

# Benchmark of efficiency calculations for PE moderated neutron counters

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# Outline

- **The origin of the benchmark:**
  - UPC MCNPX flat configuration.
  - Comparative calculations for the UPC flat configuration
  
- The benchmark simulation:
  - Definitions.
  - Results for configuration 1.
  - Results for configuration 2.
  
- Remarks.

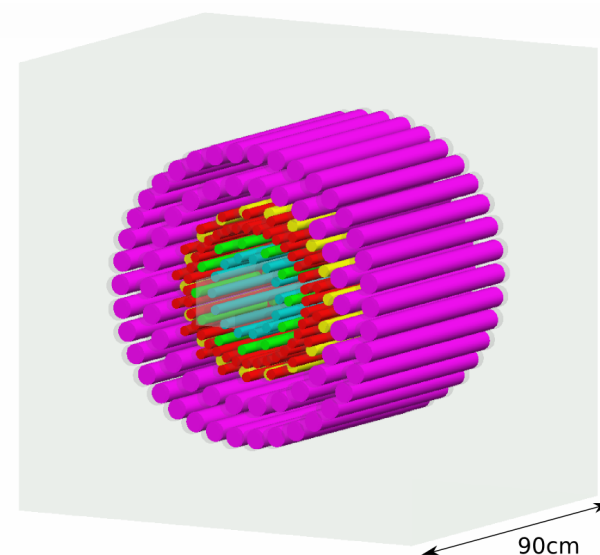
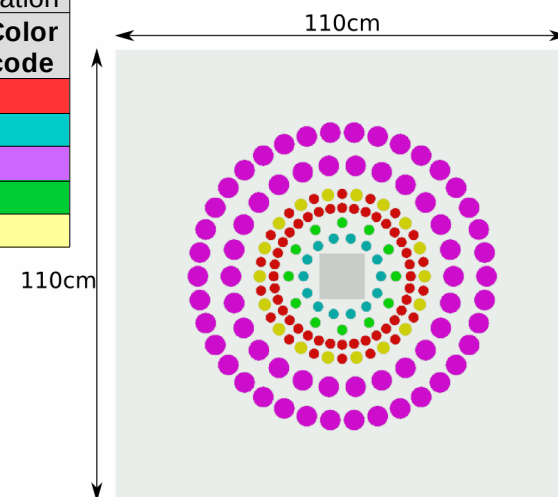
# The UPC MCNPX flat configuration: Detector construction proposal

Configuration of the UPC flat BRIKEN neutron detector <sup>(1)</sup>

Ring	Ring-Radius (cm)	Number of <sup>3</sup> He tubes	Pressure (atm)	Diameter (inch)	Institute
1	9.4	14	10	1	ORNL
2	13	12+12 <sup>(*)</sup>	5.13	1	RIKEN
3	16.8	10+26	10/8	1	GSI / UPC
4	20	18+18 <sup>(*)</sup>	5/8	1.18/1	JINR / UPC
5	27	26	10	2	ORNL
6	35	38	10	2	ORNL

(\*) Ring made from two sections along the beam axis.

UPC flat efficiency configuration		
Owner group	Used counters	Color code
UPC + GSI	54	
ORNL	14	
ORNL	64	
RIKEN	24	
JINR	18	
<b>TOTAL</b>	<b>174</b>	

