UTA GEM DHCAL Update

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For GEM/DHCAL Group
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CALICE Meeting, Kobe

- Introduction
- 30cmx30cm Prototype GEM chamber Development
- Beam Test Activities
- What next?
- Summary

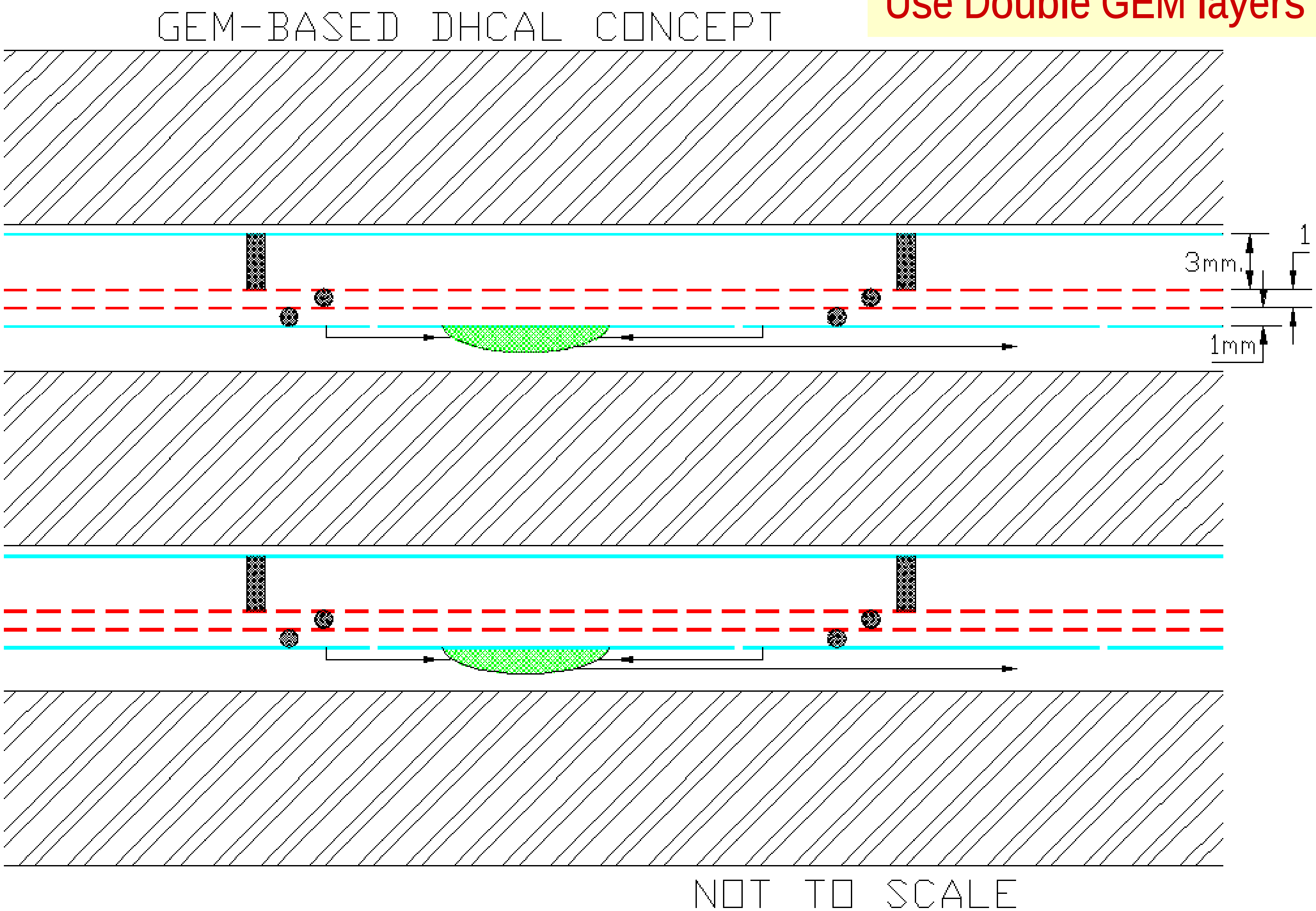
* UTA, U.Washington, Changwon Nat.U., Tsinghua U.

Why GEM's?

- Flexible configurations: allows small anode pads for high granularity
- Robust: survives $\sim 10^{12}$ particles/mm^2 with no changes
- Fast: based on electron collection, ~few ns rise time
- Uses simple gas (Argon/CO_2) – no long-term issues
- Runs at low HV (~400V across a foil)
- Stable operation

GEM-based Digital Calorimeter Concept

Use Double GEM layers



~6.5mm

GEM – Operation

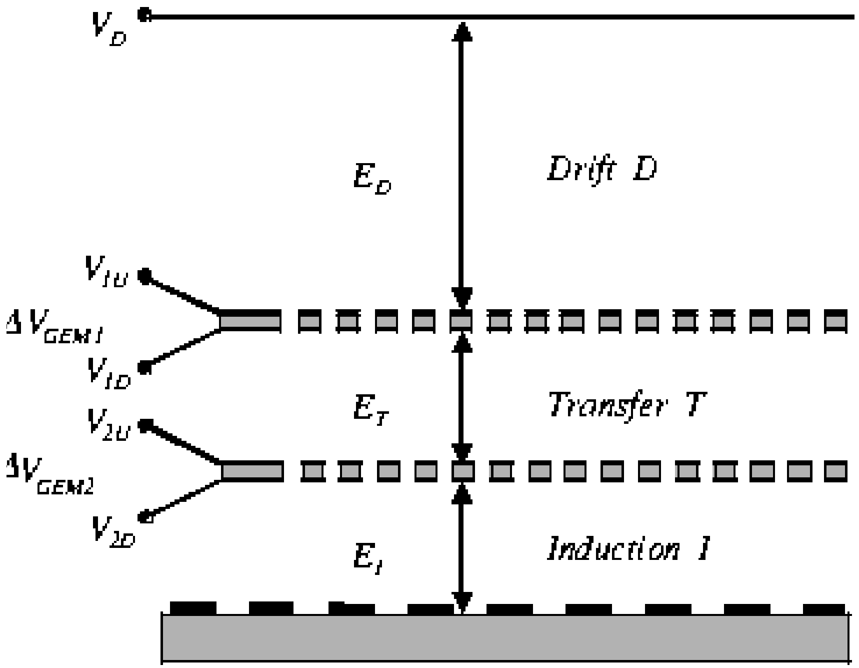


Fig. 1: Schematics of a double-GEM detector.

-2100V

ΔV ~400V → E~6.7x10^5V/cm

ΔV ~400V

0V

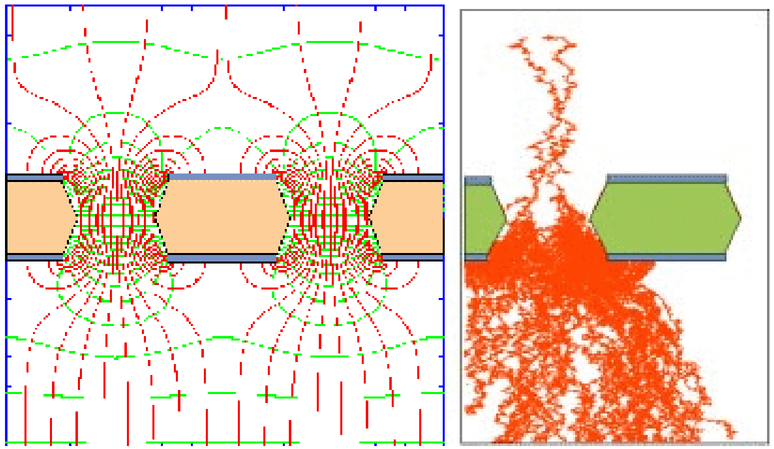


Fig. 15(a) Electric Field and (b) an avalanche across a GEM channel

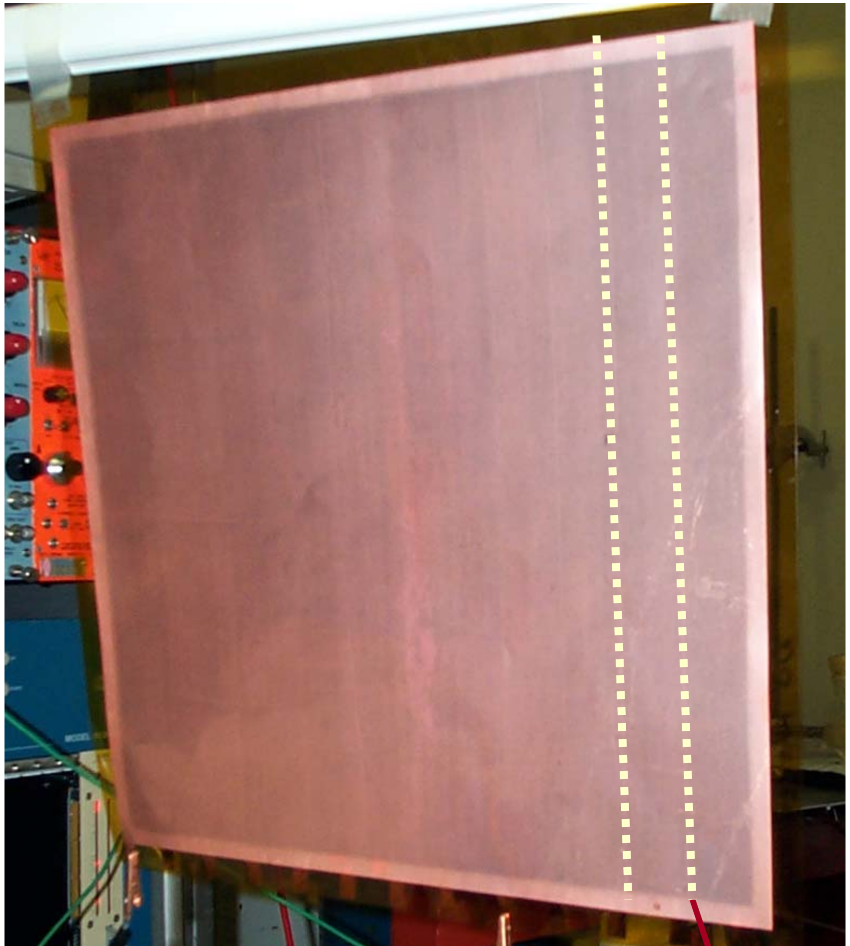
Coupled with a drift electrode above and a readout electrode below, it acts as a highly performing micropattern detector. The essential and advantageous feature of this detector is that amplification and detection are decoupled, and the readout is at zero potential. Permitting charge transfer to a second amplification device, this opens up the possibility of using a GEM in tandem with an MSGC or a second GEM.

