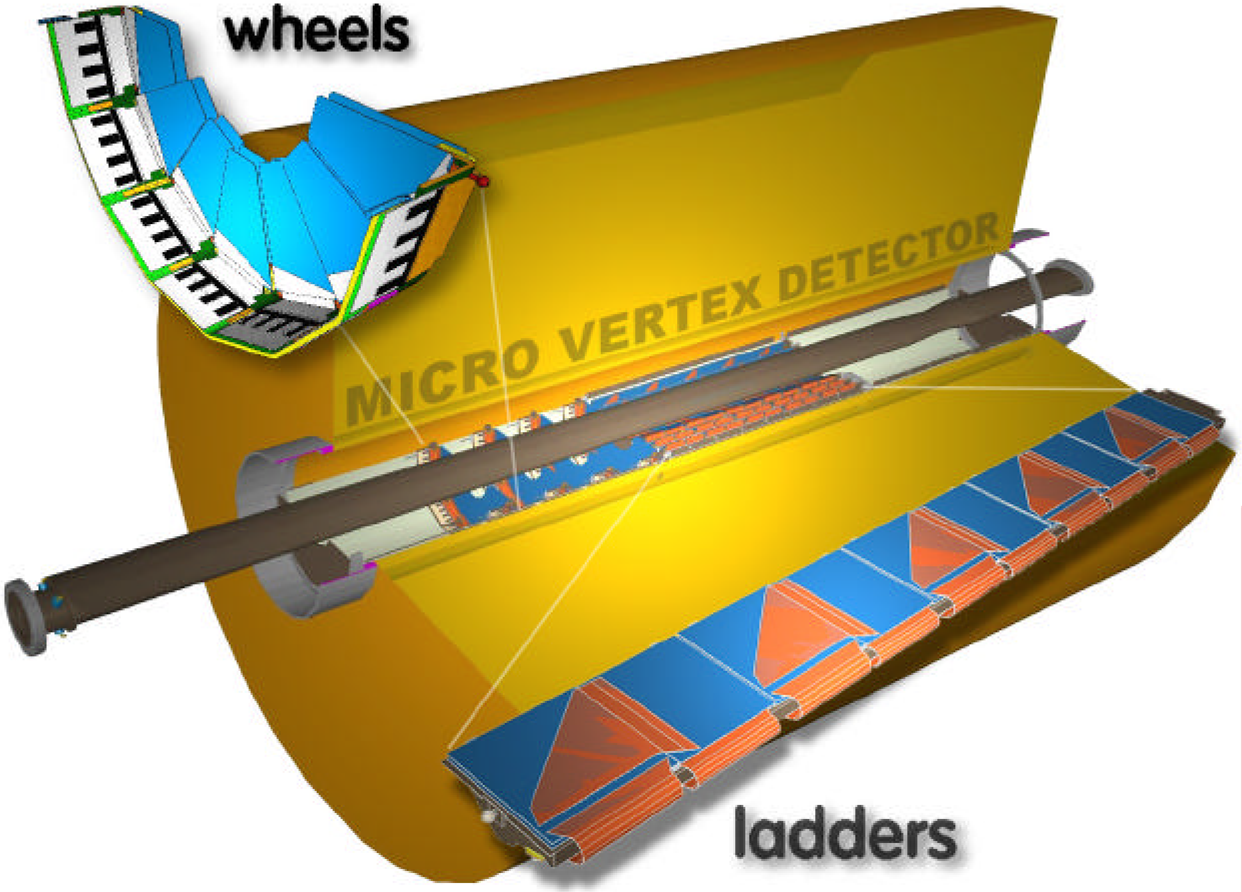
The Quality Assurance during the production of the ZEUS Micro Vertex Detector



A.Garfagnini

CERN, 17th May 2001

Universitaet Hamburg
for the ZEUS MVD Group

ZEUS MVD GROUP:
Bonn Univ., DESY-Hamburg, DESY-Zeuthen, Hamburg Univ., KEK-Japan, NIKHEF-Amsterdam, Oxford Univ., Padova, Torino, Bologna and Firenze Univ. INFN, UCL.

HERA Luminosity Upgrade

Increase instantaneous luminosity to

$L = 7.5\ 10^{31}\ cm^{-2}\ s^{-1}$ (now 1.5)

Expected to deliver ~ 150 pb^{-1}/year.

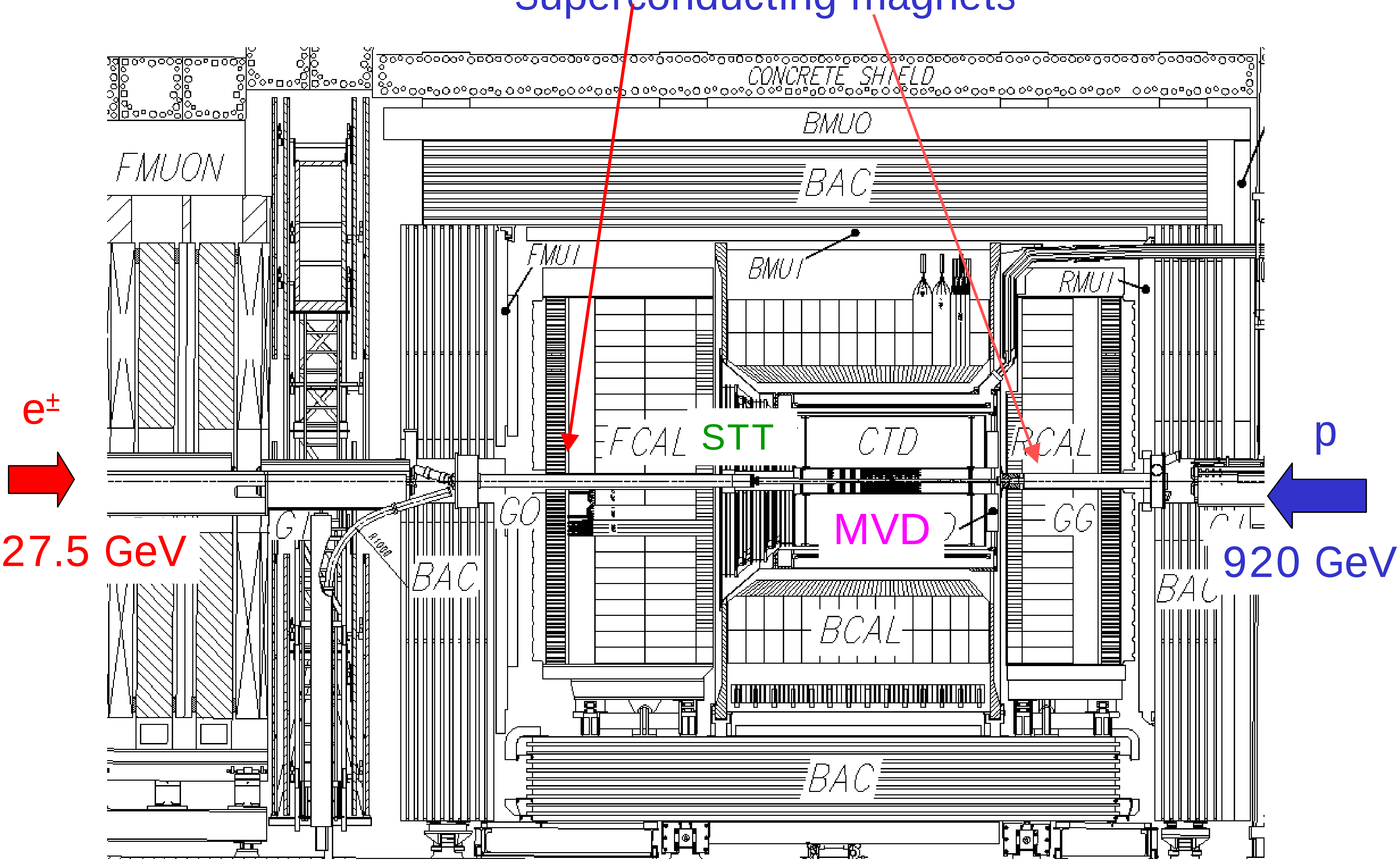
→ higher sensitivity to low *ep* x-sections.

The ZEUS experiment has prepared a general upgrade of the tracking system: silicon Micro Vertex Detector (MVD) and Straw Tube Tracker (STT) close to the beam pipe.

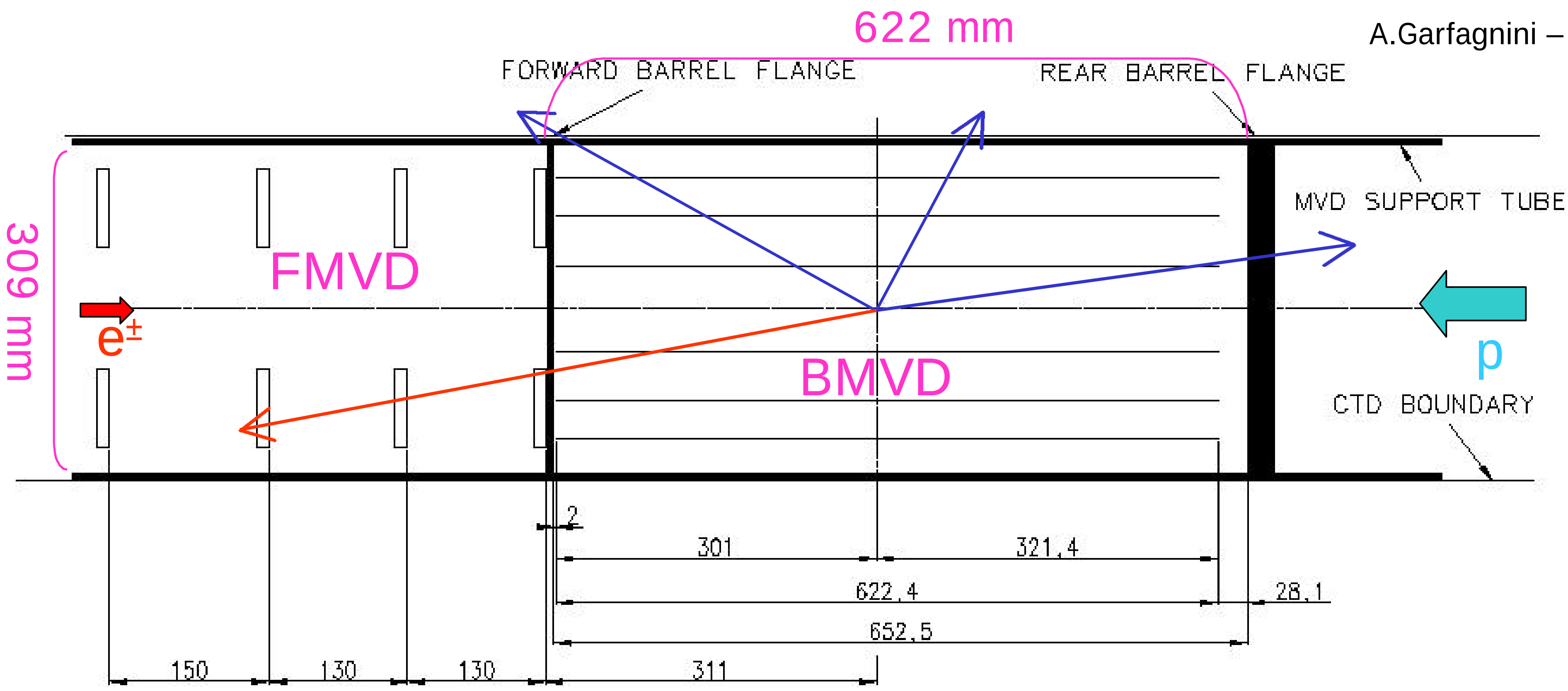
<u>Aim:</u>

- identify 'long-lived' states ($c\tau$ ~ 300 μm);
- reconstruct secondary vertices;
- extend detector acceptance in forward region (high Q^2 events);
- improve overall performances of the tracking system.

Superconducting magnets



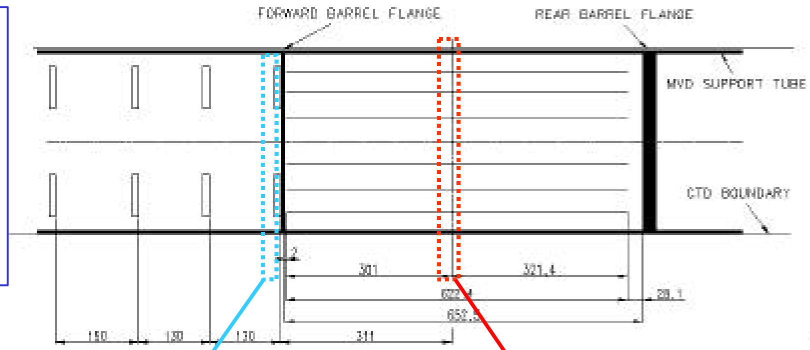
bunch crossing time: 96 ns



<u>Requirements / design goals</u>:

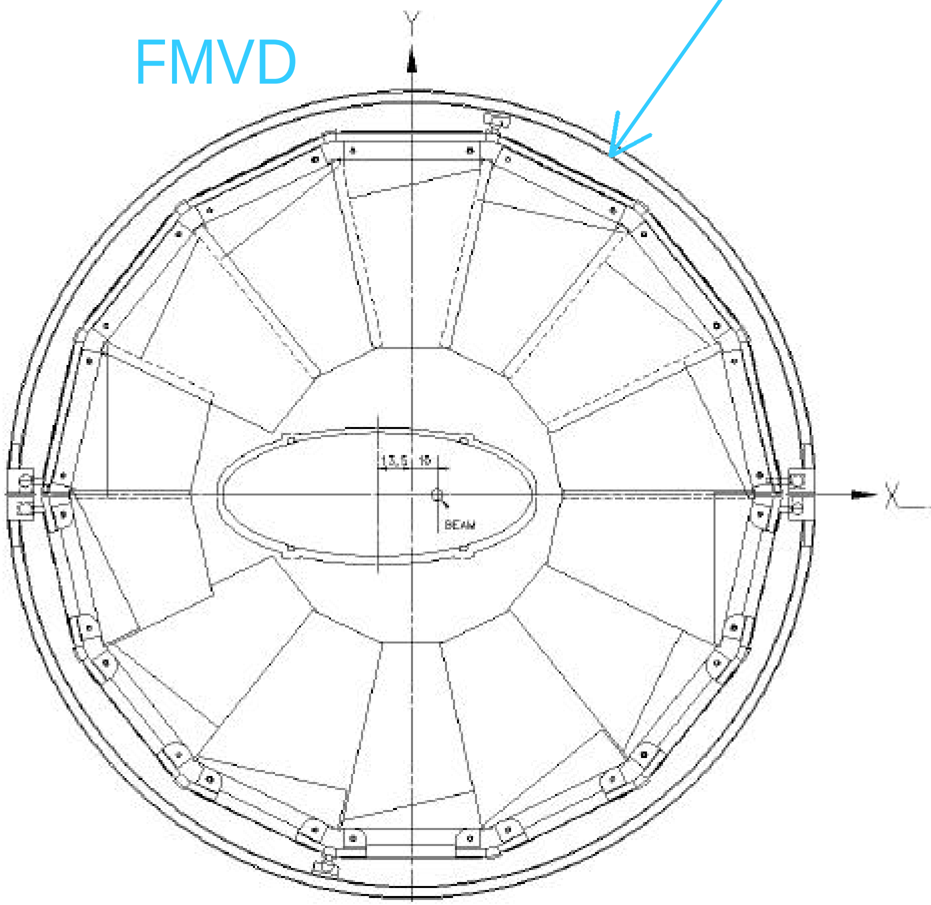
- good matching w/ existing tracking devices (fit into existing space → readout chip inside active area);
- long interaction range: σ_z ~ 10 cm;
- polar angle coverage 10° - 160°;
- 3 spatial measurements, in two projection each, per track;
- 10 μm intrinsic hit resolution;
- operate for ≥ 5 years (survive 3kGy w/o losses of performances);

112 wedge shaped detectors;
r-ϕ measurement @ fixed z.

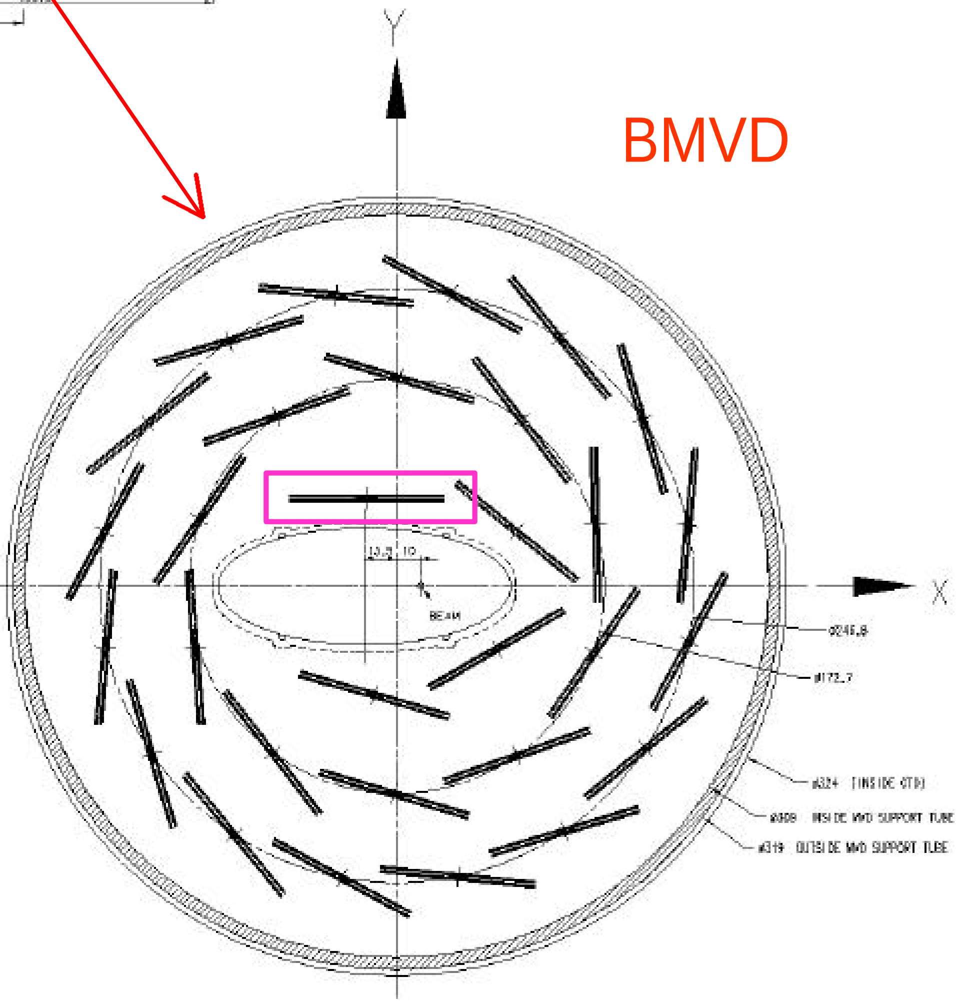


600 square detectors;
r-ϕ and r-z measurements.

