Main Injector/RR R&D Status

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11/28/12

MI/RR R&D Goals

- Focus on Project X stage 1
  - Understand MI/RR Requirements.
  - Identify Operational Issues.
  - Develop a Plan.

- Maintain a small effort on RR Injection (mainly stripping) Issues.

MI/RR Performance in Project X Stage 1

	NOvA/LBNE		PX Stage 1		
MI/Recycler					
Beam Energy	120	60	120	60	GeV
Cycle Time	1.33	0.80	1.20	0.80	sec
Protons per pulse	4.9E+13	4.9E+13	7.5E+13	7.5E+13	ppp
Slip Stacking Efficiency	95	95	95	95	%
Beam Power	0.70	0.58	1.20	0.90	MW
Normalized Beam Emittance (95%)	15	15	20	20	π mm-mr
Bunching Factor	0.50	0.50	0.50	0.50	
Laslett Tune Shift (injection)	-0.05	-0.05	-0.06	-0.06	

- 50% Increase in intensity with the same Slip Stacking Efficiency.
- 10% Reduction in MI cycle time.
- 70% Increase in Power Loss!

MI/RR Issues in Stage 1

- MI RF
  - Do we have enough rf power to accelerate 50% more beam?
- MI/RR SPACE CHARGE
  - Are there any space charge issues with 50% more intensity per bunch?
- MI/RR E-CLOUD
- MI TRANSITION CROSSING
  - Do we need a gamma-t jump for Stage 1?
- MI/RR LOSS CONTROL
  - Do we need RR collimators?

Present MI RF Capabilities

J. Dey, I. Kourbanis

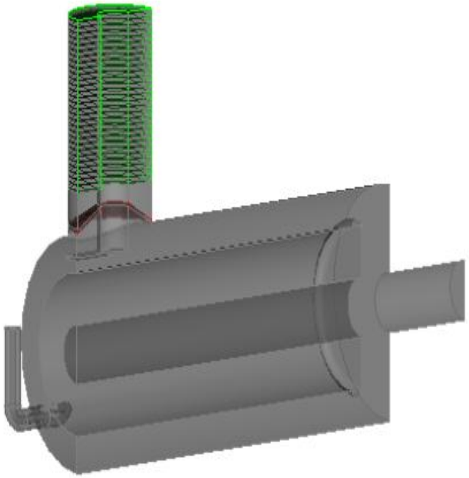
	Present Main Injector	NOvA	Project X 7.5e13 Protons	Project X 6.24e13 Protons
Harmonic Number	588	588	588	588
Number of Filled Buckets	504	504	504	504
Frequency:	52.8114-53.104 MHz	52.8114-53.104 MHz	52.8114-53.104 MHz	52.8114-53.104 MHz
Acceleration Ramp Slope:	205 GeV/s	240 GeV/s	240 GeV/s	240 GeV/s
Beam Intensity:	4.5e13 Protons	4.9e13 Protons	7.5e13 Protons	6.24e13 Protons
Main Injector Ramp Rate:	2.2 s	1.333 s	1.2 s	1.2 s
Beam Power at 120 GeV:	392.7 kW	705.6 kW	1.2 MW	998.8 kW
Beam Accelerating Power:	1.476 MW	1.882 MW	2.88 MW	2.40 MW
Number of Accelerating Cavities:	18	20	20	20
Cavity R/Q:	104	104	104	104
Maximum Cavity Accelerating Voltage:	235 kV/Cavity	235 kV/Cavity	235 kV/Cavity	235 kV/Cavity
Operating Peak Voltage:	205.56 kV/Cavity	210 kV/Cavity	210 kV/Cavity	210 kV/Cavity
Accelerating Voltage Required: $V\sin\phi_s$	2.27 MV	2.66 MV	2.66 MV	2.66 MV
Total Accelerating Voltage Available:	4.23 MV	4.7 MV	4.7 MV	4.7 MV
Total Operating Voltage:	3.7 MV	4.2 MV	4.2 MV	4.2 MV
Cavity Power Loss:	43.22 kW/Cavity	45.11 kW/Cavity	45.11 kW/Cavity	45.11 kW/Cavity
Total Apparent Power:	132.5 kVA/Cavity	165.7 kVA/Cavity	240.5 kVA/Cavity	204.2 kVA/Cavity
Robinson Stability Factor:	4	4	4	4

