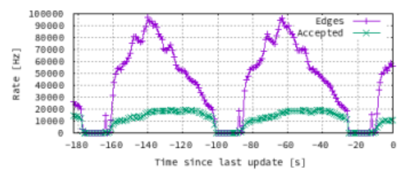
HADES

Rates: 7-8 kHz / strip

Central Trigger System

- Status overview

Counter	Counts	Rate
Trigger asserted	1563540855 clks.	57.70 Kcnt/s
Trigger rising edges	1563540855 edges	57.70 KHz
Trigger accepted	384696050 events	11.42 KHz
Last Idle Time	8670 ns	
Last Dead Time	4190 ns	238.66 KHz
Total Dead Time	45620899 ns	4.6%
Throttle	☐ Limit Trigger Rate to 1 KHz	
Full Stop	☐ Ignore all events	
Export CTS Configuration	as TrbCmd script	as shell script



Click on the image to switch between short and long plotting intervals

- Trigger Channels

#	Enable	Trg. Cond.	Assignment	TrbNet Type	Asserted	Edges
0	☐	R. Edge	Ext. Logic - CBM	0x1_physics_trigger	0.00 cnt/s	0.00 Hz
1	☐	R. Edge	Periodical Pulser 0	0xd_tdc_calibration_trigger	10.00 Kcnt/s	10.00 KHz
2	☐	R. Edge	Periodical Pulser 1	0x1_physics_trigger	44.49 cnt/s	44.49 Hz
3	☐	R. Edge	Periodical Pulser 2	0x1_physics_trigger	0.00 cnt/s	0.00 Hz
4	☐	R. Edge	Random Pulser 0	0x1_physics_trigger	0.00 cnt/s	0.00 Hz
5	☑	R. Edge	AddOn Multiplexer 0	0x1_physics_trigger	167.15 Kcnt/s	57.73 KHz
6	☐	R. Edge	AddOn Multiplexer 1	0x1_physics_trigger	11.48 Mcnt/s	25.01 KHz
7	☐	R. Edge	AddOn Multiplexer 2	0x1_physics_trigger	100.00 Mcnt/s	0.00 Hz
8	☐	R. Edge	AddOn Multiplexer 3	0x1_physics_trigger	0.00 cnt/s	0.00 Hz
9	☐	R. Edge	Coincidence Module 0	0x1_physics_trigger	100.00 Mcnt/s	0.00 Hz

0		17093		17093		17093		17093	
1	☐	0	☐	0	☑	6642	☑	7526	☐
2	☐	0	☐	0	☑	7223	☑	7907	☐
3	☐	0	☐	0	☑	7703	☑	8903	☐
4	☐	0	☐	0	☑	7617	☑	8397	☐
5	☐	0	☐	0	☑	8382	☑	8082	☐
6	☐	0	☐	0	☑	8692	☑	6965	☐
7	☐	0	☐	0	☑	267	☑	8154	☐
8	☐	0	☐	0	☑	8825	☑	7008	☐
9	☑	8588	☑	7620	☐	0	☐	0	☐
10	☑	8248	☑	7306	☐	0	☐	0	☐
11	☑	7957	☑	0	☐	0	☐	0	☐
12	☑	7814	☑	7389	☐	0	☐	29510177	☐
13	☑	7418	☑	7310	☐	0	☐	0	☐
14	☑	7441	☑	7394	☐	651	☐	0	☐
15	☑	6857	☑	7786	☐	0	☐	0	☐
16	☑	6140	☑	7163	☐	5086778	☐	0	☐
17	☐	0	☑	17908	☐	0	☐	0	☐
18	☐	0	☐	14139	☐	0	☐	0	☐

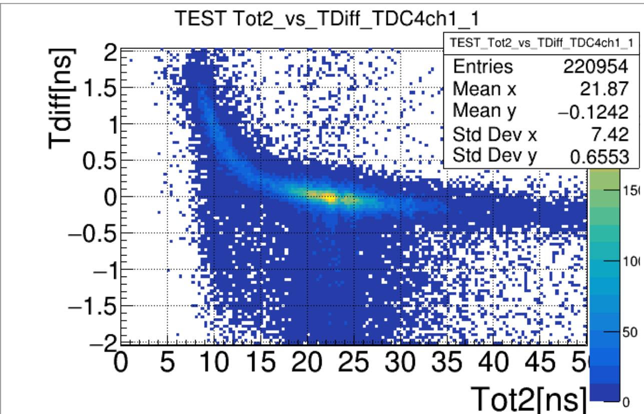
07.11.2019 15:18,
back to 250V / 300V,
Thresholds:

