THE MODIFIED MINI-FOBOS SETUP

D.V. Kamanin[1], A.A. Alexandrov[1], I.A. Alexandrova[1], S.V. Denisov[1], S.V. Khlebnikov[3], T.E. Kuzmina[3], E.A. Kuznetsova[1], S.V. Mitrofanov[1], V.G. Tishchenko[1], A.N. Tjukavkin[1,2], I.P. Tsurin[1], Yu.V.Ryabov[4], Yu.E. Penionzhkevich[1], Yu.V. Pyatkov[2], E.A. Sokol[1], S.R. Yamaletdinov[1,5]

[1] Joint Institute for Nuclear Research, 141980 Dubna, Moscow region, Russia
[2] Moscow Engineering Physics Institute, 115409 Moscow, Russia
[3] Khlopin-Radium-Insntute, 194021 St. Petersburg, Russia
[4] Institute for Nuclear Research RAN, 117312 Moscow, Russia
[5] Department of Physics, University of Jyväskylä, FIN-40014 Finland

ABSTRACT

The present paper is devoted to the new mobile double-arm TOF-E-Z spectrometer of the charged fragments named the Modified Mini-FOBOS setup (MMF) turned into operation in 2004. It inherits the modular structure and the standard detector modules of the 4 spectrometer of charged particles FOBOS [1]. The main feature of the FOBOS detector modules is the independent measurement of the velocity vector, mass and charge for each fragment without any kinematical assumptions on the reaction mechanism. This makes possible precise study of the reactions in the most general case - non-binary processes with some missing mass. These excellent capabilities in registering charged products of nuclear reactions have been confirmed in different experiments dedicated to the study of multi-body decays both with HI beams [2] and with the spontaneously fissile sources [3].

The general idea of the MMF consists in using a small reaction chamber, which might be unique for each experiment and the basic universal system maintaining the detectors. The FOBOS-modules are fit to the reaction chamber by means of the adapting cones. Our spectrometer is currently provided by the universal reaction chamber of 44 cm in the diameter with the available arm-angles of 65, 90 and 135 deg in the reaction plane for both detector modules. The direction of the beam can be reversed increasing thus the number of possible angles between the detectors. The flight-path in this configuration amounts to 50 cm, i.e. the same as at the FOBOS setup. Hence, we keep the resolution parameters specific for FOBOS. Such a configuration of the spectrometer is well suited for study of heavy-ion induced reactions and for spontaneous fission as well.

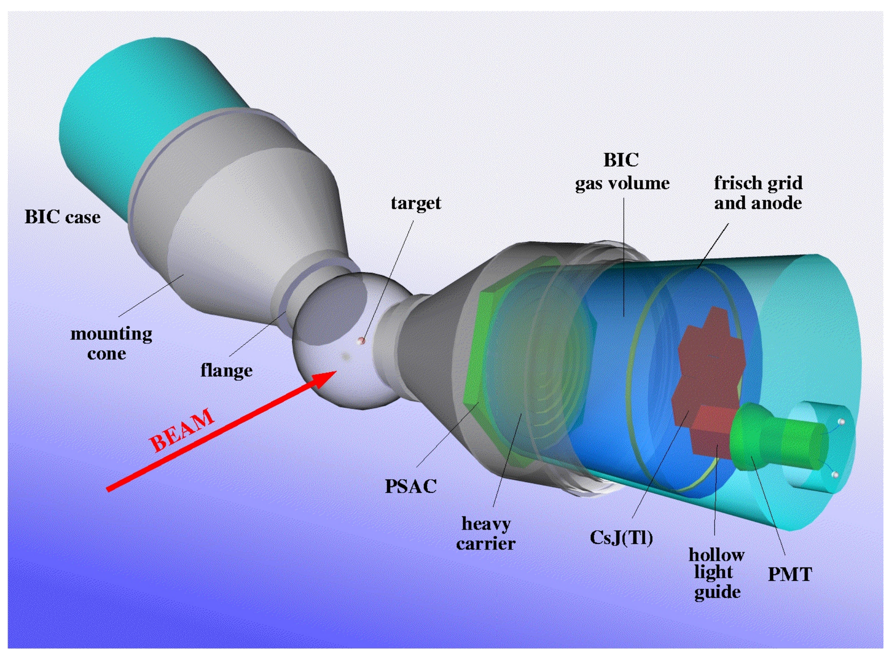
Thus, all the advantages of the FOBOS spectrometer (except of the declared geometrical efficiency closed to 4) have been adopted entirely by the Mini-FOBOS spectrometer. Depending on demands of the particular experiments the additional detectors can easily be installed (gamma-detectors, neutron-detectors, forward-angle arrays, etc.). In particular, the high-efficiency neutron counter has been coupled to the spectrometer during the last experiment on the search for the collinear cluster tripartition [4,5]. Besides this, modifications have concerned the start detector, the electronics and the data acquisition system. Also the completely new independent gas-supplying system has been developed.

