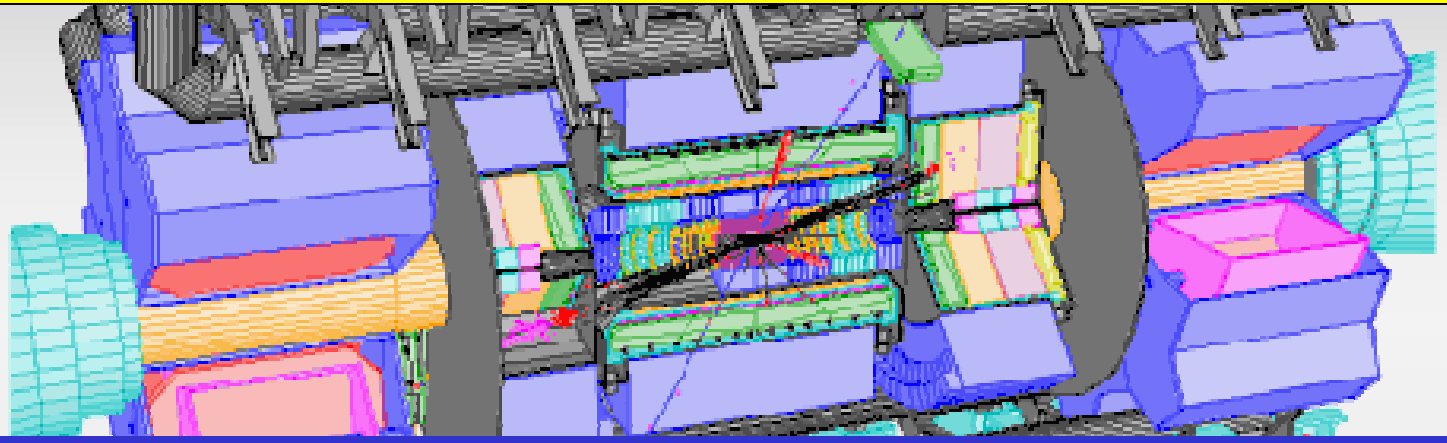
Endcap Modules for the ATLAS SemiConductor Tracker



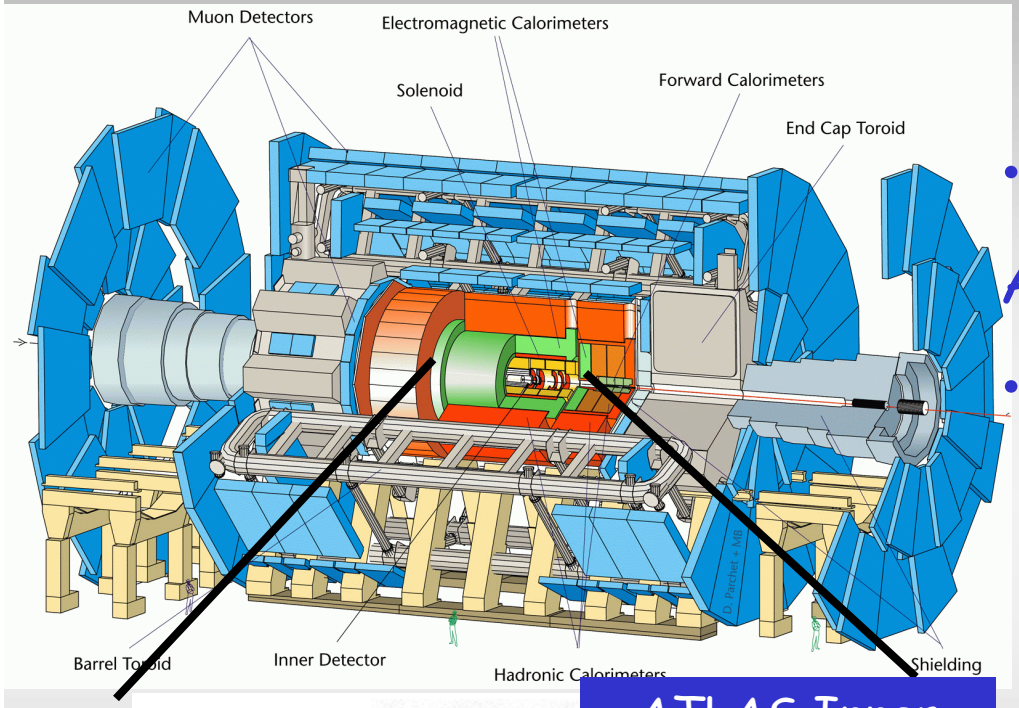
Jochen Schieck

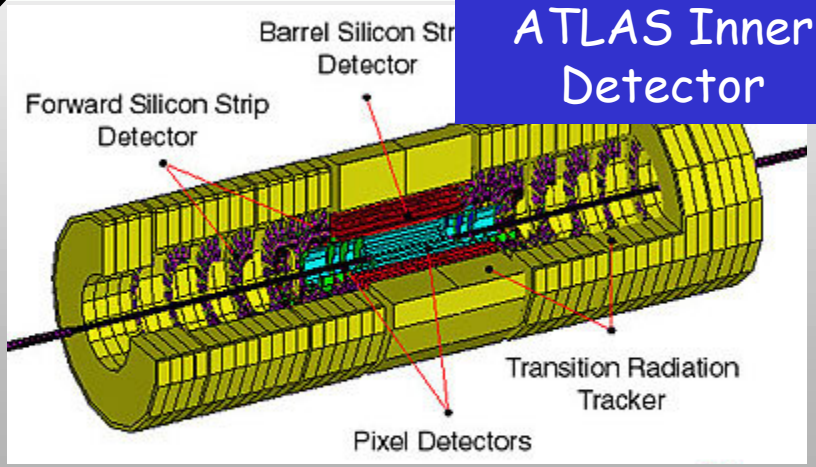
Max-Planck-Institut für Physik

München

for the ATLAS-SCT Collaboration

The ATLAS Detector and SCT

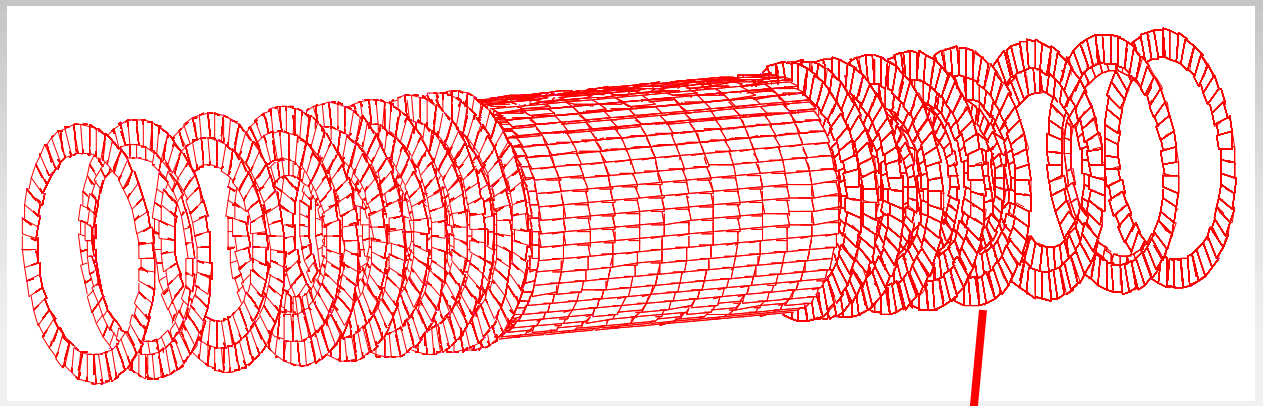


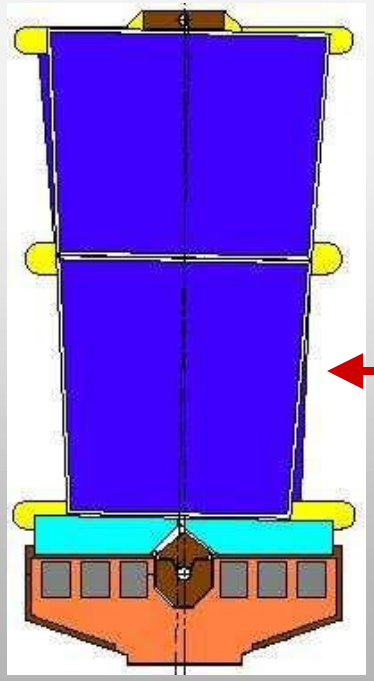


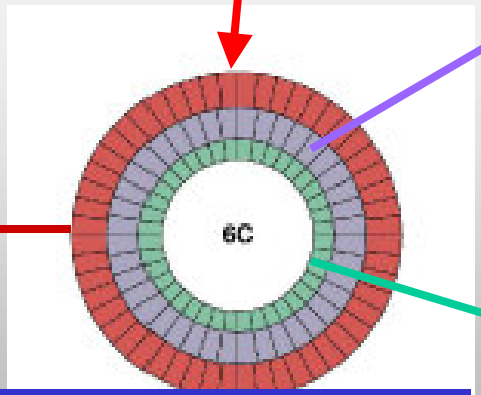
ATLAS Inner Detector

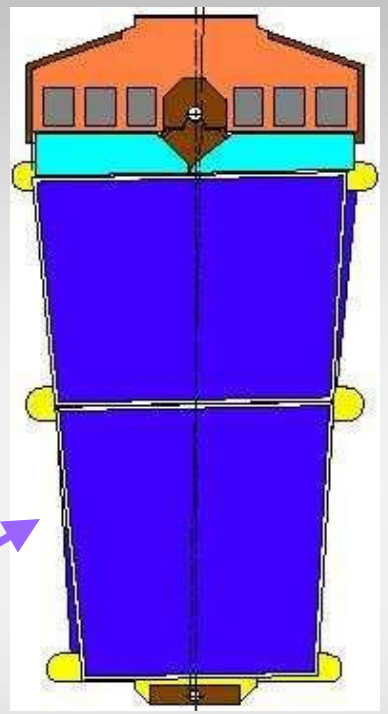
- the SCT is part of the ATLAS Inner Detector
- 4088 silicon strip modules
  - 2112 in the barrel region with 4 layers
  - 1976 in the endcap region distributed on 2 x 9 discs
- pitch between 50 and 90 μm
- 6.3 x 10^6 readout channels

