Fast electronics /detector options

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EIC Polarimetry working group

Improving speed of detectors

- For faster repetition rates, it is desirable to have detector response faster than bunch frequency (relevant for electron and ion polarimetry)
- Can have very segmented detector
- Solid state detector actually fast collection time but small charge, typically need shaping and high gain amplification
- Need to be close from detector for best signal to noise ratio and timing resolution

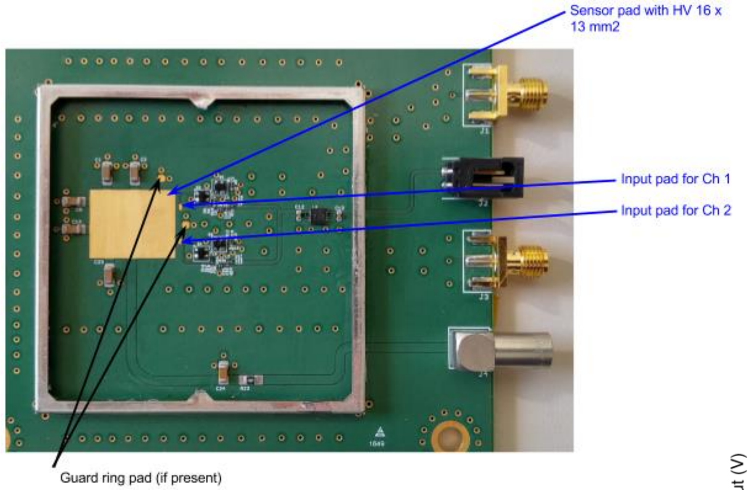
Detectors side

- Detector options
  - Silicon
  - MAPS
  - Diamond
  - LGAD
- Fast preamplifiers
  - TOTEM Kansas preamp
  - Alphacore preamp:
    - ASIC 8 channels
  - VMM3 chip (designed for GEM / Micromegas)
    - 64 channels

Electronics for very fast detectors

TOTEM electronics designed by Kansas University

A two channels board was designed and manufactured for the characterization of different solid state detectors.



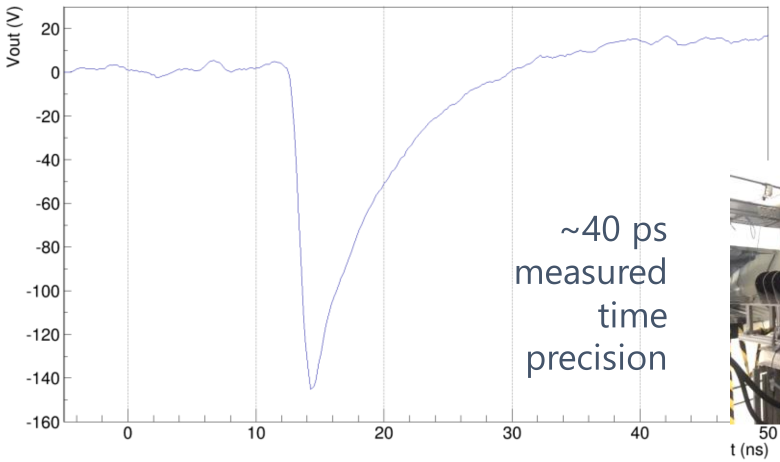
Sensors up to 16x13 mm^2 can be glued and bonded.

The components can be easily adapted to accommodate:

- Diamond sensors: ~1 nA bias current, both polarities, small signal
- Silicon sensors: ~100 nA bias current, small signal
- UFSD ~100 nA bias current, ~ larger signal
- SiPM: ~ 5 uA bias current, large signal

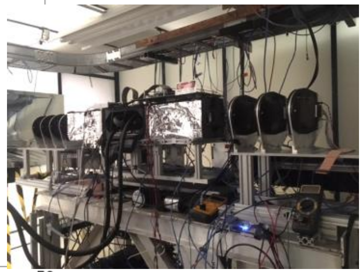
The board was optimized to achieve a good time precision with different sensors, however it can be modified to have an output signal shorter (but less precise)

