

Development of Hybrid Structure for the ATLAS barrel Silicon Microstrip Tracker

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representing

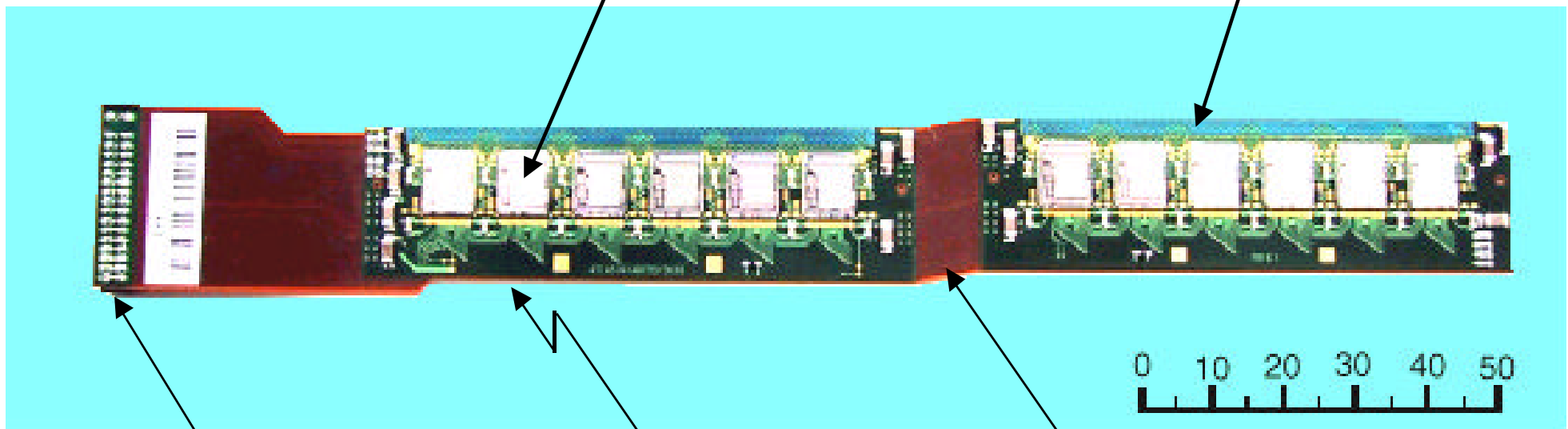
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Hybrid of the barrel ATLAS SCT

ABCD3T chips
(12 x 128 ch)

glass pitch-adaptor
(2 x 6 x 128 ch)



connector

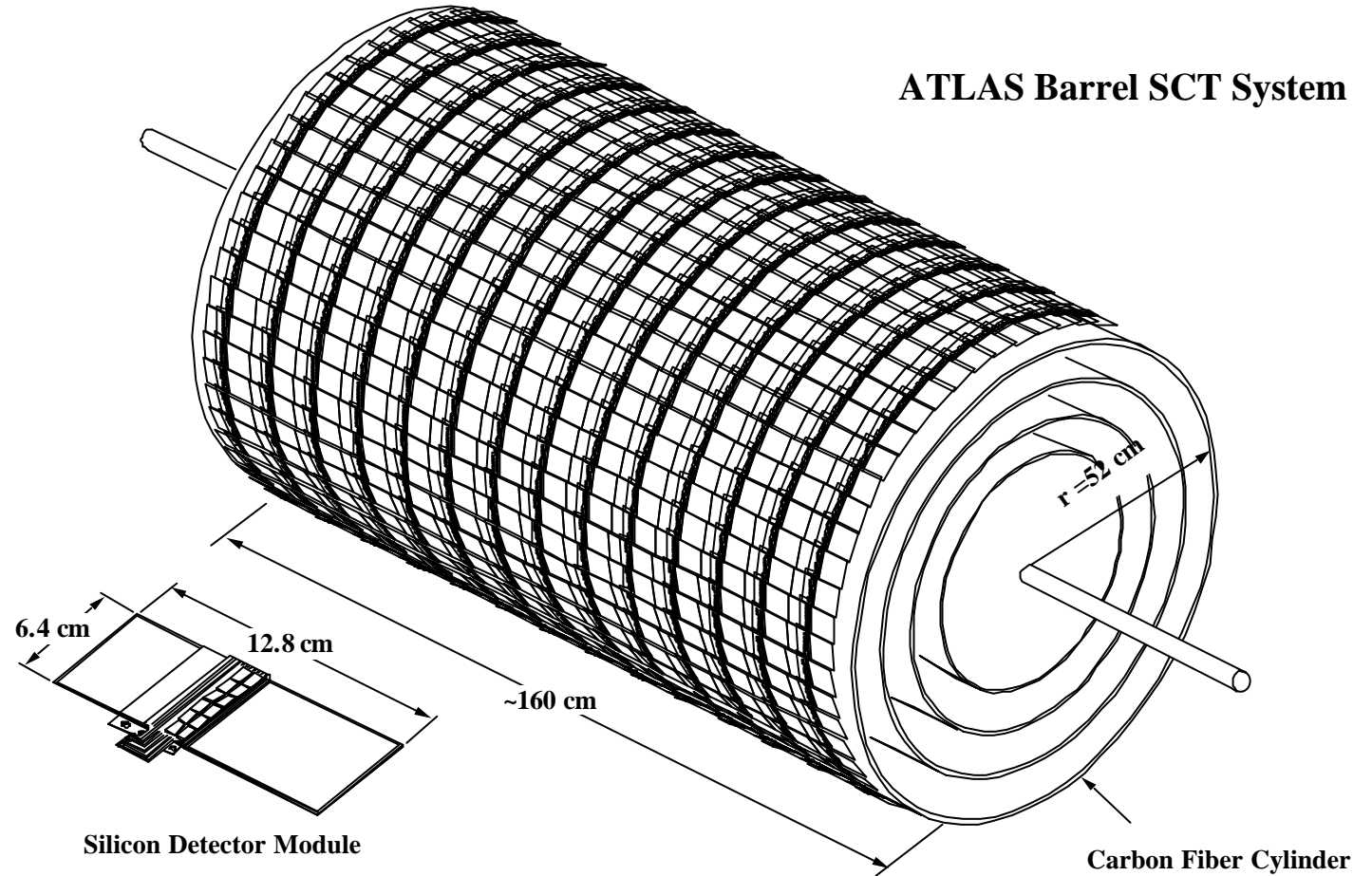
carbon-carbon bridge
(underneath)