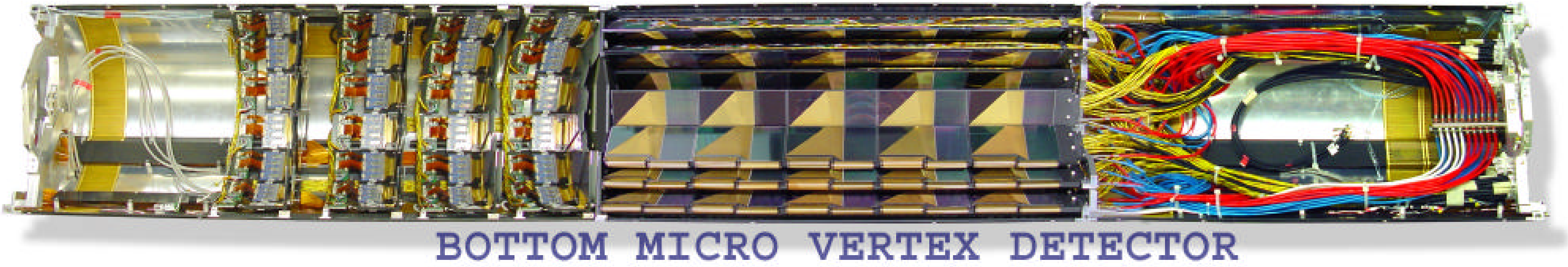
FMVD

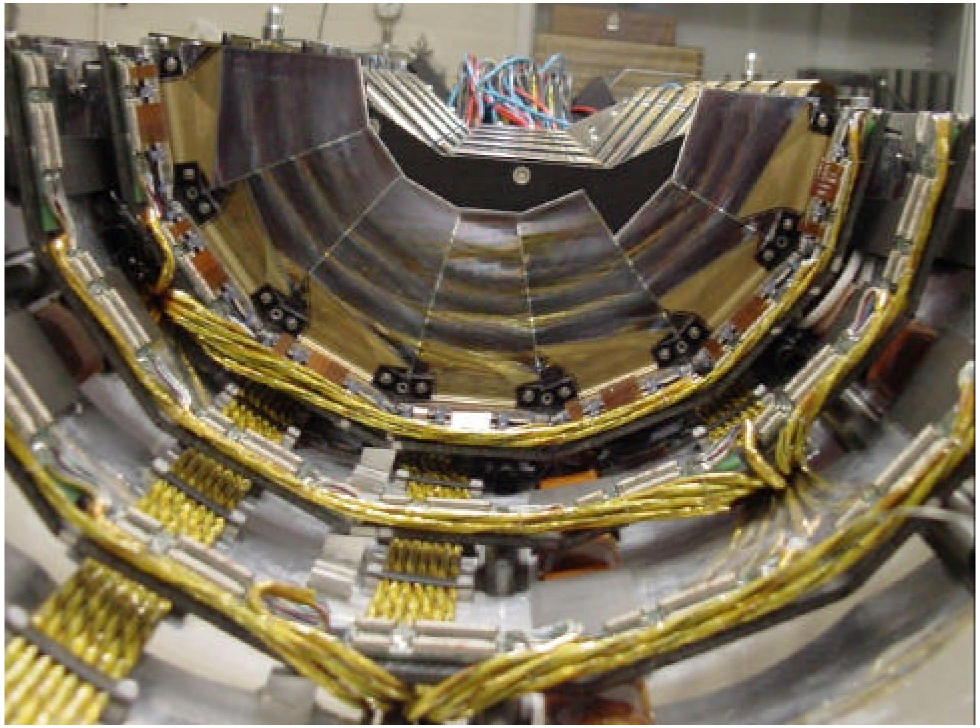


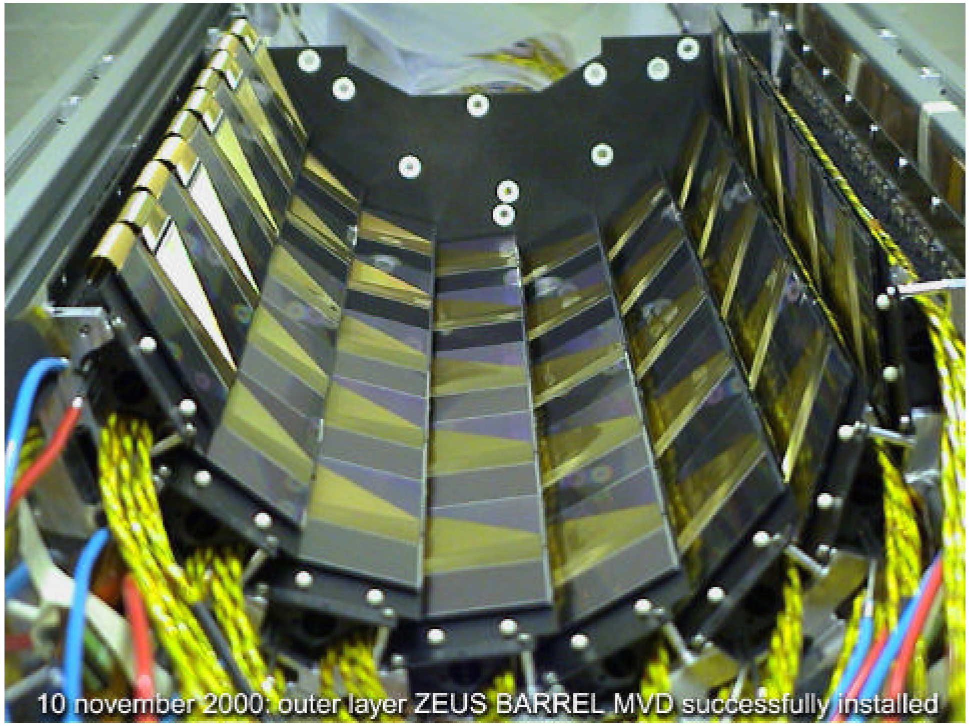
BMVD



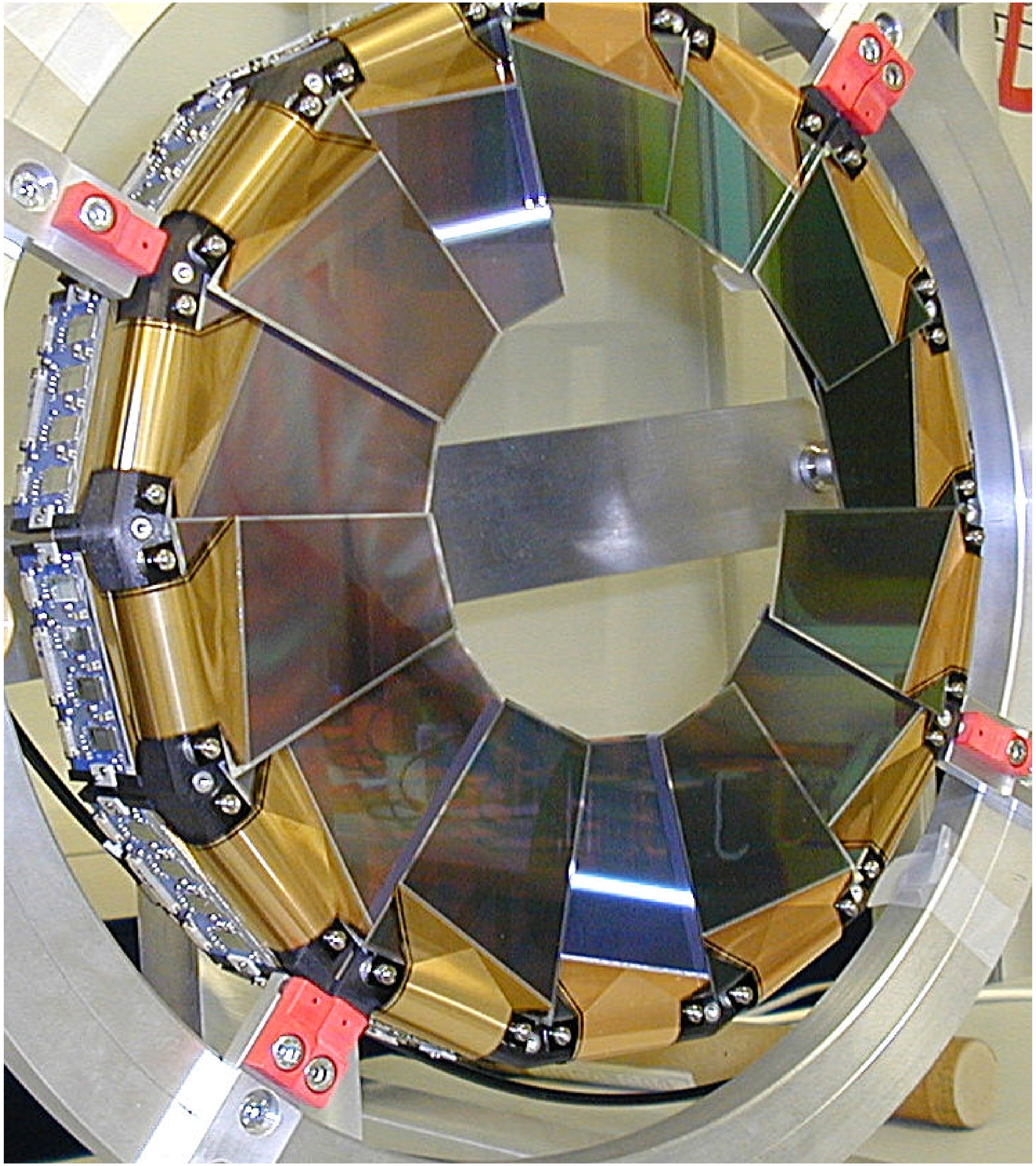
MVD layout

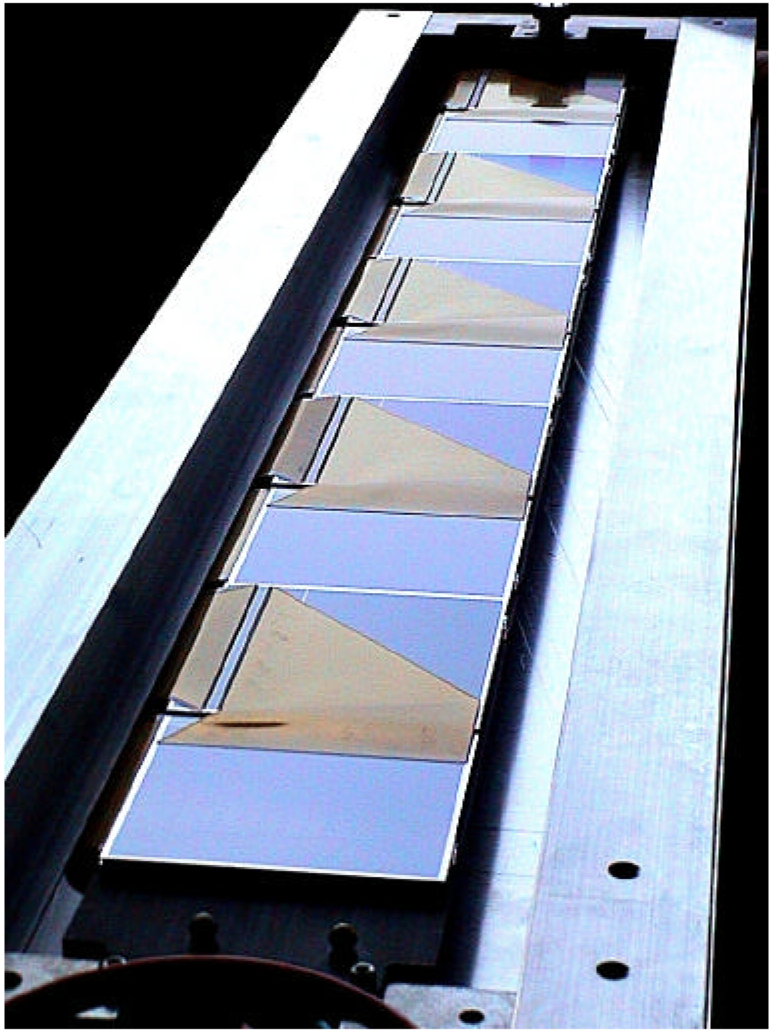

BOTTOM MICRO VERTEX DETECTOR

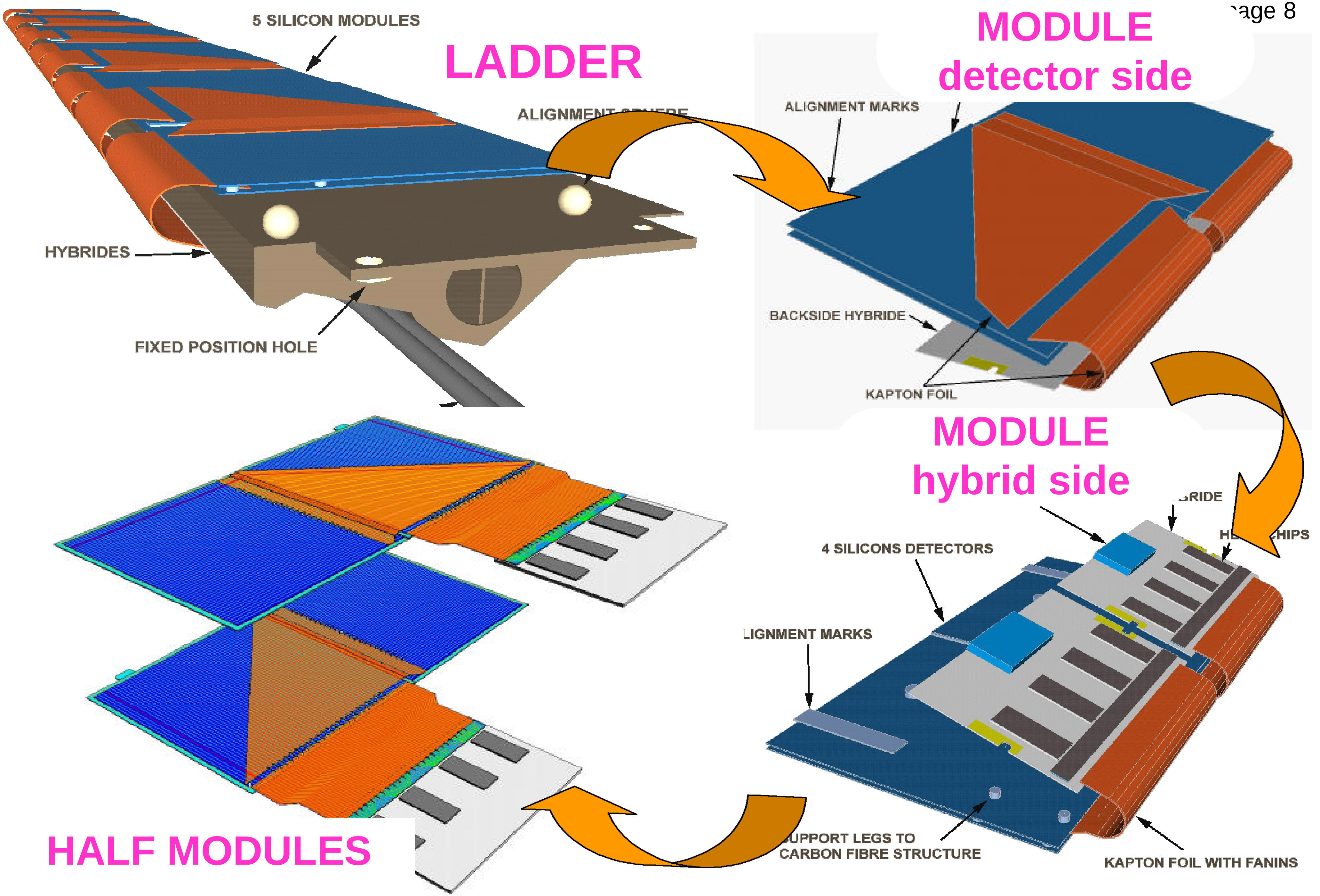



10 november 2000: outer layer ZEUS BARREL MVD successfully installed

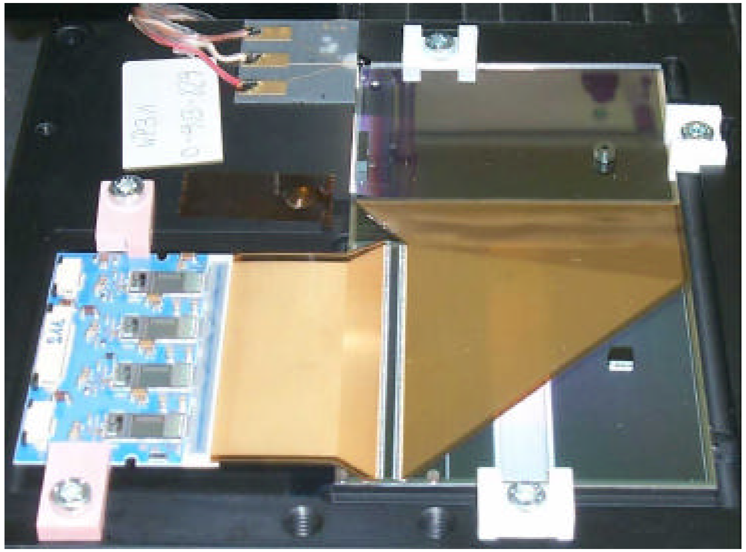
MVD Wheel
MVD ladder

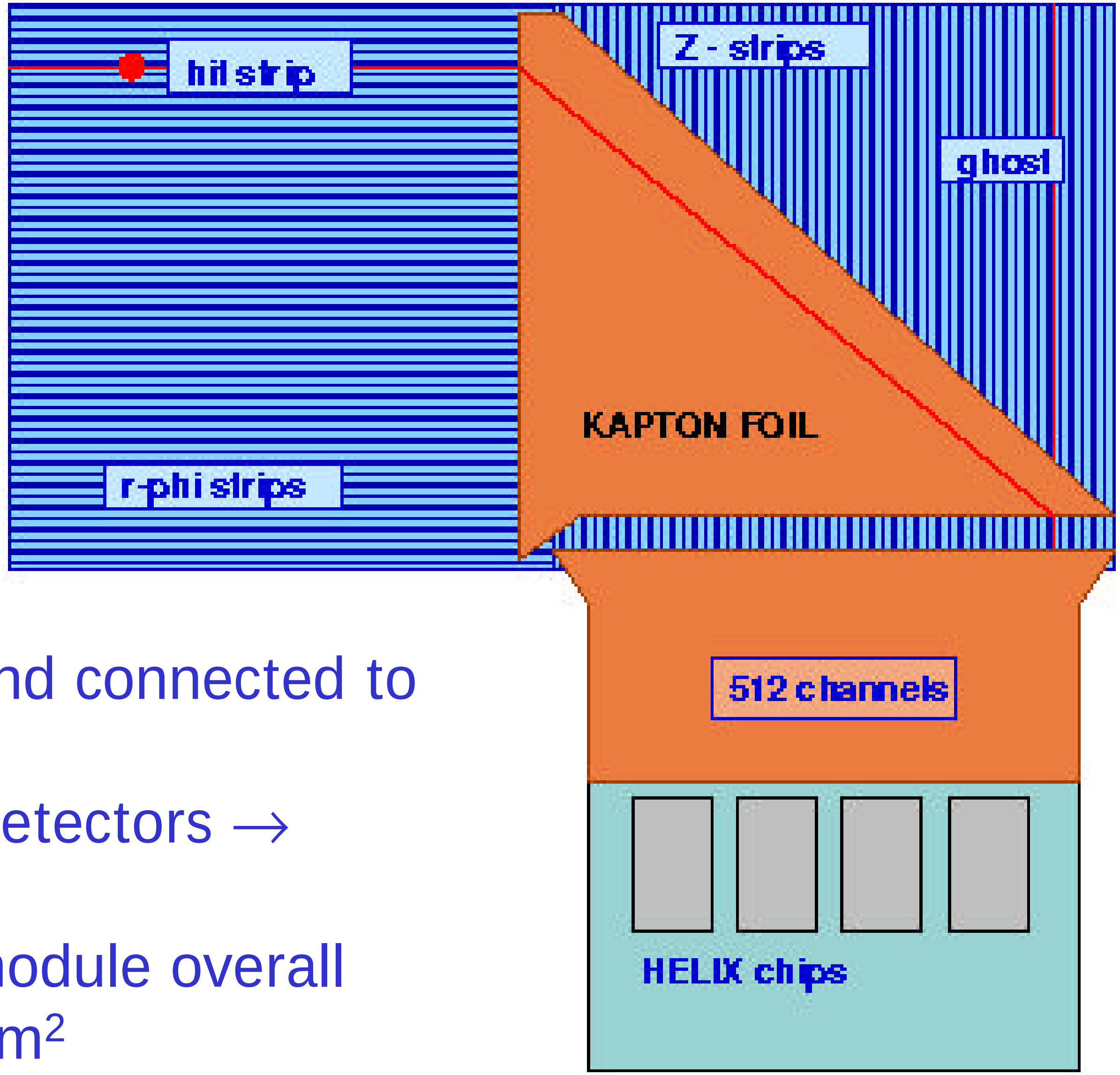





LADDER
5 SILICON MODULES
ALIGNMENT
HYBRIDES
FIXED POSITION HOLE
MODULE
detector side
ALIGNMENT MARKS
BACKSIDE HYBRIDE
KAPTON FOIL
MODULE
hybrid side
4 SILICONS DETECTORS
LIGNMENT MARKS
UPPORT LEGS TO
CARBON FIBRE STRUCTURE
KAPTON FOIL WITH FANINS
HALF MODULES

BMVD half-module

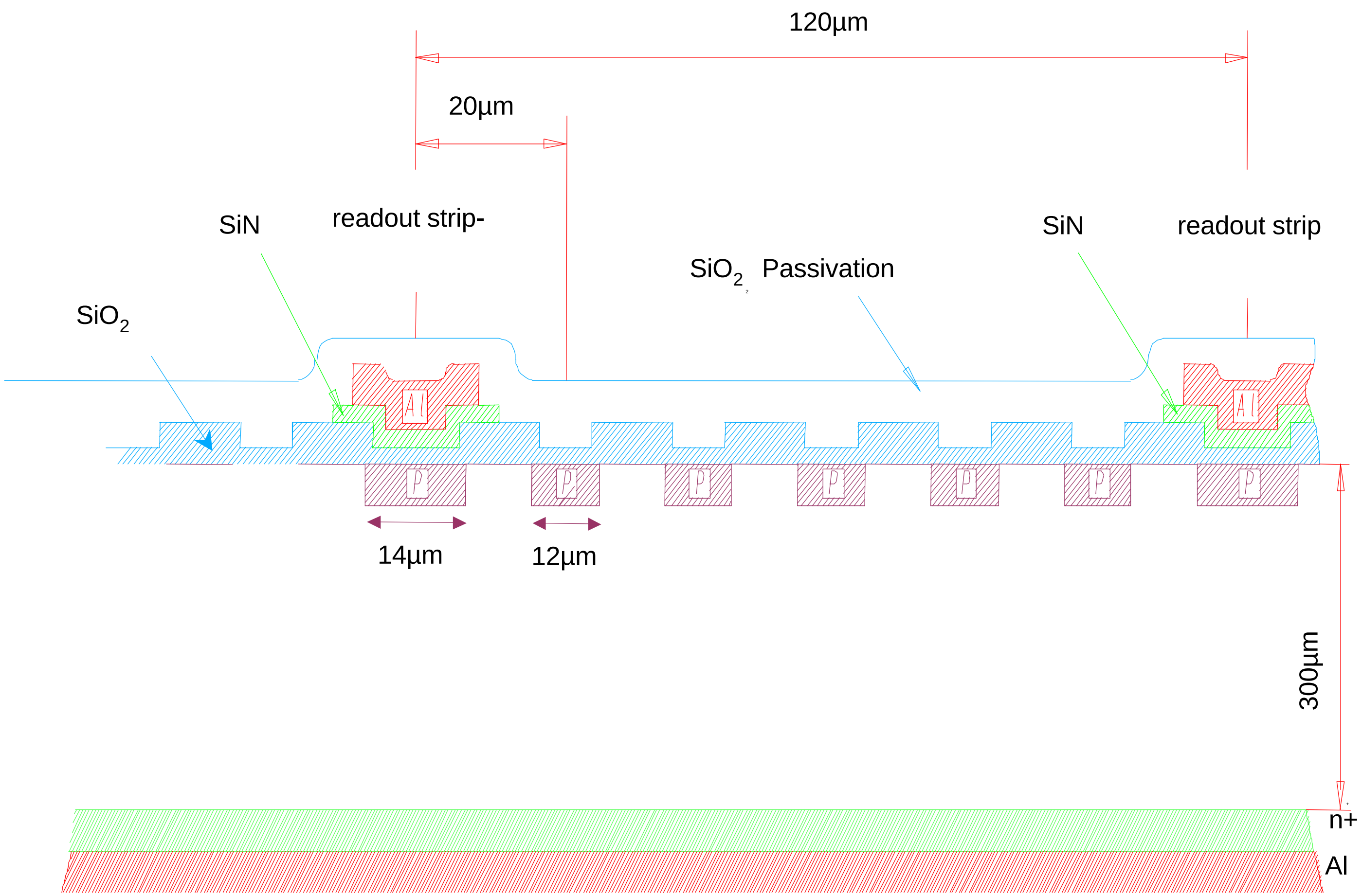




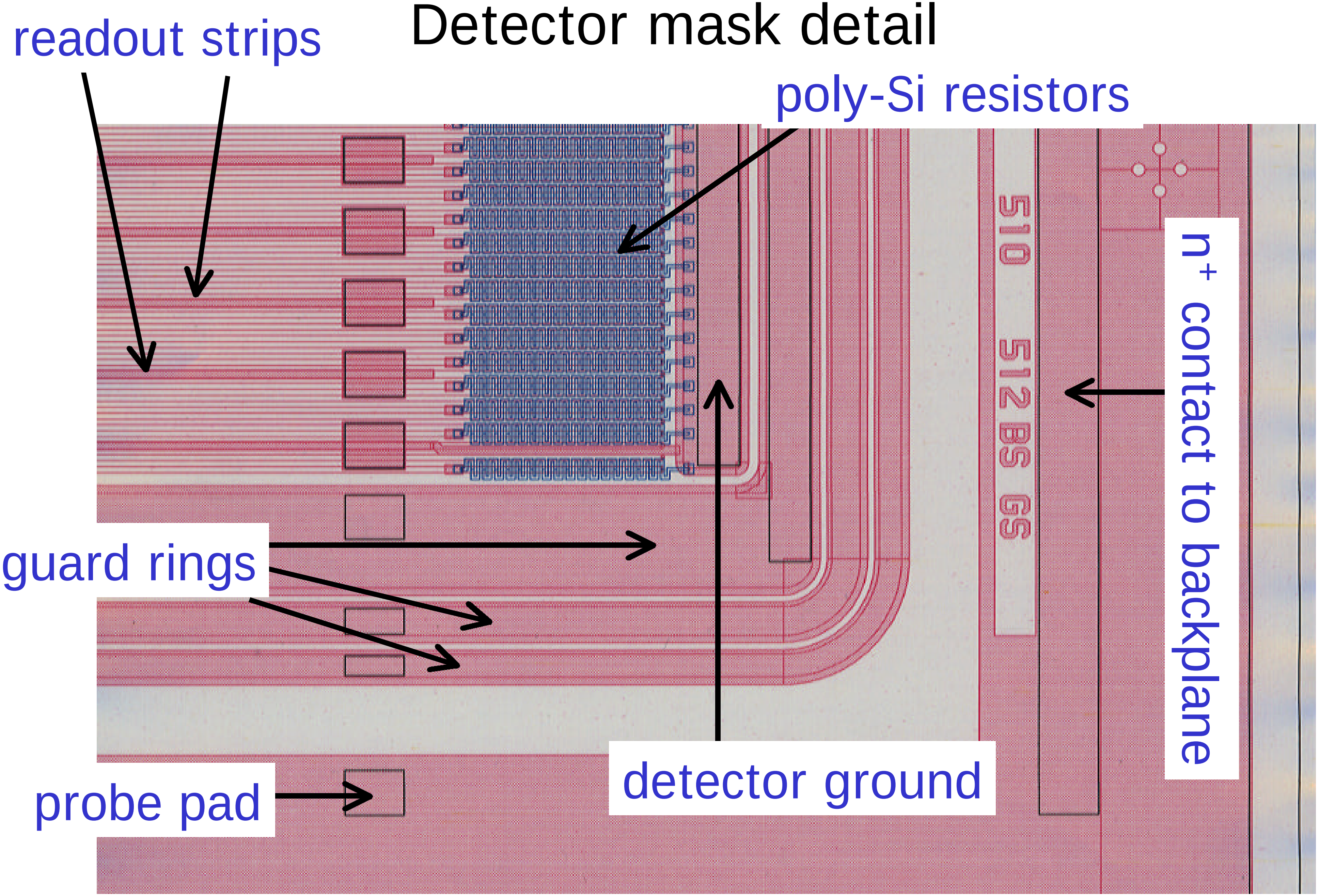
- two detectors coupled and connected to FE electronics;
- small overlap between detectors $\rightarrow$ minimize dead areas;
- r-φ, r-z readout cells / module overall dimensions: 125×64 mm^2

Si detector layout

- Single sided high resistivity diodes (Hamamatsu);
