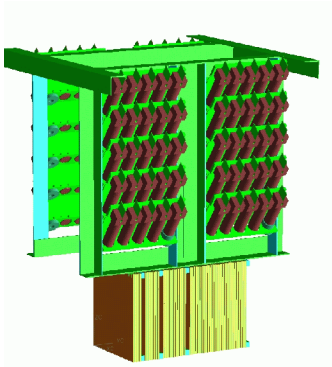
Status report from LCCAL



Talk Summary:

- Prototype description
- Test beam results
- Conclusions and next plans

LCCAL: Official INFN R&D project, official DESY R&D project PRC R&D 00/02

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ECFA-Study :
Physics & Detectors for LC 13/11/2003
Montpellier

Design principles :

From the LC Physics requirements:

- high granularity,(Energy Flow)
- σ_E O$(10\%/\sqrt{E} + 1\%)$
- longitudinal segment. (e/π) separation
- working in magnetic field
- high density (25-30 X_0 in $\sim$ 50 cm)

Tesla TDR solutions:

- **Si W**
- **Shashlik (thanks to**

The LCCAL Proposed solution:

❑ **Keep Si-W advantages (flat geometry, high granularity)**

❑ **Erec not from Si but from Scintillator-WLS fibers**

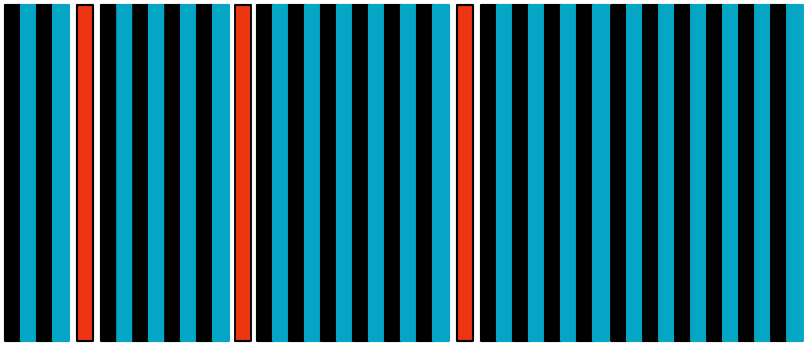
❑ **Reduce (factor >10) the number of channels**

Prototype description: an hybrid em calorimeter

- **50 layers → 45 layers** (budget!!)
- **25 × 25 × 0.3 cm³ Pb**
- **25 × 25 × 0.3 cm³ Scint.:**

  25 cells 5 × 5 cm²
- **3 Silicon planes (at 2, 6, 12 X_0)**

Pb/Sc + Si



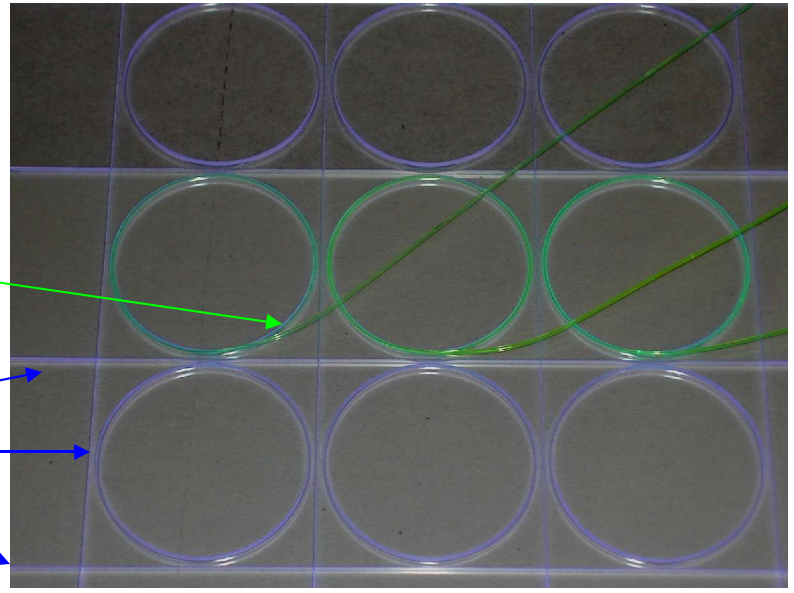
- **625 → 252 Silicon Pads** (budget!!)

  0.9 × 0.9 cm² Si Pads

Scintillation light transported with WLS σ tail fibers:

Coupled with clear fibers (to PM)

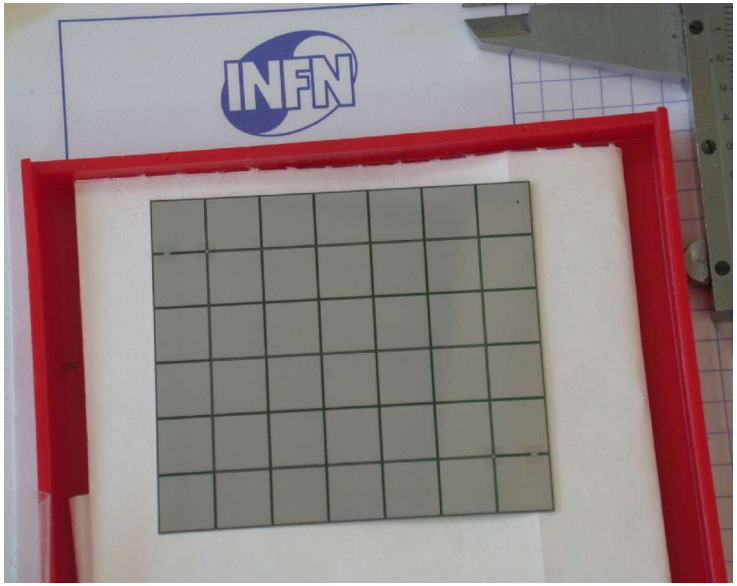
Cell separation with grooves in Sc. plates with Tyvec strips inside



Prototype : 3 planes of Si Pads

Goal: shower-shower separation, position measurement, e/h identification:

- **Pad dimension < shower dimension:**
  0.9 x 0.9 cm²
- **Longitudinal sampling:**
  3 planes
- **Analogic ReadOut**
  VA hdr9c from IDEas
- **See parallel session talk for details**



Pad diode AC (old)-DC (new) coupled

Actual design:

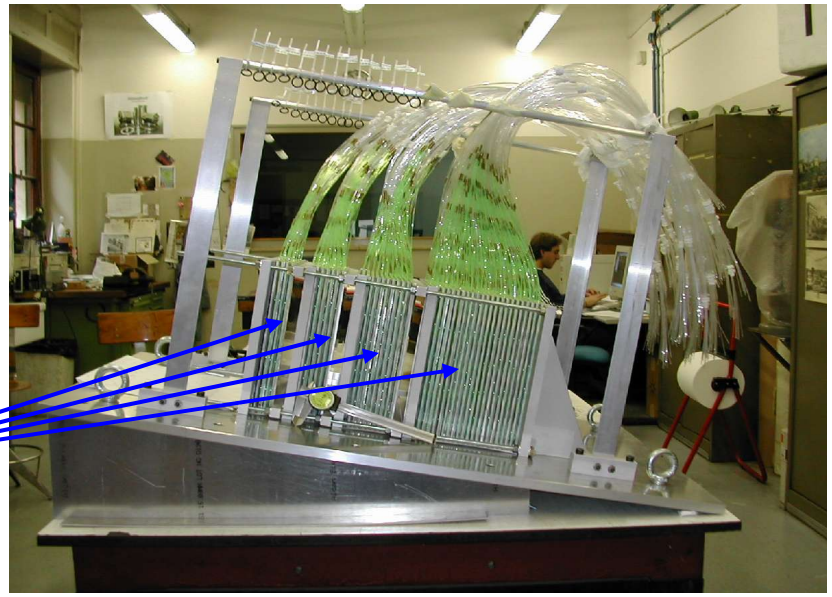
- **Each sensor: 6x7 pads**
- **Plane: 3x2 detectors**

PCB contact with conductive glue

Detector Assembling:

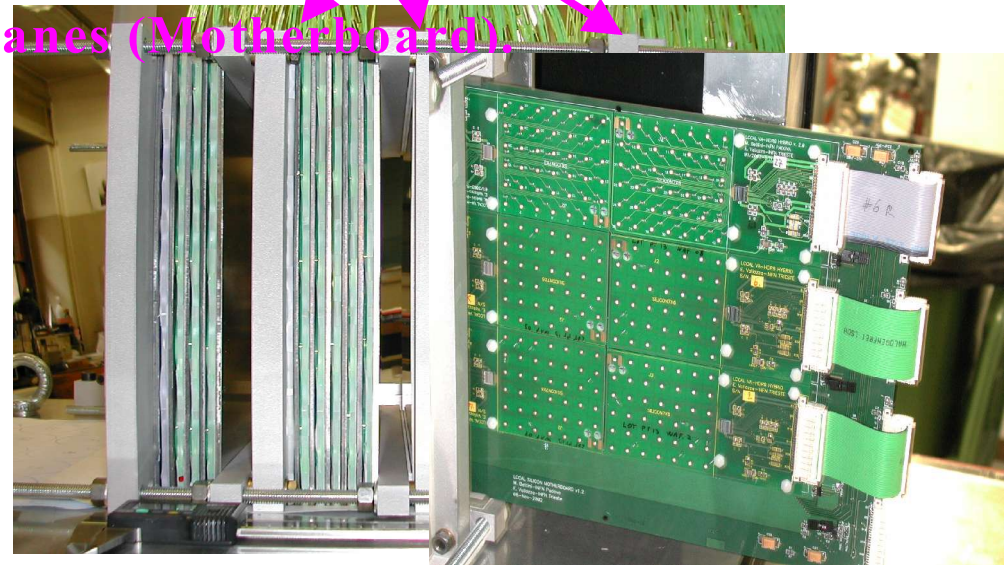
45 Layers calorimeter prototype completely built in 2002

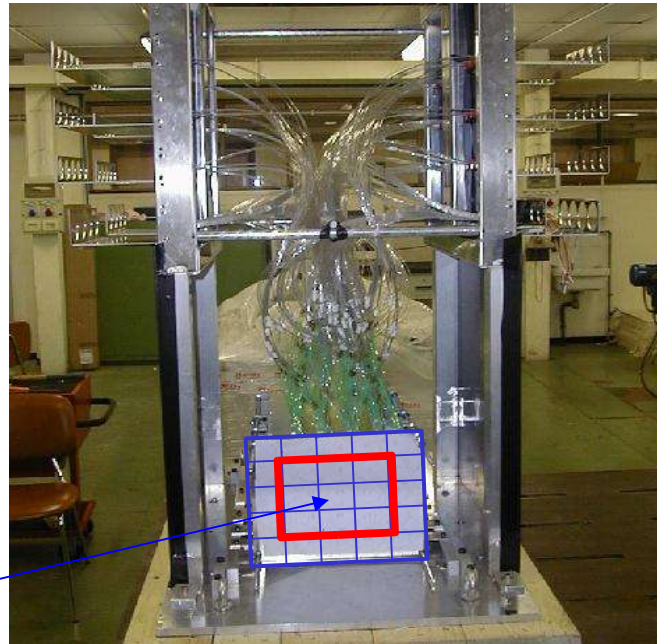
Fibres grouped into 25x4 bundles making a 4-fold longitudinal segmentation.



Mechanical support for Photomultipliers

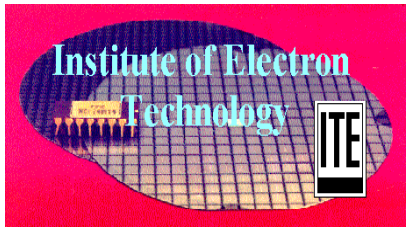
Slots for the insertion of the 3 Si pad planes (Motherboard).





Single PM readout only in the 3x3 central

History of Silicon sensors production



3 technological runs

First batch of 11 sensors (spring ’02)

Soft Breakdown

Second batch of 9 sensors (summer ’02)

GOOD!

