Digital Hadron Calorimetry for the ILC using Gas Electron Multiplier Technology

Andy White

For GEM/DHCAL Group*

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

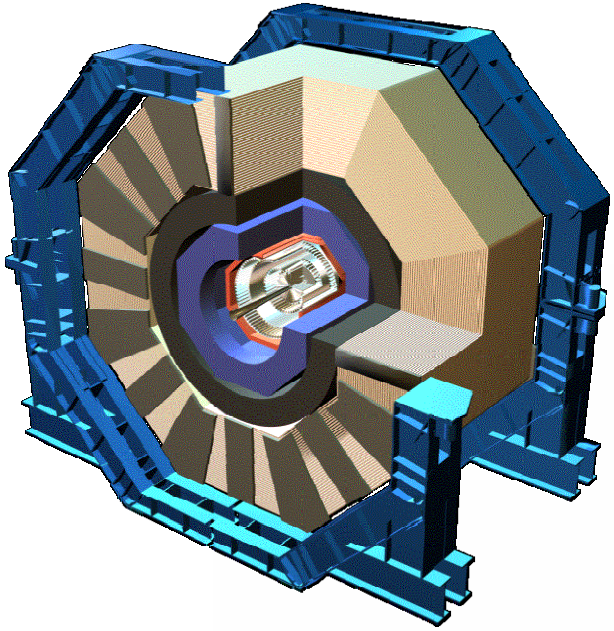
GEM-based DHCAL

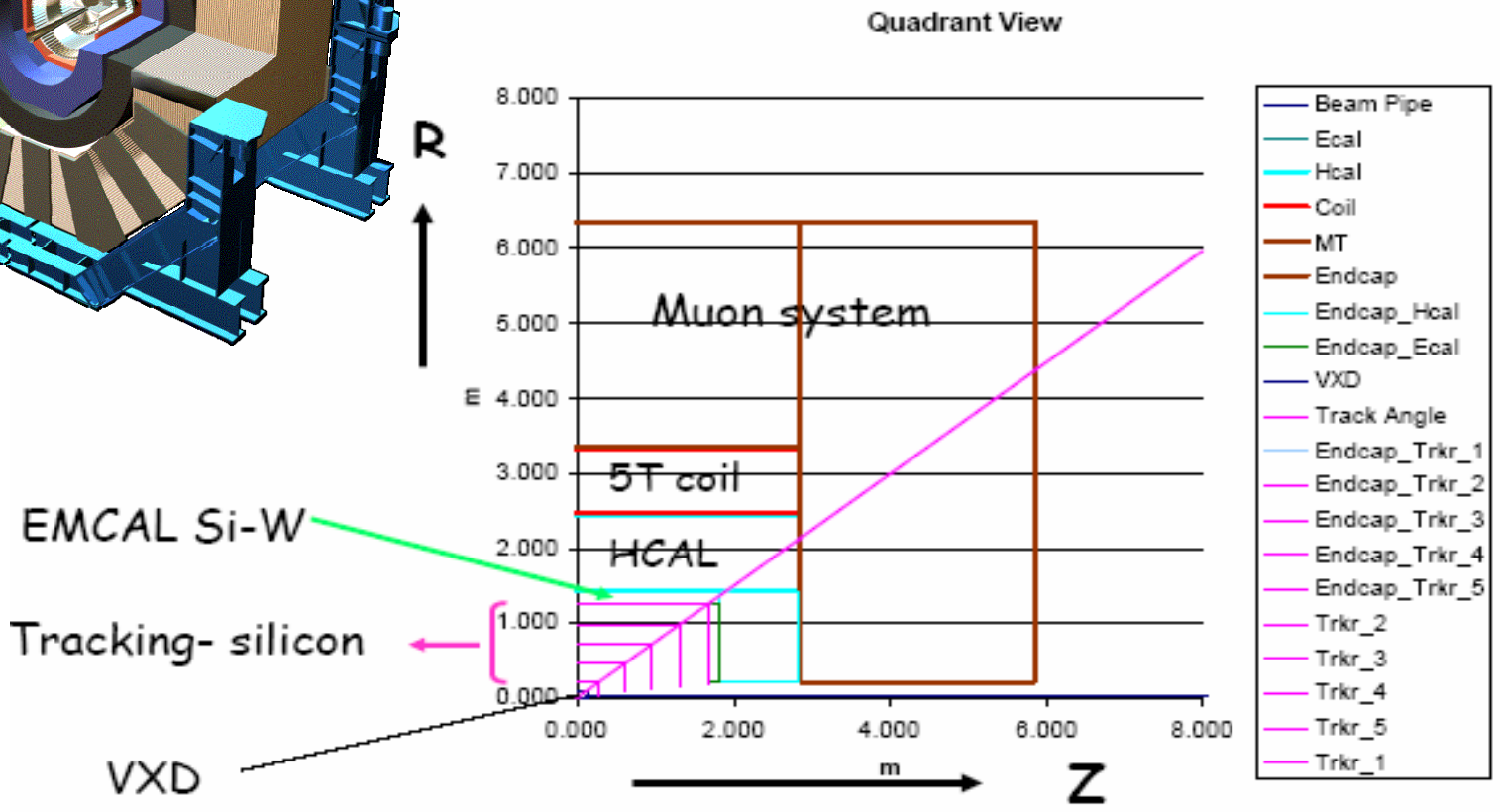
- GOAL: Develop a high granularity digital hadron calorimeter for the ILC, as part of a system to use the Particle Flow Algorithm approach for high-precision jet energy measurement.

- Many aspects are joint with the RPC-based developments.

- Specific studies and design are within the SiD Detector Concept, but also as part of the CALICE collaboration.

SiD




Quadrant View
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Z
m
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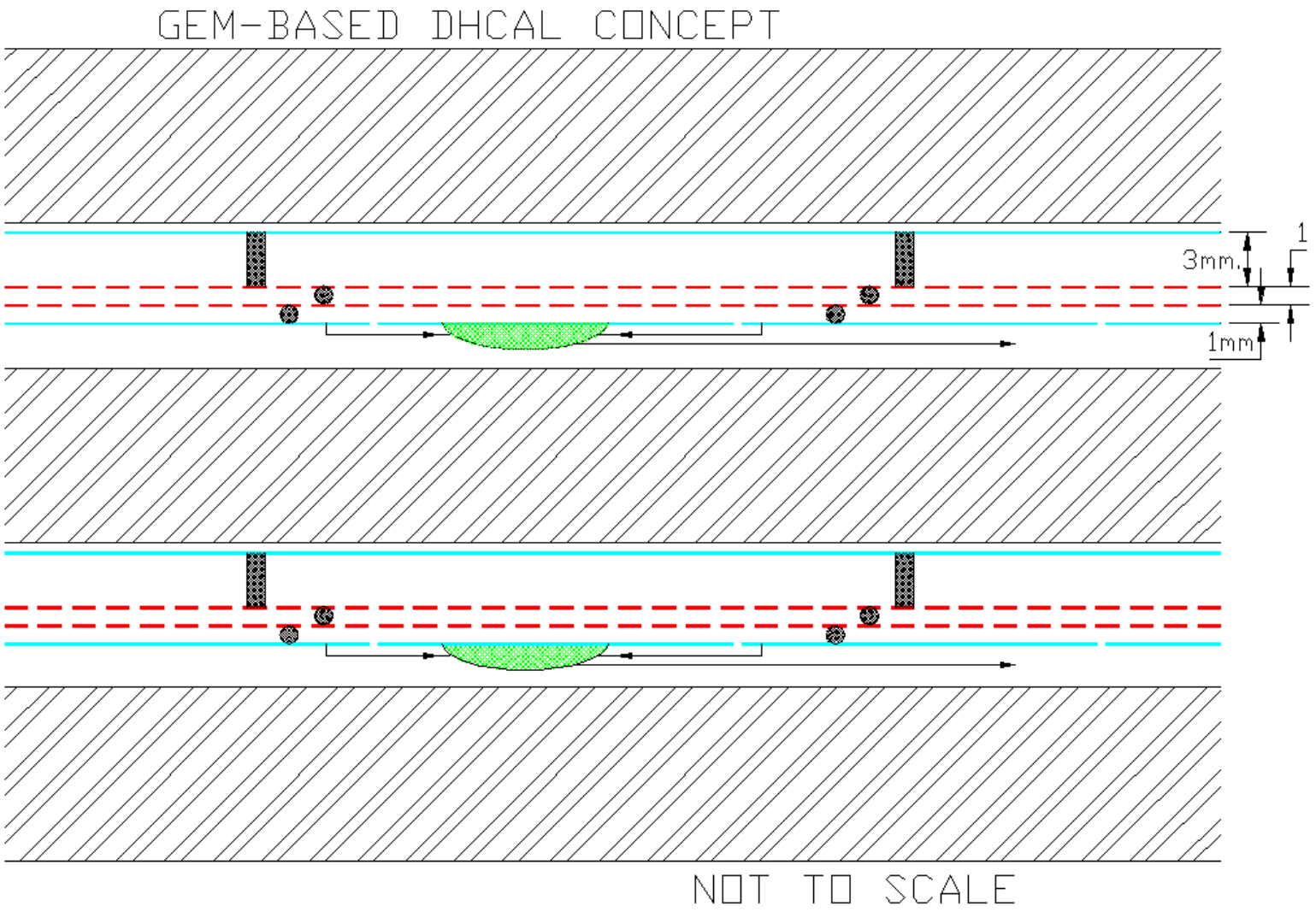
Muon system
5T coil
HCAL
EMCAL Si-W
Tracking- silicon
VXD
Beam Pipe
Ecal
Hcal
Coil
MT
Endcap
Endcap_Hcal
Endcap_Ecal
VXD
Track Angle
Endcap_Trkr_1
Endcap_Trkr_2
Endcap_Trkr_3
Endcap_Trkr_4
Endcap_Trkr_5
Trkr_2
Trkr_3
Trkr_4
Trkr_5
Trkr_1

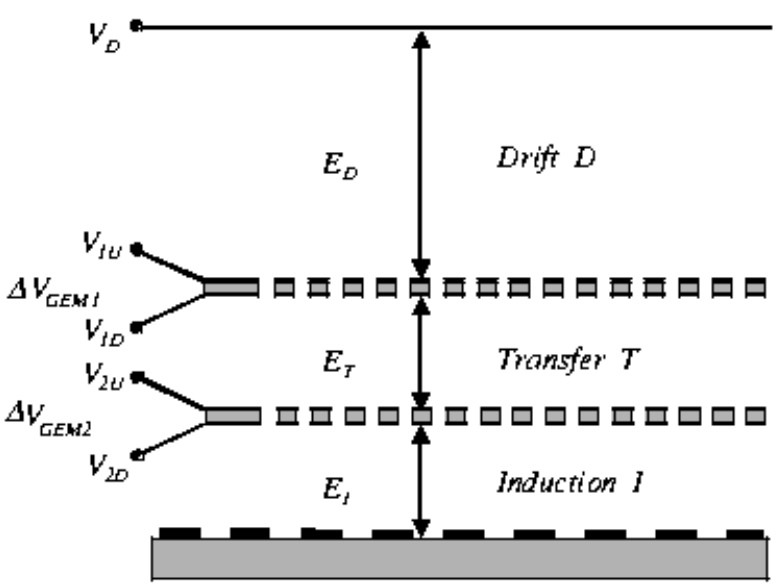
GEM-based Digital Calorimeter Concept



Why use GEM's ?

