Advanced Energy Systems: Overview & Electron Sources

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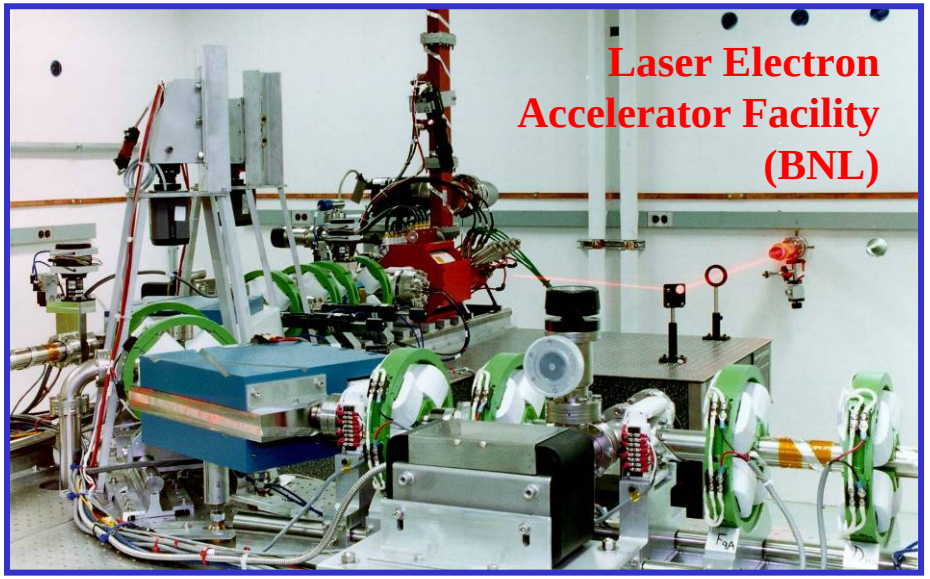
Outline

- ***AES Overview***
- Integrated Engineering and Physics Services
- Advanced Radiation Sources
  - High-Current Electron Injectors
    - Photocathode
    - Thermionic
  - High-Current Cryomodules
  - High-Power RF Couplers and Windows
- Turnkey Accelerators and Components
  - SRF Cavity Projects
  - Turnkey Beamlines
- Contacts

Advanced Energy Systems (AES)

Mission Statement

AES seeks to be the supplier of choice for advanced radiation sources based on high-brightness electron accelerator technology. AES teams with market leaders in the medical imaging, homeland security, defense and other industries to provide systems for cancer and drug discovery, non-destructive evaluation and force protection. AES is committed to providing best value and AES reliability with unsurpassed after sale support.



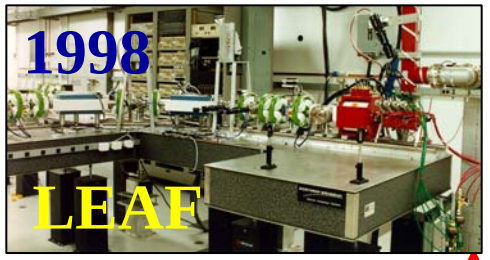
Corporate Profile

- Privately held company incorporated in New York in September 1998 (formerly an operating group of Northrop Grumman)
- Headquartered in Medford, NY with offices in Princeton, NJ and Newport News, VA
- 24 employees
- Annual sales of ~ $6M
- NC prototype machine shop including buffered chemical polishing (BCP) lab and e-beam welding capability
- State-of-the-art engineering and physics design and analysis capability
- ISO 9001-2008 with Design re-certified in July 2012

AES Evolution

- Formed within Grumman in 1975 to support the Tokamak Fusion Test Reactor (TFTR) project at the Princeton Plasma Physics Laboratory (PPPL)
- Strategic Defense Initiative (SDI) involvement in Accelerator Technology began in 1984 with the Beam Experiments Aboard Rockets (BEAR) project
- Relativistic Heavy Ion Collider (RHIC) superconducting magnet fabrication from 1992 to 1994
- Monochromatic X-Ray Imaging System (MXIS) & Laser Electron Accelerator Facility (LEAF) are examples of AES transition to accelerator applications
- Spun off by Northrop Grumman in September 1998
- Over $400M in Sales between from 1975 to 1998

ACCELERATOR TECHNOLOGY



SDI

FUSION

MAGNETS

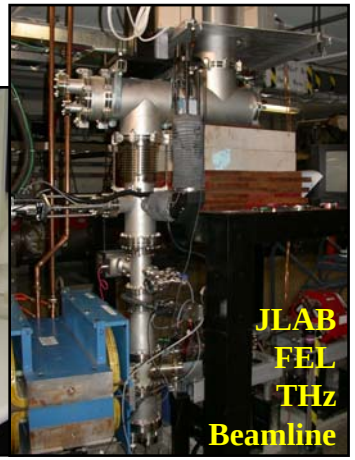
Advanced Energy Systems

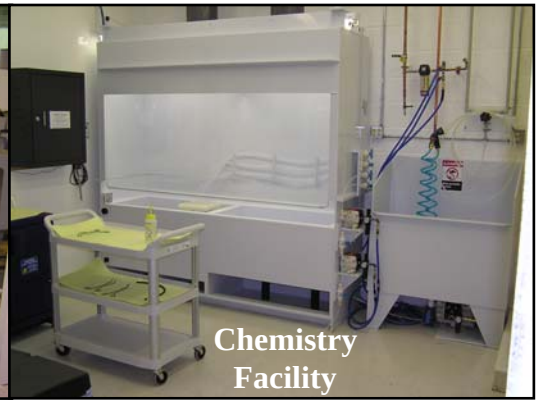
Mission Statement

AES seeks to be the supplier of choice for advanced radiation sources based on high-brightness electron accelerator technology.

Product Areas

- ***Advanced Radiation Sources***
  - Free Electron Lasers (FEL)
  - High-Power Microwaves (HPM)
  - High-Power TeraHertz (THz) Sources
  - Tunable, Monochromatic X-Ray Sources
- ***Turnkey Accelerator Systems & Components***
  - Photocathode Injectors
  - Superconducting RF (SRF) Accelerators
  - Normal-Conducting Accelerators
  - Beam & Optical Transport Systems
  - Turnkey Beamlines
- ***Integrated Engineering & Physics Services***



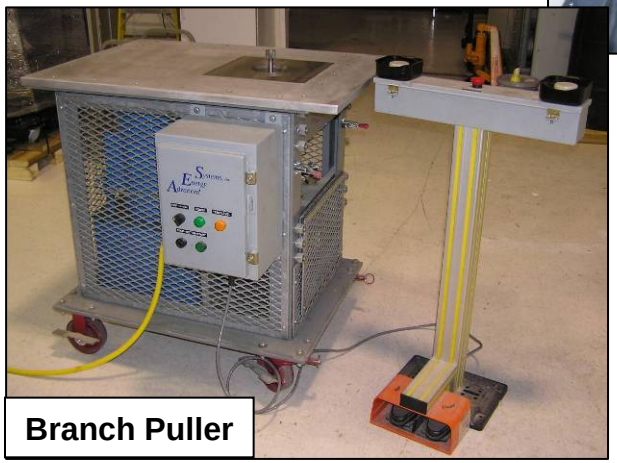


AES Medford Machining and SRF Facilities

CNC Machine Shop & Forming


300 Ton Press


CNC Machine Shop


Branch Puller


Tube Drawing Press And Die Sets

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AES Manufacturing Capability

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Medford Facility has 12,000 ft^2 of Manufacturing Space

Machine Tools

- HAAS VF-8/50 3 Axis CNC Mill, 64”x40”x30”
- HAAS VF-5/50 3 Axis CNC Mill, 50”x26”x26”
- Okuma 3 Axis CNC Mill, 40”x20”x20”
- HAAS SL-40 CNC Lathe, ϕ40”x 44” Length of turn
- Okuma CNC Lathe, ϕ17.7” x 20” Length of turn
- HAAS TL-3 Hybrid Manual/CNC Lathe
- (2) Series 1 Bridgeport Mills - 30” Travel
- Harrison Gap Bed Lathe ϕ16.5” x 40” Length of turn (ϕ24” w/ gap removed)
- Hardinge Tool Room Lathe ϕ6” x 15” Length of turn

Sheet Metal – Metal Forming

- LUNA Plate Bending Roller – 50” x 10 ga.
- Niagara Power Shear - 10 gage x 48 in.
- Whitey Metal Tool Sheet Metal Notcher
- 20 in. Hand Roller
- LVD Power Brake - ¾ Mild Steel x 48 in.
- Leaf Brake 16 Gage x 24 in.
- KR Wilson - 50 Ton Hydraulic Press

Welding Equipment

- Hobart 400 Amp Arc Welder
- (2) Linde 300 Amp TIG Welders
- Cobramatic 300A MIG Welder
- Gas Cutting & Welding Outfit
- Cajon Orbital Arc Welder
- Argon Enclosure for Nb & Ti Welding

Vacuum Test Equipment

- Varian Model 979 Mass Spectrometer Leak Detector with 1x10^{-11} Sensitivity
- Veeco Model MS-20T Mass Spectrometer Leak Detector with 1x10^{-9} Sensitivity
- Turbomolecular pumping station

Inspection Equipment

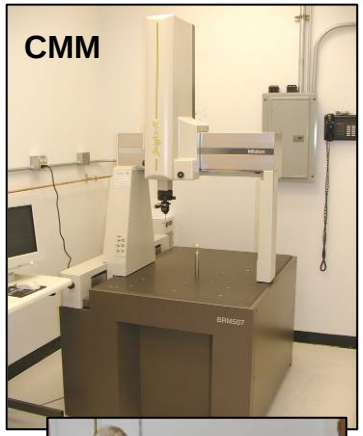
- Mitutoyo BRT-M507 Coordinate Measuring Machine – 20” x 28” x 16”

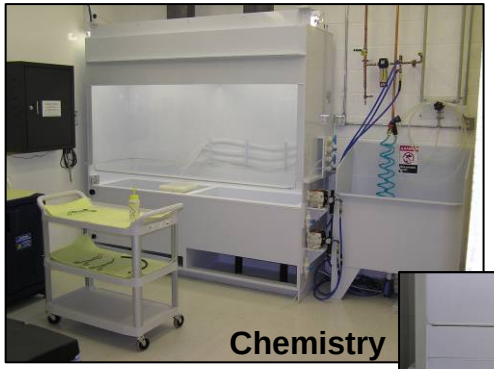
Metrology Equipment

- (3) Brunson Optical Transit Squares
- (2) Wild Precision Optical Levels
- (2) Wild T-2 Theodolites
- (2) Taylor-Hobson Line Scopes
- (2) Talyvel Electronic Levels
- (3) Alignment Lasers
- Scope Stands, Scales, Targets, etc

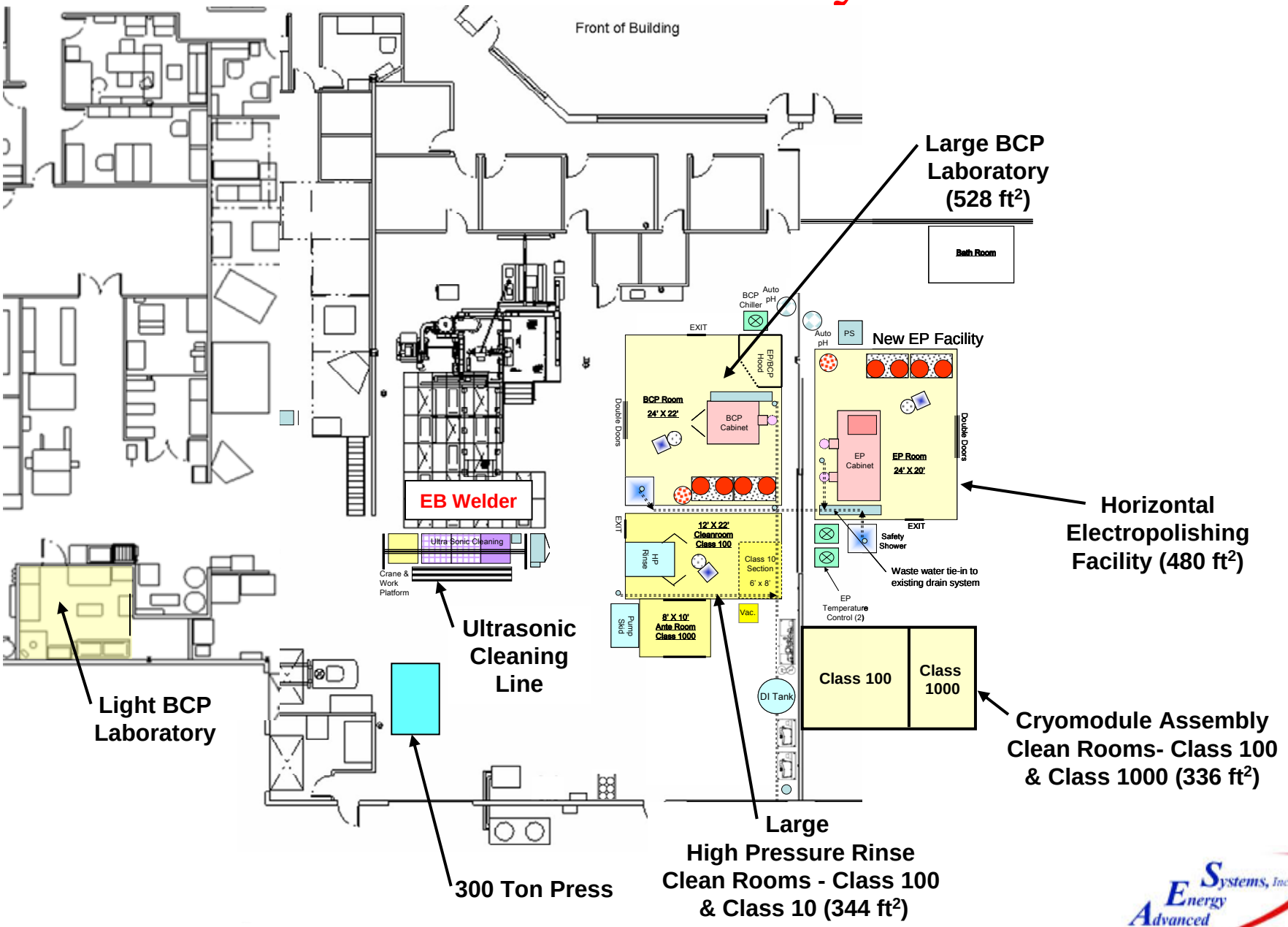
Chemical Treatment

- For pre-weld BCP of Nb components
- Millipore 35 lph Ultra-pure Water System w/ 350 liter storage
- Negative pressure room with 1200 CFM fume hood
- Class 10 laminar flow bench for drying and bagging

