Thermal performance of carbon foams used as heat sink for the pixel MVD-Panda.

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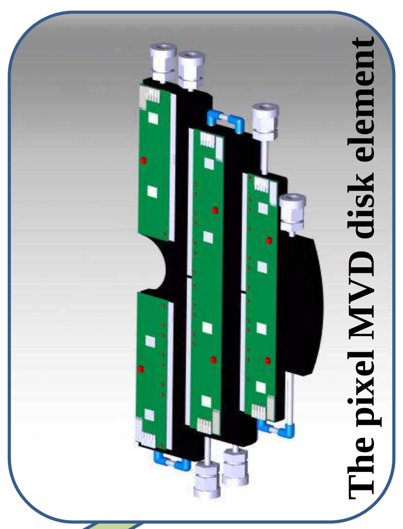
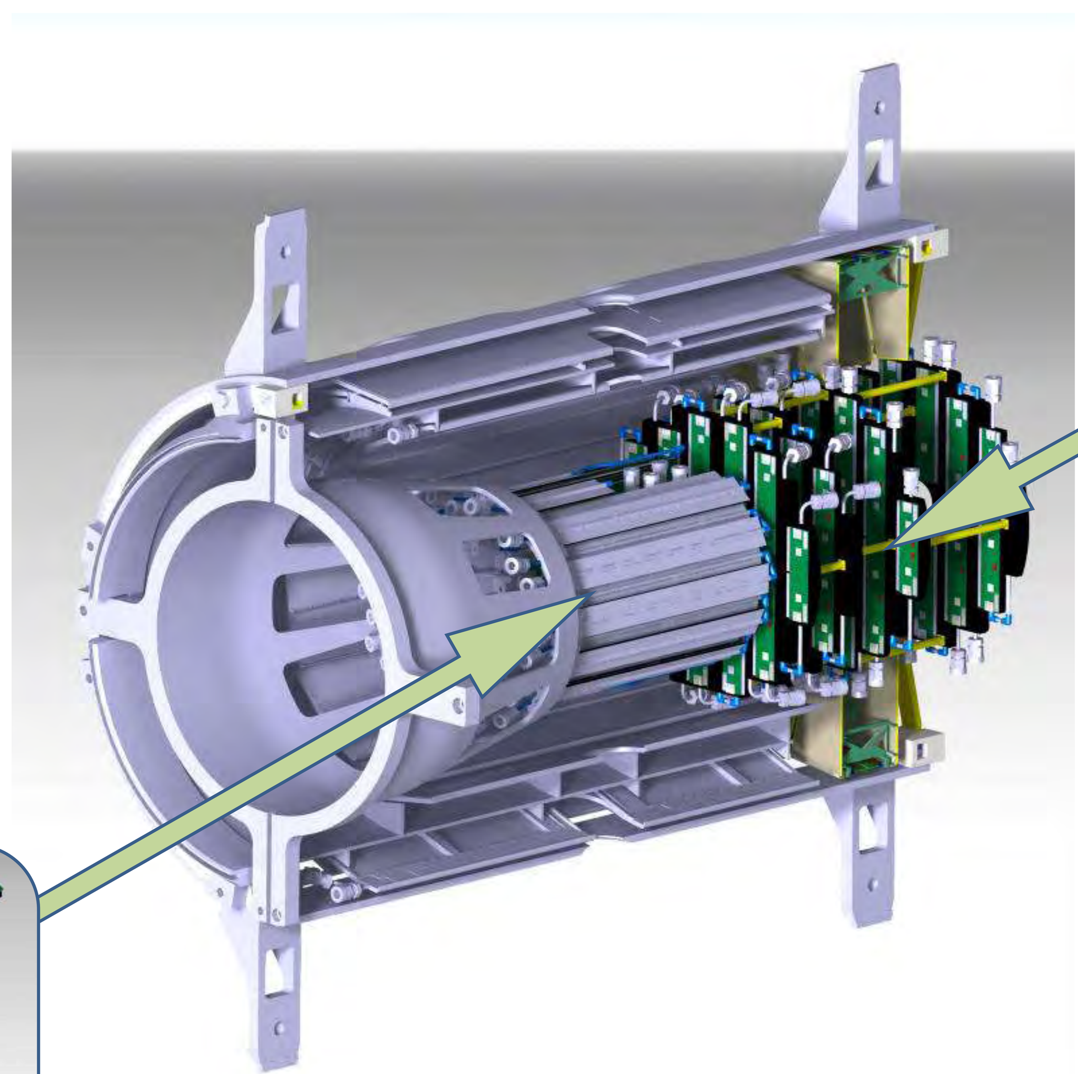
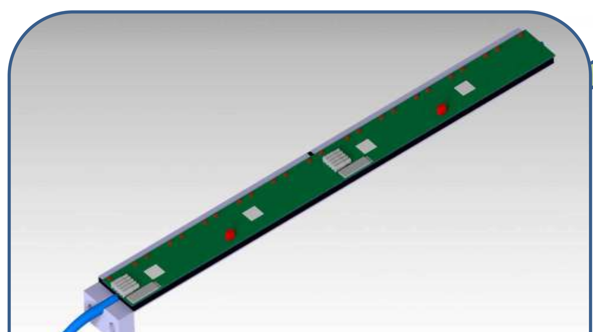
The *Micro Vertex Detector* (the MVD) for the *Panda* experiment at GSI-DARMSTADT is optimized for the detection of the secondary vertices and for maximum acceptance close to the interaction point. The experimental setup requires sophisticated solutions for the detector integration in order to maintain a stringent material budget. The thermal power produced by the "on board" read-out electronics is fast removed using carbon foam as heat sink. Two types of carbon foam are under evaluation. Both, the mechanical and thermal properties behaviour under radiating field are studied. Results from finite element thermal analyses and test bench are also presented.



