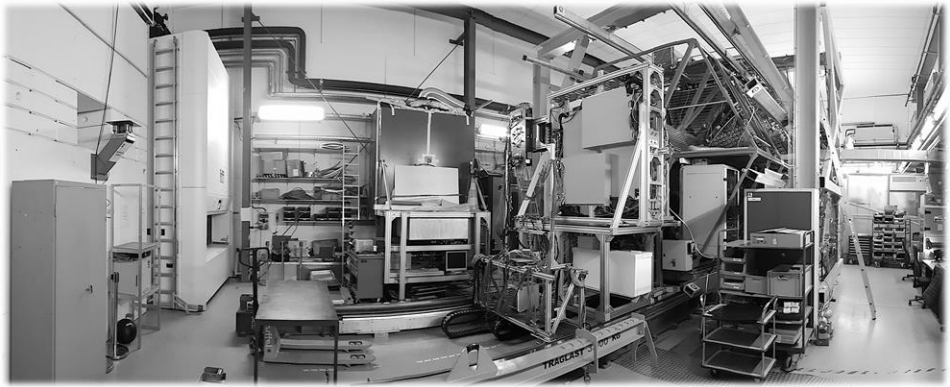
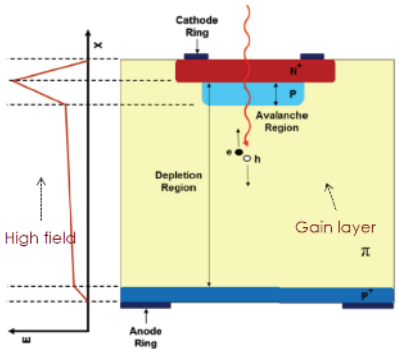
LGAD activities at GSI

Jerzy Pietraszko for the GSI LGAD team

Jan. 31, 2025



LGAD Technology in HADES



Nicolo Cartiglia, INFN, Torino - Berlin 12/06/18
G. Pellegrini, et al. NIM A765 (2014) 12–16

Low Gain Avalanche Detectors (LGAD) technology

(proposed and manufactured by National Center for Micro-electronics, Barcelona)

- Thin gain layer exhibits electric fields (>300 kV/cm)
  - Leads to intrinsic signal amplification
  - Signals with short rise times (<1ns)
- Simultaneous position (<30µm) and time measurement (<50ps), thickness < 200µm

J. Pietraszko[1,a], T. Galatyuk[1,2], V. Kedych[2], M. Kis[1], W. Koenig[1], M. Koziel[3], W. Krüger[2], R. Lalik[4], S. Linev[1], J. Michel[3], S. Moneta[5], A. Rost[2], A. Schemm[6], C. J. Schmidt[1], K. Sumara[4], M. Träger[1], M. Traxler[1], Ch. Wendisch[1]

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Helmholtz Innovation Pool (MU / MT)

The *Tangerine* Project
Towards Next Generation Silicon Detectors

Assosiated partner (w/o funds) of

HIGH-D

HADES
GSI FAIR

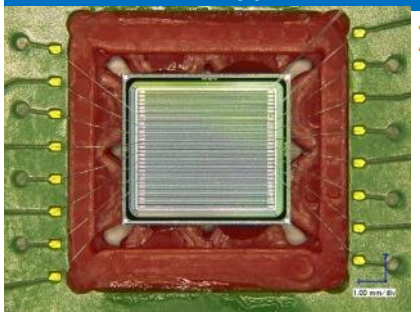
ÖAW HEPHY

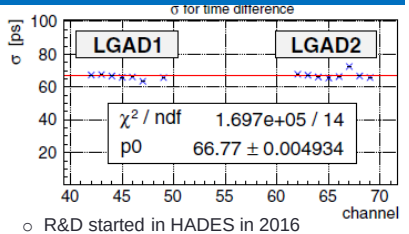
TU WIEN ATOMINSTITUT

CMM CENTER FOR MATERIALS AND MICROSYSTEMS
FONDAZIONE BRUNO KESSLER

INFN TORINO

HADES Prototype LGAD T0 sensor and performance





- R&D started in HADES in 2016
- Excellent performance demonstrated in 2020
  - Time precision below 50ps
  - Rate capability MHz/channel
  - Operation at room temperature

