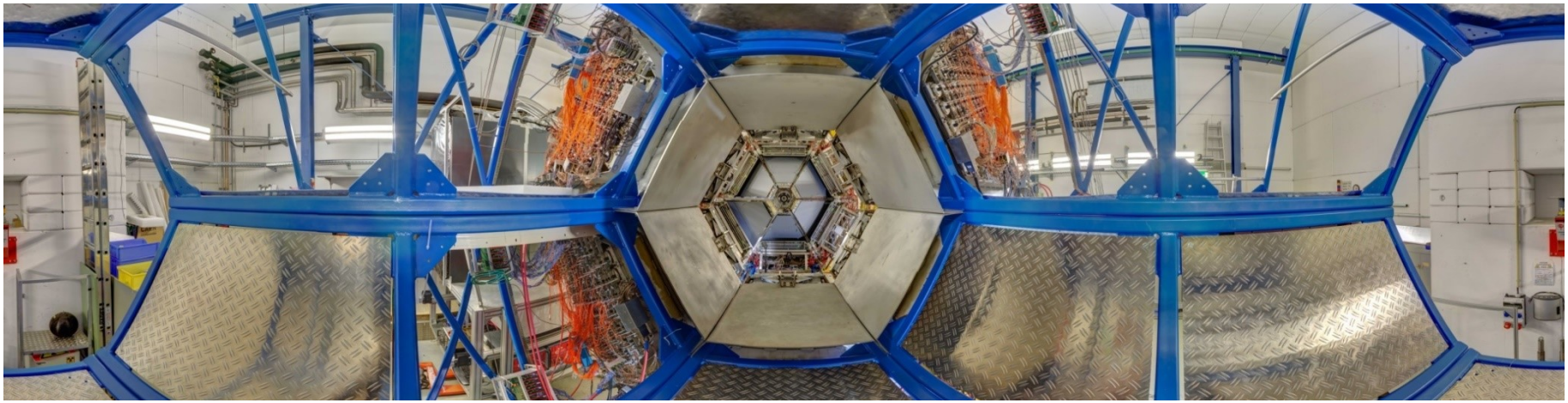
Design and performance of KISS read-out-electronics in HADES*

KISS = Keep it small and simple



Adrian Rost[1]
[1]Institut für Kernphysik, TU Darmstadt, Germany

for the **HADES collaboration**

*Supported by the DFG through GRK 2128 and VH-NG-823

Content

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- Motivation for the HADES ECAL upgrade
- First KISS application:
  →ECAL read-out electronics
- First ECAL beam time results
- Second KISS application:
  →UFSD detectors for HADES
- Summary and outlook

The HADES at SIS18 of GSI:
High-Acceptance Dielectron Spectrometer

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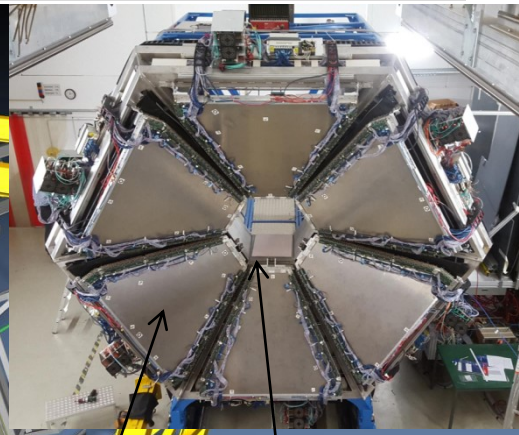
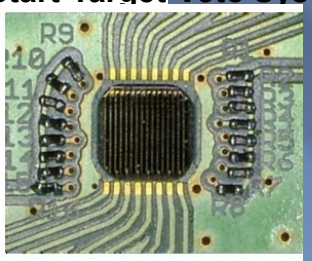
- Interaction rate - 20kHz
- High acceptance - 35% for lepton pairs
- Electron and hadron identification:
  - → Lepton identification: RICH
  - → Time of flight measurement: TOF and RPC
  - → Tracking: low-mass MDC and Magnet
  - → Energy loss: MDC and TOF
  - → Photon measurement: ECAL
- Role of ECAL:
  - → detection of photons (p0, eta, Sigma...)
  - → e/hadron separation at high momenta





Start-Target-Veto System

Start detector
(scCVD diamond)

RICH

MDC I

MDC II

Magnet

MDC III

MDC IV

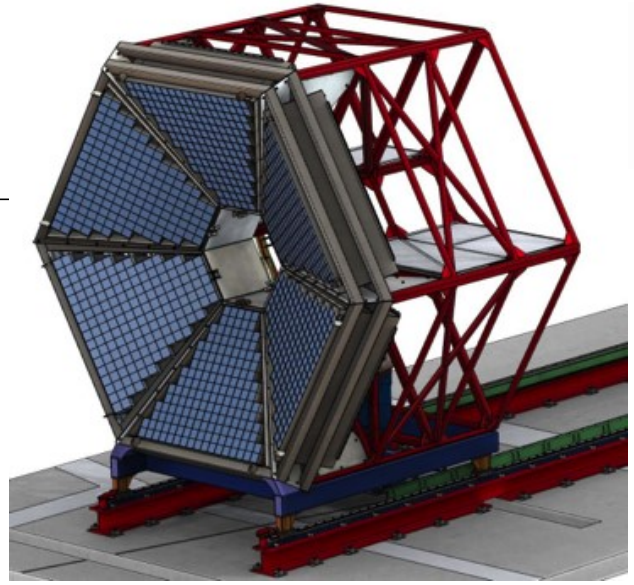
TOF

RPC

ECAL

Location: GSI, Darmstadt, Germany

The ECAL upgrade in HADES

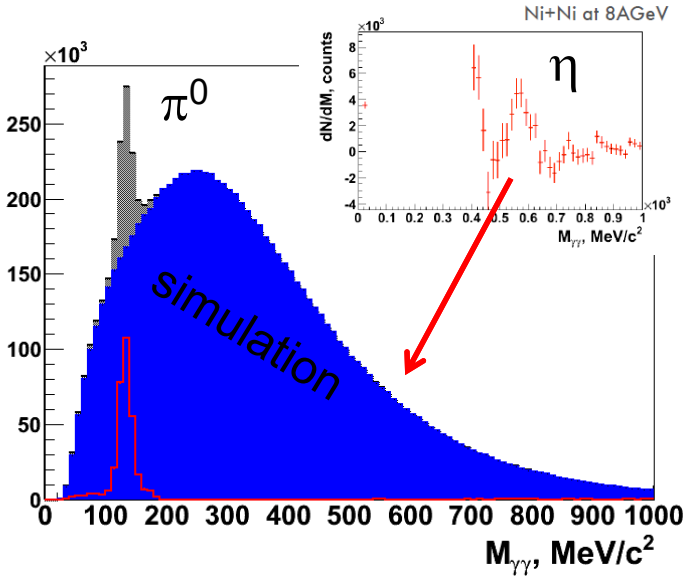


For SIS18 at GSI and SIS100 at FAIR

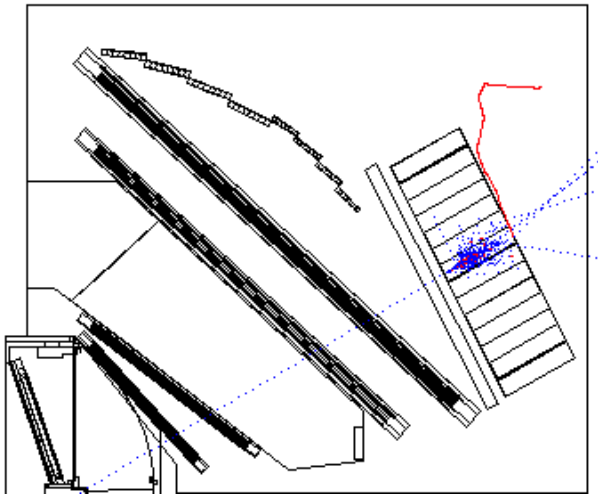
- 978 modules of lead glass + photomultiplier
- Polar angle coverage: 12° - 45°
- **Novel read-out electronics concept**

