Design of an 0.8 A, 300 keV Accelerator of Positive Hydrogen Ions

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Abstract

The design and construction of an 0.8 A, 300 keV accelerator of positive hydrogen ions is presented. This system consists of an RF positive ion source with AlN discharge chamber and uses a multi-aperture four electrode extraction system for ion beam formation. Six 50 kV power supplies, connected in series produces 300 kV for beam acceleration. The ion source and accelerator are being manufactured under an Italian contract to be used to produce Mo-99 using D-D and D-T fusion neutrons from Mo-100.

Schematic diagram of 0.8 A, 300 keV, hydrogen ions accelerator

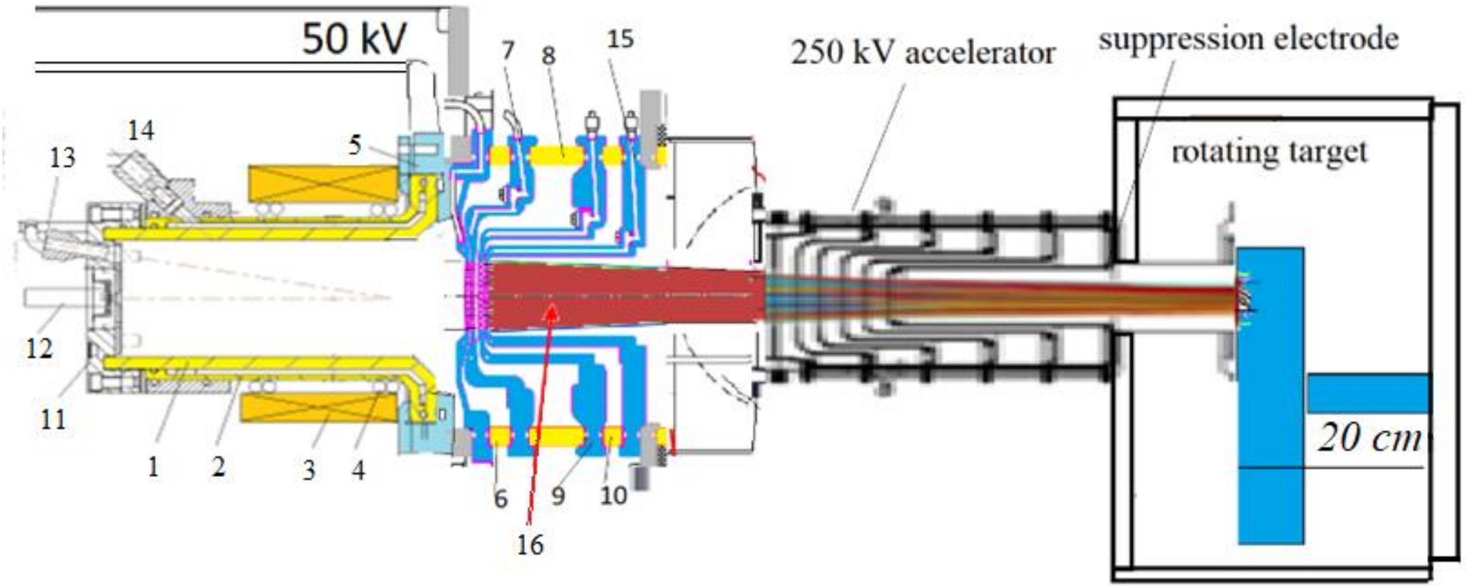


Fig.1.

The components of the initially proposed ion source and extraction system are shown above:
1 - Aluminum Nitride ceramic gas discharge chamber, 2- cooling jacket made from PEEK, 3 - 50 turn 200 Gauss solenoid, 4- RF antenna, 5 - plasma electrode, 6 - extractor insulator, 7- extractor electrode, 8 - high voltage insulator, 9 - suppression electrode, 10 - suppression insulator, 11- back flange, 12 - gas tube, 13 - optical window, 14 - water connectors, 15 -grounded electrode. 16 - ion beam.

Ion beam accelerates up to 300 keV by accelerating tube and dumped to rotating target.
Note that "ground" in the ion source is actually +250 kV in the accelerator.

