20um LGAD sensors recent results

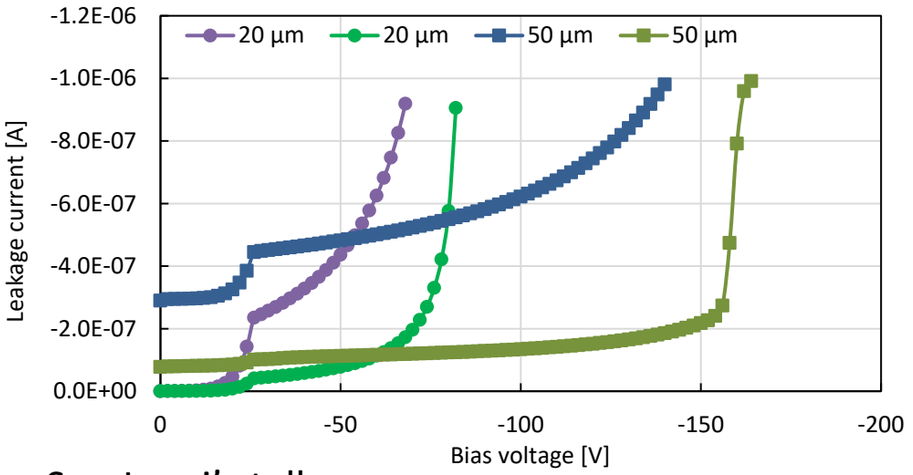
Simone Mazza for the SCIPP group

SCIPP
SANTA CRUZ INSTITUTE
FOR PARTICLE PHYSICS
UC SANTA CRUZ

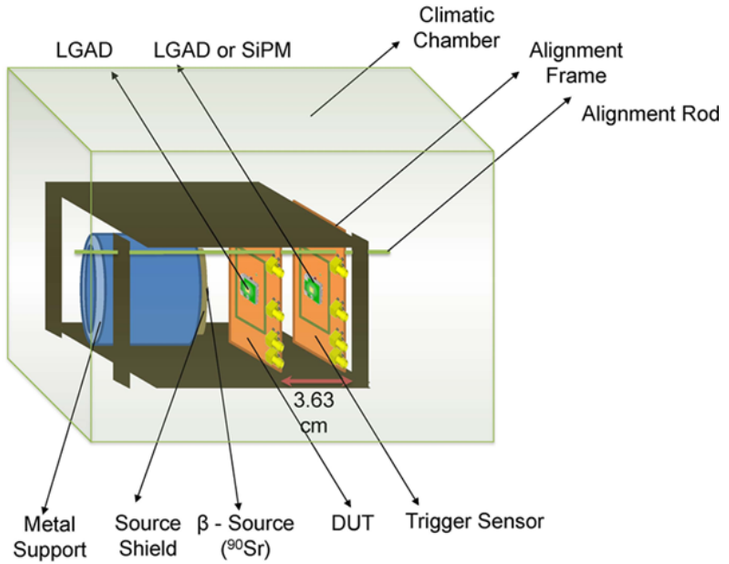
BNL 20um sensor

20um BNL device

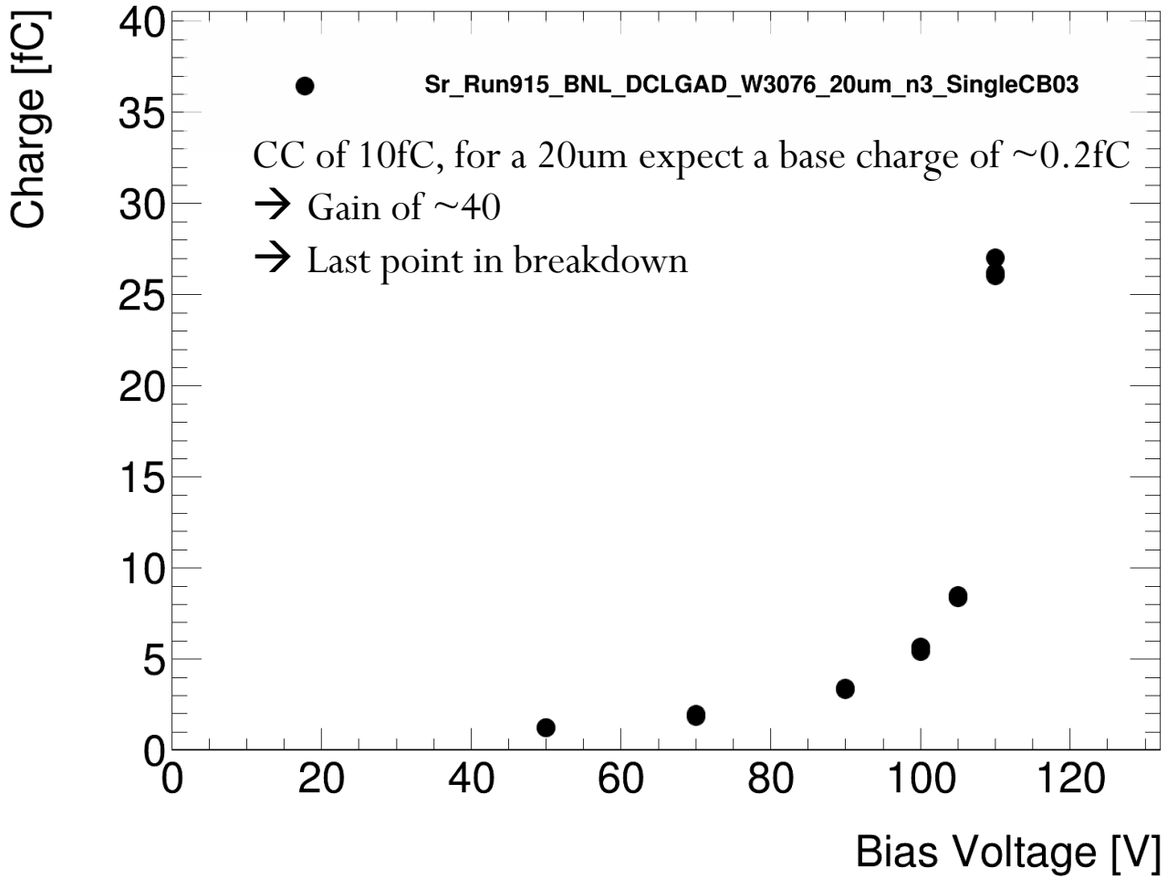
- Received new BNL production a few months ago
  - 50um and 20um devices
  - Standard DC-LGADs with 1.3x1.3 mm pad size
- 50um had some issue during testing (no results)
- Tested two 20um device, one had higher current than the other (still few uA)
  - Higher input capacitance for a 1.3mmx1.3mm device (as expected): 10 pF
  - Break down ~110V #1 and ~95V #2
- Tested both BNL LGADs with the betascope
  - Mounted on UCSC 1ch board

