Silicon Sensors Prototype for LumiCal

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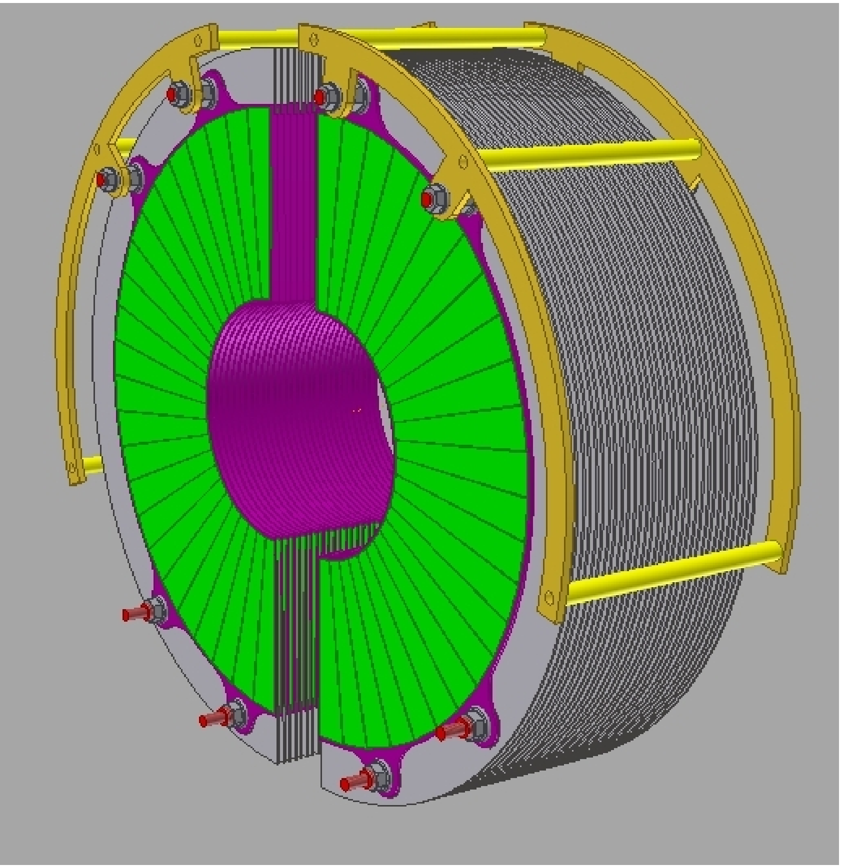
LumiCal calorimeter - towards the prototype

LumiCal detector – high precision ($\Delta L/L \sim 10^{-3}$) in luminosity measurement at ILC

In case of ILD detector – two identical calorimeters placed 227 cm from IP

The current design:

decreased death material - tungsten,
FE electronics on Kapton foil, ceramic outside the tungsten plane.



EM calorimeter with 30 layers of tungsten absorber plates interleaved with layers of Silicon sensors with the following thicknesses:

tungsten layer -	3.5 mm
Silicon sensor layer -	0.32 mm
support -	0.6 mm
electronic space -	0.1 mm

inner radius of the active area -	80 mm
outer radius -	195 mm

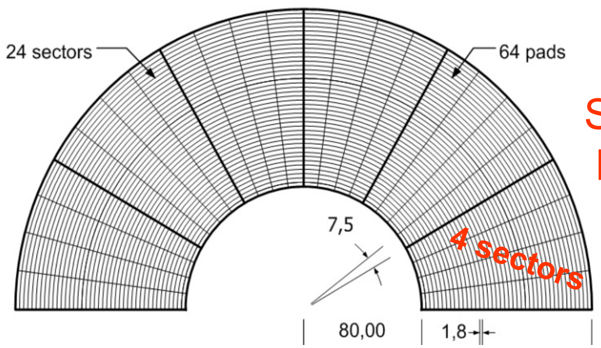
Sensor segmentation -
64 cylinders with 48 sectors in azimuth

Angular coverage (sensors) from ~ 32 mrad to 76 mrad (for ILD instalation place)

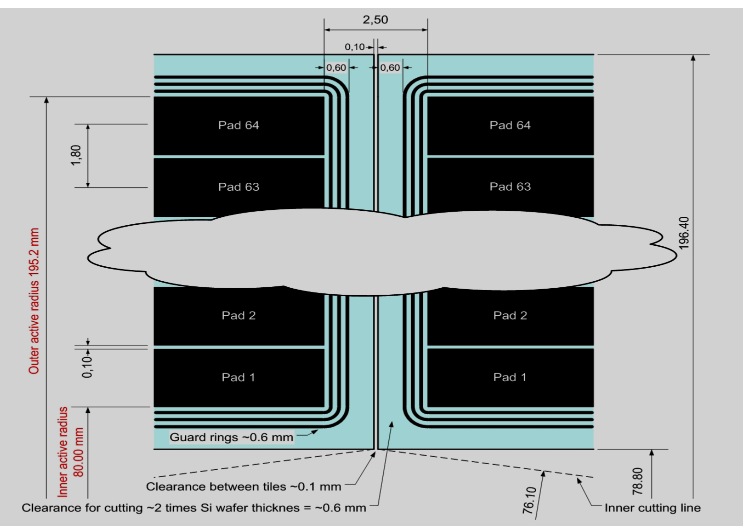
Silicon sensors - prototype design

At the design stage we take into account:

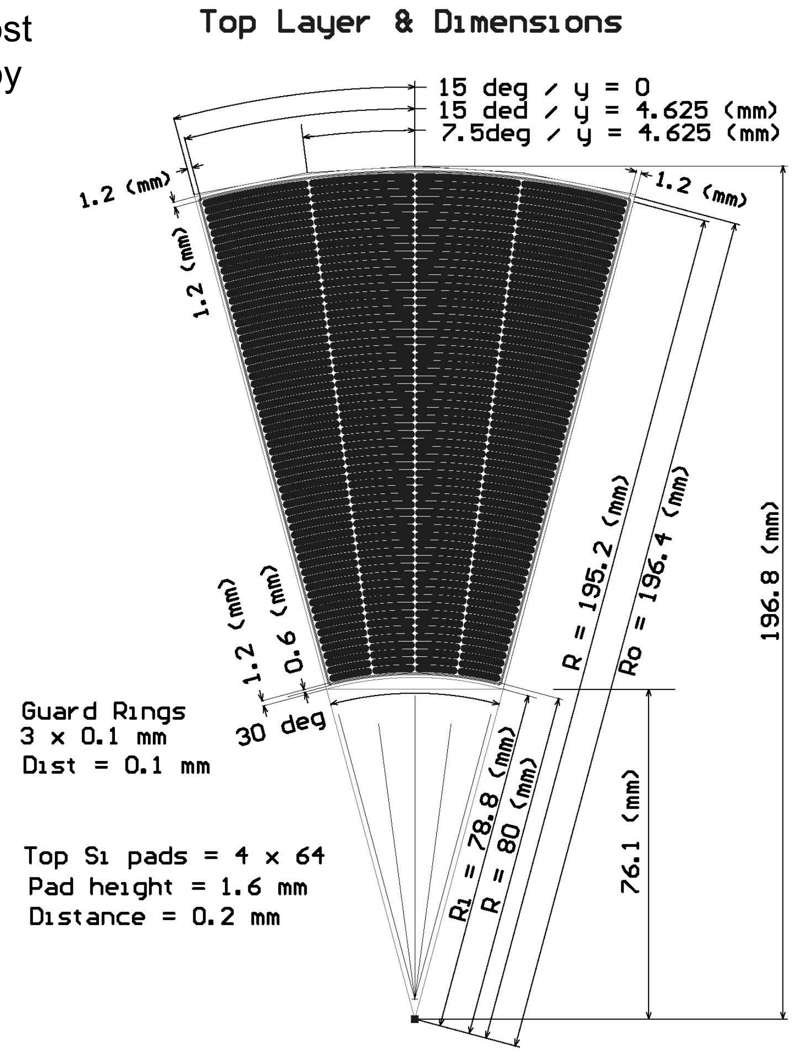
- results of Monte Carlo studies on angular resolution
- available (standard) silicon sensor technology
- requirement of FE electronics, number of channels and cost
- possible improvement of shower reconstruction accuracy by simple increase pads granularity (e.g. azimuth)
- remarks from Hamamatsu engineers



