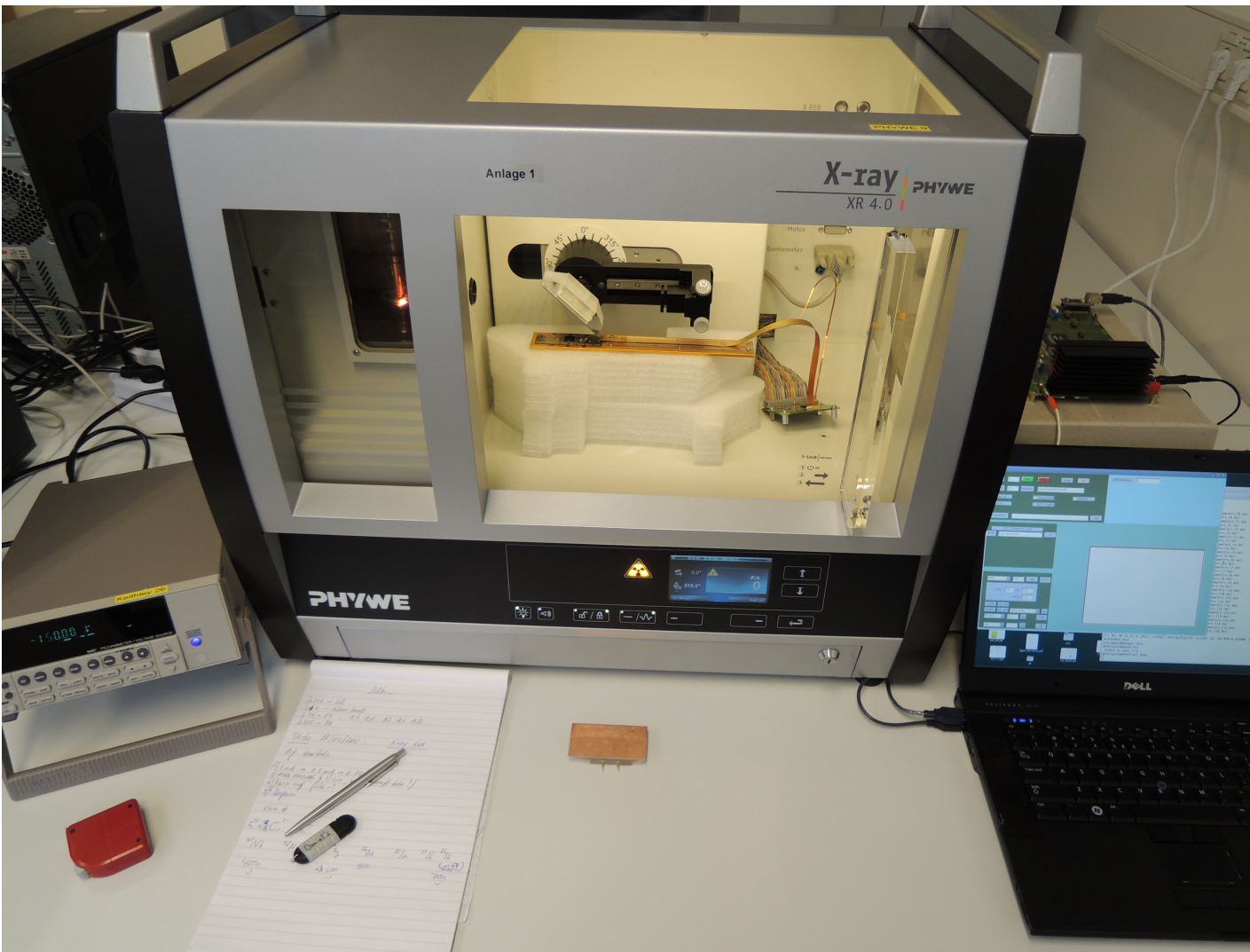


Module production preparation at DESY and Uni Hamburg



Daniel Pitzl

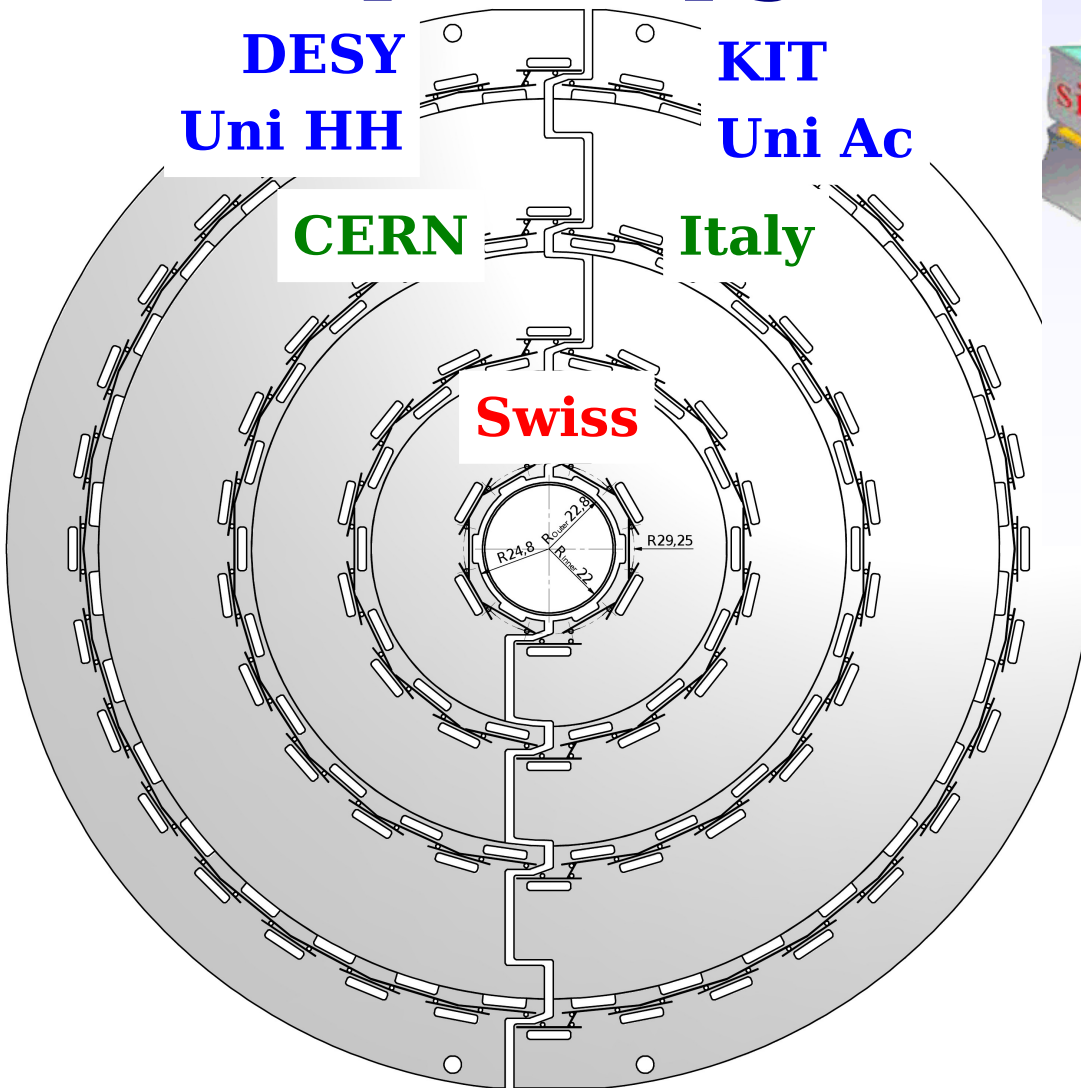
CMS barrel pixel module production meeting
CERN 19.7.2012



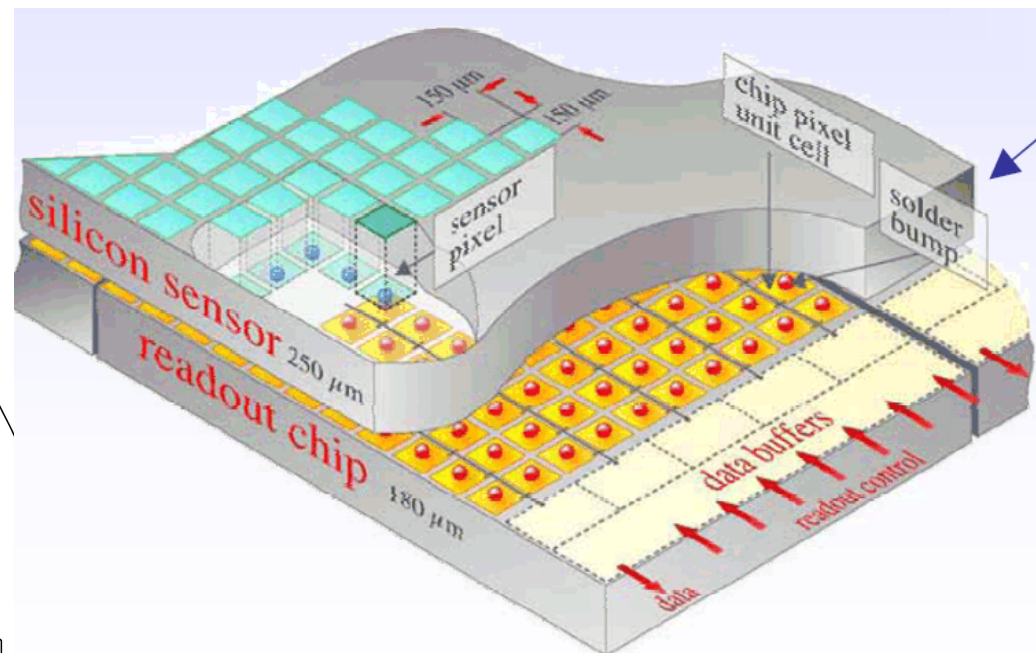
- Production sequence and locations
- Status of individual steps

