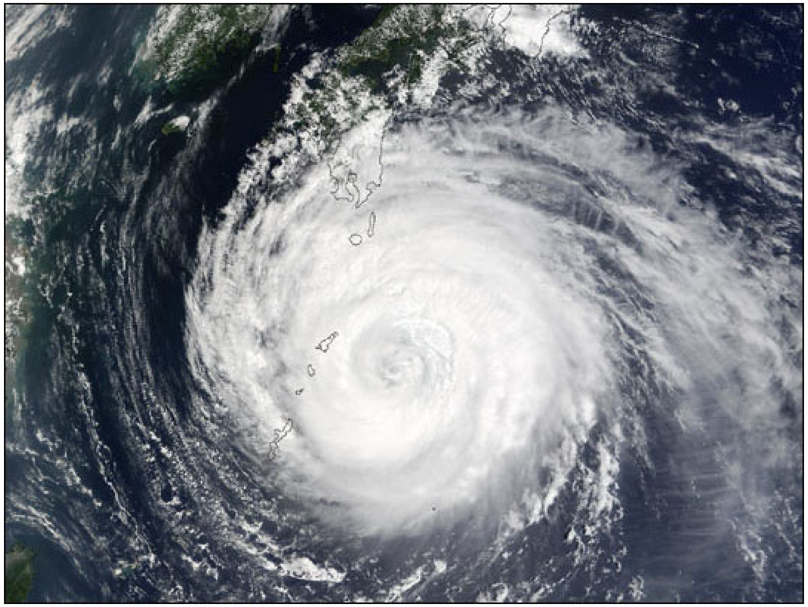
Report from Calorimeter Sessions at LCWS 2002, Jeju Island, Korea

- I will go through the summary talk I gave for Session H (Calorimetry, muons, masks, …)
  - Very active sessions
  - Pretty lively



- All of the Session H talks (including the summary) are available at the Cal. WG web:

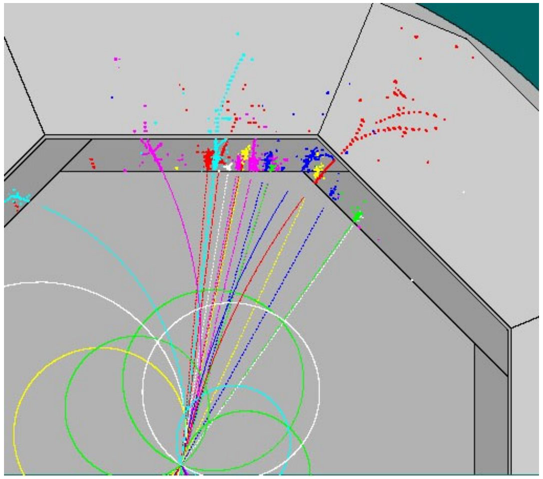
http://www.slac.stanford.edu/xorg/lcd/calorimeter/

Summary of the Group H Sessions
(Calorimetry, muons, masks, …)

Ray Frey

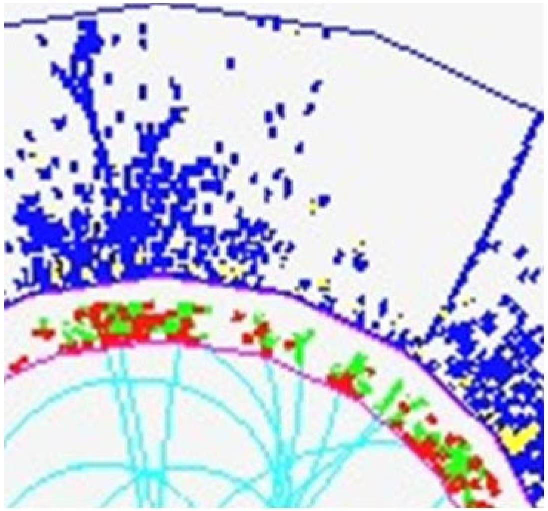
U. Oregon Dept. of Physics

and Oregon Center for HEP



LCWS2002, Jeju Island, Korea

August 30, 2002



Thanks to the organizers and hosts !

Calorimeter Parallel Sessions

Session 1, General, Tues 14:00-15:30 (R. Frey, Chair)

- Henri Videau, LLR "How to Test Energy Flow" 35
- Renyuan Zhu, CalTech "Comments on LC Calorimetry" 25
- Marcello Piccolo, INFN Frascati "Muon Detectors Status" 30

Session 2, ECal I, Weds 11:00-12:40 (P. Dauncy, Chair)

- Jean-Claude Brient, LLR "Mechanical aspect of the R&D for the TESLA ECAL" 20
- Ray Frey, U. Oregon "Silicon/tungsten ECal for the SD Detector" 20
- Vaclav Vrba, Prague "Silicon wafers production and processing for the TESLA W-SI ECAL" 20
- Samuel Manen, LPC Clermont "Very front end electronics for a silicon tungsten calorimeter" 20
- George Bashindzhagyan, Moscow St. U. "Silicon Calorimetry for a Linear Collider" 20

Session 3, ECal II, Weds 14:00-15:35 (M. Piccolo, Chair)

- Yoshiaki Fujii, KEK "Simulation and design optimization of fine-granularity Tile/Fiber EM calorimeter" 20
- Hiroyuki Matsunaga, U. Tsukuba "Design and performance of fine-granularity scint.-strip EM calor." 20
- Toshi Abe, U. Colorado “A new scint. ECal design and Si/W photon reconstruction results” 15
- Paolo Checchia, INFN Padova "LCcal: A R&D Project for the Electromagnetic Barrel Calorimeter" 20
- Wolfgang Lohmann, DESY "Design options for the very forward TESLA calorimeter" 20

Calorimeter Sessions (contd.)

Session 4, HCal, Weds 19:00-20:30 (Y. Fujii, Chair)

- Volker Korbel, DESY "Progress report on the TESLA Tile HCal Option" 20
- Jean-Claude Brient, LLR "A short report on the hardware R&D on the TESLA Digital HCal" 15
- Paul Dauncey, Imperial C. "Readout Electronics for the CALICE ECal and tile HCal" 15
- Manuel Martin, NIU/NICADD "A general high resolution digital hadron cal. using scint. tiles" 20
- Jaehoon Yu, U Texas, Arl. "Design of a Digital HCal with GEMs" 20

Session 5, combined H+J (Calor. +Sim.), Thurs 9:00-10:30 (K. Fujii, Chair)

- Norman Graf, SLAC "International Calorimeter Simulation Effort" 20
- Henri Videau, LLR "Mokka (Si-W simulation framework):Present and future" 20
- Manuel Martin, NICADD/NIU, "Dev. of s/w to support … general geometry in Geant 4, and EFA using a Digital Hcal" 15
- Jean-Claude Brient, LLR "REPIC package for photon and neutral hadron reconstruction" 20
- Steve Magill, ANL "Optimization of the HCal for energy flow jet reconstruction" 15

Session 6, combined G+H (Tracking+Calor.), Thurs 11:00-12:30 (D. Karlen, Chair)

- Klaus Moenig, DESY "Forward tracking in the TESLA detector" 20
- Hwanbae Park, Kyungpook U. "Fabrication of a silicon pixel/pad for dE/dx measurement" 15
- David Miller, UC London "Calorimeter questions in measuring the luminosity spectrum" 20
- David Cinabro, Wayne St. U. "Measurement requirements on the luminosity spectrum" 15
- Gene Fisk, FNAL "Test Beams Availability and Plans" 20

- LC environment allows us to push detectors to a new level
  - Tiny, fixed IP
  - Known initial state, without gluons
  - No (little) underlying event background

…based on our collider detector experience

- We can *amplify* LHC by measuring hadronic final states well

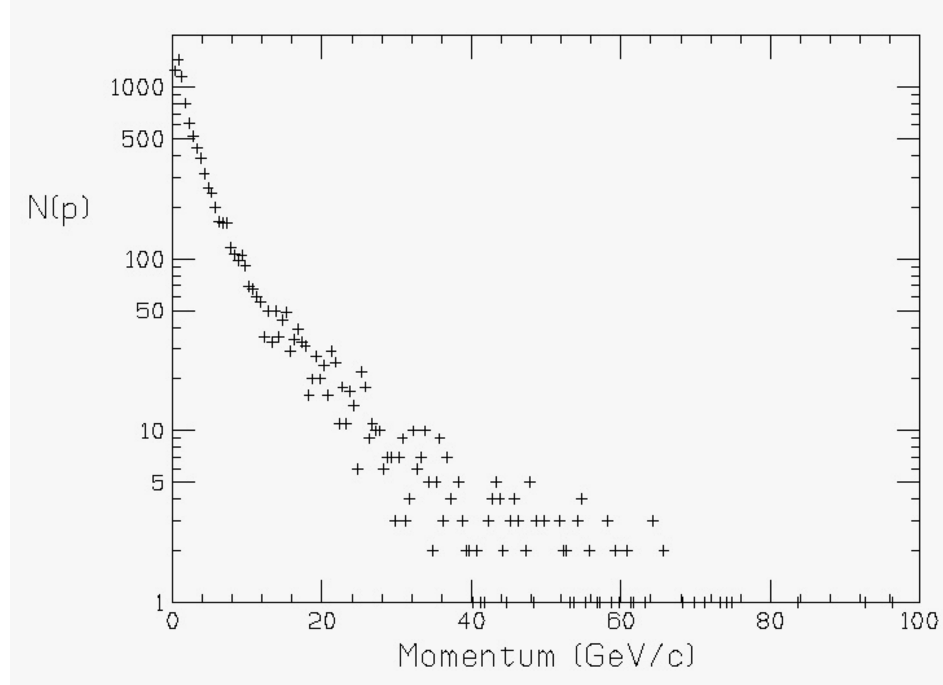
$\rightarrow$**We must try !**

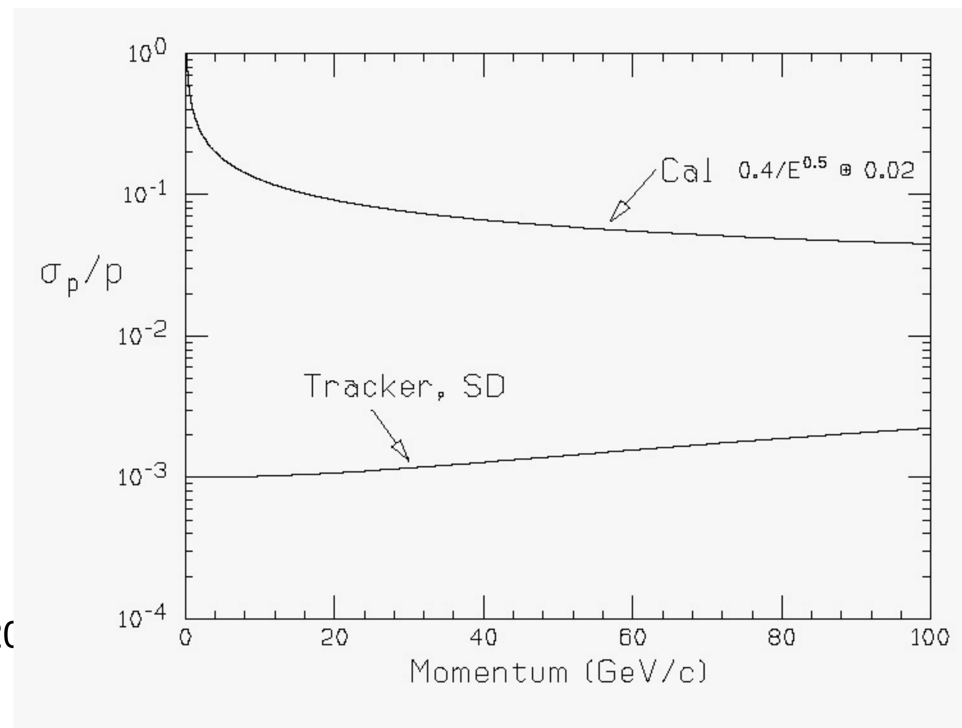
- A calorimeter which provides this will also provide excellent capabilities for electrons, photons, muons, taus, …

Energy Flow

1. Charged particles in jets more precisely measured in tracker
2. Typical multi-jet event :
   - 64% charged energy
   - 25% photons
   - 11% neutral hadrons

- Use tracker for charged
- Calorimeter for neutrals
- Must locate and remove charged calor. energy

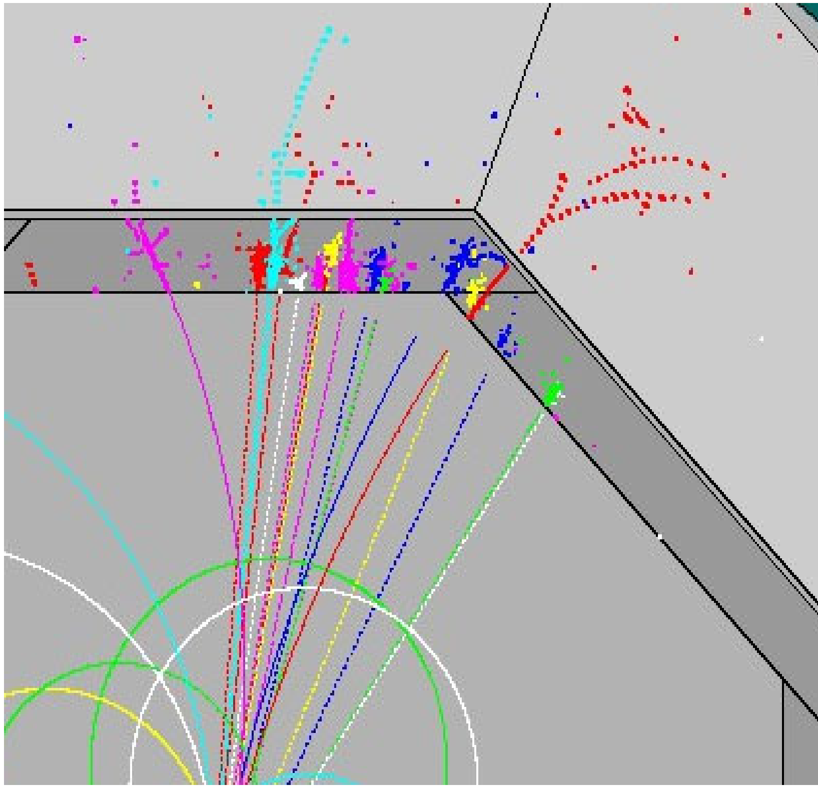




Prevailing paradigm:

Implementing Energy Flow requires separating charged/neutral with **dense, highly-segmented (in 3-d) calorimetry**

(An "Imaging Calorimeter'')



$\sigma_E / E = 30\% / \sqrt{E_{jet}}$ or better

Figures of merit:

- ECal: BR^2 / R_m large
- Transverse seg.~ R_m
- X_0 / λ_I small

$\tau \to \rho\nu \to \pi^+\pi^o\nu$

The main lines of the design

An affair of common sense

minimise the reinteractions,
separate the traces of the particles in the detector
build a very accurate detector

have
a precise (large?) and transparent track detector
from interaction point up to the calorimeter
a dense, granular and hermetic calorimeter
at large distance
a strong field (if radius insufficient)
to spread further the charged tracks

hermetic concerns low angles, cracks and depth

Le bon sens est la chose du monde la mieux partagée

Renyuan Zhu talk:

(his opinions)

- Will not be able to do better than subtracting *average* cal. energy depositions
- Therefore do not need highly segmented calor.

- Consider crystals as an option for ECal

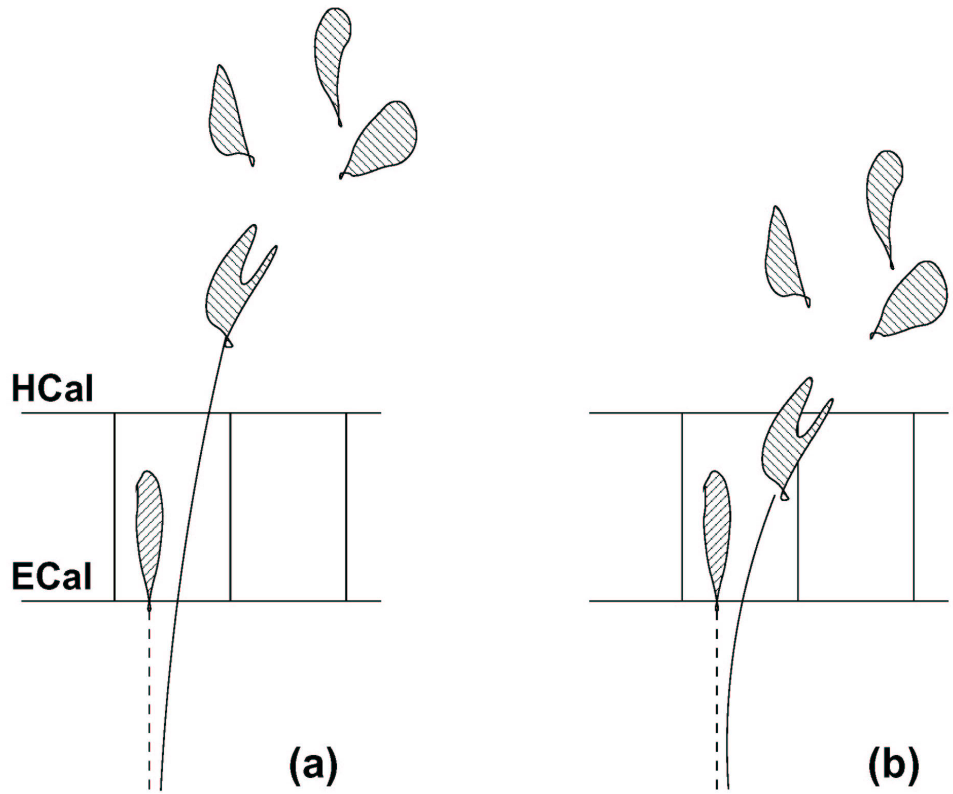
Energy Flow Summary

- **Classical energy flow** improves jet energy resolution by 30%, to ~60% stochastic term. Further improvement must also address the physics limitations.
- The **energy flow** is less effective at high energies: tracker resolution & shower overlap.
- Jet direction is better measured. Less than 30% stochastic term is already achieved by using 4C fit, which is also available **free** at LC.
- Before spending tax payer's money in calorimeter segmentation, full simulation and verification with test beam are required to understand limitations to the jet measurement.

Summary: Crystal Calorimetry for LC

- To maximize physics reach, calorimetry for LC should have precision measurement on electrons, photons and jets.
- Crystal calorimetry provides the best achievable EM resolution, good missing energy and jet resolution.
- Some heavy crystal scintillator, such as PWO, may provide a cost effective precision EM calorimeter solution.

