Adhesives in silicon strip modules

Glue evaluation and irradiation studies

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Title of Presentation

PETTL-Meeting, December 1 2014

Content

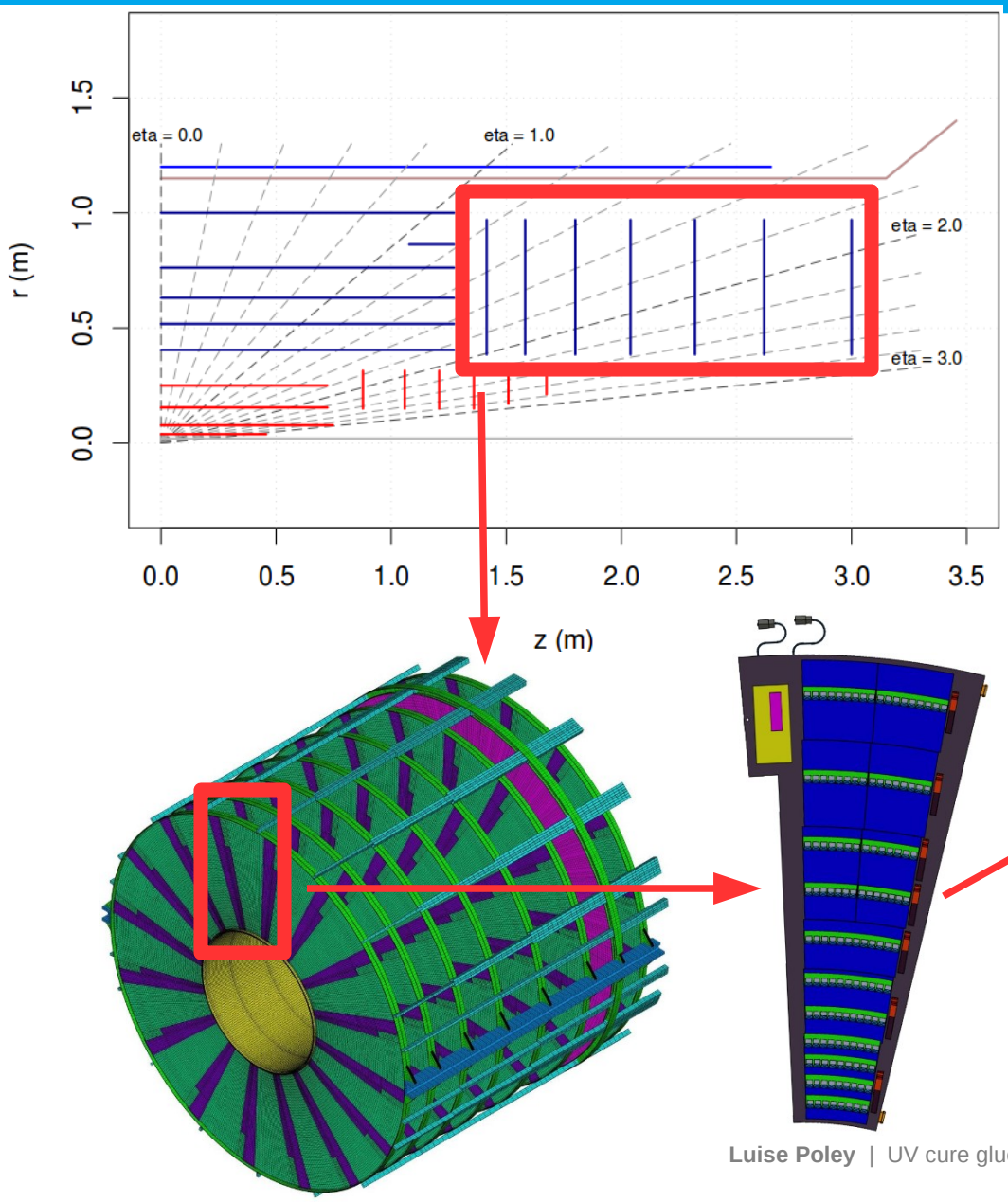
Overview of ongoing glue studies

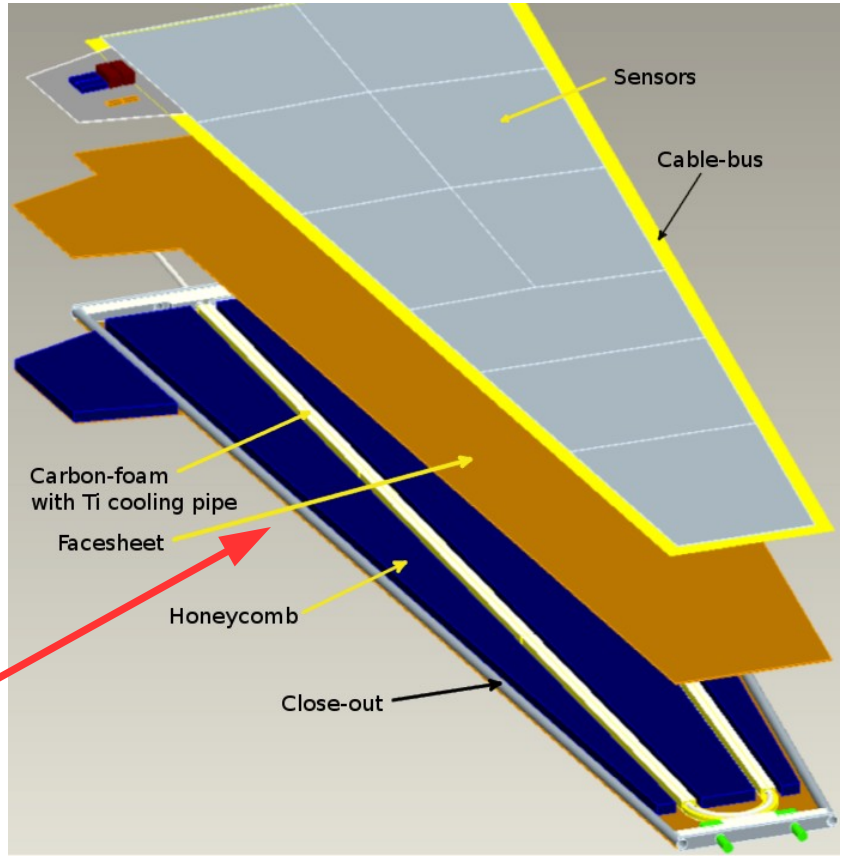
> UV cure glue as replacement for silver epoxy glue

> Glue characteristics

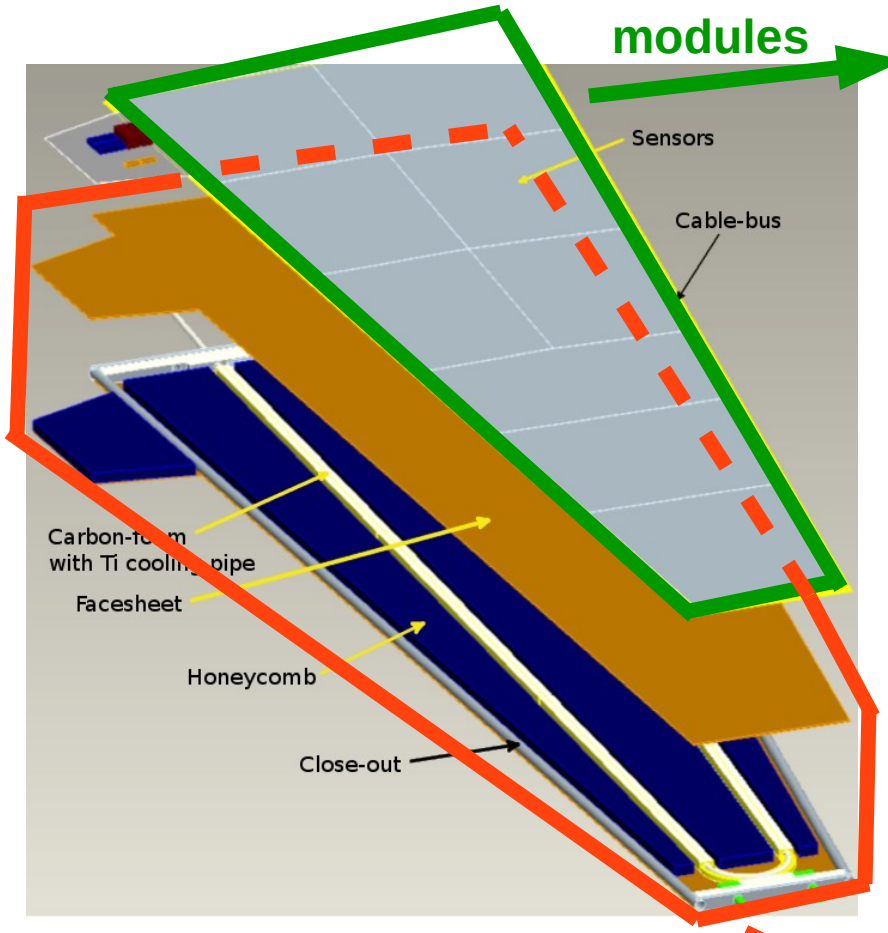
> UV cure glue as replacement for optical glue on sensor

