DEVELOPMENT OF A 10 MW SHEET BEAM KLYSTRON FOR THE ILC*

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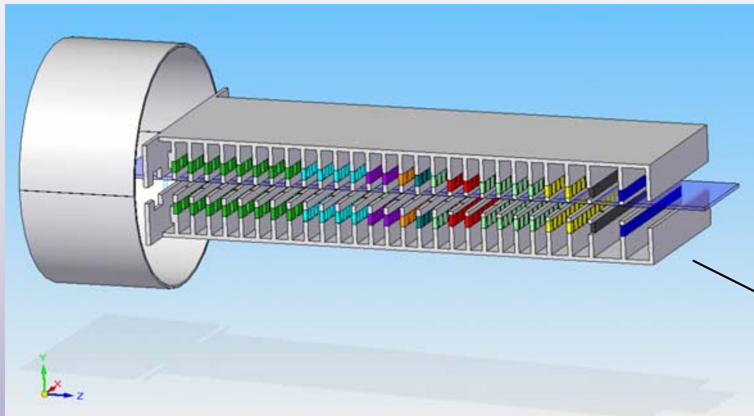
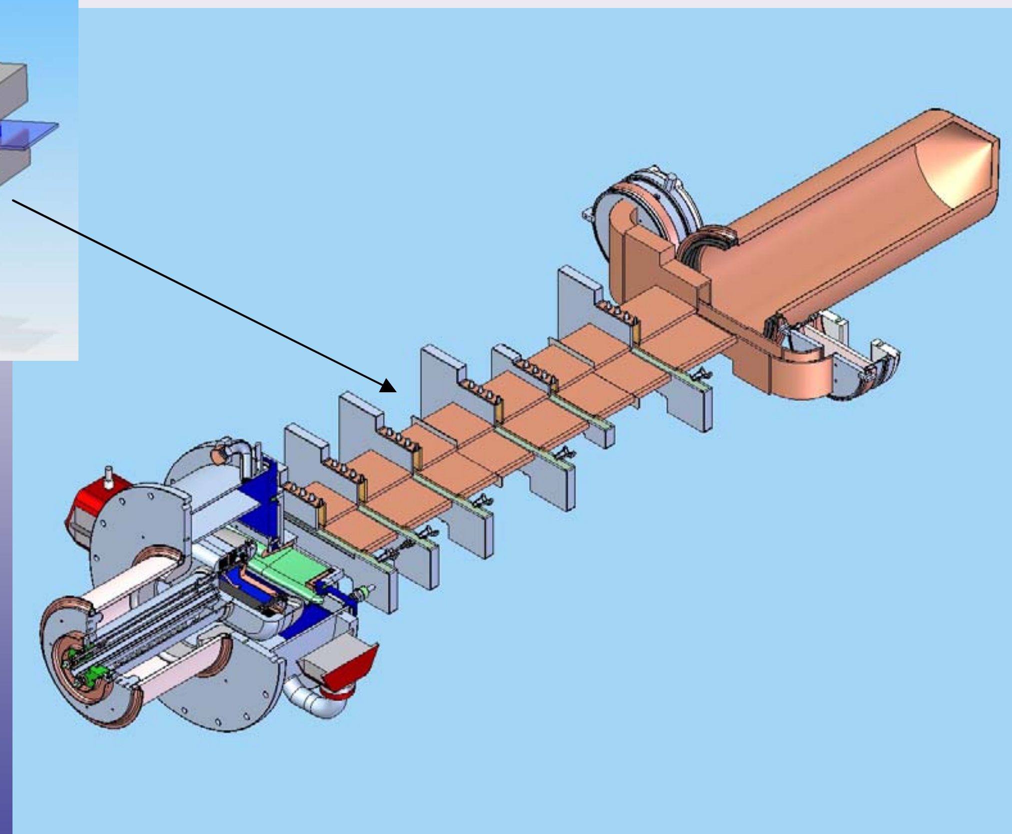
ILC Sheet Beam Klystron

- Plug compatible alternative for ILC source
  - “Better” → Could be a talk unto itself
- If possible, use permanent magnets
- Challenges - **Everything is 3D!**
  - 3D PIC takes a LONG time
  - Discover how to use 2D effectively
  - Concern of 3D gun→ perform BSD first
  - Adjustable gun during prototype experiment

In brief – PCM to focus SBK (115kV, 130A, 5Hz, 1.6ms, 1.3GHz)

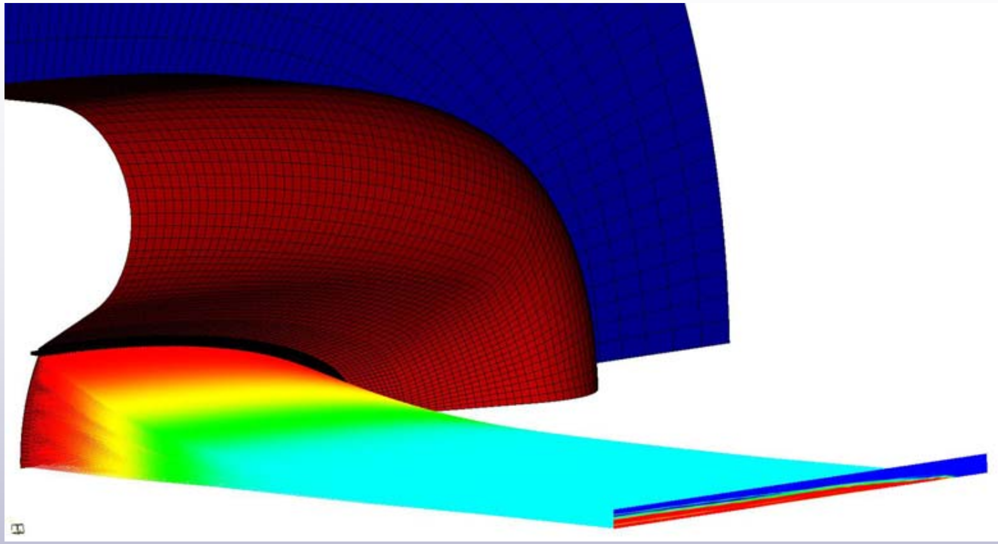




XP3 HV seal and PEP collector parts

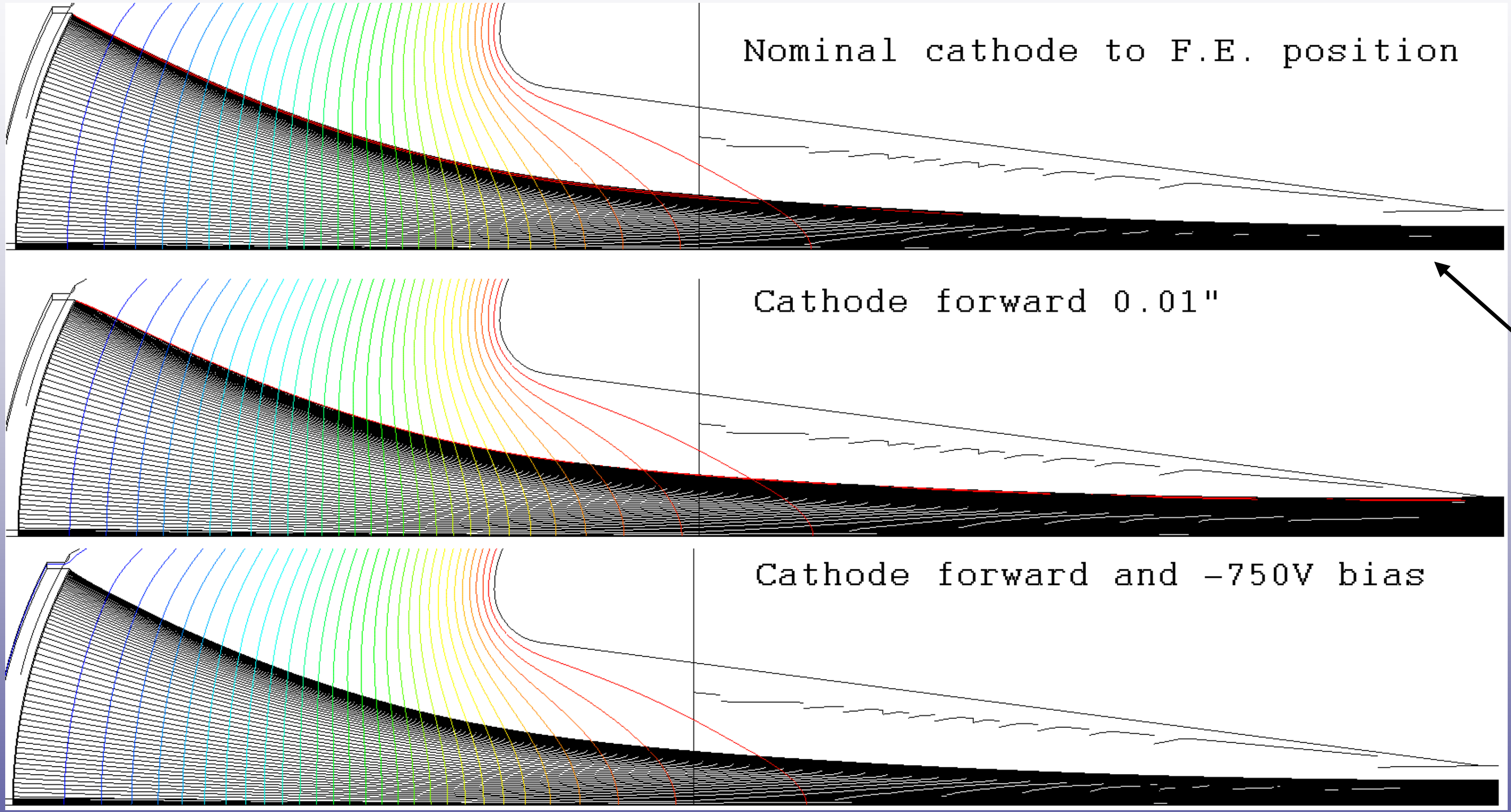
Horizontal operation

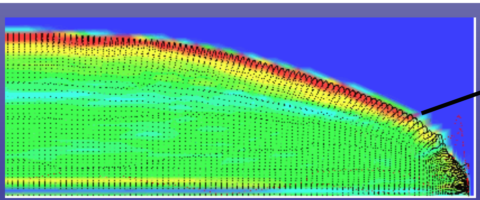
Electron Gun

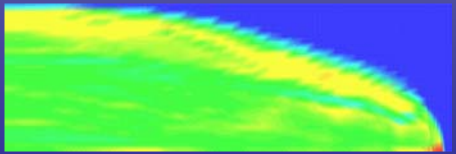


- Features
  - 2A/cm^2
  - Gradients ~BFK
  - Linear convergence
- For experiments
  - Adjustable A-K gap during operation
  - Adjustable upper/lower bias voltages ~0 to -1kV
  - Easily removable FE for possible upgrade
  - Split anode to measure interception of top or bottom of beam
- Downside – definitely for prototype
  - Oil cooling required to accommodate the “For Experiments”

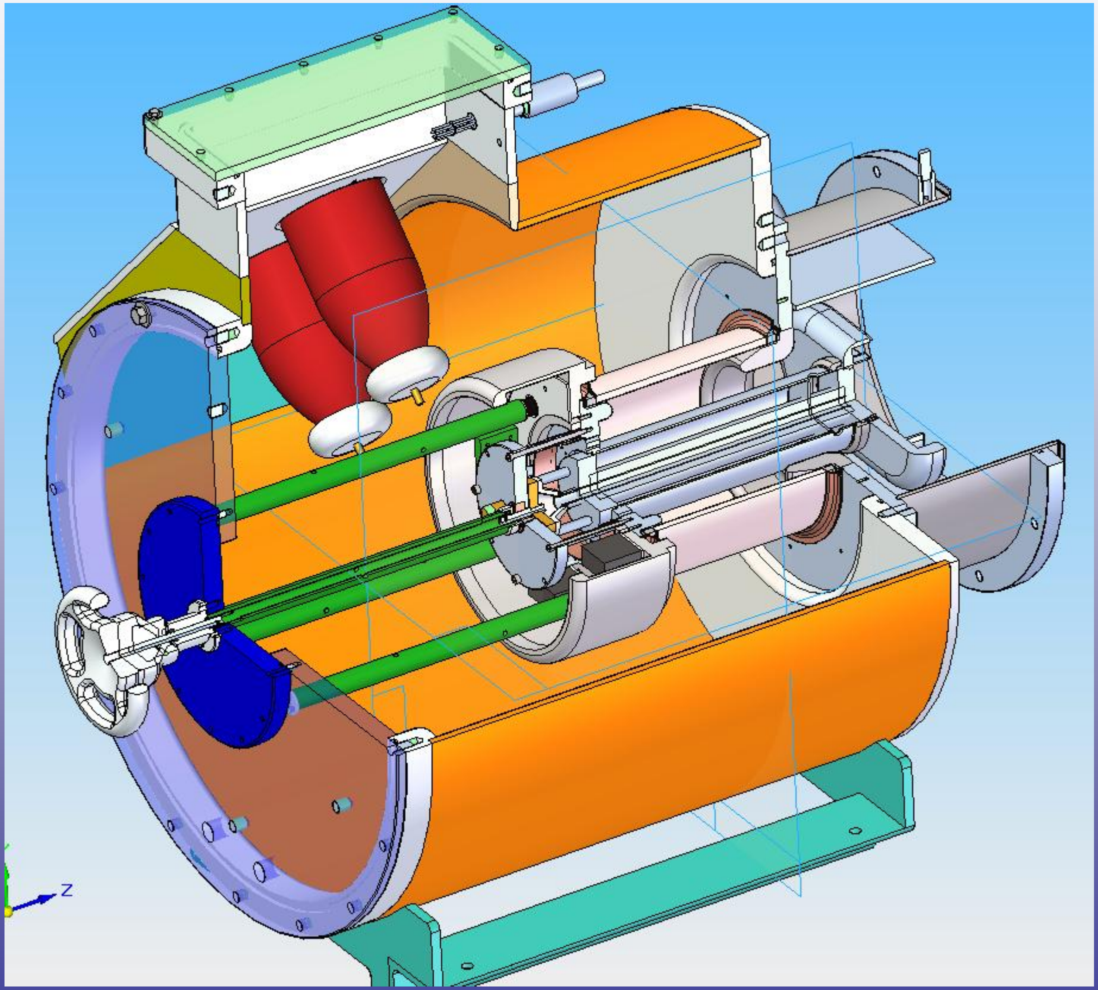
F.E. bias allows for some recovery from mechanical misalignments



