

Dielectric Based Compact Accelerator for Industrial Applications

A. Kanareykin, C. Jing, R. Kostin, P. Avrakhov

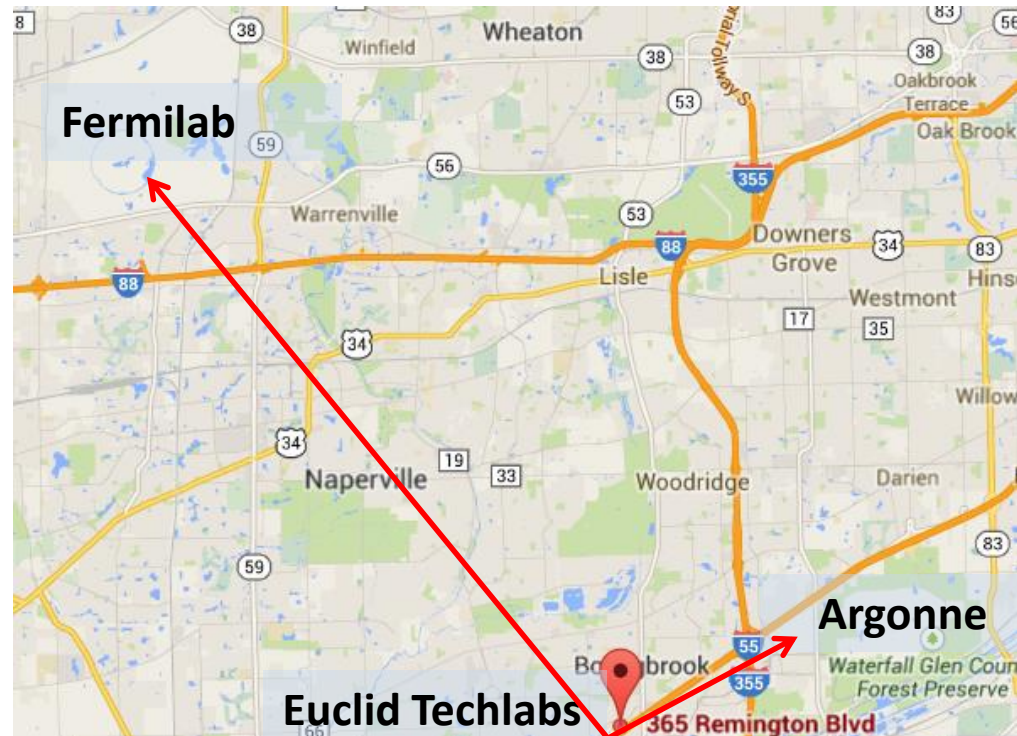
Euclid Beamlabs LLC

13th Workshop on Breakdown Science
and High Gradient Accelerator
Technology, HG2021

Euclid Techlabs/Beamlabs

Euclid Techlabs/Beamlabs is a research and development companies specializing in linear particle accelerators, ultrafast electron microscopy, and advanced material technologies for energy, defense, and medical applications. The company special interest is in the development of advanced high power components based on new “smart” materials and designs intended for beam physics and accelerator applications.

- 2 offices: Bolingbrook, IL and Gaithersburg, MD
- Close collaboration with National Labs: ANL, BNL, JLAB, FNAL, CERN, SLAC, NIST and universities.

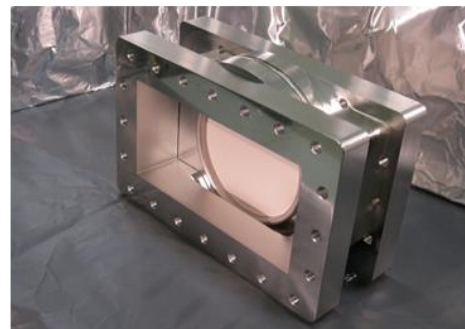


Key Euclid Technologies

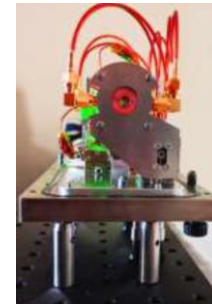
- Ultra-compact low energy accelerator (dielectric based)
- Stroboscopic pulser for Transmission Electron Microscope
- Electron guns for accelerators: Photo-, thermo-, field emission (FE)- and SRF guns
- Ferroelectric based fast tuner
- UNC Diamond based FE and photo cathodes
- Accelerator components (RF windows, couplers...)
- Other beam physics instrumentation



Fast ferroelectric 400 MHz tuner
successfully tested at CERN



L-band RF window
for AWA ANL

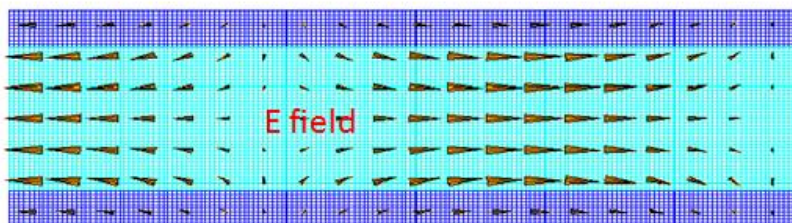
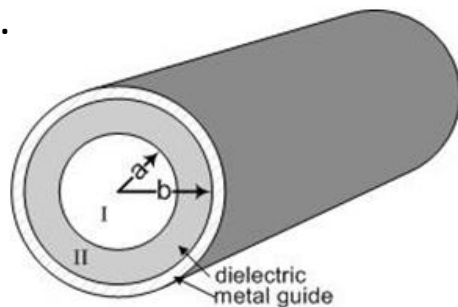


5 GHz kicker
for TEM,
BES/NIST



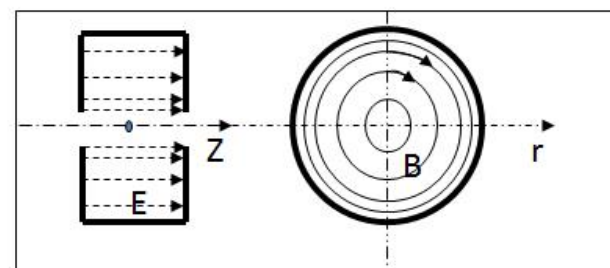
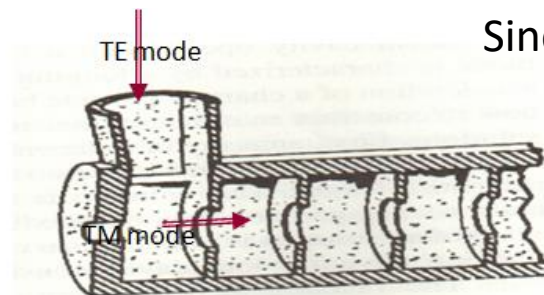
Dielectric vs. Copper

Since 1948...



