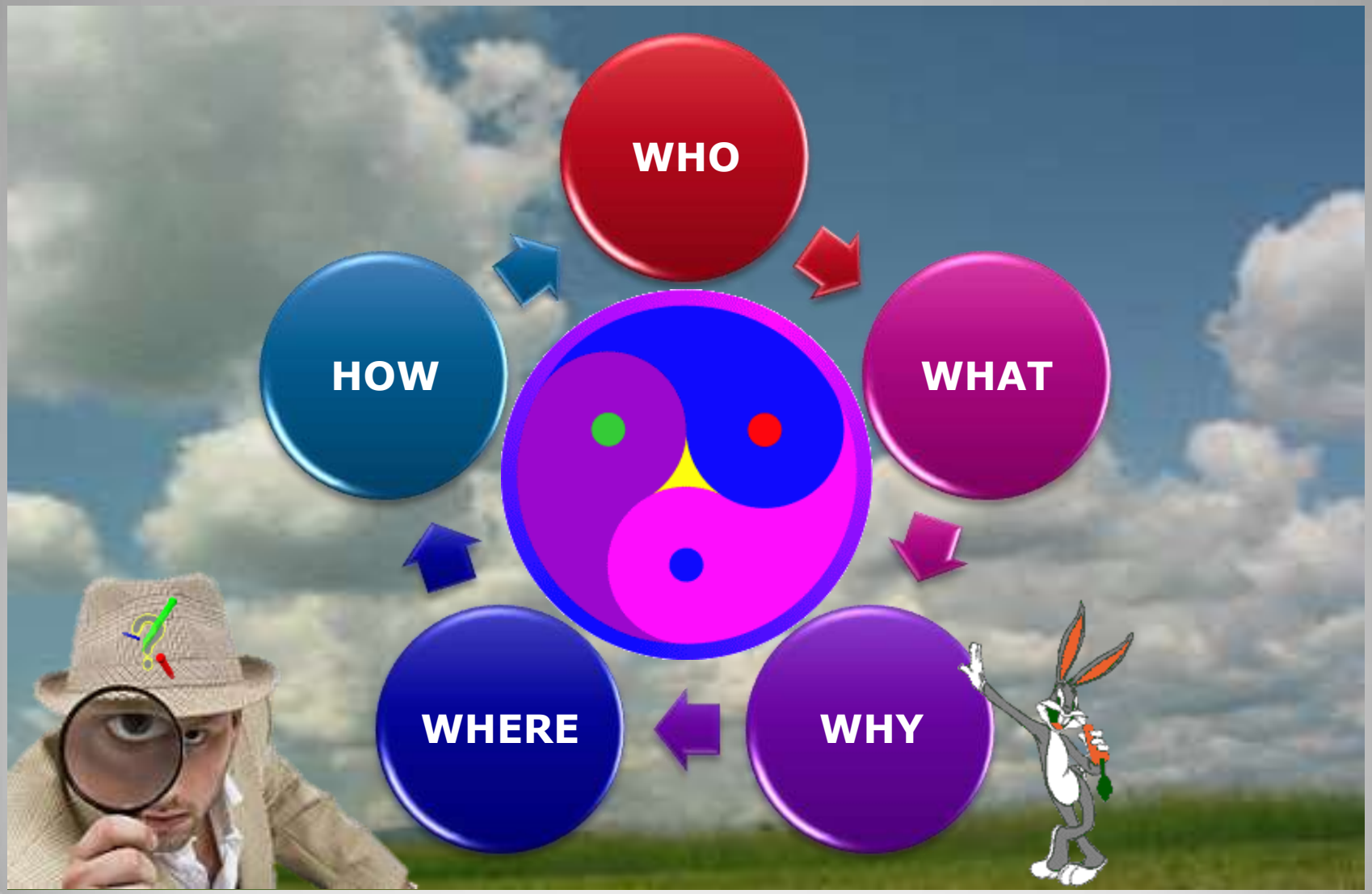
ISINN-20

Alushta, Ukraine, May 21 –26, 2012

20th International Seminar on Interaction of Neutrons with Nuclei:

«Fundamental Interactions & Neutrons, Nuclear Structure, Ultracold Neutrons, Related Topics»

Dedicated to the Memory of Ilia M. Frank and Fedor L. Shapiro the founders of the Laboratory of Neutron Physics



Standard questions

Fluctuation of the Prompt Gamma-emission Yield in Resonance Neutron Induced Fission of ^{239}Pu

I. Ruskov et all. ruskoiv@nf.jinr.ru, ivan@inrne.bas.bg

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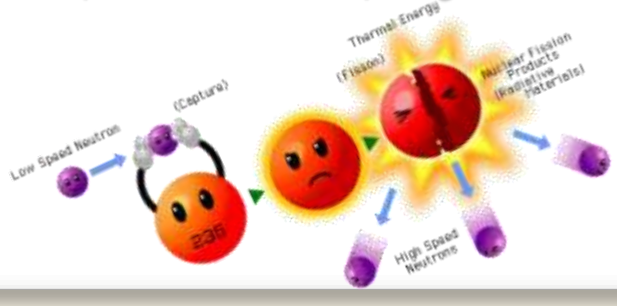
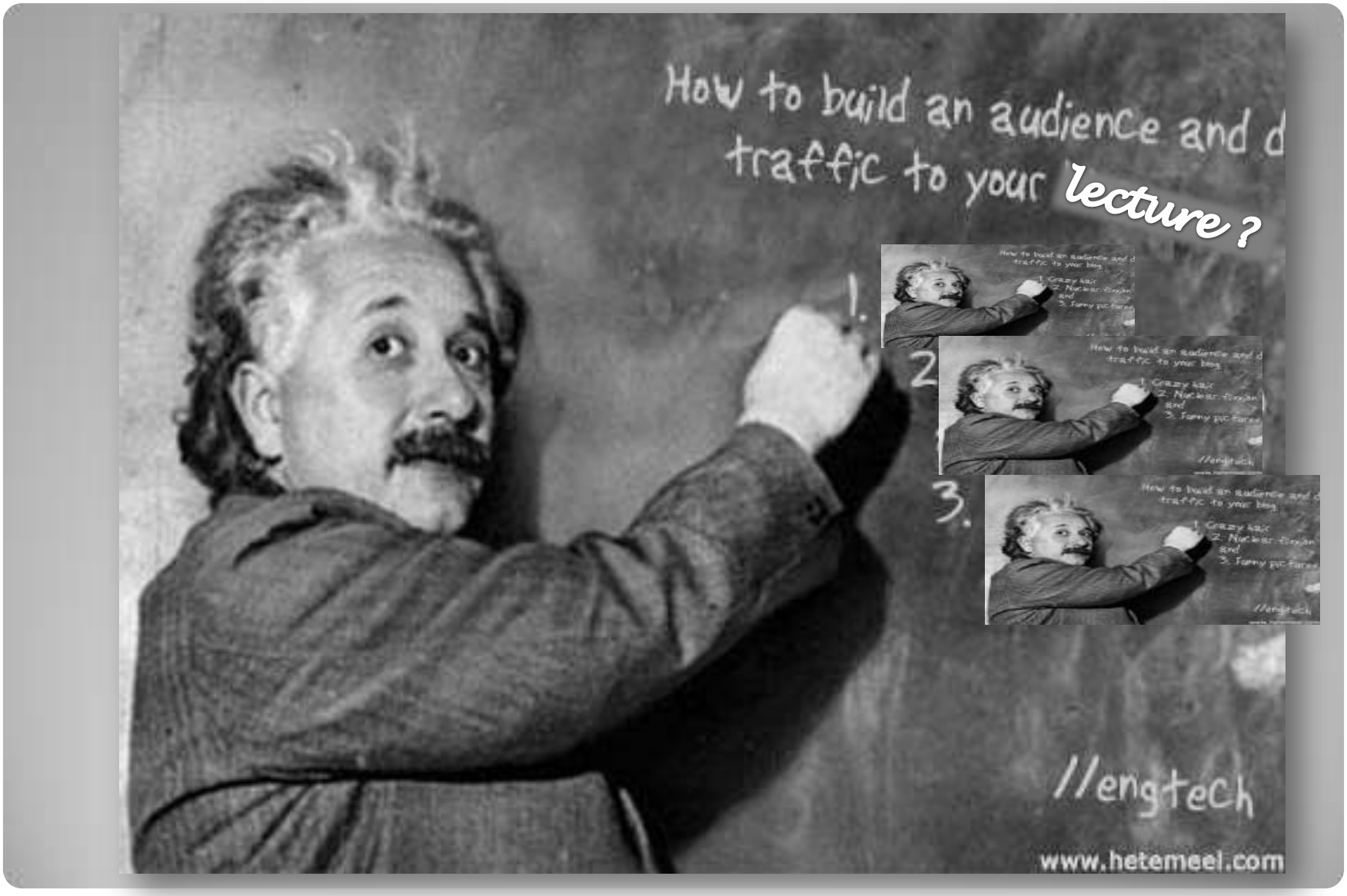
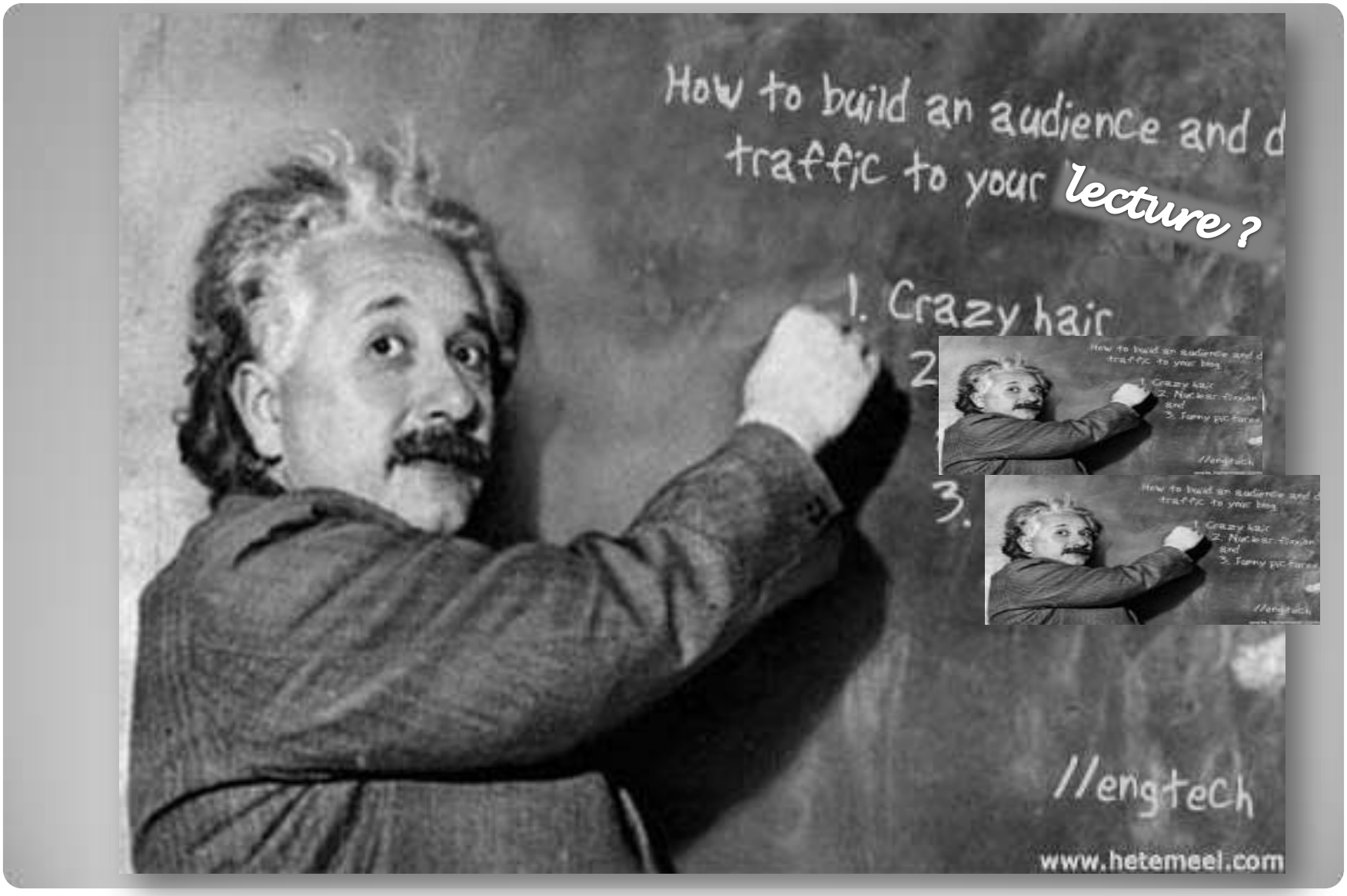
72 Tzarigradsko chausee blvd., BG-1784 Sofia, Bulgaria

Joint Institute for Nuclear Research (JINR),
Joliot-Curie 6, RU-141980, Dubna, Russia




How to build an audience and d
traffic to your lecture ?
1.
2.
3.
//engtech
www.hetemeel.com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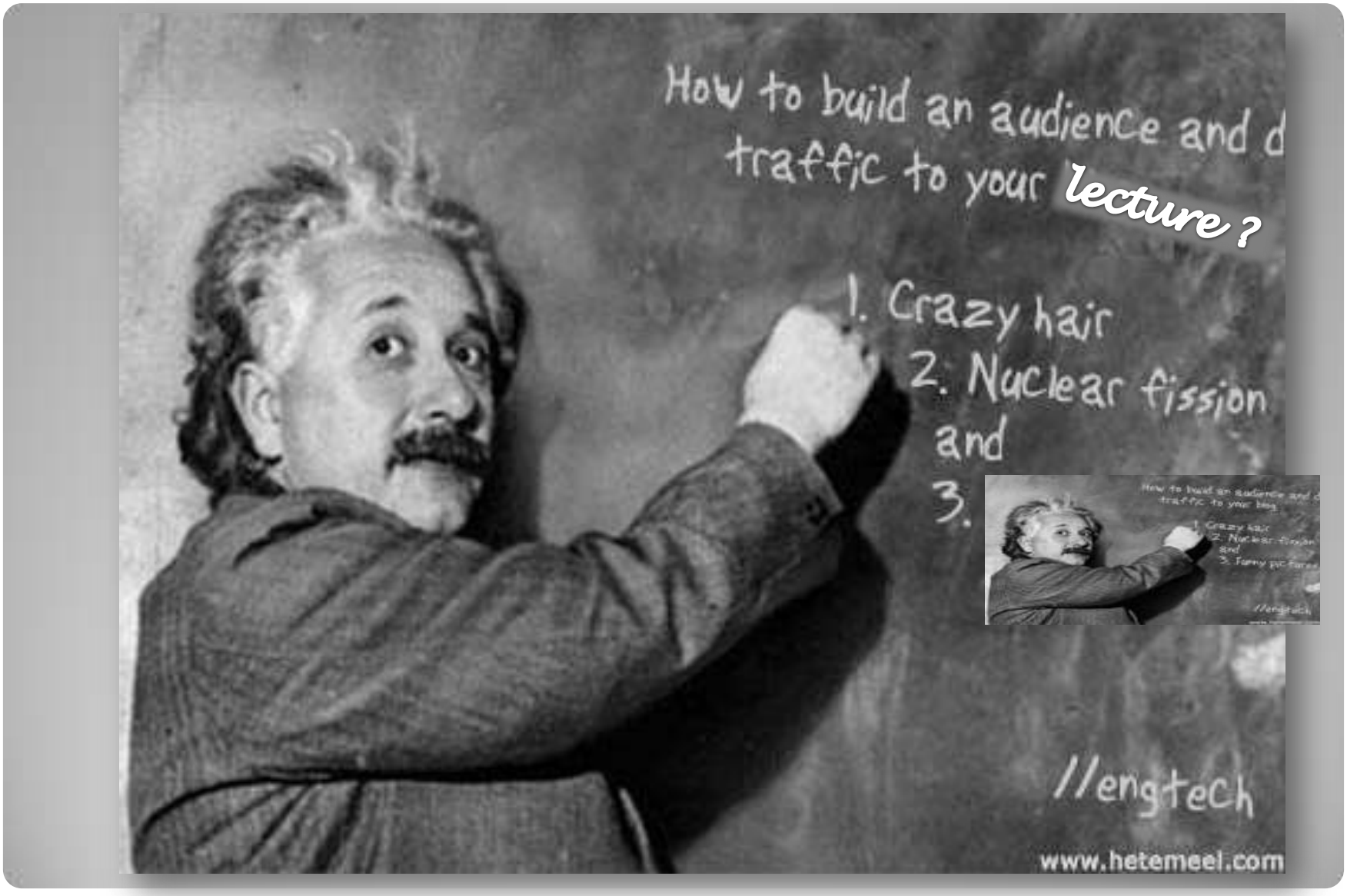
1. Crazy hair
2
3.
//engtech
www.hetemeel.com