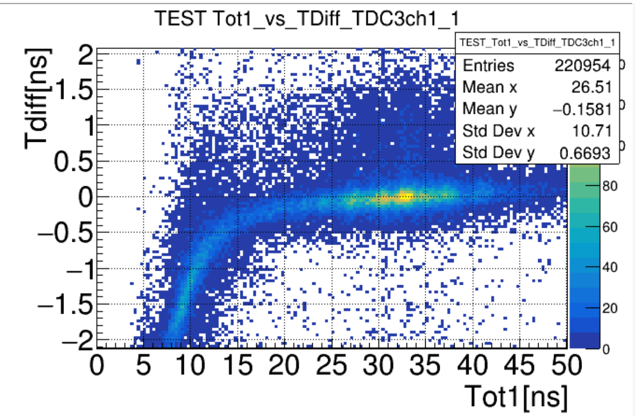
NINO: 0xe – global, 0xd loc(nino),
padiwa (0x7b95 + 3000) + 150 mV in padiwa,

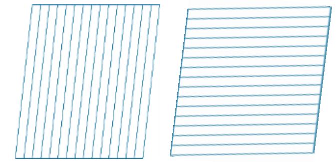
LV increased to 1.6V,
High intens. up 20kHz/strip/s

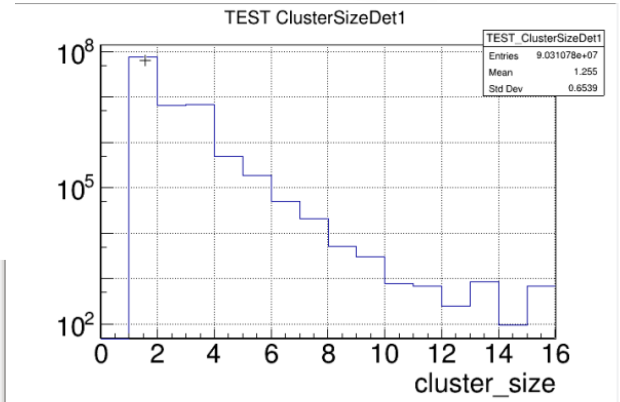
Performance of UFSD for HADES

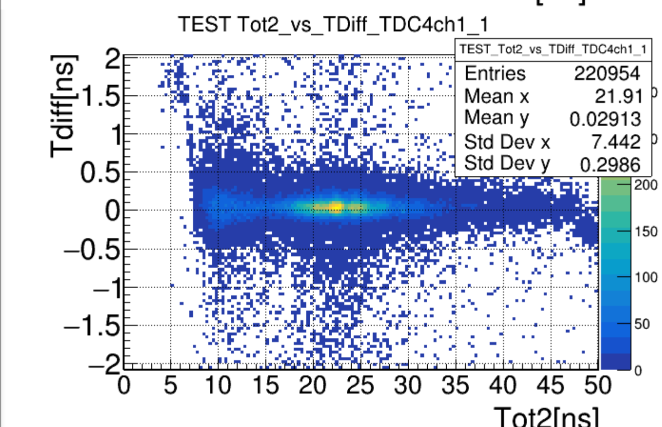
NINO discriminator, time precision with walk corrections

