



Project: MPW Production of LGADs at BNL

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4th DRD3 week on Solid State Detectors R&D - <https://indico.cern.ch/event/1581713/timetable/#20251111.detailed>

November 11th 2025



Scope of the project

At BNL, we have been distributing LGADs and AC-LGADs (and other types of silicon devices) to anyone requesting them.

With this project, we want to form a consortium of interested parties to fund a BNL Multi-Project Wafer fabrication, with the devices of interest to the consortium

BNL established standard processes: LGADs and AC LGADs

We seek DRD3 Common Funds for producing sensors that can be distributed and used by the broader DRD3 community, beyond the consortium.

New ideas welcome from the consortium (that can be done with standard techniques), both designs and process.

New mask set: layout done by BNL, collecting all the inputs (use of old masksets still possible, in addition to new one)

Support on TCAD simulations as well

As in the past, we'll provide diced chips, previously tested by I-V and C-V

About 10 4" or 6" wafers.

Clean Rooms for sensor fabrications

- Class-100 clean room dedicated to silicon sensors
- Class-1000 clean room for germanium, diamond, selenium, high-Z
- CFN user facility at BNL for PECVD deposition (and spare instrumentation)
- other external facilities are leveraged and outsourced for additional capabilities
 - Ion implantation
 - Photolithographic mask production
 - PECVD, polysilicon deposition
- Process flow and design are custom and application driven
- Fully functional sensors starting from bare substrates
- Testing capabilities



Furnaces for
dry oxidations
and annealings



Double-sided
mask aligner



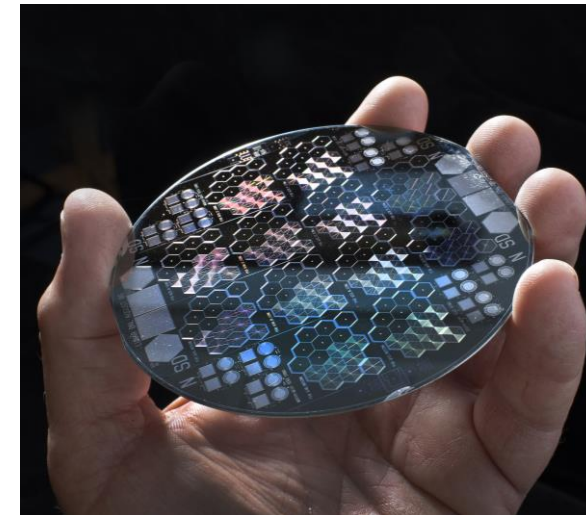
Wet bench
(HF, RCA I & II,
polyetch, ...)



Sputtering
(Al, Al1%Si, Ti)



Laser dicing



Available technologies:

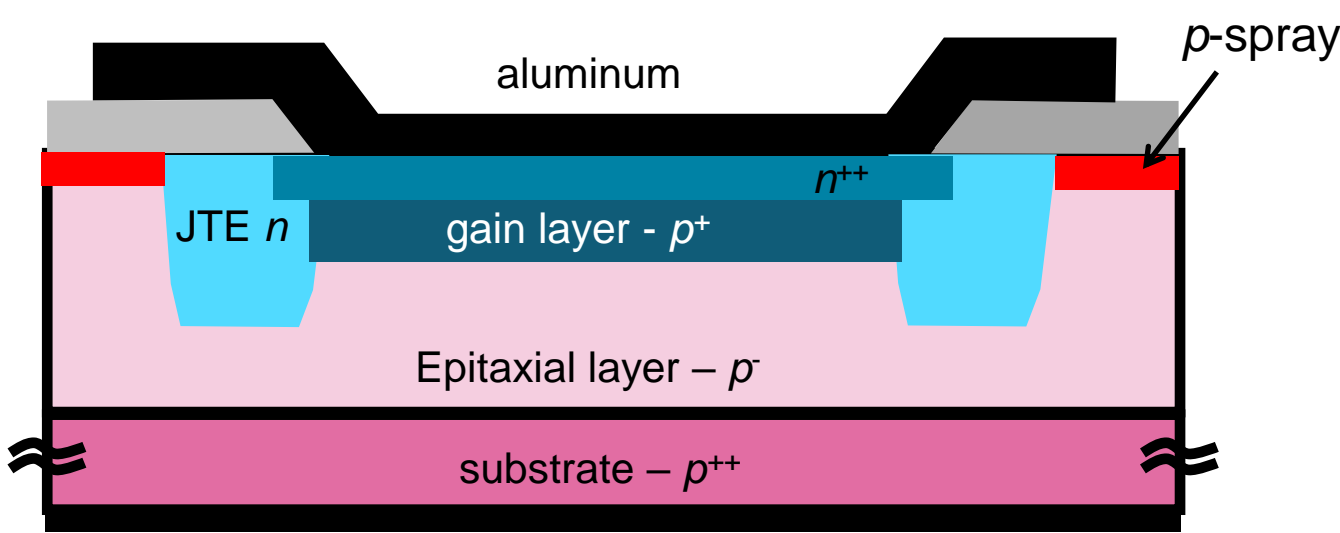
- 1) DC – LGADs
- 2) AC – LGADs
- 3) Recent technology for AC/DC LGADs
- 4) P-on-n LGADs