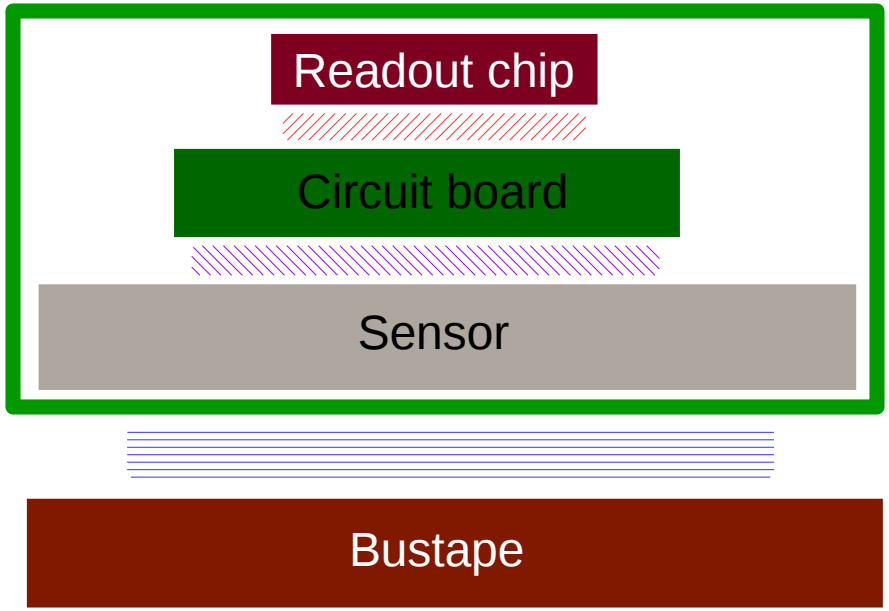
Strip detector for the Atlas High-Luminosity Upgrade