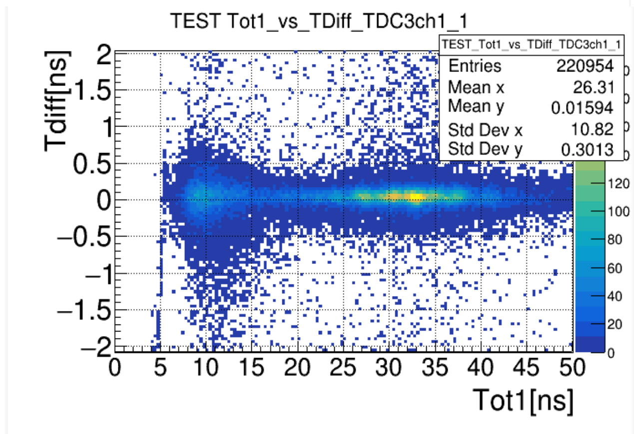


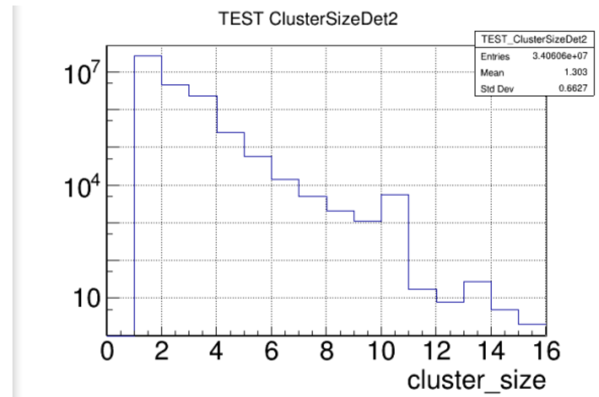


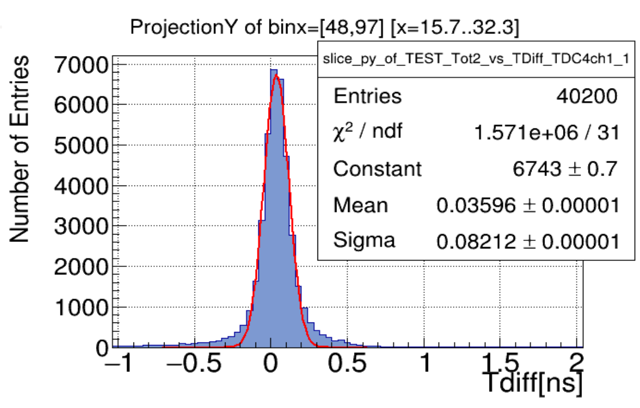


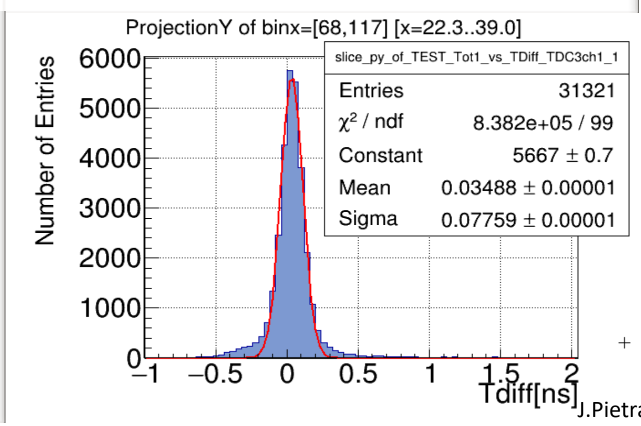












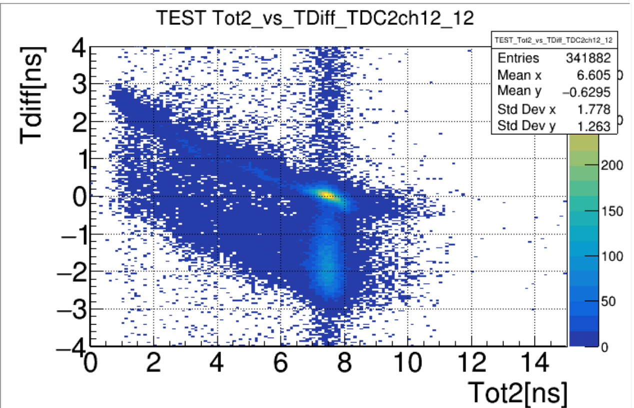
Example Results

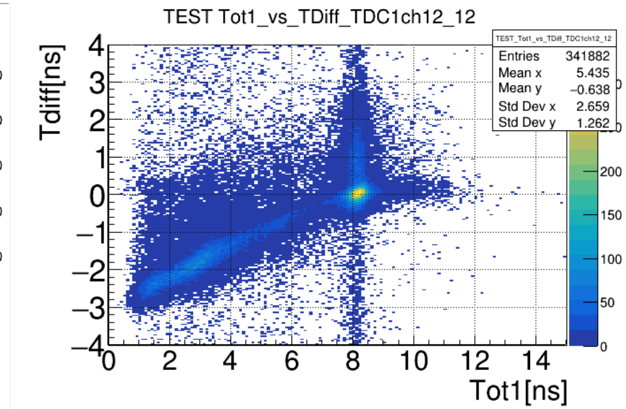
NINO with walk correction:

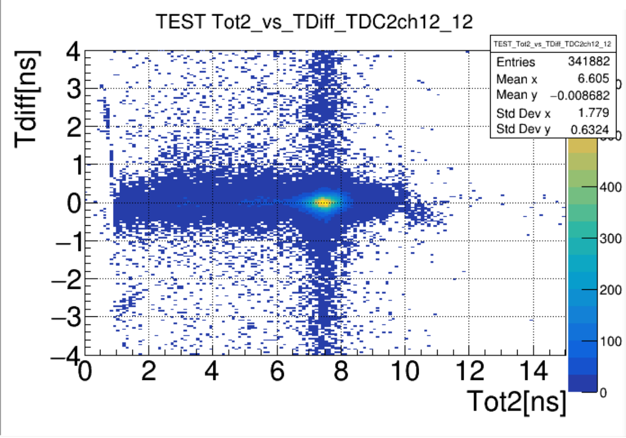
80ps / 1.4 = 57 ps

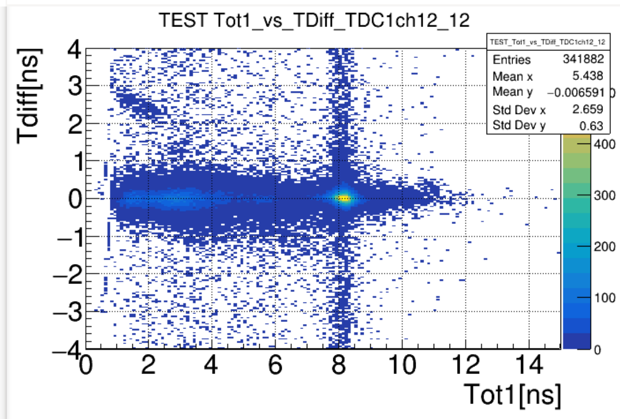
Performance of UFSD for HADES

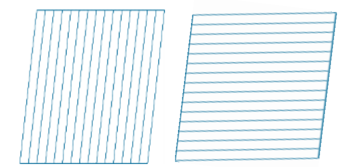
PADIWA discriminator, time precision with walk corrections











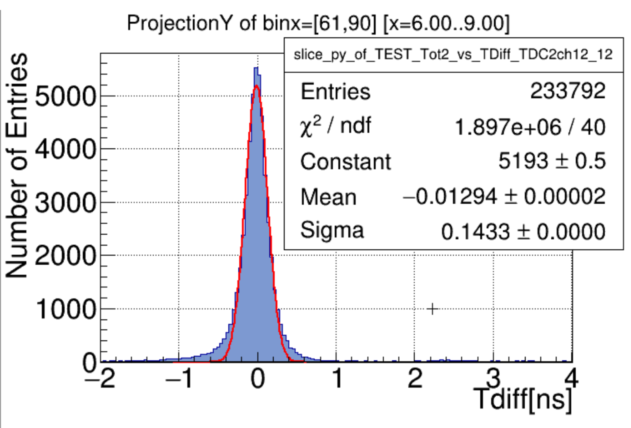
Example Results

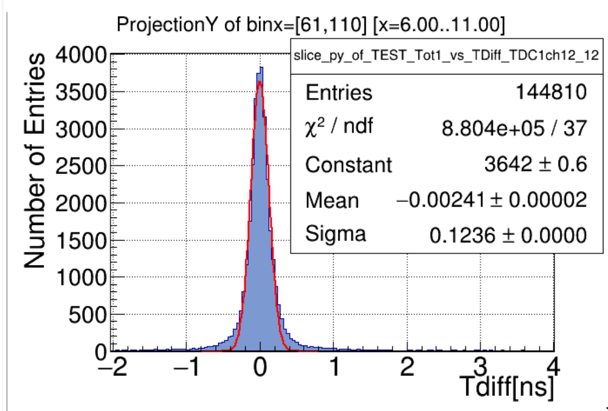
PADIWA with walk correction:

140ps / 1.4 = 100 ps

→ with contribution from small ToT

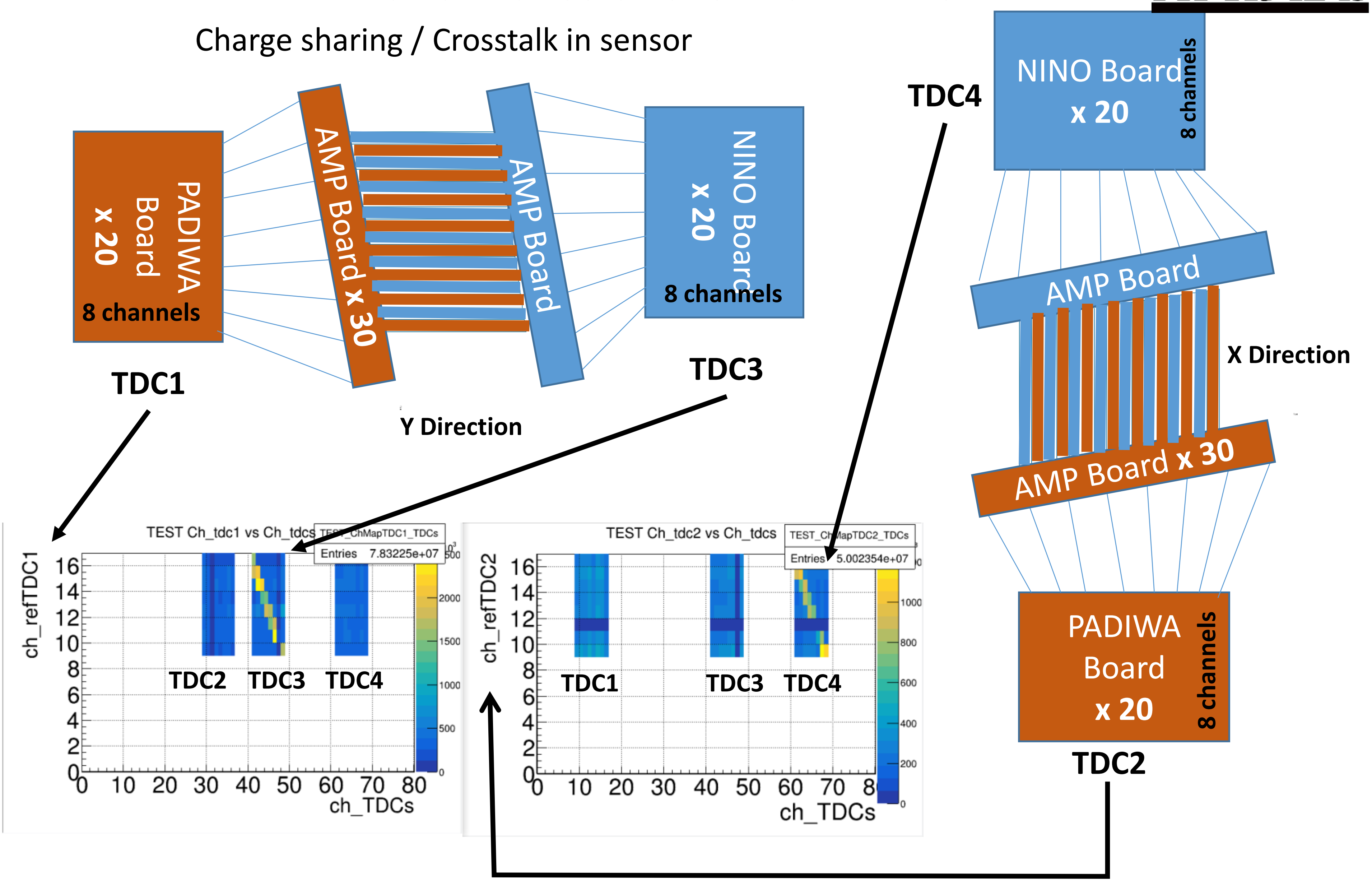
→ relatively high thresholds





Performance of UFSD for HADES

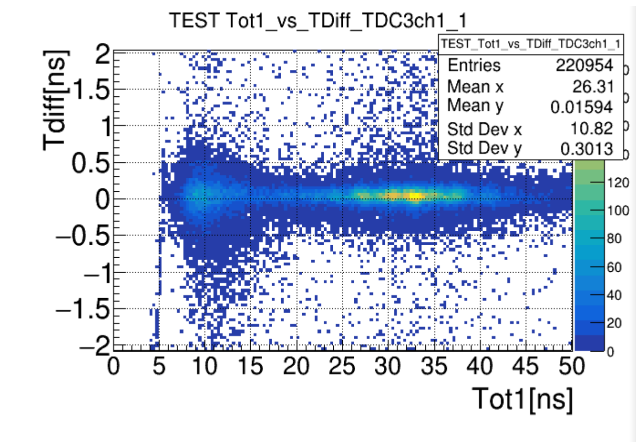
Charge sharing / Crosstalk in sensor

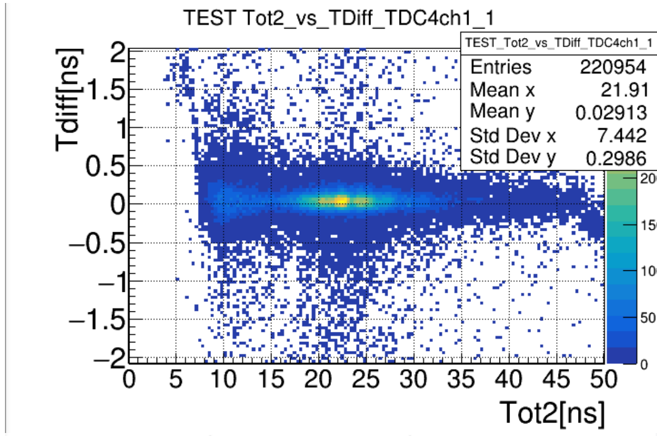


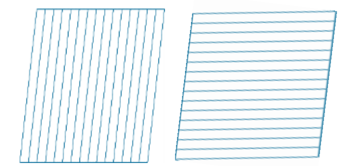
→ **Charge sharing in sensor clearly visible**