flexible Cu/PI circuit

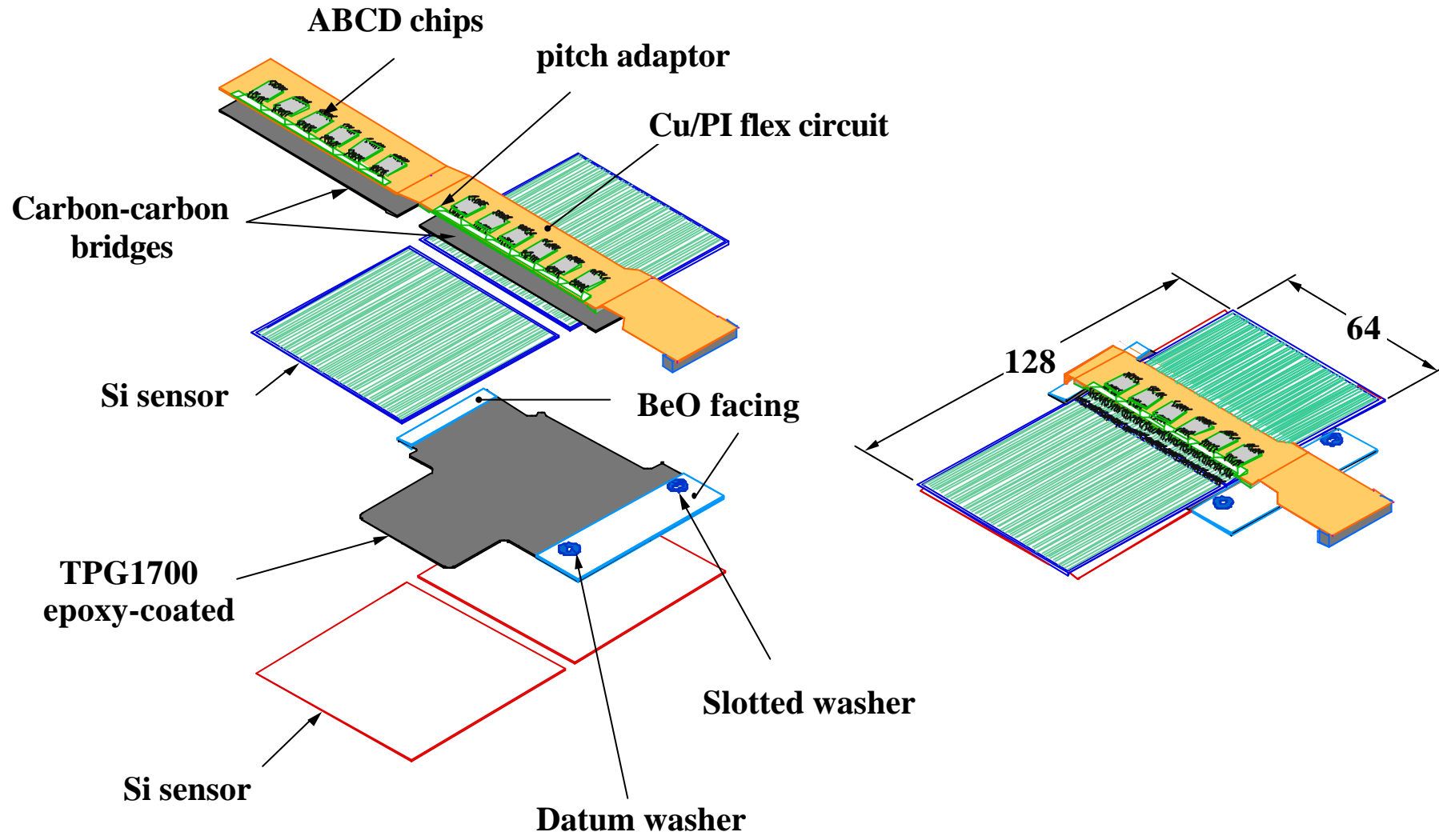
ATLAS Barrel SCT

radius	# modules
300 mm	384
373 mm	480
447 mm	576
520 mm	672

Total 2112 modules
8448 sensors
34.4 m²

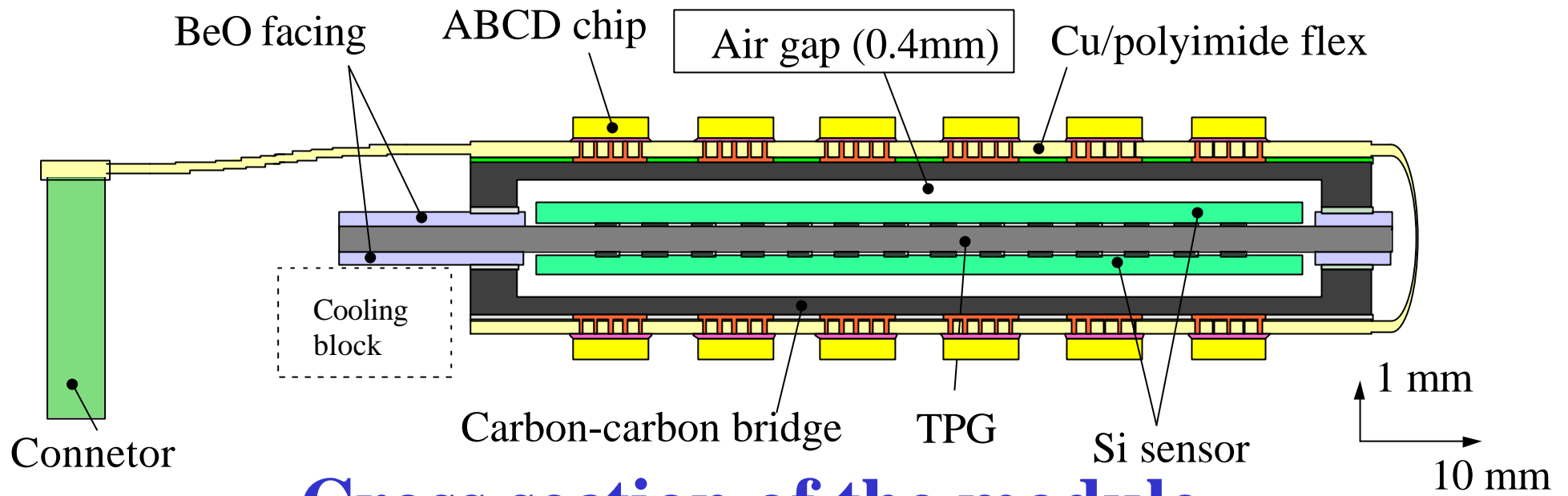


Module components

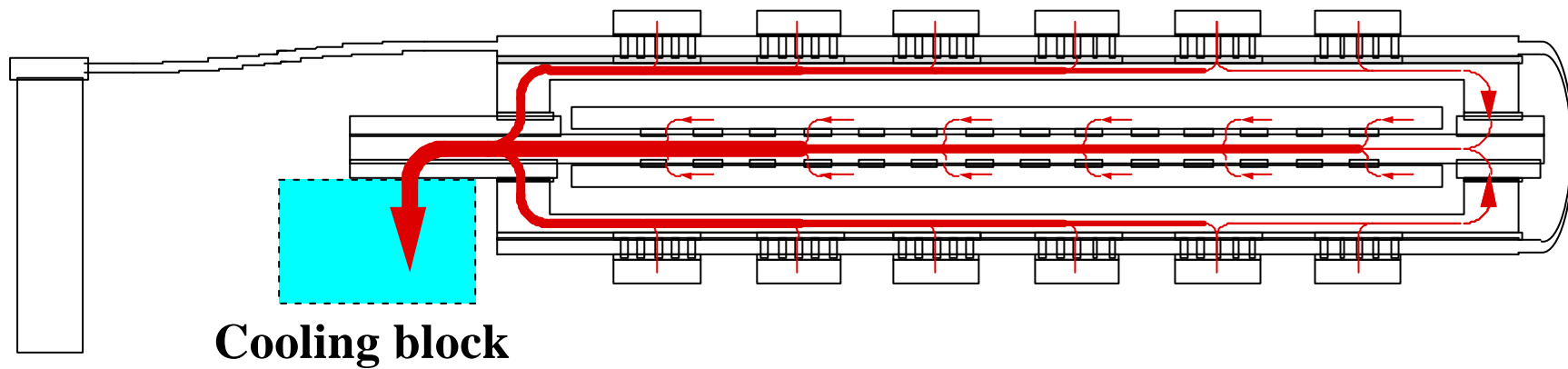


Barrel module parameters

- **Sensors** : 63.56 x 63.96 mm², p-in-n, single-sided
- **Strip directions** : ± 20 mrad
- **Operating temperature** : - 7°C
- **Total chip power** : 6.0 W nom., **8.1 W max.**
- **Thermal runaway heat flux**: **> 240 mW/mm² at 0°C**
- **Mechanical precisions** :
 - **back-to-back**: **< 5 mm** (in-plane lateral), **< 10 mm** (in-plane longitudinal), **< 50 mm** (out-of-plane)
 - **Fixation point**: **< 30 mm** (in-plane)
- **Radiation length**: **< 1.2% X₀**

