DIAGNOSTICS AND MONITORING OF NUCLOTRON EXTRACTED BEAMS FOR APPLIED RESEARCH

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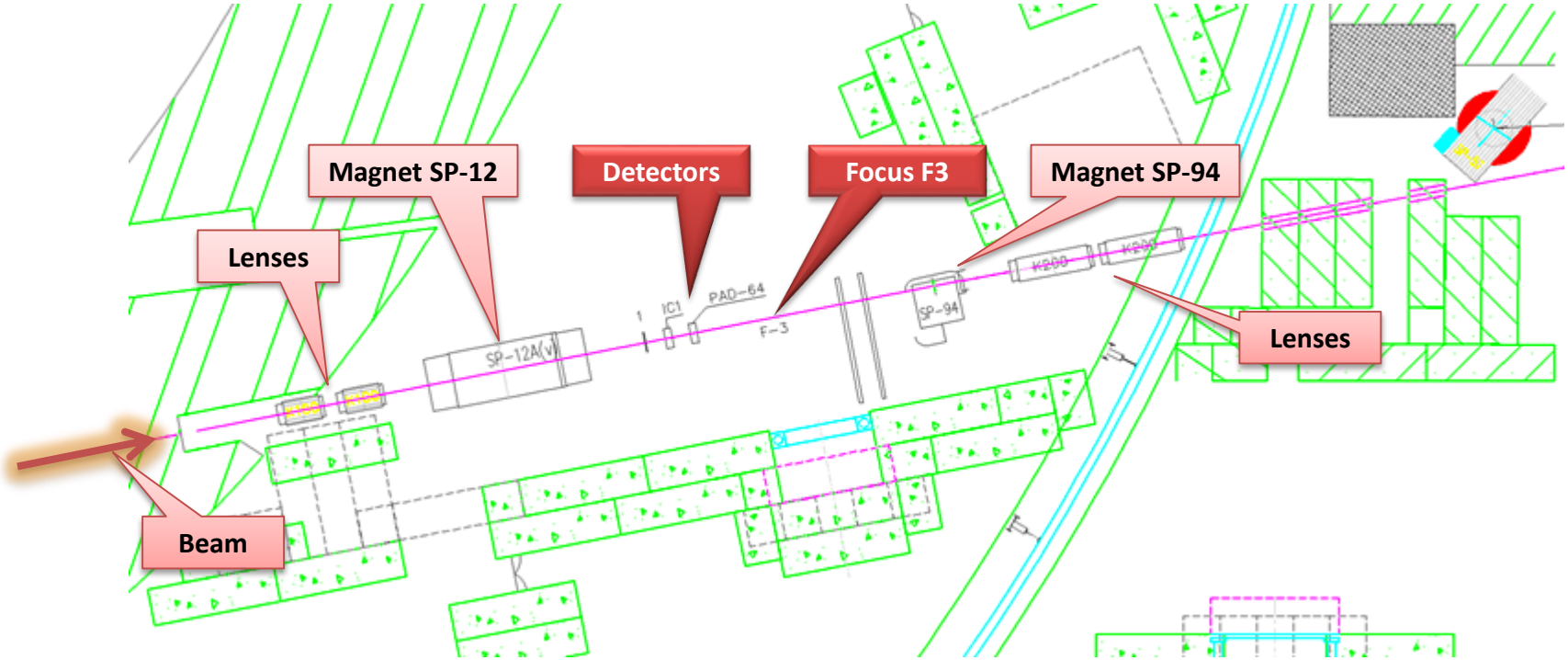
Diagnostics of the focused beam in the experimental hall “F3”

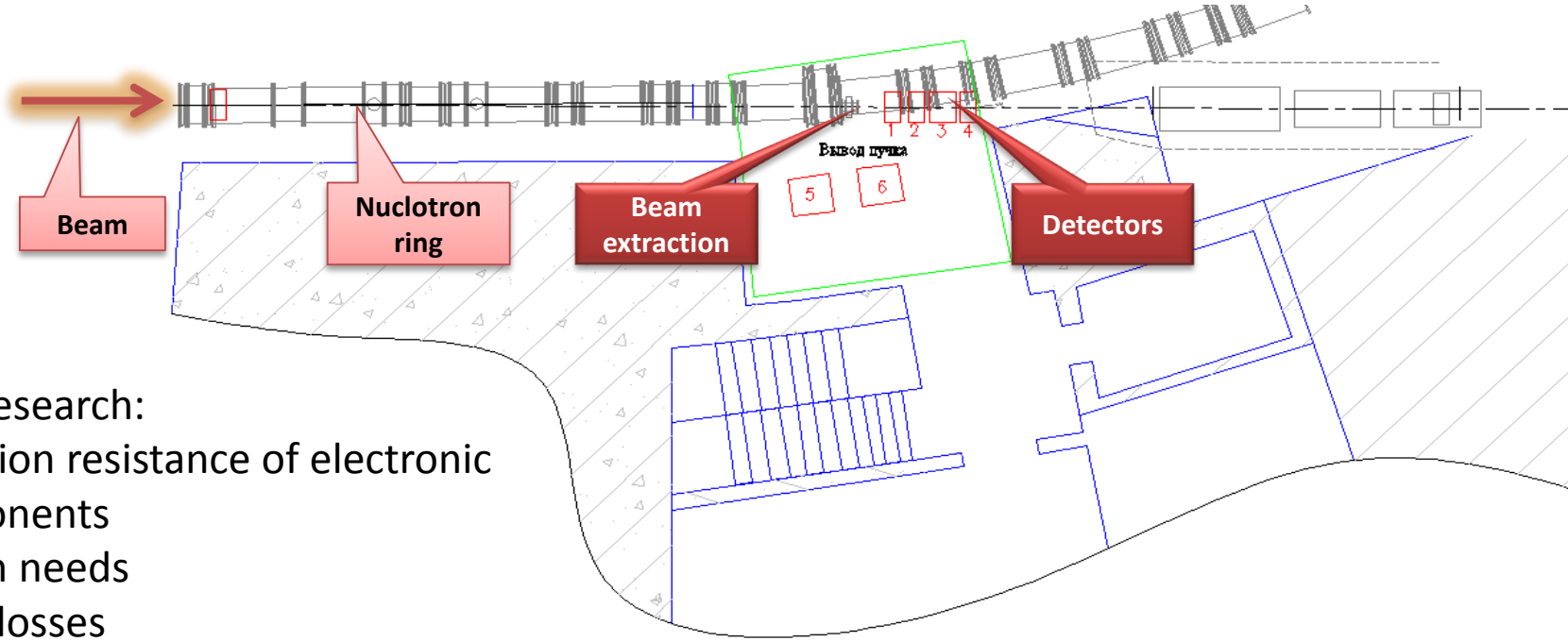
Applied research:

- Energy and Transmutation;
- Biological research;
- Radiation resistance of electronic components.



Experimental hall

Diagnostics of the beam extracted from Nuclotron



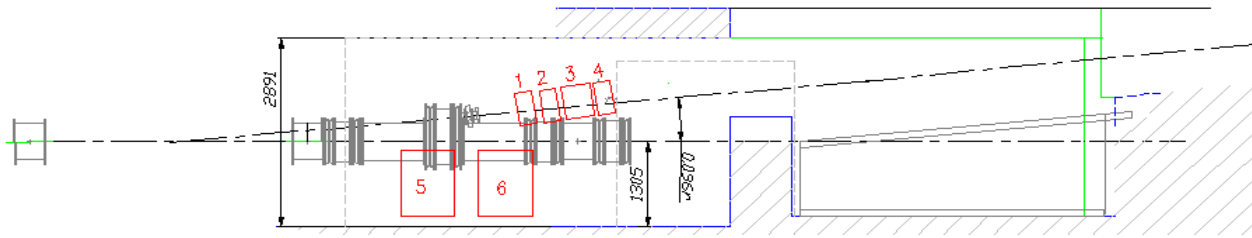
Applied research:

- Radiation resistance of electronic components

Nuclotron needs

- Beam losses
- Beam transport

Area of the beam extraction (top view)

