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Investigation of the dependence of the time resolution of Si- detectors on the bias voltage

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The aim of the work…

to check the possibility:

- **of the preliminary fast adjustment and calibration with satisfactory accuracy of the spectrometer time channel**

to develop recommendations:

- **for improving the time parameters of the Si- detector signal**

- **for selecting the operating mode of the Si- detector to achieve the required parameters**

Important notes :

- **The investigated detectors are those that we had in stock, mainly PIPS (partly made in ORTEC, partly made in our laboratory 30 years ago)**

- **The measurements were carried out with the available equipment. <u>The detectors themselves and the preamplifiers used are especially important for the results</u>**

<u>The dependences on the bias voltage was measured for each detector for:</u>

- **the amplitude and time resolution**
- **signal-to-noise ratio in the time and amplitude channels**
- **the duration and form of the signal front**
- **surface temperature, leakage current**

***almost all graphs for results in coincidences mode have statistics obtained during 30 minutes measurements**

Some of our measurements are carried out on a two arm spectrometer at the SINP accelerator (У-120 НИИЯФ МГУ).

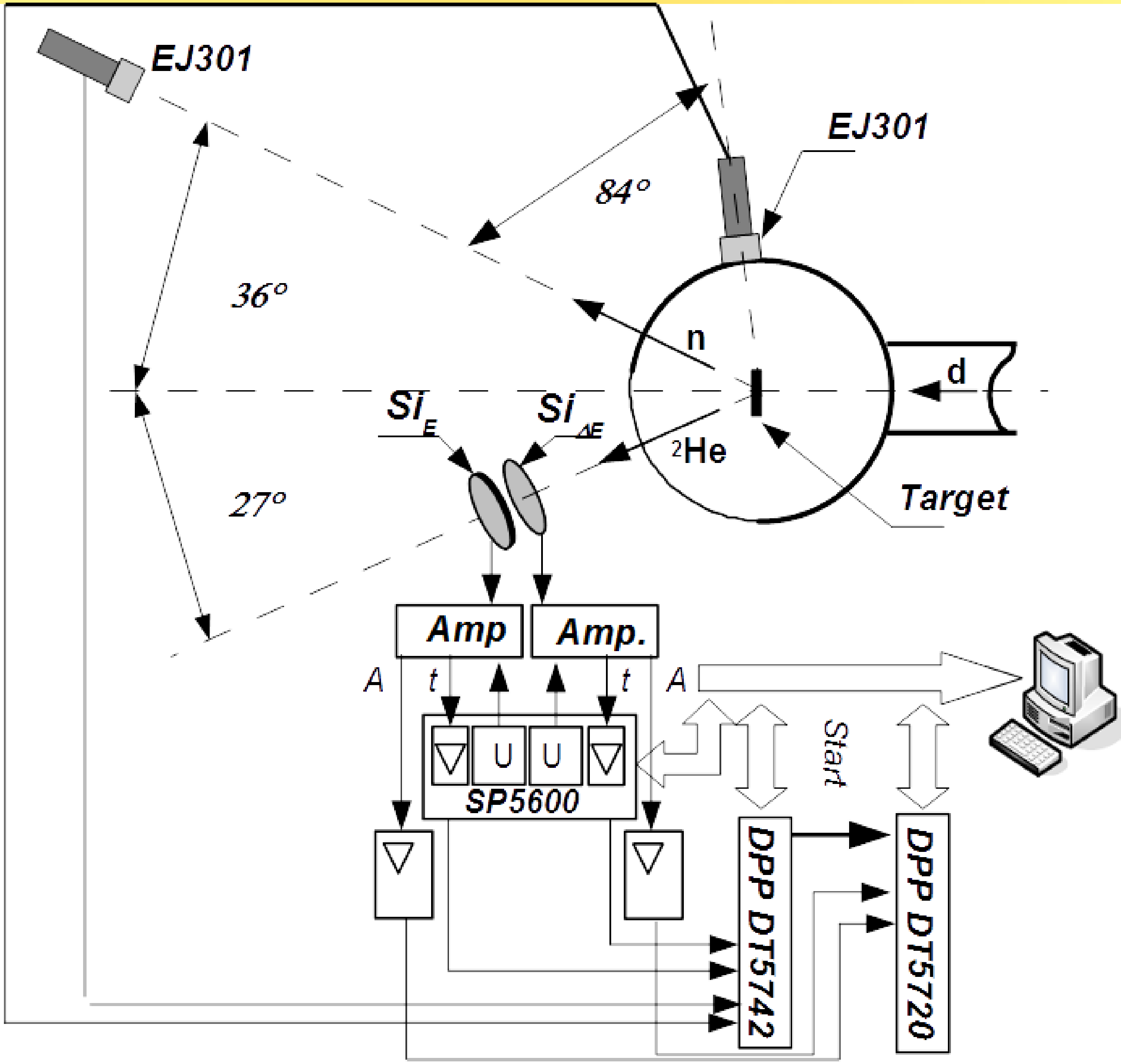
It consists of an $\Delta E - E$ telescope of silicon surface-barrier detectors for charged particles and scintillation detectors in the other arm.

The telescope determines the energy and type of charged particles, scintillation detectors separate neutron events from gamma by the pulse shape and determine the neutron energy by time of flight.