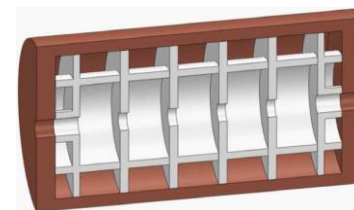
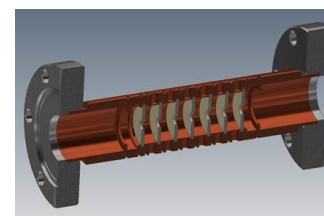
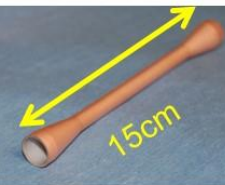
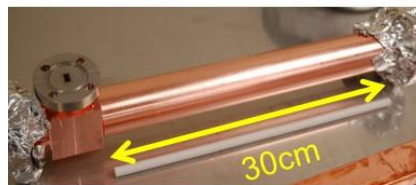
(a) Dielectric loaded accelerator

Since 1947

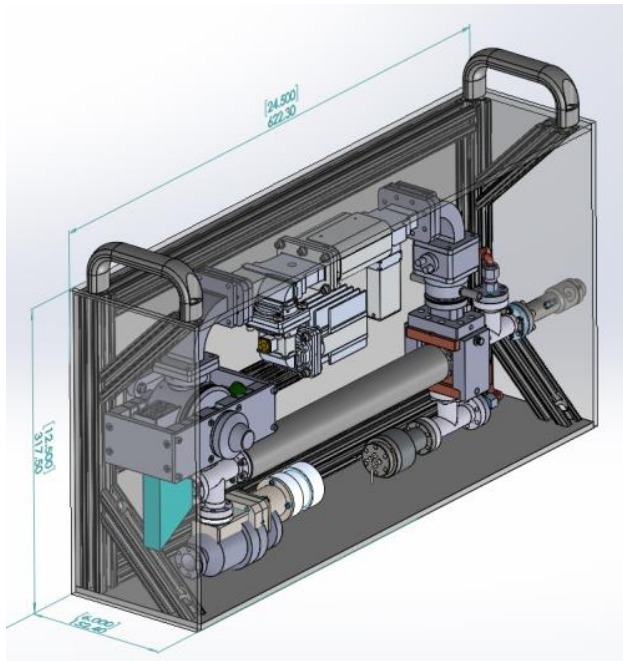


(b) Metallic disk-loaded accelerator

Dielectric accelerating structures



Introduction



With this talk, Euclid presents a portable lightweight and cost-effective \sim MeV range accelerator that is compact enough to operate as a module for an easy stack-up to increase the deliverable radiation dose.

Focus on:

- the technology to replace the conventional copper linac with a significantly lighter and more compact dielectric accelerator.
- reduce the transverse size of the accelerating structure comparable to that of an ordinary pencil (factor ~ 5 OD, factor ~ 25 surface-wise).
- -weight reduction of the structure
- weight reduction of the lead shielding

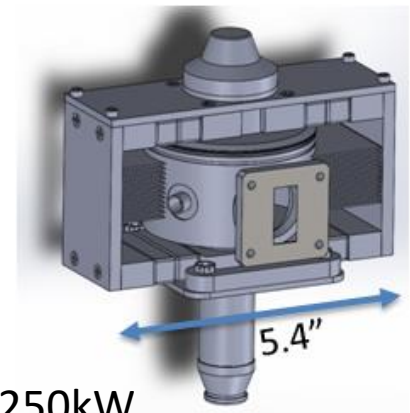
Key Challenges

Trade offs among dose rate - energy, and weight/ size

- Parameters of rf source
- Modulator (customized)
- One charge operational time vs. battery time
- Energy vs. shielding

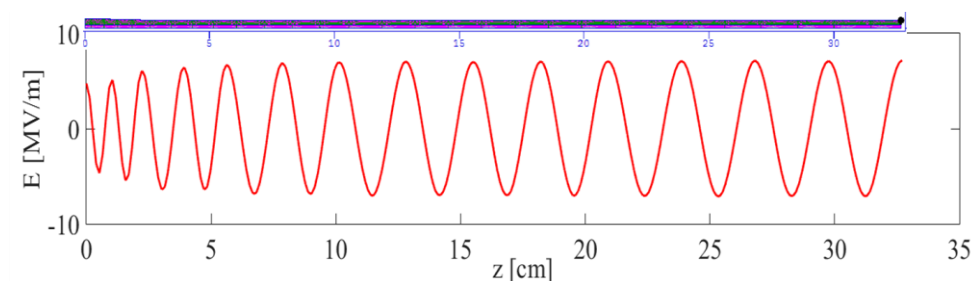
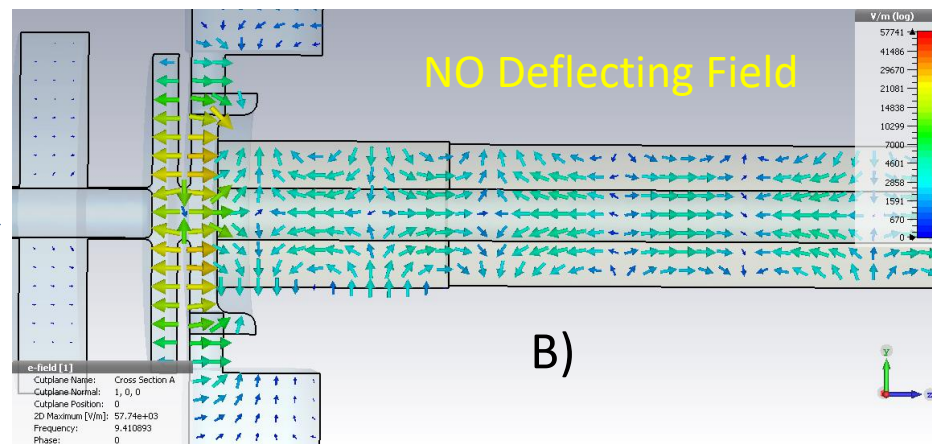
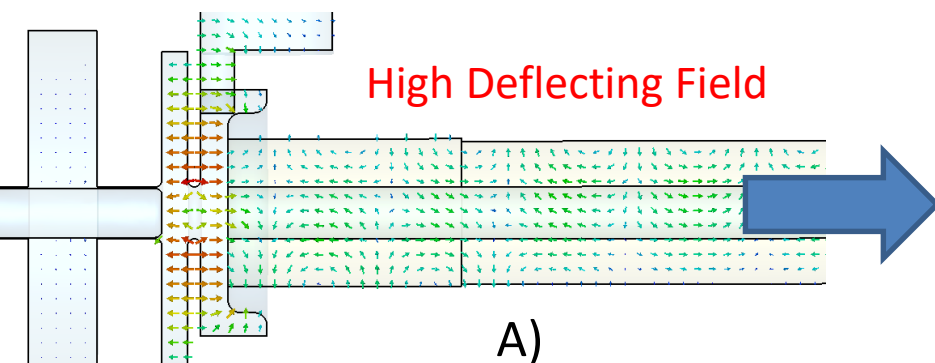
Robust system performance in “real” environment

