



High Efficiency Beam Extraction for 80 MeV H- Isochronous Cyclotron

S.A. Artamonov, A.N. Chernov,
E.M. Ivanov, G.A. Riabov, V.A. Tonkih
PNPI NRC “Kurchatov Institute”, Gatchina
Leningrad district, 188300, Russia



The start up of a new high intensity isochronous cyclotron at Gatchina in November of 2016

- **Beam energy from 40 up to 80 MeV**
- **Beam current of 100**

The cyclotron is intended for

- **production of high quality medicine isotopes,**
- **organization of eye melanoma treatment facility,**
- **treatment of surface forms of cancer and radiation resistance tests of the electronics for the aviation and space.**



The external view of the C-80 cyclotron and the first part of the transport line.



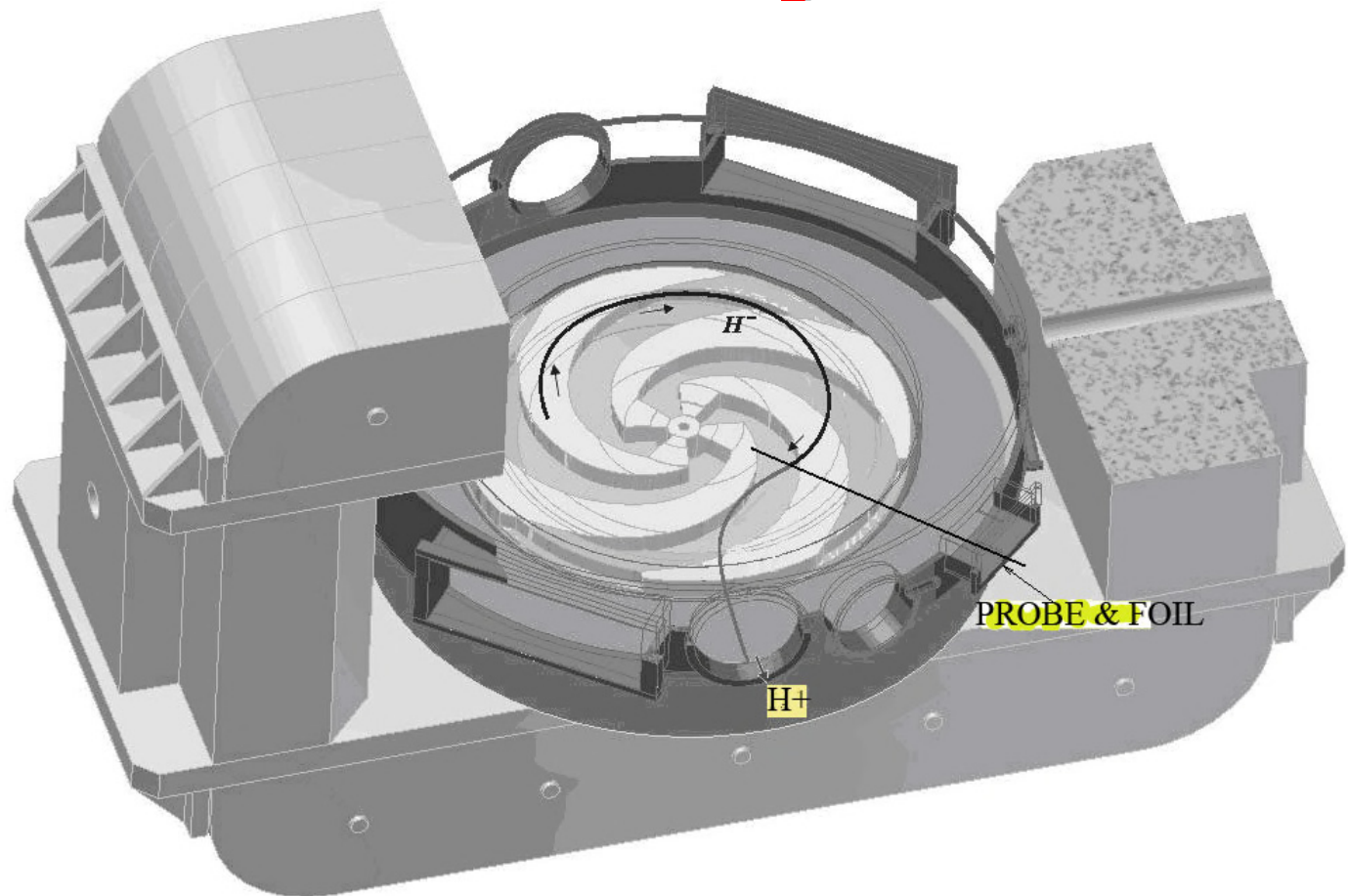


WHY H- minus cyclotron ?

- Advantage of H – minus cyclotron is that **high intensity internal beam can be extracted from the acceleration chamber with practically 100% efficiency by stripping H- ions to H+ ions using thin foils**