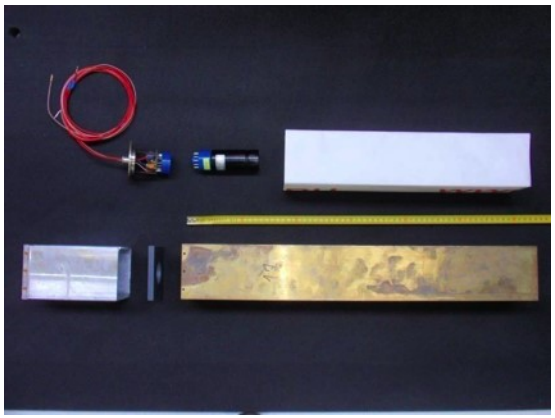
Motivation:

- Measurements of π^0 and η via $\gamma\gamma$-decay channel
  → E_{kin} = 2 – 11A GeV no measurements exist
- Spectroscopy of $\Lambda(1405)$ and $\Sigma(1385)$
- Measurement of a_1 spectral function
- Better electron/pion suppression for large momenta (p>400 MeV/c)



ECAL for HADES





Detector modules:

- Cherenkov lead glass modules from OPAL end cap calorimeter (163 modules x 6 sectors = 978; each 16 kg)
- Module dimensions: 9.4 x 9.4 x 60 cm^3
- Energy resolution: ~ 5%/√E, E in GeV

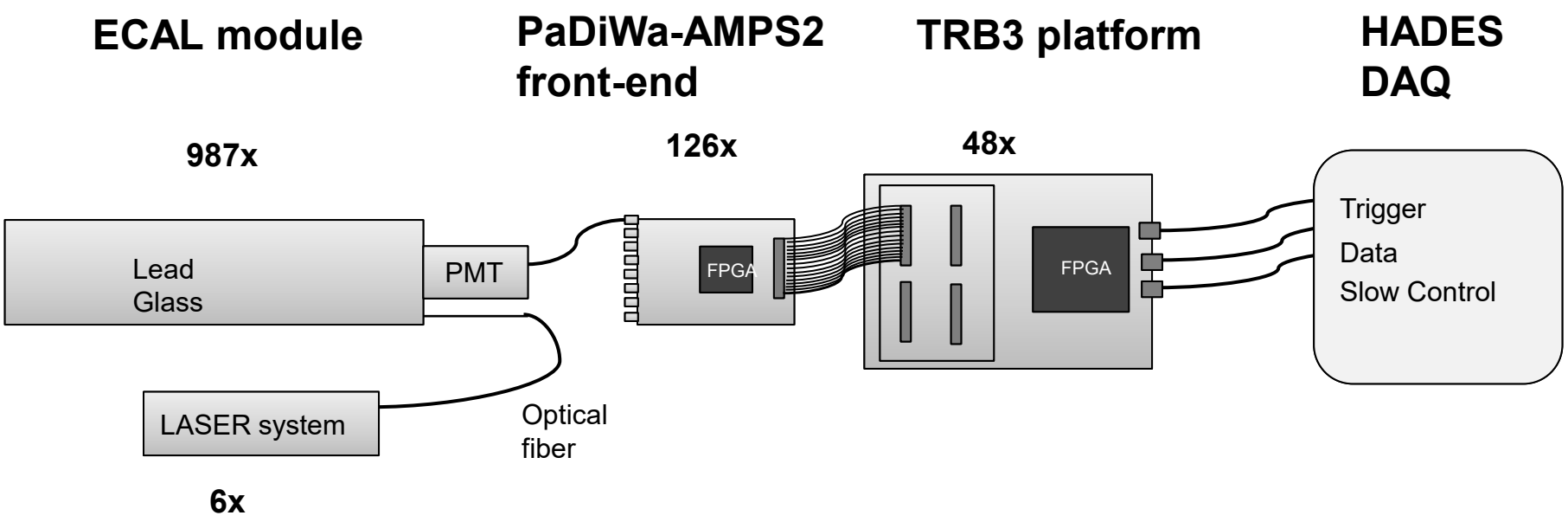
PMT read-out:

- EMI 9903KB (1.5″) (WA98 hadron calorimeter) ~600 PMT's
- Hamamatsu R6091 (3″)

Digitizing board:

- HADES Trigger and Readout Board v3 (TRBv3) with PaDiWa-AMPS front-end

The ECAL read-out scheme



TRB3 platform
FPGA TDC and multi purpose DAQ

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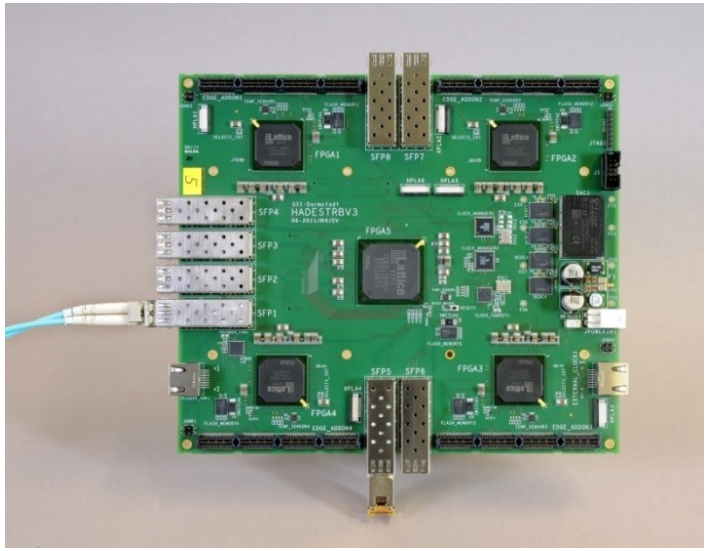
Time precision
8 ps RMS

C. Ugur et al. “A novel approach for pulse width measurements with a high precision (8 ps RMS) TDC in an FPGA”, *JINST*, vol. 11, no. 01, p. C01046, 2016.

4 FPGAs with
260 TDC channels



Single edge & ToT measurements

Usable in large systems & stand alone

50 MHz hit rate per channel

Only **48 V** and GbE needed to take data

Internal trigger system and slow control

Expandable by several Add-Ons and FEEs

(developed at GSI, see: http://trb.gsi.de/)

