BRIKEN design, The UPC approach with MCNPX

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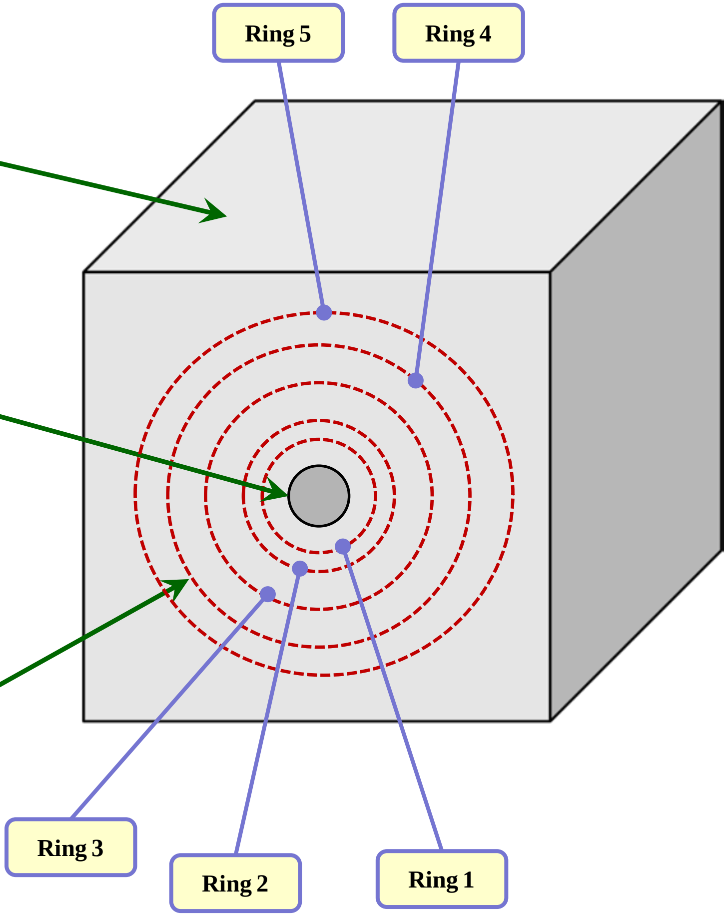
1. Geometry proposed

Polyethylene matrix :

Section: 90 cm x 90 cm
Length: 80 cm

Beam hole: 16 cm diameter

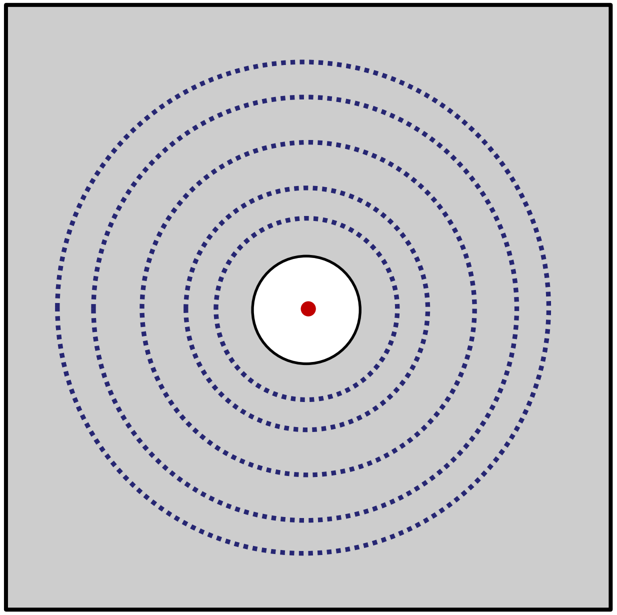
5 Concentric rings centered to the beam hole axis



2. Counters employed for the detector design

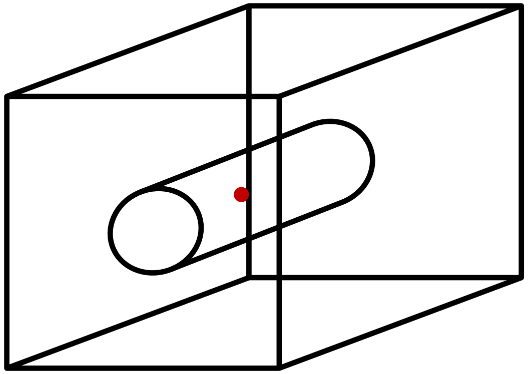
INSTITUTE	FILLING GAS	PRESSURE (atm)	DIMENSIONS Diameter (inch/cm)	DIMENSIONS Effective Length (inch/mm)	NUMBER OF COUNTERS
GSI	He-3	10	1 / 2.54	23.62/600	10
JINR	He-3	4	1.18 / 3.0	19.69/500	20
ORNL	He-3	10	2 / 5.08	24/609.6	58
	He-3	10	1 / 2.54	24/609.6	16
RIKEN	He-3	5.13	1 / 2.54	118.1/300	26
UPC	He-3	8	1 / 2.54	23.62/600	42
TOTAL					172

3. Simulations



Neutron source ●

- Point source
- Inside the beam hole
- Centered in the matrix
- Neutrons emitted in all directions (isotropic distribution)



Neutron energies simulated

- 0.0001 MeV
- 0.001 MeV
- 0.01 MeV
- 0.1 MeV
- 1 MeV
- 2 MeV
- 3 MeV
- 4 MeV
- 5 MeV

3. Simulations

Analysis done

- **Study of efficiency vs ring radii**, for 1 inch diameter counters at 8 atm
- **3 matrix configurations to obtain a flat efficiency.** One configuration for each maximum neutron energy of :
  - 1 MeV **---** Efficiency for **1-neutro**n emission and **2-neutron** emission
  - 3 MeV **---** Efficiency for **1-neutron** emission and **2-neutron** emission
  - 5 MeV **----** Efficiency for **1-neutron** emission and **2-neutro**n emission