J. Pietraszko, *et al.*, Eur. Phys. J. A 56, 183 (2020)

LGAD Technology in HADES

HADES LGAD Production in 2021

(Metal-Metal distance 14um, Gain-Gain distance 24um)

1. Sensor size: 20 mm x 20mm
   - 2 x 48 half strips (9.28mm long)
   - pitch about 387 um, Die size 19.9 x 19.9mm2
2. Sensor size 1cm x 1cm
   - 45 strips (about 9 mm long)
   - pitch about 192 um
3. Sensor size 1cm x 1cm
   - about 57 strips (about 9 mm long)
   - pitch 150 um
4. **Sensor size 1cm x 1cm (fill factor: 75%)**
   - **about 86 strips (9 mm long)**
   - **pitch 100 um**
5. Sensor size 1cm x 0.5 cm
   - about 73 strips (about 9 mm long)
   - pitch 50 um

Upcoming Production in 2025 at FBK

- 200µm/100µm/50µm
- Trench Isolation technology (fill factor: 96% for 100 µm pitch)
- Low material budget: 200µm → further thinning to 100µm possible

Helmholtz Innovation Pool (MU / MT)

The *Tangerine* Project
Towards Next Generation Silicon Detectors

Assosiated partner (w/o funds) of HIGH-D

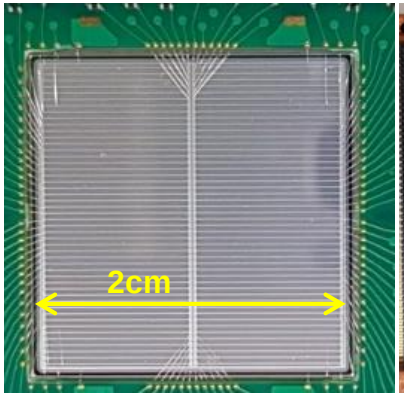
LGAD Technology in HADES

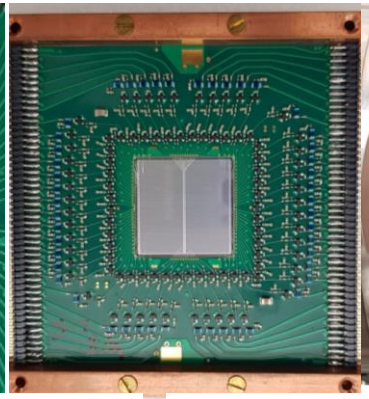
Achieved performance of the HADES T0 detector

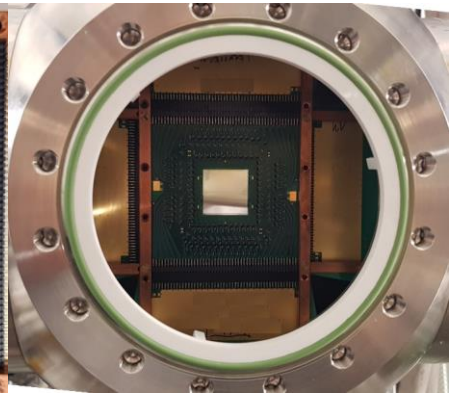
Running conditions at HADES
- **p beam, 4.5 GeV**
- **beam intensity: 10^8 p/s**

