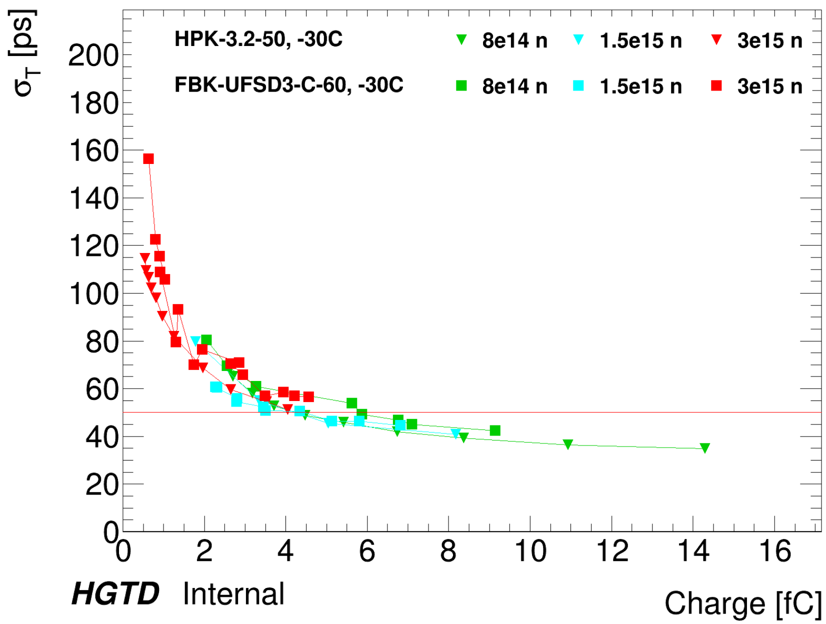
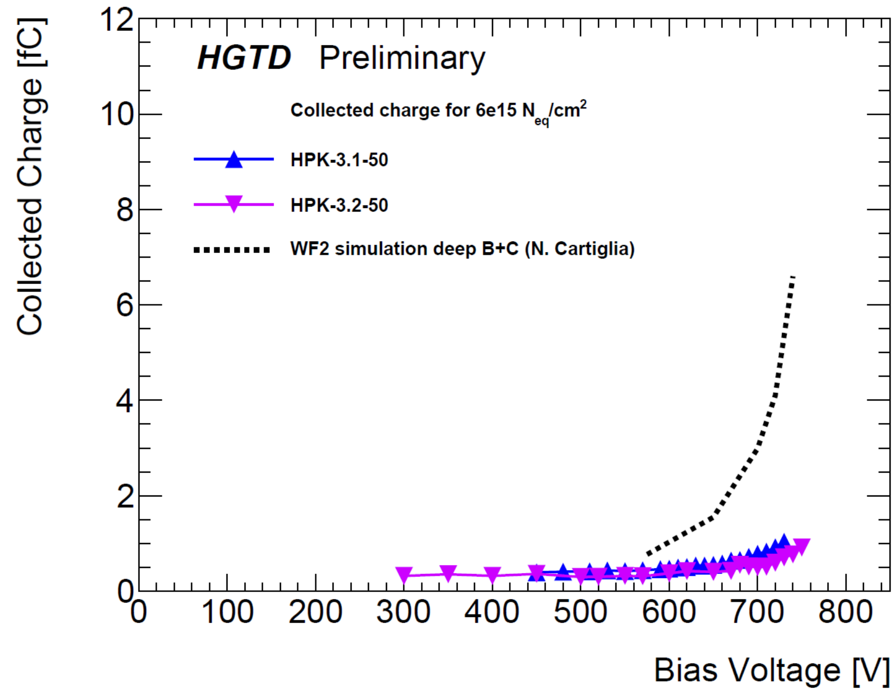
Solid State and Tracking Summary

Sally Seidel
CPAD2019
10 December 2019

R&D on LGAD Radiation Tolerance: the HL-LHC and Beyond -Simone Mazza (UCSC)

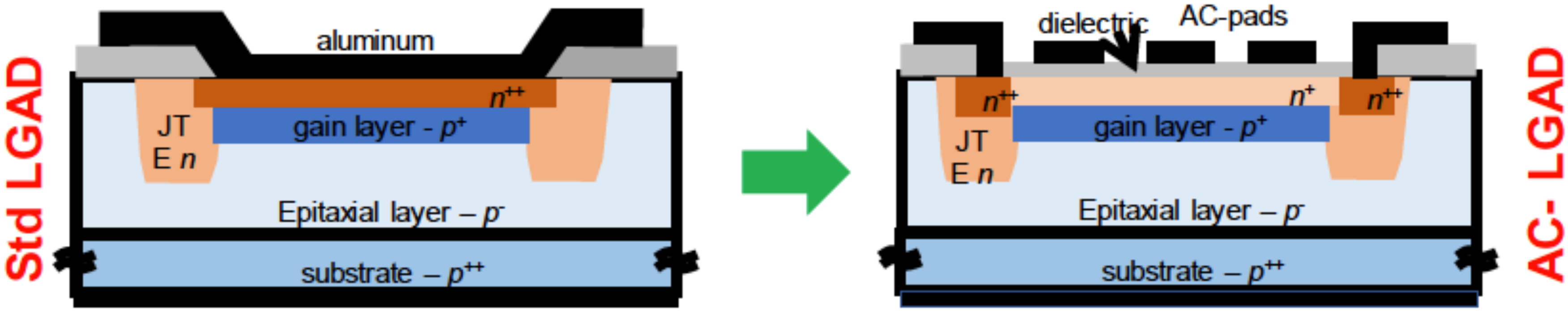


Time resolution vs. collected charge is mostly independent of radiation damage up to 3×10^{15} neq with gain (8-10) and time resolution (50-60 ps).