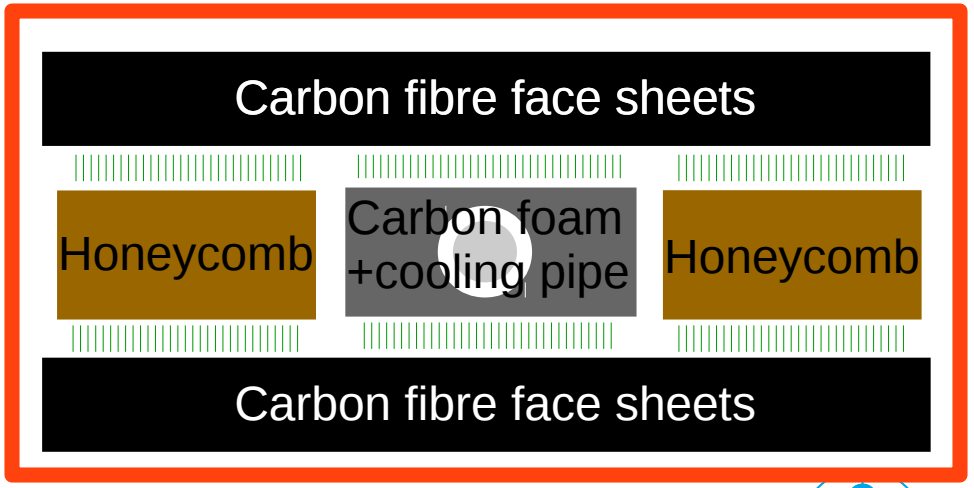




Strip detector for the Atlas High-Luminosity Upgrade

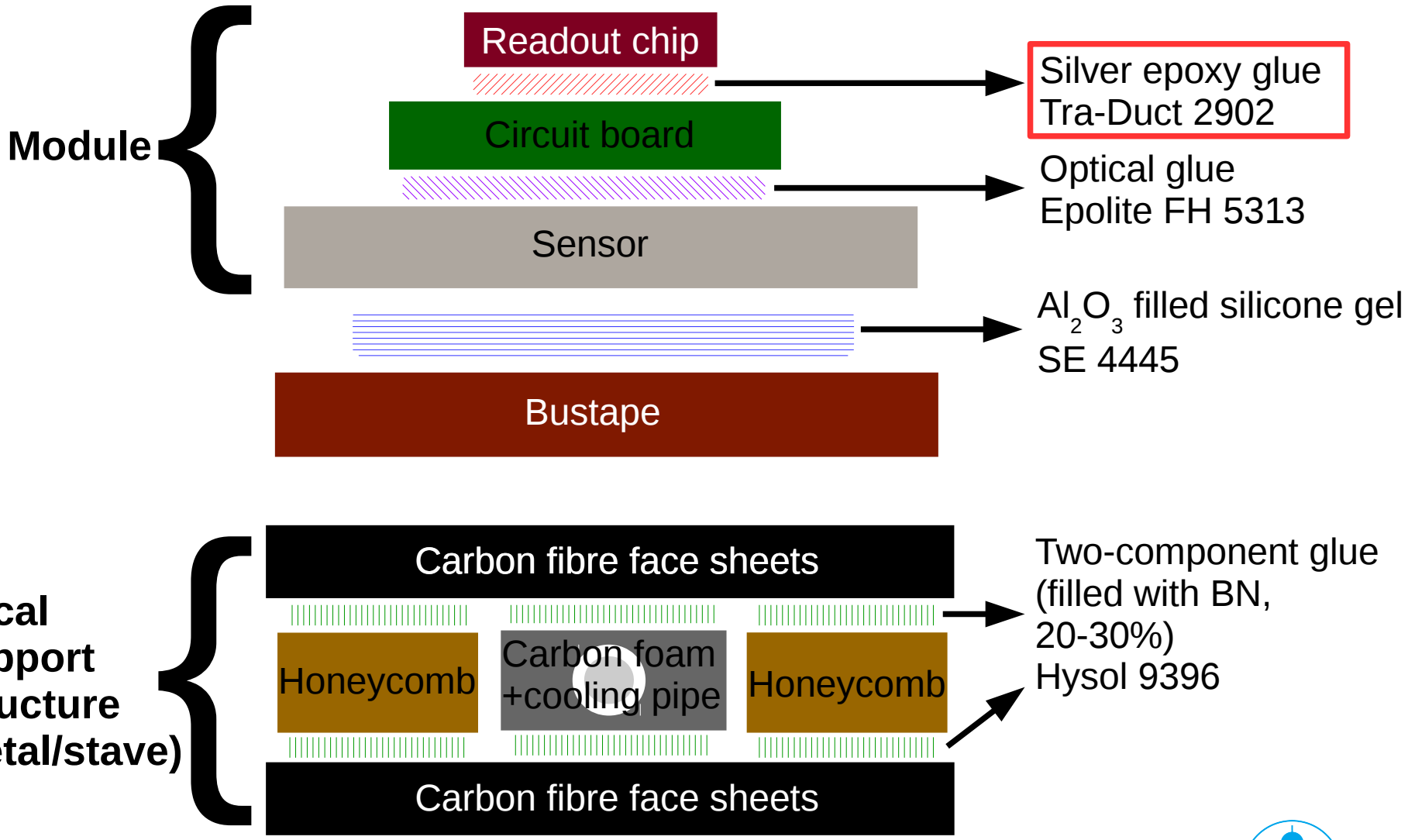






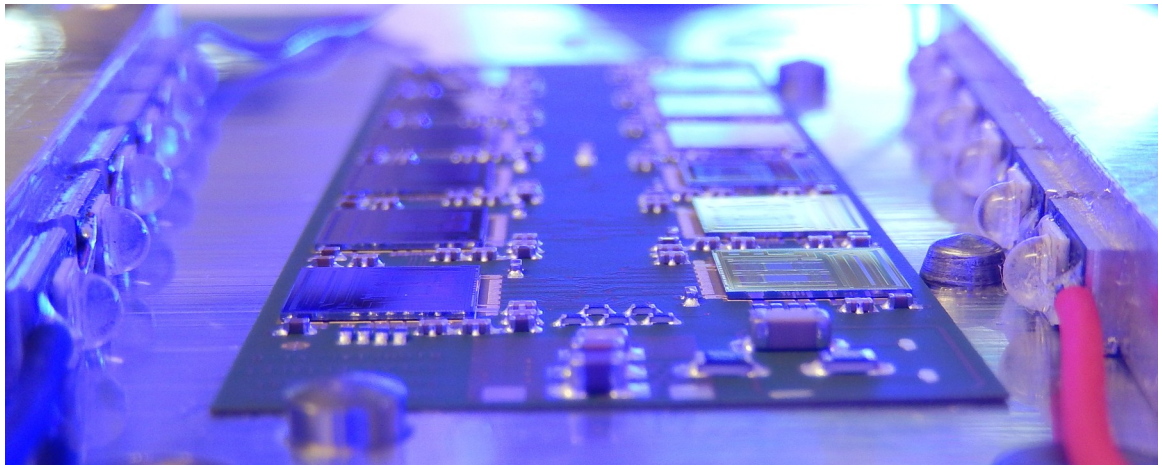
UV cure glue as replacement for silver epoxy glue

Glues used in the detector



UV cure glues between ASIC and hybrid: summary

- Glue currently in use has issues
  (long curing time, expensive, short radiation length, high activation …)
- Seven possible alternatives (6 UV cure glues, 1 glue pad) selected
  (short curing time, sufficient working temperature range, low toxicity classification, cost-efficient …)
- Performed tests:
  - Dispensing
  - UV curing
  - Bonding
  - Corrosion
  - Irradiation
  - Thermal cycling
  - Thermal conduction
  - Shear strength



- 3 good candidates remained (DYMAX 3013, 6-621, LOCTITE 3525)

UV cure glues between ASIC and hybrid: summary

	Silver epoxy glue	UV cure glues (3 good candidates)
Cost	40 $ for 2.65 g → 15.1 $/g	400 $ for 1l → 0.4 $/g
Construction	Successfully used	Successfully used
Curing time	6 hours	10 minutes
Thermal conduction	good	good
Thermal cycling	no changes observed	no changes observed
Irradiation	no changes observed	thermal conduction and shear strength improved
Shear strength	> 50 N	> 50 N
Radiation length	1.3 cm	20 – 22 cm

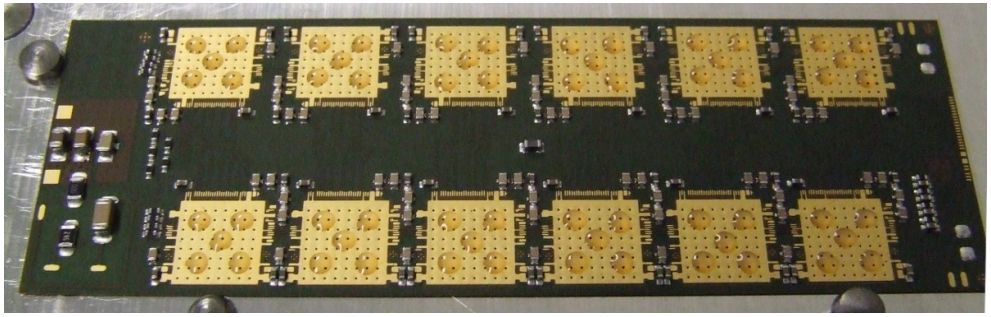
UV cure glues between ASICs and hybrid: currently

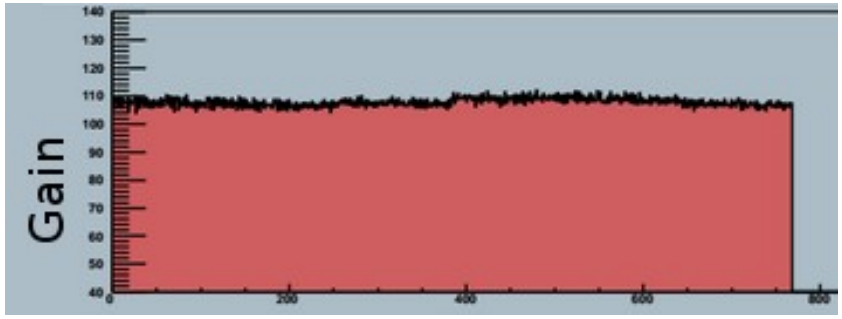
- Chemistry in glues: organic (carbon chains, hydrogen bonds, …)
- Effects of irradiation probably depend on particle type and energy
- Current investigation of different types of irradiation on glues
  - Previously: 23 MeV protons (KIT)
  - Next:
  - 800-900 MeV protons (Los Alamos), December 2014
  - Reactor neutrons (Ljubljana), soon
  - 23 GeV protons (CERN), 2015?

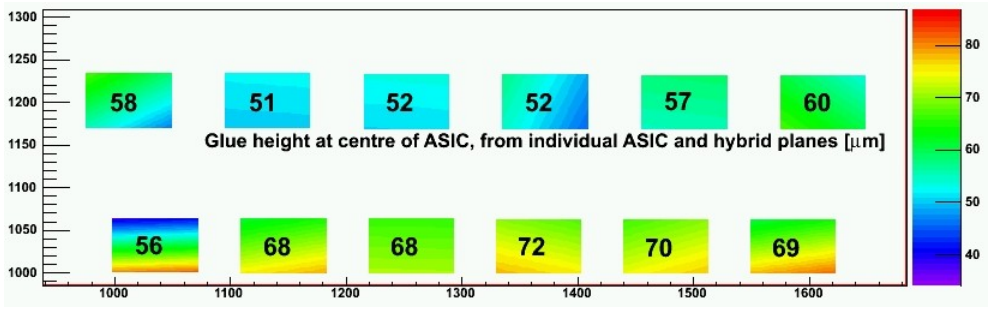
- Shear tests of all samples to be performed after irradiations

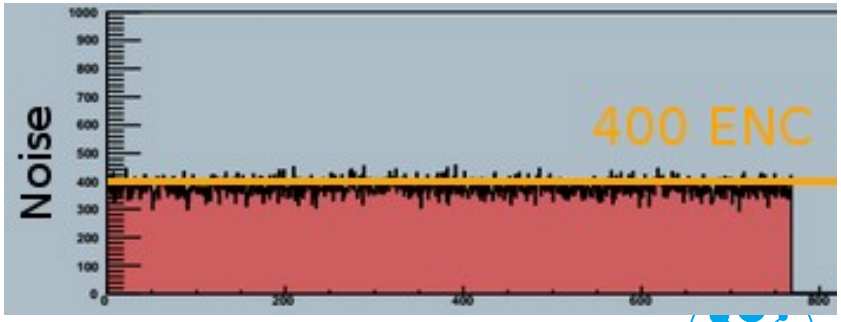
UV cure glues between hybrid and ASICs: first hybrid

