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Test of the new GR9 graphite calorimeter Comparison with GR8

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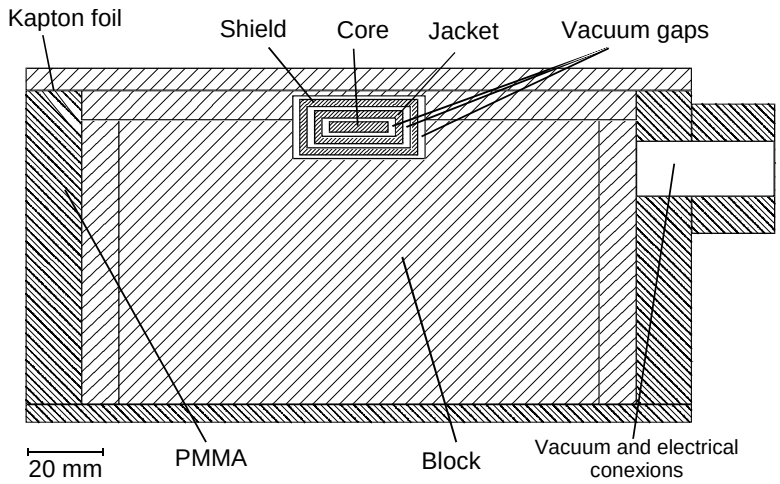
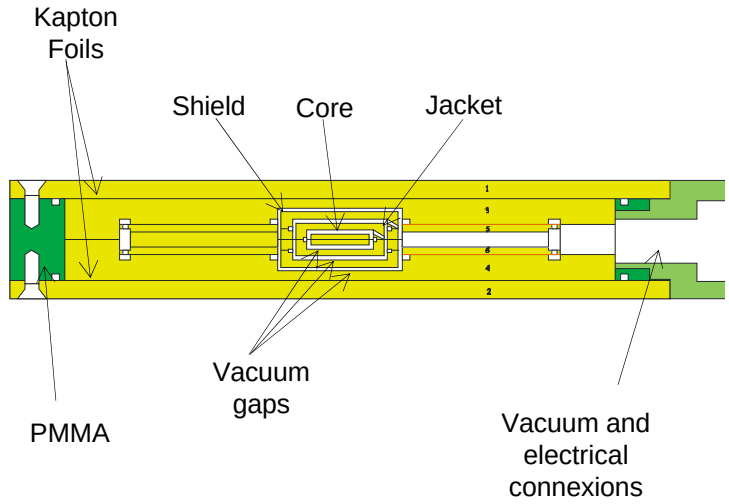
- GR8 graphite calorimeter
  - ✓ built in 1984
  - ✓ still perfectly working
  - ✓ two operating modes
    - Quasi adiabatic mode (with thermal feedback : 1976)
    - Constant-temperature (2003)
- GR9 graphite calorimeter
  - ✓ ensure continuity
  - ✓ built in 2006
  - ✓ tests 1st term 2007

