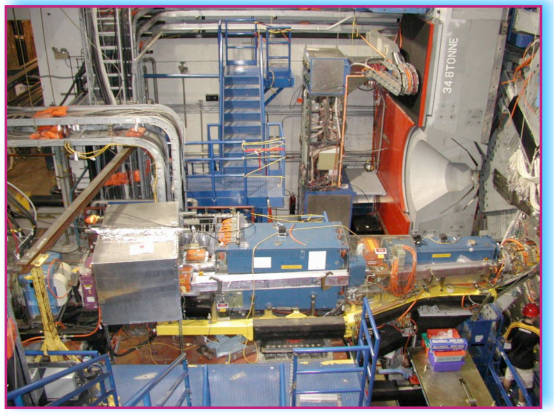
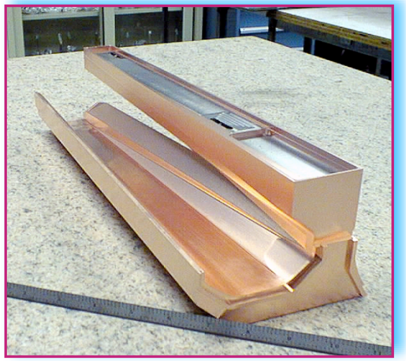
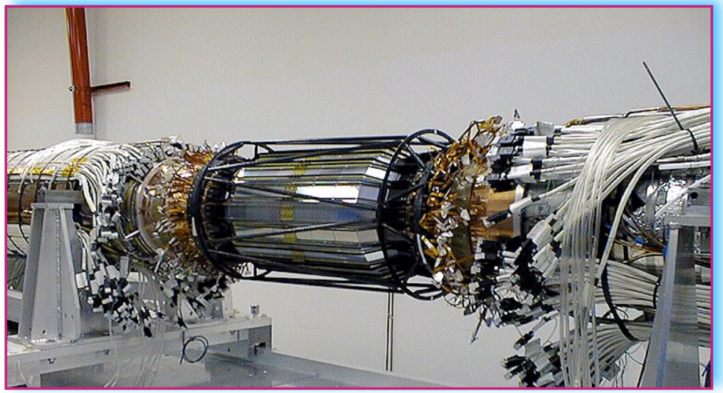
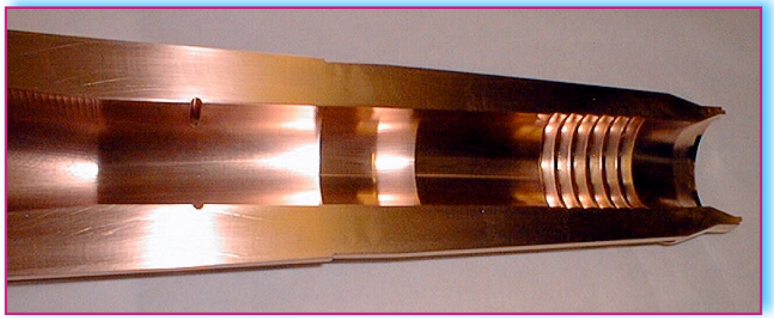
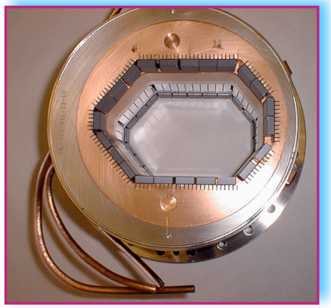
PEP-II Upgrade Vacuum System

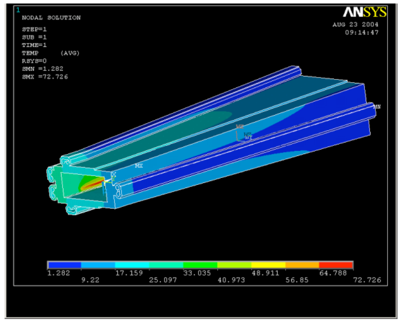












Machine Advisory Committee Meeting
December 13, 2004

Nadine Kurita

Outline

- Current & Energy Future Requirements
- Work Plan
- Status
  - Near IR
  - Far IR
  - Diagnostics
  - Additional upgrades
  - Future upgrades
- Summary

Upgrade Plan
Current & Energy Requirements

❍ LER – main ring

- Chambers design limit - 3.0 A on 3.5 GeV
- FY2005 Goal : 3.6 A, 3.1 GeV
  - FY2005 SR power is less than the design limit.
- FY2007 Goal: 4.5A, 3.1 GeV
  - FY2007 SR power is less than the design limit.
- Verifying that all chambers met the original CDR design parameters.

❍ HER – main ring

- Chambers design limit - 3.0 A on 9.0 GeV
- FY2005 Goal : 1.8 A, 9.0 GeV
  - FY2005 SR power is less than the design limit.
- FY2007 Goal: 2.2 A, 9.0 GeV
  - FY2007 SR power is less than the design limit.

Upgrade Plan
Current & Energy Requirements (cont.)

❍ Interaction Region (IR)

- **LER Beam Power**
  - **Chambers design limit - 3.0 A on 3.1 GeV**
  - **FY2005 Goal : 3.9 A, 3.1 GeV**
    - **FY2005 – 22% increase in SR power.**
  - **FY2007 Goal: 4.5A, 3.1 GeV**
    - **FY2007 50% increase in SR power.**
- **HER Beam Power**
  - **Chambers design limit - 2.0 A on 9.0 GeV**
  - **FY2005 Goal : 1.8 A, 9.0 GeV**
    - **FY2005 – SR power is less than the design limit.**
  - **FY2007 Goal: 2.2 A, 9.0 GeV**
    - **FY2007 10% increase in SR power.**

Upgrade Plan
Other Requirements

- **Increased HOM Heating, RF shielding**
  - **Bunch Length**
    - **2004: 1.16 cm**
    - **2006: 0.9 cm**
  - **Bunch Current**
    - **LER 45% increase**
    - **HER 30% increase**
- **New Lattice**
  - **IR Lattice and BSC received 11/4/04**

PEP-II Work Plan

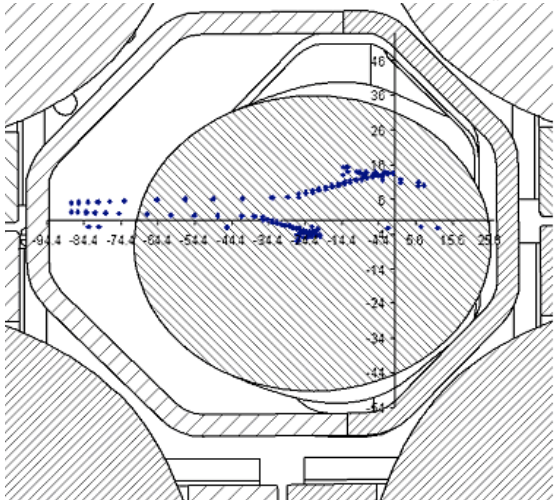
- Goal –create a work plan to reach the increased luminosity schedule.
- Identified chambers for analysis to determine upgrade needs.
  - Created Vacuum System Shortlist
    - Looked at current limitations, operational failures and limits to determine chambers that need to be evaluated and possibly rebuilt.
    - Re-analyzed chambers.
      - B1 LEB/HEB chamber
      - Q2 Backward Chamber
      - Q2 Forward Chamber
      - Q1 Chambers
      - Luminosity Chamber
      - High Power Dump Chamber

PEP-II Work Plan (cont.)

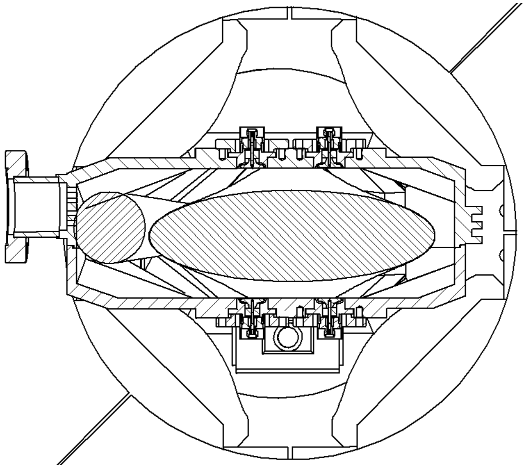
- Gathered drawings and design reviews for items on the Shortlist.
  - Received additional documentation from LLNL.
- Strategize work for projected downtimes and short term goals.
- Opened Accelerator Improvement Projects
  - Completed preliminary conceptual designs
  - Detailed engineering estimates
  - Opened AIP projects
    - ♦ Vertex Chamber
    - ♦ B1/Vertex Bellows
    - ♦ Q1/Q2 Bellows
    - ♦ HER & LER Q4/Q5 chambers
    - ♦ Q4/Q5 Bellows Module
    - ♦ IR HER HOM absorbers
    - ♦ IR LER HOM absorbers
    - ♦ IR Radial Ion Pump
    - ♦ Q2 Backward Chamber
    - ♦ HER & LER RF stations
    - ✓ LER SLM
    - ✓ Frascatti Kicker

IR Design Challenges

- **Beam Stay-Clear and Magnet Stay-Clear**
  - Keep existing magnets
  - Beta *s for HER & LER
    - Beta x* = 28 cm
    - Beta y* = 7 mm
  - Emittances for HER & LER
    - Emittance x = 60 nm-rad
    - Emittance y = 24 nm-rad
  - 12 σ + 0 mm in X
  - 9 σ + 0 mm in Y
  - Luminosity Cone : ~6.24σ
  - Space Constraints
    - Limits pumping, diagnostics, cooling
- **Limiting BSC through Q2 is**
  - 12 σ + 0 mm in X
  - 8.5 σ + 0 mm in Y
  - New chambers will be within the BSC defined by Q2.



Outboard Q4R

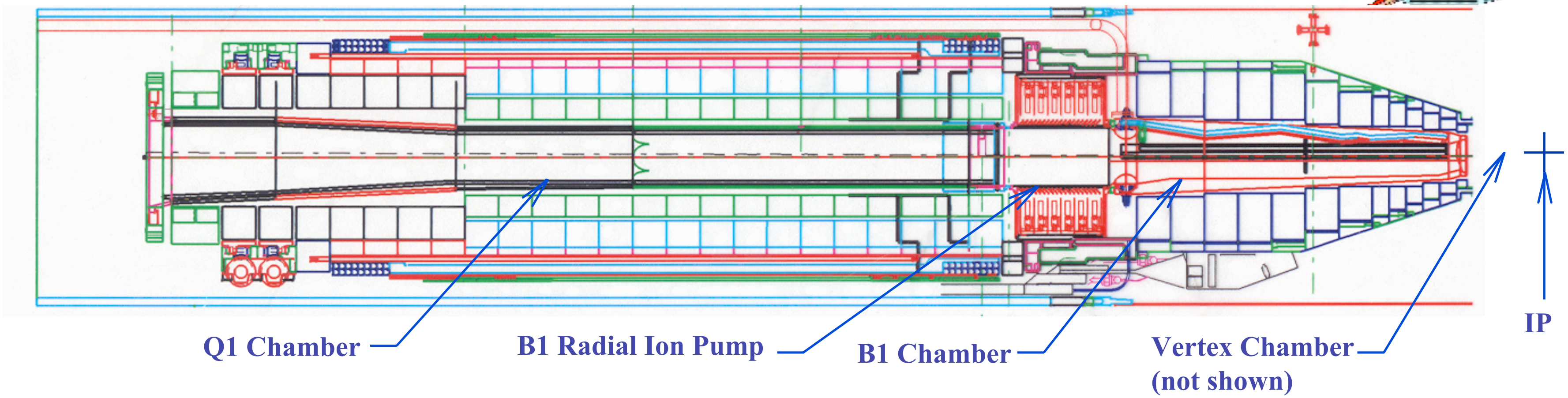


Outboard Q5L

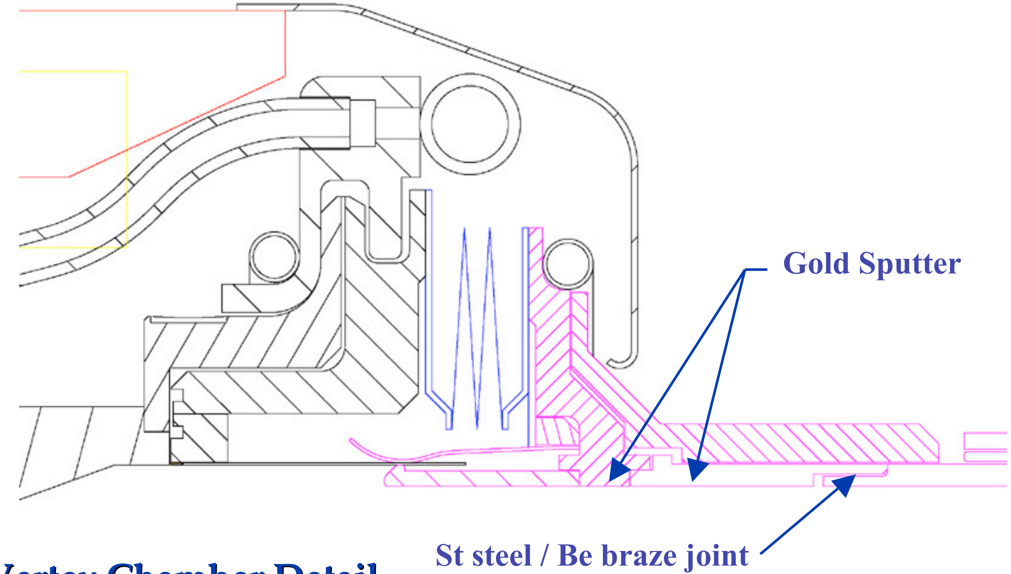
IR Design Challenges

- **HOM Power**
  - IR geometry inherently produces a trapped area
    - Two larger ring chambers (BSC driven) into a small IP chamber
  - Shorter bunches & higher current increases HOM power trapped in the near IR chambers.
- **Backgrounds**
  - Constrains chamber and mask geometries.
- **SR power**
  - SR fans in this area have high linear heat loads.
    - B1R (Forward) is 660 W/mm. Three times higher than any linear density in the PEP-II vacuum system
    - Intercepting B1 fans during mis-steers could cause permanent damage to chambers – actively safe system required.