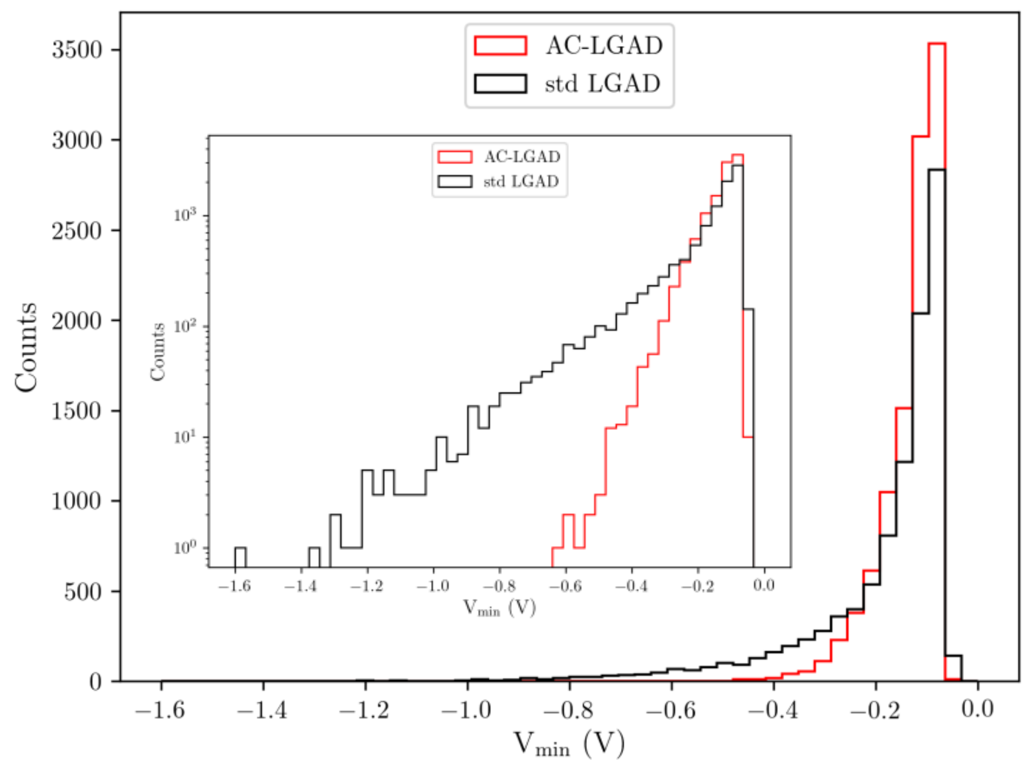
Promising simulation of thin sensor with gain (~4) for fluence >10^{17} neq with carbon and deep layer implantation, sufficient for tracking but timing resolution is compromised to ~80 ps

From LGADs to AC-coupled LGADs for fast timing applications -Gabriele Giacomini (BNL)

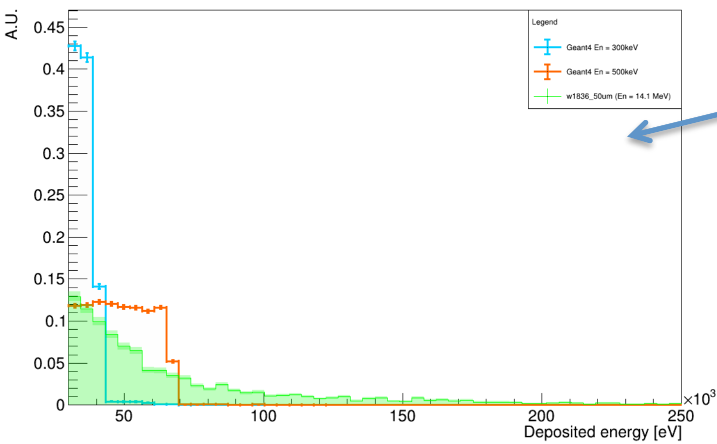


LGADs have been fabricated at BNL, and these formed the basis for AC-LGADs after modification of a few masks and tuning of the process flow.

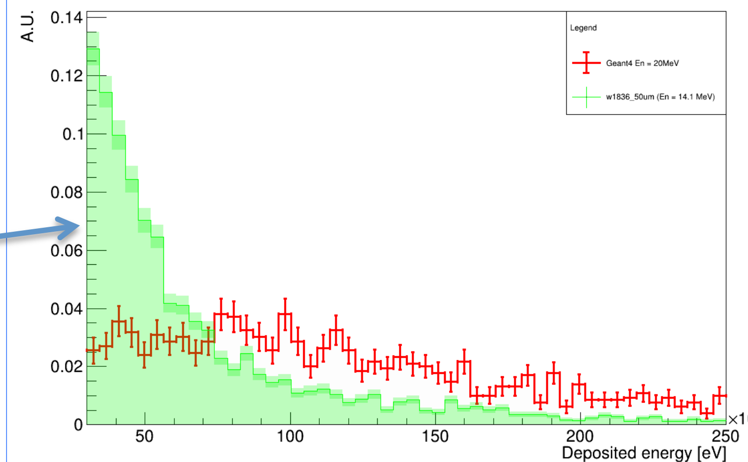
Nearly same gain for equal bias conditions. Optimization ongoing, e.g., to improve peripheral cross-talk.

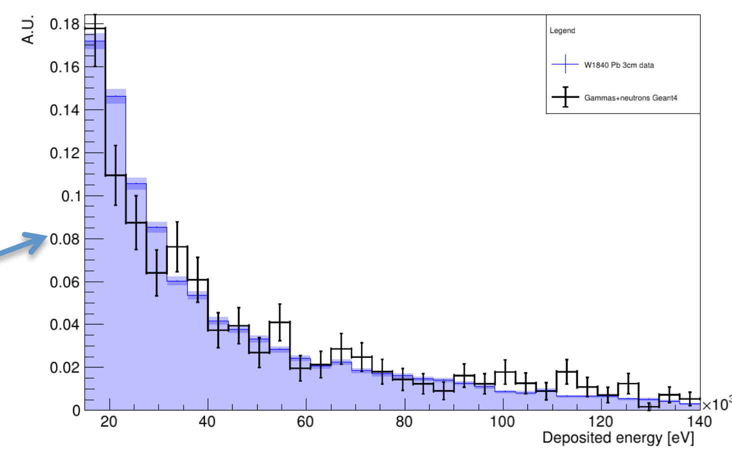


Performance of LGADs and AC-LGADs towards 4D Tracking -Gabriele D'Amen (BNL)



LGADs can be used to detect neutrons from 300 keV up to few MeV in high flux conditions with 20-30 ps resolution. Simulations predict possible sensitivity also for energy range [15-140] keV