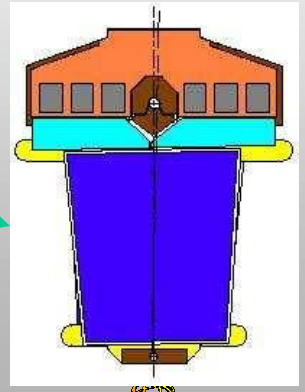
Endcap Module Types





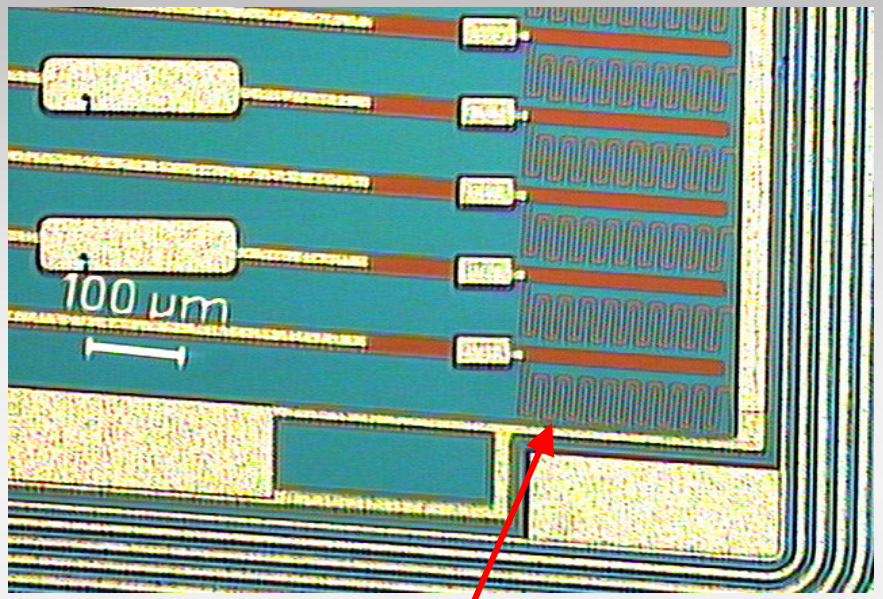






52+40+40=132 modules
on a full disc

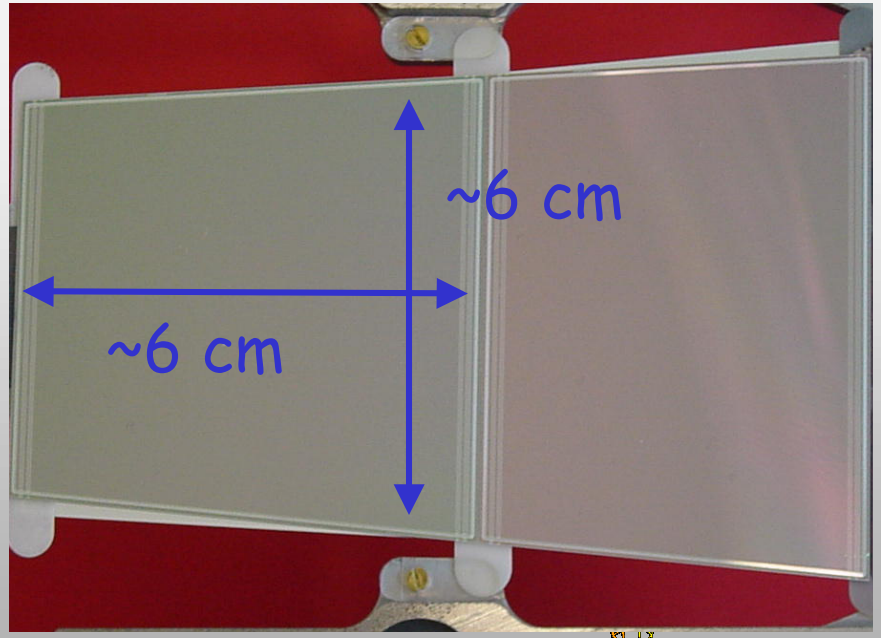
Sensors



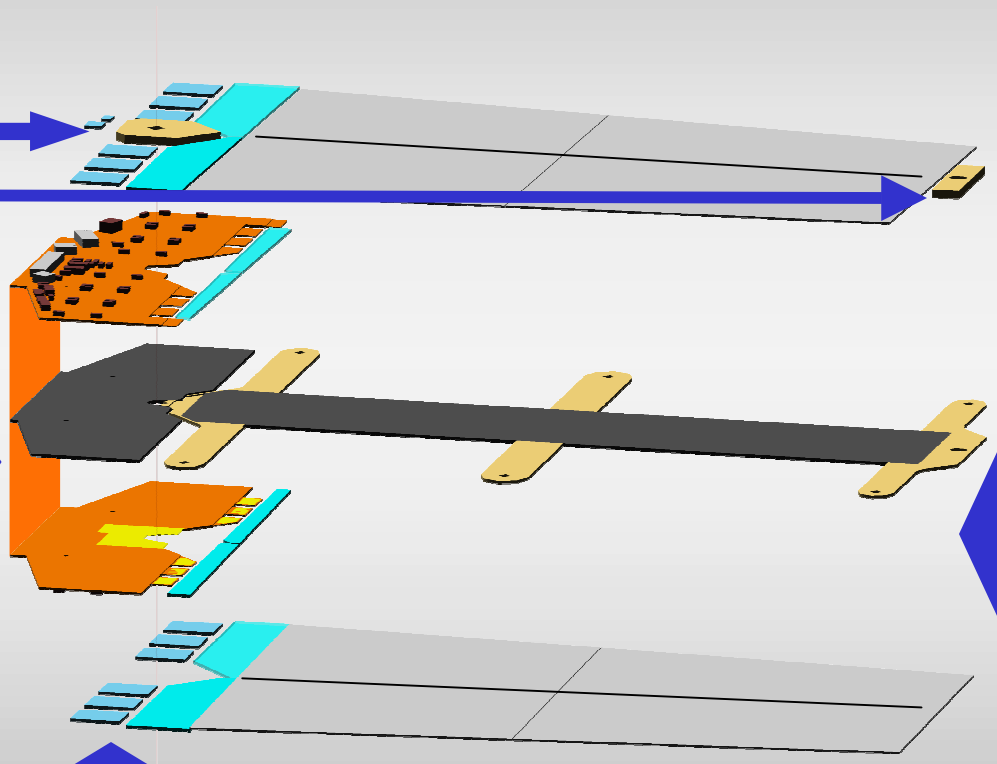
- p-on-n single sided detectors
- 285 µm thickness
- 5 different wedge shapes
- 768 readout strips
- AC-coupled readout

- implanted resistor (CiS only)

- (multi-)guard ring structure for HV stability
- bias current 1-10 µA at 350V
- sensors produced by Hamamatsu and CiS



Forward Module Assembly



mounting points and cooling contacts

4 (2) sensors glued back-to back

flex circuit on carbon-substrate

support-structure (Spine) for heat removal (TPG,1700 W/m/K)

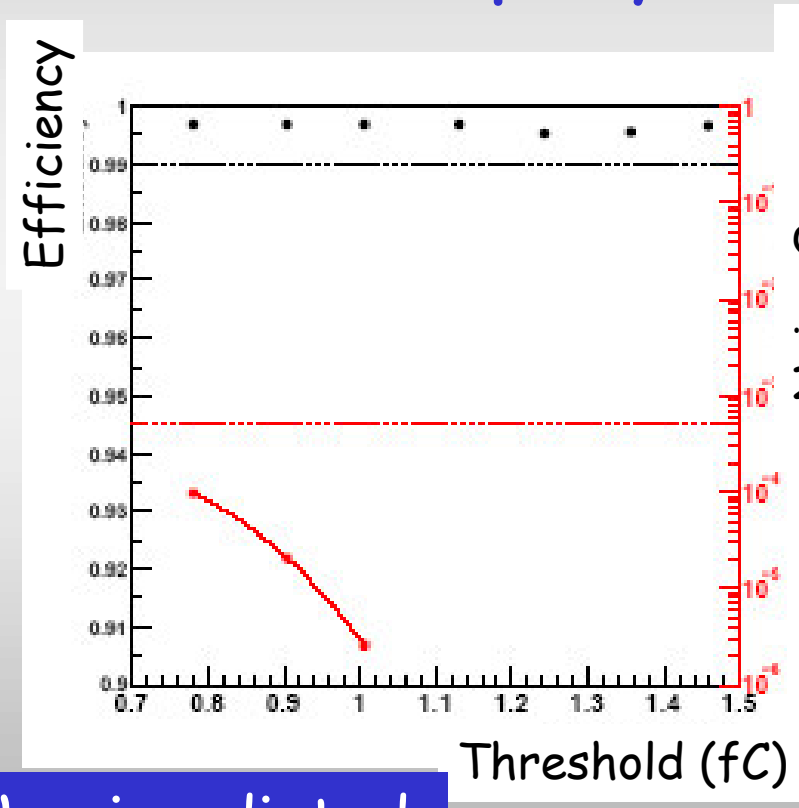
12 ABCD3TA binary read-out chips (DMILL)

