Isochronous cyclotron U-120M and related activities

Status report

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Libčice nad Vltavou
Brandys nad Labem-Stará Bol
Roztoky
Praha
Hostivice
Rudná
Říčany
Černošice
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NUCLEAR PHYSICS INSTITUTE ASCR p.r.i.

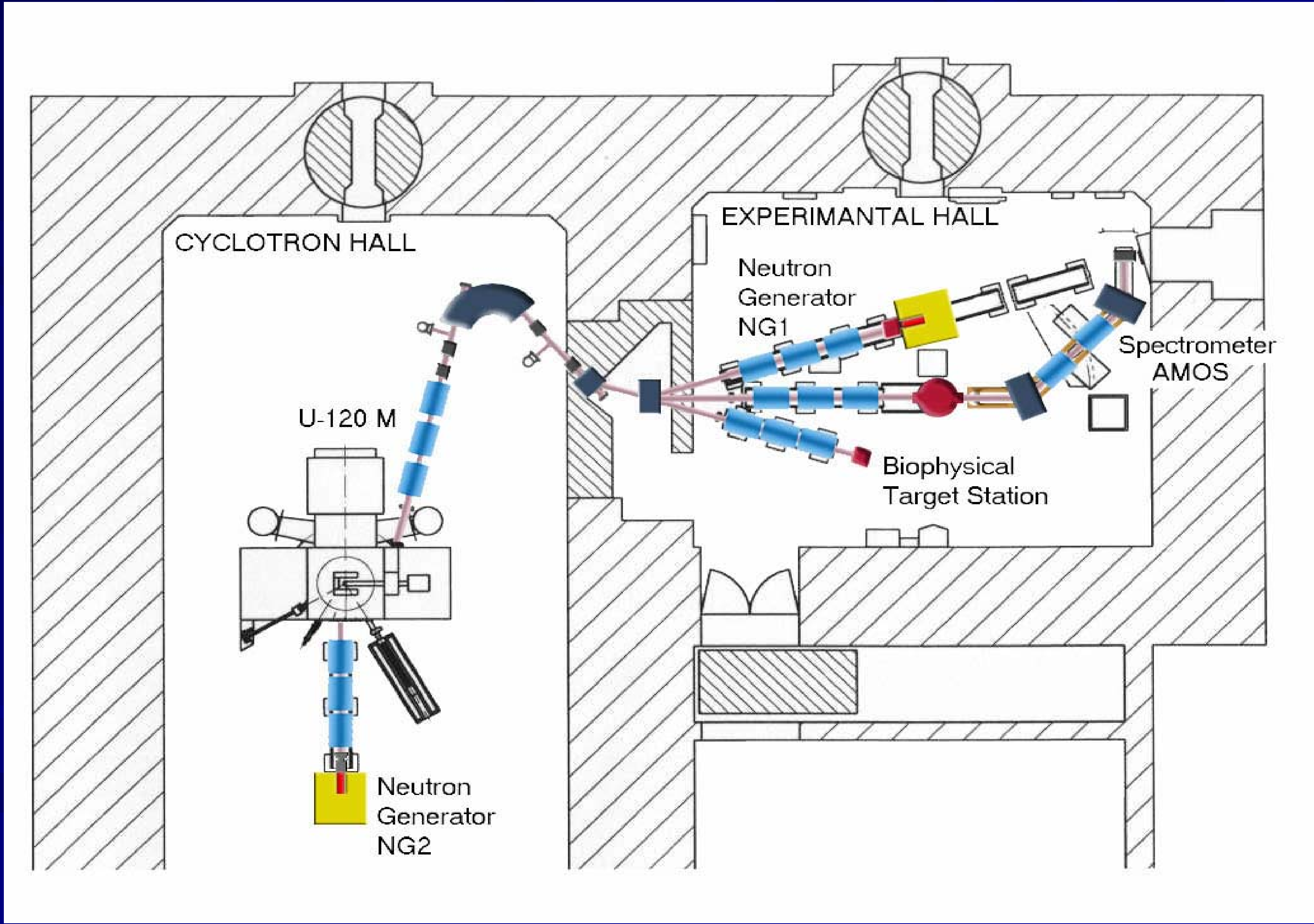
- **Major Czech institution in nuclear physics field**
- **~ 200 employees ~ 70 scientists**

Mission:

- **use of nuclear physics methods in interdisciplinary scientific and research areas**
- **basis research in nuclear physics and related disciplines**

Department of Theoretical Physics
Department of Nuclear Spectroscopy
Department of Neutron Physics *(accel.: VdG, Tandetron)*
Department of Nuclear Reactions
Department of Radiation Dosimetry
Department of Radiopharmaceuticals
Department of Accelerators *(accel: cyclotron, microtron - 2003)*

