# Summary of CALICE Activities and Results


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(for the CALICE Collaboration)

DESY-PRC May 27, 2004

# Summary of CALICE Activities and Results

- Physics requirements/calorimeter design
- Detector configurations
- Electromagnetic calorimeter – Si/W
- Hadronic Calorimeter
    - Digital – GEM, RPC
    - Analog/Semi-digital – Tile
- Particle Flow Algorithm(s) development
- Test Beam Plans

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# Physics examples driving calorimeter design and requirements

**Higgs production** e.g. $e^+e^- \to Z\,h$ ← Missing mass peak or bbar jets

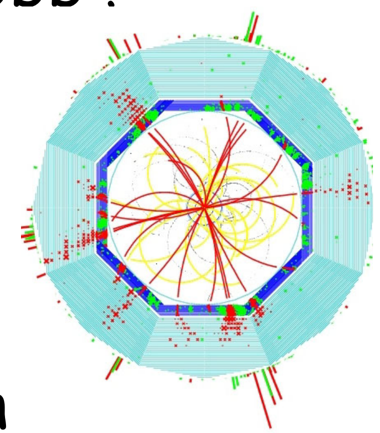
separate from WW, ZZ (in all jet modes)

**Higgs couplings** e.g.

- $g_{tth}$ from $e^+e^- \to tth \to WWbbbb \to qqqqbbbb$ !

- $g_{hhh}$ from $e^+e^- \to Zhh$

Zhh→qqbbbb



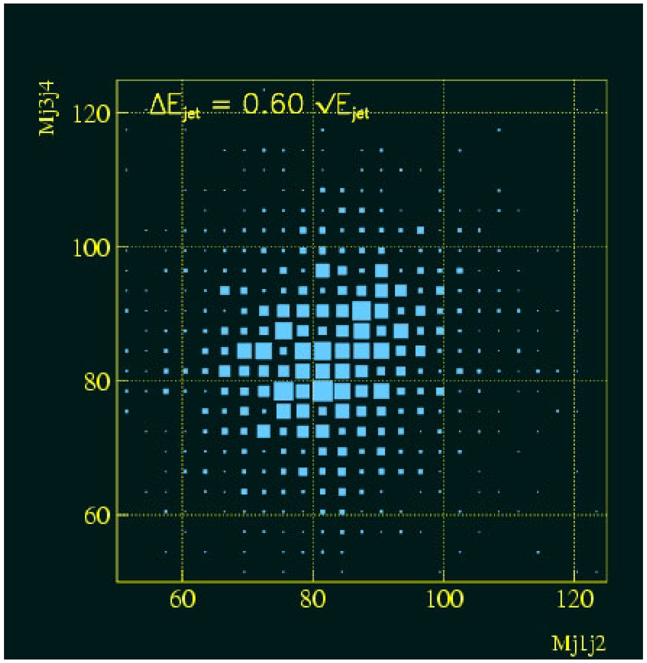
**Higgs branching ratios** $h \to bb$, $WW^*$, cc, gg, $\tau\tau$

(all demand efficient jet reconstruction/separation excellent jet energy resolution)

**Strong WW scattering**: separation of

$e^+e^- \to \nu\nu WW \to \nu\nu qqqq$ and $e^+e^- \to \nu\nu ZZ \to \nu\nu qqqq$

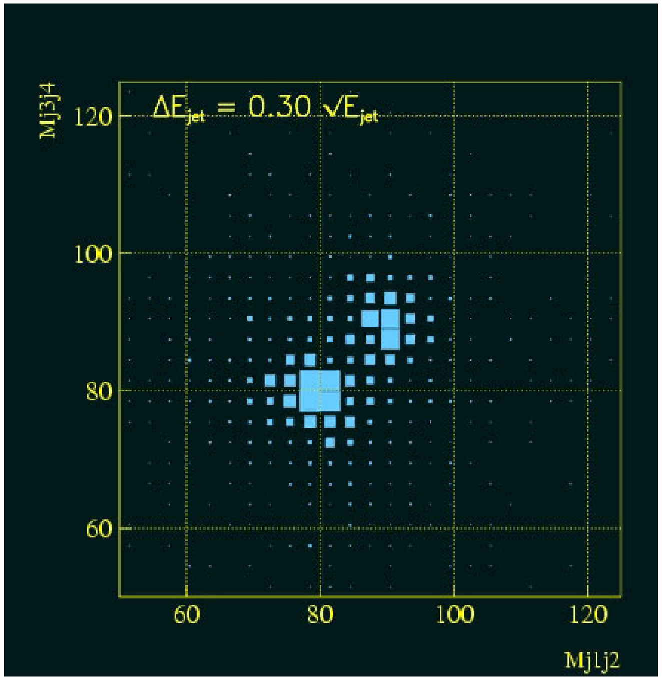
# Importance of good jet energy resolution




60%/√E

Simulation of W, Z reconstructed masses in hadronic mode.

30%/√E




(from CALICE studies, H.Videau,

shown at ALCPG/Cornell: M. Schumacher)

# Calorimeter System Design

LC Physics demands excellent jet i.d./energy resolution, and jet-jet invariant mass resolution.

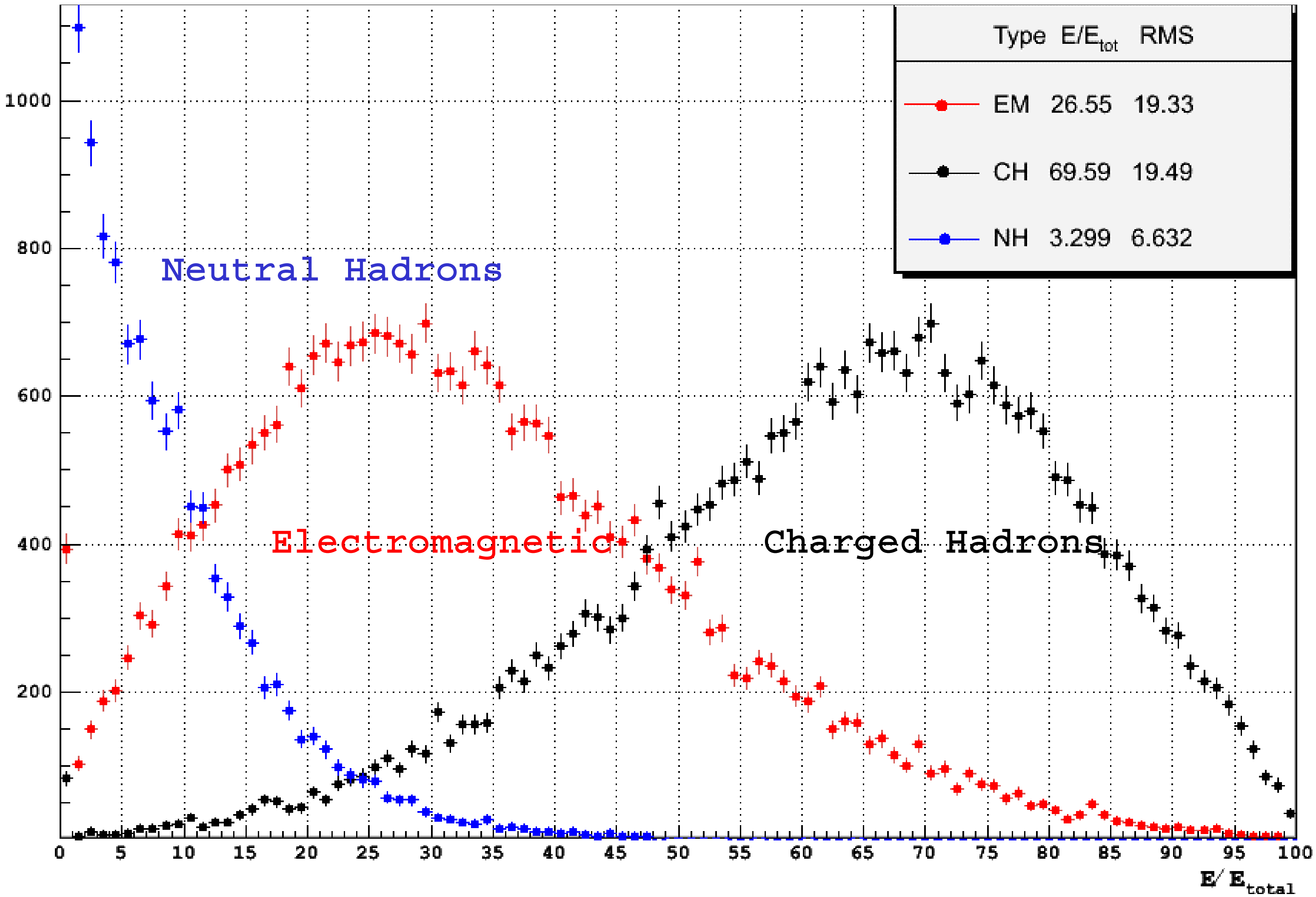
Energy or Particle Flow(PFA) approach holds promise of required solution.

-> Use tracker to measure Pt of dominant, charged particle energy contributions in jets

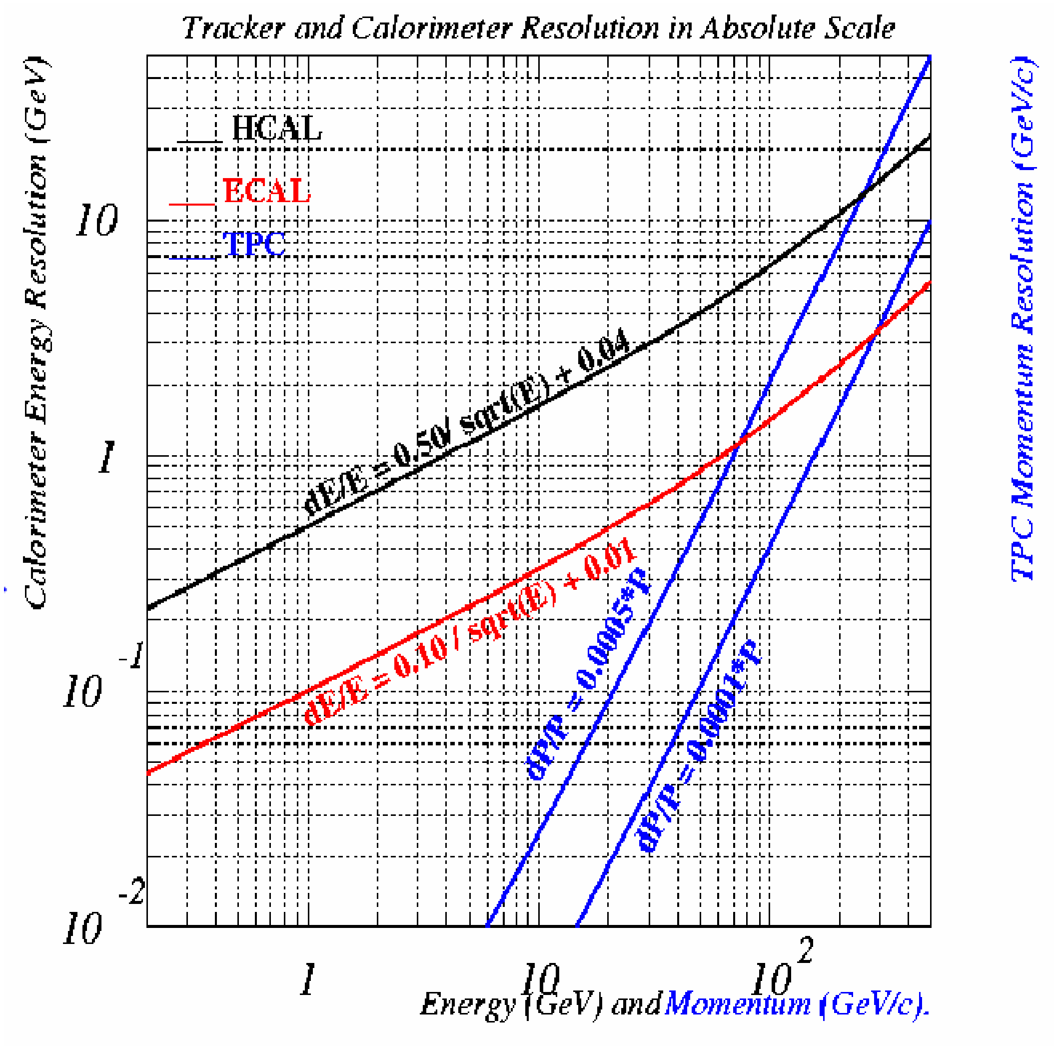
-> Need efficient separation of different types of energy deposition throughout calorimeter system

-> Energy measurement of relatively small neutral hadron contribution de-emphasizes intrinsic energy resolution, but highlights need for very efficient "pattern recognition" in calorimeter.

# Fraction Energy of Particles in Jets



# Calorimeter System Design



# Calorimeter System Design

- Identify and measure each jet energy component as well as possible

Following charged particles through calorimeter demands high granularity…

CALICE has been exploring two options in detail:

(1) Analog ECal + Analog Hcal/semi-Digital

- for HCal: cost of system for required granularity?

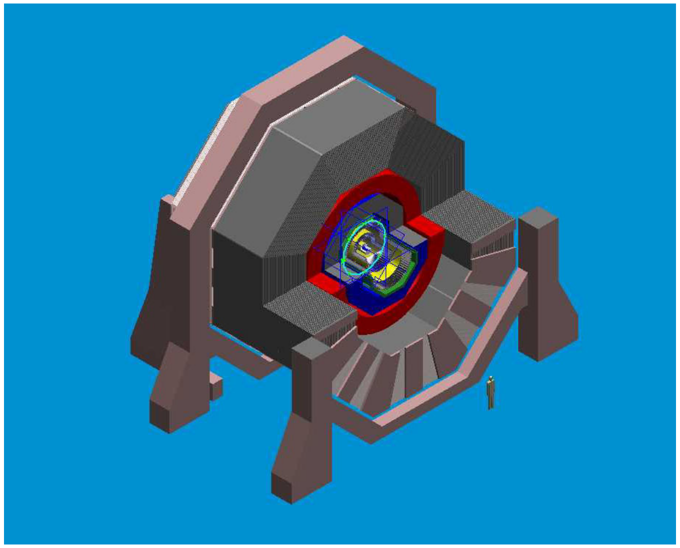
(2) Analog ECal + Digital Hcal

- high granularity suggests a digital solution
- resolution (for residual neutral energy) of a purely digital calorimeter??

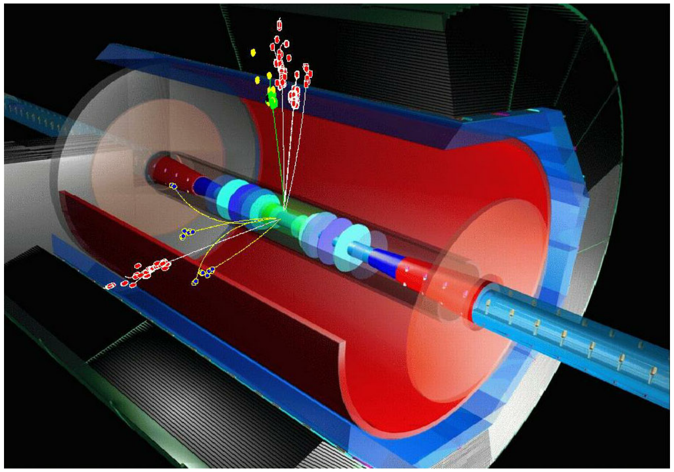
# LC Detector Configurations

Two main approaches (so far):

1) Silicon/Small Detector (SiD)

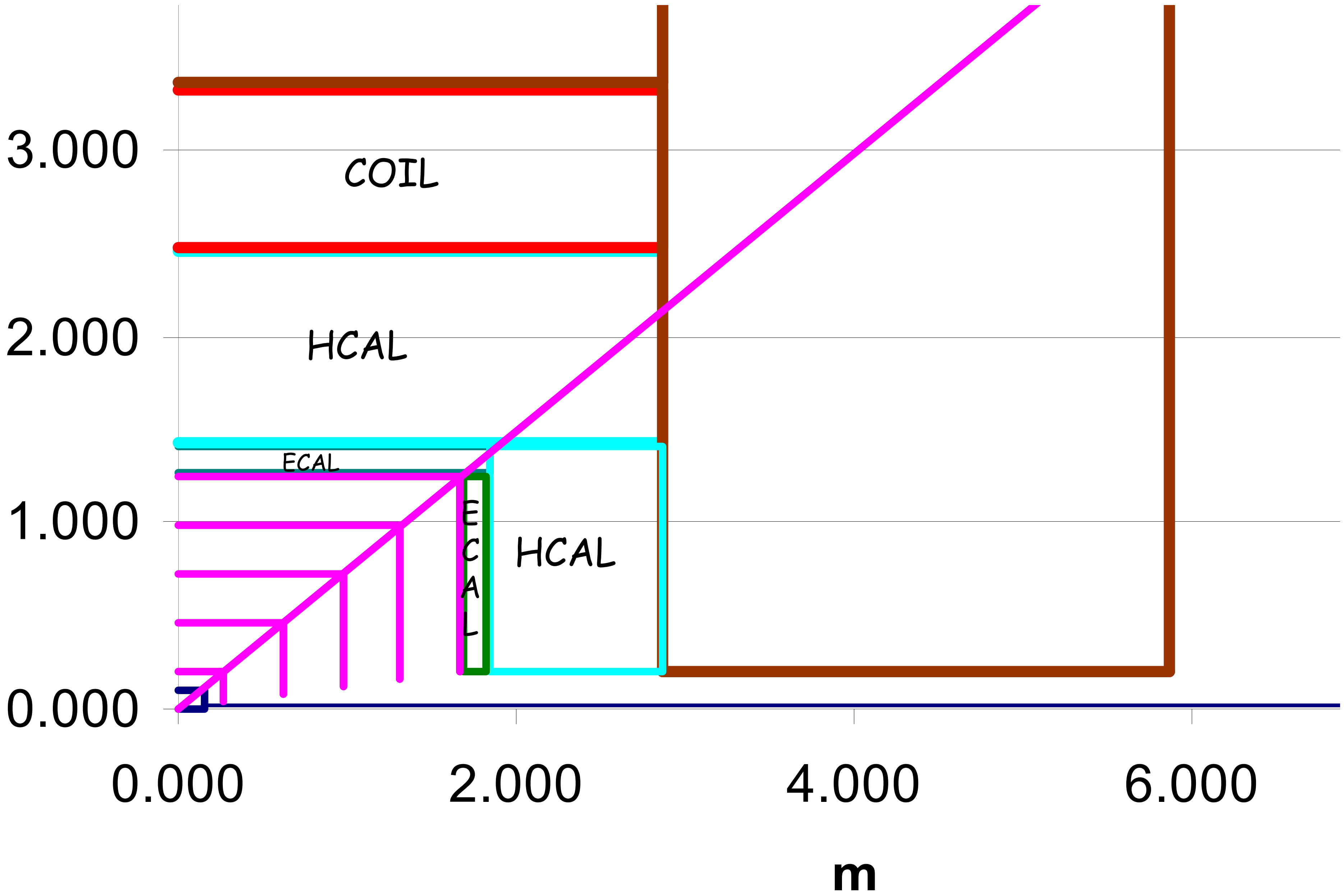


2) TESLA/Large Detector

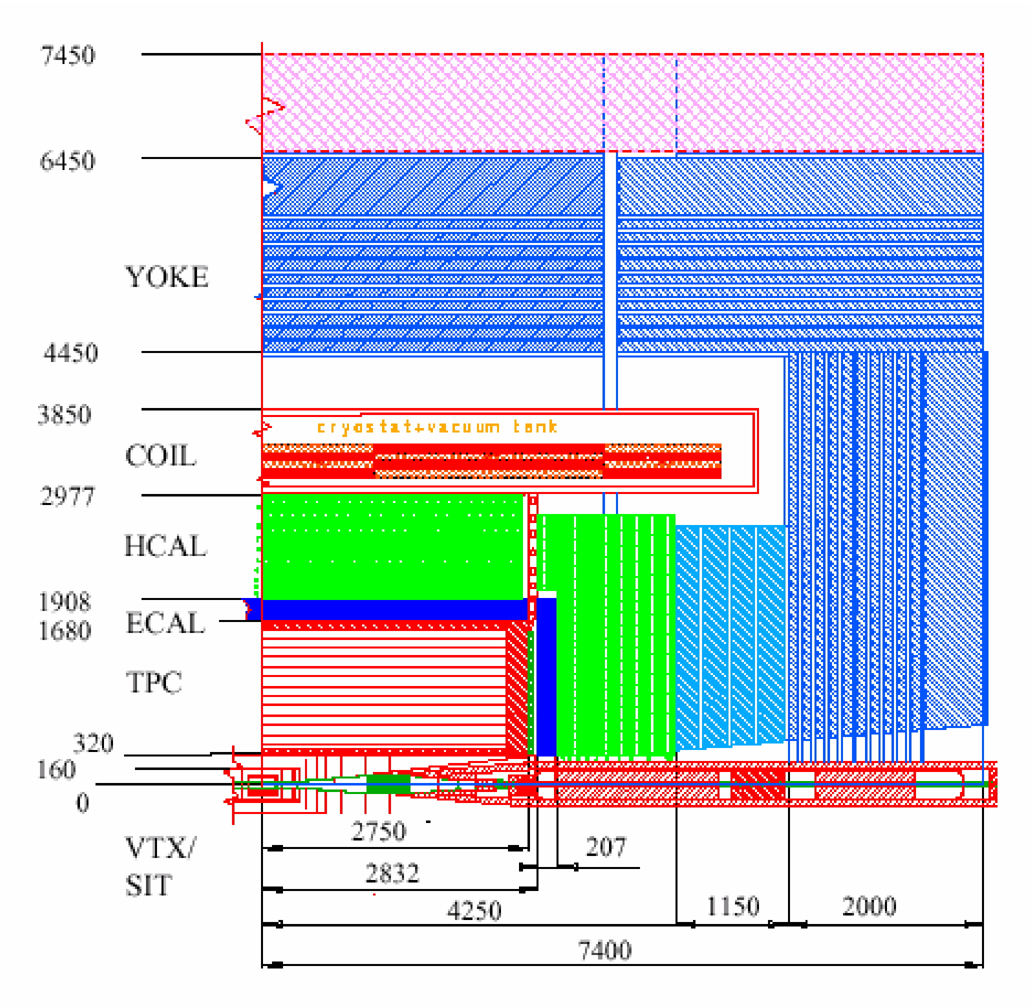


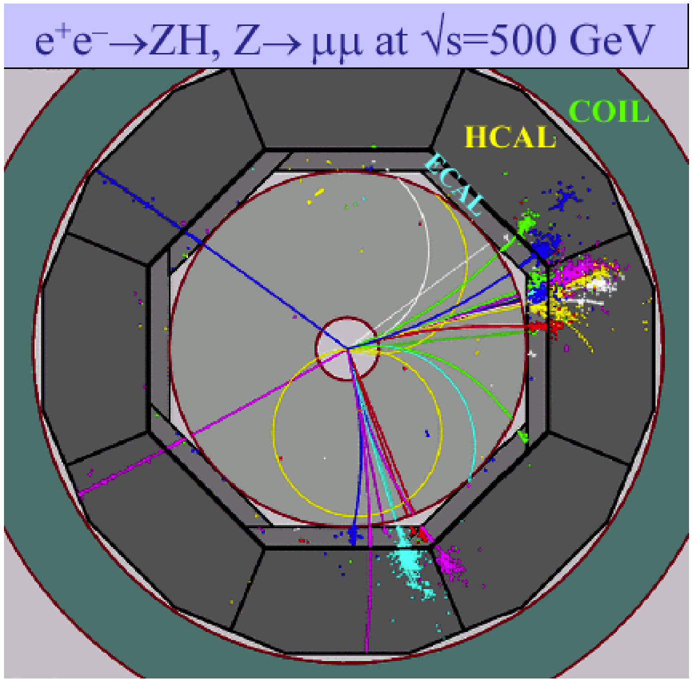
No strong constraints from calorimeter technology on these designs (or vice-versa)

# SiD Detector – enlarged quadrant



# TESLA Detector – enlarged quadrant



# ECAL Requirements

Physics requirements emphasize segmentation/granularity (transverse AND longitudinal) over intrinsic energy resolution.