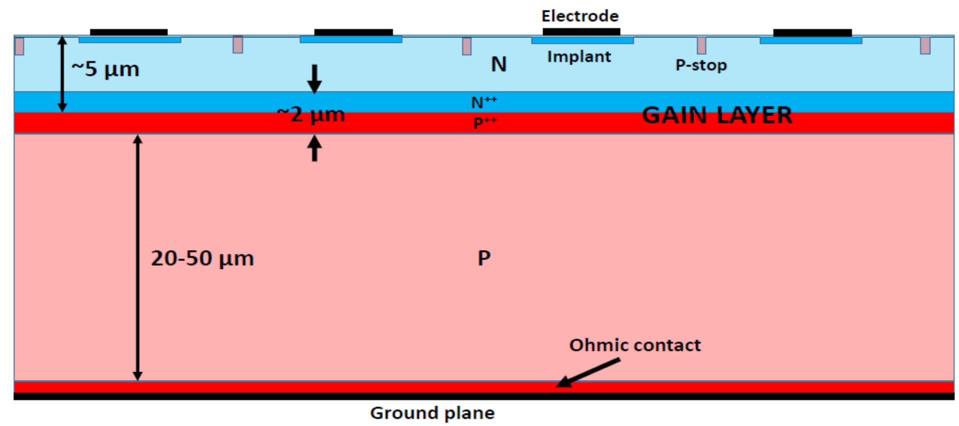




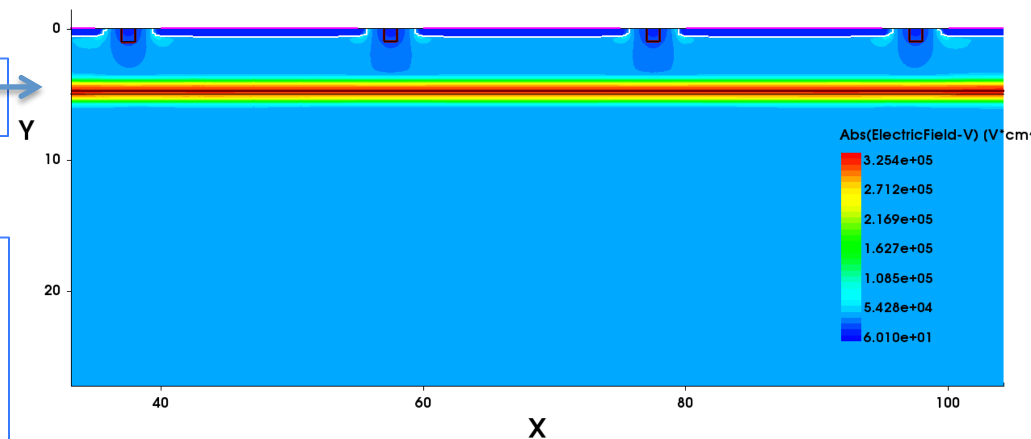
AC-LGADs with 50-100 micron spatial resolution produced

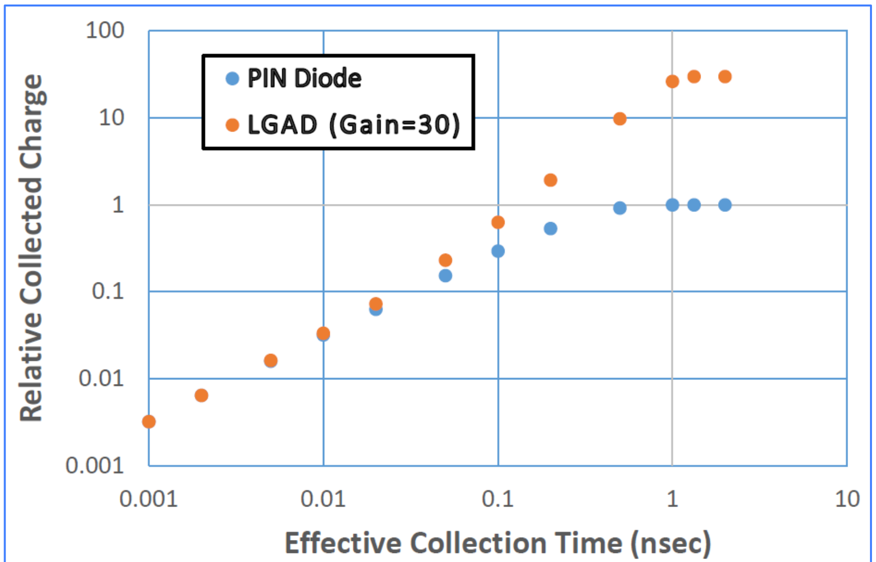
Low Gain Avalanche Detectors: Towards Higher Granularity and Repetition Rate -Bruce Schumm (UCSC)

Deep-Junction LGAD concept: symmetric p-n junction produces a locally large capacitive field – creates impact ionization – and bury this to maintain low field at surface but without gain-free regions.



Simulated performance is promising.



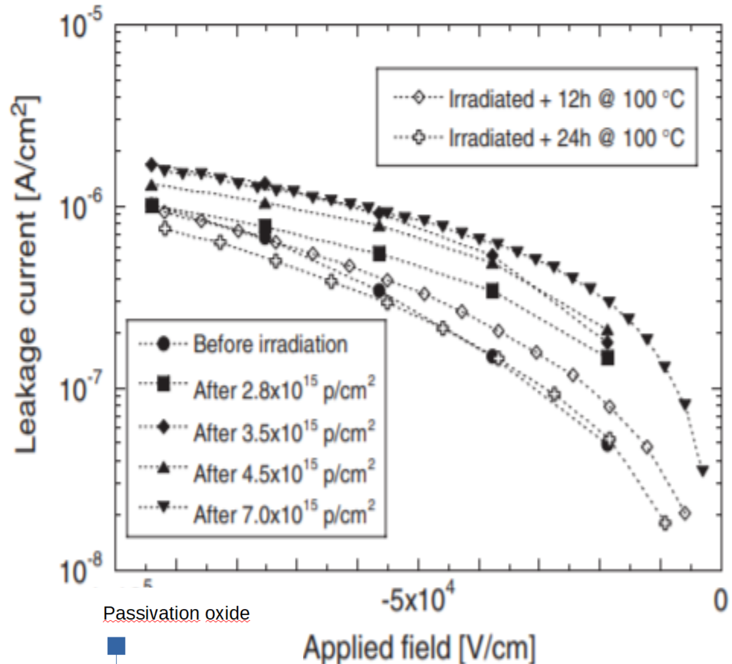


Study of fundamental properties of impact ionization and solid-state charge collection suggests that LGADs are advantageous to frame rates up to 10+ GHz