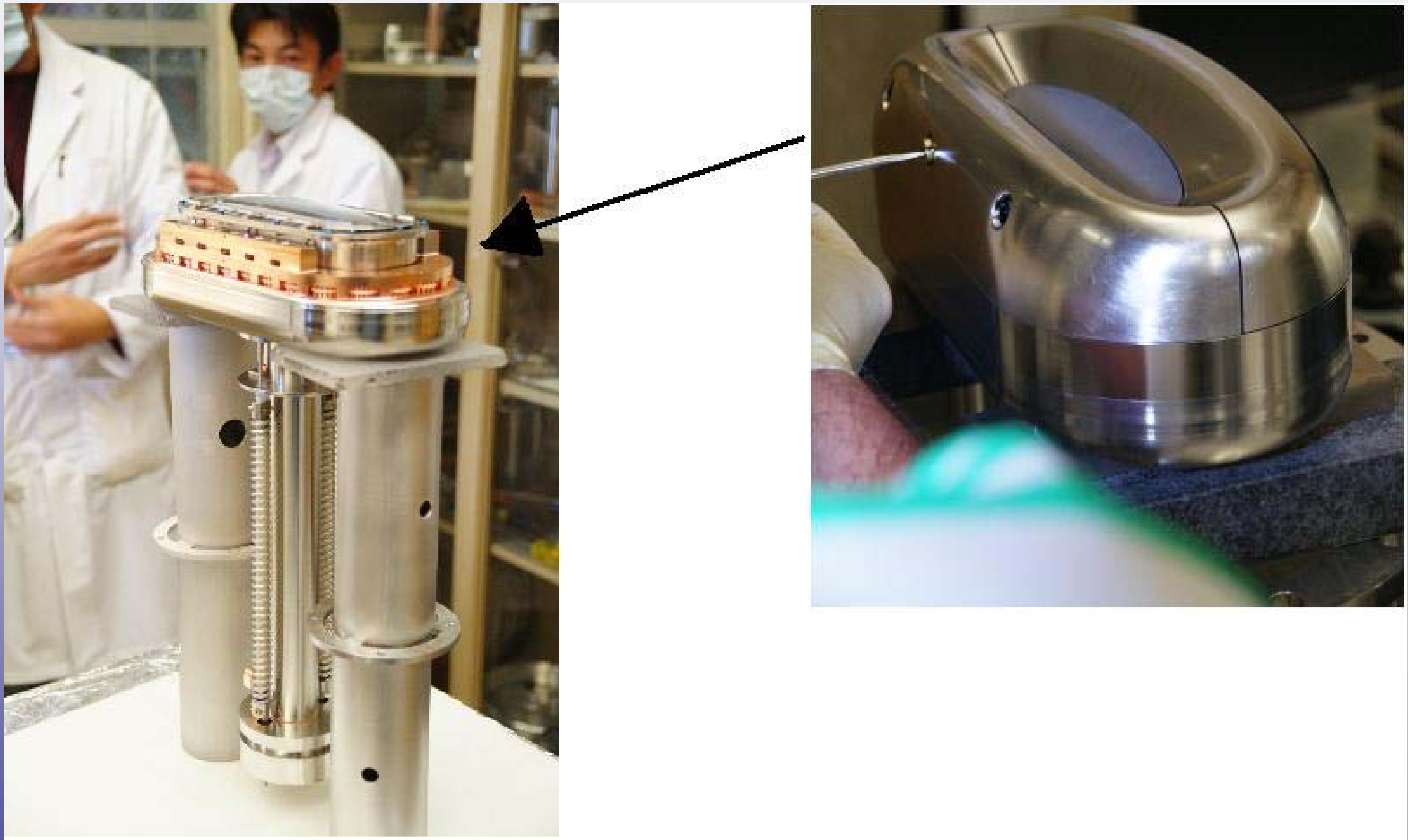




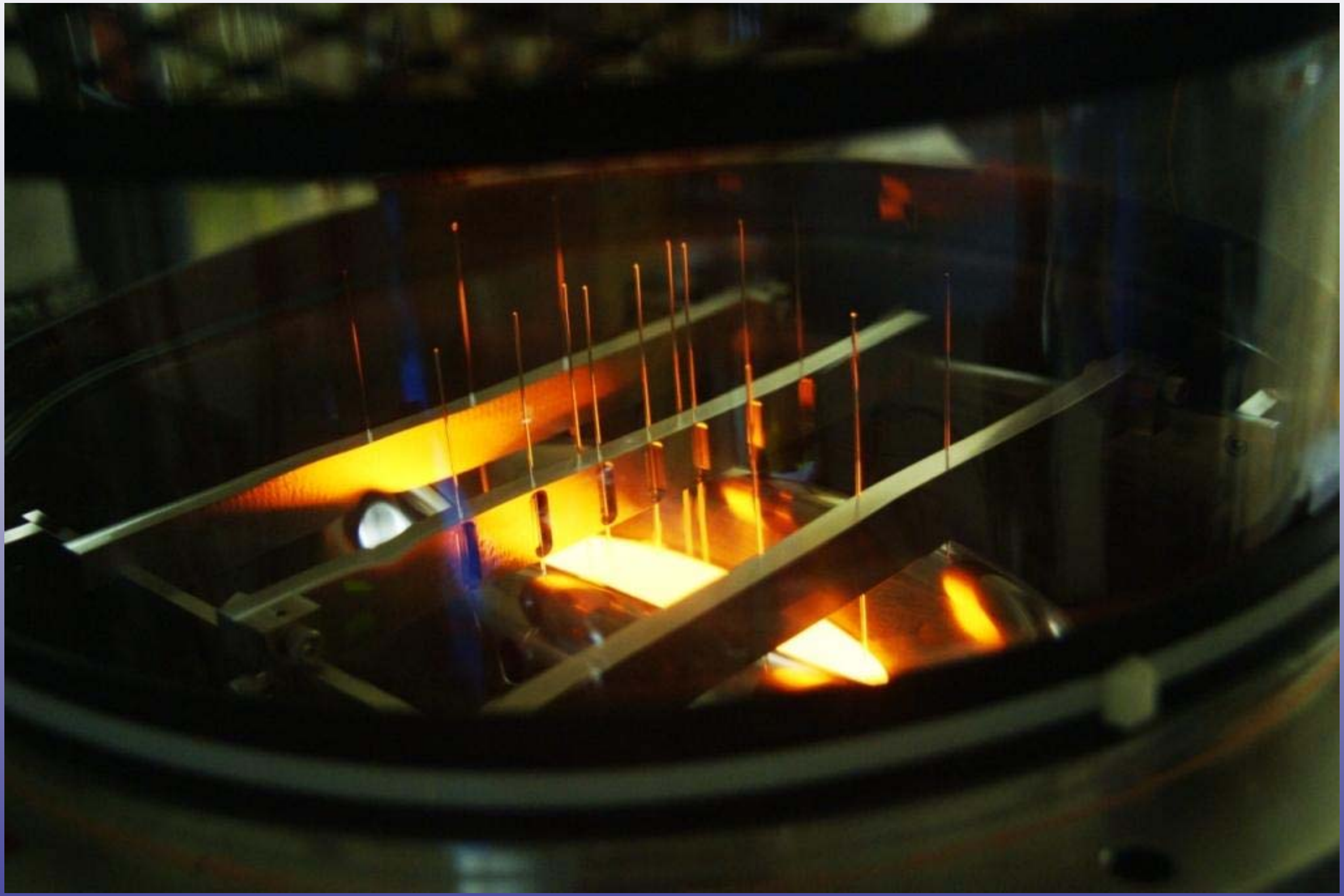
Tank and gun showing K-A gap adjustment mechanism



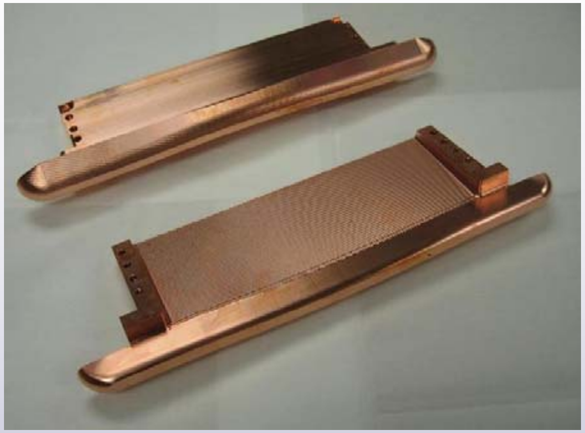
Electron Gun construction and F.E. mounting



Electron Gun – measure hot mechanical movements



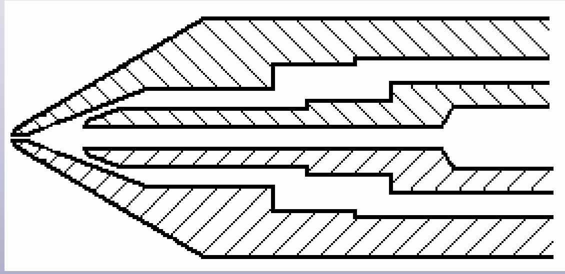
Anode



- For experiments
  - Isolated to measure interception from top and bottom planes separately
  - Easily removable for possible upgrade
- Downside – definitely for prototype
  - Complex: cooling, isolated, removable
  - Requires precise alignment to F.E.