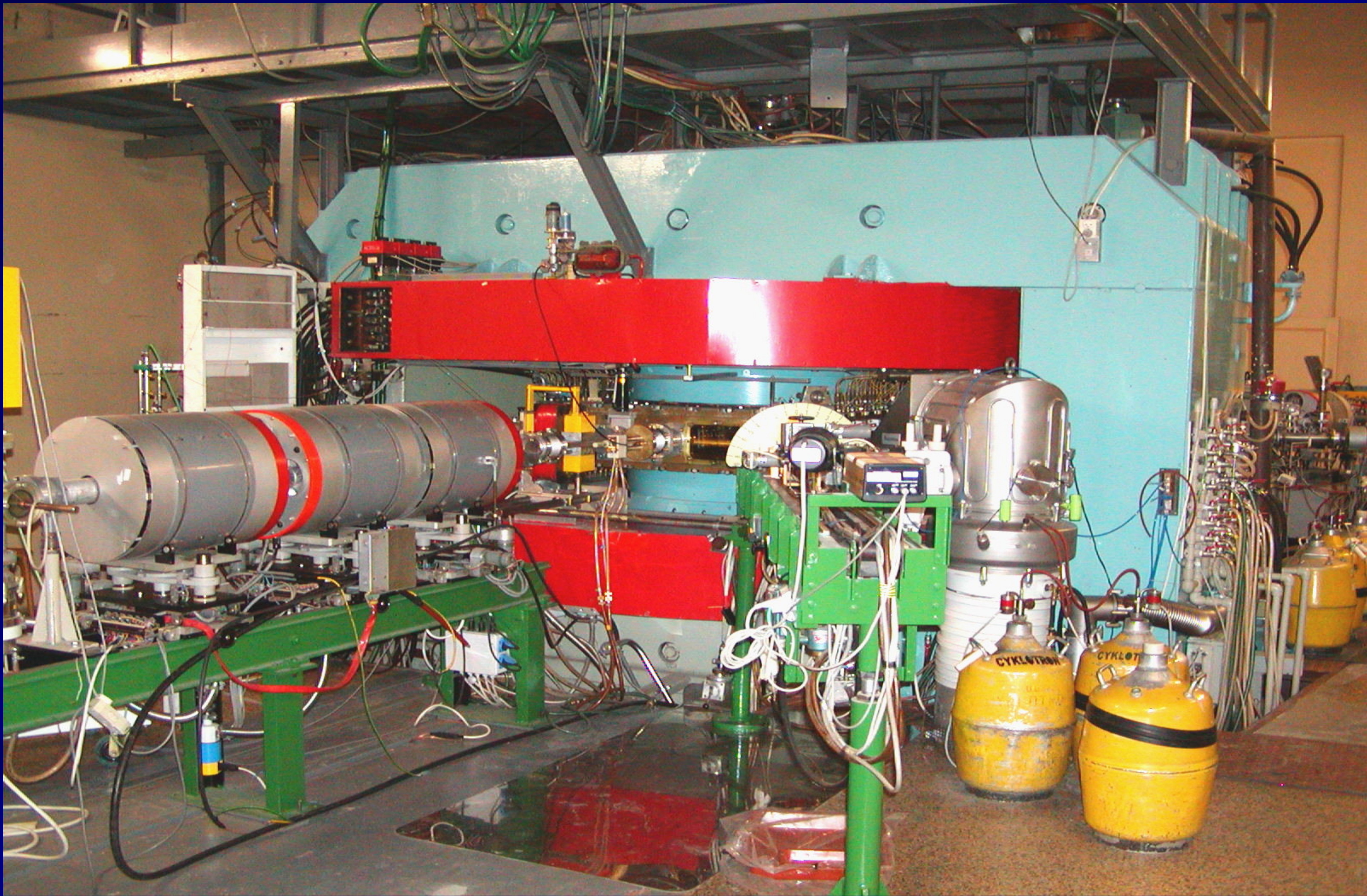
Layout of the cyclotron U-120M



Beam parameters

ion	E [MeV]	I_{max} [μA]
p (internal beam) p (external beam) H^- (external beam)	10–38 10–25 10–38	100 5 40–15
d (internal beam) d (external beam) D^- (external beam)	10–20 10–20 10–20	80 5 25–10
^{3}He (internal beam) ^{3}He (external beam)	17–53 17–53	20 2
α (internal beam) α (external beam)	20–40 20–40	40 5

Cyclotron U-120M



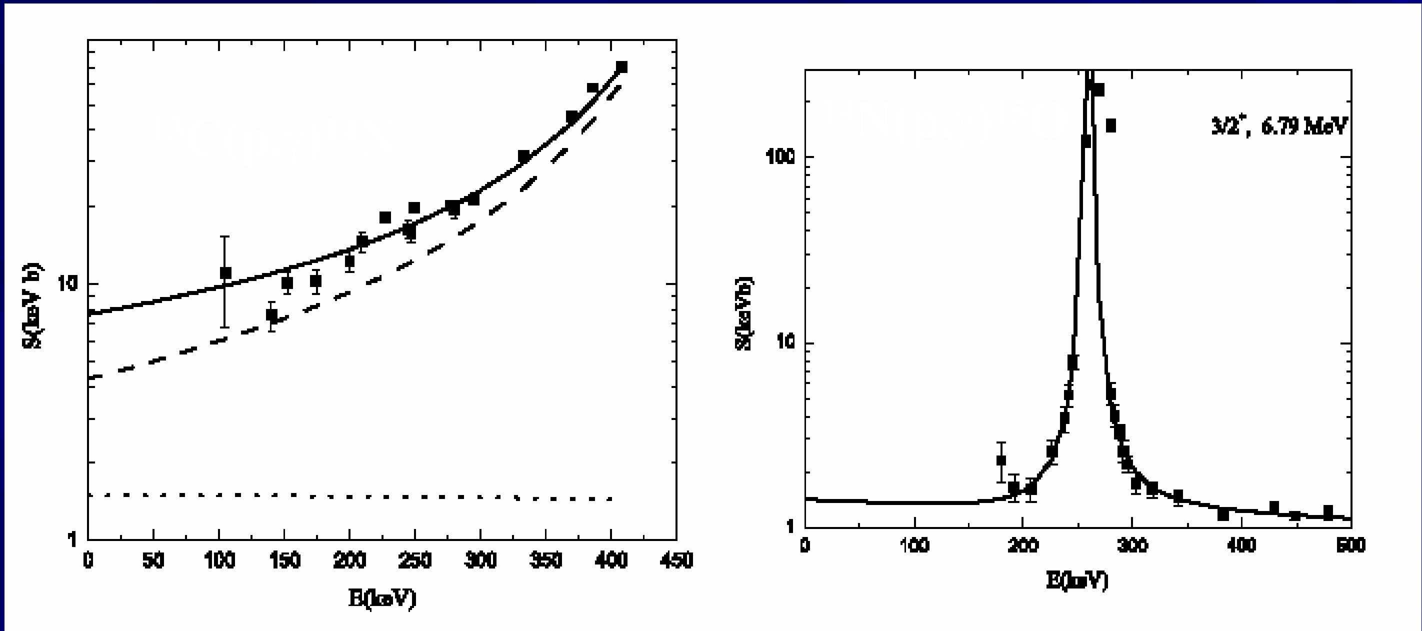
Experiments & Research & Development

- Nuclear astrophysics experiments
- Fast neutron generation
- Research and developement of cyclotron based radiopharmaceuticals
- Development of target systems for medical radionuclides
- Mathematical simulations of accelerated beam properties

Nuclear astrophysics experiments

Václav Kroha

Cooperation: Texas A&M University, INFN Catania



direct part of (p,γ)

(^{3}He,d),etc.

