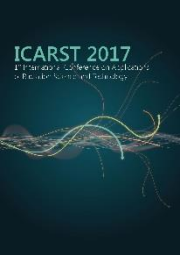
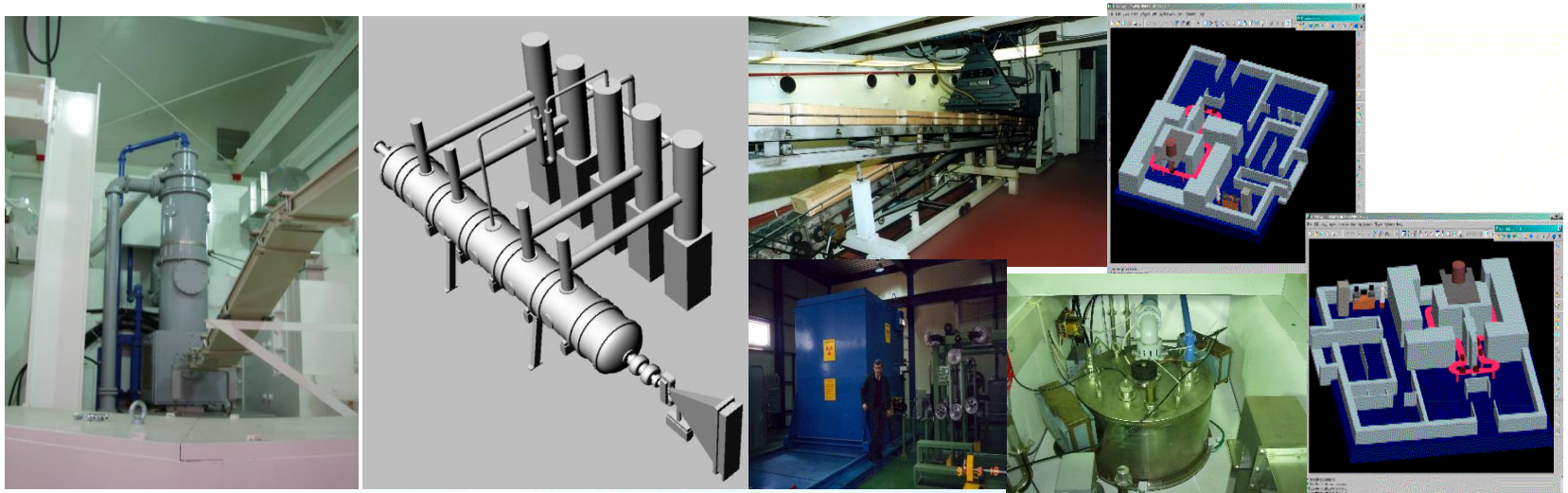


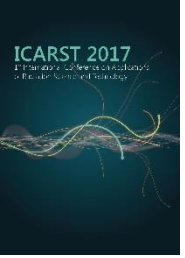
ILU industrial electron accelerators.