“Leaky” pads

Third batch of 9 sensors (summer ’03)

Next batch will be ready next months

Silicon detectors: Signal to Noise ratio

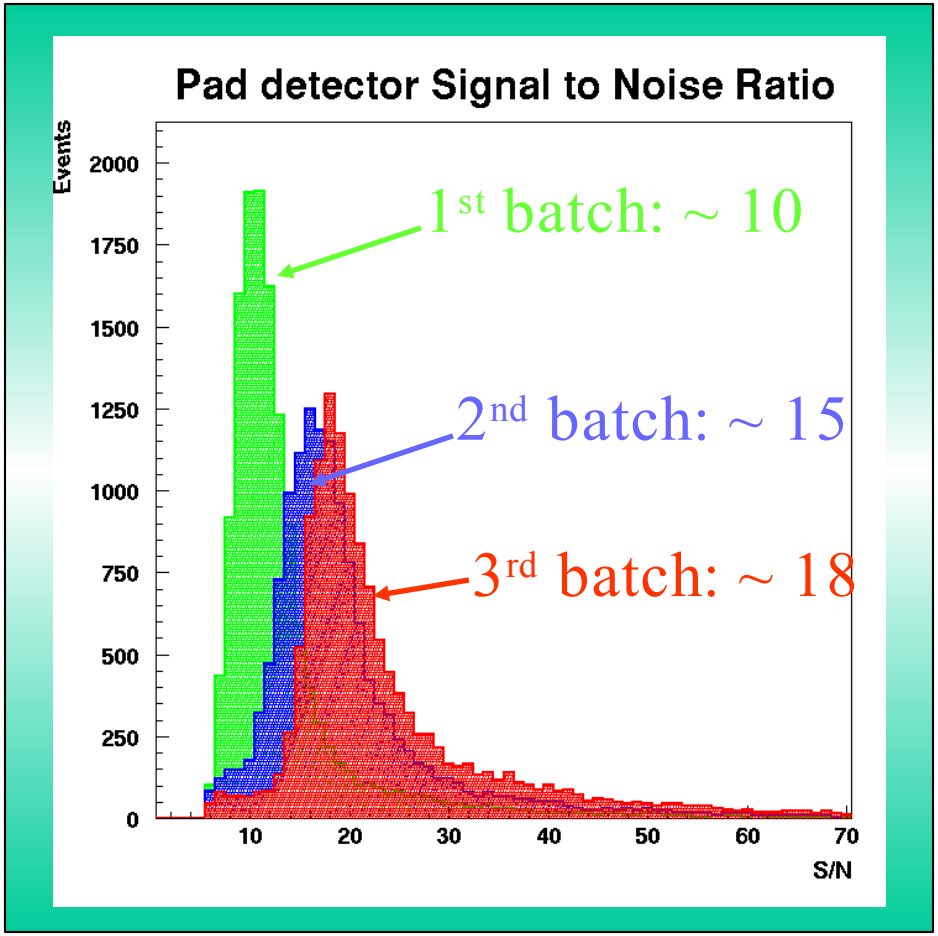
Theory:

$$ENC = A + \frac{B}{pF} \quad \approx 1000e^- \quad \text{Front-End}$$

$$ENC = \frac{e}{q}\sqrt{\frac{qI_lT_p}{4}} \quad \approx 30e^- \quad \text{I Leakage}$$

$$ENC = \frac{e}{q}\sqrt{\frac{T_pk_BT}{2R}} \quad \approx 230e^- \quad \text{Bias Resistance}$$

$$\approx 1260e^-$$



MIPS = (80 e-/ μm) x 300 μm

≈ 24000 e-

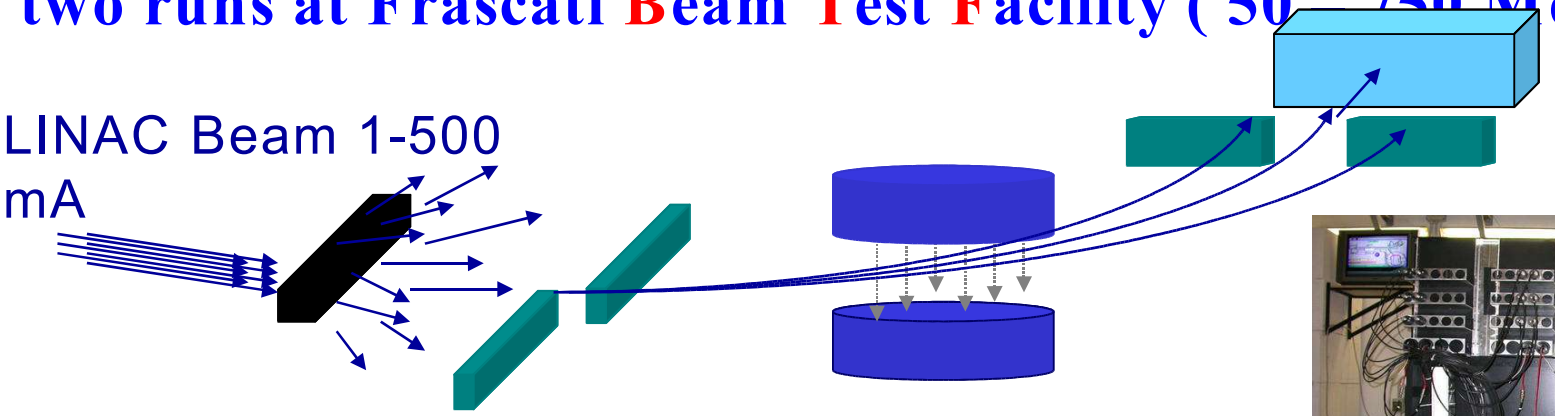
Theoretical*
SNR ~ 20

*** Value obtained for detector of the 3rd batch**

Test Beam activities

- **after a 2002 pre test with the 1st layer only (2.1 X_0) at CERN**

- **two runs at Frascati Beam Test Facility (50 – 750 MeV)**

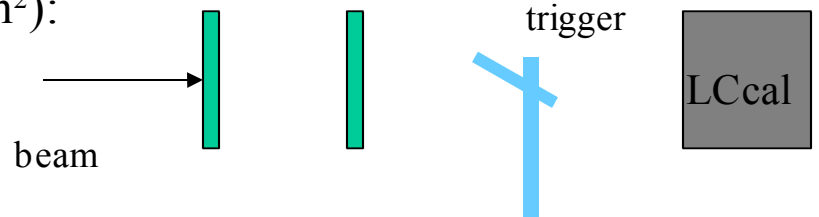


Multiplicity can be tuned .....

- **run at CERN SPS H6 beam line (e/π 5 – 150 GeV)**

All tests: two beam position monitors (telescope) in front of the calorimeter covering the central area of the prototype (9.5 × 9.5 cm^2):

each detector consisting of 400×400 x–y Si strips with a pitch of 240 μm

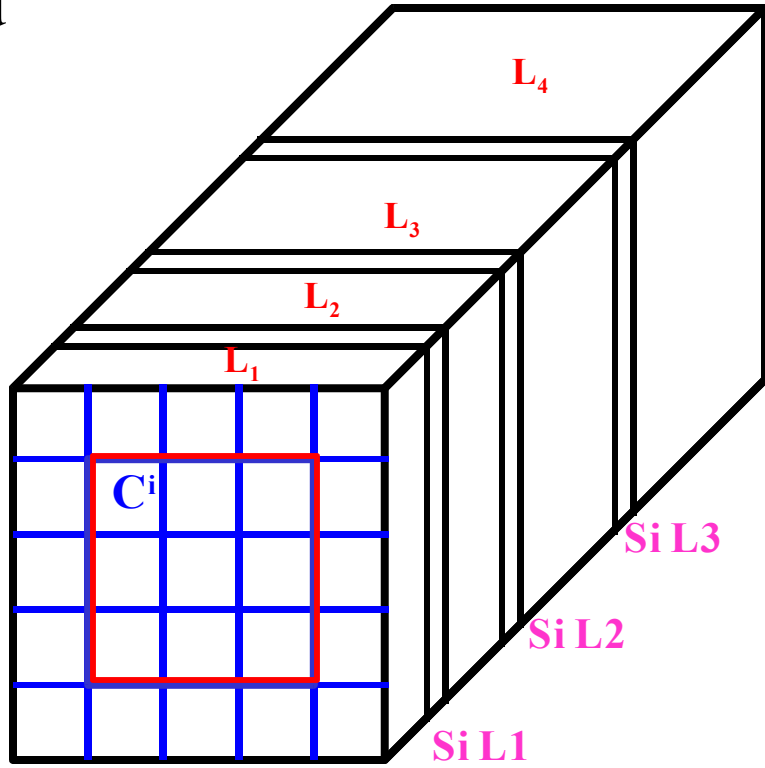


Test Beam: detector calibration

Define the 'cell-energy' as the calibrated sum of the four longitudinal layers on the same lateral position:

$$C^i = b^i \sum^4_{j=1} (a_j L^i_j)$$

(4-1+9-1+16 parameters)



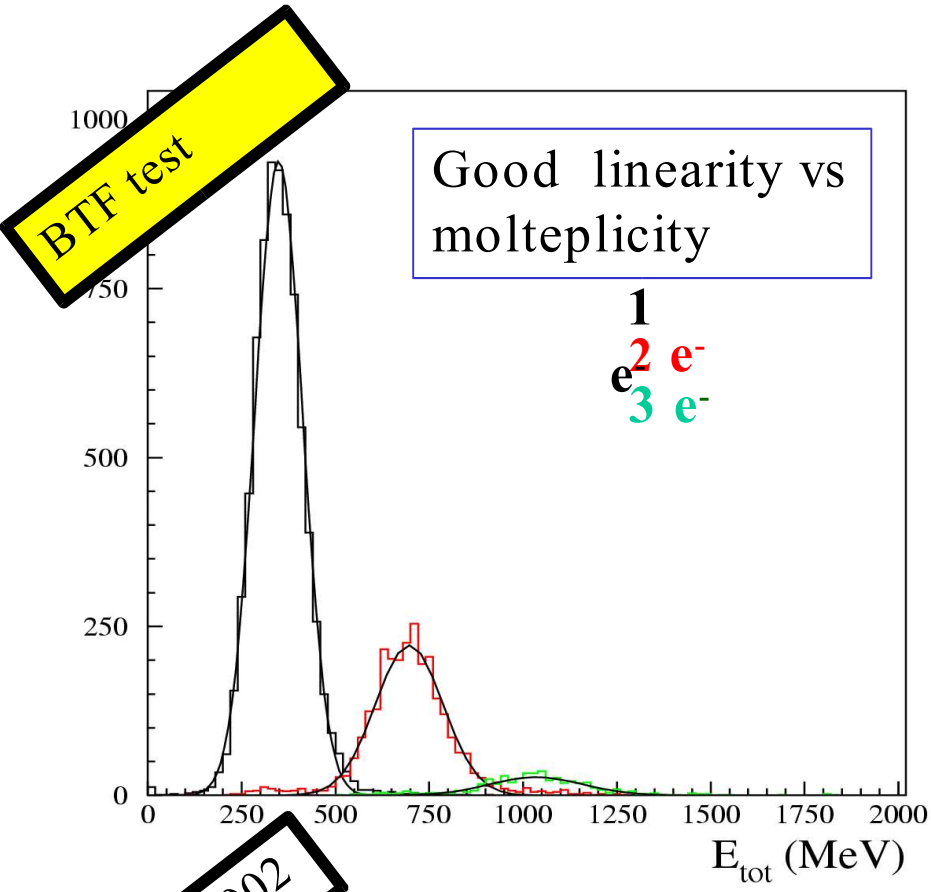
Calibration procedure in two steps:

- equalise the layer response to the same incoming energy $L^i_j = b^k/b^i \; L^k_j$
- minimise the Energy spread on the sum of 9 cells **(iterative procedure)**

a_j | min. width $E_{cal}=\Sigma_{n=1,9} C^n$

Linearity and Energy Resolution (I)

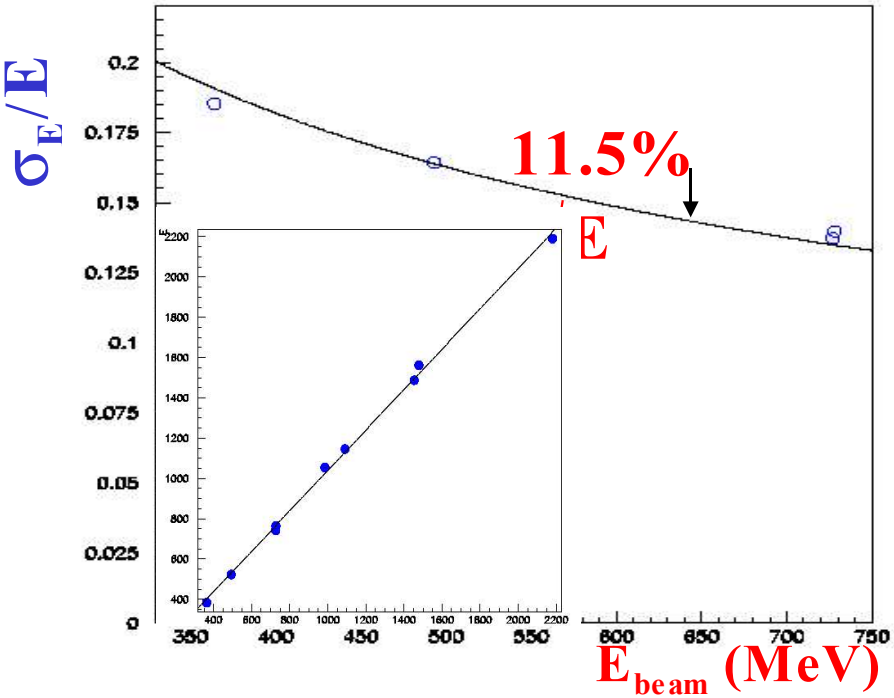
BTF test



Cern TB 2002

N_{phe}>5.1 /layer →**Cal(45 layers) ~ 250 MeV/Mip ~ 800Npe/GeV**

OK also @ BTF (E ~500 MeV)