The pixel MVD disk element



The MVD: Foreground is the barrel sector, in the background the forward disks sector is shown.

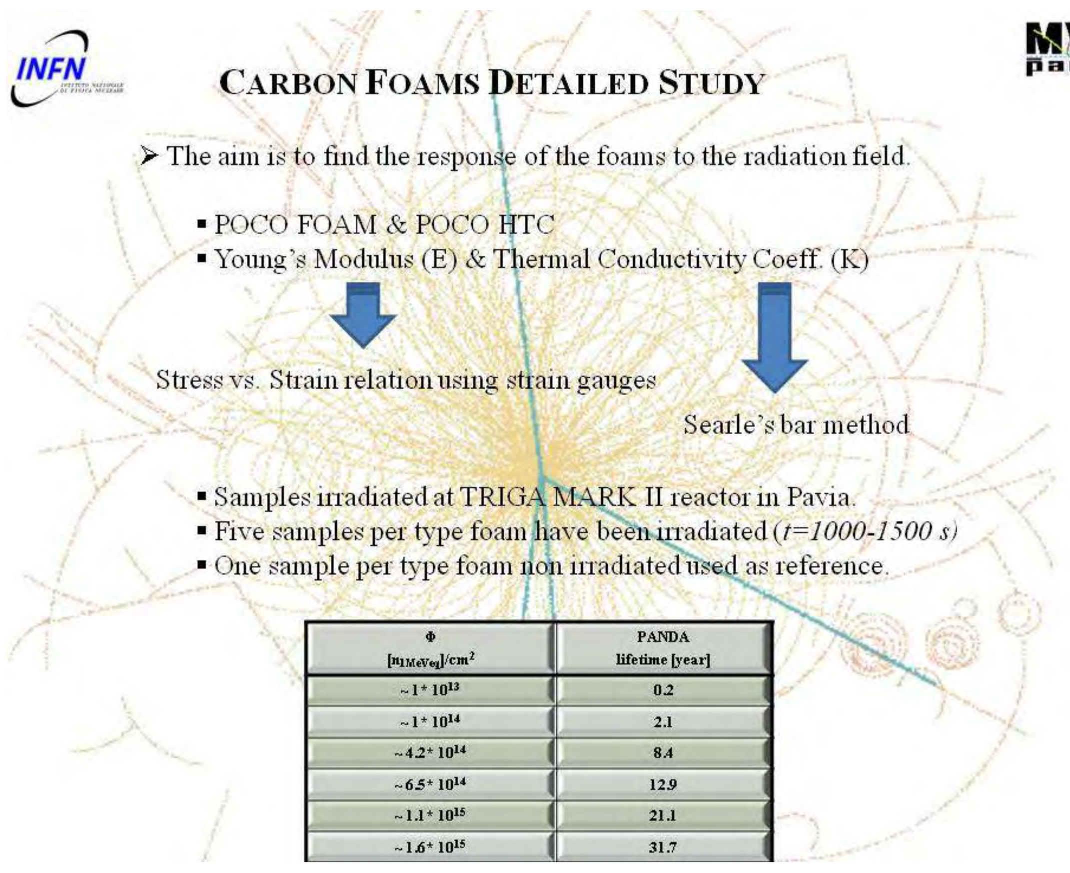


The pixel MVD barrel element

The MVD consists of four cylindrical layers of silicon detectors located in the backward region (called barrel), and six planar layers located in the forward region (called disks). Hybrid silicon pixel detectors compose the two innermost layers of the barrel, while the two outmost layers are equipped with double side silicon micro strips. The barrel layers are arranged around the beam pipe axis. Concerning the forward part, the four disks nearest to the interaction point are equipped with pixel detectors, while the last two ones use both pixel detectors, in the area close to the beam pipe axis, and strip detectors in the external area. The pixel part and the strip part of the disks are mechanically independent. The planar faces of the disks are perpendicular to the beam pipe axis. The MVD occupies a 460 mm long cylindrical volume with external diameter of 300 mm, in which 810 pixel detectors, and relative chips, dissipate 1W/cm², with a total thermal power of about 1.4 kW.

For the cooling system design a material with low density, high thermal conductivity, low thermal expansion coefficient, machinable, gluable, stable at different temperatures and radiation resistant has been searched. The material which complied to all these requirements was the carbon foam: the open pore structure in graphite creates a material with high thermal properties at low density.

POCO HTC		
DENSITY	0.9 g/cm³	
THERMAL CONDUCTIVITY	IN PLANE 245 W/m·K	OUT OF PLANE 70 W/m·K
POCO FOAM		
DENSITY	0.6 g/cm³	
THERMAL CONDUCTIVITY	IN PLANE 135 W/m·K	OUT OF PLANE 45 W/m·K



CARBON FOAMS DETAILED STUDY

- The aim is to find the response of the foams to the radiation field.
  - POCO FOAM & POCO HTC
  - Young's Modulus (E) & Thermal Conductivity Coeff. (K)

Stress vs. Strain relation using strain gauges

Searle's bar method

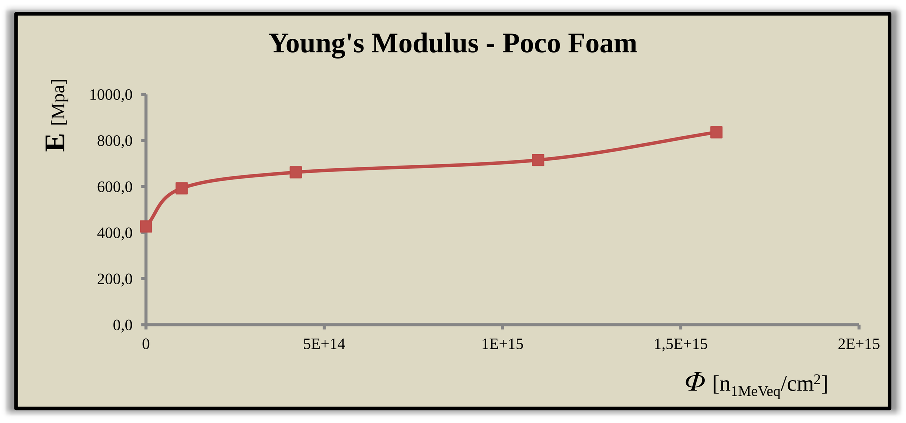
- Samples irradiated at TRIGA MARK II reactor in Pavia.
- Five samples per type foam have been irradiated (*t=1000-1500 s*)
- One sample per type foam non irradiated used as reference.