GEM Foils From 3M

- 30cm x 30cm foils made with three types of coating:
  - Bare copper
  - “organic polymer” coating
  - gold plating
- HV tests made on all three types
  - Prefer to use the uncoated foils
- All 30cm x 30cm chambers built w/ uncoated foils
- 3M is setting up a formal internal project to develop larger foils for the 1m^3 prototype stack
  - 30x30cm^2 foil did not require 3M process modification

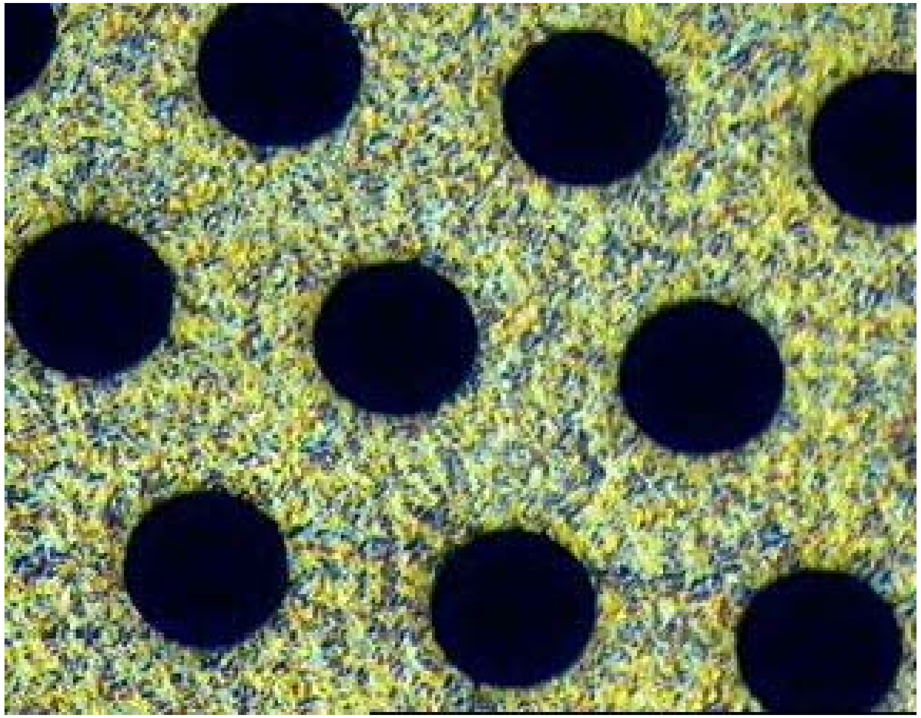
30cm x 30cm 3M GEM foils

12 HV sectors on one side of each foil.



HV Sector Boundary

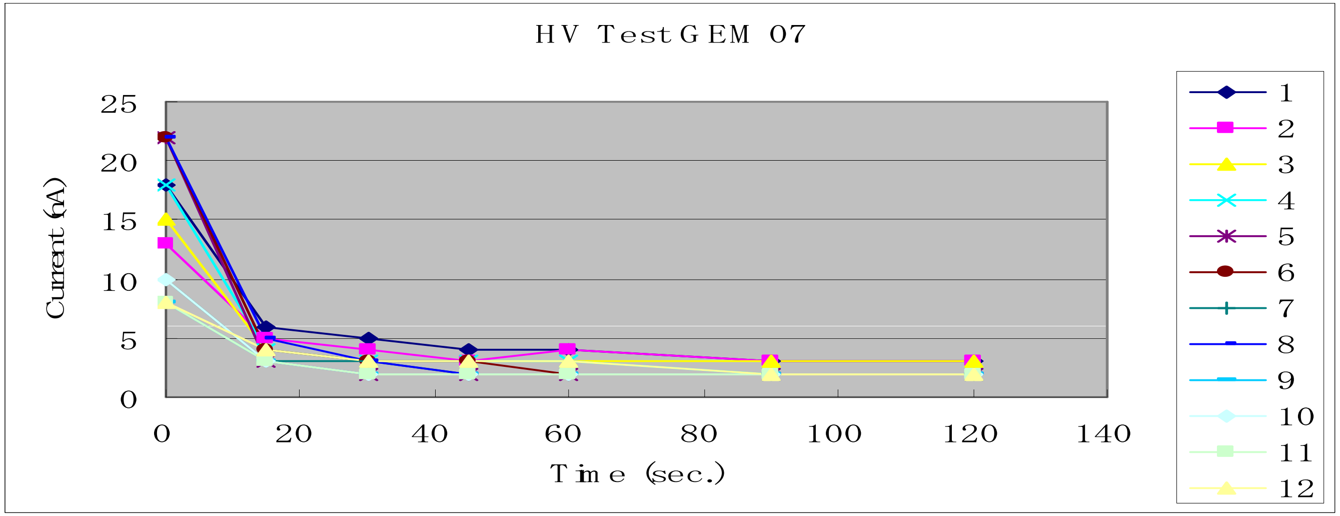
Magnified section of a 3M GEM foil.



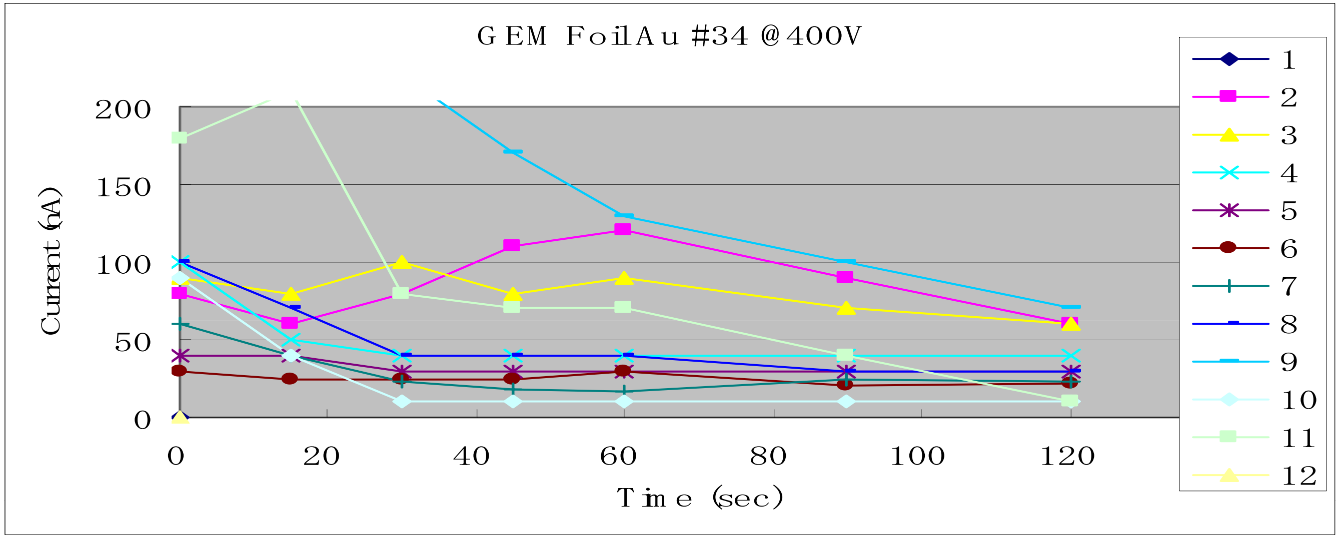
30cm x 30cm GEM Chamber Development

- Foils HV tested and certified
- Jigs made to mount foils, stack chamber

HV Tests on 30cmx30cm 3M GEM foils



Uncoated foils settle at below 5nA in less than 1 min



Au coated foils settle at 20 – 70nA and take longer to settle

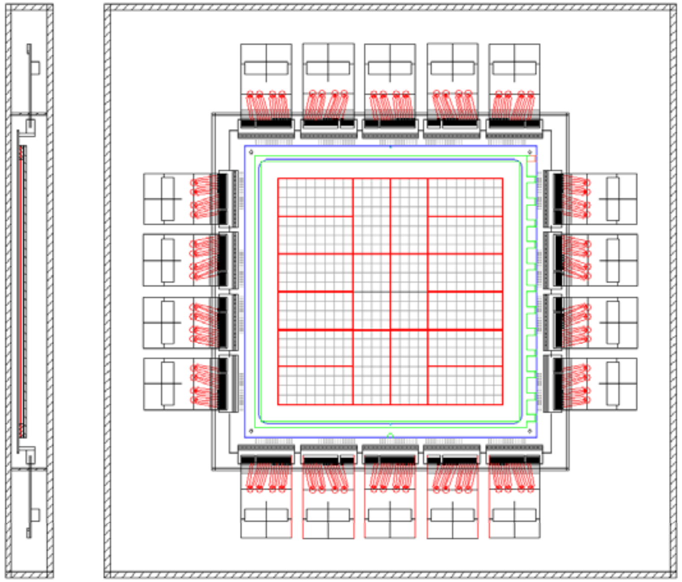
GEM 30cmx30cm Foil Mounting Jig

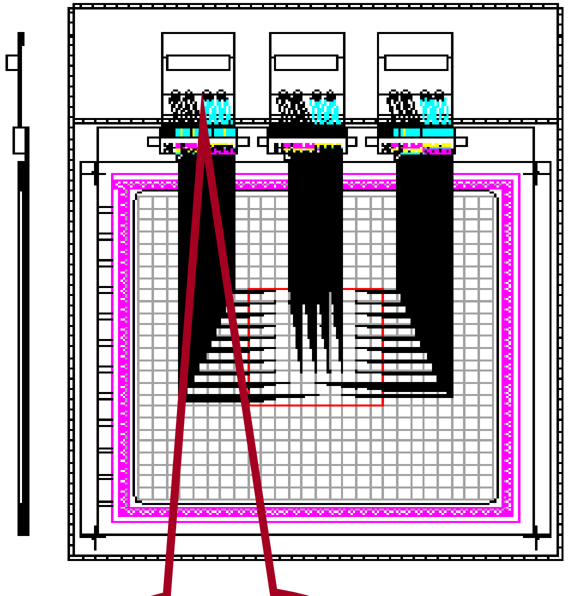
N

30cm x 30cm GEM Chamber Development

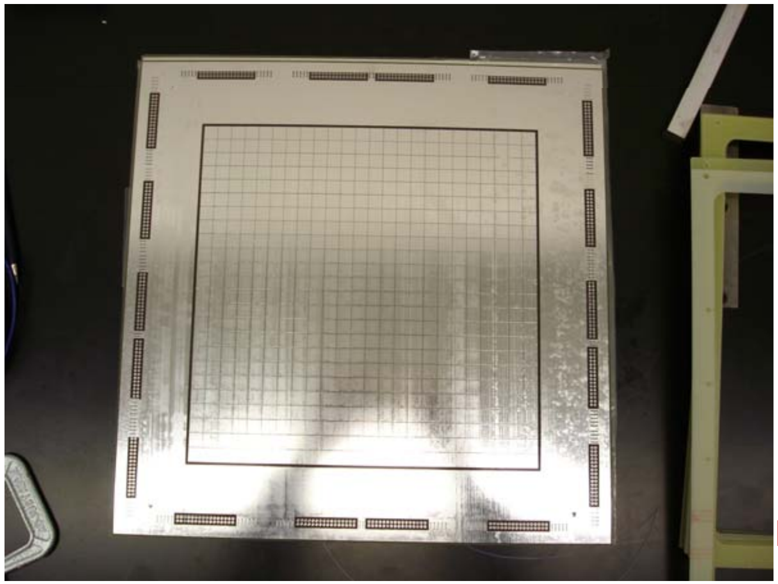
- Foils HV tested and certified
- Jigs made to mount foils, stack chamber.
- Multilayer 30cmx30cm anode board made to work w/ Fermilab QPA02-based preamp cards

