Neutron and energy distribution in massive uranium target irradiated by high energy ion beams

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- **Aim and conditions of the simulations**
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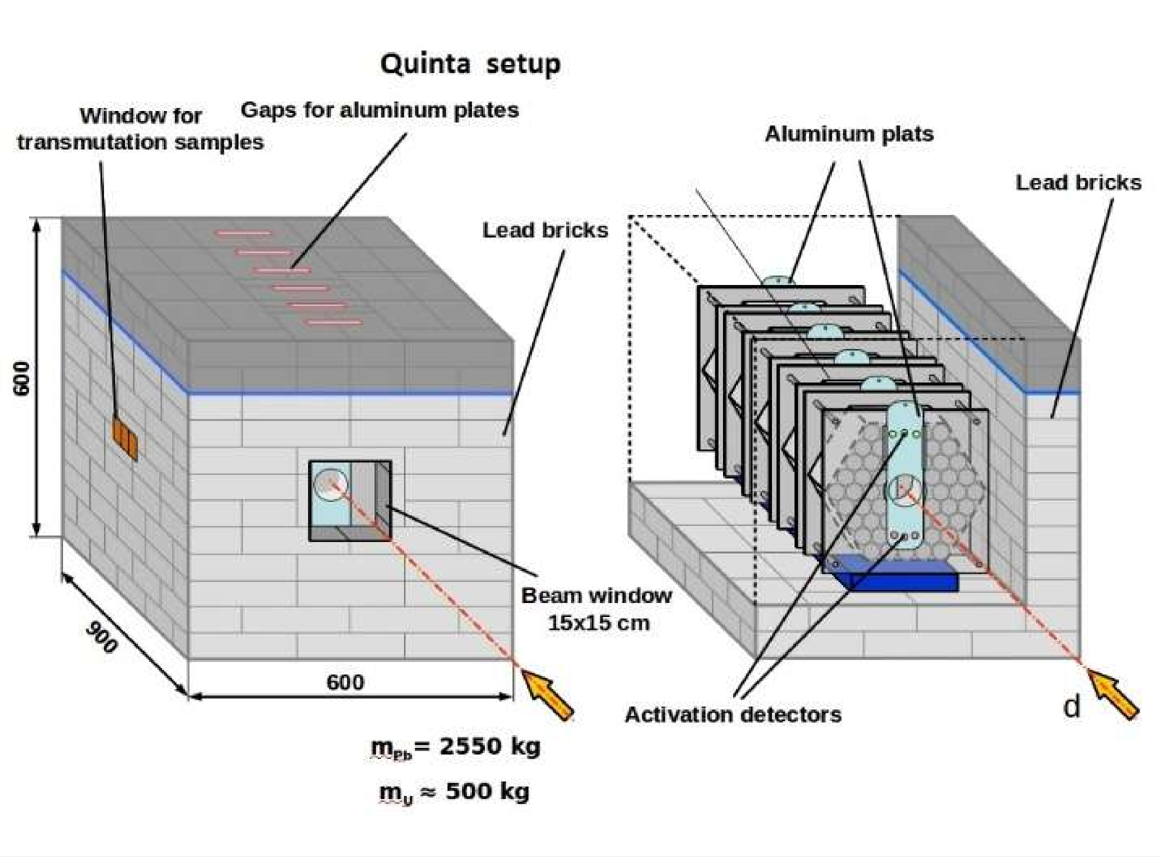
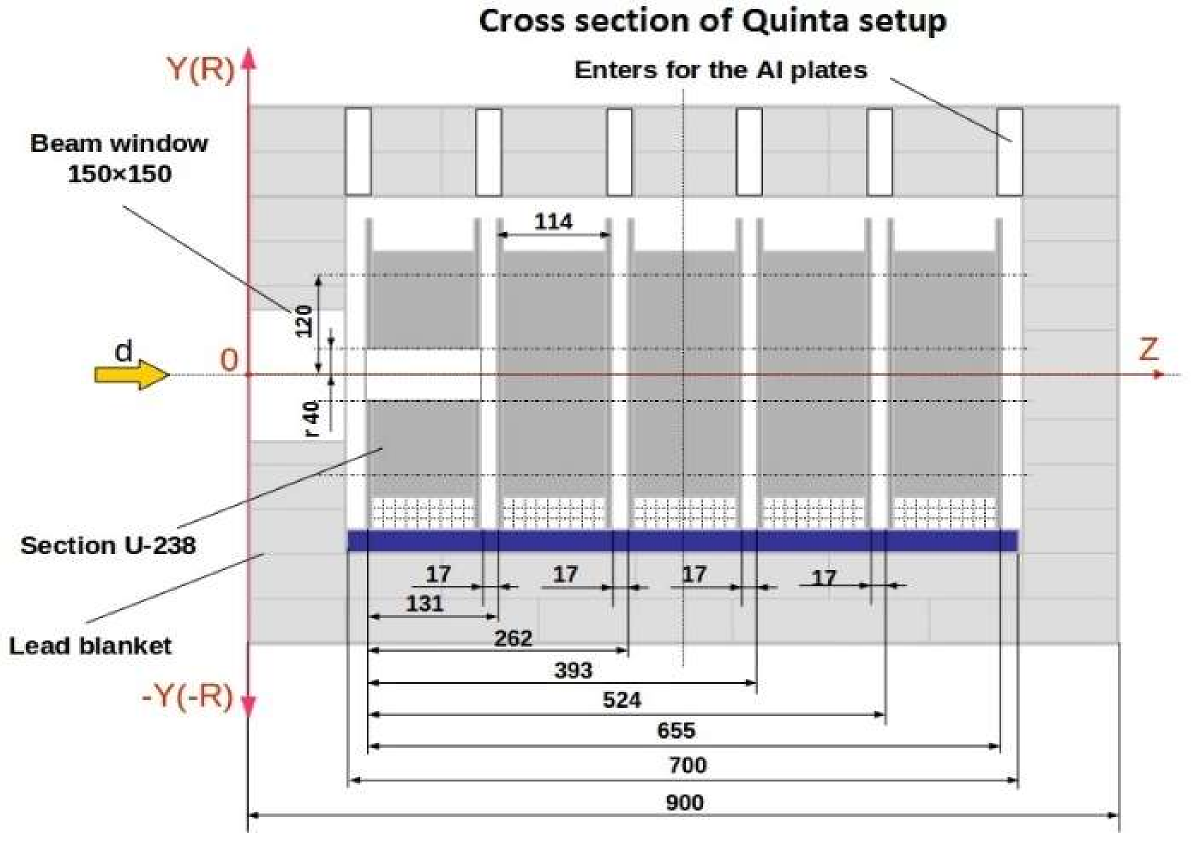
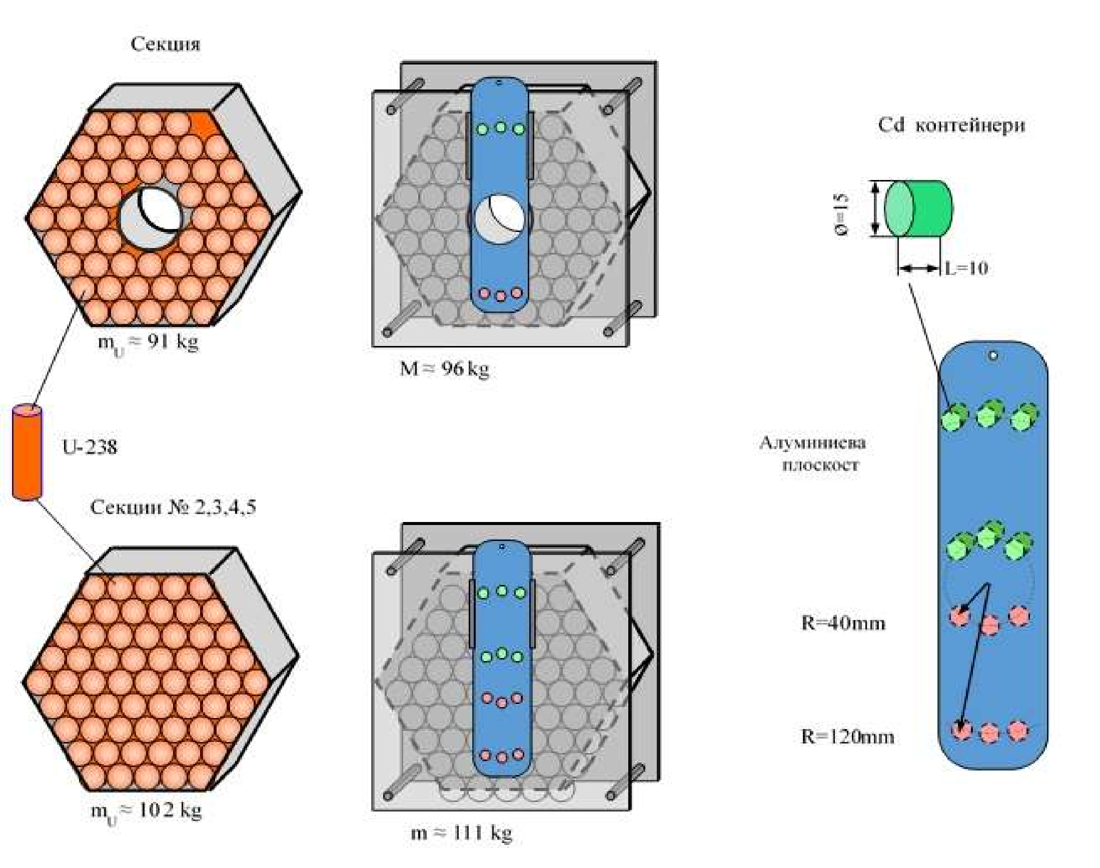
Quinta experimental set up





