LCcal*: a Si-Scintillator hybrid technique for ECAL

TALK SUMMARY

- **Design principles**
- **Prototype description**
- **Construction (+SI pad) 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

Contributors (Como, ITE-Warsaw, LNF, Padova, Trieste): M. Alemi, A.Anashkin, M. Anelli, M.Bettini, S.Bertolucci, E. Borsato, M. Caccia, P.C, C. Fanin, J.Marczewski, S. Miscetti, V. Morgunov, B.Nadalut, M. Nicoletto, M. Prest, R. Peghin, L. Ramina, F. Simonetto, E. Vallazza

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)

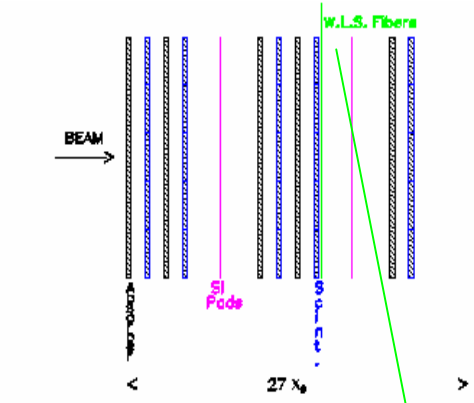
Erec. not from Si but from Scintillator-WLS fibers

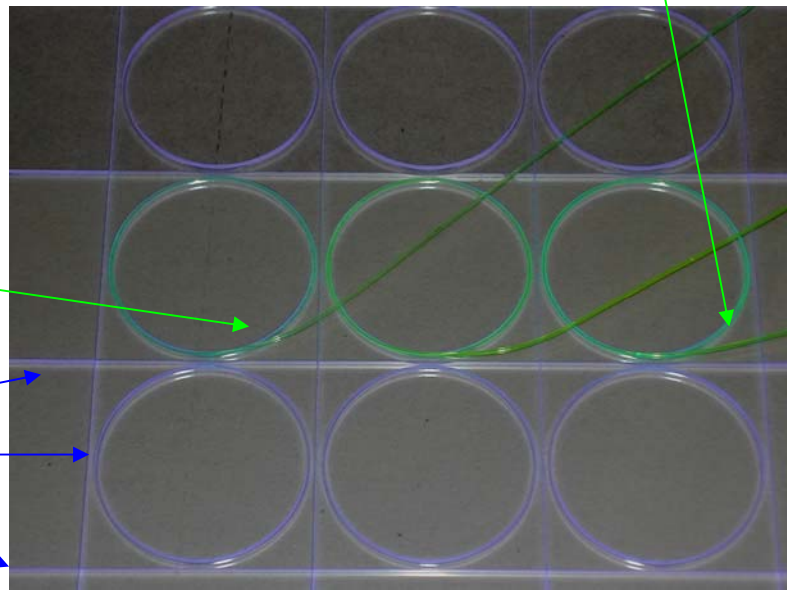
Reduce (factor >10) the number of channels

Prototype description

Pb/Sc + Si

- 45 layers
- 25 × 25 × 0.3 cm^3 Pb
- 25 × 25 × 0.3 cm^3 Scint.: 25 cells 5 × 5 cm^2
- 3 planes:
- 252 .9 × .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)

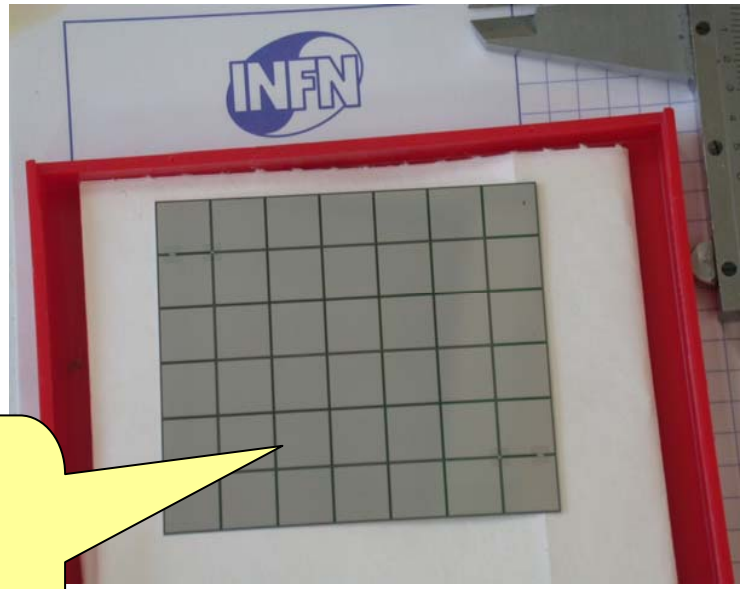
Cell separation with grooves in Sc. plates with Tyvec strips inside (light leakage!?)

Prototype (cntd)

3 Si planes

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

- **Pad dimension< shower dimension:**
  .9x.9 cm^2
- **Longitudinal sampling:**
  3 planes
- **Analogic RO**
  VA hdr9c from IDEas



Pad diode ac(old)-dc(new) coupled

pcb contact with conductive glue

Actual design:

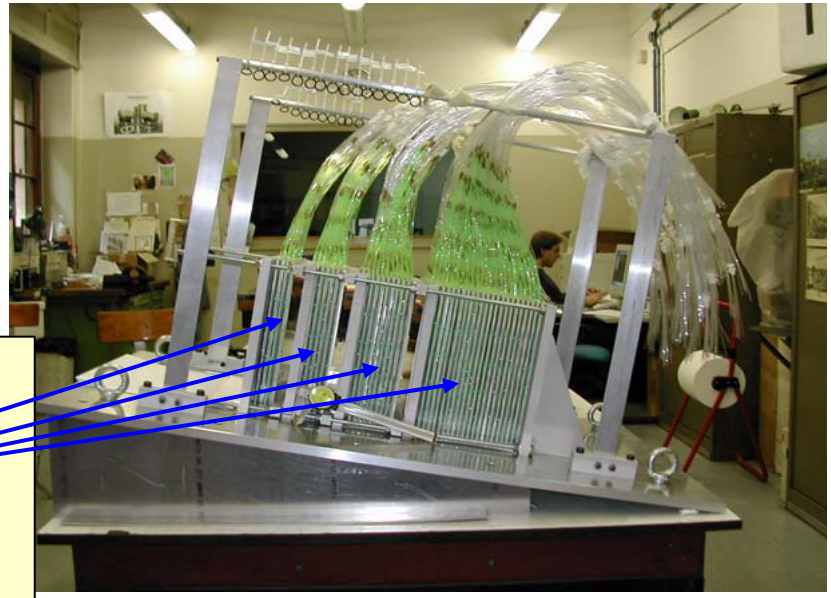
- **Detector: 6x7 pads**
- **Plane: 3x2 detectors**

Construction Details

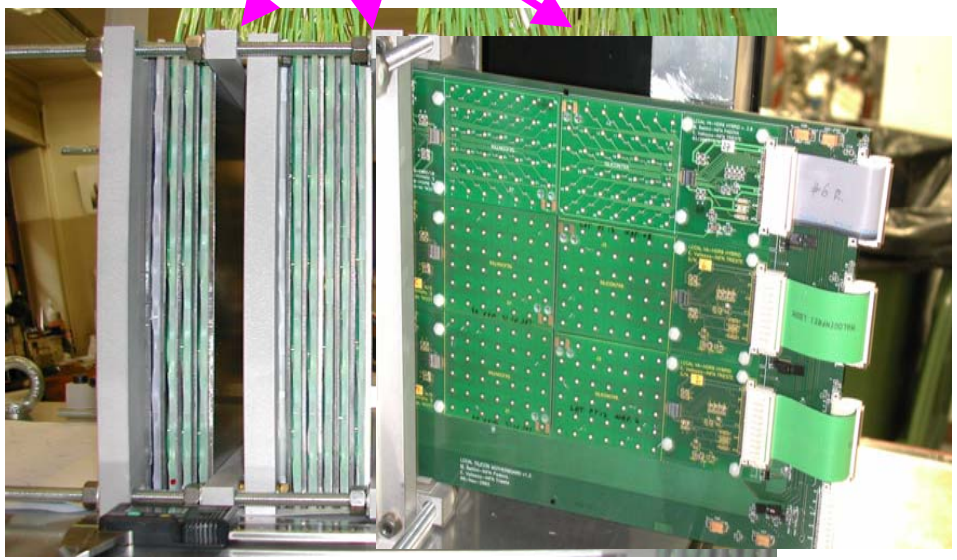
45 Layers calorimeter prototype completely built in 2002

