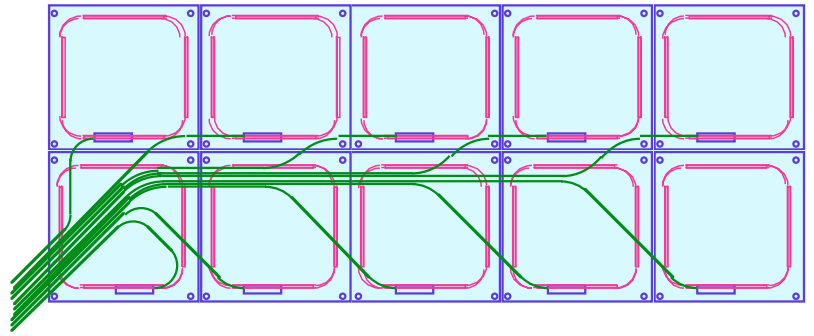


# Calorimeter

## 1. Baseline Design

- **Scheme : Tile/Fiber with hardware compensation**



### *Why hardware compensation ?*

- **Excellent hadron energy resolution**
  - **Excellent linearity**
  - **Gaussian response, high density, no extra-cost**
  - **Relatively low photon yield ; have been almost overcome**
- **Material/Composition : determines Energy Resolution**  
**Lead/Plastic scintillator Sandwich** (tungsten should do better but costly)  
EM : Pb/Sci=4mm/1mm be  $15\%/\sqrt{E}$  ; Crystal-grade unnecessary  
had : Pb/Sci=8mm/2mm be  $40\%/\sqrt{E}$
  - **Granularity : determines Topological Reconstruction ability**

### **Baseline Rect-Tile**

EM : 4cm x 4cm (24mrad) x 3 (or more) longitudinal samplings

had : 14cmx14cm (72mrad) x 4 (or more) longitudinal samplings

### **Strip-EM option**

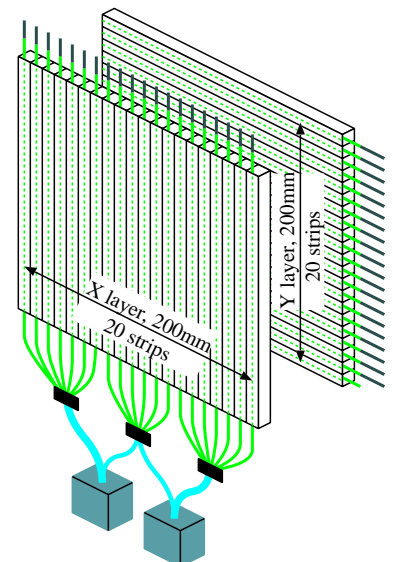
1cm-wide strip-array (x-y layers)

x ~20 longitudinal samplings

- **Shower Max Detector**

**Baseline** : 1cm-wide strip-array (x-y layers)

**Option** : 1cm x 1cm Si-pad



## 2.Performances

### 1) Single-particle response (measured with testbeam 1-200GeV)

- $\sigma_{E/E} = 15.4\%/\sqrt{E} + 0.2\%$  for electrons (ZUES-type)
- $\sigma_{E/E} = 46.7\%/\sqrt{E} + 0.9\%$  for pions (why worse already identified)
- $\sigma_X = 2\sim 3\text{mm}$  even at  $>50\text{GeV}$  (need improvement)
- pion rejection = 1/1400 at  $\epsilon_e = 98\%$  (reasonable)

### 2) Jet response : under full-simulation study (GEANT3)

- Closely related to granularity studies
- Precise hadron clustering : new algorithm may be needed.