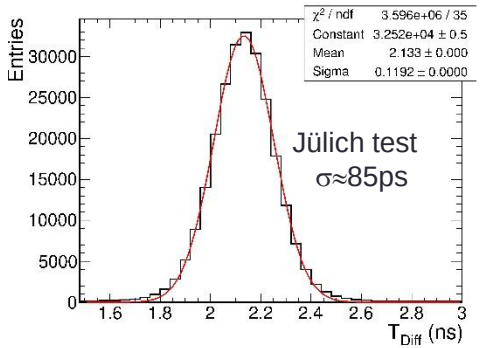
Sensor size: 20 mm x 20mm
- 2 x 48 half strips (9.28mm long)
- pitch about 387 um,
- die size 19.9 x 19.9 mm^2

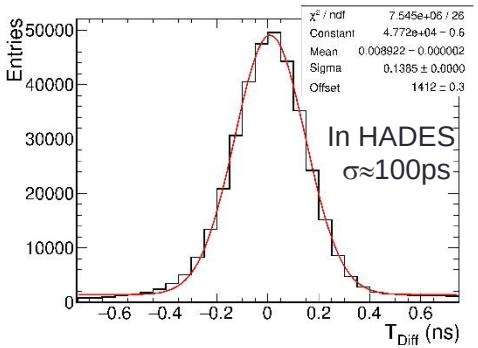
Sensor fill factor: 94 %
Strip capacitance: 10 pF → limited timing perf.
Passive cooling
Timing performance:
Jülich test at COSY in air: σ≈85ps
In HADES in vacuum: σ≈100ps











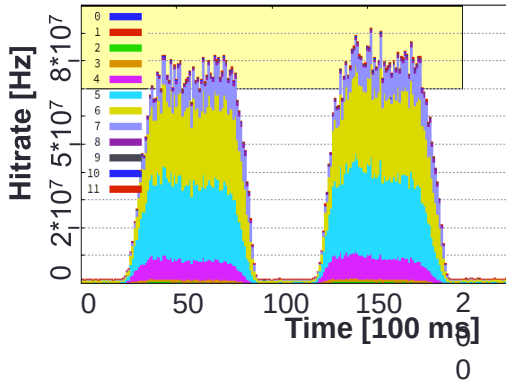
LGAD Technology in HADES

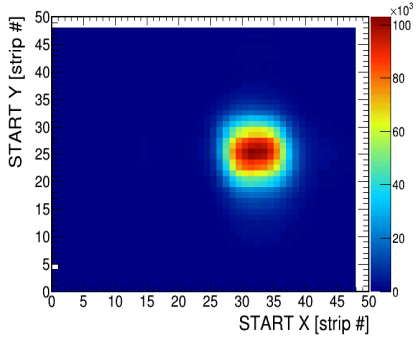
Performance of the HADES T0 detector

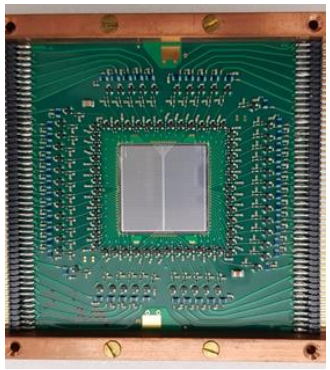
- **p beam, 4.5 GeV**
- **beam intensity: 10^8 p/s**

Utilized for:

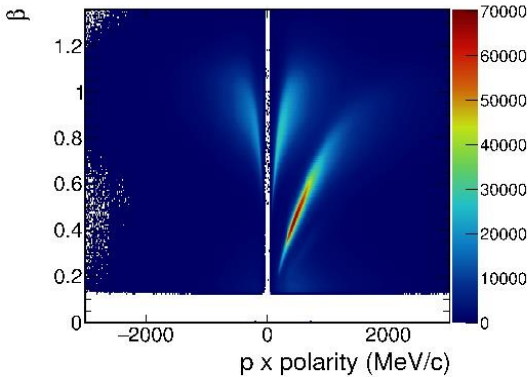
- Beam monitoring
- T0 determination
- Particle identification