Module Performance

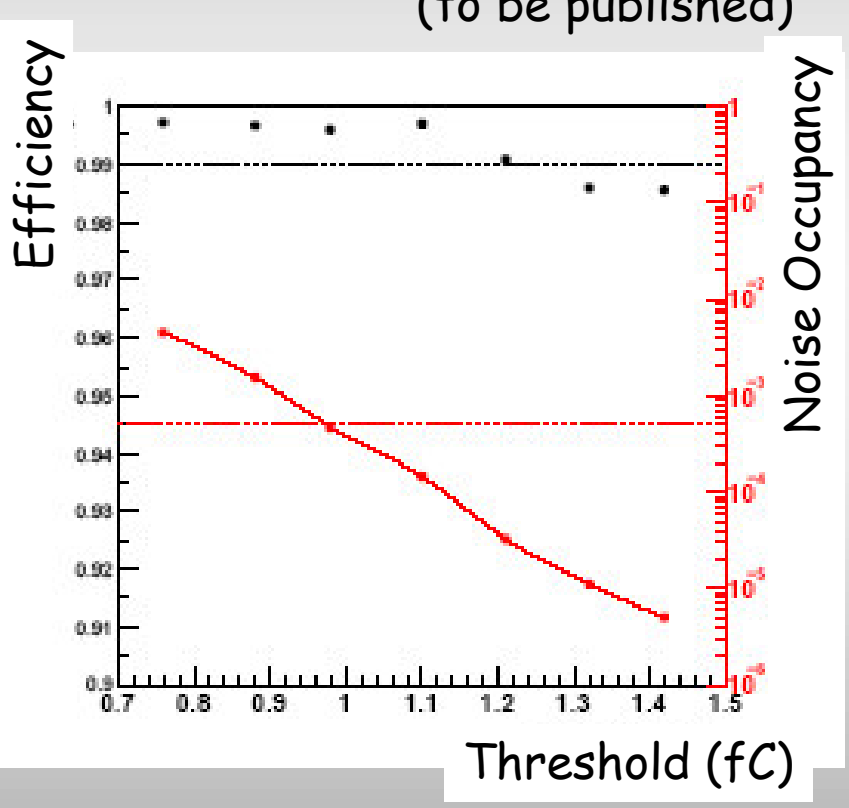
important parameters for a module:

- efficiency > 99%
- noise occupancy < 5×10^{-4}

results from testbeam
(to be published)



Non-irradiated

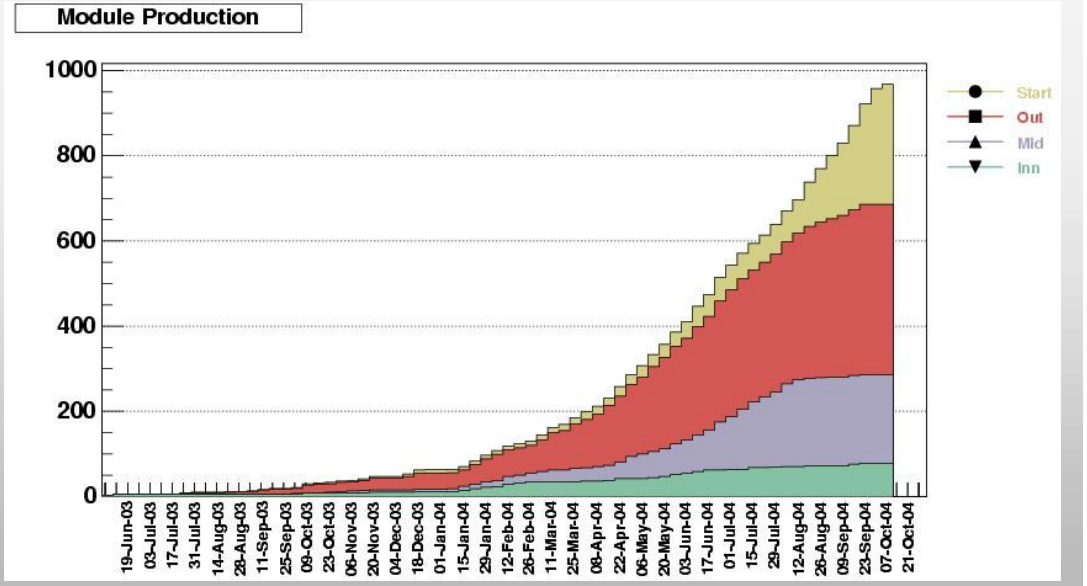


Irradiated (3×10^{14} p/cm^2)

ATLAS Module Production

- worldwide production of modules
  - 7 forward module assembly sites in Australia, Germany, Netherlands, Spain, Switzerland and the UK
- endcap module production runs smoothly since Jul '03

module started:	971
modules tested:	722
yield:	91.3%



(numbers and plot by Carlos Lacasta, 5th Oct)

MPI Module Production

- 400 (+20% contingency) out of 1976 modules will be build at the Max-Planck-Institut in Munich

- only one module type assembled in Munich (middle)
  - middle (4 sensors) and short middle (2 sensors replaced by glass dummy)
- production since Apr' 04

- MPI uses only CiS sensors for the production
- (17% of all (barrel + endcap) sensors have been made by CiS)

Module Building – Production Steps

Version 2.0.2
September 15, 2004

SCT Middle Module Production Sheet for Module

20220270300 = (MPI – Mod–) Eval : Date :

1) Wafer - spine assembly

Wafer (20220940xxxxxx, Spine (20220yyyxxxxxx) Date: _____ Who: _____

Wafer Serial Number	ASide-W21 202209404	ASide-W22 202209405	BSide-W21 202209404	BSide-W22 202209405	Spine 20220	Turn-plate
Serial Number						
I [μA] (350V)					Σ =	

Observations: _____

2) xyz-Survey after gluing *'ag'* **(mm/mrad)** Date: _____ Who: _____

Hybrid Hole - x	Hybrid Hole - y	Farend Slot - x	Farend Slot - y	
Δ *mhx* ($\pm$0.020)	Δ *mhy* ($\pm$0.020)	Δ *msx* ($\pm$0.100)	Δ *msy* ($\pm$0.020)	
Δ *midx f* ($\pm$0.010)	Δ *midy f* ($\pm$0.005)	Δ *sepf* ($\pm$0.010)	Δ *sepb* ($\pm$0.010)	
Δ *a1* ($\pm$0.130)	Δ *a2* ($\pm$0.130)	Δ *a3* ($\pm$0.130)	Δ *a4* ($\pm$0.130)	Δ *stereo* ($\pm$0.130)
Front: 0.760 / 0.875 / 0.990 min / mean / max		Back: -0.490 / -0.375 / -0.260 min / mean / max		DBase
/	/	/	/	/

3) Wafer IV curves *'ag'* ($I < 20\mu A$, $\Delta I(1) < 1\mu A$) Date: _____ Who: _____

Wafer	ASide-W21 150/350 V	ASide-W22 150/350 V	BSide-W21 150/350 V	BSide-W22 150/350 V	Σ 150/350 V	DBase
I [μA]						

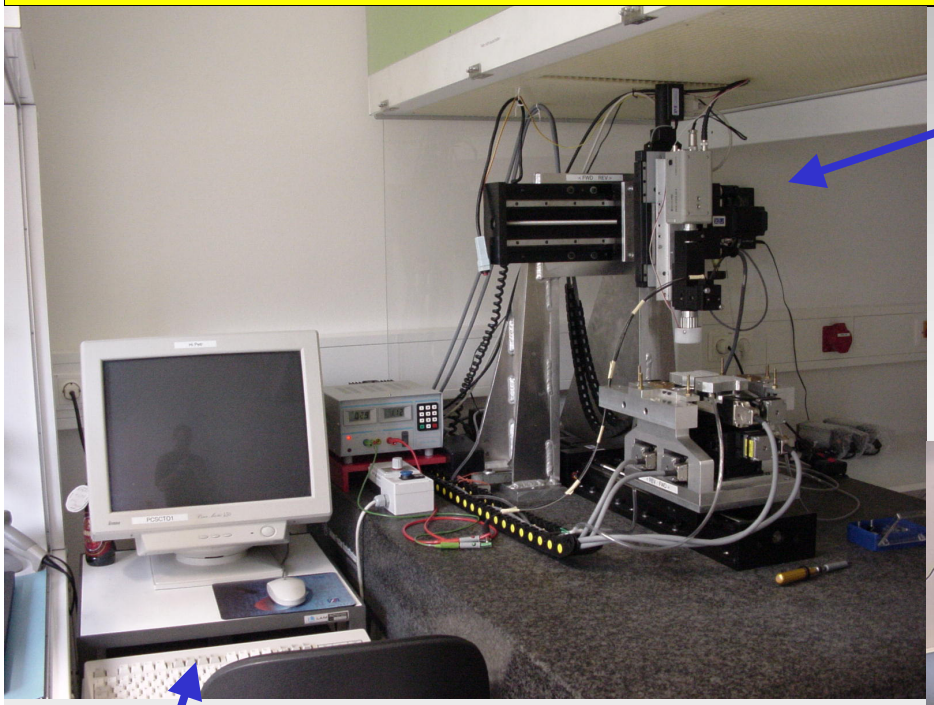
4) Gluing of Hybrid and Fan-ins **DBase** _____ Date: _____ Who: _____

Object Serial Number	Hybrid 2022055	Fan-in (L/R) (20220990/20220990)	Glue (el/mech) 20220990291534/	Hybrid-Washer
Serial Number			20220990290646	20220990288551

