PS Impedance Model Status

SPS Injection Losses Review: 30/11/17

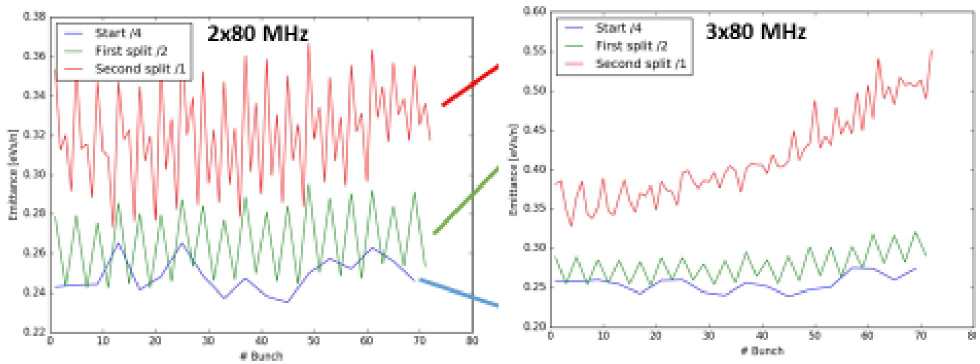
B. Popovic

Acknowledgements: C. Vollinger, A. Lasheen, H. Damerau

Overview: Sources of Emittance Blow Up

From A. Lasheen Talk: PS beam injected into SPS : measurements & simulations

Emittance blow-up during splittings



- Longitudinal emittance evaluated at different steps of the splittings
- Measured emittance blow-up during the double splittings for an intensity of $4 \times 2.0 \times 10^{11}$ ppb
- Longitudinal emittance blow-up along the batch during splitting with 3x80 MHz cavity gaps open
- The future Multi Harmonic Feedback should be a sufficient mitigation. Nevertheless, the sources of emittance blow-up should be minimized as much as possible (i.e. other impedance sources)

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1. Large impedances at low frequencies
   - Coupled bunch instabilities
   - Especially the cavities
2. Broadband impedance sources
   - Loss of Landau damping
3. Large impedance sources at high frequencies
   - Microwave instabilities

Introduction to PS Impedance Model

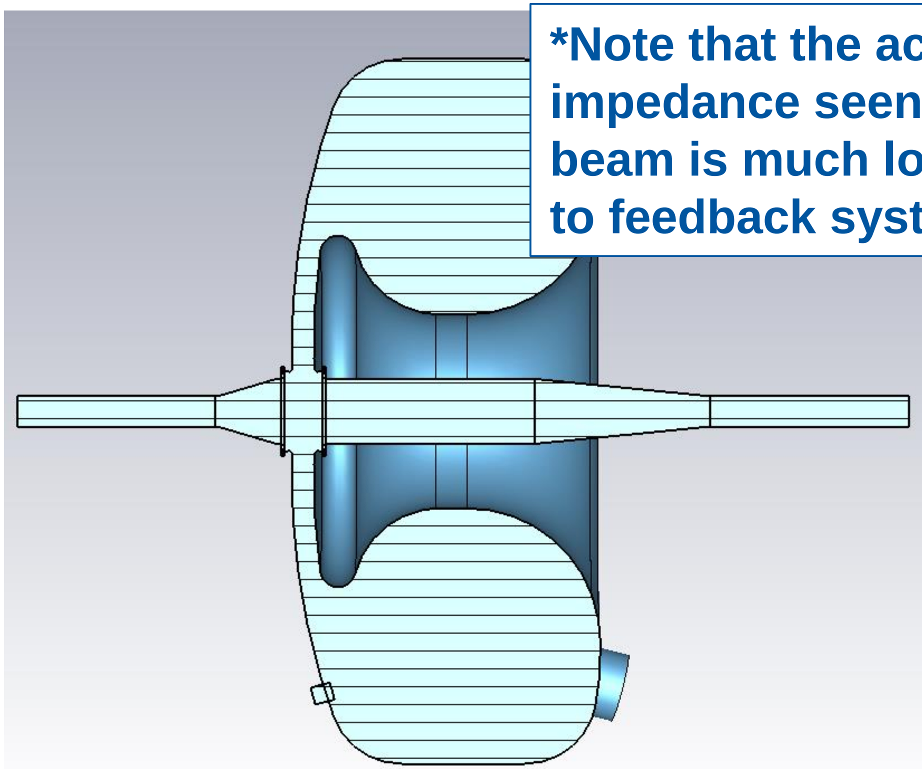
- Necessary to continue to build & maintain a longitudinal impedance model of the PS machine
- Build CST models for Wakefield & Eigenmode simulations
  - From CATIA files (when available), otherwise 2D drawings
- Confirm Wakefield & Eigenmode simulations with measurement (when possible and required)
  - RF measurements
  - Beam based impedance measurements
- Provide confirmed results for BLonD code
- Identify objects whose impedance can be reduced

Overview of Model Elements so Far

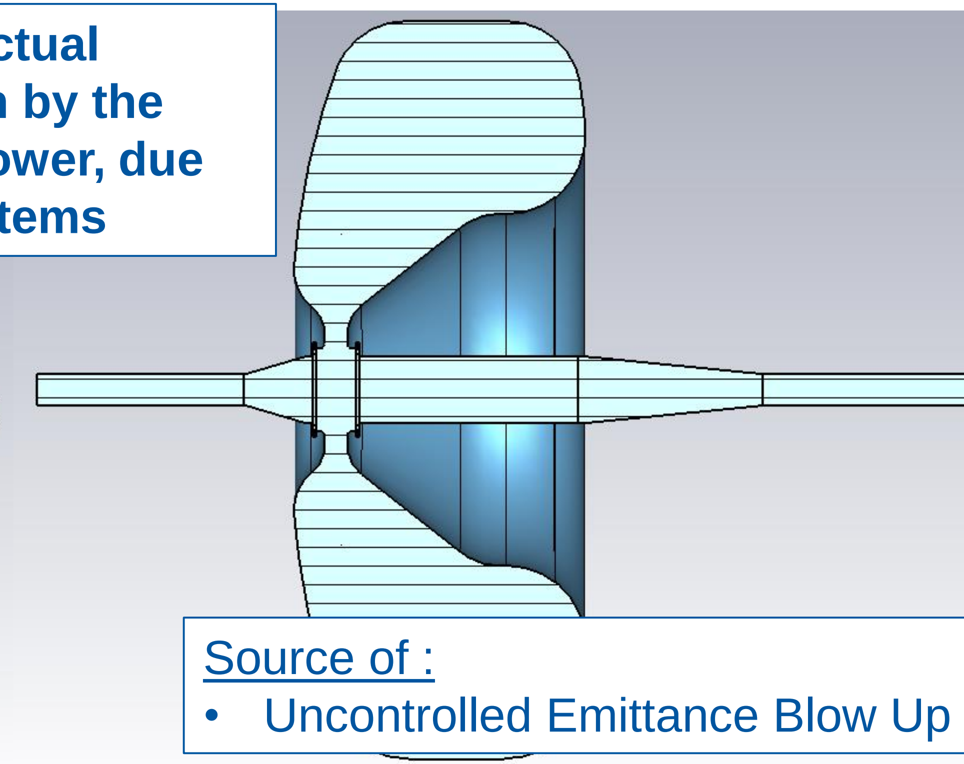
- 40 & 80 MHz Cavities
  - CST Models of the **bare** cavities created
    - No feedback system effects
    - No HOM couplers or frequency tuners
- 10 MHz Cavity Model developed by G. Favia
- Transmission Line Kickers
  - CST Models of the KFA13, KFA21, KFA45, KFA71 & KFA79 created
    - Compare longitudinal impedances to previous CST models (S. Persichelli, Transverse)
    - Ferrite material from previous CST models (S. Persichelli, Transverse)
- Baseline Magnet Unit Section
  - CST models of the most common pumping manifold & bellows types
- UHV Gate Valves
  - 10 Valves in the PS
  - CST model (including internal mechanisms) created
    - Model confirmed via EM measurements
- PS Dump
  - CST model of the two identical dumps currently in the machine
  - Working with EN-STI on the replacement dump design to reduce its impedance*

*IWG #14 : https://indico.cern.ch/event/671318/

40/80 MHz **Bare*** Cavities: CST Models



*Note that the actual impedance seen by the beam is much lower, due to feedback systems



Source of :

- Uncontrolled Emittance Blow Up

40 MHz cavity	Eigenmode	Measured
Res. Freq	39.03 MHz	40.06 MHz
Q	25,795	13,352
R/Q	33.7	-

80 MHz cavity	Eigenmode	Measured
Res. Freq	79.96 MHz	80.11 MHz
Q	37,246	19,300
R/Q	57.4	-

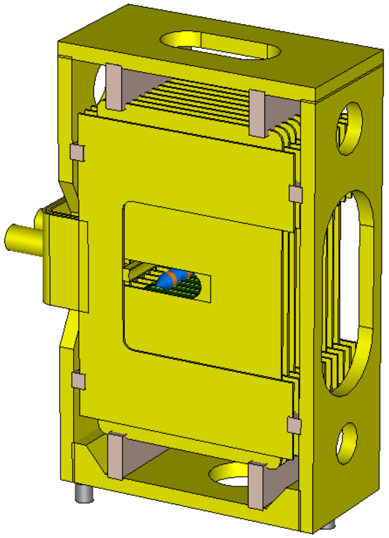
40/80 MHz Cavities: Model Summary

- **Impedance performance is dominated by feedback systems**
  - **Necessary to incorporate the effect of feedback systems**
  - **CST Model is just one small part of the model**
- Options proposed for dealing with the feedback
  - Model cavity together with feedback loops as was done with the PS 10 MHz cavity (presented by H. Damerau today)
  - Obtain impedance of 80 MHz cavity using measurements of gap voltage instead of modeling the feedback loops
- Geometry is starting point for the model
- Shape of mechanical short is included
  - Separate model of the mechanical short has been analyzed
- Does not include tuners that adjust frequency
- Does not include HOM dampers
  - Explore how to implement this in Wakefield Simulations

