Project Title:

Superconducting RF electron Gun

Collaborators:

Stony Brook University	Lead PI Prof. V.N. Litvinenko, Co-PI Dr. I. Petrushina
Brookhaven National Laboratory	Co-PI Dr. Y. Jing
Fermi National Accelerator Laboratory	Co-PI Dr. V. Yakovlev
Thomas Jefferson National Accelerator Laboratory	Co-PI Dr. R. Suleiman

PI Exchange meeting

NP Accelerator R&D

November 29, 2022

Content:

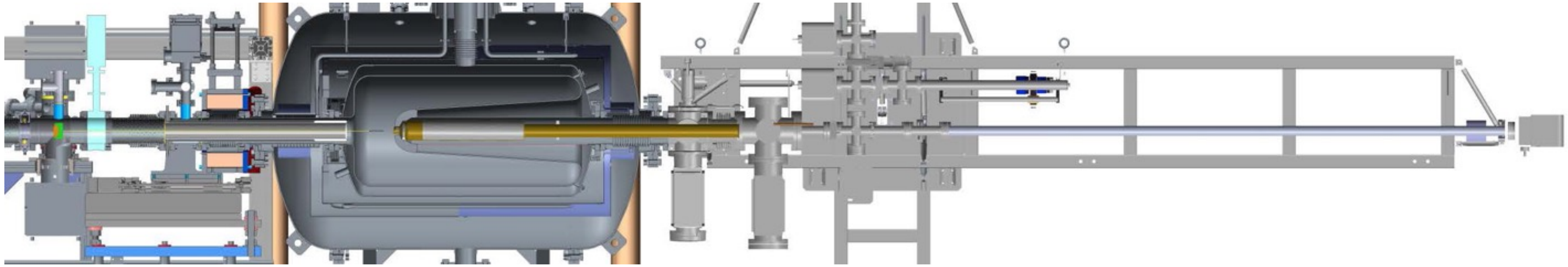
- ❑ Introduction
- ❑Beam dynamics, High current and Polarized beam operations and Experience with SRF gun Treatment
- ❑ Design of 100 kW FPC and plasma treatment system
- ❑ Development of e-beam polarimeter
- ❑ Plans for next two years

Project opportunities & goals:

Exploration of **capabilities of the unique 1.5 MV SRF gun** generating electron beam with record low transverse emittance and providing "year-long" operation with a single CsK_2Sb cathode

The main ultimate goals:

- Demonstration of a reliable **operation of the SRF gun with beam current up to 100 mA**
- Generation of **polarized electron beams from the SRF gun**



Project goals & deliverables:

➢ Phase 1, Year 1 goals:

1. **Prepare for operation with 1-3 mA** ☑
2. **Test gun conditioning techniques** ☑
3. **Design 100 kW Fundamental Power Coupler (FPC)** ☑

Deliverable	Completion Status
Simulations of beam dynamics	☑
Deliver beam from the gun to high-power dump	☑
Evaluate beam quality for 2 nC bunches	☑
Complete simulations of the 100 kW RF system	☑
Design and build electron beam polarimeter	☑
Develop and test reliable He conditioning technique	☑

Project goals & deliverables:

- **Phase 1, Year 2 goals:**

1. **Gun operation with 1-3 mA CW current – postponed**
2. **Test GaAs operation in SRF gun – postponed**
3. **Complete the polarimeter ☑**
4. **Finalize 100 kW FPC design ☑**
5. **Finalize supporting simulations and prepare for Phase 2**

Deliverable	Completion Status
Design the laser for Phase 2 30-100 mA operation	**In progress**
Optimize gun settings for generating maximum beam current	**In progress**
Complete design of the 100 kW RF system	☑
Upgrade cathode deposition and transport system for GaAs	**In progress**
Introduce GaAs cathode into the SRF gun	**postponed**
Complete simulations and design of plasma processing system for CeC SRF gun	☑

Set-backs with SRF gun operations

- We had number of significant number of set-backs during RHIC runs 21 and 22, which affected possibility to implement our experimental program with testing GaAs cathodes in the SRF gun
    - We lost a lot of operation time
    - The cathode transfer system was damaged and has to be replaced/re-baked
    - SRF gun was contaminated by damage to the cathodes
- Our attempt of generating high average current was put on halt by excessive outgassing in the full-power beam dump in the diagnostics beam-line. This problem was resolved during this shut-down by backing-out the dump.
- The only “silver lining” was additional – and very successful – recovery of the SRF gun performance using He conditioning: *First experience with He conditioning of a superconducting rf photoinjector, I. Petrushina et al., Phys. Rev. Accel. Beams 25, 092001 (2022)*

Budgets

	FY20 ($k)	FY21 ($k)	Totals. ($k)
Stony Brook University			
a) Funds allocated	201.3	201.3	402.6
b) Actual costs to date	201.3	7.8	239.1
Brookhaven National Laboratory			
a) Funds allocated	180.6	180.6	361.2
b) Actual costs to date	180.6	179.3	359.9
Fermi National Accelerator Laboratory			
a) Funds allocated	139.1	139.1	278.2
b) Actual costs to date	139.1	138.3	277.4
Thomas Jefferson National Accelerator Laboratory			
a) Funds allocated	200.1	200.1	400.2
b) Actual costs to date	200.1	114.6	314.7
TOTAL			
a) Funds allocated	721.1	721.1	1,442.1
b) Actual costs to date	721.1	440.0	1,161.1

Status of high current and polarized beam operations
Beam dynamics and practical experience with SRF gun treatment

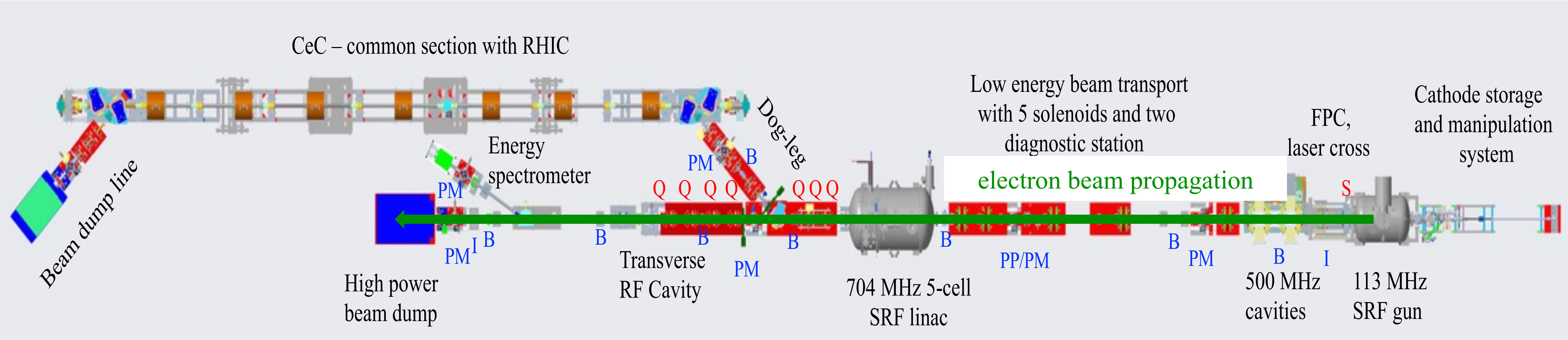
Milestones & Achievements

- Beam dynamics simulations for the high current gun operation completed and tested
- We were able to restore and improve the SRF gun operation after two major contamination events:
  - Demonstrated successful He conditioning
  - Achieved 1.5 MV CW and 1.7 MV pulsed voltages
  - Reduced dark current 3-fold at operation voltages
  - Observed the lowest radiation and LeHe consumption of the gun operation


BNL and SBU co-PIs: Yichao Jing and Irina Petrushina

Preparation for the gun operation with 1-3 mA

High current SRF gun experiment employs the existing Coherent electron Cooling (CeC) accelerator.



This spring we attempted to propagate high current CW beam to the High-power beam dump in the diagnostics beamline, but it resulted in excessive outgassing, which overloaded ion pumps.

The system underwent the following modifications:

1. **New solenoid was installed for lossless propagation of MeV-range e-beam**
2. **Nearly lossless propagation of 1.25 MeV bunches to the High-power beam dump was demonstrated**
3. **Upgrade to the Machine Protection System (MPS) was implemented**
4. **DCCT is installed to measure CW beam current**
5. **New high rep-rate seed laser is installed**
6. **The High-power beam dump was baked and achieved E-10 range in vacuum**

Beam dynamics studies

Desired beam parameters to deliver 1-3 mA

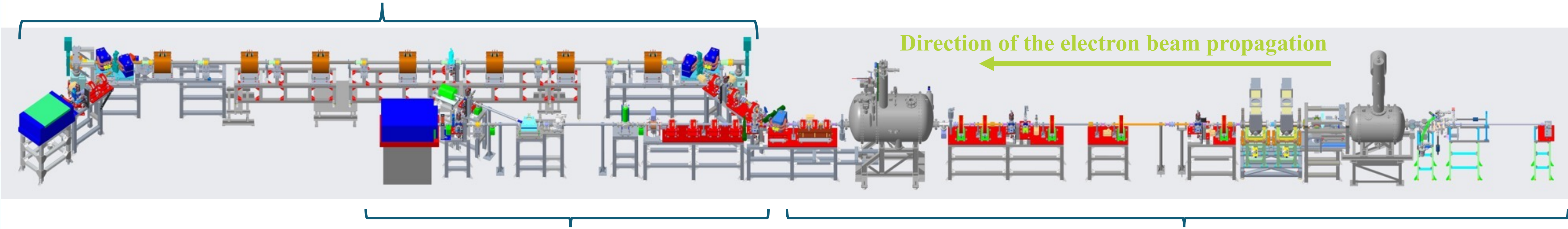
- Charge/bunch: 1.5-3.5 nC
- Operational repetition rate:
  - If using linac & buncher: 0.837 MHz
  - No linac & buncher: 2.974 MHz
- Higher current (3-10 mA) can be achieved by scaling up charge/bunch or repetition rate.

Operation without linac

P [kW]	I_{beam} [mA]	V_{gun} [MV]	Q_{bunch} [nC]
2.5	1	1.35	0.34
f [MHz]	2	1.25	0.67
2.974	3	0.833	1.01
	4	0.625	1.34
	5	0.5	1.68

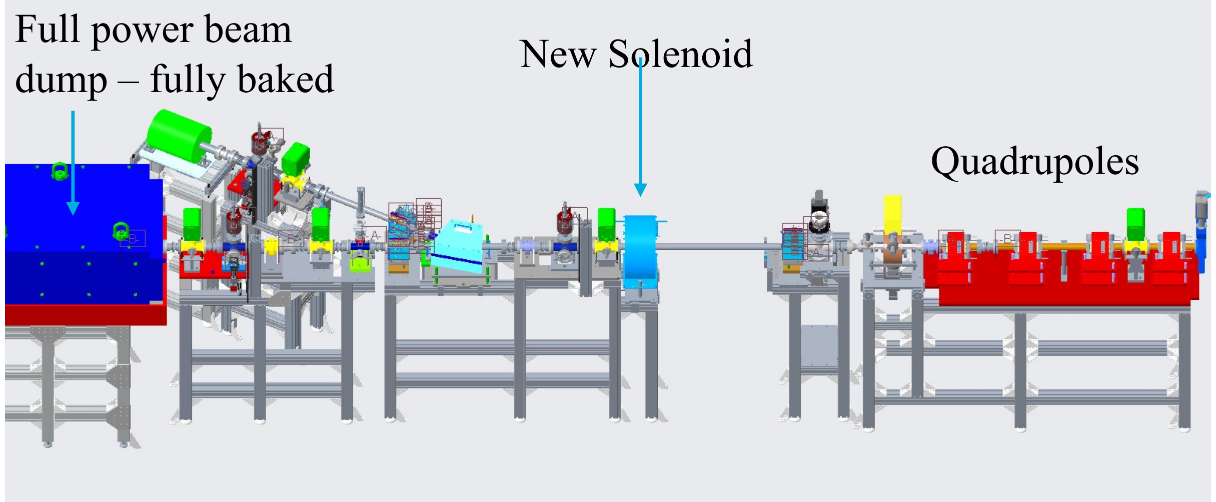
Operation with linac @ 3-6 MV

P [kW]	I_{beam} [mA]	V_{gun} [MV]	Q_{bunch} [nC]
2.5	1	1.35	1.19
f [MHz]	2	1.25	2.39
0.837	3	0.833	3.58
	4	0.625	4.78
	5	0.5	5.97



Beam dynamics studies

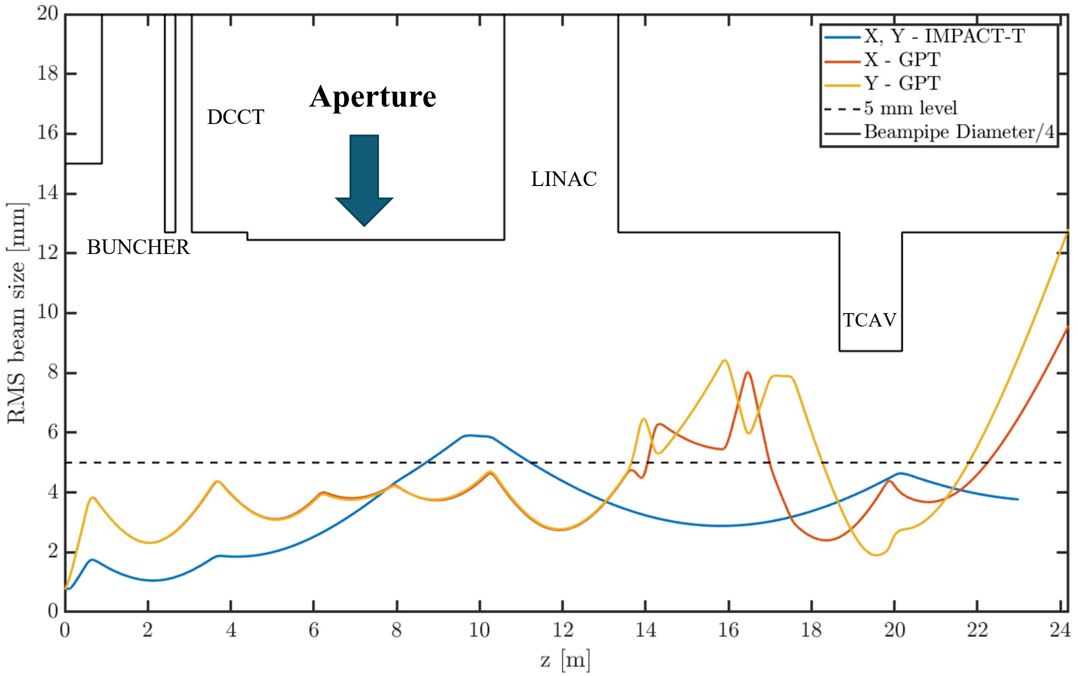
Parameter	Value
Bunch charge [nC]	1.5
Beam current @ 0.837 MHz [mA]	1.25
Laser pulse length [ps]	750
Gun voltage [kV]	833



New solenoid provides additional focusing for low energy beam between quadrupoles and the full power beam dump

We tested propagation of 1.5 nC 1.25 MeV bunches to the beam dump with very low losses

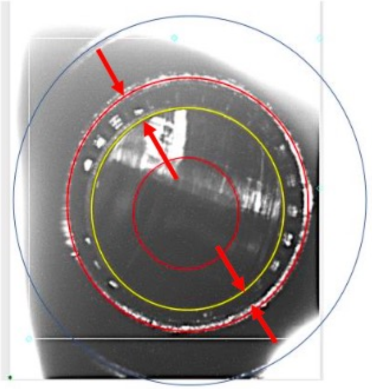
Linac & buncher are OFF



Practical experience with SRF gun performance recovery

Setbacks during RHIC runs 21 and 22 gave us a lot of opportunities…

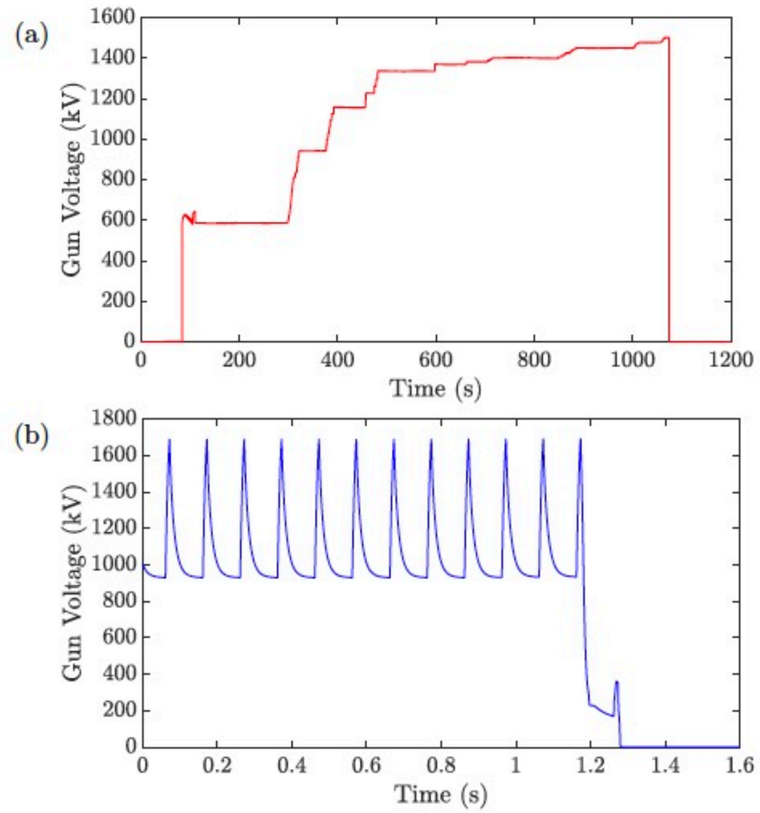
In **February 2021** the gun showed signs of significant performance degradation: rapid decay of the cathode quantum efficiency, appearance of new low-level multipacting barriers, increased radiation and LHe consumption compared to the routine operation levels. Upon inspection, damage was found to the cathode end effector within the gun and RF fingers. The damage cause significant contamination of the SRF gun cavity and drastic reduction in performance



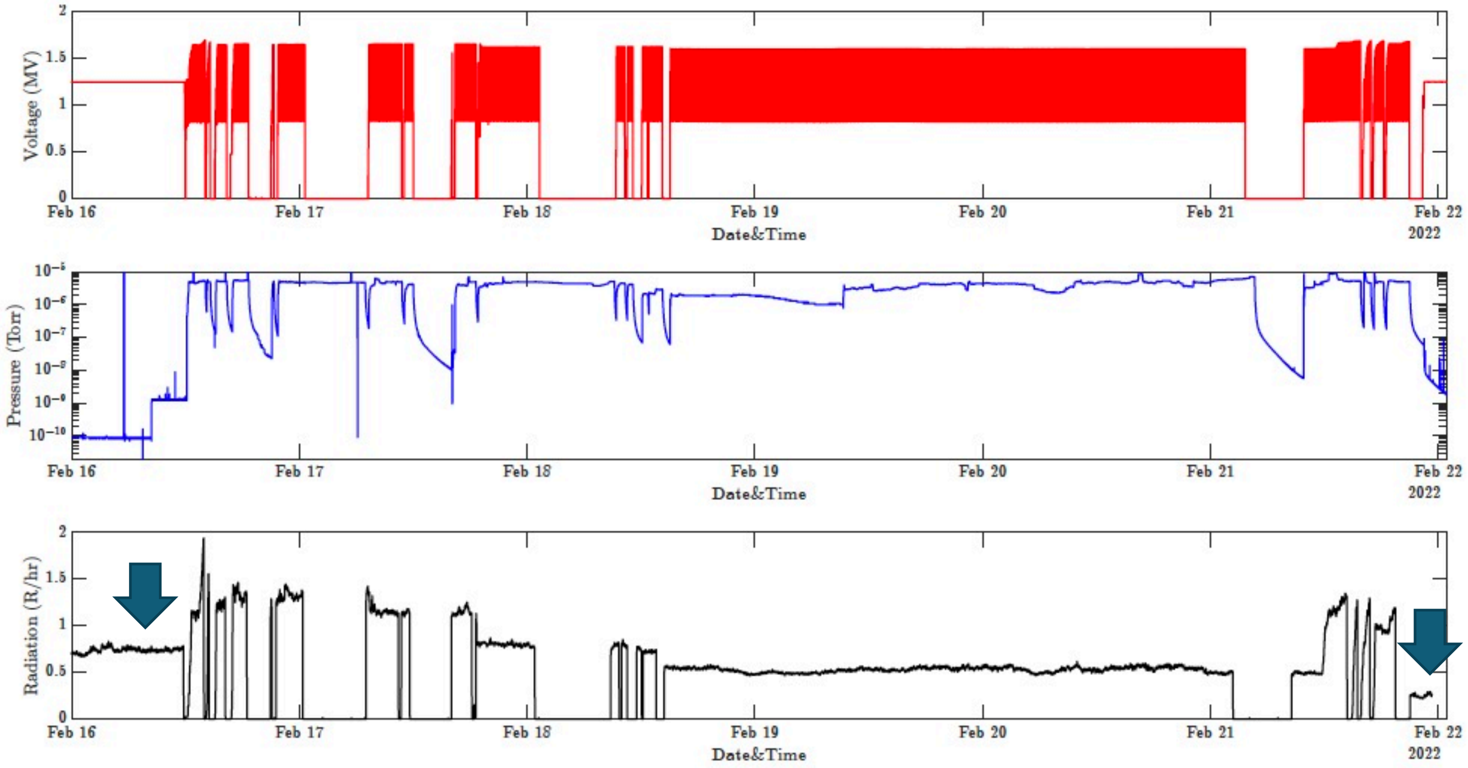
In **February 2022**, during a mundane cathode exchange, it was found that the cathode puck wasn't fully engaged with the end effector of the cathode manipulator once the old cathode was extracted. While attempting to insert a replacement cathode, an obstacle was encountered inside the cathode stalk that prevented the team from inserting the cathode….The cathode was installed, but the cavity demonstrated an immediate performance degradation: although the MP barriers were surpassed, the cavity would not be able to exceed 600 kV, showing significant amount of dark current in the cathode area and several spots of visibly glowing emitters….