Localization of e.m. showers and e.m./hadron separation -> dense (small $X_0$) ECal with fine segmentation.

Moliere radius -> O(1 cm.) – from min. charged/neutral separation.

Transverse segmentation ≈ Moliere radius

Tracking charged particles through ECal -> fine longitudinal segmentation and high MIP efficiency.

Excellent photon direction determination (e.g. GMSB)

Keep the cost (Si) under control!

# CALICE - Electromagnetic Calorimeter

- A tungsten/silicon sampling calorimeter

- Design well advanced

- First stack produced

- Silicon wafers in production – high quality verified

- Readout PCB designed – production set

- Very front-end readout chips produced

- Single Slab DAQ system developed for first full chain readout and channel calibration

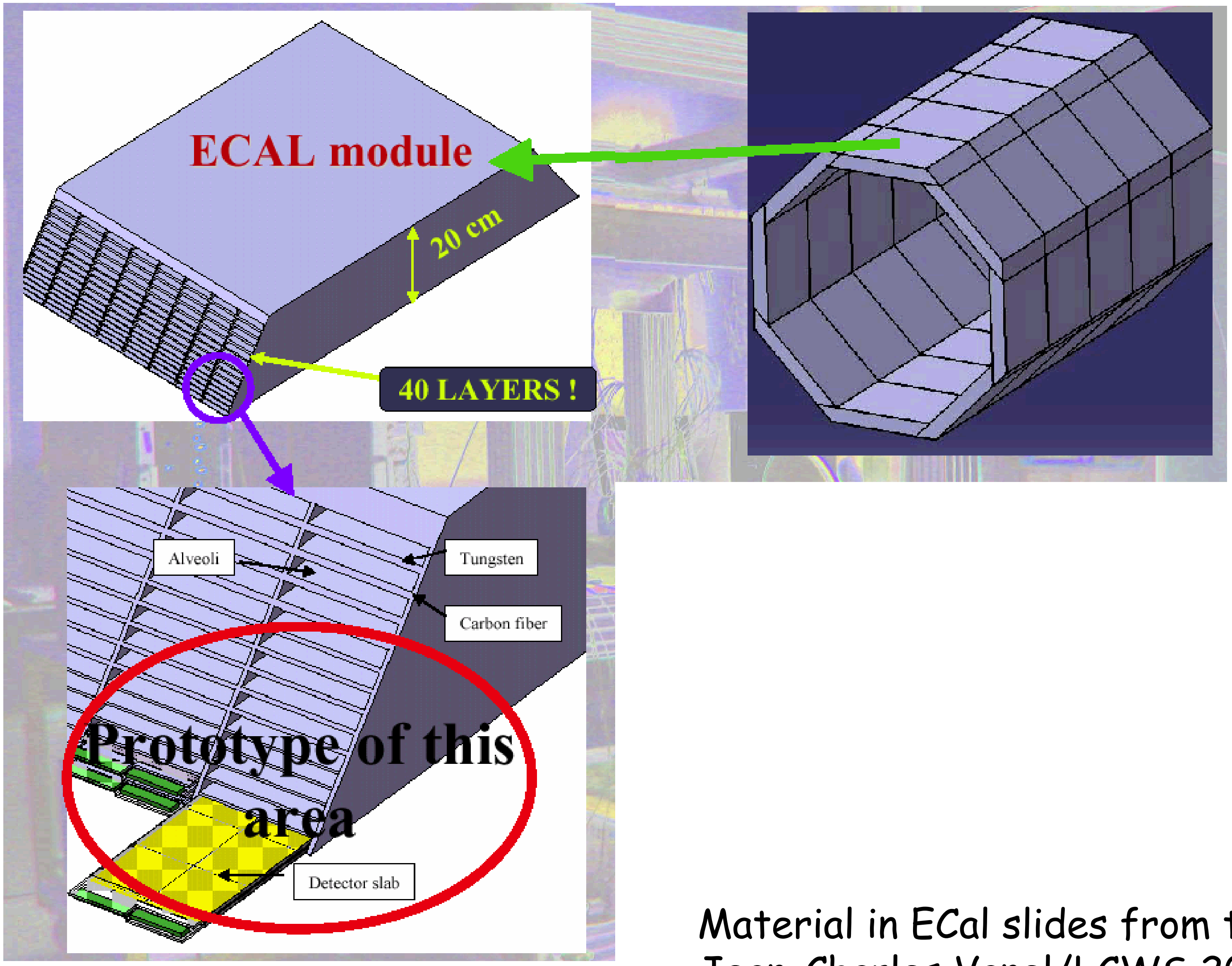
- VME DAQ system for full prototype being developed

⇒Very active program towards test beam

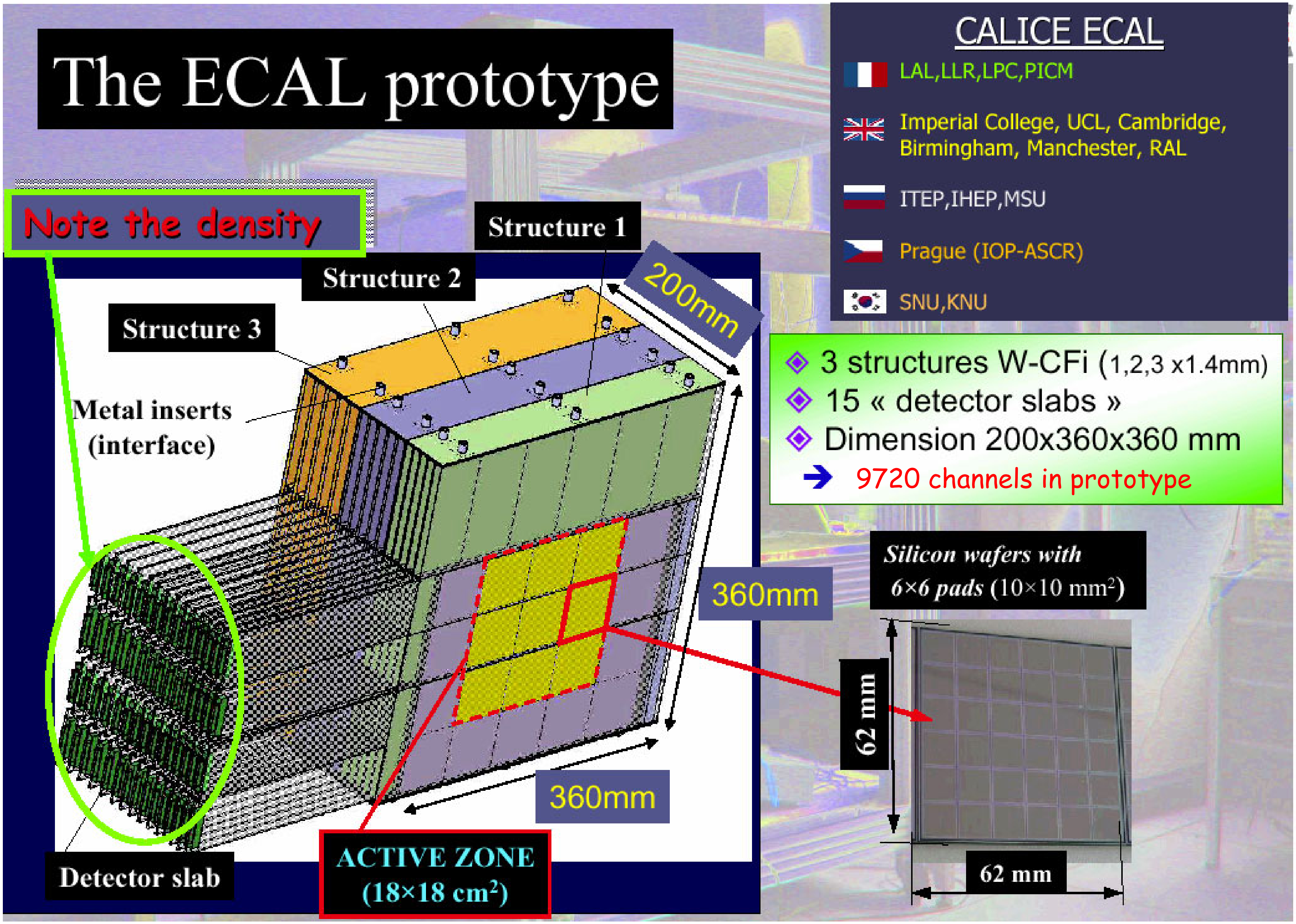
  – end of 2004 (low energy electrons)

  - 2005-6… hadrons and electrons

# ECal System Design

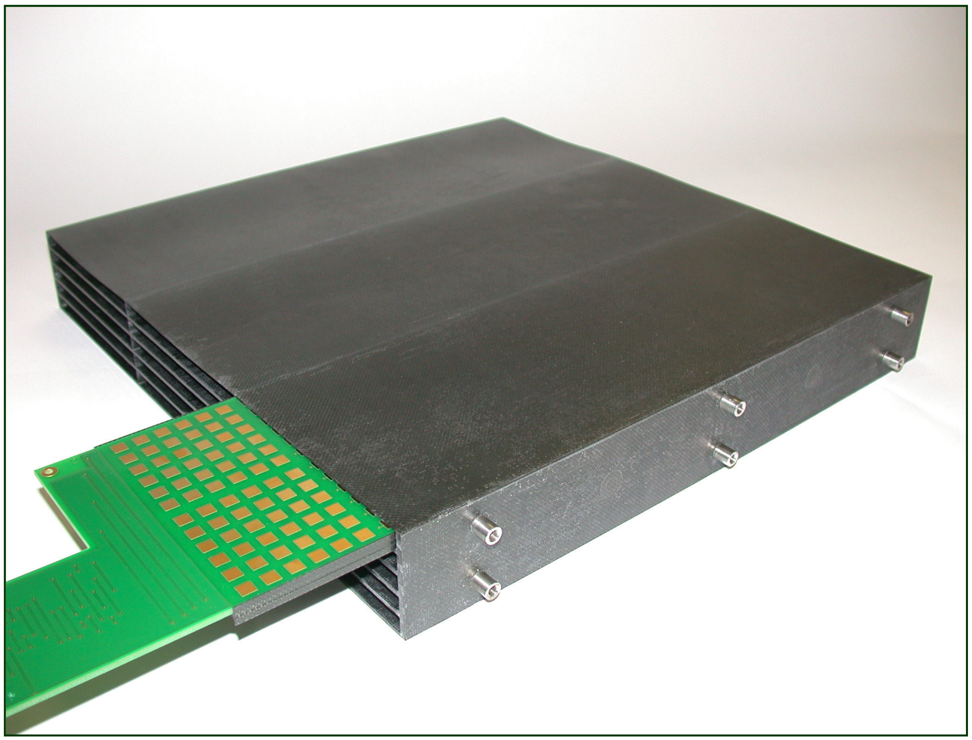



Material in ECal slides from talk by Jean-Charles Vanel/LCWS 2004

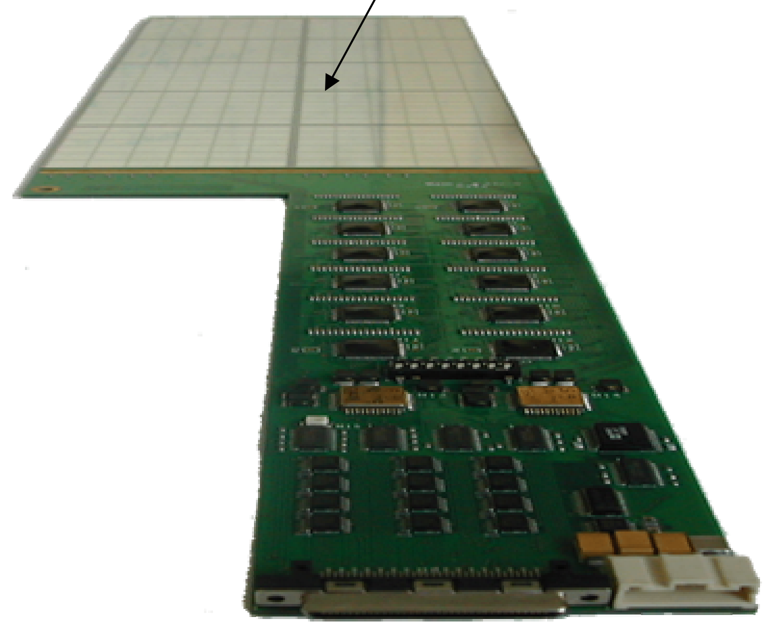

The ECAL prototype
CALICE ECAL
LAL,LLR,LPC,PICM
Imperial College, UCL, Cambridge, Birmingham, Manchester, RAL
ITEP,IHEP,MSU
Prague (IOP-ASCR)
SNU,KNU
Note the density
Structure 1
Structure 2
Structure 3
Metal inserts (interface)
200mm
360mm
360mm
3 structures W-CFi (1,2,3 x1.4mm)
15 « detector slabs »
Dimension 200x360x360 mm
➔ 9720 channels in prototype
Silicon wafers with 6×6 pads (10×10 mm²)
62 mm
62 mm
Detector slab
ACTIVE ZONE (18×18 cm²)

# First stack elements

First structure from LLR

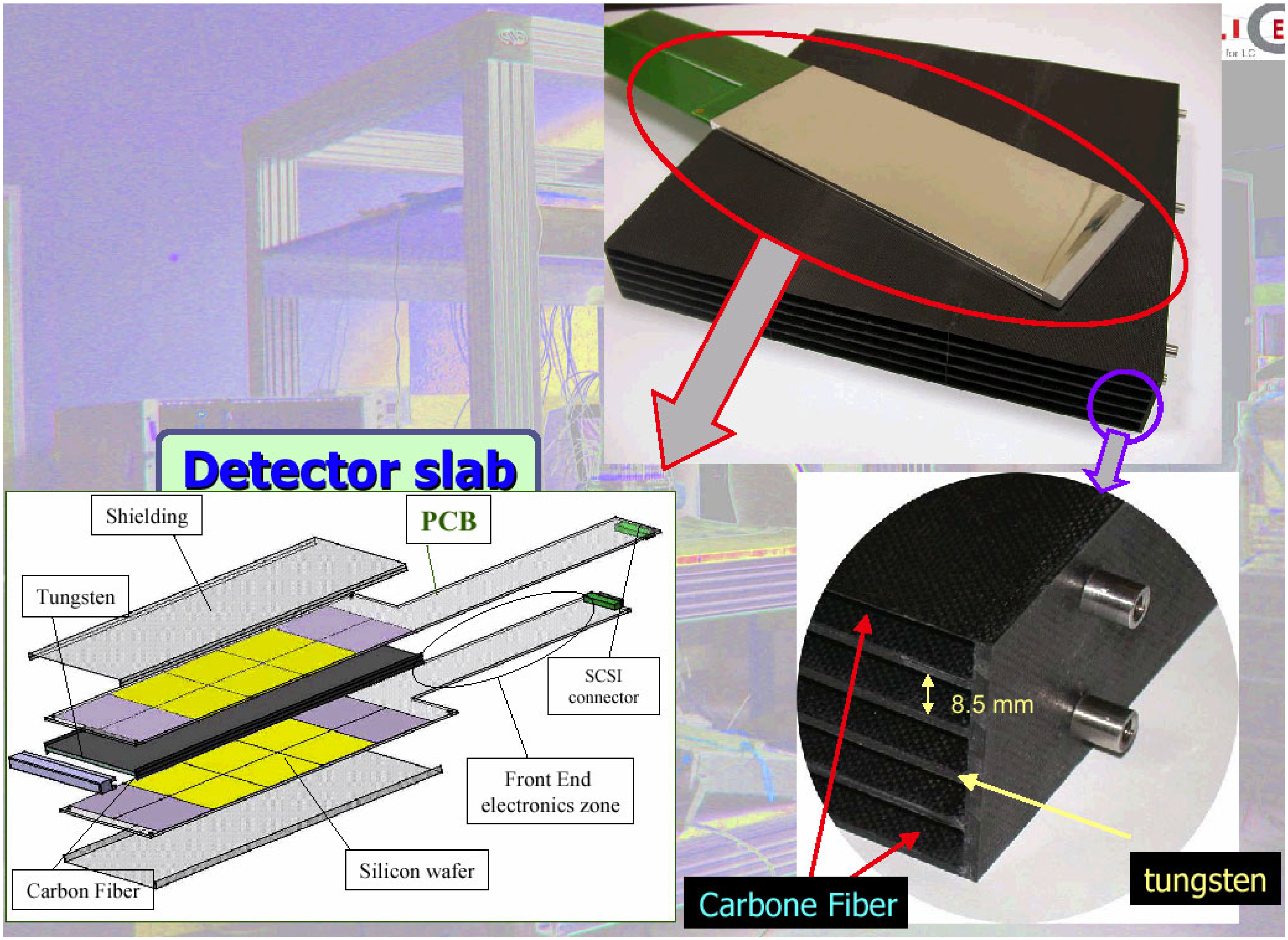


Wafers:
Russia/MSU and
Prague



PCB: LAL design,
production – Korea/KNU

# Detector slab details



# ECal – Si Wafers for Prototype

4” High resistive wafer : 5 KΩcm

Thickness : 525 microns ± 3 %

Tile side : 62.0 + 0.0
- 0.1 mm

Guard ring

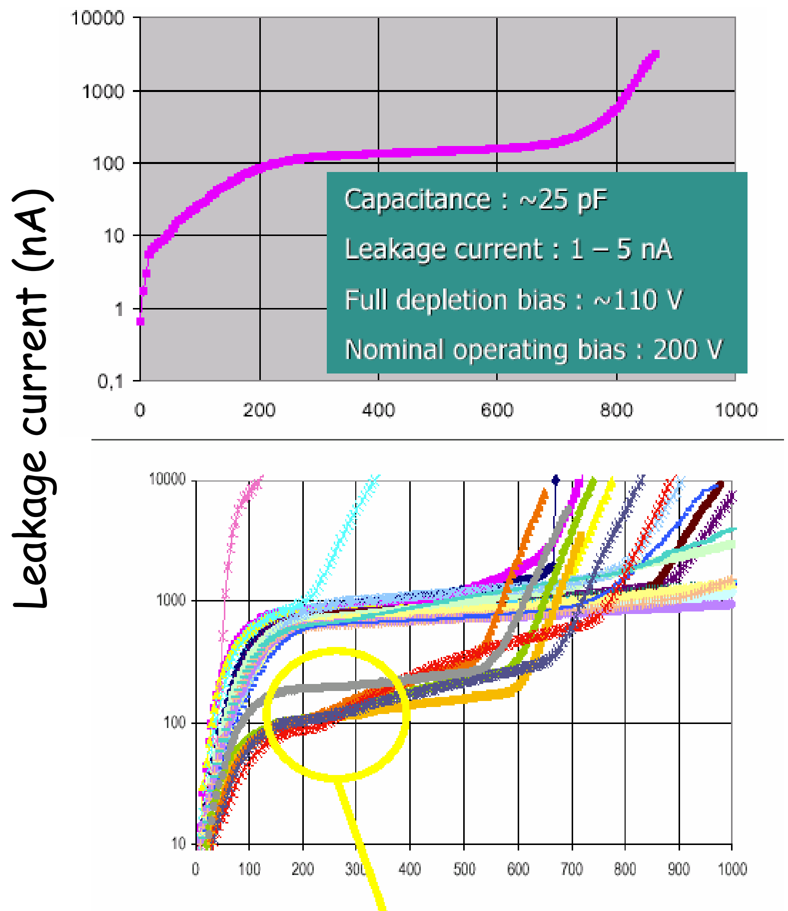
In Silicone ~80 e-h pairs / micron ⇒ 42000 $e^-$ /MiP