- "Ideal ECal":
  Transparent to hadrons
  (h/e → 0)
- But λ_I not zero
- **Need segmentation** to make correct associations



- Subject for 16 of the 28 talks was detector hardware R&D

- Most related to the proposed detector designs from the 3 regions

	TESLA	SD	LD	JLC
Tracker type	TPC	Silicon	TPC	Jet-cell drift
ECal				
$R_{\rm min}$ barrel (m)	1.68	1.27	2.00	1.60
Type	Si pad/W	Si pad/W	scint. tile/Pb	scint. tile/Pb
Sampling	$30 \times 0.4X_0$ $+10 \times 1.2X_0$	$30 \times 0.71X_0$	$40 \times 0.71X_0$	$38 \times 0.71X_0$
Gaps (active) (mm)	2.5 (0.5 Si)	2.5 (0.3 Si)	1 (scint.)	1 (scint.)
Long. readouts	40	30	10	3
Trans. seg. (cm)	≈ 1	0.5	5.2	4
Channels ($\times 10^3$)	32000	50000	135	5
$z_{\rm min}$ endcap (m)	2.8	1.7	3.0	1.9
HCal				
$R_{\rm min}$ (m) barrel	1.91	1.43	2.50	2.0
Type	T: scint. tile/S.Steel D: digital/S.Steel	digital	scint. tile/Pb	scint. tile/Pb
Sampling	$38 \times 0.12\lambda$ (B), $53 \times 0.12\lambda$ (EC)	$34 \times 0.12\lambda$	$120 \times 0.047\lambda$	$130 \times 0.047\lambda$
Gaps (active) (mm)	T: 6.5 (5 scint.) D: 6.5 (TBD)	1 (TBD)	2 (scint.)	2 (scint.)
Longitudinal readouts	T: 9(B), 12(EC) D: 38(B), 53(EC)	34	3	4
Transverse segmentation (cm)	T: 5–25 D: 1	1	19	14
$\theta_{\rm min}$ endcap	5°	2°	2°	8°
Coil				
$R_{\rm min}$ (m)	3.0	2.5	3.7	3.7
B (T)	4	5	3	3
Comment	Shashlik ECal option in TDR discontinued		option: Si pad shower max. det.	scint. strip (1 cm) shower max. det. (2 layers)

The CALICE –ECAL*

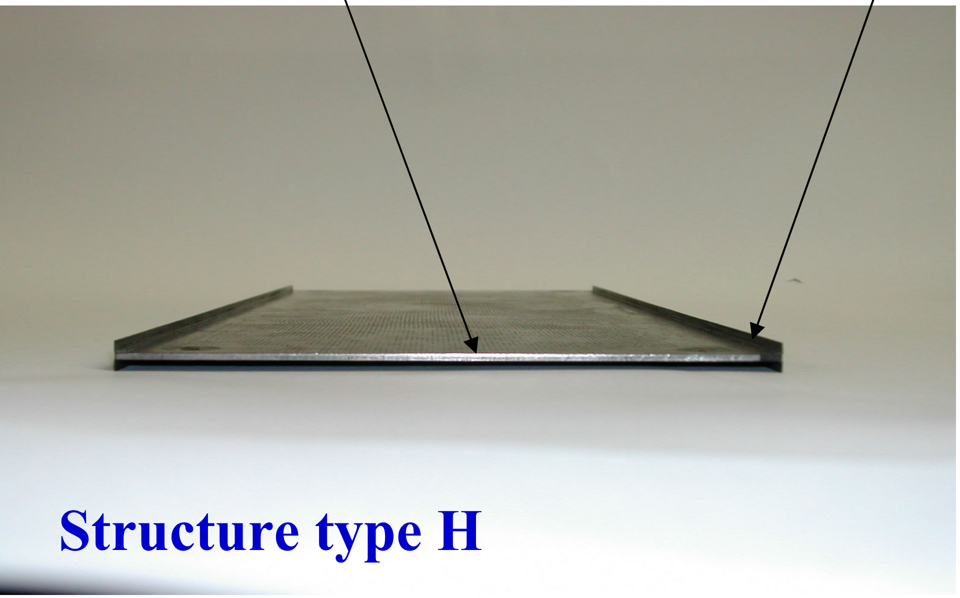
Presentation on the hardware R&D

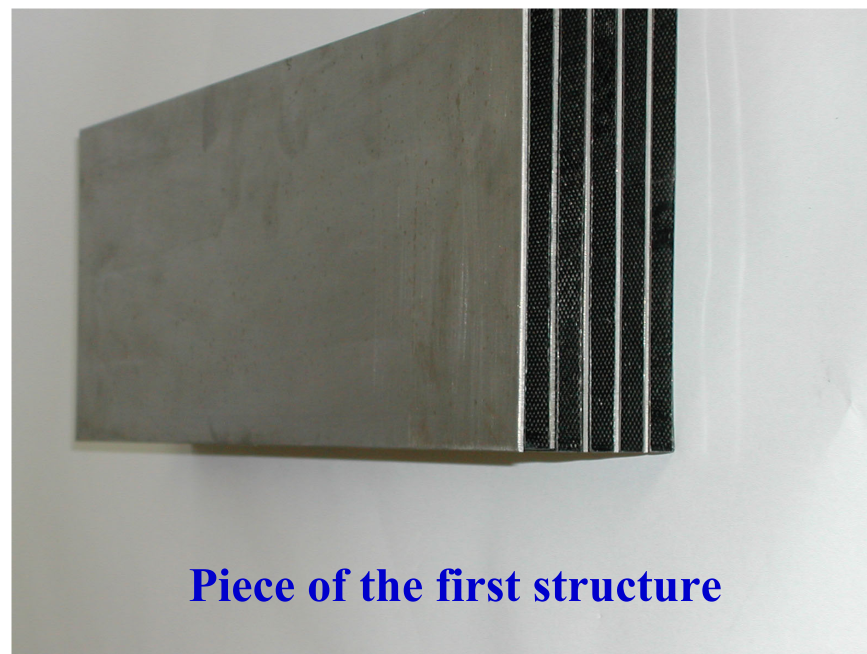
Silicon - **V. Vrba**
Very FE - **S. Manen**
Readout/DAQ - **P. Dauncey**
Mechanics … - **Myself**

OUTLINE

- ➔ **status on the physics prototype (mechanics)**
- ➔ **status of the technological R&D on the new design**

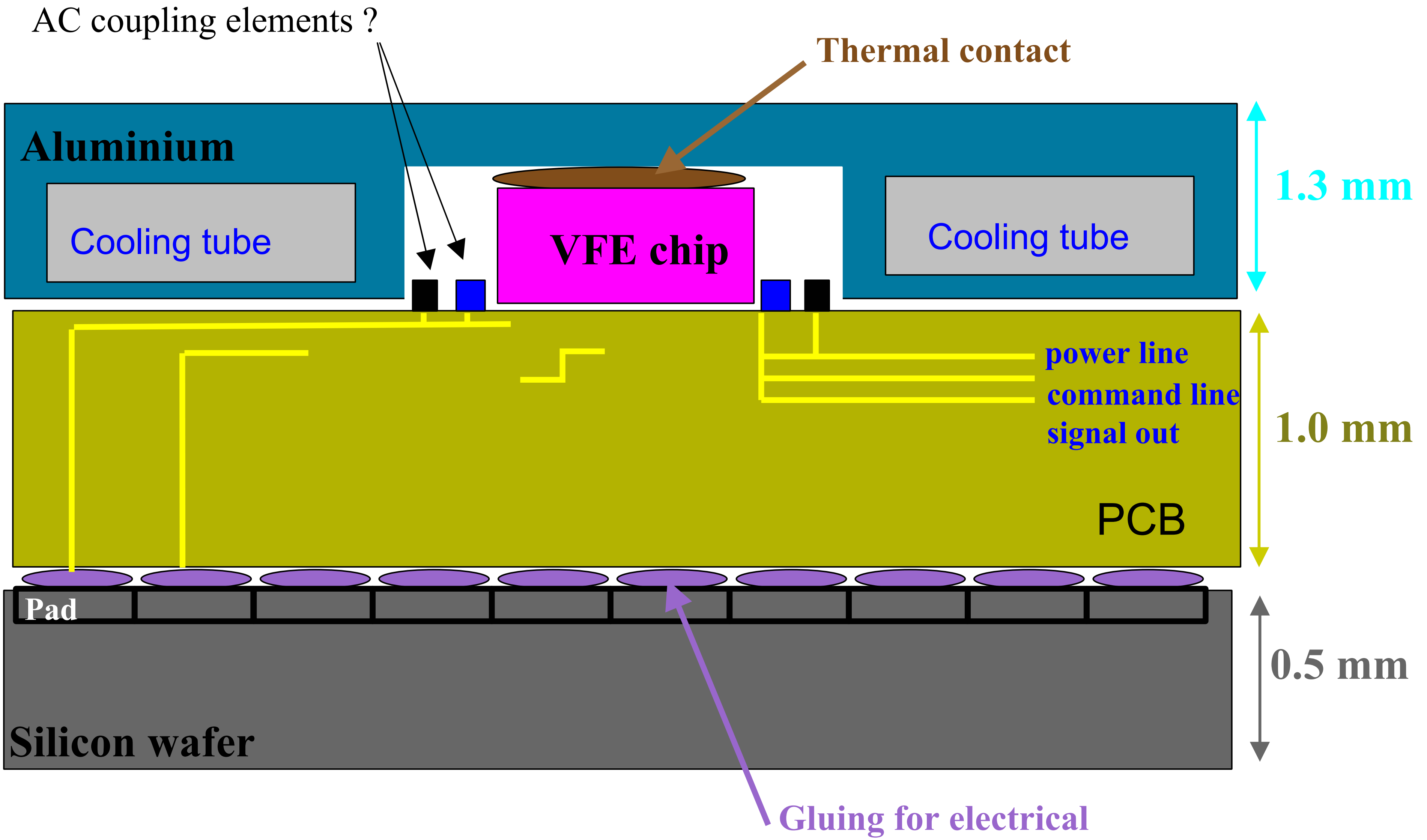
* *To remember : Tungsten-silicon sampling calorimeter*


Tungsten 1.4 mm thick
Carbon fiber
Structure type H


Structure W-Cfi
5 alveola (10 layers)
Piece of the first structure

detector

A design with electronics inside detect



Conclusion

The prototype

- More or less in the scheduled time *(ready for beam at the end of 2003)*
- Carbon-fiber and tungsten have good behavior …

Beam $5<P<50$ GeV/c

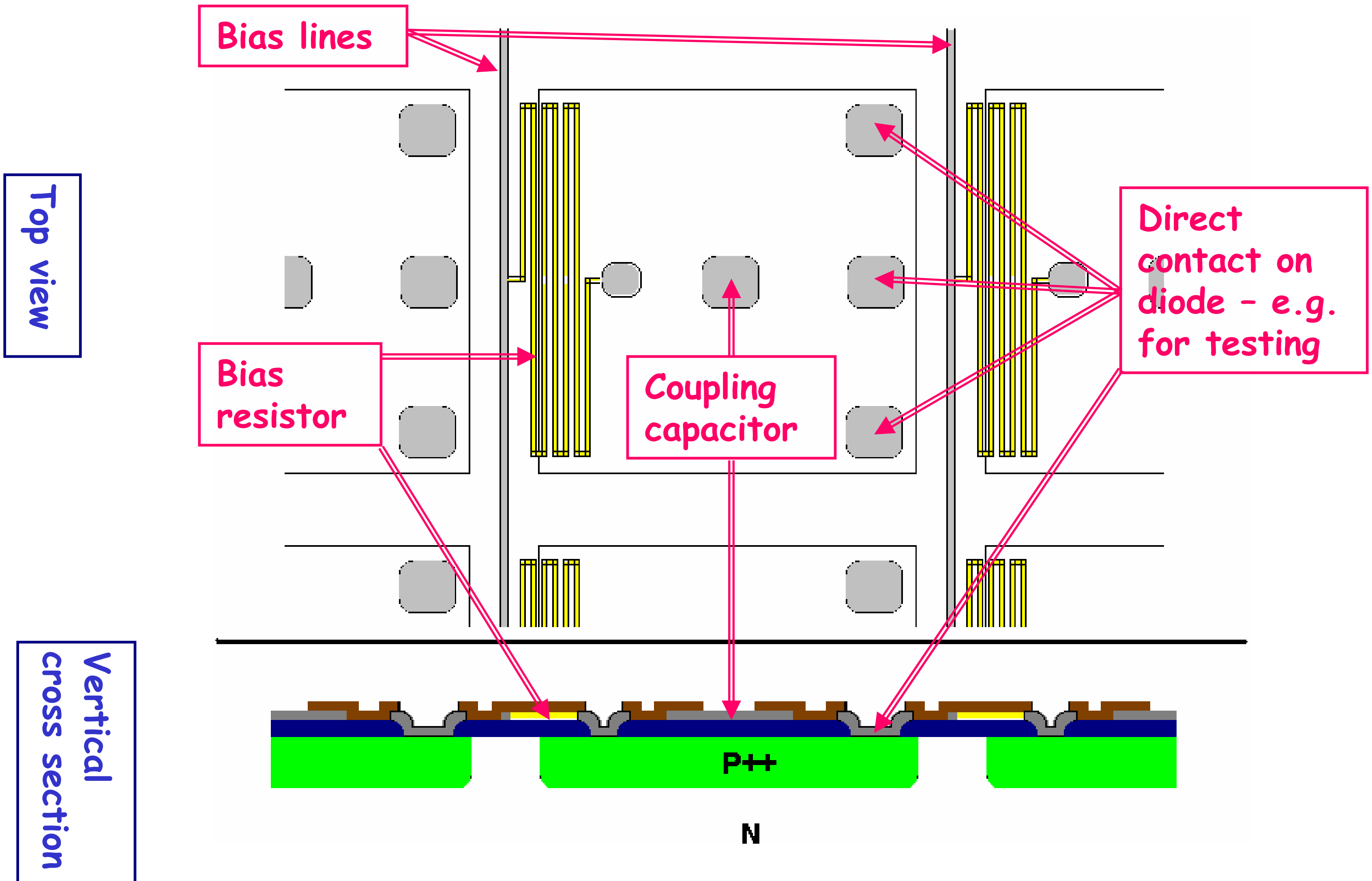
Pion/electron beam in 2004 –2005 ?????

New design of the detector slab

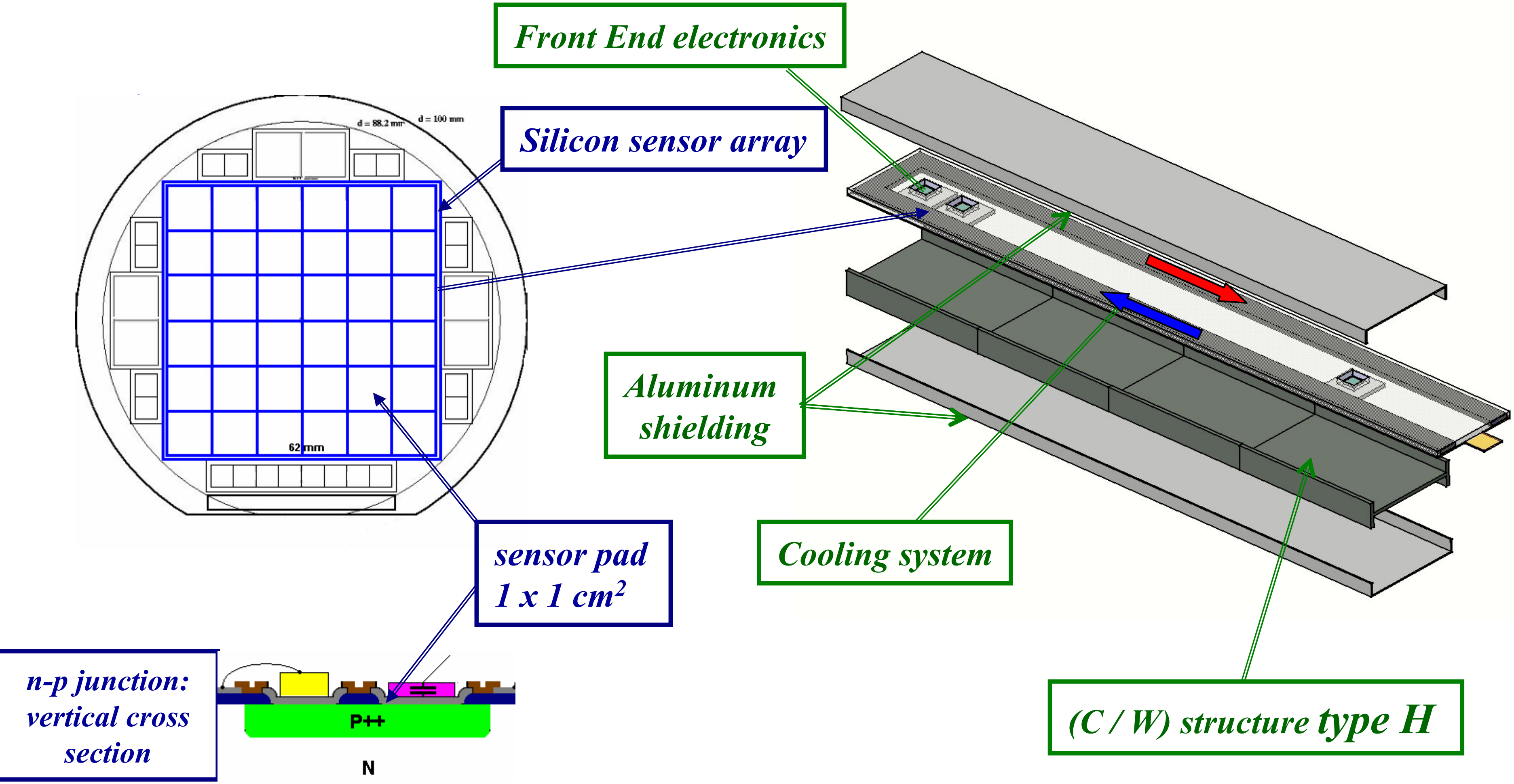
- Thermal studies begin ….
- The behavior of the VFE with 400 GeV e.m. shower ??? **Volunte**

Same problem for SLAC/Oregon design !!!

Design consideration: *Polysilicon resistors*



ECal slab components



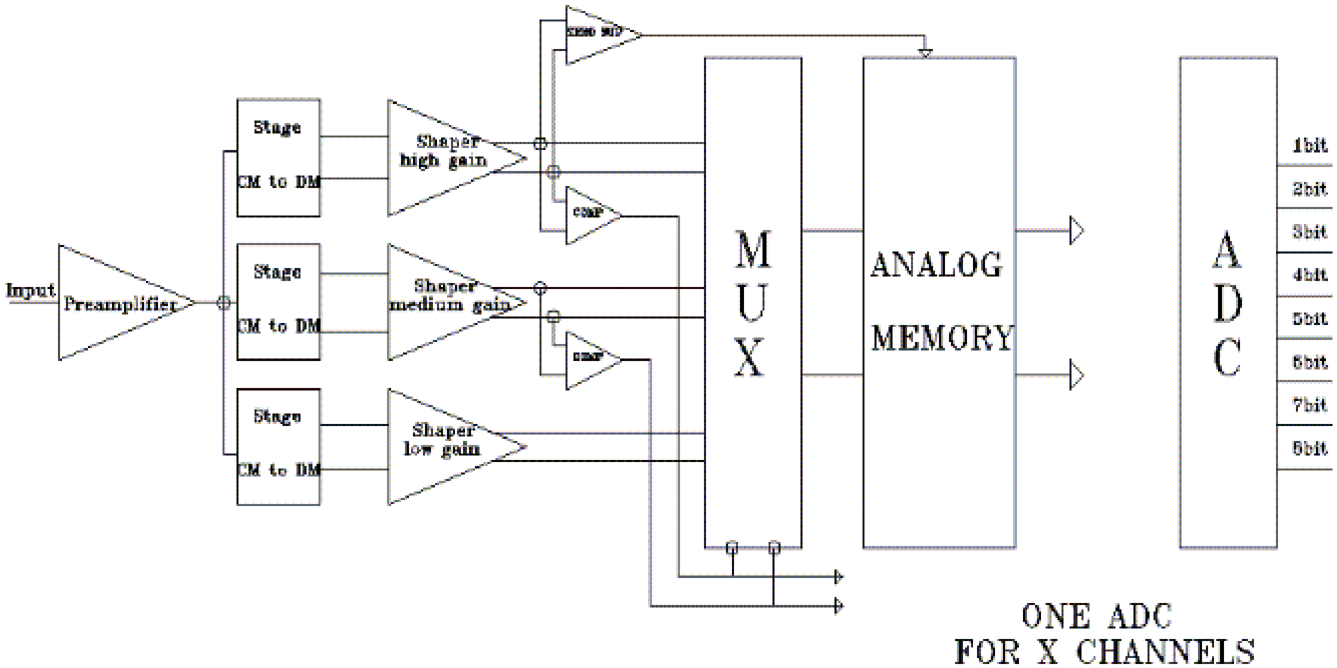
REQUIREMENTS

- 30 Millions channels with 4mW/channel max.
- Maximum energy : up to 1 Tev

  => bunch crossing = 150ns.
- Train = 3000 bunch crossing, with one train every 200ms.
- Dynamic = signal/noise = 14−15 bits.
- Accuracy: 0,4 % so 8 bits.

manen@clermont.in2p3.fr

DESIGN



MANEN Samuel

manen@clermont.in2p3.fr

CONCLUSION

- Amplifier simulations are solid.

  Very good agreement between experimental and measurements.

- Next Steps :
  - Technology : Cmos or SiGe...
  - Adaptation stage between amplifier and preamplifier.
  - Consumption ADC.

