

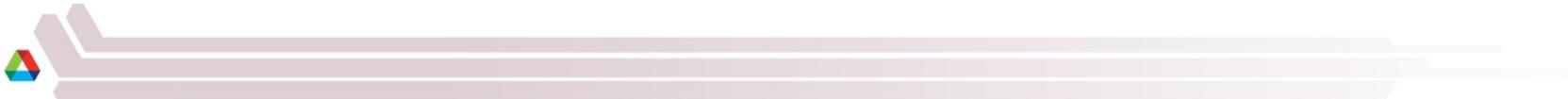
# Mechanical Design and Analysis of an Electron Beam Scraper/Spoiler at the Advanced Photon Source

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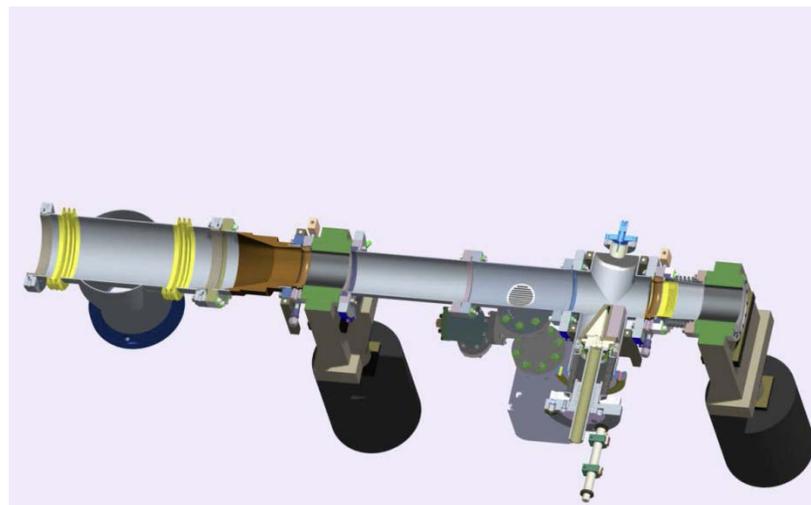
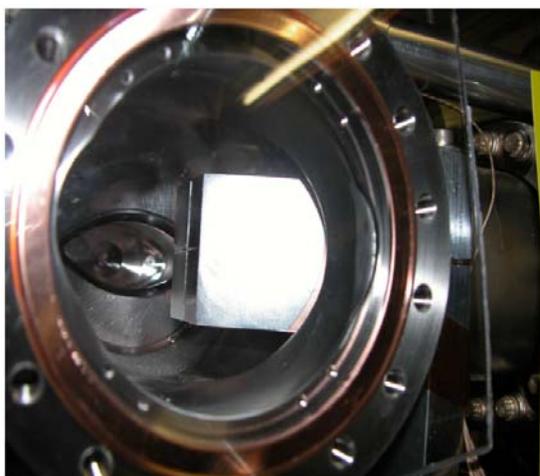
# Outline

- **Background**
- **Design Requirements**
- **Mechanical Design**
  - Components and Function
  - Precision
  - Cooling
  - Thermal conductance
  - Motion and motion control
- **Finite Element Analysis**
  - Beam Dump
  - RF
  - Synchrotron Thermal
- **Installation**



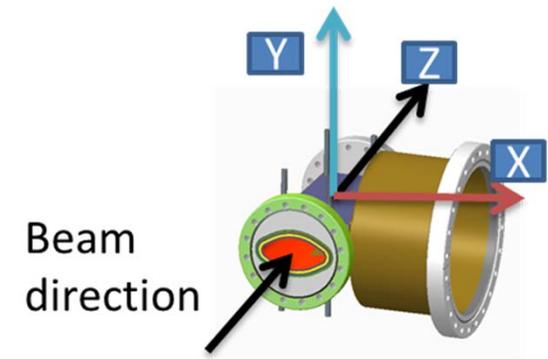
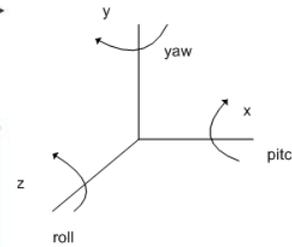
## Background

- **Scraper installed at S37 at APS to protect down stream ID from Touschek scattering and dumped beam**
- **Damages of the scraper were observed in 2011**
- **Studies shown that the damage was due to too much energy deposited by a beam dump**
- **A scraper/spoiler design is proposed**



# Geometrical and Material Requirements

- Scraper dimensions, the thickness is 5 mm, the width is 39.91 mm and length 160 mm



- $0.9 \pm 0.1$  mm gap all-around between scraper blade and the vacuum chamber
- The travel range of the scraper body X: -10 mm to 42.35mm
- The installation tolerance: Yaw:  $6.25 \mu\text{rad}$ , Roll:  $25 \mu\text{rad}$
- Beam dump plate can only be Al (6063T5) or Ti (Ti6Al4V)
- Screws are allowed only when  $|Y| \geq 15\text{mm}$



# Thermal Restrictions

## Heat Load for the scraper

- On scraper blade from RF is 70 W@150 mA
- On vacuum chamber from RF is about 180 W@150 mA
- From synchrotron radiation on blade is 20.3 W@150 mA
- From beam dump @ 100 mA is 141 J (TiA) and 47 J (Al)
- At 100mA beam current:

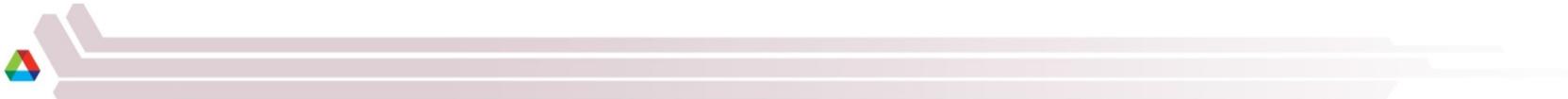
$\Delta T \leq 300^{\circ} \text{ C}$  to reach melting point of Ti

