Studies on the CMS Tracker Upgrade Project

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sLHC

$$\frac{dN}{dt} = \sigma L$$

Luminosity Depends only on the machine!!

To have a greater event rate at LHC an upgrade is needed.

sLHC:

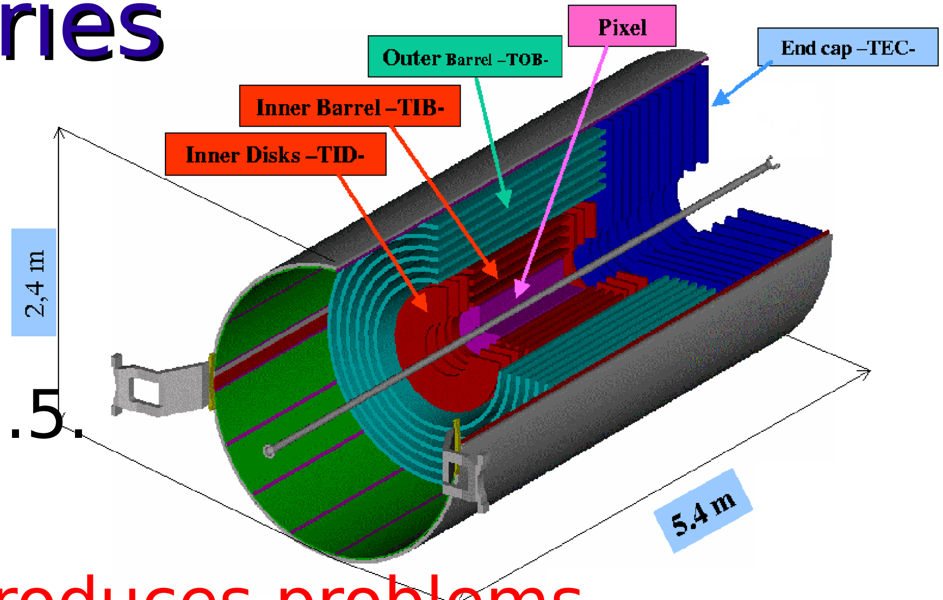
super Large Hadron Collider

$$L = 10^{34} cm^{-2} s^{-1} \rightarrow 10^{35} cm^{-2} s^{-1}$$

Principle aim - MORE STATISTICS

- improved accuracy of SM parameters;
- extend discovery in high mass regions;
- improve sensitivity to rare processes.

Silicon detector system - measures trajectories



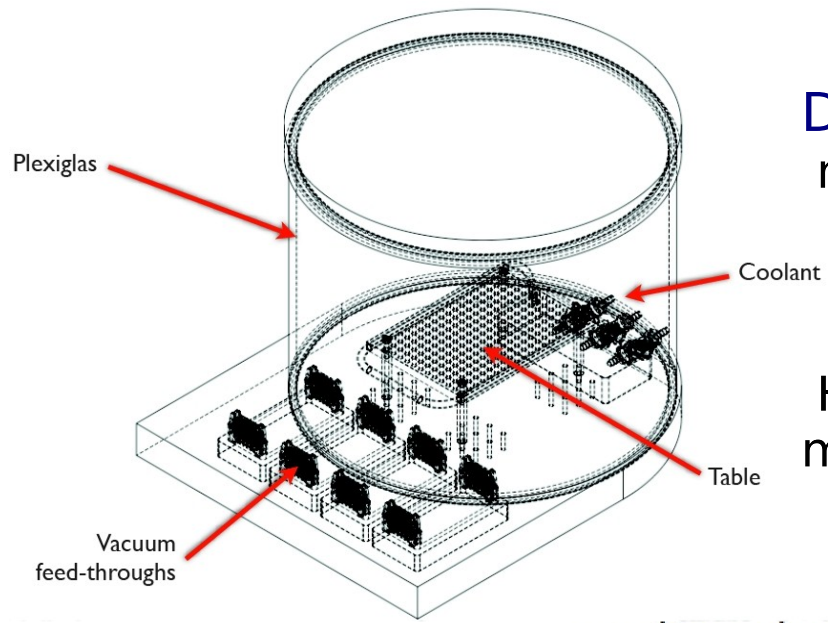
- Barrel:
  - Inner pixel layer;
  - outer microstrip layer.
- Endcaps: coverage up to $|\eta| < 2.5$.

Large luminosity increase introduces problems

- Radiation damage:
  - lower temperature required to have higher radiation hardness → new cooling system
- Over occupancy:
  - Higher granularity required → more electronics, more material, more unwanted interactions

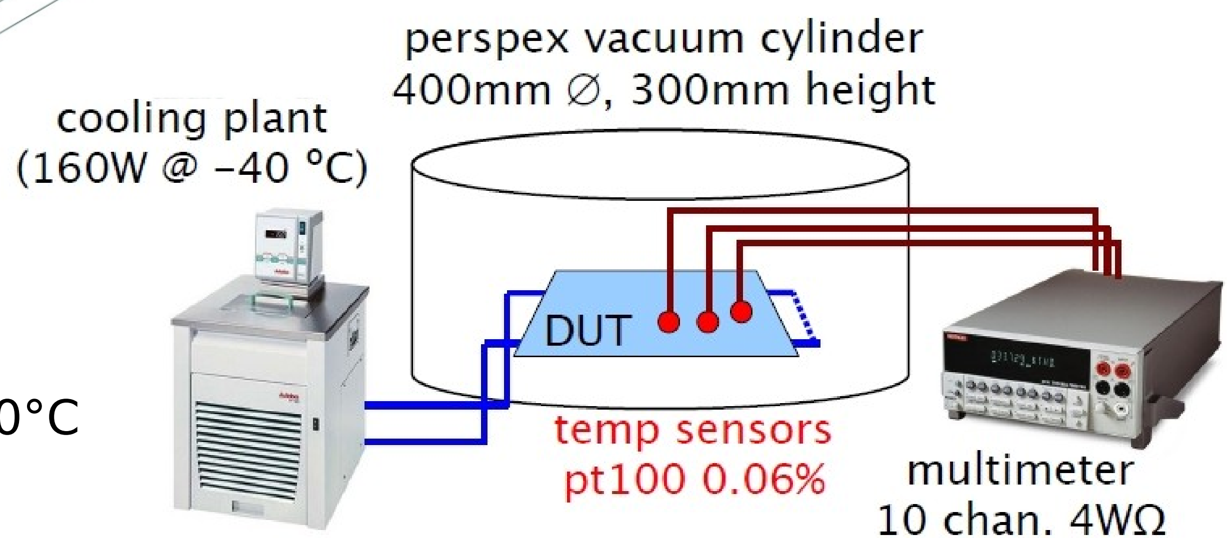
New detector module design needed →

Set up a Prototype Test Lab



Design goals:

