GEM-DHCAL Status Report

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for the GEM-DHCAL Group

(UTA - UW - CNU)

ALCPG07 Workshop, Fermilab
October 2007

GEM-DHCAL Development Plan 2007

- Build and test various 30cm x 30cm GEM chambers:

  1) Basic double-GEM chamber with FNAL 32-channel discrete channel readout.

  -> beam tests at MTBF/FNAL Spring 2007

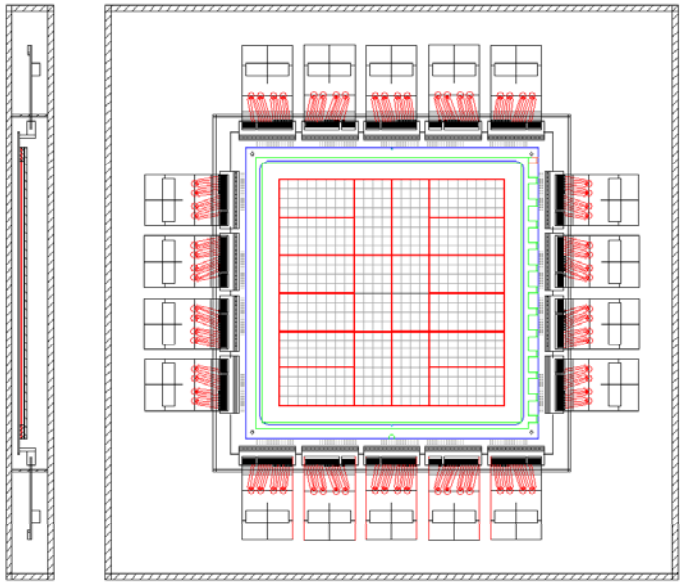
  2) Double-GEM chamber with ANL/DCAL chip readout using dedicated pad board DCAL-FE board.

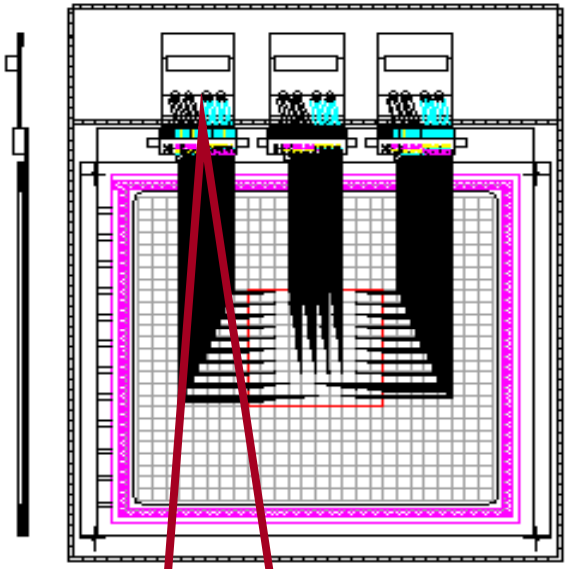
  -> beam tests (VST) at FNAL/MTBF Summer/Fall 2007

  3) Double-GEM chamber with SLAC/KPiX chip readout using a dedicated pad board.

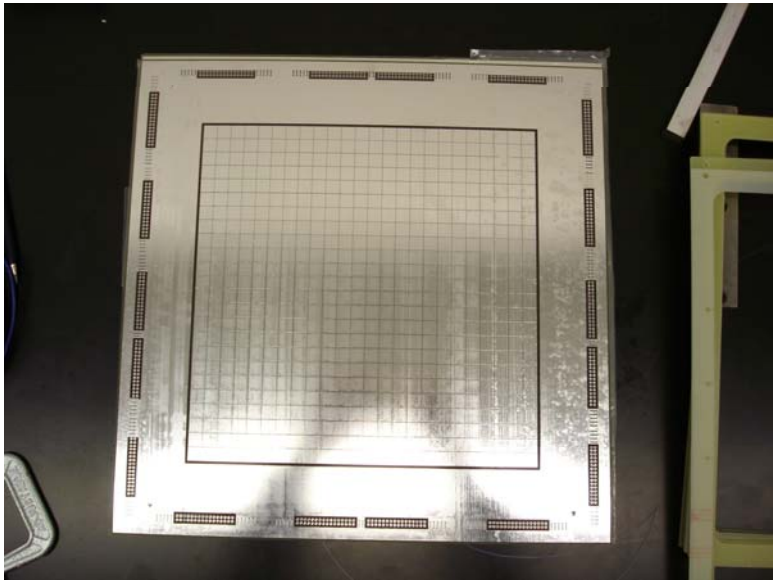
  -> beam tests at FNAL/MTBF Summer/Fall 2007

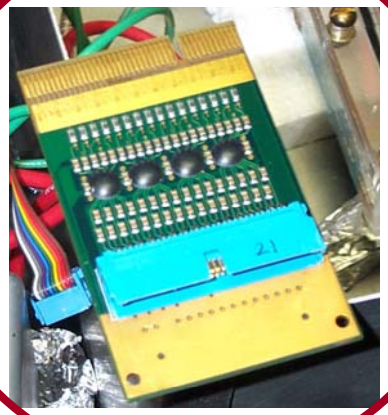
Anode Board & Preamp for 30cm x 30cm Chamber





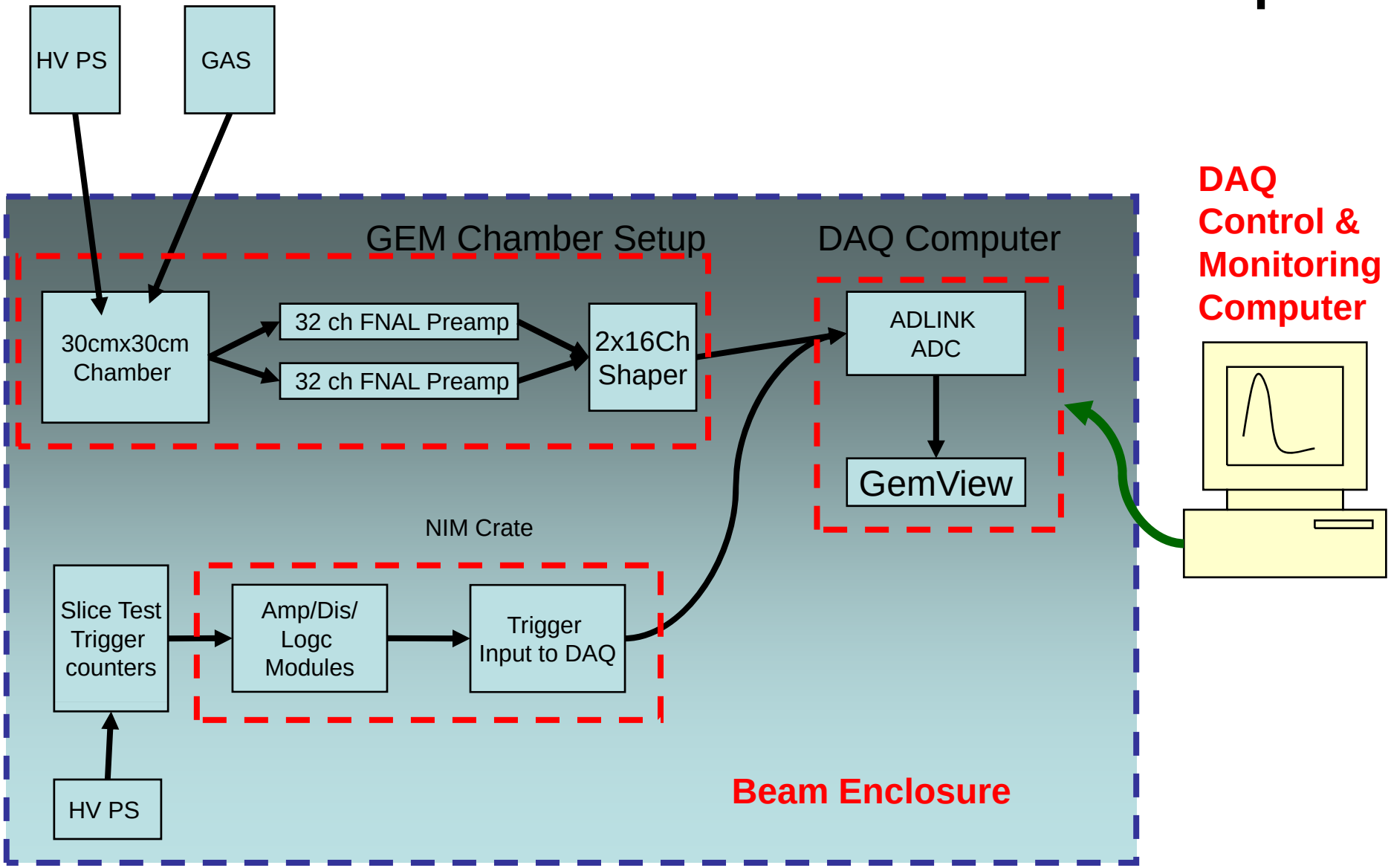
Preamps configured to read up to 96 pads in the center



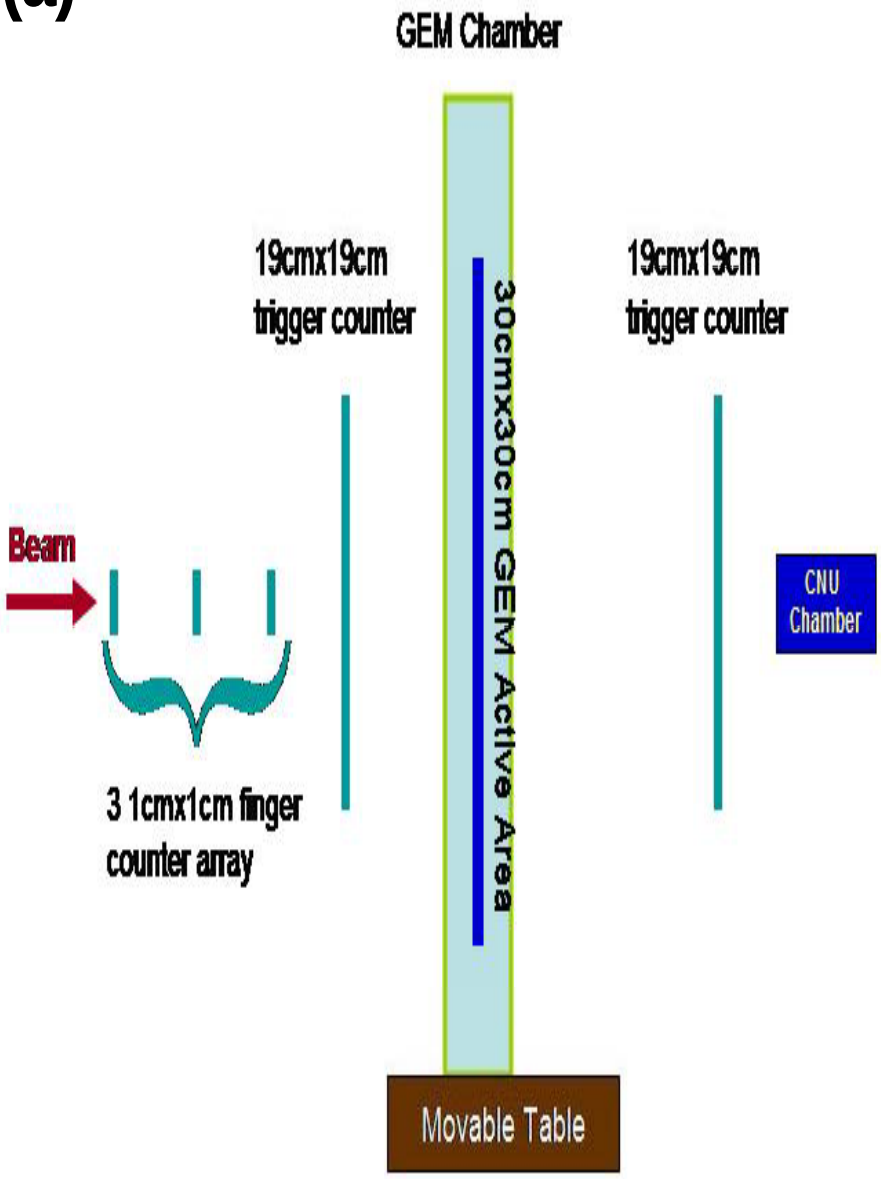


Use 32 channel FNAL preamps (QPA02)

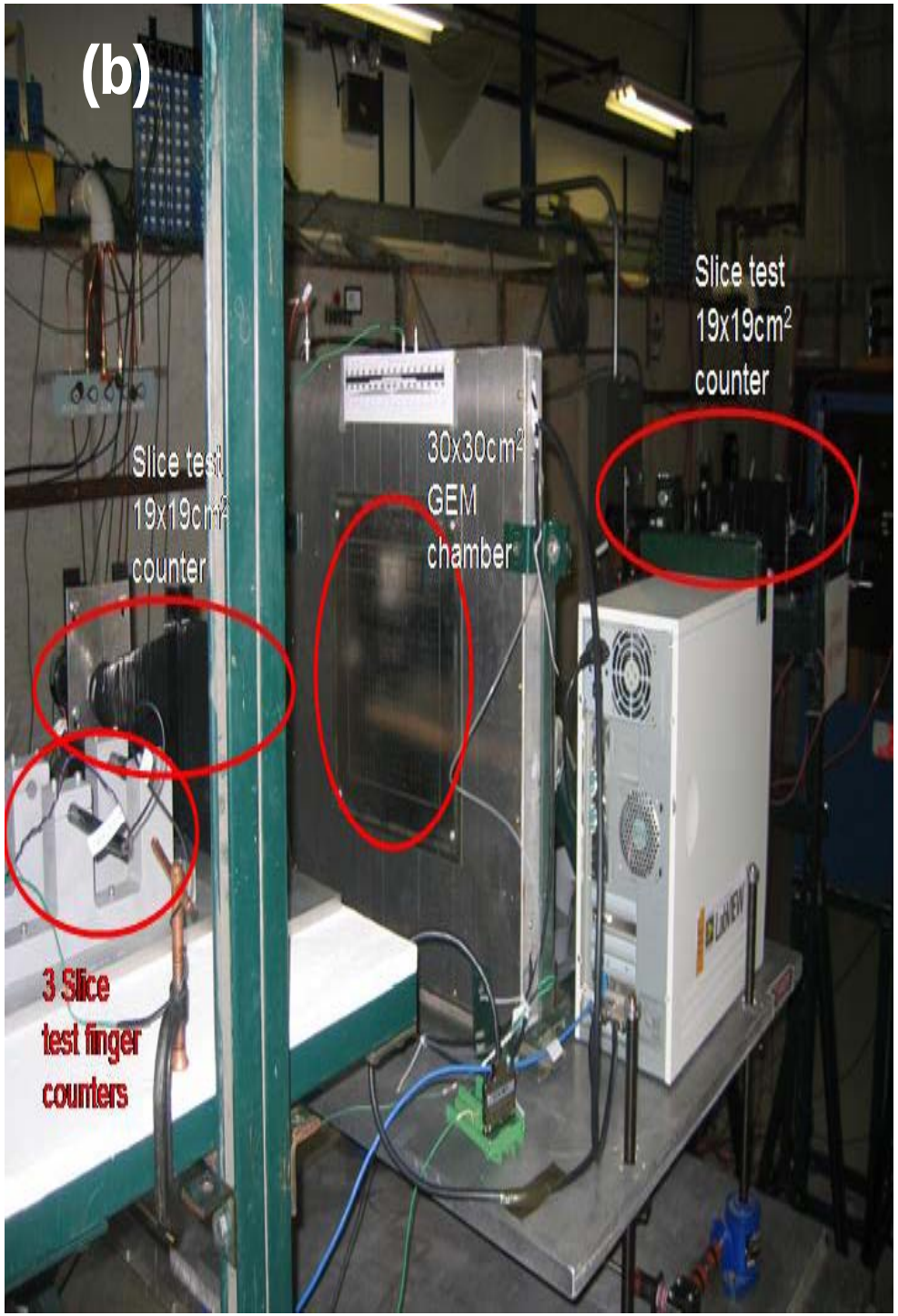
UTA MTBF Beam Test Setup



(a)



(b)



Trigger counters provided by UTA for Vertical Slice Test

Trigger Types

- Beam Trigger – 5Fold scintillation counters
  - Three 1cmx1cm finger counters, 10cm apart, are located in front of the setup
  - Two 19cmx19cm counters envelop the chamber active area, separated by about 3m's
    - One counter located about 40cm upstream of the chamber and the other about 2.5 m downstream of the chamber
  - Coincidence of all 5 counters defines a beam spot less than or equal to 1cmx1cm ➔ The size of one readout pad
- GEM Chamber self trigger
  - Use negative chamber output
- Beam constrained chamber trigger formed of 5F*GEM: 6Fold
  - Allowed us to look at data from neighboring pads while triggering on the pad centered at the beam

MTBF Beam Test Experience

- 120GeV P and 8GeV pion tunes established
  - 120GeV P: Beam spot size at the MT6-2C dump
    - σ_x: 11.5mm, σ_y: 9.1mm
    - Rate: Can vary in a wide range
    - Can go as high as radiation safety allows
  - 8GeV mixed beam: Did not measure beam spot size but seems to be about 2 – 3 times larger than 120GeV protons
    - Rate: over 4kHz at the 10cmx10cm TOF paddle right behind our detector
- Beam available for 12 hours 6am – 6pm
  - One 6 sec spill with 4s flat-top/min ➔ 5% program limit
  - Shot setups
    - Recycler transfer: Some interruptions (<3 – 5 times in 12 hr period) of 10~20 min each
    - HEP Shot: over 1.5 hrs each but avoided during the 12 hr period
- A lot more pleasant environment than before
- Many standard Fermilab logic modules/scalers failed to function correctly – a major issue: absolute rates compromised.