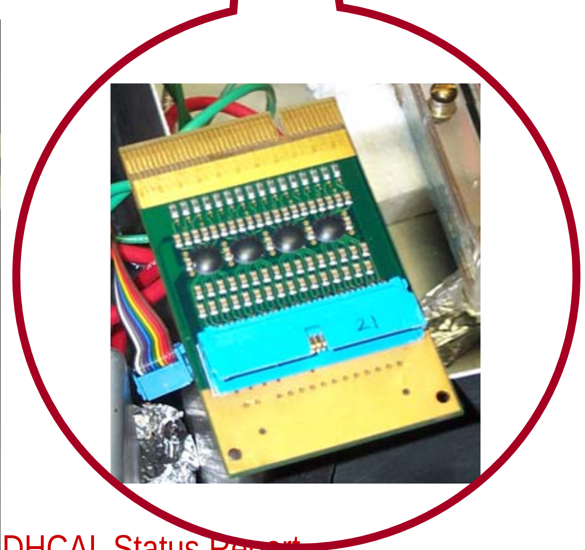
Anode Board & Preamp for 30cm x 30cm Chamber





Preamps configured to read 96 pads in the center



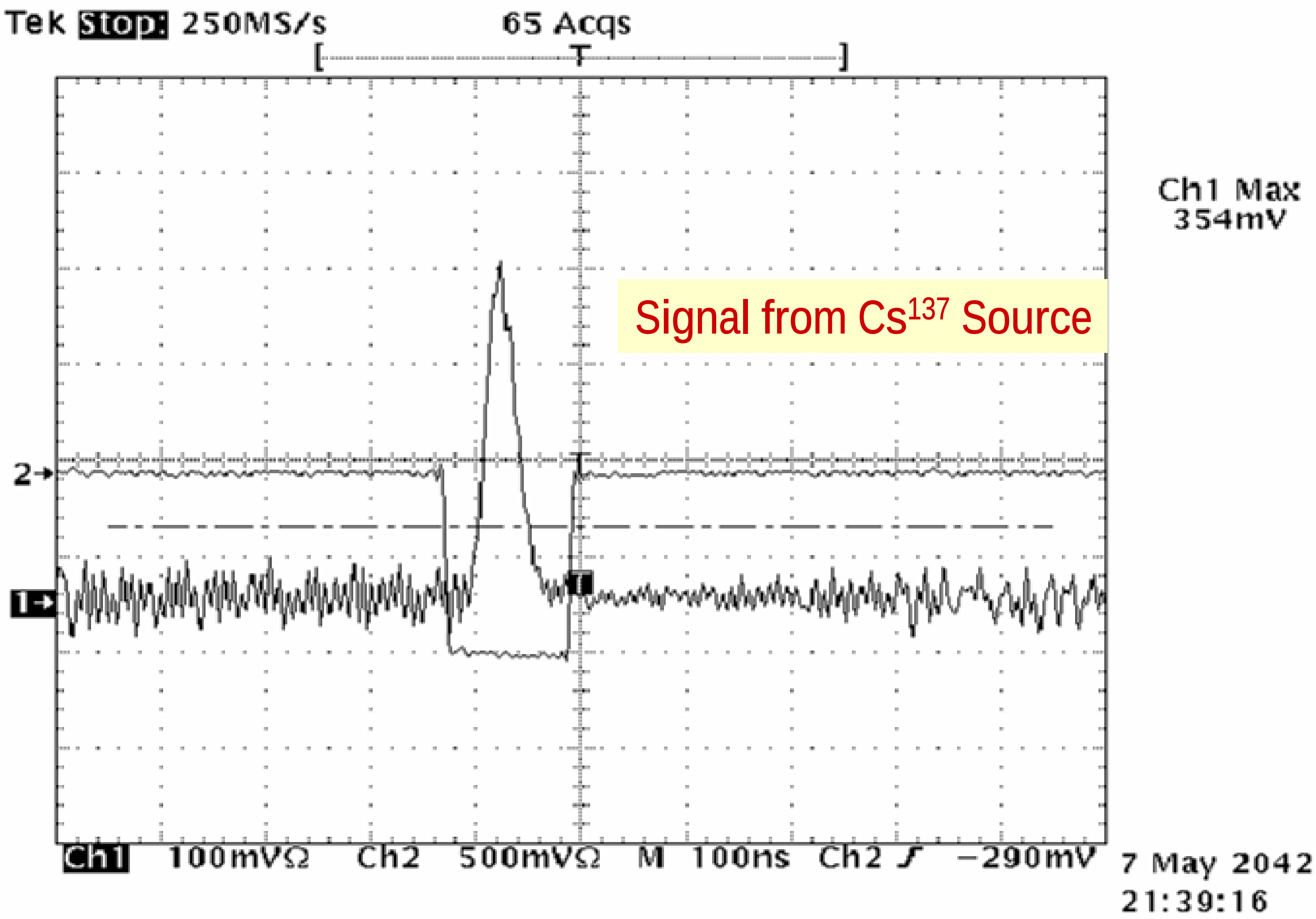


Use 32 channel FNAL preamps

30cm x 30cm GEM Chamber Development

- Foils HV tested and certified
- Jigs made to mount foils, stack chamber.
- Multilayer 30cmx30cm anode board made to work w/ Fermilab QPA02-based preamp cards
- Verified aspects of chamber operation:
  - Stability
  - pulse characteristics (cf. 10cm x 10cm chamber using CERN foils)

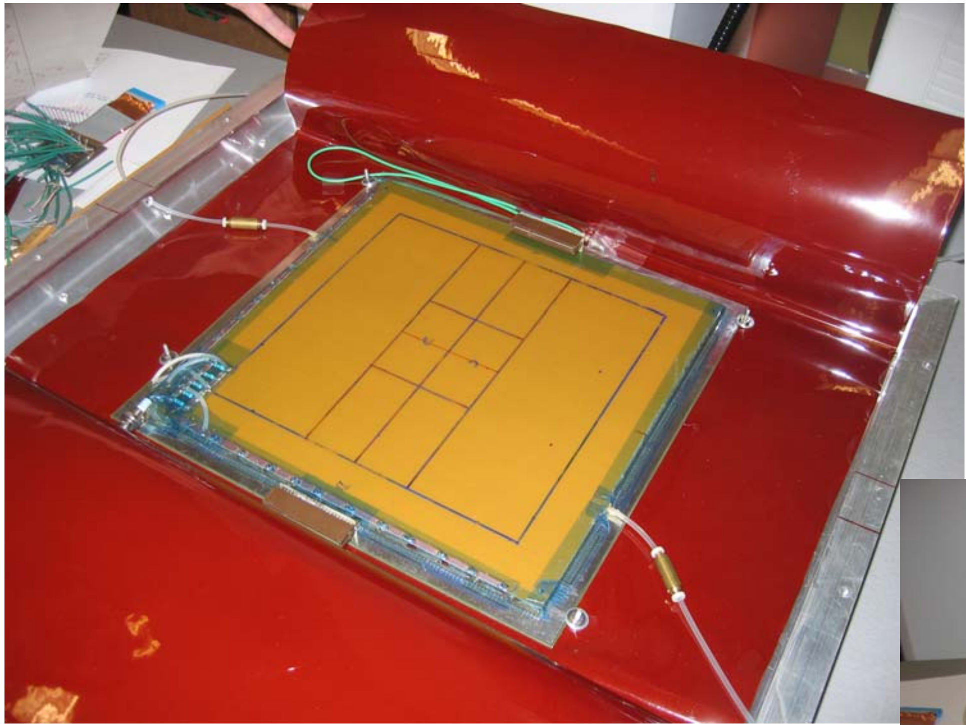
30cmx30cm D-GEM Detector Signal



30cm x 30cm GEM Chamber Development

- Foils HV tested and certified
- Jigs made to mount foils, stack chamber.
- Multilayer 30cmx30cm anode board made to work w/ Fermilab QPA02-based preamp cards
- Verify aspects of chamber operation:
  - Stability
  - pulse characteristics (cf. 10cm x 10cm chamber using CERN foils)
- Exposed a 30cmx30cm chamber to 10MeV high intensity electron beams at Korea/KAERI beam tests in May, 2006

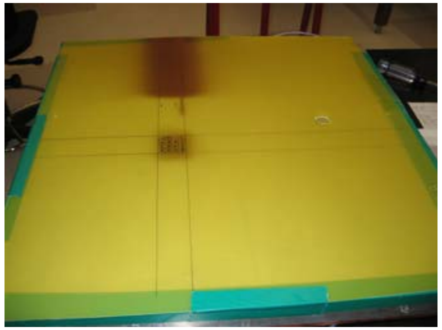
30cm x 30cm GEM Chamber for KAERI Beam Exposure

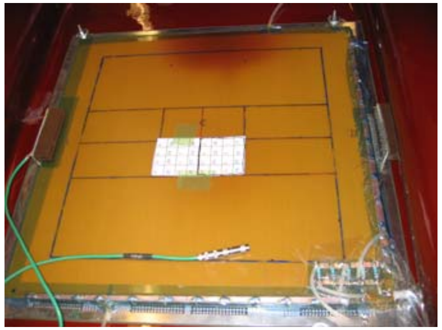


UTA GEM Chamber in KAERI Electron Beam

- e^- beam: 10^{10} particles in 30ps pulse ~every 43μs
- Scans 4cmx60cm area every 2 seconds

4-pad area (2cm x 2cm) exposed to scanning beams for ~2000 sec.