- 512 (480) readout strips, AC coupled, use charge division;
- biasing trough poly-Si resistors.



Detector mask detail



Electrical specifications of MVD detectors

Parameter		Specification	measured value	measured at
$V_{Depletion}$	depletion voltage	60..95V	60..70V	Detector
ρ_n	resistivity of n-material	3..6 kΩcm	5.3 kΩcm	Detector
$I_{leakage}$	leakage current	<2μA @ 200V, 20°C	20 nA .. 100 nA	Detector
R_{PolySi}	Biasing resistor	1.5 ± 0.5 MΩ	2.1 .. 2.8 MΩ, ±0.02 MΩ	Test-structure
R_{p+}	p+-resistance	<150 kΩ/cm	100 kΩ/cm (interstr.) 90 kΩ/cm (readout-str.)	Test-structure
R_{Al}	Al-strip resistance	<20 Ω/cm	<20 Ω/cm	Test-structure
C_C	Coupling capacitance	>20 pF/cm	≈ 30 pF/cm	Detector/Test-structure
I_{Cc}	Max. leakage current through C_C	<100 pA @ Vcc=60V	≤20 pA	Test-structure

Single diode QA

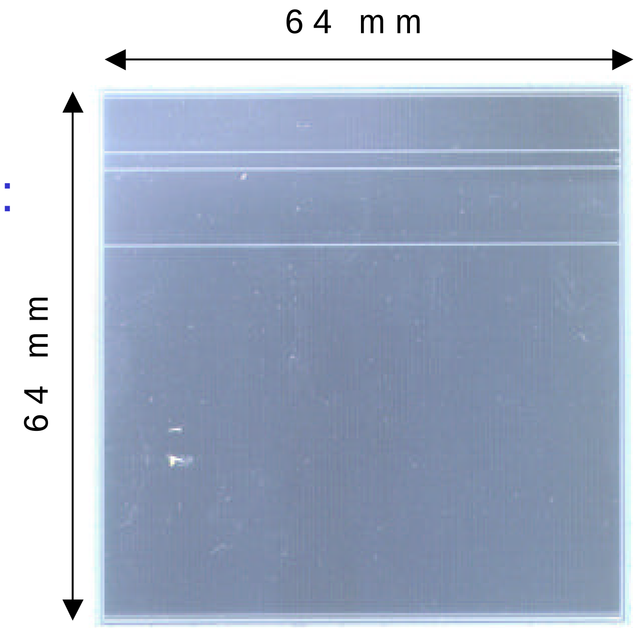
Set of QA performed by producer (Hamamatsu):

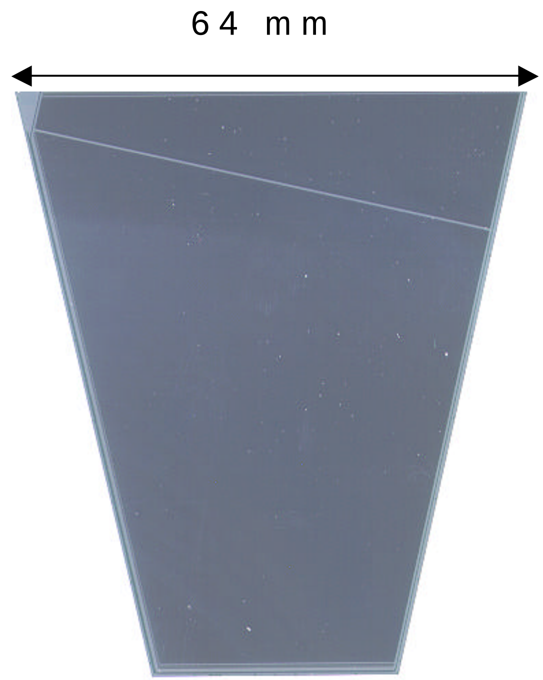
- C/V and I/V characteristics (BR and GR separately);
- Checks of strip defects:
  - Broken Al lines;
  - Shorts strip-strip and p^+-Al.

Yield: 94% of detectors no strip errors, 6% have less than 0.4% of strip errors.