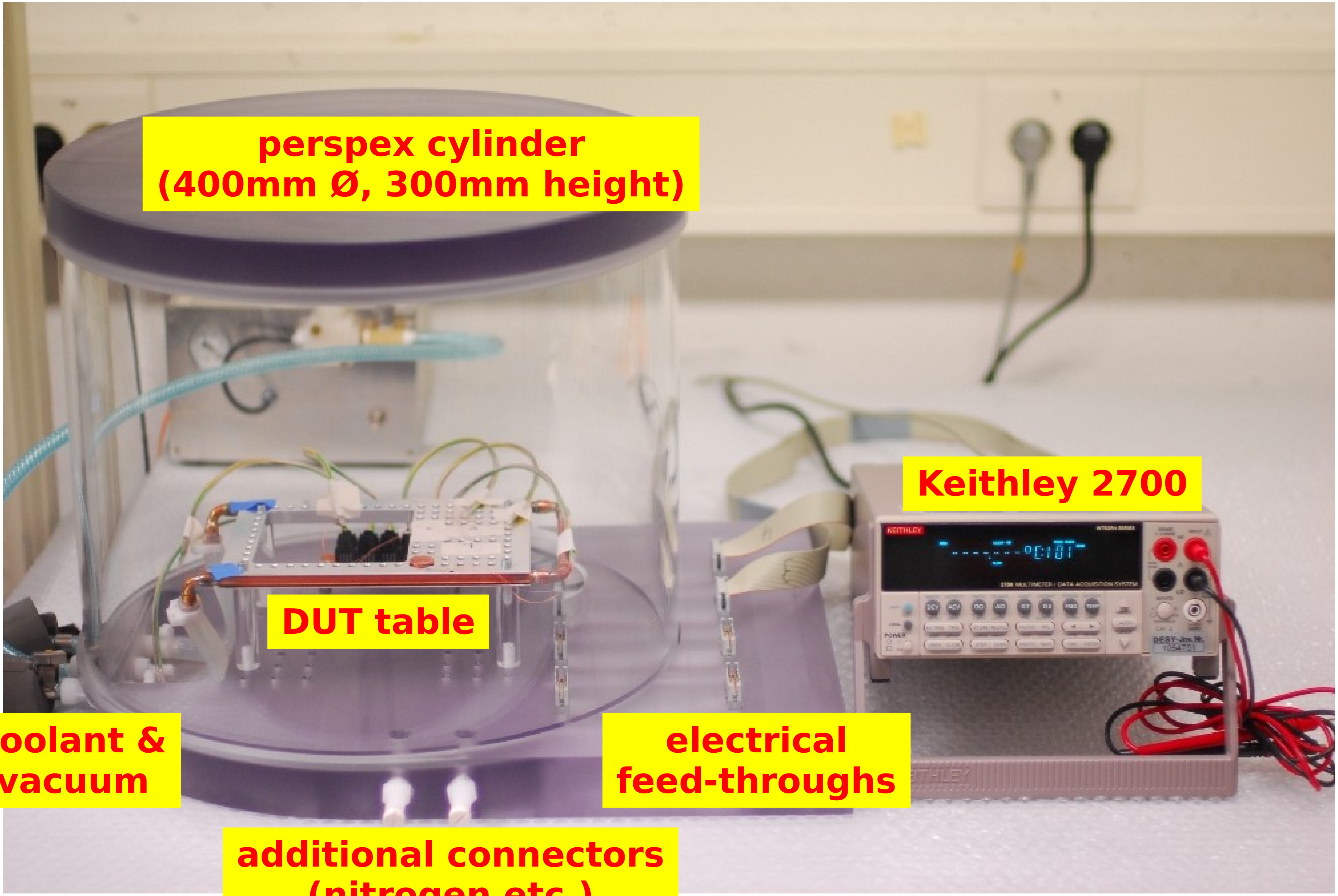
measure cooling efficiency of test structures and module prototypes;
possibility of vacuum evacuation to determine influence of convection;
High precision temperature measurements.



