THERMAL SIMULATIONS of TOTEM MODULES

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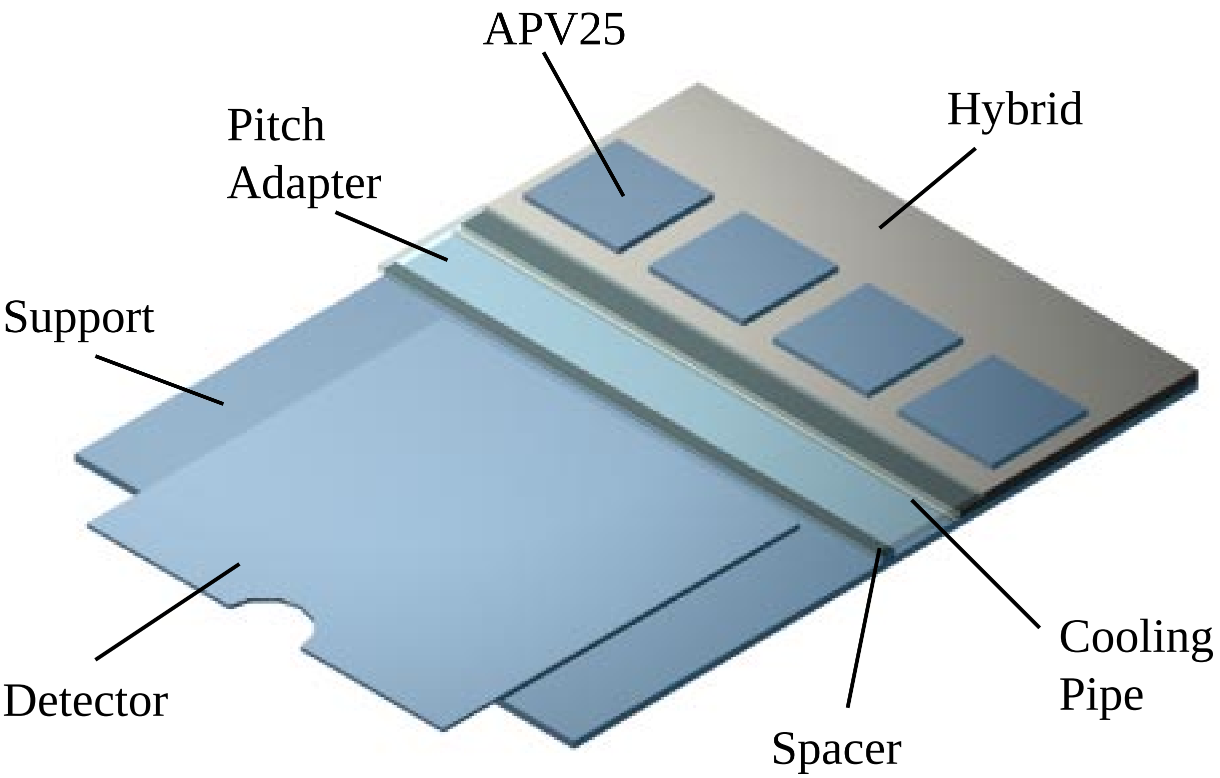
AGENDA

- Prototype module
- Thermal Simulations
  - readout electronics and other thermal loads
  - modeling of the thermal behavior
  - mechanical design and choice of materials
  - results for different materials and cooling
- Thermal - Stress Simulations
- Conclusions - Next Steps

MECHANICAL DESIGN



SUMMARY OF HEAT LOADS

THERMAL LOADS

READOUT CHIPS

Detector Surface:	30 x 30 mm
Segmentation:	≈50 µm
Number of channels:	1280

APV-25 readout electronics

Power dissipation per channel:	2.31 mW
Number of channels per chip:	128
Number of chips per module:	10
Power dissipation per module:	3.0 W