How to build an audience and d
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1. Crazy hair
2. Nuclear fission
and
3.
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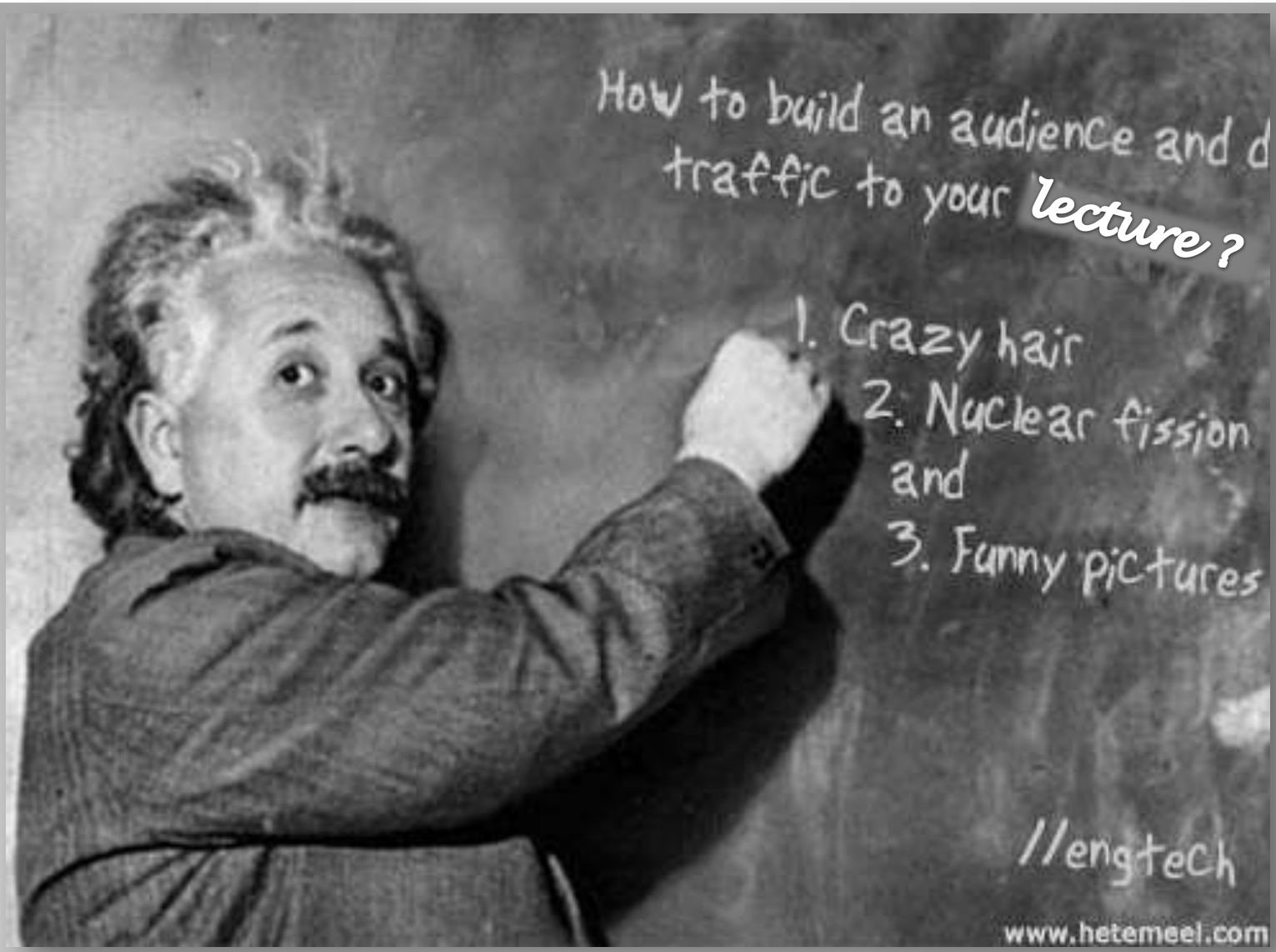
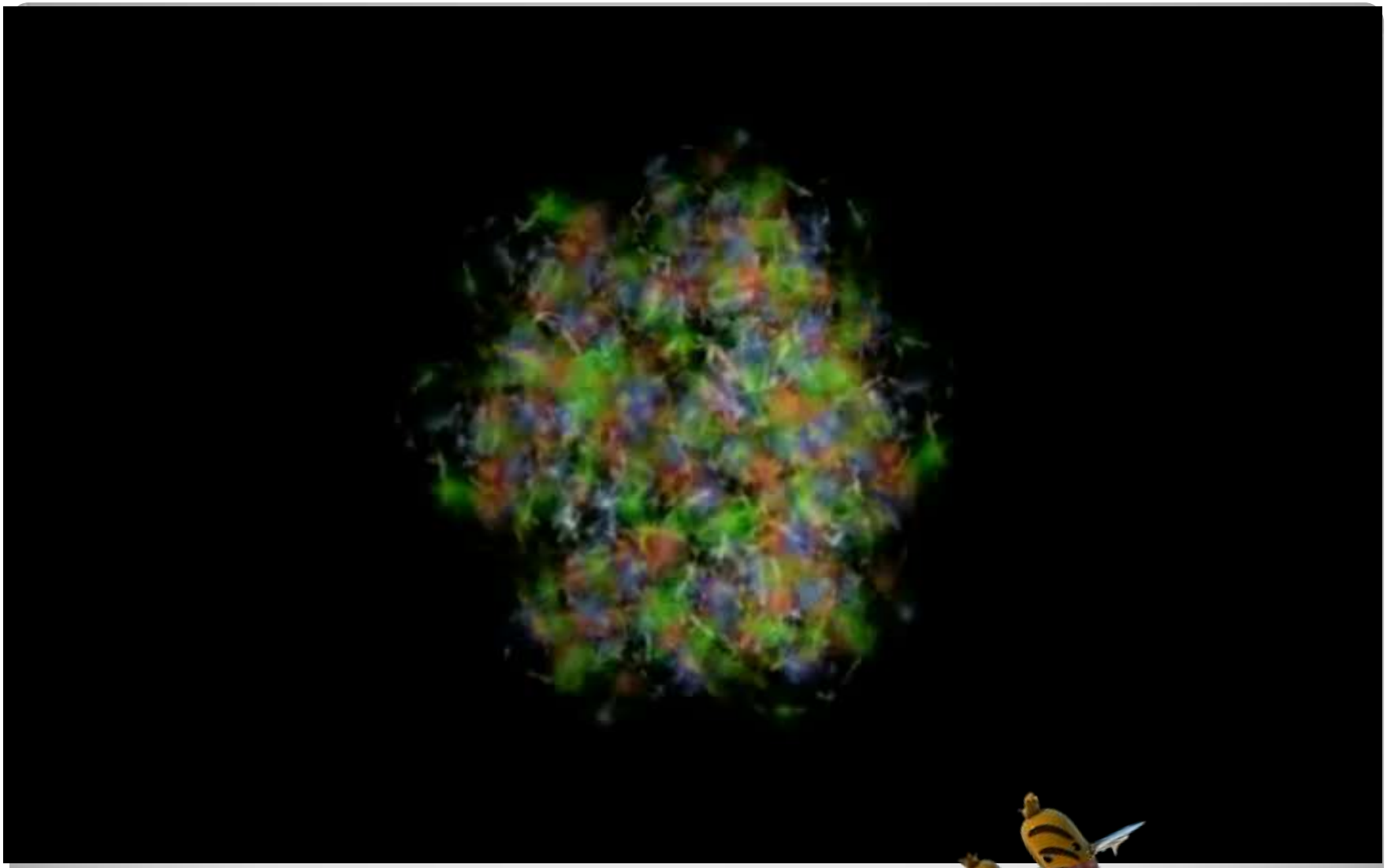
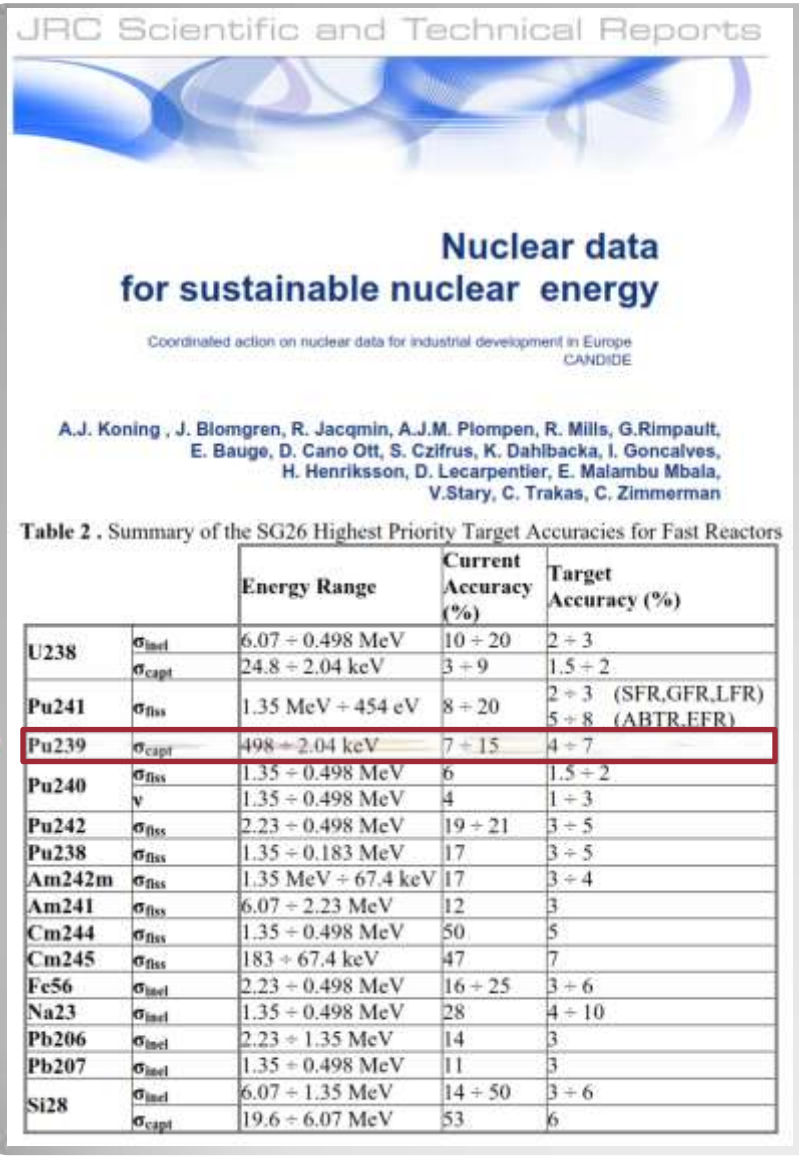

How to build an audience and d
traffic to your lecture ?
1. Crazy hair
2. Nuclear fission
and
3. Funny pictures
//engtech
www.hetemeel.com



Binary Fission



JRC Scientific and Technical Reports

Nuclear data
for sustainable nuclear energy

Coordinated action on nuclear data for industrial development in Europe
CANDIDE

A.J. Koning , J. Blomgren, R. Jacqmin, A.J.M. Plompen, R. Mills, G.Rimpault,
E. Bauge, D. Cano Ott, S. Czifrus, K. Dahlbacka, I. Goncalves,
H. Henriksson, D. Lecarpentier, E. Malambu Mbala,
V.Stary, C. Trakas, C. Zimmerman

Table 2 . Summary of the SG26 Highest Priority Target Accuracies for Fast Reactors

		Energy Range	Current Accuracy (%)	Target Accuracy (%)
U238	σ_{inel}	6.07 ÷ 0.498 MeV	10 ÷ 20	2 ÷ 3
	σ_{capt}	24.8 ÷ 2.04 keV	3 ÷ 9	1.5 ÷ 2
Pu241	σ_{fiss}	1.35 MeV ÷ 454 eV	8 ÷ 20	2 ÷ 3 (SFR,GFR,LFR) 5 ÷ 8 (ABTR,EFR)
Pu239	σ_{capt}	498 ÷ 2.04 keV	7 ÷ 15	4 ÷ 7
Pu240	σ_{fiss}	1.35 ÷ 0.498 MeV	6	1.5 ÷ 2
	ν	1.35 ÷ 0.498 MeV	4	1 ÷ 3
Pu242	σ_{fiss}	2.23 ÷ 0.498 MeV	19 ÷ 21	3 ÷ 5
Pu238	σ_{fiss}	1.35 ÷ 0.183 MeV	17	3 ÷ 5
Am242m	σ_{fiss}	1.35 MeV ÷ 67.4 keV	17	3 ÷ 4
Am241	σ_{fiss}	6.07 ÷ 2.23 MeV	12	3
Cm244	σ_{fiss}	1.35 ÷ 0.498 MeV	50	5
Cm245	σ_{fiss}	183 ÷ 67.4 keV	47	7
Fe56	σ_{inel}	2.23 ÷ 0.498 MeV	16 ÷ 25	3 ÷ 6
Na23	σ_{inel}	1.35 ÷ 0.498 MeV	28	4 ÷ 10
Pb206	σ_{inel}	2.23 ÷ 1.35 MeV	14	3
Pb207	σ_{inel}	1.35 ÷ 0.498 MeV	11	3
Si28	σ_{inel}	6.07 ÷ 1.35 MeV	14 ÷ 50	3 ÷ 6
	σ_{capt}	19.6 ÷ 6.07 MeV	53	6

Capture v/s Fission

For the fissile nucleus ^{239}Pu fission tagging is essential to separate the gamma-ray response due to fission from that due to the capture process.

However, the importance of improving the ^{239}Pu(n,γ) cross section uncertainty even below 4% cannot be overstated.

A very high accuracy for this cross section will alleviate some of the other very tight requirements for advanced reactors, in particular also for the ^{238}U inelastic cross section.

БЪЛГАРСКА АКАДЕМИЯ на НАУКИТЕ

INRNE

Motivation – PPView

FLNP JINR

- Fluctuations of e.g. prompt neutron number ν_p and γ-multiplicity have been observed.
- Fluctuations on ν_p have a significant impact on some applications, especially, on the reactivity coefficients of advanced water reactors.
- ν_p is the nuclear constant needed for application which is requested with the most stringent accuracy (0.25-0.5% in general).
- For ^{239}Pu the major difficulty in evaluating the ν_p is the presence in the low energy range of fluctuations, associated with the resonances with a significant impact on the reactor k_{eff} (*Fort et al.* NSE 99 (1988)).

The importance of ν_p& ν_γ

In the case of ^{235}U, where fission proceed through a larger number of transition states, well pronounced fluctuations of fragments' energy and mass distributions in the resonance neutron energy region have been observed.

The $^{239}Pu(n,f)$ reaction at resonance neutron energies is only possible via well separated transition states ($\Delta E^* \sim 1.25$ MeV) with $J^\pi = 0^+$ and $J^\pi = 1^+$. Are there any FF (TKE,A)-fluctuations?

