Design of the ultrashort electron bunch complex at Budker Institute of Nuclear Physics (Novosibirsk)

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Outline

- Introduction
- Main elements of the complex
- Possible use: plasma wakefield acceleration
- Mm wavelength structure excitation
- Focusing system for mm wavelength structures: estimations and simulations
- Conclusion

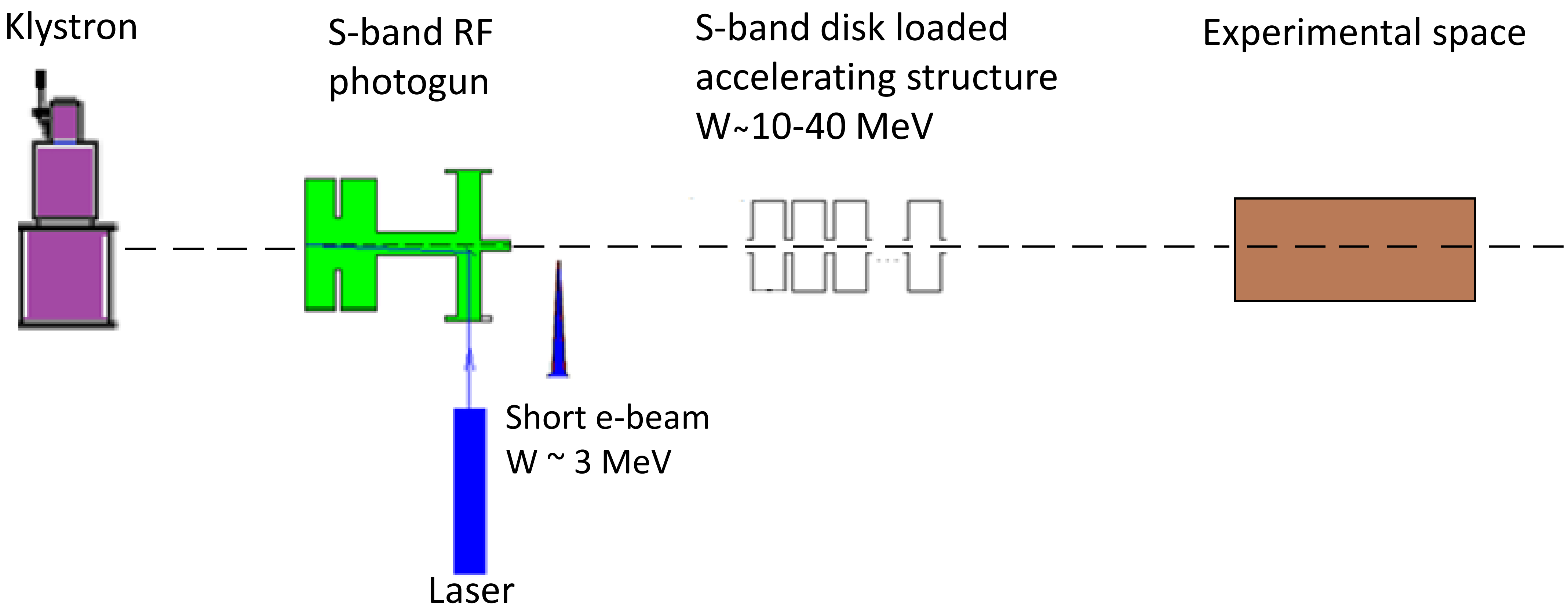
Introduction

- Mm wavelength structures allow obtaining higher acceleration gradient (cavities and dielectric structures)
- Perspectives for use: excitation of mm wavelength structures, plasma wakefield acceleration, fast electron diffraction
- There is need in focusing system for small apertures: is it possible to create such a system? What should it be?

Goal: taking into account structure sizes and beam parameters, study transverse dynamics and possibility of focusing