THERMAL RADIATION

Aluminium Pot 300 K

Detector module 130 K

Total thermal radiation load 235 mW

THERMAL RADIATION LOAD

- **Two diffuse-gray surfaces forming a cylindrical or spherical enclosure:**

$$q_{1-2} = \frac{\sigma A_1 (T_1^4 - T_2^4)}{\frac{1}{\varepsilon_1} + \frac{A_1}{A_2}\left(\frac{1}{\varepsilon_2} - 1\right)}$$

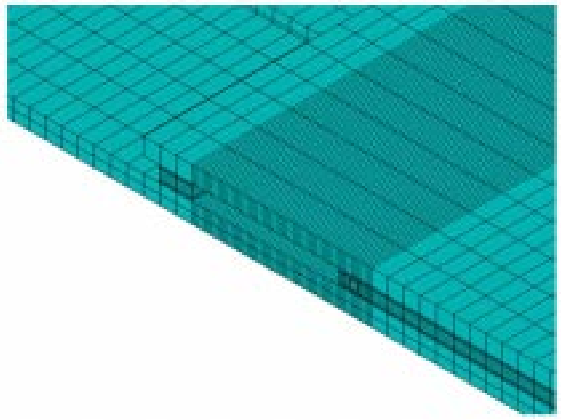
- **Assumptions:**
  - Silicon Module (ε_1=0.19 ▪ A_1=38 cm^2) at 130 K
  - Aluminium Pot (ε_2=0.06 ▪ A_2=345 cm^2) at 300 K

