Accurate on-line nuclear heating measurements for MARIA&JHR MTR's

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Plan of presentation

- Nuclear heating from gamma
- CEA-NCBJ-AMU colaboration
- Gamma-heating calculations
- Gamma-heating on-line instrumentation and measurements
- NCBJ innovations in gamma-calorimetry
- MARIA experimental measurements campaign

Nuclear heating from gamma

- The local energy photon deposit must be accounted accurately for Gen-IV fast reactors, advanced light-water nuclear reactors (Gen-III+) and the new experimental Jules Horowitz Reactor (JHR). The gamma energy accounts for about 10% of the total energy released in the core of a thermal or fast reactor. Because of the propagation of gamma from the core regions to the neighbouring fuel-free assemblies, the contribution of gamma energy to the total heating can be dominant. Power reactors require a 7.5% (1sigma) uncertainty for the energy deposition in non-fuelled zones. For the JHR material-testing reactor. [1]
- Optimizing the life cycle of nuclear systems under safety constraints requires high-performance experimental programs to reduce uncertainties on margins and limits. In addition to improvement in modeling and simulation, innovation in instrumentation is crucial for analytical and integral experiments conducted in research reactors.
- The quality of nuclear research programs relies obviously on an excellent knowledge of their experimental environment which constantly calls for better online determination of neutron and gamma flux. [2]

- The Jules Horowitz Reactor (JHR) is an international Material-Testing Reactor currently under construction at CEA Cadarache. The determination of gamma heating levels in this future commercial reactor is of crucial importance as gamma heating affects both safety and performance parameters of the JHR. Required accuracy (5% at one standard deviation) makes it necessary to calibrate bias and uncertainty associated with JHR gamma-heating calculations. [3] The maximum nuclear heating rate expected in the future JHR reactor is 20W/g, which is well above the 13W/g currently reached in the OSIRIS irradiation reactor at the CEA/Saclay Center [4][5]
- γ−heating in a center of a typical reactor core comes from:

  20% from the γ produced in radiative capture

  40% from the prompt γ emitted by fission fragments

  30% from the delayed γ produced by fission products

  10% from the inelastic scattering reactions.[6]

OBJECTIVE OF THE PROJECT

The main objective of this project is to develop calculation scheme for the best precission evaluation of the gamma heating at any chosen location for both Jules-Horowitz and MARIA reactors.

For that purpose both, simulation codes and experimental setup is being developed. The general task of simulation procedures is being develop with JHR (CEA Cadarache) and experimental confirmation in MARIA MTR (NCBJ Otwock-Świerk)

GAMMA MAJOR project

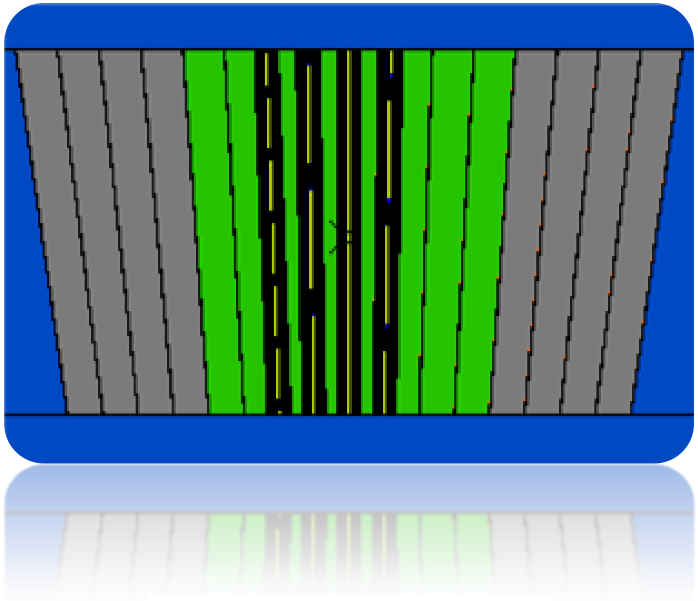
CEA – NCBJ - AMU colaboration

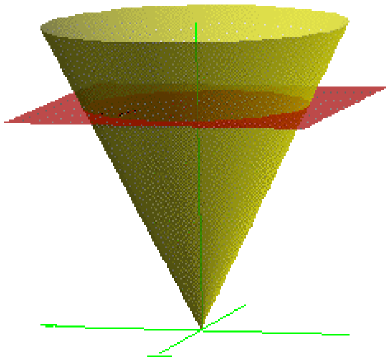
Development and qualification of a deterministic scheme for the evaluation of gamma heating in experimental reactors.

Application to JHR and to the reactor MARIA.

MARIA MODELING

- 3D MARIA model in TRIPOLI4 (Monte Carlo code) with fully reflected geometry for neutron-photon-electron calculations and gamma-heating estimation
- Fuel elements burn-up composition has been calculated in APOLLO2 (thanks to Malgorzata Wroblewska)