Scaled drawing of multi-aperture four-electrode extraction system

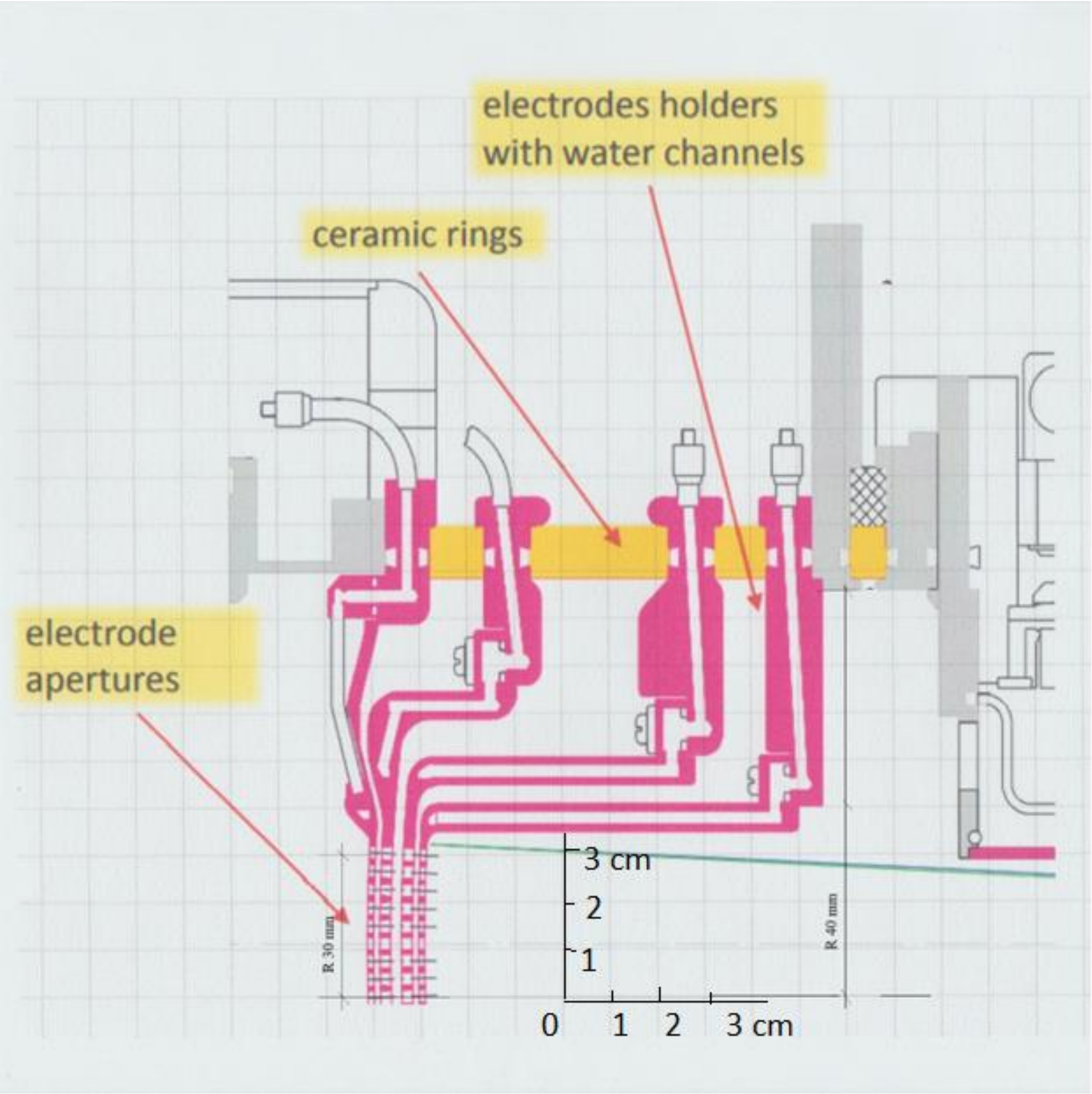


Fig.2.

Figure 2 shows the details of the extraction electrode construction in scale.

The electrodes have spherical form with radius of 0.5 m for ballistic focusing of the beam. They are made of chromium zirconium bronze, and they have 100 round apertures with a diameter of 4 mm arranged in a hexagonal pattern inside a diameter of 6 cm. The transparency of the electrodes is about 50%. Each electrode has a water-cooling channel surrounding the apertures. Water channels are inside the electrode holders and go out through the flanges compressed between alumina ceramics insulators.

The finished pieces is brazed to the holder with oxygen-free copper. Manufacturing Ion Optic System (IOS) electrodes with cooling channels is a challenging technological problem.

Emission current density is 60 mA/cm2

RF power from RF generator ~5 kW.

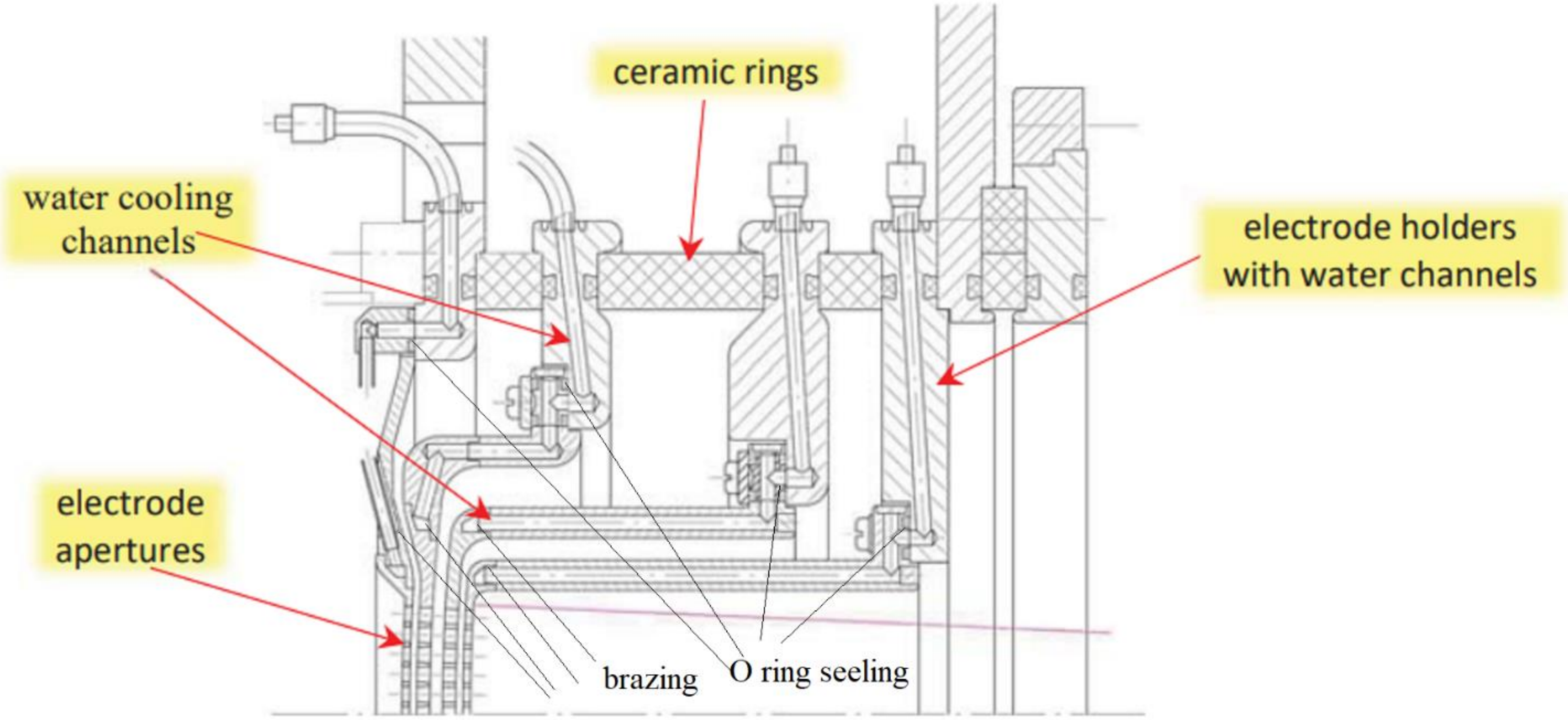


Fig. 2A. Drawing of four electrode, multi-aperture extraction system.

