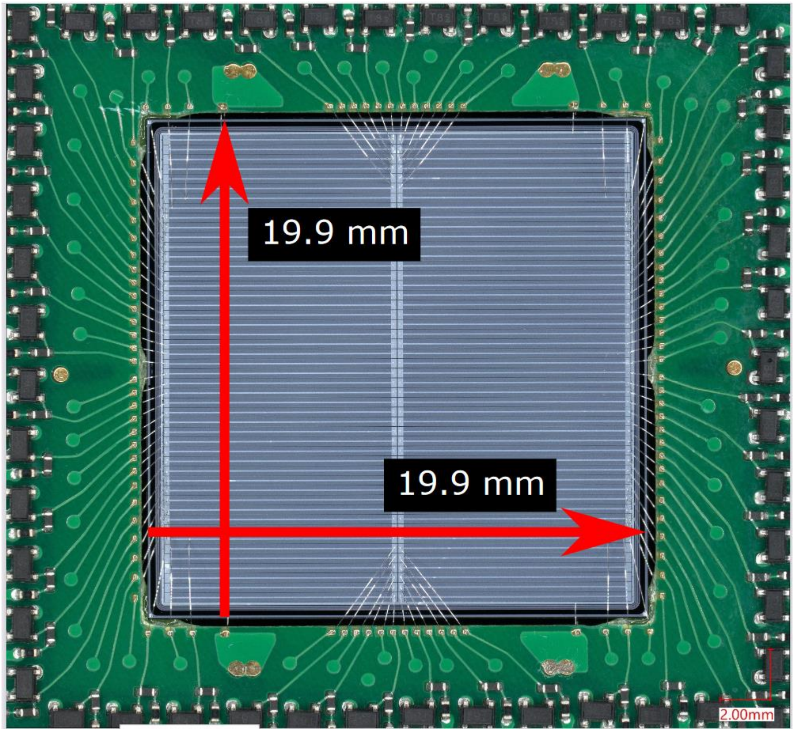
Performance of the LGAD-based in-beam detector at HADES

Wilhelm Krüger

For the HADES LGAD-Team



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Sergey Linev, Jerzy Pietraszko, Christian Joachim Schmidt, Michael Träger, Michael Traxler, Felix Ulrich-Pur