- Flexible configurations: allows small anode pads for high granularity.
- Robust: survives ~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 – operation



-2100V

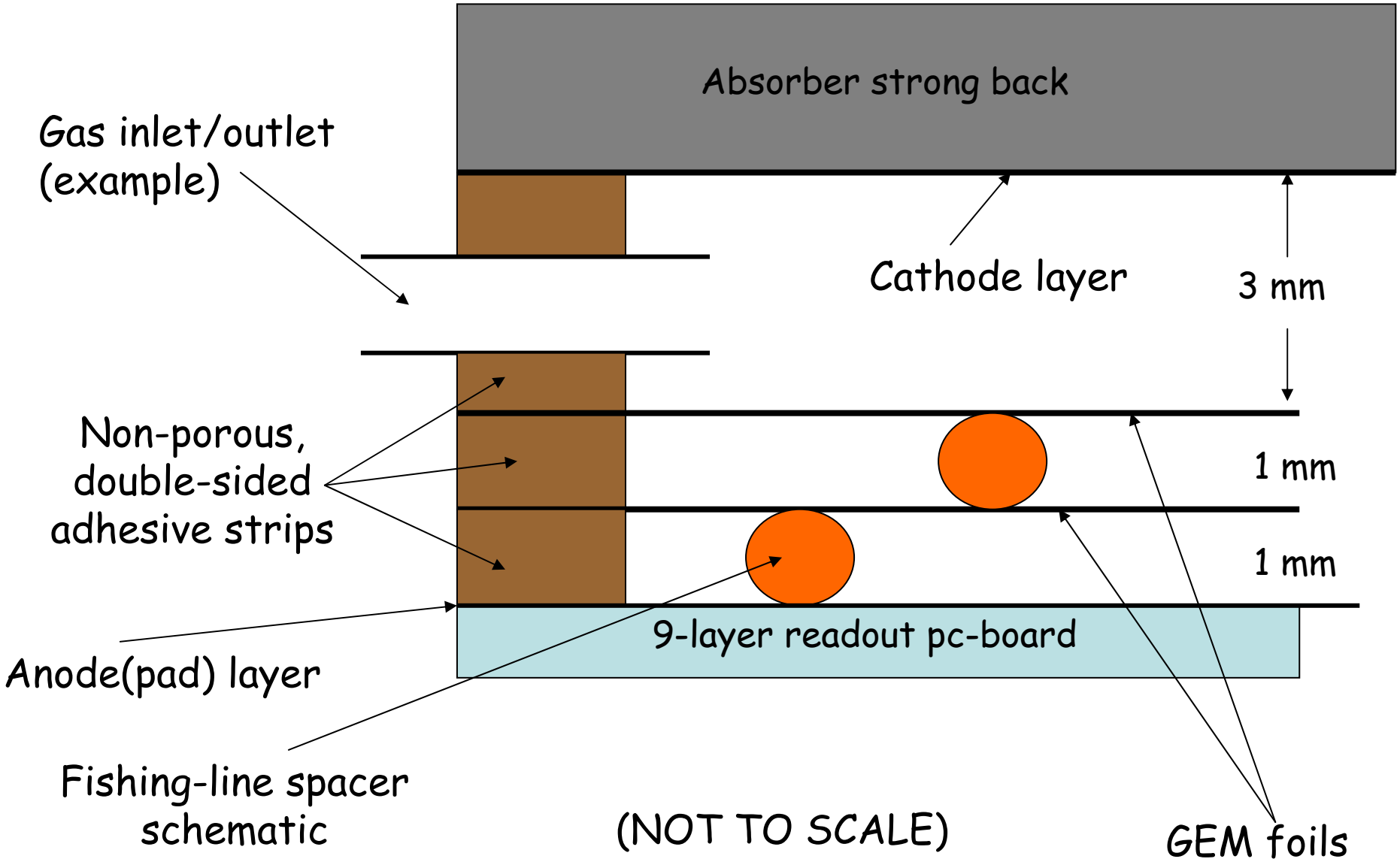
ΔV ~400V

ΔV ~400V

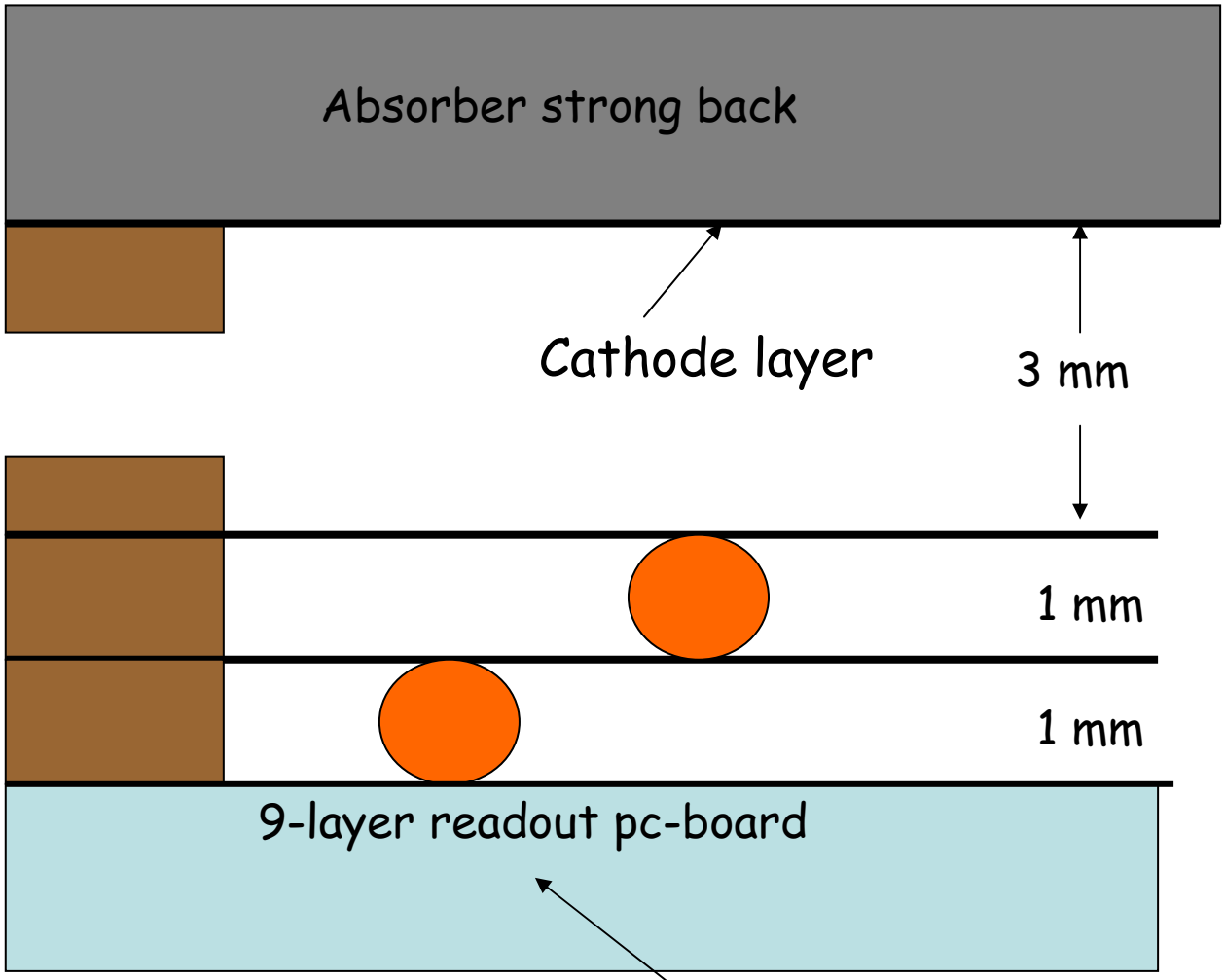
0V

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

Development of GEM sensitive layer



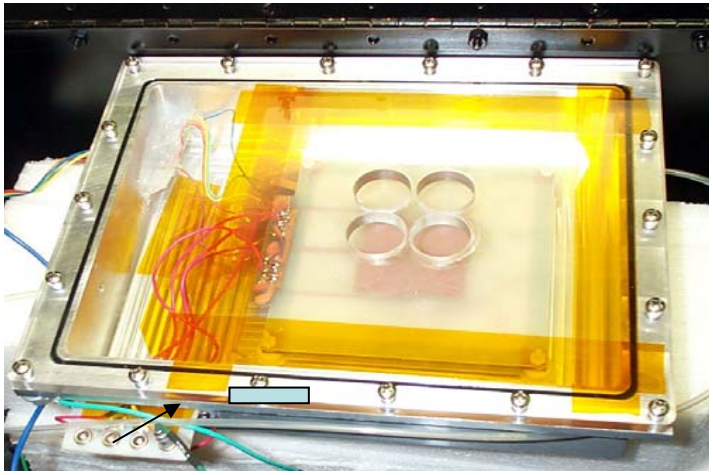
GEM/DHCAL Active layer

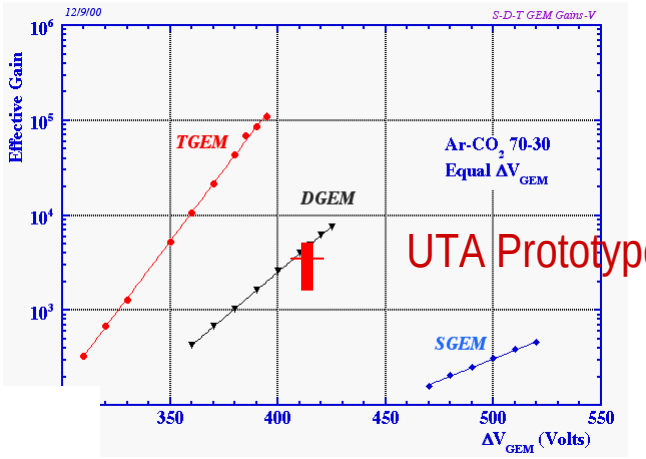


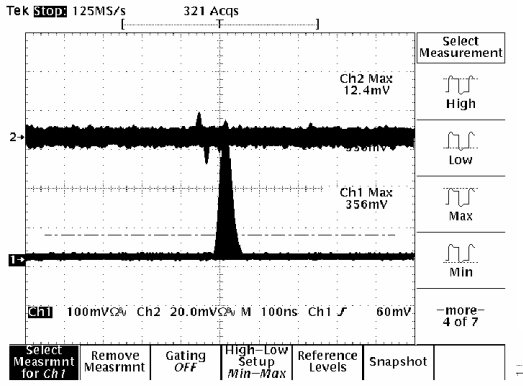
Goal 7-8 mm thickness for the total active layer: reduce overall HCal thickness and COST.

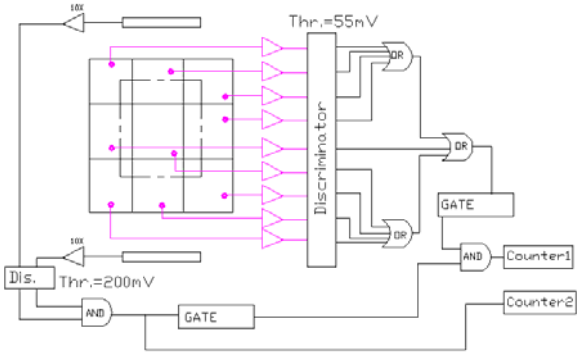
Must include multilayer (10?) board and ASIC's

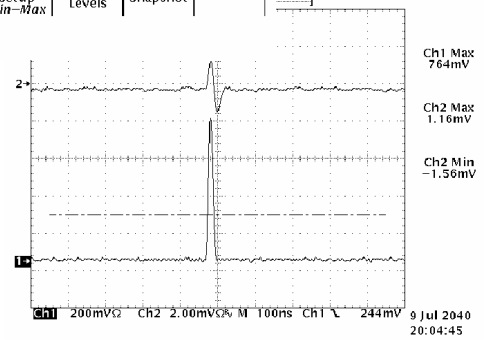
Summary of first prototype GEM studies