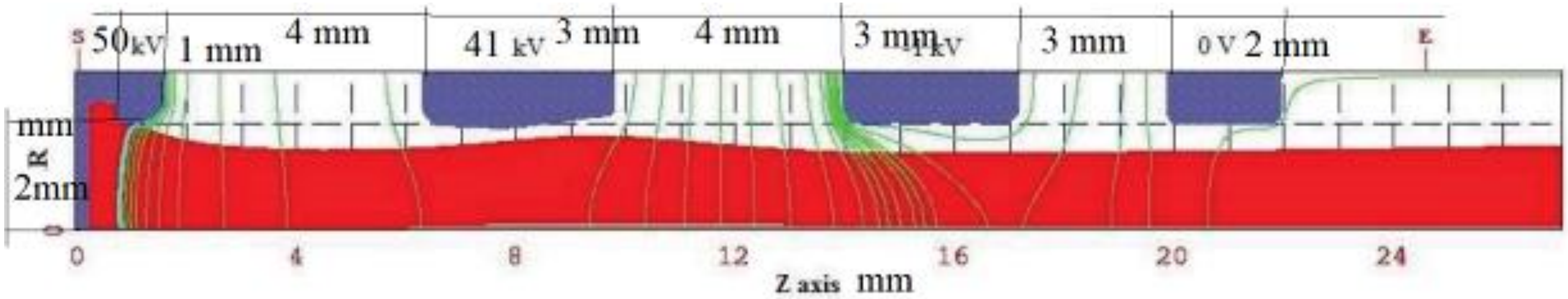


Fig. 3. Computer simulation of ion beam extraction/formation in one emission aperture (shape of electrodes).

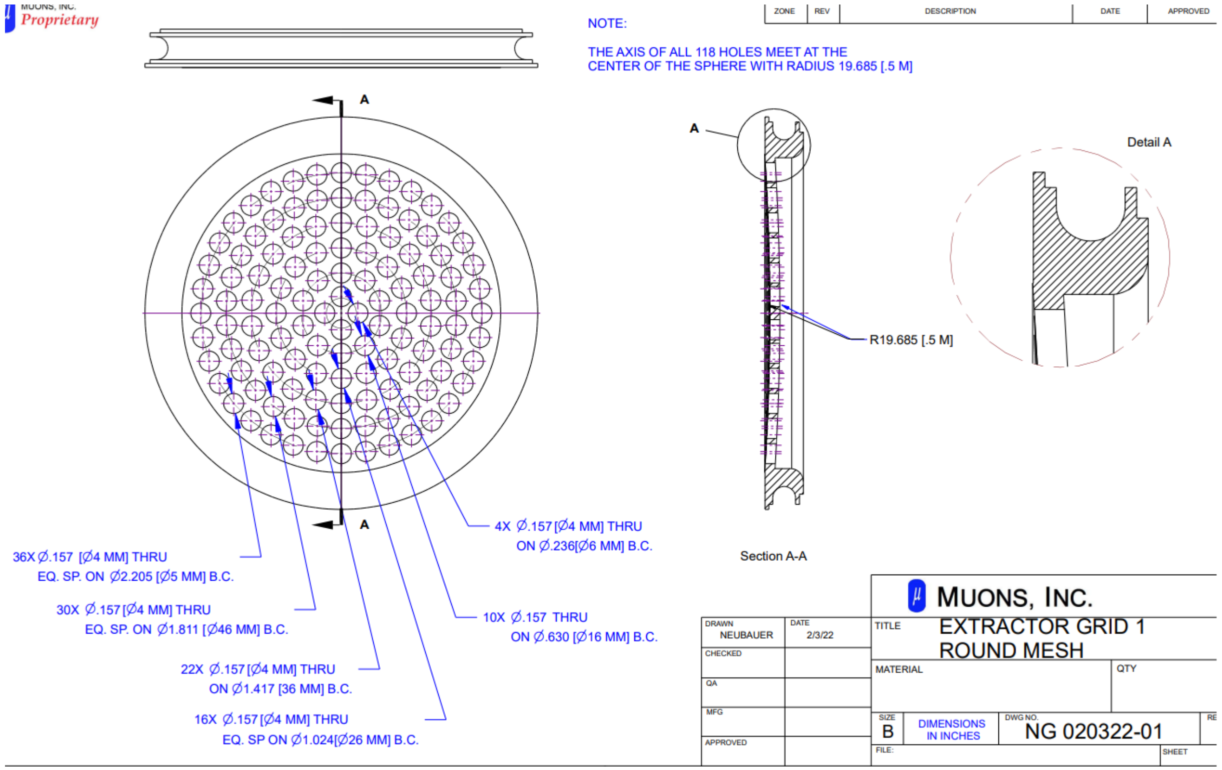


Fig. 4. Drawing of multiaperture plasma electrode with spherical radius ~ 0.5 m.