Observations: _____

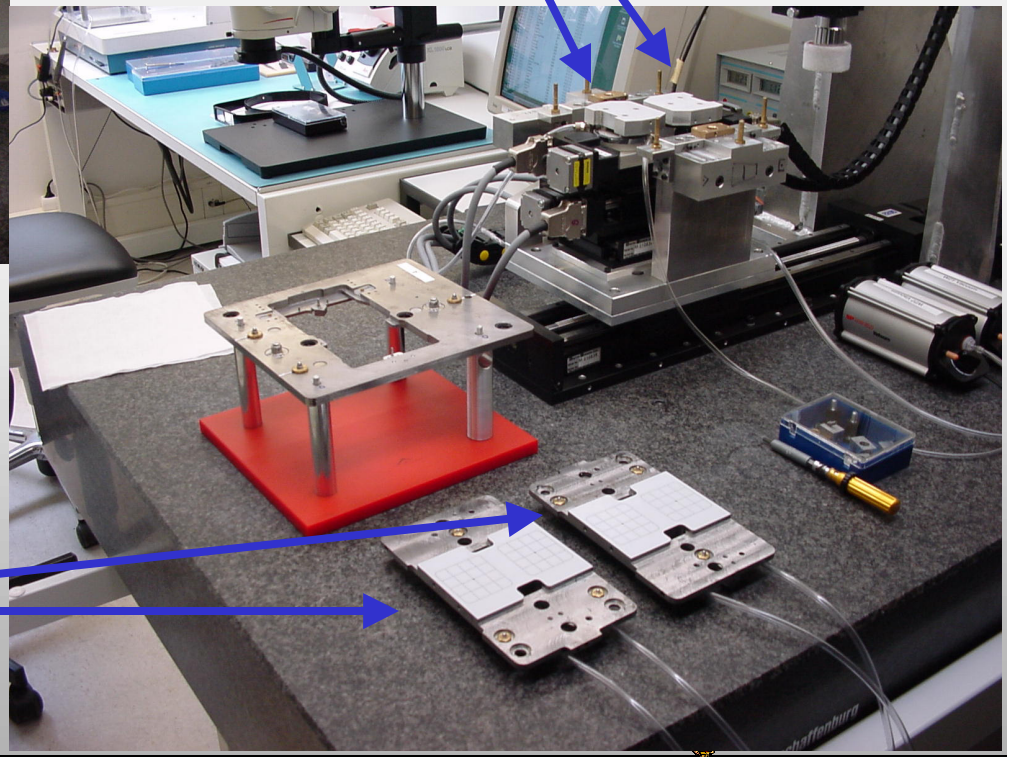
1. check sensors
   - visual inspection
   - IV-curve
2. assemble module
   - glue sensors to spine
   - glue hybrid to module
3. measure metrology of module
   - survey in XY and Z
4. bonding of module
5. perform electrical tests
6. thermal cycling and check metrology
7. ship module to Prague for complete electrical tests

Mechanical Construction



camera for fiducial mark recognition

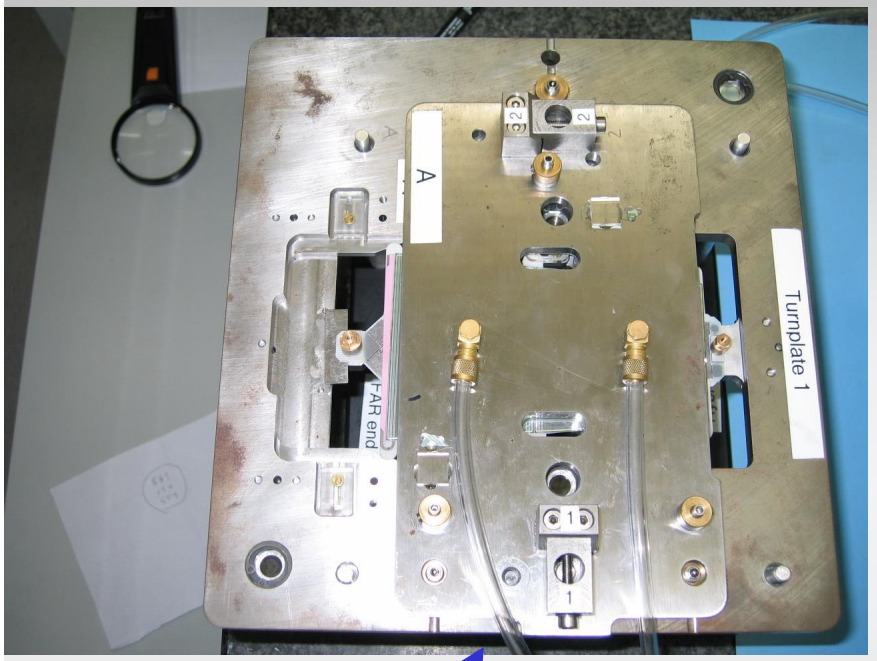
stages for positioning of sensors



PC with LabView for stage control

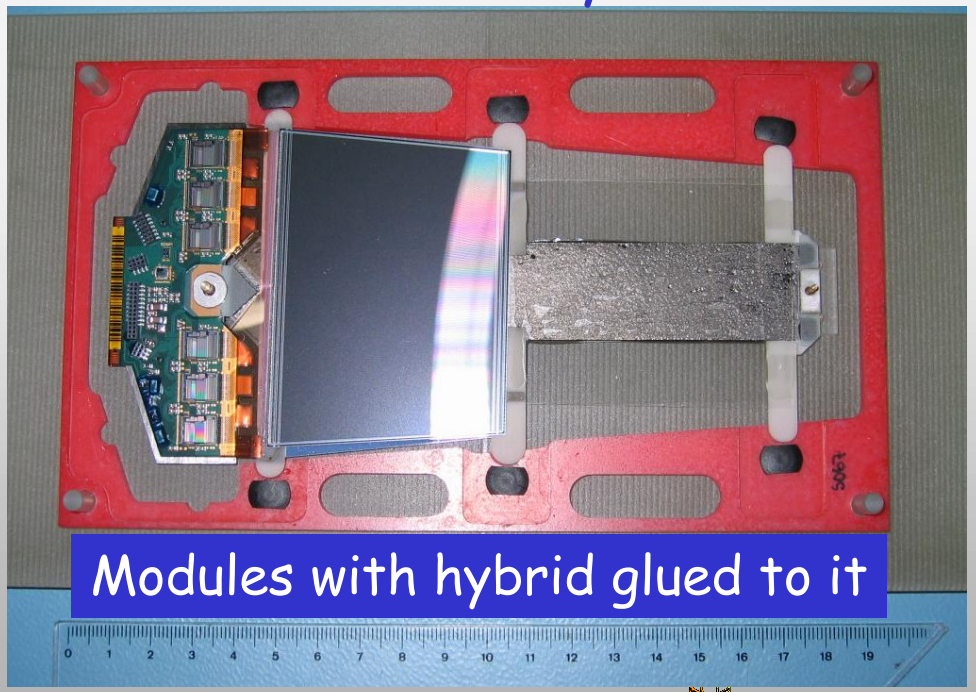
transfer of sensors with vacuum

Mechanical Construction

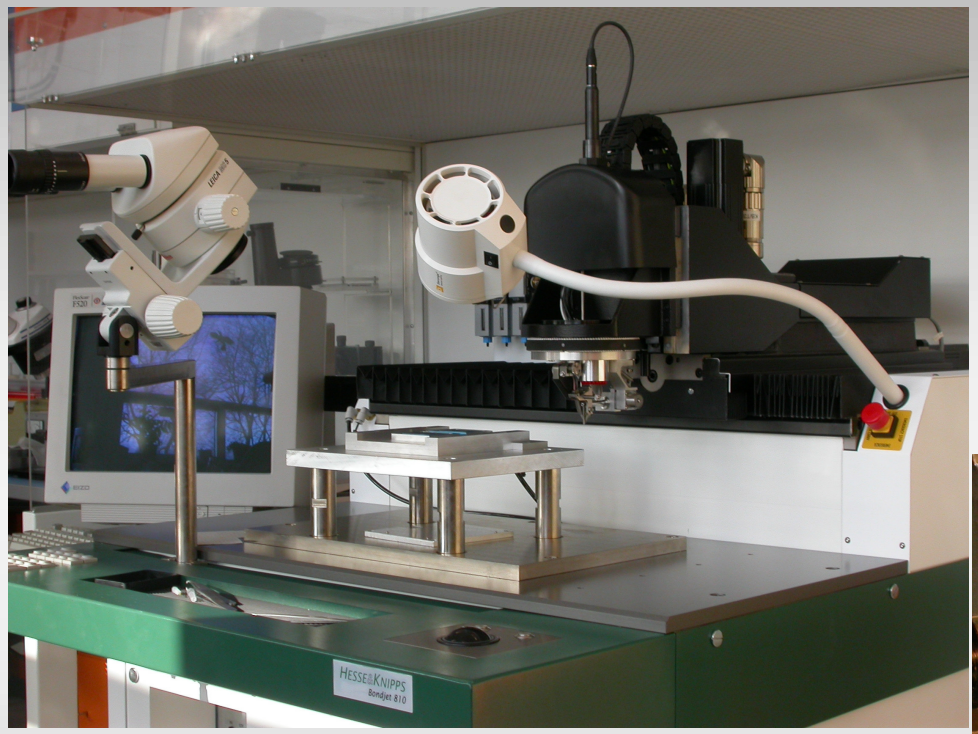


assembled sandwich of spine and sensors

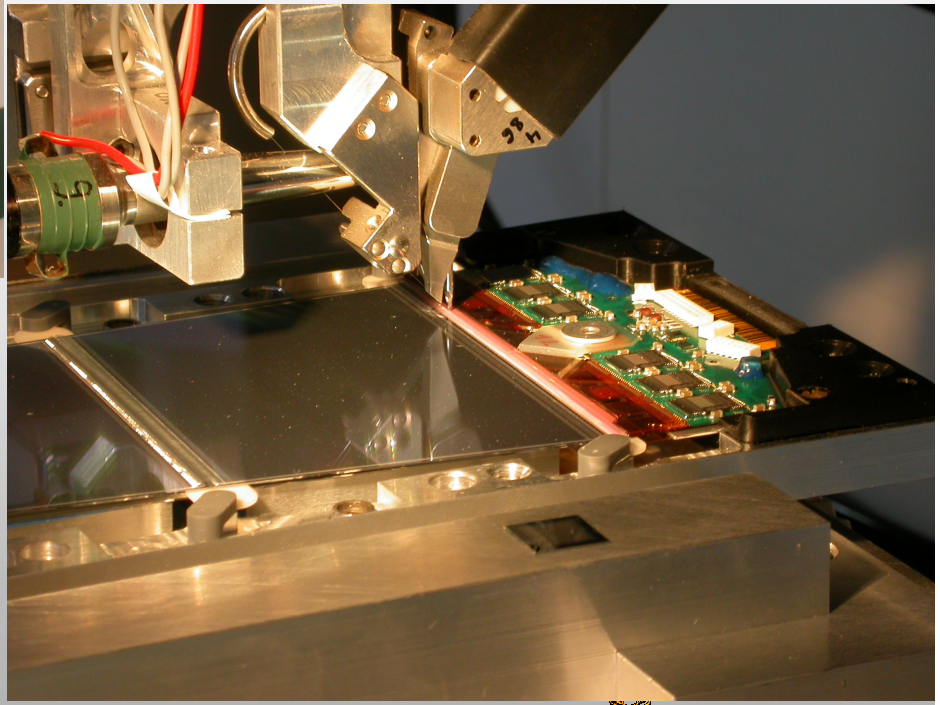
'short' middle module with glass plate for mechanical stability