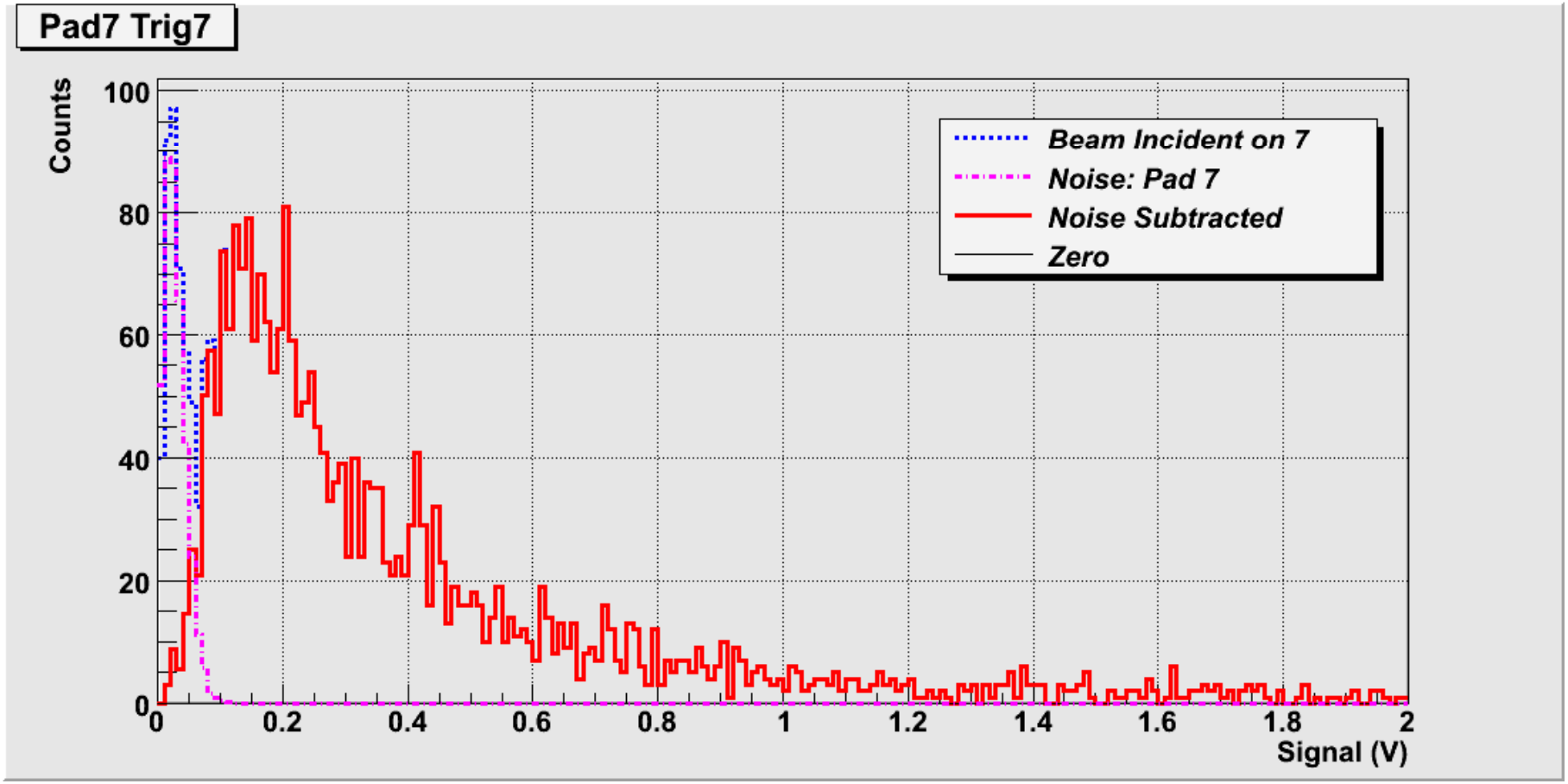
Spring 2007 GEM chamber TB

- Initial results from cleaned up data

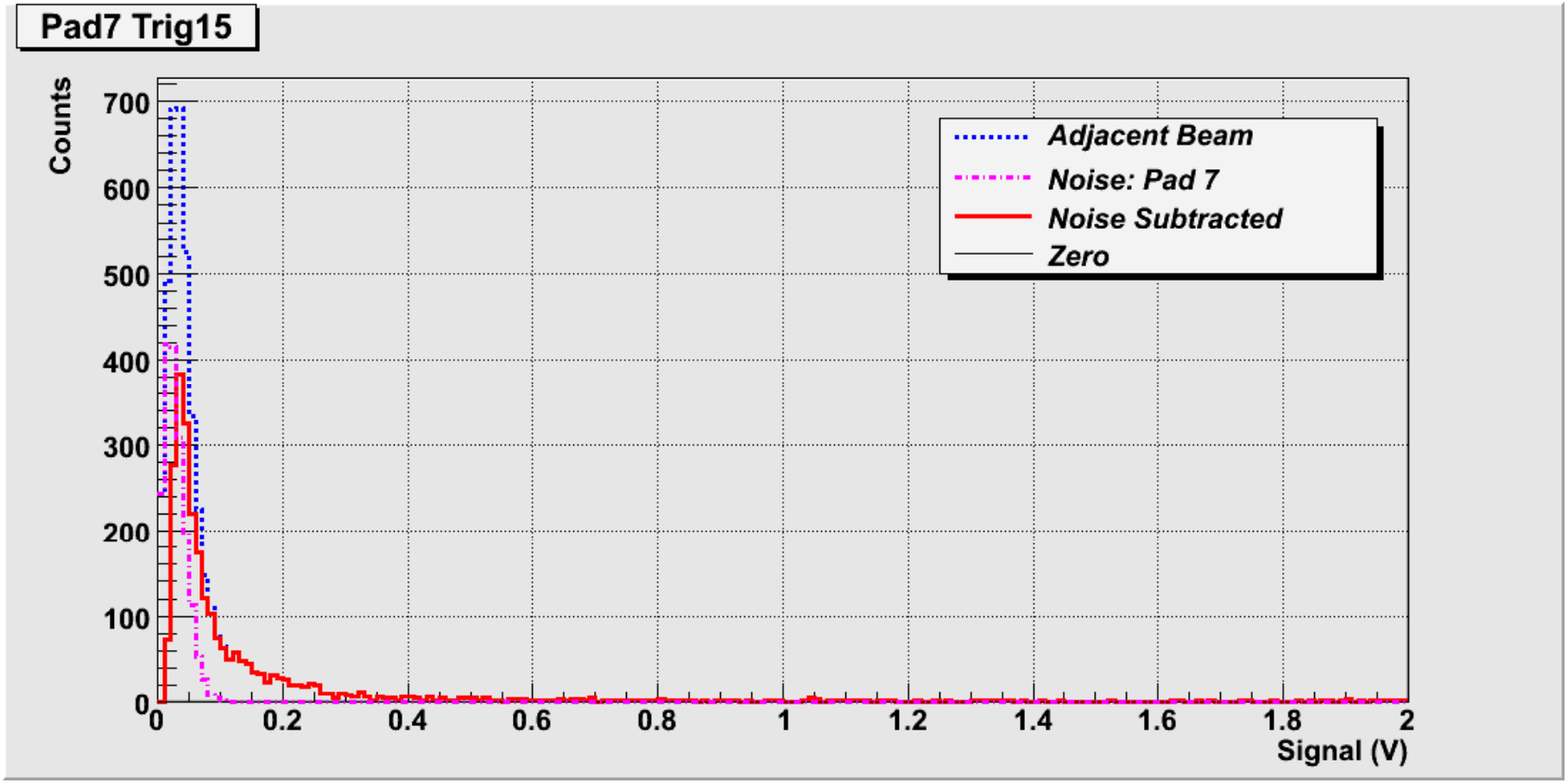
- Single pad studies

- Cross talk studies – adjacent pad(s)

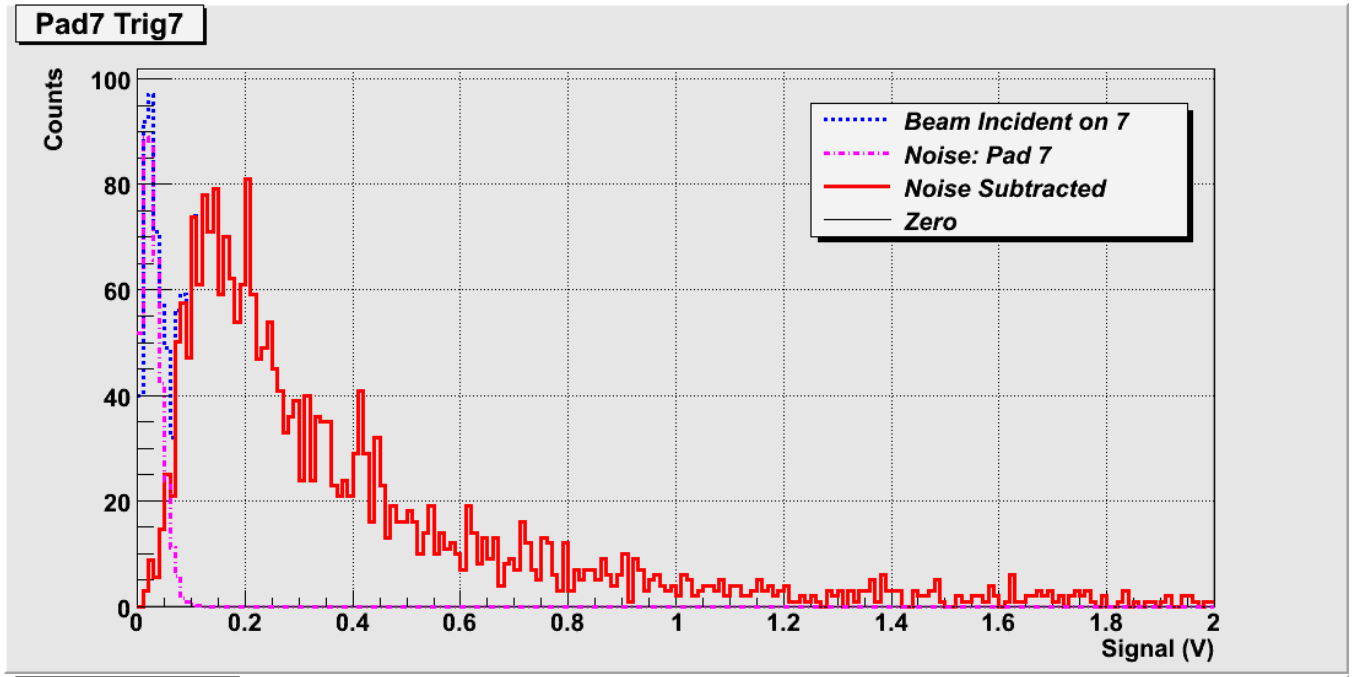
- Analysis ongoing – more pads, more uniformity, crosstalk studies,…subject of Jacob Smith's Masters thesis.

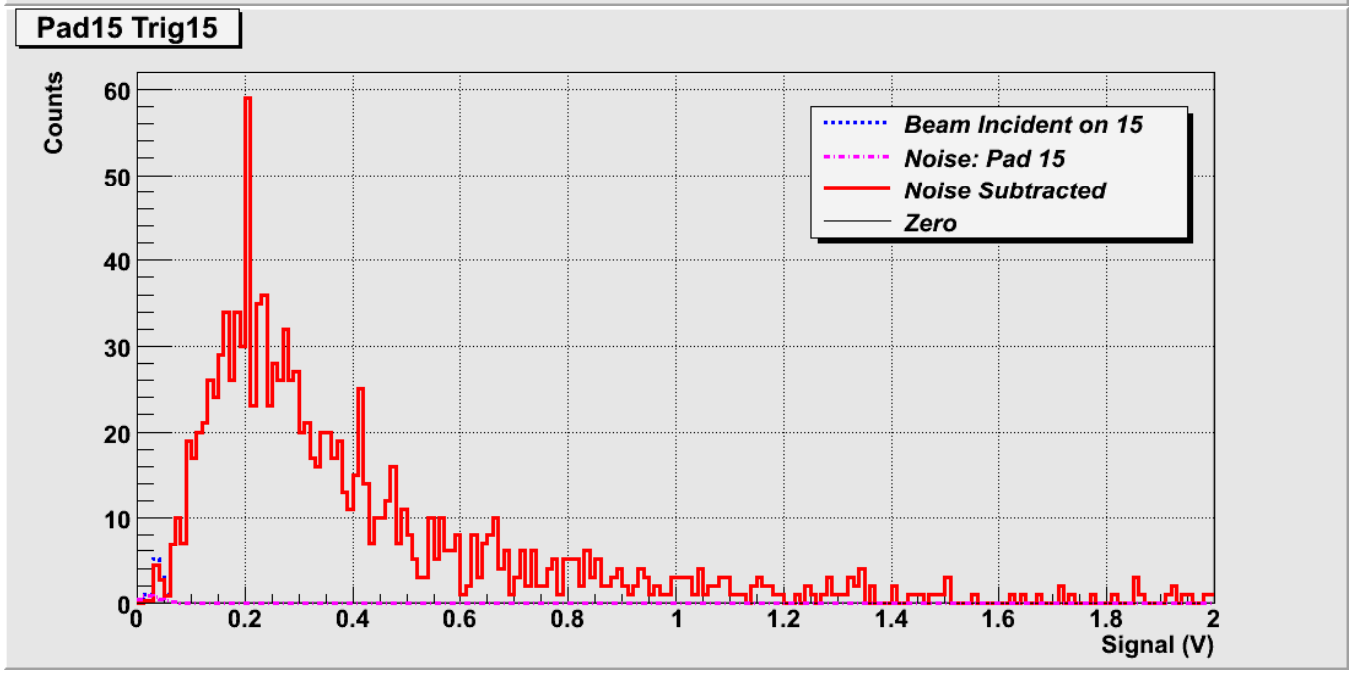


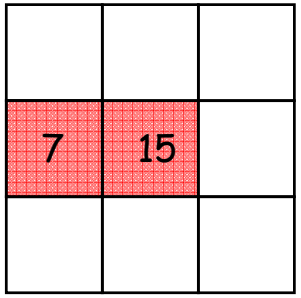
Beam centered on a given pad

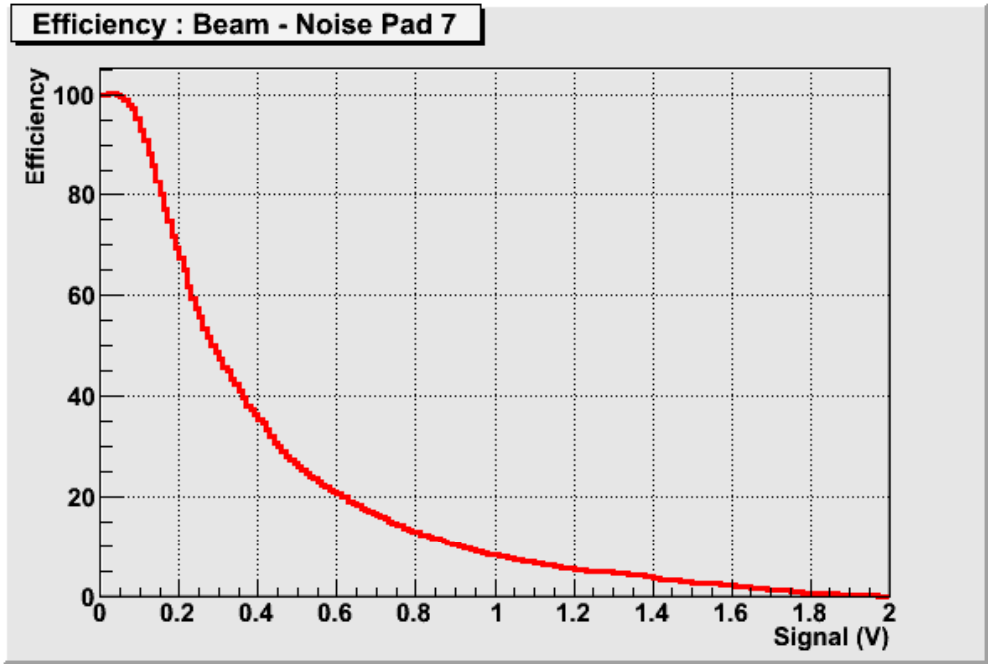


Beam centered on adjacent pad, triggered on that pad; readout from neighboring pad.