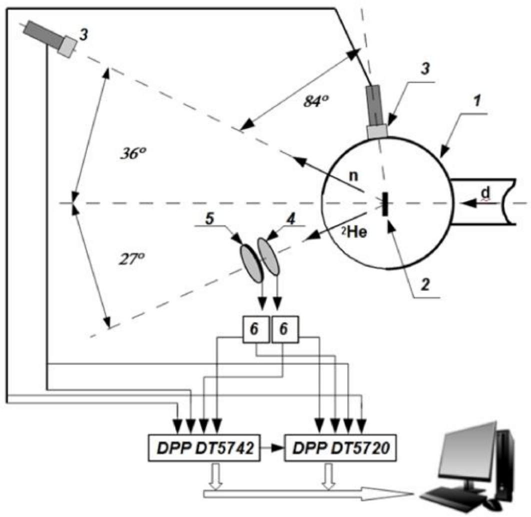
example of investigated reactions :

d + 2H → 2He + n + n

EXPERIMENTAL SETUP at SINP



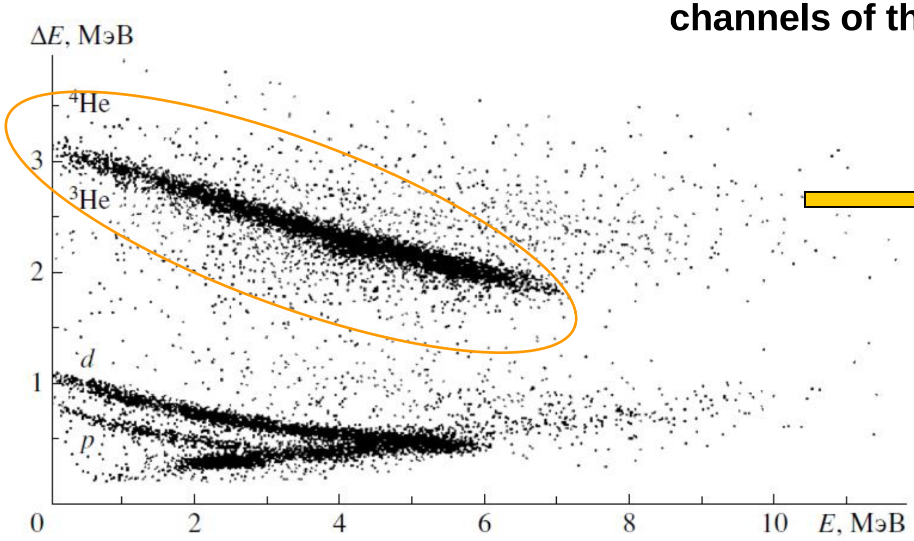
EXPERIMENTAL SETUP at SINP

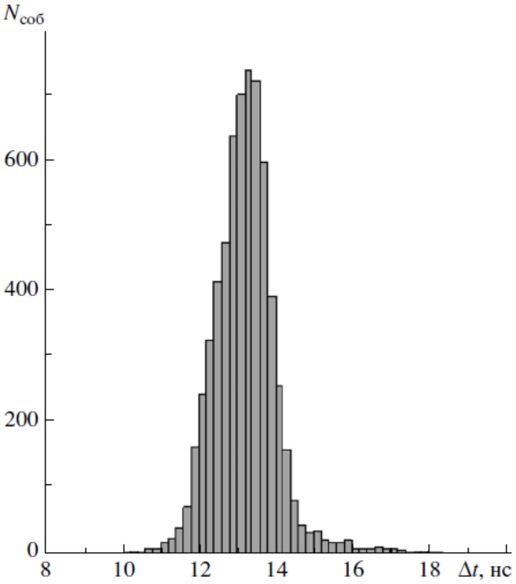


- To determine the neutron energy from the time of flight you need time calibration of the channel and knowledge of the time resolution parameters of the start (Si) and stop (EJ301) detectors.

- Time calibration can be performed, for example, by registering a particle (3He) from a two-particle reaction d + 2H → 3He + n at a calculated emission angle (i.e., in fact, with a certain energy)

- In the time distribution (Δt= start Ej301 - stop Si) events was selected corresponding to the 3He locus in the ΔE-E diagram we obtain the channel time resolution and calibration (here 1.5 ns and 13 ns is the difference between the hardware delays in the channels of the E- and neutron detectors)





Choosing a method for detectors adjustment:

Some of the existing methods can be mentioned::

Accelerators beam   - minus - expensive time

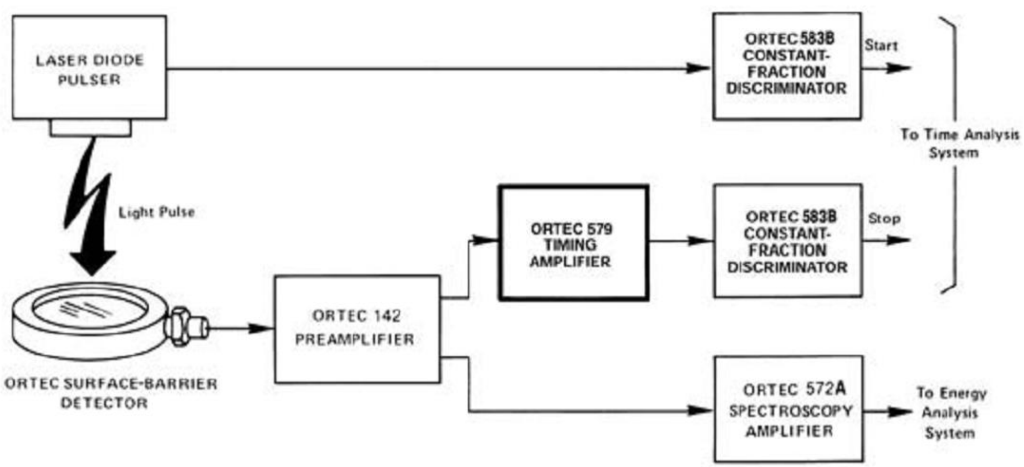
- plus - as close as possible to the required conditions