Transmission Line Kickers

- CST models built from old drawings and CATIA
- KFA13, 21, 71 & 79 all contain identical modules
  - KFA13 & KFA21 are identical units
- Important step would be to measure at least one module to benchmark simulations
- 8C11 Ferrite
  - Using ABP provided definition*
  - Ferrite sample to be characterized

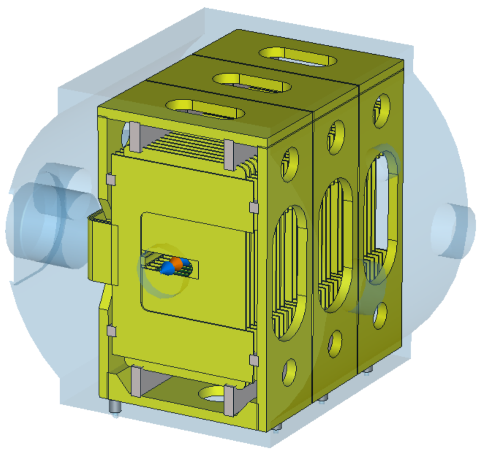
Module



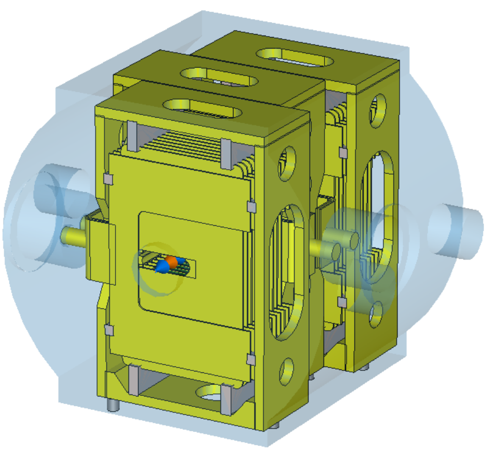
*https://impedance.web.cern.ch/impedance/PS.htm

