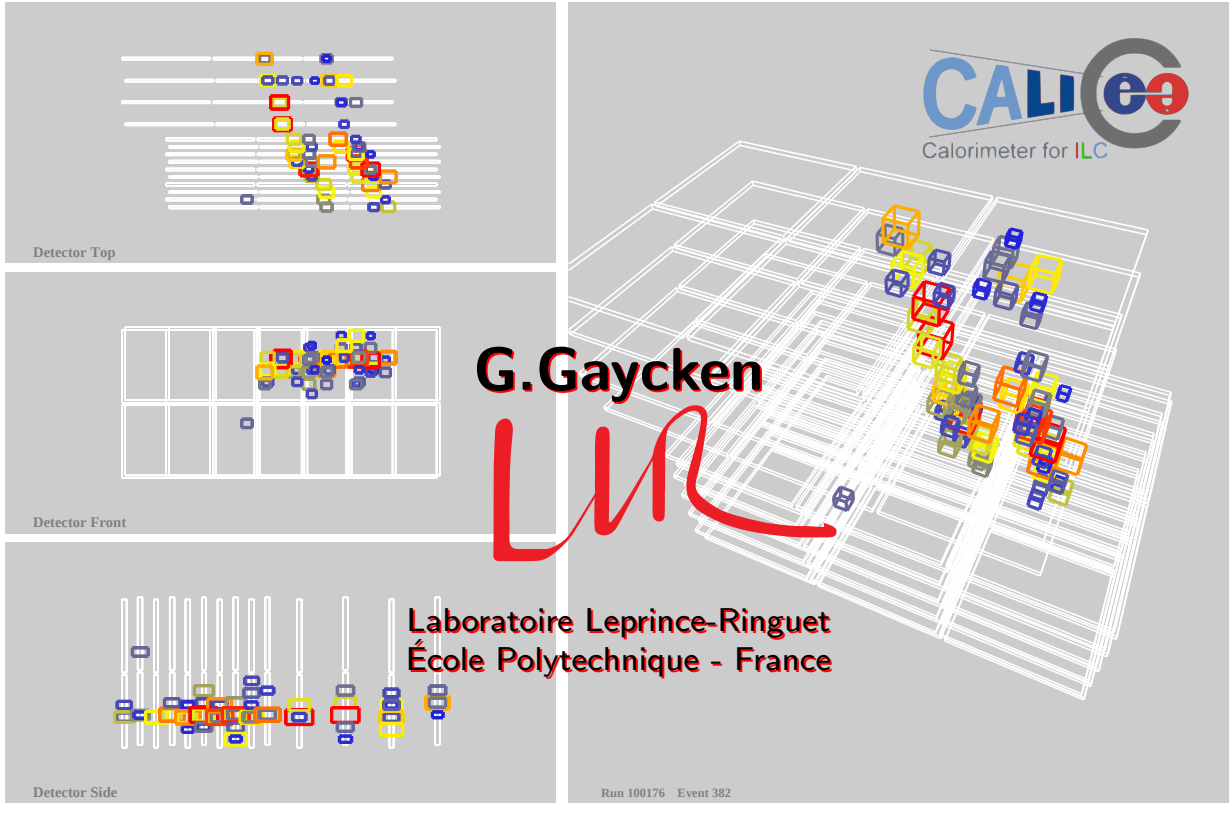
Calice ECAL Status and Prospects



G.Gaycken

Laboratoire Leprince-Ringuet
École Polytechnique - France

LCWS Bangalore 2006

Outline

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1. The Calice Project
2. The CALICE ECAL prototype
   - Description
   - Status
   - The Silicon Matrices.
3. Outlook

The Calice Project

Final Goal: Calorimeter Design for ILC

Intermediate Goals:

1. Proof of principle of the technologies.
2. Verification of Geant 4
   (tuned Geant 4 required for detector optimisation)
3. Full scale prototype module.
4. optimised calorimeter design.

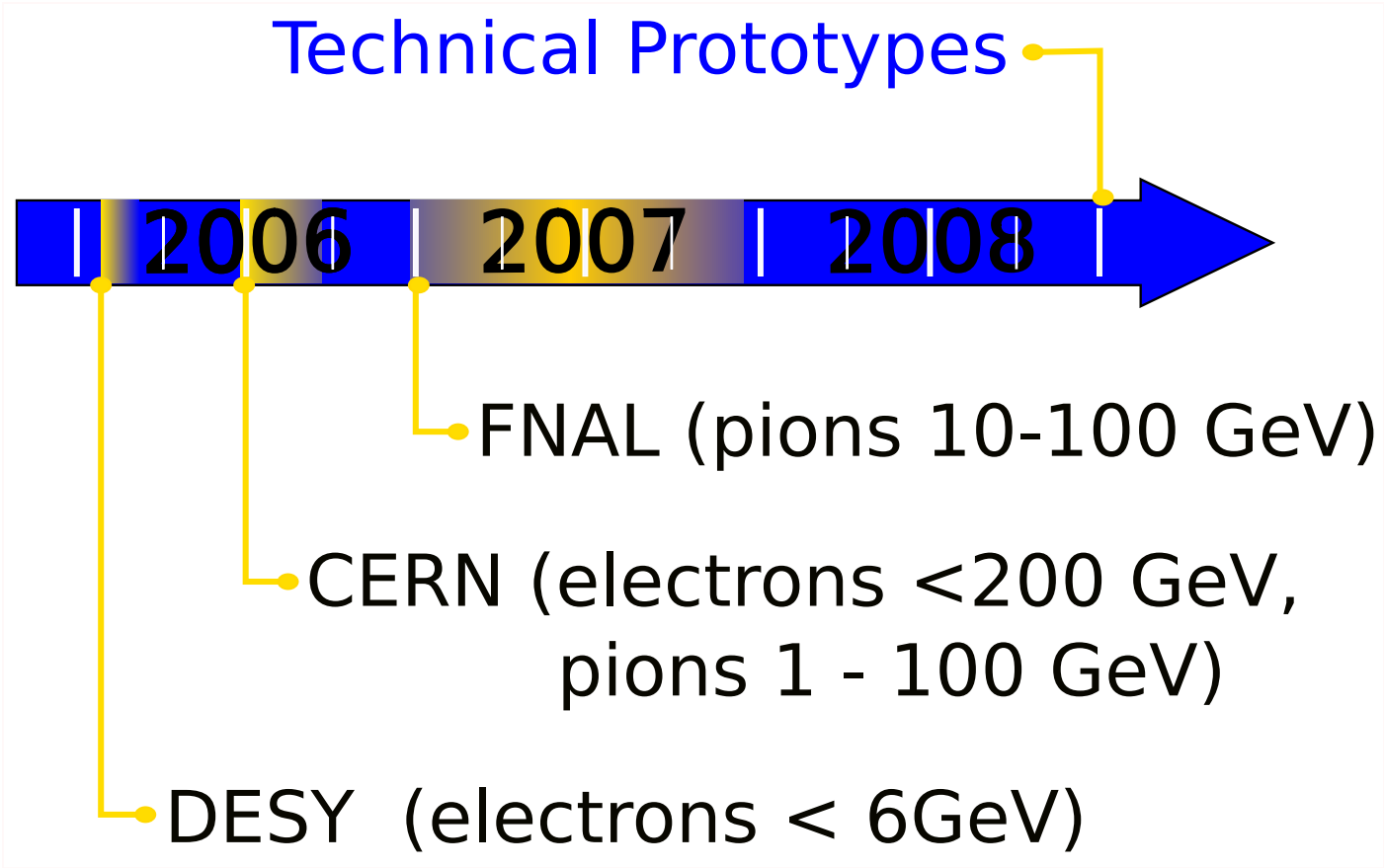
1. & 2. $\rightarrow$ Testbeam program

Considered Calorimeter Options

Currently considered calorimeter options:

- ECAL options: Si/W
- HCAL options:
  - tungsten/stainless steel
  - analog scintillator
  - digital gas (rpc/gem)
- Tail catcher:
  scintillator/stainless steel

Test beam program



The Calice ECAL Prototype

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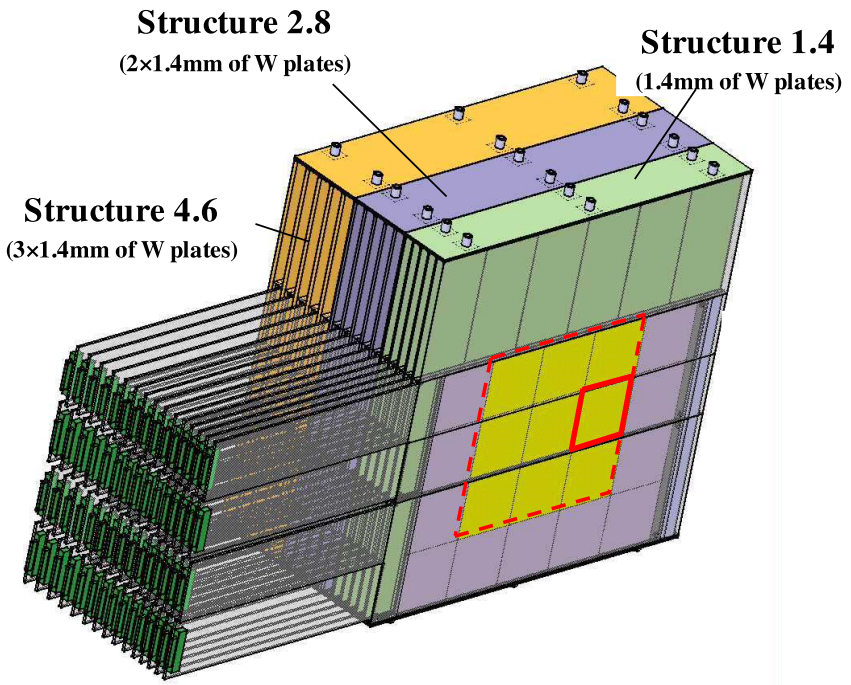
Specifications

- Si/W Sandwich
- 24 X_0
- high granularity:
  - $1 \times 1\,\mathrm{cm}^2$ cell size.
  - 30 sensitive layers.
  - 3×3 Si wafer with 6×6 pads.