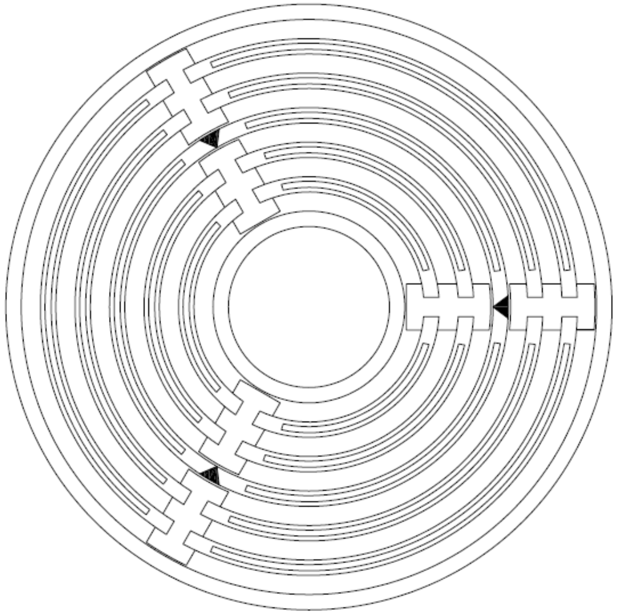




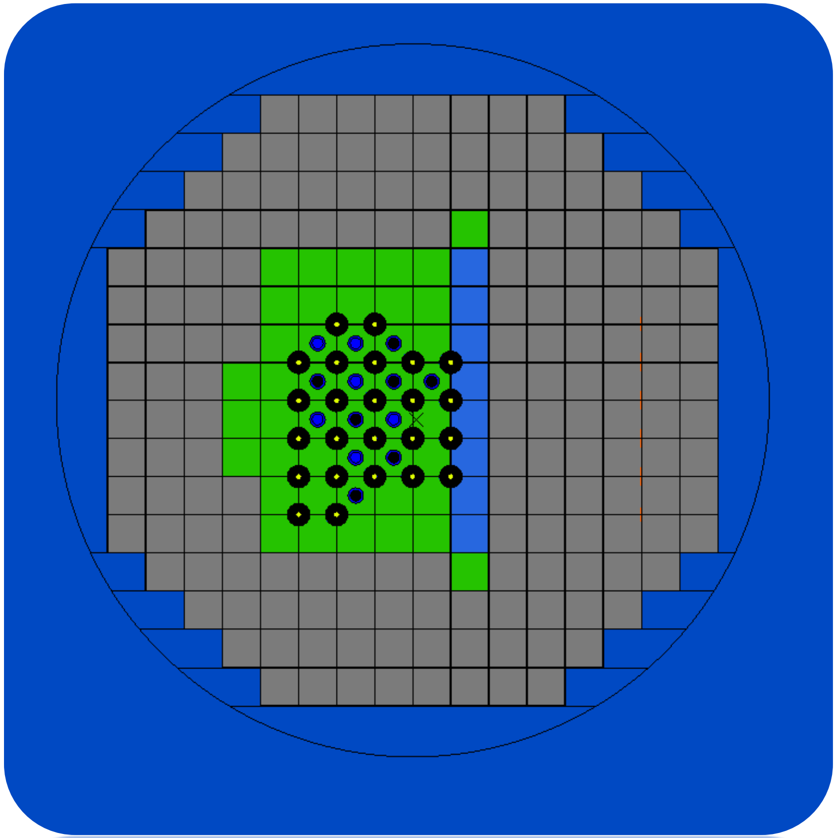
MARIA and JHR similarities

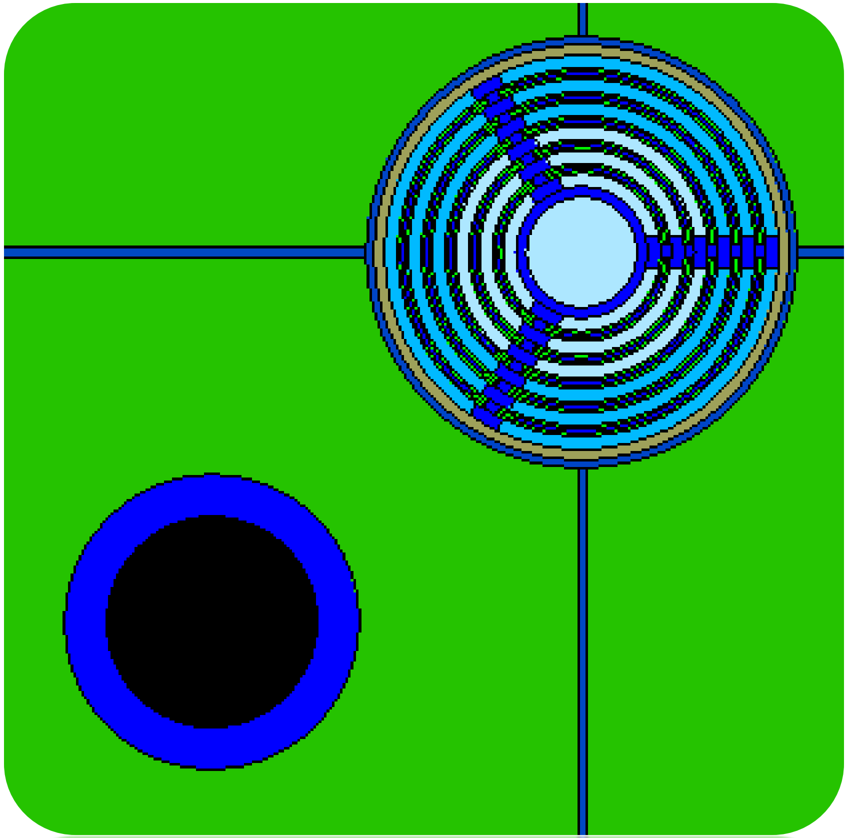
- Construction of fuel elements (same CERCA manufacturer)