Results:

- **development of new method for indirect determination of the astrophysical S - factors: Method of Asymptotic Normalization Coefficients (ANC)**
- **the main test of ANC method was realized on U-120M cyclotron using $^{16}O(^{3}He,d)^{17}F$ reaction**
- **determination of the reaction rate for $^{14}N + p \rightarrow\ ^{15}O$ synthesis the most accurate value ot total S - factor was obtained (reaction $^{14}N(^{3}He,d)^{15}O$ was studied at the energy 26.3MeV)**

Fast neutron generation

Pavel Bém

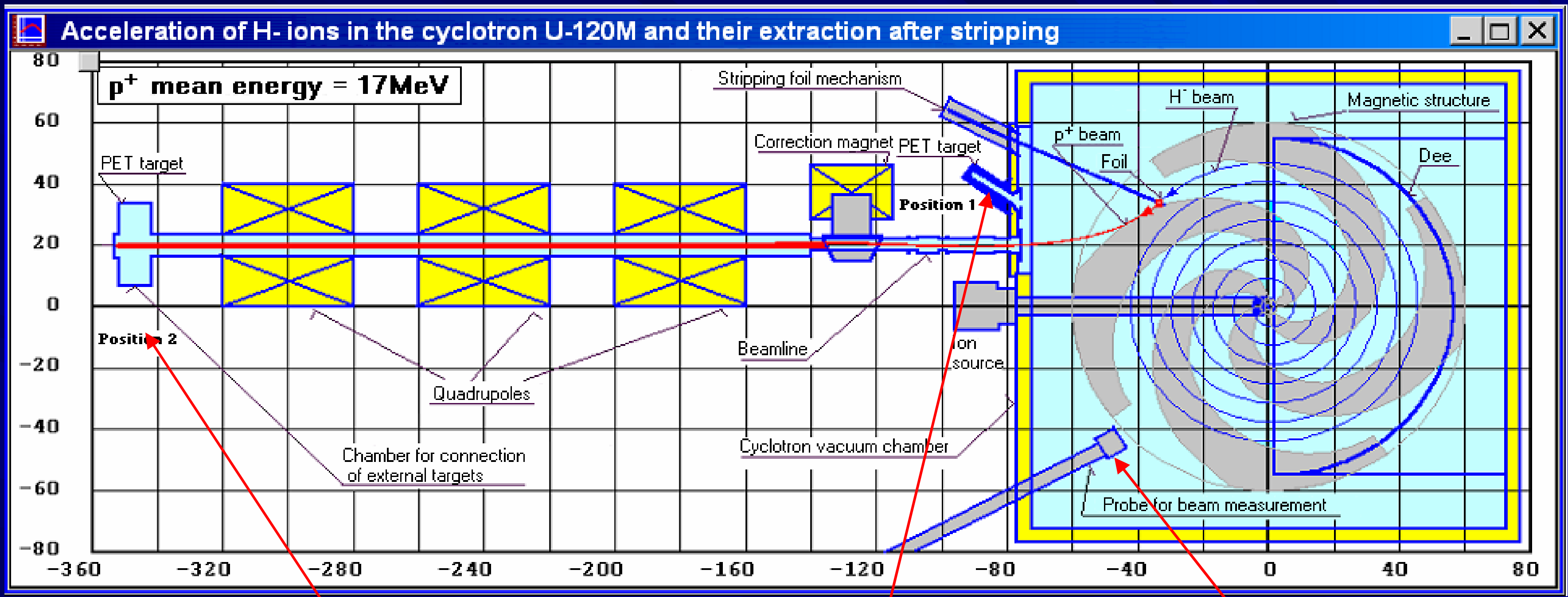
Cooperation: CEA Cadarach, ENEA Frascati, FZ Karlsruhe, UKAEA Culham

- long-term experience in the design, construction and verification of various type of Fast Neutron Facilities on the U-120M

Target station	NG1	NG2
Particles/Energy range	Protons/12 - 24MeV Deuterons/12 - 17MeV ^{3,4}He ions/20 - 40MeV	Protons/16 - 36MeV Deuterons/12 - 17MeV
Max. beam current	2 μA	20 μA
Type of target	Gaseous (He, D) Thick solid (Li, Be) Liquid (D_2O)	Thick solid (Be) Liquid (D_2O stream)
Neutron spectrum mean energy energy range	White 4 - 15MeV ≤32MeV	White 7/15 MeV ≤16/≤33 MeV
Source strength	≤ $5x10^{10}$ n/s	≤ $3x10^{12}$ n/s

The NPI FNF - the only lab with the IFMIF (International Fusion Material Irradiation Facility) neutron spectrum

Production of radionuclides – current status

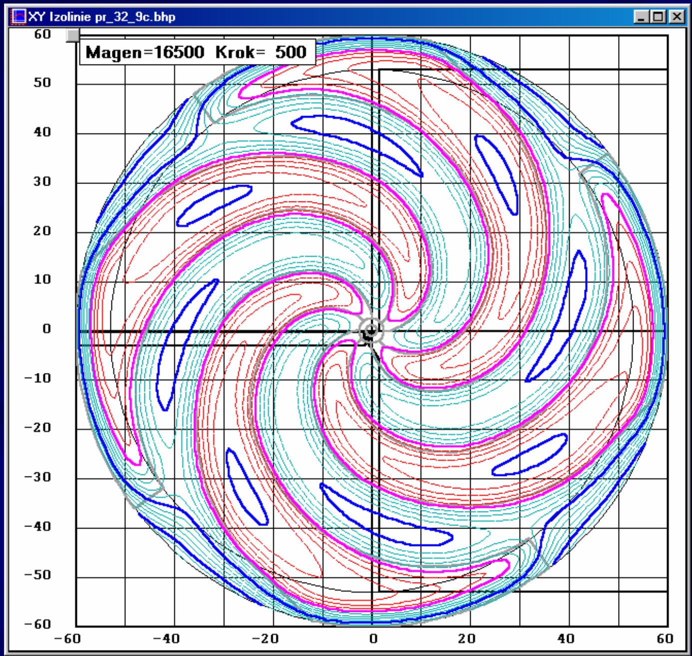


Position 1:
liquid target $H_2{}^{18}O$,
$^{18}O(p,n)^{18}F$
PET studies

Position 2:
gaseous target, production of $^{81}Rb/^{81m}Kr$ generator
gaseous target, production ^{123}I, ^{124}I
targets for production noncomertial radionuclides

