NOVEL ACCELERATOR TECHNOLOGIES FOR RADIATION THERAPY

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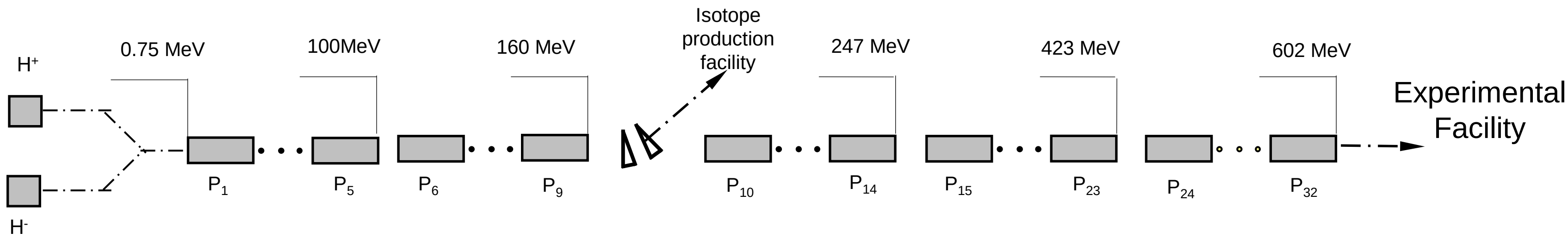
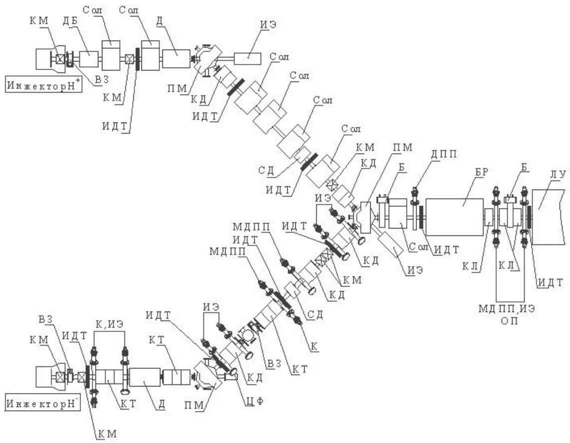
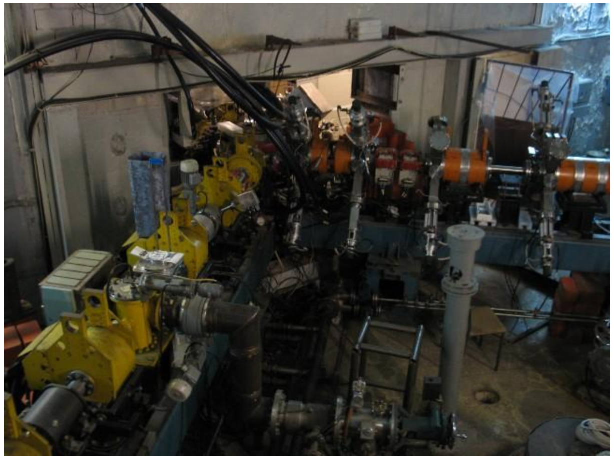
Some materials were kindly provided by L.Kravchuk (INR), G.Klenov and V.Khoroshkov (ITEP).

Design of linac of INR







injector

Beam channels

Initial part of linac (100 MэВ)

20 MeV	49 MeV	74 MeV	94 MeV	100 MeV
Tank 1	Tank 2	Tank 3	Tank 4	Tank 5

5 drift tube cavities

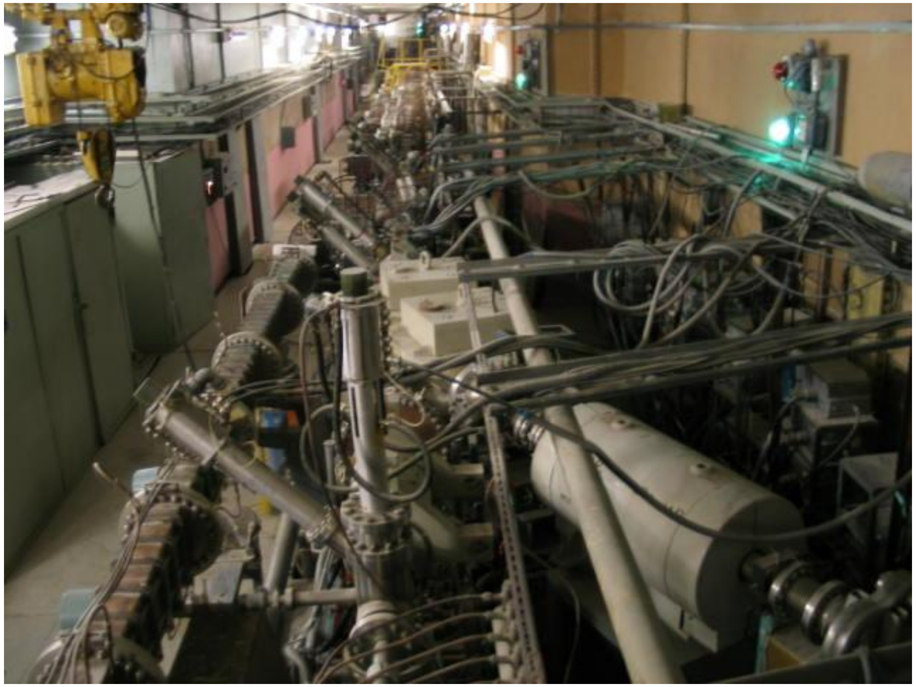
Frequency – 198.2 MHz

Output energy - 100 MeV

Main part of linac (100-600 MeV)

Accelerating resonators

Gallery of HF generators



Beam extraction (160 MeV)

Isotope production facility

Complex of radiotherapy of INR

Main task:

treatment of tumors by proton therapy and boost radiotherapy (combined with photon and x-ray irradiation)

Basic equipment:

- proton linac with optimal beam parameters
  proton energy 74 – 247 MeV,
  frequency of micropulses – up to 100 Hz,
  duration of micropulses up to 100 mcsec
  (no analogy in Russia!)
- medical electron accelerator SL-75-5- MT
  (electron energy 6 MeV).

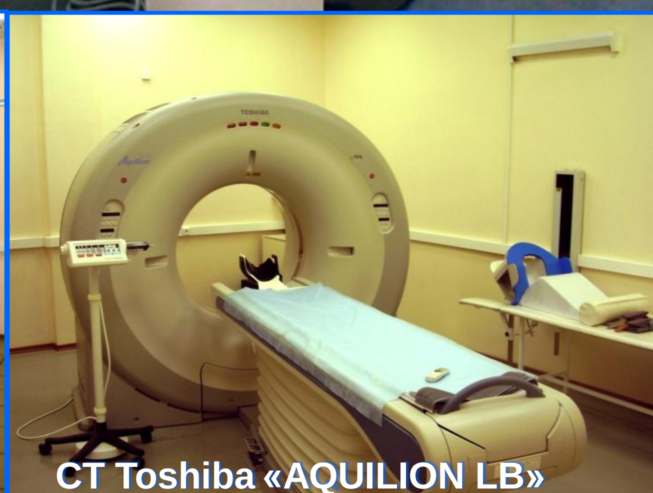
Additional equipment:

- x-ray radiotherapy,
- CT (Toshiba Aquilion LB-16),
- ambulatory for 40 patients per day,