Note: 204.2 KW is the Design Power of the Present MI Power Amplifier

- **WE CANNOT ACCELERATE 7.5E13 PARTICLES WITH THE CURRENT MI RF SYSTEM!**

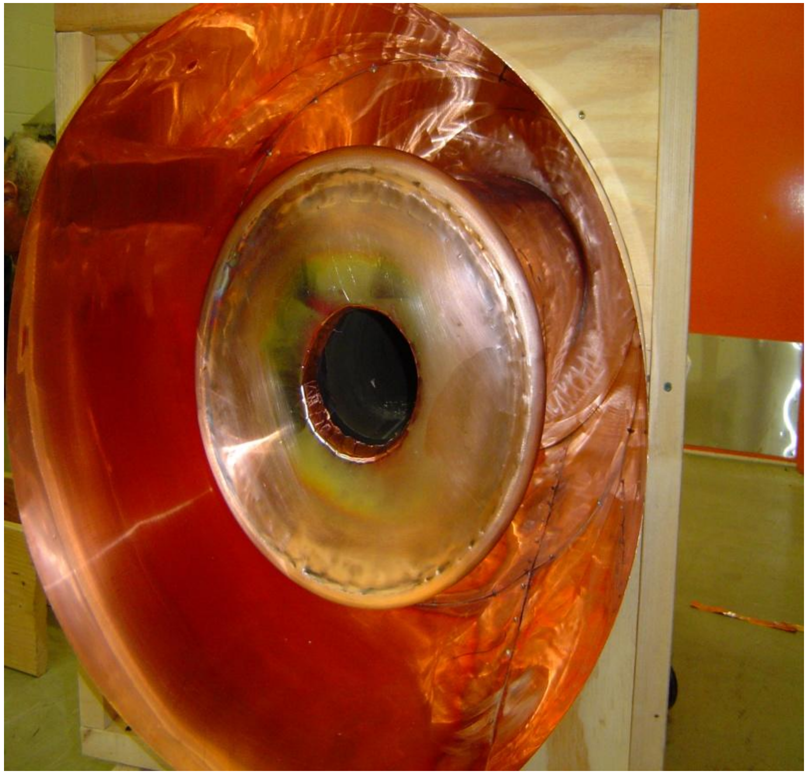
MI RF Status and Plans

- We have finalized the design of the new 53 MHz cavity.
  - We have a preliminary 106 MHz design based on the 53 MHz design.
- Have constructed a mockup of the new 53 MHz Cavity and began taking measurements.
- We plan to continue the SLAC Simulations of the new MI53 MHz Ferrite loaded RF Cavity with emphasis on thermal calculations (L. Xiao, C. Ng).
- Plan to investigate the assembly and cooling of the new Cavity Ferrite Tuners (J. Dey).



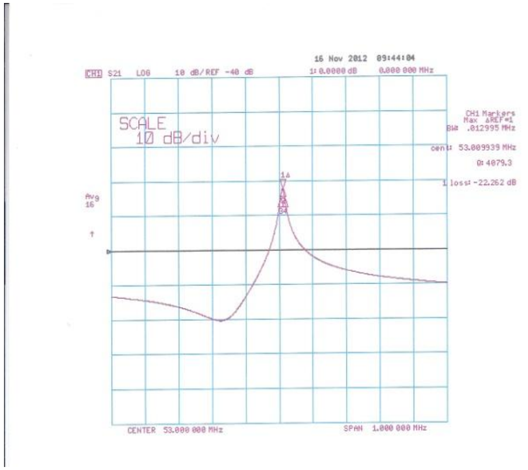
Cavity I with two mirrored HOM dampers w/o filter

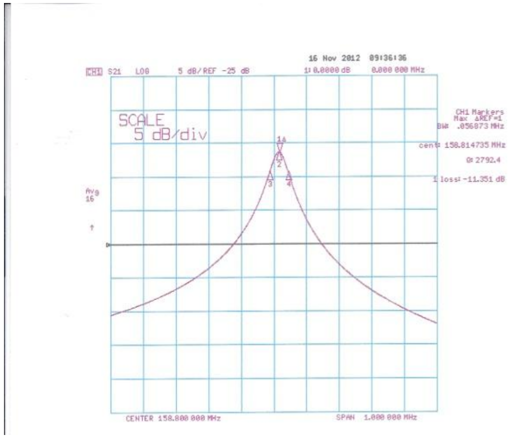
New 53 MHz Cavity Mockup (J.Dey)

