Low-Gain Avalanche Detector (LGAD) for 4D Tracking

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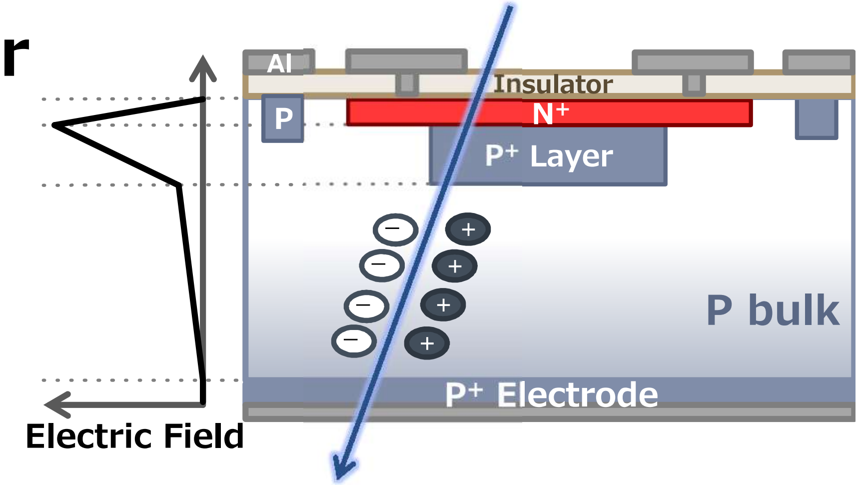
Talk Outline

- Introduction of LGAD
- Application for HEP
- Sample from HPK
- Testbeam for Time Resolution Measurements
- Summary

Introduction

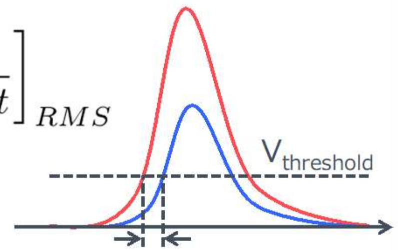
Low Gain Avalanche Detector

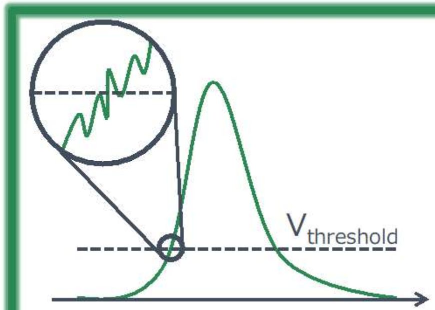
- Uniform high electric field @ N^+-P^+ junction (thin multiplication layer)
  - Avalanche
  - Low Gain (~10)
    - **Good S/N**
  - Thinner detector possible
    - **Minimise fluctuations**
    - **Small t_{rise} (fast signal)**



$$\sigma^2_{det} = \sigma^2_{Landau} + \sigma^2_{TimeWalk} + \sigma^2_{Jitter}$$

$$\sigma_{TimeWalk} = \left[\frac{V_{th}}{S/t_{rise}}\right]_{RMS} \propto \left[\frac{N}{dV/dt}\right]_{RMS}$$