- Beryllium moderator in MARIA, Beryllium reflector in JHR

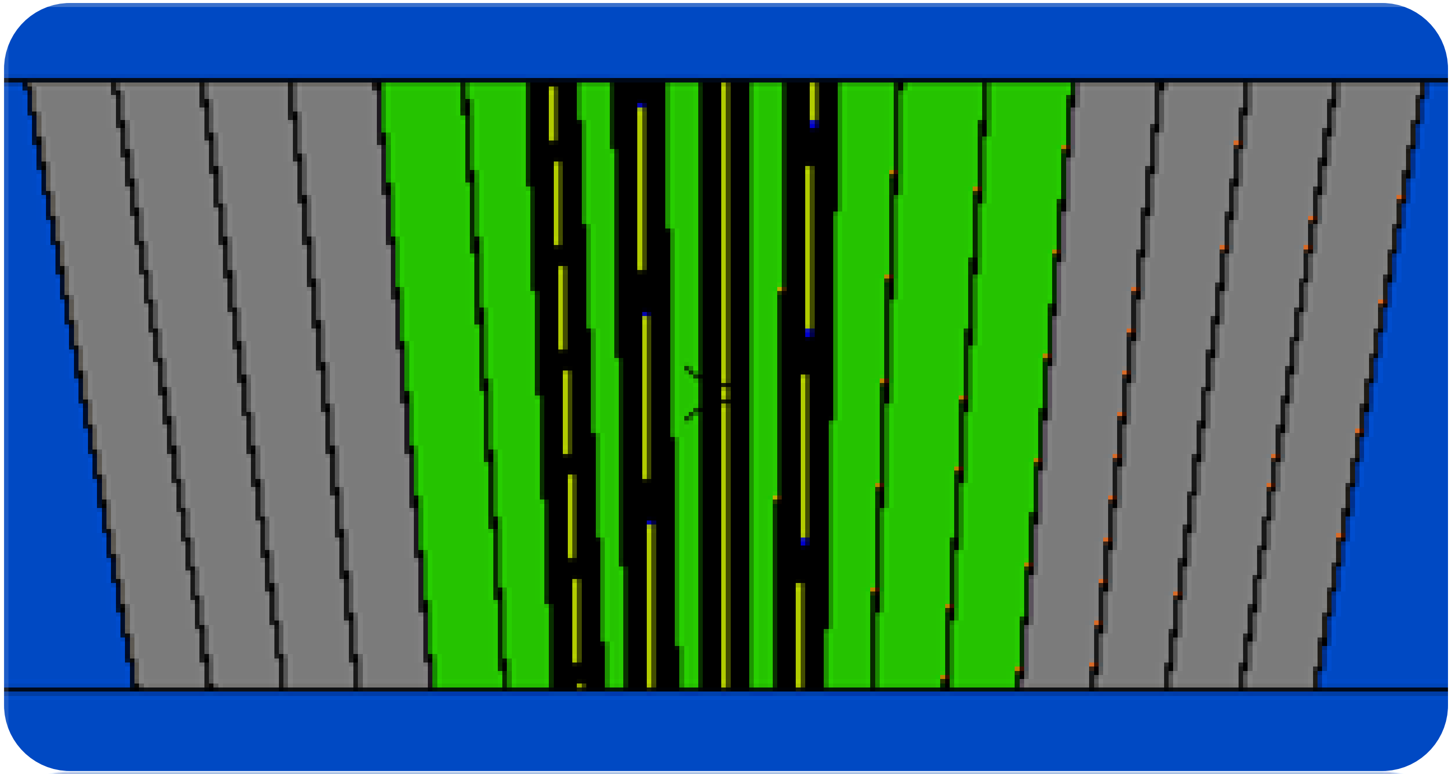


MARIA – TRIPOLI4 MODEL

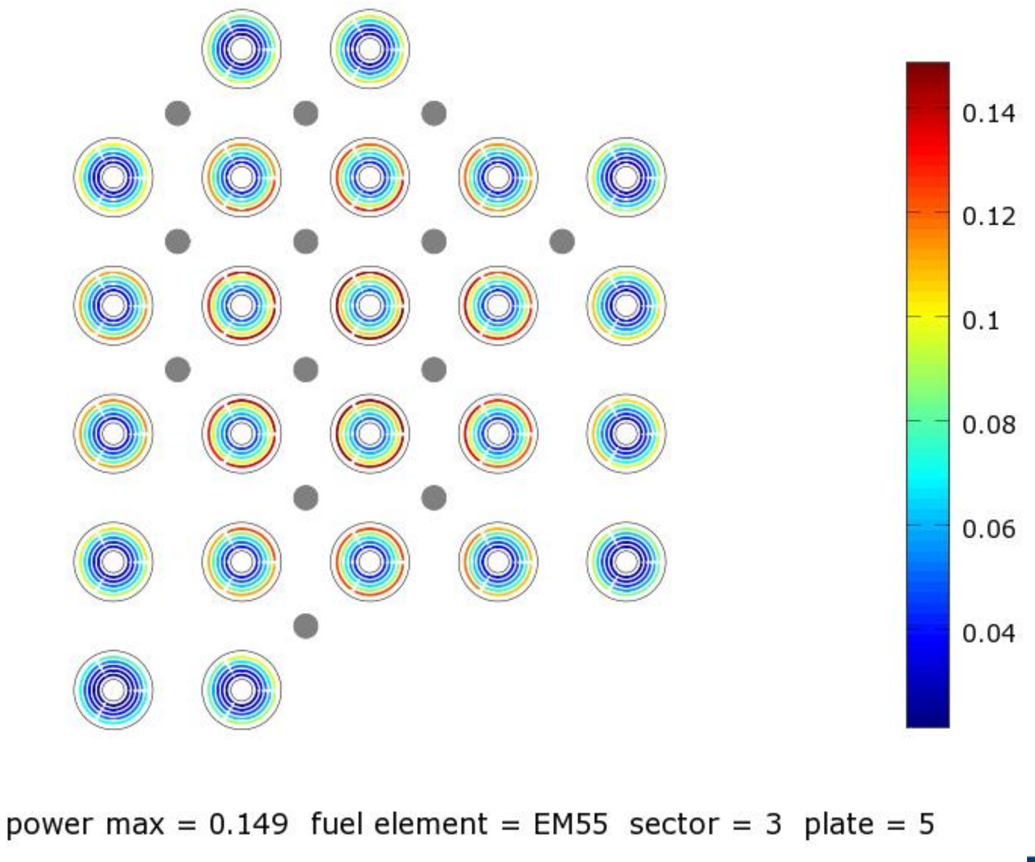


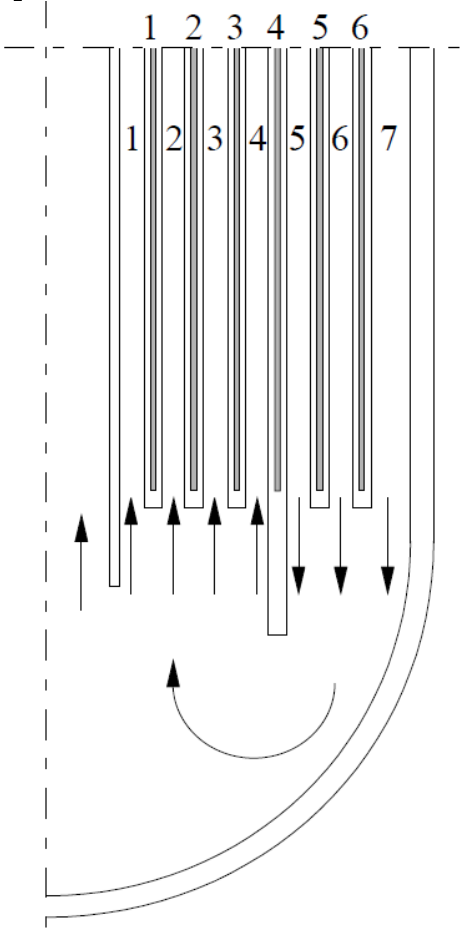


MARIA – TRIPOLI4 MODEL



TRIPOLI4 calculations results of MARIA core
Power distribution per plate in MW
(15 plates x 24 fuel elements)



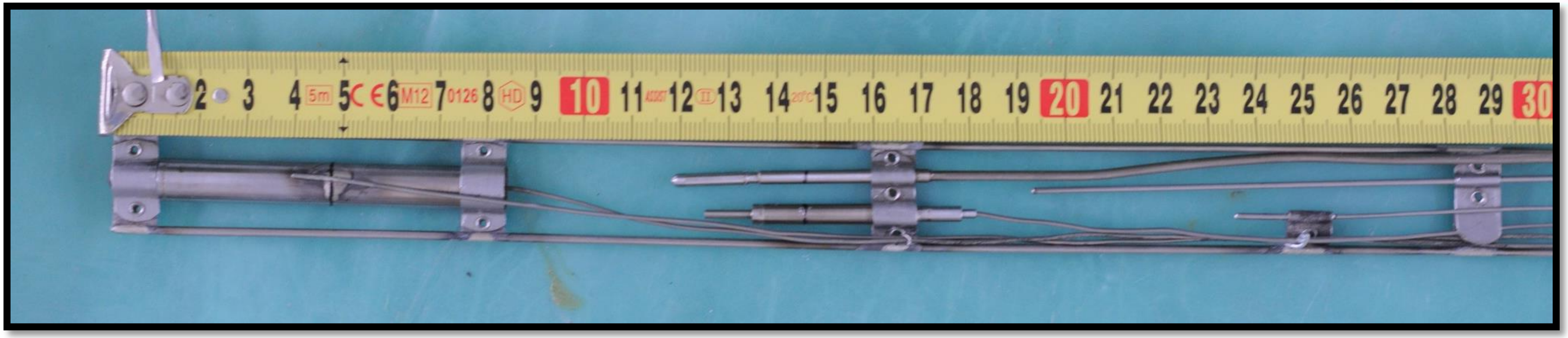


Gamma-heating on-line instrumentation and measurements

Gamma fluxes measurements in the reactor MARIA were done on September 2014. Dedicated 6 days campaign has been devoted exclusively for this purpose. GAMMA MAJOR program is being perform in full colaboration between CEA&NCBJ&AMU personel from design, through experiment realisation up to interpretation of the results.