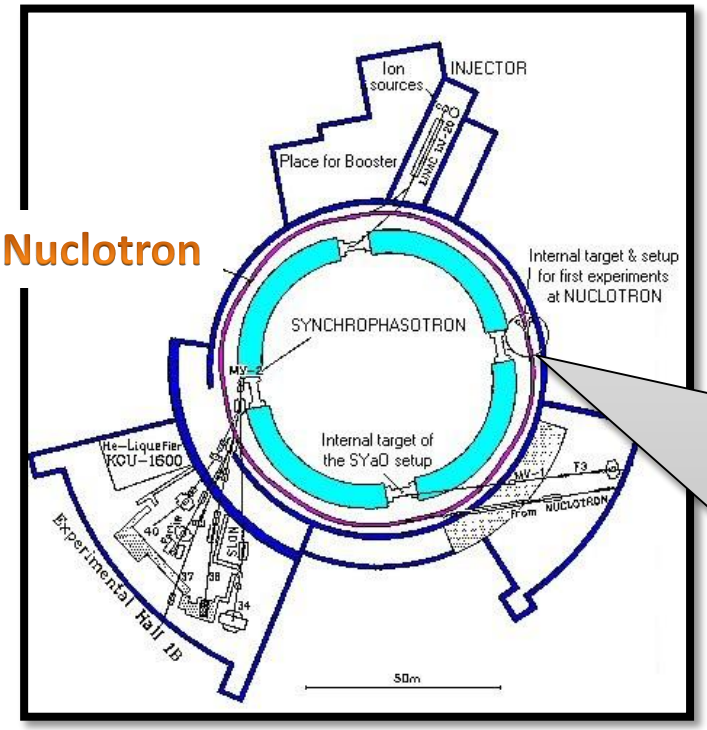


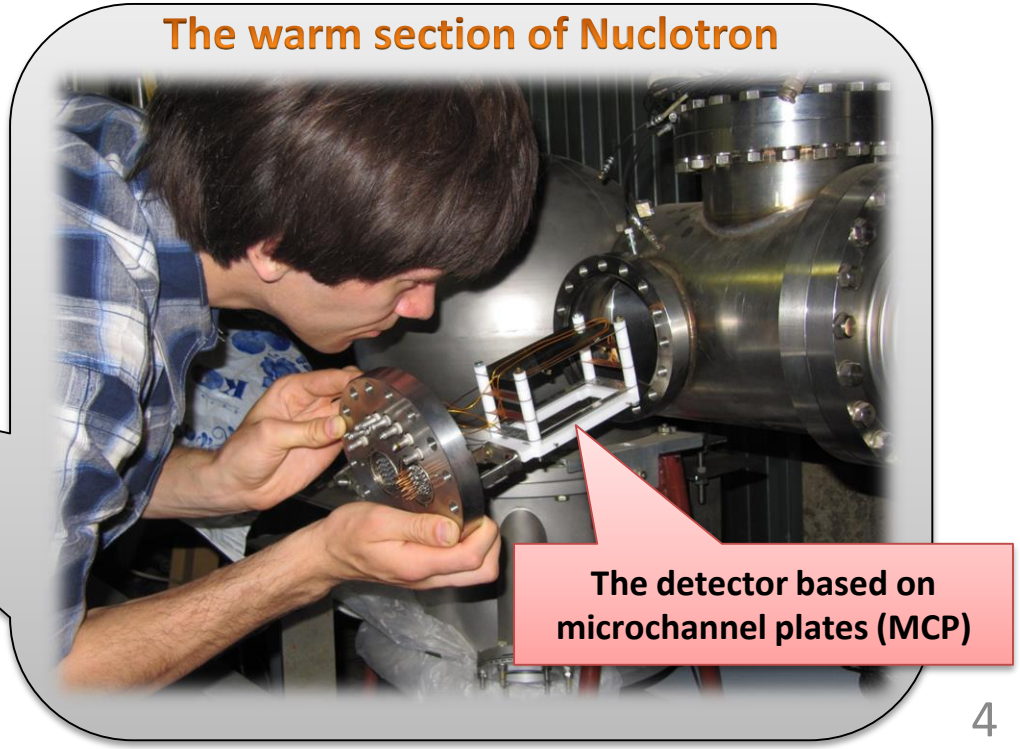
Side view

Diagnostics of circulating beam

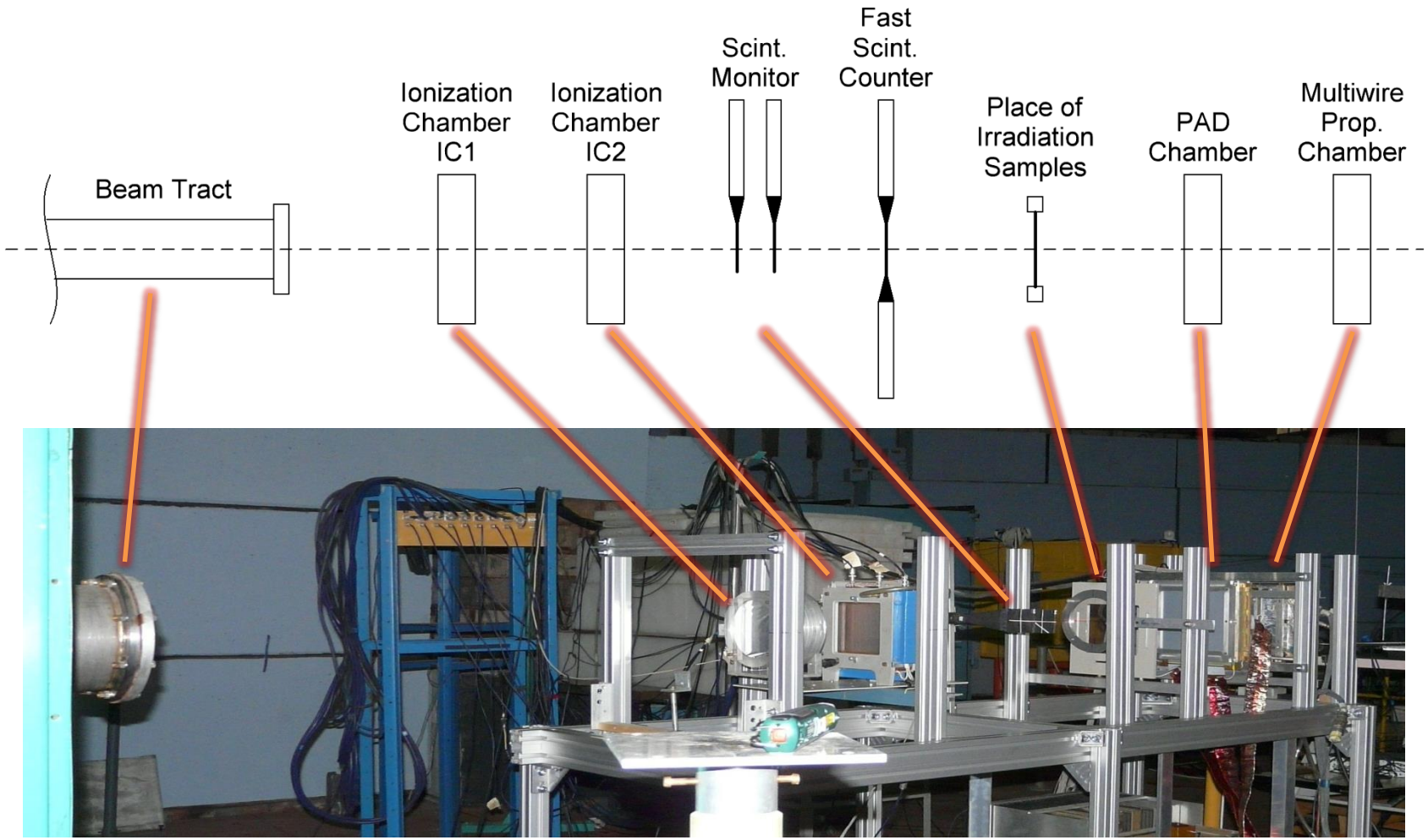
Creation of modern nondestructive control systems of space-time characteristics of the beam during acceleration and extraction is the one of the most important tasks for exploitation of the Nuclotron accelerator complex (JINR LHEP).

The detector was developed for registration of the space-time characteristics of the radial beam component. The system provides measurements in the intensity range of 10^6 – 10^8 for singly charged ions which is not covered by existing measuring devices.





Diagnostics of the focused beam in the experimental hall “F3”



Diagnostics of the beam in “F3” focus. Problems of monitoring

- Absolute values of beam intensity (calibration of ionization chamber)
    a) The activation analysis method (using Al foils)
    b) Calibration by the fast scintillation counter (using carbon beams)

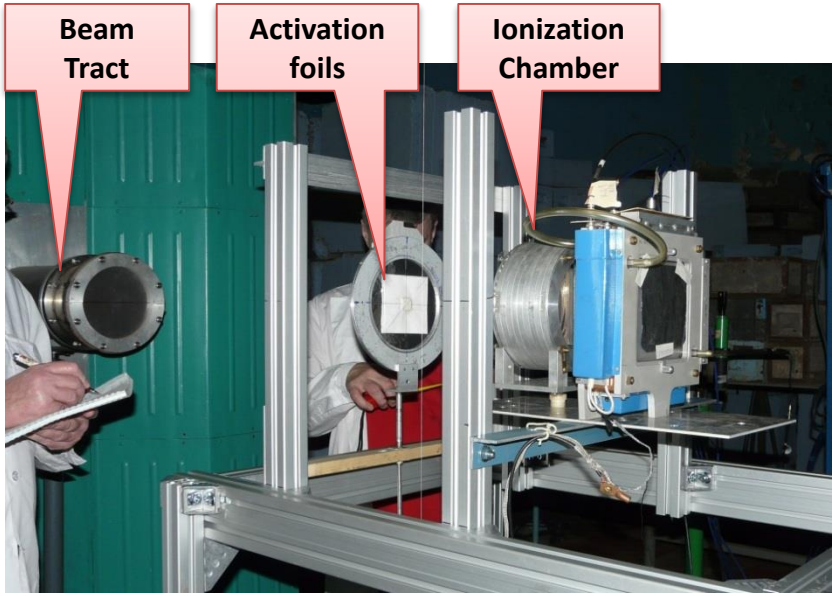
- The dependence of the ionization chamber response from : gas; temperature; electronic stability; the beam parameters.

