SCRF Research at JAI@RHUL

(John Adams Institute at Royal Holloway, University of London)

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Monday, 29th March 2010

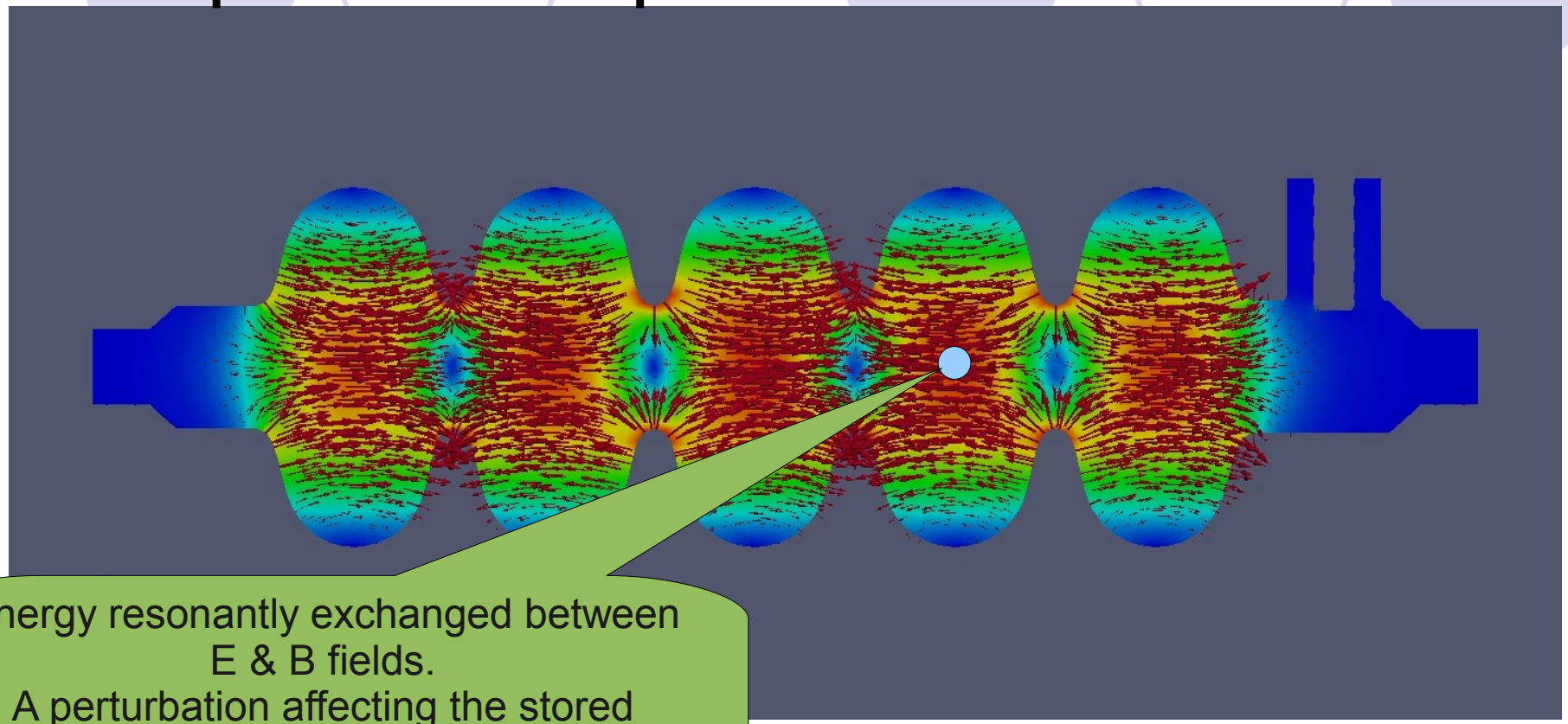
Overview of presentation

- Research plans
  - Physical measurements
    - e.g. bead-pull
  - Simulations
    - e.g. intra-cavity coupling
  - Beam measurements
    - e.g. HOM-based diagnostics
- Available resources
  - People
  - Infrastructure
  - Software

Current plans (1)

- Physical measurements
  - Bead-pull facility
    - Cavity prototypes
    - Investigations of dangerous modes
    - Field profile, flatness, coupling, ...
- “Large scale” simulations
  - Intra-cavity mode coupling
  - Multipacting (fundamental/HOM coupler)
  - Intra-cavity field emission

Bead-pull technique



Energy resonantly exchanged between
E & B fields.
A perturbation affecting the stored
energy
will therefore alter the frequency.