G10 boards in the exposed area discolorized. But no damage to the GEM foils

UTA GEM-DHCAL Beam Exposure

- In collaboration with Changwon National University, Korea
- Beam scans ~600mm x 40mm area every 2 sec, with 30ps pulse of 10^{10} e^-/pulse over a 5 cm^2 area ➔ ~10^9 e^-/sec on an anode pad
- Total exposure ~2000sec
  - Estimate ~2 x 10^{12} e^-/pad (~ 1.6 x 10^{-2} mC/mm^2) accumulation
  - GEM chamber continued operate normally afterward

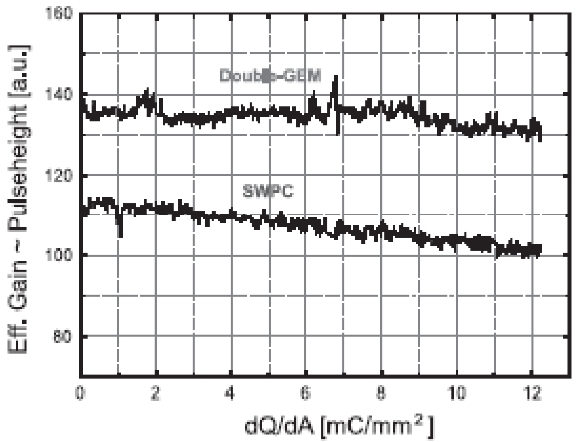


Fig. 3. Previous aging measurement of a double-GEM detector with Ar–CO_2 (70:30): effective gain versus accumulated charge dQ/dA.

- Much above total hits/10y/pad at ILC
- Much below any damage region for decrease in gain.

30cm x 30cm GEM Chamber Development

- Foils HV tested and certified
- Jigs made to mount foils, stack chamber.
- Multilayer 30cmx30cm anode board made to work w/ Fermilab QPA02-based preamp cards
- Verify aspects of chamber operation:
  - Stability
  - pulse characteristics (cf. 10cm x 10cm chamber using CERN foils)
- Exposed a 30cmx30cm chamber to 10MeV electron beams at Korea/KAERI beam tests in May, 2006
- Exposed to 8GeV π and 120GeV protons at FNAL – MTBF in Mar. – Apr. 2007

GEM Chamber Characteristics Run

- Constructed a 30cmx30cm GEM chamber using 3M foils
  - Different chamber than the one we took to Korea last year
- Constructed 5 home-made 16 channel shaper cards
  - Works with Fermilab QPM02 chip based fast preamps
- Used the trigger counters for the UTA-ANL joint Vertical Slice test for GEM and RPC
- Constructed a LabView based DAQ program that works with a PCI based 100 channel AdLink ADC card

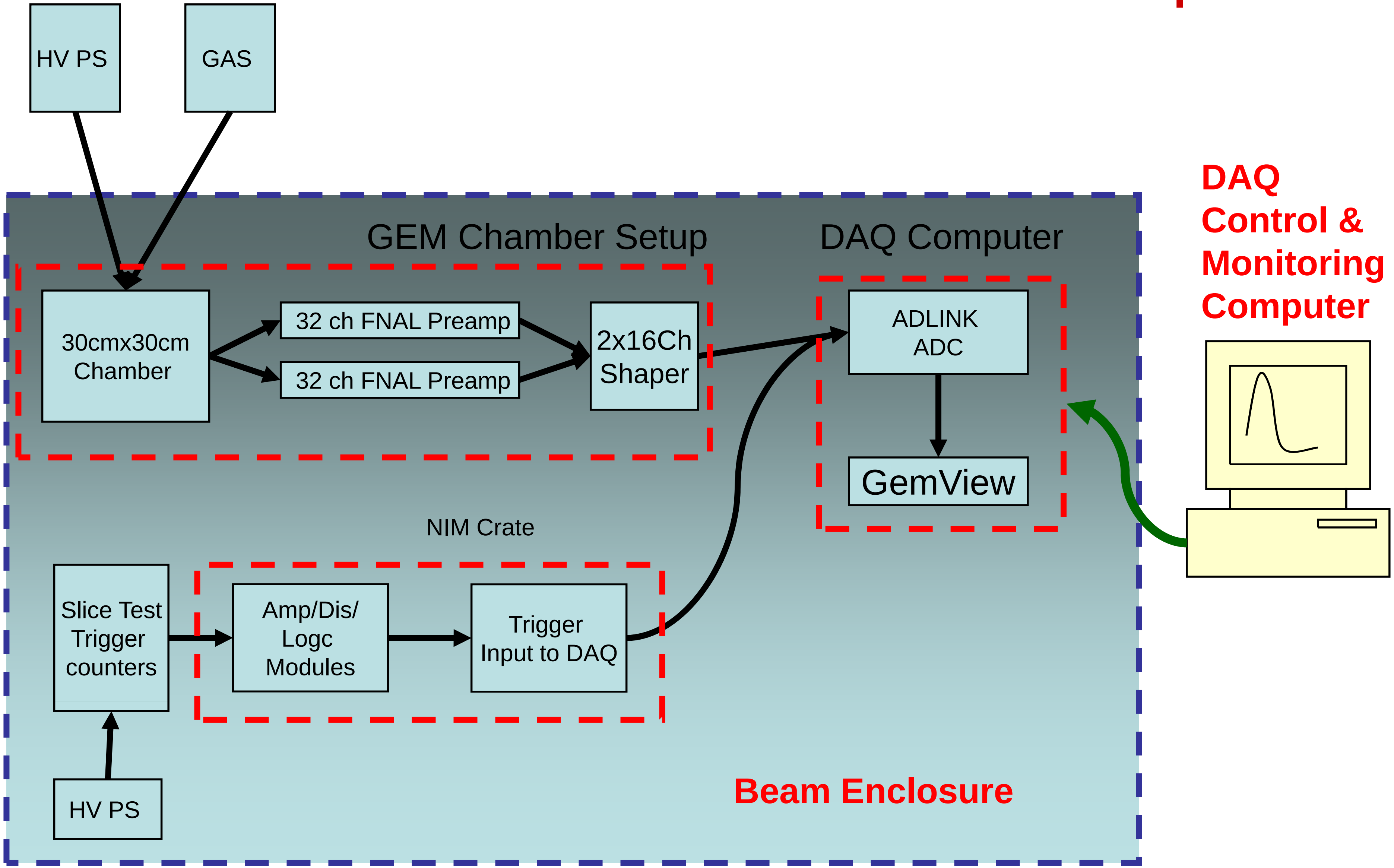
MTBF Run Goals – Chamber gains and ε

- Measure the MiP using protons at 120GeV
- Measure chamber efficiencies and gains
  - Efficiencies of several pads around the given central pad at a fixed gas mixture and fixed HV
  - As a function of gas mixture proportions
    - 2 Gas mixtures: 70:30, 80:20
  - As a function of HV
    - For 70:30: 350 – 450
    - For 80:20: 300 – 400
- Exercise simultaneous 32 channel readout

GEM Beam Test Goals

- Measure Pad Occupancy
  - As a function of HV
  - Compare to previous measurements
  - Measure this at a few different positions
- Measure cross talk and noise rates
  - As a function of distance to the triggered pad
- Measure the uniformity of the chamber responses
- Measure rate capabilities of the chamber
  - Measure the efficiency variation as a function of beam trigger rates

UTA MTBF Beam Test Setup



GEM MTBF Runs

- As a secondary: Mar. 21 – Mar. 27, 2007
  - Joint run with ChangWon National University, Korea
  - Run behind a straw tube detector group
  - 8 GeV mixed beams
  - Trigger counter timing completed
  - Commissioned the detector and readout system
  - Running as a secondary puts large restrictions on operations
- As the primary: Apr. 4 – 10, 2007
  - Beam: 120GeV proton alone
  - Chamber analog signal patched outside the enclosure

GEM Beam Test Detector Setup

Trigger Types

- Beam Trigger – 5Fold scintillation counters
  - Three 1cmx1cm finger counters, 5cm 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 ➔ Size of one readout pad
- GEM Chamber self trigger
  - Use negative chamber output
  - Threshold set at 30mV
- Beam constrained chamber trigger formed of 5F*GEM: 6Fold
  - Allows to look at data from neighboring pads while triggering on the pad centered at the beam

Resolved A Chamber Design Issue

- Field across the 3mm ionization gap was ~290V/cm
  - Drift speed ~1cm/μs ➔ 310ns drift time
- Too long for QPM02 chip based FNAL preamp to catch all the charges in one sampling
  - Multiple small peaks
  - Efficiency ➔ ~40% on 1cmx1cm pad
- Increased the field to ~1kV/cm
  - Drift speed 4.5cm/μs ➔ ~67ns drift time
  - Efficiency of ~90% achieved on 1cmx1cm pad