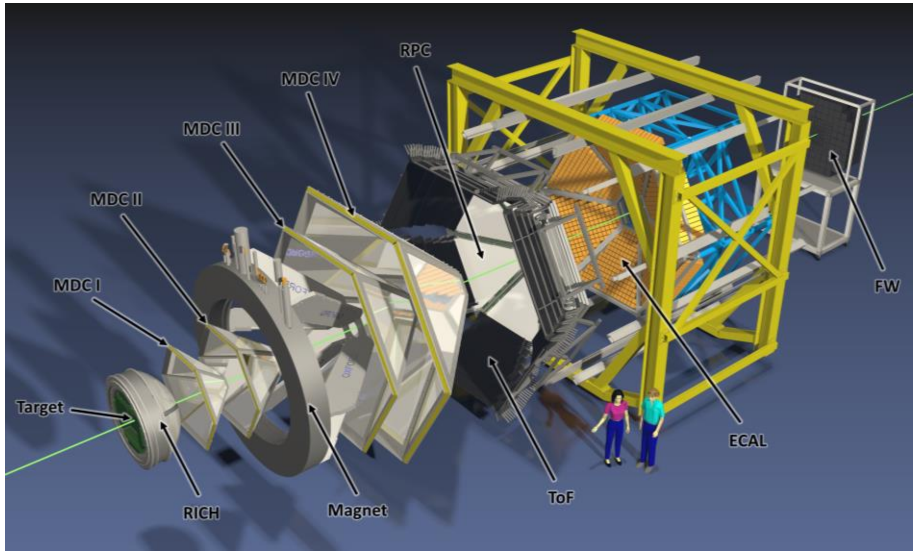
Goethe University Frankfurt:
Jan Michel

Fair GmbH:
Adrian Rost

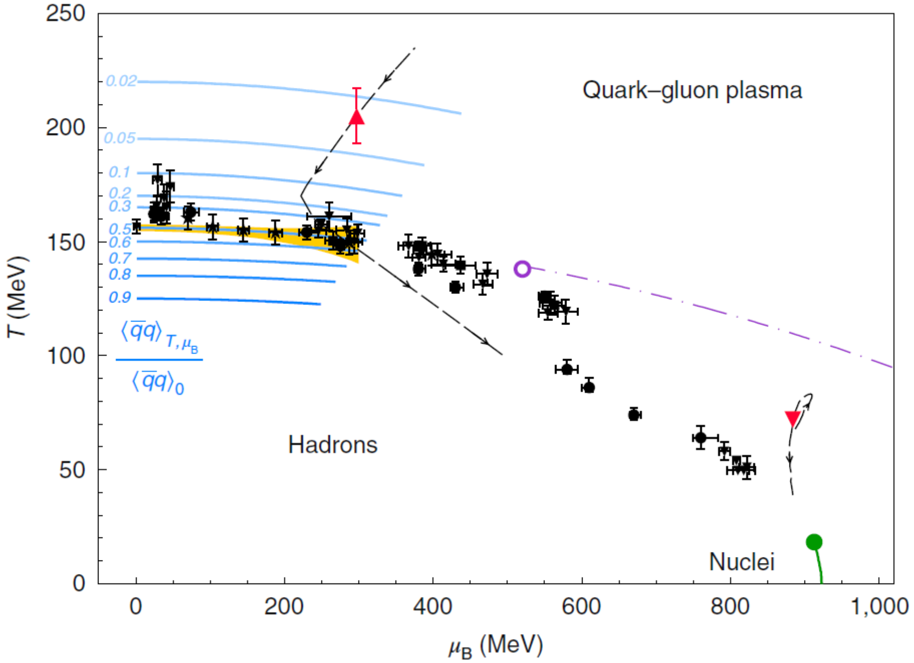
Introduction to HADES

HADES, Eur.Phys.J.A 41 (2009) 243-277

- **H**igh **A**cceptance **D**i-**E**lectron **S**pectrometer
- Fixed target experiment at SIS 18, GSI Darmstadt
  - Heavy ion, proton and secondary π beams
  - Energies of few GeV (per nucleon)
- PID using: **Time of Flight** (ToF), energy loss ($\frac{dE}{dx}$), Cherenkov effect, …



S. Spies



HADES, Nature Phys. 15 (2019) 10

HADES explores the phase diagram of strongly interacting matter at high μ_B:

- Rare and penetrating probes: di-electrons, subthreshold strangeness production, …

In-Beam Detector

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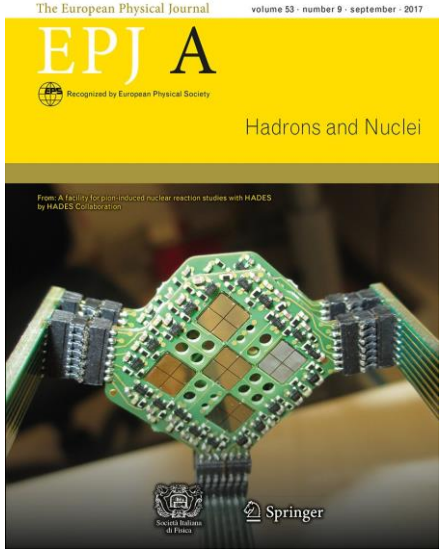
In-beam detector used for:

- T0 determination
- Beam quality monitoring
- Luminosity monitoring

Requirements:

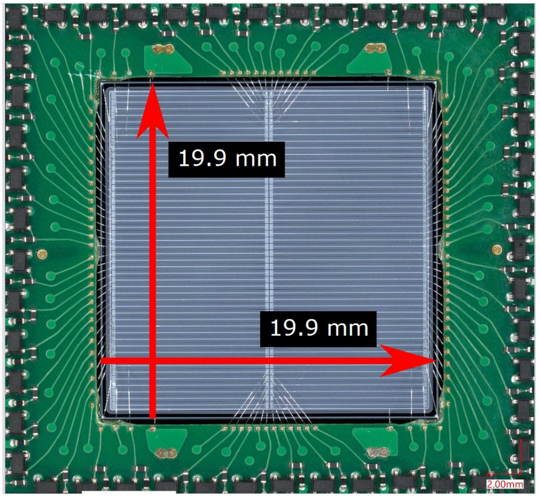
- Timing precision below **100 ps**
- Position determination better than **0.5 mm**
- Low Material budget
- High radiation hardness
- **Single particle detection at 10^8 protons/s**

