Low Gain Avalanche Diodes for Beam Monitoring and T0 Determination in HADES

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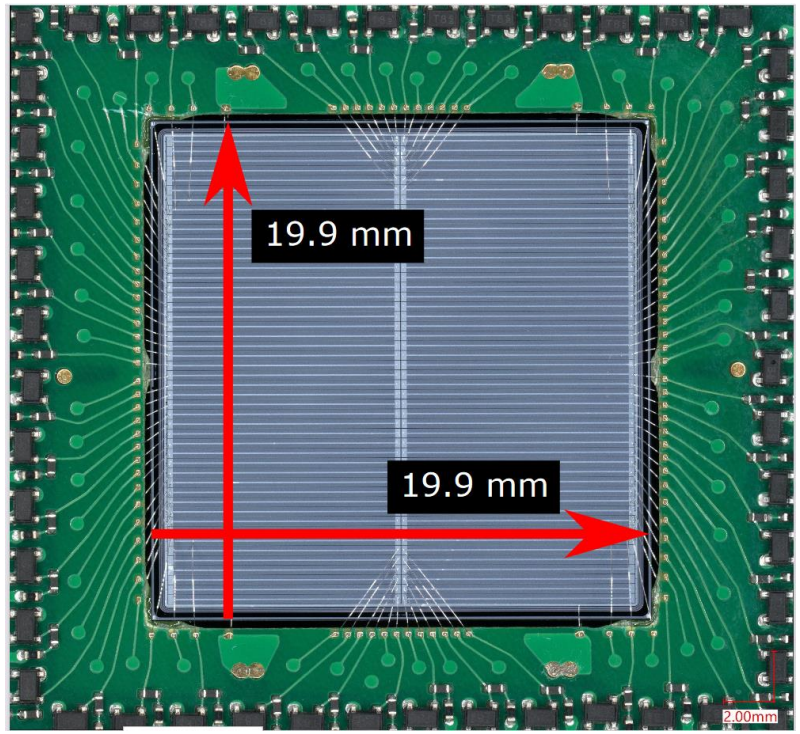
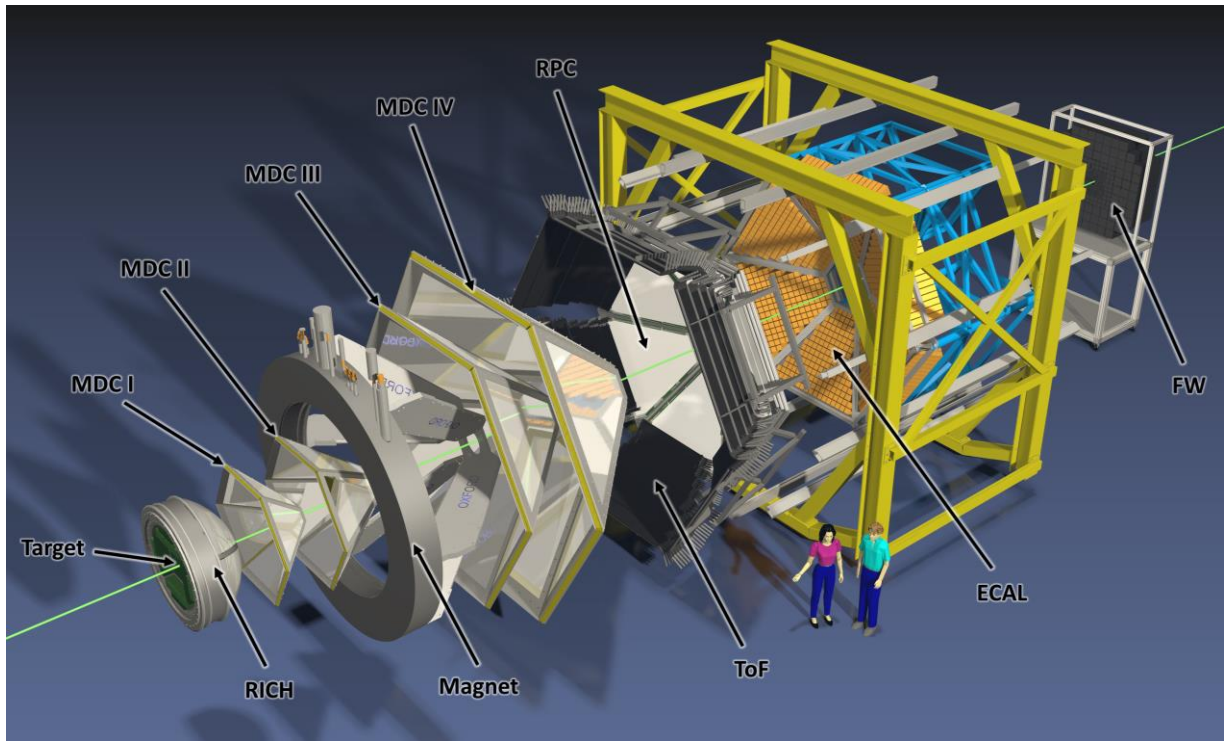
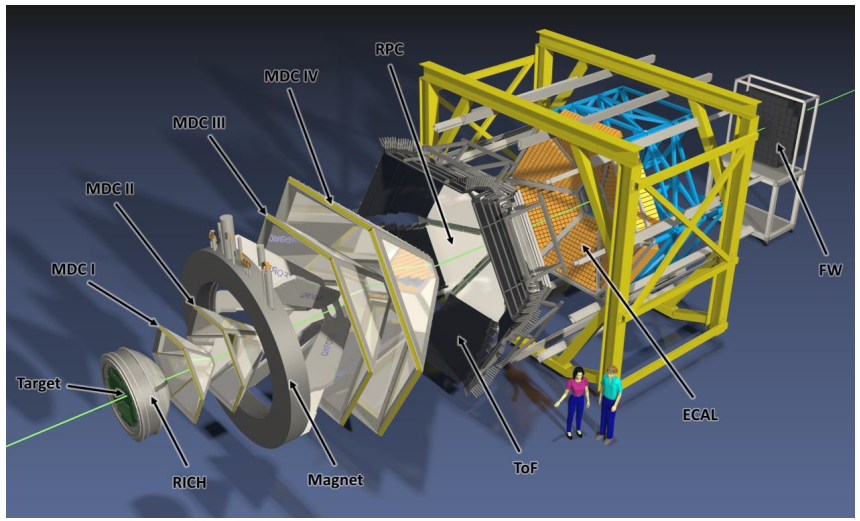