In both cases, the damage was result of poor RF and thermal contacts with the water-cooled cathode stalk and generation of debris contaminating SRF gun.
Regular high-power RF pulsing was insufficient to restore SRF gun performance but using He conditioning was very effective. **In fact, it allowed us to improve SRF gun performance above previously demonstrated level.**

Practical experience with He conditioning of SRF gun



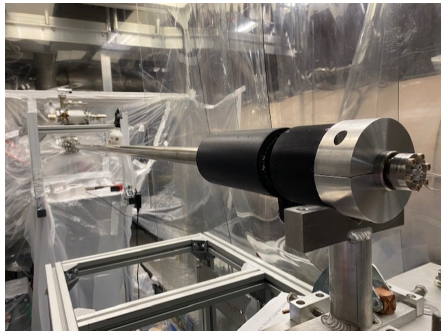
The highest achieved CW (a) and pulsed (b) cavity voltage after the first case of He conditioning.



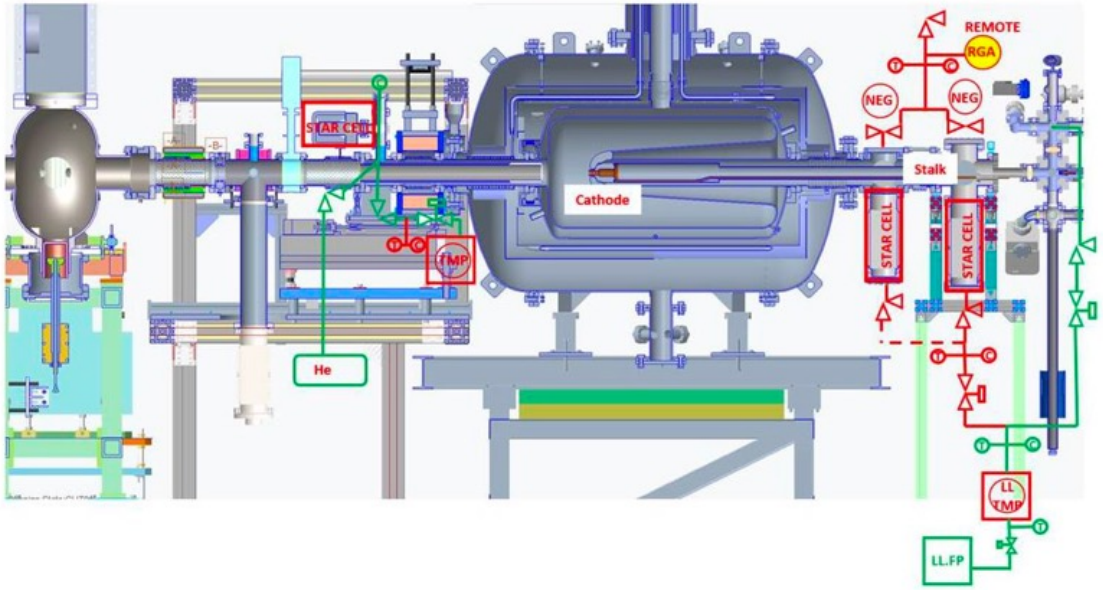
Gun voltage, pressure in the cavity and radiation levels during He conditioning.

- Quench-like limit occurs at **peak voltage of 1.7 MV**.
- The maximum **CW voltage of 1.5 MV** is limited by the LiHe consumption (max. available 8 g/sec).
- **At the operational voltage of 1.25 MV** X-ray radiation from the cavity was reduced to 250 mR/hr, compared to 750 mR/hr right after the incident.

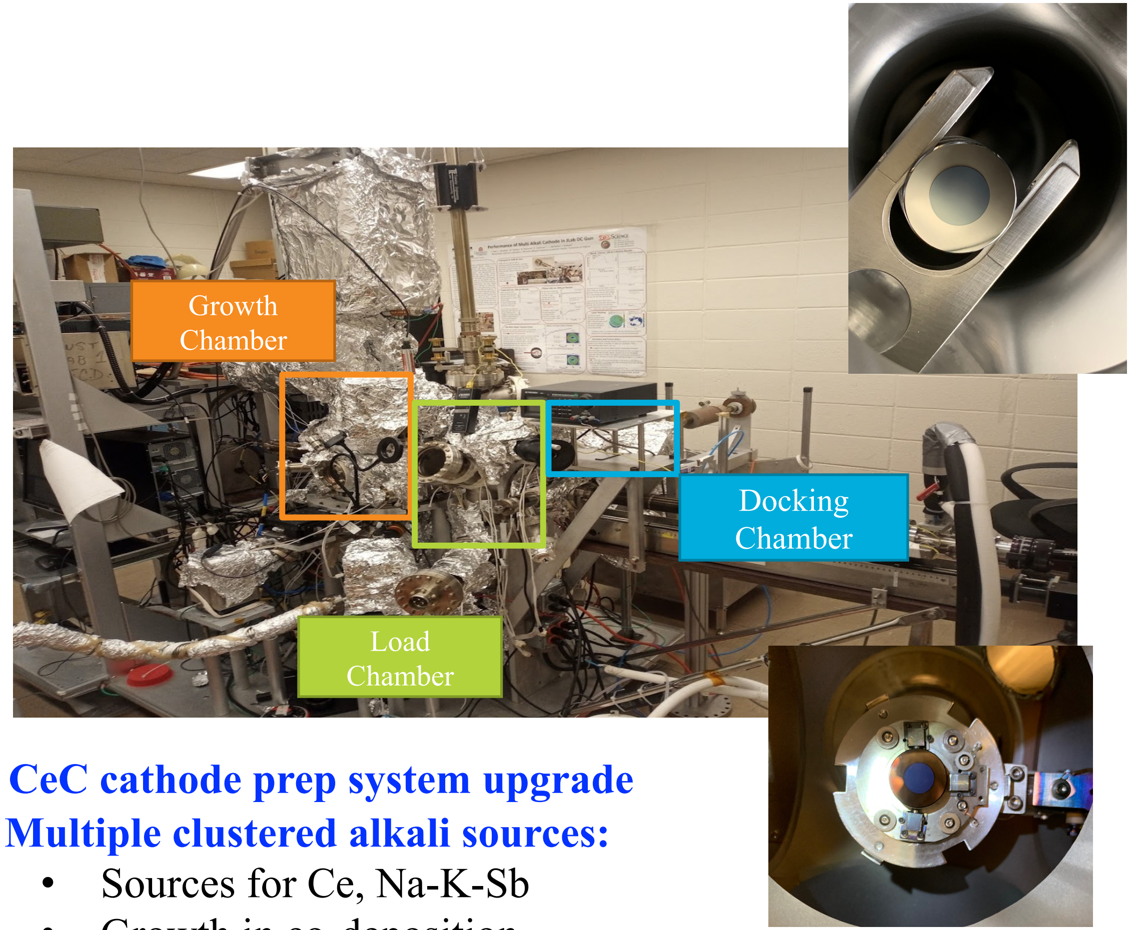
Preparation for polarized beam operation



1. Upgrade cathode deposition and transport system for GaAs CsTe-coated cathodes– **completed**
2. Load lock, transfer suit (“garage”) and cathode transfer chambers achieved 10^{-12} Torr vacuum range.
3. Major upgrade of SRF gun vacuum system - **in progress**
4. Introduce GaAs cathode into the SRF gun **– planned for Run 23**



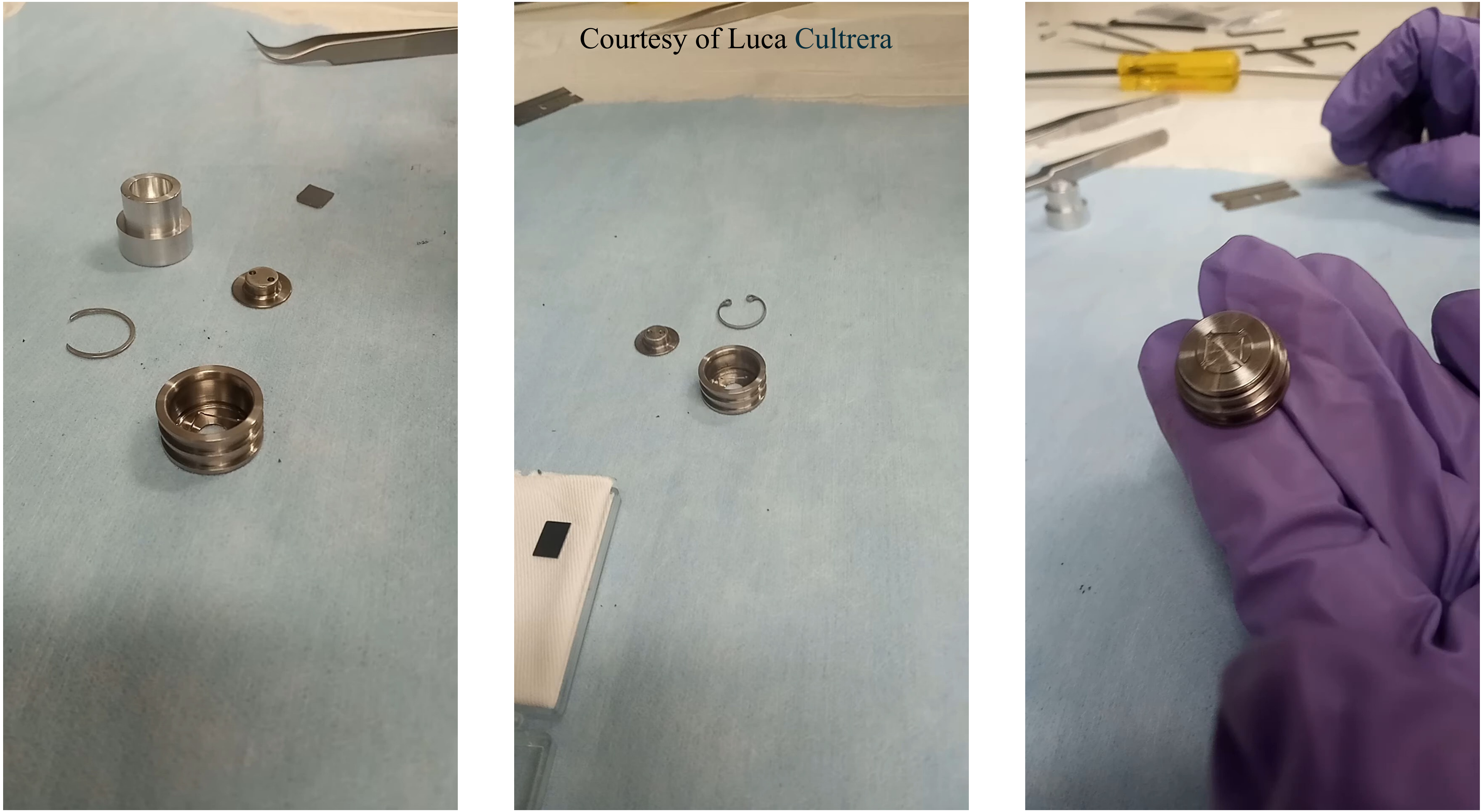
Upgrade of the SRF gun vacuum system should improve vacuum in the cathode stalk area by an order of magnitude. GaAs cathode transfer and insertion will be tested after the modification is completed to check it survivability before the start of RHIC Run 23.



CeC cathode prep system upgrade

- **Multiple clustered alkali sources:**
  - Sources for Ce, Na-K-Sb
  - Growth in co-deposition
  - Te and O_2 leak valve for GaAs
  - Protective coatings

Progress with modifying SRF gun puck for GaAs wafer



Courtesy of Luca Cultrera

Design of 100 kW FPC and plasma treatment system

Achievements & Milestones

Design of 100 kW FPC:

- Found the configurations of couplers which can be accommodated by existing facility with minimum changes.
- The couplers satisfy technical requirements:
  - Operating power 100 kW; Q_{ext} ~9.4e+5;
  - Tuning range > ±3.5 kHz;
  - Multipactor is suppressed by HV bias.
- RF and thermal designs of coupler(s) are finished.
- RF design of the waveguide elements is finished.
- Mechanical design of the coupler and the waveguide system is completed.

FNAL co-PI: Vyacheslav Yakovlev

Plasma treatment system:

- Analysis shows that plasma processing looks easily applicable to the 112 MHz SRF gun;
- Plasma ignition can be achieved by exciting the cavity at its fundamental mode by using few Watt of power. It should be experimentally verified. E_{pk} needed for ignition may be higher than in case of elliptical cavities, requiring more power than calculated
- No risk of igniting plasma at the antenna tip since field is maximized at the cavity surface;
- SRF gun system is a minor modifications of FNAL gas injection and vacuum cart.

Design of 100 kW FPC

Constrains of the design:

- **No change in** cavity **geometry** (single port D = 100 mm);
- Keep the **same beam channel**, D = 60mm;
- Coupler must provide an ability to **tune the cavity 7 kHz** (± 3.5 kHz);
- **Keep existing solenoid** configuration (desirable);
- New configuration must **fit into space** L = 862 mm

Possible problems:

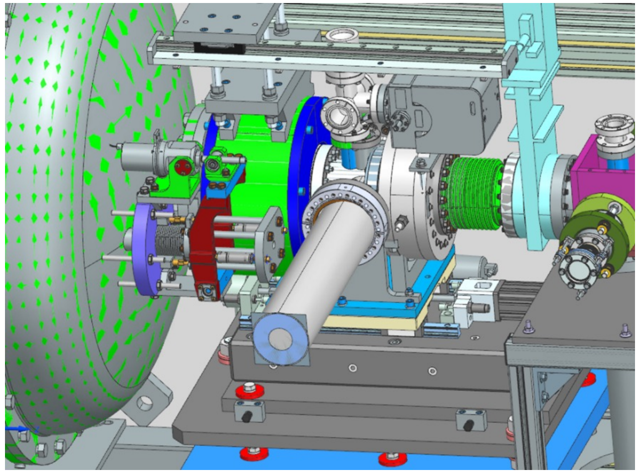
- **High thermal losses in antenna**. To avoid high losses in antenna the RF mode in coupler shall be close to pure traveling wave.
- **Inconsistency of tuning range** (7 kHz) and coupler matching
- **Multipactor** can be in antenna channel and ceramic window(s). Multipactor can be suppressed by HV bias. If we use a HV bias, antenna has to be DC isolated from "ground" and water cannot be used as cooling media of antenna.

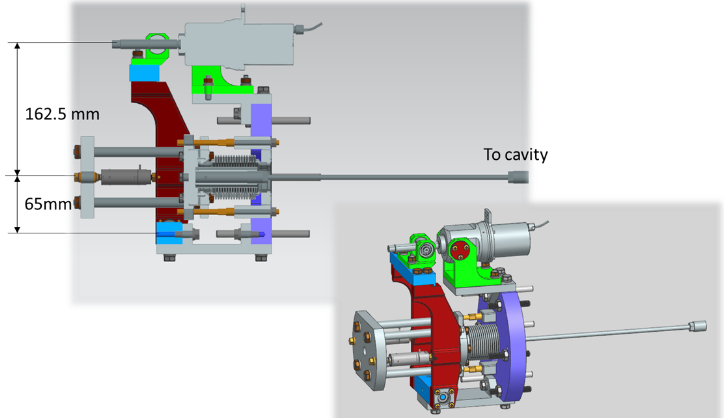
Design of 100 kW FPC - completed

Coupler parameters (the same antenna configuration as the existing)

Air can be used for antenna cooling

Parameter	Value	Unit
Coupler length (approximate)	680	mm
Outer conductor diameter	97.4	mm
Antenna diameter	80	mm
Outer conductor total resistance	6.14e-3	Ohm
Antenna total resistance	7.47e-3	Ohm
Coupler impedance	11.81	Ohm
Input power	100	kW
Current (ampl.)	130.1	A
Voltage (ampl.)	1.537	kV
Losses in outer conductor	**52**	**W**
Losses in antenna	**63.2**	**W**

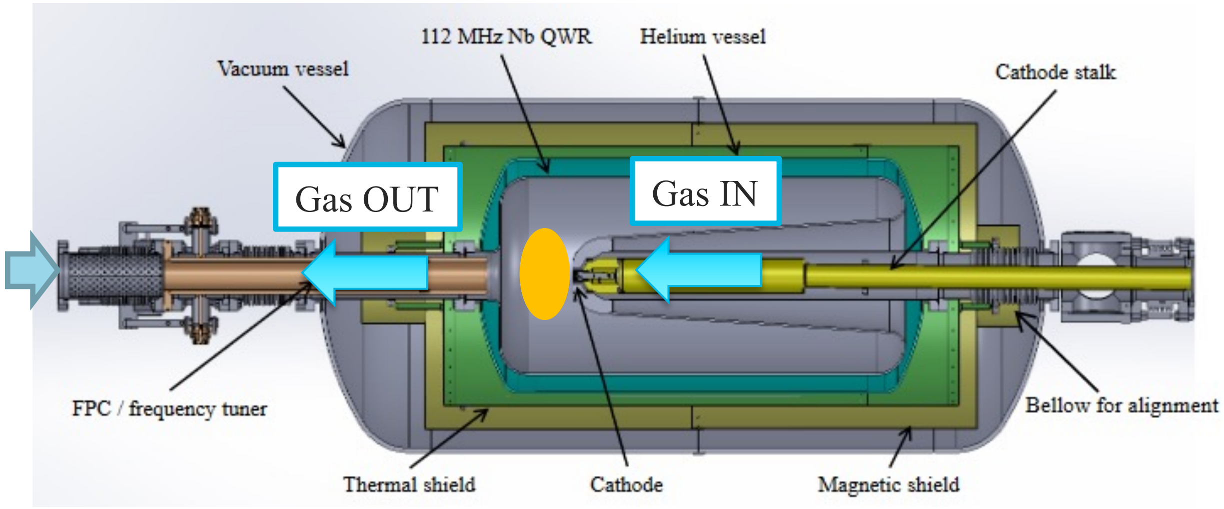




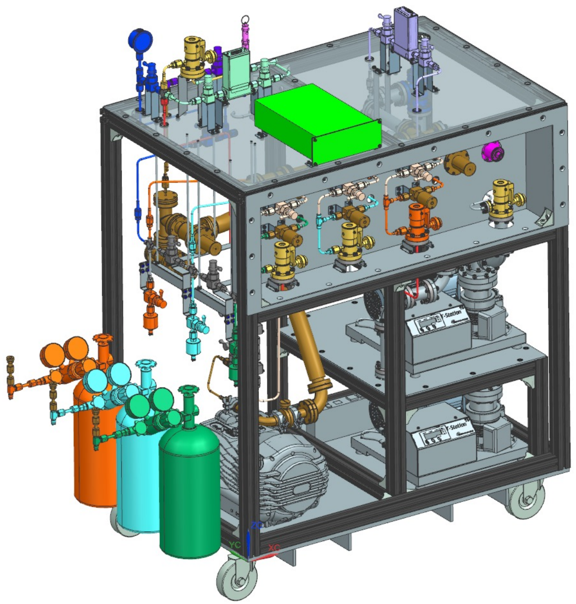
3D model of the proposed SRF cavity tuner.