$\Delta T \leq 80^{\circ} \text{ C}$  to reach melting point of Al

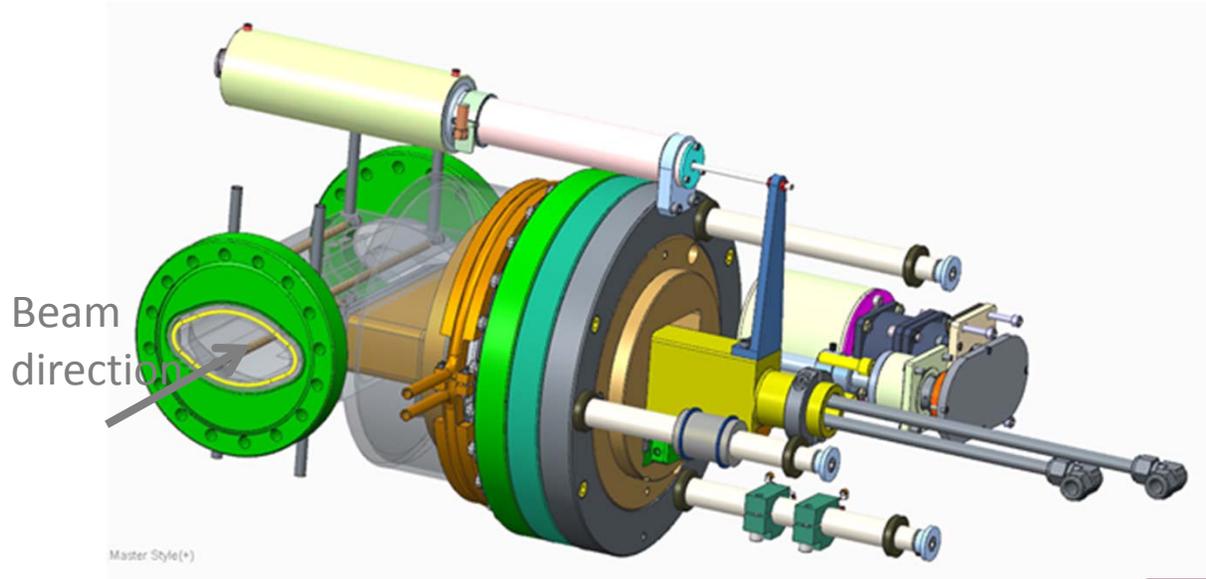
## Temperature rise requirement

Temperature rise at all flanges  $< 100^{\circ} \text{ C}$

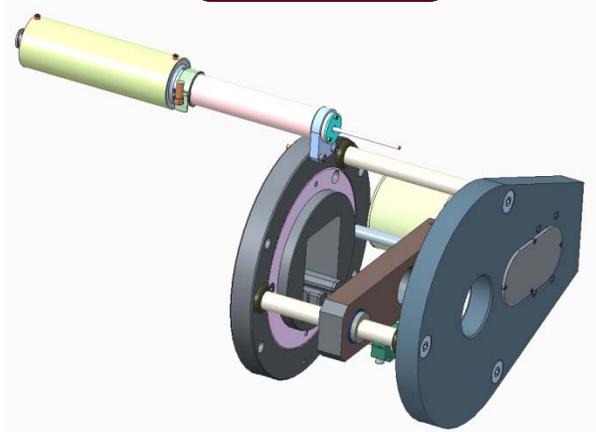
Temperature at the blade cannot exceed material melting point



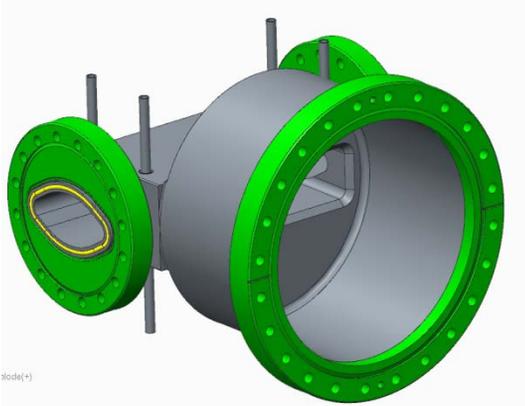
# Mechanical Design



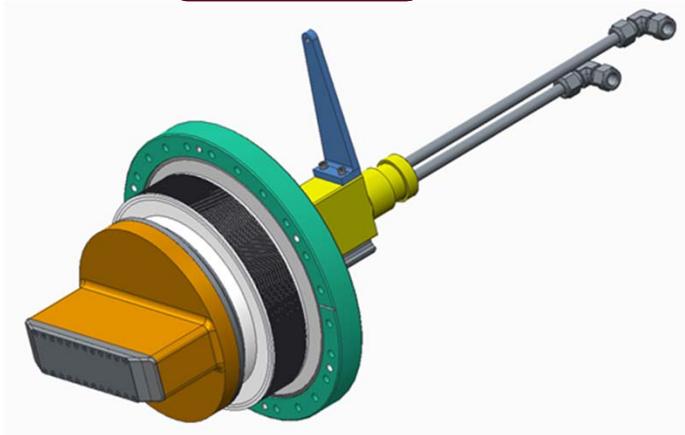
Drive System



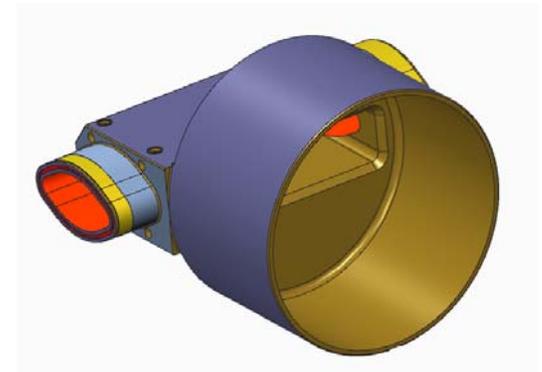
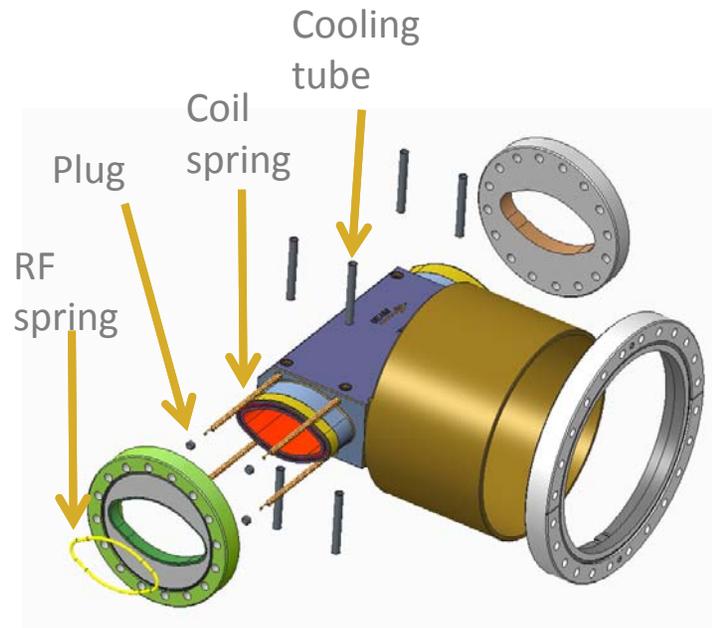
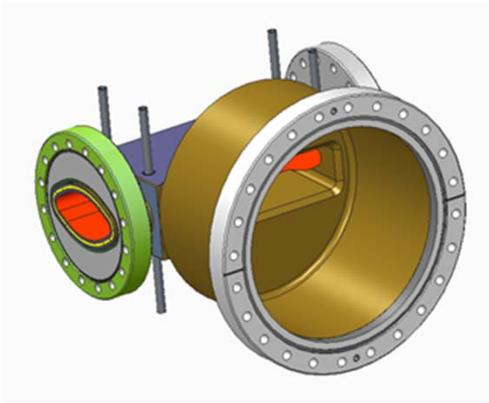
Vacuum Chamber