- The impact of irradiated samples on the monitoring system

- The parameters of the extracted beam vary in a wide range
    a) Beam intensity
    b) Type of beam ions (from proton to heavy ions)
    c) Time structure of the beam extraction

Activation analysis method for monitoring and calibration

E&T collaboration groups from JINR, Ukraine, Belarus and Czech used activation method to calibrate detectors and to get absolute values of the beam intensity.

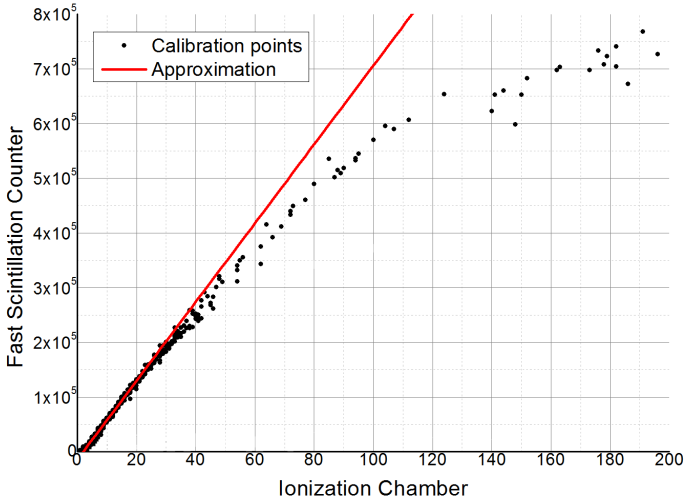


Integrals of the intensities

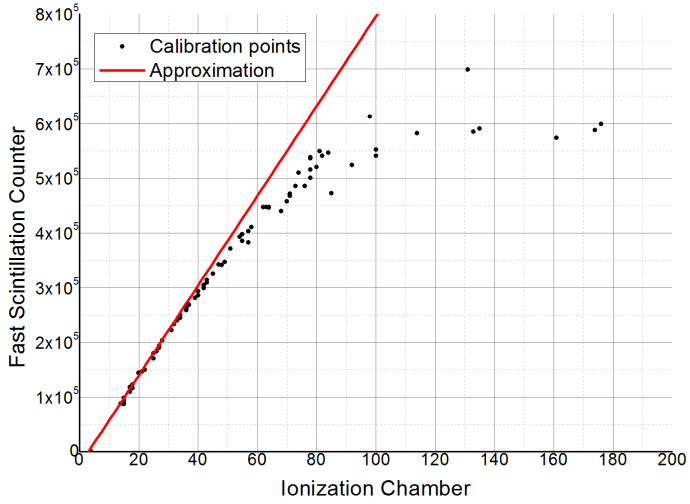
RUN Date	ENERGY GeV/u	GROUP	INTENSITY E+13
47 March 2013	0.66	BALDIN	1.35
		BALDIN new	1.05
		VLADIMIROVA	0.89
		CZECH	0.906(5)
		UKRAINE	0.9
	1	BALDIN	5.91
		BALDIN new	4.56
		VLADIMIROVA	4.19
		CZECH	4.01(4)
		UKRAINE	3.95
	2	BALDIN	2.72
		BALDIN new	2.18
		VLADIMIROVA	1.95
		CZECH	1.861(19)
		UKRAINE	1.82
	4	BALDIN	0.291
		BALDIN new	0.232
		VLADIMIROVA	0.222
		CZECH	---
		UKRAINE	0.225
48 December 2013	2	BALDIN	3.16
		BALDIN new	2.24
		PARAIPAN	1.89 ± 16%
		CZECH	2.32(12)
	4	BALDIN	0.622
		PARAIPAN	0.476 ± 16%
		CZECH	0.648(33)
	Carbon 2	BALDIN	0.0175
		PARAIPAN	0.0215± 18%
		CZECH	---
	Carbon 4	BALDIN	0.0048
		PARAIPAN	0.0051± 21%
		CZECH	---