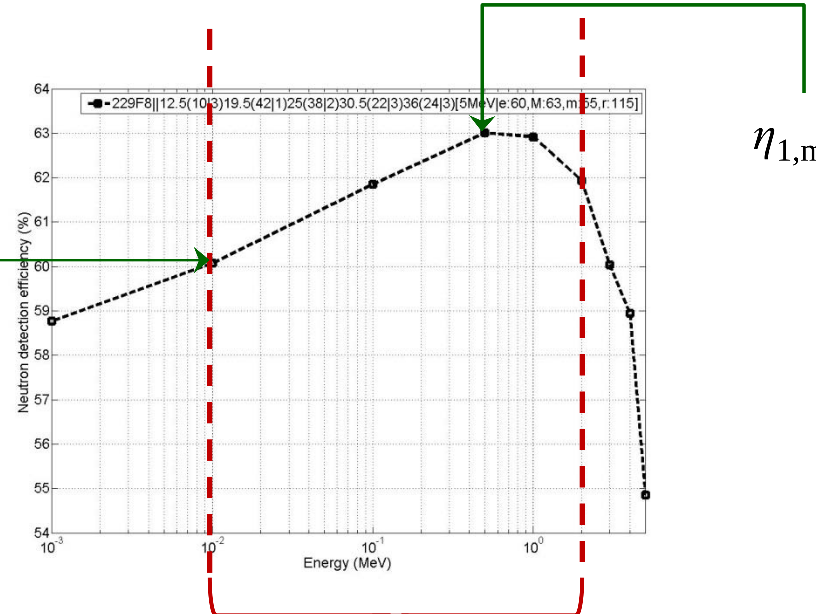
3. Simulations

Parameter used to define the planarity of neutron detection efficiency

Efficiency factor, F: The relation between the maximum efficiency, η_{max}, and the minimum efficiency, η_{min} ,at a defined interval of neutron energies

$$F = \frac{\eta_{max}}{\eta_{min}}$$

$\eta_{1,min}$



$\eta_{1,max}$

Example

Neutron energy interval : 10 keV – 2 MeV

$$F_1 = \frac{\eta_{1,max}}{\eta_{1,min}} = \frac{63.0}{60.1} = 1.048$$

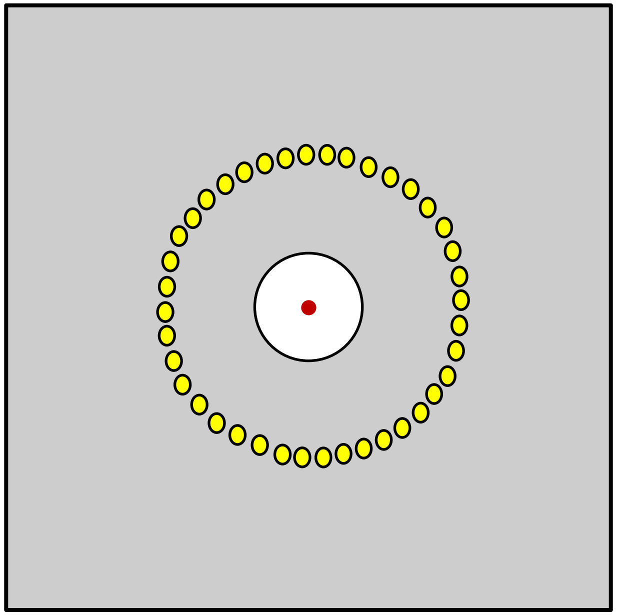
4. Results

4.1. Analysis of ring radii for 1” diameter counters at 8 atm

- This analysis consist on a single ring filled with ^{3}He counters at 8 atm and 1’’ diameter
- Each curve is related with a ring radii
- Ring radii variation from 11 cm (simulation 90F8) to 30 cm (simulation 110F8)
- Minimum distance between counters is 4 mm

As the ring radii increases, the efficiency decreases and the neutron energy at which the efficiency is maximum increases

90F8||11(24|1)[5MeV|e:39,M:61,m:17,r:356]
91F8||12(26|1)[5MeV|e:38,M:51,m:19,r:262]
92F8||13(28|1)[5MeV|e:34,M:43,m:21,r:204]
93F8||14(30|1)[5MeV|e:30,M:36,m:22,r:163]
94F8||15(33|1)[5MeV|e:25,M:31,m:18,r:175]
95F8||16(35|1)[5MeV|e:21,M:27,m:12,r:227]
96F8||17(37|1)[5MeV|e:17,M:24,m:8,r:307]
97F8||18(39|1)[5MeV|e:14,M:21,m:5,r:394]
98F8||19(42|1)[5MeV|e:12,M:19,m:4,r:509]
99F8||20(44|1)[5MeV|e:10,M:17,m:2,r:769]
100F8||21(46|1)[5MeV|e:8,M:16,m:1,r:1092]
101F8||22(48|1)[5MeV|e:7,M:14,m:1,r:1472]
102F8||22(47|1)[5MeV|e:7,M:14,m:1,r:1441]
103F8||23(50|1)[5MeV|e:5,M:12,m:1,r:1966]
104F8||24(52|1)[5MeV|e:4,M:11,m:0,r:2782]
105F8||25(54|1)[5MeV|e:4,M:10,m:0,r:4092]
106F8||26(56|1)[5MeV|e:3,M:8,m:0,r:5493]
107F8||27(58|1)[5MeV|e:2,M:5,m:0,r:11625]
108F8||28(60|1)[5MeV|e:1,M:4,m:0,r:11667]
109F8||29(63|1)[5MeV|e:1,M:2,m:0,r:24500]
110F8||30(65|1)[5MeV|e:1,M:2,m:0,r:Inf]



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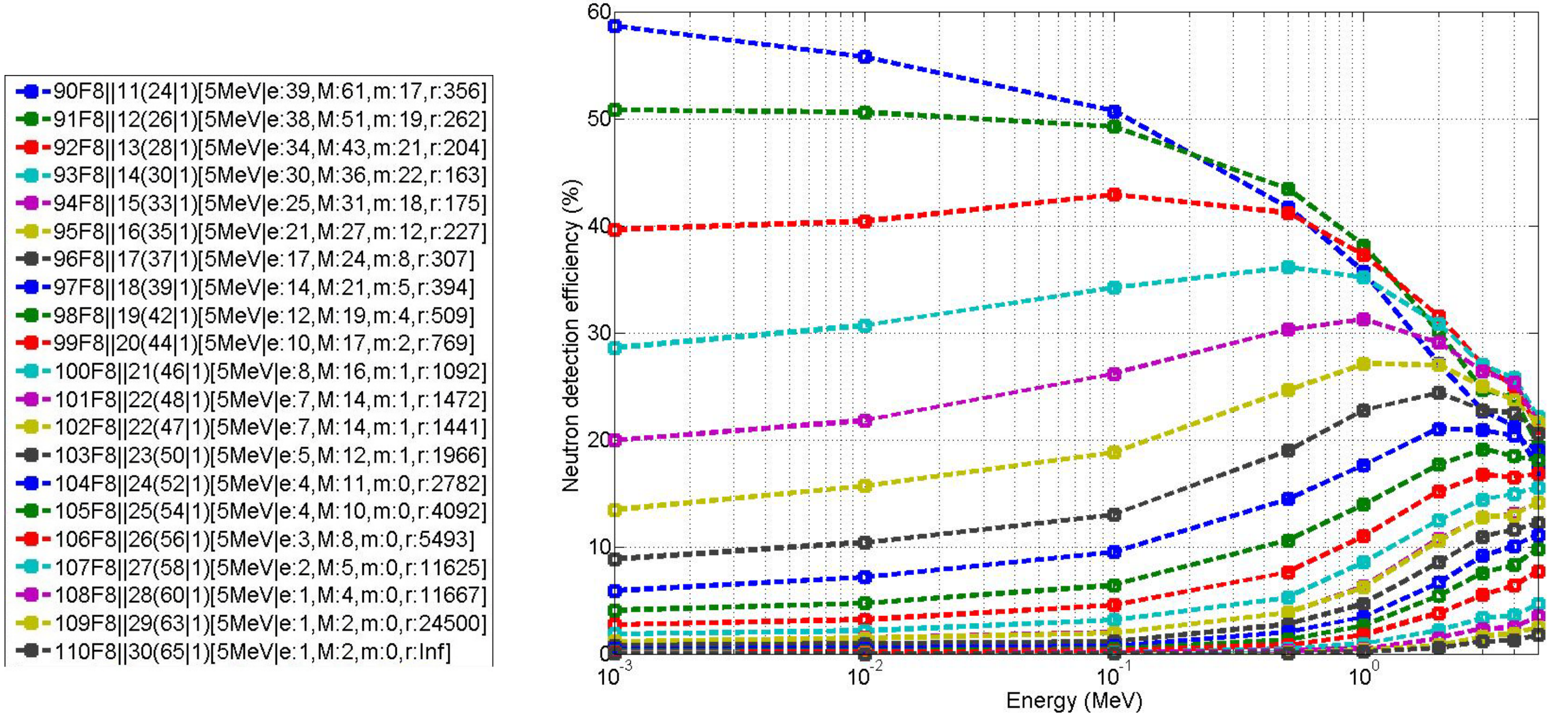
As the ring radii increases, the efficiency decreases and the neutron energy at which the efficiency is maximum increases