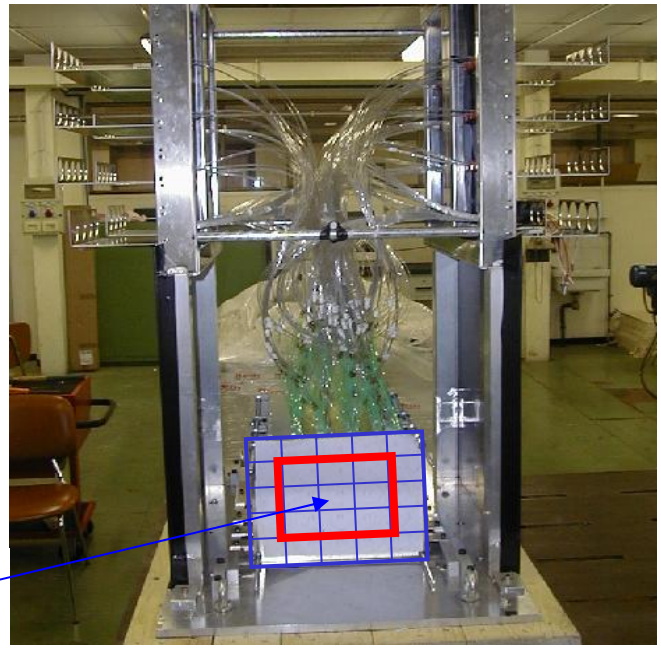
Fibres grouped into 25x4 bundles making a 4-fold longitudinal segmentation.

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



Mechanical support for Photomultipliers



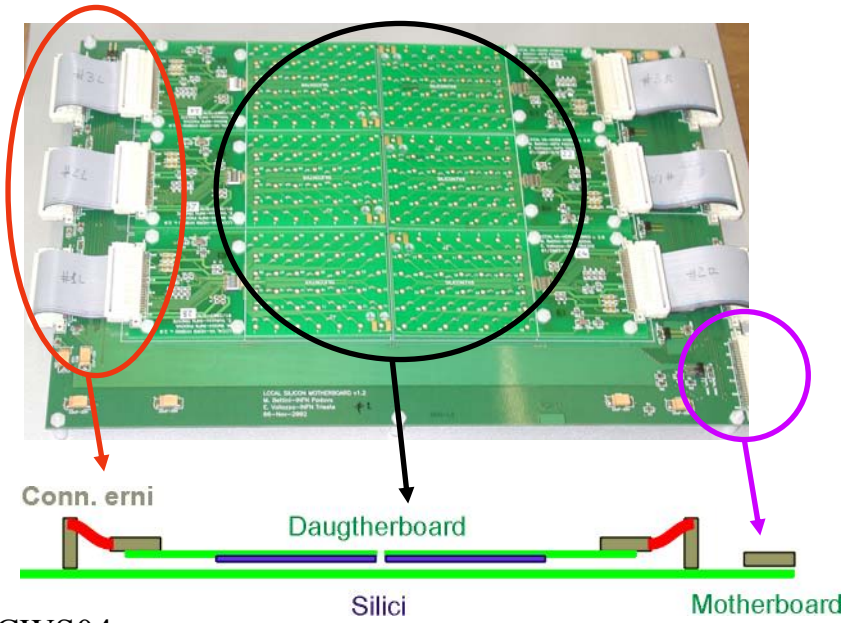


in the 3x3 central cells

Si Production details

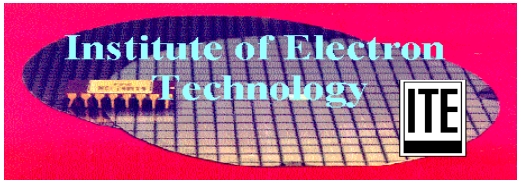
Motherboard design

- 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



3 technological runs

First batch of
11 sensors
(spring ’02)

Soft
Breakdown

Second batch of
9 sensors
(summer ’02)

“Leaky”
pads

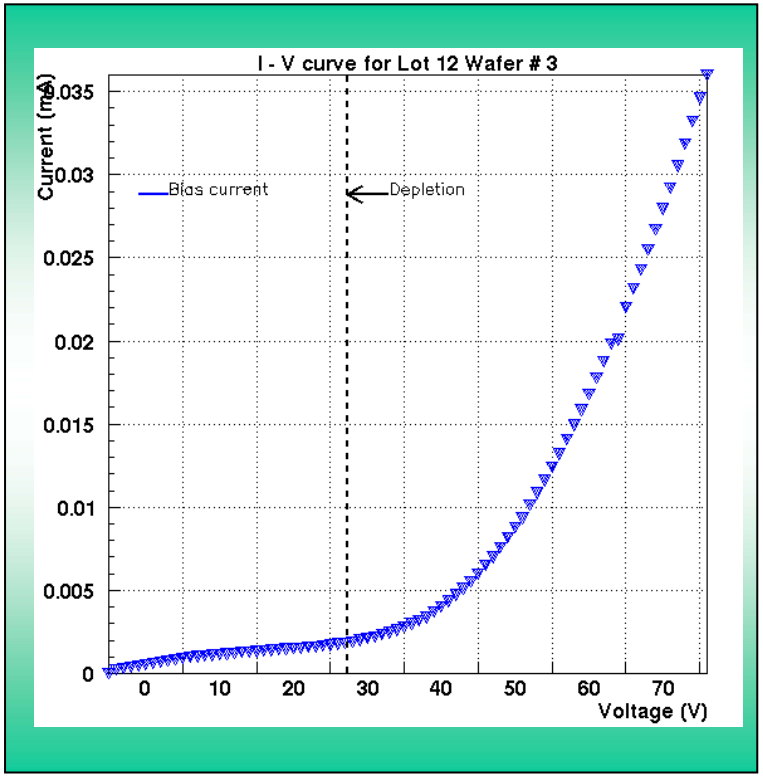
Third batch of
9 sensors
(summer ’03)

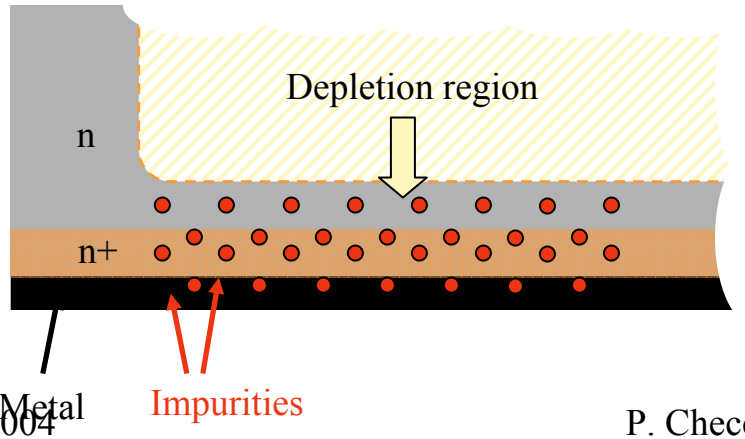
GOOD!