$\longrightarrow$ 10k Channels

Design, Production and Integration at LLR - Polytechnique



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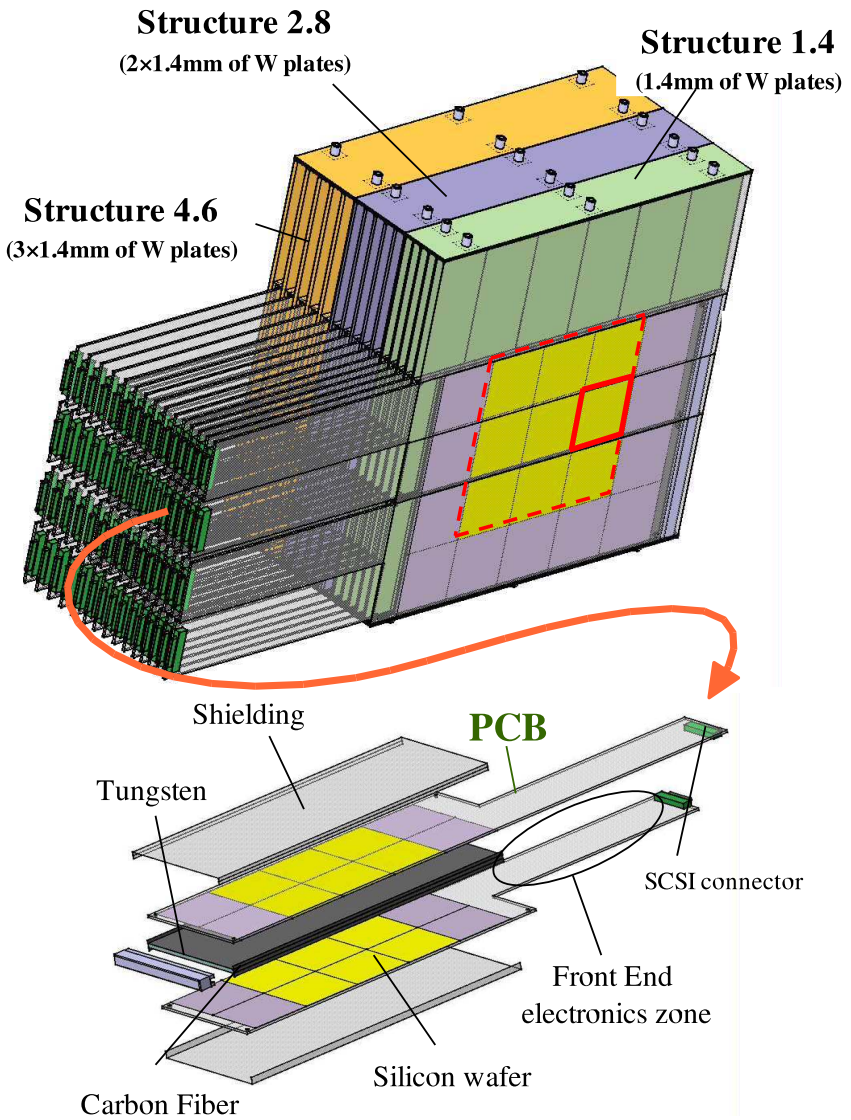
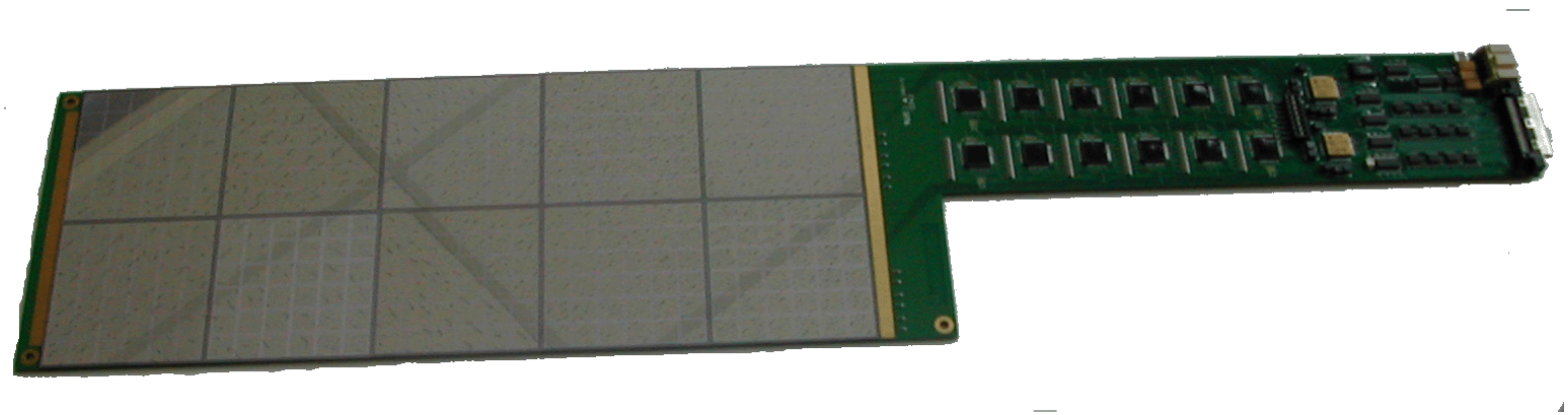


Front-End PCB

(see talk by J. Fleury)



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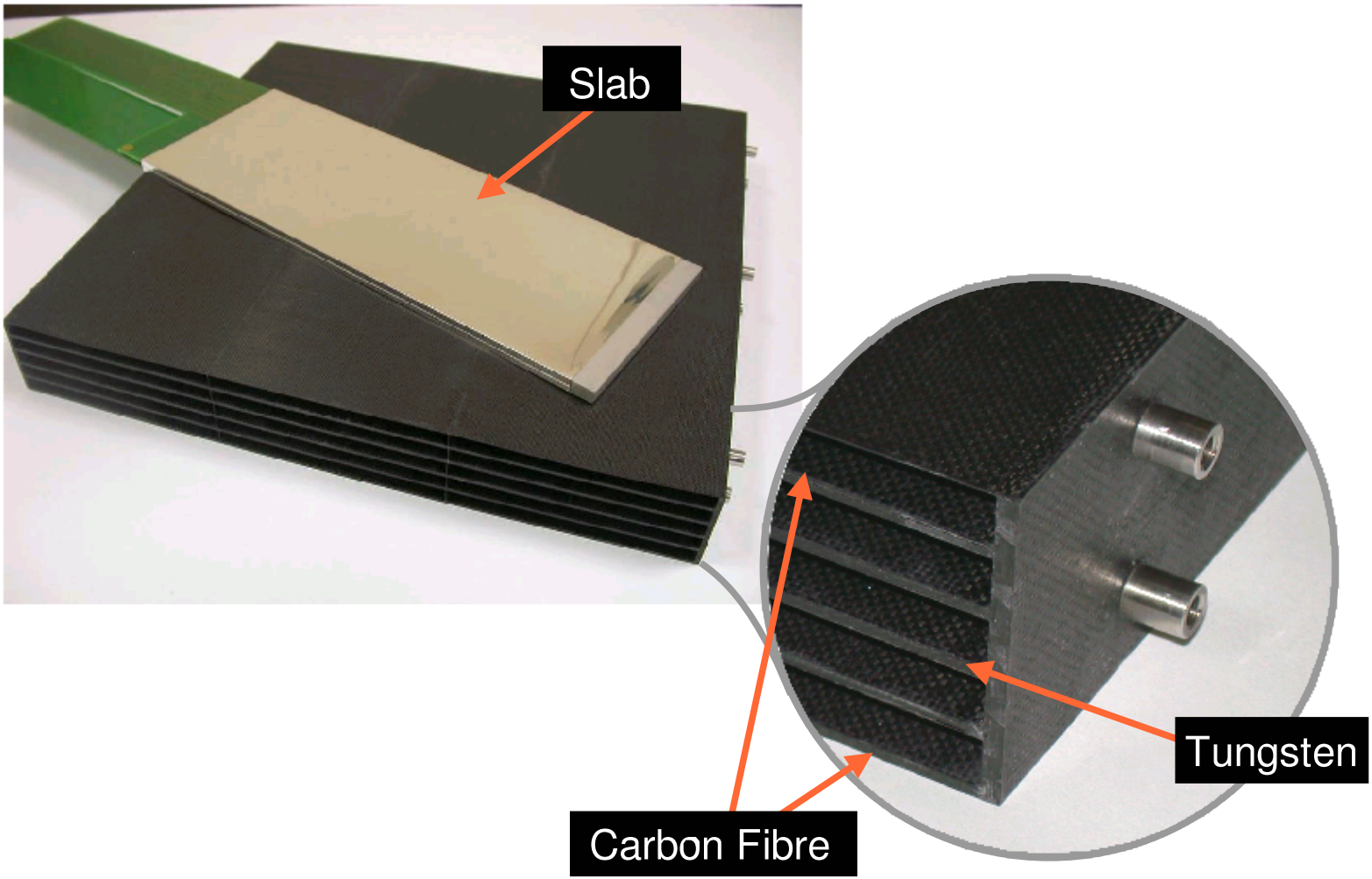