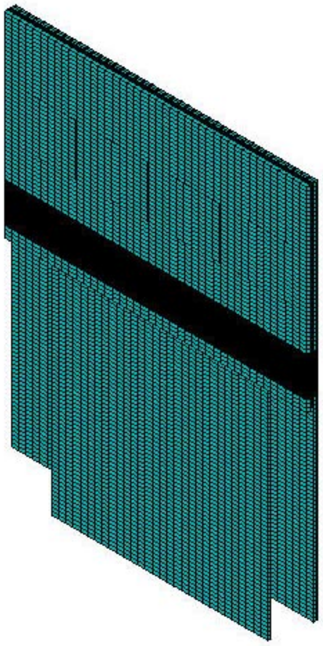
ANSYS THERMAL MODEL

MESHING

Spatial accuracy = 0,5 mm

Number of Nodes ≈ 51.000

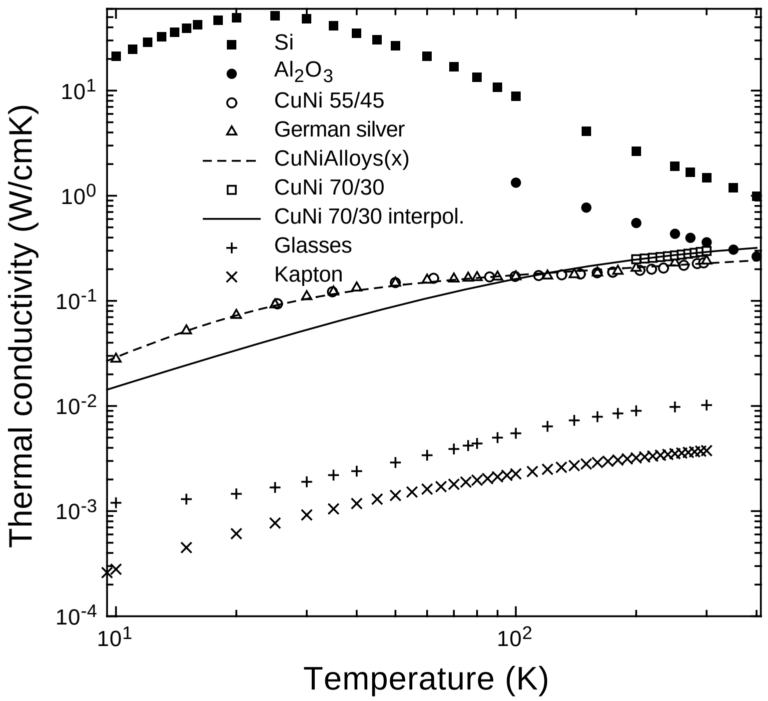


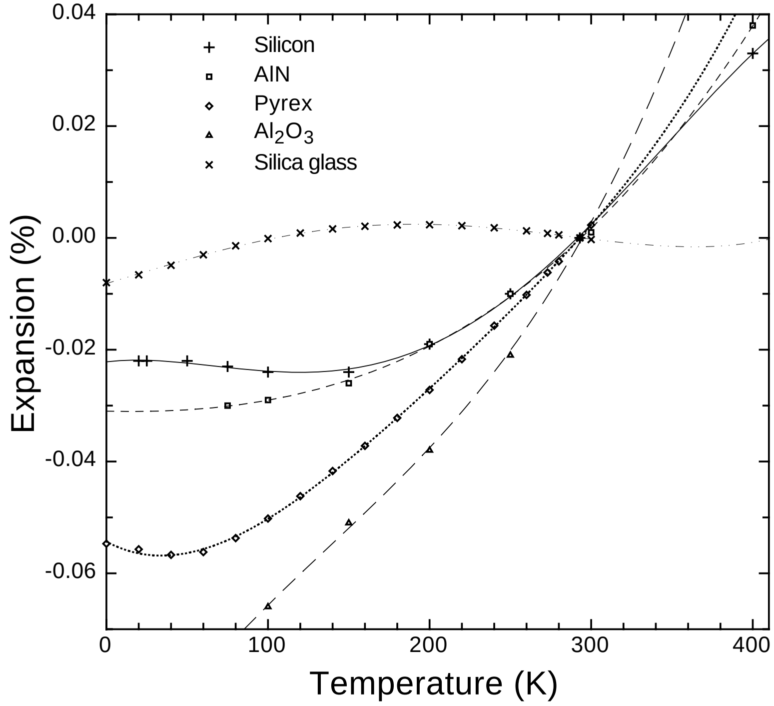


BOUNDARY CONDITIONS

Heat Loads	▪ Heat Flux
Heat Sink	▪ Bulk T fluid (110 K – 120 K) Convection coefficient 10^4 W/m^2K

THERMAL CONDUCTIVITY AND LINEAR EXPANSION





ANSYS MODEL

Materials of the reference module:

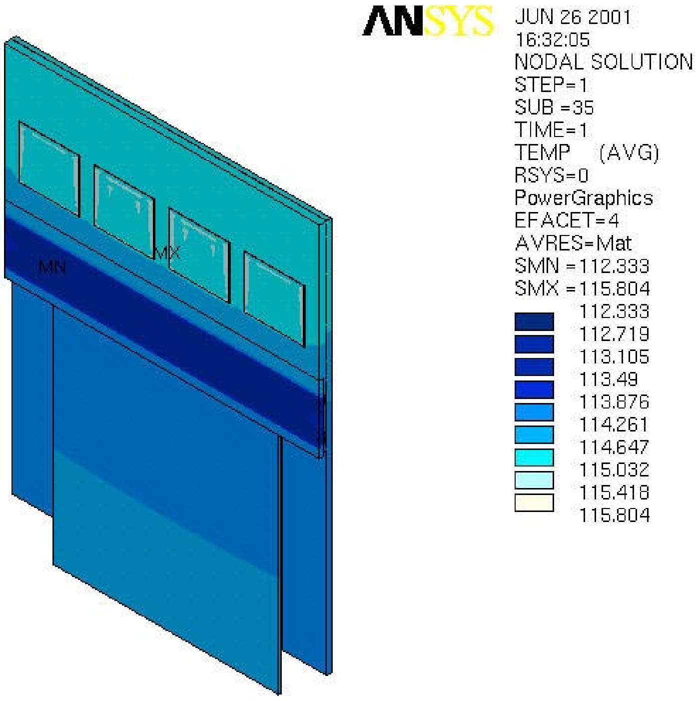
strip detector	silicon
support	silicon
hybrid	aluminum oxide
pitch-adapter	glass
cooling pipe	copper-nickel
spacer	silicon

Components are glued together with radiation resistant cryogenic epoxy.