ACCELENCE

KISS charge and time measurement principle: *Modified Wilkinson ADC*

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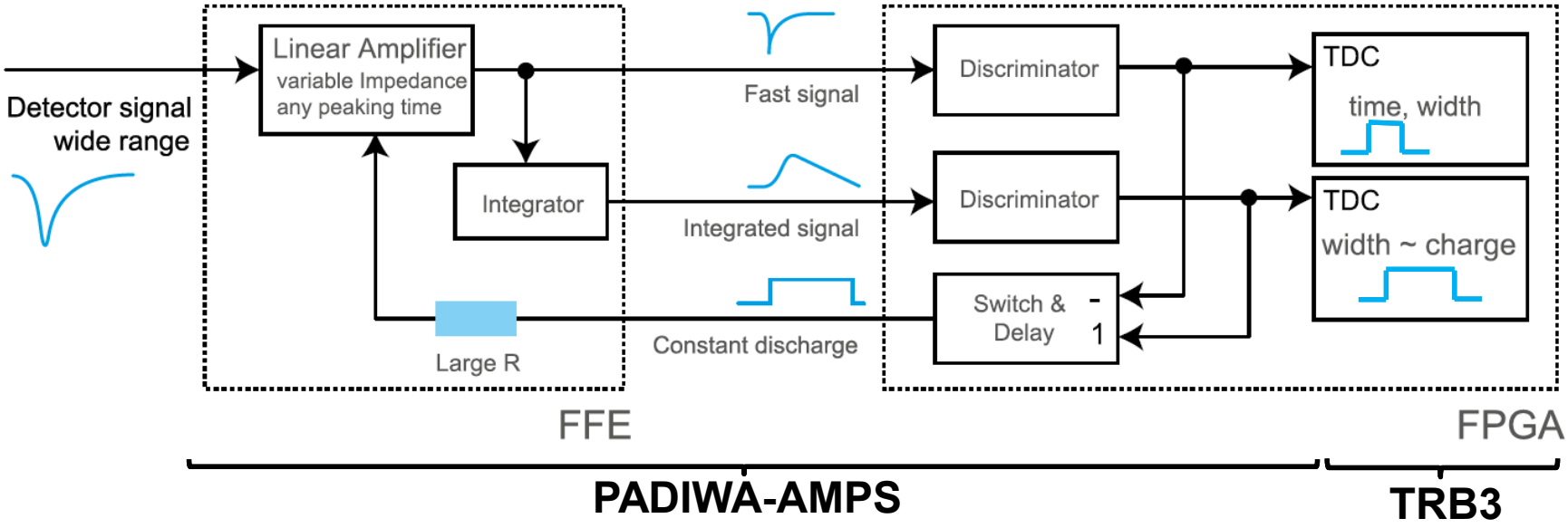
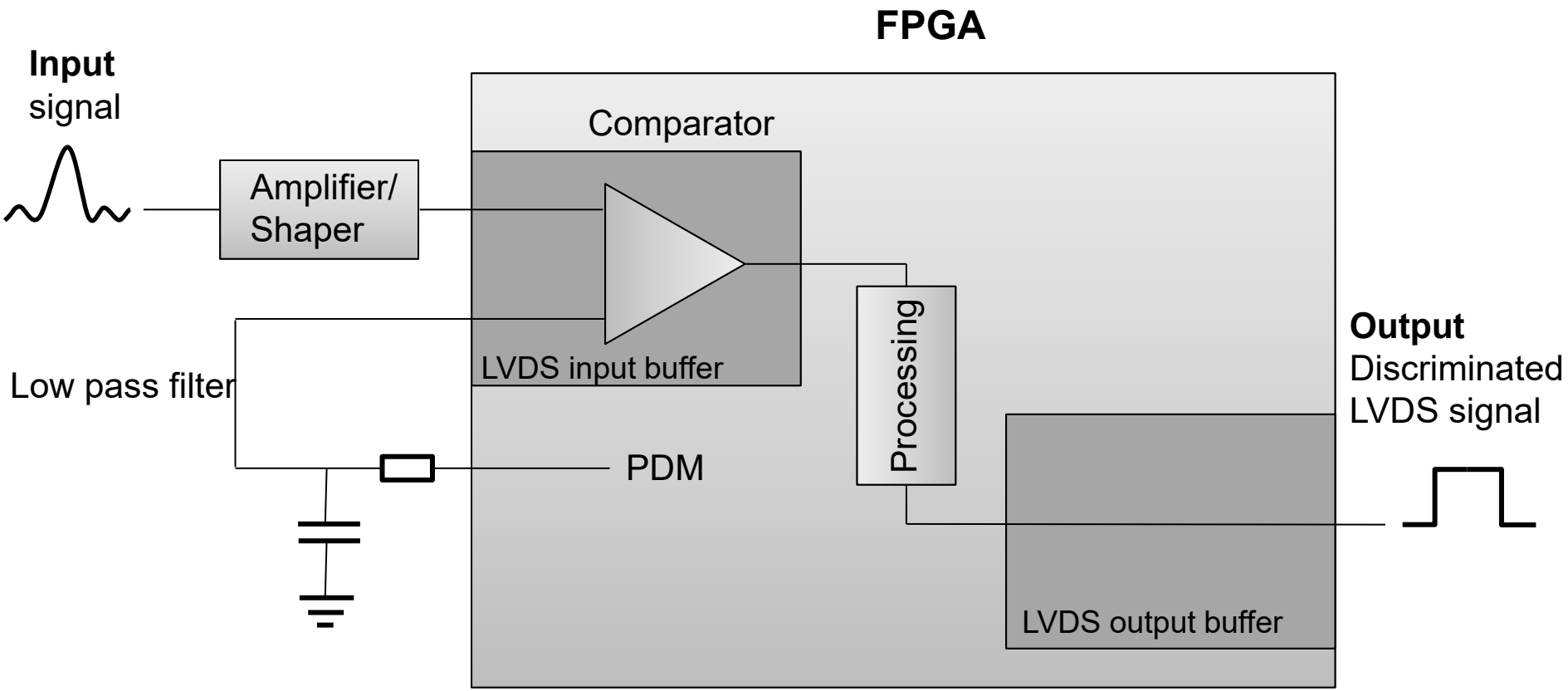
KISS = Keep it small and simple



- Input signal is integrated with a capacitor
- Capacitor is discharged using a constant current source triggered by the input signal

→ Measure ToT of integrated signal ~ **charge**
→ Measure leading edge of fast signal ~ **timing**

Signal discrimination with the help of an FPGA



PaDiWa-AMPS2 QDC and TDC front-end board for HADES ECAL

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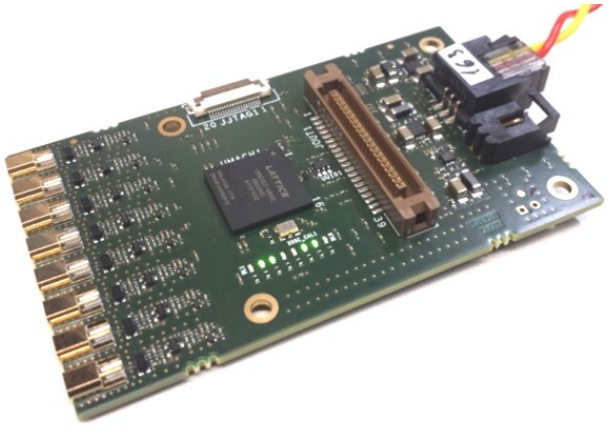
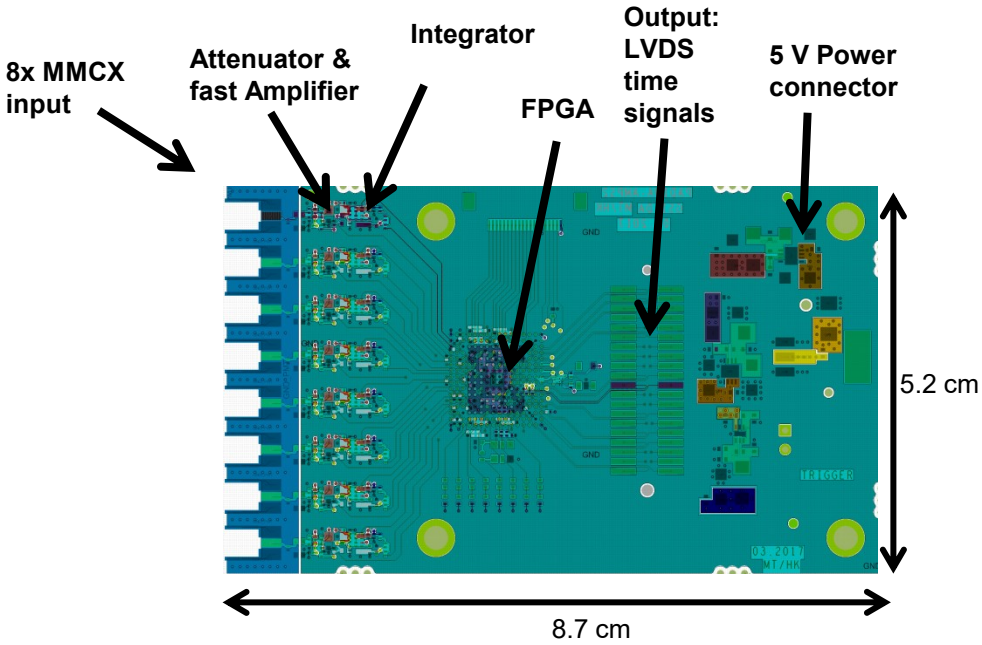


→ Layout and large scale production of 150 boards performed at GSI department for experimental electronics.



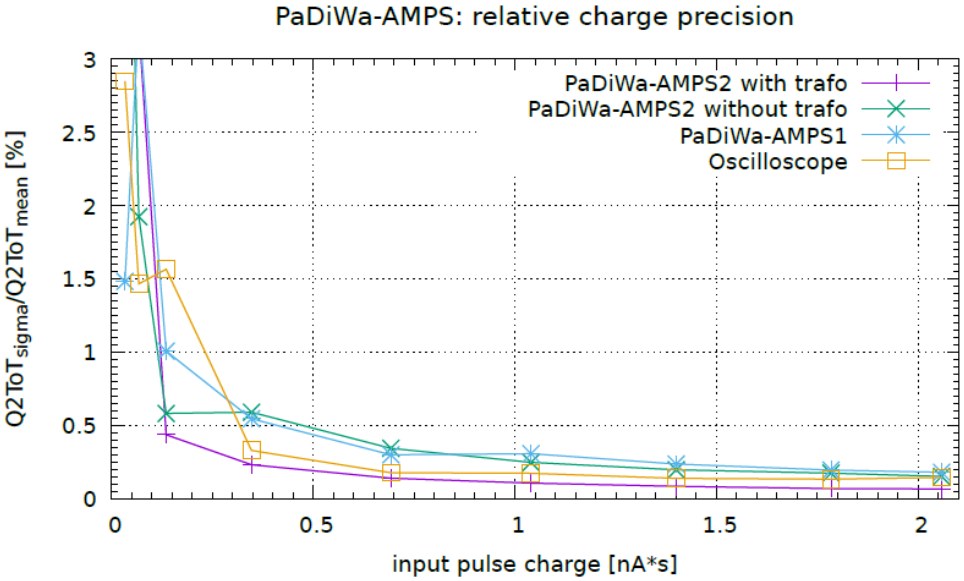
Key facts:

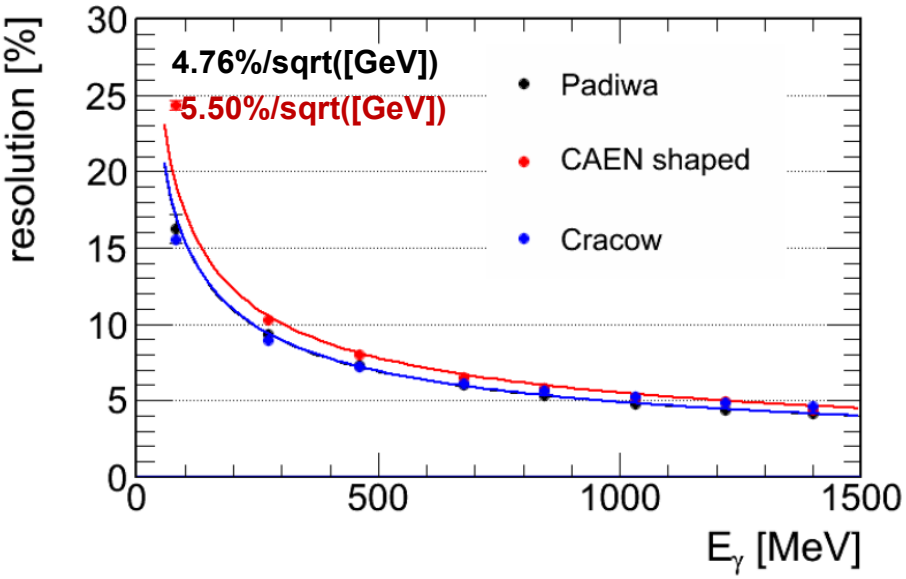
- Front-end for the TRB3 family
- Charge-to-width conversion and FPGA-discriminator
- 8 MMCX input channels
- 1 Lattice MachXO3-4000 FPGA
- 0201 package size

Performance:

- Time precision: ~ 19 ps
- Relative charge resolution: < 0.5 % (for pulser signals >1 V)
- Dynamic range: ~ 150
- Max. rate capability: ~ 100 kHz
- Power consumption: 1.5 W

Precision of the charge measurement and calorimeter resolution





- Relative charge precision was measured in the laboratory
  → for charges > 0.5 nA*s it is <0.5 %

- Calorimeter resolution was tested with secondary photons at the MAMI facility in Mainz
  → ~5.50%/sqrt([GeV])

Time precision for pulser measurements

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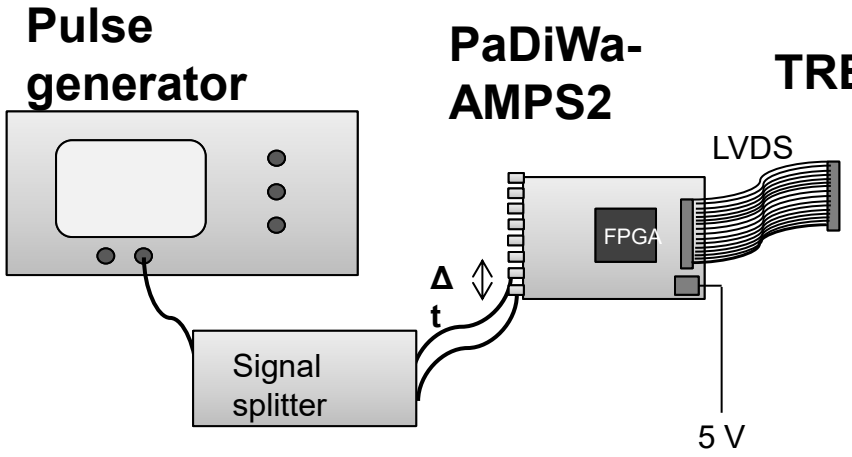
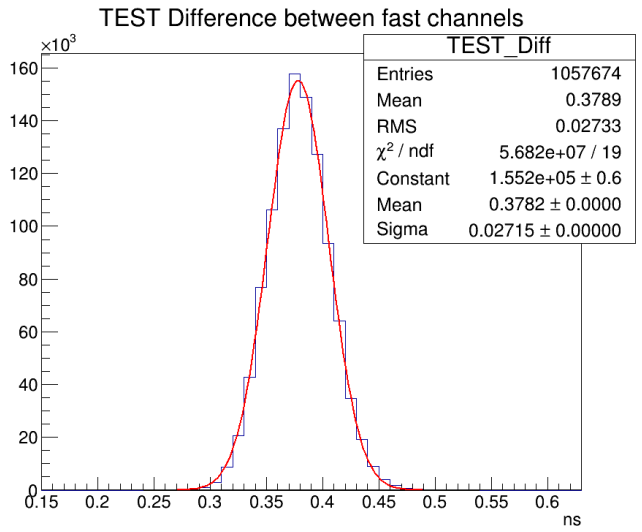
- PMT like pulser signal as input into PaDiWa-AMPS
- Measured was the jitter between two FAST channels

→ Time precision (characterized by sigma) of about **~ 27 ps / $\sqrt{2}$ = 19 ps**





