# Fully Superconducting Gun

## BNL, Upton, NY, July 22, 2004

Advanced Energy Systems, Inc.

Scientific Research
Homeland Security
Medical Imaging
Drug Discovery
Defense


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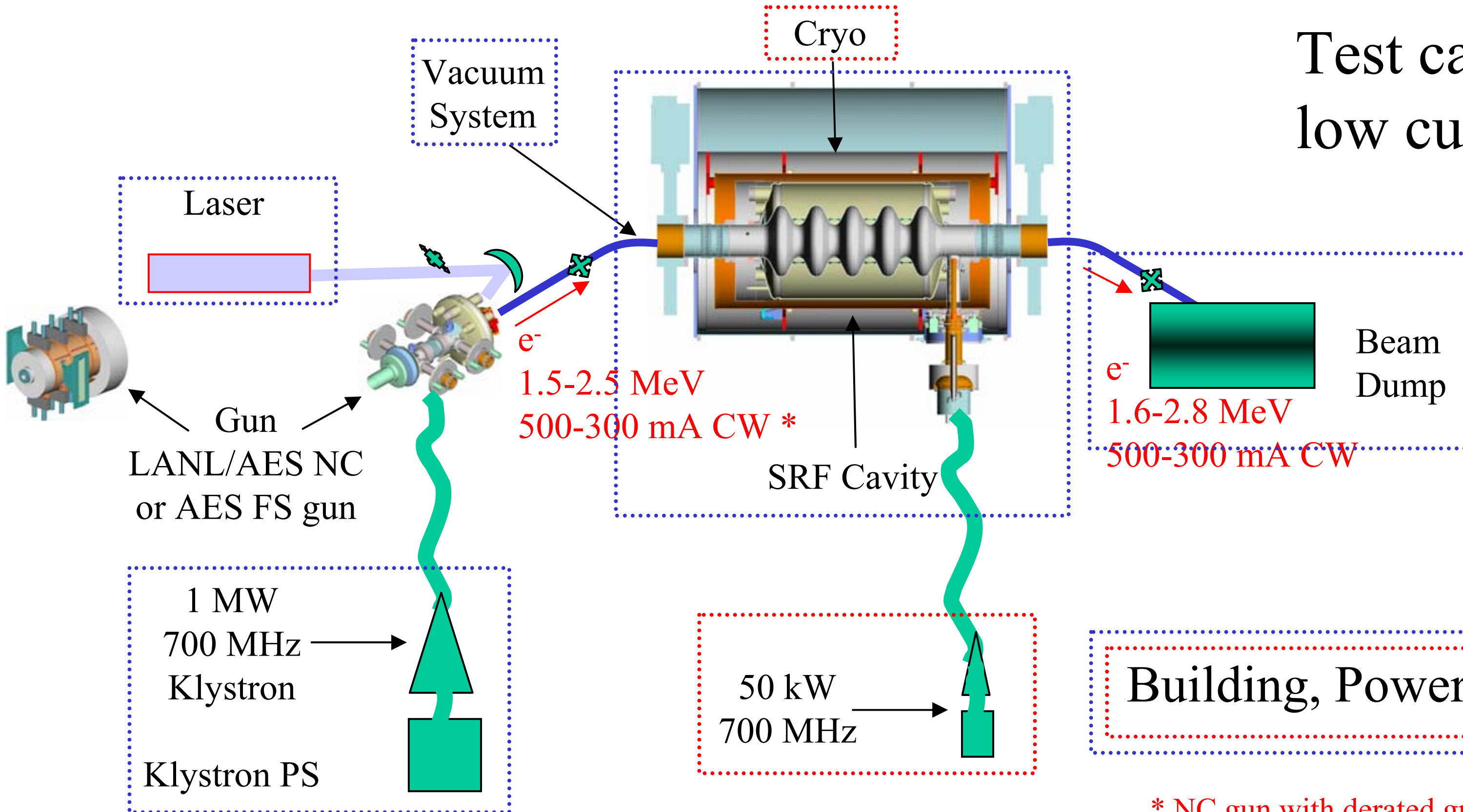
Putting Accelerator Technology to Work

