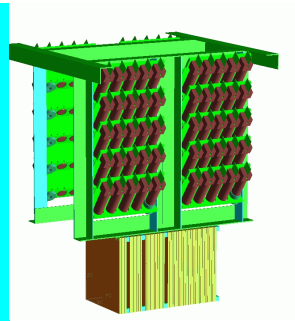
LCcal*: a Si−Scintillator hybrid technique for ECAL



TALK SUMMARY

- **Design Principles**
- **Prototype Description**
- **Construction Details**
- **Test Beam Results**
- **Conclusions and Future Plans**

*LCcal: Official INFN R&D project, official DESY R&D project PRC R&D 00/02
http://www.pd.infn.it/~checchia/lccal/Welcome.html

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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 CALEIDO)**

Alternatives:

- **Cristals**
- **Fully compensating Ecal+Hcal**

Proposed solution:

Keep SiW advantages (flat geometry, high granularity)

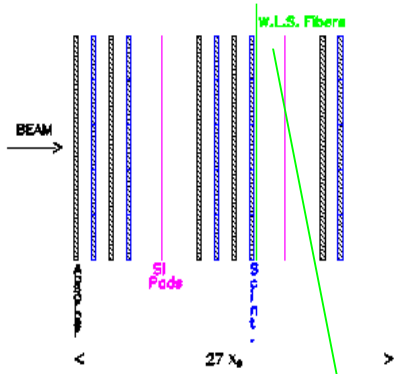
Erec. not from Si but from Scintillator−WLS fibers

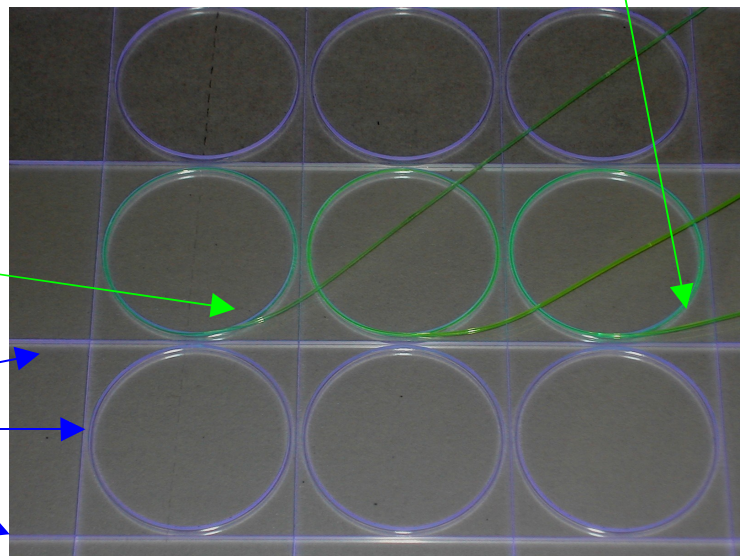
Reduce (factor >10) the number of channels

Prototype description

Pb/Sc + Si

- 45 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:
- 252 0.9×0.9 cm^2 Si Pads at: 2, 6, 12 X_0





Scintillation light transported with WLS σ tail fibers:

Coupled with clear fibers (to PM)

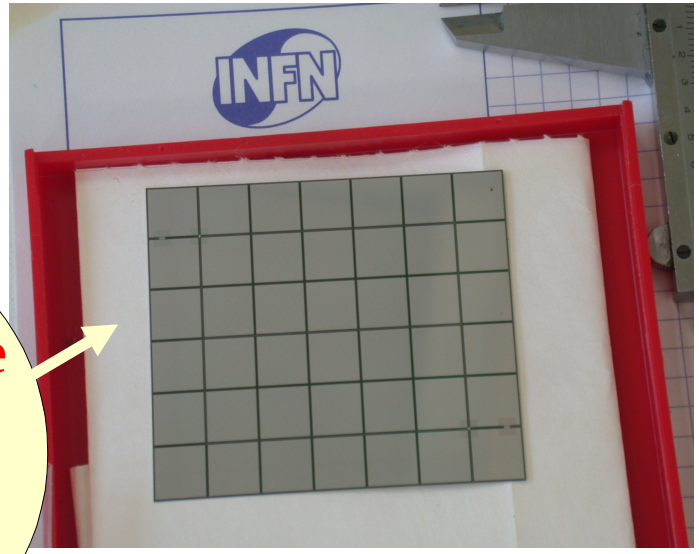
Cell separation with grooves in Sc. plates with Tyvec strips inside (light leakage!?)

Prototype Description

3 Si planes

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

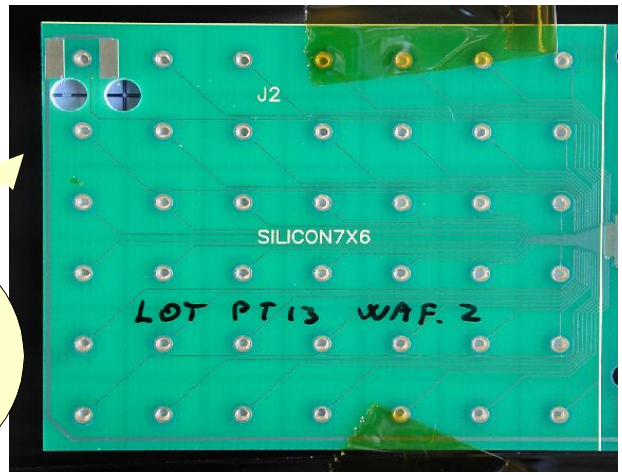
- **Pad dimension< shower dimension:**
  0.9 x 0.9 cm^2
- **Longitudinal sampling:**
  3 planes
- **Analogic RO**
  VA hdr9c from IDEas



Pad diode ac(old)− dc(new) coupled

Actual design:

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



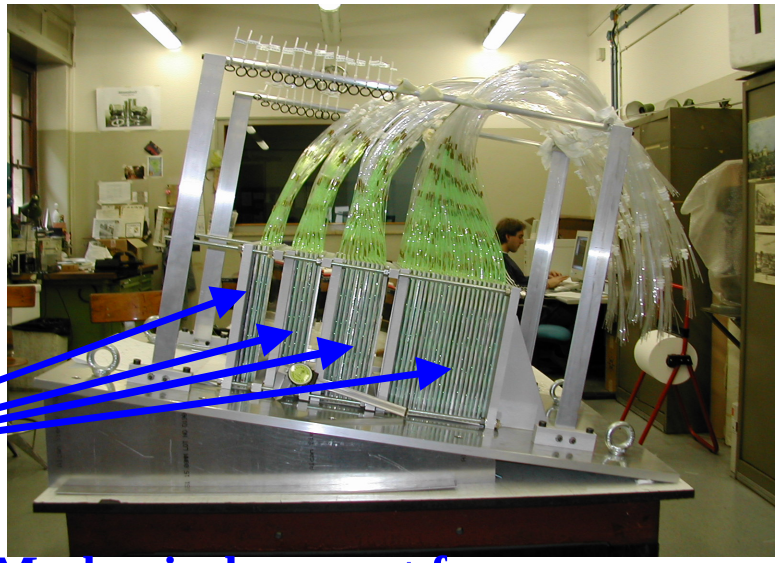
Pcb contact with conductive glue

Construction Details

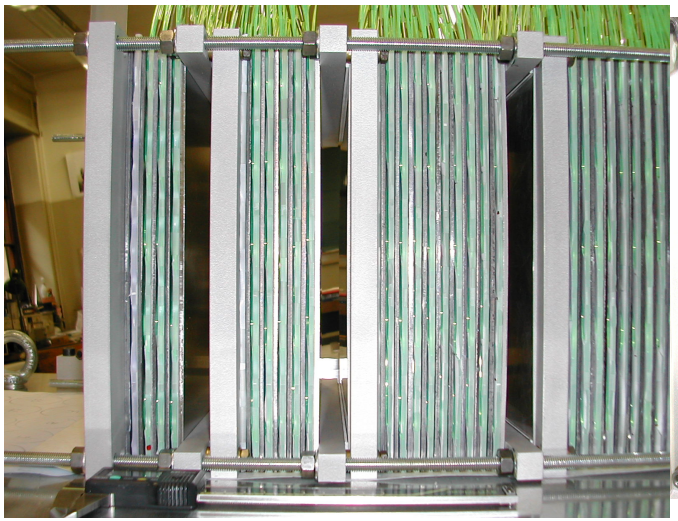
45 Layers calorimeter prototype completely built in 2002

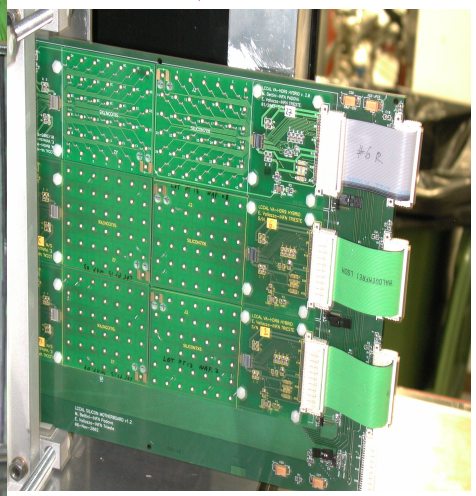
Fibres grouped into 25x4 bundles making a 4−fold longitudinal segmentation.