Introduction

HADES



High **A**cceptance **D**i-**E**lectron **S**pectrometer (**HADES**)

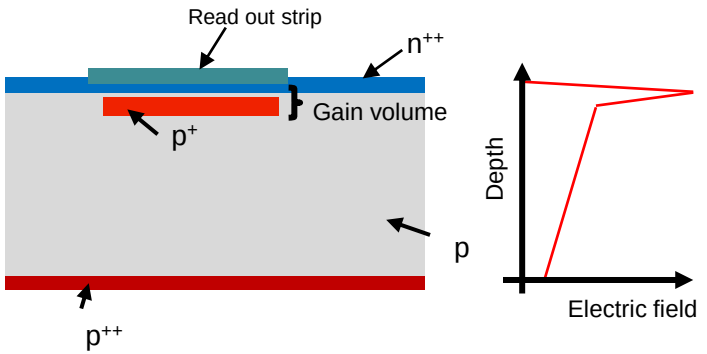
- Fixed target experiment at SIS18, GSI
- Heavy-ion, **proton** and secondary pion beams with energies of a few AGeV
- Up to 50 kHz trigger rate
- PID via: **Time-of-Flight (ToF)**, energy loss ($\frac{dE}{dx}$), Cherenkov effect …

T0 Detector in HADES

HADES T0 detector:

- Precise reaction time determination to be used in **P**article **I**dentification (PID)
- Beam monitoring (micro/macro spill structure)
- Placed in-beam in front of the target
  - Radiation hardness and rate capability is crucial
- Heavy-ion: scCVD Diamond
- **4.5 GeV protons** (10^8 protons/s) in 02/22: **LGADs**