Thermal boundary conditions:

APV25 power dissipation	1.2 W
thermal radiation	235 mW
fluid bulk temperature	120 K
heat transfer coefficient	10^4 W/m^2K

THERMAL SIMULATION▪ Pyrex PA▪Al_2O_3 Hybrid▪ Silicon



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PowerGraphics
EFACET=4
AVRES=Mat
SMN =112.333
SMX =115.804
          112.333
          112.719
          113.105
          113.49
          113.876
          114.261
          114.647
          115.032
          115.418
          115.804
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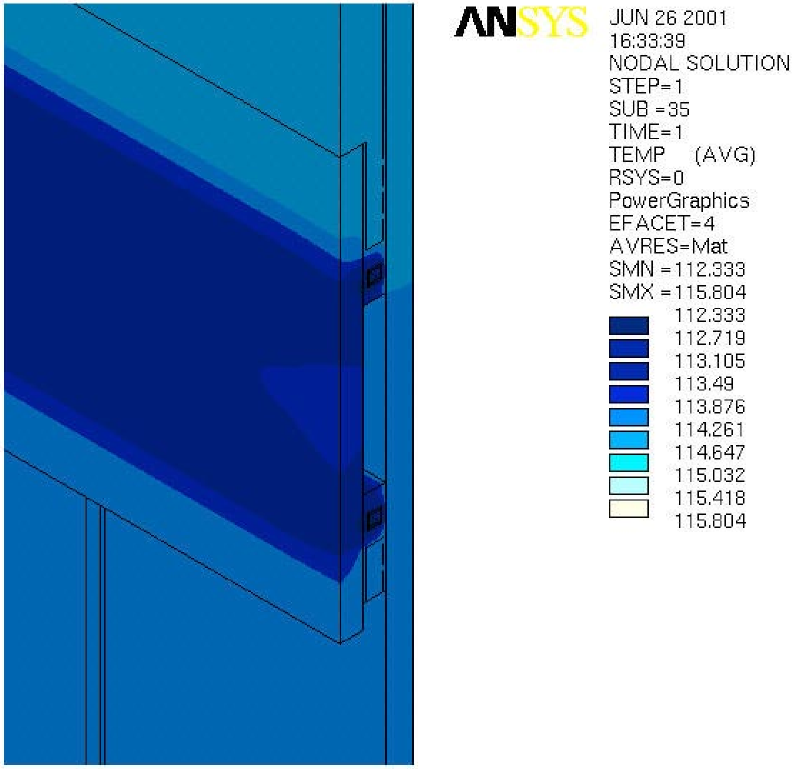

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SMX =115.804
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          112.719
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          113.876
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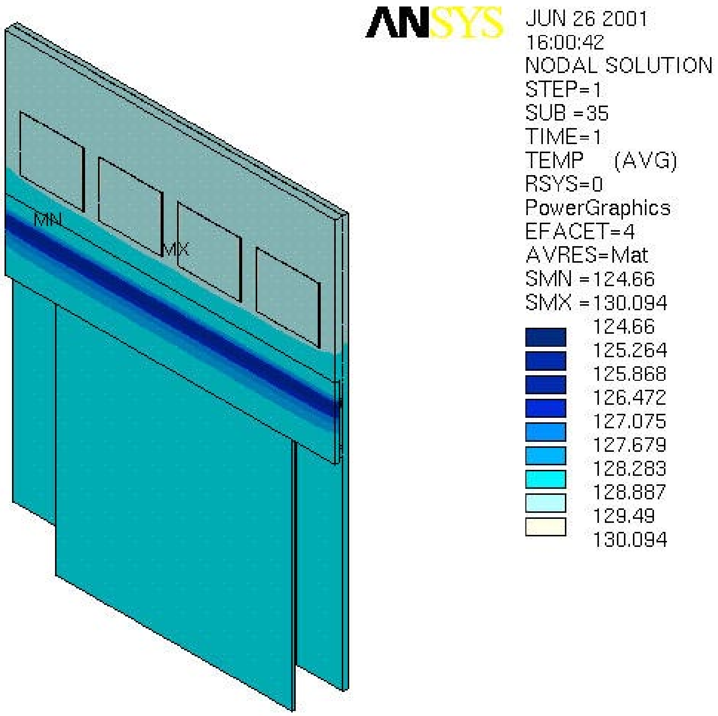
THERMAL SIMULATION ▪ Pyrex PA ▪ Al_2O_3 Hybrid ▪ Silicon