HADES cave in September 2017

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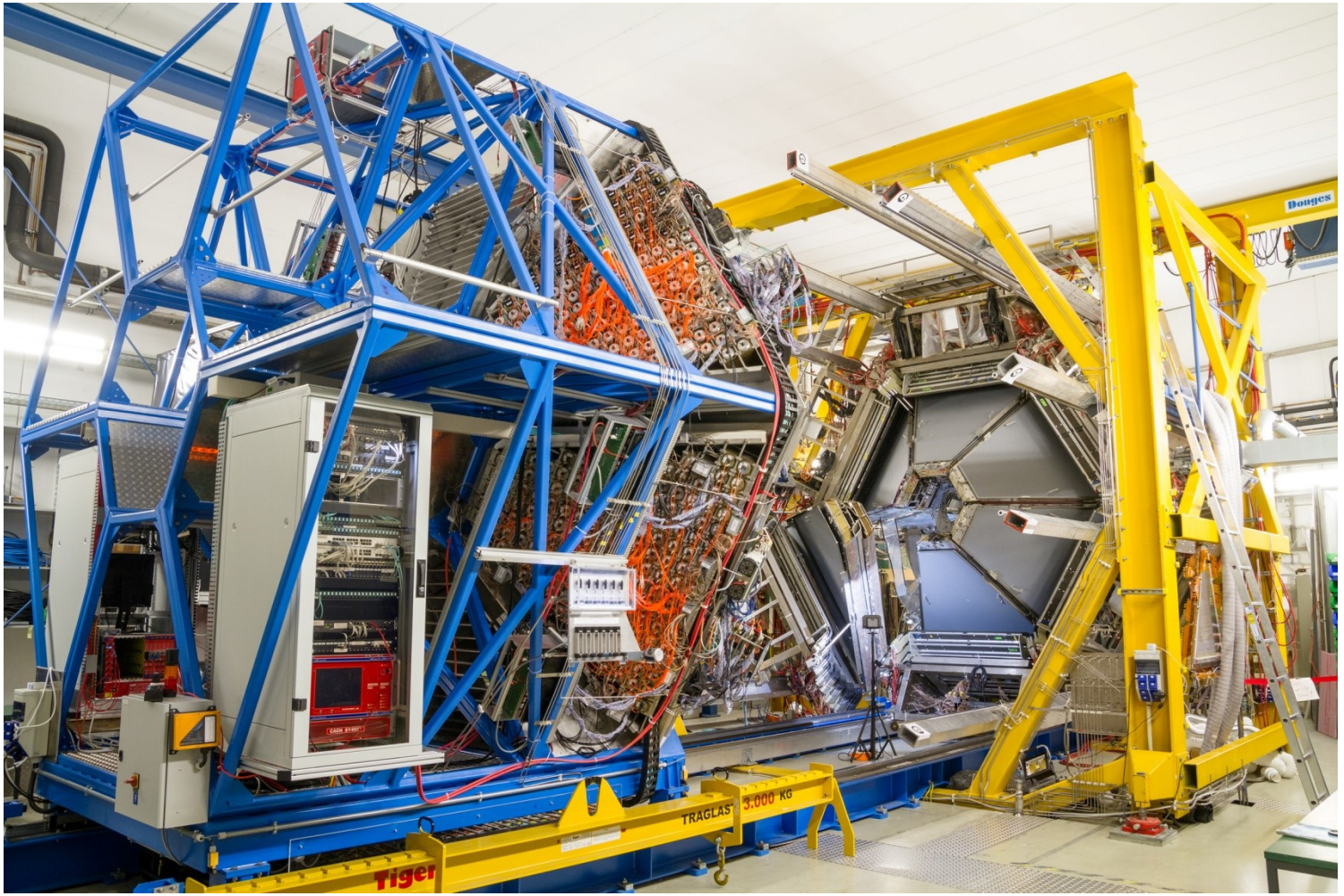
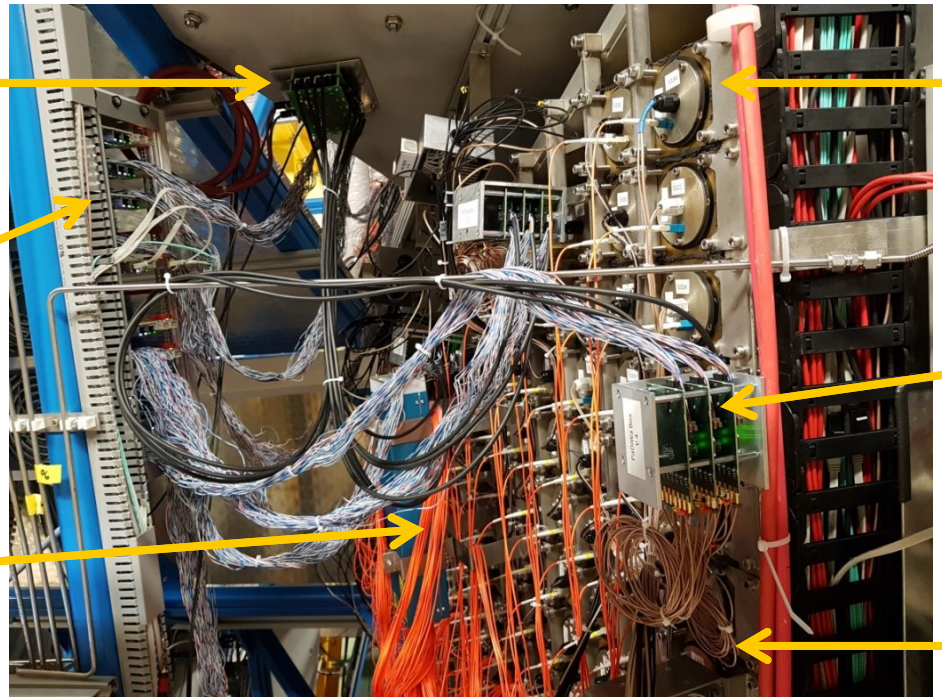
HADES cave in October 2018

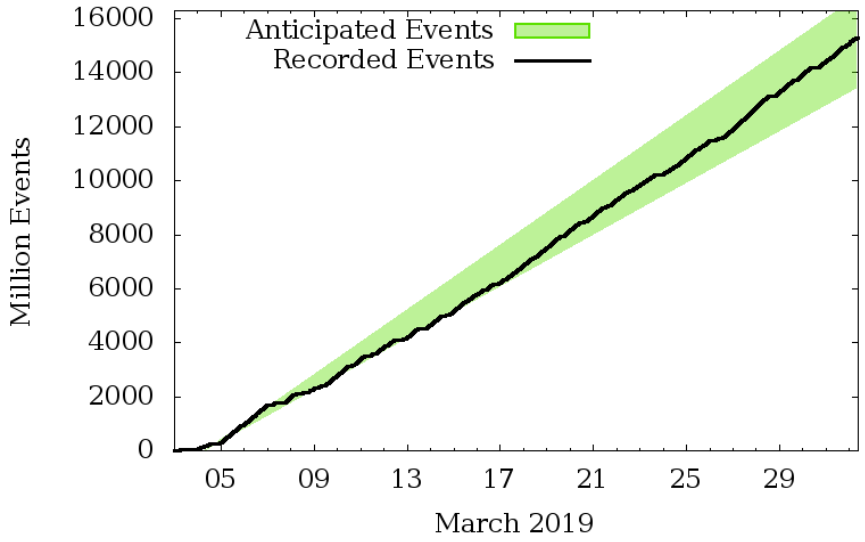


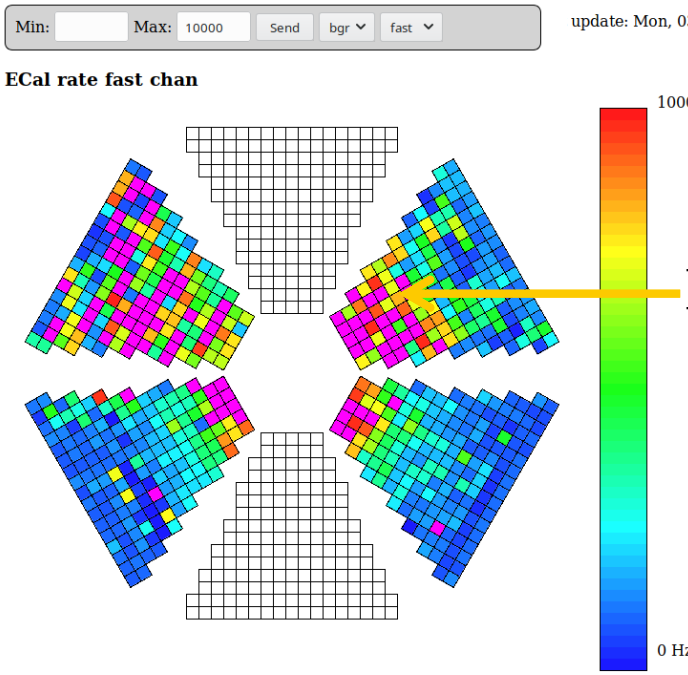
Installation of read-out electronics



Read-out of **one** ECAL sector:
21x PADIWA-AMPS2 boards
6x TRB3sc → TDCs
1x TRB3sc Hub → data transport