Main elements of the complex

All the elements are being produced at BINP

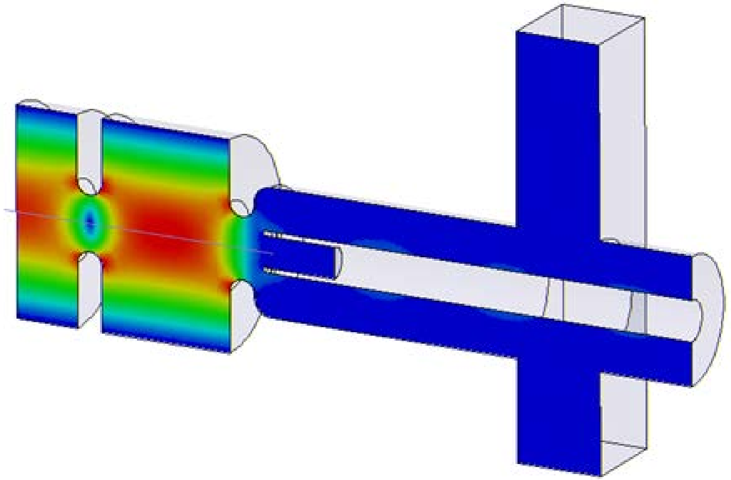


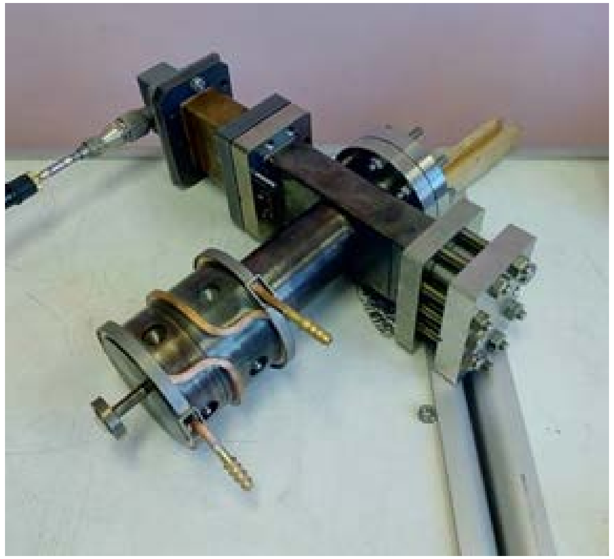
Klystron

Parameter	Value
Frequency	2856 MHz
Peak power	50 MW
Average power	10 kW

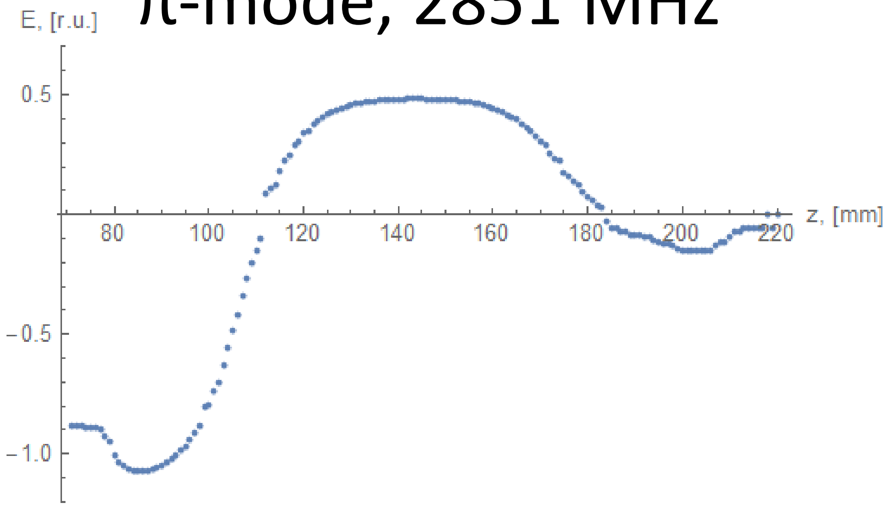
RF photogun

Accelerating structure





π-mode, 2851 MHz



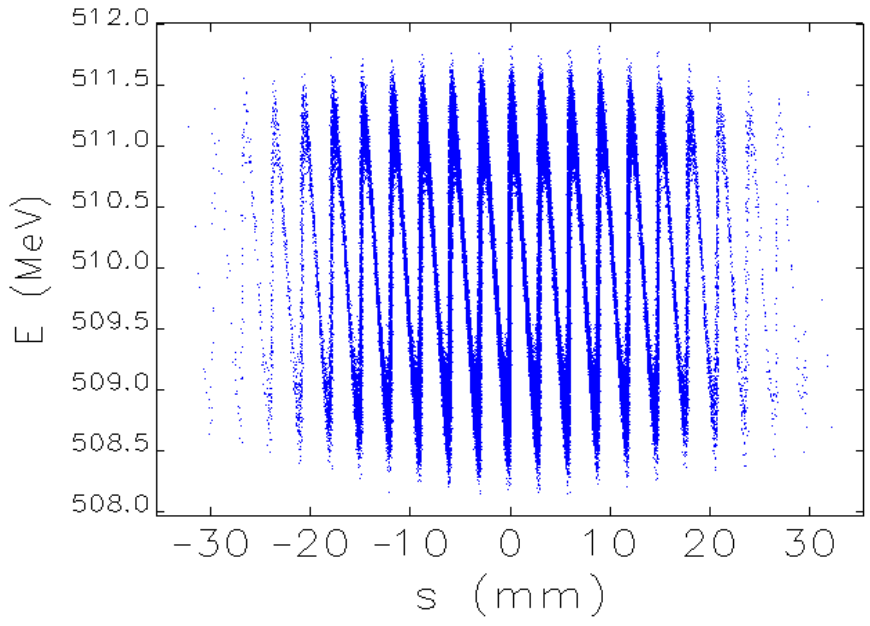
S-band disk loaded accelerating structure

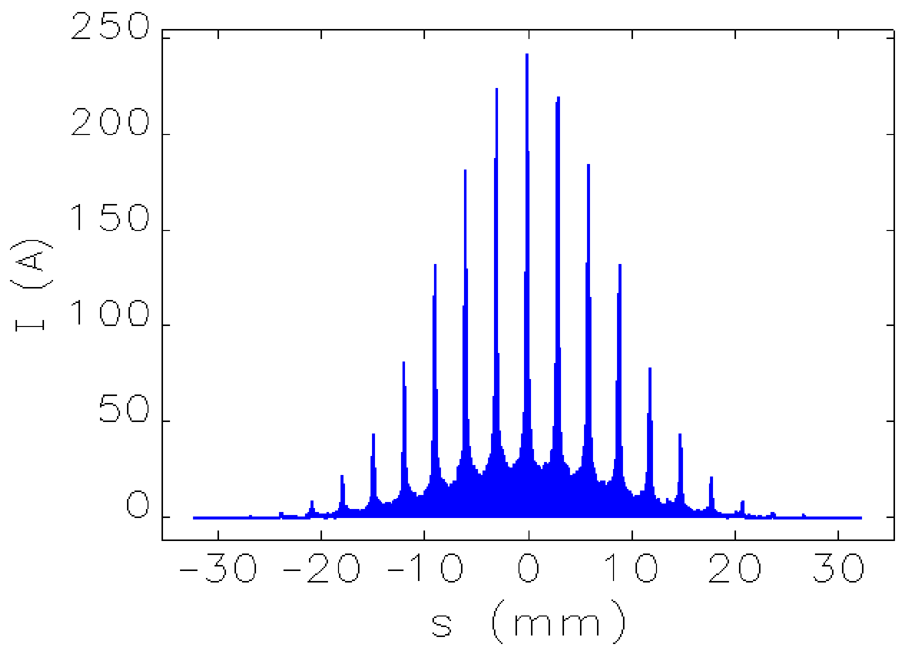
Possible use: plasma wakefield acceleration

Advantages of the method (in comparison with self-modulation of the long beam in plasma, private discussion with A. Petrenko):

- Higher accelerating gradient
- More beam stability
- Perspectives for proton beams (it is difficult to obtain short proton beam)

It's enough ±1.2 MeV energy spread for 500 MeV beam to bunch it after dispersion magnet system