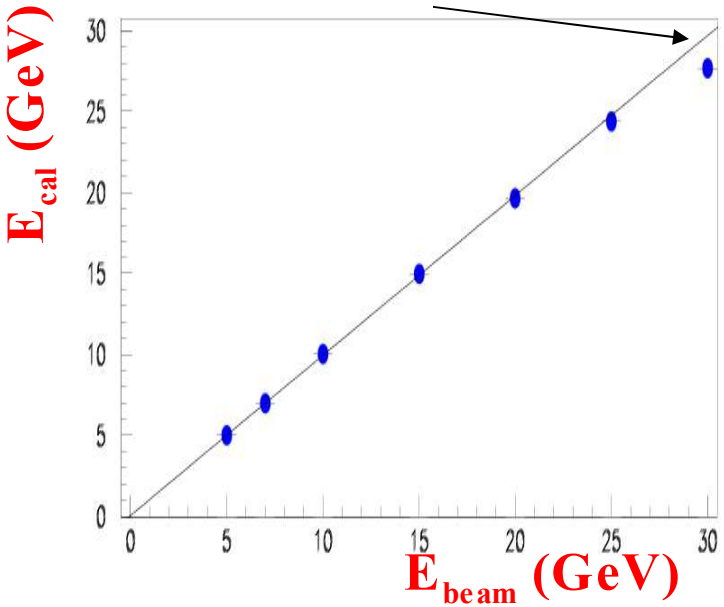


1. Photoelectron statistics **negligible**
2. Stocastic Term **11.5% as in MC**
3. Light disuniformity **<<10%** .. Better measurement at **SPS** together with effects in resolution on **Aug03**

Linearity and Energy Resolution (II)

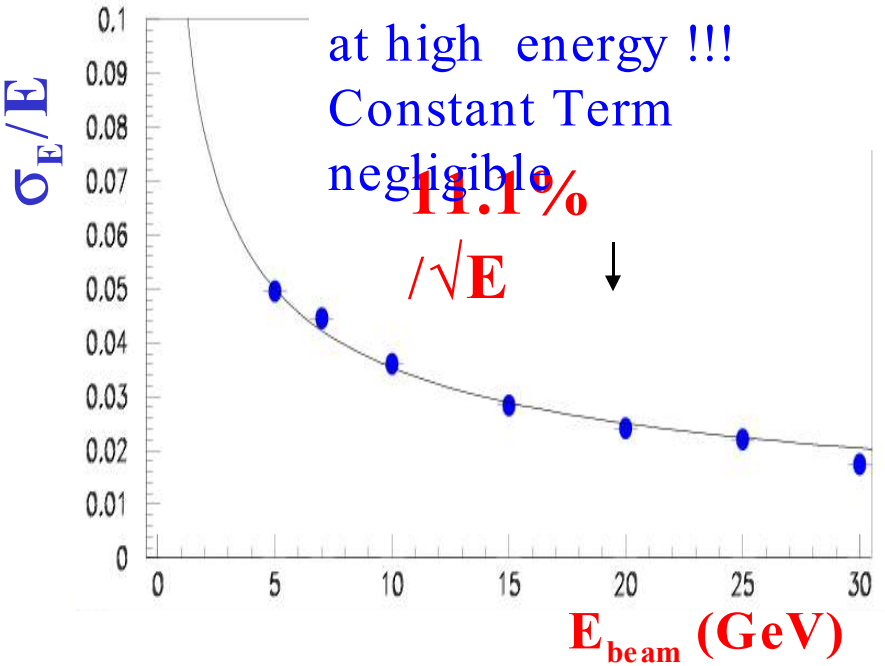
Cern TB 2003

PM saturation

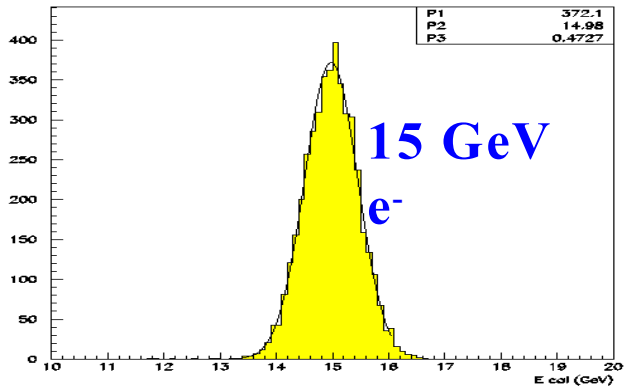


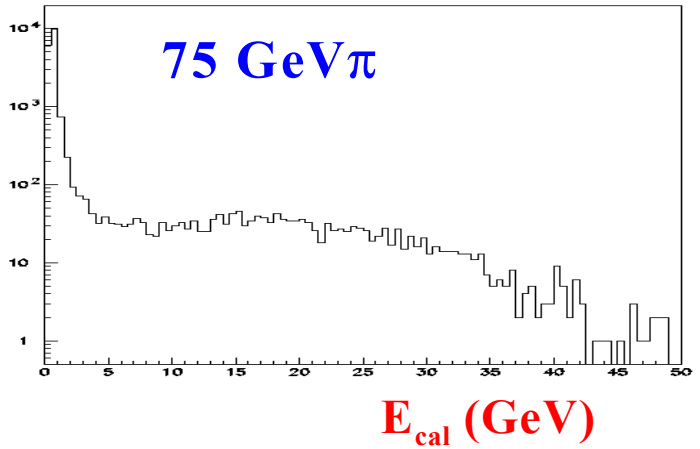
e^-

BTF results confirmed at high energy !!!
Constant Term negligible

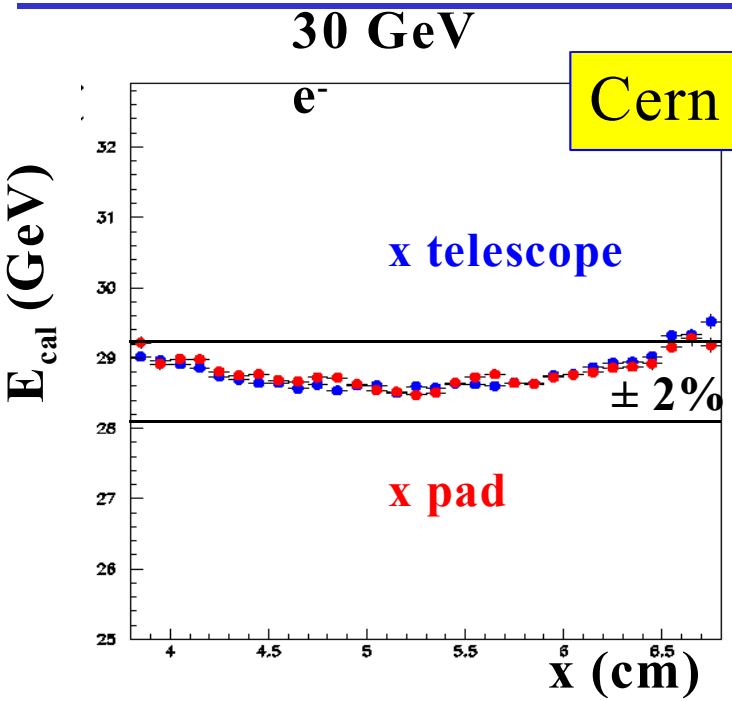


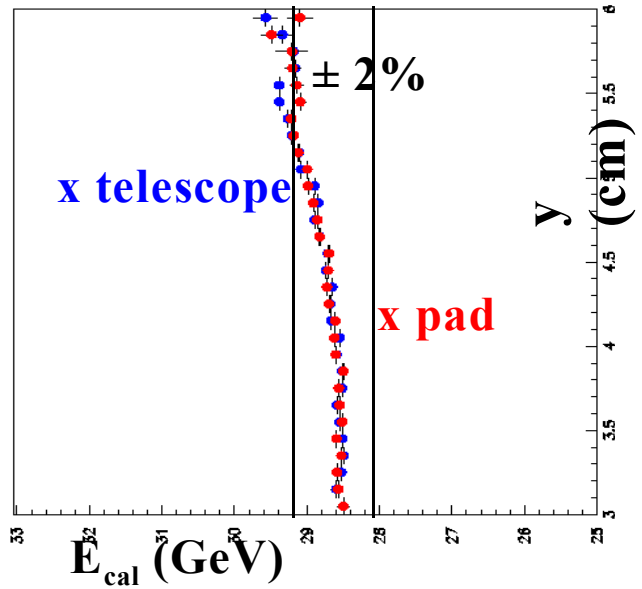
11.1%
$/\sqrt{E}$





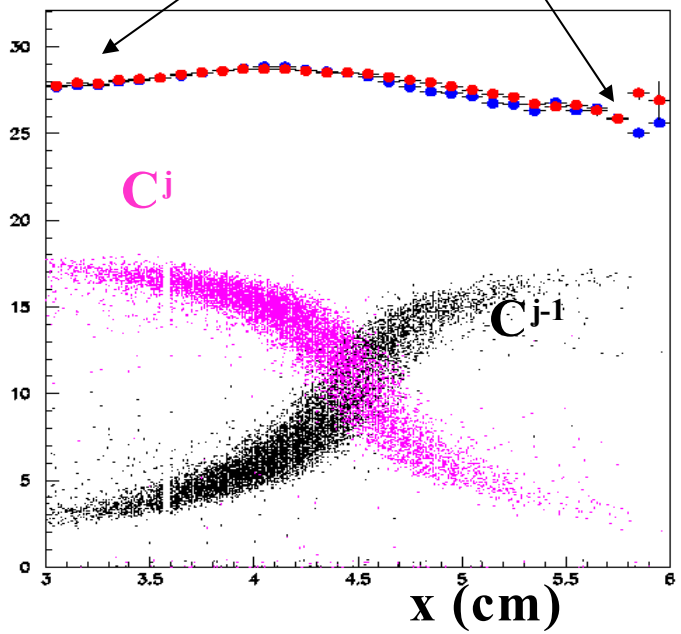
Uniformity in (light) Energy response





- **disuniformity < 2% .. Consistent with negligible constant term on energy resolution.**
- **correction on energy response from pad reconstruction can be**

PRELIMINARY: cell border effects dominated by residual miscalibration

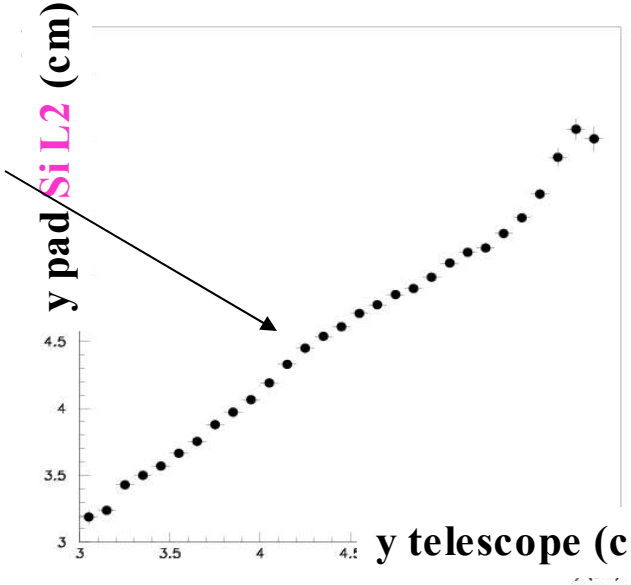


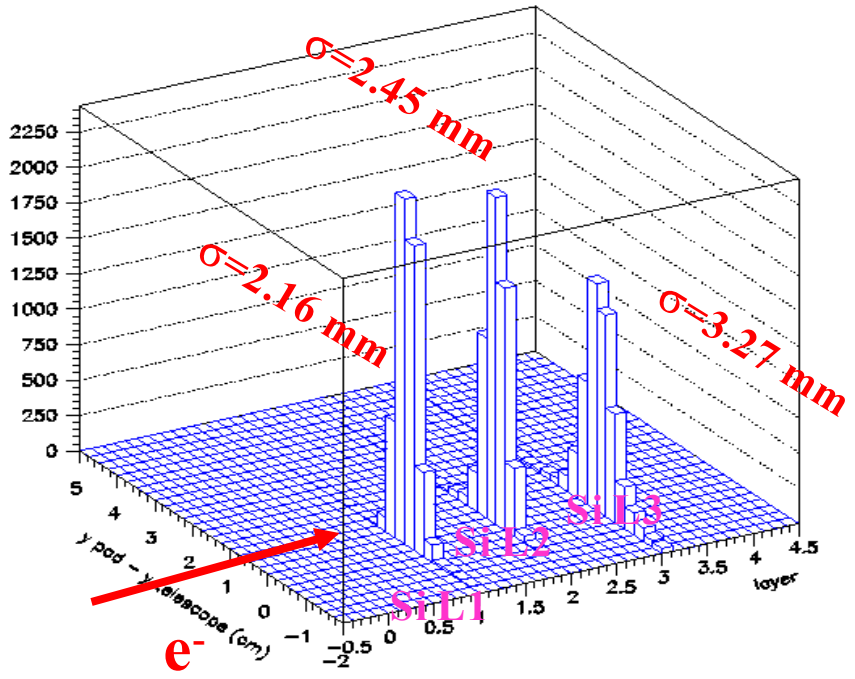
Si pad detector (Position Meas.)