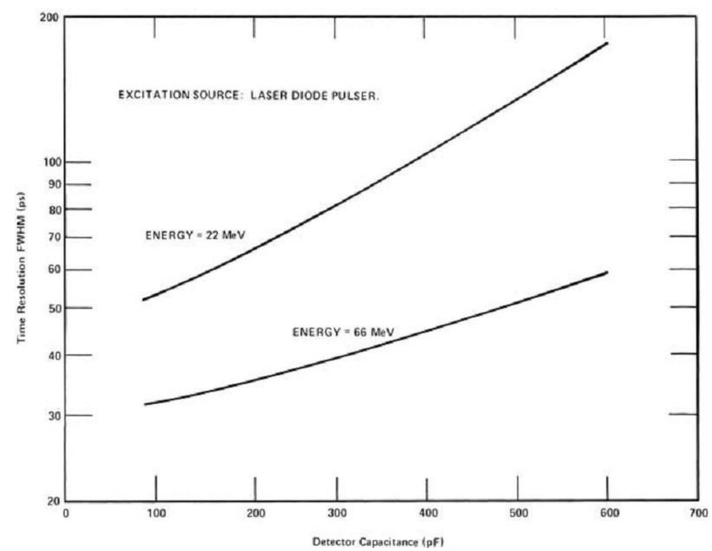
By means of ***runaway electron beam*** of subnanosecond duration generated by discharge in open atmosphere at high overvolatges [L. P. Babich, T. V. Loiko, A. V. Rodigin /PTE. 2014. № 3. P. 21–27]

By simulation the effect of the charged particle by ***using a Laser diode*** with a sub-nanosecond pulse width [https://www.ortec-online.com/-/media/ametekortec/other/fast-timing-discriminator-introduction.pdf?la=en]

By registering ***correlated particles from decays*** of a radioactive source:

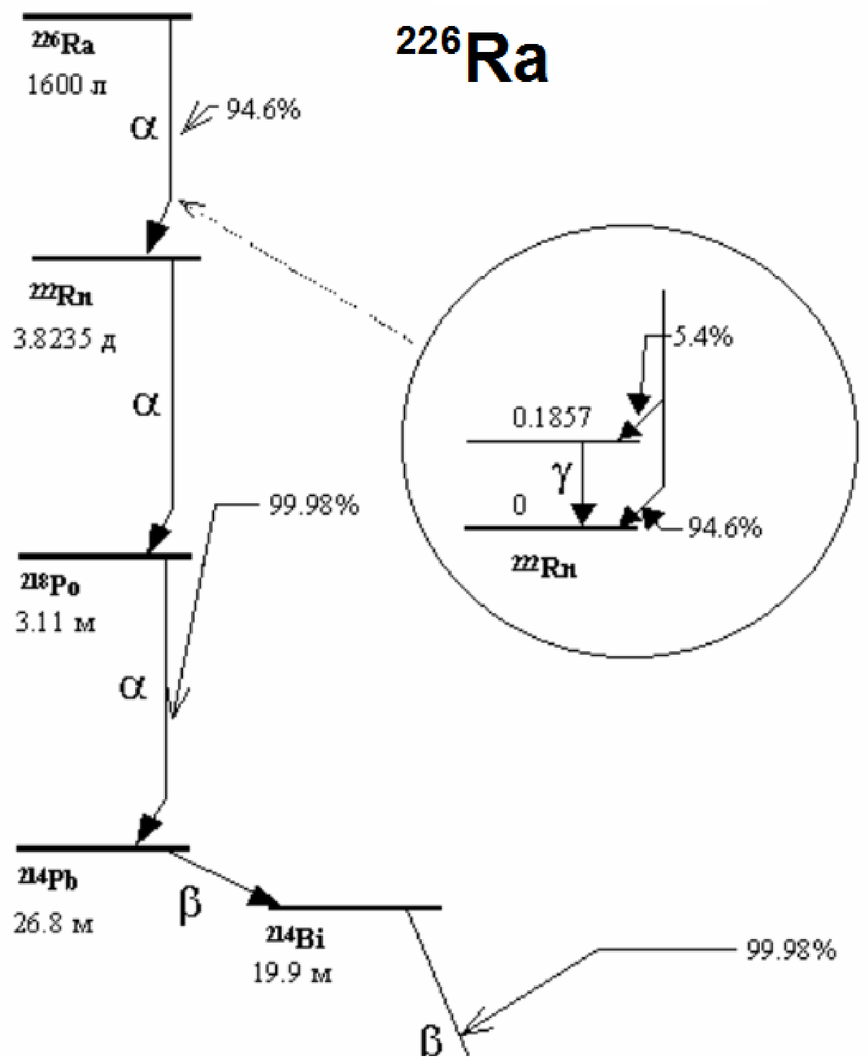
- plus - if one of the particles is alpha - then it looks like an experimental conditions
- minus - usually gamma quanta are of low energies, low intensities of the required decay modes.