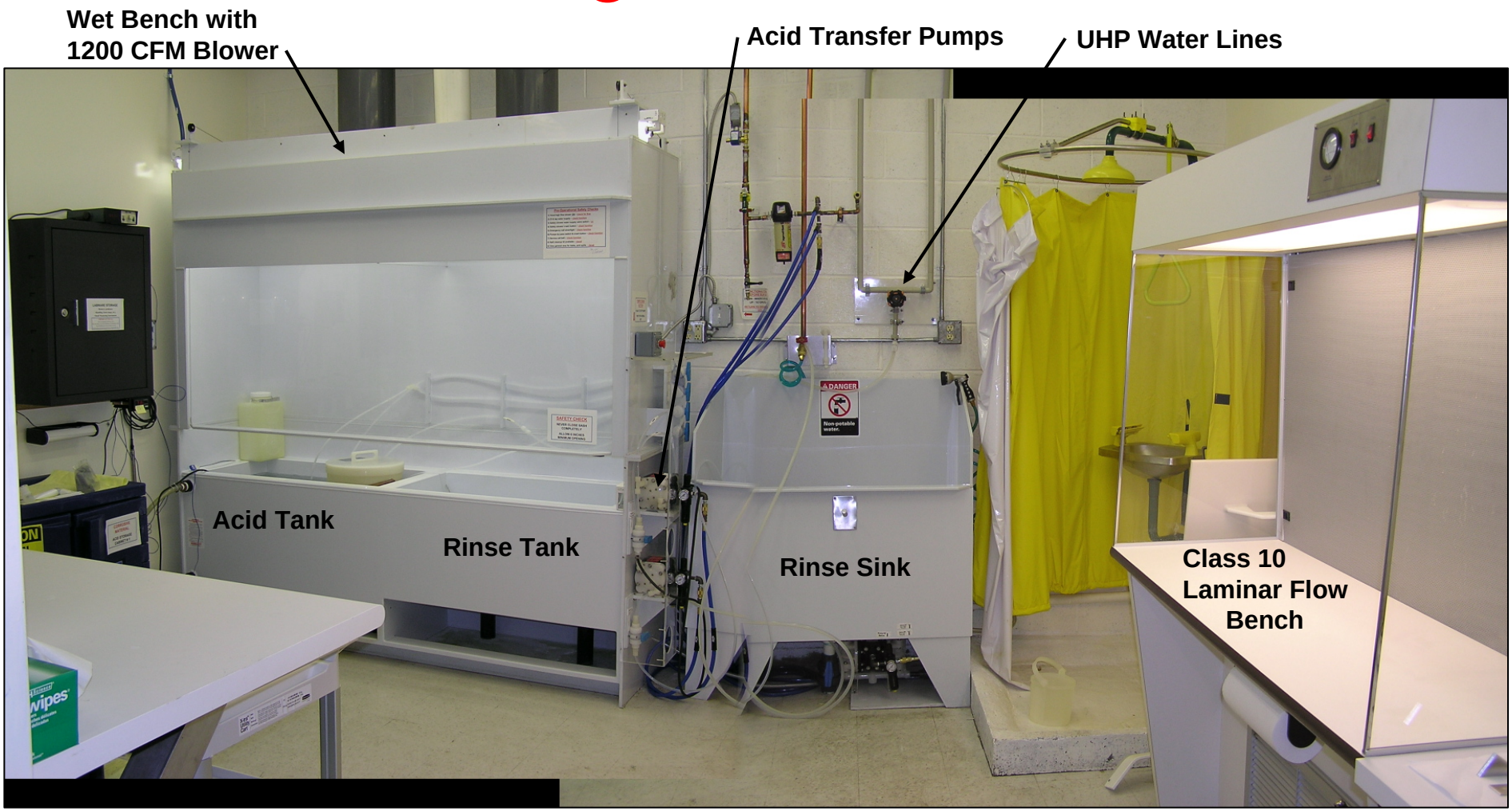




EB Welder and Chemistry Facilities

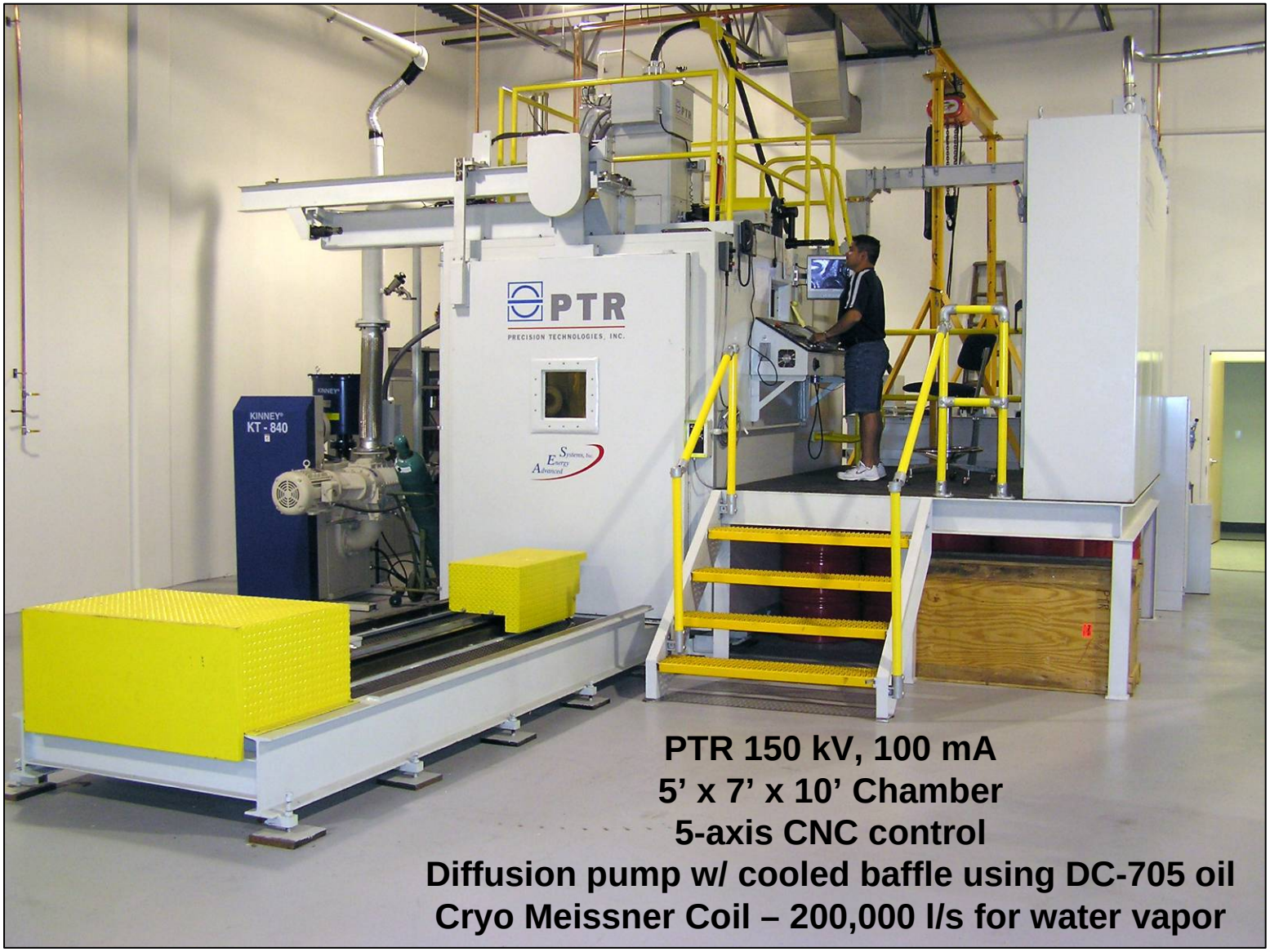


Light BCP Lab



- 200 sq. ft. negative pressure room – filtered inlet vents (not HEPA)
- Double-wall cooled acid tank – 12 kW chiller
- Millipore UHP water system provides 100 l/hr at >10MΩ, .05 mm filtered, 2500 liter storage

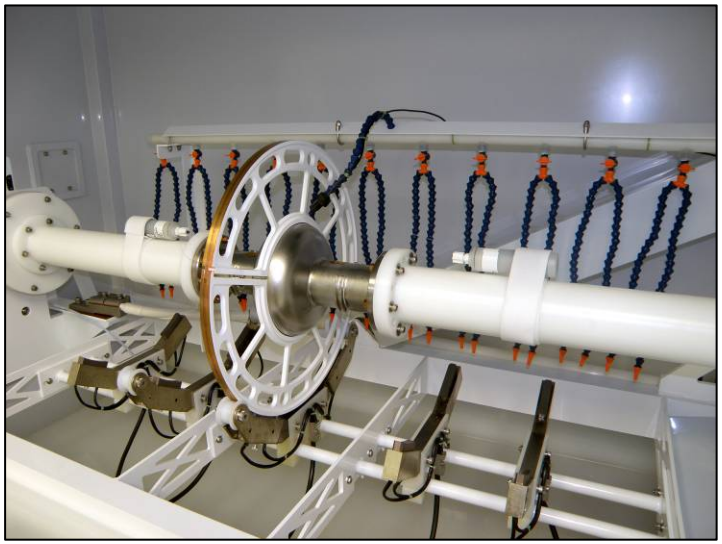
EB Welder at AES (Shown Prior to Clean Room Instl)



PTR 150 kV, 100 mA
5' x 7' x 10' Chamber
5-axis CNC control
Diffusion pump w/ cooled baffle using DC-705 oil
Cryo Meissner Coil – 200,000 l/s for water vapor

BNL/AES BCP and HPR Facilities at AES

Electropolishing Facility



- Designed and Built under contract to Fermlab

AES Princeton RF & THz Test Facility

AES Princeton Office
100 Forrestal Road
Suite E
Princeton, NJ 08540

Princeton University
Forrestal Campus

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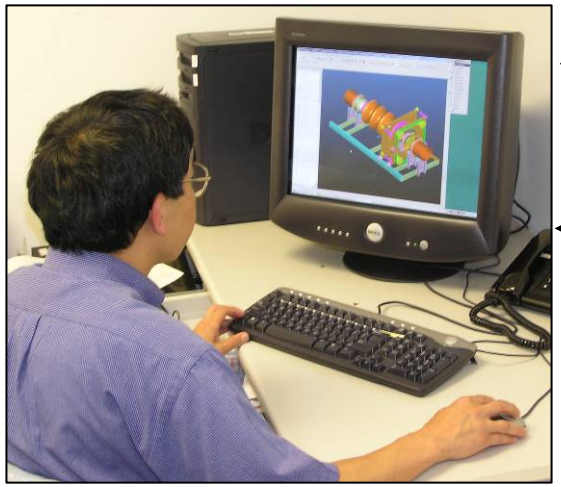
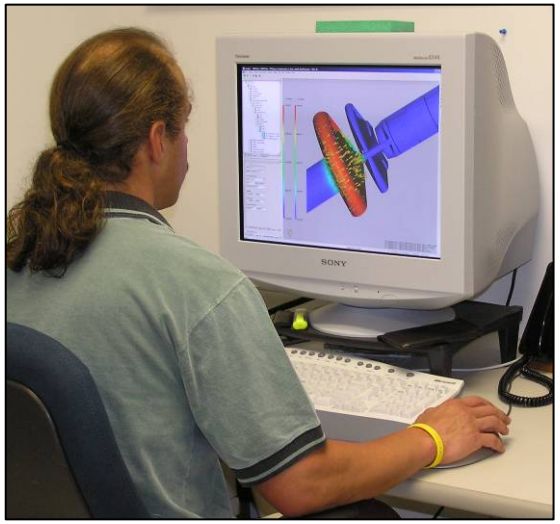
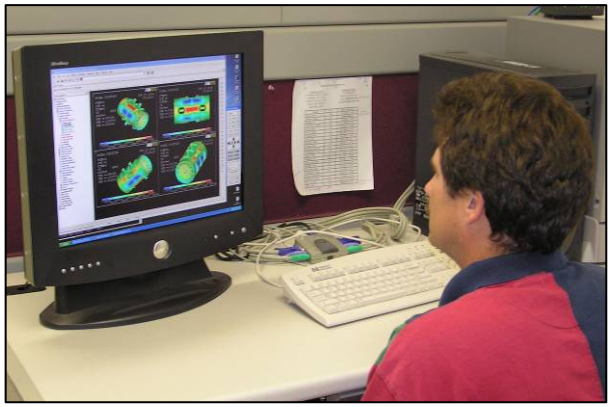
Integrated Engineering & Physics Services



←Design – Pro/ENGINEER
- Solidworks

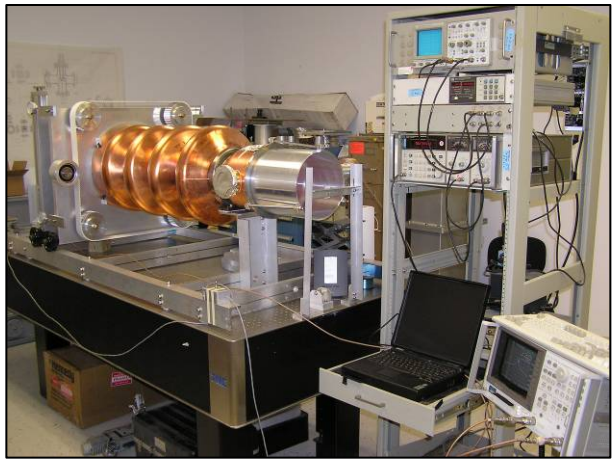


RF Analysis – ANALYST →
- ANSYS



←Engineering Analysis
– ANSYS Multiphysics

TEST
RF Structures Lab →



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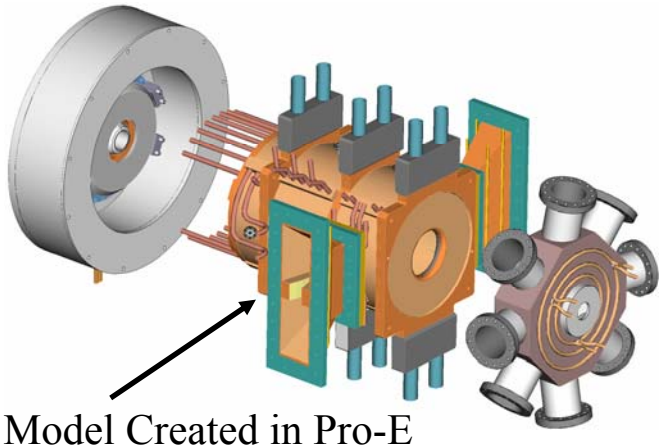
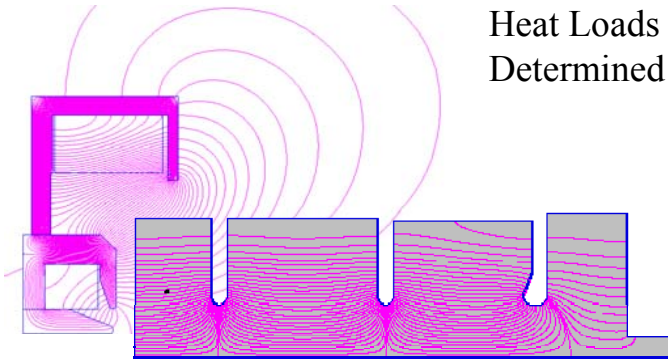
Engineering Design Process