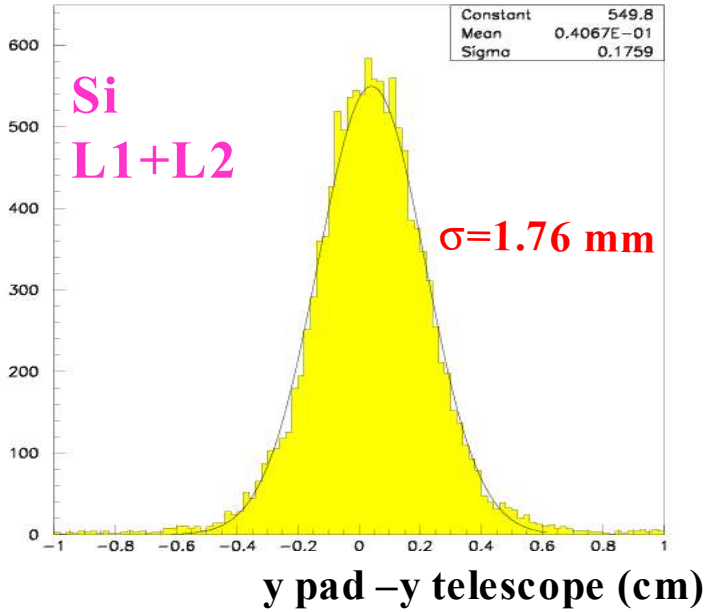
Cern TB 2003

Pad size effect!
More sophisticated
"centroid" algorithm
can be applied

30 GeV electrons





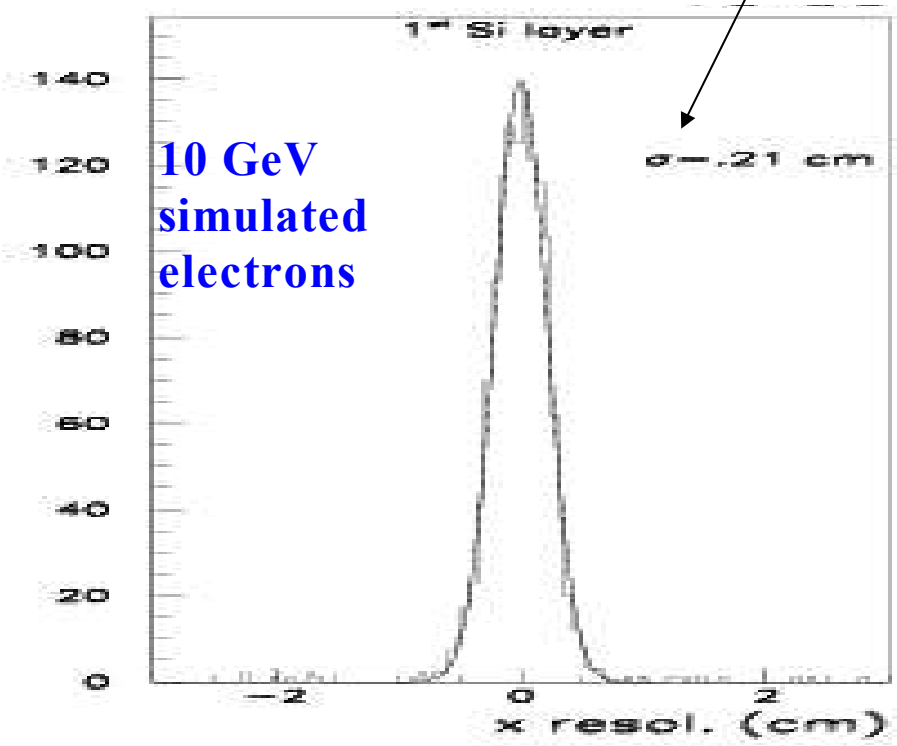


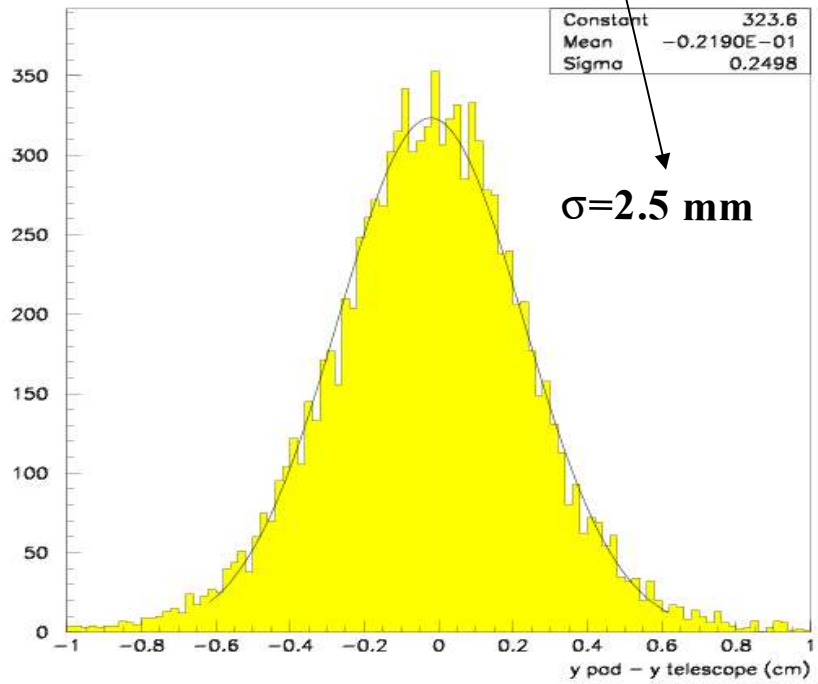
Si pad detector (Position resolution)

PRELIMINARY analysis: pad noise subtraction not optimised

10 GeV electrons

- **Position resolution ~ 2.5 mm**
- **not far from Monte Carlo**
- **.. still worse than last year!**
- **beam multiplicity under investigation**



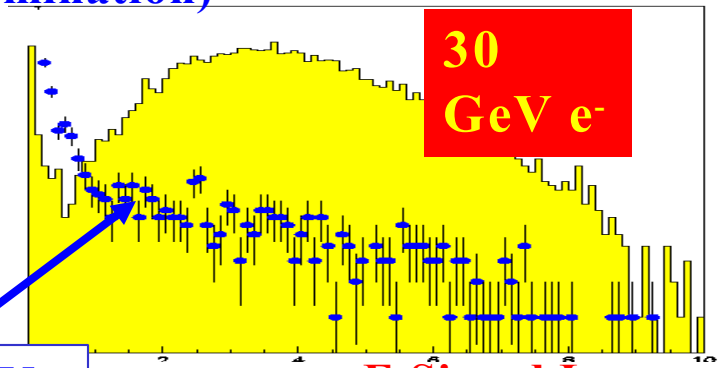


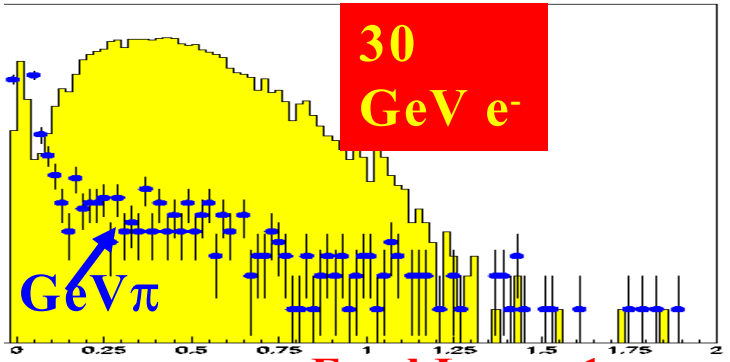
LCCAL: e/π rejection

- **the redundancy of the information on longitudinal lateral shower development makes the rejection very easy**

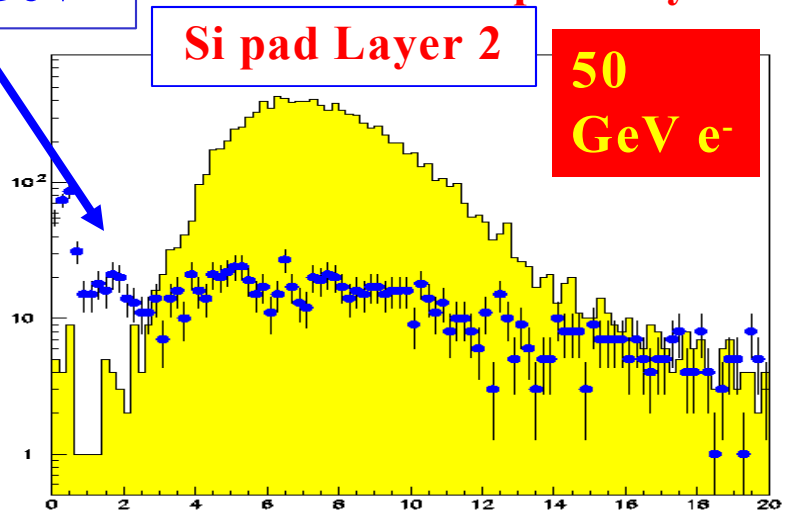
Cern TB 2003

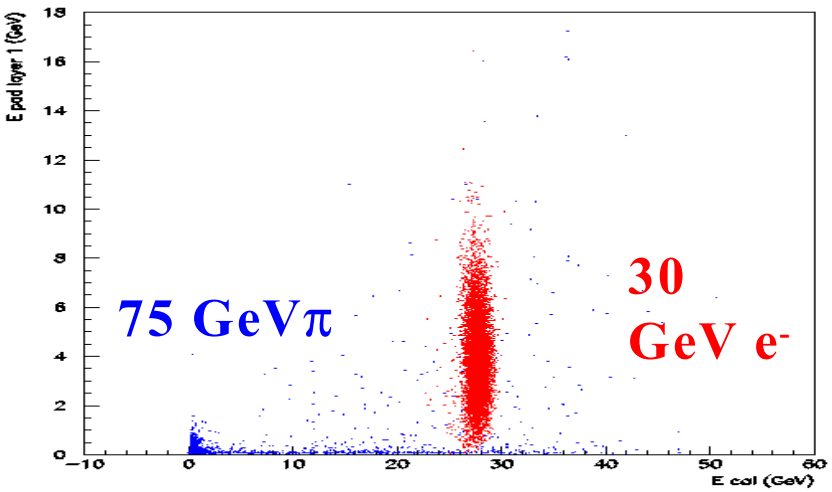
- **(difficult to quantify below 10^{-3} due to beam contamination)**





30 GeV π





shower variance: $\sum_i r_i^2 E_i \Big/ \sum_i E_i$

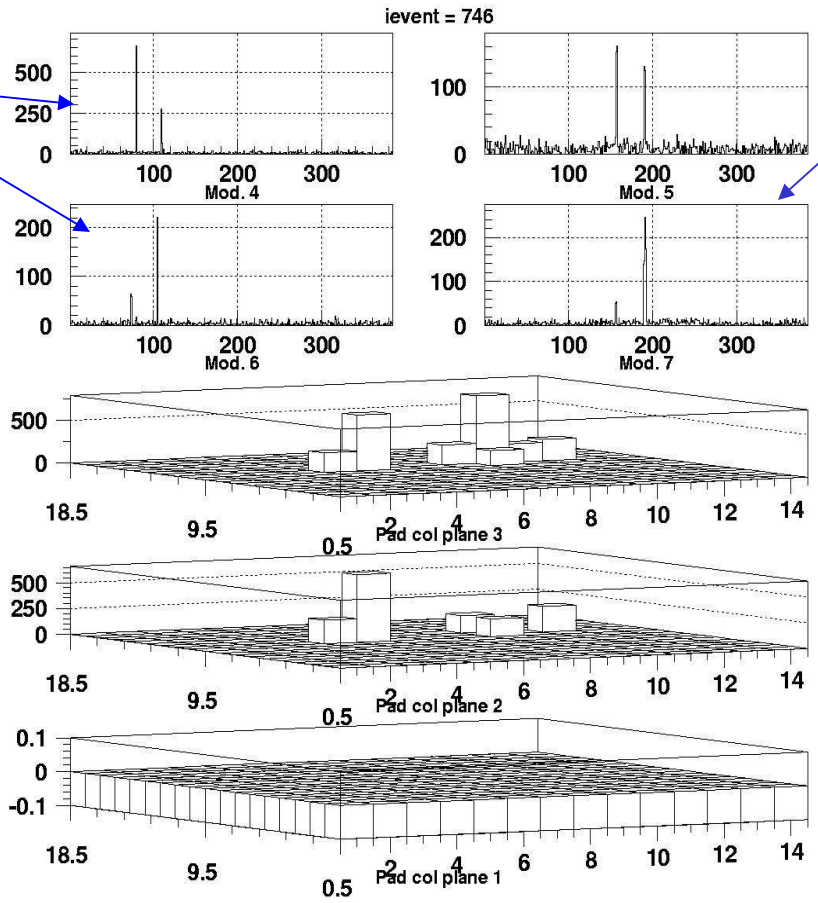
Si Pads: two particles separation (BTF)