Calibration of the ionization chambers by the fast scintillation counter

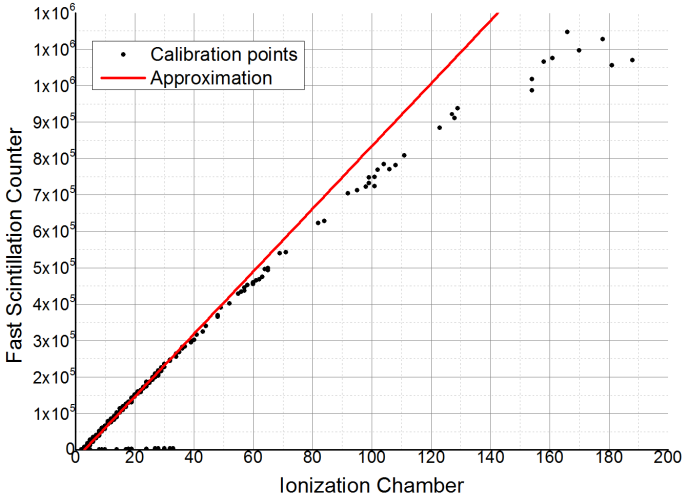
1 GeV Carbon



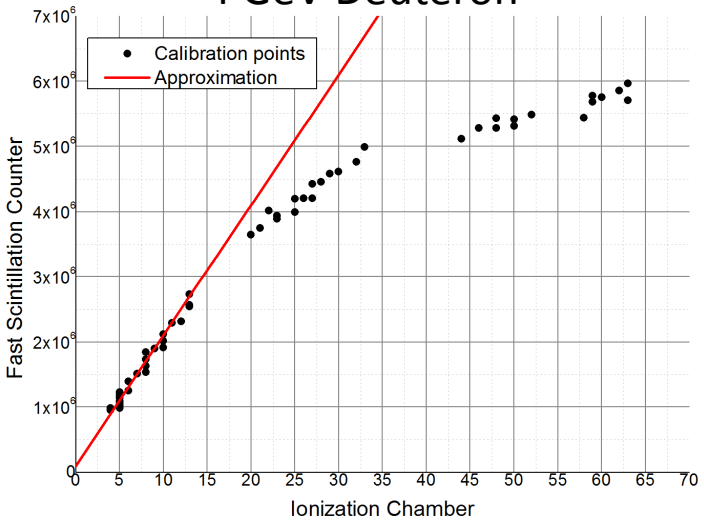
2 GeV Carbon



4 GeV Carbon



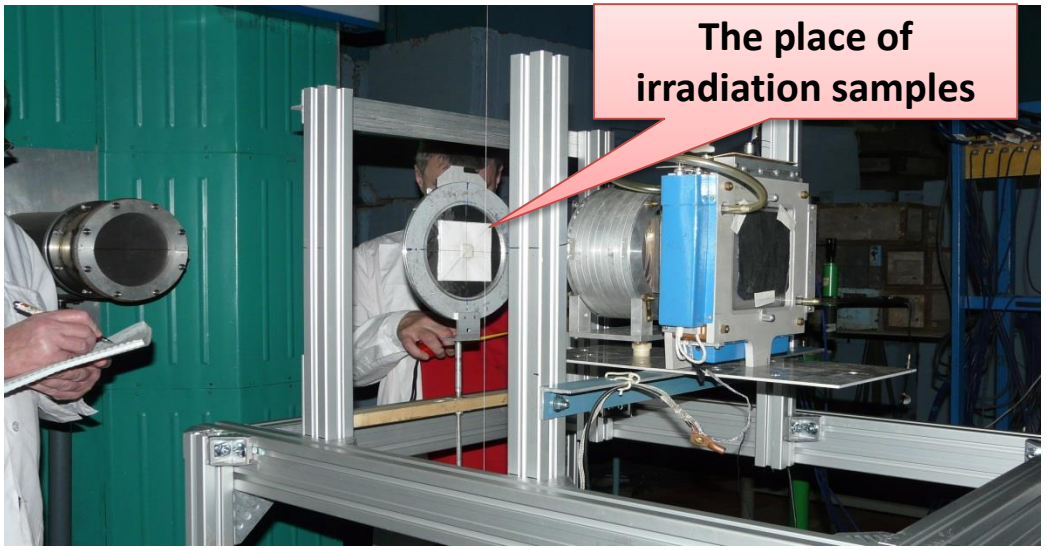
4 GeV Deuteron

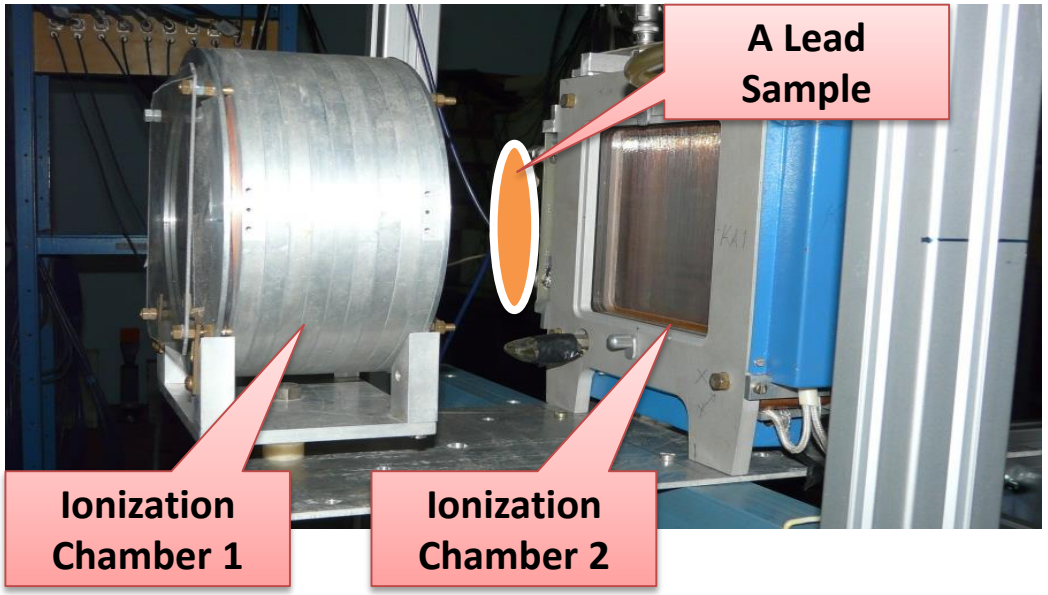


Study of the impact of irradiated samples on the monitoring system

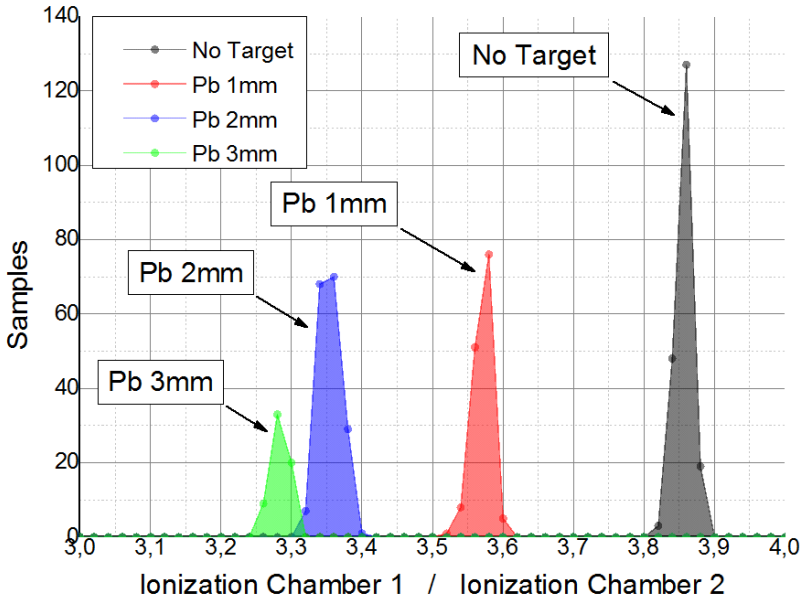
To explain the differences of the activation analysis method between the groups we studied the effect of the samples impacting on the beam parameters and on the monitoring system.
To study this effect, we placed lead samples of different thickness between two ionization chambers. Then we observed dependence of the ratio of two chambers from the lead thickness.

The lead samples:
Pb 1 mm;
Pb 2 mm;
Pb 3 mm.

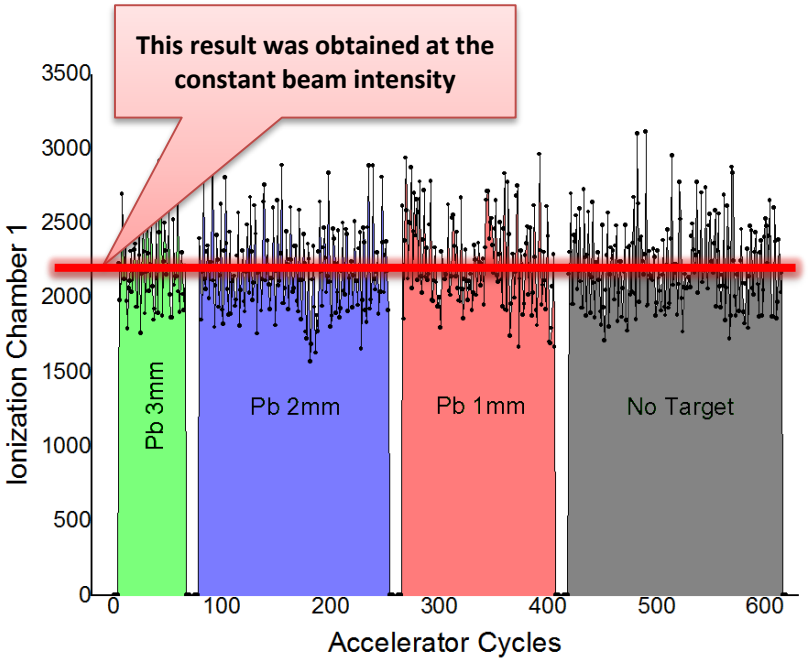




Study of the impact of irradiated samples on the monitoring system



Histogram of the dependence of the ratio of two chambers from the lead thickness.

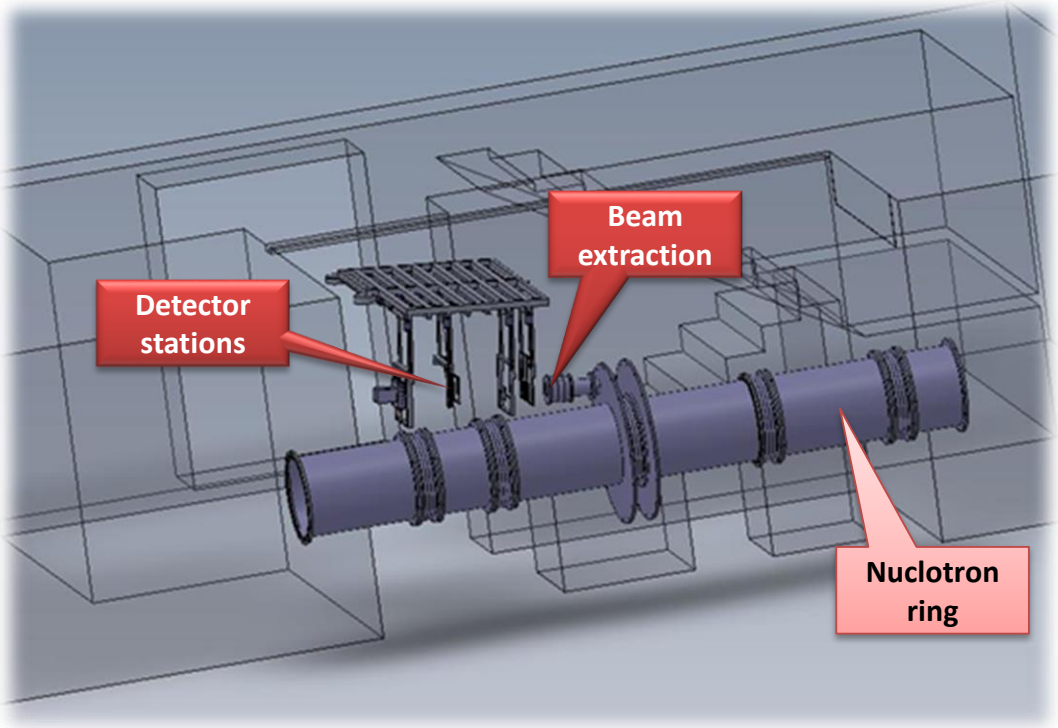


Relative intensity of the extracted beam at the measurement time. Deuteron 2 GeV/n.