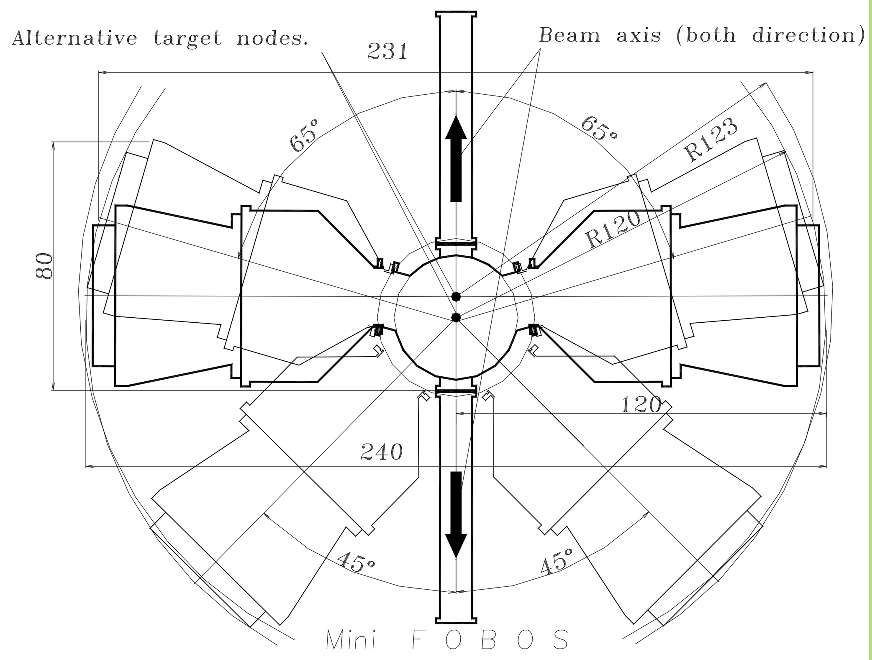
We are planning to exploit the advantages of the MMF setup in forthcoming experiments dedicated to the study of collinear cluster tripartition in the different reactions with light particle beams and neutrons.