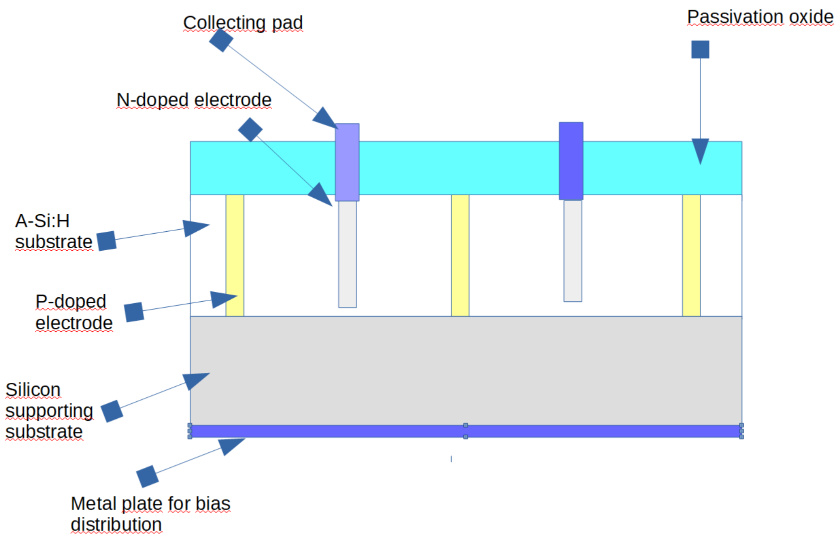
Development of a 3D Detector on a Hydrogenous Amorphous Silicon Substrate -Mauro Menichelli (INFN Perugia)

A-Si:H: extremely low radiation damage, low cost production, allows deposition onto many substrates,

but: low CCE, high $I_{leakage}$, high V_{dep}, low mobility, substrates limited to 150 μm thickness.



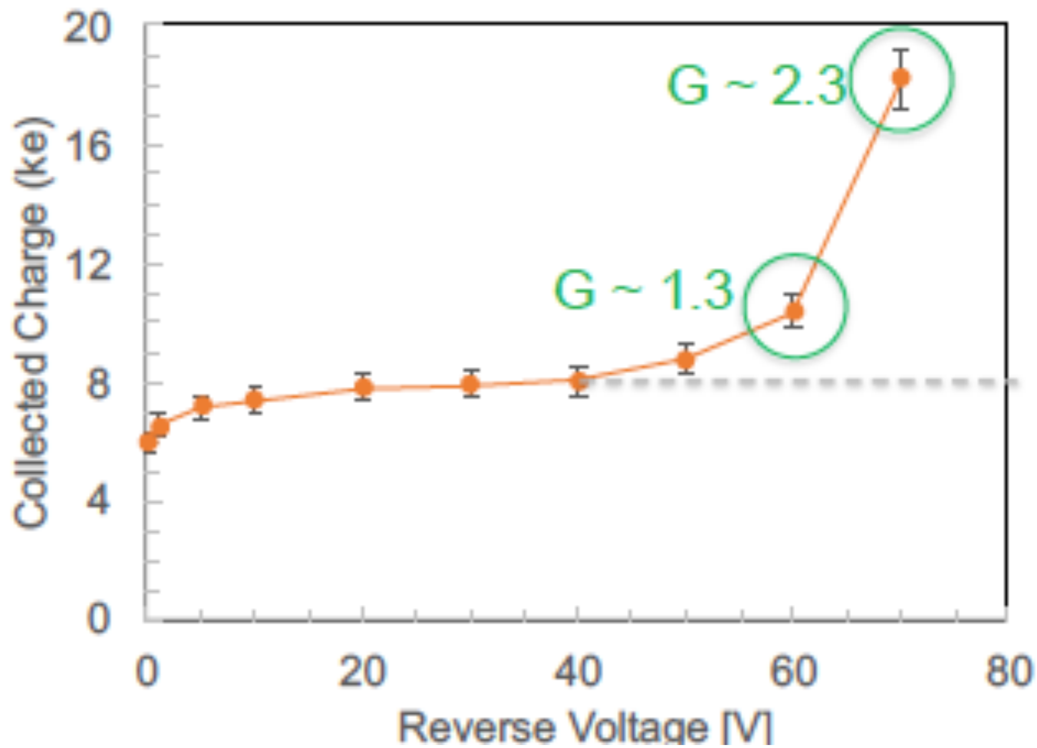
A proposed 3D design, never previously attempted:



Prototype program: Doping techniques under study in planar geometry, for transfer to 3D with various configurations

Feasibility Study of Charge Multiplication by Design in Thin Silicon 3D Sensors -Sally Seidel (Univ. of New Mexico)

Charge multiplication in irradiated 3D sensors has been known for some years. Can we design ultra-small pitch (25 μm x 25 μm) cells in thin (130 μm) devices, to multiply charge even before irradiation, while keeping capacitance low?

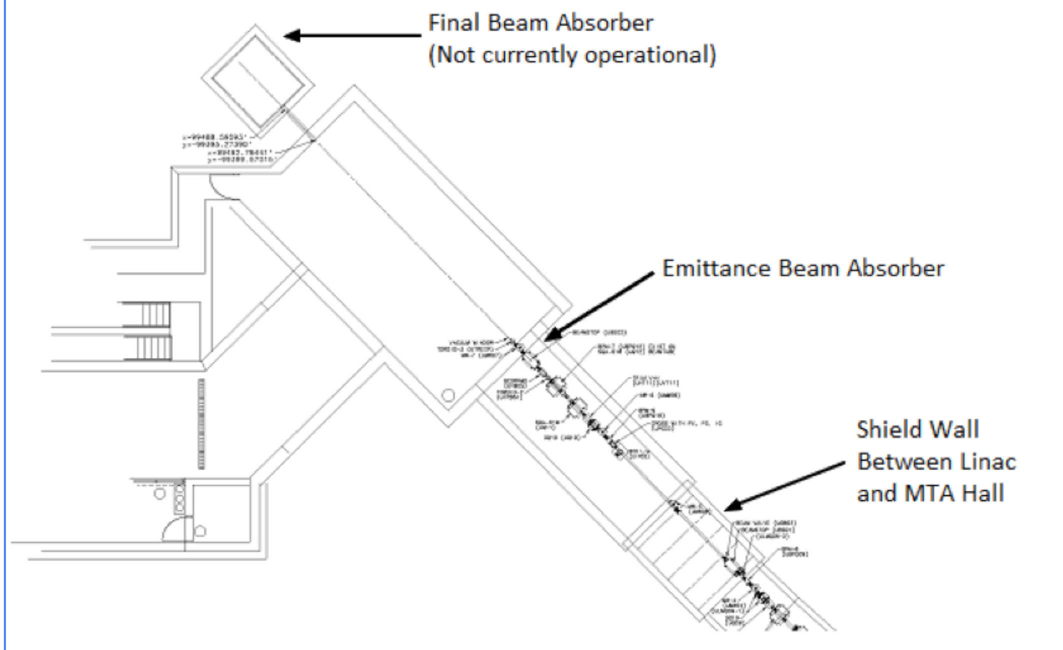


Gain up to ~2 observed in 1N-1P devices with $I_{leakage}$ and capacitance comparable to traditional pitch devices; study ongoing to understand spatial distribution of the multiplication.