Eff. = 94.6%

after ensuring that cosmics must hit a pad

- 9-pad (3x3) GEM Chamber – double GEM
- Ar/CO2 80:20
- Threshold 40mV -> 95% efficiency
- Sr-90 source/scintillator trigger

-> Result: Average multiplicity = 1.27

GEM Foils from 3M

- 30cm x 30cm foils made with three types of coating:

  a) bare copper

  b) "organic polymer" coating

  c) gold plating

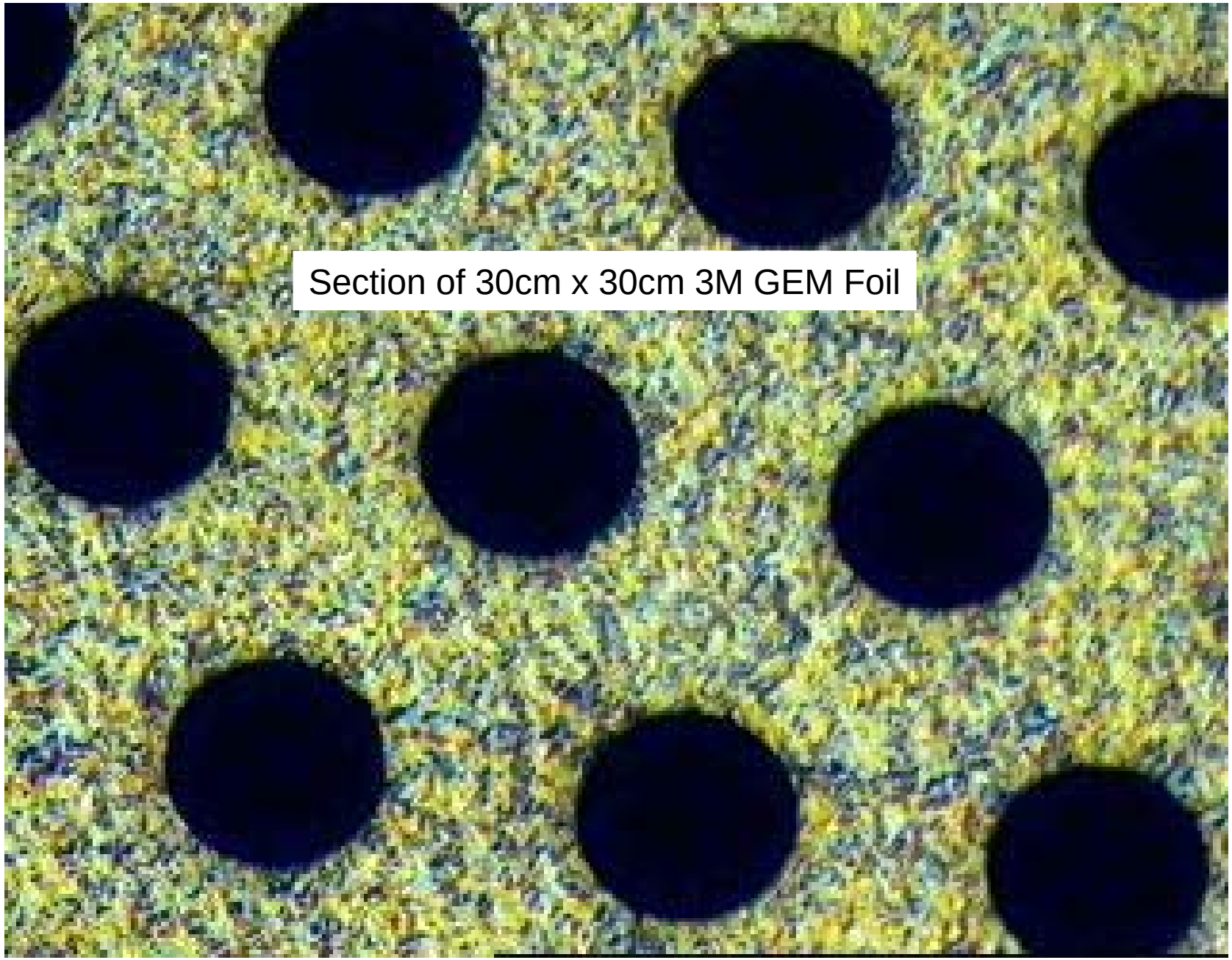
- HV tests made on all three types -> conclusion is that we prefer to use the uncoated foils.

- We are using the uncoated foils in our new 30cm x 30cm chambers.

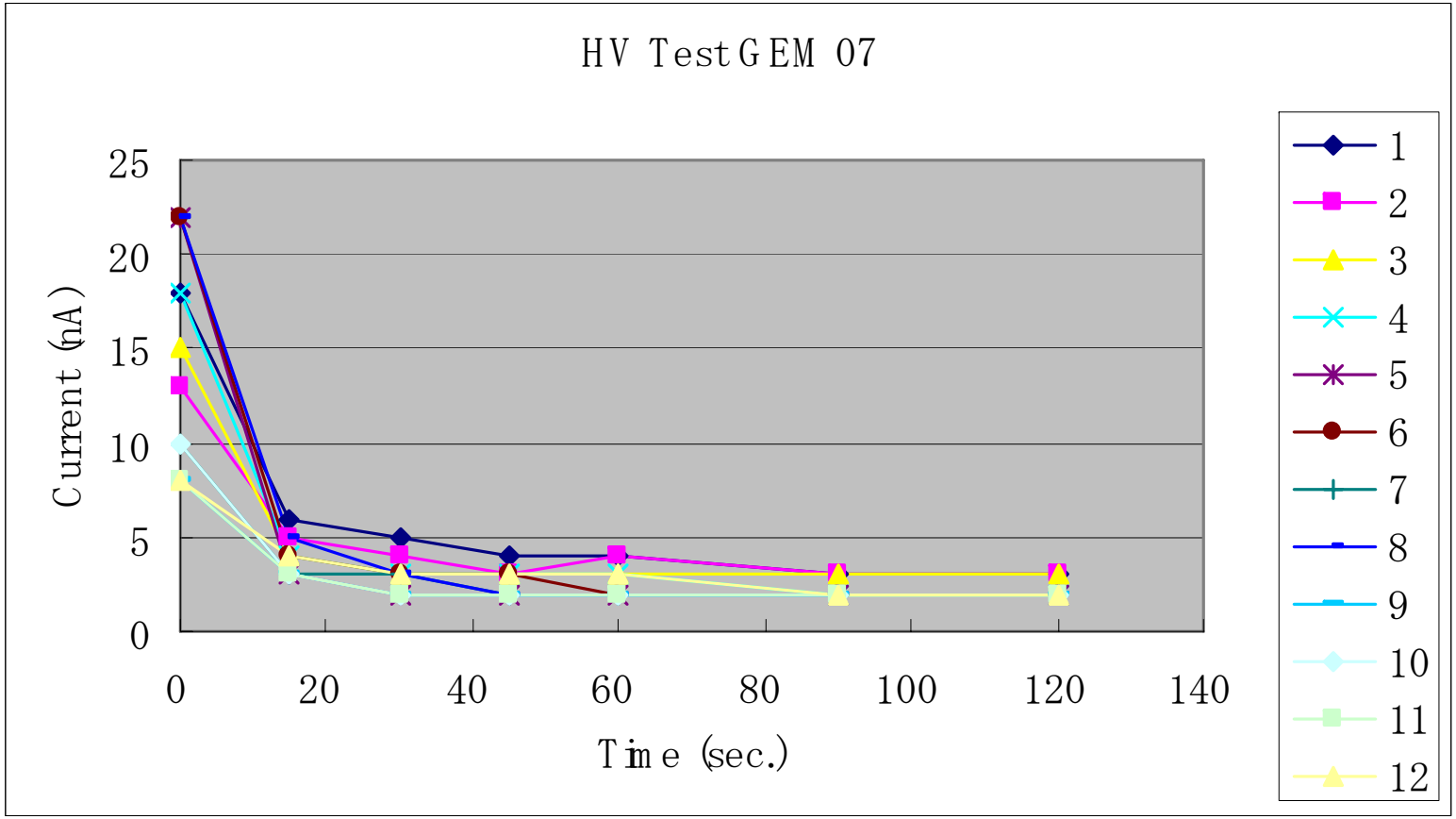
- 3M is setting up a formal internal project to develop larger foils for the $1m^3$ prototype stack (the $30x30cm^2$ foil development did not require 3M process modification).

