Emittance Exchange at FNPL

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November 28nd, 2006

Overview

- Motivation & Overview
- Planned Experiment
- Present Status
  - Beam line design
  - Beam line simulation
  - TM_{110} RF cavity
- Timeline

Motivation

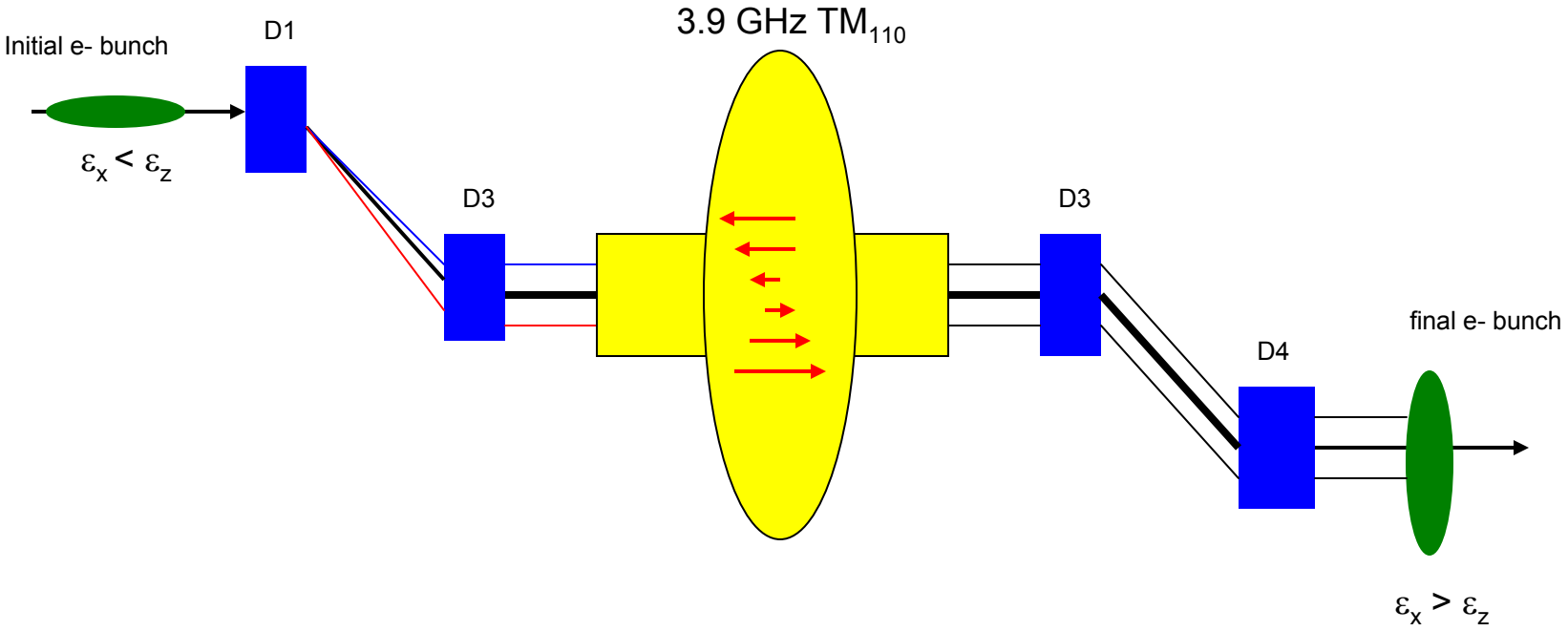
For FEL applications it is desirable to have a small transverse emittance and high brightness. A longitudinal to transverse emittance exchange has been proposed to achieve this goal. *

The A0 Photo Injector wishes to show a proof of principle of the emittance exchange.