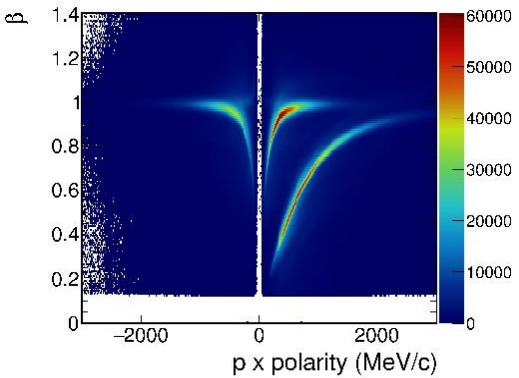




PID w/o LGAD



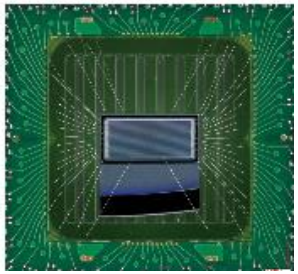
PID with LGAD

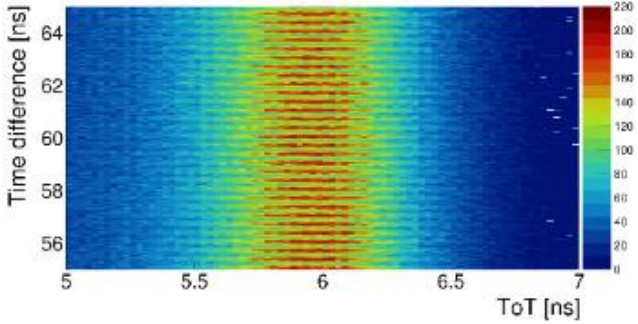


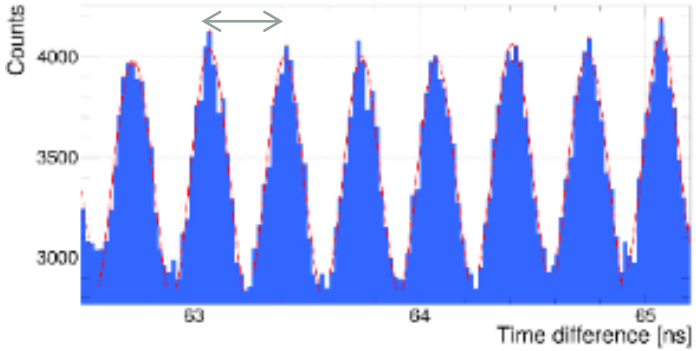
LGAD Technology in HADES and Other Applications

LGAD at S-DALINAC in Darmstadt

- Beam monitoring (time structure) in the energy recovery mode
- 3/6 GHz bunch time structure in the normal/ER modes







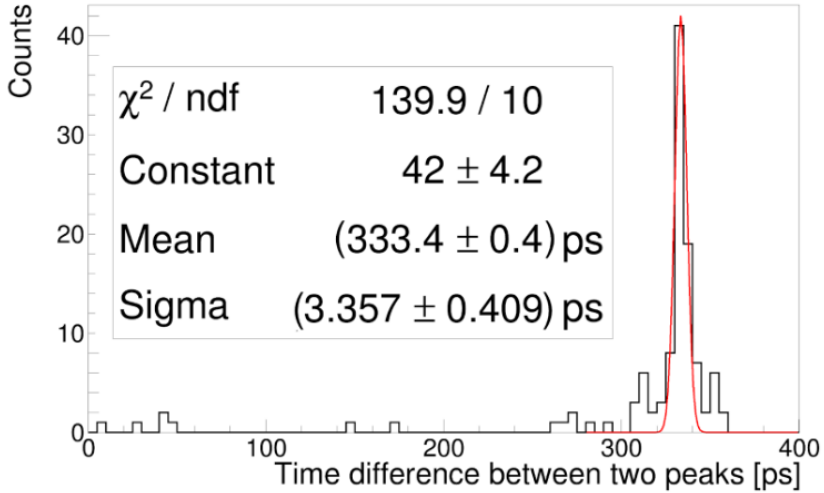
nature physics

Article https://doi.org/10.1038/s41567-022-01856-w

Realization of a multi-turn energy recovery accelerator

Received: 28 March 2022
Accepted: 26 October 2022
Published online: 26 January 2023