Quinta set up sections

The first section has a beam window. Al – plates are 2 mm thick



^{nat}U – detectors – d_i located on all six aluminum plates at a distance form the Quinta axis Z, R=0, 4, 8 and 12 cm

AIM OF THE SIMULATIONS

What can we measure in Quinta set up?

1. fissU, $(n,\gamma)^{238}U$, $(n,2n)^{238}U$ reactions in ^{nat}U detectors.

What can't we measure in Quinta set up?

1. The average neutron energy $<E_n>$ in the ^{nat}U activation detectors and uranium rods in the sections
2. The neutron induced reactions in the uranium rods and Eion dep. energy in detectors and rods.

Can we make an approximation and an estimation of the neutron induced reactions in the uranium rods (sections) based on ^{nat}U activation detectors?

Can we measure ionization + fission deposition energy in ^{nat}U activation detectors placed between sections in Quinta set up?

Estimation of detectors distribution, locations and conditions of measurements of neutron induced reactions in and far from the central part of the quasi infinity BURAN set up (20 tons of depleted uranium) - approximately 40-50% of E_{fiss} in Buran set up is in the central part cylinder D=20, L=80cm and 25% is in cylinder D=20 L=30cm

SIMULATIONS

1. **Distribution of fission energy deposition in rods (sections) and ^{nat}U activation detectors induced by neutrons.**
2. **Distribution of ionization energy deposition (protons, deuterons, pions, electrons and heavy ions) in rods (sections) and ^{nat}U activation detectors.**
3. **Calculation of average neutron energy $\langle E_n \rangle$ in rods and ^{nat}U detectors.**
4. **Comparison of the reaction rates in ^{nat}U detectors and in the rods between them**
5. **Neutron and energy leakage from Quinta set up**

Simulation conditions

MCNPX .27 transport code, ENDF70, INCL4 and LAQGSM nuclear models

For more accurate conclusions the beam parameters are the same for all simulations

The average neutron energy <E$_n$> [MeV] in rods placed on R=0cm and R=12cm for five sections and E_d=1,2,4 and 8 GeV and E_c=24 and 48 GeV energies