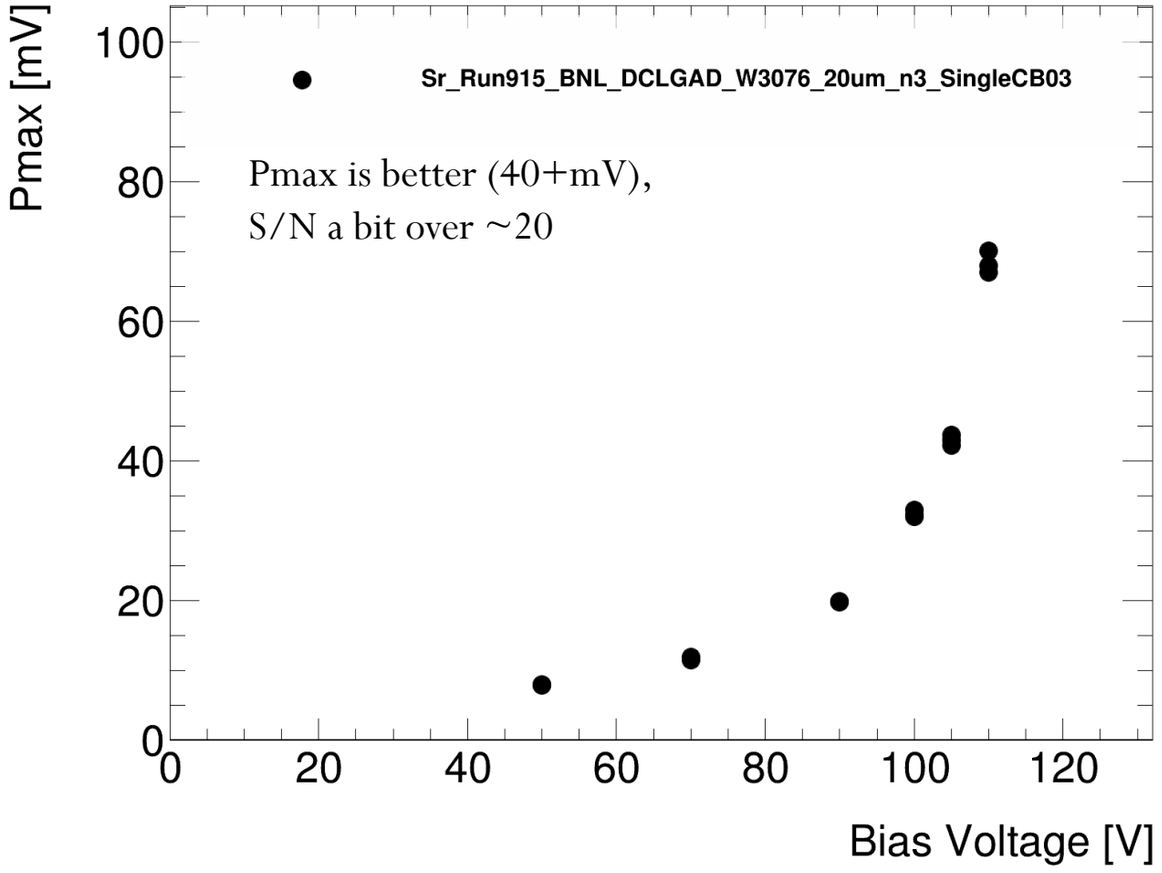


See Jenni's talk

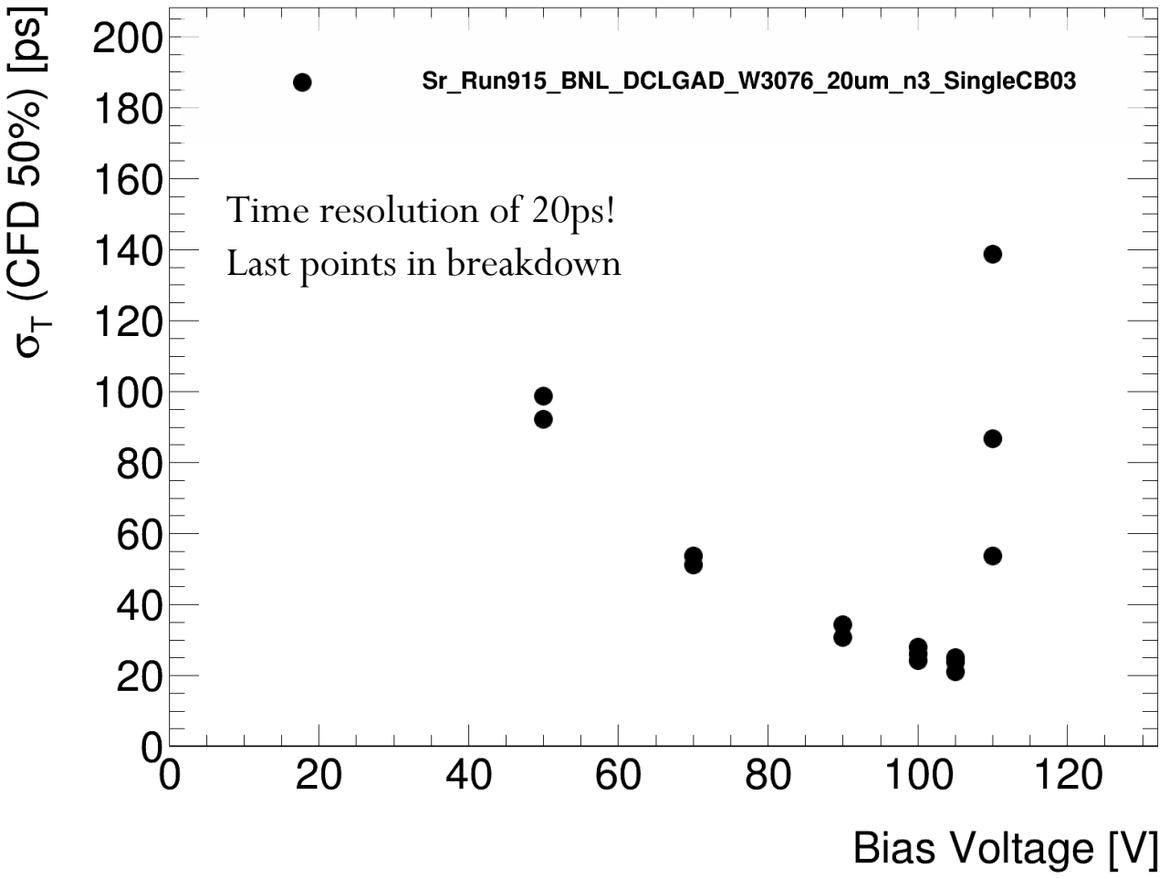


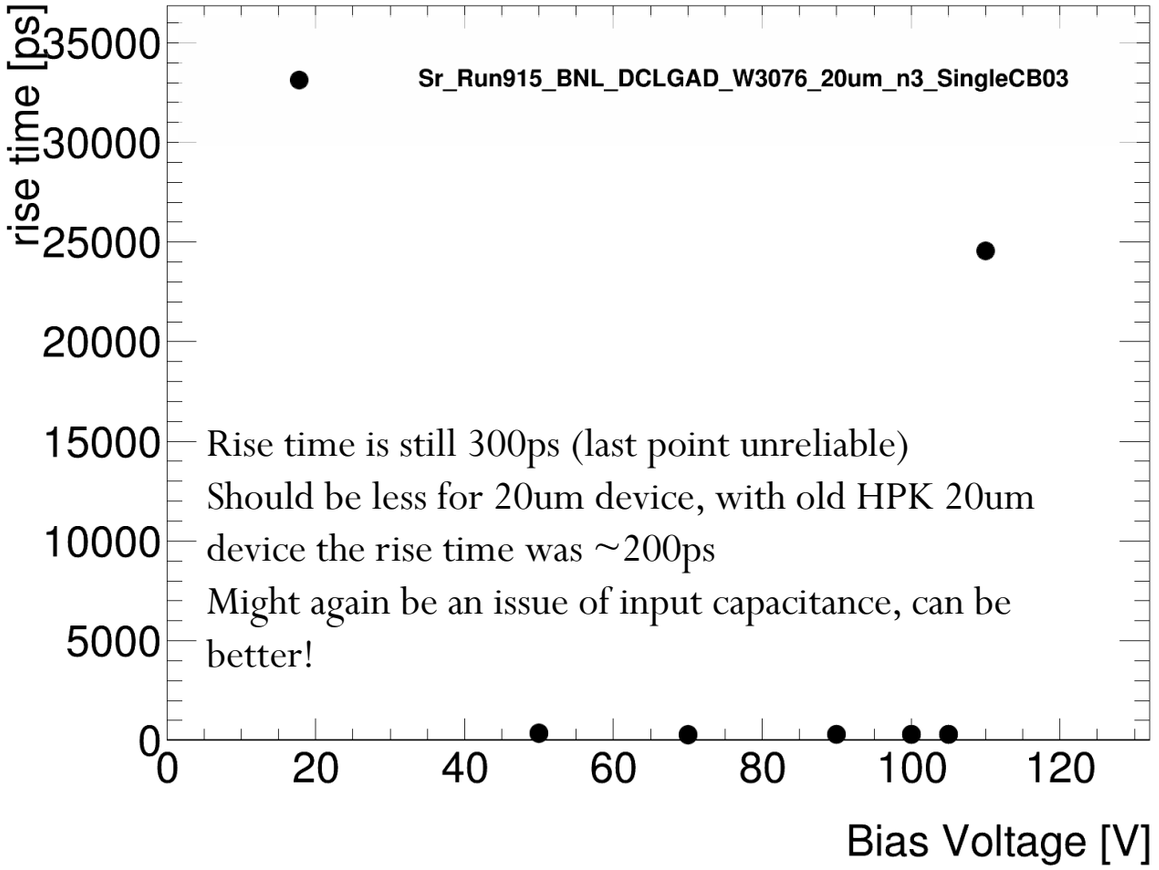
Charge/Pmax


Charge [fC]
Sr_Run915_BNL_DCLGAD_W3076_20um_n3_SingleCB03