QA performed by the purchaser:

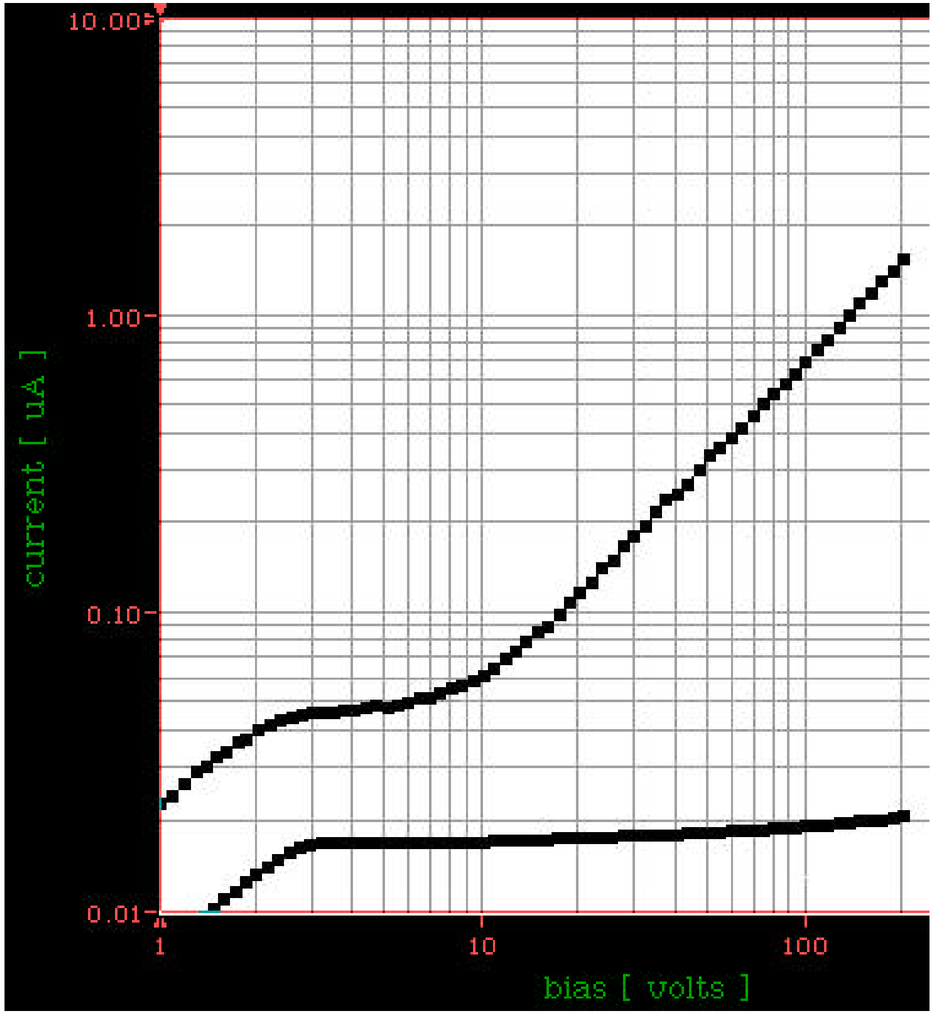
- Verification of technological parameters (test structures);
- Long Term Test of leakage current;
- shape measurements.



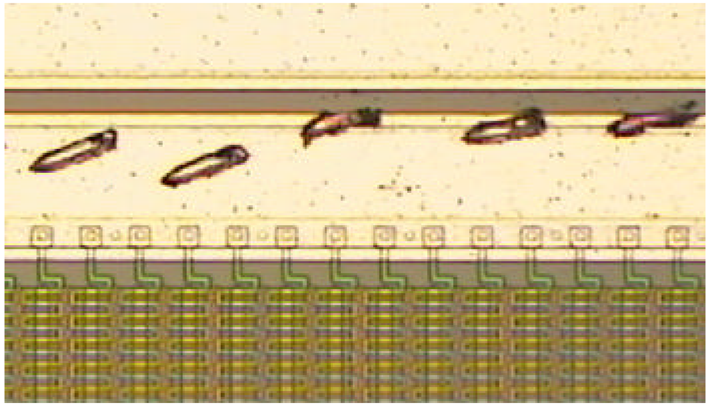


Damage by Probe Needles

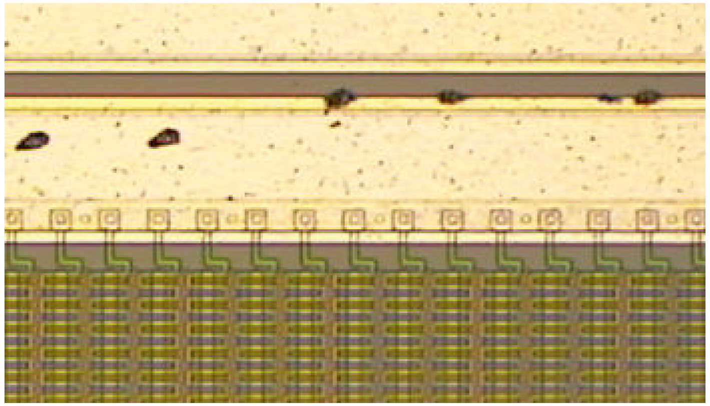
Force extorted by probe needle (Ø = 14 μm) may produce damage
20 g prober force $\rightarrow$ 10 t/cm^2 $\rightarrow$ 1 μm penetration depth



20 g



5 g

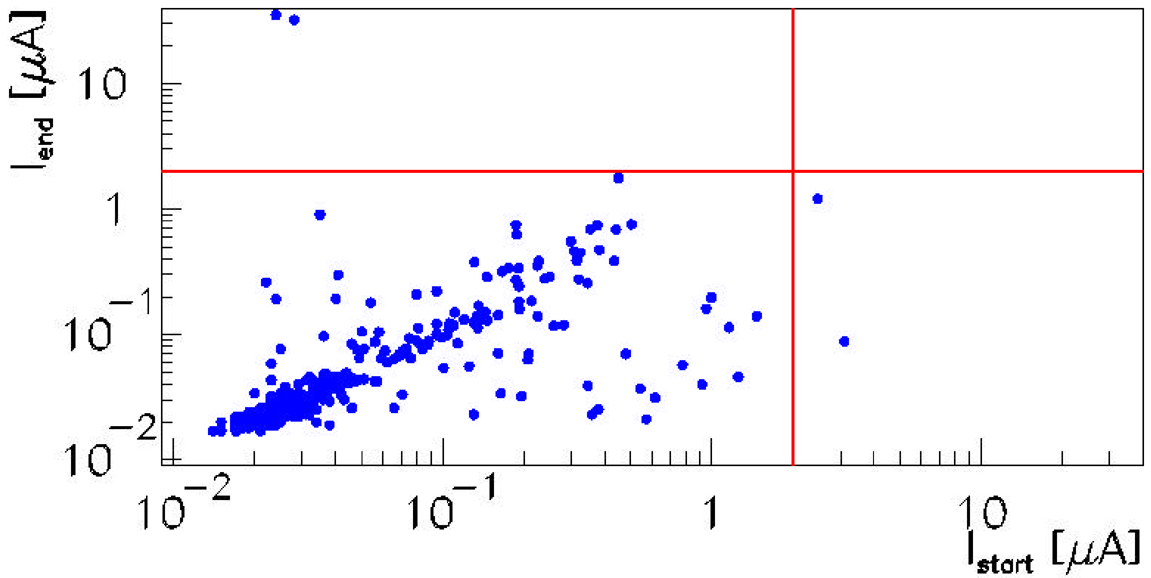


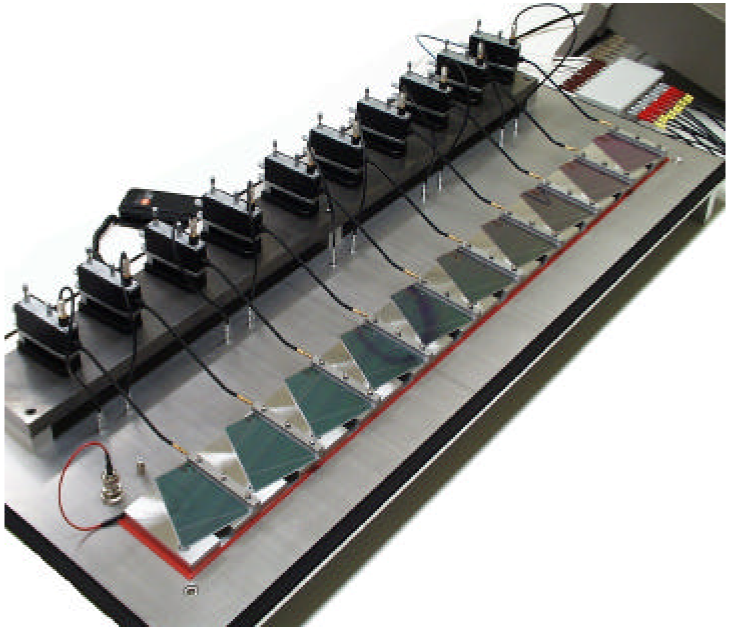
Single Diode Long Term Test

AIM: check stability of detectors over time.

$\longrightarrow$ G.Barichello et al., CERN-EP/98-21

- detector under bias (200 V) for 24/48 h;
- measure current.

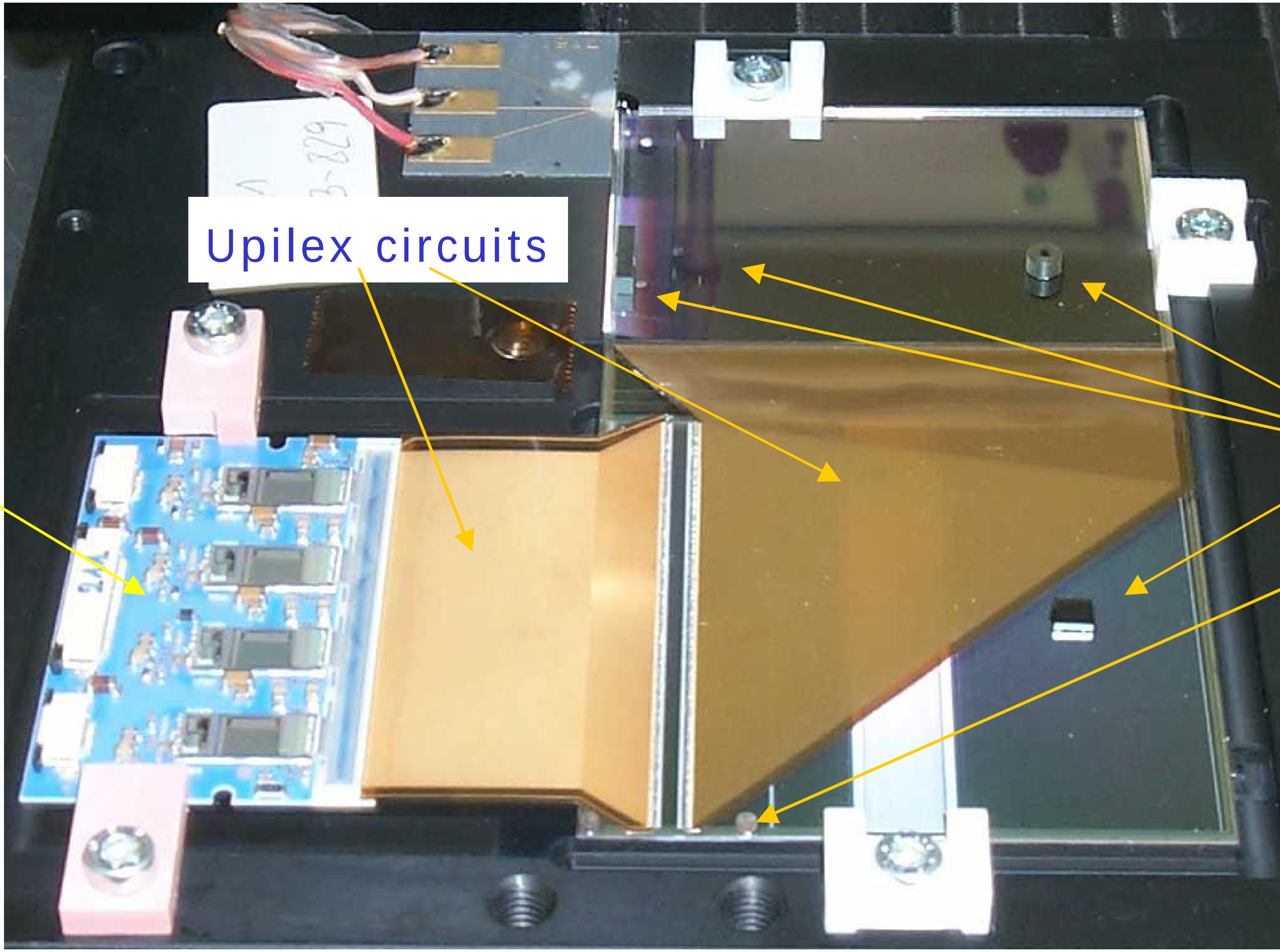




~1000 detector tested. Yield: 0.3%

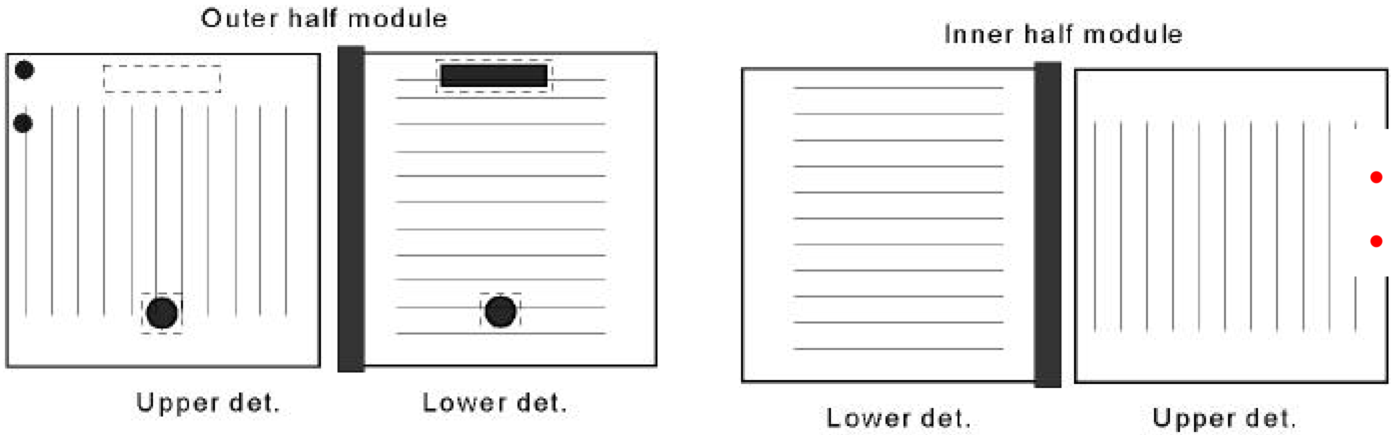
Half module assembly

Readout Hybrid



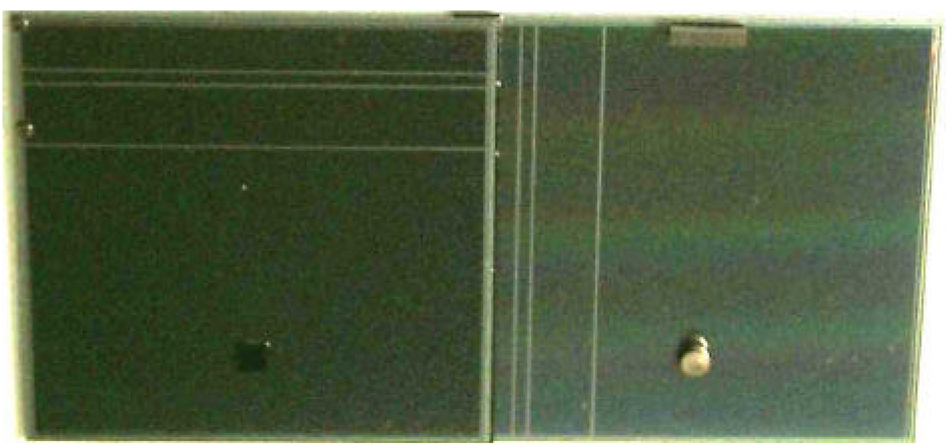
Spacers

(1) spacers gluing



- I/V measurement;
- shape measurement.

(2) Half Module gluing



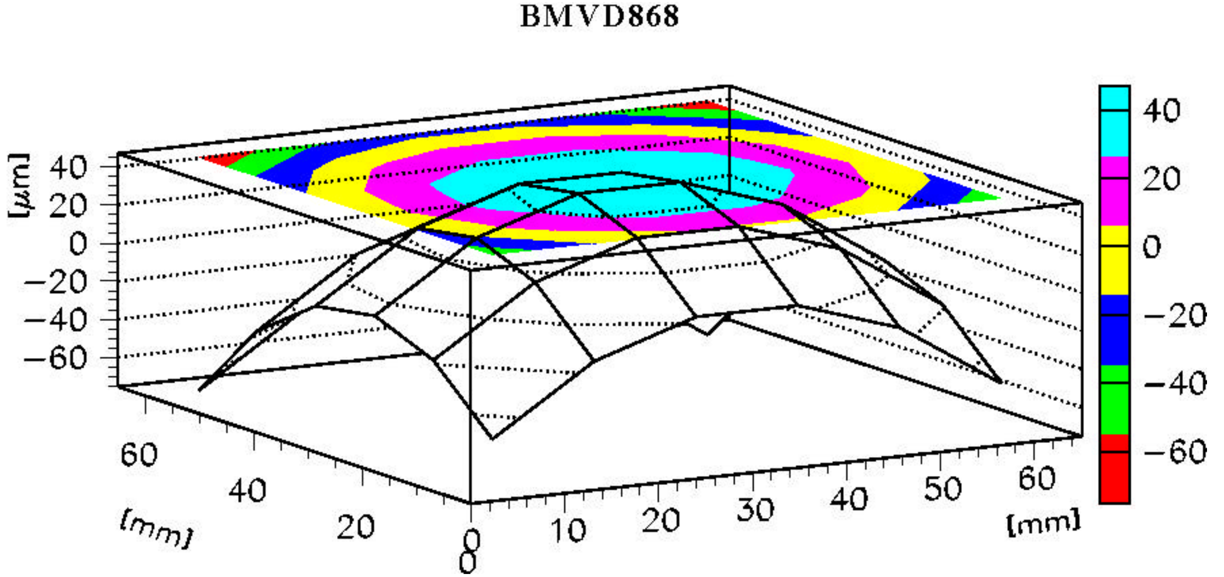
- Alignment meas.
- I/V meas.
- shape meas.