GR8 and GR9 graphite calorimeter designs

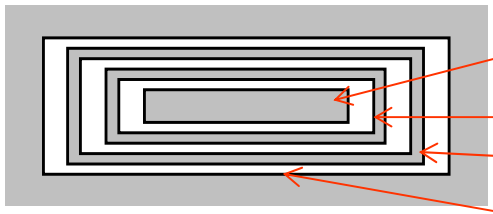
GR8



GR9

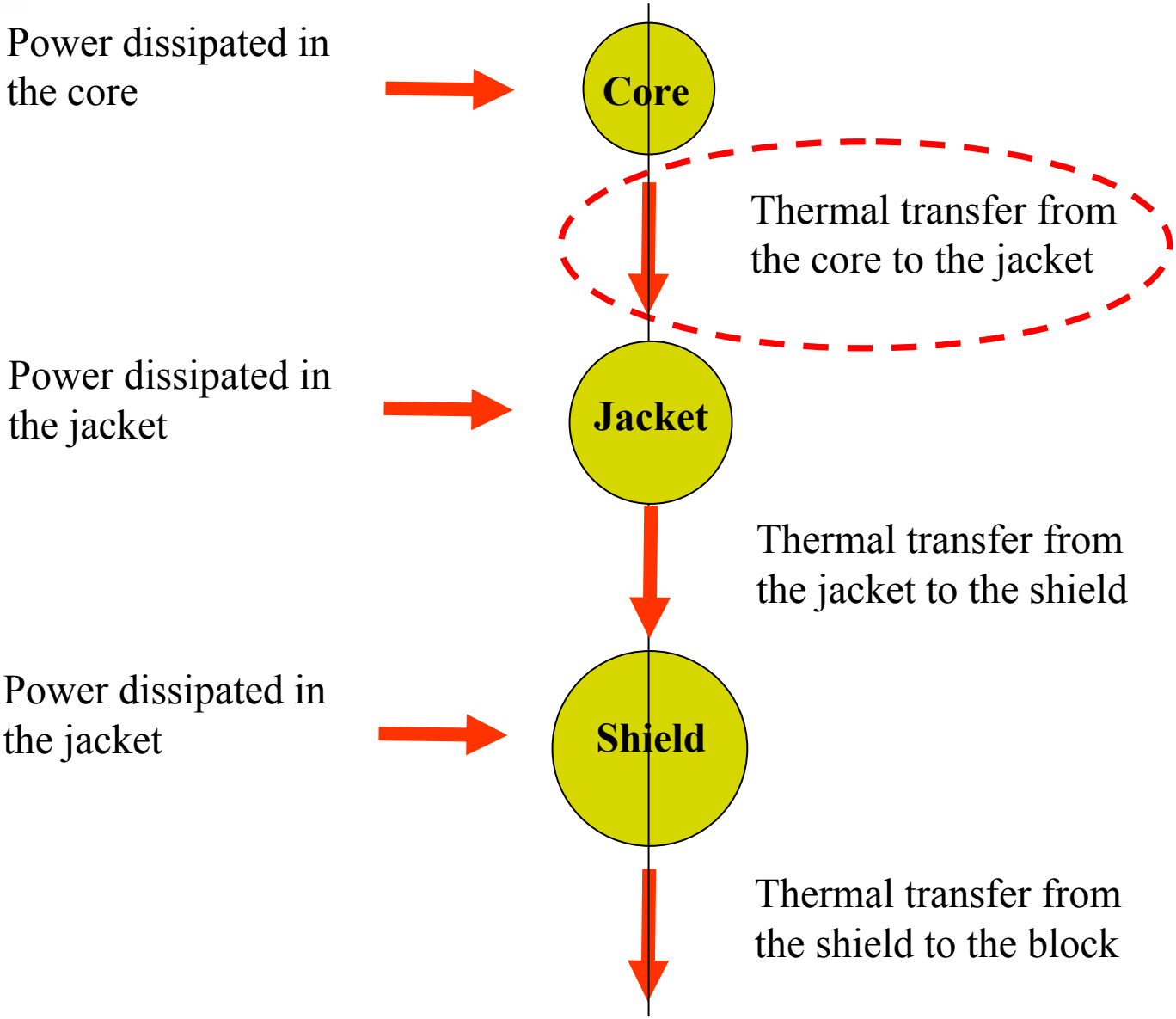


Calorimeter central part

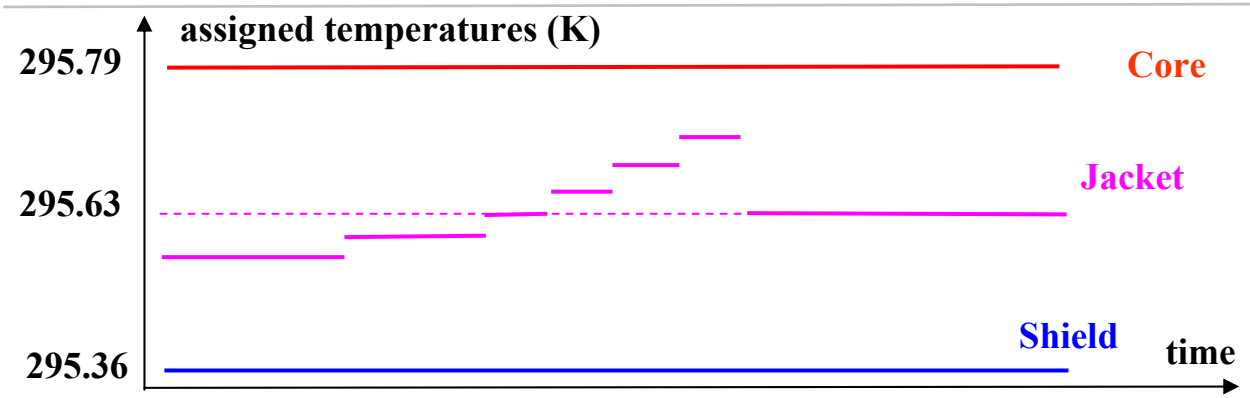


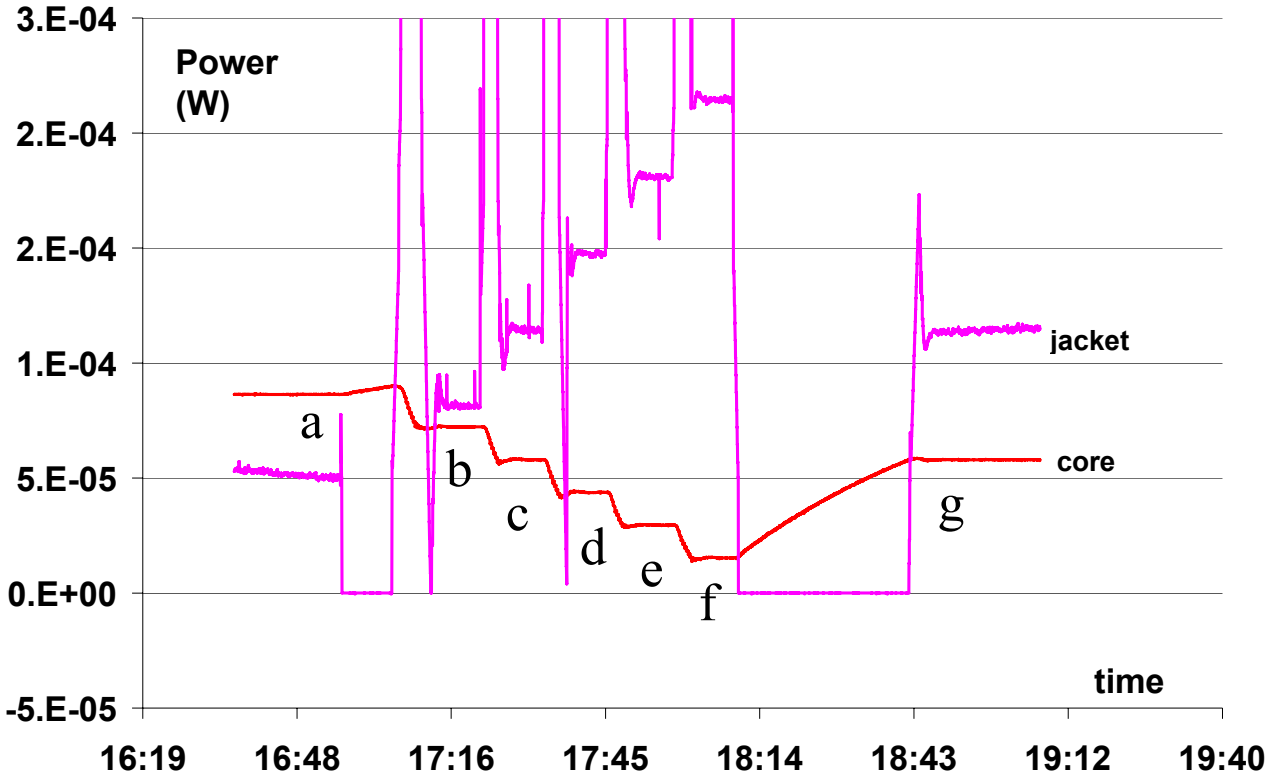
Core	**3**	**mm**	**thick**
	16	**mm**	**diameter**
Shield	**2**	**mm**	**thick**
Jacket	**2**	**mm**	**thick**
Axial vacuum gaps	**1**	**mm**	