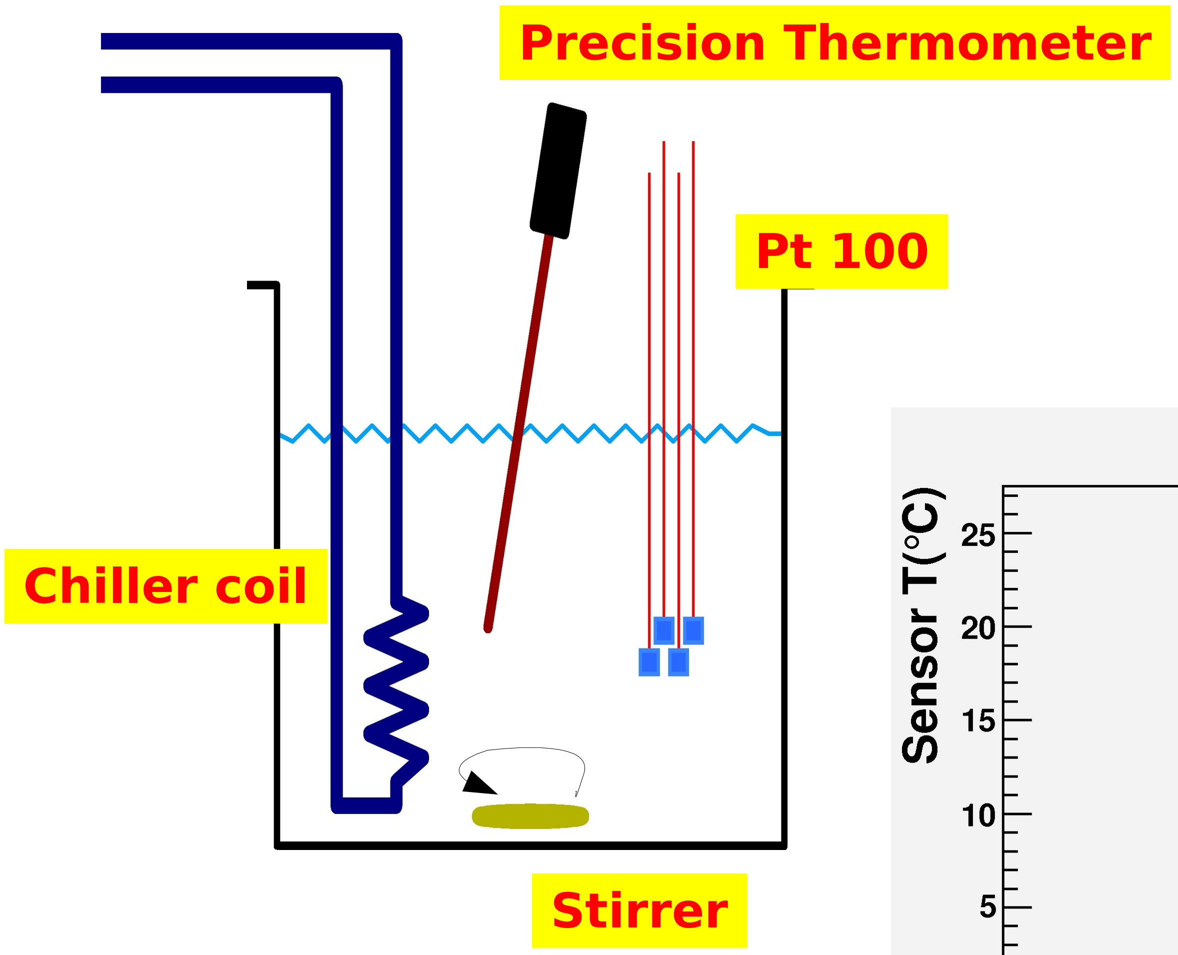
Cooling:

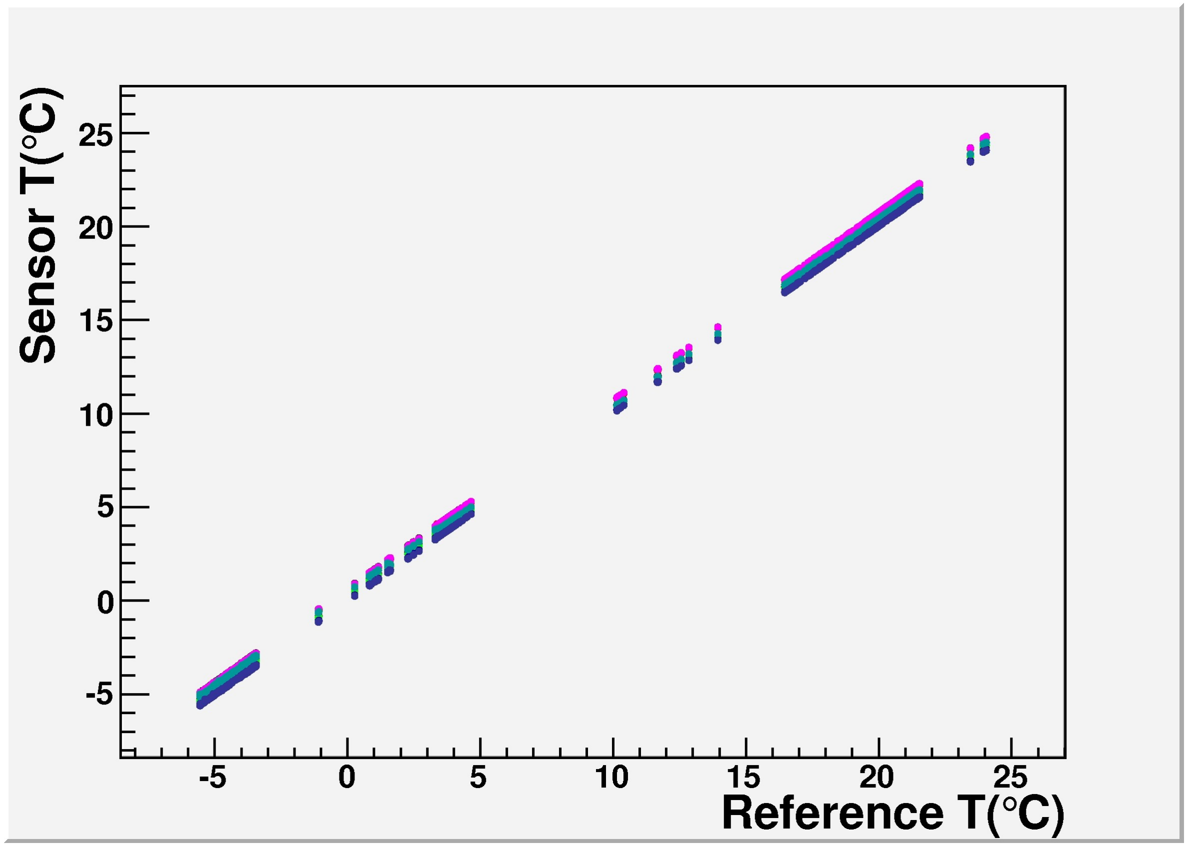
conventional chiller (Julabo FP50-MC)
160W cooling power @ -40°C
0.45 bar+
Coolant: silicon oil