# Beyond This Program I

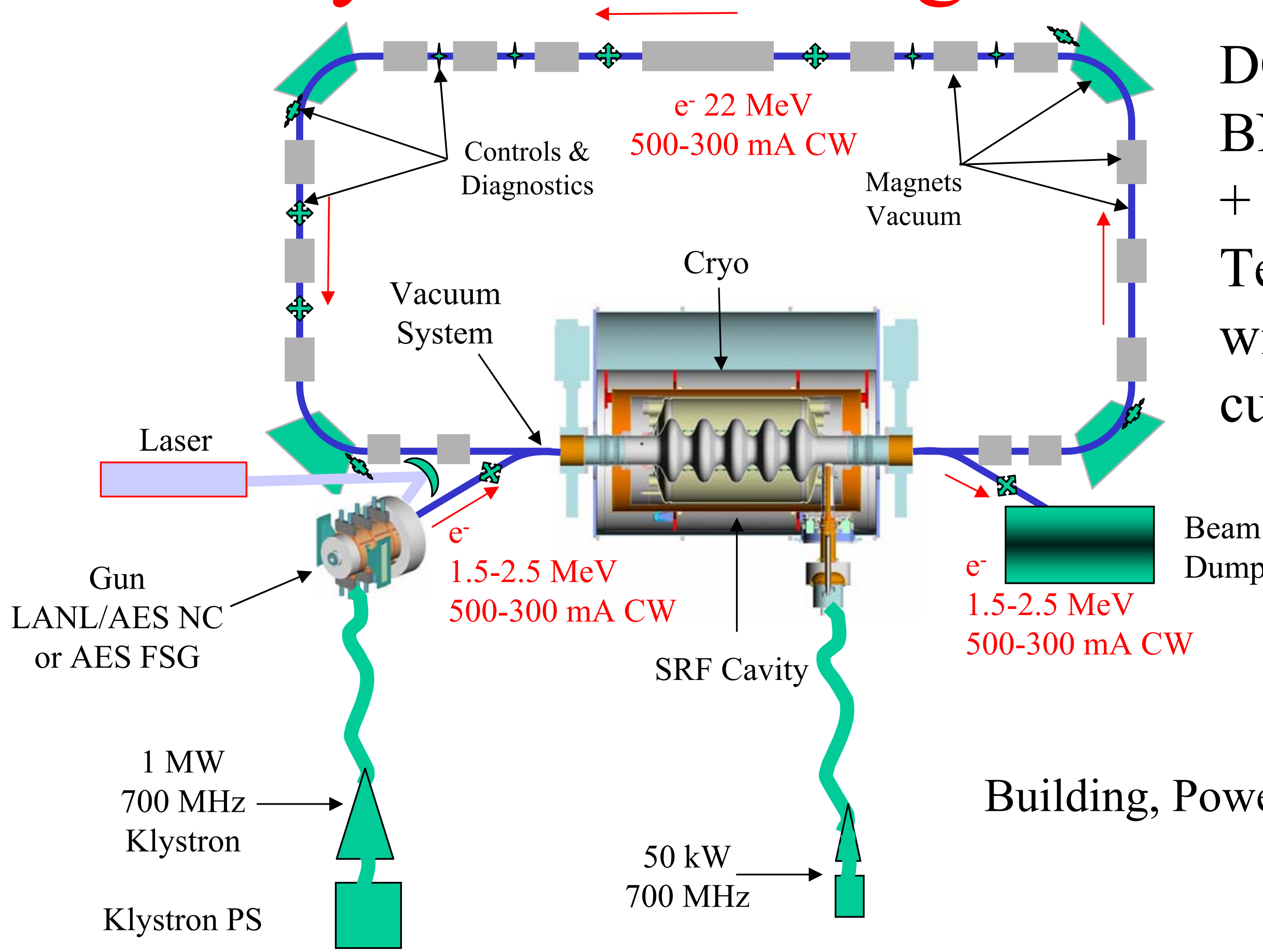
DOE and
BNL funding:
Test cavity with
low current beam