Additional batch
ready

Soft breakdown

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



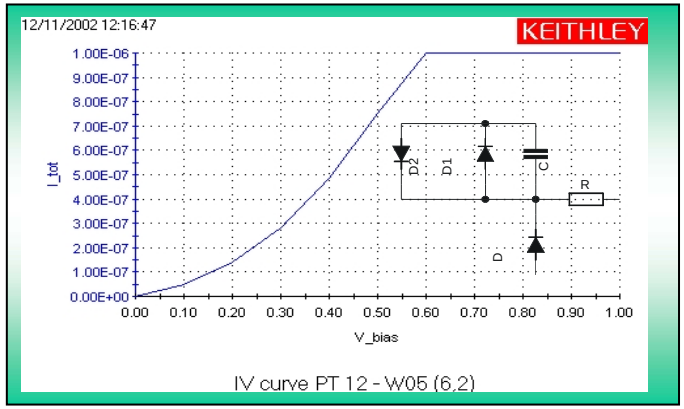


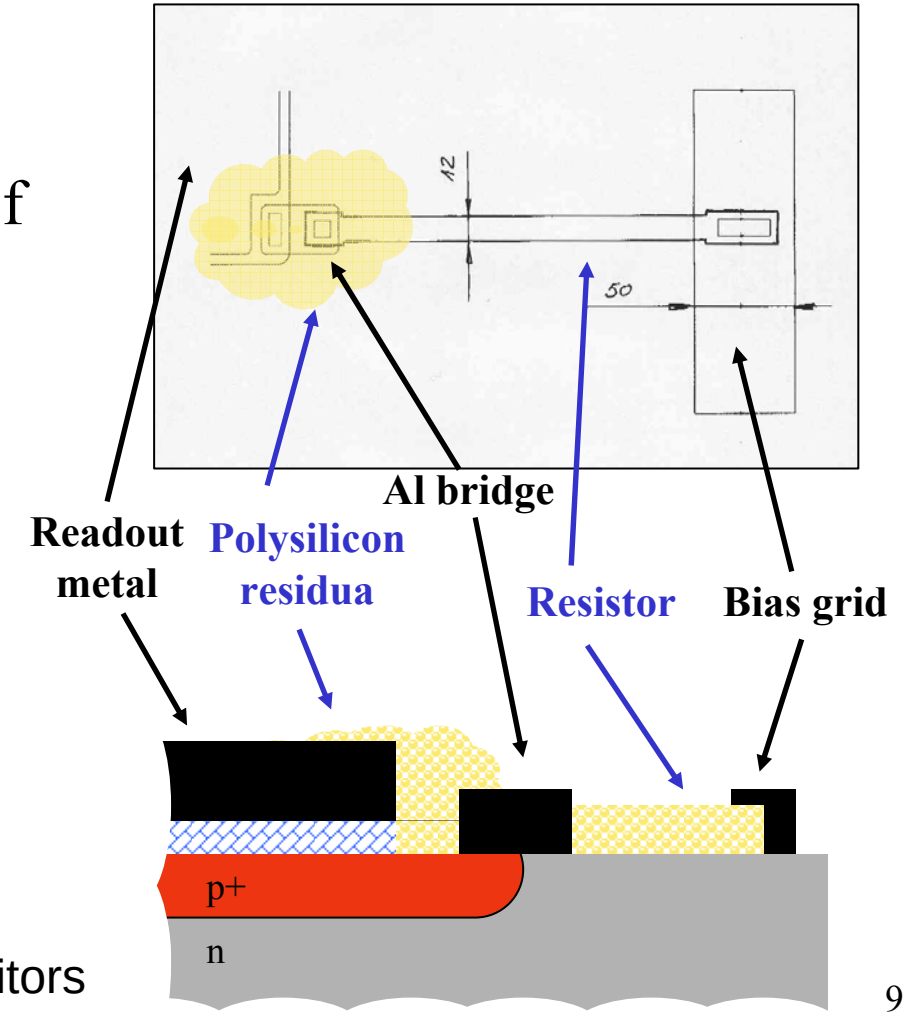
Solution 1: replace the implanted backside contact with a diffused one, but it does not work!

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

“Leaky” pads: a surface effect

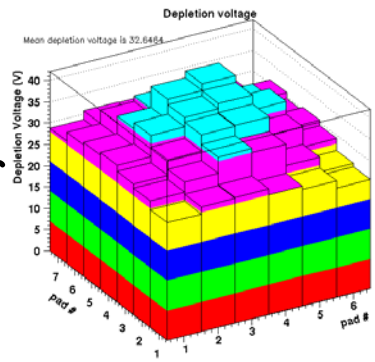
- No pin holes in SiO_2
- Surface leakage → residua of polysilicon after the etching of the polysilicon layer
- Equivalent circuit with two opposite diodes.



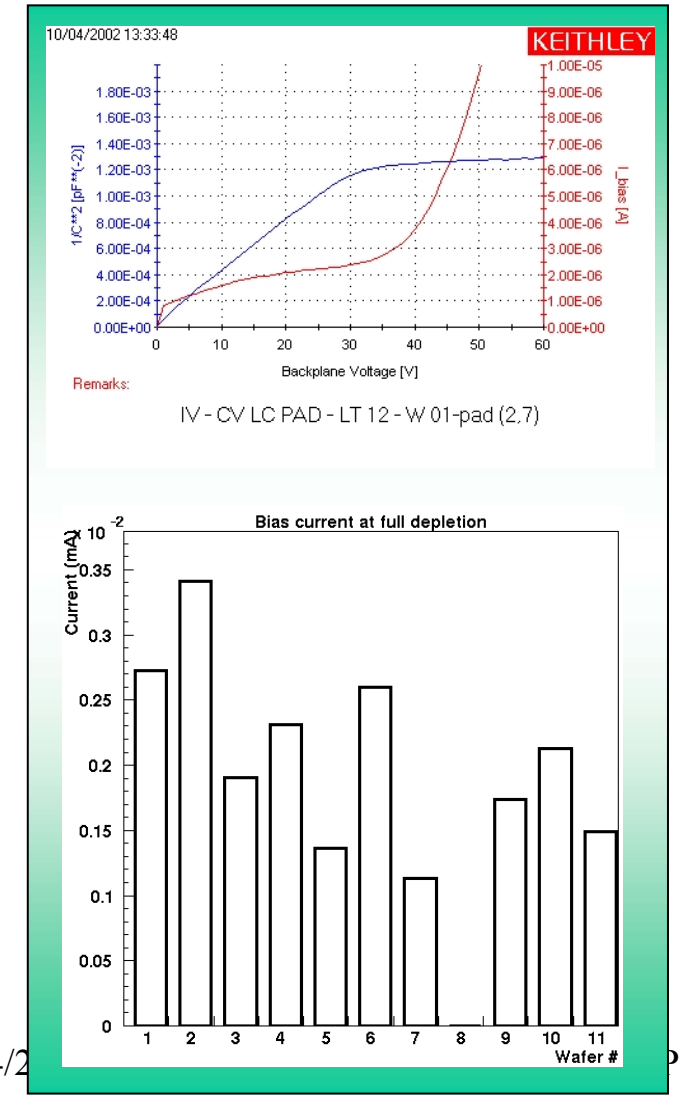


Solution: remove the integrated capacitors

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

Si Production details

MIP Signal to Noise ratio

Theory:

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

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

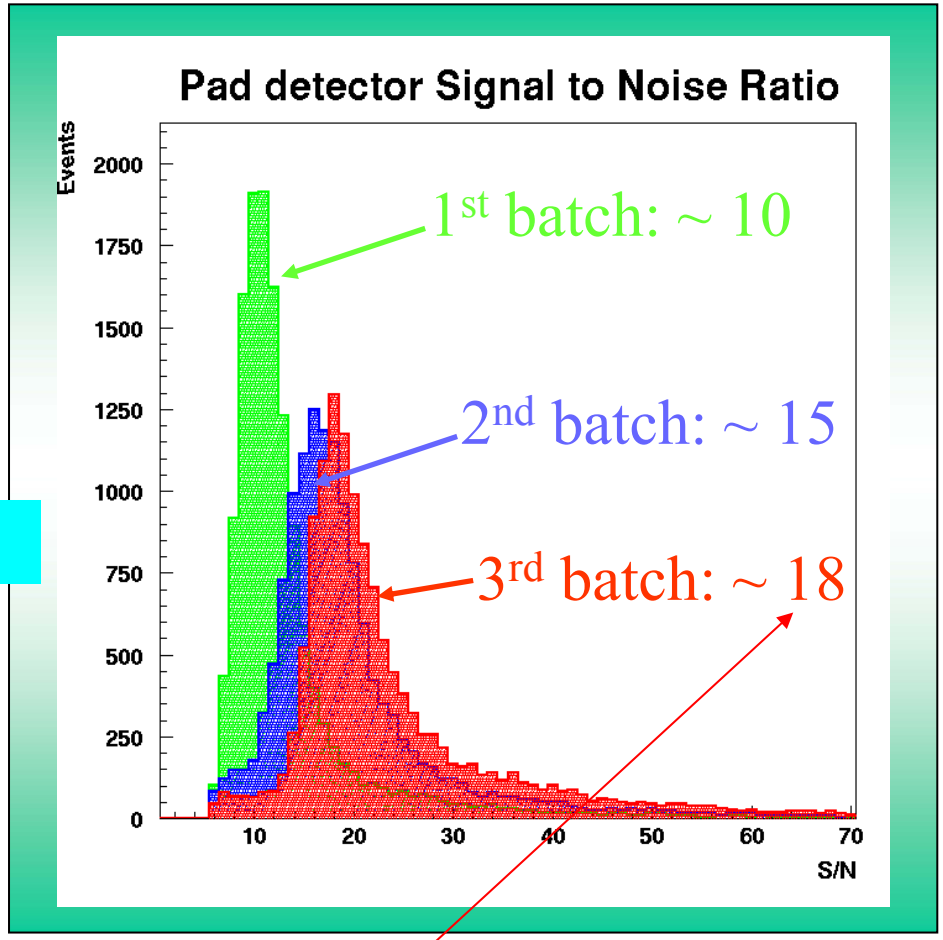
$$\mathrm{ENC} = \frac{e}{q}\sqrt{\frac{T_p k_B T}{2R}}$$