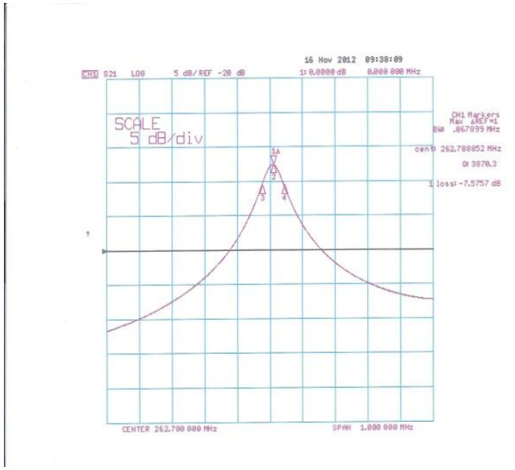


Inner Conductor

Mockup Cavity Measurements (J. Dey)







53 MHz; Q=4079

159 MHz; Q=2792

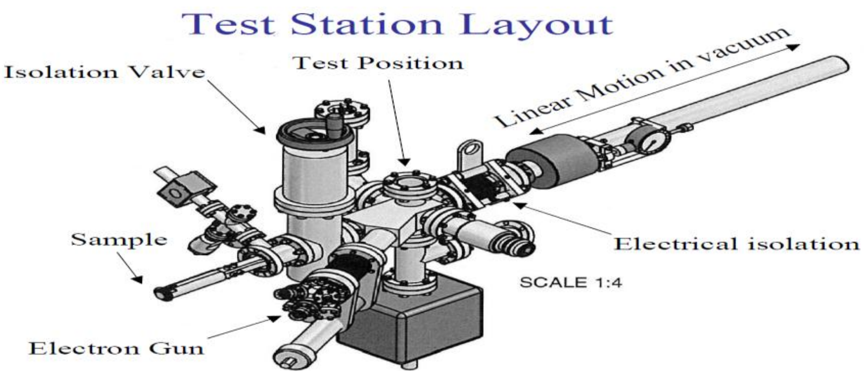
263 MHz; Q=3870

E-Cloud R&D Status and Plans

- Have established a coating facility at E4R
  - Successfully coated with TiN an MI round beam pipe.
  - We are ready to estimate the effort to in situ coat the MI beam pipe.
  - Can use it to coat test coupons for SEY measurements in MI.
- We plan to install the SEY measuring stand in MI (MI-10) this shutdown.
  - Measure the effect of beam scrubbing in situ for different kinds of ss including steel with TiN coating.

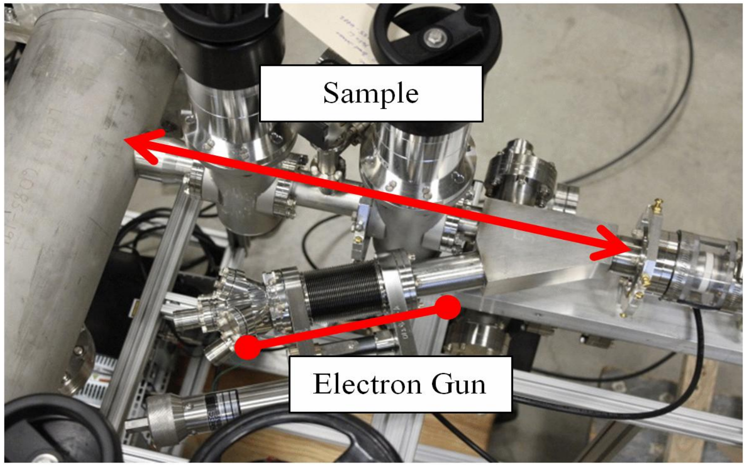
In-situ SEY Measurements (D. Scott, K. Duel, P. Lebrun, B. Zwaska)