HADES Ag+Ag 1.58A GeV beam time in March 2019



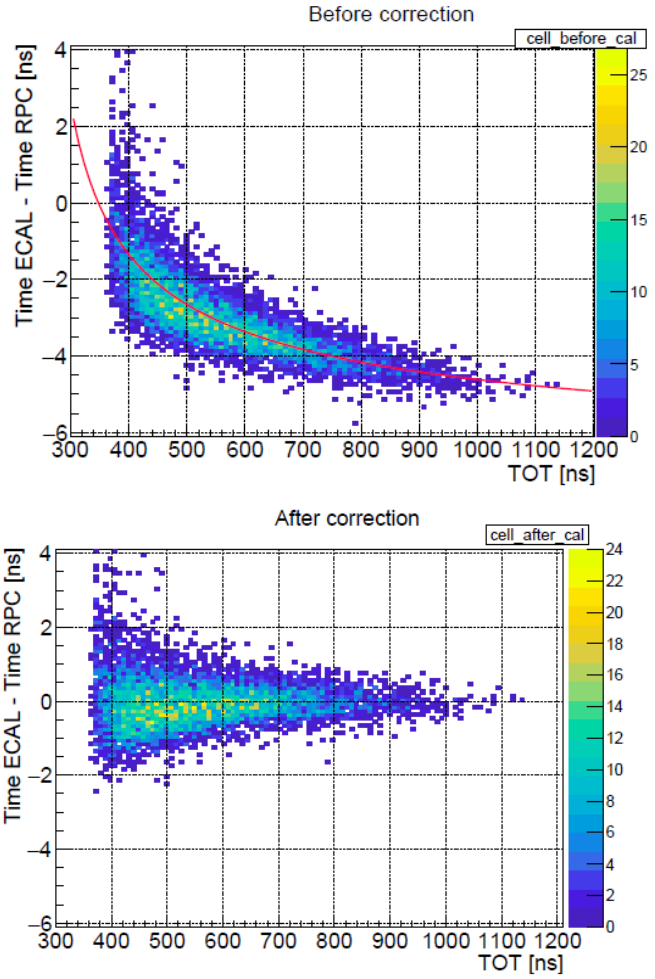


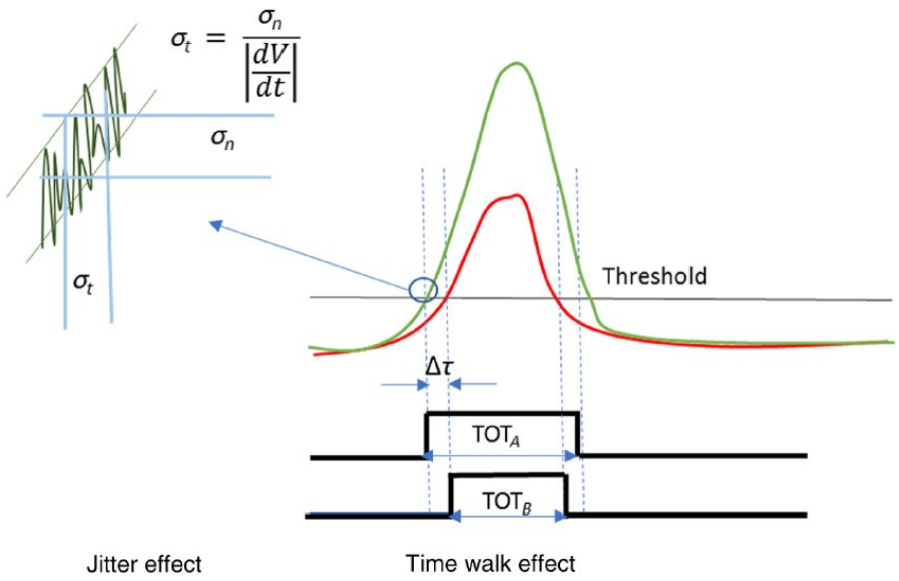
Higher rates in upper two sectors are due to a shielding issue
→ See P. Chudoba

HADES run statistics:
Read-out rate: 10 kHz
Data stored: 359.32 TB

ECAL configuration:
Two upper sectors: 3 inch PMTs
Two lower sectors: 1.5 inch PMTs

Ongoing work: Time walk correction & Calibration of ECAL





- Time-walk correction with the help of the RPC detector which is located 10 cm in front of ECAL

Ongoing work: Energy calibration

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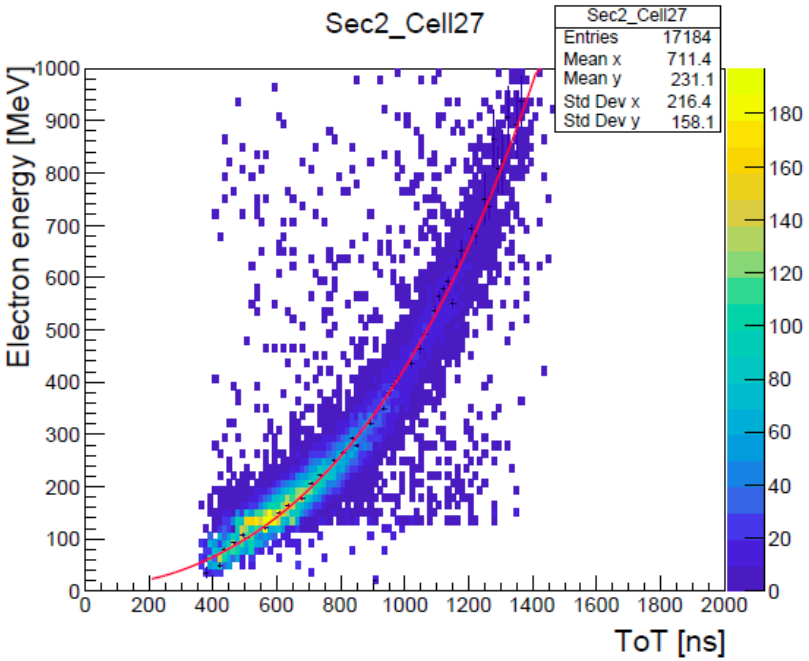
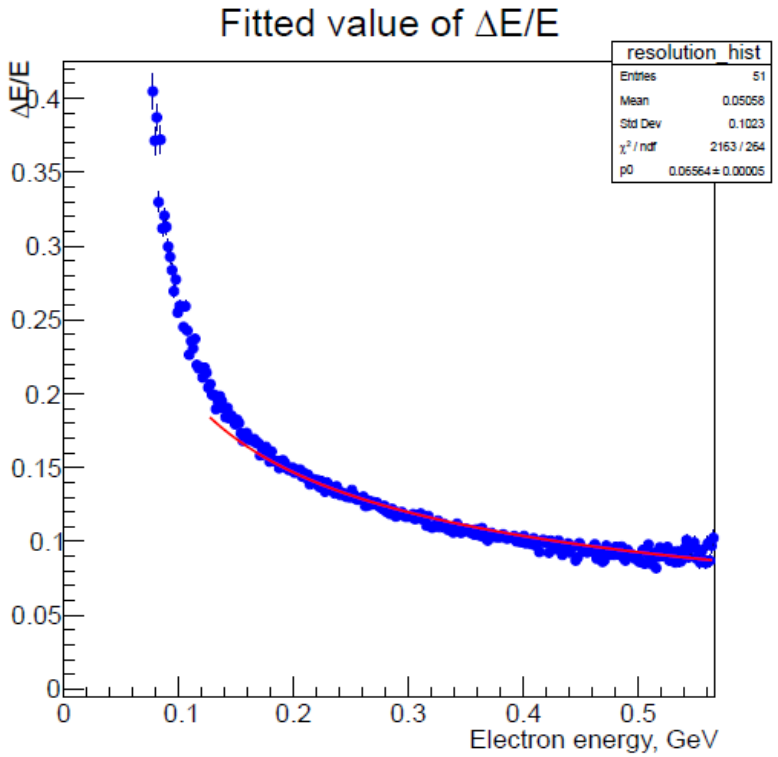
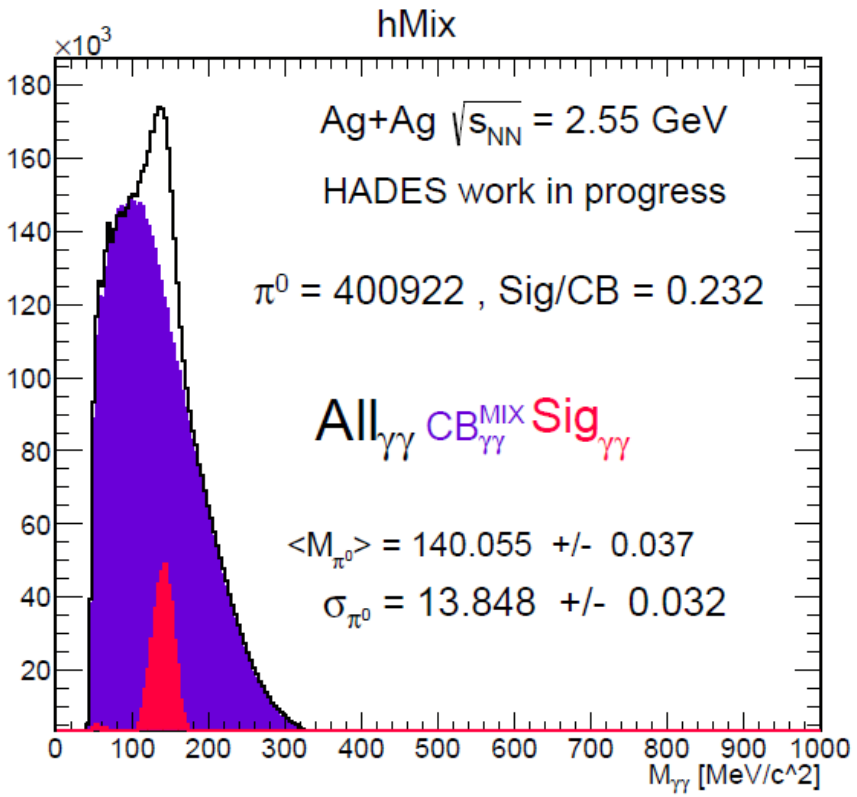




- Energy calibration of ECAL with electrons measured by the HADES tracking system
- Preliminary energy resolution is: 6.6%/√E[GeV]