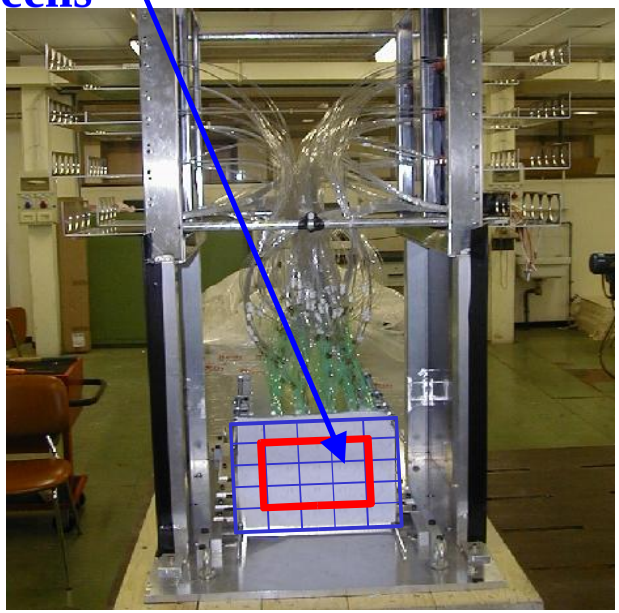
Slots for the insertion of the 3 Si pad planes (Motherboard).



Mechanical support for Photomultipliers in the 3X3 central cells



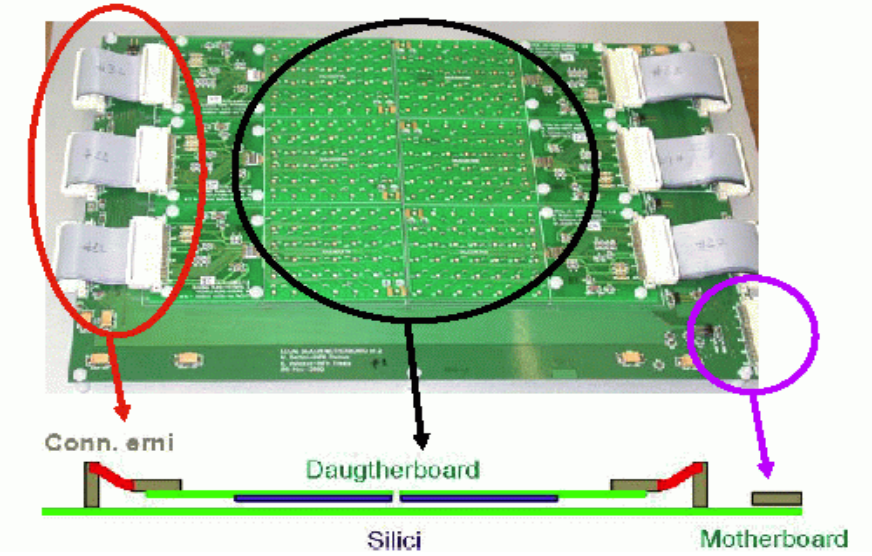




Si Production details

Motherboard design

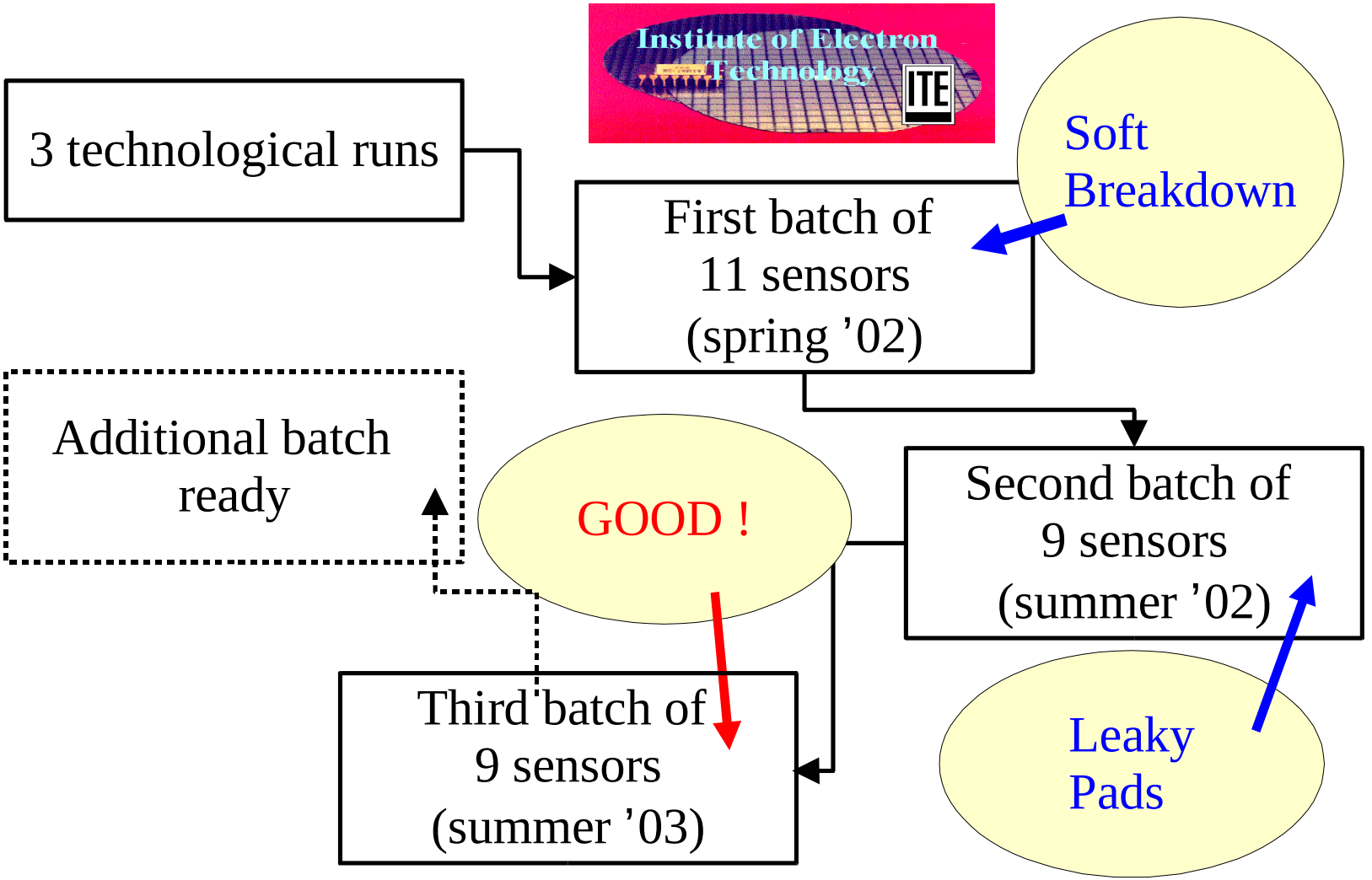
- 6 sensors per motherboard with serial readout.
- Status of production:
  - 24 sensors available
  - 3 motherboards fully and 2 partially equipped
- Signal routing through Erni connectors



Si Production details

How

we get there… Step by step



Si Production details

MIP Signal to Noise ratio

Theory:

$$\mathrm{ENC} = A + \frac{B}{pF}$$

$$\mathrm{ENC} = \frac{e}{q}\sqrt{\frac{qI_l T_p}{4}}$$

$$\mathrm{ENC} = \frac{e}{q}\sqrt{\frac{T_p k_B T}{2R}}$$

Front–end

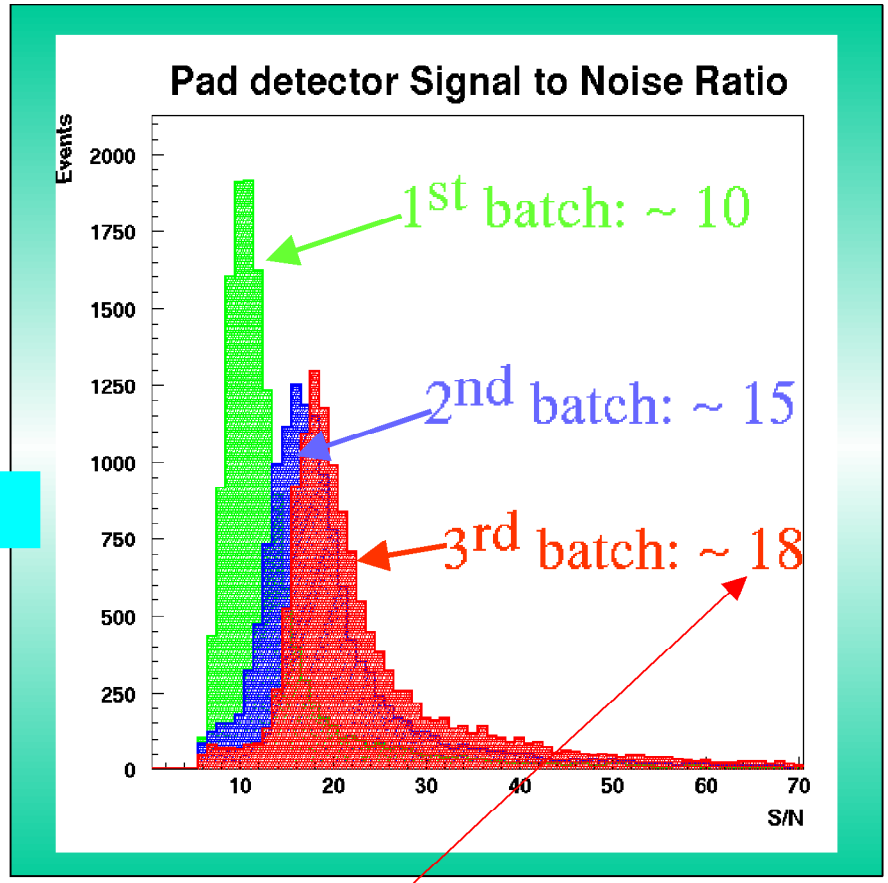
$\approx 1000\, e^- +$

Leakage

$\approx 30 e^- +$

Bias Resistance

$\approx 230 e^- =$



MIP ~ 23000 e⁻

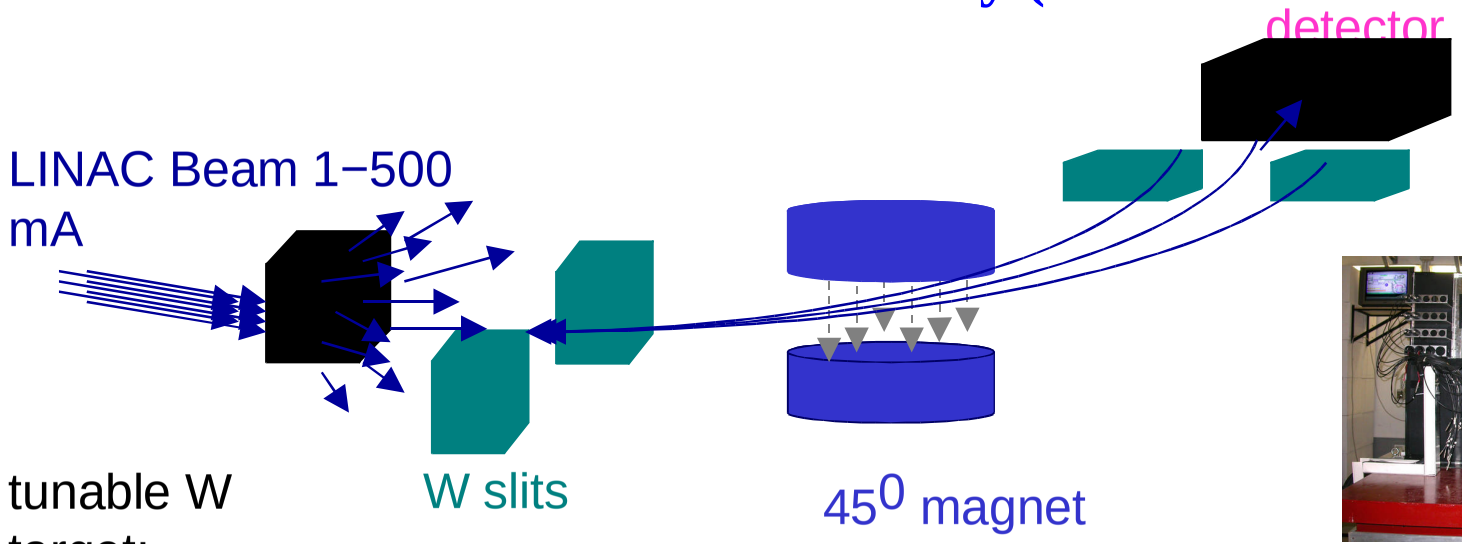
SNR ~ 22

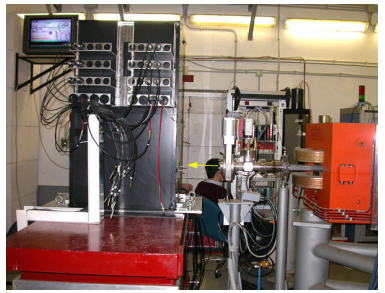
Value close to what achieved for the 3rd batch detectors

Test beam activity

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

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





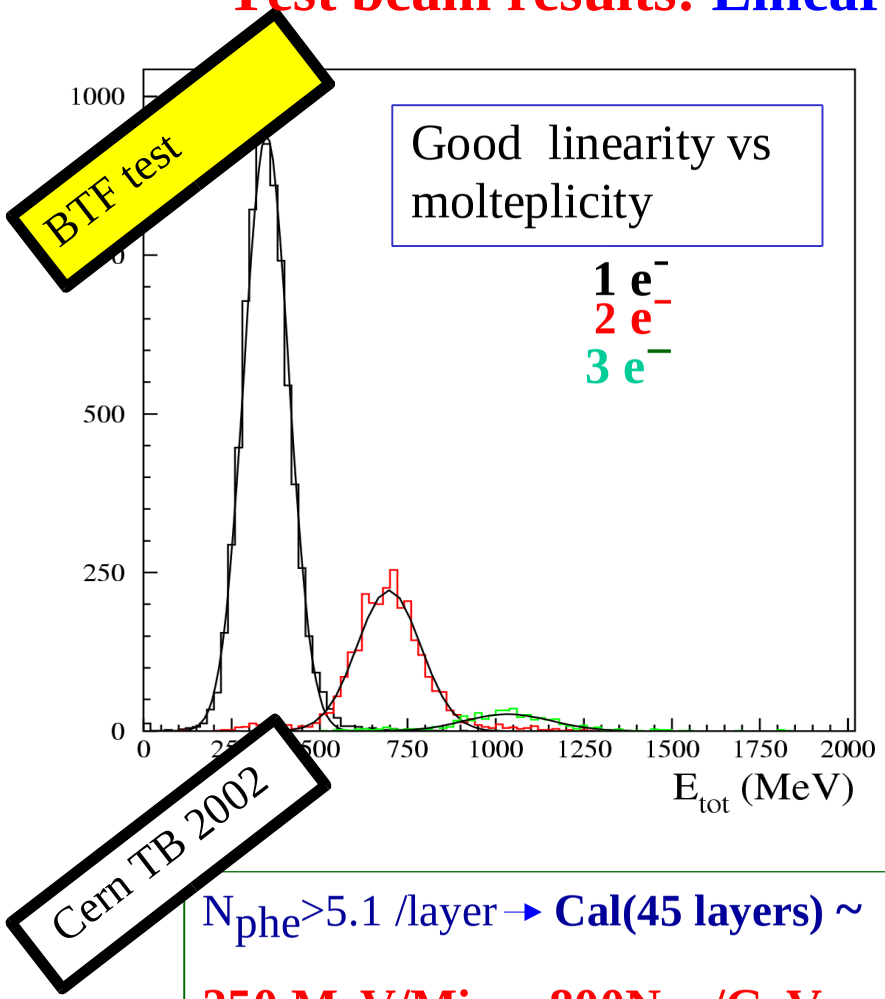
it is possible to tune the multeplicity.....

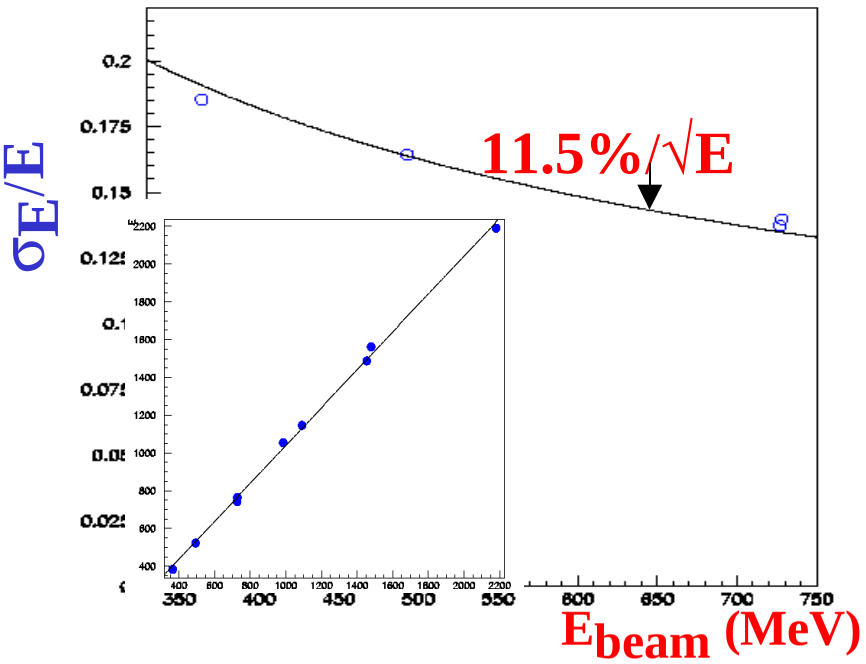
- **run at CERN SPS H6 beam line (e/π 5 – 150 GeV)**

All tests: two beam position monitors (telescope) put in front of the calorimeter.