Radiological equipment of INR

Proton therapy treatment room

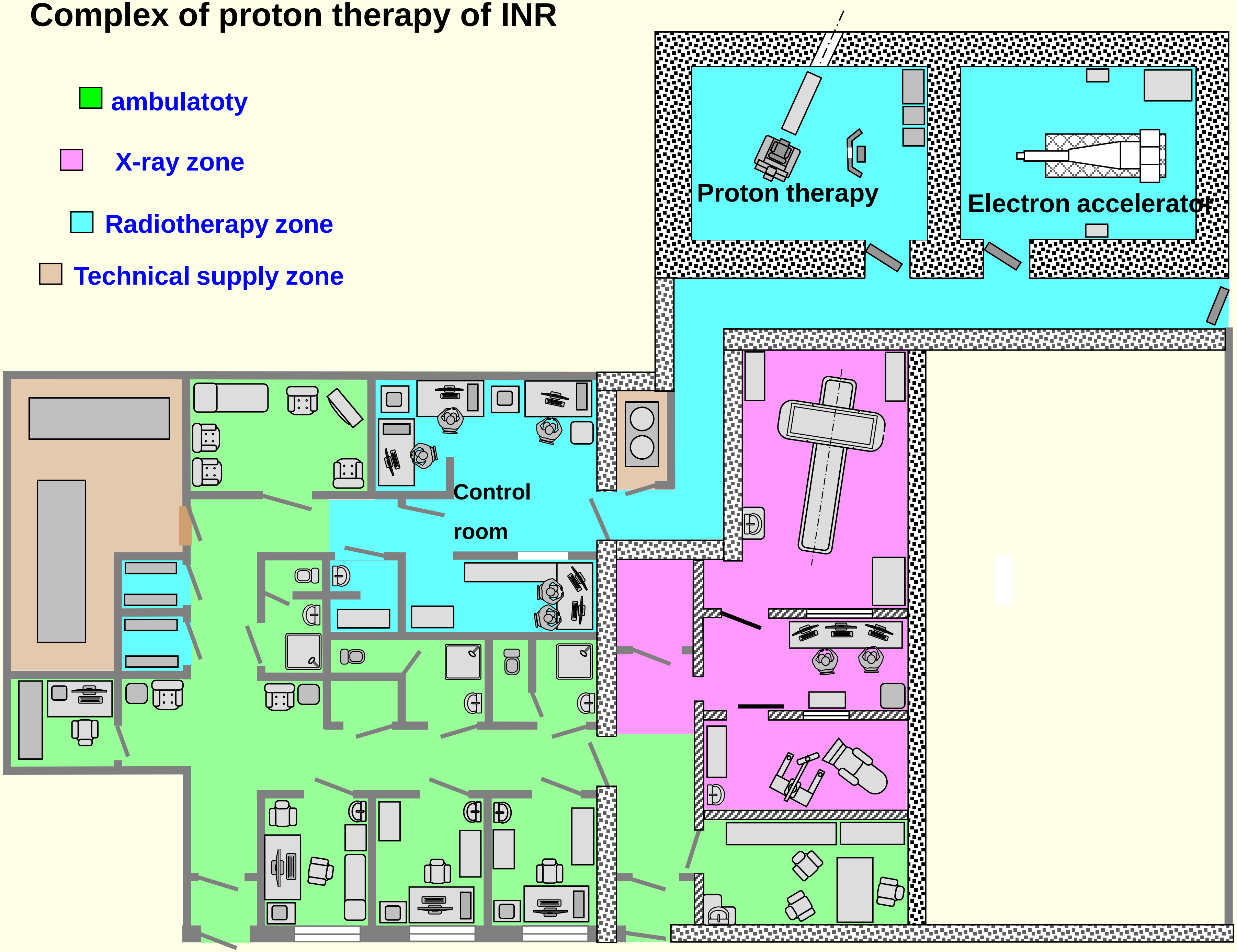
Electron accelerator SL-75



CT Toshiba «AQUILION LB»

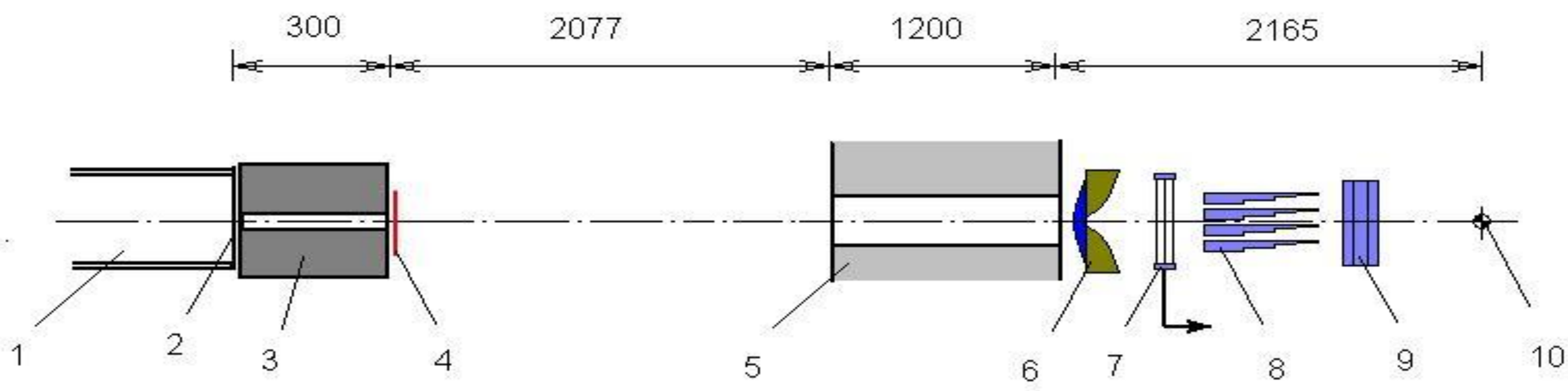
X-ray apparatus

Complex of proton therapy of INR



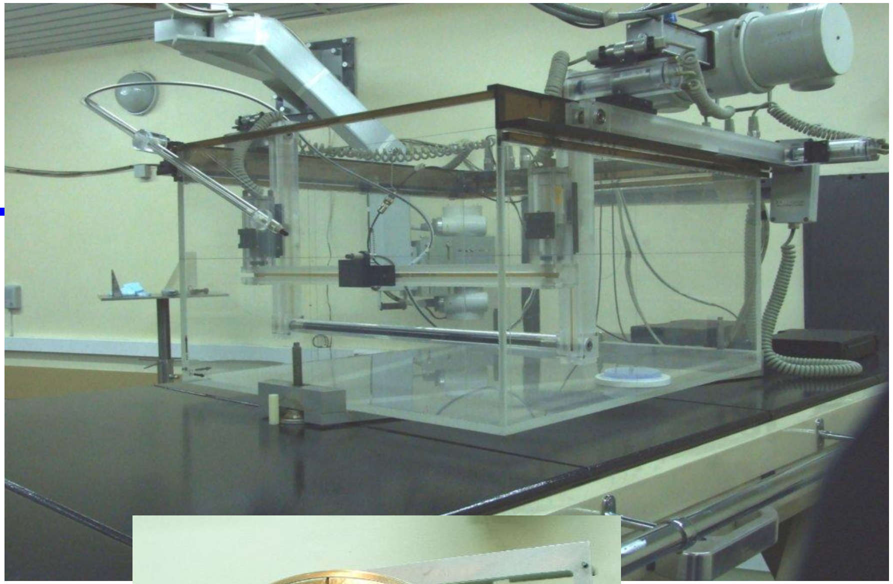
Proton beam formation system (April 2010 г.)

- 1- vacuum channel,
- 2 – Aluminum foil,
- 3 – carbon collimator (hole of 10 mm),
- 4- primary scatterer,
- 5- protection wall,
- 6- secondary scatterer,
- 7- beam monitor (ion camber 150 mm),
- 8- brass filter,
- 9- individual block (bolus and collimator),
- 10 – isocenter of treatment room
- (dimensions in mm).

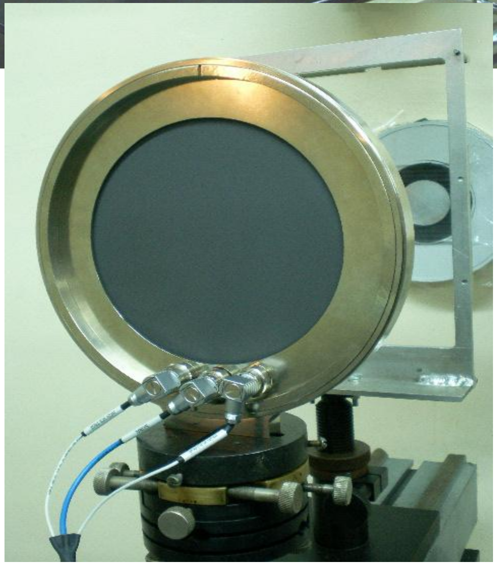


Detectors and monitor equipment

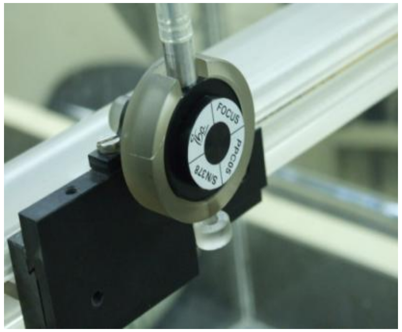
- **3D Pantom Wellhofer WP600, with camera IC-10 on the patient desk.**