- Solid RF coupling
- Solid beam source
- Robust beam alignment
- Multipactor



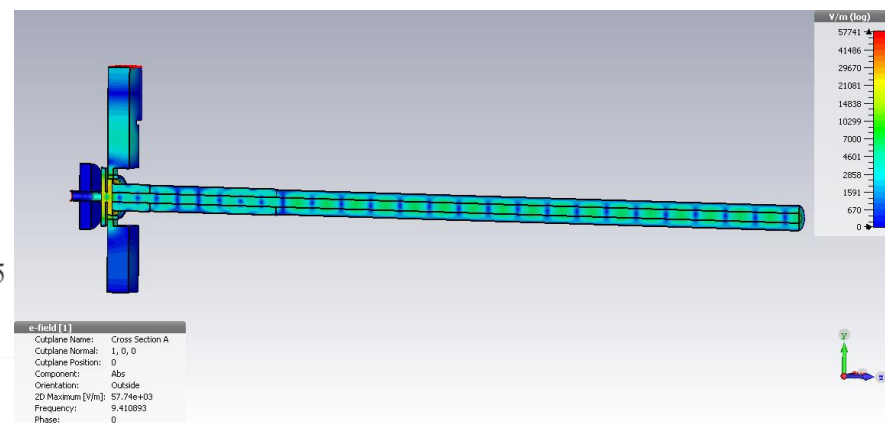
Outer dimensions of the 250kW
light-weight Magnetron, SFD352NM

Symmetry Waveguide



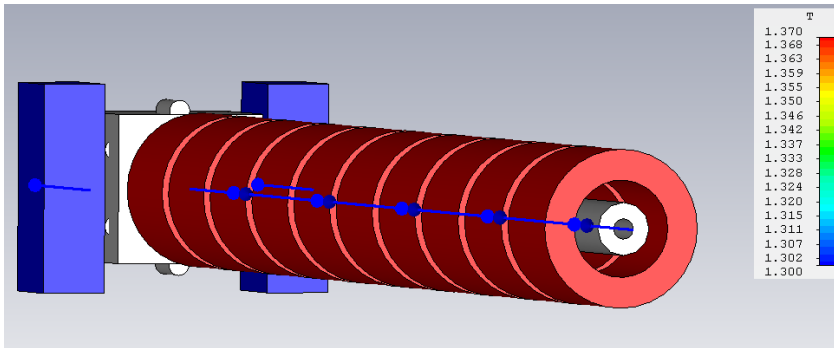
Symmetry WG was added.

- Field balance tuned by cells OD's
- Coupling was good
- S11=-40dB, S12=-80dB, S13=-120dB
@F=9.41GHz

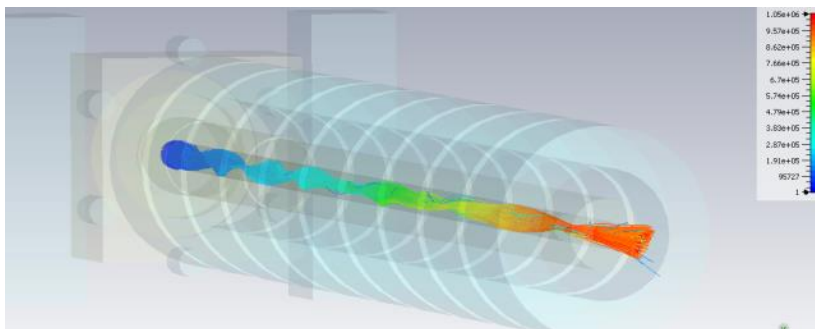


Focusing System Design Optimization

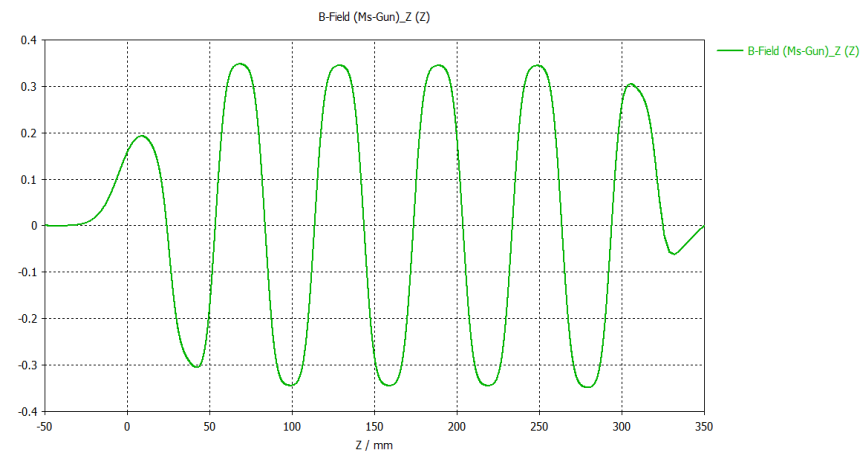
PPM along the tube plus PM blocks in the coupler