Building, Power, Water…

* NC gun with derated gradient
FS gun permits 25% higher current

# Beyond This Program II

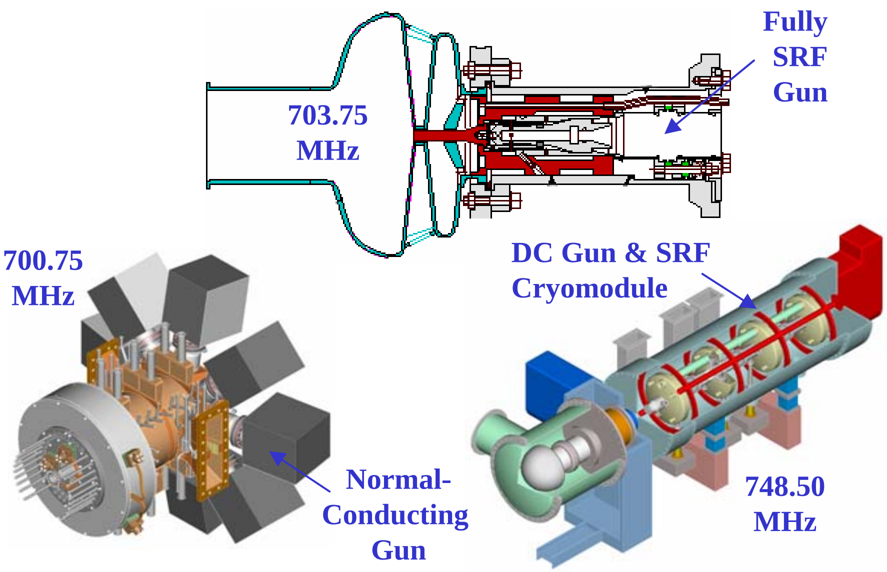



DOE and BNL funding + JTO?

Test cavity with high current beam

Building, Power, Water…

# FEL High-Current Injector Options




## Performance

- RF frequency of 600-800 MHz
- High CW electron current
- Delivered beam energy of ~ 7 MeV
- Transverse normalized rms emittance < 10 mm-mrad
- Longitudinal rms emittance < 100 keV-psec
- Output beam energy spread < 0.5%
- Electron rms bunch length < 15 psec

## Programs and Status

*High-current injector development is a key technology issue for FEL weapon systems*

- **JLAB: DC Gun & SRF Cryomodule at 748.5 MHz**

  Most SRF booster components will be delivered to JLAB by October 2004

  Cleaning and assembly required at JLAB with AES participation is not presently funded (AES and JLAB proposals will be submitted shortly to NAVSEA PMS 405)

  Requires Navy authorization of JLAB Injector Test Stand

  ~18 months to delivery of RF and ~30 months to high-current testing (AES not JLAB estimate)

- **Los Alamos: Normal-Conducting Gun at 700.75 MHz**

  AES will deliver gun to Los Alamos in mid 2005

  Available 1 MW of RF only delivers thermal test in late 2005

  Another 1 MW for beam test will be expensive to commission and is not presently authorized by the Navy

- **BNL: Fully Superconducting Gun at 703.75 MHz**

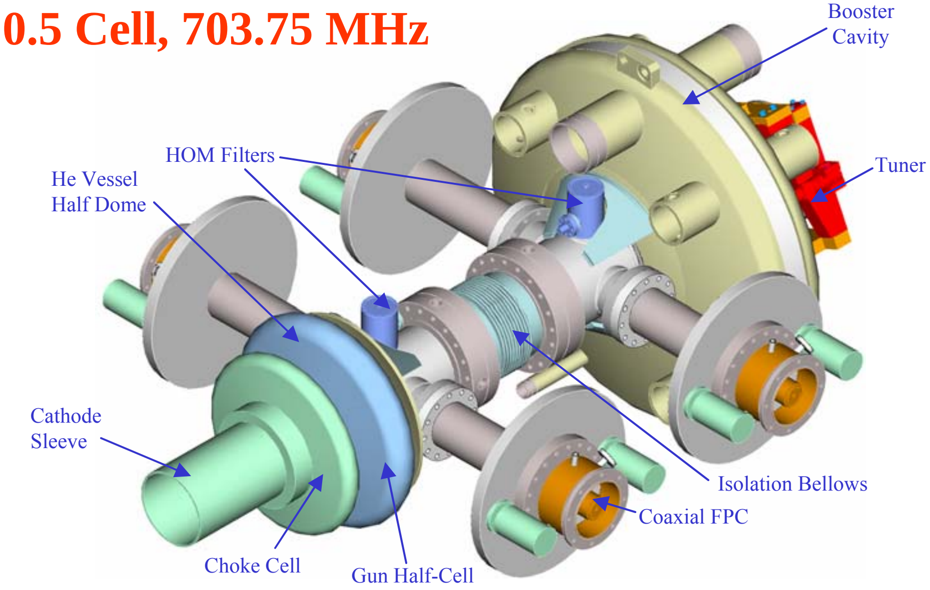
  Least mature option

  Design review 12/04 with subsequent Navy fabrication decision

  Leveraged BNL facility capable of demonstrating 0.5A tests within ~ two years if gun can be delivered

# Fully-SRF Injector

## 0.5 Cell, 703.75 MHz




## *Deliverables*

- Envisioneering task completed (6/04)
- Completion of NGC JTO phase (8/04)
- Engineering design review of fully SRF gun (12/04)
- Final report with ETC for fabrication & testing (12/04)