CC of 10fC, for a 20um expect a base charge of ~0.2fC
→ Gain of ~40
→ Last point in breakdown
Bias Voltage [V]

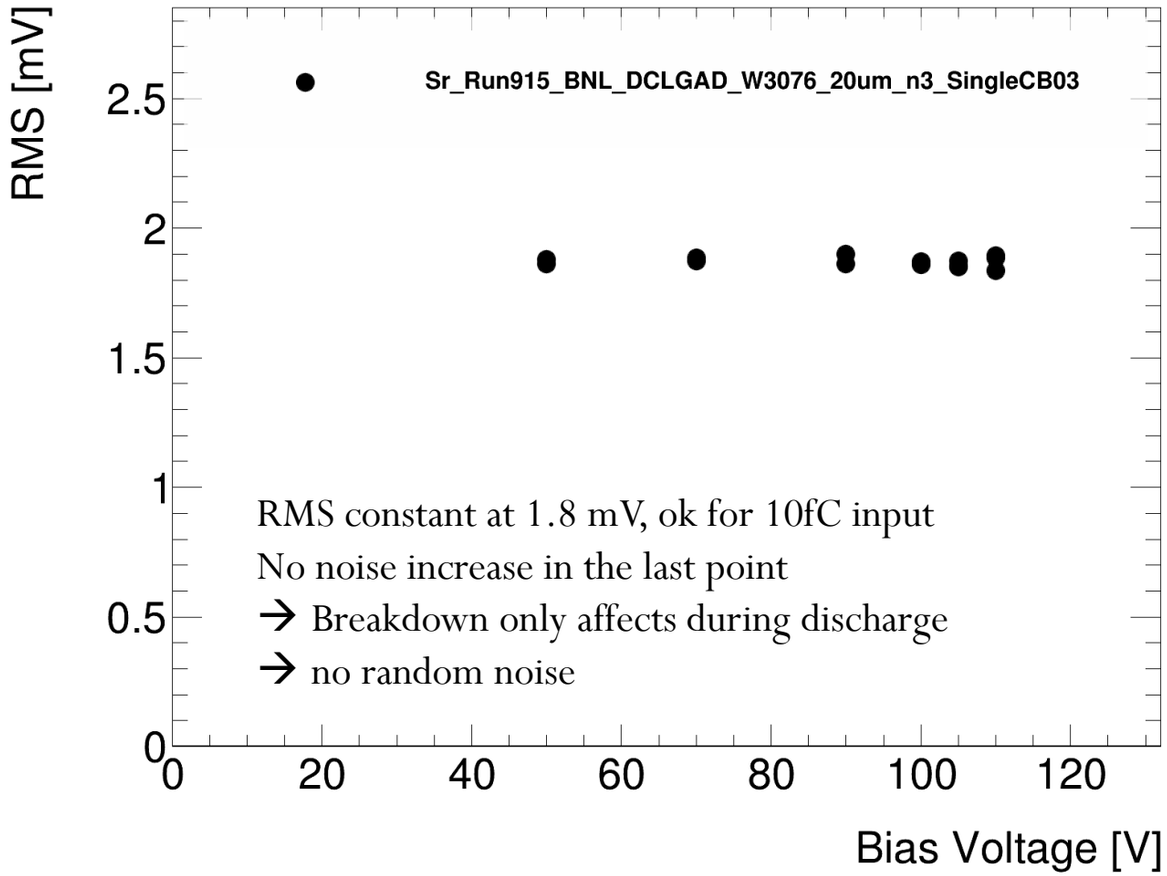

Pmax [mV]
Sr_Run915_BNL_DCLGAD_W3076_20um_n3_SingleCB03
Pmax is better (40+mV),
S/N a bit over ~20
Bias Voltage [V]