- **Each detector consisting of 400×400 x−y Si strips with a pitch of 240 μm**
- **They cover the central area of the prototype (9.5 × 9.5 cm^2)**

Test beam results: Linearity and Energy Resolution





N_{phe}>5.1 /layer → **Cal(45 layers) ~**

250 MeV/Mip ~ 800Npe/GeV

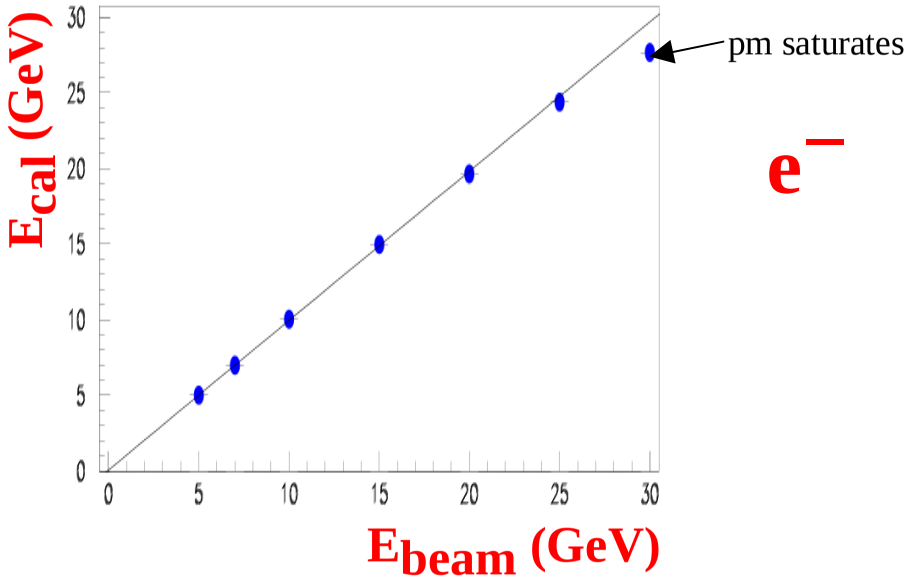
OK also @ BTF (E ~500 MeV)

1. Photoelectron statistics **negligble**
2. Stocastic Term **11.5% as in MC**

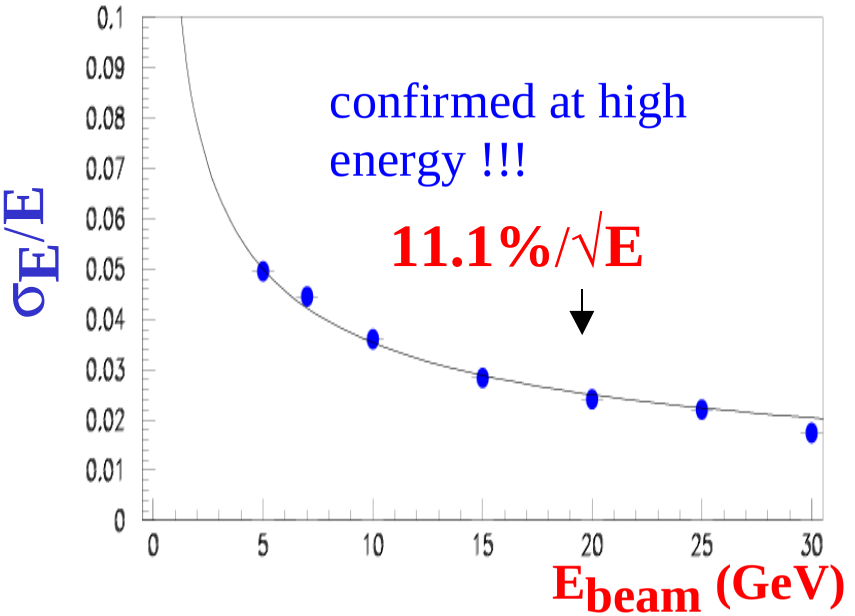
- Light disuniformity **<<10%**
  Effects on resolution to be measured at **SPS (August 2003)**→

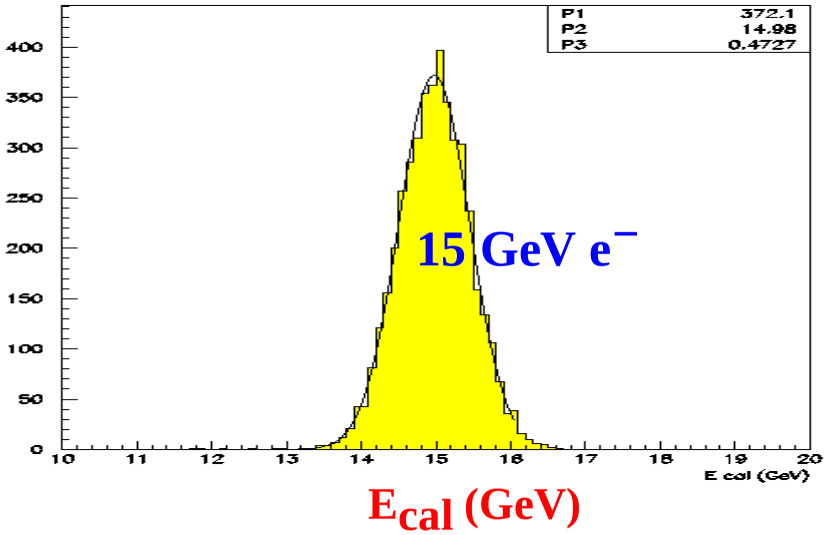
Test beam results: Linearity and Energy Resolution