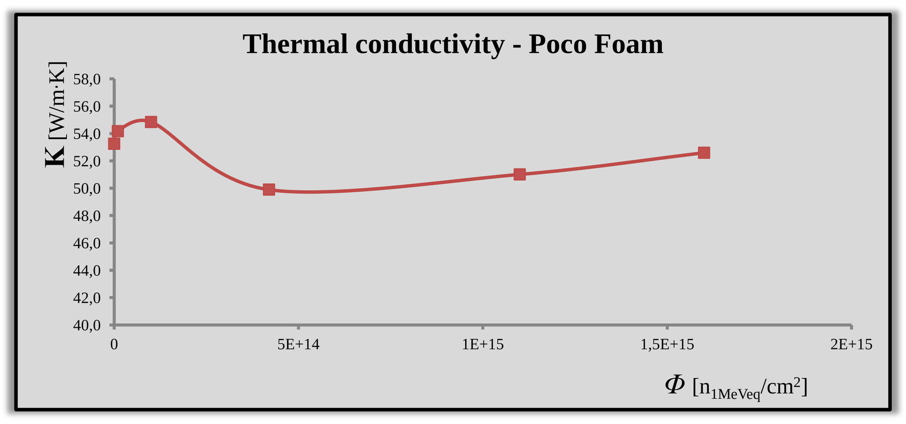
Φ [n_{1MeVeq}]/cm²	PANDA lifetime [year]
~1* 10^{13}	0.2
~1* 10^{14}	2.1
~4.2* 10^{14}	8.4
~6.5* 10^{14}	12.9
~1.1* 10^{15}	21.1
~1.6* 10^{15}	31.7

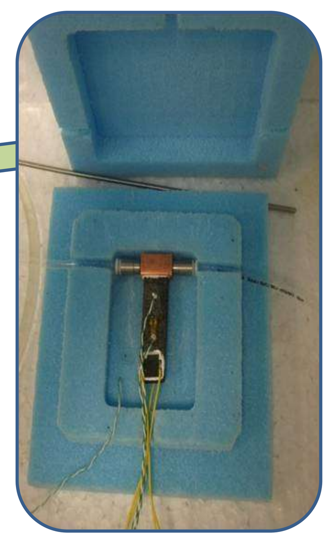
With the aim of measuring the properties of the material at different radiation levels, specimens of the two types of carbon foam, *POCO FOAM* and *POCO HTC*, were immersed in a radiation field at the TRIGA MARK II reactor in Pavia. Five samples per foam type are immersed in the radiating field at different reactor power for a time of 1000-1500s, while one sample per type was non irradiated and used as reference.

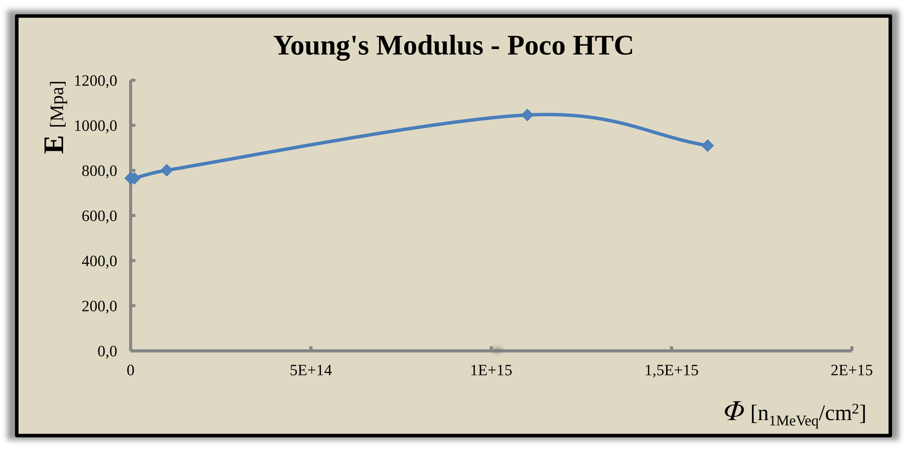
The tests for the Young's modulus estimation consisted on the irradiated carbon foam specimens tensioned to a set of loads. For the evaluation of the Young's modulus, strain gauges have been glued on the specimens. Test results show the variation of the elastic modulus at different radiation loads.