Focusing System



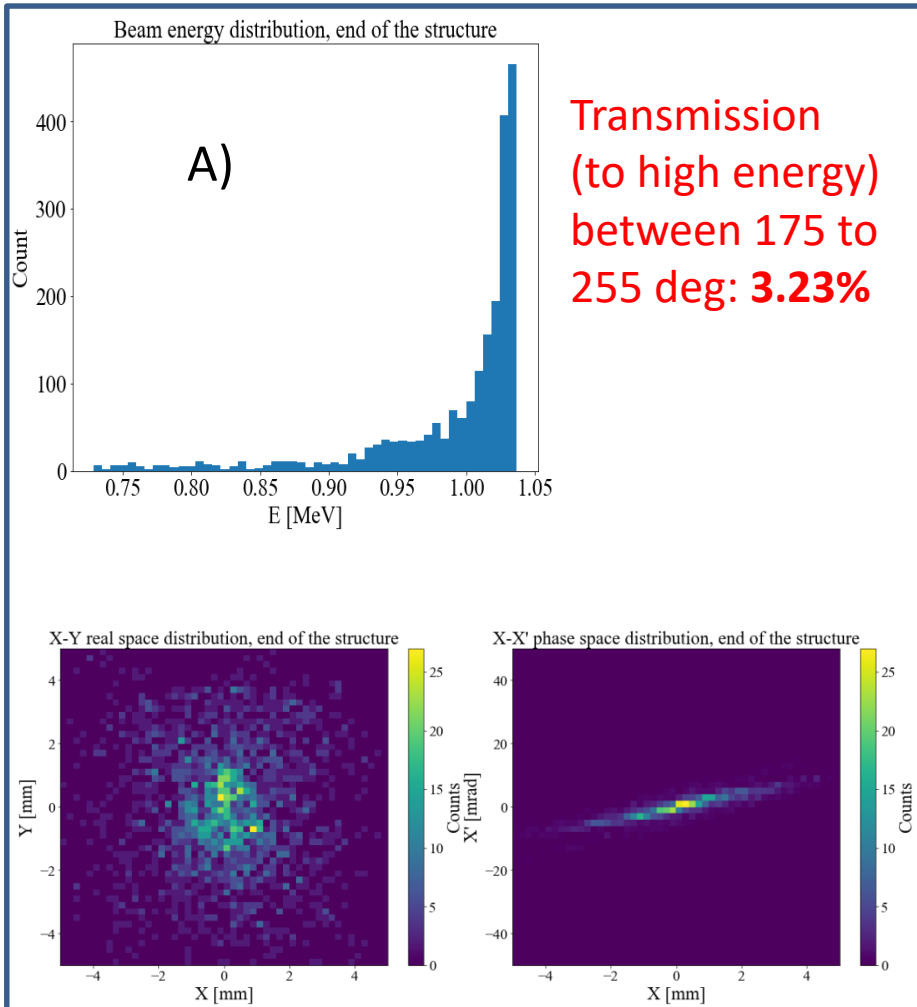
Beam tracking



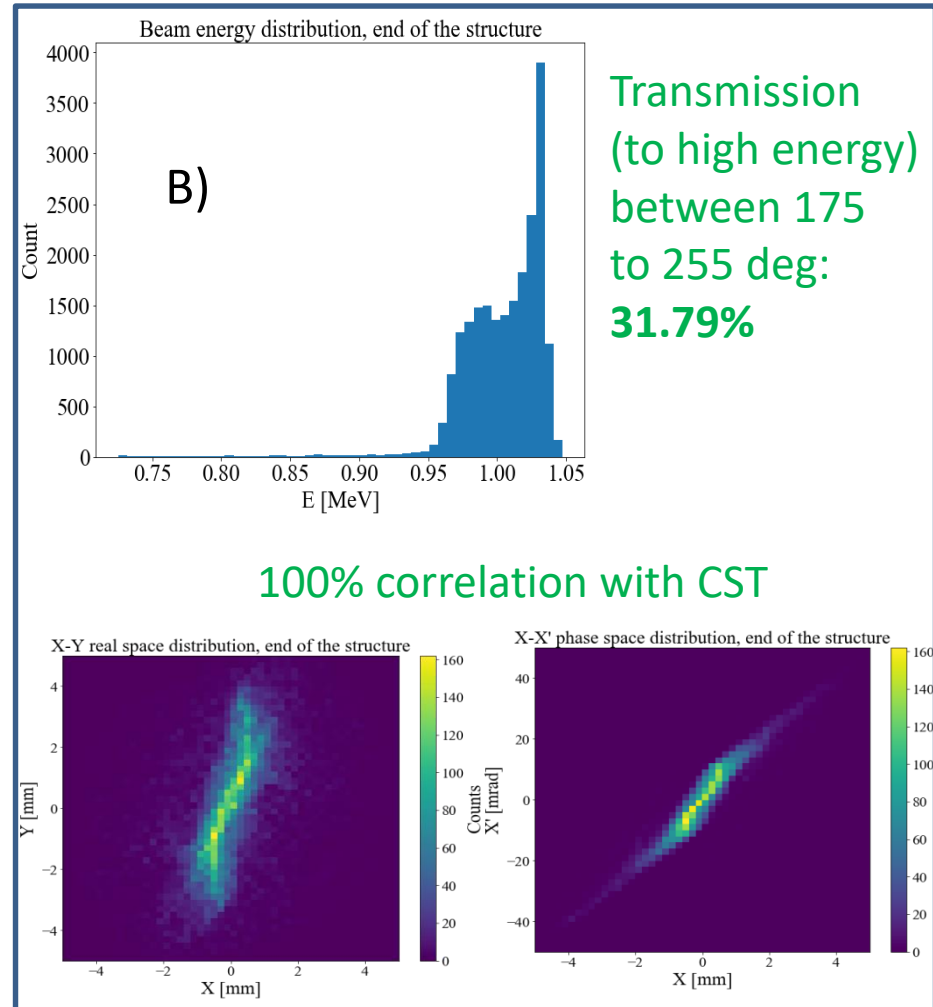
Magnetic field (T) on axis vs. Z (mm)