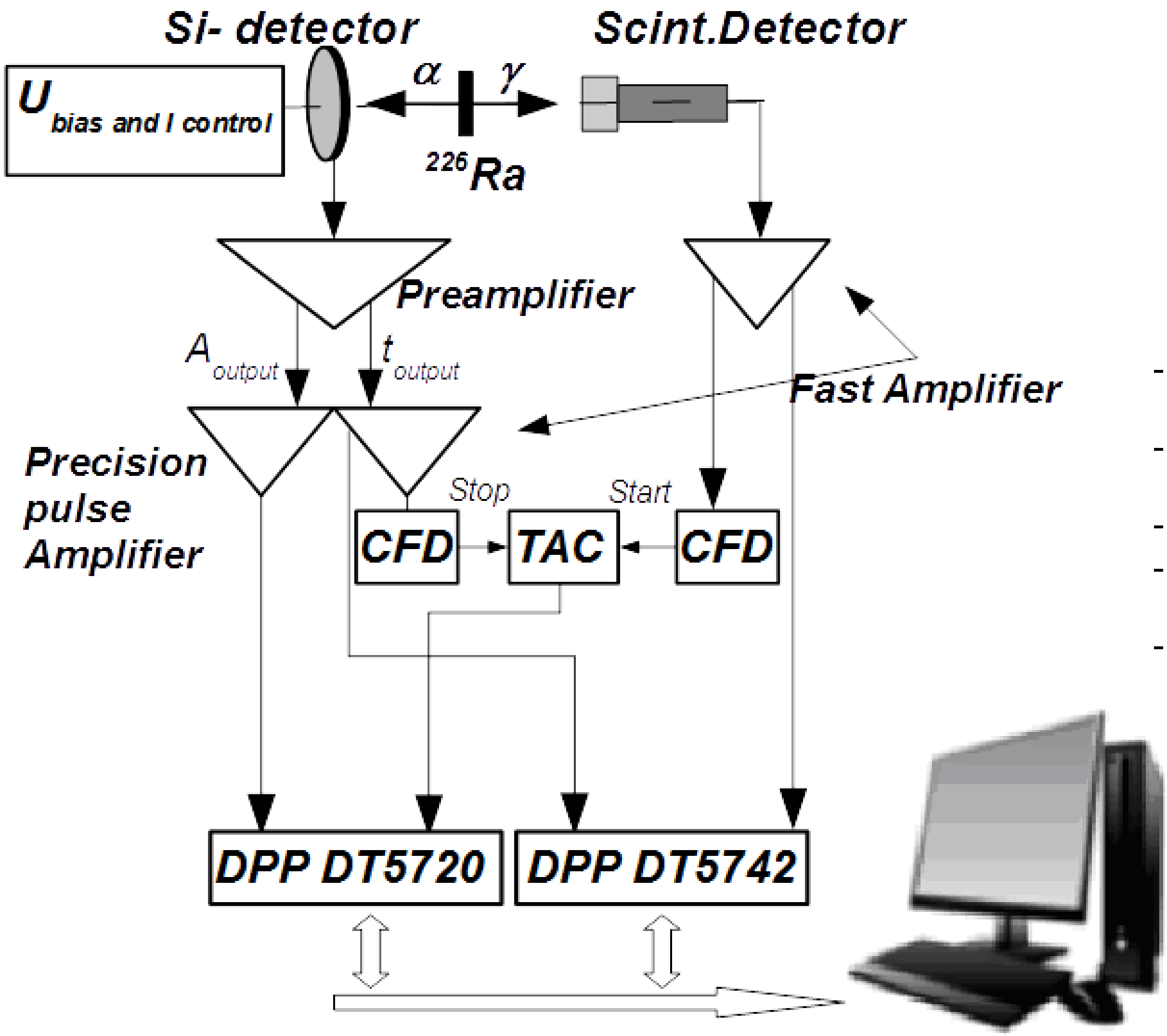


Particle source used :

We used the ***standard α-source Ra-226*** (RSAS).



EXPERIMENTAL SETUP



- Scintillation detectors –Hamamatsu 2083 PMT EJ301 or EJ315
- Preamplifier - CANBERRA 2003BT and ORTEC142
- Fast amplifier Philips 7177
- Precision pulse amplifier - ORTEC 472
- Constant fraction discriminator - CANBERRA TC 454 QUAD

TAC - Intertecniq TA22

CAEN DPP5720 - 4 ns/ch, 5742 - 0.2 ns/ch

It is known that if all other conditions are equal, then:

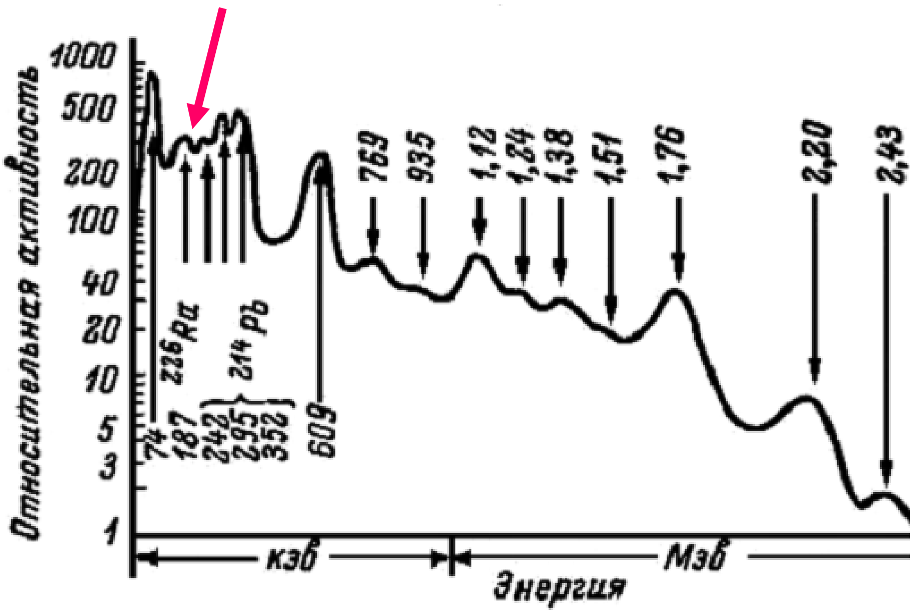
- \- time resolution is determined by the leading edge of the signal - noise/slope ratio