Felix Schliessmann, Michaela Arnold, Lars Juergensen, Norbert Pietralla, Manuel Dutine, Marco Fischer, Ruben Grewe, Manuel Steinhorst, Lennart Stobbe & Simon Weih



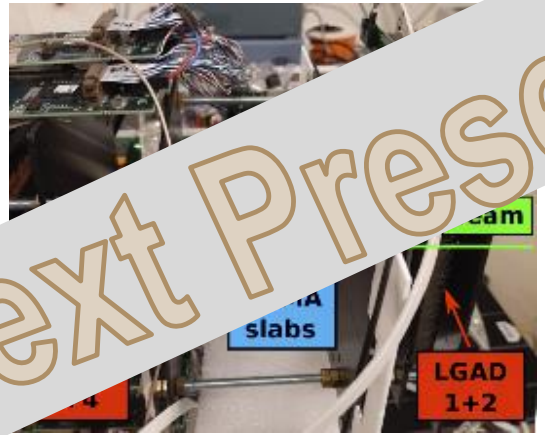
Krüger, W. et al. NIM A 1039 (2022) 167046, LGAD technology for HADES, accelerator and medical applications .

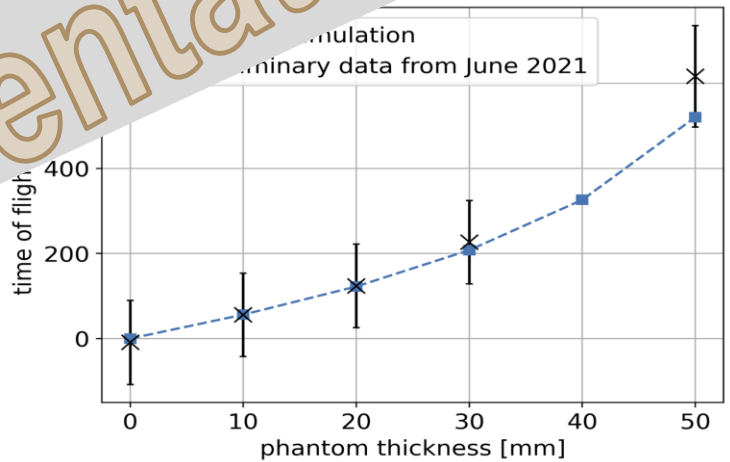
LGAD Technology in HADES and Other Applications

Medical Applications – Ion Imaging

- Relative stopping power distribution inside a patient
- LGAD – Energy measurement by Time-of-Flight
- First proof-of-principle measurement at MedAustron (1)(2)

LGAD ionCT at Med





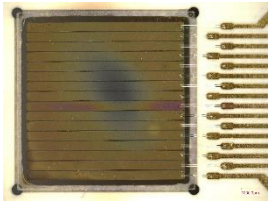
(1) Ulrich-Pur, Felix et al. (Mar. 2022) Physics in Medicine & Biology. ISSN: 0031-9155, 1361-6560
(2) Krüger, W. et al. NIM A 1039 (2022) 167046, LGAD technology for HADES, accelerator and medical applications .