## *Outyear Program (Unfunded)*

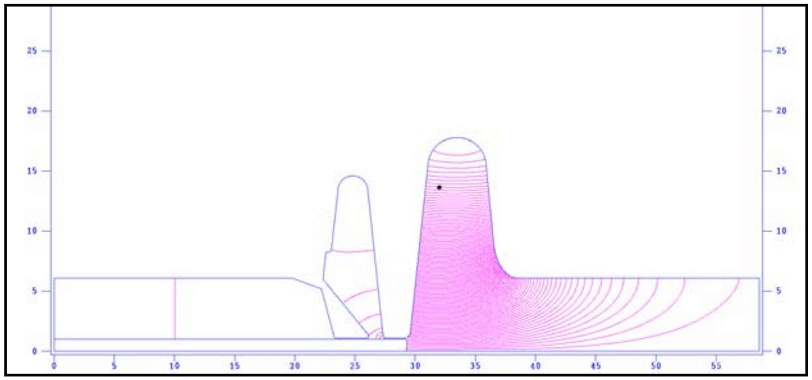
- Fabricate gun, choke joint and cathode insertion mechanism, cathode preparation chamber and cryomodule
- Perform testing at BNL

## *Status*

- Project initiated 10/03
- Engineering kick-off meeting 11/03 at AES, Medford
- 1½ & ½ cell, 1 A physics designs (Lewellen) completed
- Collaboration with FZR initiated 1/04
- Quarter wave choke joint experiments authorized 2/04
- Customer frequency change 748.5 to 703.75 MHz (7/04)

## *Performance*

- BNL 703.75 MHz selected by customer for testing
- At 1 MW, BNL will be limited to 500 mA initial operation