Barrel pixel upgrade

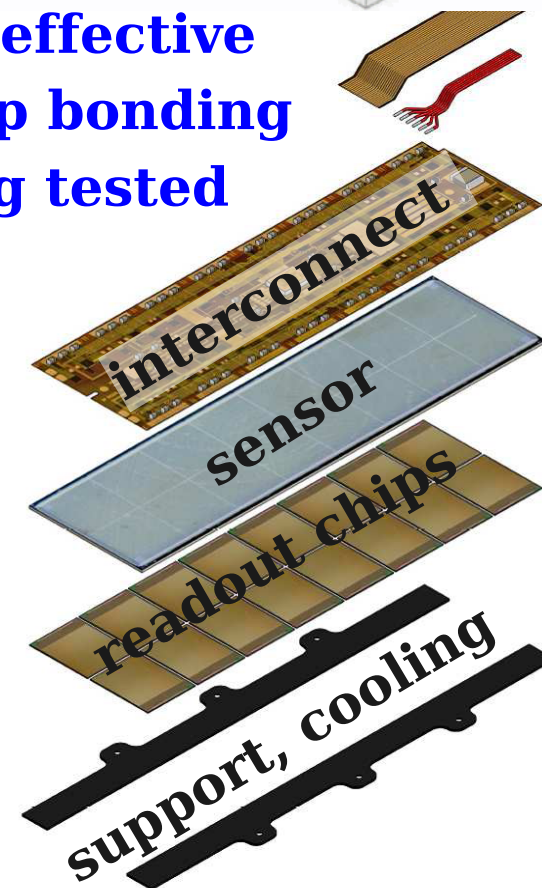
DESY
Uni HH
CERN
KIT
Uni Ac
Italy
Swiss



**384 modules to be built
at DESY& Uni HH by 2016**



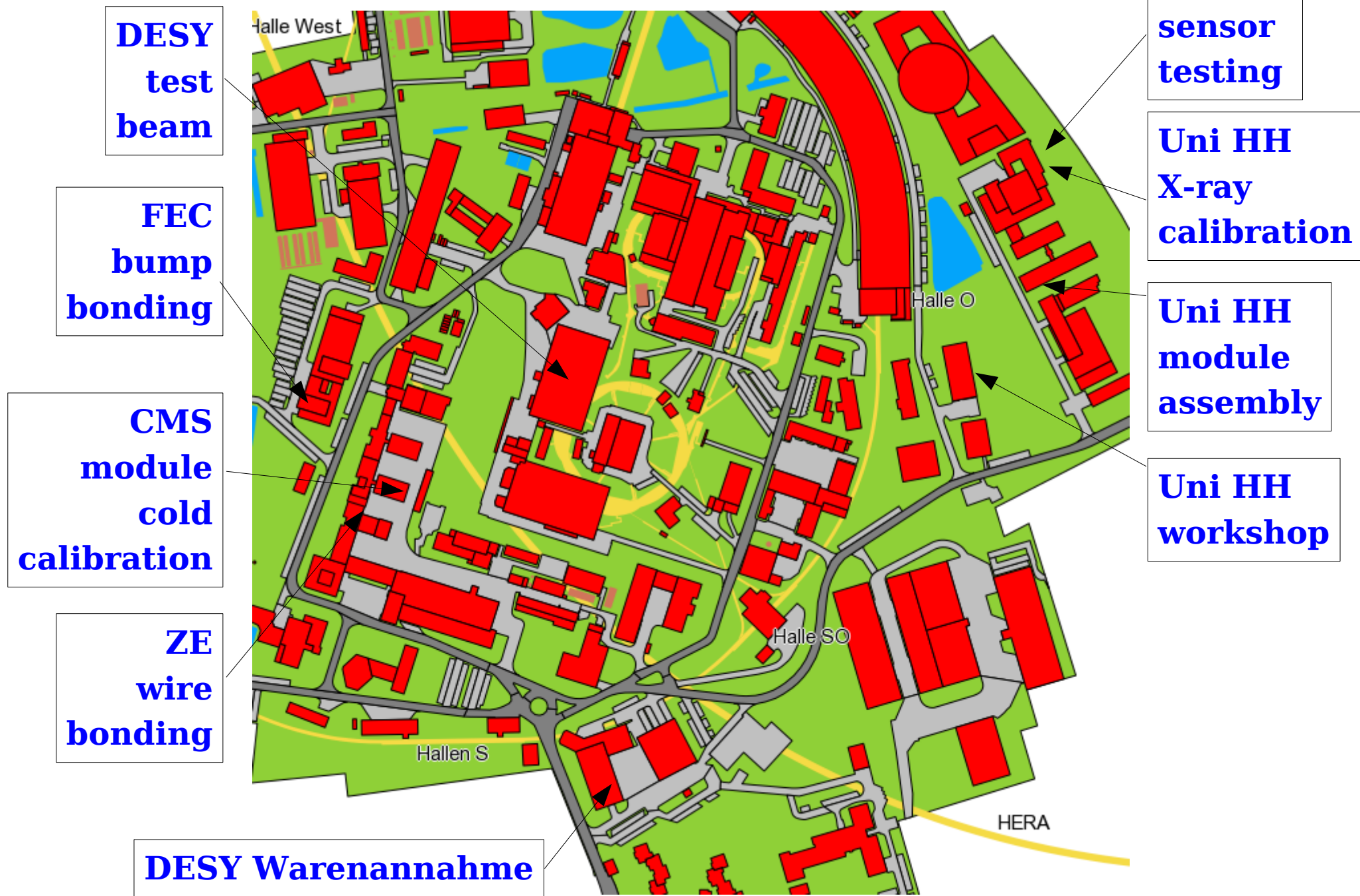
**cost effective
bump bonding
being tested**



Barrel pixel upgrade: tasks and tools

- Assemble and calibrate 256 (+spares) barrel pixel modules 2014-15
- Flip chip bump bonding of sensor and readout chips:
 - tests with industry completed, place order for machines Jul 2012
 - establish solder jet bump bonding at DESY 2013
- Glue high density interconnect to sensor, wire bond to ROCs
 - gluing jigs re-built at Uni HH (PSI design), first modules 2012-13
 - order new wire bonder for DESY ZE done
- Test and calibrate modules:
 - determine operational parameters down to -20°C cold box 2013
 - set pixel threshold for uniform response code developed
 - gain and threshold calibration with X-rays (Mo, Ag, Te) at Uni HH
- Assemble and test 4th layer
 - Lab at DESY available setup in 2014

DESY map



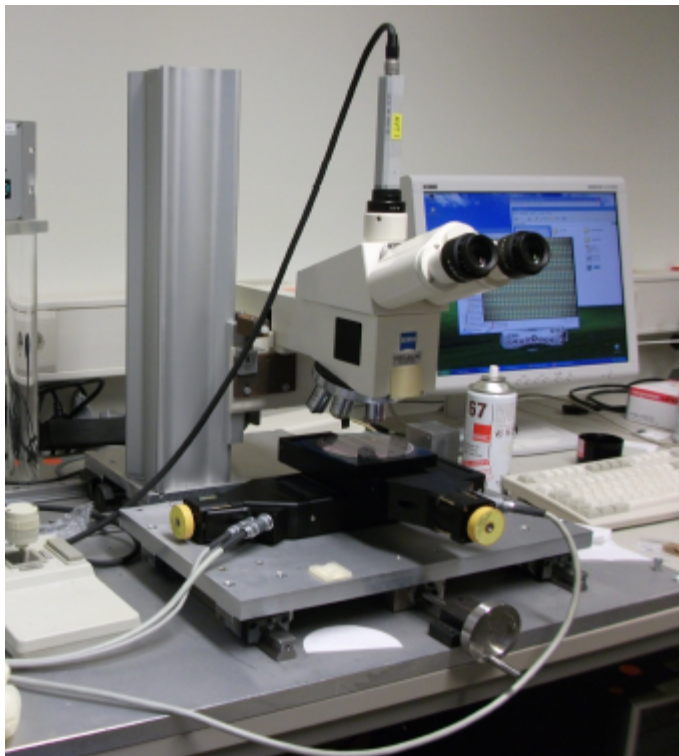
module production task sharing in HH

- sensor inspection, I-V, C-V Uni HH
- UBM, wafer thinning, dicing Pactech
- bump bonding DESY FEC
- bare module testing, re-work DESY CMS & FEC
- HDI test, TBM gluing Uni HH
- TBM wire bonding DESY ZE
- Module gluing: HDI, cable, base strips Uni HH
- ROC to HDI wire bonding DESY ZE
- Module testing, cold calibration DESY CMS
- X-ray calibration Uni HH
- layer assembly and ladder test DESY CMS