Silicon sensor half plane



Details of the structure: gap between tiles and guard rings



Segmentation of 4 sectors - they were produced by Hamamatsu

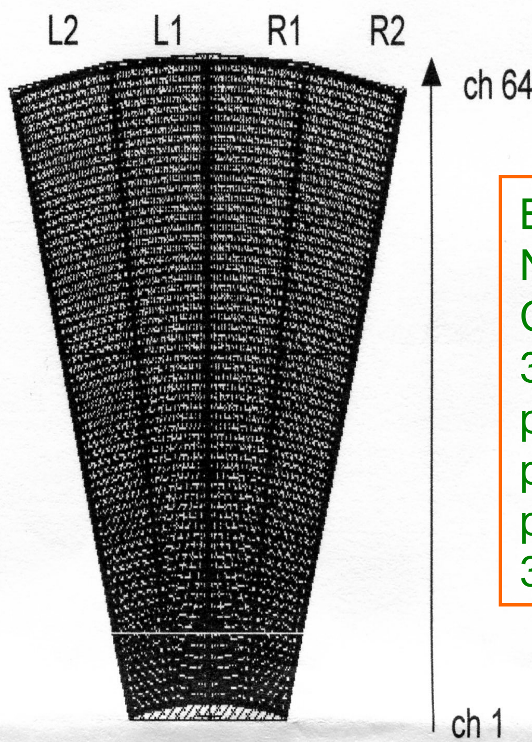
Hamamatsu: sensors fabrication

Hamamatsu: EUDET-Pad-Detector Project -

40 silicon detectors: 20 Cracow, 10 Zeuthen, 10 Tel Aviv

chipNo.	Number of NGCh	NGch
25	0	
26	1	L2-49 Leaky
27	0	
29	0	
36	1	L1-29 Leaky
42	1	L1-29 Leaky
50	0	
51	0	
52	0	
53	0	
55	0	
56	0	
57	0	
58	0	
59	0	
60	0	
61	0	
62	0	
63	1	L2-44 Leaky
64	0	

Pads number description



Hamamatsu S10938-8380

6 inch wafers

Basic sensors parameters:
N-type silicon, p^+ strips, n^+ backplane
Crystal orientation <100>
320 μm thickness ± 15 μm
pad pitch 1.8 mm
pad p^+ width 1.6 mm
pad Al metallization width 1.7 mm
3 guard rings

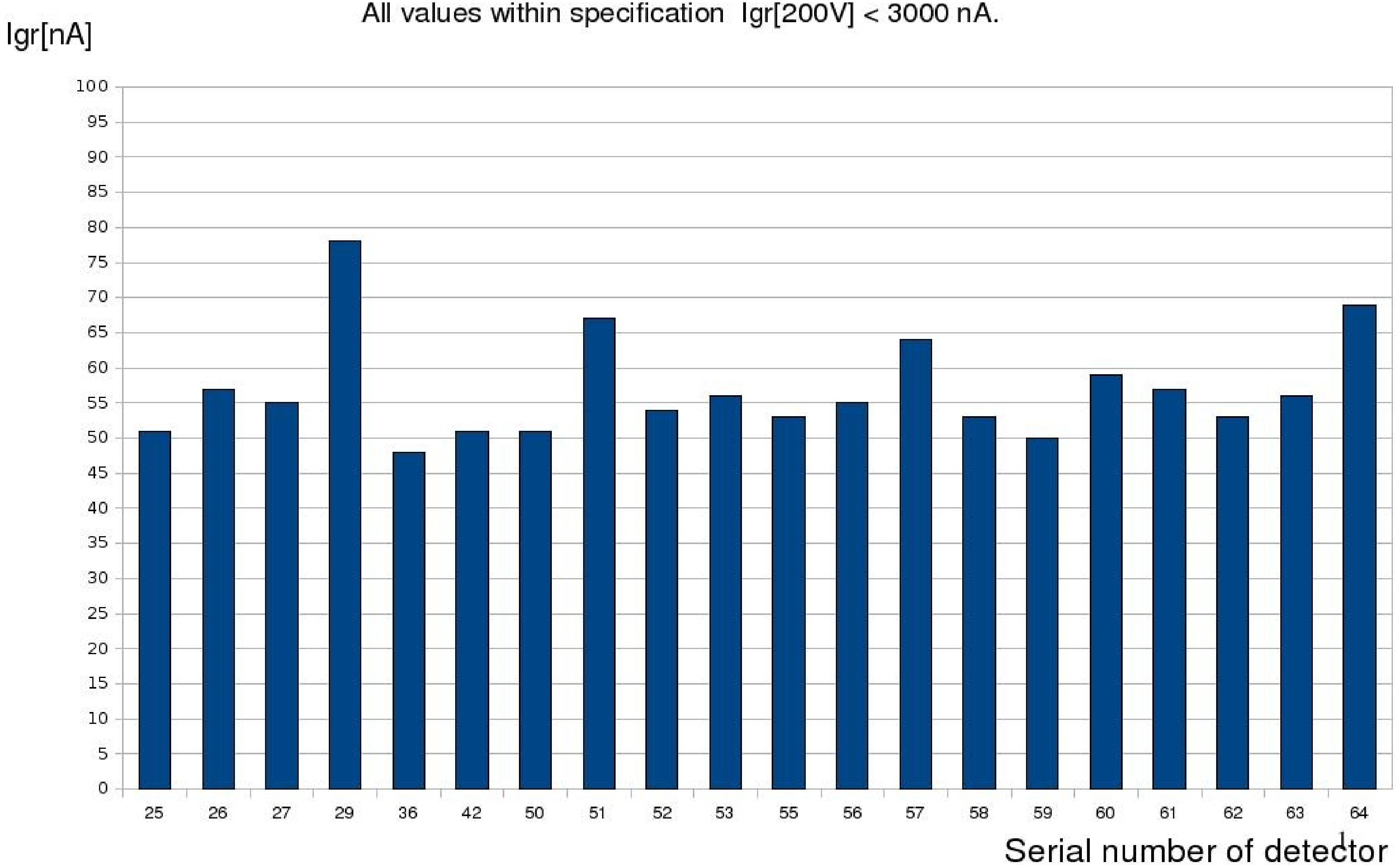
Test of sensors : I(V) and C(V) measurements using Probe Stations were done in Cracow (INPPAS, UST-AGH), DESY and Tel Aviv