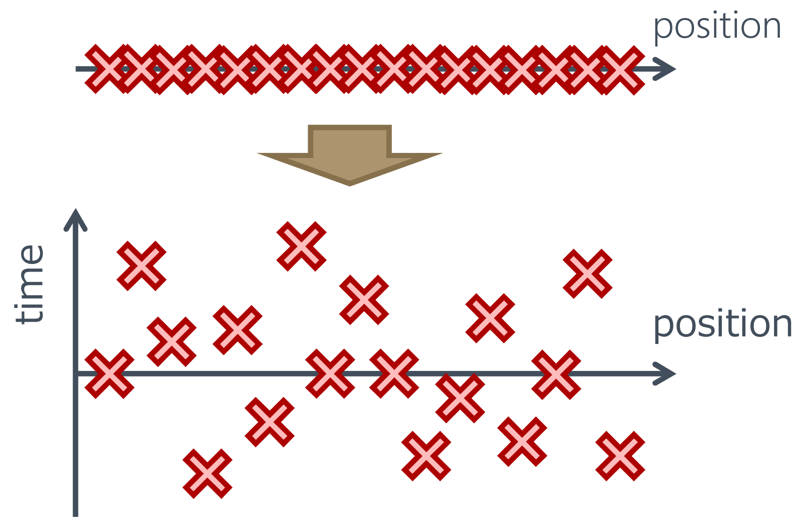


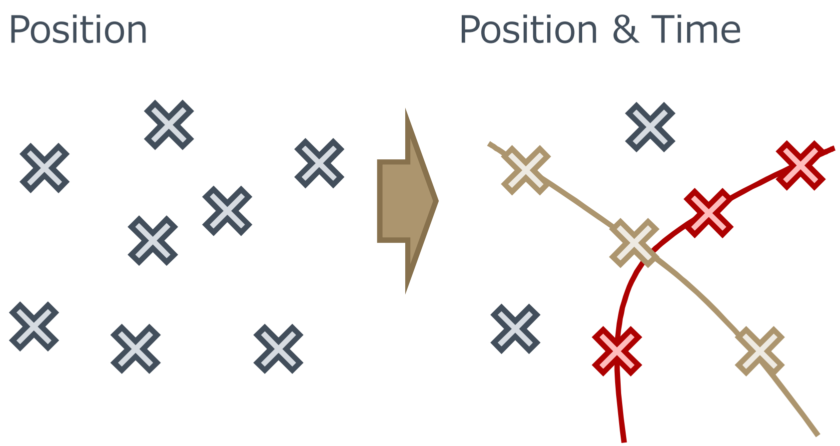
$$\sigma_{Jitter} = \frac{N}{(dV/dt)} \simeq \frac{t_{rise}}{(S/N)}$$

To realize 4D detector good for position and time measurements

Application for HEP

- Pile-up mitigation with timing
- Use 2-dimensional track information: position & timing
- Timing helps reject tracks from pile-up vertices at same position but different time
- Timing can also improve tracking algorithm
- Pile-up at HL-LHC (2026~): <μ>=200
  - 1.6 vertices/mm on average
  - Need $\sigma(z_0)<0.6$mm for track-vertex association