Transmission Line Kicker Models

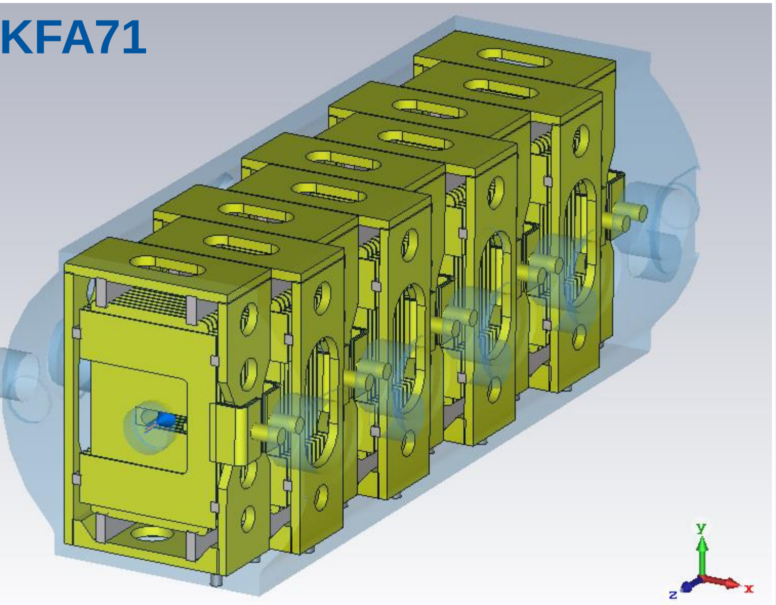
KFA13 & KFA21

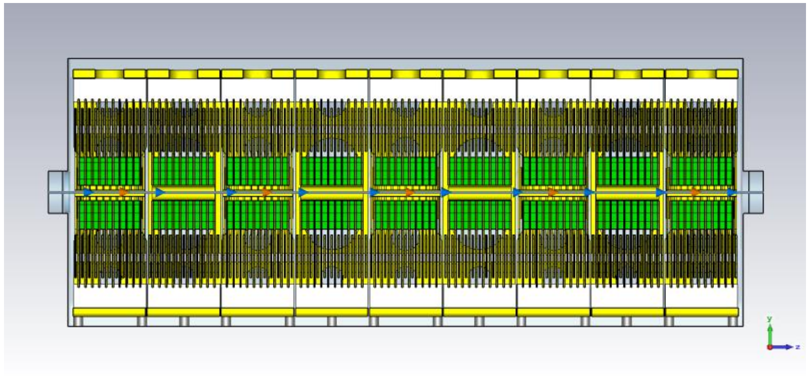


KFA79

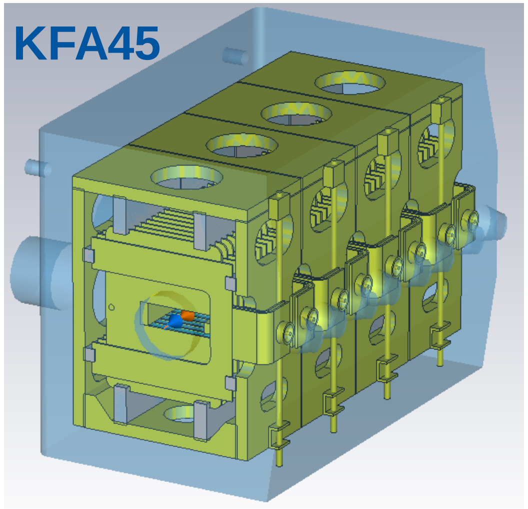


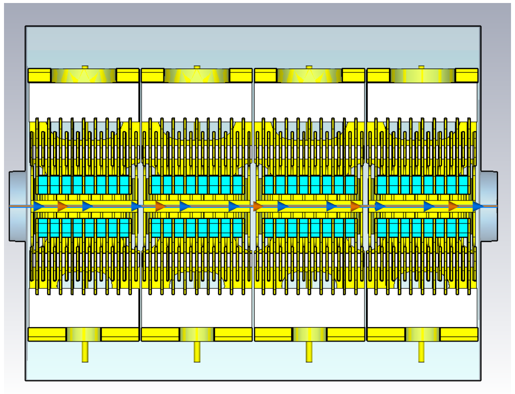
KFA71





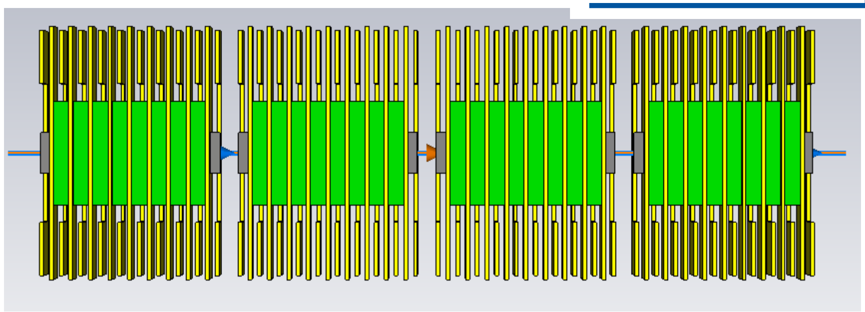
KFA45

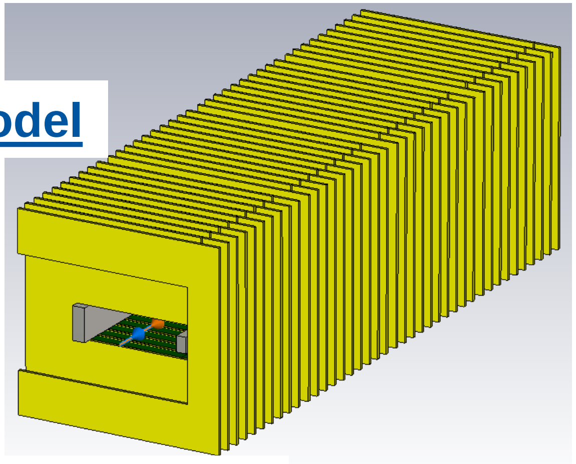




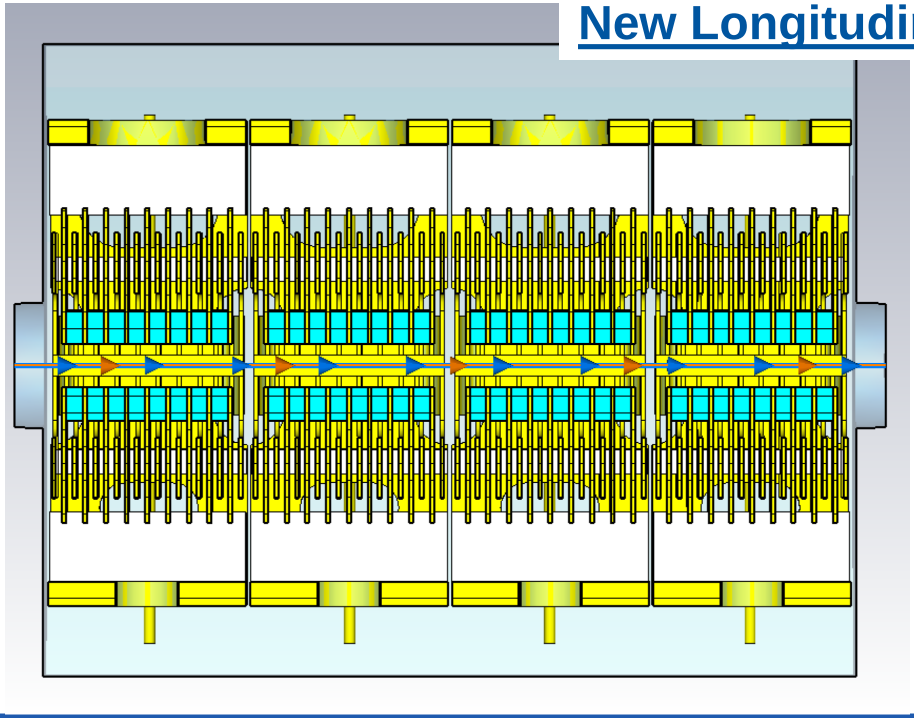
KFA45: Models

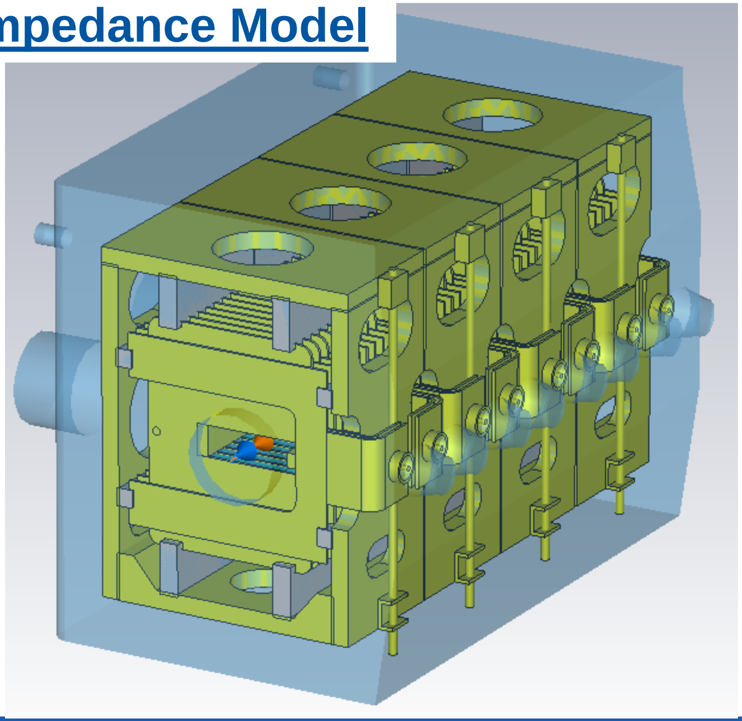
Previous Impedance Model



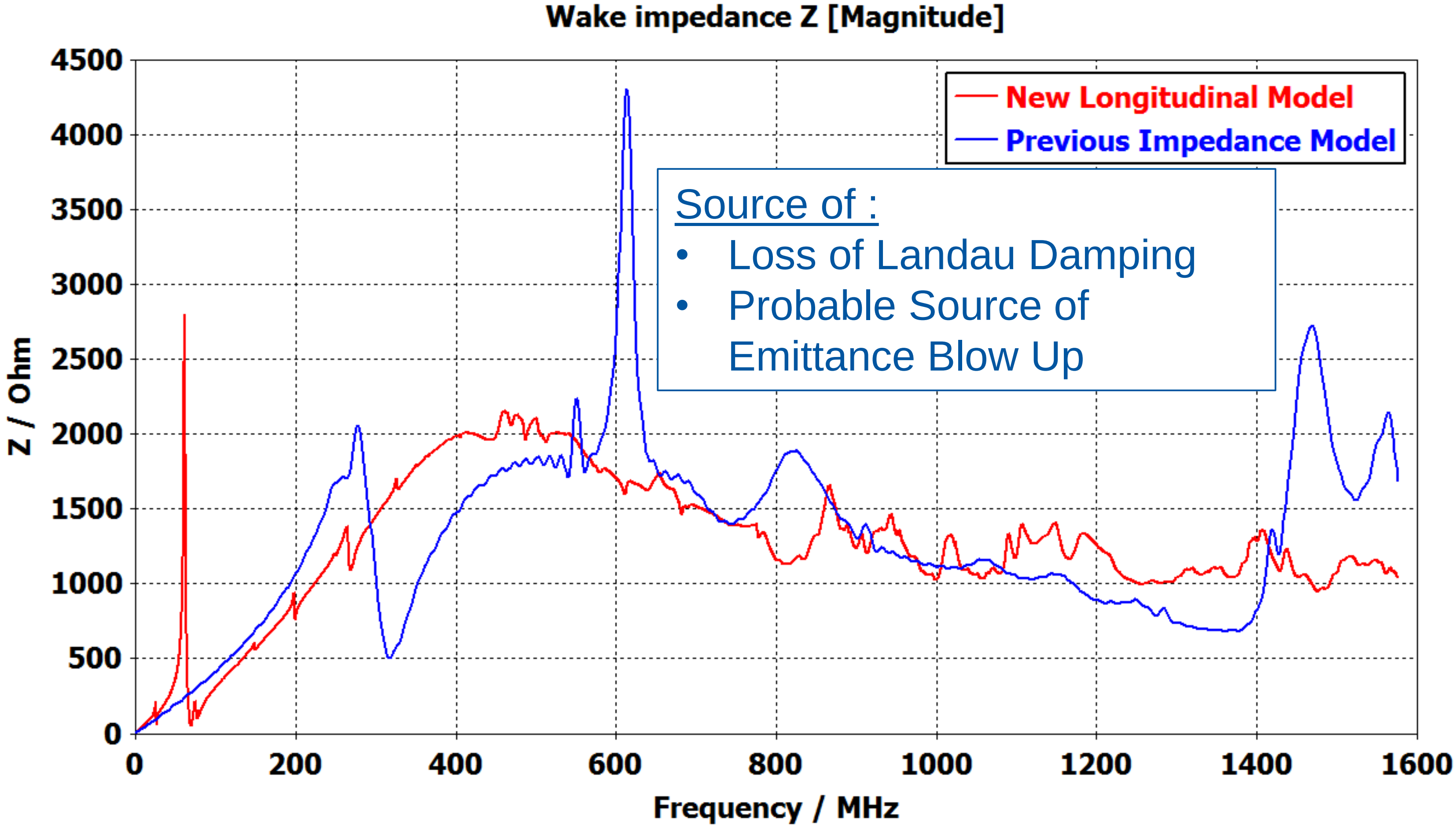


New Longitudinal Impedance Model





KFA45: Comparing Wakefield Simulation Results



Source of :

- Loss of Landau Damping
- Probable Source of Emittance Blow Up

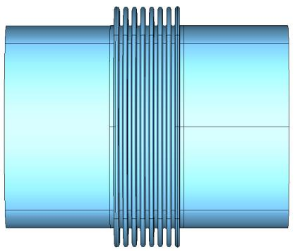
Vacuum Elements of MU Sections (100 Total)

Upstream Assembly Types (99):
- Standard (67)
- Enlarged (25)
- 'Exotic' Variations (7)
  - Wide, special, etc.

Pumping Manifold Slot (99):
- Pickup Assembly
  - Standard (40)
  - Large (12)
- Group Pumping Coupling (8)
- Actuator of SEM Grid Detector (3)
- Cover/Empty (36)

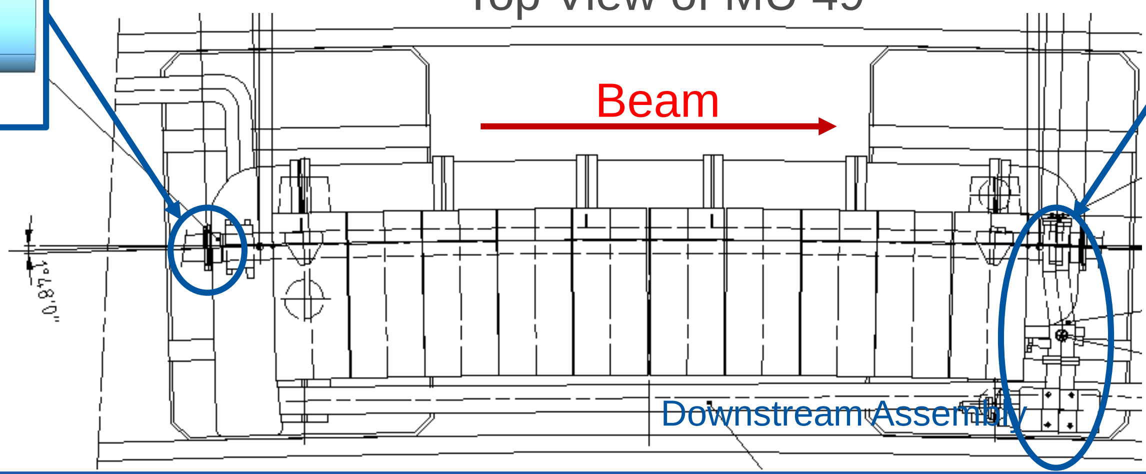
Pumping Manifold Types (100):
- Internal (29) & External (37)
- Enlarged Internal (10) & External (8)
- Remainder (16) are 'exotic' variations
  - Wide, Narrow etc.