4. Results

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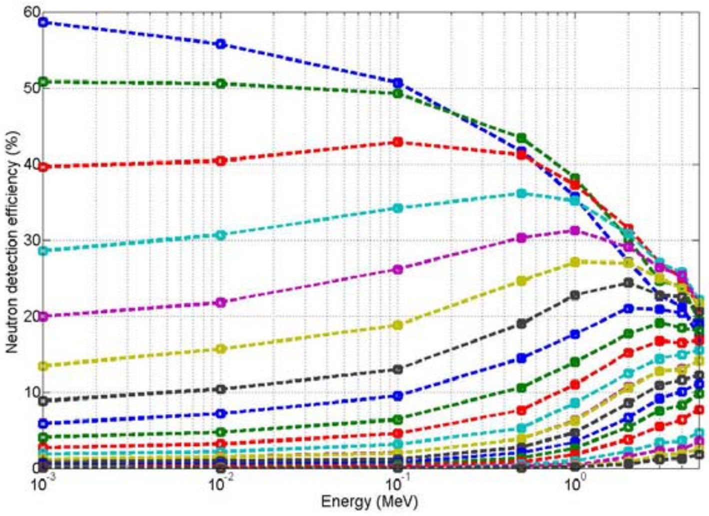
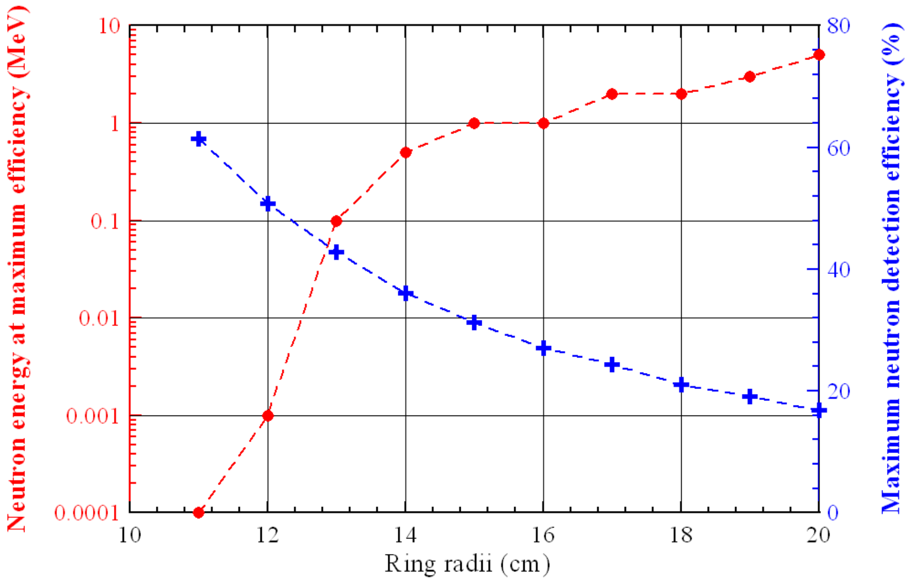
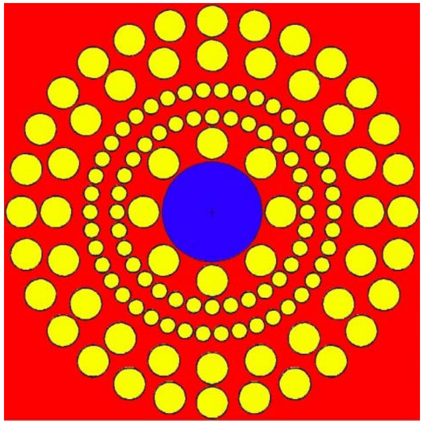