*Putting Accelerator Technology to Work*

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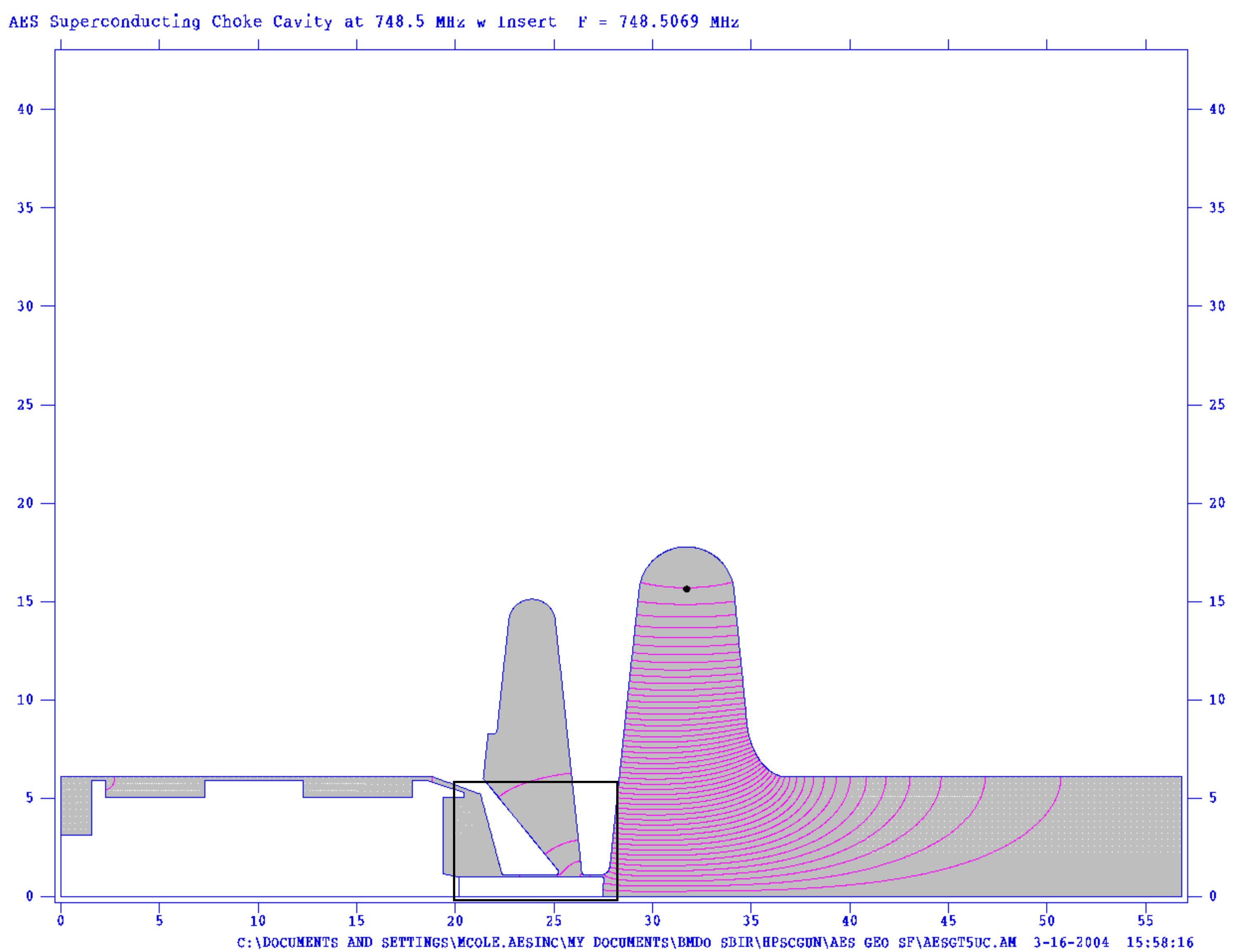
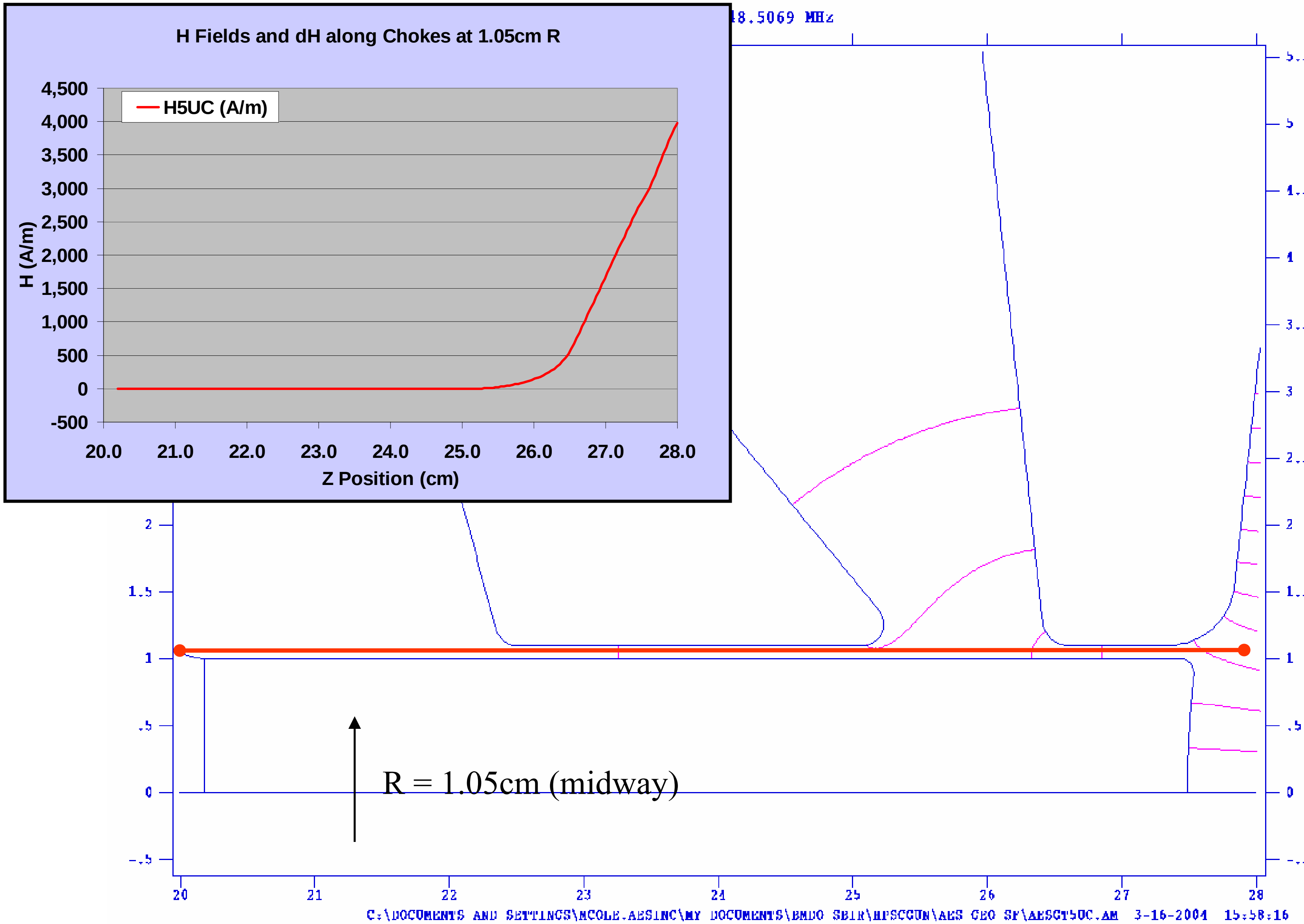
# Performance Requirements