Experimental instrumentation:

INSTRUMENTATION	Supplier
KAROLINA – new designed gamma differential calorimeter	NCBJ
Gamma Thermometer	LDCI CEA
Ionization Chamber	LDCI CEA
Rhodium SPND	LDCI CEA
Silver SPND	LDCI CEA
Activation Detectors [Al-Co,Al-Au,Ni,Ti,Nb,Y,Fe]	NCBJ
*) CALMOS - type two cell gamma differential calorimeter	Aix-Marseille University, CEA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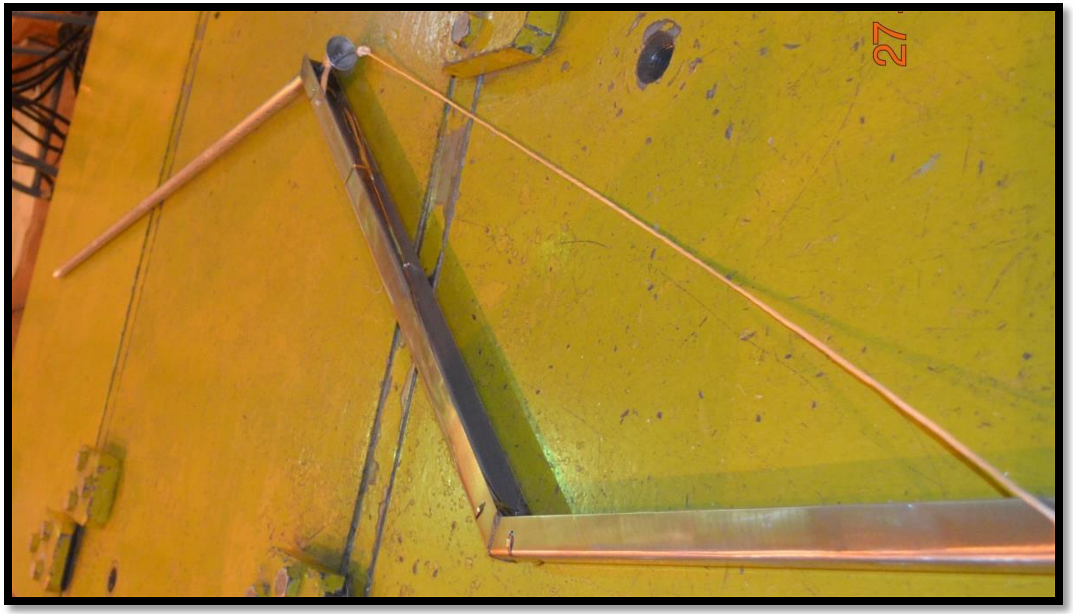
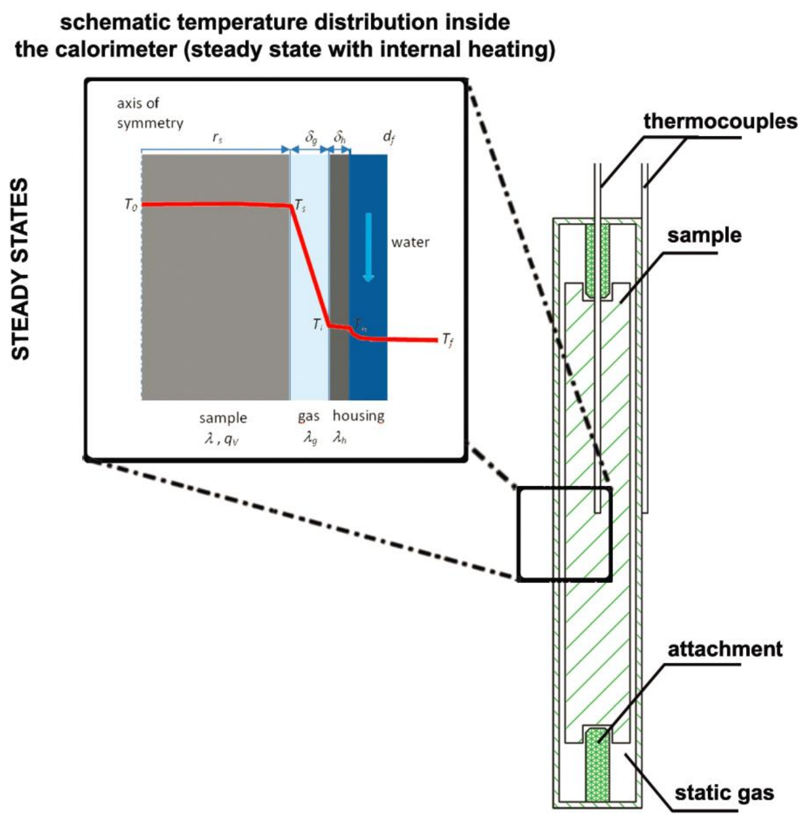