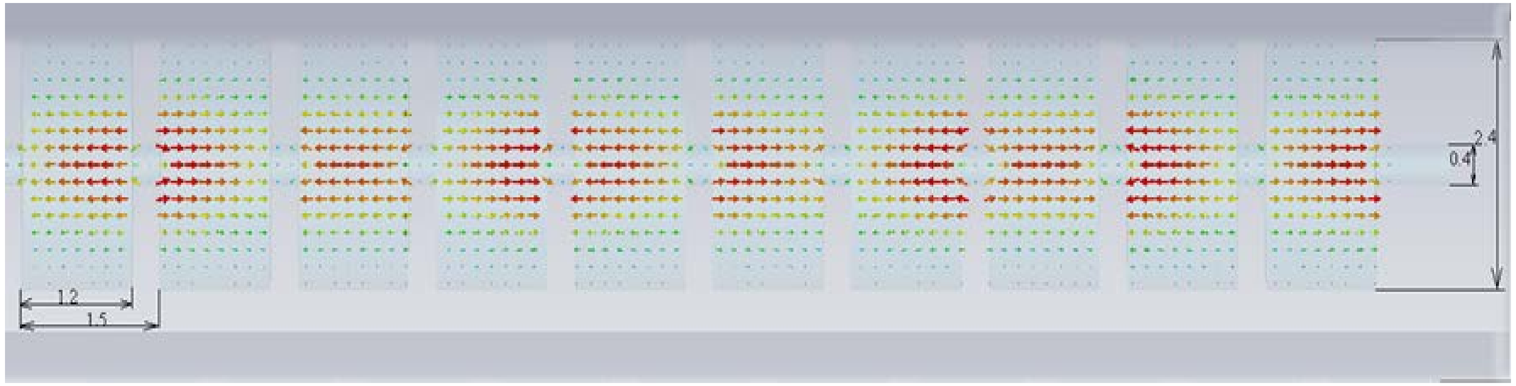


Mm WL structure excitation

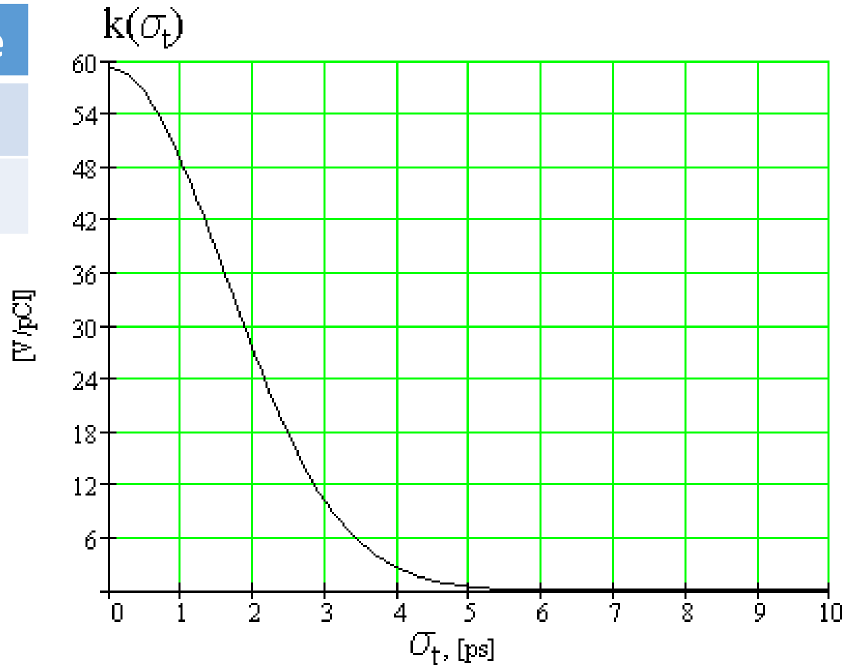
For PWFA: energy spread ΔE=±1.2 MeV

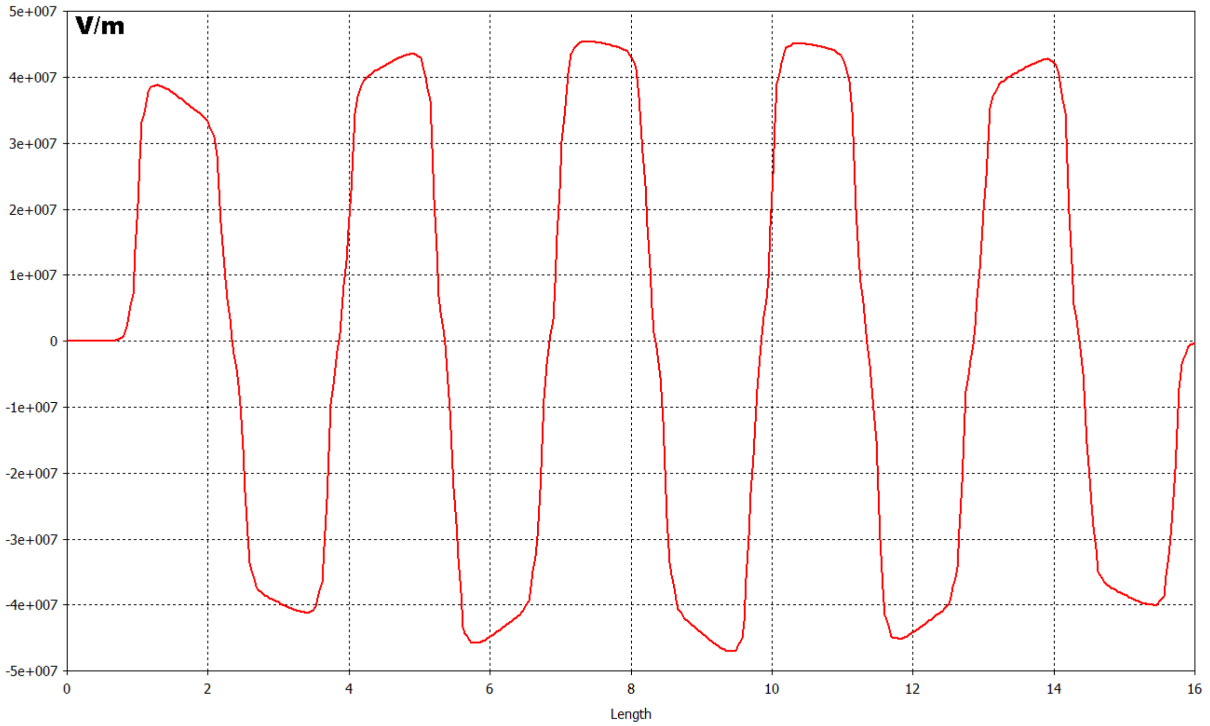
$$V_b = 2k \cdot q$$

$$k(\sigma_t) = \frac{L}{2\varepsilon_0 \pi R^2 J_1(\nu_{01})} \exp\left(-\frac{\omega_0^2 \sigma_t^2}{2}\right)$$