- First hybrids built using UV cure glues
  - Dispensed with microliter pipette at DESY
  - Dispensed with fully automatic glue dispenser in Birmingham
  - Dispensing tests in progress in Glasgow
- Hybrids can be operated, show good results and do not overheat



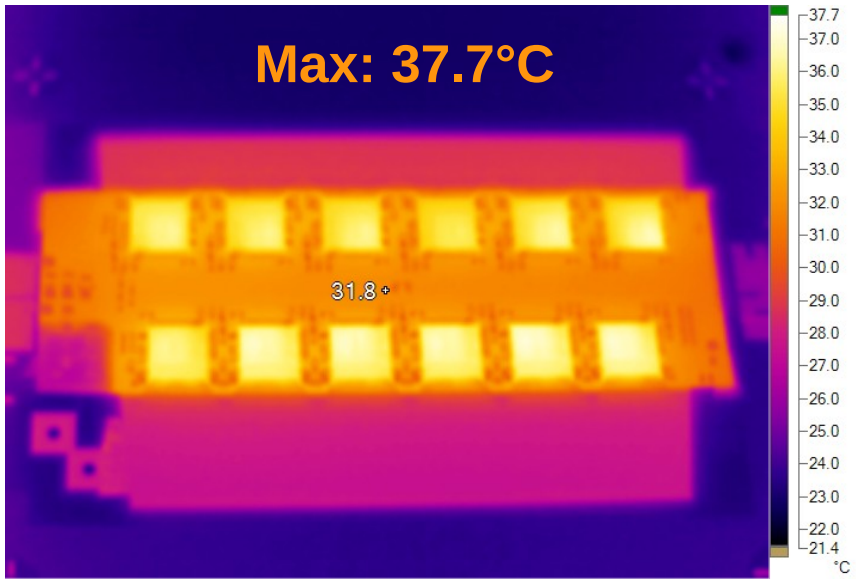


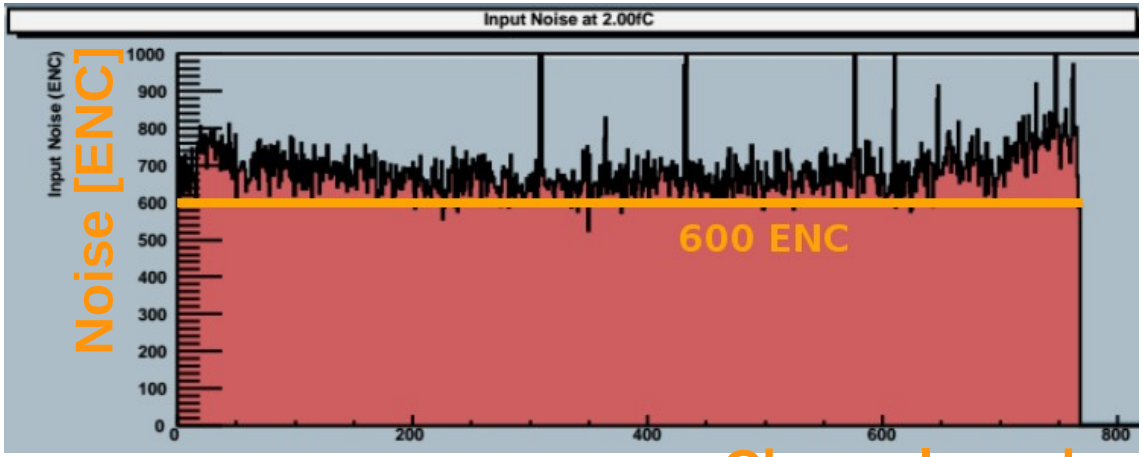




UV cure glues between hybrid and ASICs: first module

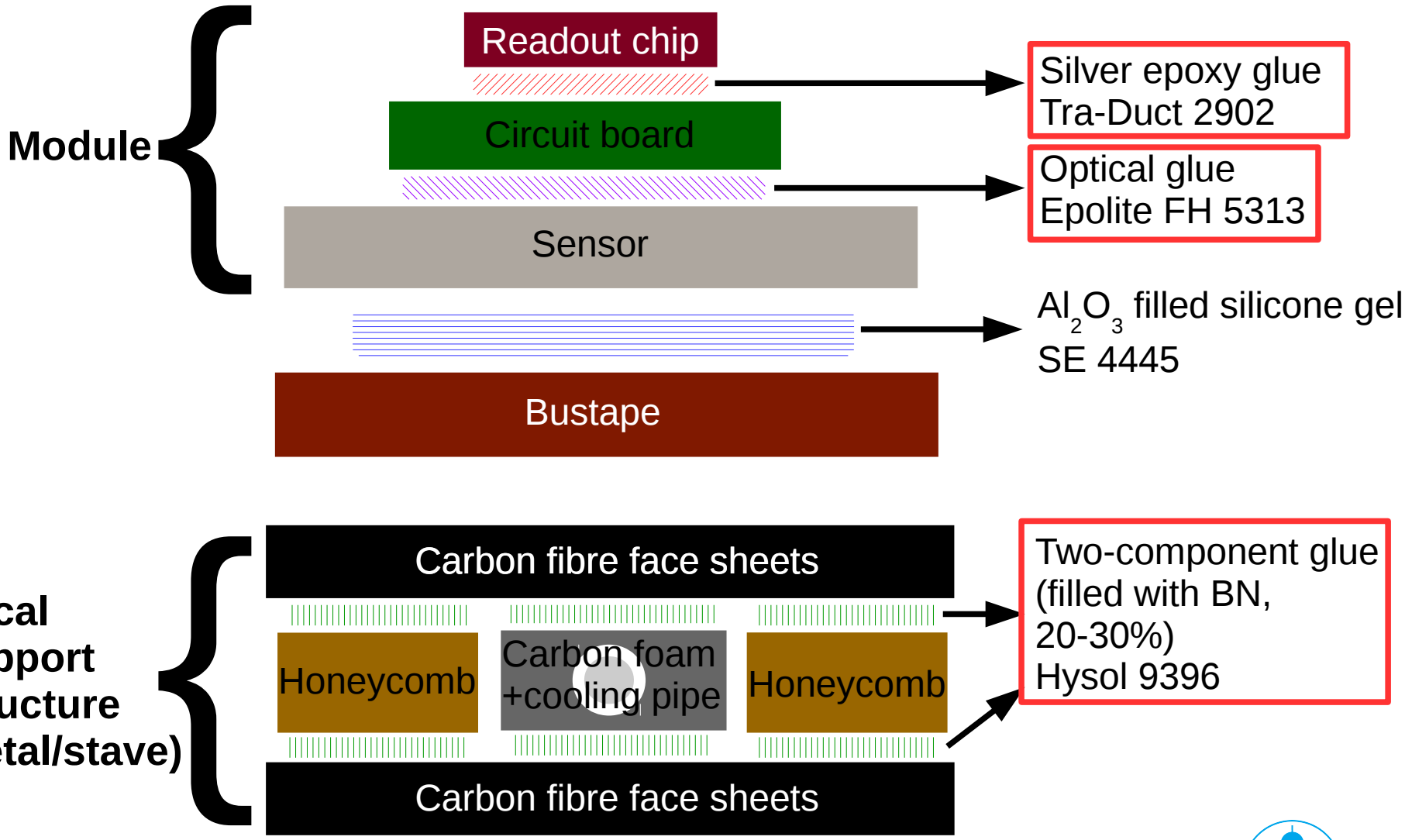
- First hybrid built with UV cure glues used in module
  - Hybrid built using DYMAX 6-621 with glue dispenser (Birmingham)
- No overheating of ASICs in operation
- Noise plot comparable to modules built with previous glue
- Decision about glue to be used in mass production will be made soon