exhaustive analysis not fully accomplished

Two electrons with energy 750 MeV

X silicon chambers

Y silicon chambers



BTF test

First layer

Second layer

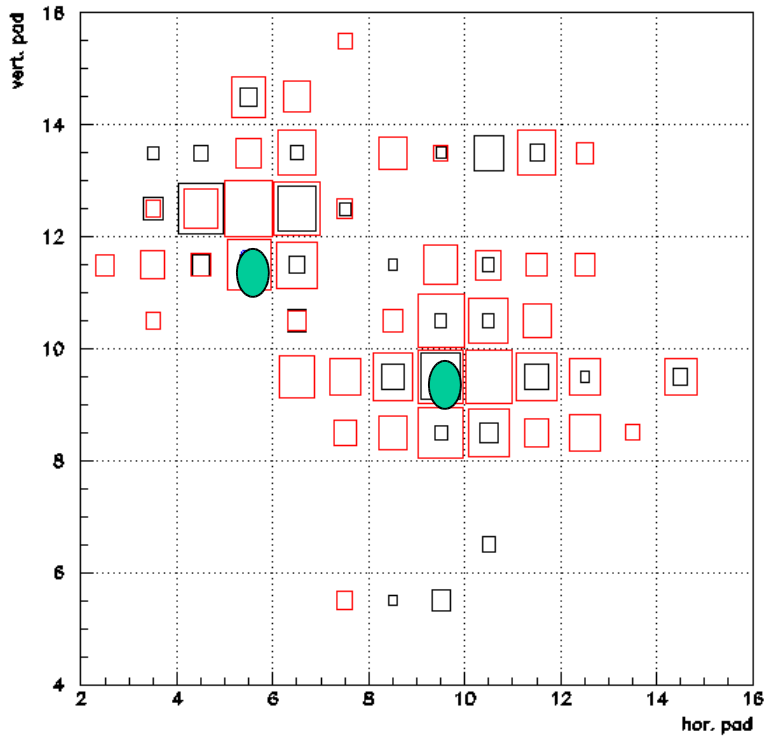
Third layer

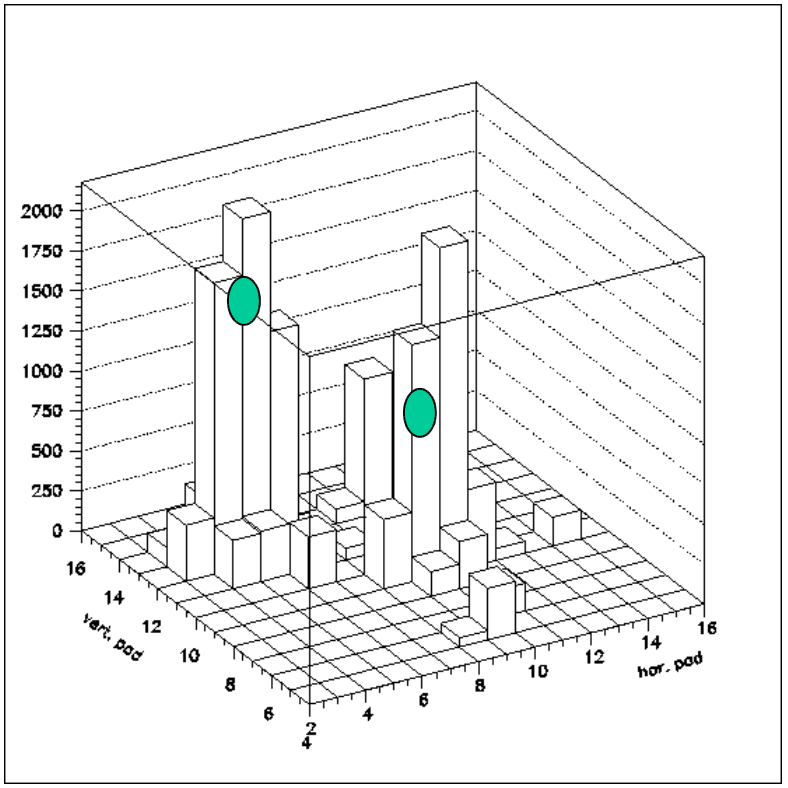
NB: not fully equipped+ problematic channels

Si Pads: two particles separation (CERN)

Particles separation studied requiring 2-tracks events from upstream conversions tagged by the external beam monitor. It looks promising! Still .. serious analysis in progress.

30 GeV e^-





First Layer

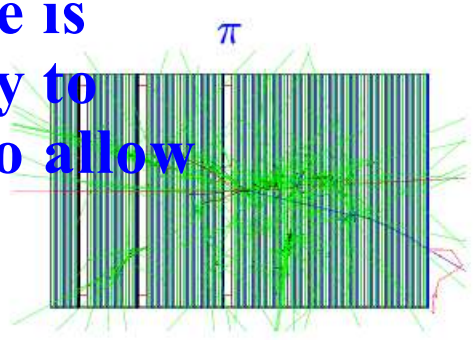
Second Layer

Position resolution improves for 1 cluster events

Conclusion and future plans

- **A calorimeter prototype with the proposed technique has been built and fully tested. All the results are preliminary.**
- **Energy and position resolution as expected:**
  σ_E/E ~11.-11.5% $/\sqrt{E}$, σ_{pos} ~2 mm (@ 30 GeV)
- **Light uniformity better than 2% !!**

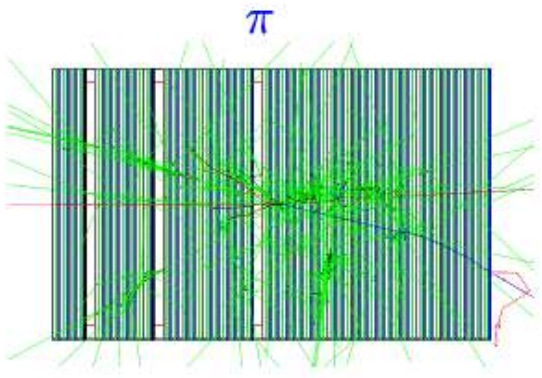
  Negligible constant term observed in energy resolution.
- **e/π rejection very good ($< 10^{-3}$).**
- **Two particles separation results coming soon. Still results looks promising.**
- **THE HARDWARE /CONSTRUCTION phase is concluded. We do not plan to ask more money to our funding agencies although costs did not to allow us to use tungsten as absorber ...**



future plans

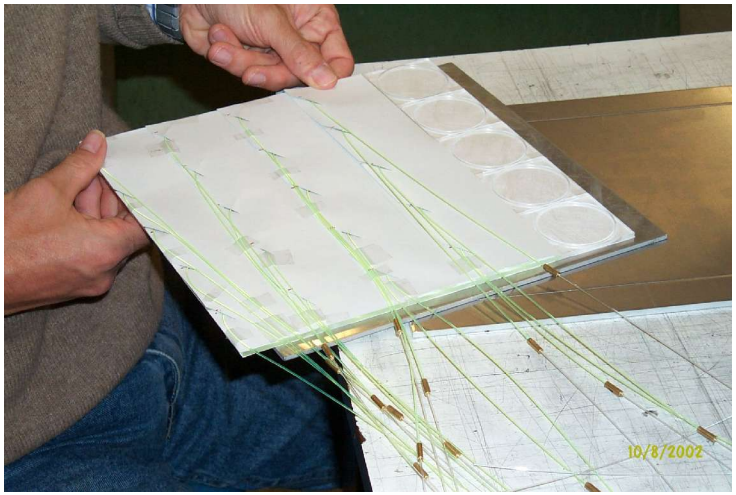
The test phase is also basically concluded. We will finalize the analysis to answer all questions concerning the use of such a detector into a LC experiment. Next steps:

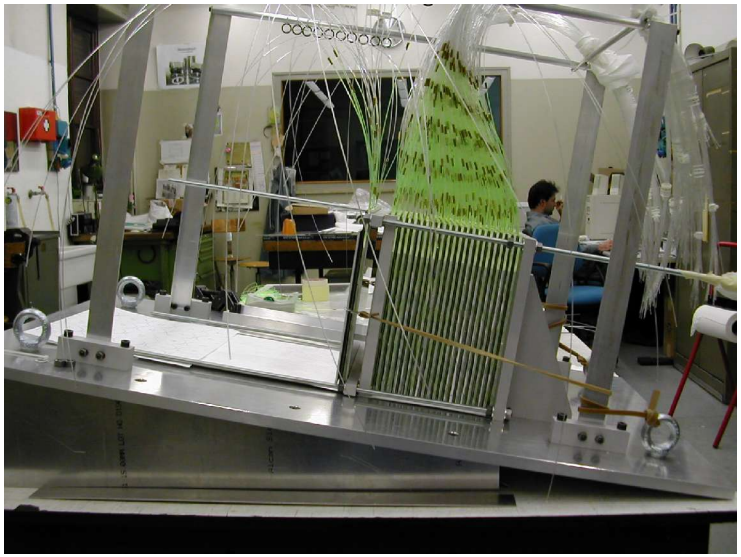
- **include a calorimeter made with this technique into the general LC simulation and Pattern recognition.**
- **Combined test with HCAL ??**
- **Begin a engineering study toward a project of a barrel electromagnetic calorimeter based on this technique.**



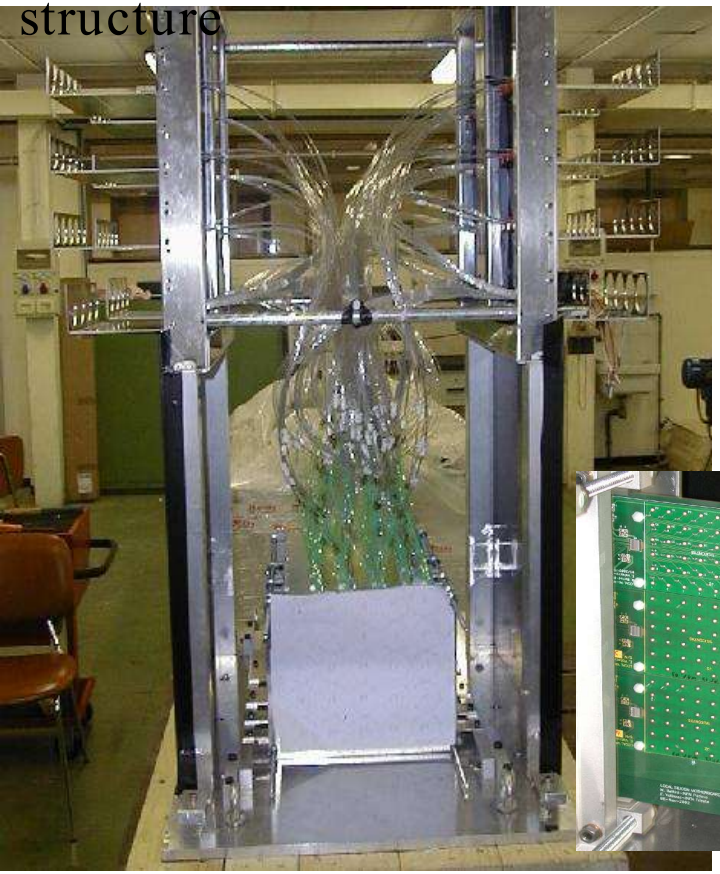
backup

Detector Assembling:

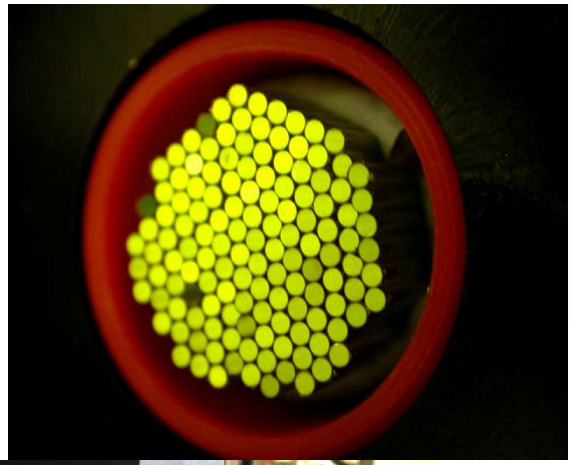


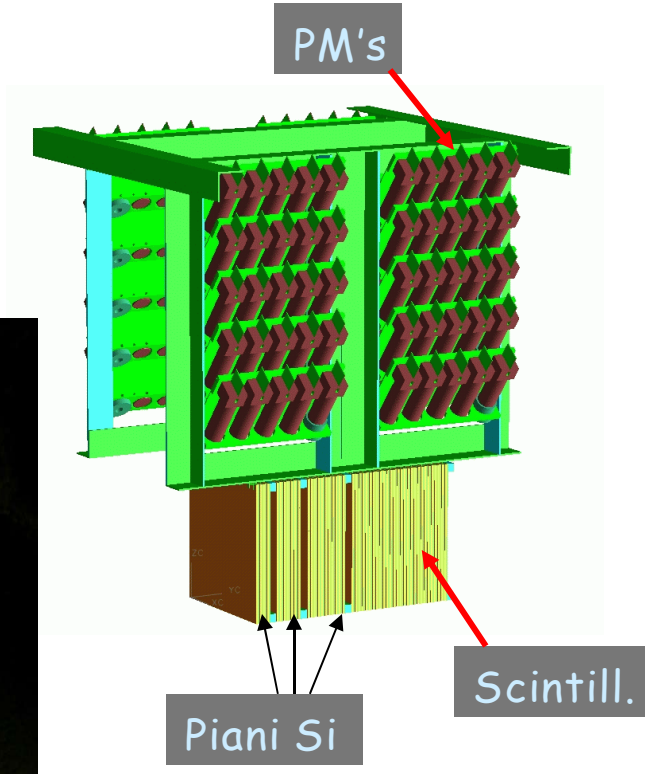


Fibres with PM support structure



Fibres faced to PMs



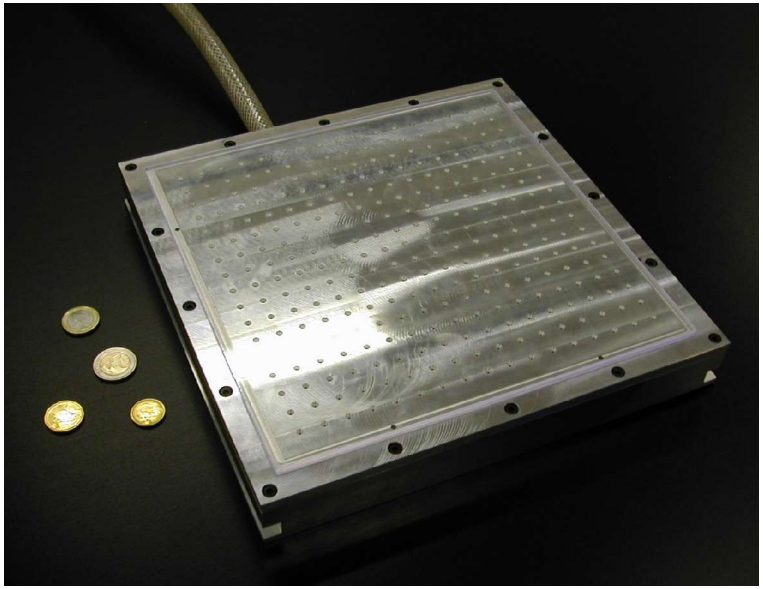


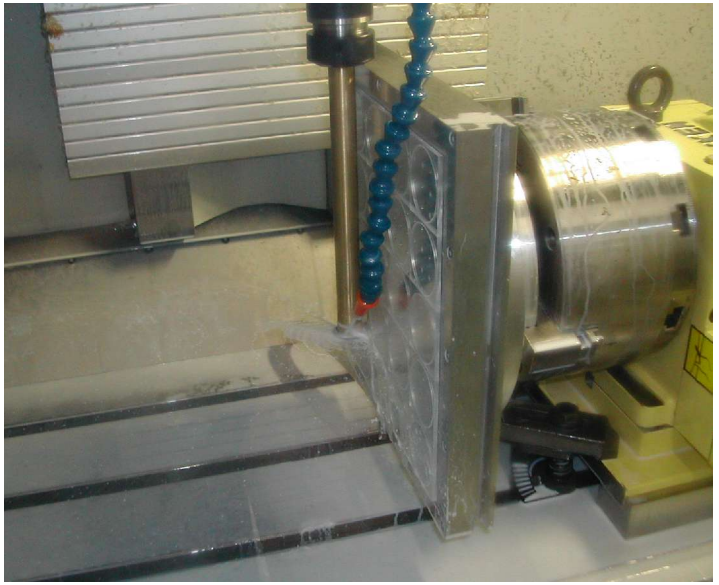
LCCAL in test @ BTF (Frascati)

Construction details:Scintillator

- 3 mm Kuraray SCSN-61 (25x25 cm^2)
- 3 mm Bicron BC-408 (25x25 cm^2)

Machined with vacuum plate as holder

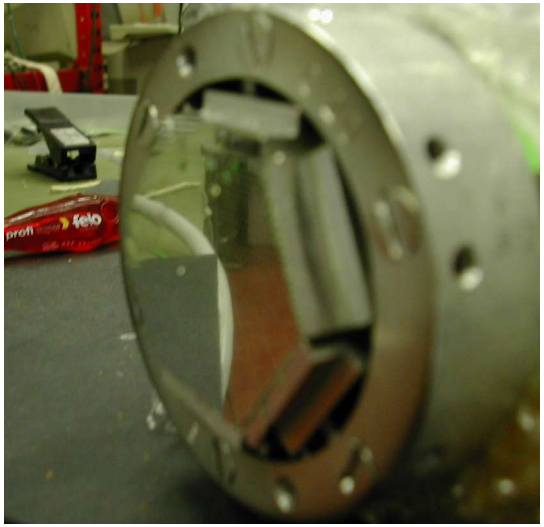




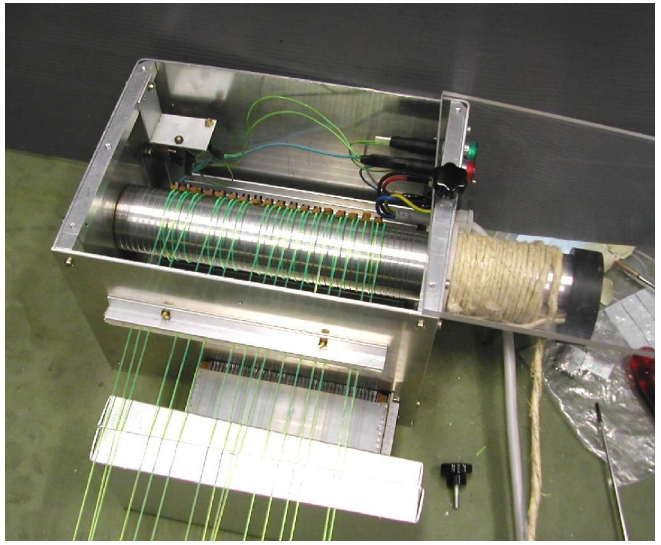
Whole Production (>50 tiles) done in september 2002

Fibers: Kuraray 1mm d. Y11 300 ppm multicladding

Face polished and alumnized by sputtering



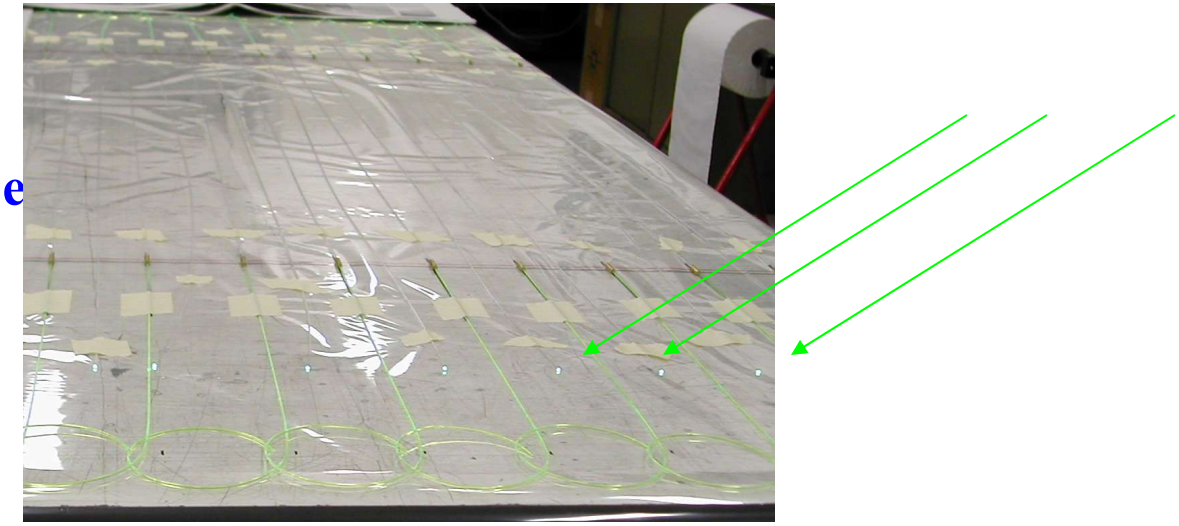
To make the 2.4 cm radius curvature : middle temperature(50^0-70^0) oven



Splicing with optical glue

and a supporting tube :

stable in >30 day time



Test beam results CALORIMETER (2.1 X_0)

4 layers

m.i.p.→check light output and uniformity in Light collection:

Ratio signal/sigma →lower limit for photoelectrons

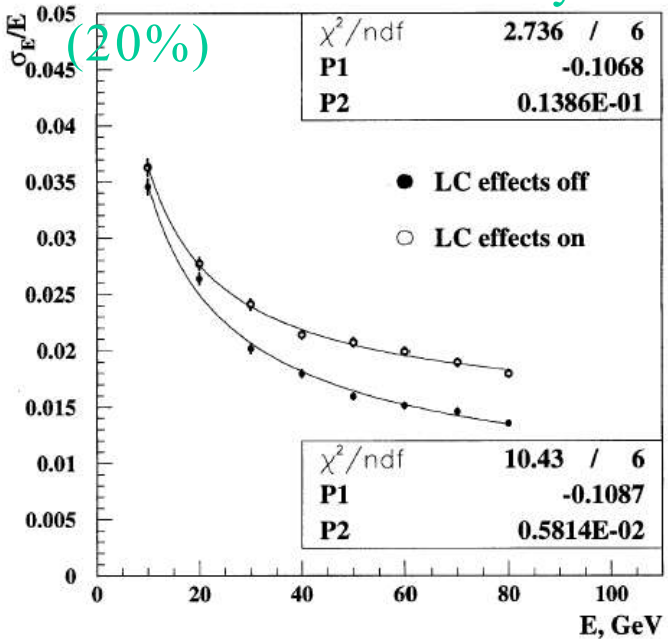
N_{phe}>5.1 /layer

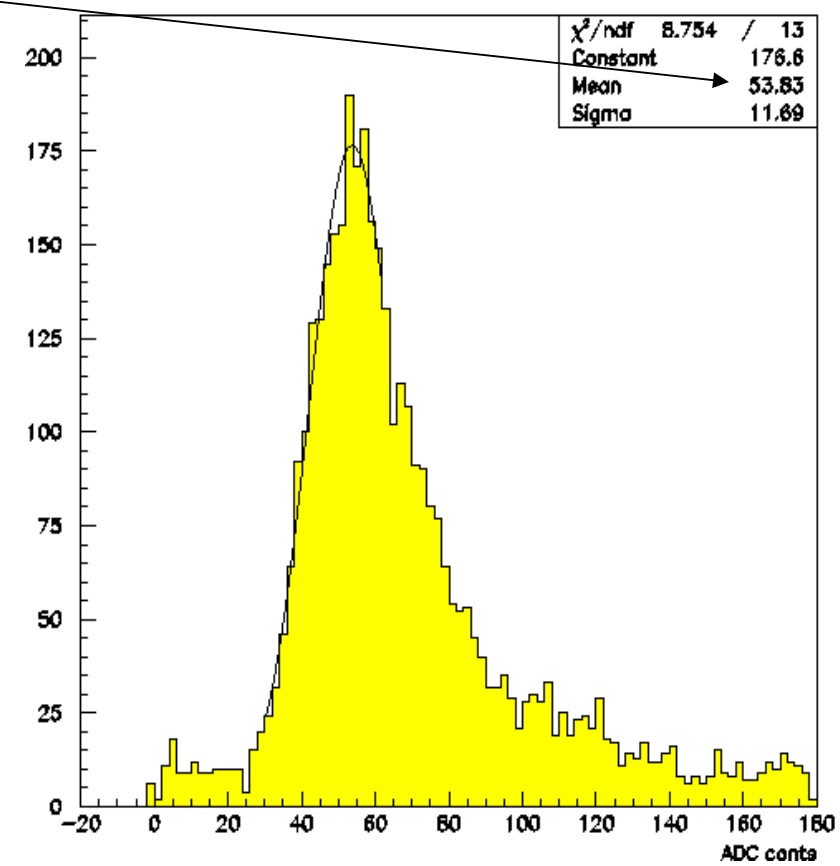
→ cal(45layers):>220

good uniformity:

phe/m.i.p.