[Test of Ultra Fast Silicon Detectors for Picosecond Time Measurements with a New Multipurpose Read-Out Board]

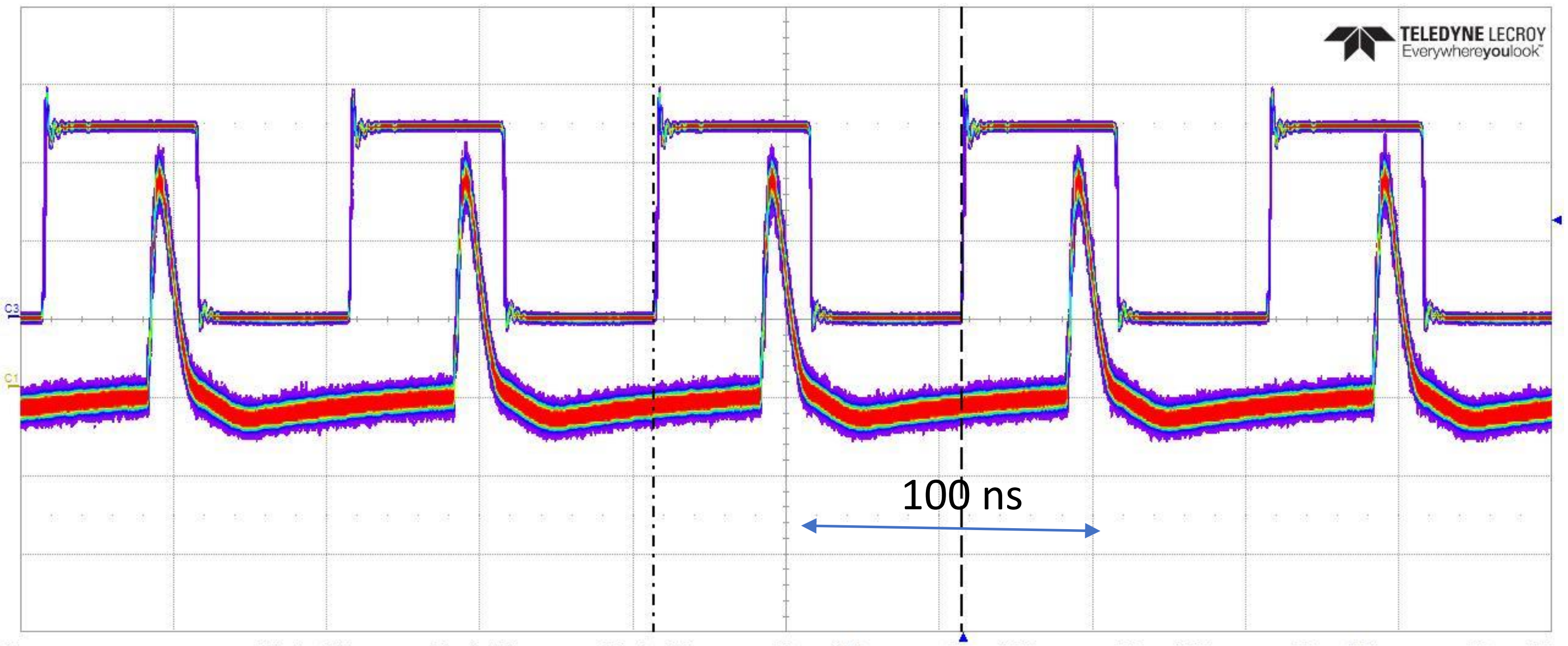


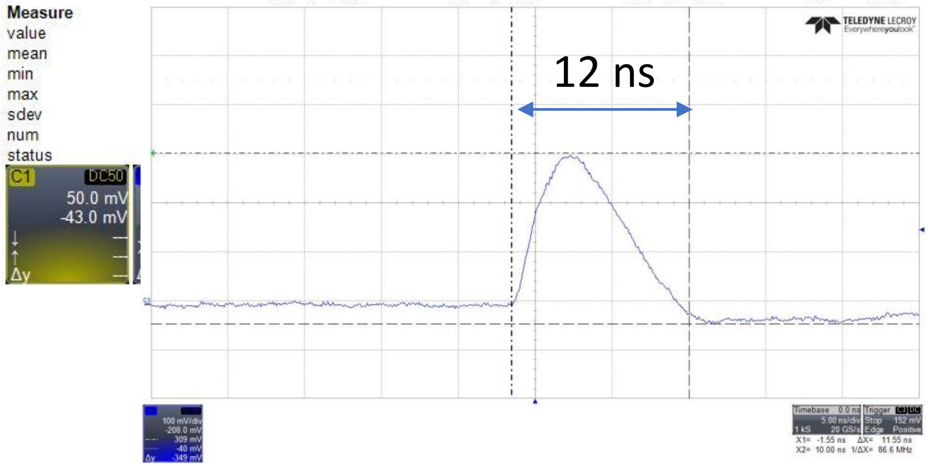
~40 ps measured time precision

3x3 mm^2 UFSD MIP beam test @ Fermilab