R(0)/R(12)	E_d=1GeV	E_d=2GeV	E_d=4GeV	E_d=8GeV	E_c=24GeV	E_c=48GeV
1st section	--/0.71	--/0.72	--/0.75	--/0.77	--/0.78	--/0.77
2nd section	14/1.1	17/1.1	20/1.2	28/1.2	24/1.2	29/1.2
3th section	11.5/1.7	17/1.67	21/1.7	27/1.73	17.8/1.8	23/1.66
4th section	7/1.8	11/1.73	16/1.8	17.5/1.74	10.5/2	14/1.86
5th section	5/1.7	7.8/1.84	12/1.9	11.6/1.8	7.5/2	9.8/2

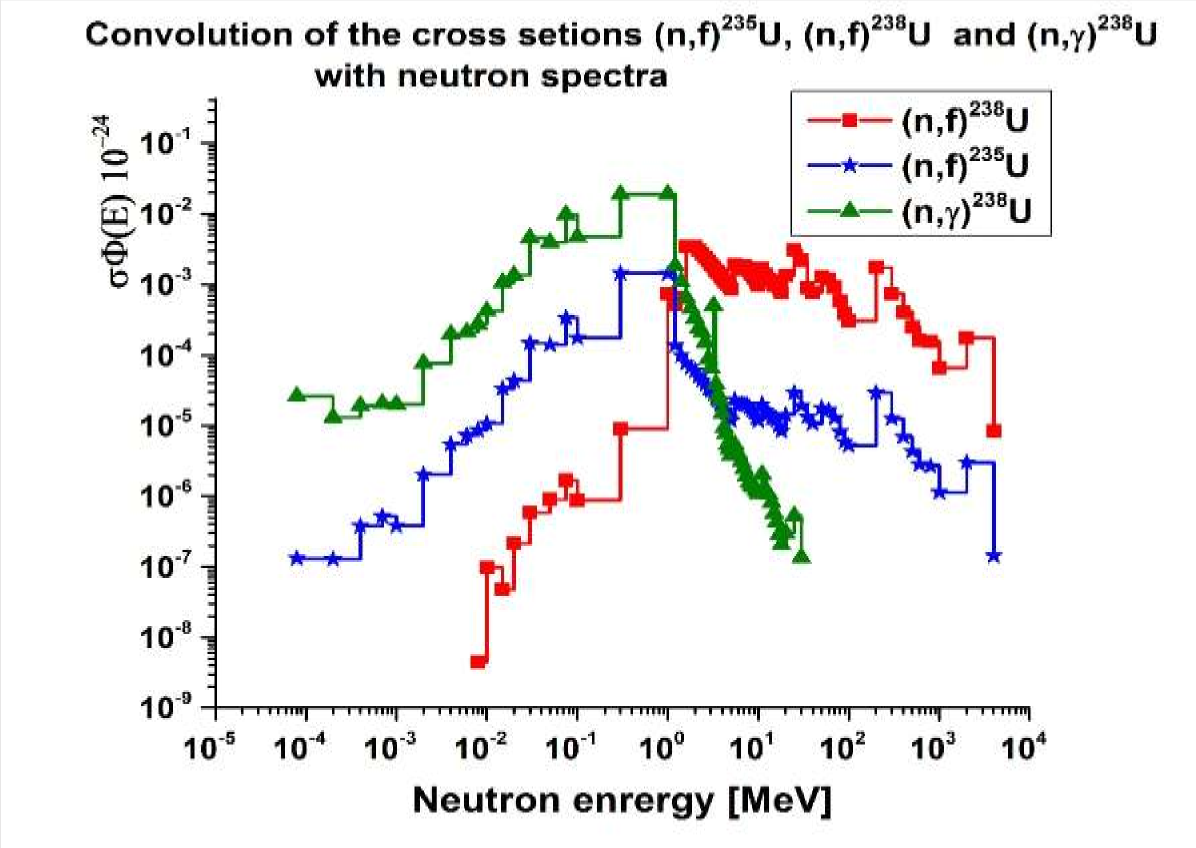
The average neutron energy <E_n> [MeV] in ^{nat}U detectors placed on the Al – plates for deuteron beam with energy E_d= 2, **4** and 8 GeV