Solid Model Created in Pro-E

RF Analysis in SUPERFISH & ANALYST

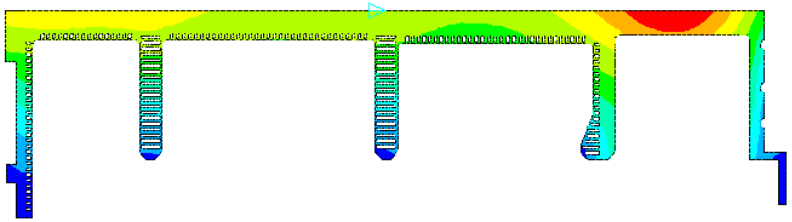
Heat Loads Determined

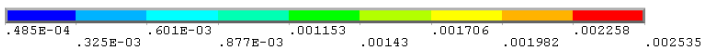


Iterate

Frequency Shift

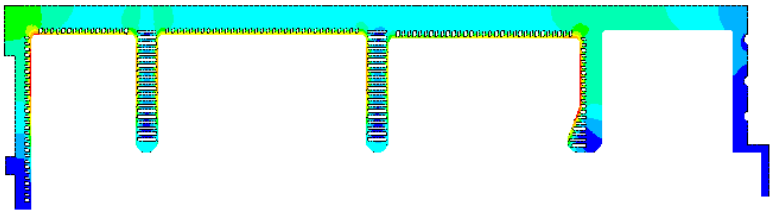
Structural Results Radial Displacements ANSYS





Radial Displacement inches

2-D Thermal Model ANSYS- Geometry from Pro-E



Temperature Distribution Determined

Temperature C

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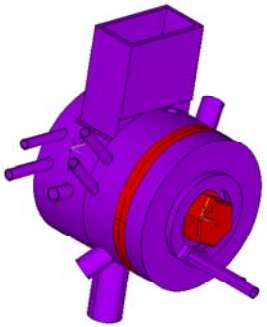
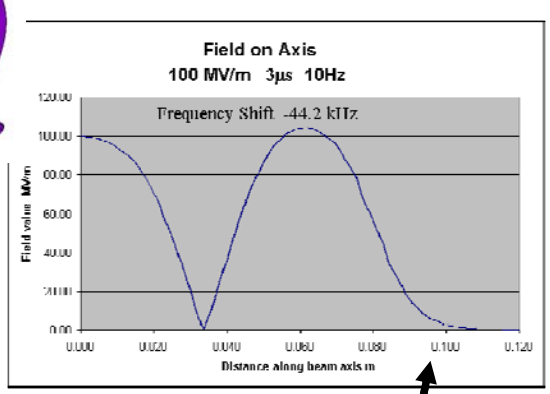
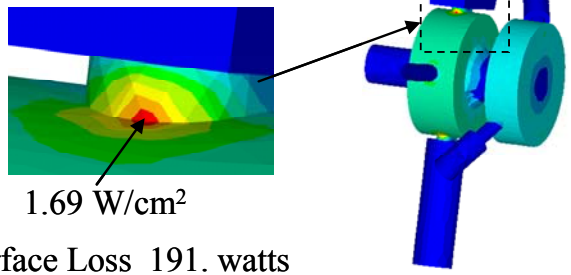
Engineering Design Process II



100 MV/m 3 ms 10 Hz



RF Heat Loads From Magnetic fields



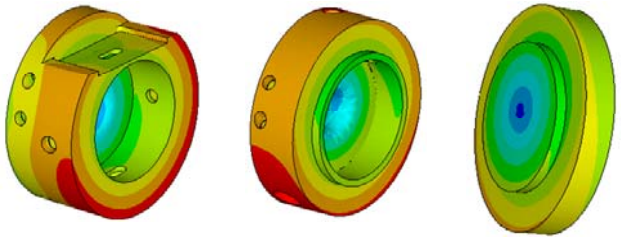
1.69 W/cm^2

Surface Loss 191. watts

RF Heat Loads on surface W/cm2

0.0 .198 .374 .561 .749 .936 1.12 1.31 1.50 1.69

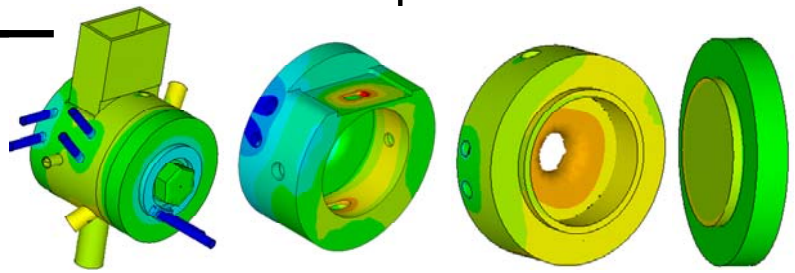
Displacements from Structural Analysis



Radial Displacements - in

-.318e-5 .214e-5 .746e-5 .128e-4 .181e-4 .234e-4 .287e-4 .341e-4 .394e-4 .447e-4

Temperatures



Temperature ºF

20. 20.16 20.32 20.48 20.63 20.79 20.95 21.11 21.27 21.42

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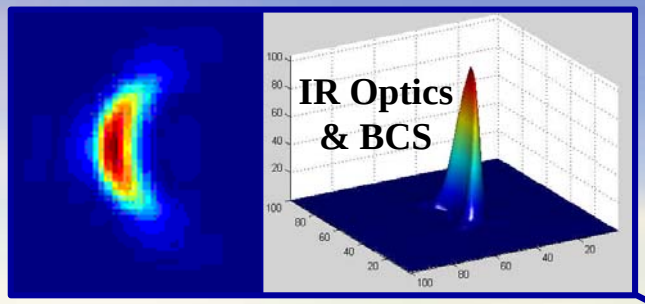
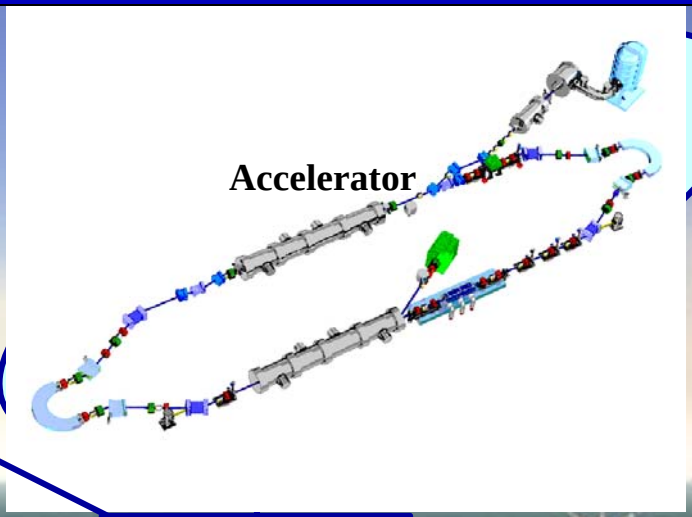
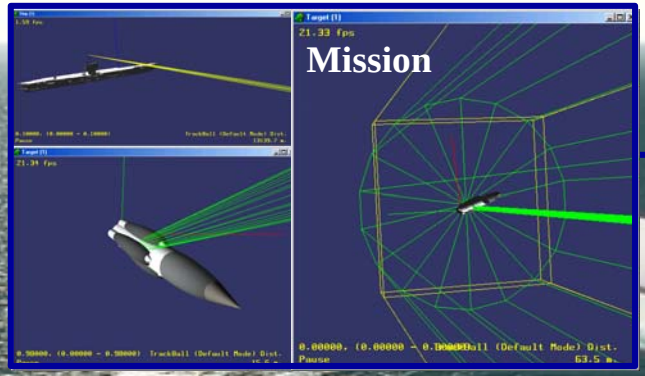
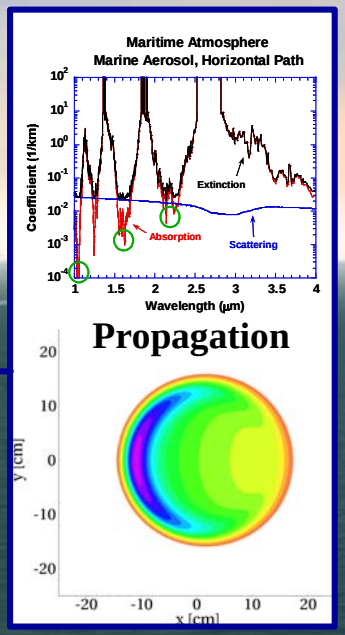
Systems Engineering Analysis & Modeling

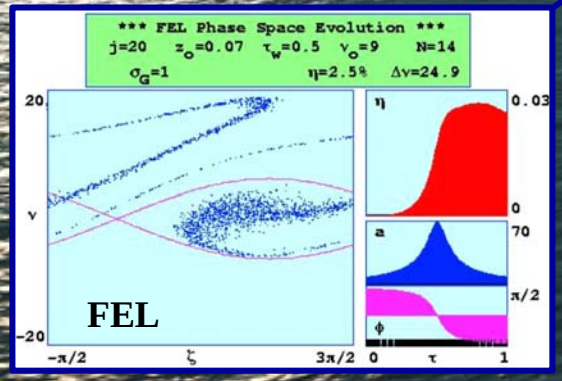


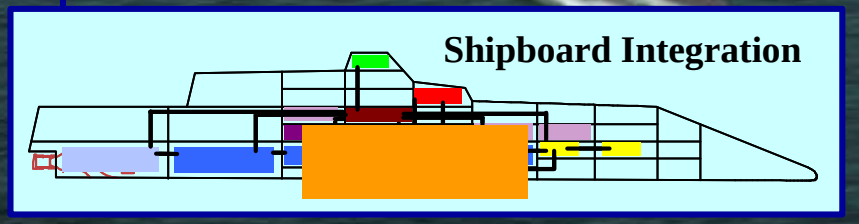




FELSIM Mediator







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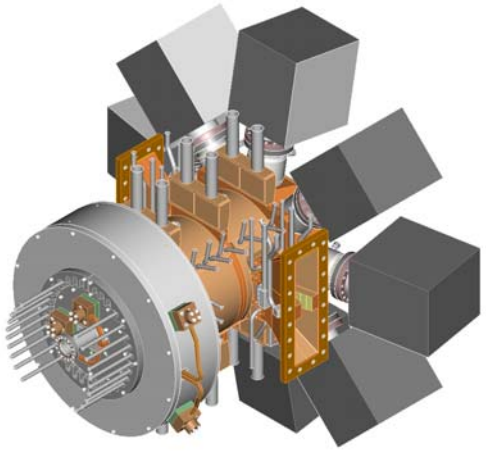
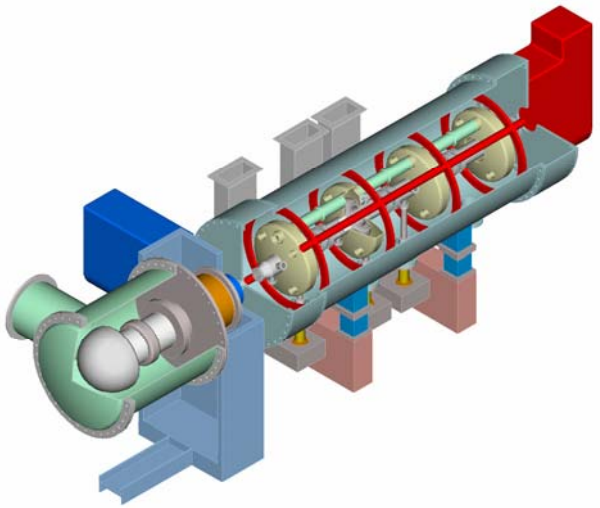
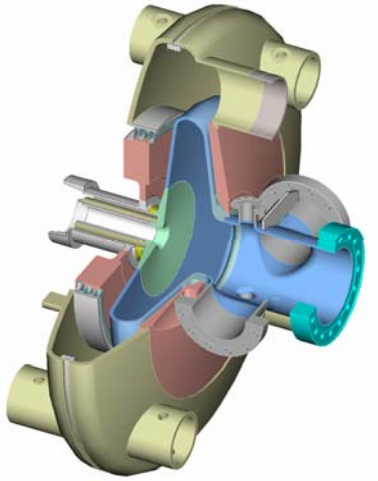
Electron Gun Performance & Requirements

	NCRF Gun	DC Gun & SRF Booster	SRF Gun
Frequency (MHz)	700.00	748.50	703.75
Output Energy (MeV)	2.5	7.0	2.0
Current (mA)	100	100	500
Bunch Charge (nC)	3.0	0.135	1.4
PRF (MHz)	33.3	748.5	351.9
Transverse Emittance (mm-mrad)	6.0	1.2	1.6
Longitudinal Emittance (keV-psec)	145	44	30
Momentum Spread (10^{-3})	5	4	5
Bunch Length (psec)	9.3	6.3	7.7