The duration and shape of the leading edge of the signal may depend

- ***- the strength of the field, under which the charges are collected***
- \- from charged particle type
- \- from the value of the run in the detector (and more over the conditions - passed / did not pass through the detector)

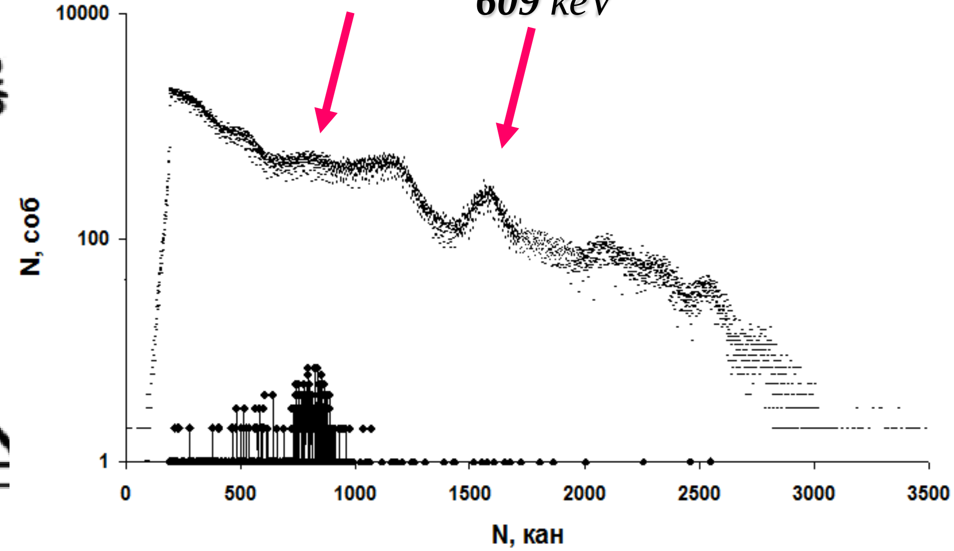
Only the first dependency is discussed here.

***187** keV*



***187** keV*

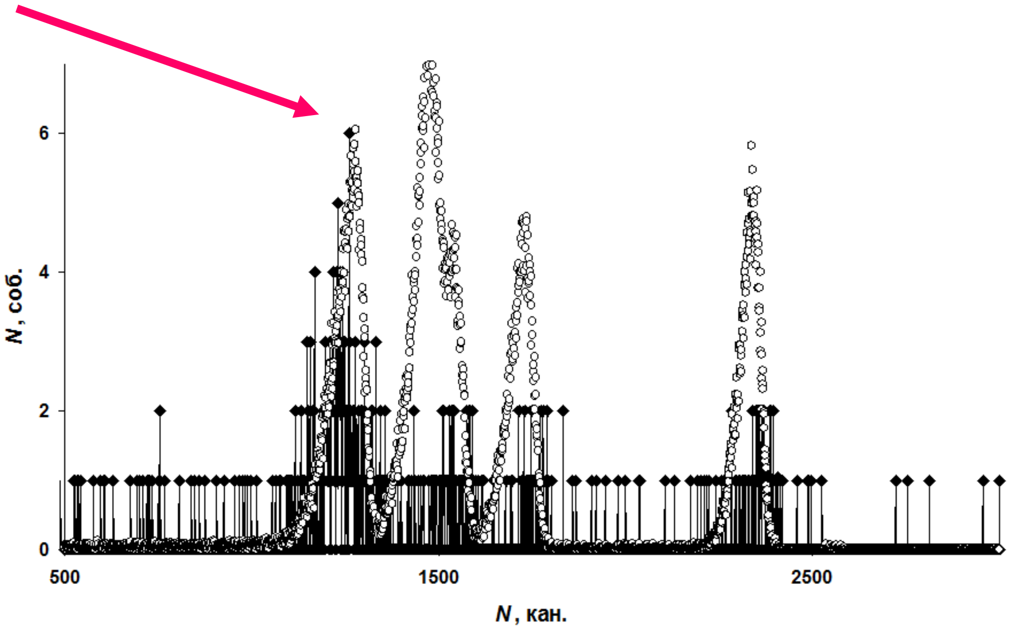
***609** keV*

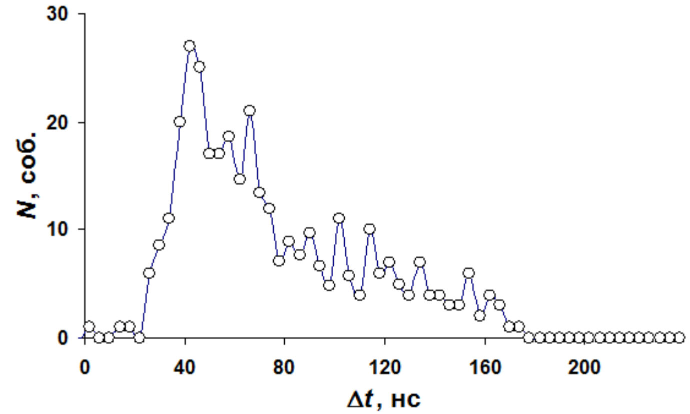


spectrum of gamma quanta. 226Ra decay

The same spectrum measured with a NaI-based detector in our mesurements ,
below - coincidences with the alpha particle detector is on