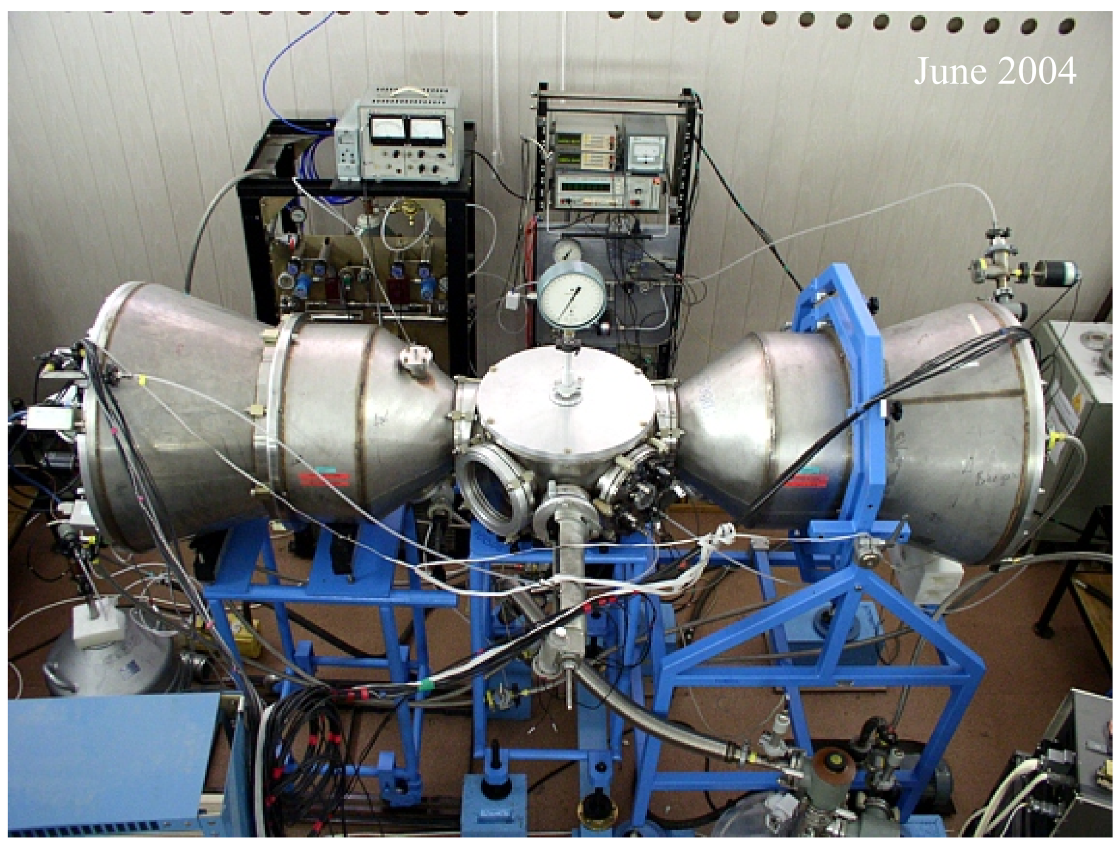
References

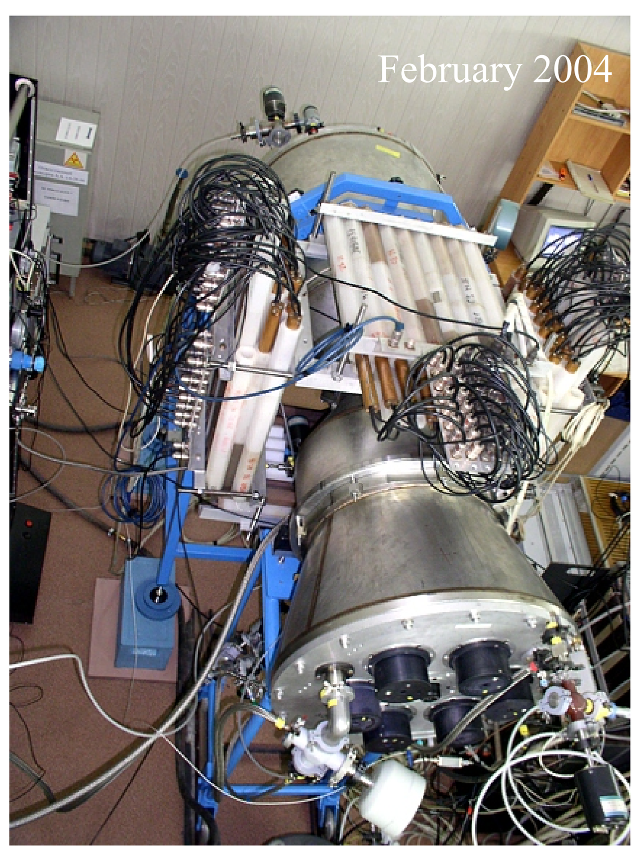
1. H.-G. Ortlepp et al. *NIM A 403 (1998) 65-97.*
2. V.G. Tishchenko et al., *Nuclear Physics A 712 (2002) 207-246.*
3. Yu.V. Pyatkov et al., *EXON 2004 (see the contributions)*
4. D.V. Kamanin et al., *Physics of Atomic Nuclei, v. 66 (2003) 1655*
5. Yu.V. Pyatkov et al.,*Physics of Atomic Nuclei,* v. 66 (2003) 1631