Aleksandr Bryazgin

Budker Institute of Nuclear Physics

Novosibirsk, Russia

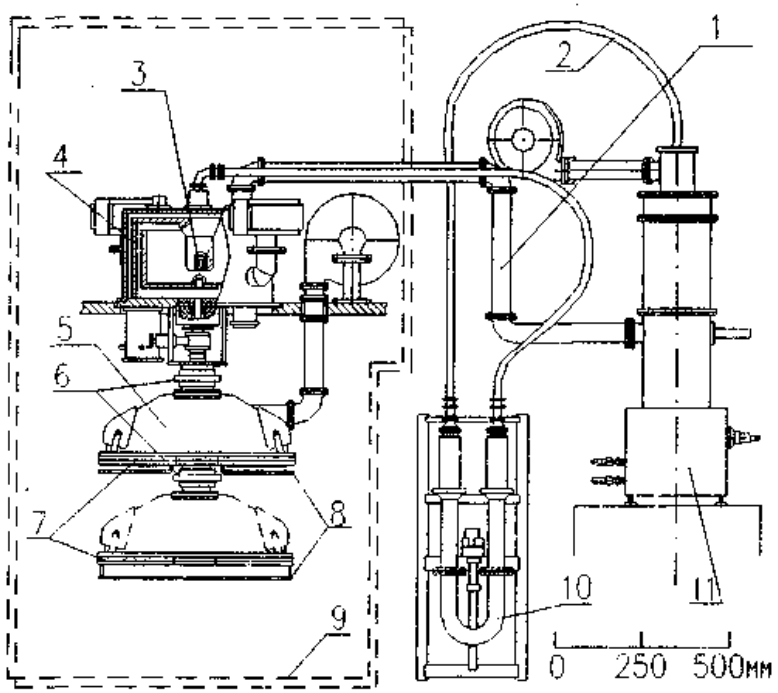


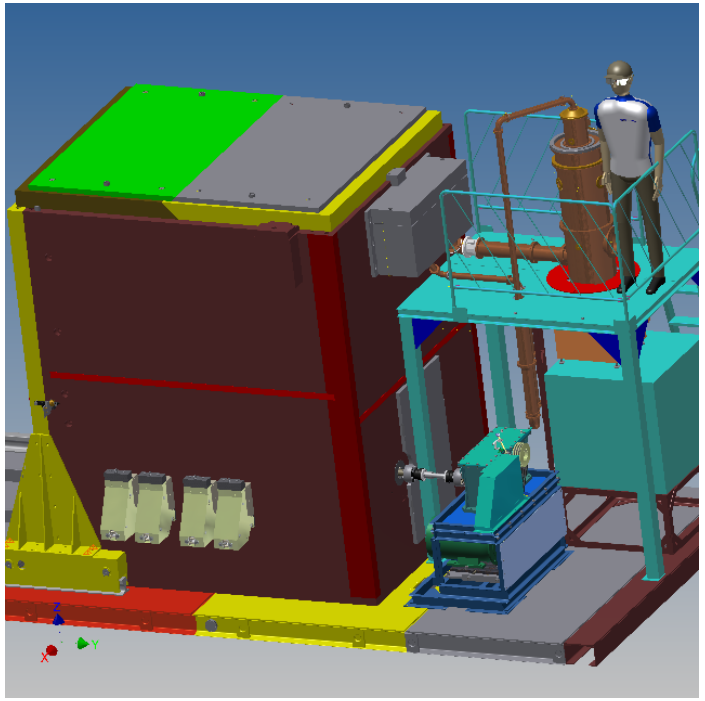


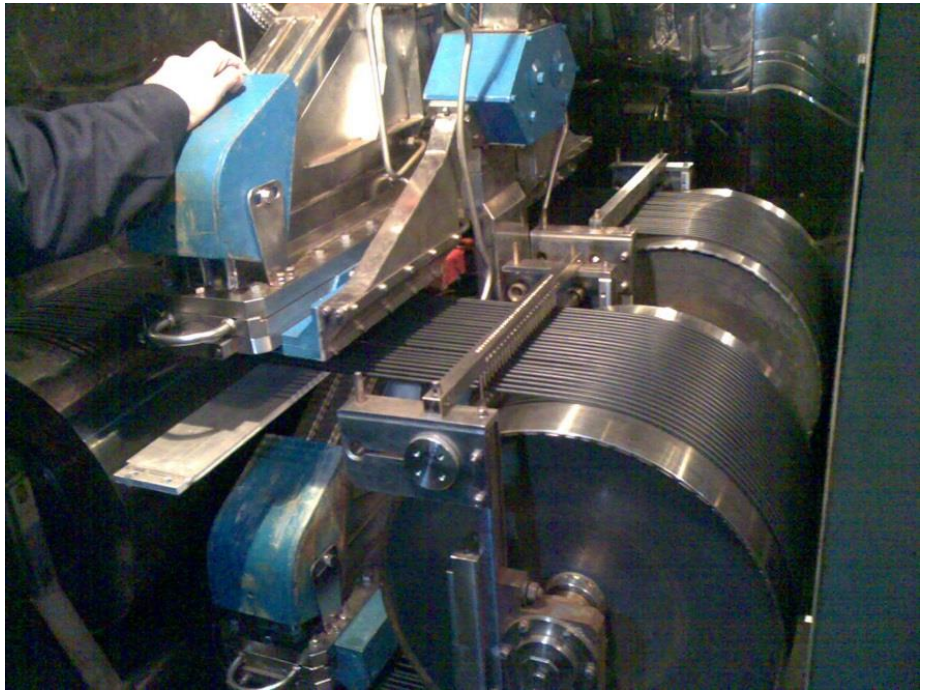
Content

- Ordinary ILU accelerators.
  - ILU-8 (1 MeV, 20 kW)
    - Design and Main features.
    - Examples in real industry
  - ILU-10 (5 MeV, 50 kW)
    - Design and main features.
    - Examples in real industry
- New multi-cavity ILU accelerators.
  - Reasons for developing
  - Design
  - ILU-14 (10 MeV, 100 kW)
  - ILU-12 (7.5 MeV, 40 kW)

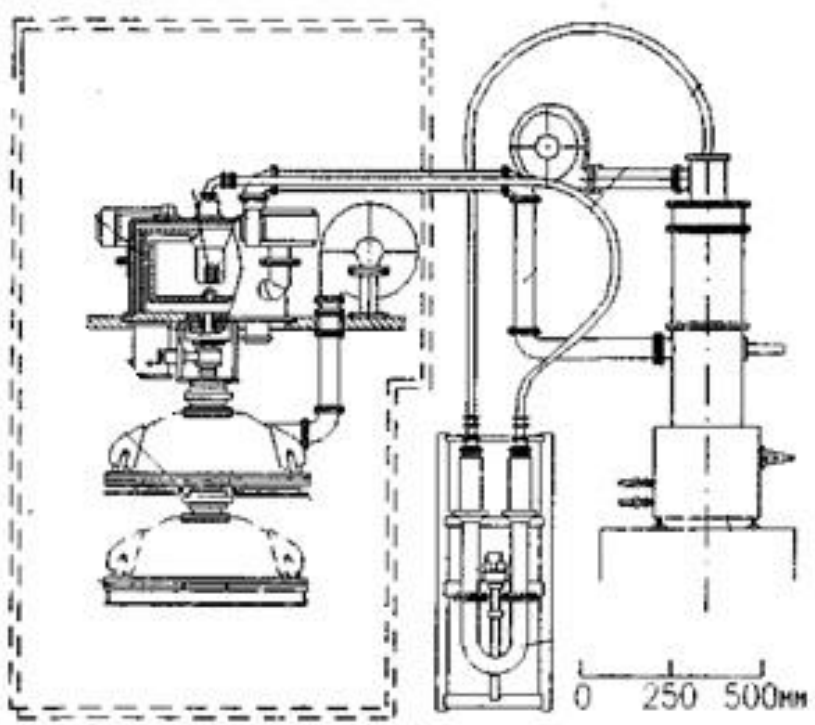
ILU-8 1 MeV 20 kW







ILU-8 1 MeV 20 kW



Compact – Local shielding,
RF-triode - cheaper operation,
Self-excitation of RF - wide temperature diapason,
Pulse – better efficiency

RF-triode GI-50A
With 2 MW RF power

Pulse duration 800 mks
Pulse repetition 1-50 Hz
RF frequency 175 MHz
Dim D800x800 mm