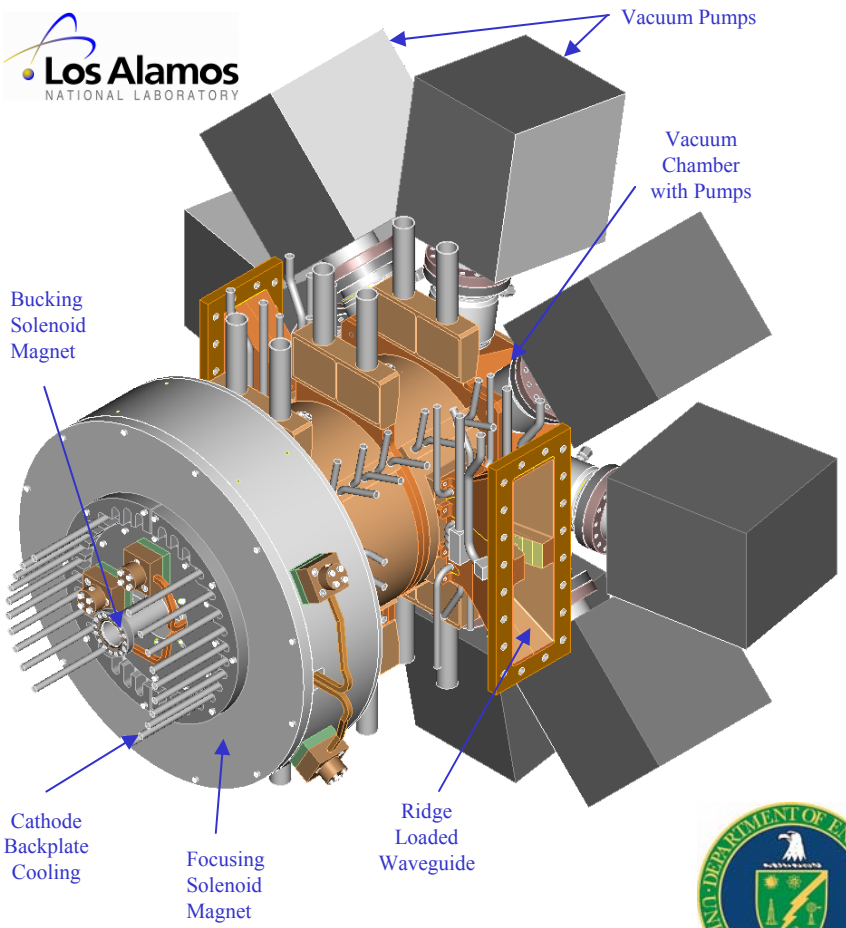




High-Current Electron Injector Options

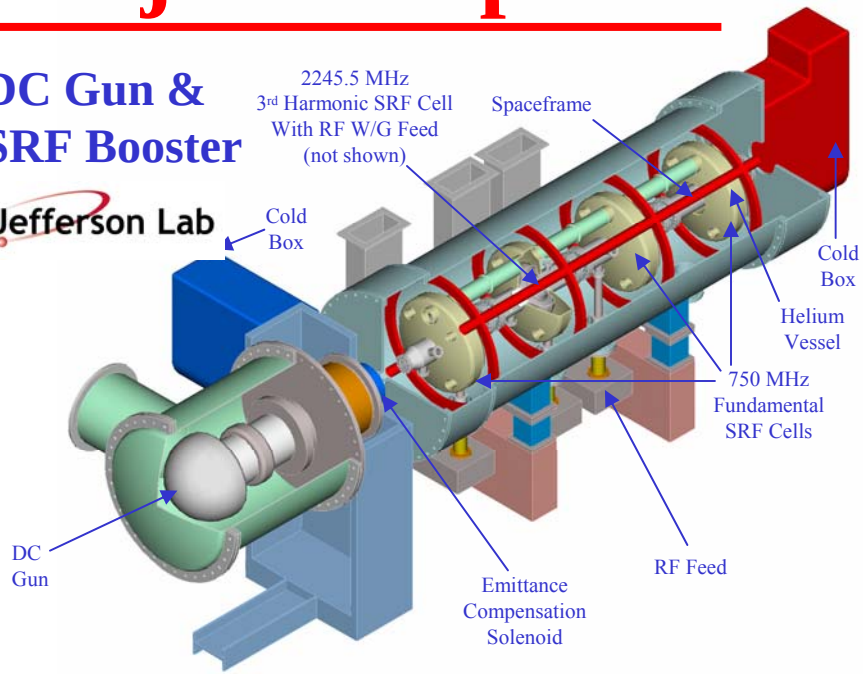
Normal Conducting Gun

Los Alamos NATIONAL LABORATORY



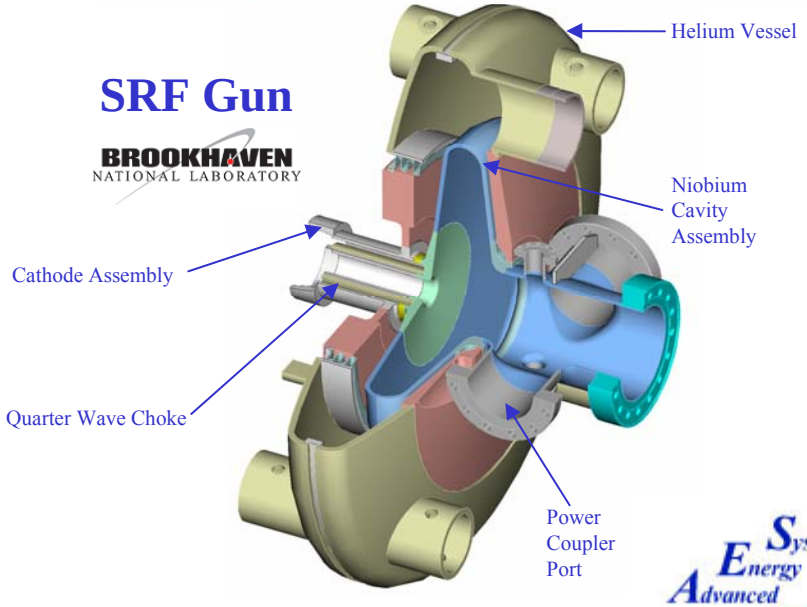
DC Gun & SRF Booster

Jefferson Lab

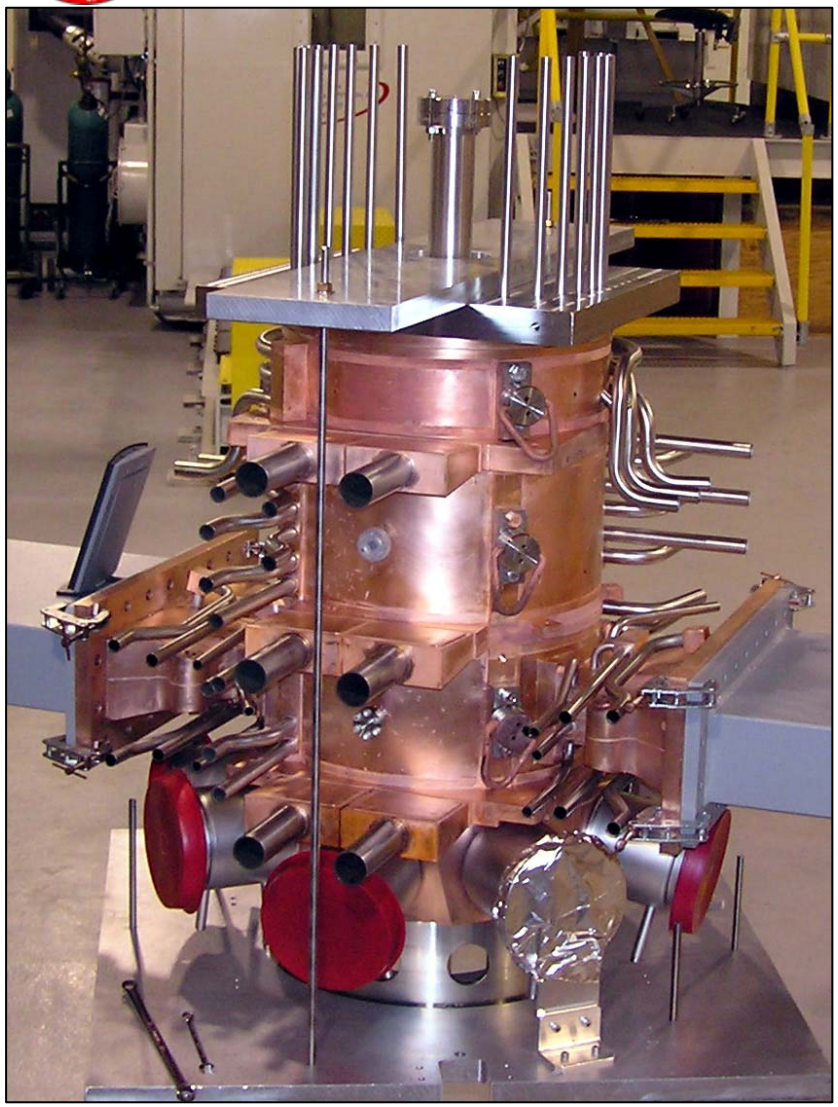


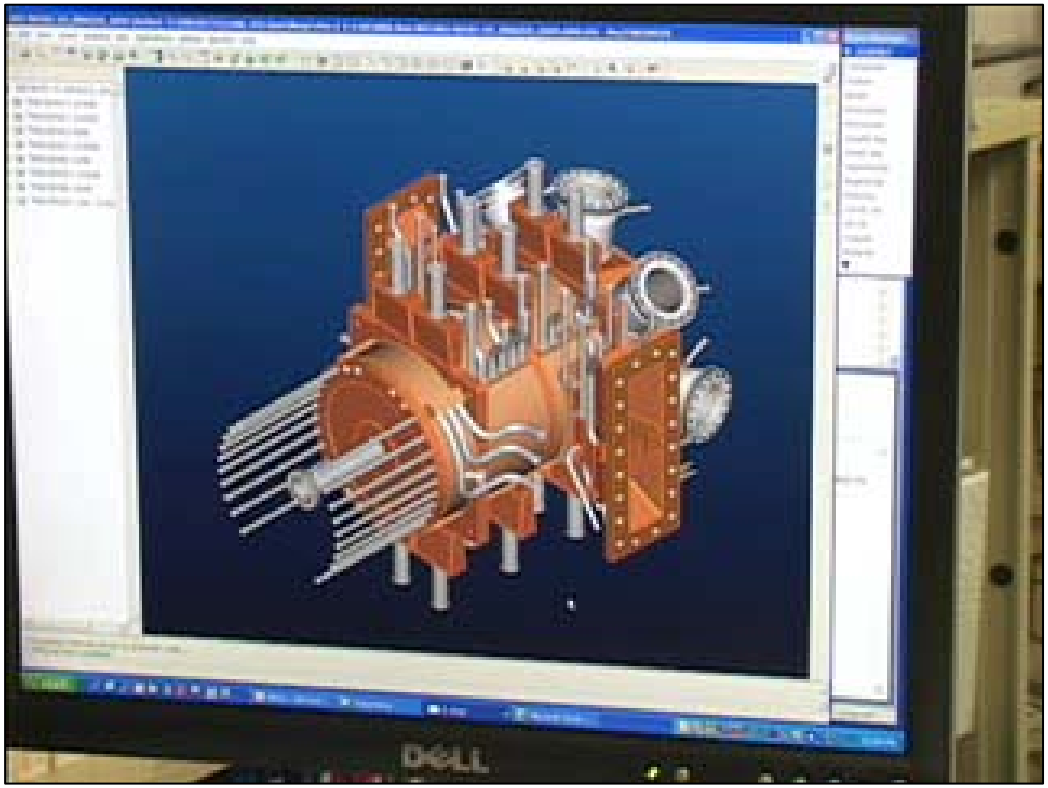
SRF Gun

BROOKHAVEN NATIONAL LABORATORY

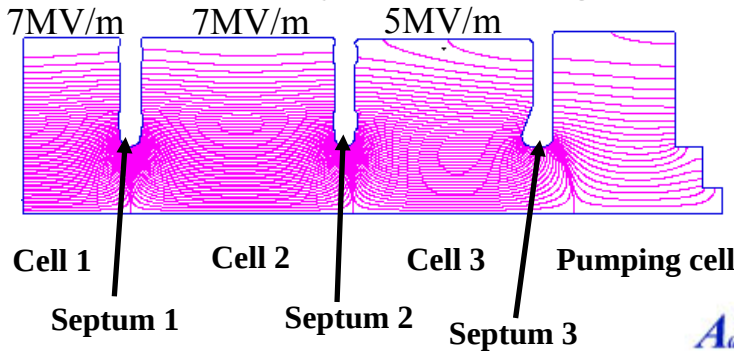


NCRF Gun Assembly

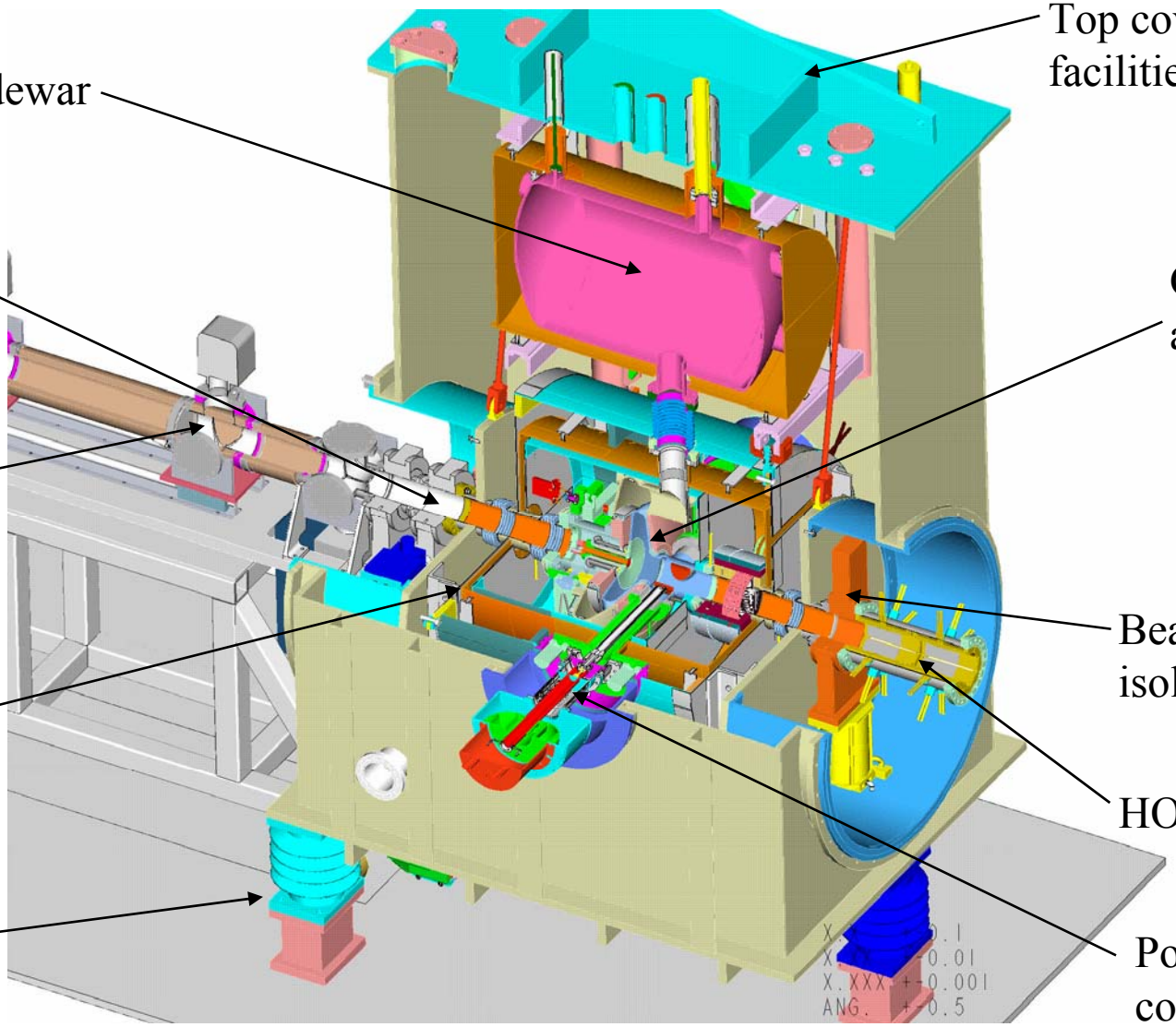




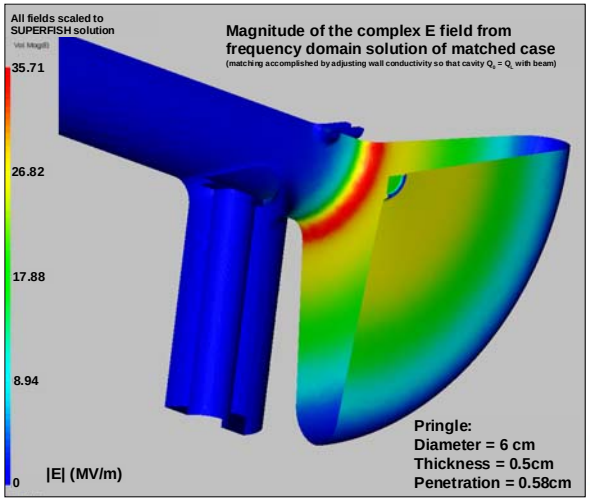
Los Alamos Physics & RF Design