Parameter	Value
Charge, nC	2
Duration, ps	2

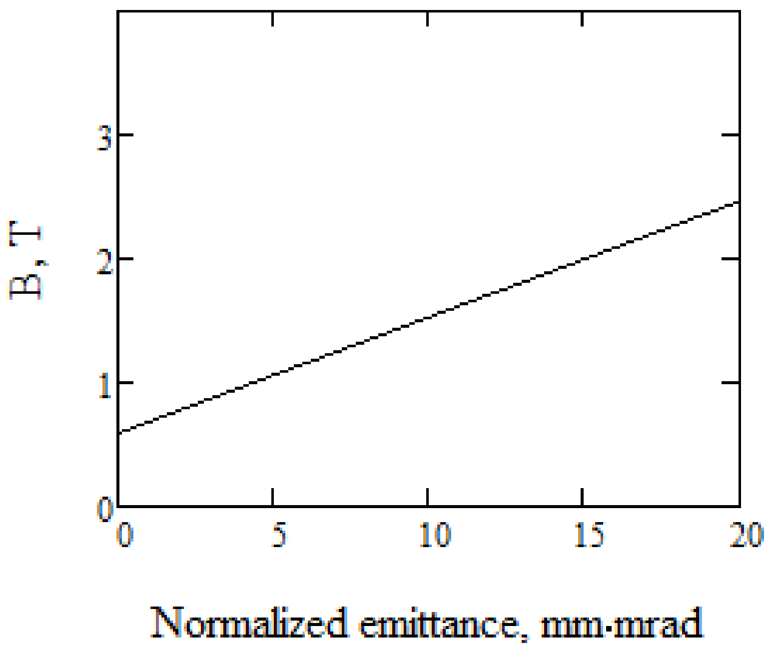


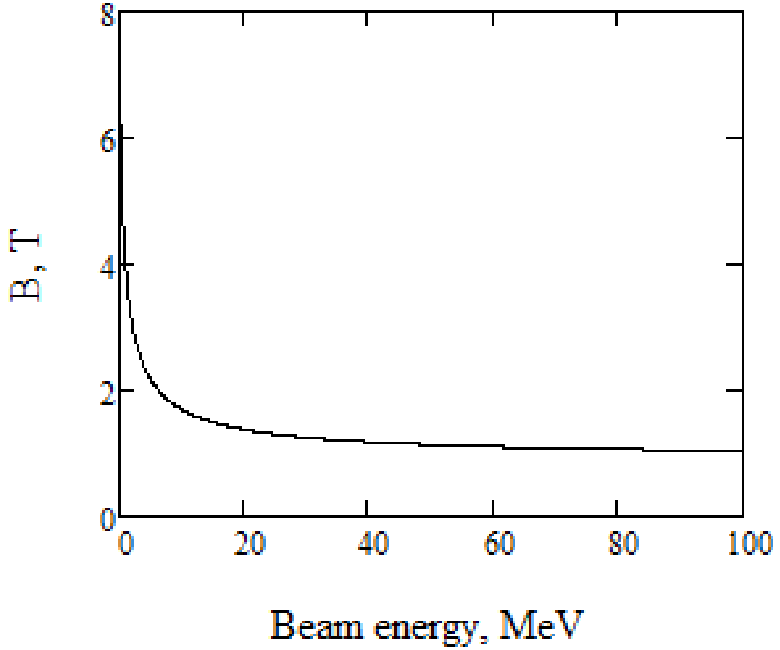


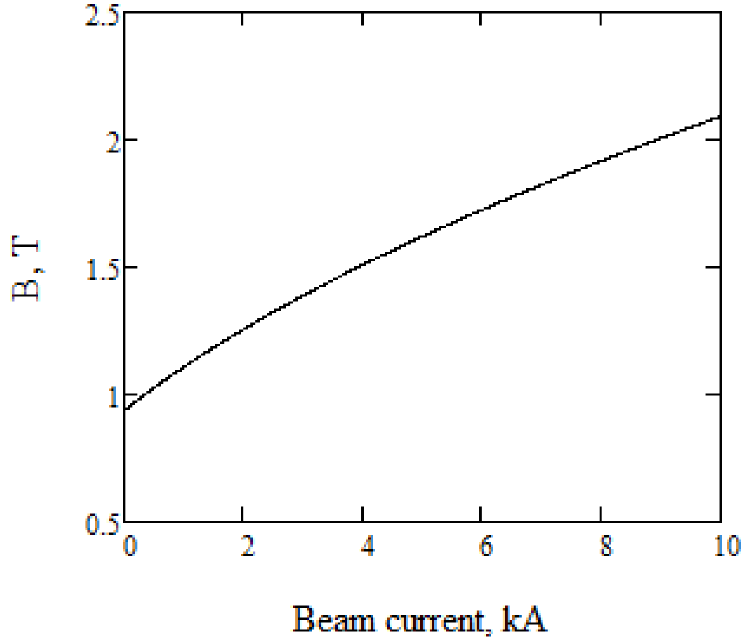
With this beam
ΔE=±1.2 MeV
is provided with
20 cavities

Focusing system: preliminary estimations

For the radius r~0.2 mm:







Beam parameter	Value
Energy, MeV	20
Charge, nC	2
Duration, ps	2
Normalized emittance, π mm·mrad	10

B ~ 2 T

$$F \sim \frac{K}{r}$$

$$k_0 = \frac{eB}{2\beta\gamma m_0 c}$$

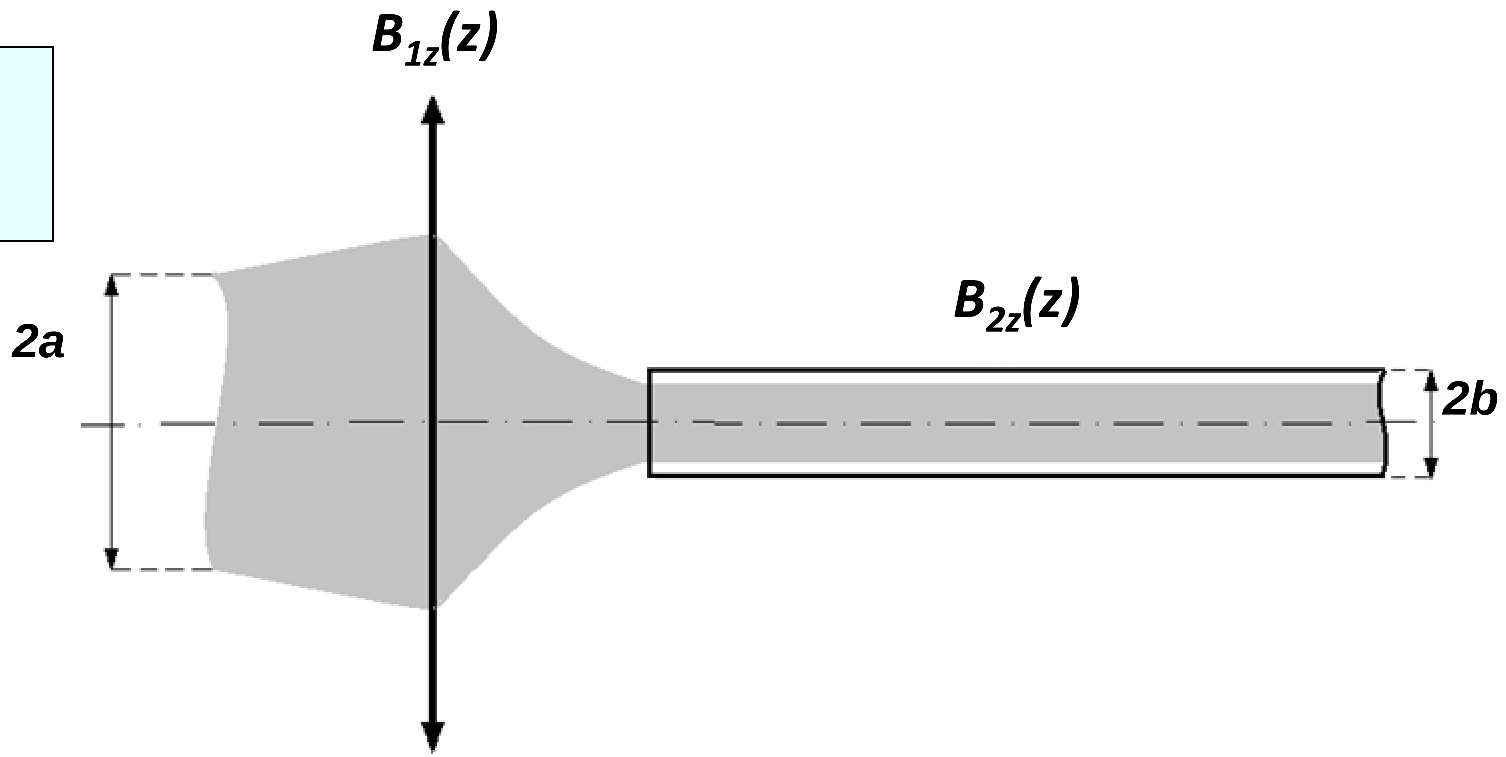
$$r^2 \sim \frac{K + \sqrt{K^2 + 4k_0^2\varepsilon^2}}{k_0^2}$$