Sensor inspection at Uni HH



**Received 5+1 wafers
from CIS via CERN**

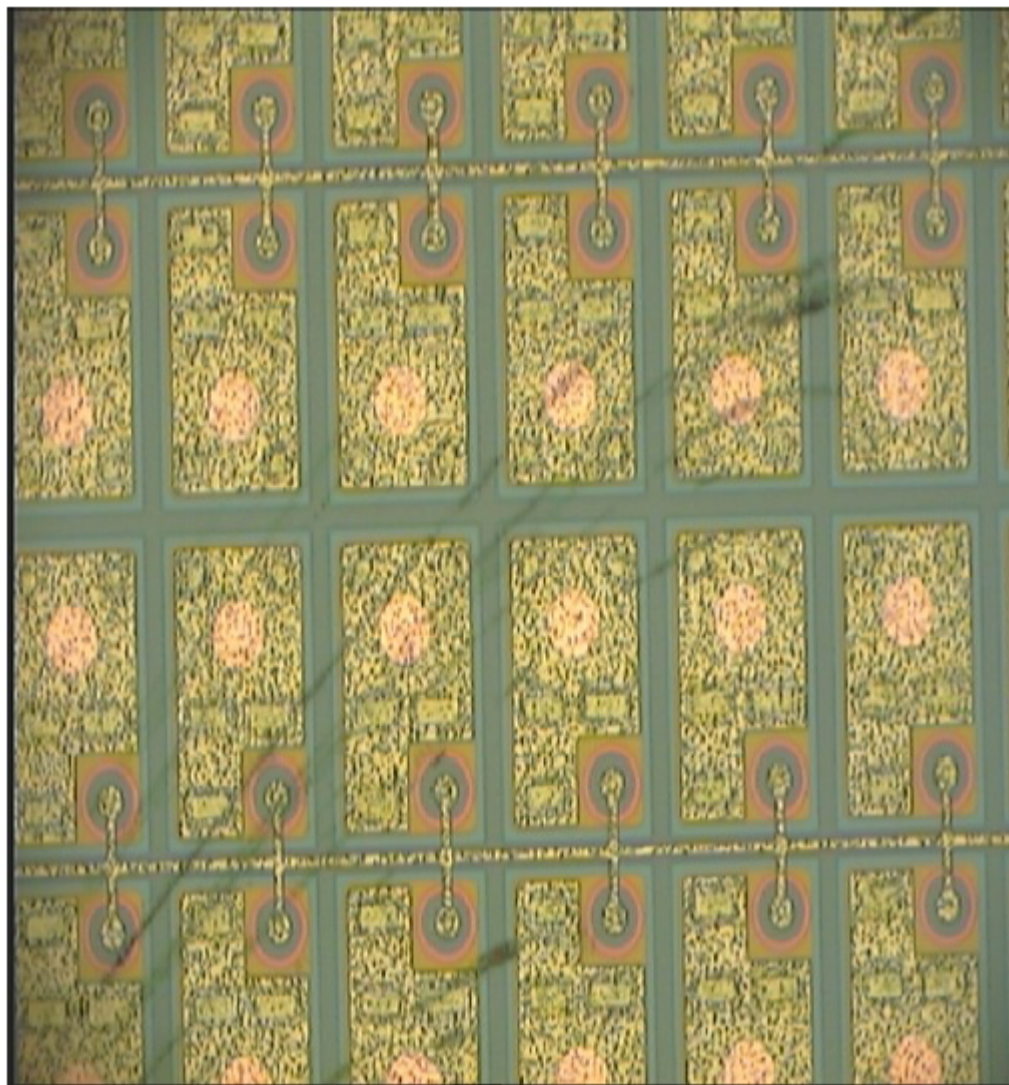


optical inspection started

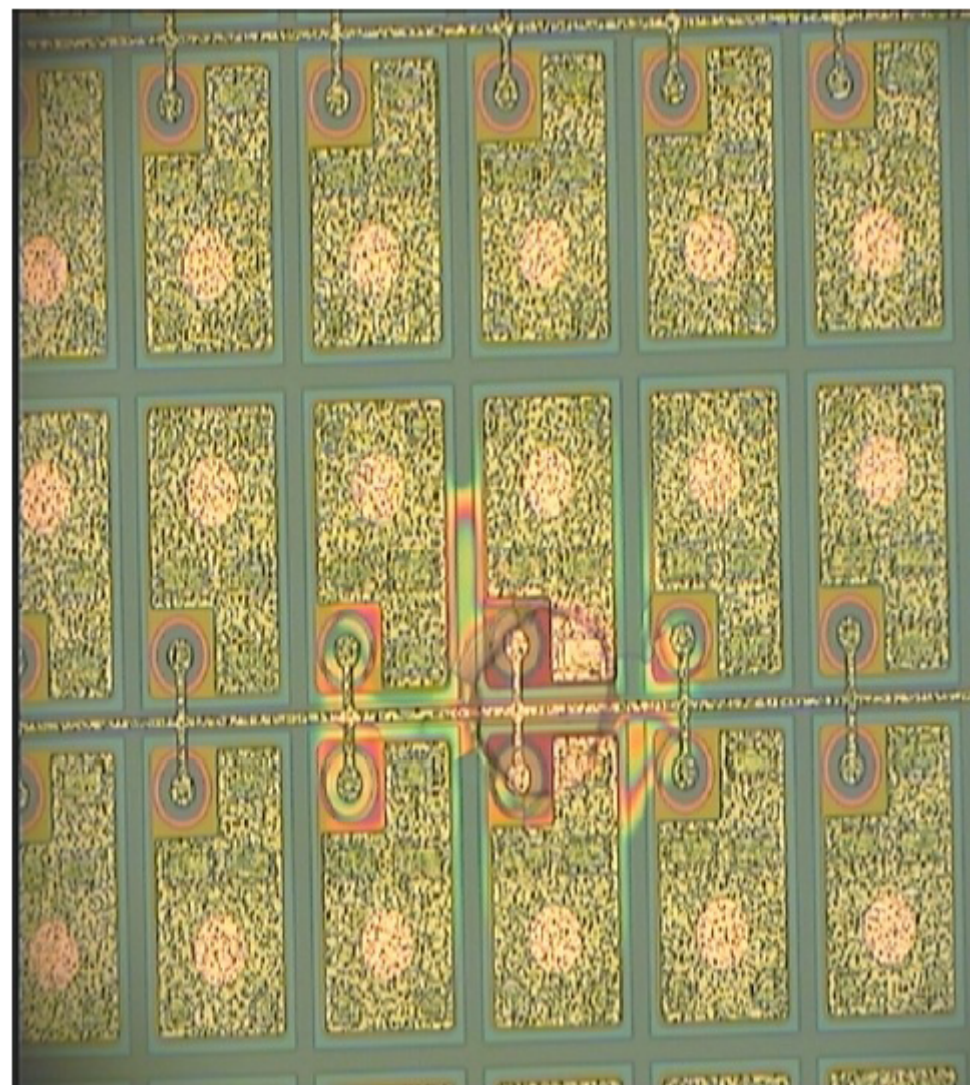
tedious procedure

**needs automation: pattern recognition
software!**

CIS sensor issues

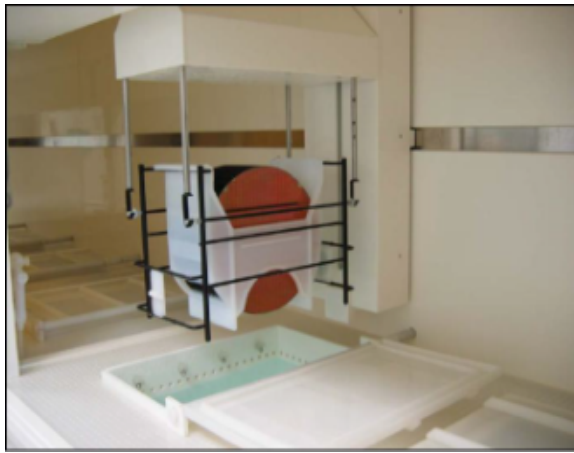


scratch



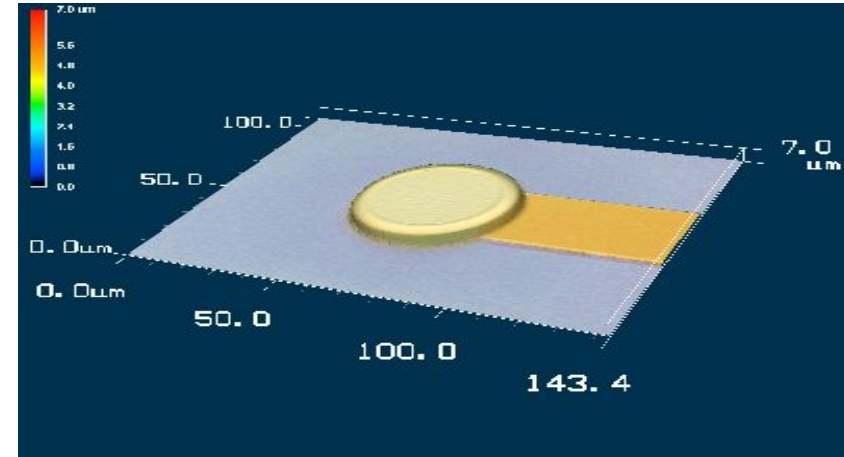
hole in passivation

Electroless under bump metal from Pactech



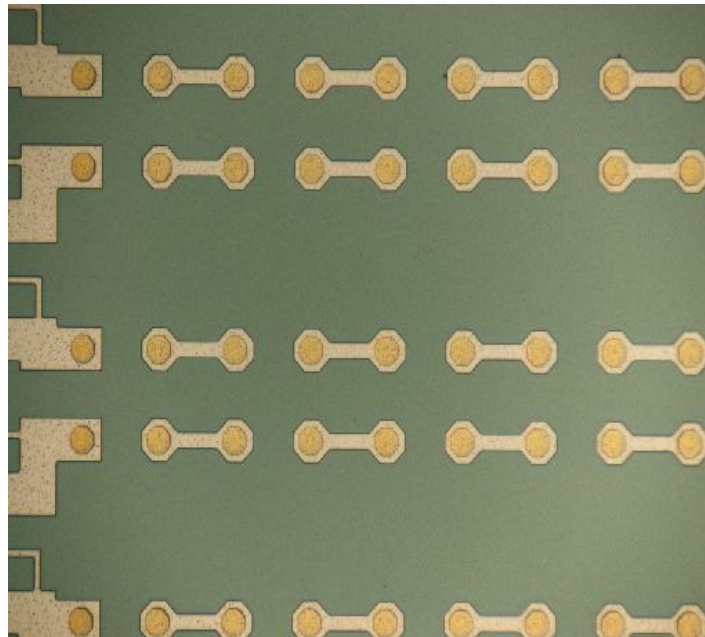
electroless UBM bath

ENEPIG UBM:
Electroless Ni-Pd-Au
5 μm Nickel
200 nm Palladium
50 nm Gold



laser scanning image

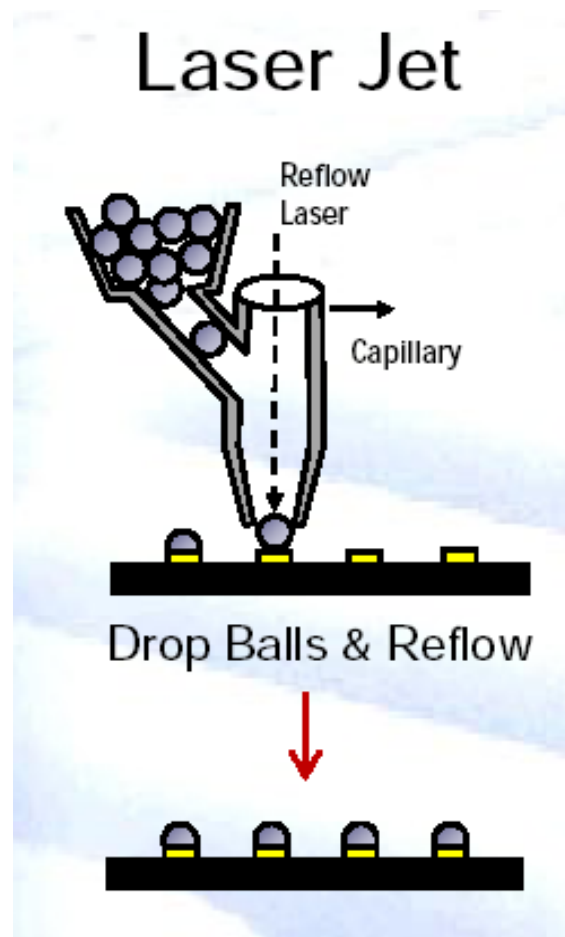
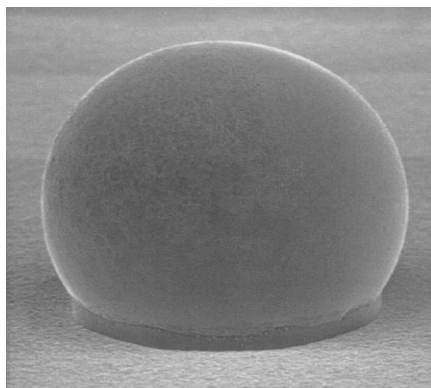
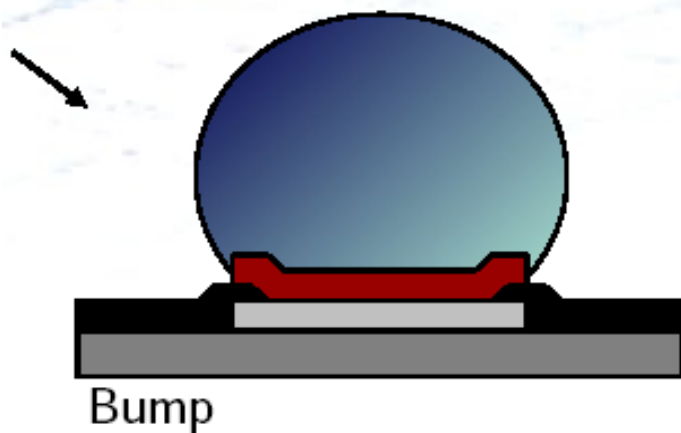
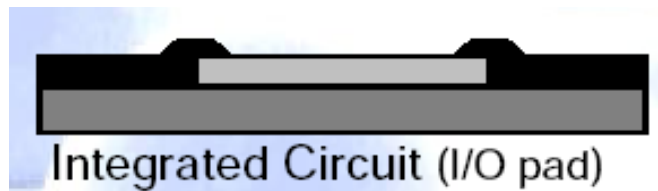