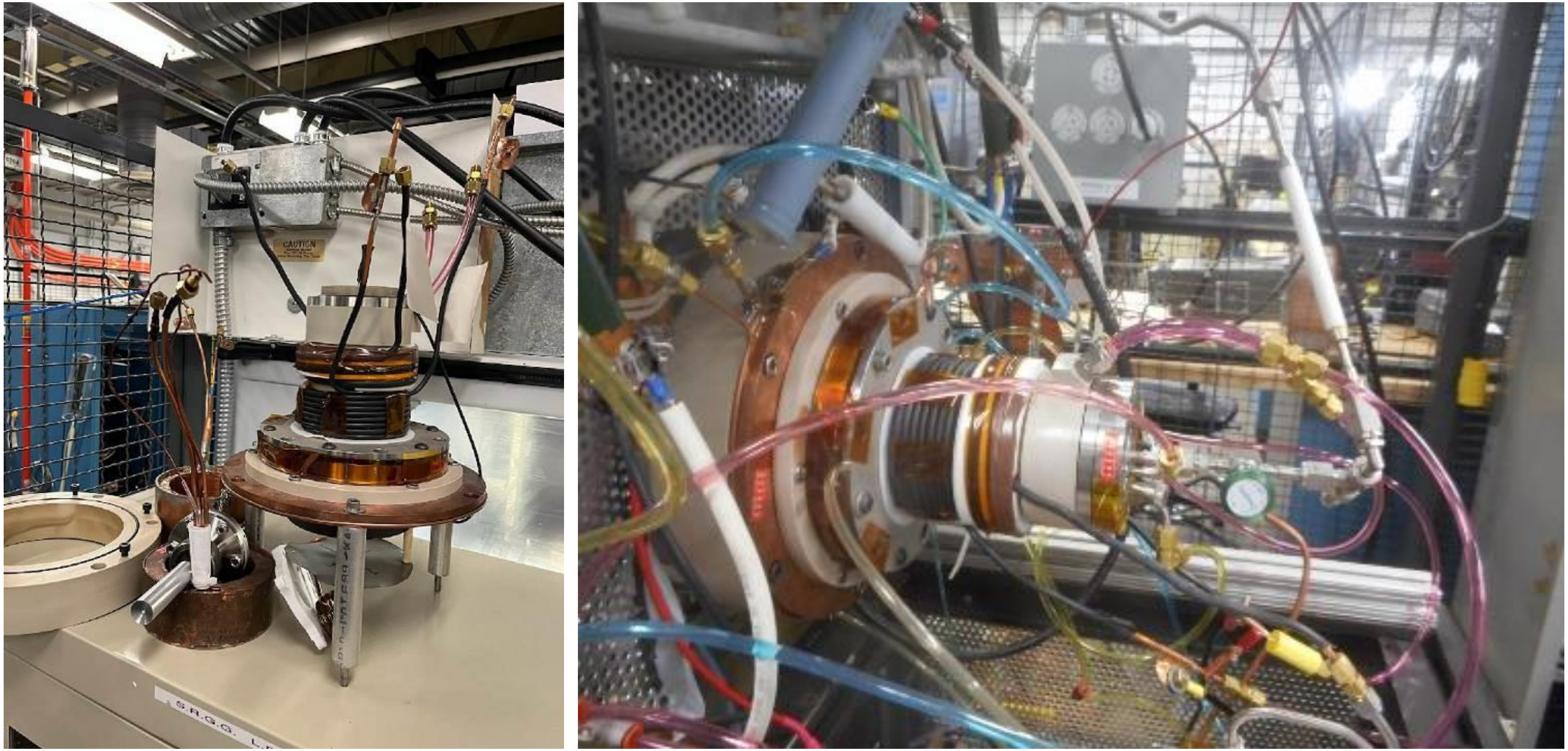


Fig. 5. Photo of RF ion source.

This ENEA Project (SBIR Phase III) was inspired and based on work done at the ORNL SNS under SBIR Grant DE-SC0011323 “Long life radio frequency surface plasma source” by Muons, Inc. and Oak Ridge National Laboratory SNS.

Fig. 7. Matching network Advanced Energy.

Fig.6. RF generator (MKS Sure Power QL6513A-OF03) at frequency 13.56 MHz and power up to 6.5kW.

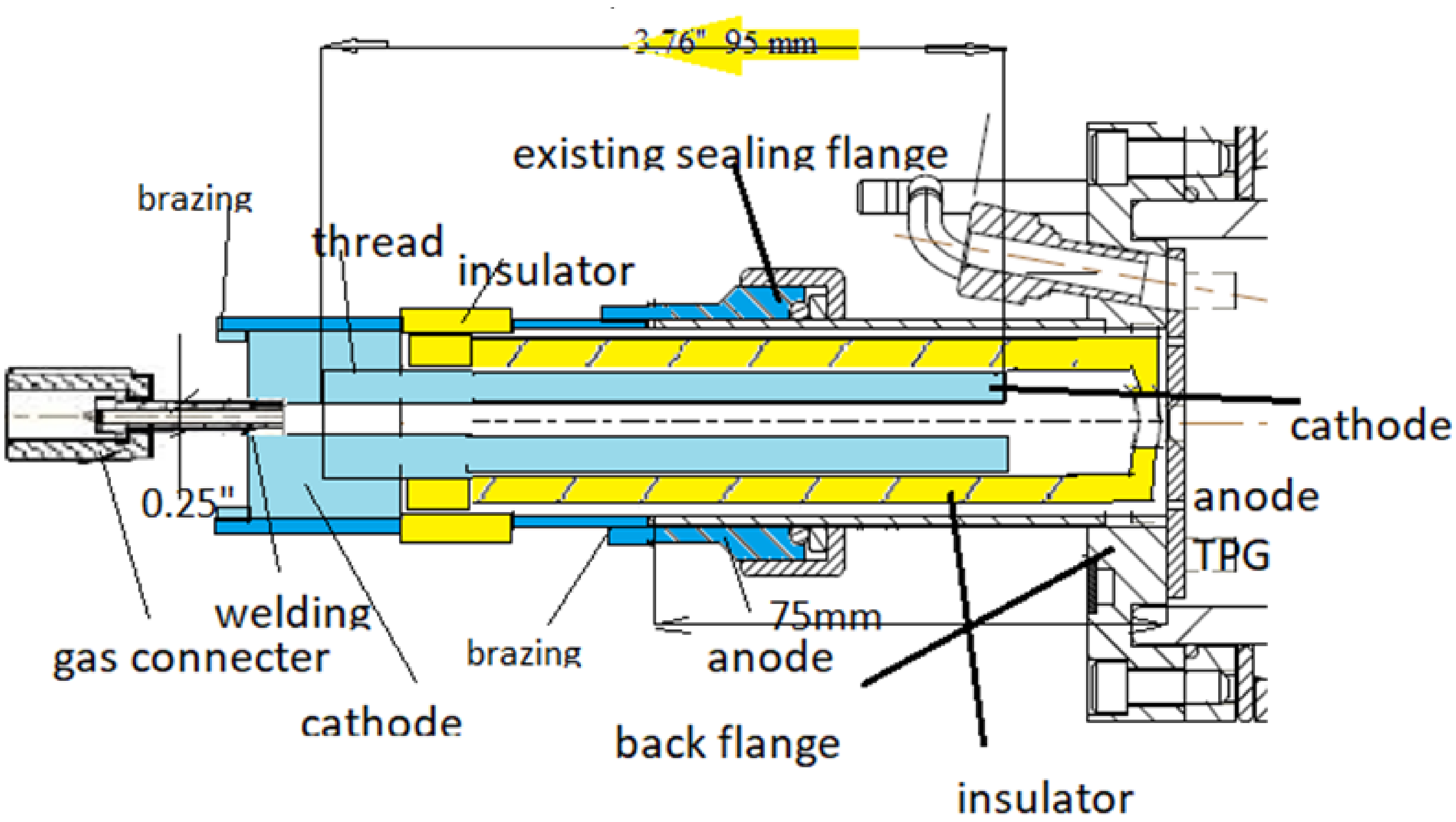


Fig.8. Schematic of Triggering Plasma Gun (TPG).