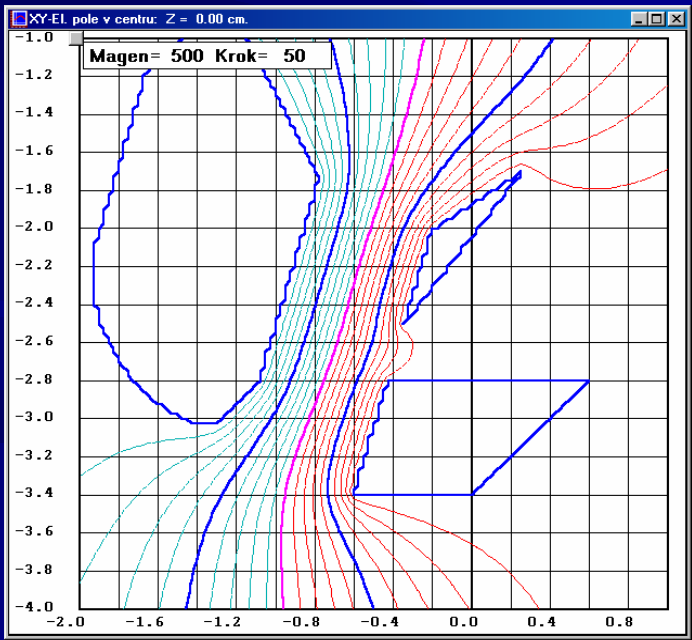
Position 3:
$^{68}Zn(p,2n)^{67}Ga$
$^{203}Tl(p,3n)^{201}Tl$
$^{112}Cd(p,2n)^{111}In$
$^{209}Bi(p,2n)^{208}Po$
$^{209}Bi(\alpha,2n)^{211}At$

Mathematical simulations



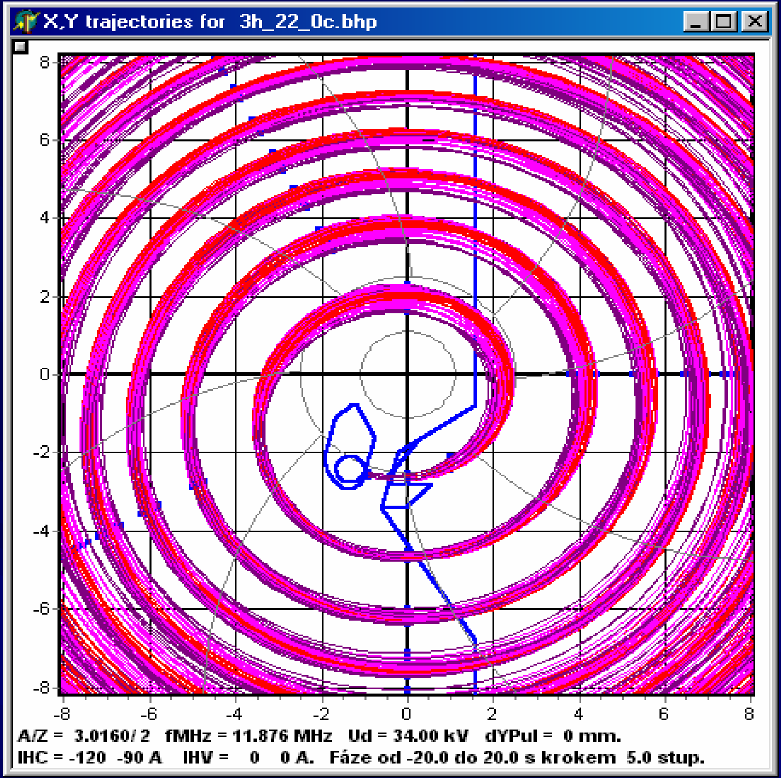
Magnetic field

The magnetic field topography in the cyclotron median plane is computed for any required accelerating regime. The results of the formerly accomplished magnetic measurements are processed to obtain satisfactory accuracy. The fields of harmonic coils are included in calculations as well.



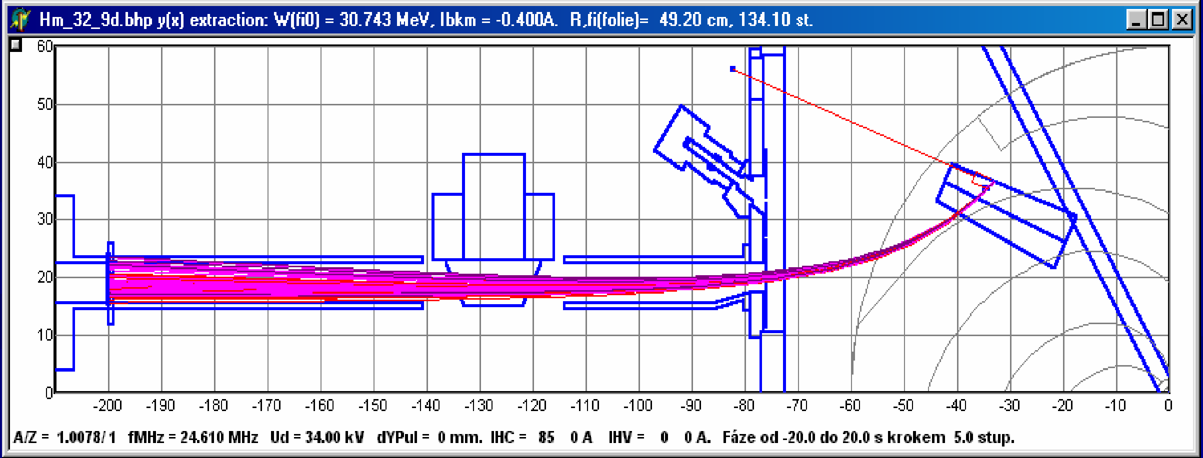
Electrostatic field

The electrostatic field of given cyclotron central part and duant structure is computed using the RELAX 3-dimensional method. Fine mesh with the step 0.25mm was used for the injection region and more coarse one with step 1.0 mm was used for the rest parts.