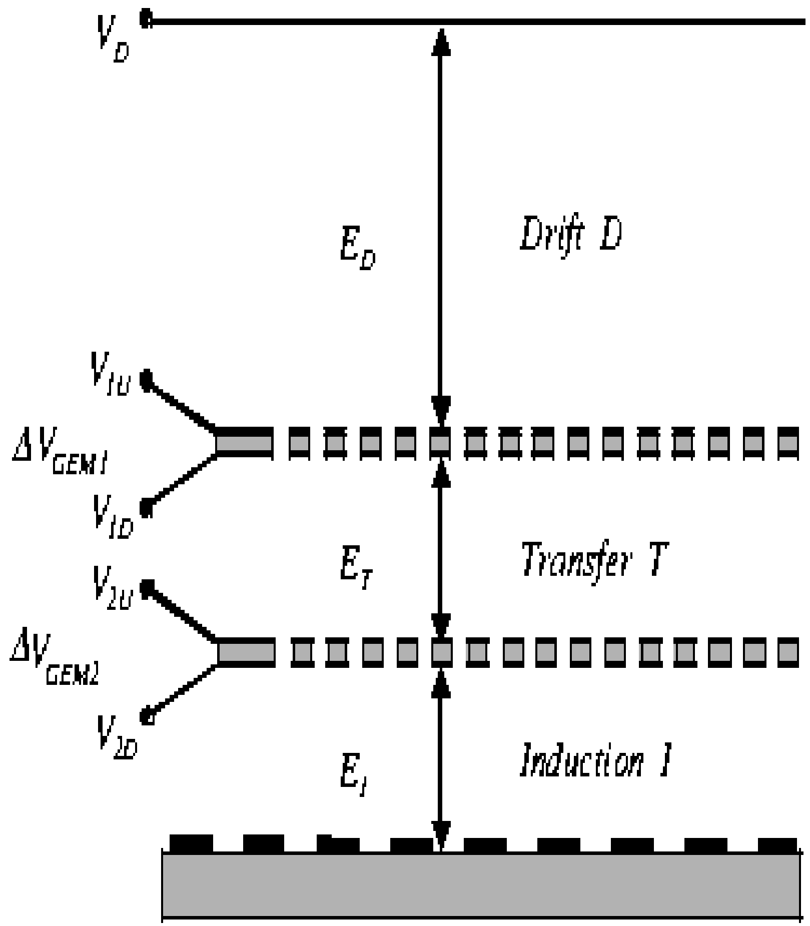
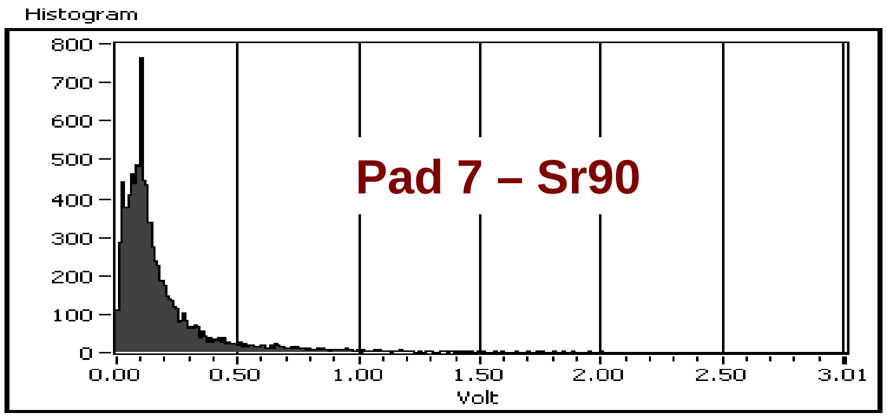
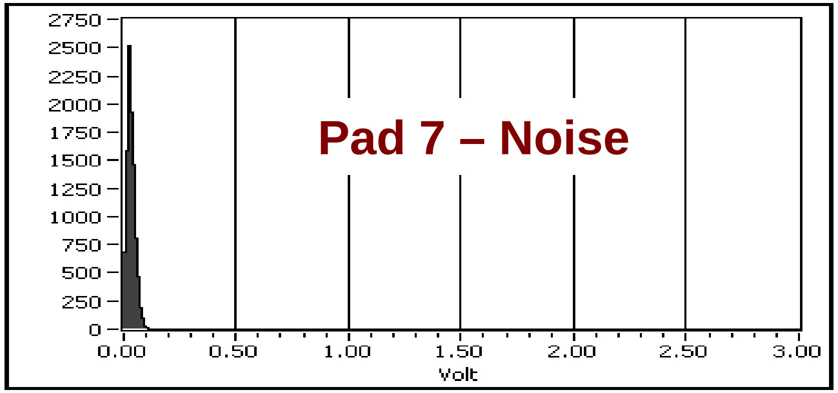
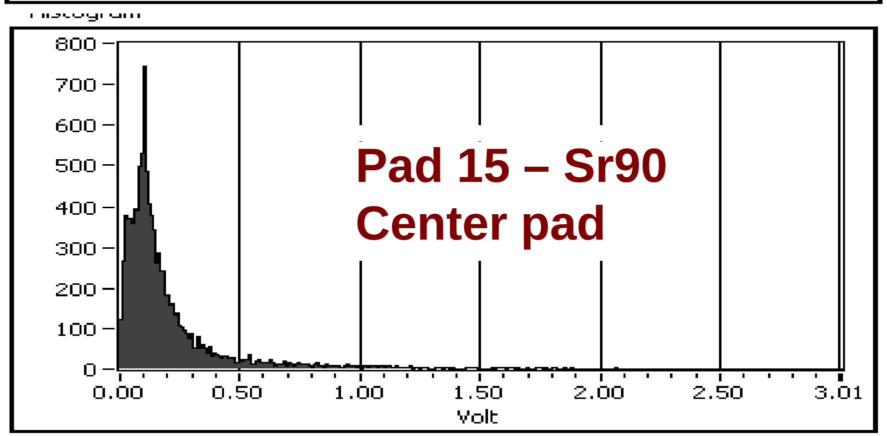


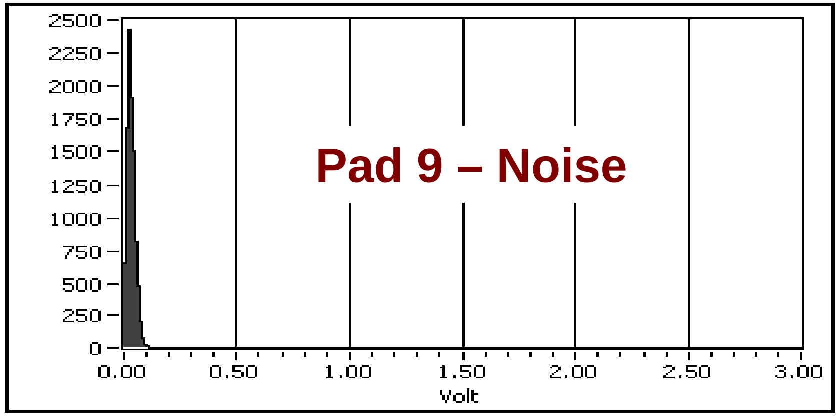
Fig. 1: Schematics of a double-GEM detector.

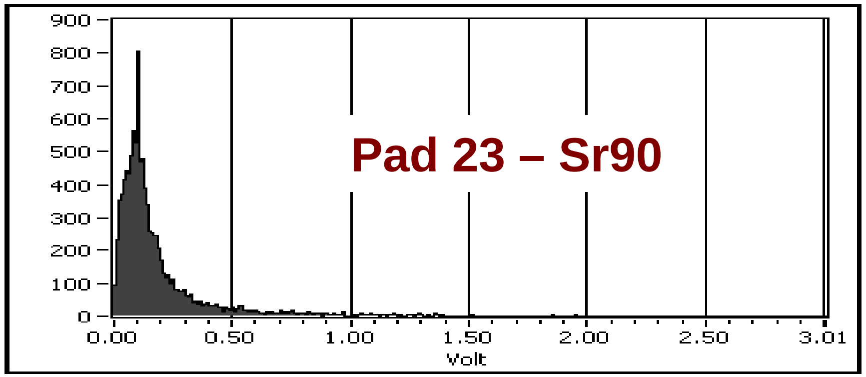
Three Pad Responses to Sr90 & Noise



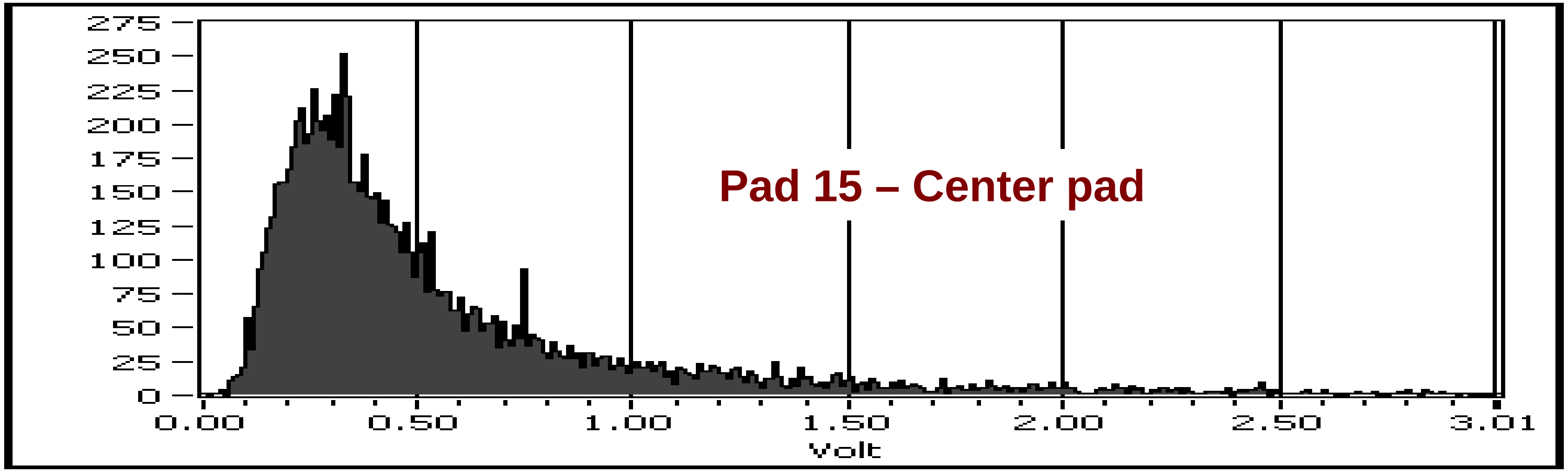


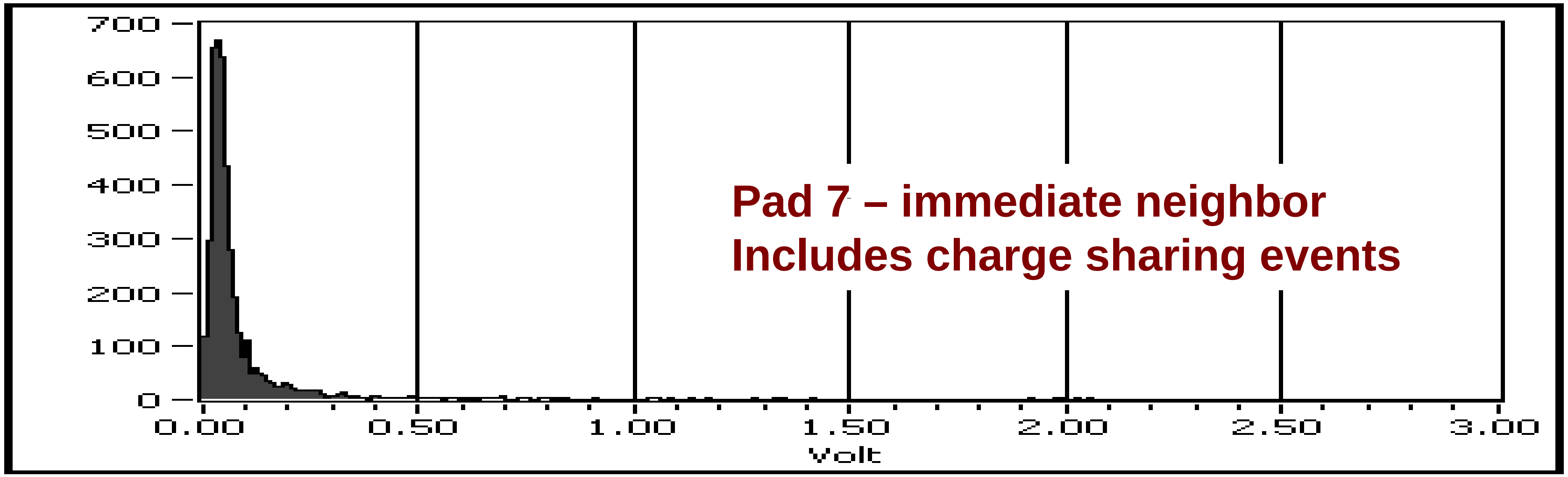






120GeV Proton – Triggered pad & Neighbor, X-Talk measurement





Some numbers: efficiency

- Initial measurement of efficiency on 1cmx1cm pad
  - ~90% on the center 1cmx1cm pad when beam is well constrained on the pad
    - Need to be corrected for double particle events in the 200ns trigger gate
  - Should be careful for multi-particle events
    - Preliminary results show about 20%

x	**15**	**x**

Using Three Neighboring Pads

23	15	7

- Looking at three neighboring pads
  - Triggering on 5 counter (1cmx1cm max shadow) *GEM (>30mV) ➔ Beam centered pad
  - Allow another means of aligning the chamber to the trigger counters ➔ Look for balanced hit counts between the two neighboring pads
  - Initial measurement of the cross talk rates
    - In the two neighboring pads ➔ ~25% but need to clean up results
      - Expect about 5% level once double proton events are cleaned up
    - In the pad immediately next to the triggering pad and the pad 2cm away
      - Some beam intensity dependence observed ➔ Indication of multiple particles within the gate
  - Initial measurement of noise : <0.2Hz with lower drift gap HV