30cm x 30cm 3M GEM foils

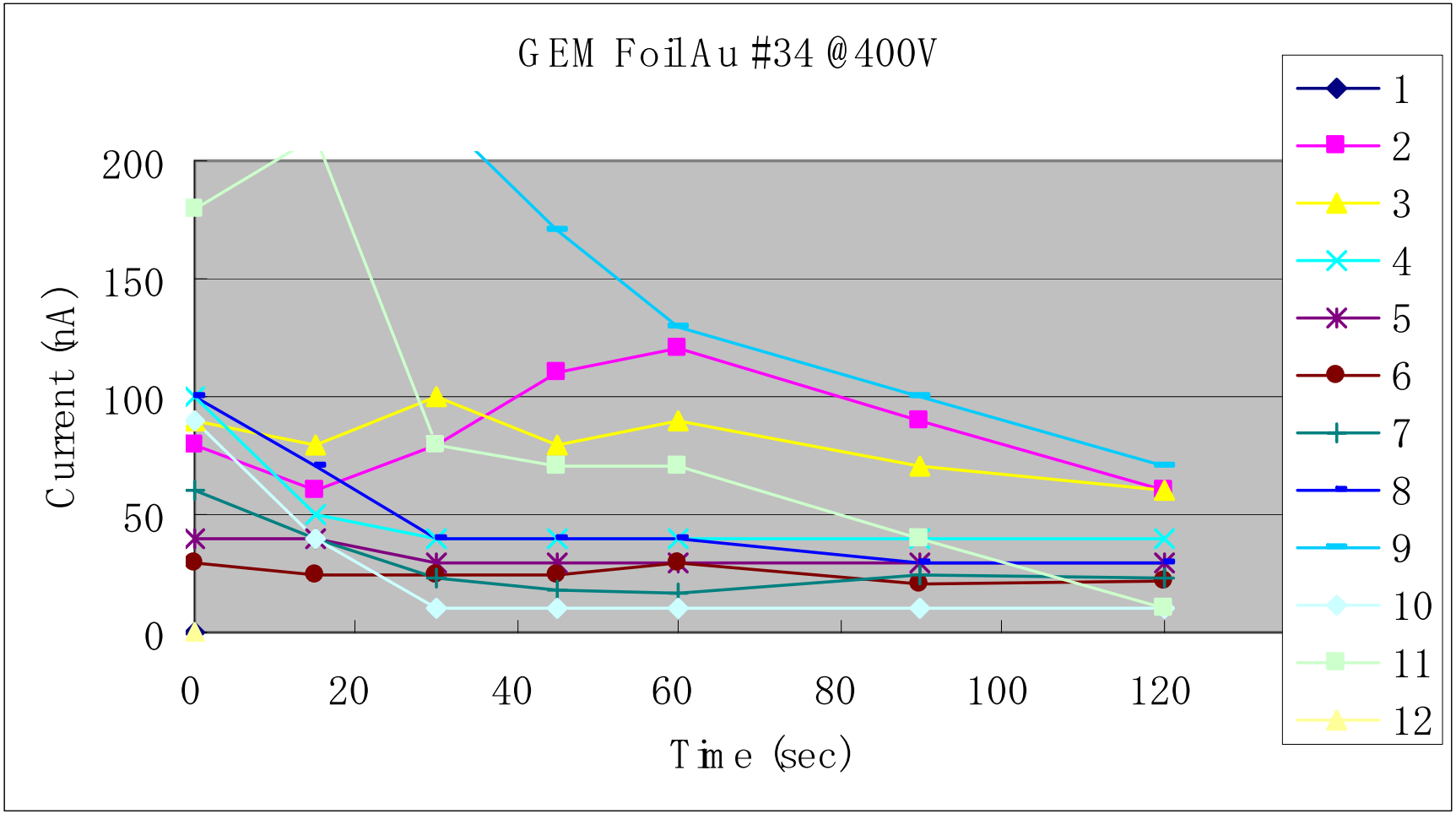
12 HV sectors on one side of each foil.


Section of 30cm x 30cm 3M GEM Foil

HV tests on uncoated GEM foil



GEM Au #34


GEM FoilAu #34 @400V
Current (nA)
200
150
100
50
0
0
20
40
60
80
100
120
Time (sec)
1
2
3
4
5
6
7
8
9
10
11
12

Development of 30cm x 30cm GEM chamber(s)

- Foils HV tested.

- Jigs made to mount foils, stack chamber.

- Initial multilayer anode board made to work with Fermilab QPA02-based preamp cards.

- Verify aspects of chamber operation:

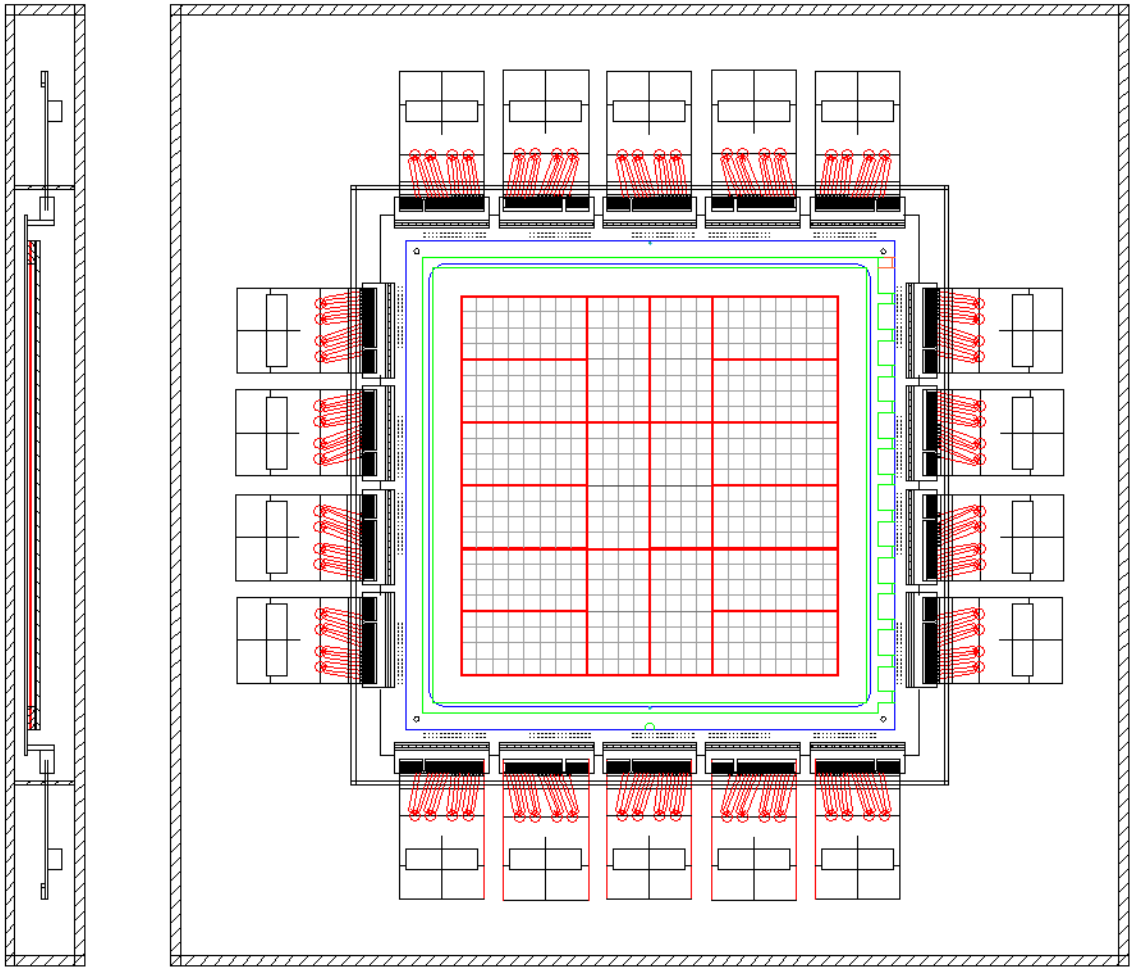
    - stability

    - pulse characteristics (cf. 10cm x 10cm chamber using CERN foils)