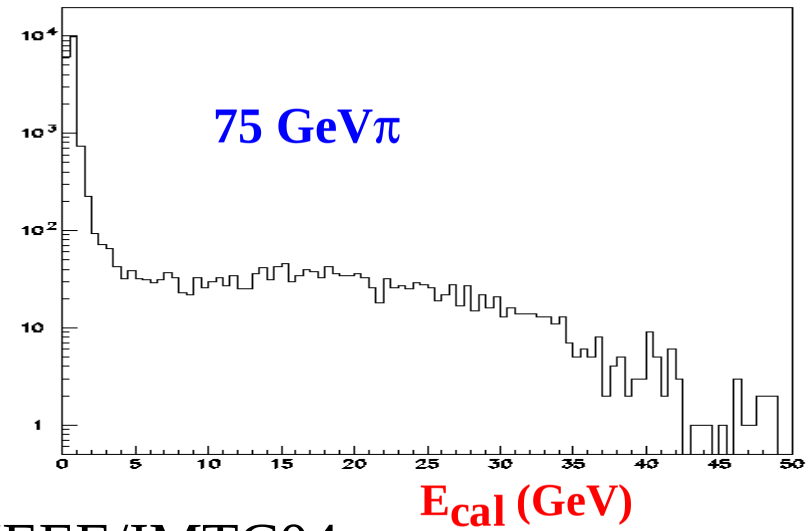
Cern TB 2003



e^-



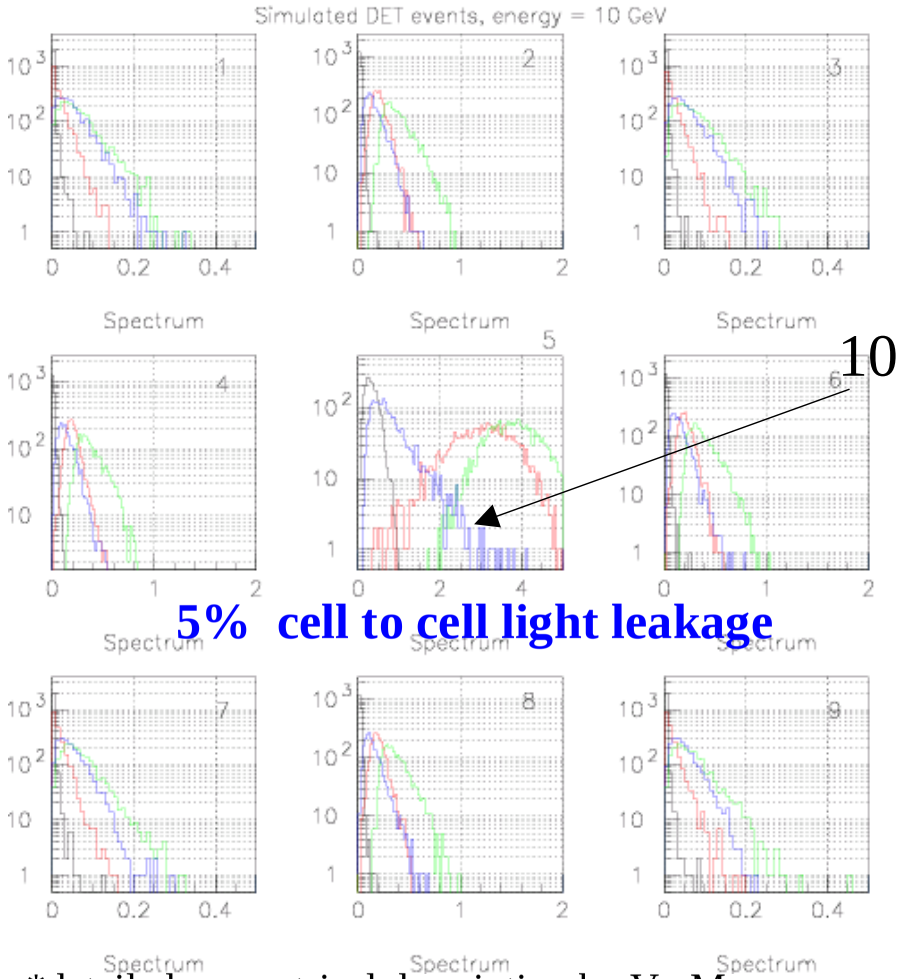




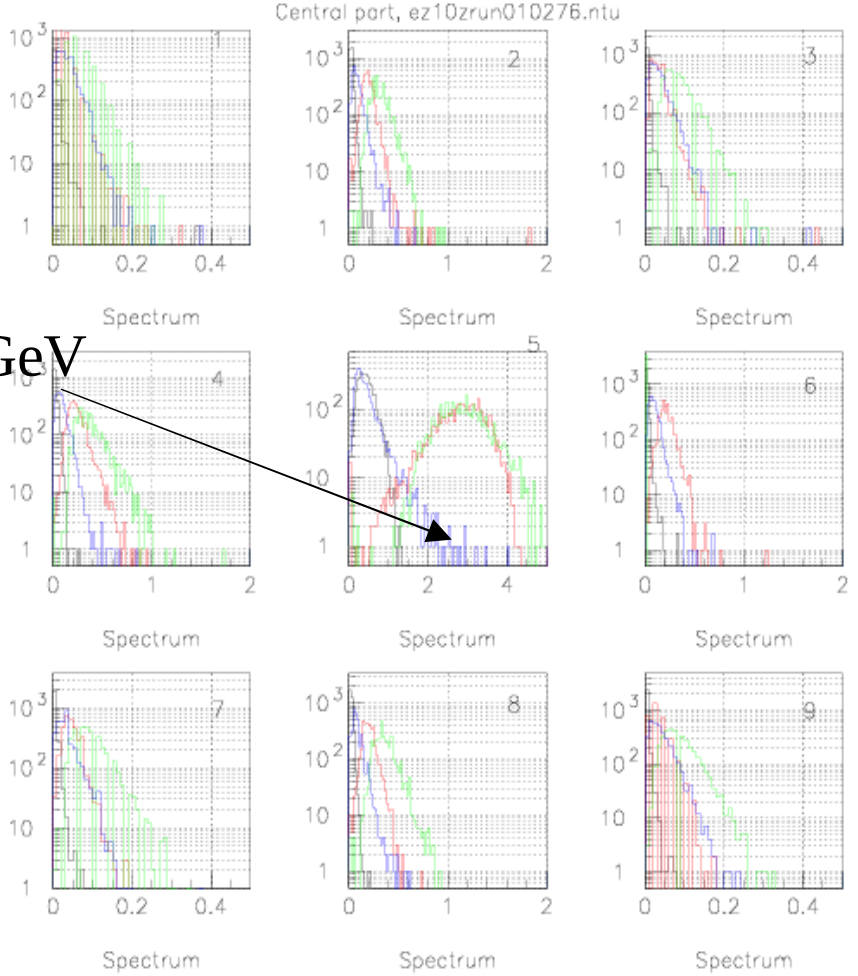
Test beam results: Comparison with MC

Cern TB 2003

Simulation (Geant 3*)



Test Data



10 GeV

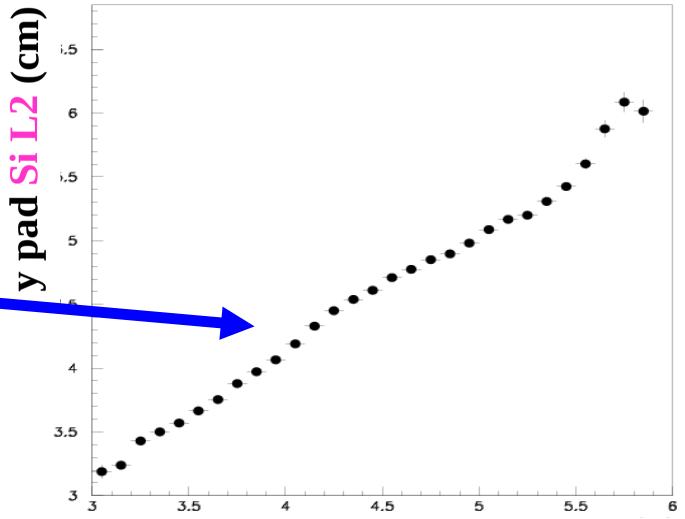
5% cell to cell light leakage

*detailed geometrical description by V. Morgunov

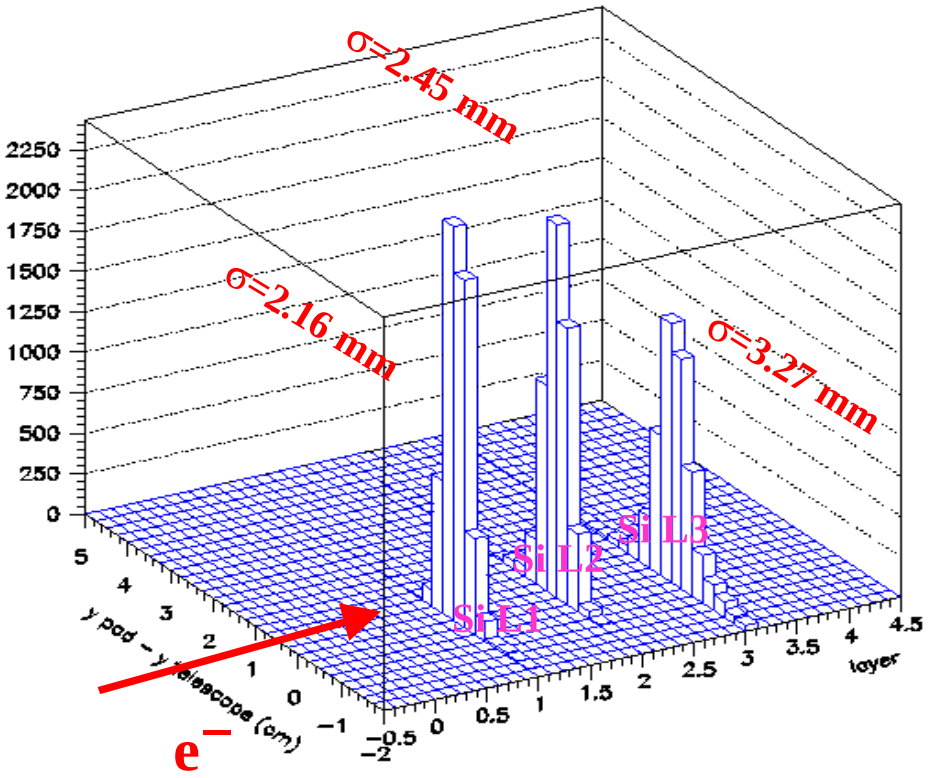
Test beam results: Si pad detector (Position Meas.)