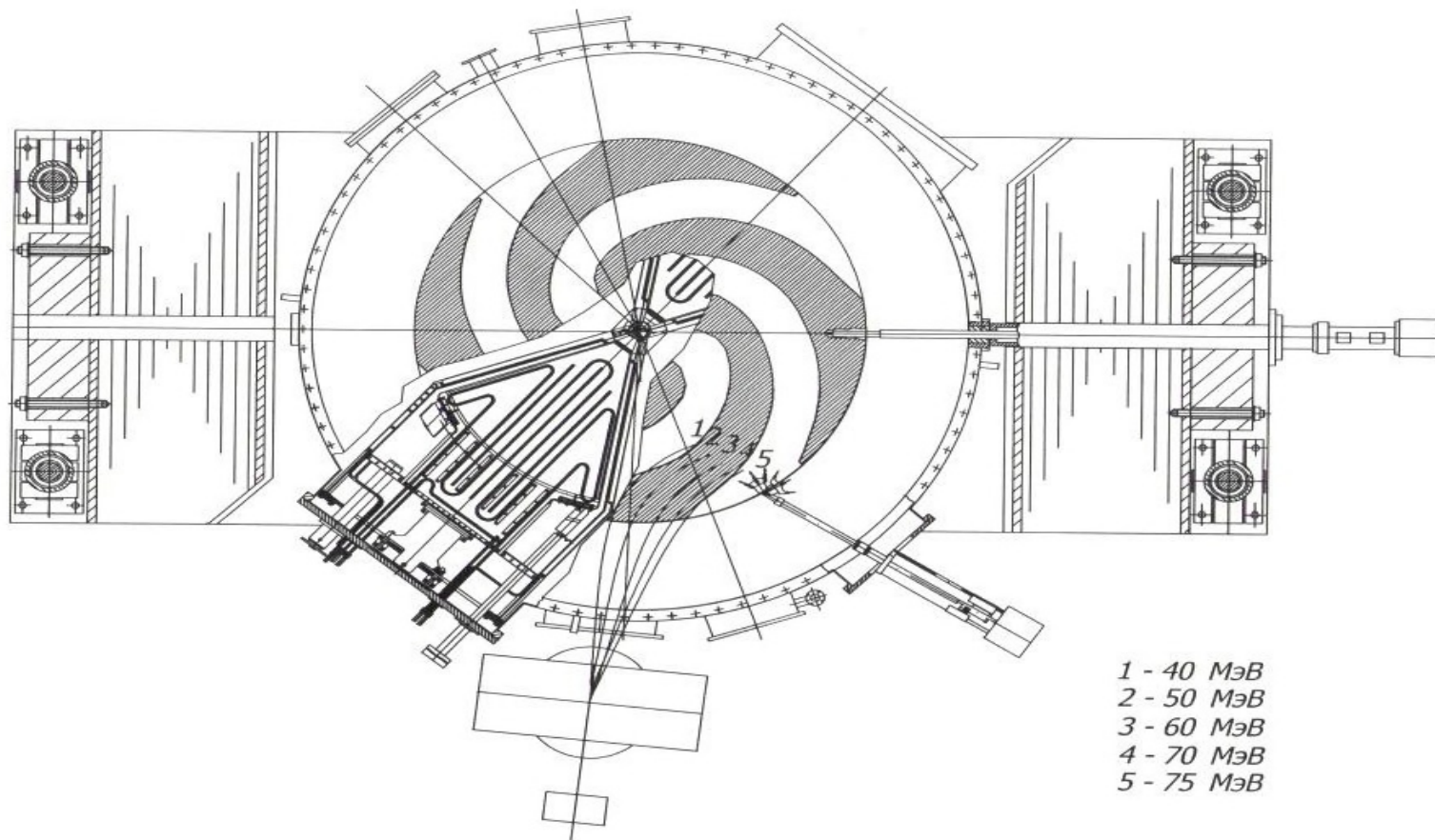


3D sketch of C-80 cyclotron and the extraction system





Schematic view of the extraction system of C-80 cyclotron





Some specific features of C-80 magnetic structure