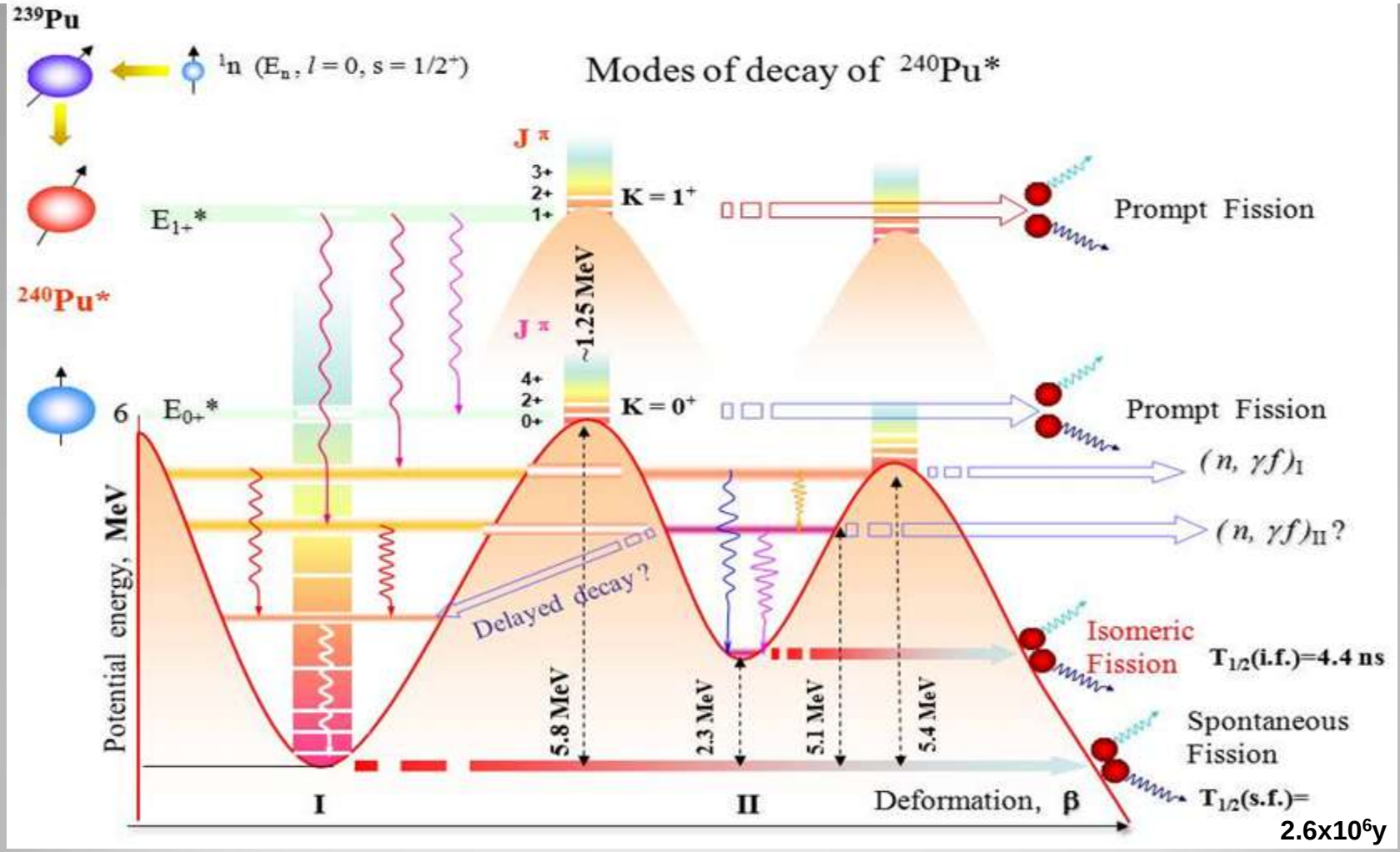
Contradicting results in previous $^{239}Pu(n,f)$ measurements [1,2];

Possible dependence of fission characteristics on the existence of $(n,\gamma f)$-reaction for resonances with $J^\pi = 1^+$ [3];

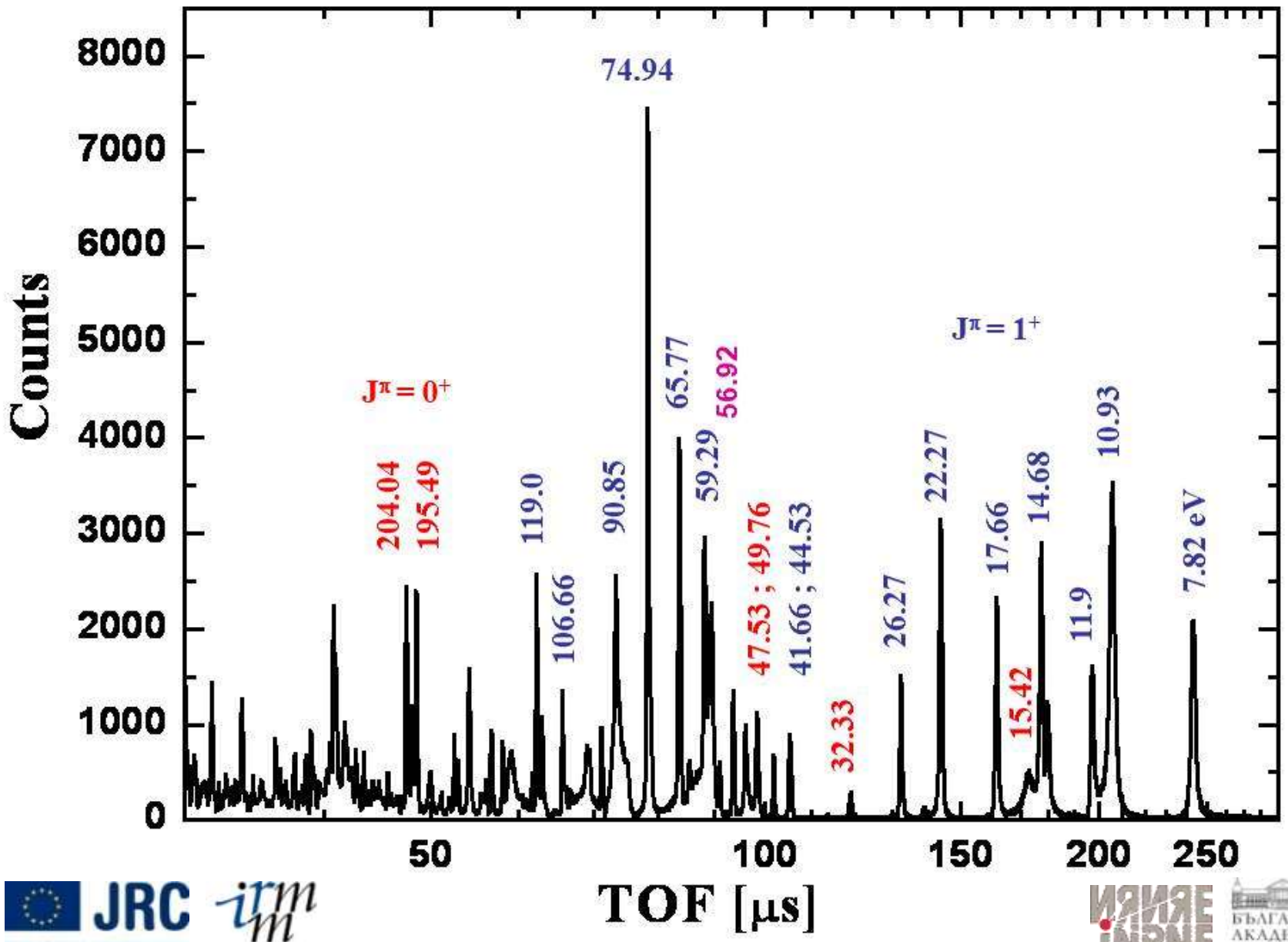
Is the Interpretation of Mass Yield fluctuations in the frame of the Multi-modal Fission Model of Brosa et al. good enough [4] ?

1). C. Wagemans *et al.*, Proc. Symp on *Physics and Chemistry of Fission 1979*, v. II, IAEA (1980), p. 143.
2). R.L. Walsh *et al.*, ibid., p. 129.
3). J. Frehaut, and D. Shackleton, Proc. Symp. on *Phys. and Chem. of Fission 1973*, v. II, IAEA (1974), p. 201.
4). U. Brosa *et al.*, Phys. Rep. 197 (1990) 167

Motivation – FPView


239Pu
1n (En, l = 0, s = 1/2+)
Modes of decay of 240Pu*
240Pu*
Jπ
3+
2+
1+
K = 1+
E1+*
~1.25 MeV
Jπ
4+
2+
0+
K = 0+
E0+*
6
Prompt Fission
Prompt Fission
(n, γf)I
(n, γf)II?
Delayed decay?
Isomeric Fission
T1/2(i.f.)=4.4 ns
Spontaneous Fission
T1/2(s.f.)=
2.6x10^6y
Potential energy, MeV
5.8 MeV
2.3 MeV
5.1 MeV
5.4 MeV
I
II
Deformation, β

239Pu (n,f)


Counts
TOF [μs]
74.94
65.77
56.92
59.29
$J^\pi = 0^+$
$J^\pi = 1^+$
204.04
195.49
119.0
106.66
90.85
47.53 ; 49.76
41.66 ; 44.53
32.33
26.27
22.27
17.66
15.42
14.68
11.9
10.93
7.82 eV

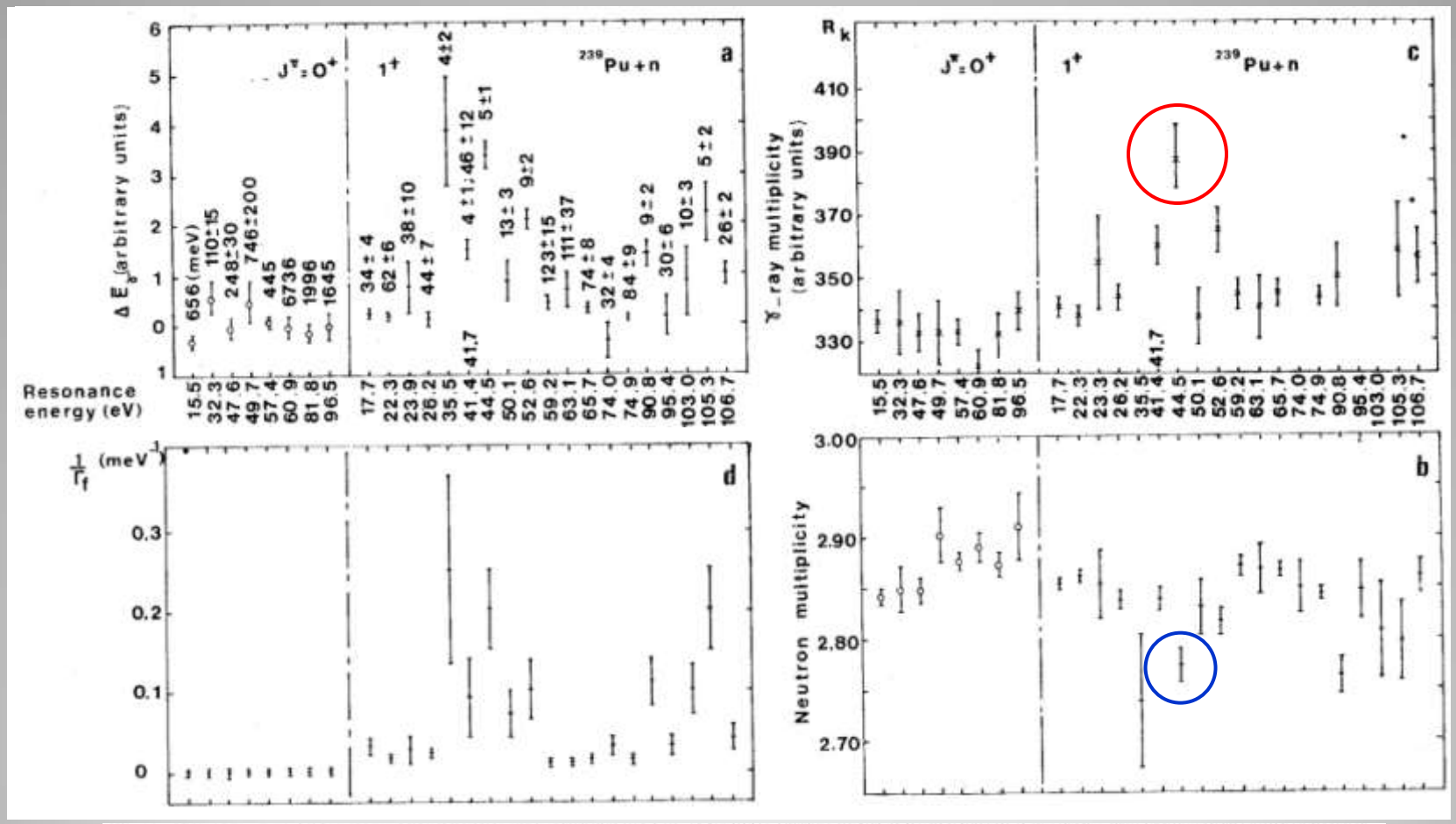


Fig. 3. Comparison of the experimental results for the resonances in common. (a) $\bar{E}_\gamma$ variations [13]). The fission width Γ_f from ref. [20]) is written for each resonance near the plotted value. (b) $\bar{\nu}$-variations [13]). (c) R-variations (this work). (d) $1/\Gamma_f$ variations [20]).

Yu. RYABOV †, J. TROCHON ††, D. SHACKLETON †††, J. FREHAUT

1972-1973

^{239}Pu(n,γf)

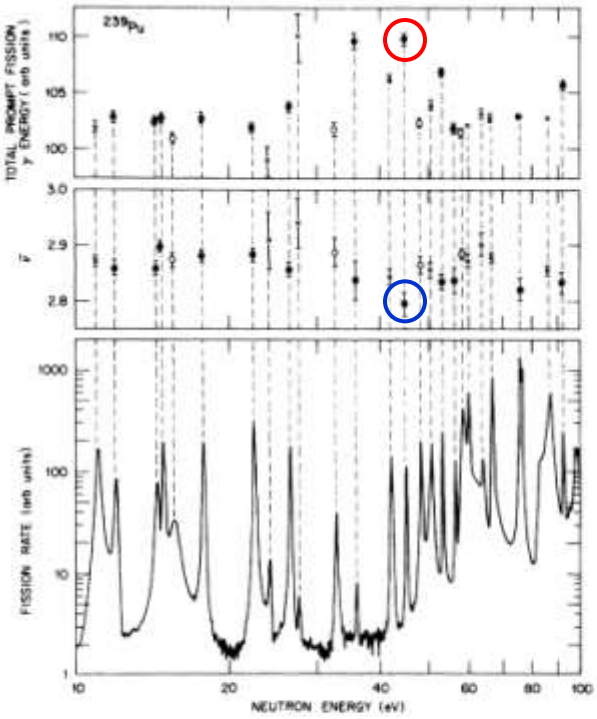


FIG. 1. The average neutron multiplicity $\bar{\nu}$ and the average total prompt γ-ray energy following fission for the resonances of ^{239}Pu in the neutron energy range of 10 to 100 eV. Open circles are $J = 0$ resonances. Closed circles are $J = 1$. Crosses are resonances of uncertain spin or unresolved groups of different J values.

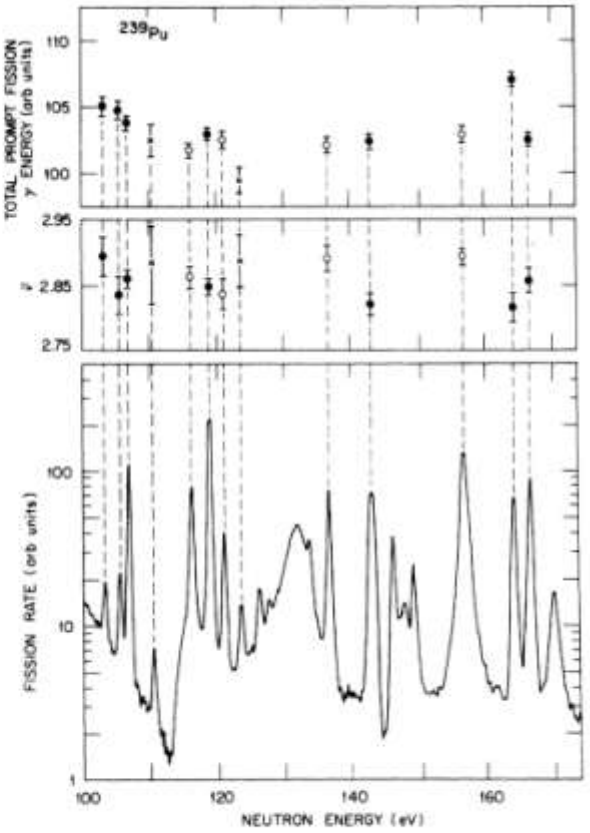
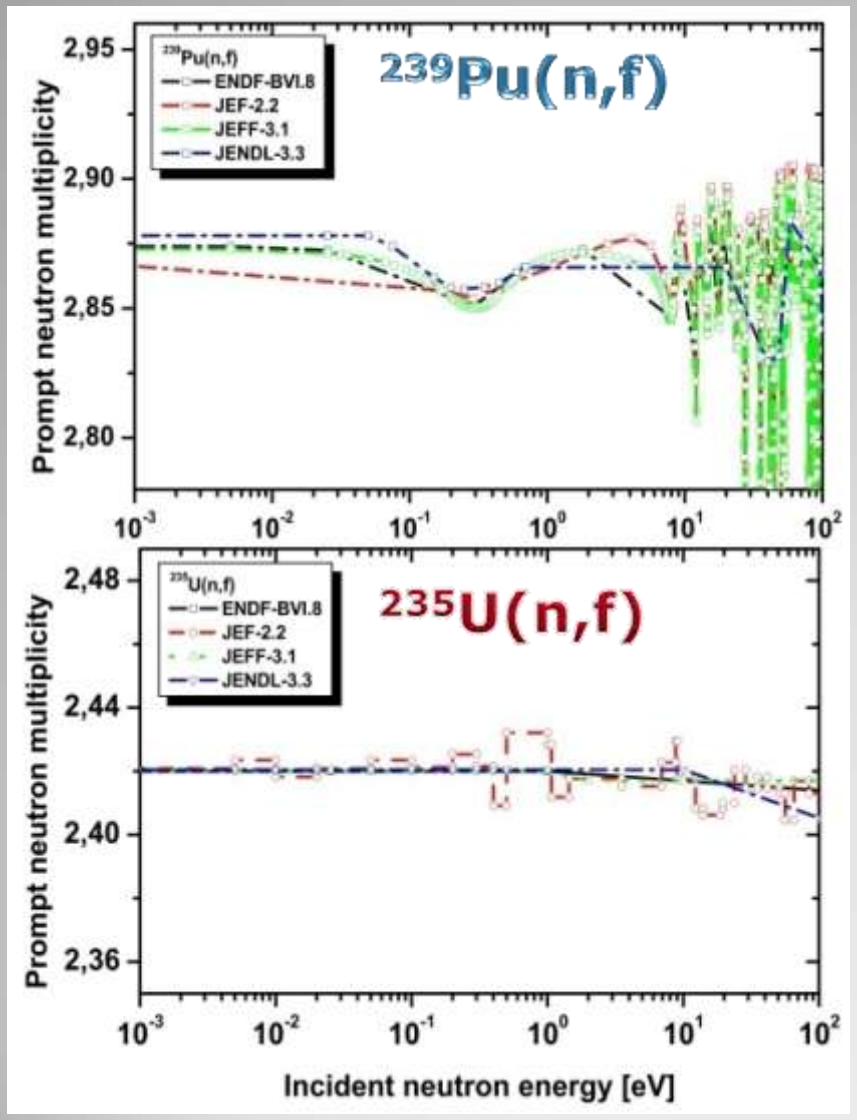


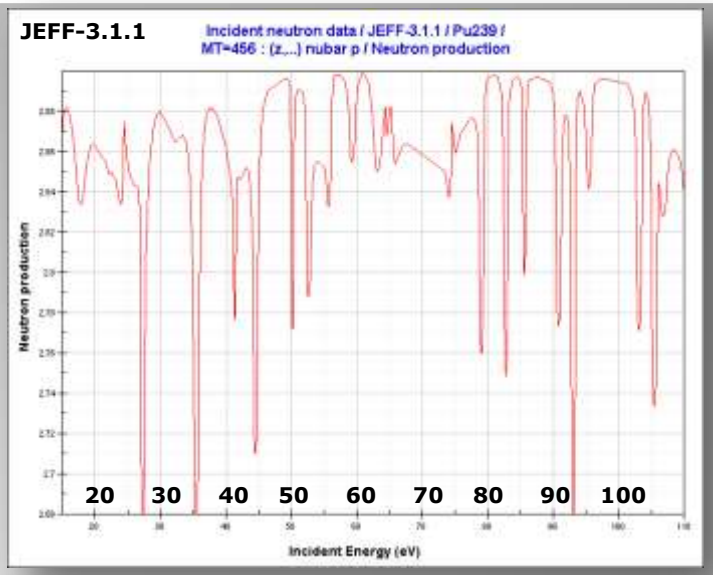
FIG. 2. The average neutron multiplicity $\bar{\nu}$ and the average total prompt γ-ray energy following fission for the resonances of ^{239}Pu in the neutron energy range of 100 to 170 eV.