$$K = \frac{eI}{4\pi\varepsilon_0 m_0 c^3 \beta^3 \gamma^3}$$

Focusing system

Problem: need in the special focusing to transport the beam through the channel with small (~0.2 mm) aperture

Beam parameter	Value
Energy, MeV	10-40
Charge, nC	2
Duration, ps	2
Normalized emittance, π mm·mrad	5-10
Initial radius *a*, mm	5
Final radius *b*, mm	0.2

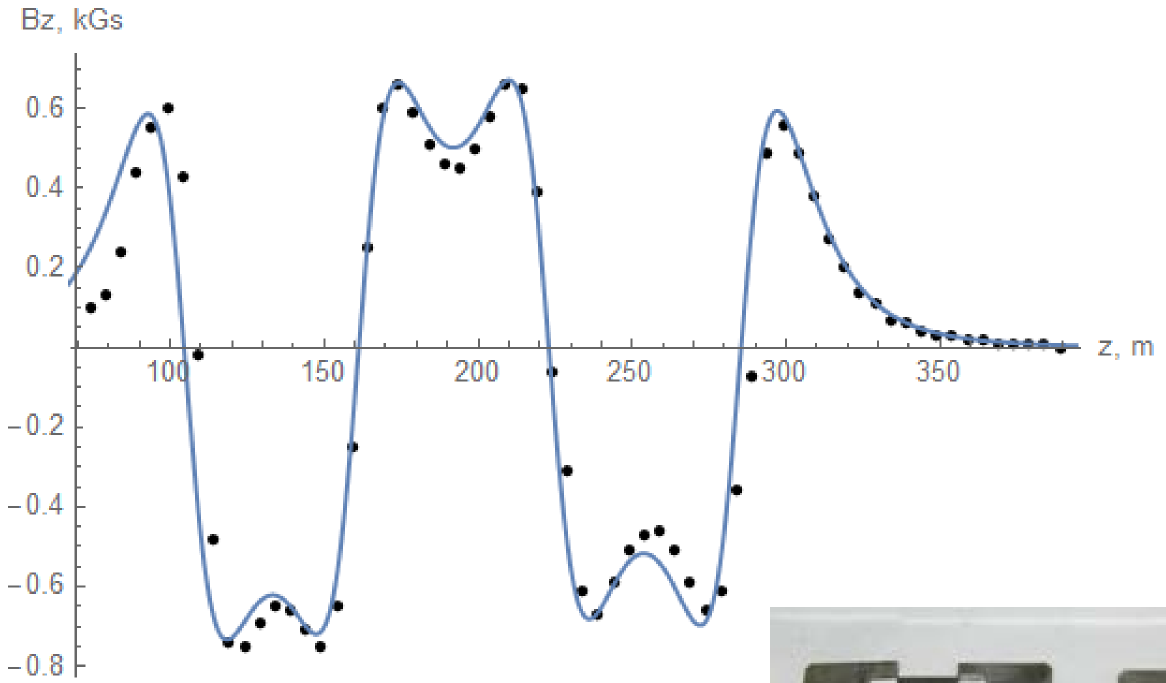


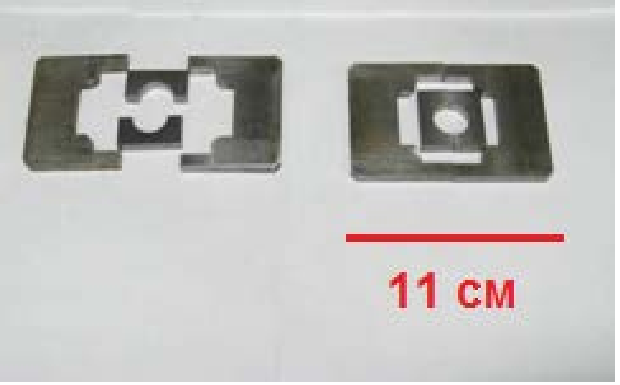
What system to choose: solenoid with 2 T is too complex device