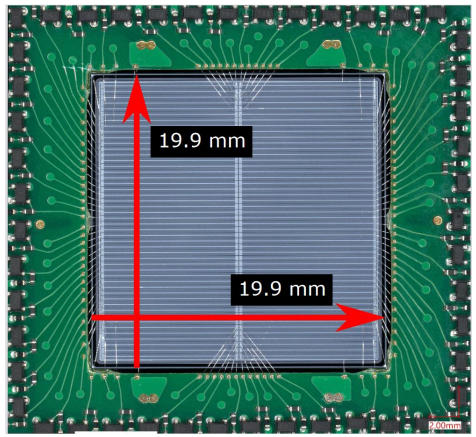
LGAD

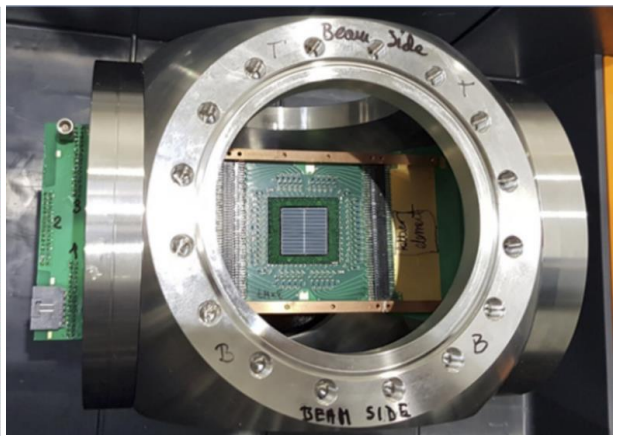


- Thin silicon sensors with an additional gain layer
- Optimized for precise timing measurements
- Usually operated at gains ≈ 10-30

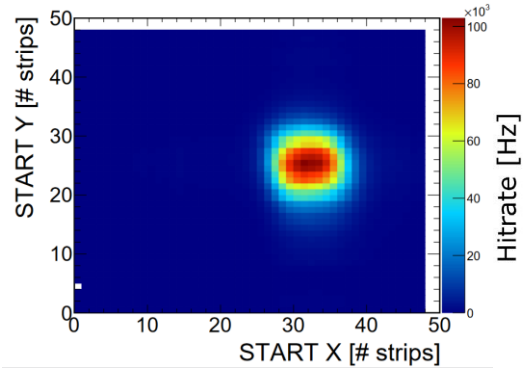
LGAD based T0 Detector in HADES

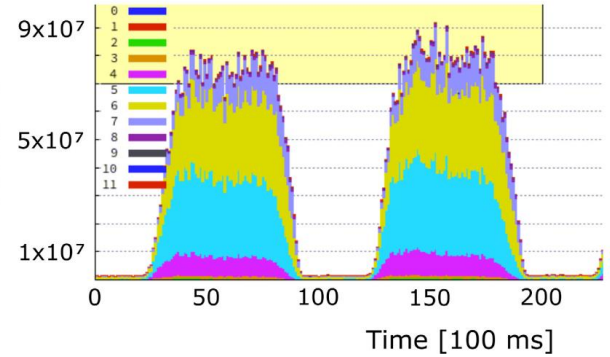
Requirements:
- Timing precision below 100 ps
- Fill factor close to 100 %
- Radiation hardness : 10^{14} n_{eq} / cm²





LGADs from **Fondazione Bruno Kessler (FBK)** as part of a larger LGAD production for HADES
- T0 detector consists of 2 sensors each: 2 x 2 cm², 96 half-strips, 387 µm pitch
- Thinned to 200 µm total thickness