Near Interaction Region Status



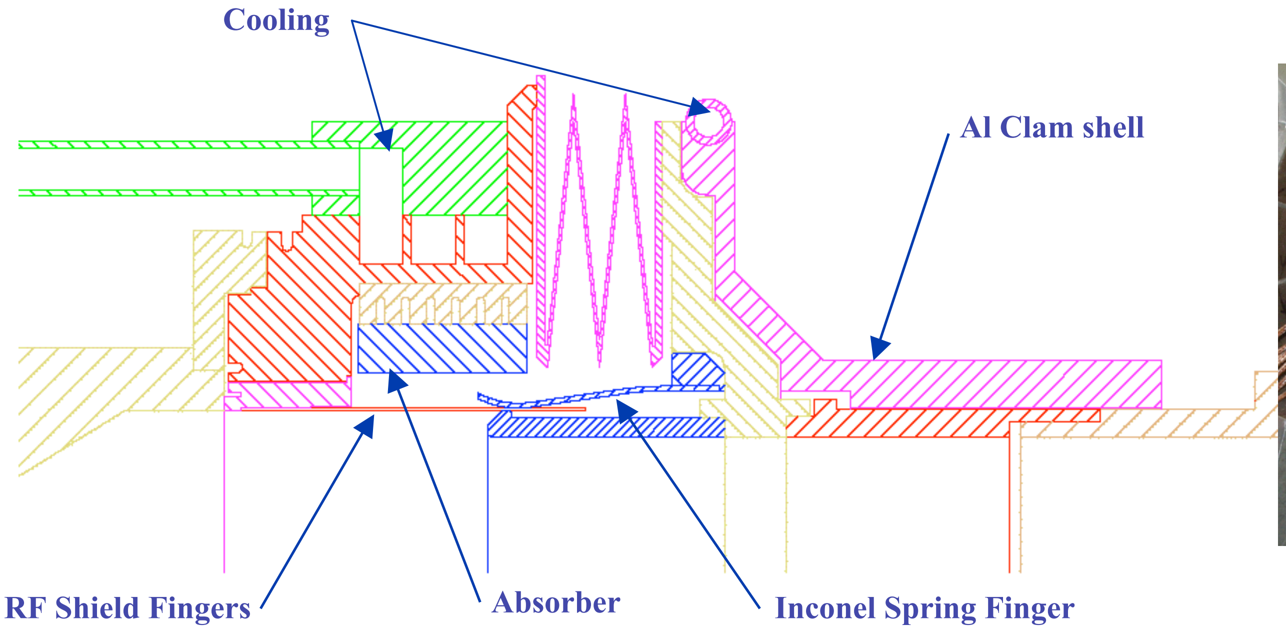
- **Spare vertex chamber exists.**
- **Gold sputtering on hold for vertex bellows redesign.**
  - Plan on gold sputtering the SS braze ends to reduce HOM and I^2R losses in this area.

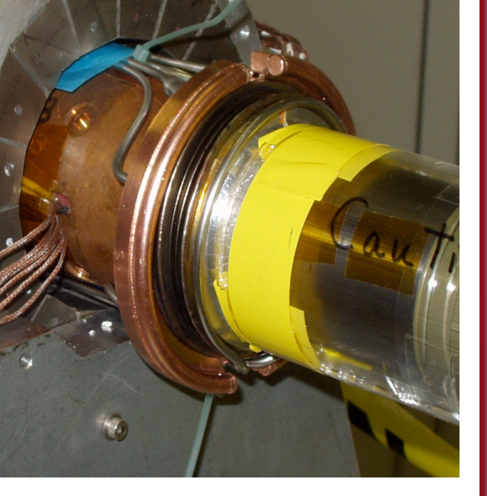


Vertex Chamber Detail

Vertex Bellows Status

- **Re-design Vertex Bellows**
  - **TE power leaks past the RF shield and heats of the stainless steel welded bellows and inconel fingers.**
  - **Reduce power into the stainless steel welded bellows cavity.**
    - **Designed small cooled AlNiSiC absorbing tiles in the bellows cavity space.**
  - **Design complete pending final design review**
    - **HOM and thermal analysis completed. (See J. Langton's talk)**

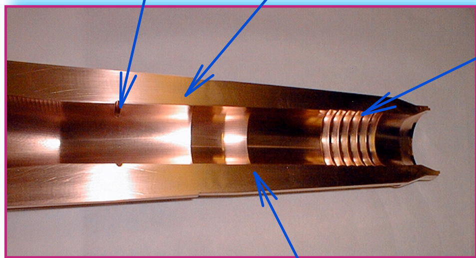


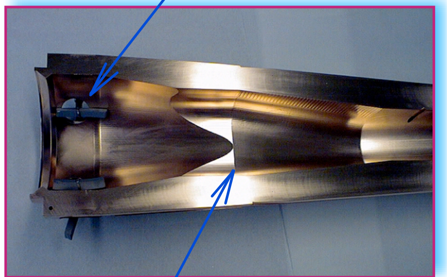


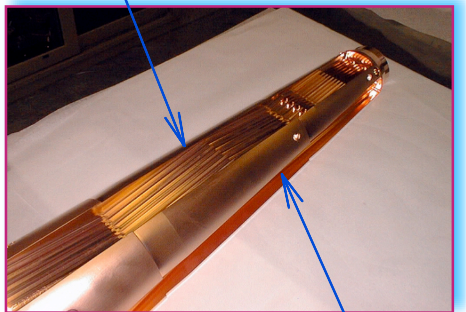
B1 LEB Chamber

B1 LEB (R, Forward) masks

- Power densities are about ~660 W/cm (4.5A, 3.1GeV) on first tip, from Q1 magnet. Power density is high due to close proximity of Q1 magnet & B1 chamber.
- New analysis combined with fatigue test data and pull tests indicates that masks are safe for 4.5 A.
- Delay making new B1 chamber
  - Manpower, cost, schedule
- Future spare B1 chamber.
  - Serrate other tips to reduce stress levels.

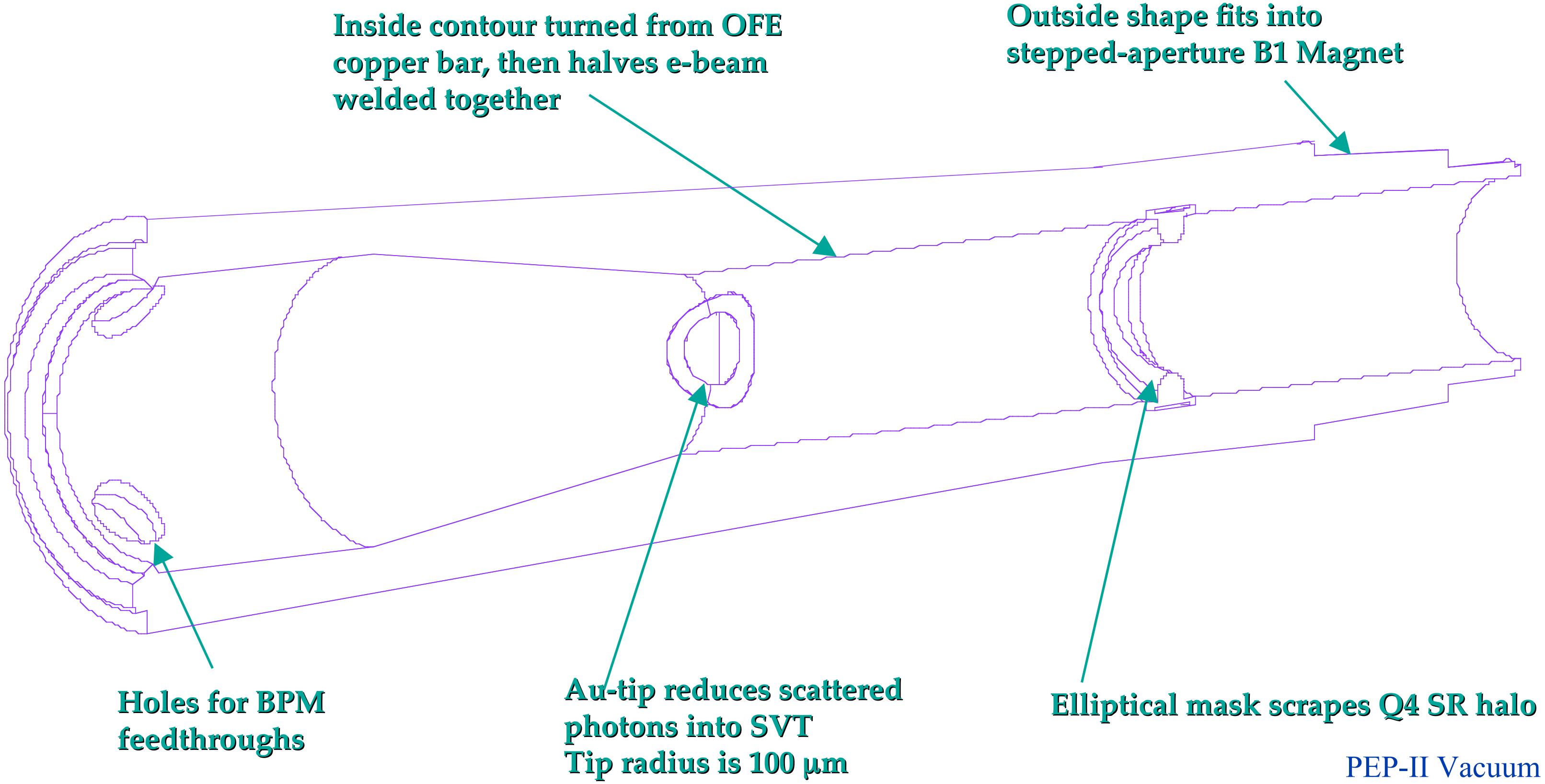






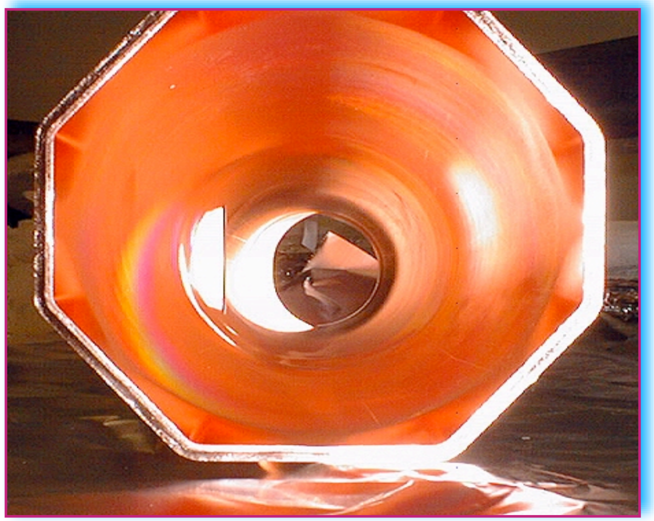
B1 HEB Vacuum Chamber

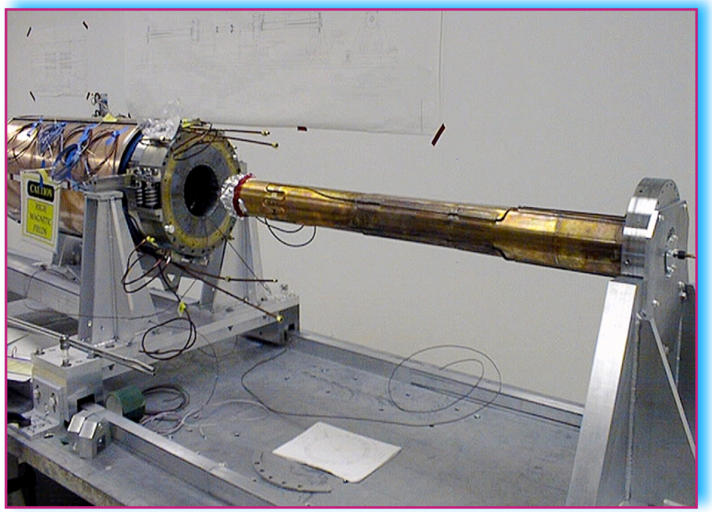
- B1 HEB –
  - Additional 10% power. Power from upstream Q4 magnet.
    - Engineering analysis reviewed and higher current operation should be acceptable. Further review is in progress.
  - Elliptical blades are not a source of excessive HOM power.
  - ➔ B1 HEB chamber will not be rebuilt.