Hamamatsu original measurements – guard ring currents

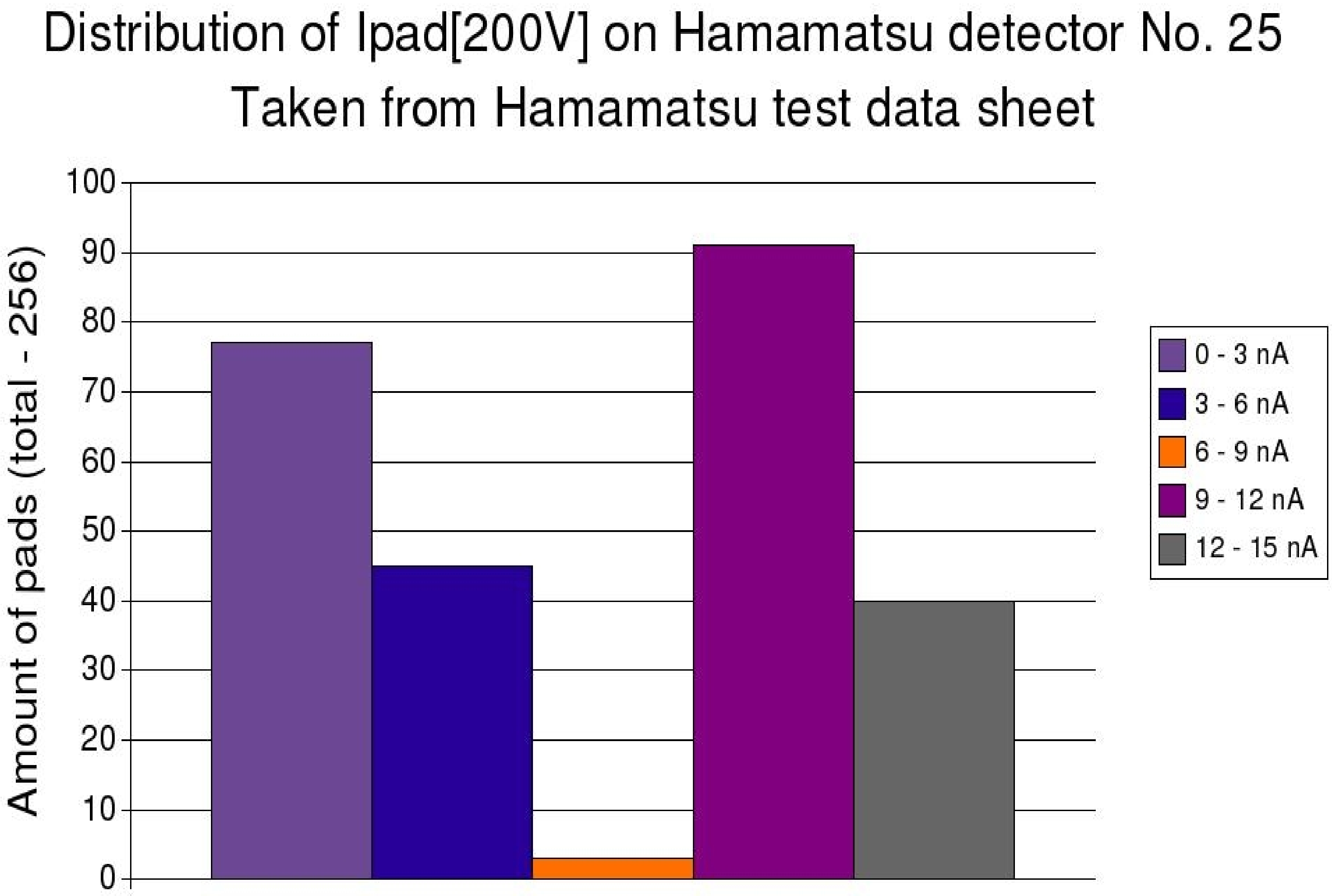
Cracow sample:

Values of Igr [200V] at most inner guard ring, taken from Hamamatsu data sheet.

All values within specification Igr[200V] < 3000 nA.



Hamamatsu original measurements - pad currents



Testing - probe station for visual inspection

Cracow: from 20 available sensors – 4 were chosen randomly for test measurements

Alessi probe station used for visual inspection of Hamamatsu detectors

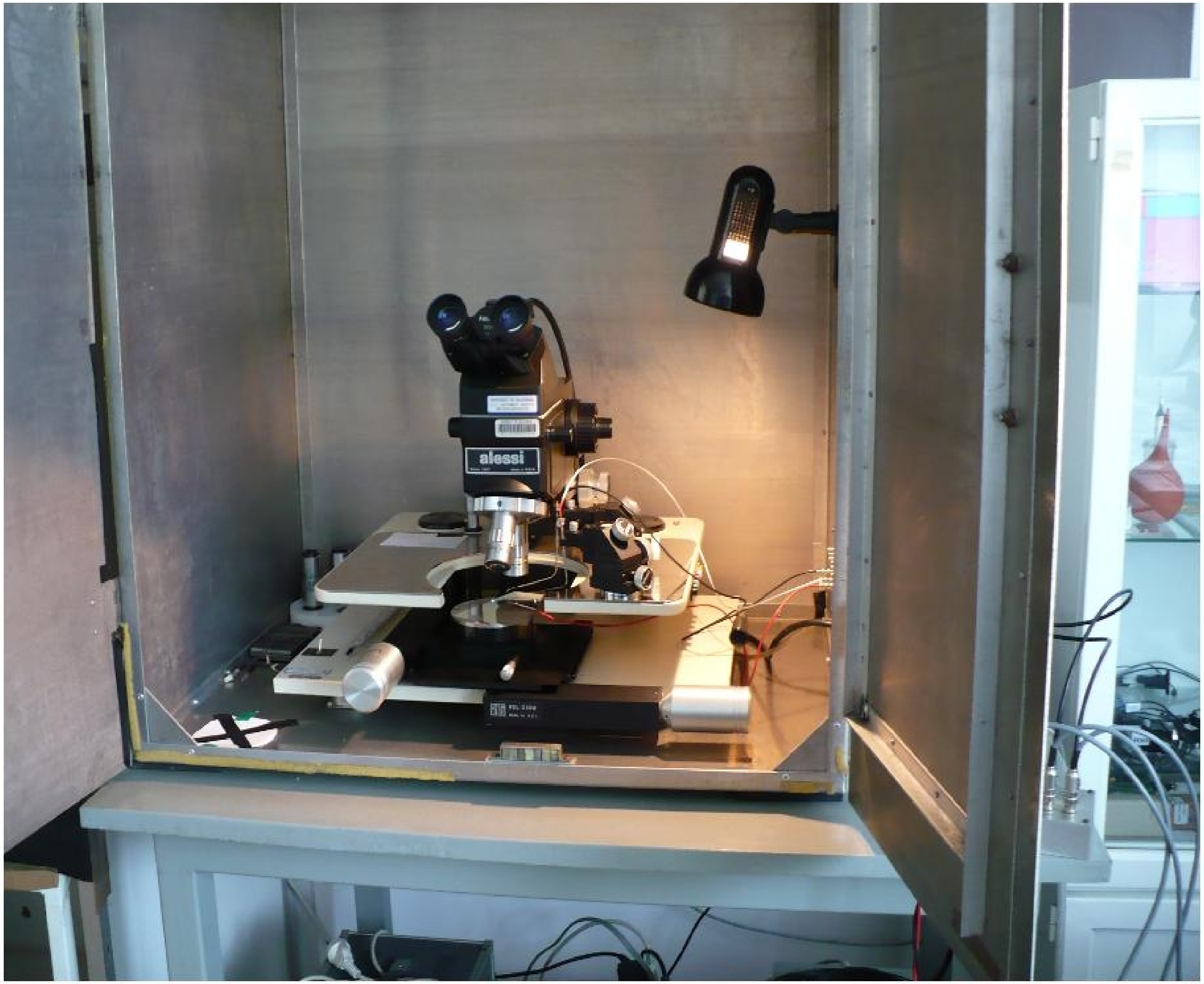
Such device is used for visual inspection only.