- Very low flatter
- Very high spiral angle
- Low field in the hill region.

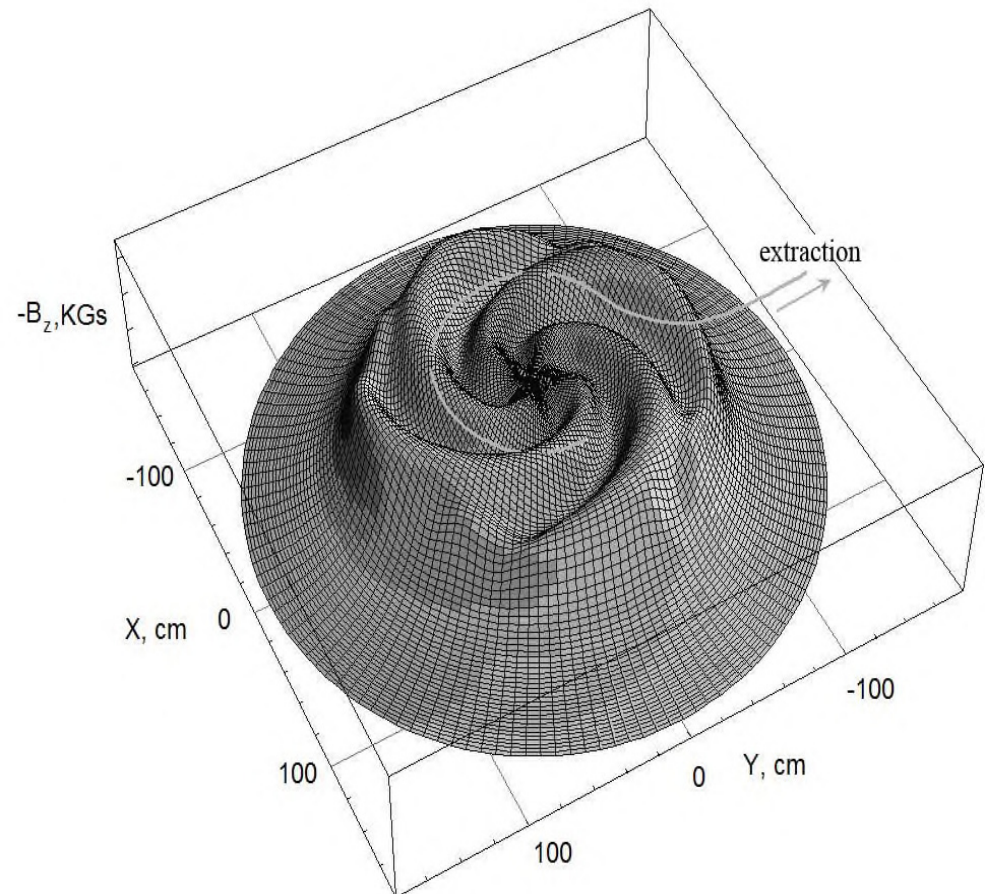
As result

This structure permits acceleration of H–minus with electro dissociation losses below 3 %.