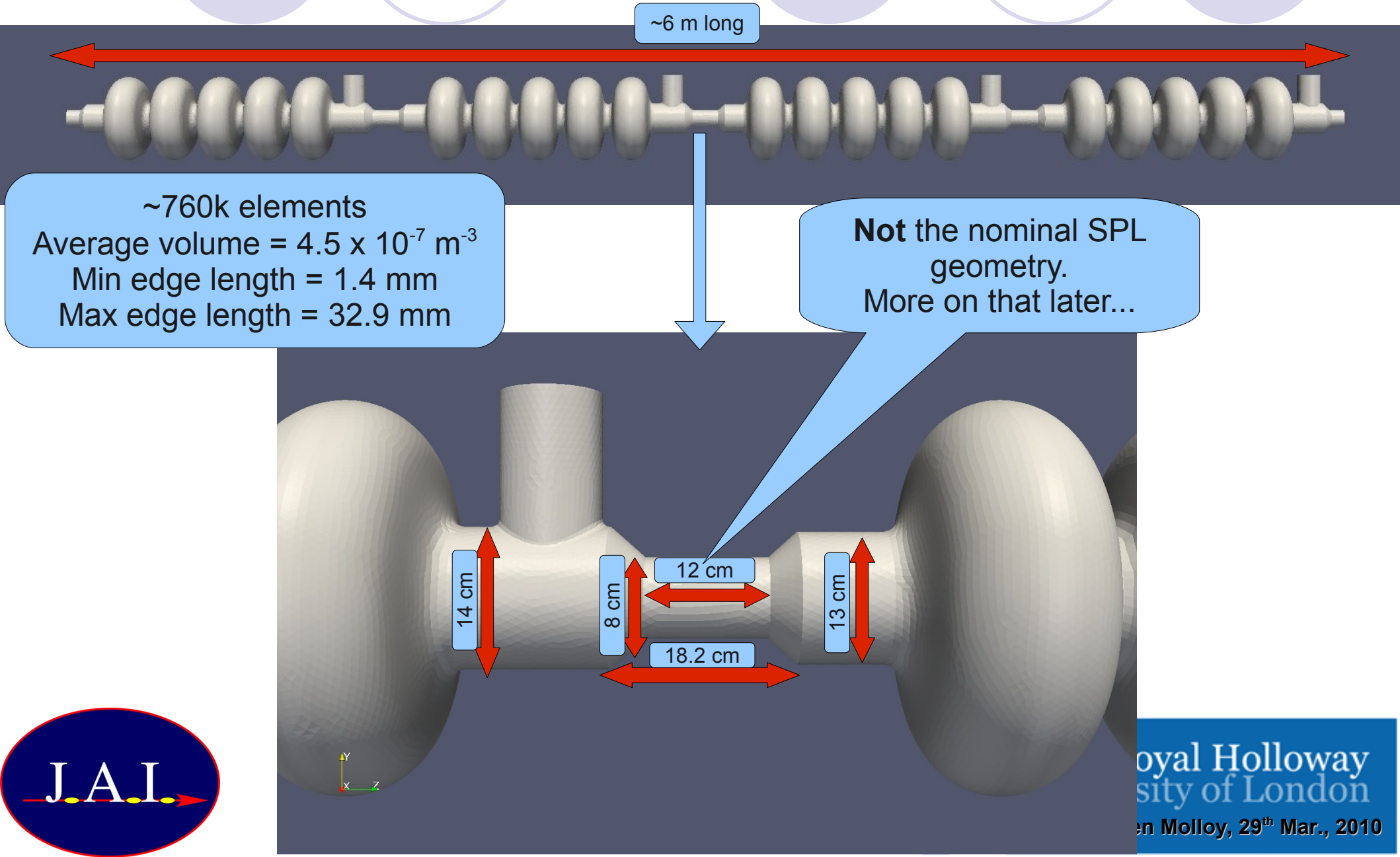
$$\left(\frac{\Delta f}{f}\right)=\left(\frac{k}{4U}\right)\iint\left(\mu H(x,y)^2-\epsilon E(x,y)^2\right)dx\,dy$$

There are many other ways to perform this calculation, including observation of phase changes, etc.

Software – SLAC's ACE3P codes

	Module Name	Description
Frequency Domain	Omega3P	Eigen-solver for resonant modes
	S3P	S-Parameters
Time Domain	Pic3P	PIC code for space-charge dominated devices
	Track3P	Particle tracking for multipacting & dark current
Multi-physics	TEM3P	EM, thermal, mechanical

