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Solid-State Timing Sensors: The Push Towards High Granularity

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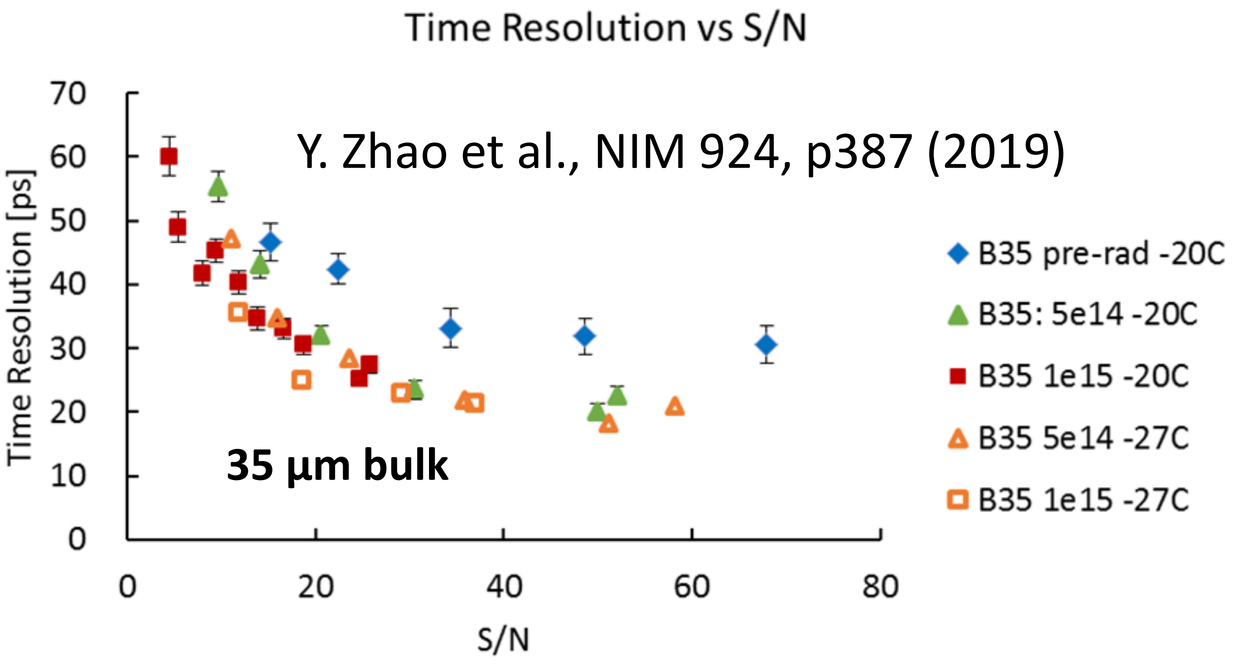
THE UNIVERSITY OF CALIFORNIA SANTA CRUZ LET THERE BE LIGHT