Q1 Chamber

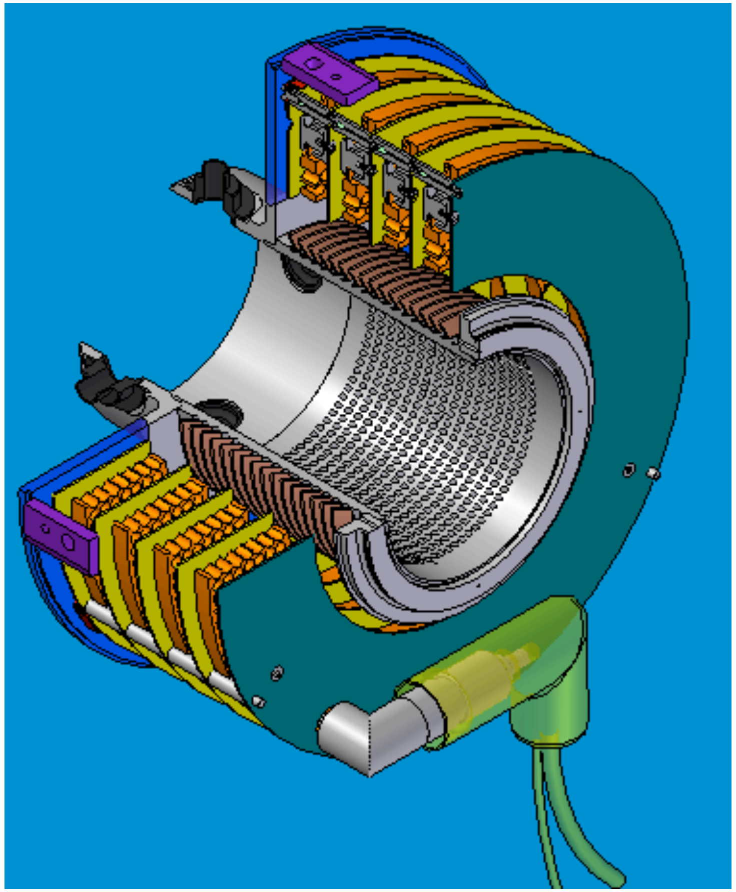
- **Q1 Chamber will not be rebuilt.**
  - Background blade masks.
    - "Blade" masks are thin and abrupt, does not have a 1:10 taper.
    - Only increases the broadband, but doesn't effect the narrowband impedance.
      - Therefore, making a smooth background mask would not reduce the HOM's stored in the IR chambers.
  - Power on mask tips.
    - Q1B (Forward)
      - Z=-1600mm (vertical) – no power
      - Z=-1100mm(elliptical)
        - 150W (2A, 9 GeV), HEB Q4 mask
    - Q1B (Backward)
      - Z= 950mm (elliptical)
        - 680 W (3A, 3.1 GeV), 1020 W (4.5A), LER BV1 fan
        - q" = 694 (3A), 1041 W/cm^2 (4.5A)
      - Z = 1200 mm (vertical) – no power
    - Scaling thermal results indicate masks are within stress limits at 4.5A.





B1 Radial Ion Pump

- New Design Complete pending final design review.
- Addresses current pump issues
  - Argon Instability
    - Noble diode pump, rebuild with tantalum plates
  - Pump failures
    - Two circuits,
    - Higher rated feedthru design
    - Improved mechanical fabrication design
  - Verified pump screen is sufficient with new bunch parameters
  - Reduce pump physical dimensions to add additional BPM set.
  - No additional shielding
- New pump ready for installation 2005 Summer Downtime.

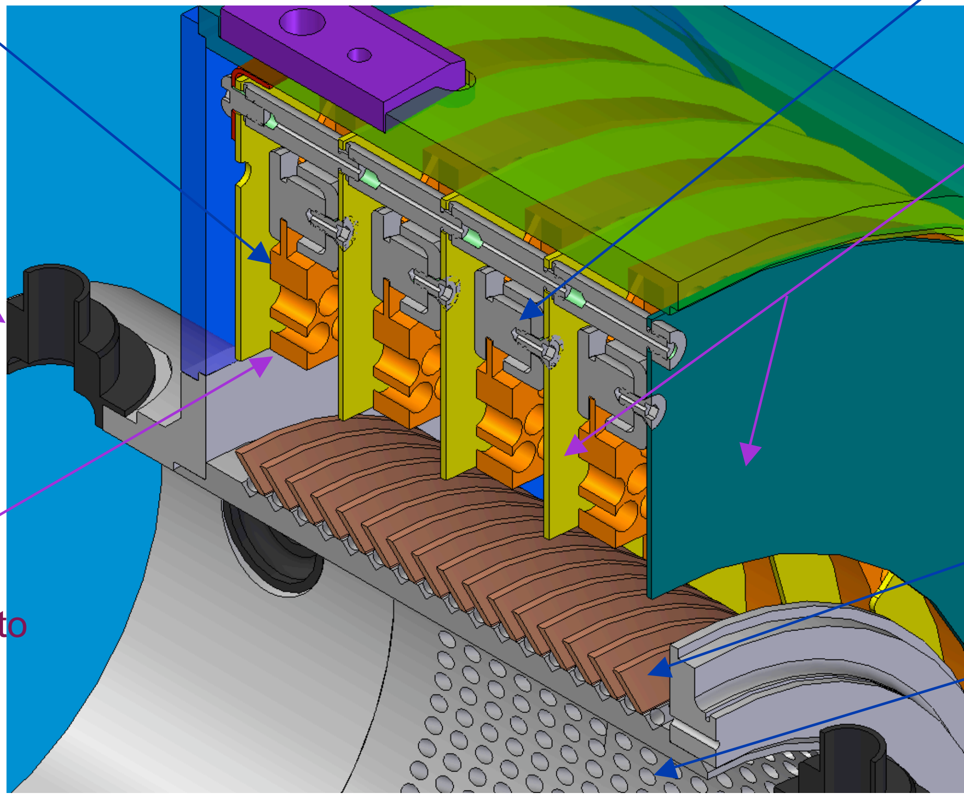


B1 Radial Ion Pump

Prodec Anode cell structure

Ceramic Standoff

Additional BPM set



Tantalum/Titanium Cathode Plates

- Modified to Ta from Ti to increase noble gas pumping and eliminate the argon instability.

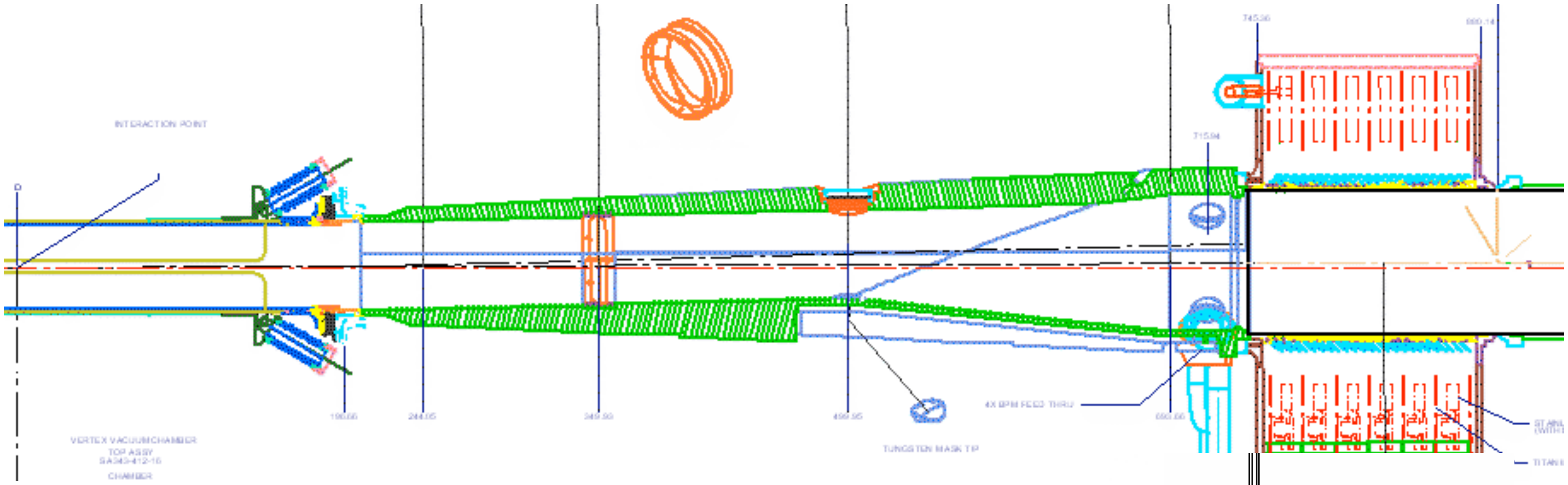
Reduced to 4 cell arrays from 6.

- Shorten pump to add BPM set.

Baffles

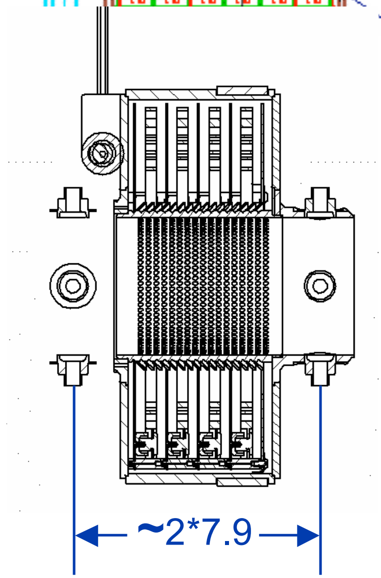
∅2mm holes

Beam Position Monitor (BPM)



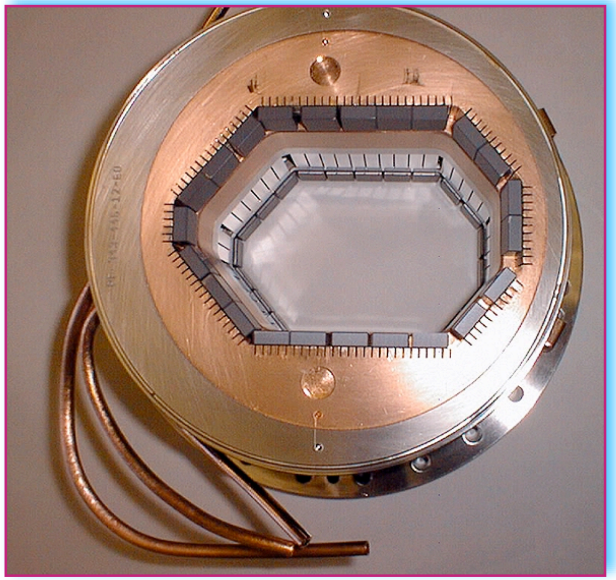
❍ Upgrade improvements

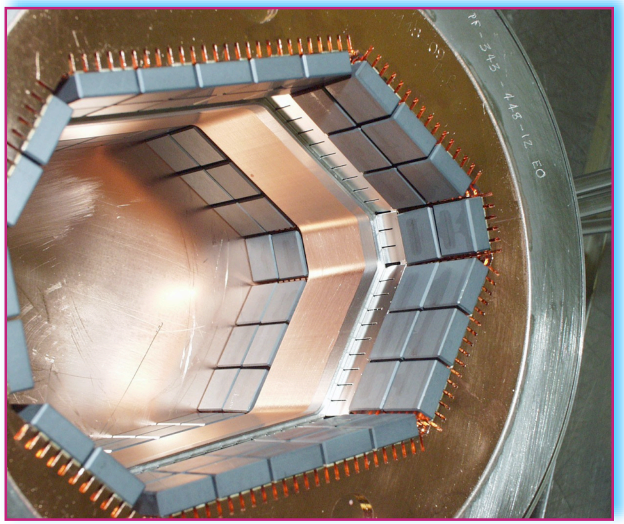
- Added BPM set at each radial ion pump.
- The new set is separated in z by ~f * 7.9 cm from the BPM’s in the B1 chamber, where f = 2.
- 7.9 cm corresponds to a quarter wavelength of 952 MHz, the BPM procesing frequency.
  - In the electronics they can then synthesize independent linear combinations of the signals which correspond to the two beams moving in opposite directions.