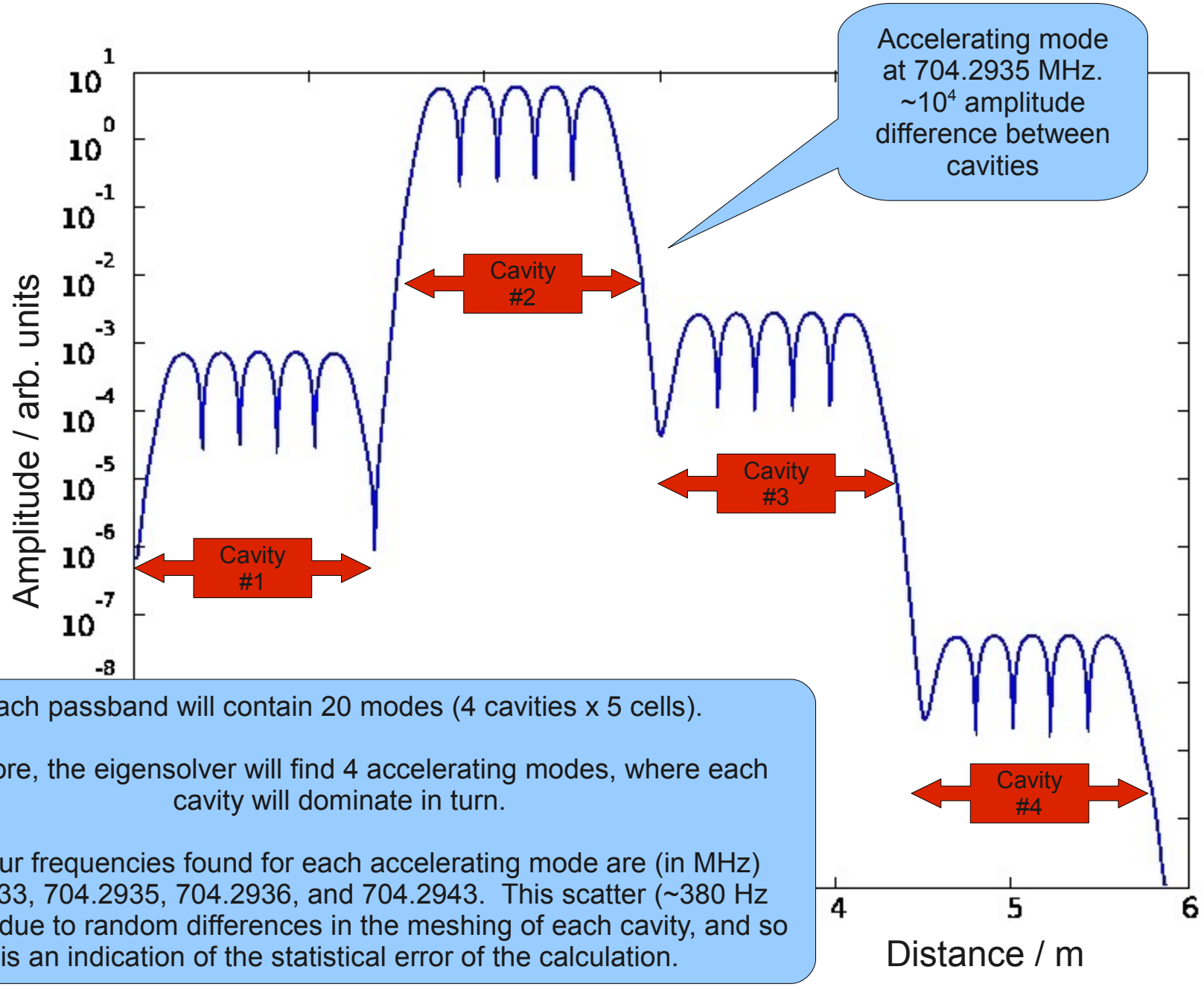
Eigensolve 4 full cavities



Intra-cavity coupling

- Each cavity mode will be found four times
  - One for each cavity
  - A single cavity will dominate each mode, however the evanescent field allows coupling.
    - Beam → Field coupling in one cavity will excite fields in all others.
  - Expect coupling to increase (non-trivially) with frequency
- Extract intra-cavity coupling from simulation
  - Coupling defined as ratio of max field in cavity to max field in cryomodule
    - Therefore, for the dominant cavity, coupling = 1!

Eigenmodes exist in **all** cavities

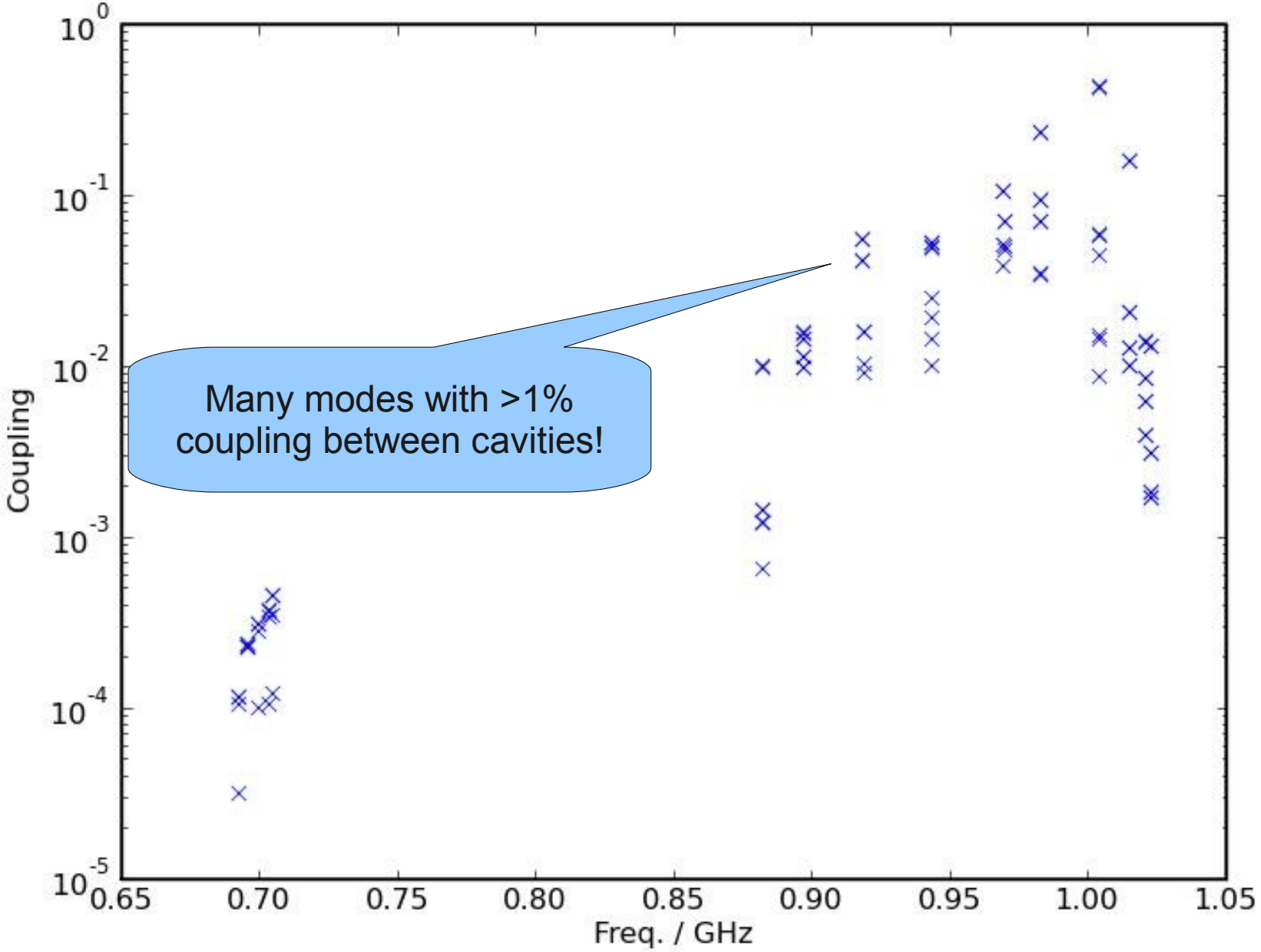


Each passband will contain 20 modes (4 cavities x 5 cells).