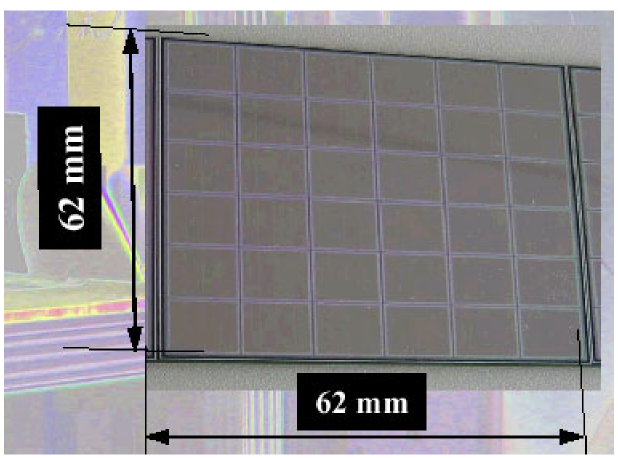
Capacitance : ~21 pF

Leakage current : 5 – 15 nA

Full depletion bias : ~150 V

Nominal operating bias : 200 V



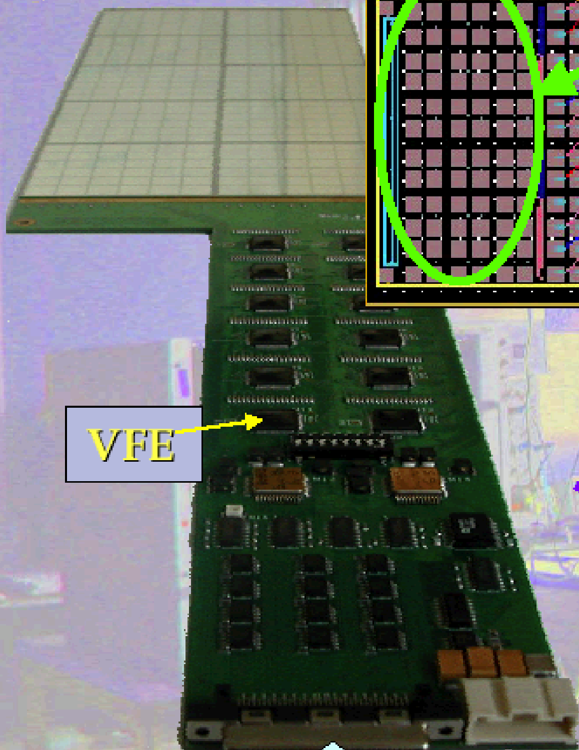

270 wafers needed:

~150 produced by MSU

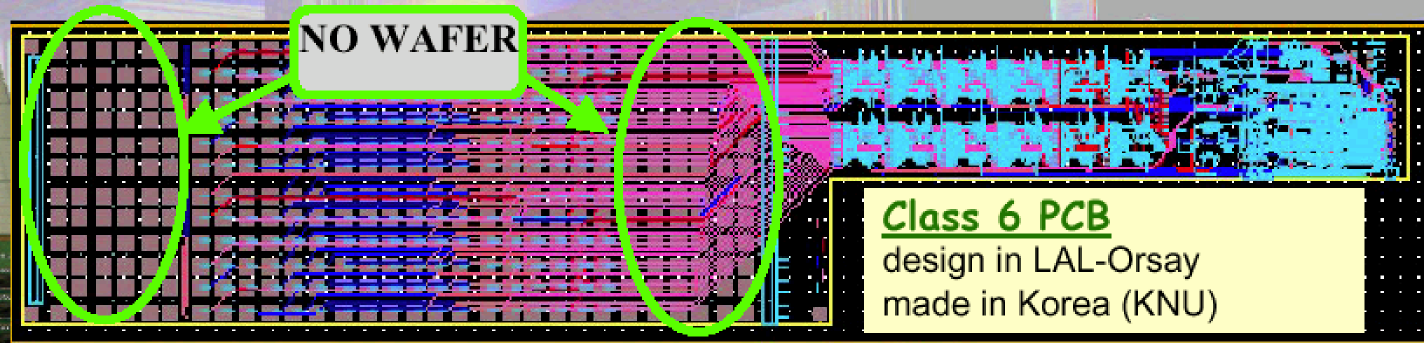
~150 in prod. by IOP/Prague

# PCB for the prototype

Silicon matrix



VFE




**Class 6 PCB**
design in LAL-Orsay
made in Korea (KNU)

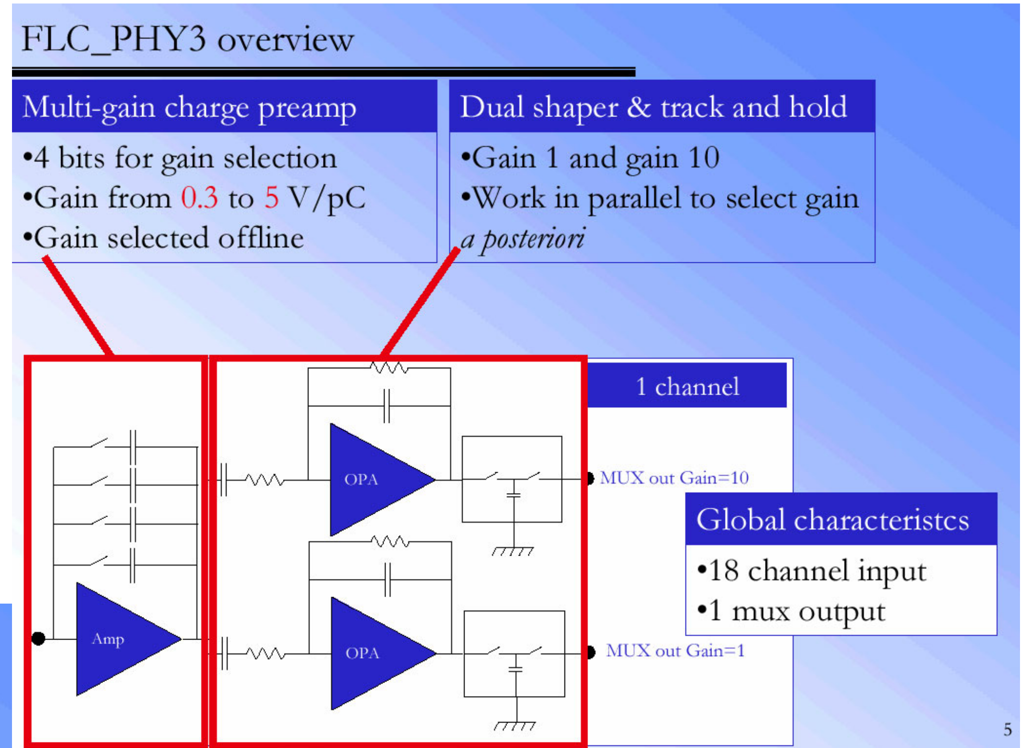
14 layers, 2 mm

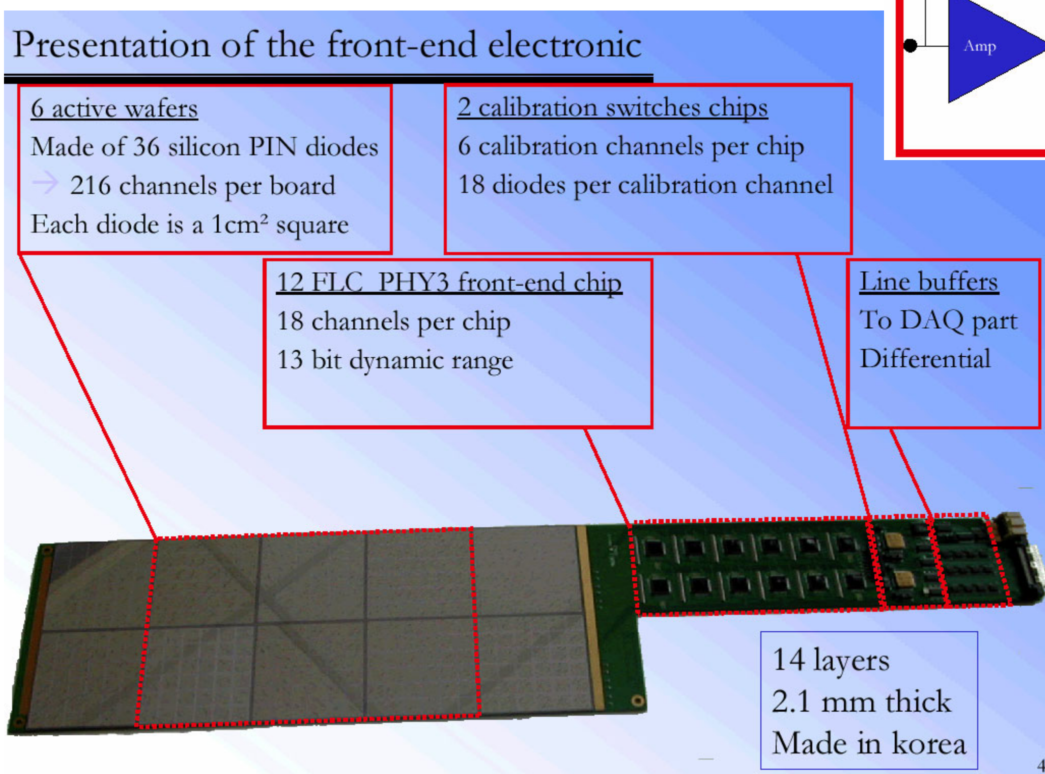
VME/PCI

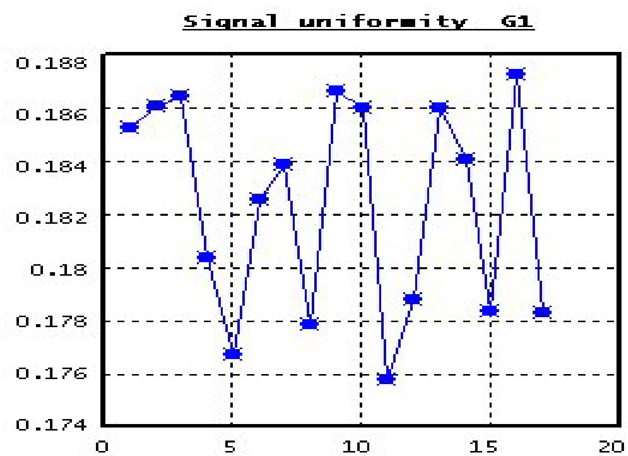
Prototype : 60 PCB → middle of July

# Front-end electronics for the prototype

LAL-Orsay

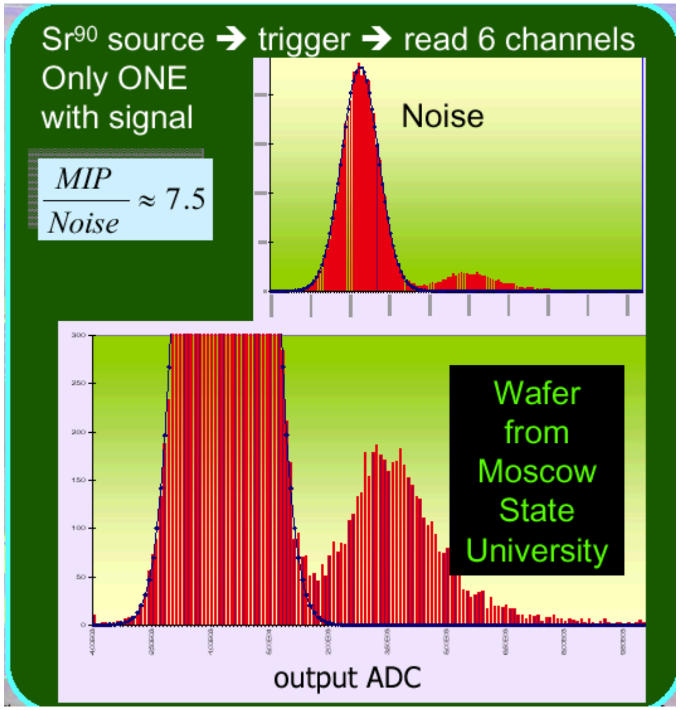


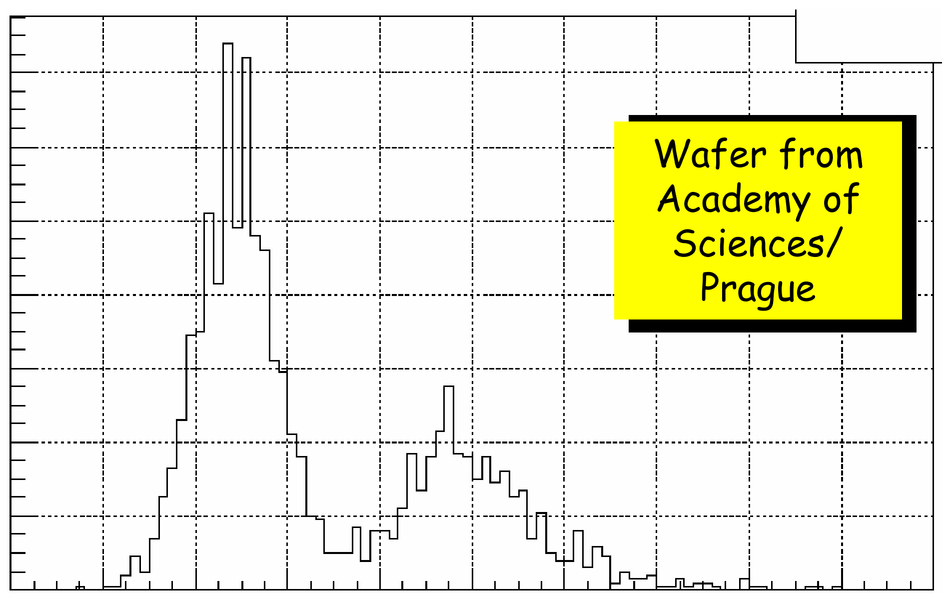

FLC_PHY3 in production

# First results with complete detector slabs




First results from source

Sr$^{90}$ source -> trigger -> read 1 channel




Coming soon: Cosmic test bench

Will allow intercalibration of channels – essential for best energy resolution

# ECal Summary/Future

- A lot of progress !

- All items required for first full prototype are in hand or in production.

- Objective/request: exposure of first full prototype to low energy electron test-beam at DESY before the end of 2004.

- Future: expose prototype to higher energy electron beam, and hadron beam at FNAL/IHEP in combination with HCal prototypes (various options).

# HCAL Requirements

Physics requirements emphasize segmentation/granularity (transverse AND longitudinal) over intrinsic energy resolution.

- Depth $\geq 4\lambda$ (not including ECal ~ $1\lambda$) + tail-catcher(?)

-Assuming PFlow:

  - sufficient segmentation to allow efficient charged particle tracking.
  - for "digital" approach – sufficiently fine segmentation to give linear energy vs. hits relation
  - efficient MIP detection
  - intrinsic, single (neutral) hadron energy resolution must not degrade jet energy resolution.

# Hadron Calorimetry

- General agreement on exploring the Particle Flow Algorithm(PFA) approach to achieve required jet energy resolution.

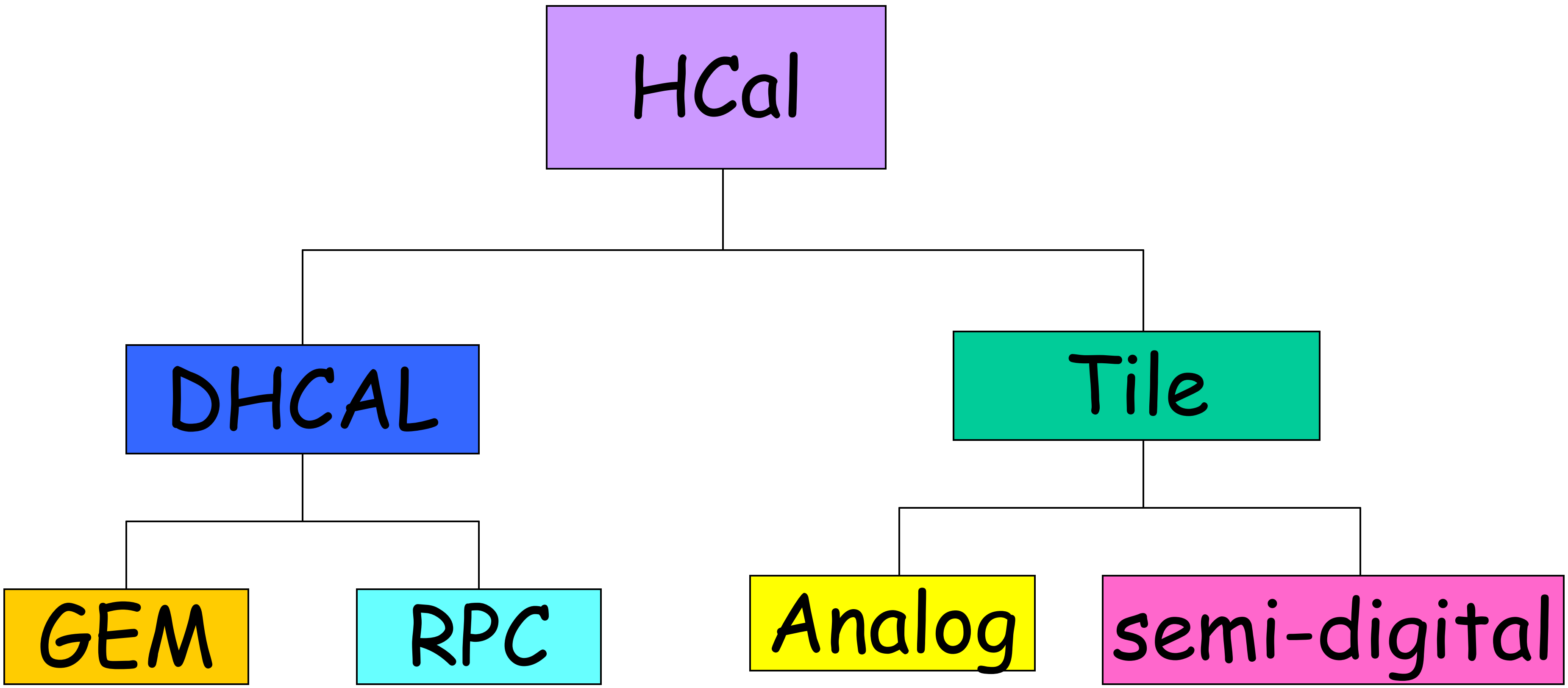
- PFA requirements translate into lateral segmentation of O(1 $cm^2$ -> 5 $cm^2$ ) and longitudinally O(30-40 layers).

?? Central question: what is the most effective way to implement the hardware for PFA??

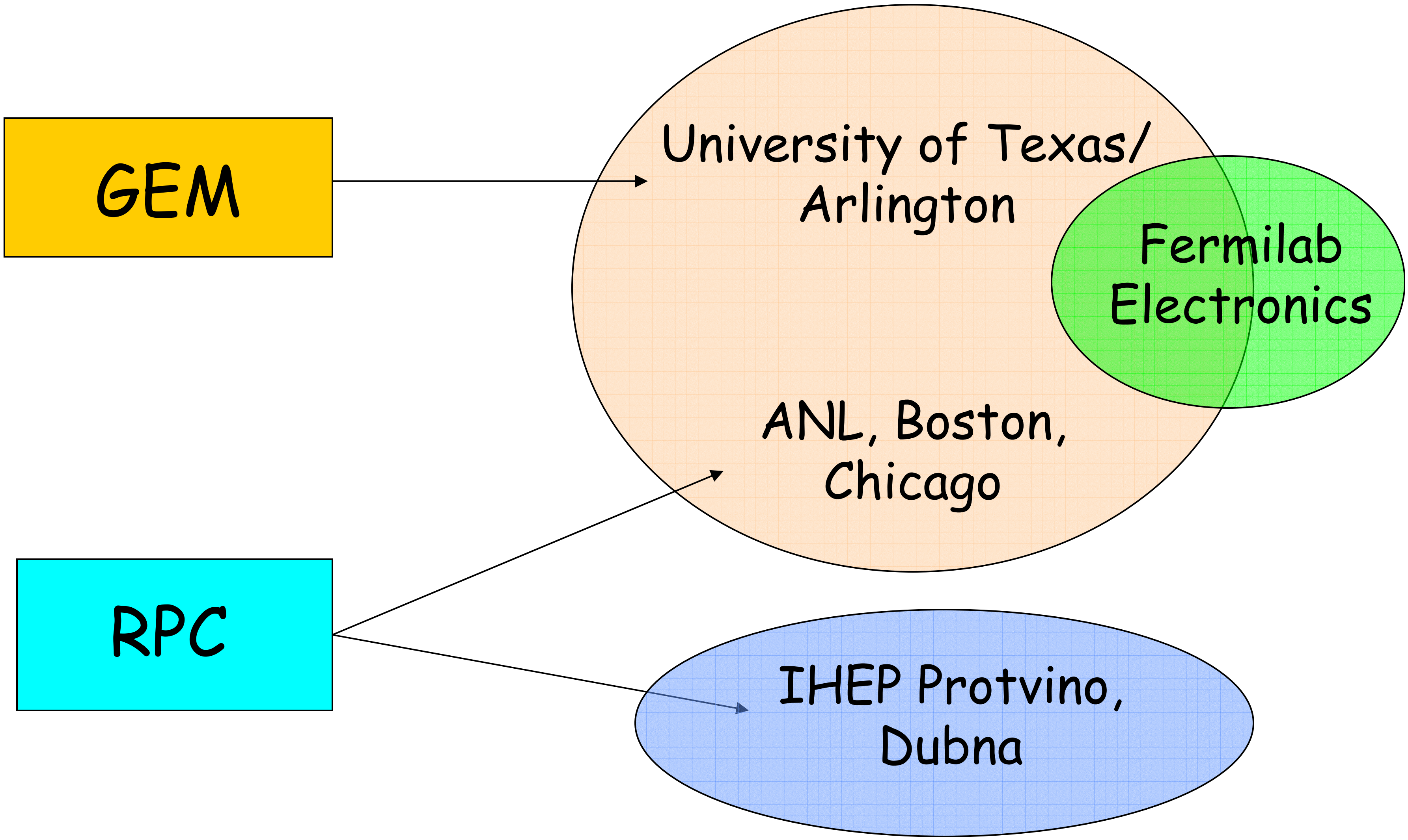
- Verification requires a combination of:

1) Test beam measurements
2) Monte Carlo verification at fine spatial resolution
3) PFA(s) development to demonstrate jet energy resolution.

# CALICE Hadron Calorimetry



# Digital Hadron Calorimetry



# DHCAL - GEM-based

## University of Texas at Arlington

- A flexible technology, easy to construct (non-demanding environment) and operate.