Ion trajectory simulations

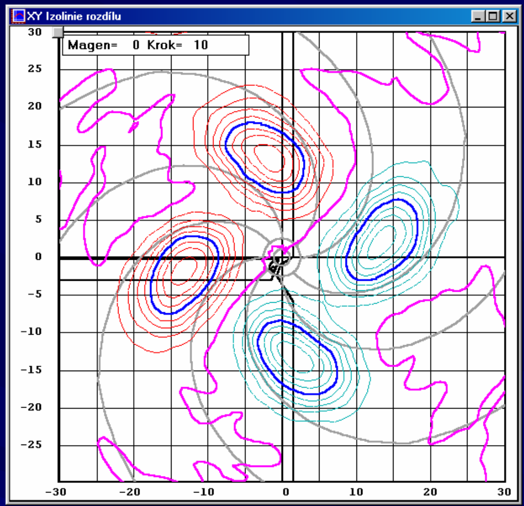
The trajectories of particular ions or beams with initial parameters and selected accelerating regime are computed using relativistic equations of motion in 3-dimensional space. The ordinary beam properties are computed and graphically presented. Off-line model is used for tuning of any accelerating regime including the beam centering before the set up of real cyclotron parameters.



Ion beam extraction by the stripping method

The trajectories of negative ions are computed after stripping on the carbon foil. The transport of the beam to various target positions is thus possible. The properties of extracted beam are computed as well.

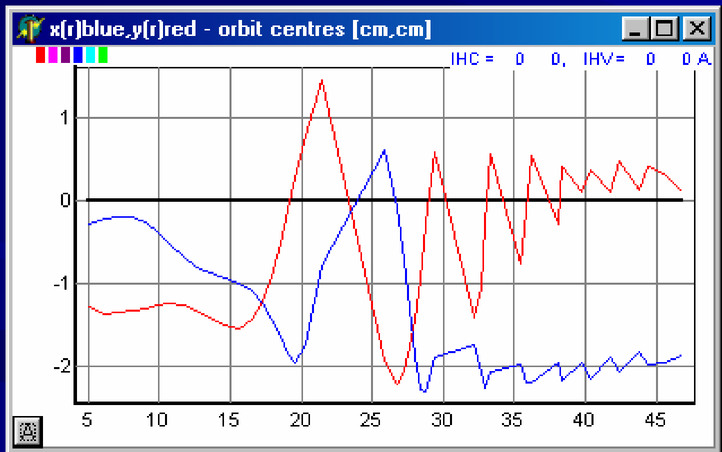
Centering of accelerated beam by harmonic coils



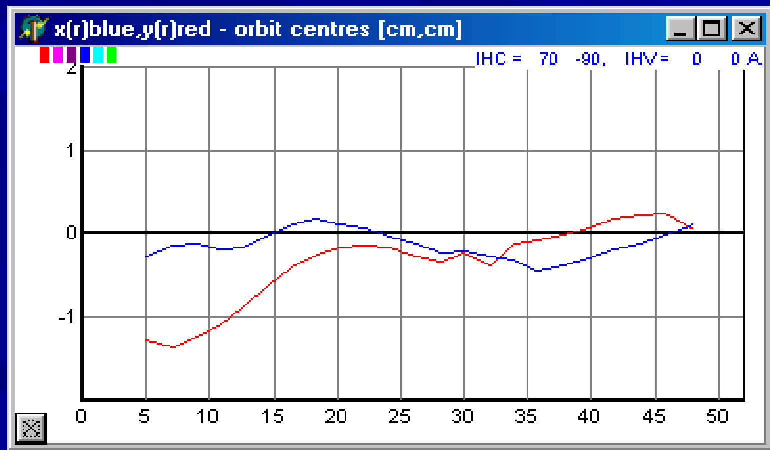
The contributions of the harmonic coils to the central magnetic field.

The cyclotron U-120M is equipped by a system of two pairs of harmonic coils, that allows to control the first harmonic of the magnetic field in the central region and so to influence the position of the orbit centers. The optimal centering of beam improve the energy spread and spatial distribution of ions in the accelerated beam.

Radial dependences of the Xc and Yc coordinates of beam centers during acceleration



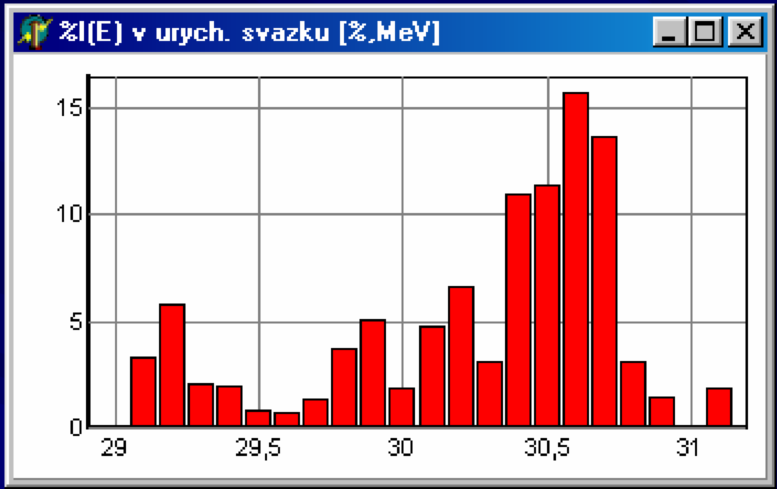
Without harmonic coils



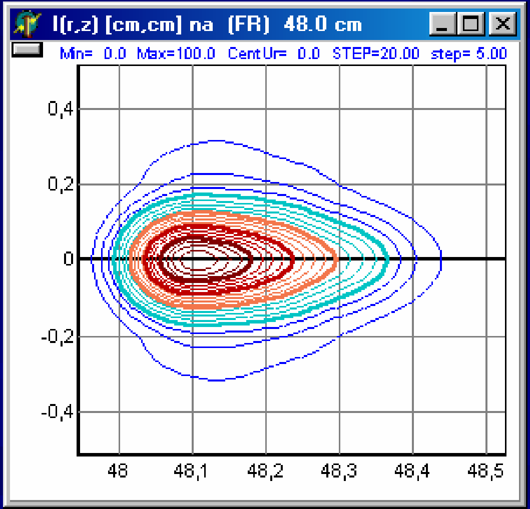
With optimal currents in harmonic coils

An effect of the centering on the beam (R_{stop} = 48.00 cm)