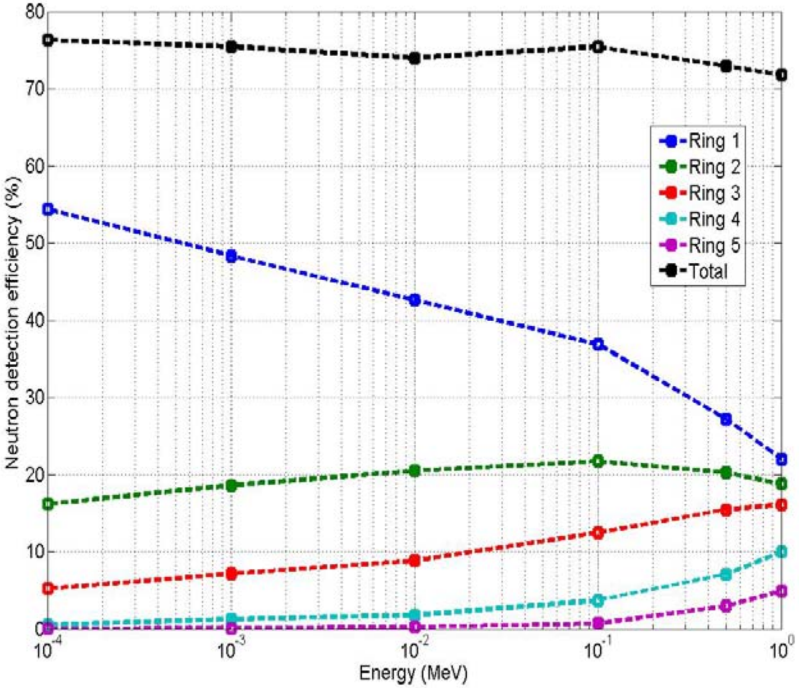


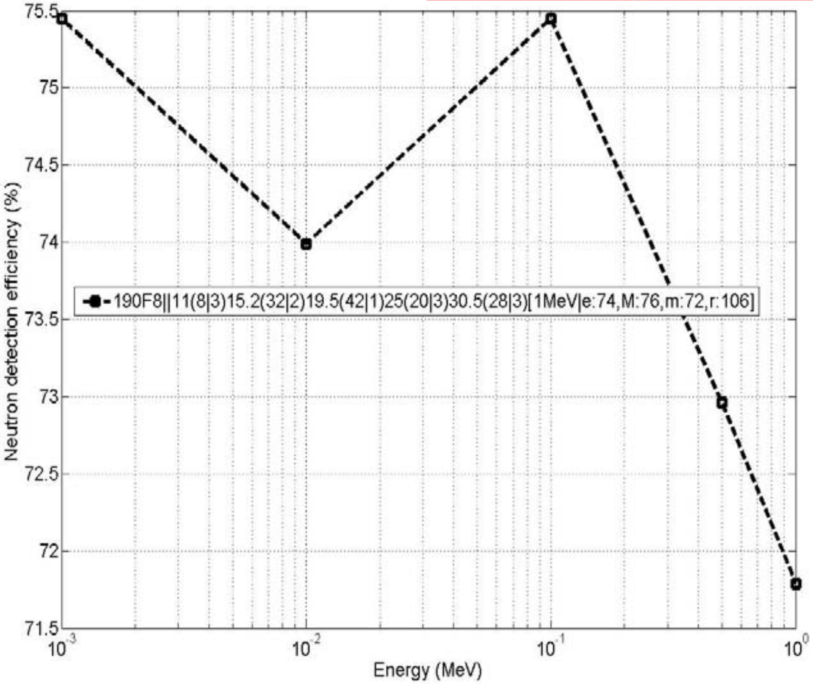
4.2 1-neutron emission. Configuration for max. neutron energies of 1 MeV

Ring	Radii (cm)	Number of counters	Pressure (atm)	Diameter (inch)	Institute
1	11	8	10	2	ORNL
2	15.2	10+13x2+9	8/5.13/4	1/1.18	GSI+RIKEN+JINR
3	19.5	42	8	1	UPC
4	25	20	10	2	ORNL
5	30.5	28	10	2	ORNL

143 ^{3}He counters

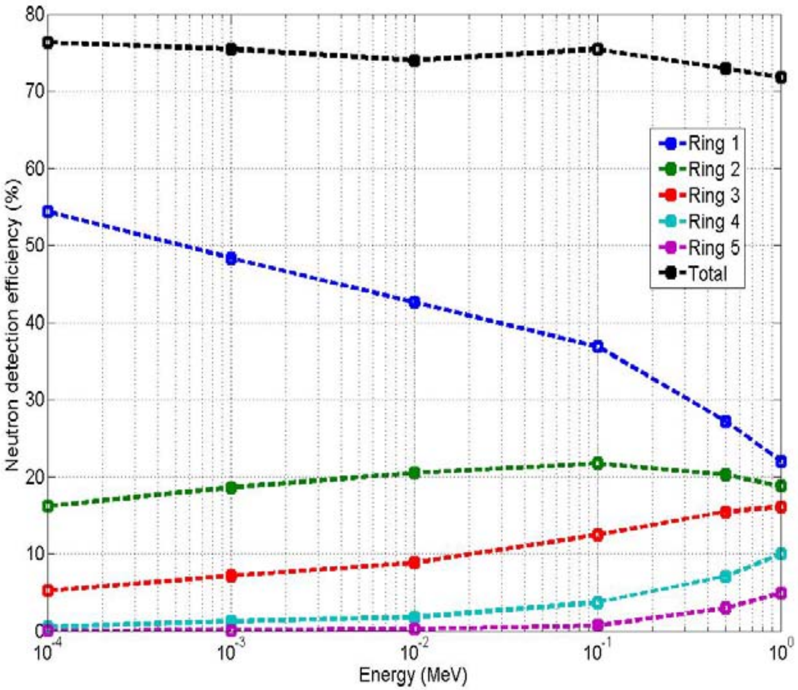


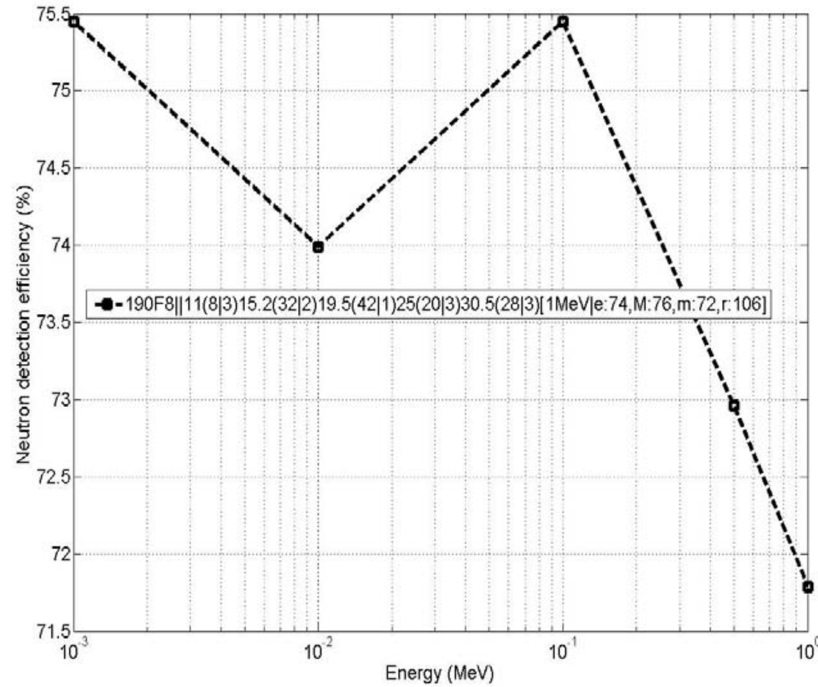




4.2 1-neutron emission. Configuration for max. neutron energies of 1 MeV

Neutron energy interval		Maximum efficiency (%)	Minimum efficiency (%)	Mean efficiency (%)	Efficiency factor, *F*
Minimum neutron energy	**Maximum neutron energy**				
0.1 keV	1 MeV	76.4	72.0	74.5	1.061
1 keV	1 MeV	75.6	72.0	74.1	1.050
0.1 keV	0.5 MeV	75.5	73.1	74.9	1.033