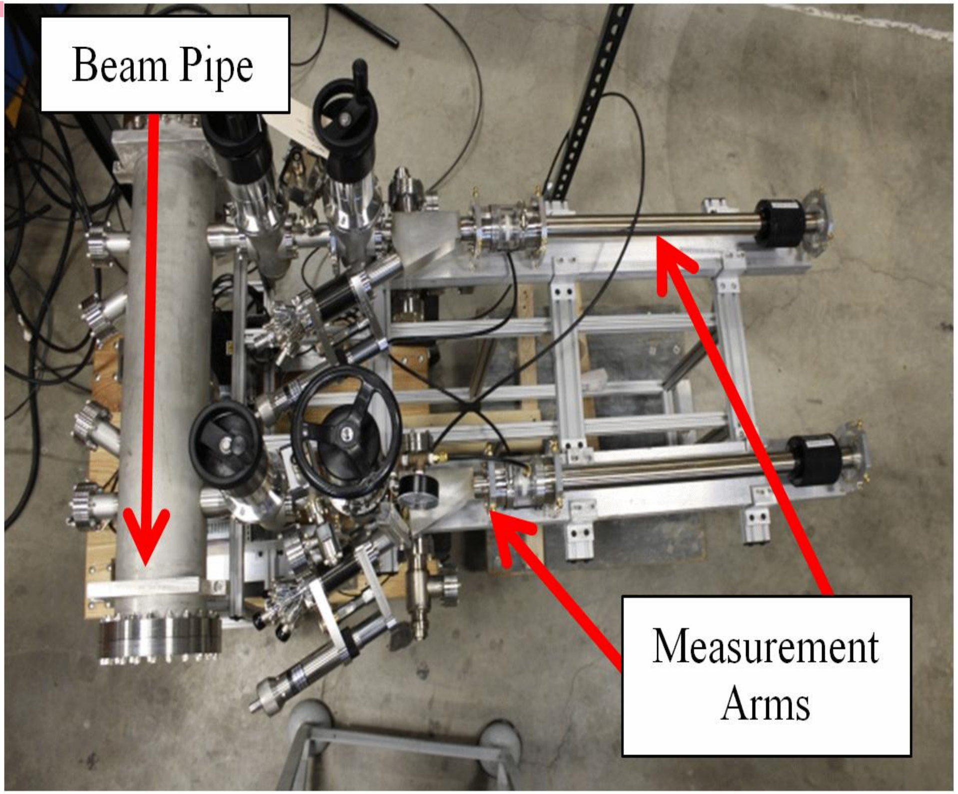
- Samples are measured in the station as installed, under vacuum
  - Small "button" samples are attached to a moveable arm.
  - They sit flush with the beam pipe and are scrubbed by the beam
- Access Opportunity
  - DAQ equipment is taken into tunnel
  - Sample retracted from beam pipe
  - SEY measured, using electron gun
  - Samples pushed back into beam pipe



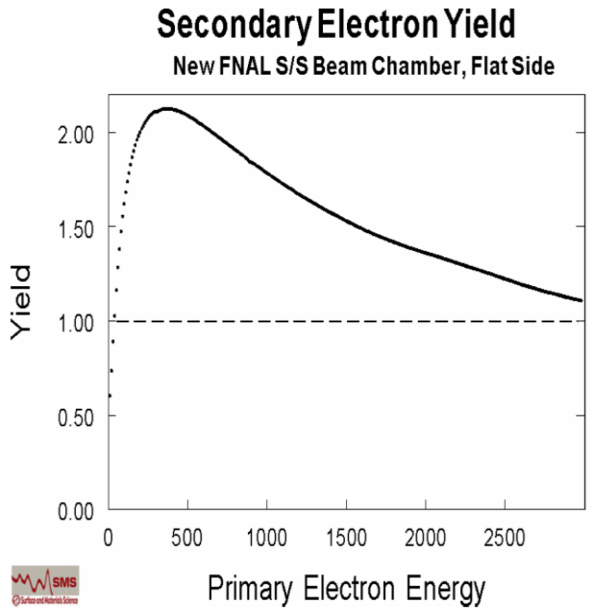
SEY Measurement Stand

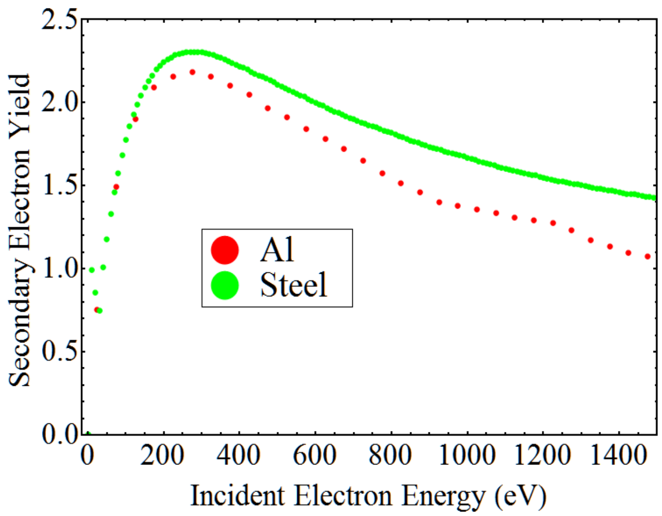
- Two identical Arms, guns etc.