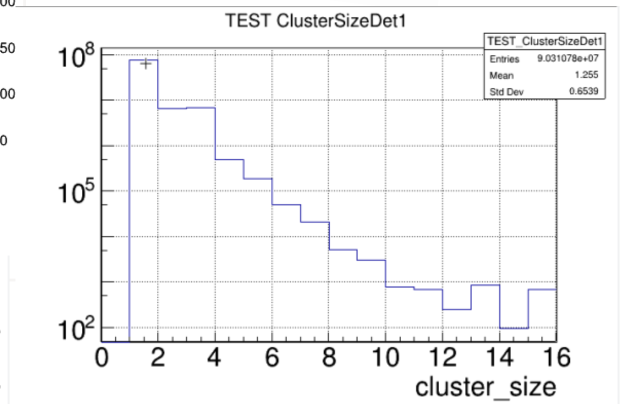
Performance of UFSD for HADES

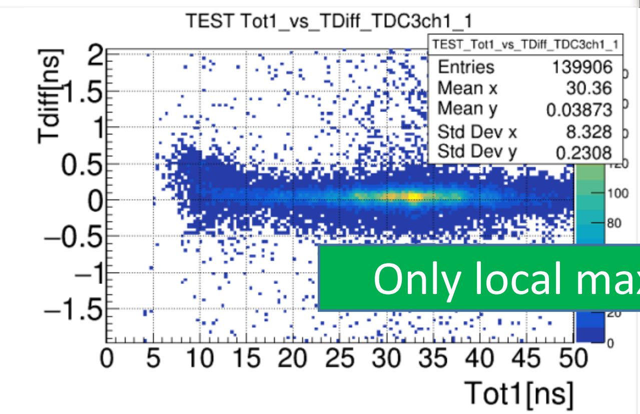
NINO discriminator, time precision with walk corrections – **Local Maxima from Clusters**