New Proton Irradiation Facility at Fermilab
-Petra Merkel (FNAL)

Fermilab Irradiation Test Area (ITA) on schedule for early spring 2020 operation.

- Pulses from the LINAC can be extracted during the 6 sec flattop of the Switchyard-120 spill with minimal effect on neutrino pulses.
- 5E12 protons available per LINAC batch
- 400 MeV
- 15 Hz
- 12 hours' availability, one day per week, 40 weeks per year



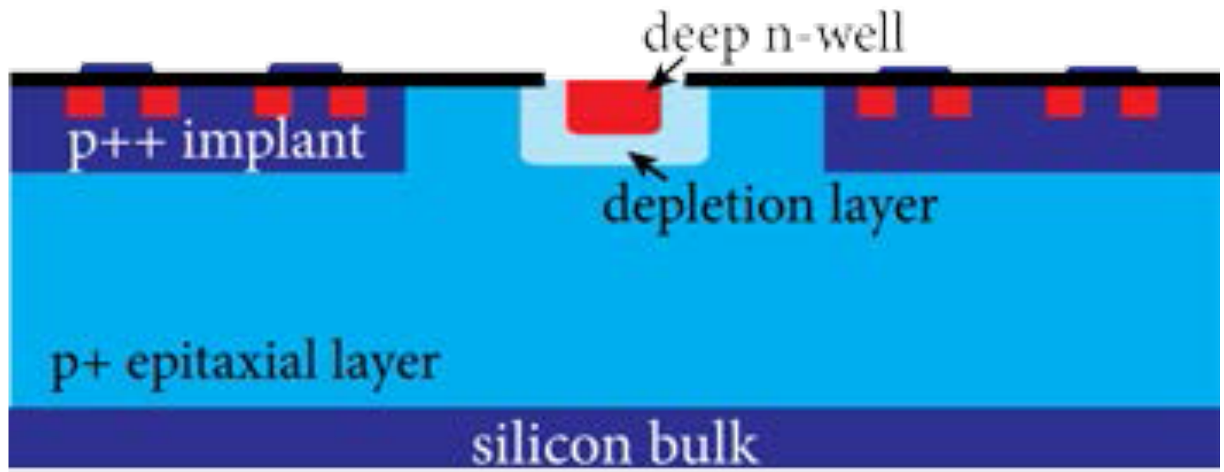
More info at https://ftbf.fnal.gov.

Chronopixel CMOS Sensor Development for the ILC -Jim Brau (Oregon)

Chronopixel Prototype 3 demonstrated a working CMOS vertex sensor that satisfies ILC design requirements – it has shallow NWELL, small capacitance, large signal, design rules waiver, but only 2.74 μm² sensor size.

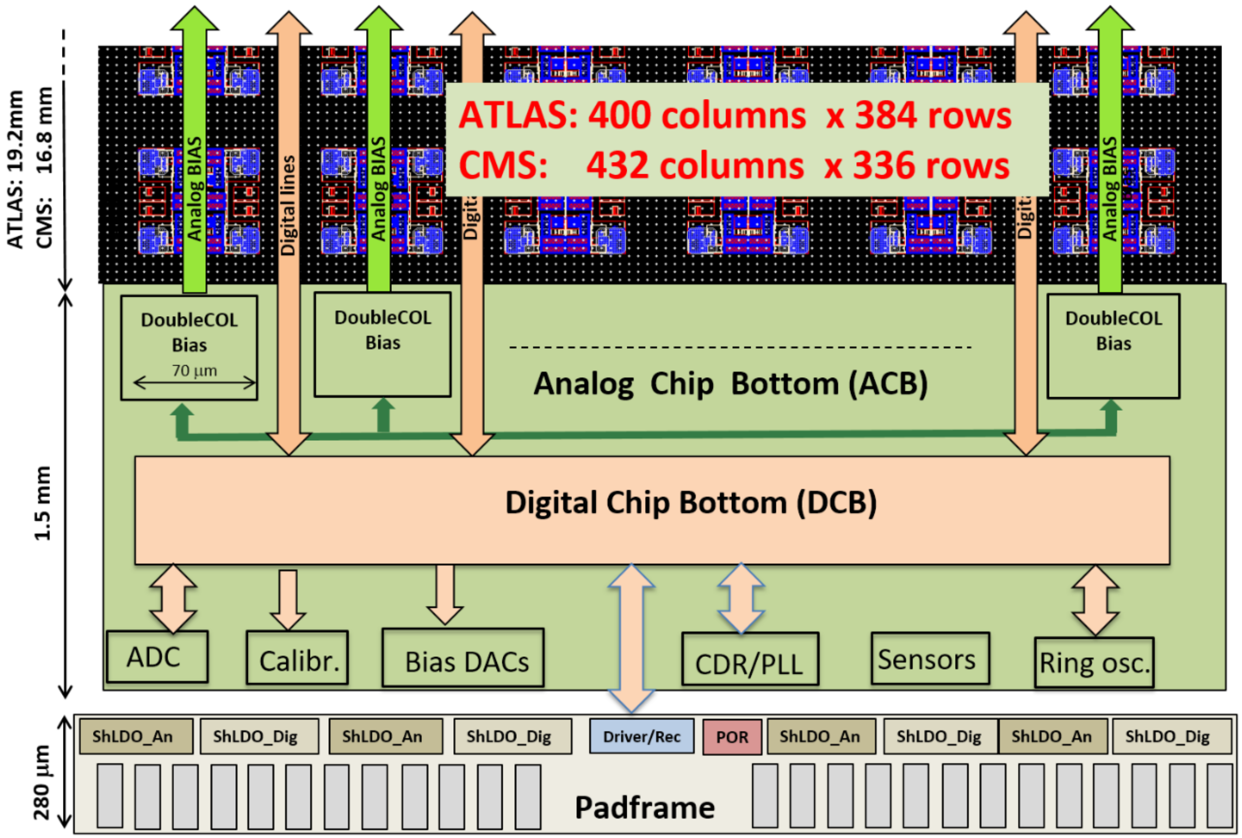
Performance is maintained for ILC radiation exposure levels.

Future development will refine, e.g., small cross talk issues, expand area, demonstrate efficiencies.