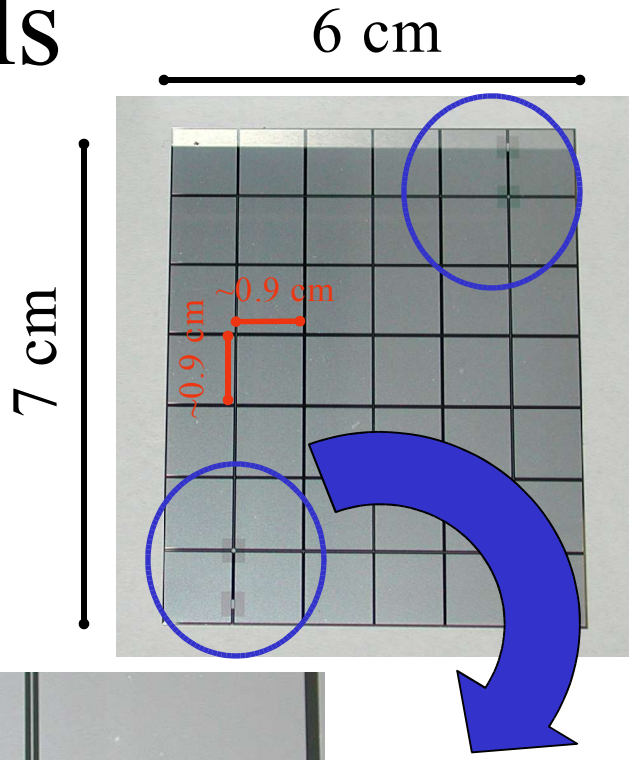
Simulated Light collection disunifority (20%)

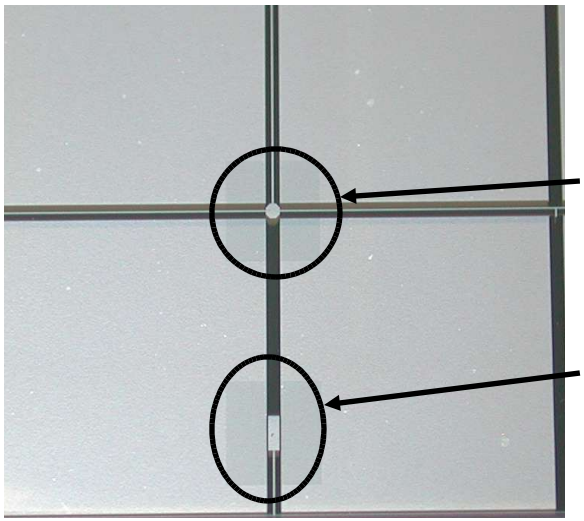




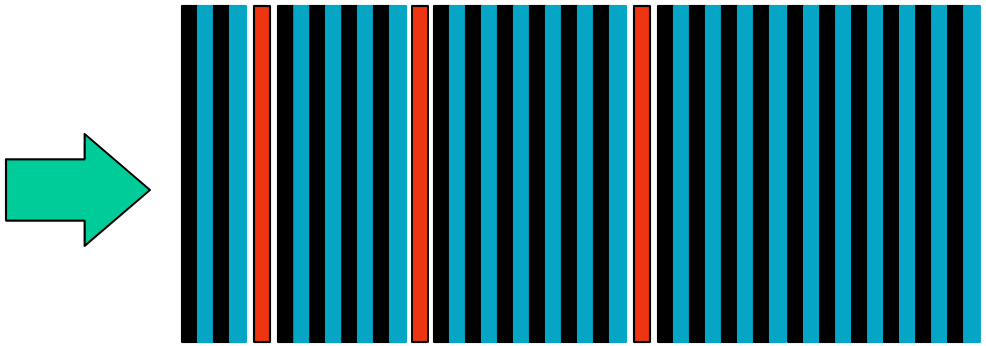
Sensor details

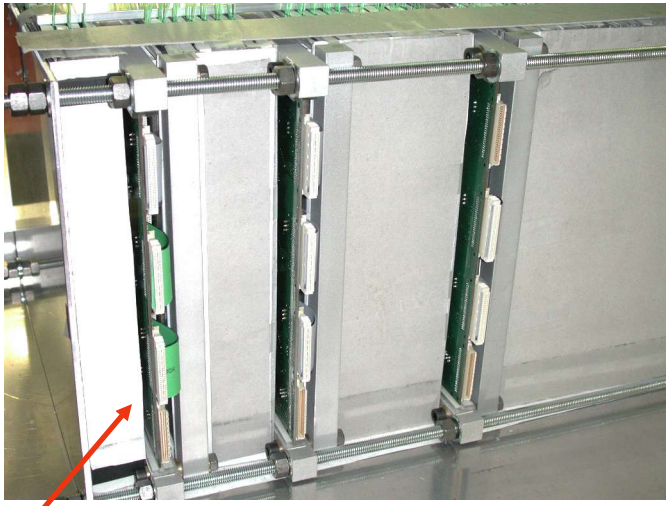
- Main characteristics:
  - Sensor thickness: 300μm
  - Resistivity: 4-6kΩ
  - AC coupling (2 ways)
    - Silicon dioxide thickness: 265 nm
    - SMD capacitors
  - Bias grid and guard ring
    - 3MΩ poly-Si bias resistors
    - Symmetric structure





Calorimeter Layout





Total of 50 layers
27 X_0

Absorber

25 x 25 x 0.3 cm^3

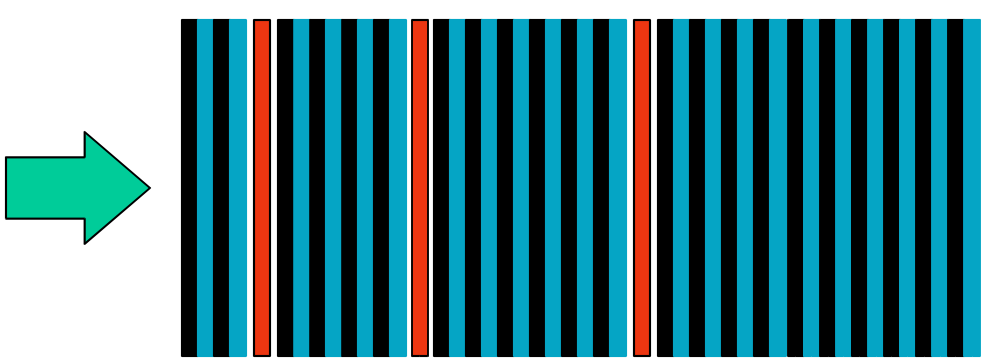
Scintillator

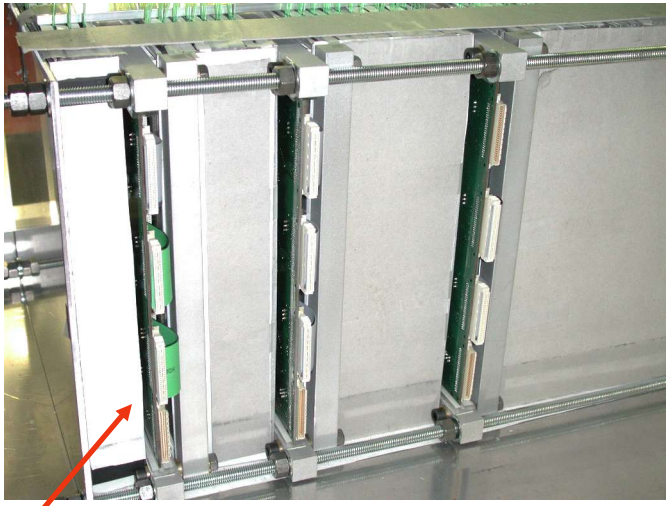
25 Cells 5 x 5 cm^2

Silicon pad detectors

3 layers
725 Pads ~ 1 x 1 cm^2
2, 6 and 12 X_0

Calorimeter Layout





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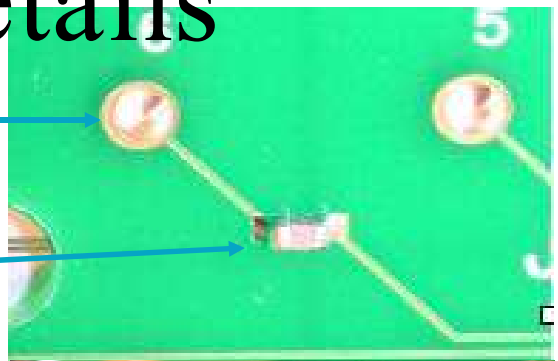
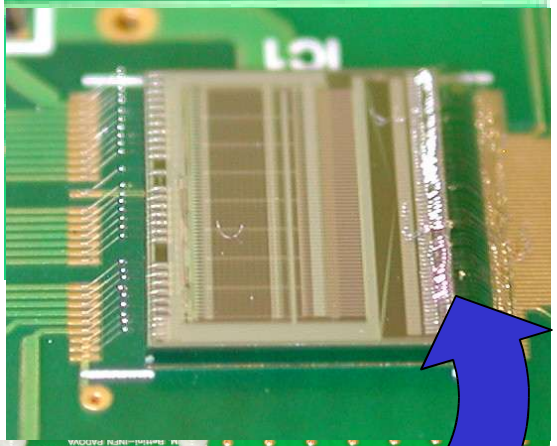
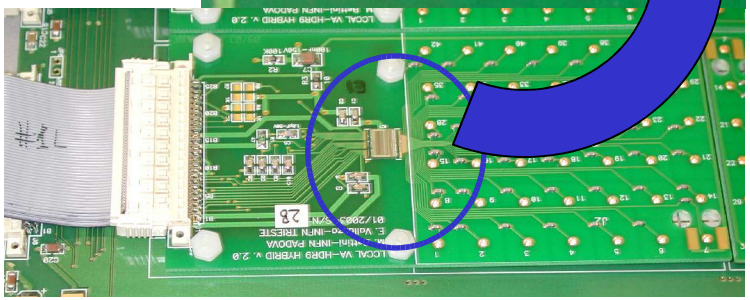
725 Pads ~ 1 x 1 cm^2
2, 6 and 12 X_0

Hybridisation details

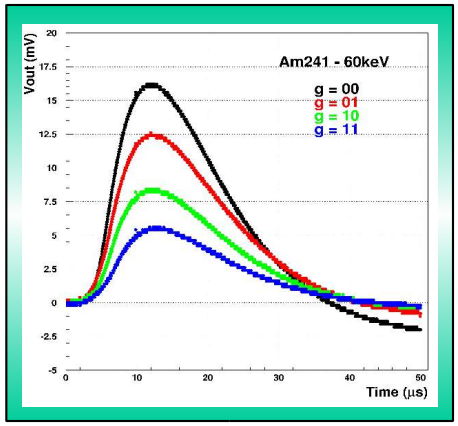
- Hybridisation through conductive glue
- Analogue Readout Chip: VA-HDR9c (IdeAs)
  - VA → Viking family
  - HDR → High dynamic range
  - 9c → Four selectable gains







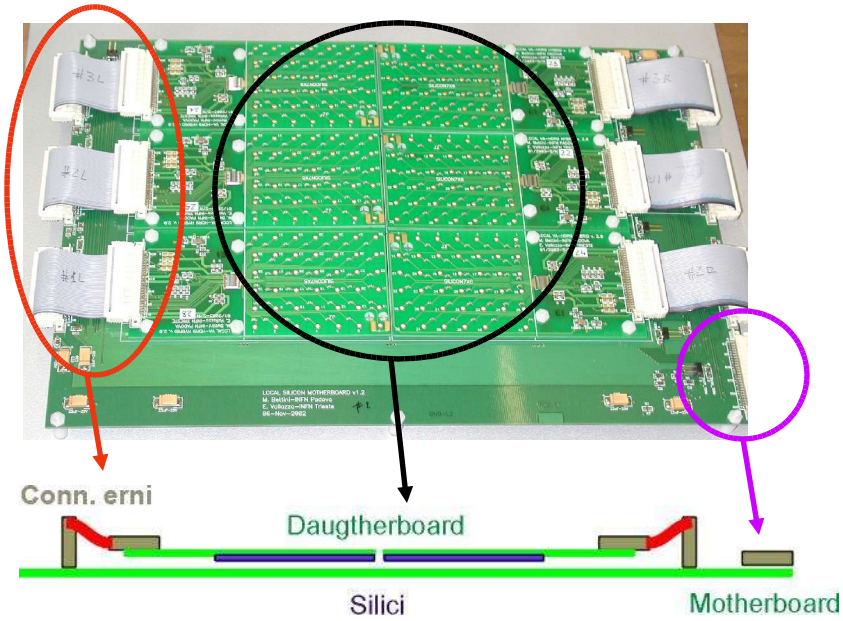
Gain* [mv/fC]	DR [mip]
3.3	± 100
2.5	± 140
1.7	± 200
1.2	± 300

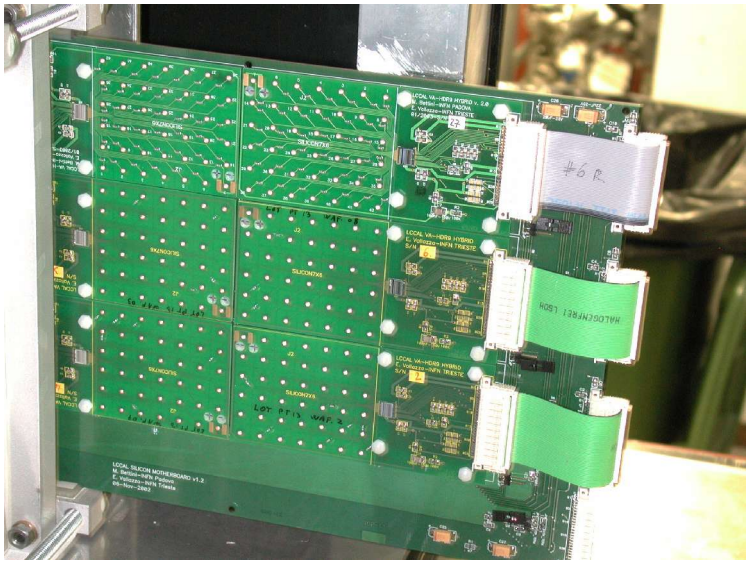


*Measured value

Motherboard design

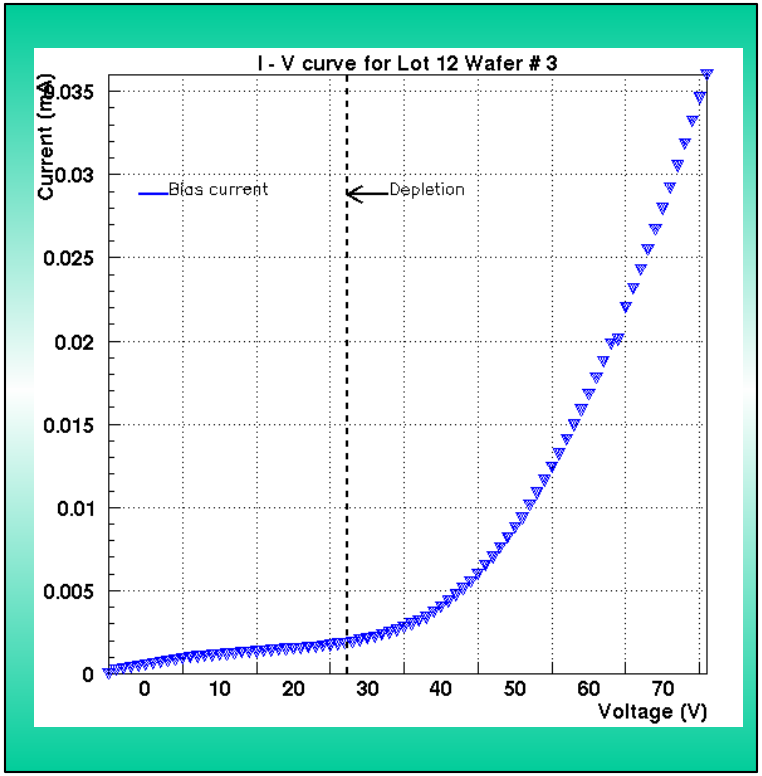
- 6 sensors per motherboard with serial readout.
- Status of production:
  - 24 sensors available
  - 3 motherboards fully and 2 partially equipped
- Signal routing through Erni connectors