C-80 magnetic field

MAGNET	
Pole diameter	2.05m
Valley gap	386 mm
Hill gap	163 mm
Magnetic field in centre	1.352 Tl.
Flatter (max.)	0.025
Spiral angle (max.)	65 degree
Number of sectors	4
Extraction radius	0.65-0.9 m
EXTRACTED BEAM	
Energy	40-80 MeV
Extraction method	stripping





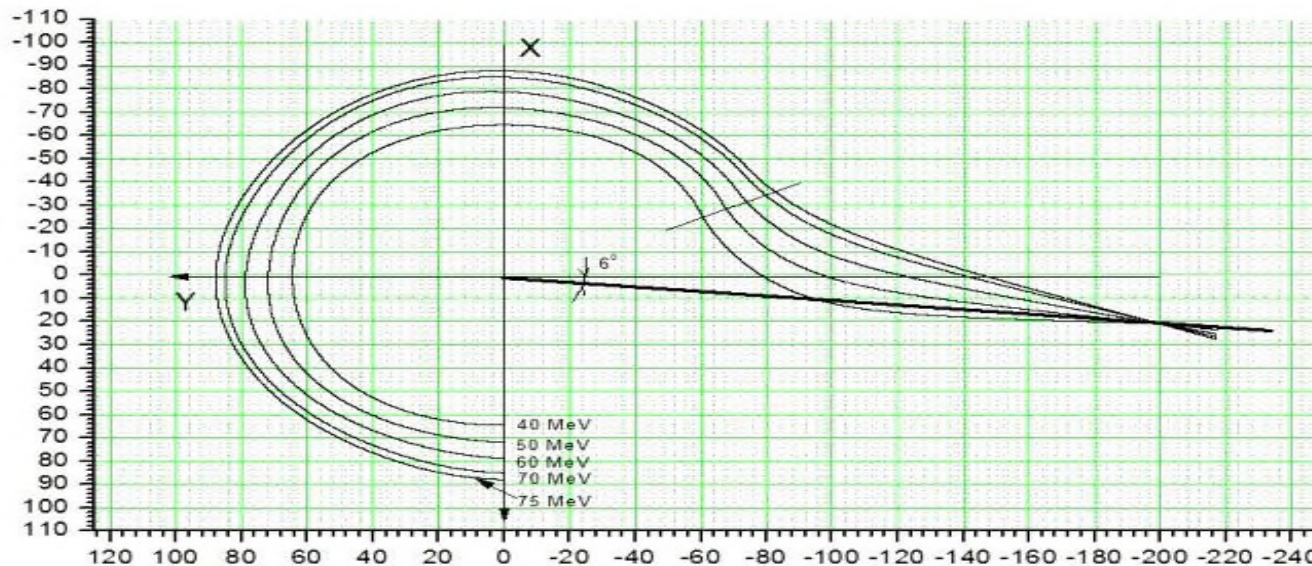
The reference trajectories for 40-80 MeV started from stable closed orbits

**Problem – to determine the stripper position on
radius and to azimuth for particles of
different energies to provide:**

- passage of particles throw extraction
window**
- gathering of all trajectories in one point at
the allaying magnet entrance**



The reference trajectories for 40-80 MeV



Main results –

- Stripper foil is moved along straight line $Y=0,88857 X - 36,27$
- The direction of the extracted beam is 6 degree with respect to longitudinal axis of the magnet
- Deviation angle of the allaying magnet from 15 up to -4 degrees