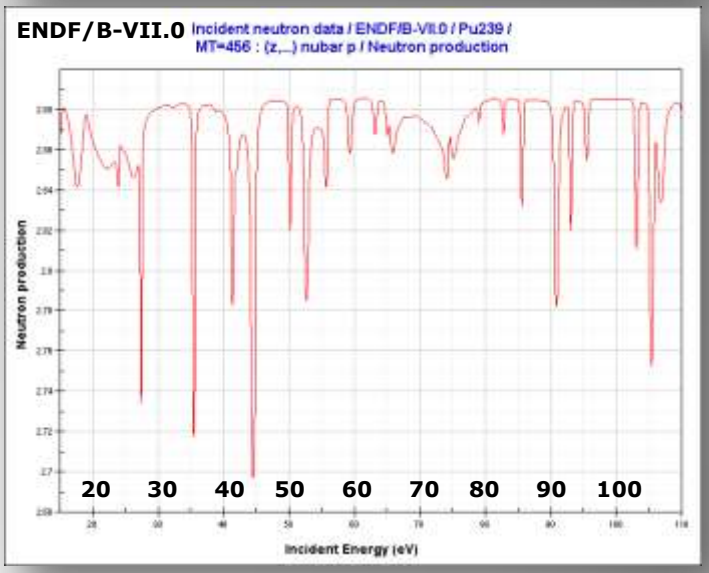
Fission-neutron multiplicity and total prompt gamma-ray energy for resonances in ^{239}Pu†

L. W. Weston and J. H. Todd
Oak Ridge National Laboratory, Oak Ridge, Tennessee 37830
(Received 1 July 1974)

^{239}Pu(n,γf)

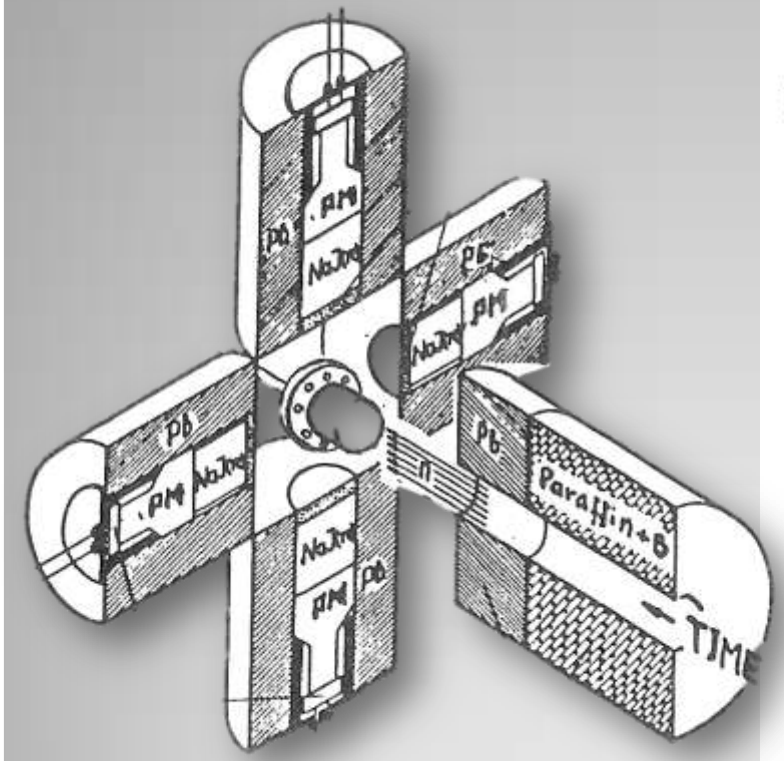


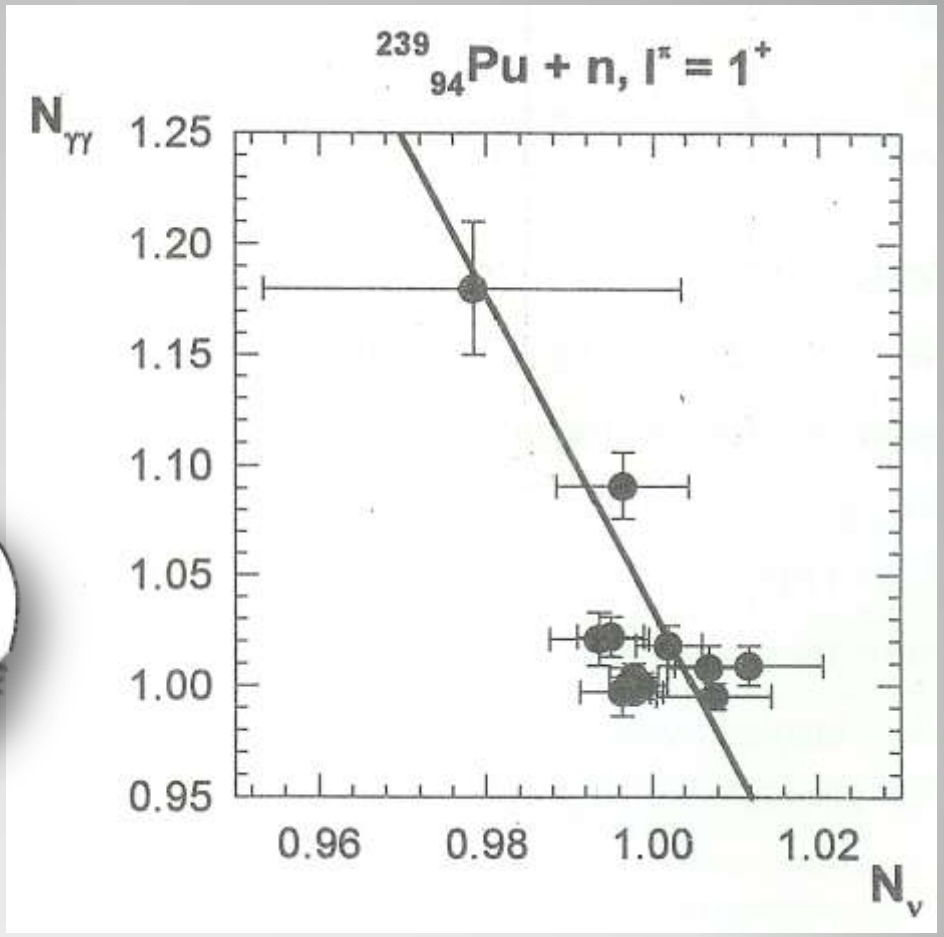




239Pu(n,f) Evaluated Data Files

The average fission γ-rays multiplicity as a function of the neutron multiplicity (r = – 0.77)

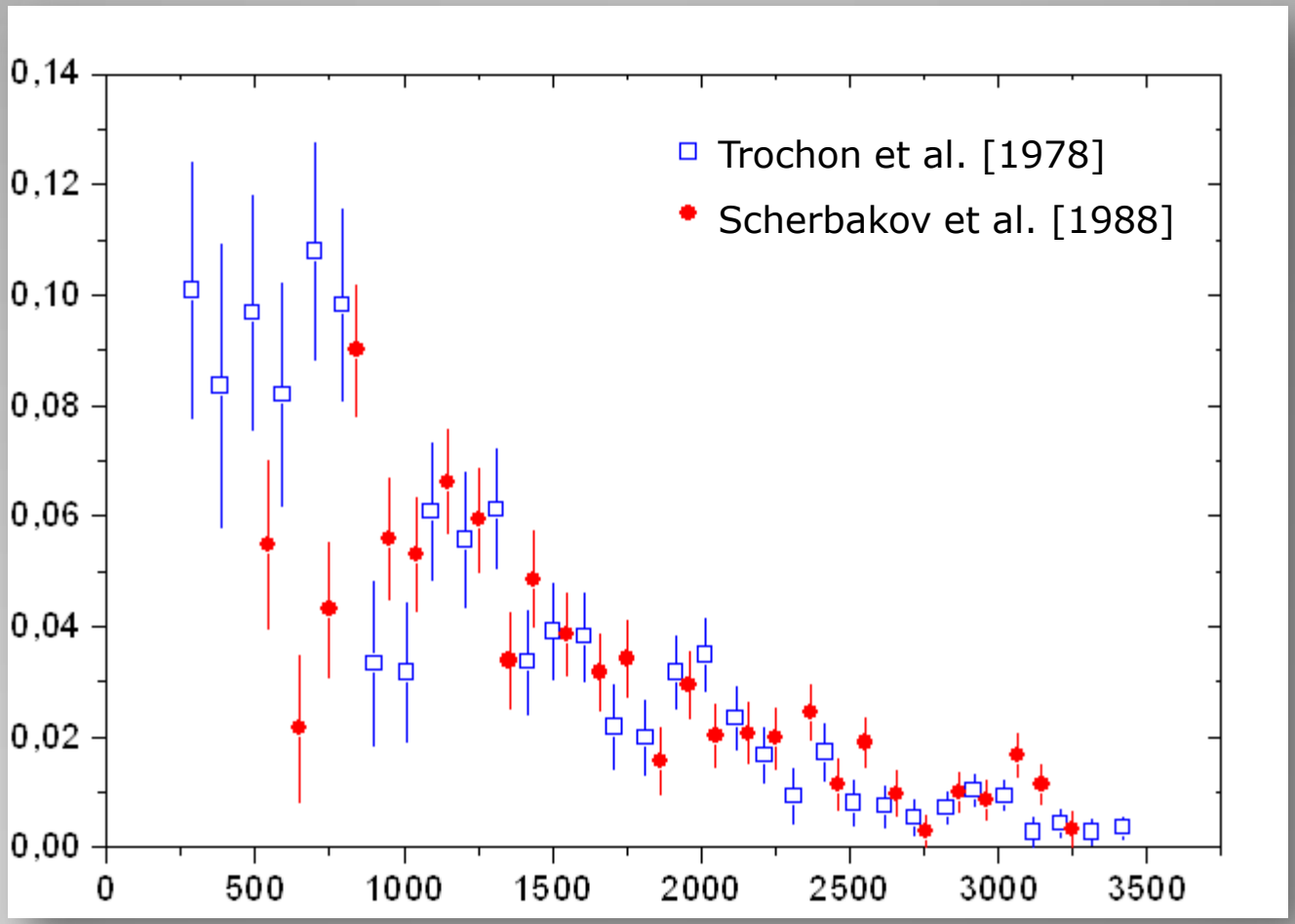




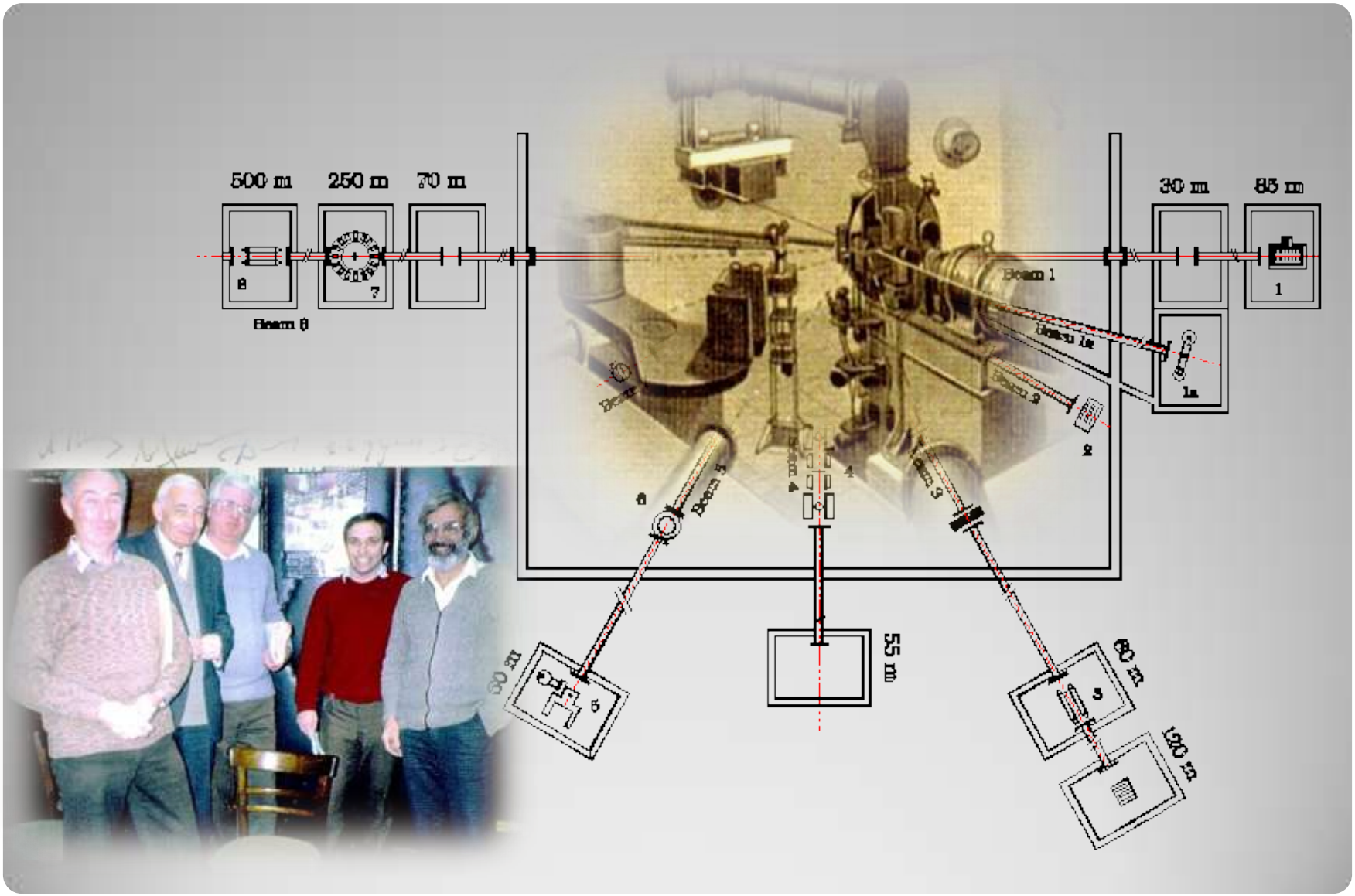
Yu.V. Ryabov, Investigations of **(n,γf)-reaction** for U-235 and **Pu-239** resonances and structure of fission barriers (1972?), ISINN-5, (1997) 422.

Щербаков О.А.,
Экспериментальные исследования (n,γf)-реакции,
ФЭЧАЯ, Т. 21, Вып. 2, 1990.