EXPERIMENTAL SETUP – Si detector spectrum



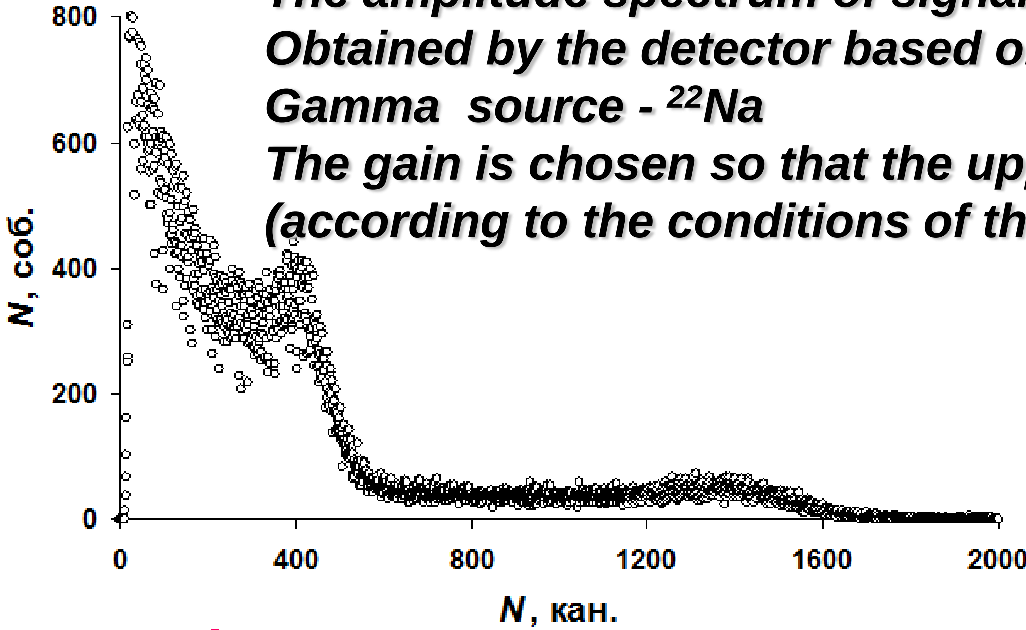


The amplitude spectrum of the registered alpha events y Si detector:
white points - without coincidence with the scintillation detector,
dark points - coincidence included.
Marked peak - 4784.4 keV

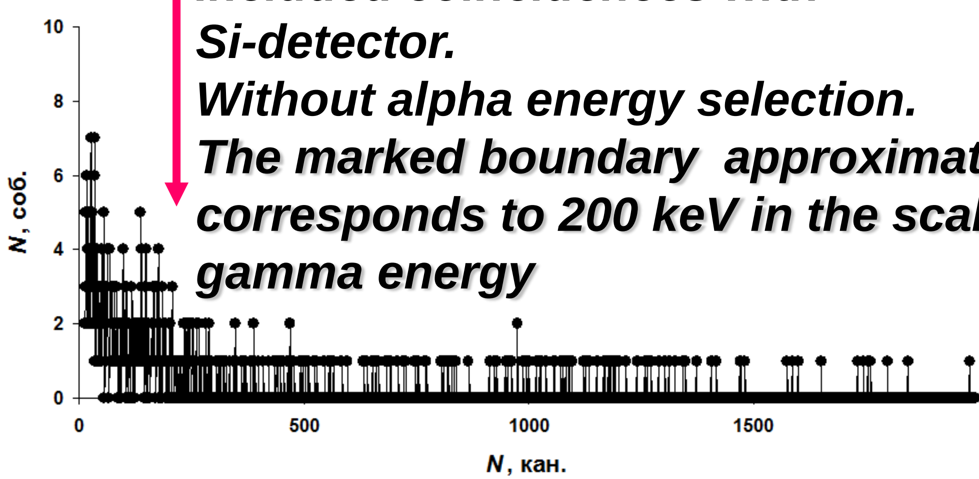
Time resolution of the NaI-Si system (^{226}Ra decay). Without any optimization. TAC used.

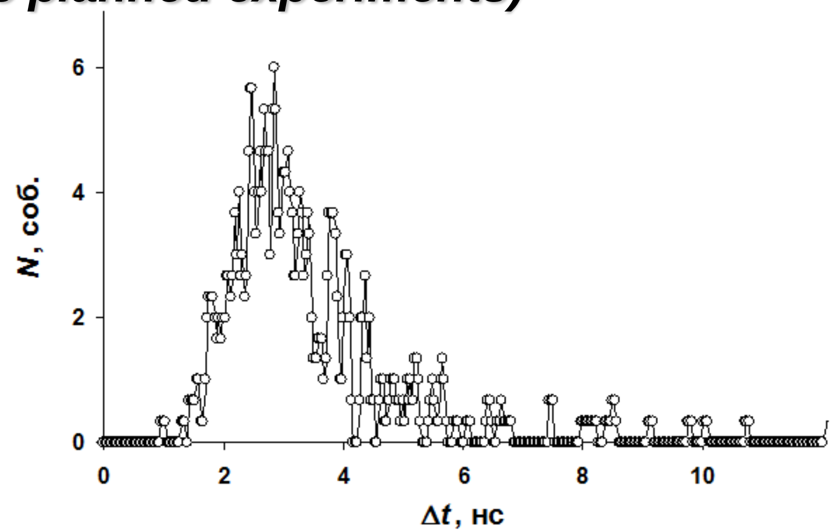
EXPERIMENTAL SETUP - EJ301 spectrum

The amplitude spectrum of signals.
Obtained by the detector based on EJ301.
Gamma source - ^{22}Na
The gain is chosen so that the upper limit E_{ee} ~ 3 MeV
(according to the conditions of the planned experiments)