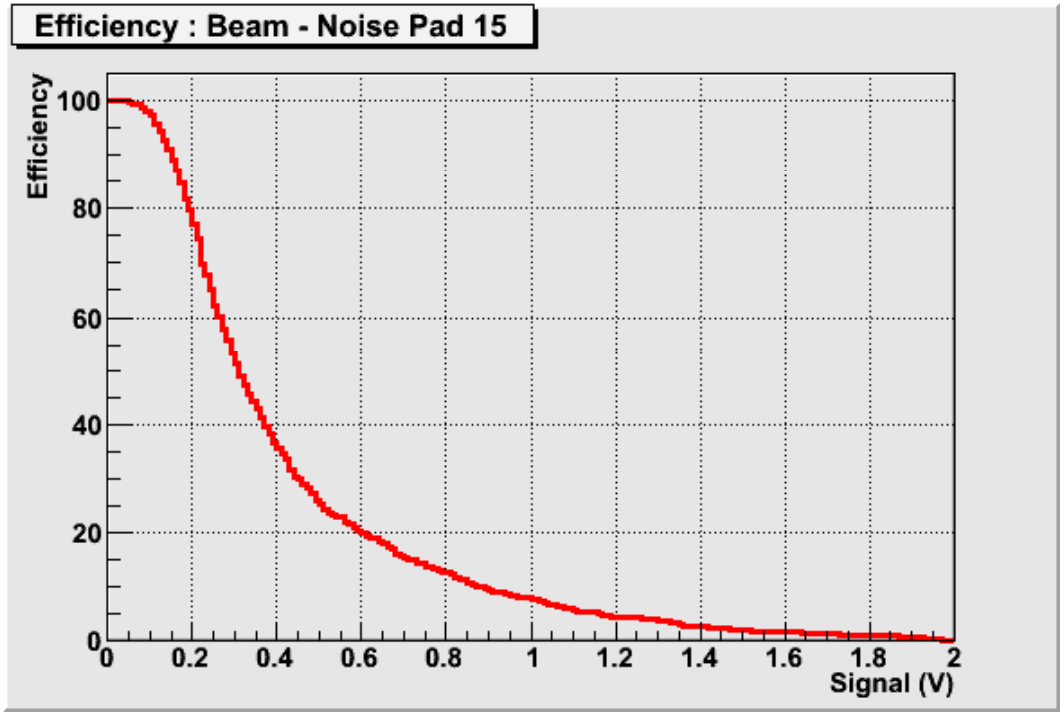

Pad7 Trig7
Counts
Signal (V)
Beam Incident on 7
Noise: Pad 7
Noise Subtracted
Zero


Pad15 Trig15
Counts
Signal (V)
Beam Incident on 15
Noise: Pad 15
Noise Subtracted
Zero

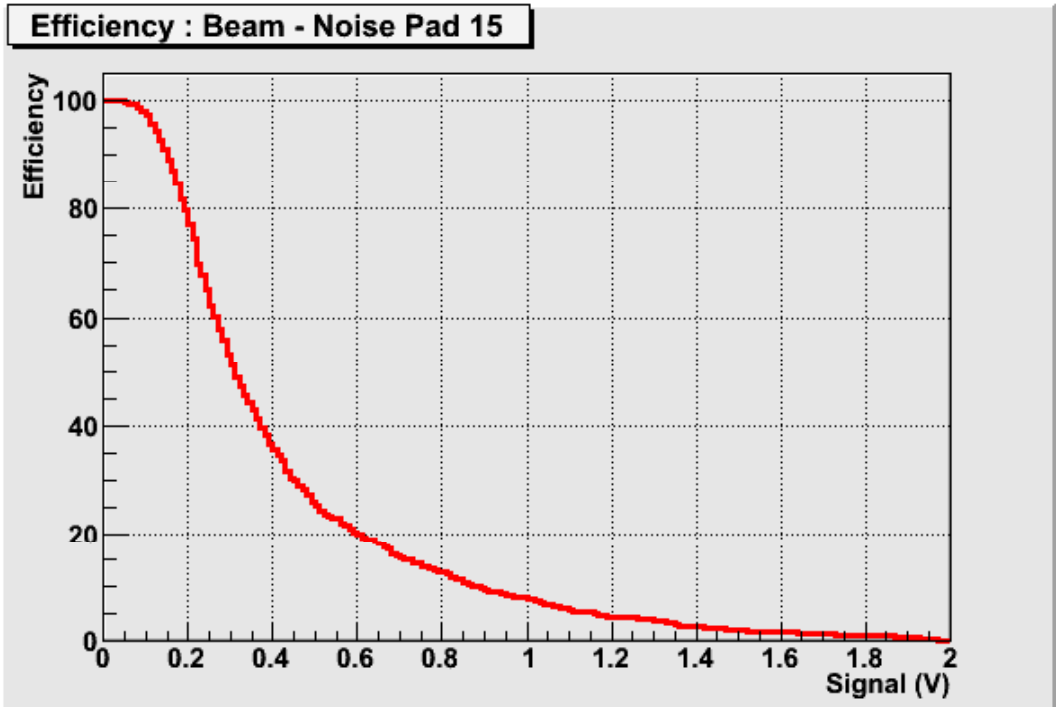

7
15

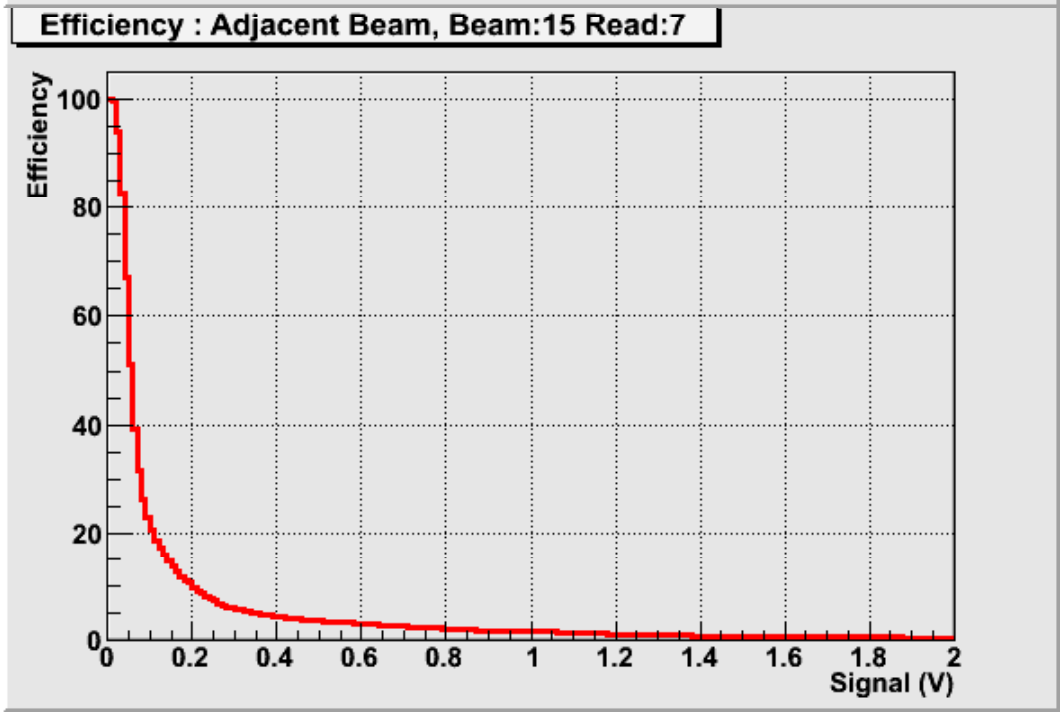


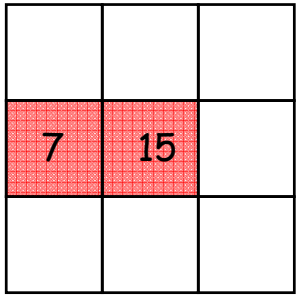
Relative efficiency for pad hit by beam vs. threshold



Previous (cosmic) measurement of absolute efficiency ~95% (40mV threshold)



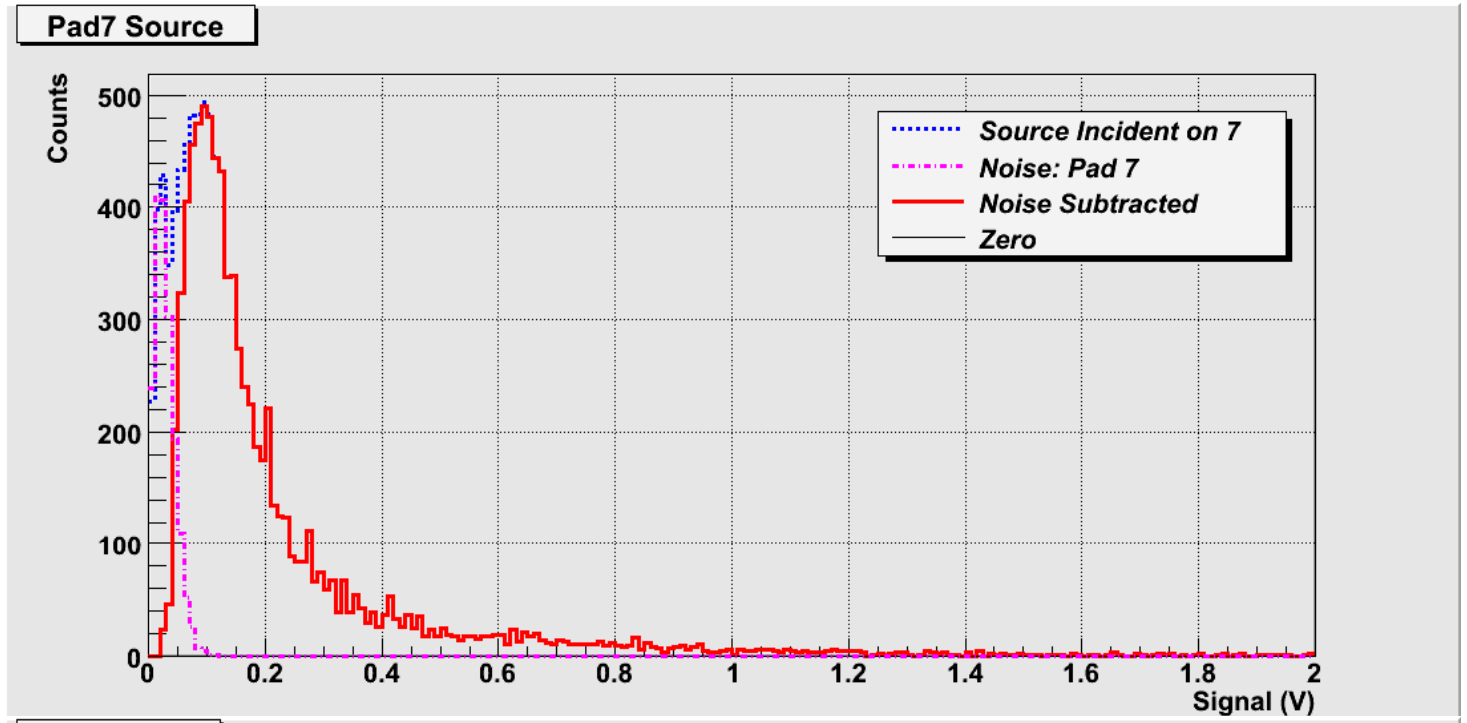


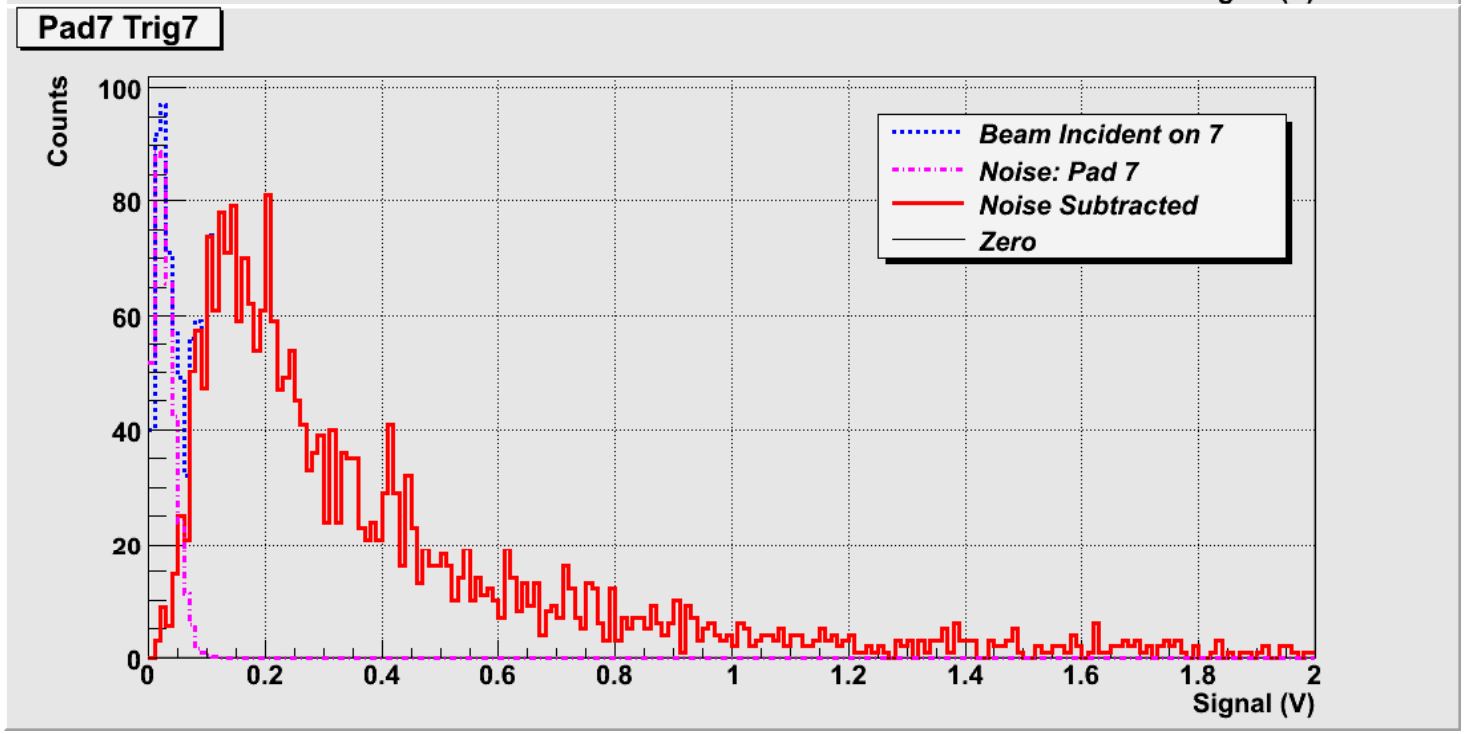


Looking at other adjacent cells (nearest and diagonal)

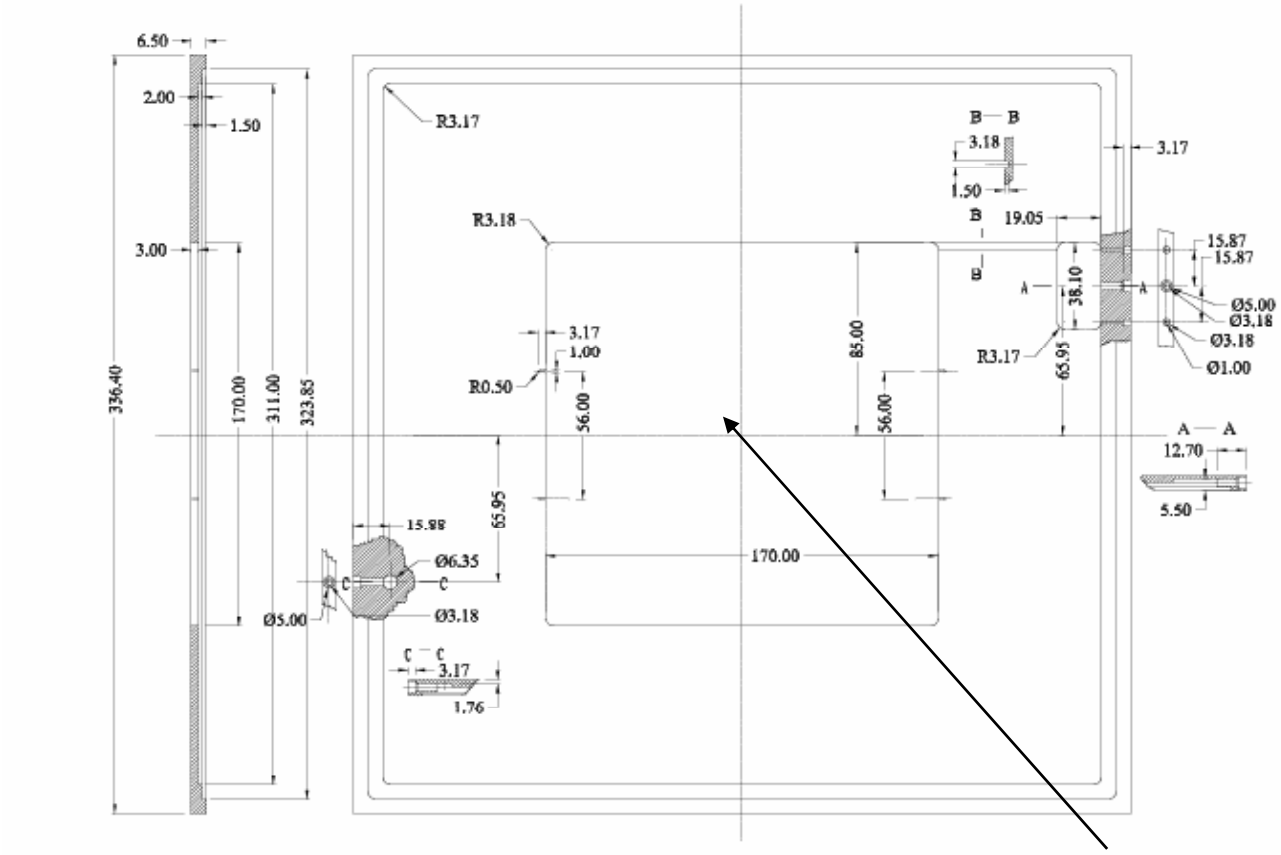
-> measure of multiplicity

-> use in simulation of GEM-DHCAL


Pad7 Source
Counts
500
400
300
200
100
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Signal (V)
Source Incident on 7
Noise: Pad 7
Noise Subtracted
Zero