The camera installed in the microscope allows us to receive the picture of the investigated sensor on the monitor screen.

Electrical movable table supplied X,Y movements in steps of 1 μm $\rightarrow$ inspection of the details of the sensor structure and the position of markers on detector surface for precision alignment

Testing - probe station for C-V, I-V measurements

Cracow:



Alessi probe station used for electrical measurements on Hamamatsu detectors

Device has a „black box” –allows for
measurements in darkness and
with screening against EMI

To check measurements, two different methods were used:
with GPIB (General Purpose Interface Bus)
for automatic transfer data between device and computer
and
old style HP instrument - multimeter

Visual inspection

Fragment of boundary region between guard-ring and pad. The difference between dimensions of metallization outstanding over p+ implants can be clearly seen. 1

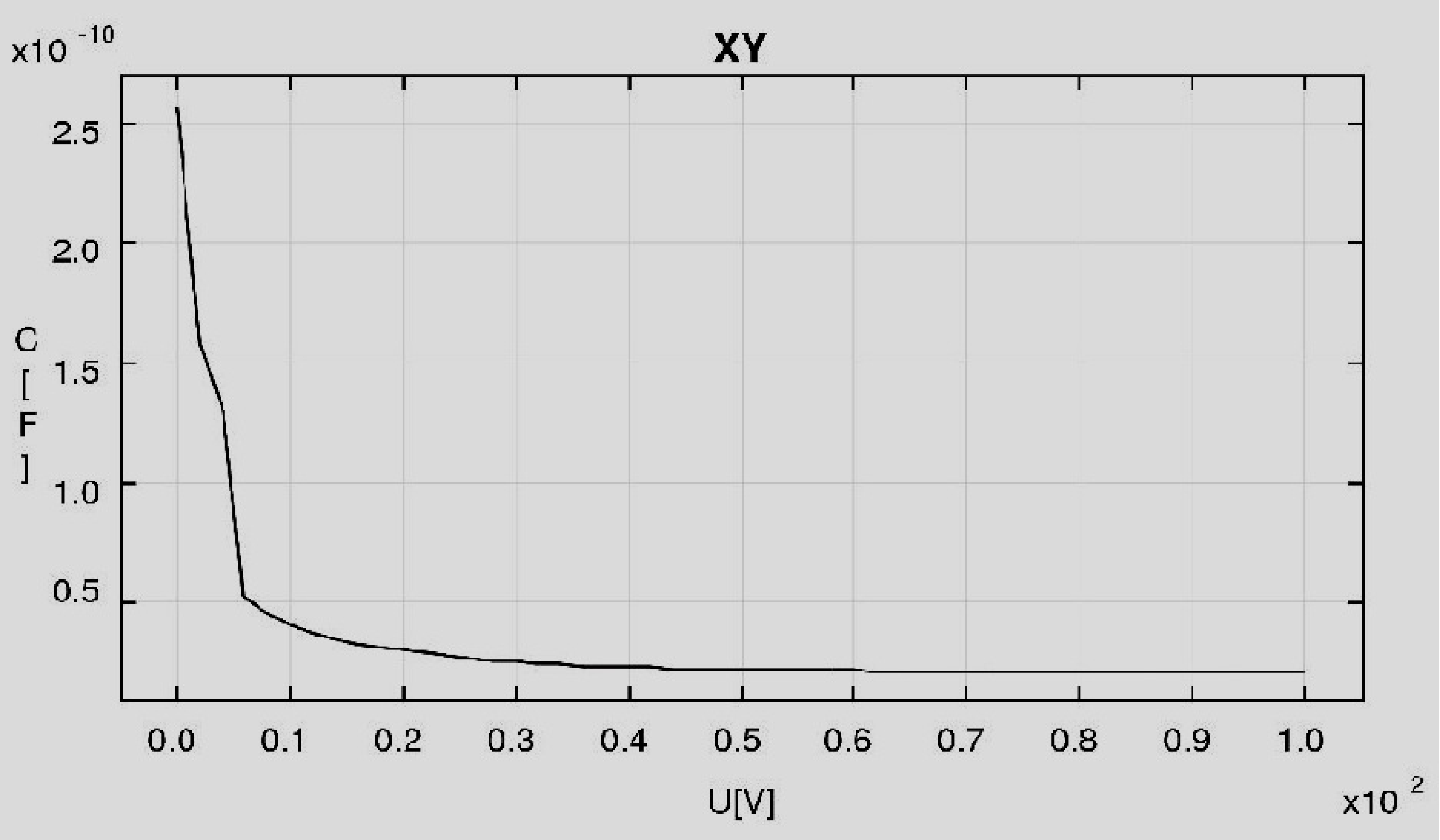
1

The corner fragment of guard-rings system

Capacitance - voltage plot

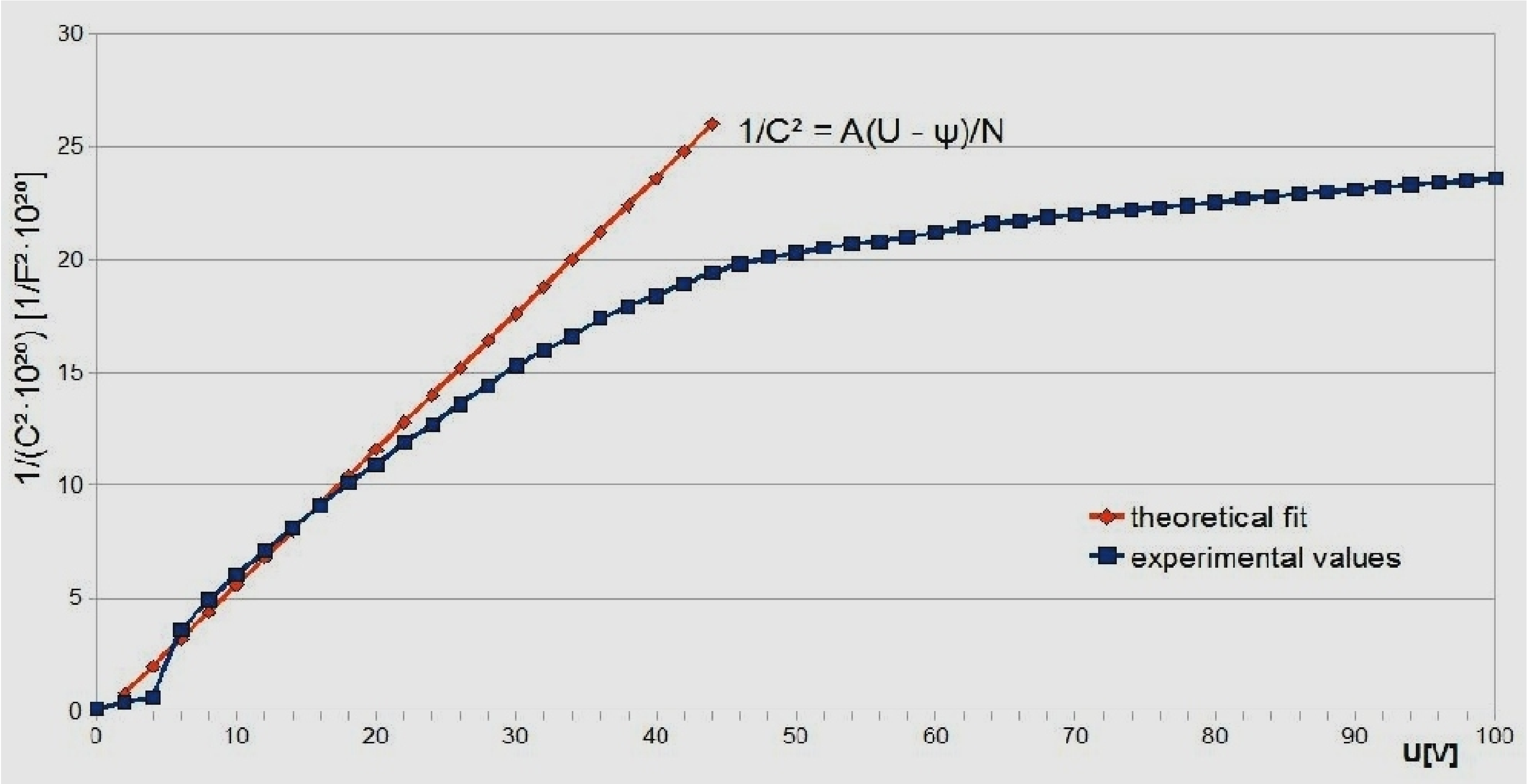
Cracow:

An example: pad L263, detector 25 - C-V measurements



Pad measurement : C-V plot transformed to $1/C^2 - V$ plot
Estimation: depletion voltage, donor concentration in Si -> resistivity

Example: pad L264 of detector 25

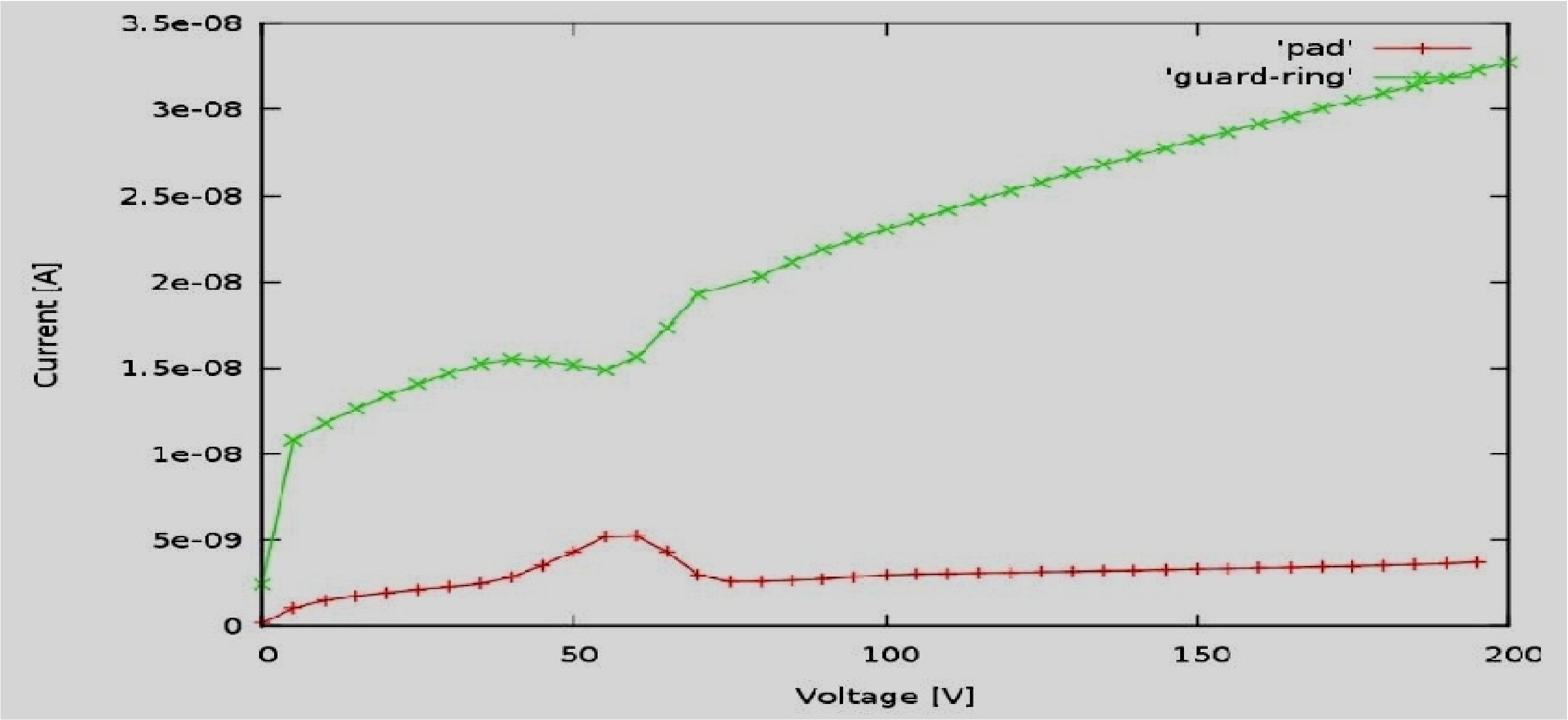


A - gemetrical/material factor,
N - donors concentration in Si bulk
Ψ- diffusion potential = 0.7 V
U, C – voltage, capacitance

From slope of linear fit one can estimates N:
$N \sim 7 \times 10^{11}\ 1/cm^3$,
hence silicon resistivity ~ 6 – 8 kΩcm,
and the depletion voltage ~ 30 – 60 V.