- Low voltage (~400V/foil) operation

- O(1 $cm^2$) cells easy to implement

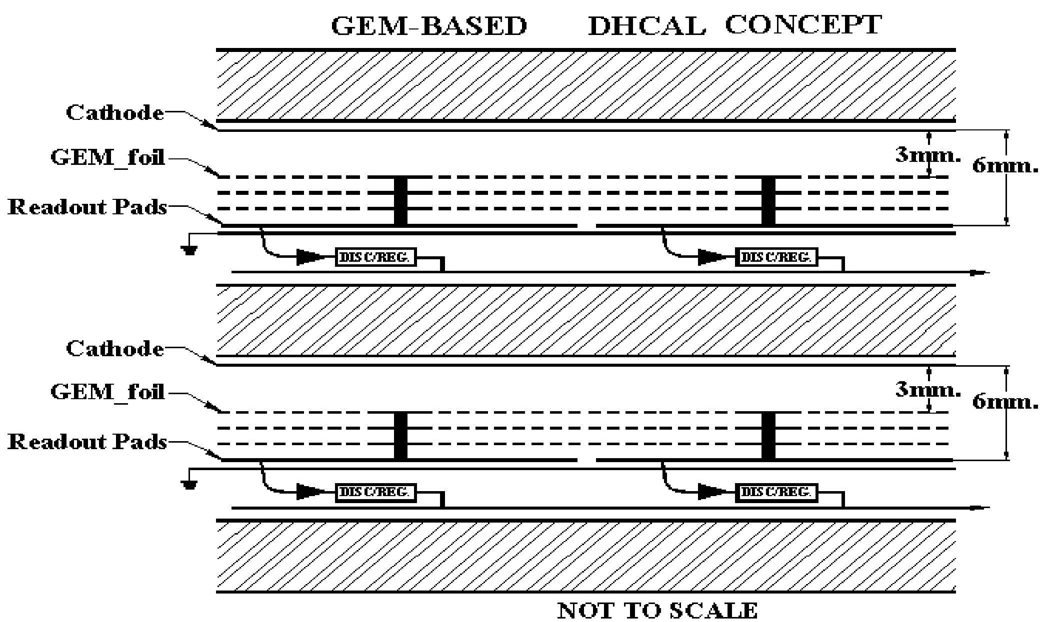
- Various small prototypes constructed to understand assembly procedures

- Prototypes tested with cosmics/source

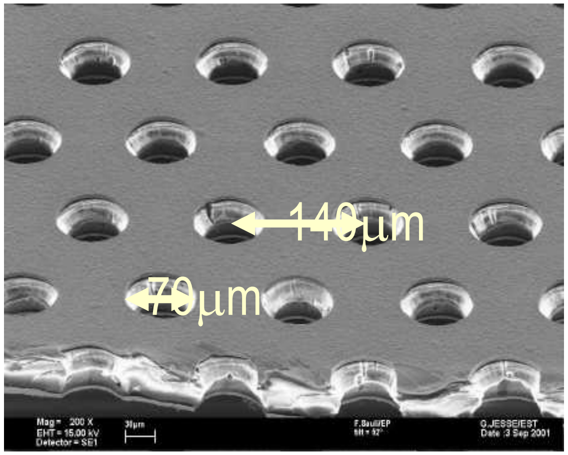
- Supplier(s) of GEM foils under consideration (promising discussions with 3M Corporation in Texas)

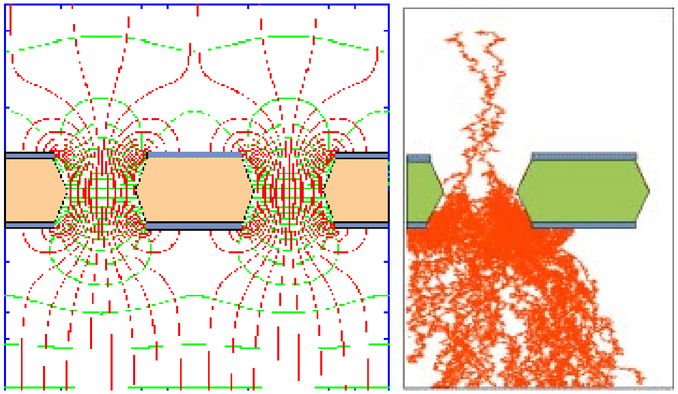
- Procedures for assembly of large scale mechanical prototypes of GEM active layers have been developed.