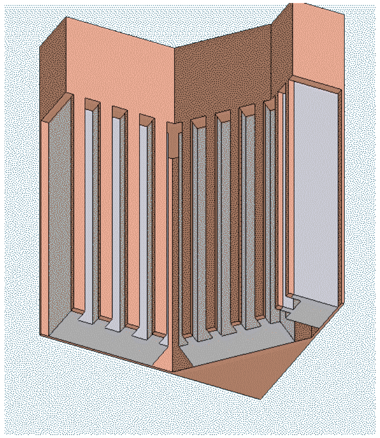
Q1/Q2 HOM Bellows

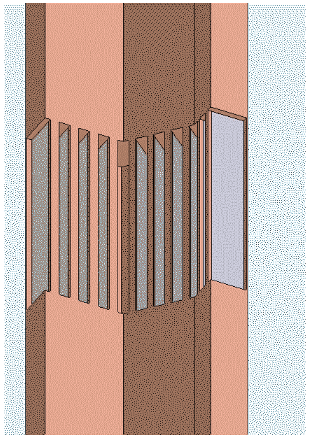
- **FY2003 added 4 layers of tiles per module.**
- **Absorbing ~10 KW presently**
- **Predict ~ 50 KW in 2007**
- **Numerous iterations on HOM absorbers have been analyzed by S. Weathersby and A. Novokhatski (38 runs).**
  - **Goal: Create a HOM absorber that doesn't generate ~50% of its absorption power.**
    - **Reduce monopole without significantly reducing dipole and quadrupole modes**
  - **Most effective design requires at minimum 4" slots as in the Straight HOM Bellows.**
  - **The optimized design for various modes must be chosen by February 2005.**
    - **A few more design/analytical iterations will be performed**
    - **Reduce power absorption, but still reduce HOM power at the vertex ends, vertex bellows and radial ion pump.**
      - **Vertex bellows will have HOM tiles**
      - **Gold plating will be extended on the vertex ends.**





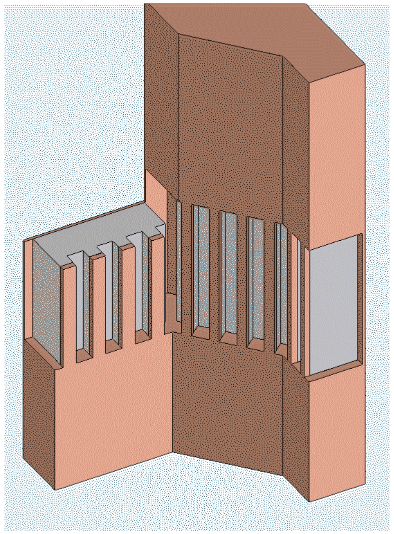
Q1/Q2 Blws - HOM Analysis

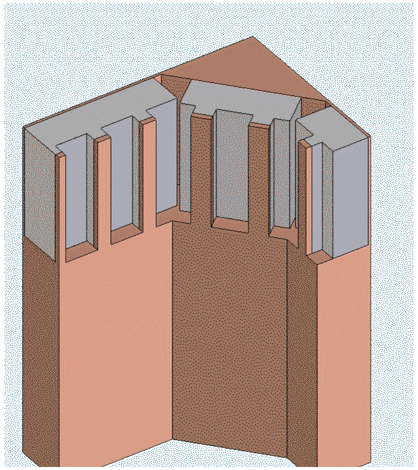


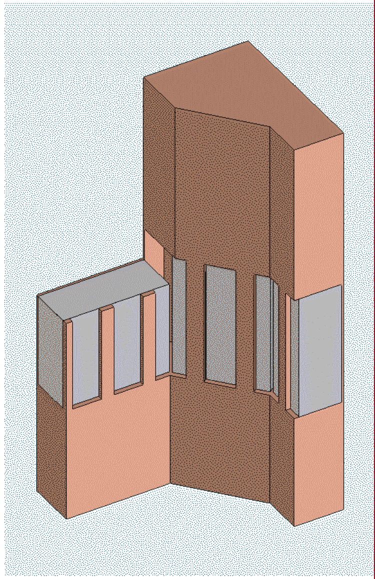


- 4" long tile sets
  - Suppresses the monopole mode without reducing the dipole and quadrupole mode
  - Sasha calculated the set back of the tiles

- Focusing on 2" long tile sets
  - Reasonable length for the 5" bellows module

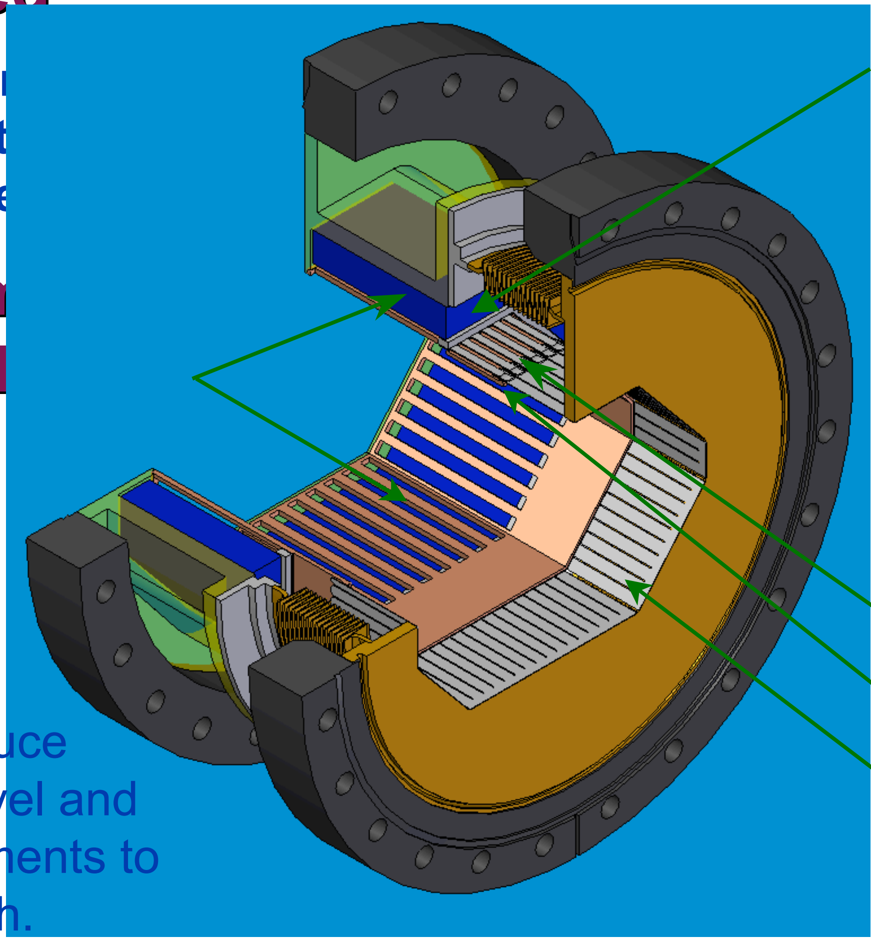






Q1/Q2 Blws - Design Status

- **New concept developed**
  - **based o**
    informat
    available
- **Maximun**
  Tile/slot l
  - **~2.4”**

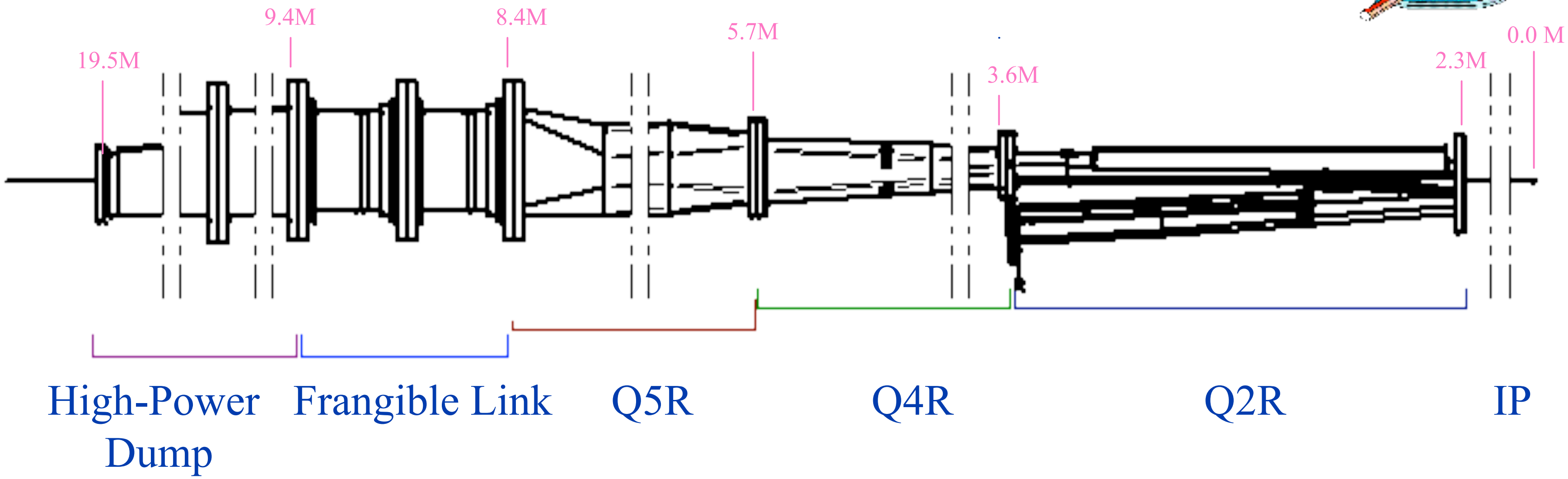


- **Absorbing tiles is open to the convolutions**
  - **No additional tile set needed in bellows cavity.**
- **HER Arc Style Bellows**
  - **Spring**
  - **Stub**
  - **RF shield**

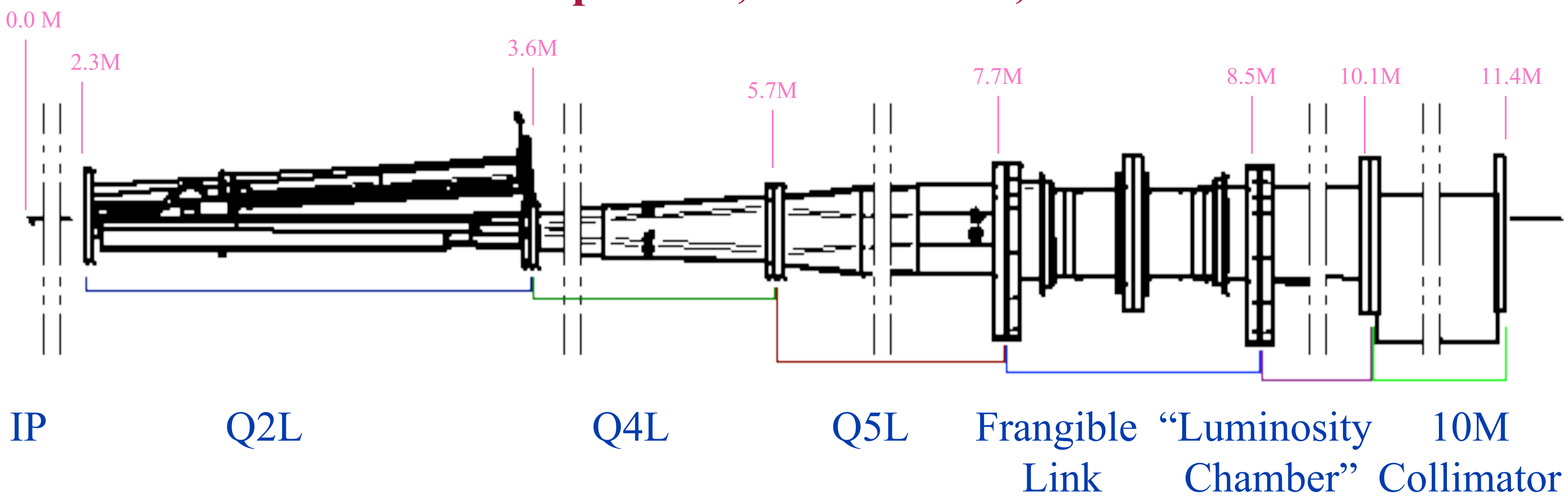
Possibly reduce further the travel and offset requirements to increase length.

Far IR

HER- Downstream, “Forward”, “Right”

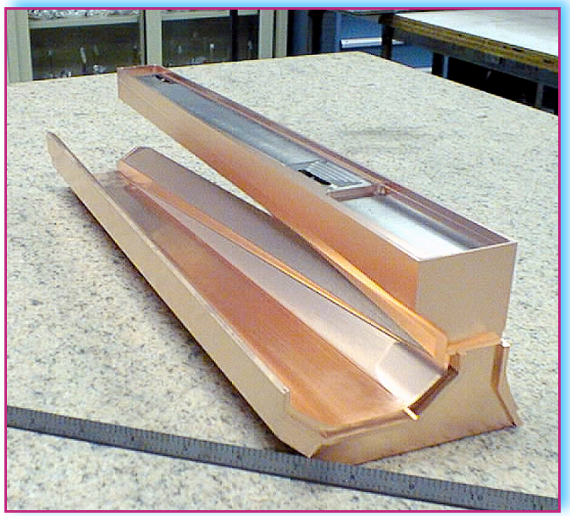


HER- Upstream, “Backward”, “Left”

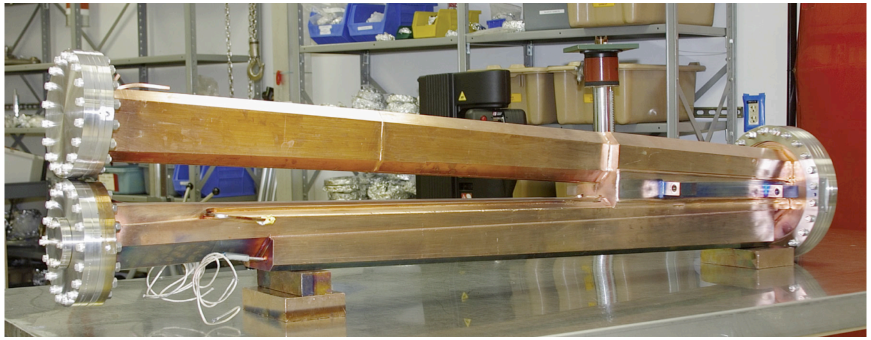


Q2 Chamber (cont.)

- **Q2L (Backward)**
  - 8KW from LEB B1 and Q1
  - Designed for three conditions
    - Solonoid on
    - Solonoid off
    - Solonoid not there
  - Heat Loads
    - Power density was highest in the 'NO" solonoid condition because it placed two beams in the same spot on the mask.
    - Re-analysis of chamber will be done with new geometry, lattice and current.
      - Analysis scheduled for January.
  - Currently no plan to rebuild this chamber.