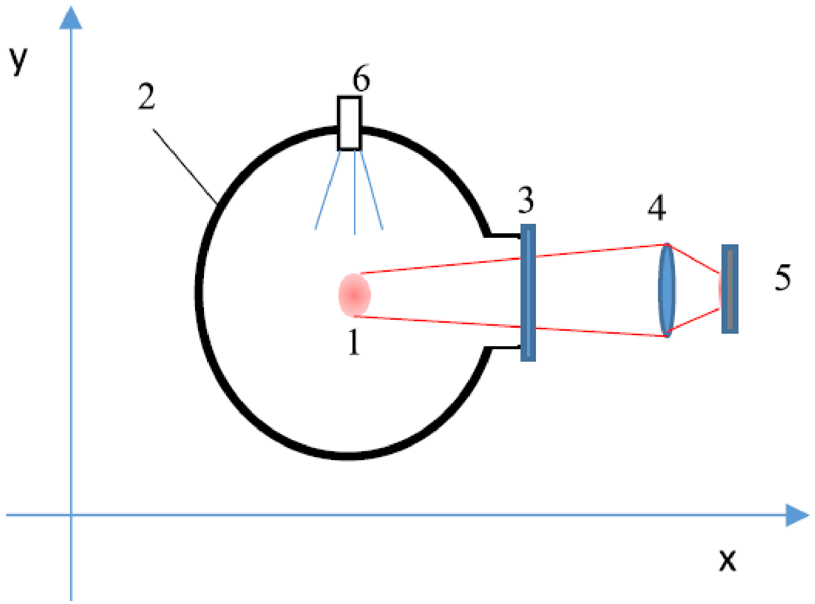


Fig. 9. Scheme of ion beam profile visualization.
1—beam cross section,
2—Low Energy Beam Transport chamber,
3—optic window,
4—lens,
5—photon sensitive element,
6—gas puffing.

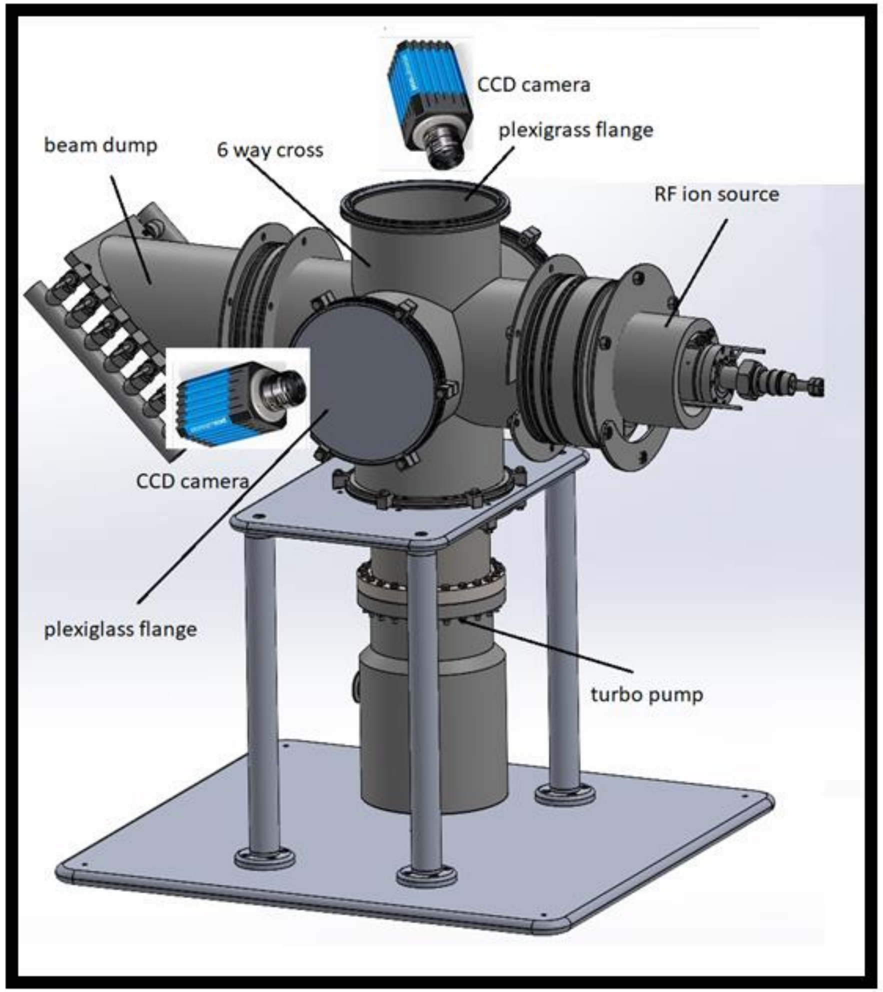


Fig. 10. Scheme of optical diagnostics of ion beam hydrogen ions accelerator.