# Design for DHCAL using GEM



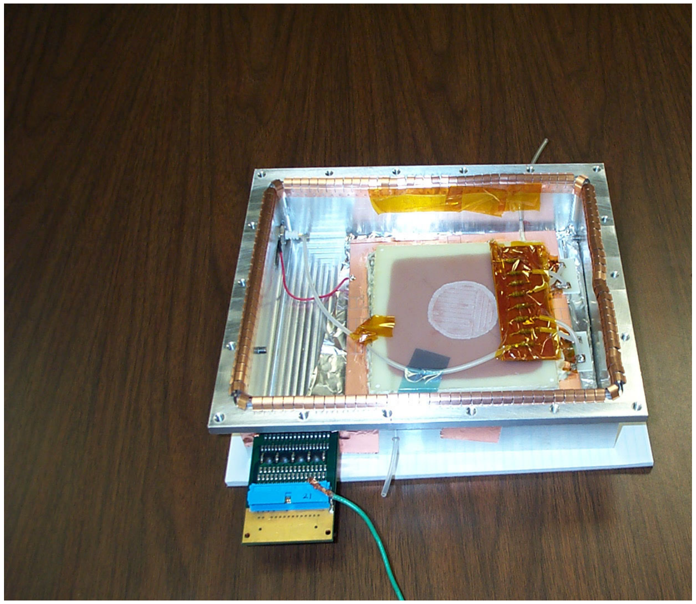

A.White (UTA) - 2001

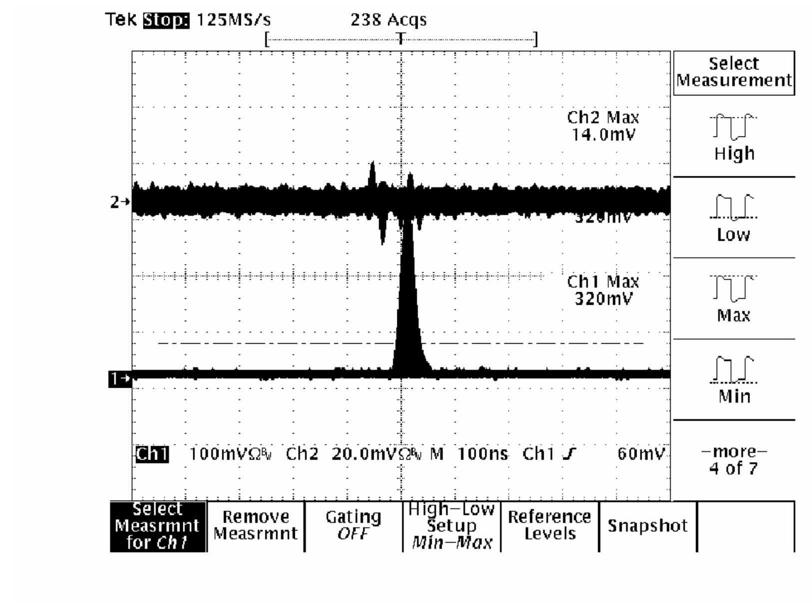


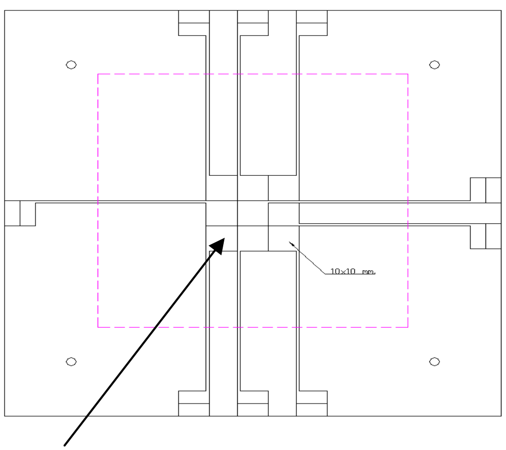



From CERN-open-2000-344, A. Sharma

# DHCAL - GEM-based - Prototype

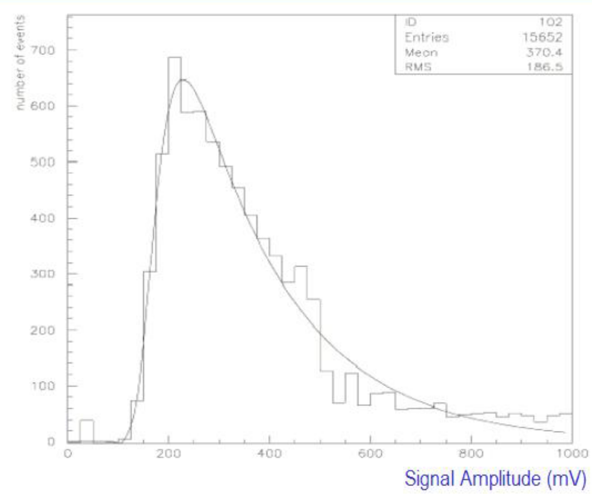




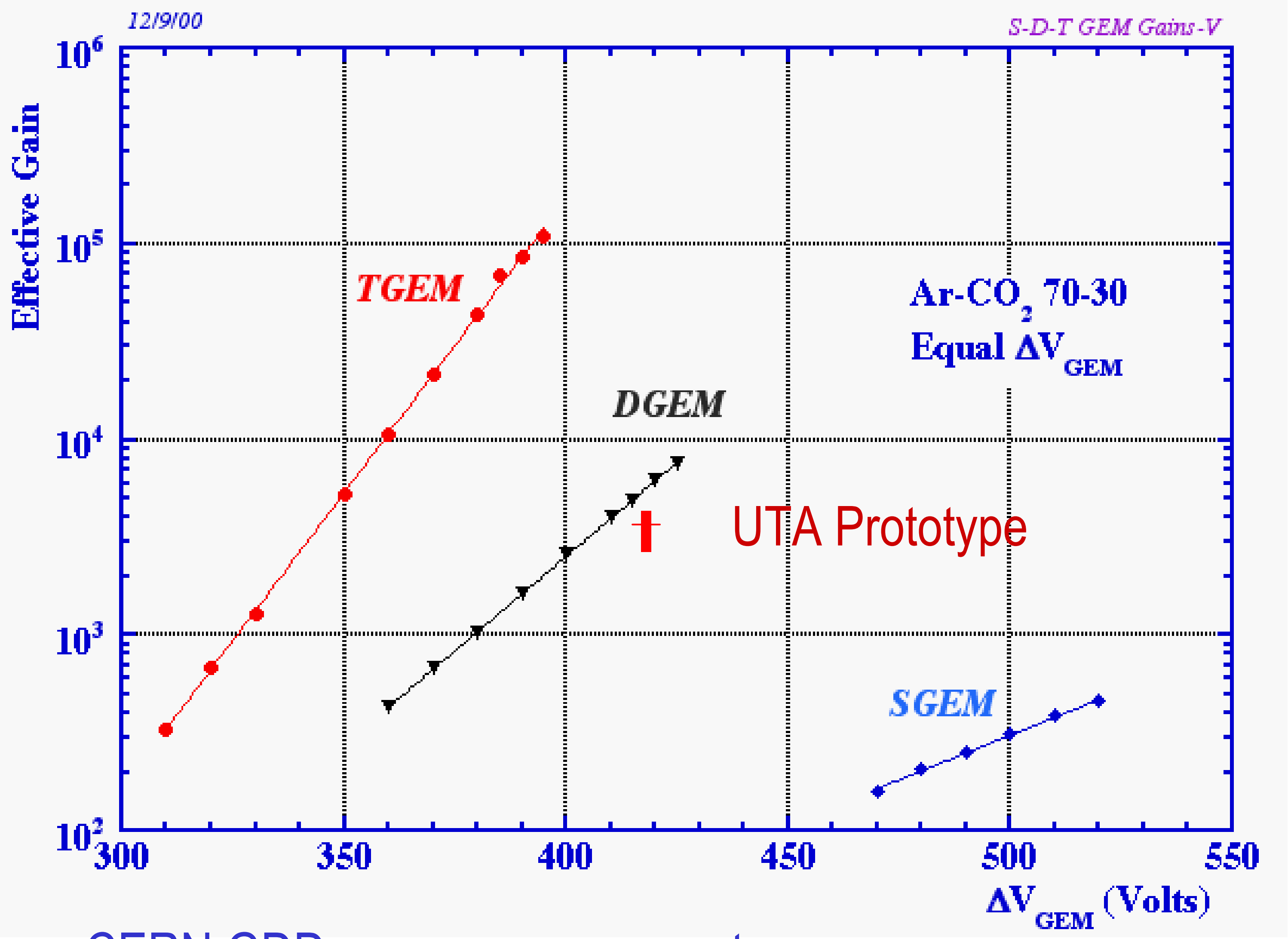




1 $cm^2$ GEM pad

## Landau Distribution from $Cs^{137}$ Source

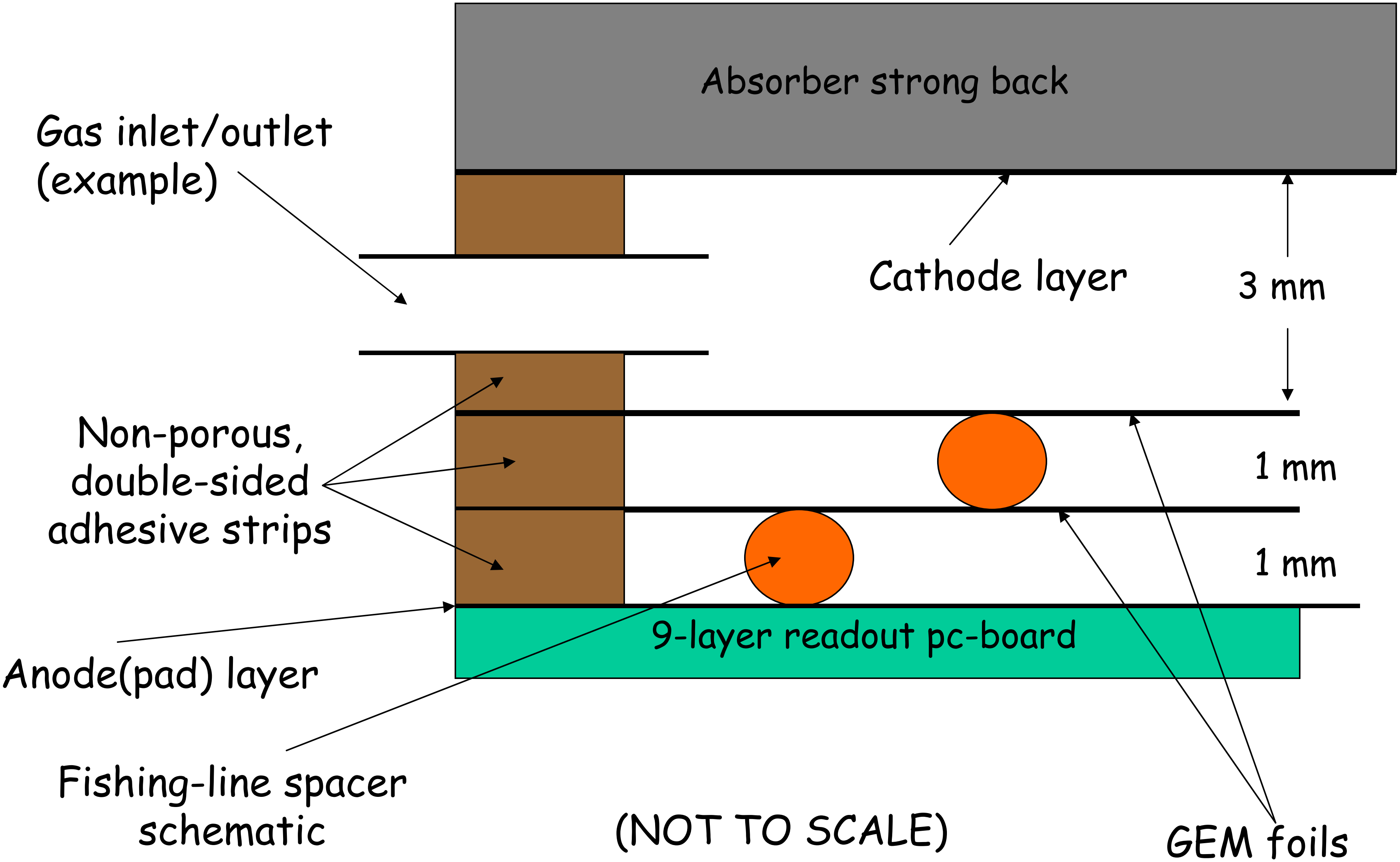


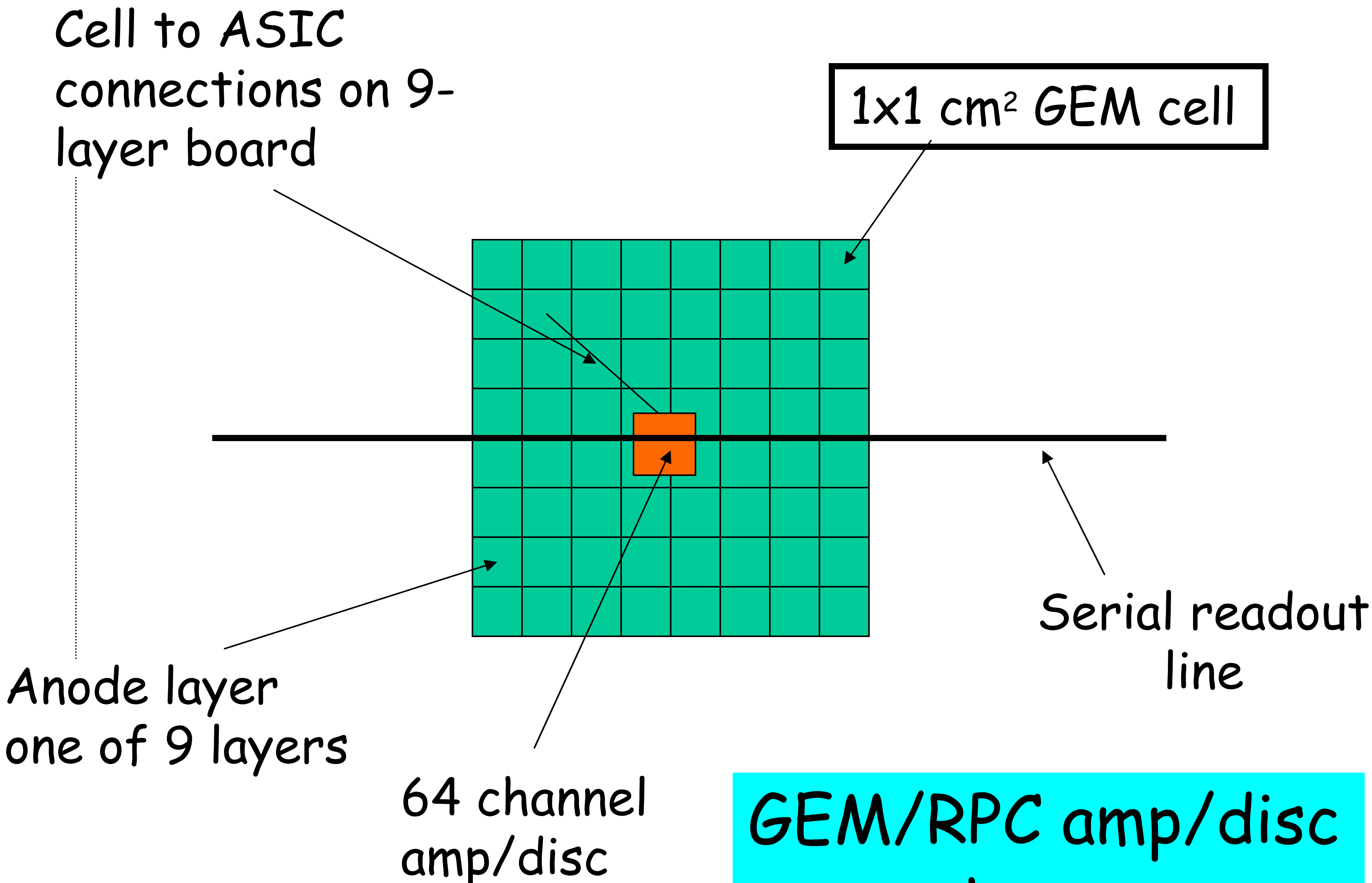
# Measured UTA GEM Gain




CERN GDD group measurements

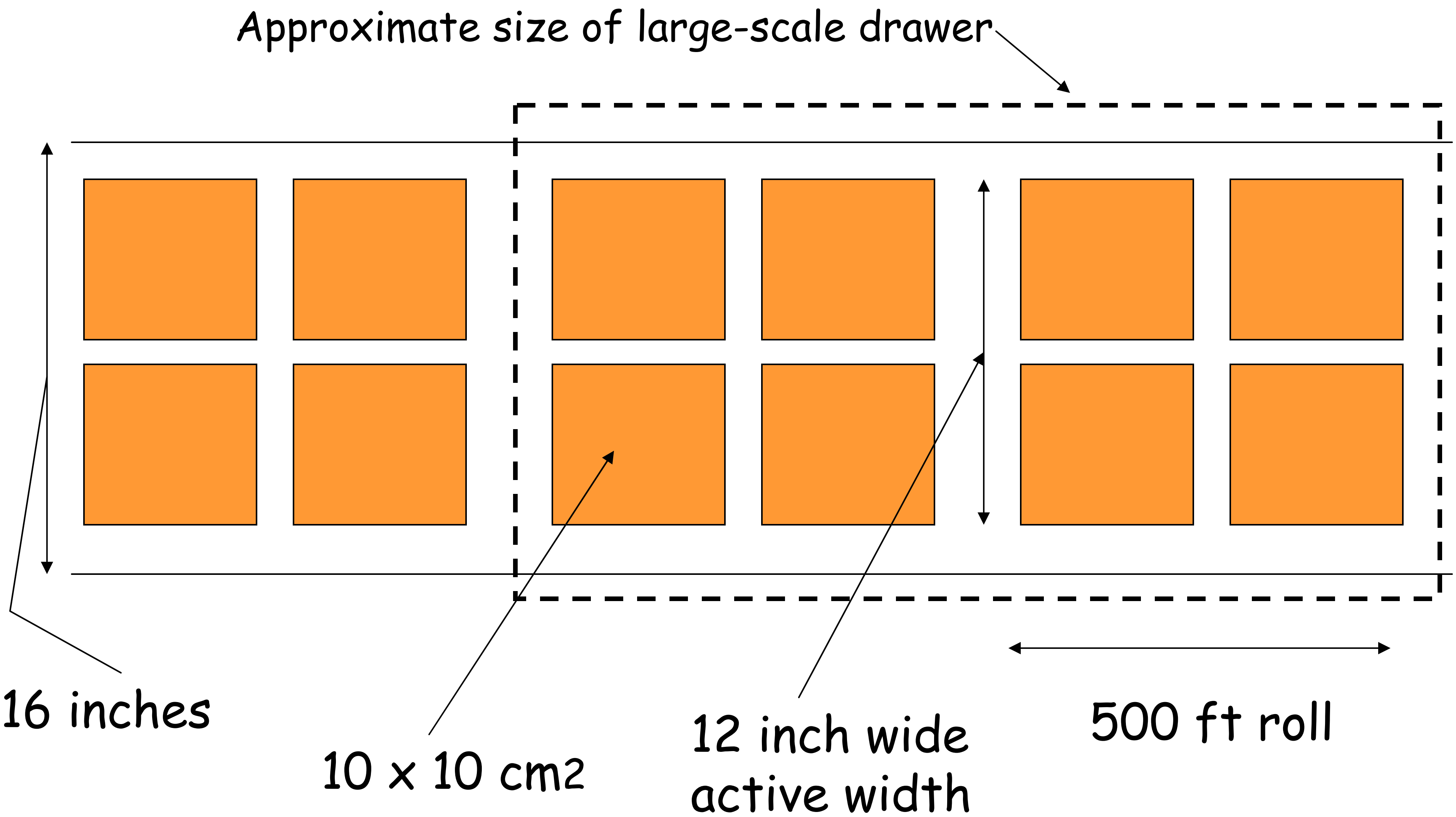
# Development of GEM sensitive layer



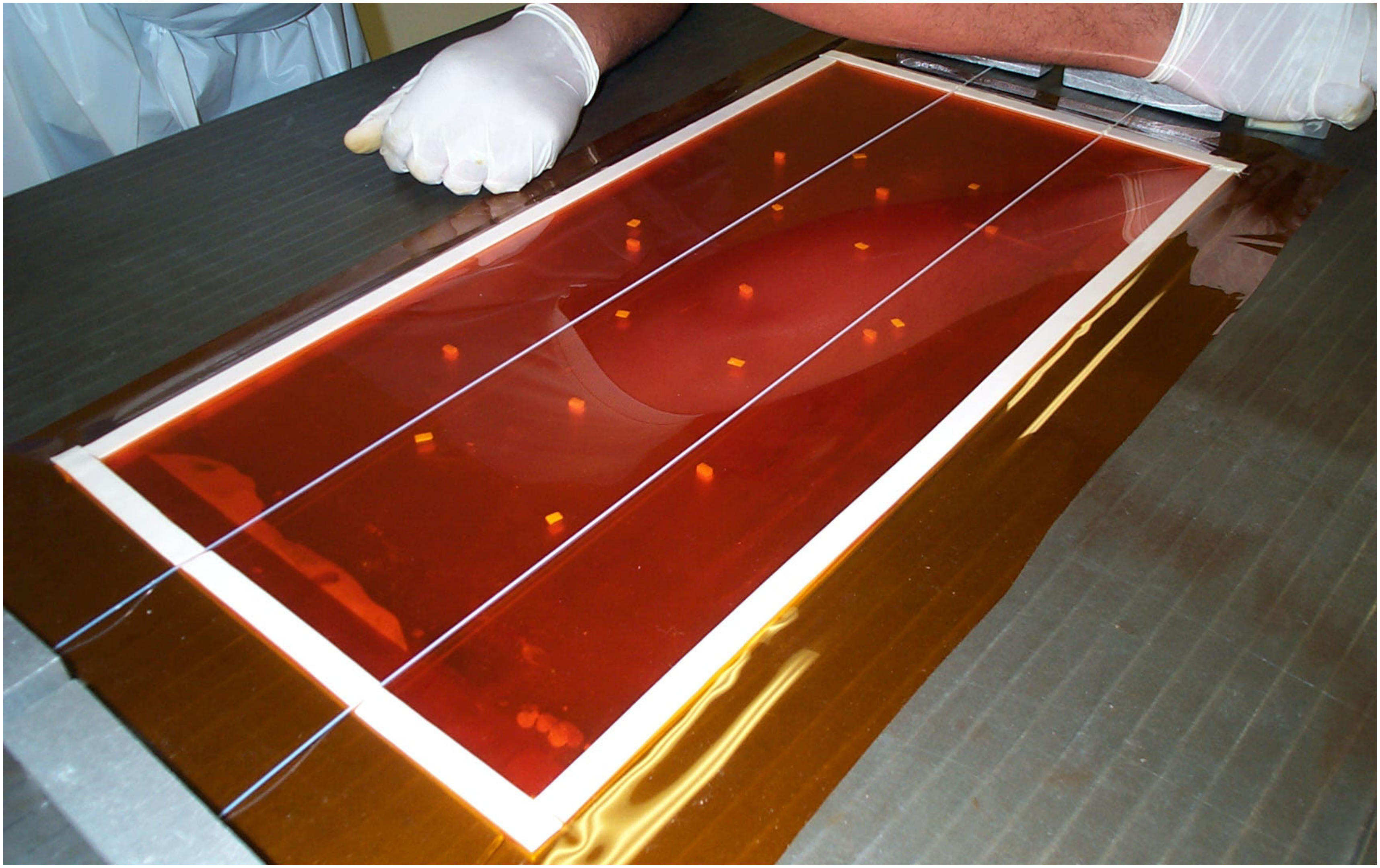



# GEM/RPC amp/disc concept

# GEM foil profile for large scale prototype(s)



“GEM” layer ready for laying down



An almost-complete mechanical double-GEM calorimeter layer

# DHCAL – GEM-based

- Assembly procedure for GEM chambers well understood.

- Basic signal characteristics established.

- Mechanical assembly procedures for large-scale GEM active layers developed.

- Assembly/testing of large-scale GEM layers awaits foil(s) purchase (3M quote next week).

- Working on common FEE with RPC (ANL).

- Work support by U.S. Dept. of Energy (ADR, LCRD), additional $70,000 just awarded.

- Goals:

  2004 – testing (source + cosmics) large layers.

  2005 – start contruction of layers for TB stack.

  2006 – joint tests with RPC group in TB

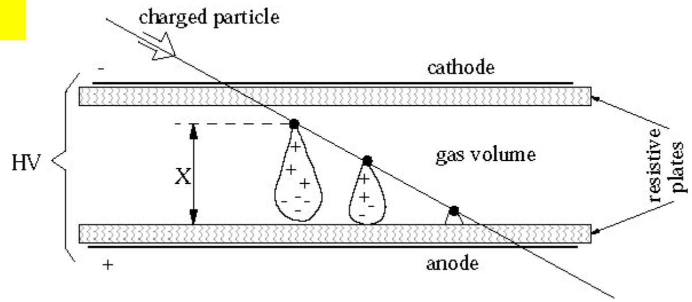
# DHCAL – RPC-based

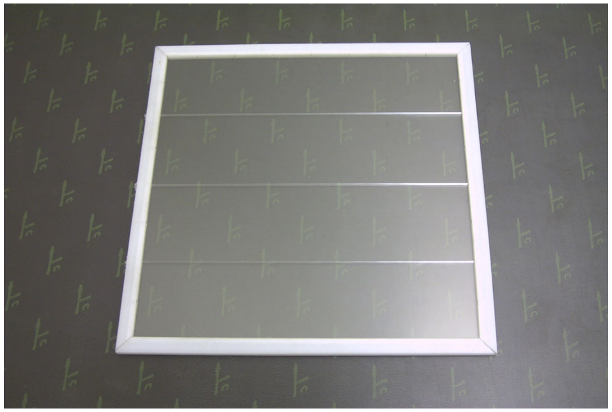
- Easy assembly techniques
- Mechanically robust layers.
- Large signal sizes (several pC's)
- High voltage operation - ~7-9 KV
- O(1 cm$^2$) cells easy to implement
- Possibility of using common RPC/GEM FEE

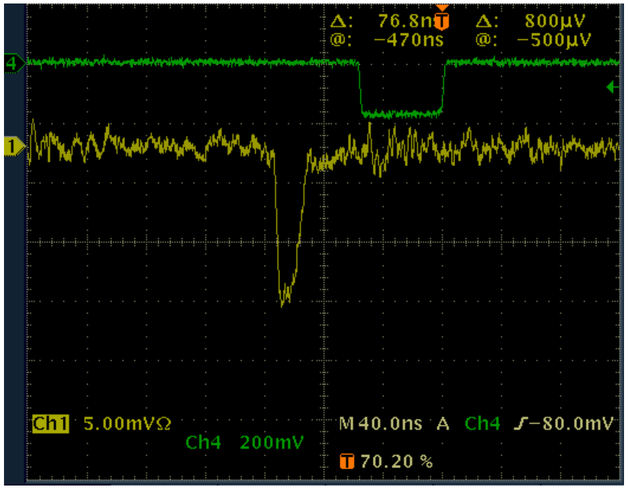
# DHCAL – RPC-based

## 1) ANL, Boston, Chicago, Fermilab

- RPCs are simple detectors
  - Parallel resistive plates
  - Enclosed gas volume
  - Apply HV across gas volume, by resistive ink layer
  - External pad(s) to pick up signal
- Basic cosmic ray test setup
  - Single test pad + analog readout
    - Signal charge, efficiency, operational modes, etc.
  - Multiple readout pads + analog readout
    - Charge distribution on pads, efficiency, hit multiplicity
  - Multiple readout pads + digital readout
    - Efficiency, hit multiplicity, noise rates
    - Close to the running condition in a digital calorimeter



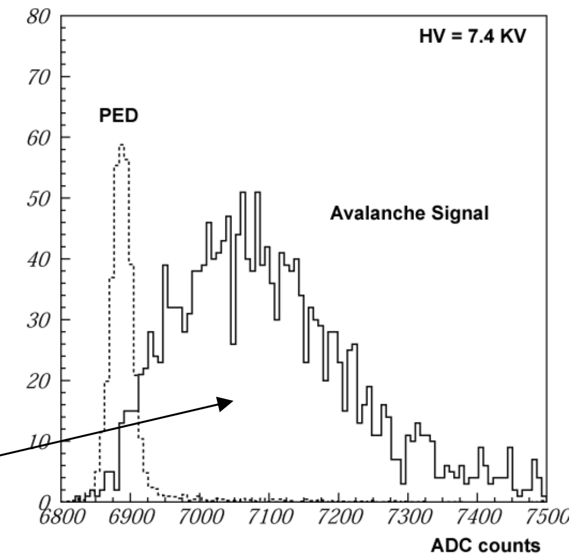


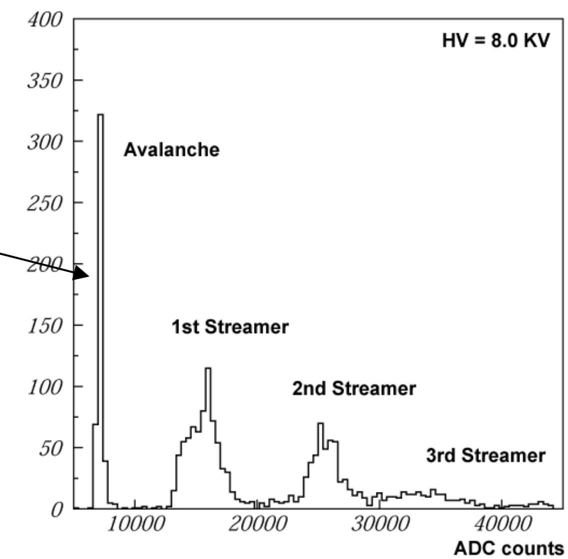
# DHCAL – RPC-based

- Large single pad to cover whole chamber
- Trigger: cosmic ray 'telescope'
  - Signal rate ~1Hz, trigger area ~10x10cm$^2$

- Analog readout: 'RABBIT' system (CDF)
  - Measure total charge of a signal
  - Charge resolution ~1.1fC/ADC bit, dynamic range ~ -6pC to ~ +60pC, very low noise level
  - Multi-channel readout

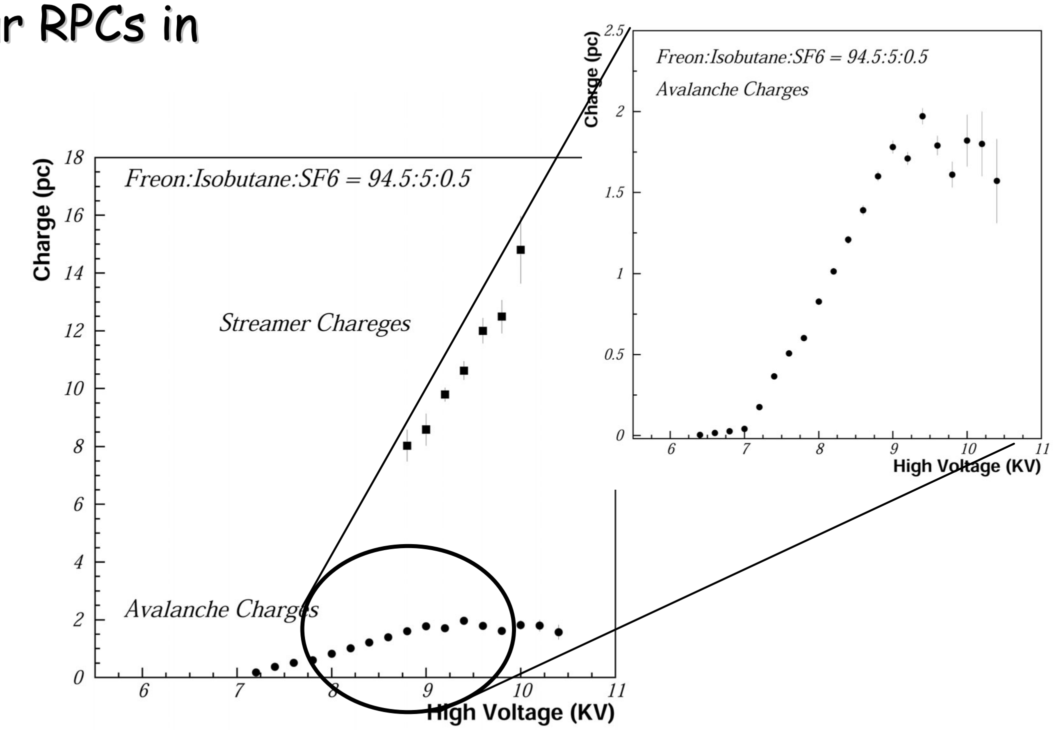
- Two modes of operation
  - Avalanche
    - Average signal charge: 0.2 – 10+ pc
    - Lower operating voltage
    - Typical efficiency ~99%
    - Very low noise level
    - Rate capability <1kHz/cm$^2$
  - Streamer
    - Average signal charge: 10 – 100+ pc
    - Higher operating voltage
    - Typical efficiency ~90%
    - Rate capability ~10Hz/cm$^2$
    - Multiple streamers



# DHCAL – RPC-based

- At low operating voltage, RPC runs in pure avalanche mode, the voltage range for this running mode is called ‘avalanche plateau’
- At higher operating voltage, streamer signal starts to appear
- We would like to operate our RPCs in avalanche mode

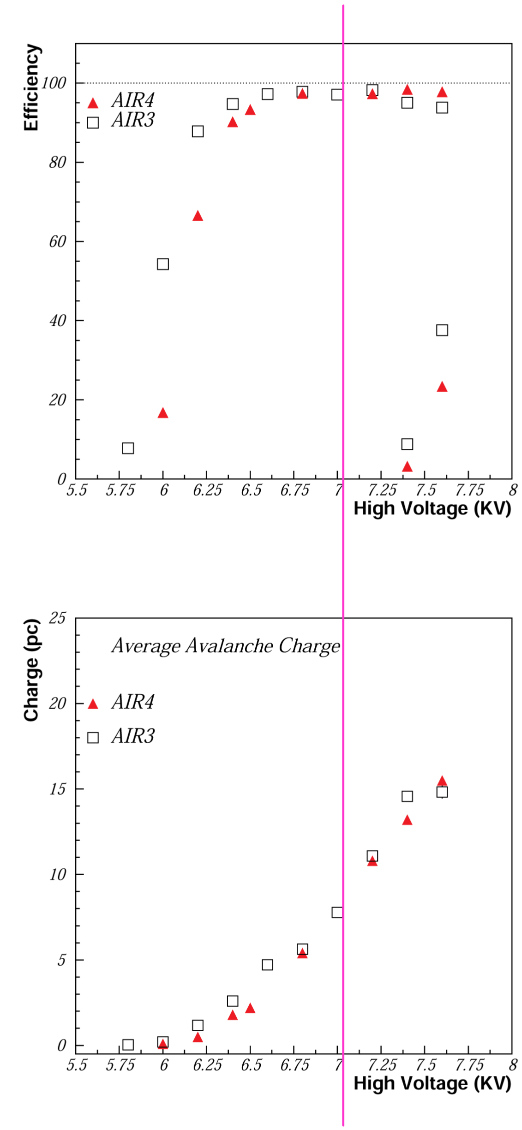


# Test results: single pad + analog readout

- Gas mixture for RPC operation
  - Avalanche mode:

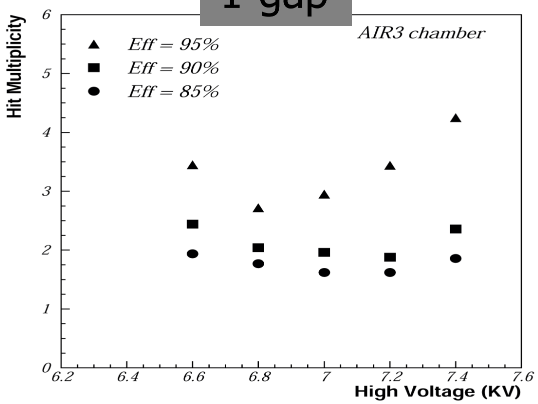
    Freon:IB:SF6 = 94.5:5:0.5
  - Streamer mode:

    Ar:Freon:IB = 30:62:8
- Results from different chamber configurations
  - Built 6 chambers with different glass thickness, number of gaps, paint resistivity – all chamber work very well
  - 1-gap chamber and 2-gap chambers, same total gap size (1.2mm)
    - 1-gap chamber: lower operating voltage (~7KV), higher signal charge, smaller plateau range (~0.6KV)
    - 2-gap chamber: higher operating voltage (~8KV), smaller signal charge, larger plateau range (~1.0KV)
  - Two chambers built separately, with same configuration:
    - Very similar results obtained – showed consistent chamber construction