KAROLINA
NCBJ innovation in gamma-calorimetry

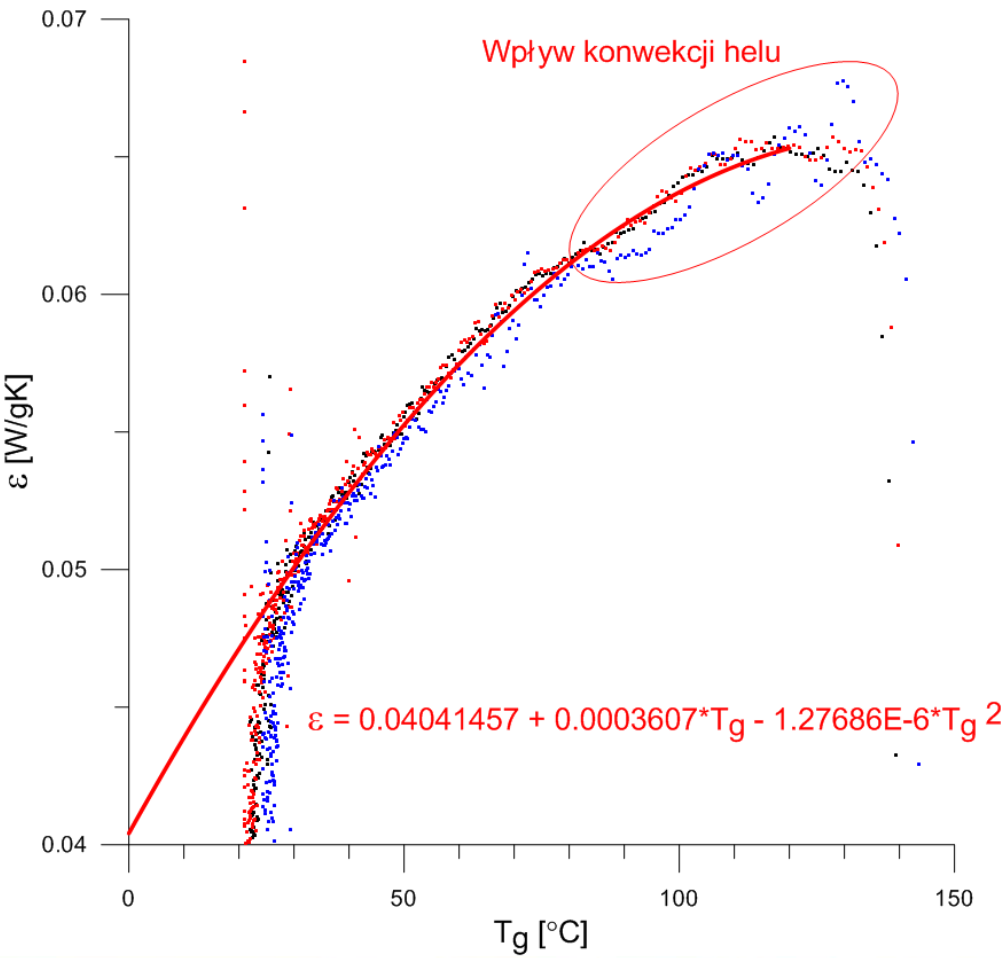


Calibration set-up

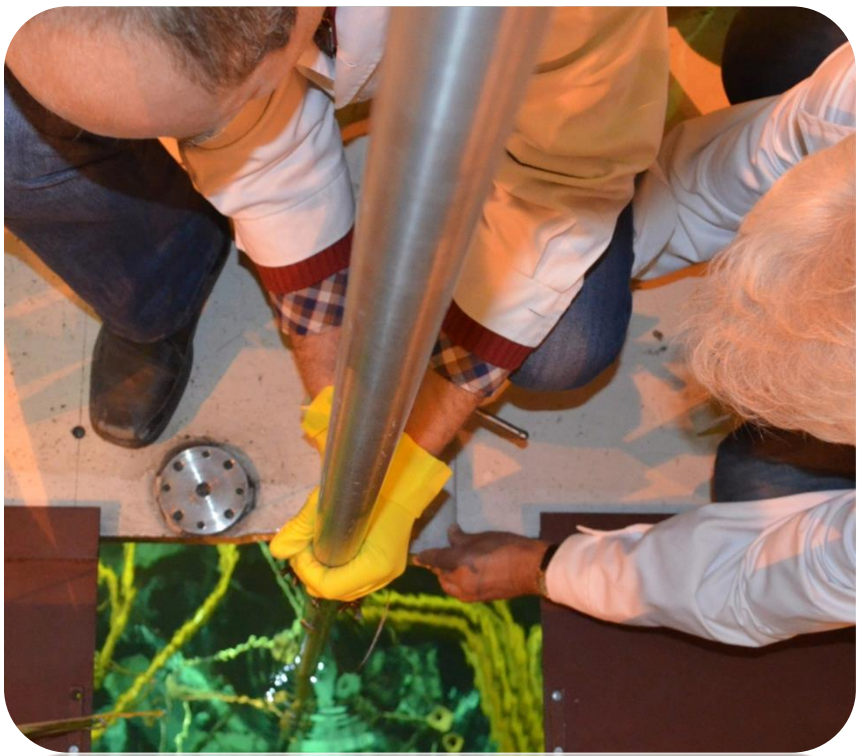
wich simulate MARIA irradiation channel
specific conditions of the cooling fluid
(geometry, temperature and fluid velocity)