Thermal transfers

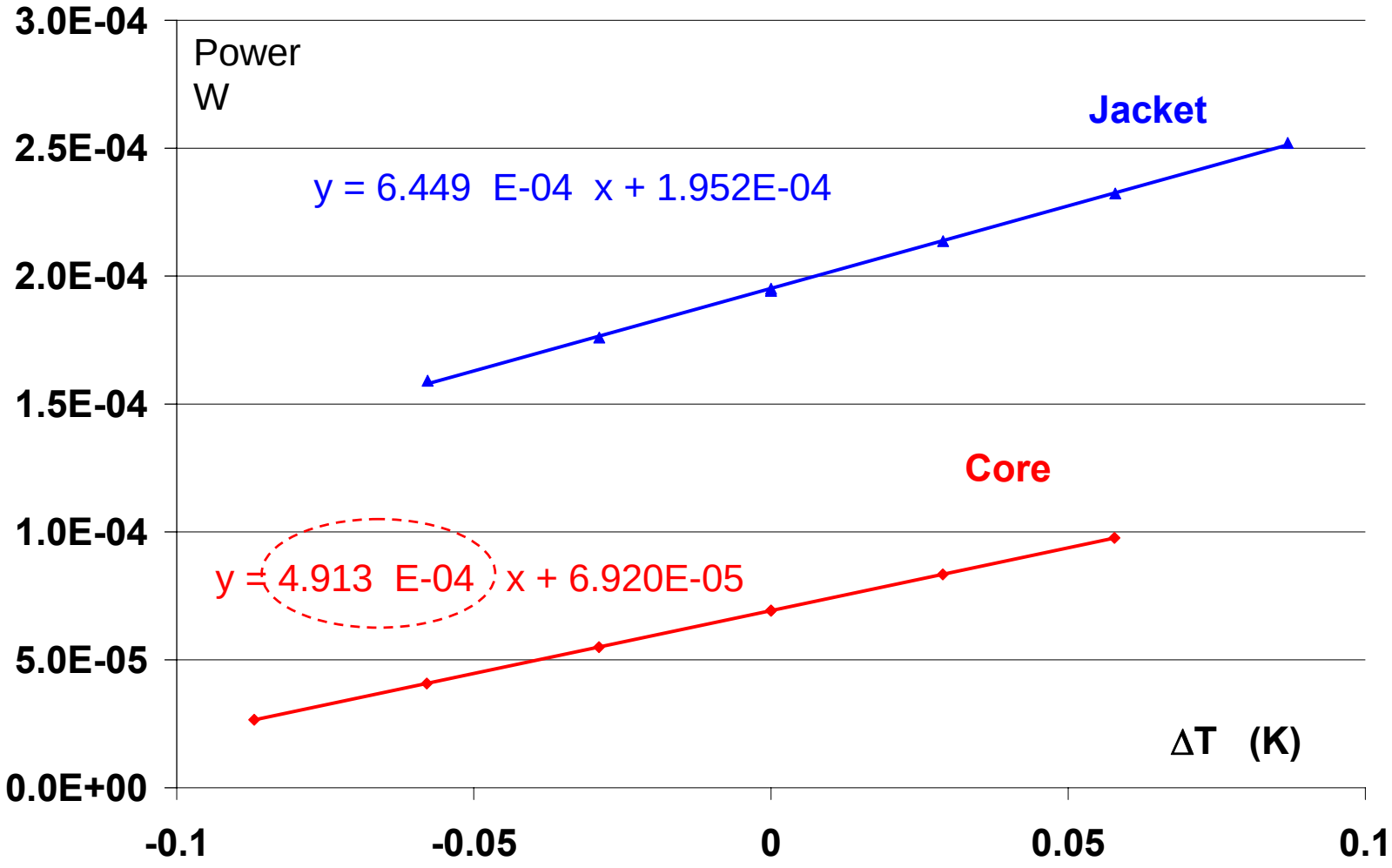


Measurement of heat transfers





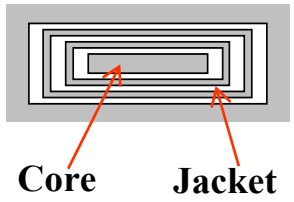
Thermal leakages



Two operating modes

Quasi-adiabatic Mode

Tj ≈ Tc
Tj assigned to Tc



Constant-temperature mode

Tj = Cst
Tc = Cst

$\Delta T'$: variation of the temperature of the thermistor in the core during irradiation

$Po - Pi$: difference of electrical power in the core to maintain its assigned temperature between beam off and beam on

$$C_p' = \frac{Q_{el}}{m \cdot \Delta T_{el}'}$$: electrical calibration factor

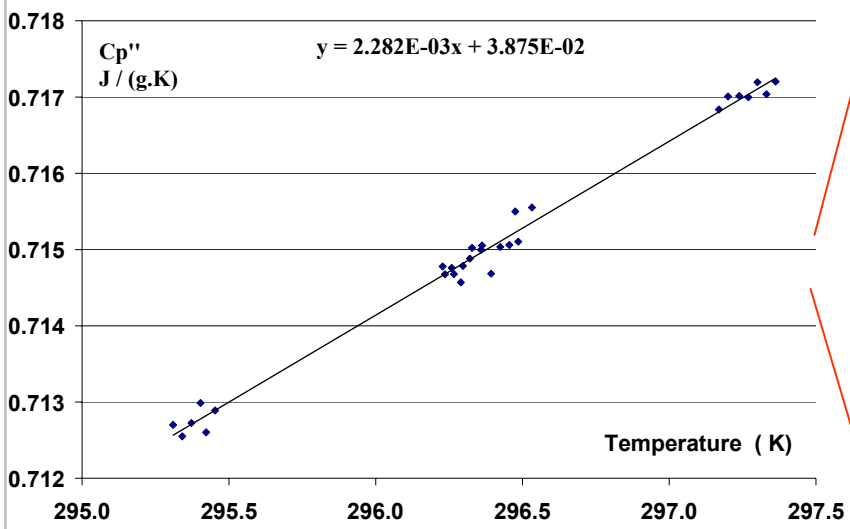
Q_{el} : heat quantity dissipated in the core by Joule effect through 4 heating thermistors