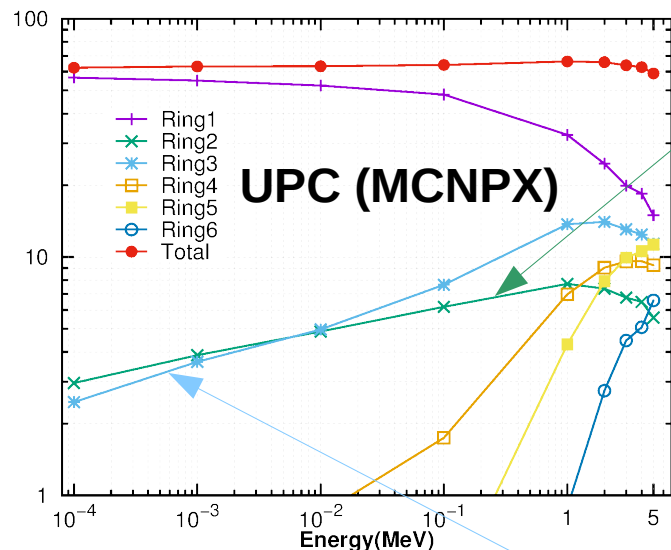


- This configuration has been proposed by the UPC team. The design has been carried out using MCNPX.
- It is a configuration without clovers.
- The moderator is a 110x110x90 cm<sup>3</sup> PE matrix.
- The hole for AIDA is squared shaped, size 11x11cm<sup>2</sup>.
- In total, the configuration uses 174 counters distributed on six rings around the AIDA hole.
- **Three months ago, comparisons for this geometry were done using MCNPX (UPC) and Geant4 (IFIC, RIKEN) calculations.**

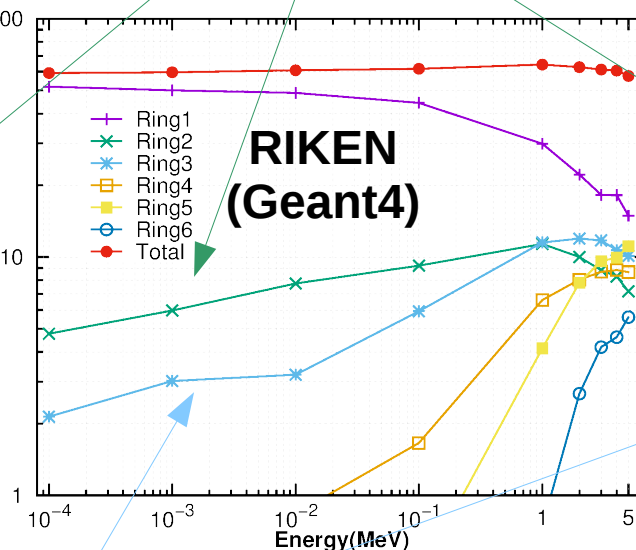
<sup>(1)</sup> Taken from RIBF NP-PAC-13, 2013.

# Comparative calculations for the UPC flat configuration

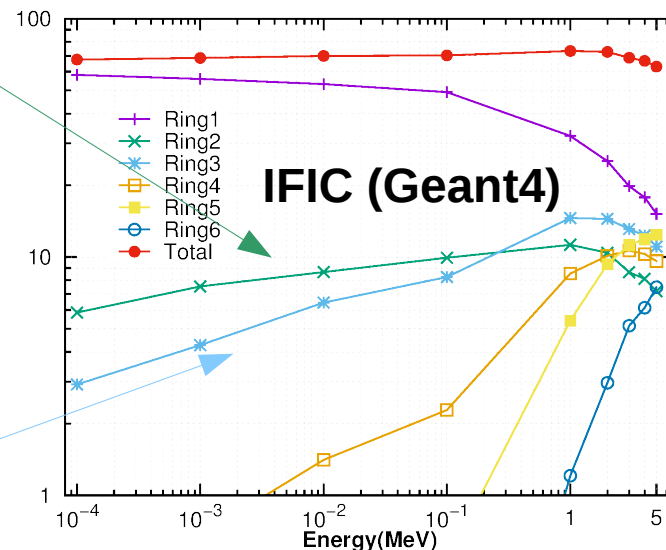
UPC flat configuration: MCNPX calculations by UPC team



UPC flat configuration: Geant4 simulation by RIKEN team



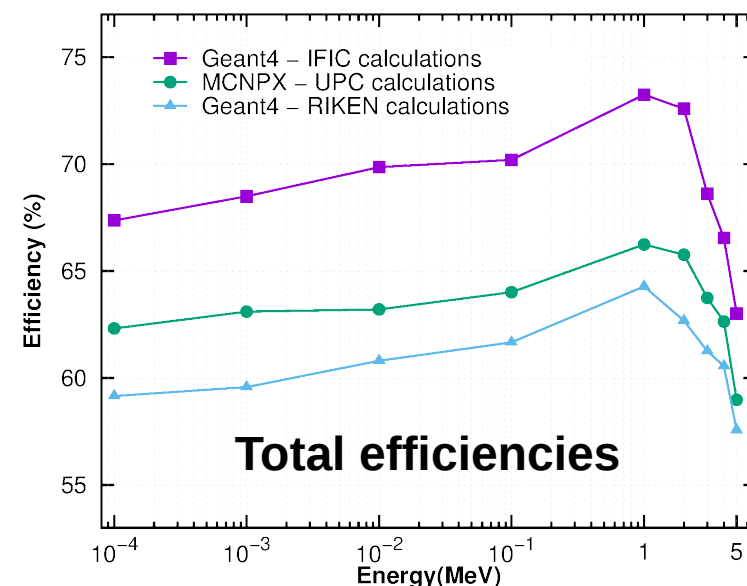
UPC flat configuration: Geant4 simulation by IFIC team