Diagnostics of the beam extracted from Nuclotron

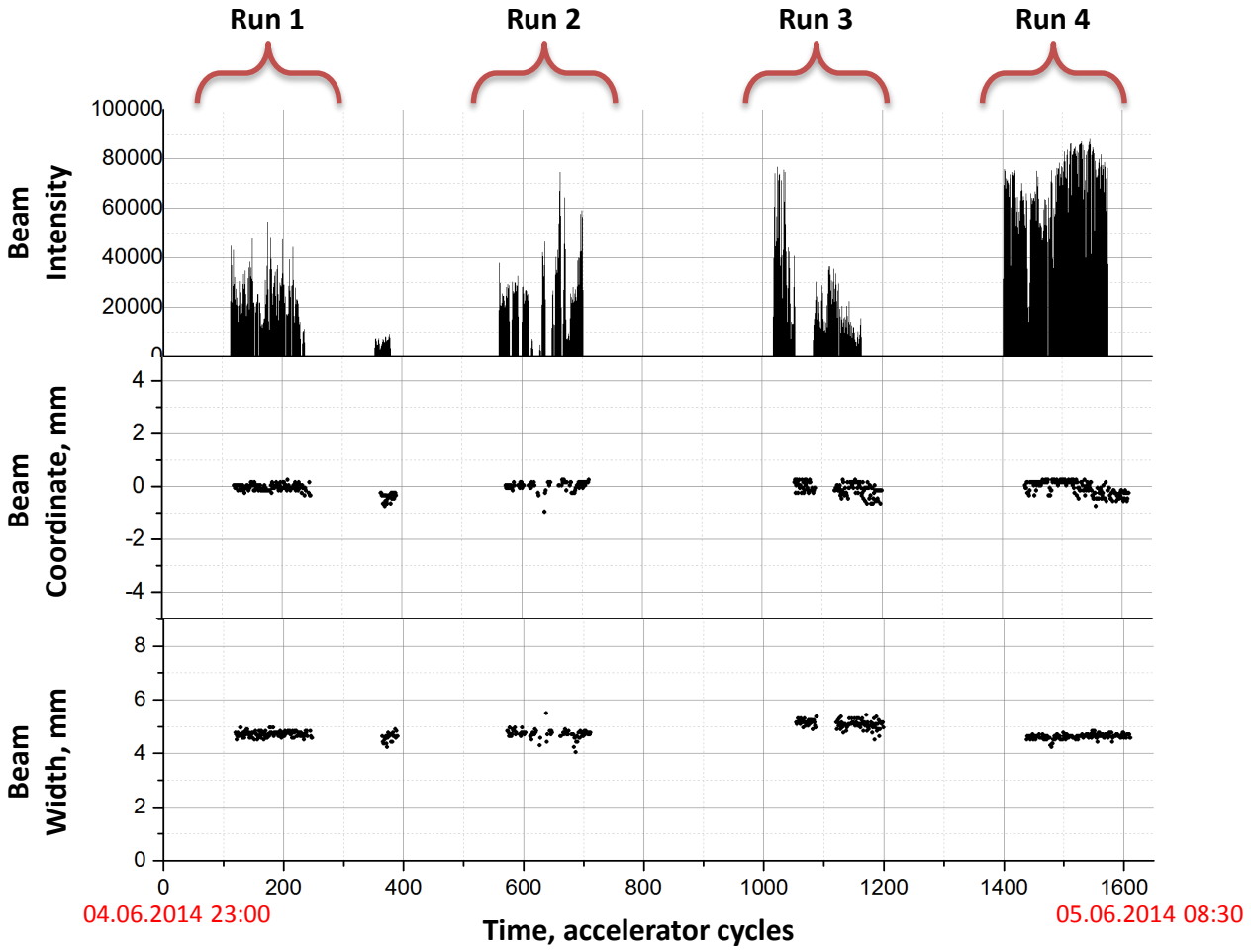
For the first time, in the latest session of Nuclotron we carried out the diagnostics of the beam extracted from Nuclotron. Also, the prototype of diagnosctics system was used for an irradiation of electronic components.

1. Nuclear photoemulsions
   Ionization chamber
2. Thin scintillation counter
   Scintillation profilometer
3. Irradiated object
4. Thick scintillation detector



Area of the beam extraction

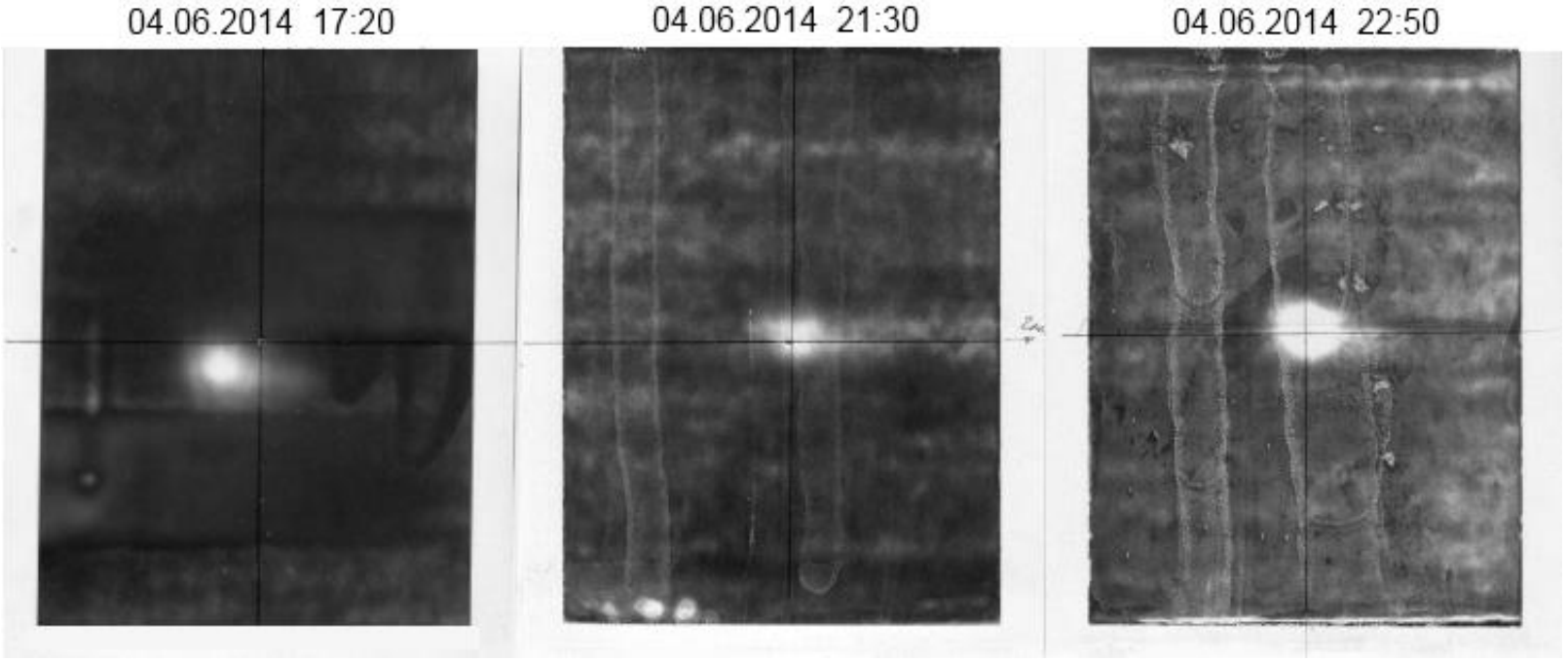
Diagnostics of the extracted beam. Ar 500 MeV/n



Beam characteristics over accelerator cycles.

Diagnostics of the extracted beam. Beam position.

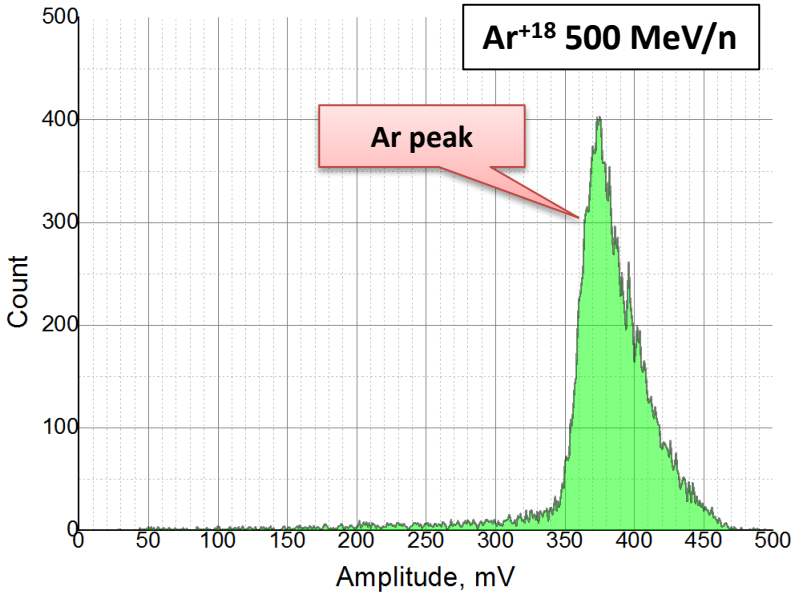
To adjust the positioning system of the detectors, we determined the position of the center of the extracted beam by Polaroid photo. Also this method was used to test the reproducibility of the positioning system.