- **Monitor IC PTW 786 on the optical desk (150mm).**

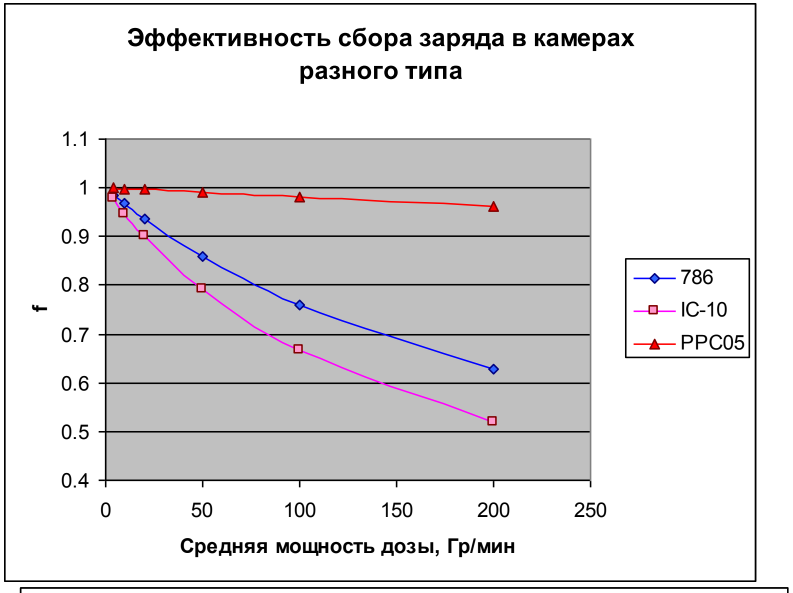


- **Plane-parallel IC PPC05.**

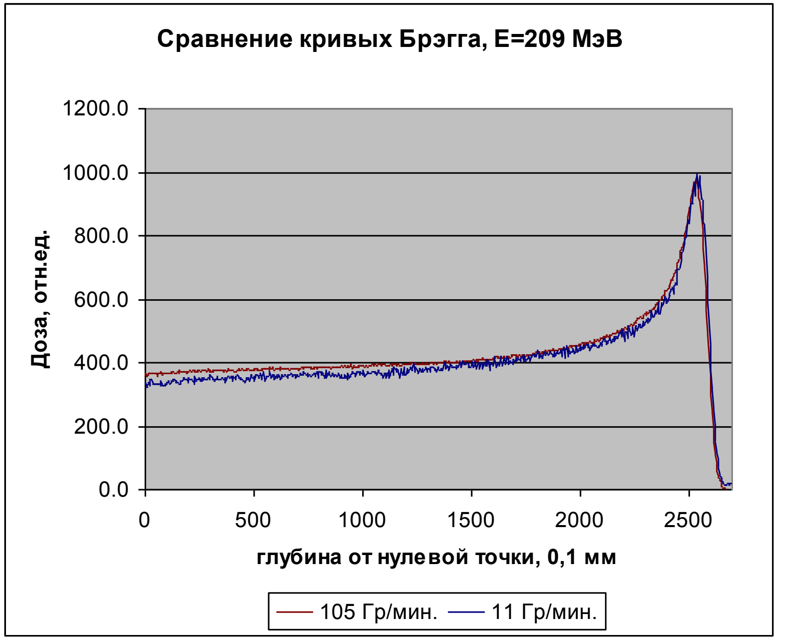


Measurements of proton depth-dose distributions

- Efficacy of charge registration (160 MeV),



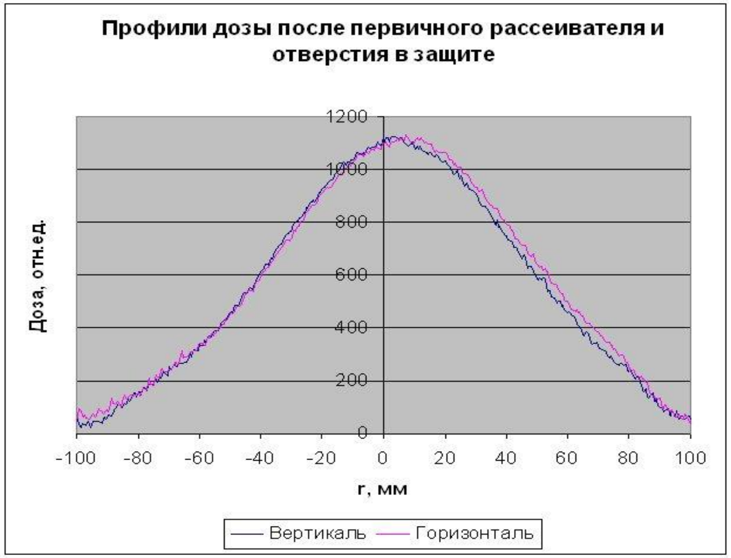
- Bragg peak for 209 MeV protons



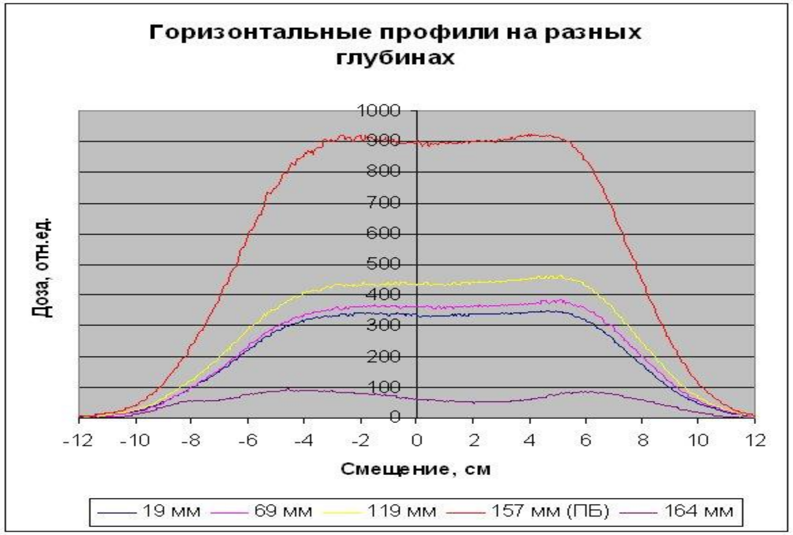
Beam profiles (160 MeV)

Conclusion: **the beam fulfill treatment requirements (homogeneity within ± 5%)**