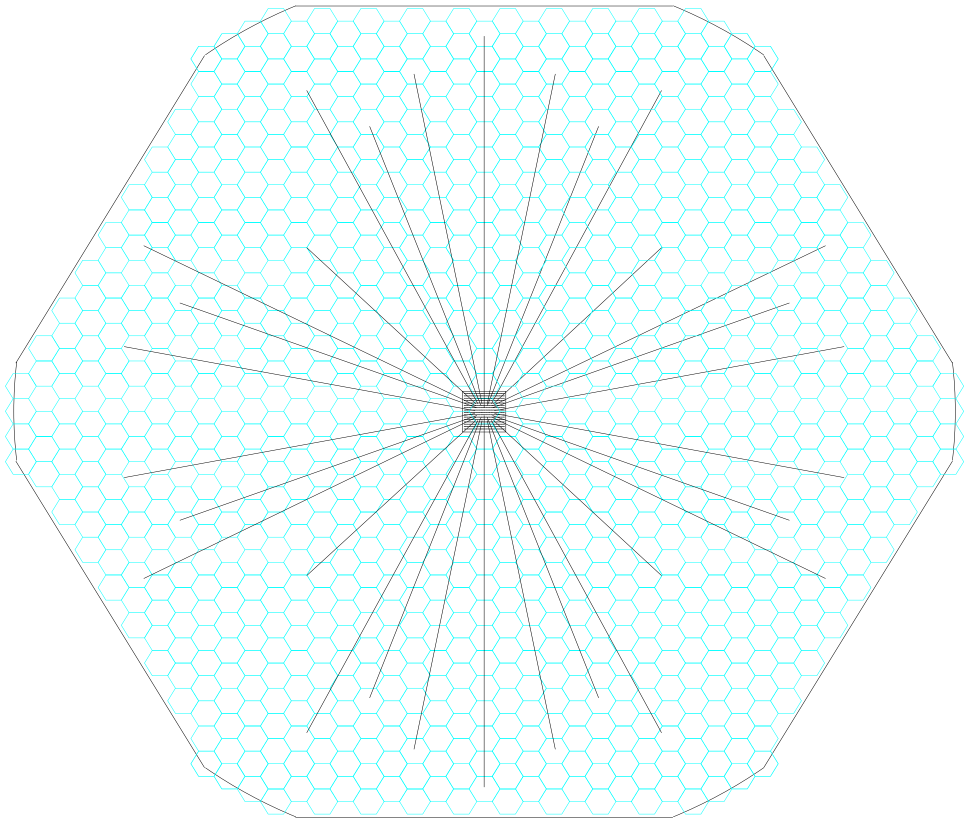
SD Si/W

- 5x5 mm^2 pixel ⇒ 50M pixels
- Do NOT scale electronics by this number
- *For each (6 inch) wafer:*
  - 1000 pixels (approx)
  - One readout chip (ROC)
- *Simple, scalable detector design:*
  - Minimum of fab. Steps
  - Use largest available wafers

⇒ Detector cost below \$2/cm^2

⇒ Electronics cost even less

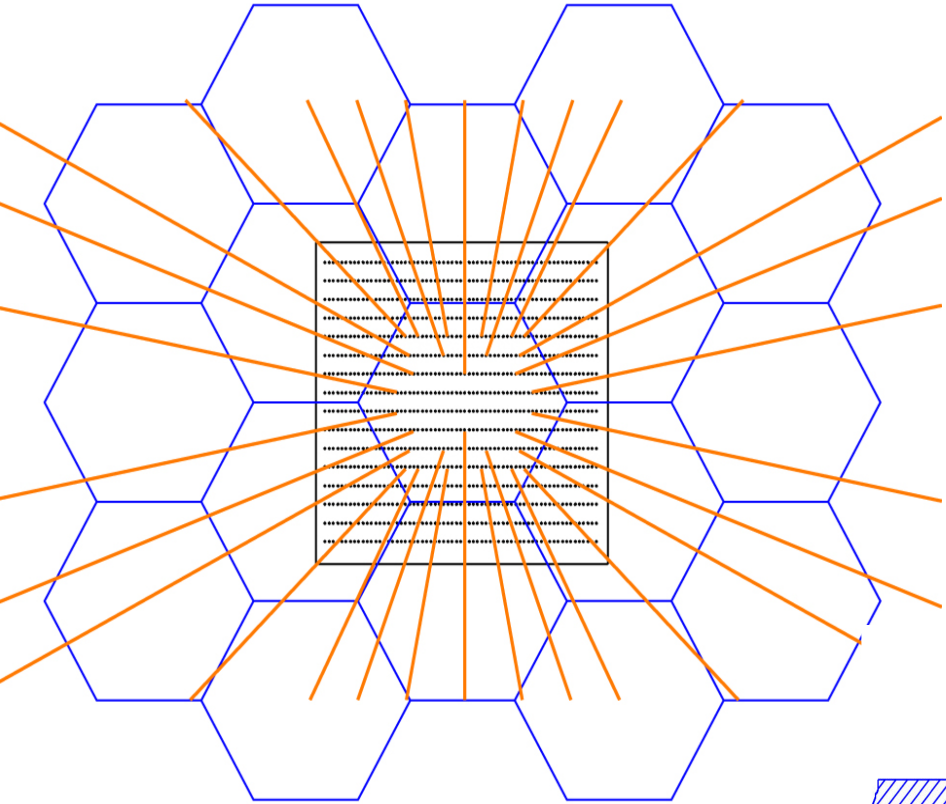
⇒ **A reasonable (cheap?) cost**



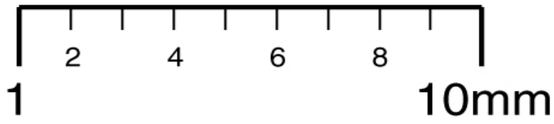
6 inch (152mm) WAFER

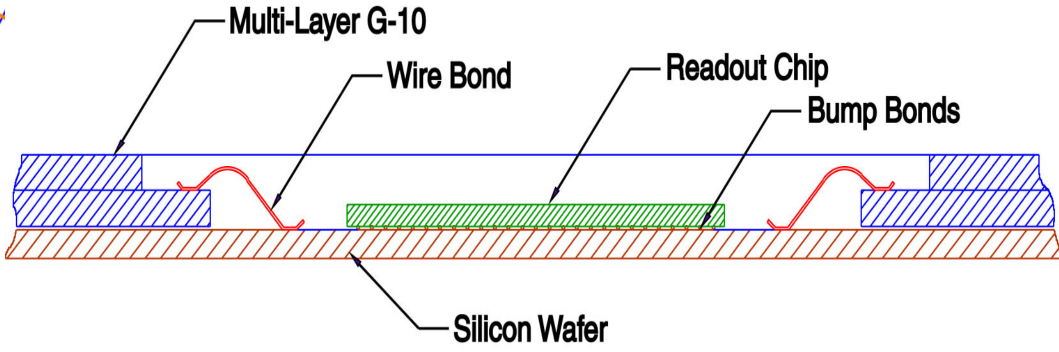
1,027 (5mm) CELLS

Wafer and readout chip



Use bump-bonding technique to mate ROC to array of pads on wafer





Heat

- Does integrated design imply fancy cooling system?
- Consider: NLC duty cycle is 5×10^{-5} (5×10^{-3} for TESLA)
    - 270 ns bunch trains at 150 Hz

$\Rightarrow$ Use power pulsing of the electronics

- For example, GLAST-equivalent readout would produce only about 1 mW average power per 1000-channel chip
    - Assumes power duty cycle of 10^{-3}… needs to be determined

- Current proposed scheme:
    - Heat conduction thru thin (6 oz) Cu layer in G10 m-board to fixed temperature heat sinks at edges of ECal modules

  $\Rightarrow \Delta T \approx 1^{o}C$
- Requires R&D to demonstrate

Design optimization, simulation and bench test of fine-granularity tile/fiber EM calorimeter test module

Yoshiaki Fujii (KEK)
JLC calorimeter group
KEK, Kobe, Konan, Niigata, Shinshu, Tsukuba

CONTENTS

Design Criteria of Detector System

- **Two-jet mass resolution** comparable to natural width of *W/Z*,
- **Hermeticiy** to determine missing momentum precisely,

and
- **Timing resolution** capable of separating bunch-crossing (2.8ns).

Hardware-compensating tile/fiber calorimeter has been chosen to achieve the criteria.

Why tile/fiber configuration

I can't help thinking about multiplying channels ($O(10^8)$) by O($10) ...... (taken from M.B. and mod'ed)

True reasons are ;

- Excellent hermeticity. (for CDF-style. SDC-style has very small dead region.)
- High potential for fine longitudinal granularity (even layer-by-layer readout possible).
- Reasonable cost and established technology.

But
- unable to achieve the finest transverse granularity ; is this really mandatory ?

Why hardware compensation

- Excellent **energy resolution** and **linearity** for hadrons.

  Already established by series of beam tests at KEK and at FNAL.

- Small Moliere radius (because of thin sensor material and heavy-metal absorber).

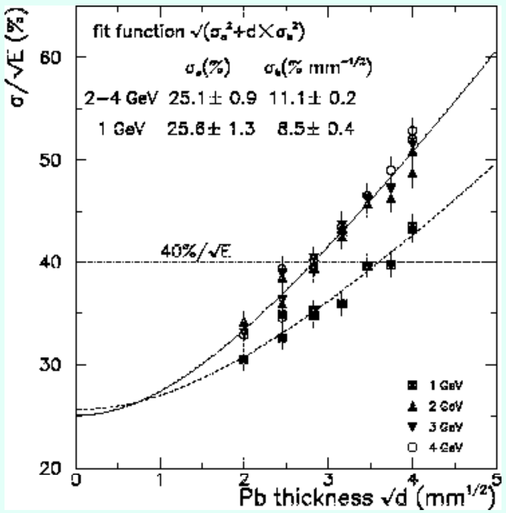
NOTE

1) Hardware-compensation sacrifices neither granularity nor EM energy resolution.

   σ_E/E for electrons has already been establised to be $15.4\%/\sqrt{E} \oplus 0.2\%$.

2) Non-compensating calorimeter gives biased energy measurement

   for overlapping hadron showers due to non-linear response.

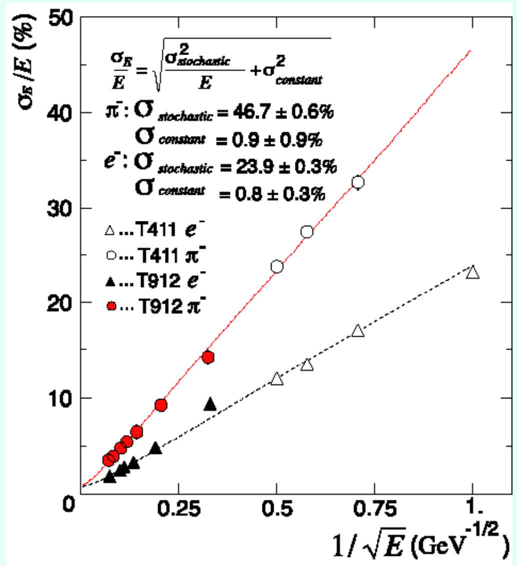


<---- SDC-type achieves

$40\%/\sqrt{E}$ for π

CDF-type achieves ----->

$46\%/\sqrt{E}$ for π



3. Test Module Design

Investigate the finest granularity achievable with tile/fiber structure within reasonable cost and effort.

Module Structure

- 4cm x 4cm x 1mm-thick scintillator tiles interleaved with 4mm-thick hard-lead (+1mm acryl).

  (Hardware-compensating ratio)

- Longitudinal sections of 3.6Xo-thick each (5-layers-ganged, 8-samplings over 28Xo-EM)

  $R_{Moliere}$ = 24mm --> Needs additional shower-position detectors

What to Examine (potential problems on hardware)

- Tile fabrication/machining is not a problem ; Mega-tile molding will work fine for any sizes.
- **Bending radius of a WLS fiber** imposes strong limits.

  Manufacturer's recommendation is r = 50mm for 0.5mm-φ fiber

  CDF established 20mm, STAR established 13mm ---> Examine by ourselves.

- **Cost of fibers** imposes another limits (smaller tiles --> more fibers).

  O($20) x 10^6 fibers (cost for test-module-scale production).

- Fabrication effort be examined (labor cost).

6. Beam Test (plan)

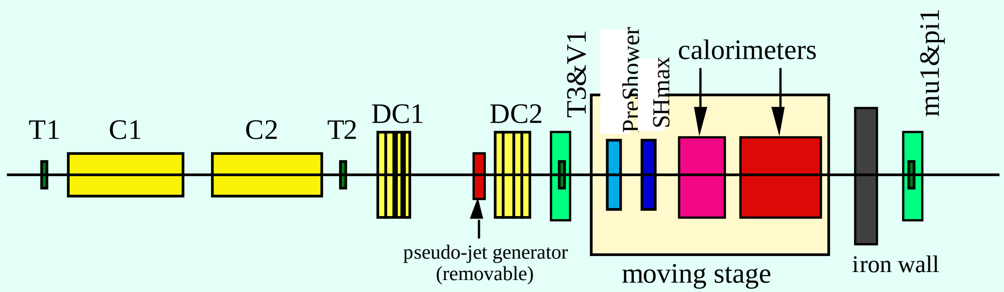
Combined test of

- **Preshower detector.**
- **SciStrip-SHmax** ; conventional WLS-fiber readout and APD direct-readout.
- **RectTile-EM** ; Only 2-SuperLayer this time. Full-module next year.
- **SciStrip-EM** ; See Matsunaga-san's talk.

To be done this fall at KEK proton synchrotron ; 1-4GeV unseparated beams.

(Test at higher energy, as done for HCAL at FNAL, is not planned ; EM response extrapolate-able)

Notes
- Use MAPMT this time. MCHPD/EBCCD not yet ready to integrate into a test module.
- Use individually-machined tiles this time instead of molded Mega-Tile.



7. Summary

- Energy resolution and granularity are essential parameters of CAL.
- Capability of compensating tile/fiber calorimeter on above under examination.
- Energy resolution & Linearity already established by beam tests (both EM&hadron).

- Granulatiry under investigation ;
  - performance estimation by simulation (rather slowly)
  - performance validation by testbeam measurement (need hurry-up)
  - establishment of technical feasibility

- **Fine-granularity EM test module under construction to test this fall ;**

  a) Establish technical feasibility for fine-granularity tile/fiber structure.

  b) Establish anomaly-less response.

  c) Measure response map and implement to full simulators.

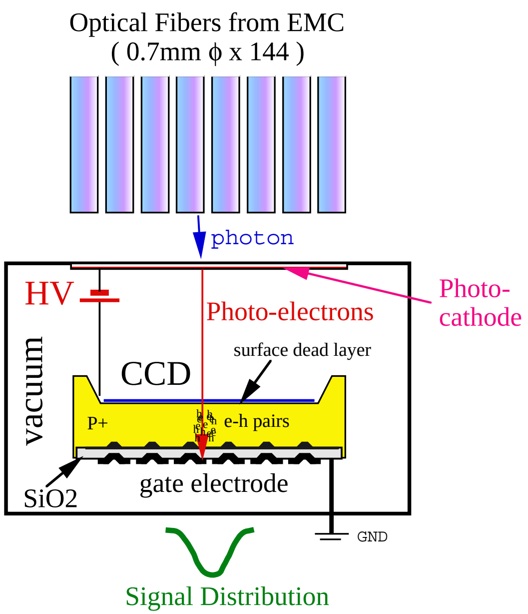
Scintillator-strip option for JLC ECal

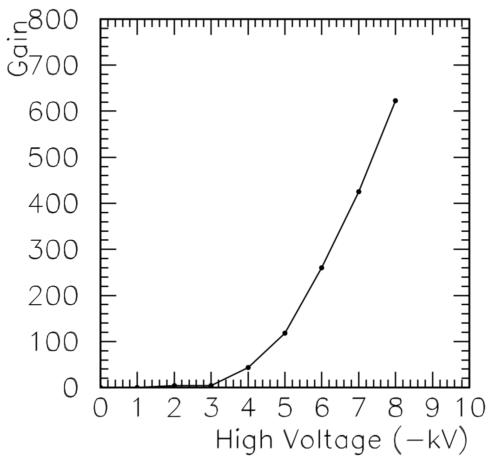
H. Matsunaga, U. Tsukuba

- Pb-scint
- X-Y layers scint strip sampling
- 1 cm x 20 cm x 2 mm each

- Goal to achieve fine seg. with Pb-scint

- 10k strips – use EBCCD readout
- Gain not high enough yet
    - Needs R&D





A new calorimeter geometry

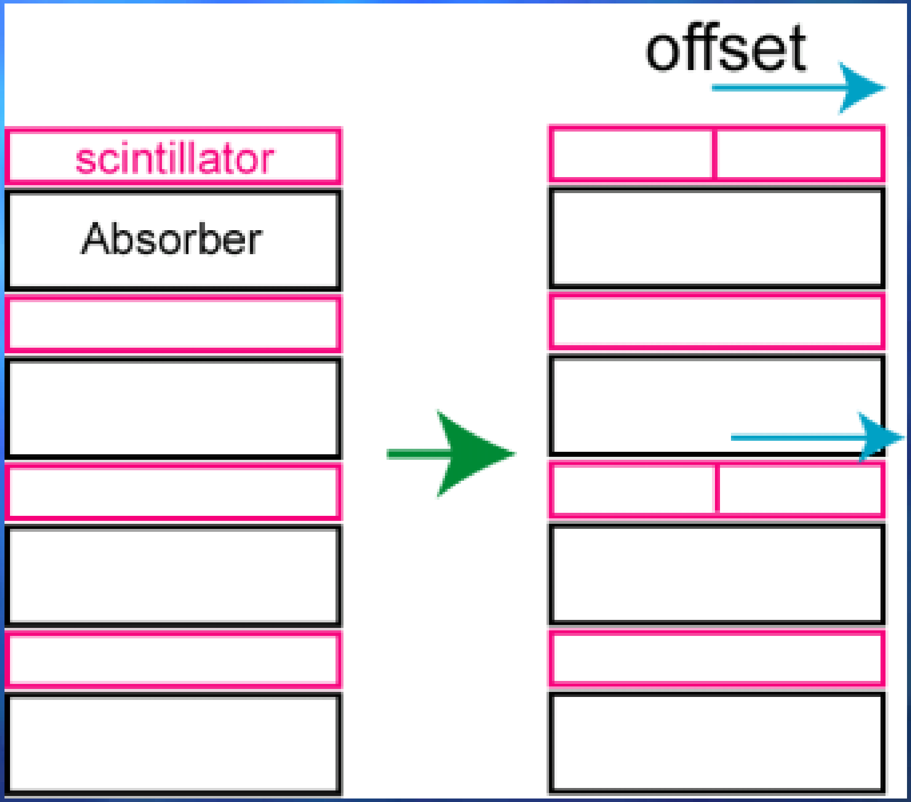
Toshinori Abe, Uriel Nauenberg, and Joseph Proulx

- A very fine granular calorimeter shows excellent performance.

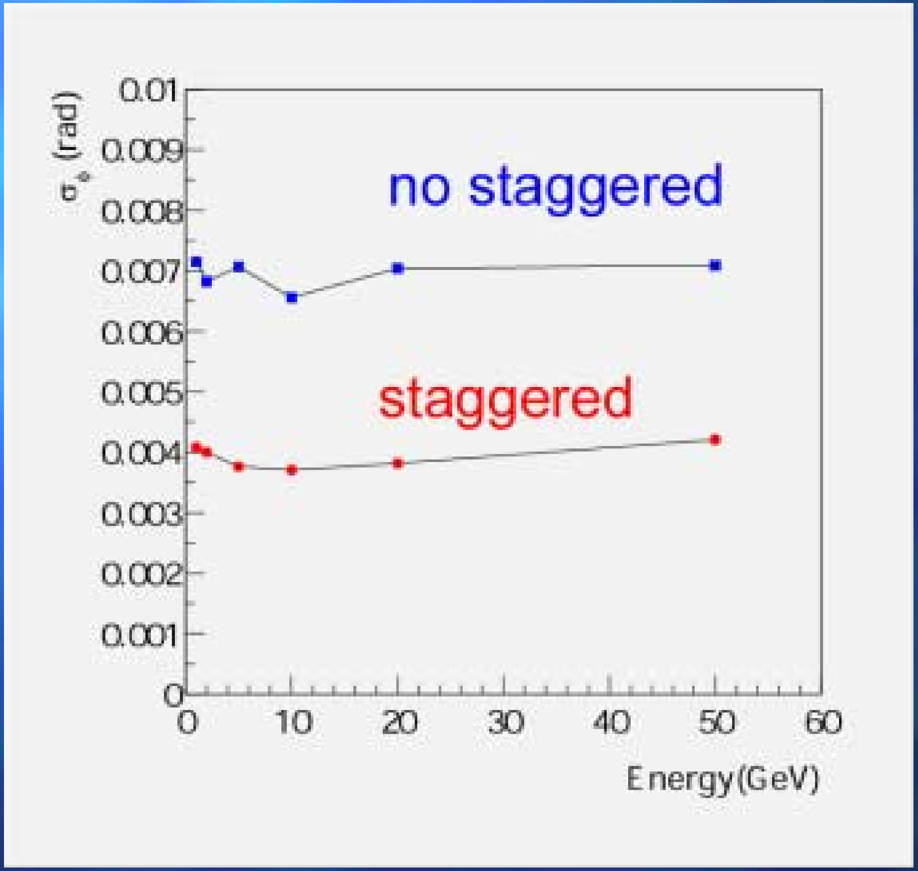
  → But it is very expensive!

- U. of Colorado proposes a new calorimeter geometry to give energy flow calorimeter with reasonable cost.

Staggered geometry



Energy vs. position resolution



G.Bashindzhagyan, *Moscow State University, Russia*
Il Park, *Ewha W. University, Seoul, Korea*
August 2002

SILICON CALORIMETRY FOR A LINEAR COLLIDER

Introduction

The advantages of silicon sensors are well known now.

The idea to use silicon in sampling EM or even Hadron calorimeter has been discussed and looks very attractive.

But there is a realistic opinion that the cost of silicon calorimeter should be 5-10 times higher than other types of EM and Hadron calorimeter.

Our goal is to minimize the cost of silicon calorimeter and make it comparable with other types.

It actually means to minimize the cost of:

1. Silicon sensors
2. Front-end electronics
3. Connections between Si sensors and to electronic chips
4. Mechanical structure
5. Assembly

1. Silicon Sensors

Three main points have strong influence on final sensor cost.

- Cost of the material (pure high resistivity silicon)
- Cost of one wafer production
- Production yield

◆ Material

One 6” wafer cost is expected to be around $30.

It can be decreased down to about $20 per wafer but unlikely les

Assuming 10×10 cm^2 active area on 6”wafer we can expect ~ $0.25/cm^2.

◆ Production cost

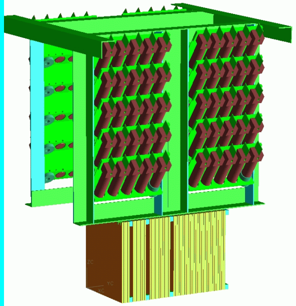
Production cost depends on sensor type, on company, country, et

The cheapest type is DC-coupled diodes.

After a few discussions with Korean and Russian companies we came to a conclusion that for DC-coupled sensors one 6” wafer production cost can be as low as $60-70.

It corresponds to $0.65/cm^2 for 10×10 cm^2 sensor or to about $0.9/cm^2 including material.

Lccal*: an R&D project for the Electromagnetic barrel Calorimeter



TALK SUMMARY

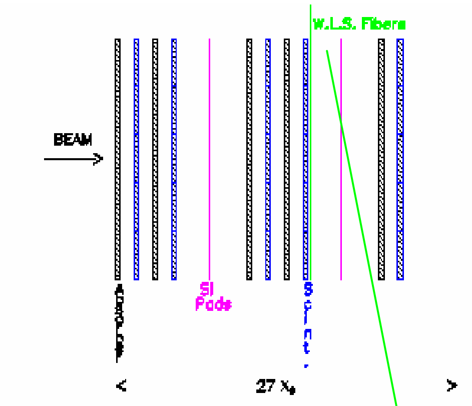
- Design principles
- Prototype description
- Status of the production
- Beam test results
- Future plans

* Official INFN R&D project, official DESY R&D project PRC R&D 00/02
Contributors (Como, LNF, Padova, Trieste):
M. Alemi, A.Anashkin, M.Bettini, S.Bertolucci, E. Borsato, M. Caccia, P.C, C. Fanin, S. Miscetti, M. Prest, R. Peghin, L. Ramina, E. Vallazza ….