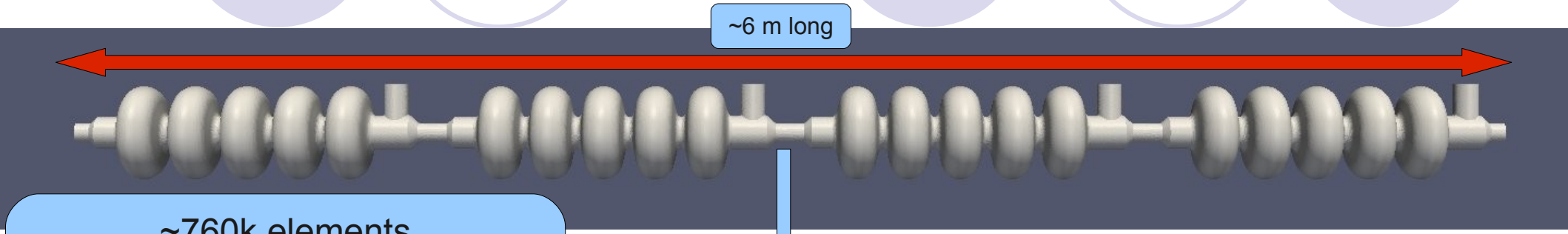
Therefore, the eigensolver will find 4 accelerating modes, where each cavity will dominate in turn.

The four frequencies found for each accelerating mode are (in MHz) 704.2933, 704.2935, 704.2936, and 704.2943. This scatter (~380 Hz RMS) is due to random differences in the meshing of each cavity, and so is an indication of the statistical error of the calculation.

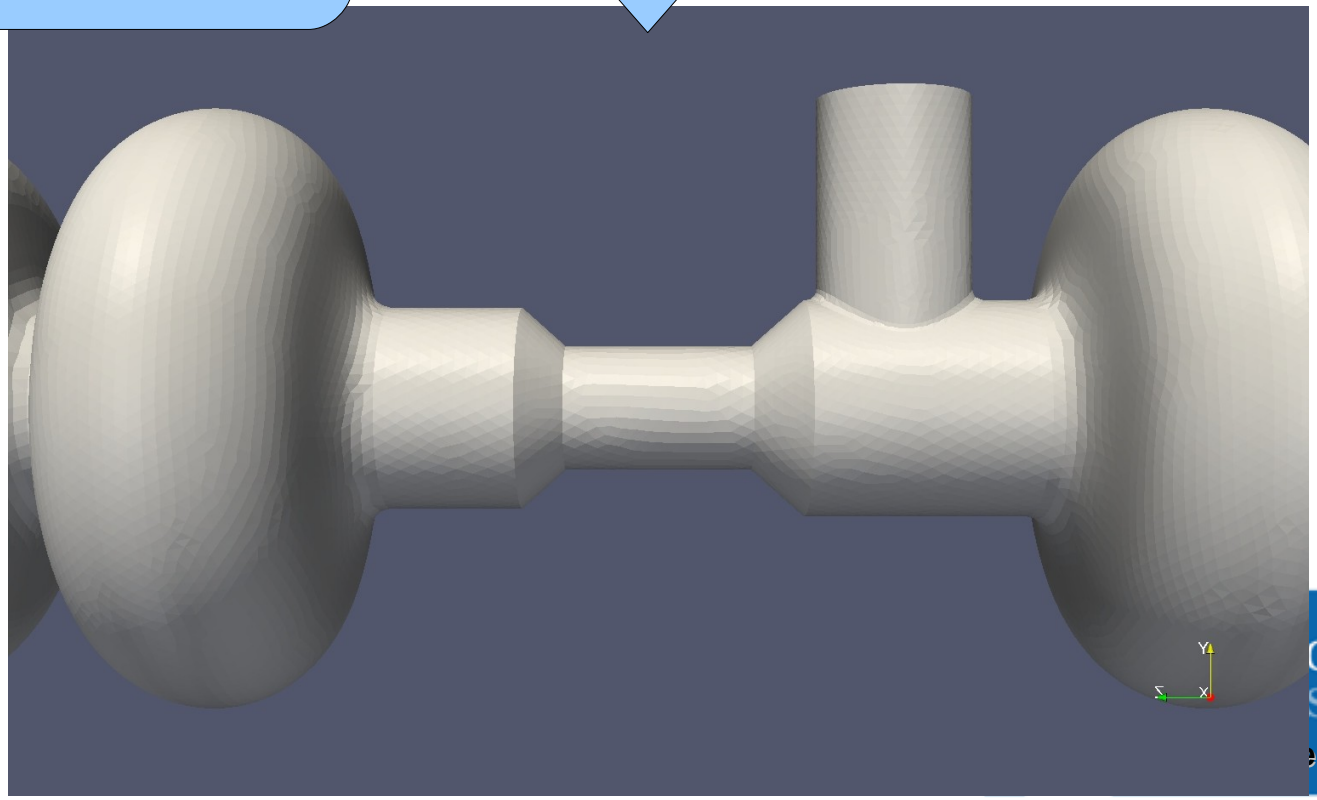
Coupling – 1st five passbands



Eigensolve 4 full cavities



~760k elements
Average volume = 4.5 x 10^{-7} m^{-3}
Min edge length = 1.4 mm
Max edge length = 32.9 mm