Without harmonic coils

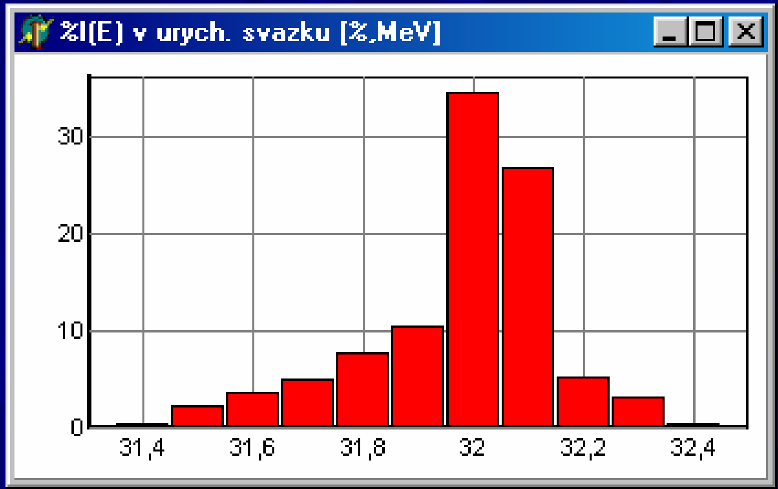


Energy spread (30.258 MeV ± 3.5 %)

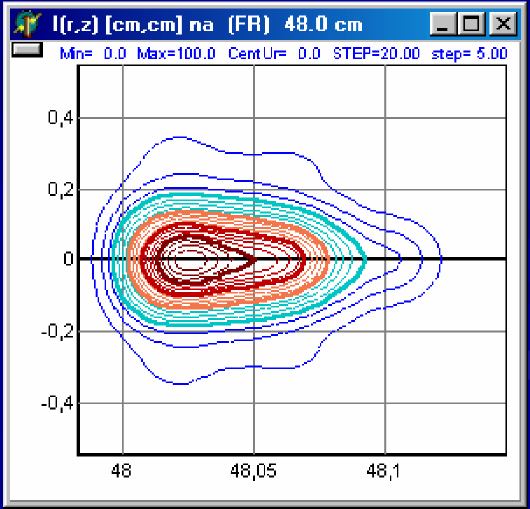


radial size of beam = 4.1 mm
radial emittance = 151.6 mm*mrad

With optimal currents in harmonic coils

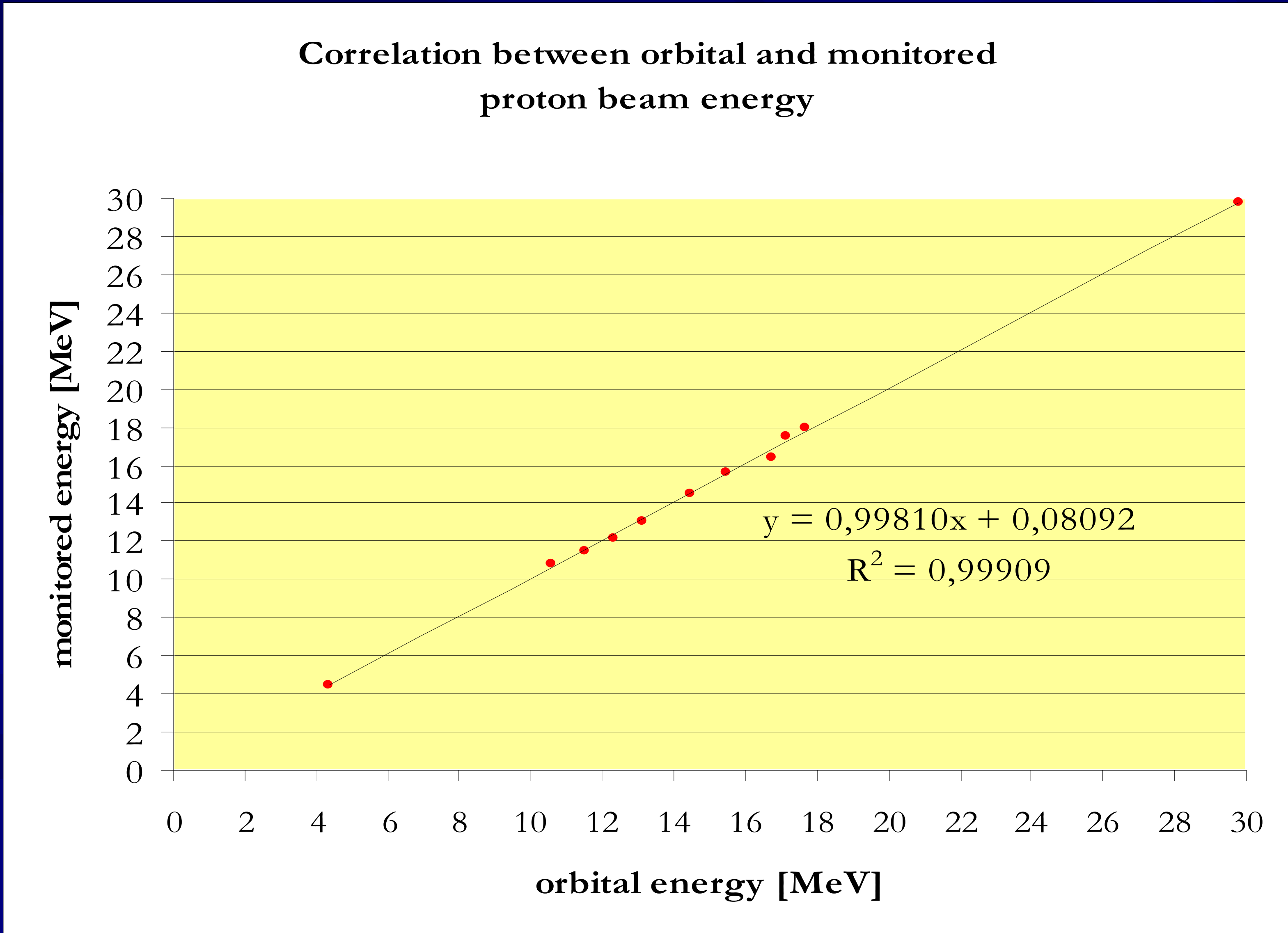


Energy spread (31.981 MeV ± 1.5 %)



radial size of beam = 1.1mm
radial emittance = 8.6mm*mrad

The correlation between the beam energies determined via beam orbit measurement and via beam monitoring by thin Cu foils



Maximum difference between both methods was found to be

2,3 %!