Standard Upstream Assembly (67)

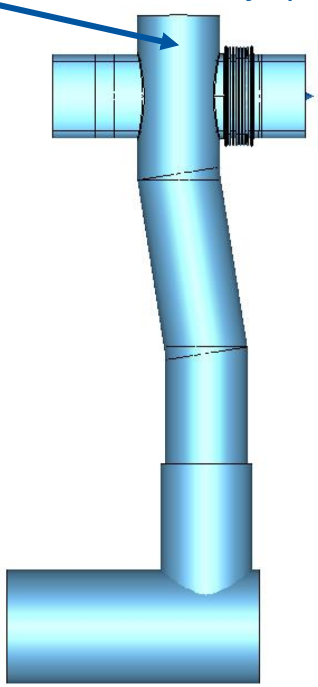


Equipment Owner to Confirm/Provide:
- Accuracy of models (number of bellow convolutions, etc.)
- Complete/detailed models (integration model only)
- Number of elements (vacuum report)

Top View of MU 49

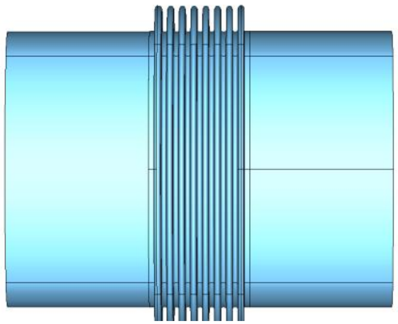


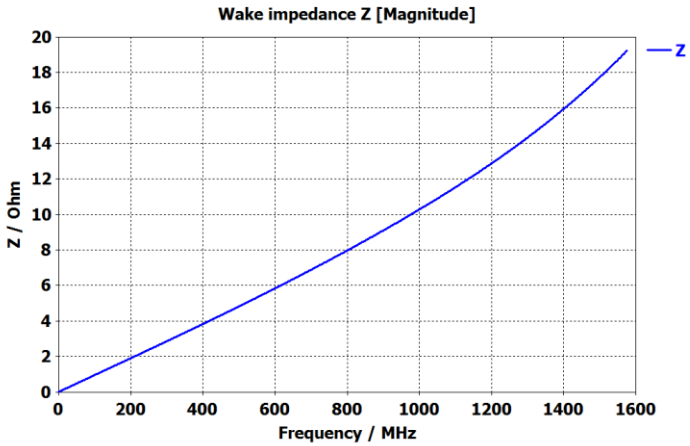
Pumping Manifold: Internal Downstream Assy. (29)



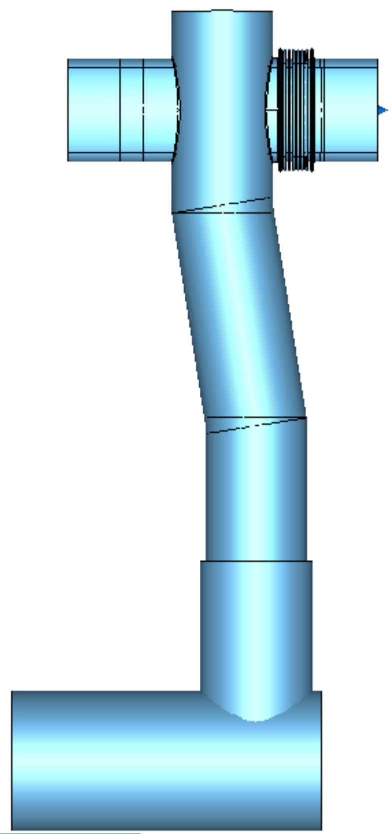
Impedance of Baseline MU Section

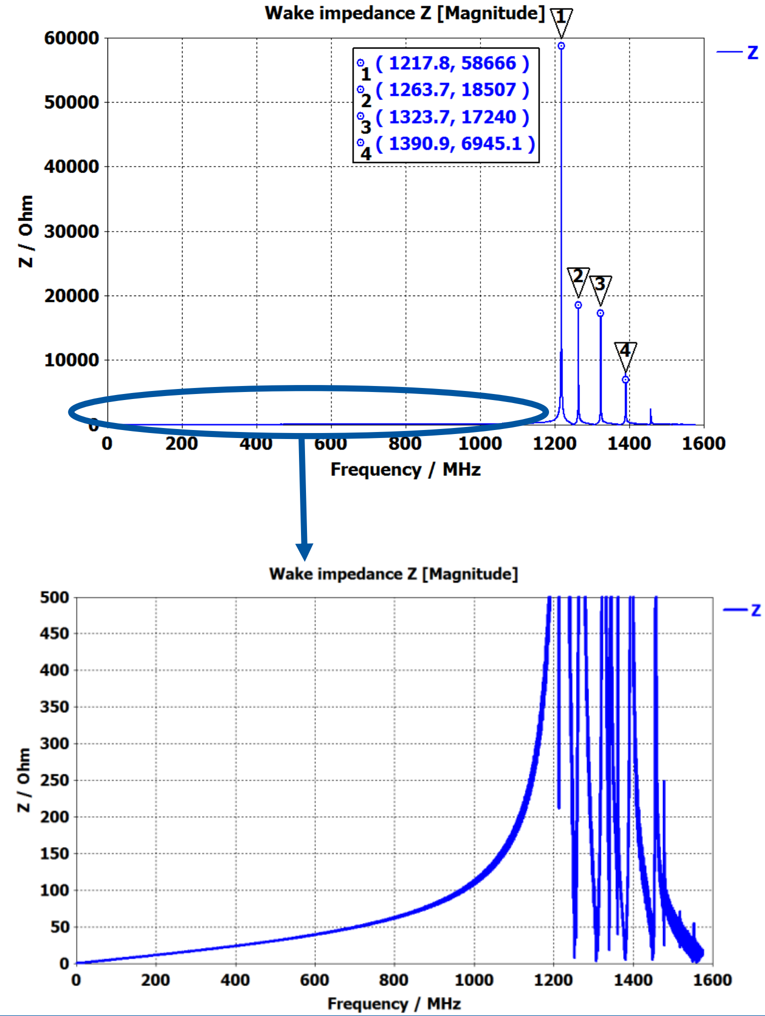
Standard Upstream Assembly (67)





Standard Internal Downstream Assy. (29)





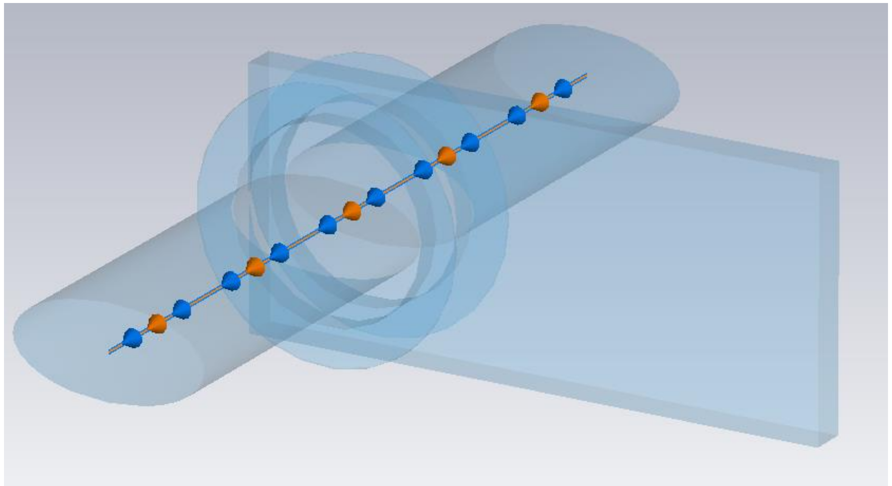
Sources of :

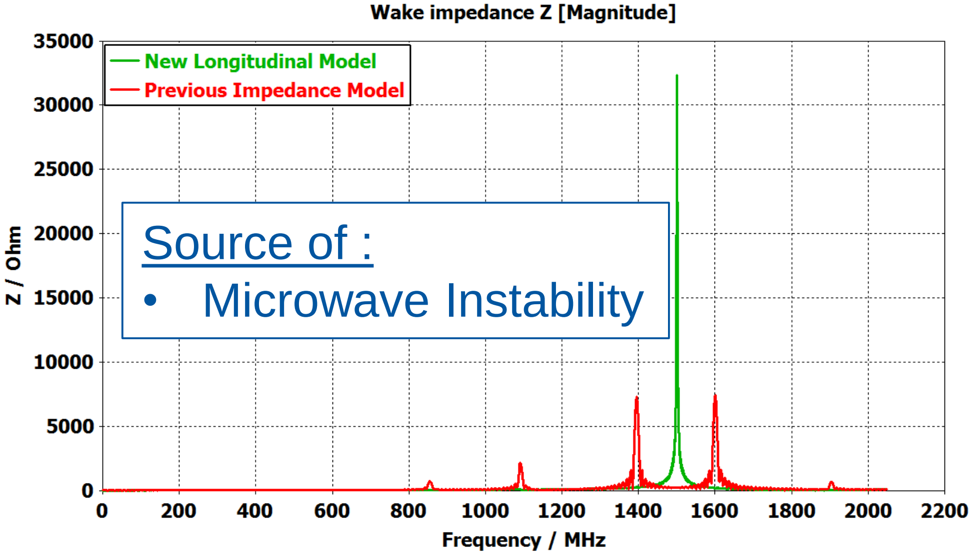
- Loss of Landau Damping
- Possible Emittance Blow Up
- Microwave Instability

UHV Gate Valve: CST Models

- 10 Valves total
- No internal model available
  - Not included in previous model
  - Proprietary
  - Drawn using datasheet
  - Measurements necessary