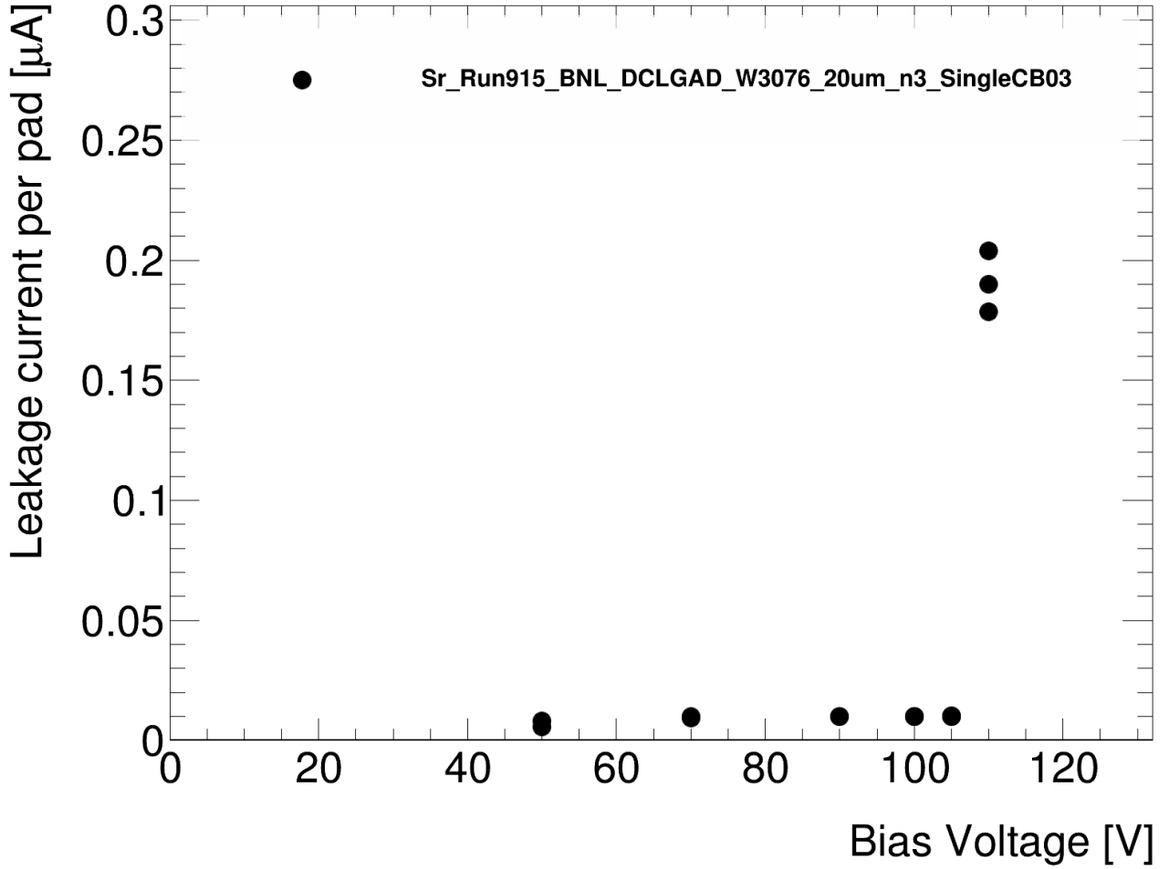
Time resolution



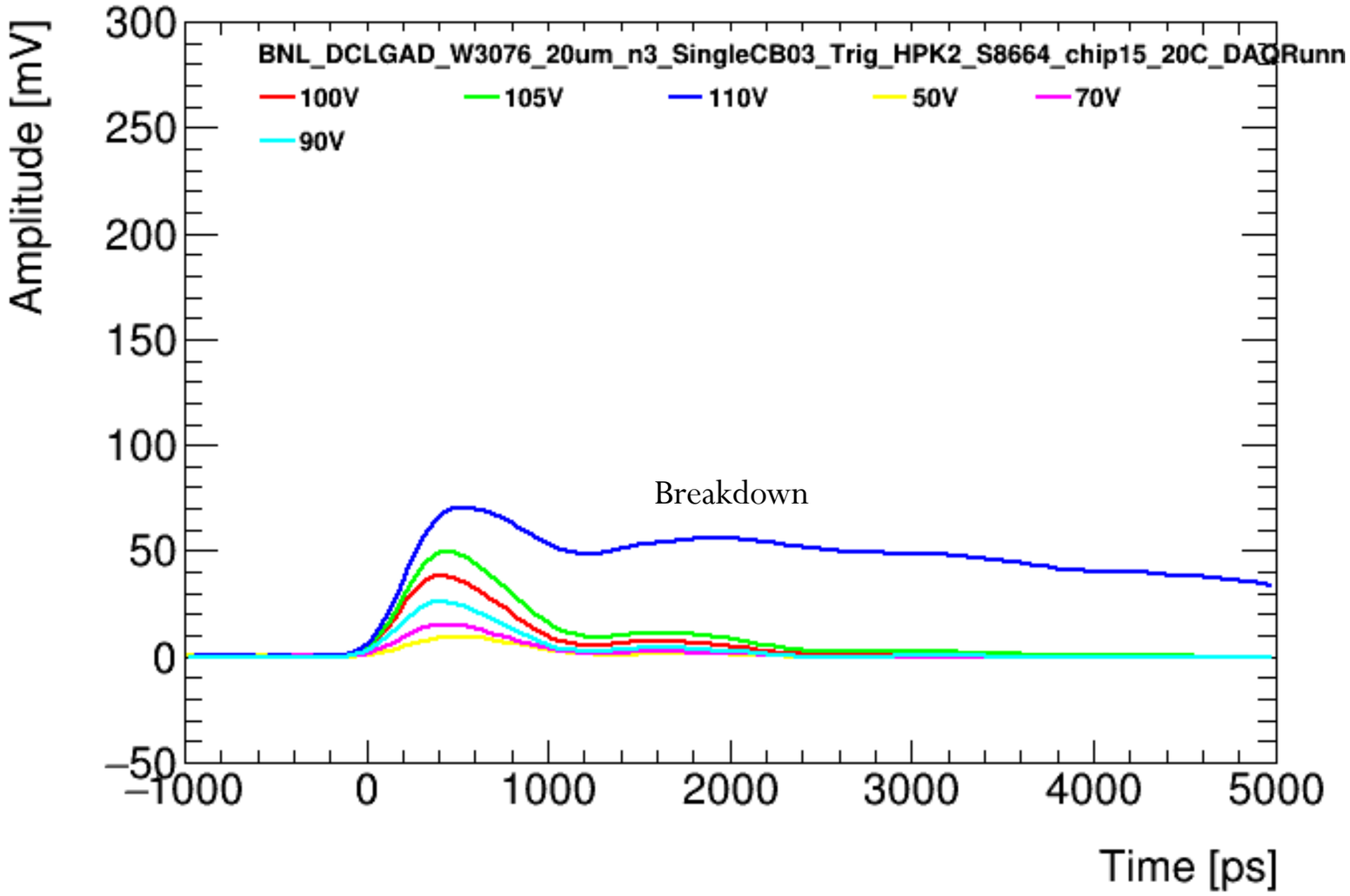


RMS, current

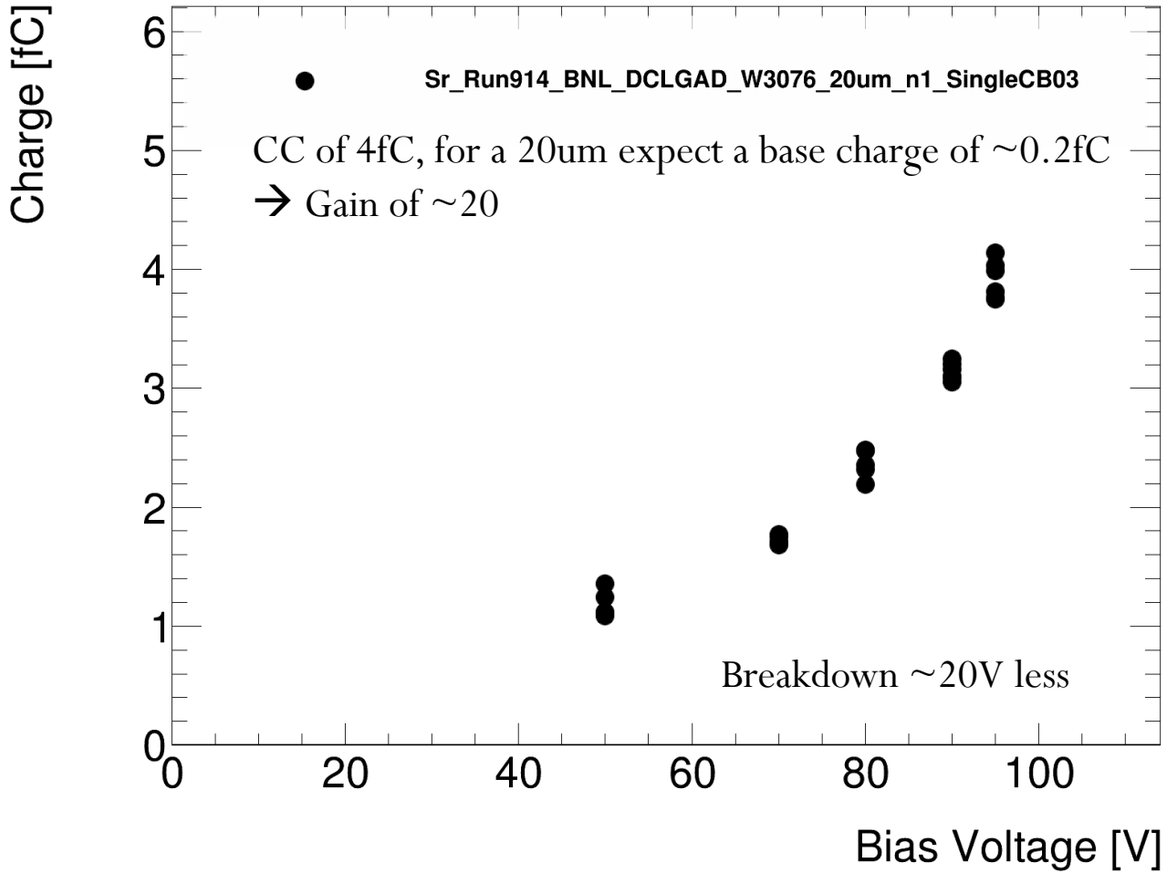

Sr_Run915_BNL_DCLGAD_W3076_20um_n3_SingleCB03
RMS [mV]
Bias Voltage [V]
RMS constant at 1.8 mV, ok for 10fC input
No noise increase in the last point
→ Breakdown only affects during discharge