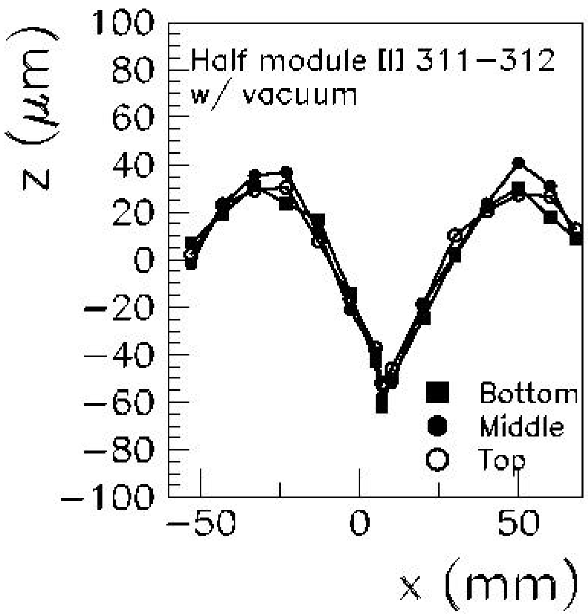
Detector/Half module shape

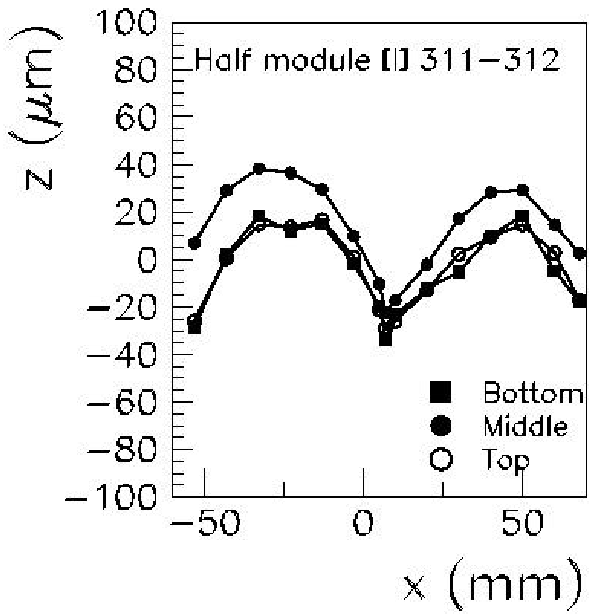
Quite big detector

$\longrightarrow$ surface not flat

Geometry further affected by spacers gluing.
Deviations even bigger after HM gluing: need a 'seagull' jig.

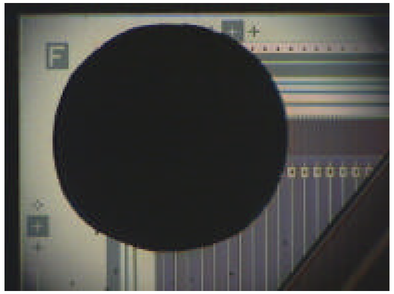






Ladder geometry measured during HM assembly @ Nikhef$\longrightarrow$ input for reconstruction.

Spacer gluing / HM gluing



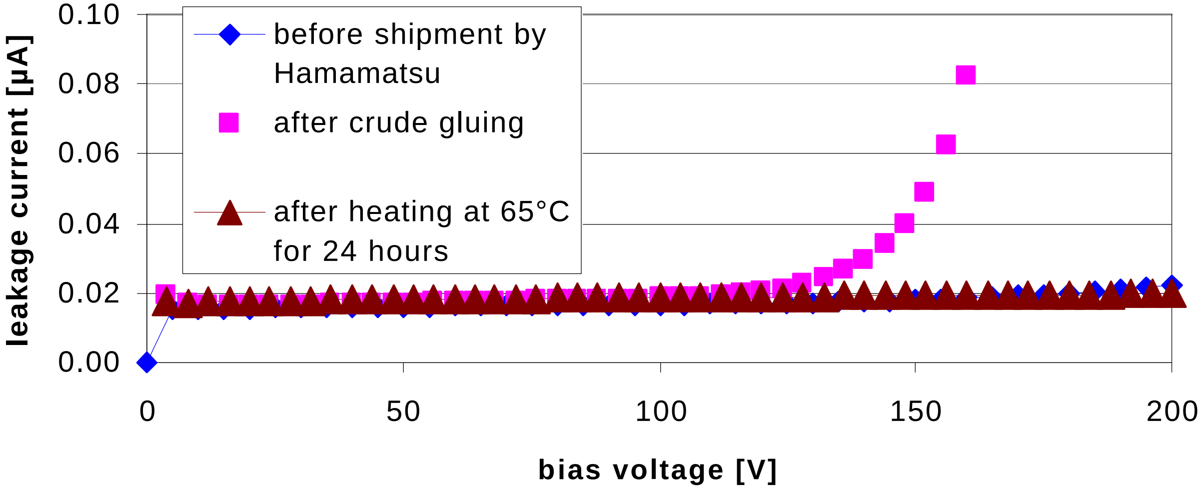
provide support for ladder and HM gluing;

- material: cirlex® (CTE = 20 10^{-6} K^{-1});
- glue: Epoxy (CTE = 60 10^{-6} K^{-1});
- Si detector (CTE = 1.6 10^{-6} K^{-1});

some spacers / glue cover the active detector area

→ increase of dark current (5% of cases)

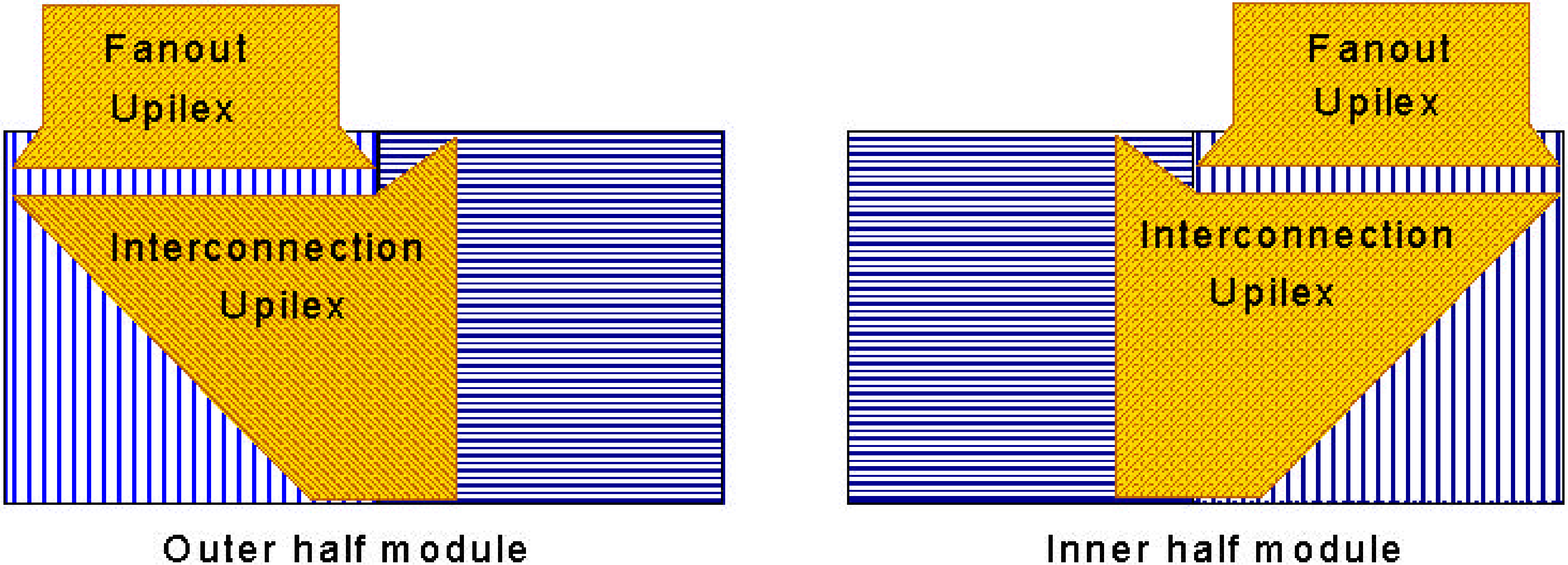
decrease of leakage current after heating



→ heating (24 h @ 65°C) reduces the problem.

(3) Shipping to DESY-Zeuthen

(4) Upilex gluing



- visual inspection;
- alignment meas.

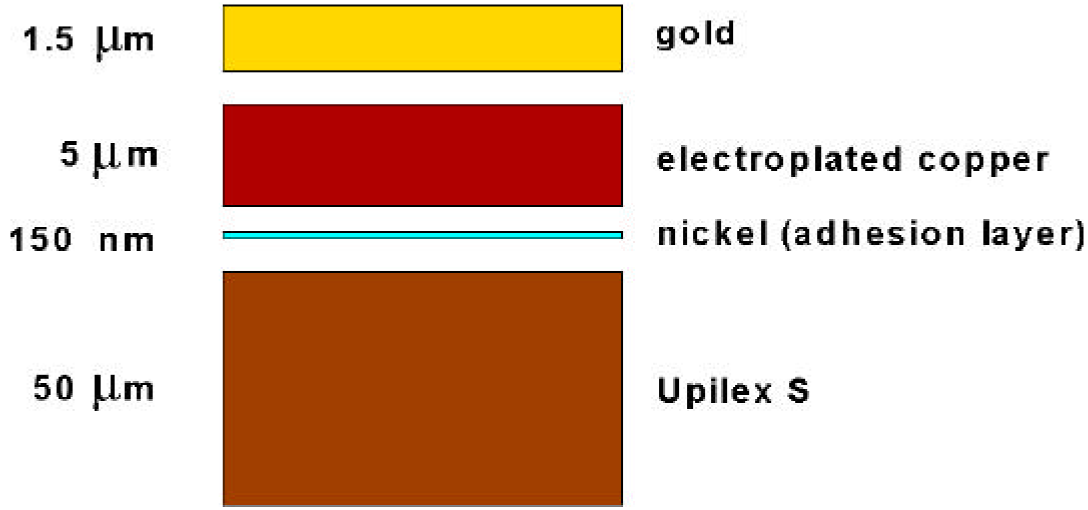
(5) Shipping to DESY-Hamburg

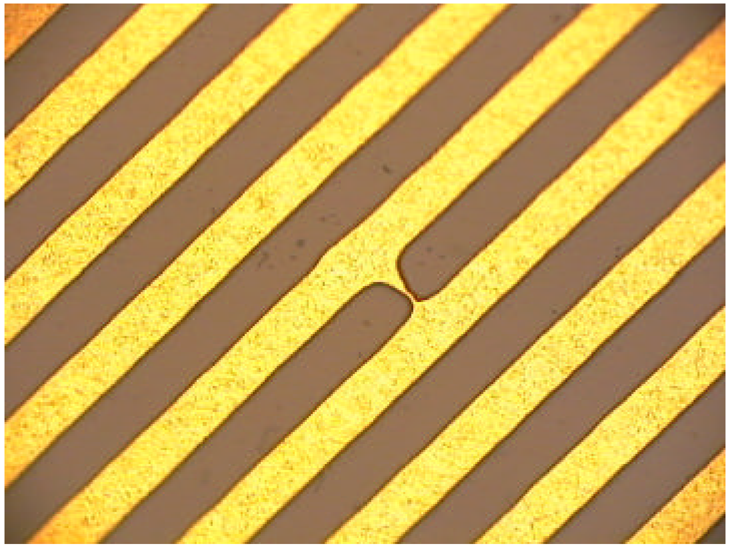
Upilex circuits

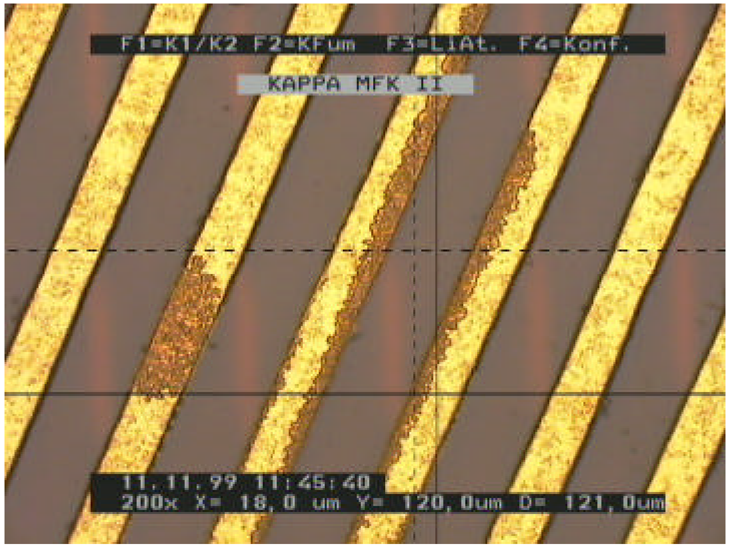
Produced @ CERN (A.Gandi's workshop)

Acceptance tests:

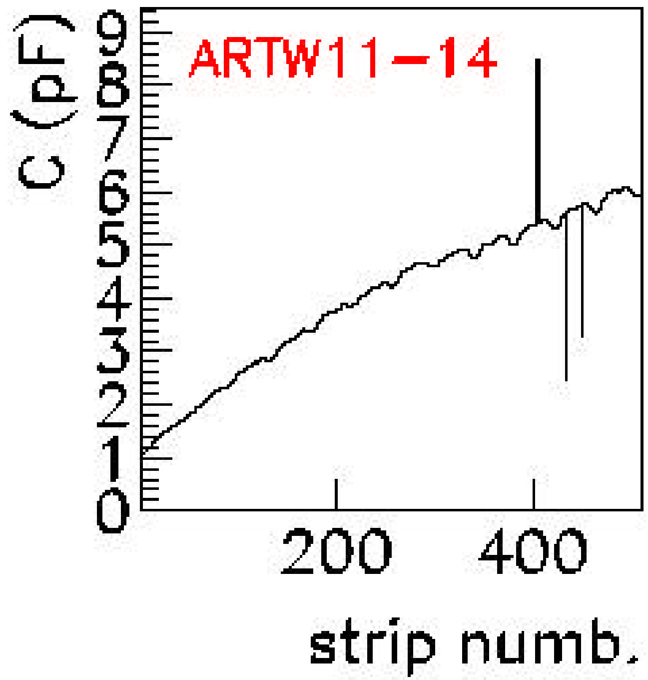
- visual scan
  - mask/cut errors;
  - missing gold (strip interruptions?)
  - quality of bond pads area;
- electrical measurements (R):
  - short between strips;







Upilex QA

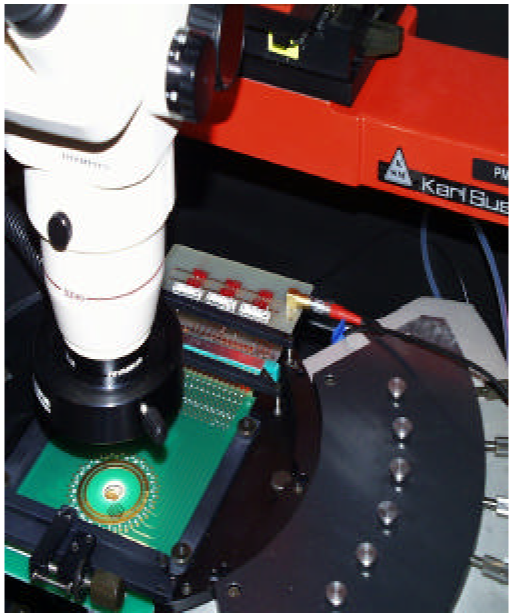


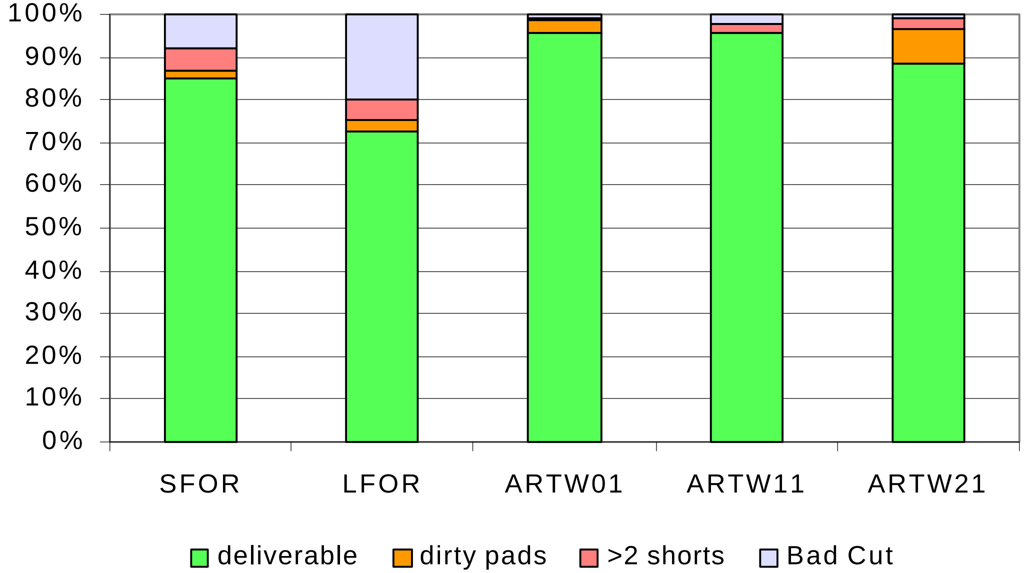
Method:

1. measure C between strip and backplane;
2. measure shorts between strips (Ohm's law)

Upilex Acceptance criteria:

- short between strips ≤ 2;
- strip interruptions ≤ 1;
- no chemical remnant on bond pads.