LAYOUT OF THE SPECTROMETER









The standard FOBOS detector module consists of three successive detectors for charged fragments ranging from protons to heavy evaporation residues produced in nuclear reactions.

position-sensitive avalanche counter (PSAC) for the measurement of the velocity vector of charged fragments by means of their TOF and coordinates and the energy loss ΔE in the gas volume of the detector

Bragg ionization chamber (BIC) for the measurement of the residual energy E_R and Z-identification of fragments. For the heavier fragments when the Bragg spectroscopy is not possible the charge drift time is used for the rough identification of Z

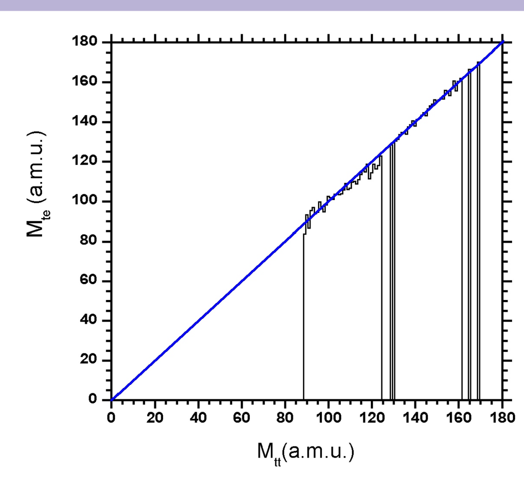
mosaic of 7 CsI(Tl) detectors for spectroscopy of light charged particles. LCP from protons to Li are recognized in charge and mass, their TOF and energy are also available

Some properties of the FOBOS module

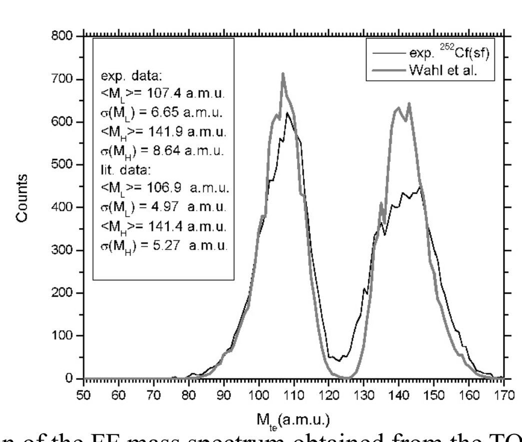
opening angle	33.08°
spatial resolution of PSAC	$\Delta x=\Delta y\sim 1.5$mm
energy resolution	$\Delta E/E \sim 0.04$
time resolution (best)	$\Delta t \sim 200$ ps
charge resolution (IMFs)	$\Delta Z/Z \sim 0.015$

The transformable neutron skin consists of the separate hexagonal modules comprising a ^{3}He-filled proportional counter, a polyethylene moderator, a high-voltage input and a preamplifier. The most of the counters operate under a gas pressure of 7 bar, being 50 cm in length and 3.2 cm in diameter, spaced by 5 cm. Efficiency ~12%

ENHANCED CALIBRATION PROCEDURE

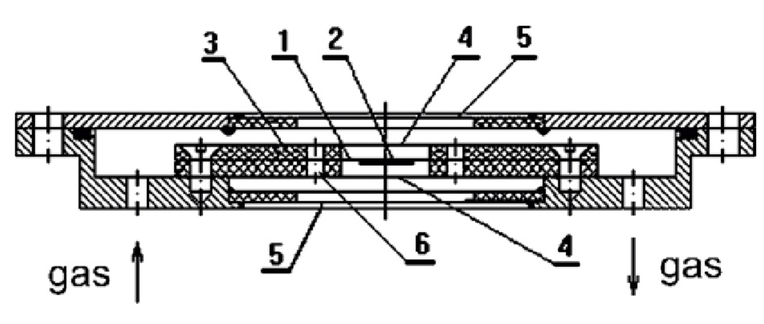


The correlation between the mass $<M_{te}>$ obtained in TOF-E analysis and the mass M_{tt} From TOF-TOF analysis.