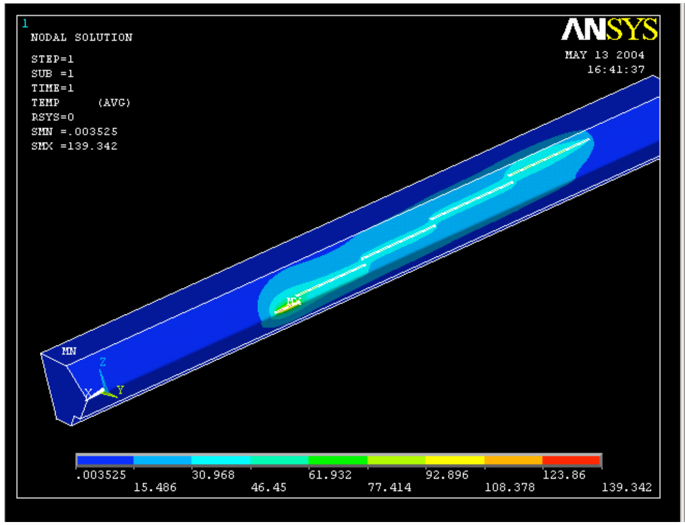


Q2L Wedge Mask



Q2 Chamber

- **Q2R (Forward)**
  - Replaced Q2R with a Q2L chamber in 2002.
    - Increase BSC acceptance and reduce HOM.
    - Failed due to material flaw in the GlidCop.
  - Original Q2R chamber replaced in 2003.
    - Clips BSC
    - No evidence that it creates increase HOMs.
  - New Q2R is in fabrication.
    - Some parts received.
    - Complete by April 2005.
  - Thermal analysis completed.
    - Simplified 3D extrusion and no fins were included in the model.
    - Peak ΔT = 139 C (tip of the mask from QD4.8).
    - Water wall ΔT = 58 C.



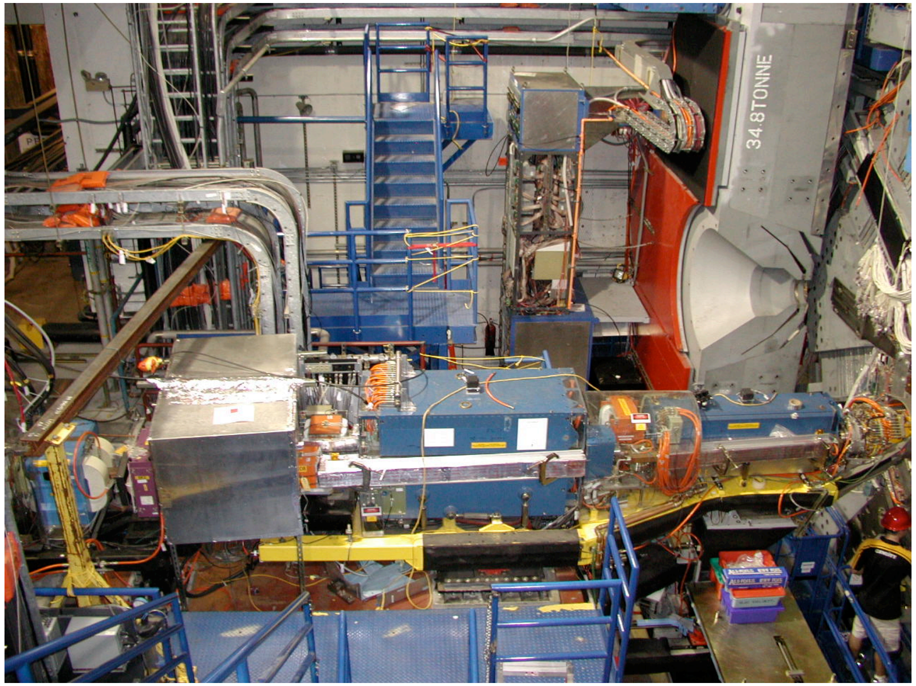
A. Sheng

	Length (inch)	Q (w/cm)	Power (w)	beam ht (in)	Peak power density (W/in^2)
QD4.4	2.2008	104.9	586.12	0.0298	8934.792
QD4.5	2.248	90.73	518.06	0.03	7687.311
QD4.6	2.0472	88.64	460.92	0.0301	7467.797
QD4.7	1.9094	83.95	407.17	0.0304	7022.742
QD4.8	0.6654	212.3	358.82	0.0307	17590.1
Q4 Total			[illegible]		

Outboard of the near IR

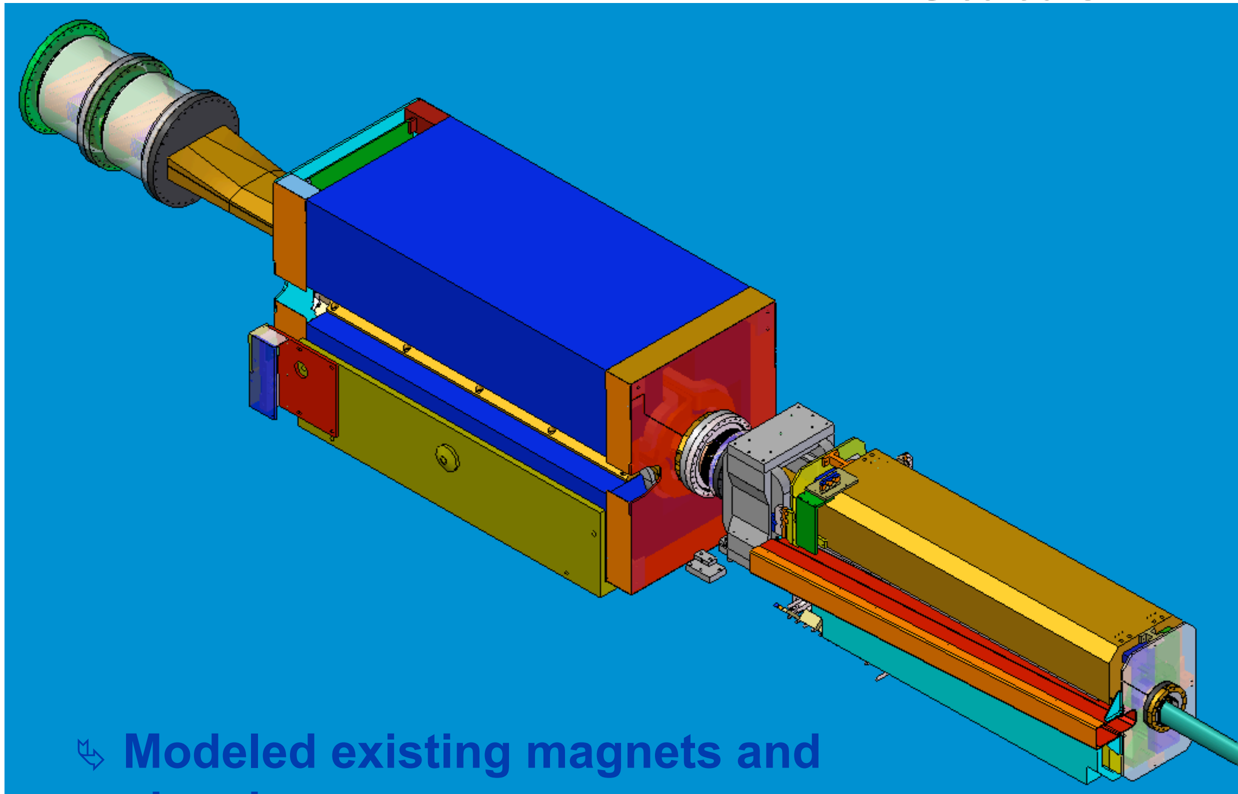
❍ Q5 & Q4 HEB Chambers

- **General problems**
  - Mechanical & HOM failures in the NEG screens
  - Beam Stay Clear (BSC) & Lumi cone.
  - Thermal motion issues?
    - Magnet instabilities
    - Q4 & Q5 are rigid chambers that have minimal to no clearance to their respective magnets.
    - Load on Q2 chamber, IR support raft, magnets
  - Global alignment error between the "Bong" Collimator and Q5.
- **Q5R (Forward End)**
  - Flange heating
  - Neg screen destorted
- **Q5L (Backward End)**
  - Masks failed and replaced
  - Neg screen detached
- **Q4R (Forward End)**
- **Q4L (Backward End)**
  - Masks failed and replaced



HER Q4 & Q5 Chambers

❍ Status



letailed
ation from LLNL 6/04

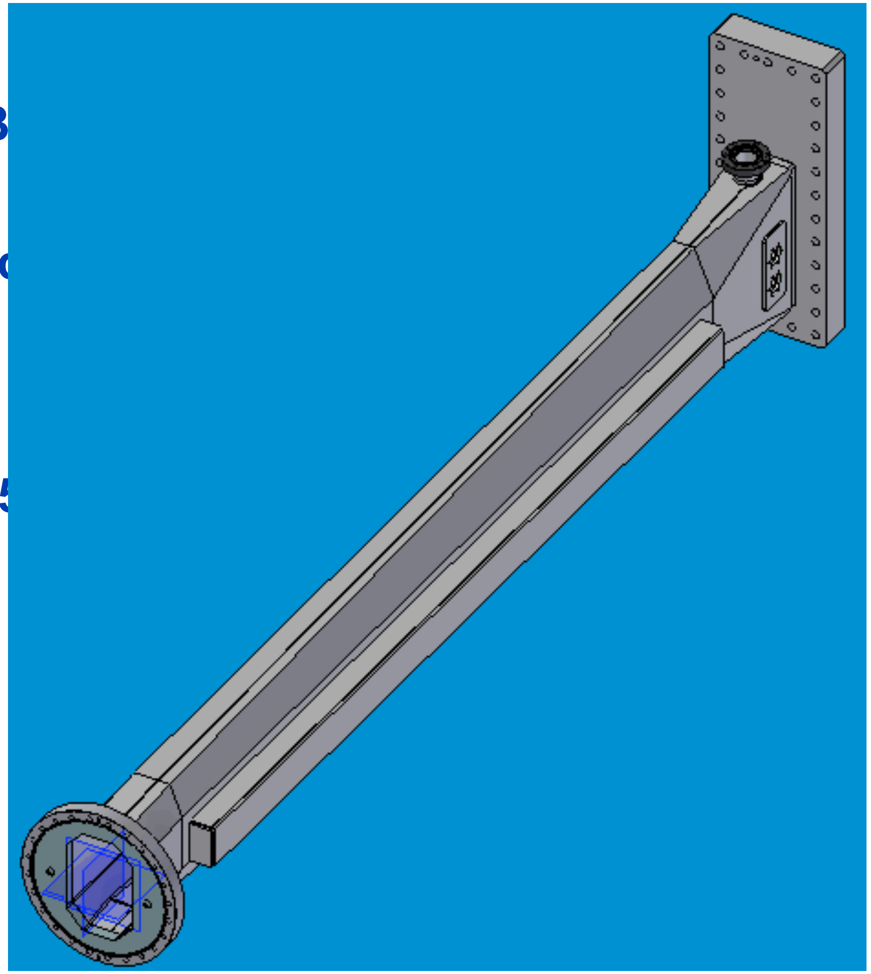
vendor quotation for
ells.

- Modeled existing magnets and chambers.
- Thermal and structural analysis completed.
- Final Design Review 2/05
- Ready for installation 8/05

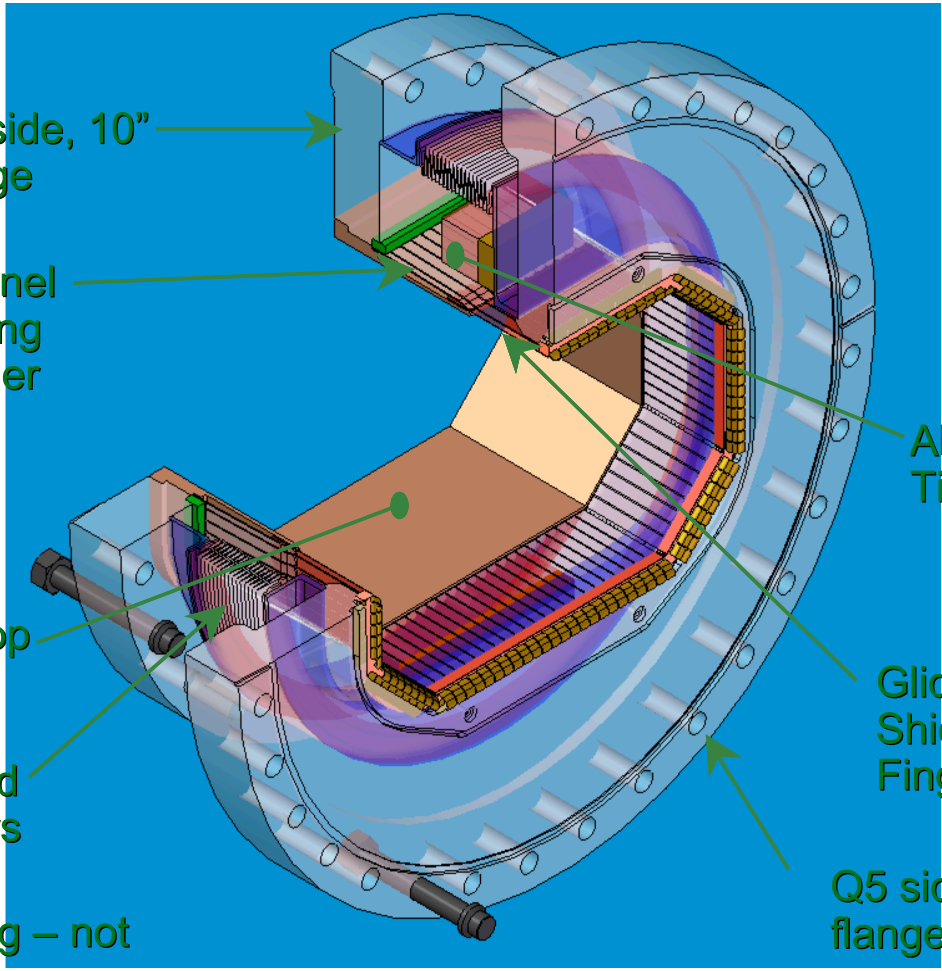
HER Q4/Q5 Chambers

❍ Goals achieved

- LER: 4.5A, HER 2.2 A
- Designed between the defined B
  existing magnets
- Maintain a 2mm gap to poles anc
- Reduce thermal gradients
  - Aluminum clamshell design
- Added a bellows between Q4, Q5
- Improve kinematics and
  stabilize BPM supports
- Decrease the TE leakage
  to the pumps
  - Screen hole diameter reduced
    to 3 mm and depth increased
    to 6mm.