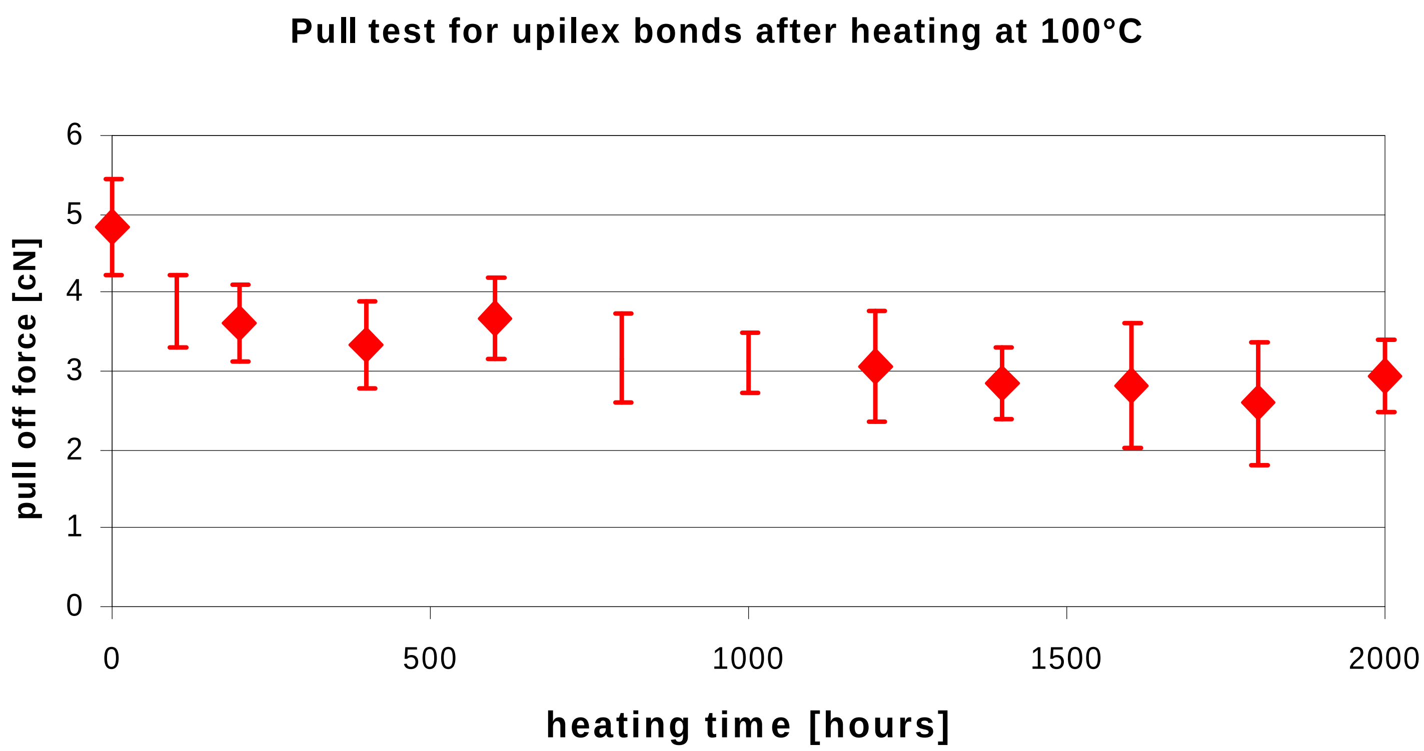


Studies on Cu → Au diffusion

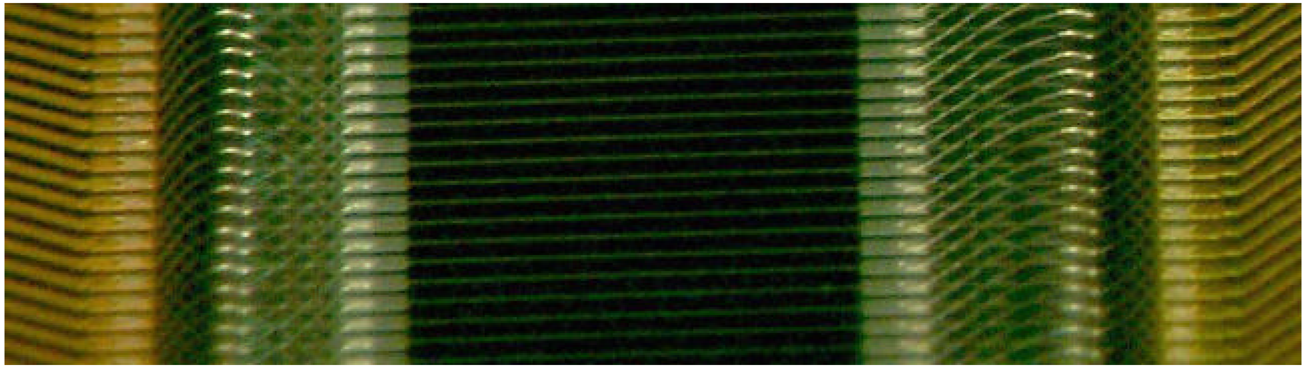
<u>Investigation of remnants/missing gold</u>:
- electron microscope;
- plasma etching @ CERN improved the bondability of Upilex
- discussion w/ chemical bath producer;

- heating tests (100 °C, up to 2000 hours)

→ no pull-offs, degradation of the wire.

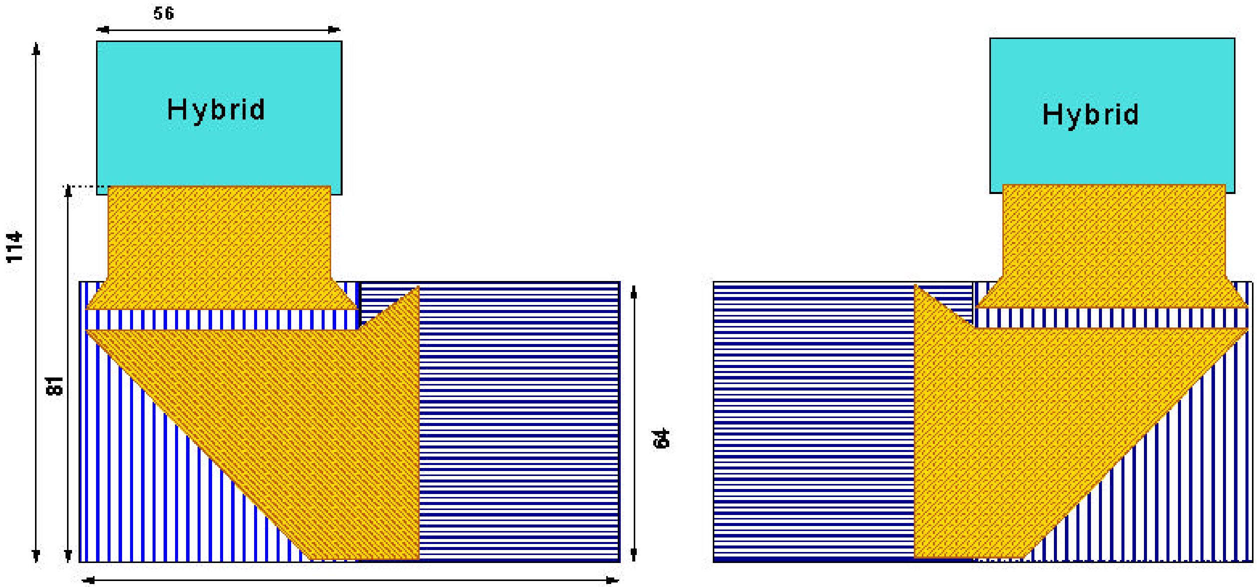


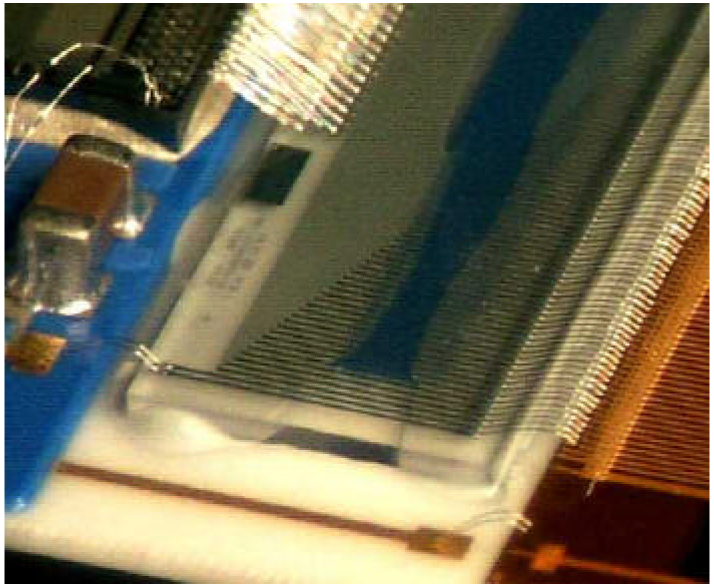
(6) Half Module bonding



- I/V (before bonding);
- I/V (after bonding).
- HM Long Term Test of leakage current

(7) Hybrid gluing/bonding





- Laser Test

Wire bonding

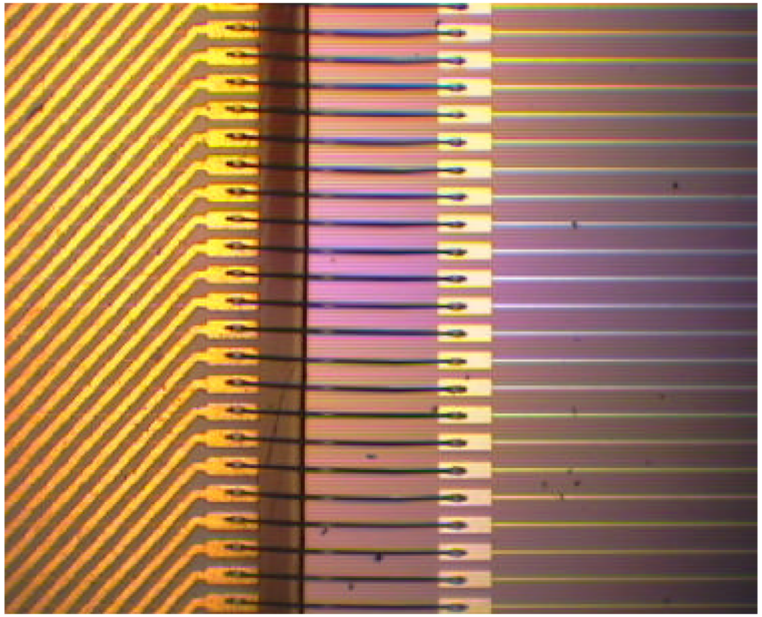
Need ~ 2000 bonds/half module

Full automatic machine : DELVOTEC 6400.

Measure the wire deformation while bonding: check bond quality.

Parameters :

- wire thickness 17.5 μm;
- bond force ~ 5 cN;
- loop height < 1 mm;



Half Module long term biasing

AIM:

✓ check the stability in current of the half-module;

PROCEDURE:

✓ half-module is biased for a period of time (usually 5days, up to 1 month) and the current is measured regularly.

CLASSIFICATION:

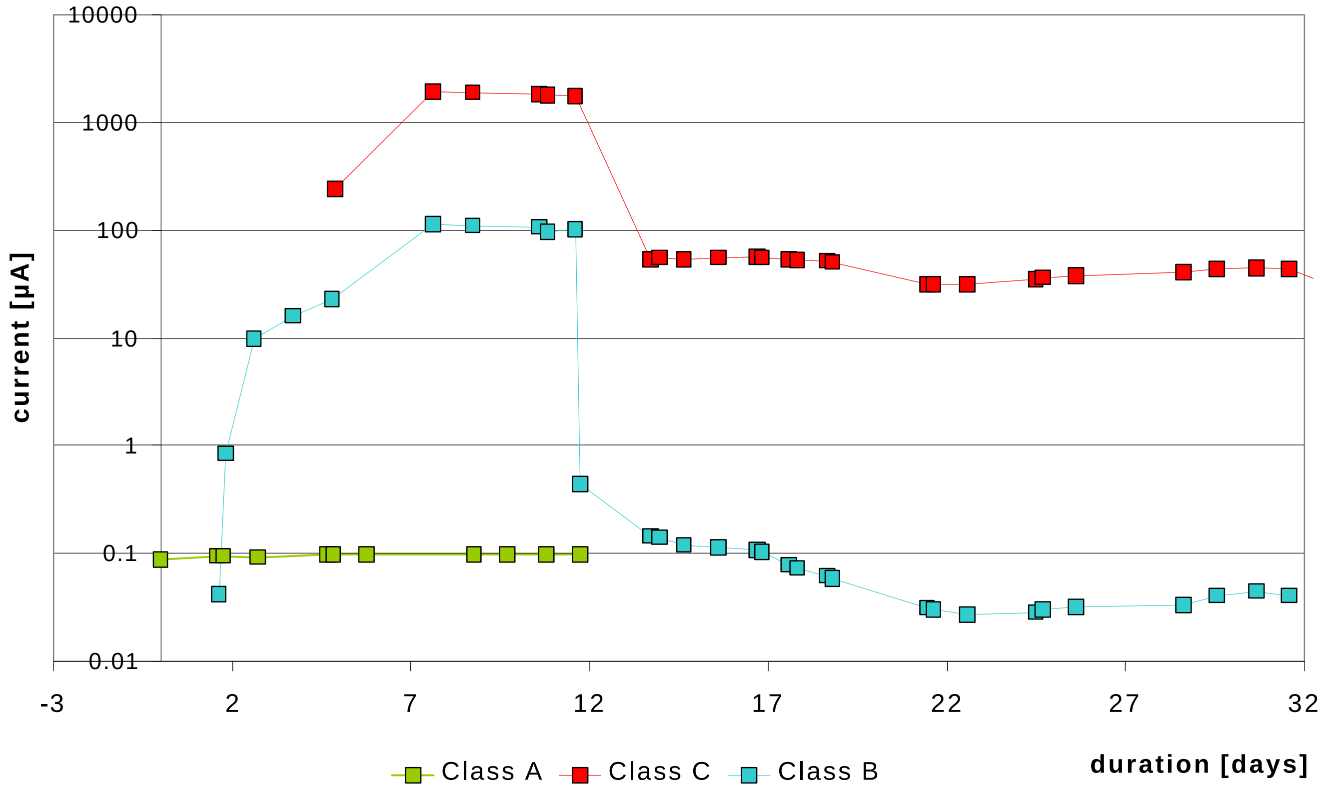
A. (I < 10 μA @200V);

B. (I < 50 μA @ 100V);

C. (I > 50 μA @ 100V)

→ not usable;

Class A+B: 96.5 % → used in production.



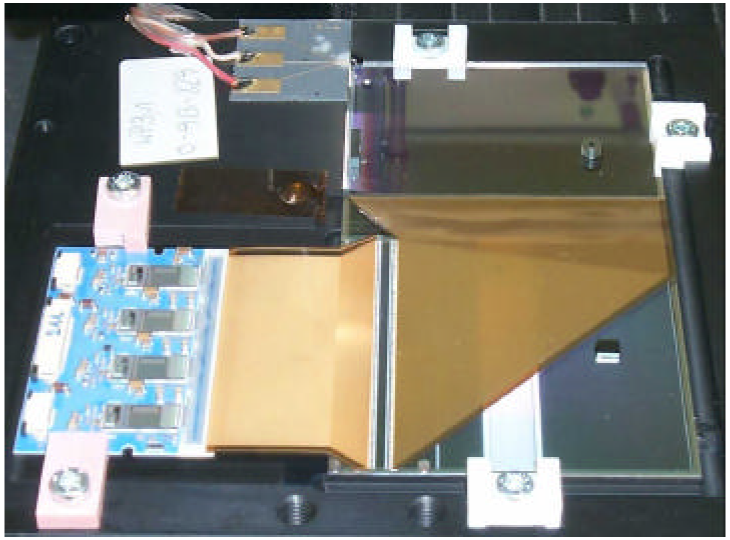
Laser Test

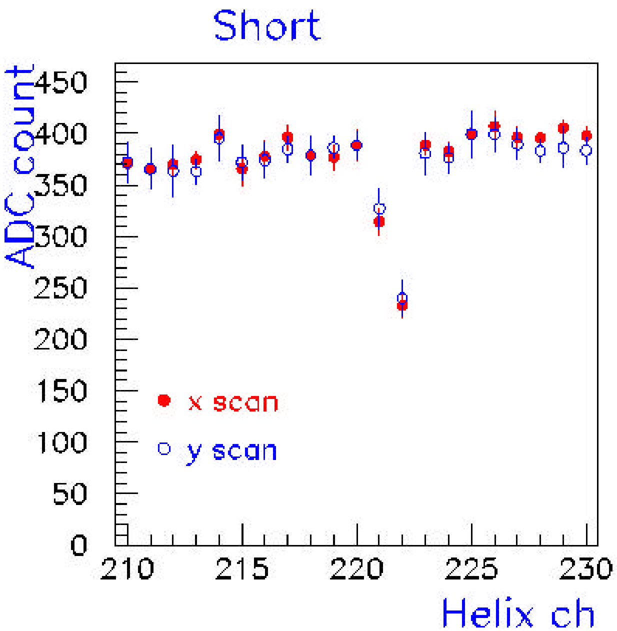
1st complete HM + readout chip test;

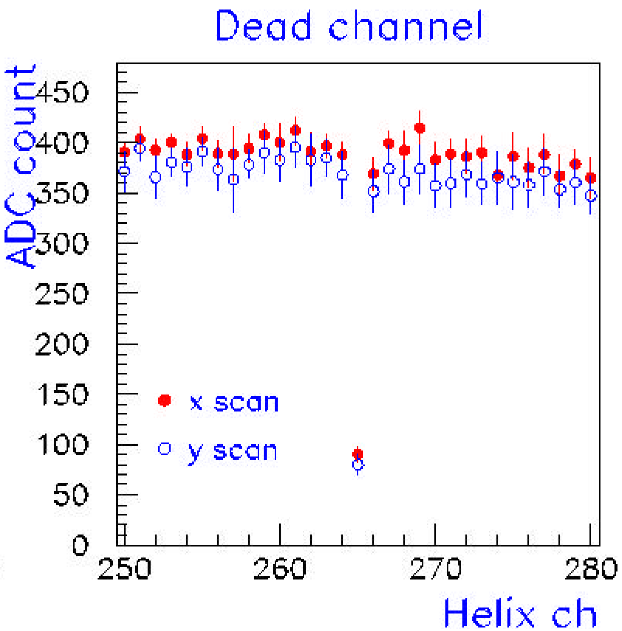
Characterization of detector:

- shorts;
- broken channels;
- HELIX/hybrid problems

Try to repair if possible.







