Tracking detectors R&D

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Snowmass white paper planning meeting

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Interests and targets

- Trackers for future colliders
  - Different requirements depending on e^+e^- or hh
    - e^+e^-: very high spatial resolution, and low material budget
    - hh: very high radiation tolerance (10^{17} n/cm^2), $\sigma_t \sim 5$ ps/hit, $\sigma_x \sim 5$ μm/hit
    - $\mu^+\mu^-$: very high spatial resolution, and low material budget PLUS timing, high radiation tolerance

- The 4D/5D trackers will play a key role at the future machines
  - Reduce backgrounds, track reconstruction, triggering all will need precision timing information, in addition to the precision position
  - Particle ID and LLP searches are new areas where we start utilizing the timing and position information
  - All of these pose unique challenges, and opportunities to detector and electronics design, and event reconstruction

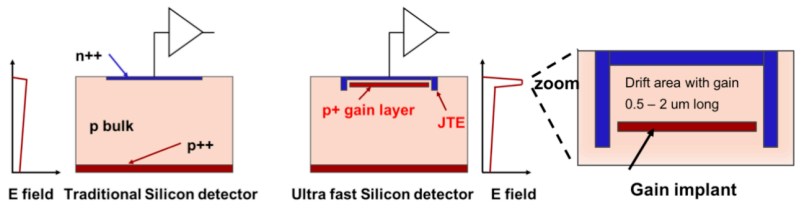
Interests and targets

- As FNAL group we have different interests in the area of tracking detectors
  - Physics simulations and/or tracking reconstruction
  - R&D on technologies to achieve the required detector performance
  - Front-end and ASIC developments
  - Trigger and backend developments

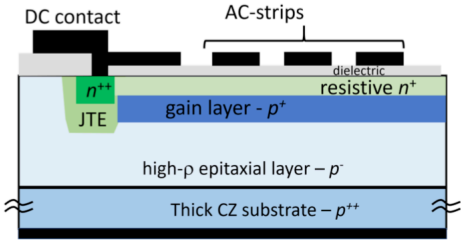
- At CMS we are building a Gen-1 4D detector
  - requires lots of R&D in "productizing" detectors and understanding how to get the physics out,
  - requires attention, and should be tightly coupled with and inform (both ways) R&D directions on future improved detector technologies

Current technology R&D in the group

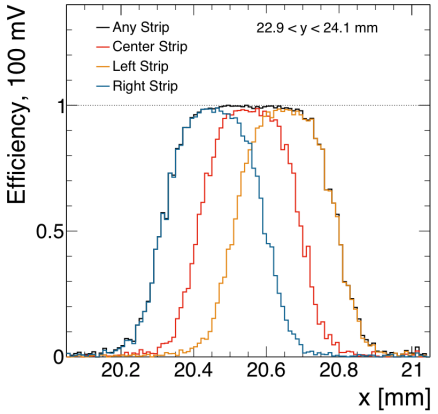
- Low-Gain Avalanche Detectors (LGAD): technology for CMS timing detector: ~30 ps
  - Silicon detectors with internal gain
  - R&D performed in our group: sensors, electronics, assembly, integration
  - Several areas to extend performance of LGADs beyond current limits
- AC-LGAD:
  - AC coupled LGAD, achieve 100% fill factor,
  - Exceptional position resolution without the need for very small pixelated electronics: use charge-sharing
  - Timing resolution similar to traditional LGAD