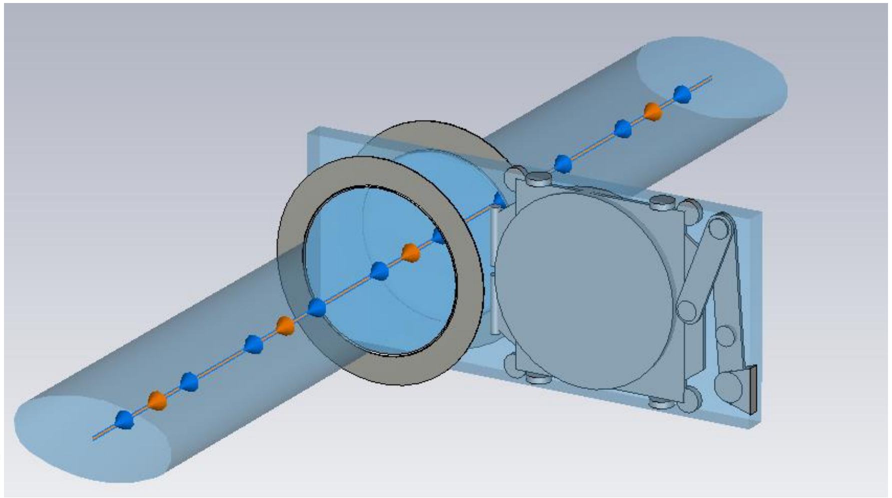
Previous Impedance Model





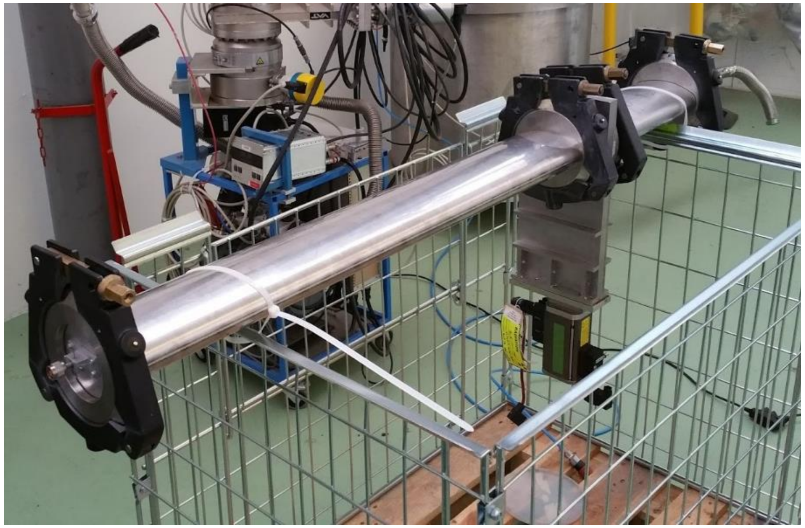
Source of :
- Microwave Instability

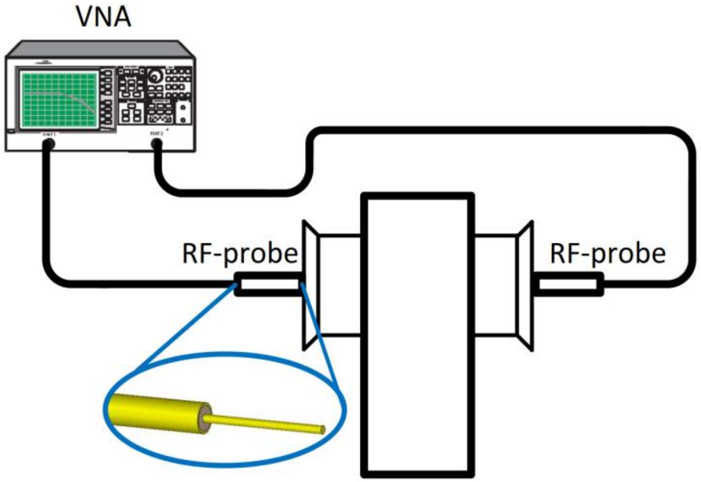
New Longitudinal Impedance Model



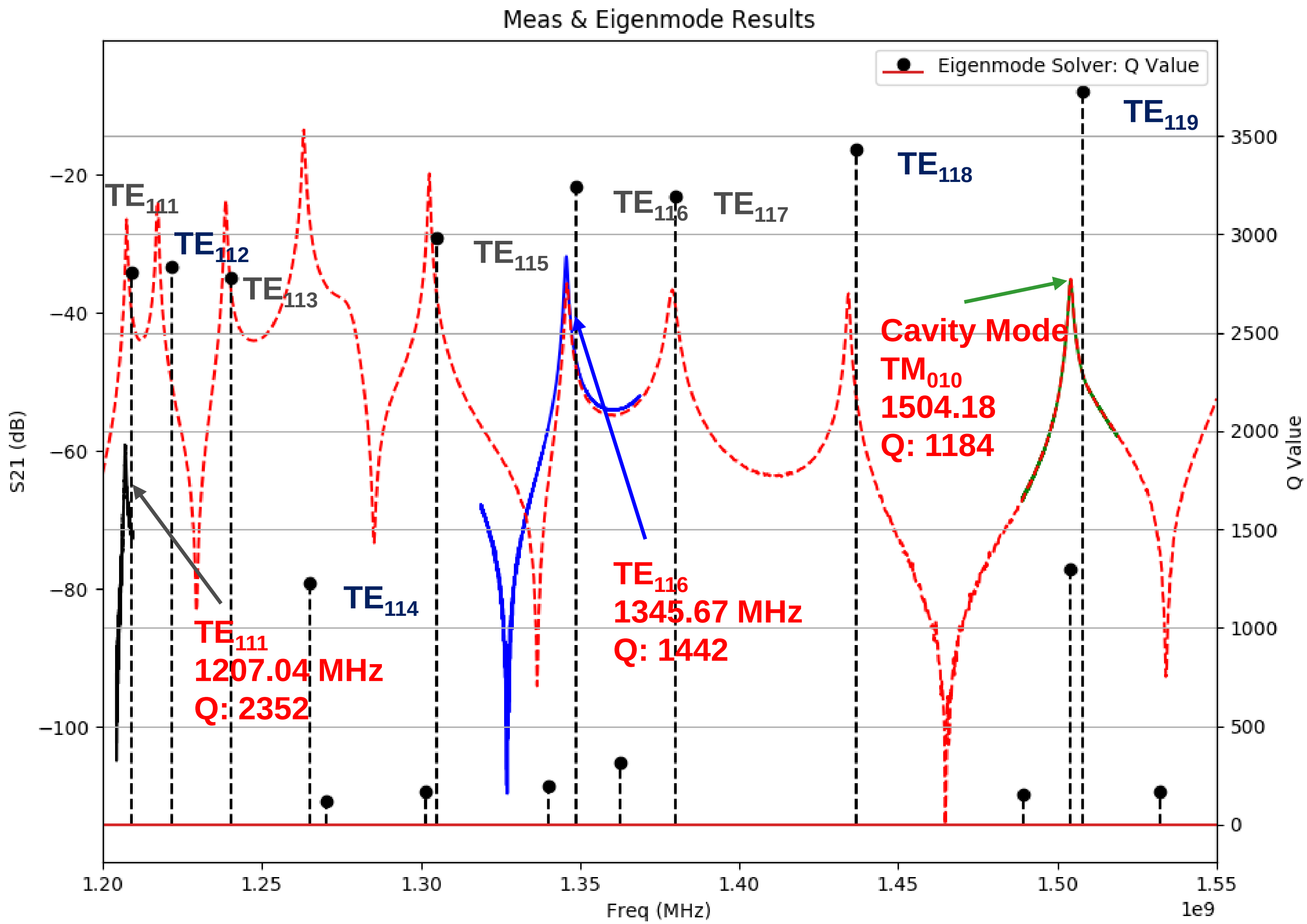
UHV Gate Valve: Measurement Setup

- Measured using probe method
- Setup closed at both ends
  - Traps travelling wave modes
  - TE_{11p}
- Investigated resonances at
  - 1.2 GHz, 1.34 GHz & 1.5 GHz





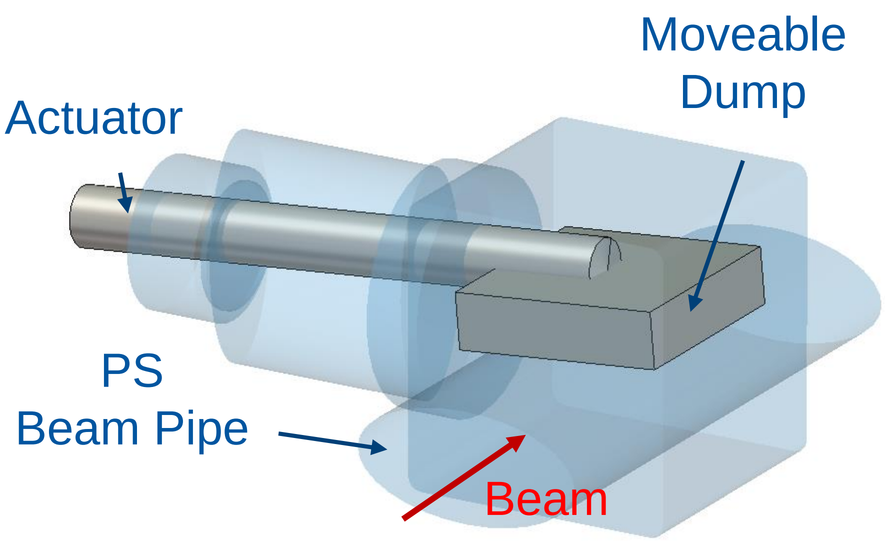
UHV Gate Valve: Comparing Measurement & Simulation Results