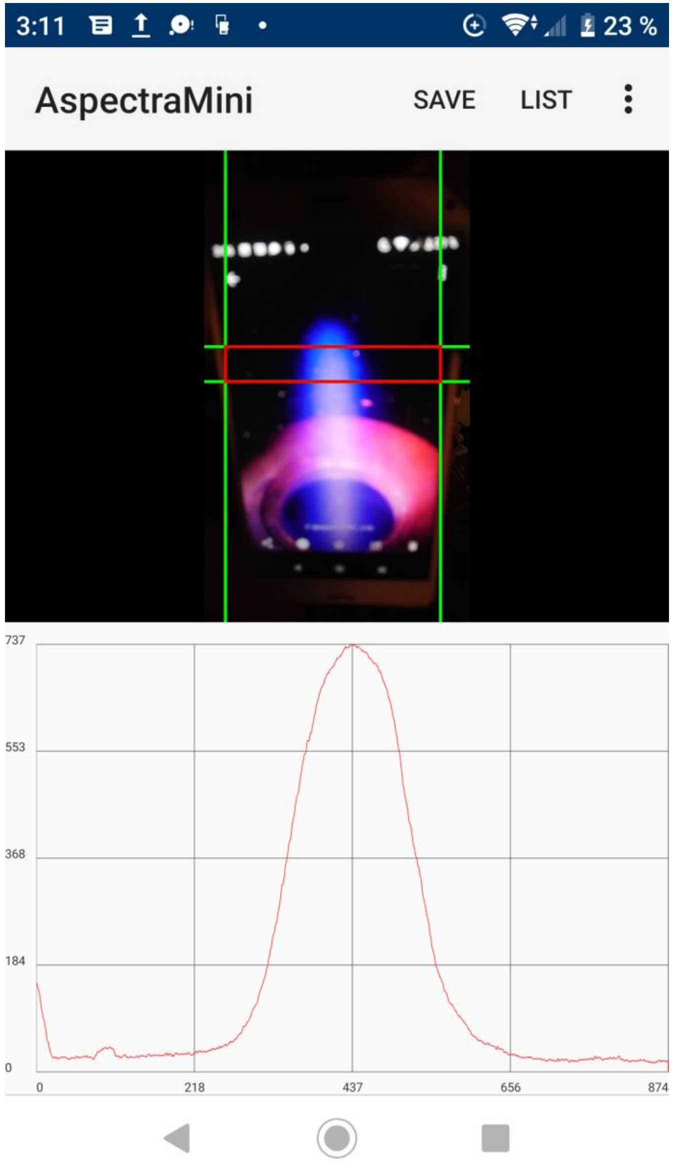


Fig. 11. Visible radiation of ion beam and brightness light distribution.

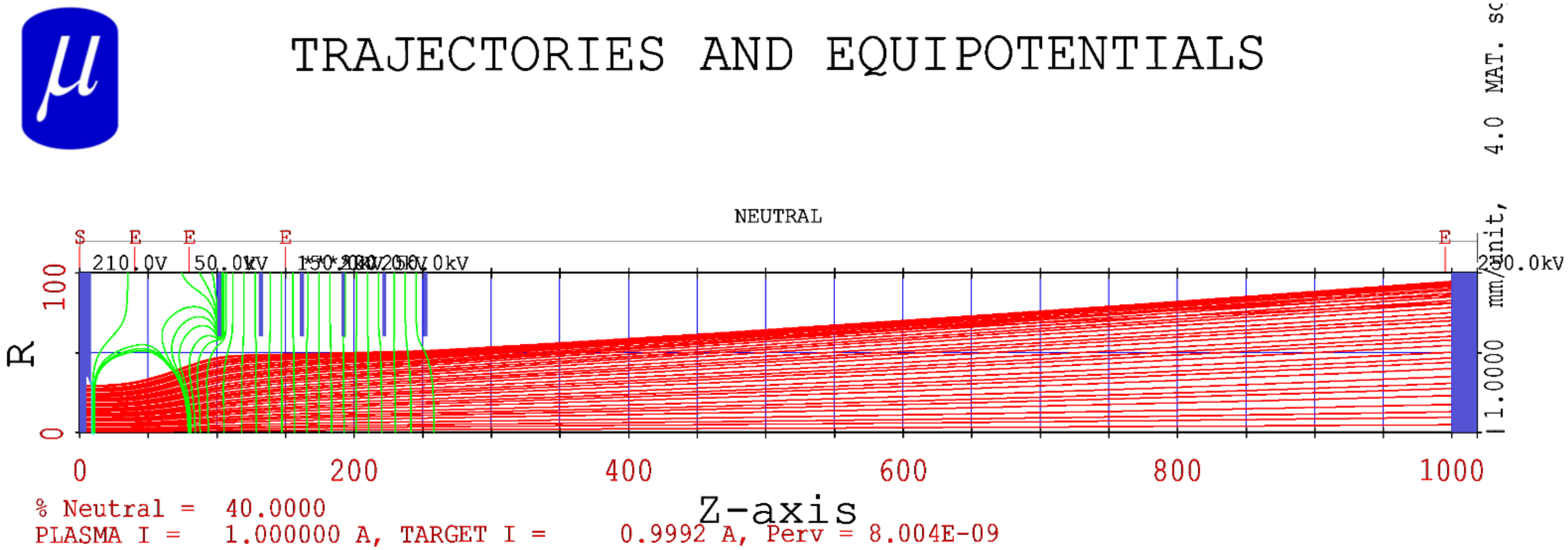


Fig. 12. Trajectories and equipotentials for 40 % of space charge neutralization (SCN) of hydrogen ion beam with current 1A, accelerated up to 300 keV in target located at 1000 mm.