Silicon pulsed with laser at 10 MHz



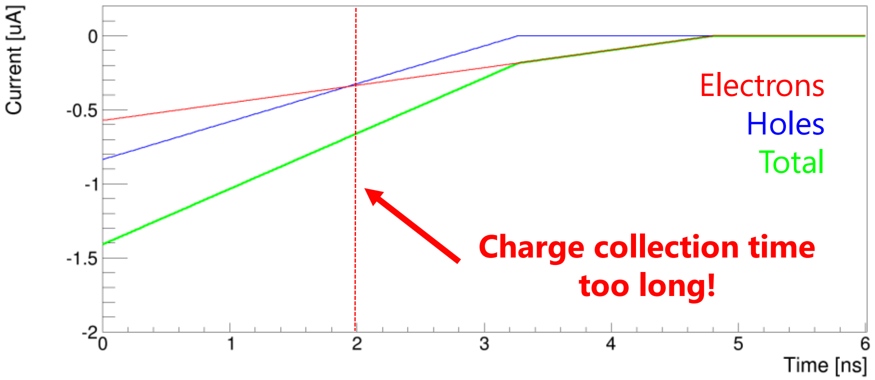


Amplifier with silicon detector fast enough to separate successive sources for eRHIC Linac Ring at 10 MHz

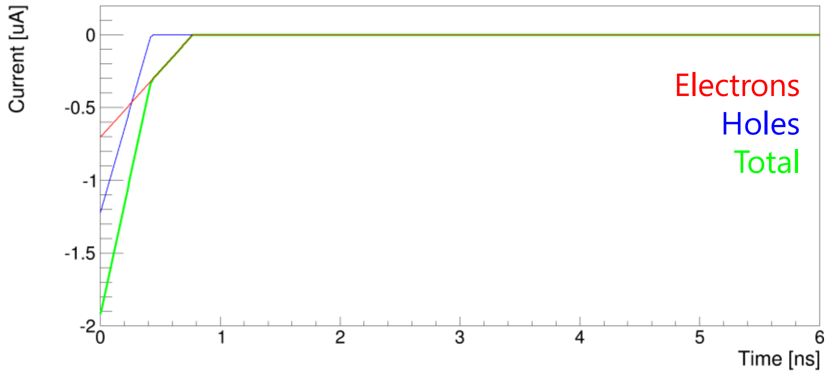
(New proposal for up to 476 MHz)