LGAD sensors

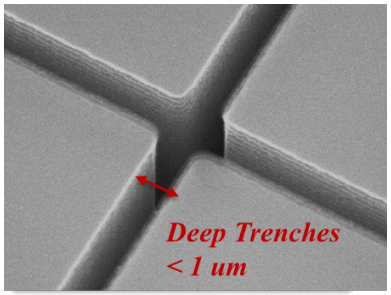


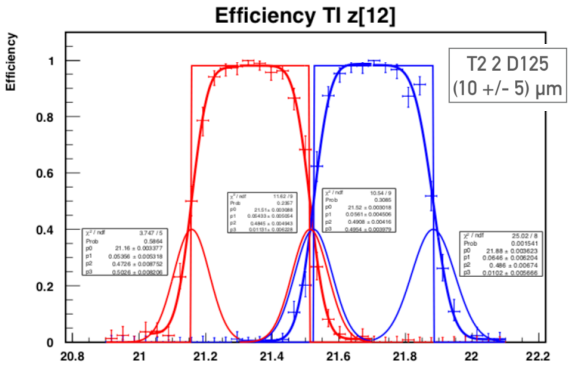
AC-LGAD sensors

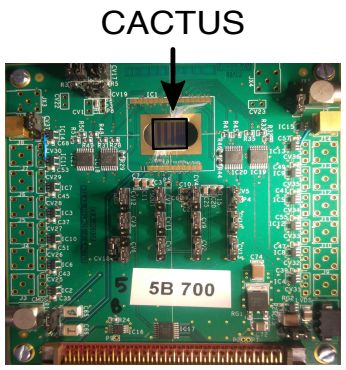


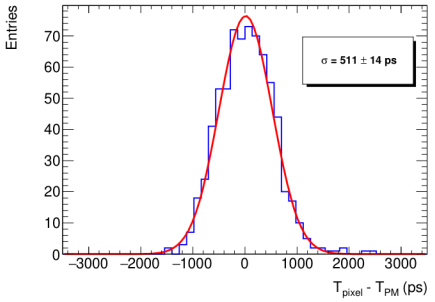
Current technology R&D in the group

- Trenches as isolation structures between LGAD pixels
  - Nominal inter-pixel gain-loss region of few μm, same signal as LGAD
- MAPS, HV-CMOS
  - Promises to be: low cost, radiation hard, and with good time resolution
- Electronics design:
  - Several generations of fast readout electronics developed in the group for studies of SiPM, Si, LGAD, AC-LGAD
  - ASICs developed for CMS and generic: ETROC, CFD-chip









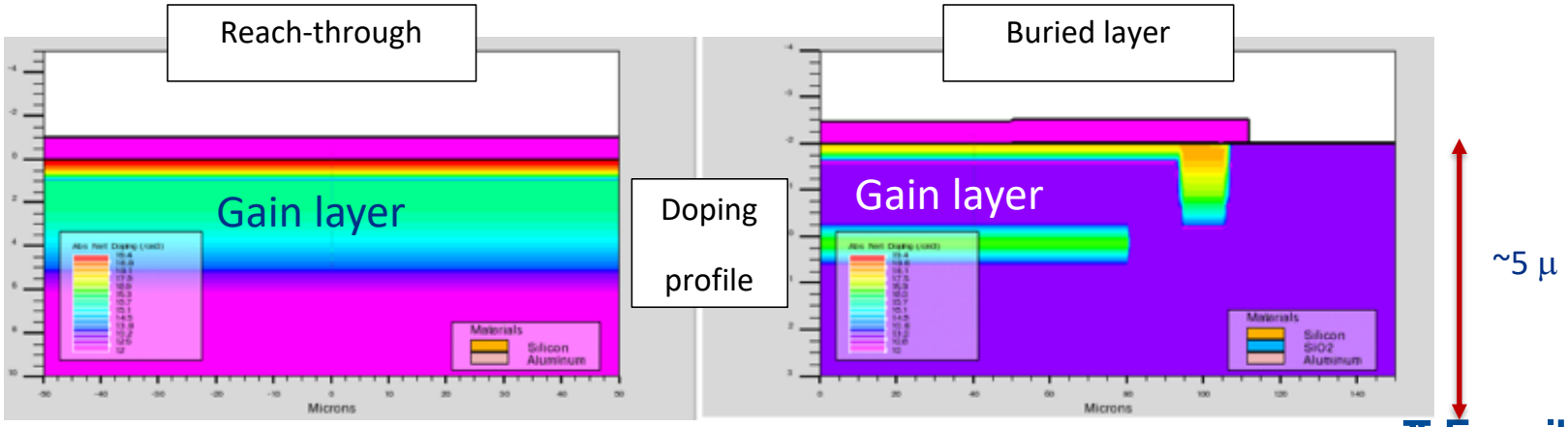
Current technology R&D in the group

We can engineer the silicon substrate to tailor the characteristics of the device

- Buried gain layer LGAD can provide a more radiation hard, stable device
- Gain layer is below epitaxy – AC coupling or more sophisticated topside processing can be integrated
- Combine with small pixels, or CMOS MAPS to design specialized sensors.

Usual reach-through implanted from top – limited options

Gain layer grown over implant – can be denser, top can be custom processed



Outline

- Submit an LoI focusing on outlining the interest in 4/5D tracking with high spatial and timing resolutions for future colliders.
  - This can be split into several white papers.

- The group of contributors
  - FNAL: A. Apresyan, L. Bauerdick, D. Berry, K. DiPetrillo, R. Heller, T. Liu, R. Lipton, C. Pena, et al,
  - BNL group (A. Tricolli, et al)
  - Caltech (M. Spiropulu, S. Xie, et al)
  - Saclay (F. Guilloux, et al)
  - Torino group (N. Cartiglia, et al)