- 703.75 MHz
- 2 opposed couplers
- 1.5 nC
- ~ 2 MeV delivered
- ½ cell => ~ 0.1 m
- 2 MeV / 0.1 m => ~ 20 MV/m

# FZR Choke Cavity Design



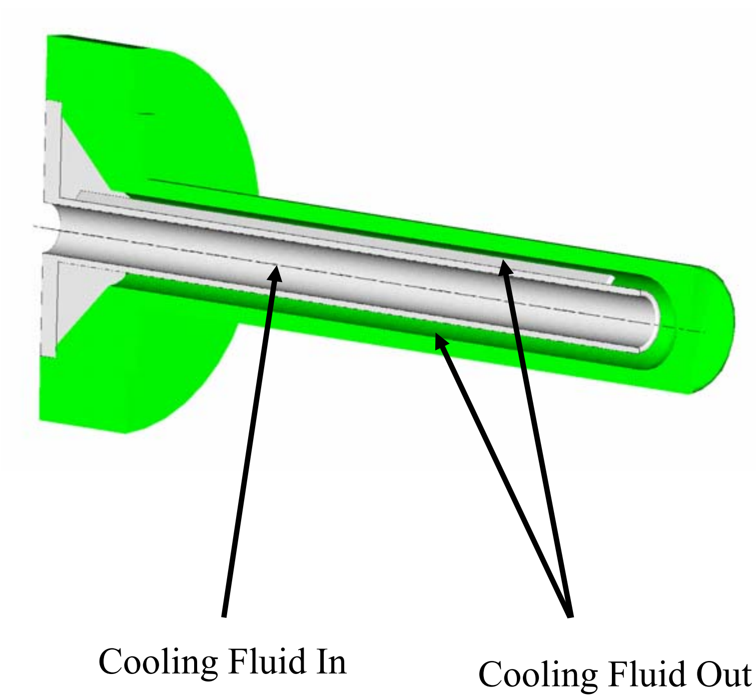
# Fields from Cathode through Choke Region

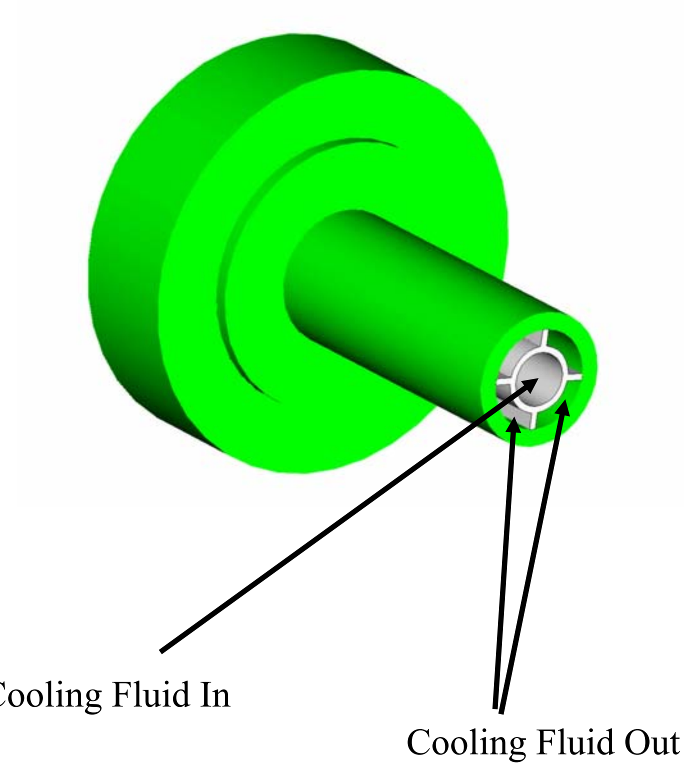


# QW Choke Selection

- Cathode stalk must be actively cooled which means significant redesign of FZR choke because it is now dominated by the RF field thermal load rather than the drive laser and cathode load of our situation
- QW choke viewed as simpler (read more reliable) and cheaper
- Engineering solutions to thermal issues and cathode insertion and accurate repositioning with QW felt to be more tractable
- Feeling that both chokes actually have similar multipacting issues
- Higher heat deposition in QW choke due to longer path length with field but also more manageable cooling geometry
- Consensus that there is sufficient wriggle room with respect to choke geometry, tapering, grooving, material and other design options to suppress multipacting
- Experimental programs are in place at AES and BNL to support choke design