Comparison of the FF mass spectrum obtained from the TOF-E analysis with the literature data

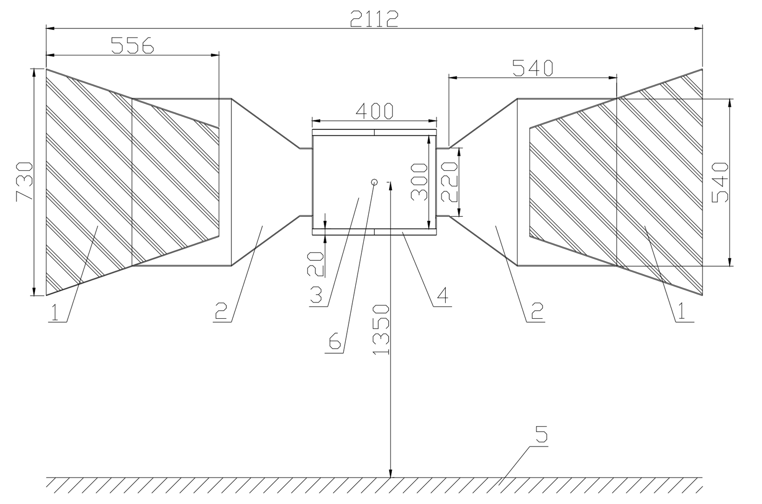
START DETECTOR WITH INTERNAL SOURCE



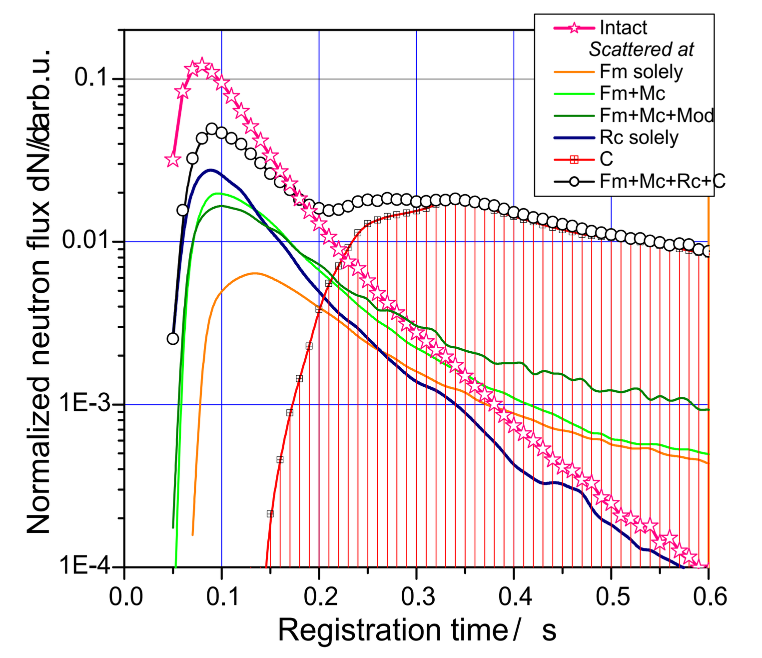
Schematic drawing of the start detector. 1 cathode, 2 layer of ^{252}Cf, 3 metallized glass textolite holders, 4 anodes, 5 metallized glass textolite holders with windows, 6 holes for gas flow.