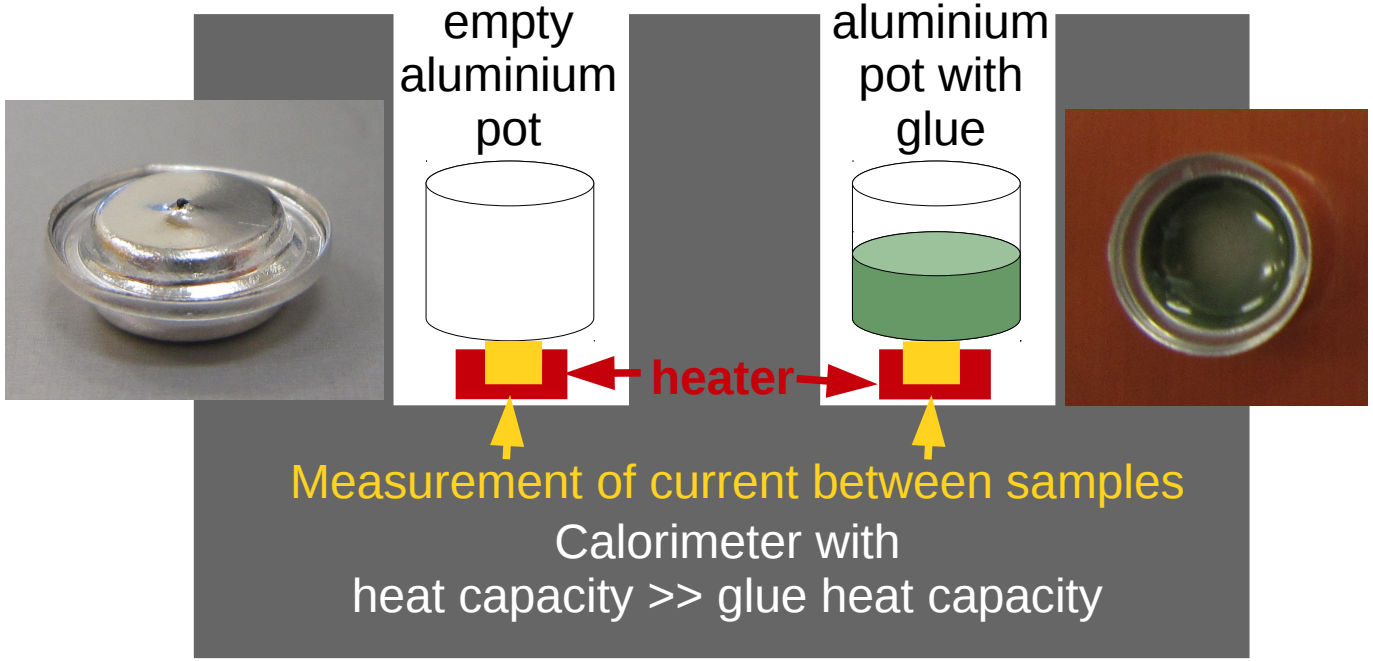
Glue characteristics

Glues used in the detector



Glue characteristics: Glass transition temperature

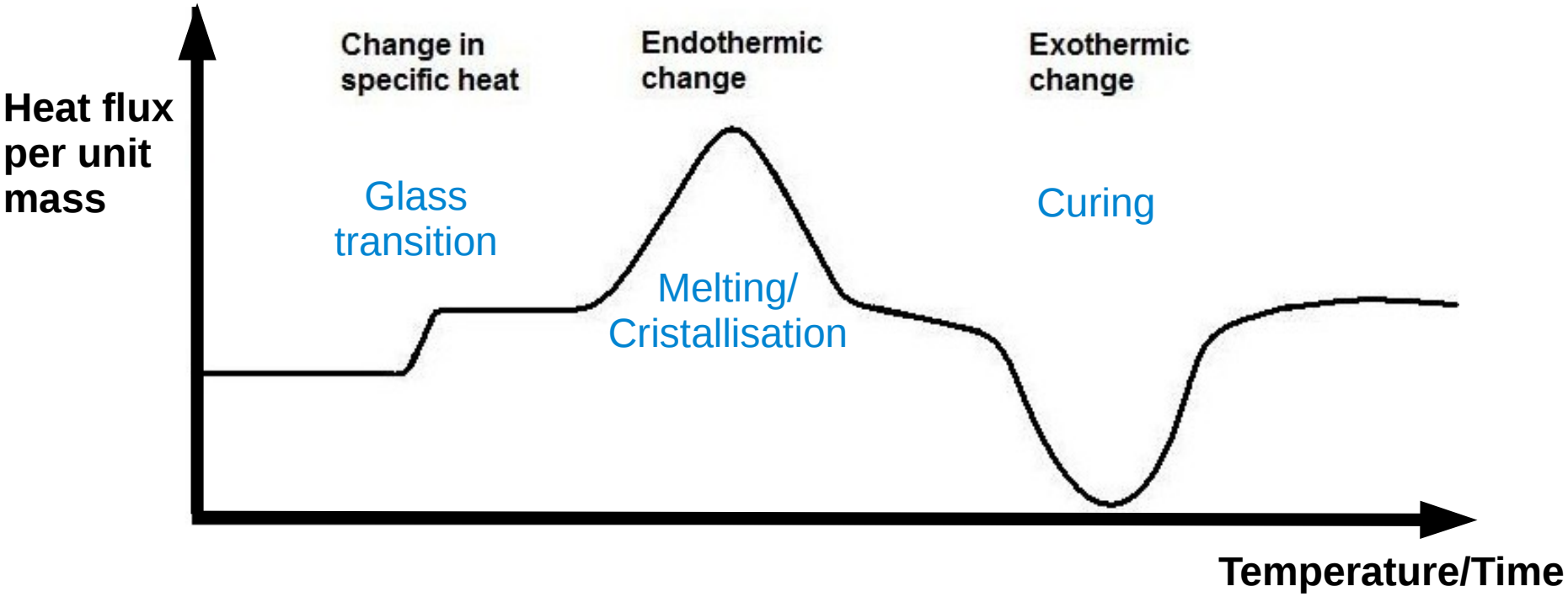
- Glass transition temperature: temperature at which consistency changes from solid to glass-like
- Should be well above operating temperature of detector
- Can be measured with differential scanning calorimetry



Measurement of heat capacity of pot with glue compared to pot without glue, i.e. heat capacity of glue over range of temperature

→ find temperatures where heat capacity, i.e. glue consistency changes

Glue characteristics: Differential scanning calorimetry



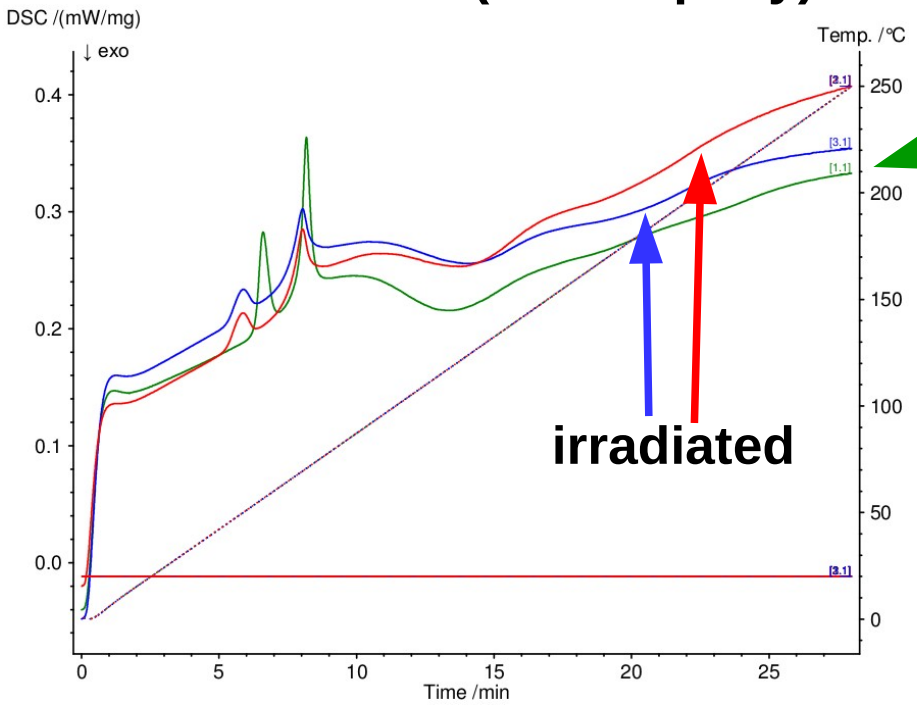
> Performed for

- Glues currently used in module production (silver epoxy glue, optical glue)
- UV cure glues (possible replacement candidates)
- Hysol (used in support structure) 0%, 10%, 20% and 30% filled