BEAM OPTICS CALCULATIONS

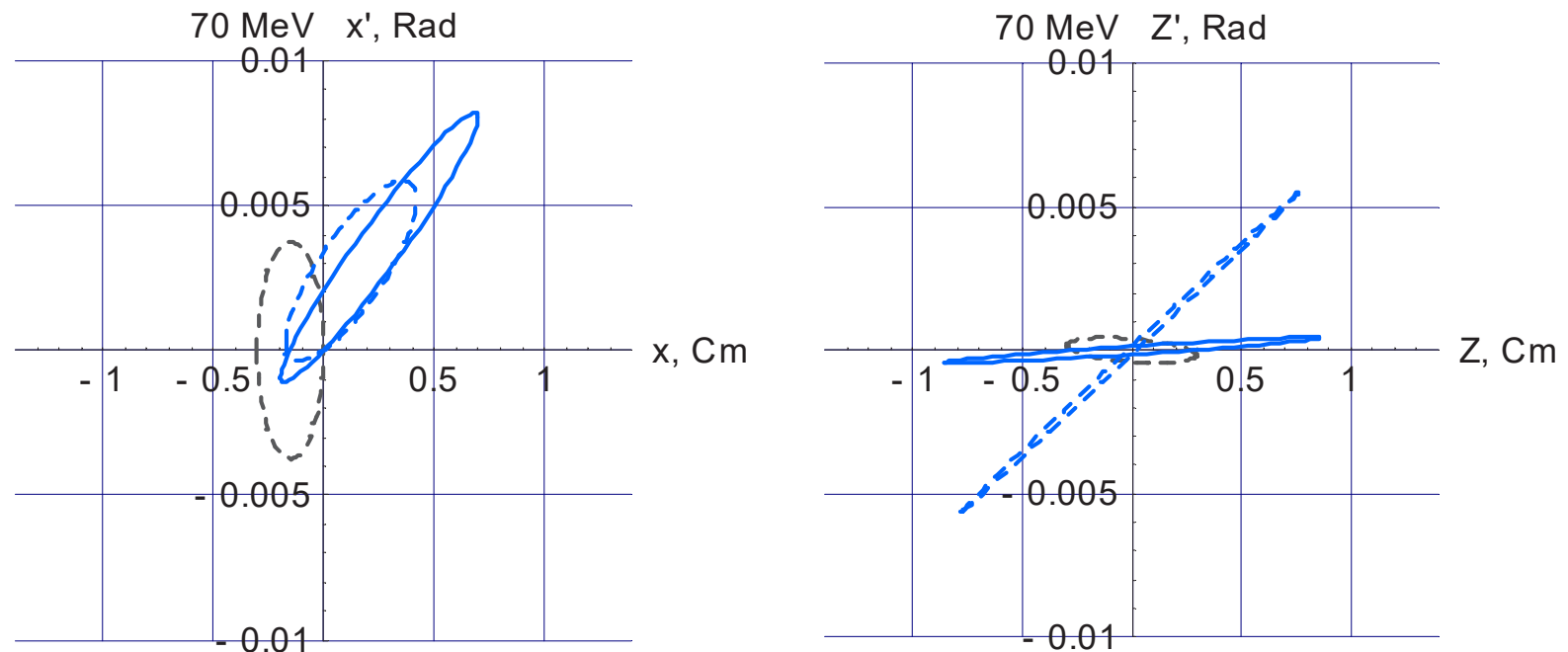
The particles nearly reference trajectory are described by two independent ellipses for horizontal and vertical planes.

The start ellipse in vertical plane defined by matched with magnetic structure ellipse and maximum beam size inside cyclotron assumed to be 6 mm.

The start ellipse in horizontal plane defined by matched with magnetic structure ellipse and beam spot on the stripper assumed to be 3 mm.