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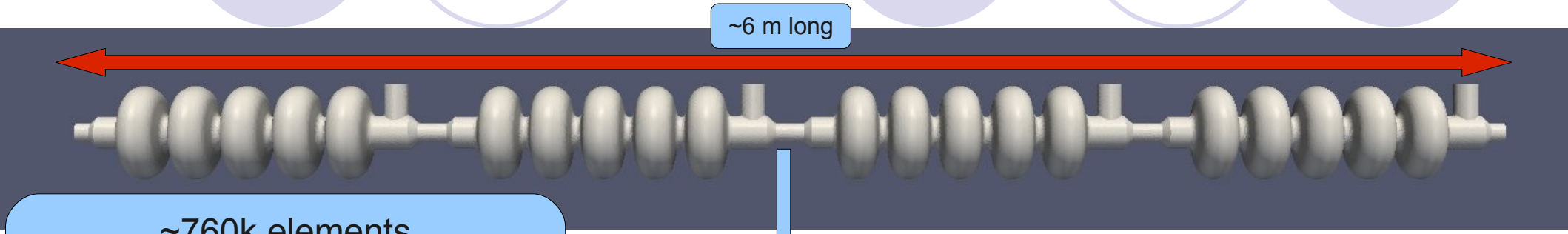

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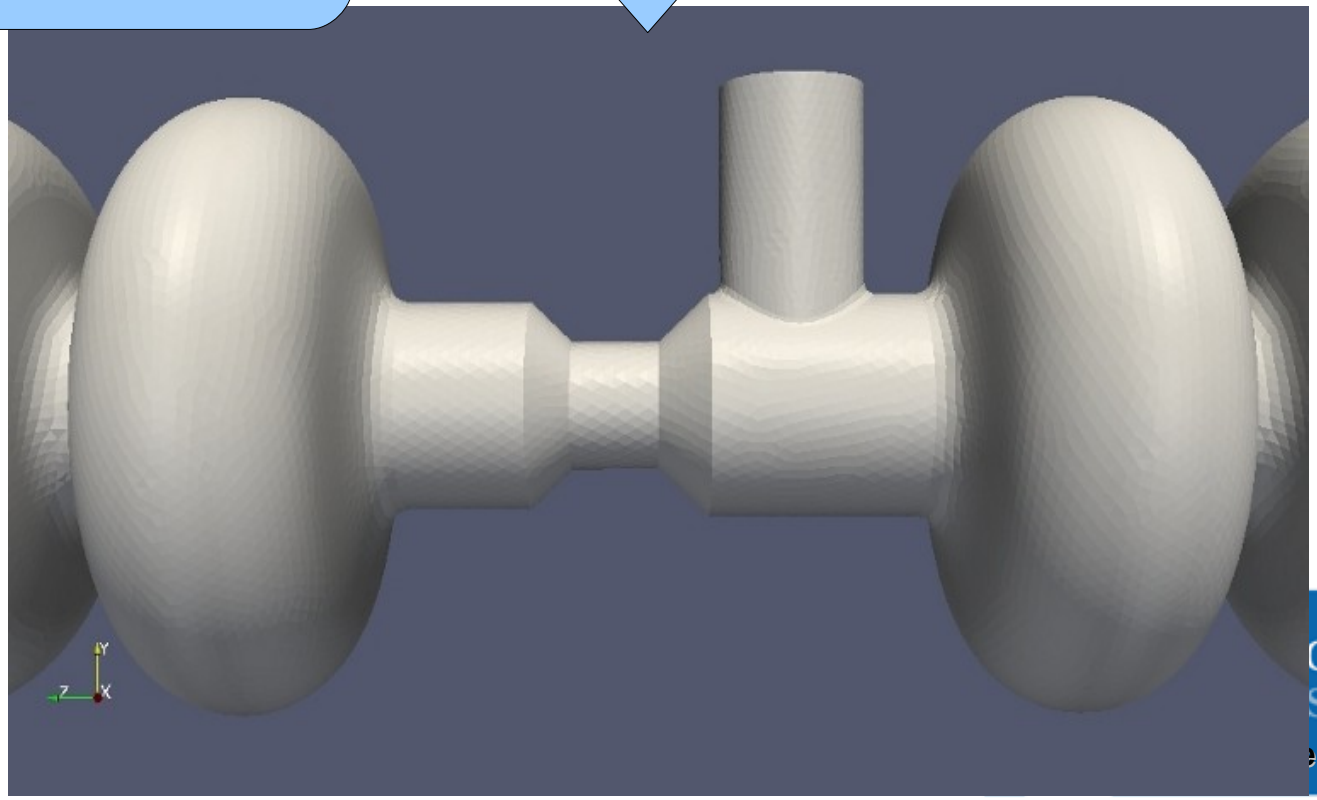