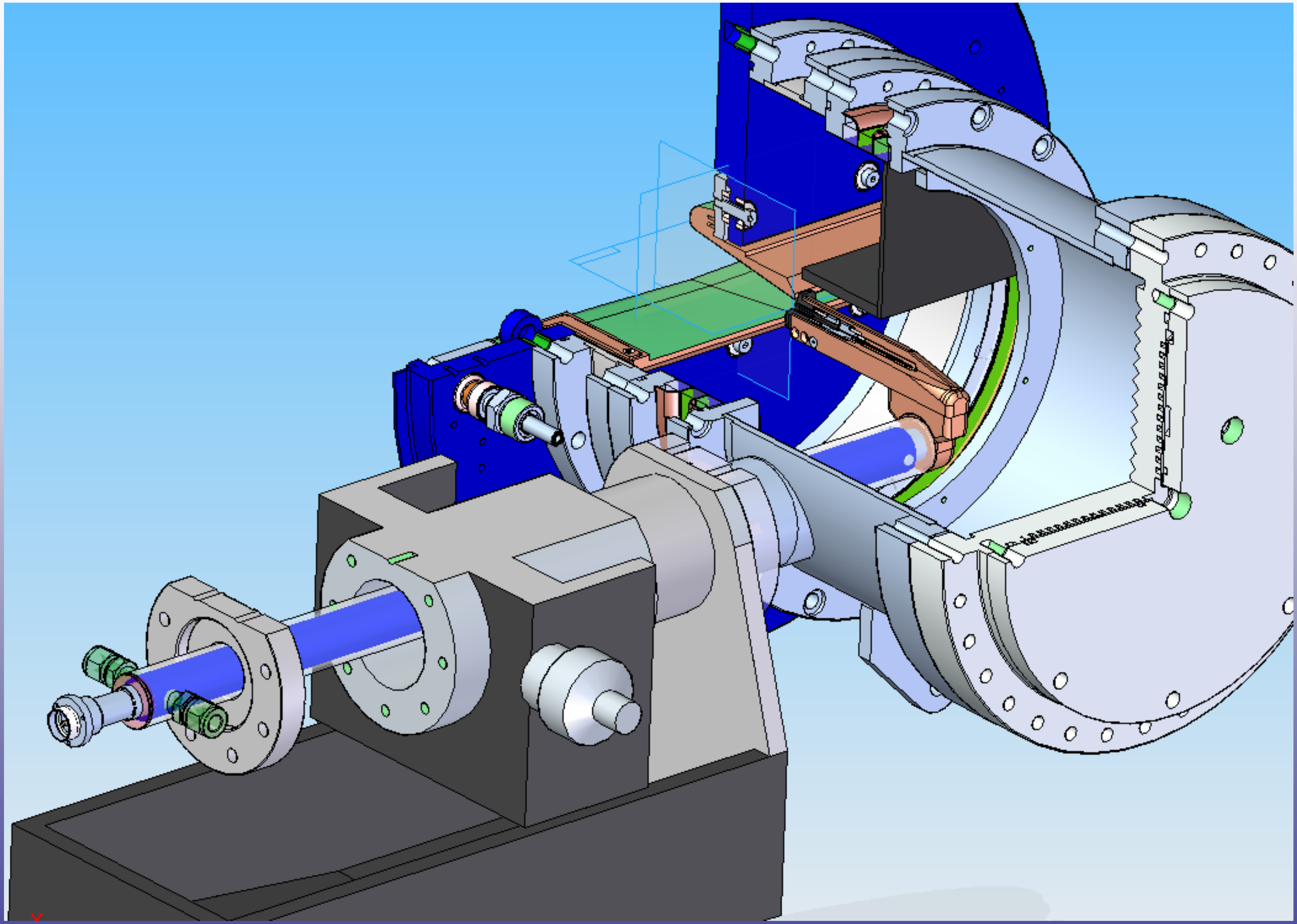
Beam Sampling Device (BSD) Requirements

- 8mil diameter, 1kV biased, carbon cup

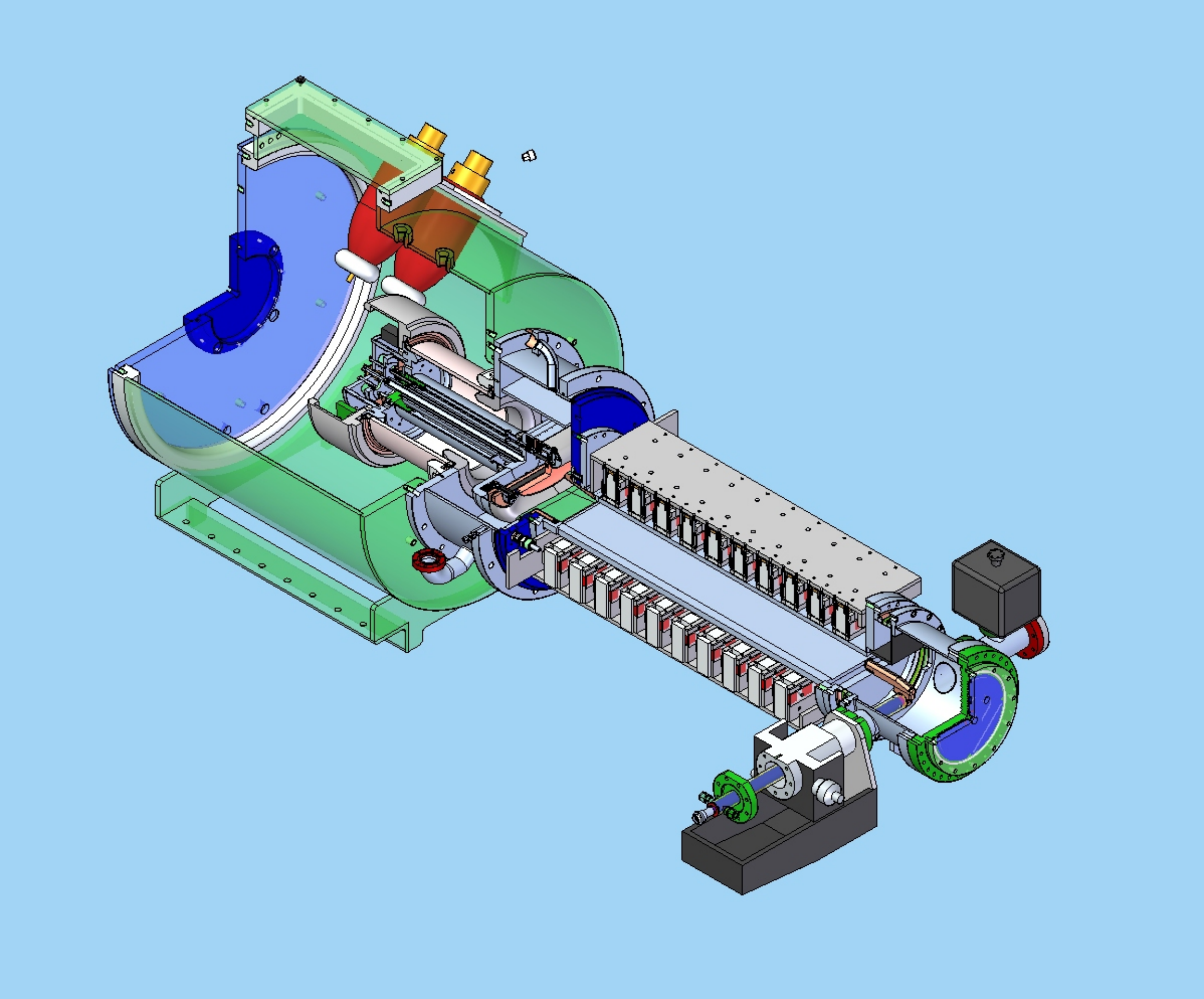


- 3 axis scanning of beam (z-axis is limited)
- Removable: Experiments go between it and gun
- Operates microsecond pulse lengths

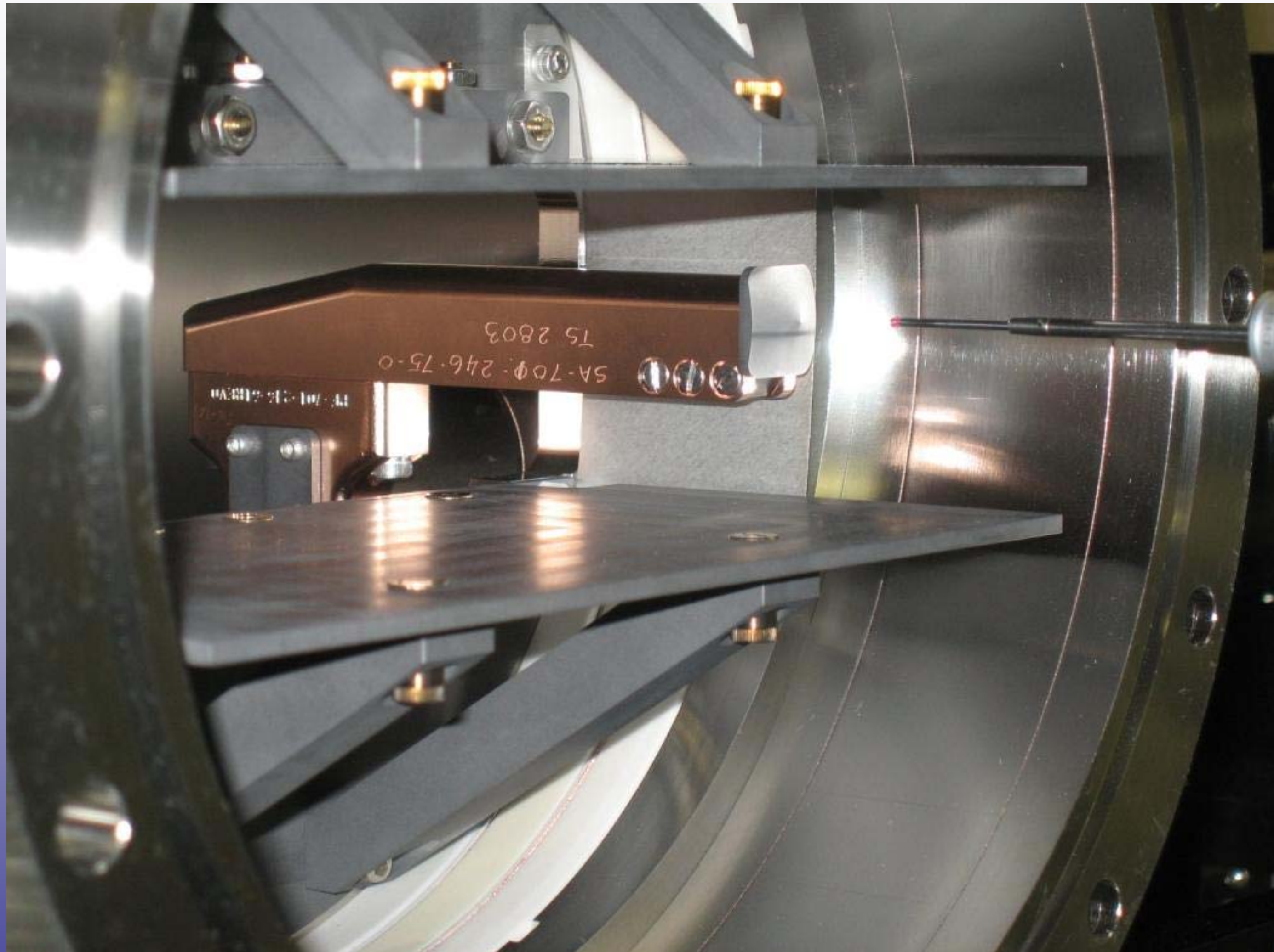
Static BSD test



Magnetic PCM with BSD test on tank



BSD Probe detail



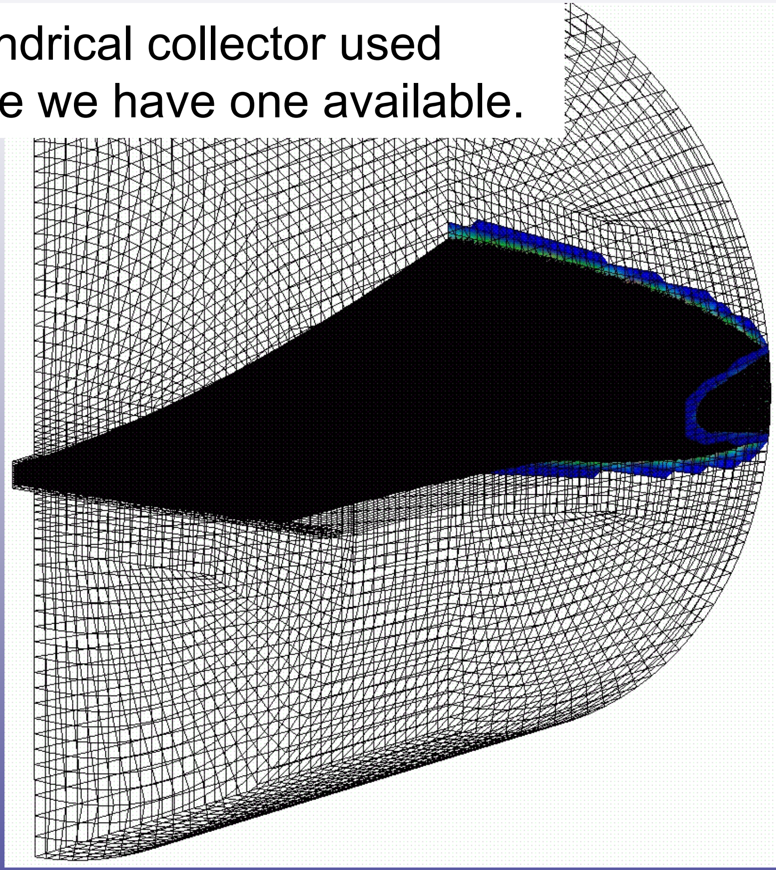
Ceramic seal

- Maintain old BFK gradients → Original smaller diameter BFK seal run at 83.5 kV
- Use the XP3 seal
- Change inner corona ring to Whale tail to reduce gradients to old BFK levels

- Result – Gradients at old BFK levels

Spent beam power using a PEP collector

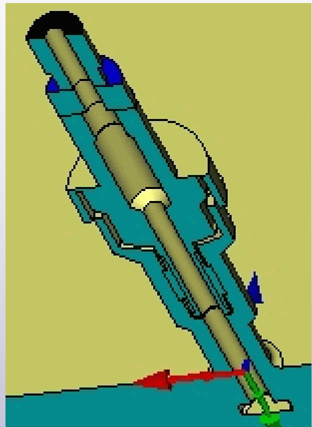
Cylindrical collector used since we have one available.

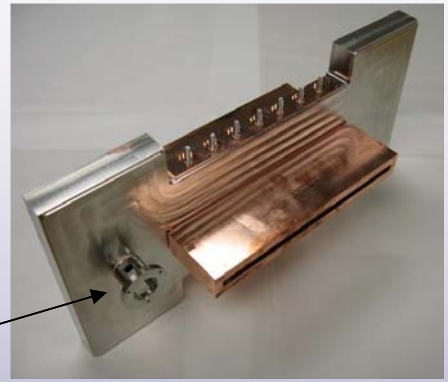


80 kW/cm^2 on the edge of the side zones

X-Compression: By field is introduced from step in last polepiece to allow the beam to spread in y-direction before impact→30kW/cm^2

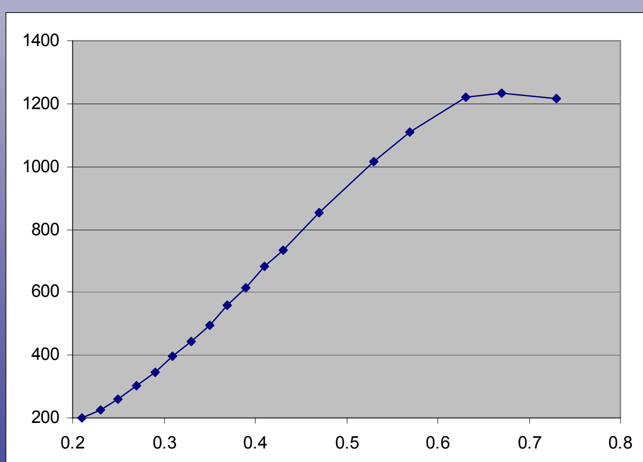
Cavities



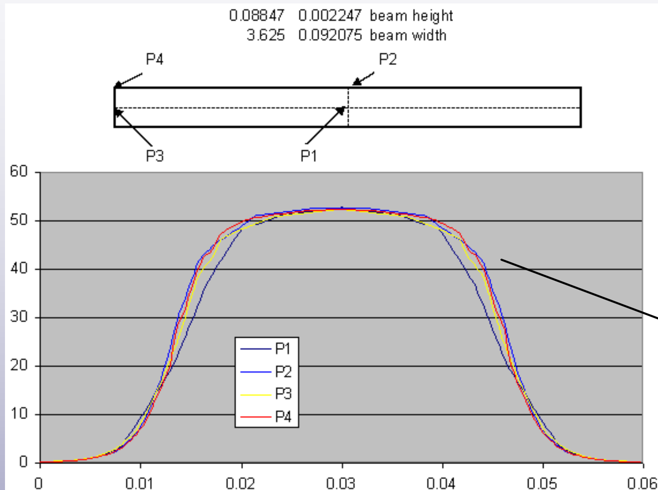


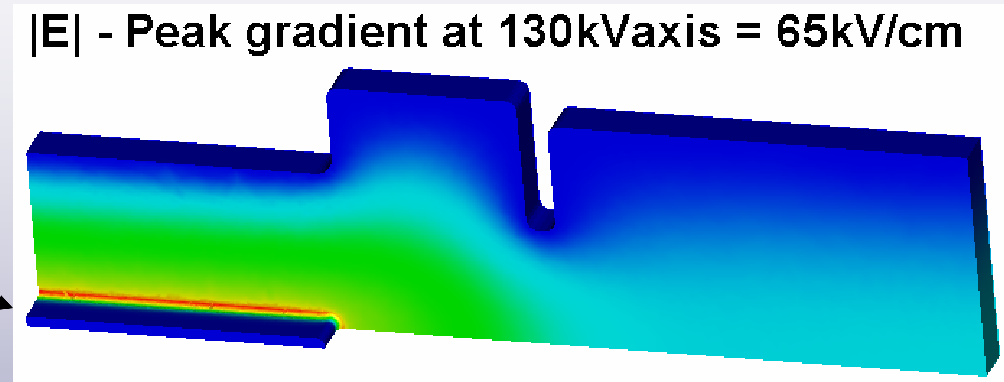
Loss coupler for setting the Q

Cold test and simulation agree on the modes



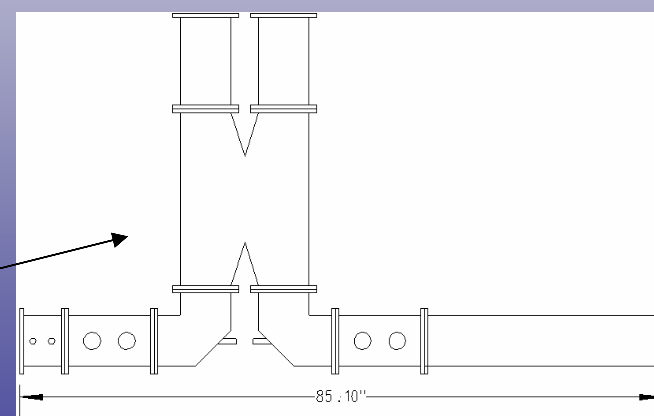
Cu Output Cavity





Q = 40, R/Q = 20, M = 0.89
(R/Q & M averaged over beam)