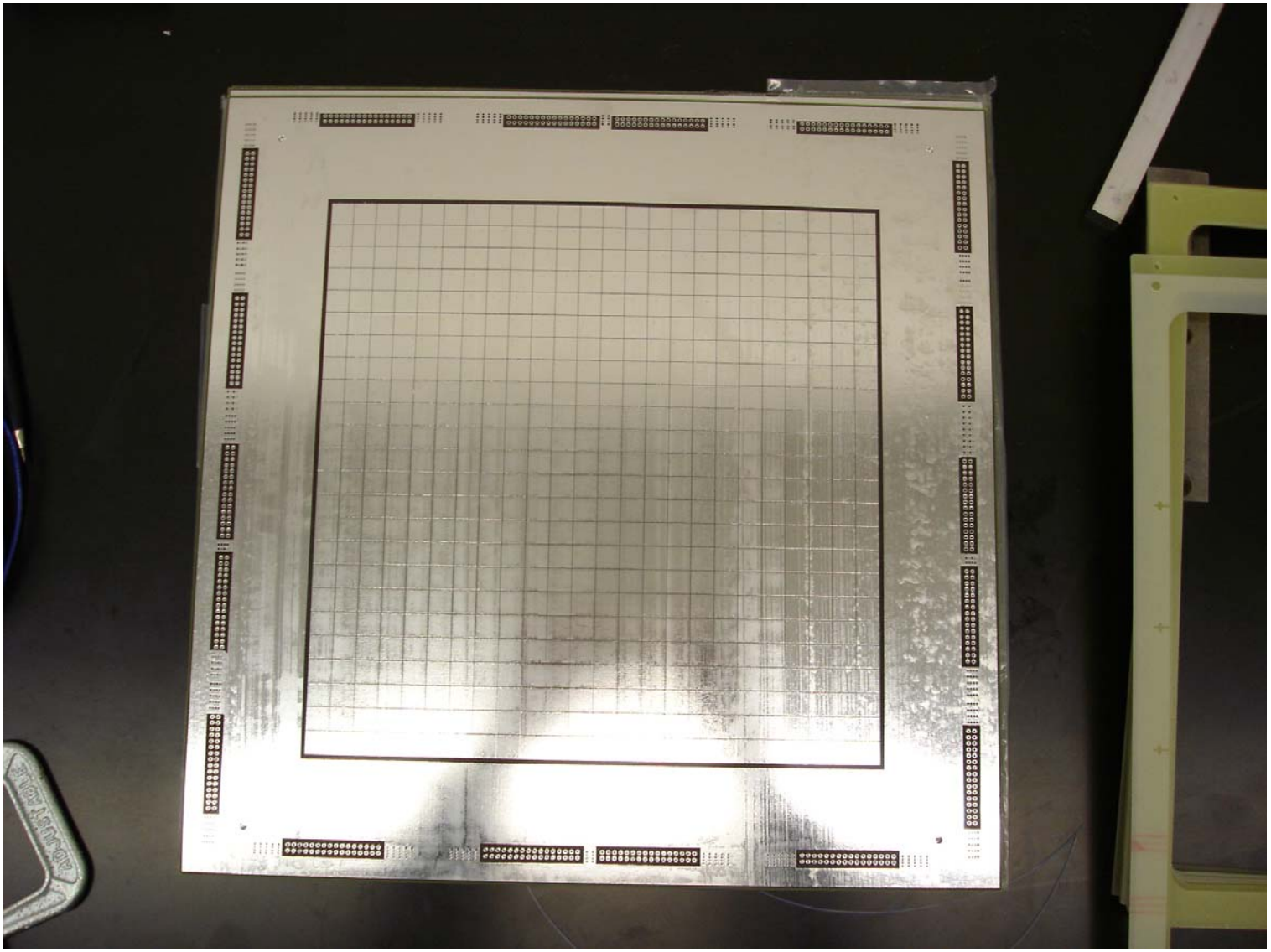
- Use for Korea/KAERI beam tests in May, then Fermilab this summer.