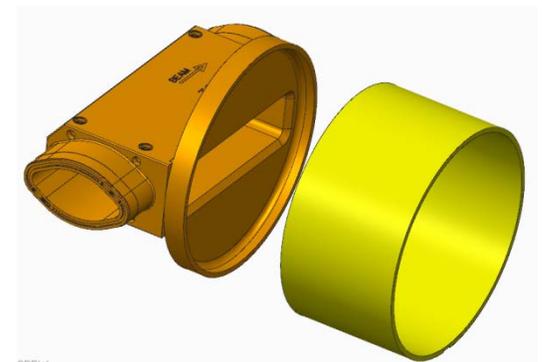
Scraper Blade



# Vacuum Chamber



One body Design

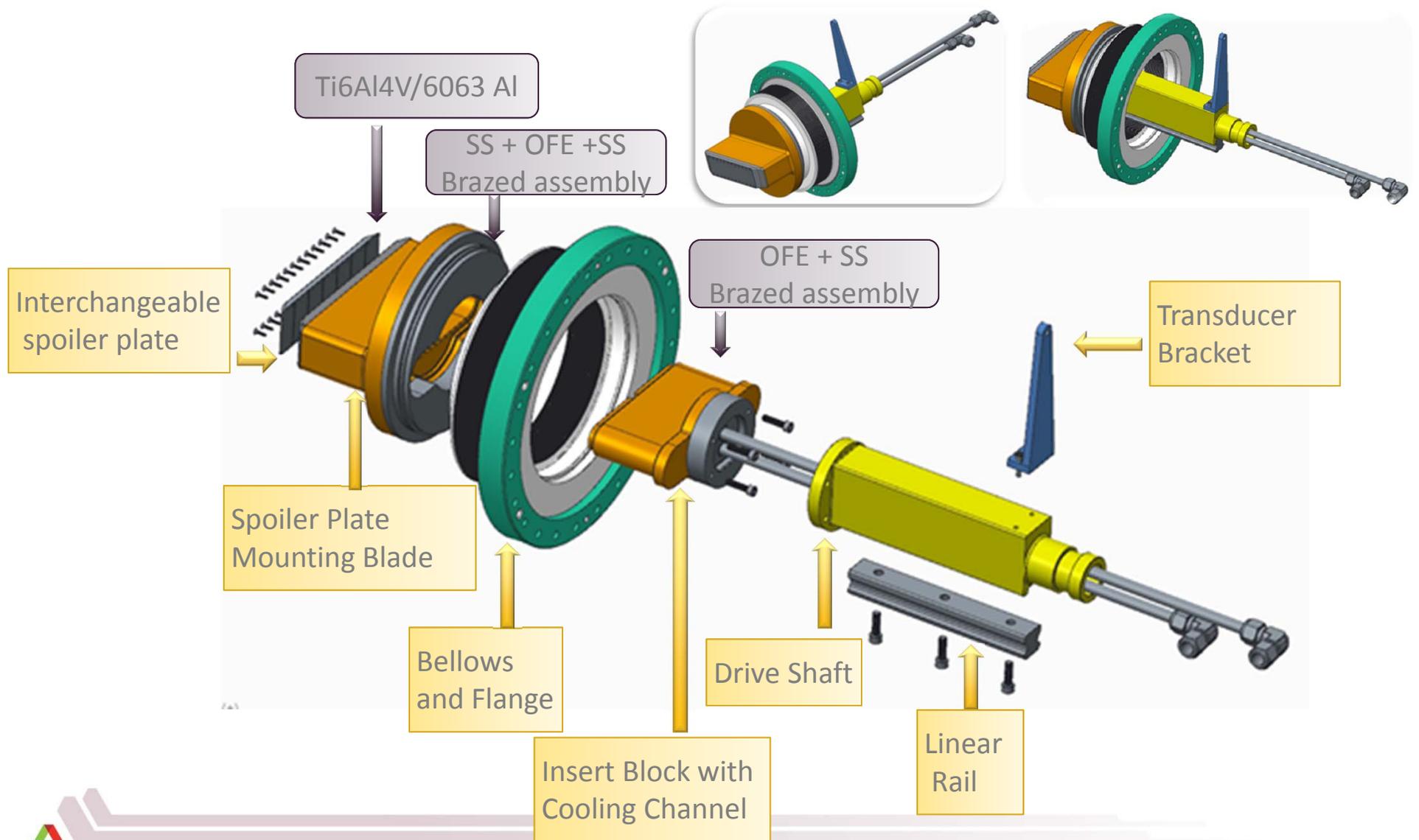


Alternative Design

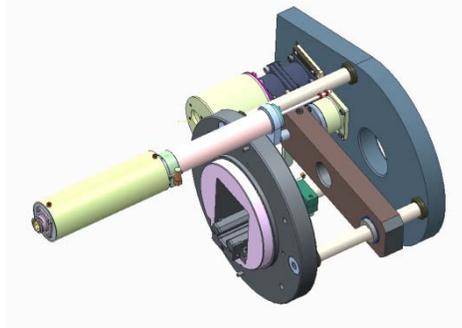
- 316L Stainless steel
- Vacuum chamber profile matches the current SR vacuum chamber
- Cooling channels with coil
- Two options: Single part machined vs. Two parts weldment



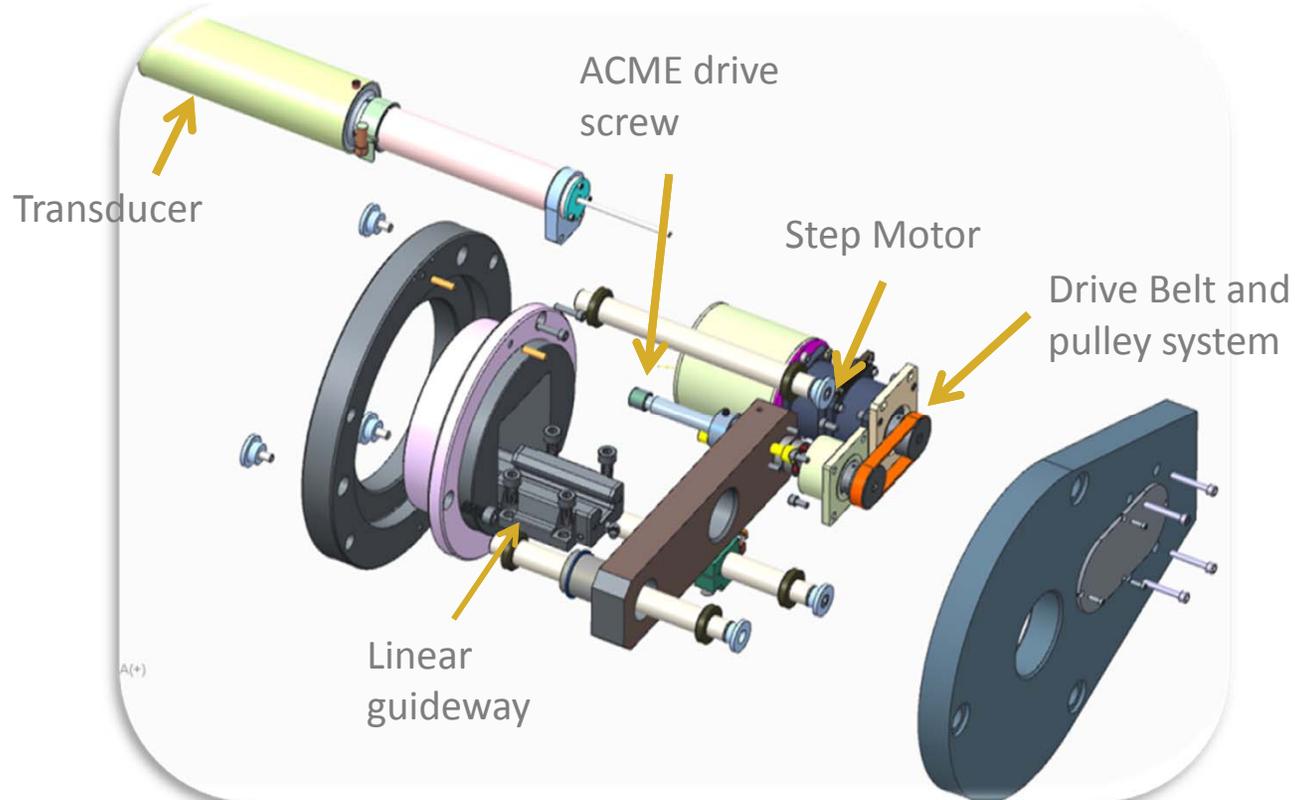
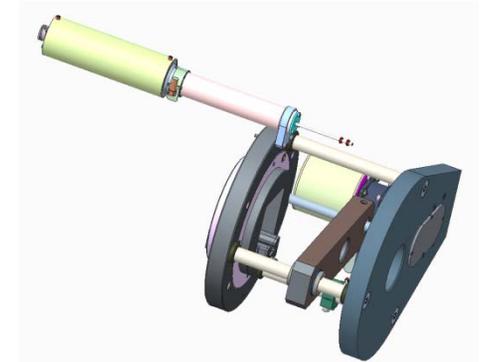
# Scraper Blade