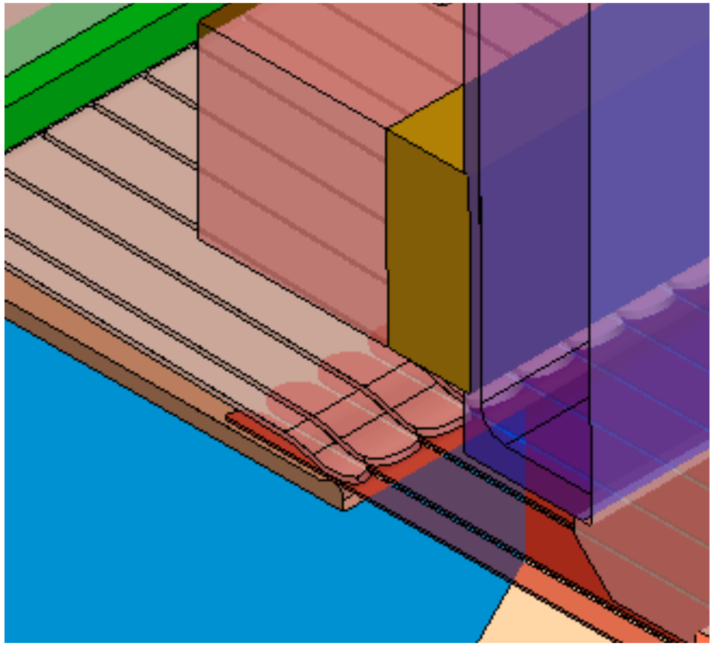
Q4/Q5 Bellows Module



- HER arc bellows concept + absorbing tile in bellows cavity.
- Design Review 12/05
- Final Design Review 2/05
- Complete 10/05

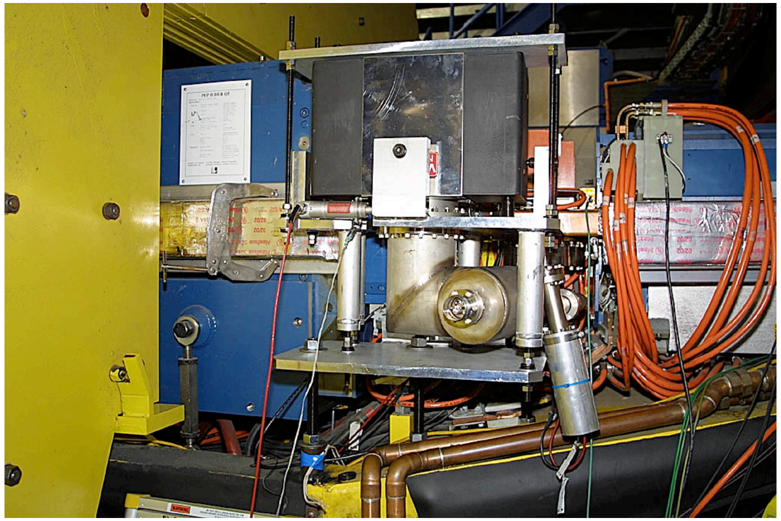
Q4/Q5 Blws Detail Design

- HER Arc Bellows concept with absorber
- Ensure failure does not result in the RF shield falling into beam tube
  - Shield fingers slide on outside of chamber stub
- Keep high stress areas away from high heat areas
- Keep steps to a minimum, reduce impedance
- Plating to minimize wear, decrease cold welding, solid lubrication

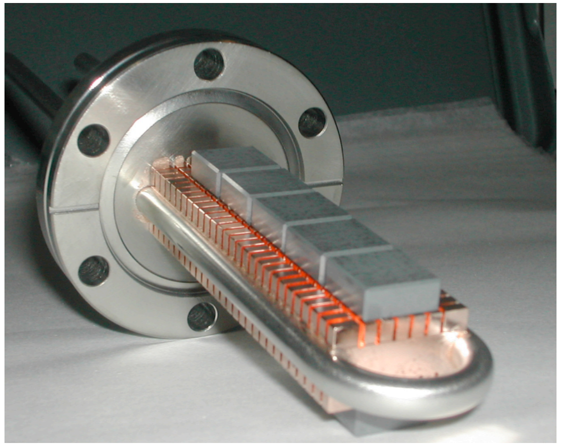


LER Q4/Q5 Low pressure chambers

- **Two major issues led to redesign**
  - **NEG heating problem**
  - **Thermal motion of the backward raft/magnets.**
- **Status**
  - **NEGs removed this summer and absorbers added to pump passages.**
  - **Added TSP/Ion pump manifold and absorber to LER Q4R Chamber.**



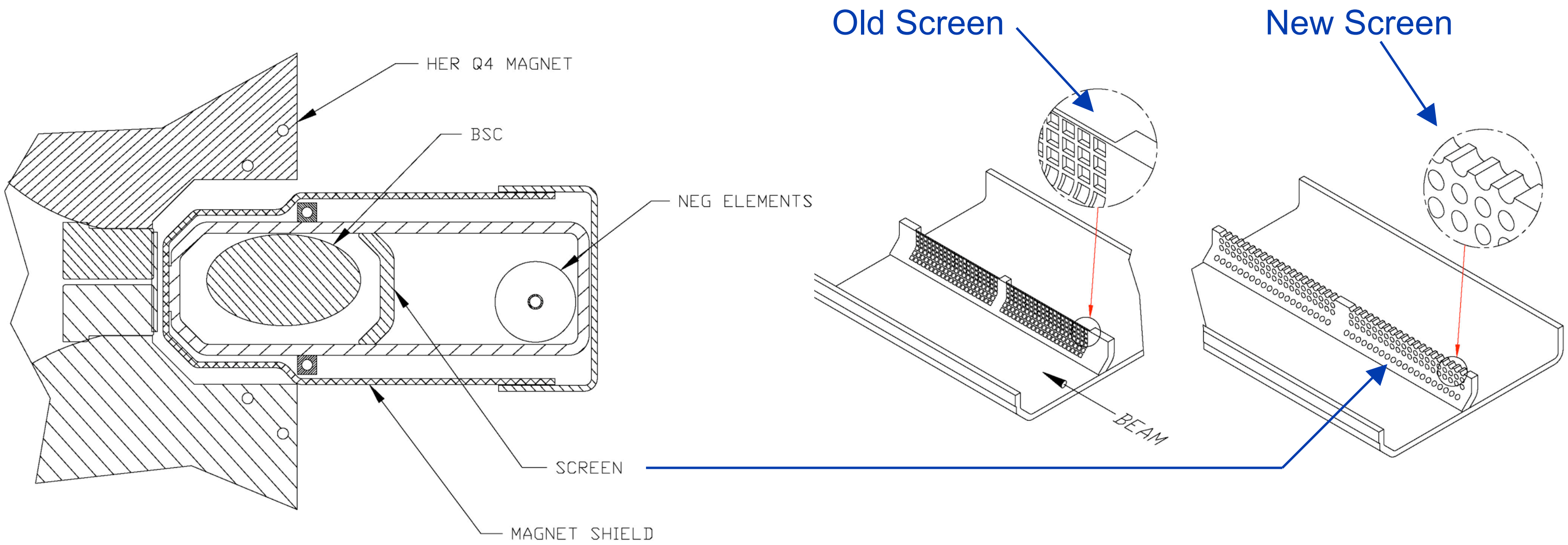
LER TSP/Ion pump manifold



LER Q4R Absorber

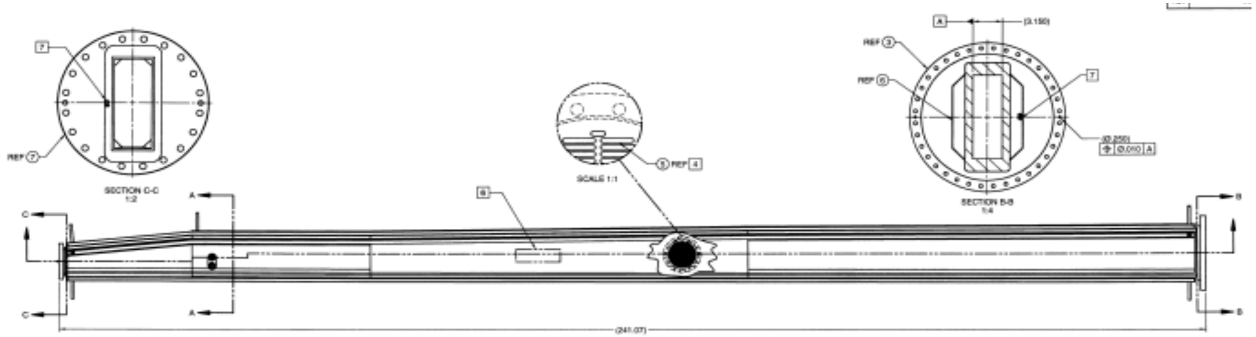
LER Q4/Q5 Low pressure chambers

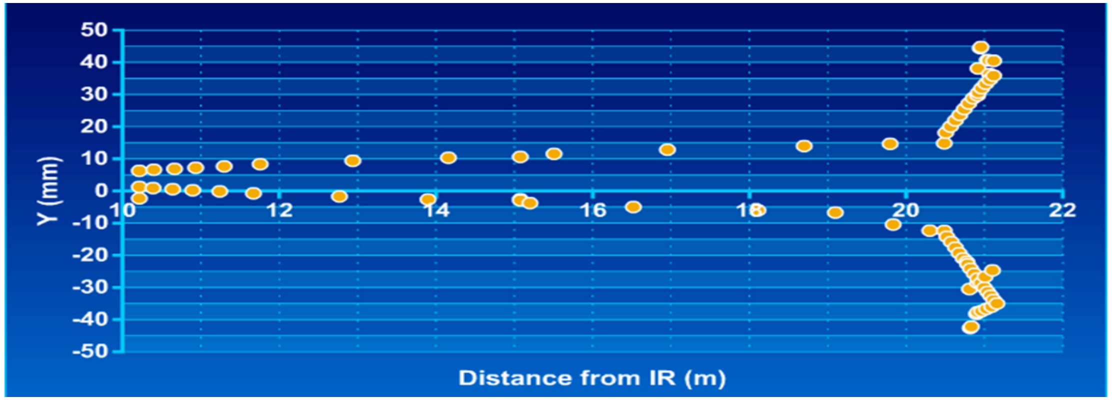
- New design for Q4 and Q5 chambers underway (see J. Langton's talk).
- Improve RF screens
- Add cooled HOM loads (TBD)



High Power Beam Dump

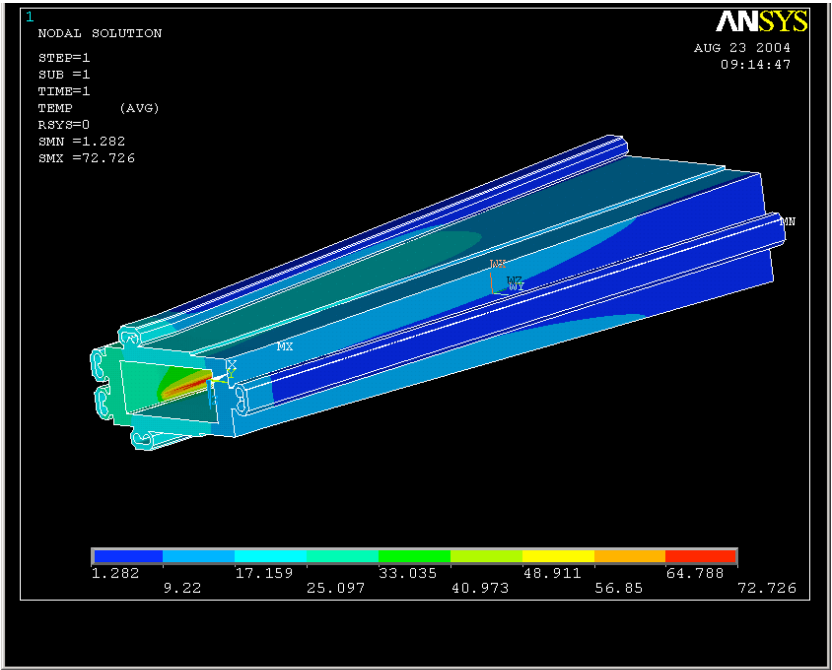
- **Current design limit 1.5 A, 9GeV**
  - 47% increase of SR at 2.2A
  - 10 – 21 m from IP on forward side.
- **Chamber re-analyzed for 2.2 A, 9GeV**
  - High power beam dump (HPBD) is subjected to 127 kw