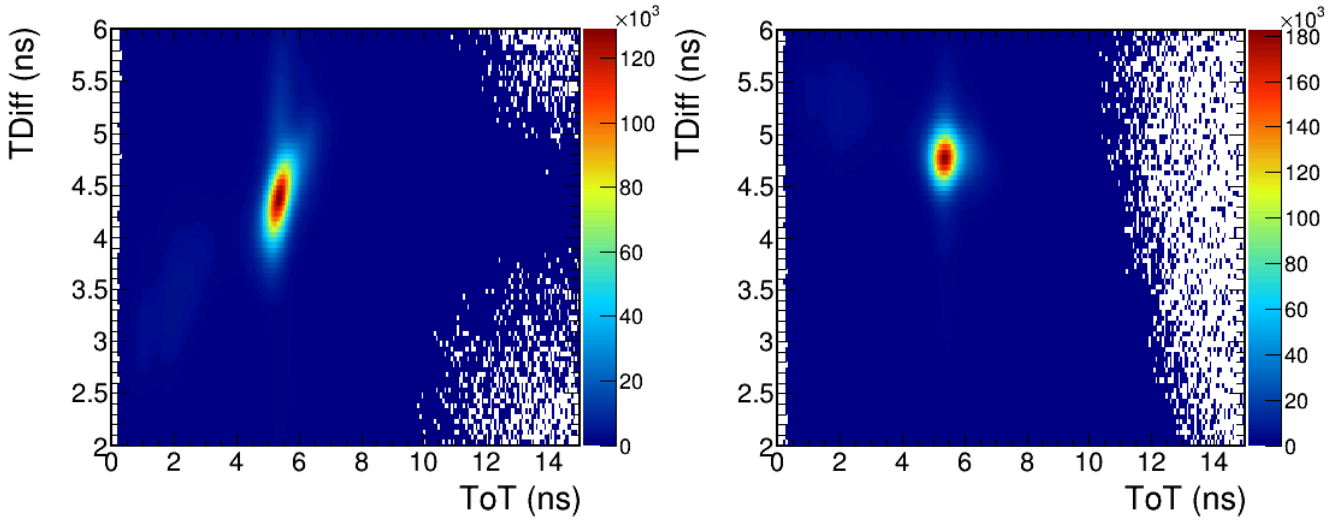


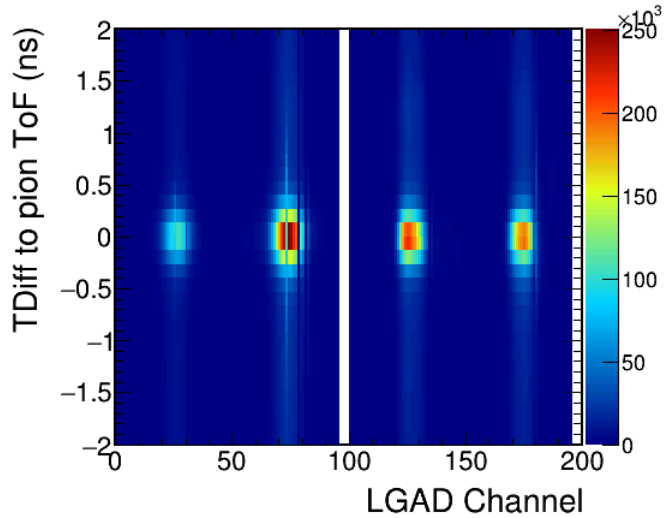
W. Krüger et al., Nucl. Instrum. Meth. A 1039 (2022), p. 167046, https://doi.org/10.1016/j.nima.2022.167046

- LGADs mounted on PCBs in vacuum
- Two stages of amplification on PCB
- Outside of vacuum: connection to PaDiWa discriminator boards and FPGA based TDCs (trb.gsi.de)
- Leading and trailing edge timing of signals recorded

LGAD Calibration

On plot: time difference between leading edge timing of single channels
in each LGAD vs Time-over-Threshold (ToT) of one channel