# Drive System

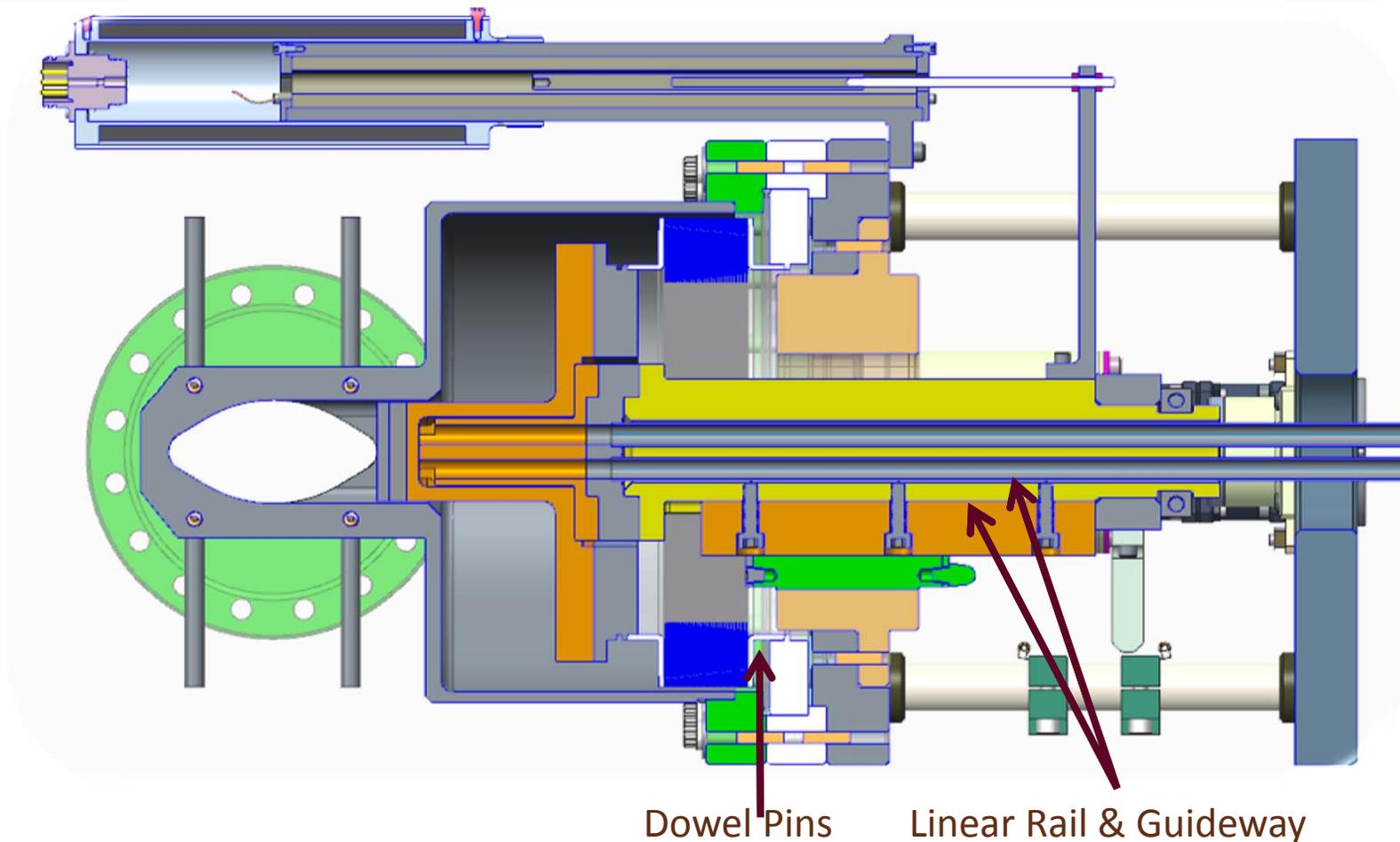


- Belt + ACME screw drive system
- Linear Guide-way



# Precision Control

- Use machining to control critical dimensions
- Guideway precision:  $0/-0.02$  mm and  $2\mu\text{m}$  running parallelism
- Dowel pins for locational precision
- Shim can be used to adjust if necessary

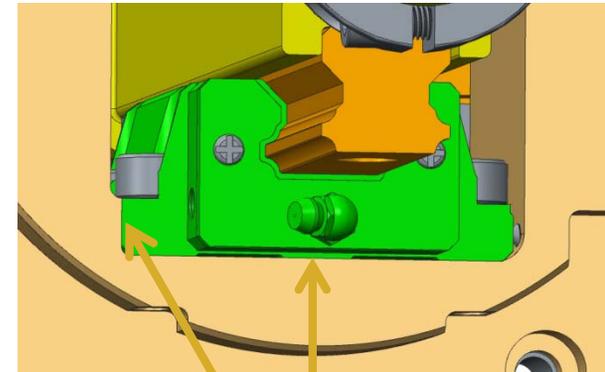


# Precision Control

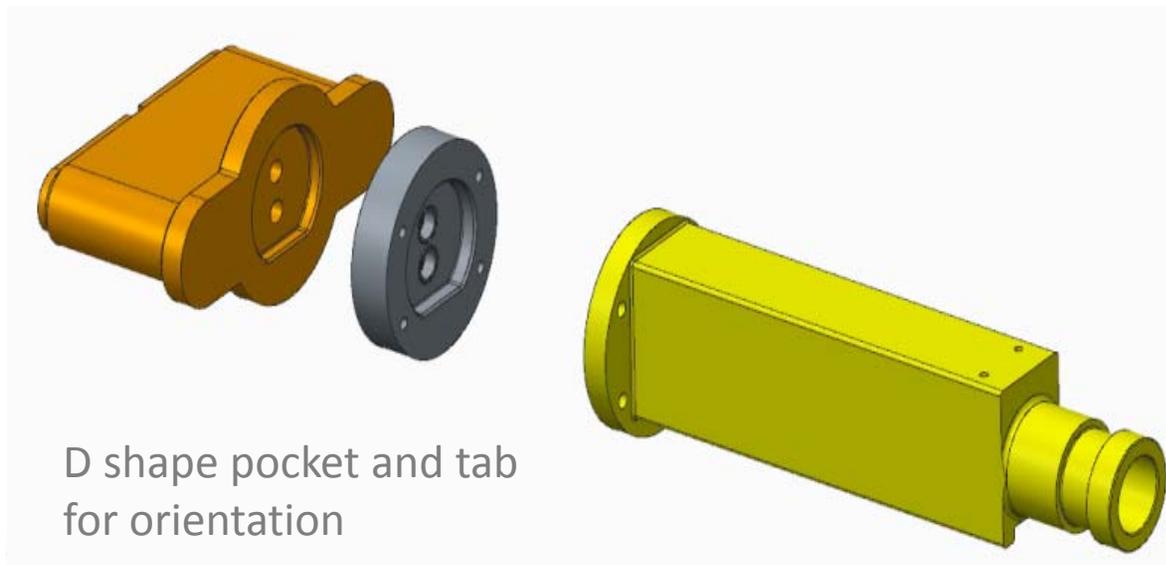
Target:  $0.9 \pm 0.1$  mm gap all-around scraper blade