LGAD Technology for Sensor Diagnostics

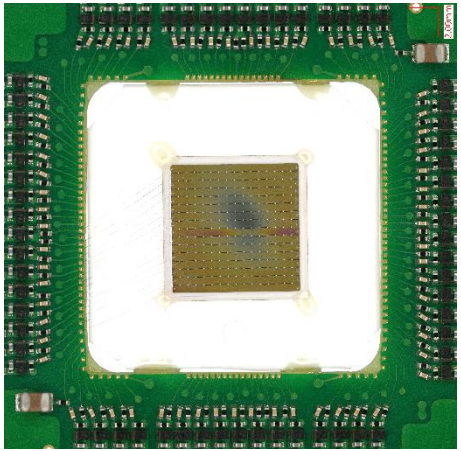
Heavy Ion induced radiation damage in pcCVD diamond

- pcCVD diamond used in mCBM – significant efficiency loss observed.
- Mitigation by adding additional amplification
- Proof-of-principle measurement at MedAustron with He and C beams

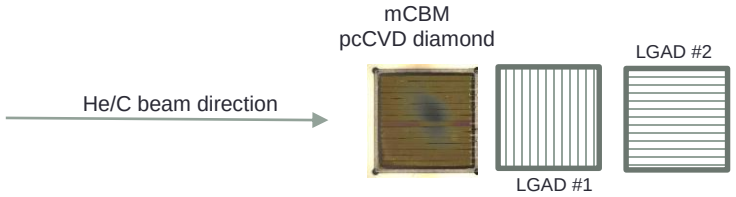
Damaged mCBM
pcCVD diamond

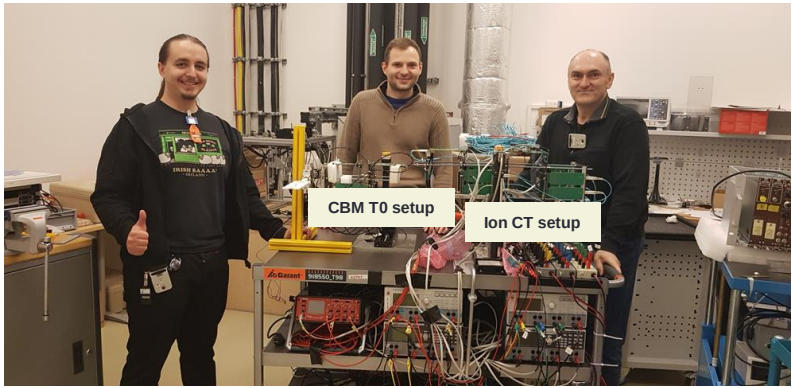


mCBM pcCVD diamond
mounted on the new AC FEE board



Beam Telescope

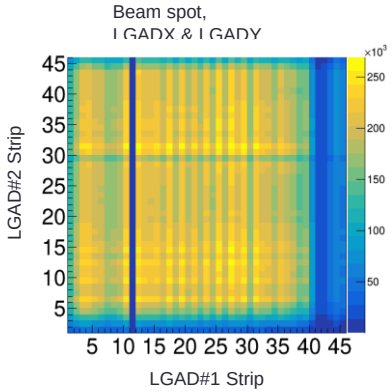


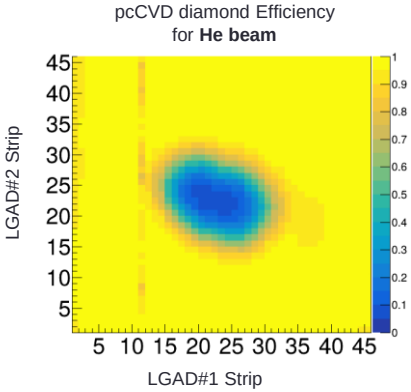


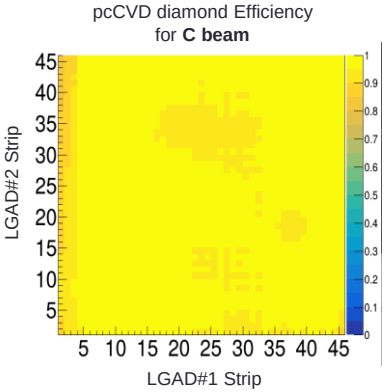
LGAD Technology for Sensor Diagnostics

Heavy Ion induced radiation damage in pcCVD diamond – MedAustron results (Nov. 2024):