Beam simulation in Astra

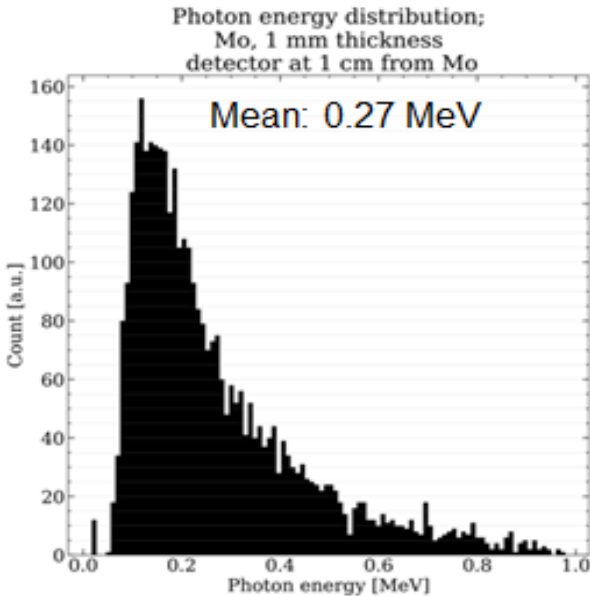
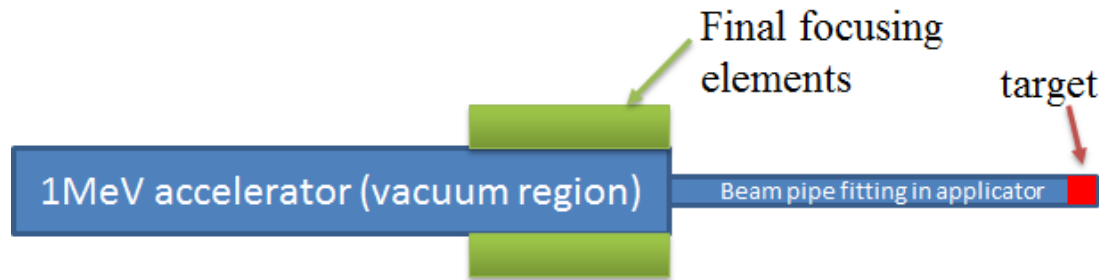
No Focusing Magnets



With Focusing Magnets



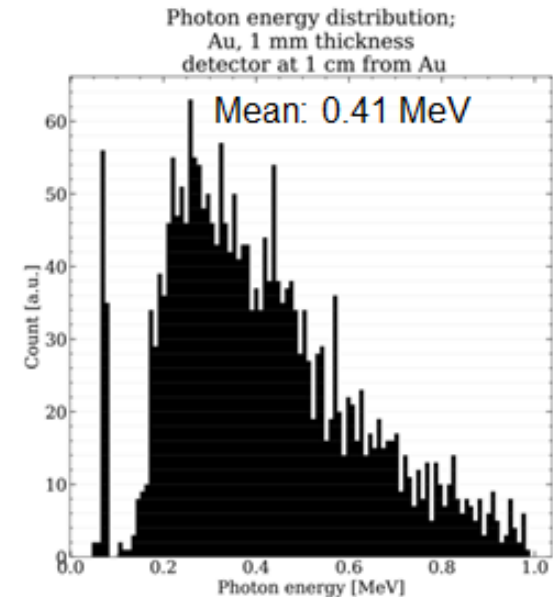
Dose Estimation for 1MeV accelerators



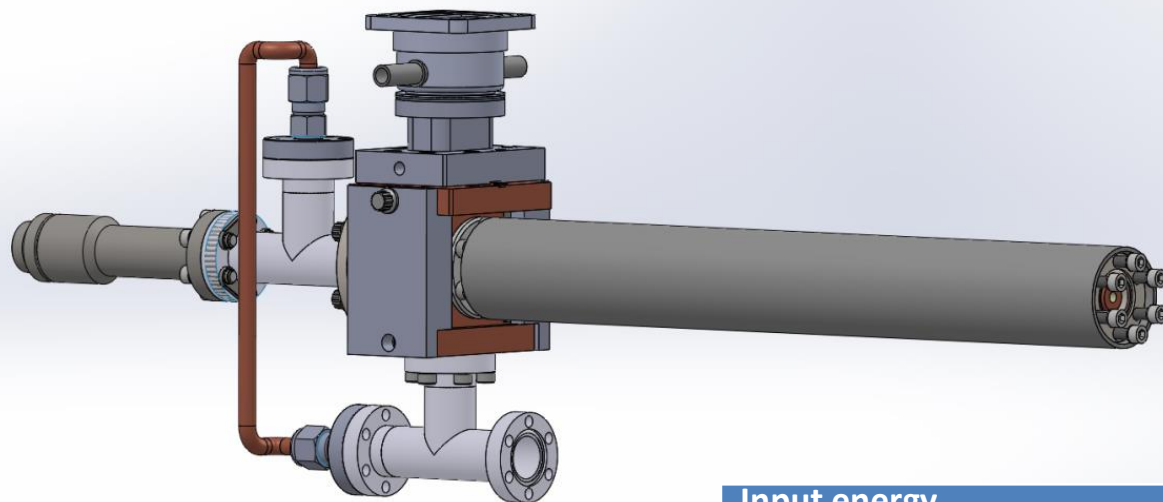
The average Dose value is **~40 mGy/min**, which can find its applications in radioactive material replacement in medical use, e.g. Electronic Brachytherapy Source.

As replacement of Ir-192

Dose can be enhanced using a higher energy beam, e.g. 3~4MeV.



1 MeV Dielectric Accelerator Engineering Design

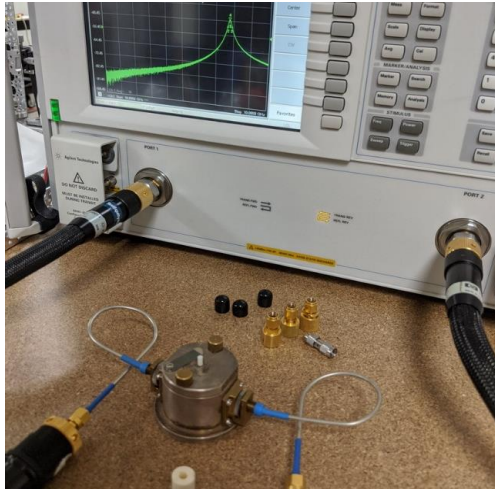


~40% of the beam is bunched and accelerated to 1 MeV after 32 cm of acceleration.