SCIPP SANTA CRUZ INSTITUTE FOR PARTICLE PHYSICS UC SANTA CRUZ

DEPARTMENT OF ENERGY UNITED STATES OF AMERICA

Conventional LGADs: Superior Timing, Limited Granularity



Inter-pixel region in Standard LGADs

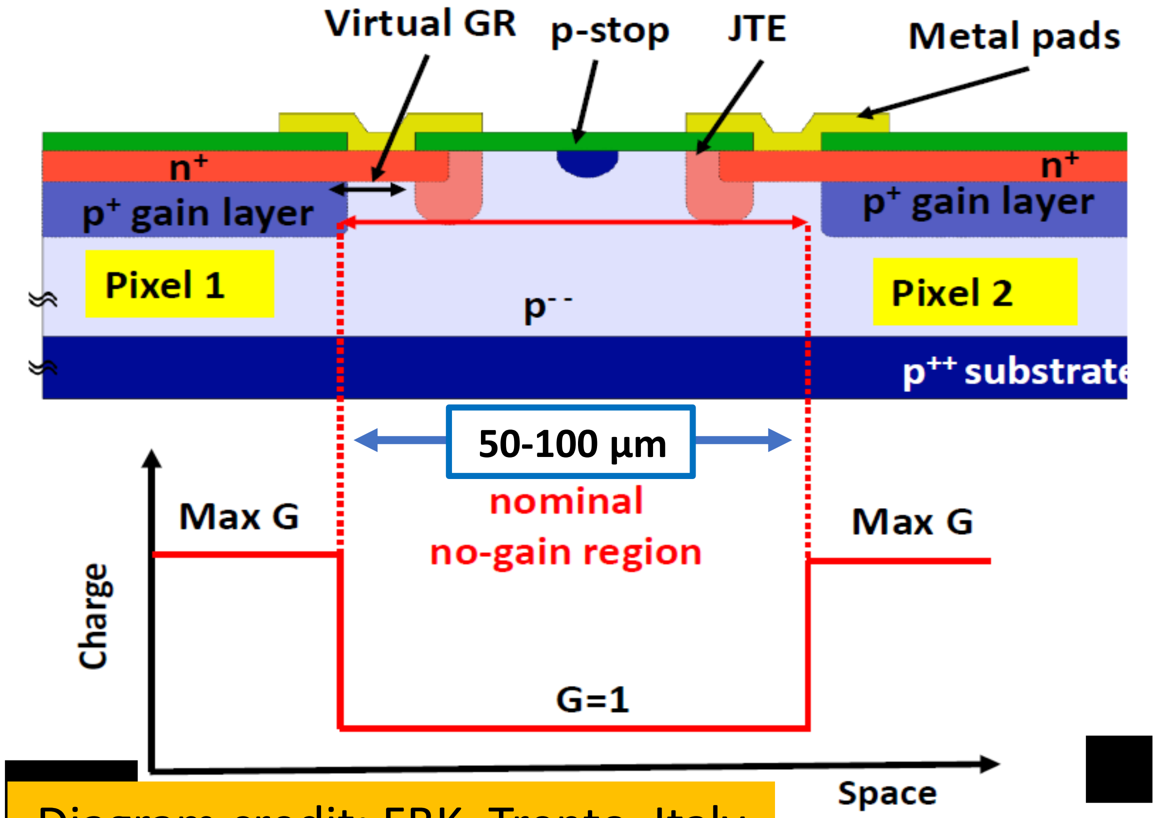
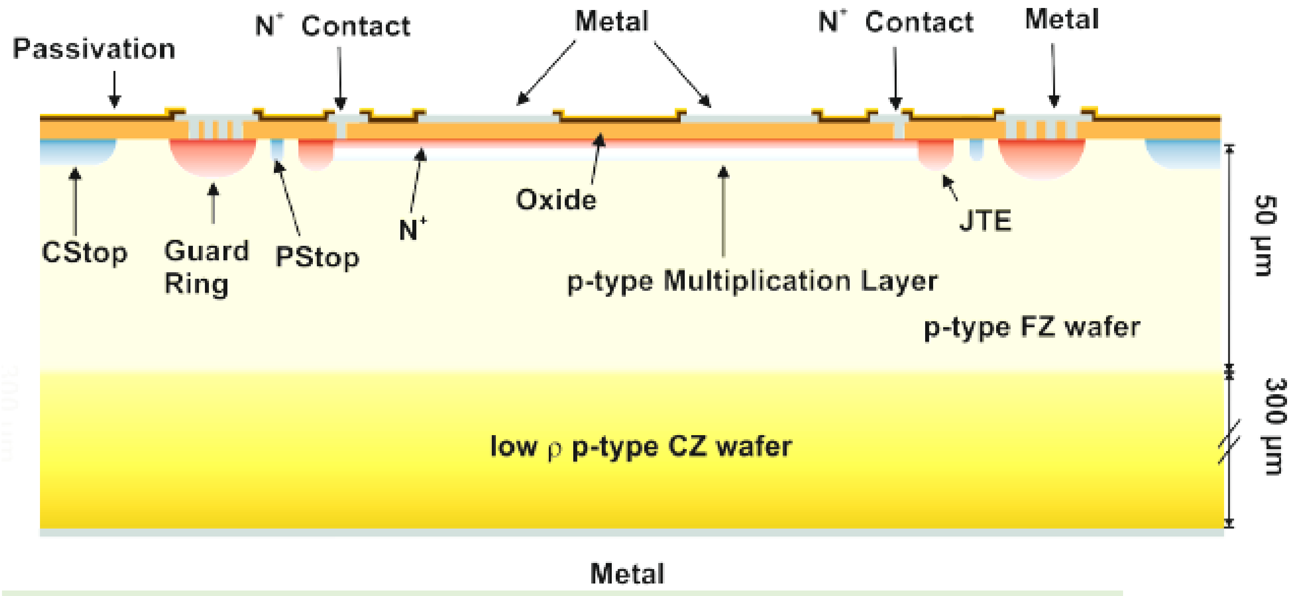


Diagram credit: FBK, Trento, Italy

For single (thin) layers, timing resolution better than 20 psec has been achieved