Prototype description

Pb/Sc + Si

- 50 layers:
- $25 \times 25 \times 0.3$ cm^3 Pb
- $25 \times 25 \times 0.3$ cm^3 Scint.: 25 Cells 5×5 cm^2
- 3 planes:
- 625 1×1 cm^2 Si Pads
- at: 2, 6, 12 X_0

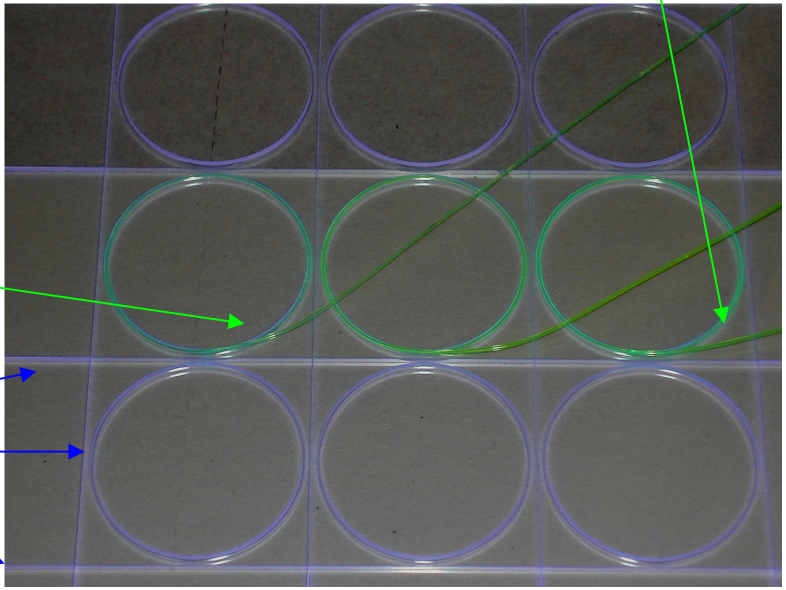


(Slightly reduced to cope with budget)

Scintillation light transported with WLS σ tail fibers:

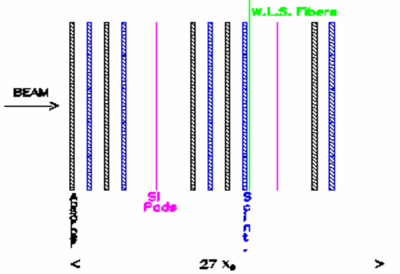
Coupled with clear fibers (to PM):

Cell separation with grooves in Sc. plates with Tyvec strips inside



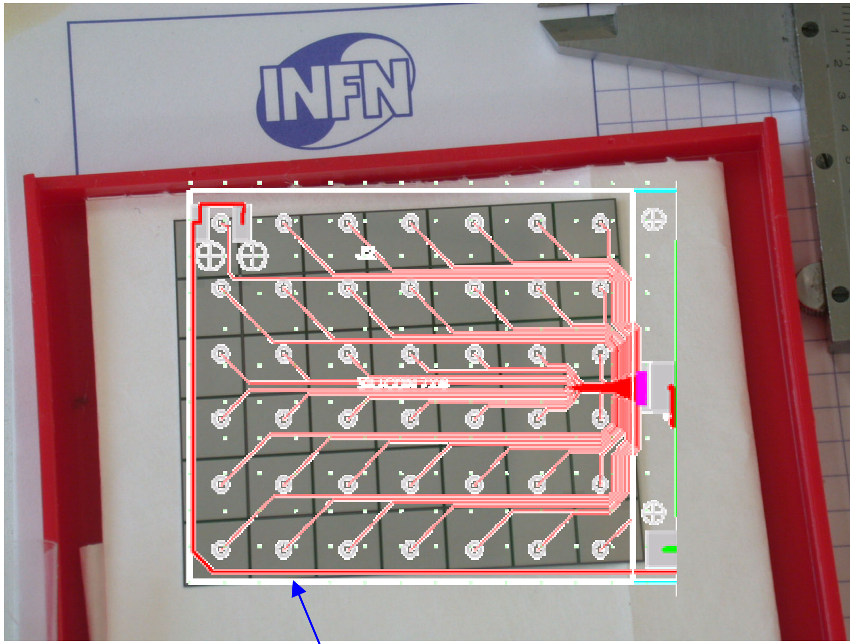
Prototype (cntd)

3 Si planes



Goal: shower-shower separation:

- **Pad dimension< shower dimension:**
  .9x.9 cm²
- **Longitudinal sampling:**
  3 planes
- **Analogic RO**
  VA hdr9c from IDEas
- **Next year: shower dimension reduction**
  W absorber



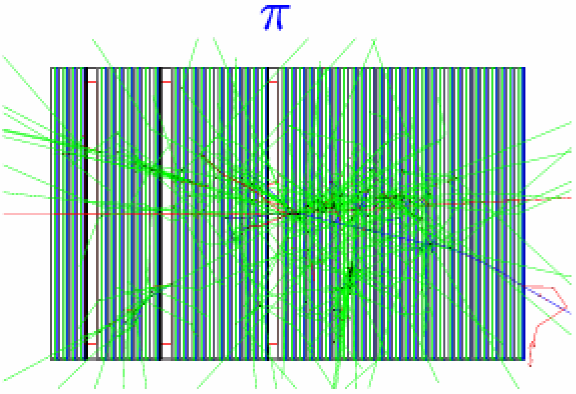
Actual design

- **Detector: 6x7 pads**
- **Plane: 3x2 detectors**

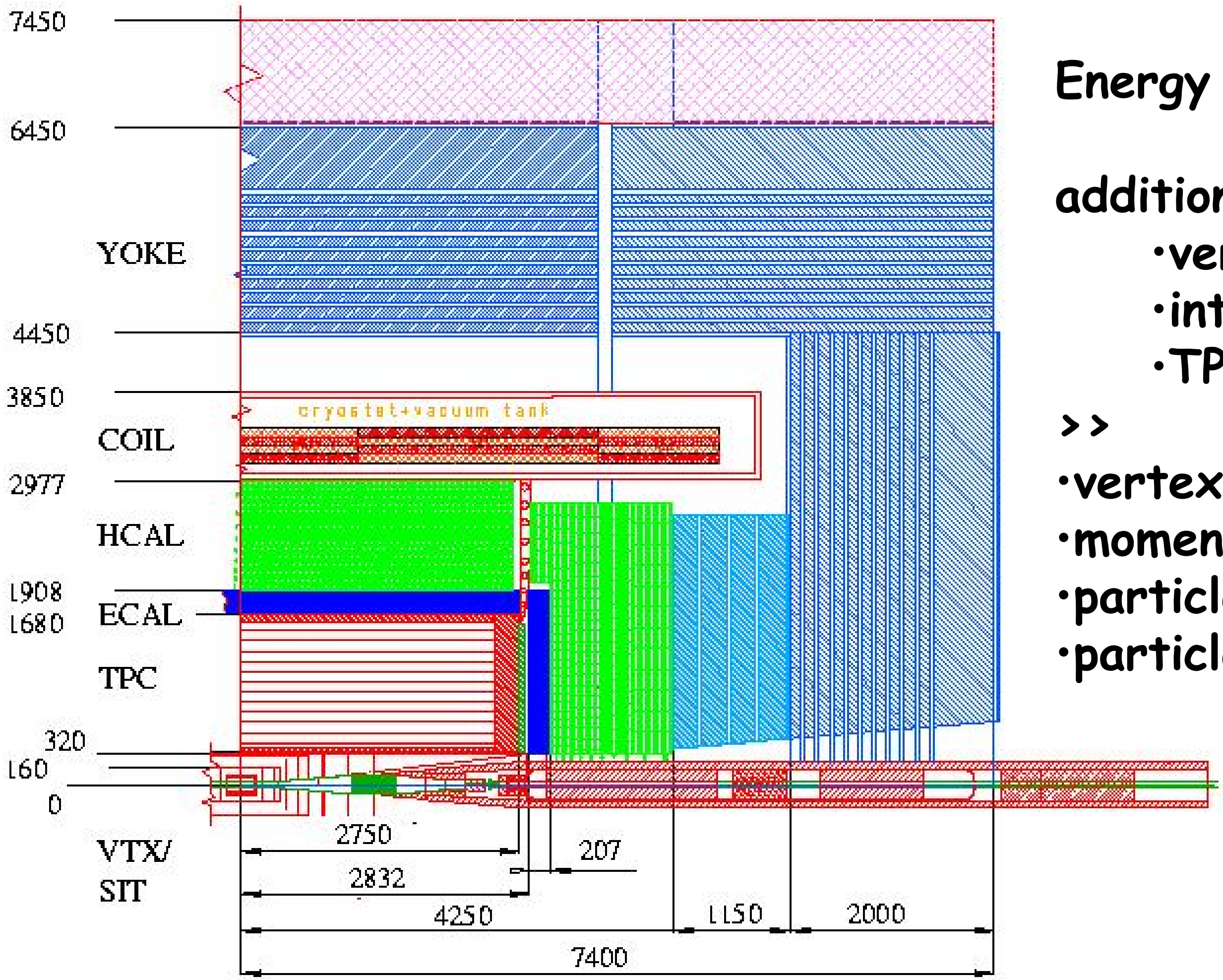
pcb contact with conductive glue

Conclusions

- The proposed prototype is going to be completed (all the production problems are solved)
- A preliminar beam test at CERN with a partial set up gave reasonable and incouraging results
- Tests with the complete detector are necessary to answer to all questions
- …. but it they will be successfully answered, why do not include a calorimeter made following this technique into the general LC simulation and Pattern recognition?



TESLA Detector, cross section



Energy Flow Measurement:

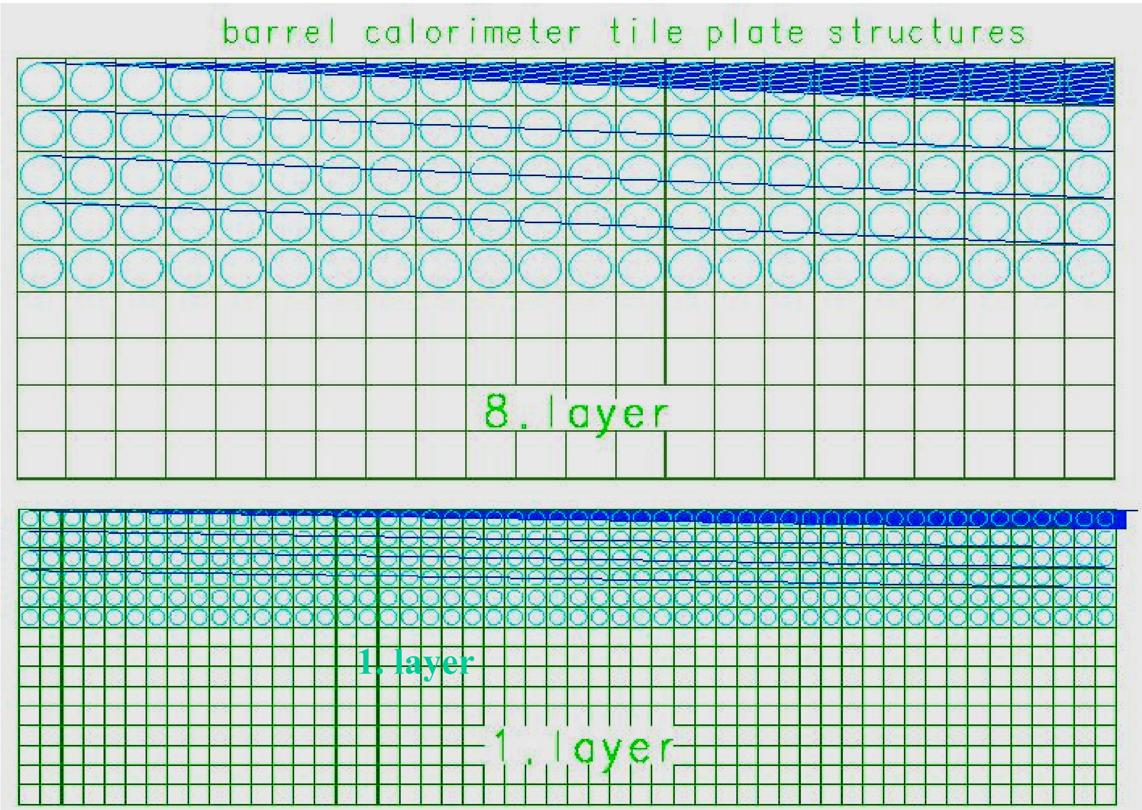
additional information from:

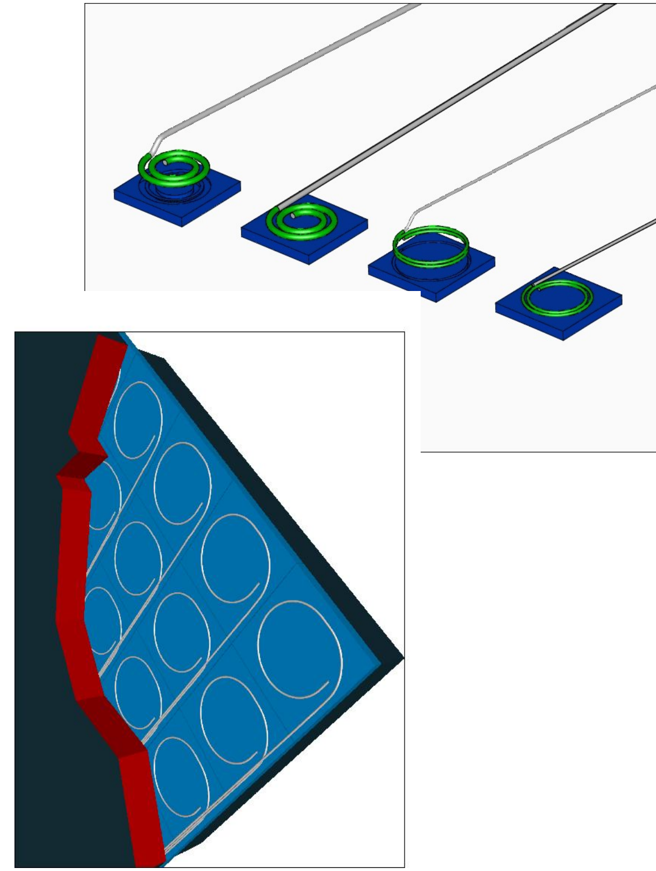
- **vertex detector**
- **intermediate trackers**
- **TPC**

>>

- **vertex of event**
- **momentum of charged tracks**
- **particle identification**
- **particle impact point at ECAL**

Original concept of tile plate read out



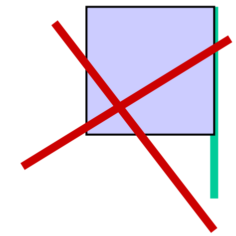


original fibre RO concept as described in the TESLA-TDR.

Problematic are the small scintillator tile sizes (~ 5x5 cm^2) to be read out

→ **Study other possibilities**

R&D studies on the tile-WLS fibre system

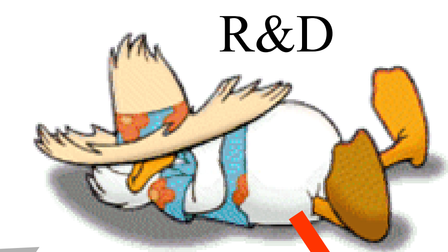


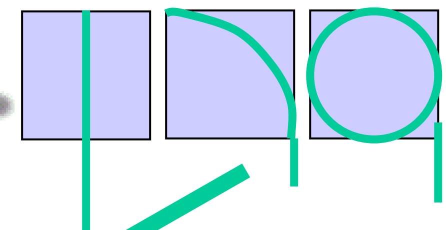
Scintillator light yield

Tile uniformity

BC-408, BC-416, SC-306, Protvino

Scintillator : ~6600 m^2, costs!





Reflector foil: mirror or diffraction, light yield

Tyvek, 3M Super-reflector

Reflector foil: LY uniformity

Green WLS fibre: attenuation length

WLS fibre: bending in small radius

Y-11, Kuraray BC-91, Bicron

WLS fibre: ageing, rad. hardness

WLS fibre: fibre end polishing and mirroring

Al-vapour, various reflector paintings,polished optimally

Tile-WLS system:
- **coupling,**
- **light yield,**
- **uniformity**

>>>> 5x5 cm^2, than: 7x7......16x16cm^2 tiles

Light yield and uniformity for tiles

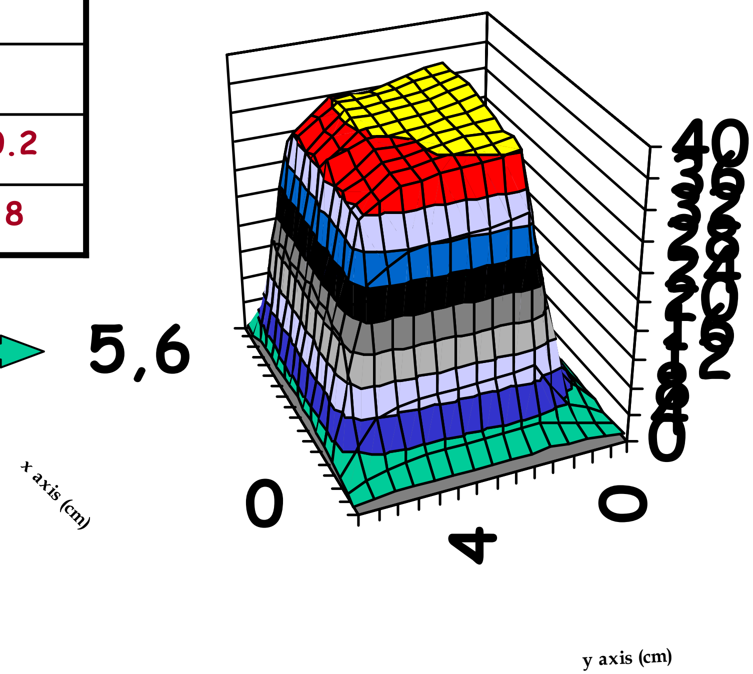
Tile a x a (cm²)	5 x 5	10 x 10	15 x 15
LY (nA)	105 +- 6	60 +- 4	39 +- 6
Relative LY	2.4 +- 0.4	1.5 +- 0.3	1
Photo e$^-$	6.5+-0.4	4 +- 0.2	2.5 +- 0.2
LY / photo e$^-$ (nA)	16 +- 1.7	15 +- 1.4	16 +- 2.8

⇧ light yield

uniformity

Tile (cm²)	5 x 5	10 x 10	15 x 15
Uniformity (%)	4.0 - 6.0	5.0 - 6.5	4.0 - 5.5

5,6



- improve LY for large tiles with WLS loops
- signal of large cells will be increased by more sampling layers
- actual established LY is ~20 pe/cell/MIP
- uniformity is ok, needs confirmation by simulation studies.