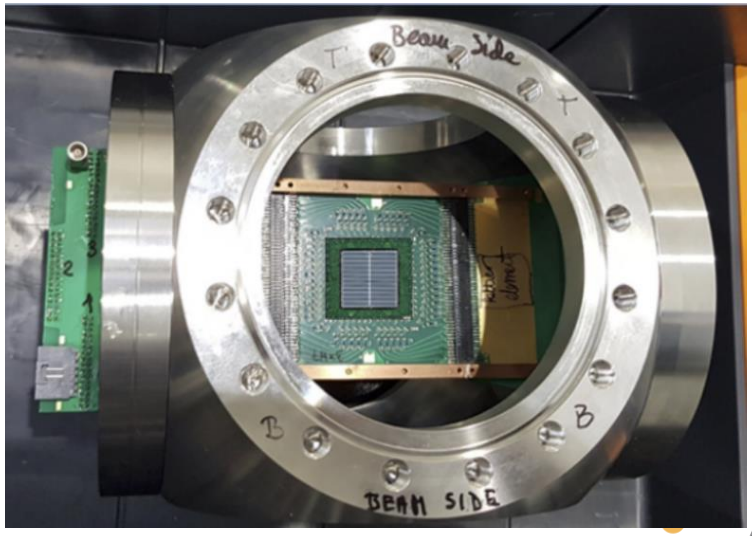
J. Adamczewski-Muschet et al.,
Eur. Phys. J. A (2017) 53: 188



Start Detector scCVD diamond

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





LGAD Sensor

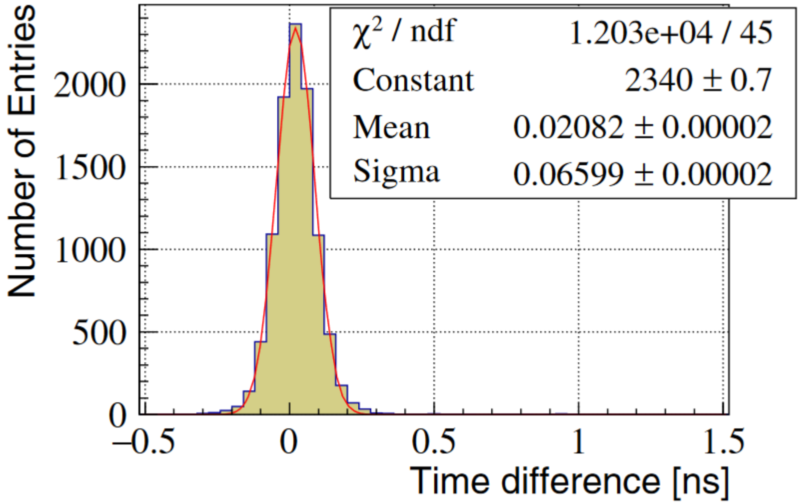
GSI HADES

Road to LGAD-based In-Beam Detector

LGAD test at COSY in Jülich 2019:

- 1.92 GeV proton beam (**MIPs**)
- Sensors: pitch 146 µm, strip-strip 20 µm, gain-gain ≈ 90 µm, active thickness 50 µm, 5.0 mm x 4.3 mm sensor size
- $\boldsymbol{\sigma_t < 50\,ps}$ $(\frac{66}{\sqrt{2}}\,ps \approx 47\,ps)$ reached

➔ Requirements achieved in prototyping phase

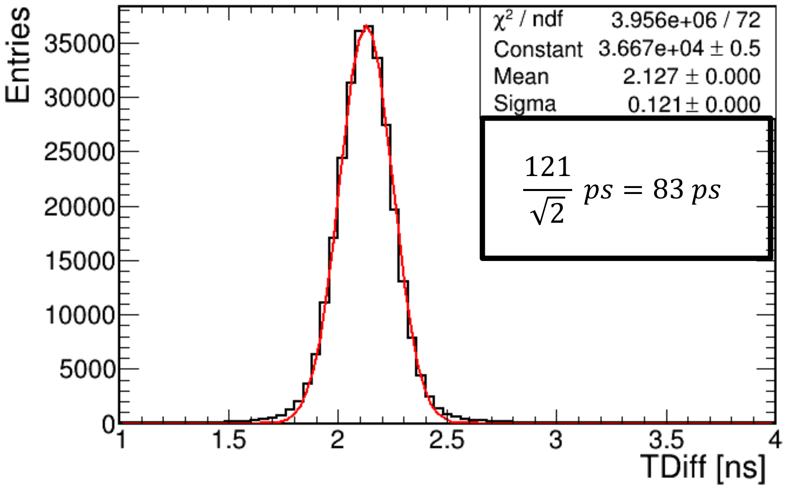


Pietraszko, J. et al., Low Gain Avalanche Detectors for the HADES reaction time (T0) Detector upgrade, Eur. Phys. J. A 56, 183 (2020)