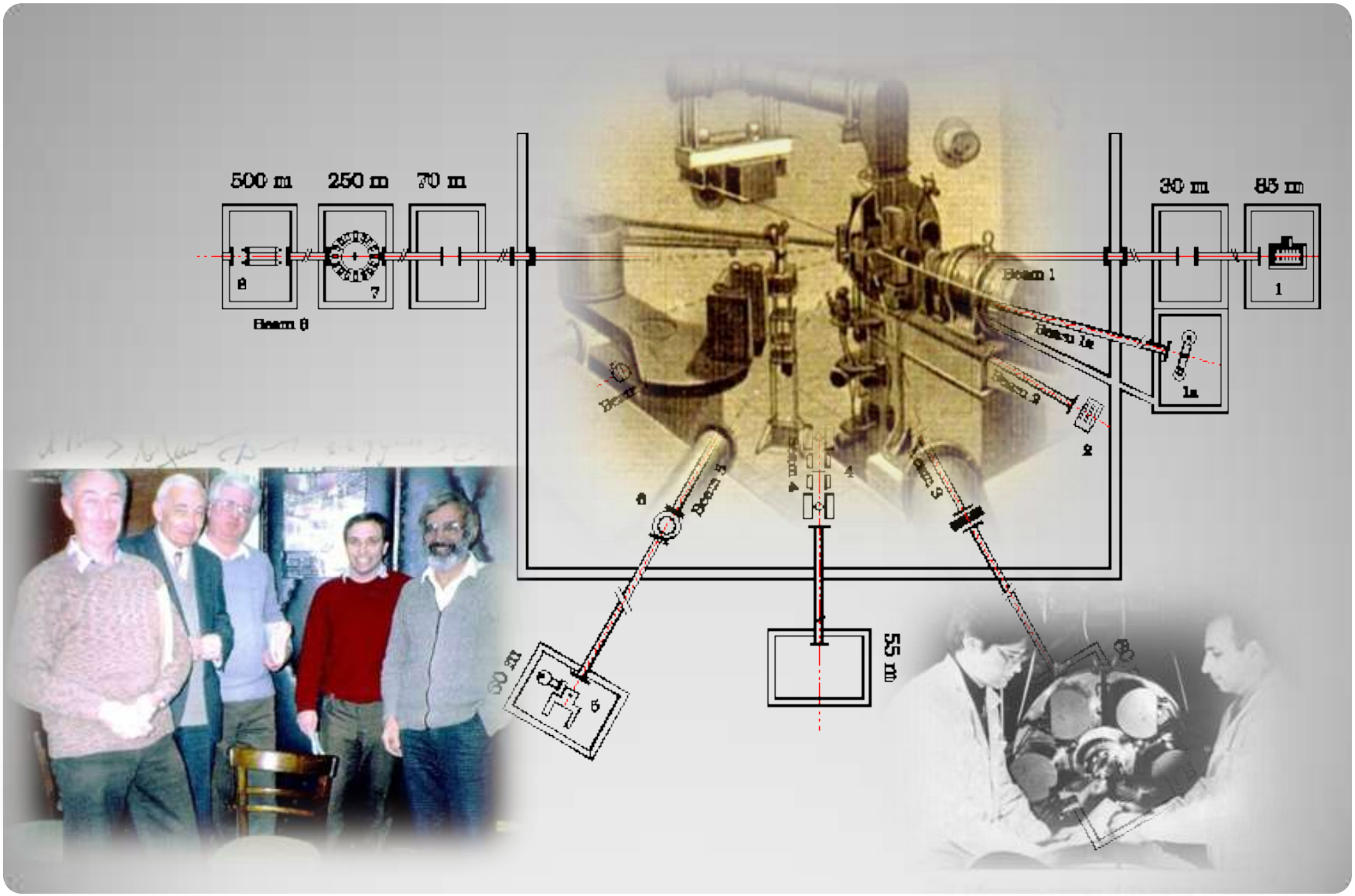
Scherbakov, O.A.
Experimental investigation on the (n,γf)-reaction,
PEPAN 21/2, 1990.