- **He beam**, energy: 147.2 MeV/u
- **C beam**, energy: 402 MeV/u
- **Au/C dE/dx ratio: $Z^2(Au) / Z^2(C) \approx 171$**
- **Additional amplification significantly extends the detector's lifetime.**



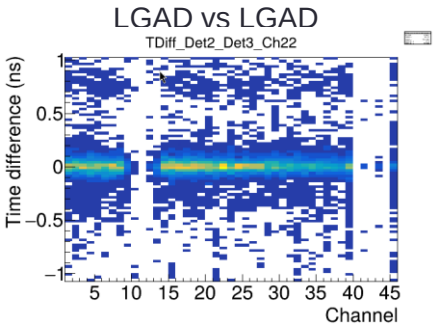


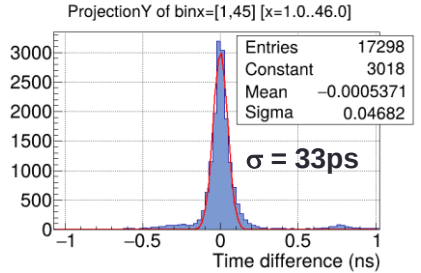


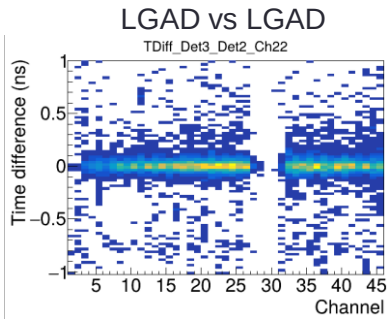
LGAD Technology for Heavy Ions

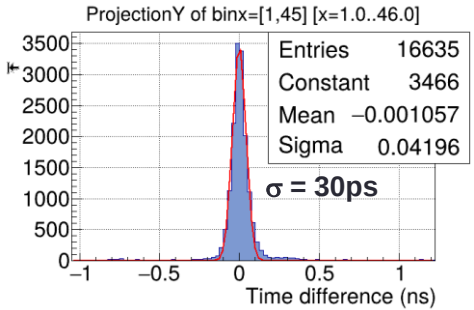
LGAD Timing Properties measured with C Beam – MedAustron results (Nov. 2024):

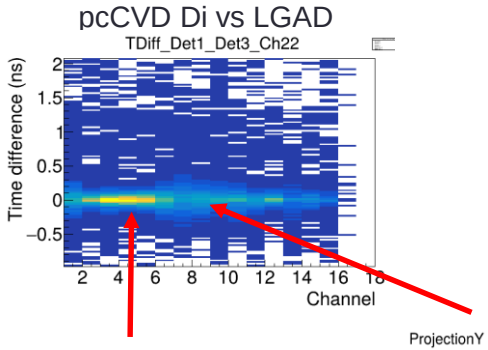
- **C beam**, energy: 402 MeV/u
- **Au/C dE/dx ratio: $Z^2(Au) / Z^2(C) \approx 171$**
- **Additional amplification significantly extends the detector's lifetime and improves timing**

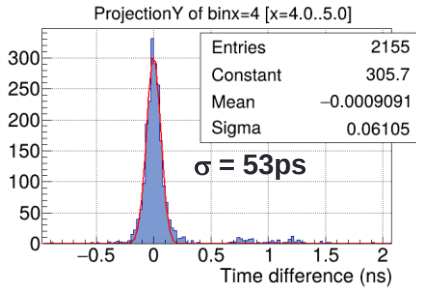


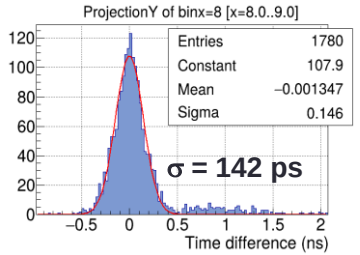












Thank you