Time walk correction

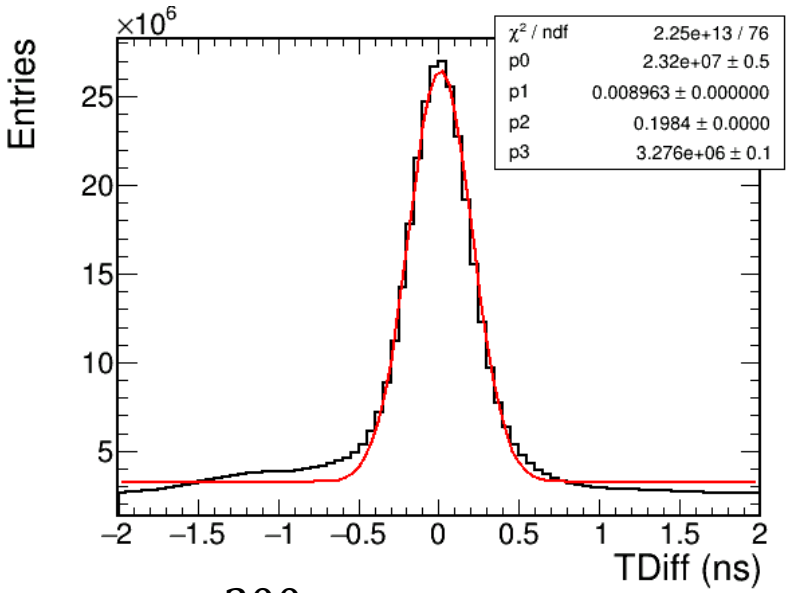
- Time walk effect: signal amplitude dependent delay of leading edge timing when using constant threshold discriminators
- Can and needs to be corrected for to reach optimal timing precision

Offset Calibration

- Using a third detector as a reference (RPC)
- Calibrate such, that ToF of reconstructed negative pions is equal to the ToF measured between T0 detector and RPC

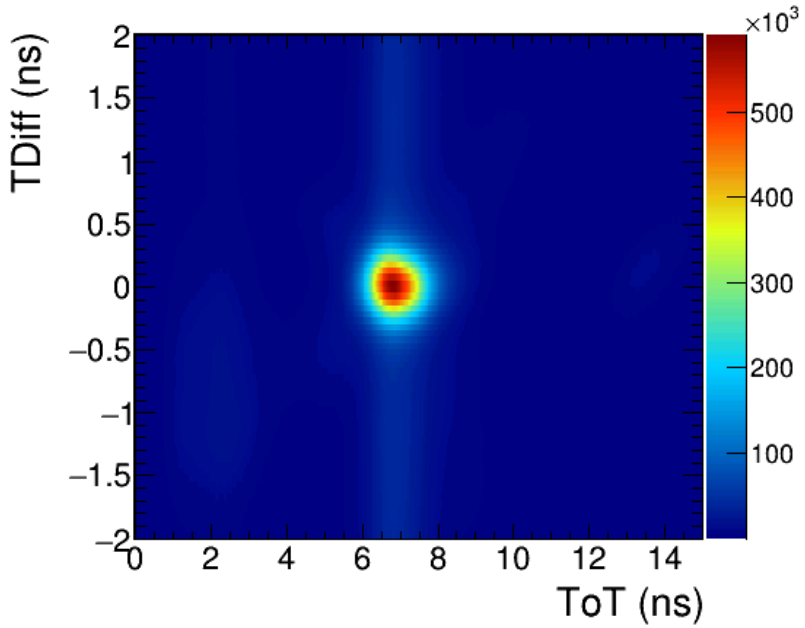
LGAD Performance

Time difference distribution between two LGADs



$$\sigma_t = \frac{200\ ps}{\sqrt{2}} \approx 140\ ps$$

- Preliminary Timing precision of 140 ps reached per sensor
- Significantly worse than performance in a full system test in Nov21 at COSY in Jülich (≈ 85 ps)
  - Possible reasons (under investigation): no cooling of the sensors, noise situation at HADES …



Current activities and outlook

- Full calibration of each strip for **each** hour of the beam time
  - In total ≈ 600 hours, where data was collected
  - **All calibration**, including Time walk corrections, to be done using reconstructed negative pions
- Investigation of various detector properties hour by hour:
  - **Timing precision**
  - **Efficiency**
  - …
- Various additional activities in our LGAD group (see also: **F. Ulrich-Pur, 8th annual MT meeting** https://indico.desy.de/event/33132/contributions/128249/)