The Alveolar Structure ($1.4\,\mathrm{mm}$ *Tungsten)*

Design criteria for the Silicon Wafers

Keep design as simple as possible
(For example: minimise the required processing steps.)

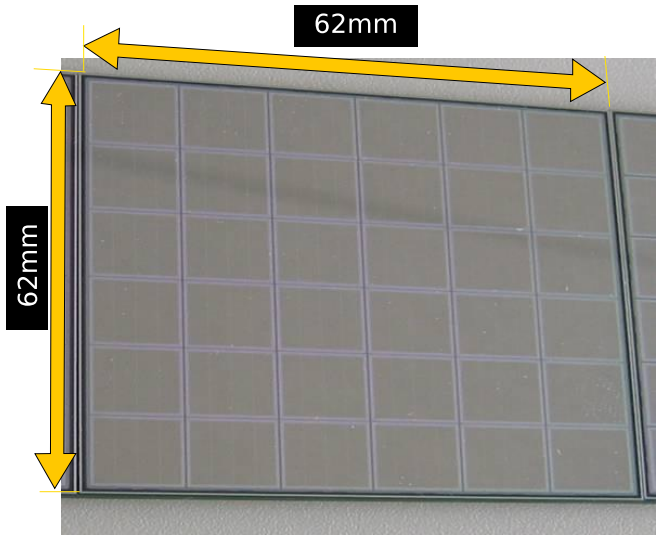
- increases number of potential producers.
- increases yield of good wafers
  (reliability and robustness).

$\longrightarrow$ keeps down cost of full scale detector

The Silicon Wafers

Properties:

- 4" high resistivity wafer : $5\,k\Omega\,\mathrm{cm}$
- Thickness : $525\,\mu\mathrm{m} \pm 3\%$
- Matrix dimension : $62.0^{+0.0}_{-0.1}\,\mathrm{mm}$
- Guard ring
- In silicon: ~ 80 eh / $\mu\mathrm{m}$
  $\rightarrow 42000\mathrm{e}^{-}$ / mip.
- Capacitance : $\sim 21\,\mathrm{pF}$ (one pixel)



6×6 sensitive pads of $1 \times 1\,\mathrm{cm}^2$

Demanded quality:

- Leakage current @ 200 V : $< 300\,\mathrm{nA}$ (Full matrix)
- Full depletion bias : $\sim 150\,\mathrm{V}$
- Nominal operating bias : $200\,\mathrm{V}$
- Break down voltage : $> 400\,\mathrm{V}$

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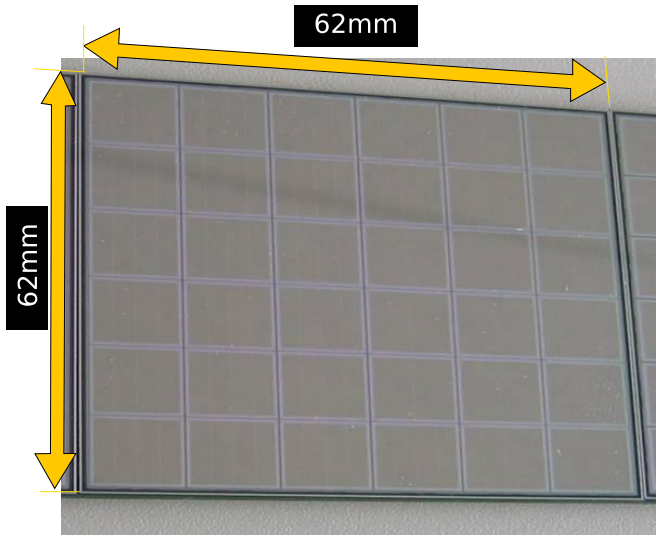

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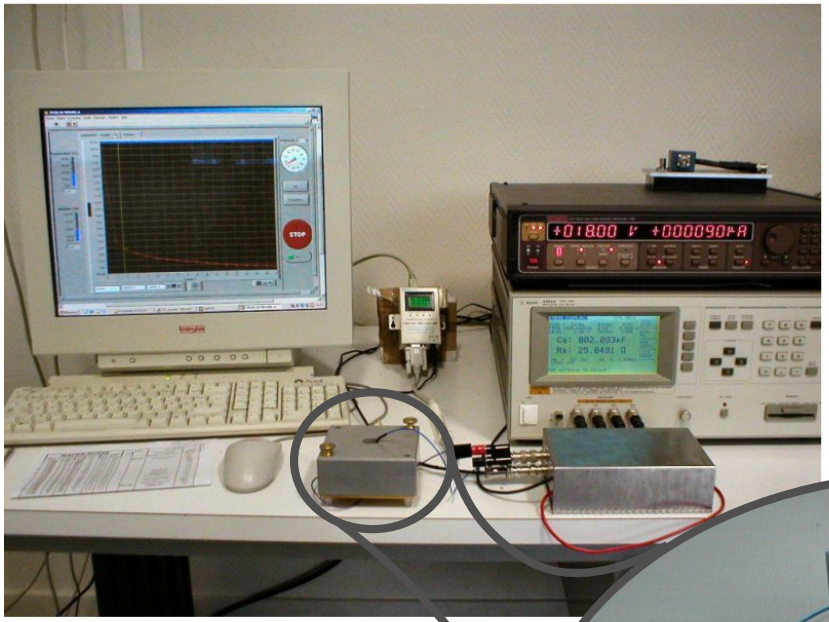
Silicon Matrices

Two independent producers:

- 150 matrices Russian production:
  Institute of Nuclear Physics – Moscow State University
  (M. Merkin, A. Savin , A. Voronin)
- 150 matrices Czech production:
  Institute of Physics, Academy of Sciences of the Czech Republic – Prague
  (V. Vrba, P. Sicho)

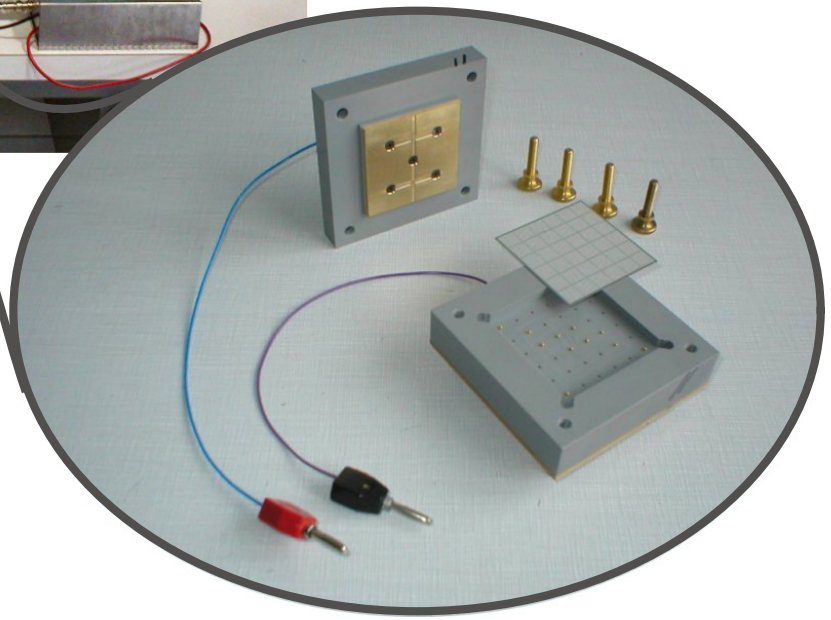
Silicon Matrix Test Bench



6×6 spring mounted point contacts.