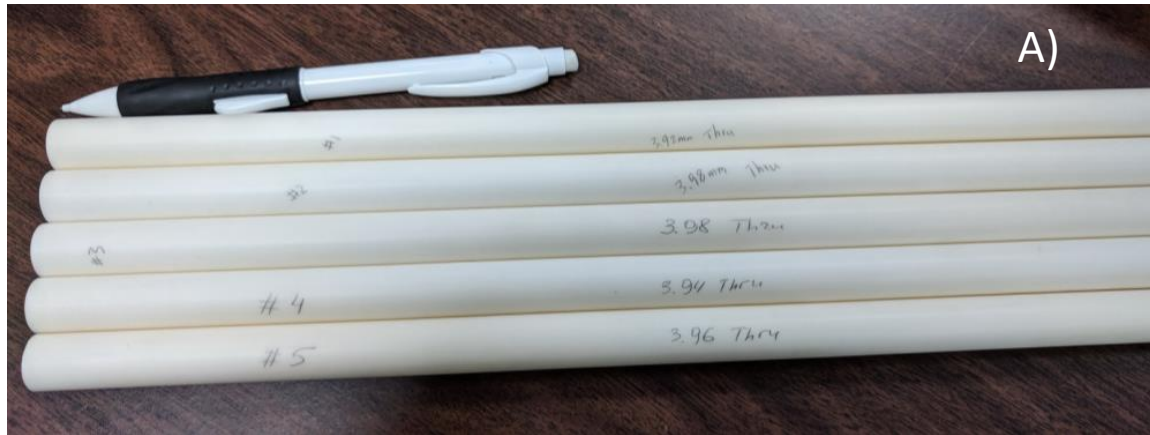
Input energy	20 keV
Input current	0.1 mA - 10 mA range
Number of cells	6
Total Length	32.70 cm
Total power	253.0 kW
Mean energy after this Section	1.01 MeV
Dielectric material	10-20 range
ID	4.0 mm
Max. OD	11.5 mm

Dielectric structure fabrication and bench test

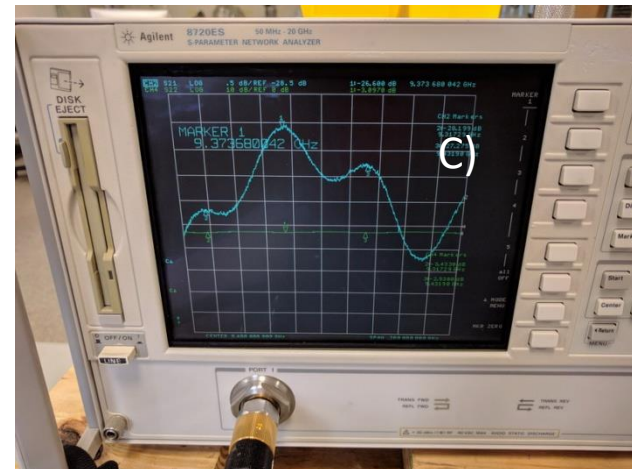
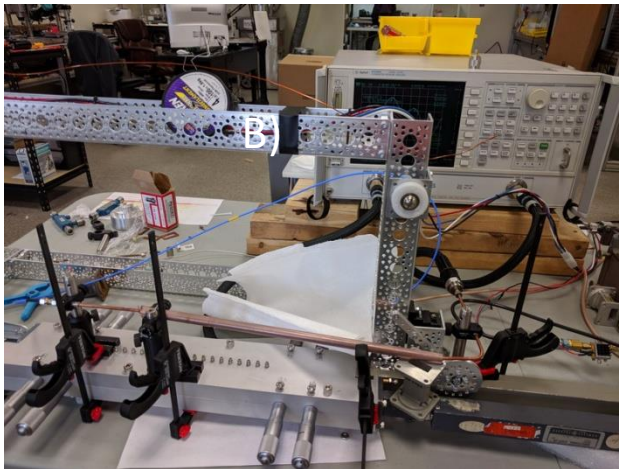
Dielectric machining upgrade and dielectric parameters measurements.



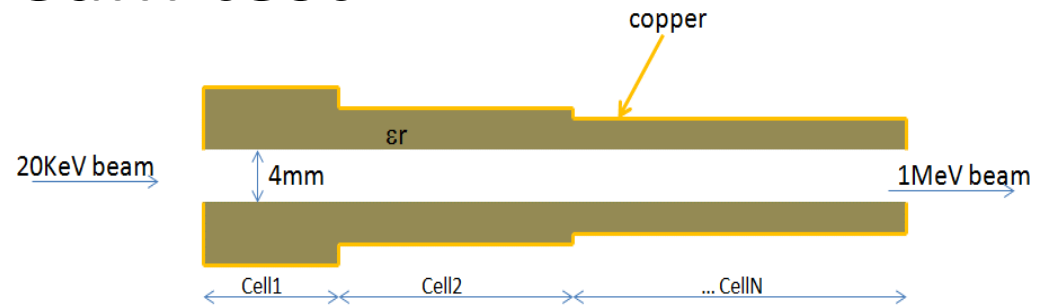
Dielectric structure fabrication and bench test