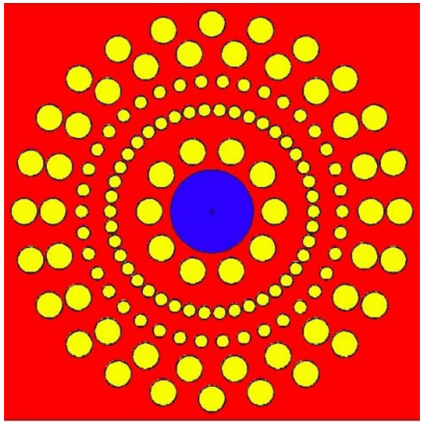


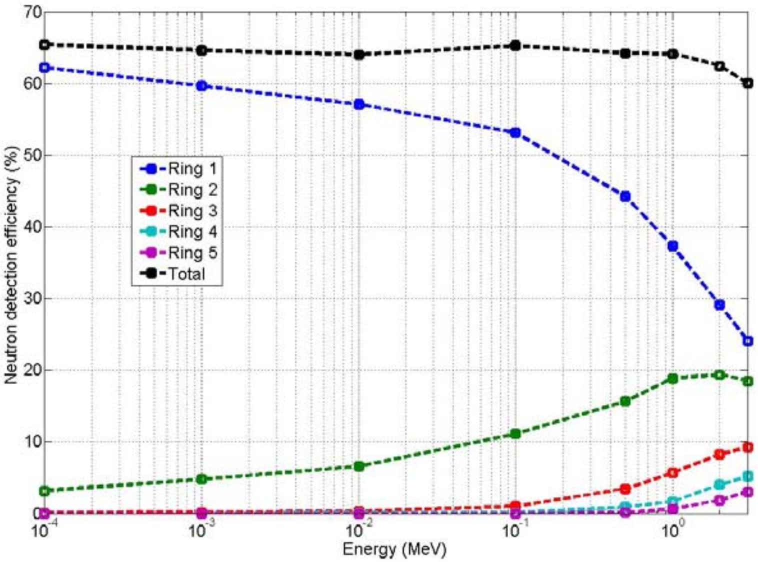


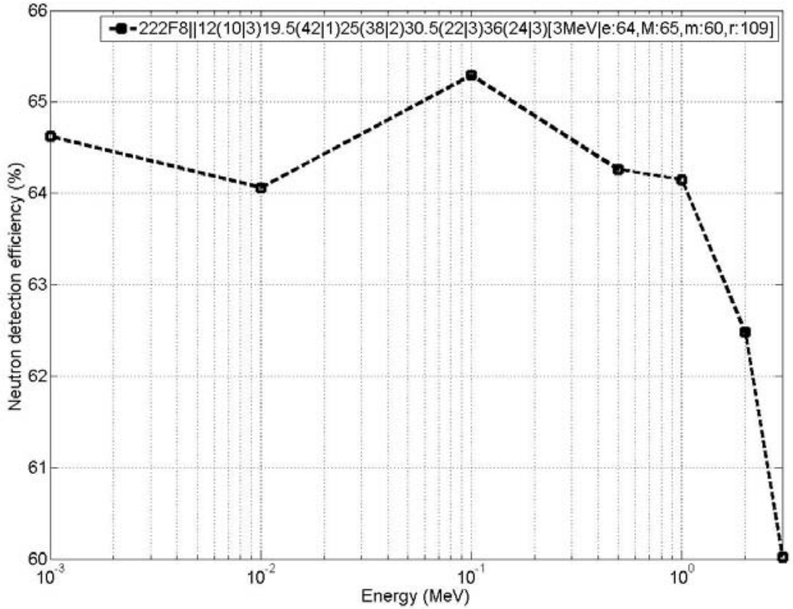
4.3 1-neutron emission. Configuration for max. neutron energies of 3 MeV

Ring	Radii (cm)	Number of counters	Pressure (atm)	Diameter (inch)	Institute
1	12.0	10	10	2	ORNL
2	19.5	42	8	1	UPC
3	25.0	10+13x2+15	8/5.13/4	1/1.18	GSI+RIKEN+JINR
4	30.5	22	10	2	ORNL
5	36.0	24	10	2	ORNL

149 ^{3}He counters

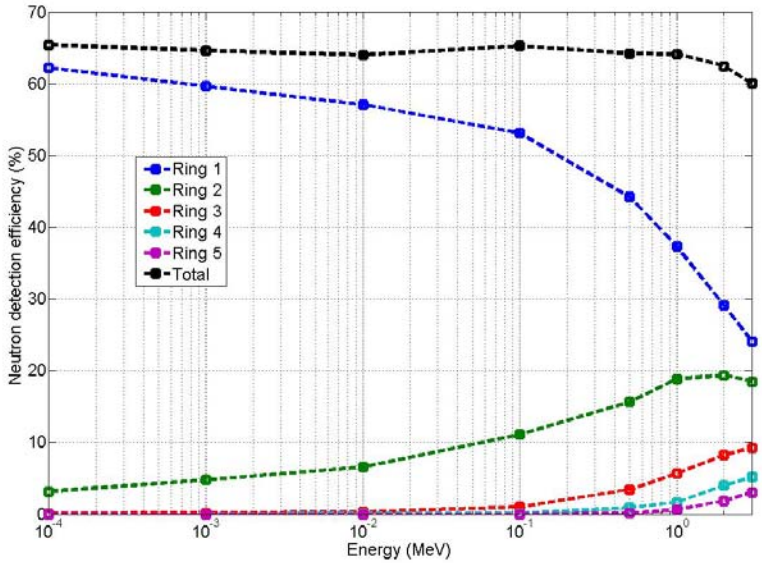


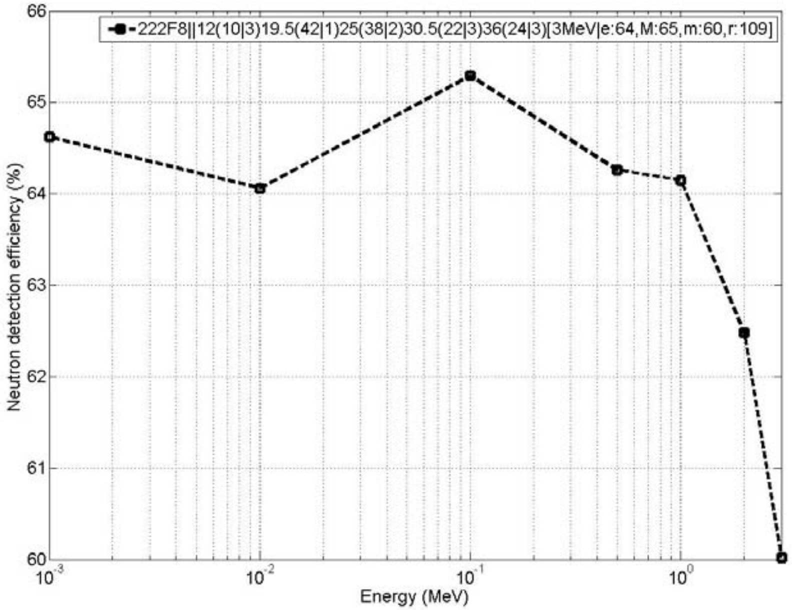




4.3 1-neutron emission. Configuration for max. neutron energies of 3 MeV

Neutron energy interval		Maximum efficiency (%)	Minimum efficiency (%)	Mean efficiency (%)	Efficiency factor, *F*
Minimum neutron energy	Maximum neutron energy				
0.1 keV	3 MeV	65.4	60.0	63.8	1.090
0.1 keV	2 MeV	65.4	62.5	64.3	1.047
0.1 keV	1 MeV	65.4	64.1	64.6	1.022