Ring 3

- There are systematic differences mainly for rings two and three.
- For the remaining rings, the efficiency has a similar shape.

UPC flat configuration: Calculated total efficiencies



## Comparative calculations for the UPC flat configuration

Value	UPC	RIKEN	IFIC	RIKEN/UPC	IFIC/UPC
Simulation	MCNPX	Geant4	Geant4	---	---
F-factor	1.123	1.117	$1.162 \pm 0.02$	0.994	1.035
Average neutron efficiency	63.3%	60.8%	$68.9\% \pm 1.0\%$	0.961	1.088
Maximum neutron efficiency	66.2%	64.3%	$73.3\% \pm 0.9\%$	0.970	1.106
88Br neutron efficiency	---	---	$71.2\% \pm 0.8\%$	---	---
84Ga neutron efficiency	---	---	$72.3\% \pm 0.9\%$	---	---
Ratio 88Br/84Ga	---	---	$0.985 \pm 0.016$	---	---

- Geant4 simulations yield biased results with respect to the UPC-MCNPX calculations.
- In previous versions of Geant4, a bug in the interpolation of the cross section for thermal treatment was found <sup>(1)</sup>. In the current version (10.0 and higher), this bug has been corrected.
- Possible explanations to the bias are differences in the description of the geometry of the moderator matrix and <sup>3</sup>He tubes. In addition, the room temperature set at the simulation can be also a source of bias.
- A benchmark simulation was proposed to understand the origin of the differences.

<sup>(1)</sup> <https://indico.cern.ch/event/245281/contribution/1/material/slides/0.pdf>

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# The benchmark simulation

## Polyethylene:

Formula: CH<sub>2</sub>

Density: 0.95 g/cm<sup>3</sup>

Temperature (for thermal libraries): 293.6K (standard for MCNPX)

## Filling Gas:

Formula: 3He

Pressure: 10 atm

Temperature: 293.6K; Density: 1.252E-3 g/cm<sup>3</sup>

**Neutron energies:** 0.001, 0.01, 0.1, 1.0, 2.0, 3.0, 4.0, 5.0 MeV

## Configuration 1: Similar to BELEN-30

Polyethylene block: 90cm x 90cm x 80cm [XYZ]

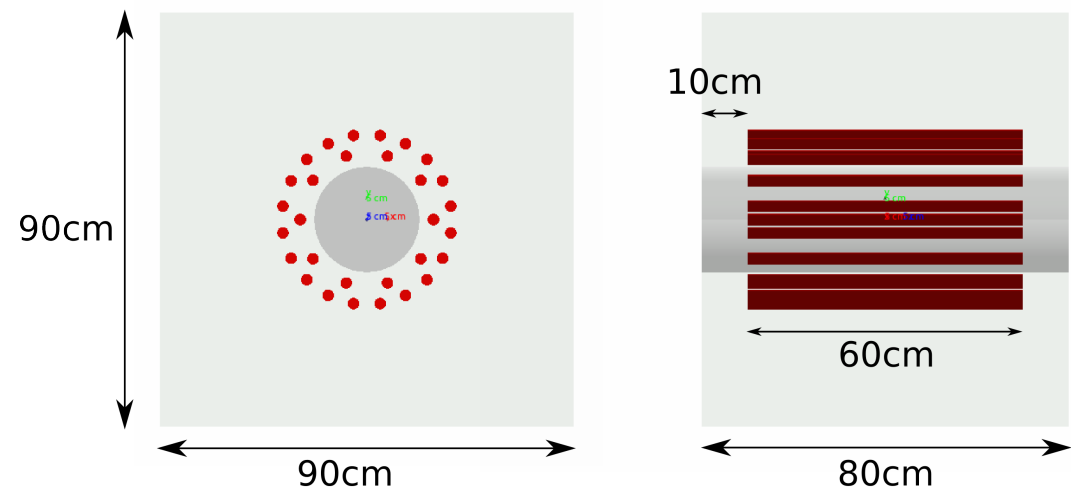
Central hole: Circular shape, radius 11.5cm