4-sided cable irradiation on ILU-8

- Beam extraction device for 4-sided irradiation

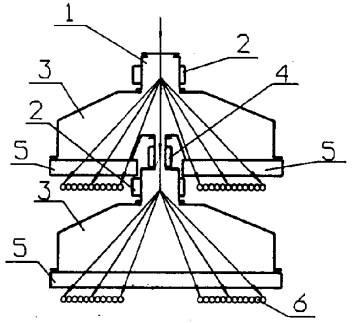
allows to increase

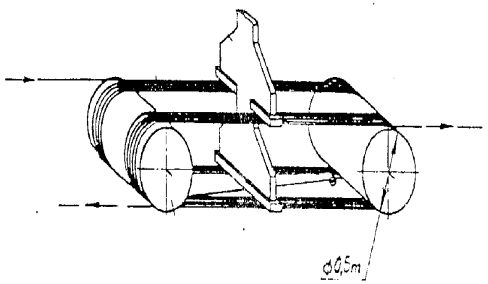
beam usage efficiency

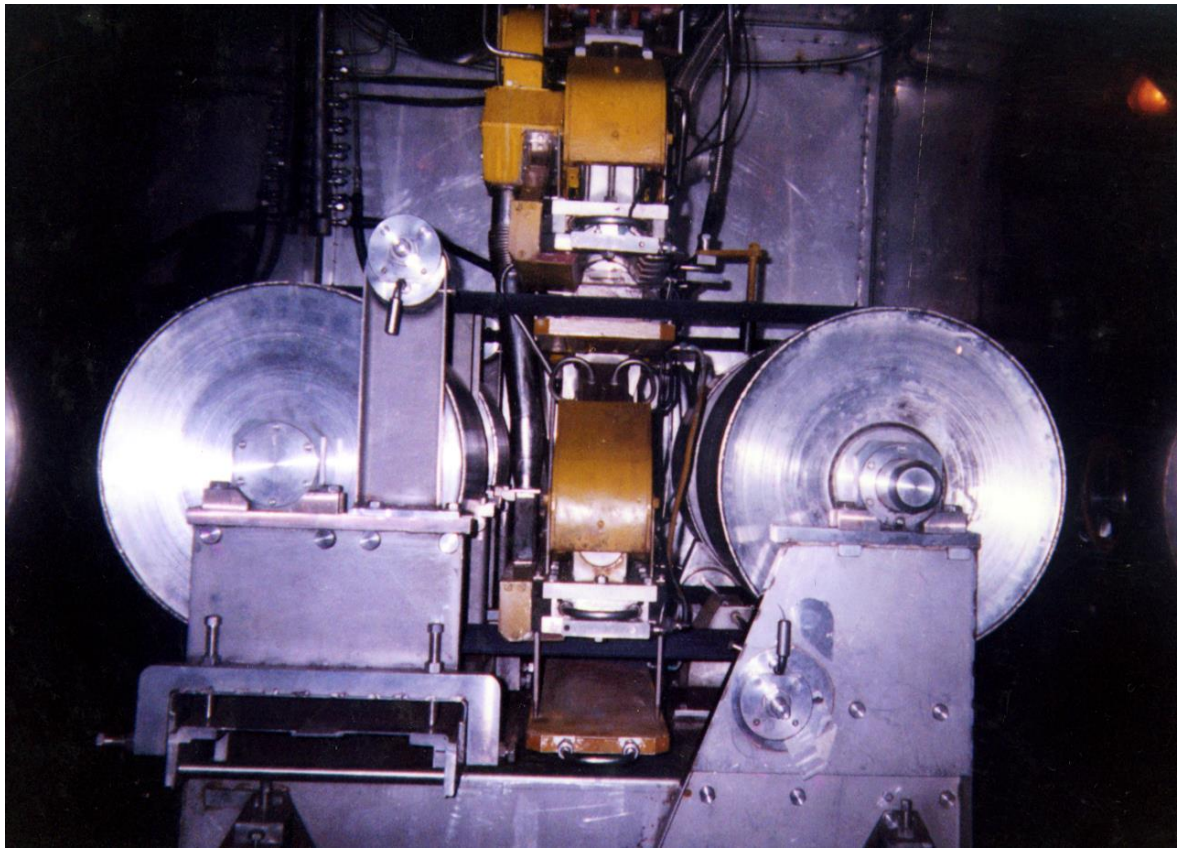
comparing with

2 sided irradiation

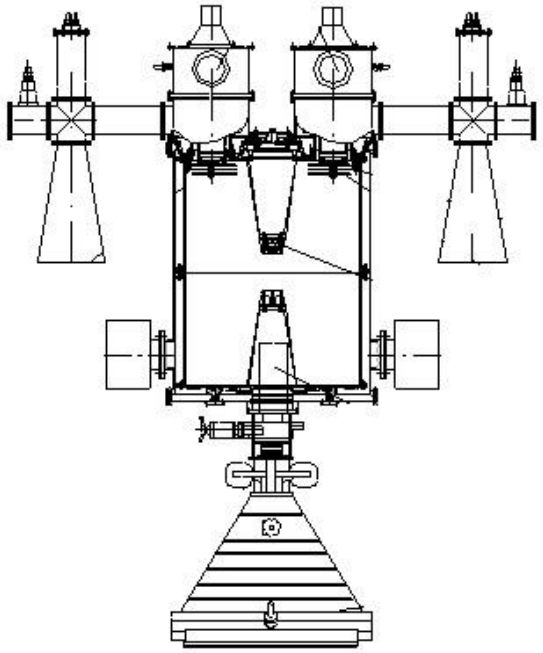
- No cable twist







ILU-10 5 MeV 50 kW



- Pulse duration 500 mks
- Pulse repetition 1-50 Hz
- RF frequency 115 MHz
- Dim. D1280x1480 mm

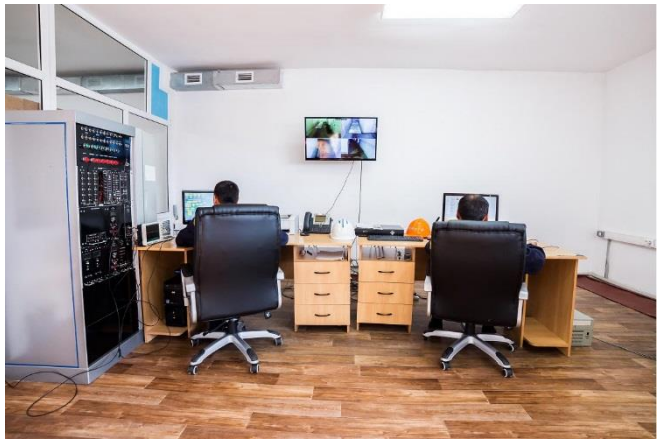
ILU-10 5 MeV 50 kW

Centre of radiation technologies.

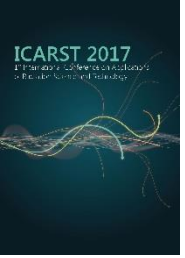
Conveyor load/unload zone.

Entrance to labyrinth.

Sterilization center based on ILU-10 in Semipalatinsk nuclear test site (STS) in Kazakhstan.



ЯДРОЛЫҚ ТЕХНОЛОГИЯЛАР ПАРКІ
PNT
PARK OF NUCLEAR TECHNOLOGIES
Парк Ядерных Технологий



Medical sterilization and food irradiation markets required more energy and power.