Bonding



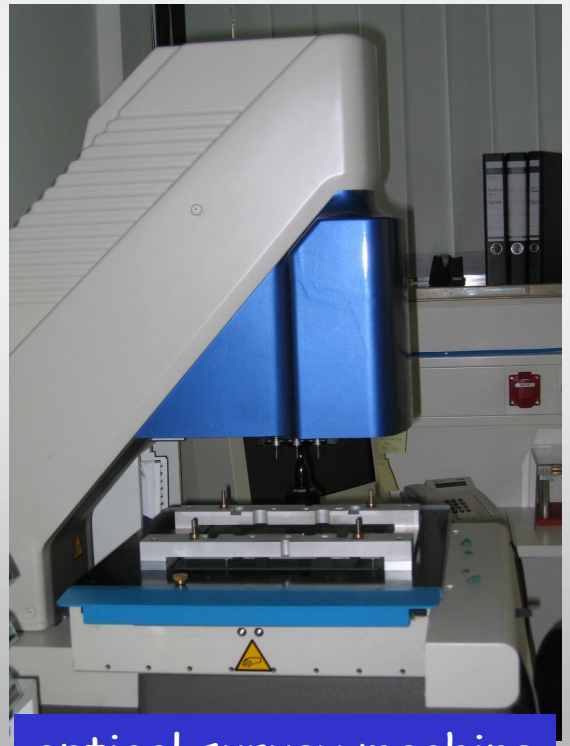
Hesse & Knipps
automatic bonder



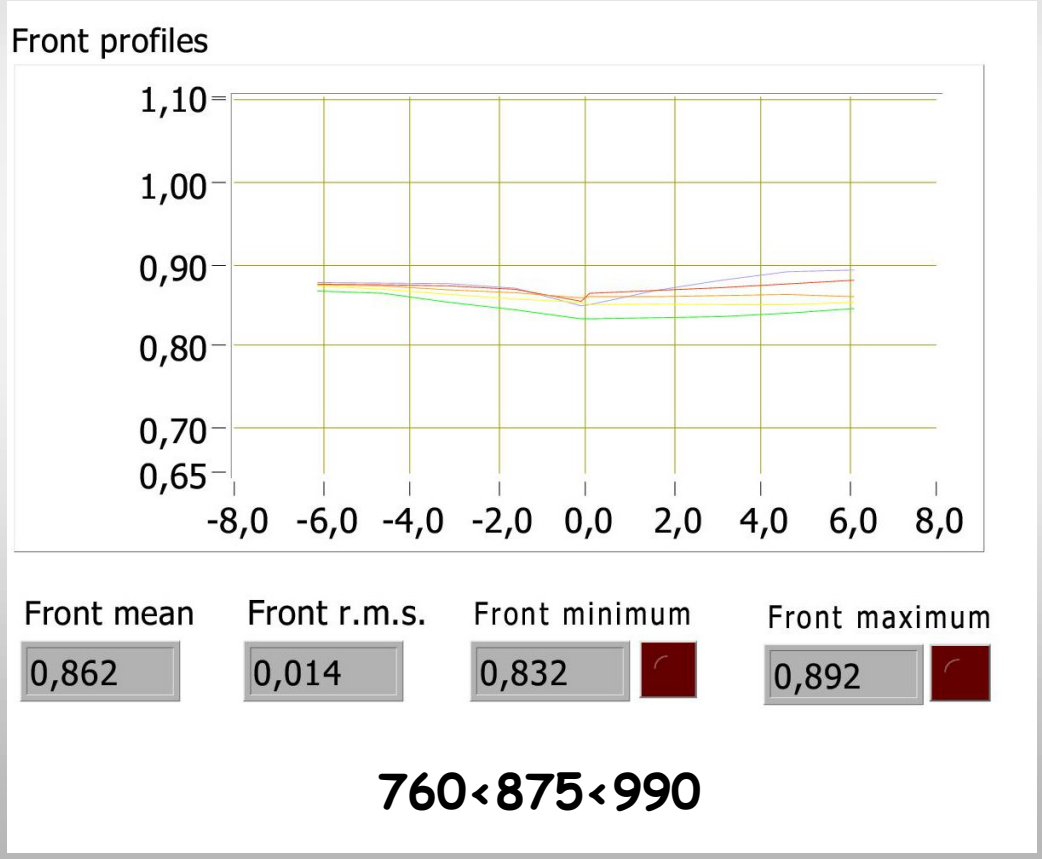
- bonding with 17µm wire
- 2-3 modules per day

Mechanical Survey

- **xyz-survey of module**
  - after each assembly step and thermal cycling
  - 30-40 min per module