Prototypes cooling efficiency test setup

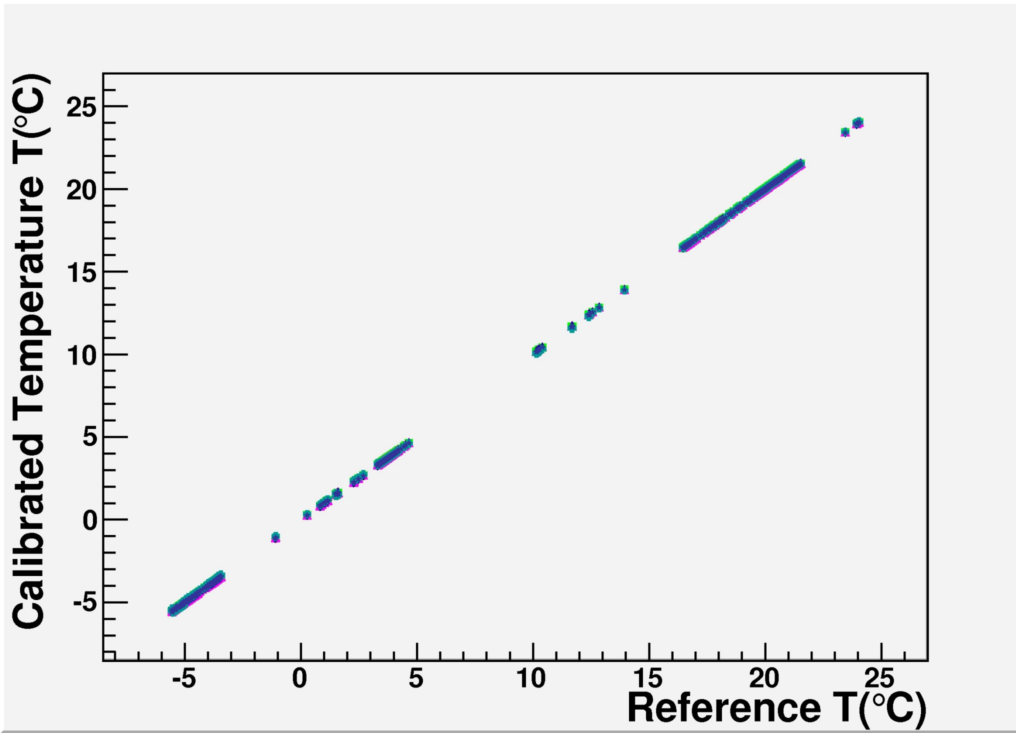


Sensor calibration setup



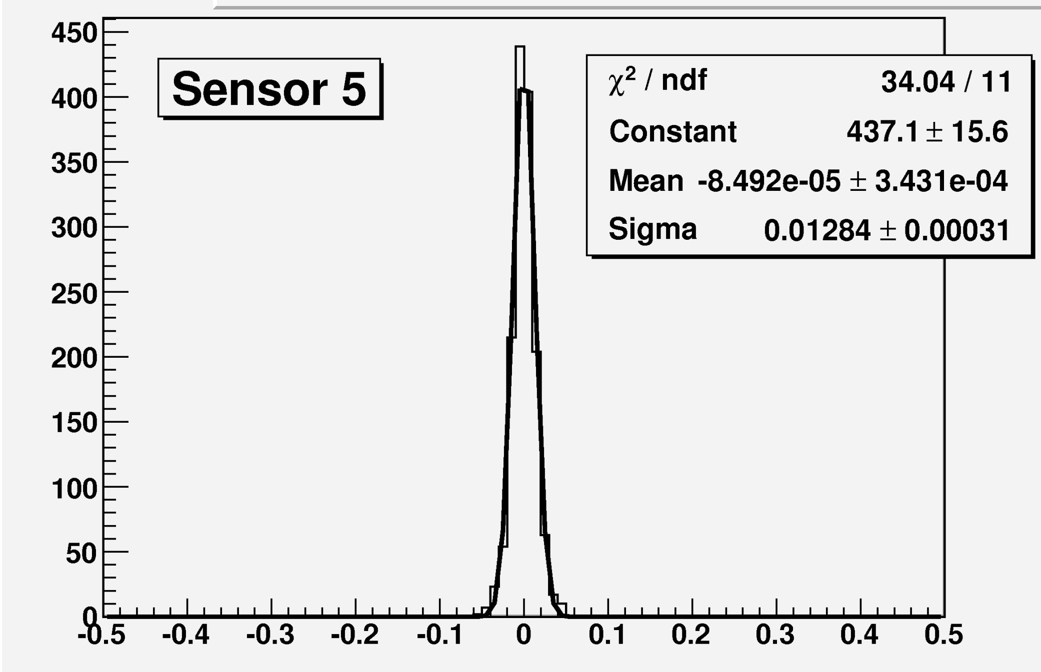


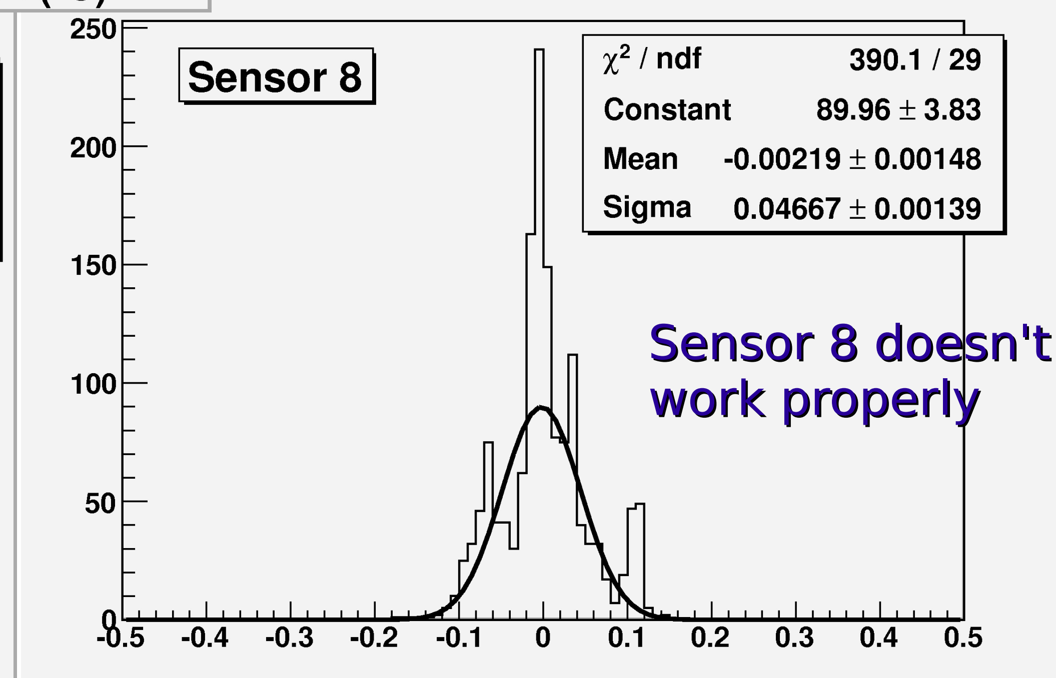
Sensor calibration results



Residual plots:

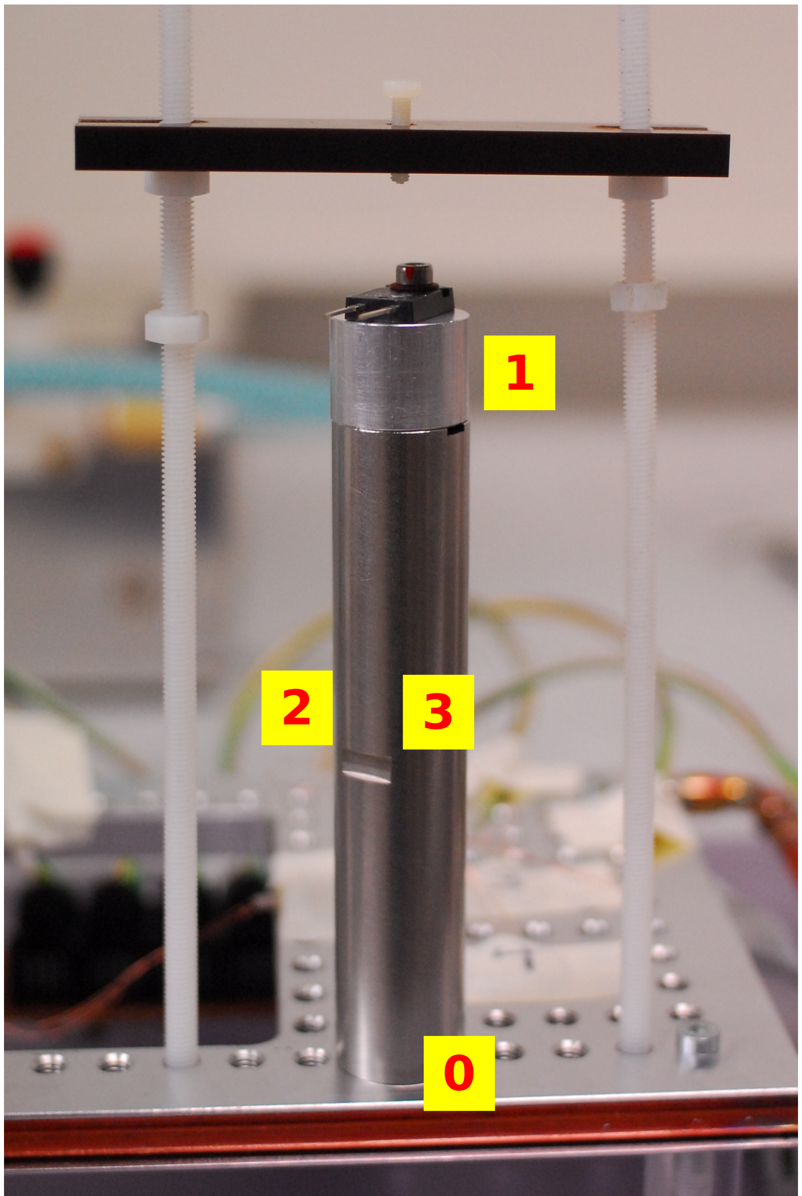
$$T_{Ref} - T_{cal}$$

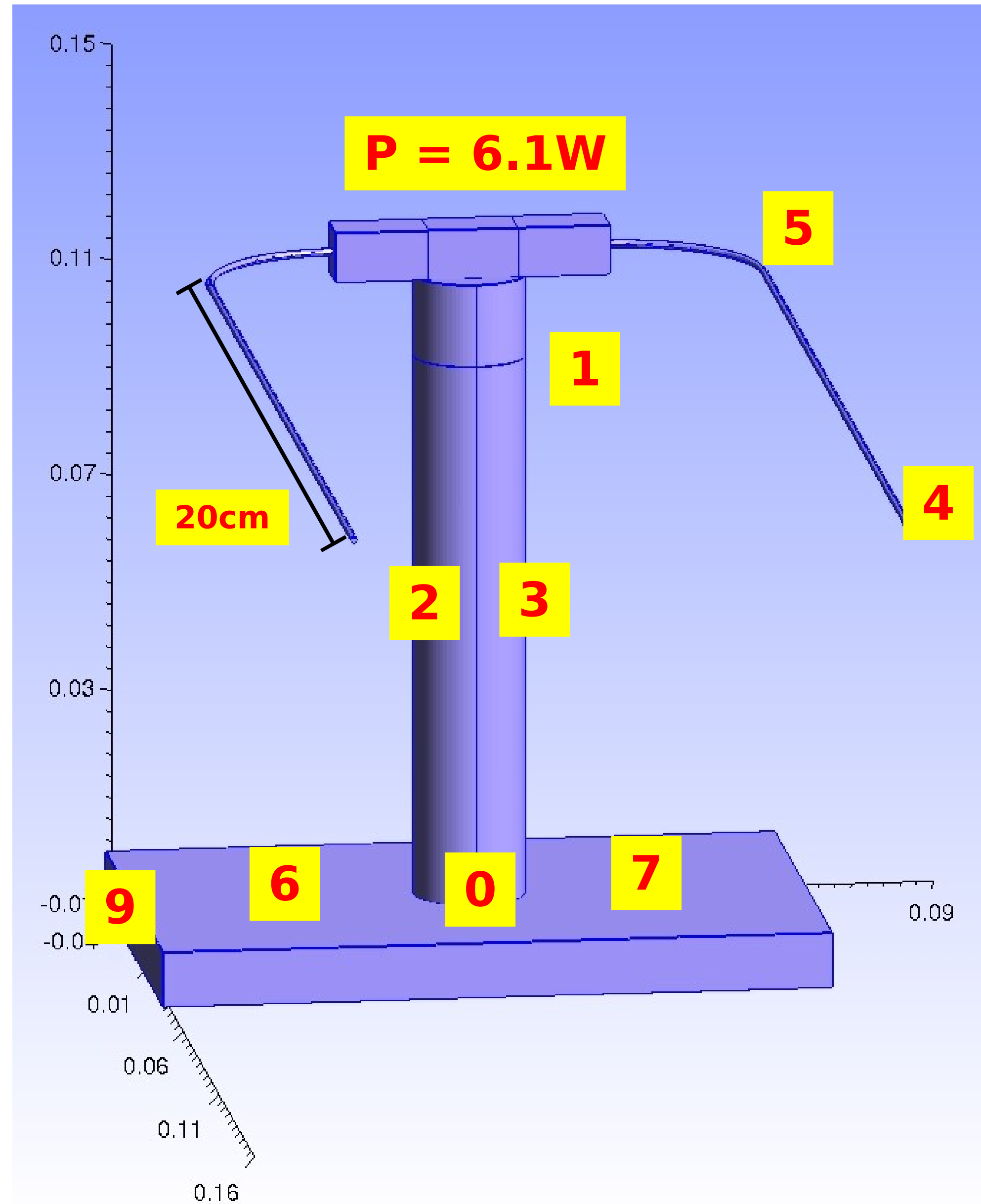




Thermal conductivity measurement setup

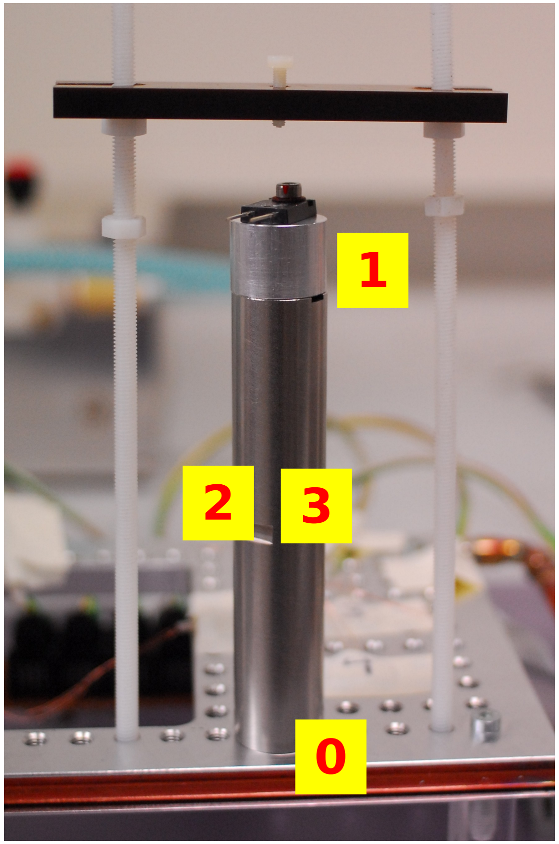
$$k = \frac{P}{A} \frac{\Delta x}{\Delta T}$$





Aluminum

(k ~ 150 W K^{-1} m^{-1})



Sensor	T(°C)	T(°C)	T(°C)
0	4	12	22
1	12.5	20.25	30
2	8.4	16.4	25.6
3	8.9	16.65	25.5
4	23	2435	25.5
5	48	48	48
6	2.3	10.5	1935
7	2.3	10.5	19.5
9	1	10	19

k	228	235	242

More than expected!!

Non-uniform temperature gradient,

uniform temperature gradient expected if convection and radiation could be neglected.

Equations

Fourier's law $\vec{q} = -k \nabla T$

Newton's law $\frac{dQ}{dt} = -h(T_{env} - T(t))ds$

Stefan – Boltzmann law $\frac{dQ}{dt} = \epsilon \sigma (T(t)^4 - T_{env}^4) ds$

$\vec{q}$ local heat flux (W/m^2)