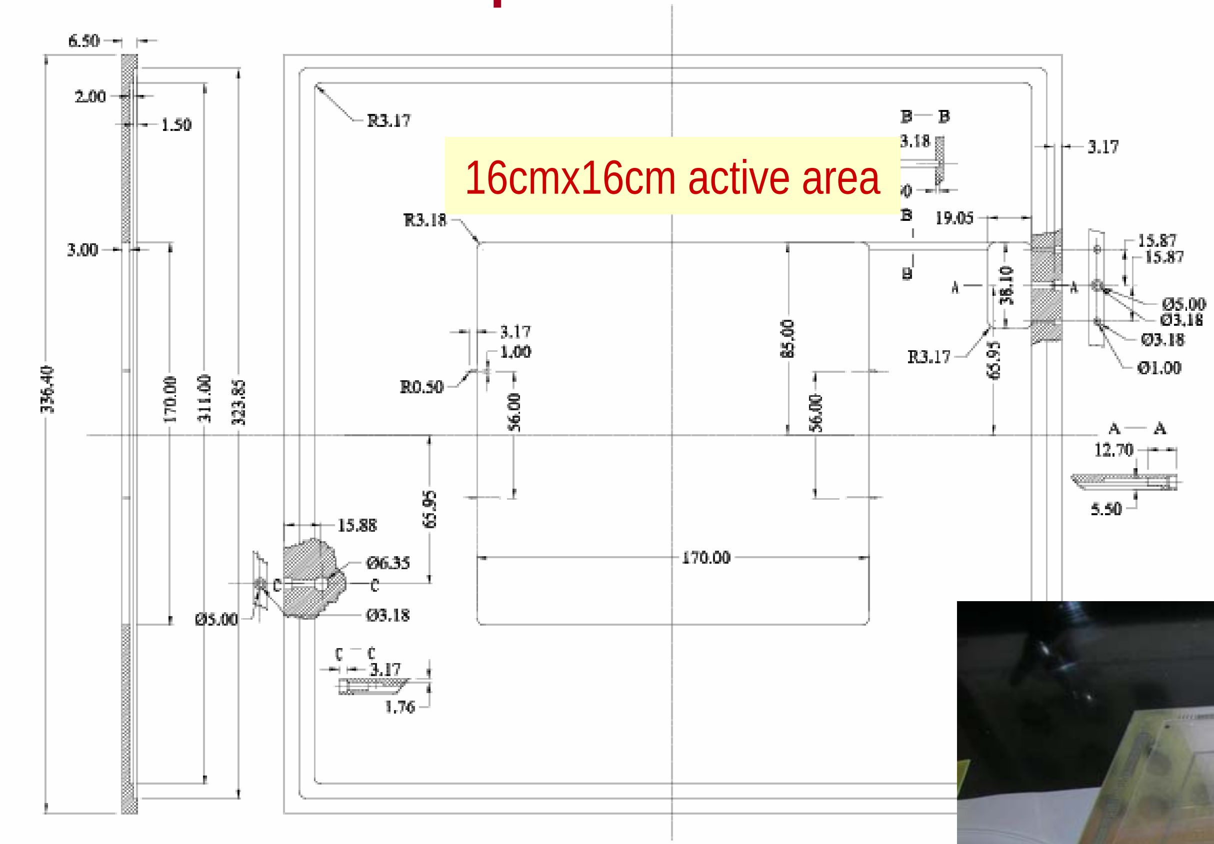
MTBF Beam Test Experience

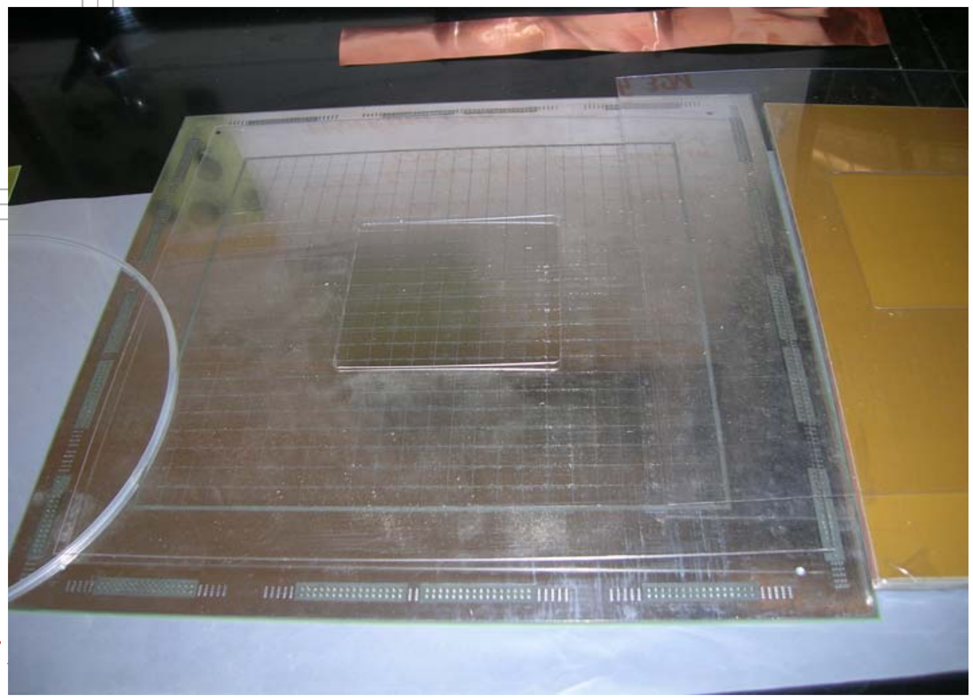
- 120GeV P and 8GeV pion tunes established
  - 120GeV P: Beam spot size at the MT6-2C dump
    - σ_x: 11.5mm, σ_y: 9.1mm
    - Rate: Can vary in a wide range
    - Can go as high as radiation safety allows
  - 8GeV pion: Did not measure beam spot size but seems to be about 2 – 3 times larger than protons
    - Rate: over 4kHz at the 10cmx10cm TOF paddle right behind our detector
  - Other low energy tunes down to 0.5 GeV established
- Beam available for 12 hours 6am – 6pm
  - One 6 sec spill with 4s flat-top/min
  - 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 our 12 hr period
- A lot more pleasant environment than before
- Many standard Fermilab logic modules failed to function correctly

Vertical Slice Test Prep

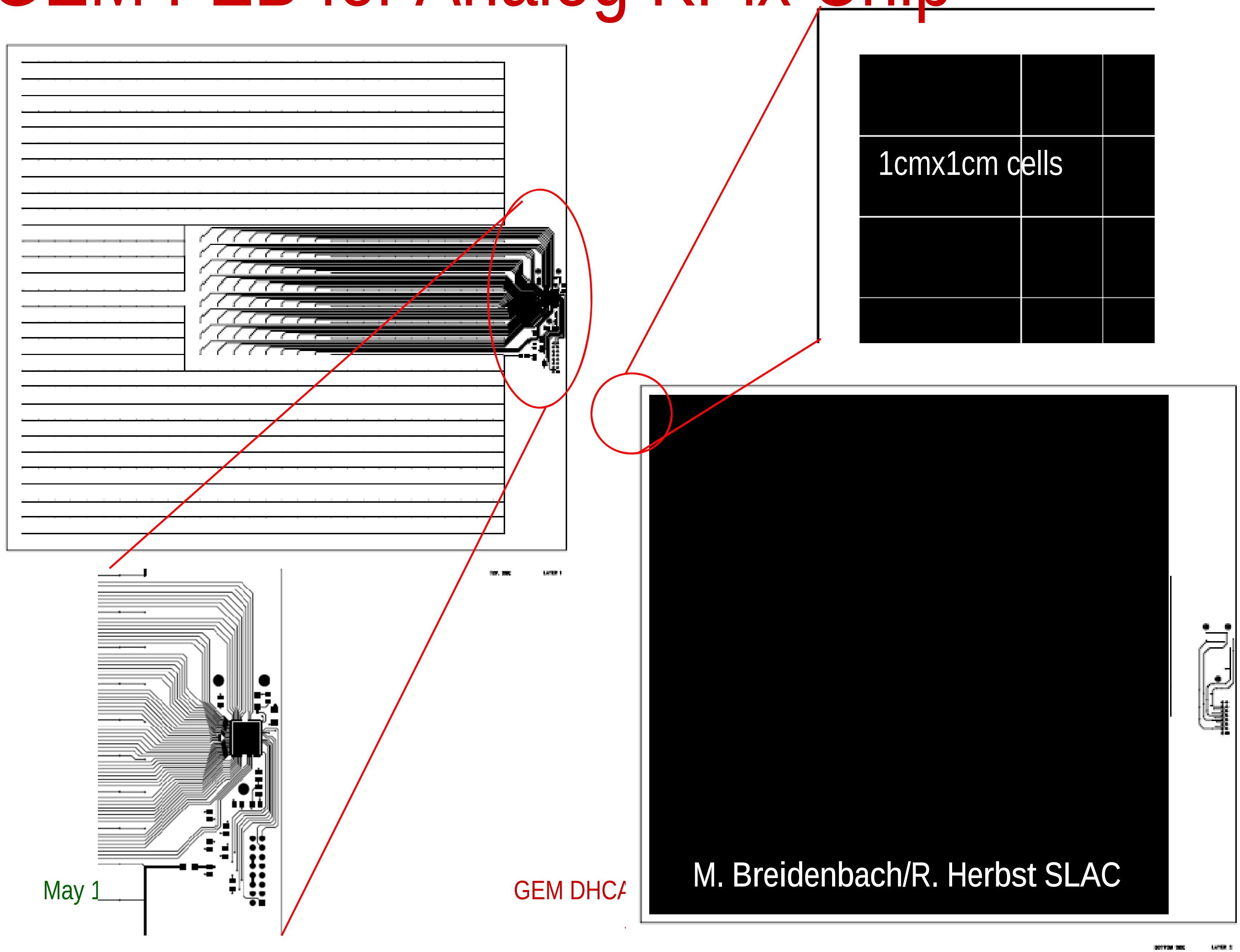
- Completed the beam telescope
  - Already used for GEM chamber characteristics run
- Constructed a test chamber with 10cmx10cm GEM foil for DCAL pad board GEM signal transfer testing
- Construction for 16x16 cm^2 active area chambers
  - 4 sets of 3M GEM foils HV tested and certified
    - For 4 chamber construction (2 w/ DCAL and 2 w/ kPix)
  - Delrin frames for all four chambers in hand
  - Awaiting for FEB arrivals