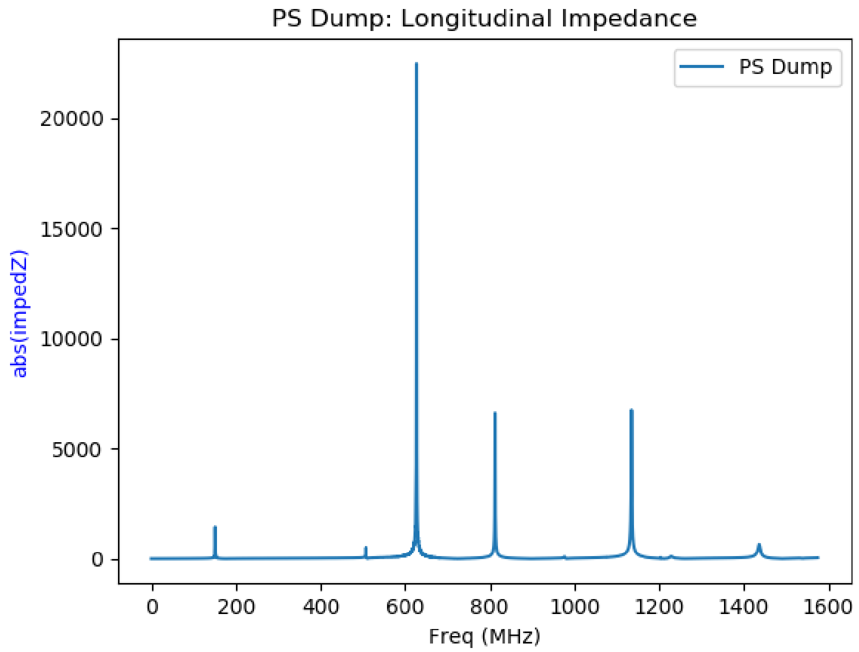


Preliminary PS Dump Model

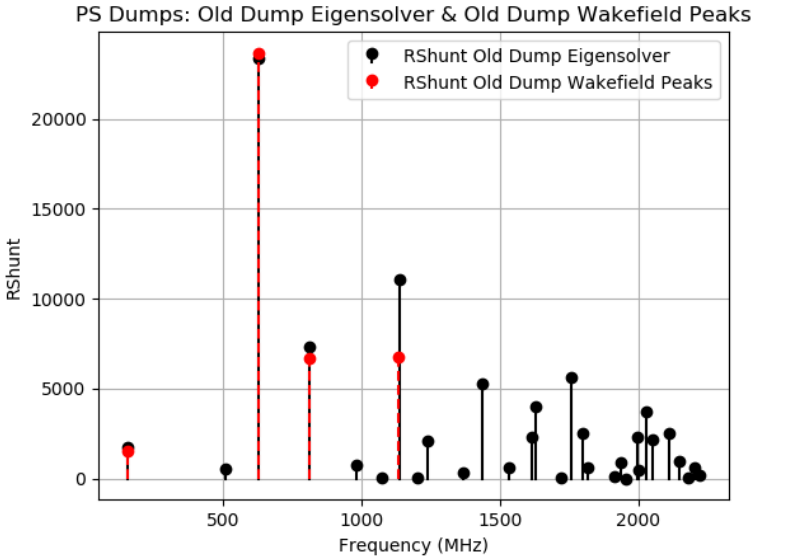
- Installed in straight sections 47 & 48
- Main problem modes are ‘Coax Cavity’-like
- Simplified moveable dump

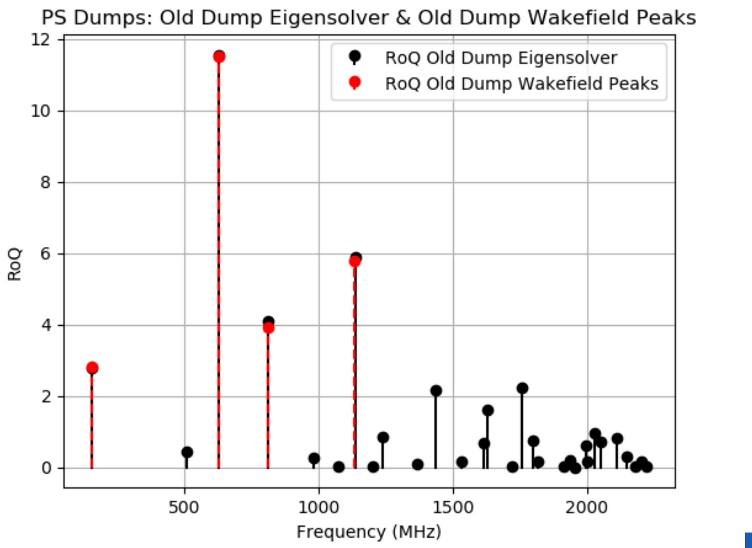
Source of :
- Emittance Blow Up
- Microwave Instability



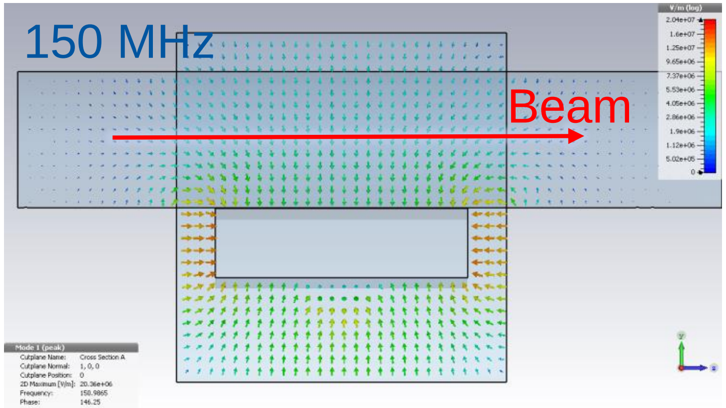


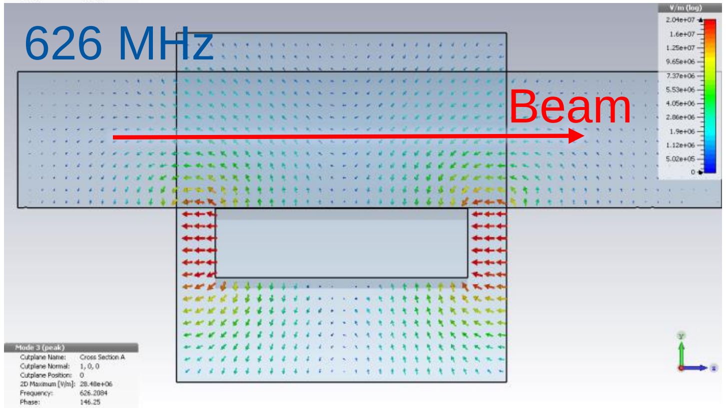
‘Coax Cavity’-like Modes

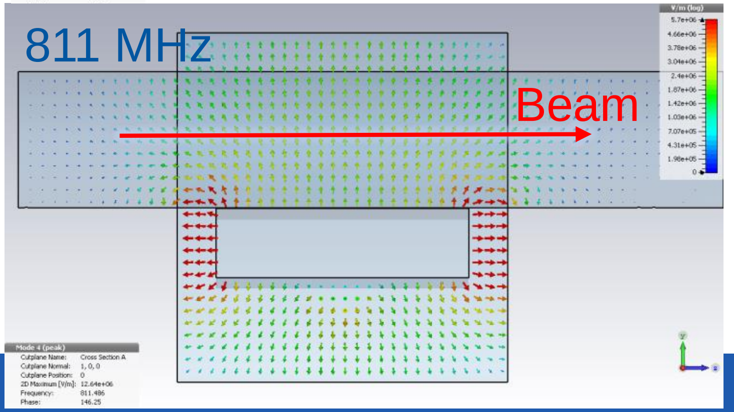




Eigenmode Solver: Front View







Path Forward

- Cavities
  - Implementing the effects of the feedback systems
  - HOM Couplers
  - Validation with measurements
- Kickers
  - Measure 8C11 Sample
    - Ferrite measurement script in development
    - 8C11 samples to be machined
  - If available, attempt to measure individual kicker modules
- Straight (SD) & Magnet (MU) Sections
  - Begin to model beam instrumentation devices (pickups, BPMs)
  - Confirm counts of passive elements
- PS Dump
  - Confirm length of actuator & electric connection
  - Add realistic material definitions to the moveable dump
  - New PS dump design is in progress (EN-STI)
    - Current replacement design is a higher impedance contributor than the current design

Further Elements to add

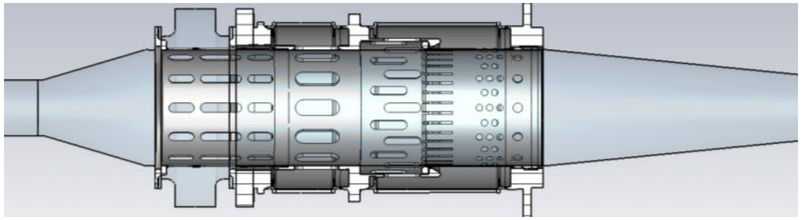
- Complete survey of straight sections (SD)
- 20 MHz & 200 MHz Cavities
- Septa
- Remaining Kickers
  - KFA4 & KFA28
- Beam instrumentation
  - Wall current monitors
  - Wire scanners
  - Pick-ups
- Vacuum elements
  - Flanges, bellows, transitions
  - Vacuum report, such as in the SPS, or similar document

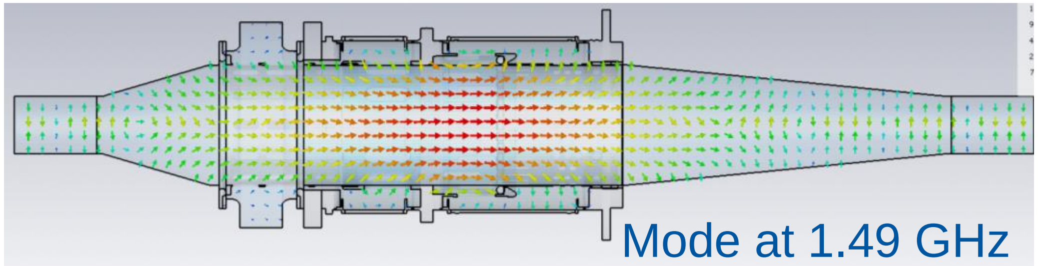
Summary

1. Cavities are most obvious candidates for admittance blow up
   - Large impedance values
   - Reduction via feedbacks (H. Damerau talk)
2. Other sources of impedances
   - Kickers' resonances at low frequency
3. Future elements need to be impedance analyzed & reduced when possible
   - Example: New beam dump design
4. Wideband impedance sources (Kickers)
   - Reductions in Landau damping
5. Microwave instabilities
   - Gate valves
   - Pumping manifolds in magnet unit (MU) sections
6. Maintenance of impedance model