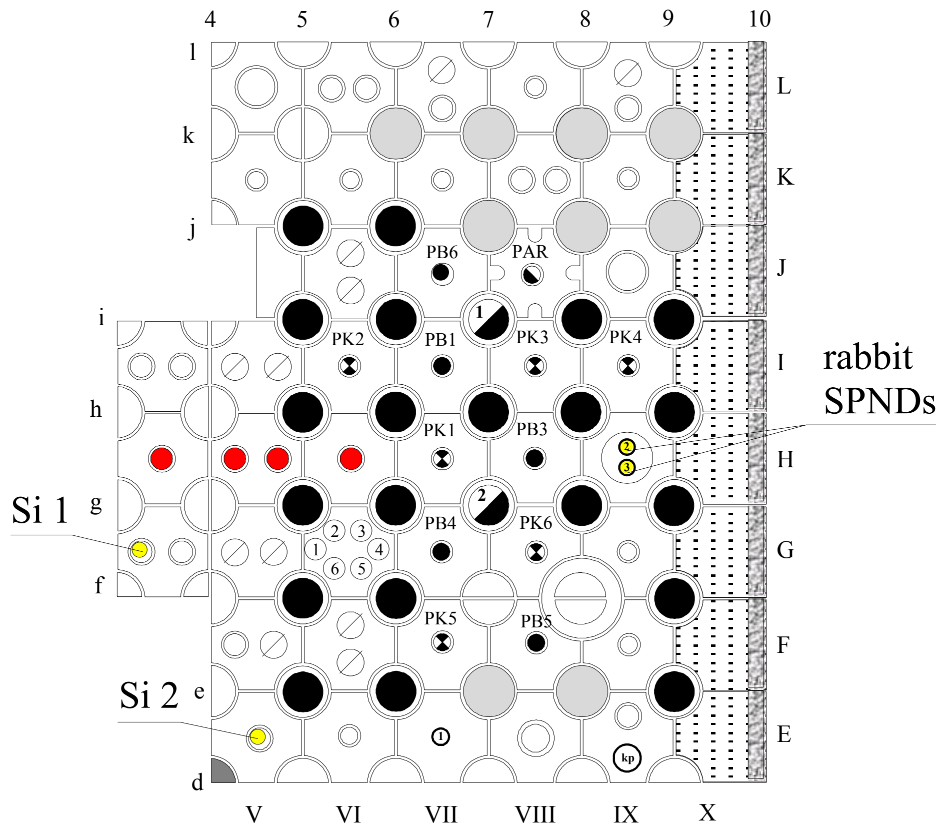
<u>KAROLINA calorimeter thermal calculations and calibrations are being made in addition in Laboratoire IM2NP UM7334 at Aix-Marseille Univerity</u>