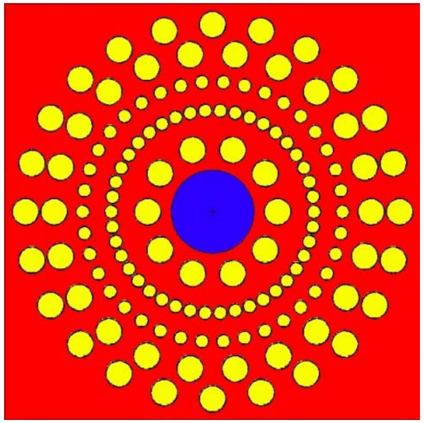


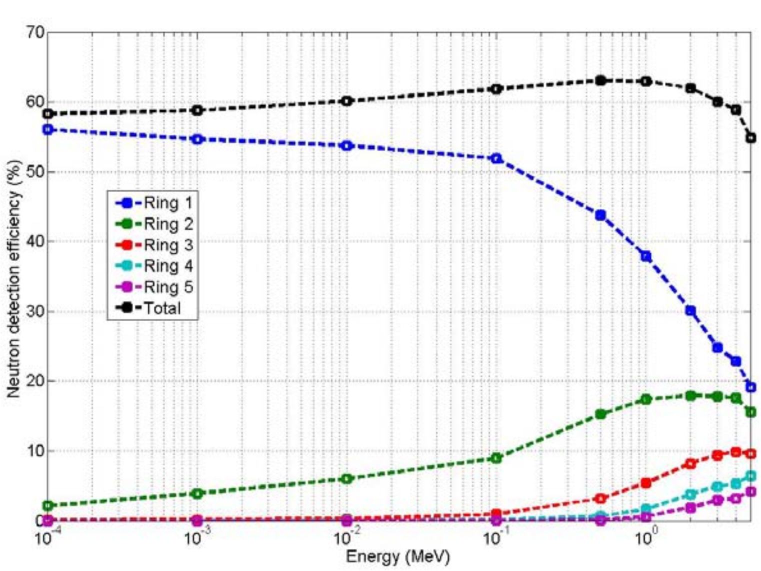


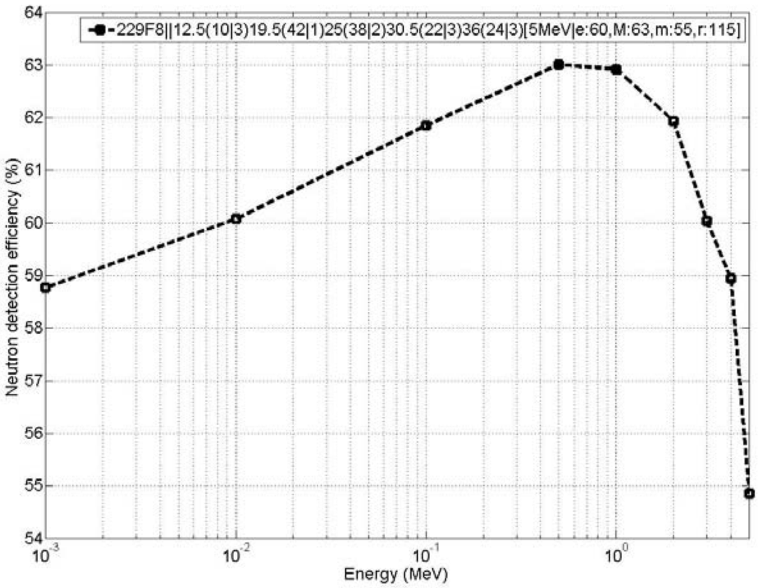
4.4 1-neutron emission. Configuration for max. neutron energies of 5 MeV

Ring	Radii (cm)	Number of counters	Pressure (atm)	Diameter (inch)	Institute
1	12.5	10	10	2	ORNL
2	19.5	42	8	1	UPC
3	25.0	10+13x2+15	8/5.13/4	1/1.18	GSI+RIKEN+JINR
4	30.5	22	10	2	ORNL
5	36.0	24	10	2	ORNL