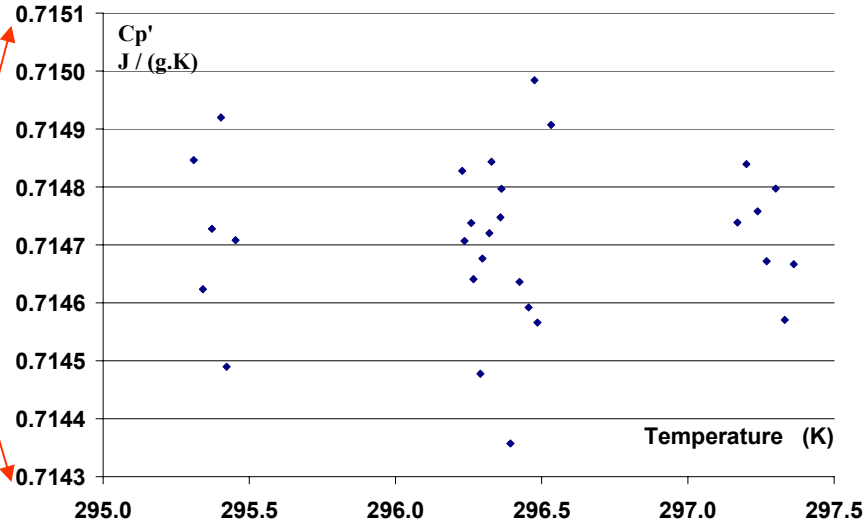
$$\overline{D} = C_p' \cdot \Delta T' \cdot \prod_i k_i$$