MCNP MODELING OF THE NEUTRON FIELD

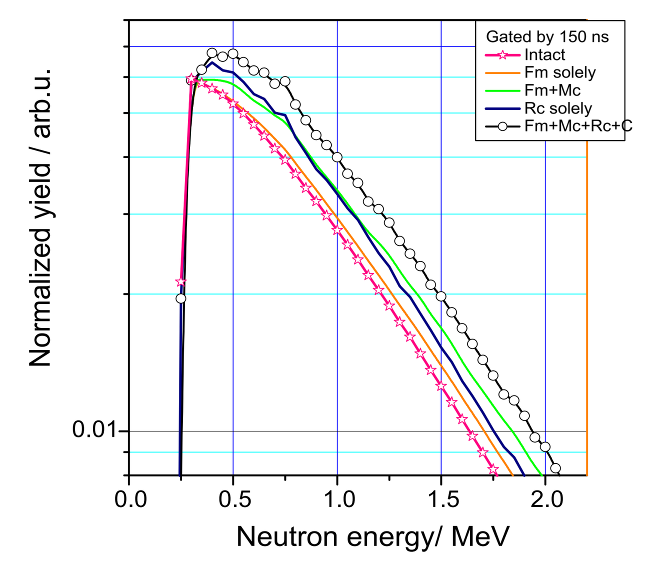
The setup is situated in the middle of a square concrete cave of a size 4x4x3 m^3. The thickness of walls and ceiling is a 1 m, the floor is as thick as 50 cm. The source is positioned at 135 cm above the floor. The setup is represented by two precisely described big FOBOS modules consisting of a PSAC and BIC and simplified reaction chamber with mounting cones. The cylindrical reaction chamber is made of 3 mm thick stainless steel and covered from both sides by 2 cm thick duralumin lids. The mounting cone is represented by a truncated cone coupled with a cylinder made also of 3 mm thick stainless steel. The detector is located at 1 m from the source in the horizontal plane normally to the spectrometer axis



Model of mini-FOBOS 1 FOBOS modules (**Fm**), 2 mounting cones (**Mc**), 3 reaction chamber covered by duralumin lids 4 (**Rc**), 5 concrete floor of cave (**C**), 6 ^{252}Cf source, **Mod** is 5 cm thick PE moderator around Fm+Mc (not shown)



TOF spectrum for neutrons scattered at different parts of mini-FOBOS for neutrons from the Maxwellian distributed moving source with T=0.5 MeV. All the spectra are normalized to the intact one set to 1. (Fm+Mc+Rc+C = whole setup, the most realistic case)



Simulated energy spectra of neutrons.

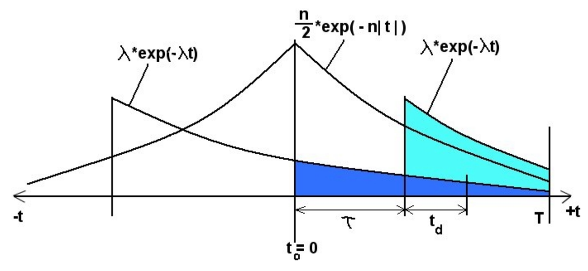
SIMULATING NEUTRON MULTIPLICITY

A contribution from three different sources of neutrons has been taken into account as follows.

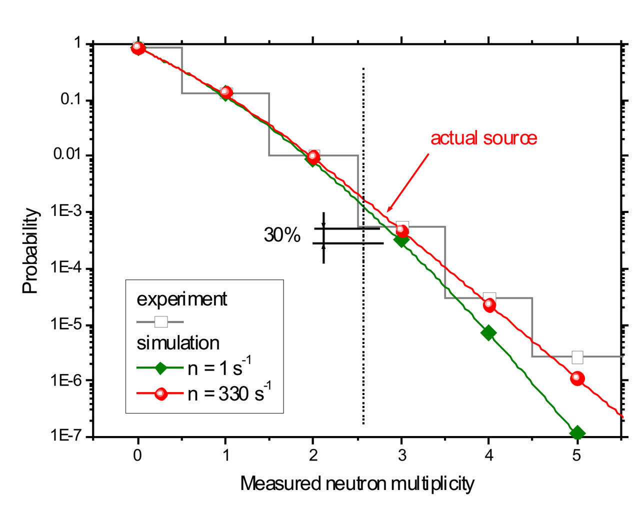
1) The moving fission fragments originated from conventional binary fission and detected in coincidence in the opposite arms of the spectrometer. Note that the time gate of 128 ms for the registration of neutrons is opened just at the point of time when the fission fragments (FF) fires the “stop” detectors.