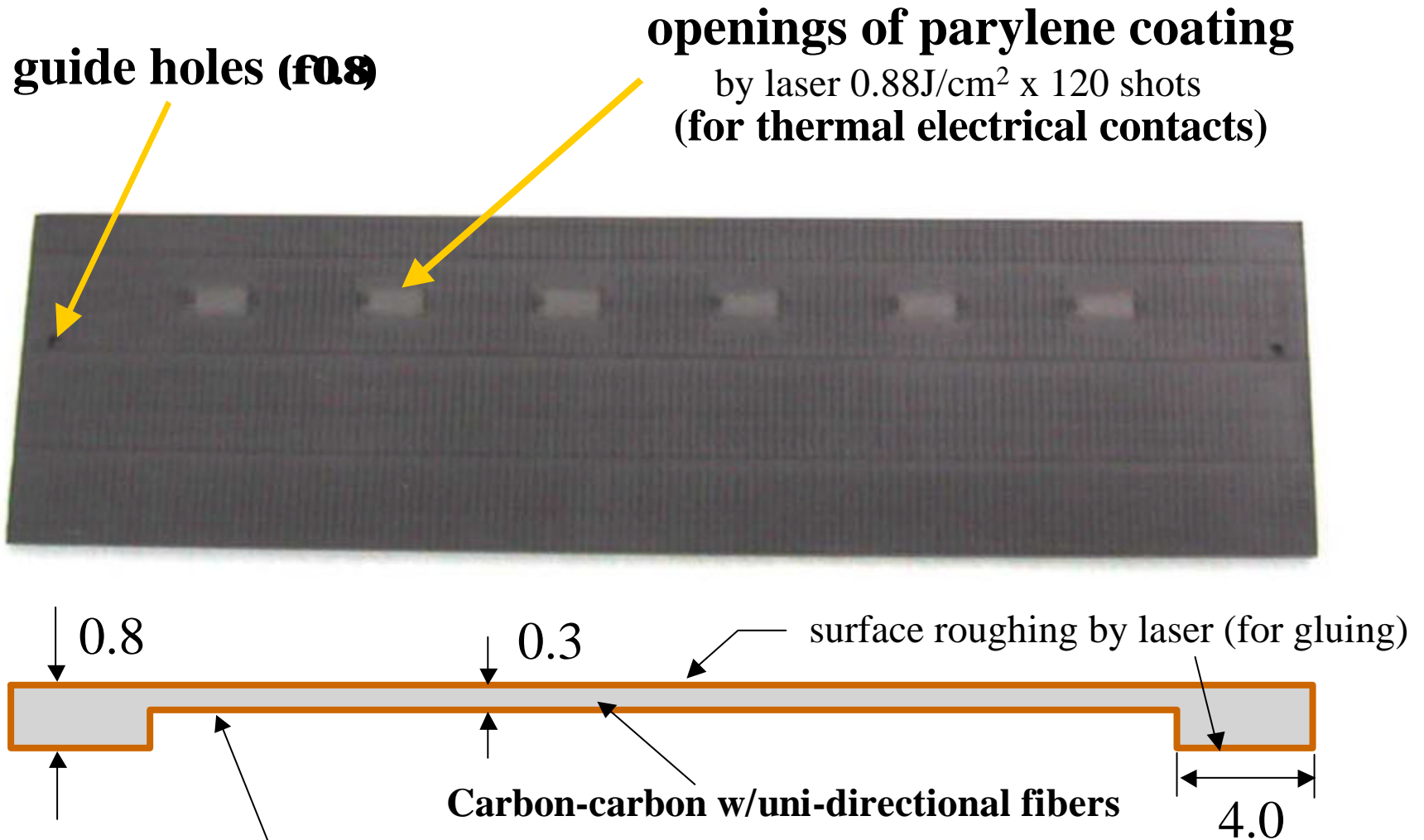


Cross section of the module



Flow paths of heat

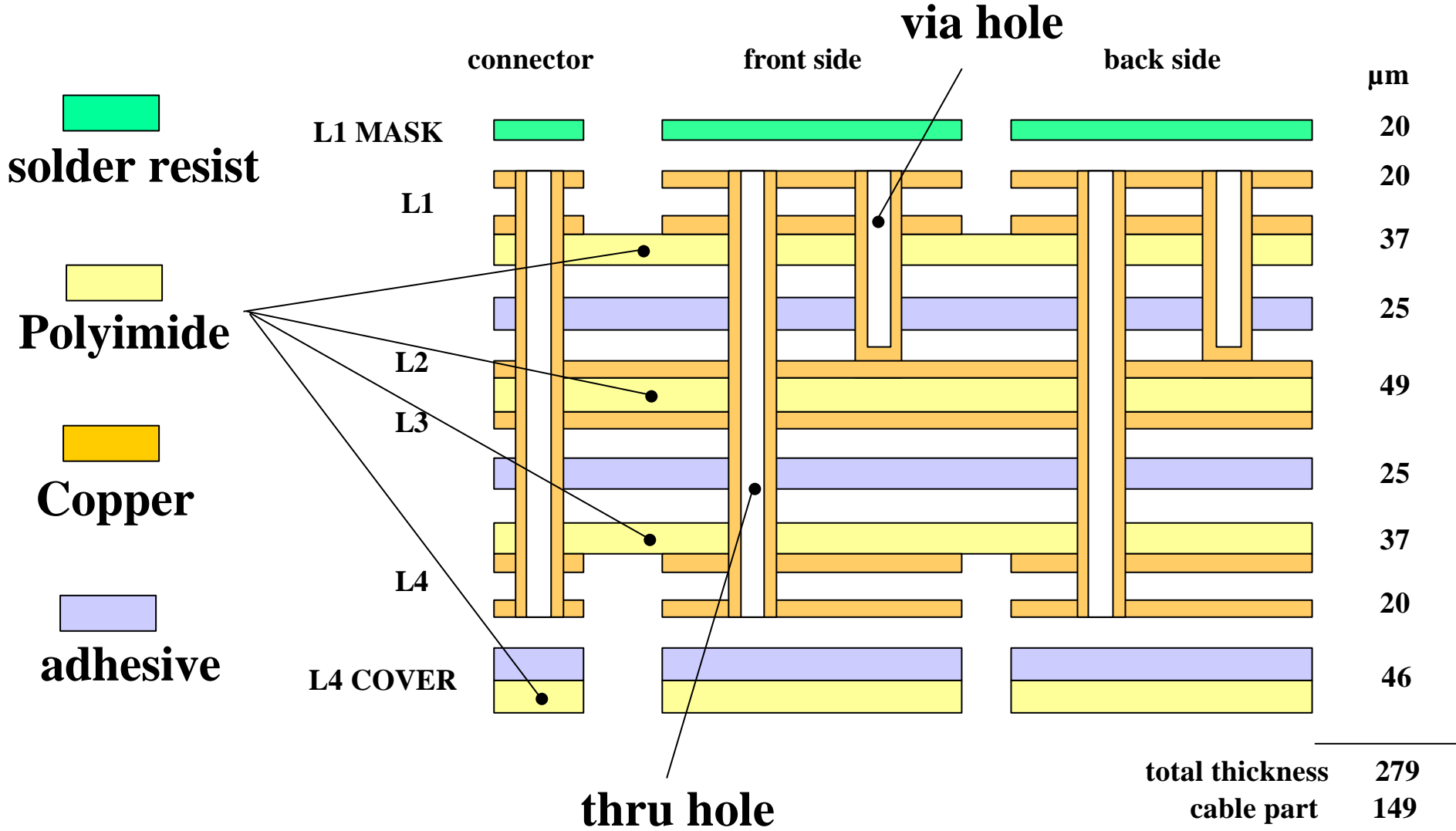
Carbon-carbon reinforcing bridge



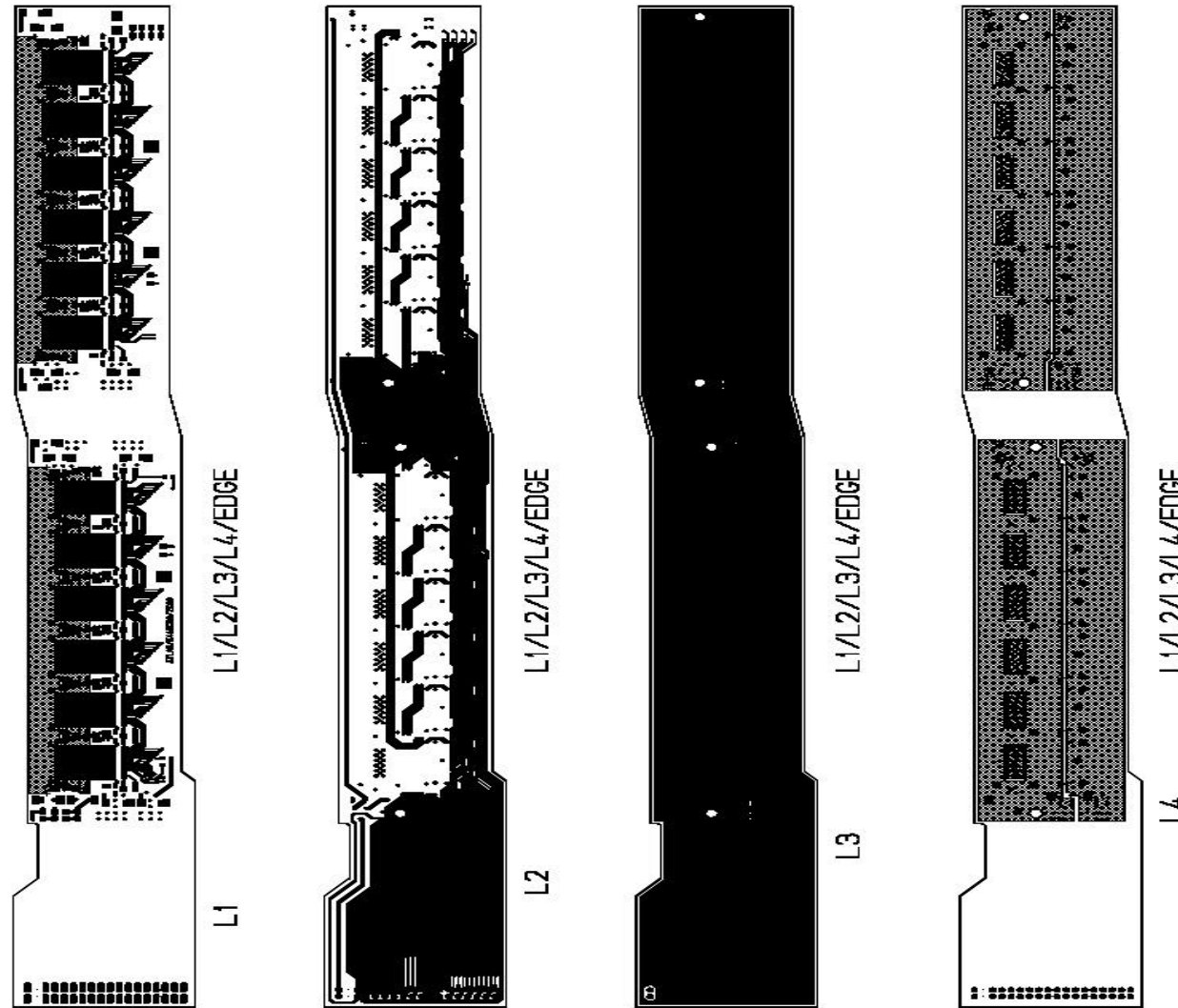
Carbon-carbon material

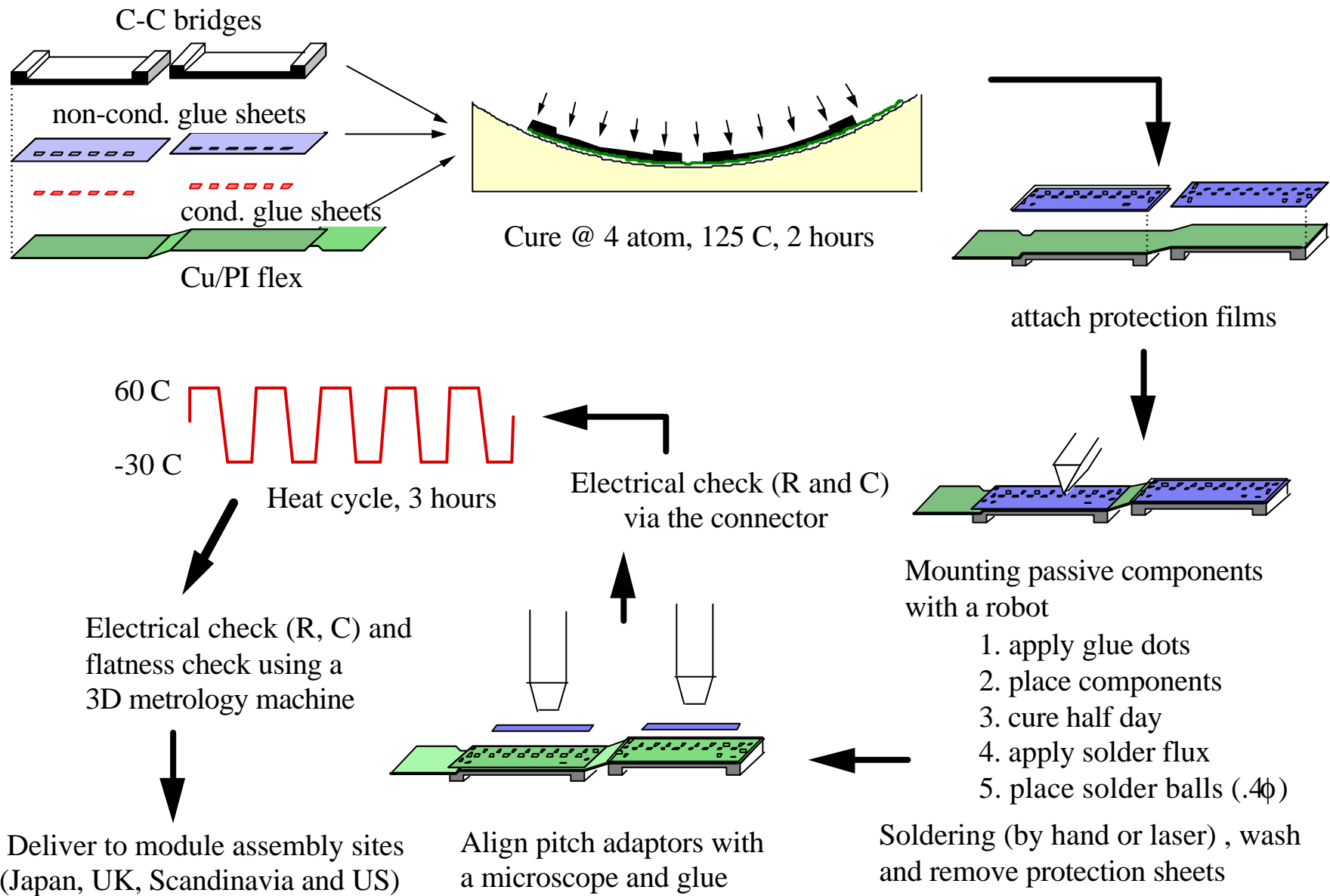
Thermal conductivity (// fiber)	700 +- 20 W/mK
(^ fiber)	35 +- 5 W/mK