→ no random noise

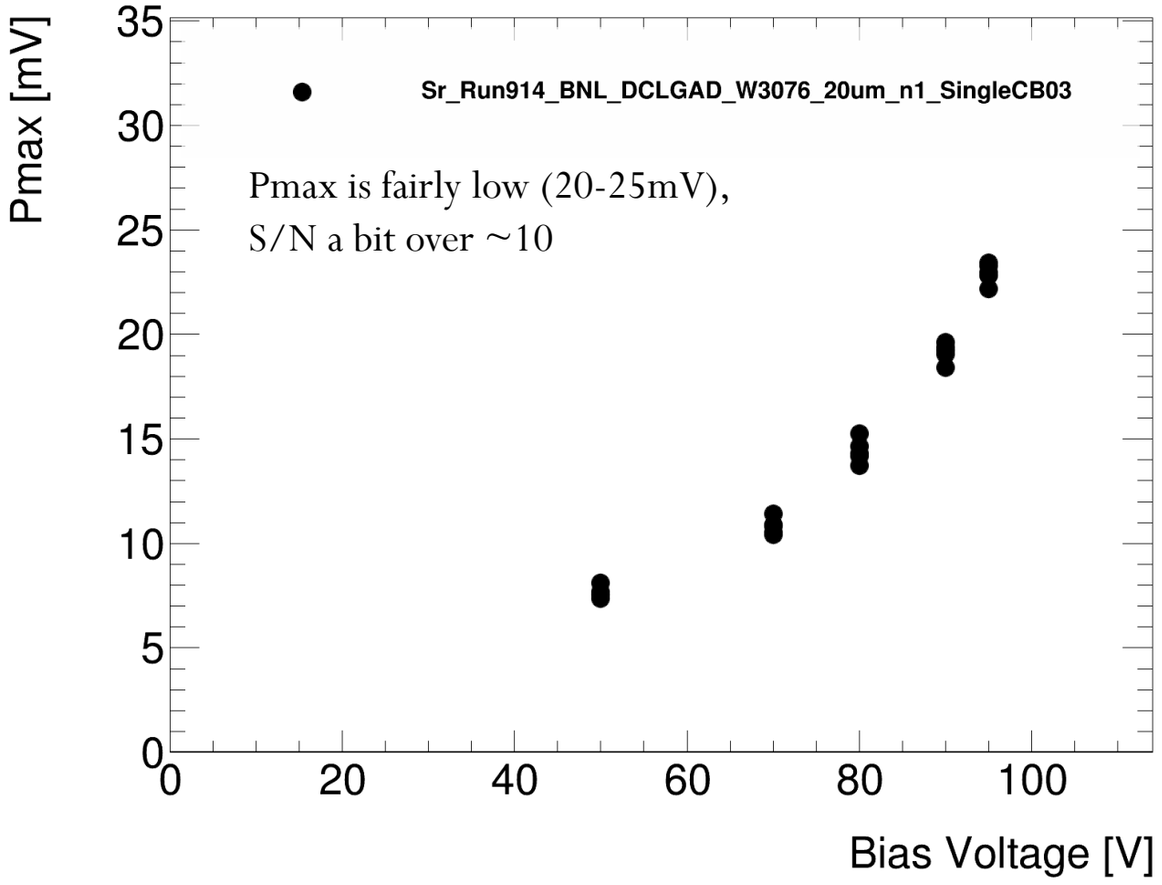

Sr_Run915_BNL_DCLGAD_W3076_20um_n3_SingleCB03
Leakage current per pad [μA]
Bias Voltage [V]

Pulse


BNL_DCLGAD_W3076_20um_n3_SingleCB03_Trig_HPK2_S8664_chip15_20C_DAQRunn
100V
105V
110V
50V
70V
90V
Breakdown
Amplitude [mV]
Time [ps]
300
250
200
150
100
50
0
−50
−1000
0
1000
2000
3000
4000
5000