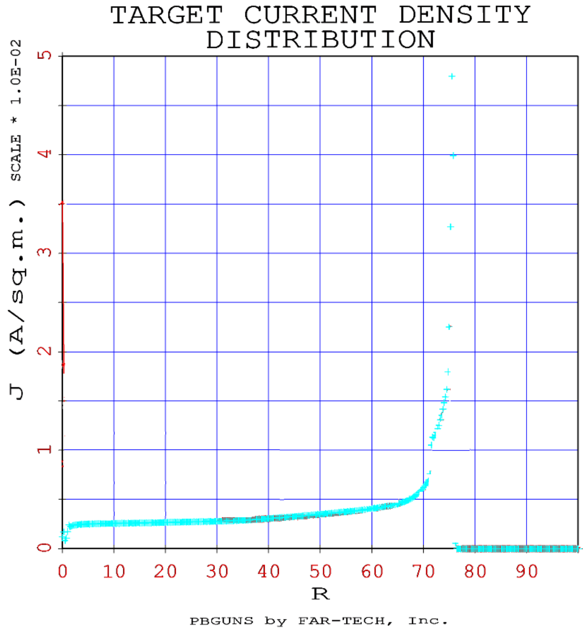
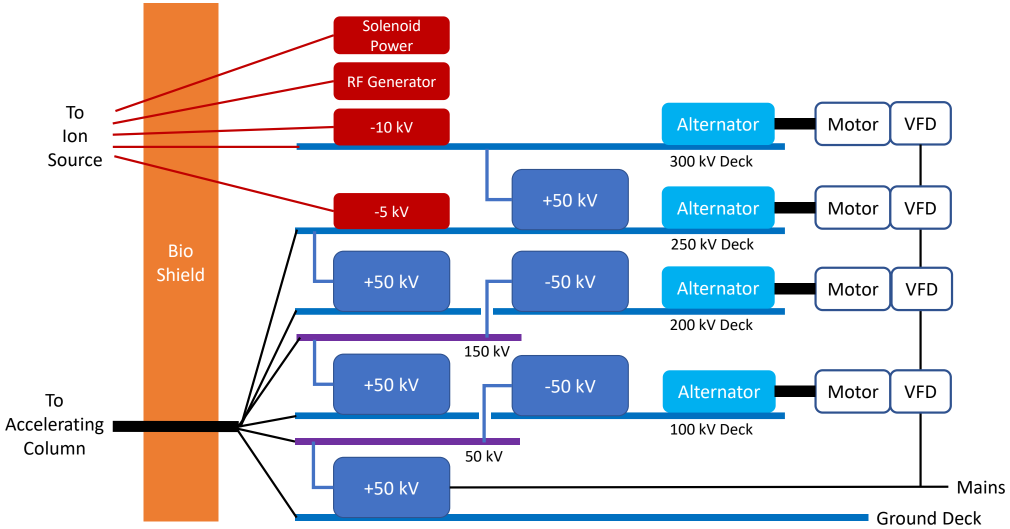
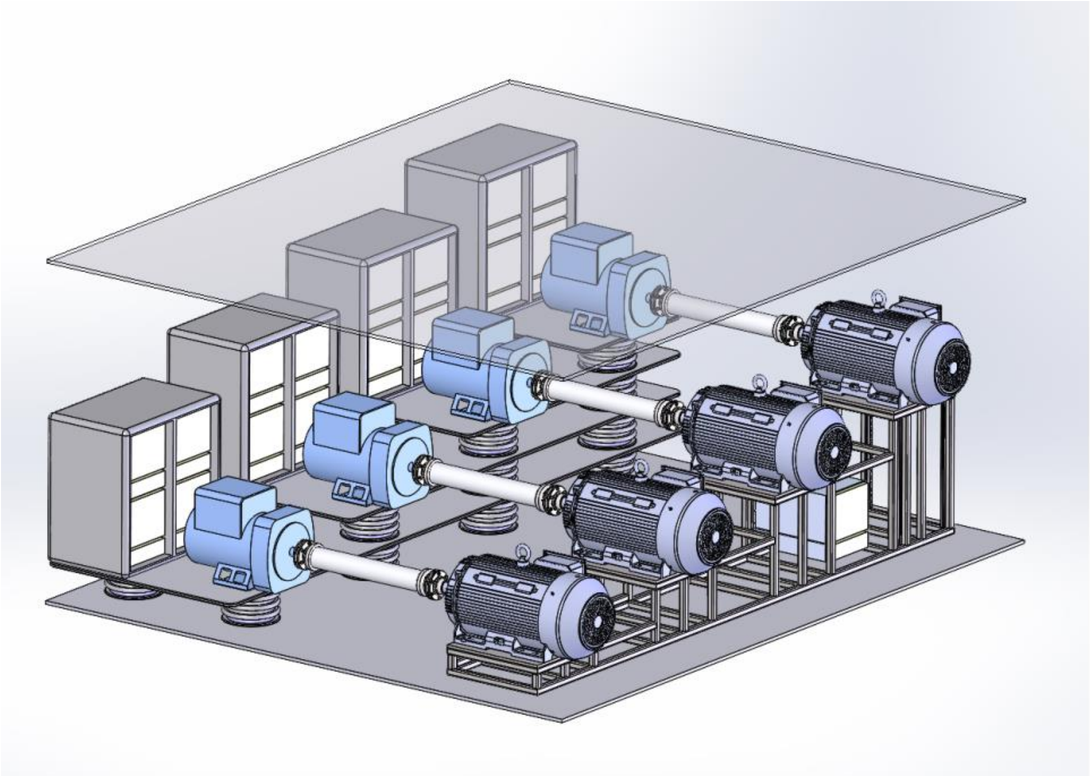


Fig.13. Ion beam current density distribution on the target for SCN 40%.
Radial beam size is 15 cm for target location of 1000 mm.
Current density ~2.5 mA/cm2.





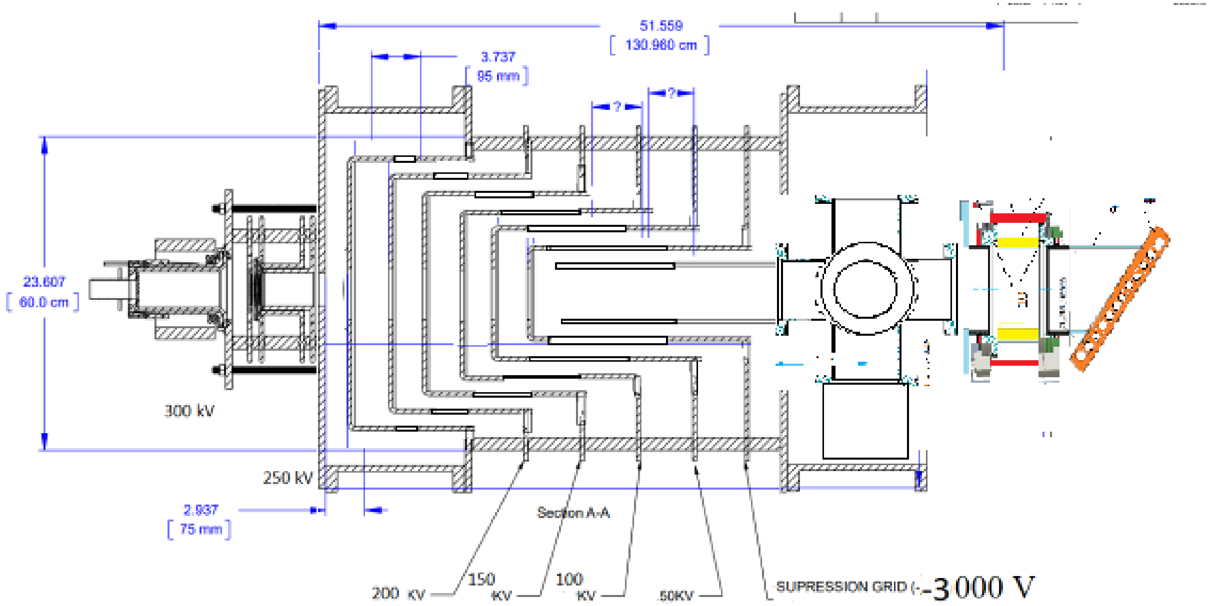


Fig. 14, 15, 16.
Schematic of power supplies for 0.9 A, 300 kV accelerator.
Motor generators with high voltage insulated alternators.
Schematic of accelerating tubes with RF ion source and beam dump.