Density	1.9 g/cm³
Young's modulus (// fiber)	294 Gpa
Tensile strength (// fiber)	294 Mpa
Thermal expansion coeff. (// fiber)	-0.8 ppm/C
(^ fiber)	10 ppm/C
Resistivity (// fiber)	2.5 x 10⁻⁶ Wm

Layer structure of Cu/Polyimide flex circuit



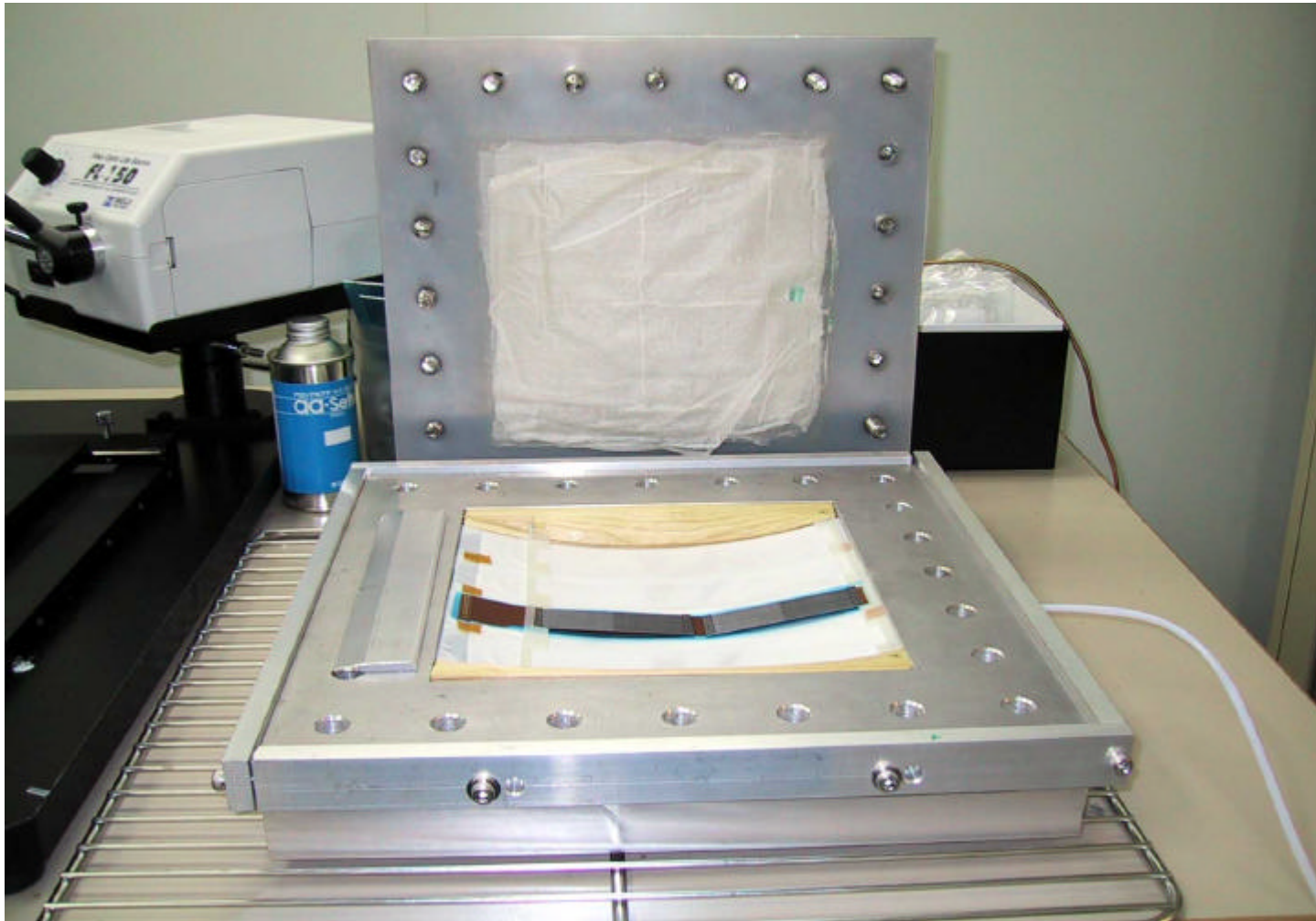
Layout of the flexible circuits: top to bottom