- Beam profiles after primary scatterer

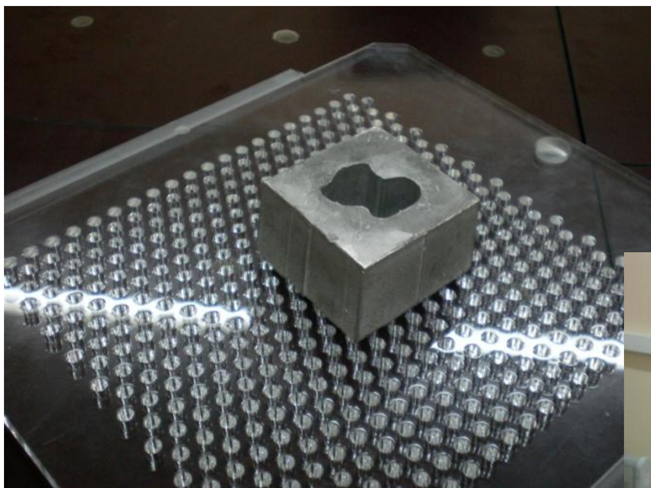


- Beam profiles in the isocenter



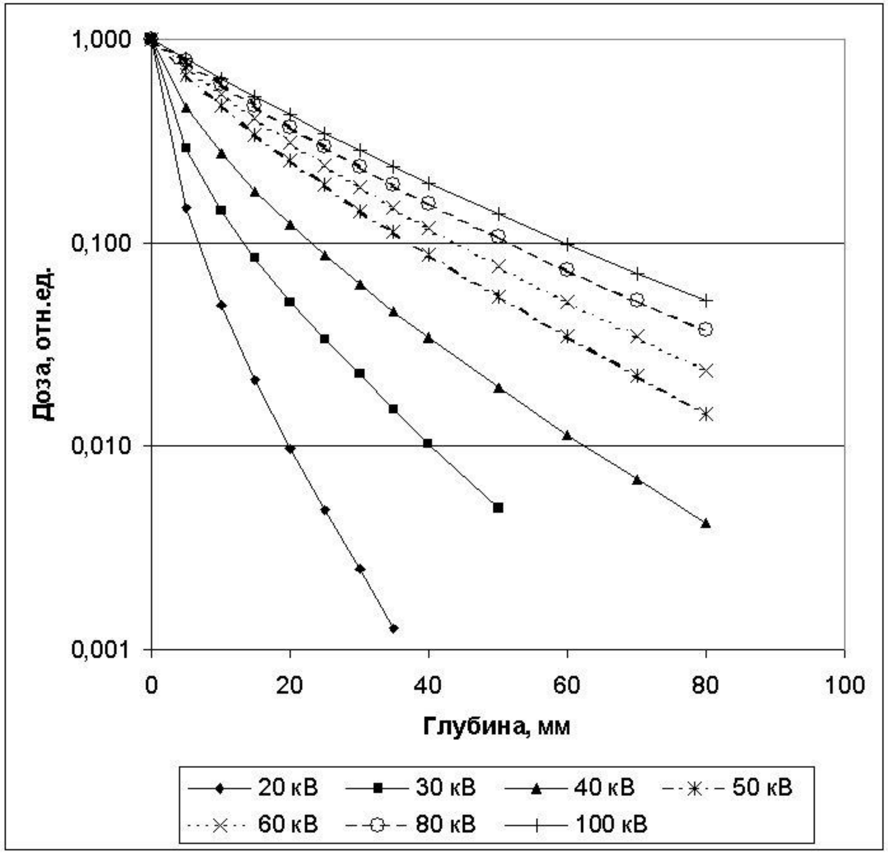
The conventional radiotherapy treatment in INR has the highest quality in Moscow region

(about 100 patients cured in 2010)



X-ray radiotherapy of superficial malformations

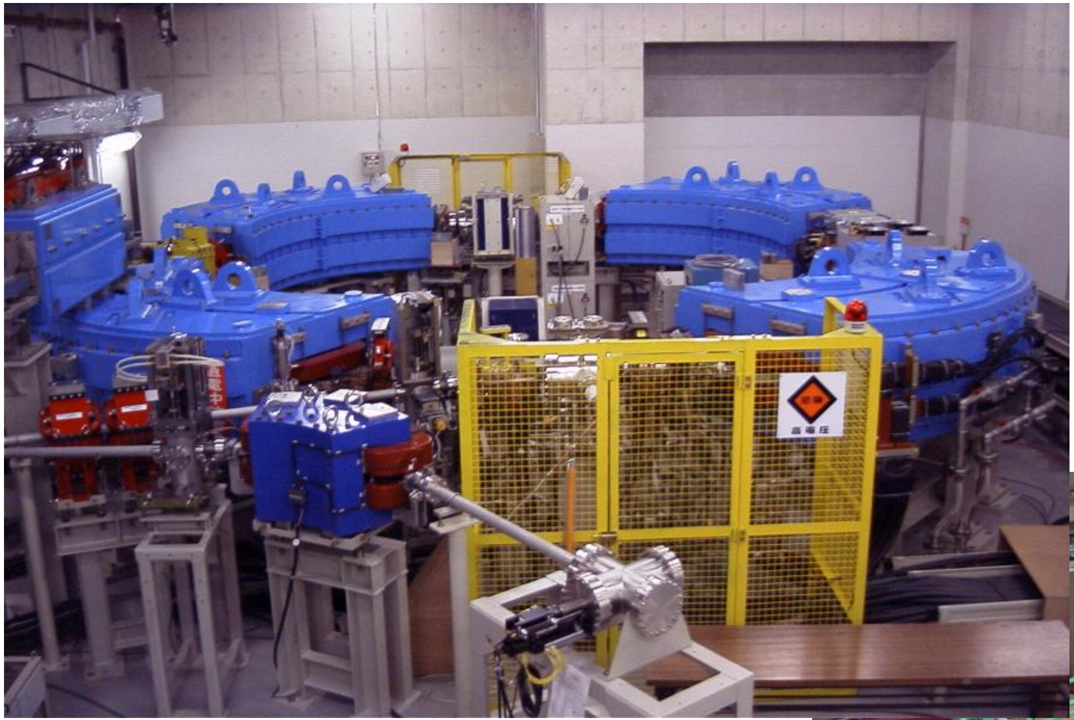
The most detailed x-ray dose-depth distribution atlas in Russia was done in INR.



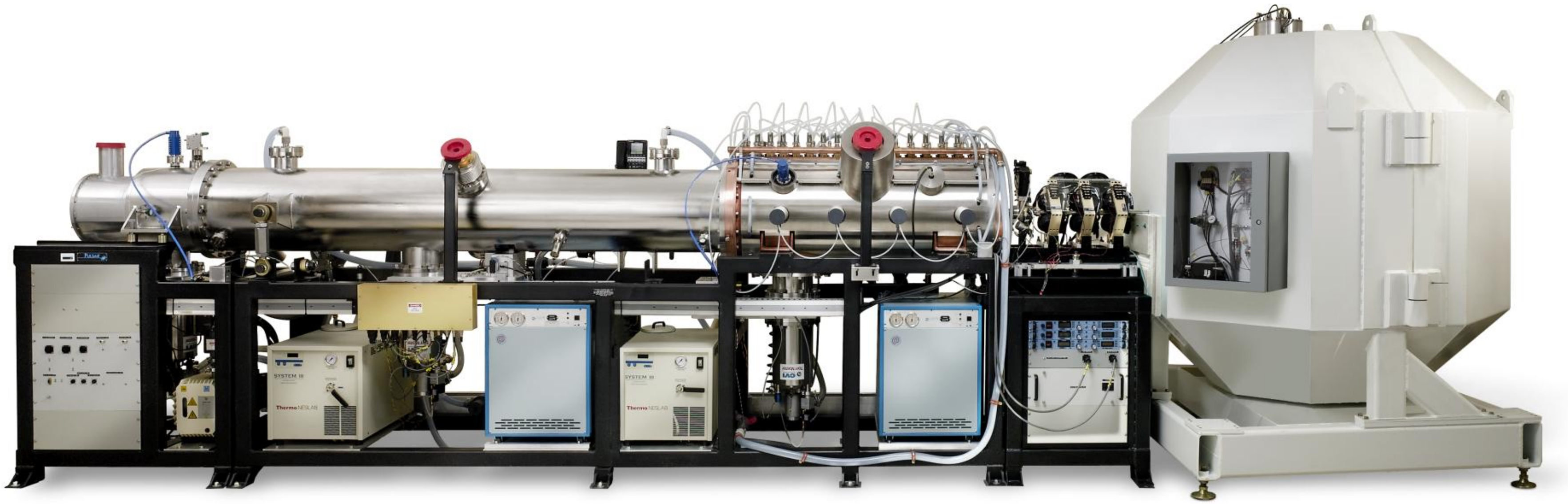
Cyclic accelerators for radiotherapy (with protons and carbon ions)

- Synchrotrons for carbon ions are produced by several firms (Hitachi, Mitsubishi, Siemens, GSI etc).
- New synchrotron for Botkin hospital in Moscow is being designed by MRTI and ITEP.
- Physical Institute of RAS developed new compact synchrotron- Injector 1.2 Mev, mean intensity about 0.1 nA, diameter less then 6 m.
- JINR is planning to develop superconducting synchrotron for carbon.
- JINR and IBA are developing new superconducting cyclotron.
- IHEP in Protvino is developing a model of accelerator chain for radiotherapy.
- INP in Novosibirsk suggests to use an accelerator cascade with electron cooling in the synchrotron circle.