Gap  $0.9 \text{ mm} \pm 0.1 \text{ mm}$  all around



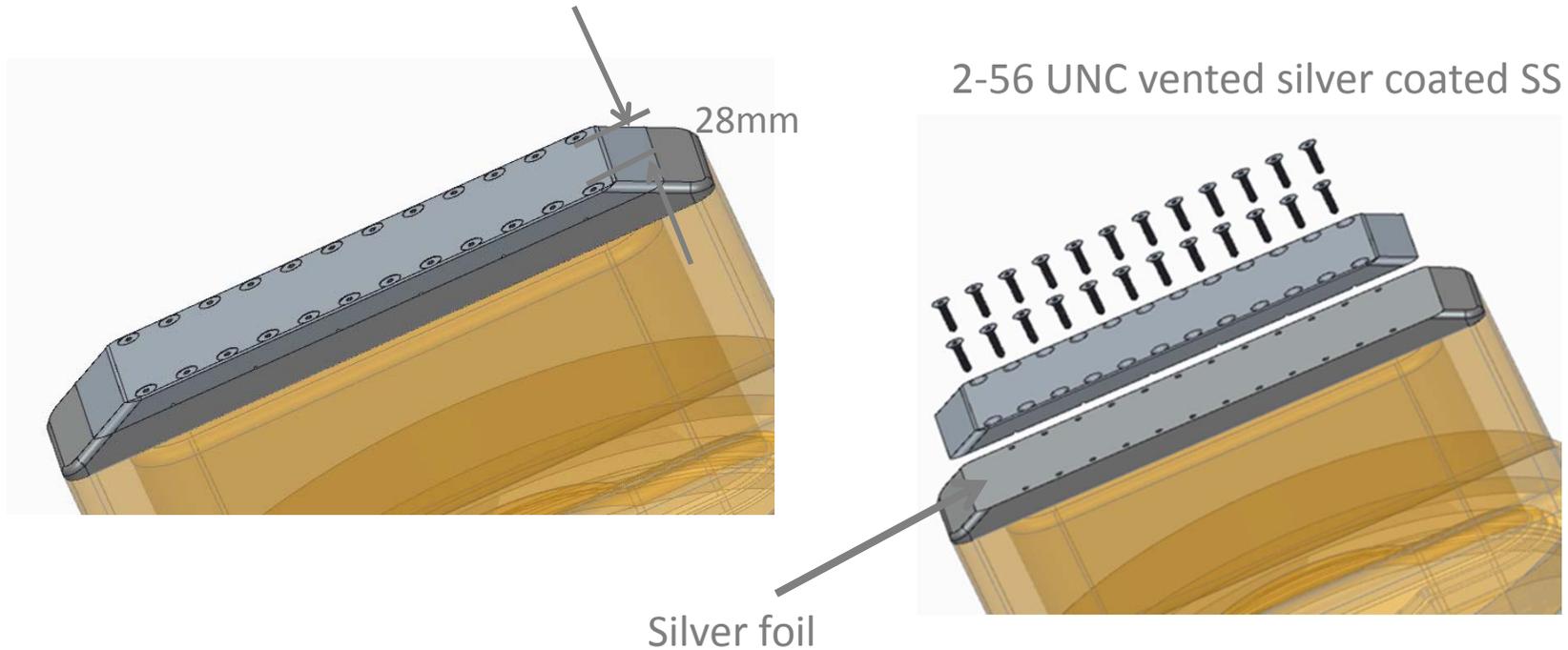
Shimming interface



D shape pocket and tab  
for orientation



# Interface Thermal Conductance



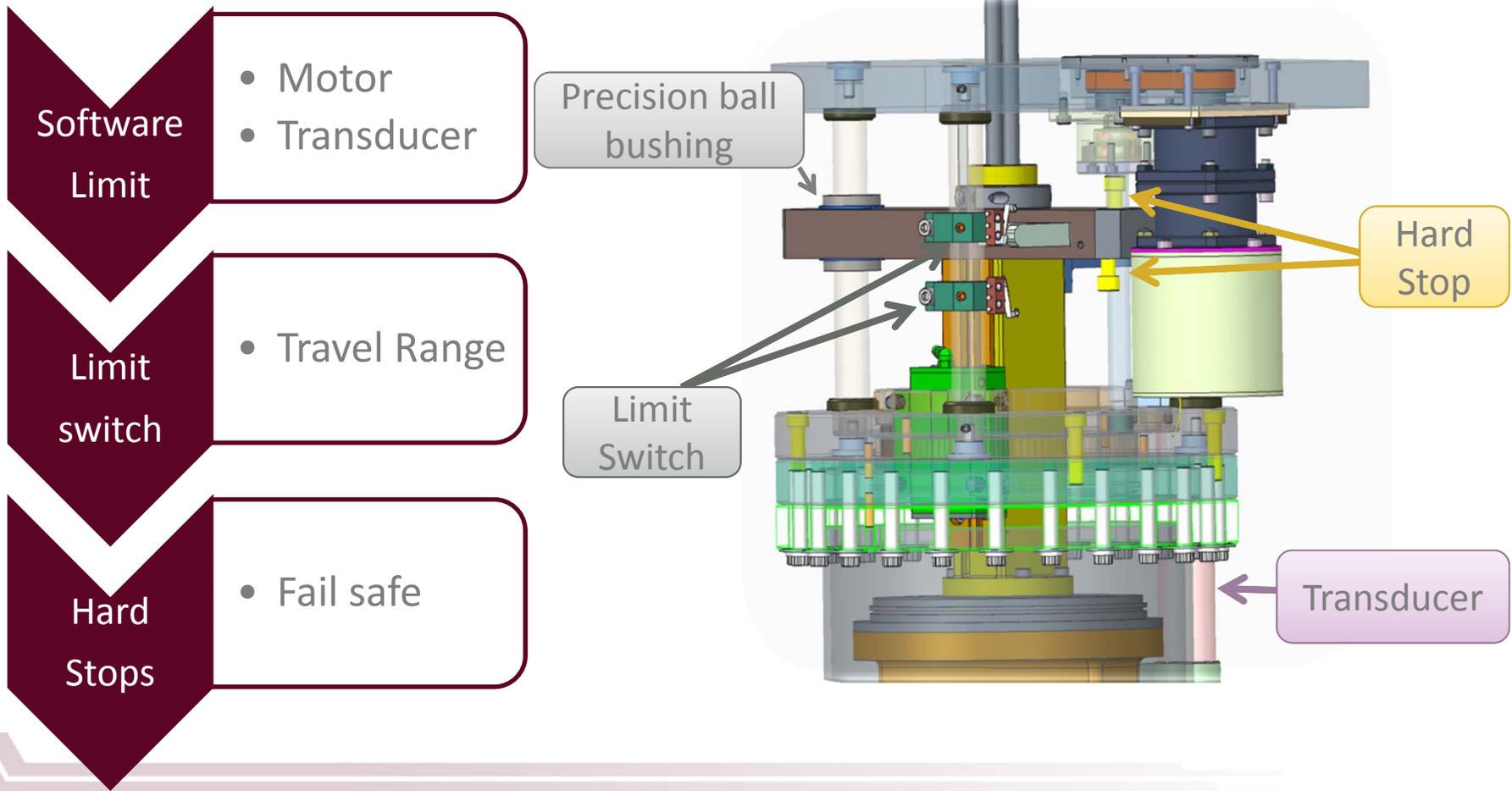
- **Silver foil interface to improve the thermal conductance, 0.002" maximum thickness**
- **24 x #2-56 screws provide 2000lbs clamping force**