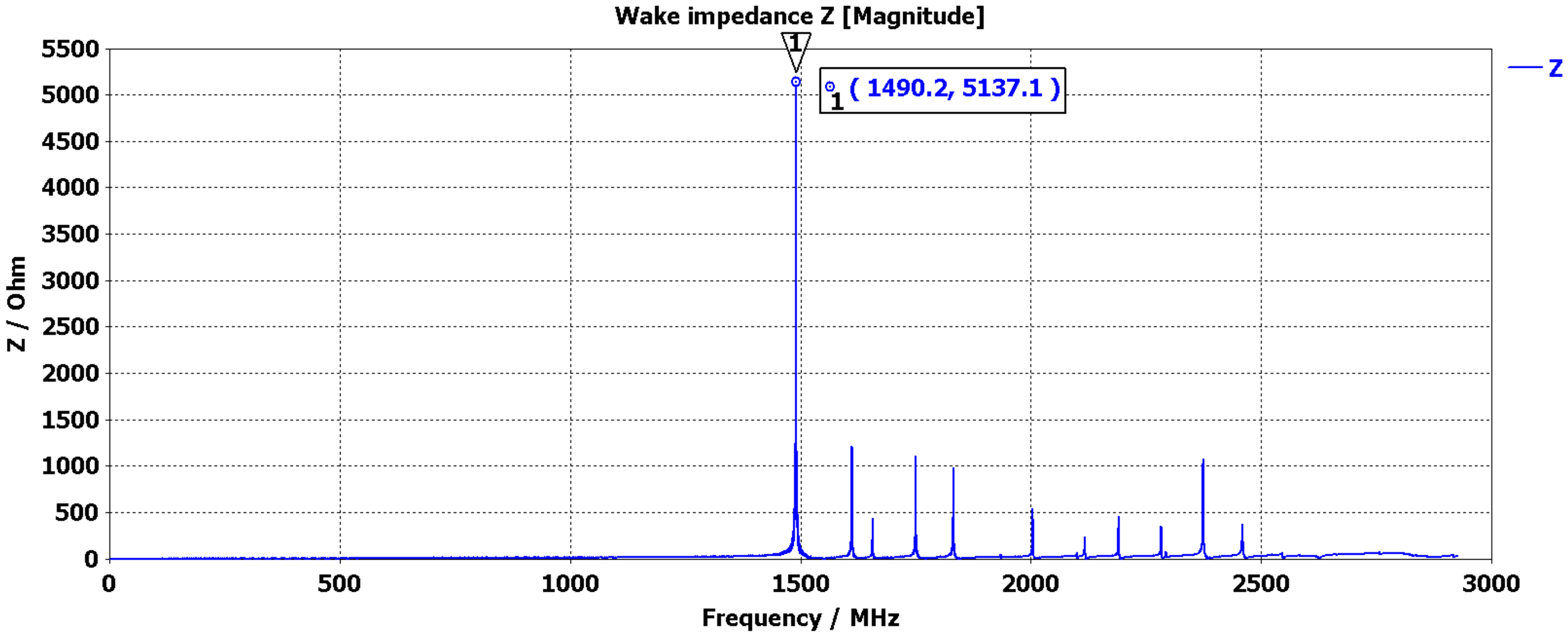
Supplemental Slides

Wakefield Simulation of the Closed Mechanical Short



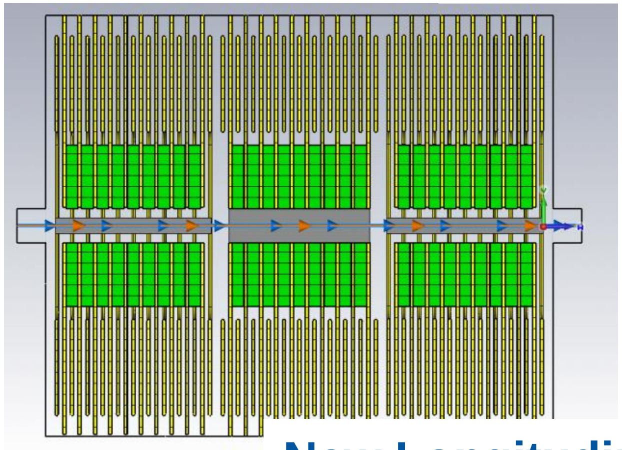


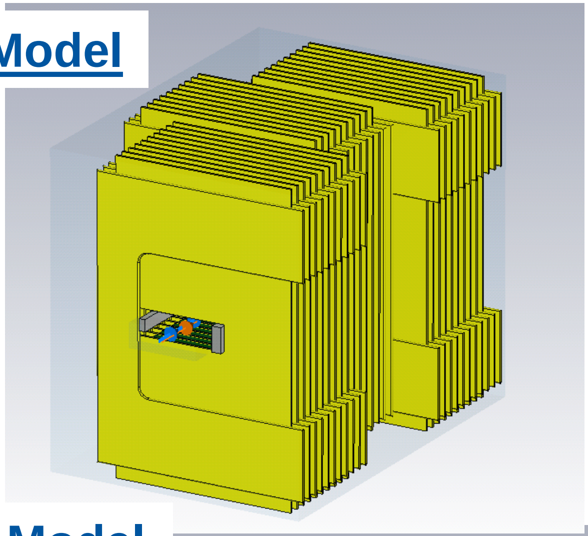
Mode at 1.49 GHz



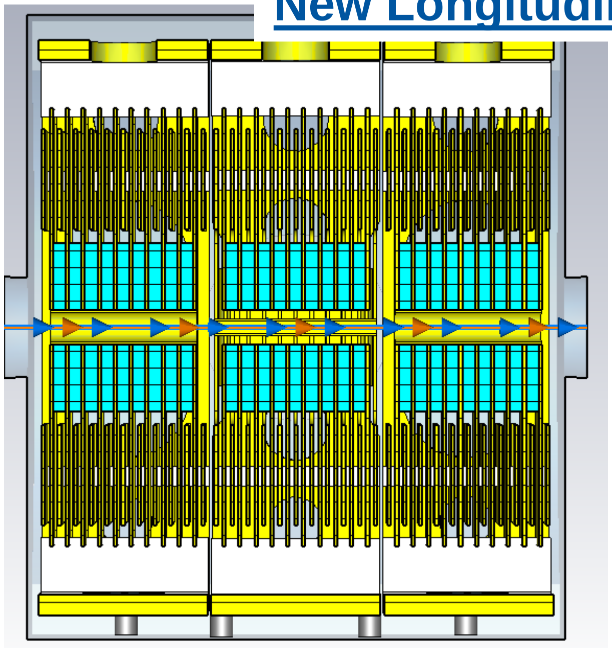
KFA79: Models

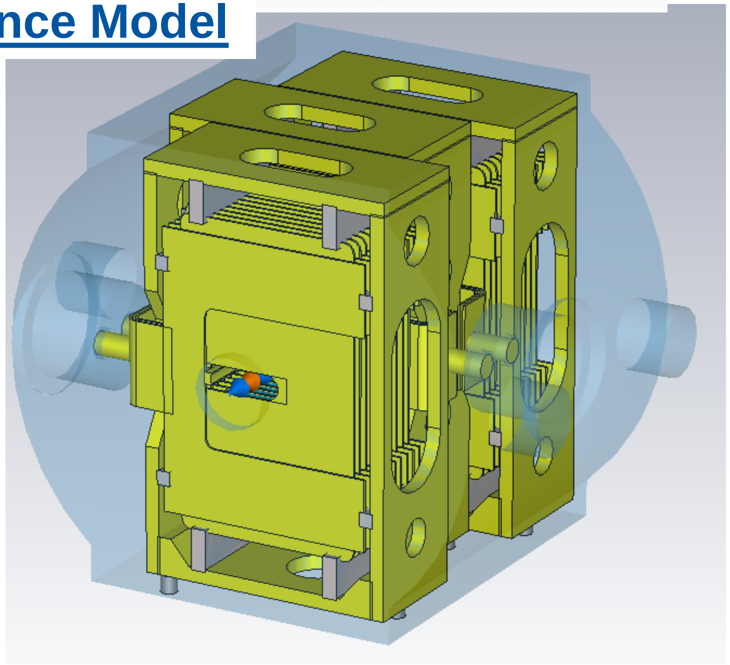
Previous Impedance Model



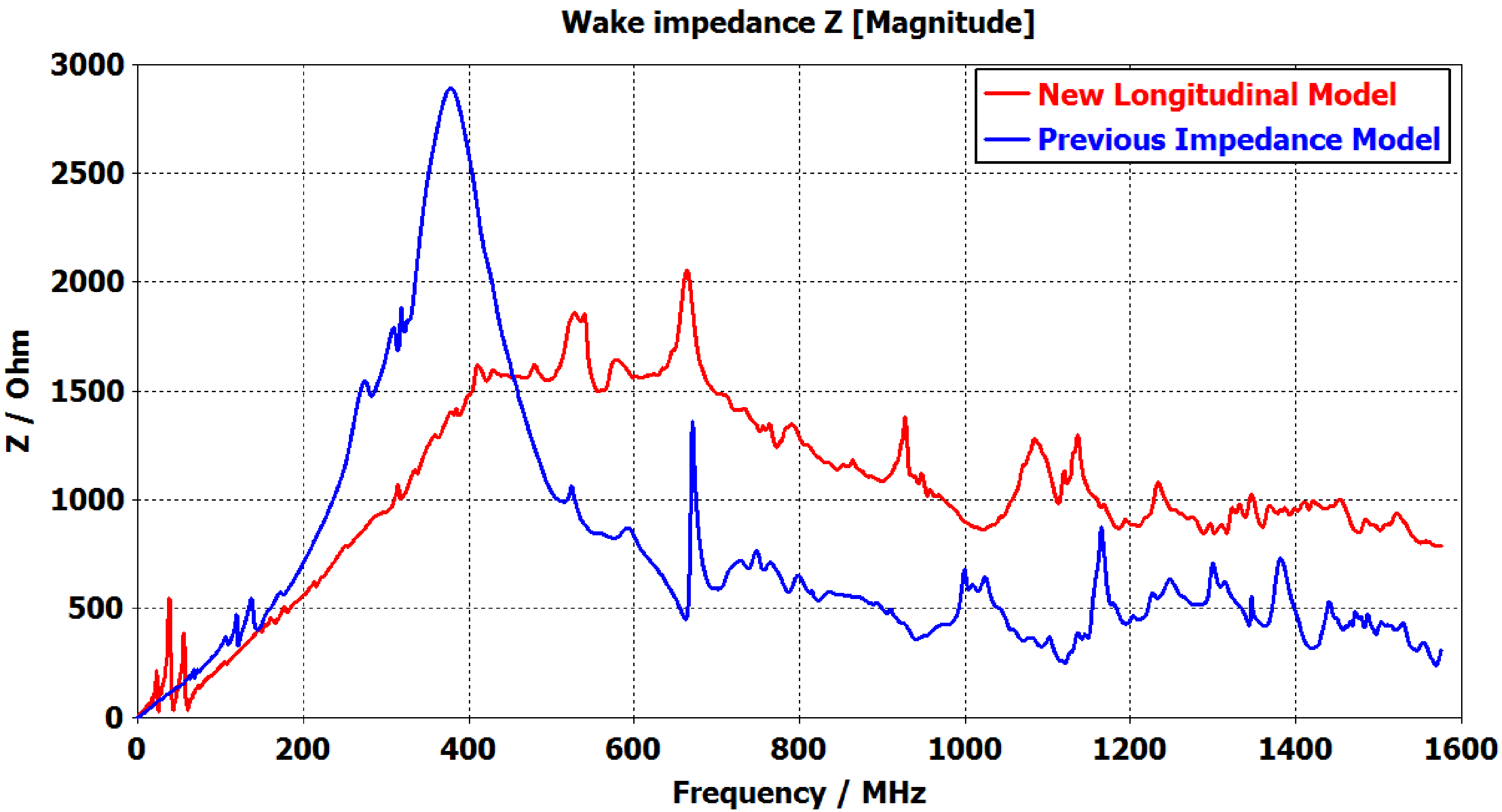


New Longitudinal Impedance Model





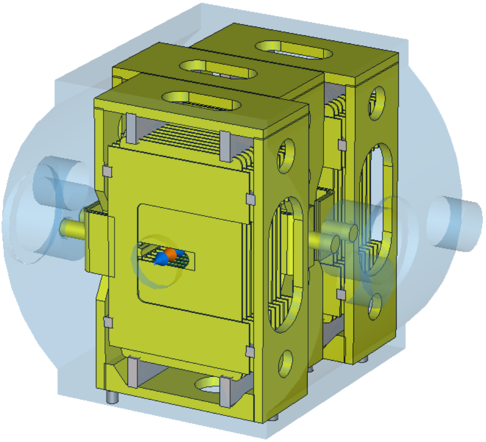
KFA79: Comparing Wakefield Simulation Results



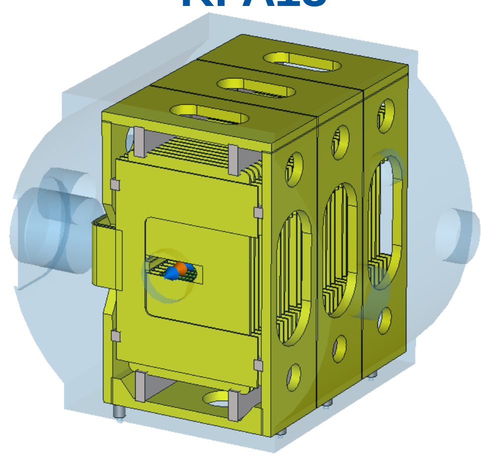
Comparing KFA79 to KFA13

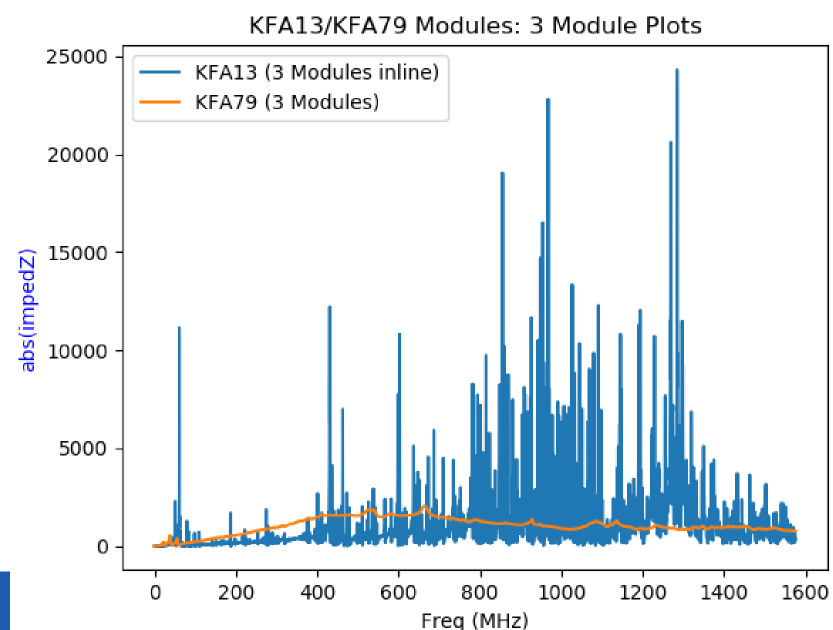