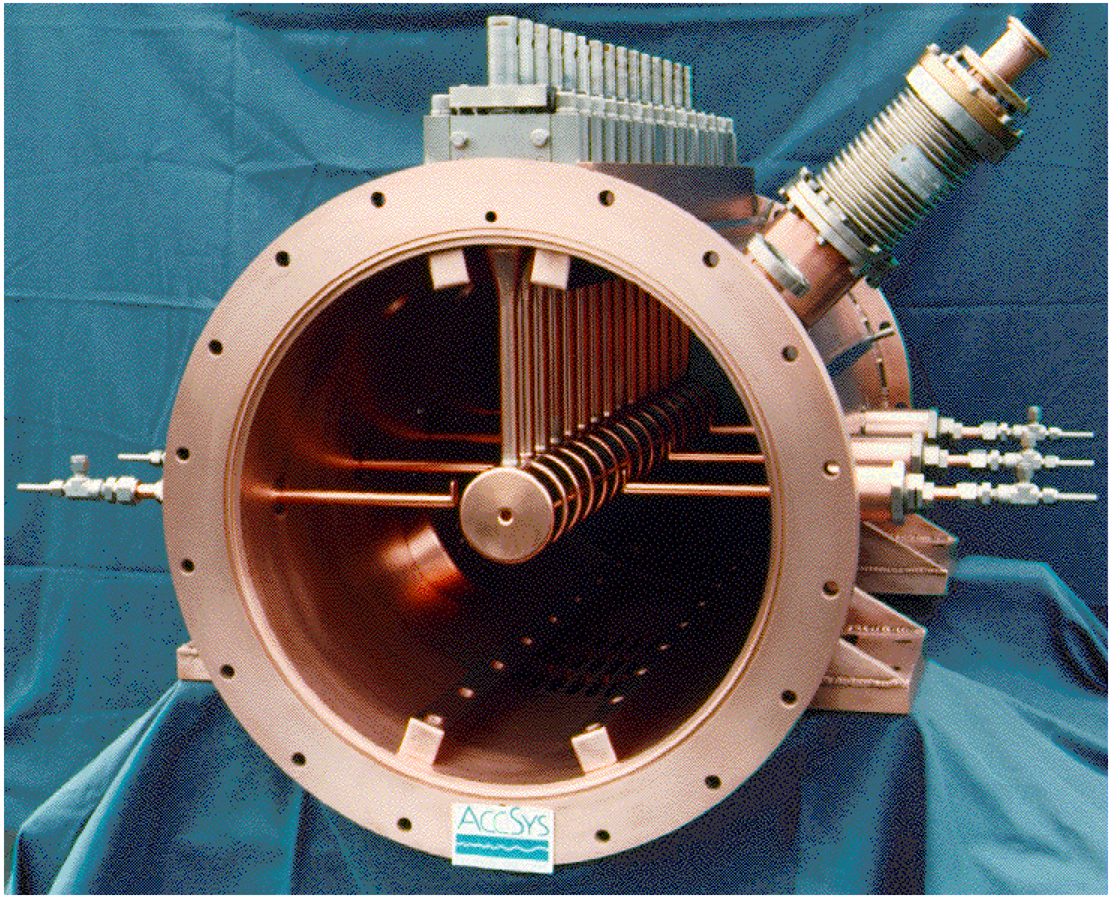
Synchrotrons of Hitachi



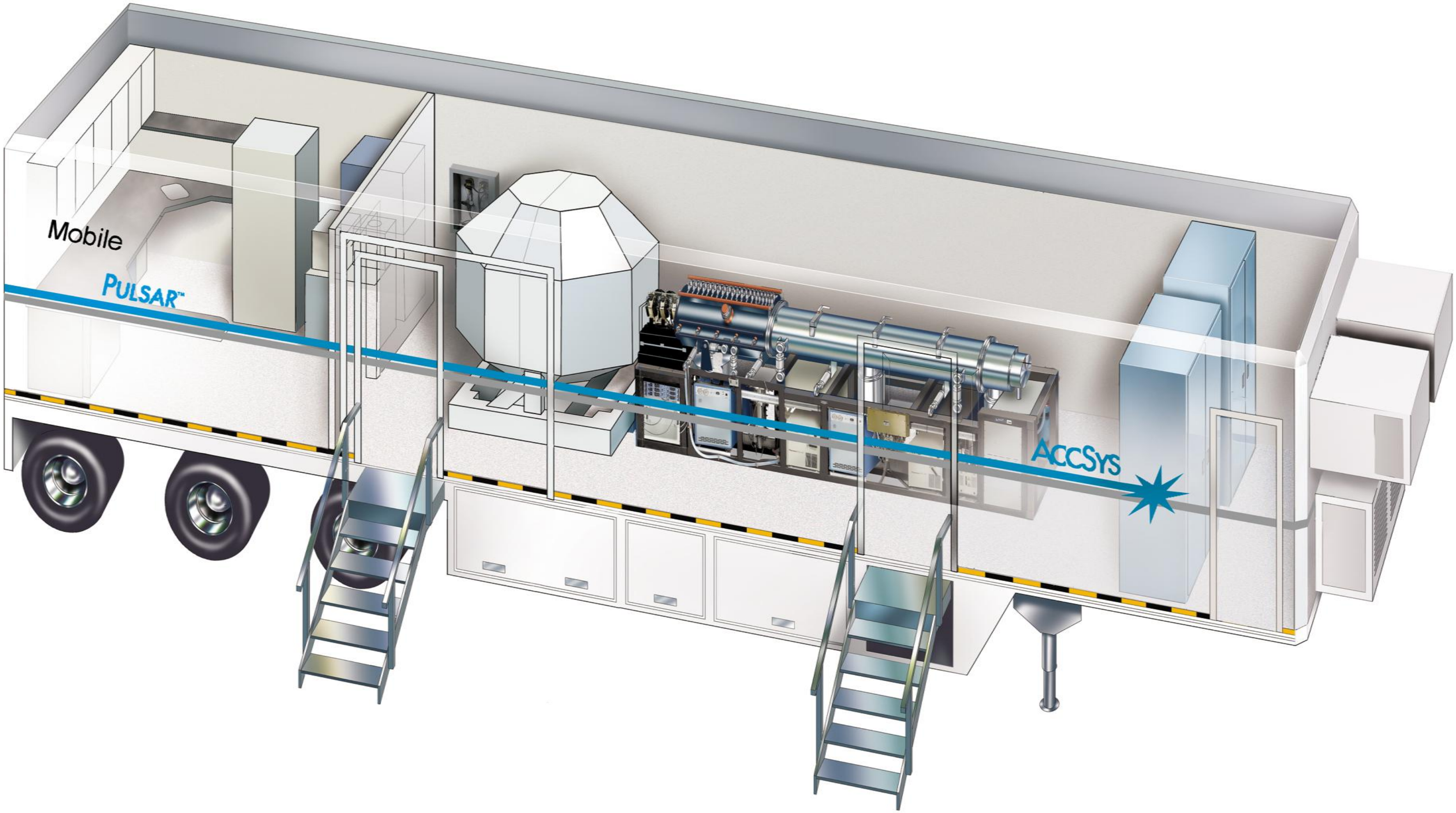
PULSAR™ 7 MeV Linear Accelerator:
- injector for synchrotrons,
- effective PET isotope production



- The Drift Tube Linac is a series of permanent magnets in an RF field
- The magnets focus the beam and the RF accelerates the protons to 7 Mev where they exit the accelerator