SEY Curves for MI steel (316L new)





Measurements done at SLAC

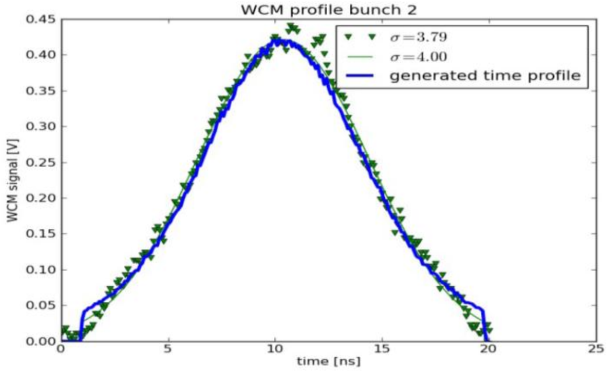
Measurements done with our SEY test stand

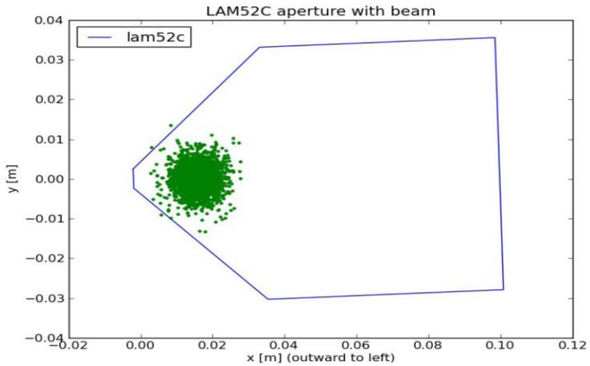
Project X Space Charge Simulations

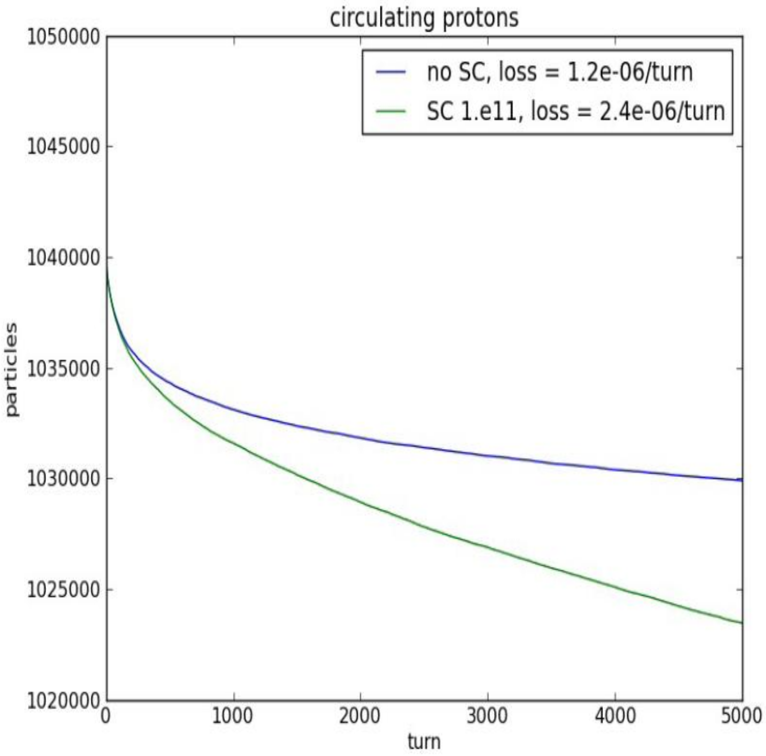
- Need to understand the space charge losses with the higher intensity slipped stacked bunches in MI and Recycler!
  - Will we need collimators in Recycler?
- We are making good progress towards realistic Space Charge MI simulations that we can compare with data.
- Plan to continue the MI Space Charge Simulations with SYNERGIA.
  - Include all apertures and magnetic multipoles
  - Compare with beam data

Status of Space Charge Simulations

Using realistic Lambertson apertures and measured longitudinal beam profiles to compare with beam measurements (E. Stern)