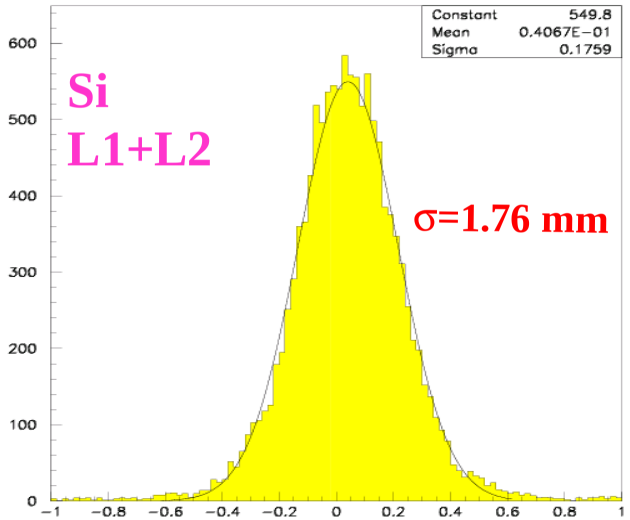
Cern TB 2003

Pad−size effect: different "center of mass" algorithms to be studied



30 GeV electrons



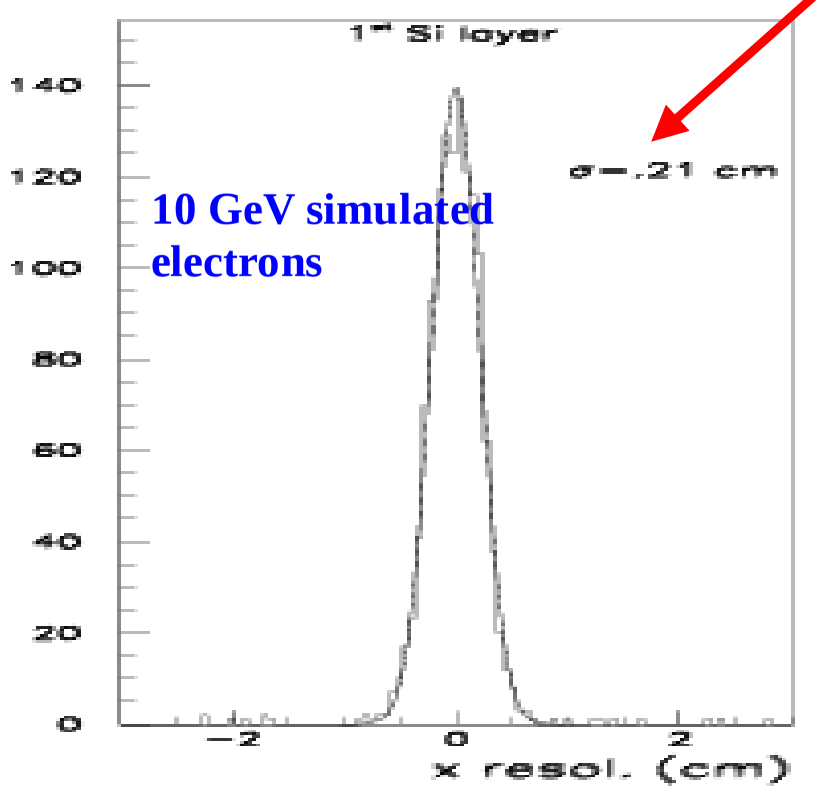


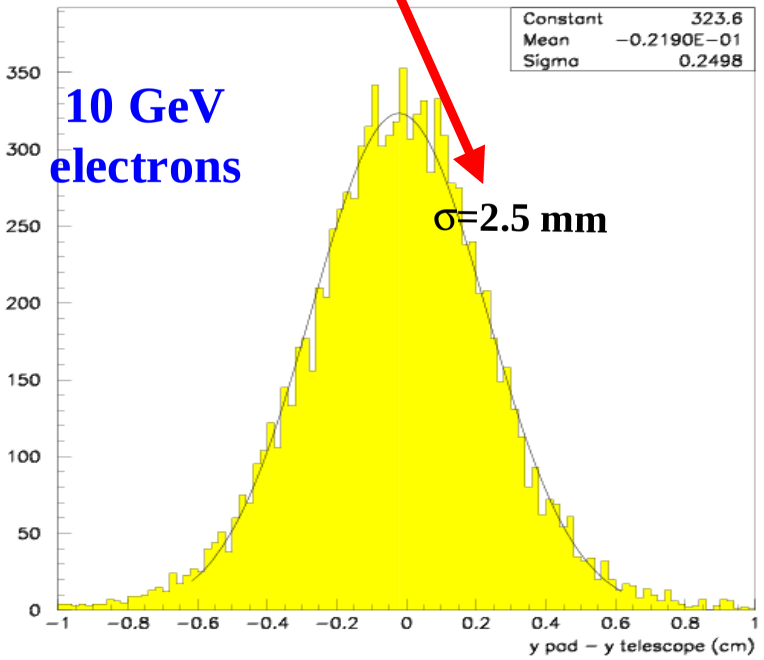
Test beam results: Si pad detector (Position Meas.)

PRELIMINARY analysis: pad noise subtraction not optimised

effects of the Front−End saturation under study

Position resolution ~ 2.5mm not far from Monte Carlo





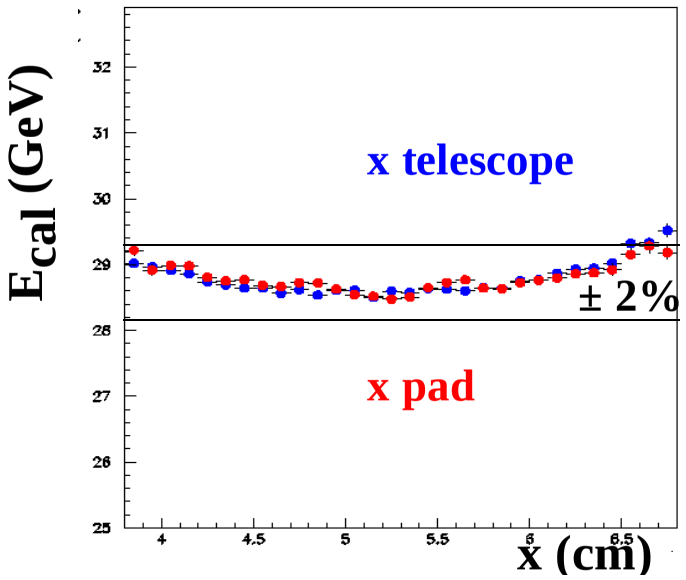
Test beam results: uniformity in (light) Energy response

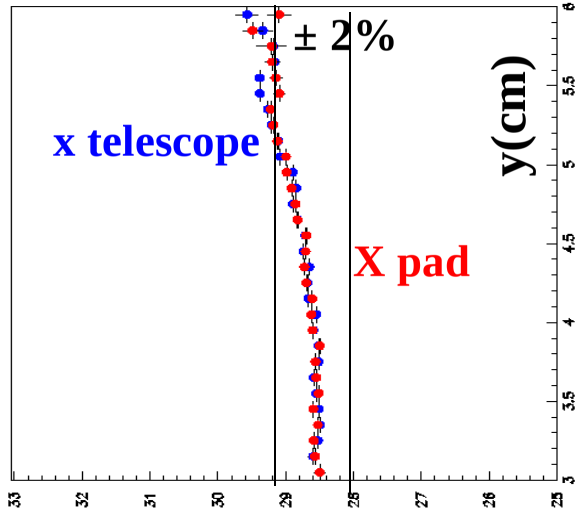
30 GeV e^-

Cern TB 2003

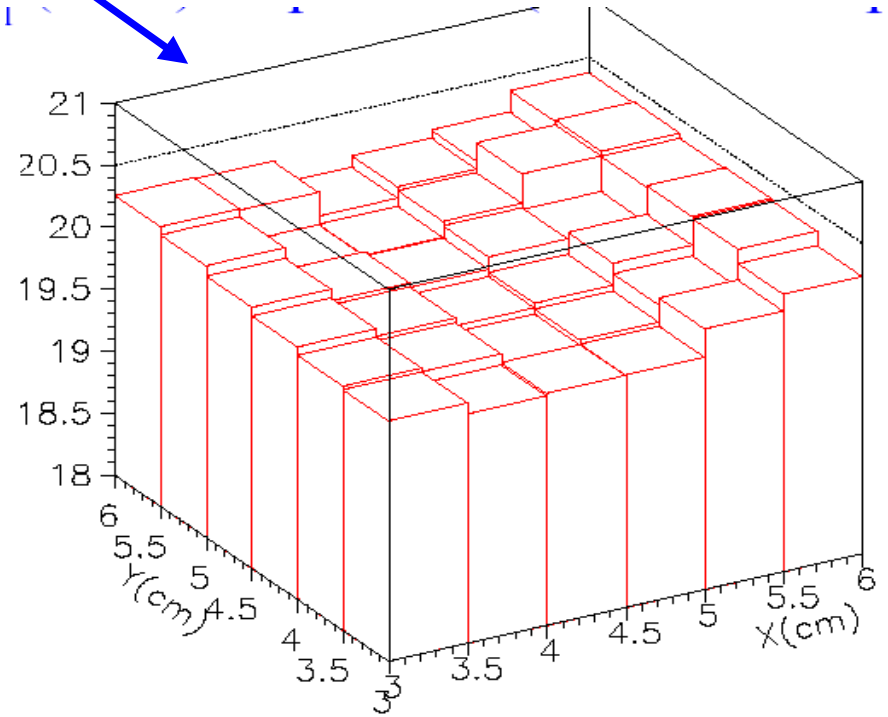
Disuniformity < 2%

Correction from pad reconstruction can be applied!





Ecal (GeV) vs position (from telescope)



Test beam results: (e/π rejection)

the redundancy of the information on the linear/lateral shower development makes the rejection very easy