Parameter	ILC Requirement	Prototype Tests
Detector Sensitivity	10 μV/electron	59 μV/electron
Detector Noise	25 electrons	29 electrons
Comparator Accuracy	0.2 mV RMS	0.2 mV RMS
Sensor Capacitance	10 fF	2.7 fF
Clocking Speed	3.3 MHz	7.3 MHz
Charge collection time	300 nsec	20 nsec
Readout Rate	25 Mbits/sec	25 Mbits/sec
Power Consumption	0.13 mW/mm²	OK by estimate
Radiation Hardness	10^{11} neutrons/cm²/yr	10^{13}neutrons/cm² or 110 Mrad

RD53 Status and the Role of Verification in Digital Design
-Cesar Gonzalez Renteria (LBNL)

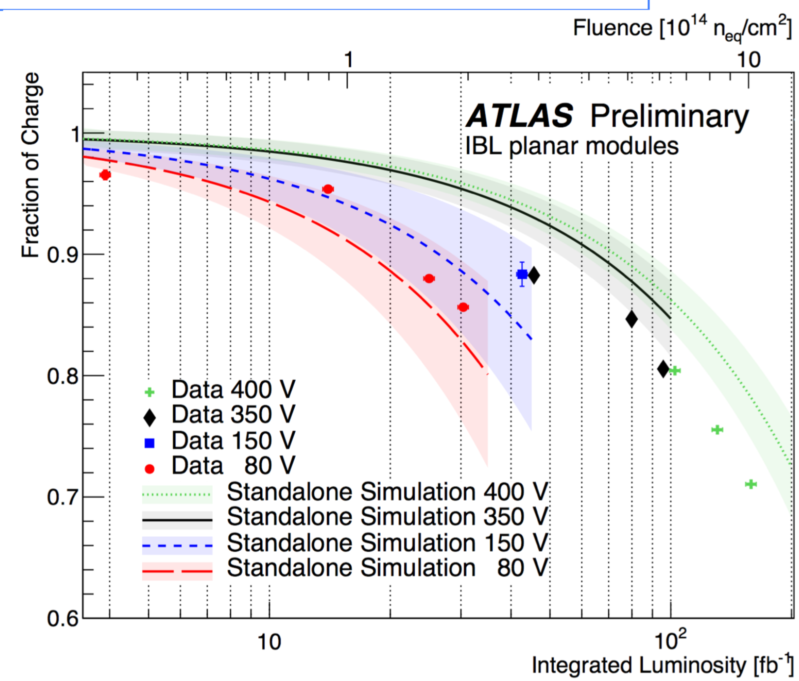


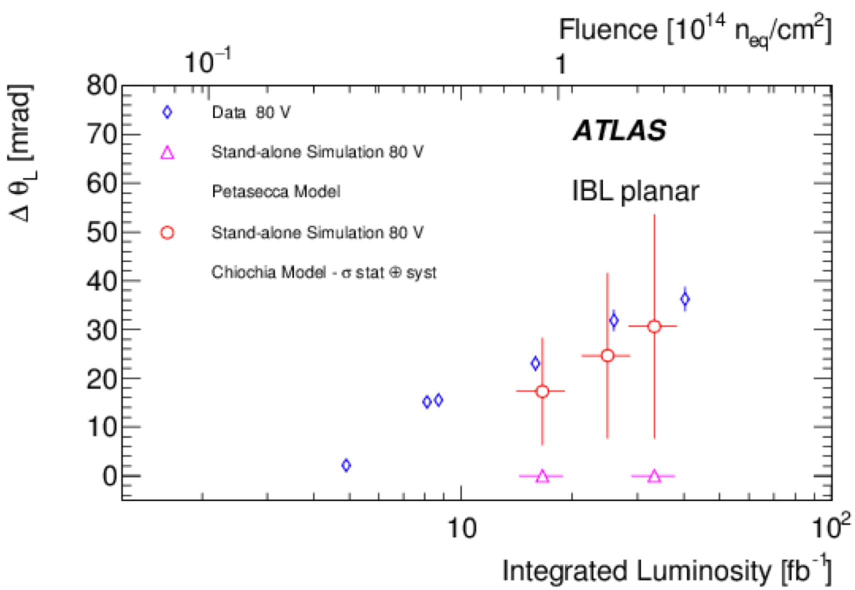
- For ATLAS (chip submission Jan 15) and CMS (a few months later).
- Verification is a cornerstone of the design and fabrication.
- Universal Verification Methodology and System Verilog are used to ensure behavior.
- Extensive simulation is essential.

Modeling Radiation Damage to Pixel Sensors in the ATLAS Detector
-Aidan Grummer (Univ. of New Mexico)

ATLAS Pixel Detector sensor leakage currents are monitored to infer fluence received. Comparison with classical Hamburg Model indicates that quality of the modeling diminishes with fluence.

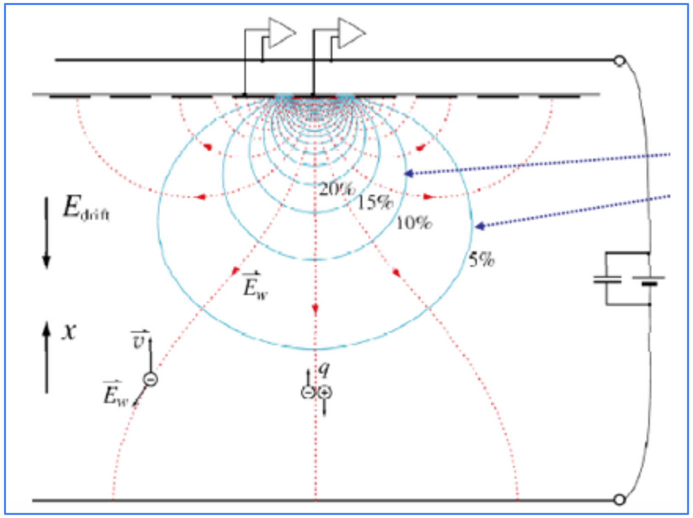
Radiation damage effects in IBL and B-Layer are modeled with TCAD to implement non-uniform E field and compute charge propagation in the bulk.