pads with UBM:



ROC and sensor wafers must have clean pads: no residue passivation

Wafer thinning and dicing also offered by Pactech

PacTech SB2 solder ball laser jet



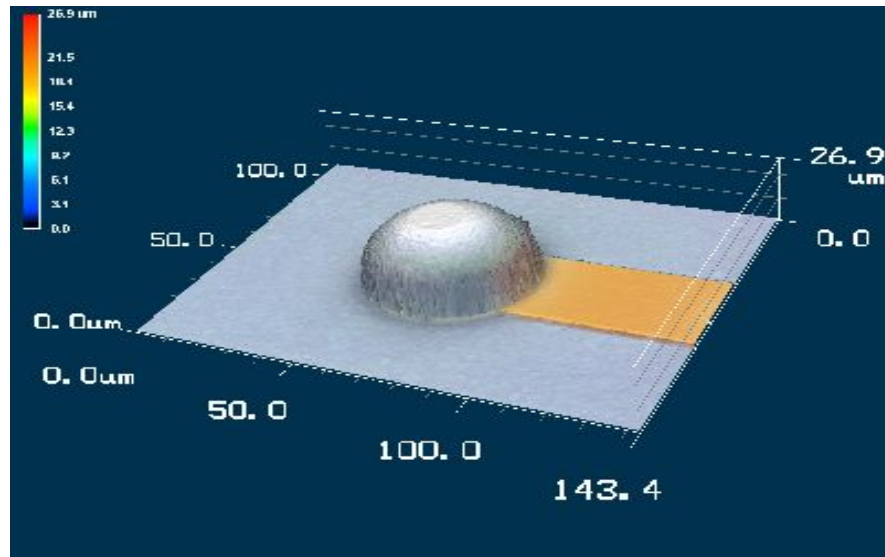
- Start with high-precision solder balls.
- 40 μm balls now,
 - 30 μm balls being certified.
- Drop through capillary towards pad.
- Melt by laser pulse during fall.
- Solidify on pad.
- Step-motor controlled.
- 5 balls / second
 - 4h / module



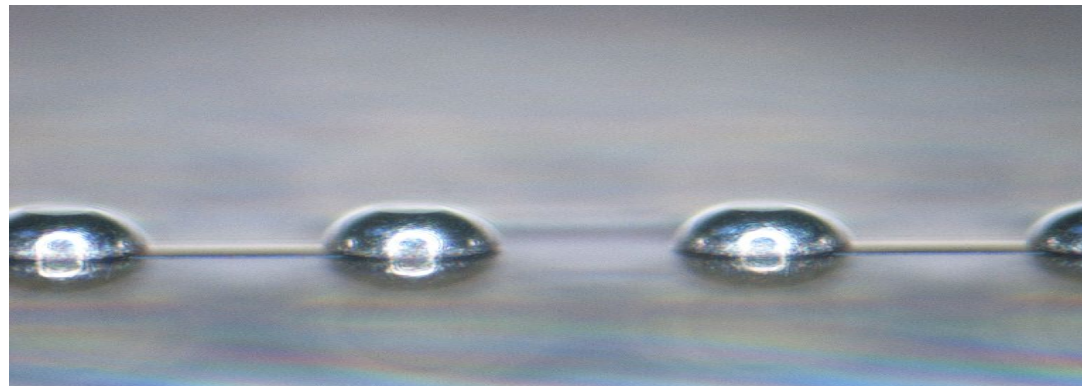
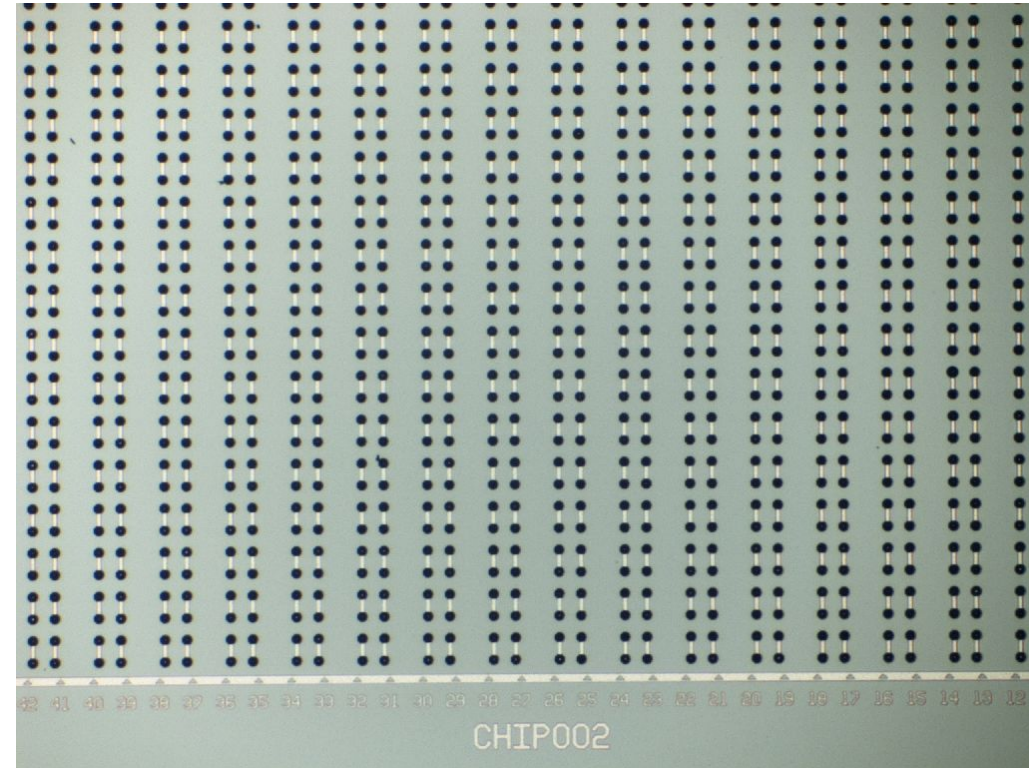
http://www.pactech.de/index.php?option=com_content&view=article&id=154&Itemid=21 pub 68

Solder balls placed with PacTech SB2

Pad bumped with
40 μm solder ball,
after re-flow:



'sensor' with solder balls:



Side view of
bumped
daisy chain
structure

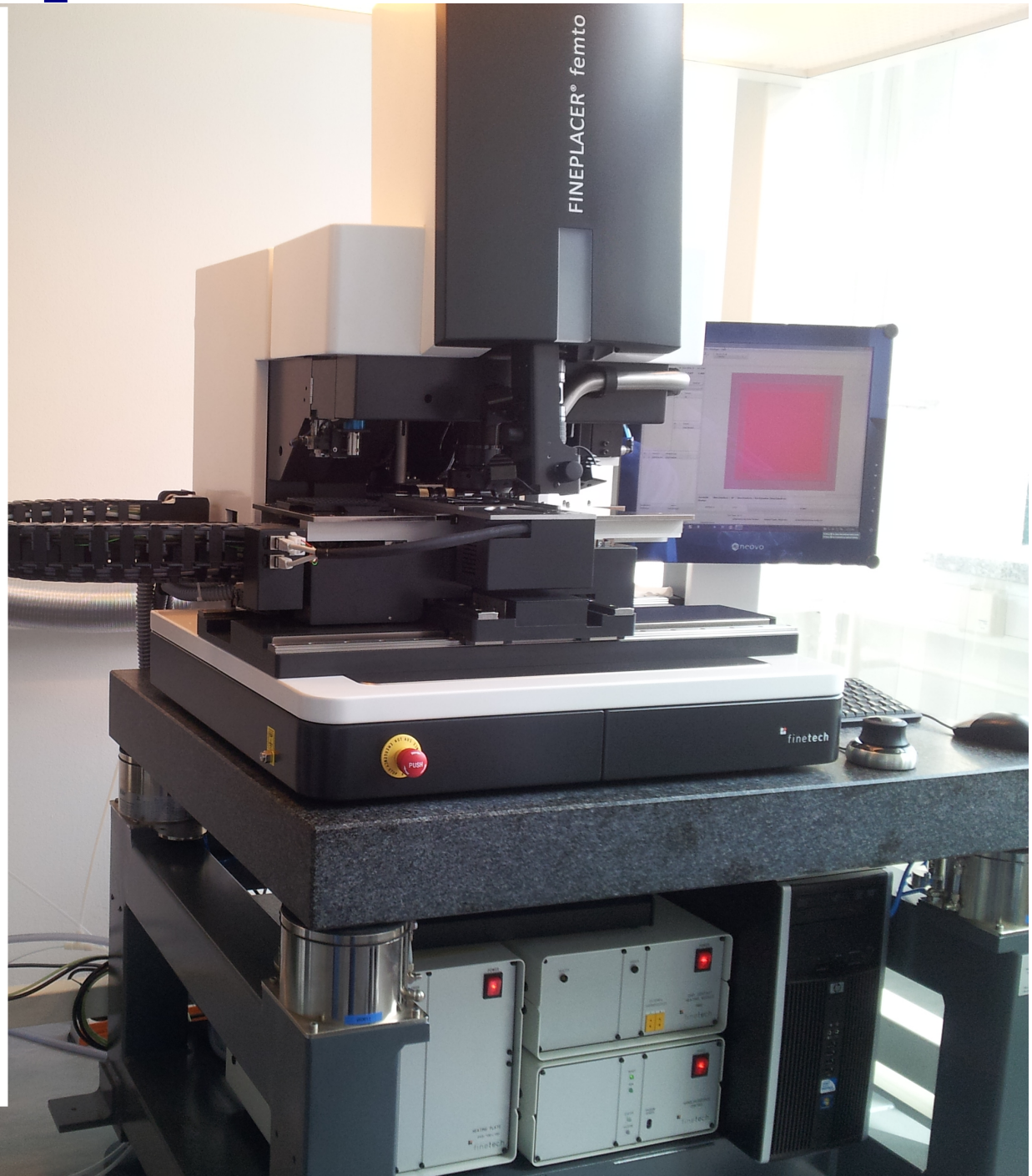
Femto flip chip bonder from FineTech

**Precision automated
flip chip bonder
Femto from Finetech**

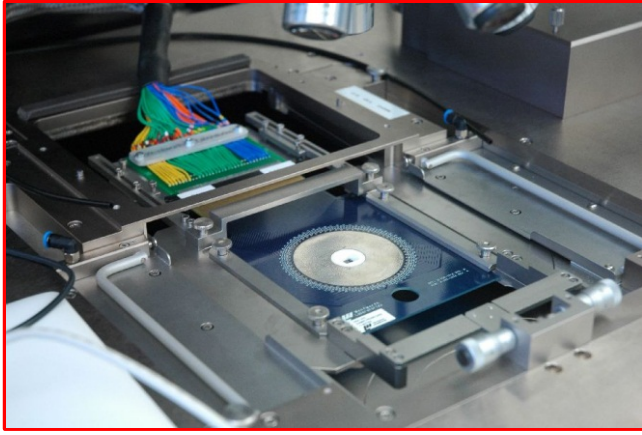
**Reflow soldering
by chuck and bond
head heating
in formic acid
atmosphere**

**Known good die test:
probe card and test
board**

**Detailed parameter
logging**



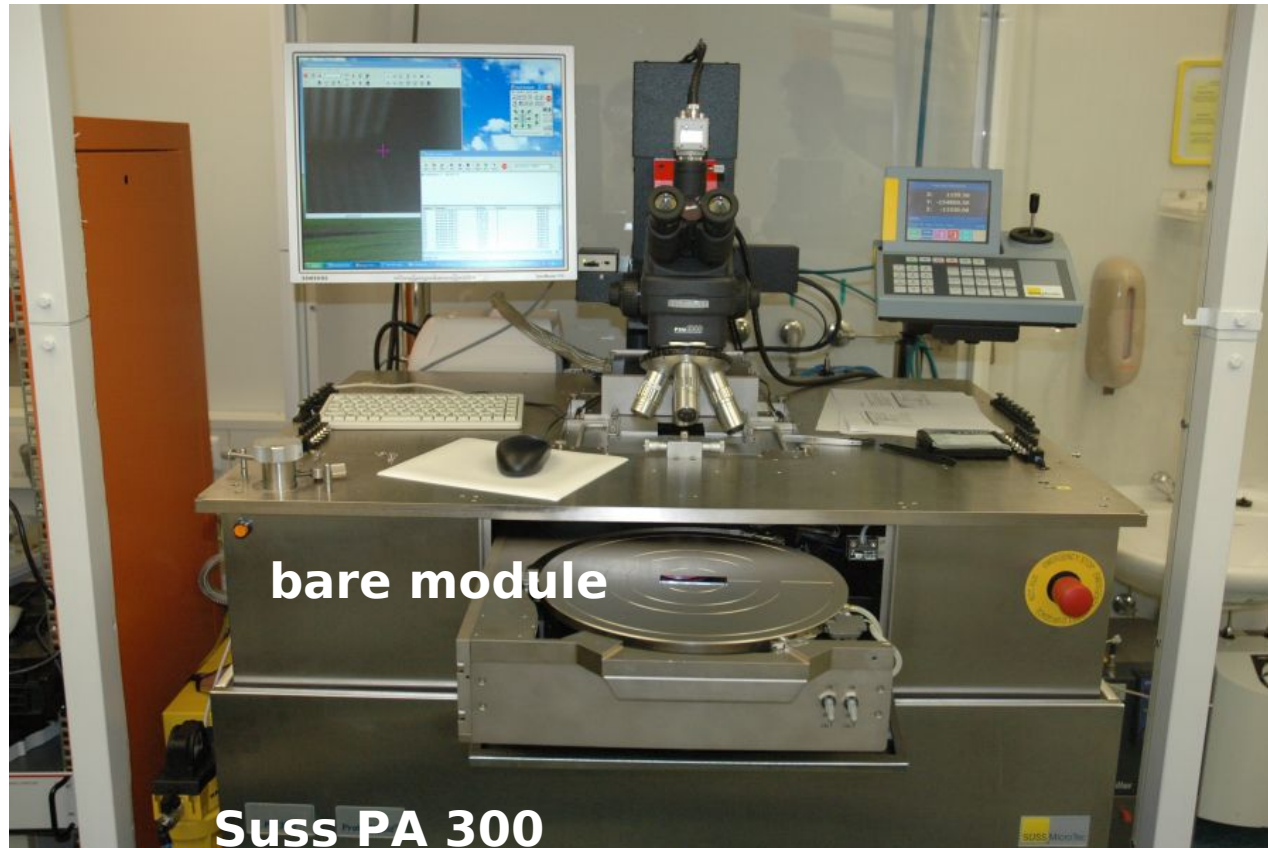
Probe station for bare module testing



Probe card holder

Probe card design for 160 MHz
digital readout from PSI?

Will need to modify for kgd test on Femto
(rotated ROCs)



at DESY FEC

Flip chip bonding quality check at DESY

Schliffbilder:

test structures
from CIS

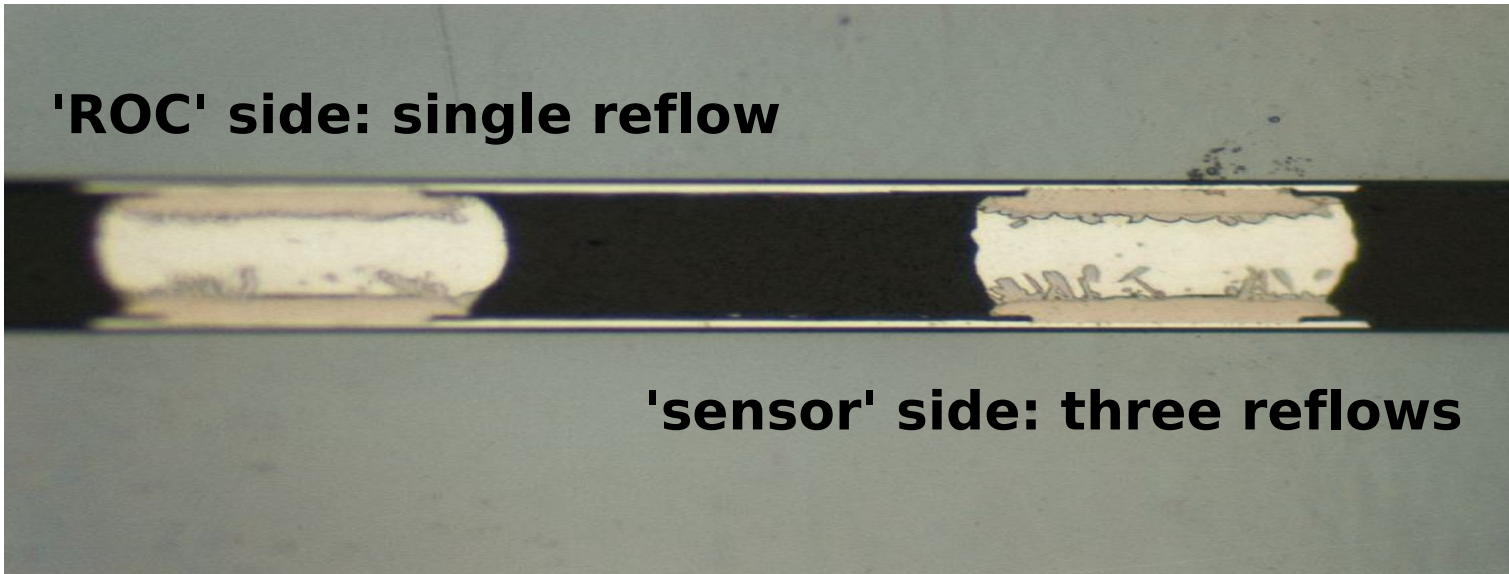


Si substrate
'ROC'

bonds

Si substrate
'sensor'