- Inline modules produce a 'forest' of resonances (KFA13)
- Inline modules seem to allow additional modes to build up along beam path
  - I.E. Higher coupling between modules

KFA79



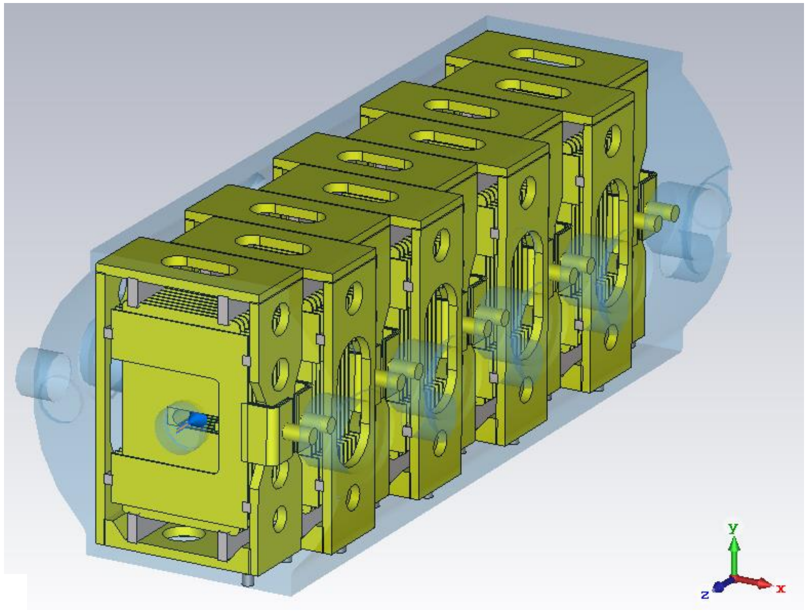
KFA13

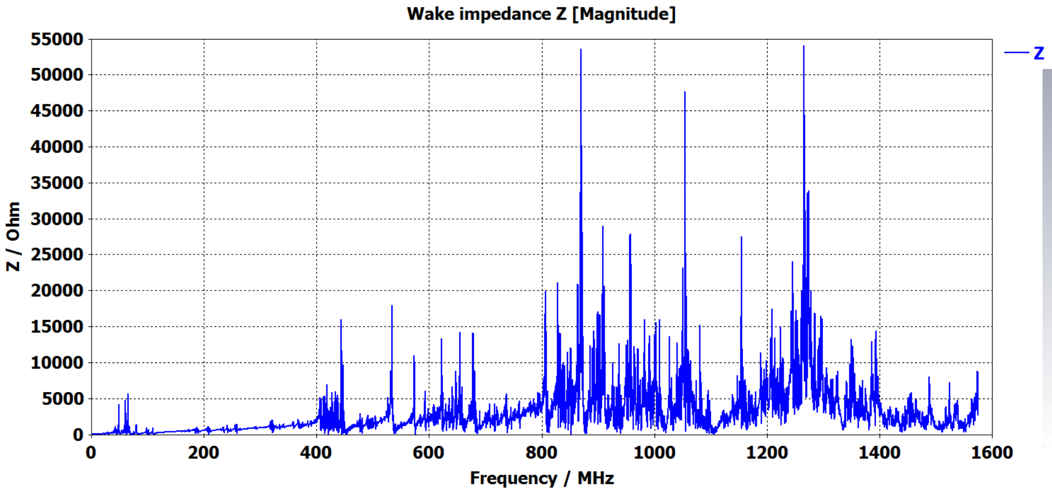


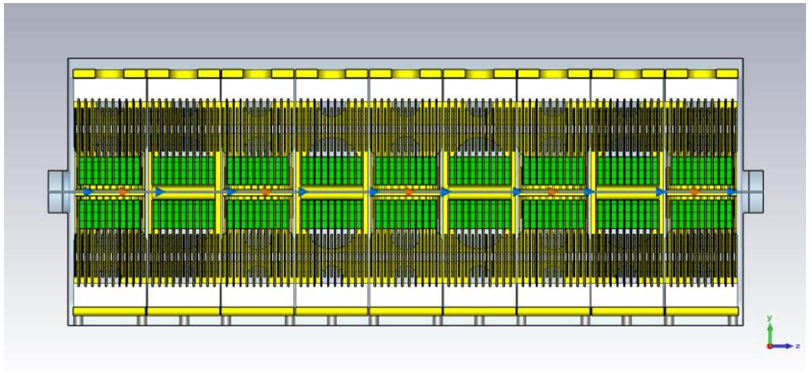


KFA71: Preliminary Wakefield Simulation Results

- Preliminary Wakefield Results
  - Need to run longer wakelength to further resolve peaks







UHV Gate Valve: TM_{010} Cavity Mode in the Valve

	Eigenmode Simulation	Wakefield Simulation	Measured
Res. Freq	1.503 GHz	1.496 GHz	1.504 GHz
Q	1294	1206	1184
R Shunt	39.0k Ohm	36.2k Ohm	-