Pad + GR measurements: I – V characteristics

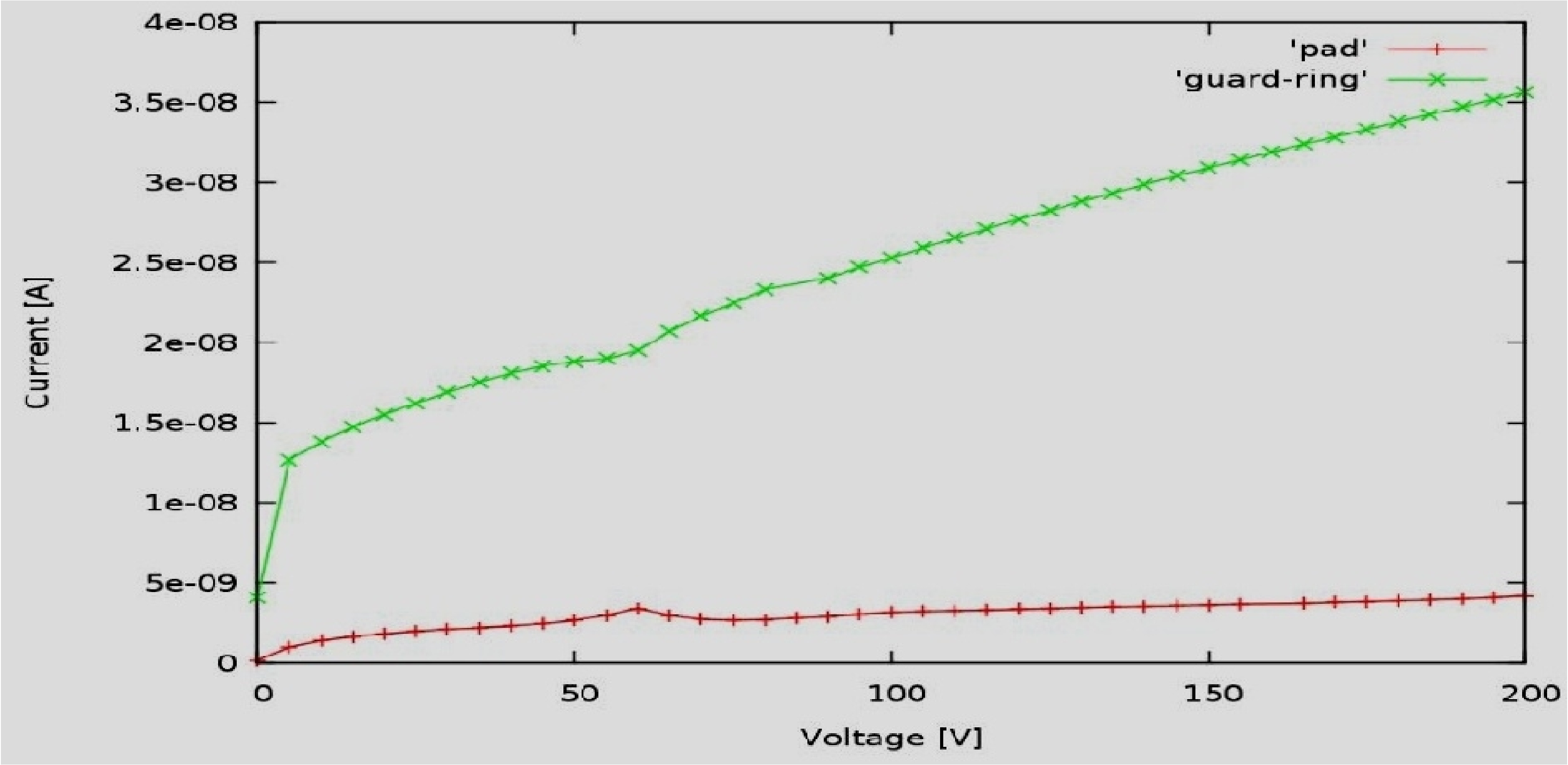
Example: measurements pad 64L2 of detector 25



The voltages on pad 64L2 and innermost guar ring were applied simultaneusly
In the region 40 – 70 V, current division between pad and guard ring is disturbed.
As a result of a specific geometry of electric field in boundary region –
Pad 64L2 has relatively long „common boundary” with quard ring ~ 28 mm.

Pad + GR measurements: I – V characteristics

Example: pad 63L2 of detector 25

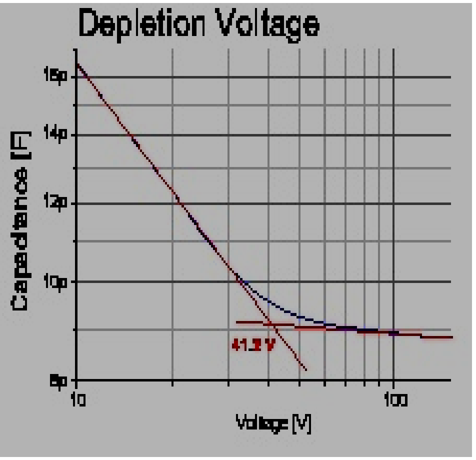


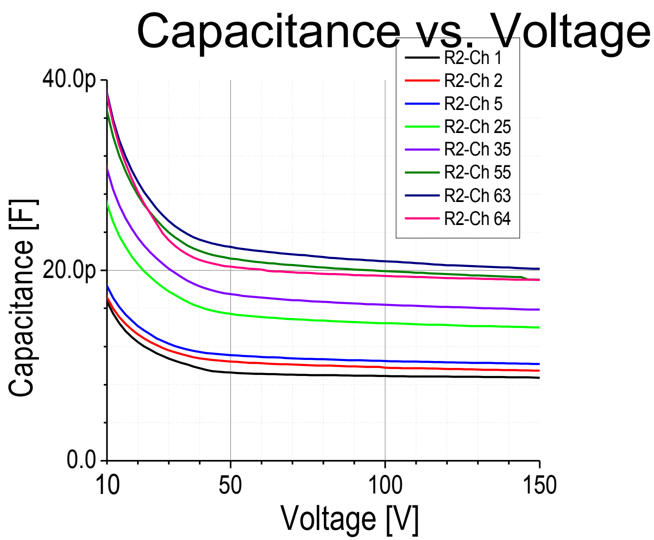
The voltages on pad 63L2 and innermost guar ring were applied simultaneusly
„Common boundary" with quard ring ~ 2 mm - small effect of the current division between pad and quard ring.