'ROC' side: single reflow



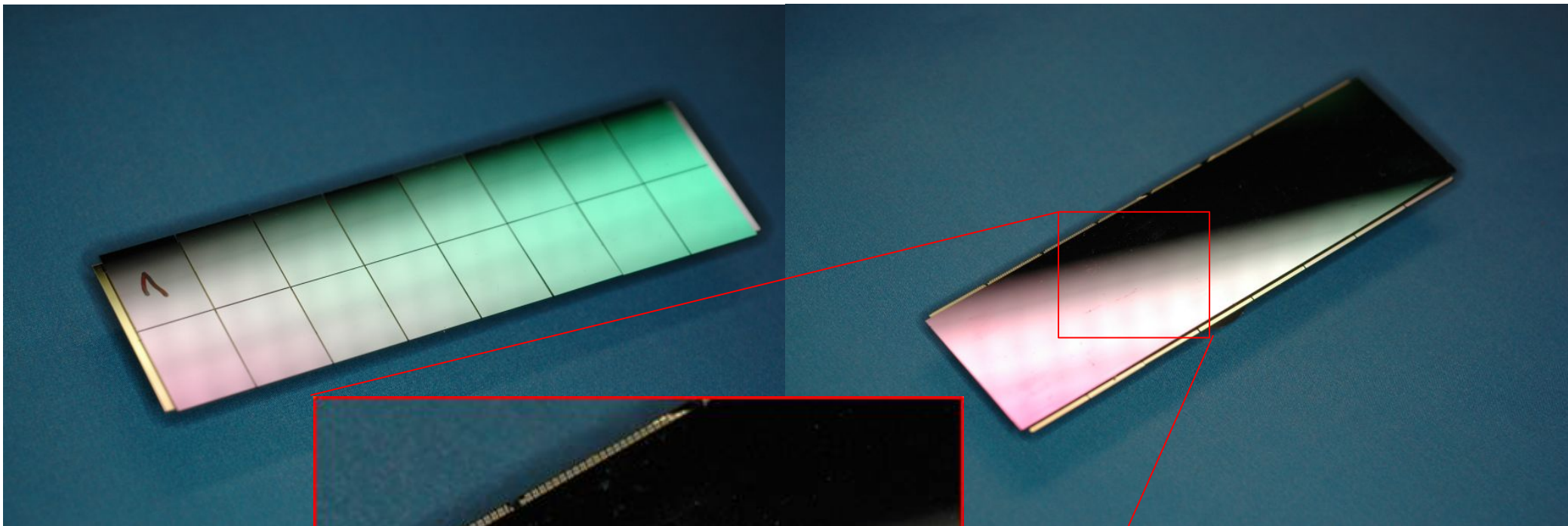
'sensor' side: three reflows

Nickel UBM
Tin solder
Nickel UBM
(grows over
passivation)

Bonded test structure module

16 ROC-like structures

sensor-like structure

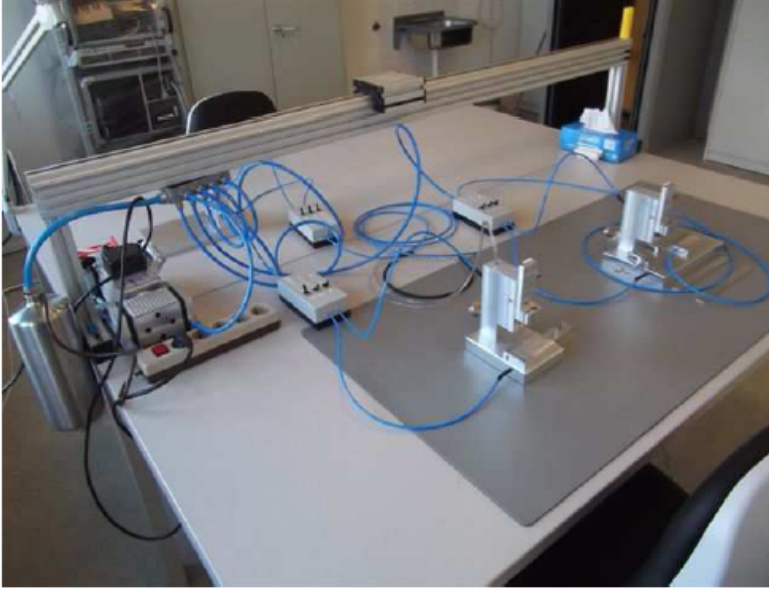


**104 contact
pads per
ROC-like
structures**



**Jan Hampe
(DESY FEC)
at Pactech
and Finetech**

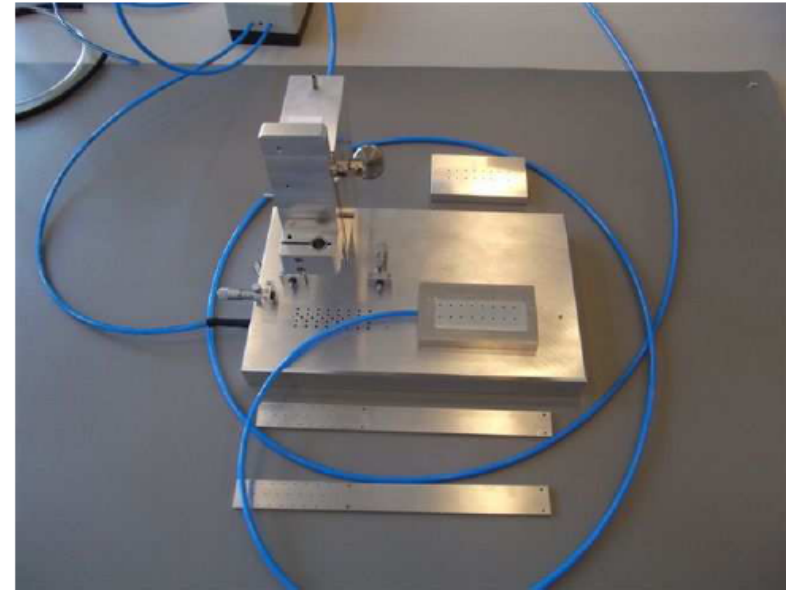
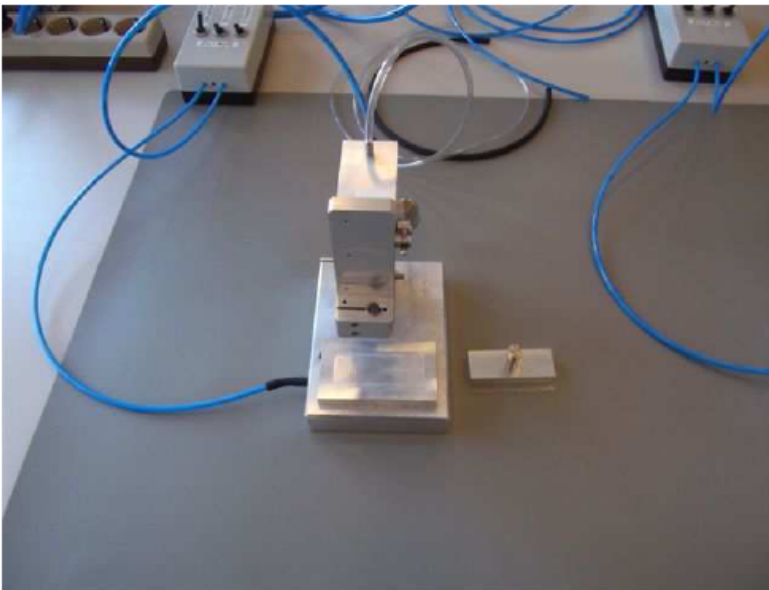
Pixel module assembly tools at Uni HH



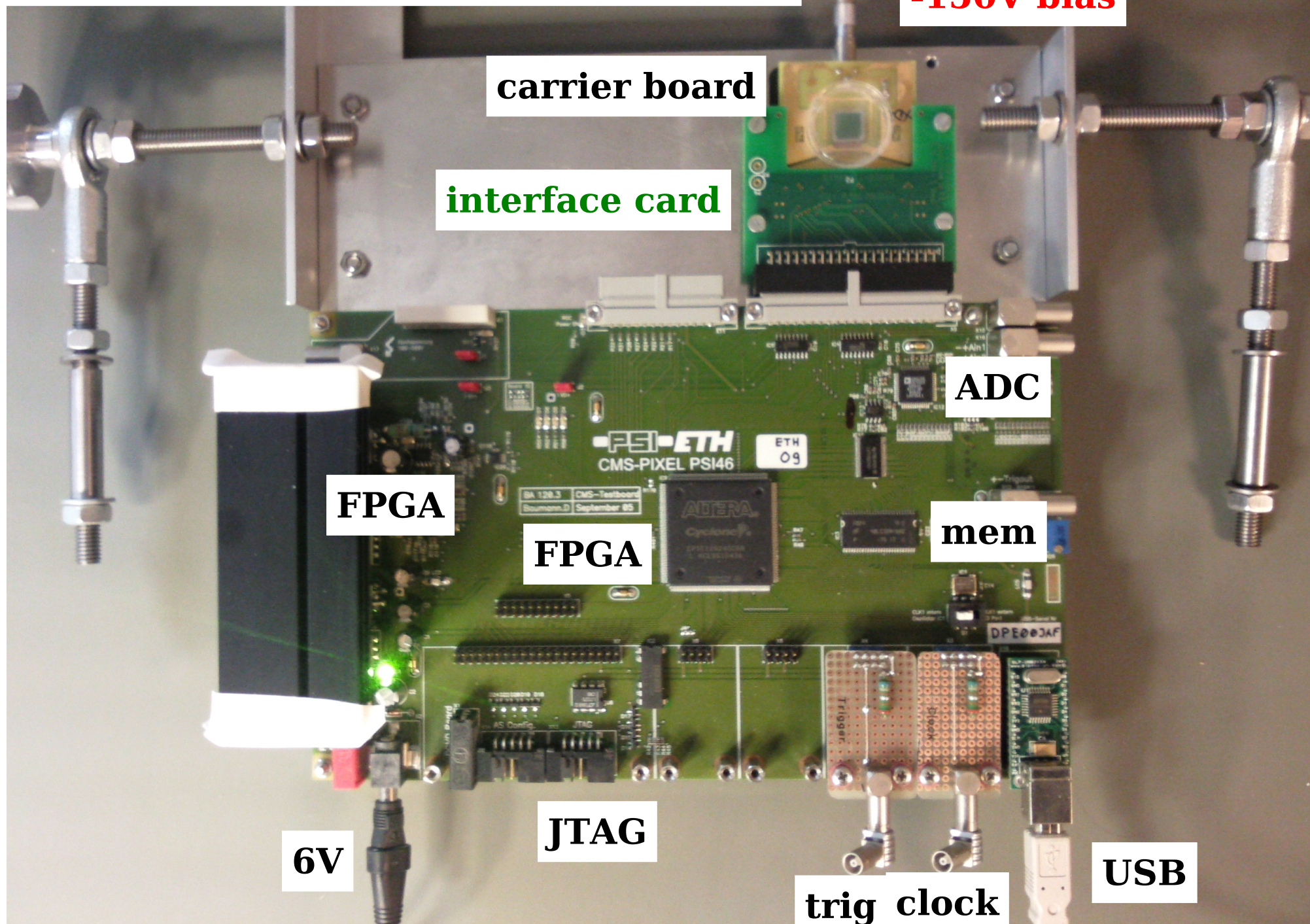
**Tool rebuilt according to
PSI CAD drawings.**