Digital HCAL readout studies

1 - Readout for Prototype

(Laboratoire Leprince-Ringuet-IN2P3)

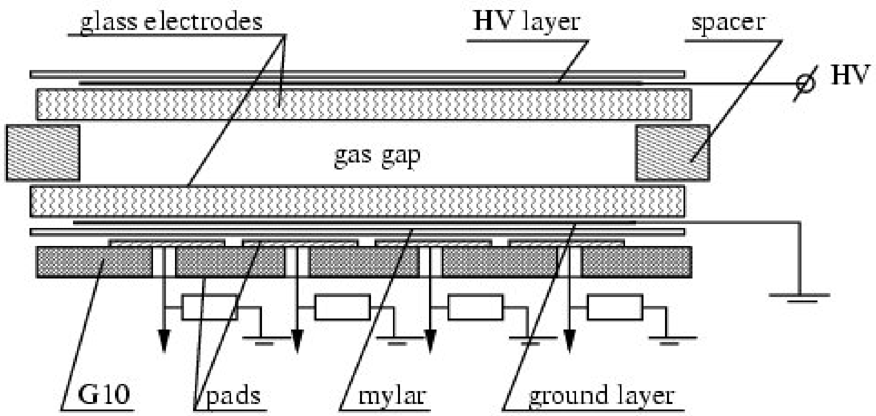
2 - Readout for a large scale detector

(SEL-SEE - Seoul National University)

Two examples of RPC as active element

by courtesy of Vladimir Ammossov

Pads outside



Pad size 1x1 cm^2

Gas gap thickness 1.2 mm

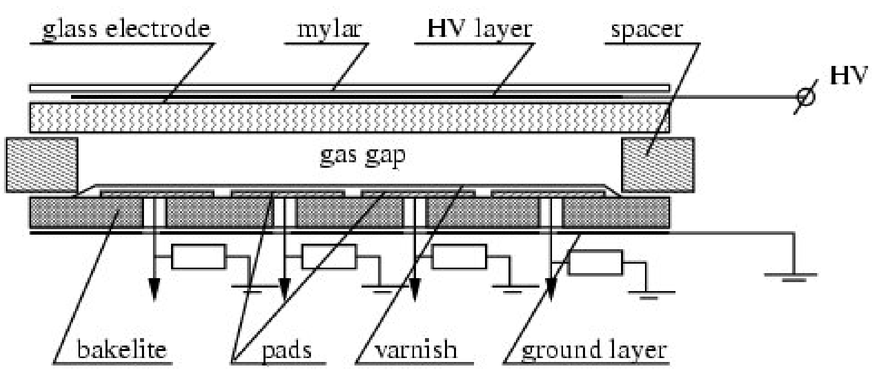
Gas mixture TFE/N2/IB 80/10/1

First measurement

Efficiency to mip > 98%

Signal on 50 Ω : 1-3 V

Pads inside



Design of Readout Electronics for digital HCAL on Linear Collider

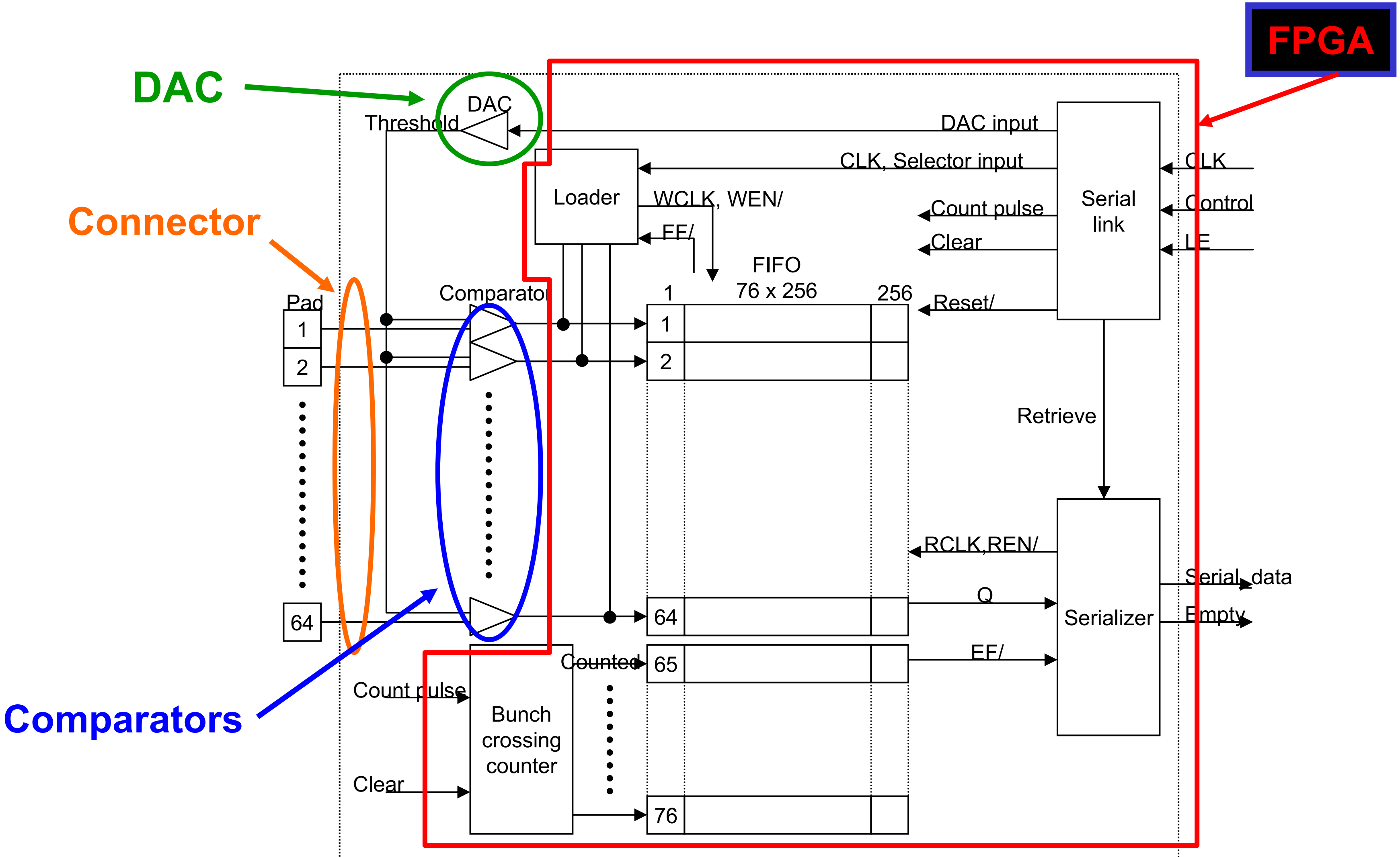
Jaehong Park, Taeyeon Lee, Jinho Sung,
Sanghyun Min, Donghwan Lee

System Electronics Laboratory
School of Electrical Engineering
Seoul National University, Seoul, Korea

Readout Electronics Design

시스템전자연구실
SYSTEM ELECTRONICS LAB.

- **Functional Block Diagram of Readout**



Conclusion

All the pieces of the puzzle have been

Designed

Built

Tested

FPGA with in front, .

a Current Mirror circuit (LLR) or ADC+discriminator (SELSEE-SNU)

We are ready to read the prototype very soon for a RPC-type signal

At least, one conclusion NOW

The possibility to design a thin, simple, cheap electronic readout for the digital HCAL, has been demonstrated

A General High Resolution Hadron Calorimeter using Scintillator Tiles

Manuel I. Martin

for NIU / NICADD

Northern Illinois University

Northern Illinois Center for Accelerator and Detector Development

Comparative Light Output Measurements

Surface Covering for the Cells

All measurements were made under the same conditions.

Source Sr-90

Hexagonal Cell l=19mm

h=5mm

Scintillator BC-408

WLSF BCF-92 Ø1mm (mirrored)

Groove 1.2x3x37mm

Fiber Length 400mm

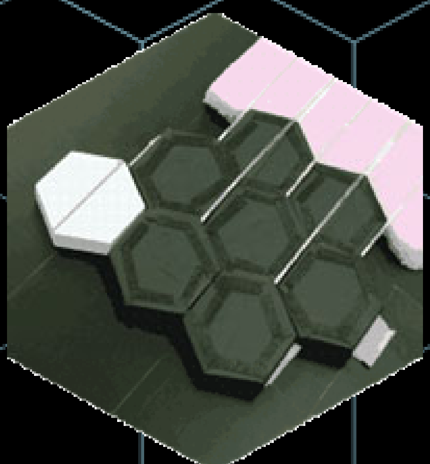
Attenuation length ~4000mm

PMT 16% Q efficiency

Surface Treatment		nA output	%
Wrapping	Tyvek	1000.9	100
	Aluminized Mylar Tape	465.9	46
Spray Painting	Vinyl	473.7	47
	Lacquer	439.4	43
	Acrylic	816.7	82
Sputtering	Al	233.5	23

Preliminary Design

Expected Yield
~ 25 PE/MIP



- **Support material**
  - **Inner Ring: Tungsten at least 5mm**
  - **Outer Ring: Aluminum structure**
  - **Radial (ends): Aluminum structure**
- **Cell Geometry**
  - **Hexagonal base Prism 19mm side**
- **Scintillator Material**
  - **BC-408 5mm thick**
- **Absorber Material**
  - **Brass 20.2mm thick**
- **Fiber Material**
  - **WLSF >> Y-11 (Kuraray) [BCF-92]**
  - **CF >> Kuraray [BCF-98]**
- **Fiber Geometry**
  - **Ø .9 mm mirror end .64mm^2 (R)**
- **Groove Geometry**
  - **Sigmoid (length ≈ 83mm)**
- **Reflector Material**
  - **Painted (Acrylic White Titanium Dioxide)**

Status of DHCAL using GEM

J. Yu

Univ. of Texas at Arlington

LCWS 2002, Aug. 26 – 30, 2002

Jeju Island, Korea

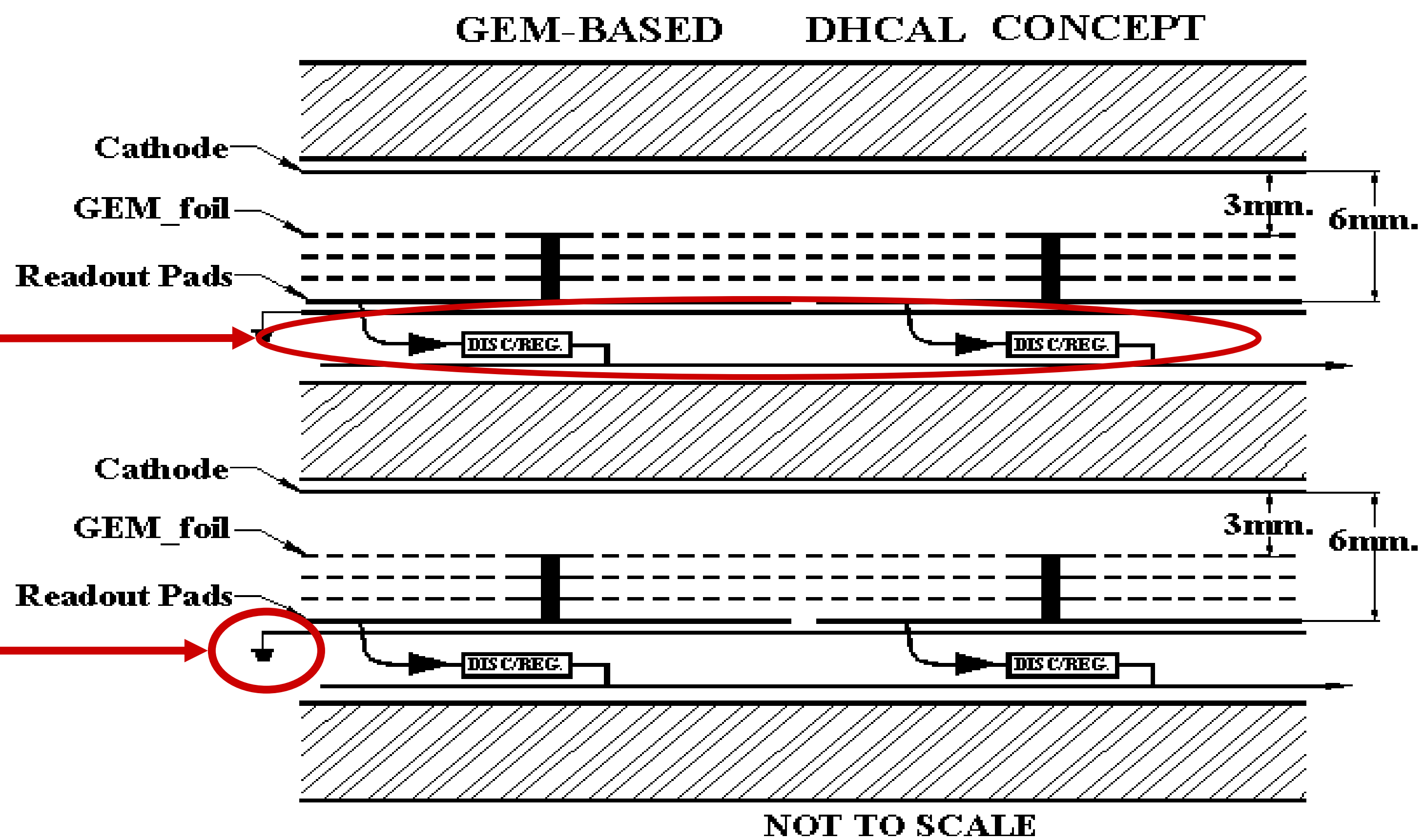
- Introduction
- Digital Hadron Calorimeter
- GEM in the sensitive gap
- Status of GEM DHCAL prototype
- Simulation study status
- Summary

(on behalf of the UTA team: A. Brandt, K. De, S. Habib, V. Kaushik, J. Li, M. Sosebee, A. White)

Design for DHCAL using Triple GEM

Embeded onboard readout

Ground to avoid cross-talk



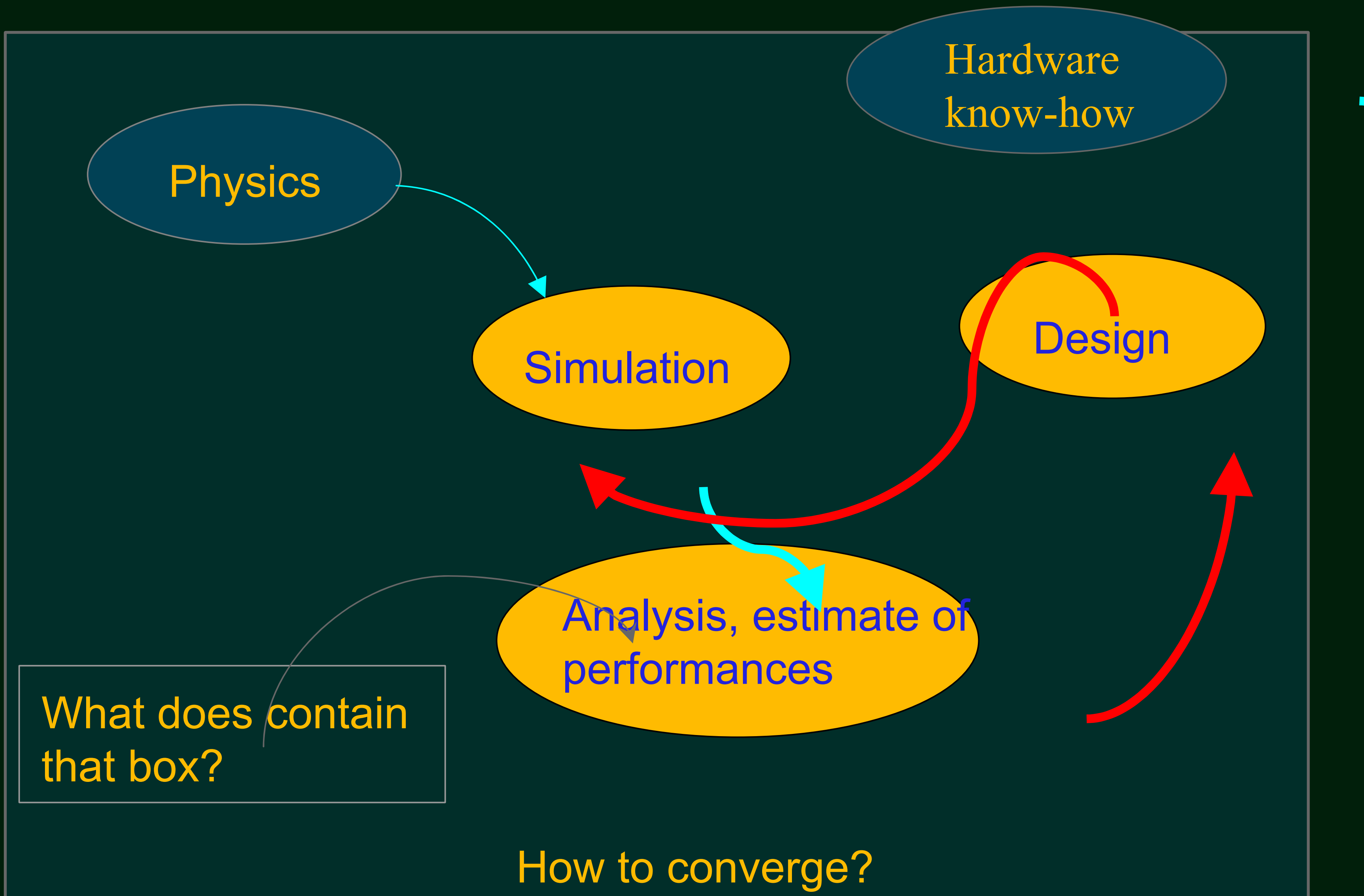
UTA GEM Prototype Status

- Constructed
  - Test chamber box
  - Readout circuit board (1cmx1cm pads)
  - HV layout design complete
  - Two GEM foils arrived and two more on the way

Calorimeter Simulations

- Framework
- Results

Optimising the design: An iterative process



International Calorimeter Simulation Effort

Norman Graf, SLAC

- A common Geant4 executable ?
- Run-time geometry description files
- Sharing algorithm code to compare different detectors
  - For how big a change does this make sense?

Software Development to support projective and non-projective geometry in Geant 4 and Energy Flow Algorithms for a DHC

Manuel I. Martin

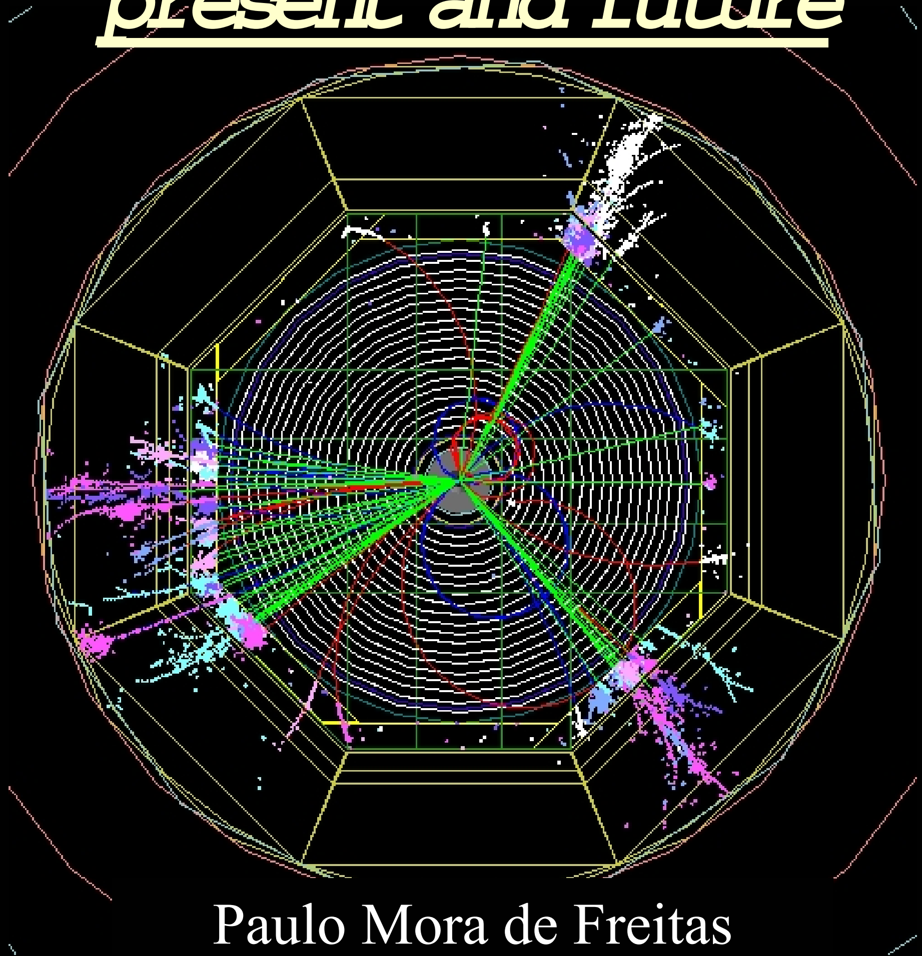
for NIU / NICADD

Northern Illinois University

WORK at NICADD

- HARDWARE (DHC using scintillating hexagonal tiles)
- SOFTWARE
  - GENERAL
    - GIGS **(Geometry Independent G4 based Software)**
    - SIMULATION
  - ALGORITHMS
    - E FLOW
    - CLUSTERING

Detector simulation with Mokka/Geant4 present and future



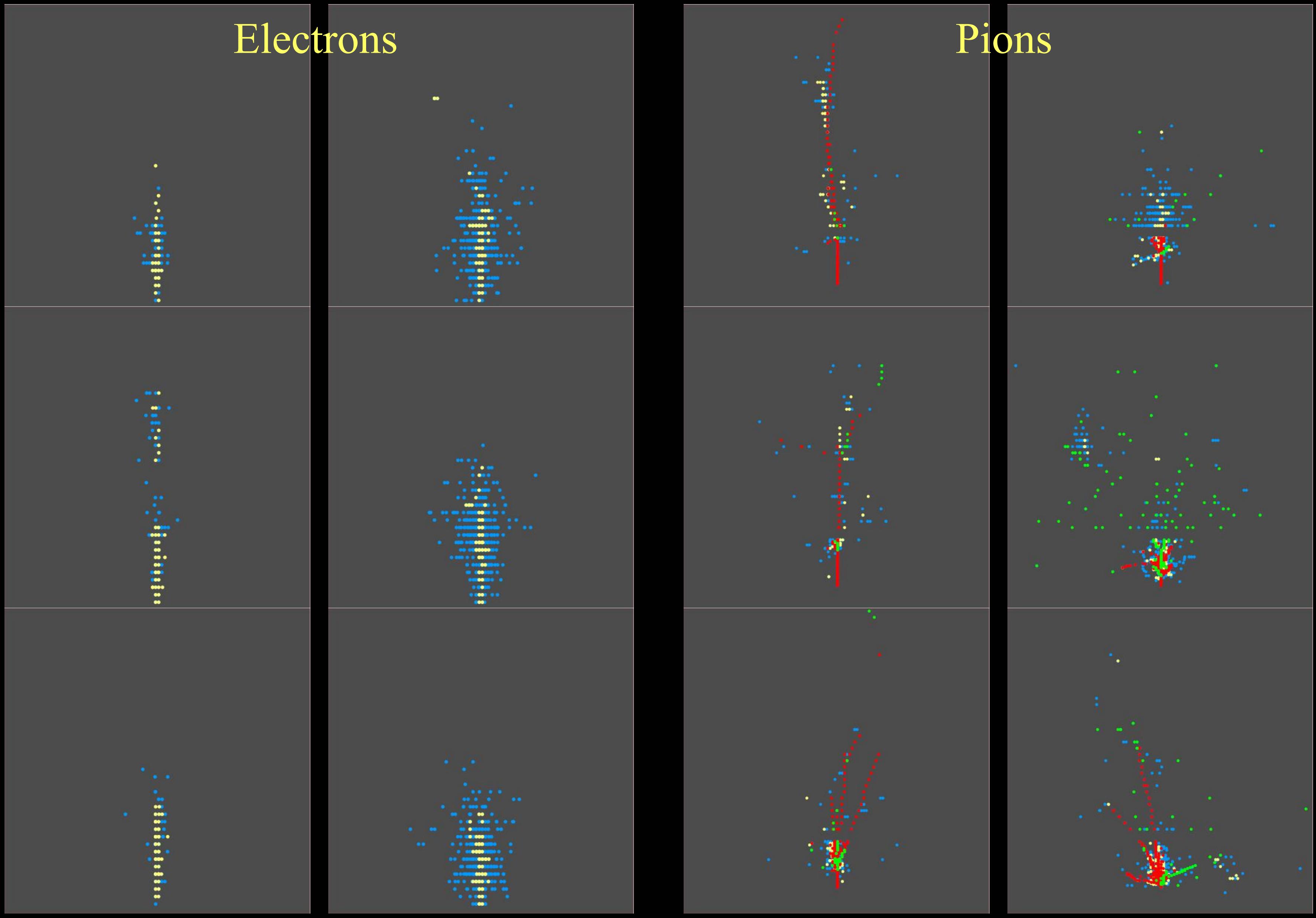
Paulo Mora de Freitas
presented by Henri Videau
L.L.R. – Ecole polytechnique

LCWS2002, Jeju Island, Korea, August 26-30, 2002

What is MOKKA ?