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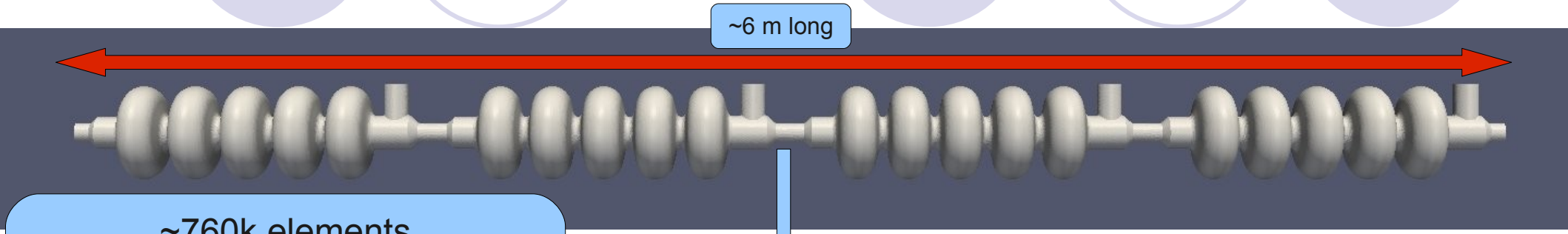

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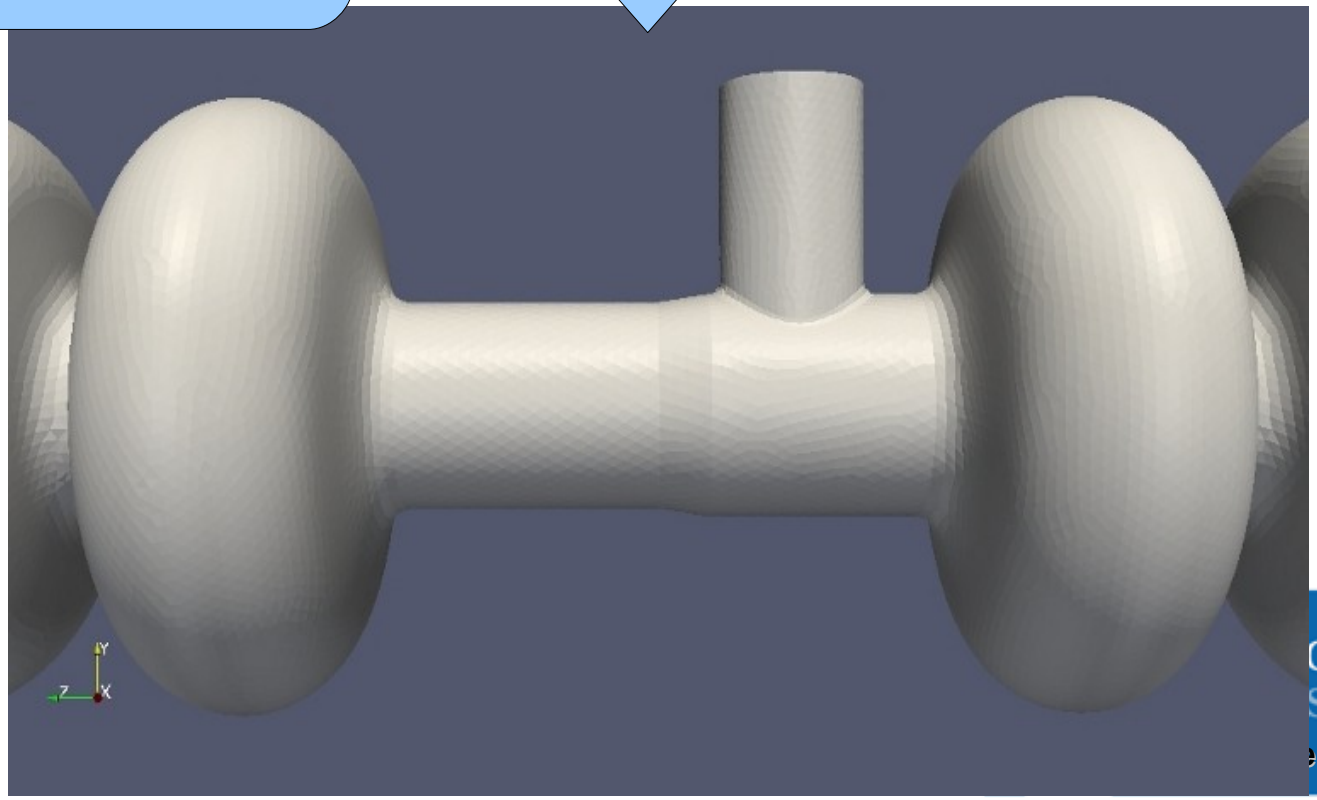
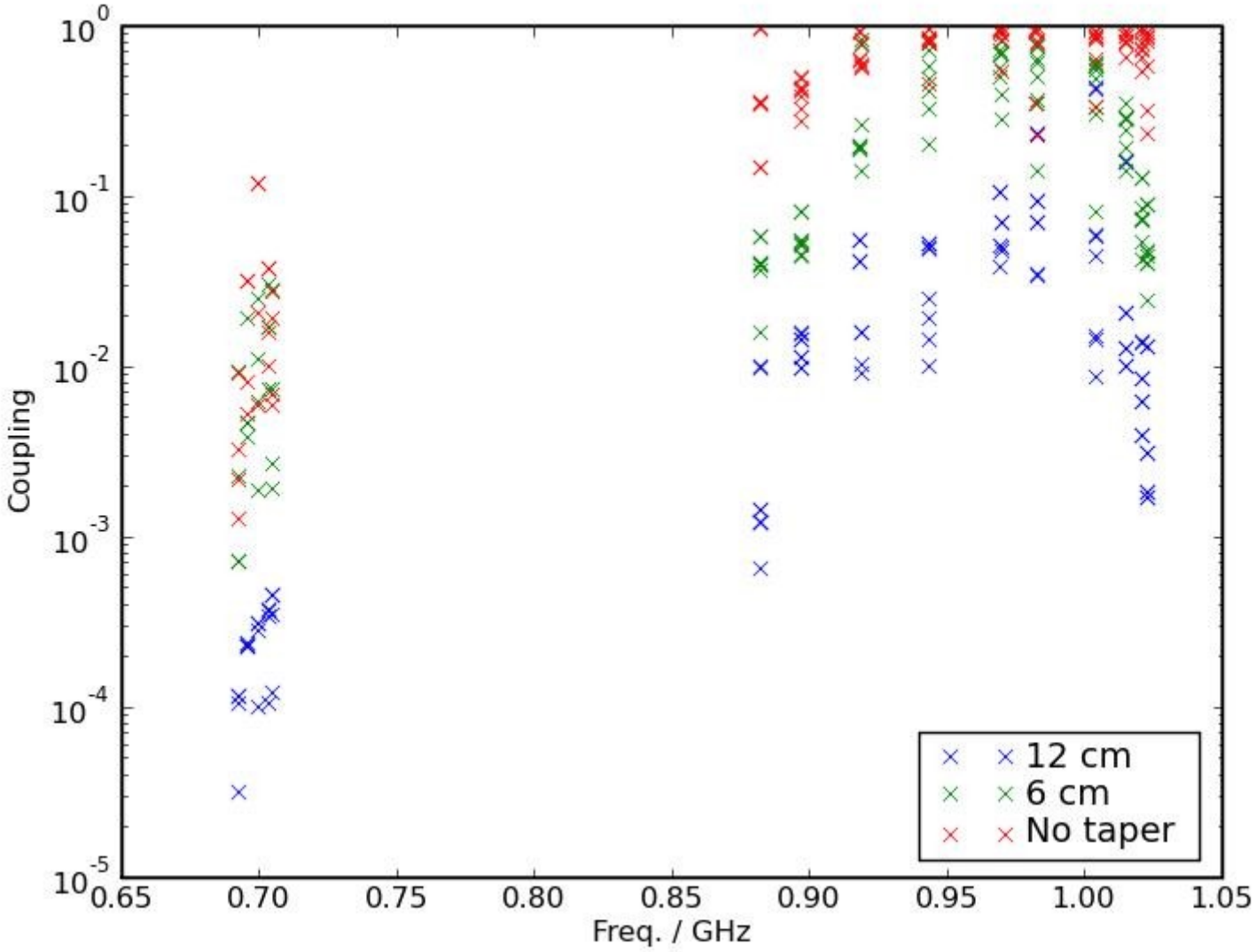