k material's conductivity $(W/m \cdot K)$

T temperature of the object

Q thermal energy

h Heat transfer coefficient $(W/m^2 k)$

ds surface area from where the heat is transferred

T_{env} temperature of the environment

ϵ emissivity coefficient of the surface

σ Stefan – Boltzmann constant

Constrains and Coefficients

$k_{table} = 130\ W/mK\ (aluminum)$

$k_{rod} = 170\ W/mK\ (aluminum)$

$k_{spreader} = 130\ W/mK\ (aluminum)$

$k_{wires} = 400\ W/mK\ (copper)$

$k_{res} = 5\ W/mK\ (carbon\ paste)$

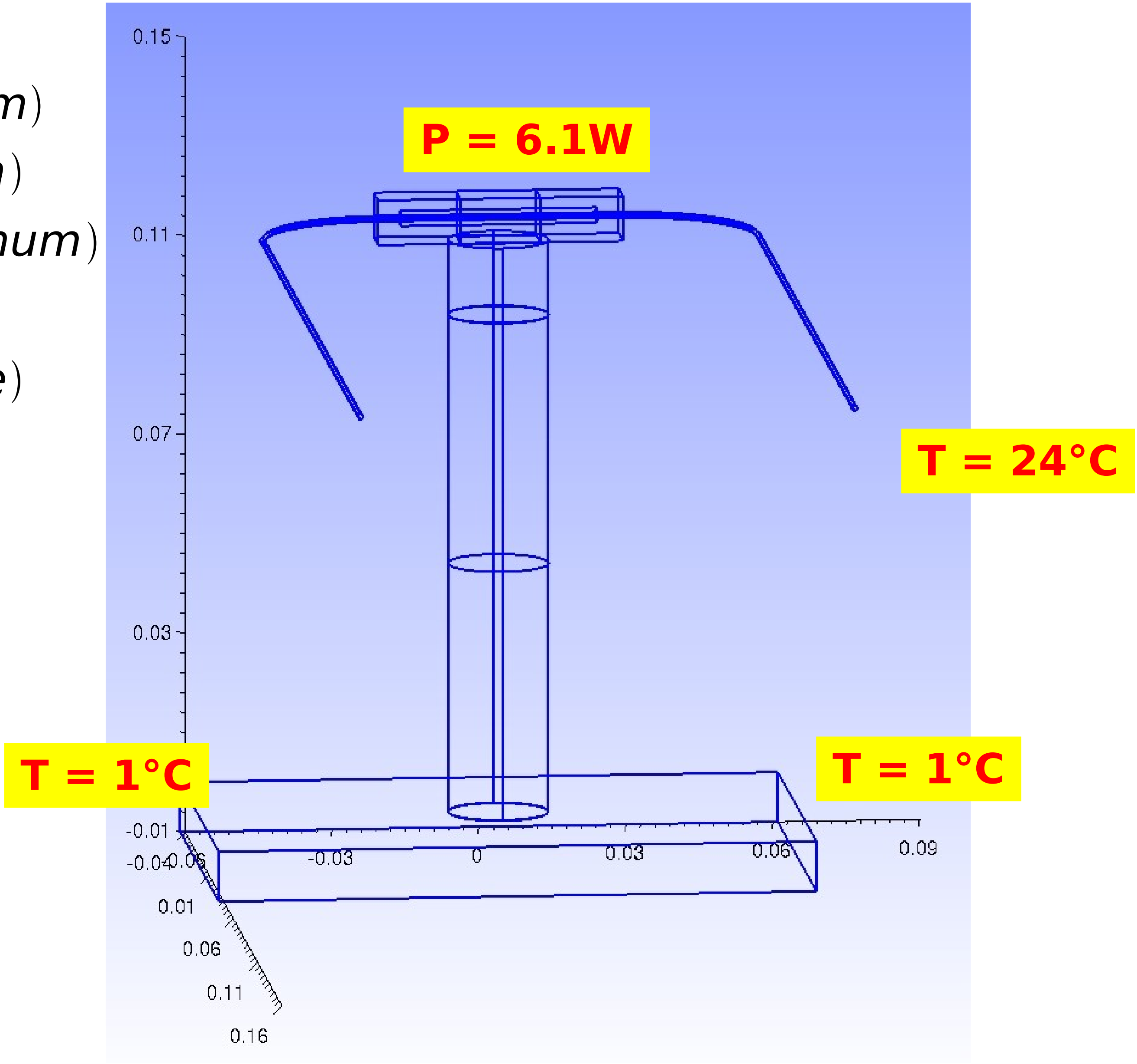
$k_{res\ env} = 2\ W/mK\ (ceramic)$

$h_{air} = 15\ W/m^2 K$

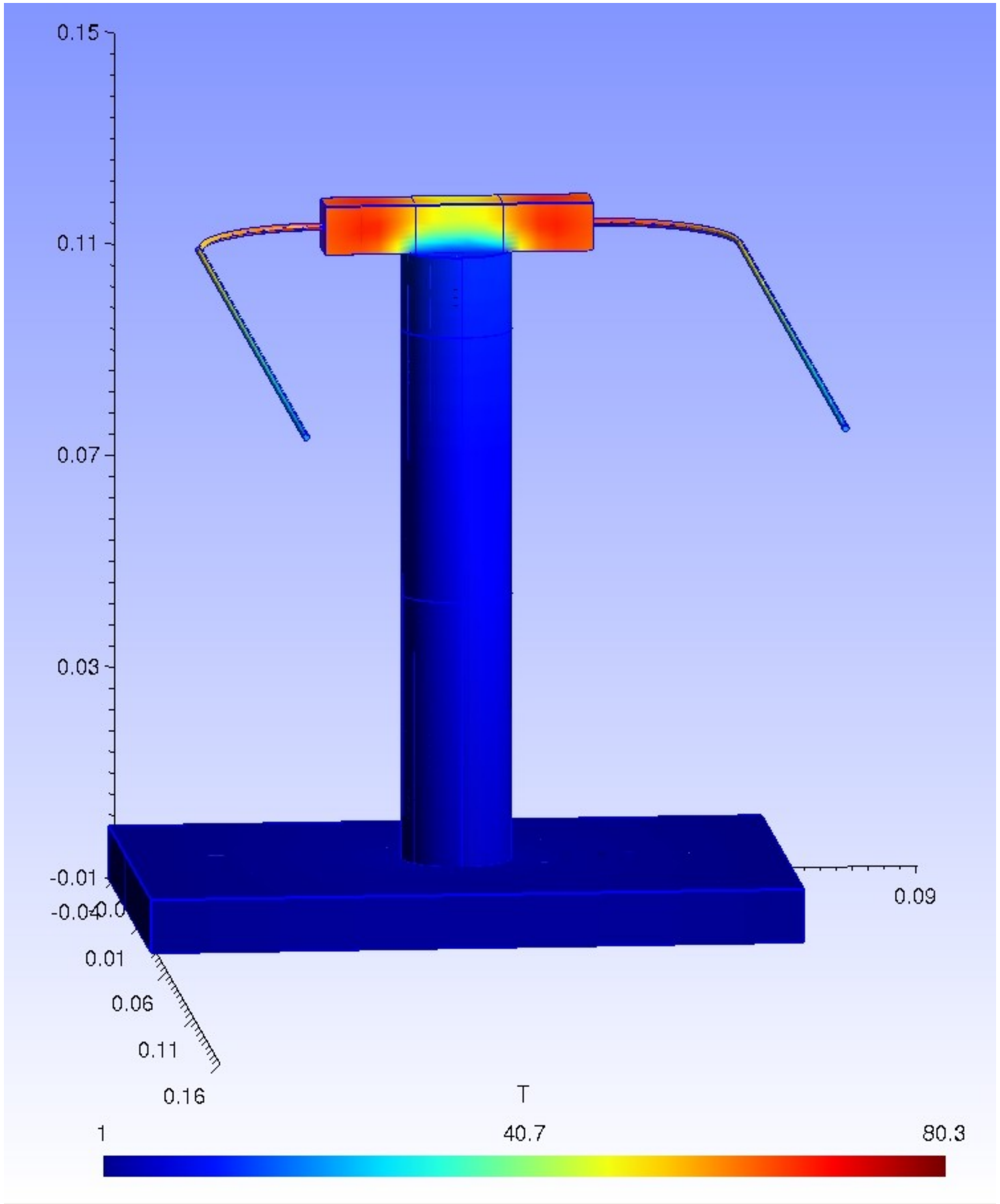
$T_{air} = 15\ K$

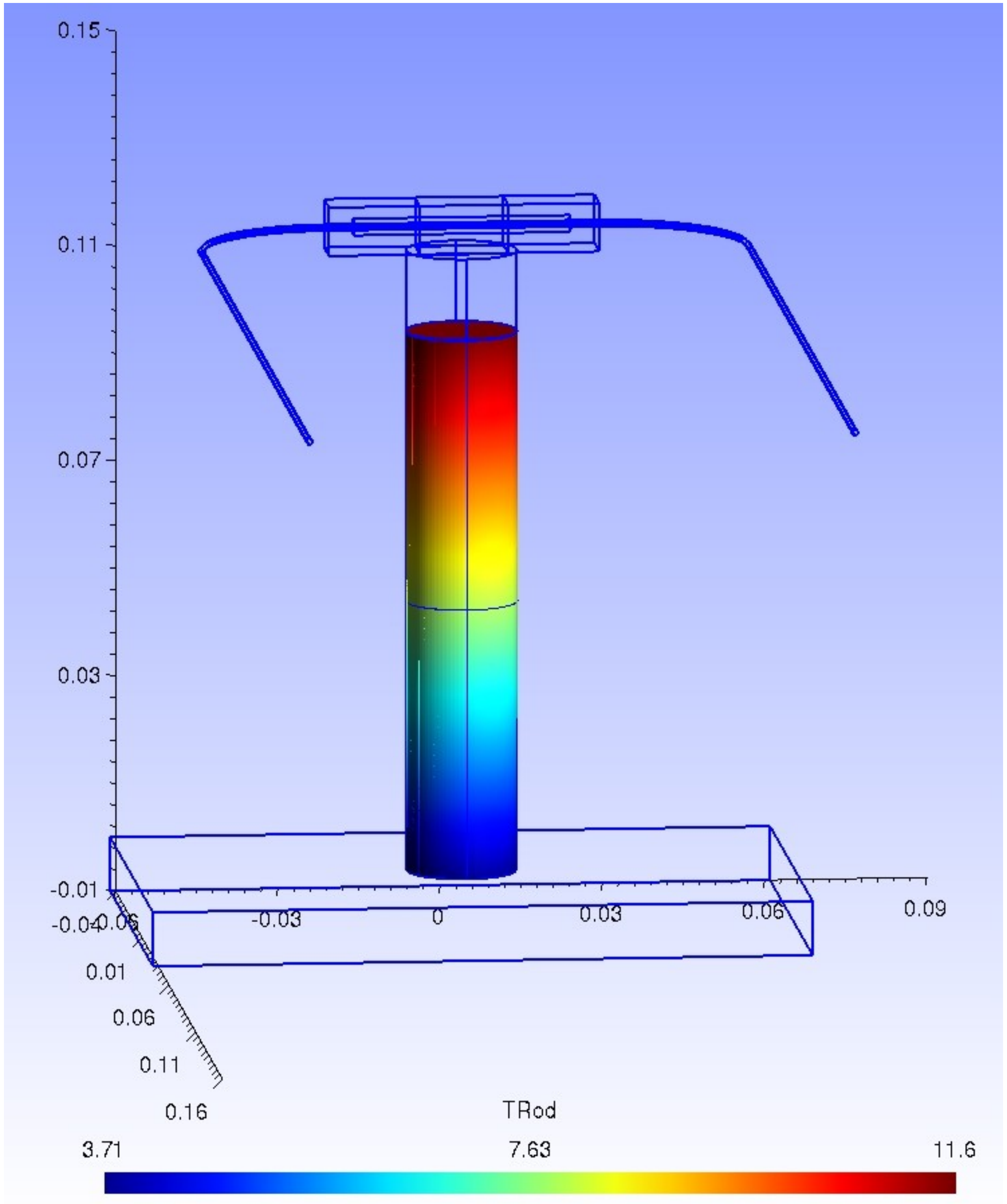
$\epsilon_{metals} = 0.2$

$\epsilon_{ceramics} = 0.8$



Simulations results





Qualitative agreement with data

Conclusions and Outlooks

Achivements:

- Temperature sensors have been correctly calibrated.
- The setup for measuring the thermal conductivity coefficient has been tested.
- A quite satisfactory simulation has been developed.

Things to be done:

- Fine tuning of the simulation parameters.
- Improvement of the setup (fixing air leak,...)

Appendix

Luminosity:

$$\frac{dN}{dt} = \sigma L$$

where:

- N is the number of interactions;
- L is the instantaneous luminosity;
- σ is the total cross-section of the process.

In a storage ring collider:

$$L = f\,k\,\frac{N_1 N_2}{A}$$

where:

- f is the revolution frequency;
- k is the number of bunches in one beam in the storage ring;
- N_i is the number of particles in each bunch;
- A is the cross section of the beam.