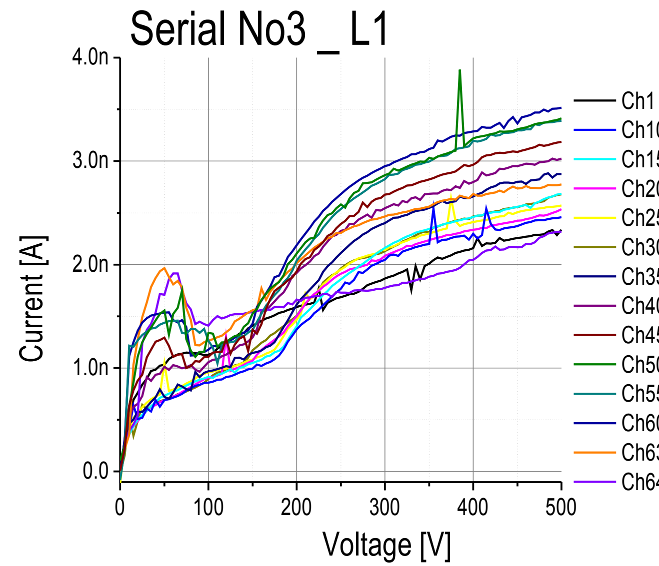
Zeuthen, Tel Aviv measurements : use SUESS probe stations

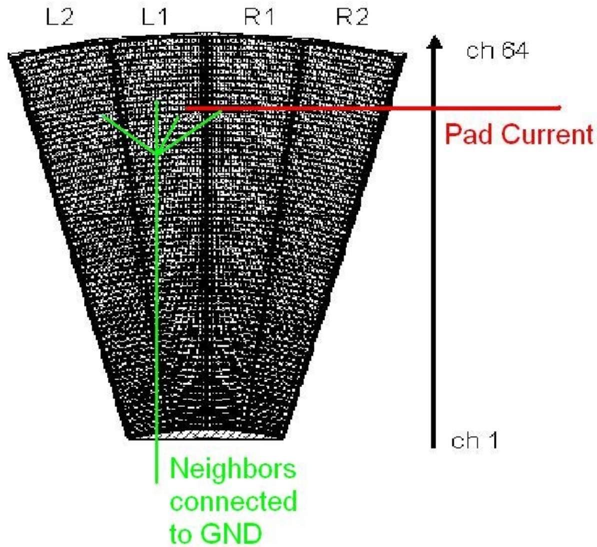
W. Lohmann, LCWA 2009, Albuquerque

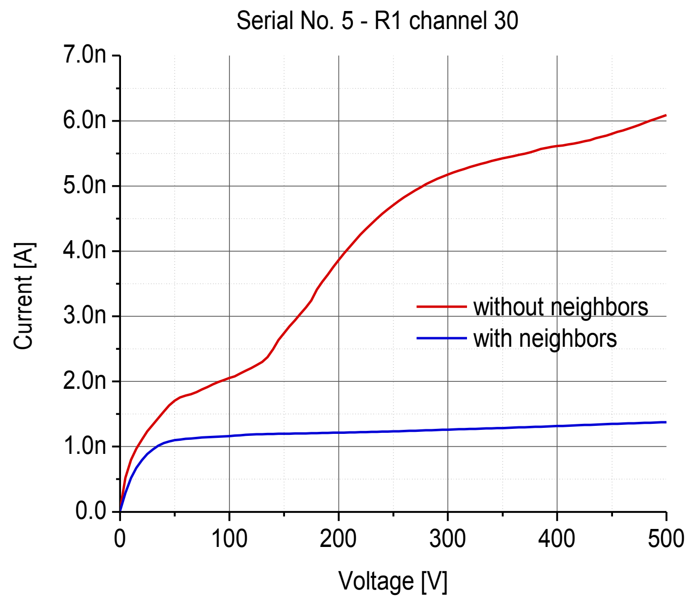
The measurement conditions: temp. 22^0 C, humidity ~ 50 %