* M. Cornacchia, P. Emma, Phys. Rev. ST Accel. Beams 5, 084001 (2002)

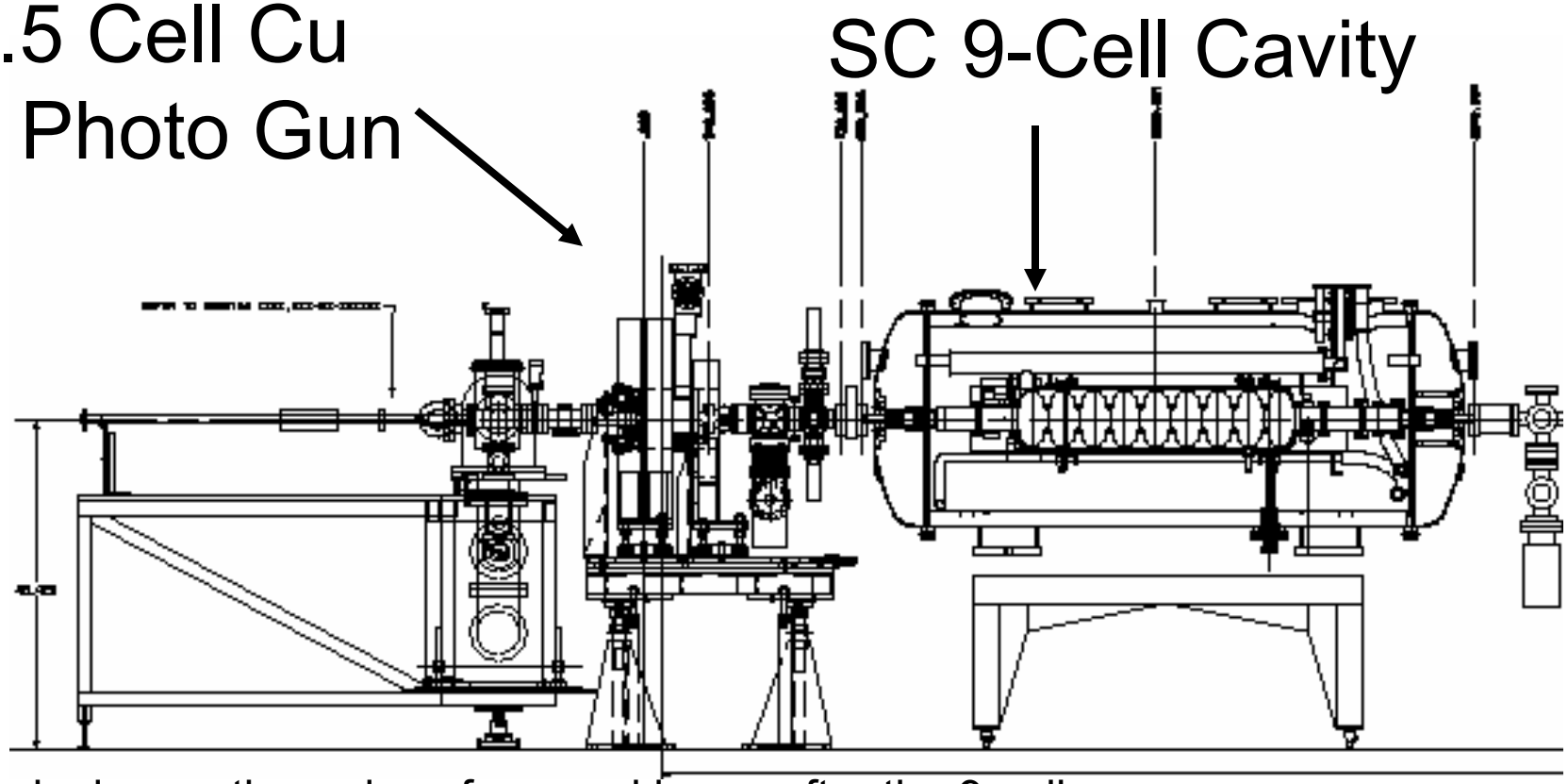
Emittance Exchange

Place a 3.9 GHz TM_{110} cavity between two dog-leg bends to reduce the momentum spread, thereby reducing the longitudinal emittance. This comes at the cost of introducing a transverse betatron amplitude, thus an increase in transverse emittance. A complete longitudinal to transverse emittance exchange should be observed