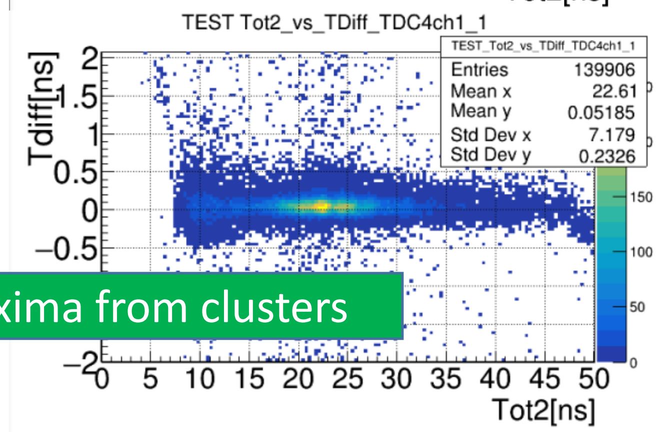




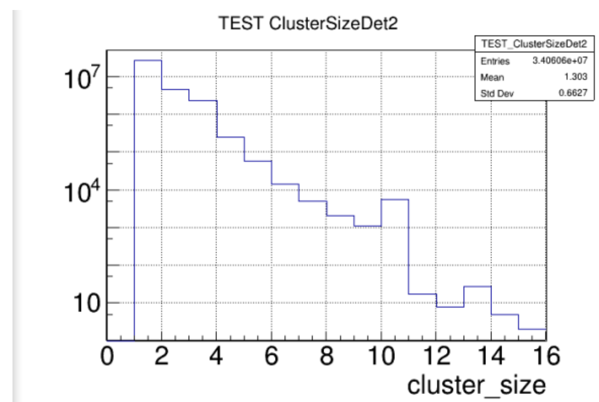


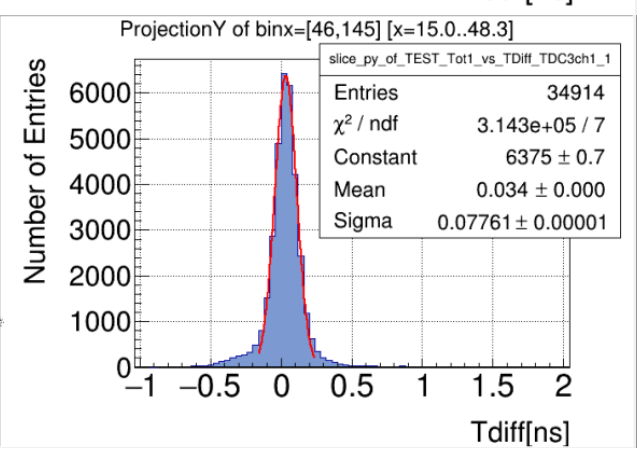


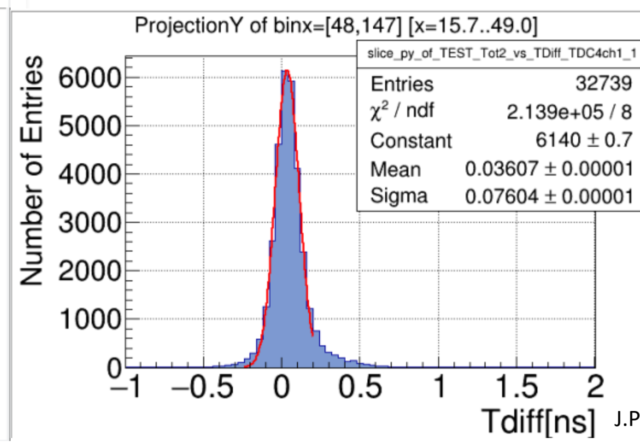




Only local maxima from clusters







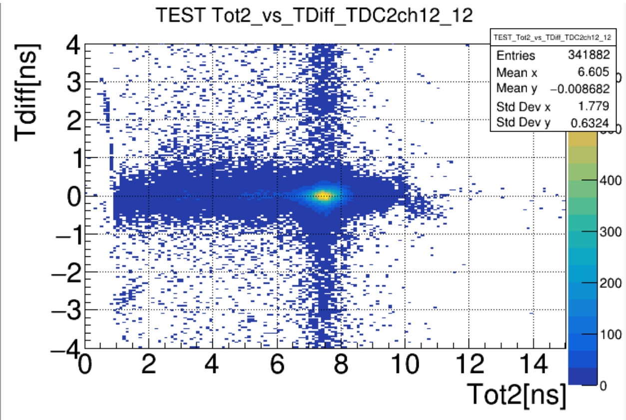
Example Results

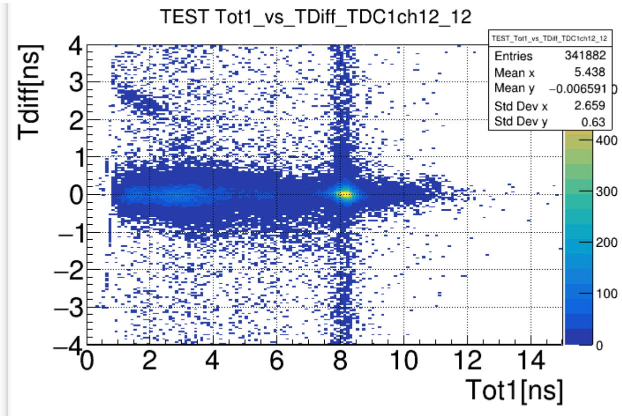
NINO with walk correction:

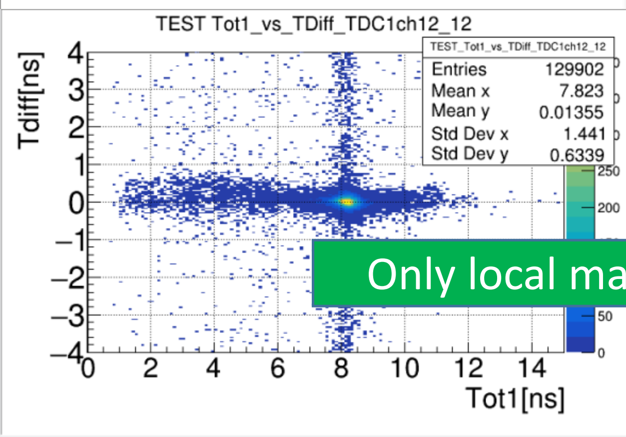
77ps / 1.4 = 55 ps

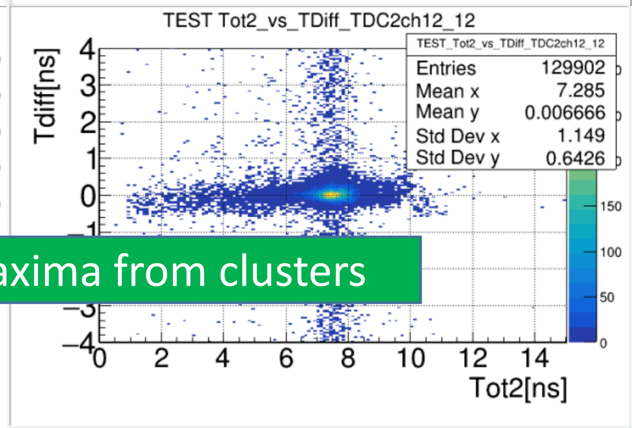
Performance of UFSD for HADES

PADIWA discriminator, time precision with walk corrections – **Local Maxima from Clusters**