Food irradiation requirements

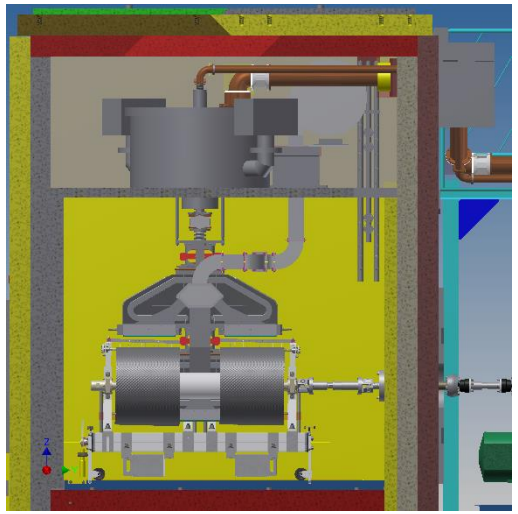
- 10 MeV E-beam → small power

- X-ray 5 MeV → huge power (conversion rate ~8%)

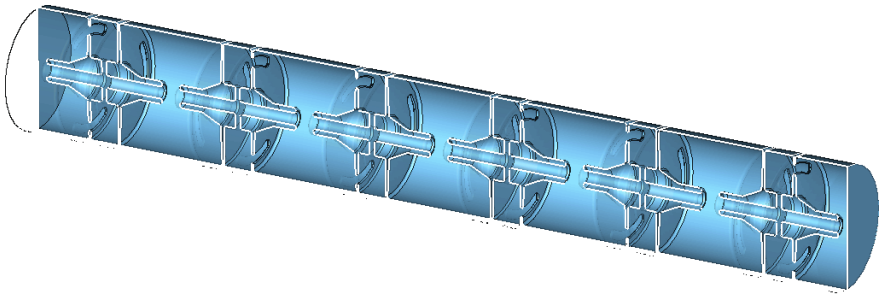
- X-ray (USA) 7.5 MeV → high power (conversion rate~13%)

New multi-cavity ILU accelerator

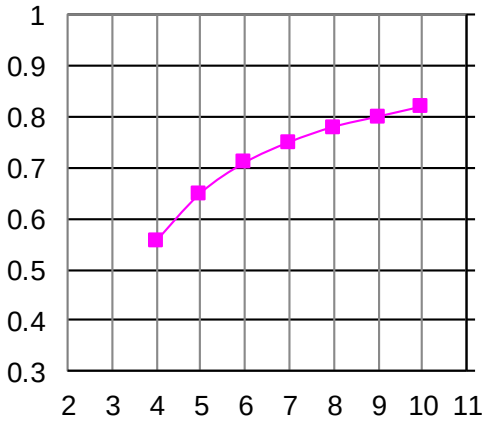
One cavity

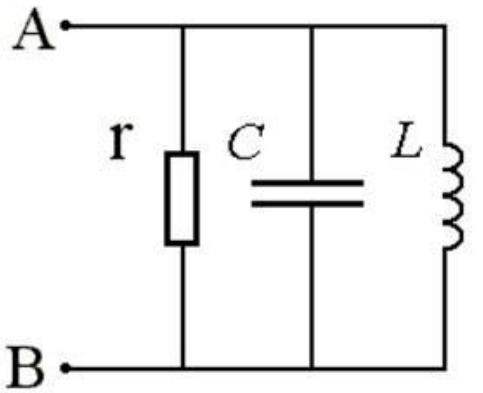


Multi-cavity



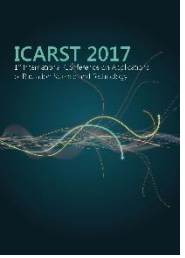
Efficiency on Number of cells





$$P_{loss} = U^2/2R_{shunt}$$

$$P_{loss} = \sum_{n} U^2/2R_{shunt}$$



New multi-cavity ILU accelerator.

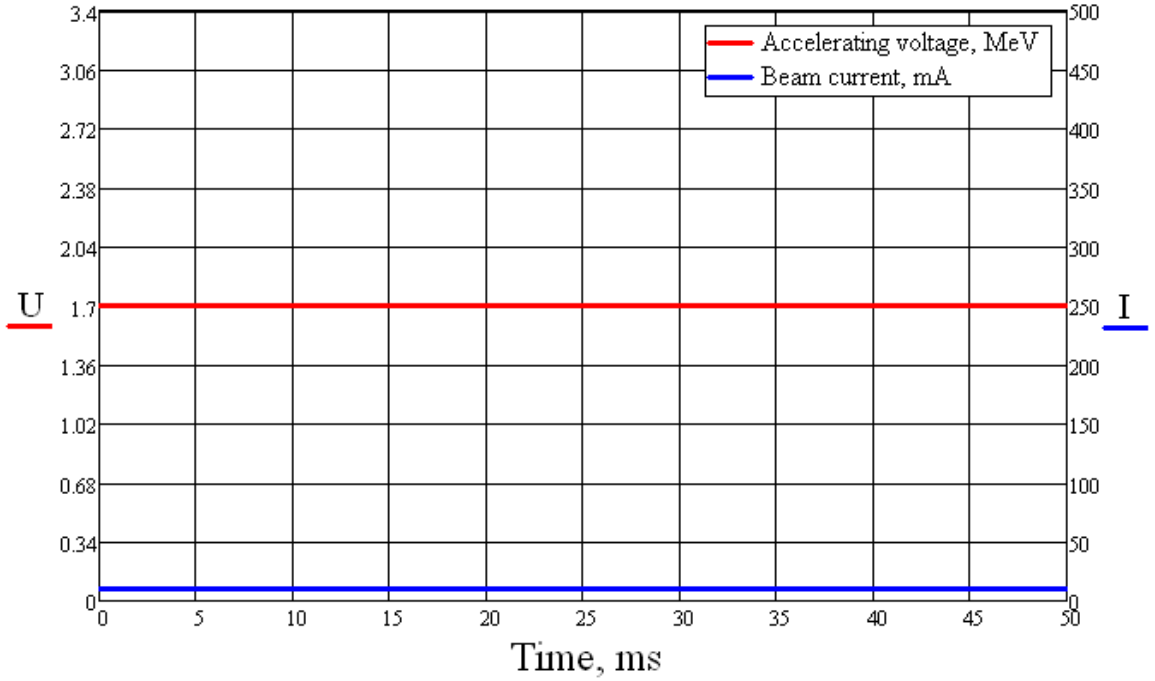
Pulse mode vs CW (Constant wave)