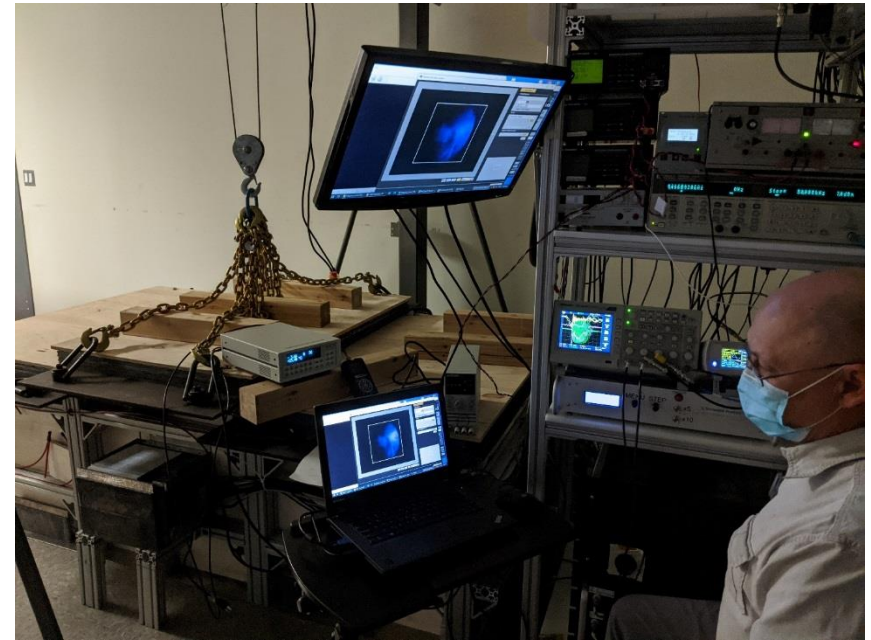
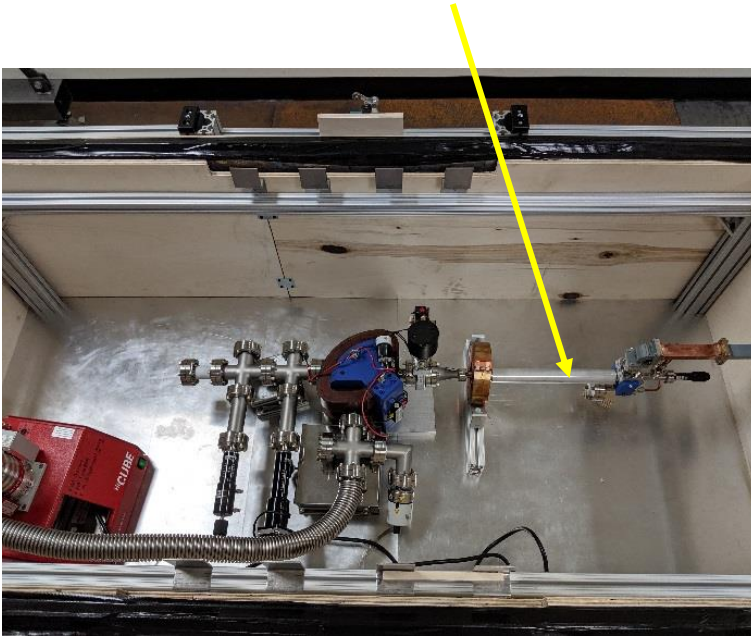
Bead-pull test



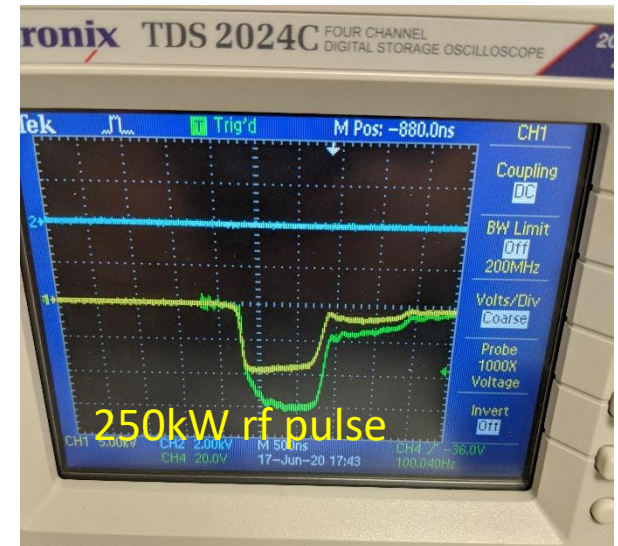
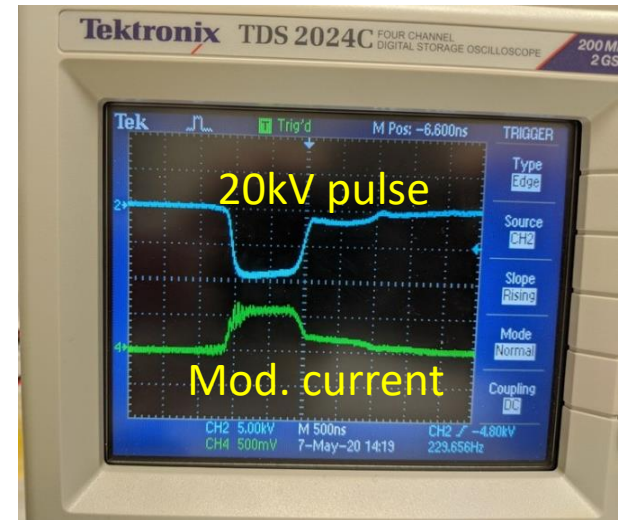
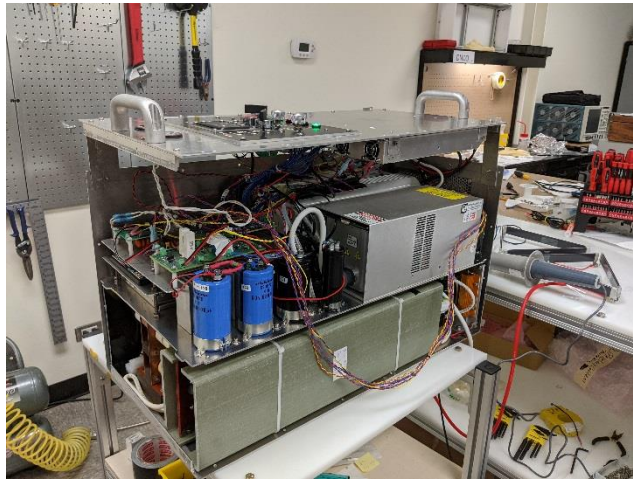
High power rf and beam test