2) The moving FF also originated from the conventional fission events occurred in a while as the time gate was open. This source will be named below “the random source”.

3) The neutron background in the experimental hall.

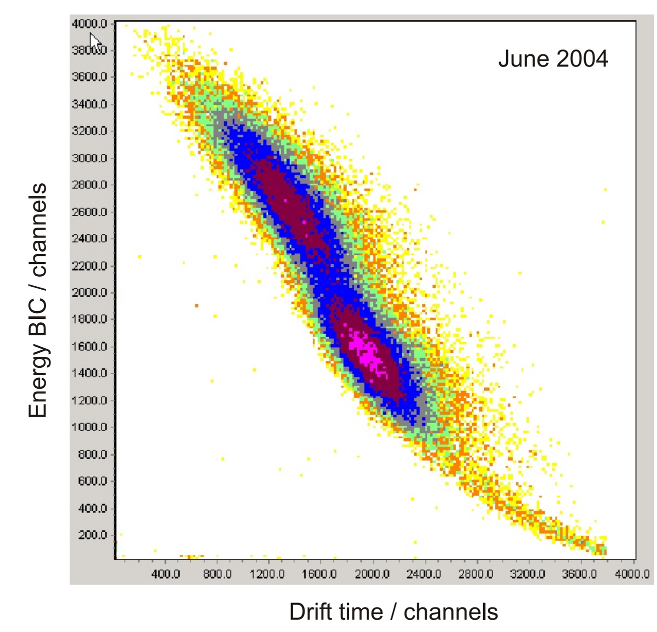


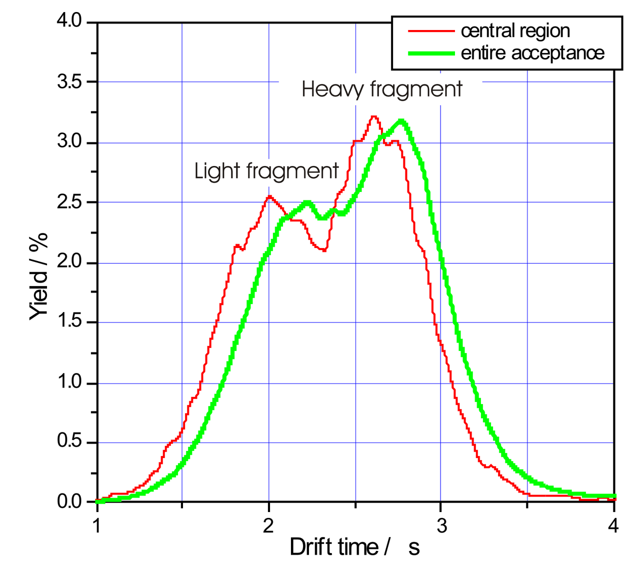
Scheme illustrating a contribution of the random source in time.