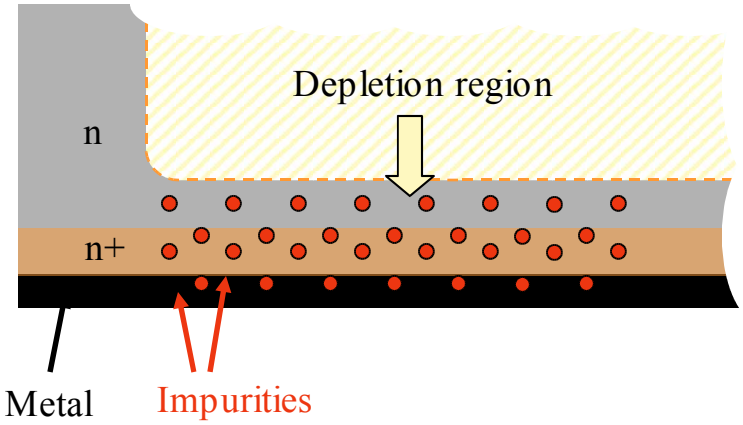




Soft breakdown

- Bias current reasonable (few μA)
- Strange shape with a "soft" breakdown
- n+ or metal shallow impurities on the backplane



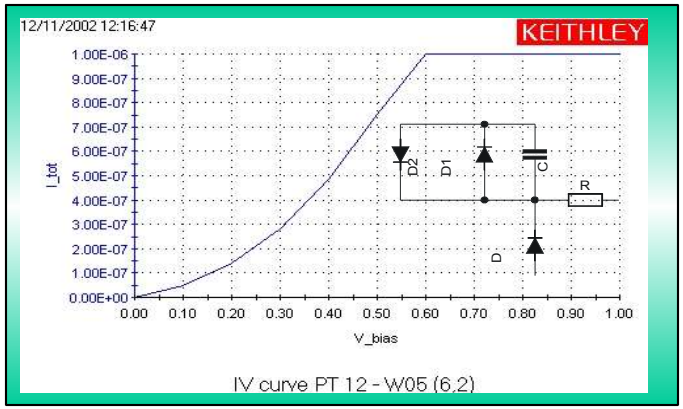


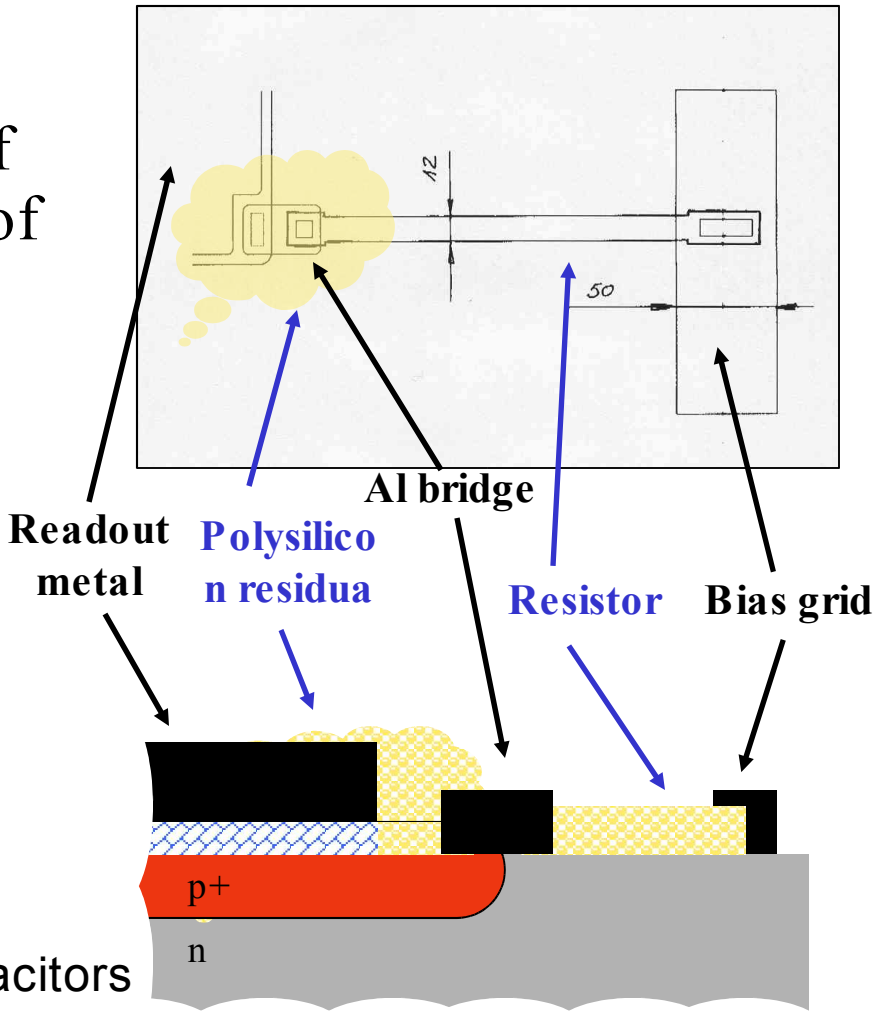
Solution 1: replace the implanted backside contact with a diffused one, but it does not work!

Solution 2: replace the mash backplane contact with a uniform one, it works!

“Leaky” pads: a surface effect

- No pin holes in SiO_2
- Surface leakage → residua of polysilicon after the etching of the polysilicon layer
- Equivalent circuit with two opposite diodes.

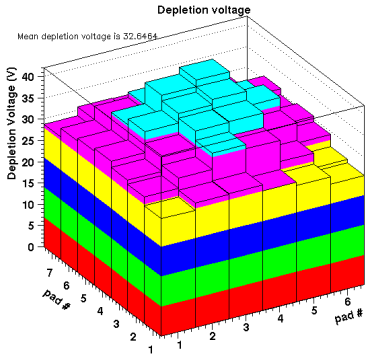


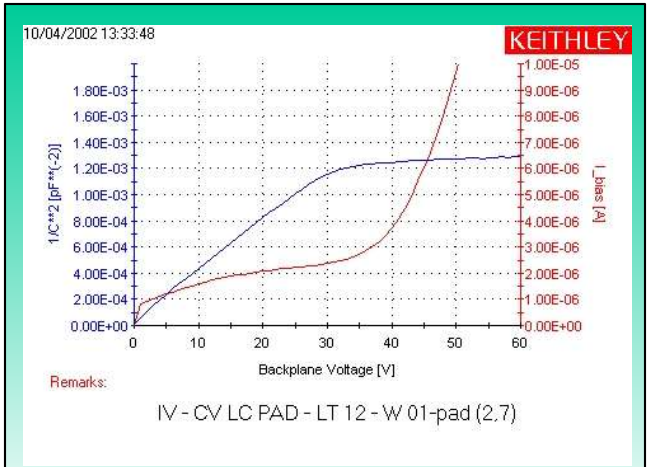


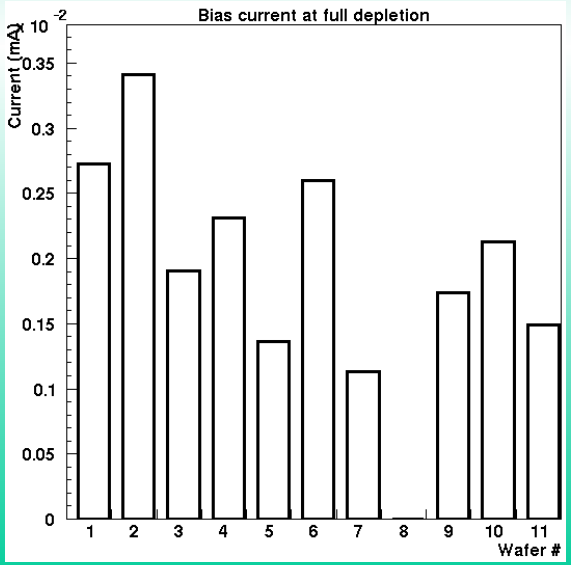
Solution: remove the integrated capacitors

Yield

Quite uniform behaviour of the depletion voltage





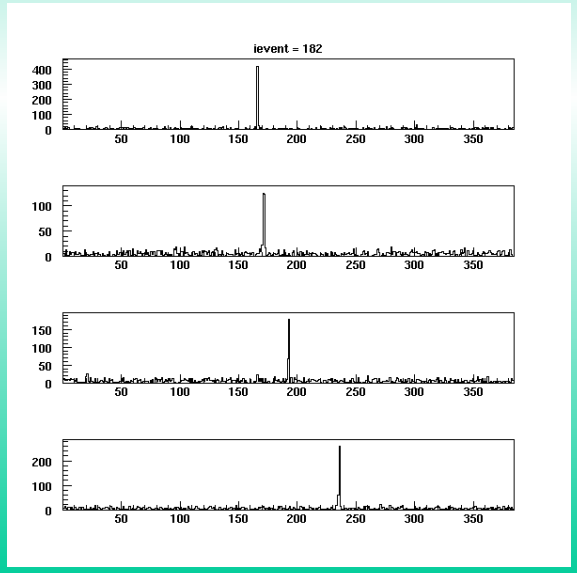


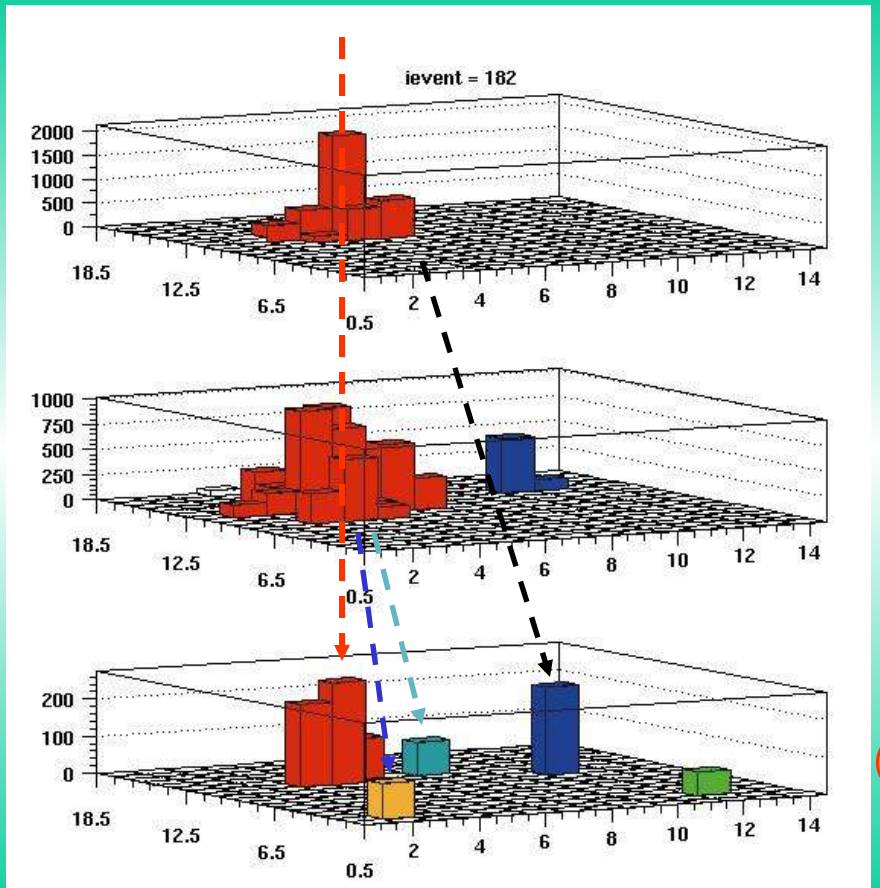
YIELD	1st Batch	2nd Batch	3rd Batch
Coupling	AC	AC	DC
Wafer Rejected	1/11	2/9	0/9
Depletion Voltage	32V	27V	28 V
Current @ depletion	2.1 μA	0.8 μA	0.6 μA
Not depleted pads	0/420	8/249	0/378

Test beam: shower reconstruction / 2

20 GeV e^-

Forward tracker





Test beam: energy linearity

- Silicon wafers rearranged in 5 planes ant tested alone
- Pb of 2.5 cm
- Electrons beam
- Error bars = sigma distribution