Ongoing work: Reconstruction of the π^0 meson



- Reconstruction of decay channel: $\pi^0 \rightarrow \gamma\gamma$
- All possible combinations of the identified photons (black histogram)
- Mixed-event combinatorial background (blue histogram)
- Signal after background subtraction (red histogram) are indicated

→ A clear π^0 peak is visible on top of the combinatorial background

Another TRB read-out application: Time of flight measurement in HADES

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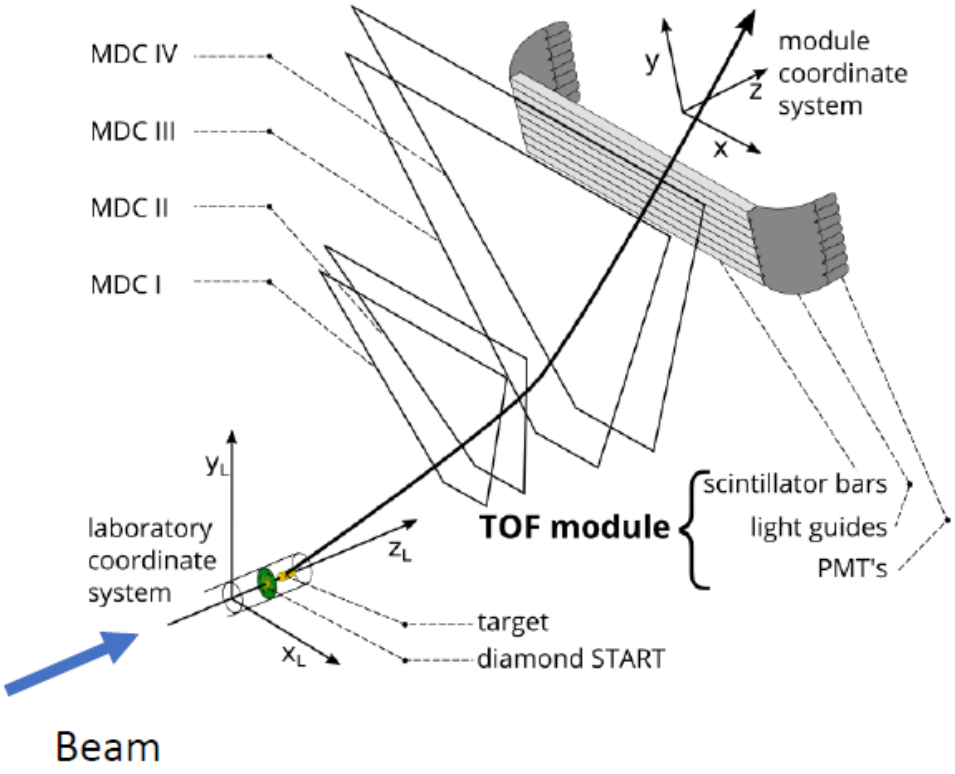
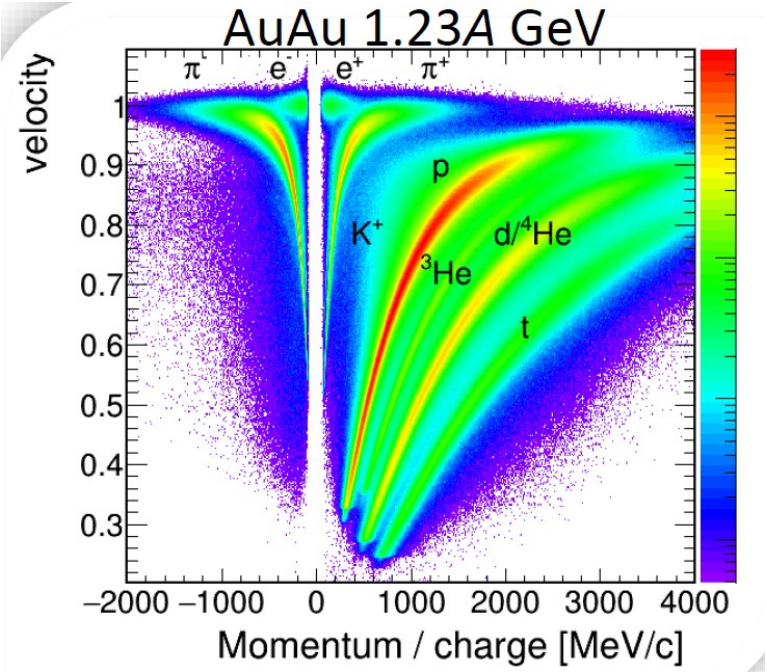
$ToF = T_{TOF} - T_{START} \rightarrow \sigma_{ToF} = \sqrt{\sigma_{TOF}^2 + \sigma_{T\_START}^2}$

β = ToF/ path c





Ongoing R&D in HADES

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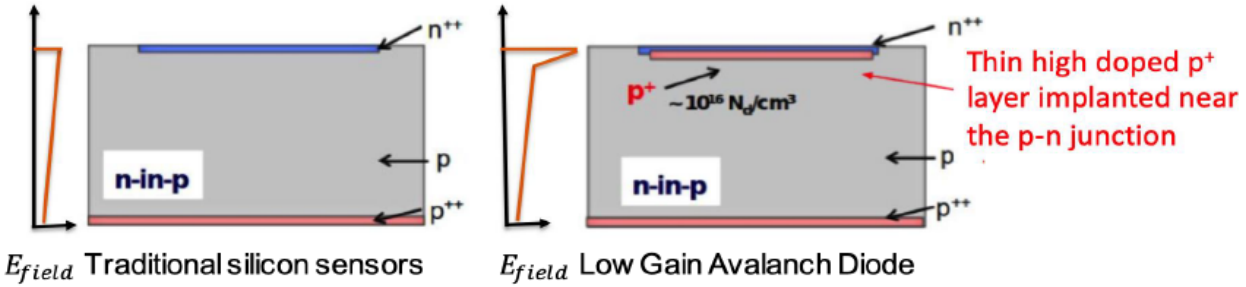
Ultra Fast Silicon Detectors (UFSD) (N. Cartiglia et al., arXiv:1312.1080)

- Very active developments in the ATLAS and CMS collaborations (Italy: INFD &FBK)
- 30 ps time precision → excellent timing detector
- implanting an extra doping layer to achieve controlled charge multiplication
- Same principle as APD, but with much lower gain
- Cheap

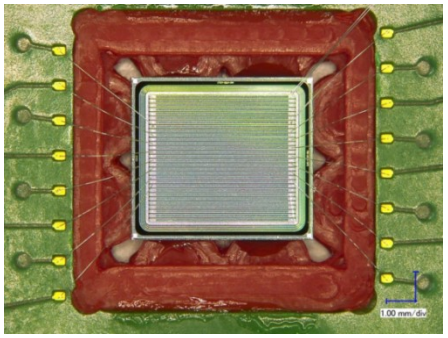


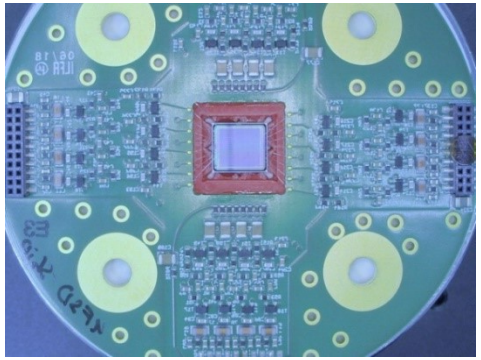
Issues:

- Read-out → TRB platform
- Radiation hardness
  → tested with n: $6*10^{15}$ cm^{-2}