Laser λ = 904 nm $\rightarrow$ 25 μm penetration in Si.

Accuracy of motors < 1 μm

<u>Acceptance criteria:</u>

- <= 2 shorts;
- <= 2 dead channels

Yield: 97 %

System test

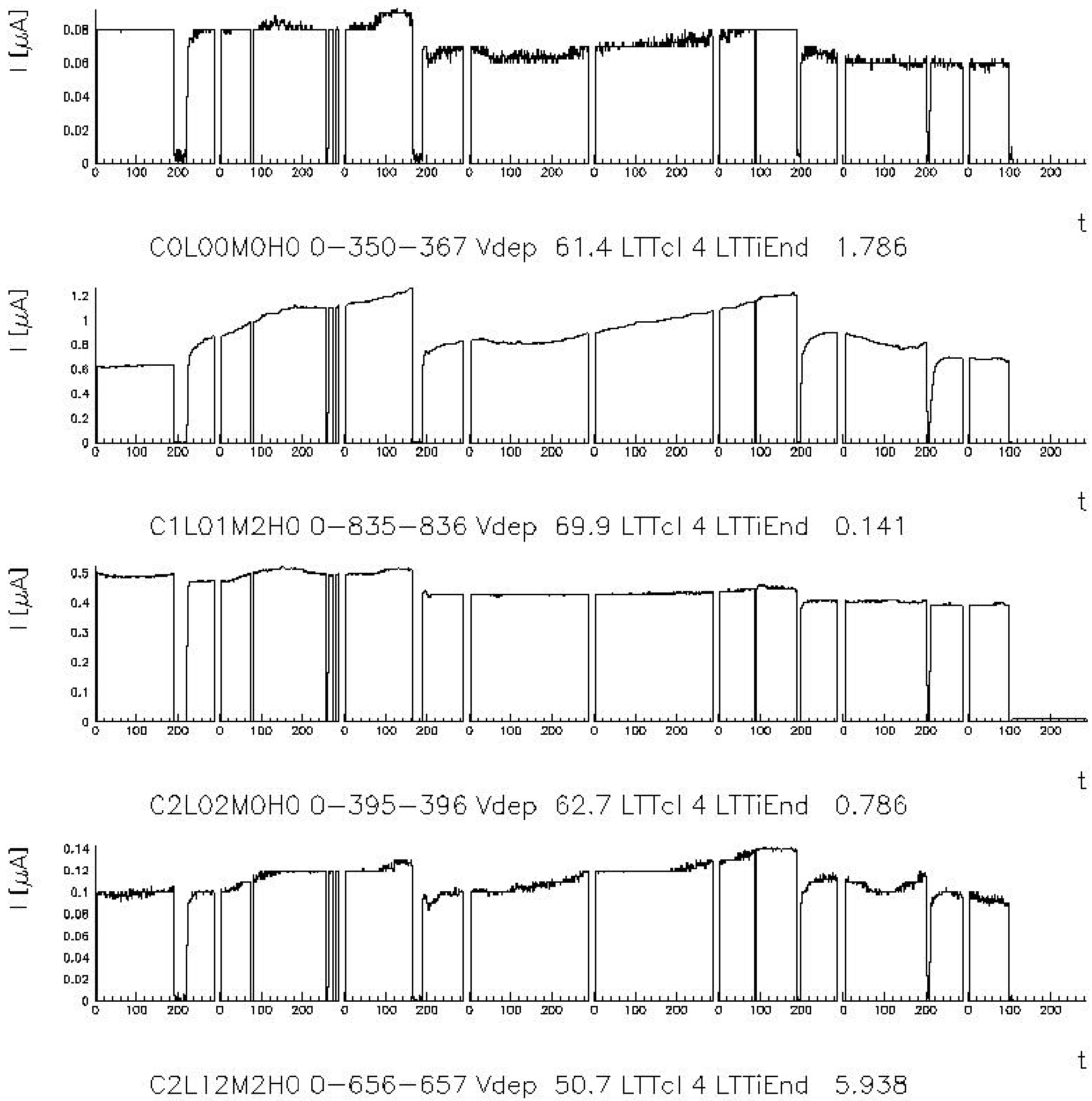
Extensive QA program developed also for:

- ✓ readout Chip/Hybrid;
- ✓ ladder/wheel assembly;
- ✓ assembly of different components in MVD.

Full detector including readout chain and DAQ tested for 3-4 weeks before installation in ZEUS:

- → test/characterization of readout chips, bad/noisy modules;
- → test of DAQ and Slow Control chains;
- → test of half-module currents long term stability;
- → run with external cosmic μ trigger (tracking).

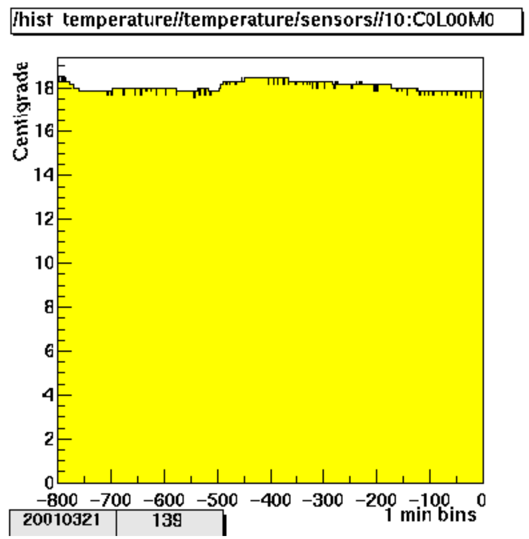
HM currents

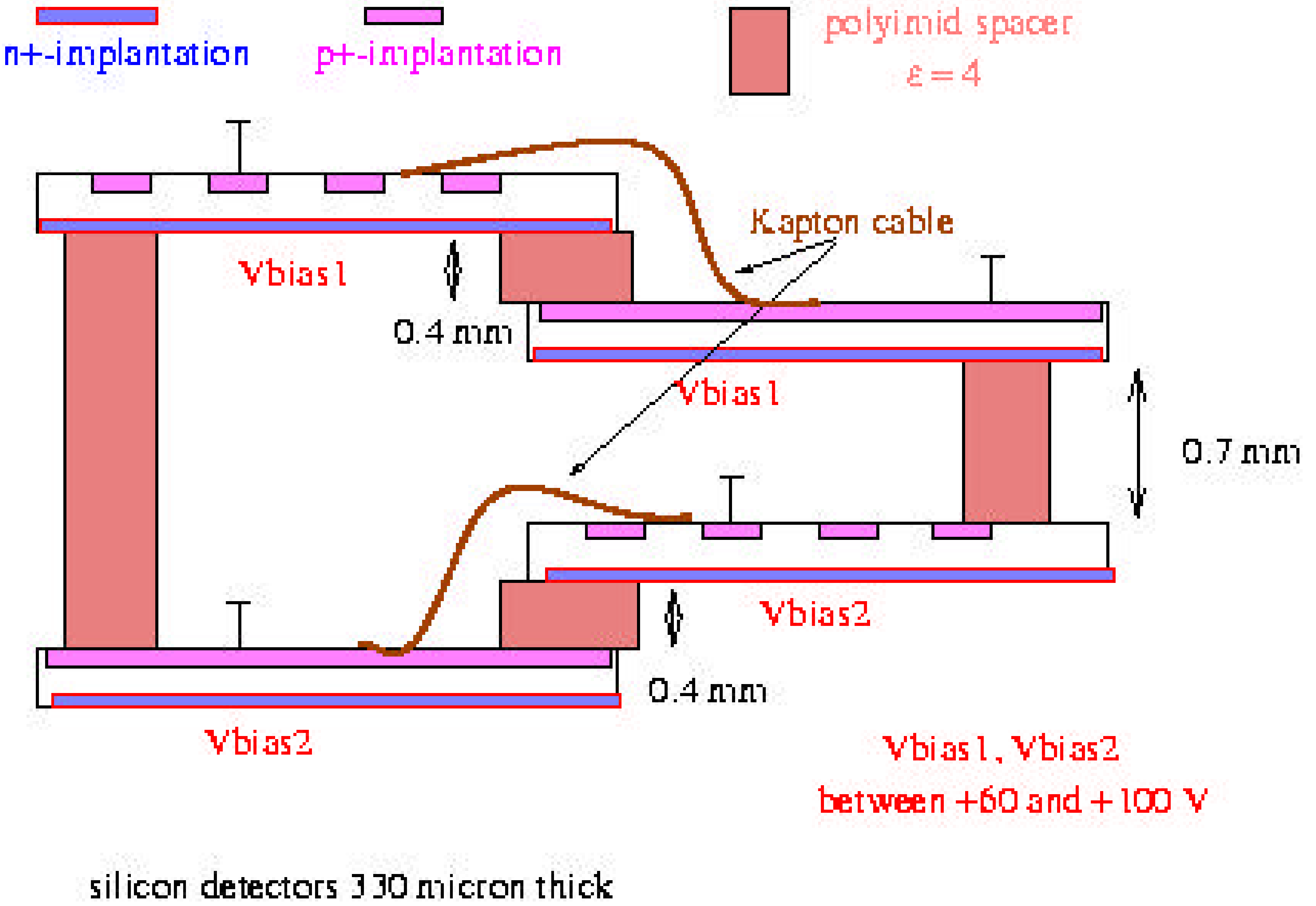


Half modules kept under bias for several weeks.

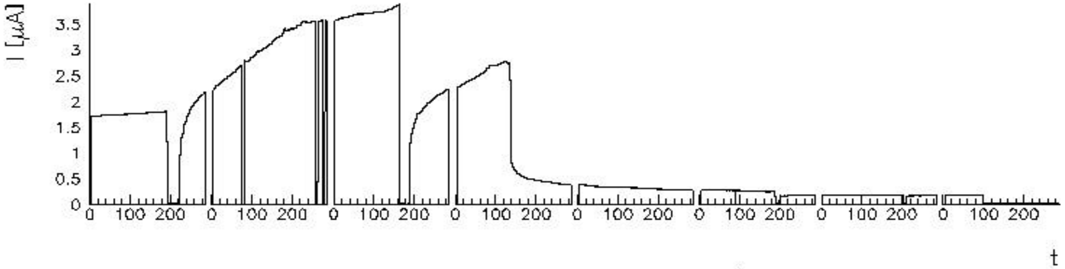
Current and temperatures monitored.

All detectors can be operated at depletion voltage with stable currents.

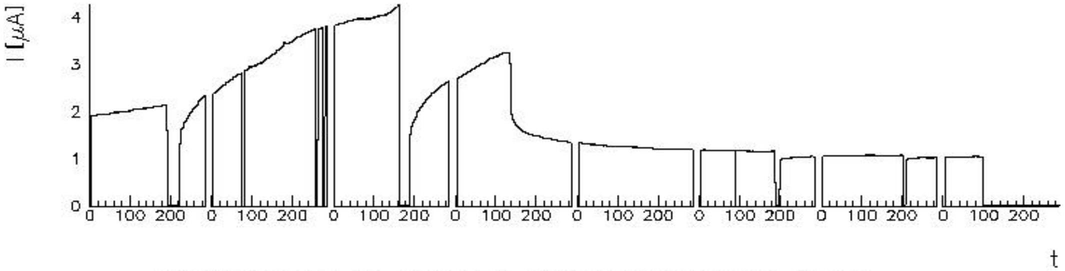



n+-implantation
p+-implantation
polyimid spacer
ε = 4
Kapton cable
Vbias1
0.4 mm
Vbias1
0.7 mm
Vbias2
0.4 mm
Vbias2
Vbias1, Vbias2
between +60 and +100 V
silicon detectors 330 micron thick

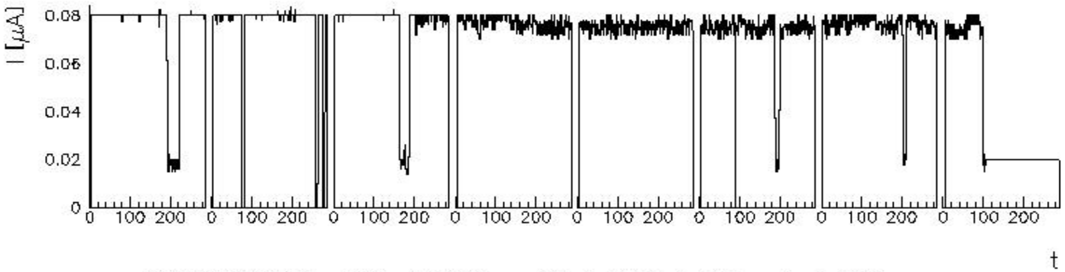
Effect of Inner HM bias Voltage on Outer HM Current



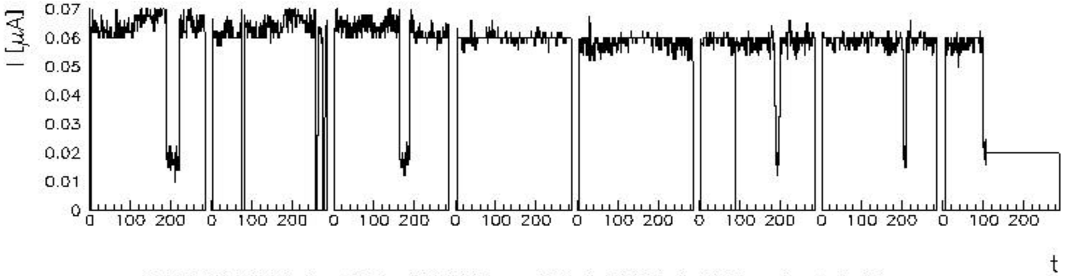
C1L03M2H0 0−825−827 Vdep 71.1 LTTcl 2 LTTiEnd 0.075



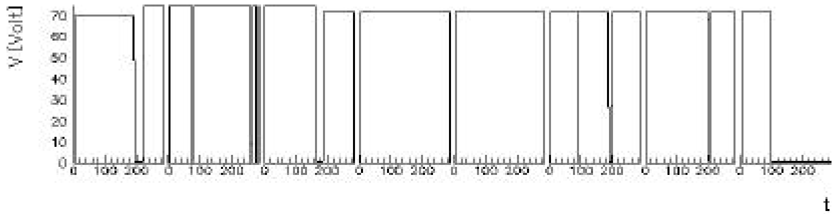
C1L03M4H0 0−98−97 Vdep 45.9 LTTcl 1 LTTiEnd 0.939



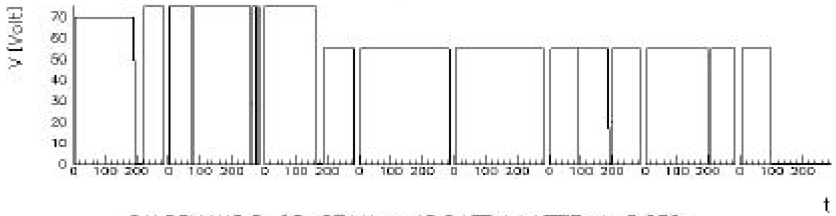
C1L03M2H1 1−692−696 Vdep 52.3 LTTcl 1 LTTiEnd 0.049



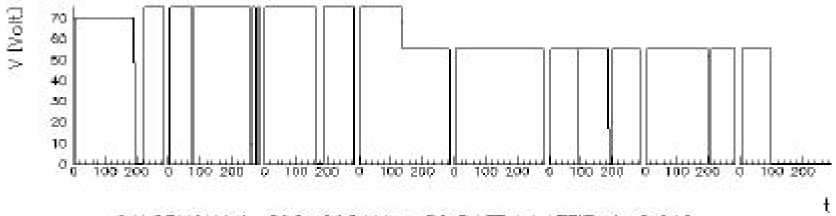
C1L03M4H1 1−636−574 Vdep 52.1 LTTcl 1 LTTiEnd 0.043