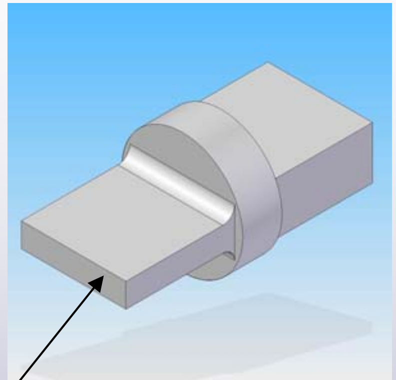
Hybrid use between output window and load to optimize the output cavity match for best performance

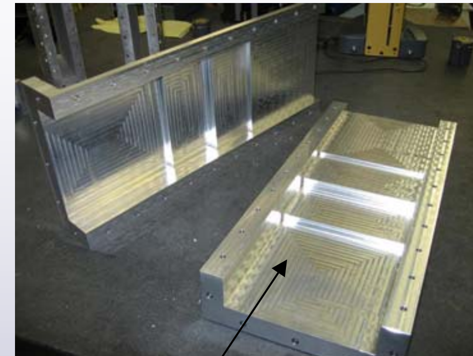


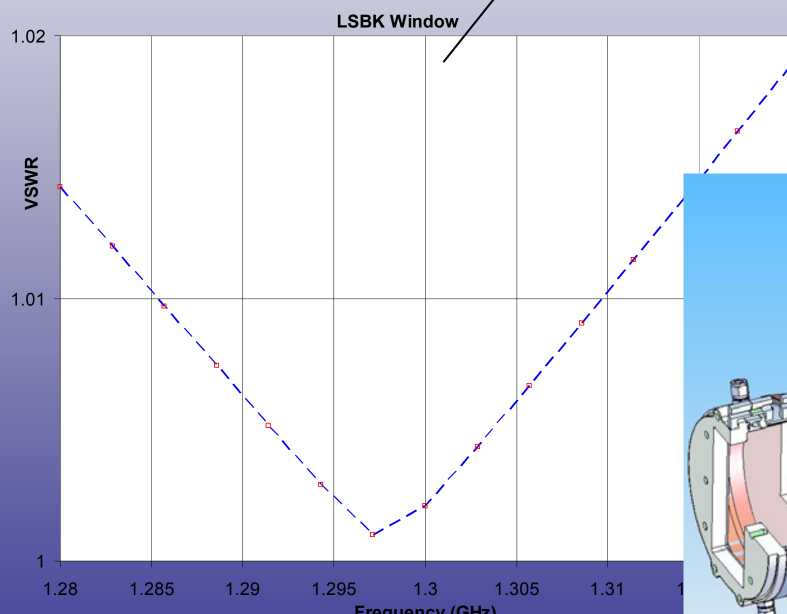
Windows and waveguide

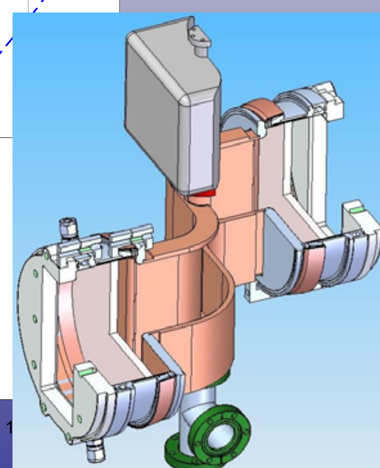
Gradients <= other designs

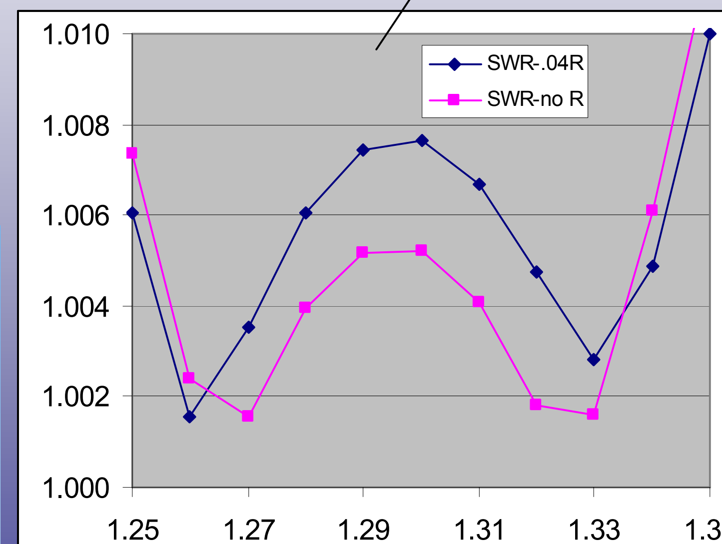
Multipactor and trapped modes were analyzed and deemed not an issue.





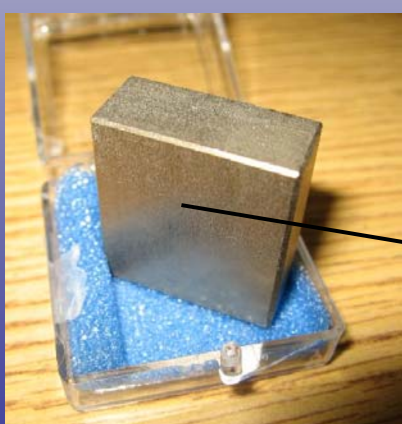


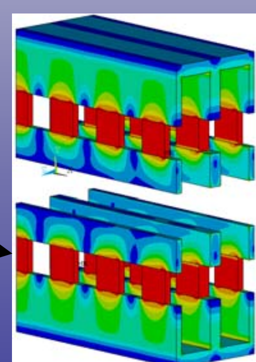


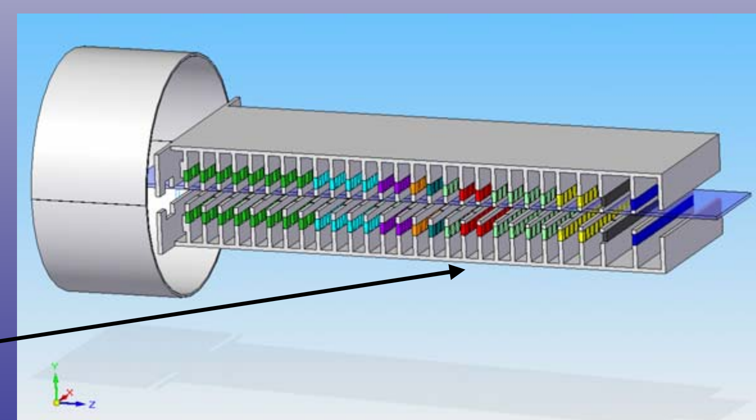


Magnet Structure Requirements

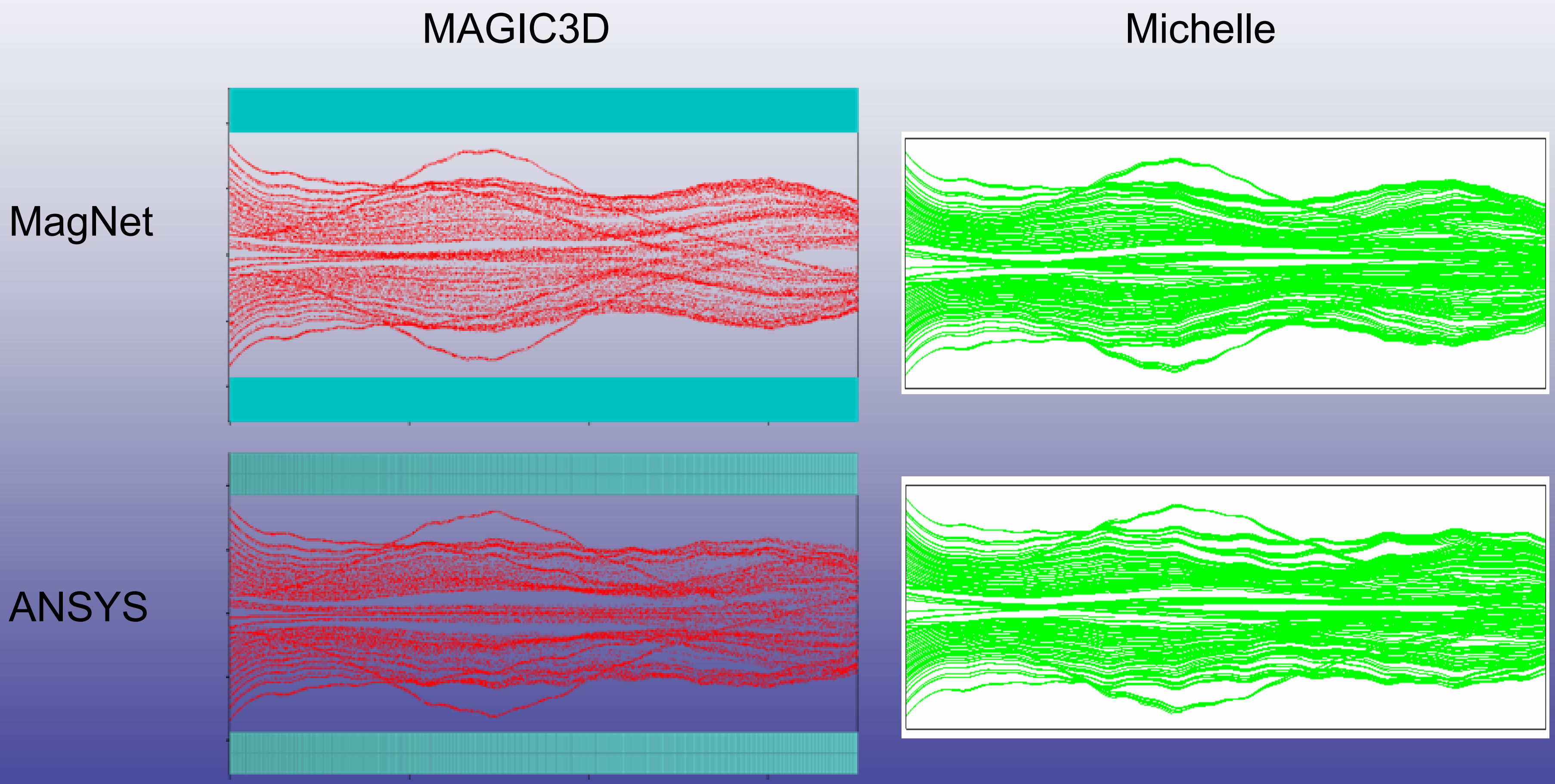
- Common magnets and pole pieces
- Shielded to external fields
- Tunable to taper field and zero the axis
- Can be measured ~exactly as it is used
- Fast replacement-don’t have to pull tube







Translation between codes looks very reasonable



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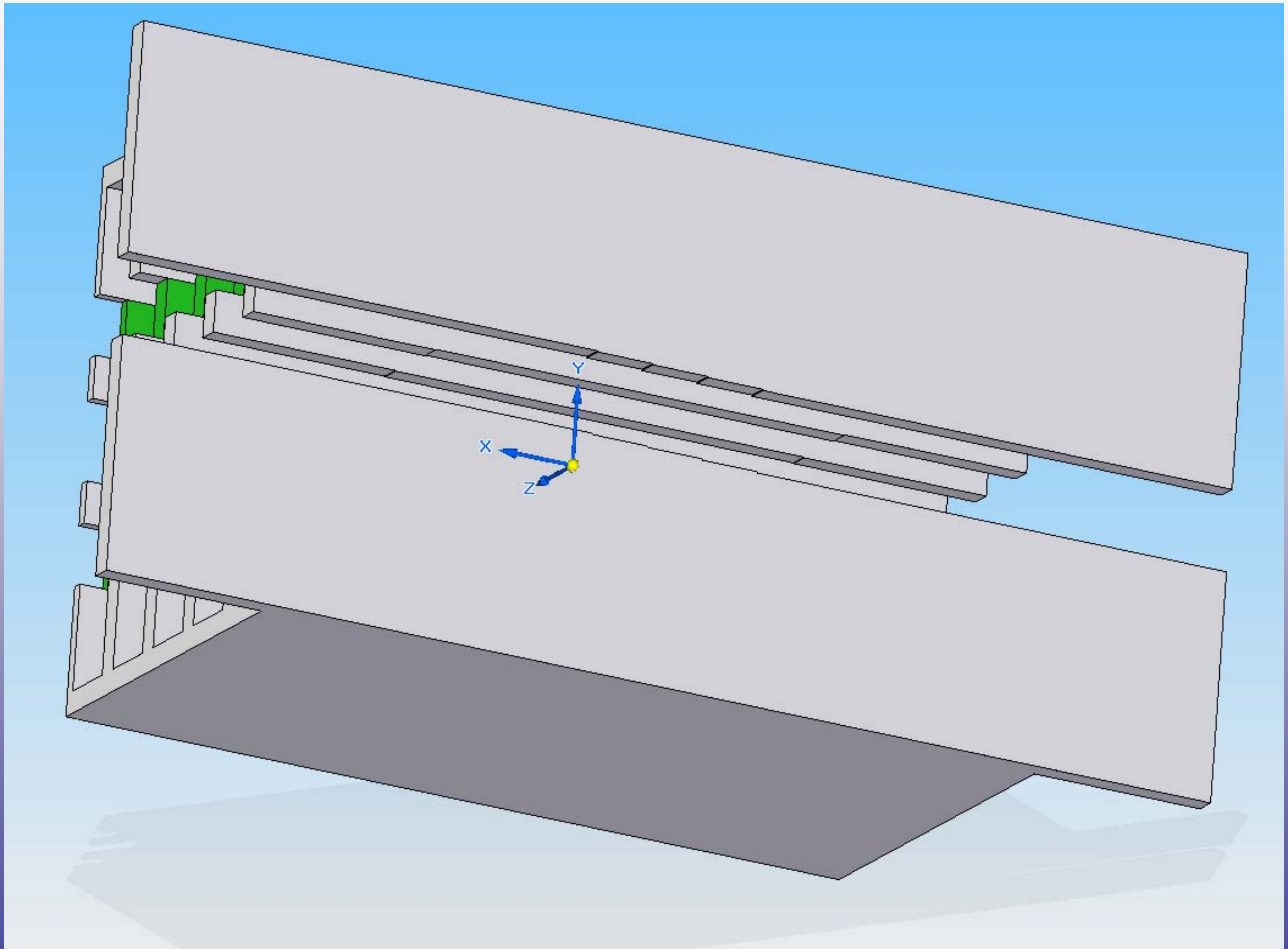
Beam entrance to PCM stack, edge focusing, and earth's field