Fast detector R&D

Diamond sensors are among the fastest available



500 µm scCVD diamond
@ 800V



80 µm scCVD diamond @
500V

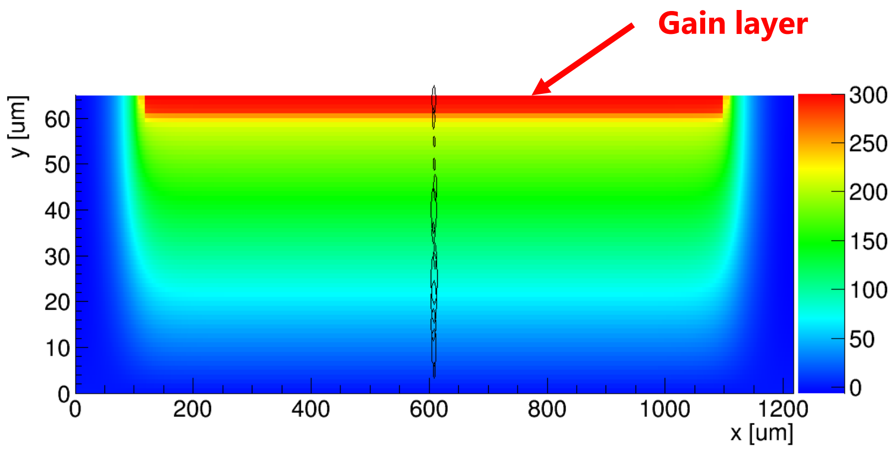
The collection time t_c depends on the thickness *d* $t_c \sim {}^{d}/_{v_s}$

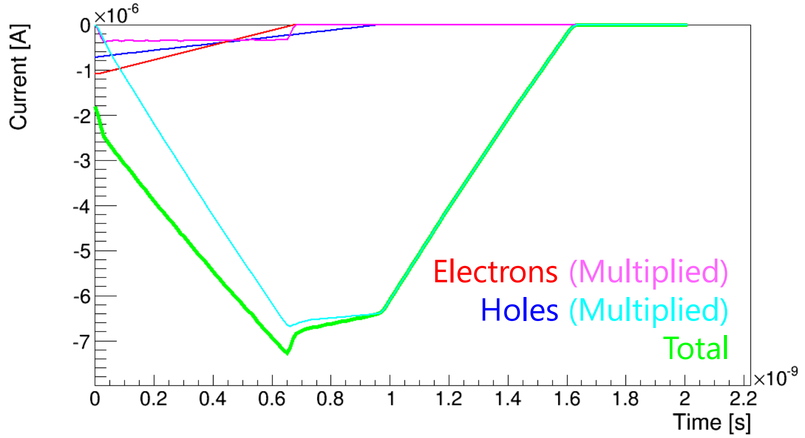
NOTE: the collected charge $Q_c = \int i\,(t)\,dt$ also depends on the thickness *d* $Q_c \sim d$

However, the deep current mainly depends on the carriers' velocities, i.e. electric field $|i_{MAX}| \sim {}^{Q_c}/_{t_c}$

Fast detector R&D

Ultra Fast Silicon Detectors: as fast as diamond, but with a gain layer!