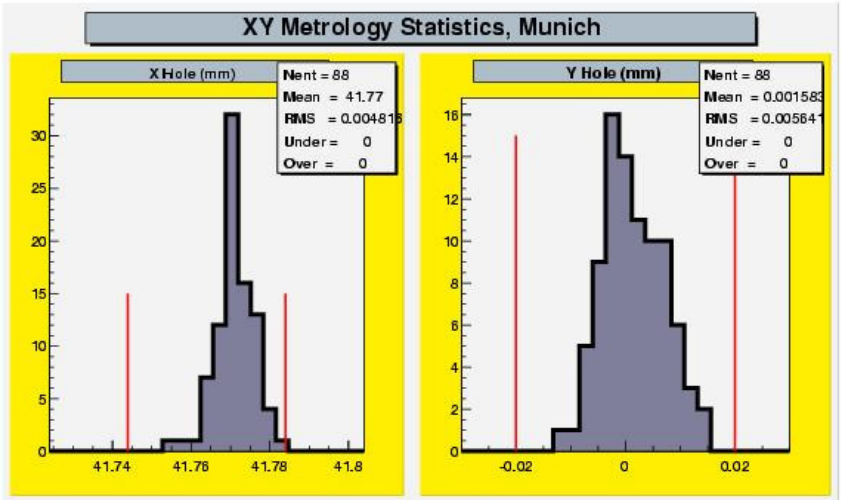


optical survey machine



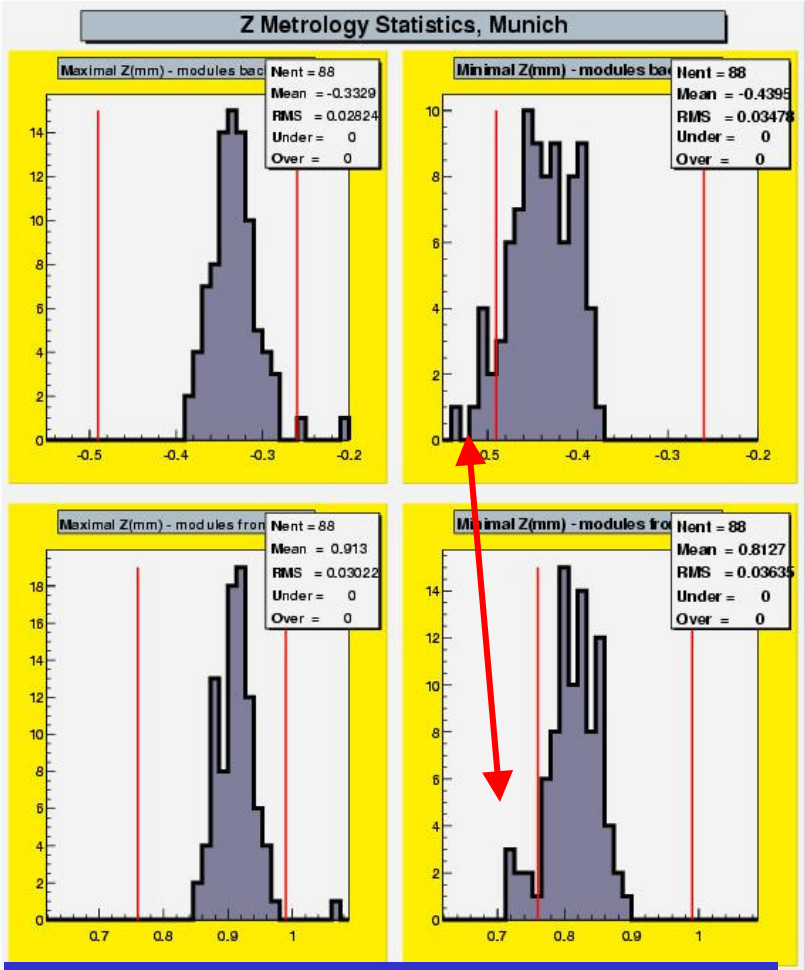
Mechanical Survey

position of the hybrid hole



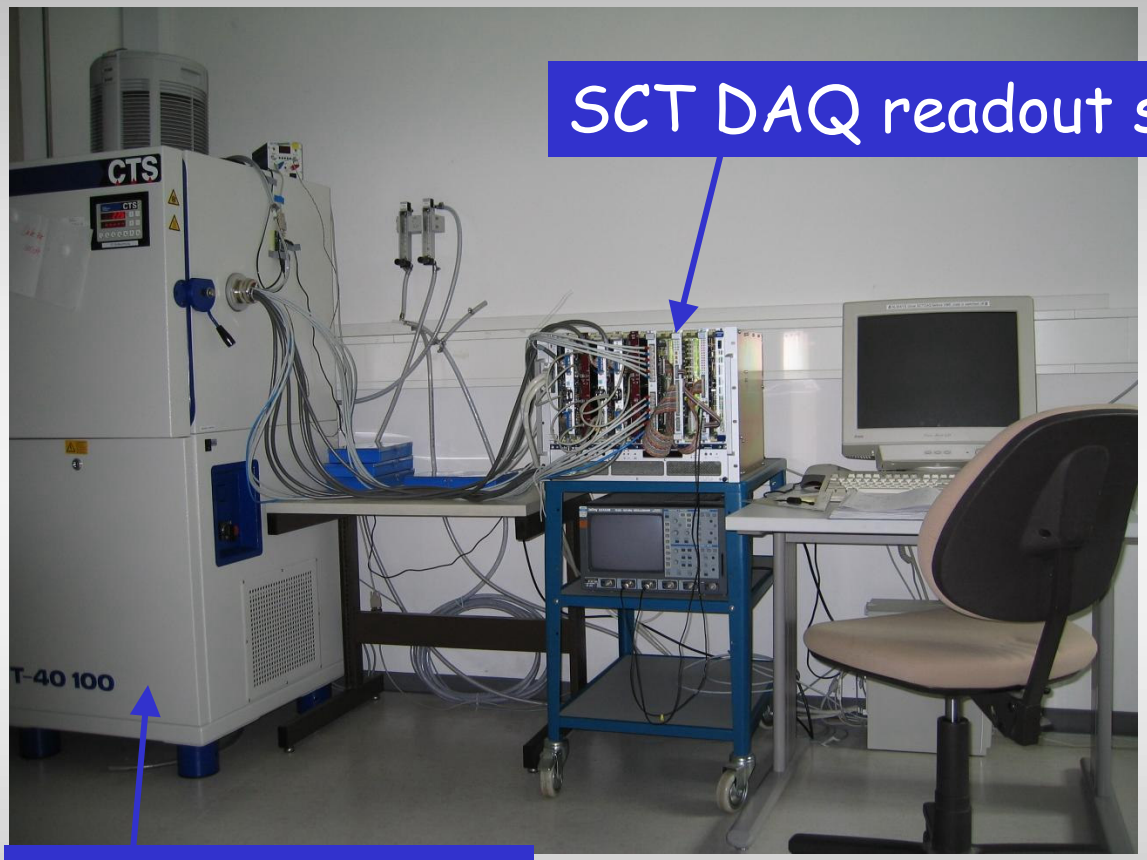
mid-point of backside sensor

min/max Z-position of front side



min/max Z-position of back side

Electrical Tests of Modules



SCT DAQ readout system

climate chamber

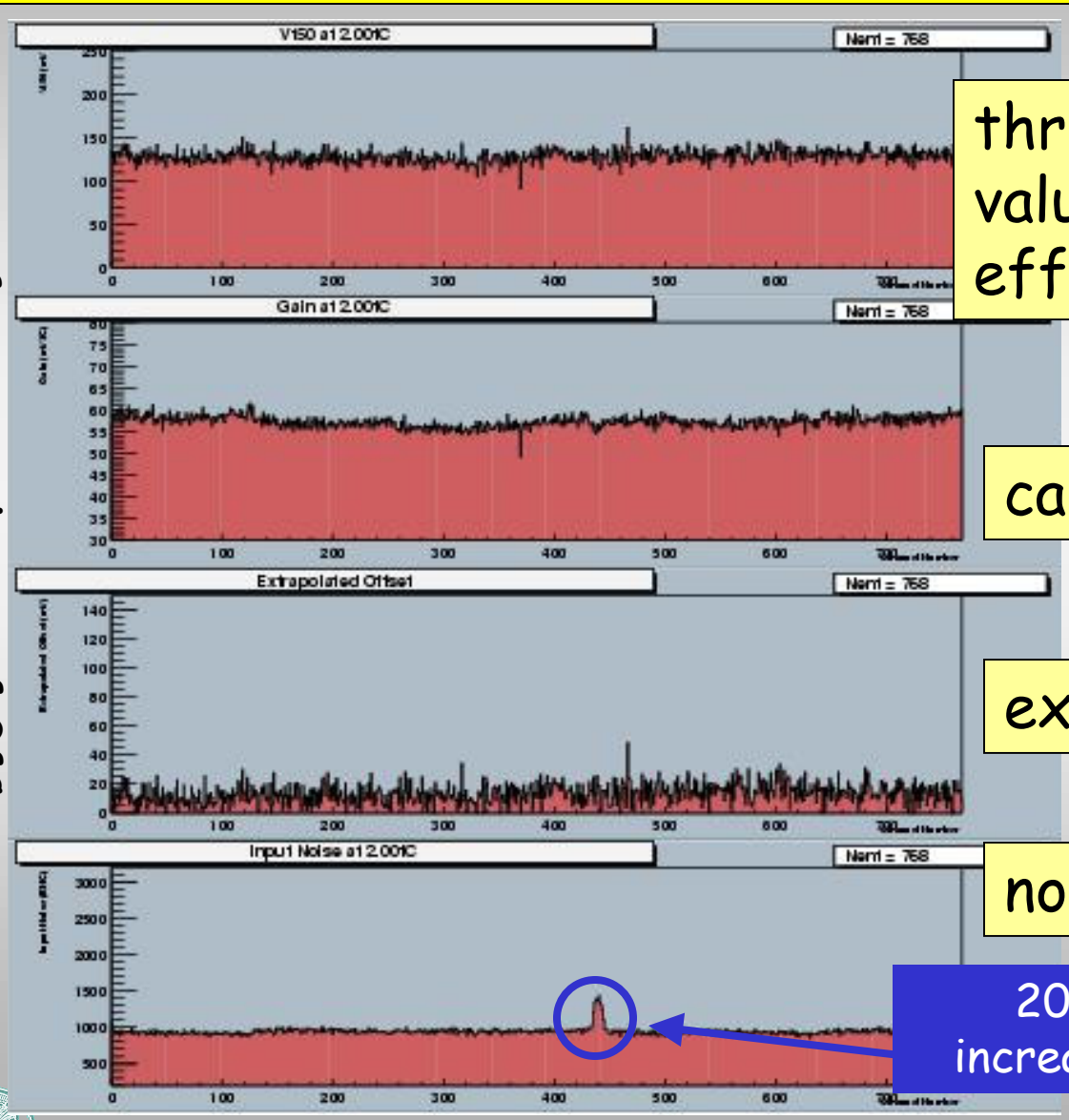
performance of module tested at local setup

- test of digital electronics on hybrid
- analog performance of module
  - measurement of gain and noise using induced charge

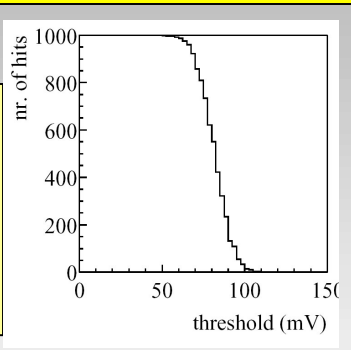
the more detailed characterization of modules is performed in Prague

Electrical Test of Modules

for input charge of 2fC



threshold value at 50% efficiency



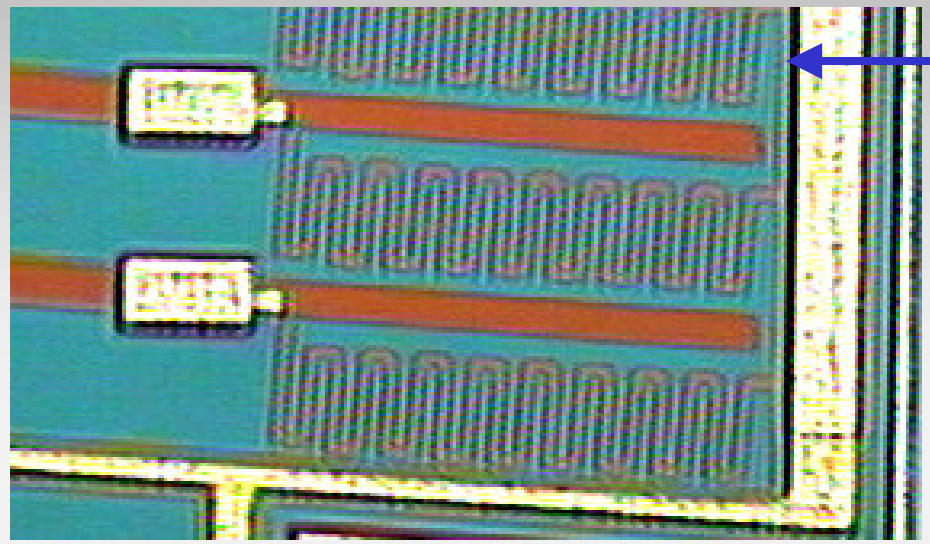
calculated gain

extrapolated offset

noise in e^- ENC

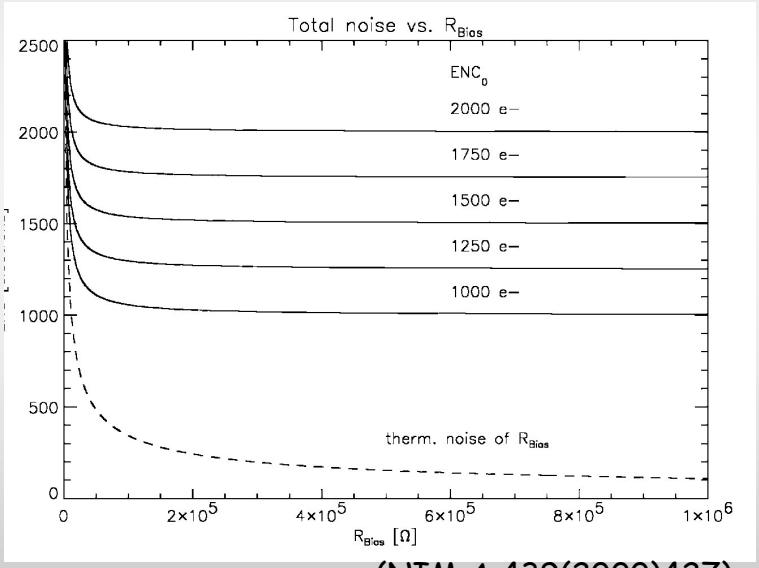
20 out of 96 modules show increased noise for 20-30 strips