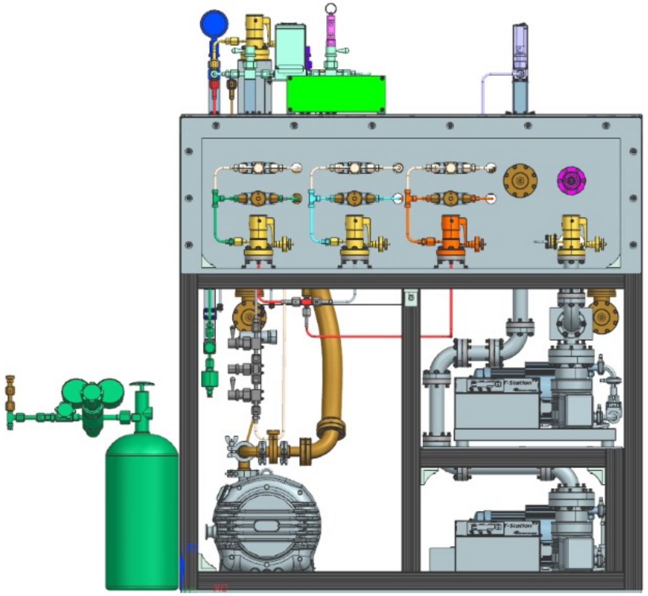
Coupler has to provide Q external ~ 9.4e4 to match 1.1 MW 100 kW electron beam

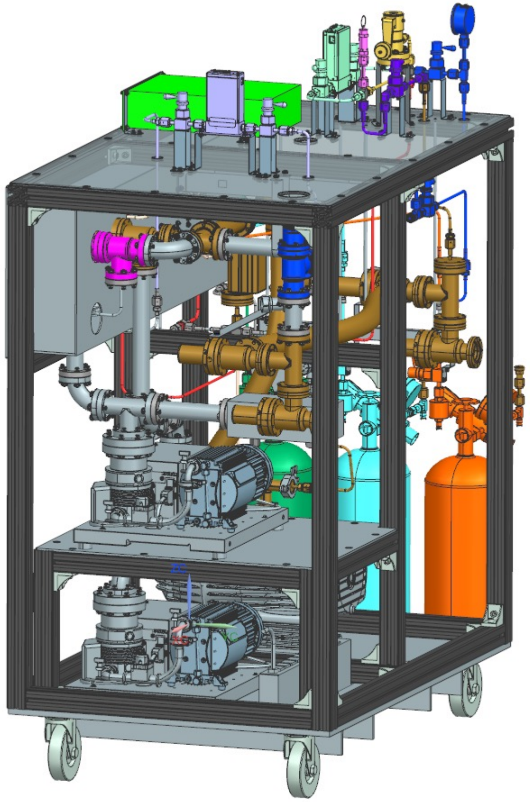
Plasma treatment system



- ➢ In order to create a gas flow inside the cavity, gas is injected from one side and pumped out from the other side; this appears to be feasible in the SRF gun system: gas can be injected from cathode side and pumped out from the FPC side;

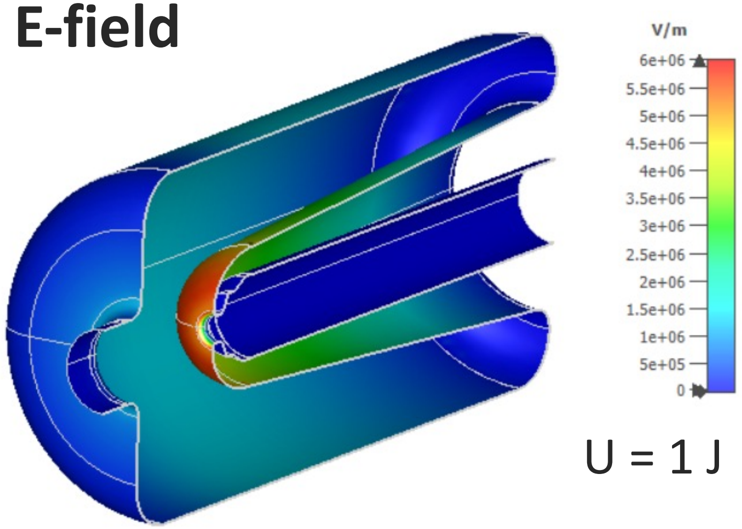






Analysis of plasma ignition in the SRF gun

E-field

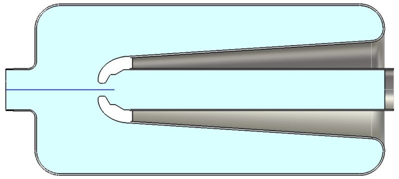


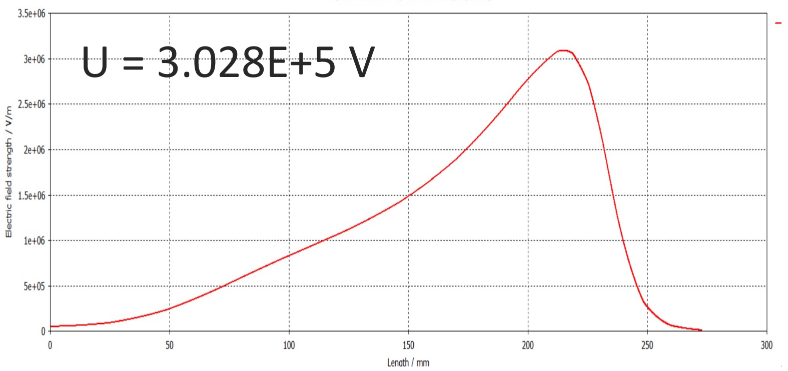
U = 1 J

Courtesy of S. Kazakov, FNAL

- Electric field maximum close to the cavity inner conductor, this is the region where plasma will ignite;
- Plasma can be ignited at room T by exciting the cavity fundamental mode with just few Watts:

E-field along curve 1:





U = 3.028E+5 V

Q_{ext}	9.3e4
Q_0	4.8e3
β	0.051
$\lvert\Gamma\rvert^2$	0.81
E_{pk} [kV/m]	10*
U [J]	2.78e-6
P_c [W]	0.41
P_f [W]	2.2 W

*E_{pk} ~ 10 kV/m needed to ignite plasma in elliptical cavities. We will need to verify experimentally that the same applies to this geometry.

Development of Beam Polarimeter for BNL SRF Gun

Achievements, Milestones, and New Timeline

Year 1:

Agreed upon basic operational parameters of polarized electron beam and polarimeter
Portable DAQ design completed and implementation started
Jefferson Lab Fast Electronics Group programmed an ethernet flash analog-to-digital convertor and worked on user interface of DAQ
Polarimeter design (radiator, magnet, and detector) was optimized using GEANT4

Year 2:

Designed iron core electro-magnet - fabricated by a local vendor
Built one polarimeter - radiator, magnet, and detector - and one portable DAQ . Second polarimeter and DAQ is in progress
Calibrated polarimeter at UITF with portable DAQ

Years 3 & 4 (NCEs):

Install and commission polarimeter at BNL in Fall 2023
When SRF photogun employs a GaAs photocathode: measure electron beam polarization
Second polarimeter and DAQ: Radiator #2 needs to be fabricated, Magnet #2 being wound at vendor –will stay at JLab
Documentations and writing a paper for publication, submitting an abstract to IPAC'23

Jlab co-PI: Riad Suleiman

Jefferson Lab

IJCLab Irène Joliot-Curie

OLD DOMINION UNIVERSITY

Goals, Timeline, and Budget

- Co-Principal Investigator: Riad Suleiman, with Joe Grames and Matt Poelker (Jefferson Lab), Eric Voutier (IJCLab, Orsay, France), and Greg Blume (graduate student – ODU)

- Jefferson Lab's contribution to this project is to provide a Compton Transmission Polarimeter, which will be used to measure beam polarization when SRF photogun employs a GaAs photocathode. IJCLab is contributing to Jefferson Lab's effort.

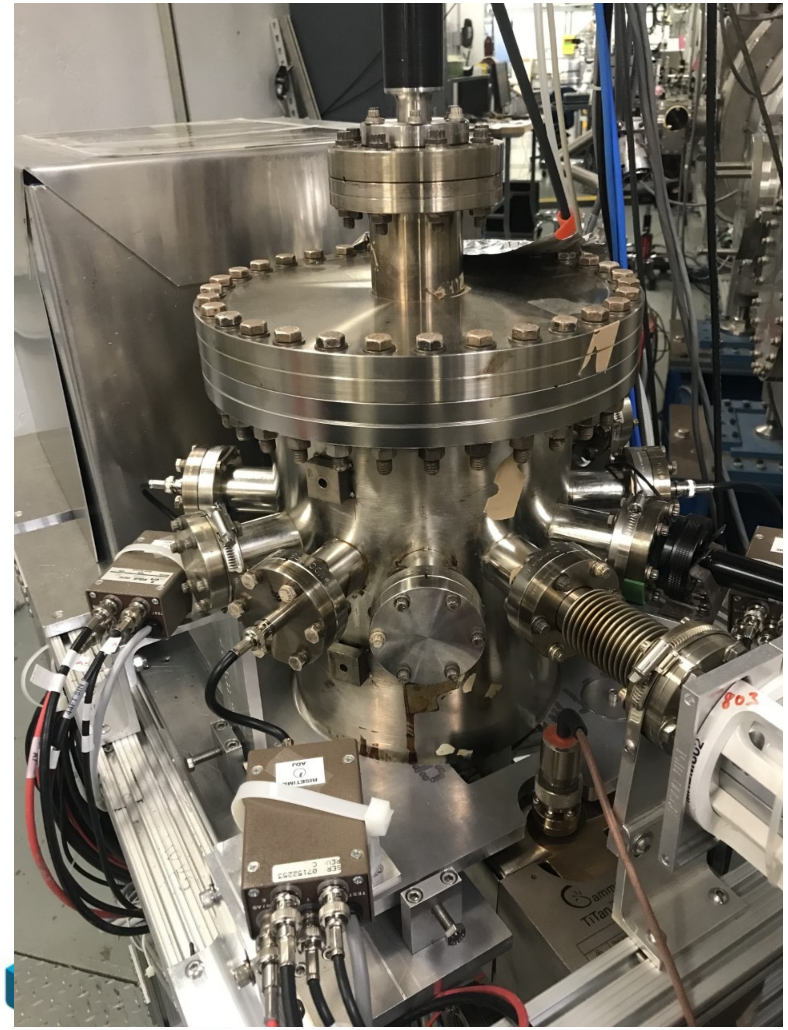
- Goals:
  - Year 1: Design and build electron beam polarimeter
  - Year 2: Install and commission polarimeter at CeC accelerator

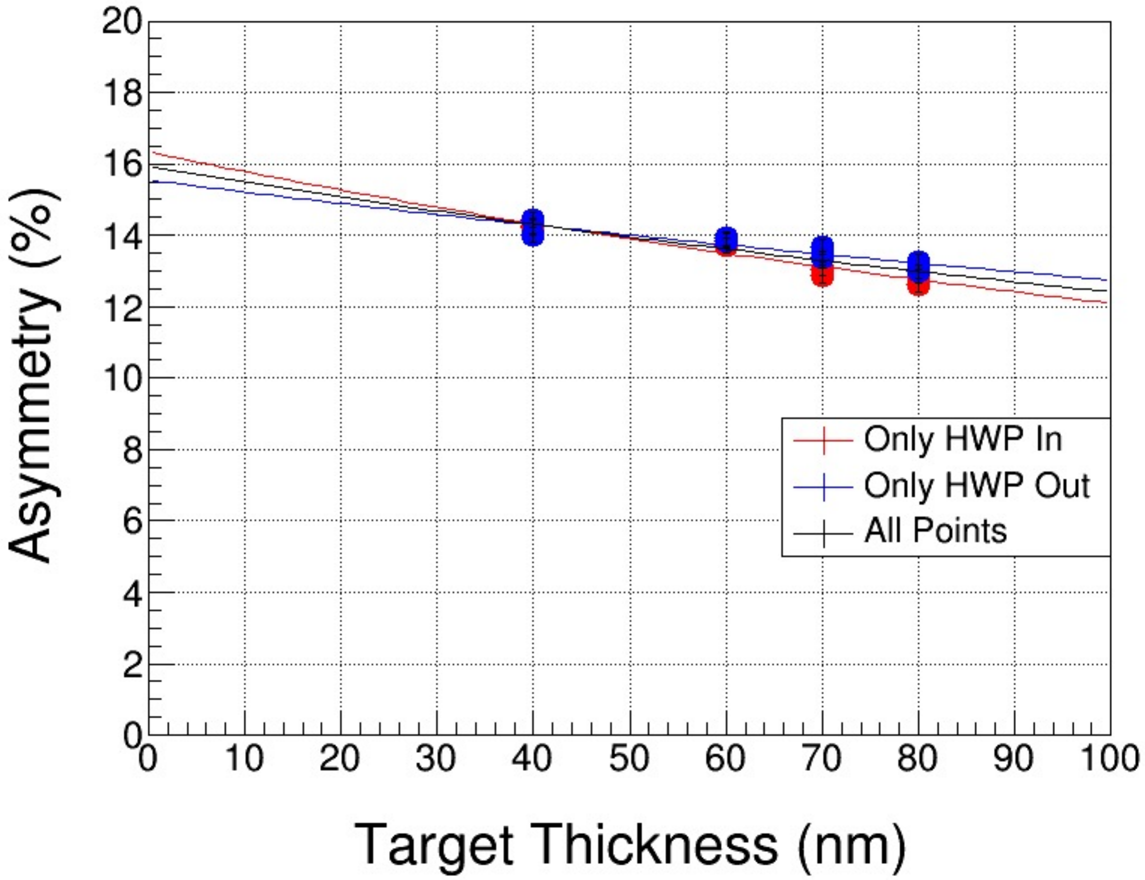
	FY20 ($k)	**FY21 ($k)**	**Totals ($k)**
a) Funds allocated	200.1	200.1	400.2
b) Actual costs to date	200.1	114.6	314.7

- Current Status:
  - Polarimeter has been designed, built, and calibrated at Jefferson Lab
  - Now under 1-year NCE that ends 9/23 – plan to submit a NCE request for another year for BNL install
  - Plan to install and commission polarimeter at BNL in Fall 2023

Measuring Beam Polarization

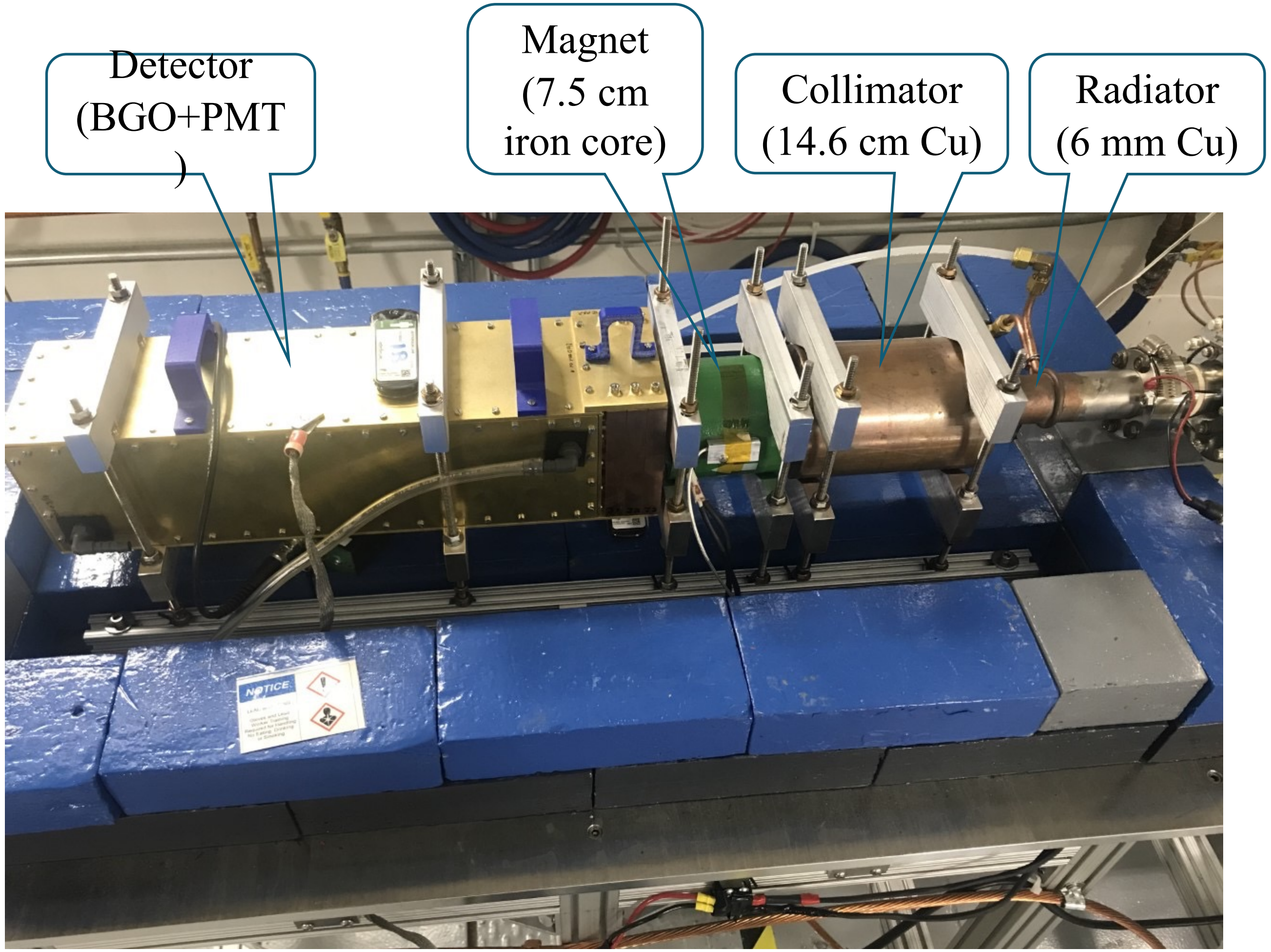
- Used Mott polarimeter at 180 kV to measure beam polarization from bulk GaAs at 780 nm