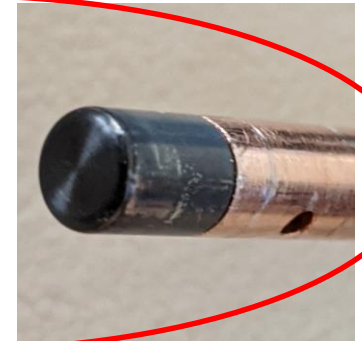
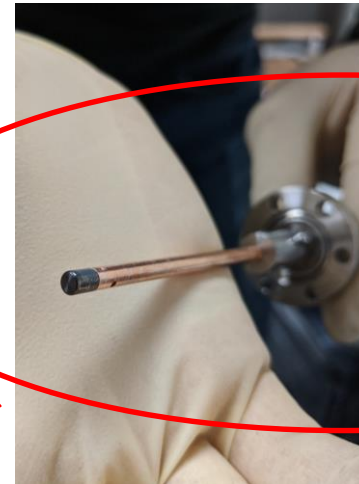
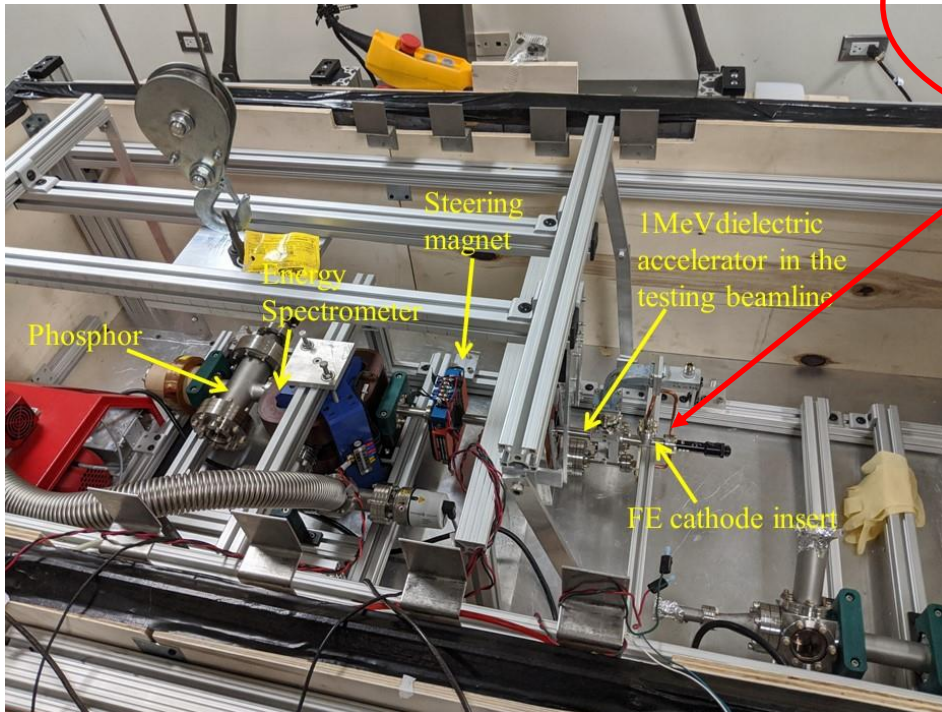
MeV e-beam Test Bunker



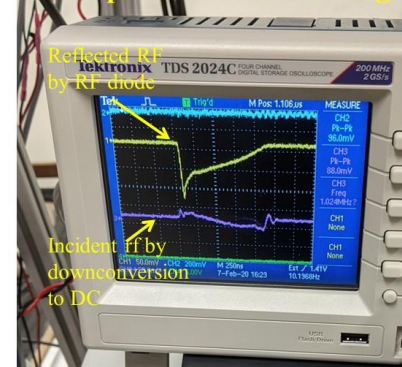
Modulator test at the test bunker



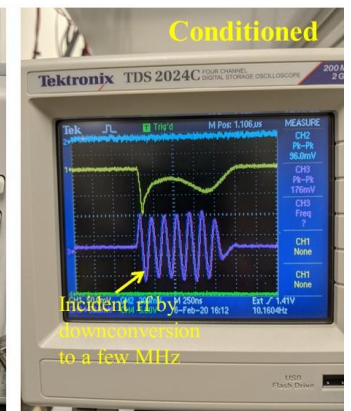
Field Emission UNCD cathode



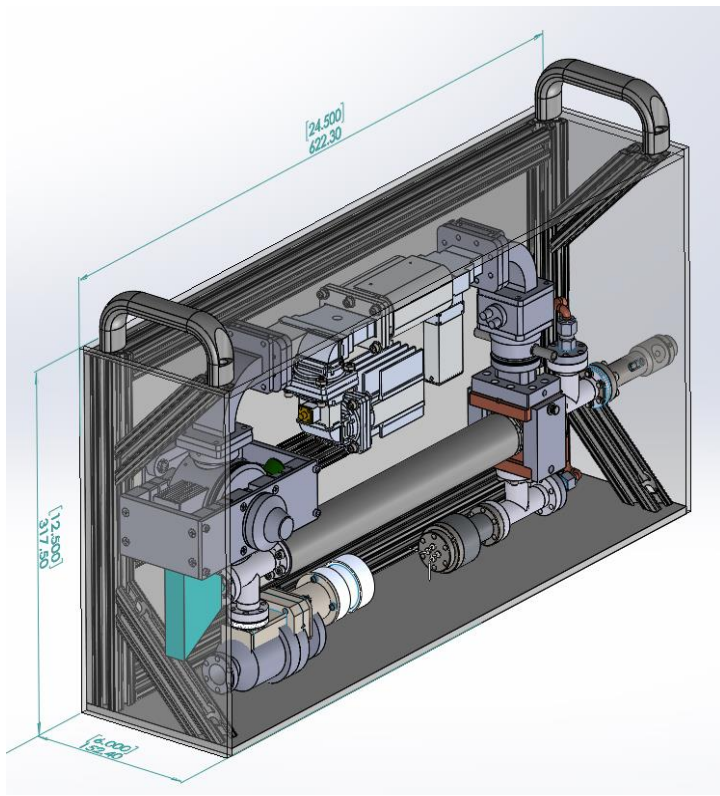
In the process of conditioning



Conditioned



Assembly



Summary

- Euclid's 1MeV dielectric based compact accelerator prototype is being developed.
- Design and fabrication were complete, bench test and high power rf test were carried out.
- We finished 4MeV dielectric based design
- Exploring new applications in Isotope Replacement and Electronic Brachytherapy (EB)

Acknowledgments



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HSHQDN-17-C-00007

References:

1. Dielectric loaded particle accelerator, US Patent 9,671,520.
2. Portable accelerator based X-ray source for active interrogation systems.
US Patent 10,910,189
3. C. Jing et al. A Portable X-ray Source Based on the Dielectric Accelerator.
PAC2018, Vancouver, BC, Canada, p.464.
4. J. Qiu, et al, IEEE Trans. on Electron Devices, 65, 3, 2018, 1132.
5. C. Jing et al. Applications of Compact Dielectric Based Accelerators.
Proceedings of LINAC'12, Tel-Aviv, Israel, p. 150.