Electrical Test of Modules



implanted R_{bias} resistors

$$ENC_{R_{bias}}(e^-) \propto \sqrt{\frac{1}{R}}$$



(NIM A 439(2000)427)

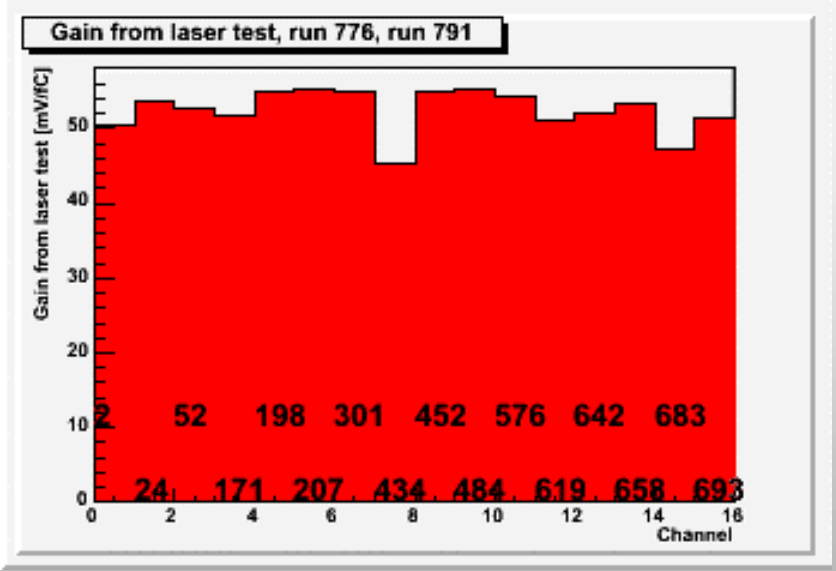
- R_{bias} design value 1±0.5 MΩ
- direct measurement of R_{bias} shows lower value
- possible problem at photolitho-graphic process of sensor production

still under investigation !

Punch Trough Channels

- some modules show increased number of channels with a short between the aluminum and implanted strip (punch through; PT)
- careful adjustment of the Bonder reduced the number of PT down to 0.4%

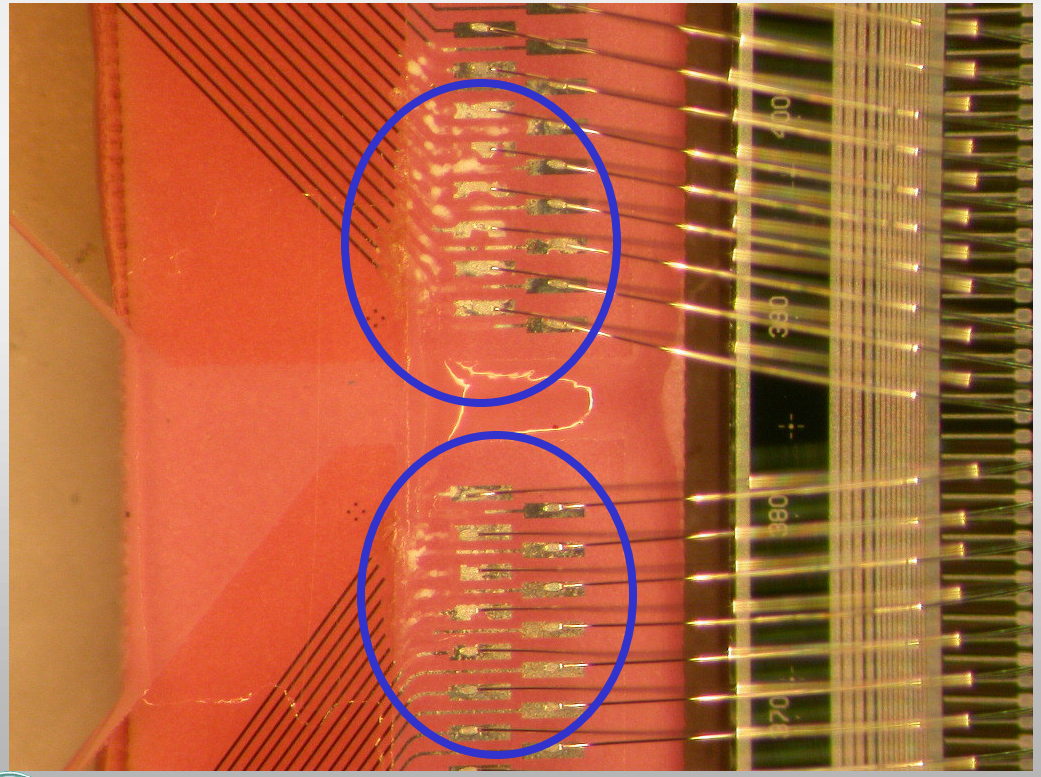
- some PT channels show low gain (~30%)
- tuning of front-end setting recovers most of the PT channels with low gain



(Analysis performed by Peter Kodys and Zdenek Dolezal)

Eroded Fanins

- two modules show erosion after thermal cycling
→ parts of the bond pads on the fanins eroded away
- module were under high voltage for 21h at ~70-80% RH



- chemical analysis was performed:
  - residuals of Sodium and Potassium
- spines are cleaned with NaOH during construction
  - no hints for Na or K found on spine

Summary of MPI Module Production

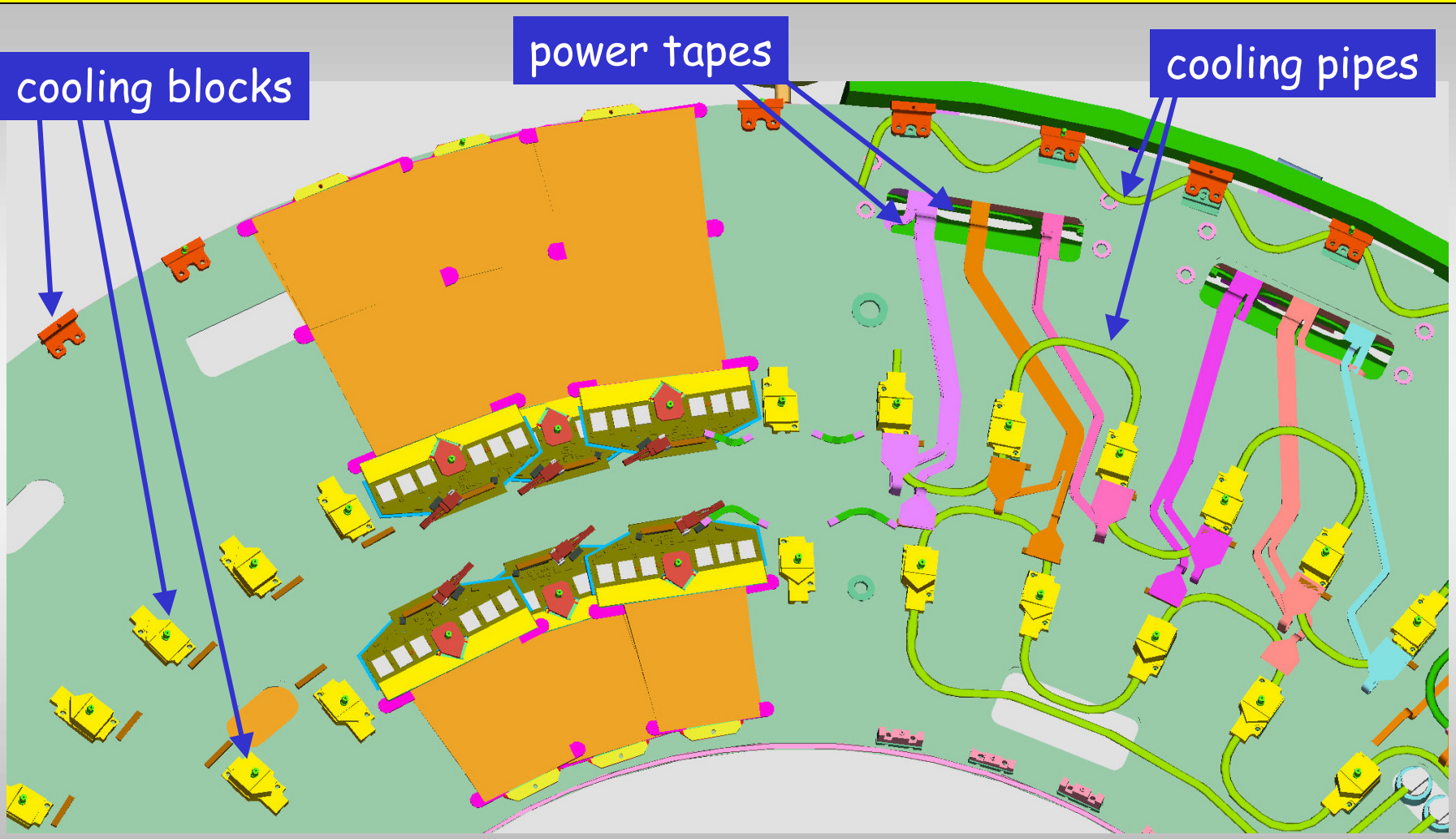
production of 96 short middle modules at the MPI finished

- production of up to 2 modules per day
- assembly efficiency > 90%
- 20 modules have high noise for several strips
  - still under investigation
- 2 module show problems with hybrid
  - 1 module needs chip replacement
  - 1 module fails digital test
- modules will be mounted on disc 8 soon

production of long middle modules started (~50)

- increased assembly efficiency of > 97%
- production stopped due to investigation for noise