Pad7 Trig7
Counts
100
80
60
40
20
0
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
2
Signal (V)
Beam Incident on 7
Noise: Pad 7
Noise Subtracted
Zero

GEM-DHCAL chamber

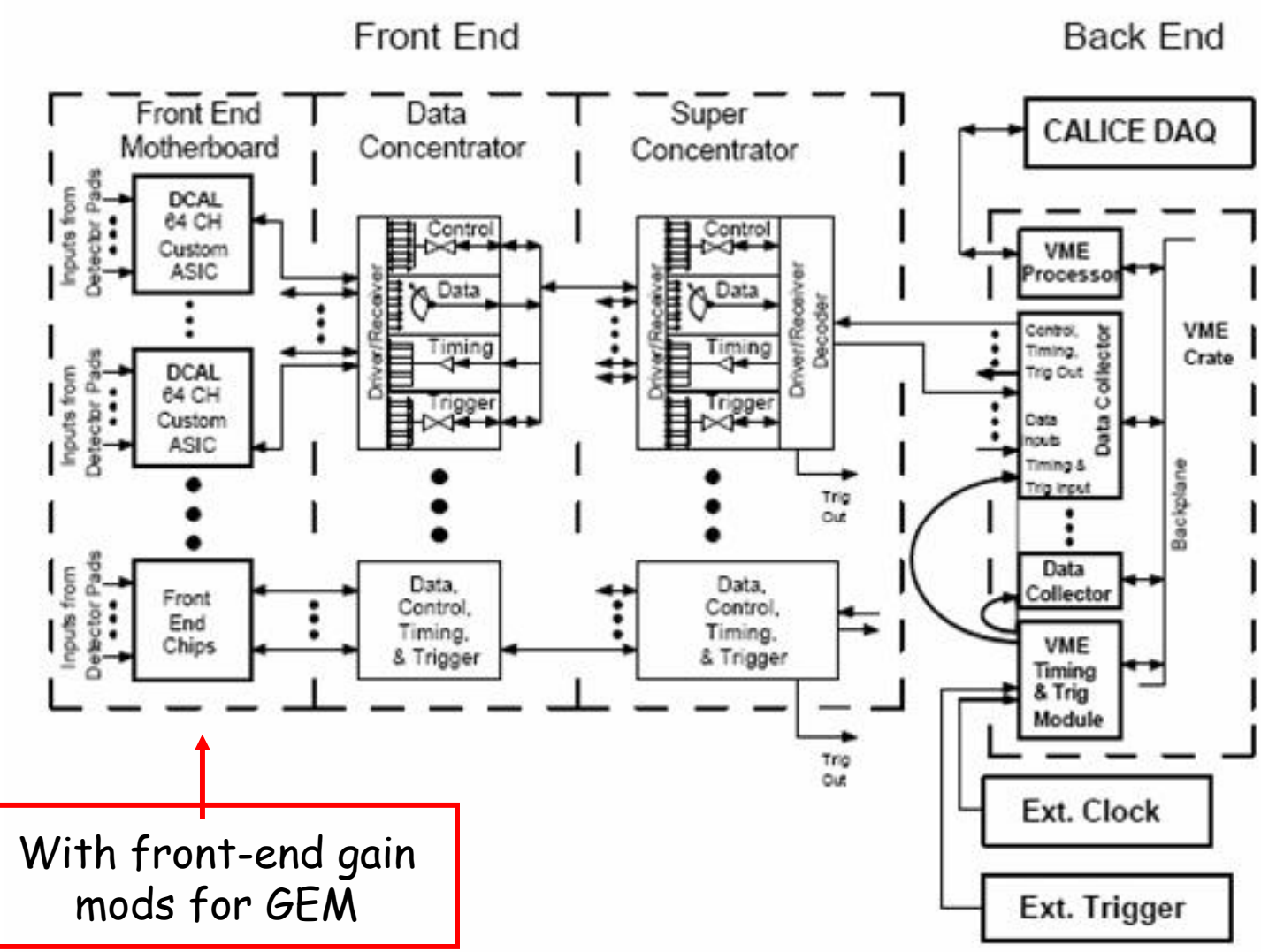


Active area 16cm x 16cm, readout with four DCAL chips

New chamber design with large Delrin spacers – source of trouble??

(GEM chamber for Spring 2007 TB using fishing line spacers)

DCAL schematic



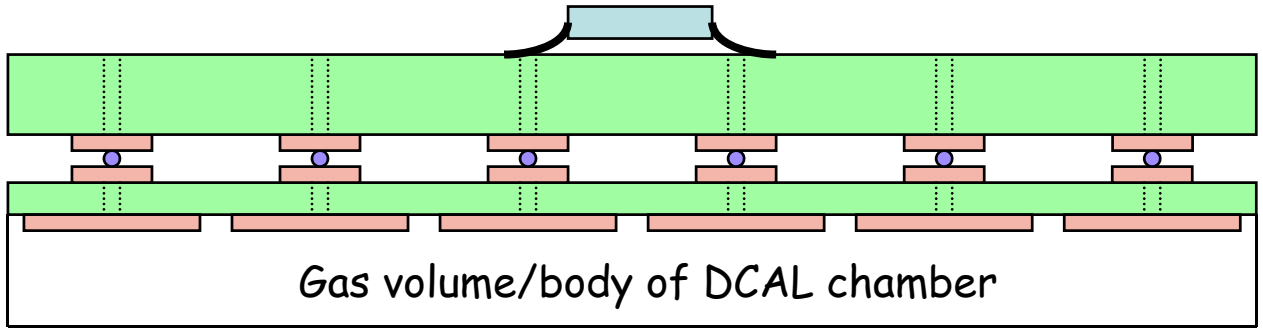
With front-end gain mods for GEM

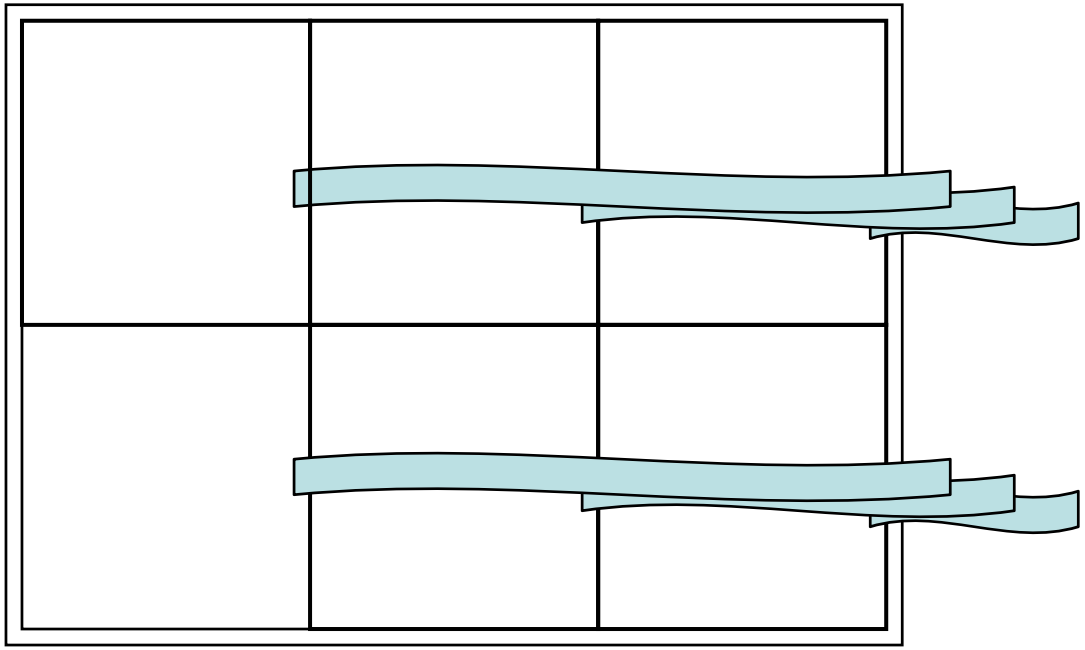
GEM signals:

minimum signal ~10fC,
maximum signal ~few pC

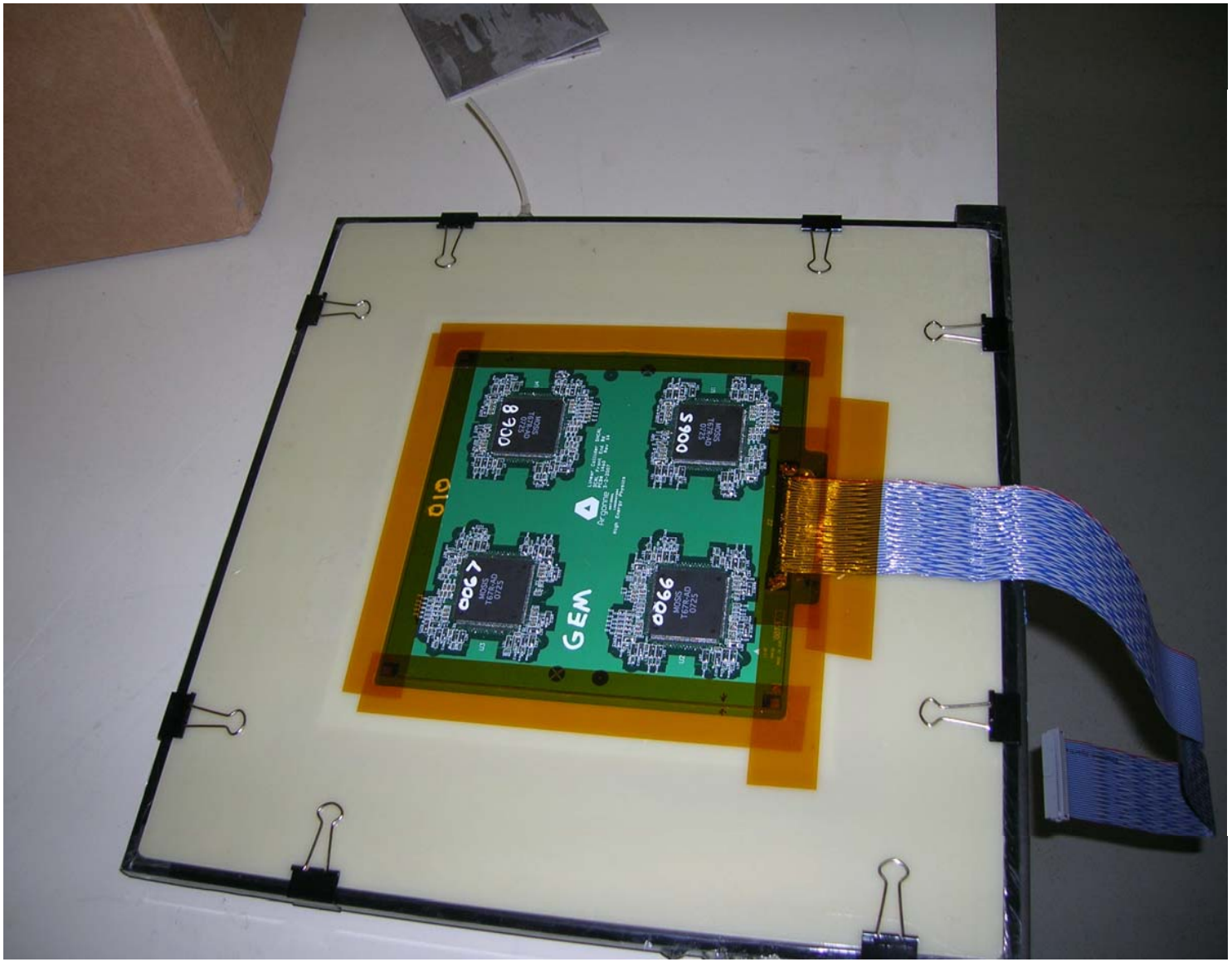
Gary Drake, ANL

GEM and RPC DCAL Chip Front end board and readout connections

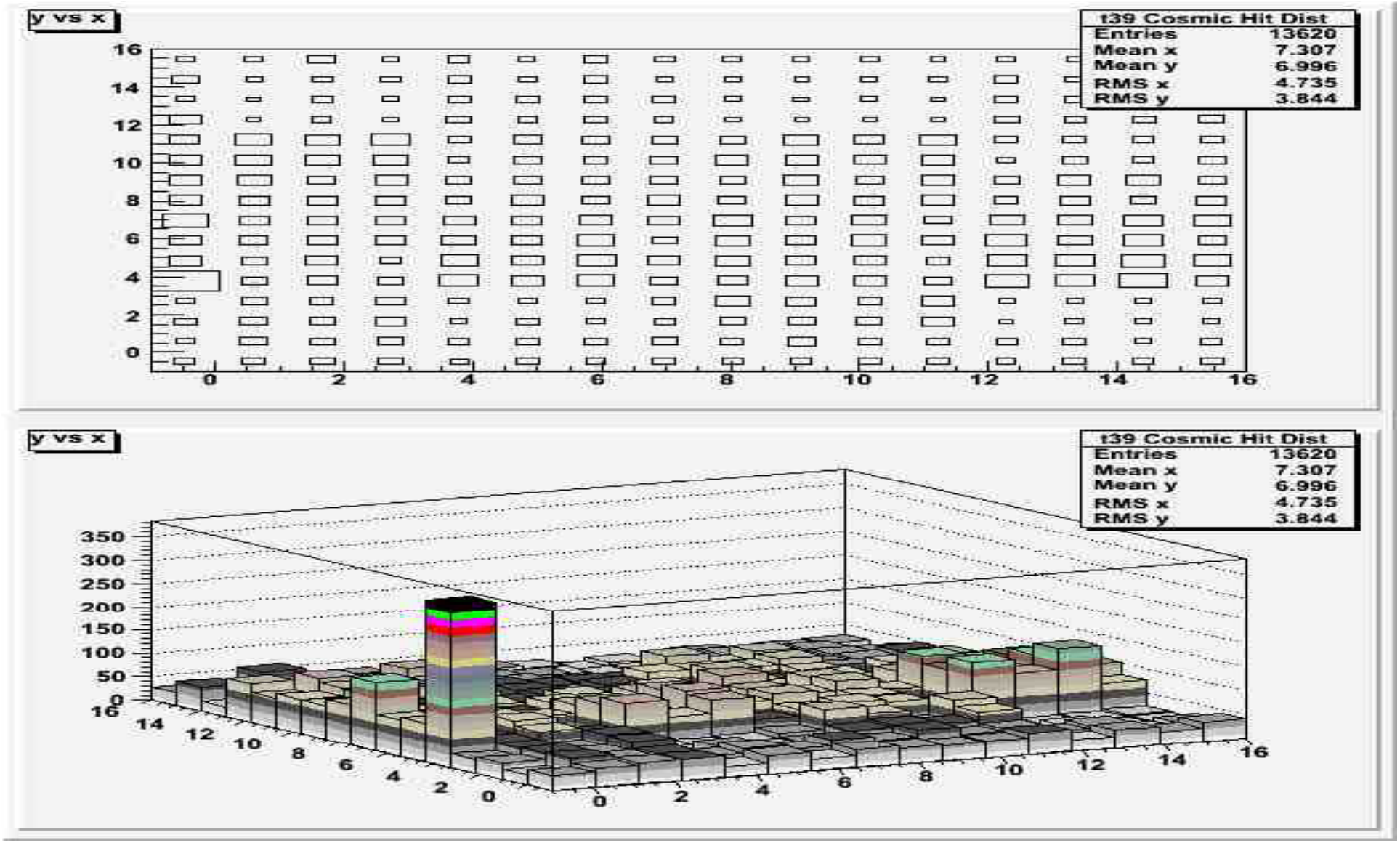


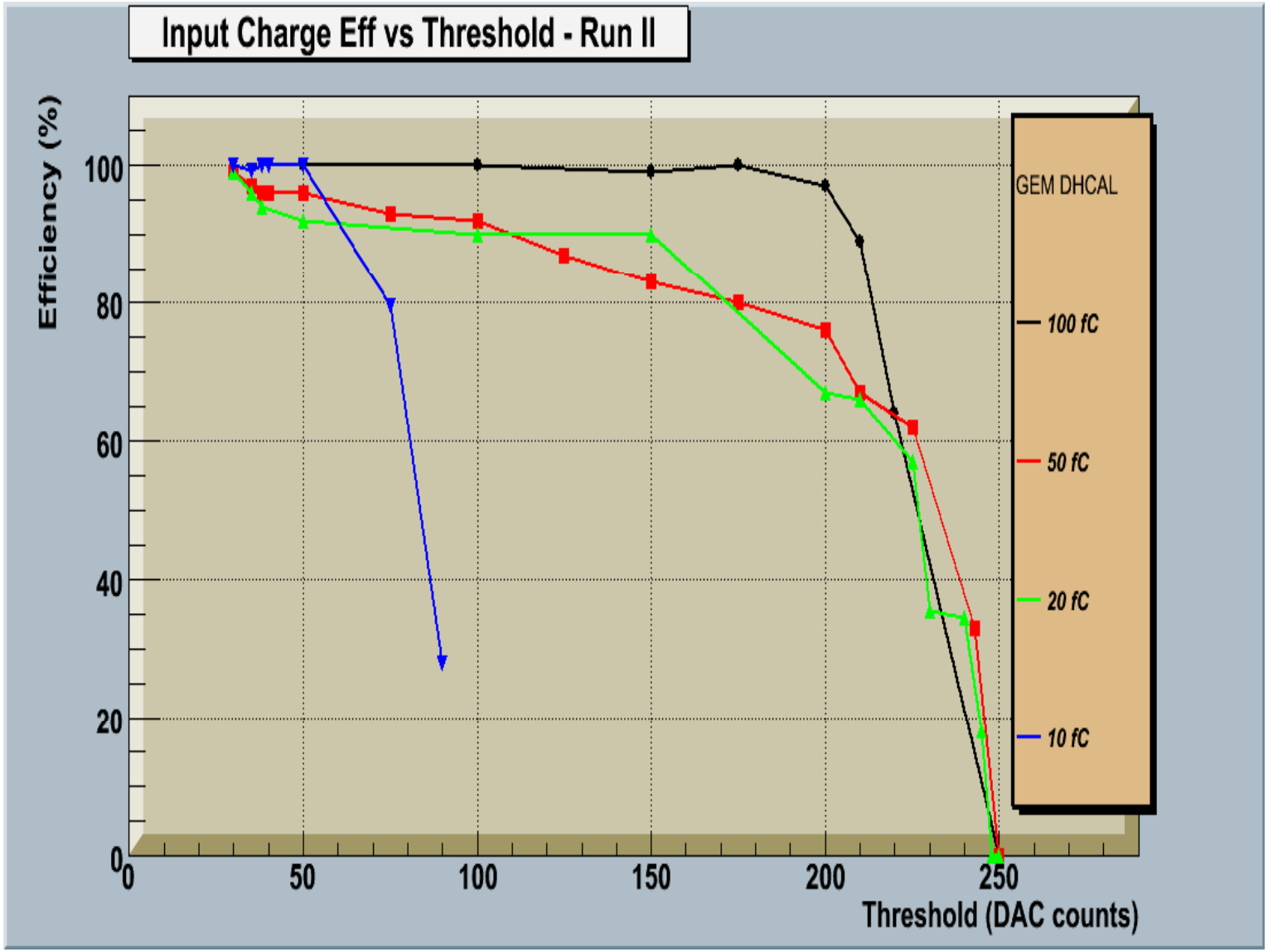


GEM-DCAL chamber under construction



Overnight Cosmic Ray Run





Test of injected charge with GEM-DCAL chamber at ANL

GEM-DHCAL chamber

-> DCAL sees injected charge down to 10fC.

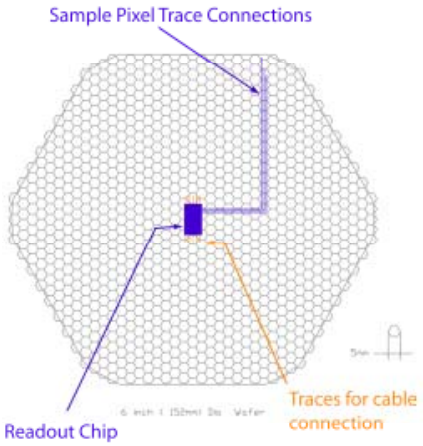
Many thanks to ANL colleagues for help with GEM-DCAL studies at ANL!

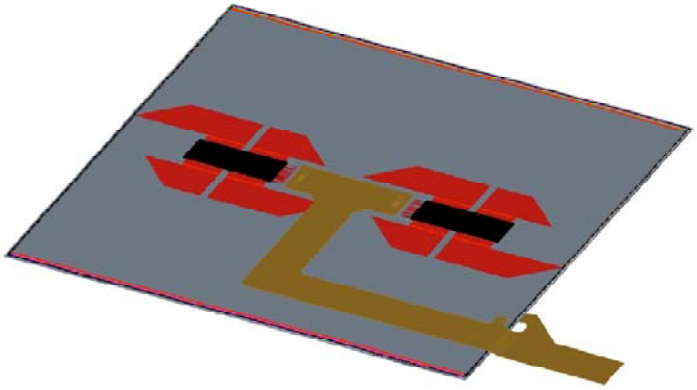
-> from previous GEM chamber studies, expect typical (average) signal to be ~30-40fC with 80/20 Ar/CO_2 mixture

=> Problem with new chamber design ??

GEM-DHCAL using KPiX readout

- KPiX originally developed for SiD/ECal readout; used for SiD tracking system readout:





- With front-end amplifier modification, now applied to GEM-DHCAL readout.

- KPiX designed for ILC beam timing structure – requires careful timing consideration when used e.g. at Fermilab test beam.

- KPiX v.4 has 2x32-channel subunits; final version will have 1024 channels.

KPiX chip

One channel of 1024

Si-W Pixel Analog Section

1 of 1024 pixels

Dynamic gain select

Si pixel

13 bit A/D

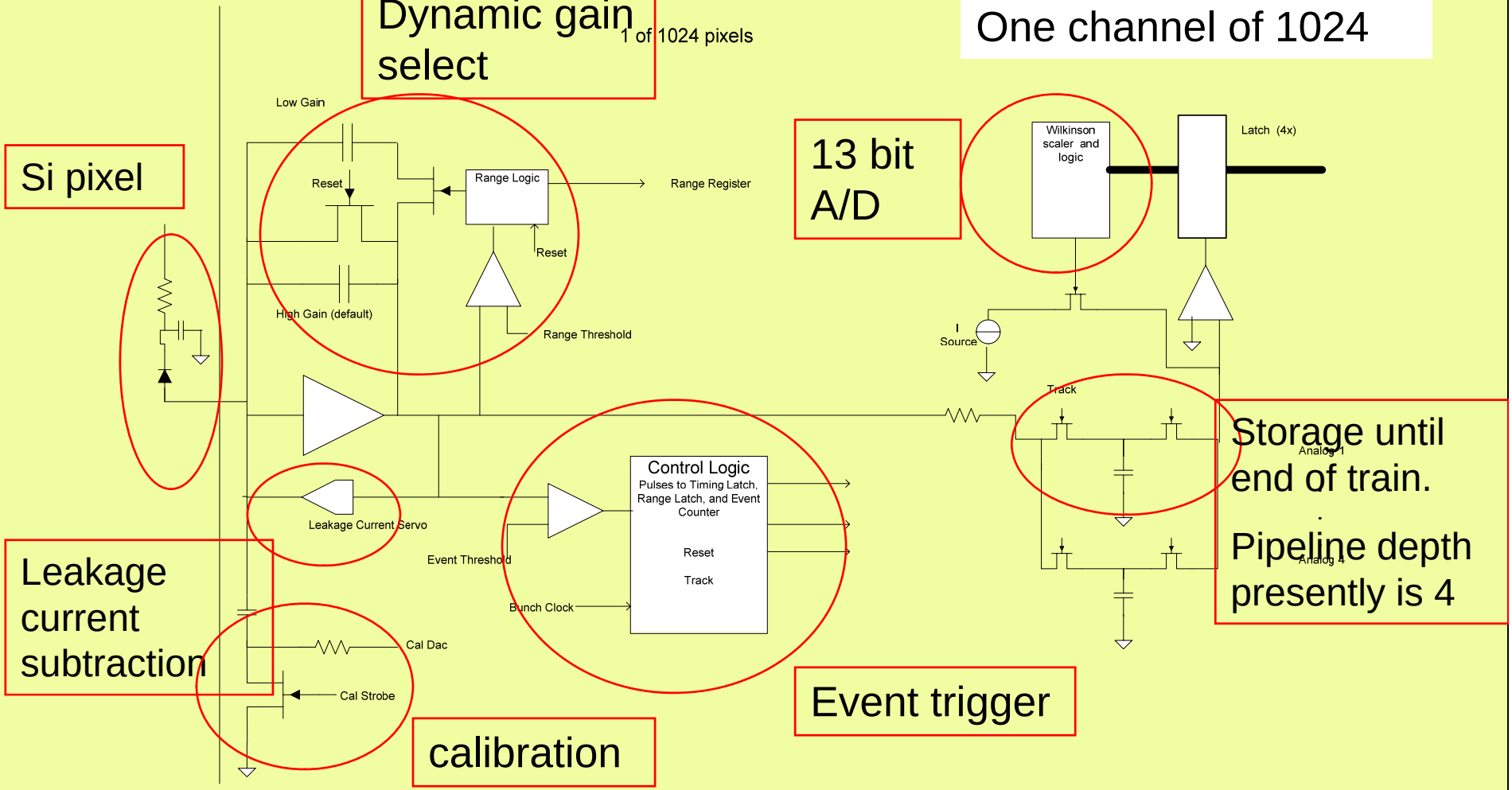
Storage until end of train.

Pipeline depth presently is 4

Leakage current subtraction

Event trigger

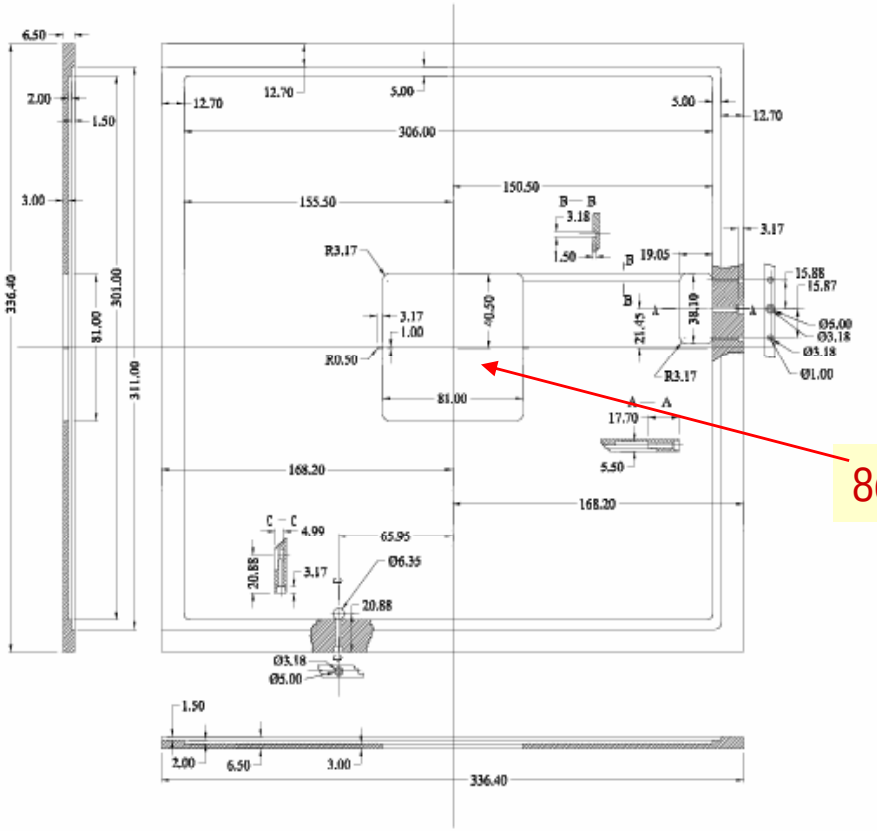
calibration



Simplified Timing:

There are ~ 3000 bunches separated by ~300 ns in a train, and trains are separated by ~200 ms.

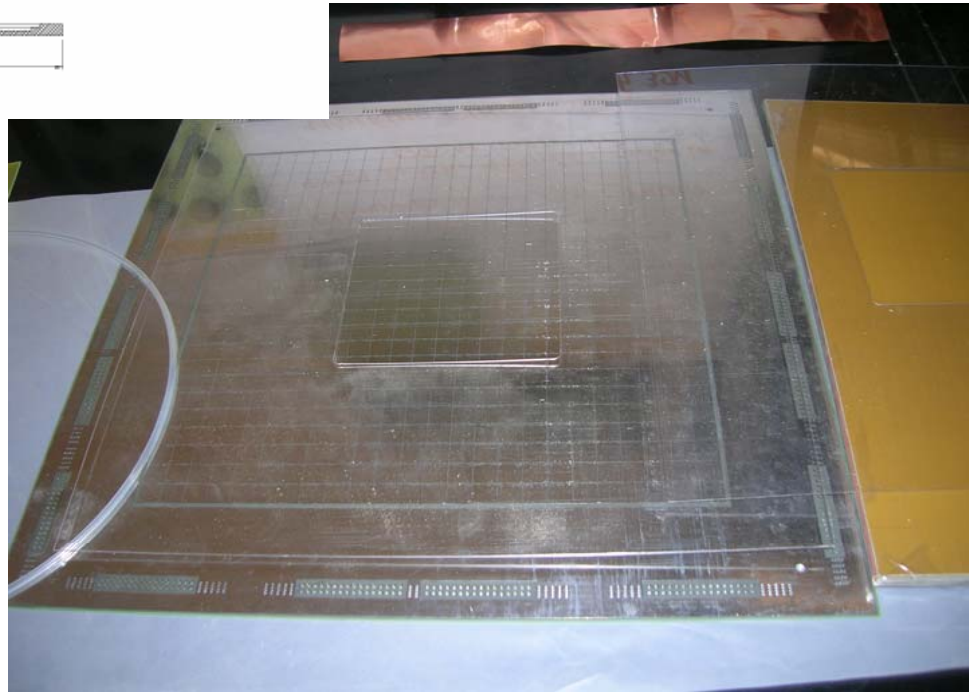
Say a signal above event threshold happens at bunch n and time T0.
The Event discriminator triggers in ~100 ns and removes resets and strobes the Timing Latch (12 bit), range latch (1 bit) and Event Counter (5 bits).
The Range discriminator triggers in ~100 ns if the signal exceeds the Range Threshold.
When the glitch from the Range switch has had time to settle, Track connects the sample capacitor to the amplifier output. (~150 ns)
The Track signal opens the switch isolating the sample capacitor at T0 + 1 micro s. At this time, the amplitude of the signal at T0 is held on the Sample Capacitor .
Reset is asserted (synched to the bunch clock) . Note that the second capacitor is reset at startup and following an event, while the high gain (small) capacitor is reset each bunch crossing (except while processing an event)
The system is ready for another signal in ~1.2 microsec.
After the bunch train, the capacitor charge is measured by a Wilkinson converter.



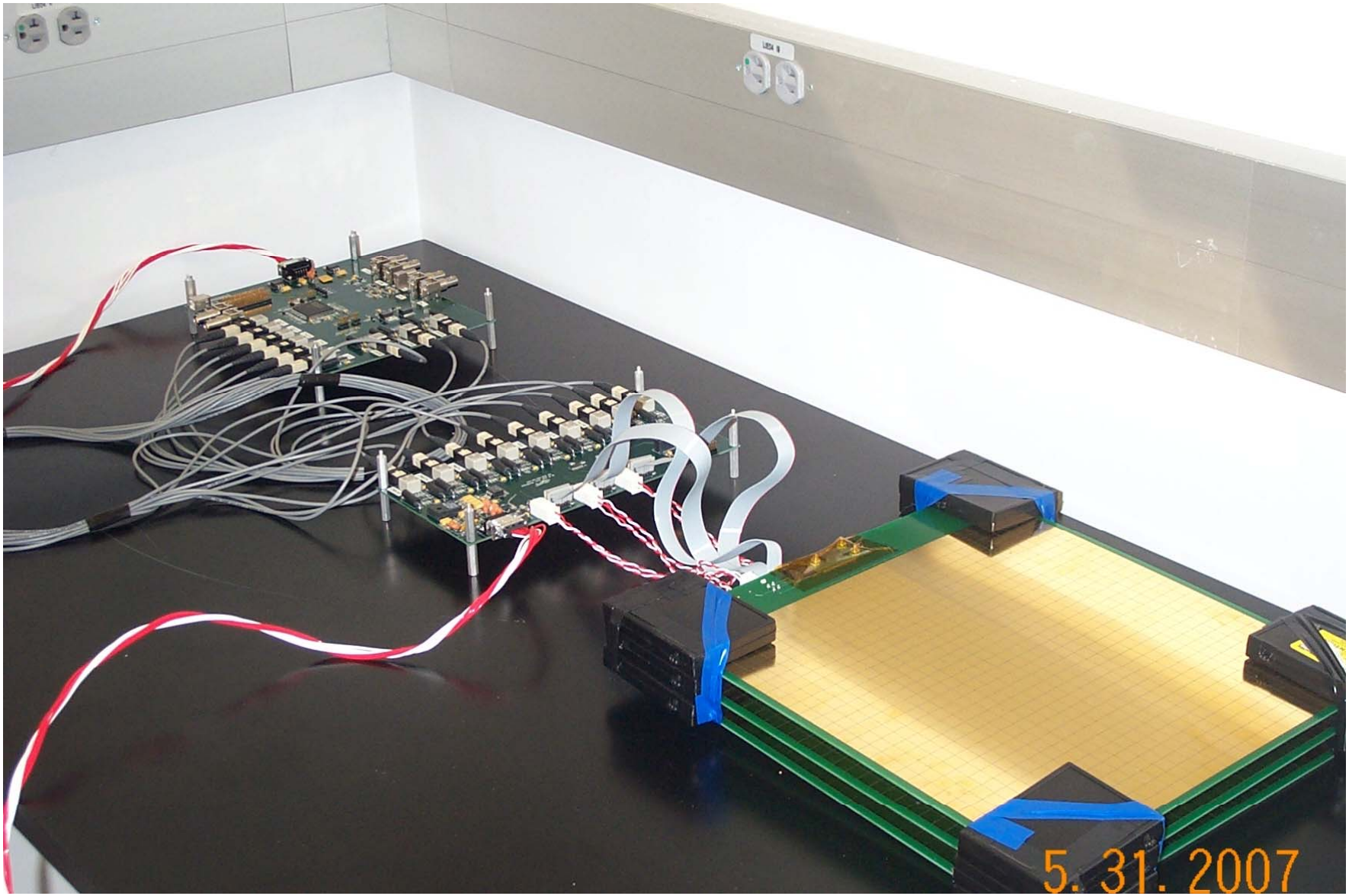
Similar new spacer as for GEM-DCAL!