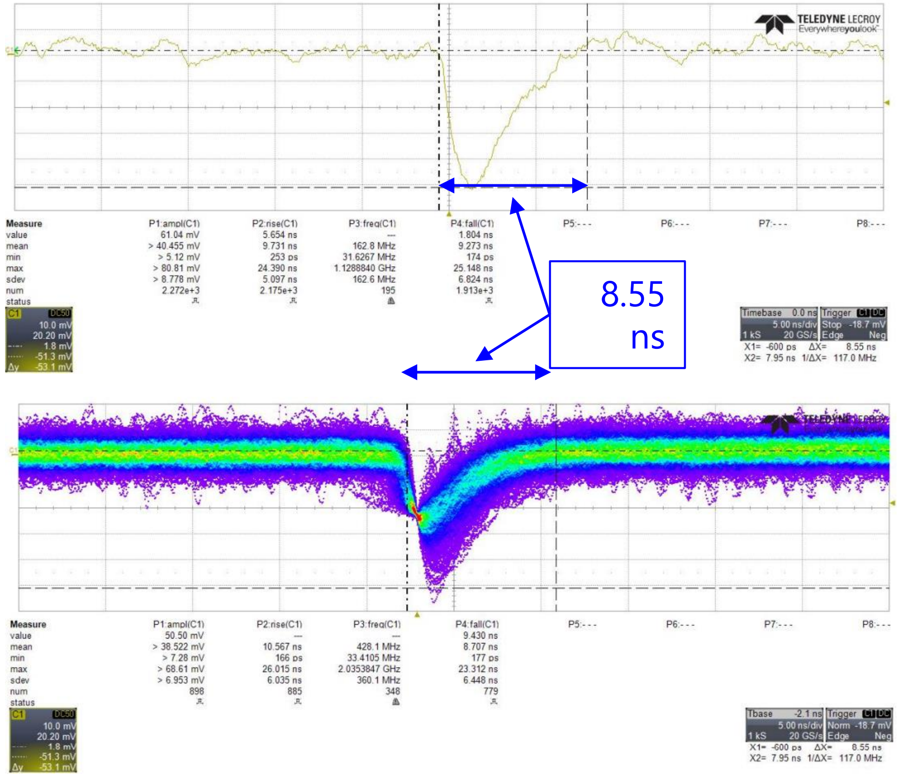


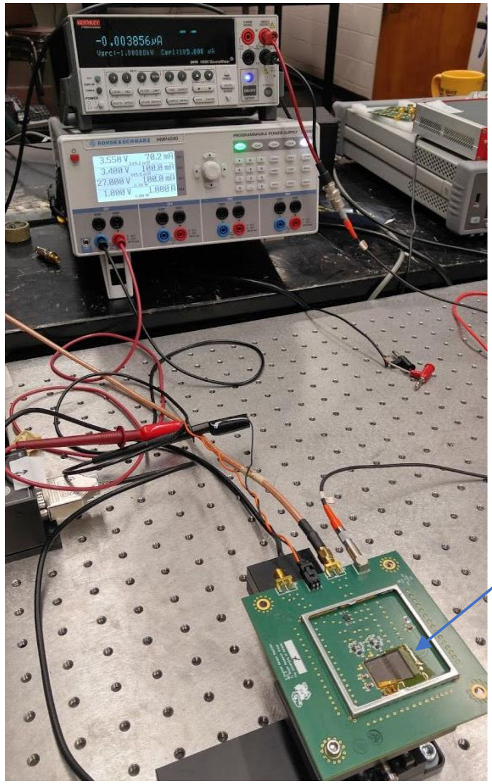
UFSD: 50 µm LGAD

Fast collection time (50 µm thick) and larger signals, thanks to the gain layer

Electronics for very fast detectors

This board was also used to test the performance of a diamond sensor using a Sr^{90} β^{-} source.



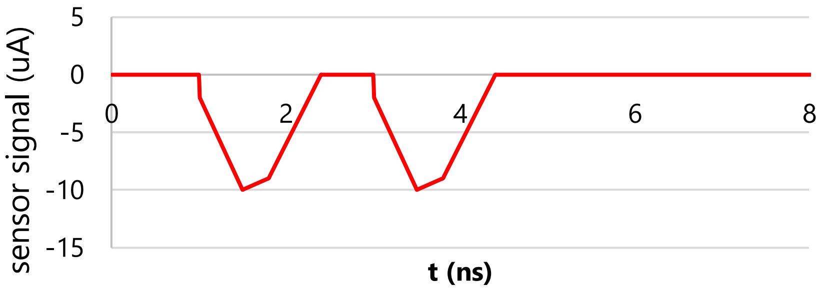


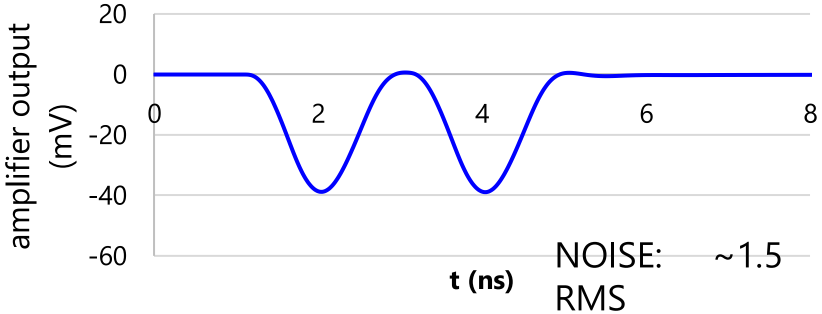
500 µm
pcCVD
diamond

Fast detector R&D

Simulated results:

UFSD

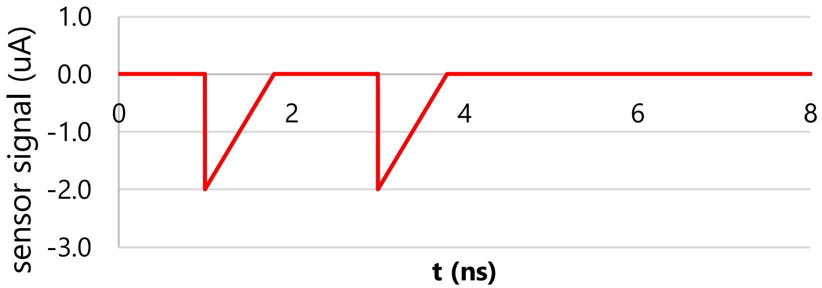


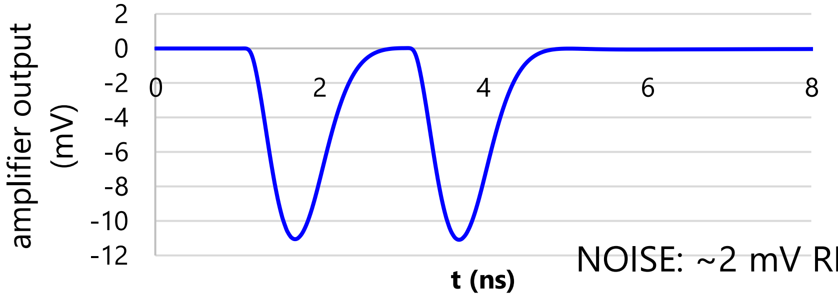


NOISE: ~1.5 mV RMS

SNR ~ 25

80 µm scCVD diamond sensor





NOISE: ~2 mV RMS

SNR ~ 5

Study by Nicola Minafra

Integrated ASIC

- Was looking at VMM3 chip
  - Gain : 0.5,1,3,4,4.5,6,9,12,16 mV/fC
  - Integration time : 25,50,100,200 ns
  - Possibility for triggering
  - Different reading mode
    - Multiplexed analog amplitude and timing
    - Digitized 10 bit amplitude 20 bit timestamp
    - ART (streaming mode)

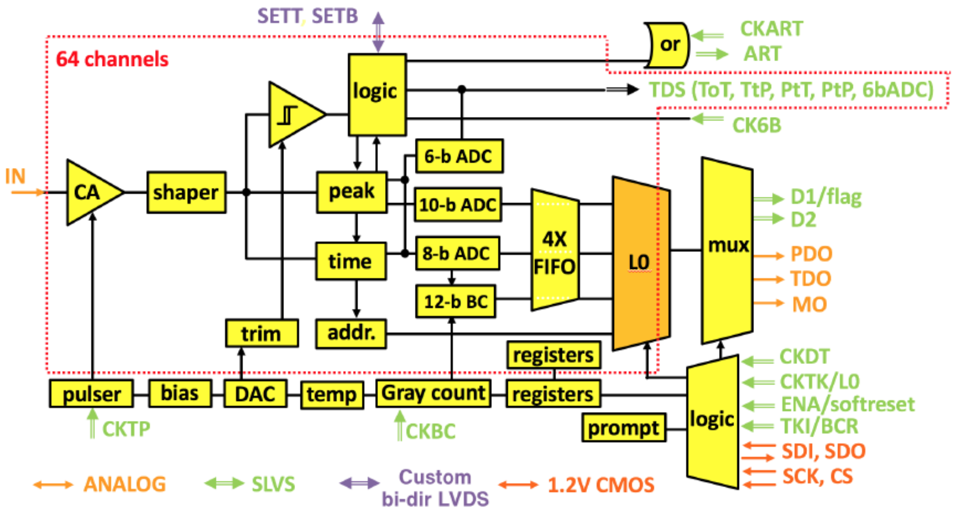
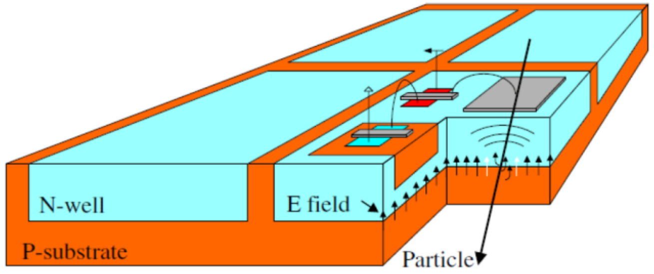