GEM foil frame mounting jig

Anode board for 30cm x 30cm chamber

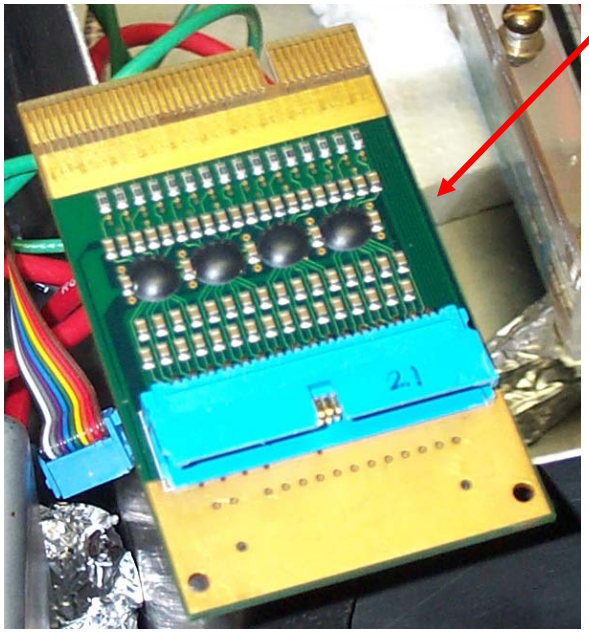


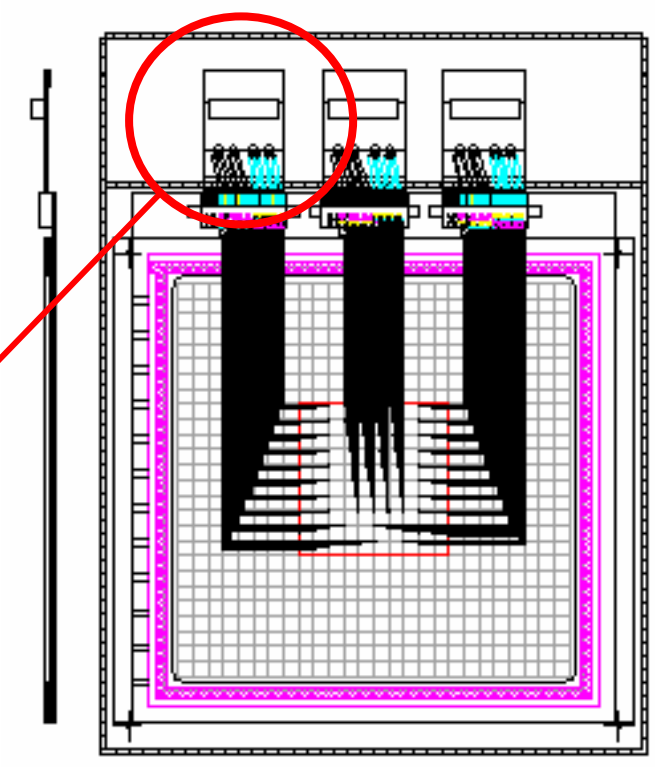
30cm x 30cm anode readout board



Preamps for 30cm^2 chamber

20 cards made by Fermilab PPD



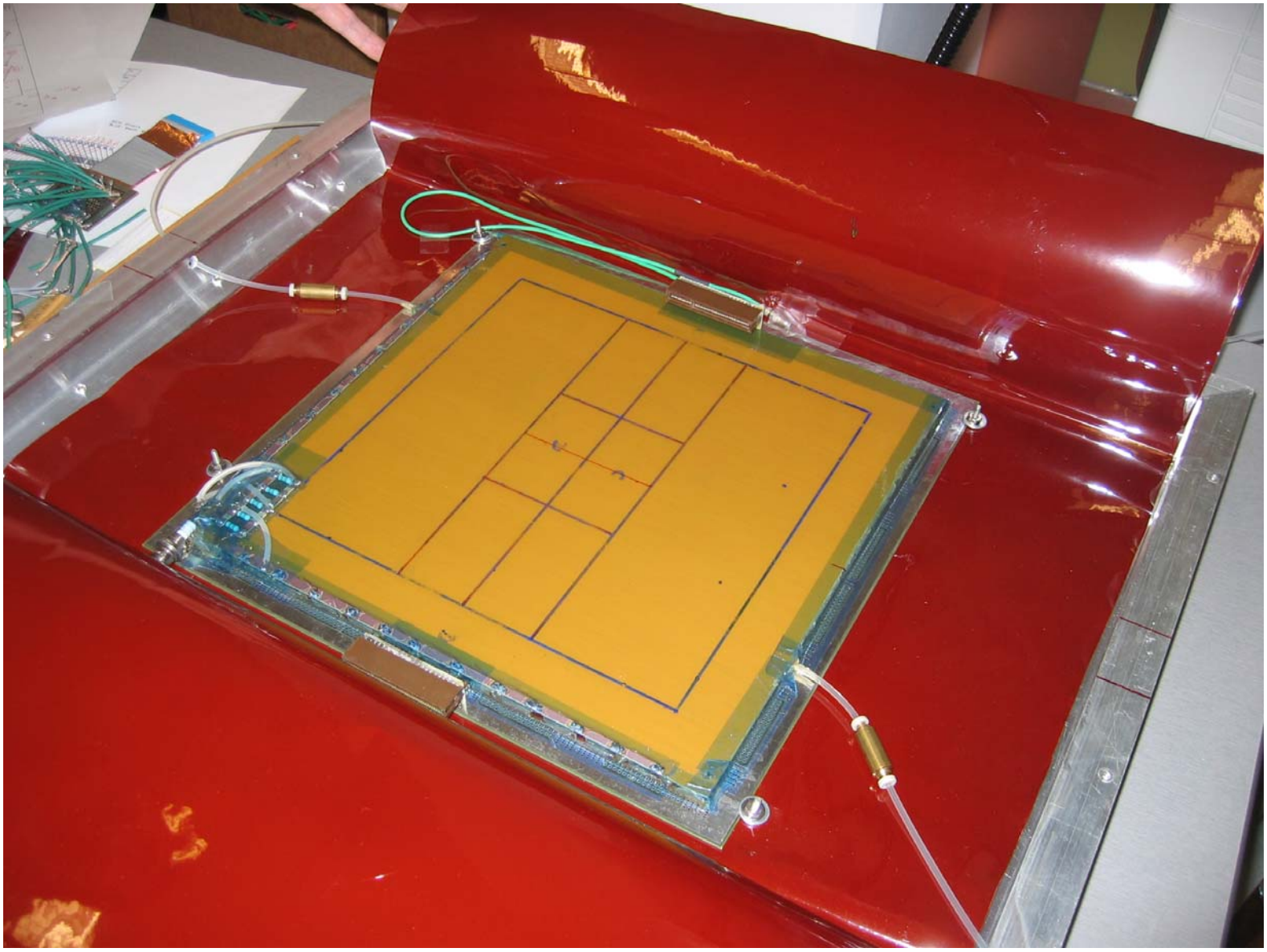


32 channels/card x 3 = 96

-> 10pads x 10pads = 100

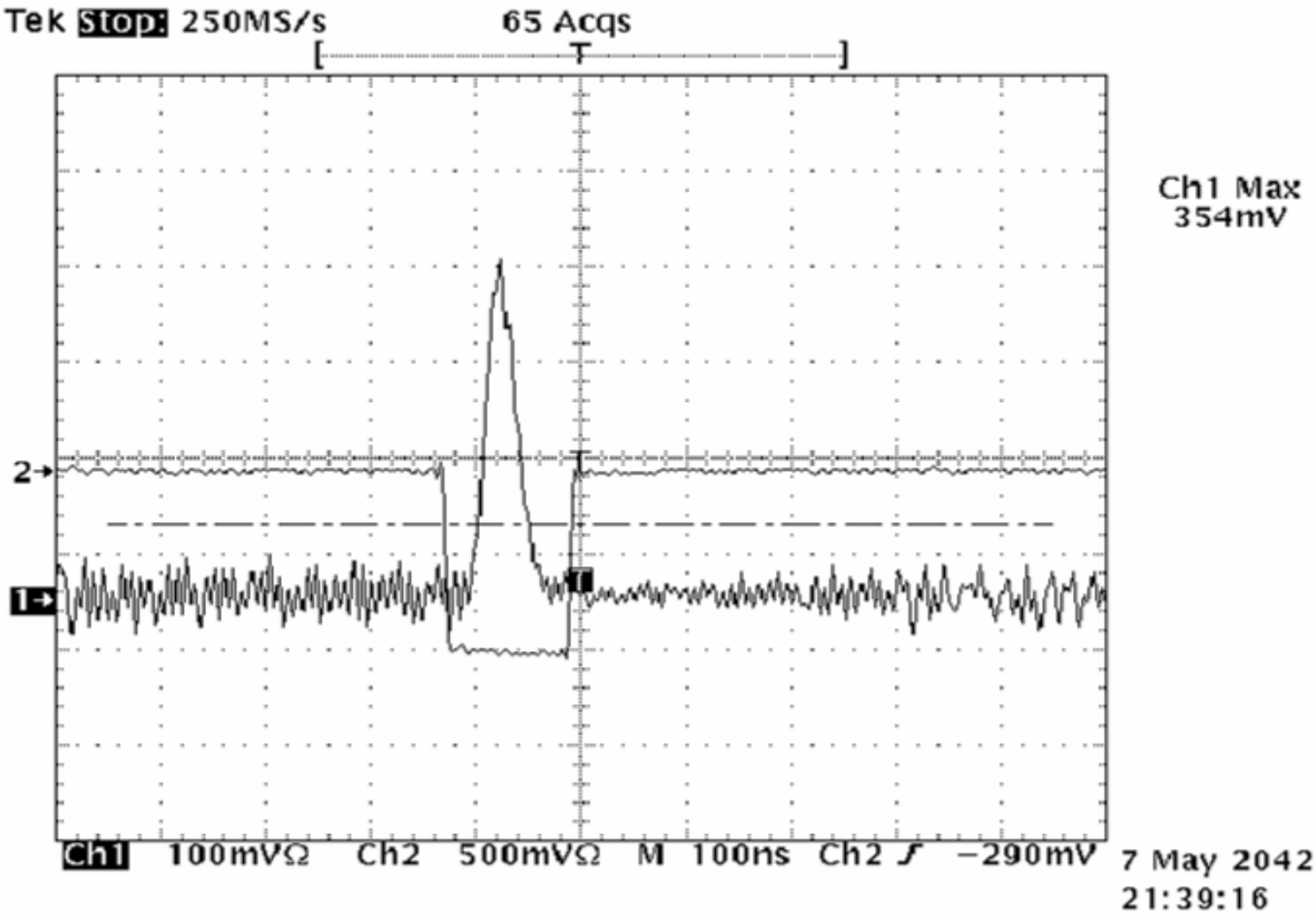
(leave out corner cells)

30cm x 30cm GEM chamber



30cm x 30cm GEM chamber

Signal from the 30x30 D-GEM Detector



Test beam in Korea/KAERI

KOREA ATOMIC ENERGY RESEARCH INSTITUTE

한국원자력연구소

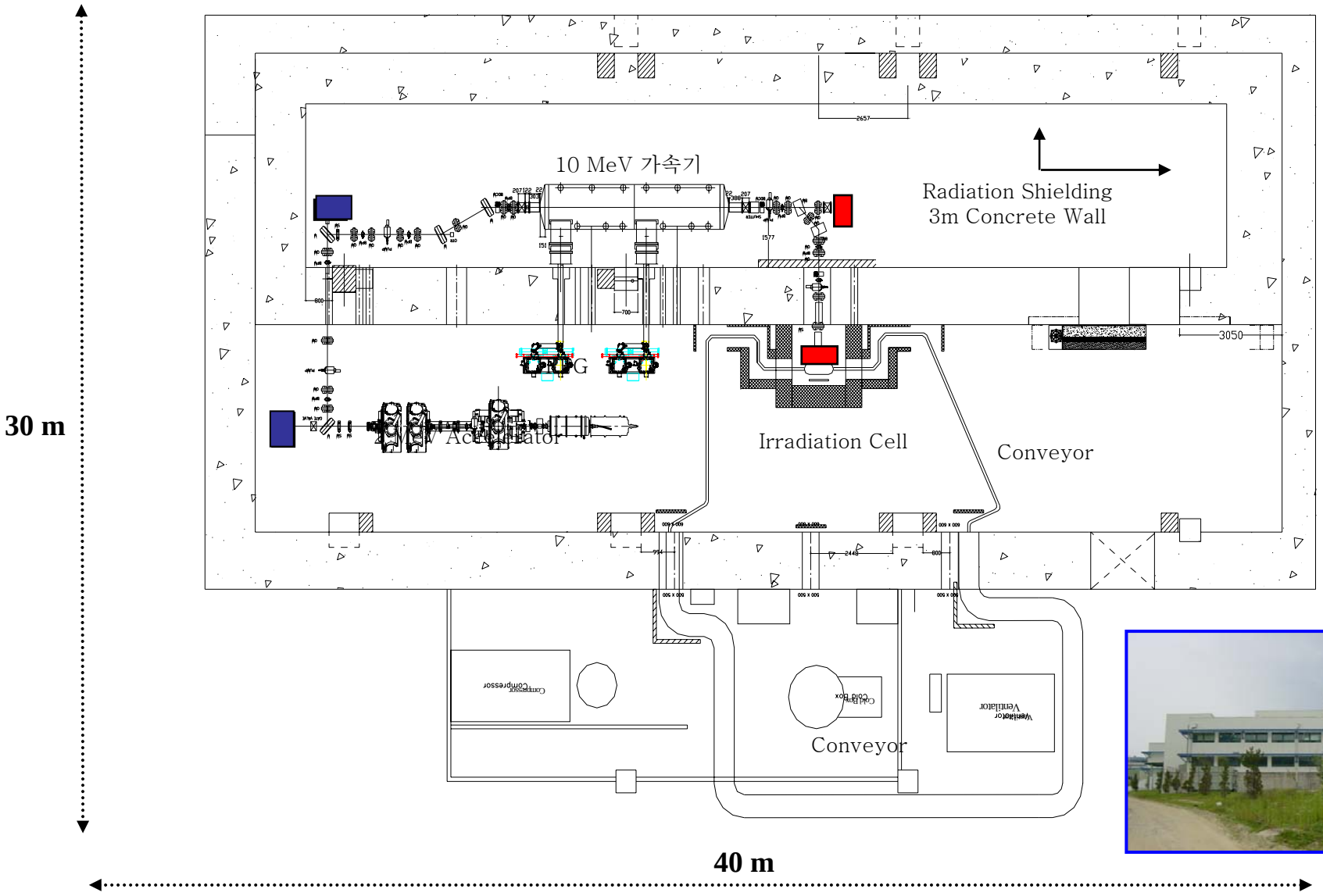
- High intensity, low energy electron beam
- Joint exercise with colleagues from CNU

중·저에너지 전자빔 조사시설

0.3~2 MeV 조사포트

2~10 MeV 조사포트

지하 : 330평
지상 : 170평
총 면적 : 500평



UTA GEM Chamber in KAERI electron beam

e^- beam: 10^{10} particles in
30ps pulse ~every 43μs

4-pad area (2cm x 2cm)
exposed to scanning beam.

UTA GEM-DHCAL exposure

- 4-pad GEM area (2 x 2 pads) exposed to full beam

- Beam scans ~800mm x 50mm area every 2 sec, with 30ps pulse of 10^{10} e^-/pulse over a 5 cm^2 area, or ~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) and GEM chamber continued normal operation.

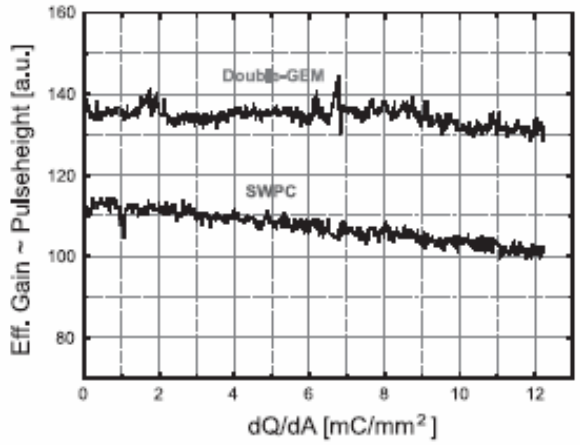
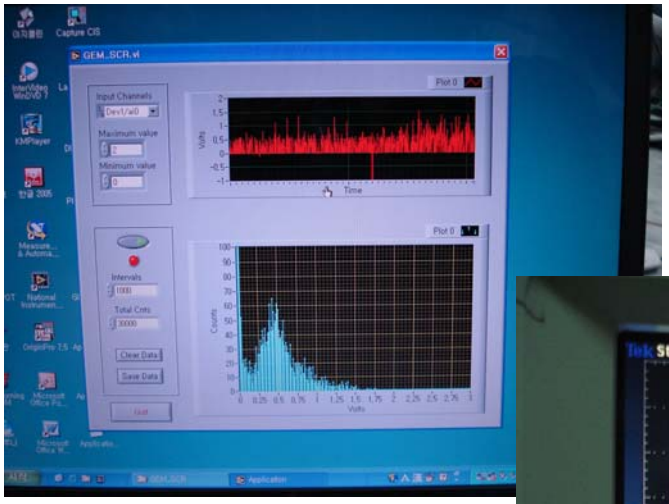
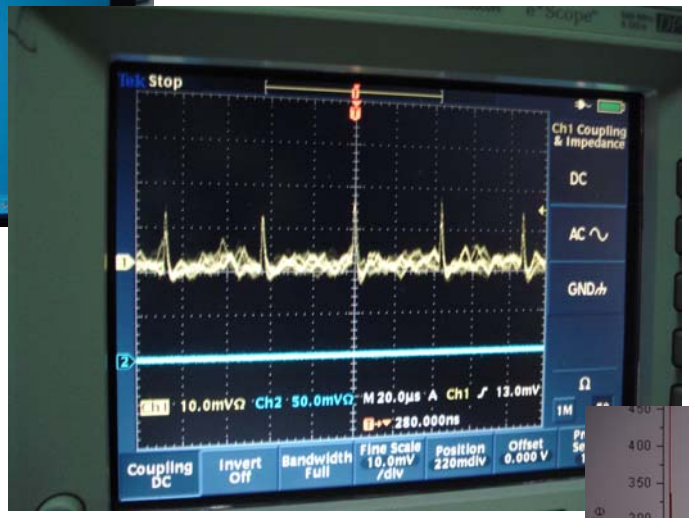


Fig. 3. Previous aging measurement of a double-GEM detector with Ar–CO_2 (70:30): effective gain versus accumulated charge dQ/dA.