# 3.Recent Studies

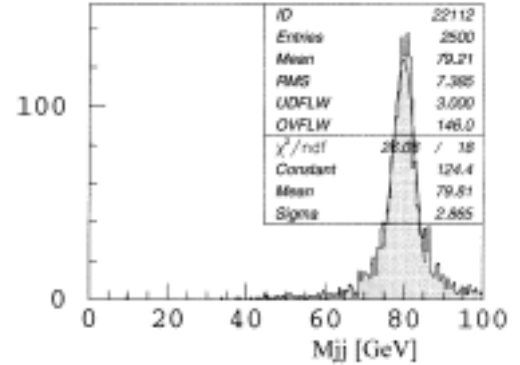
## [I] Granularity Optimization with Full Simulation (GEANT3)

Analysis of quick-simulation data gives very good performance

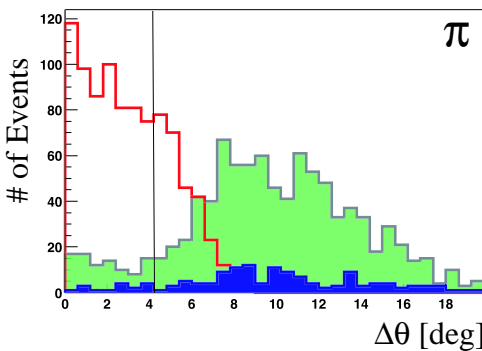
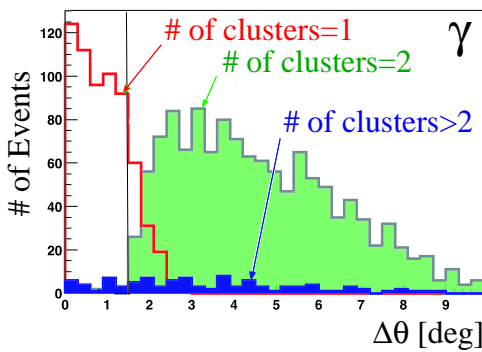
... but it is not the end of the story.

### 1) Construction of full-simulator

- Done for baseline design (Rect-Tile).
- not yet for optional design (strip-EM).



## 2) Hadron shower clustering ; in progress but very difficult



### a) hadron shower clustering algorithms

- 2D-JADE ; not successful yet
- 2D-contiguous ; not successful yet
- 3D-contiguous ; not successful yet
- **Super-cluster = French method should be tried (below)**

• **New algorithm needed ?**

### Algorithm

- Geometrical approach
- First step: link together all hits within a certain angle and distance

- Second step: find baricenter and direction for each cluster and link together clusters within a certain angle and distance
- Four geometrical parameters (two distances and two angles)

First Approach To Particle Recognition - Detectors Online (J.P.VE - XI)

### b) decomposition of overlapping showers

... under study.

### c) track-cluster association ... under study

whether **one-to-one** needed

or **plural-to-one** is enough ?

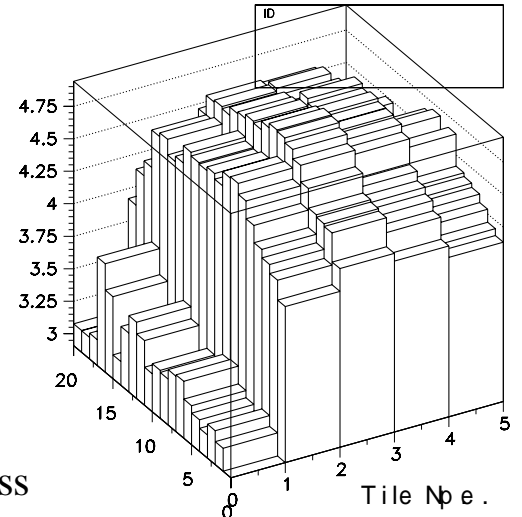
## [Studies - II] Hardware Studies

### 1) Small Rect-Tiles (4cm x 4cm x 1mm-thick)

- WLS-fiber shape, layout and dye optimization ; calculation almost done.
- Bench-measurement on photon yield and uniformity in progress  
6p.e./MIP obtained. Be 14p.e. by dye optimization.  
= enough even as EM (Crystal-grade EM is not needed)

### 2) Strip EM option

- Bench test on photon yield and uniformity ----->  
in progress
- Simulator of above optical properties  
under construction