R	1st plate	2nd plate	3th plate	4th plate	5th plate	6th plate
0 cm	//	8/**8.5**/9.6	24/ **32**/44	12.6/**24**/27	7.9/**16**/15	6.9/**14**/13.2
4 cm	1.1/**1.2**/1.7	1.9/**1.8**/2.1	4.9/**4.8**/5.7	5/**4.5**/5.6	4.8/**4.5**/5.6	5.3/**5.6**/6.9
8 cm	0.8/**0.86**/0.8	1.3/**1.2**/1.2	2.3/**2.3**/2.2	2.6/**2.5**/2.4	2.6/**2.4**/2.4	3/**2.8**/3.1
12 cm	0.7/**0.72**/0.6	1/**1**/1	1.7/**1.6**/1.5	1.9/**1.8**/1.7	2/**2**/1.8	2.2/**2.1**/2.15

Ionization and fission energy deposition E_{ion}/E_{fiss} [10^4eV/gr/particle] in ^{nat}U detectors placed on central axis Z (R=0cm) for E_d=1,2,4 and 8 GeV and E_c=24 и 48 GeV

E_{ion}/E_{fiss}	E_d=1GeV	E_d=2GeV	E_d=4GeV	E_d=8GeV	E_c=24GeV	E_c=48GeV
2nd plate	25/4.1	25/4.7	32/7	40/10	610/11	780/22
3th plate	10/3	14/5.3	20/8.5	31/15.8	180/25	280/65
4th plate	2/1	4.1/2.3	7.5/4.2	11/9.3	38/16.4	68/38
5th plate	0.2/0.32	1/0.96	2.5/2	4.4/5.3	5.7/10	19/19
6th plate	0.06/0.1	0.3/0.35	0.8/0.87	1.8/2.4	1.8/4.5	6.5/7.8

Convolution of the reactions $(n,f)^{235,238}U$ и $(n,\gamma)^{238}U$ for natural uranium detector placed on the third Al - palate R=4 cm and E_d=2GeV



Fission and ionization energy deposition [GeV/particle] in every section of Quinta set up for deuteron beam E_d=1, 2, 4 and 8 GV and carbon beam E_c=24 and 48 GeV

	E_d =1GeV	E_d=2GeV	E_d=4GeV	E_d=8GeV	E_c=24GeV	E_c=48GeV
1st	0.1/0.03	0.2/0.04	0.31/0.06	0.48/0.12	1/0.3	2.2/0.51
2nd	0.70/0.58	1.3/0.81	2/1.1	3.1/1.6	6.6/10	15/16
3th	0.51/0.32	1.1/0.57	2/0.91	3.4/1.57	7.3/5.5	16/10
4th	0.28/0.08	0.68/0.3	1.4/0.63	2.7/1.2	5.6/2.8	11.1/6
5th	0.13/0.04	0.37/0.15	0.9/0.38	1.8/0.8	3.42/1.2	6.4/3.2
sum	1.72/1.05	3.65/1.87	6.61/3.08	11.48/5.29	23.92/19.8	50.7/35.7

Distribution of (n,γ)^{238}U reaction in all sections for deuterons with E_d= 2, 4 и 8 GeV, and carbon beam with energies E_c=24 и 48 GeV

$E_{d,c}$ [MeV]	2	4	8	24	48
1 - section	2,3	3,7	5,93	11,9	26,6
2- section	6,1	10,2	16,7	33,7	75,7
3 – section	6,15	11,4	19,8	39,8	87,8
4 – section	4,5	9,1	16,9	33,3	68,5
5 - section	2,6	5,74	11,2	21,1	41,6
sum	22	40	51	140	300

Ratio of (n,f)^{nat}U and capture reactions in the cylinders and detectors for E_d=8GeV