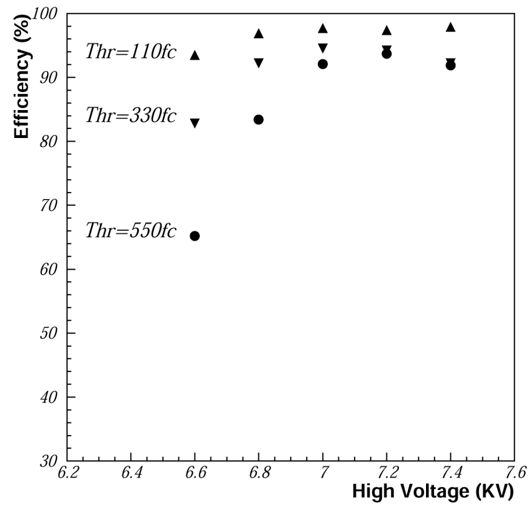


# Multiple readout pads + analog readout: hit multiplicity with avalanche signal

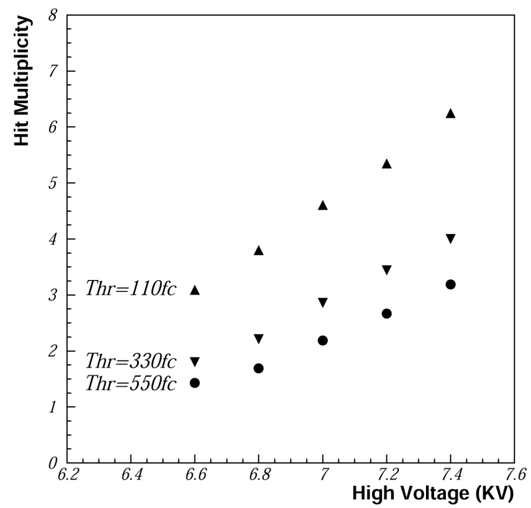
1-gap

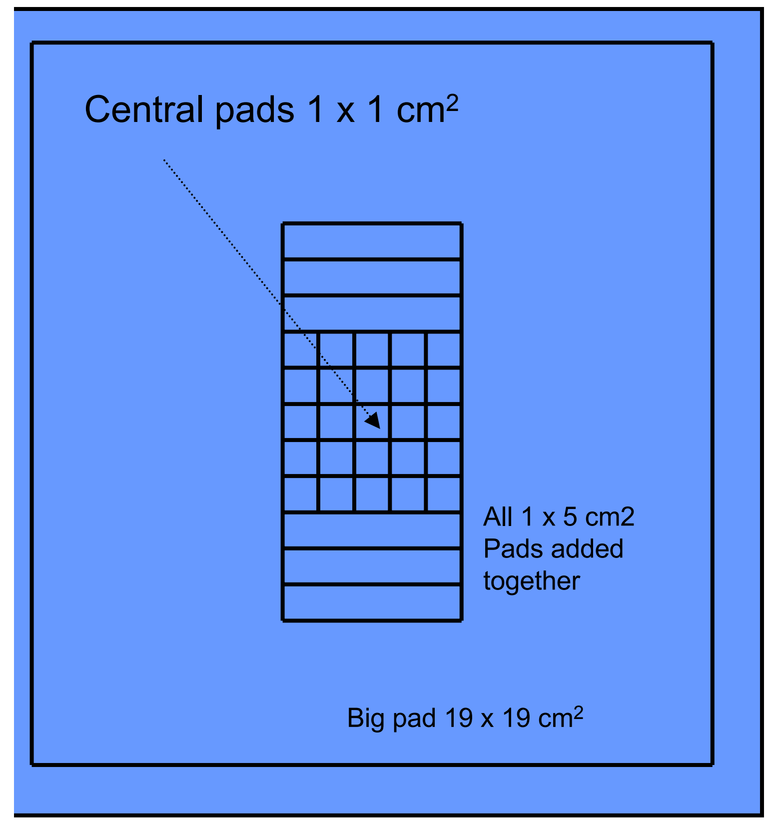



**M ~ 2.7, for eff = 95%**
**M ~ 1.9, for eff = 90%**
**M ~ 1.6, for eff = 85%**



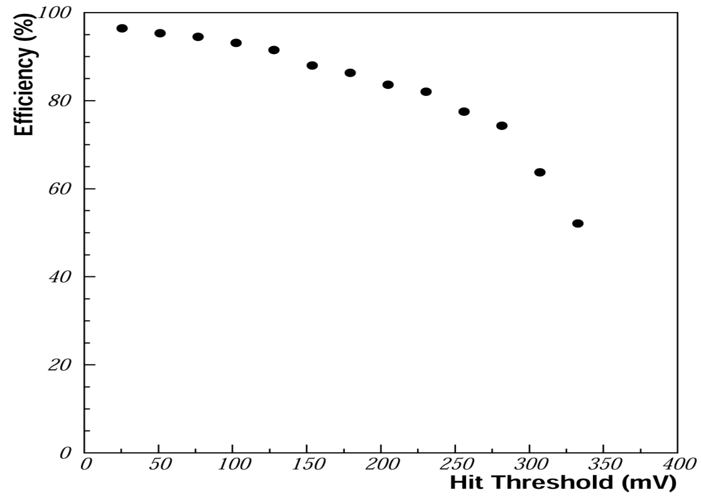

Hit multiplicity →

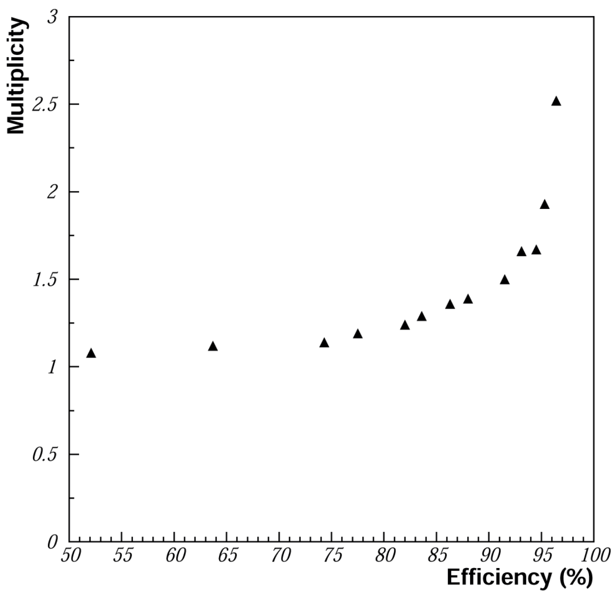


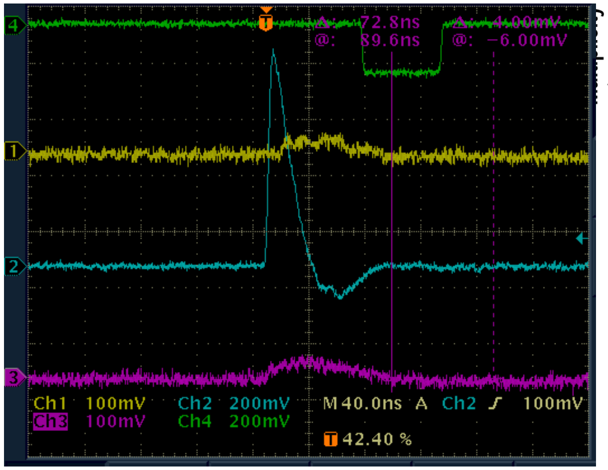



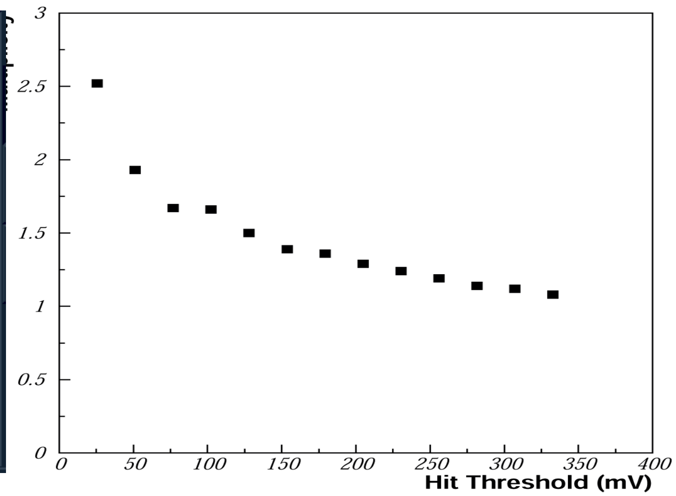
# Multiple pads + digital readout: hit multiplicity with avalanche signal

- Test with 1-gap chamber, 8x8 pads, 6.8KV
  - Avalanche mode, eff ~ 97%
- Better hit multiplicity at higher threshold, at the cost of lower efficiency
- Number of pads seeing signal:
  - Most of events: 1 or 2 pads
  - Small fraction: 3 or 4
  - Almost none: 5 or more



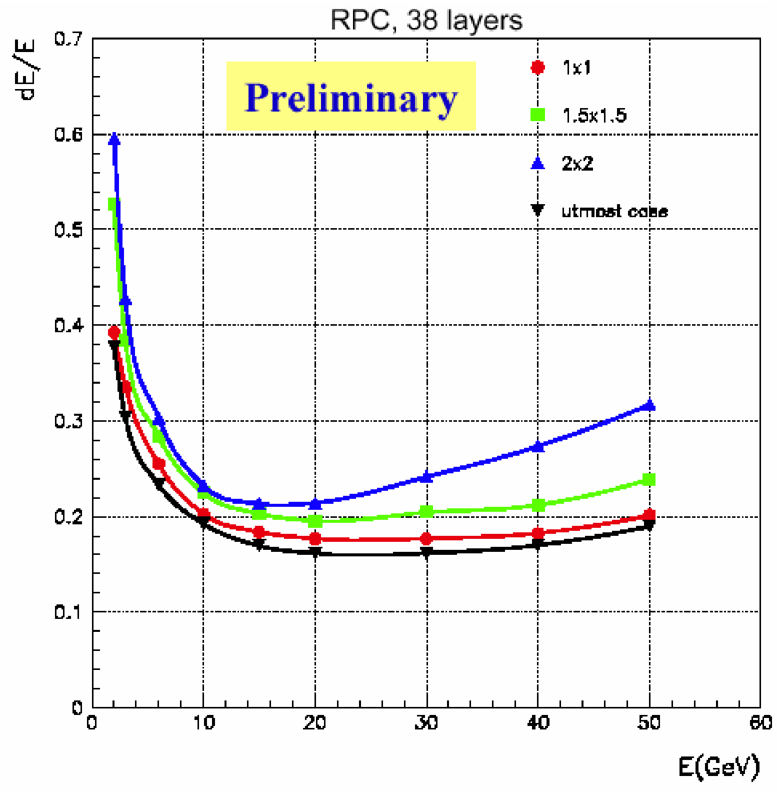



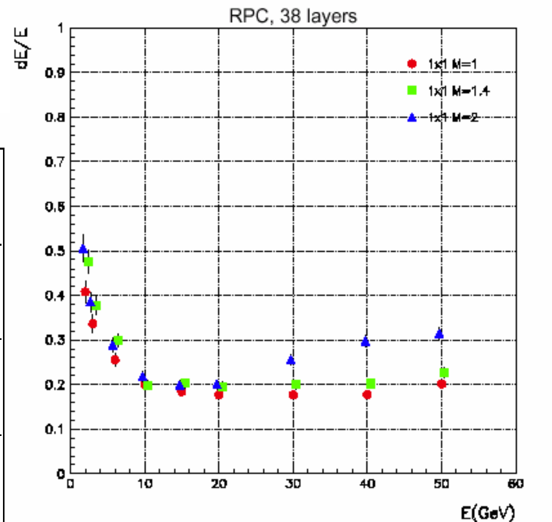



# DHCAL – RPC-based

## 2) IHEP-Protvino

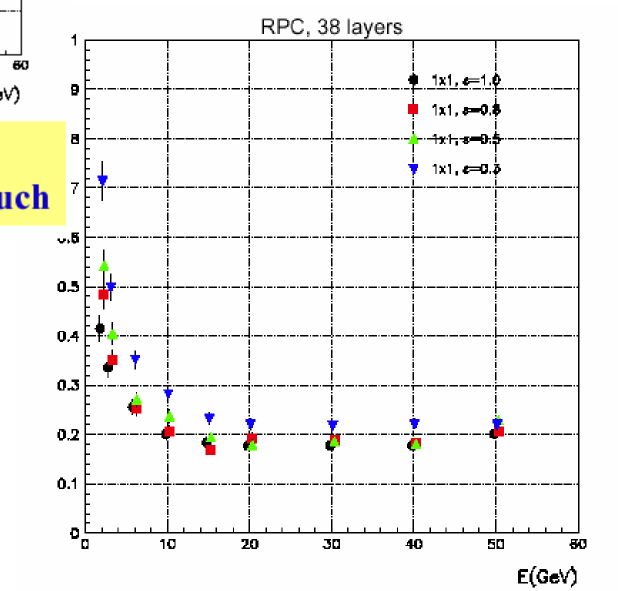
Pad size simulation study




It seems <m> up to 1.4-1.5 does not hurt resolution much

From V.Ammosov/LCWS 2004



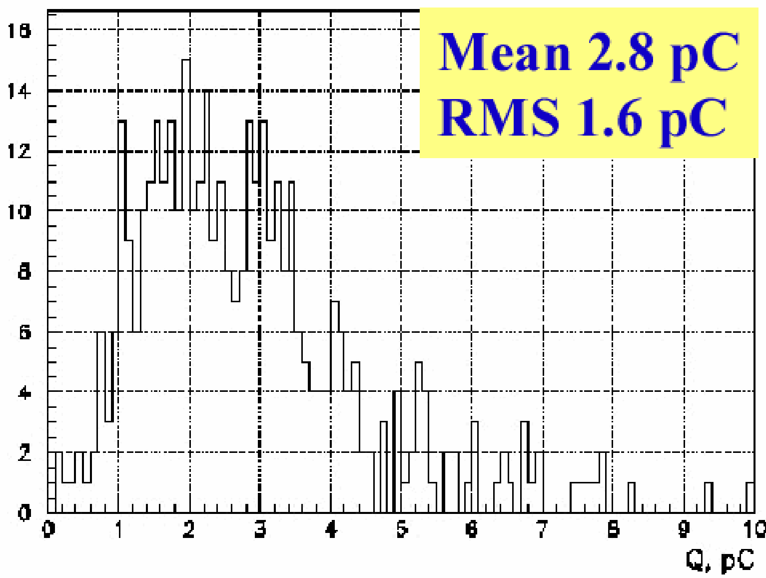

It seems eff down to 80% does not hurt resolution much

# DHCAL – RPC-based

## RPC in avalanche mode

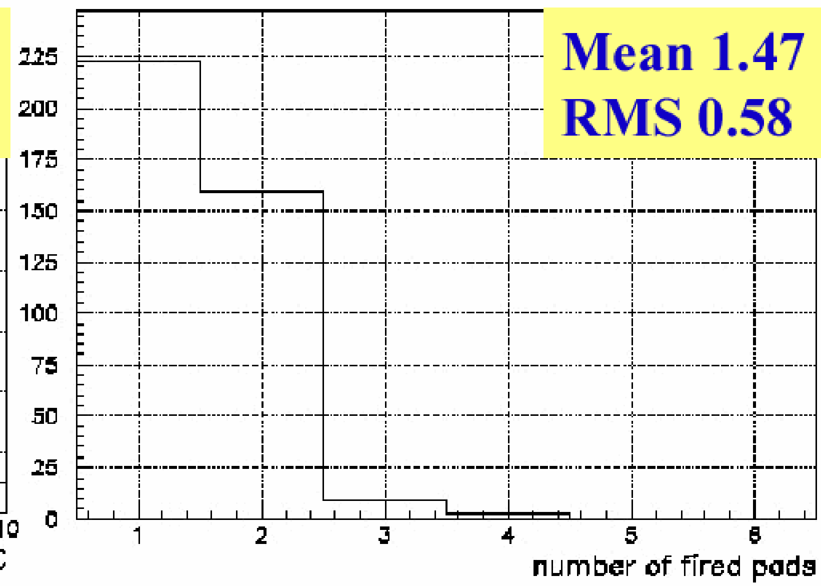
**Typical Q and m distributions**

**1.2 mm, 2% $SF_6$, 8.4 kV - working point, 2.2 mV thr**




**Mean 2.8 pC**
**RMS 1.6 pC**

**Q ~ $10^7$ e**




**Mean 1.47**
**RMS 0.58**

**2 adj pads**

# DHCAL – RPC-based

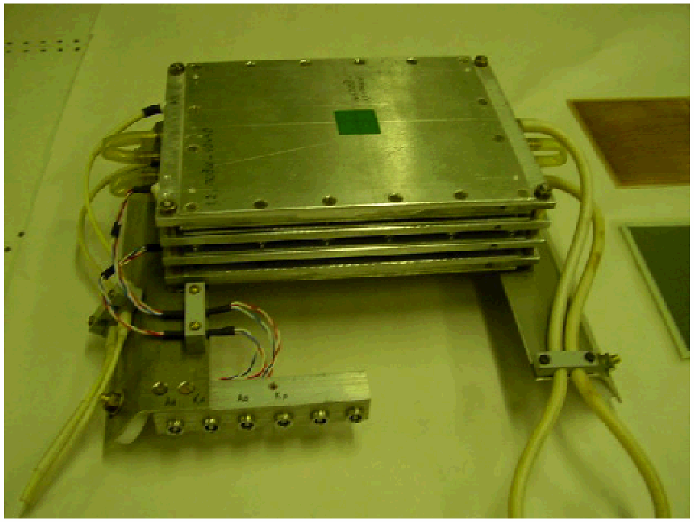
## Summary of RPC features

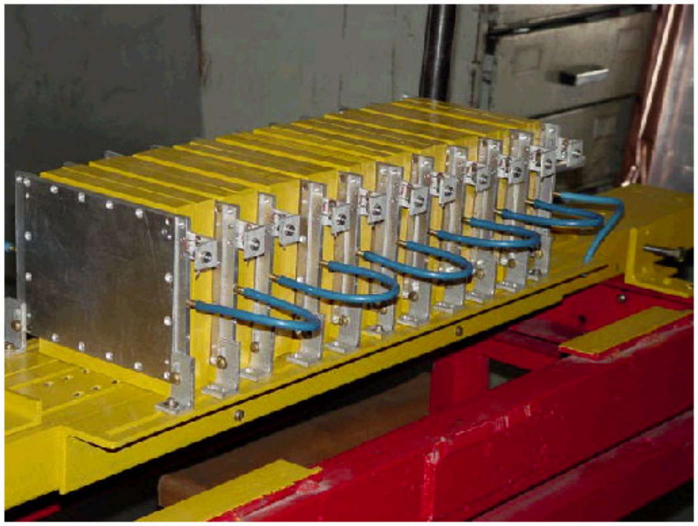
| № | Item | Value | Comments |
|---|---|---|---|
| 1 | Pad size | 1x1 cm2 | |
| 2 | Number of gaps | monogap | |
| 3 | Mode of operation | saturated avalanche | |
| 4 | Working mixture | TFE/Iso/SF6=93/5/2 | |
| 5 | Gas gap | 1.2 mm | 1.6 mm can be used |
| 6 | Resistive plates | thin glass,10^13 Ω·cm | |
| 7 | HV working point, kV | 7.4 | |
| 8 | Induced charge, pC | ~3 | |
| 9 | Threshold on 50Ω, mV | 1-2 | |
| 10 | Efficiency, % | ~98 | |
| 11 | HV plateau | ~600 V | |
| 12 | $\sigma_Q$ / Q | ~ 1 | |
| 13 | Pad multiplicity | 1.4-1.5 ? | |
| 14 | Noise, Hz/cm$^2$ | ~ 0.5 | |
| 15 | Rate capability, Hz/cm$^2$ | ≤100 | |
| 16 | Resistivity of HV coverage | > 10^6 Ω/ sq | |
| 17 | Control of RPC work | Q RO of cathode strips | |
| 18 | Maximal own RPC thickness<br>with 2 mm SS cups | 6 mm<br>10 + 0.5 mm | try to keep 5 mm |

# DHCAL – RPC-based

## Planned activities

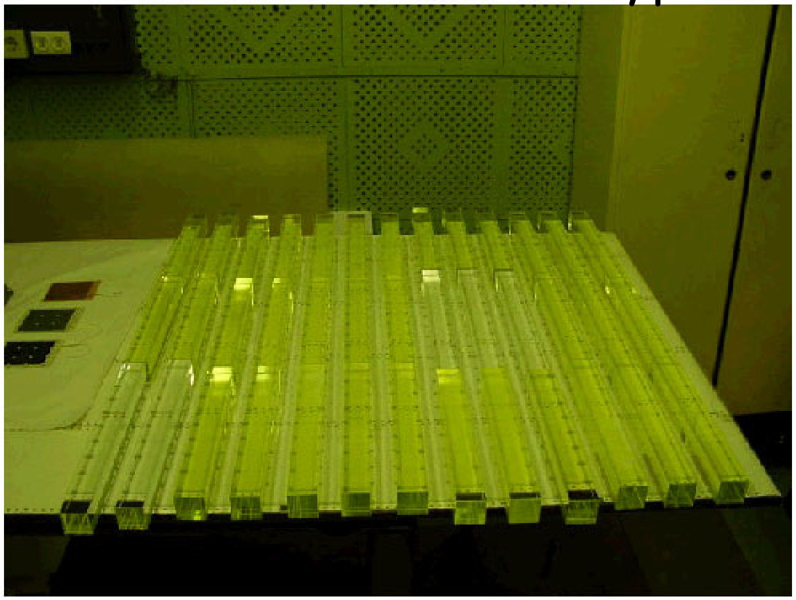
5T test





Mini DHCAL

1 $m^3$ DHCAL Prototype



Readout: Minsk chip/ALTERA FPGA

| | |
|---|---|
| - 5T mag field test | June04 |
| - Mini DHCAL test in e-beam | Dec04 |
| - production of 40 units of 1m2 RPC planes for 1m3 DHCAL prototype | Apr05 |
| - beam tests of 1m3 DHCAL prototype | Dec05 |

# Tile Calorimeter

Prague, DESY, Hamburg, ITEP, JINR, LPI, MEPhI, NIU, LAL, UK

- Combines well-known scintillator/wavelength shifting fiber technology with new photo-detector devices.

- Small tiles required for implementation of PFA.

- Explore analog and semi-digital approaches – optimize spatial and analog information use.

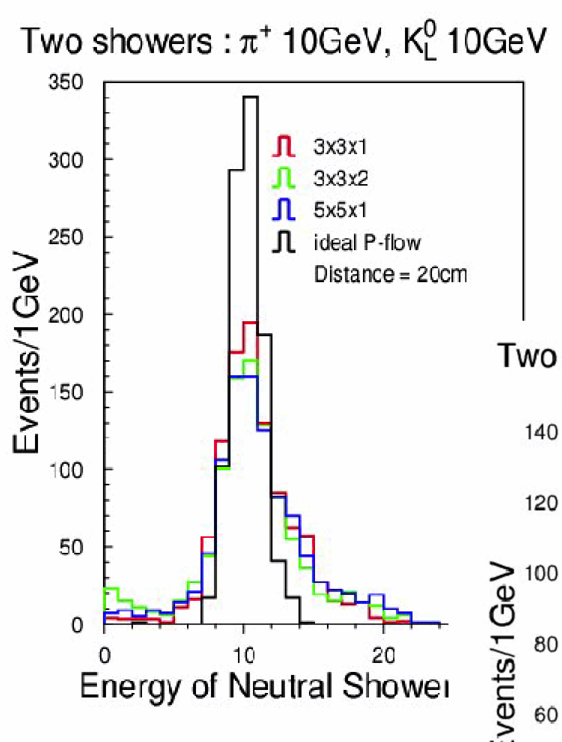
- Must verify simulation description of hadronic showers at high granularity.

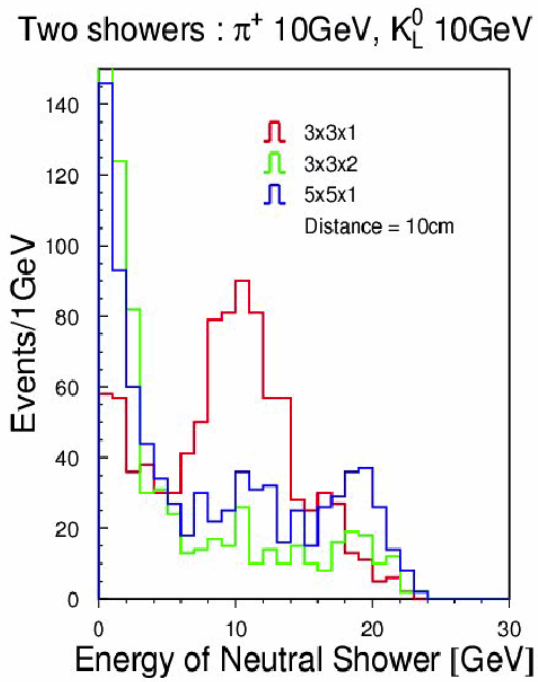
- Results from “minical” prototype

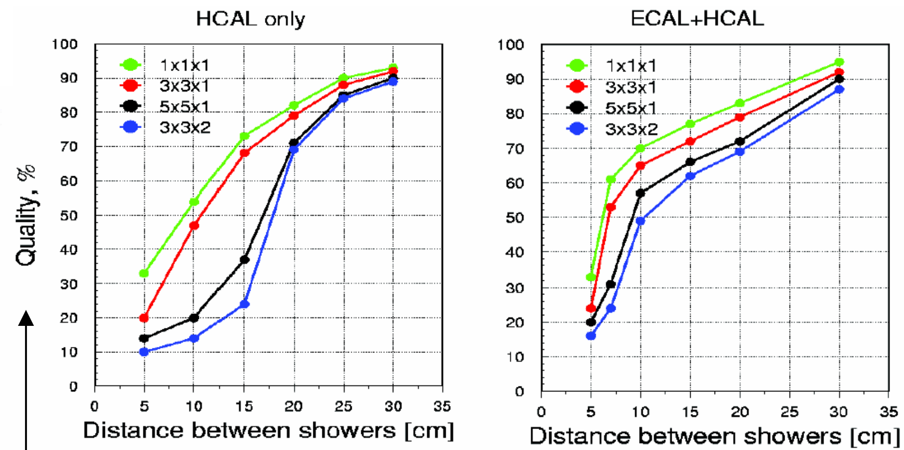
- Plans for cubic-meter stack

# Tile HCal - Granularity

DESY simulation – tree algorithm



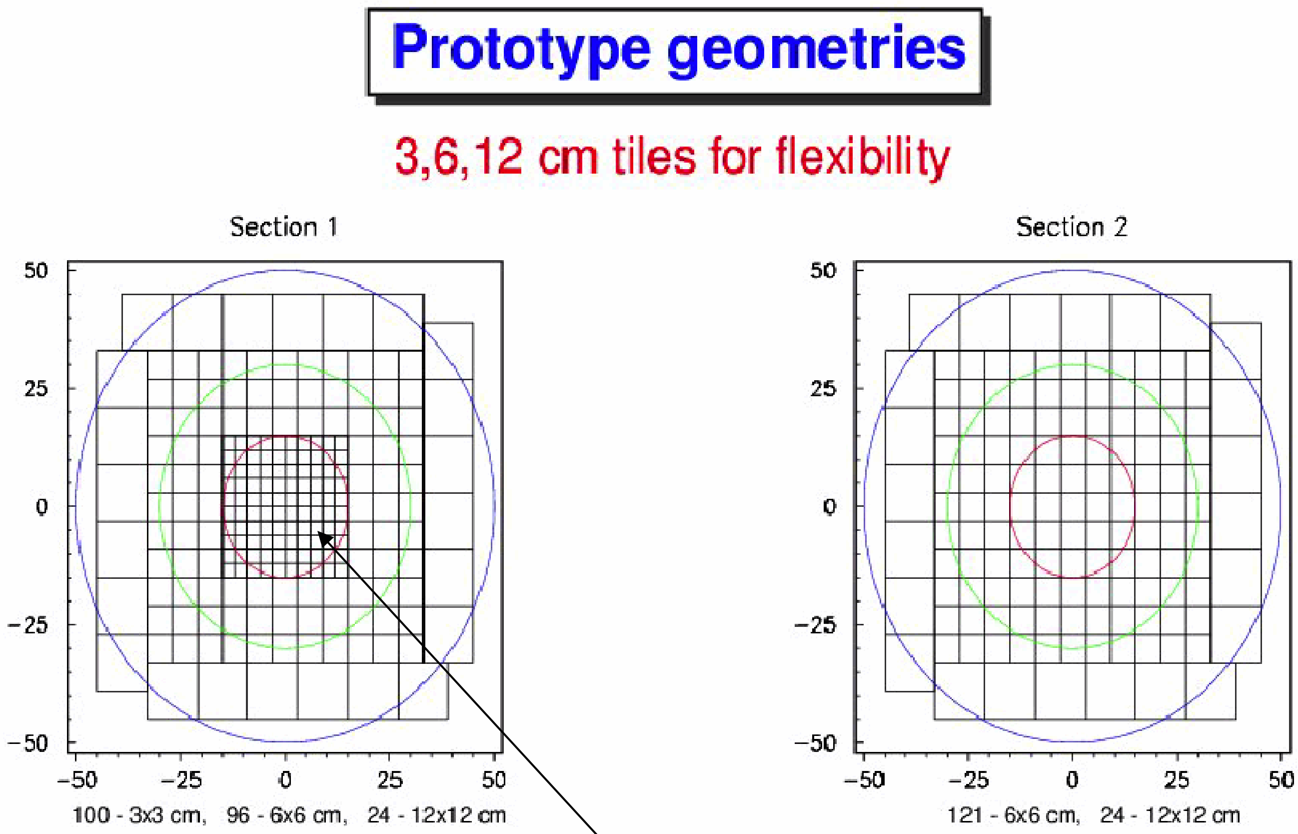




Shower sepn. quality: fraction of events with E(neutral) within 3$\sigma$ of reconstructed isolated neutral shower.