Front-end $\approx 1000e^- +$

Leakage $\approx 30e^- +$

Bias Resistance $\approx 230e^- =$

$\approx 1030e^-$



MIP ~ 23000 e-

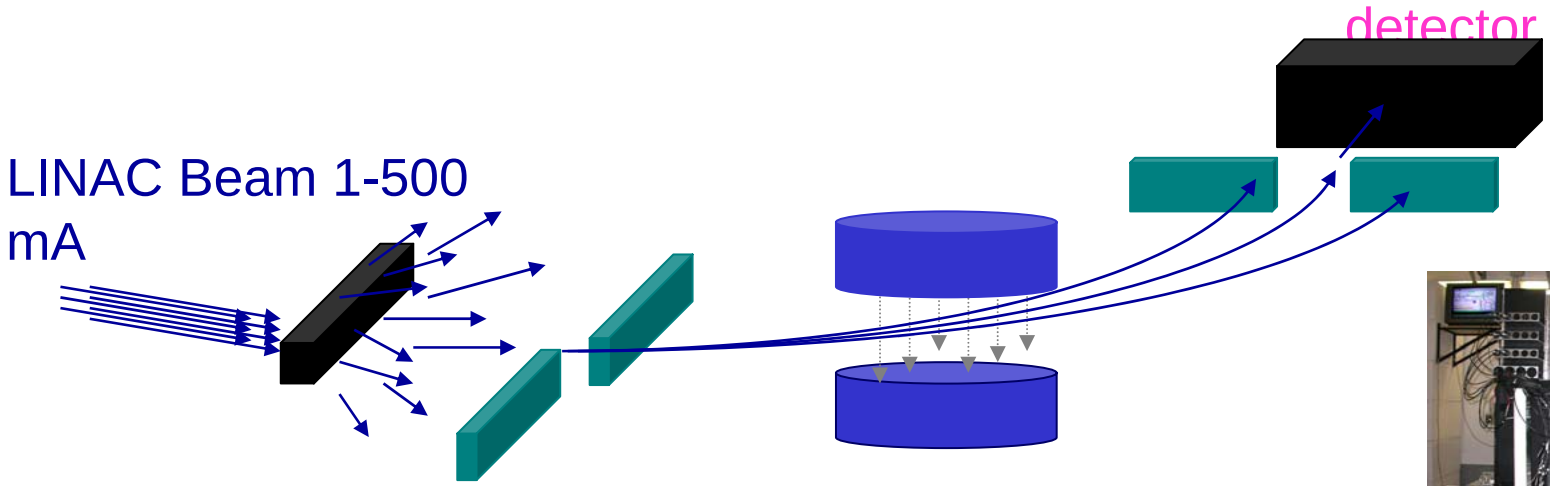
SNR ~ 22

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)**



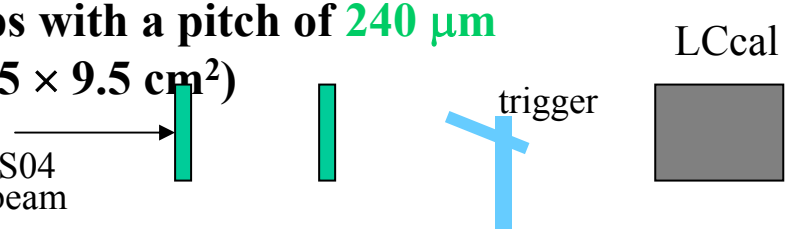
it is possible to tune the multeplicity.....

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

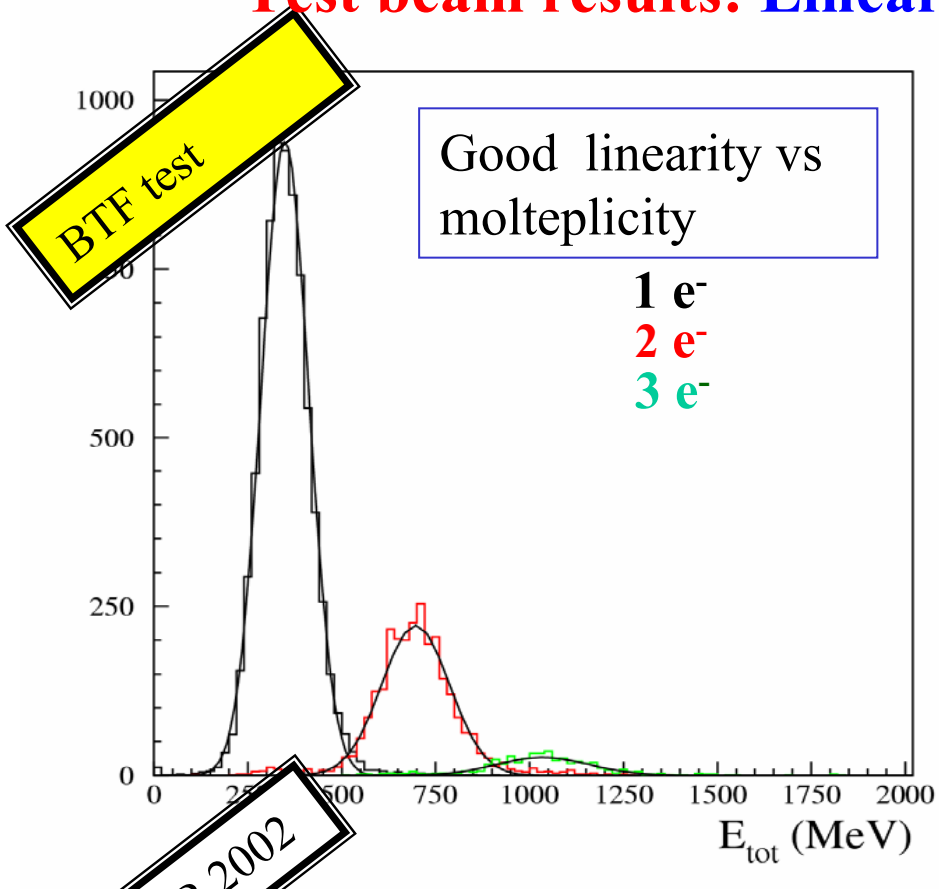
All tests: two beam position monitors (telescope) put in front of the calorimeter.

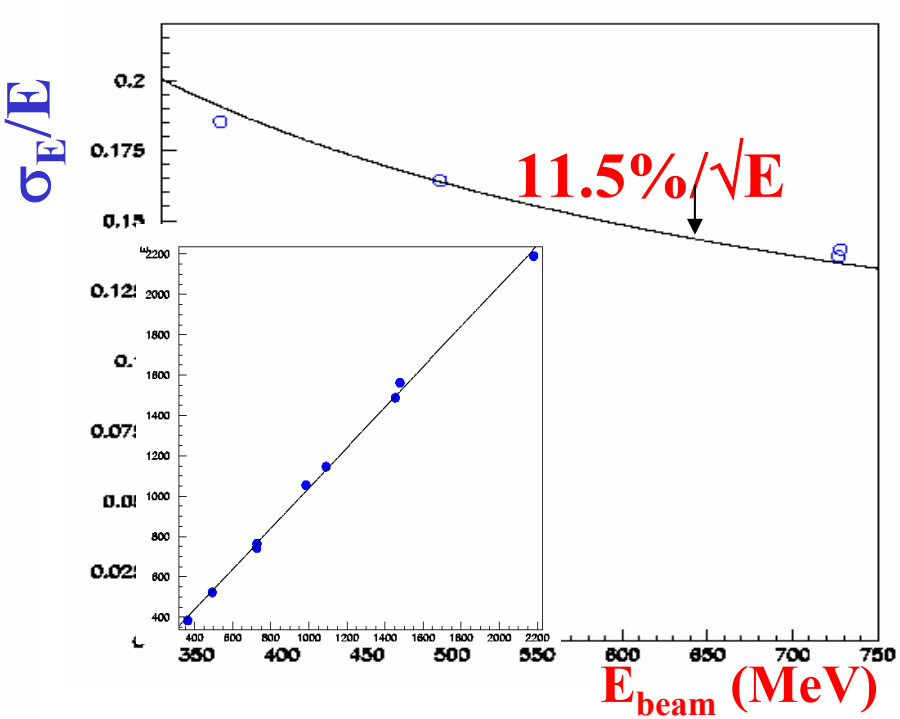
- Each detector consisting of 400×400 x–y Si strips with a pitch of 240 μm

- They cover the central area of the prototype (9.5 × 9.5 cm^2)