Sensor #2, Charge/Pmax are lower time res. is worse

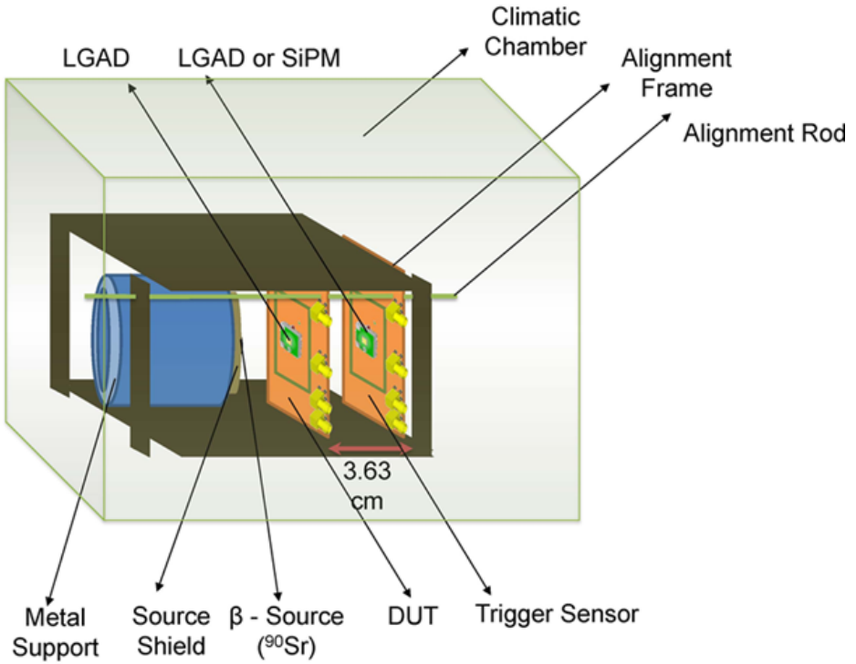




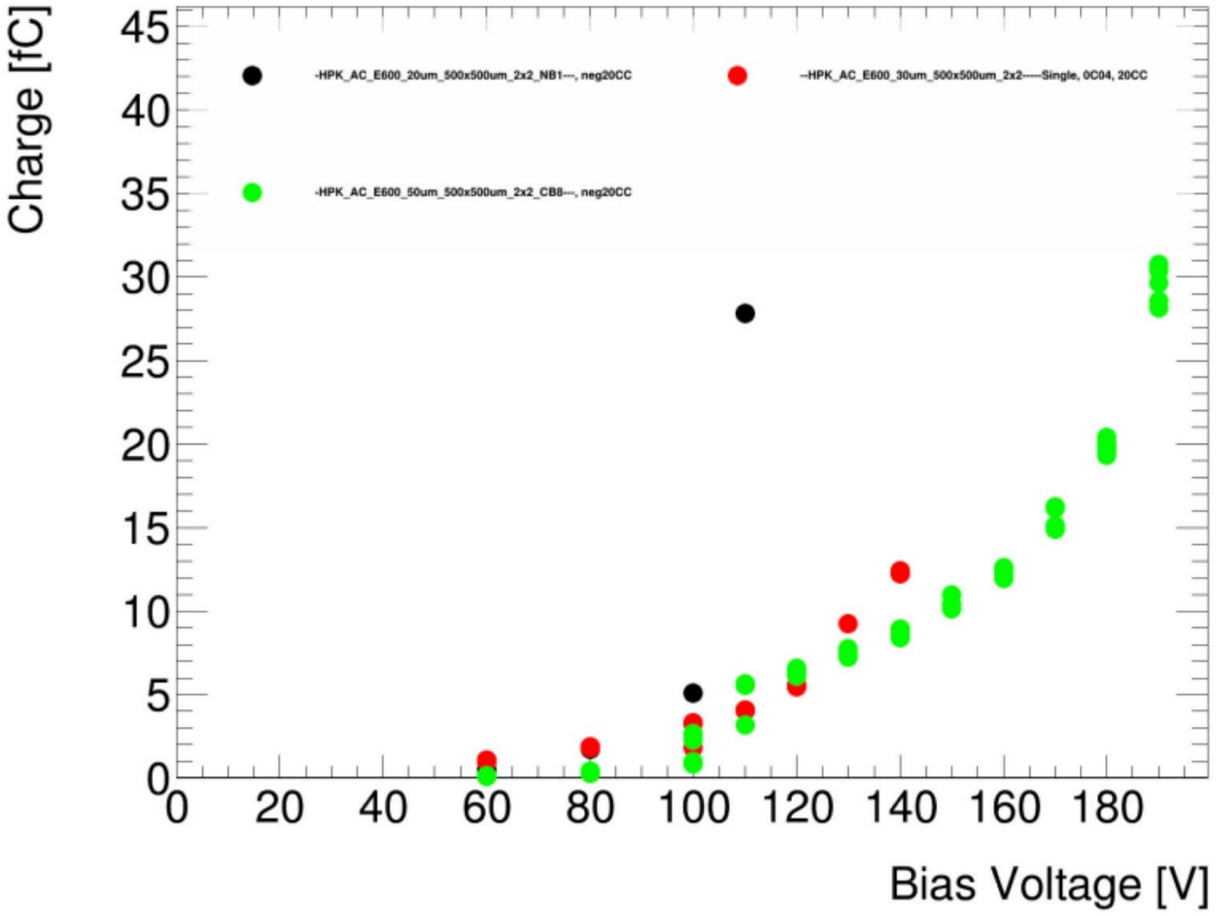
HPK 20/30/50um AC-LGADs

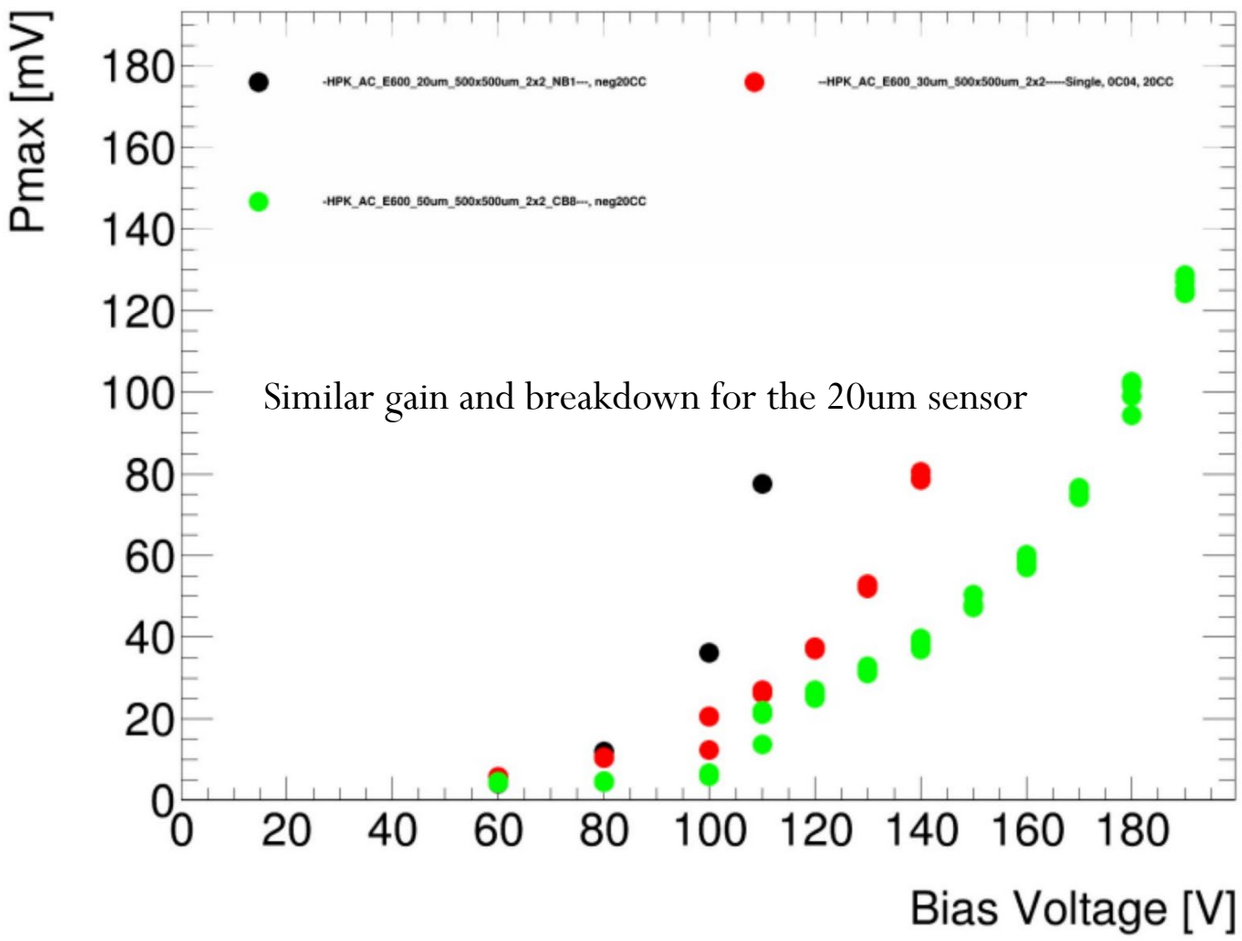
20/30/50um HPK device

- HPK AC-LGAD production with 20/30/50um
- Sensor size AC-LGAD array 2x2
  - 500um pitch and ~500um pad size
  - Same geometry for all pads
- Tested with beta scope on 1ch boards
  - Pad is large enough to be centered with the hole in the 1ch board
  - Results likely very similar to a DC-LGAD since the response under the metal pad is roughly constant
  - At least in the center where the hole is