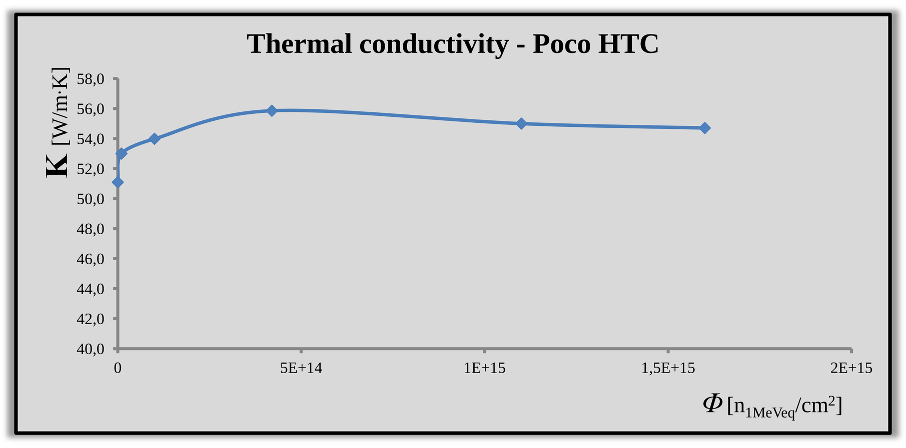
The tests for the thermal conductivity estimation consists on the same irradiated carbon foam specimens heated on one side by resistances and cooled on the other side. For the evaluation of the thermal conductivity, two thermocouples, arranged at a well known distance, have been glued on the specimens. Test results show stable thermal conductivity values at different radiation loads.