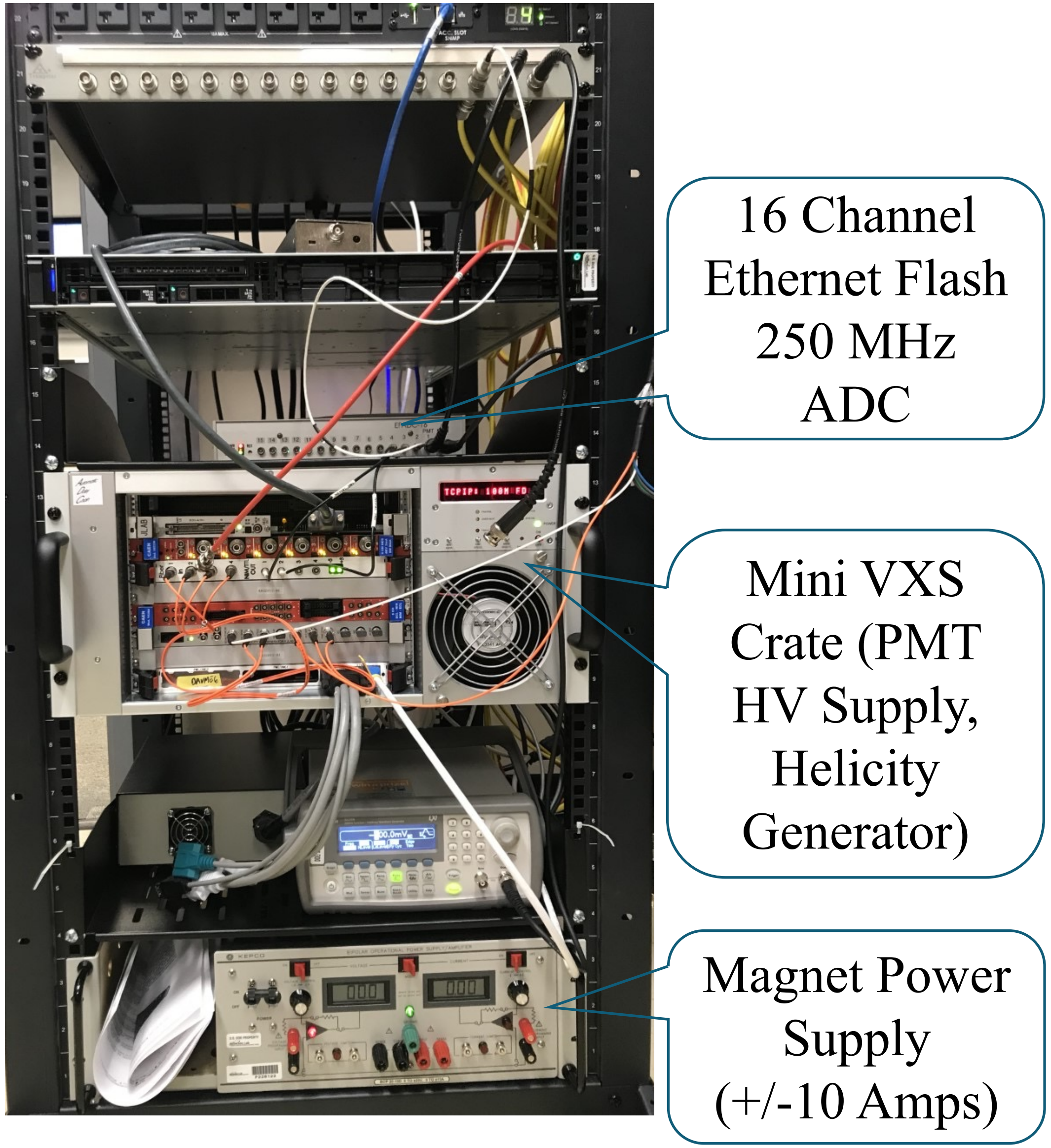




$$\text{Beam Pol} = \frac{A_0}{ShFunc} = \frac{15.926\%}{0.426135} = 37.4 \pm 0.9(\text{stat})\ \%$$

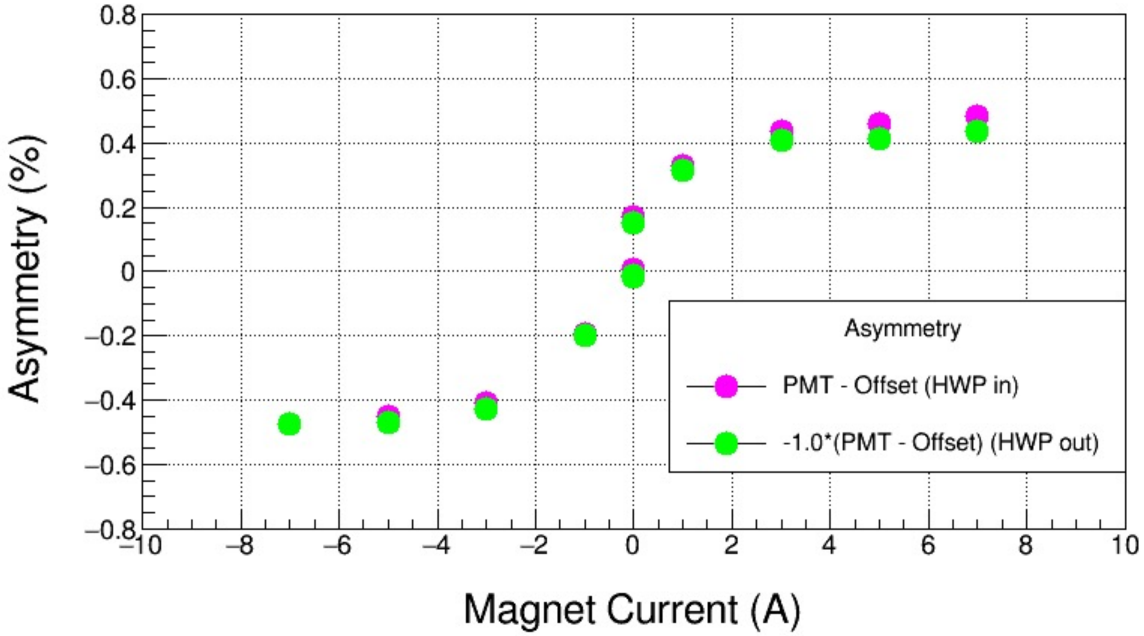
Compton Transmission Polarimeter





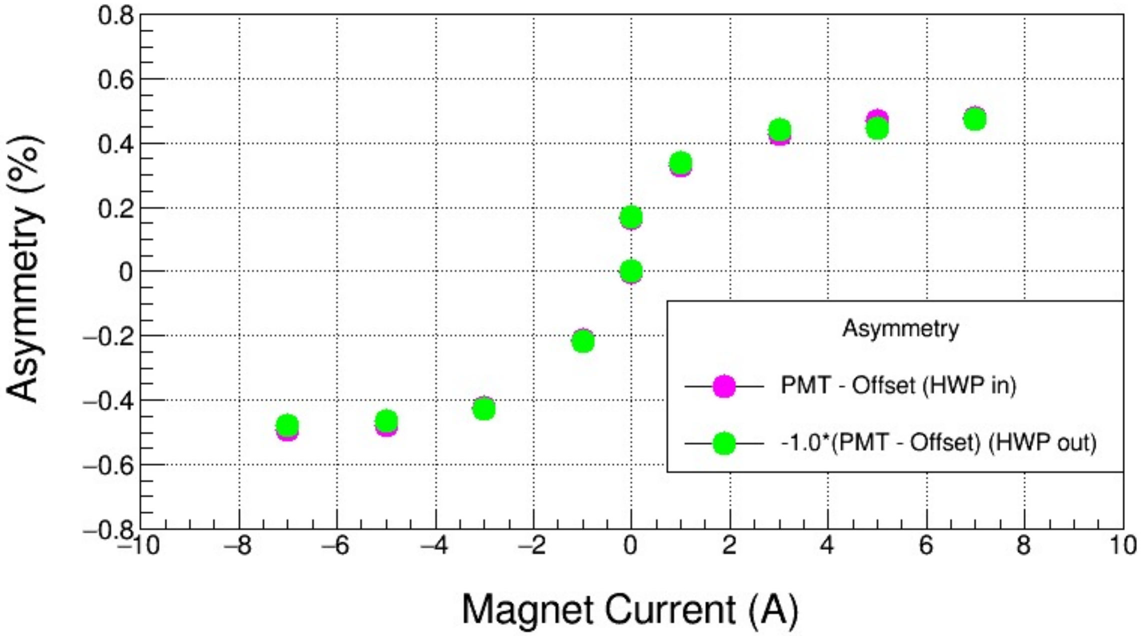
Compton Polarimeter Calibration

Beam Kinetic Energy = 5 MeV



Compton Polarimeter
Analyzing Power (5 Amps):
$\frac{0.4507\%}{37.4\%}$=1.21±0.04 (stat)%

Beam Kinetic Energy = 7 MeV



Compton Polarimeter
Analyzing Power (5 Amps):
$\frac{0.4622\%}{37.4\%}$=1.24±0.03 (stat)%

What is next?

Plans for next two years

We are committed to complete Phase 1 of our SRF gun experimental program of testing operation with GaAs cathode and operating with mA-scale average beam current using CsK_2Sb cathode

RHIC run 23

- First tests of GaAs photocathode in SRF gun, measure QE in green
- Demonstrate average beam current of 1 mA using CsK2Sb photocathode
- Evaluate lifetime and charge capacity of CsK_2Sb photocathode
- Identify potential show-stopers

Shut down between RHIC runs 23 and 24

- Analyze data, remove potential show-stopers
- Install Compton polarimeter

RHIC run 24:

- Optimize SRF gun setting for generating maximum beam current
- Increase average beam current towards 3 mA
- Evaluate lifetime and charge capacity of CsK2Sb photocathode
- Produce a set of CeTe coated GaAs photocathodes
- Test SRF gun operation with GaAs photocathodes
- Evaluate performance of GaAs photocathodes in SRF gun
- Commission Compton polarimeter

Thank you for listening

List of Participants:

- SBU: V.N Litvinenko (PI), I. Petrushina (co-PI), K. Shih, A. Coakley, machine shop
- BNL: Y. Jing (co-PI), W. Fischer, I. Pinayev, J. Ma, G. Wang, J. C. Brutus, P. Inacker, E. Wang, J. Skaritka, L. Cultrera, T. Rao, P. Bachek, G. Narayan, T. Hayes, A. Zaltsman, F. F. Severino, D. Weiss, L. A. Smart, K. Decker, Z. F. Altinbas, R. Michnoff, M. Minty, M. Paniccia
- FNAL: V. Yakovlev (co-PI), S. Belomestnykh, S. Kazakov, T. Khabiboulline, P. Berrutt M. Martinelli, J. Helsper, Y. M. Pischalnikov
- JLab: R. Suleiman (co-PI), M. Poelker, J. Grames, E. Voutier, B.F. Neres

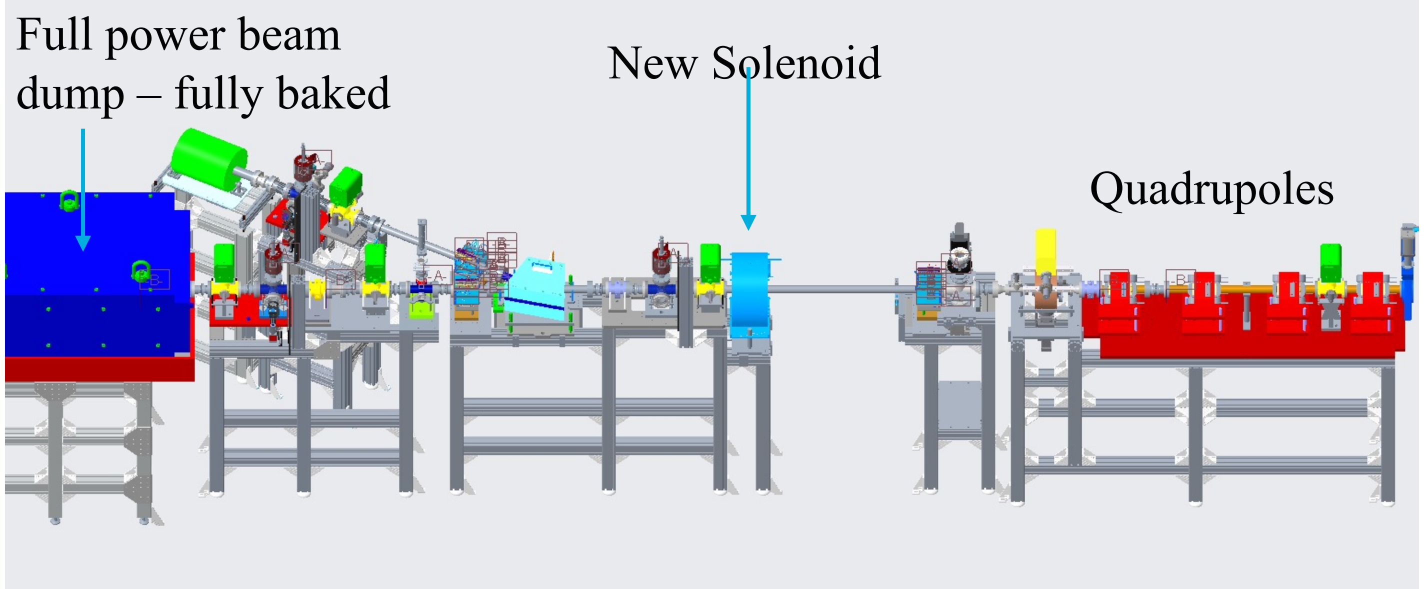
Back-up slides

BNL back-up

Preparation for the gun operation with 1-3 mA:

Diagnostics beamline upgrade – new solenoid installed

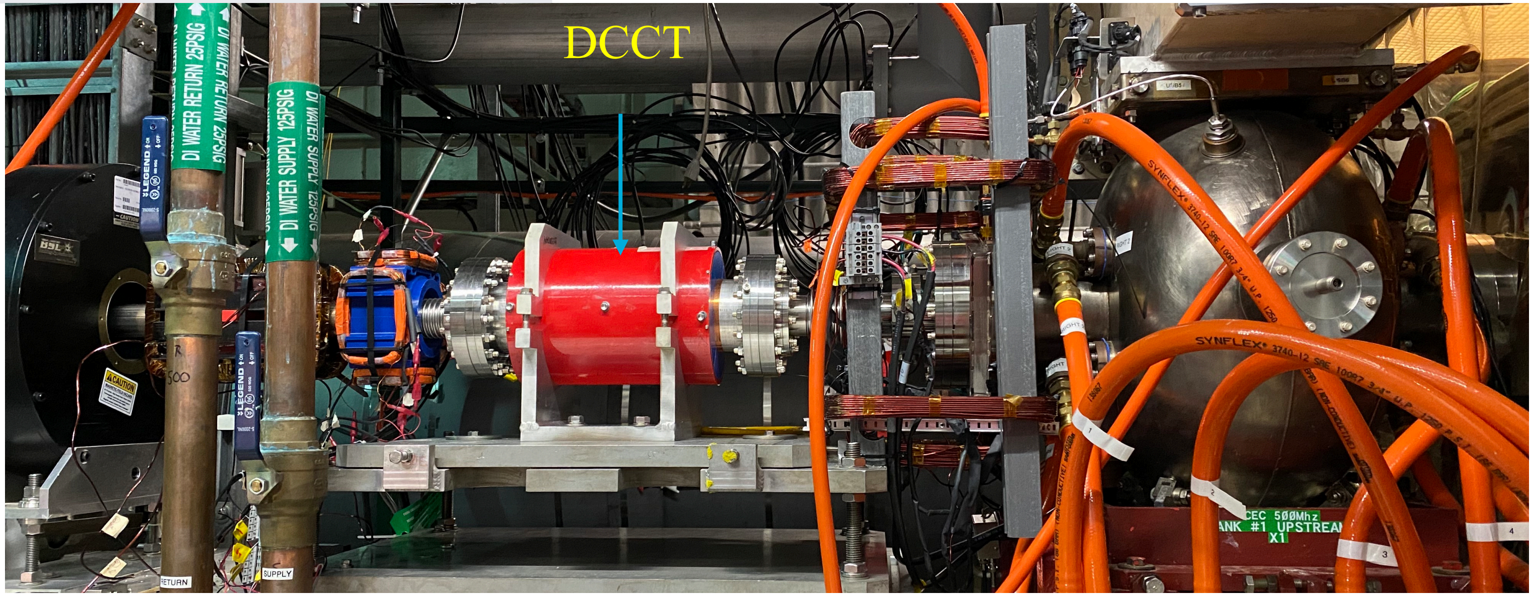
Additional diagnostics installation – DCCT installed



New solenoid provides additional focusing for low energy beam between quadrupoles and the full power beam dump

Full power beam dump in the diagnostics beamline was not baked and had extensive outgassing. It was baked this summer and now had 10-range vacuum

This DCCT will use an updated version of the electronics package that is designed to be more stable during thermal variations. This signal will then be processed with a spare channel in the existing Zynq system.