- P_{losses} does not depend on beam current and depend on U.
- We may achieve required average power and energy by:
  - Short pulse and big pulse current
  - Long pulse and small pulse current or even CW
- Then shorter t_{pulse} and more $P_{pulse}=U_{beam}*I_{beam}$ then less P_{losses}
- => efficiency of cavity - $\acute{\eta}_{pulse} > \acute{\eta}_{CW}$

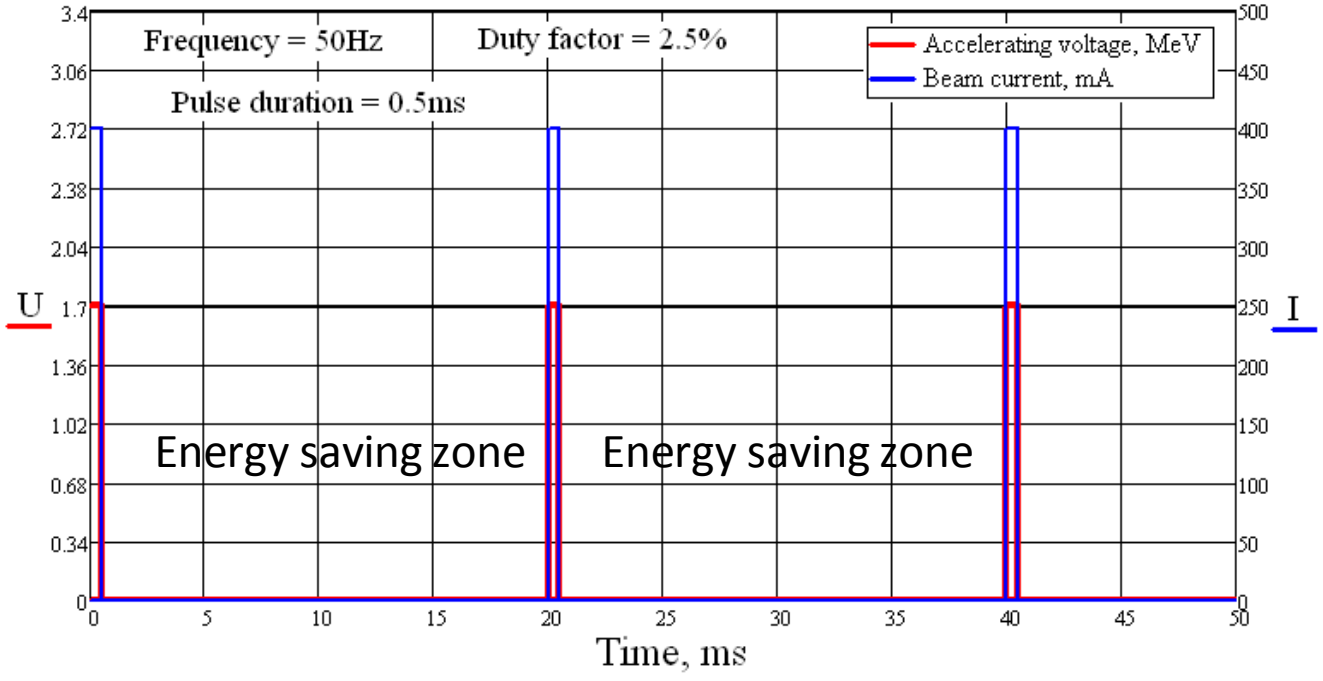
- **Pulse Linear Accelerator PLA=*ИЛУ* (ILU) in Russian**

Cavity voltage and beam current for one cavity.

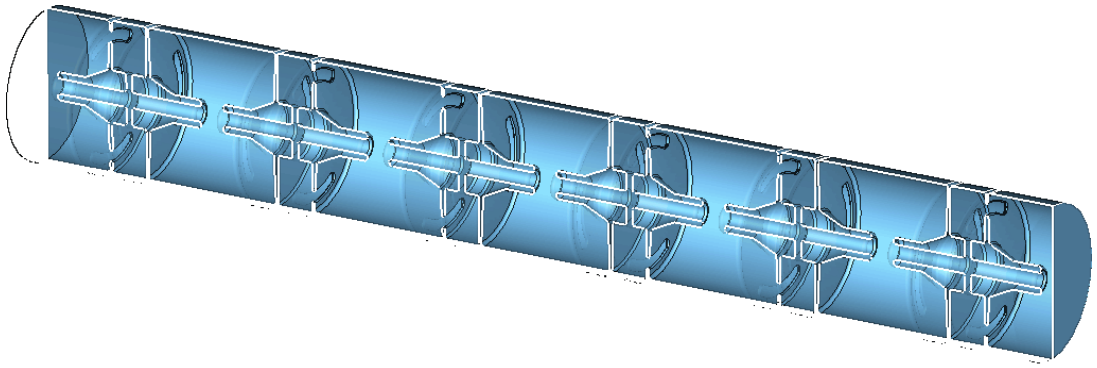
CW



Pulse



New multi-cavity ILU accelerator.