Intra-cavity coupling



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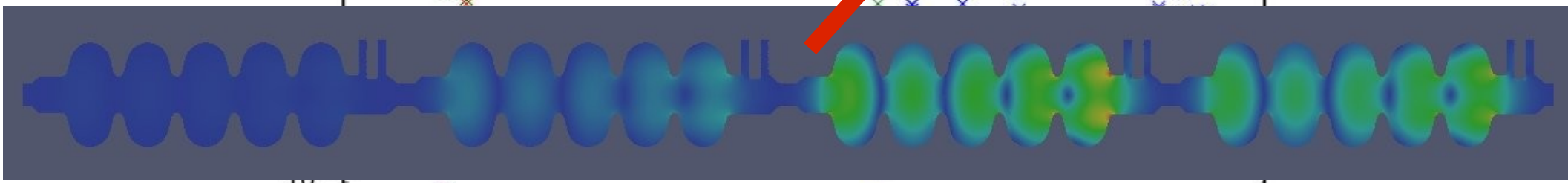


Current plans (2)

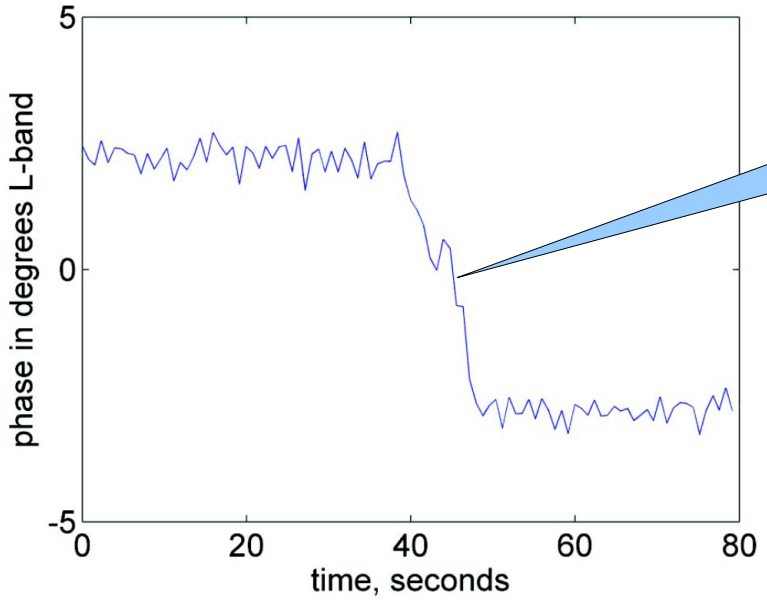
- HOM diagnostics
  - Builds on my postdoc research at SLAC
- HOMS destructive and to be avoided
  - However
  - High resolution diagnostic capabilities
    - 5D beam position
    - (Everything except for momentum)
  - Internal cryomodule alignment
  - Cavity deformations