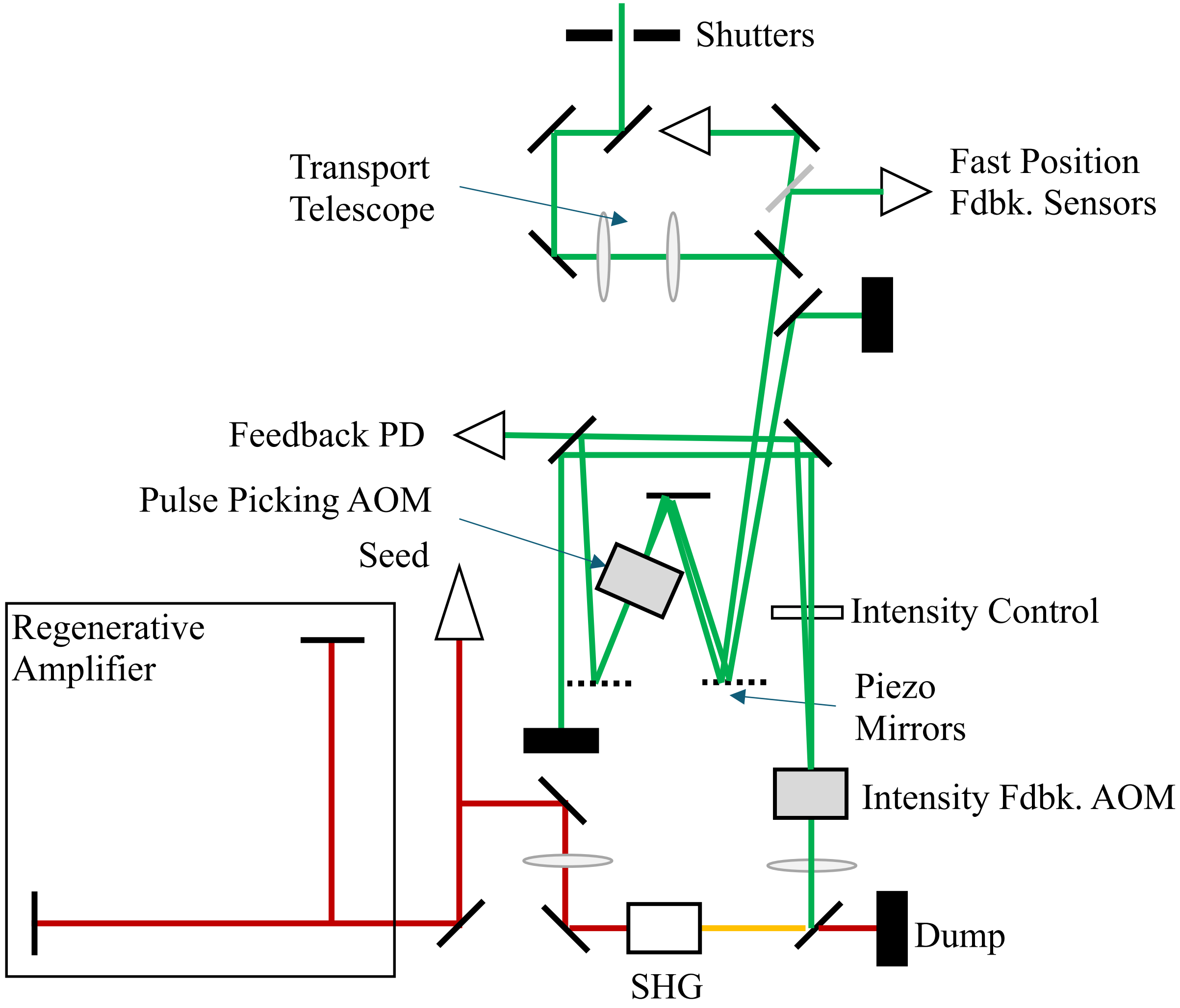


Preparation for the gun operation with 1-3 mA

- Exchange of IR Pockels Cell Pulse Picker with AOM to enable 0-100% duty cycle operation for high repetition rate operation (1-5MHz)

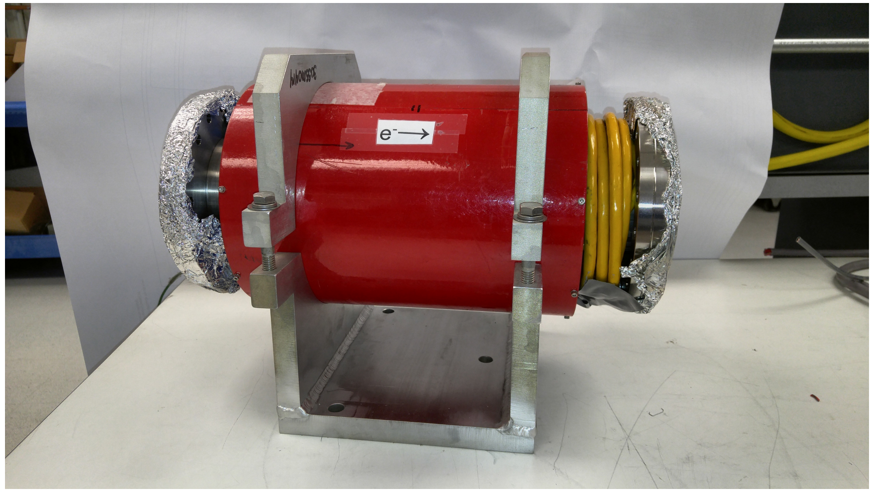
- Maintaining CW beam throughout the entire system to enable high bandwidth position and intensity feedbacks and limit thermal effects from repetition rate changes

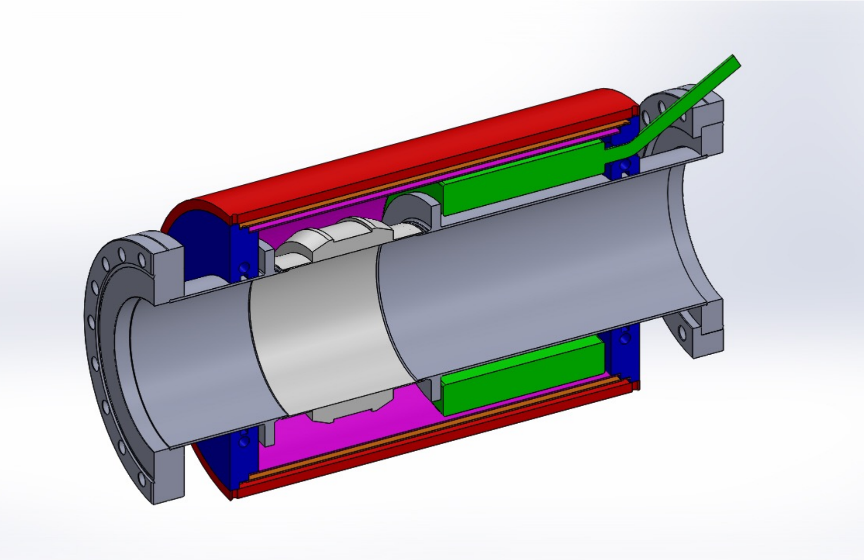
- Addition of second AOM for fast intensity feedback
  - Still need to work out efficient noise detection method to reach 2kHz Fdbk. Bandwidth for operation at variable repetition rates (78kHz-5MHz)



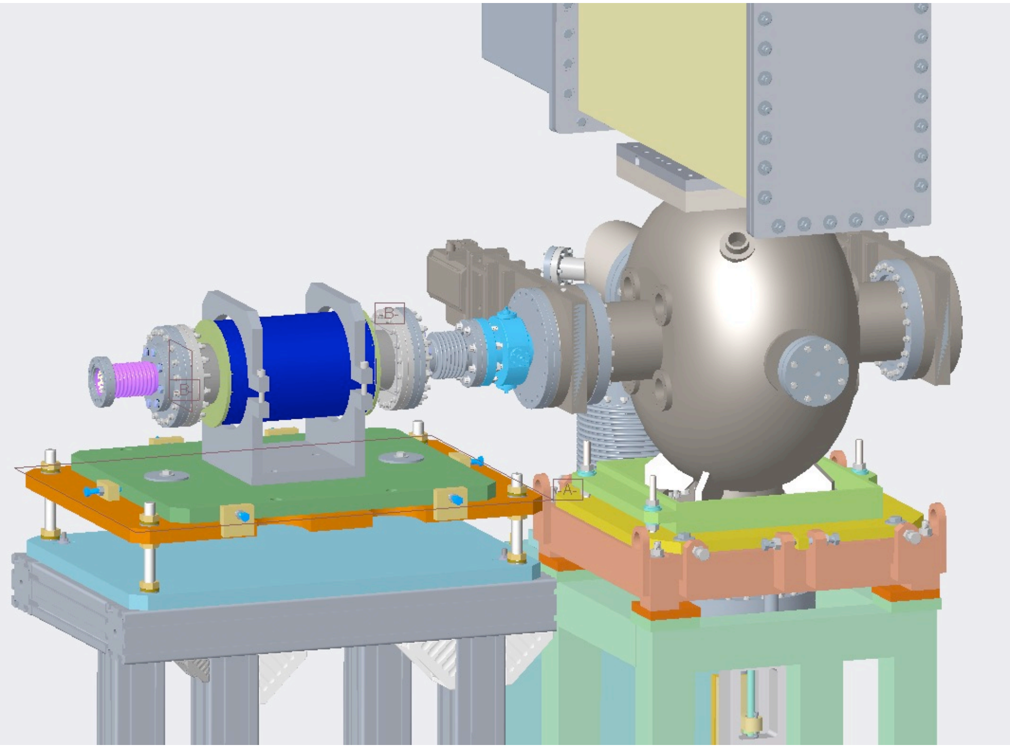
Preparation for the gun operation with 1-3 mA:

- The second of the two **DCCTs** that were used in ERL **has been rebuilt to have a larger aperture** than the original.
- It was **installed** in place of the second 500MHz cavity that was removed.





This DCCT will use an updated version of the electronics package that is designed to be more stable during thermal variations. This signal will then be processed with a spare channel in the existing Zynq system.



Laser Expected Performance

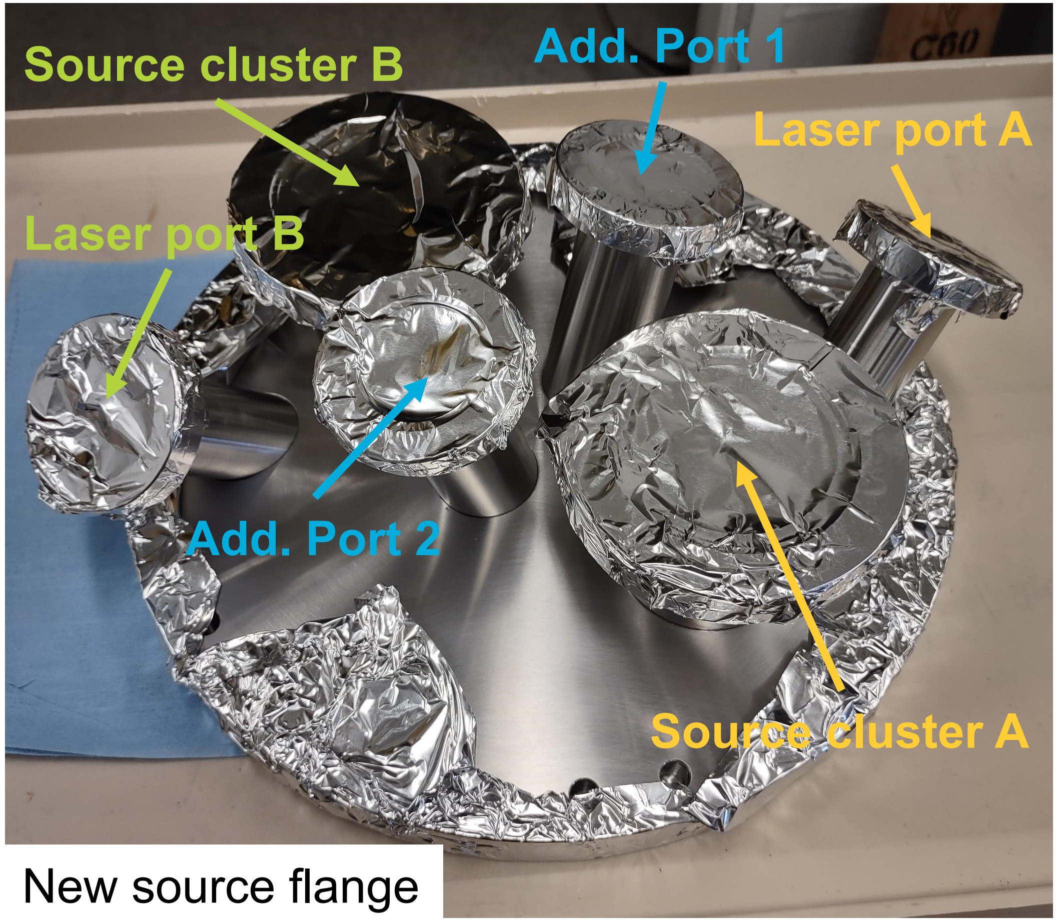
	Unit	Min	Typ.	Max
Seed Wavelength			1064.2	
Output Wavelength	λ		532.1	
Bandwidth	nm		0.05	
Pulse duration (depends on Seed Option)	Ps	50	350	750
Pulse Shape (Identical to Seed)	-		Flat-Top	
Repetition Rate	kHz	10	78	5000
Average Power (532nm)	W	5	6	5
Pulse Energy	μJ	500	75	1
Charge equivalent after spatial shaping (1%QE)	nC	1000	150	2

- The planned CeC upgrade is straight forward, with most specifications already demonstrated at a sister system located at Stony Brook university
- Most parts are in house already, no delays are expected

Main growth chamber

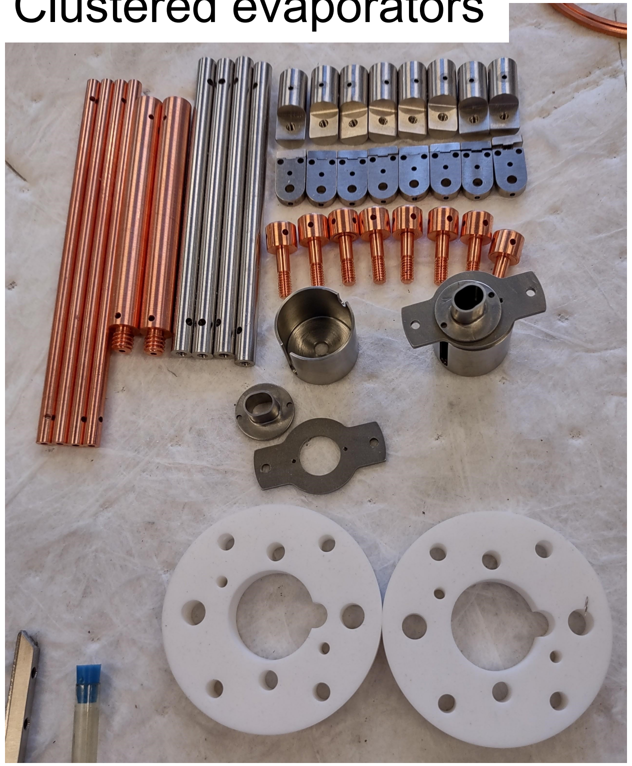
- Replace the main UHV chamber to allow
  - Hosting two cluster of sources (better alignment, co-deposition);
  - 2 additional port for future R&D on protective coatings;

New main chamber



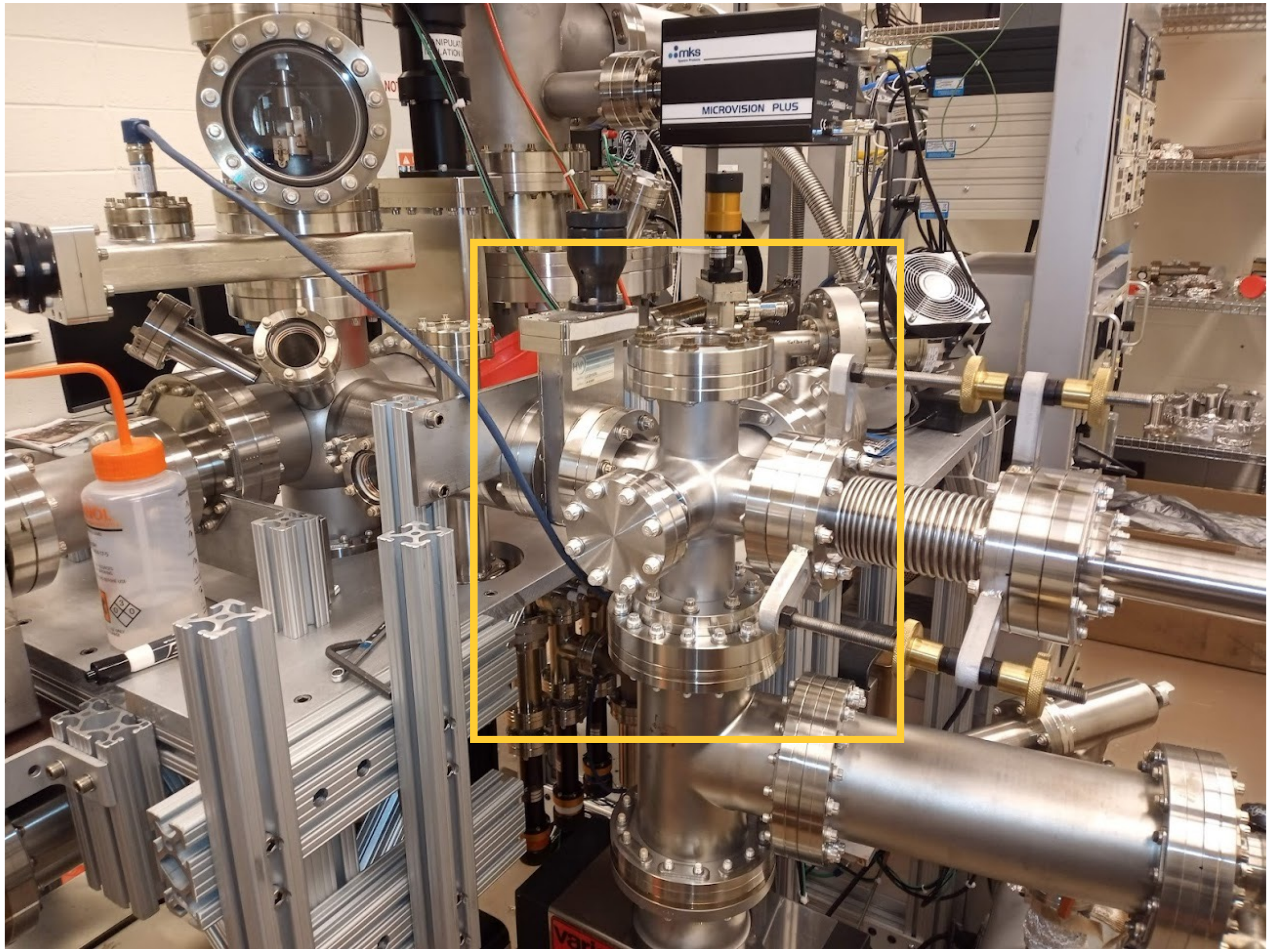
New source flange

Clustered evaporators



Installation of the new evaporators assembly has been delayed to Dec 2021-Jan 2022 because of delays in the delivery of some required vacuum components.

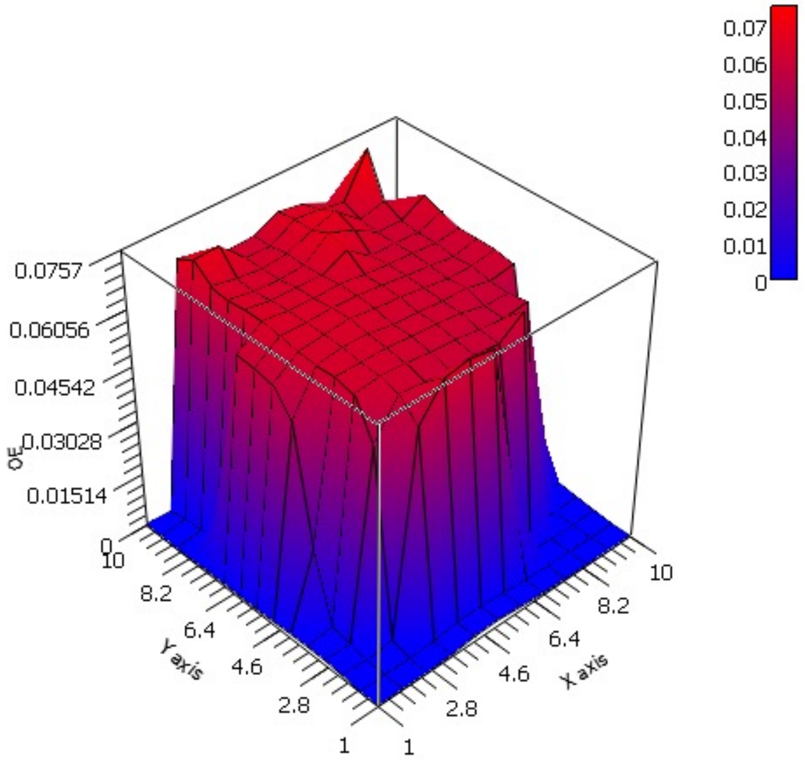
New docking chamber



A new docking chamber with a 3.375” port allows for a larger clearance around the magazine minimizing the chances of scraping and of particulate production;

QE 2D scan capability is included

QE map of cathode #2 grown on 10/28/2021



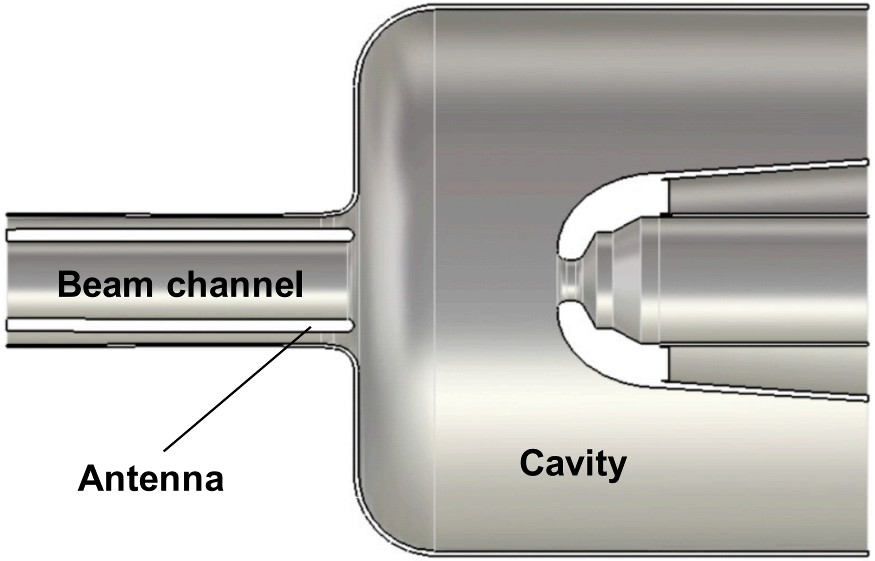
- Piezo motors are probably not the best choice due to their large backlash;
- looking to replace them with stepper motors;