**Gluing tests on dummy
modules done.**

**Await final dimensions:
ROC size, HDI cable, base
strip screw holes**



PSI46xdb test board



ROC testing procedures

- chip testing in the lab:
 - determine ROC operation parameters established
 - bare module test with probe card to be done
 - full module test: 16 ROCs + TBM established
- stand-alone source and test beam established
- resolution measurement in test beam:
 - pixel residuals w.r.t. telescope tracks, with tilt established
- efficiency:
 - pixel w.r.t. to telescope + timing plane established
- low temperature testing: cold box being designed
- X-ray test: Uni HH
 - X-ray tubes taken into operation
 - gain and threshold calibration procedure being developed

CMS pixel planes in the telescope

Mimosa26 pixel
telescope: 3 μm

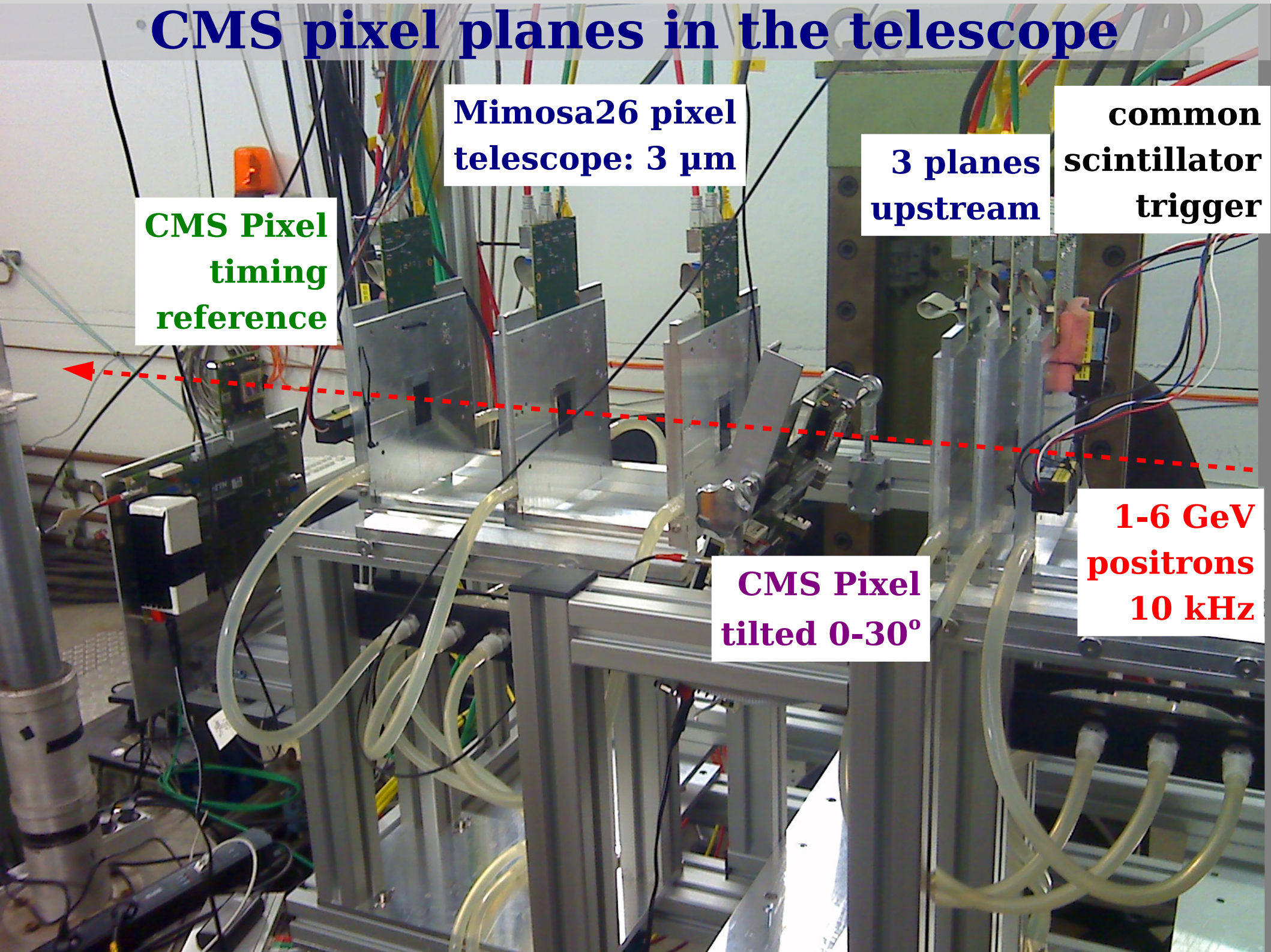
3 planes
upstream

common
scintillator
trigger

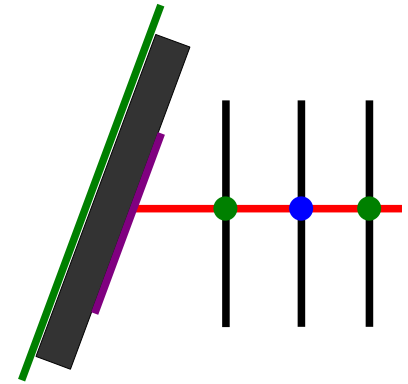
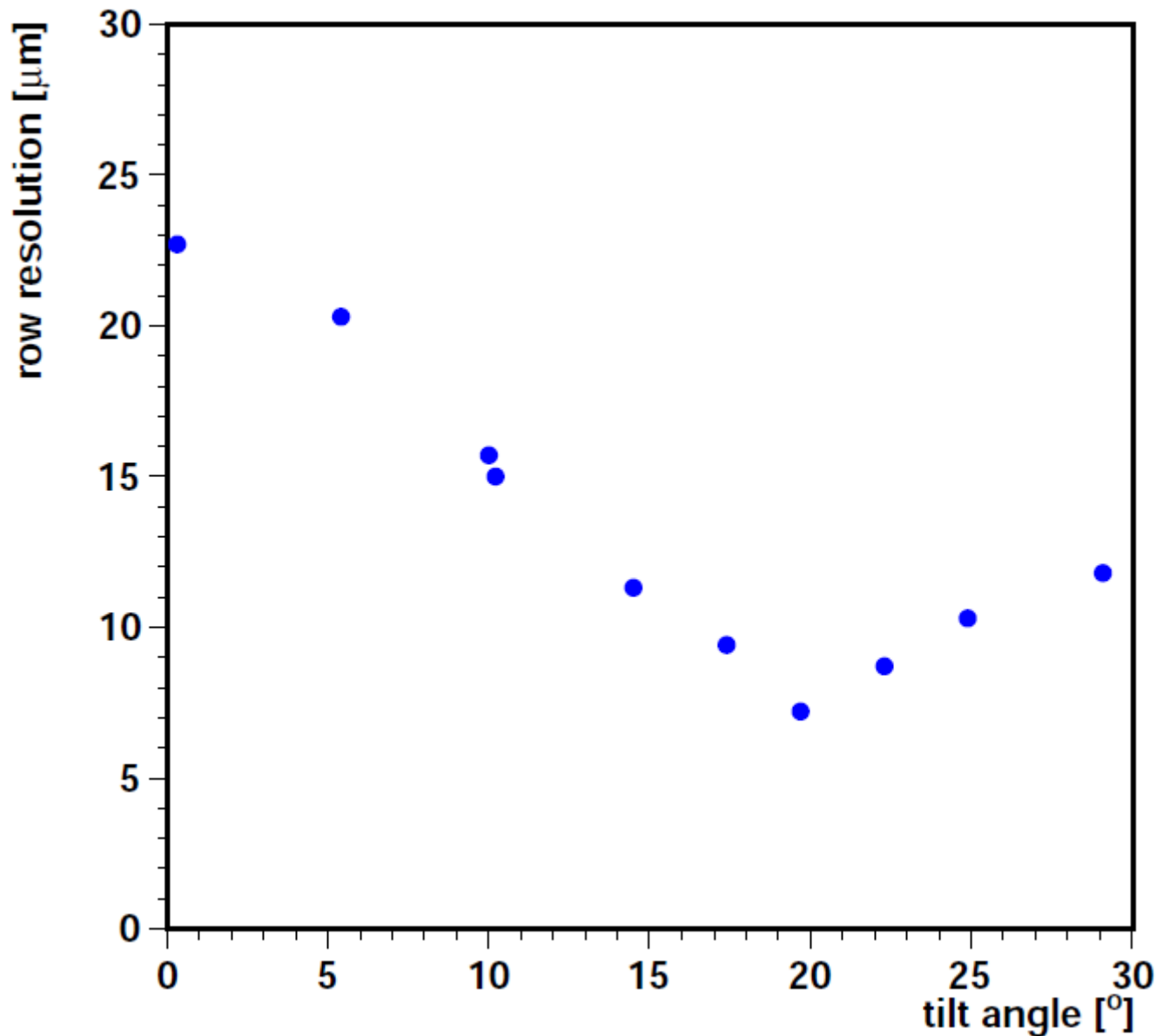
CMS Pixel
timing
reference

CMS Pixel
tilted 0-30°

1-6 GeV
positrons
10 kHz



CMS pixel row resolution vs tilt angle



- Chip 10, 5.6 GeV, telescope extrapolation uncertainty subtracted.
- row pixels = 100 μm.
- Binary:
 - $\sigma = 100 / \sqrt{12} = 29 \mu\text{m}$
- Optimal angle 19.5°:
 - $\sigma = 7 \mu\text{m}$.