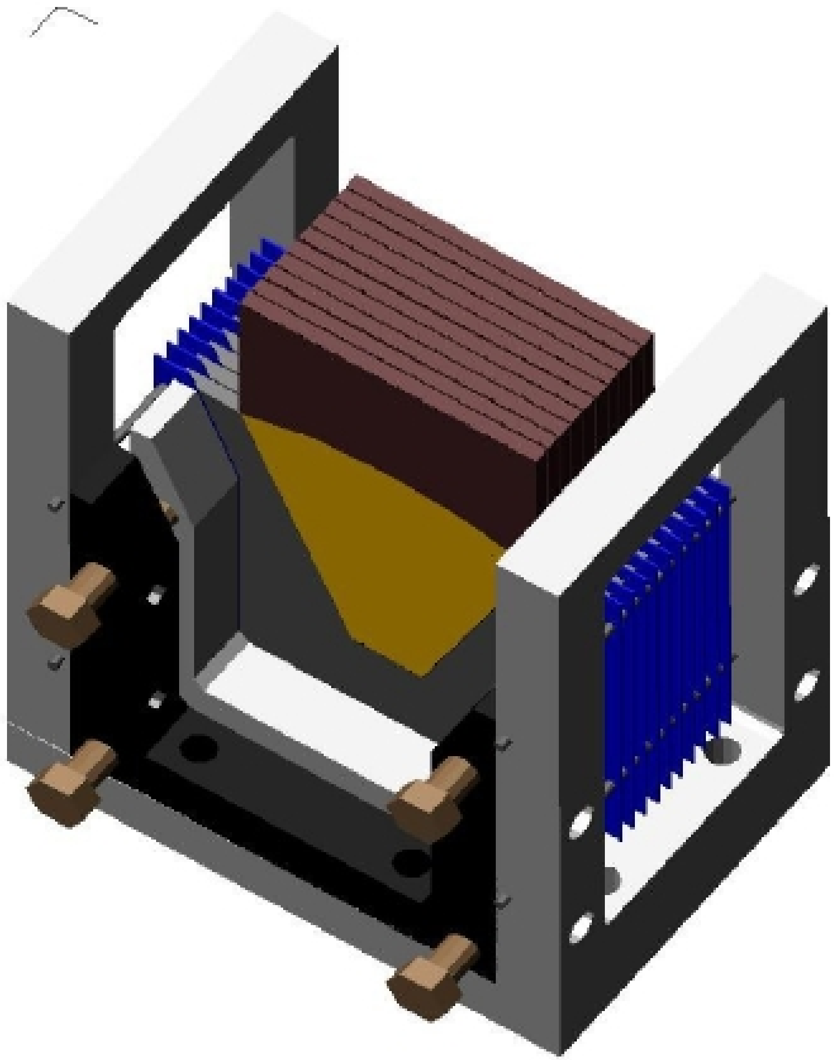


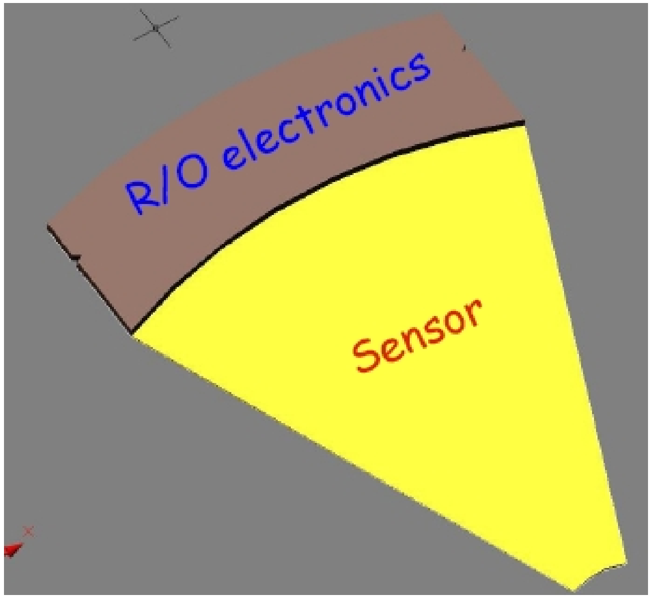


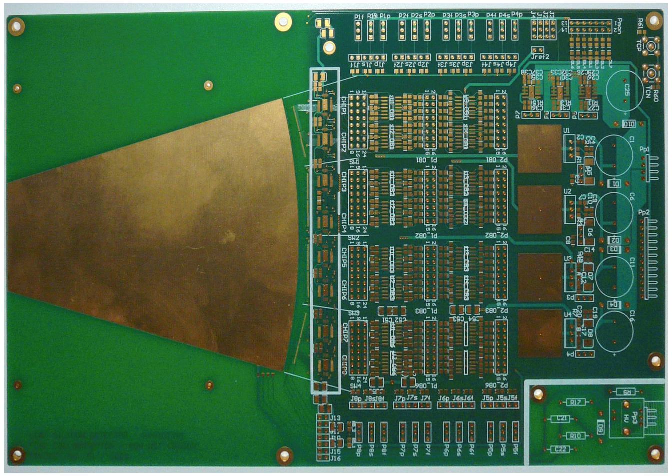
Next steps : towards test beam (1)

W. Lohmann: FCAL–AIDA (FP7) proposal

Very precise (micrometers), flexible mechanical construction with 10 (or more) Hamamatsu silicon sensor detectors

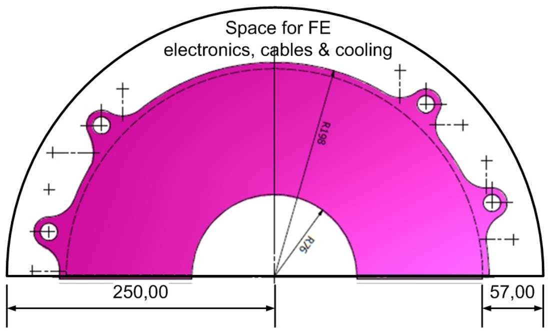


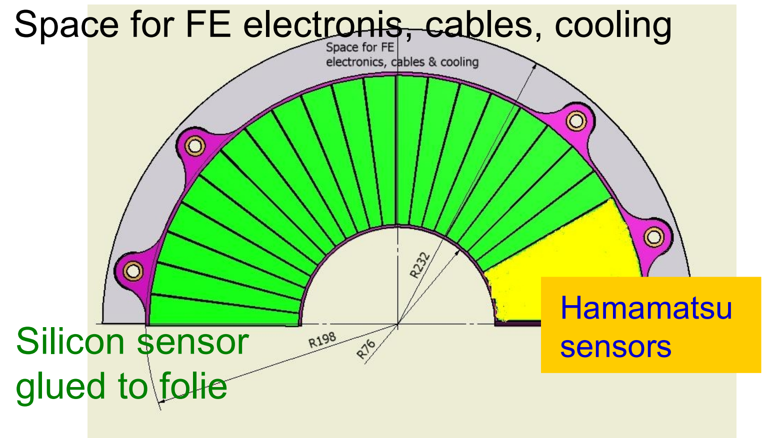




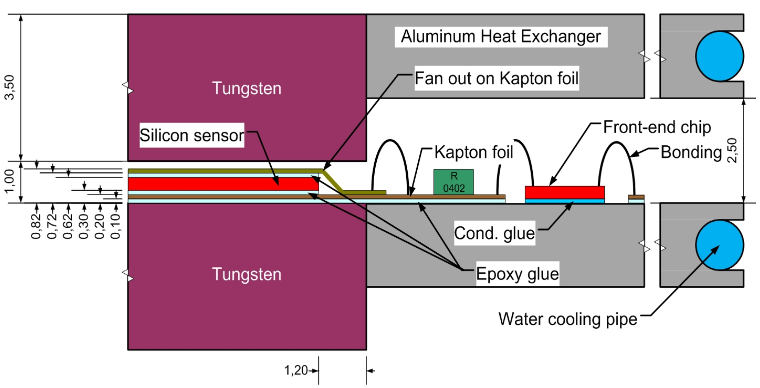
R&D: Basic modul of the LumiCal calorimeter

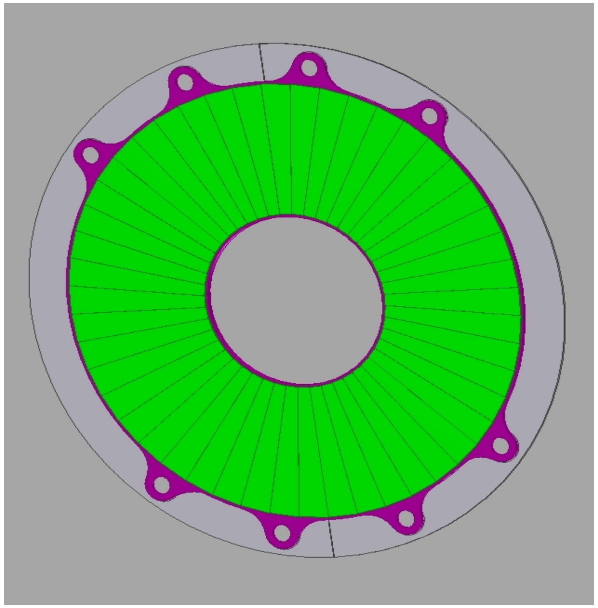
Half ring shape of a tungsten layer





Fan out glued to tungsten





Goal:
test of complete basic modul:
tungsten +
sensors +
FE electronics +
elements of
alignment system

Conclusions

- The sensors measurements were done on randomly chosen detectors (from 20 – Cracow) supplied by Hamamatsu. All the measured values were within specification.
  The results are comparable with those obtained at Zeuthen and Tel Aviv laboratories.

- C-V measurements indicate that Si material used by Hamamatsu has very high resistivity, which results in a relatively low value of depletion voltage

- Low values of currents in I –V test measurements prove that minority carriers lifetime in Si is long (over 1 ms), which confirms high quality of Si material used by H-u company

- The visual inspection, good uniformity of current values from pad to pad, non degraded value of minority carriers lifetime and small values of pad currents at $U > 3\ U_{depletion}$ confirm an excellent technological process used by Hamamatsu

- Obtained results and good reputation of H-u company allow to believe that non-investigated detectors are also of the same high quality

- Next step : use these detectors together with FE electronics in beam tests (DESY,…)