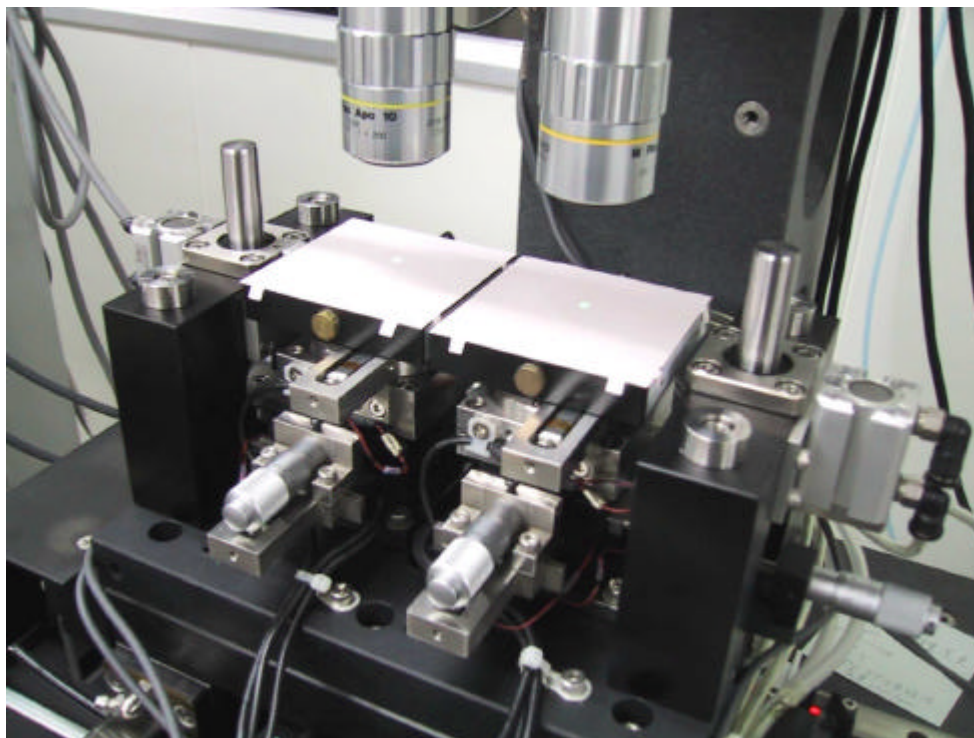


Assembly of Hybrid

Glue & cure press for Cu/polyimide flex and CC bridge

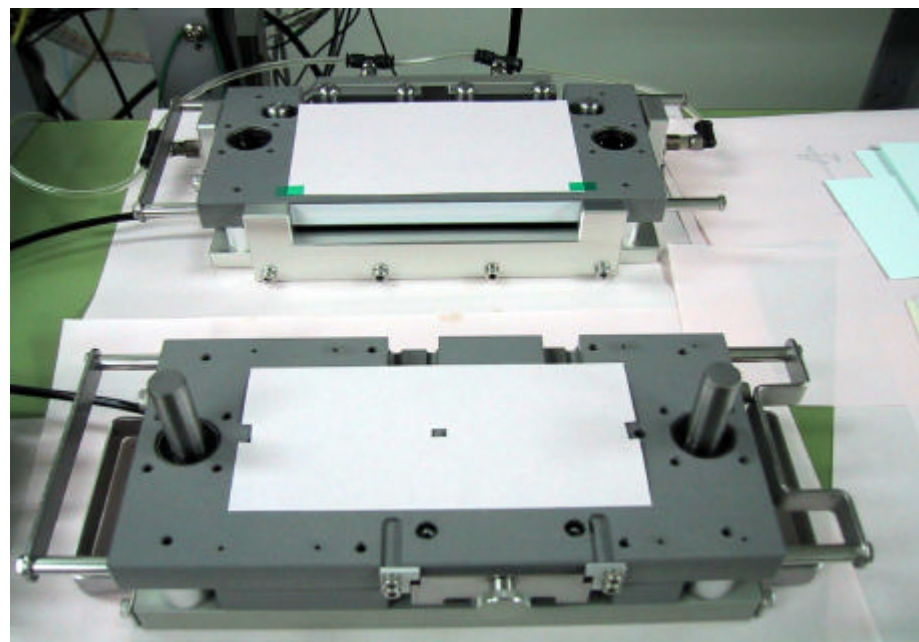


Curing at 125°C for 2 hrs

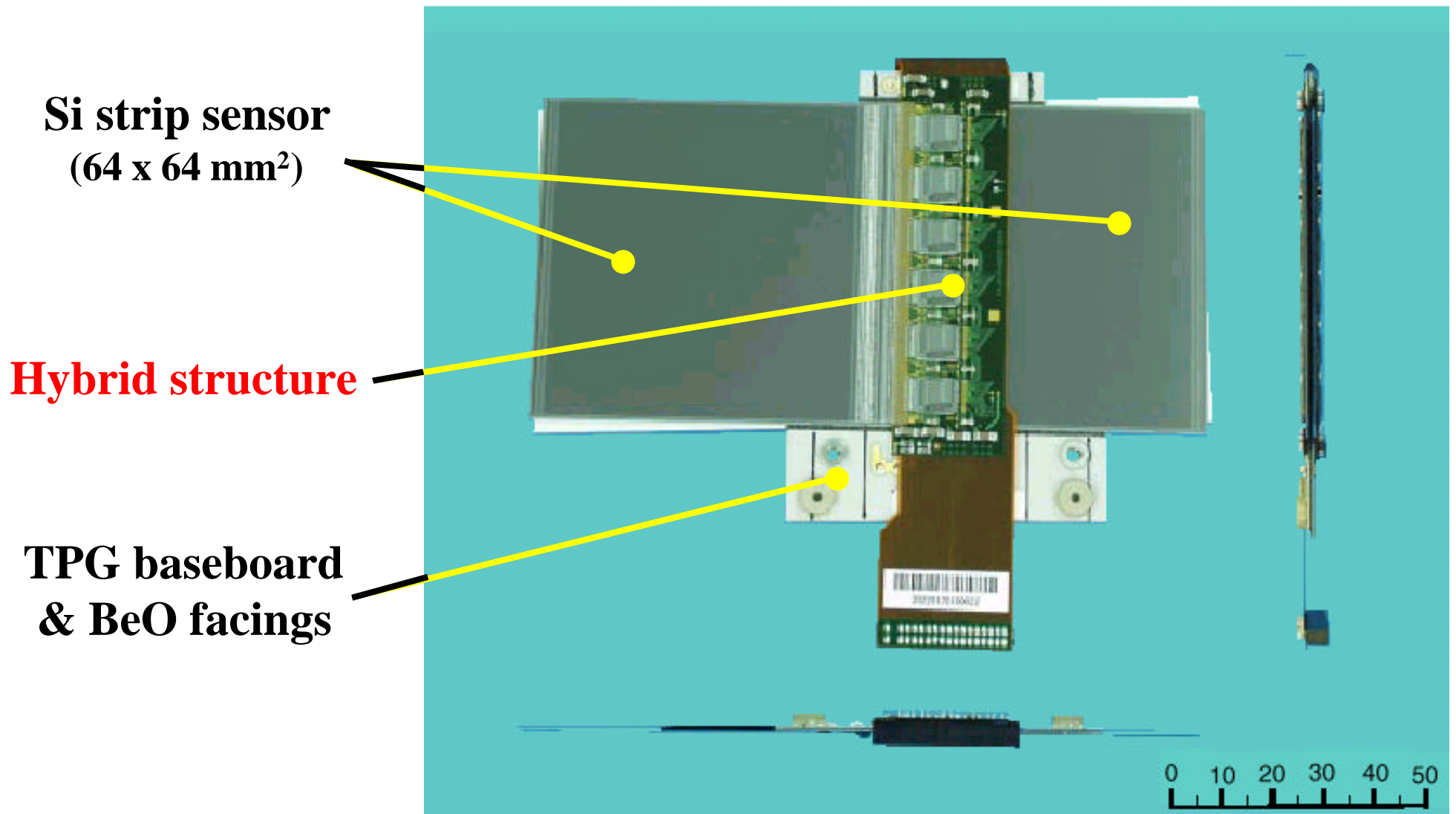


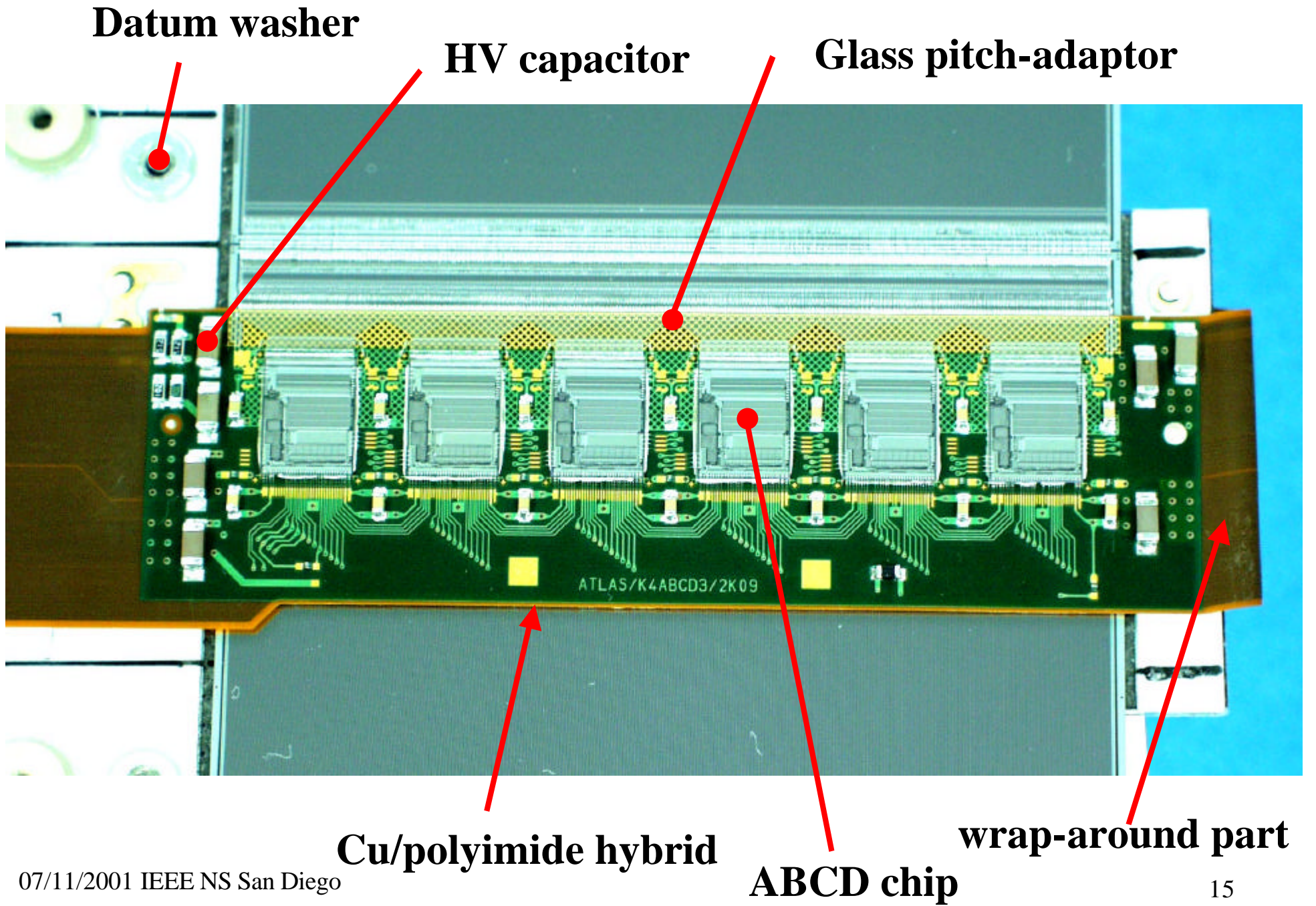
Module assembly