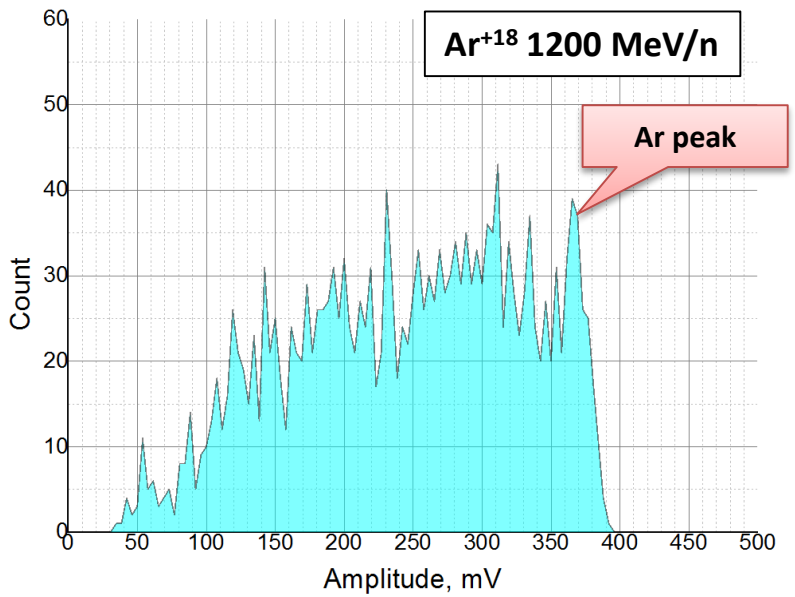


Extracted beam of Ar^{+18} 500 MeV/n registered by Polaroid photo

Diagnostics of the extracted beam. Beam composition.

We conduct the measurements of the composition of the extracted beam by the thick scintillation detector. For example you can see the amplitude spectrums of the extracted beam for two different energies.

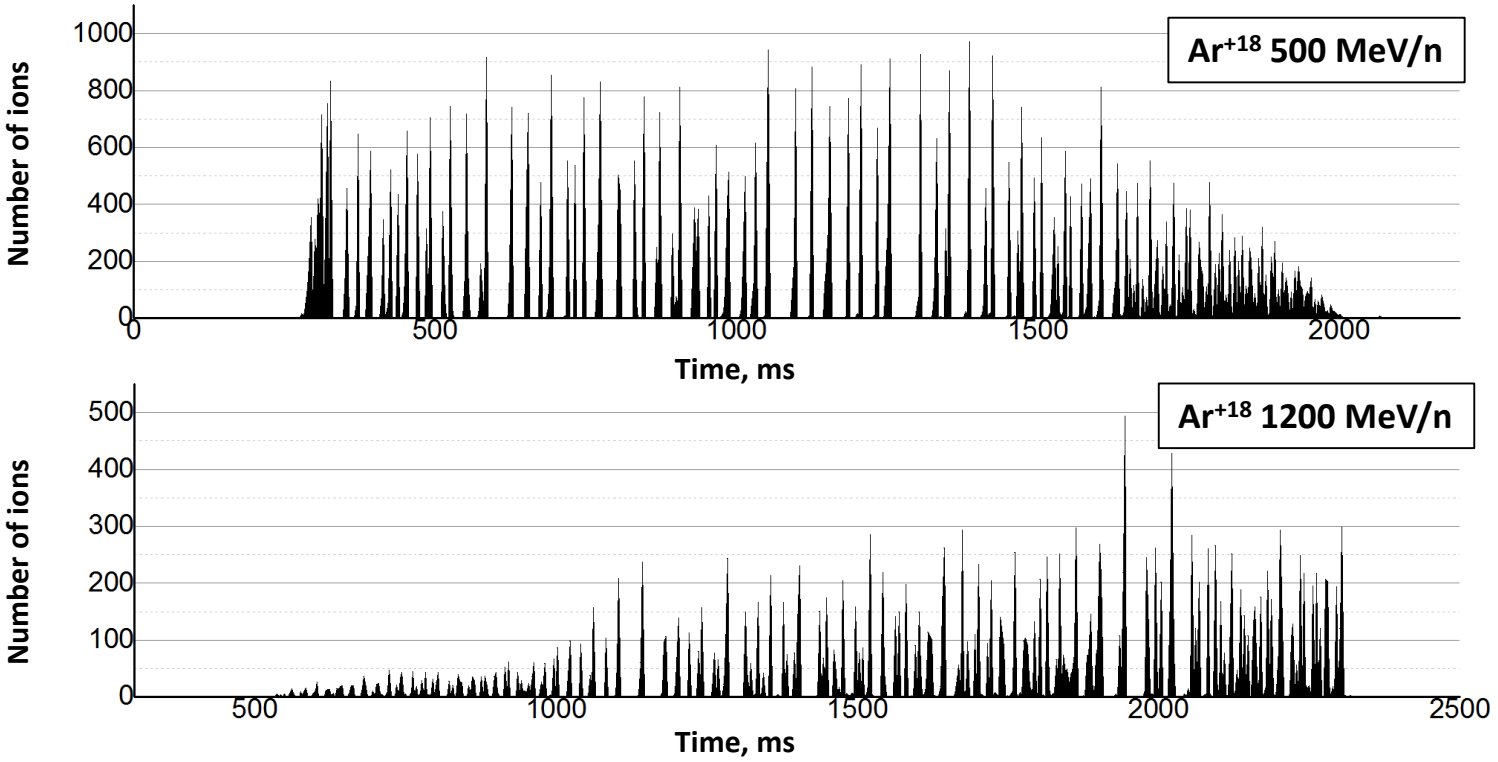




The amplitude spectrum of the extracted beam registered by the thick scintillation detector.

Diagnostics of the extracted beam. Intensity and time structure.

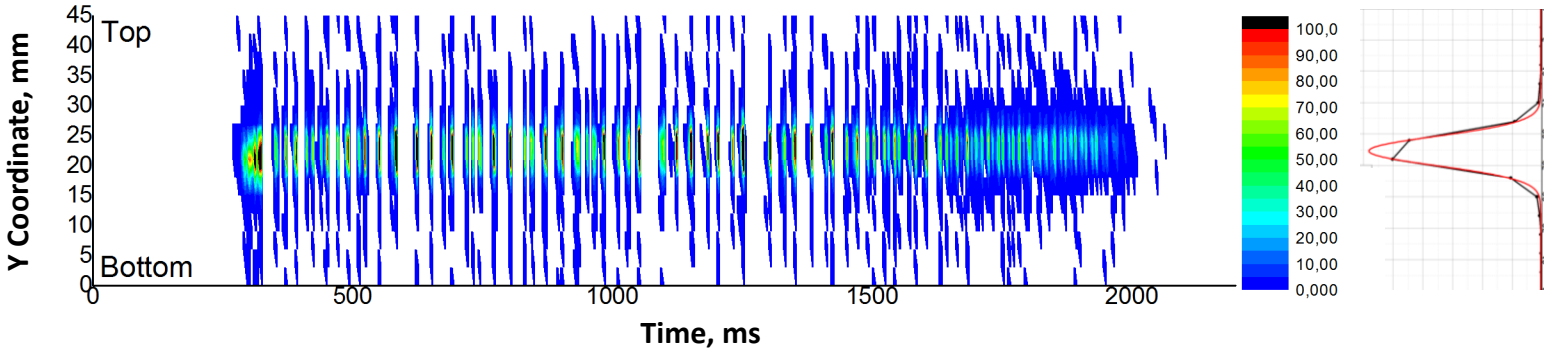
The intensity and the time structure of the extracted beam were registered by the thin scintillation counter.