# Motion and Control

Travel Range: -10mm to 42.4 mm

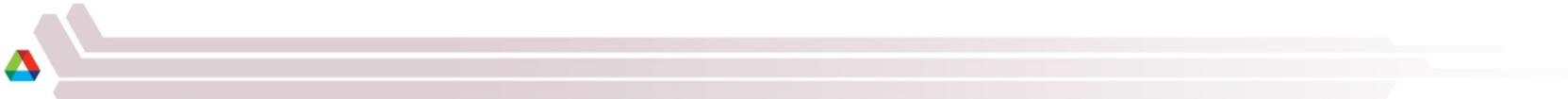
3 Levels of motion control



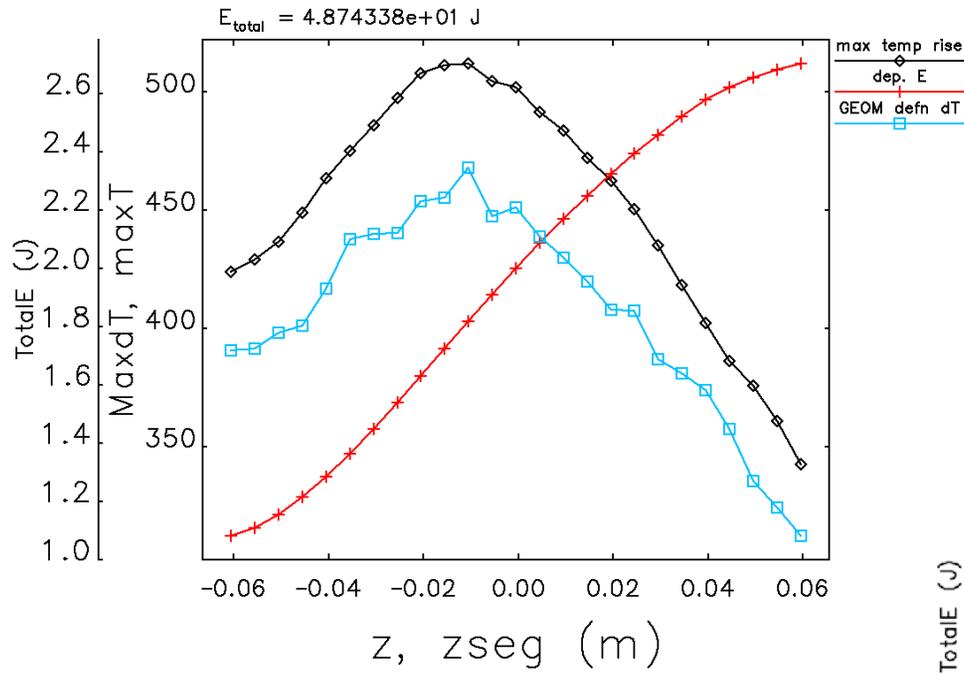


# Finite Element Thermal Analysis

- **Finite Element Analysis**
  - Beam Dump
  - RF
  - Synchrotron Thermal

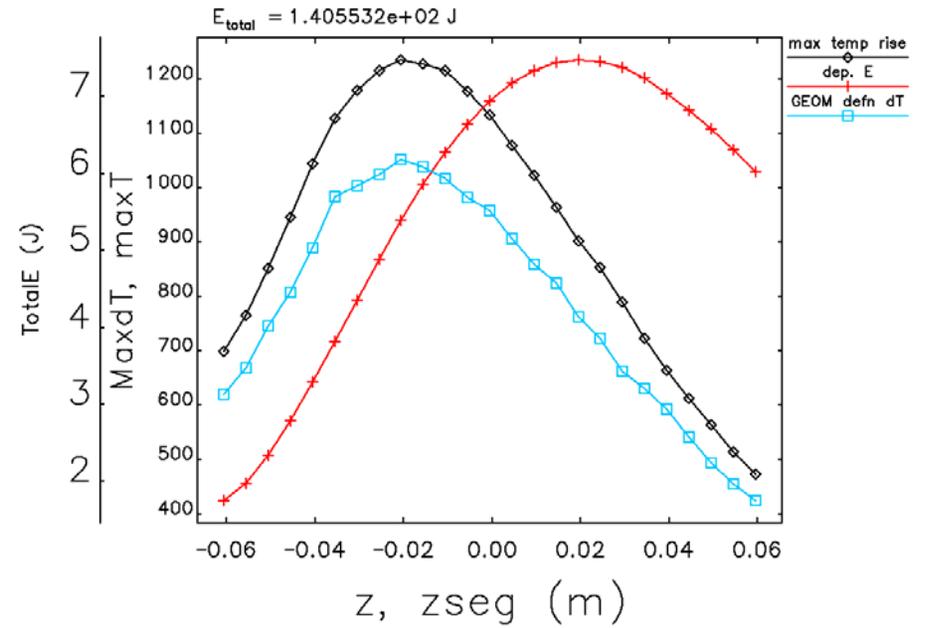


# Beam Dump

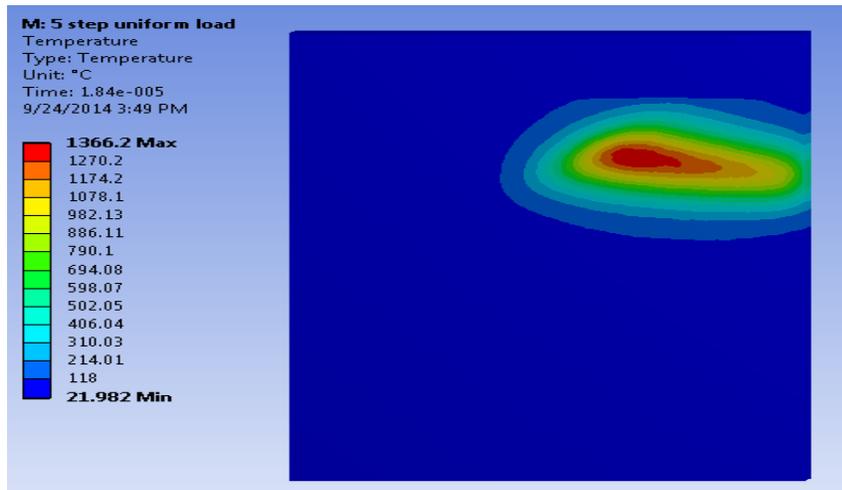
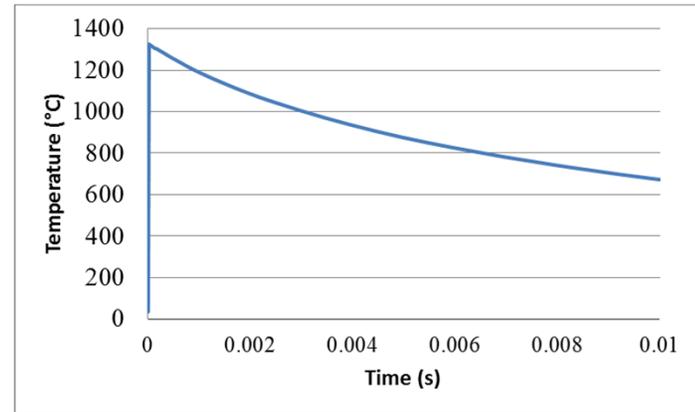
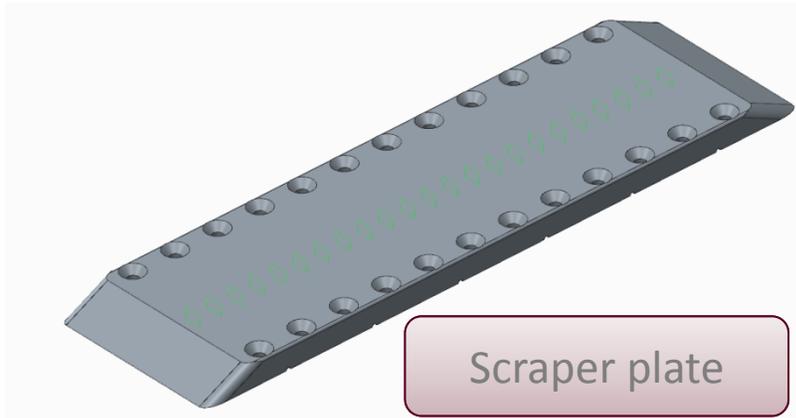