> Before and after irradiation (compare glass transition temperatures)

Glue characteristics: changes by irradiation

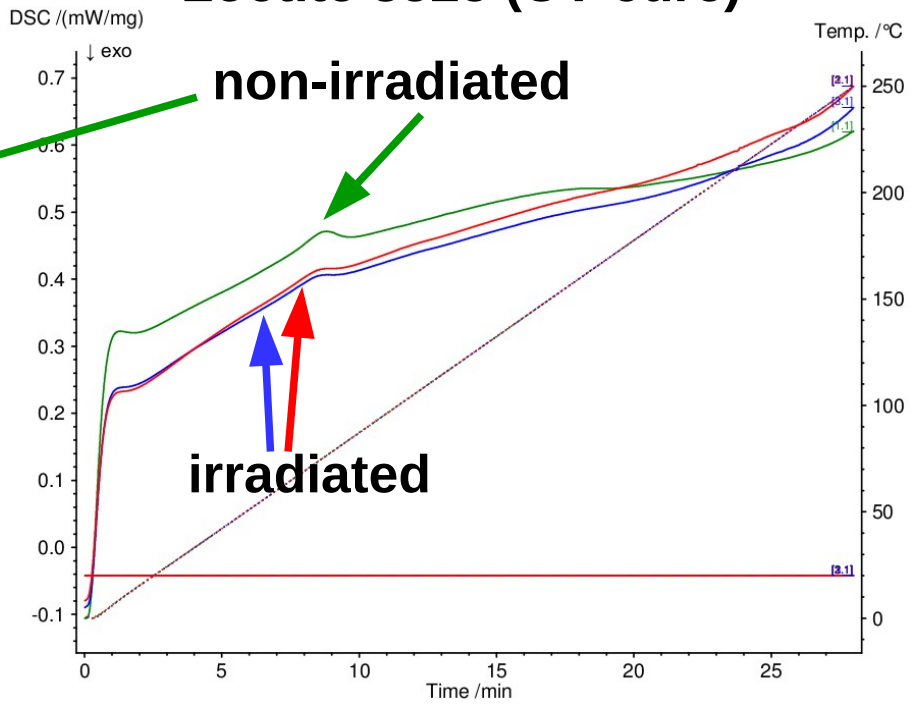
Tra-Duct 2902 (silver epoxy)



> Irradiated samples show first endothermic peak at lower temperatures than non-irradiated samples

> Peak's position moved from 46°C down to 39°C

Loctite 3525 (UV cure)



> Endothermic peak at same positions for irradiated and non-irradiated samples

> Peak well above detector's working temperature (at 68°C)

Glue characteristics: degree of curing

Information found in calorimetry

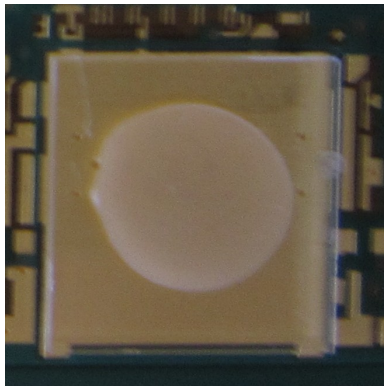
- By comparing heat quantity released by uncured glue and cured glue curing grade can be determined
- Degree of curing corresponds to quality of glue connection (strength)

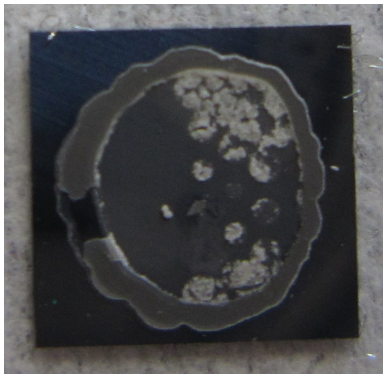
	0% BN	10% BN	20% BN	30% BN
Heat released from uncured glue [J/g]	-576,8	-546,2	-456,8	-403,7
Curing degree after 1 hour @ 60°C [%]	75,7	78,1	75,5	76,1
Curing degree after 3 days @ 20°C [%]	97,6	77,0	74,2	68,8

- Glue cured in oven shows lower curing degree than glue cured at room temperature
- For higher percentages of boron nitride filling glues cured in oven show higher curing degree

Glue characteristics: structure changes by irradiation

- Previous investigations of irradiated glue samples: thermo-mechanical (changes in thermal conduction, strength)
- Now: investigation of chemical/microscopical properties





- Currently: investigation of structure changes in glues caused by different types of irradiation
  - 3 most promising UV cure glues, silver epoxy glue and optical glue
  - 23 MeV protons, 800-900 MeV protons, reactor neutrons
  - 4 fluences each ($1 \cdot 10^{15}$ n_{eq}/cm^2 to $4 \cdot 10^{15}$ n_{eq}/cm^2)
- Investigate structure changes using Raman-spectroscopy (or combined Raman-REM?)