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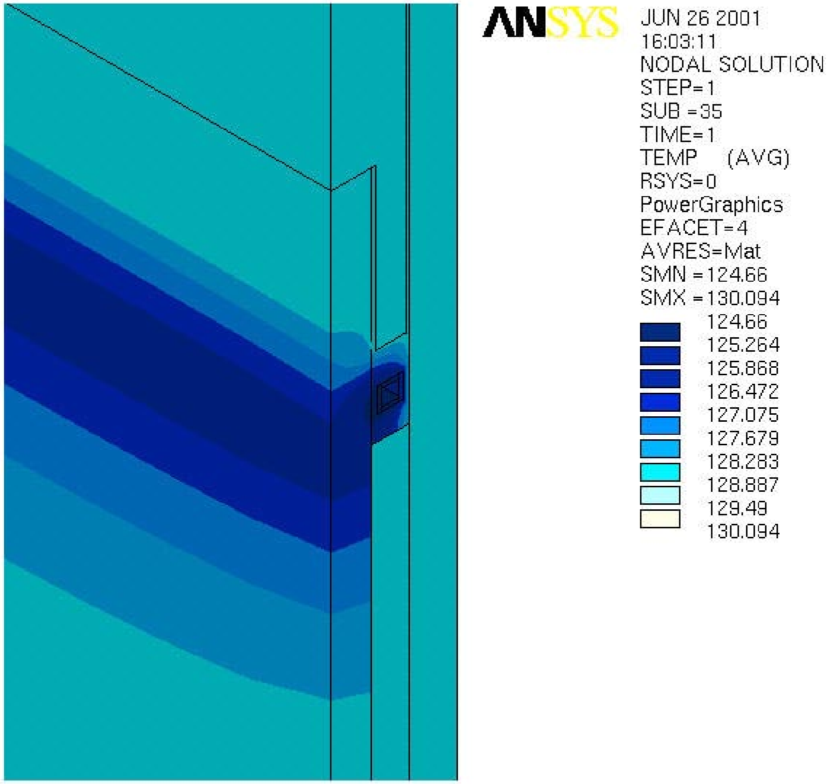