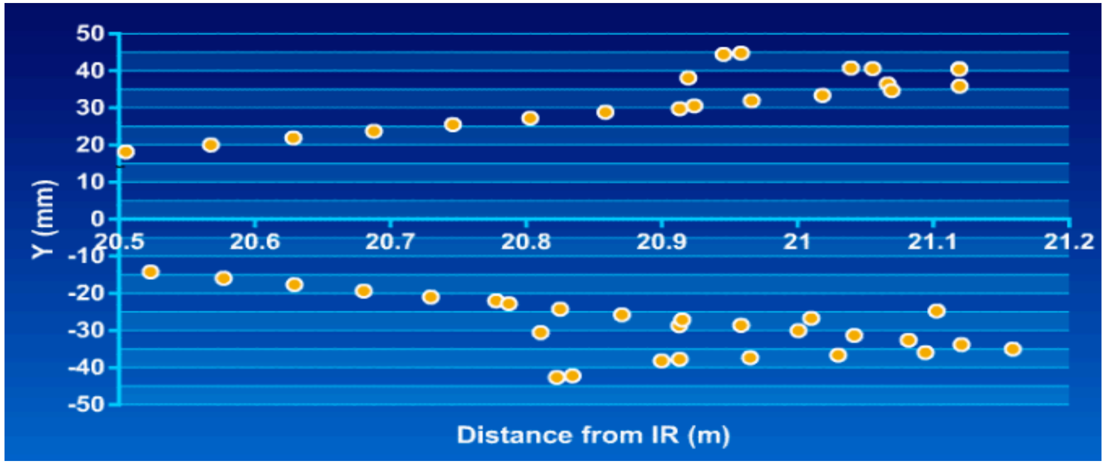




High Power Dump Chamber

- ΔTmax = 72 C at section 3.
- σmax = 13 KSI (combined thermal and mechanical stress).
  - In half hard copper and not in the weld joint.
- Temperature analysis fits well with thermocouples data.
- HPBD is passively safe at HER beam current 2.2 A.

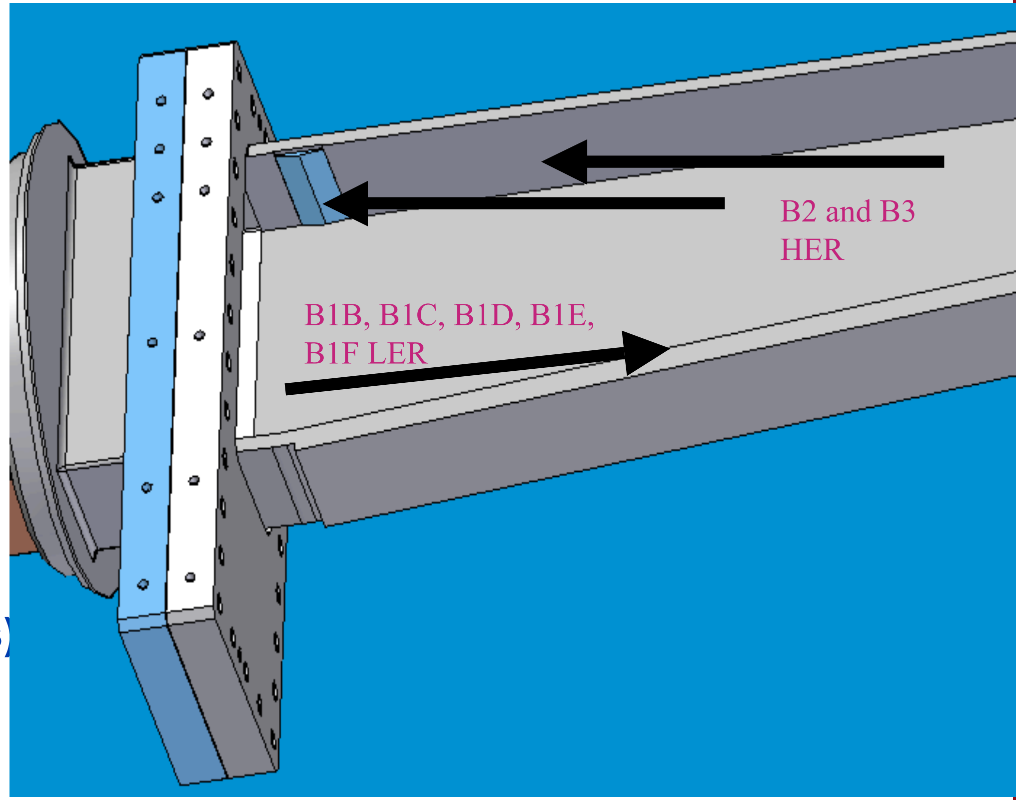




A. Sheng

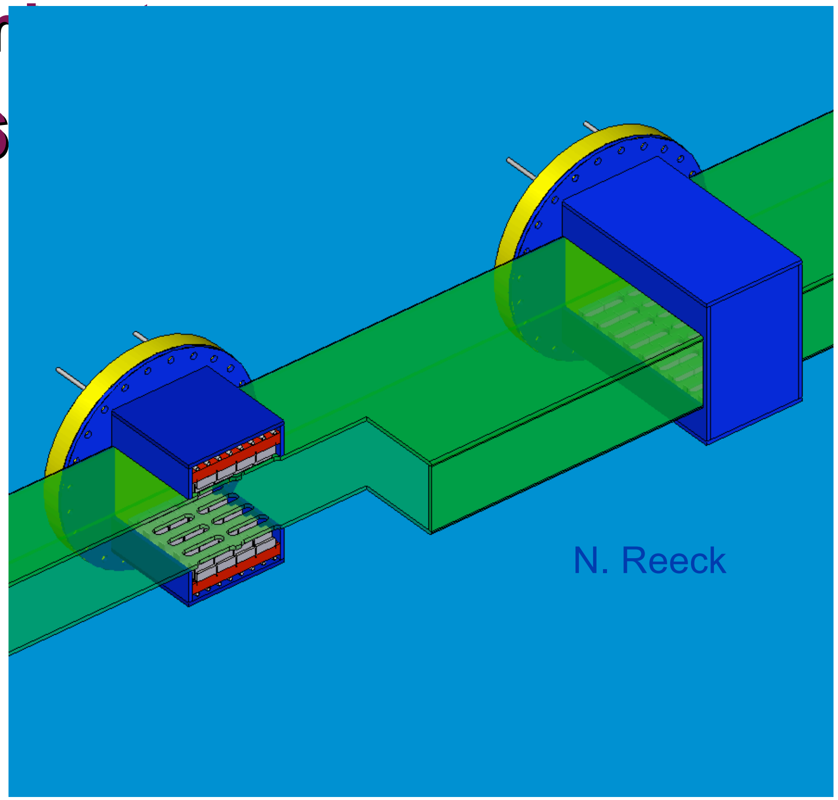
Luminosity Chamber

- Chamber reanalyzed
  - 2,560 W of LER @ 4.5 A,
  - 323 W of HER @ 2.2 A,
  - 10% reflected power (288.3 W)
  - 1kW/m HOM (1,625 W)
- ΔTmax = 65 C at mask tip.
  - σmax = 16 KSI (combined thermal and mechanical stress)
- Luminosity chamber is safe at LER 4.5 A and HER 2.2 A beam current.



HER Moveable Collimator

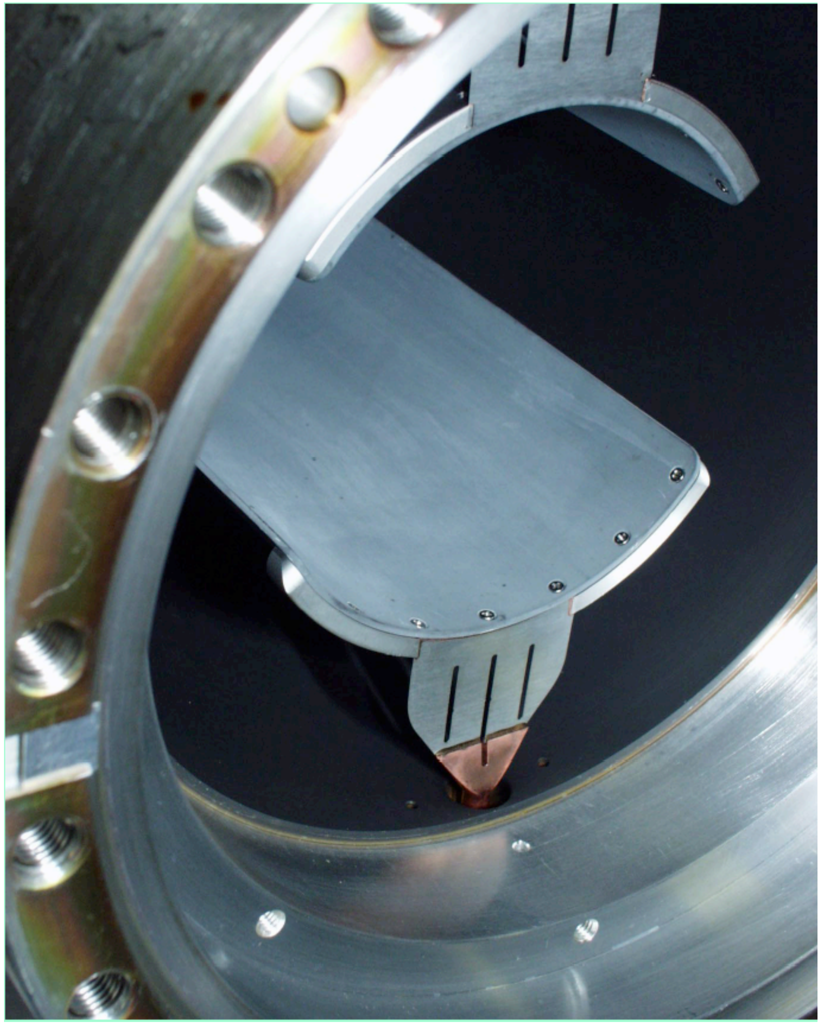
- Chamber screen is not passively safe for > 1A on 3.5 GeV during a vertical mis-steer
- Run with the known risk and have a spool ready if it fails from a high current m
- Build new chamber for 2006
  - Fixed collimator
  - HER absorber added to chamber
- Status
  - AIP started
  - New chamber designs underway
  - HOM calculations performed and designs is being optimized to absorb HOMs.



Diagnostics Upgrades

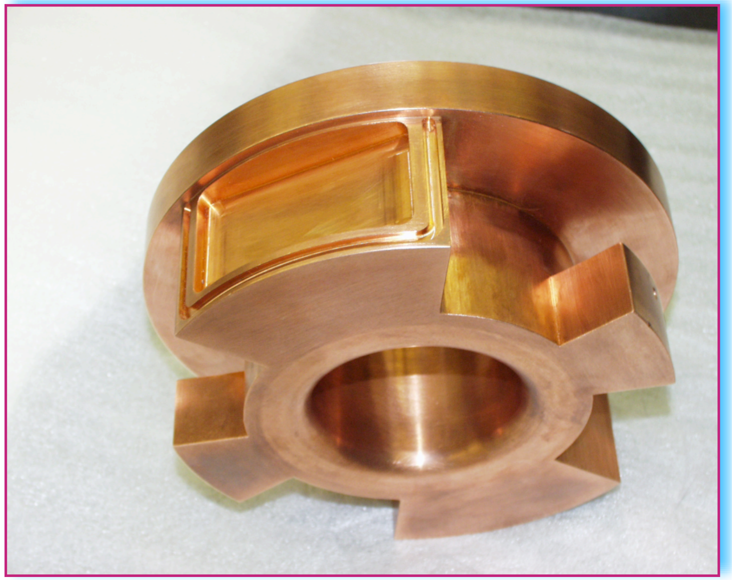
❍ Diagnostics

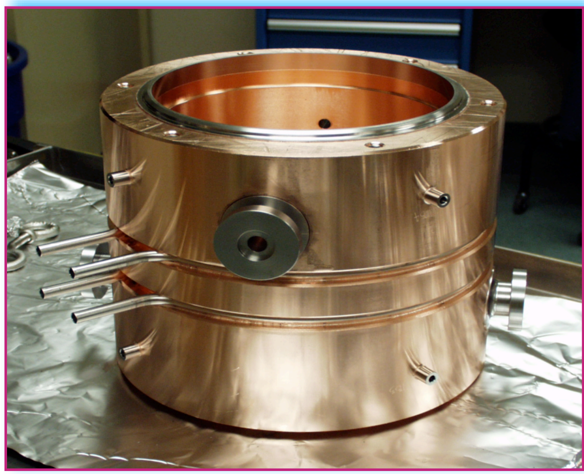
- Transverse Feedback Chambers
  - Thermal/power issues
    - Kicker feedthrus/connectors
    - Aluminum electrode
  - New Molybdenum electrode and flexure design complete and fabricated.
  - Spare chamber retrofited with new electrodes and flexures.
  - Installed this summer.