8cmx8cm active area

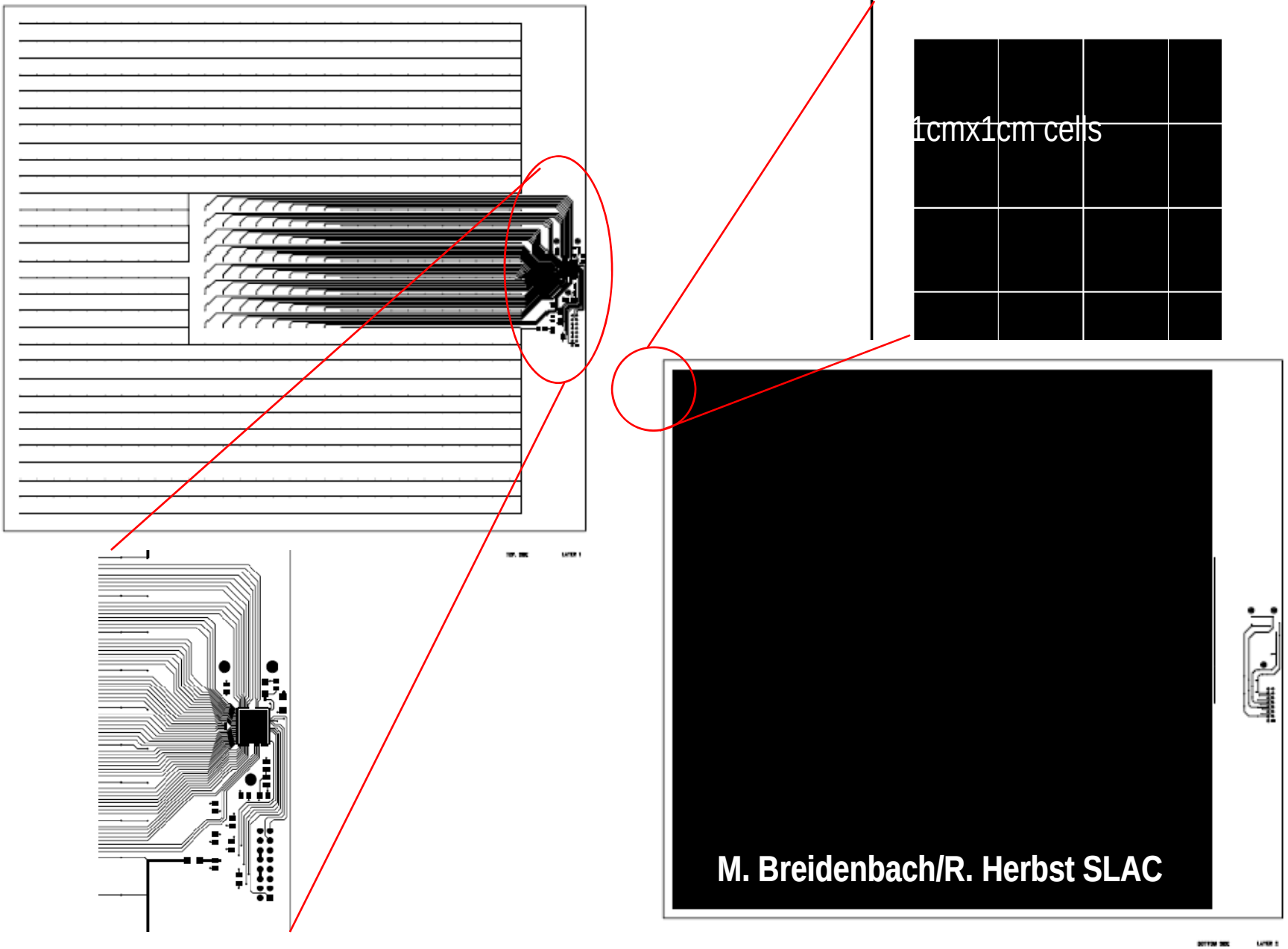
GEM-DHCAL/KPiX chamber design



GEM-DHCAL/KPiX boards with Interface and FPGA boards



GEM FEB for Analog KPix Chip



- Initial problems with timing of KPiX – time between formation of external trigger and its delivery to KPiX was too long relative to data reset internally. This was resolved with help from SLAC. Thanks to Ryan, Dieter, Marty, Gunther!

- As for cosmic data taking with GEM-DCAL, test beam exposure at Fermilab of GEM-KPiX gave no appreciable signals above noise.

Possible causes of lack of signal:

1) Signal from chamber too small to be seen – checked that 10fc signal directly injected on a pad can be seen (this was done for both DCAL and KPiX). Expect average signal ~30-40fC.

2) Grounding, floating pads issue? Checked with SLAC for KPiX -> HV ground tied to AVDD as required.

3) This leaves the new structure of the chambers, with large Delrin spacers.

New 30cm x 30cm chamber ->

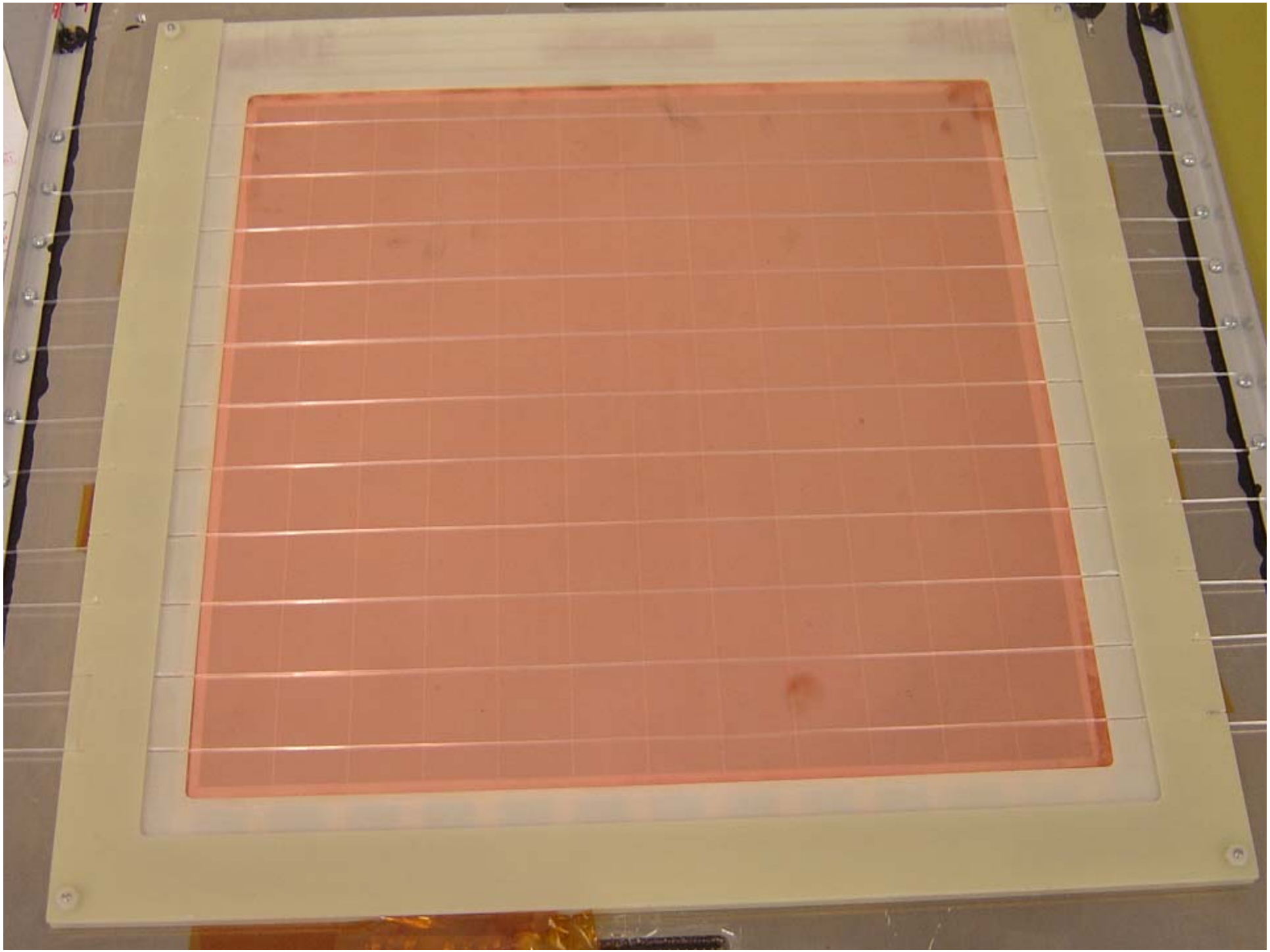
New design for 30cm x 30cm GEM Chamber

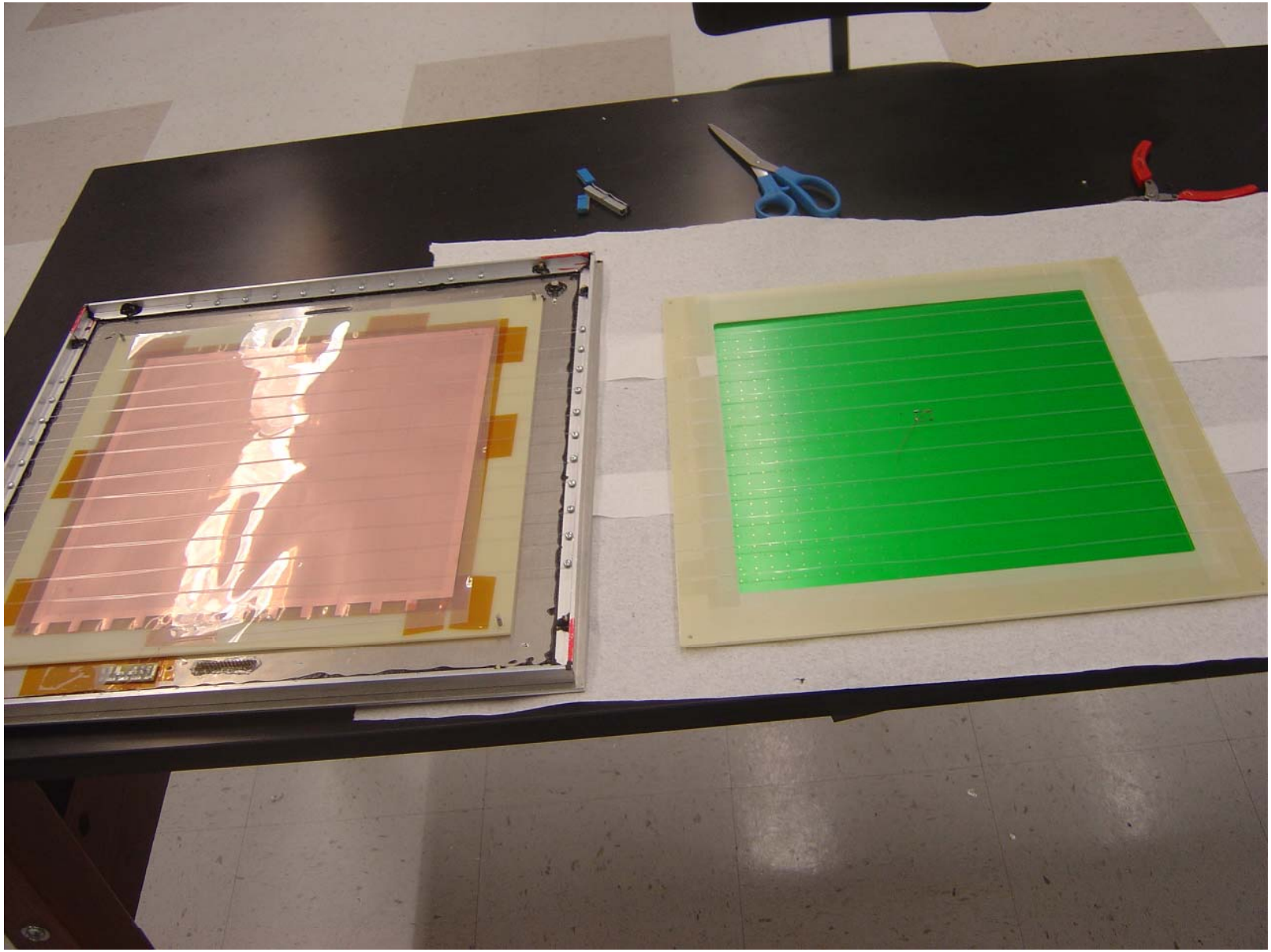
- Return to "fishing line" spacer design – no more Delrin.

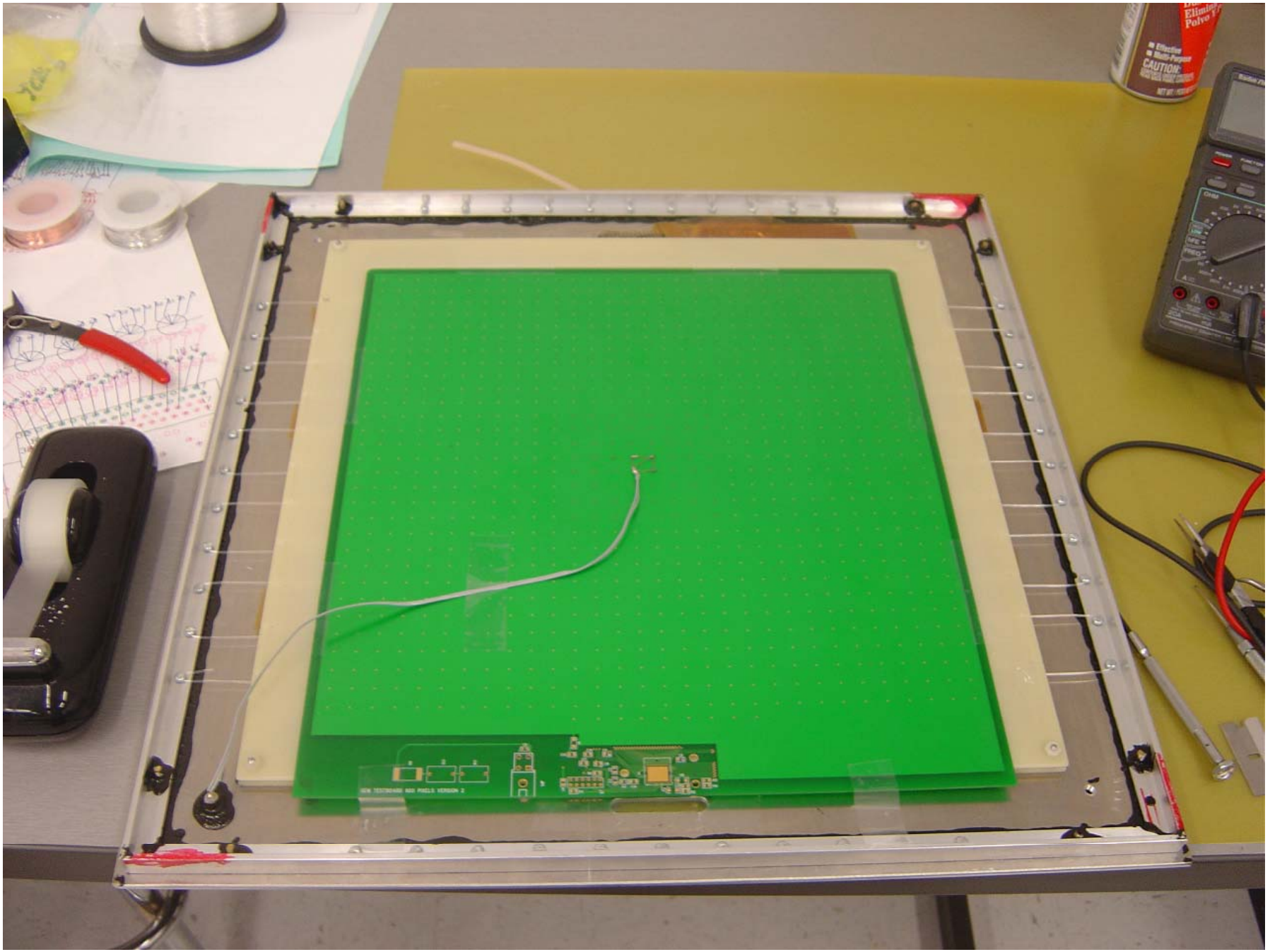
- Test with source/cosmics on small pad array.