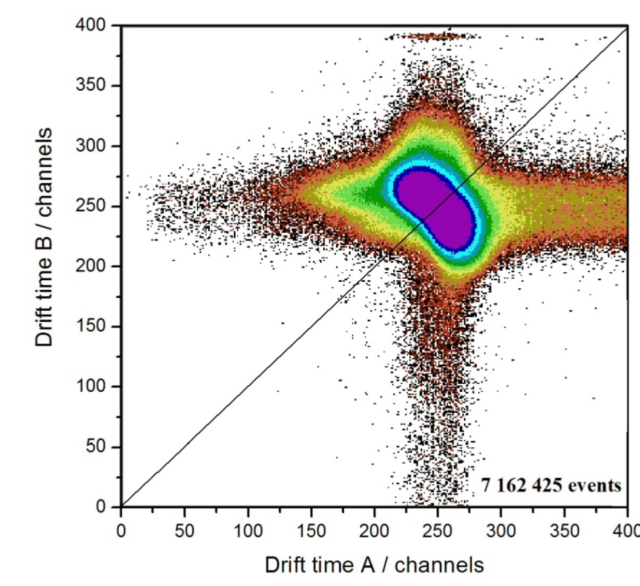


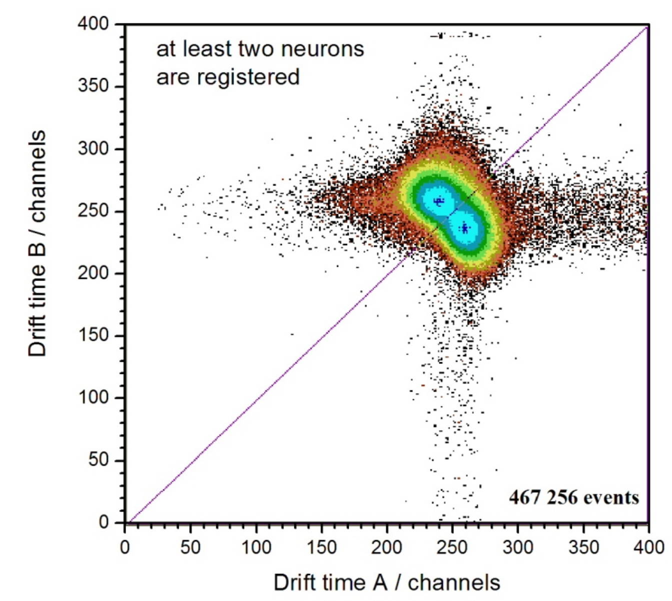
Comparison of the simulated neutron multiplicity with the experimentally measured one. The difference of highest 30% between the probability of 3-fold neutron event from the actual source applied during the experiment and the free of background ideal case (n=1) means high reliability of the measured high-fold neutron data in searching for the true high-multiplicity events.

MEASURING THE NUCLEAR CHARGE BY MEANS OF THE DRIFT TIME IN BIC



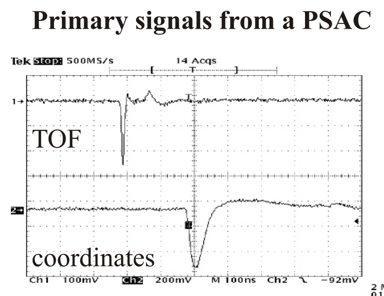




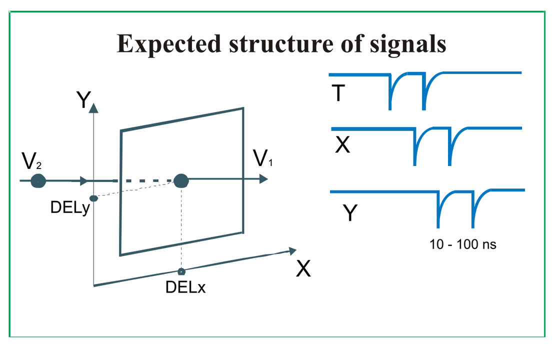


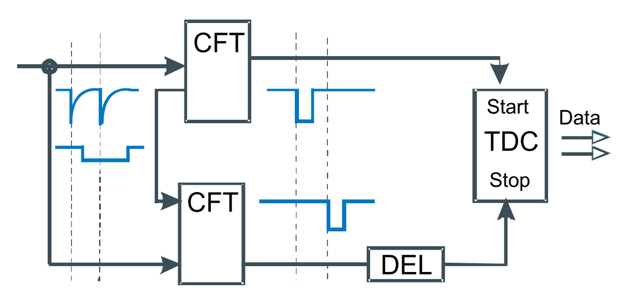
REGISTRATION OF MULTIPLE FRAGMENTS

Primary signals from a PSAC

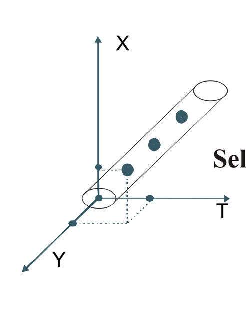


Expected structure of signals





Splitting of double-hits



Selection of collinear events