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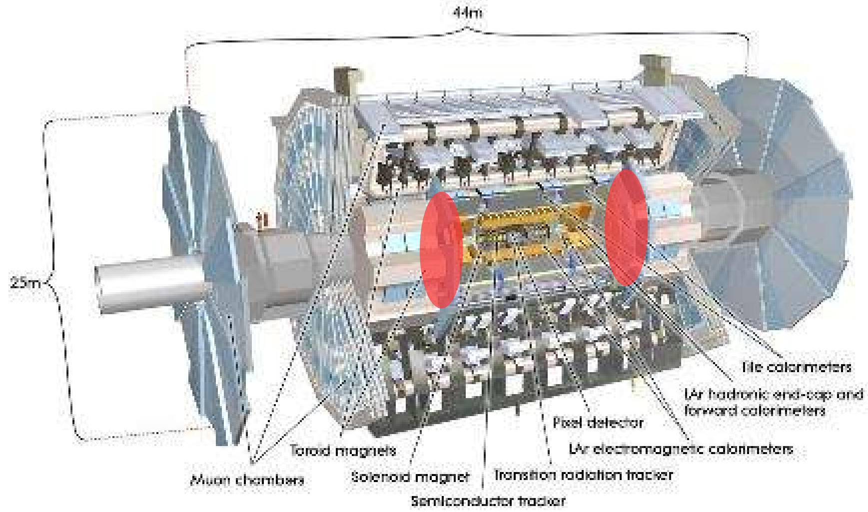
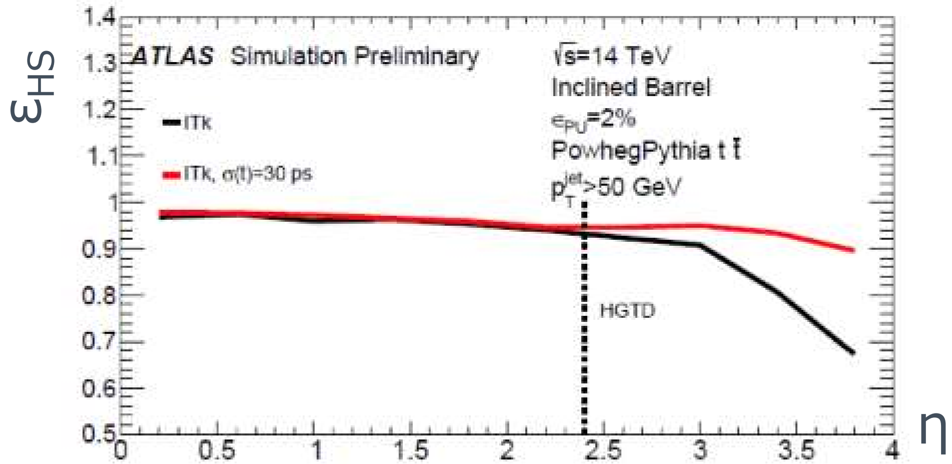
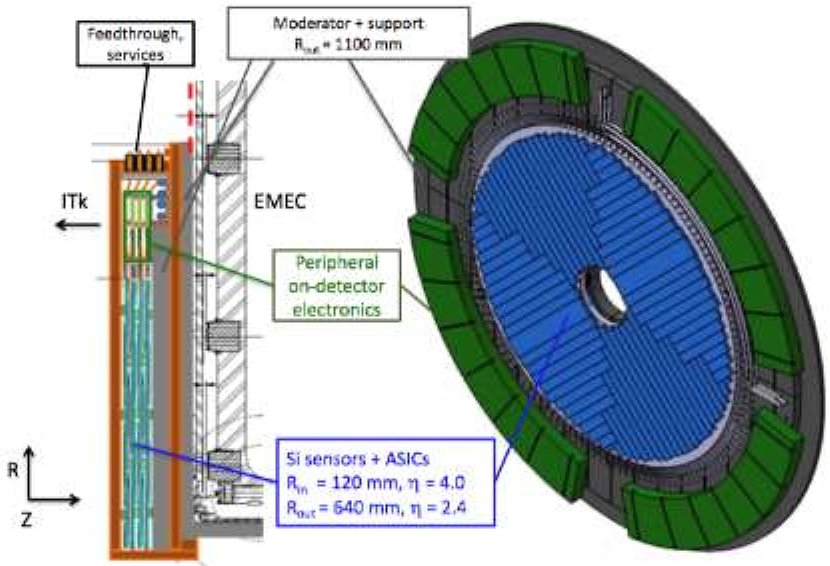
HGTD for ATLAS

- High-Granularity Timing Detector
  - Phase-Ⅱ upgrade of ATLAS (2024~)
- Design & requirements
  - z=3420-3545mm (3435-3485mm)
  - 2.4<|η|<4.0 (Forward region)
  - R=110-1100mm (120-640mm)
  - Time resolution: **30ps**/tarck
  - Pad size: **1.3 × 1.3 mm²**