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SMX =130.094
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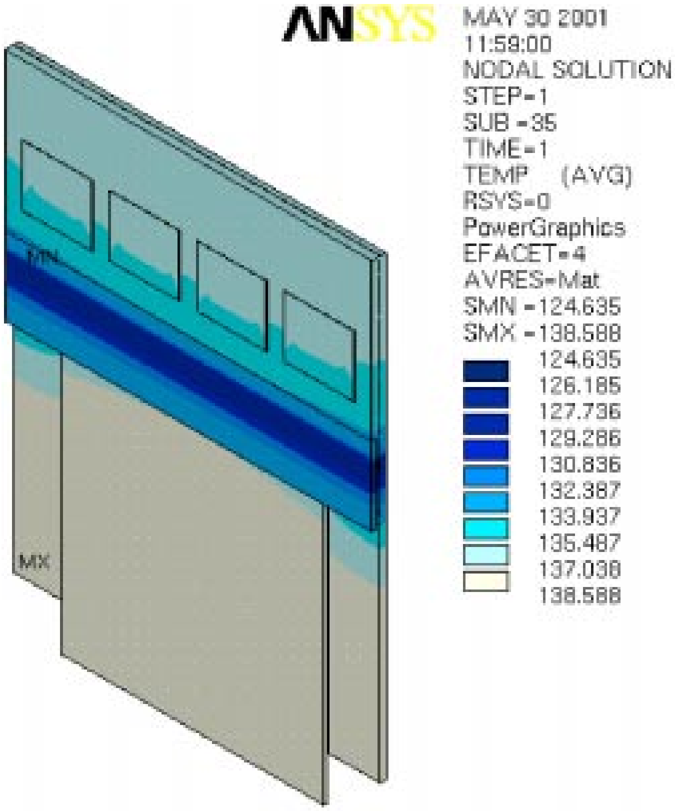
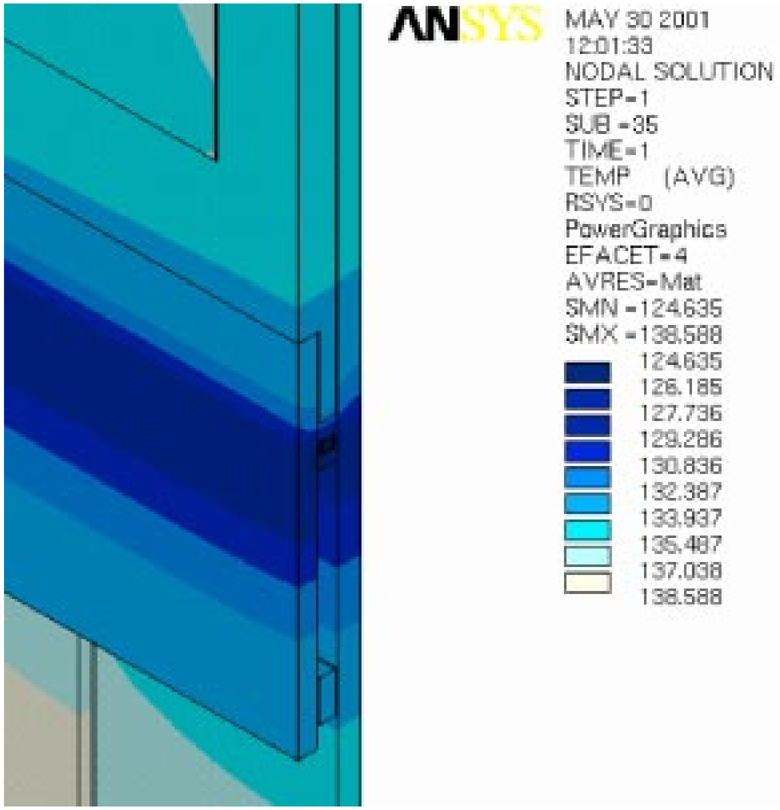
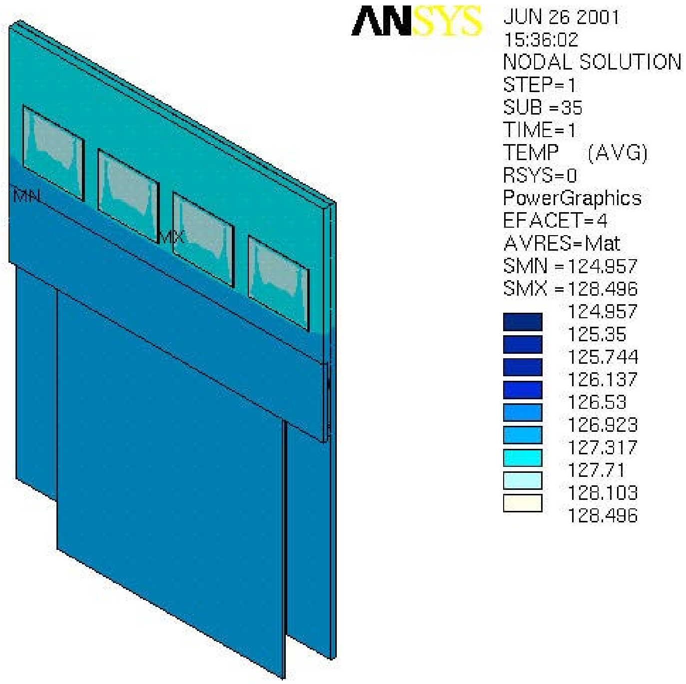
125.264
125.868
126.472
127.075
127.679
128.283
128.887
129.49
130.094