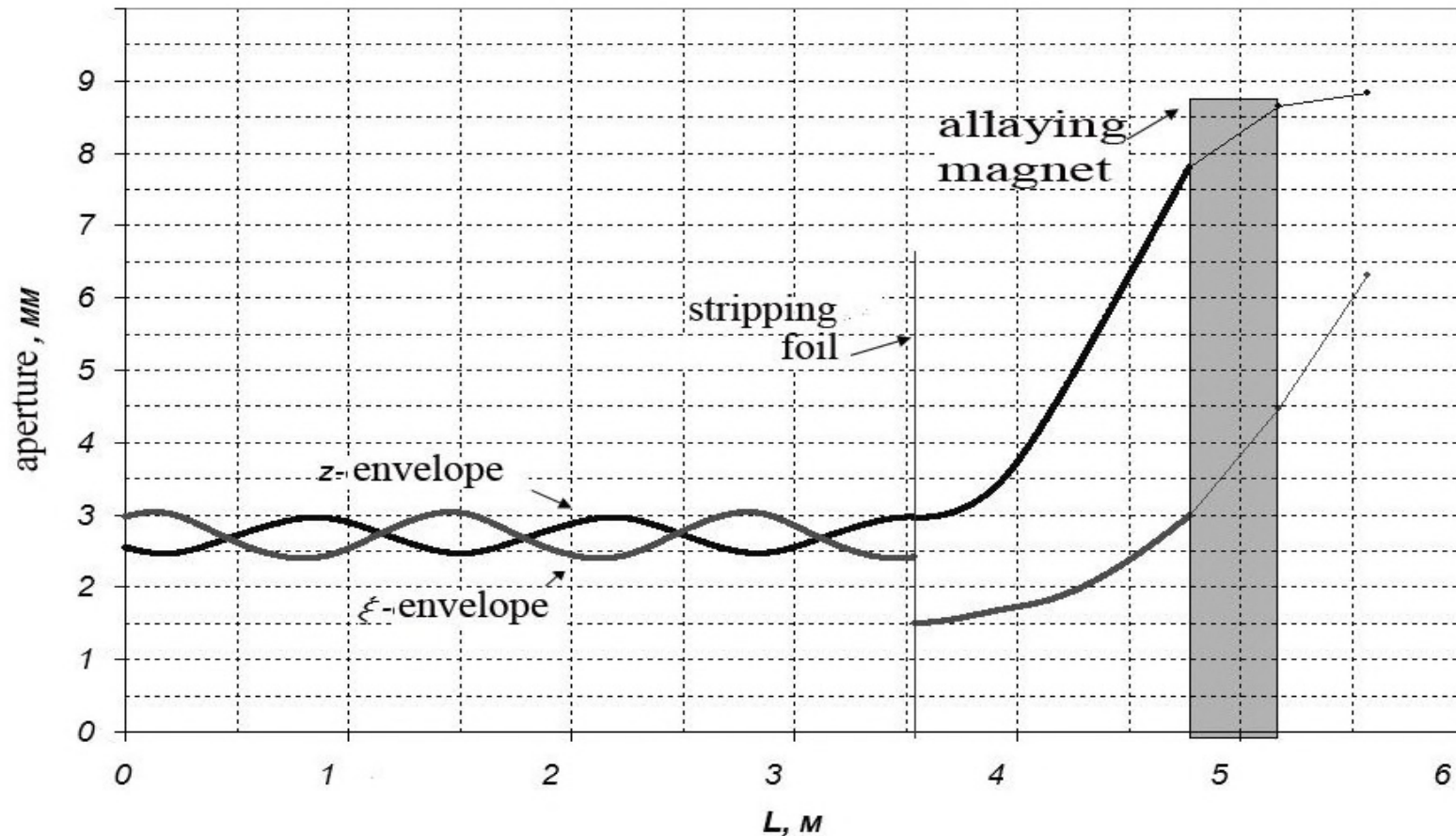
The 70 MeV phase ellipses transformation in extraction process



- **Black ellipse on the stripper position**
- **Dotted blue – allaying magnet entrance**
- **Blue - allaying magnet exit**



The beam envelope transformation in extraction process





500 particles trajectory calculated in the experimentally measured magnetic map

500 trajectories calculated from inflector up to allaying magnet to a great extent confirmed the previous results

- in stripper position**
- in direction of extracted beam and beam parameters**

In addition was determined

- beam size on stripper in horizontal plane is 3mmh**
- the beam energy uncertainty is about 1%**
- beam quality in cyclotron depends on central optic tuning, the first and third harmonics, the second and fifth harmonics have no effect on the beam emittance.**



EXPERIMENT

Design beam parameters were achieved in November.

- The extracted beam has been obtained in the energy range from 40 up to 78 MeV.
- **Extraction efficiency** estimated as a ratio of the current on the first in beam line Faraday cap and current on the internal probe is **80-100%**. The beam is directed into the beam line, which position was defined from computer simulations. The energy range was obtained by moving the stripper probe along the calculated line.
- **Results of computer simulations have been confirmed by experiment.**



ACKNOWLEDGMENT

- In conclusion we have a pleasure to express our appreciation to Yu.N.Gavrish, V.G.Mudrolubov and especially to A.V.Galchuk for the help and fruitful discussions.



- Thank you for your attention