149 ^{3}He counters

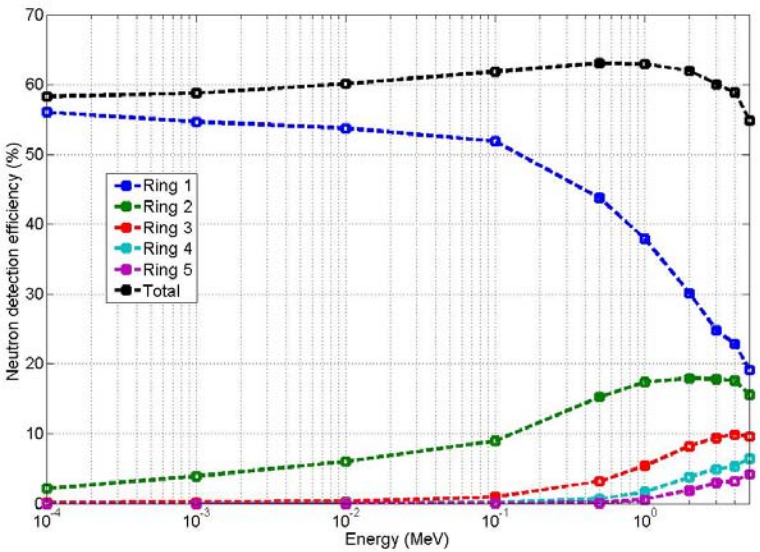


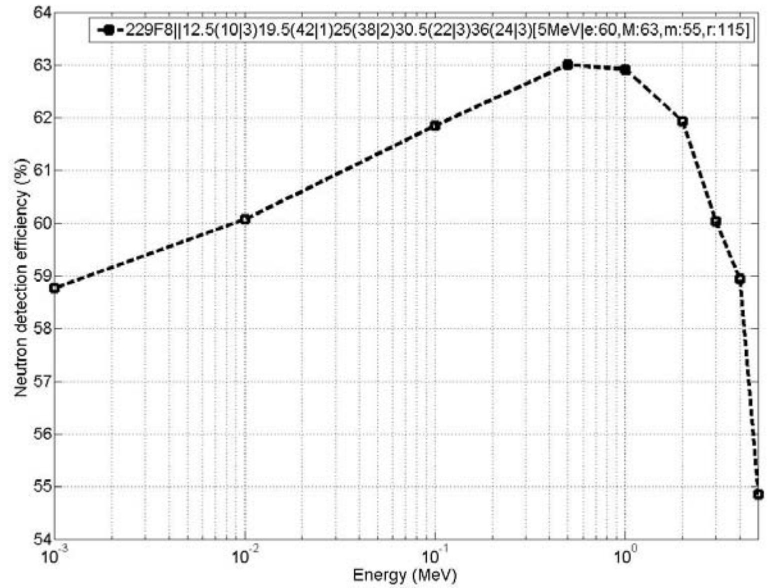




4.4 1-neutron emission. Configuration for max. neutron energies of 5 MeV

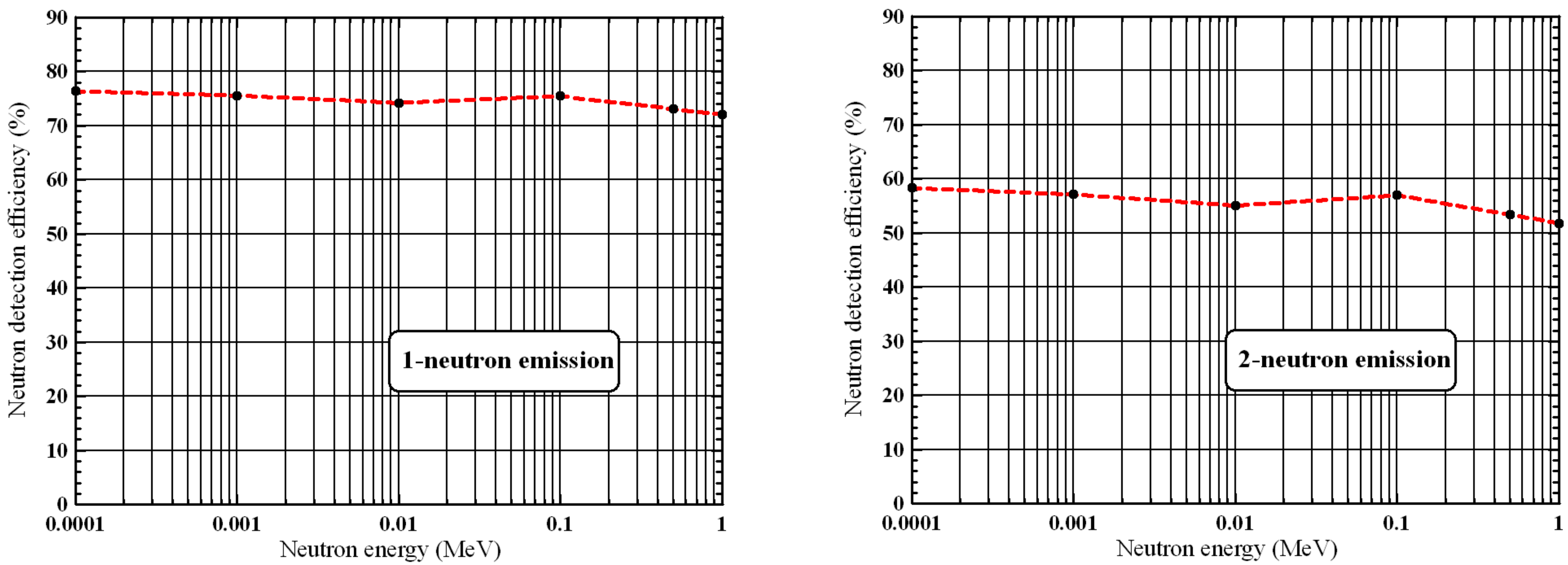
Neutron energy interval		Maximum efficiency (%)	Minimum efficiency (%)	Mean efficiency (%)	Efficiency factor, *F*
Minimum neutron energy	**Maximum neutron energy**				
0.1 keV	**5 MeV**	**63.0**	**58.3**	**60.9**	**1.080**
0.1 keV	**4 MeV**	**63.0**	**58.3**	**60.7**	**1.080**
0.1 keV	**3 MeV**	**63.0**	**58.3**	**60.9**	**1.080**
0.1 keV	**2 MeV**	**63.0**	**58.3**	**61.0**	**1.080**





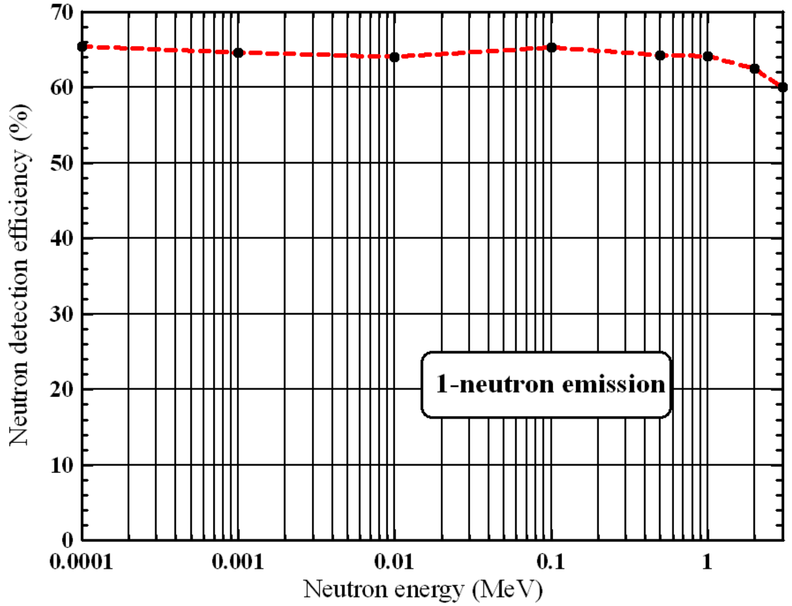
4.5 2-neutron emission. Configuration for max. neutron energies of 1 MeV