# Cathode Cooling Configuration

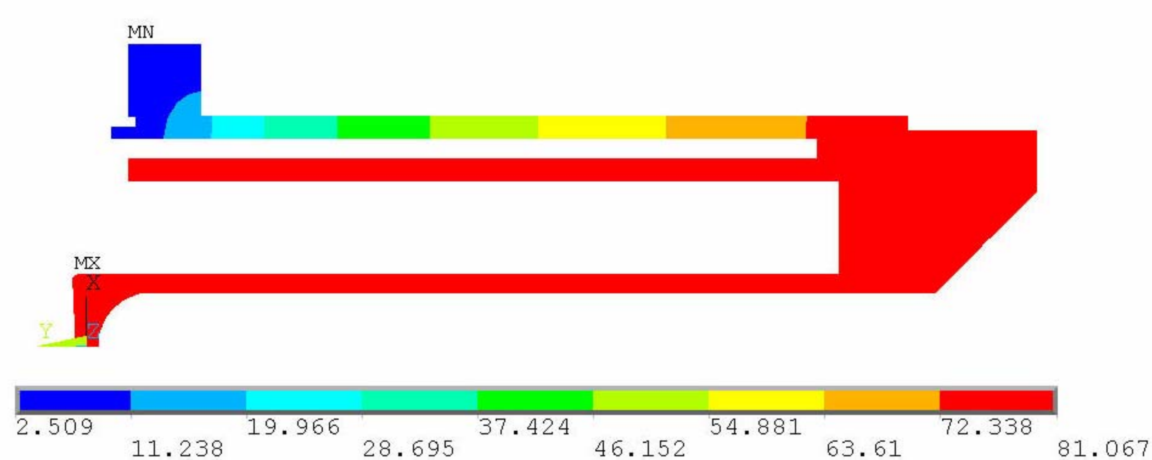


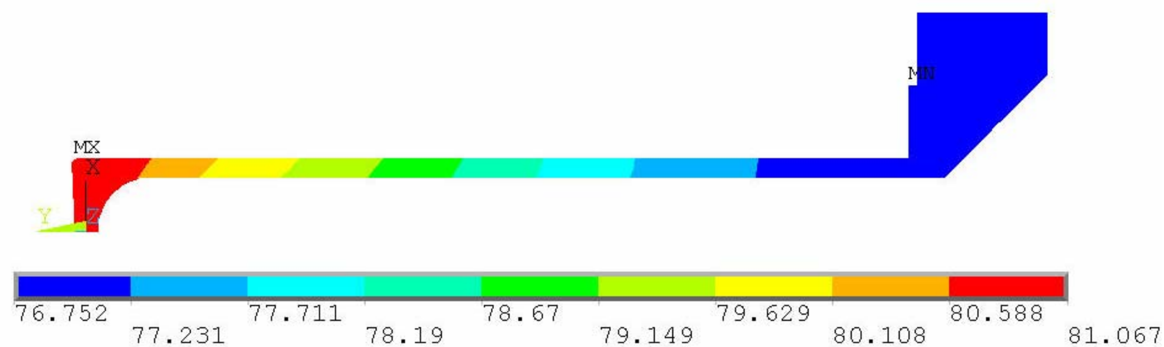
# Thermal Analysis Assumptions

- Photocathode drive laser and diamond cathode thermal loads NOT included
  => a further 25 - 85 W of thermal load needs to be included in analysis
  (~ doubles the load)
- Distributed heat load due to RF loss in the cavity and on the cathode was incorporated from SUPERFISH output
- A 5.0 K boundary condition was added to represent cooling at the flanges of the RF cavity and choke regions
- A 77 K boundary condition was added to represent liquid nitrogen cooling of the cathode and cathode cooling insert
- The internal region of the cathode is hollow to allow cooling fluid to pass through
- The heat is removed from the cathode by means of forced convection to 77 K liquid nitrogen passing through the hollow center of the cathode

# Thermal Profile




**Temperature (K)**




**Temperature (K)**

CATHODE

# Cooled QW ChokeResults

- The hardware that is in contact with the liquid helium is between 2.00 K and 2.3 K. Once outside the helium vessel the temperature rises as it gets closer to the two flanges which are 5 K.
- The cathode temperature rises 4.1 K to a maximum temperature of 81.1 K.
- The heat into the cavity due to RF resistance is 4.44 W
- The heat into the cathode due to RF resistance is 73.87 W
- The heat entering the model from the 5 K flanges is 1.23 W
- Total of 79.54 W (does not include 25 – 85 W for laser and cathode).
- The heat absorbed by the liquid helium is 7.72 W (That is from cavity RF resistance, heat conducted from the 5 K flanges, heat conducted from the cathode, and a small amount of heat radiated from the cathode). The heat absorbed by the liquid nitrogen is 71.92 W.
- The maximum heat per area into the liquid helium due to thermal convection is .0646 W/cm**2 (.417 W/in**2).