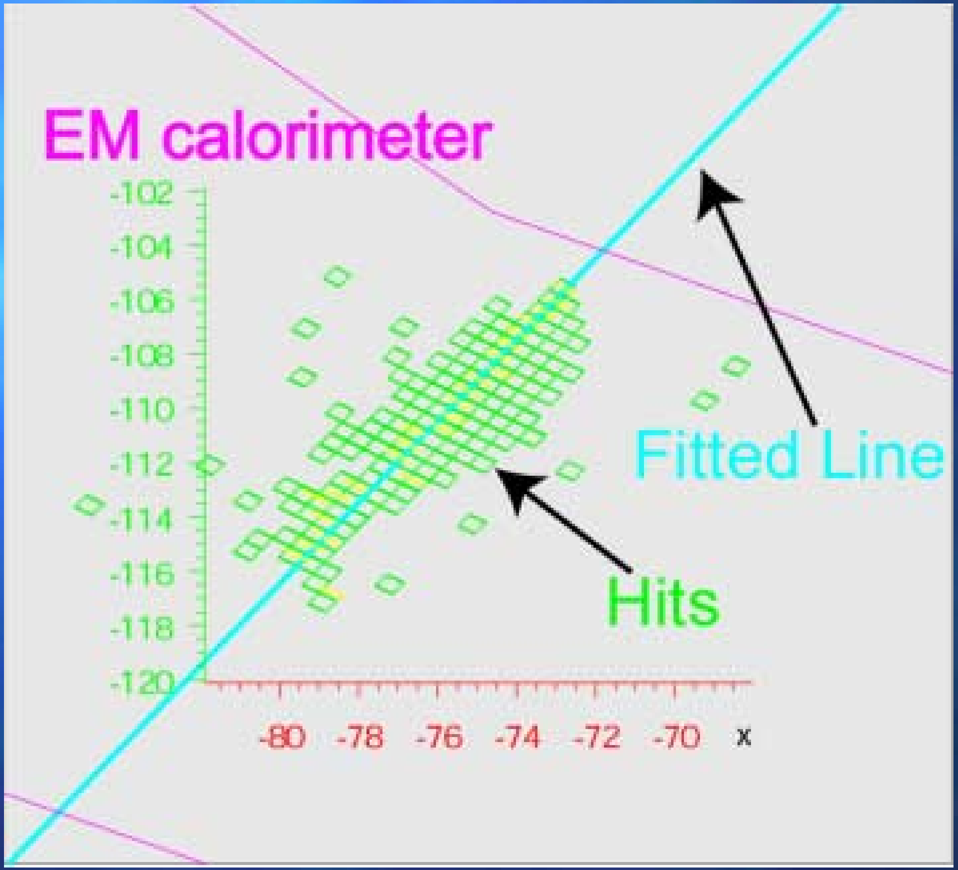
- A Geant4 full simulation for the Tesla detector calorimeters since December 1999, extensively used for the TESLA T.D.R. calorimeter energy flow studies.
- Able now to simulate several detector and prototype models thanks to its Geometry Database.
- Automatic Fortran code generation to export the calorimeters geometry to Brahms.
- Work in progress, several new features in its last release.
- Open for a wide collaborative use and development.

Mokka, impact of the gas in HCAL

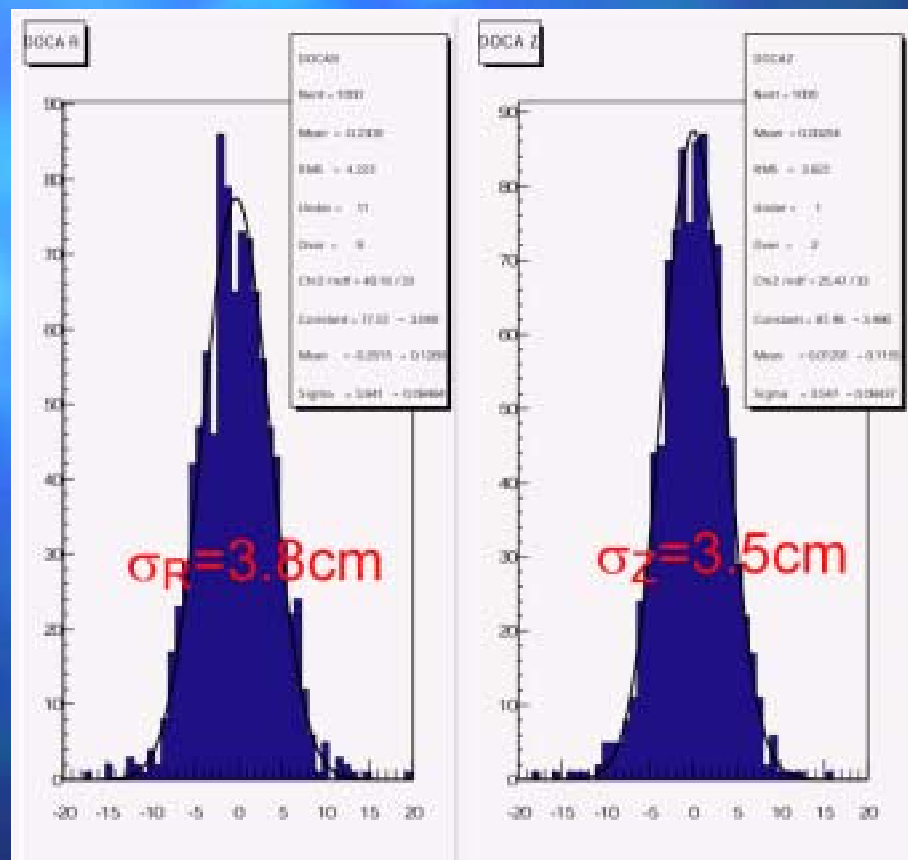


P. Mora de Freitas / H. Videau, L.L.R. – Ecole polytechnique

Line fitting of photon clusters



DOCA resolution



10GeV gamma from I.P.

Luminosity Measurement questions; calorimeter-related

Stewart Takashi Boogert and David John Miller
Department of Physics and Astronomy
University College London
sboogert@hep.ucl.ac.uk, djm@hep.ucl.ac.uk

1. First order optimism (duplicates MDI session talk).
2. Forward tracking plus endcap calorimetry.
3. Smaller angle measurements.
4. Work planned.

Endcap best?

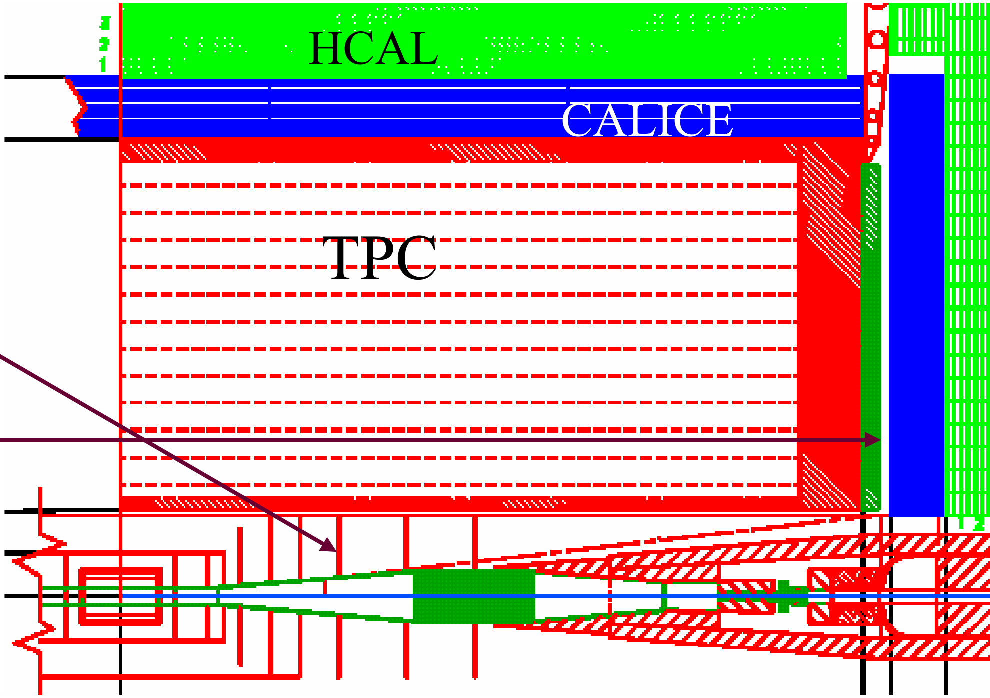
For small θ_A and Gaussian errors, $\sigma_{\sqrt{s}} ; \sigma_{\Delta p} ; \sigma_{\theta_A} \frac{p_b}{\sin\theta} ; \sqrt{2}\sigma_{p_b}$,

so with fixed angular resolution σ_{θ_A} the error on √s blows up at small Bhabha scattering angle θ.

But the Bhabha rate for $100 \leq \theta \leq 450$ millirads is already > 400 times the μμ rate.

And above ~100 milliradians there is good forward-tracking (7 layers of pixels/Si in TDR)

with calorimetric backing
(CALICE endcap)



David Cinabro
Wayne State University

LCWS 29 Aug 2002

Measurement Requirements on the Luminosity Spectrum

I $d\mathcal{L}/dE$ Reminder

- A ISR
- B Beamstrahlung
- C Linac Energy Spread

II Physics Examples

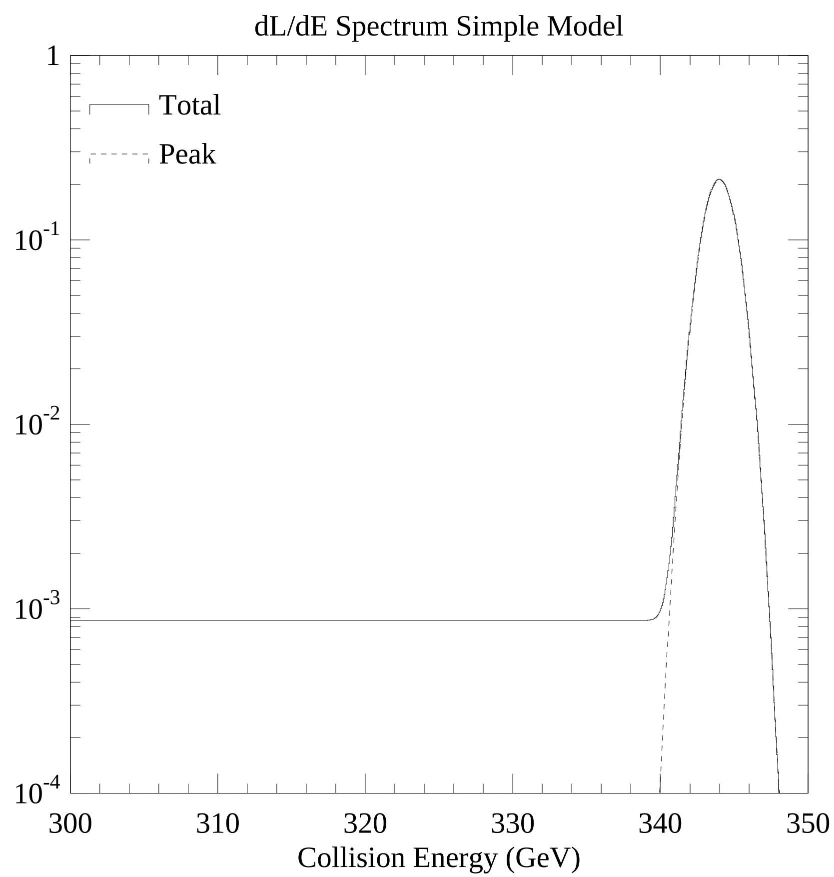
- A Simple Model of $d\mathcal{L}/dE$
- B $t\bar{t}$ Threshold
- C $e^+e^- \rightarrow \tilde{e}^+\tilde{e}^-$ Cross Section

III Note on Techniques

IV Implications, Plans and Conclusions

Simple Model of $d\mathcal{L}/dE$

Divide into a peak, sum of two equal area Gaussians with the same mean, and a flat tail. Consider variations in A_{rat}, the ratio of the area in the tail to the total, σ_{E}, the width of the peak, and Shap, ratio of width of wide to narrow Gaussian in peak. Then look how changes in A_{rat}, σ_{E}, and Shap impact physics.



Implications, Plans, and Conclusions

- We must measure d$\mathcal{L}$/dE with a precision, width of the peak energy spread and amount lost to tail, better than 1% or uncertainty on it can dominate extraction of parameters in threshold scans.

- d$\mathcal{L}$/dE Not as crucial above threshold, absolute luminosity can be measured to a few $\pm 10^{-4}$, but still thinking on processes to consider. Suggestions from you?

- Multiple techniques to measure d$\mathcal{L}$/dE will be needed to make cross checks. Will need real time monitors to insure stability.

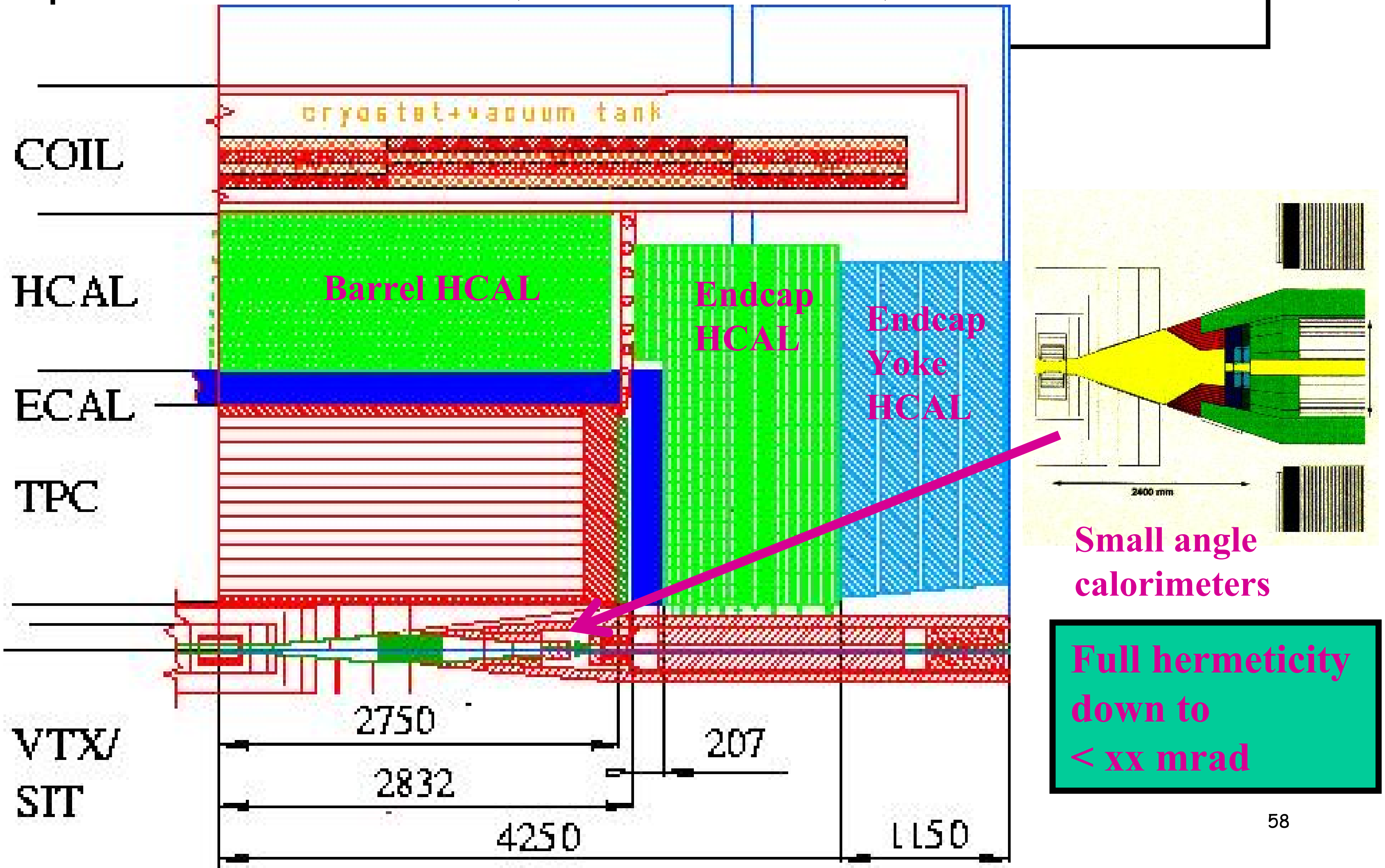
- Need detailed studies of d$\mathcal{L}$/dE techniques and detector/monitor designs. Must include effects of backgrounds. Lots of simulation effort is needed here.

- Can easily be studied by you with Pandora by Peskin. All the tools to vary $d\mathcal{L}/dE$ are in place. We intend to guide community with suggestions as to “reasonable” variations.

- American IP Beam Instrumentation Working Group actively working on simulations and detectors for Luminosity, Beam Energy, and Polarization at the LC.

`http://www.slac.stanford.edu/~torrence/ipbi/`

TESLA Detector, cross section, more details



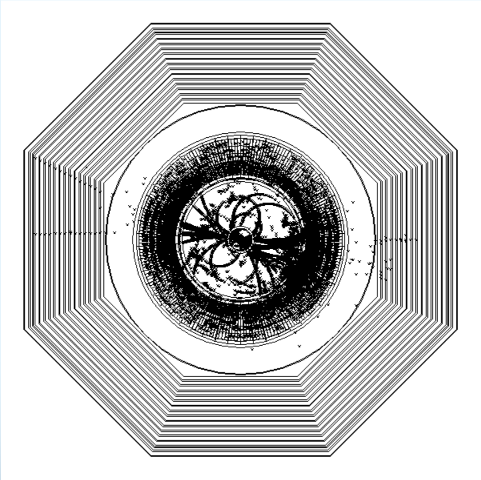
Full hermeticity
down to
< xx mrad

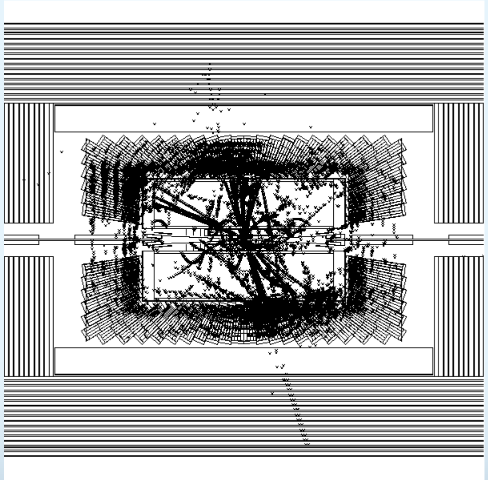
TESLA Very Forward Calorimeter
W. Lohmann, DESY

- Angle 5-30 mrad
- Want to tag electrons in background:
  - 6 TeV/crossing
  - 10 MGy/year
  - Average electron/positron energy 100 MeV

- Segmented tungsten; fiber readout
- Simulations look promising

Linear collider muon detector: an overview

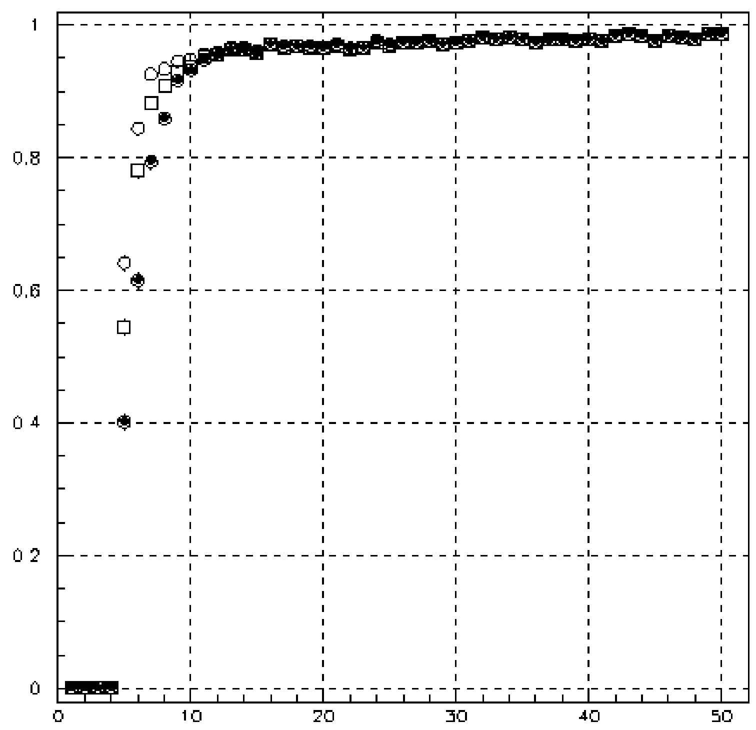




Marcello Piccolo

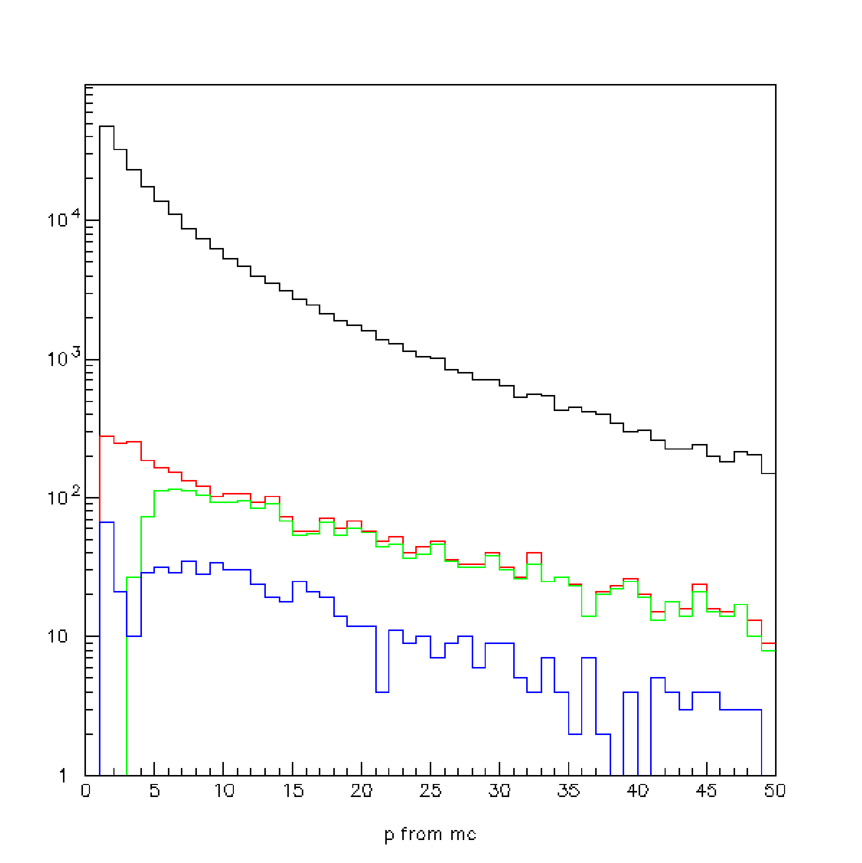
Jeju island , Aug. 2002

Single positive muon efficiency (Cont.)