$$\dot{\overline{D}} = \frac{(P_o - P_i)}{m} \cdot \prod_i k_i$$

GR9 Quasi-adiabatic mode Electrical calibration

$$Cp'' = \frac{Q_{el}}{m \cdot \Delta T'_{el}} \qquad Cp' = Cp'' \cdot f(T)$$

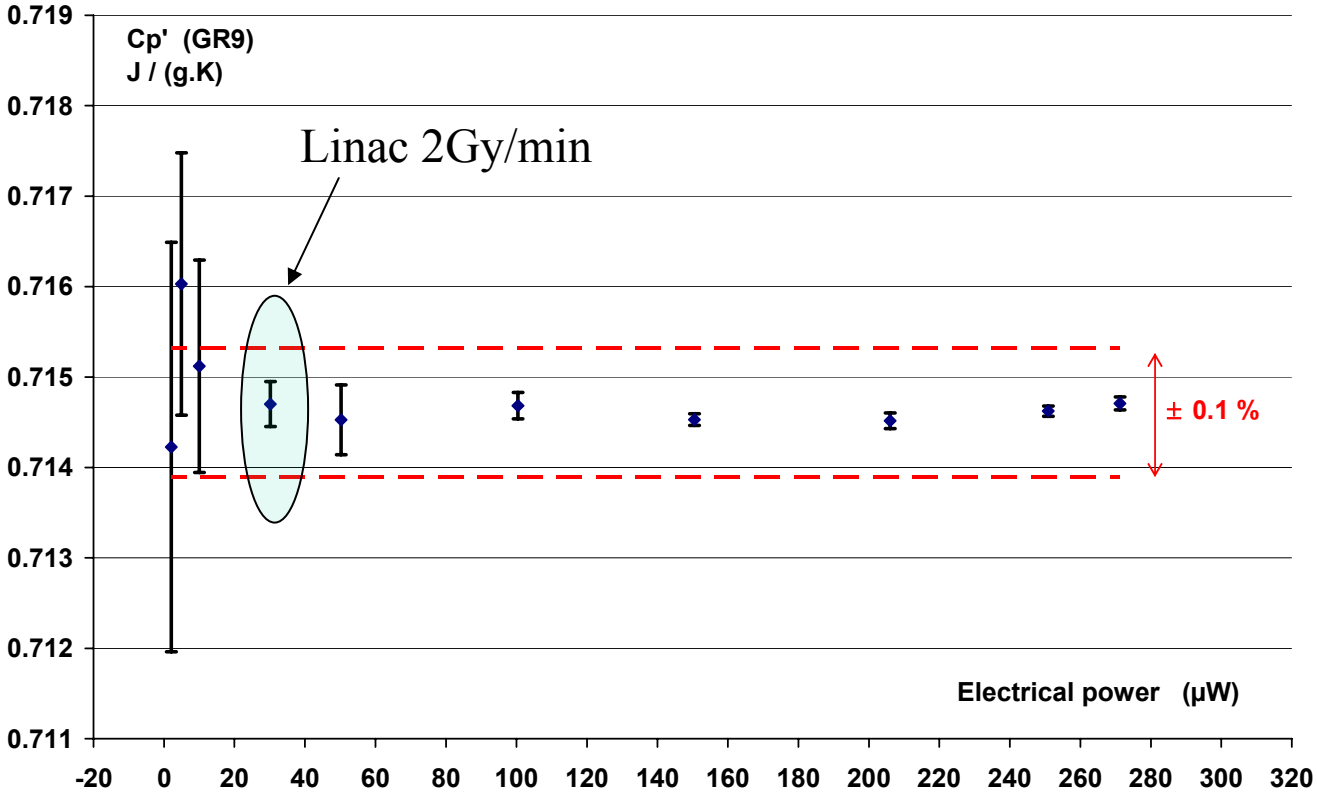




3 different temperatures of the shield

- *Cp* of graphite

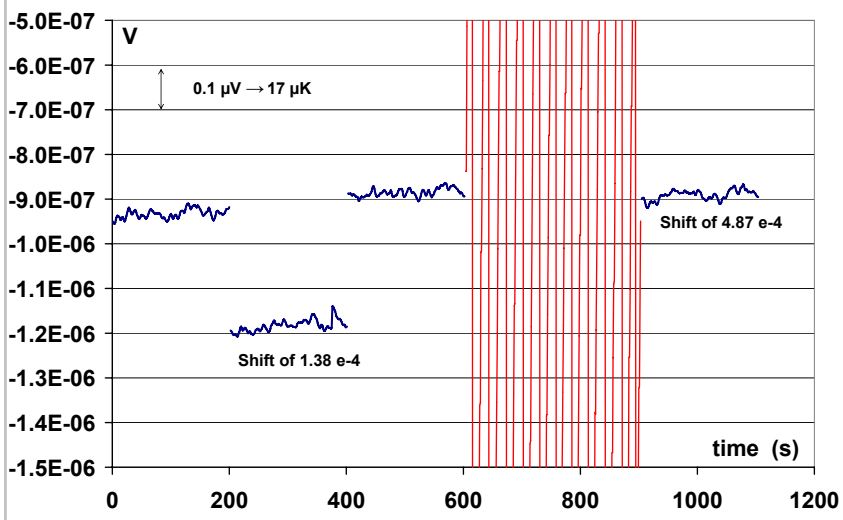
Quasi-adiabatic mode : Electrical calibration against power



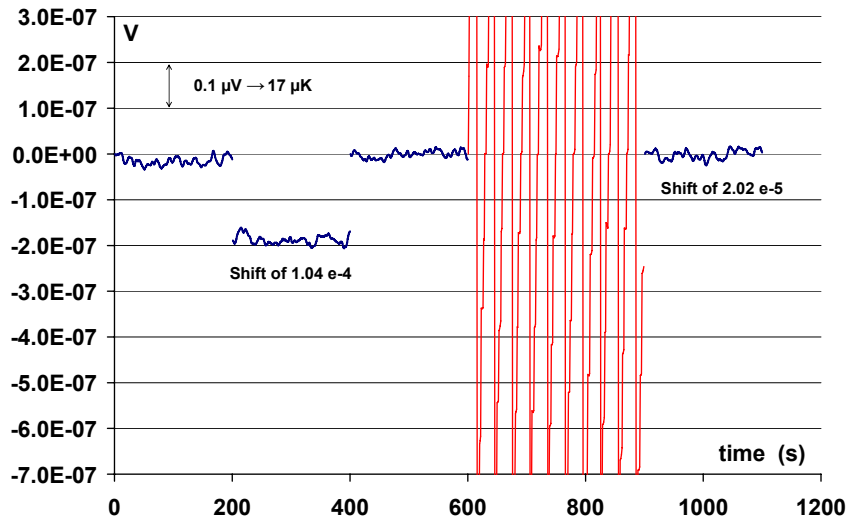
Lower value 2µW (0.12 Gy/min) > sd =0.2%
Higher value 270µW (16 Gy/min) > sd = 0.014%