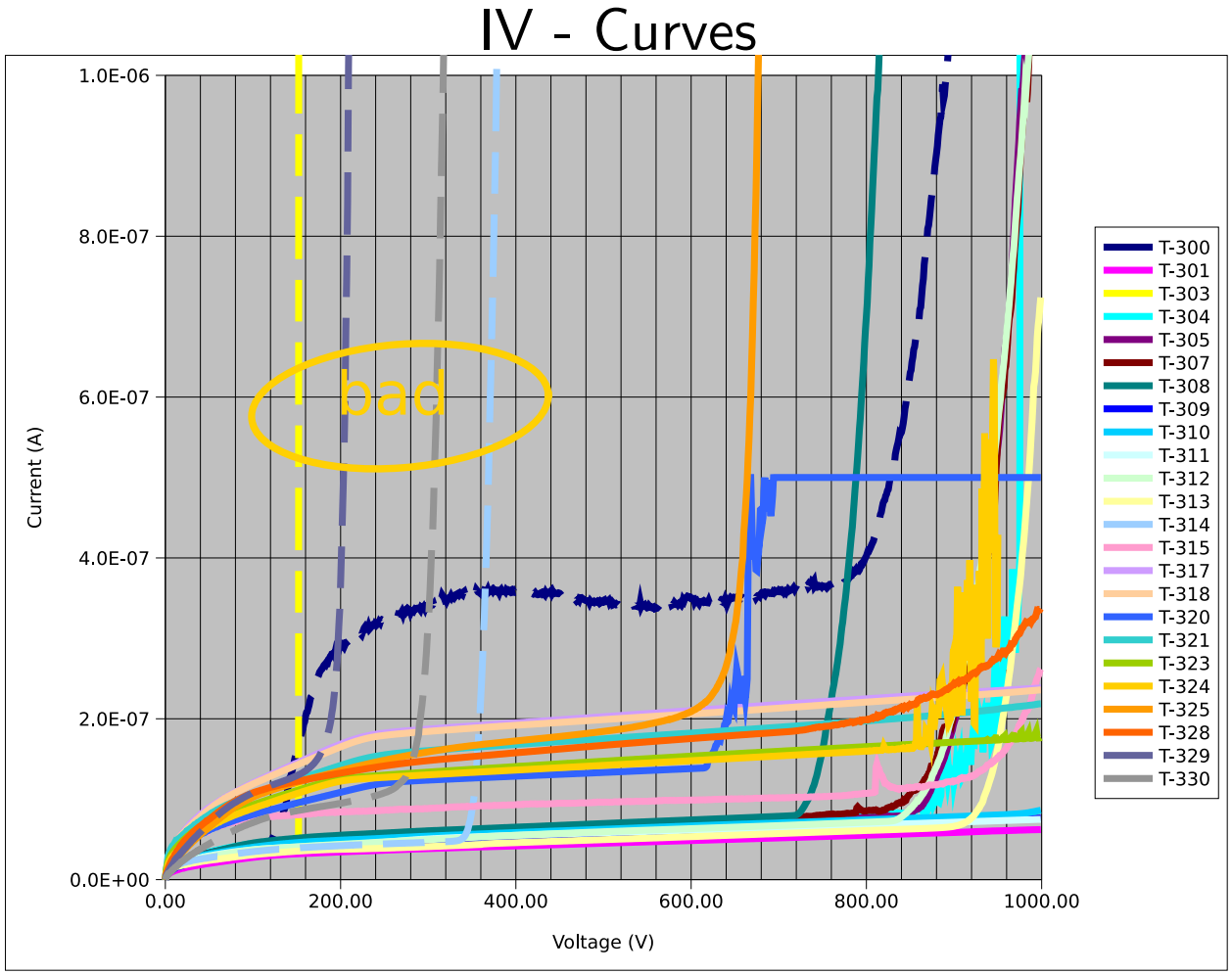
Measurements:

- C-V curve.
- I-V curve



- C-V meter
- pico Ampère meter
- temperature monitoring
- humidity monitoring

Wafers of 2. Russian Production



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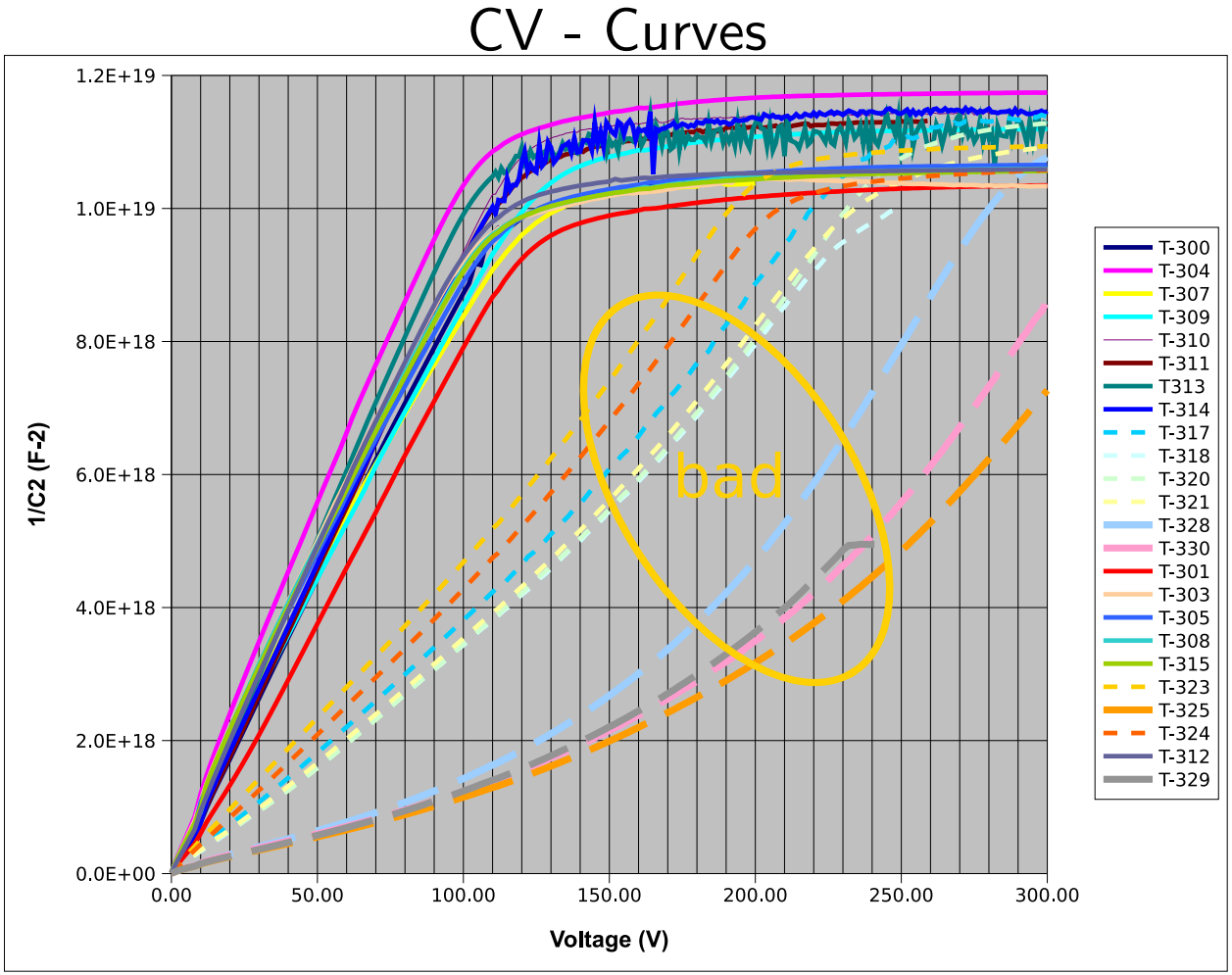
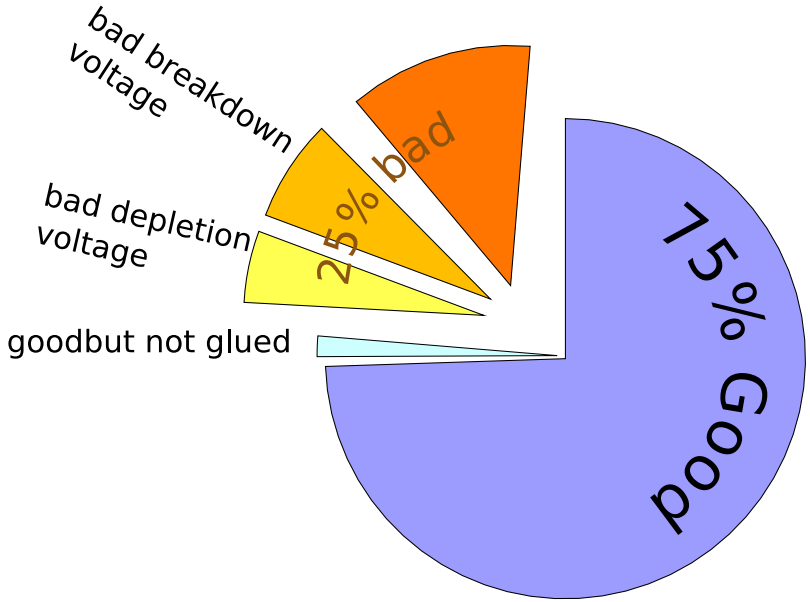


Wafers of Russian Production

1. Batch: 145 Wafers



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Institute will sent new batch.