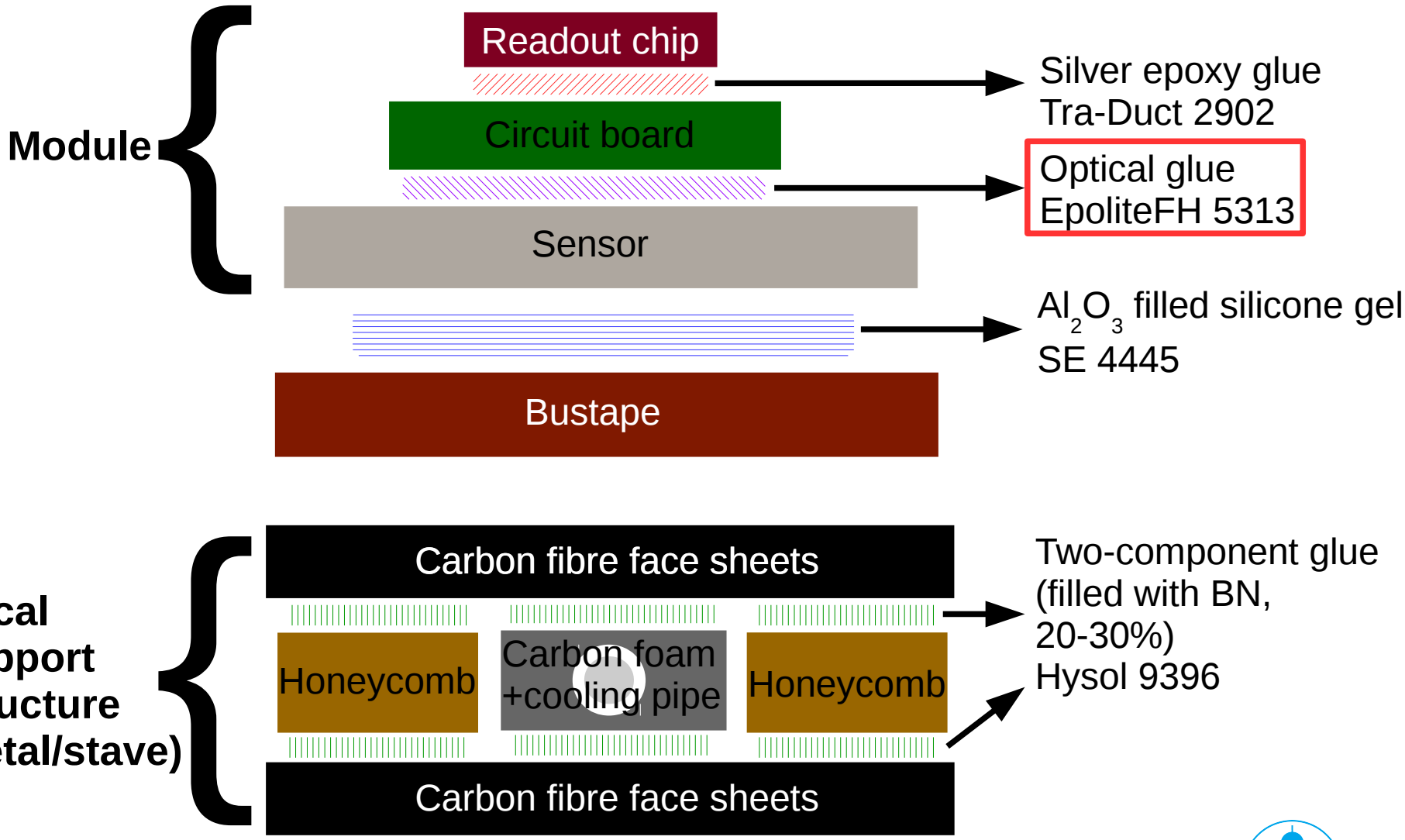
In progress

Next steps

DESY

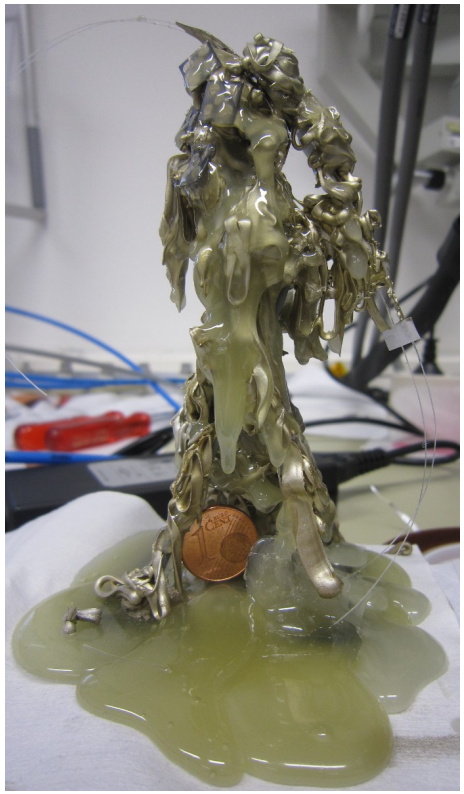
UV cure glue as replacement for optical glue on sensor

Glues used in the detector



UV cure glues between hybrids and sensor: why?

> Glue currently used between hybrid and sensor:
Epolite FH-5313 (two-component non-conductive epoxy)



> Practical issues:

- long curing time (24 hrs)
- very brittle after curing

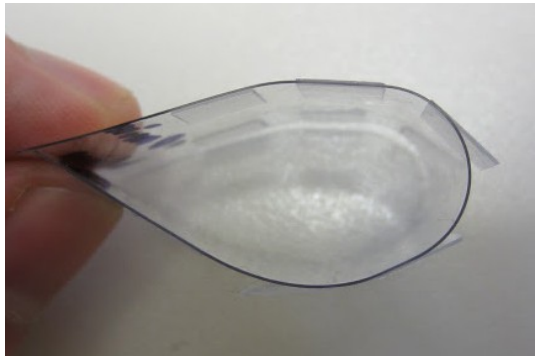
> Organisational issues:

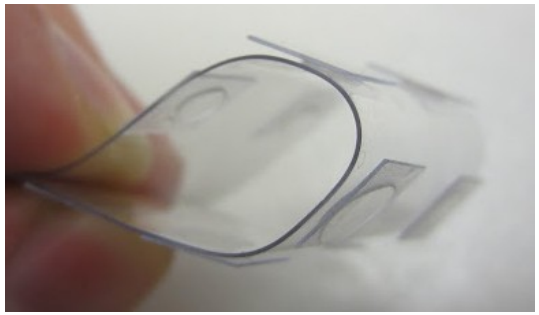
- one component changed since use in Atlas SCT
- not sold to German companies (export regulations)
- most of it wasted
- expensive (≈200.000 € for 10.000 modules)

UV cure glues between hybrids and sensor: why?

> Glue currently used between hybrid and sensor:
Epolite 5313 (two-component non-conductive epoxy)

> Whereas for UV cure glues ...





> Practical issues:

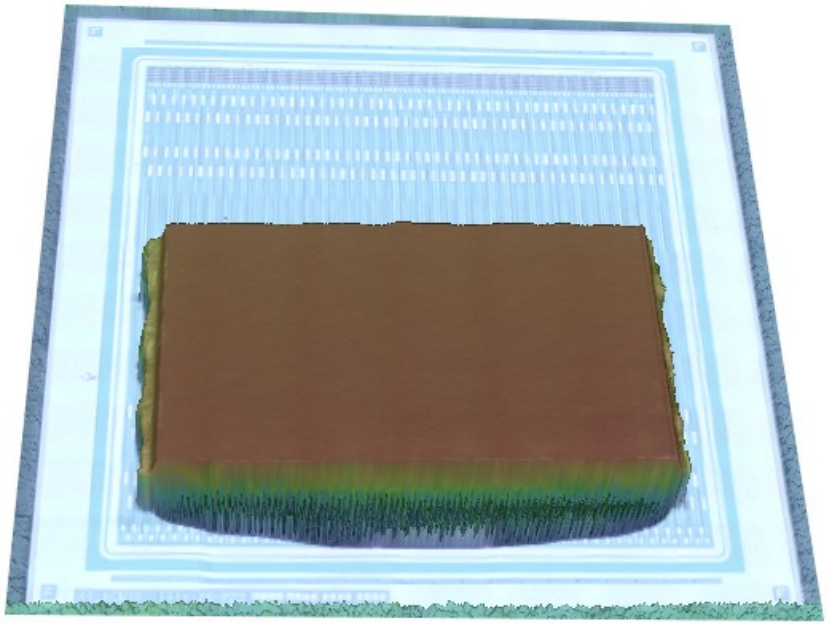
- long curing time (24 hrs) short curing time (5 min)
- very brittle after curing flexible after curing

> Organisational issues:

- one component changed since use in Atlas
- not sold to German companies (export regulations) can be ordered everywhere
- most of it wasted very cost-efficient
- expensive (≈200.000 € for 10.000 modules) (≈5.000 € for 10.000 modules)

UV cure glues between hybrid and sensor: glues

- UV cure glue candidates (same as before)



- LOCTITE 3525
- DYMAX 6-621
- DYMAX 3013

  compared to Epolite FH-5313

- For tests:

  applied 2.5 µl of glue to sensor

  piece of FR4 (without copper, covered with solder resist similar to hybrids) placed on top