RF frequency 175 MHz

Accelerating structure with 6 cavities

4 RF-triodes – Σ8 MW of RF power

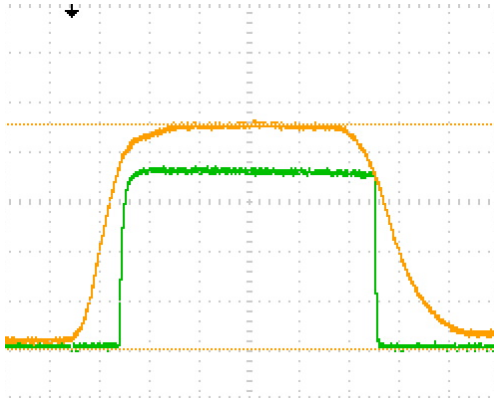
Duty cycle 2.5%

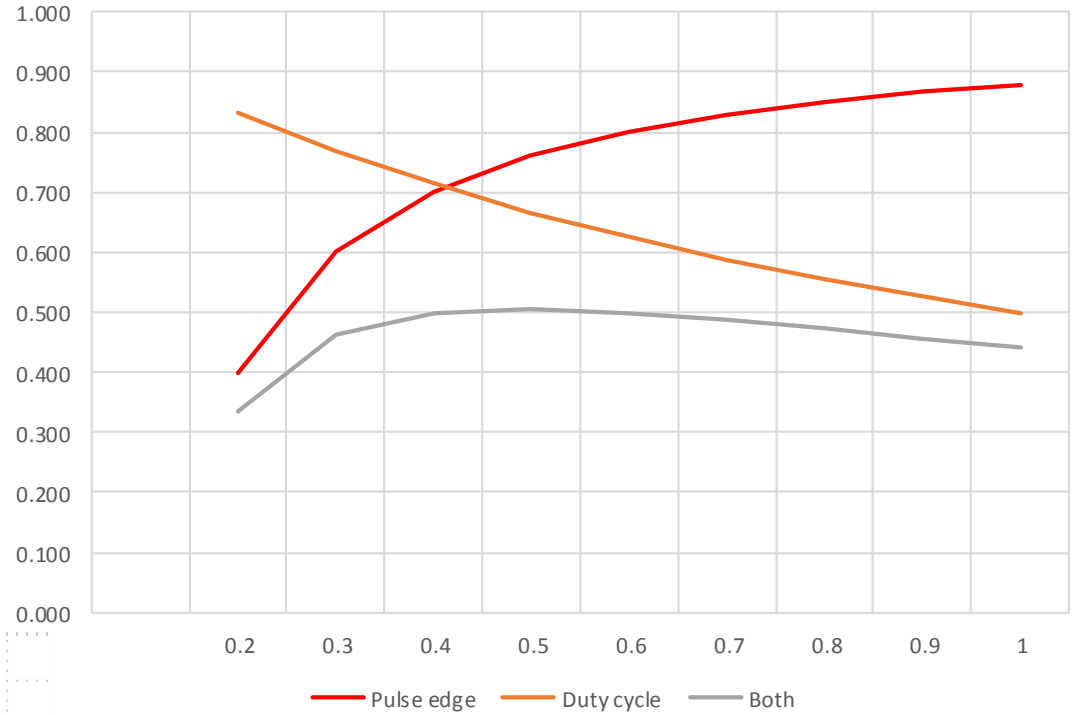
Pulse repetition rate 50 Hz

Pulse duration 500 mks

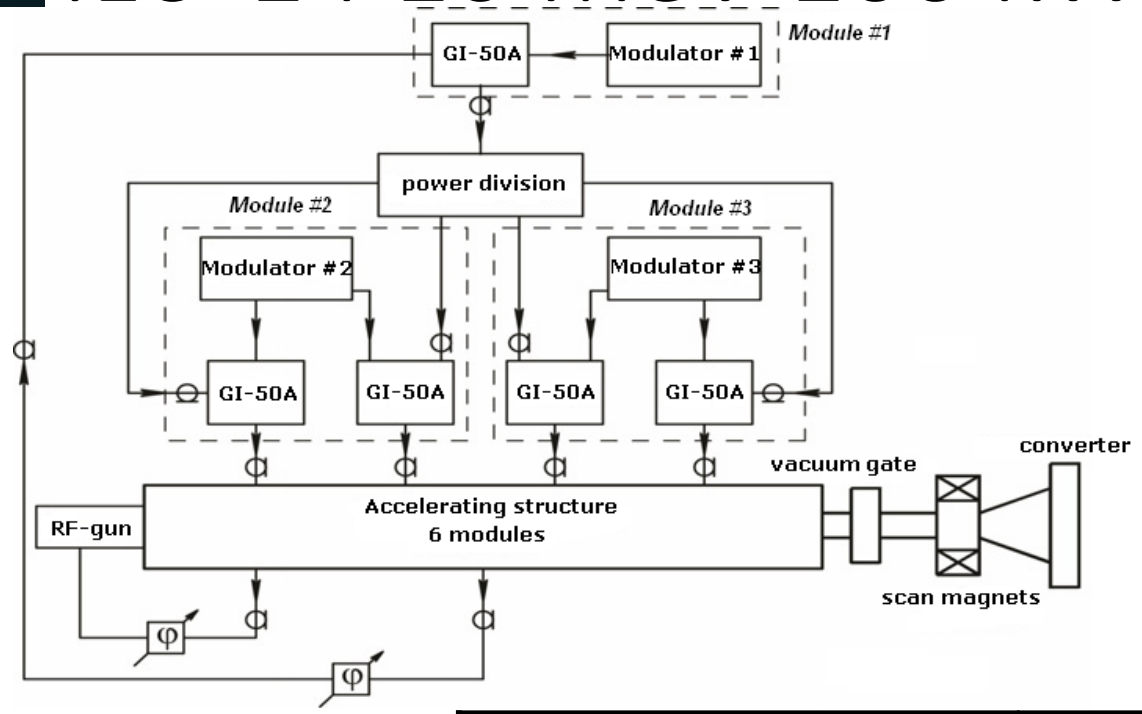
Pulse edge 50 mks

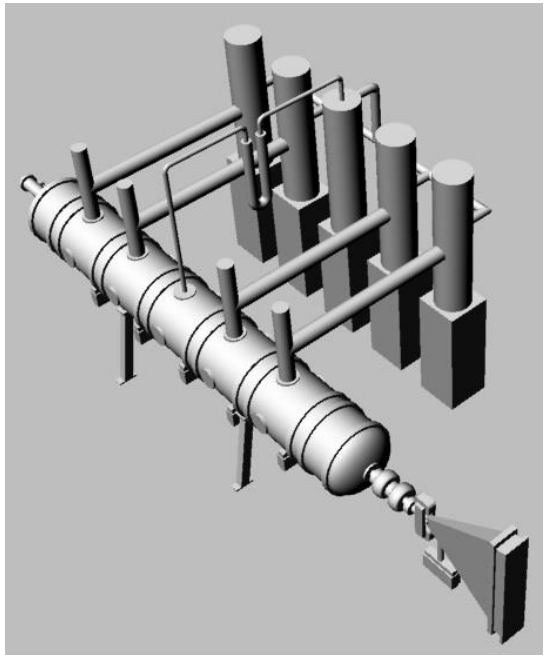
No need stainless vacuum tank.