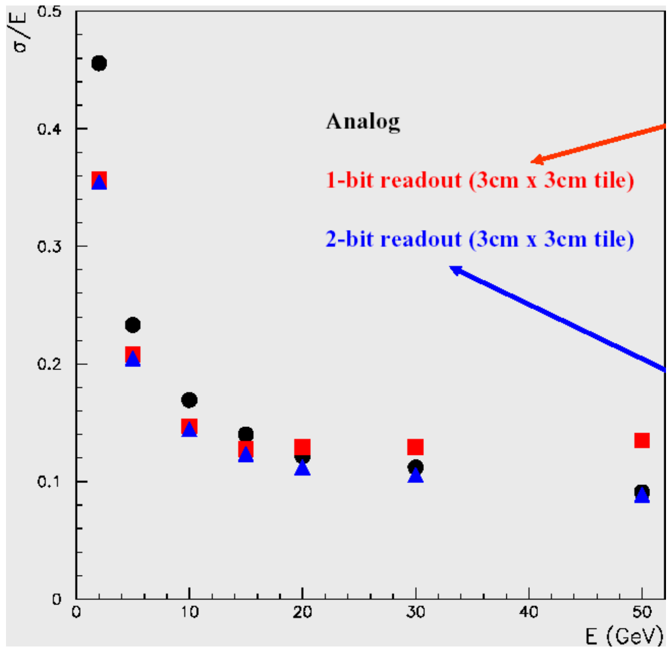
3 x 3 x 1 looks a good practical choice

# Tile HCal – Granularity for Prototype




Cost constraints limit prototype to
core-only maximum granularity

# Tile HCal – Semi-digital option (NIU)

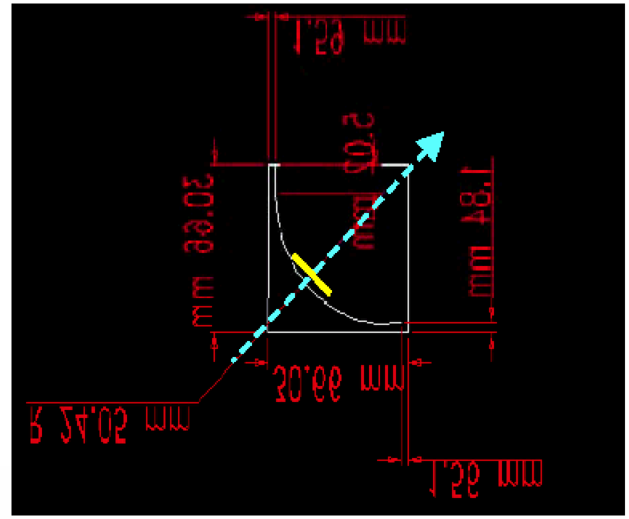



Improvement seen in simulations with 2-bit readout for 3cm x 3cm tiles – overcomes multiple hits/cell issue in dense showers.

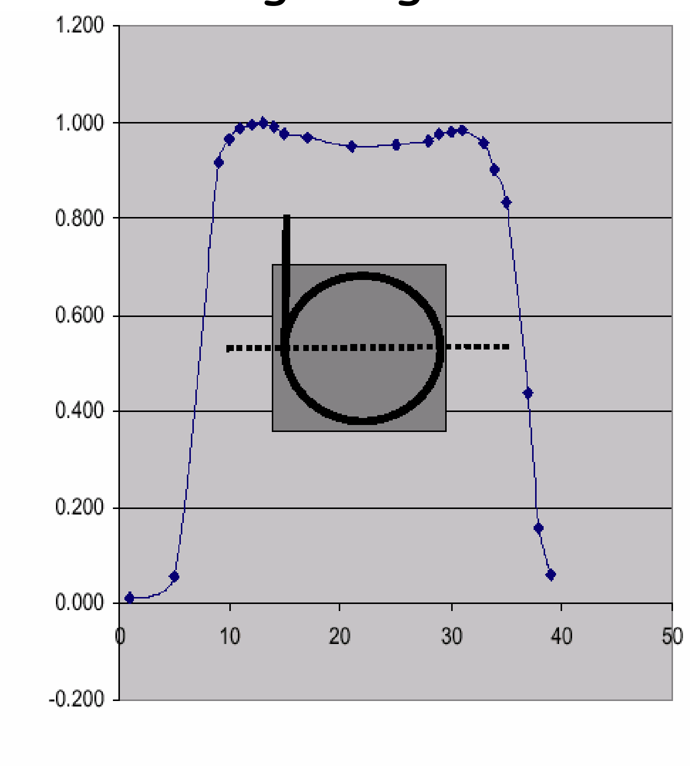
# Tile HCal – Scintillator tile/fiber

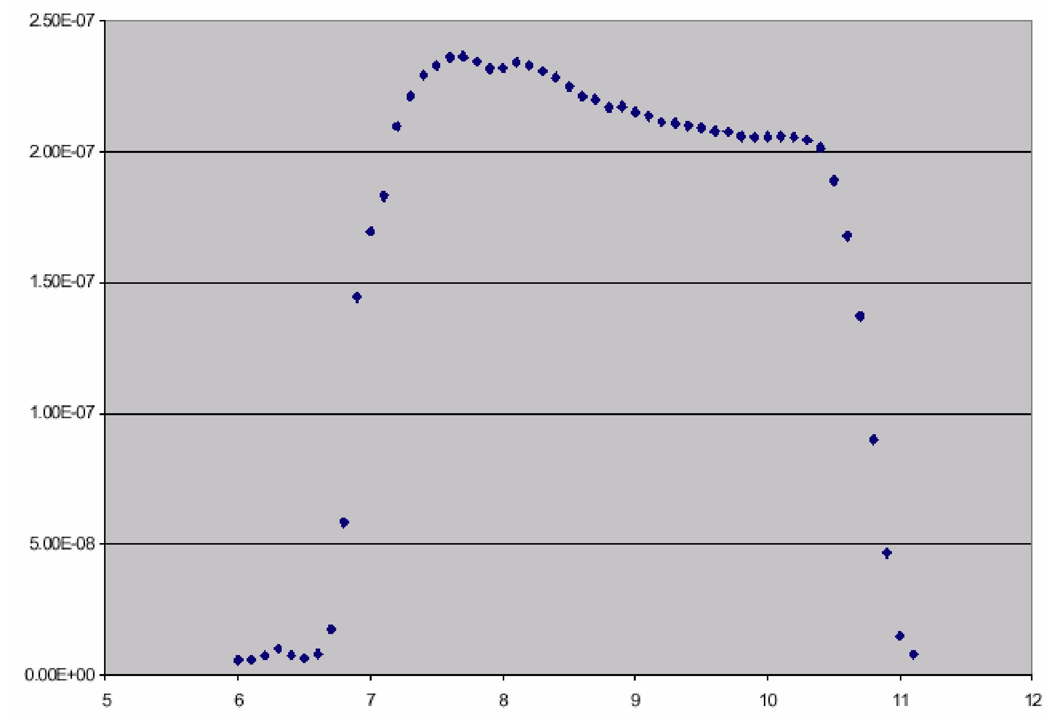
Vladimir scintillator
+ Kuraray Y11

"Rainbow
groove



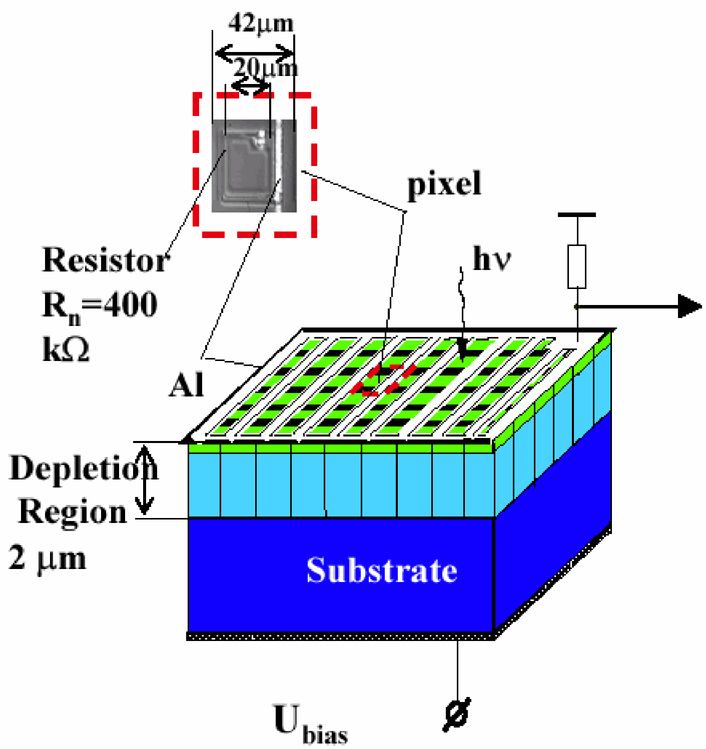
"Sigma" groove



# Tile HCal – SiPM Photodetector

## SiPM main characteristics




- Pixel size ~20-30μm
- 

Electrical inter-pixel cross-talk minimized by:
- decoupling quenching resistor for each pixel
- boundaries between pixels to decouple them
  ➔ reduction of sensitive area and geometrical efficiency

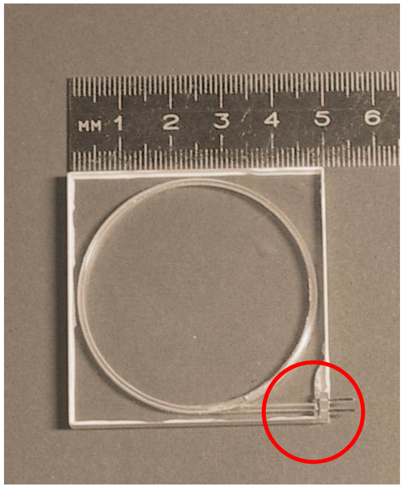
• Optical inter-pixel cross -talk:
-due to photons from Geiger discharge initiated by one electron and collected on adjacent pixel

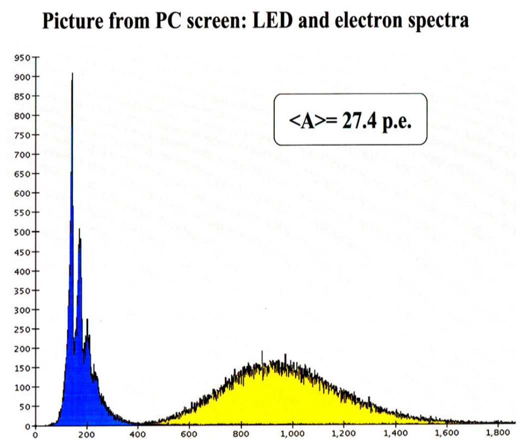
- Working point: $V_{Bias} = V_{breakdown} + \Delta V \sim 50\text{-}60$ V
  $\Delta V \sim 3$V above breakdown voltage

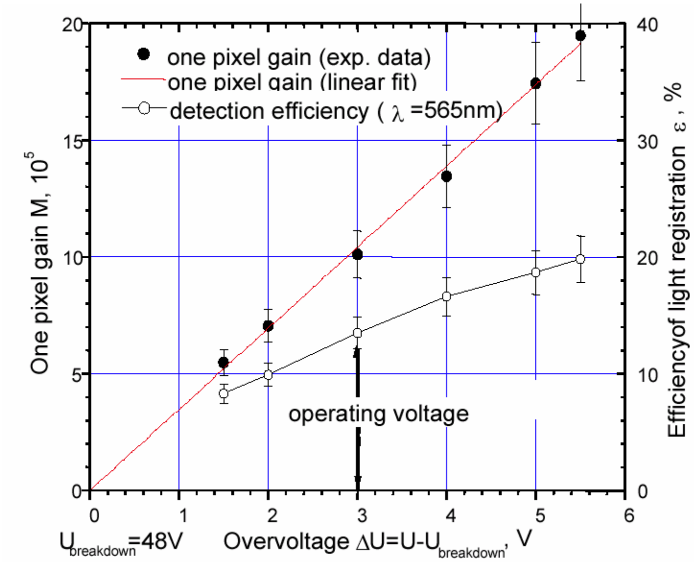
Each pixel behaves as a Geiger counter with
$Q_{pixel} = \Delta V\, C_{pixel}$
with $C_{pixel}$~50fmF ➔ $Q_{pixel}$~150fmC=$10^6$e

Dynamic range ~ number of pixels (1024)
➔ saturation

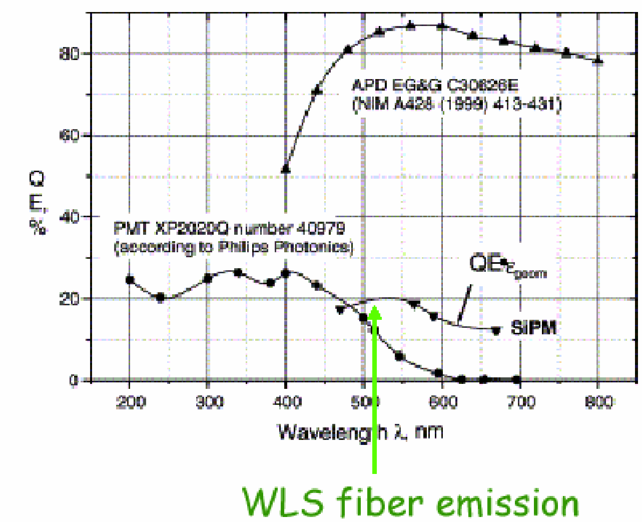
# Tile HCal – SiPM Photodetector






Photon detection efficiency $\varepsilon = QE \cdot \varepsilon_{geom}$

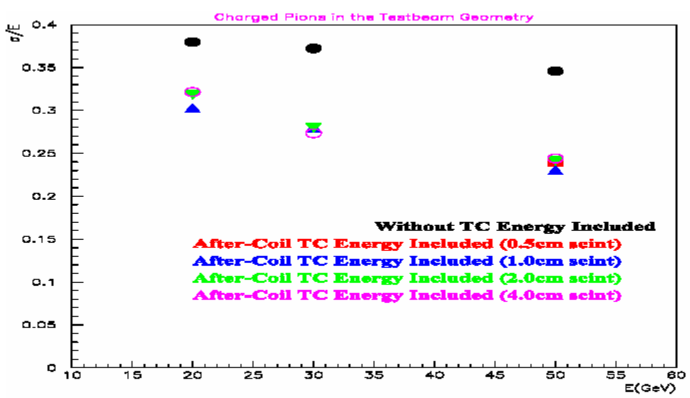



- no magnetic field effect at 5T to 1%
- long term tests (20 SiPM x 1500 hrs) OK
- temperature insensitivity verified

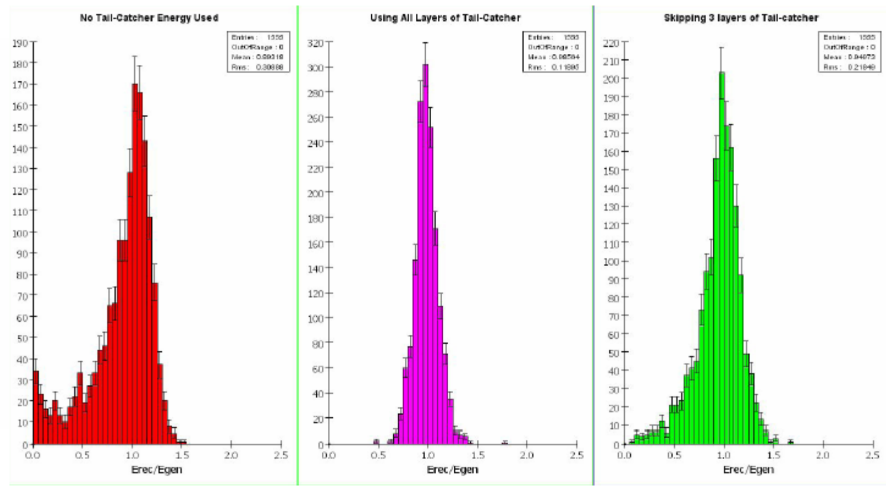
# Tail-catcher

HCal is inside the coil – and only ~4$\lambda$ $\therefore$ some energy not measured .

NIU -> 5cm scintillator strips as first part of muon system.




135%/sqrt(E)




- "Fine" section (8 layers)

  2cm Steel, 0.5 cm thick scintillator
- Following "coarse" section (8 layers)

  10cm Steel, 0.5 cm scintillator
- 5cm wide strips, 1m long
- Tyvek wrapping
- Alternating x-y orientation
- Si-PM photo-detection

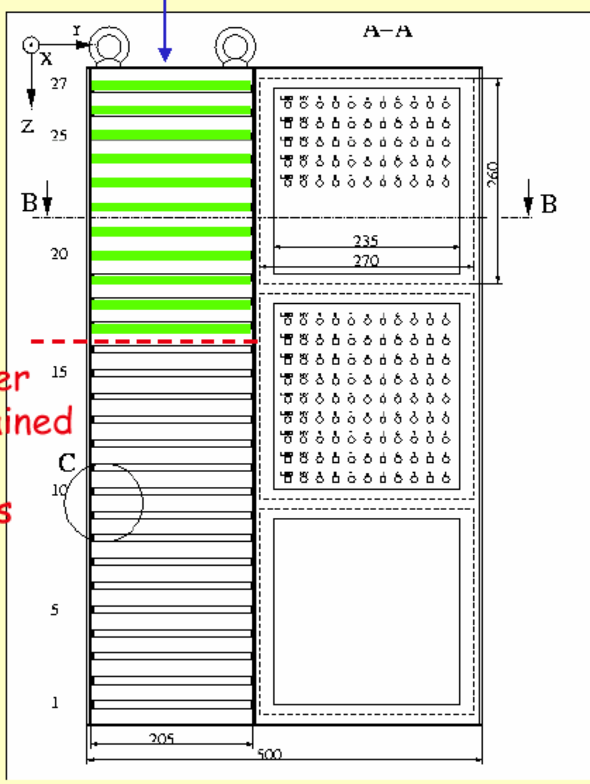
**Fermi-NICADD Extruder Line**

# Tile HCal - Prototypes

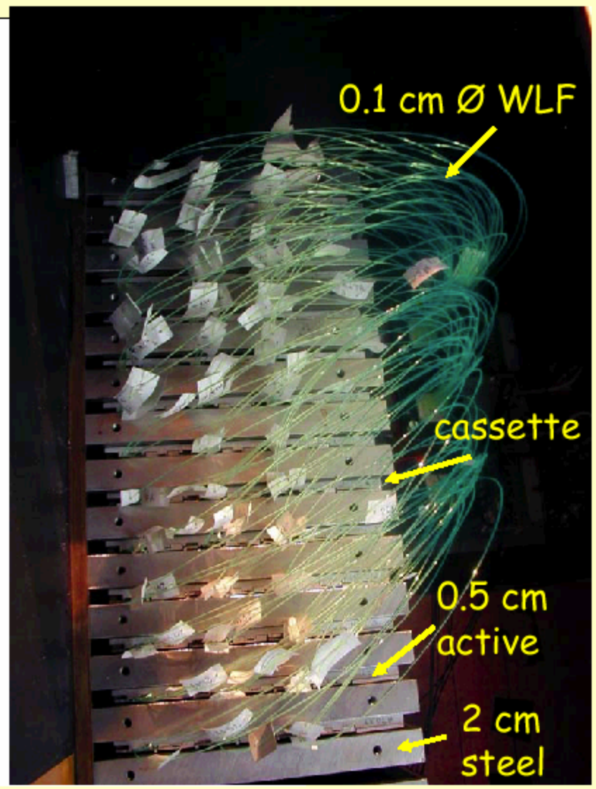
## 1) Minical

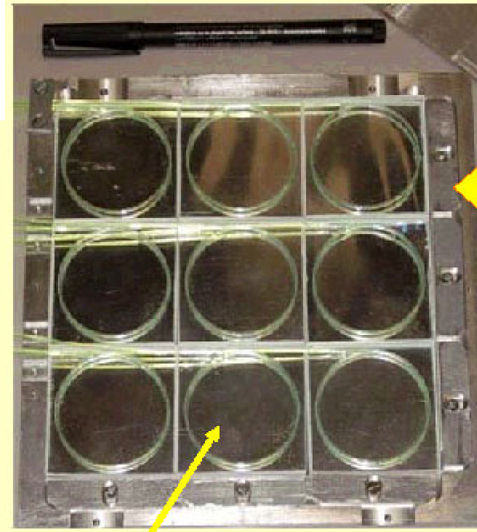
### The MiniCal Prototype

e+ 1-6 GeV




97% shower contained in 11 layers



1-loop or curve-diagonal WLS-fiber (Y11) placed in groove (not glued) Single tiles covered by 3M reflector

Photodetectors: SiPM, APD, PM

From E. Garutti/LCWS 2004

# Tile HCal - Prototypes

## 1) Minical

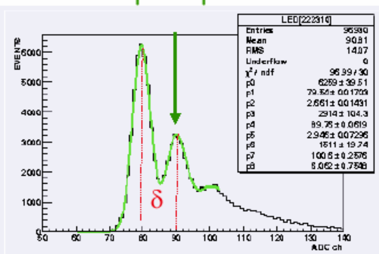
### SiPM Calibration

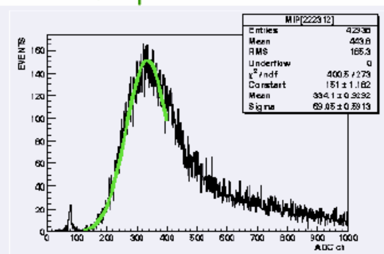
- MIP calibration with beam of all tiles w/o pre-amplifier
- Single pixel peak visible with fast pre-amplifier ➔ for calibration only

One pixel peak

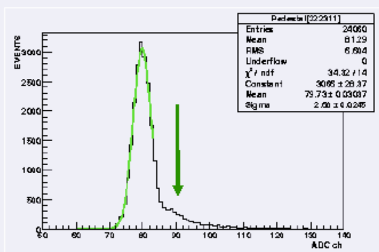
MIP peak

With low intensity LED




Without LED light
1 pixel noise visible




RESULTS FOR THE TILE 231:

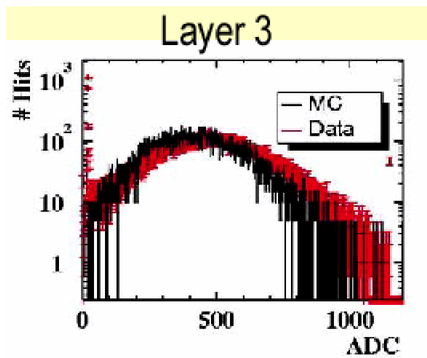
Ped pos = 79.54 ch.