Transverse Diagnostics

- Dipole modes couple to transverse offsets
  - Position **and** angle
  - Each dipole mode has 4 degrees of freedom
    - Amplitude & phase for two polarisations
    - Calibrate these against 4D beam position
- Installed at FLASH
  - Resolution of ~microns
    - <100 nm should be possible
- Multi-bunch is tricky
  - Finite Q causes bunch-to-bunch overlap
  - Technique developed
    - Needs to be tested

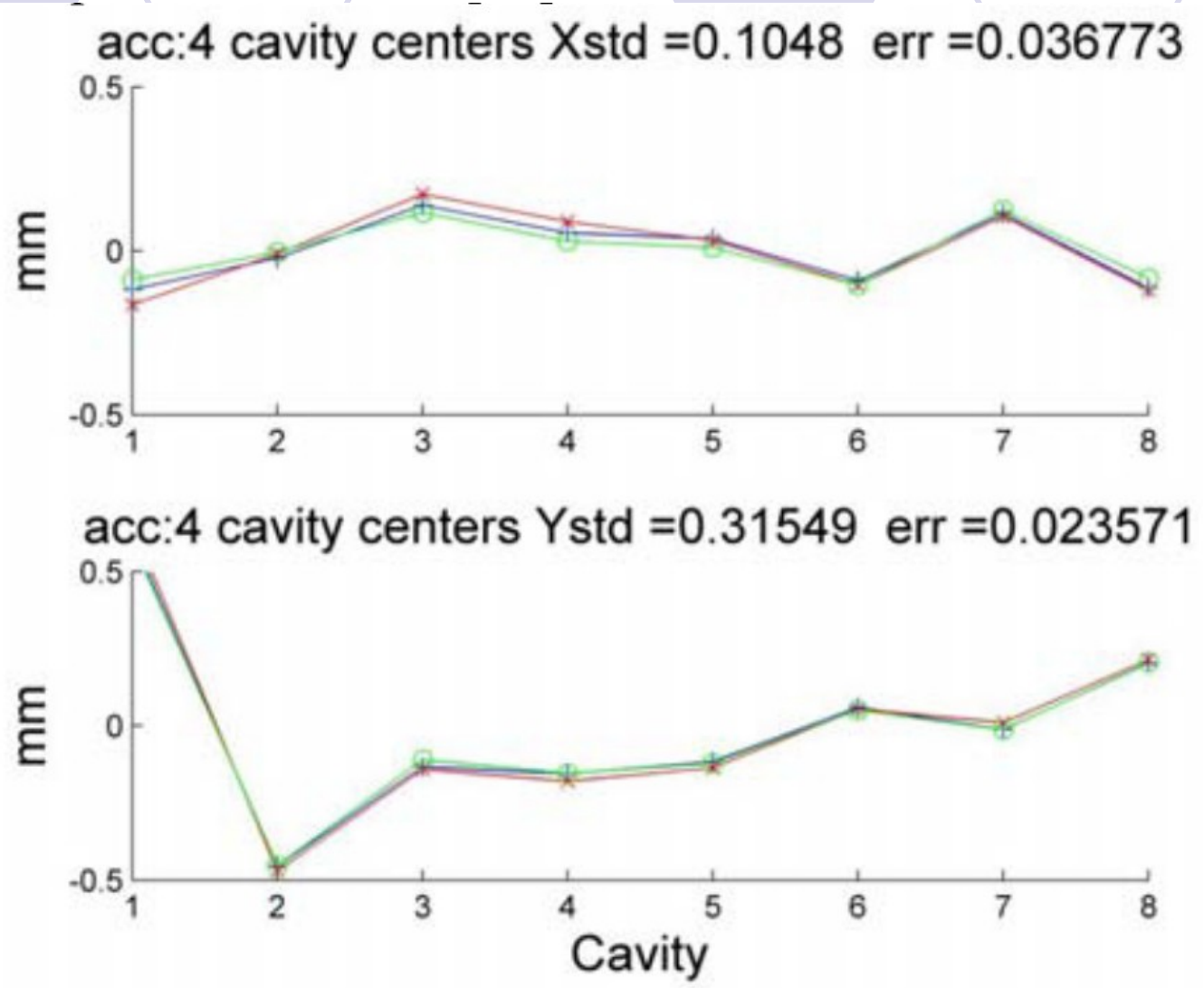
Longitudinal Diagnostics

- Acceleration phase
  - i.e. arrival time of beam wrt to accelerating RF
  - Beam arrival monitors have long term stability issues
    - Cable length drifts with temperature, etc.
- Acc. mode also coupled out HOM port
  - Compare with beam generated monopole



5° phase change from control system

Cavity alignment within cryomodule



Research Staff

- Me!
  - Full time academic
  - Some fraction of my time devoted to this
- Research Assistant
    - Held interviews yesterday!
  - 75% → 100% on this topic
- PhD Student
  - Starts this summer
  - 100% on this topic

Resources

- RF laboratory
  - Digitisers, sources, spectrum analysers, vector network analysers, …
    - ≤18 GHz
  - In discussions with college to extend
    - > doubling the lab's area!
    - Will include a cavity RF measurement space
      - Bead-pull facility
- Simulations
  - NERSC: Franklin → 15th fastest supercomputer in world!
  - 38642 cores
  - 150k CPU.hours reserved for us.
    - Likely to increase

Thanks for listening!