Test beam results: Linearity and Energy Resolution





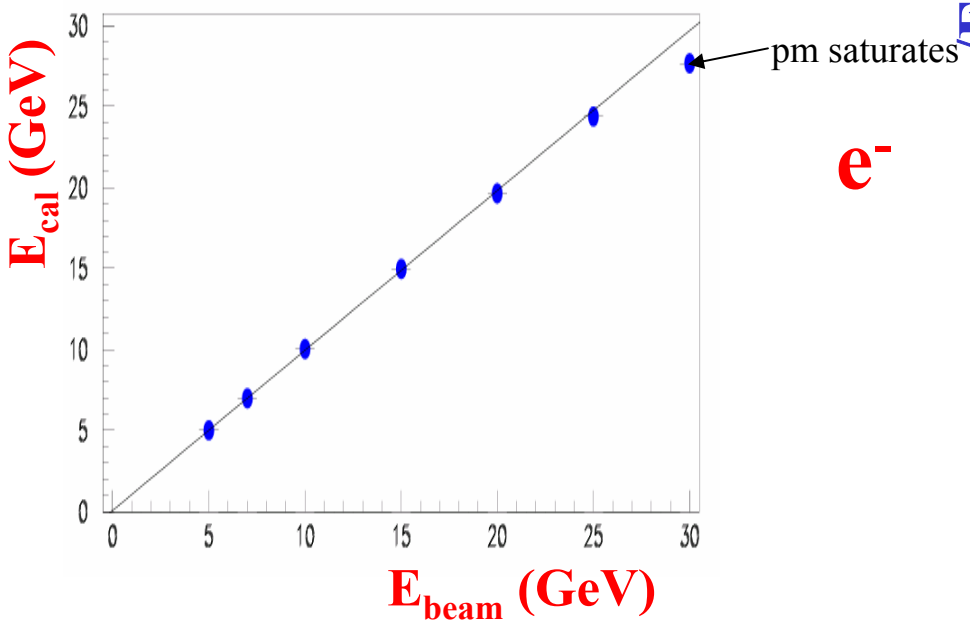
N_{phe}>5.1 /layer →**Cal(45 layers) ~ 250 MeV/Mip ~ 800Npe/GeV**

OK also @ BTF (E ~500 MeV)

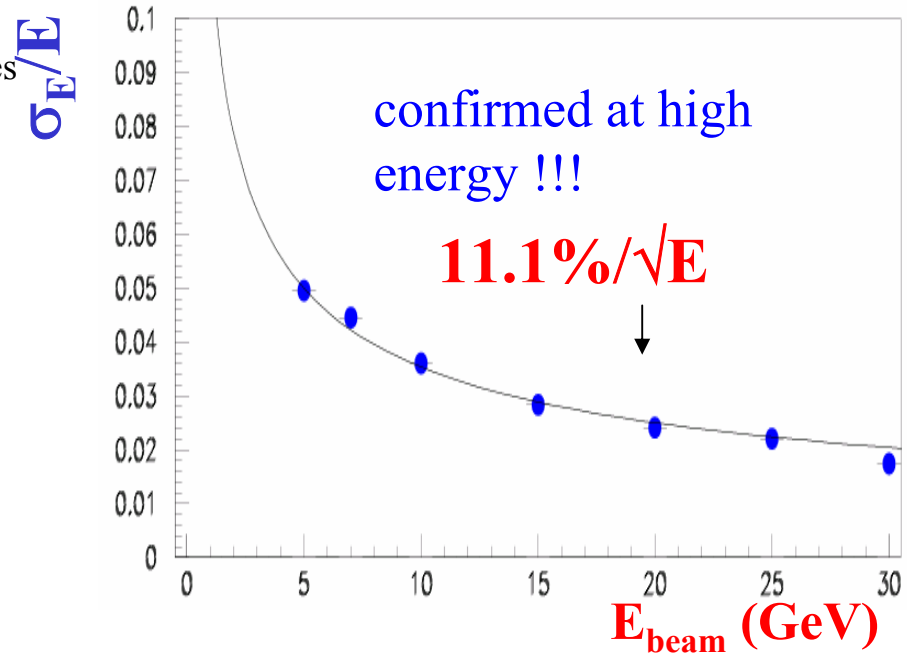
1. Photoelectron statistics **negligble**
2. Stocastic Term **11.5% as in MC**
3. Light disuniformity **<<10%** Effects on resolution to be measured at **SPS (August 2003)→**

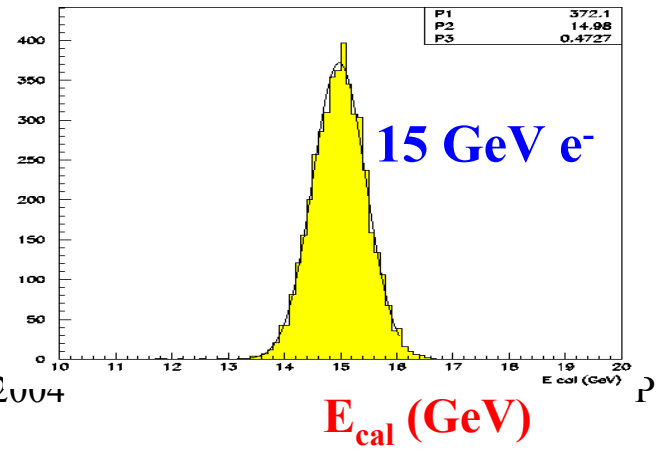
Test beam results: Linearity and Energy Resolution

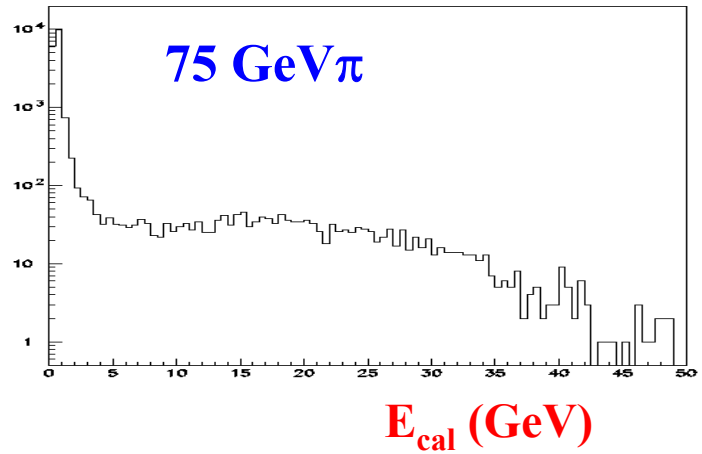
Cern TB 2003



e^-





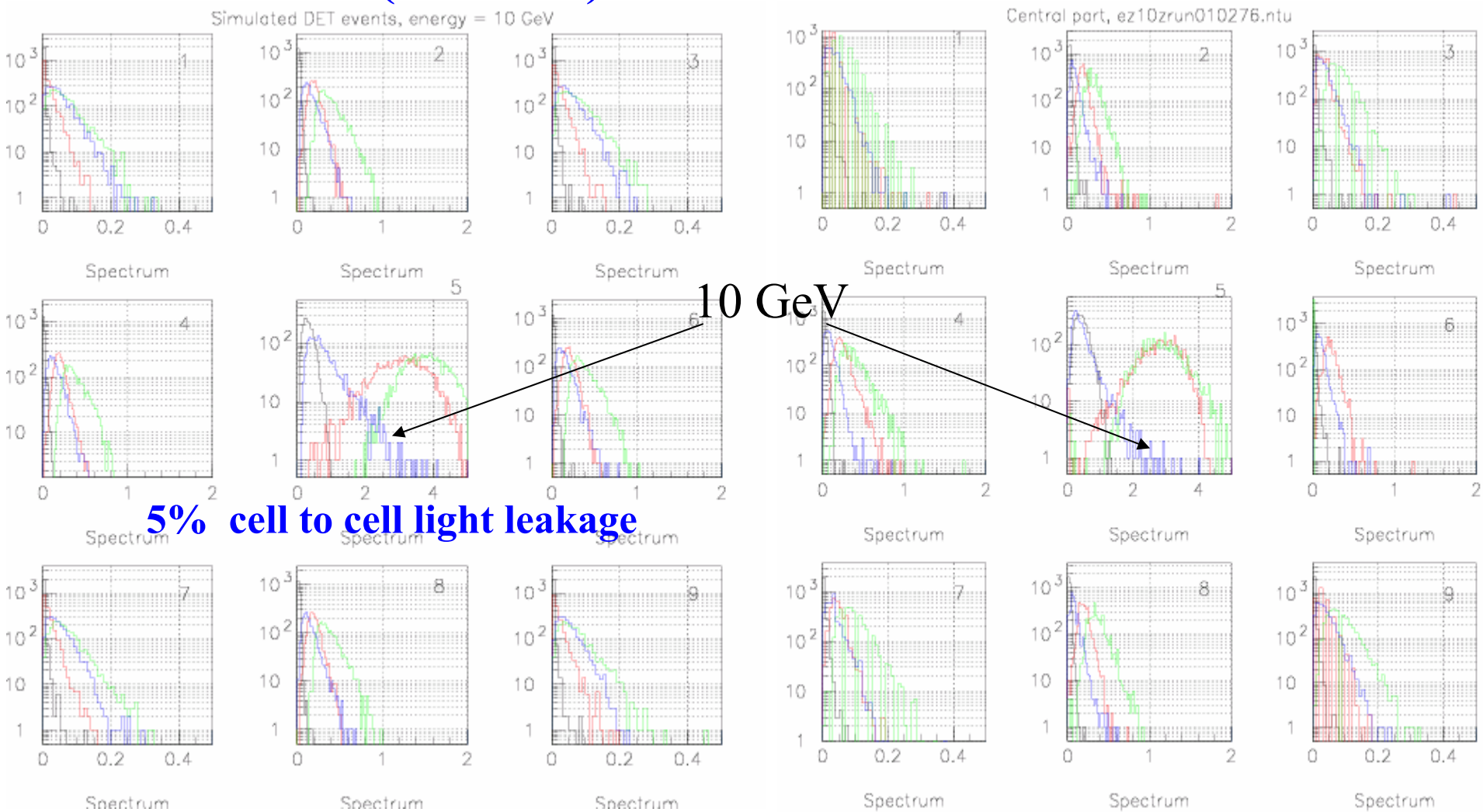


Test beam results: Comparison with MC

Cern TB 2003

Simulation (Geant 3*)