FNAL back-up

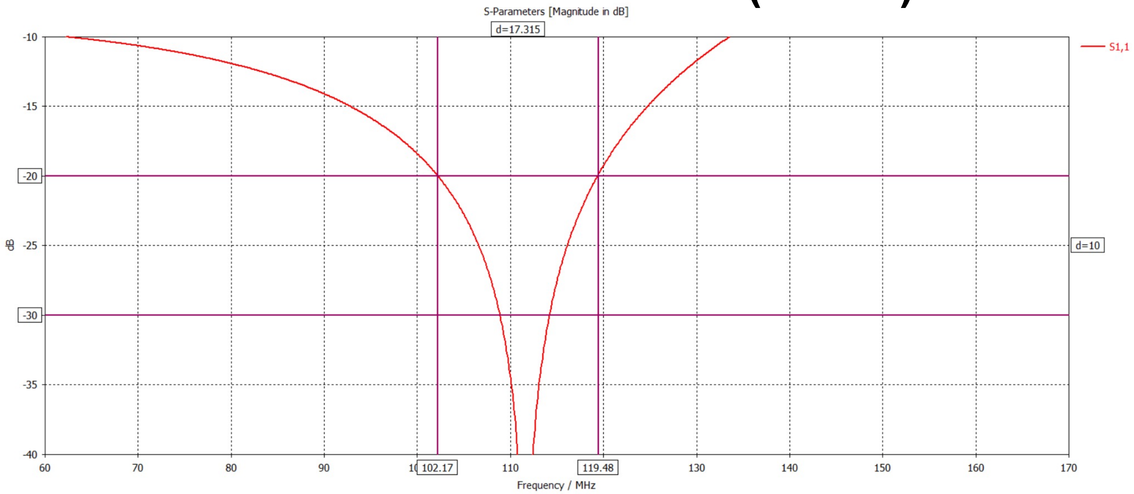
Design of 100 kW FPC

RF configuration of 100 kW coupler(s)

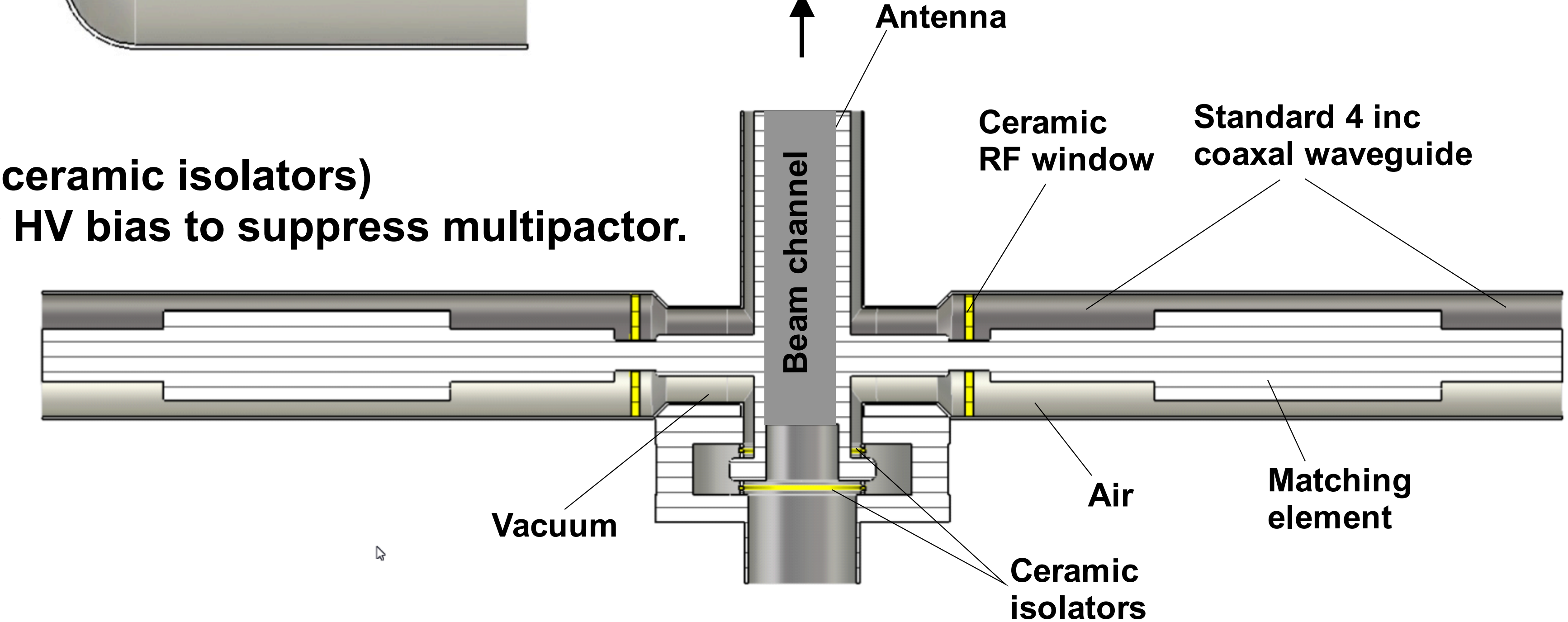
Antenna position of $Q_{ext} = 9.4e4$



Passband ~18 MHz (~ 16%)



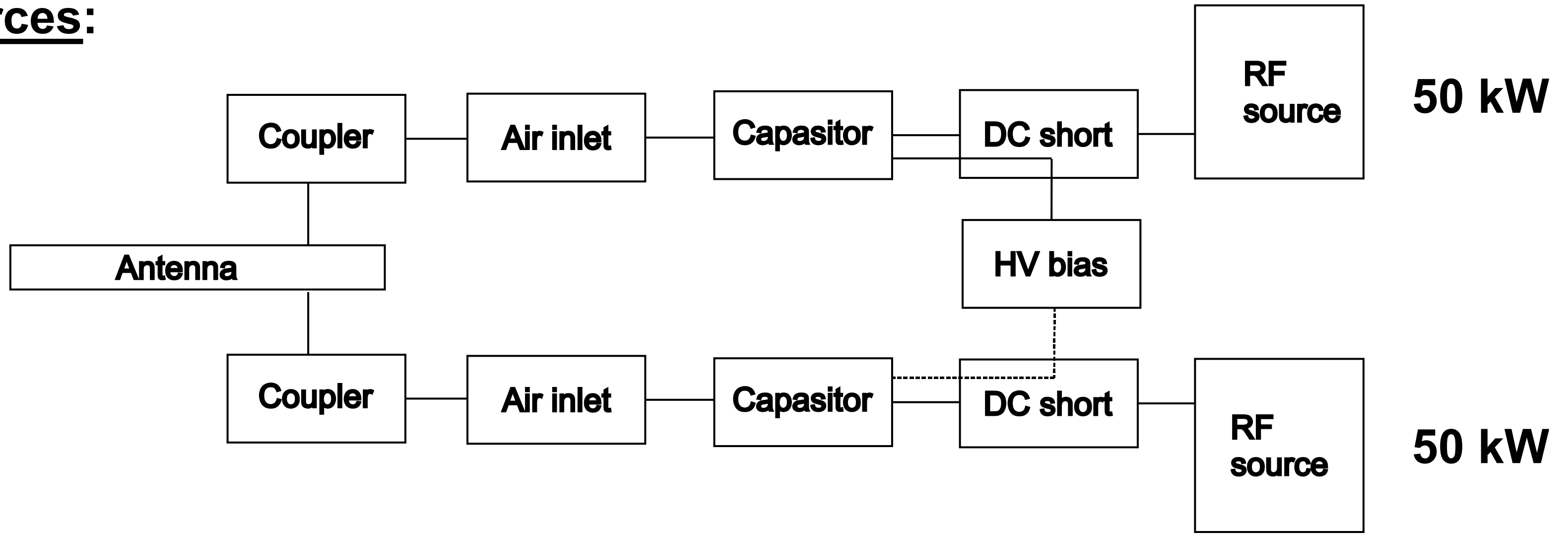
Configuration (ceramic isolators)
allows to apply HV bias to suppress multipactor.



Design of 100 kW FPC

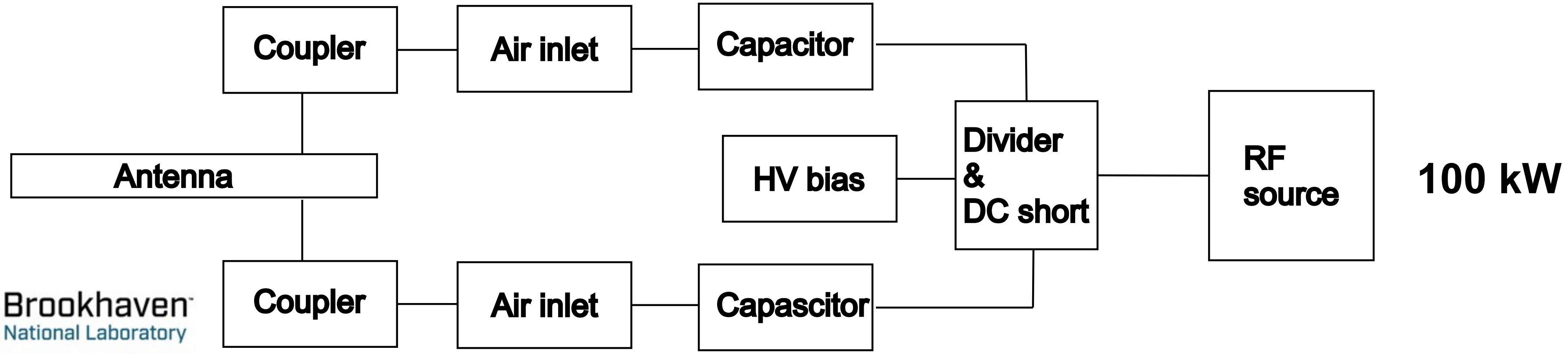
Possible RF configuration

Two RF sources:



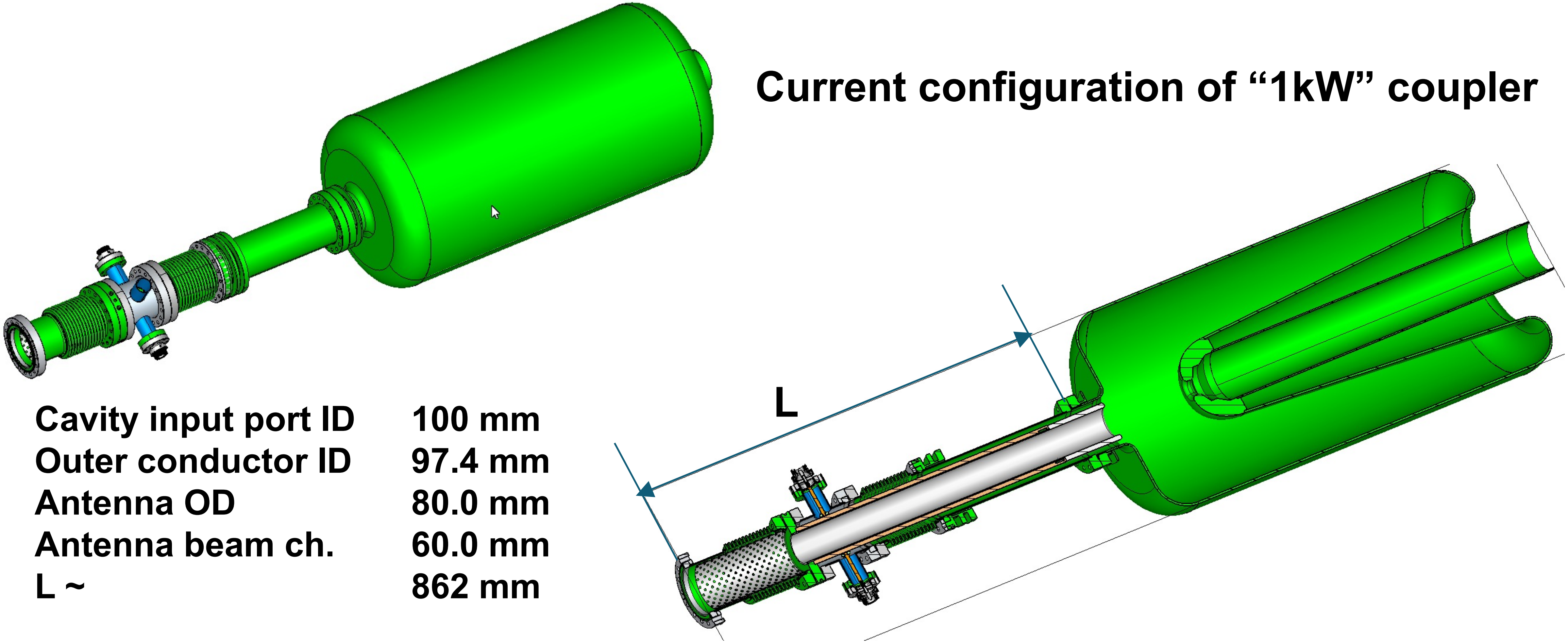
One RF source:

All elements between RF source and divider (including divider) are 6-inch diameter.
All elements between divider and coupler are 4-inch diameter.



Design of 100 kW FPC

Task: replace existing input 1 kW coupler by a 100 kW coupler with minimum change of configuration.



Current configuration of “1kW” coupler

Cavity input port ID	100 mm
Outer conductor ID	97.4 mm
Antenna OD	80.0 mm
Antenna beam ch.	60.0 mm
L ~	862 mm

Achievements & Milestones

Design of 100 kW FPC:

- Found the configurations of couplers which can be accommodated by existing facility with minimum changes.
- According to the simulations the couplers satisfy technical requirements:

  Operating power 100 kW;
  Q_{ext} ~9.4e+5;
  Tuning range > ±3.5 kHz;
  Multipactor is suppressed by HV bias.
- RF, thermal designs of coupler(s) are practically finished.
- RF design of the waveguide elements is done.
- Mechanical design of the coupler and the waveguide system is under way.

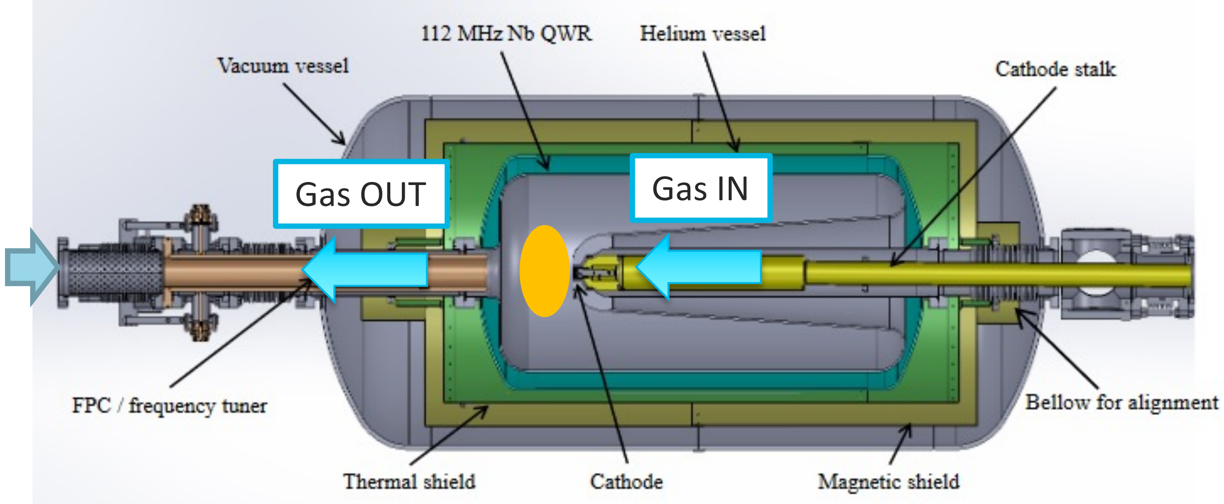
Achievements & Milestones

Plasma treatment system:

- Preliminary analysis suggests that plasma processing looks easily applicable to the 112 MHz SRF gun;
- From simulation it appears as **plasma ignition can be achieved** by exciting the cavity at its fundamental mode by using few Watt -> needs to be experimentally verified, Epk needed for ignition may be higher than in case of elliptical cavities, requiring more power than the one calculated;
- **No risk of igniting plasma at the antenna tip** since field is maximized at the cavity surface;
- FNAL gas injection and vacuum **cart design can be applied to SRF gun system**, only minor modifications expected.

Plasma treatment system

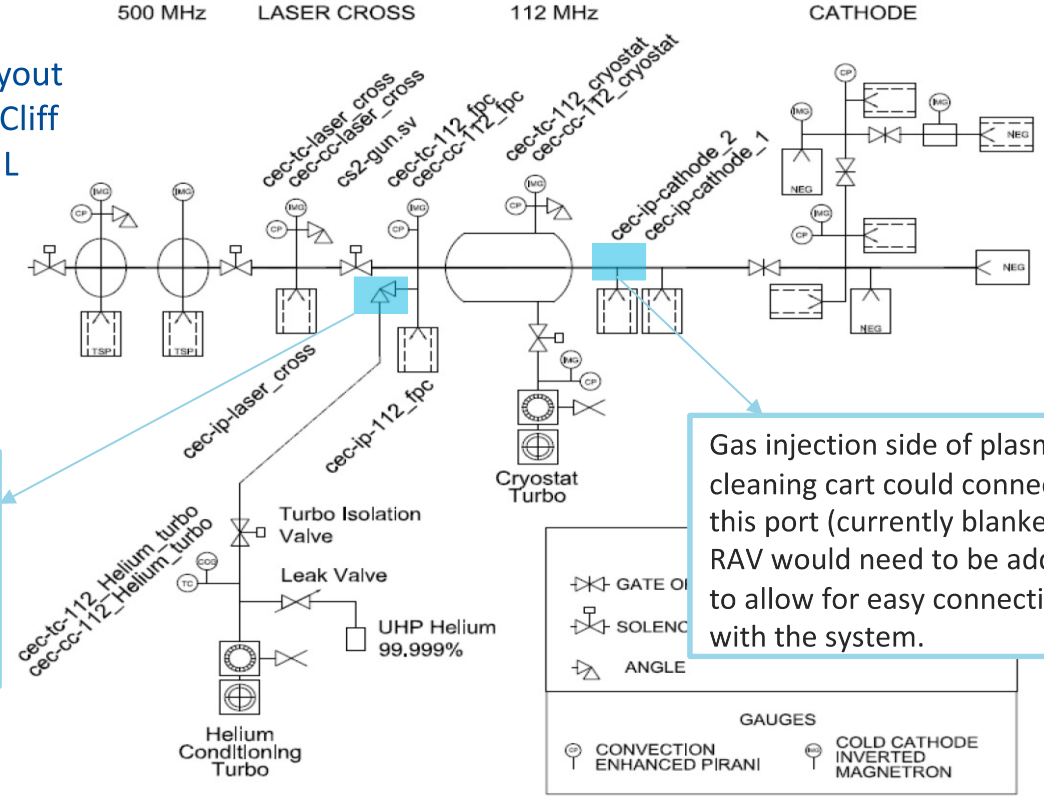
RF excitation



- In order to create a gas flow inside the cavity, gas is injected from one side and pumped out from the other side; this appears to be feasible in the SRF gun system: gas can be injected from cathode side and pumped out from the FPC side;

L. Smart
04 Mar 2021

SRF gun layout curtesy of Cliff Brutus, BNL



Vacuum side of plasma cleaning cart could connect to this RAV.