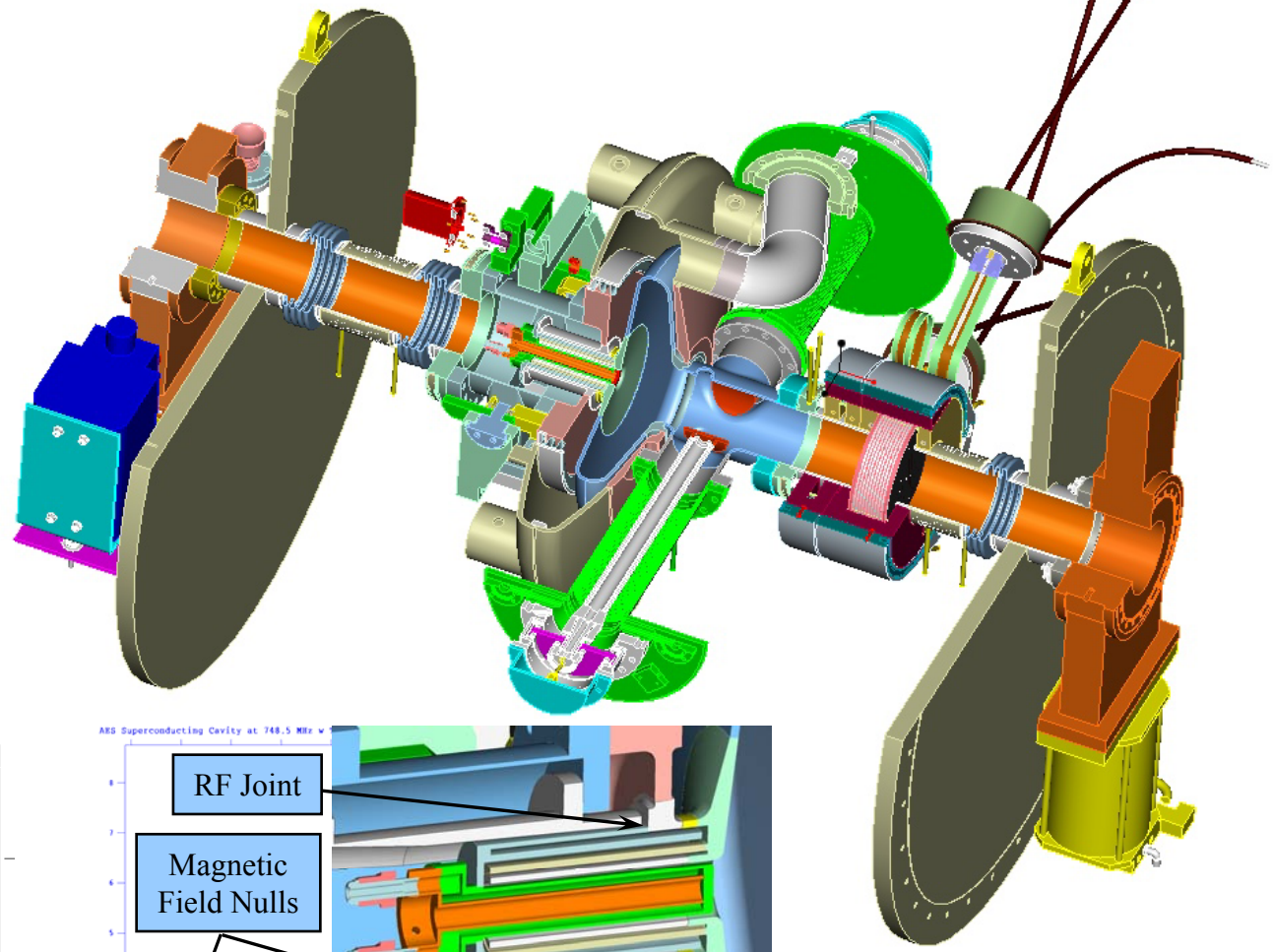


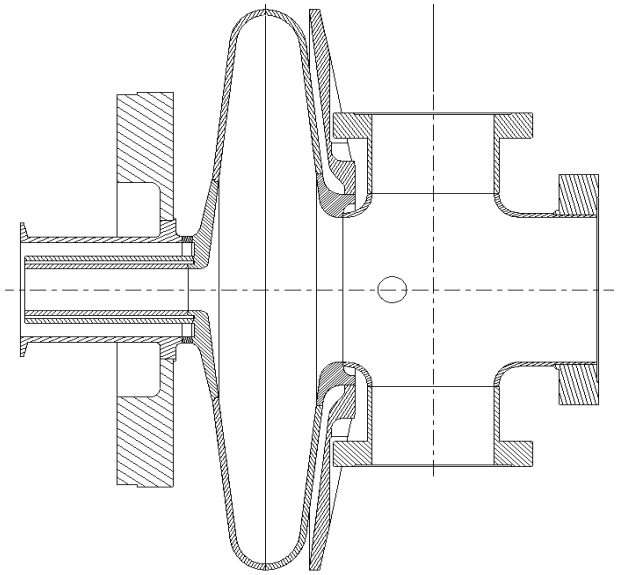
SRF Gun Cryomodule

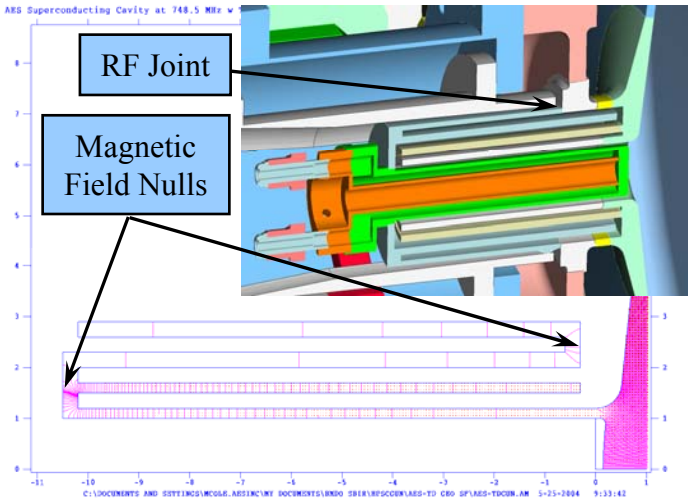


SRF Gun Cavity String









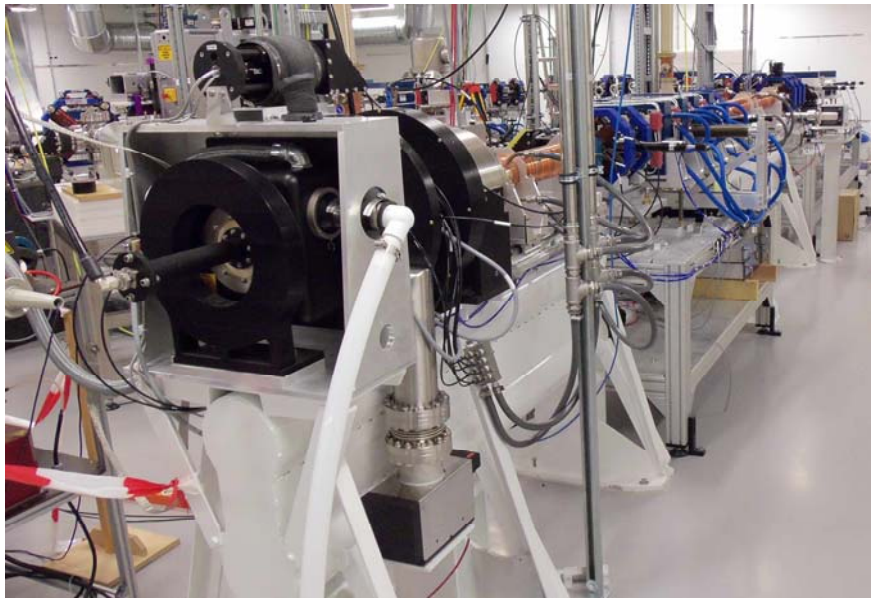
Double QW Choke After:
V. Nguyen-Tuong,
L. Phillips and J. Preble

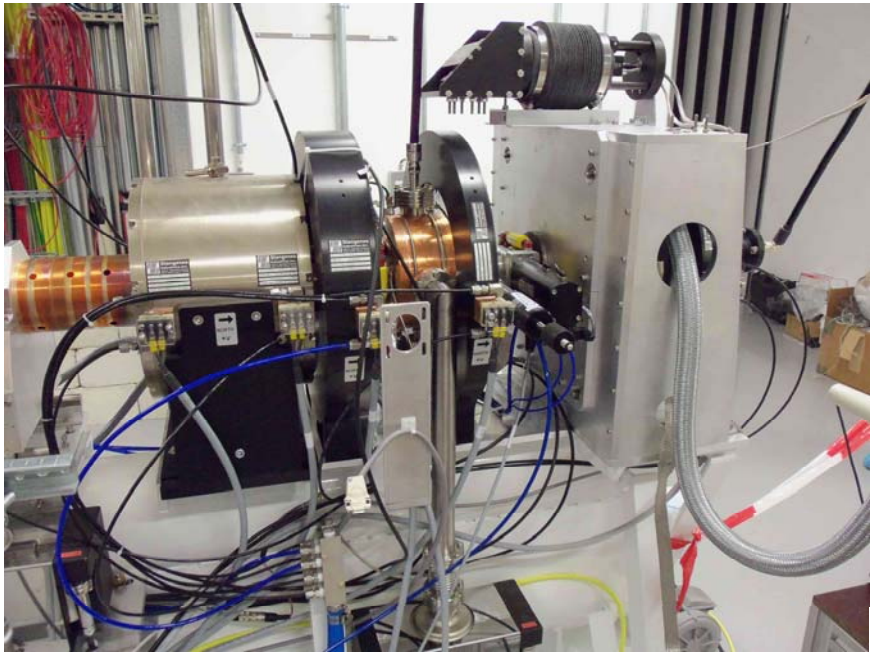
Motivation for Gridded Thermionic Gun

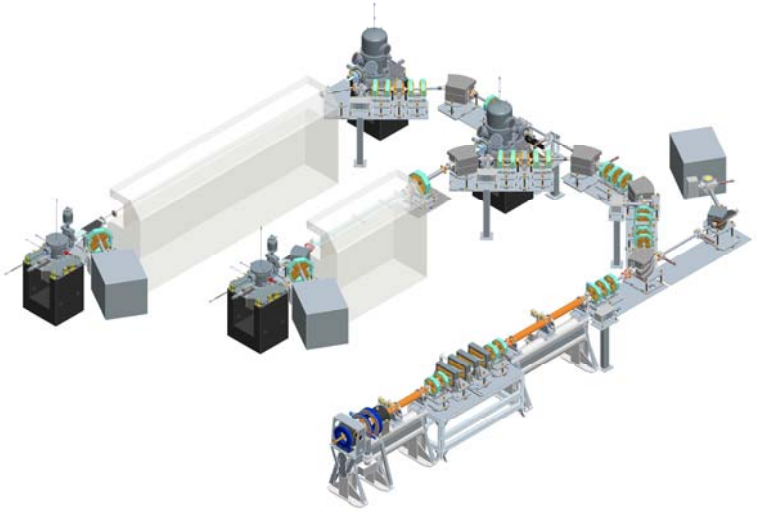
- Would like a thermionic electron gun for either high-performance or high-power applications where robustness, economics or footprint preclude a photocathode system.