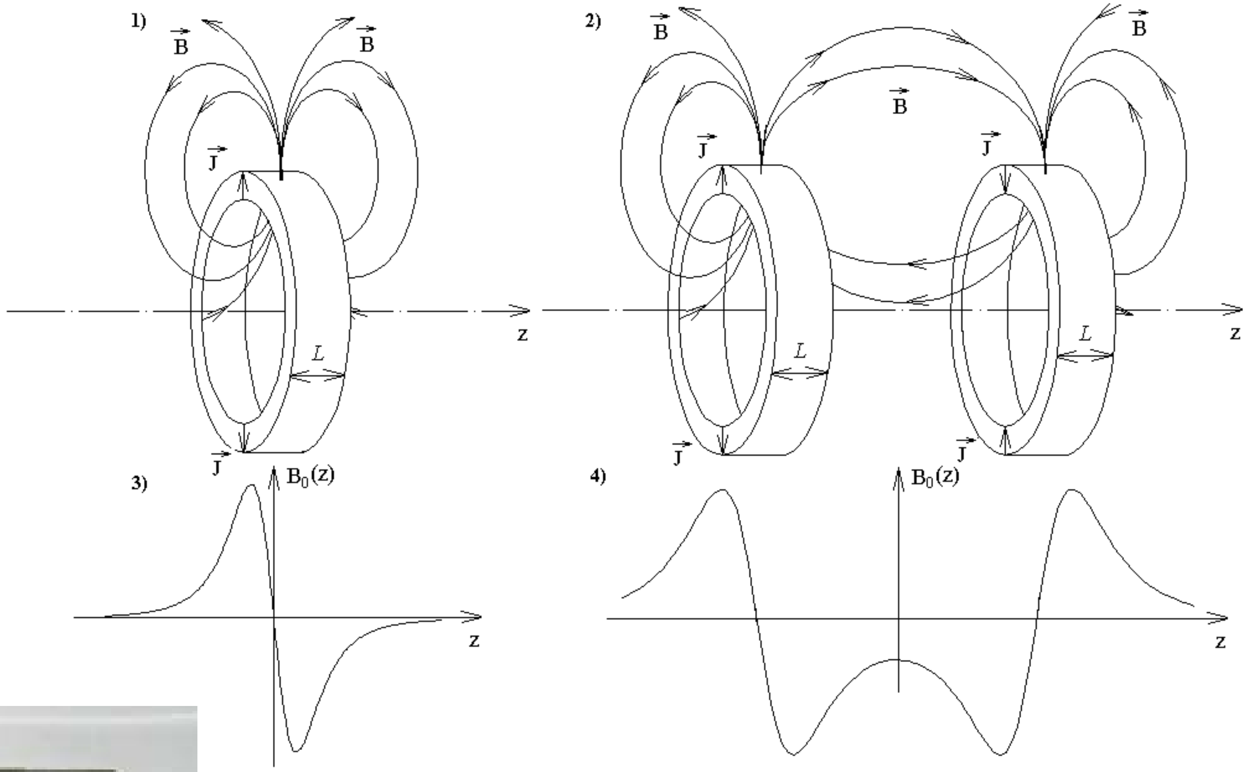
To what distance it is possible to transport the beam trough the small aperture?

Focusing system

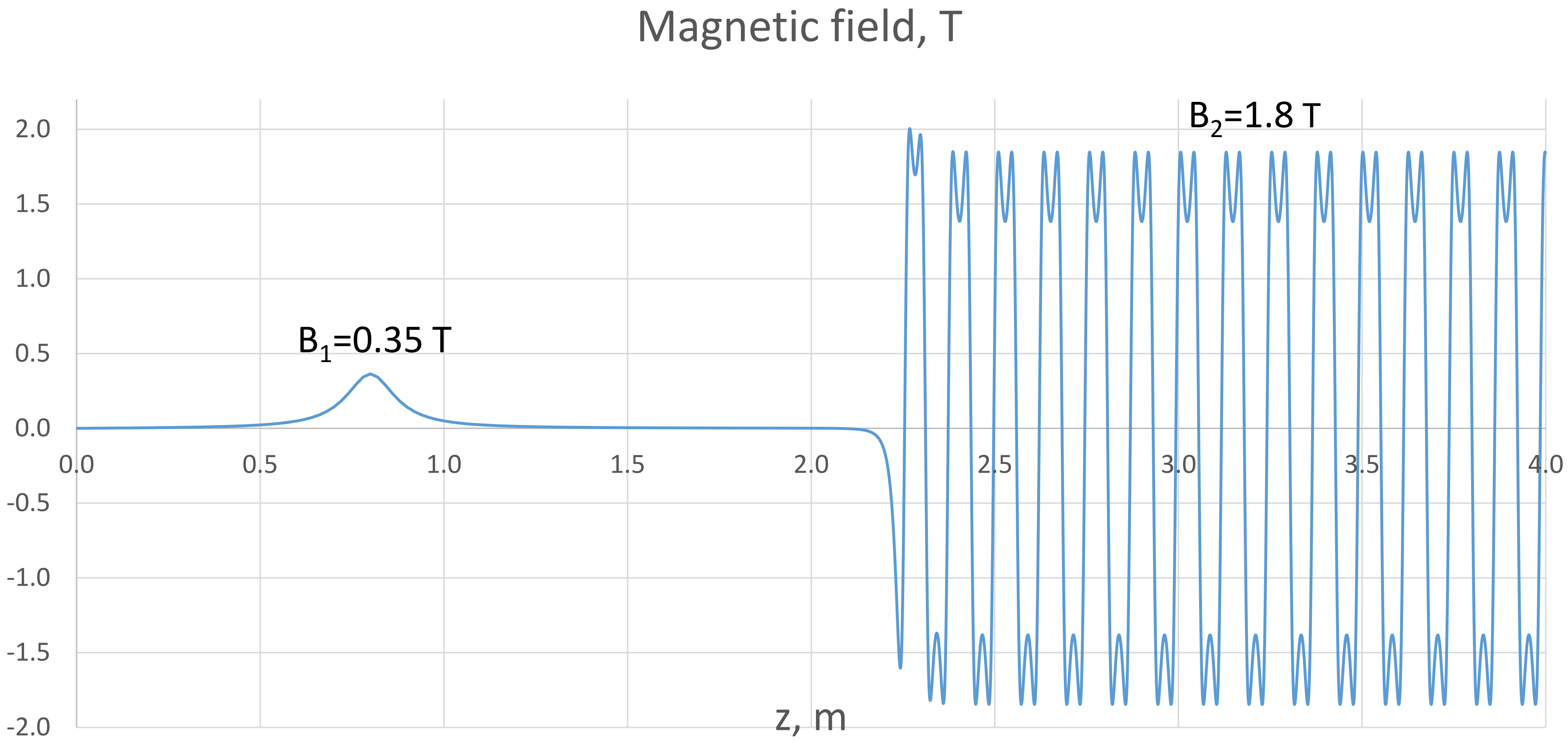
<u>Possible solution</u>: permanent magnets