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

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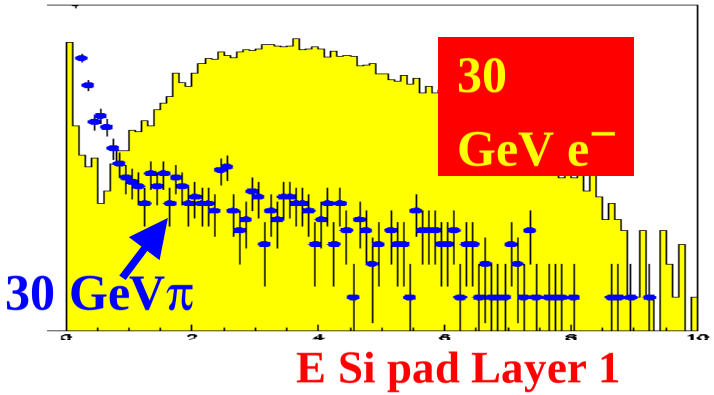
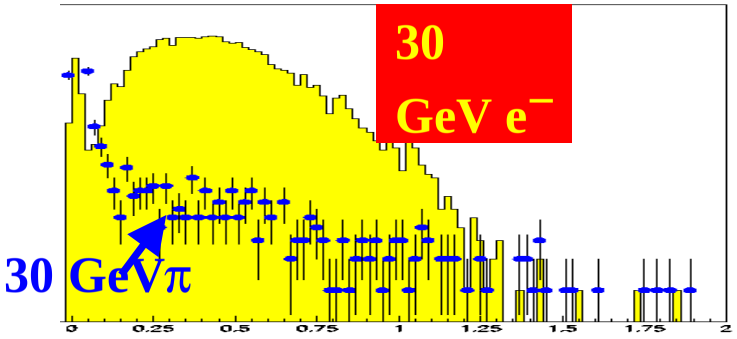
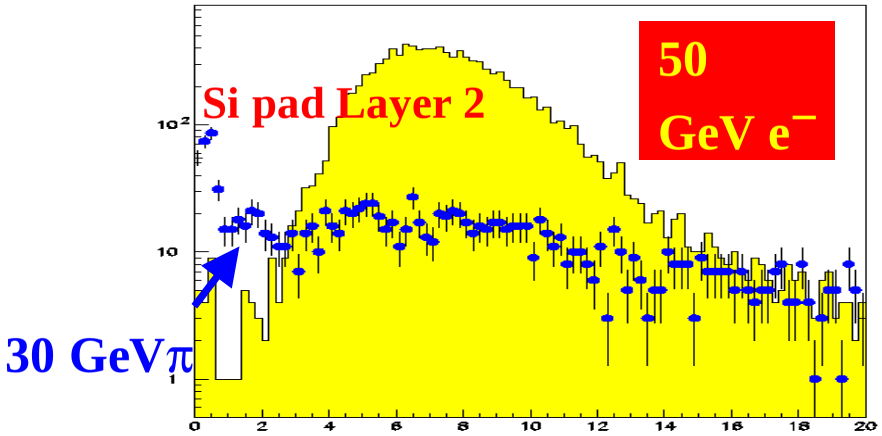
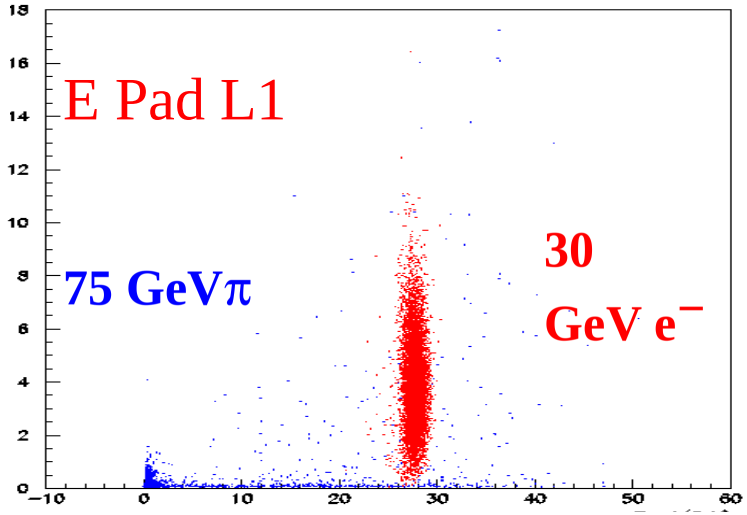


E Si pad Layer 1



E cal Layer 1





E Cal

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

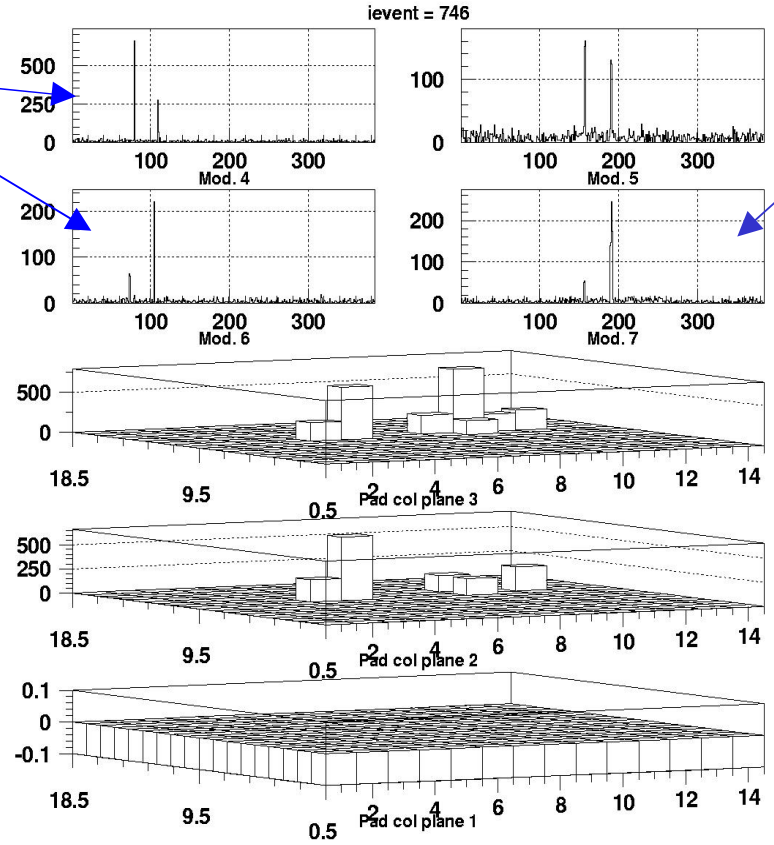
Test beam results: Si Pad two particle separation