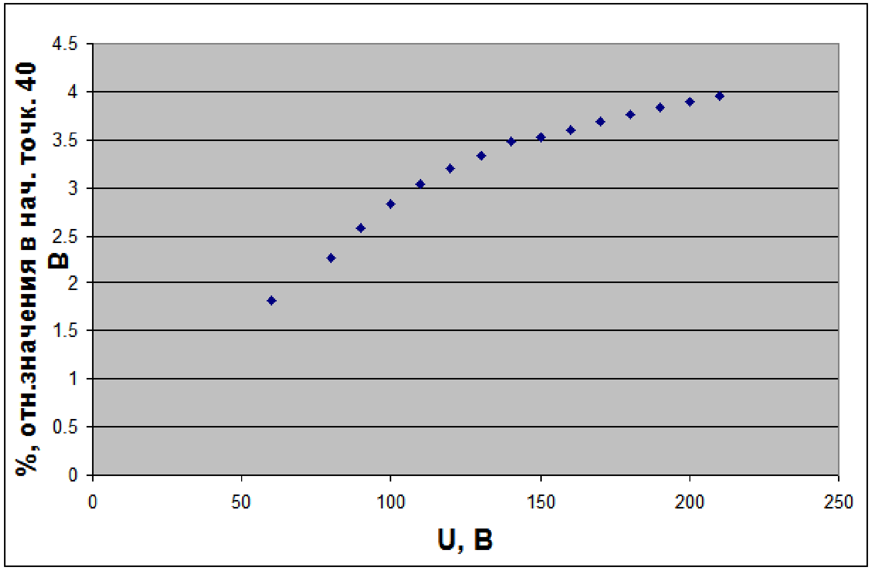


γ– from the decay of ^{226}Ra.
Included coincidences with
Si-detector.
Without alpha energy selection.
The marked boundary approximately
corresponds to 200 keV in the scale of
gamma energy

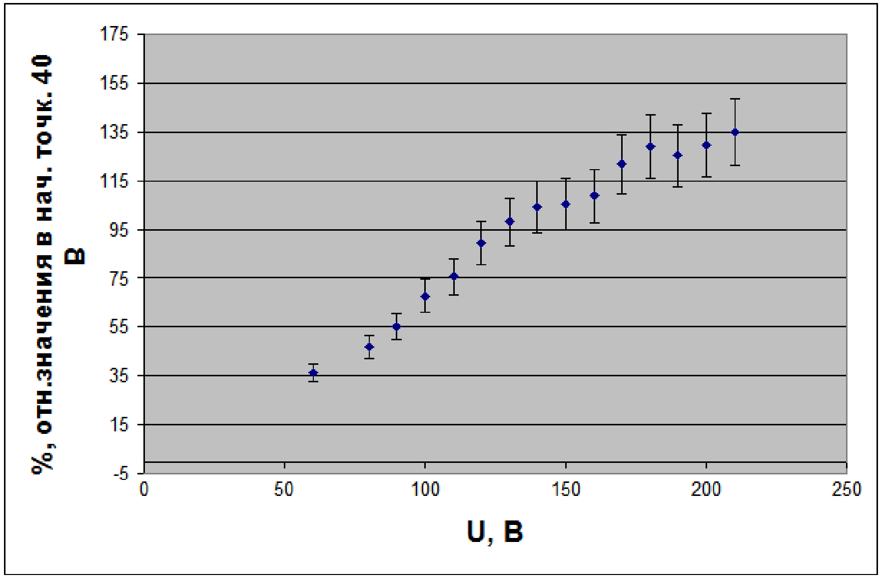




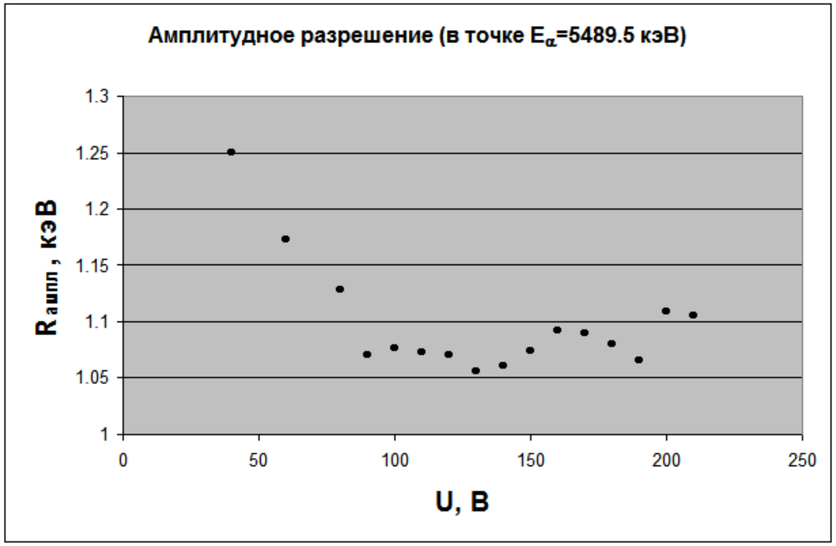
Time resolution of the EJ301-Si system (^{226}Ra decay). Obtained at recommended Ubias for Si-detector. Without any optimization. TAC used.