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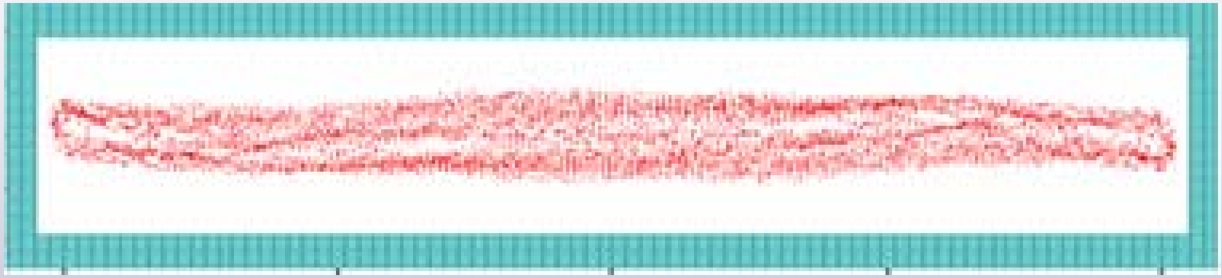
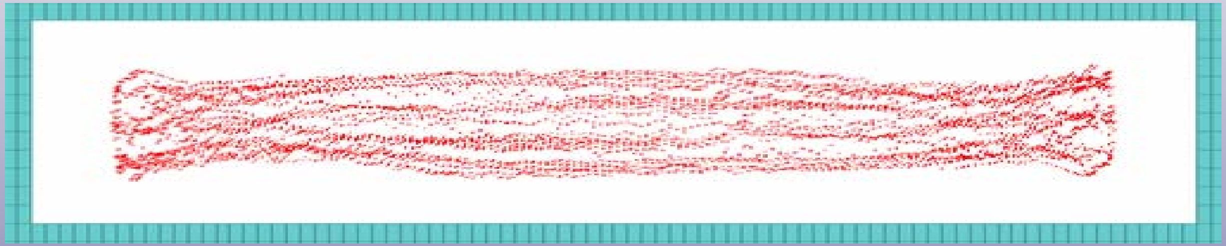
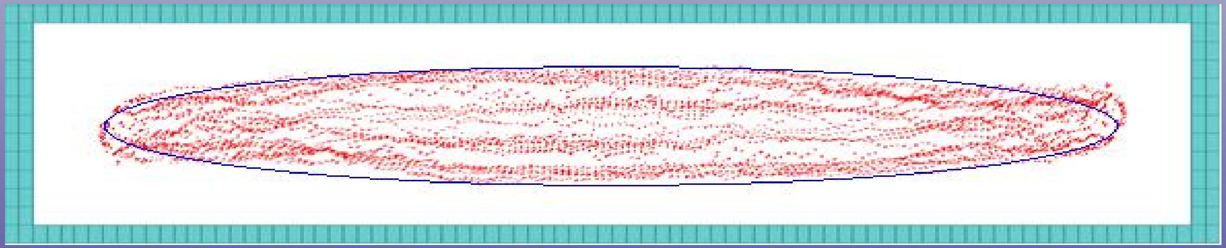
Edge Focusing Selection



Too little

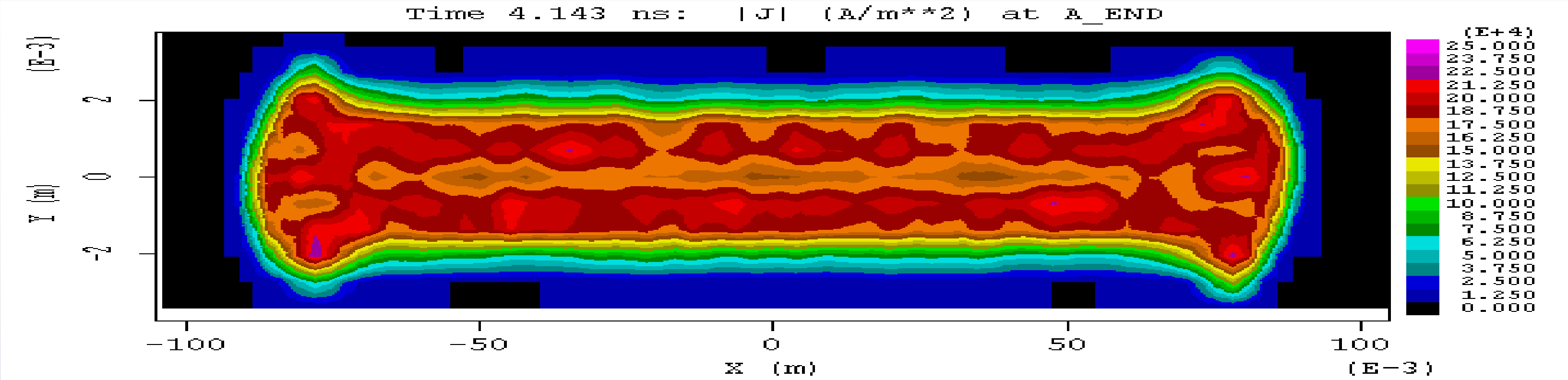


Too much

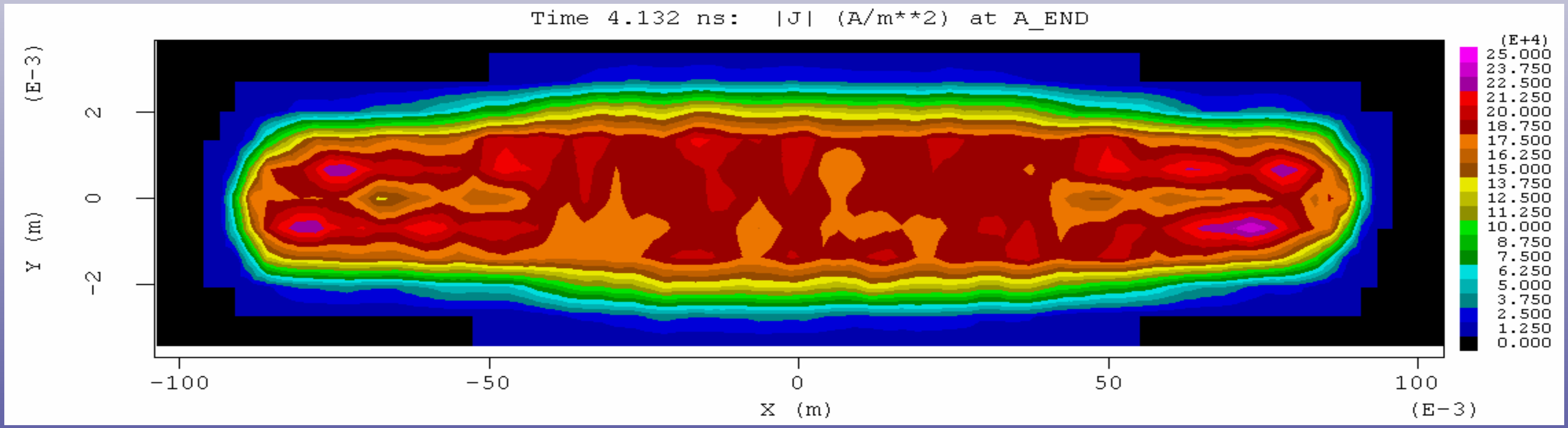


Just right

Entrance tilt Selection



MICHELLE Beam @ z=84cm

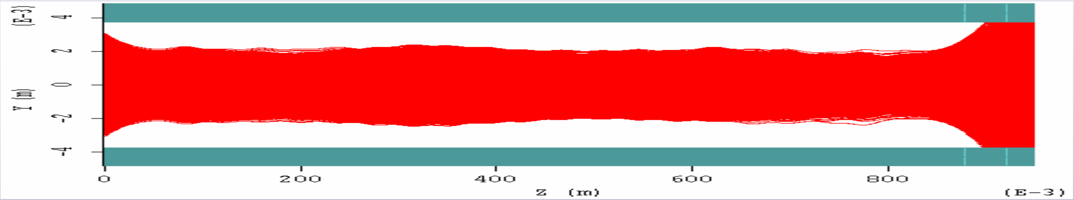


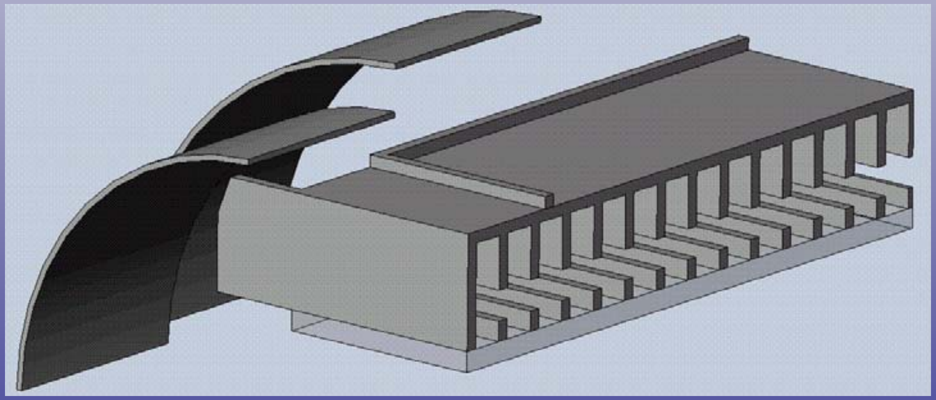
MICHELLE Beam @ z=84cm with Px(z=0) = 0

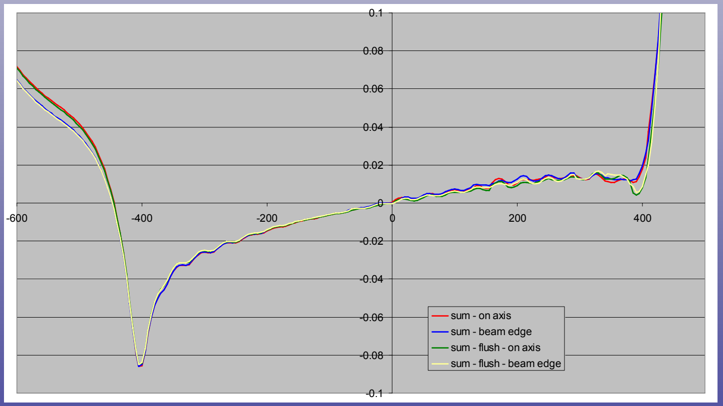
Earth field cancellation

No cancellation

With cancellation
(coil on @ 20 A Turns)







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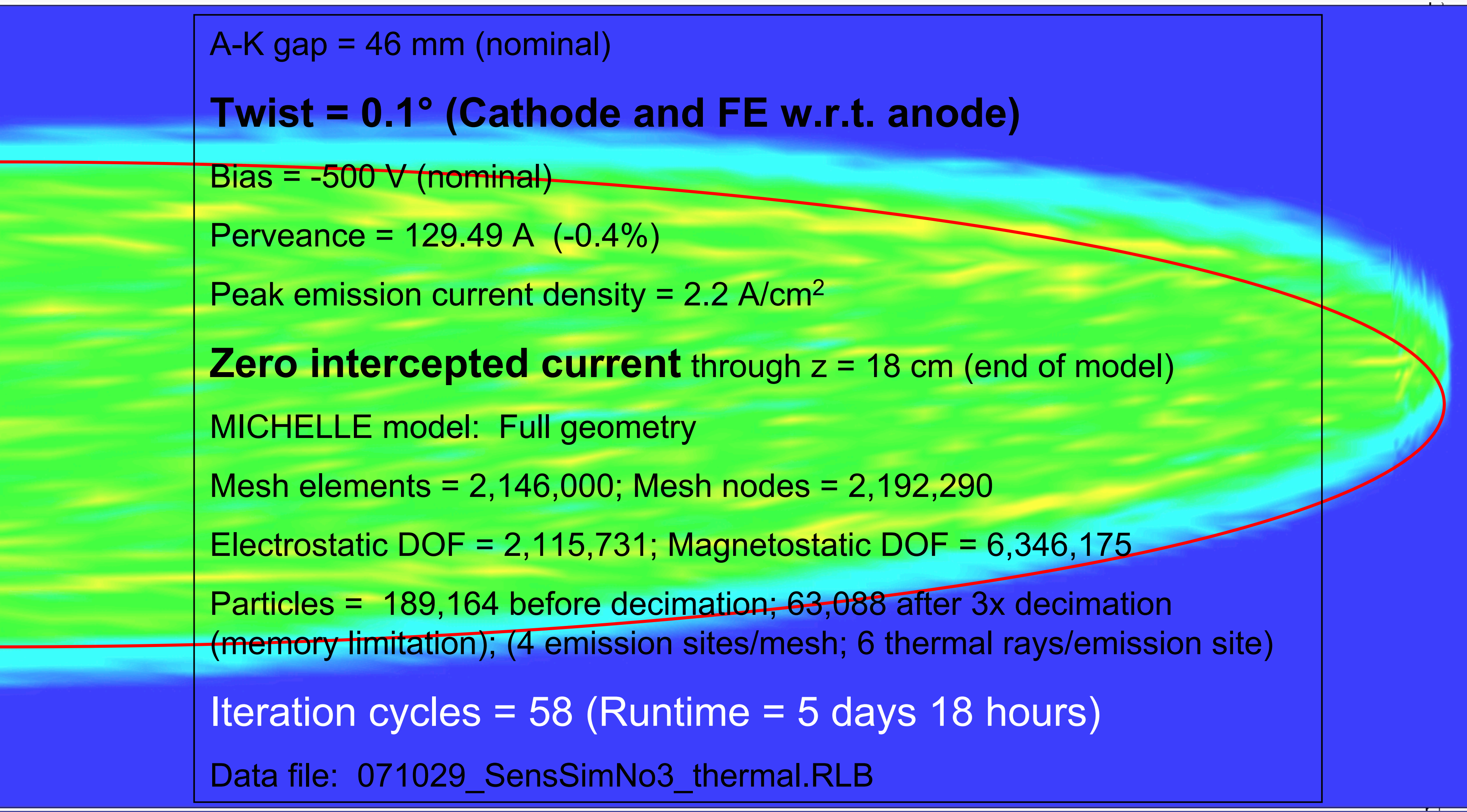
Sensitivity simulation #3 – thermal beam
Gun stem (cathode + FE) twist w.r.t. anode