Test Data

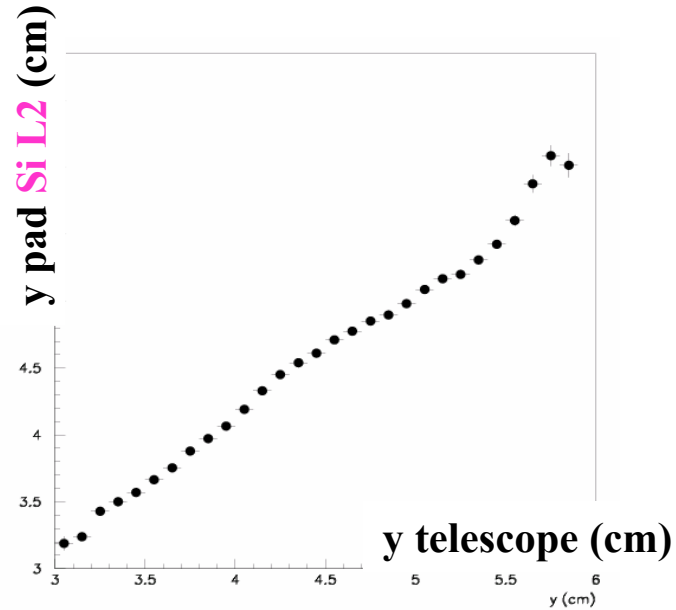


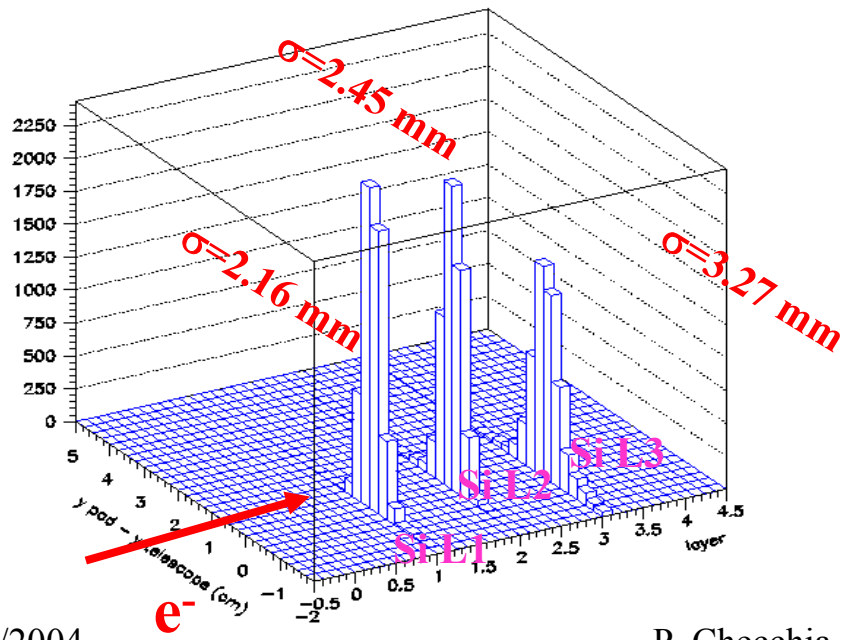
*detailed geometrical description by V. Morgunov

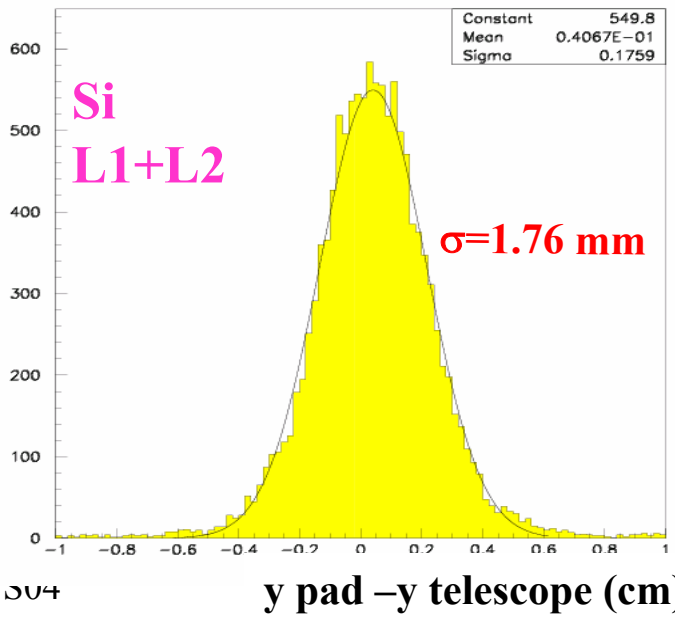
Test beam results: Si pad detector (Position Meas.)

Cern TB 2003

30 GeV electrons







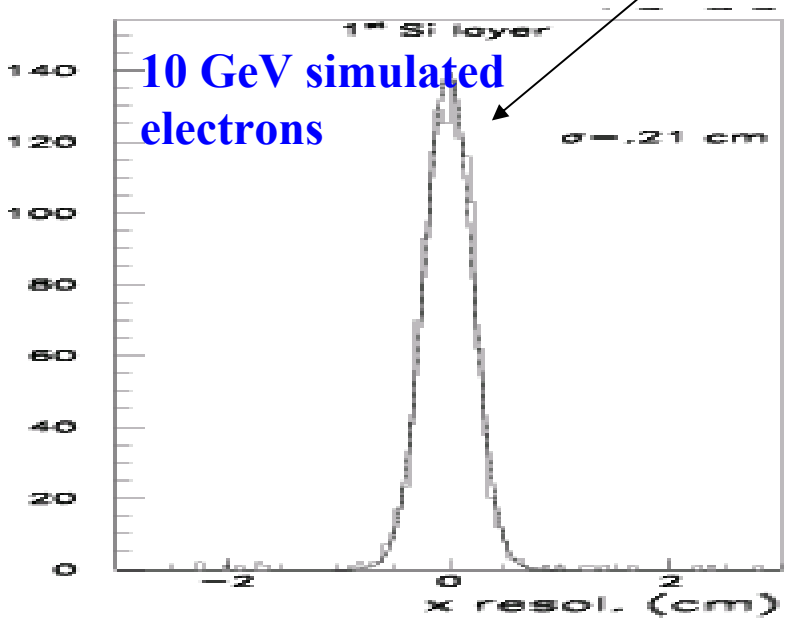
Test beam results: Si pad detector (Position Meas.)

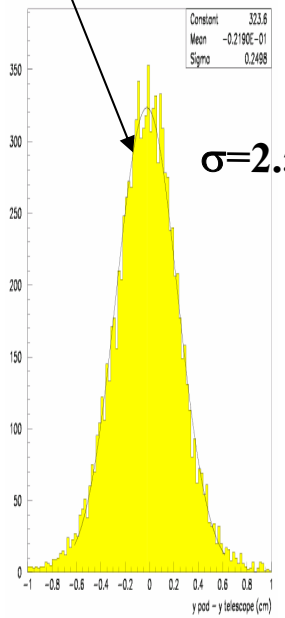
PRELIMINARY analysis: pad noise subtraction not optimised