exhaustive analysis not fully accomplished

Two electrons with energy 750 MeV

X silicon chambers

Y silicon chambers



BTF test

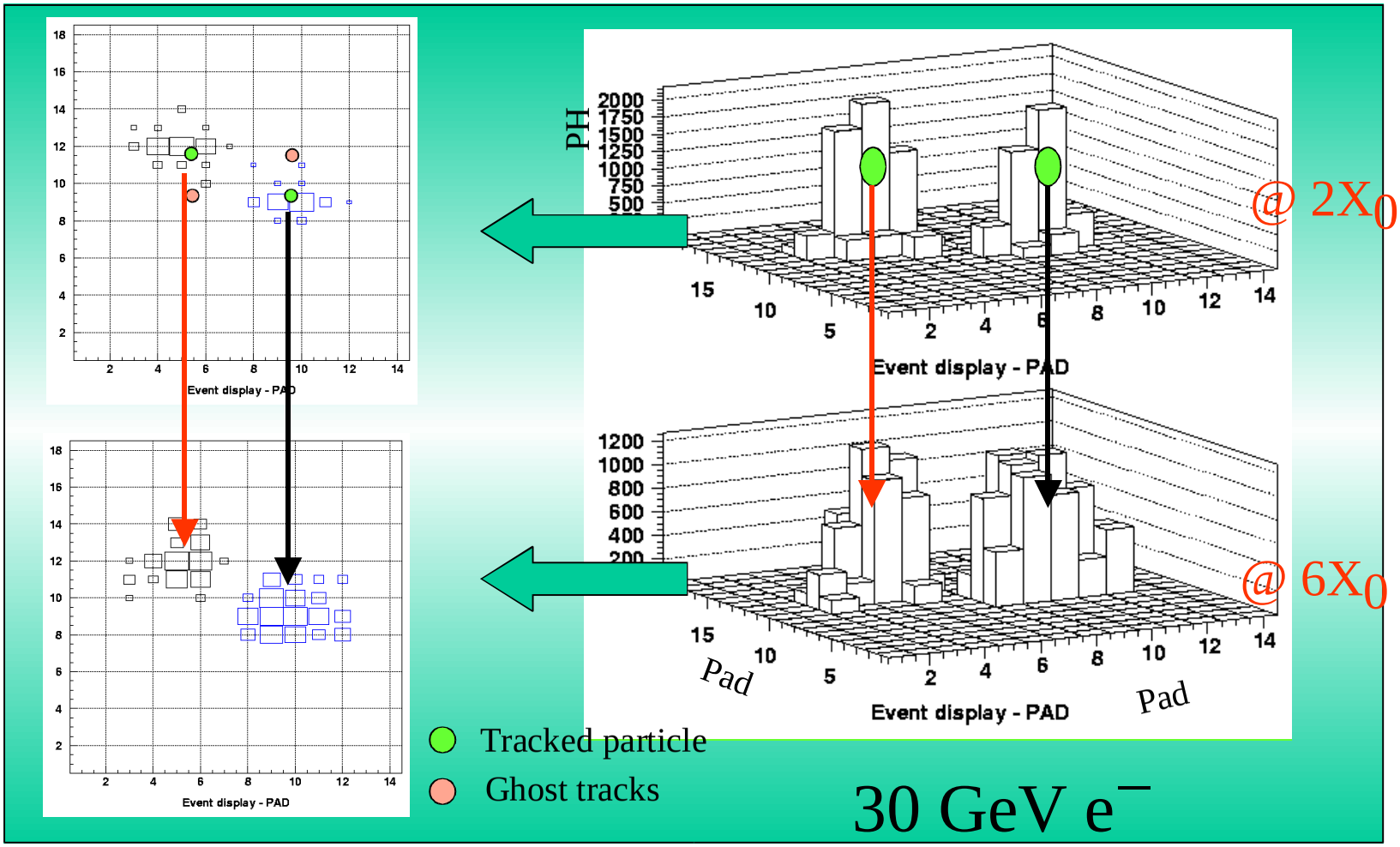
First layer

Second layer

Third layer

NB: not fully equipped+ problematic channels

Test beam results: Si Pad two particle separation



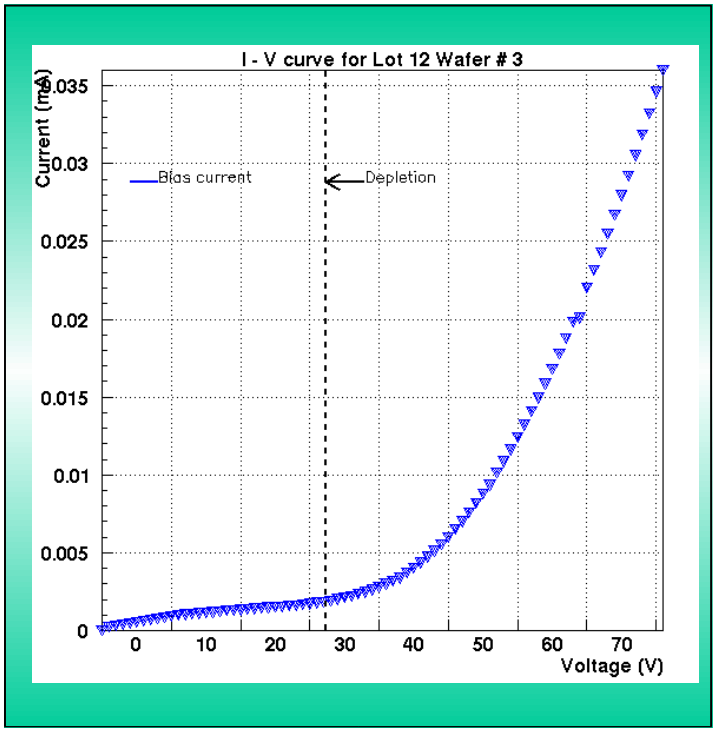
Conclusions and Future plans

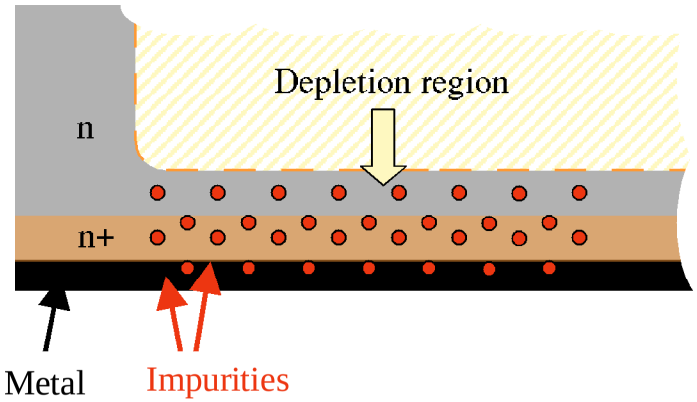
- **A calorimeter prototype with the proposed technique has been built and fully tested. All the results are preliminary.**
- **Energy and position resolution as expected: σ_E/E ~11.−11.5% /√E, σ_{pos} ~2 mm (@ 30 GeV)**
- **Light uniformity acceptable ~ 2%.**
- **e/π rejection very good ($<10^{-3}$).**
- **Detector response during test beam under detailed study (preliminary to the particle separation).**
- **Next steps: study geometrical−construction optimisation (MC) . Include a calorimeter made following this technique into the general LC simulation and Pattern recognition.**
- **Combined test with Hcal (?)**

backup

Soft breakdown

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



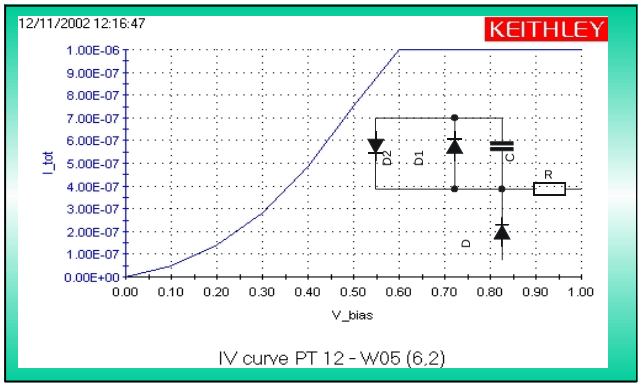


Solution 1: replace the implanted backside contact with a diffused one, but it does not work!

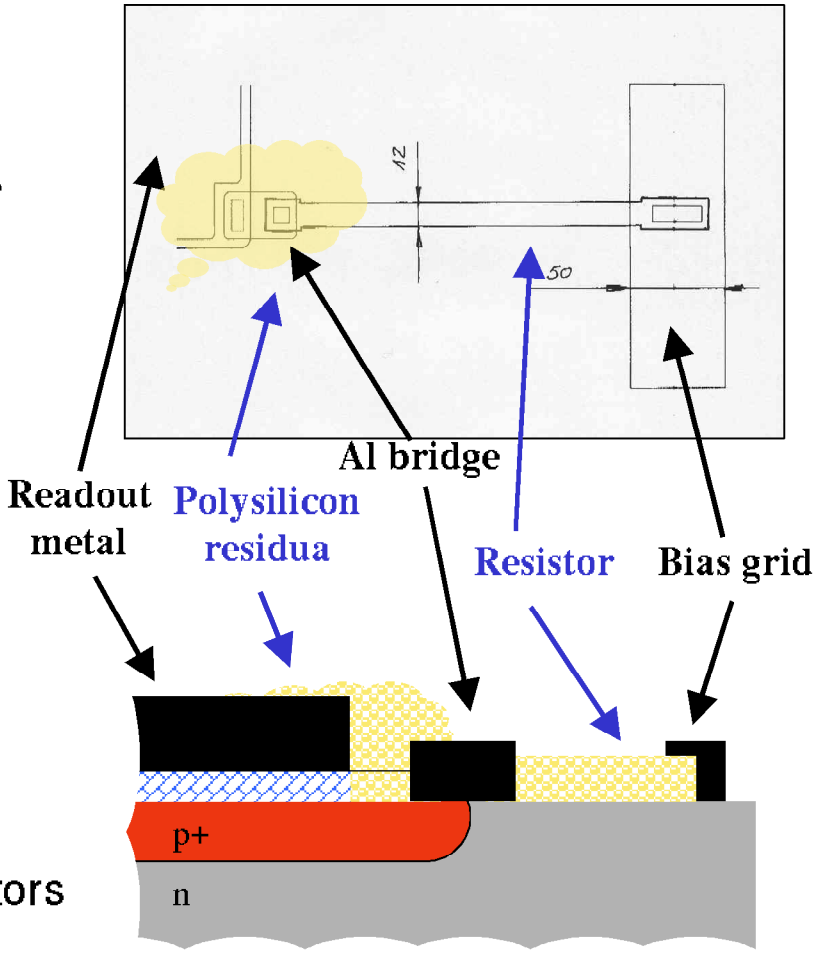
Solution 2: replace the mesh backplane contact with a uniform one, it works!

“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.

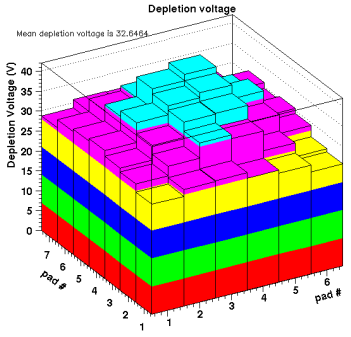


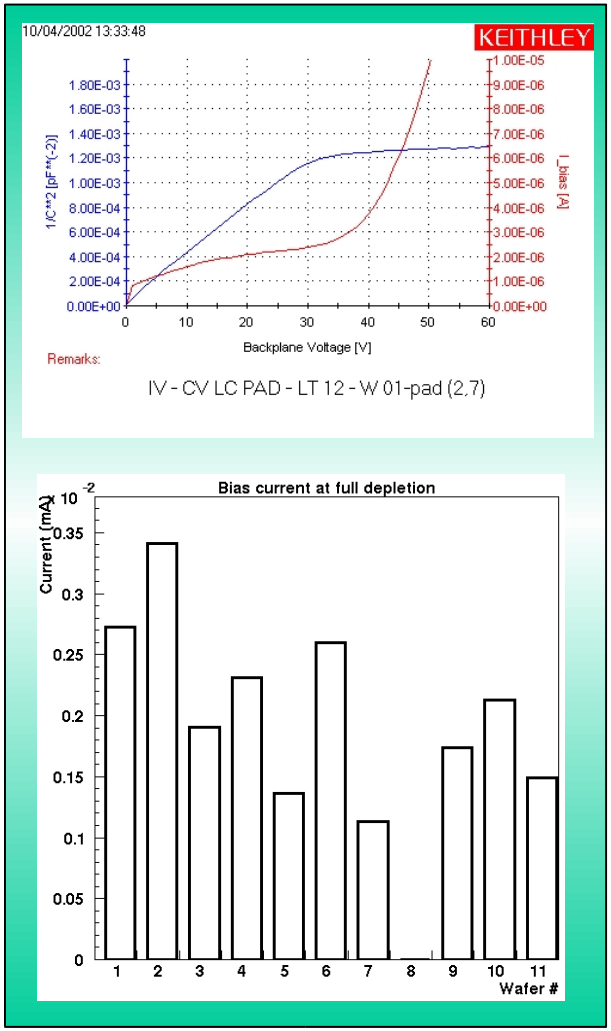
Solution: remove the integrated capacitors



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 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 phe/m.i.p.

good uniformity:

Simulated Light collection disuniformity(20%)