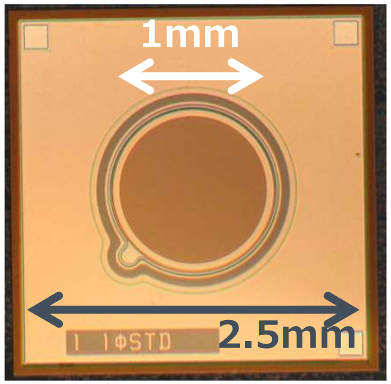




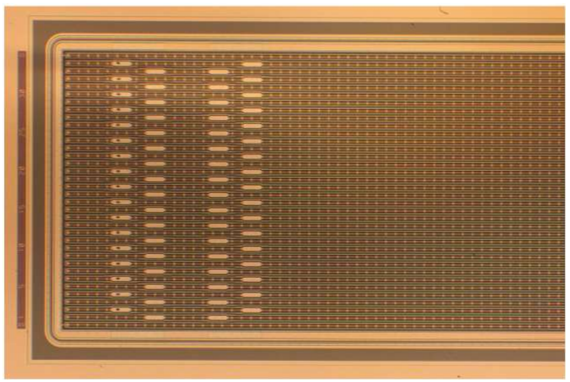


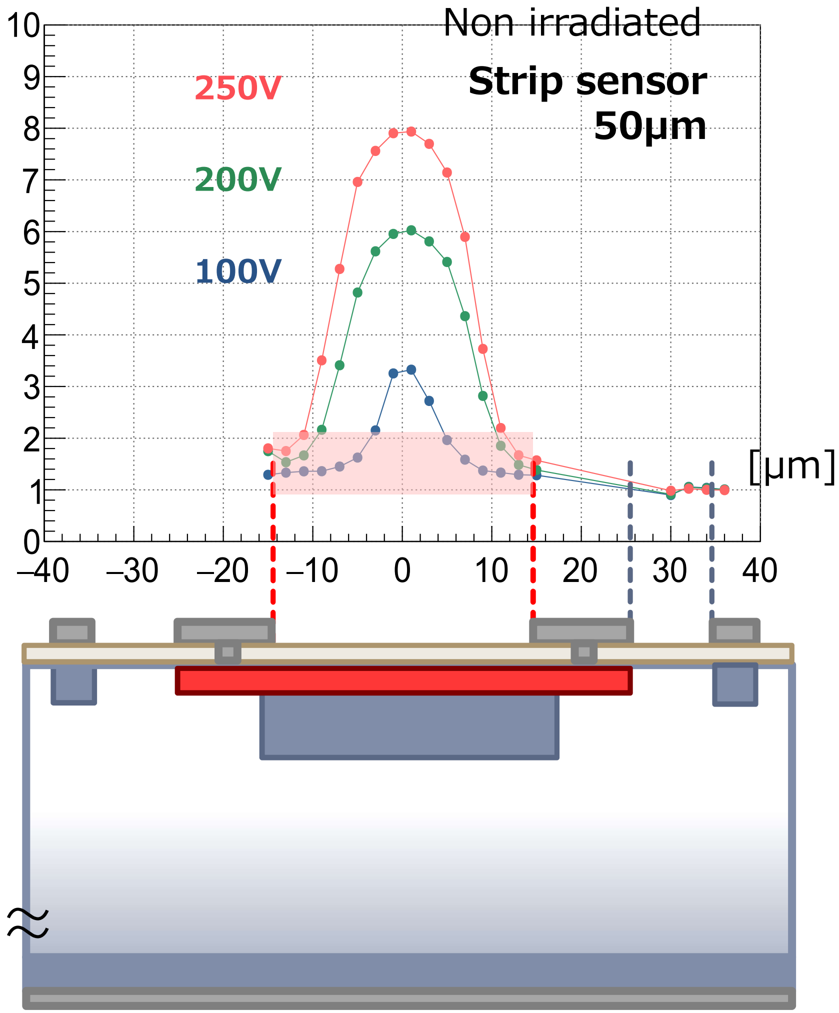
Samples from HPK

- Samples from HPK
  - Miniature Diode
    - Chip Size: 2.5 × 2.5 mm^2
    - Window: 1 mmφ
  - Strip Sensor
    - Stirp pitch: 80µm
  - Active thickness
    - 50µm or 80µm