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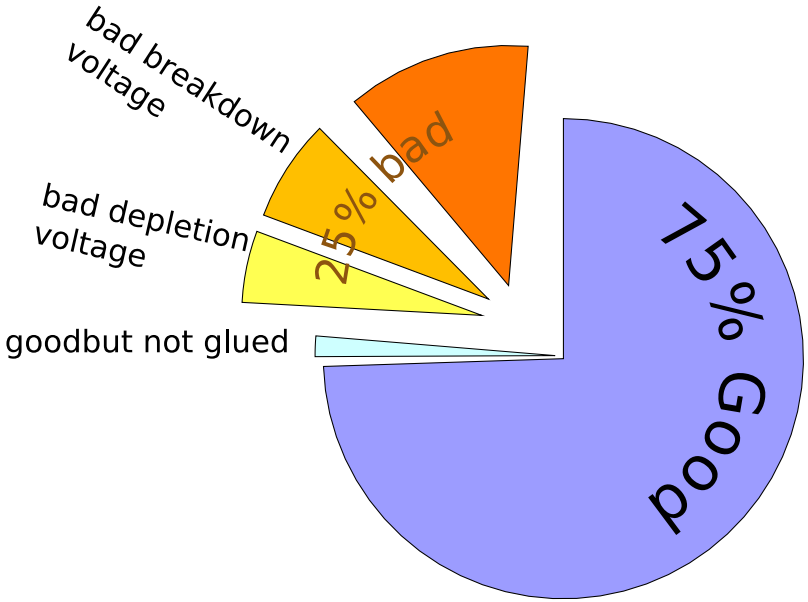
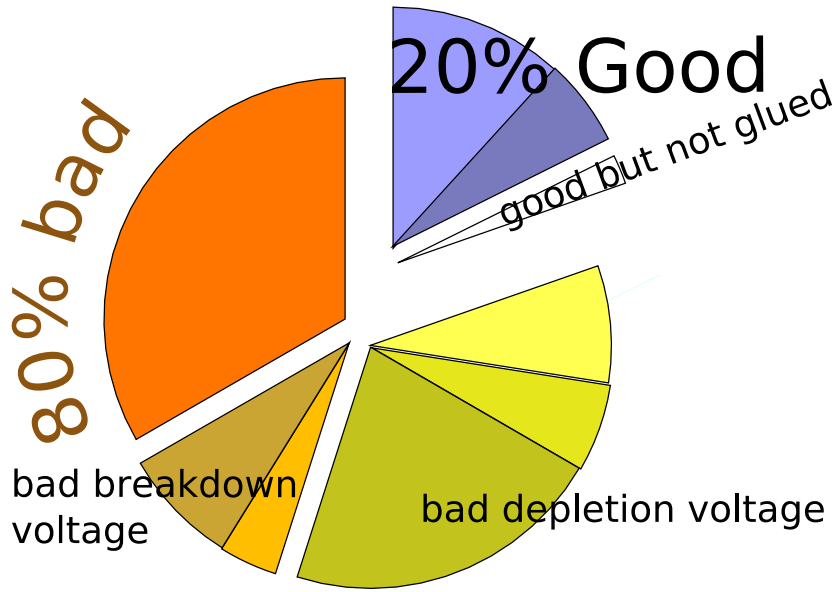


2. Batch: 100 Wafers



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Wafers of Czech Production

Q1 2005:

- Wafers are of excellent quality.
  (Very low leakage currents before gluing)
- Gluing procedure attacks passivation.
  (Leakage currents increase by orders of magnitude after gluing, Breakdown voltage drops.)

Problem was not solved by Chemical surface treatment or different gluing protocols (time, temperature).

New Czech Production

Q3 2005: New production, tested by ONsemi:

- leakage current still $\sim$ 10 times higher after gluing,
- but breakdown voltage is stable.

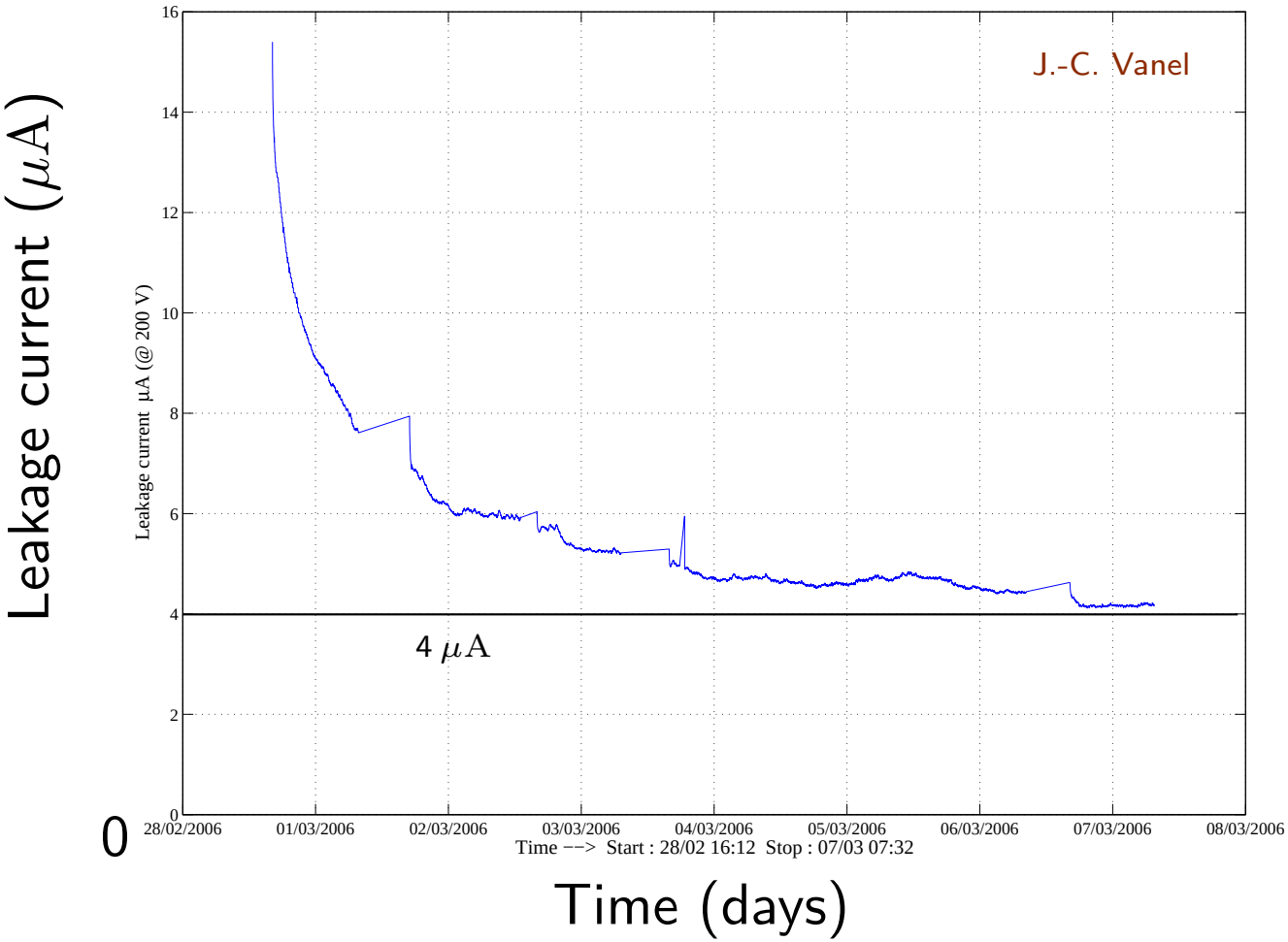
Batch of 20 Wafers tested at LLR:

- 14 good wafers (before gluing) $\rightarrow$ yield 70%
- Glued 6 wafers on PCB.