KAROLINA out-pile calibration

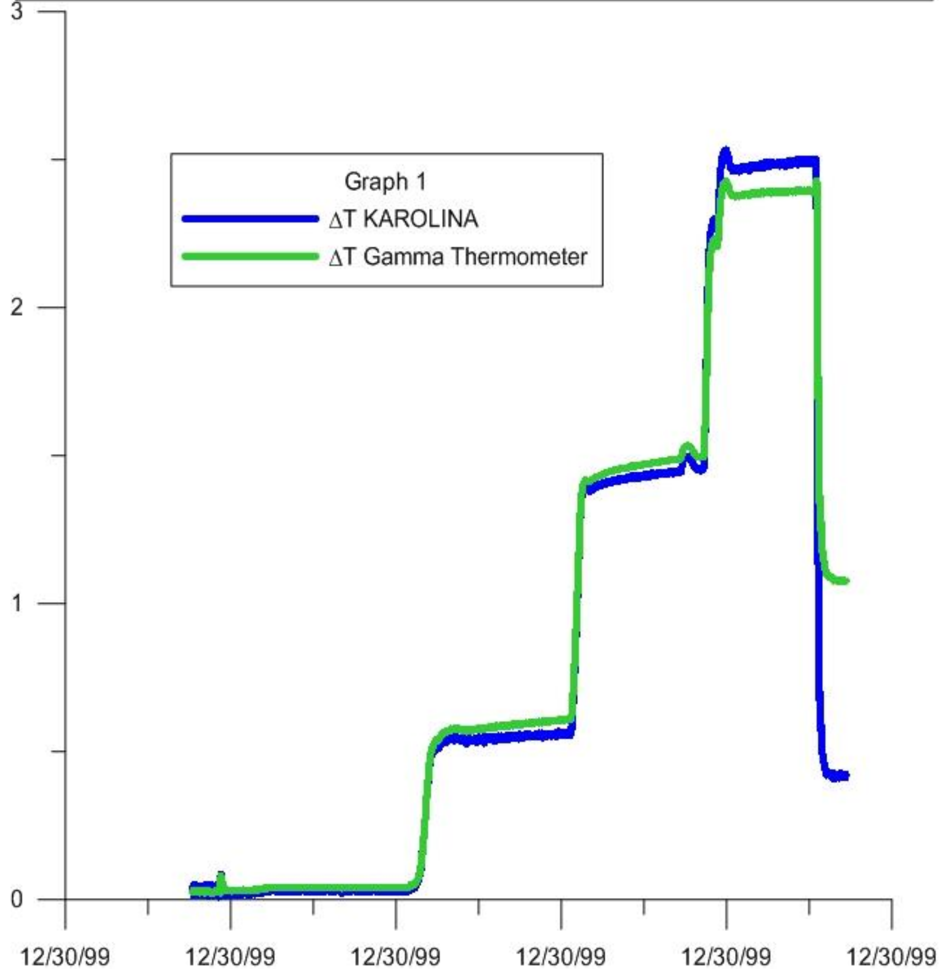


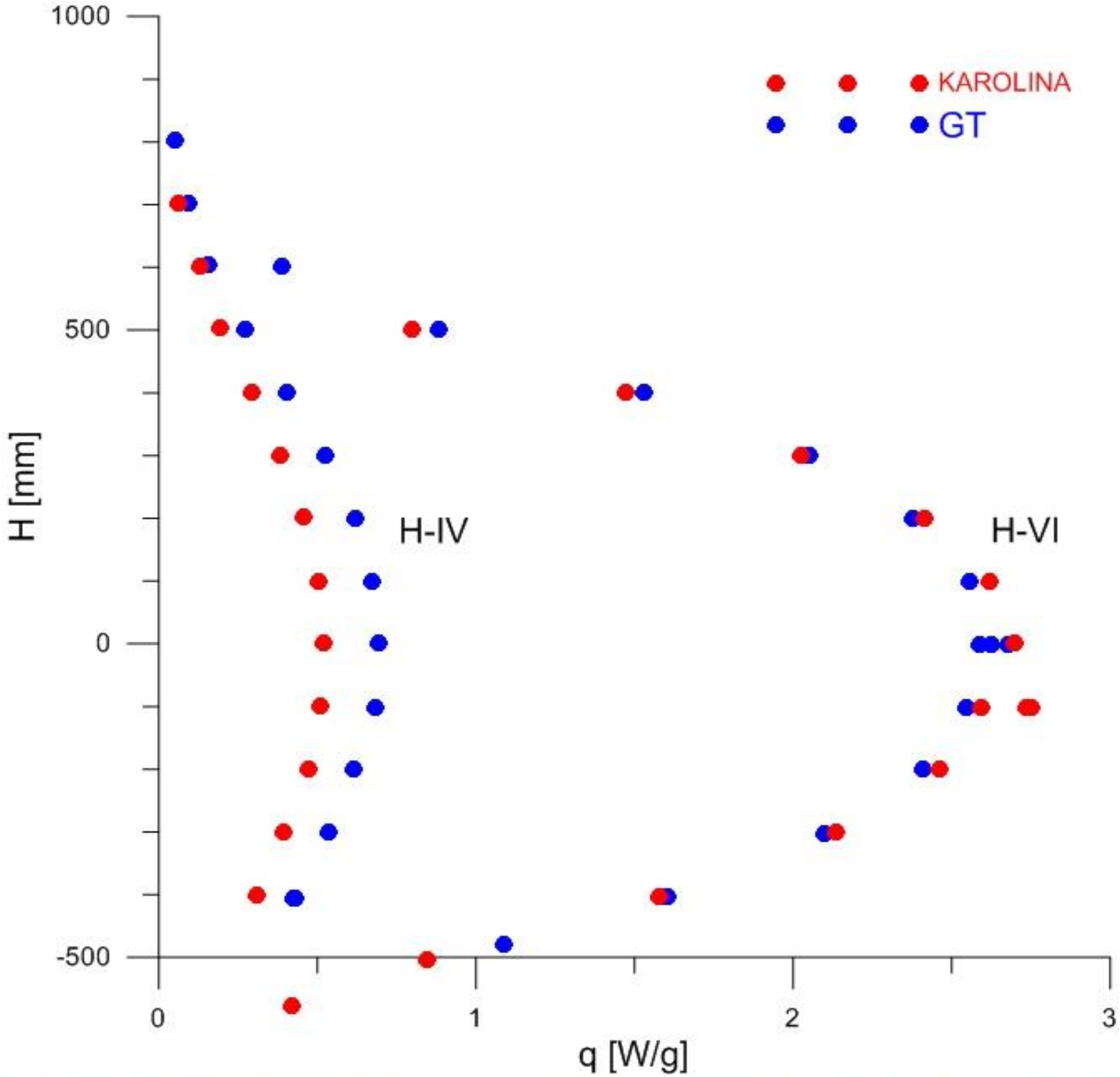
MARIA experimental measurements campaign





Gamma Thermometer and Calorimeter KAROLINA delta T during MARIA startup in four steps: 0MW - 4MW - 8MW - 15MW




KAROLINA
GT
H-IV
H-VI
1000
500
0
-500
H [mm]
0
1
2
3
q [W/g]

GAMMA MAJOR goals overwiev

1. Development of MARIA Gamma Heating Model using CEA calculation codes (TRIPOLI4 and APOLLO2)
2. n-γ transport model development for MARIA reactor using TRIPOLI4 and APOLLO2 due to recognize positions with simmilar neutronic properties to JHR
3. Experimental validation of Gamma Heating Model for MARIA reactor, by measurements of photon fluxes in MARIA reactor with the best possible precission and comparison with calculations.
4. Development of capabilities in-pile measurements in colaboration between National Centre for Nuclear Research, Alternative Energies and Atomic Energy Commission and Aix Marseille University.
5. Instrumentation development for in-pile on-line measurements

[1] G. Rimpault et al., “Needs of Accurate Prompt and Delayed Gamma-Spectrum and Multiplicity for Nuclear Reactor Designs,” Physics Procedia, no. 31, pp. 3-12, 2012.
[2] J-F.Villard, M.Schyns„Innovations for In-Pile Measurements in the Framework of the CEA-SCK•CEN Joint Instrumentation Laboratory”
[3] M.Lemaire et al.,”For a Better Estimation of Gamma Heating in Experimental Reactors and Devices: Stakes and Work Plan from Calculation Methods to Nuclear Data”
[4] H. Carcreff, et al., IEEE Transactions on Nuclear Science NS 59 (2012) 1369.
[5] G. Rimpaulta, et al. „ Needs of accurate prompt and delayed γ-spectrum and multiplicity for Nuclear Reactor Designs”
[6] A. Lüthi, R. Chawla, and G. Rimpault, Nucl. Sci. Eng. 138 (2001) 3.
[7]http://jwilson.coe.uga.edu/EMAT6680Fa05/Mercimek/ConeHalfFull/image1.gif

Thank You