ILU-14 10 MeV 100 kW

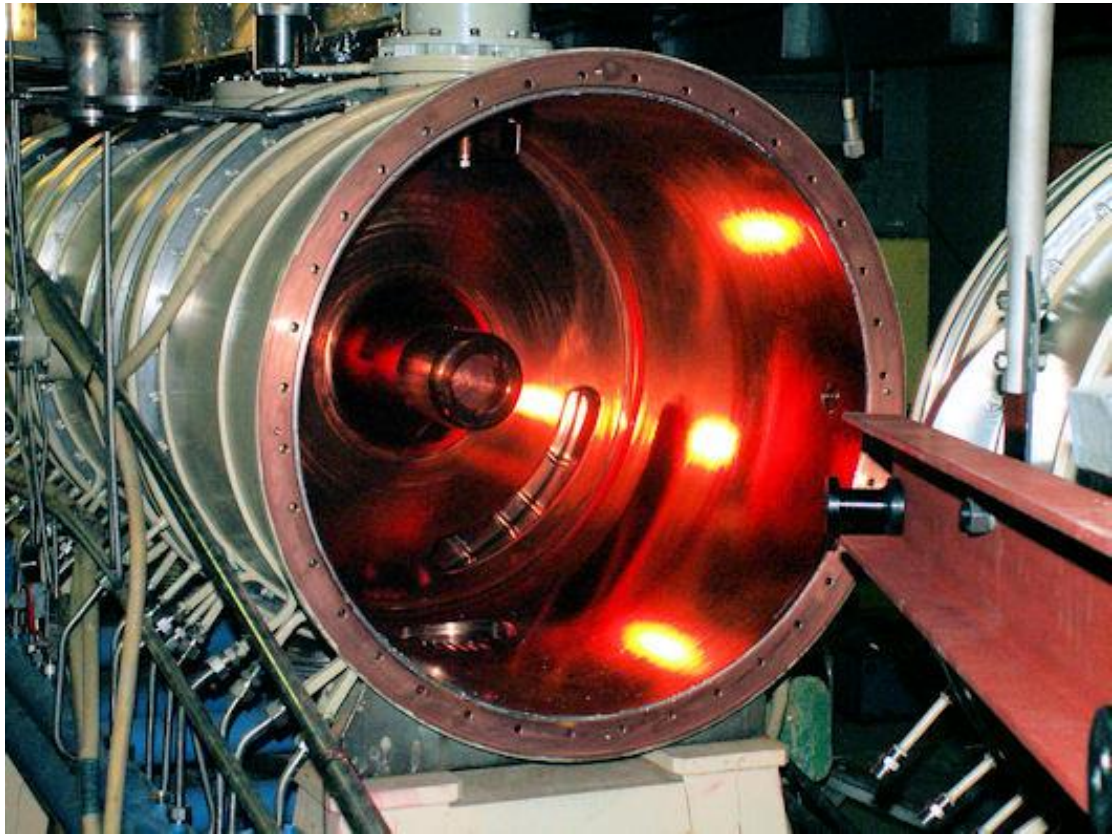




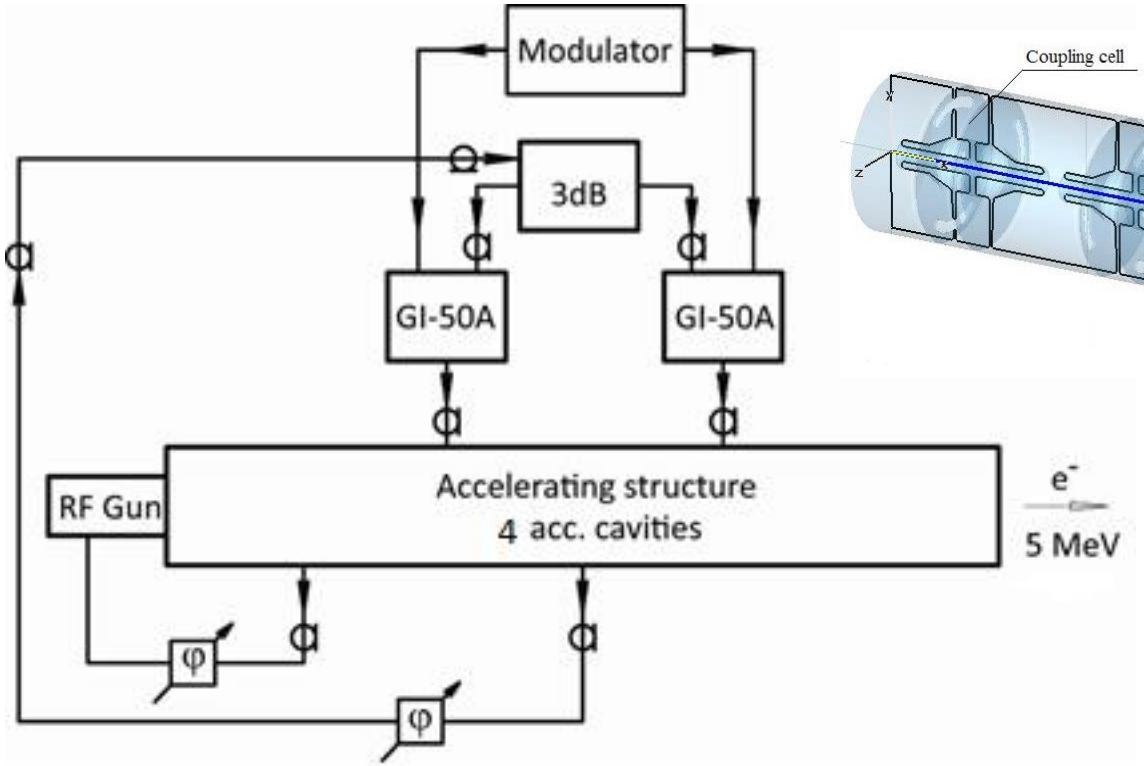
Operating frequency, MHz	*176*	*Full efficiency, %*	*26*
Electron energy, MeV	*7,5-10*	*Modulator pulse duration, μs*	*500*
Average beam power, kW	*100*	*Repetition rate, Hz*	*Up to 50*