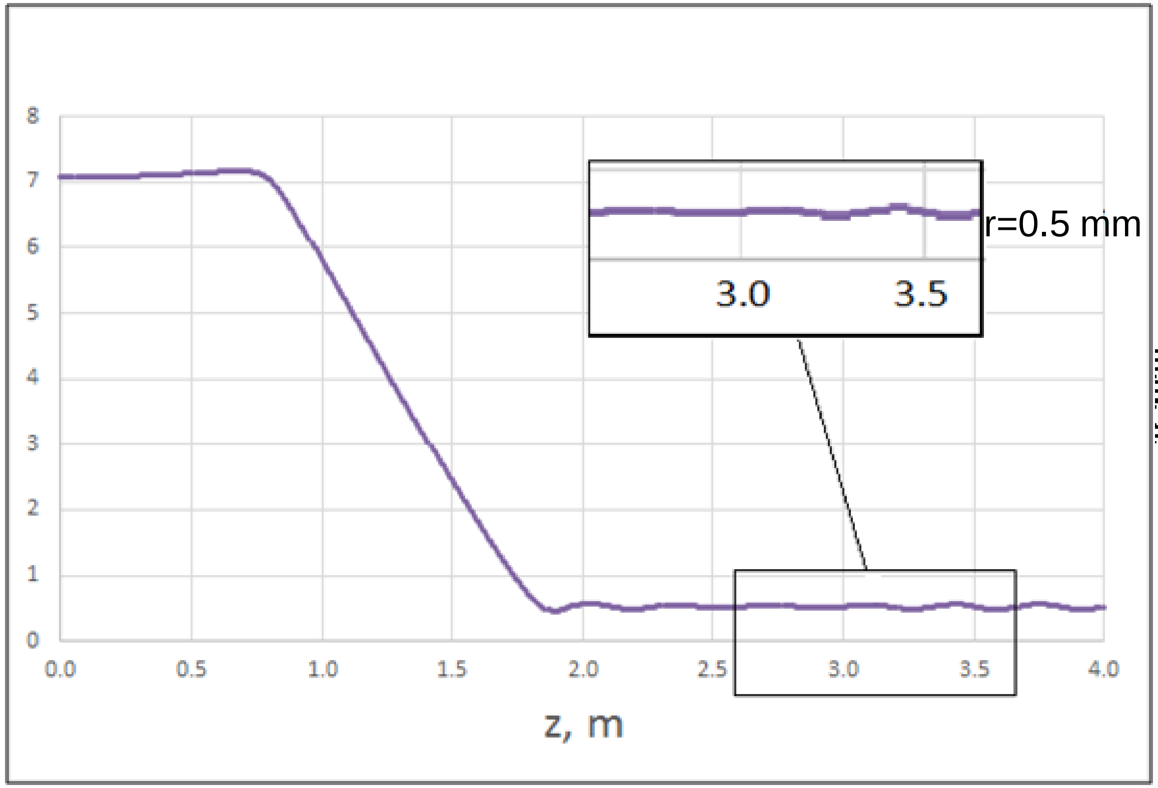
Focusing system field



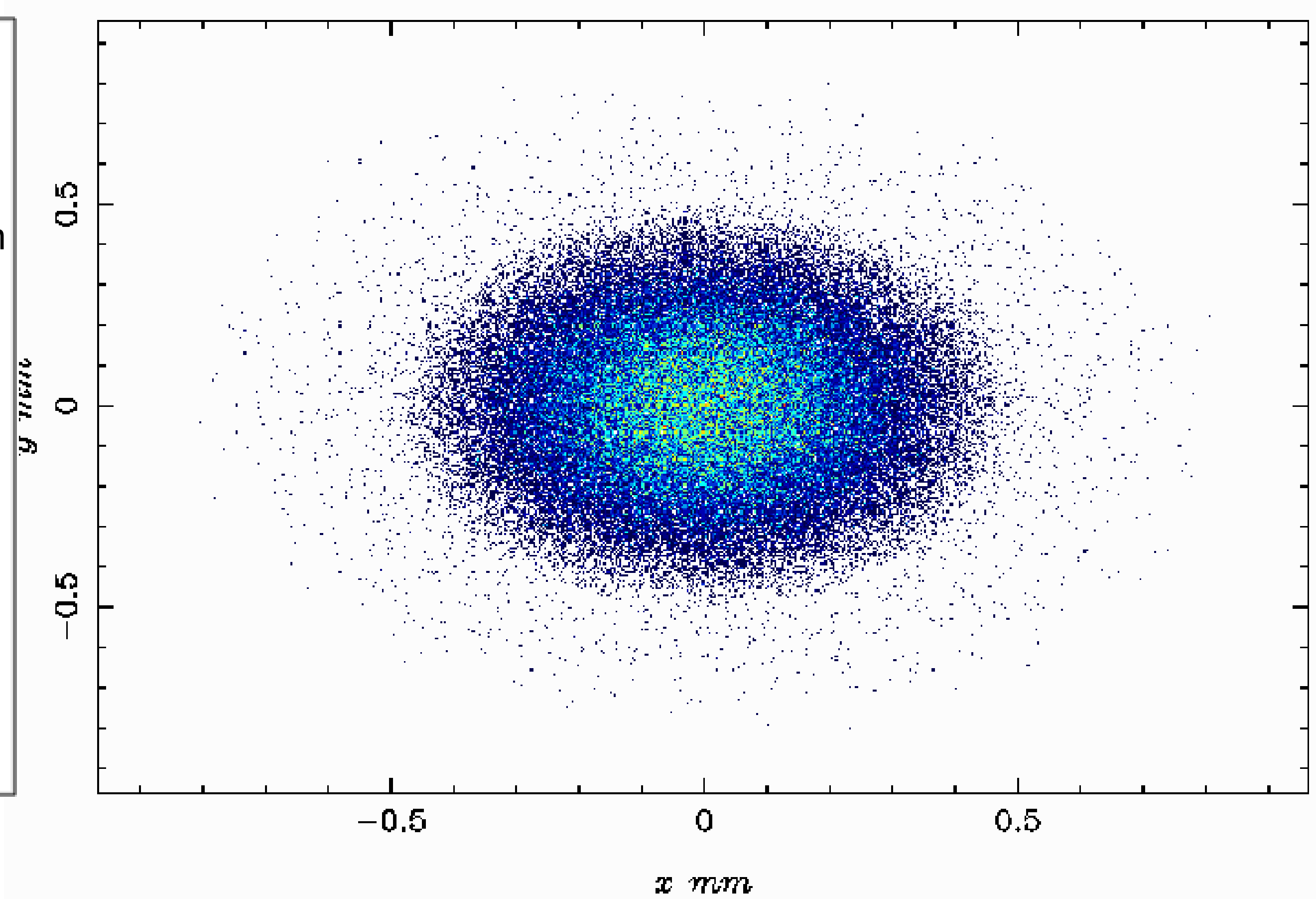
Focusing system: ASTRA simulations

$$\varepsilon_n = 10\pi \cdot mm \cdot mrad$$

Beam radius, mm



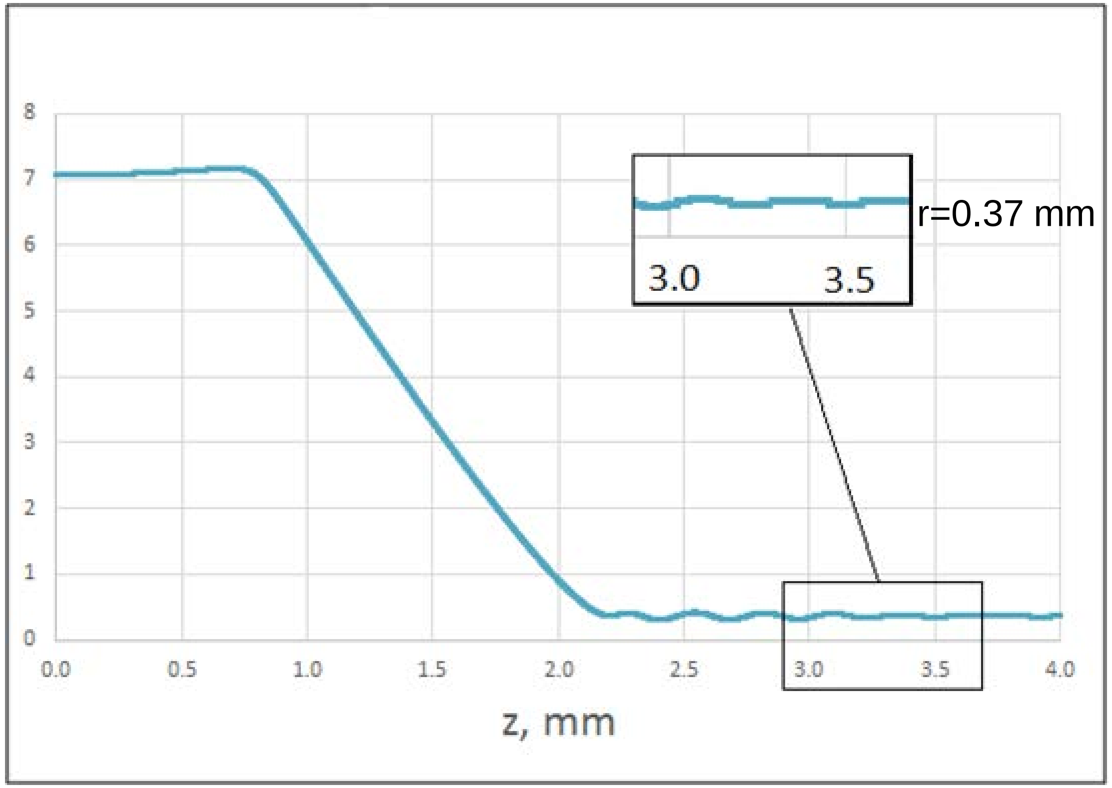
Beam profile



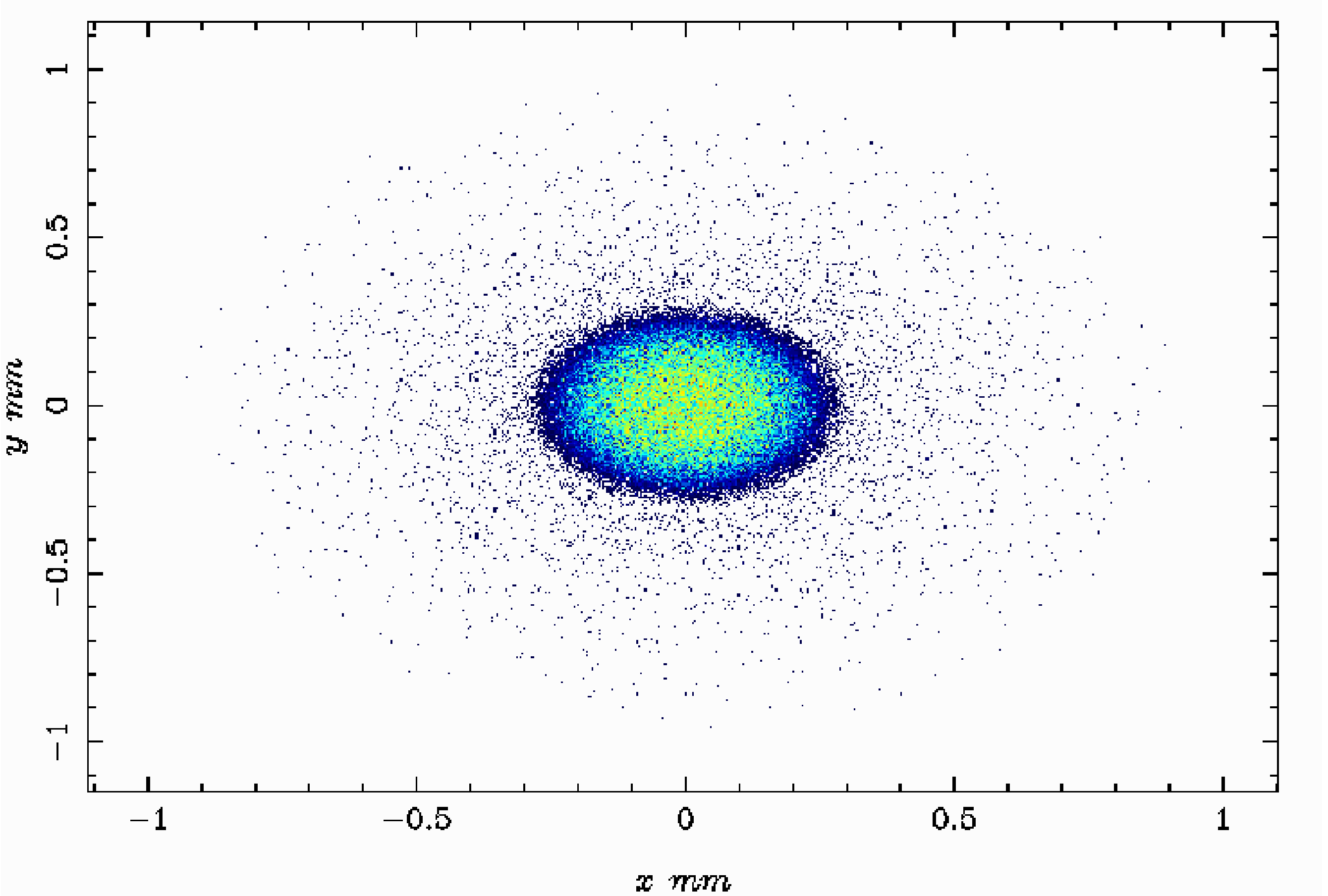
Focusing system: ASTRA simulations

$$\varepsilon_n = 5\pi \cdot mm \cdot mrad$$

Beam radius, mm



Beam profile



Conclusion

- Complex with ultrashort electron bunches is being developed
- Taking into account feasible beam parameters after the gun, we studied possibility of focusing to the mm wavelength structures
- It was proposed to use permanent magnet system with radial magnetization
- Beam dynamics confirmed possibility to obtain small beam size in such a system
- It is possible to transport the beam in the proposed system to the needed distance

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Thank you for your attention!