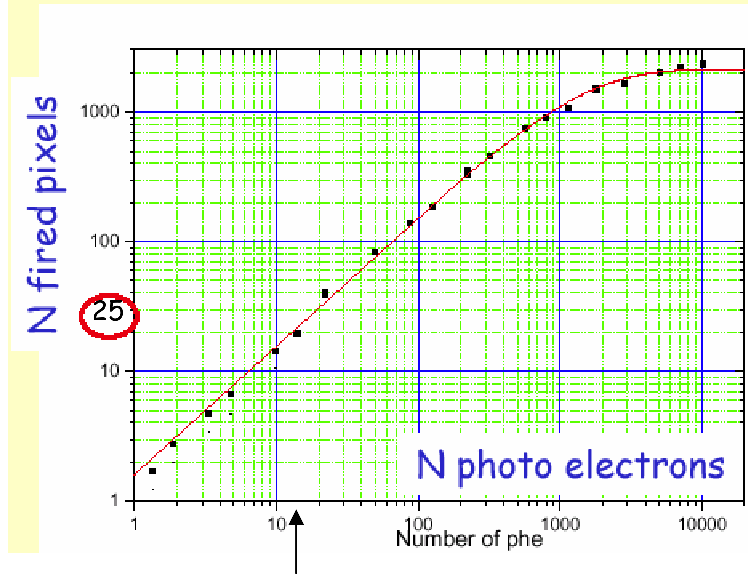
Delta = 10.22 ch/cell

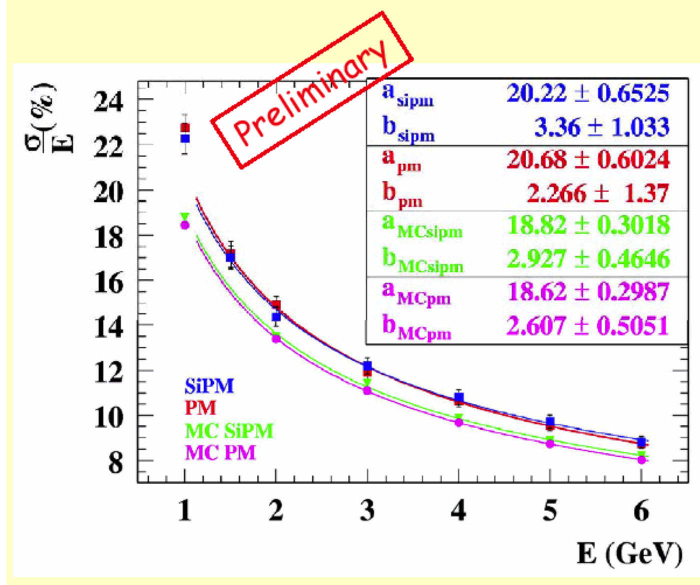
MIP Amplit. = 254.55 ch/MIP

N phe = 24.91 phe

1 MIP = 25 pixels



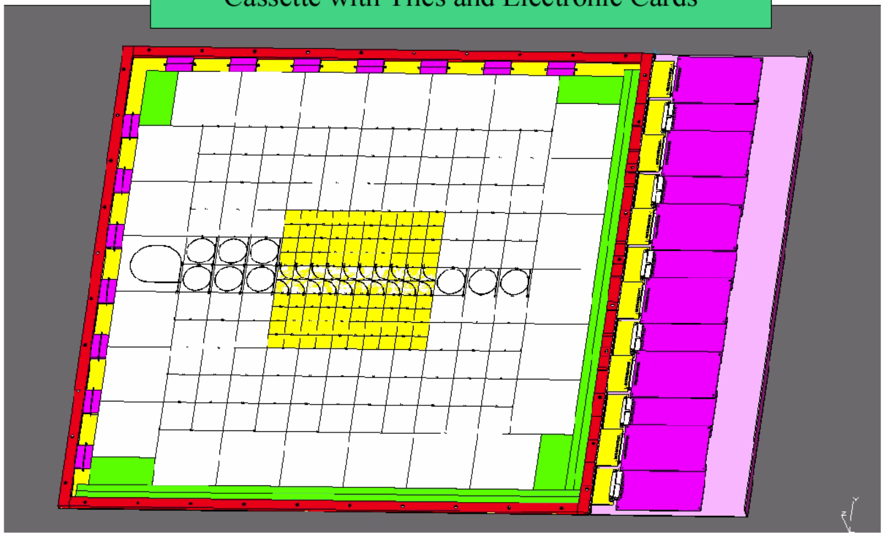



# Tile HCal - Prototypes

## 2) 1 m$^3$ stack (PPT)

Cassette with Tiles and Electronic Cards

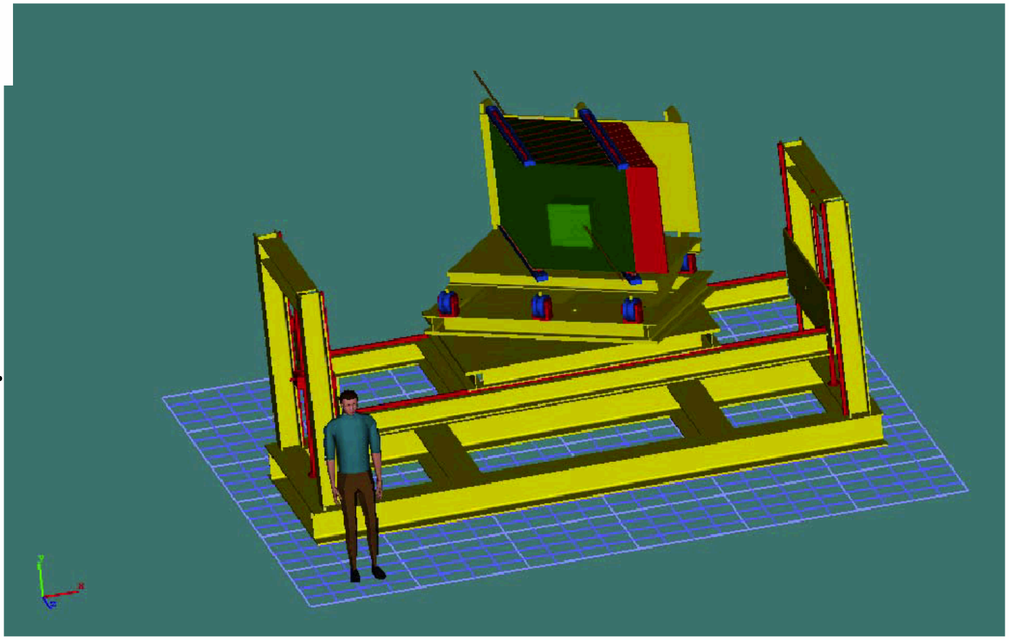


Baseline photodetector: SiPM

Baseline FE: ECal FEE with new shaping, also look at FADC/FPGA

Flexible absorber stack/many orientations

Absorber and Support Structure



Injection molded tiles

Measure each SiPM characteristics

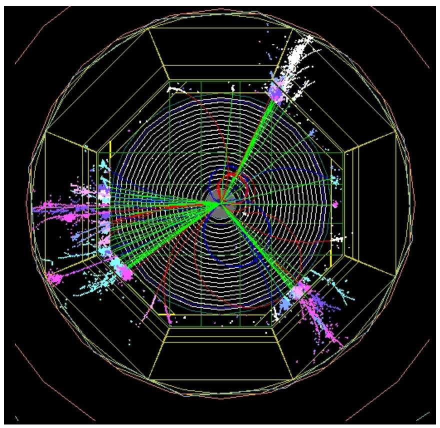
Parts made at DESY - assembled at ITEP

# Simulations/Particle Flow Algorithms

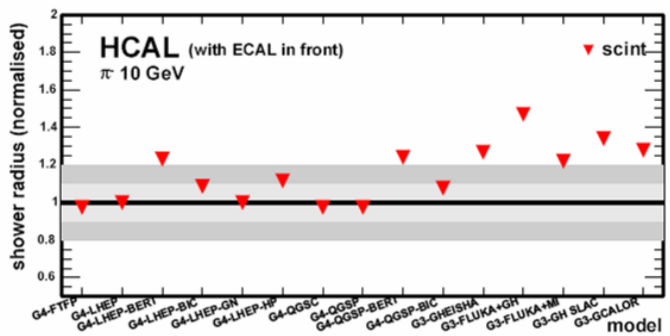
Essential components: Comparison/validation of shower simulations.

Identification/separation of energy from the various jet components.

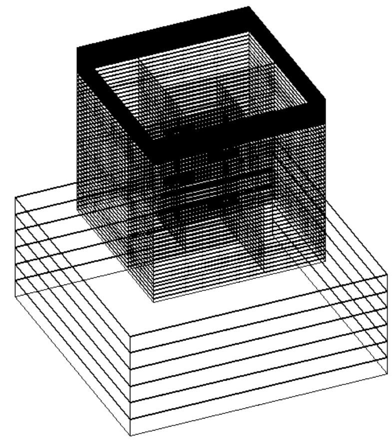
GEANT4/Mokka

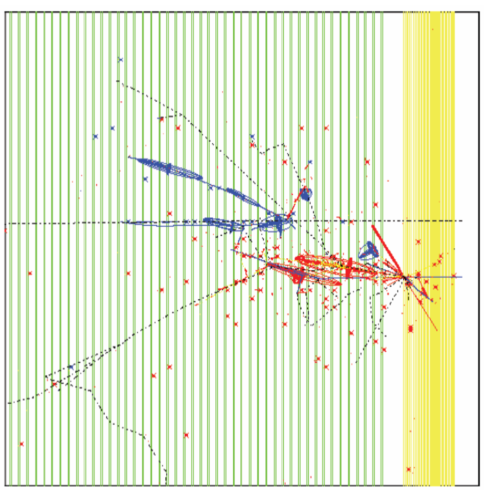


Shower radius vs. models

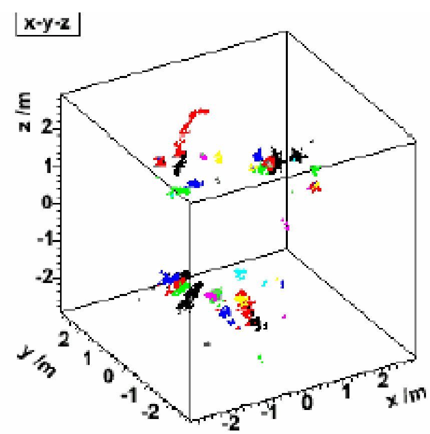



Test Beam modules

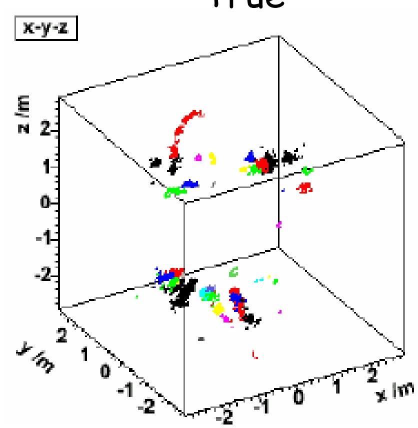




Reconstructed




True



# Test Beam Plans

2004(late)

ECal exposure to low energy electron beam at DESY.

Mini DHCAL (RPC – IHEP/Protvino) tests in electron beam.

2005-6 e/$\pi$/p to ~80GeV

Module combinations:

| | | |
|---|---|---|
| CALICE ECal<br>US ECal | $\oplus$ | HCal/RPC + GEM 1m$^3$ prototypes<br>HCal/Tile 1m$^3$ prototype |

# Time Scale

| Time | T=2015 | Tasks |
|---|---|---|
| T – >10~11 | Before 2005 | Detector R&D |
| T – 10~11 | 2005~6 | Test Beam I |
| T – 8~9 | 2006~7 | •Detector Technology chosen.<br>•Detector Development and design begins |
| T – 6 | 2009 | Detector Construction begins<br>Test Beam II (Calibration) |
| T | 2015 | LC and Detector ready |

# Conclusions

✮ A lot of progress on many fronts!

✮ Following hardware implementation of Particle Flow approach.

✮ ECal – Silicon/Tungsten – well advanced

✮ HCal – several approaches

✮ Common need to verify Monte Carlo at high spatial resolution

✮ Critical role of test beams!

# Backup Slides

# Calorimeter System Design

"Figure of Merit" ~ $BR^2/R_{moliere}$

(Separation of charged hadrons from photons in a jet)

Other design issues:

-Timing reqs? ( <- Accelerator technology choice)

- Operation in a strong magnetic field.

- Hermetic – minimize intrusions, gaps, dead material.

- Minimize costs – design for ease of production.

- Robust, reliable design.

- Long term stability.

# Silicon Wafers for the prototype

4″ High resistive wafer : 5 KΩcm

Thickness : 525 microns ± 3 %

Tile side : 62.0 + 0.0

- 0.1 mm

Guard ring

In Silicone ~80 e-h pairs / micron ⇒ 42000 $e^-$ /MiP

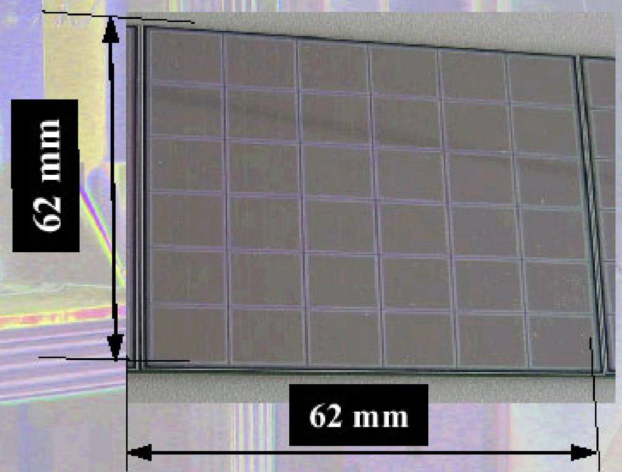
Capacitance : ~21 pF

Leakage current : 5 – 15 nA

Full depletion bias : ~150 V

Nominal operating bias : 200 V

Si Wafer :
6×6 pads of detection
(10×10 $mm^2$)

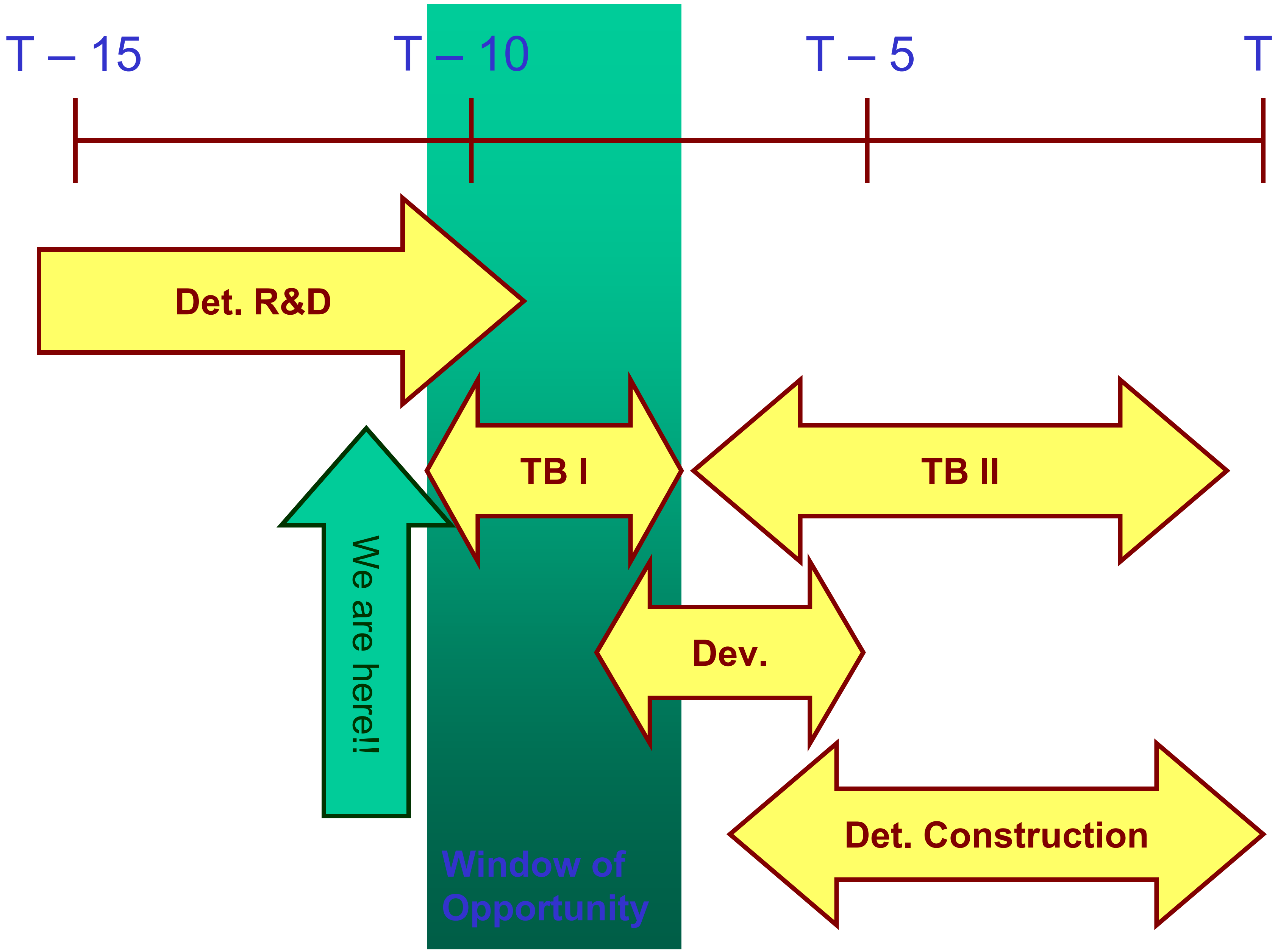



One wafer is a Matrix of 6 x 6 pixel of 1 $cm^2$.

Important point : manufacturing must be as simple as possible to be near of what could be the real production for full scale detector in order to :

- Keep lower price (a minimum of step during processing)
- Low rate of rejected processed wafer
- good reliability and large robustness

# LC Detector Time Scale



# Summary of TB Facilities

| Facilities | Particles | p-ranges | Availability | Note |
|---|---|---|---|---|
| FNAL MTBF | p, K, π, μ, e | $E_\pi = 5 – 80$ GeV<br>$E_p < 120$ GeV,<br>$E_e < 20$ GeV(?) | From 2003 | 8 BTeV MOU's |
| SLAC–ESA | γ, $e^+$, hadrons | $E_e < 45$ GeV<br>$E_h < 13$ GeV | Currently Available | Competition with other projects |
| IHEP-Protvino | had, e, μ | $E_e < 45$ GeV<br>$E_h = 33 – 45$ GeV | From 2004 | Competition not yet well known |
| BNL-AGSB2 | e, p, K, π, μ | <10GeV | Dependent on AGS Status | |
| JLab | | | N/A 2007-8 due to upgrade | |
| CERN (PS/SPS) | | | Possibly on 2006 | H. Videau will cross check |
| DESY | $e^+$, $e^-$ | 0.5 – 7 GeV | 2003 – 2005 and beyond? | F. Sefkow will cross check |
| Frascati | $e^-$ | 50 – 750 MeV | Available now | M. Piccolo |
| KEK | | | Most likely not available >2005 | Koji Yoshimura |
| Other | IHEP (China), JPARC (Japan) .. | <2GeV<br>~20GeV | Available now<br>Possibly >2008 | |