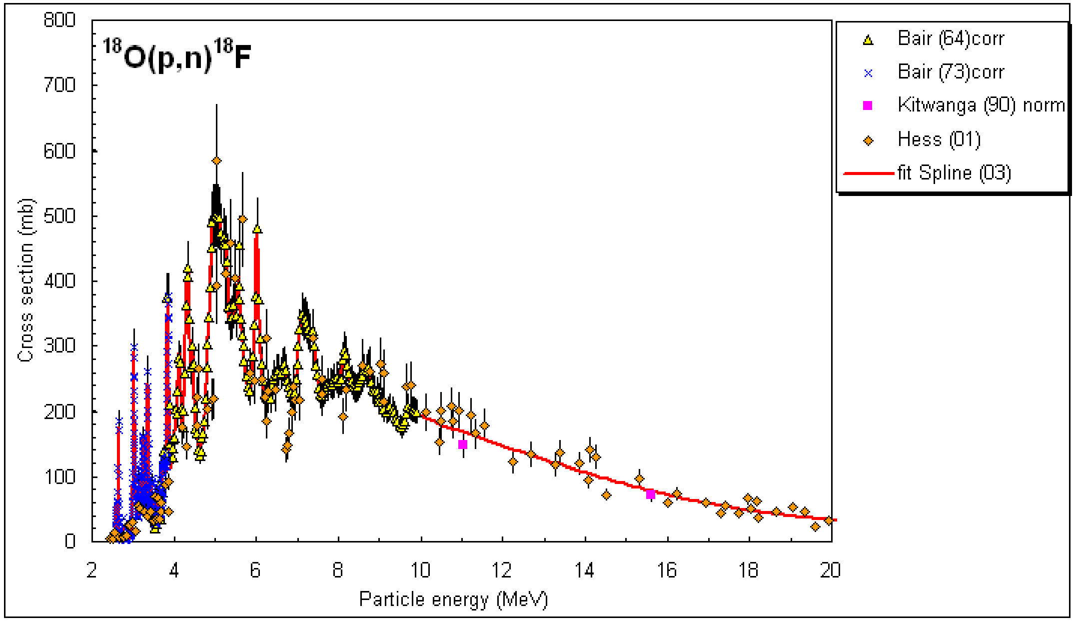


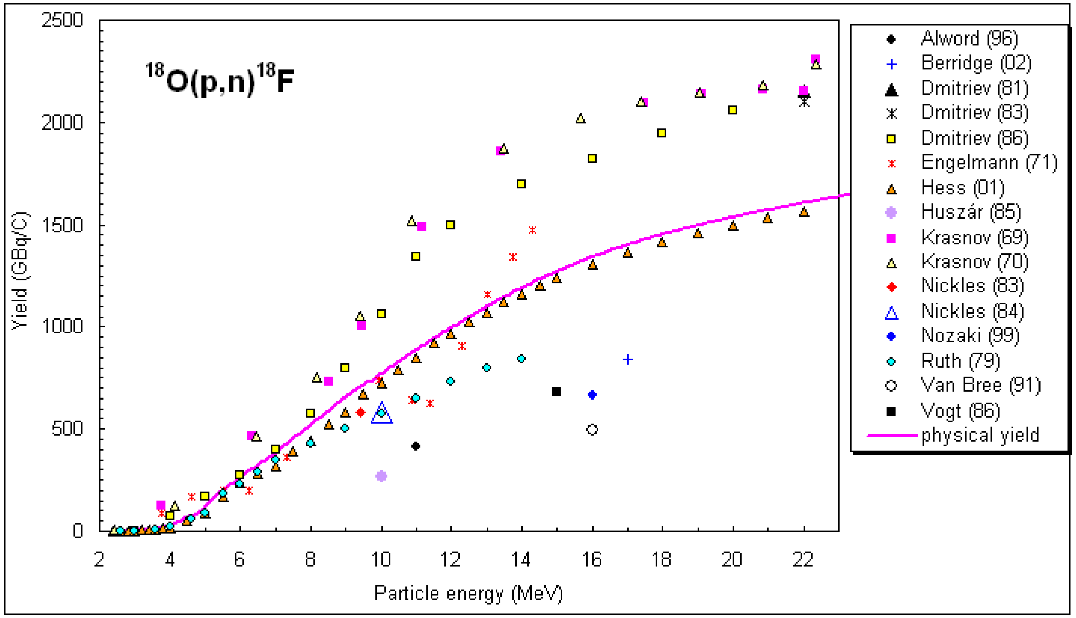
Mobile PULSAR™ PET Isotope Laboratory



F18 Production with Pulsar

- 1 Curie (37 GBq) in a one hour run
- Less than ½ ml of water per run
- 10 minutes between runs
- Fully automatic target operation





Proton synchrotron of Lebedev PI RAS

1. Injector; 2. Accelerator ring. 3. Scanning magnet;

E = 300 MeV

Irradiation at stay position

Intensity =

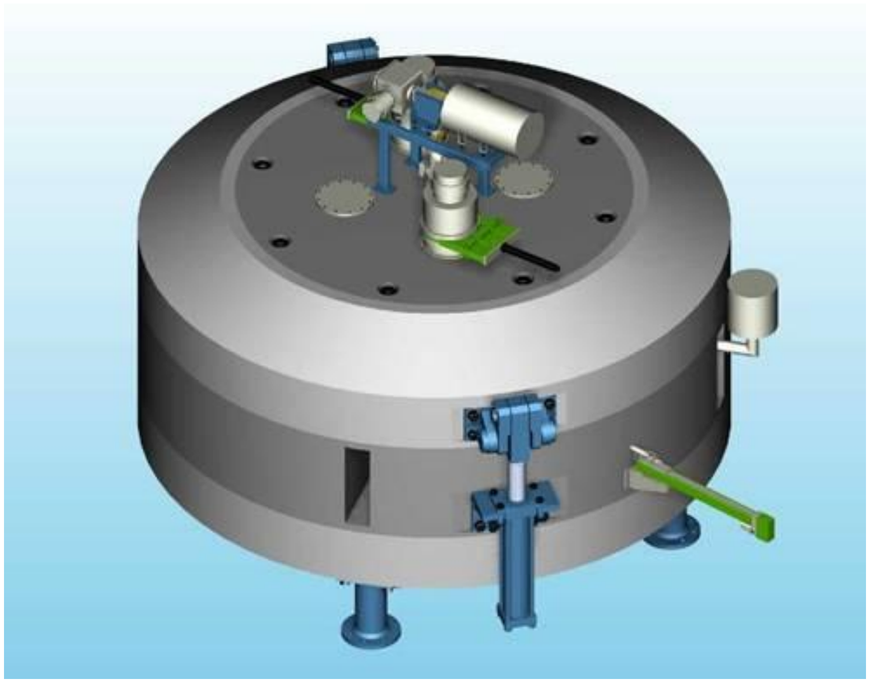
$$2.10^{8}\, p/c$$

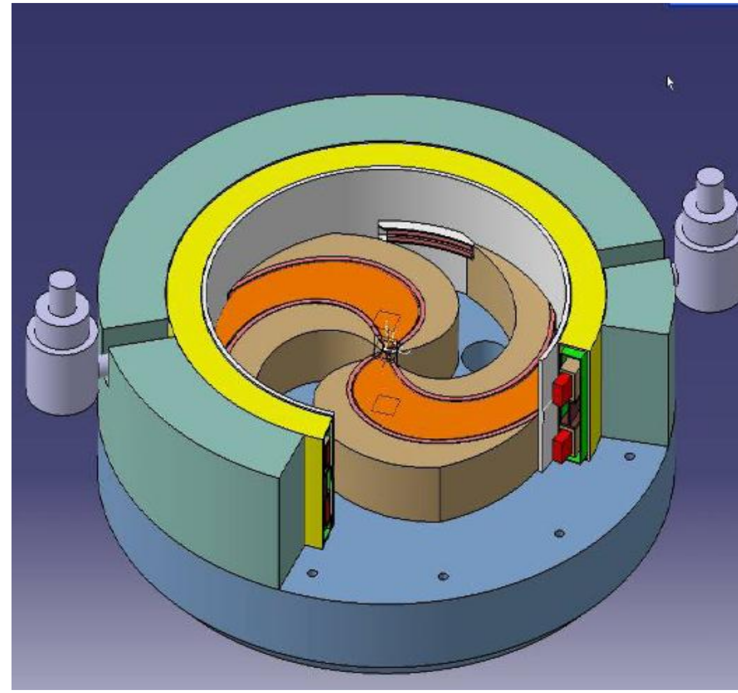
Injection energy=

1.2MeV

Active dose delivery system

Superconducting cyclotron JINR and IBA





(weight 700 т, diameter 6,3м)

Fix energy; HF (75 МГц, 4th harmonic)