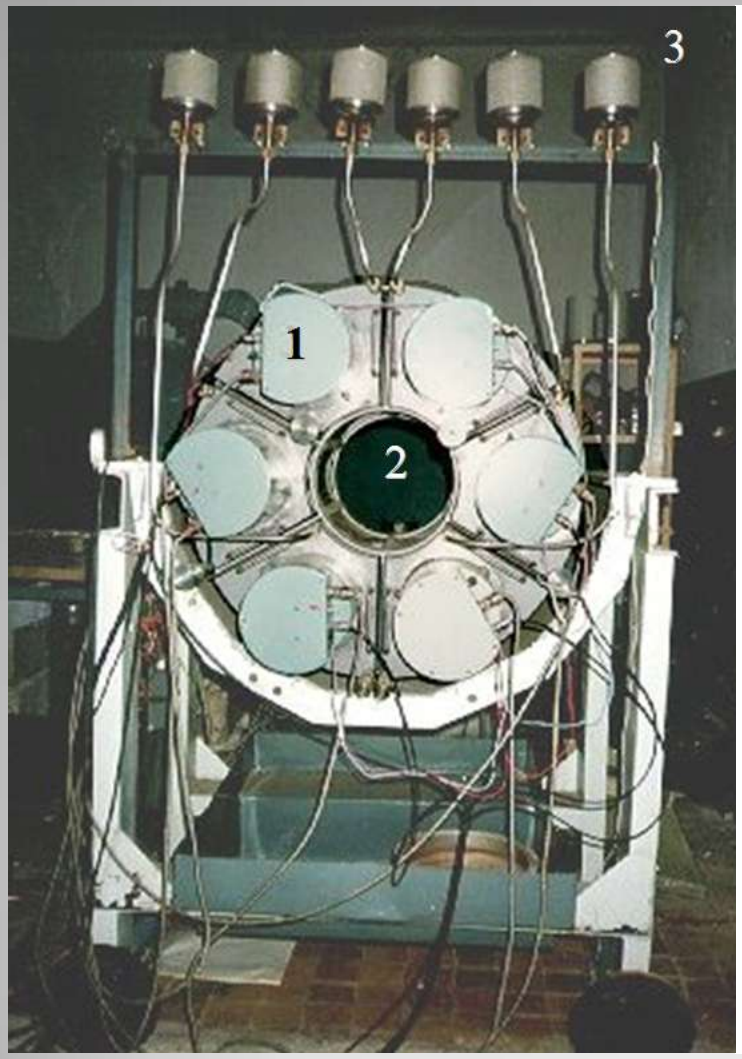
$^{239}Pu(n,\gamma f)$

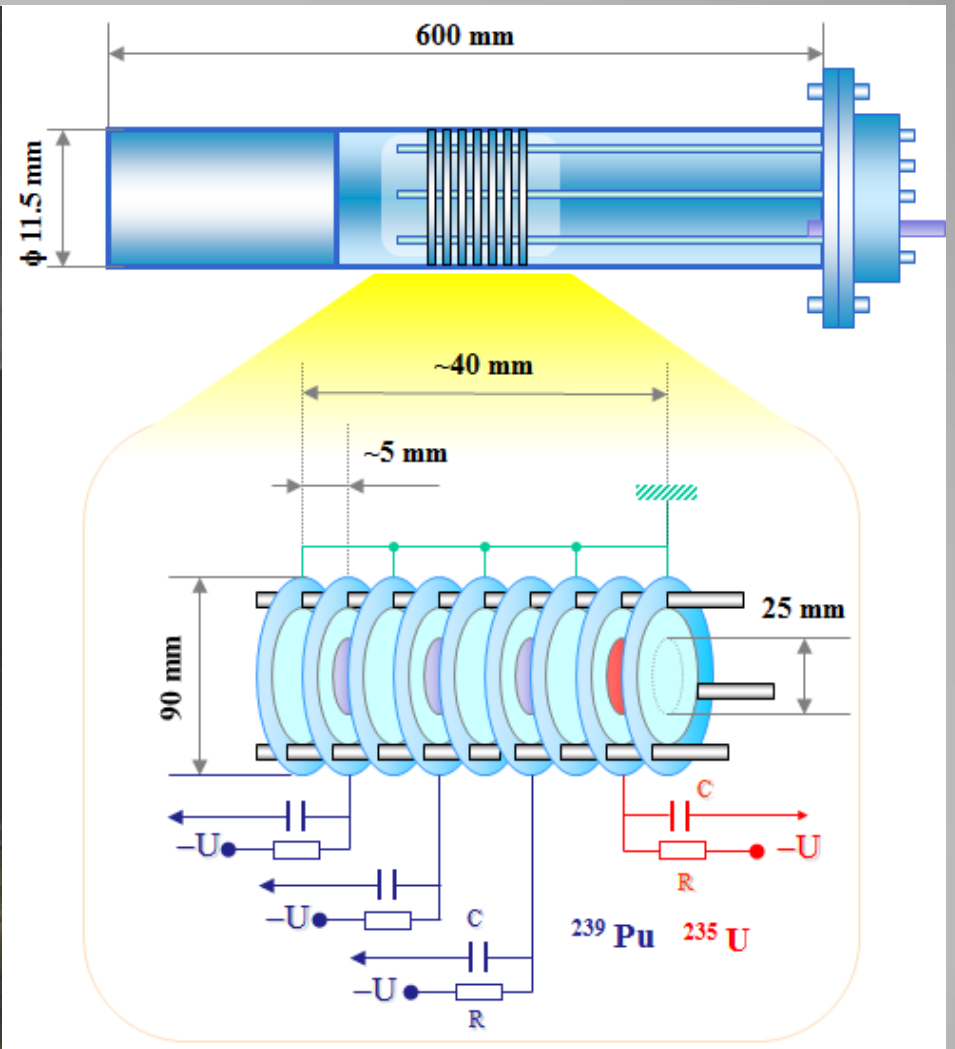


JINR LUE-40+IBR-30 pulsed reactor

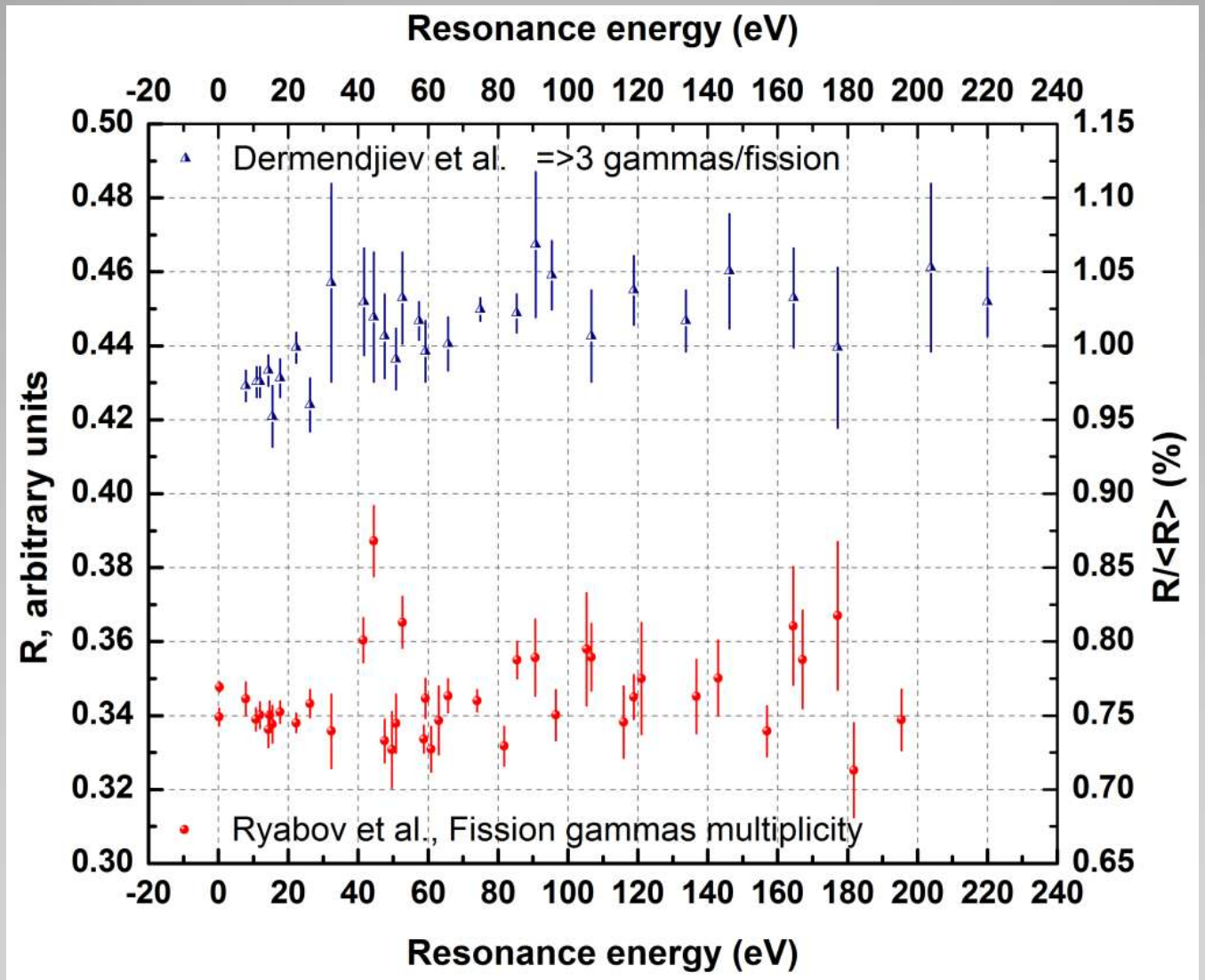


JINR LUE-40+IBR-30 pulsed reactor



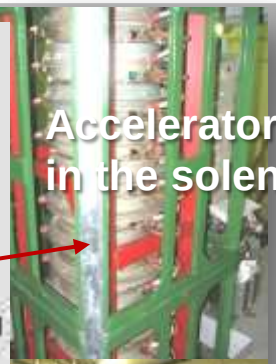


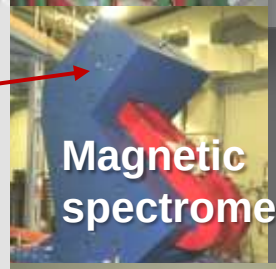
LLSD & Fission chamber

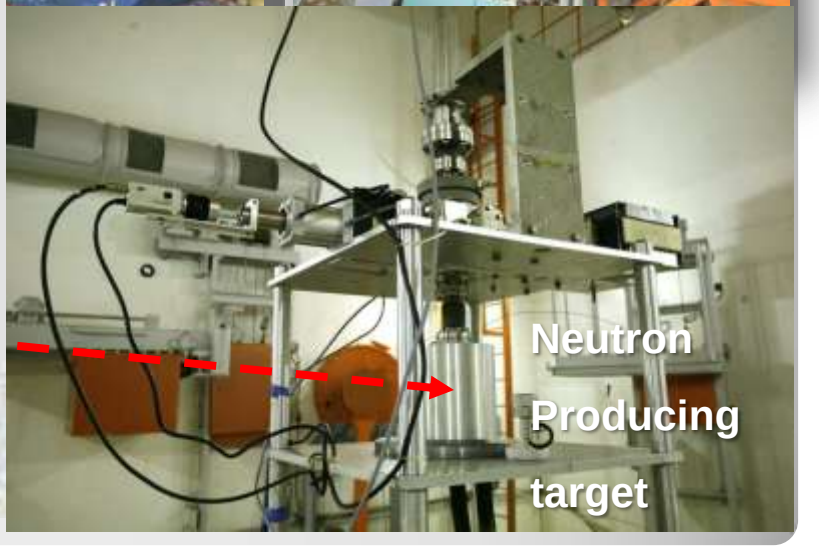


Gamma-ray "multiplicity" variation

Modulators







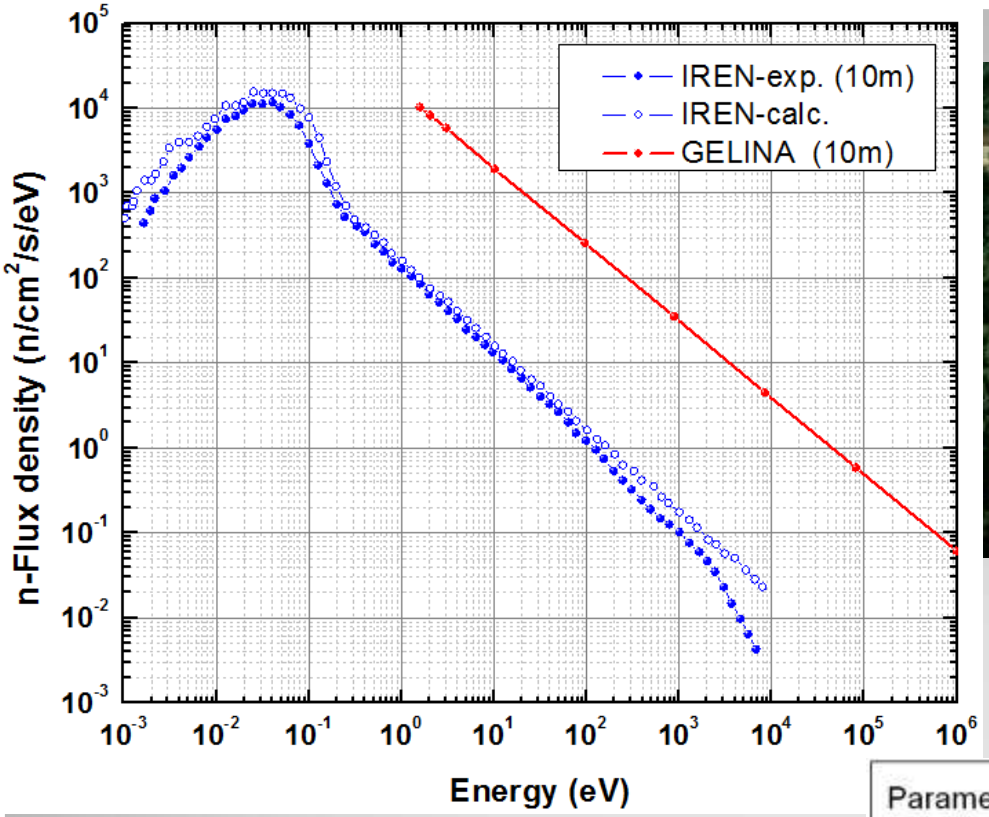
БЪЛГАРСКА АКАДЕМИЯ на НАУКИТЕ

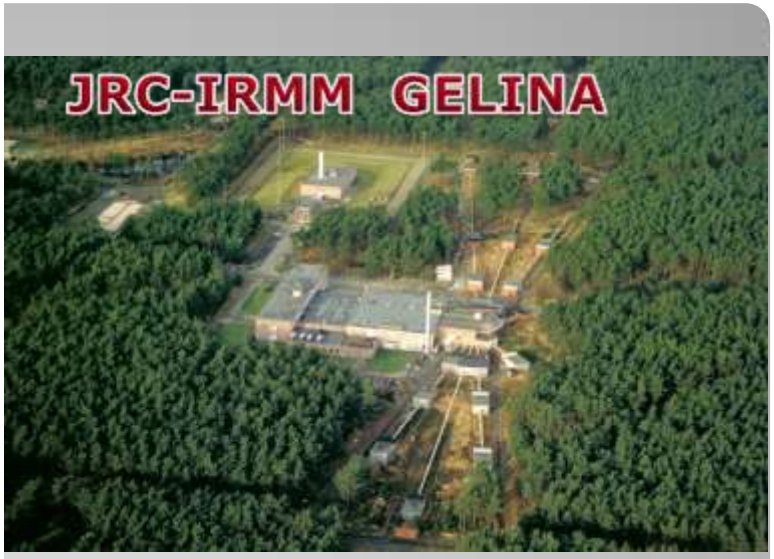
ИЯИЯЕ INRNE

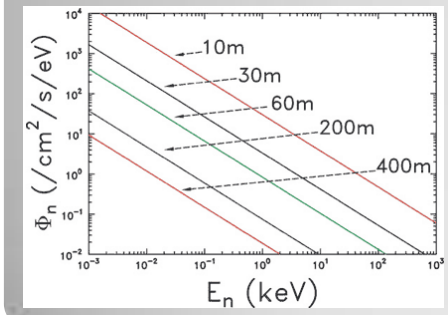
http://flnp.jinr.ru/244/

IREN facility

FLNP JINR







Parameter	Achieved 2010	Project 2015
Electron energy, MeV	<30>	<=200
Pulse beam current, A	1.5-2	1.5-2
Accelerated electron pulse width, ns	100	250
Repetition rate, Hz	25-50	150
<Accelerating rate>, MeV/m	35	35
Beam power, kW	0.1	9-12
Neutron producing target	tungsten	plutonium
Integral neutron yield, n/s	2.10^11	10^15
Pulse width, ns	250	600

JRC EUROPEAN COMMISSION

irmm Institute for Reference Materials and Measurements

GELINA - IREN

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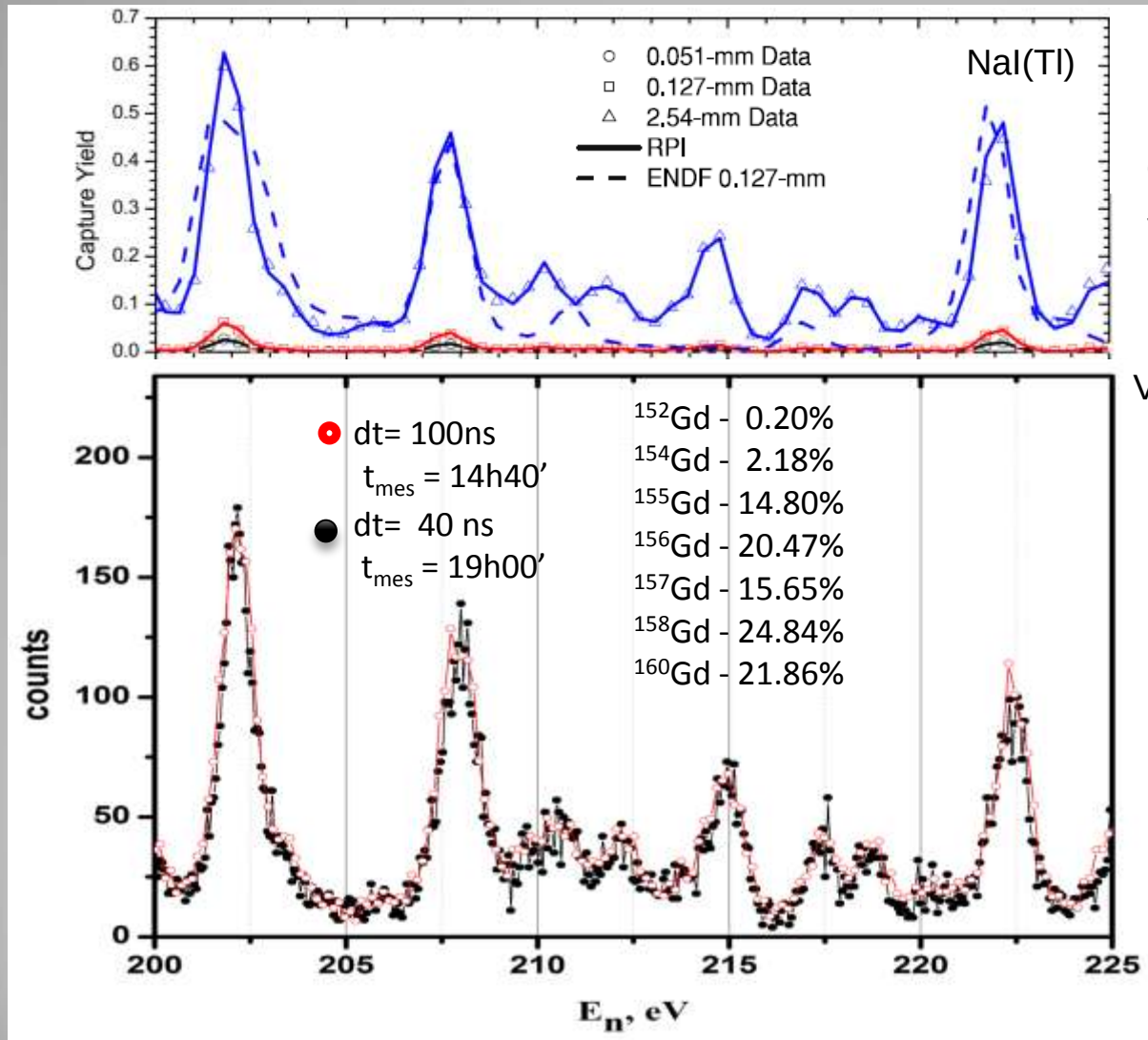


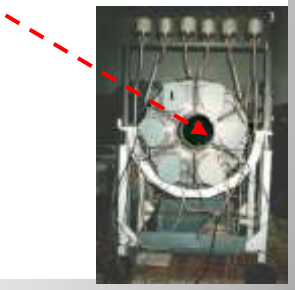
^{nat}Gd (n, γ)

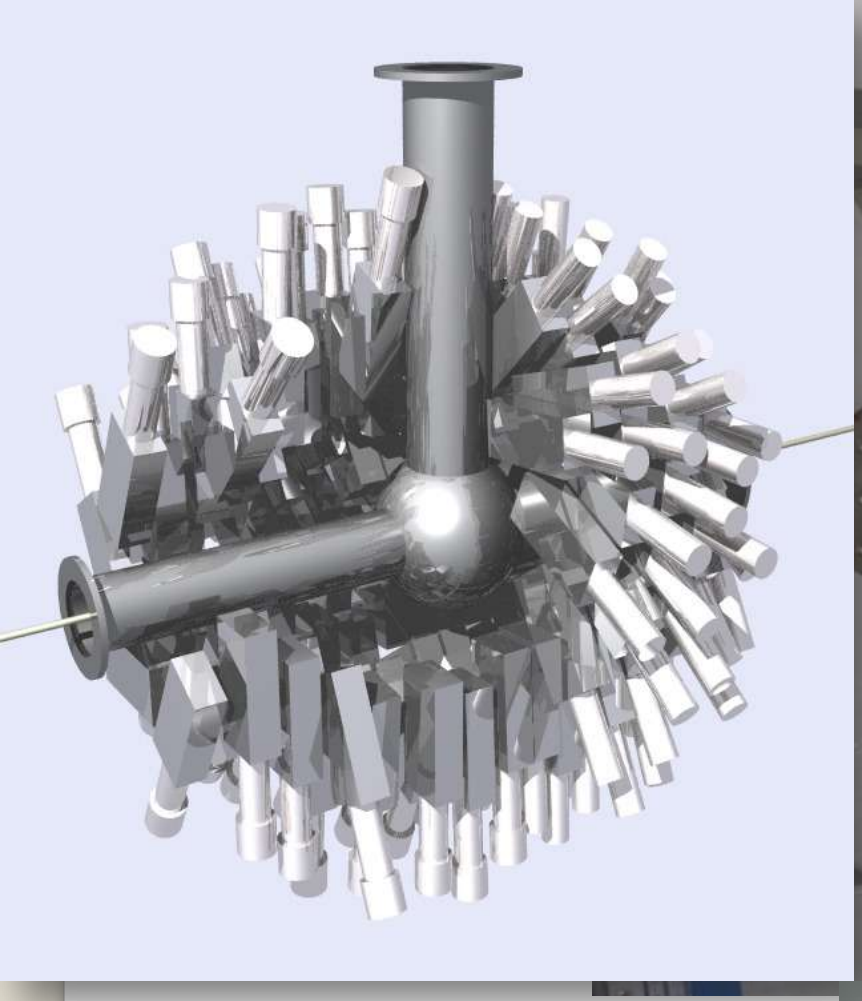
G. Leinweber et al., *Nucl. Sci. Eng., 154 (2006) 256*, RPI Linac, **10^{13} n/s**, L=25m

V.N. Shvetsov et al. (2010)

IREN, Dubna,**10^{11} n/s**
f = 25 Hz, I_e = 2A;
t_e=100ns
L = 58.6m

Sample: m_g = 172.8 g
-size: 11.2 x 14.5 cm^2
-ρ: 1.064039 g/cm^2
-d: 1.35mm

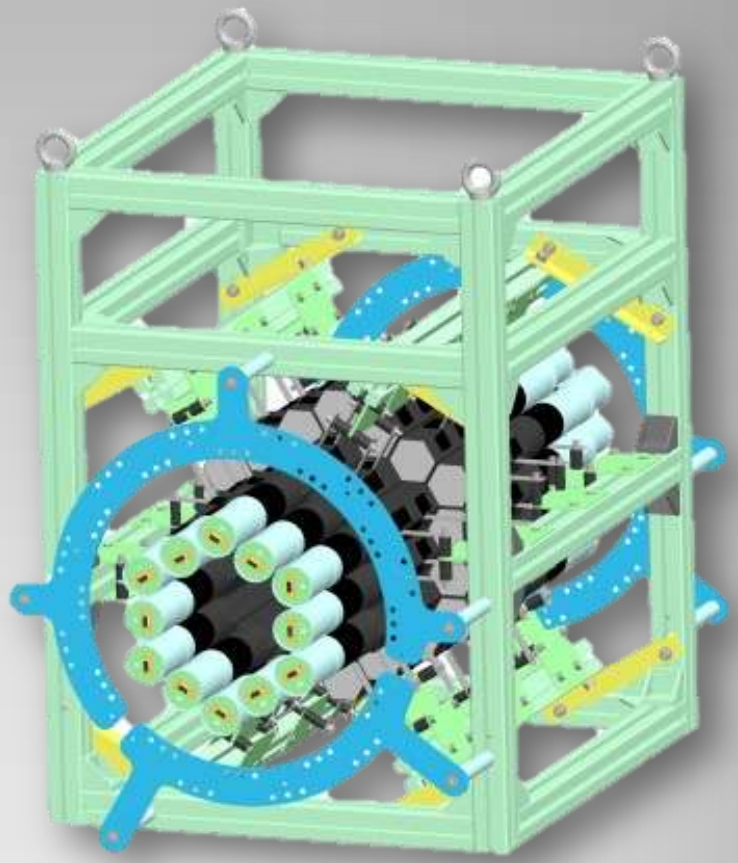




DALI2 is a high efficiency and high energy-resolution gamma-ray detector array designed for in-beam gamma-ray spectroscopy experiments using fast RI-beams. DALI2 consists of 160 NaI(Tl) scintillators covering polar angle from 20-degrees to 160-degrees.

SCIONIX製 80個	
結晶の大きさ	40 x 80 x 160 mm^3
分解能 @662keV (平均)	9.5%(FWHM)

For neutron capture gamma-rays, a BaF_2scintillation detector array of up to 60 crystals is being built, as shown in the figure. The sample position is in the center of the ring formed by the scintillators, which together cover 80% of the total solid angle.
The crystals are 19cm long and have a hexagonal cross section with an inner diameter of 53mm. They are read out by fast **Hamamatsu R2059 PM tubes**, which are UV sensitive to be able to measure both the slow and the fast component of the BaF_2scintillation light. Thereby pulse shape discrimination (PSD) can be utilized to separate photon signals from intrinsic alpha-particle background. **The time resolution** attained **with a ^{60}Co gamma-source is typically 650ps** (FWHM). The readout will be performed with dedicated **ADC/TAC modules that allow simultaneous measurement of timing and energy signals including PSD** in VME-bus standard. The system will be controlled by a RIO3 real-time Unix computer.

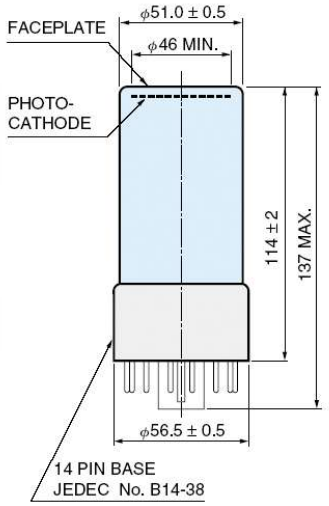


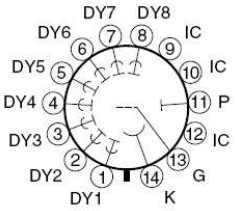
Helmholtz-Zentrum Dresden-Rossendorf (HZDR)
n-capture gamma-rays spectrometer

www.hzdr.de/pls/rois/Cms?pNid=317

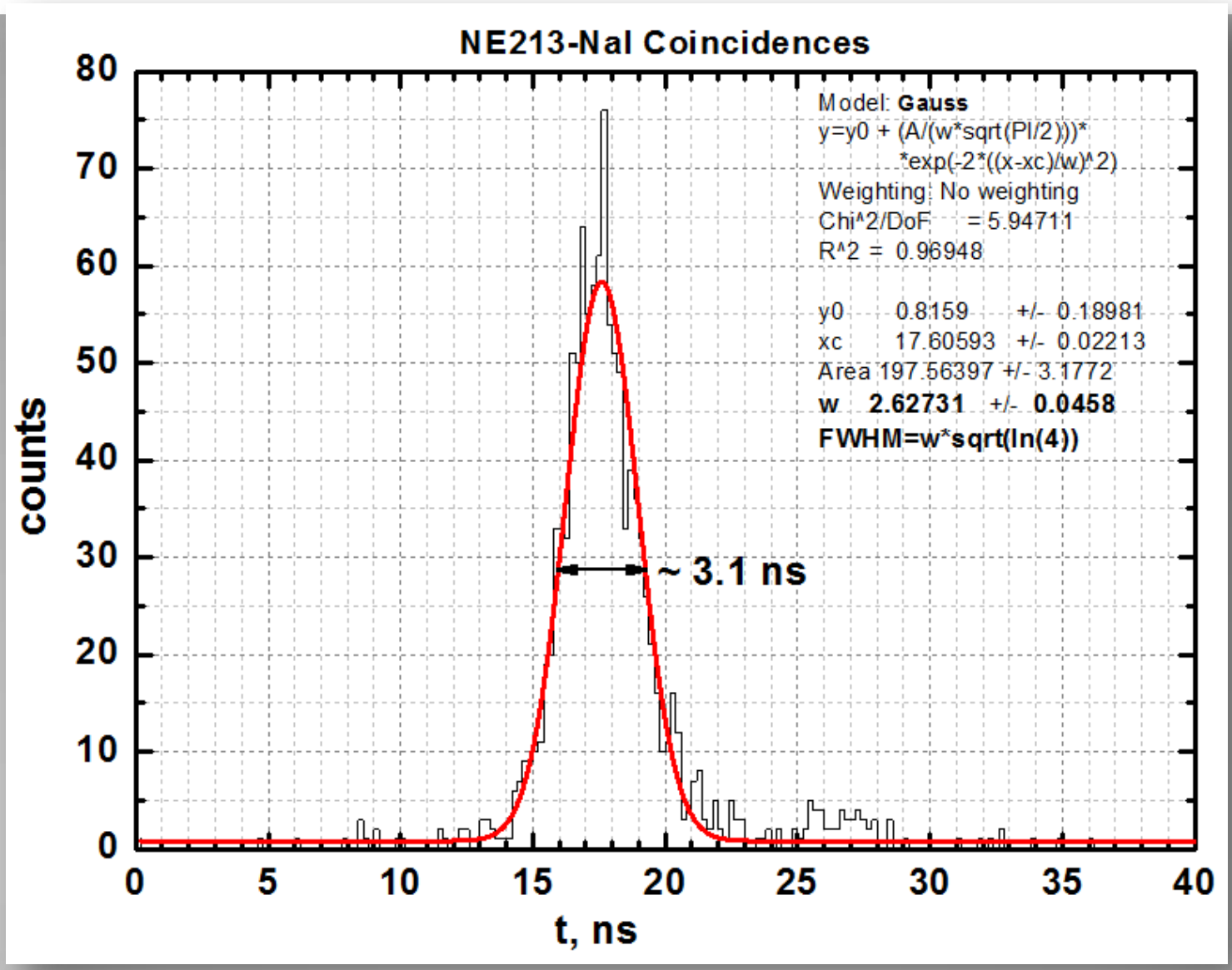
Part Number	R1306
Type	Head on
Size	51mm
ActiveDia/L	46mm
Min λ	300nm
Max λ	650nm
Peak Sens.	420nm
Cathode Radiant Sensitivity	95mA/W
Window	Borosilicate
Cathode Type	Bialkali
Cathode Luminous Sensitivity	110μA/lm
Cathode Blue Sensitivity Index	12
Red White Ratio	-
Anode Luminous Sensitivity	30A/lm
Gain	2.7E+05
Dark Current after 30 min.	2nA
Rise Time	7ns
Transit Time	60ns
Number of Dynodes	8
Applied Voltage	1000V
Multi Anode	N
Notes	For visible range and scintillation counting. electron transit time 60ns
Magnetic Shield	E989-05
Socket Bare	E678-14V
Socket + bleeder assy.	E1198-05 E1198-20
Power Supply	C3830 c9525-50 C9619
Amplifier	C7319 C6438 C5594 M7279 M8879