Tandetron accelerator

Václav Voseček

Tandetron specifications:	Terminal voltage range	0.2 – 3 MeV
	Terminal voltage stability	300 V
	X-Ray level	<2 uSv/hr

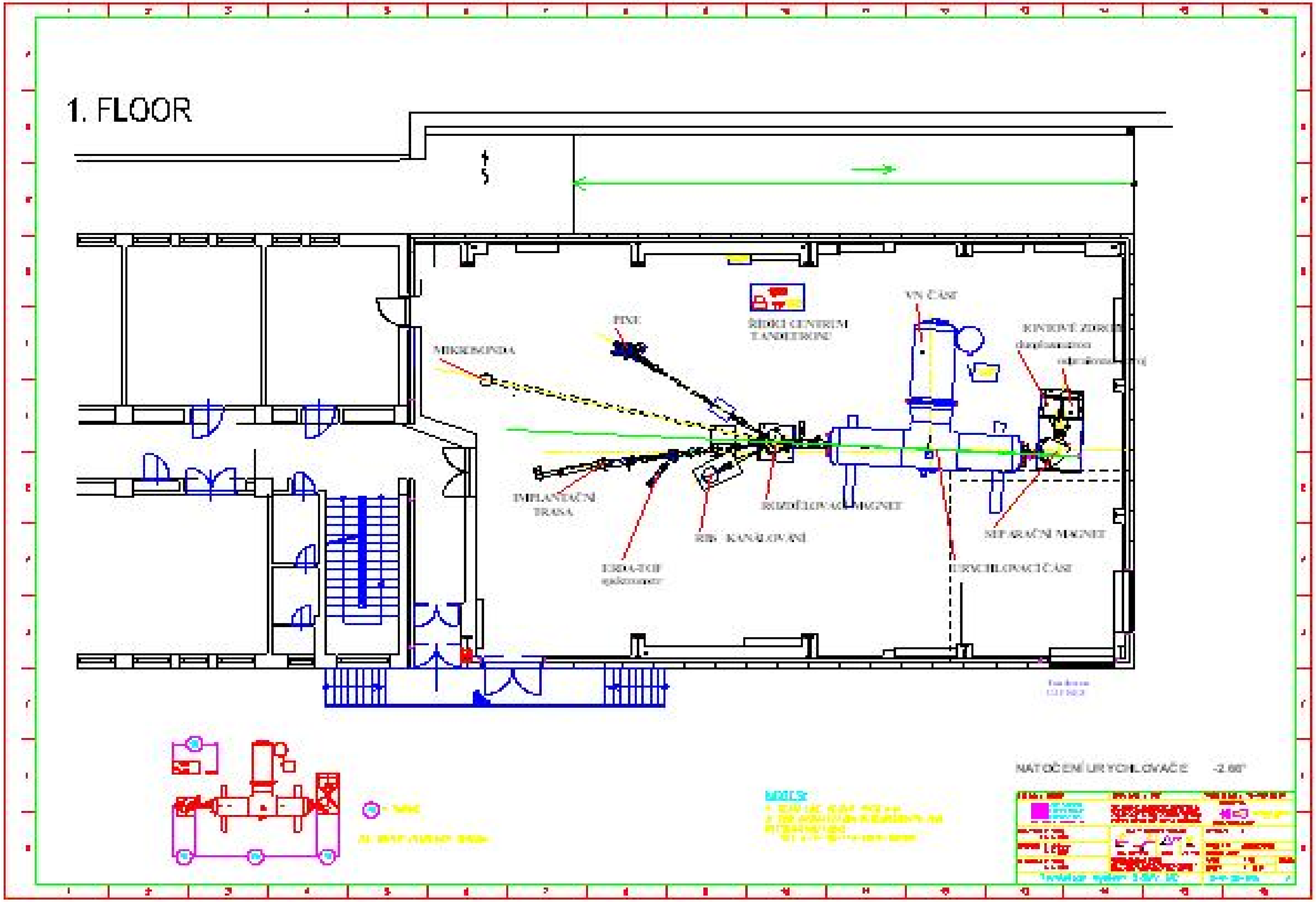
- Particles/Beam currents/energy (e.g.)

1H+	5 uA	max.6 MeV
4He2+	1 uA	max.9 MeV
2C5+	2 nA	max.18 MeV
28Si3+	40 uA	max.12 MeV
63Cu2+	25 uA	max.9 MeV
197Au2+	20 uA	max.9 MeV