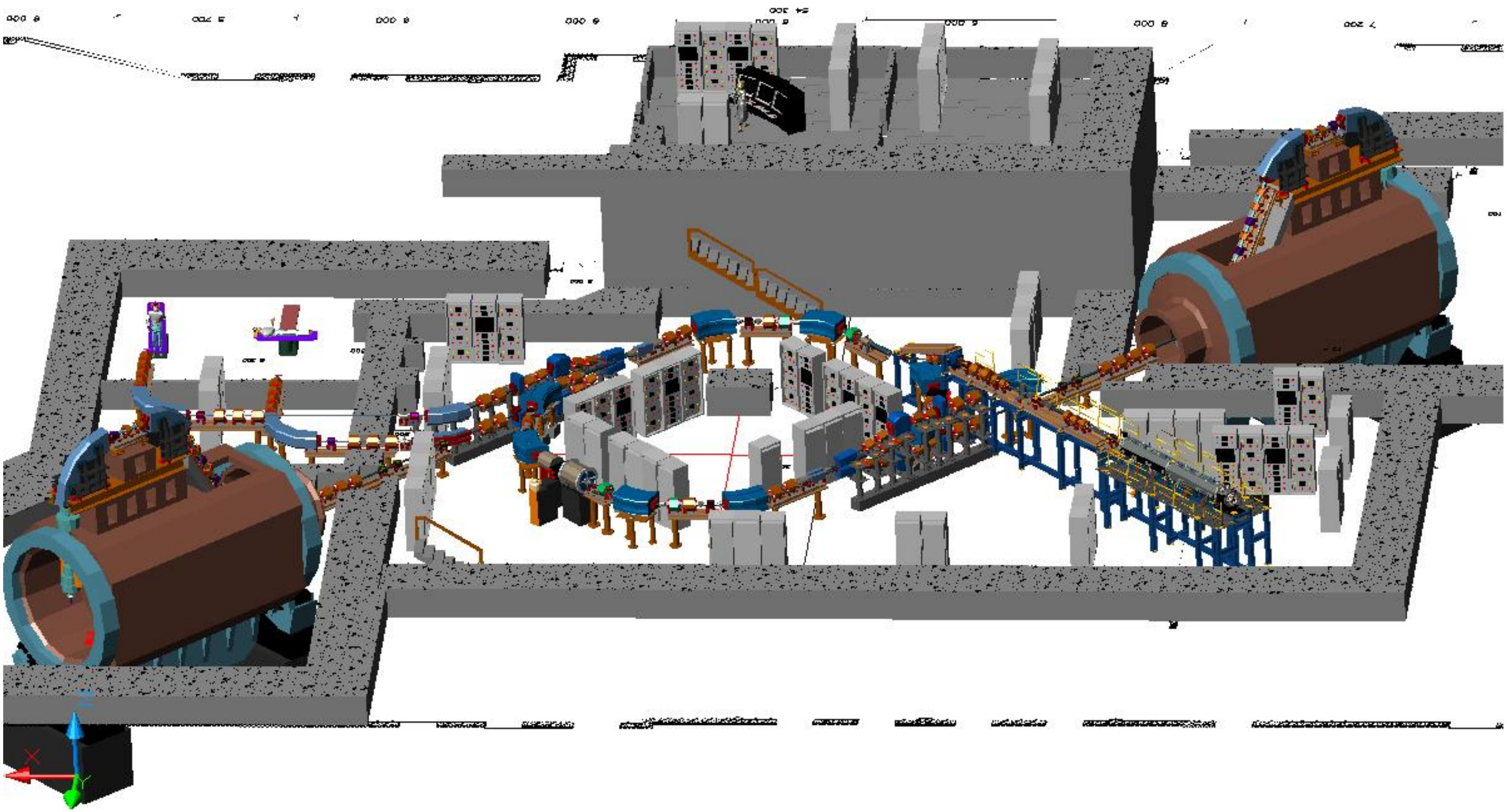
Accelerated particles: Q/M=1/2 ⇒ 400 MeV/n (p-260 МэВ)

- **H^{2+}, $^{4}He^{2+}$, ($^{6}Li^{3+}$), ($^{10}B^{5+}$), $^{12}C^{6+}$**
- **Superconducting coil ($B_{мах}/B_{min}$=4.5/2.5 T)**
- **External axial injection (spiral inflector)**
- **Ejection H^{2+} ions – through foil, other ions by means electrostatic deflector (140 кV/см)**

Institute High Energy Physics

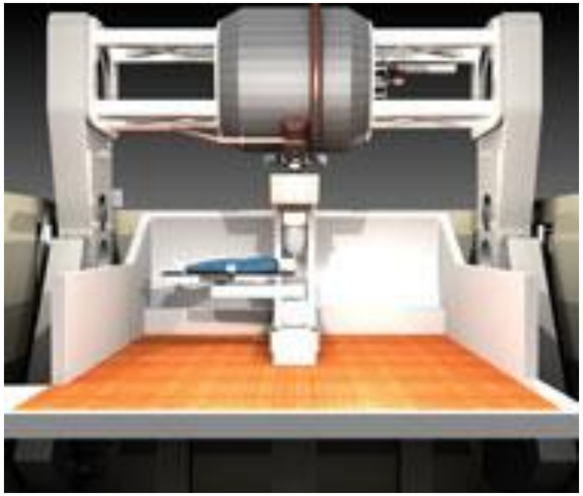
Injector I-100; Buster 1 GeV

Proton synchrotron, two Gantries and treatment room with fixed, horizontal beams for two treatments units



- Lasers of new generation (fenta lasers) can be used for acceleration of protons and carbon ions. Some problems have to be resolved:
- Capacity of lasers should be increased,
- Energy spectrum must be defined,
- Dosimetry and patient protection must be provided.

