Performance of UFSD for HADES
Test on 04-10 Nov 2019

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Projection Y of binx=41 [x=13.3..13.7]

Entries 5078
\( \chi^2 / \text{ndf} \) 1.511e+04 / 13
Constant 649.7 ± 0.6
Mean 0.06731 ± 0.0
Sigma 0.101 ± 0.0

J. Pietraszko, 8th ADAMAS Workshop, GSI, Darmstadt, 9-10.12.2019
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.

![Diagram showing UFSD principle of operation](image)

$E_{field}$ Traditional silicon sensors  $E_{field}$ Low Gain Avalanche Diode

Timing layers, 4D- and 5D-tracking, Cartiglia, N. INFN, Torino - Berlin 12/06/18

J.Pietraszko, 8th ADAMAS Workshop, GSI, Darmstadt, 9-10.12.2019
- 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 $6 \times 10^{15}$ cm$^{-2}$
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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

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


2 amplification stages close to the sensor
Performance of UFSD for HADES

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

beam $p$

$E_k = 1.92$ GeV

UFSD W3_Strip  
UFSD W15_1A

NINO Board
8 channels
AMP Board
8 channels
PADIWA Board

Parallel test of both Amp/Discriminator boards

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Amplifications at individual stages

Amplification scheme

PADIWA Board x 20
8 channels

AMP Board x 30

AMP Board

NINO Board
x 20
8 channels

UFSD_w3_@300 V after x20 x 30 (in front of Padiwa/Nino)

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

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

The best performance at thresholds at 5mV!
Performance of UFSD for HADES

Best performance at thresholds at 5mV!

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

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 (\( V_{th} \approx 10 \times N \)).


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)

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

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Best performance at 5mV threshold – consequences

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

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

Result: 90ps / 1.4 = 64ps
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Running conditions

Rates: 7-8 kHz / strip

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
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NINO discriminator, time precision with walk corrections

Example Results
NINO with walk correction:
80ps / 1.4 = 57 ps

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PADIWA discriminator, time precision with walk corrections

Example Results

PADIWA with walk correction:

\[ 140\text{ps} / 1.4 = 100 \text{ps} \]

→ with contribution from small ToT

→ relatively high thresholds

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Charge sharing / Crosstalk in sensor

→ Charge sharing in sensor clearly visible

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

Example Results
NINO with walk correction: 77ps / 1.4 = 55 ps

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PADIWA discriminator, time precision with walk corrections – 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

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Performance of UFSD for HADES
PADIWA discriminator, time precision with walk corrections – Local Maxima from Clusters

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

\[80\text{ps} / 1.4 = 56 \text{ps}\]

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

\[110\text{ps} / 1.4 = 80 \text{ps}\]
Summary and Outlook

→ Very good timing performance has been demonstrated, 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.