Al Alloy

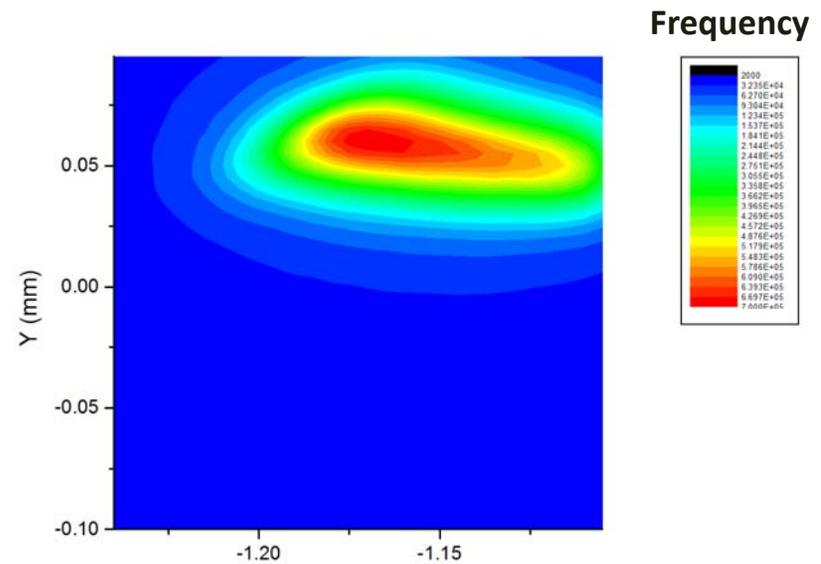
Ti Alloy



# Beam Dump



Temperature at cross-section

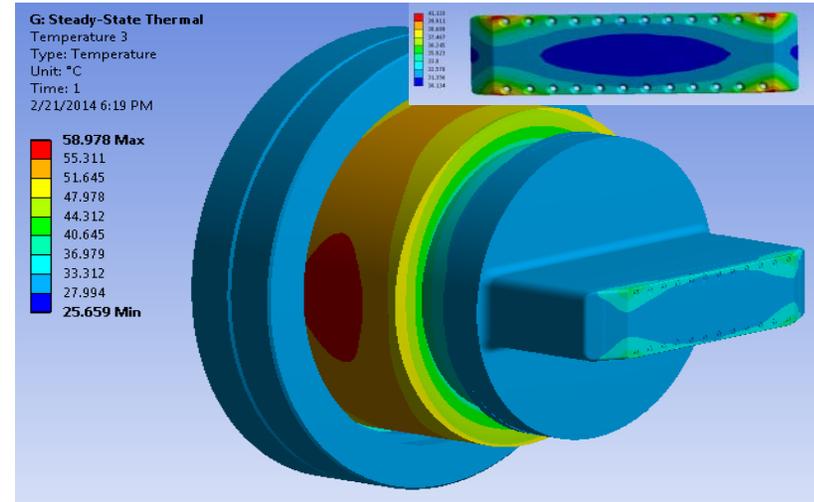
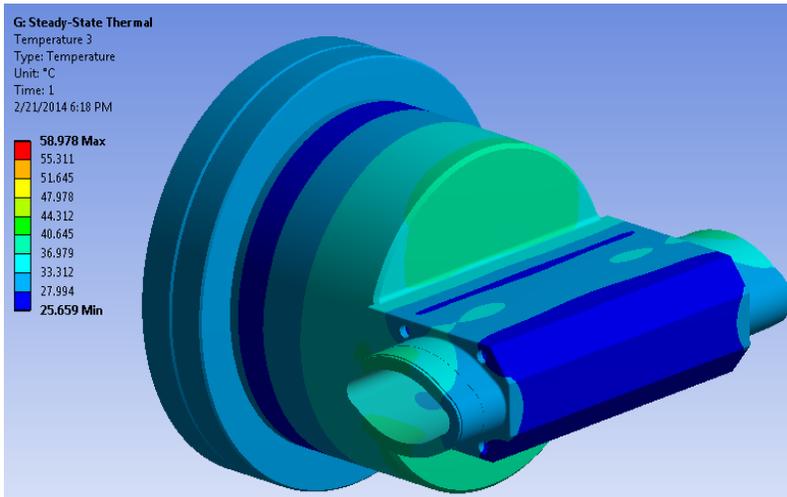
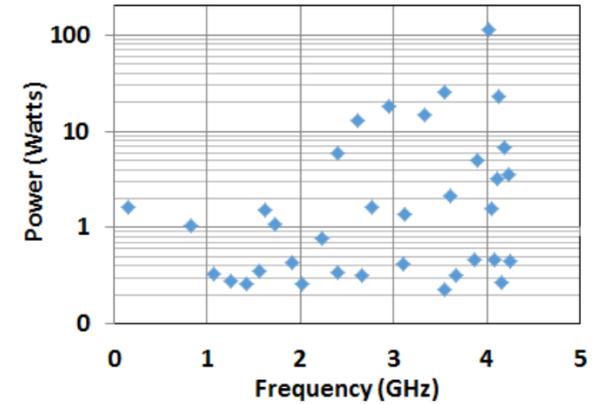
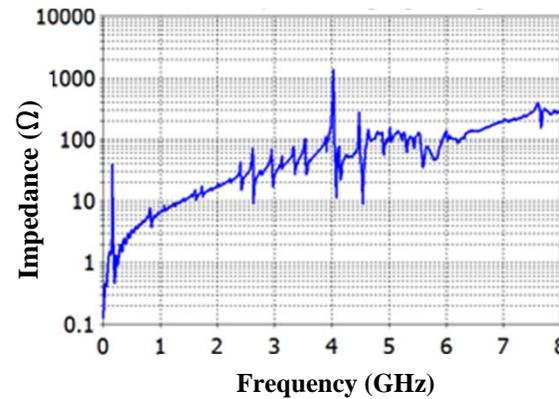


Particle distribution



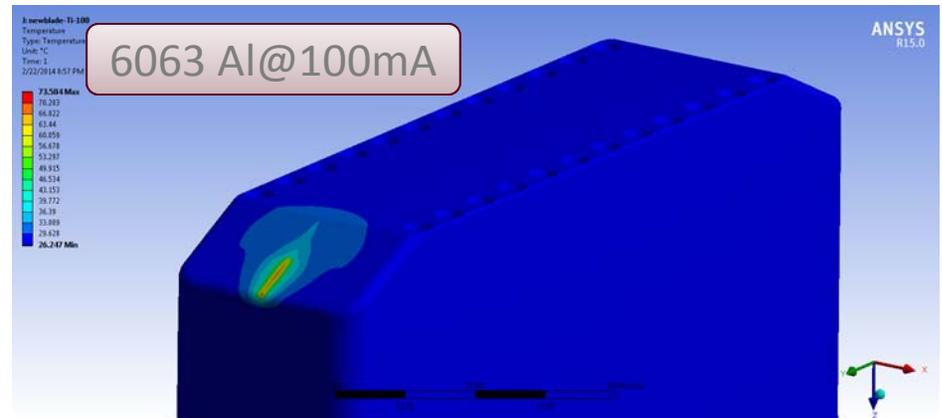
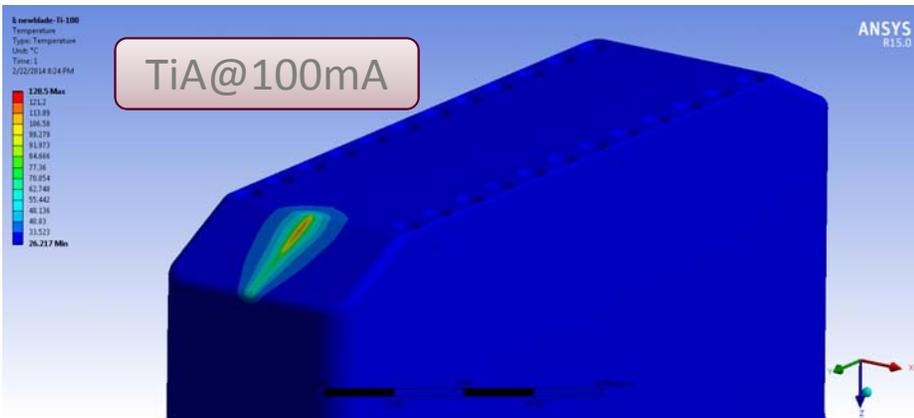
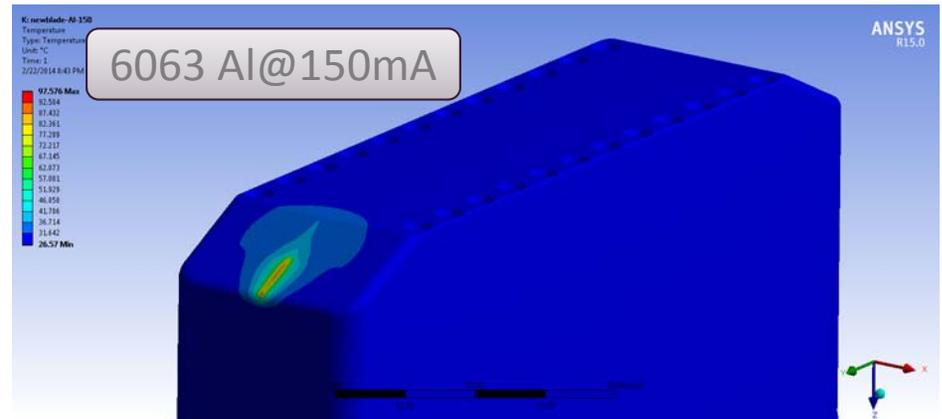
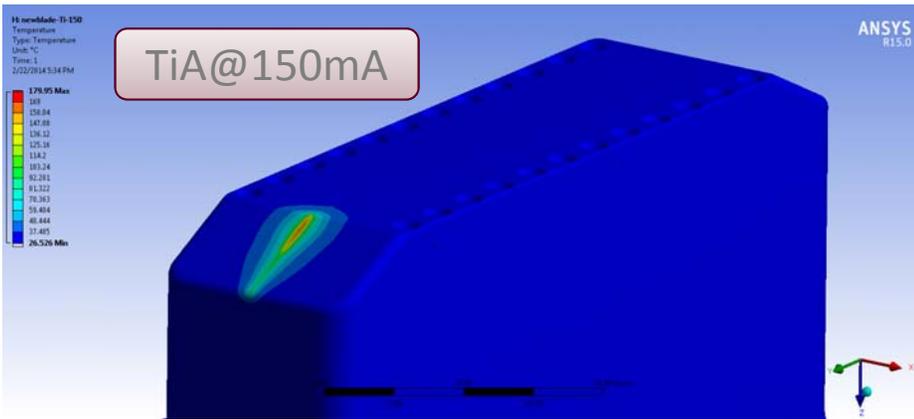
# RF