Quasi-adiabatic mode : GR8 and GR9

GR8

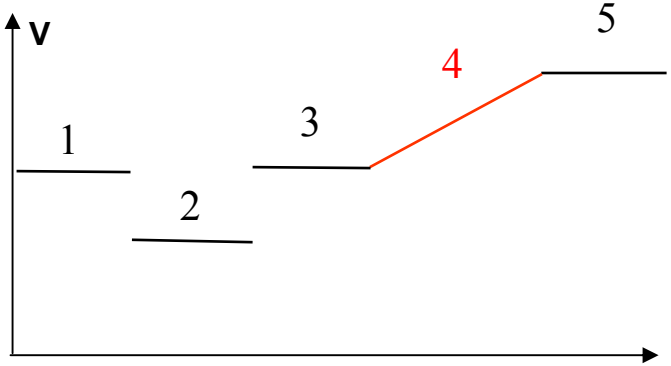


GR9



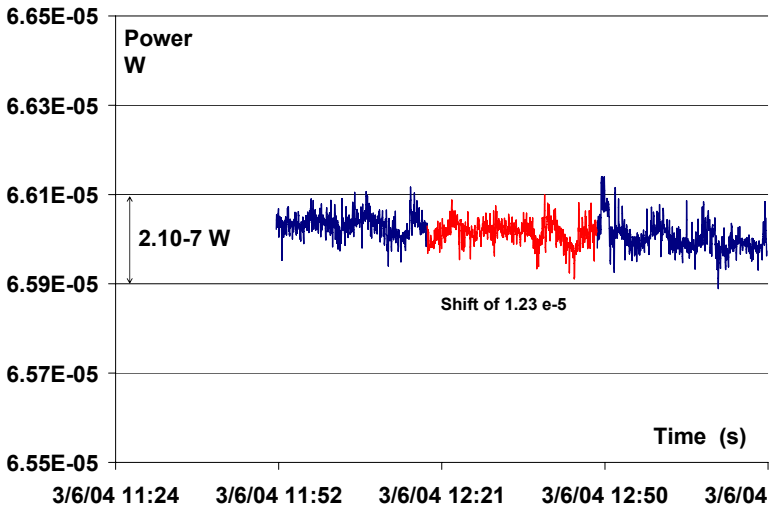
Beam off

Irradiation

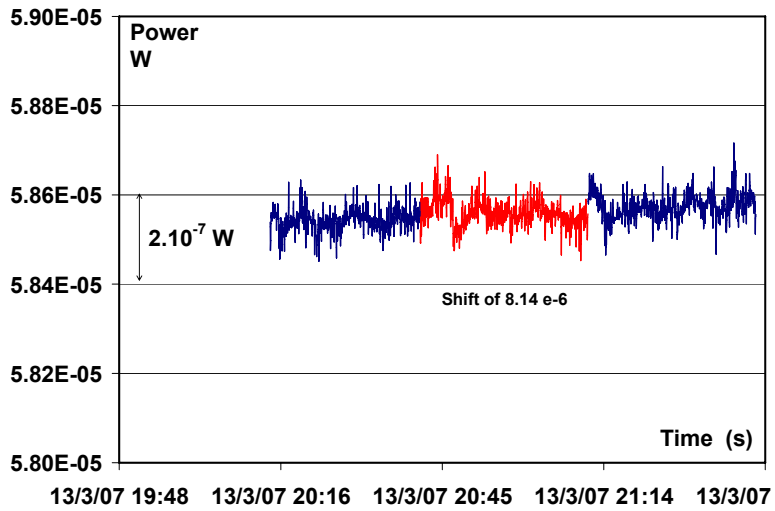


GR8 and GR9 Constant-temperature mode

GR8

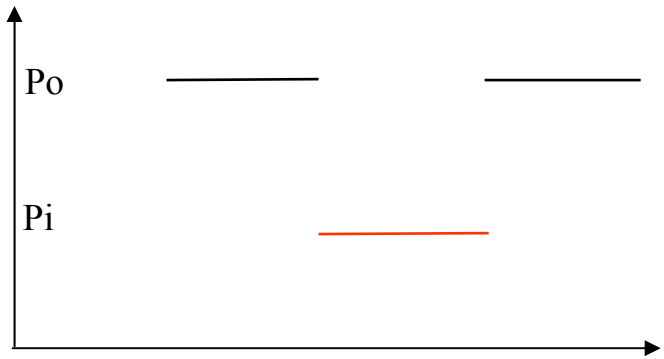


GR9



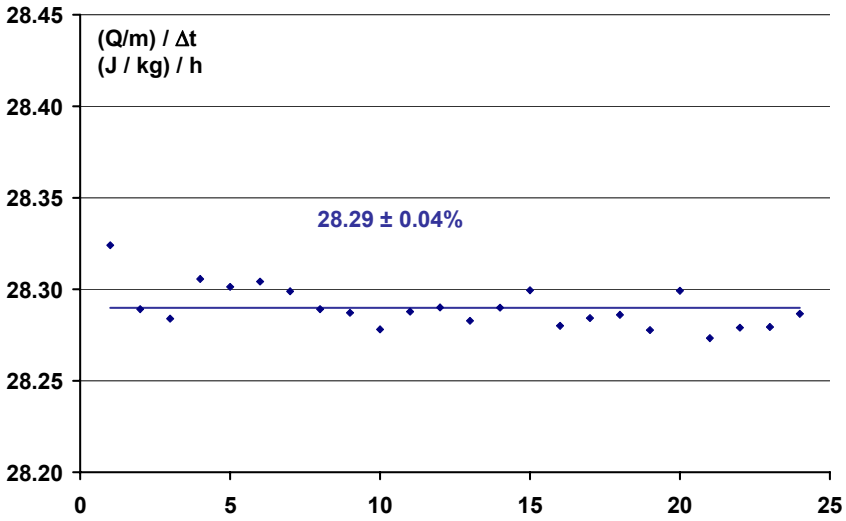
Beam off

Irradiation



GR9 calorimeter : First measurements

Constant-temperature mode

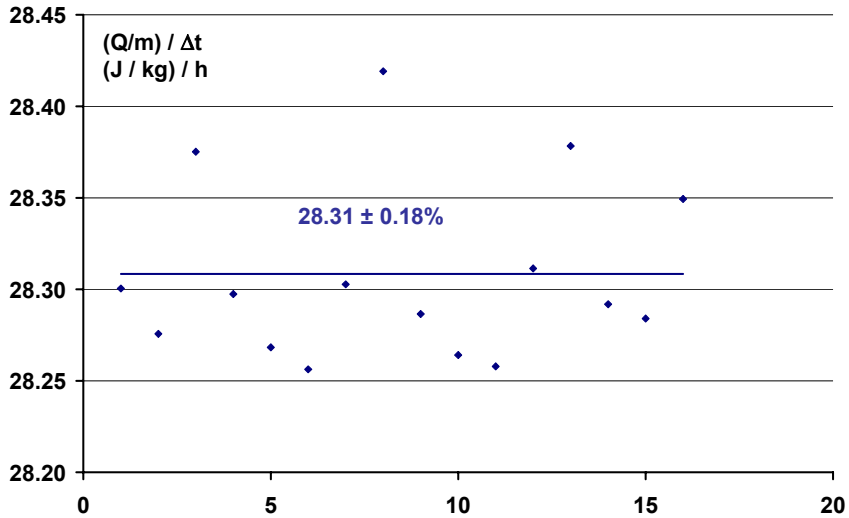


GR9 evacuated for the first time
5 days pumping before the first measurement

No variation of the response up to 340 Gy
=> no heat defect

Experimental standard deviation : 0.04 %
None of the measurements have been discarded

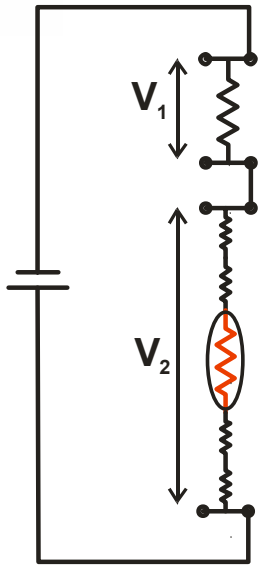
Quasi-adiabatic mode



Quasi-adiabatic mode presents no significant difference with Constant temperature mode