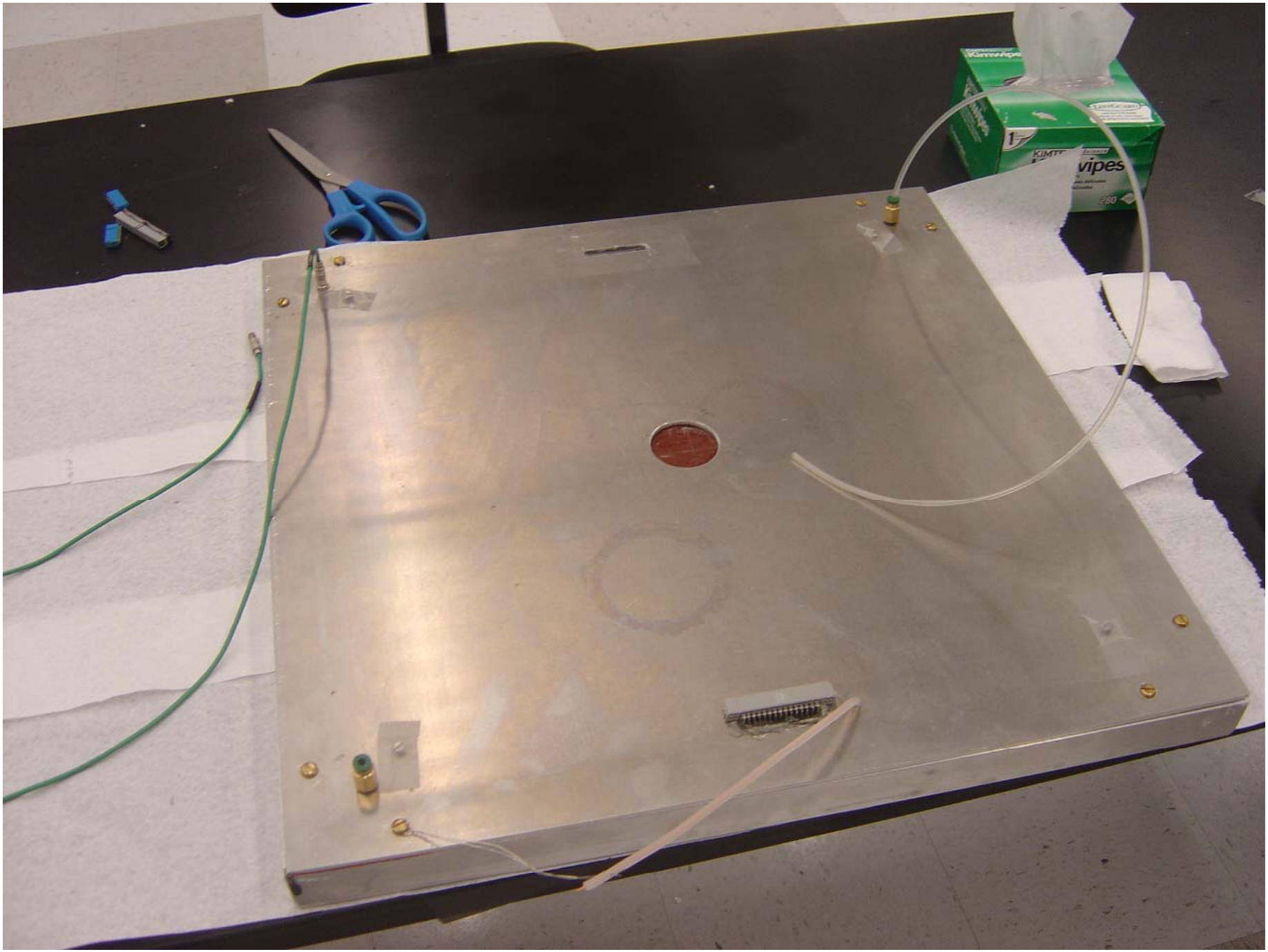
- Then use KPiX and DCal versions of pad boards/readout.

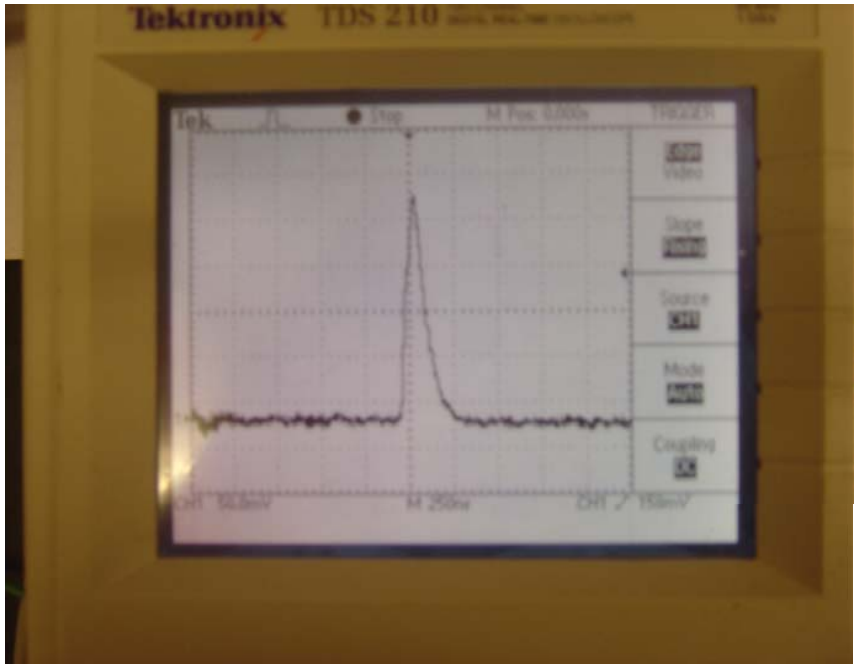
- We know from chamber tests in the Spring that the fishing line design works. We also know from charge injection tests on the KPiX board that the level of signals from the chamber can be seen via the KPiX readout. So we are now about to test the combination…

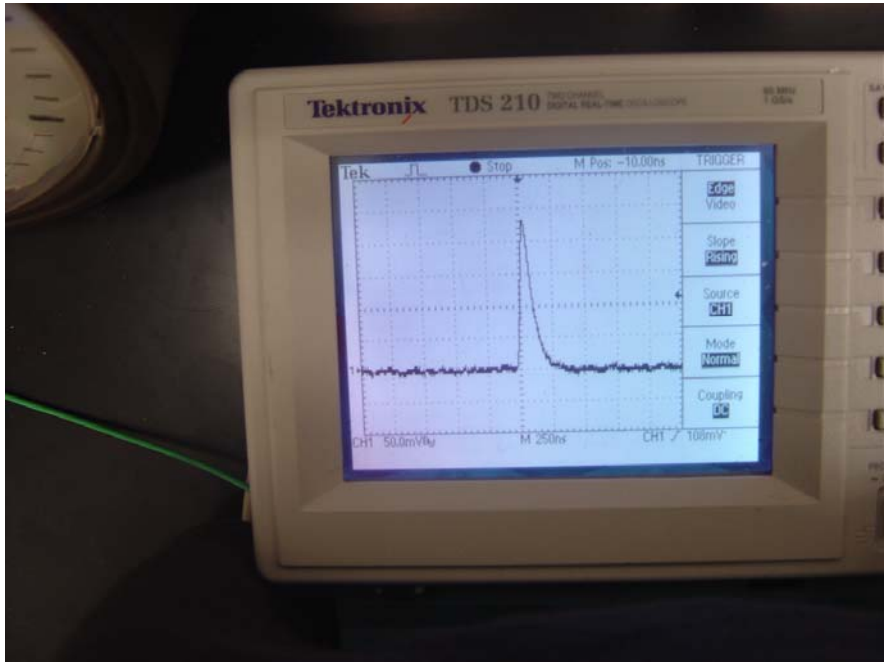


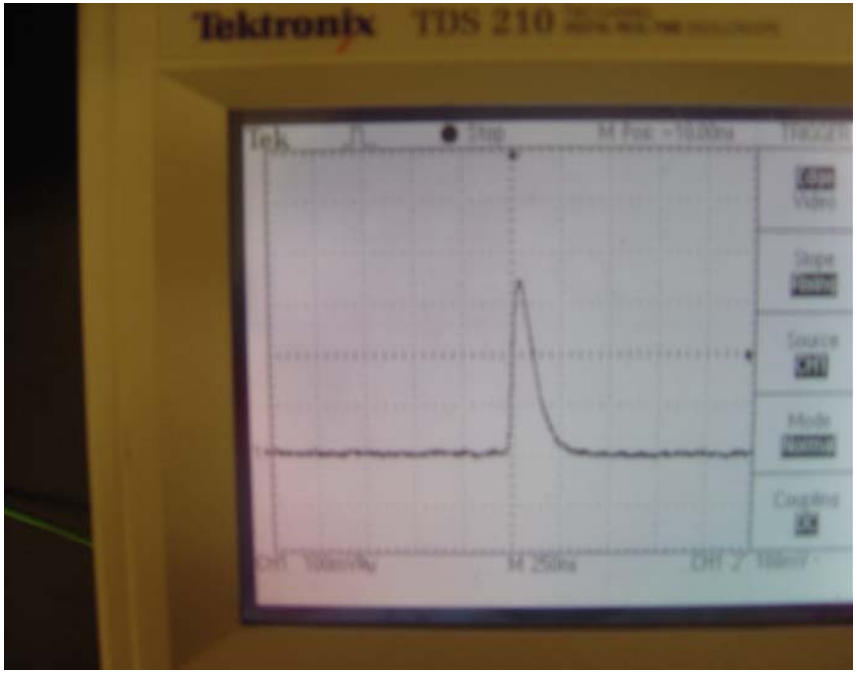


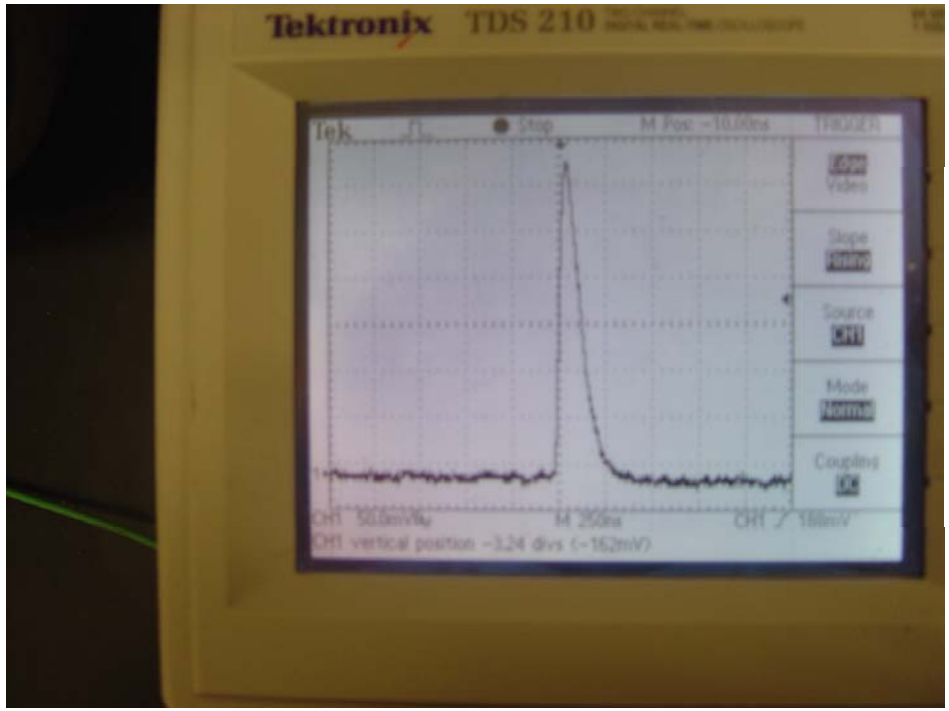

CAUTION:

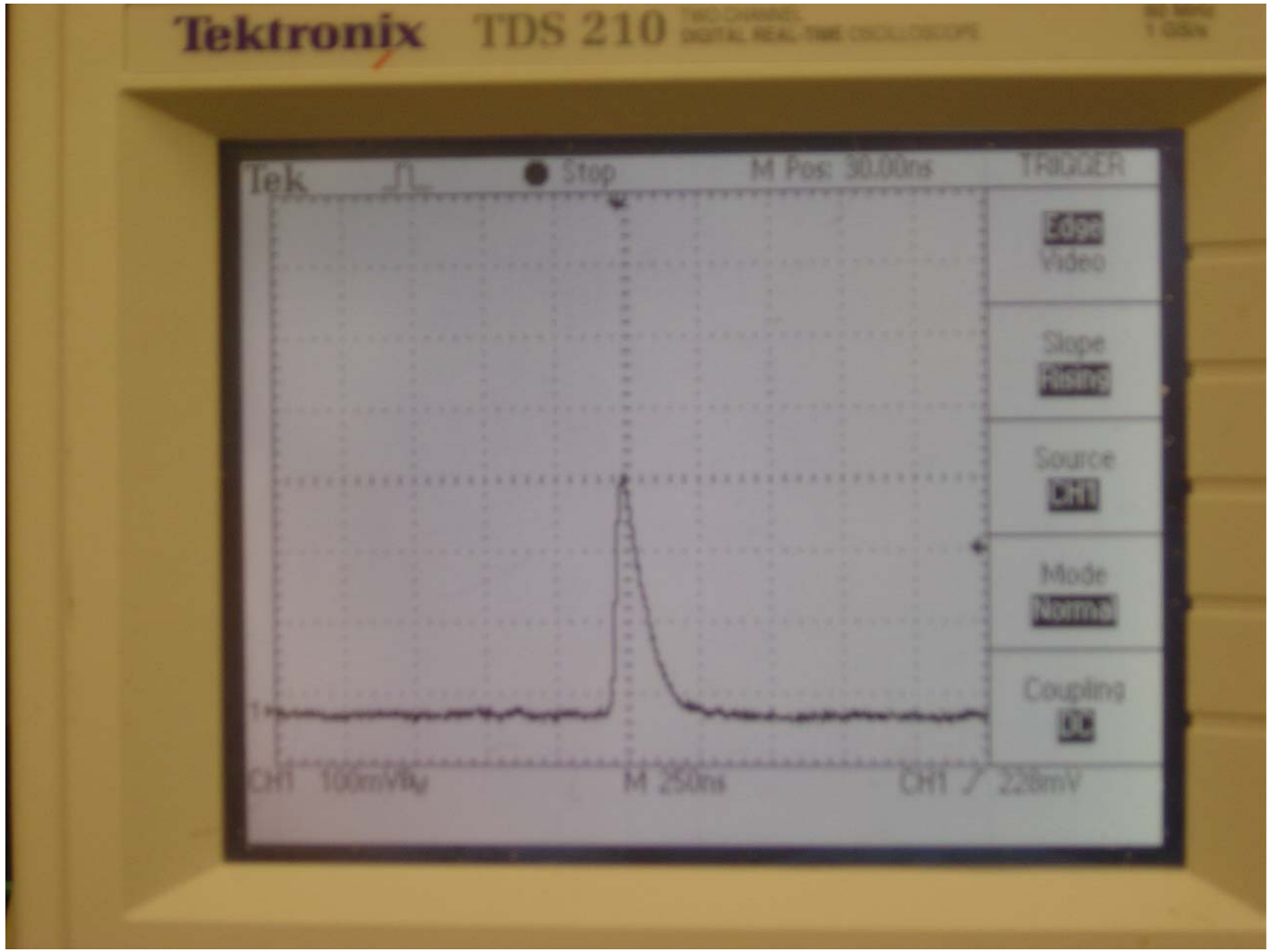

vipes


Tektronix TDS 210
Tek
Stop
Source
CH1
Mode
Coupling


Tektronix TDS 210
Tek
Stop
M Pos: -10.00ns
TRIGGER
Edge
Video
Slope
Rising
Source
CH1
Mode
Norma
Coupling
DC
CH1 50.0mV/Div
M 250ns
CH1 / 108mV

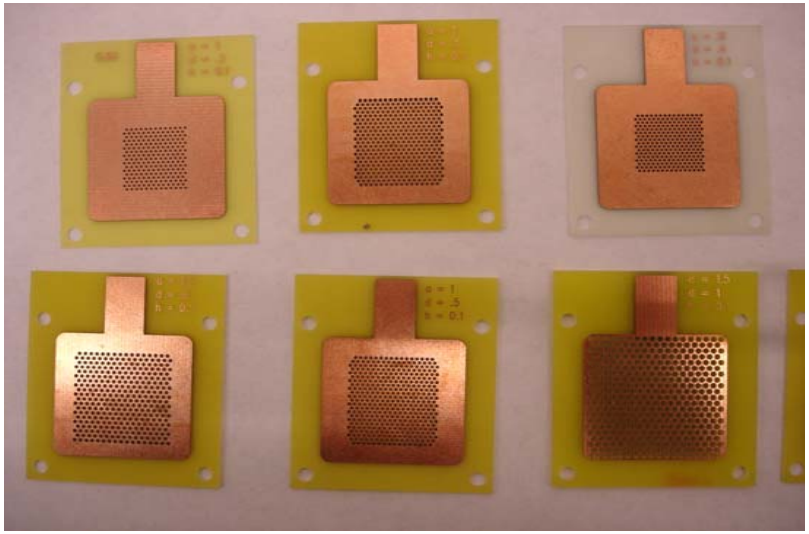

Tektronix TDS 210
Tek
Stop
Source
CH1
Mode
Coupling
M 250ns

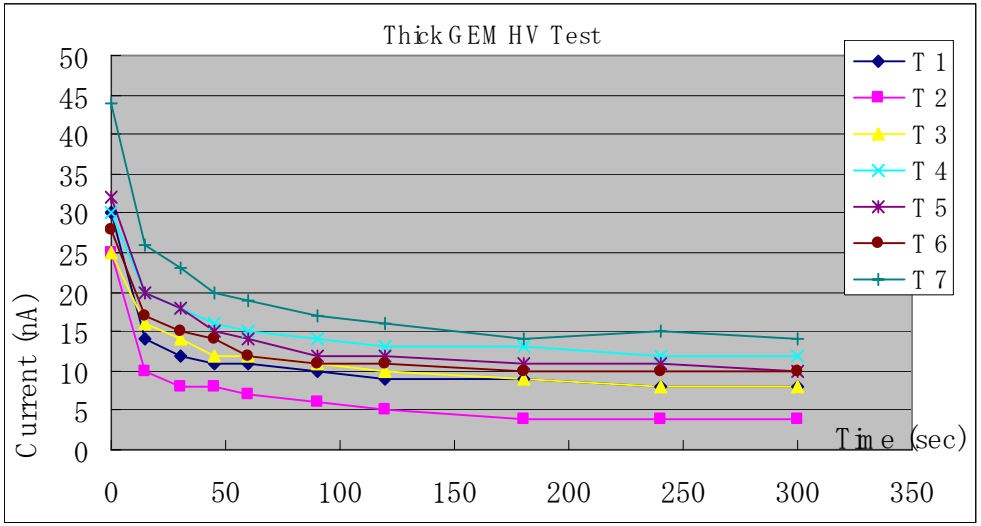

Tektronix TDS 210
Tek
Stop
Source
CH1
Mode
Coupling
M 250ns
CH1 vertical position -3.24 divs (-162mV)