DCAL Chip 16cm x16cm Slice Test Chamber

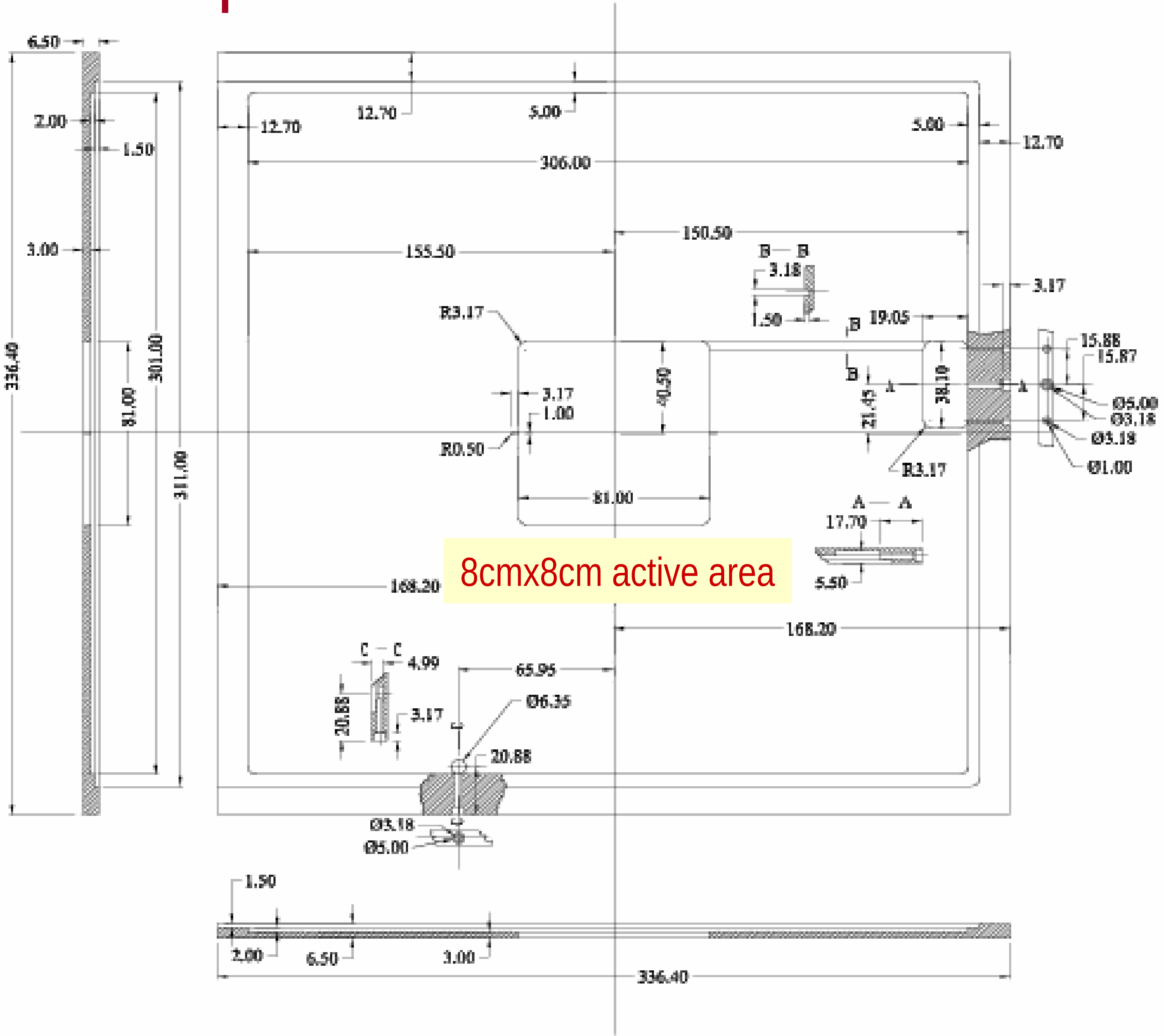




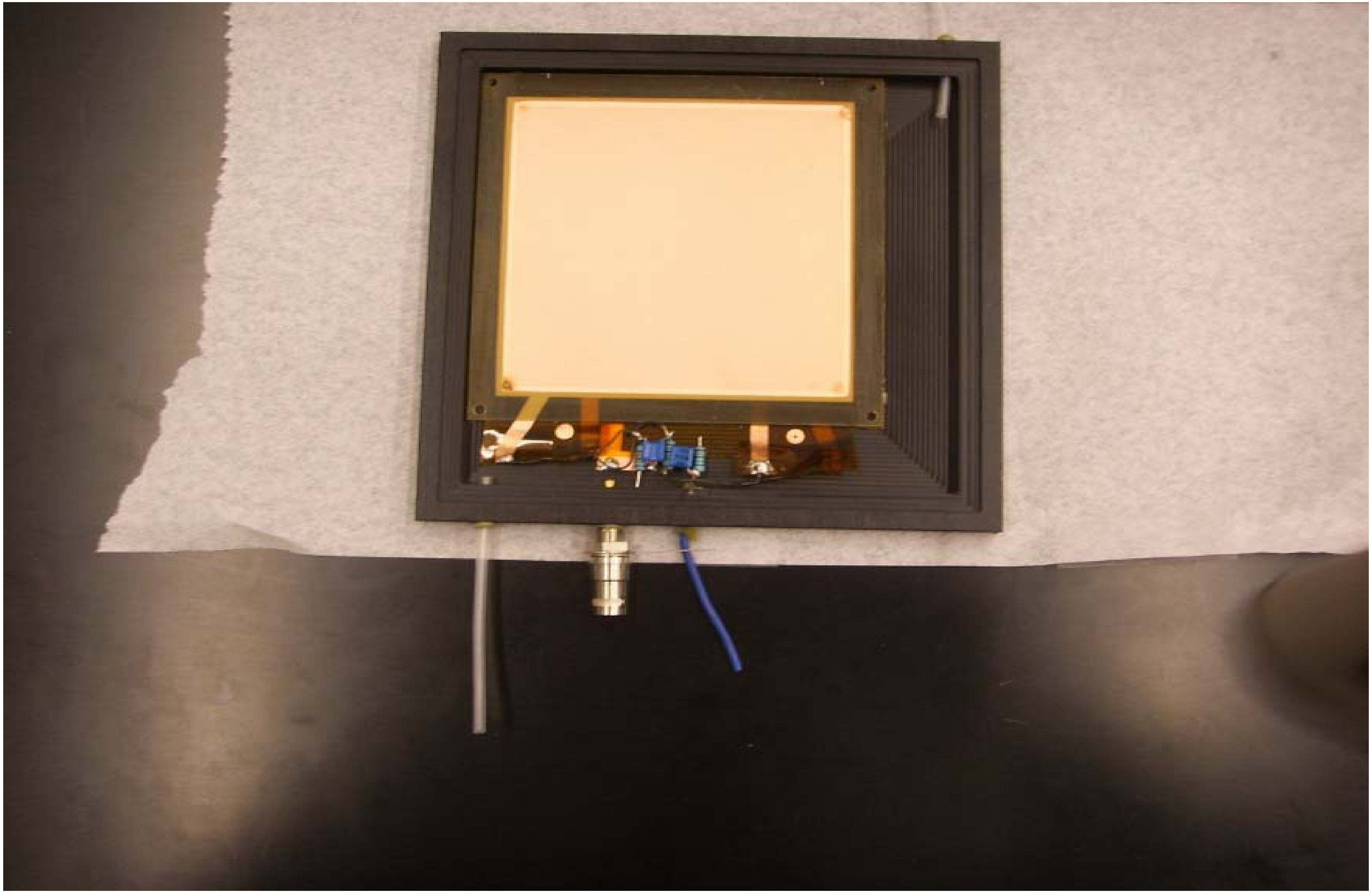
GEM FEB for Analog KPix Chip



kPix Chip 8cmx8cm Slice Test Chamber



10cm x 10cm Pad Board Test Chamber



What next?

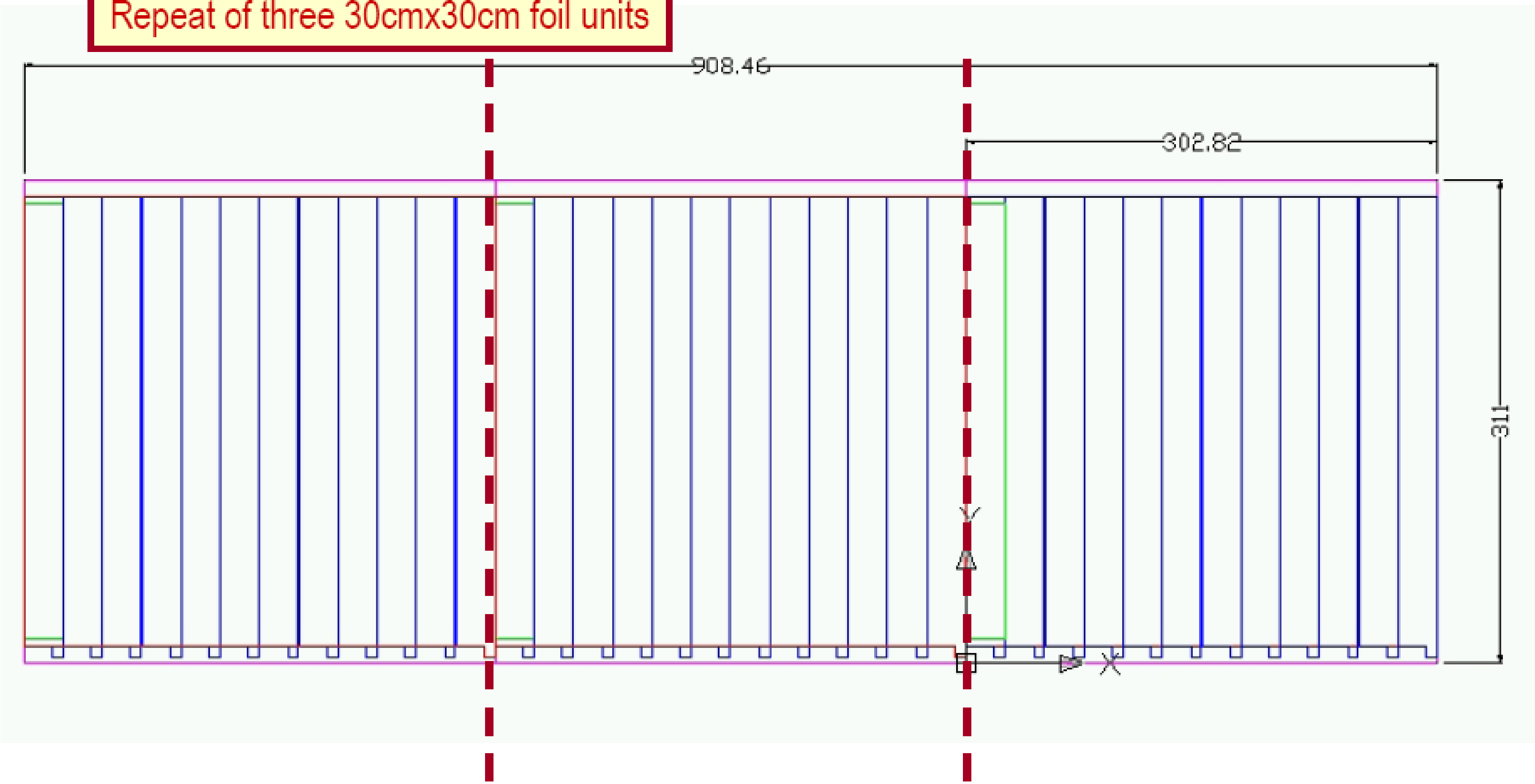
- Late 2007/early 2008
  - Construct large scale unit boards (30cmx1m)
  - Test unit boards
  - Start producing GEM chambers for $1m^3$ prototype if funding allows
  - Numerous tests, including beam tests for chamber properties, as the large chambers get produced

3M Long (1mx30cm) GEM Foils

- We are working with 3M to develop larger foils for the 1m^3 prototype stack
- Minimally modified new artwork (masks) deriving from the 30cm x 30cm foil development
- Small area needed for re-registration as foil moves through etching station.
- Anticipate first sample in fall ’07.
- First long chamber construction will follow the electronics slice test at Fermilab late ‘07.