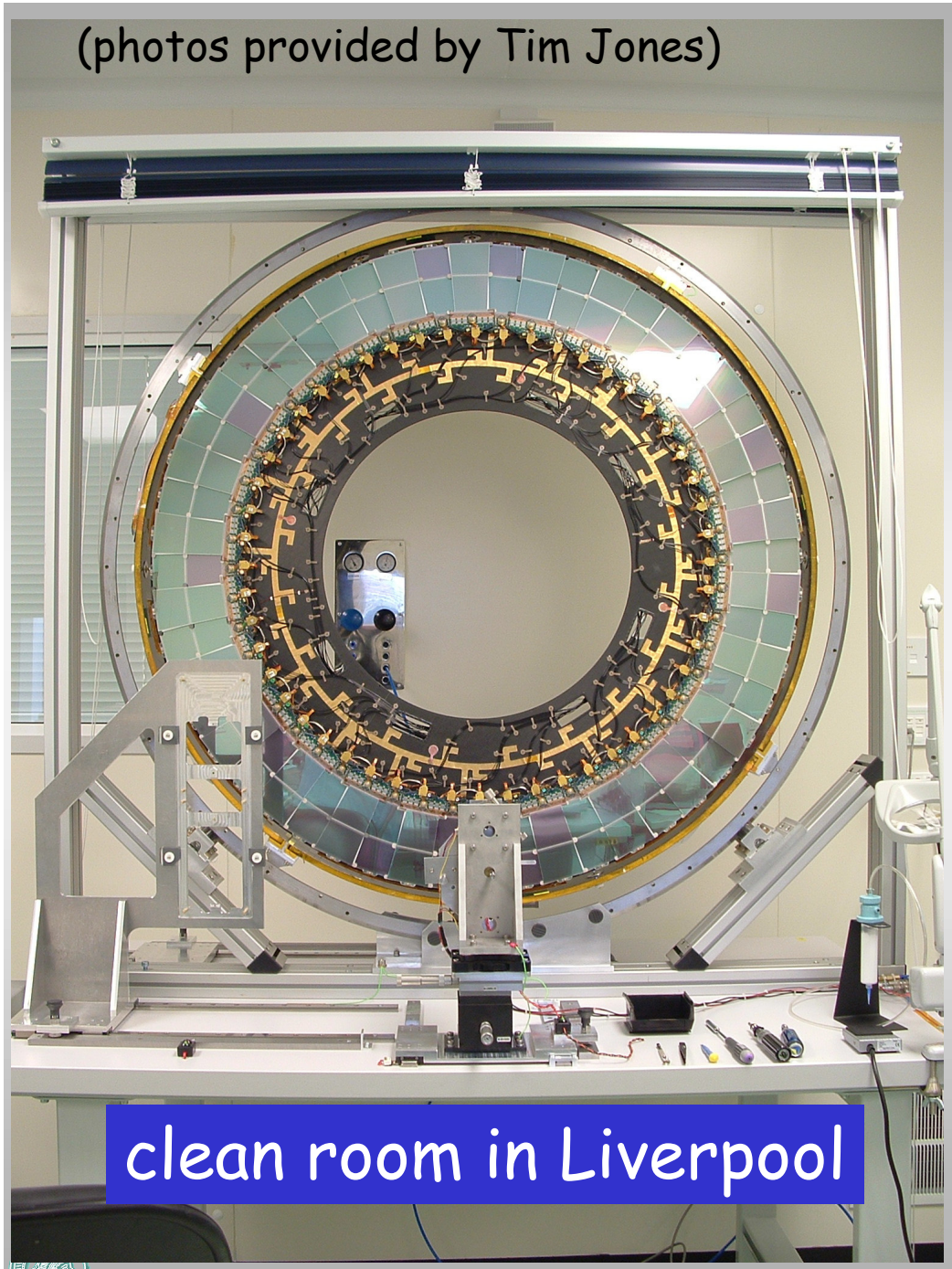
Mounting of modules on Disc



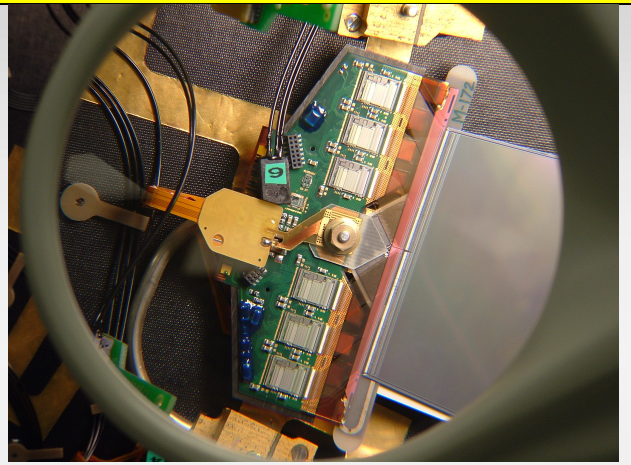
middle modules are mounted on the backside of the disc

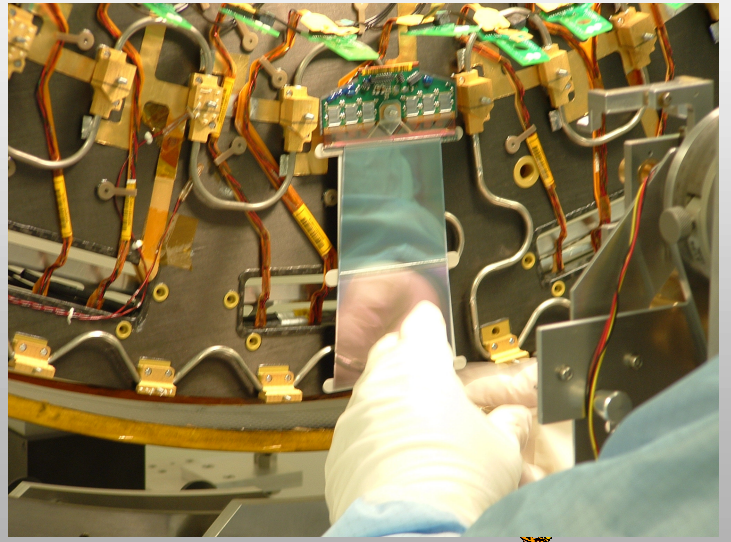
Mounting on Disc 9

(photos provided by Tim Jones)



clean room in Liverpool



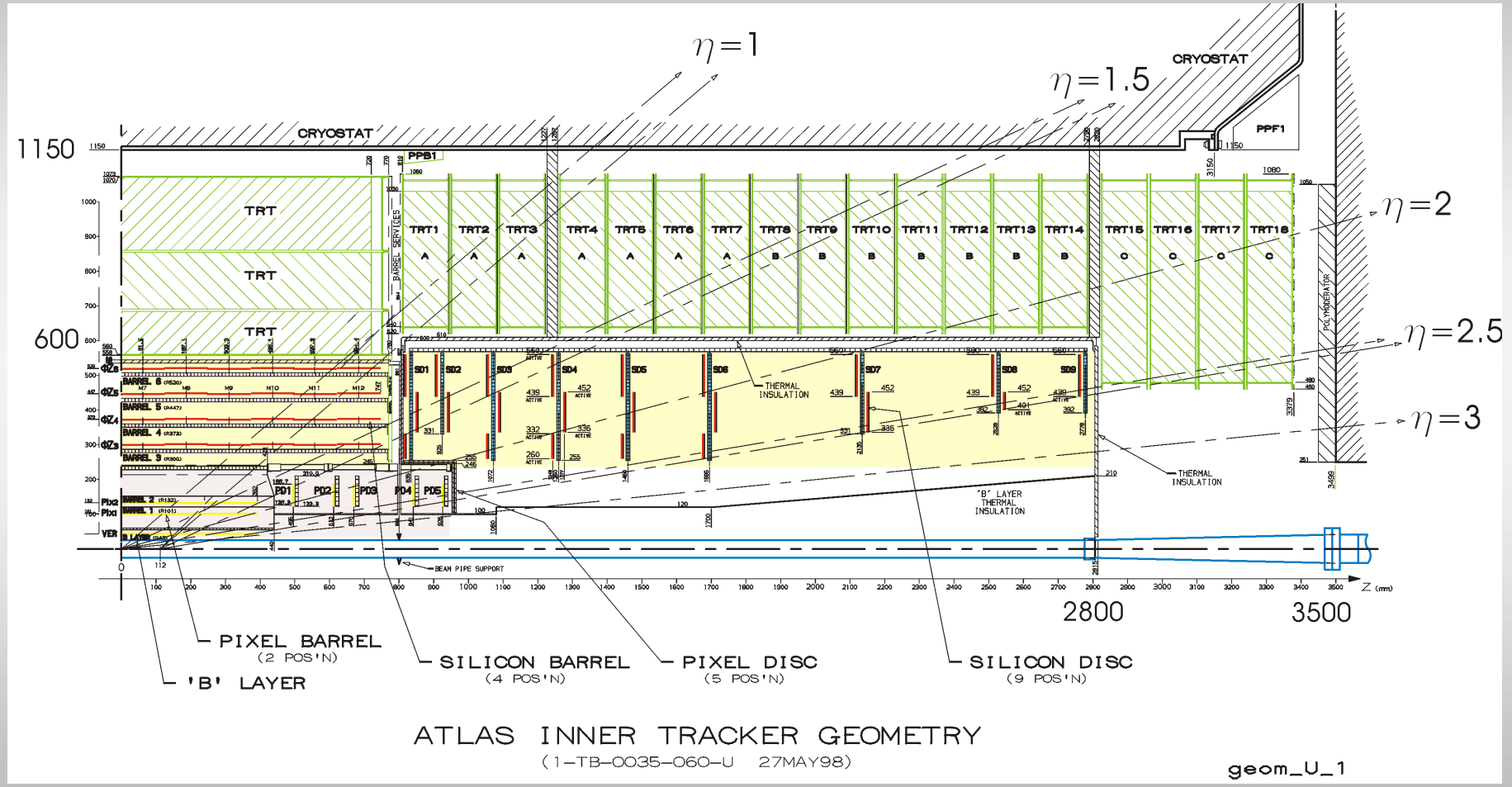


Conclusion

- the production of the SCT modules is in a very good shape
  - barrel module production is nearly finished
  - endcap module production under way, ~1/3 of all modules are built
  - the yield of the production is > 90%
- first modules are mounted on the support structure (barrel and endcap)
- estimated end of production: may 2005

Backup Slides

The ATLAS Inner Detector



ATLAS INNER TRACKER GEOMETRY

(1-TB-0035-060-U 27MAY98)

geom_U_1

Insertion of Endcaps