- **Here we see what happens varying the matching of the tracks and the muon stub in the muon filter.**

Here are the overall results: ZH events @500 GeV



The four spectra refer to:

Black: generated primary particles
Red : generated μ
Green: identified μ
Blue : misidentified π

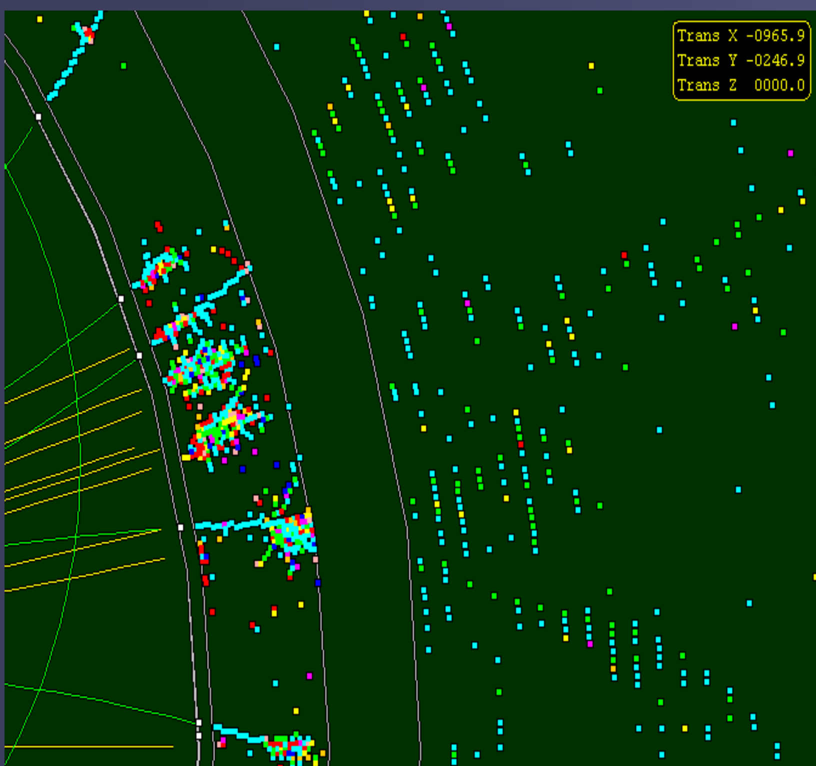
Outlook and Conclusions

- The design philosophy for the muon detector doesn't seem to present major show stopper(s).
- More detailed simulation needed to evaluate π rejection rate in jetty events.
- R&D studies started
  - Basic requirements for the proposed detectors on hand.
  - Some of the proposed devices could be used also in the (digital) Had. Cal.

Optimization of the Hadron Calorimeter for Energy-Flow Jet Reconstruction

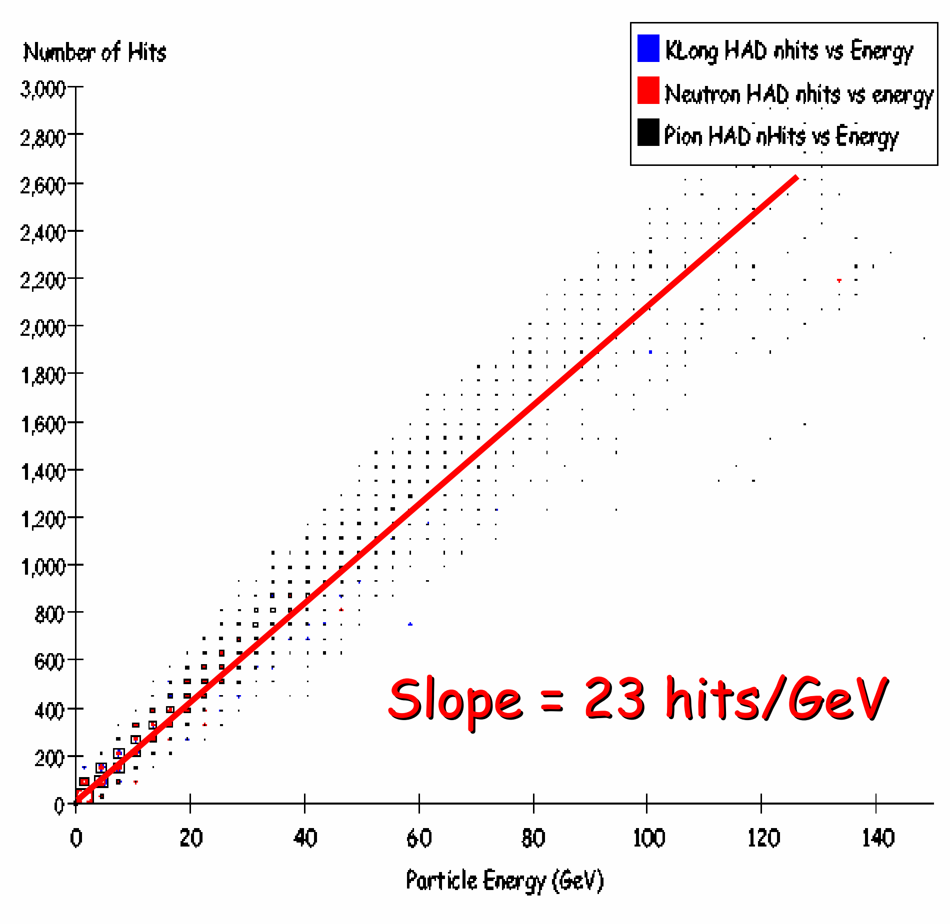
Stephen R. Magill

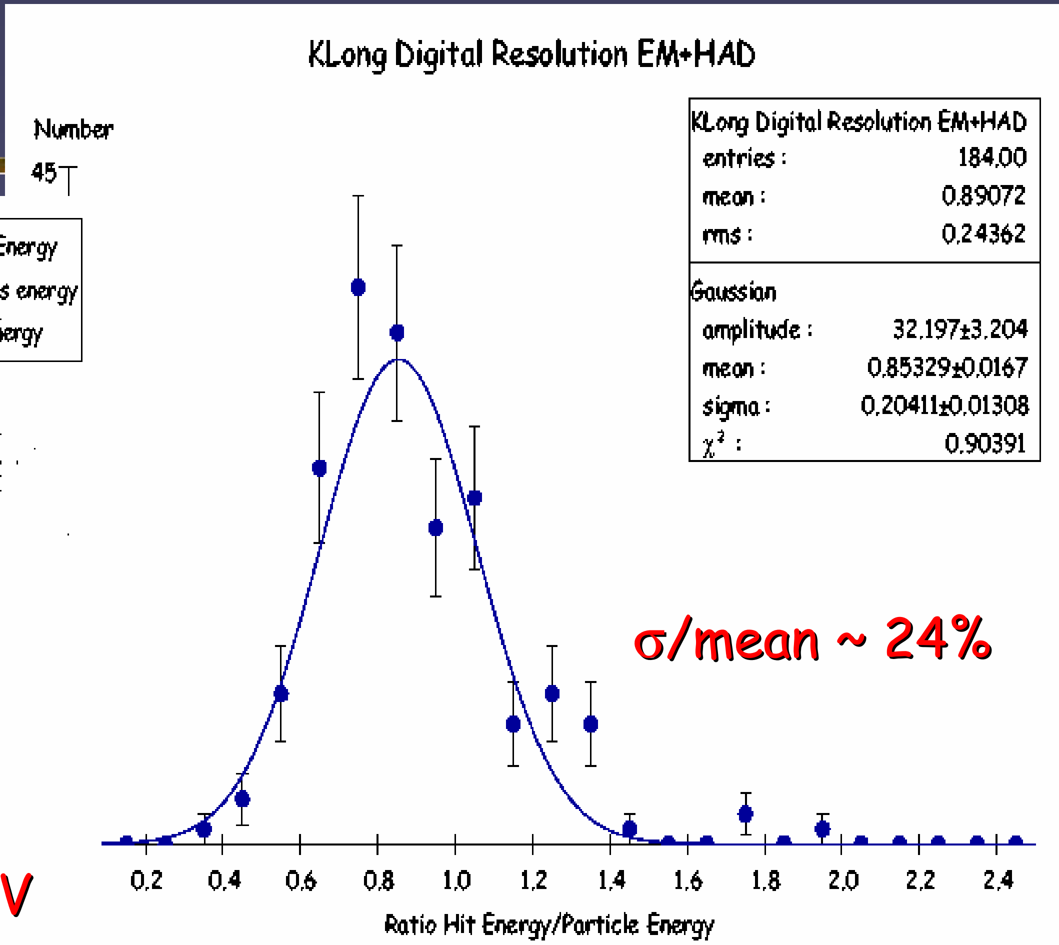
Argonne National Laboratory



- *Performance Goals -> Motivation*
- *Analog/Digital Comparisons*
- *E-flow Algorithm Development*
- *Summary*

K_L^0 Analysis – SD Detector Digital Readout



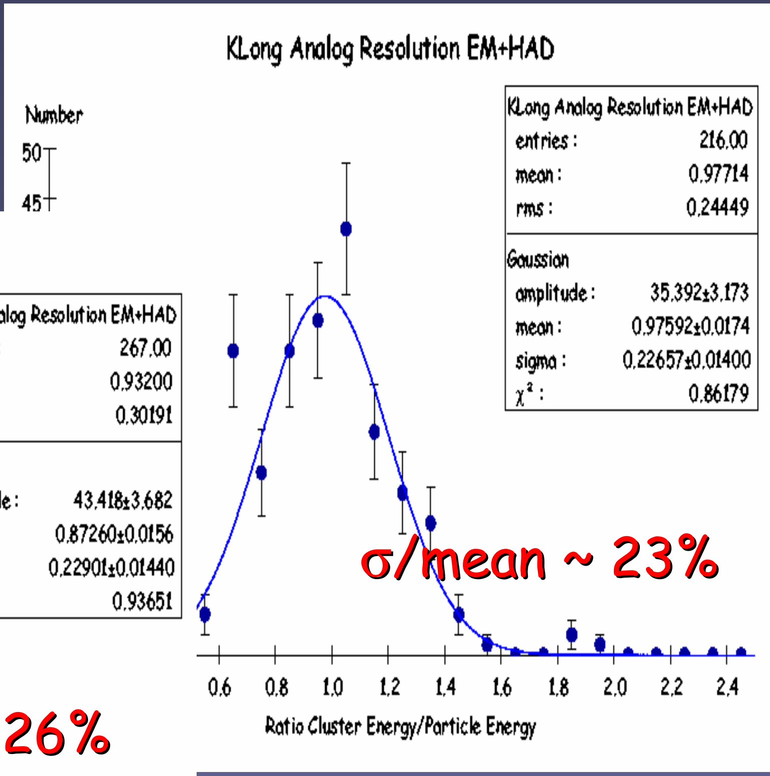


Average : ~43 MeV/hit

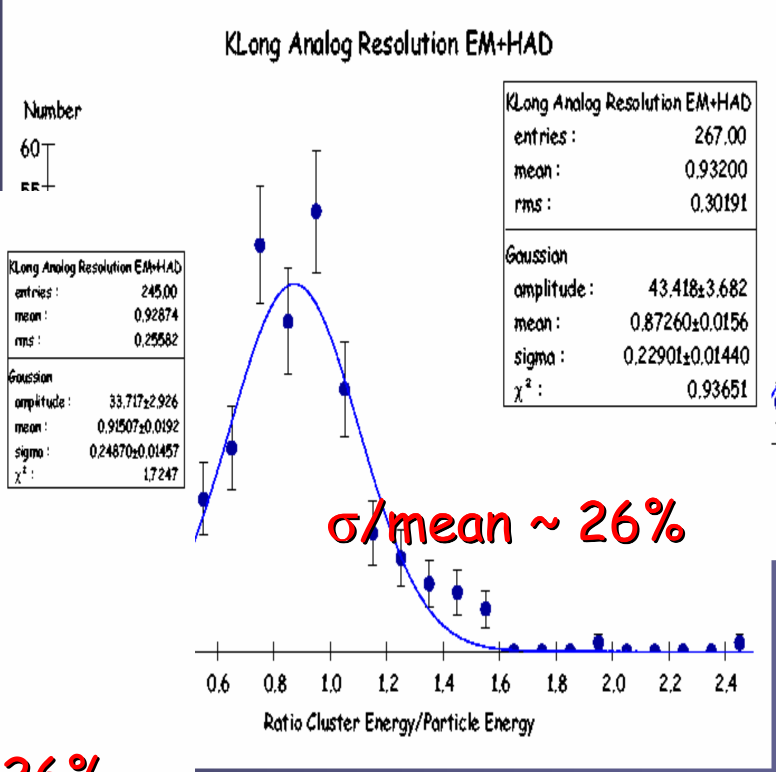
Analog EM + Digital HAD x calibration

K_L^0 Analysis – Modified SD Detector Analog Readout

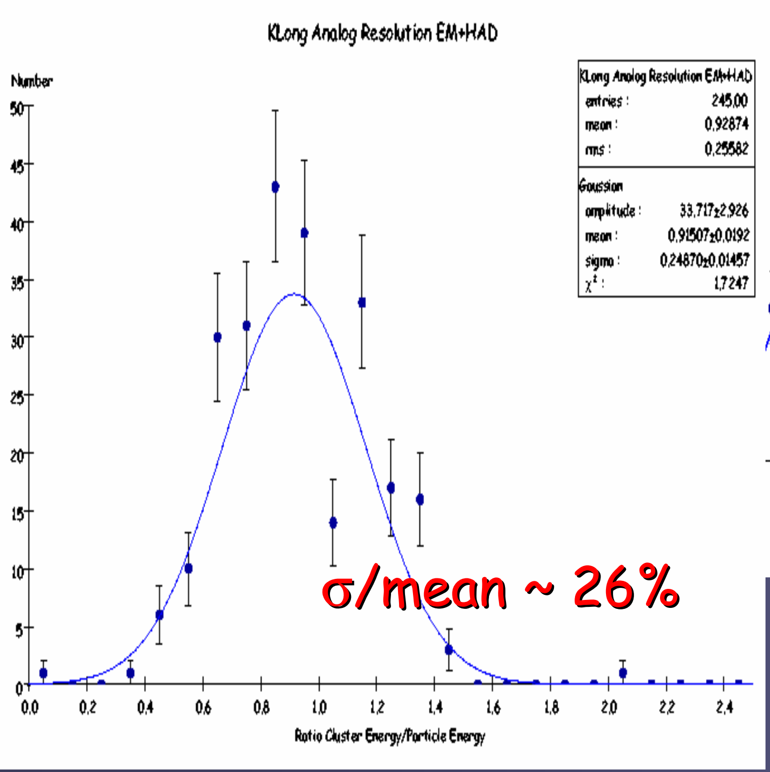
SD C (5 cm X 5 cm)



SD B (3 cm X 3 cm)



SD A (1 cm X 1 cm)



No-Clustering E-Flow Algorithm

Systematic Approach : Tracks first (60%), Photons next (25%), Neutral hadrons last (15%)

1st step - *Track extrapolation thru Cal – substitute for Cal cells in road (core + tuned outlyers) – Cal granularity optimized for separation of charged/neutral clusters*

2nd step - *Photon finder (use analytic long./trans. energy profiles, ECAL shower max, etc.)*

3rd step - *Jet Algorithm on Tracks and Photons*

4th step – *include remaining Cal cells (neutral hadron energy) in jet (cone?) -> Digital HCAL?*

Needs no cal cell clustering!

REPLIC
REconstruction Package for the LInear Collider

A FORTRAN package to reconstruct simulated LC events
Working on LINUX RH6.2

- Read MC informations (format HEPEvt)
- Read hits files (from GEANT4 and MOKKA)
- <u>**Perform a reconstruction**</u> (adapted for a W-Si ECAL and digital HCAL)
- Analysis Just a example with PAW

http://polywww.in2p3.fr/tesla/calice_software.ht

Help and work on REPLIC
J-C Brient, P. Mora de Freitas, A. Sokolov, H. Videau
LLR , IHEP

RECONSTRUCTION

WARNING:
the order
is important

TRACK FINDER

-**TODAY** fast simulation …. Not so good (see later)
-FUTURE will use last TPC point and direction at this last point
to mimic tracks reconstruction
(*OR use a true track finder (i.e.from BRAHMS or …)*)

PHOTON FINDER *PFD.06 to version PFD.07*

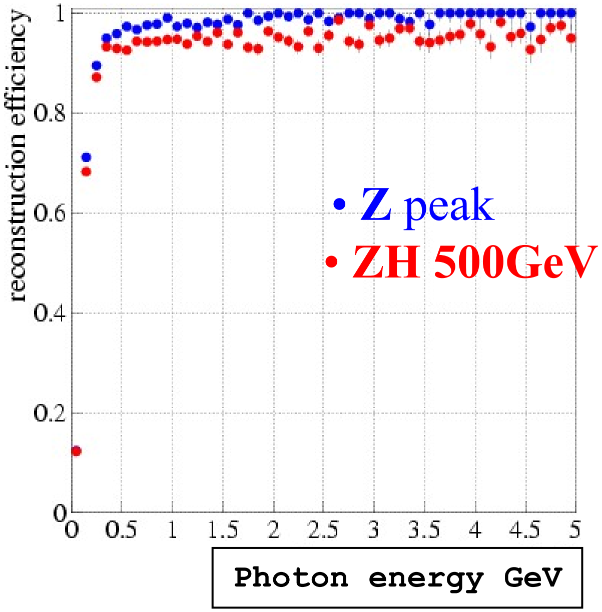
-**TODAY** Classical clustering (CC) …
-FUTURE Improved CC or new technique ?