Funding will be limited so little space for extensive R&D,
only standard/planar techniques

Available technology:

1) LGAD

Std LGAD



- Fabrication on 20, 30, 50 μm thick HR p-type epi substrates (4")
- Migrating to 6" with next wafer purchase

- Uniform unpatterned p-spray to compensate for oxide charge and isolate n+ electrodes
- Deep Junction Termination Extension for n+ edge protection against BreakDowns
- N++ to make good ohmic contact
- Gain energy as per supplier and dose calibrated to have specific breakdown voltage
 - 20 μm $\rightarrow V_{\text{BD}} \sim < 100\text{V}$
 - 30 μm $\rightarrow V_{\text{BD}} \sim 120\text{V}$
 - 50 μm $\rightarrow V_{\text{BD}} \sim 200\text{V}$ (at RT)

Some past LGAD productions

Single channels (1.3mm x1.3mm), mainly for test purposes

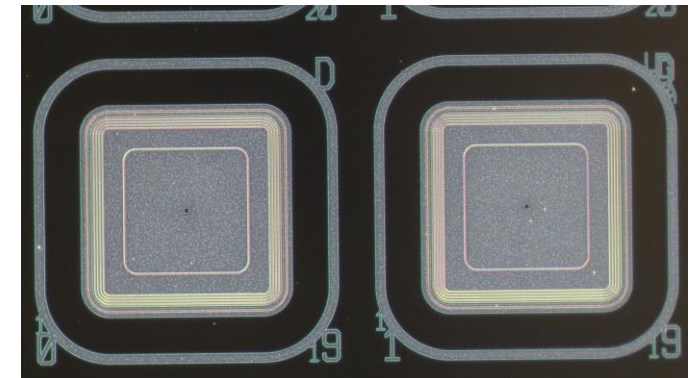
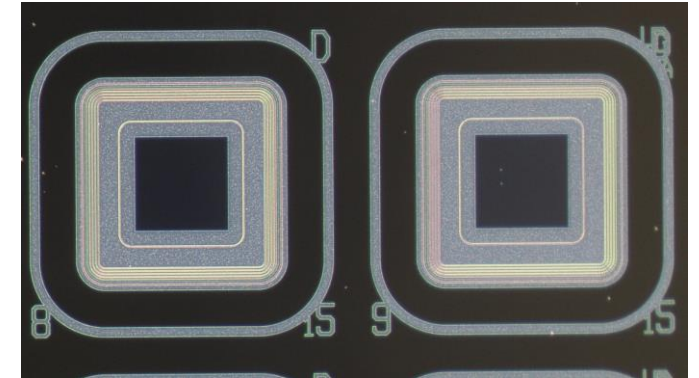
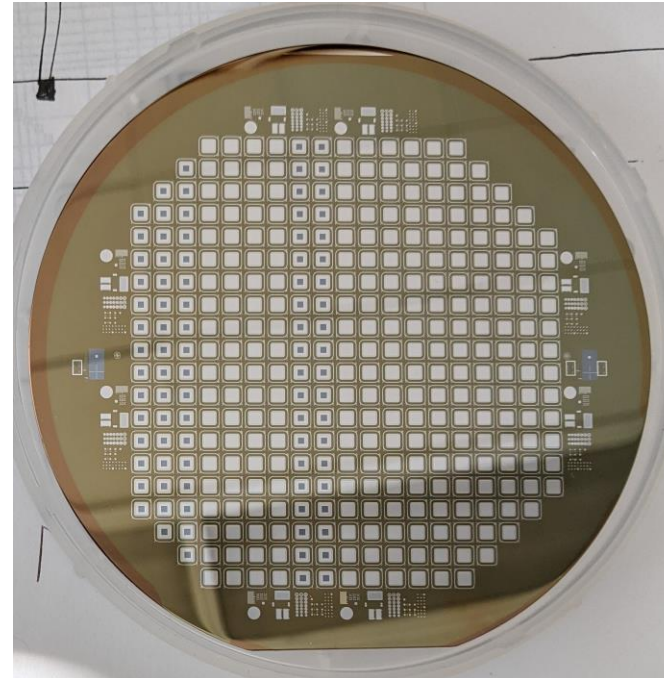
Substrate thickness:

- Epi:20, 30, 50um
- FZ: 300um (X-rays)

Gain implant energy

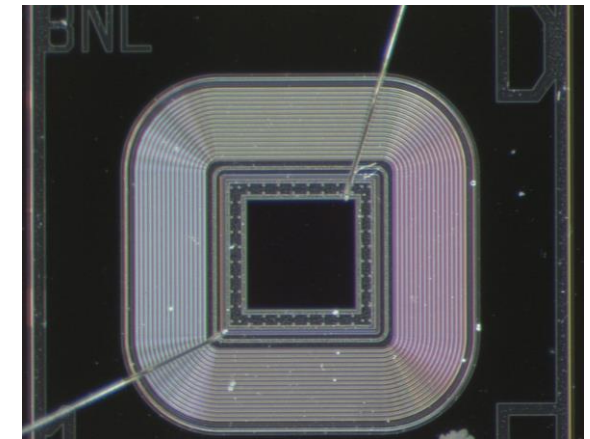
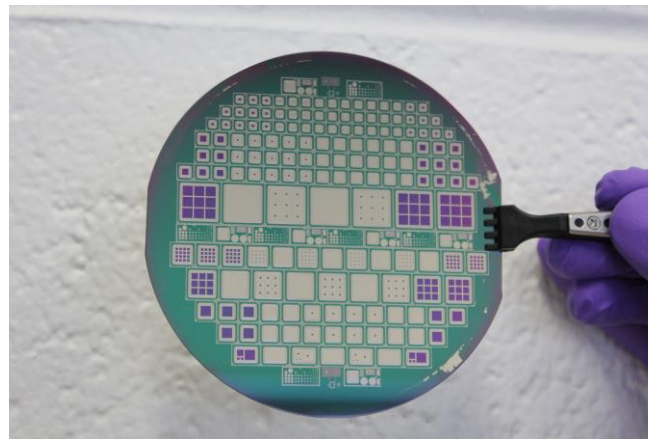
(calibrated by productions)

- 380keV
- 1MeV
- 1.5MeV



2017 LGAD layout

- 1mm x 1mm
- 2mm x 2mm
- 3mm x 3mm
- And arrays



Available technology:

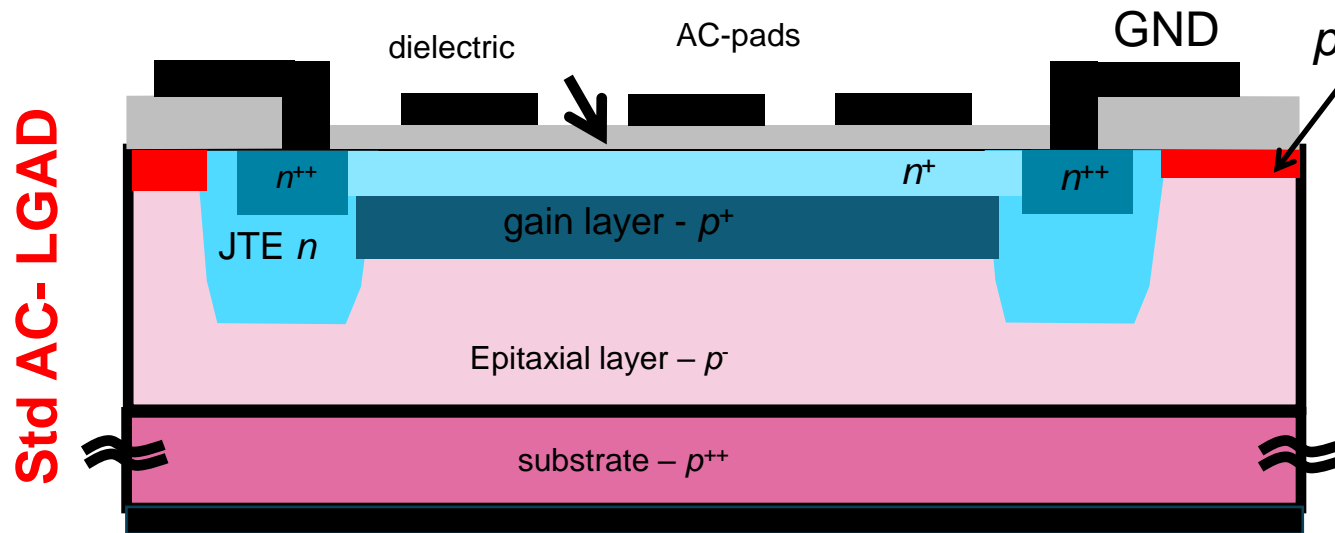
2) AC-LGAD

Two main differences wrt LGAD:

1. one large low-doped high- ρ n^+ implant running overall the active area, instead of a high-doped low- ρ n^{++}
2. A thin insulator over the n^+ , where fine-pitch electrodes are placed.

100% Fill Factor and **fast timing information at a per-pixel level** both achieved!!!

- Signal is still generated by drift of multiplied holes into the substrate and AC-coupled through dielectric
- Electrons collect at the resistive n^+ and then slowly flow to an ohmic contact at the edge.



- p-spray as in LGADs
- Deep Junction Termination Extension for n+ edge protection against BreakDowns with embedded N++ to make good ohmic contact
- Gain dose re-calibrated wrt LGADs to keep the same breakdown voltage as in LGADs
 - 20 μm $\rightarrow V_{\text{BD}} \sim < 100\text{V}$
 - 30 μm $\rightarrow V_{\text{BD}} \sim 120\text{V}$
 - 50 μm $\rightarrow V_{\text{BD}} \sim 200\text{V}$
(at RT)

Some past std AC-LGAD productions

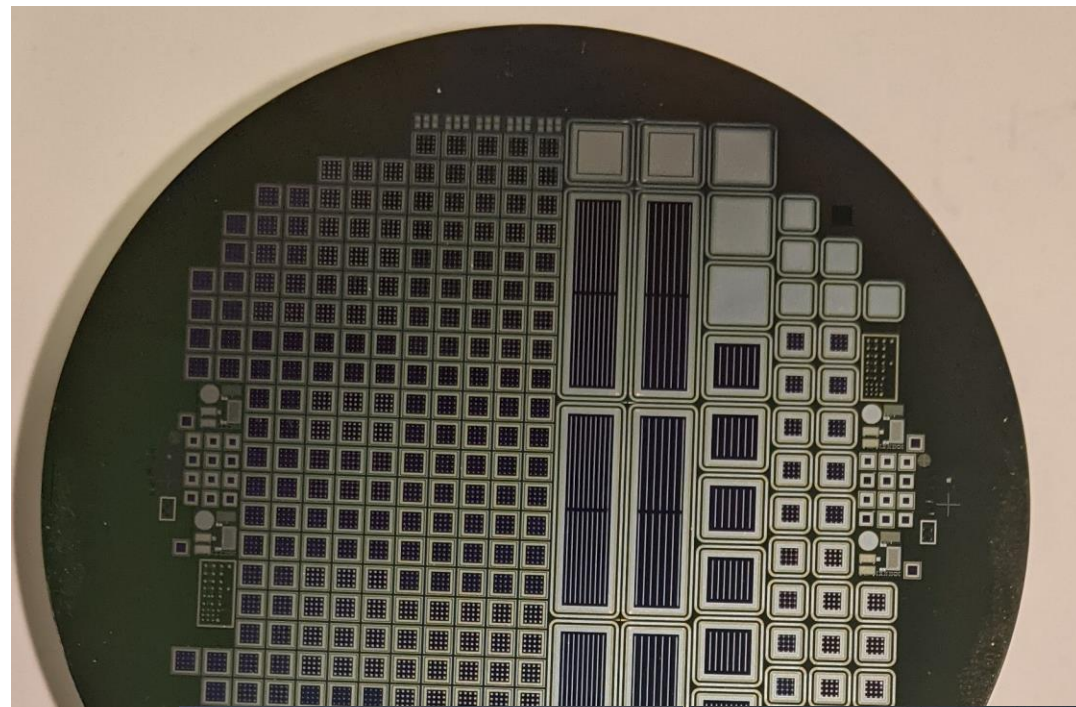
Several productions, differing for metal shapes, gain implant energy