effects of the Front-End saturation under study

Position resolution ~ 2.5mm not far from Monte Carlo

10 GeV electrons

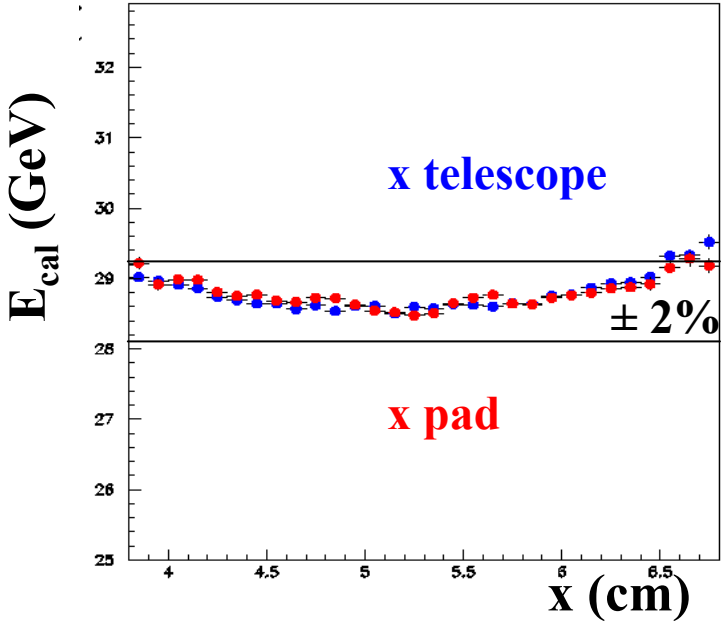


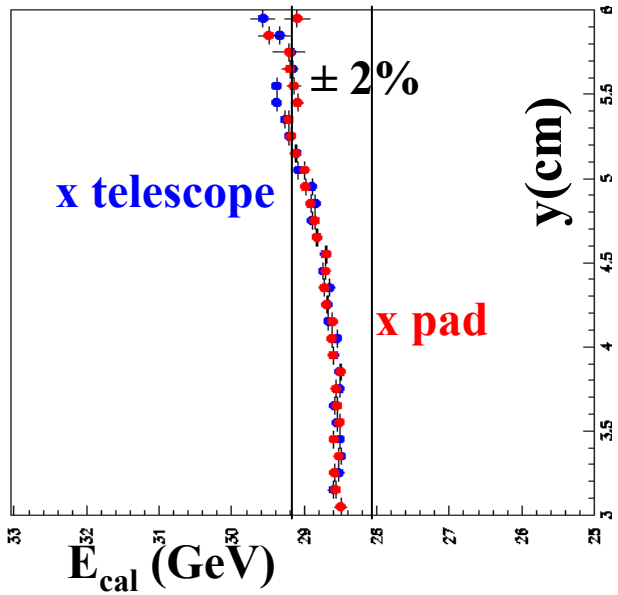


Test beam results: uniformity in (light) Energy response

30 GeV e-

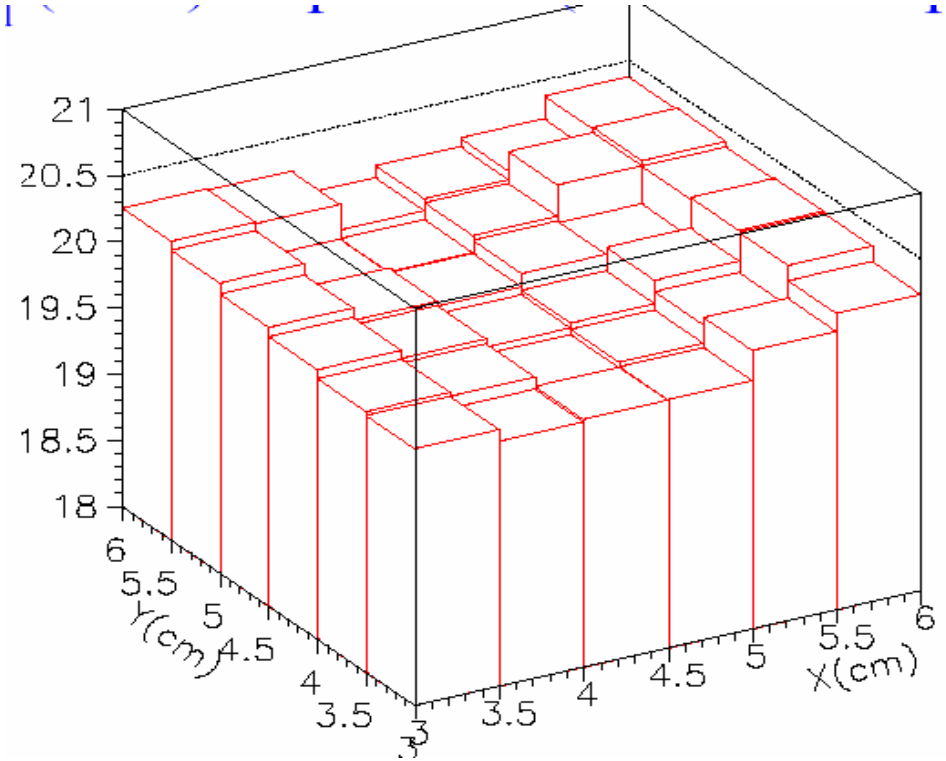
Cern TB 2003





disuniformity < 2%

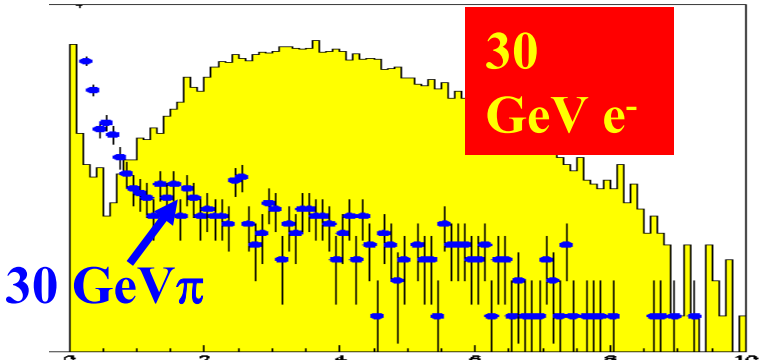
correction from pad reconstruction can be applied!



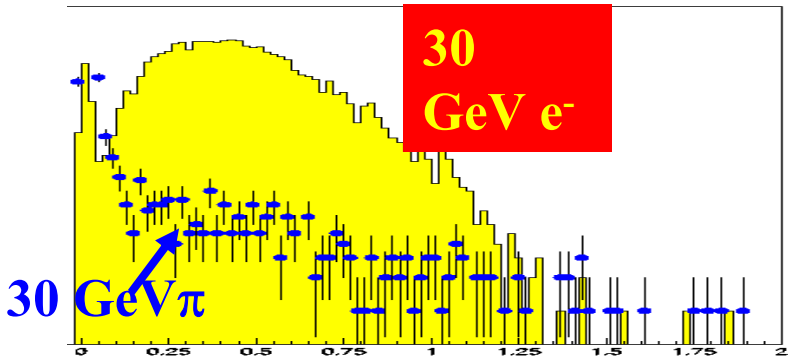
Test beam results: (e/π rejection)

Cern TB 2003

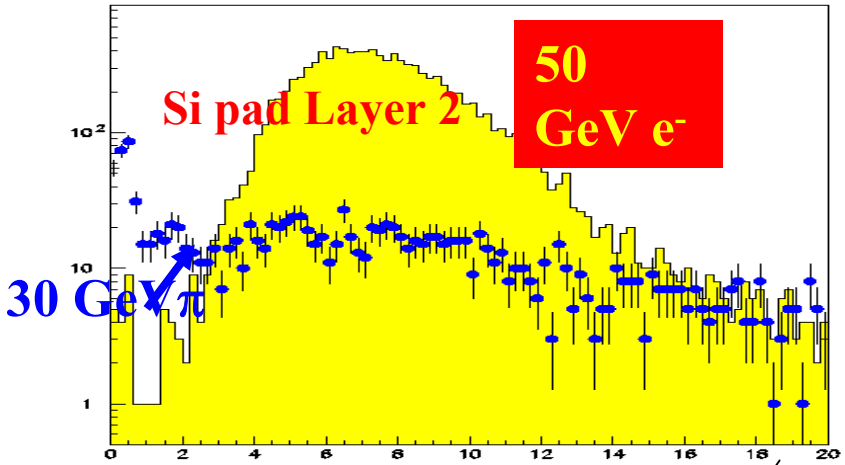
the redundancy of the information on the linear/lateral shower development makes the rejection very easy (difficult to quantify below 10^{-3} due to beam contamination)