Uni HH
Bldg 67
Lab 4
2973

X-ray tight windows

35 kV
1 mA

Ag
target

PSI46
test board

signal
cable

W anode:
flat
Compton
spectrum

pixel module

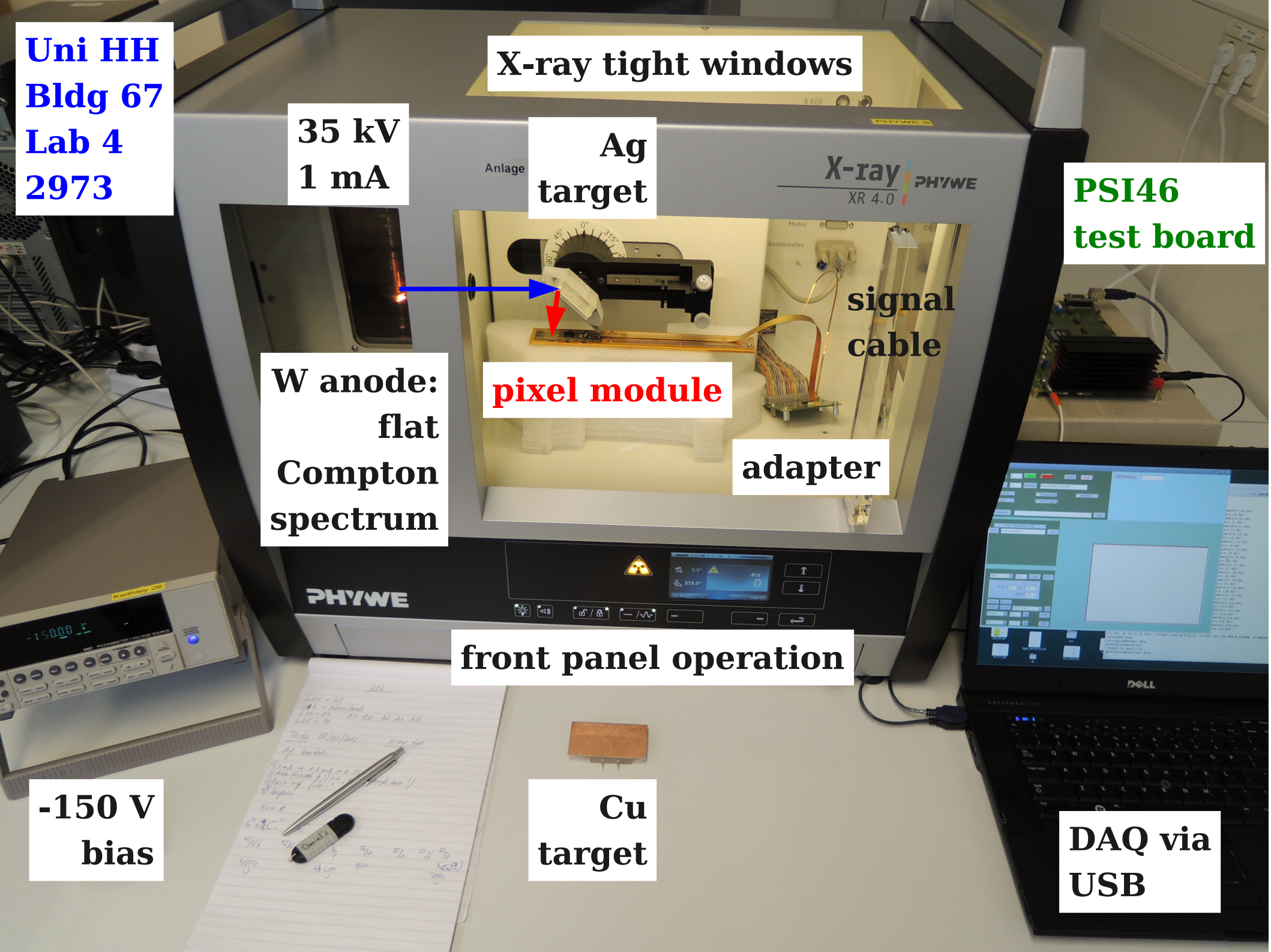
adapter

front panel operation

-150 V
bias

Cu
target

DAQ via
USB



X-ray map through the HDI

SMD
caps

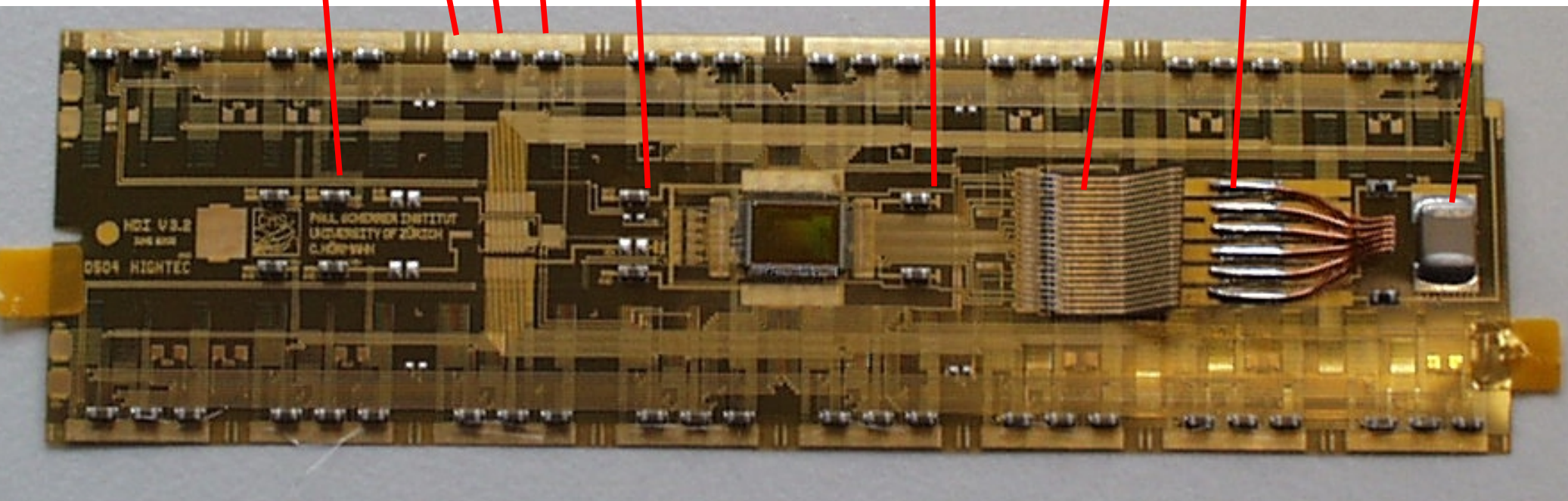
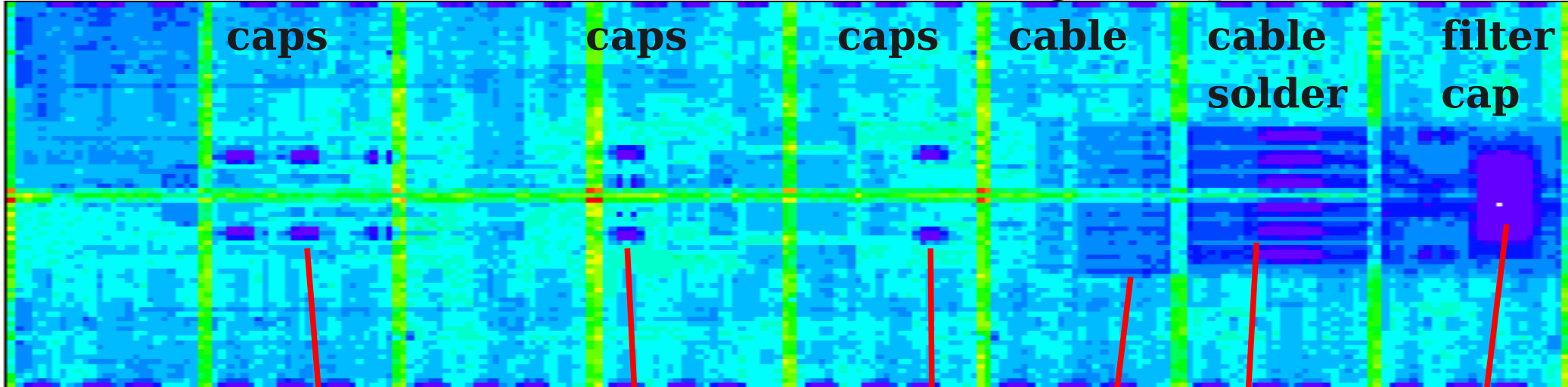
SMD
caps

SMD
caps

signal
cable

power
cable
solder

bias
filter
cap



X-ray box status



- PHYWE XR 4.0 box 2 operational
 - 35 keV, 1 mA
- Fe, Ni, Cu, Zn, Ag targets available
- readout and analysis software available
- Mo and Te targets ordered
- Rotating target holder designed, in production
- Cooled module holder being designed
 - vertical for high rate test in primary X-ray beam 300 MHz/cm²
 - horizontal for calibration with fluorescent X-rays
- Well staffed:
 - 2 post-docs, 2 PhD students

DESY/Uni HH status May 2012

- chip testing in the lab:
 - determine ROC operation parameters established
 - X-ray calibration under development
 - cold test box to be built
- beam test with DESY telescope:
 - take reference data with present ROC done
 - resolution and efficiency vs tilt, threshold, bias measured
 - test new PSI46xdb June/July
- bump bonding:
 - tests at PacTech and FineTech done
 - order machines imminent
 - expected delivery Christmas
 - first live module Spring 2013

Summary

- The CMS barrel pixel project at DESY has advanced well:
 - The group has grown to sufficient size (need to attract the next generation of post-docs and students).
 - The present readout chip is operated in the lab and in beam. We are ready to test the upgrade chip.
 - Cost effective bump bonding has been developed with industry. The order for the machines is imminent (350k + 250k).
 - The X-ray test is established at Uni HH.
- The goals for 2012 are:
 - Beam test of the present and new ROC (efficiency and resolution).
 - Commissioning of the machines for bump bonding.
- Milestone for 2013:
 - assembly of the first module