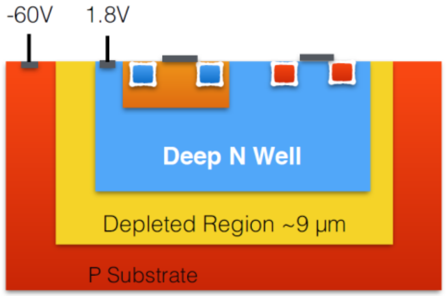
Figure 1: Architecture of VMM3.

MAPS option

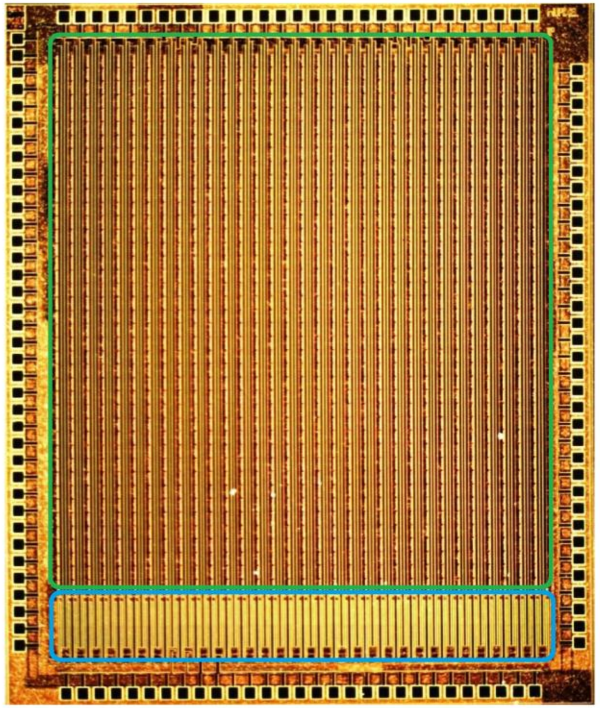
- Silicon detector can be thinned up to 80 um
- Integrated analog and digital electronics
- Well adapted for pixelized detector since less external electronics
- Cons : not sure about energy resolution, mostly optimized for timing but chip detector could be tailored to need

HV MAPS





- Pixellized detector MuPix for Mu3e
- 80 um x 80 um x 50 um
- Electronics in integrated with pixel (amplification and readout)
- Being investigated by University of Manitoba
- Timing resolution around 16 ns
- 380 Mrad radiation hardness
- Should work in vacuum
- Might work at low temperature



32x40 pixels Mupix4

Sampling chips

- Analog sampling
  - PSEC4, DRS4 : 1 to 10 GSps 8 channels
  - ASOC : 1 to 3 GSps 4 channels
  - AARDVARC : 10 to 14 Gsps 4 channels 12 bits
- FADCs :
  - JLAB FADC : 250 MHz 12 bit 16 channels
  - Alphacore ASIC : 10 bit 0.5,1,3 Gsps 6 bit 10 Gsps
  - CAEN, Struck :
    - 250 MHz 14 bit 8 or 16 channels
    - 500 MHz 14 bit 8 or 16 channels
    - 1 GHz to 2 GHz 10 bit
    - 4 GHz 10 bit 2 channels