Acceleration tube for voltage 400 kV

1- input apperture; 2- electrodes;
3- isolating rings; 4- dielectric pins.

Fig.17. 3D drawing of accelerating tube.

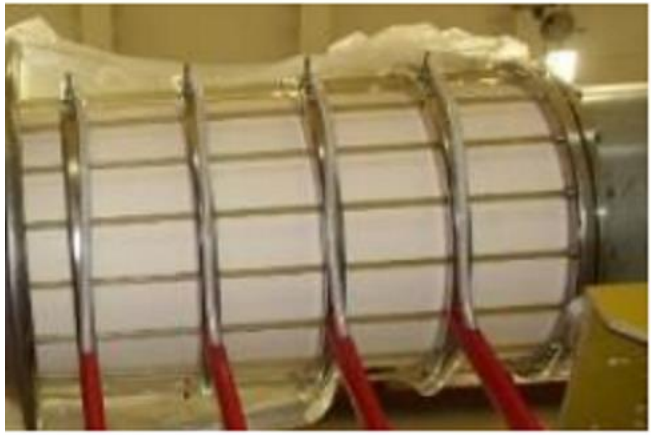


Fig.18. Photo of accelerating tube.

Fig. 19. Photo of electrodes accelerating tube.

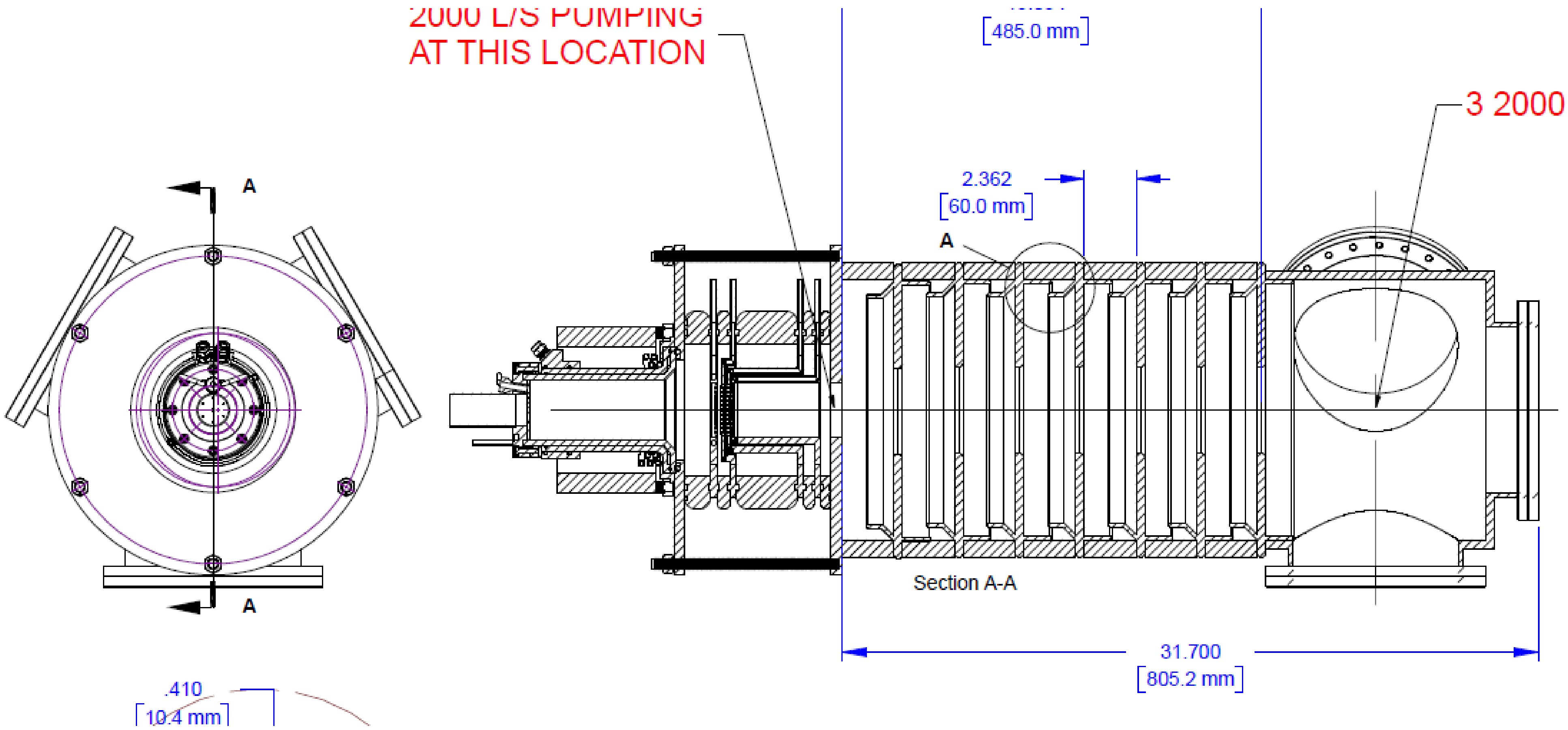


Fig. 20. Accelerating tube with ion source.

Conclusion

The design of 0.8 A, 300 kV accelerator of positive hydrogen ions was proposed as shown above in a successful bid to ENEA (Italian gov. agency). The design is being developed and constructed now. This system consists of an RF positive ion source with AlN discharge chamber and uses a multi-aperture four electrode extraction system for ion beam formation. The emission current density is 60 mA/cm^2. RF generator power is ~5 kW. Six 50 kV, 900 mA Technix-HV power supplies, connected in series, will produce 300 kV for beam acceleration. Electric power is supplied by 4 motor-alternator sets. It will be tested at the Brasimone, Italy site by the end of this year. This accelerator will be used as a prototype for a powerful neutron generator.

Thank You for your attention.