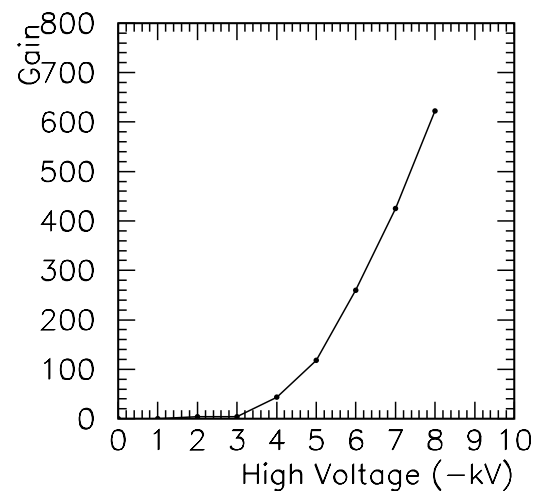


### 3) Direct-readout SHmax option ; Bench test in progress

- PIN-Si ; gain too low
- APD ; under study ... might be operational but costly

### 4) Photon Detector Studies

- Multi-channel HPD ; toward  $S_{\text{Single Photon Peak}}$
- Single-channel HAPD ; toward multi-channel
- EBCCD ; toward High Gain ----->
- High-QE photo-cathode (40% @540nm)
- <---> WLS dye optimization for Rect-Tile

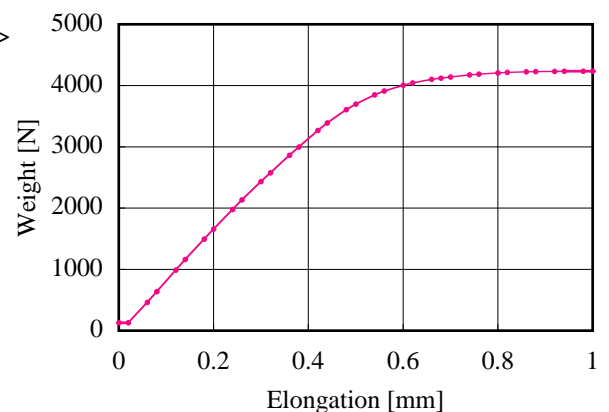


### 5) Lead Alloy

#### a) Strength and Young modulus measurement -->

- dopants ; Sb, Ca/Sn ... in progress  
As ... hopeful but difficult to make
- treatment ; heat / mechanical  
in progress

#### b) Hybrid material : Paper-work only



## 4. Coming R&D plans within a few years

### 1) Further full-simulation studies on Granularity Optimization

### 2) Beam tests of fine-granularity EM module

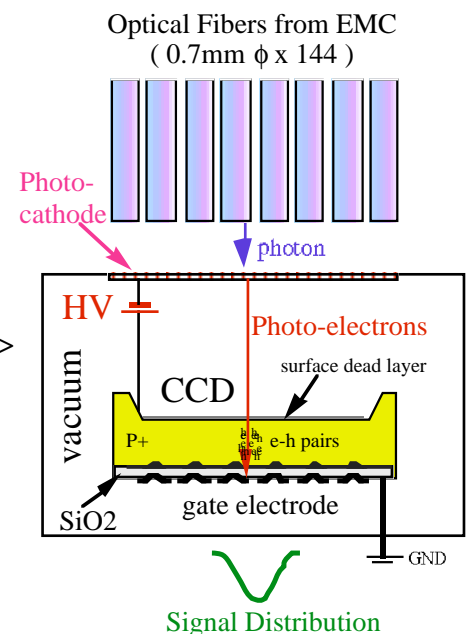
- Rect-Tile EMC
- Strip-EMC option
- Conventional and Direct-readout SHmax detectors
- Optimum photon detectors for each

### 3) Photon Detectors

= **Key component for fine granularity**

(almost no restriction from tiles or fibers)

- EBCCD ; essential in strip-EM option ----->
- multi-channel HAPD
- multi-channel HPD = baseline



### 4) Mass production of tiles and fiber assemblies

- Tiles ; Design optimization for "moldable" tiles  
MEGA-tile structure, groove cross section, embedded WLS, etc.
- Fiber assemblies ; low-cost heat-splicing, mirroring, etc.

### 5) Lead alloy and structures

- Further studies on alloys and hybrid materials  
Actual studies on SUS-Pb sandwich
- Engineering studies on structure be initiated