A-K gap = 46 mm (nominal)

Twist = 0.1° (Cathode and FE w.r.t. anode)

Bias = -500 V (nominal)

Perveance = 129.49 A (-0.4%)

Peak emission current density = 2.2 A/cm^2

Zero intercepted current through z = 18 cm (end of model)

MICHELLE model: Full geometry

Mesh elements = 2,146,000; Mesh nodes = 2,192,290

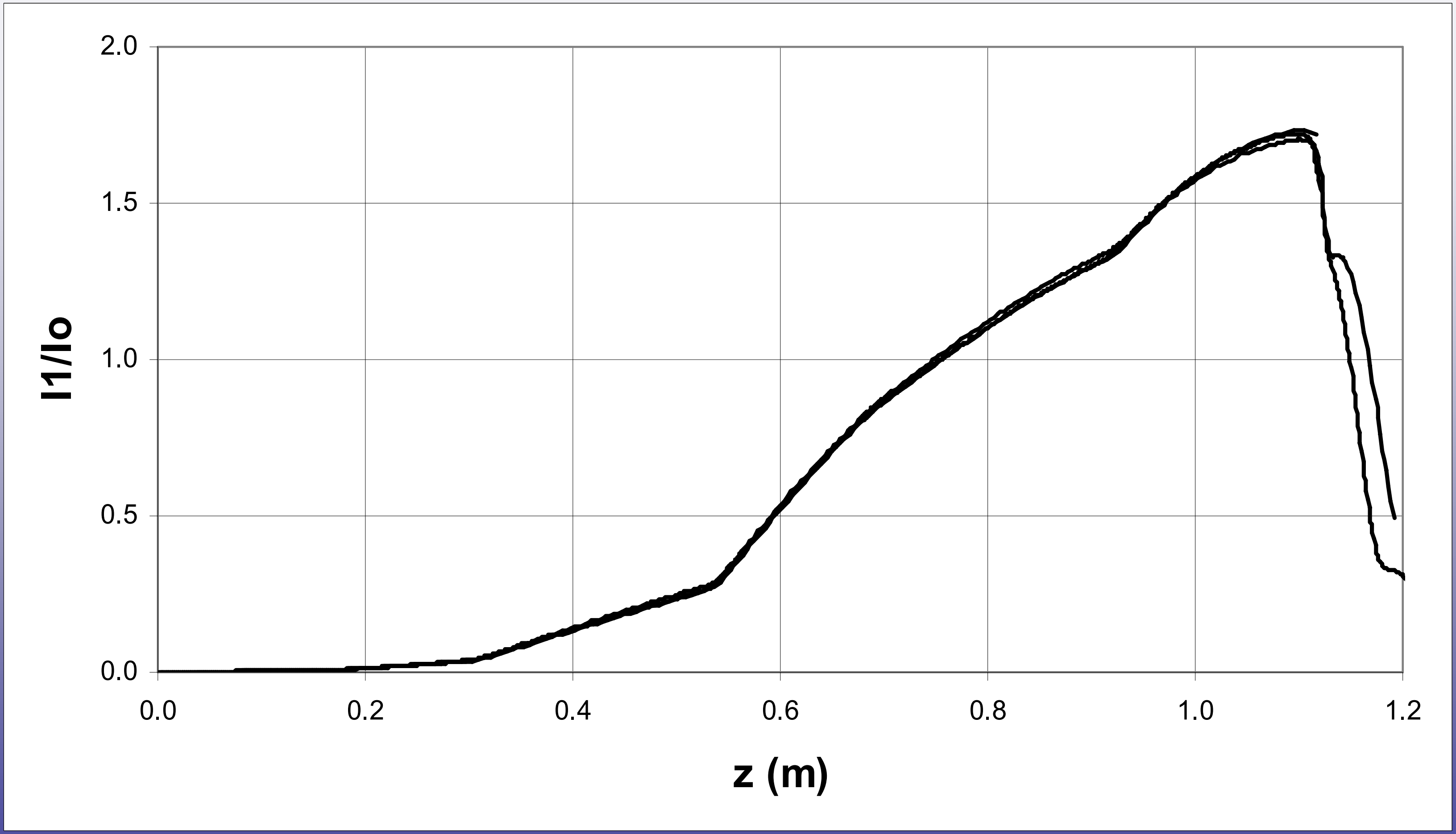
Electrostatic DOF = 2,115,731; Magnetostatic DOF = 6,346,175

Particles = 189,164 before decimation; 63,088 after 3x decimation (memory limitation); (4 emission sites/mesh; 6 thermal rays/emission site)

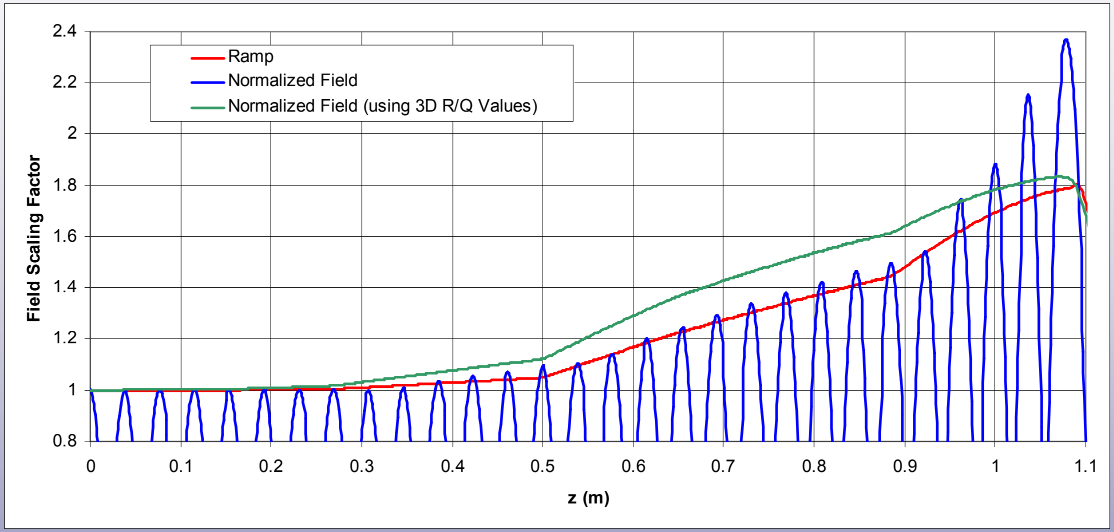
Iteration cycles = 58 (Runtime = 5 days 18 hours)

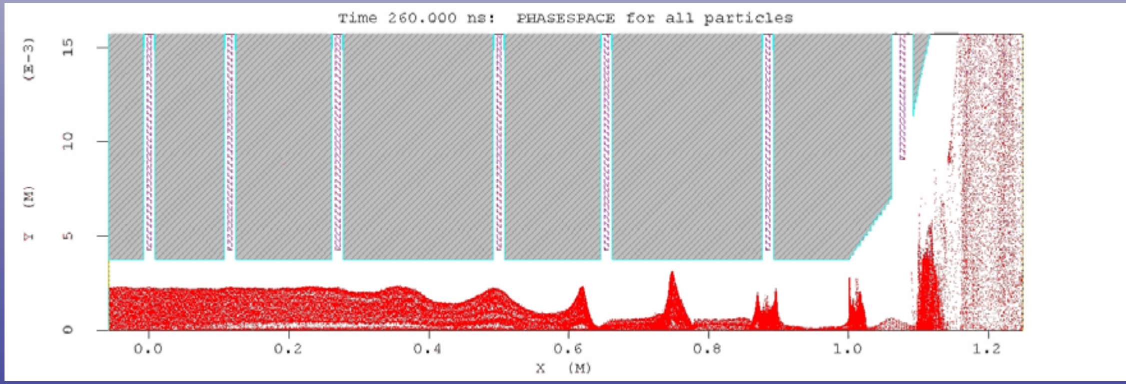
Data file: 071029_SensSimNo3_thermal.RLB

Start by getting agreement with 1D, 2D and 3D simulations using a sheet beam geometry with a solenoid→ done.



Field profile and 2D MAGIC runs of PCM SBK using 2D MAGNET and a symmetry plane at the y=0 axis.





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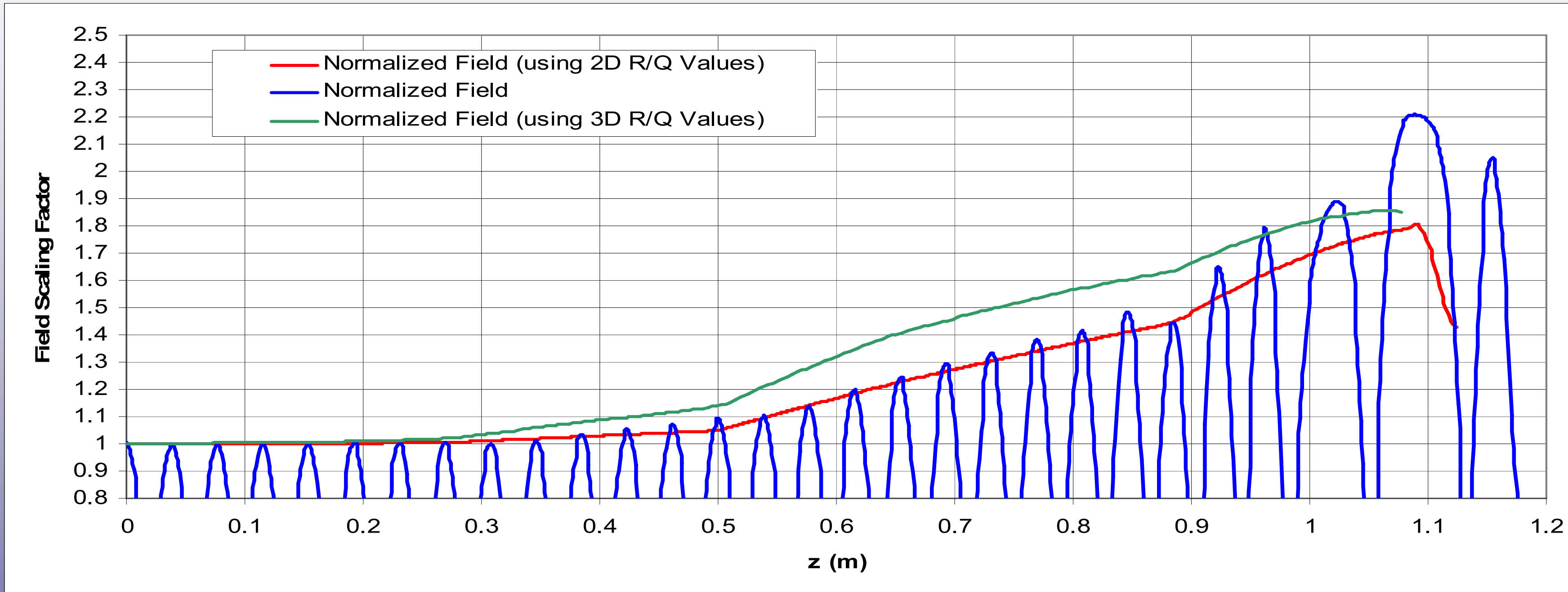
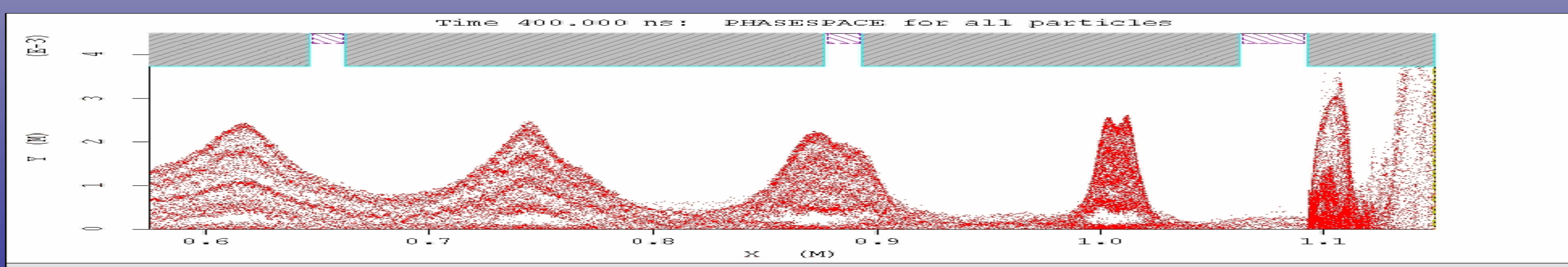
Field ramp and beam of 3D MAGIC runs using 3D MAGNET and a symmetry plane at the y=0 axis.