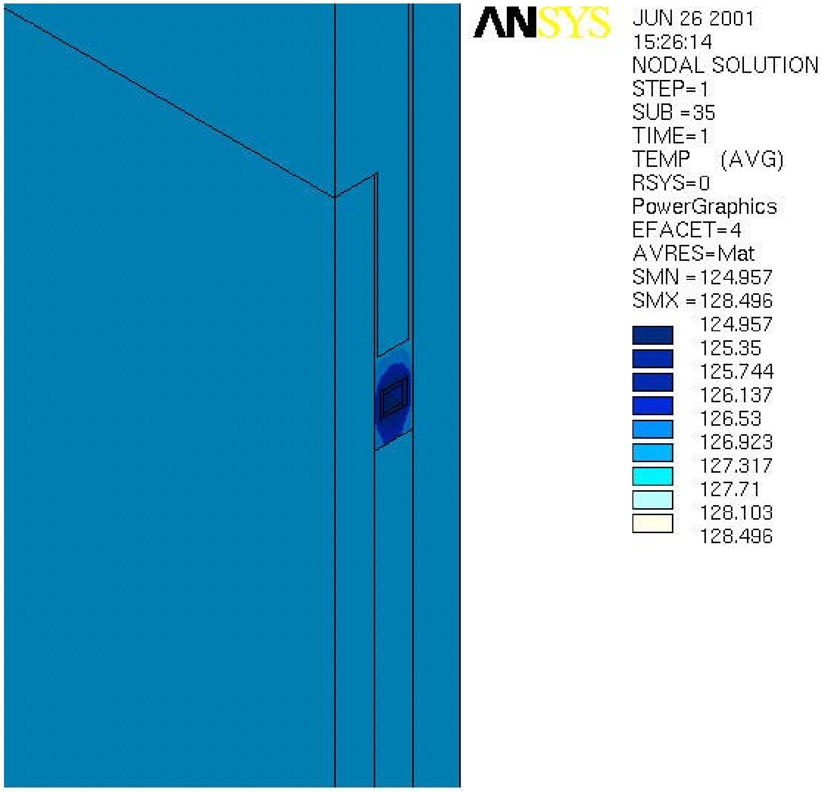
THERMAL SIMULATION▪ Pyrex PA▪AlN Support▪ Silicon





THERMAL SIMULATION▪ Silicon PA▪Al_2O_3 Hybrid▪ Silicon





THERMAL – STRESS SIMULATION

- Study the stresses that result from temperature gradient and different thermal dilatation coefficients of the materials

- Glue : high thermal dilatation coefficient, fillers

- Minimize displacements of the module with symmetric structures

CONCLUSION ▪ NEXT STEPS

- Silicon, which is an excellent heat spreader at low temperatures, will be also used as constructive material.
- Evaporative cooling in microtubes provides ideal thermal separation of the heat source from the sensor and leads to a very homogeneous temperature profile in the module.
- Experiments are planned to validate the thermal and stress simulations (tooling and conductivity tests).
- Alignment of the detector relative to the pot
- Characterization of the APV-25 at low temperature