**Fixtures at the Japanese
module assembly site**

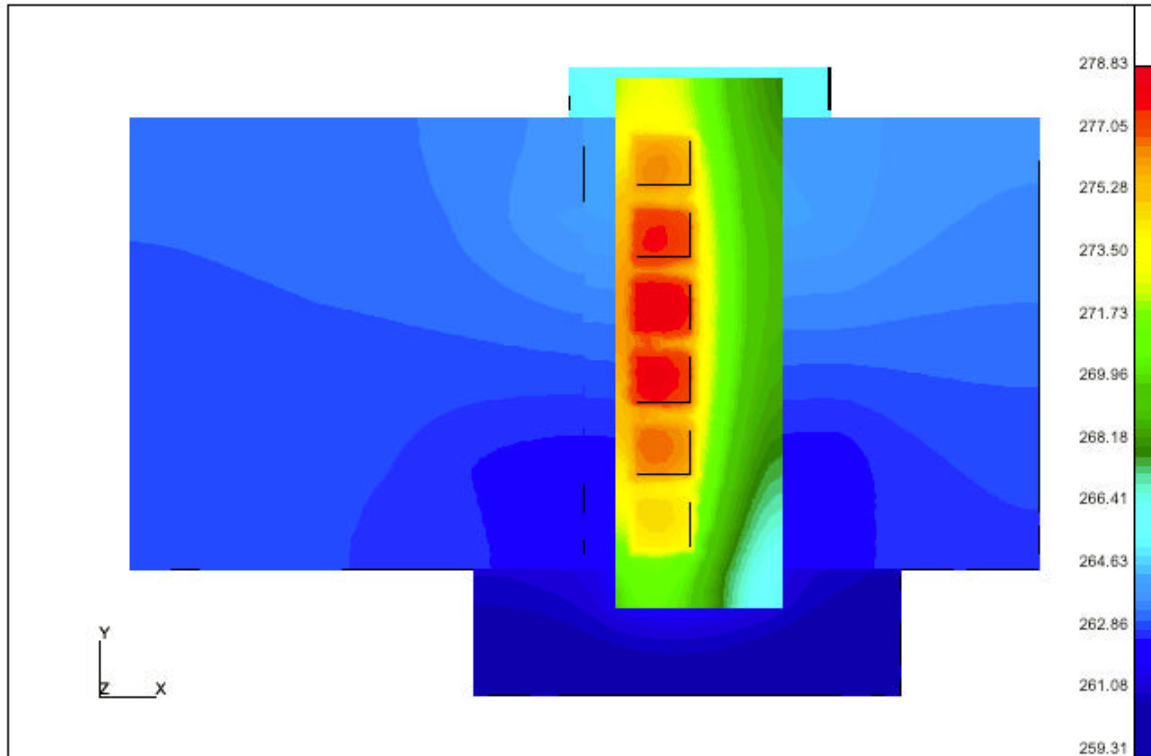


Module of the ATLAS barrel SCT

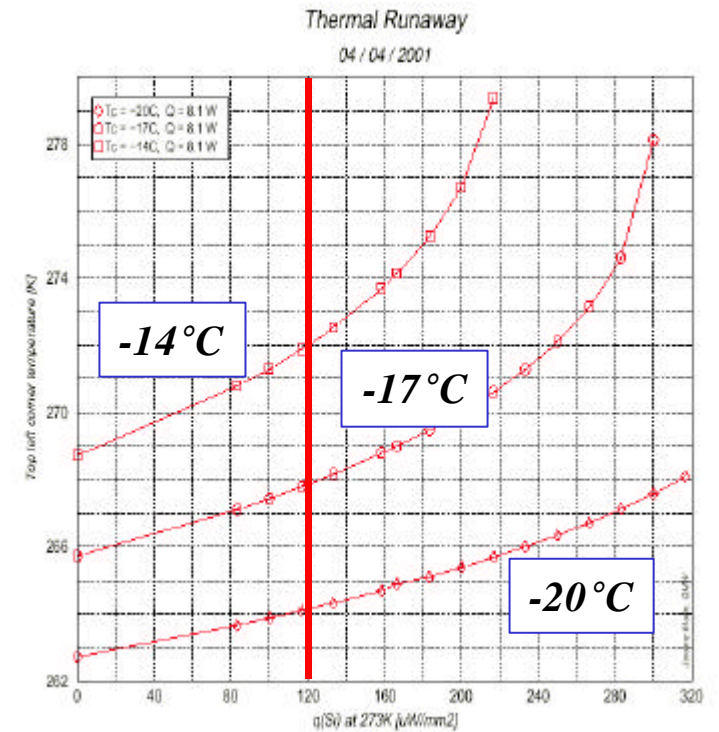




Thermal Properties



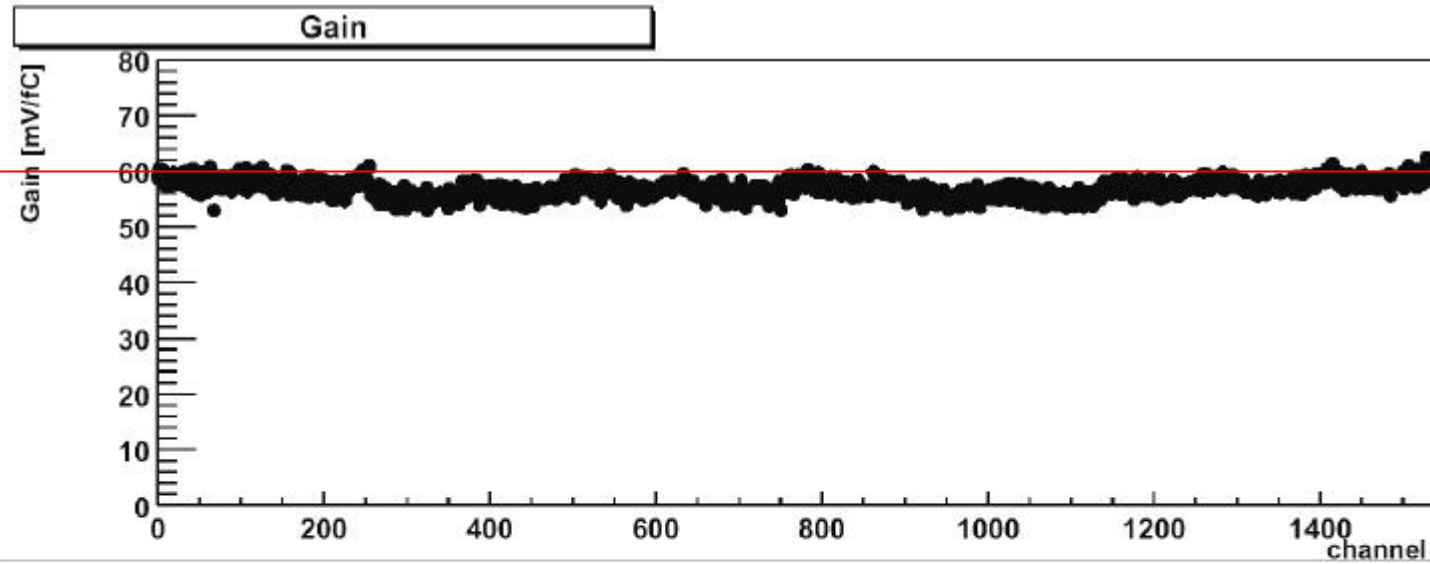
Simulated thermal profile with $Q_{chip}=6W$



bulk heat generation ($mW/mm^2@0^\circ C$)