  cured with UV LEDs for 10 minutes

UV cure glues between hybrid and sensor: tests

- Possible effects of glue+FR4 on a sensor we considered most important

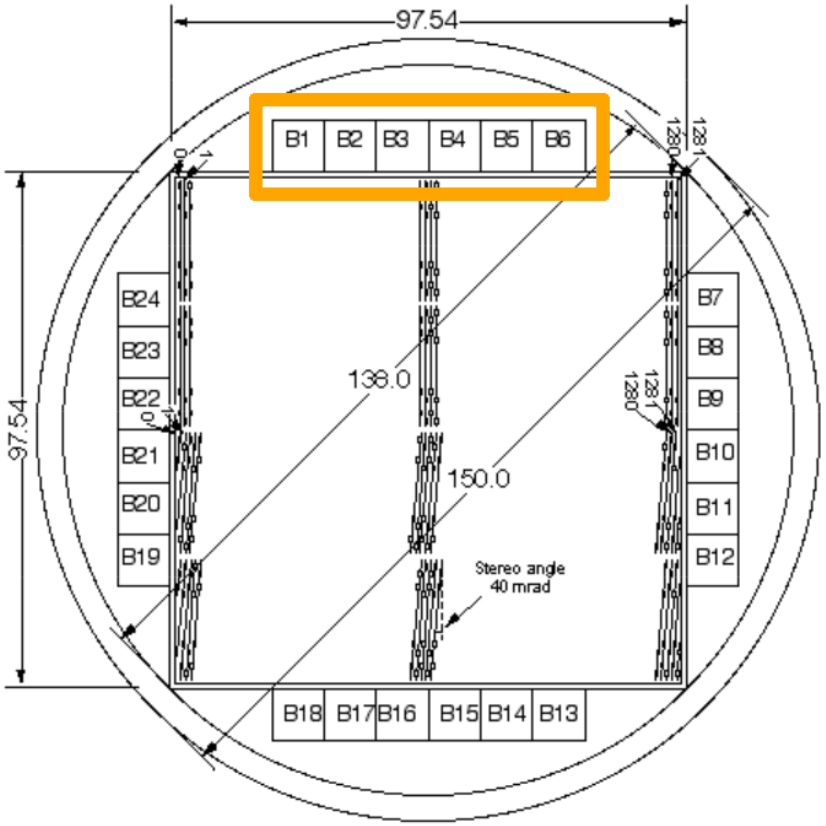
- Curing (volume loss → contraction) might cause tension on sensor
- Glue might chemically react with sensor (corrosion/diffusion)
- Outgassing (curing/ageing) might lead to chemical reaction of sensor

- Irradiation (compare blank and Epolite minis with UV cure glue minis)
  - With 23 MeV protons (KIT)
  - With 900 MeV protons (Los Alamos)
  - With reactor neutrons (Ljubljana)
- Thermal cycling
- Thermal cycling + irradiation (with 23 MeV protons)

DESY

UV cure glues between hybrid and sensor: measurements

- Investigate effects of glue on sensor using silicon strip sensor prototype miniatures
- IV/CV/C_int, R_int before gluing, after gluing, after treatment
- Laser microscope images (monitor corrosive effects)



- For good sensors: connect to AliBaVa test setup (DESY test beam)

Next steps

- After performing every possible test: measure shear strength

UV cure glues between hybrid and sensor: problem

- Every test to be performed for four glues (original + 3 UV cure)
- Irradiation and ageing require additionally blank sensor (reference)
- For (less than?) a minimum of statistics: two sensors per glue and test
- Each test requires 8-10 mini sensors

- Problem: miniature sensors were created for tests of different realisations of new n-in-p-sensor-architecture (p-stop, p-spray, …)

- We have 90 Atlas miniature sensors …

BUT

DESY

UV cure glues between hybrid and sensor: problem

> They are very different

	FZ1		FZ2	
	32		58	
	spray	no spray	spray	no spray
	18	14	15	43
BZ1 (no p-stop)	-	3	-	8
BZ2 (common p-stop)	3	-	4	4
BZ3 (individual p-stop)	5	-	1	5
BZ4 (different punch-through)	6	11	2	12
BZ5 (underhanging strip metal)	-	-	5	5
BZ6 (different strip pitch)	4	-	3	9

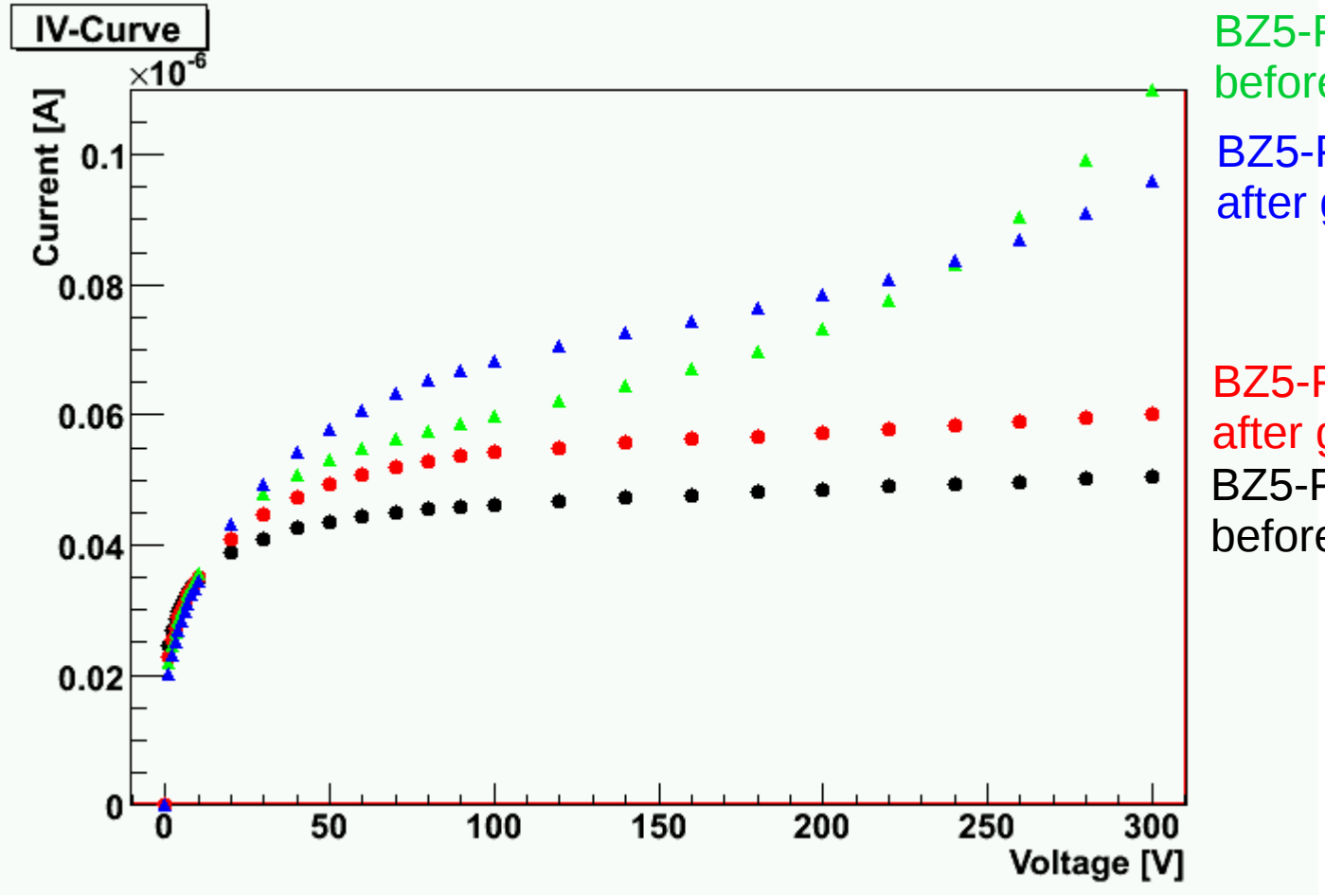
> hardly enough mini sensors of any type for test with 8-10 minis

> combination of similar types required (comparability?)

UV cure glues between hybrid and sensor: problem

> On top of everything else:

sensors which should be the same ...



BZ5-P23-W205, before gluing

BZ5-P23-W205, after gluing

BZ5-P11-W205, after gluing

BZ5-P11-W205, before gluing

UV cure glues between hybrid and sensor: problem

- So what can we learn from these studies?
  - Changes in a sensor from blank → glued → irradiated for every glue
  - Comparison between different glues difficult for sensors already show large differences between similar types
  - We will be able to identify serious problems
  - We might find a spread in results for the same glue

    → eliminate glues with serious issues, select candidate(s) for prototype module

- In parallel: investigate sensor performance changes caused by gluing hybrid on top (using current glue)

  → gain better understanding of effects of gluing on silicon

- Collect knowledge for first module to be built with convincing UV cure glue

Next steps

Conclusion

- Studies to replace silver epoxy glue with UV cure glue almost concluded
- First prototypes built with good test results
- Use for mass production (dispensing systems) under investigation

- Studies about changes of glue characteristics caused by irradiation ongoing

- Investigation of use of UV cure glue on sensor ongoing

- PETTL has enabled these studies: thank you very much!