Experimental standard deviation : 0.18%

GR9 : Determination of the thermistor lead wires R= ρ·l/A



← R_{St} = 7999.78 Ω

← R_{Cu} = 8.44 Ω
← R_{Pt} = 0.253 Ω

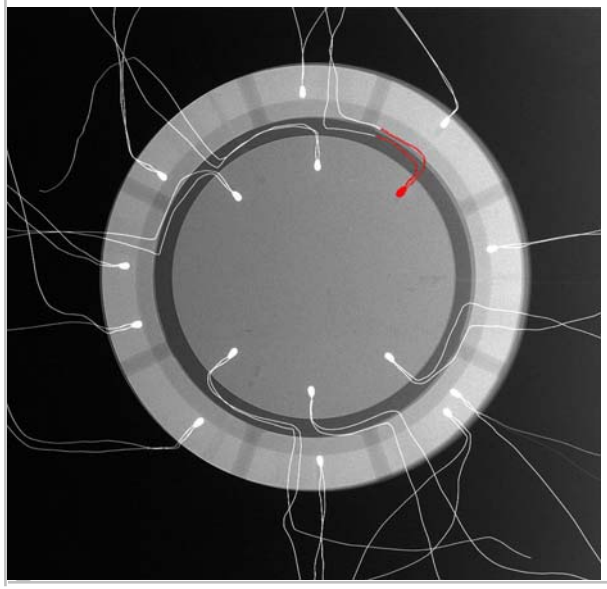
← Thermistors

← R_{Pt} = 0.253 Ω
← R_{Cu} = 8.44 Ω

$I = V_1 / R_{St}$

$P = V_2 \cdot I - 2 \cdot R_{lw} \cdot I^2$

$R_{lw} = 2 \cdot (R_{Pt} + R_{Cu})$



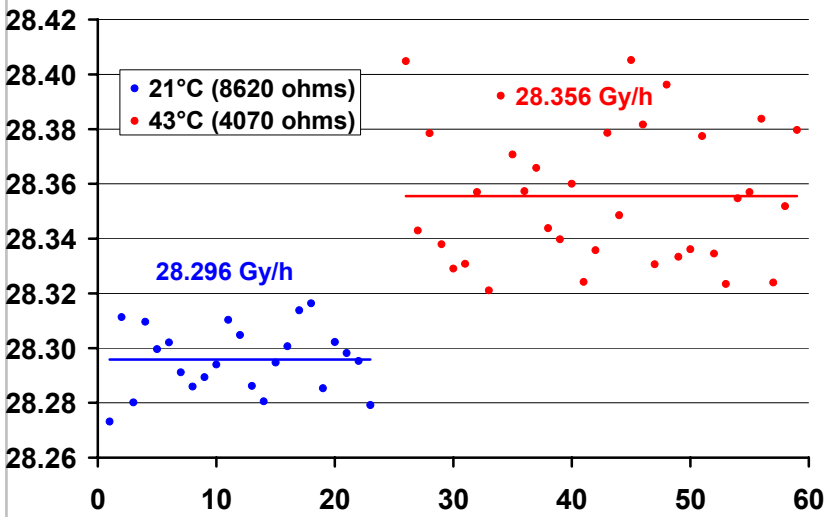
The red part of the lead wires are involved in the energy dissipation in the core.

R_{lw} is the remaining part

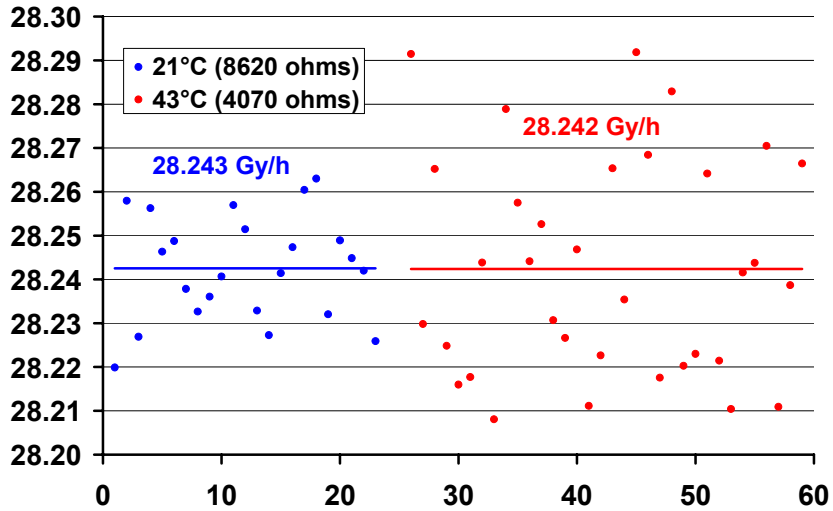
Application of : $R = \rho \cdot l / A$
Measurement of :
ρ resistivity
A cross section
l length (radiography)

R_{lw} = 17.38 Ω

GR9 : Measurement of the thermistor lead wires
Constant-temperature mode at 21°C and 43°C



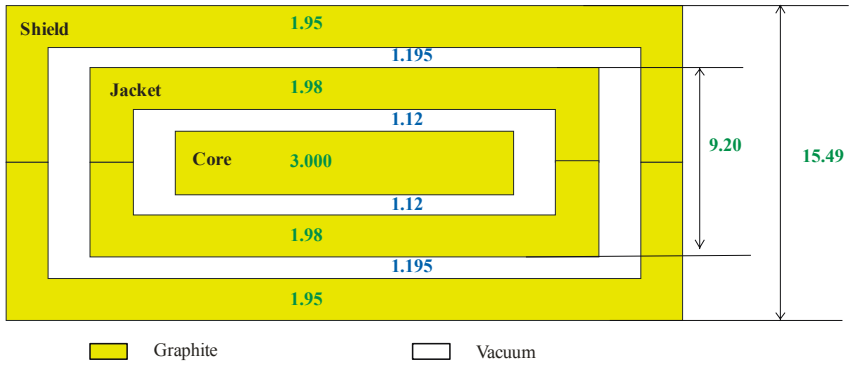
Absorbed dose calculated with R_{lw} = 0 Ω

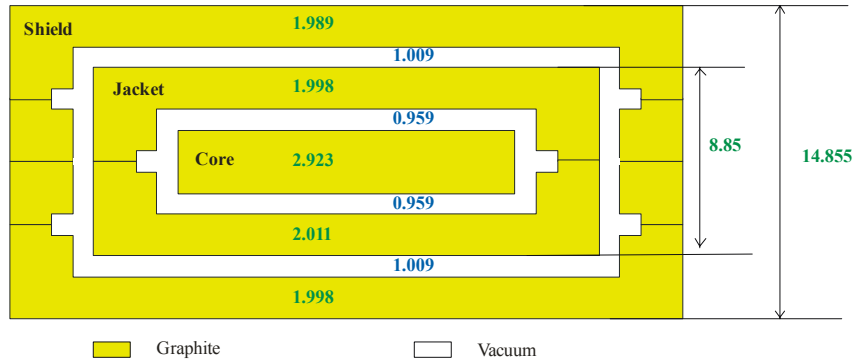


Absorbed dose calculated with R_{lw} = 16.24 Ω

Comparison of GR8 and GR9 calorimeters

- The very first comparison between GR8 and GR9 calorimeters in ^{60}Co beam shows a slight difference (0.3%)
  - ✓ **Vacuum correction has to be carefully calculated**