1. Amplitude of the positive ("slow") signal vs Ubias



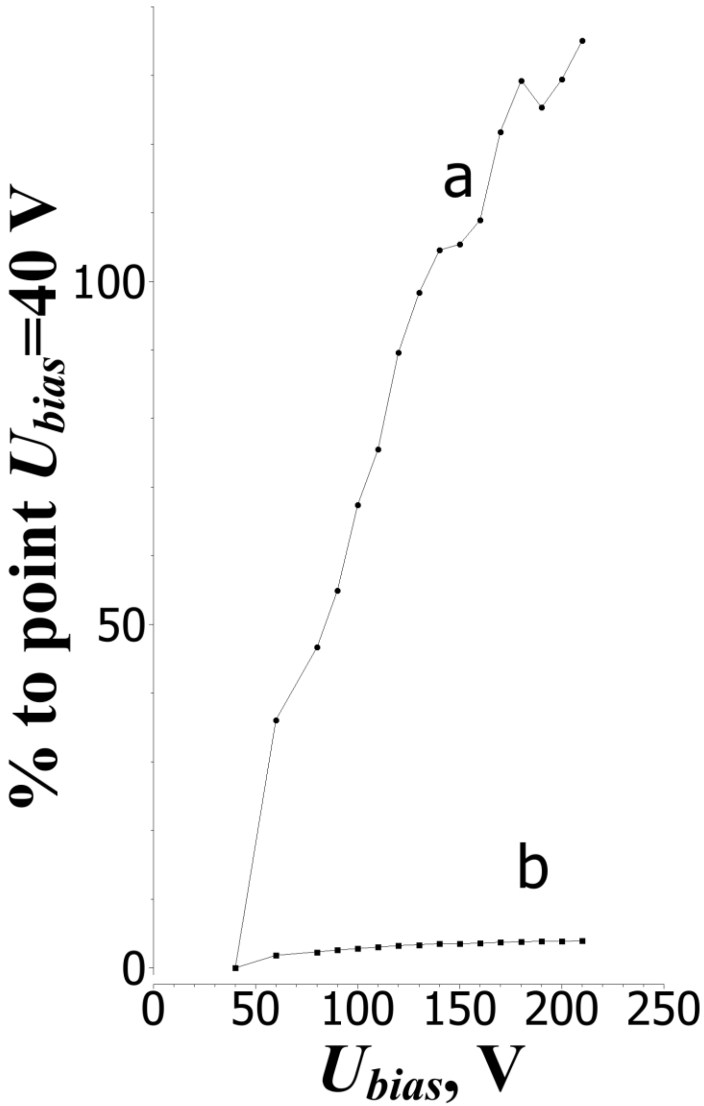
3. Amplitude of the negative ("fast") signal vs Ubias

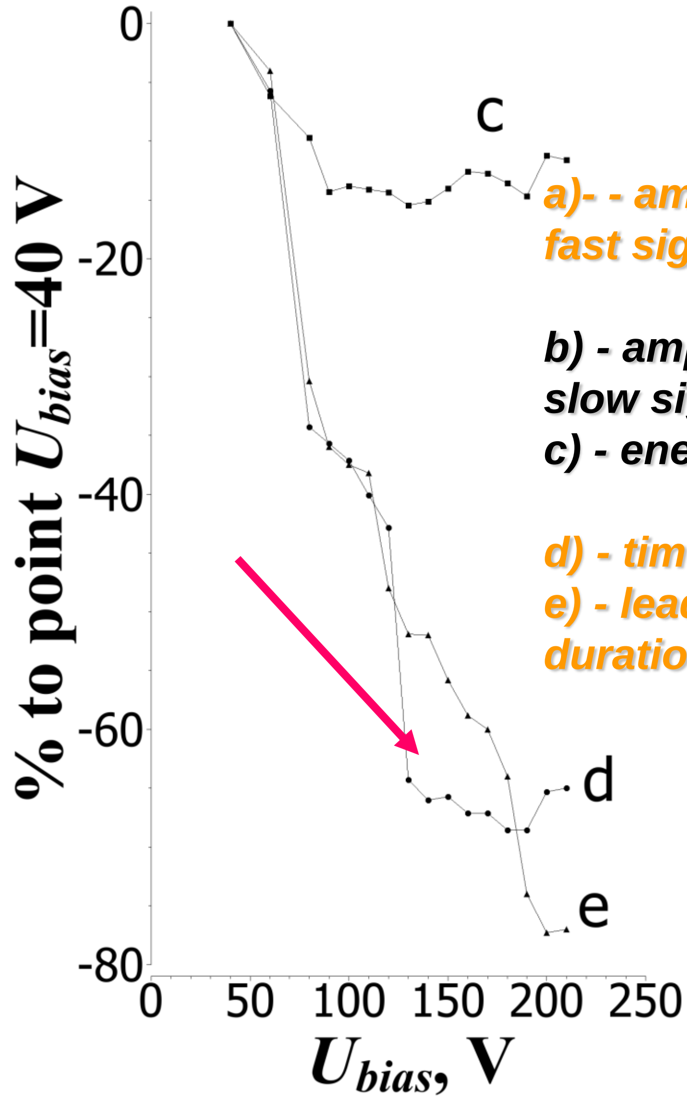


2. Amplitude resolution (based on positive signals) vs Ubias

RESULTS

•Similar dependences were obtained for a set of the detectors with an active layer thickness from 100 to 500 µm





a)- - amplitude of the fast signal

b) - amplitude of the slow signal

c) - energy resolution

d) - time resolution

e) - leading edge duration

CONCLUSIONS

- *The time channel can be debugged and calibrated before experiment. It can be done in a reasonable time*
- *For Si- detectors under consideration (PIPS) the operating point of the best time resolution (for the selected set of equipment) does not coincide with that for the amplitude resolution and is achieved at higher voltages*
- *The plateau in the dependence of time resolution from Ubias occurs much earlier than the minimum rise time is reached. So to achieve the best time resolution you must measure it during the changing Ubias.*
- *To achieve the minimum threshold for the registration of charged particles it is necessary to increase Ubias to the level that is possible for safety reasons. In this case, also the achievement of the best amplitude and time resolution is most likely*
- *This work was funded by RFBR according to the research project №18-32-00944.*

Thank you!