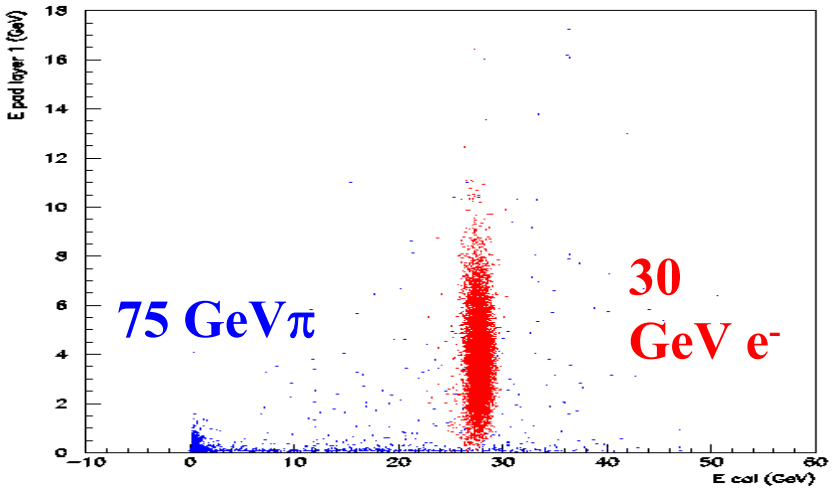


E Si pad Layer 1



E cal Layer 1





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

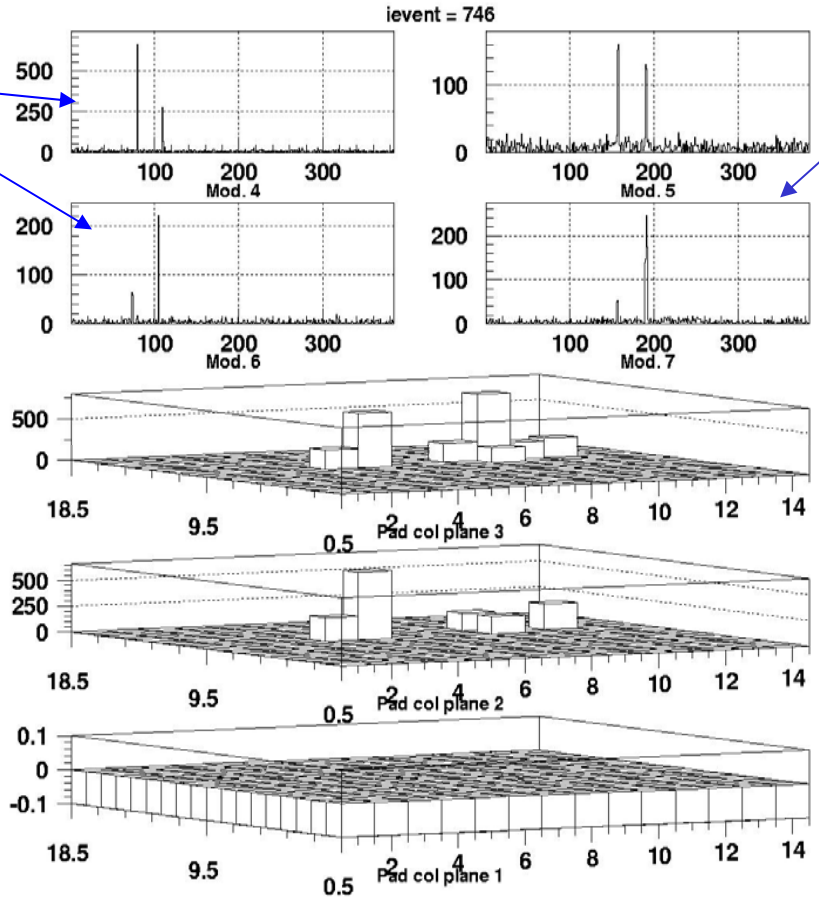
Test beam results: Si Pad two particle separation

exhaustive analysis not fully accomplished

Two electrons with energy 750 MeV

X silicon chambers

Y silicon chambers



BTF test

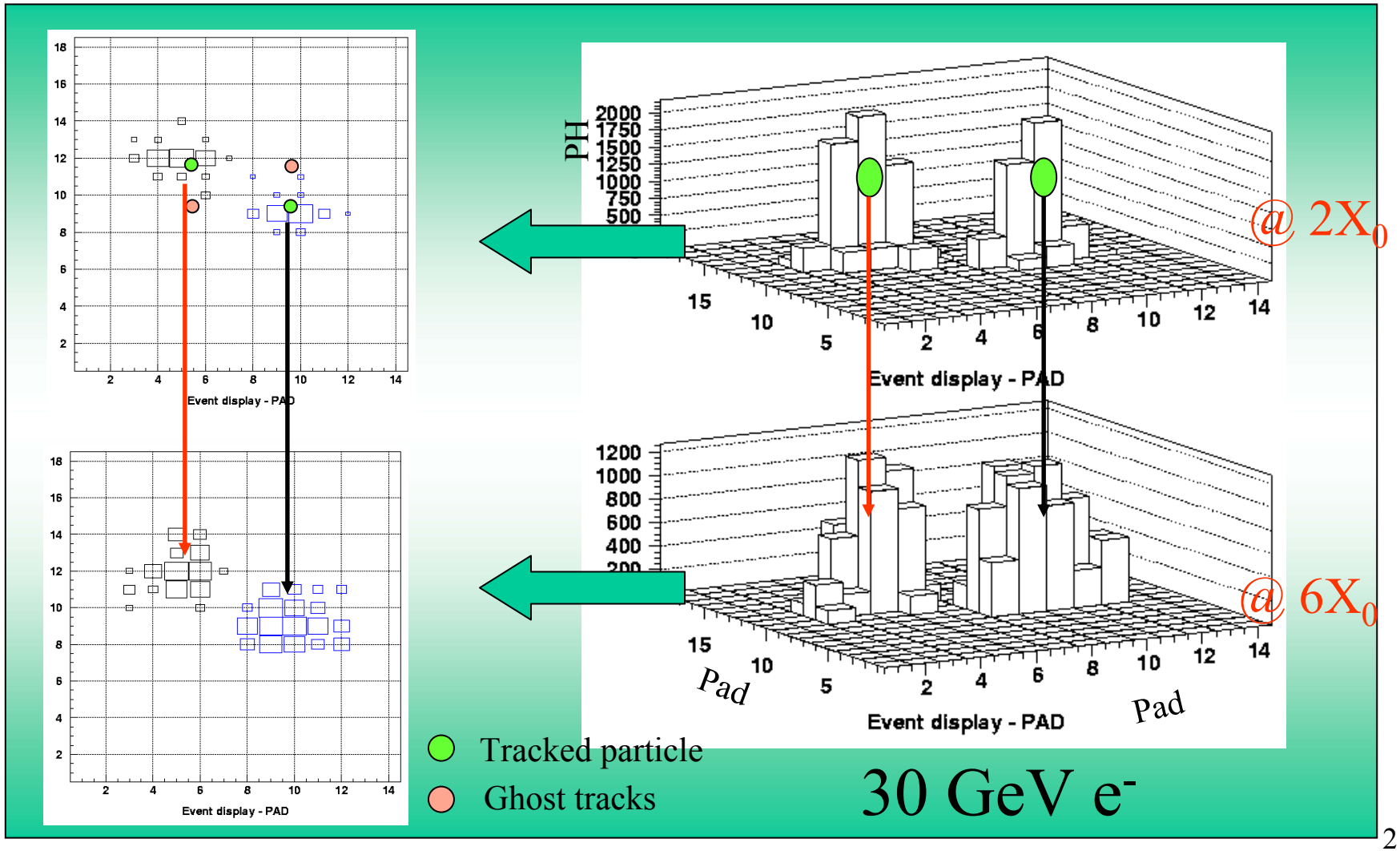
First layer

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:**
  $\sigma_E/E \sim 11.\text{-}11.5\% / \sqrt{E}$, $\sigma_{pos} \sim 2$ mm (@ 30 GeV)
- **Light uniformity acceptable.**
- **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

Test beam results CALORIMETER (2.1 X_0)

4 layers

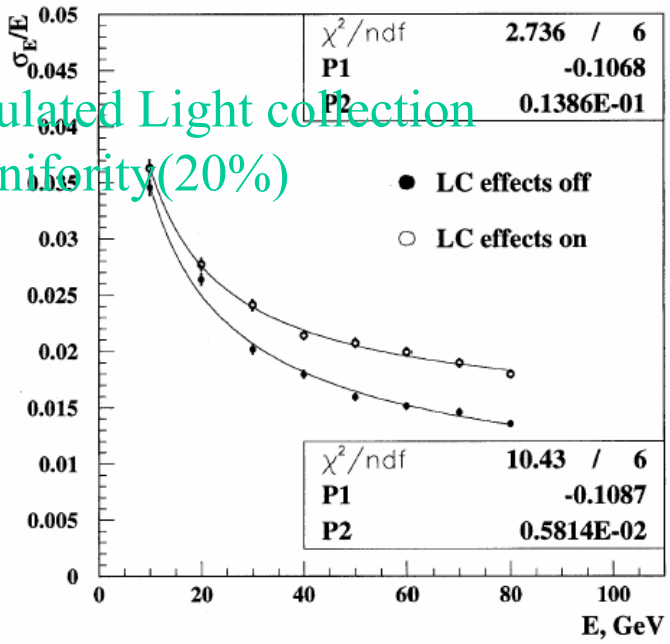
m.i.p.→check light output and uniformity in Light collection:

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%)