- Much above total hits/10y/pad at ILC

- Much below any damage region for decrease in gain.





Tests of CNU GEM chamber

(not directly in beam and behind shielding lead blocks)

GEM-DHCAL Readout

- Early studies used discrete electronics.

- Evolving towards chip-based readout for individual/multiple chamber beam tests and $1m^3$ stack.

- Two options (so far):

    1) DCAL (ANL/Fermilab) – v2 submission May 2006

    2) KPix (SLAC) – v2 submitted, v3 (with GEM mods.) 64 ch, expected availability – late summer 2006. v4 with 64/128/1024(?) channels – availability??

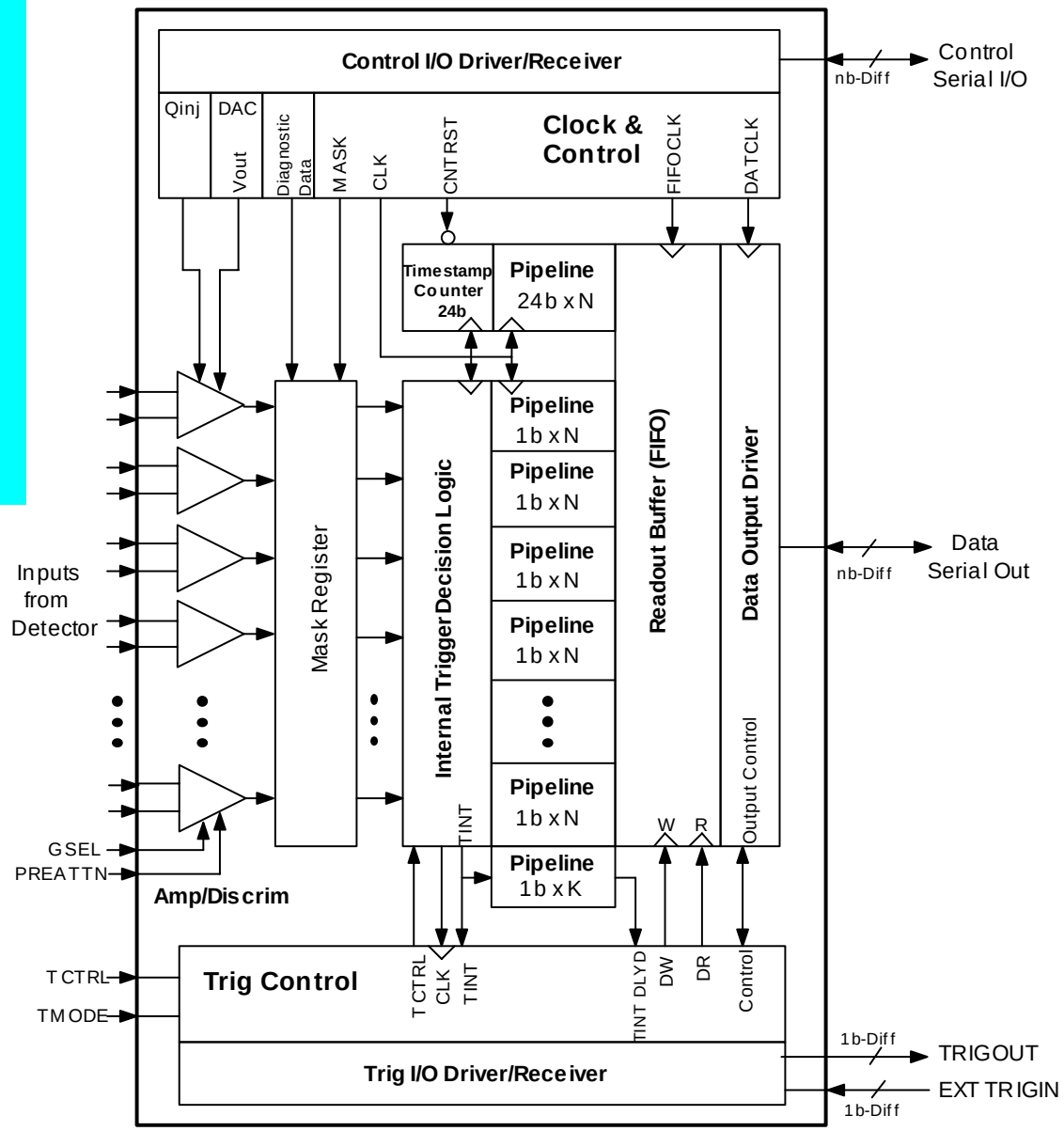
- Individual chamber beam tests at Fermilab – Fall 2006

- Selection of readout for $1m^3$ stack – Spring 2007?

DCAL chip ANL/FNAL

Digital hit output

RPC and GEM capabilities



Common anode board for RPC/GEM – GEM has board "built-in". Size 30cm x 1m/n?

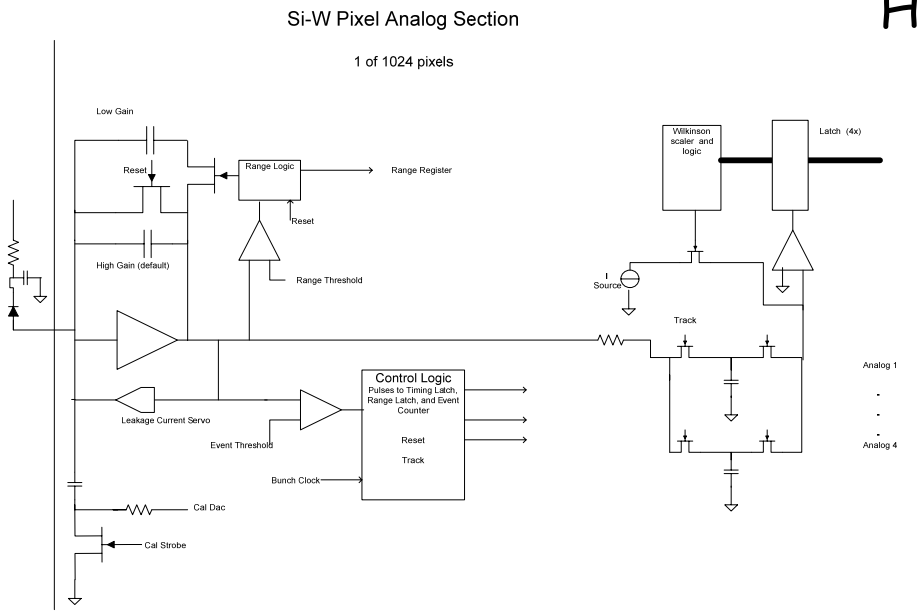
GEM signals:

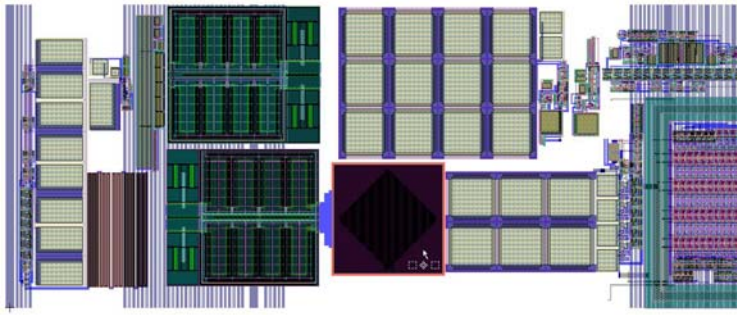
minimum signal ~10fC, maximum signal ~few pC

KPix Readout chip/SLAC

Analog output. Two gain ranges

High: 0 – 500fC, Low: 0 – 10pC



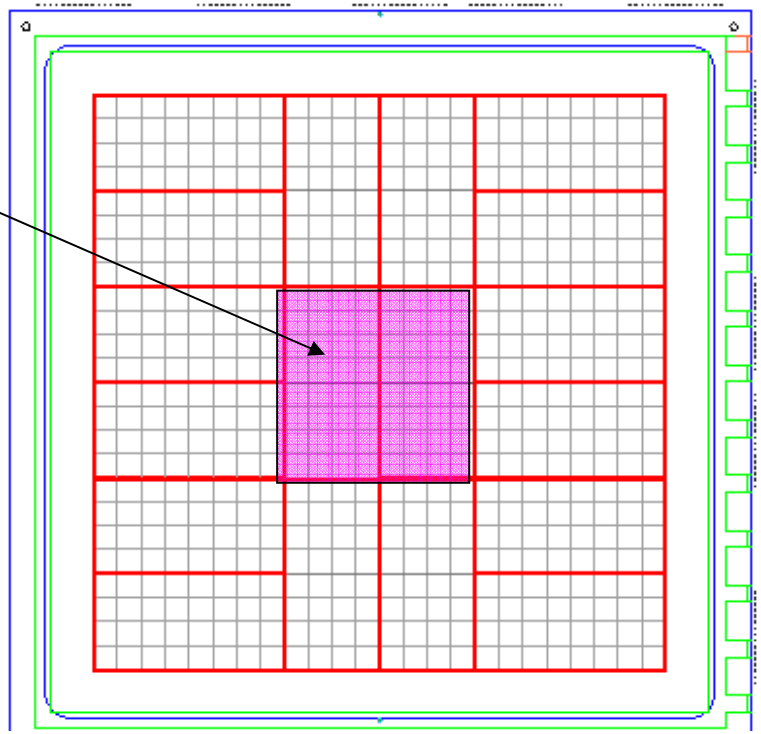


v3 – 64 channels – September 2006 (with GEM changes)

v4 – 64/128/1024 channels(??) end of 2006/early 2007?