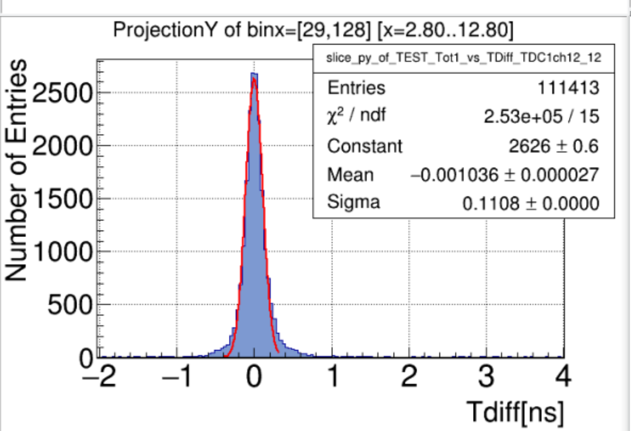


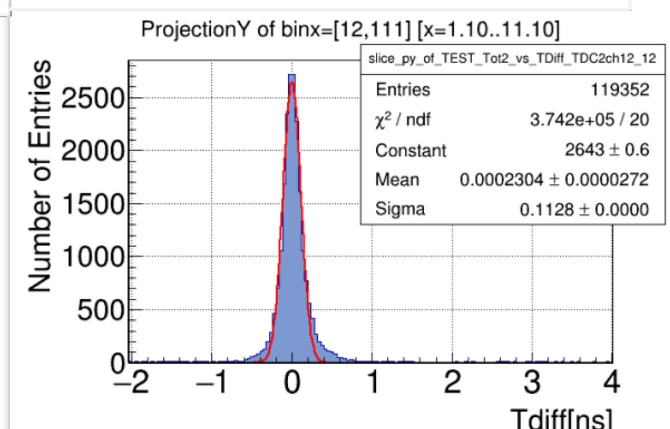


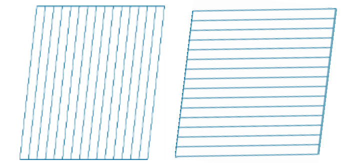




Only local maxima from clusters







Example Results

PADIWA with walk correction and cluster finder

→ only local maxima

112ps / 1.4 = 80 ps

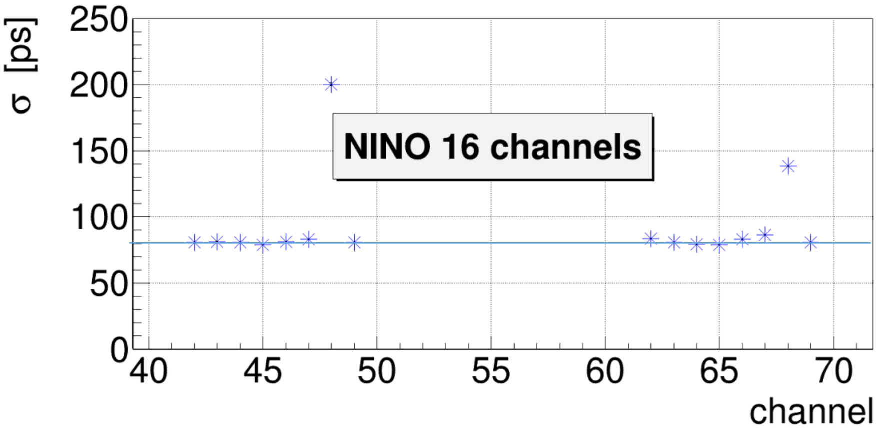
→ reduced contribution from small ToT

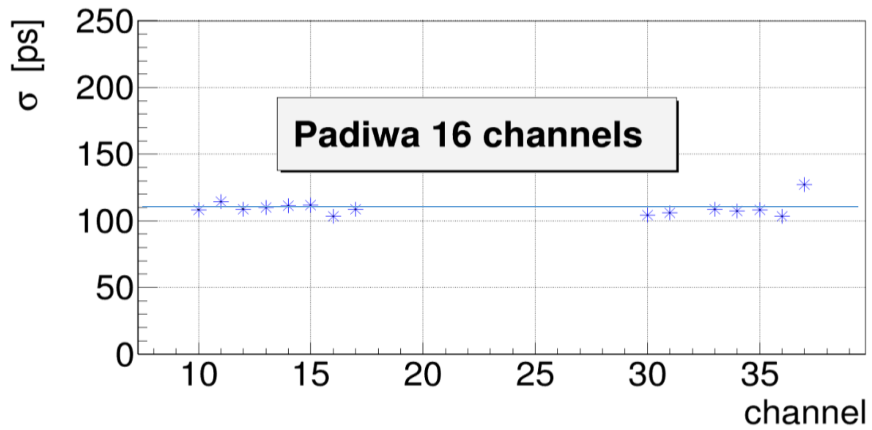
→ relatively high thresholds

Performance of UFSD for HADES

HADES

PADIWA discriminator, time precision with walk corrections – **Local Maxima from Clusters**





NINO with walk correction and cluster finder, local maxima
Time precision:

<u>80ps / 1.4 = 56 ps</u>

PADIWA with walk correction and cluster finder, local maxima
Time precision:

<u>110ps / 1.4 = 80 ps</u>

HADES

Summary and Outlook

→ Very good timing performance has been demonstated, time precision close to 50ps for NINO and 80ps for PADIWA
→ Charge sharing in sensor observed
→ Better time performance using only local maxima hits: NINO (57ps→55ps), PADIWA (100ps → 80ps)
→ Operation in air, without the need for cooling

Next Steps

→ New sensors, fill factor almost 100%, cluster size?
→ Checking the behaviour at high beam intensities, MHz/ch
→ New PCBs with more channels, 64 channel version ready for tests.