But need to isolate segments creates 50-100 µm gap that limits granularity to the millimeter scale

THE AC LGAD



AC LGAD Design

- Gain layer is planar ➔ no need for JTE structure separating segments
- Charge coupled capacitively to surface through thin (~500 nm) oxide layer
- Segmentation provided by simply by surface electrode pattern

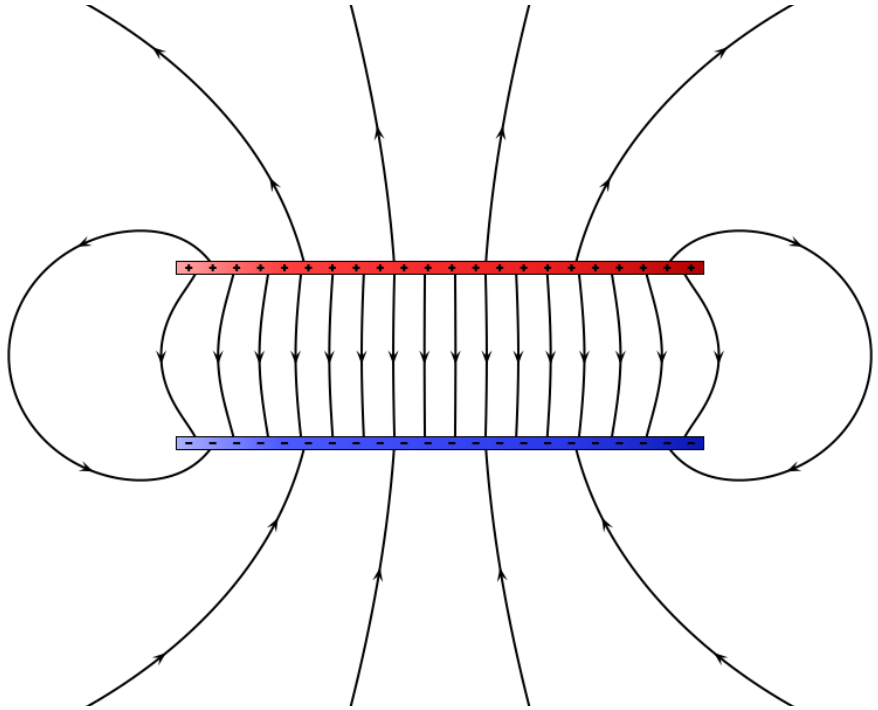
Advantages

- Good (5 µm) resolution with sparse readout (100's of µm pixel size through charge sharing)
- Low power consumption (high resolution with relatively large pixel)
- In relatively advanced stage of development
- Being pursued by broad international community

Possible Disadvantages

- Charge sharing may put limits on pixel pitch for some (high-density) applications
- AC coupled; return to baseline might impose rate limitations for highest frame-rate applications

THE DEEP JUNCTION LGAD (DJ-LGAD)



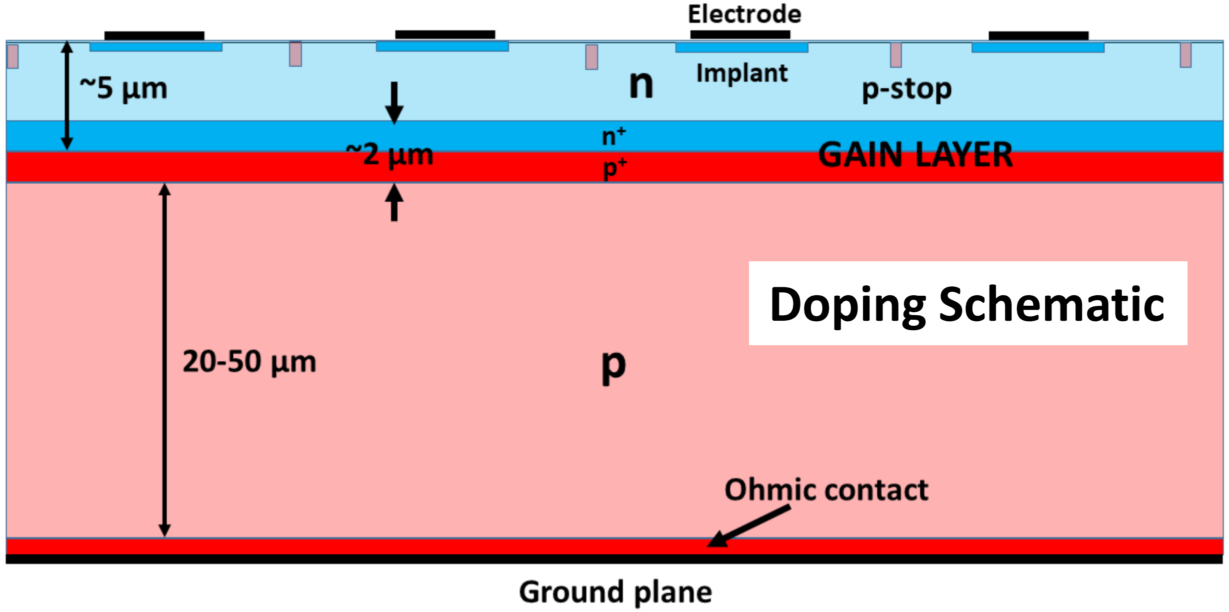
Basic inspiration is that of the capacitive field: Locally large, but surrounded by low-field region beyond the plates.