ACLGAD strips

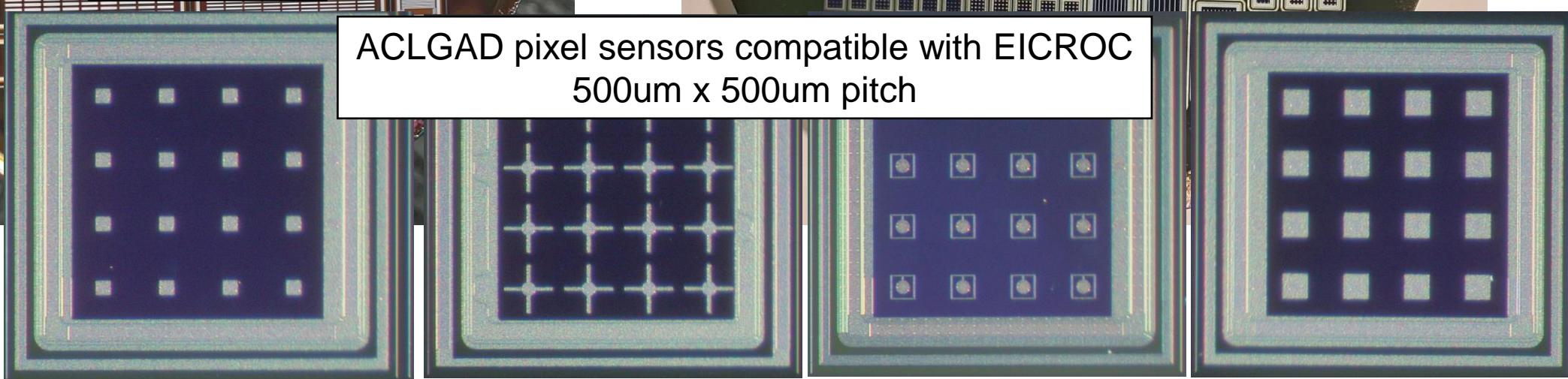
0.5cm length

1cm length

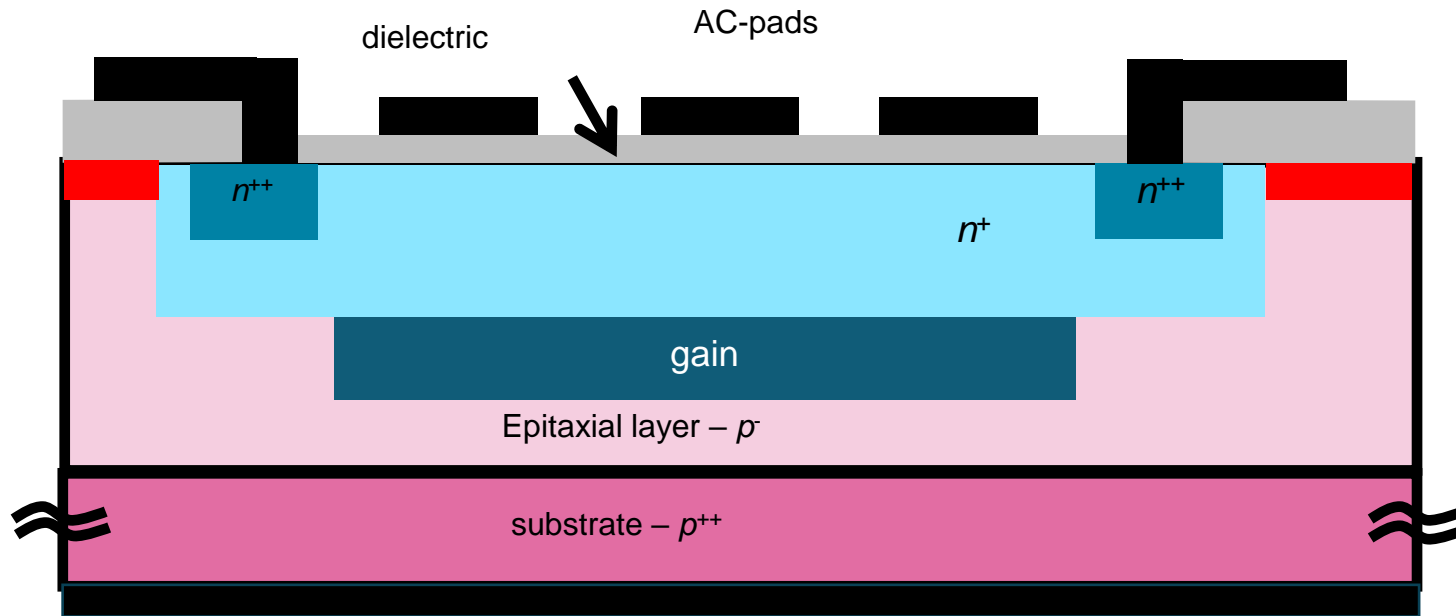
2.5cm length



ACLGAD pixel sensors compatible with EICROC
500um x 500um pitch



Available technology: 3) New AC-LGAD



- No JTE
- Resistive n^{+} layer as deep as JTE self-protects from high electric fields at the edge
- Gain layer very deep to offset for the deeper n^{+}
- N^{++} embedded into n^{+} does not cause yield issues
- Process compatible with LGAD

Pilot production done, technology available.

Available technology: 4) p-on-n LGADs

For low penetrating particles, done only on FZ wafers.

What can we fabricate in a MPW

Process flow:

Considering the sought-after funding, only established technologies with planar process (no expensive processes both in terms of R&D time or techniques, such as wafer bonding, thinning, epi deposition)
DC-LGADs / AC-LGAD/Diodes

Wafers:

possibly, only wafers we have already (epi 20,30, 50 um and FZ)

Implants:

those already used in existing developed processes: boron up to 1.5MeV

Layout:

Device area: as is a MPW, cannot make super large devices (few 1cm² OK), also yield needs to be factored in

Layout to be carried out by BNL