$\rightarrow$

Leakage Current – New Czech Production

Leakage current of PCB with 6 glued wafers



ECAL Prototype Status

- alveolar structures: 3 of 3 — OK
- H-structures: 30 of 30 — OK
- fully equipped PCB:
  - central PCB: 30(+spares) of 30 — OK
  - bottom PCB : 30 (+spares) of 30 — OK
- Silicon Matrices: 96 / 270 — Problem!
  - central part: 96 (+24) of 180
    $\rightarrow$ Currently 16 Layers (+4 in about 2 weeks)
    $\rightarrow \sim 9X_0$ ($\sim 12X_0$)
  - bottom part: 0 of 90

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Wafers for the Calice ECAL

- Completion of Calice ECAL prototype.
  Assuming 150 good quality wafers are available:
  - $\sim$ at least two weeks to complete central part.
    (min. 2 days per slab)
  - $\sim$ at least six weeks to complete bottom part.
- New batches of Russian and Czech wafers.
- Contact to additional producers:
  - 50 wafers will be produced in Korea .
  - 100 wafers ordered from Brazilian institute.
  - in contact with Hamamatsu.
  - in contact with Indian institute.

  (High resistivity raw wafers are available.)

Results With the Calice ECAL Prototype

1. 2 weeks cosmics (Dec 2004)
   10^6 events with 10 layers.
2. 2 weeks (+ commissioning) e^- test beam at DESY (Feb 2005)
   (see talk by G. Mavromanolakis)
3. new cosmics test together with A-HCAL (started Dec 2005)
   - first test of combined acquisition (debug run).
   - could confirm results of 1.

Cosmics Test

- 15 days of continuous data taking
- 10 layers (central part) ($\sim 2\mathrm{k}$ channels)
- 1 million events recorded $\rightarrow$ 1% calibration
- Will be repeated with 16 layers in December.

Signal and Noise of all channels of 1 million events:

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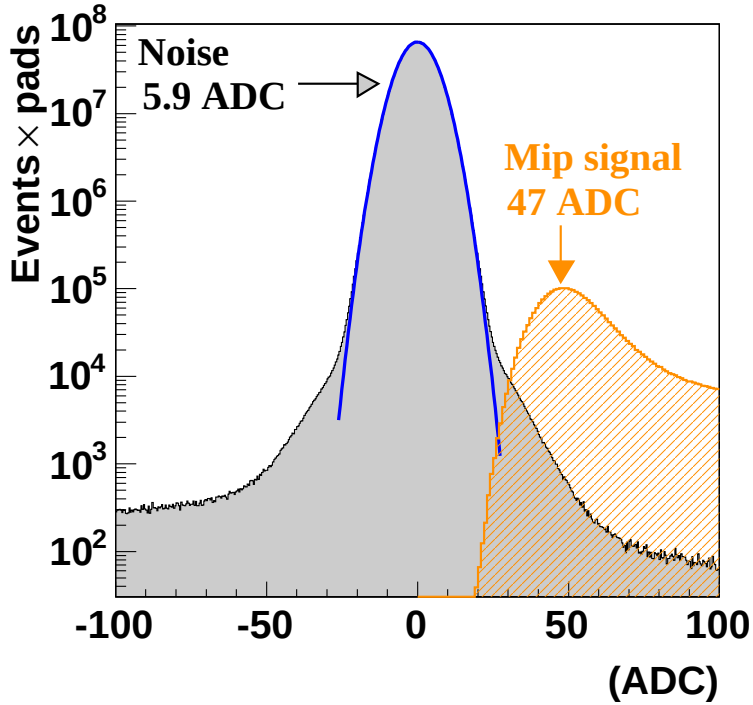
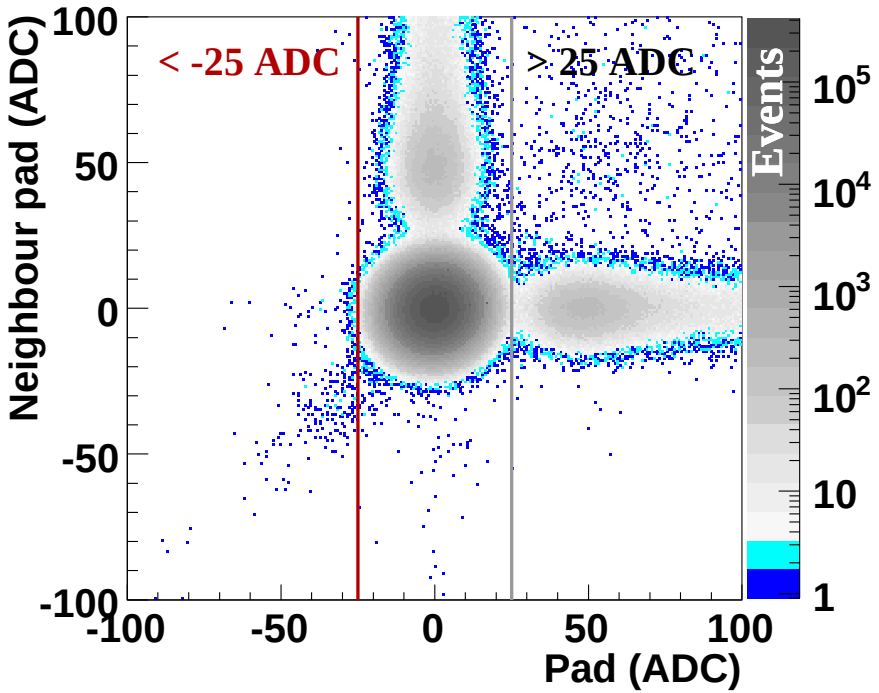


$\longrightarrow$ signal/noise $\simeq 8$

Correlation between Neighbour Pads



Similar correlation between pads of different half wafers / wafers.

Summary and Outlook

- The partially completed Calice ECAL has operated in the test beam and the cosmics test as expected.
  - little coherent noise.
  - signal over noise ~ 8.
- An exciting test beam program is awaiting us.
- But for the test beams, additional wafers are needed:
  - e^-: central part is crucial: $\rightarrow$ 60 wafers!
  - hadrons: central and bottom parts are crucial: $\rightarrow$ 150 wafers!
- Test beam at DESY soon: A-HCAL + ECAL (at least 20 ECAL layers.)