- AES developed a CPI gridded thermionic electron gun integrated into a RF cavity for the Fritz Haber Institute as part of an IR and THz FEL
  - H. P. Bluem, D. Dowell, A. M .M. Todd, L. M. Young, "High Brightness Thermionic Electron Gun Performance," WG1010, Proceedings of ERL2011, Tsukuba, Japan.
- Budker Institute of Nuclear Physics (BINP) developed a normal conducting thermionic-cathode injector
  - "First test Results of RF Gun for the RacepTrack Microtron Recuperator of BINP SB RAS," Proc of RUPAC2012, tuppb049, St. Petersburg, Russia.
- NRL proposed a gridded thermionic electron gun for high power FELs
  - Physical Review Special Topics Accelerators and Beams 14, 020702 (2011)
    - "High Average Current Electron Gun for High Power Free Electron Lasers" Spangle, et.al.

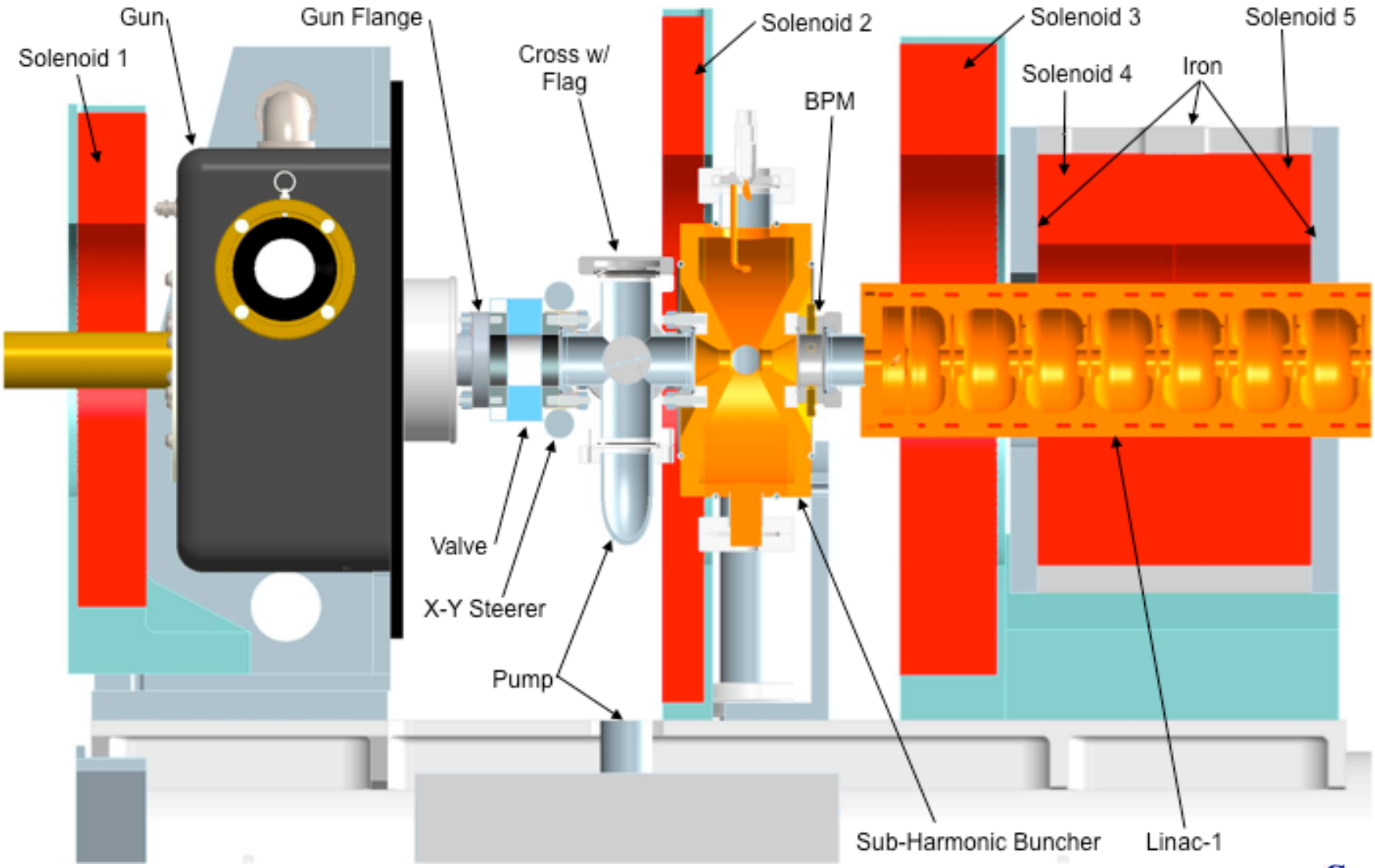
FHI IR & THz FEL



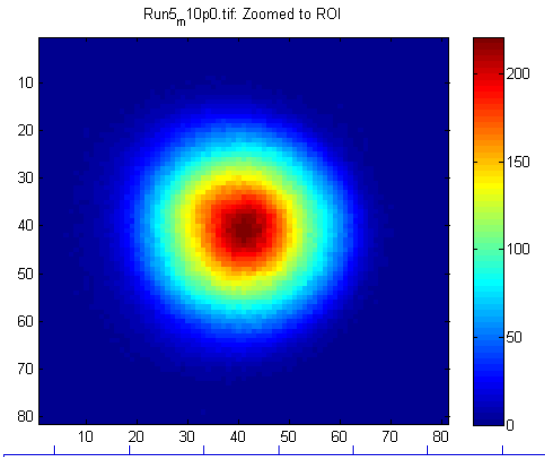


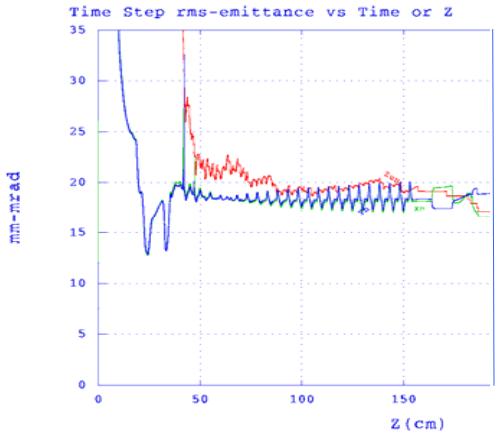


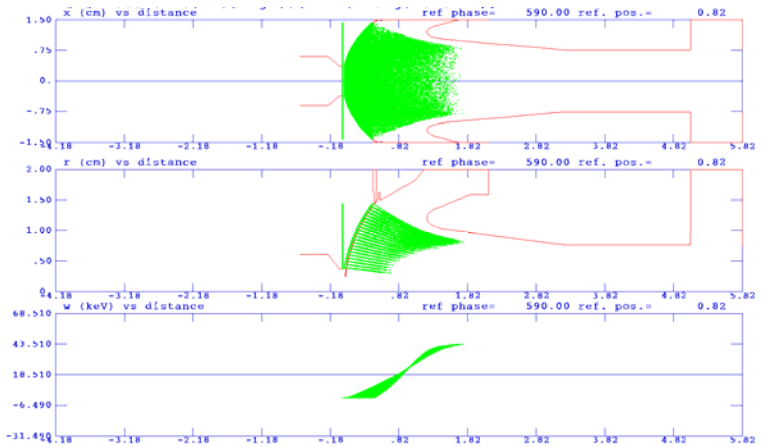
FHI Accelerator Front End

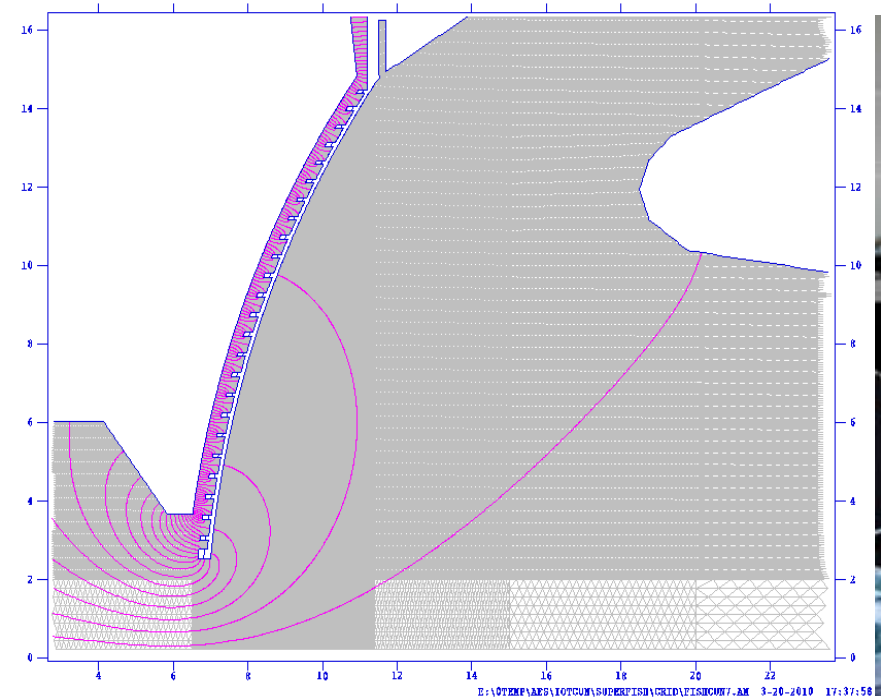


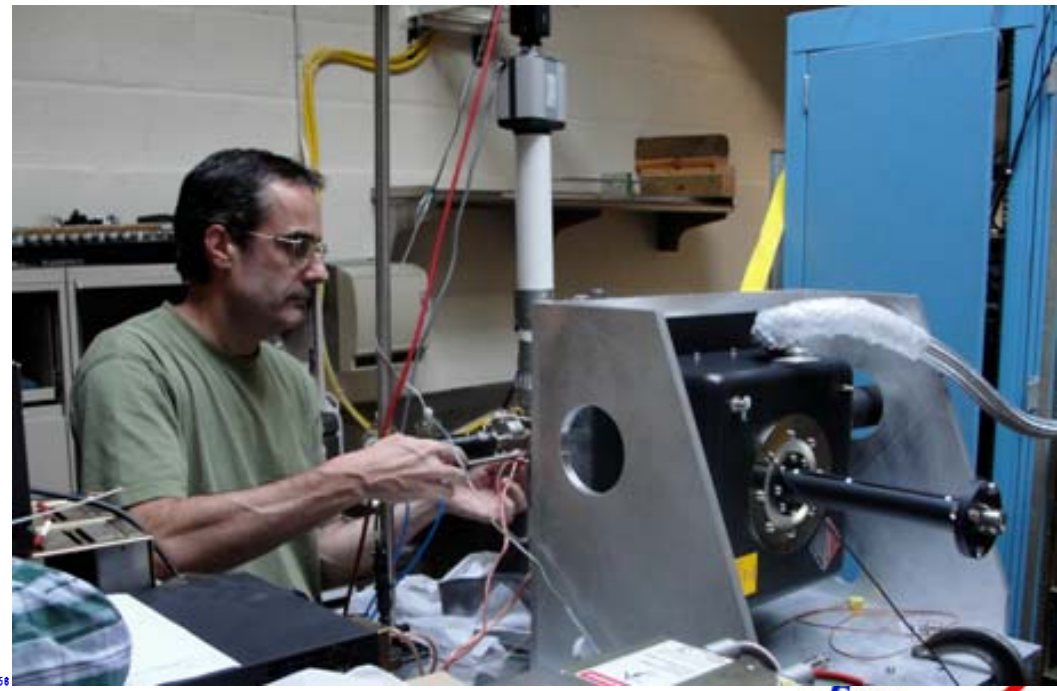
Thermionic Electron Gun Simulation and Testing





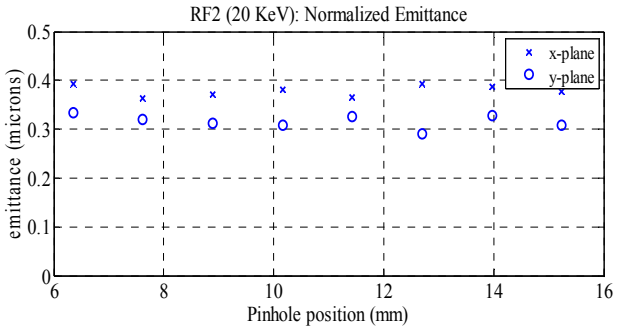


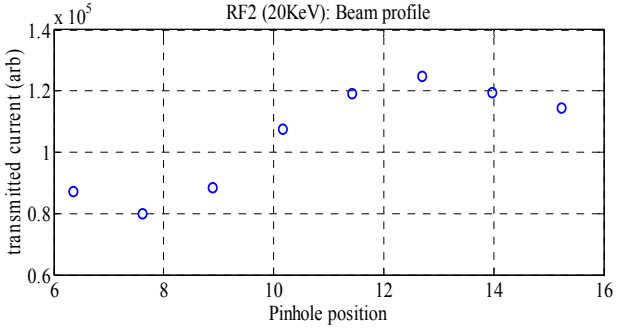


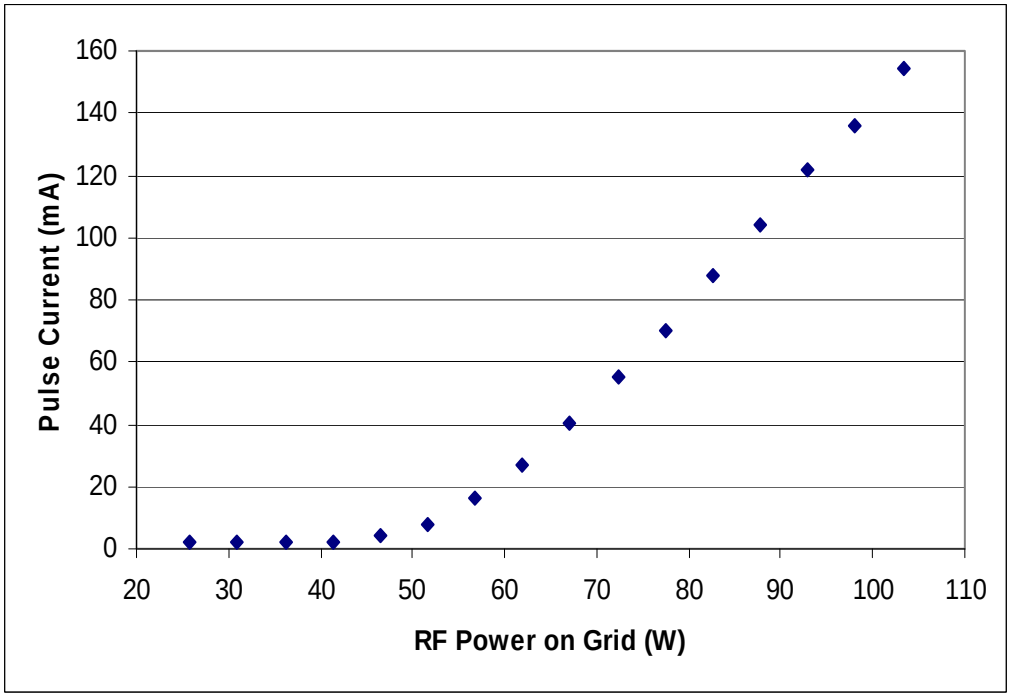


Thermionic Gun Measurements

- Pulsed 26mA beam @ 14kV rms emittance ~ 4μ
- Pulsed 100mA beam @ 20kV rms emittance ~ 8μ
- Idle current and gun HVPS limited operation
- Highest achieved voltage was 32.5kV => 214mA @ 100W of RF grid power (test limit)
- **FHI test 45kV=>600mA @ 200W RF grid power**