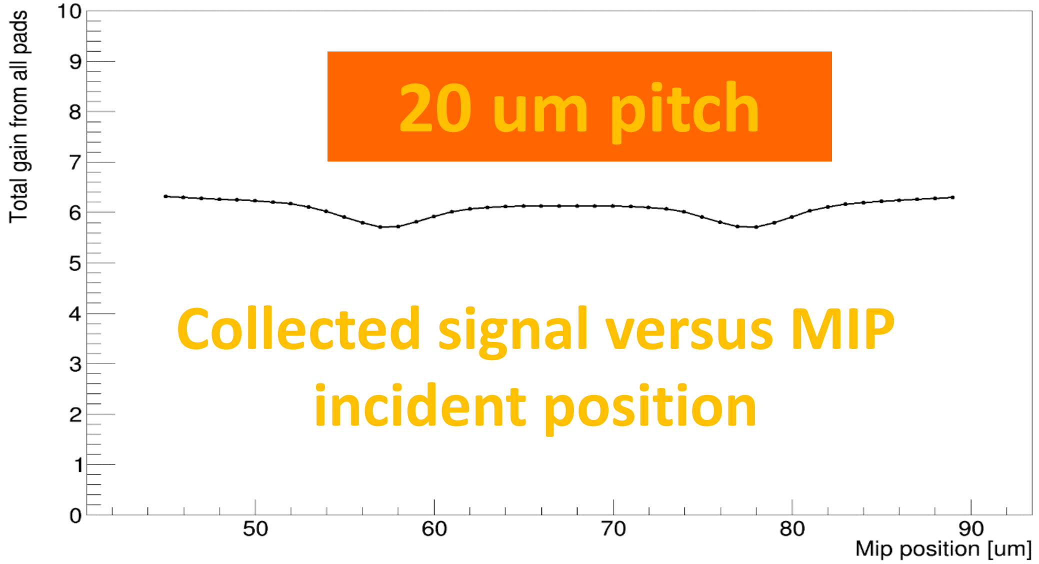
Idea:

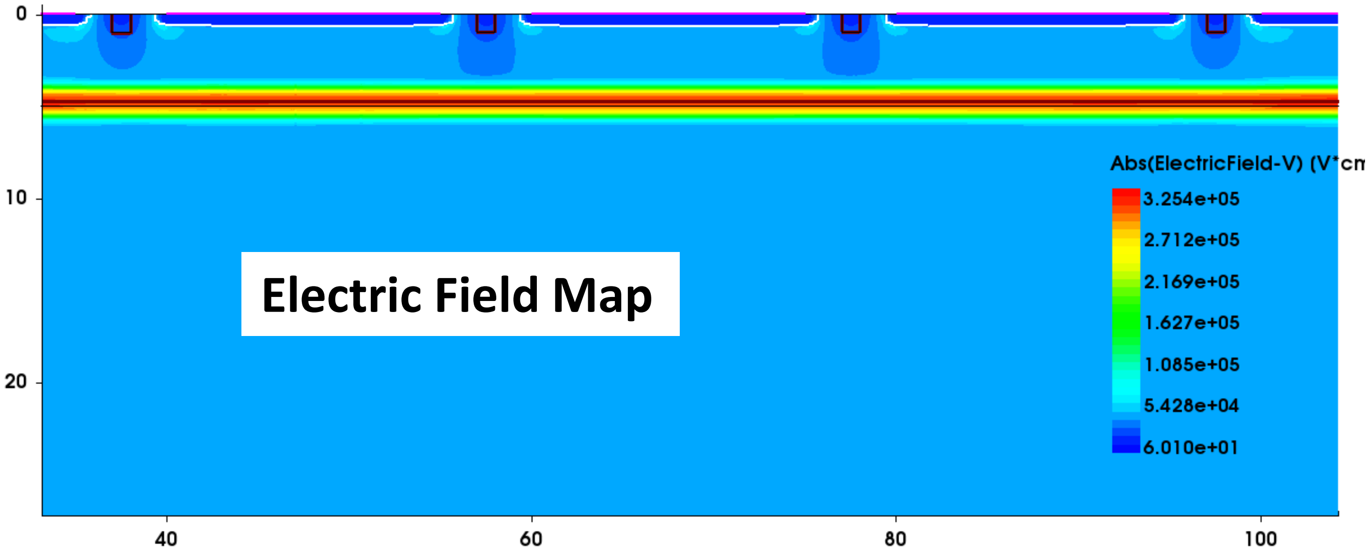
- Use symmetric P-N junction to act as an effective capacitor
- Localized high field in junction region creates impact ionization
- Bury the P-N junction so that fields are low at the surface, allowing conventional granularization