HADES LGAD production by Fondazione Bruno Kessler (FBK):

- **50 µm** active thickness, 200 µm total thickness
- **14 µm** strip-strip**, 24 µm** gain-gain
- **387 µm** pitch, 19.9 mm x 19.9 mm sensor size
- 96 channels divided into 2 x 48 half-strips
- Strip capacitance about **10 pF**
- Full-system test in Nov 2021 at COSY

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



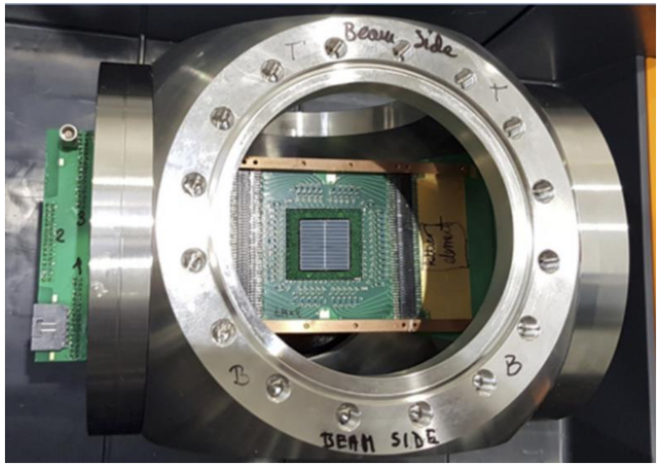
HADES In-Beam Detector Performance in February 2022 (4.5 GeV Protons @ 10^8 protons/s)

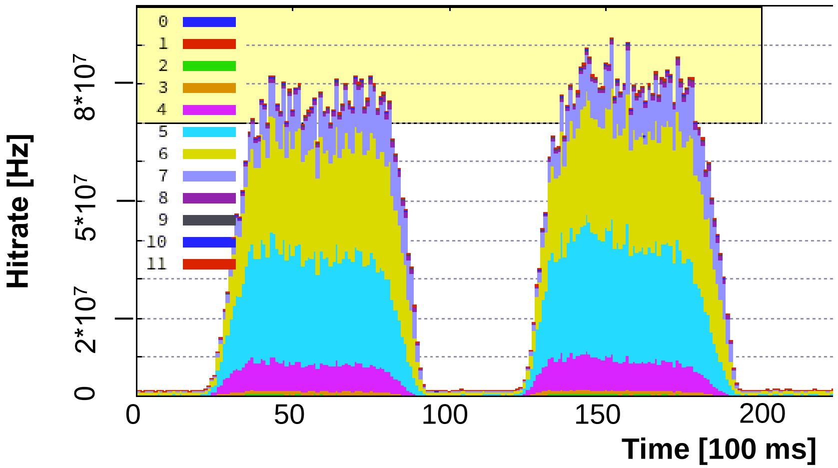
- **Two LGADs (x and y) mounted in vacuum**
  - Two amplification stages on PCB
  - Constant threshold discriminators (PaDiWa) and FPGA based TDCs (www.trb.gsi.de)
- $\boldsymbol{\sigma_t \approx 140\, ps}$ **per detector reached during operation in HADES**
  - LGADs operated in vacuum, without cooling, significant worse noise situation than at COSY, high rate …