Miniature Diode

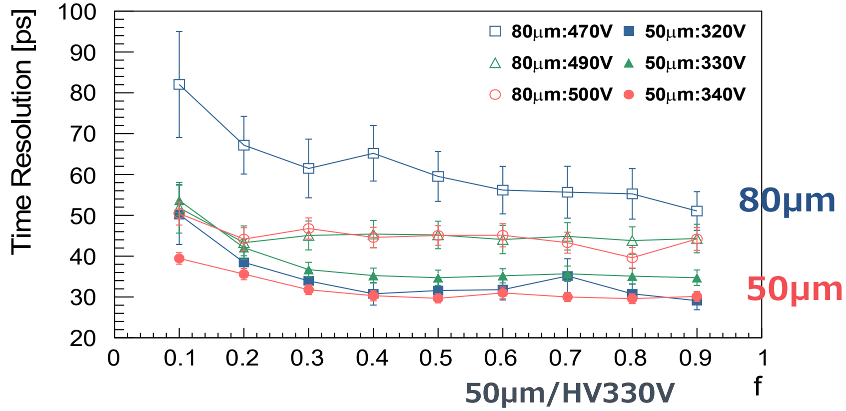

Strip Sensor

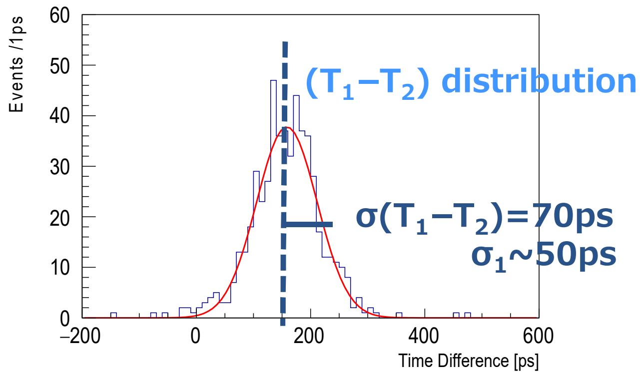


Testbeam

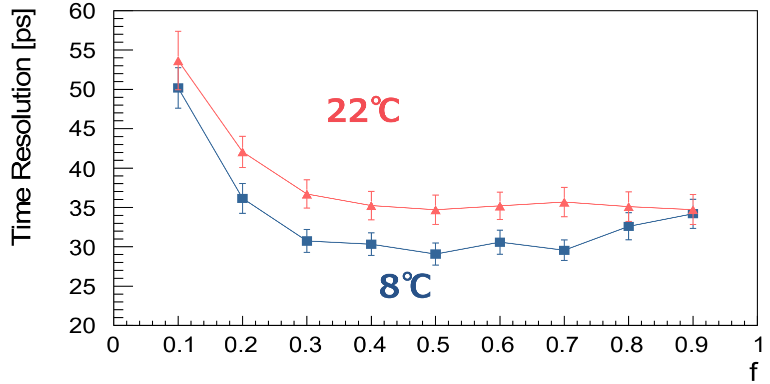
- Feb.-Mar. 2018 @Fermilab (Chicago) / 120GeV proton beam
- Time resolution:
  - 50μm ~ 30ps @ 340V
  - 80μm ~ 45ps @ 500V
- Better time resolution:
  - Higher bias voltage
  - Lower temperature
- Analysis still on going

$$V_{thresh} = f \times V_{peak}$$





50μm/HV330V



Summary

- Presented basic idea and application of LGAD
- We are evaluating characteristics of HPK LGAD samples.
- LGAD has potential to play active part in high luminosity experiments.
- HGTD of ATLAS has been accepted for technical detector design.
- Measurements of time resolution of irradiated samples are in progress.

- Acknowledgement AIDA 2020 Fermilab