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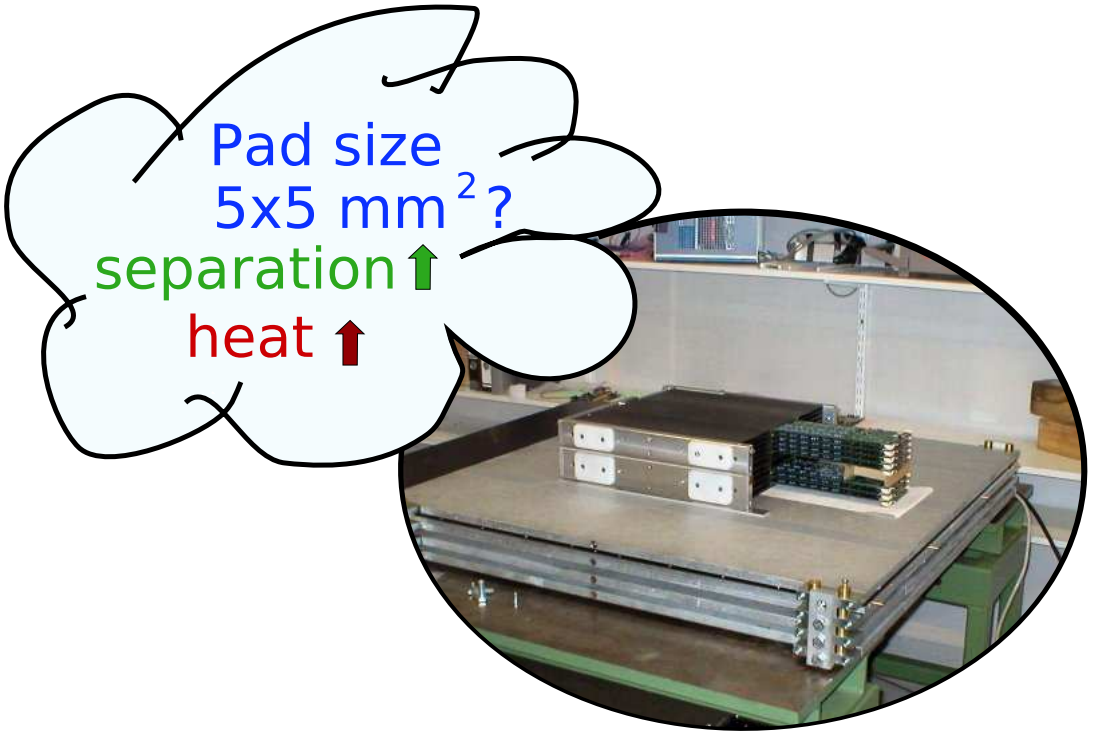
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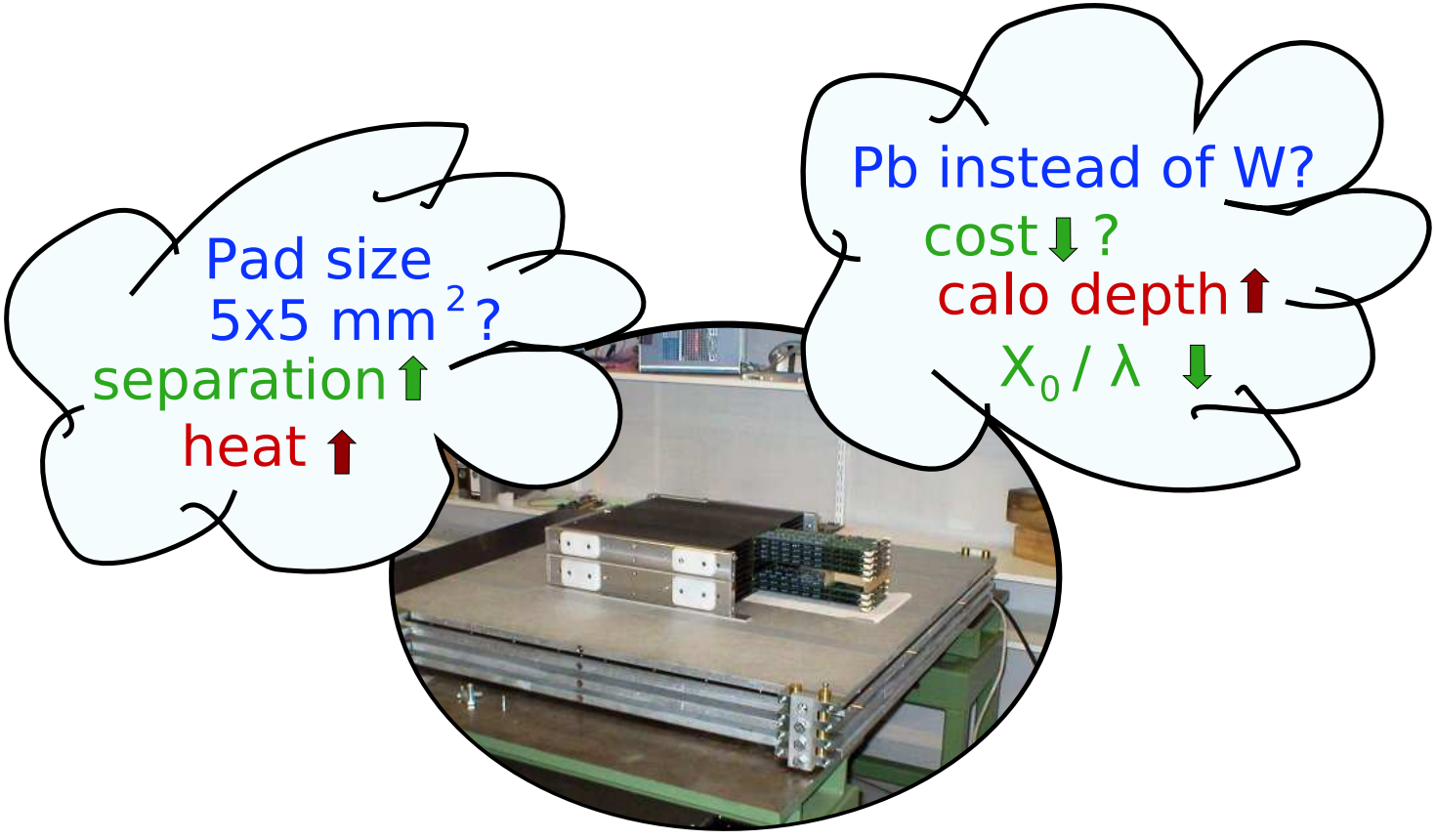
5x5 mm^2?
separation ⬆
heat ⬆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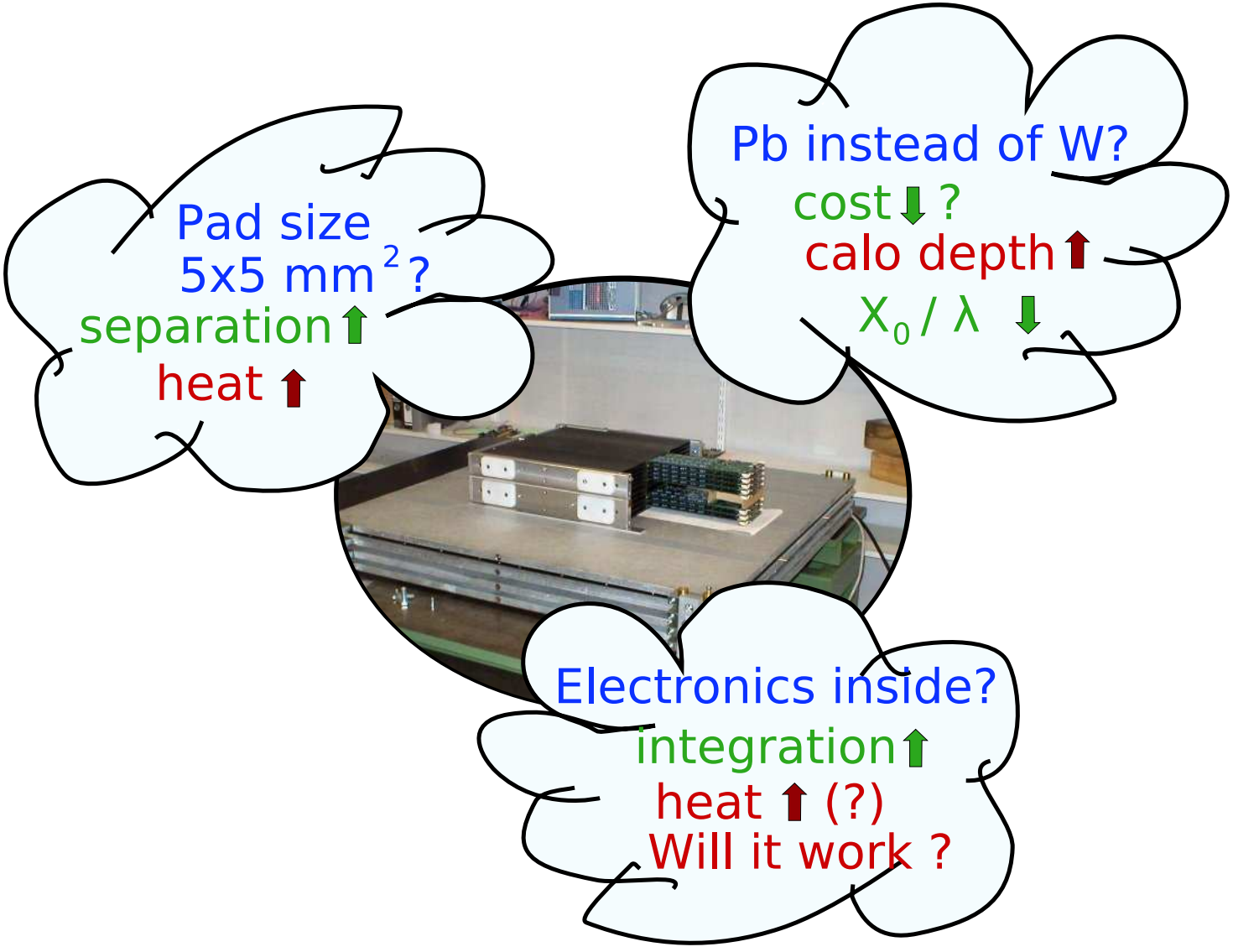
separation ⬆
heat ⬆
Pb instead of W?
cost ⬇ ?
calo depth ⬆
X_0 / λ ⬇


Pad size
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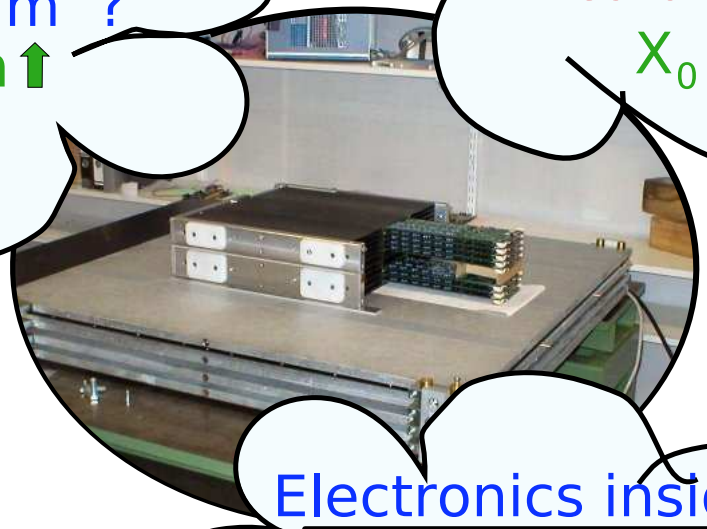
separation ⬆
heat ⬆
Pb instead of W?
cost ⬇ ?
calo depth ⬆
X_0 / λ ⬇
Electronics inside?
integration ⬆
heat ⬆ (?)
Will it work ?