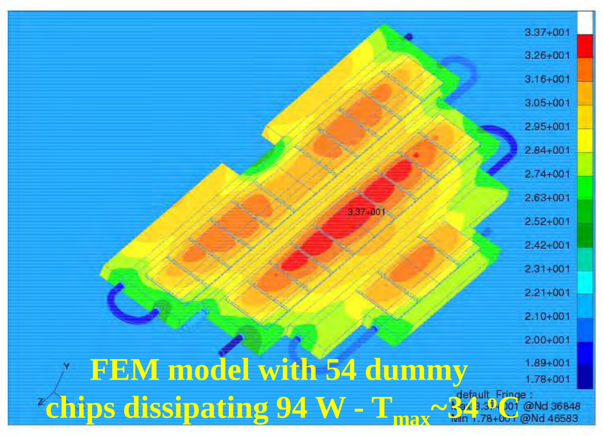


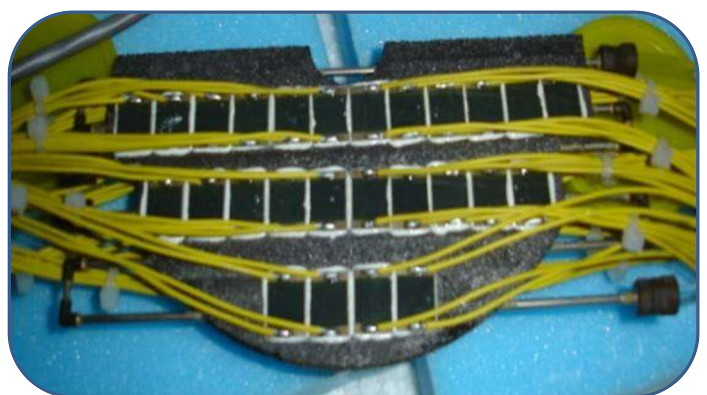




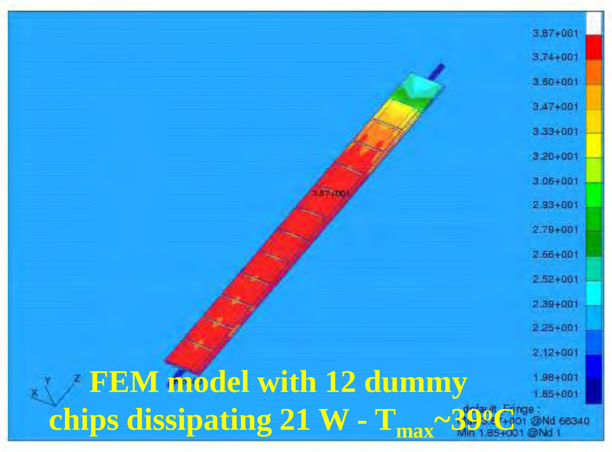


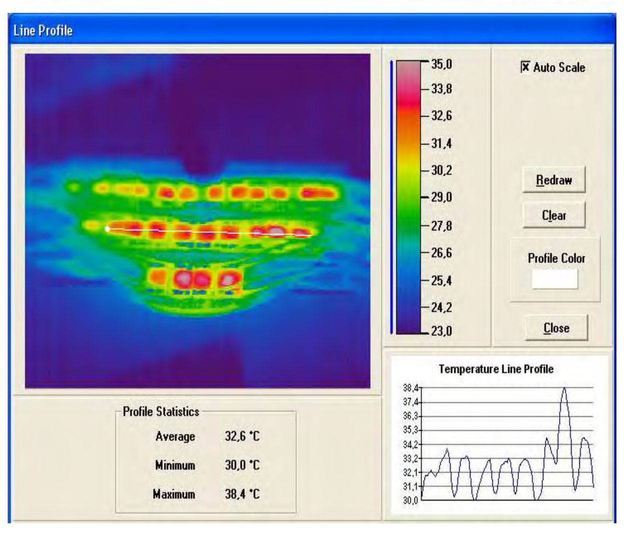
Four half-disks of 75mm of diameter, dissipating 70W and eight half-disks of 150mm of diameters, dissipating 740W, constitute the pixel disk-group of the Panda MVD.
The cooling system for the disks consists of a 2mm external diameter tube, made by Nikel-Cobalt alloy (MP35N), inserted in a 4mm thick carbon foam half disk, on which detectors are directly glued on both sides. FEM simulations have been conducted, considering different carbon foam thickness, tube diameters, flow rates and cooling tube number, with the aim to assign the most thermal efficient configuration for the half disk. Test results on prototypes validates FEM analyses.