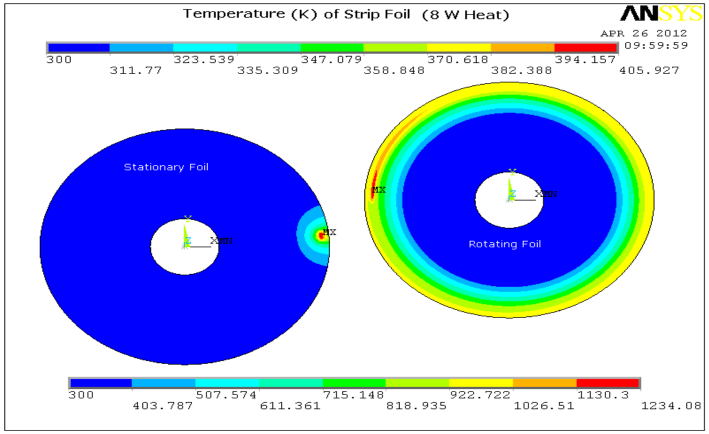




Recycler Injection (D. Johnson)

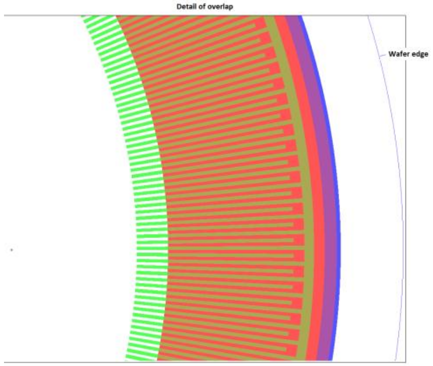
- Multi-turn injection will be into the Recycler at RR-10 due to the utilization of the MI-10 for LBNE 120 GeV extraction.
- Recycler injection implies a fixed linac (kinetic) energy of 8 GeV and lends itself to permanent magnet transfer lines.
  - Modification to Recycler straight section to create a symmetric straight section are required. This has been discussed previously on numerous occasions.
  - Recycler to MI transfers are being installed now for NOVA
- Low linac current <1mA> implies multiple injections of 4.3 ms pulse length.
- Foil heating could become an issue depending on the specific painting scenario.
  - Investigation of painting scenarios continues at low level
  - Other potential mitigation schemes
    - Use of Laser Assisted stripping effort at SNS being followed closely.
    - R&D on rotating injection foil technology
      - Ultra Nano Crystalline Diamond technology
      - Rotating graphene foil technology

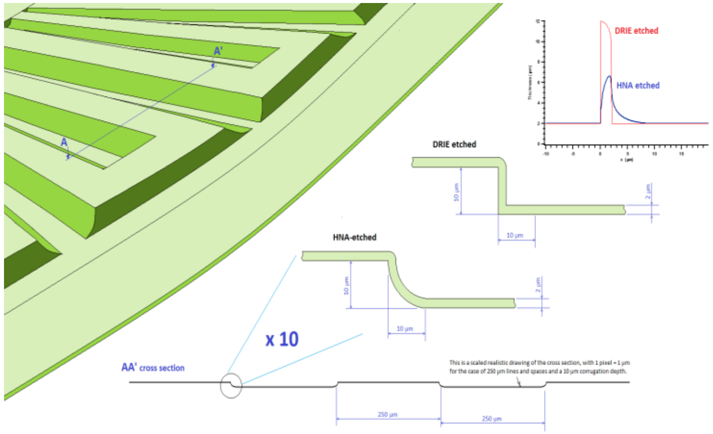
Project X UNCD Foil Technology R&D



ANSYS simulations comparing stationary and rotating foil heating due to a continuous 8W heating load. Zhijing Tang (PPD)

Working with Advanced Diamond Technologies, a spin-off of the Argonne Center for Nano Materials, to create a structured rotating UNCD foil for rotational and heating tests





Creation of corrugated UNCD annulus

Conclusions

- We are focusing the MI/RR R&D Plan on Project X Stage 1.
- We will need a New MI RF System to Accelerate 50% more beam.
  - Making good progress towards a 53 MHz cavity prototype.
- We need to understand the space charge losses with the higher intensity beam.
  - We are making progress developing realistic space charge simulations.
- Continuing the electron cloud measurements.
  - Installing a SEY measuring stand in MI during this shutdown.
- Maintaining a small effort on RR stripping Issues.