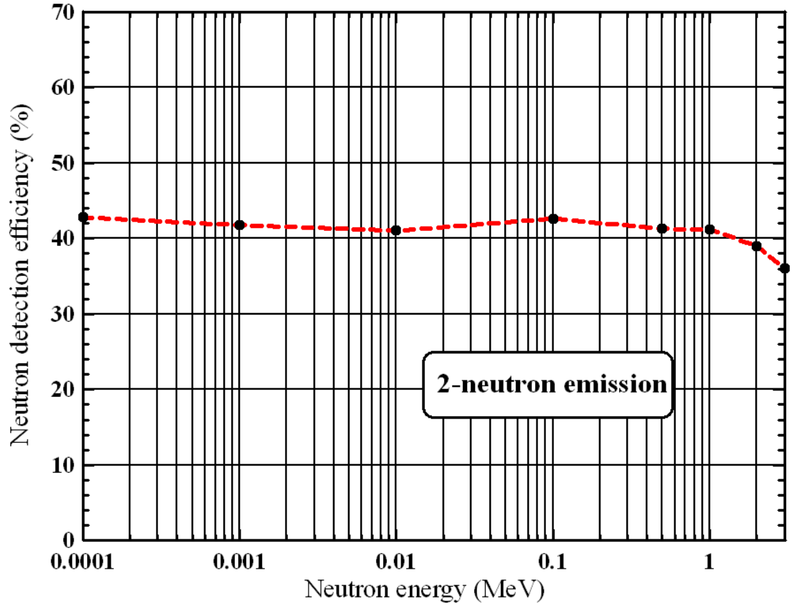
Neutron energy interval		Maximum efficiency (%)	Minimum efficiency (%)	Mean efficiency (%)	Efficiency factor, *F*
Minimum neutron energy	Maximum neutron energy				
0.1 keV	1 MeV	58.3	51.8	55.5	1.125
1 keV	1 MeV	57.1	51.8	54.9	1.102
0.1 keV	0.5 MeV	58.3	53.4	56.2	1.092



4.6 2-neutron emission. Configuration for max. neutron energies of 3 MeV

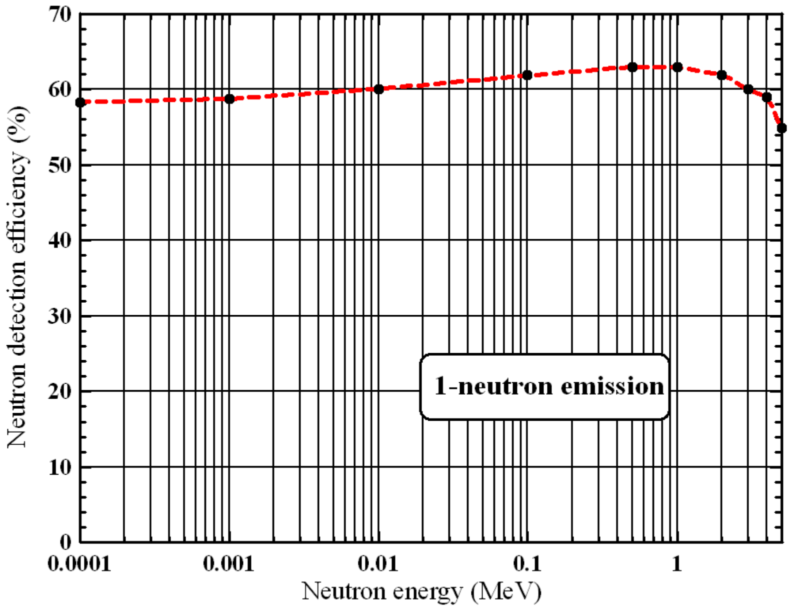
Neutron energy interval		Maximum efficiency (%)	Minimum efficiency (%)	Mean efficiency (%)	Efficiency factor, *F*
Minimum neutron energy	Maximum neutron energy				
0.1 keV	3 MeV	42.8	36.0	40.7	1.189
0.1 keV	2 MeV	42.8	39.0	41.4	1.097
0.1 keV	1 MeV	42.8	41.0	41.8	1.044

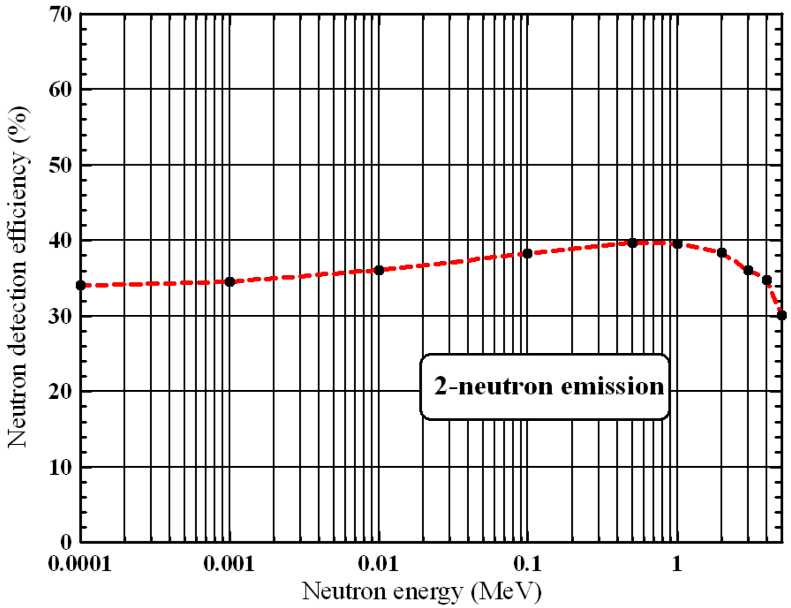




4.7 2-neutron emission. Configuration for max. neutron energies of 5 MeV

Neutron energy interval		Maximum efficiency (%)	Minimum efficiency (%)	Mean efficiency (%)	Efficiency factor, *F*
Minimum neutron energy	Maximum neutron energy				
0.1 keV	5 MeV	39.7	30.1	36.2	1.319
0.1 keV	4 MeV	39.7	34.0	36.8	1.168
0.1 keV	3 MeV	39.7	34.0	37.1	1.168
0.1 keV	2 MeV	39.7	34.0	37.2	1.168
0.1 keV	1 MeV	39.7	34.0	37.0	1.168





5. Conclusions

- Polyethylene matrix of 90 cm x 90 cm and 80 cm length for neutron moderation
- We have employed 143 to 149 He-3 counters at different pressures, diameters and length
- He-3 counters distributed in 5 concentric rings
- Optimization of the neutron detection efficiency to obtain a high and flat efficiency
- 3 geometries for 3 maximum neutron energies: 1 MeV, 3 MeV and 5 MeV
- The mean efficiencies and efficiency factors for 1-n emission are:
  - Max neutron energy of 1 MeV: $\eta = 74.5$ % & F= 1.061
  - Max neutron energy of 3 MeV: $\eta = 63.8$ % & F= 1.090
  - Max neutron energy of 5 MeV: $\eta = 60.9$ % & F= 1.080
- The mean efficiencies and efficiency factors for 2-n emission are:
  - Max neutron energy of 1 MeV: $\eta = 55.5$ % & F= 1.125
  - Max neutron energy of 3 MeV: $\eta = 40.7$ % & F= 1.189
  - Max neutron energy of 5 MeV: $\eta = 36.2$ % & F= 1.319
- Possibility to define new geometries to optimize the neutron detection efficiency for higher neutron energies than 5 MeV
- Possibility to optimize the geometries shown in this presentation to increase the mean efficiency

Thank you for your attention