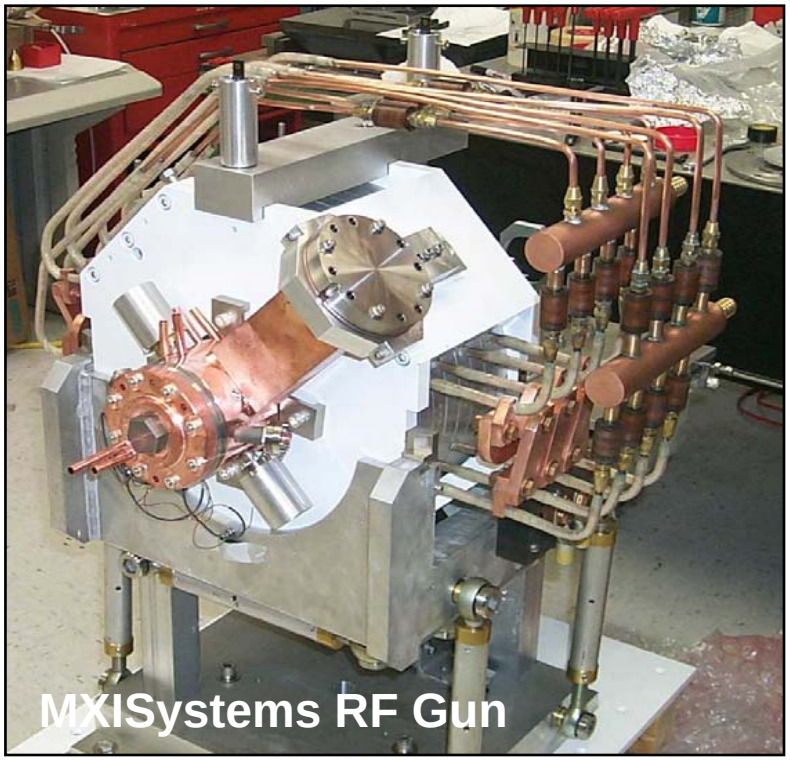


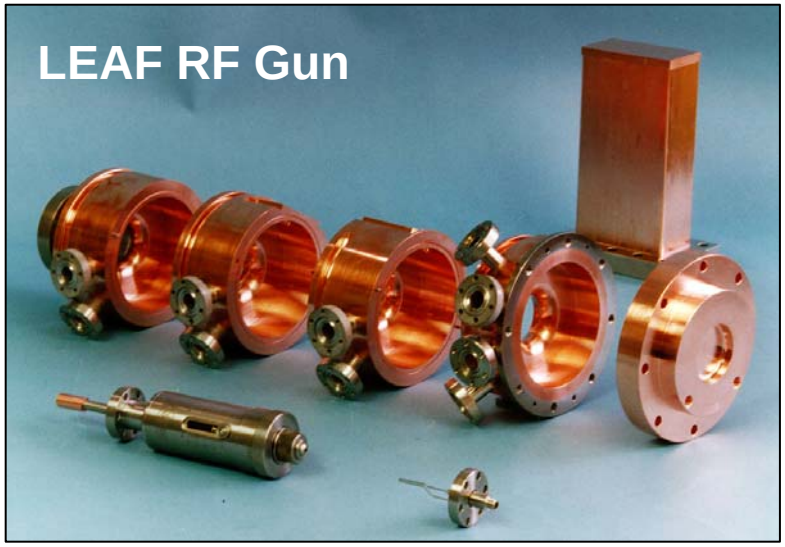


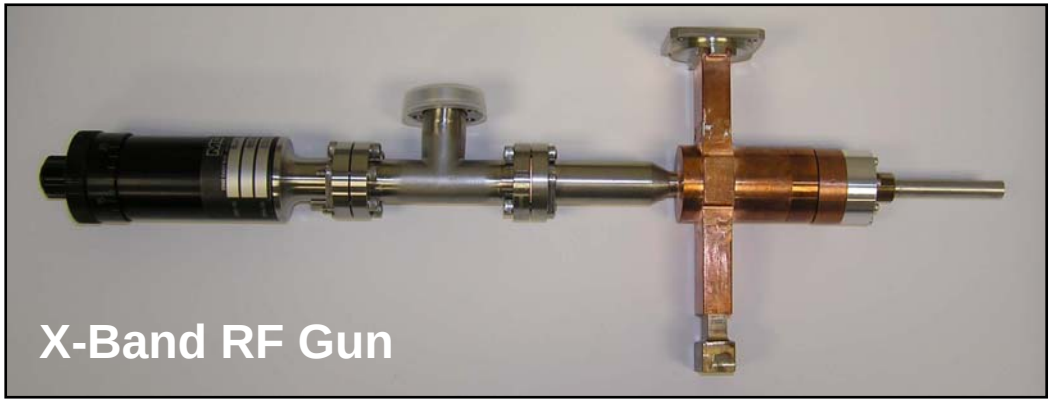


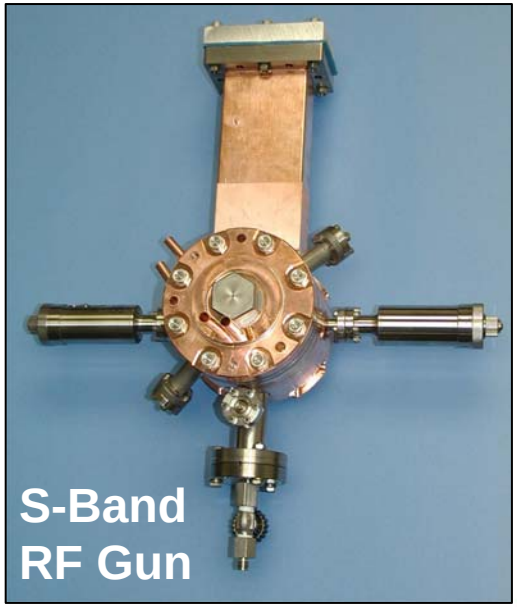
- Results suggest Ampere-level average currents with transverse rms emittance < 20mm-mrad should be possible