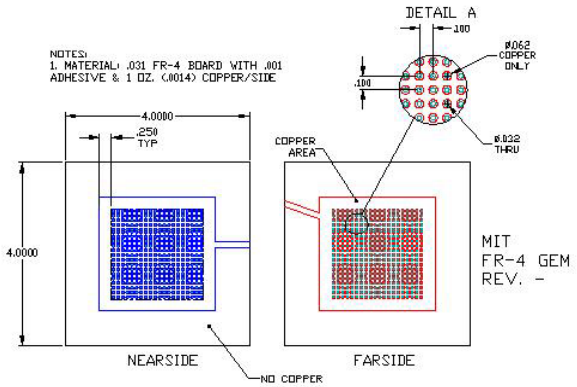
Chamber works well, and we have the KPiX setup ready to be used…

Thick GEM development

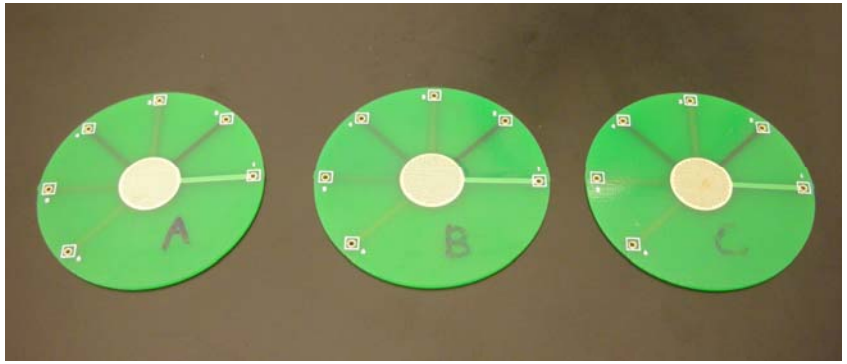




Weizmann/A. Breskin



New design TGEM from MIT



CNU/Korea

Looking into production of large area thick GEMs.

Future Plans

-> Finish Spring 2007 TB data analysis.

-> About to test new 30cm x 30cm chamber coupled to KPiX. Then move to MTBF for full 64-channel tests, and efficiency, multiplicity, etc. measurements.

-> Build a number of 30cm x 30cm chambers for stack test at MTBF.

-> Build 1m x ~30cm GEM chambers. Check HV characteristics and leakage currents, and operate. Identified as critical scalability issue in DoE/NSF Review.

Future Plans (cont.)

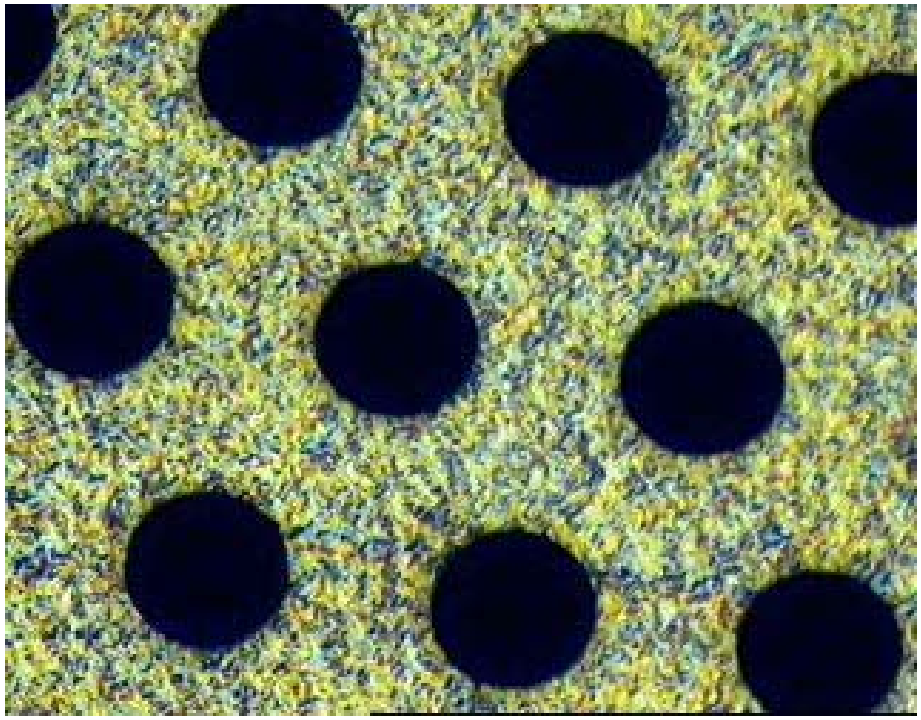
-> Develop design of 1m x 1m planes – build/test.

-> Plan for $1m^3$ GEM stack assembly/testing.

-> Need 2008 Supplemental and regular LCDRD support.

30cm x 30cm 3M GEM foils

12 HV sectors on one side of each foil.

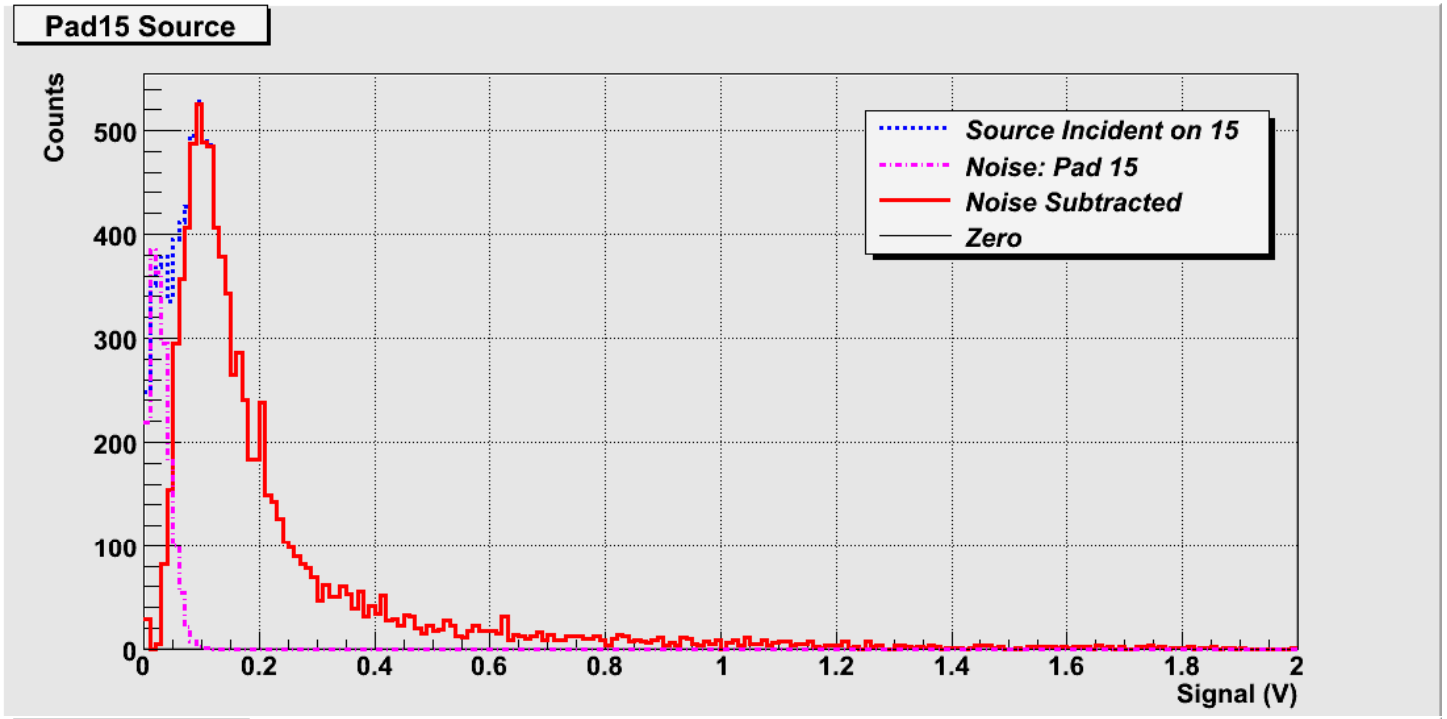


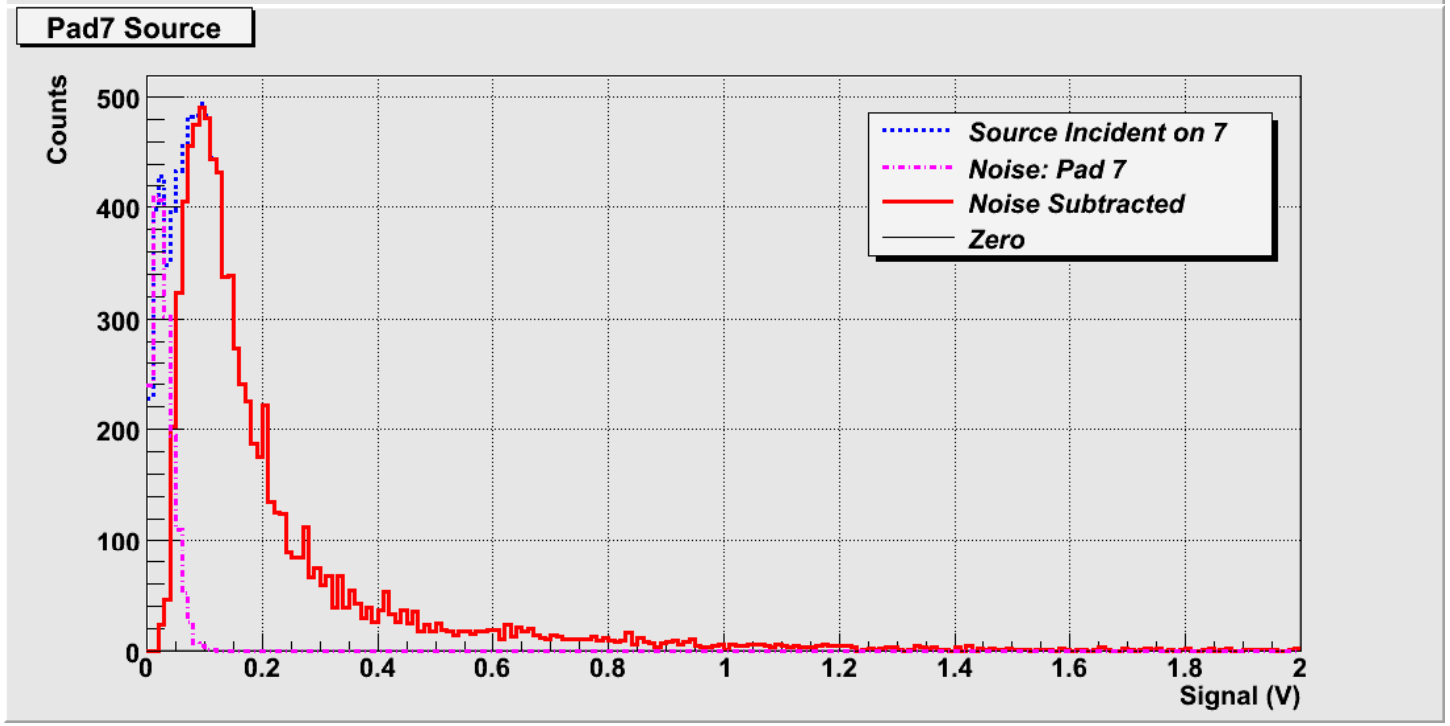
- Suspected significant level of double-proton events (confirmed by Accelerator Division): estimated at 20% - makes crosstalk interpretation difficult.

- Beam spot size was somewhat larger than the 1cm^2 pad size – also demands a correction factor in crosstalk for beam particles near the edge of the main pad.

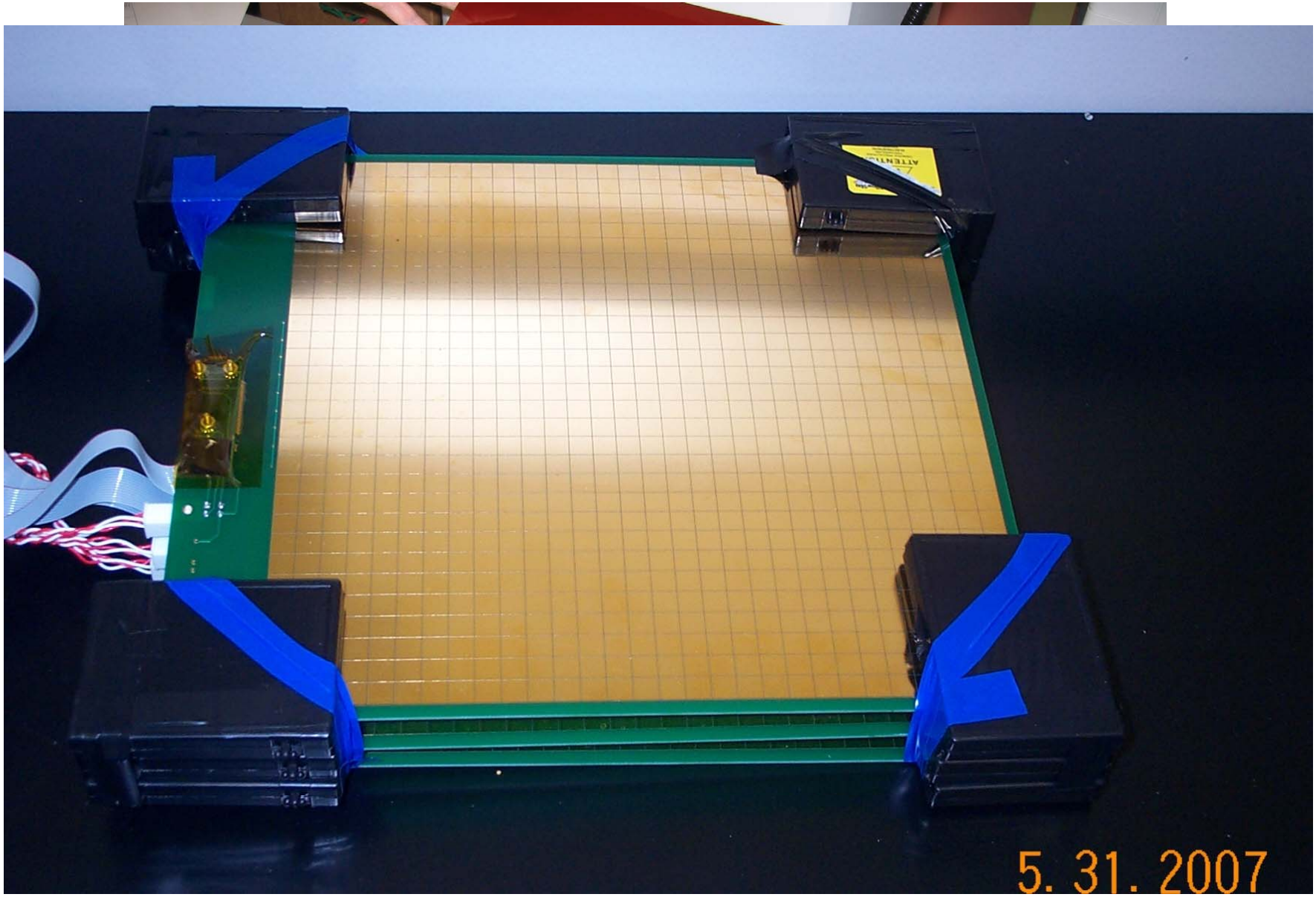
- With the above factors, the crosstalk estimates are (so far) upper estimates.

- Following plots are from work of Jacob Smith for his Master's thesis – completion Spring 2008.


Pad15 Source
Counts
Signal (V)
Source Incident on 15
Noise: Pad 15
Noise Subtracted
Zero


Pad7 Source
Counts
Signal (V)
Source Incident on 7
Noise: Pad 7
Noise Subtracted
Zero

GEM-DHCAL anode pad board, with KPiX



Thick GEM Test Assembly