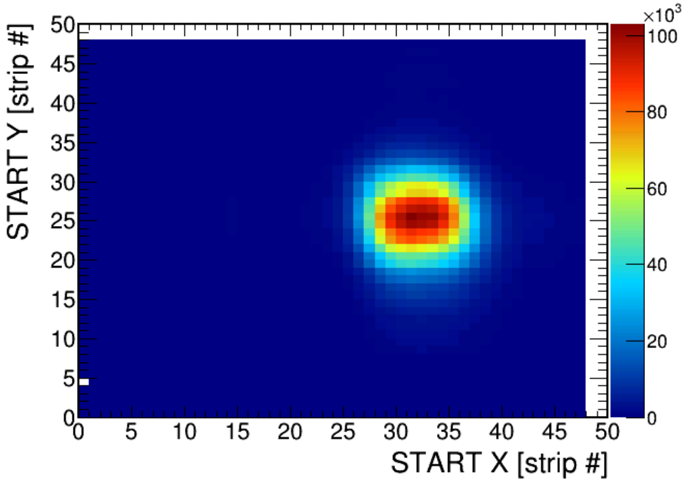
However:

- LGADs successfully used for **beam monitoring**
  - Macro- and micro-spill structure
  - Beam position
- **Part of PID process** via ToF measurements
- T0 possibly useable for background rejection

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







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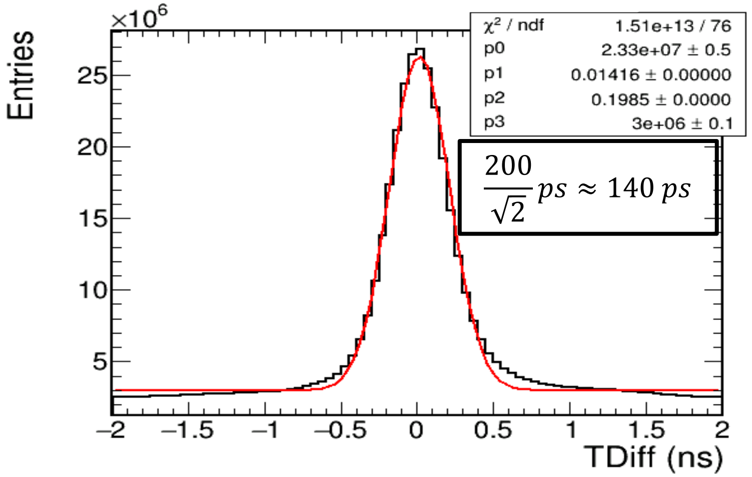