$^{nat}U(n,f)_{cyl}/\langle ^{nat}U(n,f)_{det}\rangle$ and $^{238}U(n,\gamma)_{cyl}/\langle ^{238}U(n,\gamma)_{det}\rangle$

R=0 and 12 cm	2nd section	3th section	4th section	5th section
$^{nat}U(n,f)$/gr.	3.3/0.8	1.5/0.9	1.4/0.9	1.3/0.91
$^{238}U(n,\gamma)$/gr.	1.9/0.95	1.3/0.93	1.2/0.92	1.2/0.94

Reaction rate ratio in rods and average for the two detectors placed on the both sides of the rod

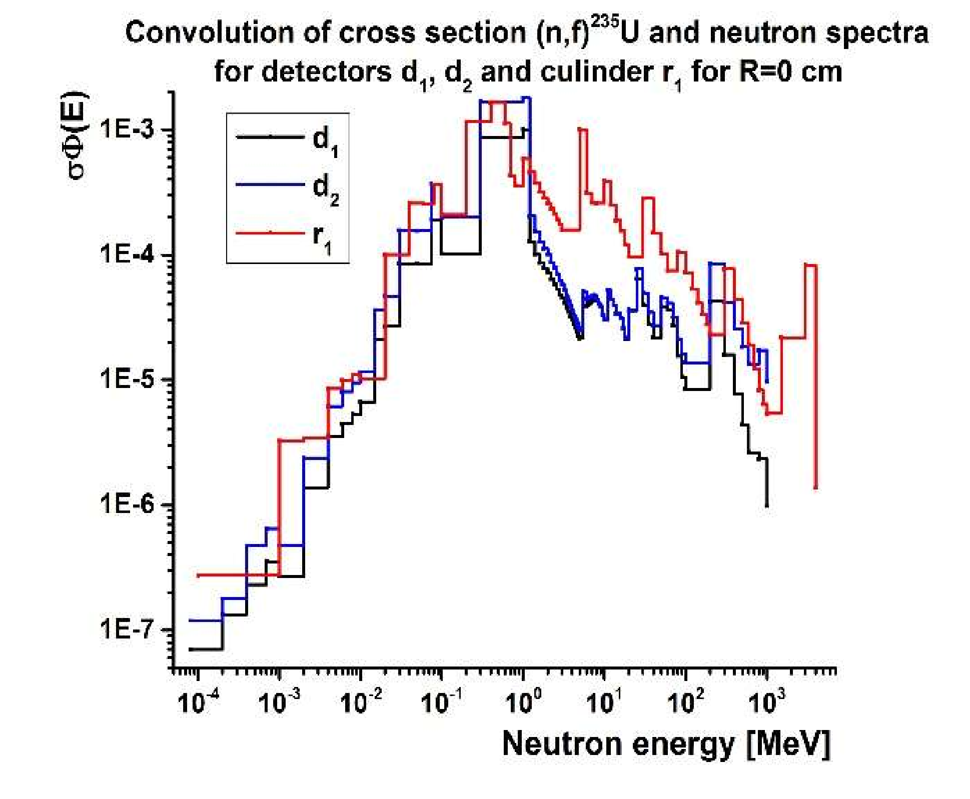
R=12cm Ep=660MeV 2rod/(d1+d2)