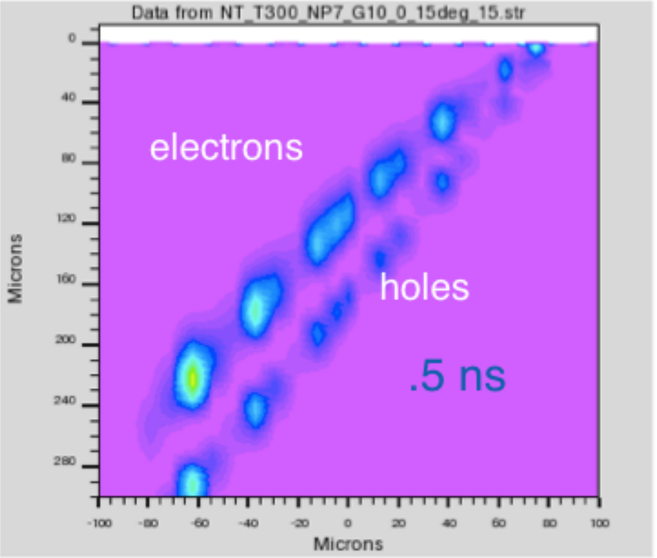


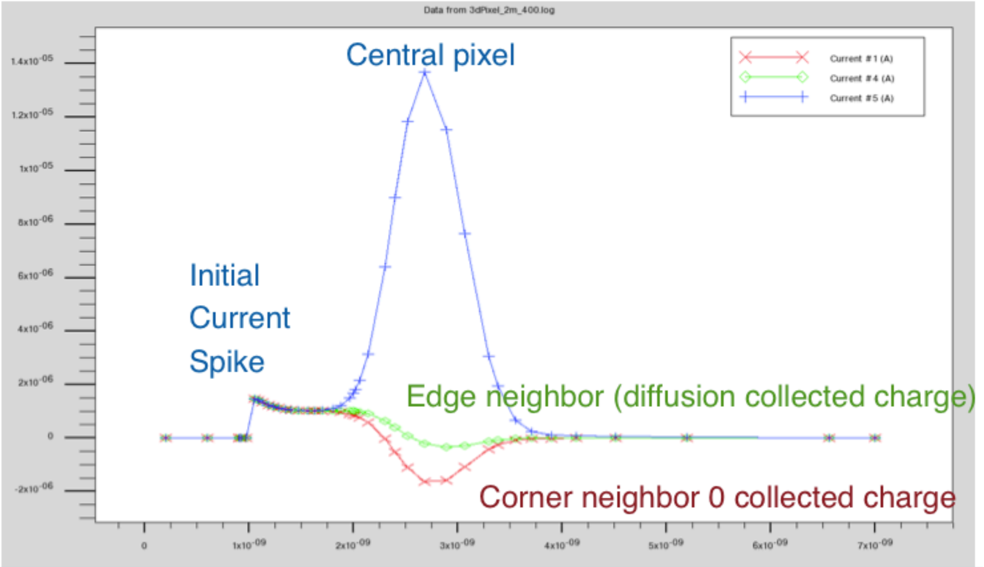
Data compare successfully to simulations for CCE and Lorentz angle.

Tracking and Timing with Induced Current Detectors -Ron Lipton (FNAL)



Possible applications of small pixels that are enabled by emerging technologies (3D integration, monolithic active devices, semiconductor substrate engineering), and draws conclusions.

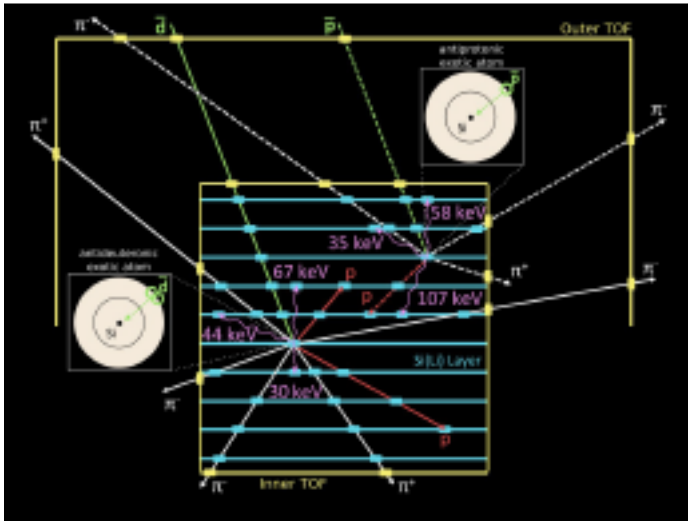




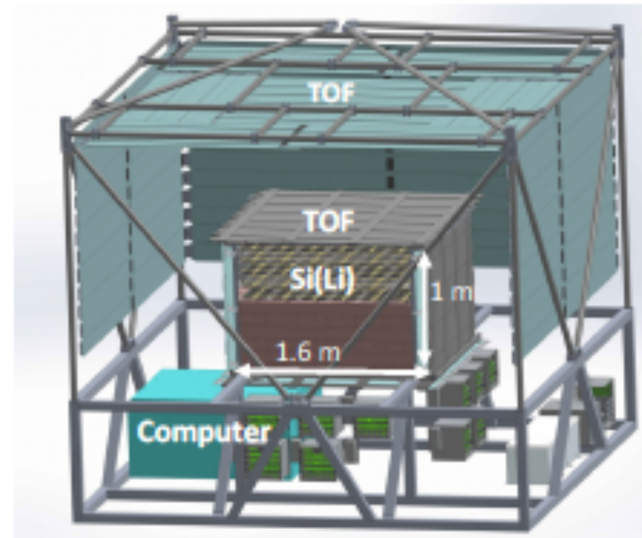
Fast timing, radiation hardness, robust response to complex event topologies may address the challenges at FCC, muon collider, EIC, etc. The next steps will transition this work from toy models to specific applications.

Large-area Si(Li) Detectors for X-ray Spectrometry and Particle Tracking for the GAPS Experiment

-Field Rogers (MIT)

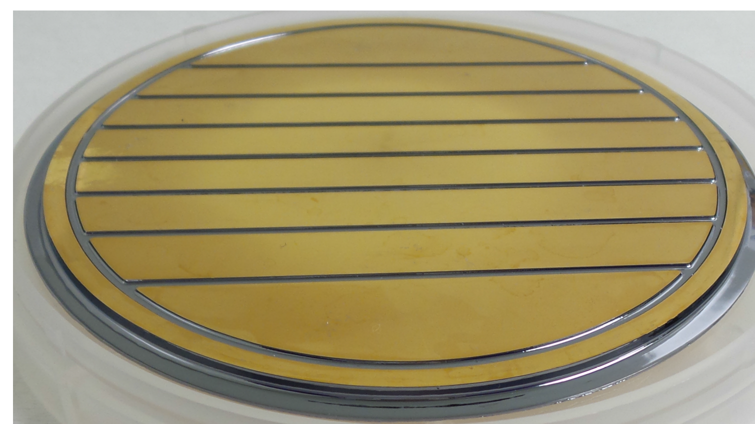


Detection of cosmic anti-nuclei using TOF as antiparticle target, de-excitation x-ray spectrometer, and antinucleus dE/dx tracker