Moving superconducting cyclotron

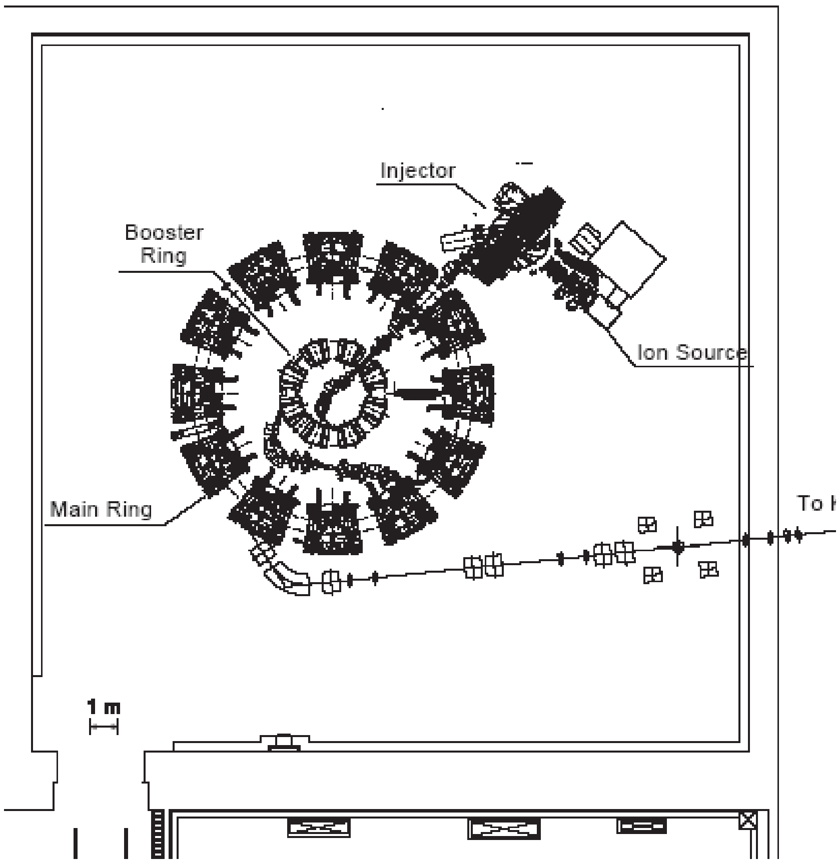


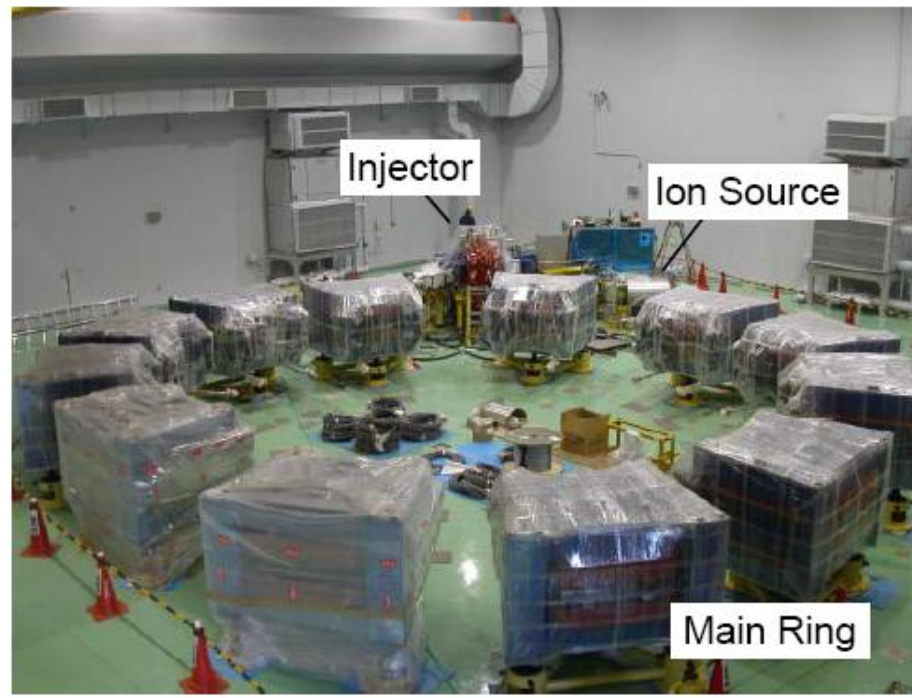
New generation of accelerators- FFAG

Table 1: Specification of the FFAG complex at KUR

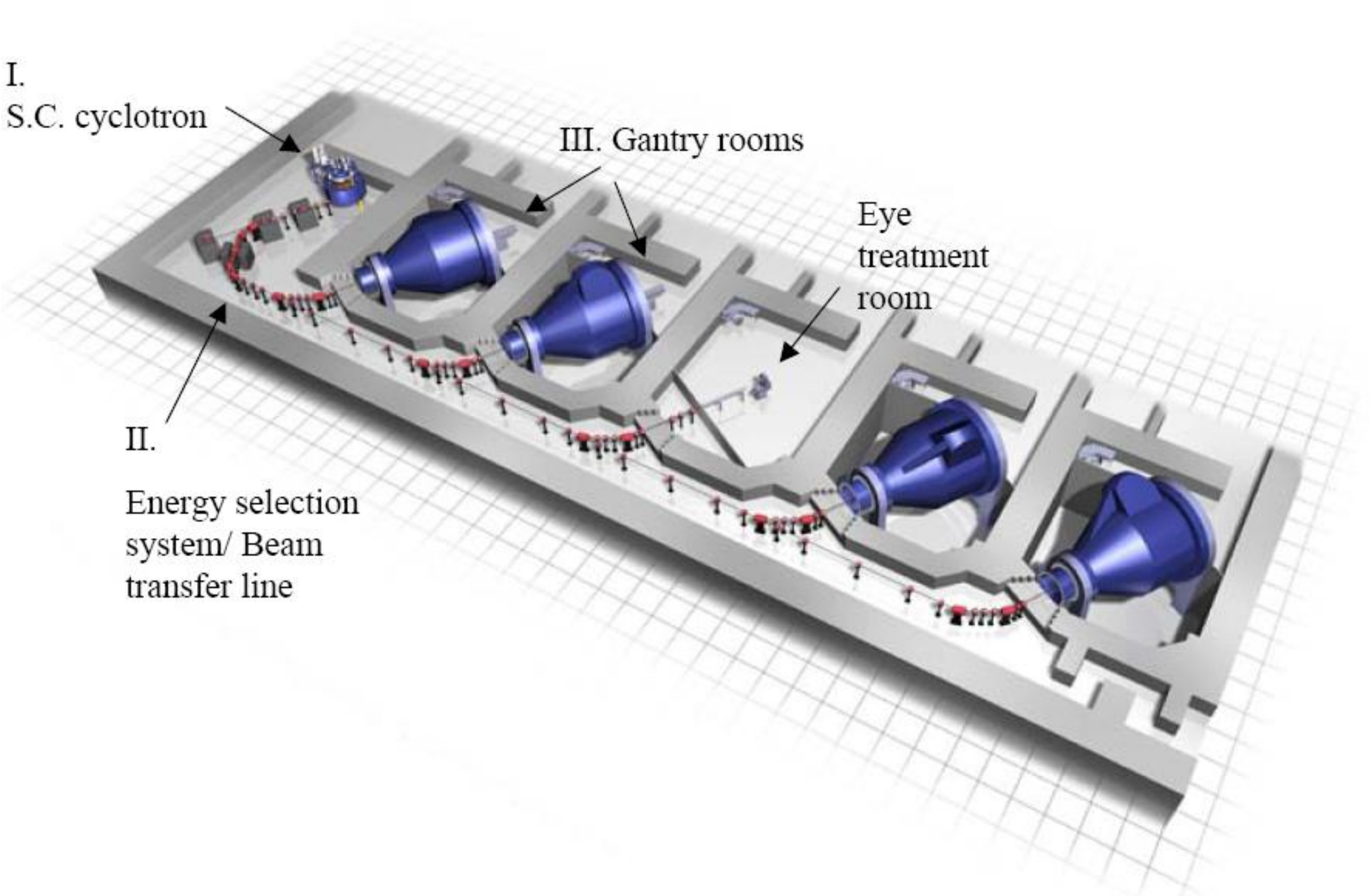
	Injector	**Booster**	**Main**
Focusing	Spiral	Radial	Radial
Acceleration	Induction	RF	RF
k	2	2.45	7.5
E_{inj}	100 keV	2.5 MeV	20 MeV
E_{ext}	2.5 MeV	20 MeV	150 MeV
p_{ext}/p_{inj}	5.00	2.84	2.83
r_{inj}	0.60 m	1.27 m	4.54 m
r_{ext}	0.99 m	1.86 m	5.12 m

Accelerators with fixed magnetic field and variable focusing FFAG (Japan, USA)



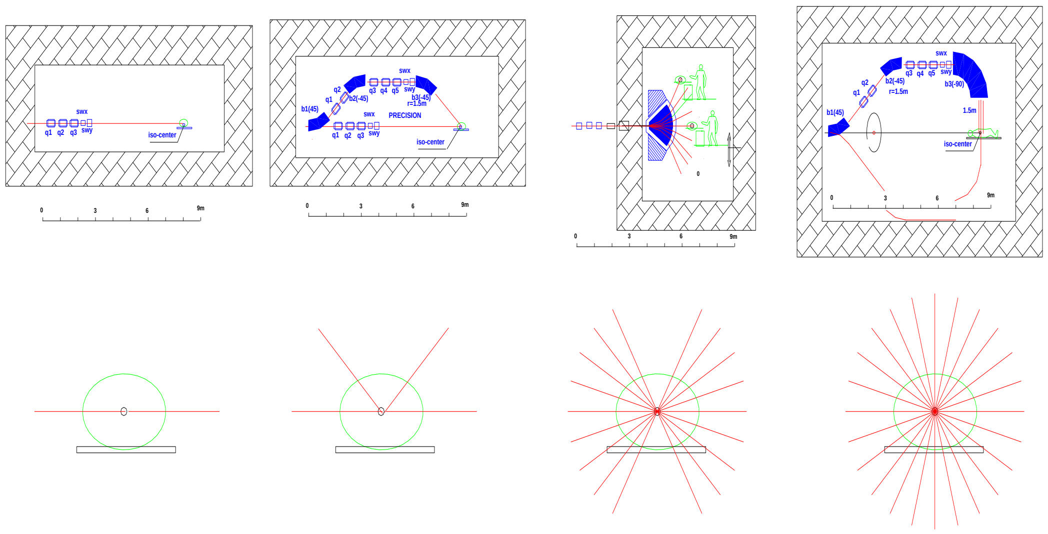


Radiological center in Munich

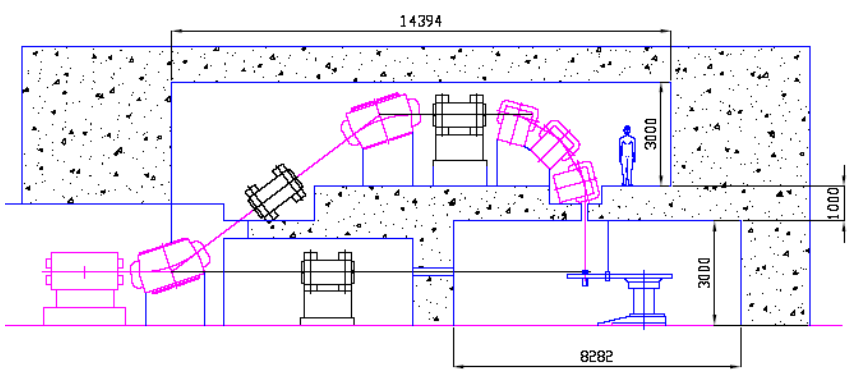


What is the most effective method of 3D dose formation?

- Possible dose formation systems (M.Kats, ITEP)



- INR proposal for second treatment room.



Thank you very much!