NaI(Tl) mono crystal with a hexagonal cross section	Photomultiplier tube (PMT) Hamamatsu R1306 [17]
Crystal dimensions	90x78x200mm
Container	Aluminium
Electronics module type	EM/2.VD.HVG
Test gamma source	Cs-137
Average Energy resolution <FWHM> at 662keV	7.14 ± 0.06%



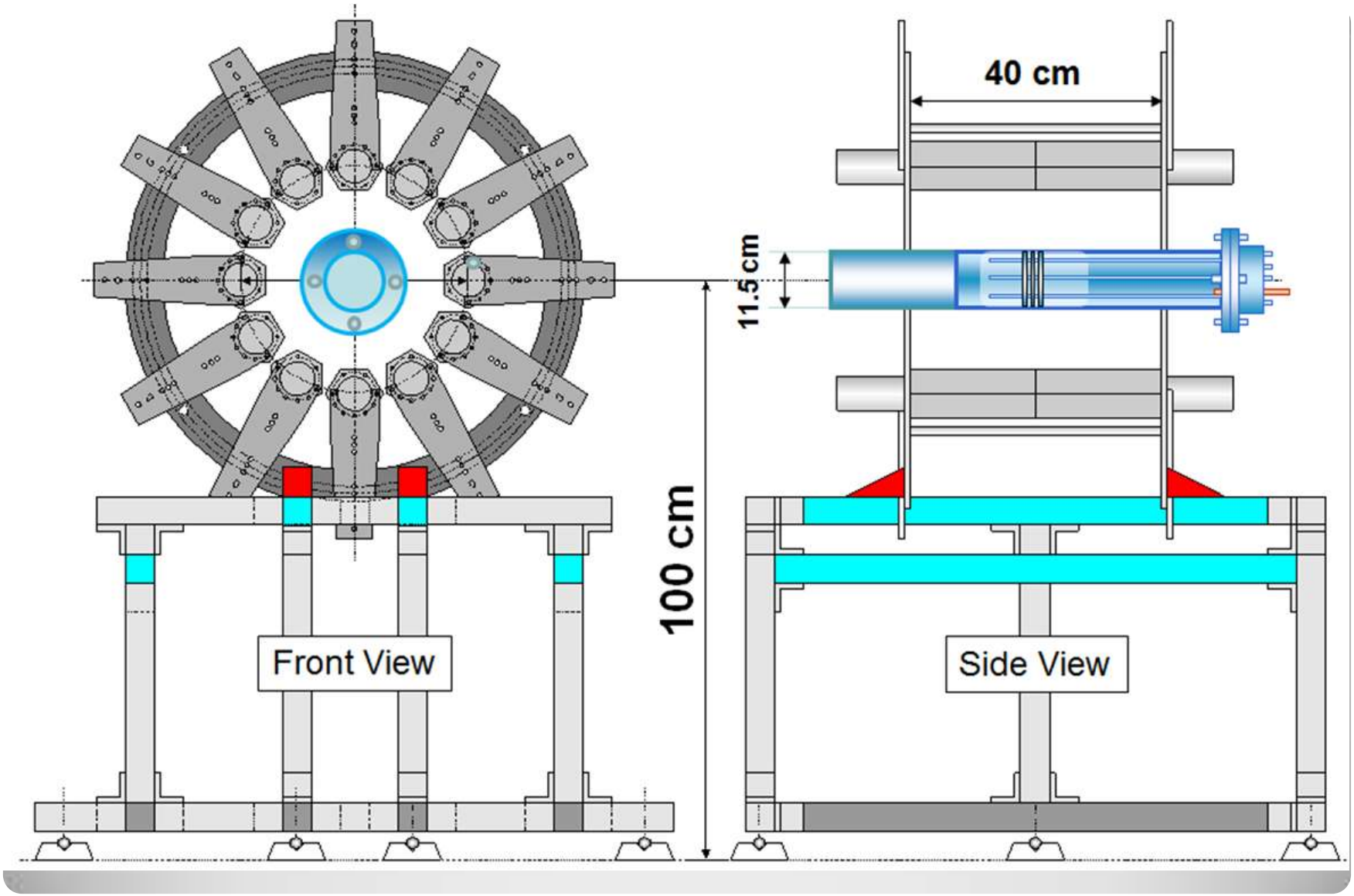


Amcrys© NaI(Tl)

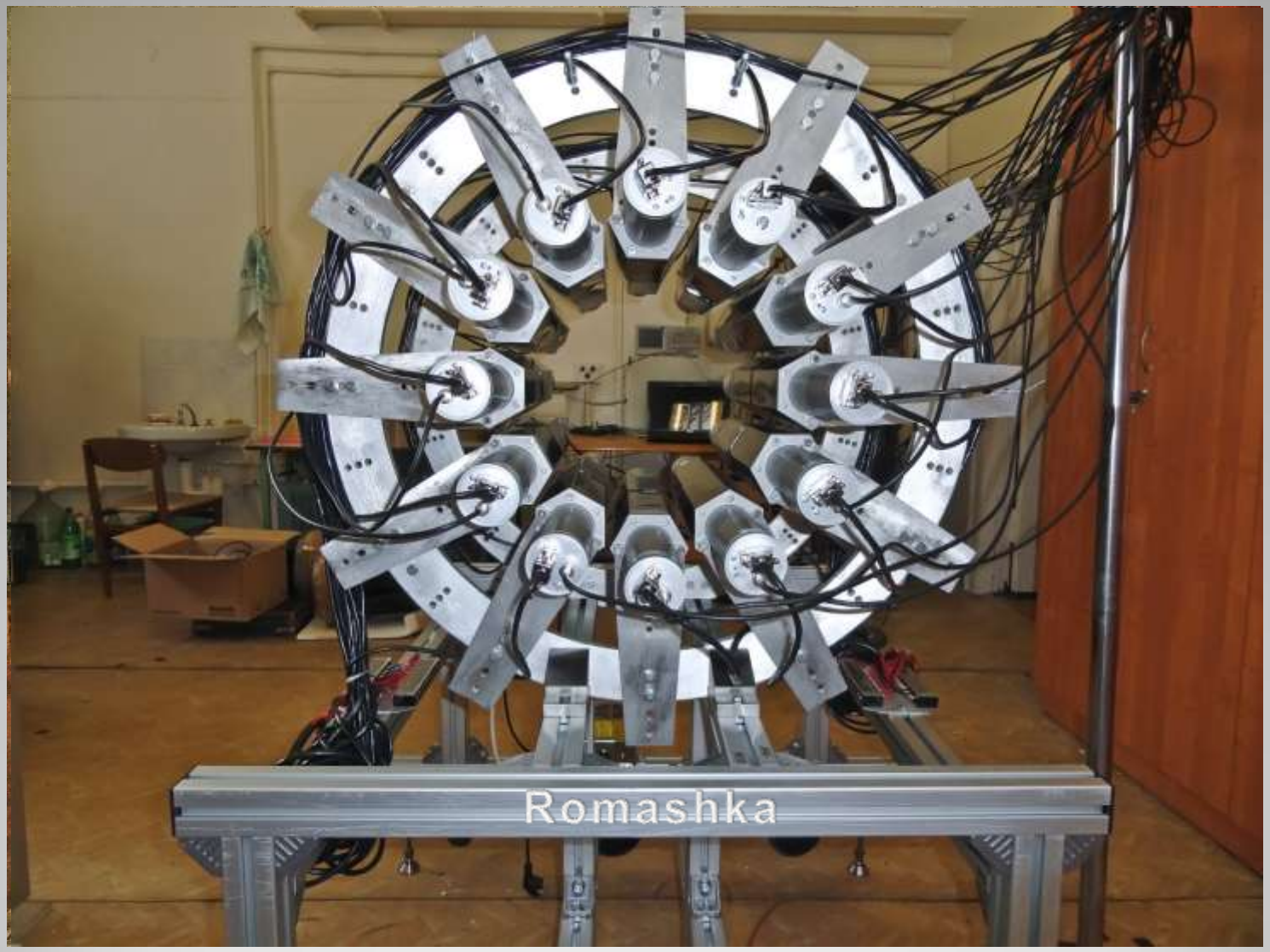


Time resolution of a single NaI with ^{60}Co

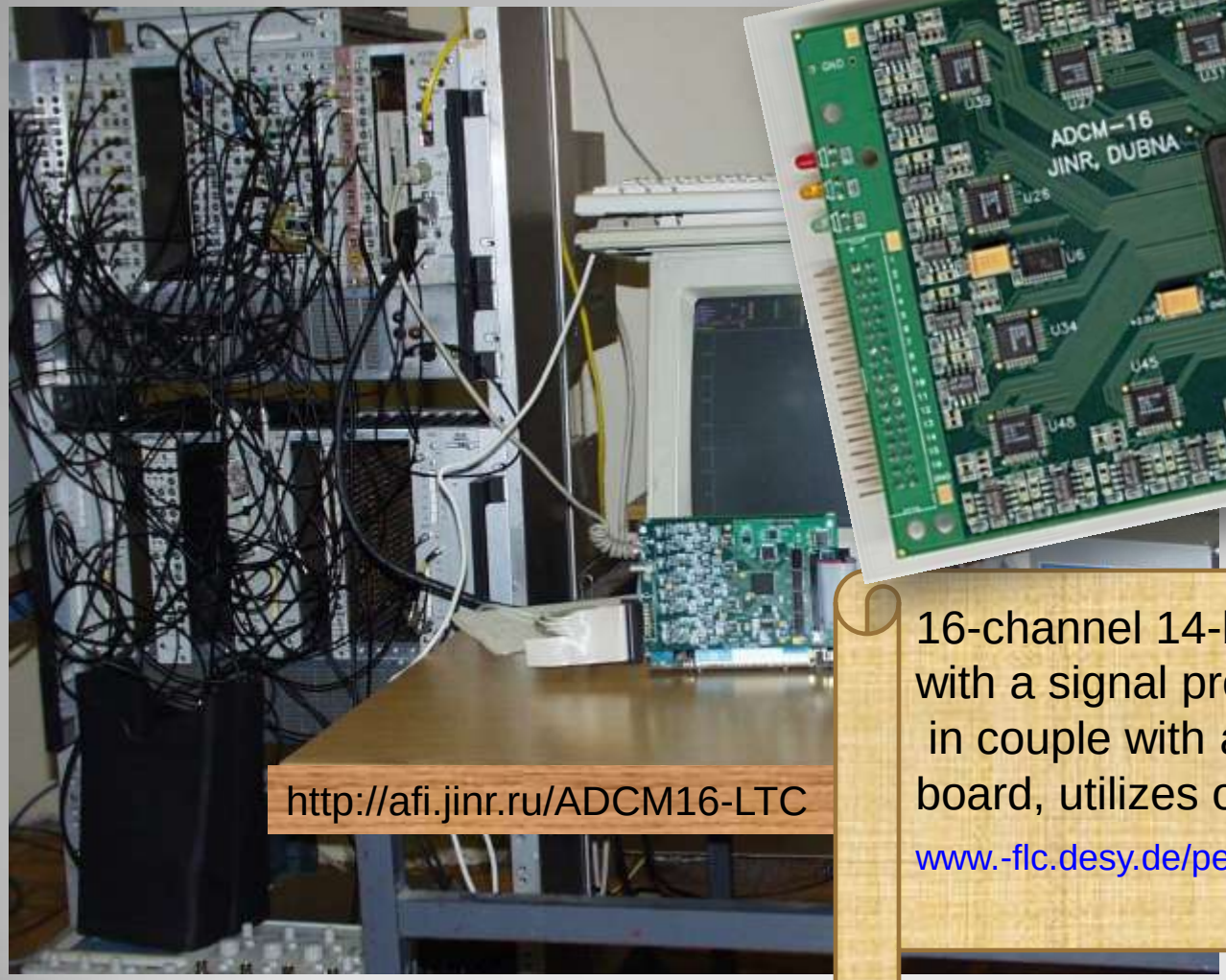
^{252}Cf n-γ TOF - separation (by 2 NaI 50 cm)

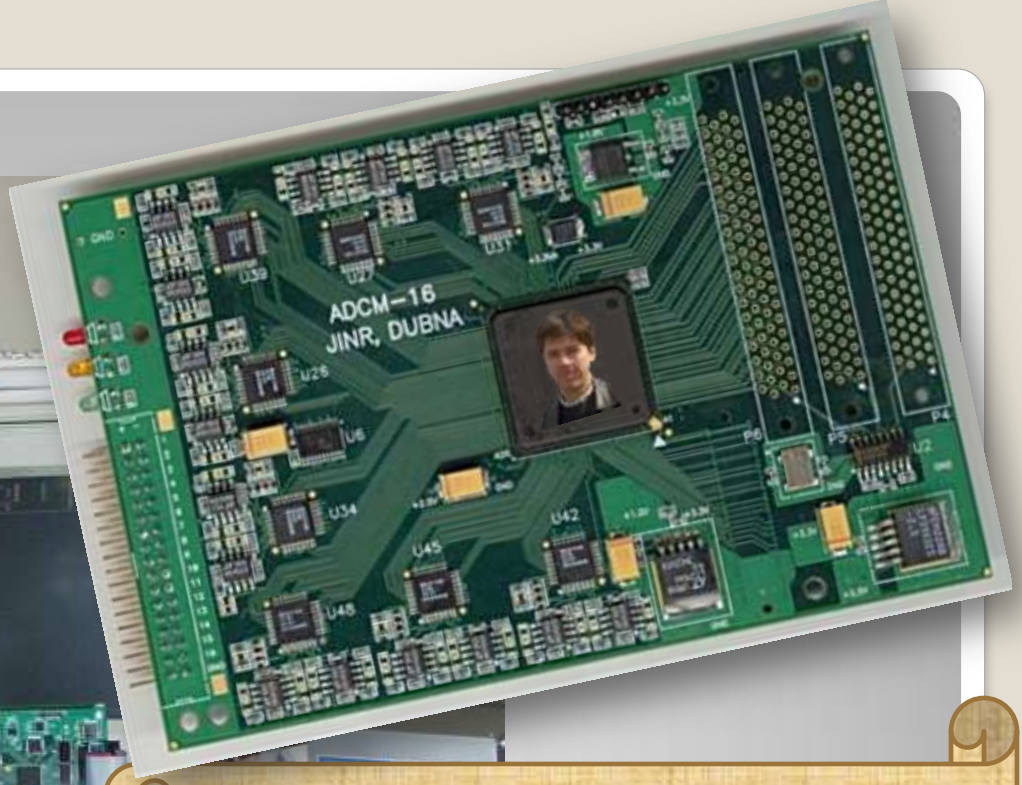


NaI(Tl) Multidetector Setup



NaI(Tl) Multidetector Setup





http://afi.jinr.ru/ADCM16-LTC

16-channel 14-bit 100 MHz Flash ADC with a signal processing core, in couple with a CCB-PCIe carrier board, utilizes one PCI slot of the PC.