Diagnostics Upgrades

- Longitudinal Feedback Chambers
  - Fracati style kicker completed and installed this summer
- SLM (LER)
  - Modified LER pumping chamber and special photon stop installed this summer.
  - Front-end components and new diagnostics installed this summer.
  - Alan Fisher will discuss this project in detail on Tuesday.





Additional Upgrades

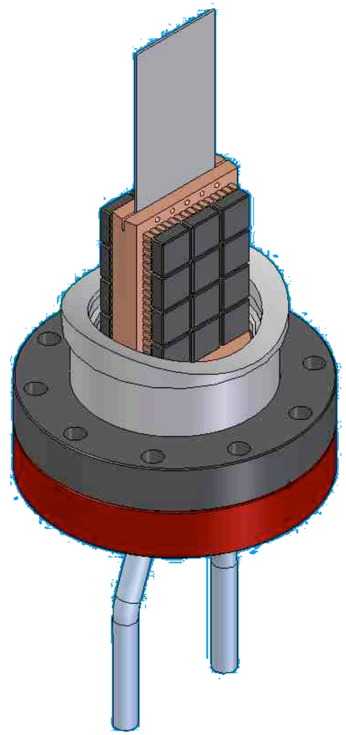
❍ Others

LER Abort Window

- Re-analyzed and verified that it will not survive 4.5A.
- Possible to build a Ti window, but it would be difficult to retrofit existing chamber.
- Titanium spoiler will be placed upstream of window.
  - More cost effective
  - HOM analysis in progress

Elliptical & Round Valves

- Elliptical valves have failed in several location.
- Delay rebuild of valves
- Test a HOM absorbing bellows near valves.

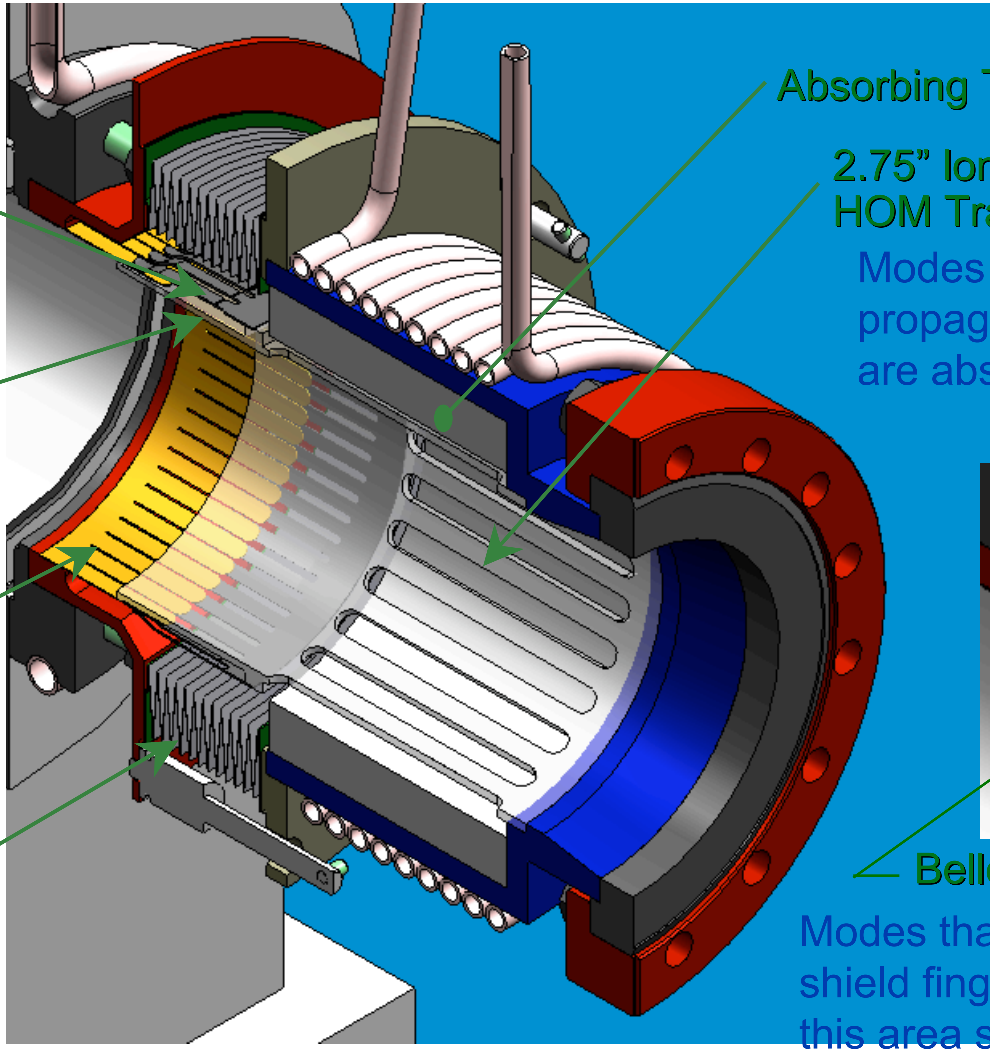


LER Abort Spoiler
M. Dormiani

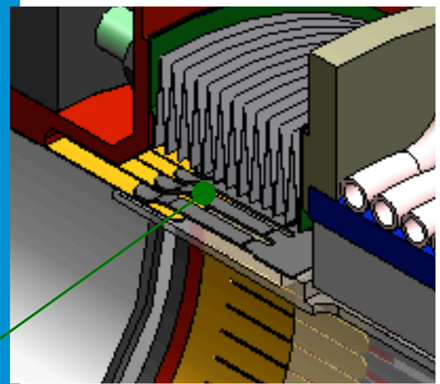
HOM Absorbing Bellows

- **New bellows designs that also function as beamline HOM absorbers.**
  - LER arc bellows
  - Straight bellows
  - Q2 bellows
- **New bellows designs that have absorbers that protect themselves from modes that leak behind their RF shields.**
  - Vertex bellows
  - Q4/Q5 bellows

Straight HOM Blws -Design Details



Modes in the chamber propagate through the slots & are absorbed by the AlNiSiC.



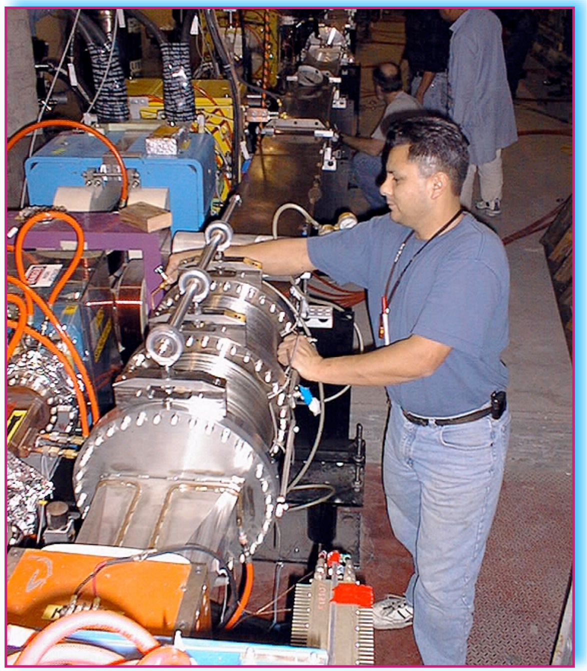
Modes that leak past the RF shield finger and are trapped in this area still see the absorber

Straight Section HOM Bellows

- **Prototype of the HOM absorbing bellows**
  - Simple round geometry
  - Locate near isolation valves to tests its impact on HOMs in neighboring components.
- **Conceptual design complete**
- **HOM calculations are being done to optimize tile size and slot dimensions.**
- **Initial HOM analysis shows that the concept works.**
  - Reduces monopole absorption while optimizing dipole and quadrupole field absorption.

Upgrades

- HER IR-2 transition
  - Conceptual design complete.
  - Thermal & structural analysis under review.
  - Final design review Jan ’05.
  - Ready for installation Aug ‘’05.



❍ Future Upgrades

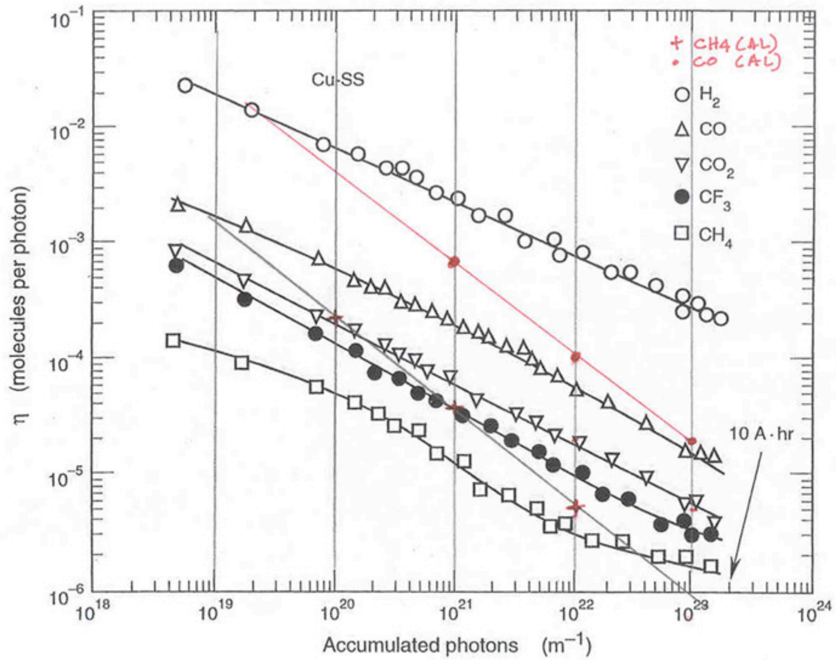
- HER & LER Frangible Links-Lumi
  - Meets current requirements
  - Possible rebuild in the future for improved maintenance.

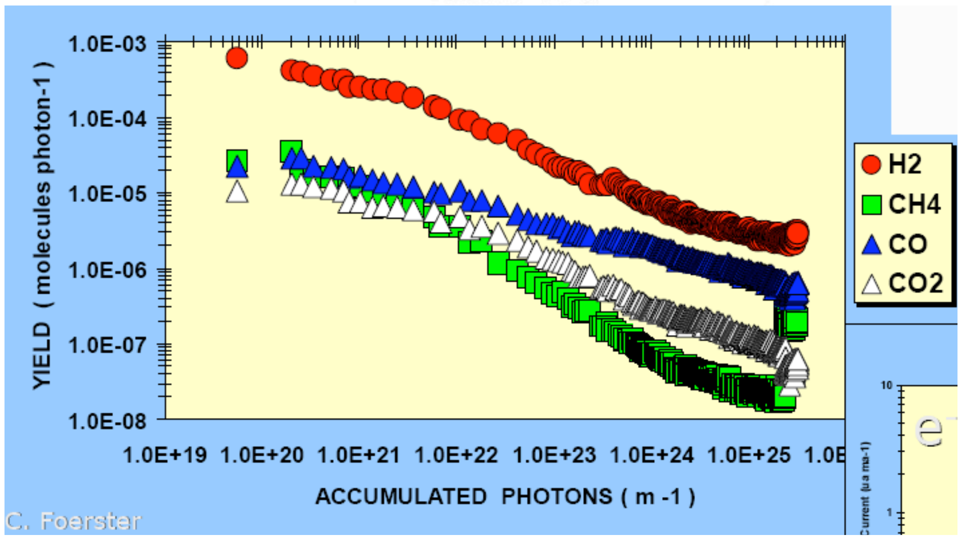
Future Upgrades (cont.)

- LER photon stops
  - Design reports indicate that the photon stops were designed for 3A and 3.5GeV, therefore it can handle 4.5A on 3.1GeV.
  - We will re-analyze the photon stops prior to 4.5A operations.
  - Transient analysis needed for water failure scenario
    - Design in MPS to prevent failure during loss of water.
      - Flow switches are costly and could cause excessive spurious trips.
      - RTD or klixon – transient analysis needed
- LER Wiggler Vacuum (IR6)
  - BPM – TE mode problems,
  - Need to re-examine wiggler power and bend magnet power – water channel problems.
- IR 10 Wiggler (NEW)
  - Required to reach higher luminosity

Vacuum Calculations

- Lou Bertolini's and Mike Sullivans vacuum calculations were updated this year.
- Rebuilt the geometry/ conductance/ pumping from drawings of the existing IR.
- New vacuum calculations should be complete early next year.
- Local areas are being reanalyzed in ANSYS.
- Improved PSD rates are planed to be used.
  - 2 orders of magnitude lower.





Summary

Progress

- Chambers needed for the upgrade have been identified and prioritized
  - Vertex Bellows
  - Radial Ion Pumps
  - Q1/Q2 Bellows
  - Q2 Forward Chamber
  - HER & LER Q4/Q5
  - Q4/Q5 Bellows
  - BPMs
  - LER Abort window
  - HER IR transition
  - LER bellows prototype
  - HER IR Collimator
- Work load has been reduced
  - Re-analyzed chambers and determined that they should survive the new beam parameters.
    - B1 LEB & HEB
    - Q1 LEB & HEB
    - High Power Dump Chamber
    - Luminosity Chamber
- Q2 Backward Chamber (TBD)

Summary (cont.)

- Chambers required for the summer ’05 downtime have progressed and fabrication will start at the beginning of ’05 and be ready for installation during the fall downtime.
- New hardware to be installed for the ’06 downtime have also been identified and projects are also progressing.