➔ **“Deep Junction” LGAD (DJ-LGAD)**

THE DEEP JUNCTION LGAD (DJ-LGAD)





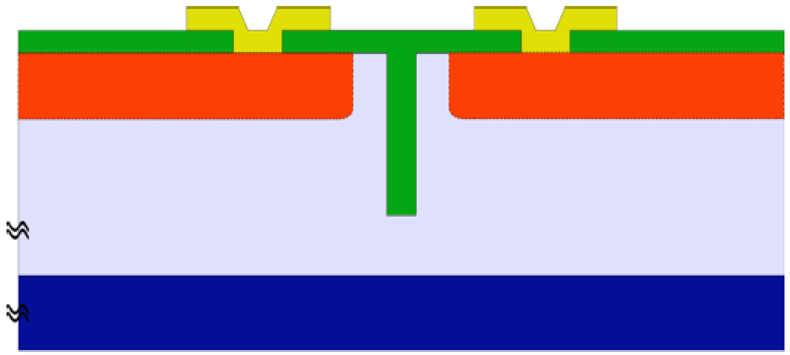


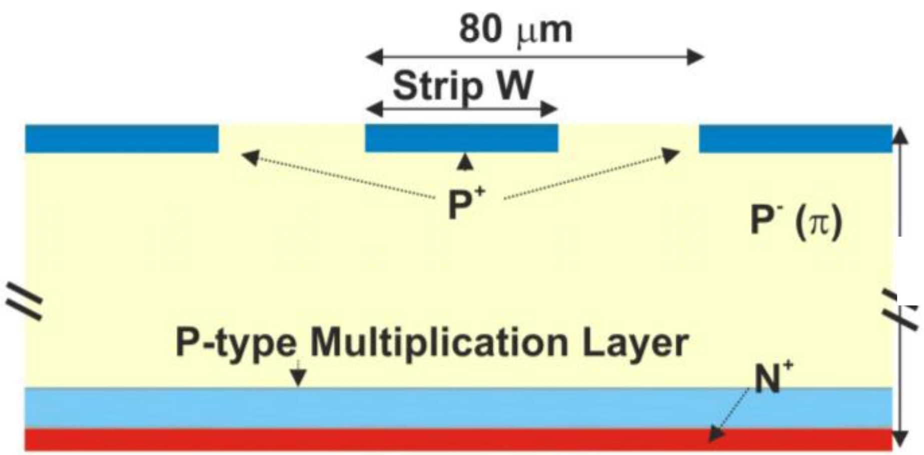
- Gain layer is again planar
- DC coupled (no pulse recovery)
- Very early stage of development
- First prototypes from small collaboration of SCIPP/Cactus Materials/BNL

OTHER APPROACHES (EARLY STAGES)

- Physical trench provides isolation between neighboring segments
- Inter-pad loss region limited to 5-10 microns

Trench-Isolated LGADs (TI-LGAD)





Inverse LGAD (iLGAD)

- Multiplication layer located at "back" (non-patterned) part of the detector ("inverse geometry").
- Signal coupled to pads inductively (weighting fields)

SUMMARY

- LGADs offer attractive timing resolution (30 psec standard; R&D pushing towards 15 psec and below
- 4D tracking applications require higher resolution
- AC LGADs will likely achieve superior resolution with lower granularity, with some compromises that may not matter for HEP
- Other approaches (DJ LGAD, TI LGAD, I-LGAD), in earlier stages of development, offer promise for truly granular systems