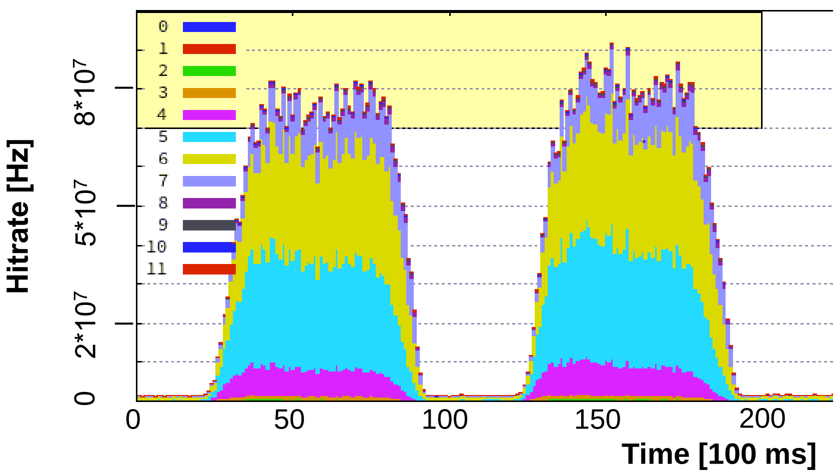

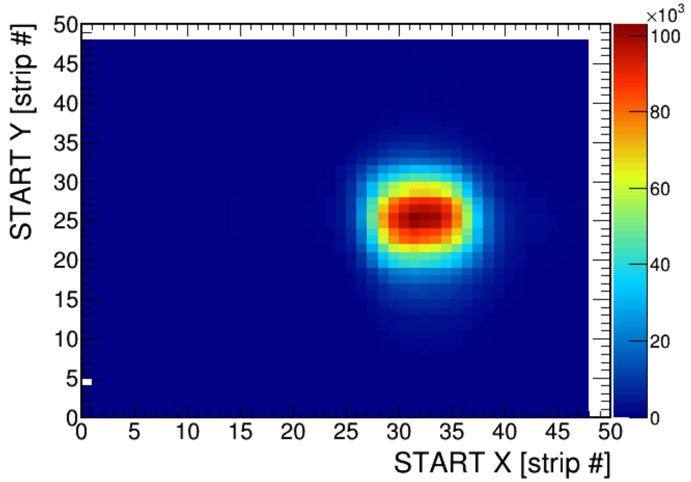

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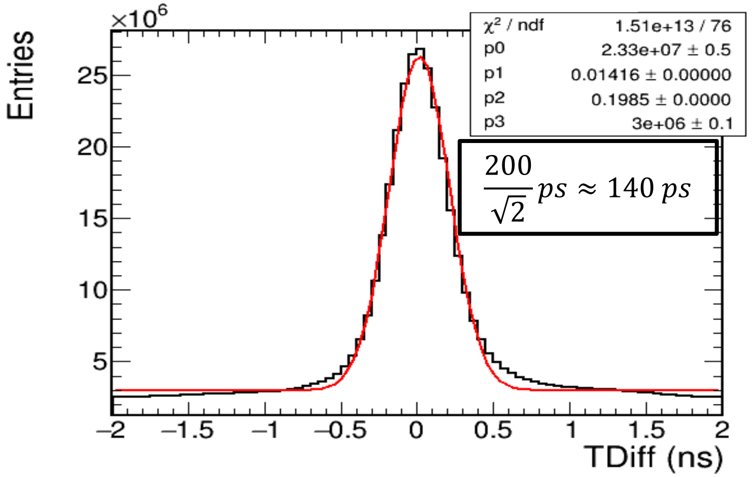

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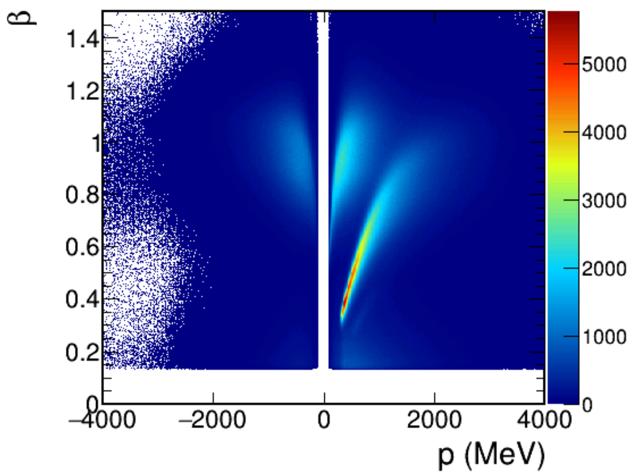
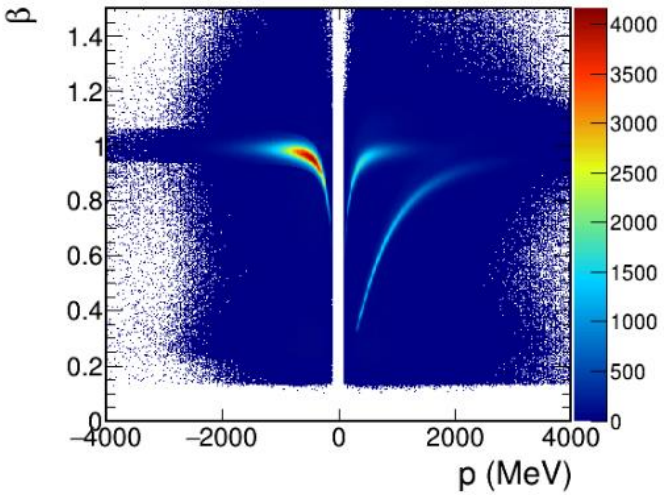


Bad T0 precision



T0 by LGAD

GSI HADES

Summary and Outlook

TECHNISCHE UNIVERSITÄT DARMSTADT

- LGADs were successfully used in the HADES high rate 4.5 GeV pp run in Feb. 2022
  - Timing precision of 140 ps per detector reached
  - Used for beam position and time structure monitoring

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

- Investigation of the influence of radiation damage sensor performance ongoing
  - Timing precision
  - Efficiency
- Additional activities for different applications of LGADs ongoing
  - LGAD for ion computed tomography
  - LGADs for beam time structure monitoring at S-DALINAC for operation in ERL mode (6 GHz time structure)

Felix Ulrich-Pur et al 2022 Phys. Med. Biol. 67 095005, DOI:10.1088/1361-6560/ac628b

V. Kedych et al, Low Gain Avalanche Detector application for beam monitoring, submitted to: IBIC 2022 Proceedings

Thank you for your attention

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