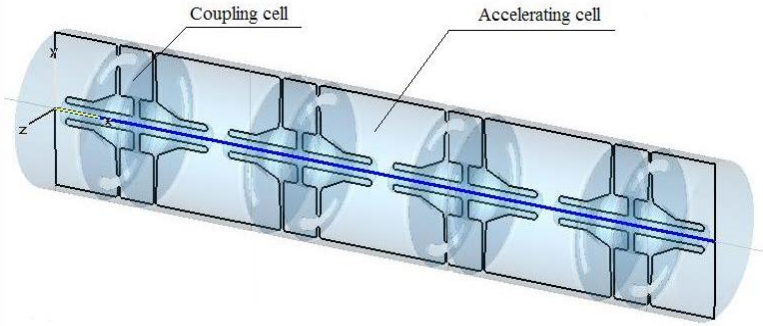
New multi-cavity ILU accelerator.

In operation from 2014 in Moscow



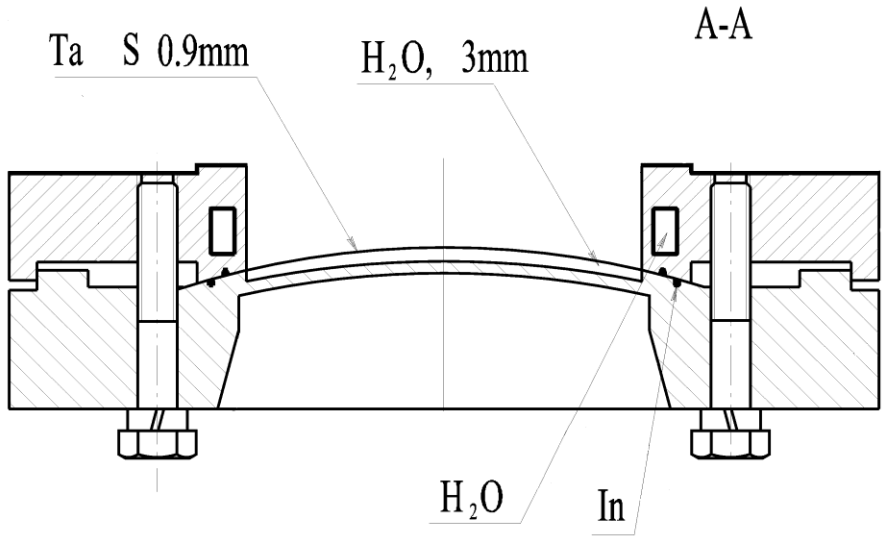
Shorter version – ILU-12

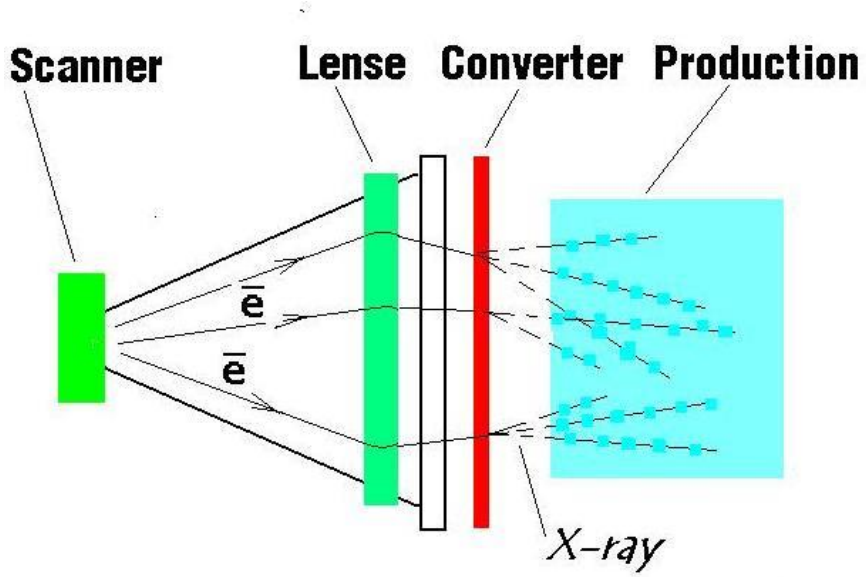




- 5 MeV 60 kW
- 7.5 MeV 40 kW
- 4 cavities
- Possible upgrade to ILU-14

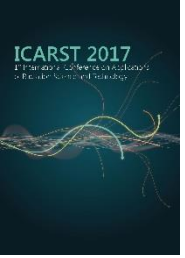
X-ray converter





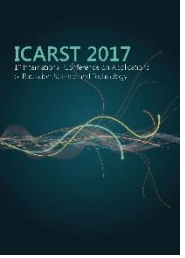
Conversion rate X/ray/Ebeam power

E(MeV)	Ta thickness	60 deg	360 deg
7.5	0.9	13,2%	16,9 %
5	0,7	8,3%	12%



Delivered ILU accelerators 2007-2017 (13 Pcs)

Accelerator	Production	City, Country	Year of start
ILU-6	Sterilization raw material (medecinal herbs)	Bisk, Russia	2007
ILU-8 2 Pcs	Wires crosslinking	Cheboksary, Russia	2008, 2017
ILU-10	Plastic tubes crosslinking	Czluchow, Poland	2008
ILU-6 (Deep modernization)	Thermo-shrinkable tubes	Czluchow, Poland	2010
ILU-10, 2 Pcs	Sterilization	Novosibirsk, Russia	2012, 2013
ILU-10	Sterilization	Kurchatov, Kazakhstan	2013
ILU-10M	R&D, food irradiation	BARC, Mumbai, India	2014
ILU-14	Sterilization	Moscow, Russia	2014
ILU-10	R&D, Sterilization	BINP, Novosibirsk, Russia	2014
ILU-8	Wires crosslinking	Mytichi, Russia	2016
ILU-10	Sterilization	Almaty, Kazakhstan	2017(under construction)
ILU-10	Sterilization	S.Korea	2017(under construction)



Thank you for your attention