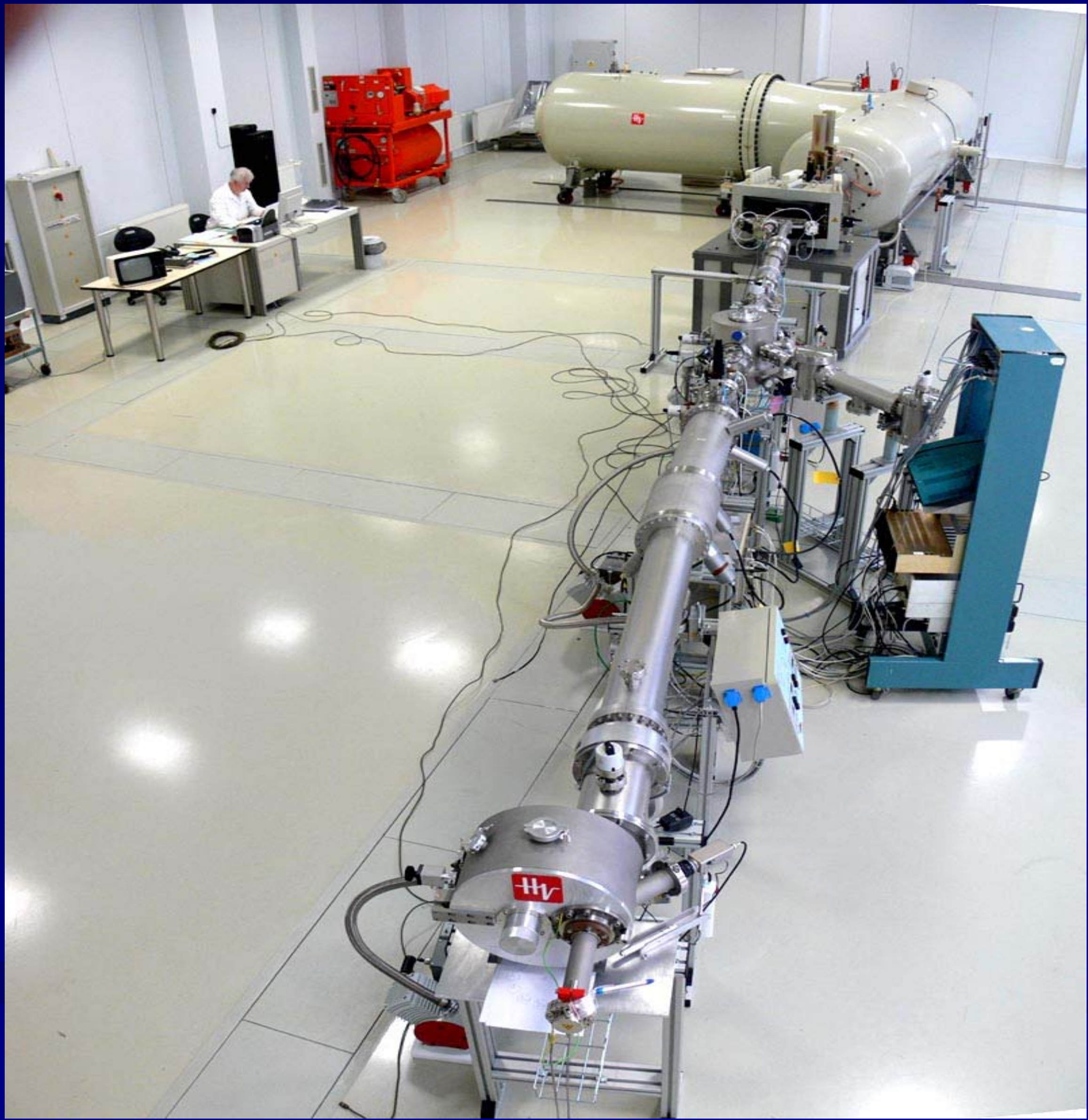
Available applications:	Ion Implantation
	Rutherford Backscattering Spectrometry (RBS)
	Particle Induced X/Ray Emission (PIXE)
	Elastic Recoil Detection (ERDA and TOF-ERDA)
	Nuclear Reaction Analysis (NRA)

http://omega.ujf.cas.cz/vdg

Tandetron floor plan



Tandetron accelerator



Microtron MT25

Miroslav Vognar

- **Basic parameters:**

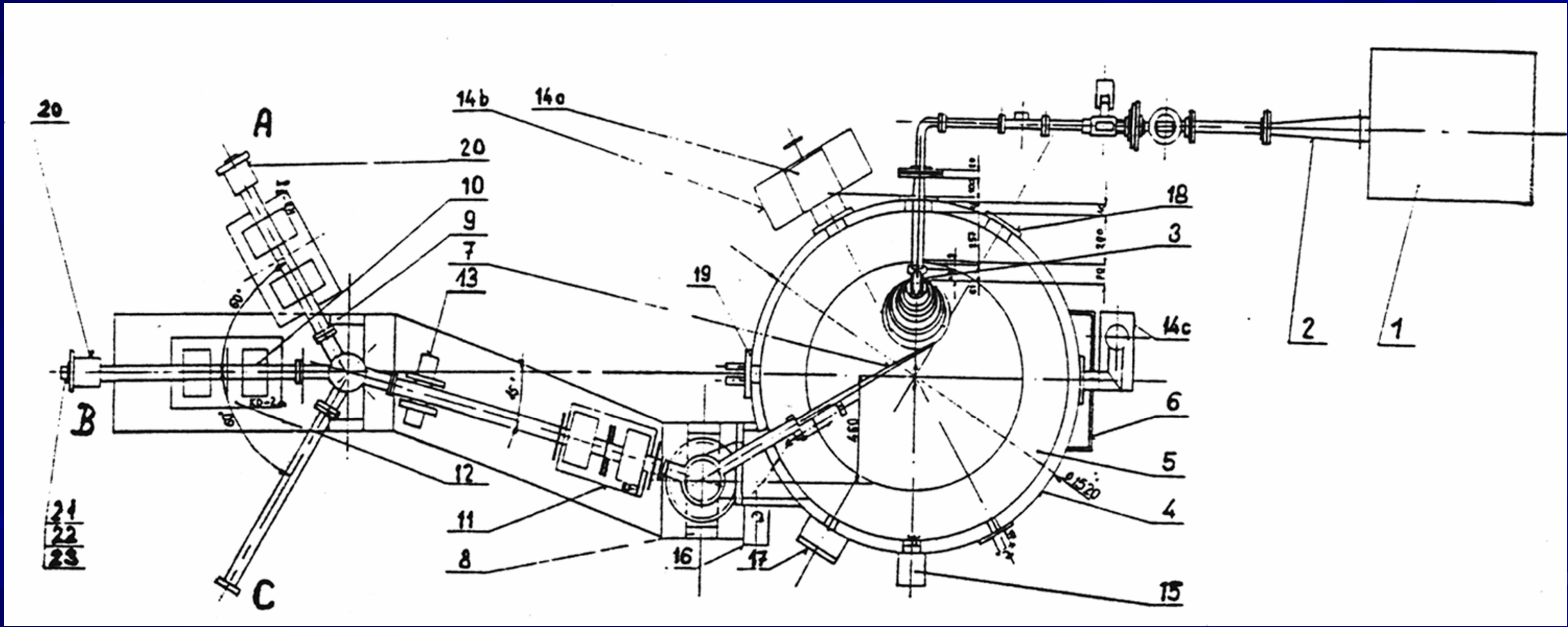
- **Before modernization** **After modernization**

	Before modernization	After modernization
Maximum energy	25 MeV	25 MeV
Energy range	6 - 25 MeV	6 - 25 MeV
Electron current	10 µA	25 µA

- **High frequency source**

	Before modernization	After modernization
Tunable magnetron	2790±50 MHz	2796±5 MHz
Peak power	2 MW	3 MW
Pulse length	3 µs	3 µs
Repetition rate	400 s-1	max.425 s-1
Resonator freq.	2784 MHz	2796 MHz
Power supply freq.	400 Hz	50 Hz

Microtron MT25 floor plan



Microtron MT25