Normal Conducting Electron Guns

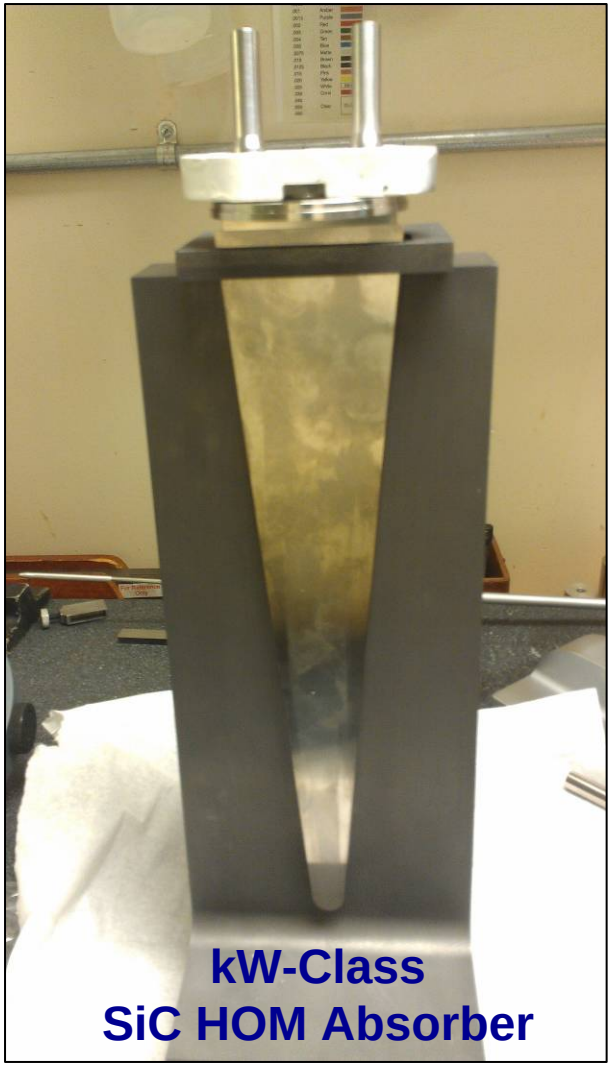






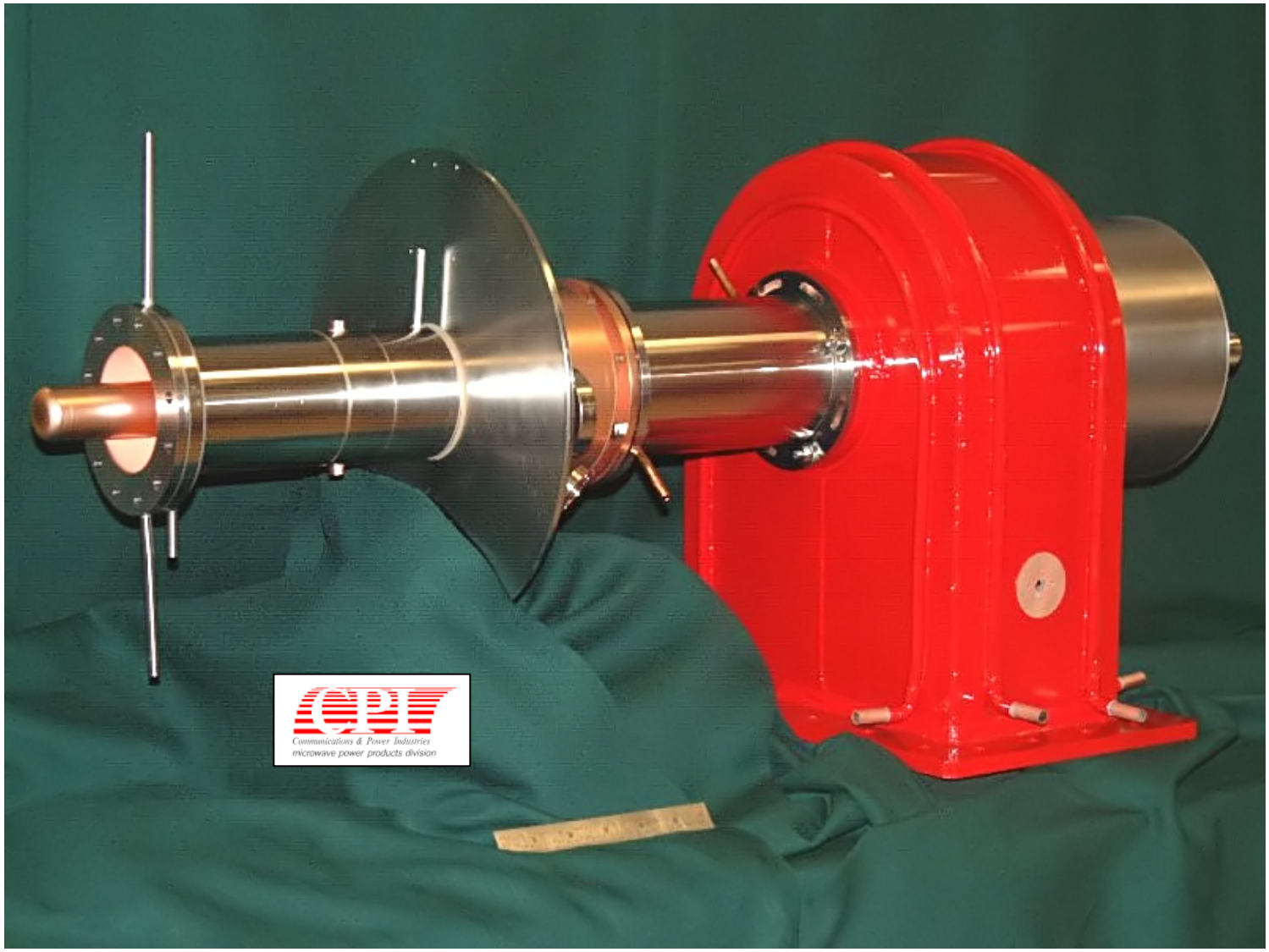


Recent AES High-Power Prototyping R&D



AES has recently prototyped key high-power FEL components with Navy support

350 kW Power Coupler

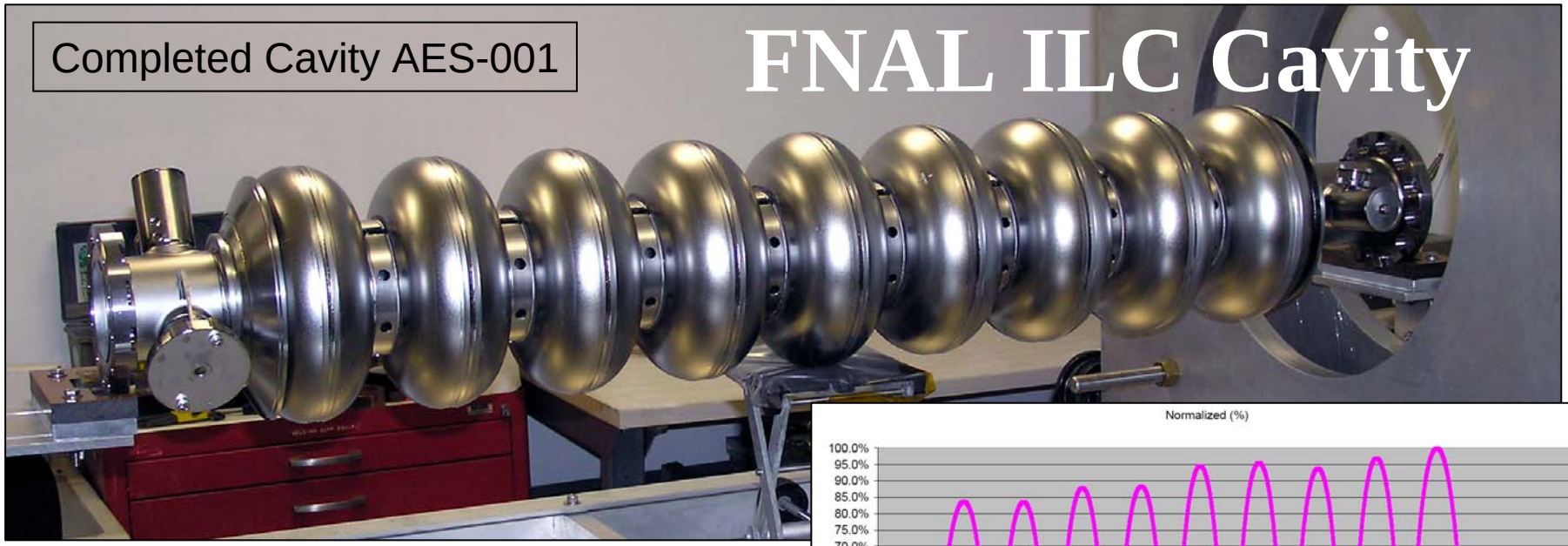


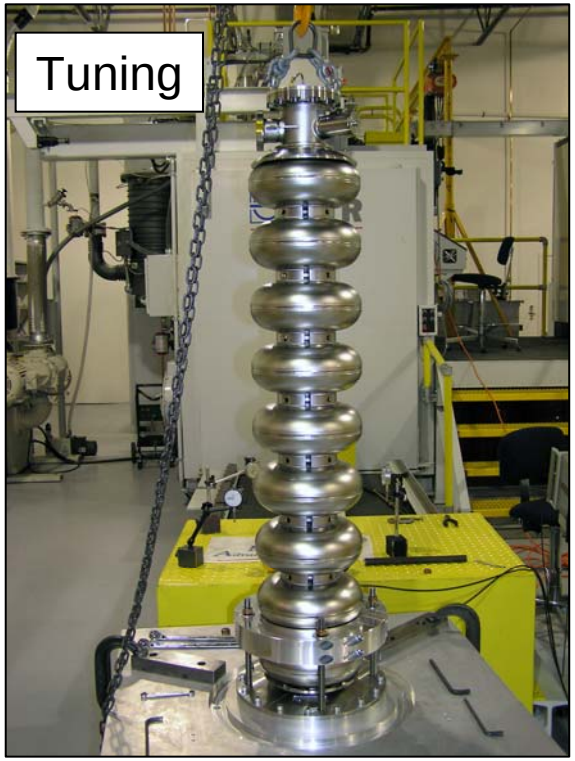
Outline

- AES Overview
- Integrated Engineering and Physics Services
- Advanced Radiation Sources
  - High-Current Electron Injectors
    - Photocathode
    - Thermionic
  - High-Current Cryomodules
  - High-Power RF Couplers and Windows
- ***Turnkey Accelerators and Components***
  - ***SRF Cavity Projects***
  - ***Turnkey Beamlines***
- Contacts

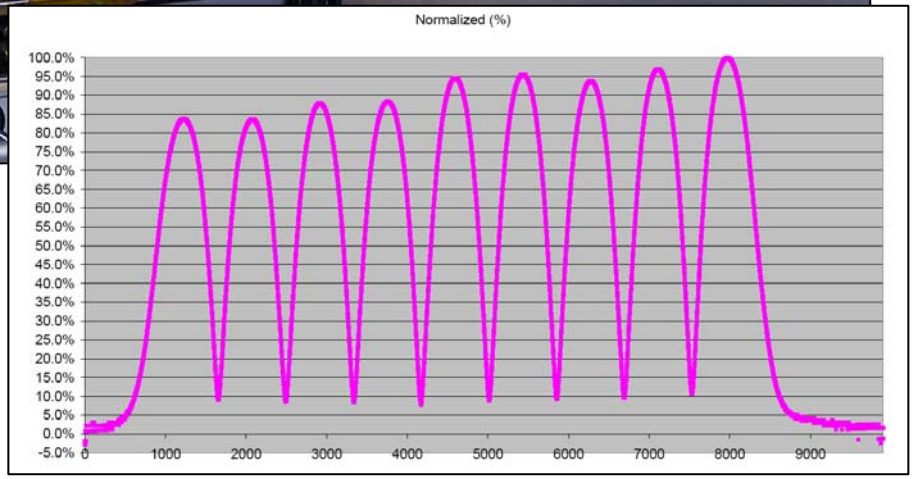
FNAL ILC Cavity

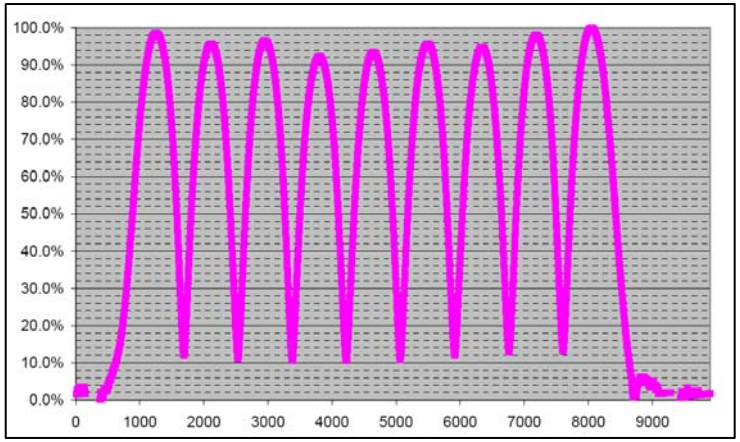
Completed Cavity AES-001





Beadpull Before Any Tuning ➔



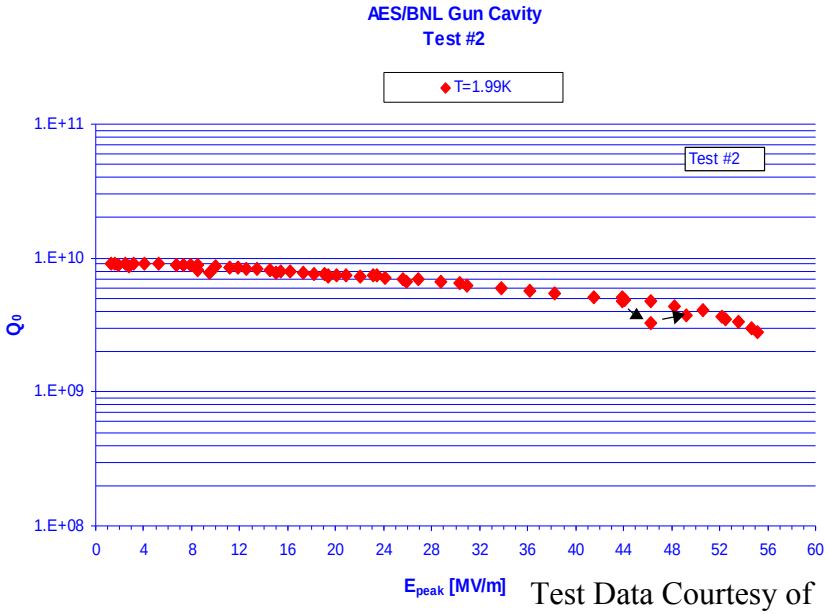


➔ Beadpull After Tuning

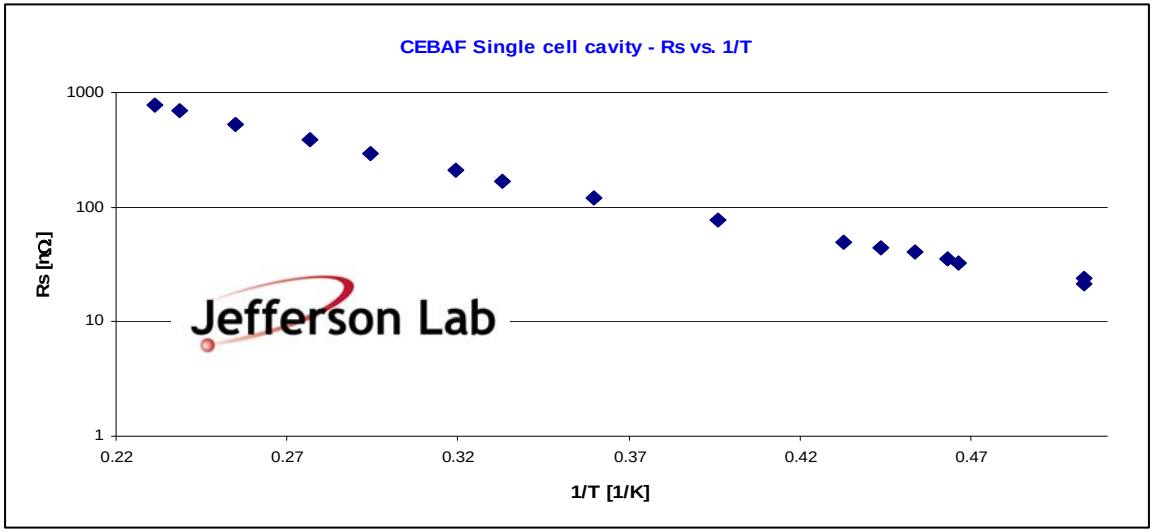
Fermilab

Advanced Energy Systems, Inc.

AES / BNL Nb Photocathode Gun

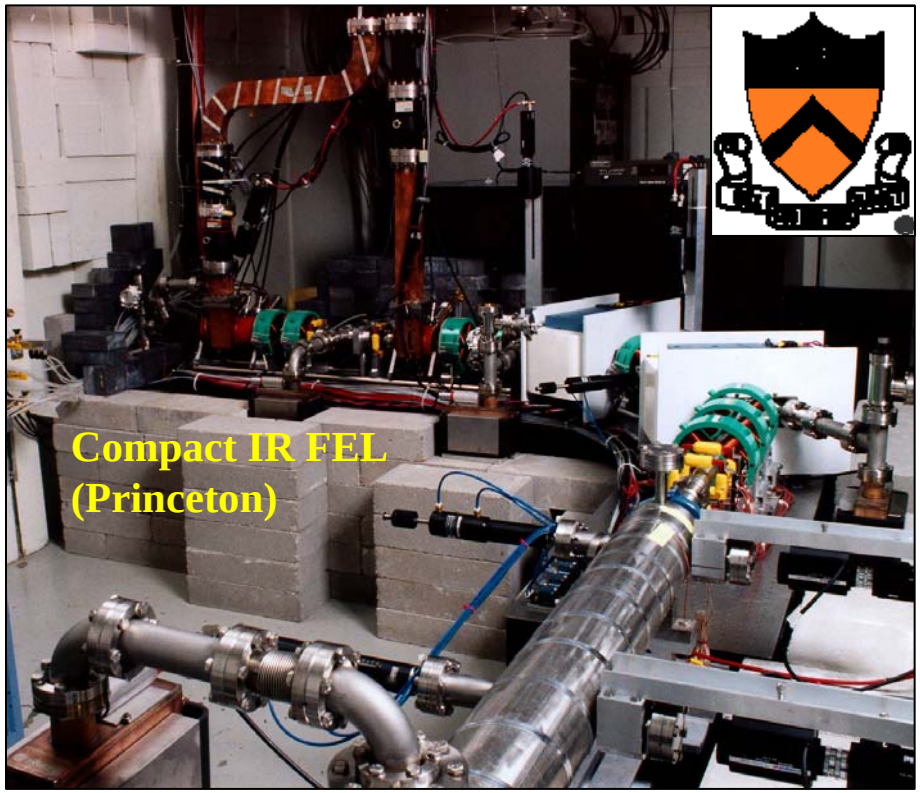


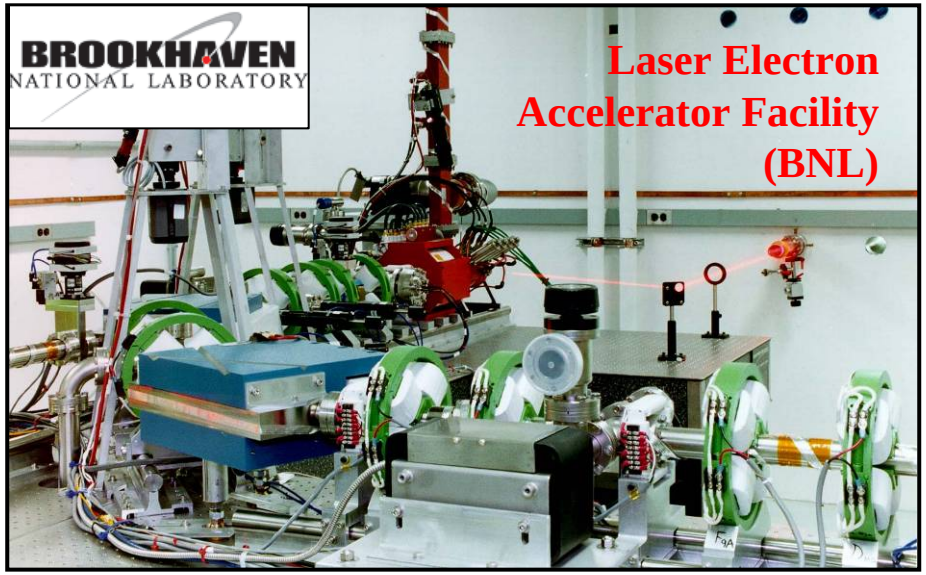
Test Data Courtesy of
P. Kneisel, Jefferson Lab



BROOKHAVEN NATIONAL LABORATORY

Turnkey Beamlines





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