Anode board detail for 64-channel

8cm x 8cm area we would like to read out e.g. using 64-channel KPix, version 3.0



SLAC developing a 30x30cm^2 anode board, then could move to a larger (20cm x 50cm?) board as a subunit of 1m^2 layer for 1m^3 stack.

Schedule/budget for GEM-DHCAL

May 2006 – 30x30cm^2 chamber built, initial tests.

- low energy e^- beam tests in Korea.

Summer 2006 – build additional 30x30cm^2 chambers.

- work with ANL/SLAC on anode board designs.

Fall 2006 – Tests of GEM chambers with KPix, DCal chips.

- build larger GEM chambers (20cm x 50cm?) when 3M foils are available

- beam tests of GEM chambers at Fermilab

Late 2006/early 2007 – test GEM chambers with v4 KPix?

Early 2007?? – selection of readout for 1m^3 stack

→

Schedule/budget for GEM-DHCAL (2)

Mid-2007 – large (20x50, 20x1m,…) anode board tests

- start production of GEM chambers for $1m^3$ (depending on FY07funding)

- cycle of HV, source, beam(?) testing of chambers as produced

Late 2007/early 2008 – completion of $1m^3$ stack

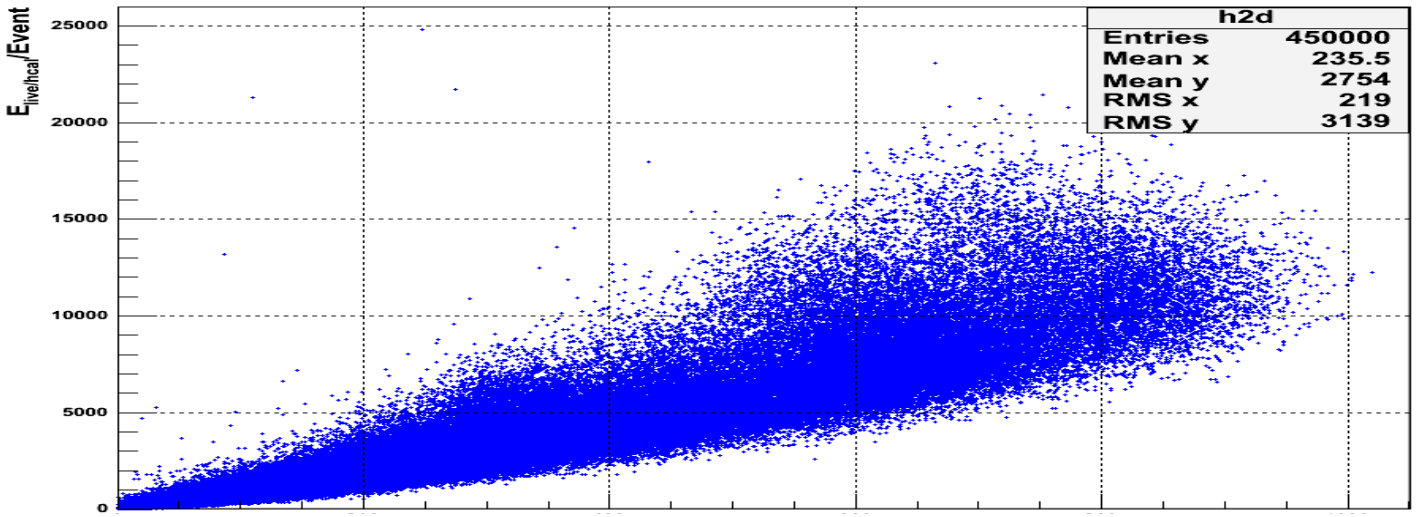
- first beam exposure in 2008

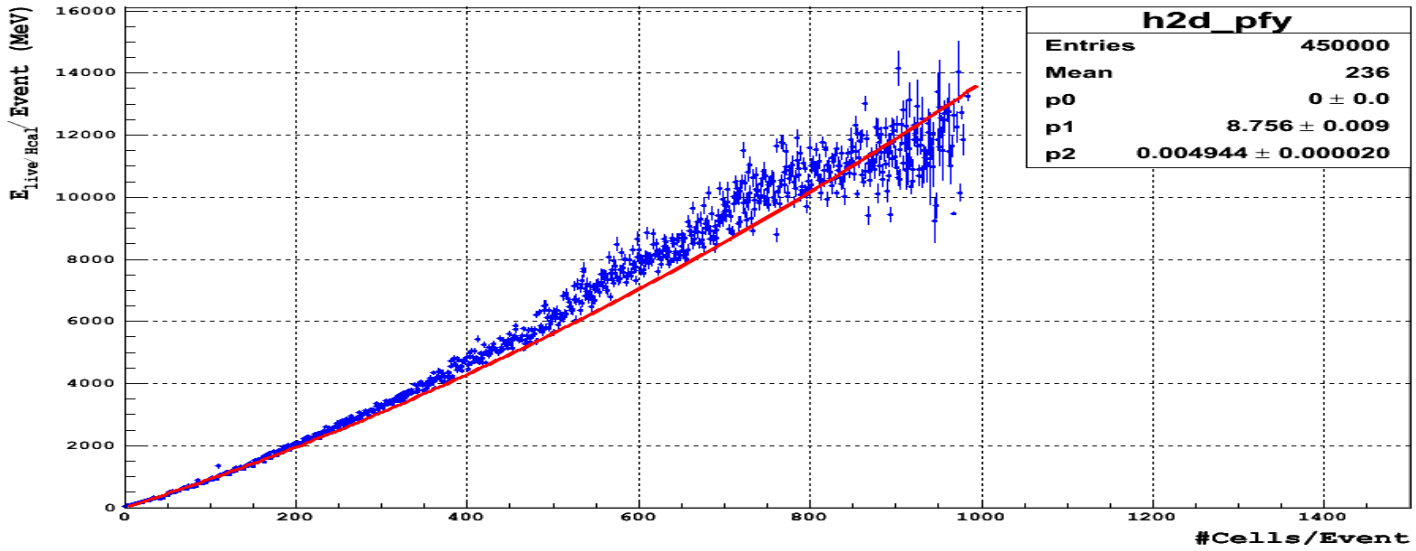
2008 – More test beam running with various technologies.

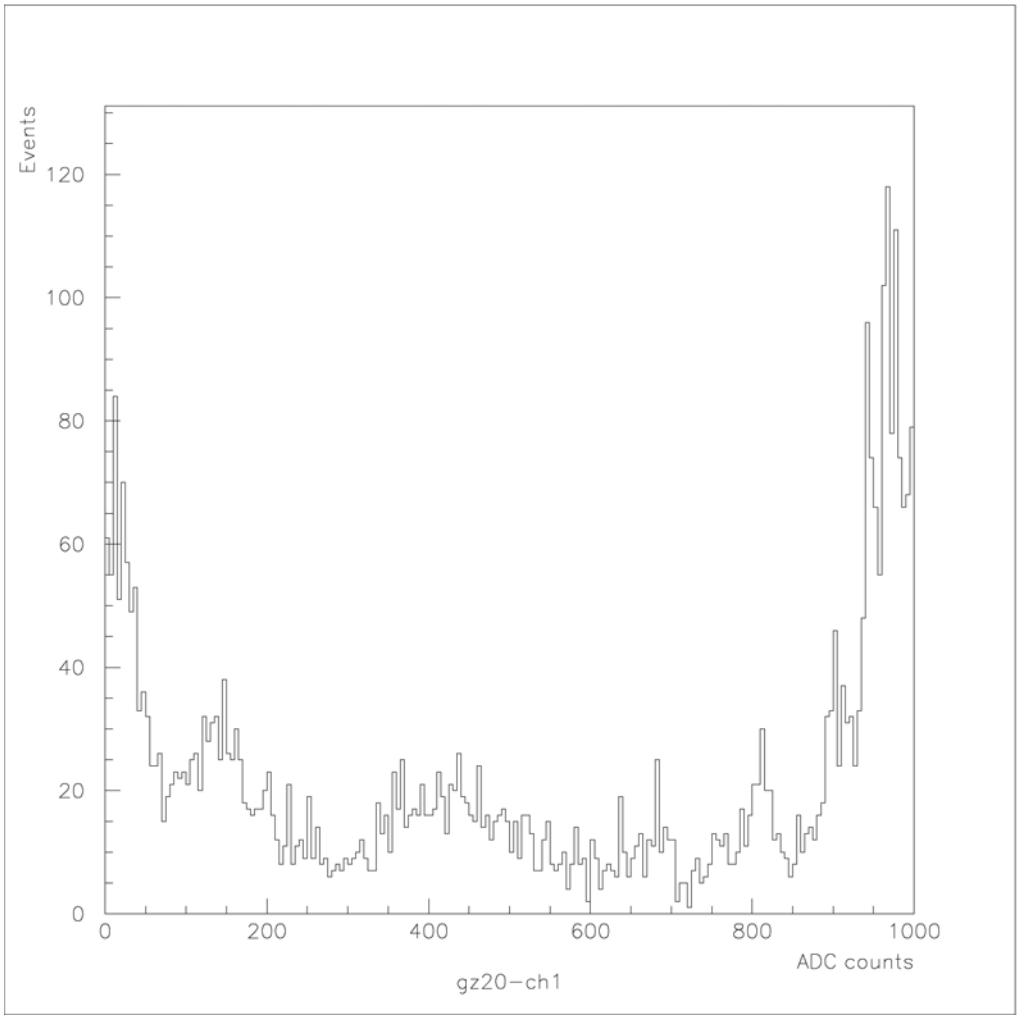
2009/10 ?? – HCal technology selection.

Extra Slides

Digital calorimetry – counting cells






Events
120
100
80
60
40
20
0
0
200
400
600
800
1000
ADC counts
gz20−ch1