Pad size
5x5 mm^2 ?
separation ⬆
heat ⬆

Pb instead of W?
cost ⬇ ?
calo depth ⬆
X_0 / λ ⬇



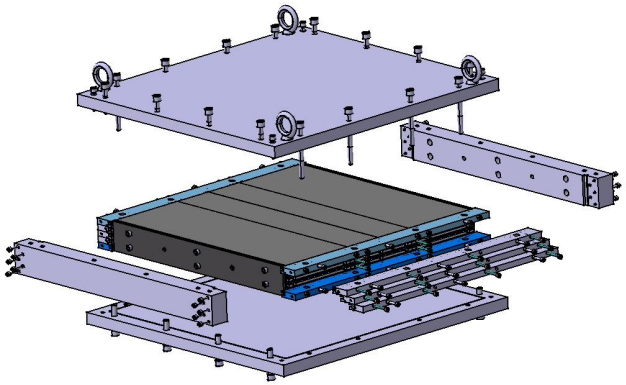
Electronics inside?

Will be tested soon.

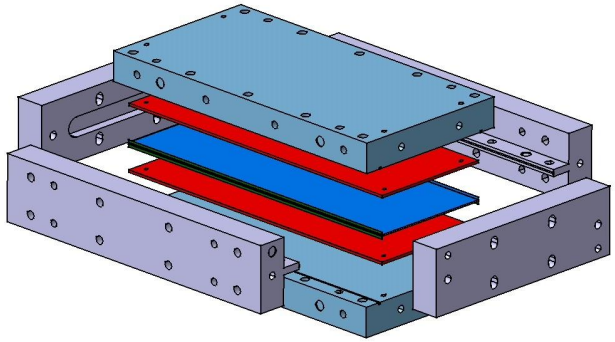
FIN

Fabrication of Composite Structures

Alveolar Structure



H-Structure



(Here: 1.4 mm of Tungsten)

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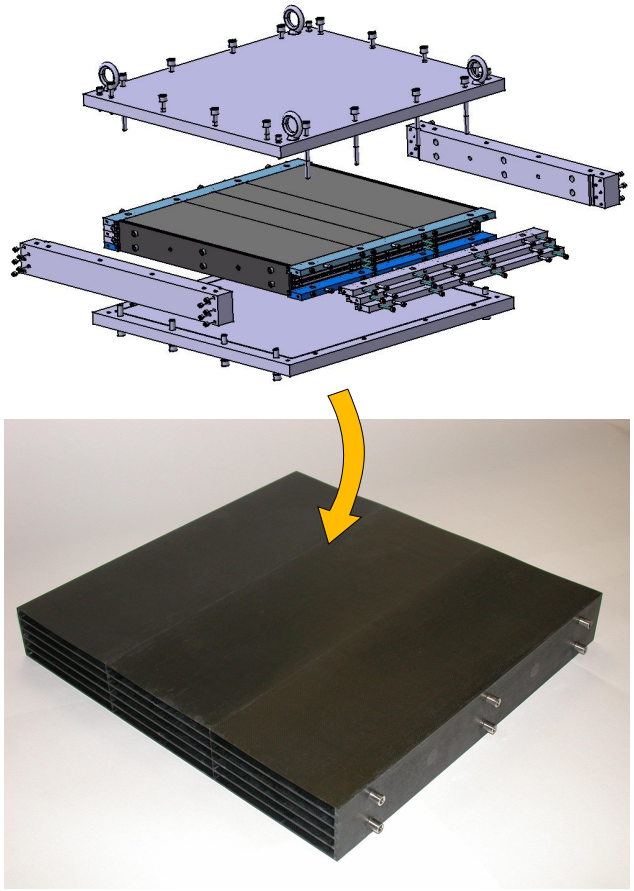

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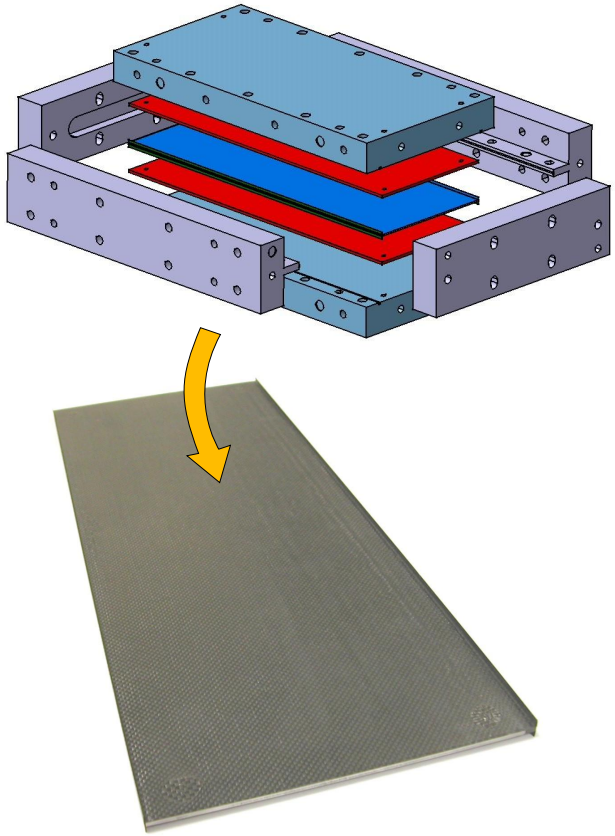

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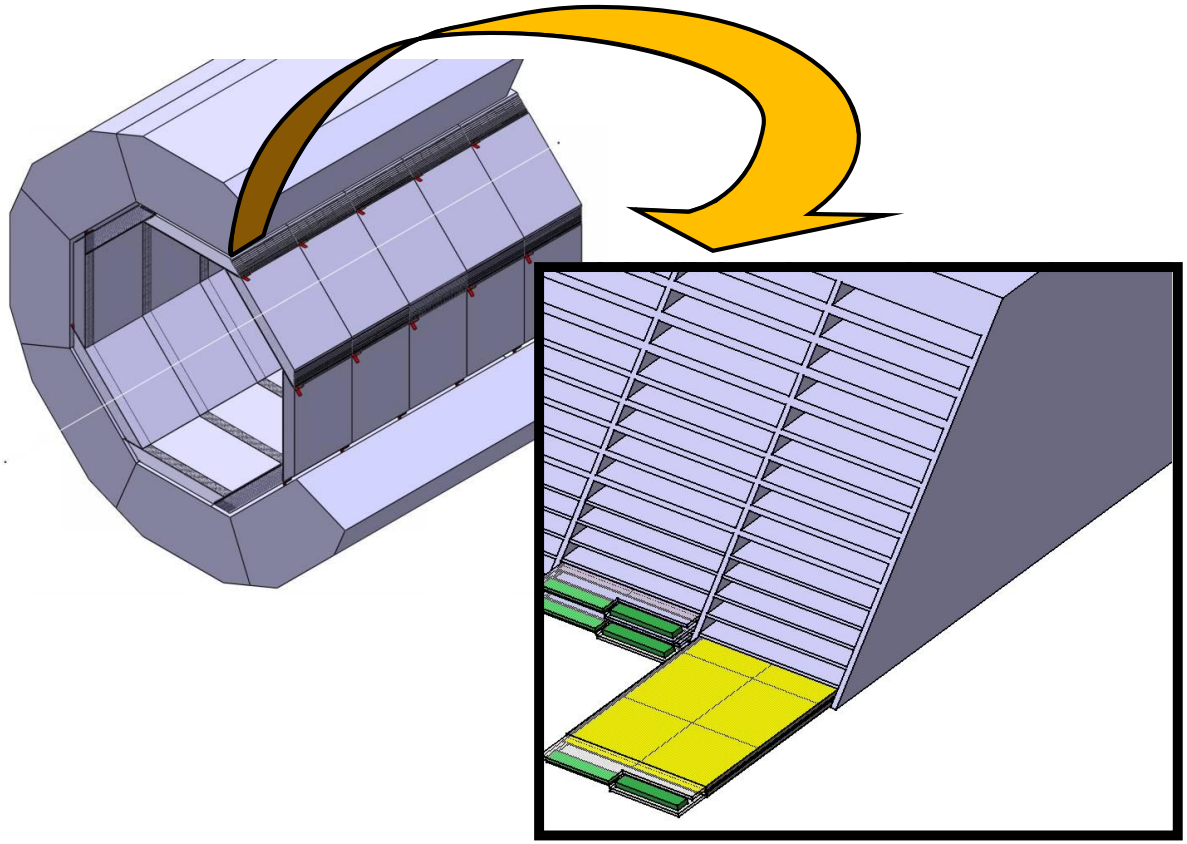
ECAL Concept



Wafers of Czech Production

Q3 2005: 10 newly processed Wafers. (ONsemi)

before gluing:

- low leakage current
- stable breakdown voltage

after gluing:

- leakage current $\times 10$.
- But breakdown voltage stable.