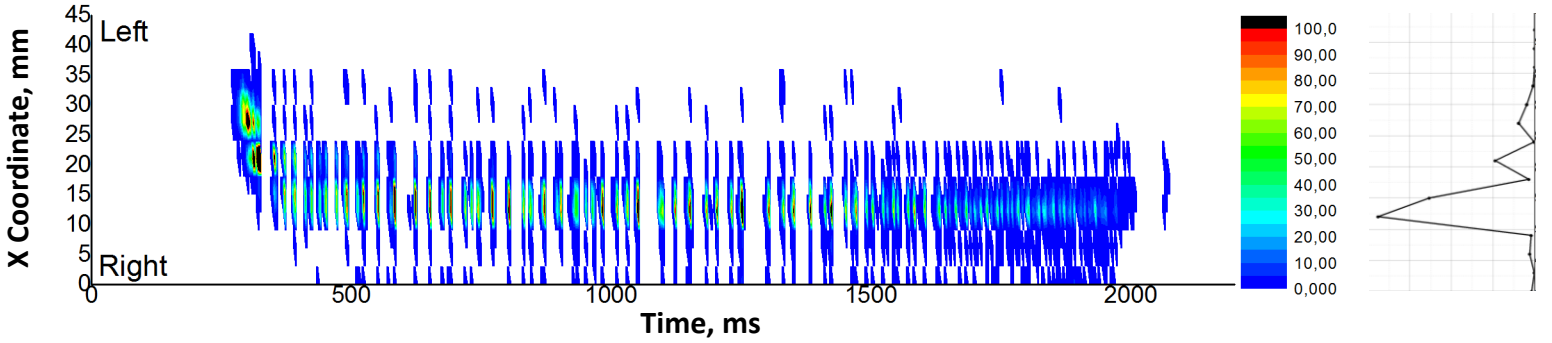
Time structure of the extracted beam registered by the thin scintillation counter.

Diagnostics of the extracted beam. Spatial Distribution.

The spatial distribution of the extracted beam was registered by the scintillation profilometer (hodoscopic PMT Hamamatsu; X, Y – 16 channels; step – 3 mm)



Vertical dynamic profile of the extracted beam of Ar^{+18} 500 MeV/n.



Horizontal dynamic profile of the extracted beam of Ar^{+18} 500 MeV/n.

Calibration of the thin scintillation counter and the scintillation profilometer

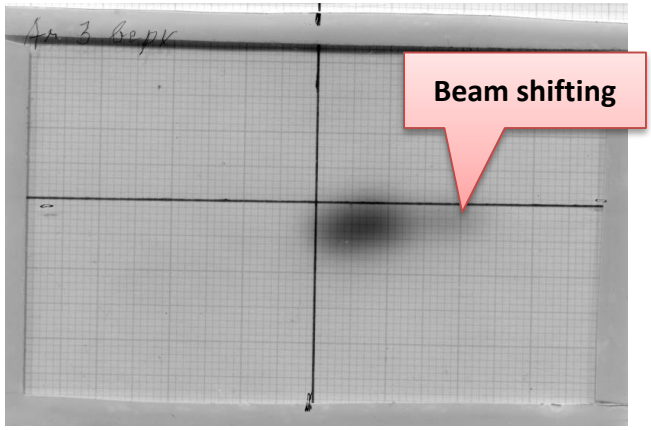


Photo of manifested nuclear emulsion of Ar^{+18} beam.

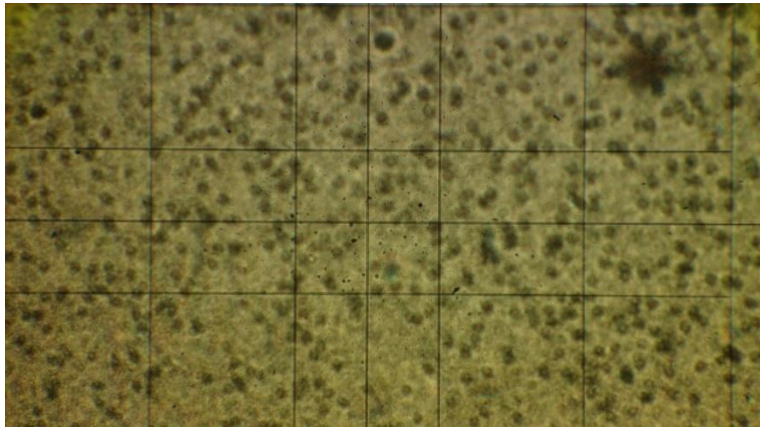
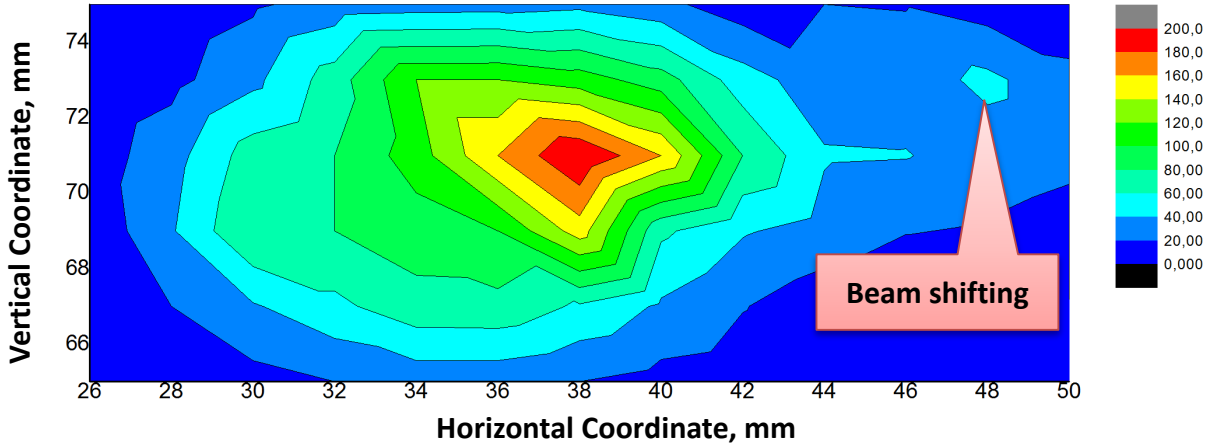
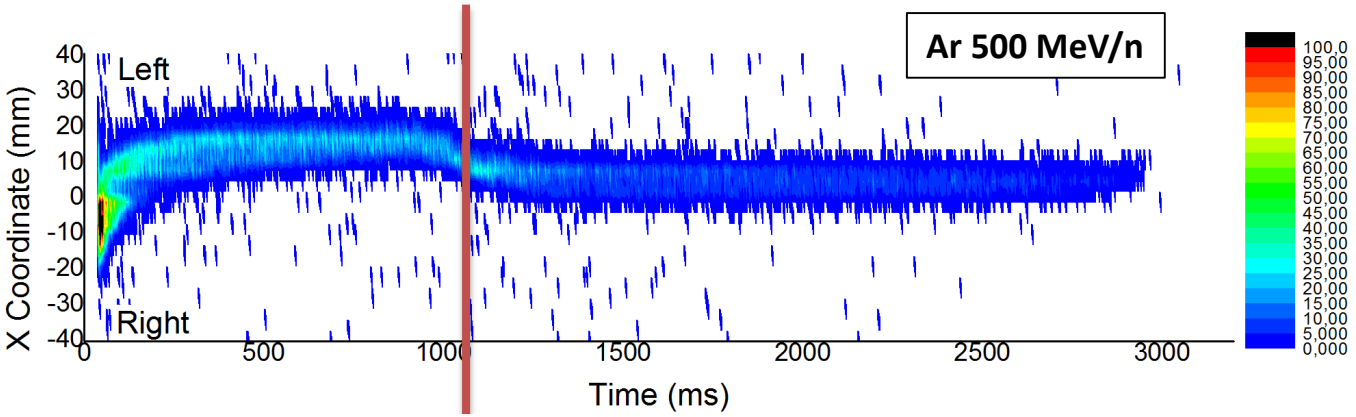


Photo of nuclear emulsion. Zoom 200.

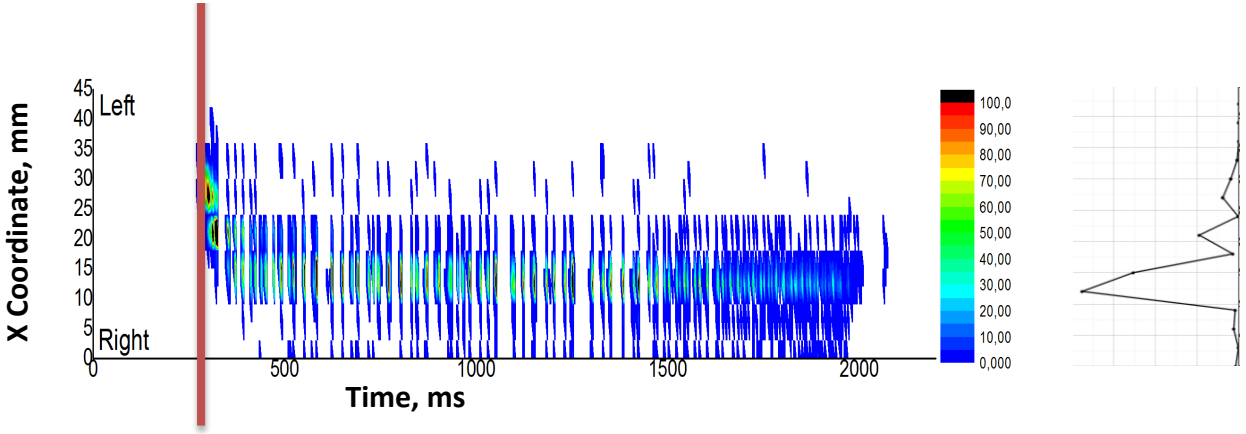


Profile of extracted beam registered by nuclear photoemulsion.