Proposed Initial 3M 30cmx100cm Foil Design

Repeat of three 30cmx30cm foil units



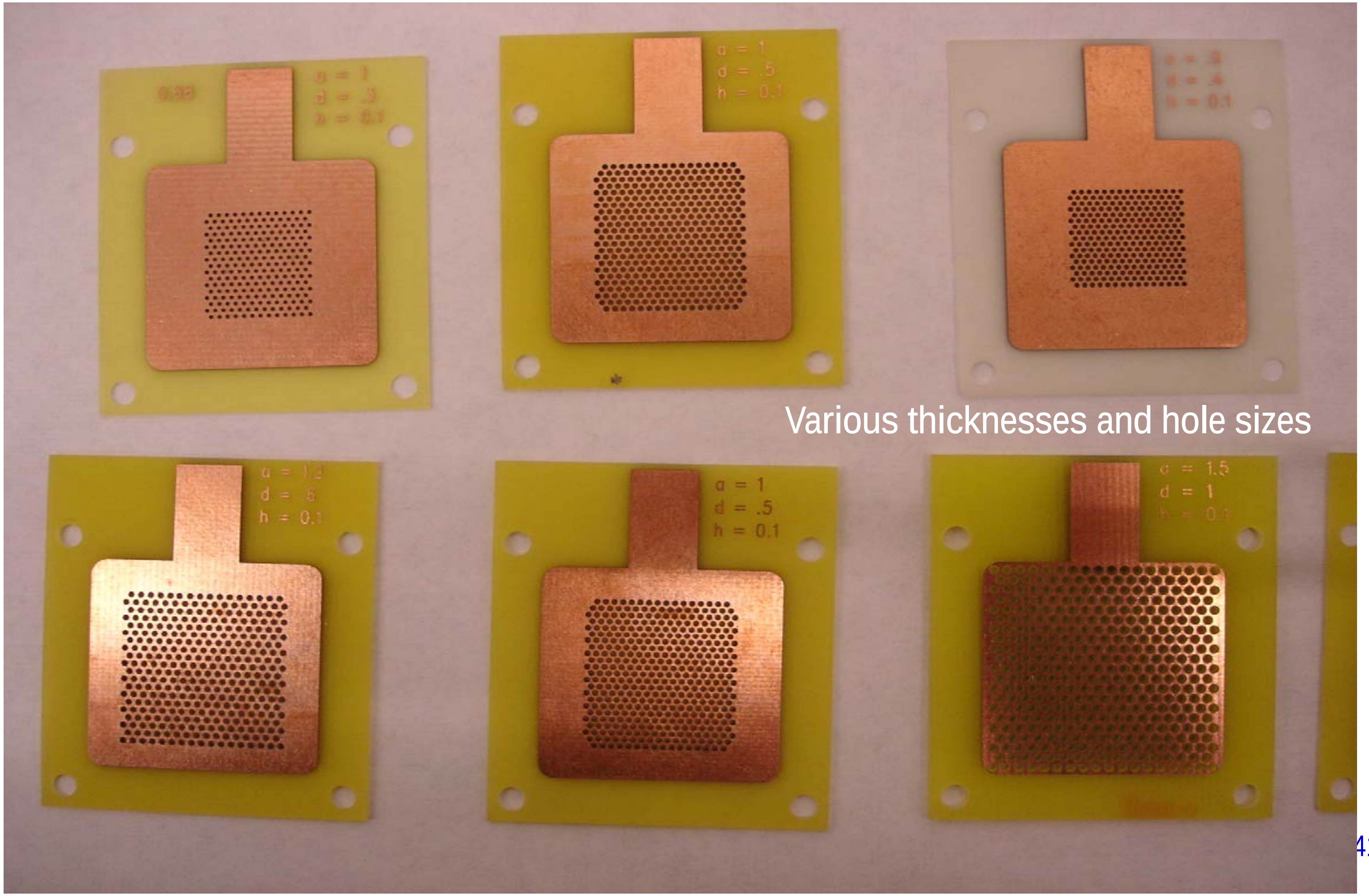
Can be produced in 6 weeks after the final specification

What next?

- Late 2007/early 2008
  - Construct large scale unit boards (30cmx1m)
  - Test unit boards
  - Start producing GEM chambers for $1m^3$ prototype if funding allows
  - Numerous tests, including beam tests for chamber properties, as the large chambers get produced
  - Develop TGEM “boards” and prototype chamber

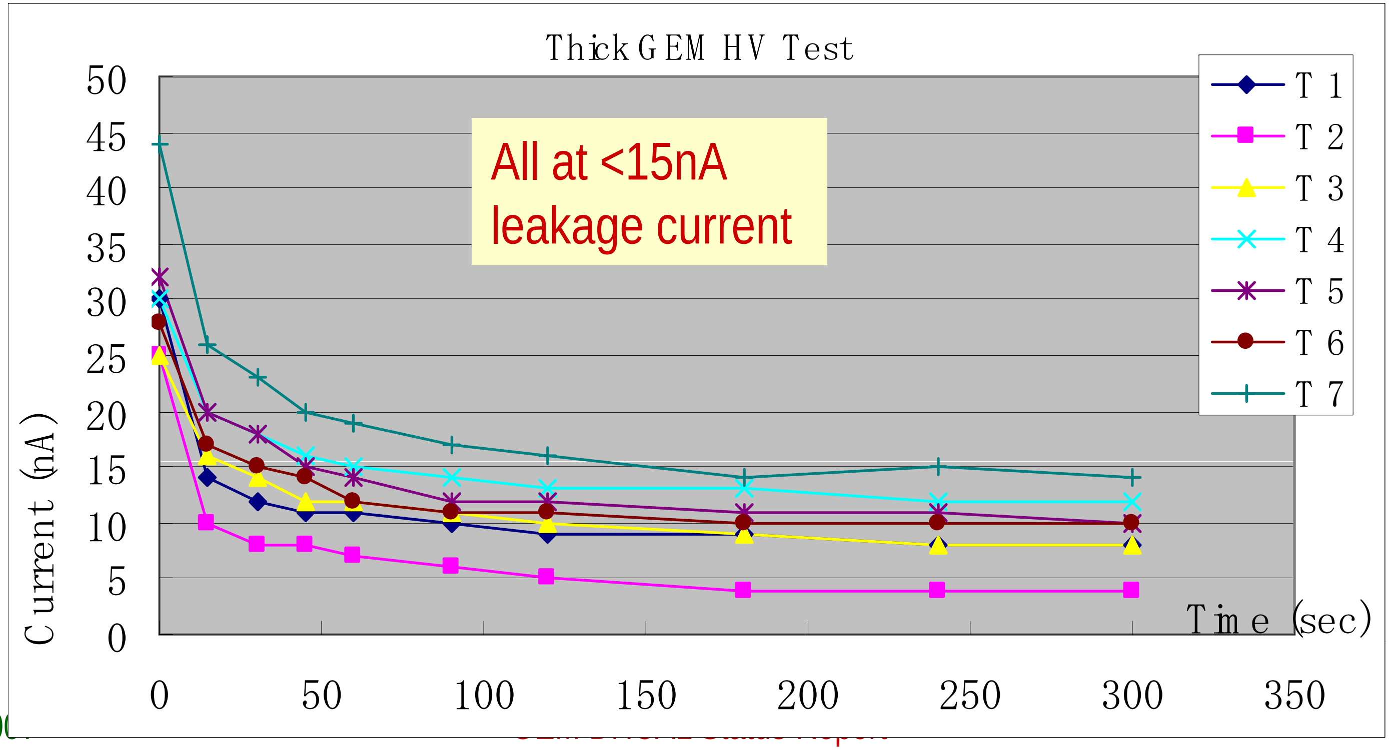
Samples of Thick GEM (TGEM)

Higher gains than thin GEMs and lower production cost ….



TGEM HV Test Results

Thick GEM ID	0	15	30	45	60	90	120	180	240	300	Voltage (V)
T 1	30	14	12	11	11	10	9	9	8	8	1000
T 2	25	10	8	8	7	6	5	4	4	4	1000
T 3	25	16	14	12	12	11	10	9	8	8	1700
T 4	30	20	18	16	15	14	13	13	12	12	1700
T 5	32	20	18	15	14	12	12	11	11	10	1700
T 6	28	17	15	14	12	11	11	10	10	10	1700
T 7	44	26	23	20	19	17	16	14	15	14	2000



What next?

- Late 2007/early 2008
  - Construct large scale unit boards (30cmx1m)
  - Test unit boards
  - Start producing GEM chambers for 1m^3 prototype if funding allows
  - Numerous tests, including beam tests for chamber properties, as the large chambers get produced
  - Develop TGEM “boards” and prototype chamber
- Mid – late 2008
  - Completion of 1m^3 stack
  - Beam test w/ full depth (40 layers) in late 2008

Conclusions

- UTA 30cmx30cm chamber built and exposed to low energy high intensity electron beam in May 2006
- Chamber characteristics test done Mar. – Apr. 07
  - Data analyses in progress
  - The experience at MTBF so far has been good and hospitable
- Electronics slice test to start in early summer 07
- Larger foil (30cmx1m) for unit chamber development on going with 3M
  - First set to be available summer 07
- 1m^3 prototype test in 2008 w/ available funding
- Thick GEM development and prototype chamber construction in progress