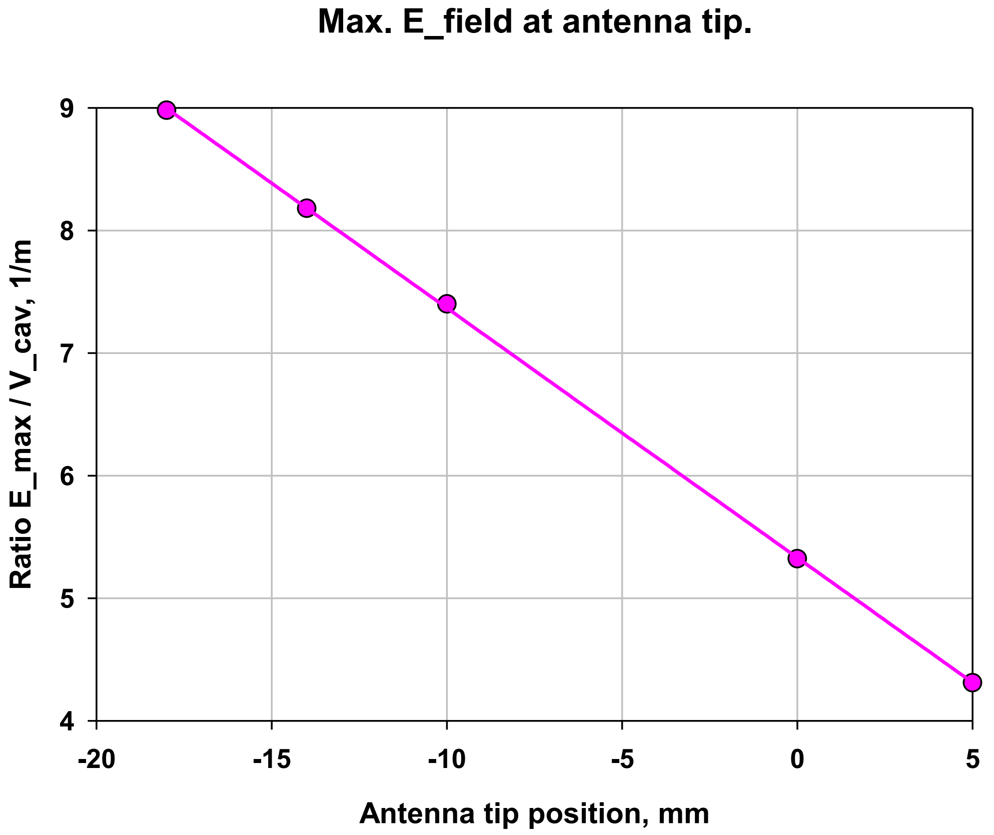
Gas injection side of plasma cleaning cart could connect to this port (currently blanked). A RAV would need to be added to allow for easy connection with the system.

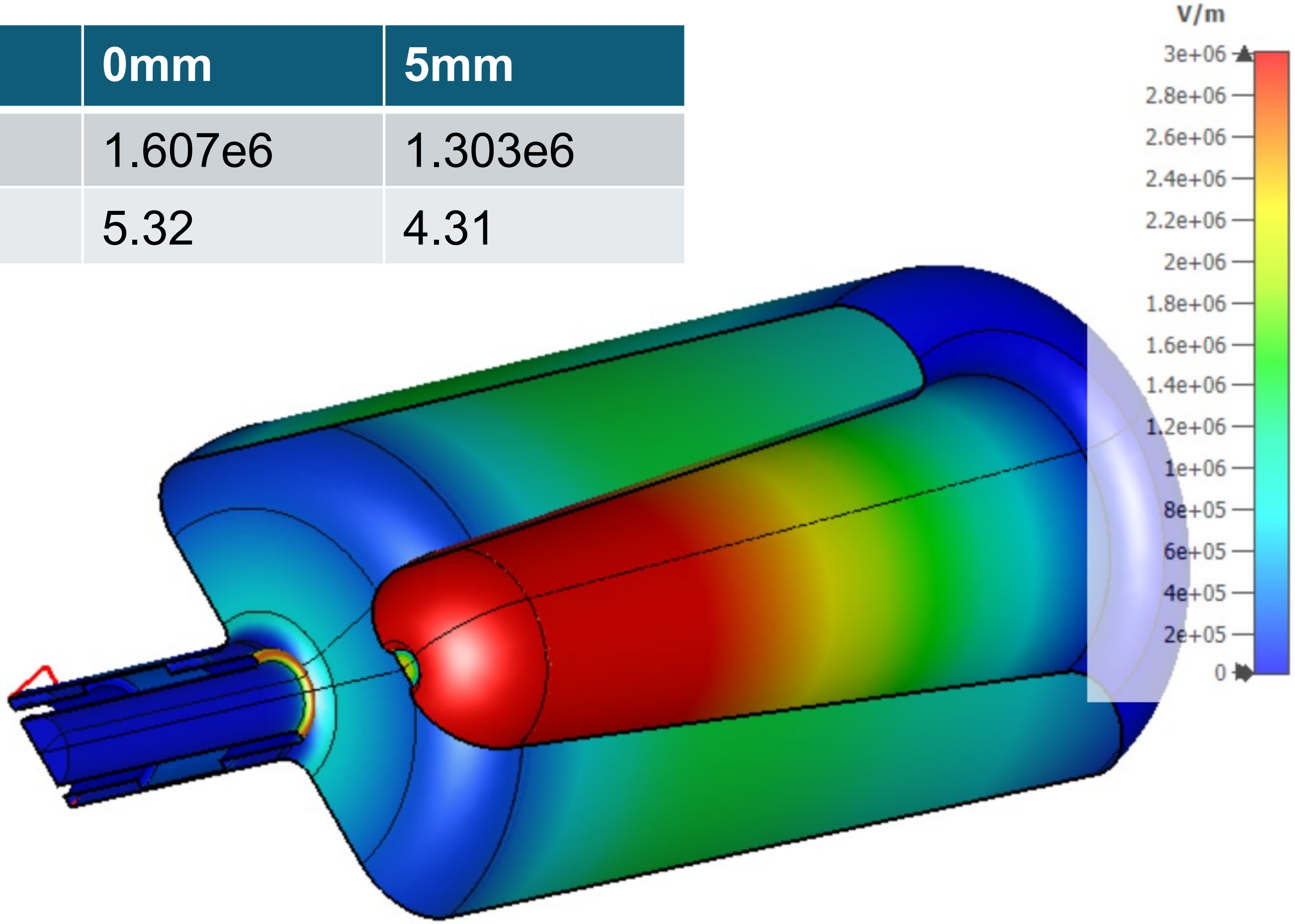
- Same design of the gas injection and vacuum system cart currently in use at Fermilab can be used.

Maximum electric field at the antenna tip

V (1J) = 3.02e5 V

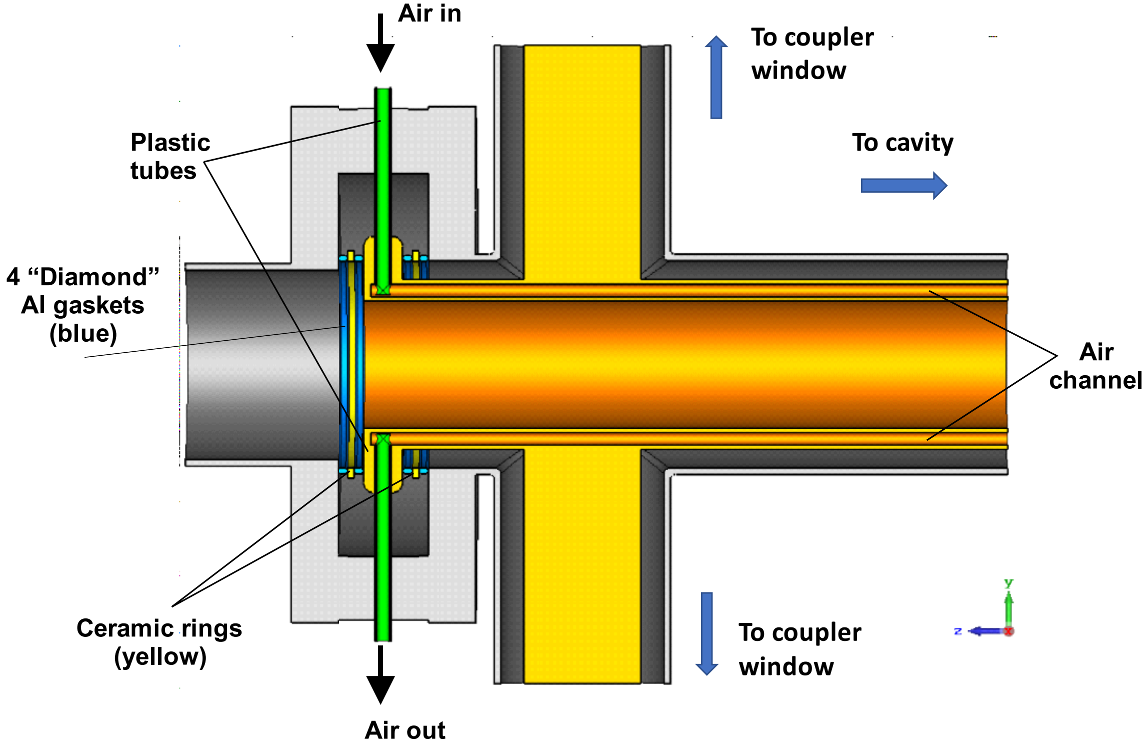
Position	-18mm	-14mm	-10mm	0mm	5mm
E_{max}	2.7107e6	2.469e6	2.234e6	1.607e6	1.303e6
E_{max}/V	8.98	8.18	7.40	5.32	4.31

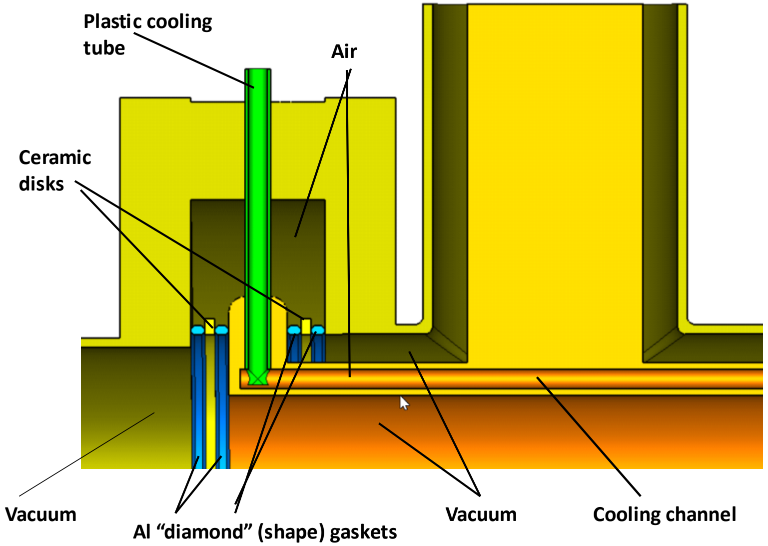




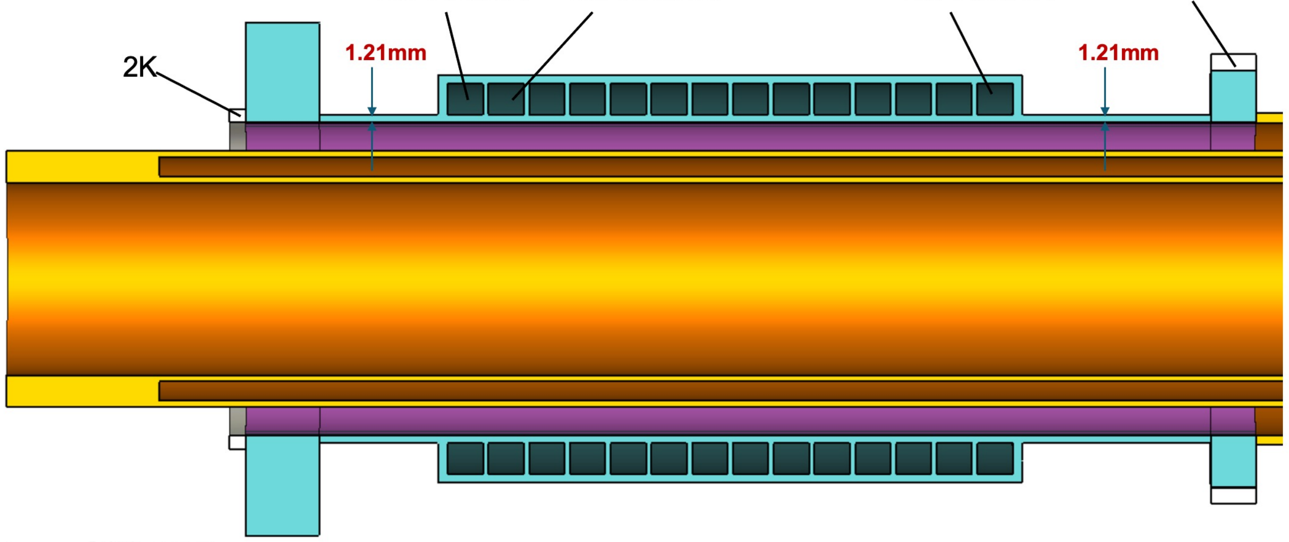
E_{max} < 9 MV/m for V = 1 MV

Schematics of the air cooling for the antenna





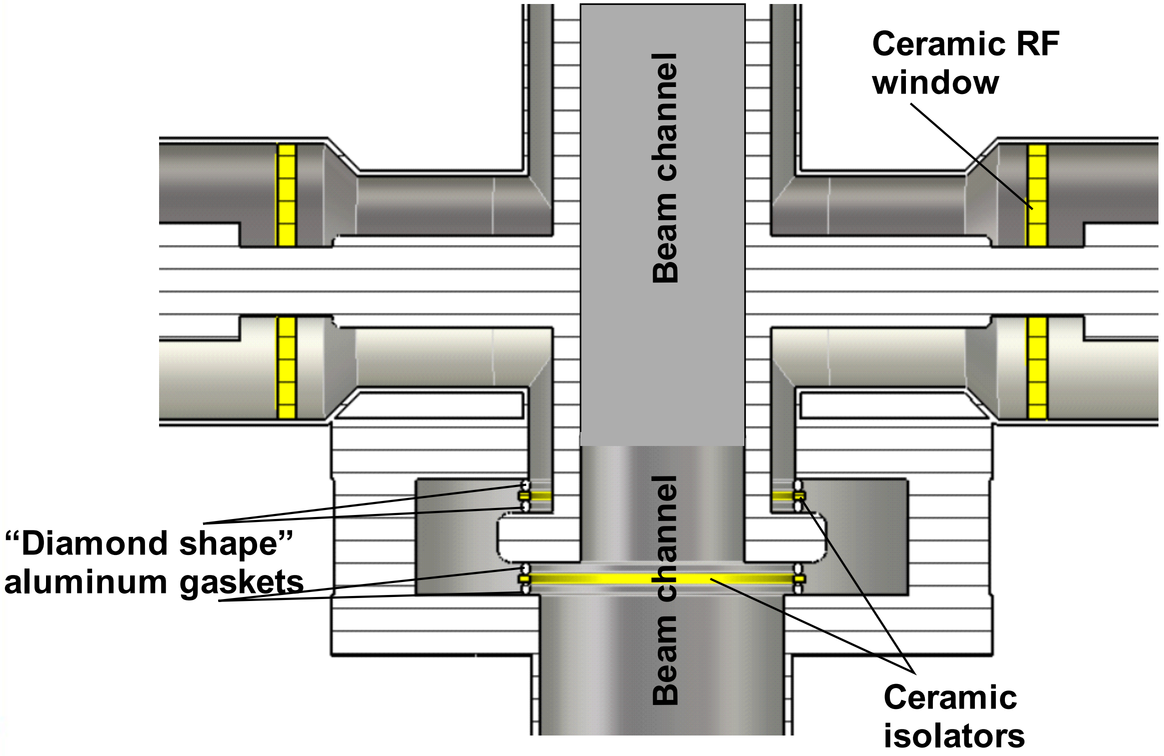
Cryogenic loading simulation, 100 kW, CW



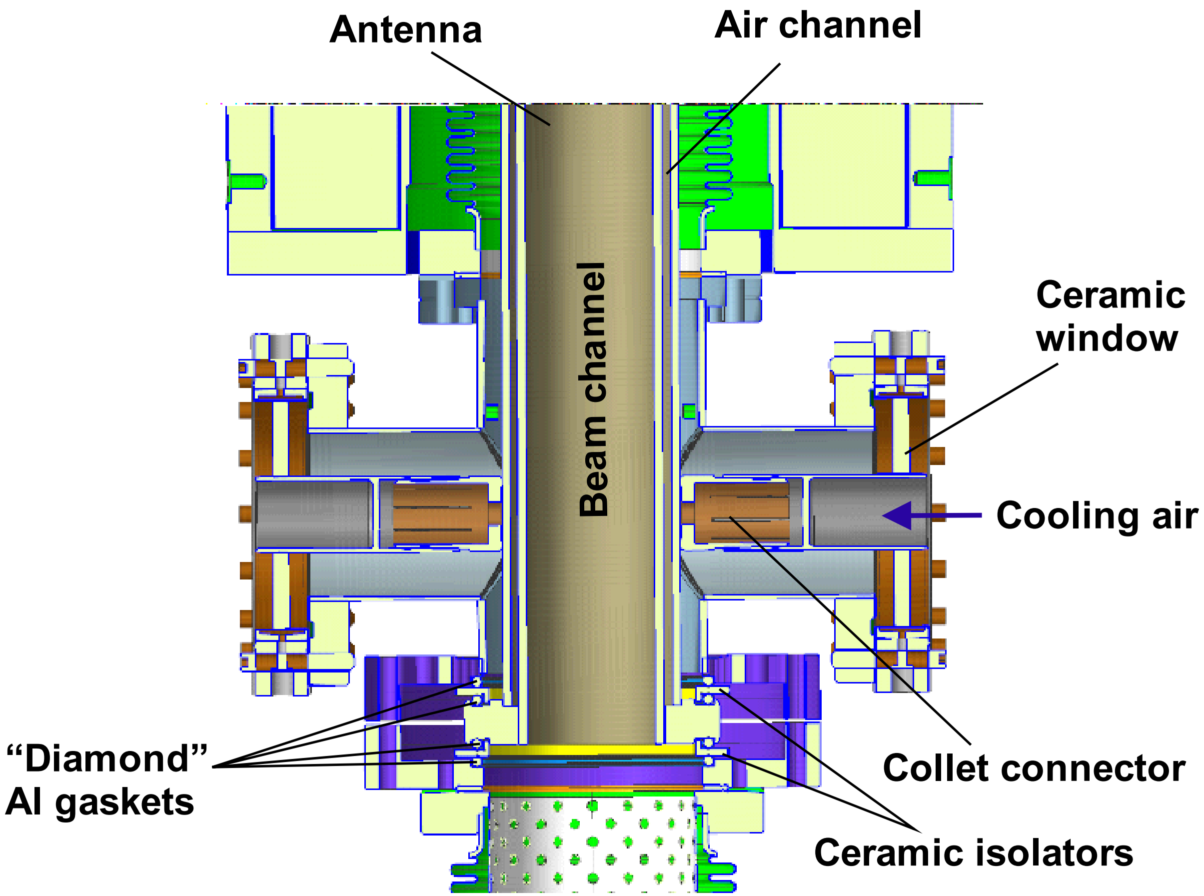
P_{in} = 100 kW P to 2K = 0.05W P to 5K He = 24.4W P from 293K = -16.4W