Diagnostics of the extracted beam. The beam orbit shifting.

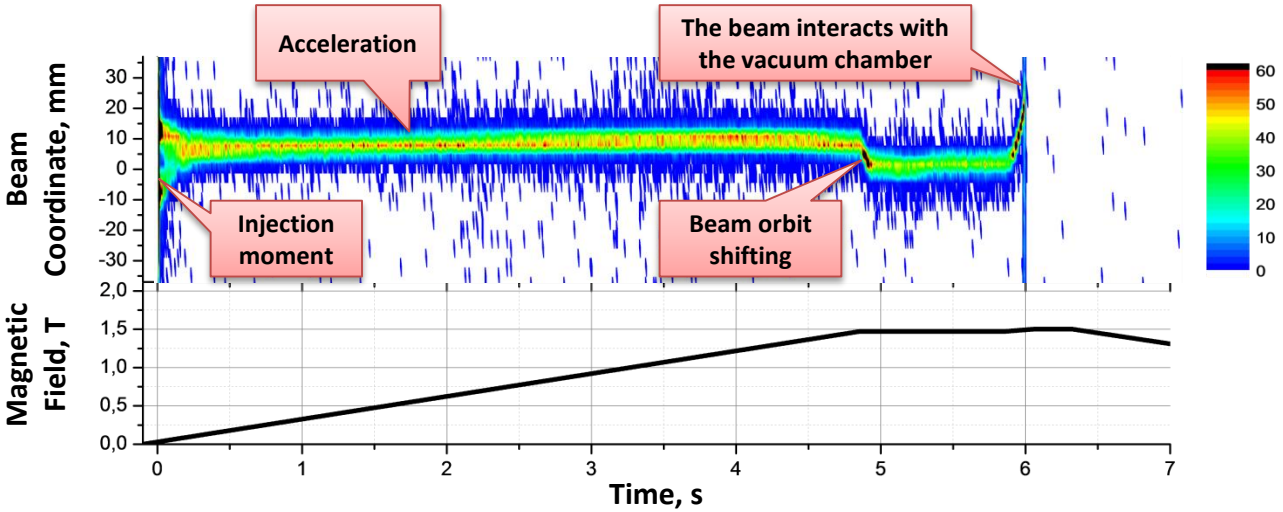


Dynamic profile of the circulating beam registered by the MCP detector.

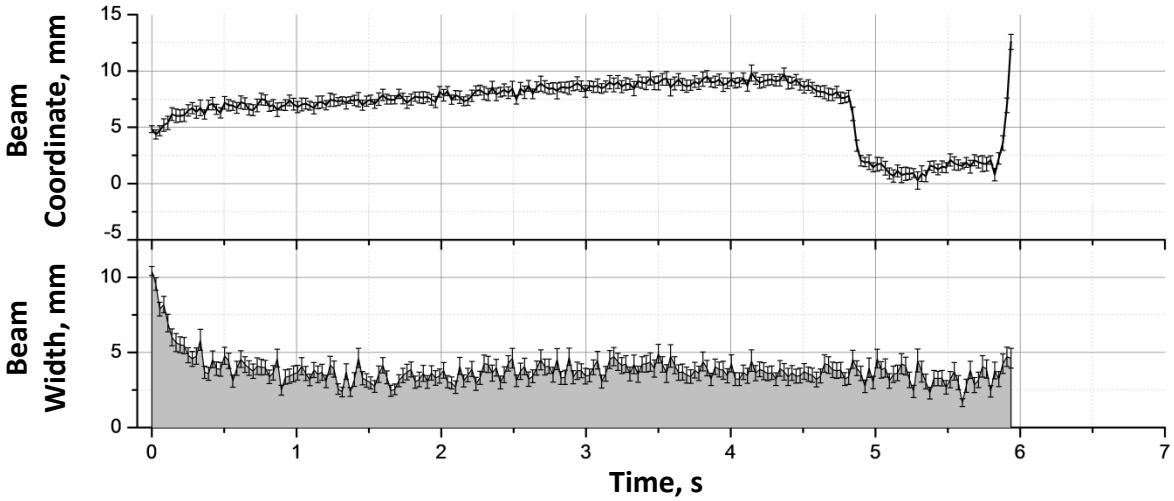


Horizontal dynamic profile of the extracted beam of Ar^{+18} 500 MeV/n.

Diagnostics of circulating beam. Deuteron 4 GeV/n



Radial beam profile (top graph) and magnetic accelerator field (bottom graph).



Radial beam coordinate (top graph) and beam width (bottom graph).

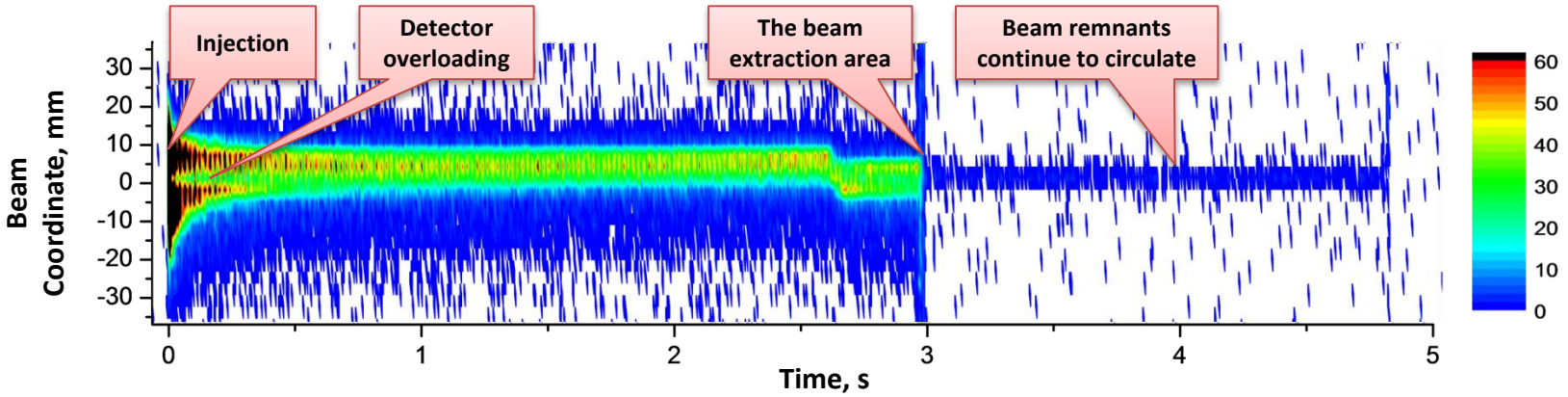
Conclusions

- The beam monitoring system has been created for E&T experiment (the beam extracted to the experimental hall F3).
- The absolute calibration of the detectors was carried out. The calibration accuracy is 10%. The accuracy of relative measurements is 5 %.
- The prototype of irradiation stand for applied research was developed and successfully tested at the area of the beam extraction from Nuclotron.
- The synchronous operation of the diagnostic systems of Nuclotron beam was demonstrated. Within the ring, at the extraction of the accelerator, and in the experimental hall F3.
- It is possible to create nondestructive diagnostic systems based on MCP for extraction of heavy ion beams.

Thank you for your attention

Diagnostics of circulating beam. Deuteron 2 GeV/n.

The graph of an accelerator cycle with fast beam extraction (50 ms) at an intensity corresponding to the upper limit of the detector operating range (10^8 single charged ions). At the beginning of the acceleration (the first 0.5 seconds from the time of injection) the detector is overloaded. After transition to the constant magnetic field the beam extraction is produced (3 seconds after injection moment) and than the circulating beam remnants is registered.



Radial beam profile.

The Beam Diagnostics Systems

- **Diagnostics of the focused beam in the experimental hall F3**
  - **Applied research:**
    - **Energy and Transmutation**
    - **Biological research**
    - **Radiation resistance of electronic components**

- **Diagnostics of the beam extracted from Nuclotron**
  - **Applied research:**
    - **Radiation resistance of electronic components**
  - **Accelerating technics (Nuclotron needs)**

- **Diagnostics of circulating beam**
  - **Accelerating technics (Nuclotron needs)**