There is room for tweaking – to be discussed.

We are collecting interested institutions to form the consortium, order of 10

We expect each institution contributing 4kCHF, with DRD3 matching the contribution

→ total of 80kCHF for the MPW production (includes all): 40kCHF from consortium, 40KCHF from DRD3.

When funds available, production of ~10 wafers will be about 4 months, followed by testing and dicing.

Interested institutes: BNL, Zhurich, Bern, NCSR Demokritos, Uni. New Mexico, Syracuse Uni., Texas Tech Uni., Santa Cruz, Brown, Uni. Hawaii

More are welcome to join!

**Current device requests
(to be confirmed)**

LGAD Type	Strip/Pixel	Electrode Pitch/Length	Matrix	Size	Notes
AC-LGAD	Pixel	500x500 um2	32x32	1.6x1.6 cm2	
AC-LGAD	Pixel	100x100 um2, 55x55 um2	32x32	3.2x3.2 mm2, etc.	
AC-LGAD	Pixel	100x100 um2, 55x55 um2	32x33	3.2x3.2 mm2, etc.	
LGAD	Pad	1.3x1.3 mm2			p-in-n for optical applications
lgads/ac- lgads	pad	3x3 mm2	2x2		continuation of the current study of LGAD performance at coarser granularity
AC-LGADs Thick LGADs/AC- LGADs	strips	500x1-2cm		1x1, 2x2cm	500um Thick LGADs
AC-LGADs	pixels	100x100 um2, 200x200, 500x500,55x55 um2 -- diamonds, squares	32x32, 16x16, 8x8	1x1	

Thanks!