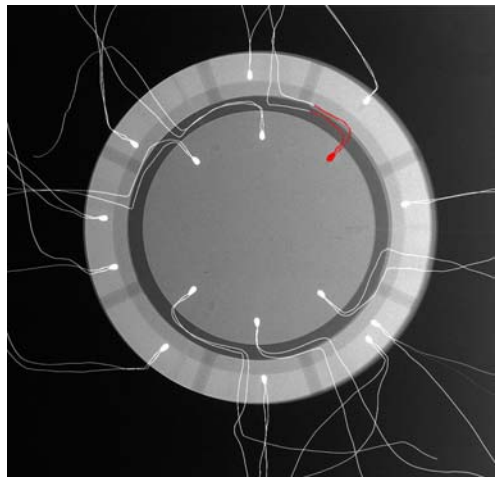


Comparison of GR8 and GR9 calorimeters

- The very first comparison between GR8 and GR9 calorimeters shows a slight difference (0.3%)
  - ✓ Vacuum correction has to be carefully calculated
  - ✓ **The mass of the core has been more accurately measured in GR9 than in GR8.**

Determination of the mass of the core

Core : element masses and fractions		
	mass / g	fraction / %
graphite	1.05743	99.41
thermistors material	0.00040	0.04
platinum wires	0.00090	0.08
glass	0.00058	0.05
glue for thermistors	0.00315	0.30
glue for silk threads	0.00089	0.08
silk threads	0.00039	0.04
total core mass	1.06374	
uncertainty (1σ)	0.00021	



Some thermistors have been sacrificed to determine their characteristics.

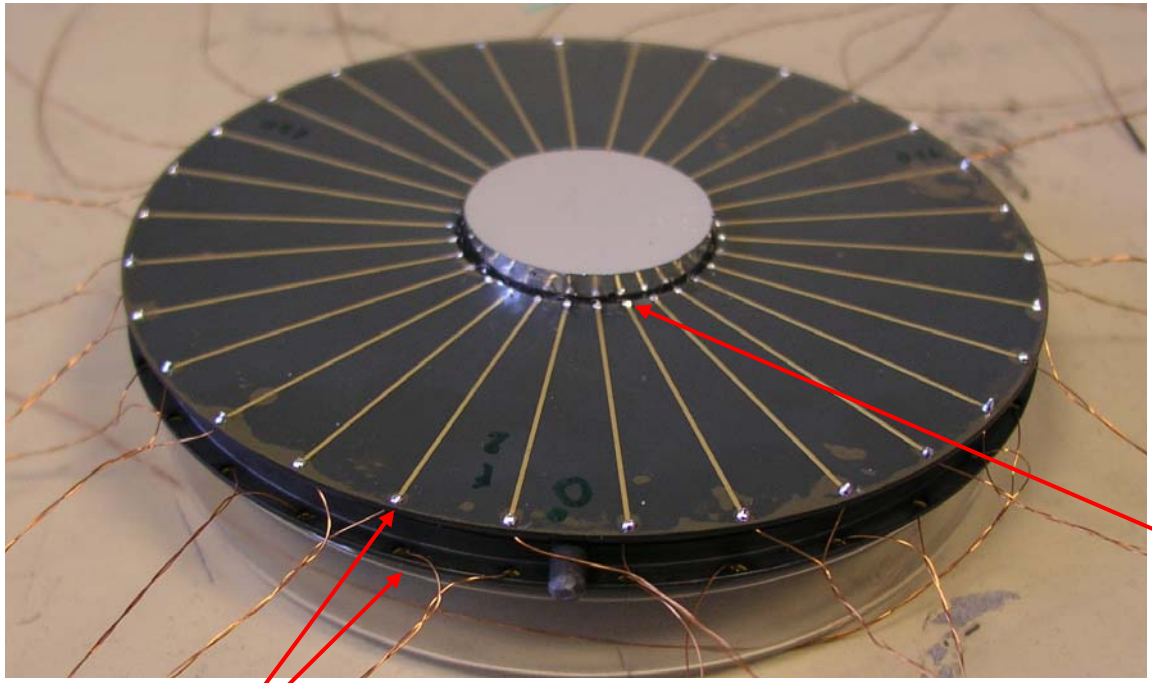
The length of the platinum wires to be taken into account in the core mass have been determined (red part) from the radiography.

The silk threads and the glue involved in the core mass has been carefully determined (a trial core was built for this purpose)

Comparison of GR8 and GR9 calorimeters

- The very first comparison between GR8 and GR9 calorimeters shows a slight difference (0.3%)
  - ✓ Vacuum correction has to be carefully calculated
  - ✓ The mass of the core has been more accurately measured in GR9 than in GR8.
  - ✓ **Impurities in the central part are very similar but soldering material has been added outside the shield**

GR9 : the flexible printed circuits and soldering



29 + 29
Soldering

two flexible printed circuits
symmetrical about the mid plane

Conclusions

- GR9 graphite calorimeter has been successfully tested
  - ✓ Good thermal insulation
  - ✓ Quasi-adiabatic mode and Constant-temperature mode operational
  - ✓ experimental standard deviation $< 0.04\%$ in Constant-temperature mode
- First comparison between GR8 and GR9 calorimeters in a ^{60}Co beam has shown a slight difference $< 0.3\%$
  - ✓ Need to be confirmed in different beams
  - ✓ Irradiation with face 2 towards the source
- Needs determination of :
  - ✓ Vacuum gaps correction
    - Monte Carlo simulation
    - Measurement
  - ✓ Impurities correction factor in the core