# QW Choke Experimental Status

- Multipacting testing delayed because of problems with high-power RF source (presently capable of 8 MV/m simulations but target is 20 MV/m)
- Test cavity built to accept biasable grooved inserts with various proposed groove geometries (six different samples prepared) at 748.5 MHz
- Low-level RF source delivering 10 to 15 watts over a broad range encompassing both 703 and 750 MHz completed
- High-power pulsed RF amplifier delivering 5 to 10 kW completed
- Very tight schedule to meet 7/31/04 deadline
- Parallel and non-interfering effort to directly measure the secondary electron yield of grooved samples using an electron gun is in place

- Use of BNL 10 kW CW source is an acceptable option if present source problems persist
- Authorization given to prepare blanks for 703.75 MHz follow on testing
- Revised QW geometry will be provided shortly

# Dates & Deliverables

- NGC JTO contract expires 8/14/04 with draft final report due 7/30/04
- Choke joint decision made – have selected quarter wave (QW) choke concept
- Recently received Navy funding to continue project through 12/04
- 12/04 deliverables are an Engineering Design Review with drawings, final report and ETC for fabrication and testing
- If fabrication is authorized by the Navy, delivery of the gun to BNL before 12/06 will require attention

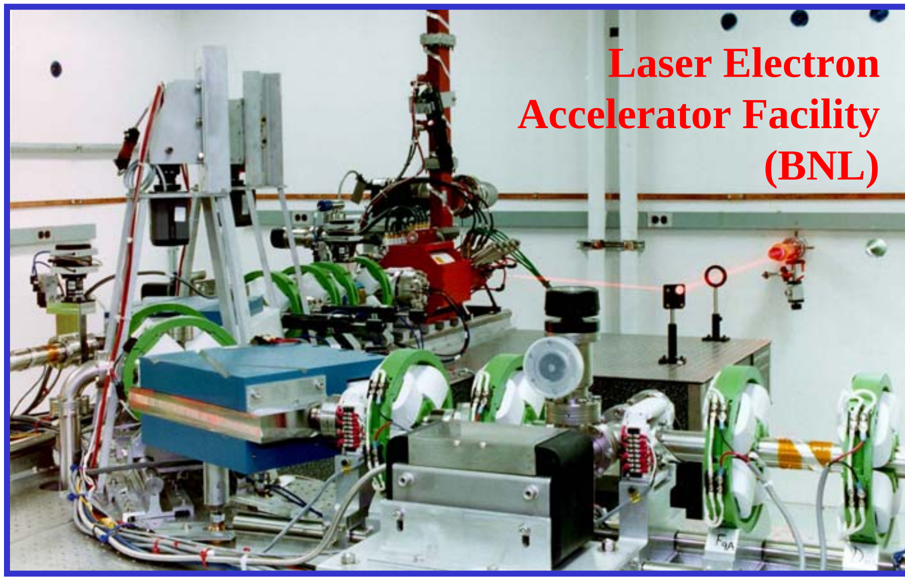
# Summary

- Design of 0.5 cell 703.75 MHz fully superconducting gun in process for 12/04 Engineering Design Review with drawings, final report and ETC for fabrication and testing
- Long lead niobium to be purchased in late 2004
- If possible cryostat should also accommodate a 1.5 cell gun
- Collaboration with BNL, *JLAB*, FZR, Stanford and others
- Quarter Wave (QW) choke joint concept selected and cathode stalk radius increased to 1.25 cm to permit higher charge beam experiments
- Navy fabrication decision in early 2005
- Gun delivery schedule to BNL is key issue

# Advanced Energy Systems

## *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 diagnostic systems for cancer and drug discovery, explosive detection, and directed energy weapon systems. AES is committed to providing best value and 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)
- Located in Medford, NY, and Princeton, NJ
- 24 employees
- Annual sales of $5.5M
- NC prototype machine shop with class 100 clean room and co-ordinate measurement capability
- State-of-the-art engineering and physics design and analysis capability

# Advanced Energy Systems

## *Product Areas*

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