Gas detector volume:

Length 60cm, Radius 1.27cm

Number of detectors: 30

Number of rings: 2



**Configuration 2:** Similar to BRIKEN construction proposal

Polyethylene block: 90cm x 90cm x 80cm [XYZ]

Central hole: Square shape, side length 11cm

Gas detector volume 1:

Length 60cm, Radius 1.27cm

Number of detectors type 1: 98

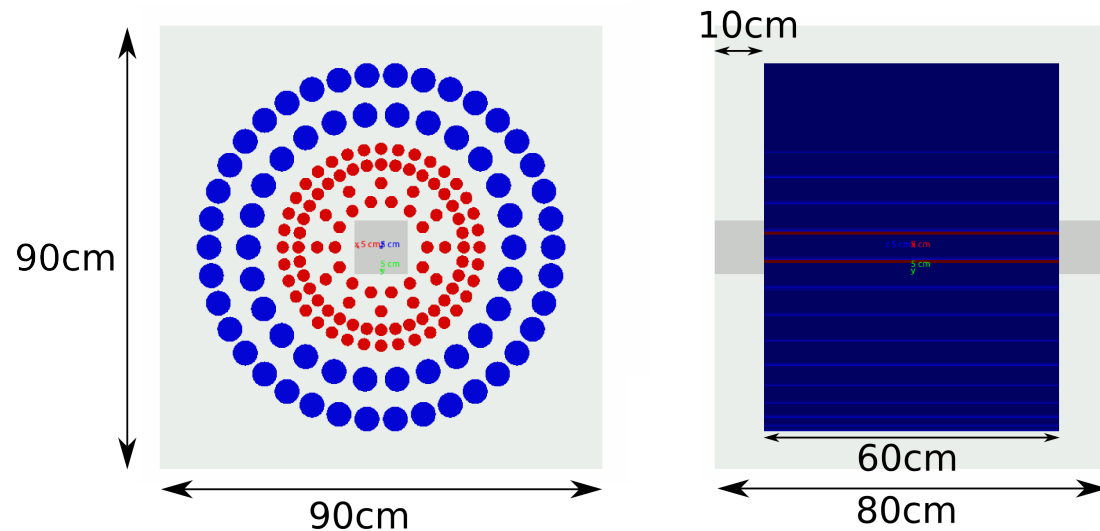
Gas detector volume 2:

Length 60cm, Radius 2.54cm

Number of detectors type 2: 64

Number of rings: 6

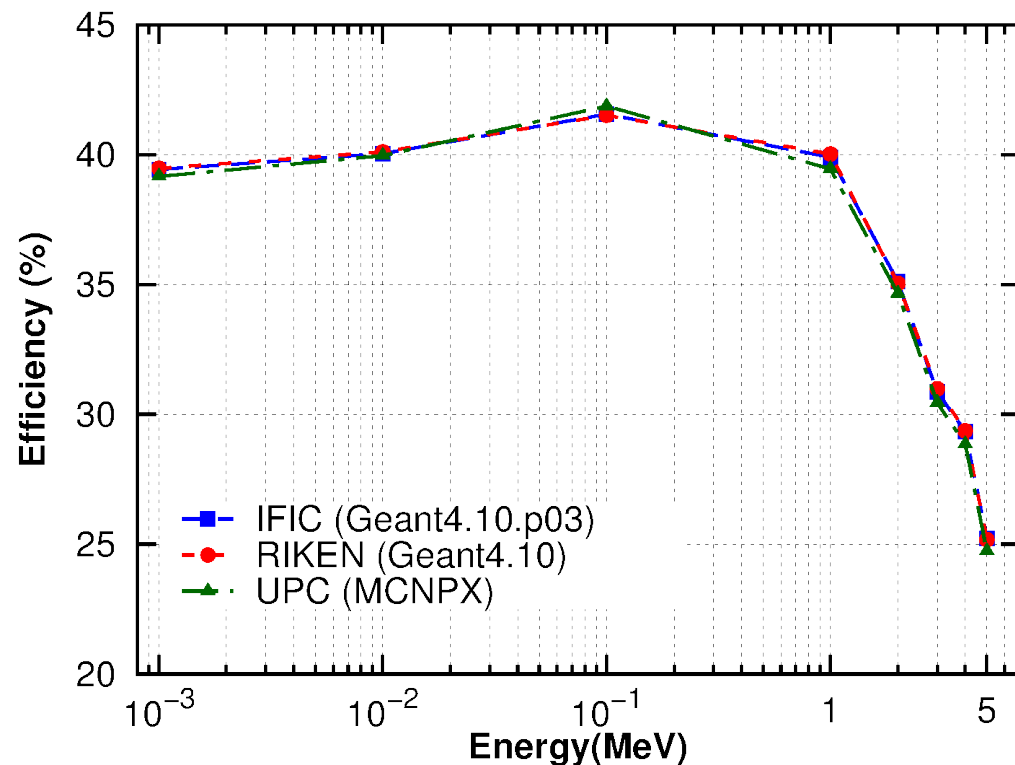
Total number of counters: 162





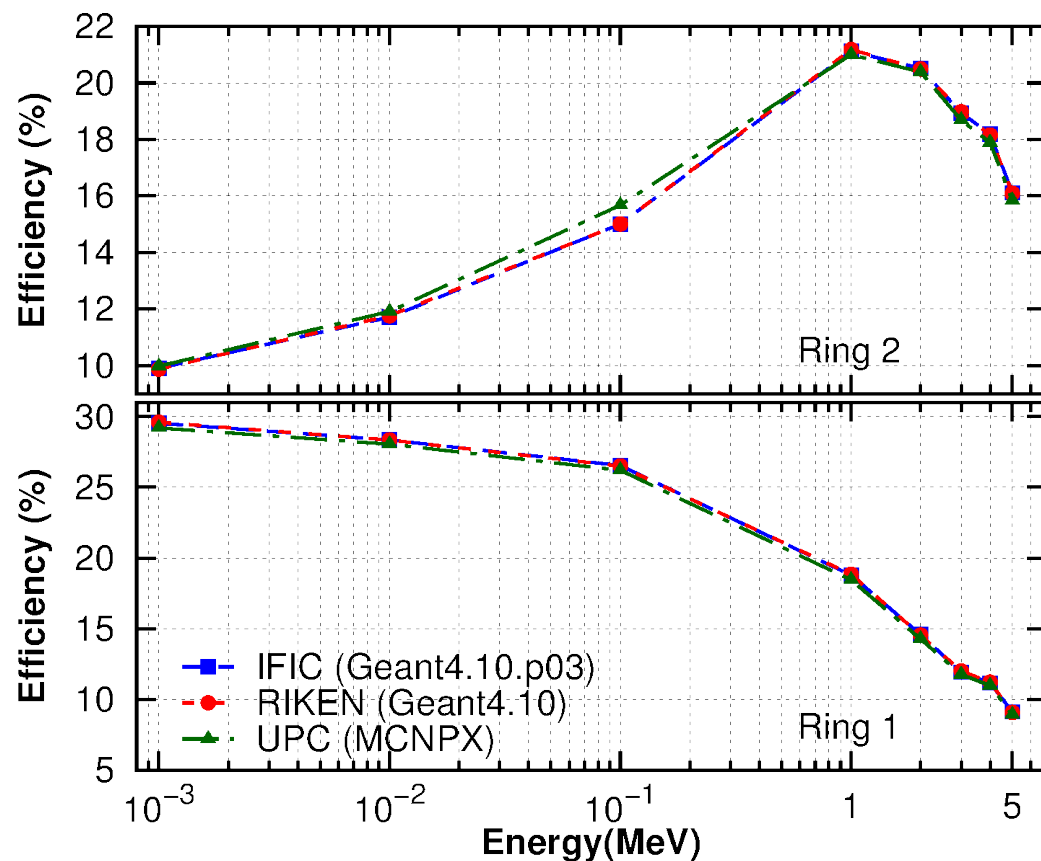
# Benchmark results: Configuration 1

Conf1: Total efficiencies

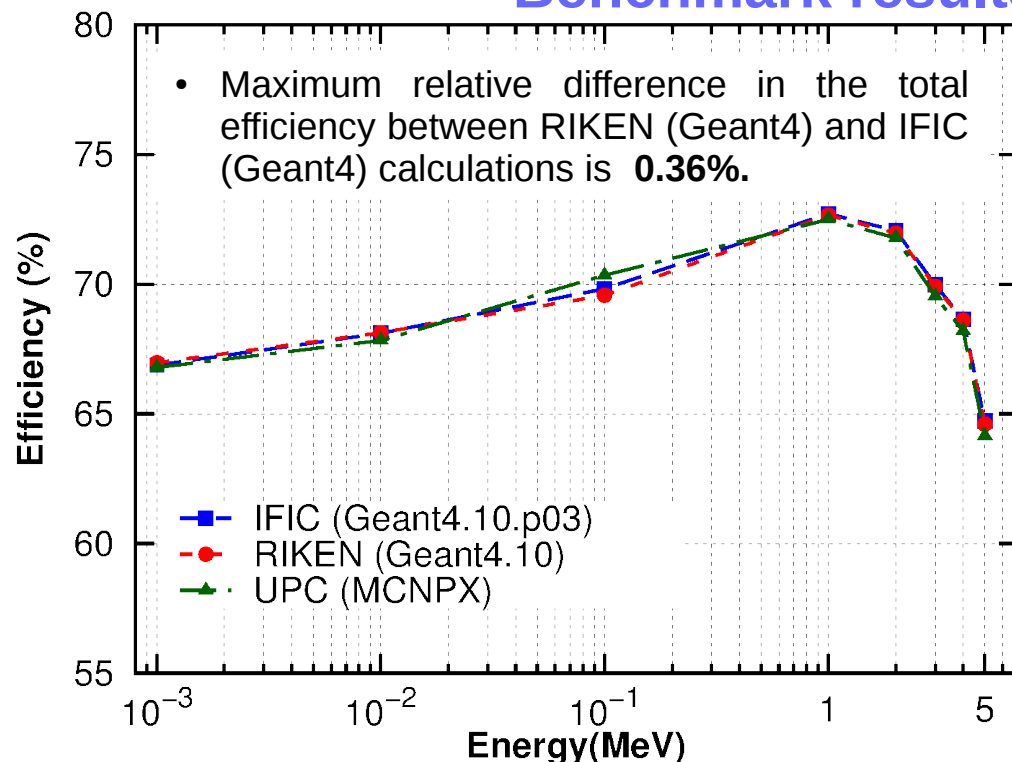


Energy (MeV)	Total Efficiency			Ratios	
	IFIC	RIKEN	UPC	RIKEN/IFIC	UPC/IFIC
0.001	39.43%	39.47%	39.17%	1.0010	0.9932
0.01	40.04%	40.11%	39.97%	1.0016	0.9980
0.1	41.56%	41.51%	41.87%	0.9989	1.0075
1	39.90%	40.03%	39.46%	1.0032	0.9889
2	35.11%	35.04%	34.65%	0.9979	0.9867
3	30.86%	30.99%	30.45%	1.0042	0.9866
4	29.35%	29.37%	28.85%	1.0009	0.9831
5	25.24%	25.18%	24.73%	0.9978	0.9801

- Maximum relative difference in the total efficiency between RIKEN (Geant4) and IFIC (Geant4) calculations is **0.42%**.
- Maximum relative difference in the total efficiency between UPC (MCNPX) and IFIC (Geant4) calculations is **1.99%**.