NEUTRAL HADRON FINDER

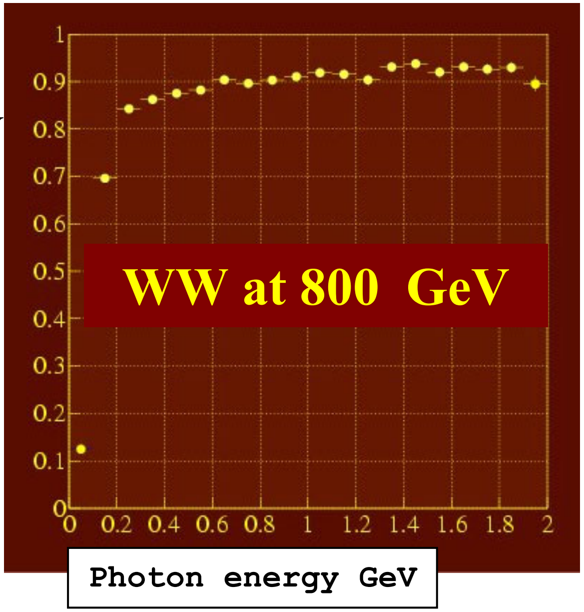
-**TODAY** 1- Start from charged track to link the
charged tracks to pads (ARBOR).
2- On the remaining pads, apply a simple cluster algorithm
(a la PFD)
-FUTURE 1-improve the energy estimation
2-improve the clustering (point 3)

LEPTON IDENTIFICATION (e,μ,h)

-**TODAY** First results on leptons in jets(not isolated lepton)
(not yet coded in REPLIC)
-FUTURE A true dedicated algorithm



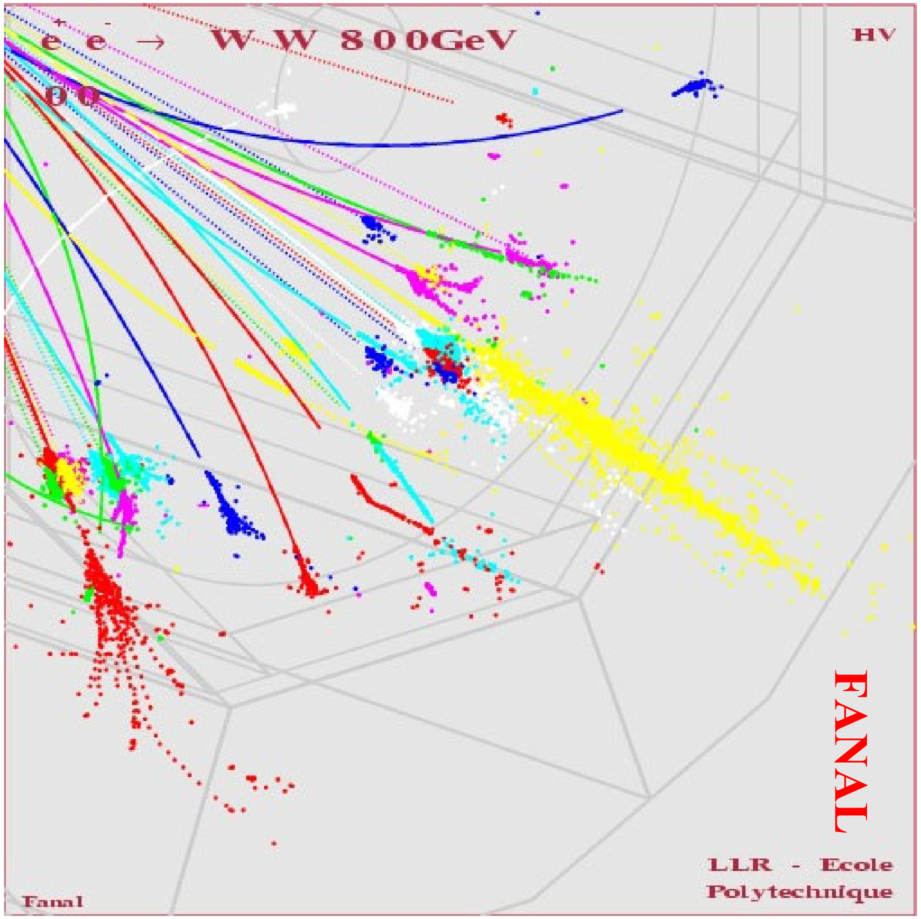
A Zoom below 2 GeV



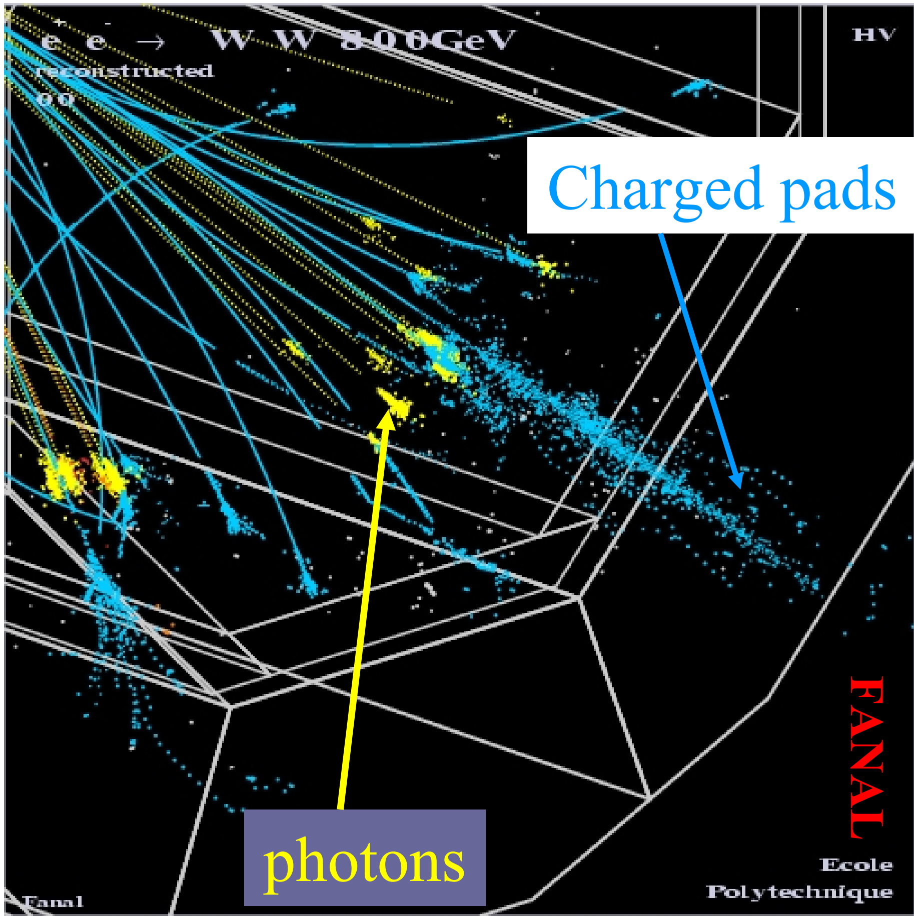
Values in percent	Z to hadrons $\sqrt{s} = 91$ GeV	ZH at $\sqrt{s} = 500$ GeV Z to neutrinos, H to hadrons
Purity (including neutral hadrons)	92.6	92.6
Purity (genuine versus charged debris)	98.2	97.1
Reconstruction efficiency ($E\gamma > 1.5$ GeV)	99.5 ± 0.2	96.0 ± 0.3
$\Delta(\Sigma E\gamma) / (\Sigma E\gamma)$	5.6 ± 0.2	6.8 ± 0.2
$\Delta(\Sigma E\gamma)$ GeV	1.1	3.6

ARBOR explained by pictures

Display from the true MC informations

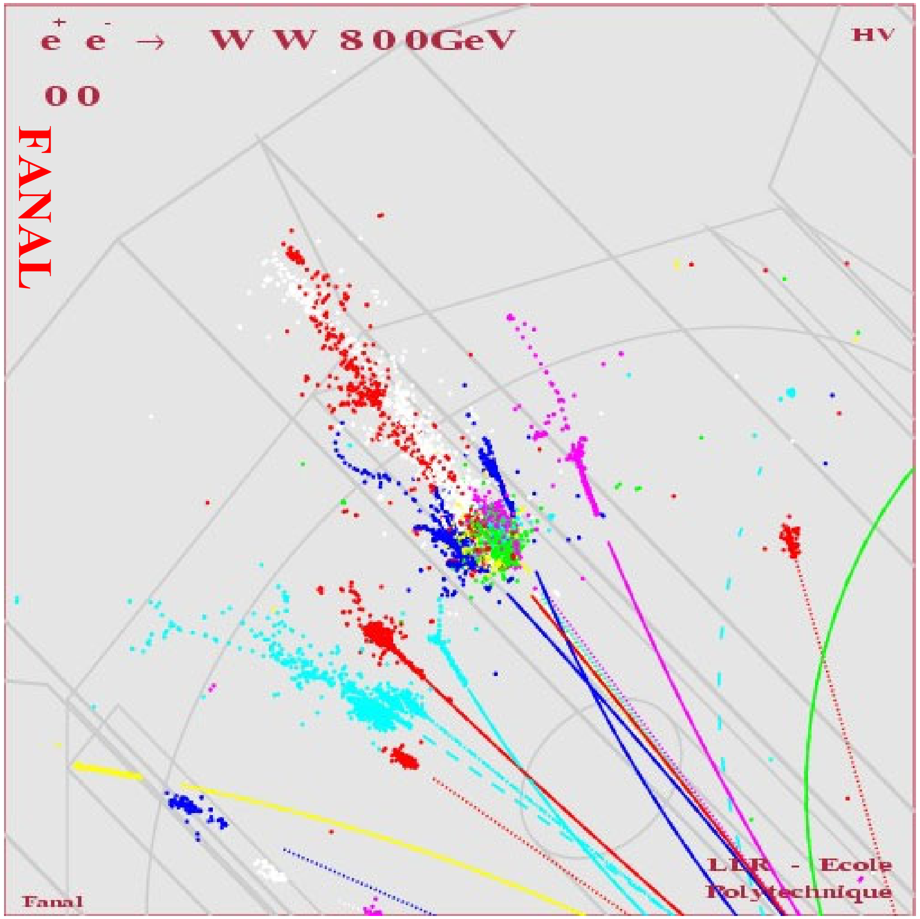


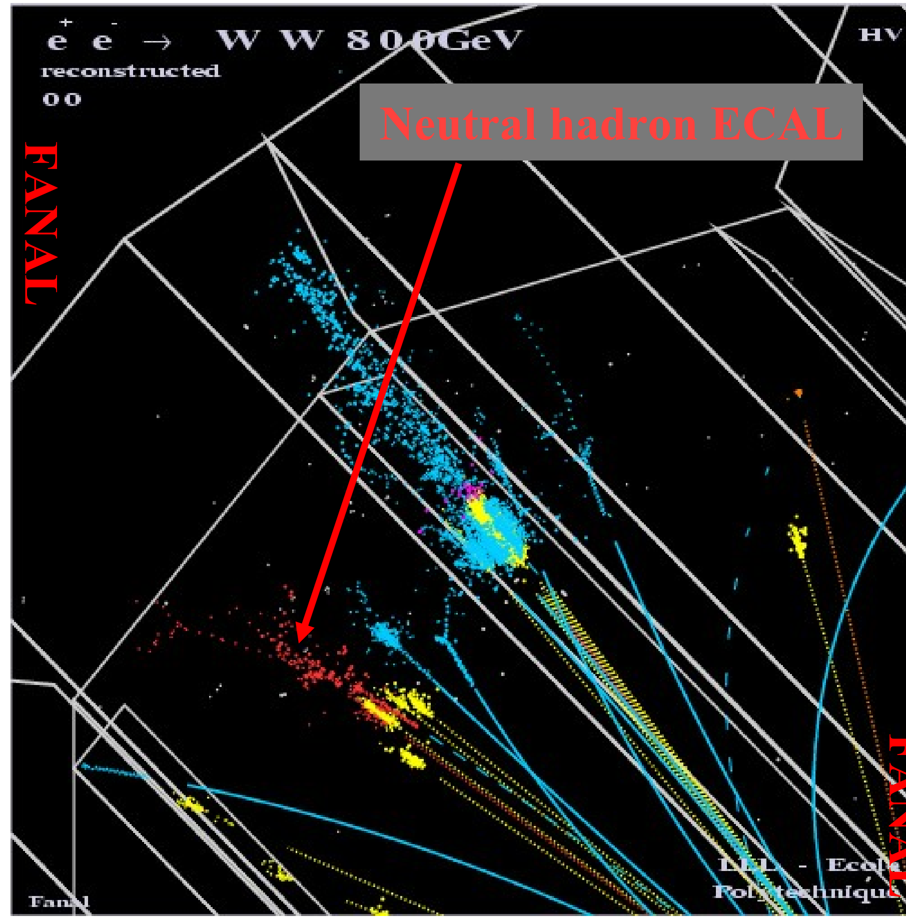
Display of the reconstructed event



CLUREST explained by pictures

And the problems of CLUREST





Performances on the neutral hadrons

Preliminary results

Values in percent	Z to hadrons $\sqrt{s}$ = 91 GeV	ZH at $\sqrt{s}$ = 500 GeV Z to neutrinos H to hadrons
Purity *(based on energy not on the number)*	**84.4**	**78.5**
Reconstruction efficiency *(based on energy not on the number)*	**81.6**	**68.5**
$\Delta (\Sigma E\gamma) / (\Sigma E\gamma)$	**Not yet**	**Not yet**

Conclusion

- **REPLIC** is a Reconstruction Software for the simulated LC events. It is coded in FORTRAN

- It is only a first version of a reconstruction program *(i.e. for charged tracks there is only a FAST-REC)*

- It gives reasonable performance for Z hadronic decays at rest, ZH at 500 GeV and WW at 800 GeV.

It shows the adequacy of the EFLOW principle from the 90 to 800 GeV

Volunteers are welcome

> Introduction of a ``real'' charged tracks reconstruction **(using the BRAHMS routine??)**
> Improvement of the neutral hadron treatment, lepton identification,etc…
> re-writing the code in JAVA using a geometry language interface (reconstruction independent of the geometry)
> to give new idea,…..

How to test the "energy flow"?

Henri Videau
Henri.Videau@ in2p3.fr

or

what drives the choice
of a detector design?

for an electron linear collider
running from Z to TeV
expecting 1 ab^{-1}

but, where does the "energy flow" concept enter the picture?

Is beam test any answer?

If you doubt your simulation accuracy,
you should build a detector, make the experiment, analyse,
redesign the detector, redo the experiment but ....

can you simply rely on beam test?

- can you make an equivalent of a jet in a test beam?
  poorly, no W or Z
- does it matter?
  no

I do not want to check the generation of the jets but validate the interaction of the different particles with the detector material

Readout electronics for the CALICE ECAL and tile HCAL

Paul Dauncey

Imperial College, University of London

For the CALICE-UK groups; Birmingham, Cambridge, Imperial, Manchester, UCL

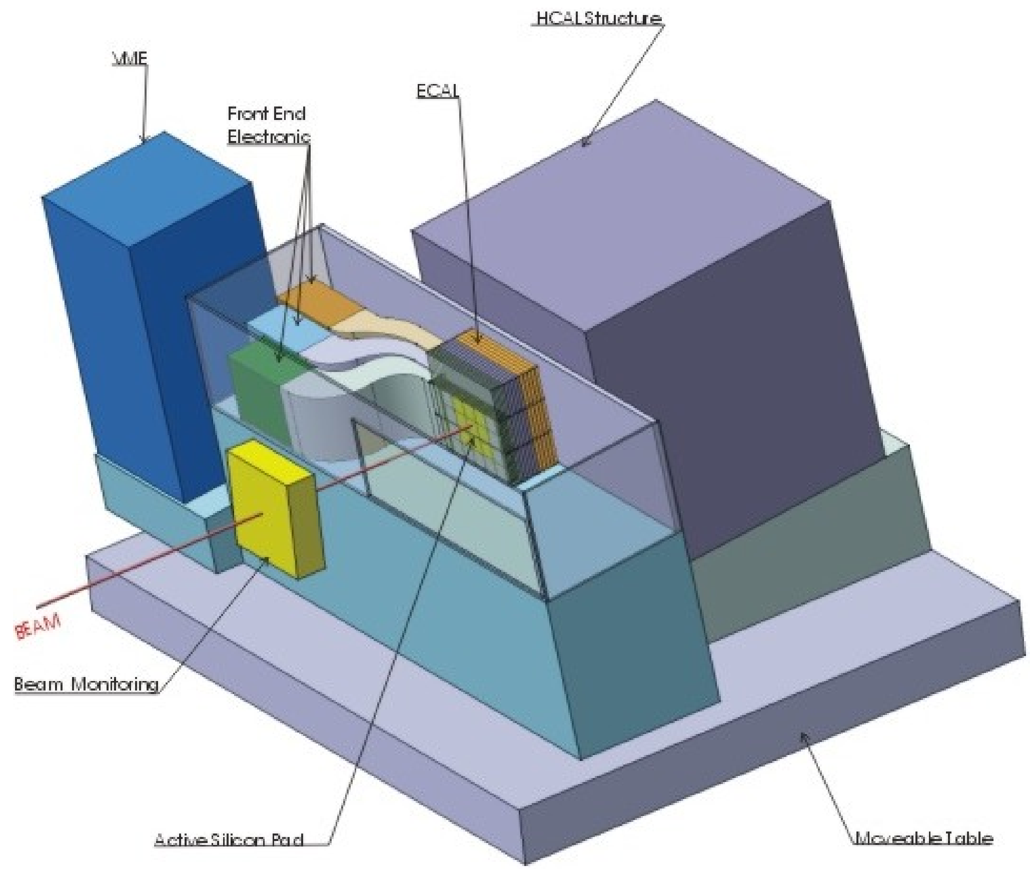
CALICE aims

Beam test with:

- Si/W ECAL
- Scintillating tile and/or digital HCAL

Data taking in 2004:

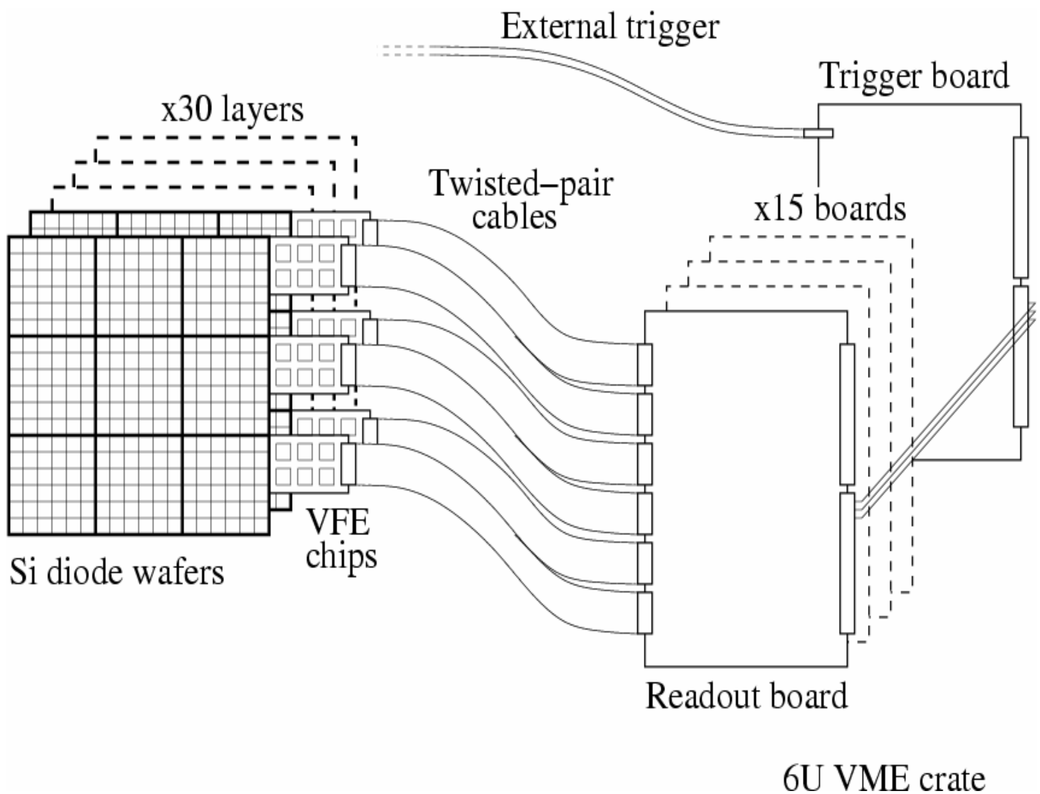
- O(10^2) configurations (HCAL × beam energies × particle types × preshower × incident angle …)
- O(10^6) events per configuration



Overview of readout system

Custom-built system as we found no available electronics which satisfied the requirements. Custom system:

- A single VME crate
- 15 "readout boards"
  - Contains all front-end handling and digitisation electronics
  - Each handles two layers of ECAL = 648 channels
- 1 "trigger board"
  - Simple board to allow VME control
  - Trigger and clock distribution via customised VME backplane



Gene Fisk – Fermilab
LCWS_2002 Jeju Do

Test Beams: Availability & Plans

- KEK
- DESY
- CERN
- Fermilab
- SLAC
- Other

CERN Beam Lines Summary

6 Beam Lines at present

- West Area: X5(w GIF) & X7 100GeV e, 120 GeV μ,h
- North Area H2, H4, H6, H8 250 GeV e, 350 GeV μ,h

Future Plans:

- West Area test beams operate in 2003, 2004.
- No SPS or PS operation in 2005.
- Under consideration 2006 and beyond:
  Stop West Area test beams;
  Keep North Area test beams operational, but limit use to no more than 2 at any time. Reduce maintenance to regular working hours.
  Keep COMPASS operational until 2008 at least.
  Keep NA48 beam line dormant; possibly move GIF to it.

Meson Test Beam Facility

Mtest – the western-most beamline in the Meson building.

- User facilities: 6 areas – MT6A1 - 2 & MT6B1 – 4.
  Two locations are enclosed with A/C, etc. Gases, data and HV cables, trigger and DAQ are supported by the Lab.
- Type of beam: Secondaries from Main Injector 120 GeV protons on an Al target at 0°.
- Modes of operation:
  "Proton" ~1 MHz of 120 GeV protons.
  "Pion" ~50 kHz of 5 – 80 GeV secondaries (rate depends on E).
  e's ~ 10-20%, μ's ~ 5%, π's ~ 80%; neg. polarity poss.
- Beam size: 1 cm^2
- Instrumentation: 80' & 50' Cerenkov counters; 0.5 & 1.0 mm beam PWCs; etc.

SLAC FFTB (cont.)

b) High intensity electron or positron. Available for very thin materials in vacuum or in some cases in air.

Momentum = 28.5 GeV

10^9 to 2×10^{10} per pulse (down to 10^7 under development).

Various possible experimental stations, all with substantial space constraints.

c) Bremsstrahlung beam

Peak energy 28.5 GeV

Radiator up to 0.02 X_o for 10^{10} /pulse electron beam

Electron beam pipe passes 30-35 cm below the gamma ray beam at the experimental station.

More Test Beams around the World

Argonne: APS contacted.
Brookhaven: No test beams.
Cornell: CHESS x-rays useful for some kinds of radiation damage studies.
Daresbury: No test beams
Frascati: 0.51 GeV e- beam from their 50 Hz linac; 1 – 1 E4 e's/pulse.
IHEP – Beijing:
IHEP – Serpukhov:
JINR:
LAL Orsay:
Novosibirsk/BINP:
RAL: No test beams.
Saclay:
TRIUMF:

If you have information on test beams that should be included in the LCWS2002 proceedings send it via E-mail to:
hefisk@fnal.gov

Summary

- Much activity, many new efforts!
- Current thinking will guide the future calorimeter
  - New ideas, designs, technologies possible
  - Optimization of current designs
  - Development of new reconstruction algorithms

$\Rightarrow$ Lots of fun !

I look forward to the next year…