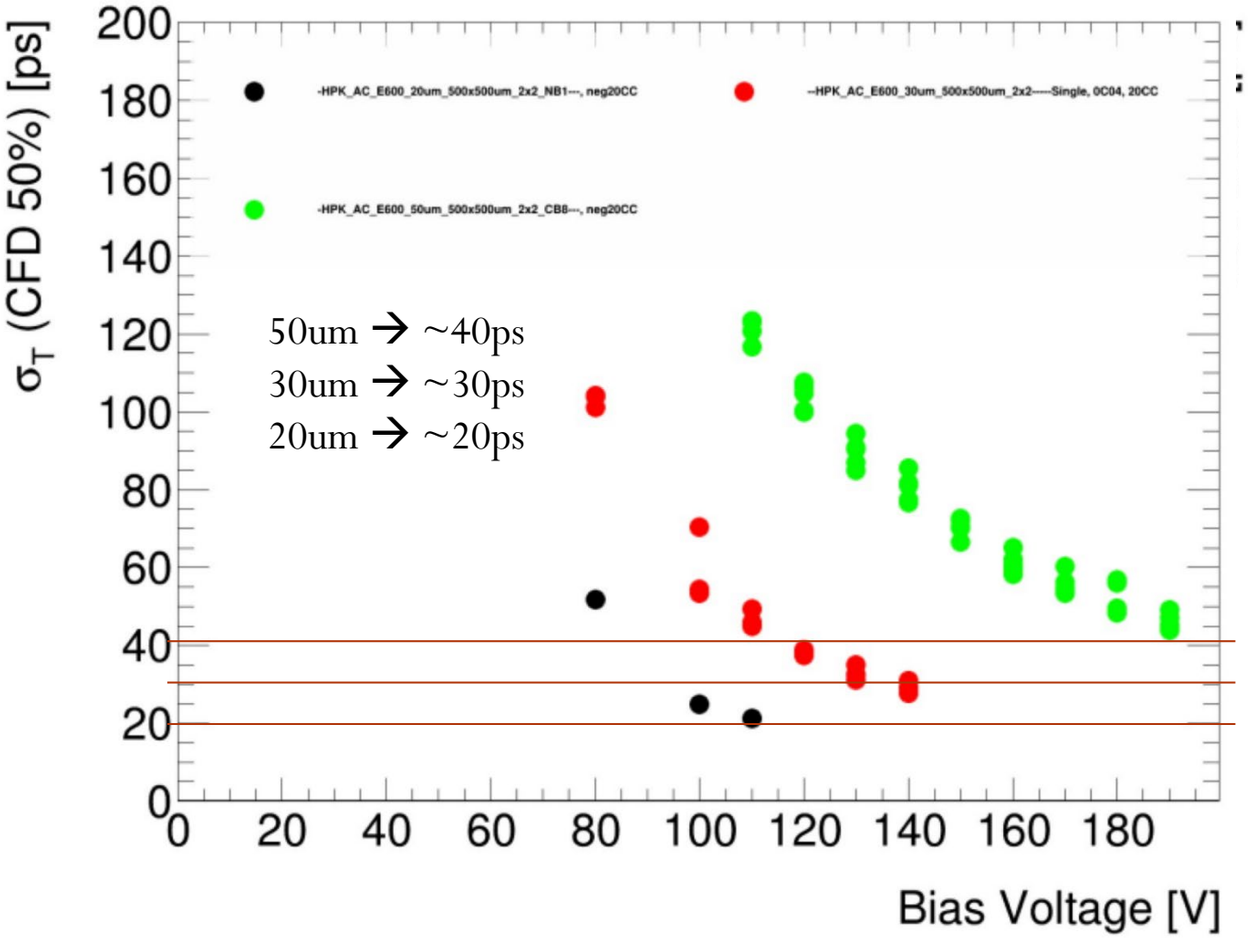


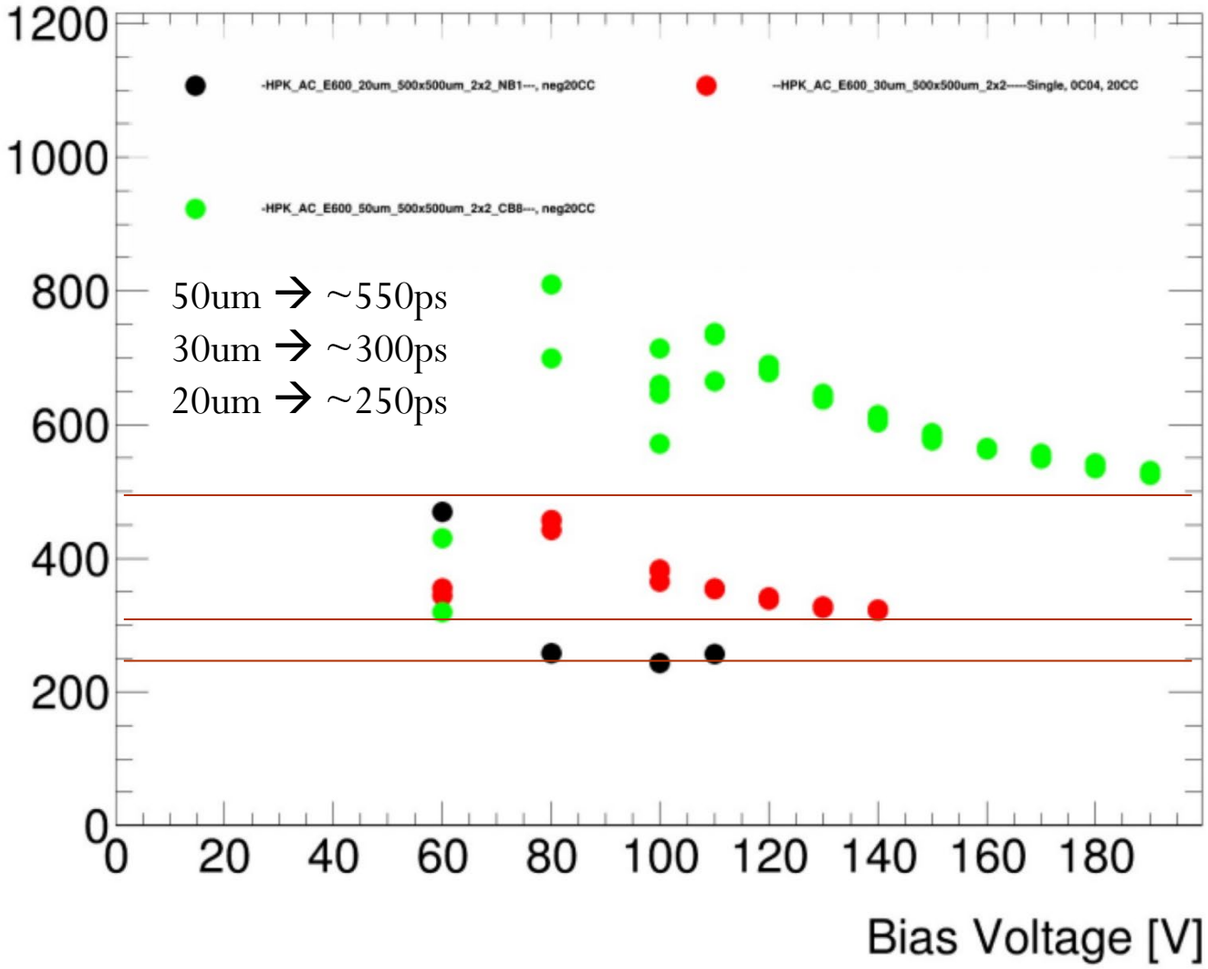
Charge/Pmax


Charge [fC]
-HPK_AC_E600_20um_500x500um_2x2_NB1---, neg20CC
--HPK_AC_E600_30um_500x500um_2x2-----Single, 0C04, 20CC
-HPK_AC_E600_50um_500x500um_2x2_CB8---, neg20CC
Bias Voltage [V]


Pmax [mV]
-HPK_AC_E600_20um_500x500um_2x2_NB1---, neg20CC
--HPK_AC_E600_30um_500x500um_2x2-----Single, 0C04, 20CC
-HPK_AC_E600_50um_500x500um_2x2_CB8---, neg20CC
Similar gain and breakdown for the 20um sensor
Bias Voltage [V]

Time resolution and rise time





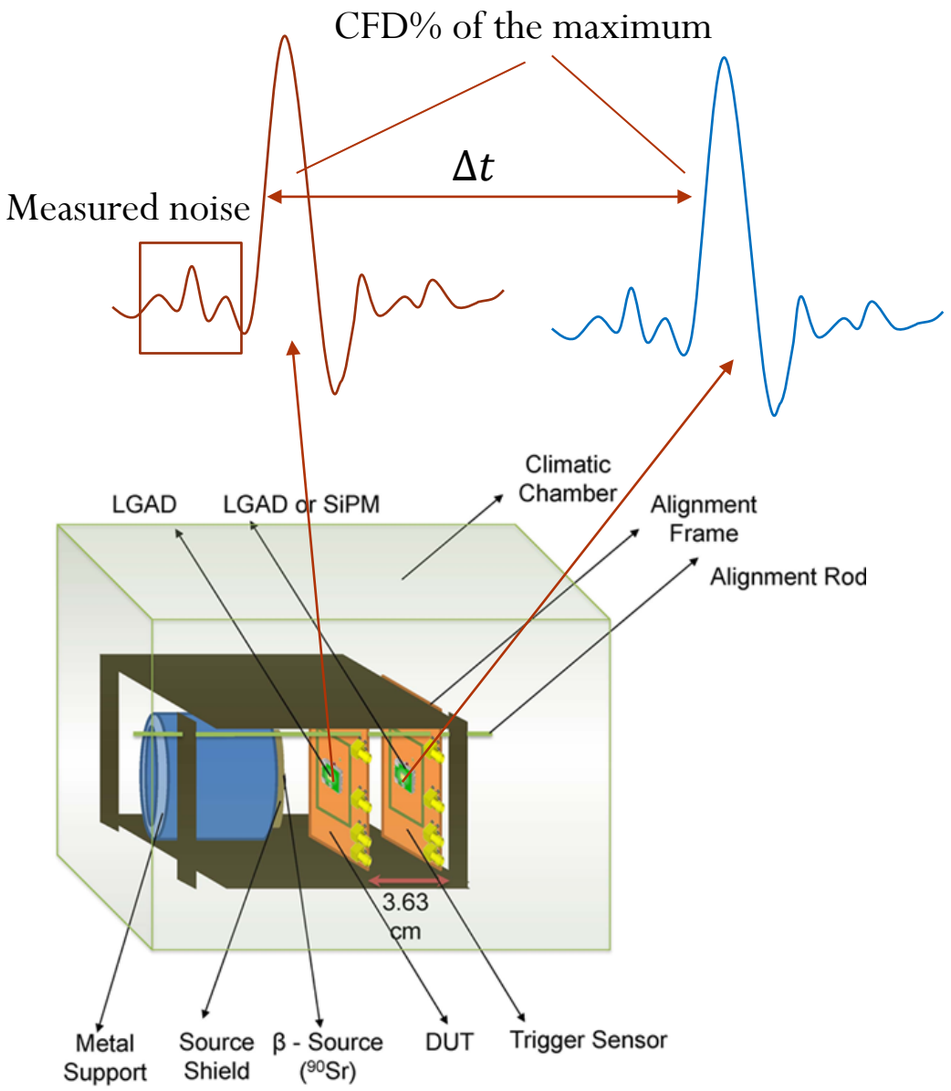
Conclusions

- First results with 20um sensors
- BNL standard DC-LGADs (1.3x1.3 mm)
  - At least one sensor is working, shows gain of 40+ and has a very fast rise time
  - However if the S/N is low (sensor #2), time resolution is suboptimal (~35ps)
  - Breakdown voltage is crucial for performance!
- HPK new AC-LGADs 20um have a similar performance
  - 30/50um have increased rise time and time resolution as expected
  - The performance is a bit worse than standard DC-LGADs (usually time resolution for 50um is 30-35ps)
- Had a similar performance for old HPK 20um device (but it had low gain)
  - Low signal, but time resolution ~20ps, see: https://arxiv.org/abs/2006.04241
  - Rise time of <200ps, pad was 500um circle (few pF of capacitance)

Backup

Sensor testing – Sr90 telescope

Details: S.M. Mazza et al. arXiv:1804.05449



- Sensors mounted on single channel fast amplifier boards (~2Ghz) and read out by a fast oscilloscope (2Ghz, 20Gs)
- Two sensors are aligned with a beta source
  - DUT (Device Under Test) to characterize
  - Trigger is an LGAD with known performance

- **Gain**: collected charge divided by collected charge in same thickness PiN
  - Increases with applied bias voltage, depends on sensor doping profile
- **Time resolution**: sigma of time difference between DUT and trigger (with known time resolution) at %CFD point (usually 50%)
  - %CFD (% of the maximum) for the time resolution minimizes time walk
  - Decreases with applied bias voltage, plateaus at a value that depends on sensor thickness (reach the Landau component)