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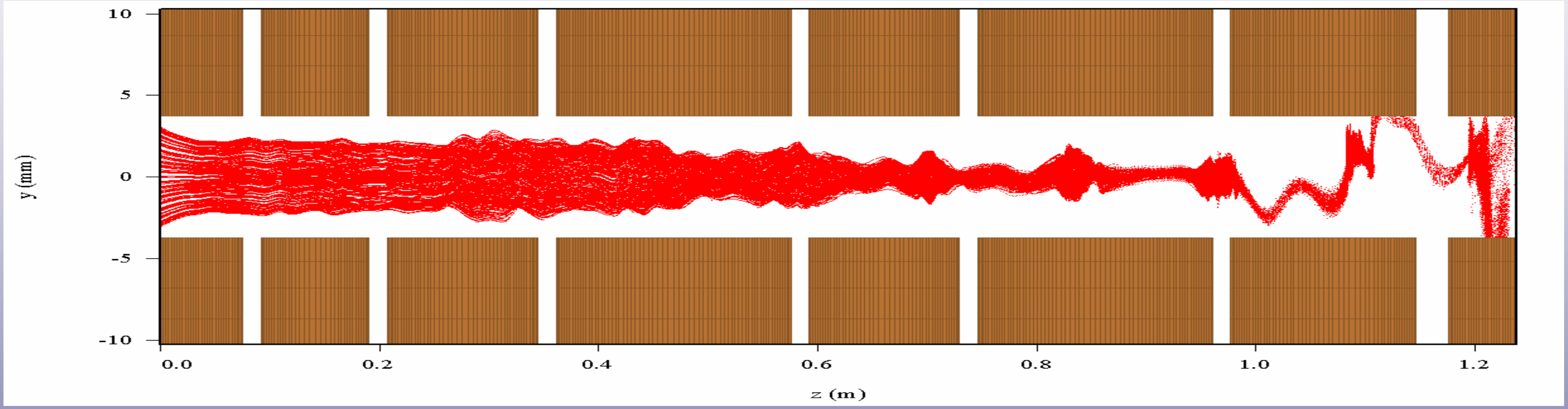
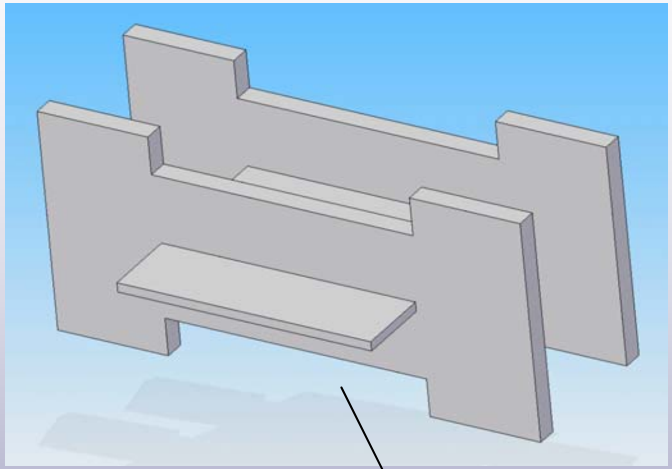
Removing the symmetry plane and beam symmetry is broken. This caused a slight detour of the original design (alter B and drift tube size).

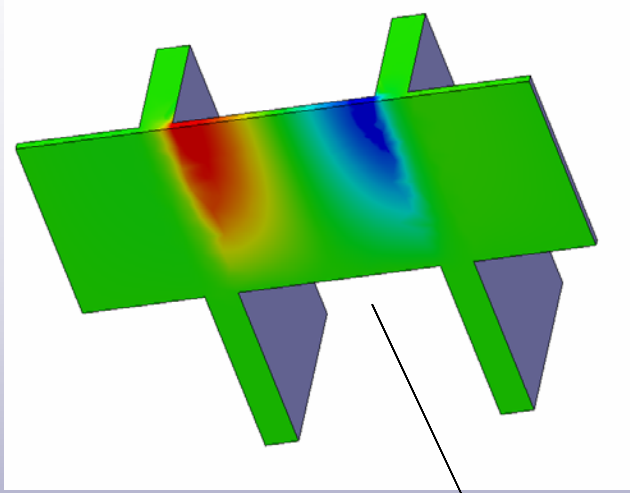


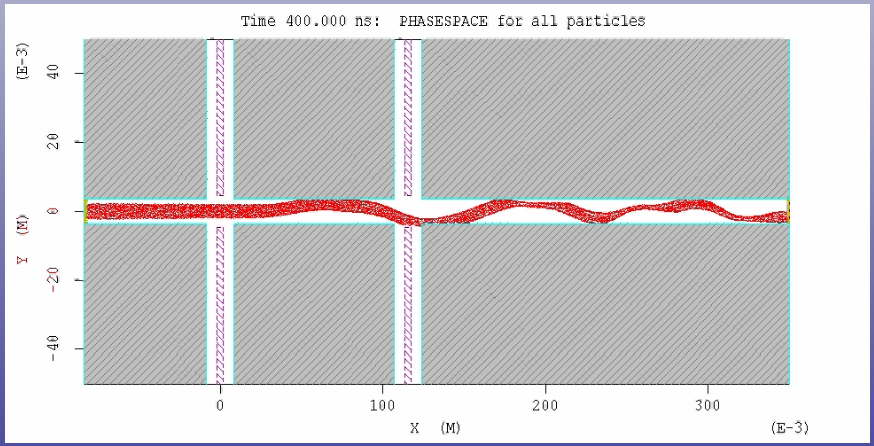
Some Theoretical analysis has been done for 2-cavity system at lower current, see

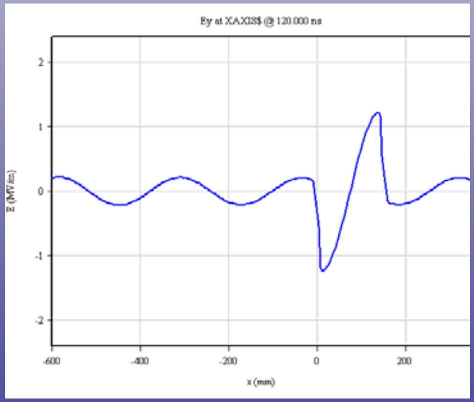
Friday 8:30-1230 poster session (FR5RFP082) K.L.F Bane et al

The frequency of the trapped mode is a function of cavity spacing and only lightly couples to the cavities. The Q has to be < ~30 for no oscillations to form.









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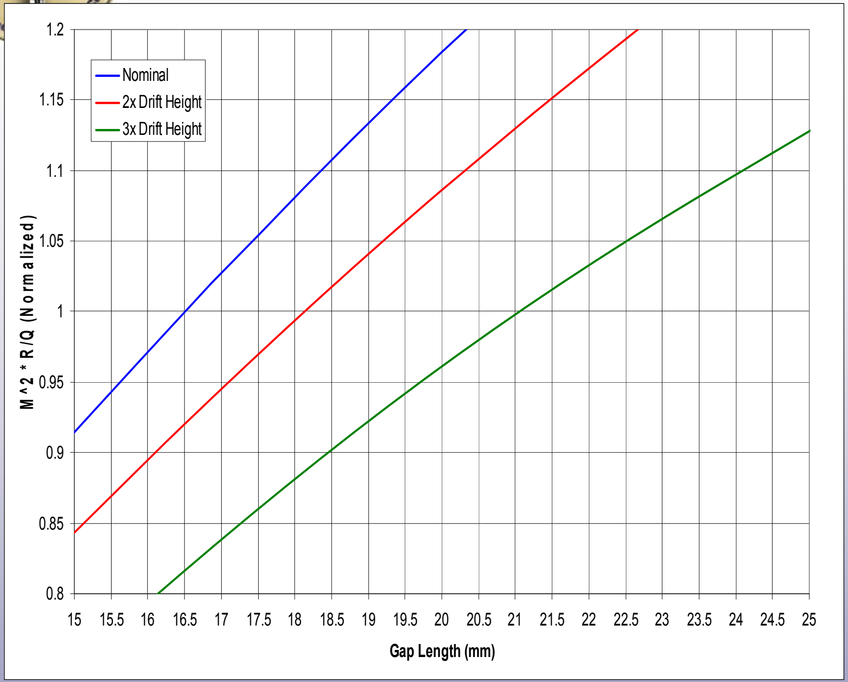
Practical Mitigation of the TE Mode

- Increase confinement field
  - Solenoid works at low fields
  - PCM more difficult, has transport bands
- Increase drift tube
  - PCM more difficult
  - Spoils the rf coupling at some point

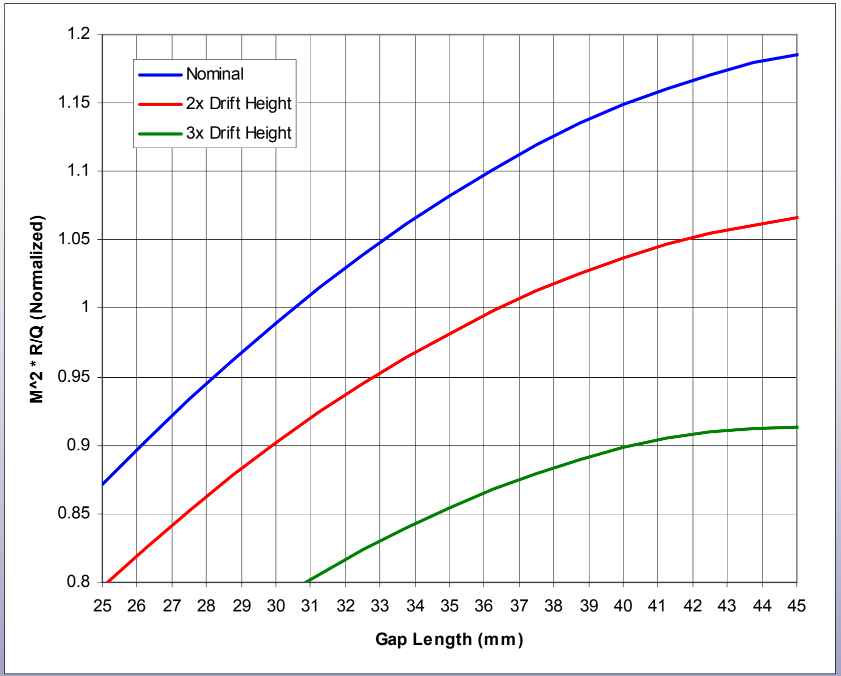
Combine

- **Add** loss or chokes
  - Tail chase (may not eliminate all modes)

Make sure the rf design is still valid!



Nominal Cavity Geometry



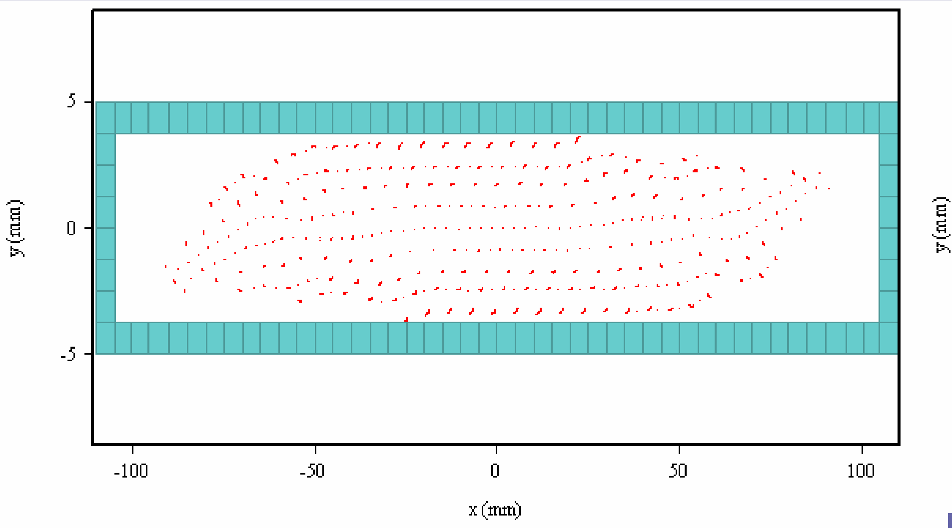
Output Cavity Geometry

To maintain M^2 * R/Q ...				
Nominal Cavity	Drift Height	Gap Width (mm)	M	R/Q (Normalized)
	1	16.5	0.958	1
	2	18.2	0.908	1.113164432
	3	21	0.83	1.332216577
Output Cavity		Gap Width (mm)	M	R/Q (Normalized)
	1	30.5	0.898	1
	2	36.5	0.819	1.20222255

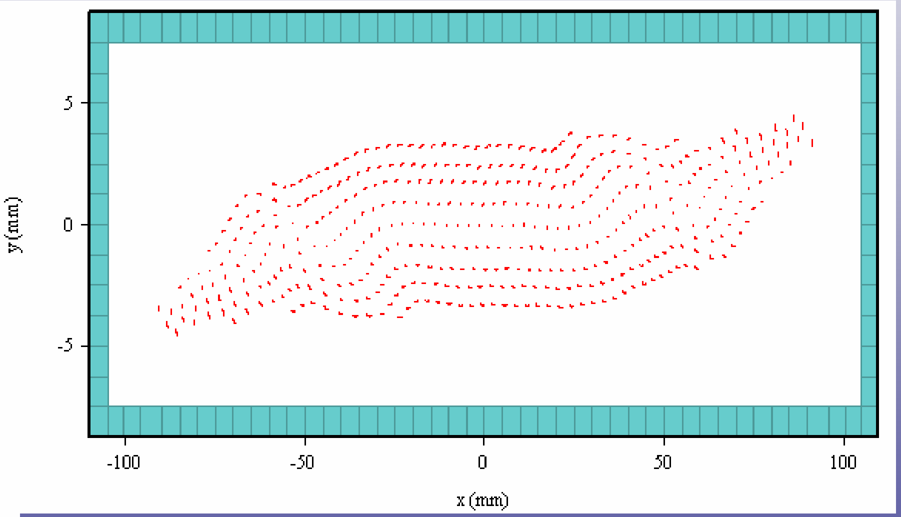
Daryl Sprehn

Backup plan – use a solenoid. Will a 400G Solenoid Beam Transport down to the output cavity plane at 85cm without doing anything different? Yes, with a slight tilt.