- On blade:  
70 W@150 mA
- On vacuum chamber:  
180 W@150 mA
- Cooling coefficient:  
15,000 W/m<sup>2</sup>·K

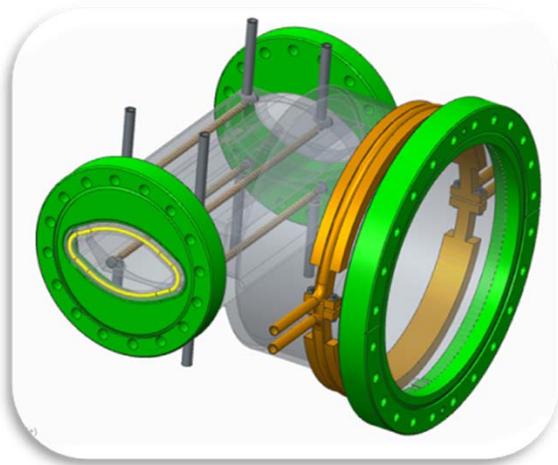


# Synchrotron Radiation

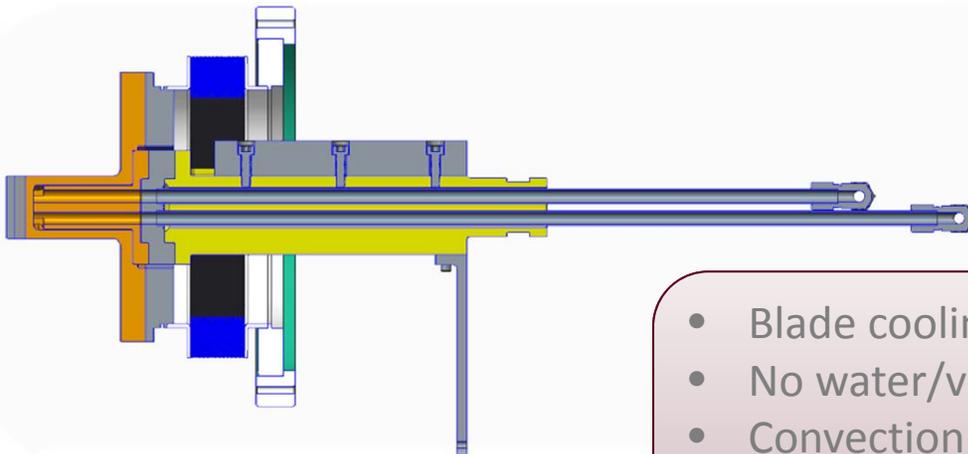
- Total Heat load: **20.325 W@150mA**, **13.55 W@100mA**



# Cooling



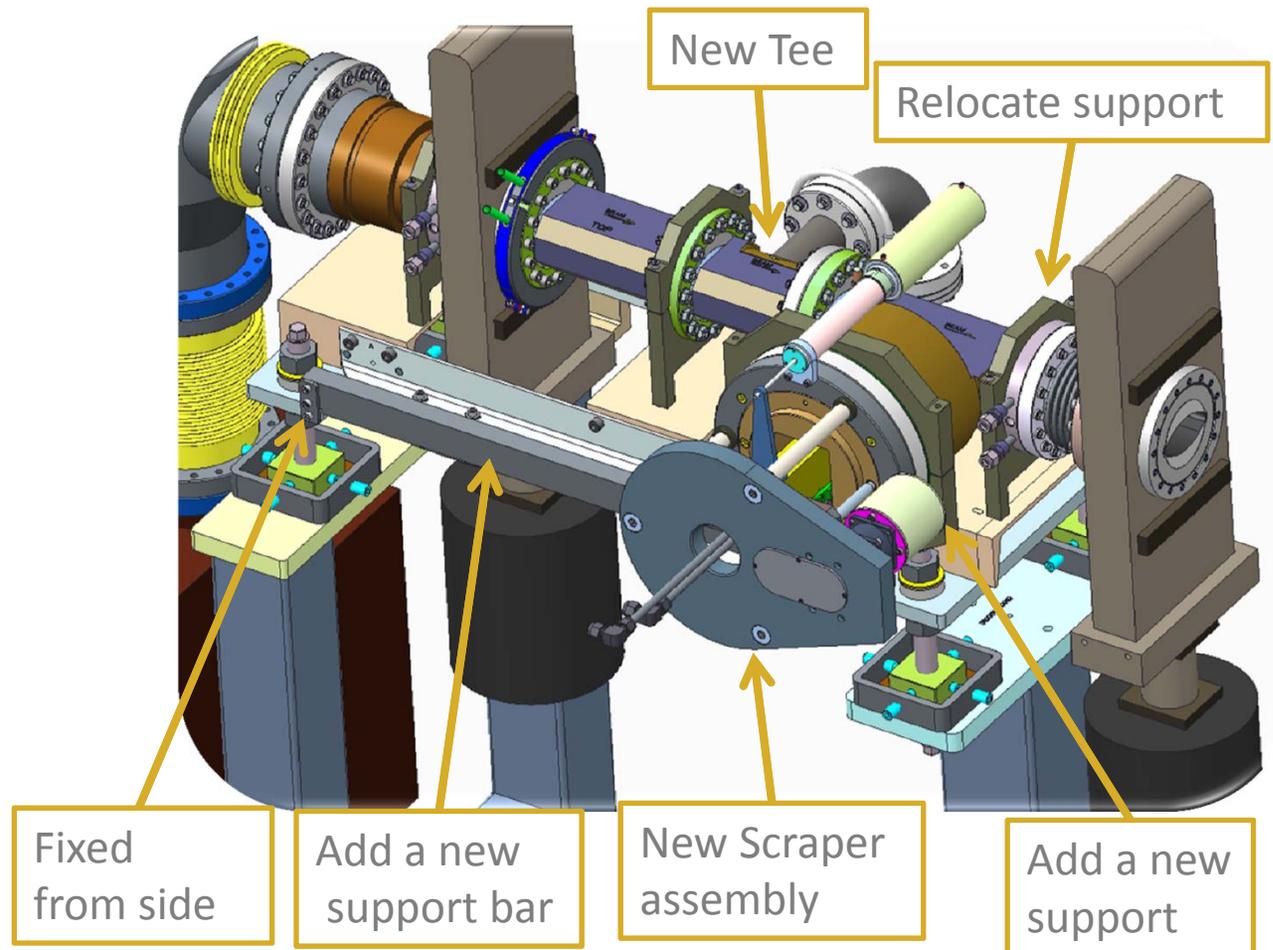
- Vacuum chamber cooling system
- 4 cooling channels along the chamber to provide critical cooling for the beam pipe:  $24,000 \text{ W/m}^2\cdot\text{K}@2.4\text{GPM}$
- Additional cooling to the body:  $11,000 \text{ W/m}^2\cdot\text{K}@1.2\text{GPM}$



- Blade cooling system
- No water/vacuum joints
- Convection coefficient:
  - $13,000 \text{ W/m}^2\cdot\text{K}@2.4 \text{ GPM}@bottom$
  - $3,700 \text{ W/m}^2\cdot\text{K}@2.4 \text{ GPM}@straight sections$



# Installation



- Changes to the current storage ring assembly are minimum
- Use a new shorter Tee for vacuum pump
- Build a new scraper replacement spool
- Modify supports



# Summary

- The design include three major components, vacuum chamber, scraper blade, and drive system;
- The design can achieve functional and precision requirements
- The design can achieve thermal requirements at 100mA, but can only achieve the thermal requirements at 100mA or at 150mA without interfering electron beam



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