Details of the window units

RF configuration

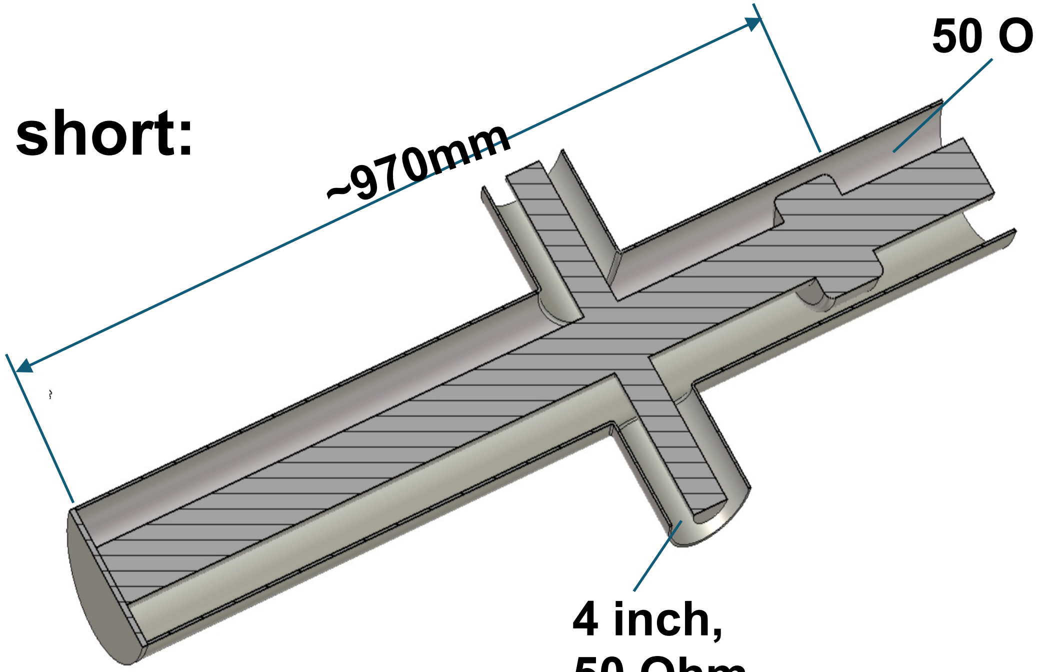


Mechanical design

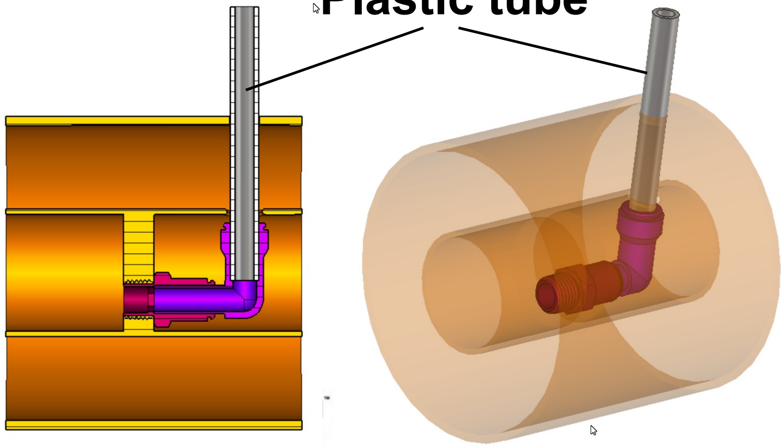


Some elements of the waveguide system

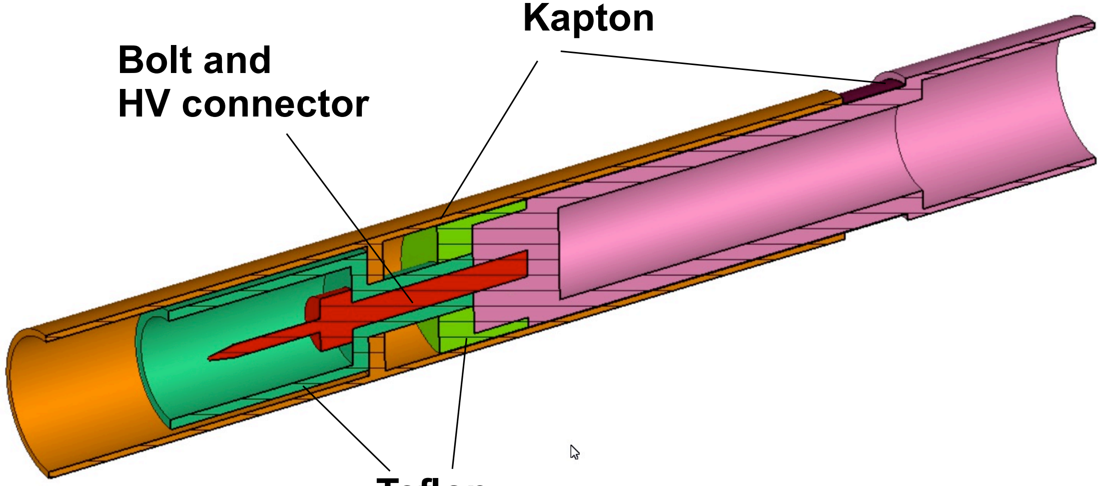
Power divider with short:



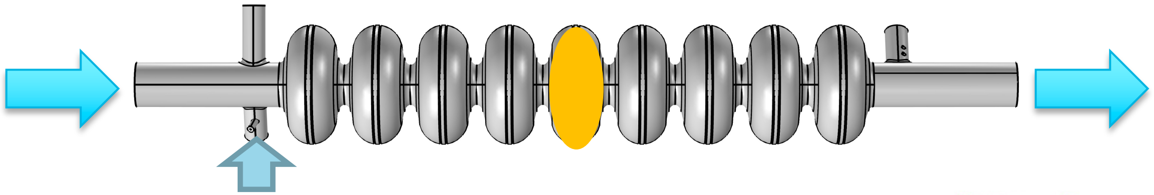
Cooling air inlet:



Inner conductor of capacitor:



Plasma processing for field emission abatement

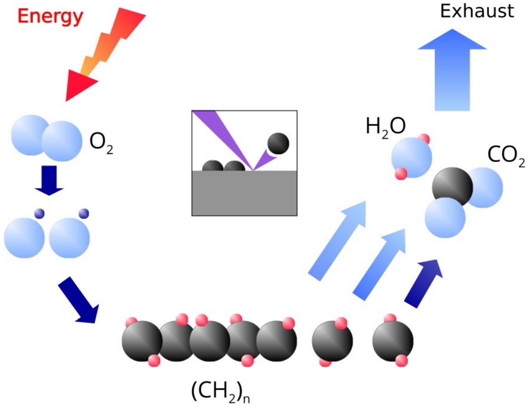


Gas IN

Gas OUT

RF excitation

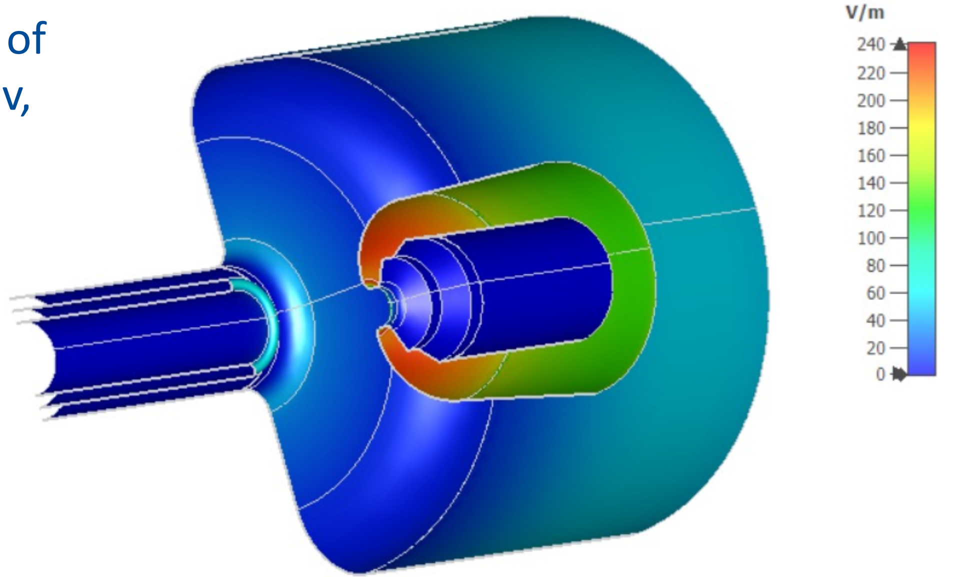
- Gas flow of Ne-O mixture (few % of O_2, mostly Ne) at p ~ 75-150mTorr;
- once plasma ignites oxygen reacts with hydrocarbons;
- reaction products (mostly CO_2, H_2O) are pumped out;
- work function increases, reducing FE;
- Successfully applied to SNS CMs by ORNL and LCLS-II HE vCM by FNAL. **MP reduction was observed as well** in both cases.



M. Doleans, J. Appl. Phys. 120, 243301 (2016)
M. Doleans et al. NIMA 812 (2016) 50-59
P. Berrutti et Al., J. of Appl. Phys. 126, 023302 (2019);
B. Giaccone et Al. Phys. Rev. Accel. Beams 24, 022002 (2021);

Analysis of plasma ignition in the SRF gun

Courtesy of
S. Kazakov,
FNAL



E field is maximized on the cavity surface, not at the antenna tip:

$$\frac{E_{pk,cavity\ surface}}{E_{pk,antenna\ tip}} = 3.7$$

There should be no risk of plasma ignition at the FPC!

Conceptual Design of the Tuner for SRF Gun

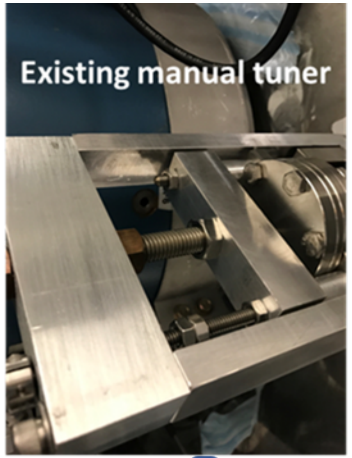
- Approach for cavity tuning will be changed. Cavity tuning by moving /inserting power coupler into cavity volume will be NOT used in upgrade SRF gun system.
- Special SRF cavity tuner will be designed. Cavity tuning will be done by stretching cavity through two rods welded to cavity walls. These rods penetrated through insulated vacuum volume to outside of vacuum vessel. These rods already used during operations of the SRF gun to manually tune cavity. Tuning was done by manually screwing nut on the rods to stretch cavity. Access to this system was very complicated for personnel.
- For upgraded SRF gun newest tuning system will be deployed. Cavity stretching will be done with stepper motor actuator & piezo-actuators. Actuators will operate in ambient environment.
- There are no requirements to tune SRF cavity after cool-down to some particular operational frequency.
- As result, there are no requirements to deploy “slow tuner” with large (10’s or 100’s kHz) range. Required slow tuner range will be in the range of several kHz.
- The fast/piezo tuner will be operated in serious with slow tuner and will have relatively small range that will cover microphonics, df/dp and other small drift of the cavity from “established& fixed operational” frequency after cavity will be cool-down to T=4K.

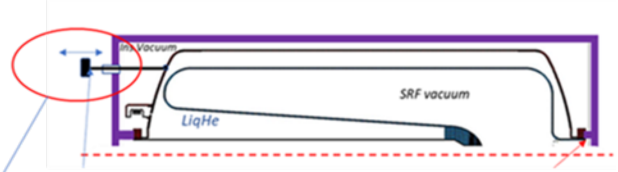
Conceptual tuner design

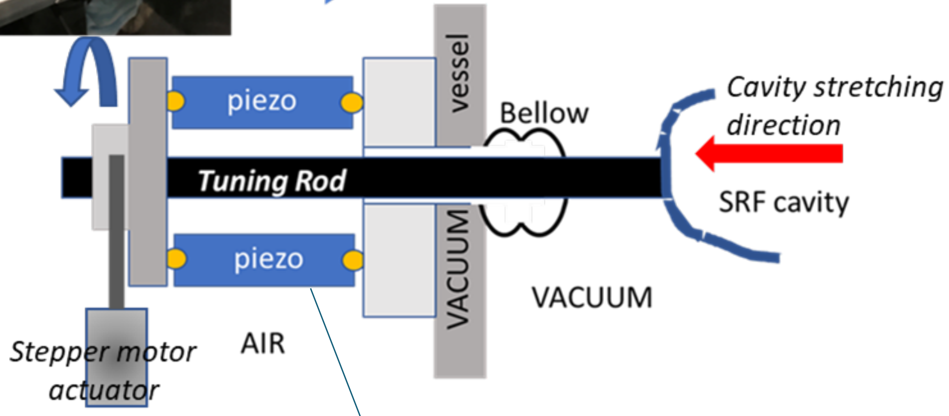
Stepper motor actuator will stretch cavity but pulling rod welded to cavity. Piezo actuator (developed by FNAL for LCLS II) will worked in serious with slow tuner. Piezo actuators could deliver up to 36um stroke (at V=120V). Stroke of 36um will retune cavity on ~300Hz. Based on previous operational experience of SRF gun, 300Hz range of cavity retuning will cover required microphonics.

Parameters for Cavity/ "double rod, manual" tuner system	
Cavity tuning sensitivity	9.3Hz/um
Cavity stiffness	1.7N/um
Cavity df/dP sensitivity	9Hz/mBar

Assuming required tuning range of fast tuner to cover microphonics ~ 100Hz and to cover df/dp (dp~10mbar) the same value ~100Hz we will need approximately 200Hz range for piezo tuner.







Summary

Review of the existing manual tuner on the SRF gun to use as main SRF cavity tuner system has been performed .

Requirements for cavity stroke (stretching) to cover tuning range of cavity has been estimated

Conceptual design of the SRF cavity tuner has been developed.

Next steps

Development of the tuner’s mechanical model that will fit into available space around SRF gun system

Performed ANSYS simulation of the model

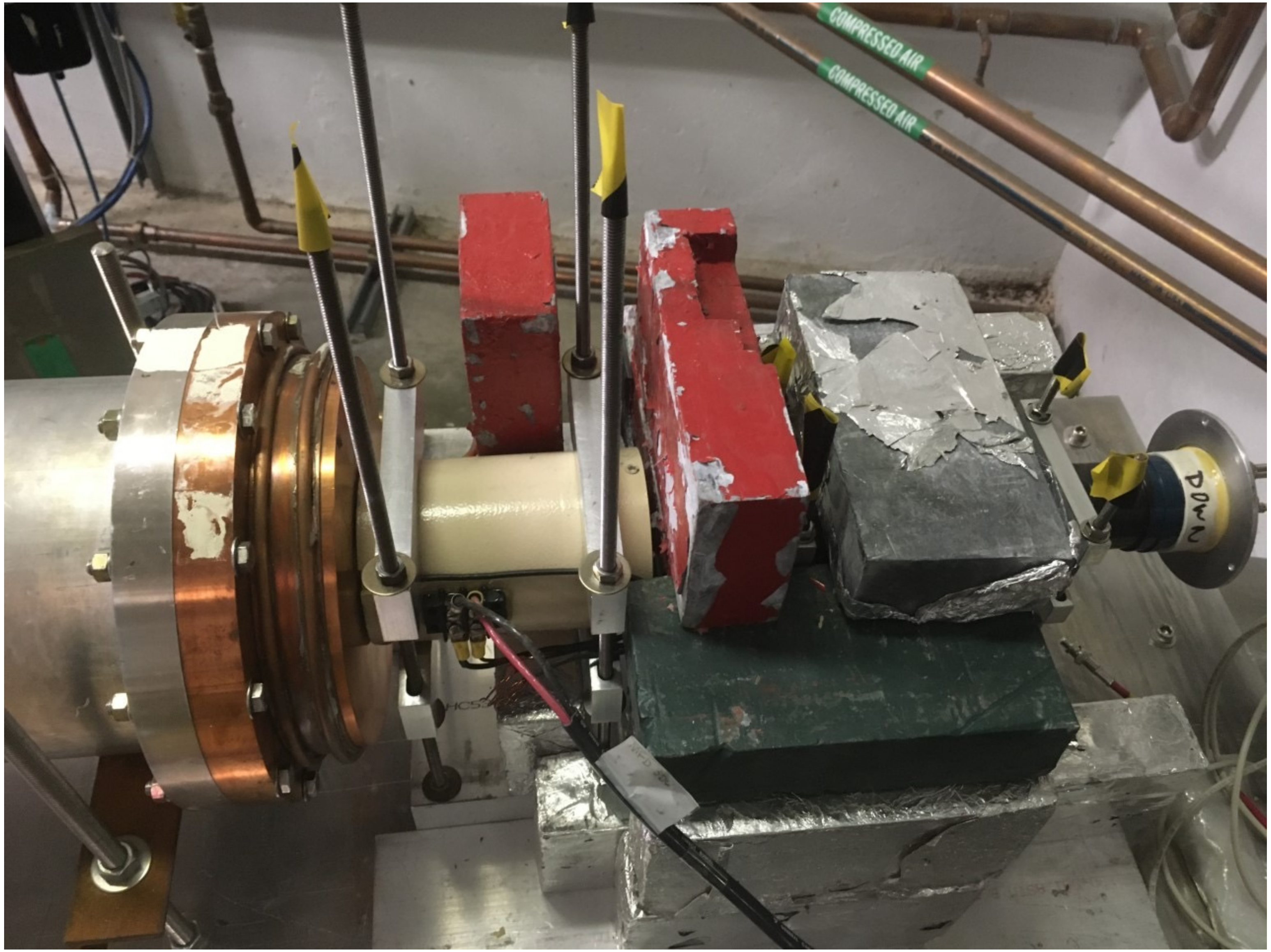
Select small size reliable stepper motor actuator

Develop/test prototype

Build new SRF gun tuning system to be ready installed as needed

JLab back-up

An Example of Polarimeter at Jefferson Lab CEBAF – Summer 2018



Goals, Timeline, and Budget

- Co-Principal Investigator: Riad Suleiman, with Joe Grames and Matt Poelker (Jefferson Lab), and Eric Voutier (IJCLab, Orsay, France)

- Jefferson Lab's contribution to this project is to provide a Compton Transmission Polarimeter, which will be used to measure beam polarization when SRF photogun employs a GaAs photocathode. IJCLab is contributing to Jefferson Lab's effort.

	FY20 ($k)	FY21 ($k)	Totals ($k)
a) Funds allocated	200.1	200.0	400.2
b) Actual costs to date	10.9		

- Goals:
  - Year 1: Design and build electron beam polarimeter
  - Year 2: Install and commission polarimeter at CeC accelerator
- Current Status:
  - Design of polarimeter and new portable data acquisition system (DAQ) is completed
  - NCE for one more year was approved

Achievements, Milestones and New Timeline

- Year 1:
  - Agreed upon basic operational parameters of polarized electron beam and polarimeter
  - Portable DAQ design completed and implementation started
  - Jefferson Lab Fast Electronics Group has finished programming of flash analog-to-digital convertor (FADC) and now working on user interface of DAQ
  - Polarimeter (radiator, magnet, and detector) design was optimized using GEANT4
- Year 2:
  - Magnet engineer started design of electro-magnet with iron core
  - Build two polarimeters (radiator, magnet, and detector) and one portable DAQ – one polarimeter will stay at CEBAF
- Year 3:
  - Calibrate polarimeter at CEBAF with portable DAQ
  - Install and commission polarimeter at CeC accelerator
- When SRF photogun employs a GaAs photocathode: Measure electron beam polarization