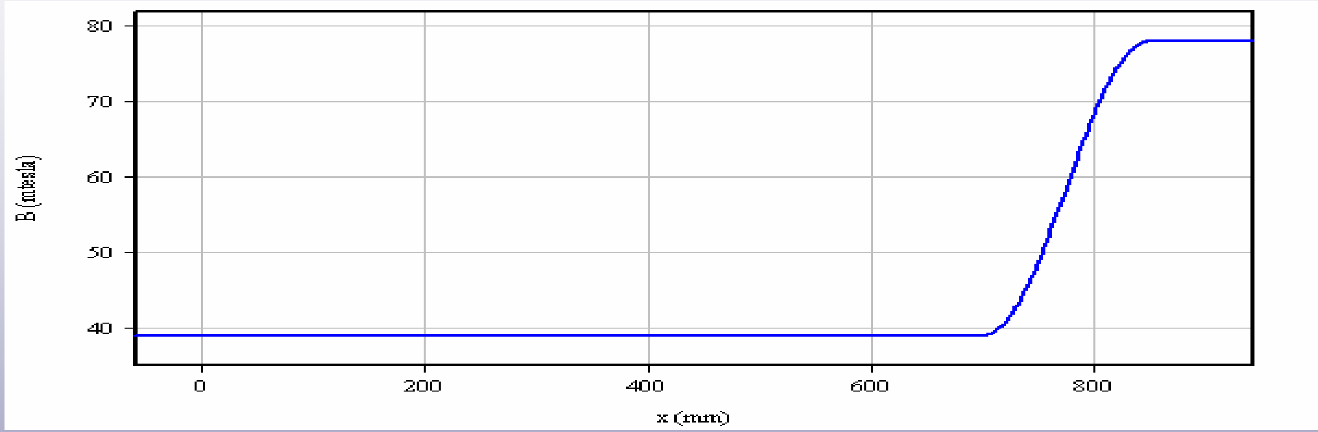
X-y view of 1x Drift

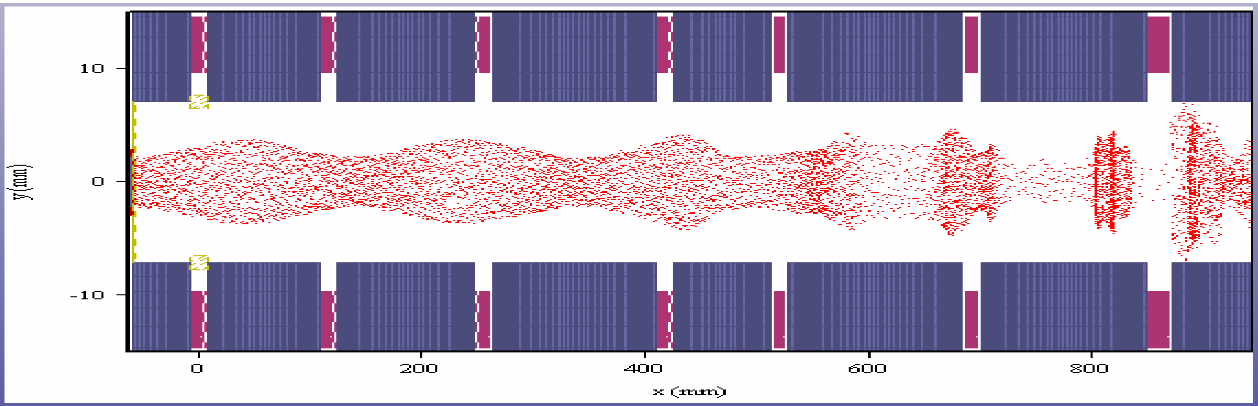


X-y view of 2x Drift



Long 2D 2x drift tube runs for the klystron (B=390G Solenoid) shows stable operation at 10MW





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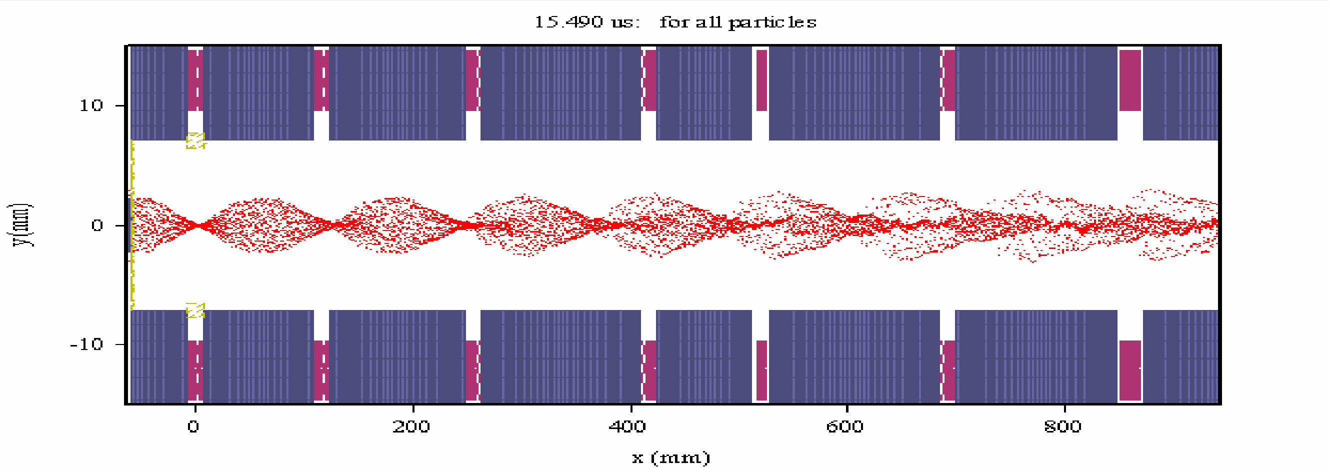
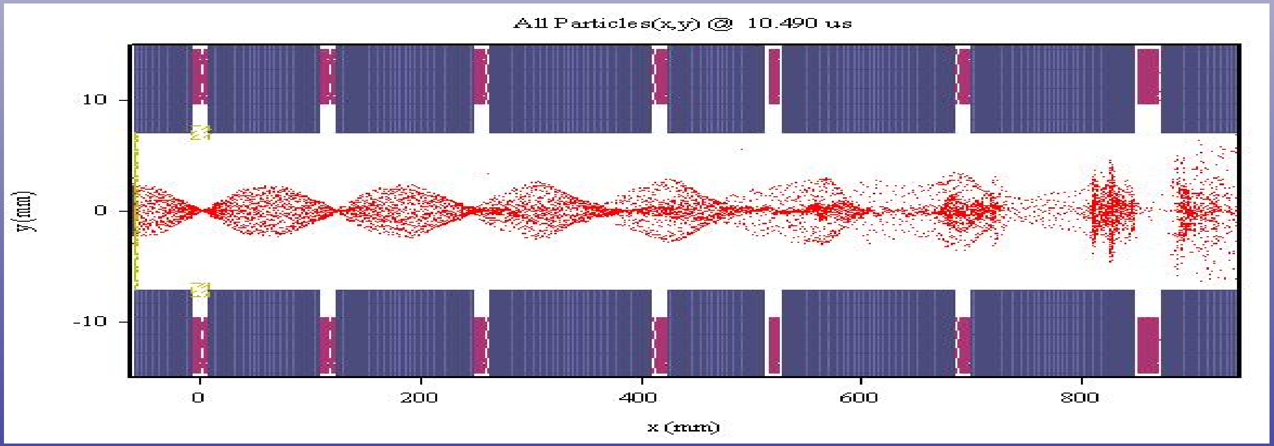
Long 2D 2x drift tube runs for the klystron (B=390G RMS PCM) shows stable operation

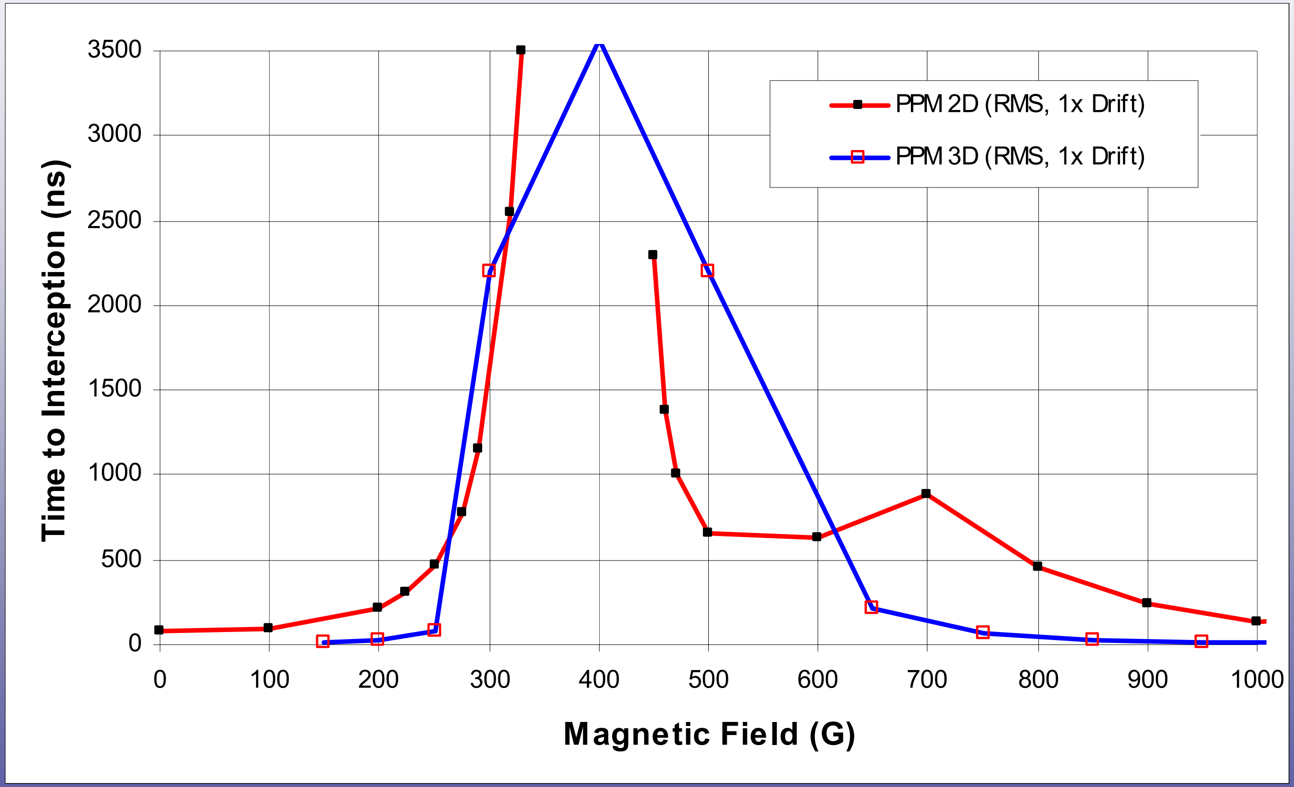
Without RF



With RF, Just shy of 10MW, in process of fine tuning



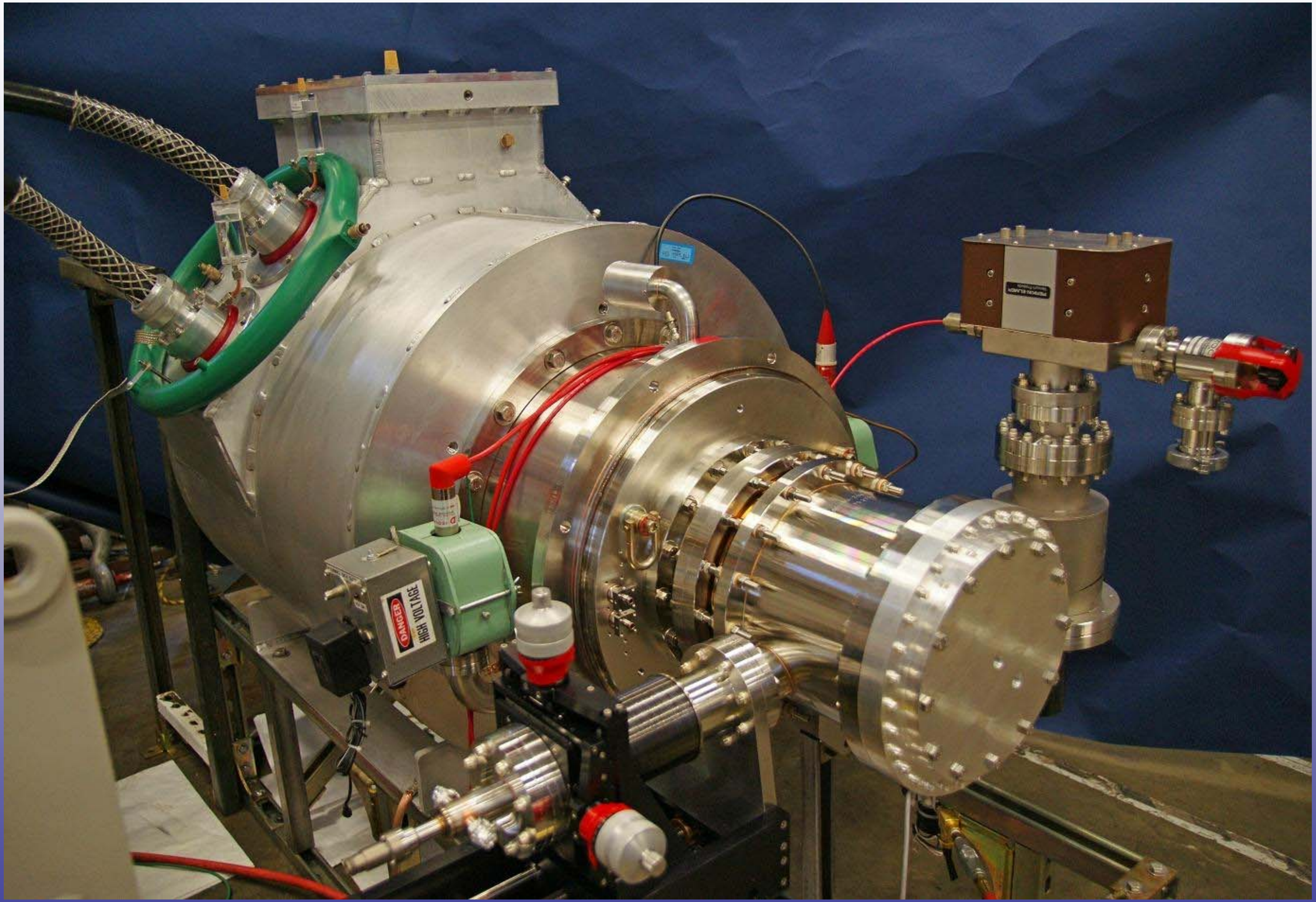
BSD Testing – Alteration of original plan to validate latest TE mode interception data for a 2-cavity system



Point – much easier to build now than solenoid, many parts in house, keeps plan on track

Klystron/Microwave Department Stanford Linear Accelerator Center

BSD test to begin Monday, May 11



Summary

- Challenges - **Everything is 3D!**
  - Good 1, 2 & 3D code agreement
  - BSD testing this Monday
  - 2-Cavity PCM transport BSD test coming next

- Plug compatible alternative for ILC source
  - PCM preference, solenoid backup
  - TE mode: increase drift tube and field
  - Design meets spec, now need to build it