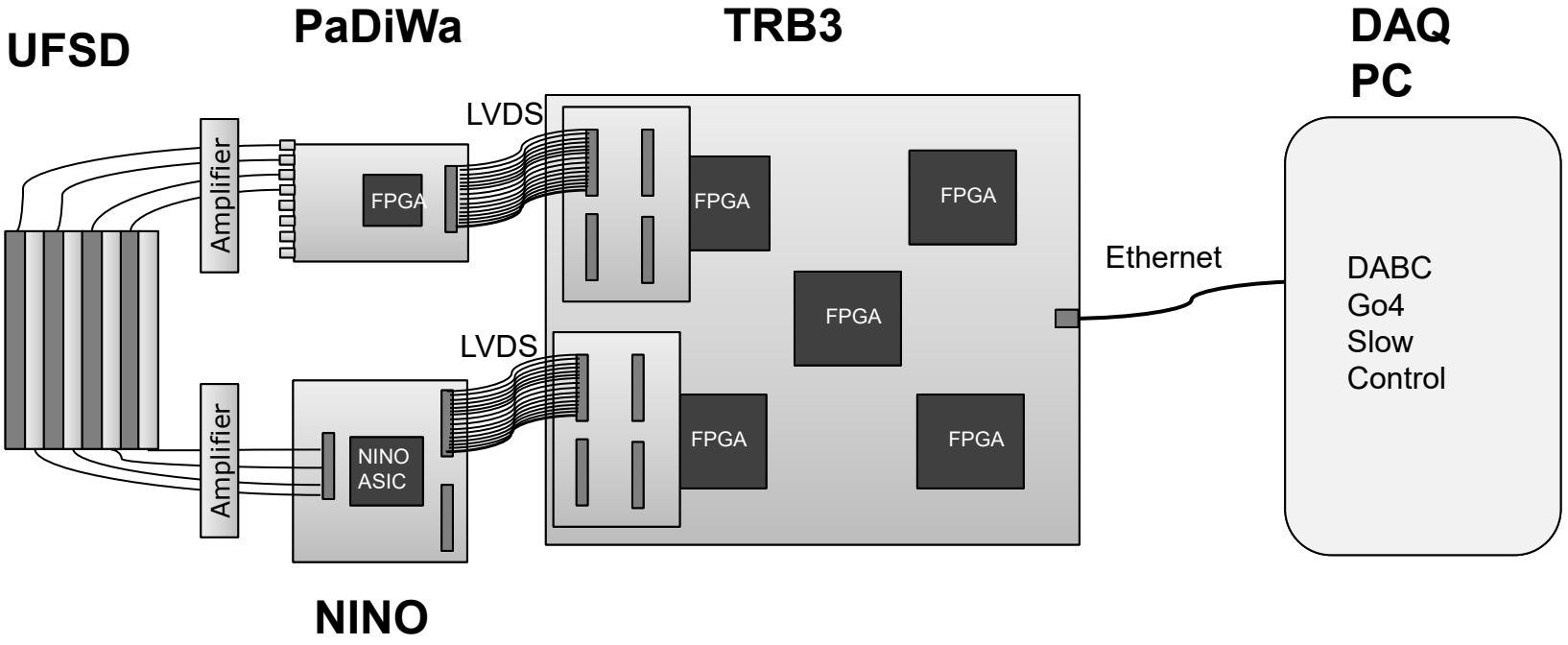
Kramberger , G. et al. Nucl . Instrum . Meth . A891 (2018) 68 77

→ Sensor at GSI for tests
→ Beam tests planed at
COSY (FZ Jülich) and
S-DALINAC (TU Darmstadt)





TRB3 bases read-out scheme of UFSD



- UFSD Prototype detector at GSI is read out by two discriminator systems:
  → Padiwa discriminator (see trb.gsi.de)
  → NINO ASIC (see F. Anghinolfi et al., "NINO: an ultrafast low-power front-end amplifier discriminator for the time-of-flight detector in the ALICE experiment," in *IEEE Transactions on Nuclear Science*, vol. 51, no. 5, pp. 1974-1978, Oct. 2004.)

Evaluation of the time precision with 1.95 GeV protons at COSY (FZ Jülich)

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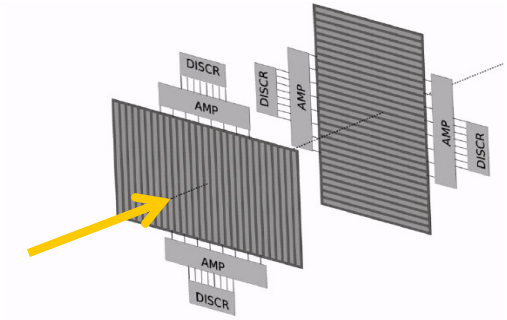

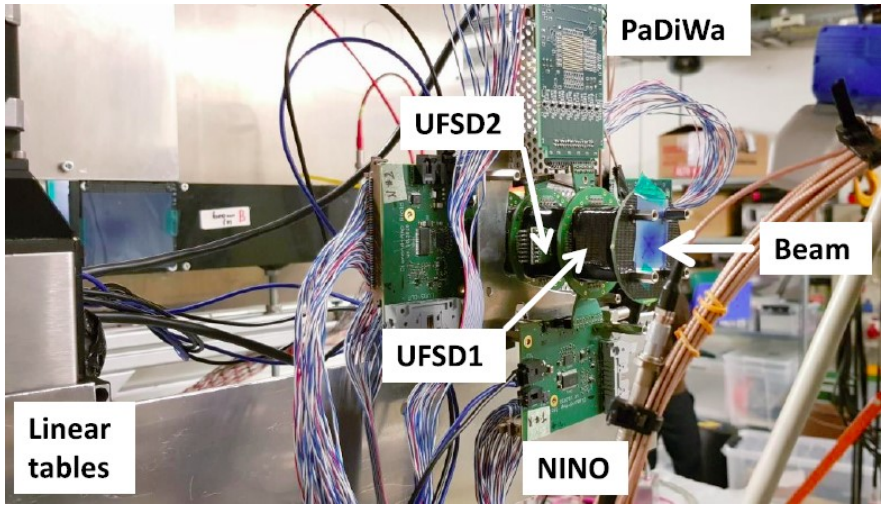

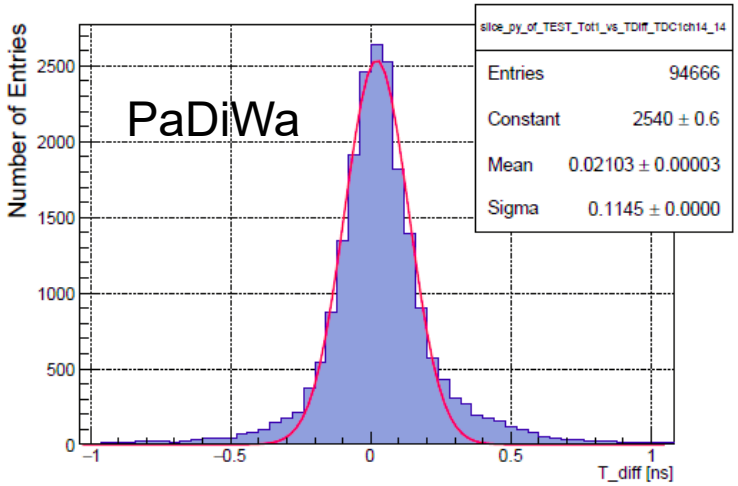

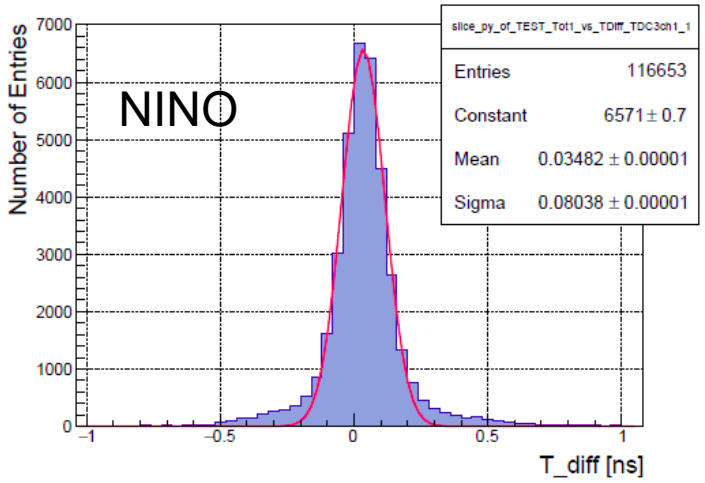

σ_{NINO} = 80 ps / $\sqrt{2}$ = 57 ps

σ_{PaDiWa} = 115 ps / $\sqrt{2}$ = 81 ps

ACCELENCE

Summary and outlook

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- KISS read-out concept for ECAL
  → Successful operation during a HADES beam time
  → Detector calibration and data analysis is ongoing → stay tuned!

- KISS read-out concept for UFSD
  → First results are promising with time precisions of ~ 56 ps
  → Further test will follow → new sensors & new read-out electronics

Thank you for your attention!!!

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HADES

Further HADES talks: Petr Chudoba (Monday), Christoph Blume (Friday)

ACCELENCE