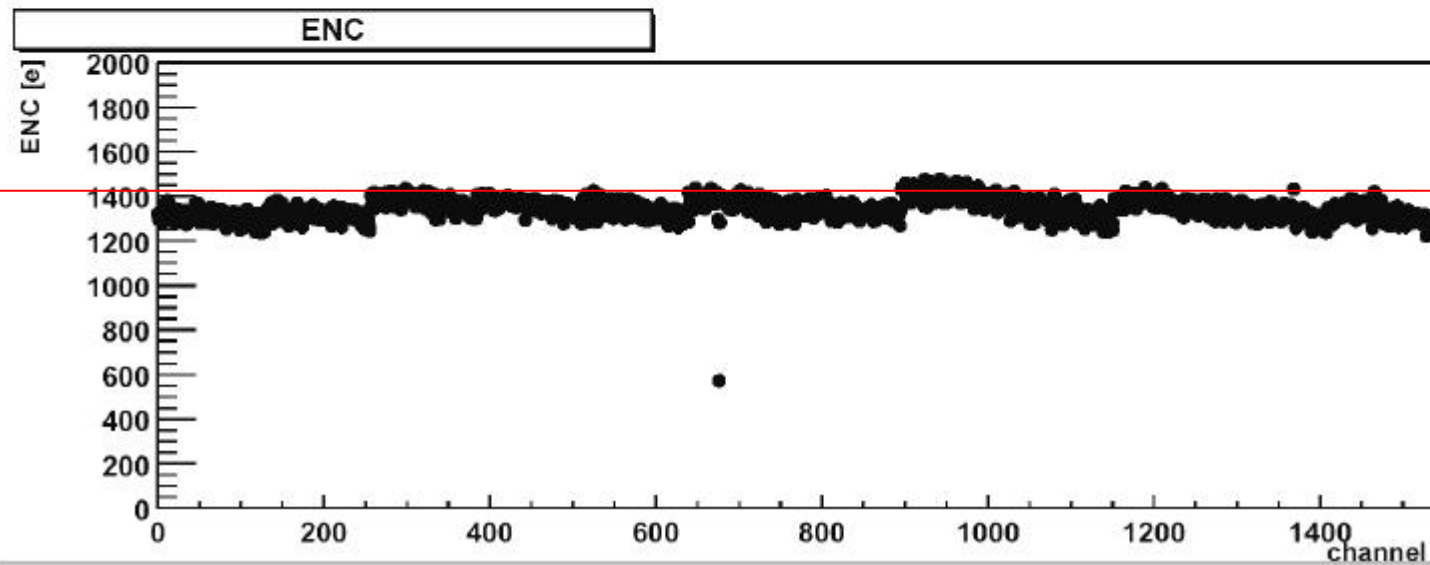
Gain

60 mV/fC



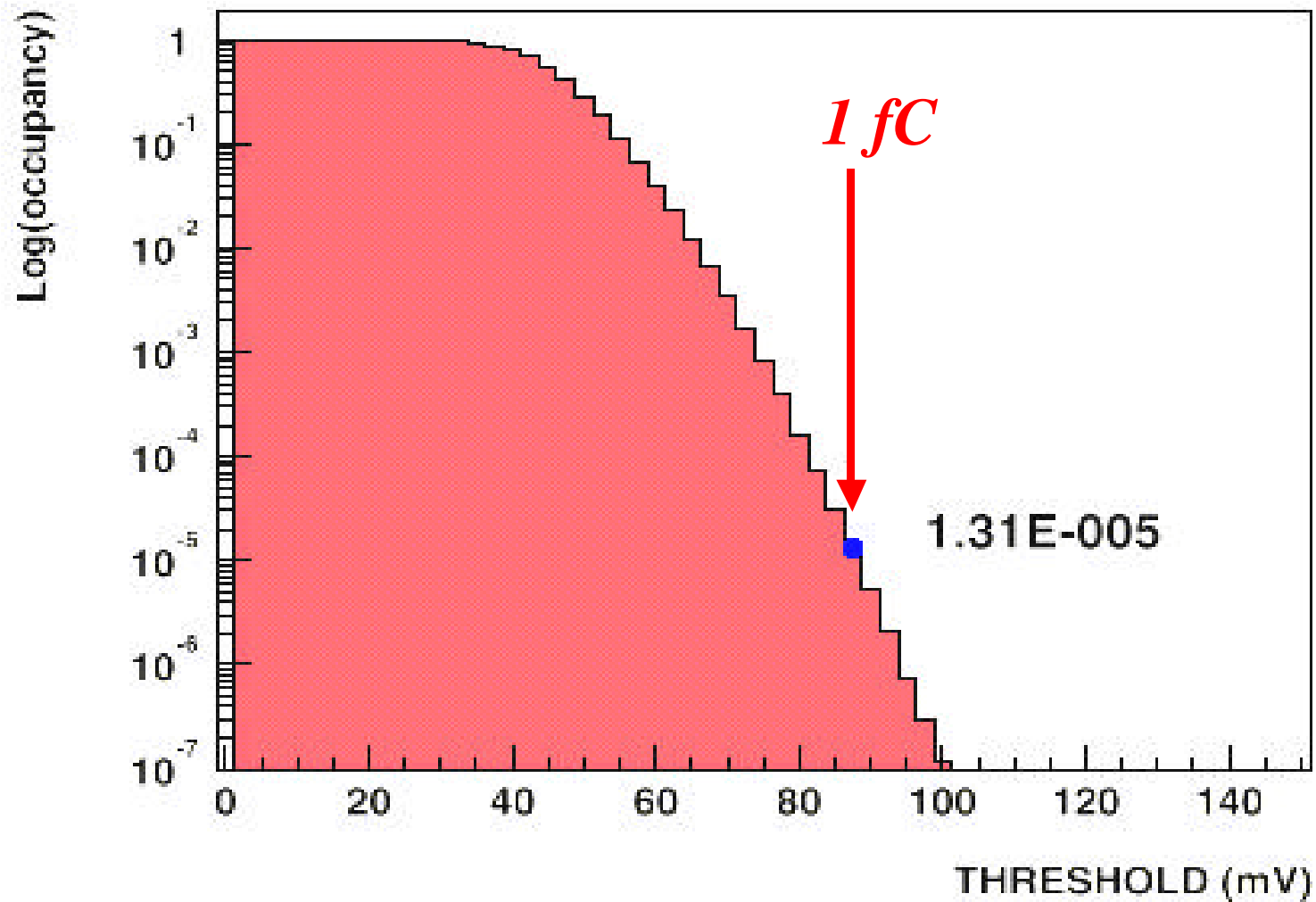
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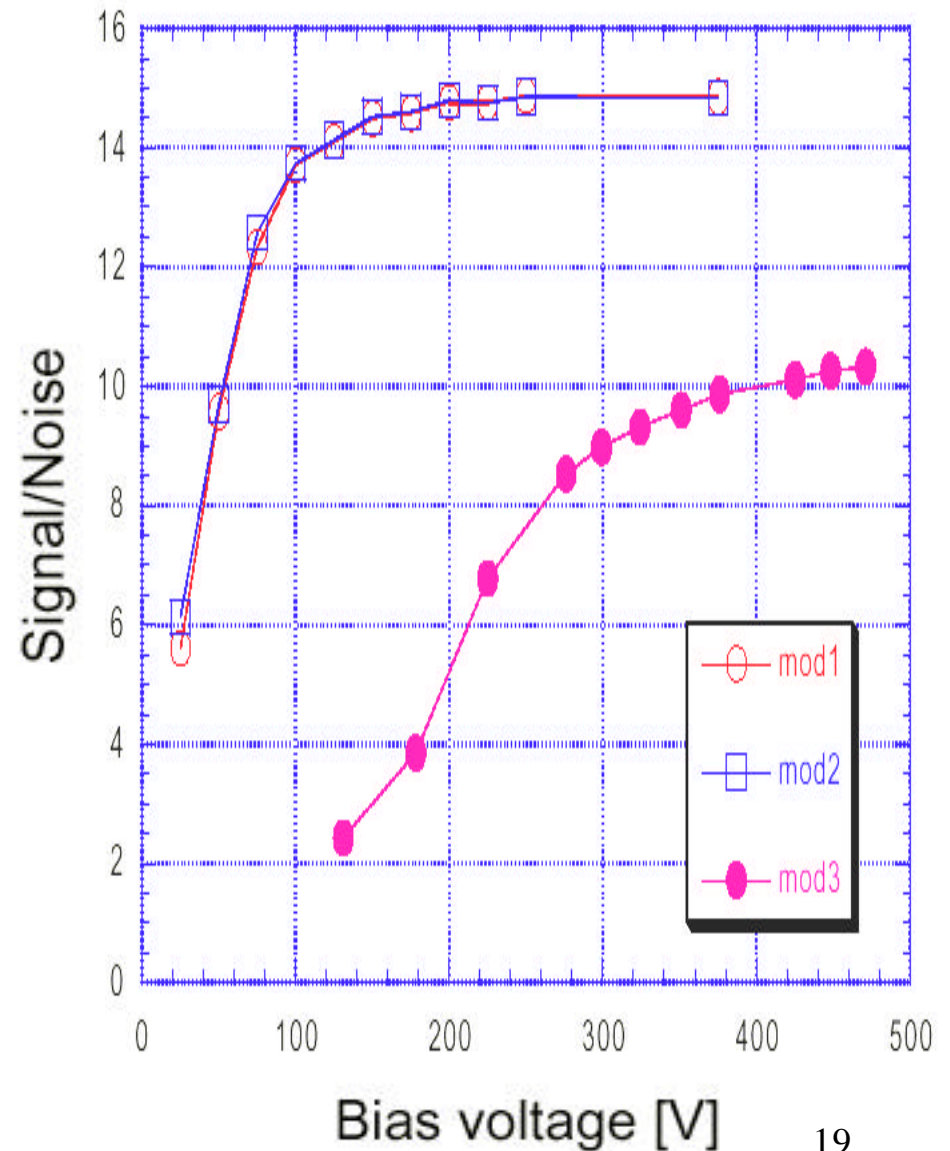
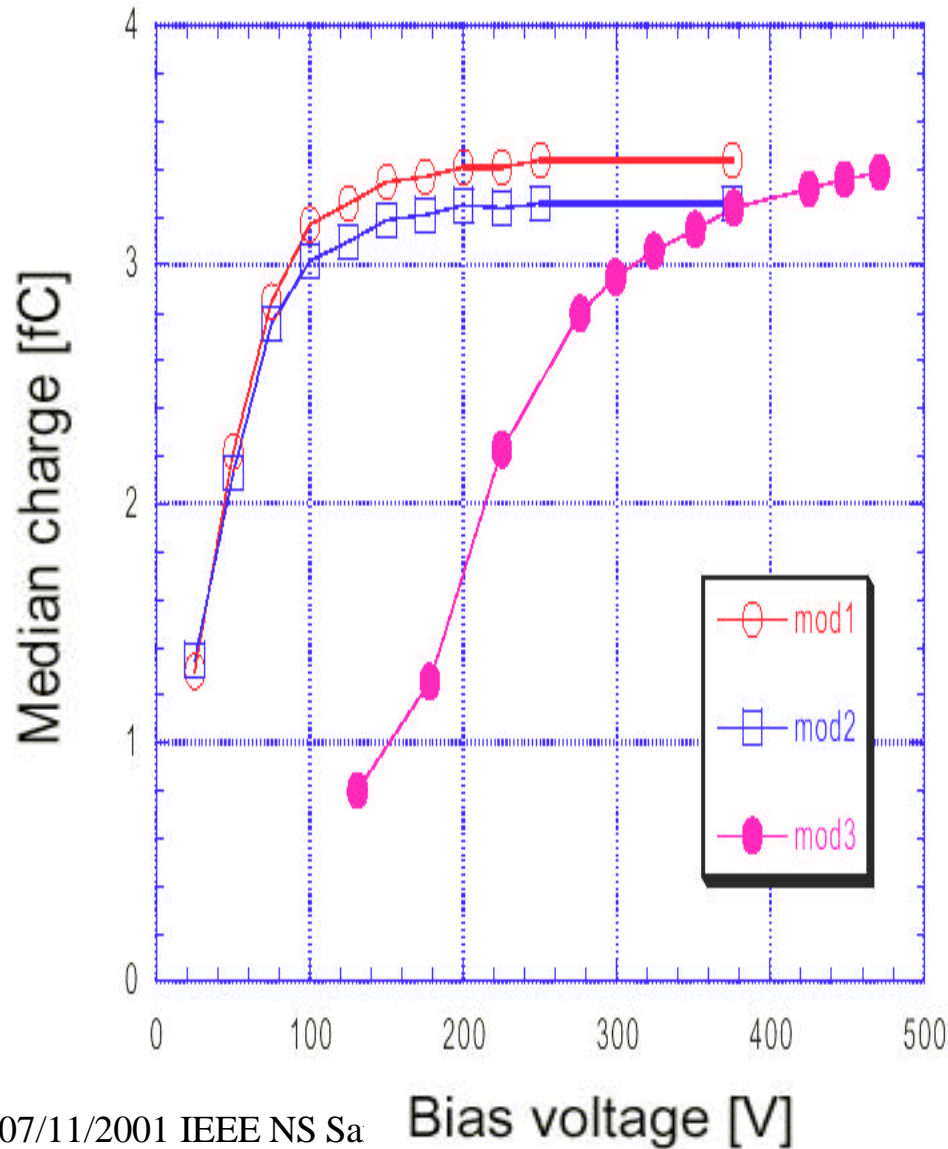
Channel # (1-1536)

*Mean Noise Occupancy, all channels
module 20220170100018, measured warm*



Median charge and S/N vs bias voltage

(mod 3 was irradiated to 3×10^{14} p/cm²,)



Summary of Electrical Performance

For non-irradiated modules :

- ◆ noise ~ 1350e at ~0°C, S/N > 14
- ◆ noise occupancy ~ 10^{-5} at 1 fC threshold
- ◆ threshold uniformity < 4 mV (~0.08fC)
- ◆ timewalk : ~ 3 ns

For irradiated modules :

- ◆ noise ~ 2050e at ~0°C, S/N ~ 10
- ◆ noise occupancy ~ 3×10^{-5} at 1 fC threshold
- ◆ threshold uniformity < 12 mV

Conclusions

- A hybrid structure with **Cu/polyimide flexible circuits** with reinforcing **Carbon-carbon bridges** was successfully developed at **KEK/Tsukuba**, for the **ATLAS barrel SCT module**.
- **All electrical performance (with ABCD3T), mechanical precision and thermal property, including radiation hardness, satisfy the severe LHC requirements.**
- **Ready for mass production.**