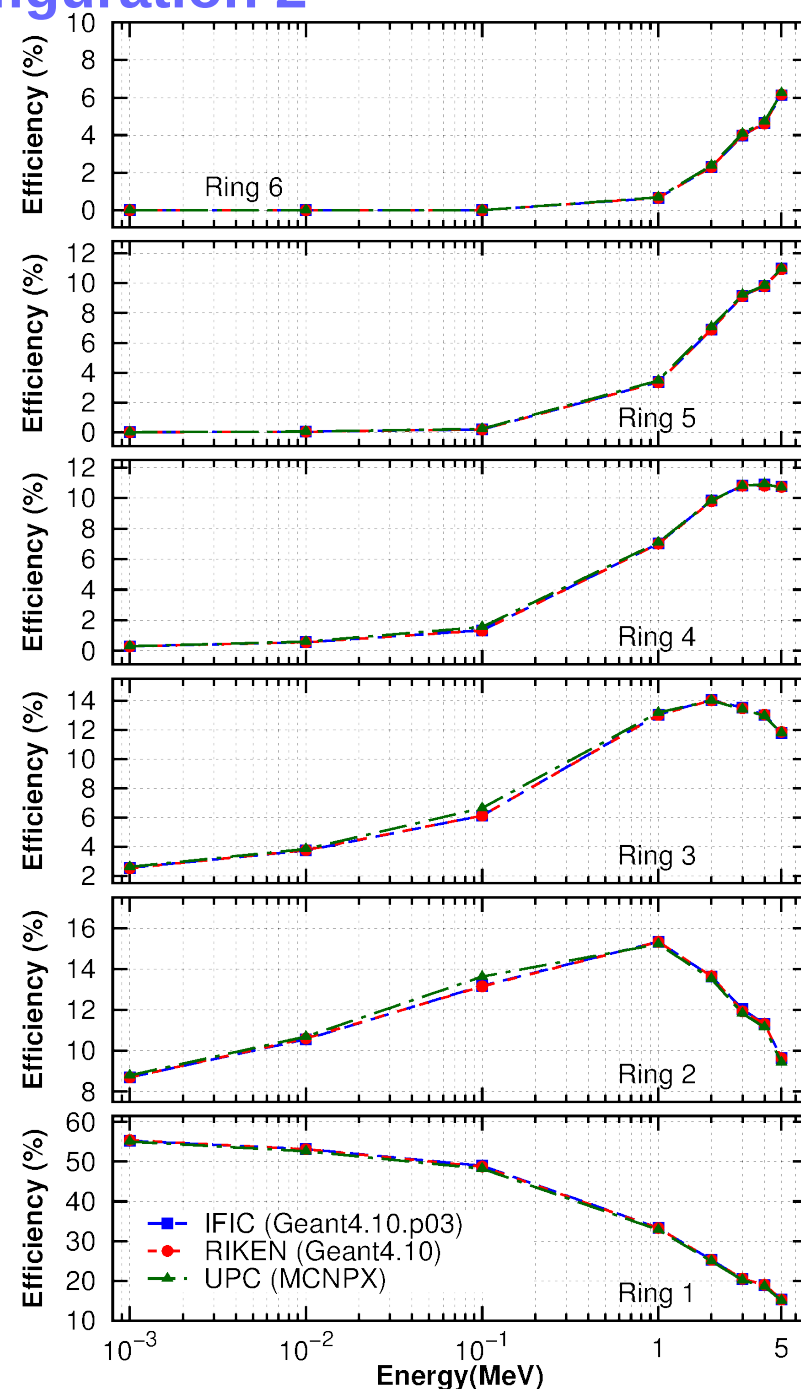


## Benchmark results: Configuration 2



- Maximum relative difference in the total efficiency between UPC (MCNPX) and IFIC (Geant4) calculations is **0.88%**.

Energy (MeV)	Total Efficiency			Ratios	
	IFIC	RIKEN	UPC	RIKEN/IFIC	UPC/IFIC
0.001	66.88%	66.97%	66.79%	1.0014	0.9986
0.01	68.11%	68.13%	67.83%	1.0003	0.9960
0.1	69.82%	69.57%	70.34%	0.9964	1.0074
1	72.71%	72.65%	72.49%	0.9992	0.9970
2	72.05%	71.97%	71.78%	0.9989	0.9962
3	69.97%	69.90%	69.54%	0.9990	0.9938
4	68.64%	68.61%	68.19%	0.9995	0.9934
5	64.72%	64.61%	64.15%	0.9982	0.9912



## Remarks

- The differences resulting from the benchmark study are much lower than those observed in Geant4 and MCNPX calculations of the proposed UPC flat configuration.
- The large differences found previously probably due to a different geometrical description and/or temperature set in the simulation.
- The main conclusion of this benchmark study is that the current version of Geant4 (10.0.X) has a similar performance with MCNPX for efficiency calculations of moderated  $^3\text{He}$  counters. Relative differences between Geant4 and MCNPX less than 2% have been found in this study.
- The agreement of MC simulations with experimental results depend on the proper description of the detector in the simulation. Therefore, the validation of the codes with calibration measurements will be an important step for future developments.

**THANKS!**