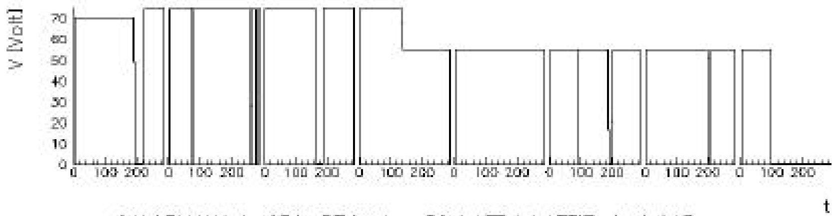
C1L03M2H0 0−825−827 Vdep 71.1 LTTcl 2 LTTiEnd 0.075



C1L03M4H0 0−98−97 Vdep 45.9 LTTcl 1 LTTiEnd 0.939



C1L03M2H1 1−692−696 Vdep 52.3 LTTcl 1 LTTiEnd 0.049

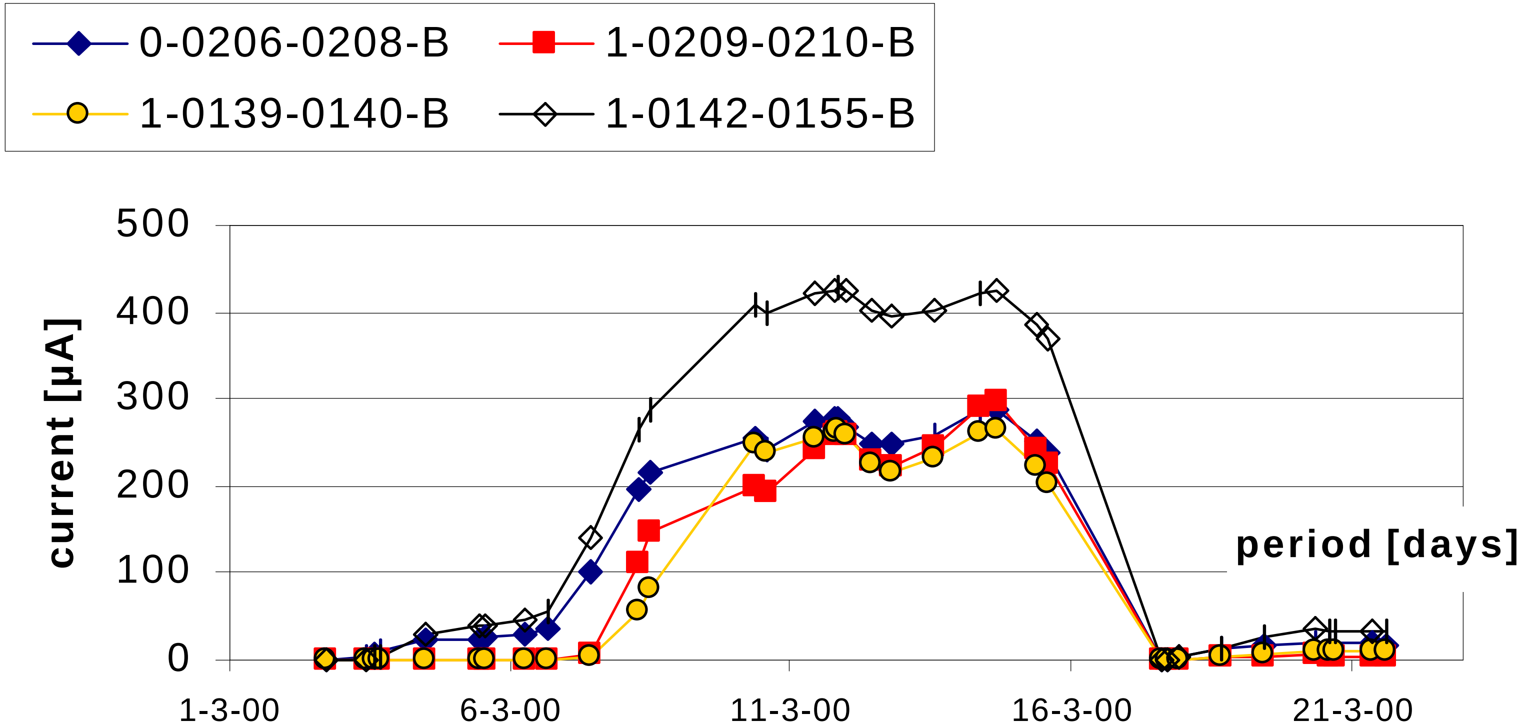


C1L03M4H1 1−636−574 Vdep 52.1 LTTcl 1 LTTiEnd 0.043

Temperature effect

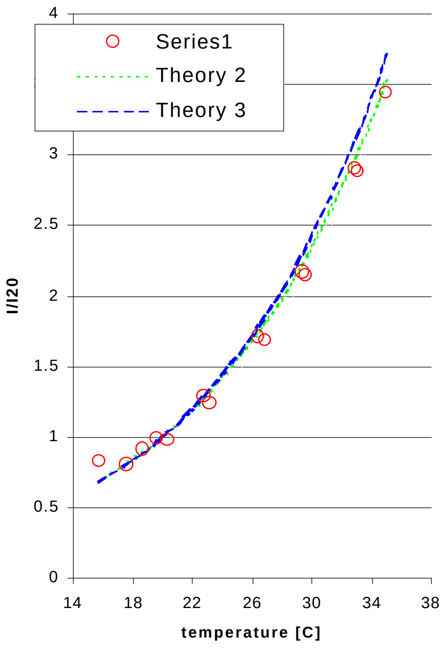
Correlations between temperature and currents have been observed during the HM long term tests:

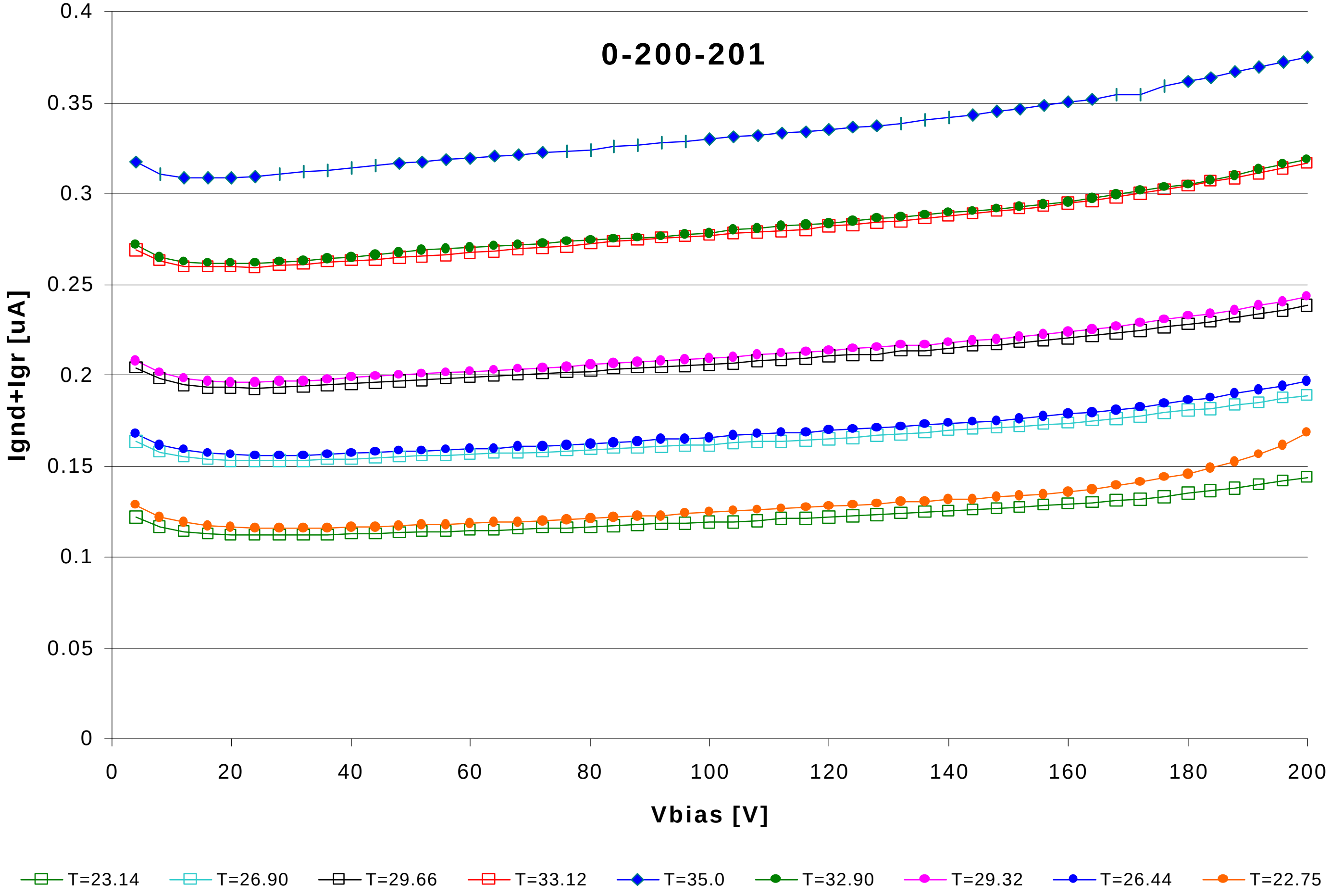
- Increase of currents observed when the temperature decreased (heating system switched OFF during weekend)



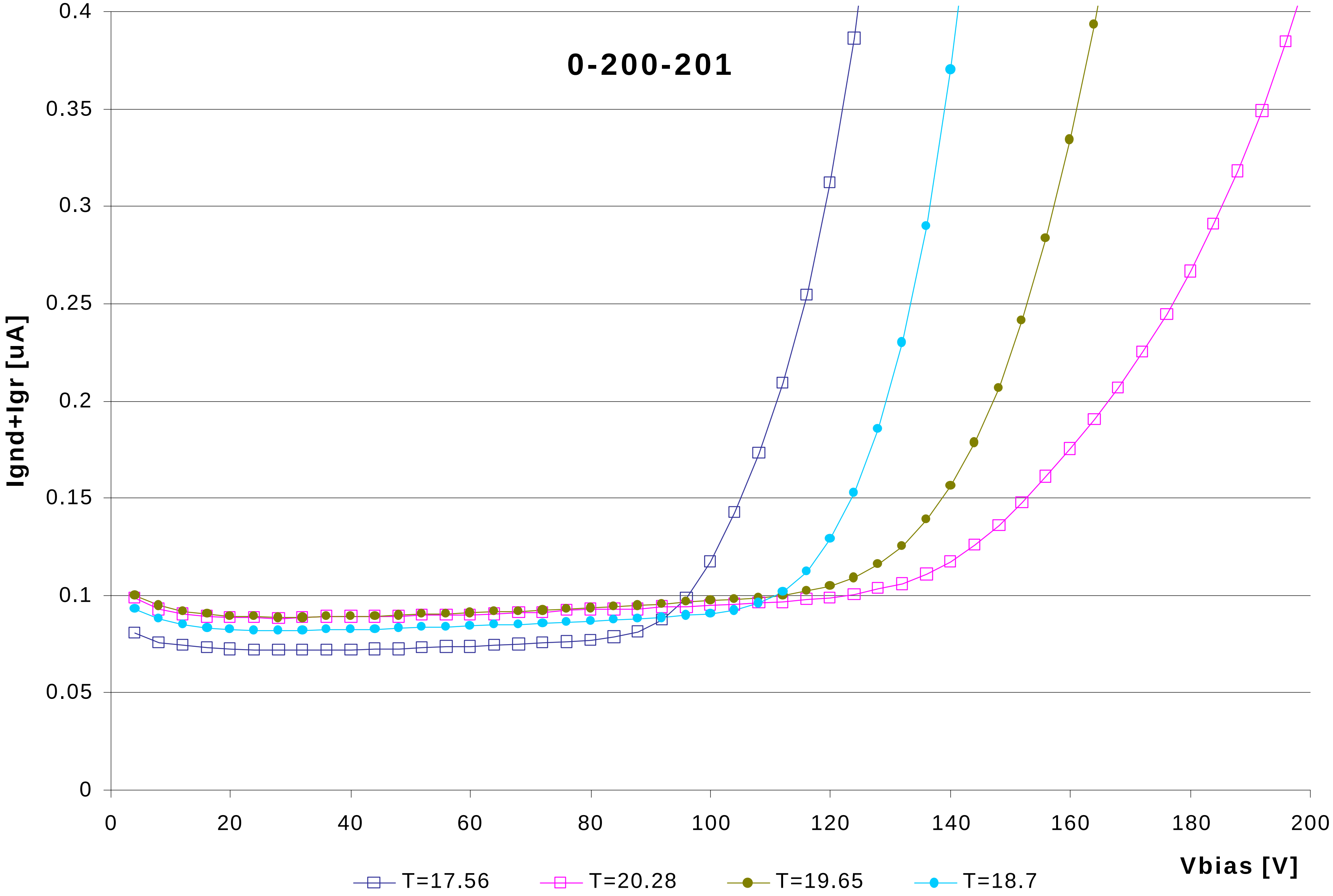
Measurements of I/V characteristics at different temperatures studied on few half-modules:

Setup: Closed box with temperature controlled wall. Temperature increased/lowered and measured for a long time until the system reaches the thermal equilibrium.

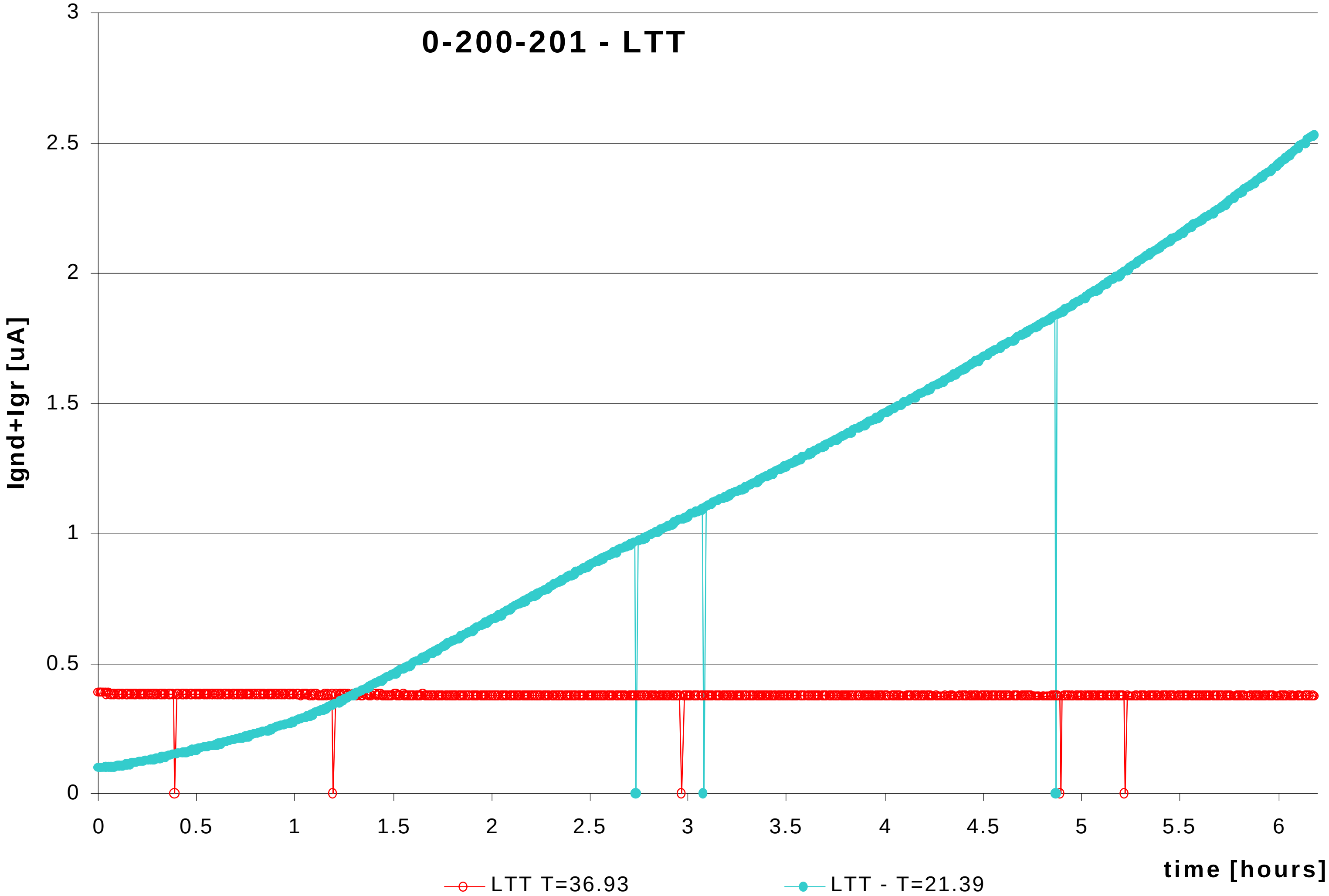




Break-trough seems to move to lower voltages for lower values of the temperature.



6-hours current test performed at two different values of the temperatures: the half-module current is stable at high temperature, but shows an increase with time at low temperatures



Conclusions

MVD design specifications fulfilled:

- charge division works, 10 μm detector resolution;
- detector tested up to 3kGy: no degradation of performances.

Very good quality half modules produced:

- small # of dead channels / shorts (< 1 ‰);

Success due to extensive QA program (several acceptance tests).

MVD installed successfully in ZEUS, new cosmic run with all ZEUS components (2 weeks in July) planned before HERA startup:

- test of survival of MVD modules (bad/noisy modules characterization in the real environment);
- Use μ to test/develop tracking algorithms, check alignment to ZEUS components.