www.-flc.desy.de/pet/projects/tofpet/index.php

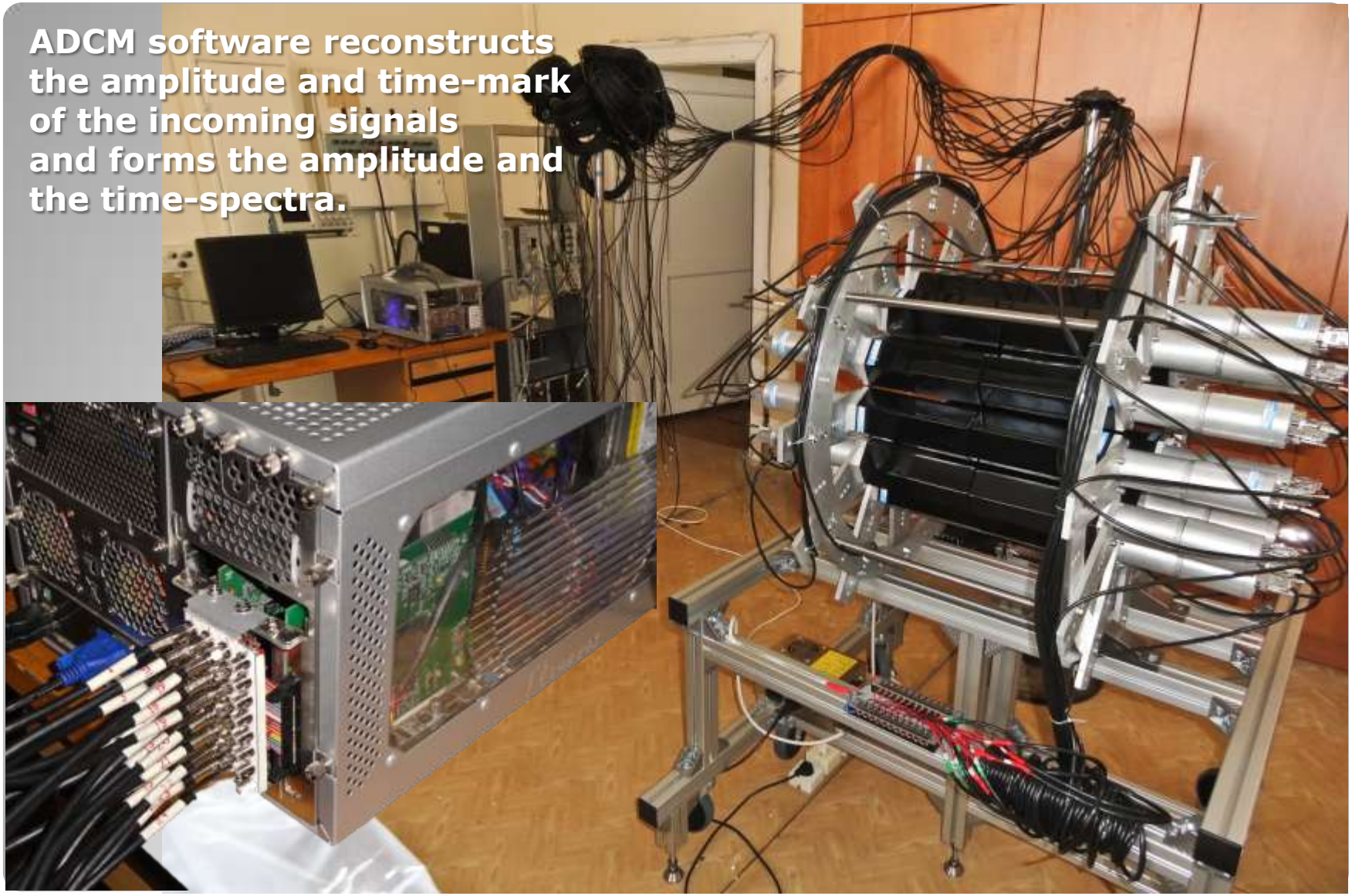
БЪЛГАРСКА АКАДЕМИЯ на НАУКИТЕ

ИЯИЯЕ INRNE

A digital pulse – processing - system for nuclear physics experiments

FLNP JINR

ADCM software reconstructs the amplitude and time-mark of the incoming signals and forms the amplitude and the time-spectra.



ADCM based Data acquisition system

^{137}Cs-^{60}Co standard sources

Applications Places System Thu May 17, 18:35:27

ADCM Control Panel

File Setup Statistics Options Help

Reset

Run

Pause

T: 0:01:10.0
MB/s: 0.000
MB: 345.4

Decoder
OFF Full
Offset Shape

CPU 0%
Disk1 5%
Disk2 88%

Network Info
MAC 8C89A536A540
IP 159.93.100.251

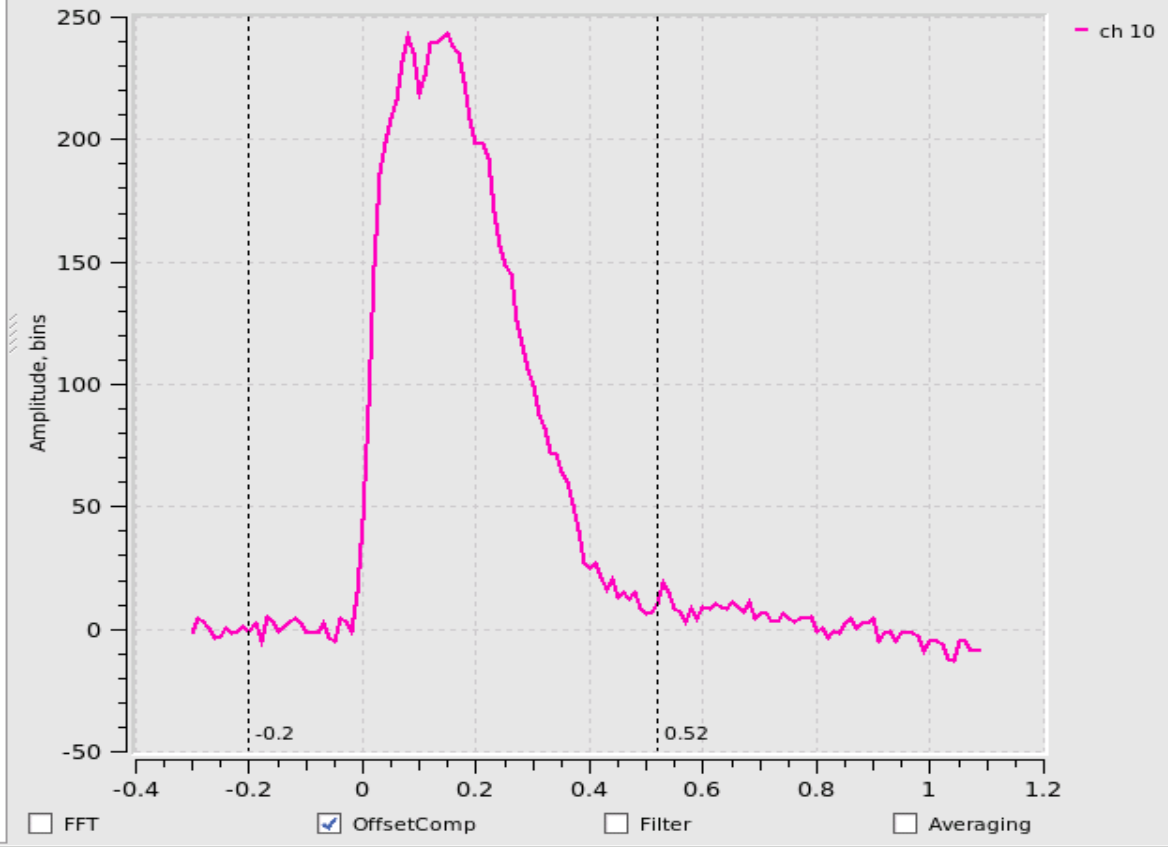
Settings | Histograms | Decoder info

	E	Z/S	Inv	γ	α	thr	f, kHz
0	☐	☑	☑	☑	☑	100	0
1	☐	☑	☑	☑	☑	100	0
2	☐	☑	☑	☑	☑	100	0
3	☐	☑	☑	☑	☑	100	0
4	☐	☑	☑	☑	☑	100	0
5	☐	☑	☑	☑	☑	100	0
6	☐	☑	☑	☑	☑	150	0
7	☐	☑	☑	☑	☑	100	0
8	☐	☑	☑	☑	☑	100	0
9	☑	☑	☑	☑	☑	30	6.405
10	☑	☑	☑	☑	☑	30	6.685
11	☑	☑	☑	☑	☑	30	6.816
12	☐	☑	☑	☑	☑	100	0
13	☐	☑	☑	☑	☑	100	0
14	☐	☑	☑	☑	☑	100	0
15	☐	☑	☑	☑	☑	100	0

Window, ns
PW -200
MW 720
Lat 300

☐ Cut, ns
L -300
R 300
L ≤ dT ≤ R

☐ Fast scope



Decoding speed: 9688.14 ev/s

ADC16-LTC Firmware ver 1.0.11048 S/N 330c 54.6 °C

adcm

ADCM DAQ software

Applications Places System Thu May 17, 15:29:40

/home/daq/adcm/adcmana13/adcmana13.x /data2/Romashka-12/run.dat Event: 500001

File Options Histograms Help

ch06 ch07 ch08

ch09 ch10 ch11

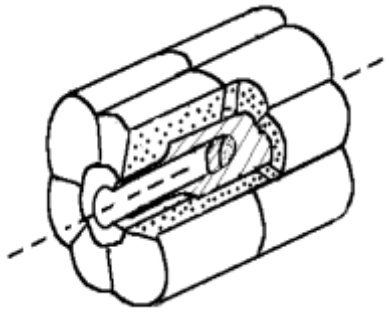
Open Reset Clear 1 ev 100000 N ev All ev FindBeam Save Exit Osc Legend

Parameters

20 Gam Threshold

-5 100 Gam Peak

20 120 Gam Pileup



Ev: 500001 Tst: 42819303(

File Edit View Options Tools Help

g: 28 0.00

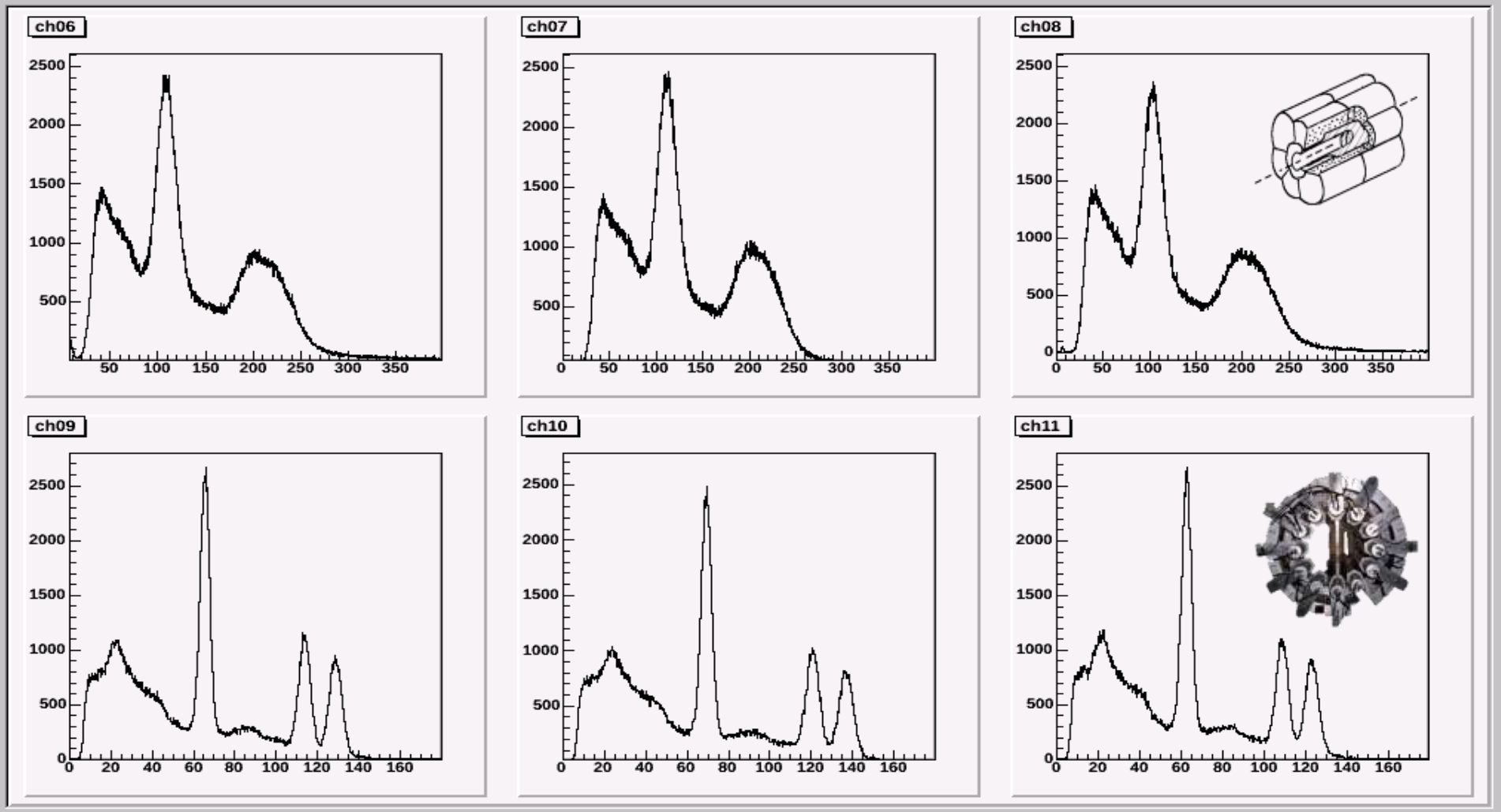
/home/daq/adcm/adcmana13.... Ev: 500001 Tst: 428193030

ADCM-ANA software

Applications Places System Thu May 17, 18:55:27

/home/daq/adcm/adcmana13/adcmana13.x /data2/Romashka-12/run.dat Event: 3527059

File Options Histograms Help



Open Reset Clear 1 ev 1000000 N ev All ev FindBeam Save Exit Osc Legend LogY

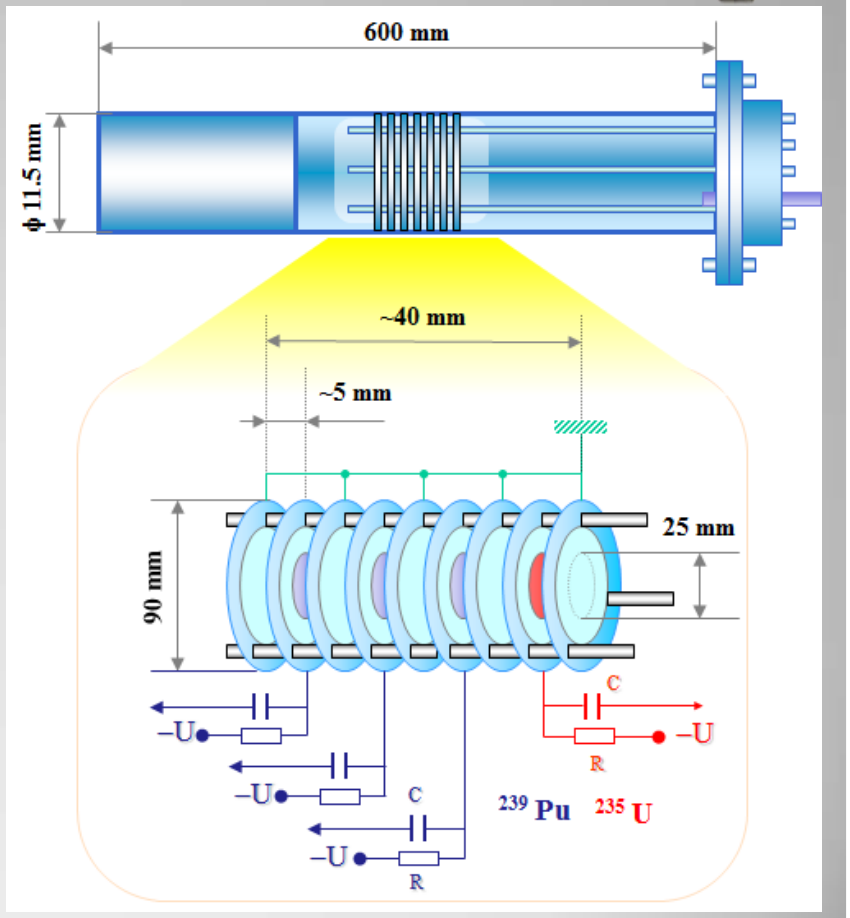
/home/daq/adcm/adcmana13/adcmana13.... Ev: 3527059 Tst: 1000149731

БЪЛГАРСКА АКАДЕМИЯ НА НАУКИТЕ

ИЯИЯЕ INRNE

^{137}Cs-^{60}Co amplitude spectra

FLNP JINR



"Romashka" + MP-FIC

Anyone is welcome


WHAT YOU SEE HERE
WHAT YOU DO HERE
WHAT YOU HEAR HERE
WHEN YOU LEAVE HERE
LET IT STAY HERE
The last, but not the least


кафе "АУДИТ"