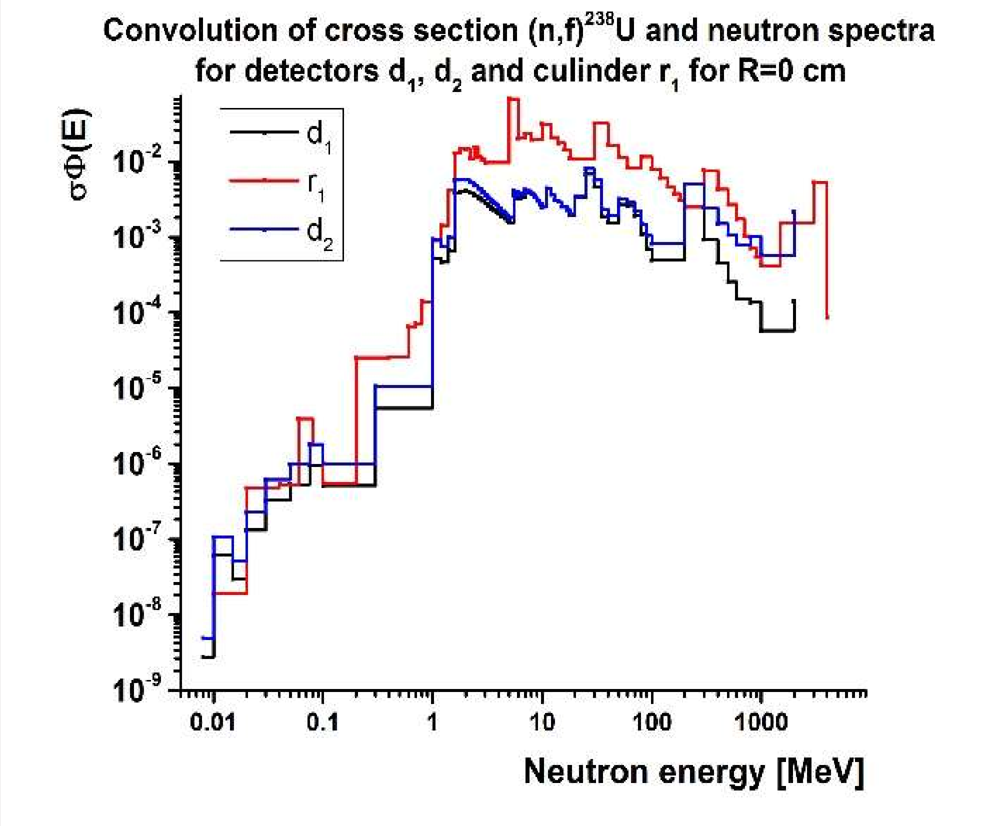
Sections	1	2	3	4	5
$(n,\gamma)^{238}U$	0.96	1.04	1.00	0.99	1.01
$(n,f)^{nat}U$	0.79	0.93	0.98	0.98	1.03

R=0cm Ep=660MeV 2rod/(d1+d2)

Sections	2	3	4	5
$(n,\gamma)^{238}U$	2.2	1.2	1.0	1.0
$(n,f)^{nat}U$	2.5	1.1	0.9	1.0

Convolution of reactions (n,f) ^{235}U and (n,f)^{238}U in detectors d1, d2 and rod r1 placed on the second and third Al – plates and the second section respectively (R = 0cm), E_d=2GeV





Neutron leakage and energy losses from Quinta set up

GeV	E_d=1	E_d=2	E_d=4	E_d=8	E_c=24	E_c=48
N_{escape}	51	101	160	315	690	1430
E_0 x10^5 [MeV]	0.47	0.95	1.6	2.95	6.51	13.4
E_{kin} [MeV]	95	230	500	941	1760	4040
$N_{(En>1.4MeV)}$/(MeV)	6.7(76)	14(190)	25(435)	46 (820)	100(1500)	210(3500)
$N_{(En>30MeV)}$ /(MeV)	0.5(53)	1.2(142)	2.3(345)	4 (650)	8(1140)	18(2740)

$N_{(En>30MeV)}/N_{esc.}$ = 0.01 - 0.013
$E_{kin}/E_{kin.esc.}$= 0.55 (E_d=1GeV) and 0.7 E_d=8 GeV

$N_{(En>1.4MeV)}/N_{esc.}$ = 0.13
$E_{kin}/E_{kin.esc.}$= 0.8 - 0.85

C o n c l u s I o n s

- The air gaps between section paly significant role for neutron spectra and flux.
- The average neutron spectra's calculated in natU detectors placed on the Z axis (R=0cm) are higher in comparison with uranium rods placed between detectors.
- For the central part of Quinta the neutron flux in natU detectors is less than in rods placed between detectors.
- Reconstruction of neutron induced reaction in rods from the central part of the Quinta by uranium activation detectors is not simple task.

Thank you for your attention!