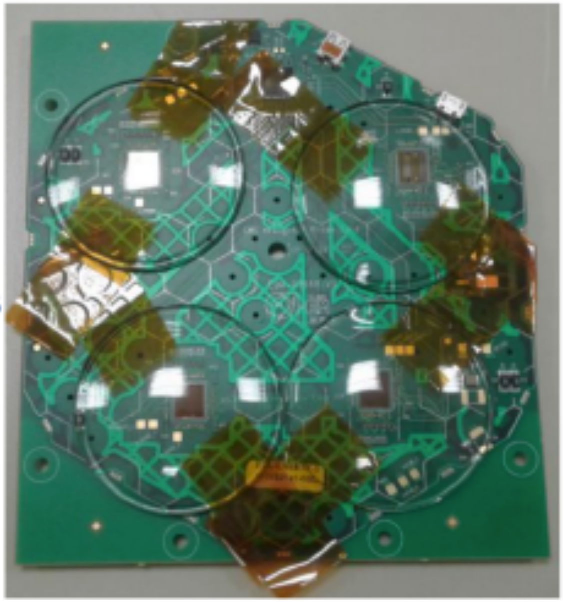
GAPS Si(Li) Detectors are

- large (10 cm diameter)
- cost effective
- operable at -30 C
- high performance (resolution < 4 keV FWHM over 20-100 keV range)
- developed over 2012-2019
- fab yield > 90%



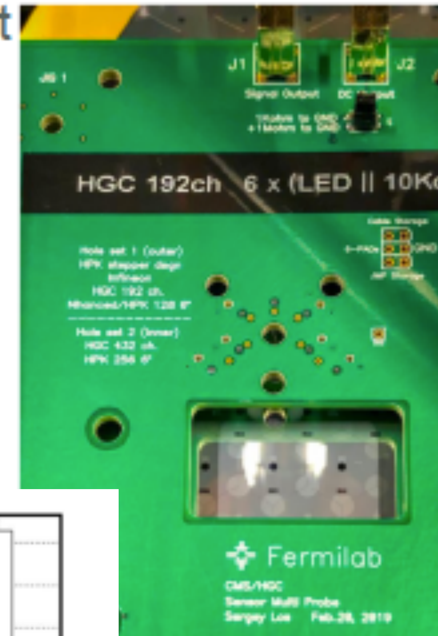
Status and Plans of the CMS High Granularity Calorimeter Upgrade Project
-Zoltan Gecse (FNAL)

Hexaboard Probe Card

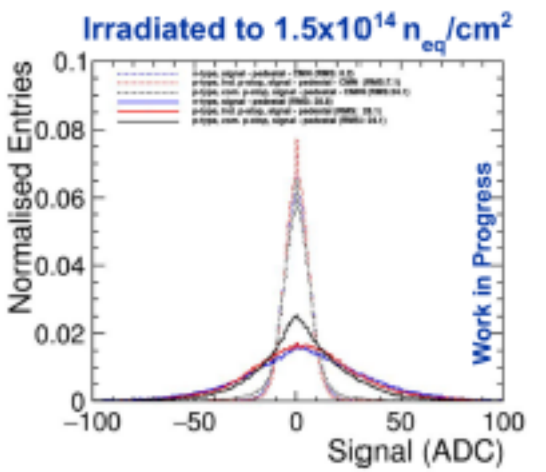


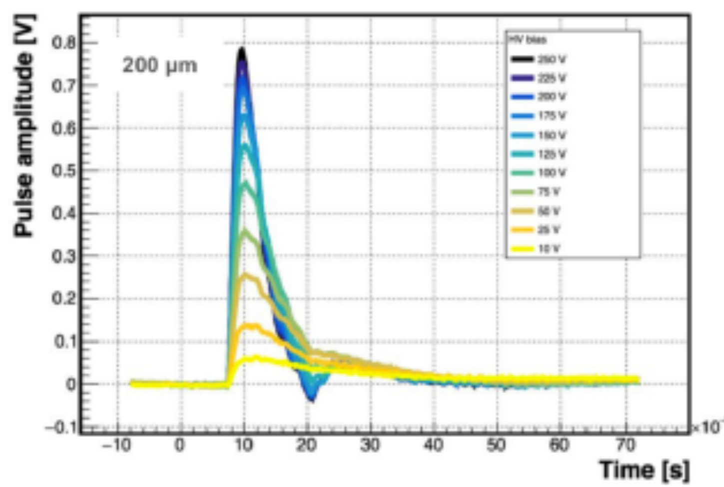
7-pin TCT board

- Developed at Fermilab
- Adoptable to different sensor layouts



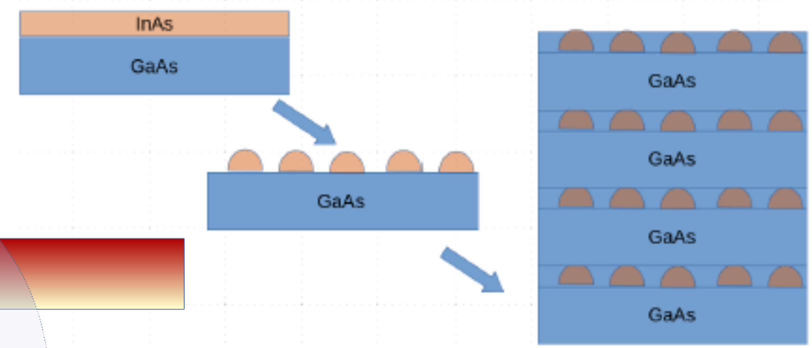
Versatile systems are developed for characterization of large area silicon sensors.

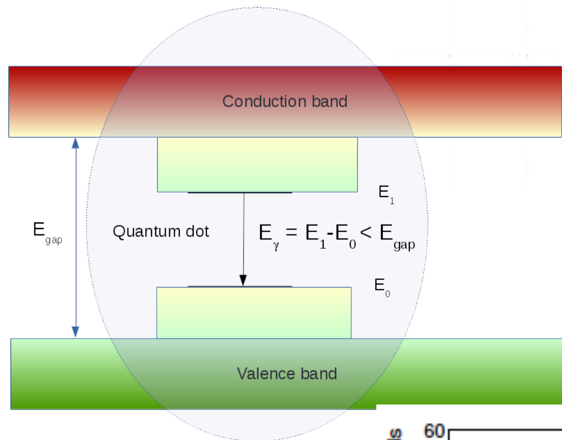




Scintillation Detector Based on InAs Quantum Dots in a GaAs Semiconductor Matrix for Charged Particle Tracking: First Measurements of the Response to alpha-particles
-Pavel Murat (FNAL)

Can one build a tracker out of scintillating wafers? Quantum dot GaAs-based sensors are fast, rad-hard, and have integrated photodiodes that can operate without external bias.





Further R&D needed to improve light collection efficiency and develop low noise readout for MIP signals.