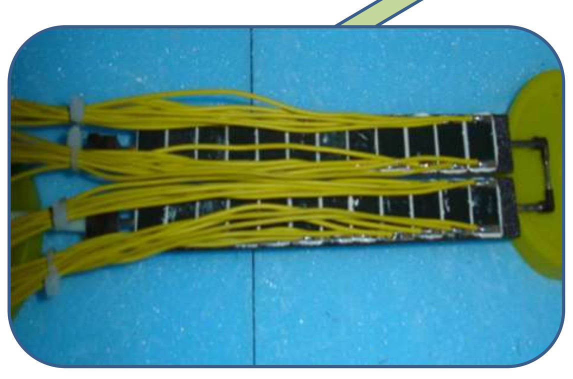


Half disk prototype

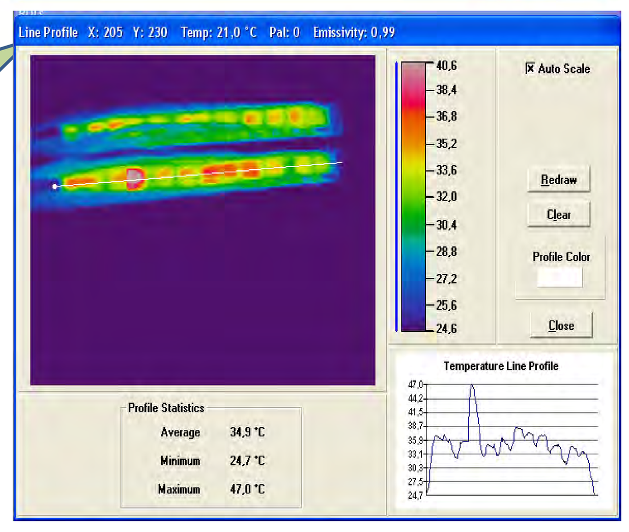




Test results



Stave prototype



Test results

Two layers of detectors, cylindrically disposed at 25 and 50mm from the beam pipe, dissipating 75W on the first layer, and 500W on the second layer, constitute the pixel barrel group of the Panda MVD.
The cooling system for the barrel consists of a 2mm external diameter tube, made by Nikel-Cobalt alloy (MP35N), inserted and glued in a sandwich of carbon foam and a carbon fibre omega structure, to provide both the drain of heat and mechanical support. The detectors and relative electronics are directly glued on the carbon foam.
FEM analyses have been useful to find out the most efficient solutions and test results are presented.