P. Emma, Z. Huang, K.-J. Kim, P. Piot, Phys. Rev. ST Accel. Beams 9, 100702 (2006)

The A0 PhotoInjector



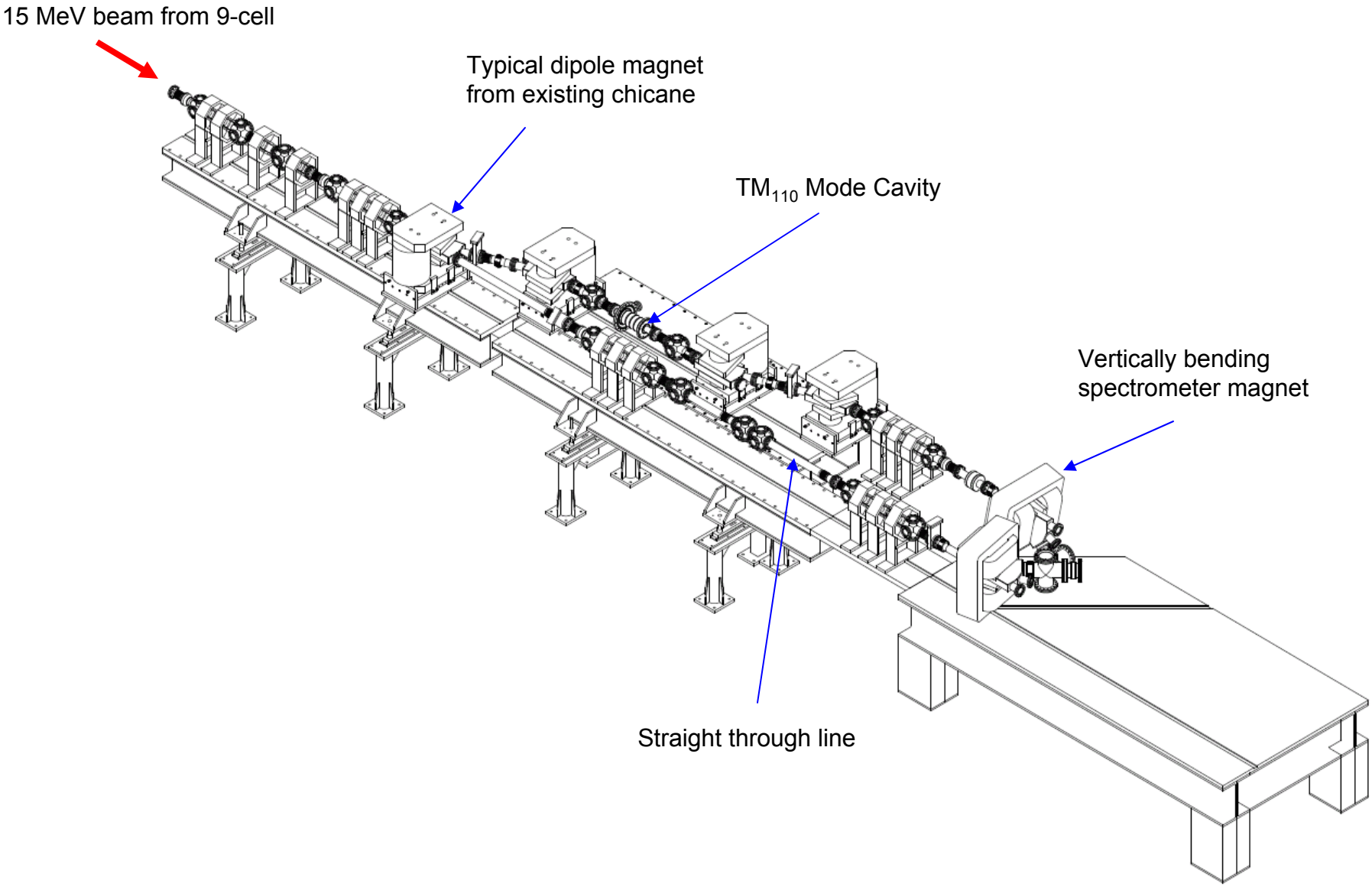
Nominal operating values for round beam after the 9-cell:

1nC/bunch (typically 10 bunches), nominal energy: 15MeV

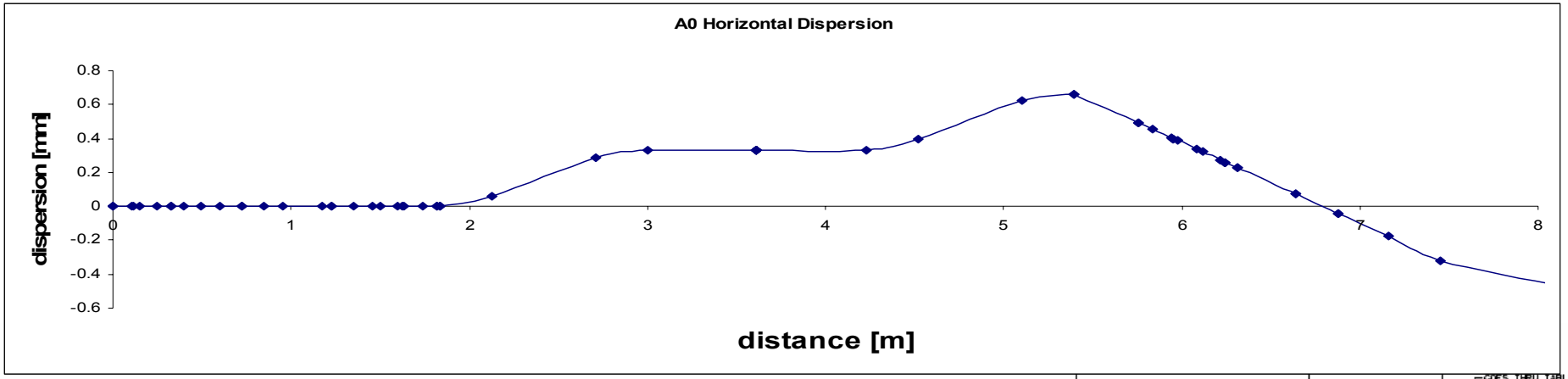
$\varepsilon_{rms\text{-}x}$ & $\varepsilon_{rms\text{-}y}$ ~ 3 mm mrad (measured & from ASTRA)

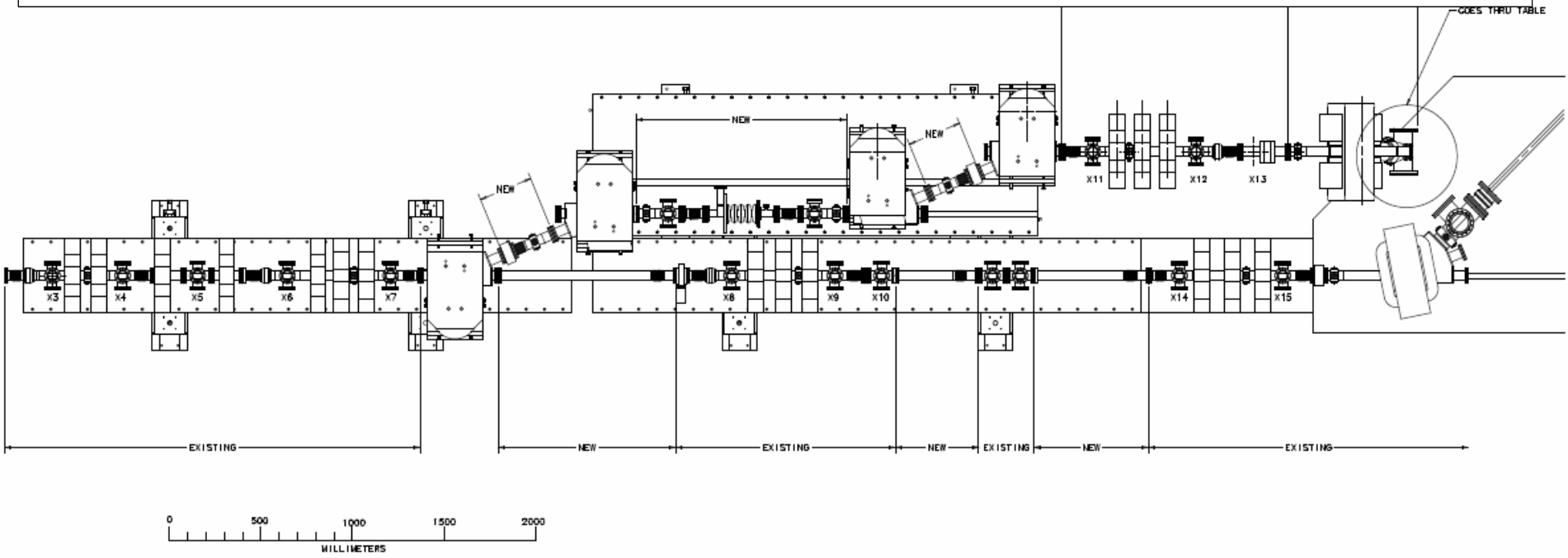
$\varepsilon_{rms\text{-}z}$= 23 mm mrad (from ASTRA)

A0 Beam Line Layout

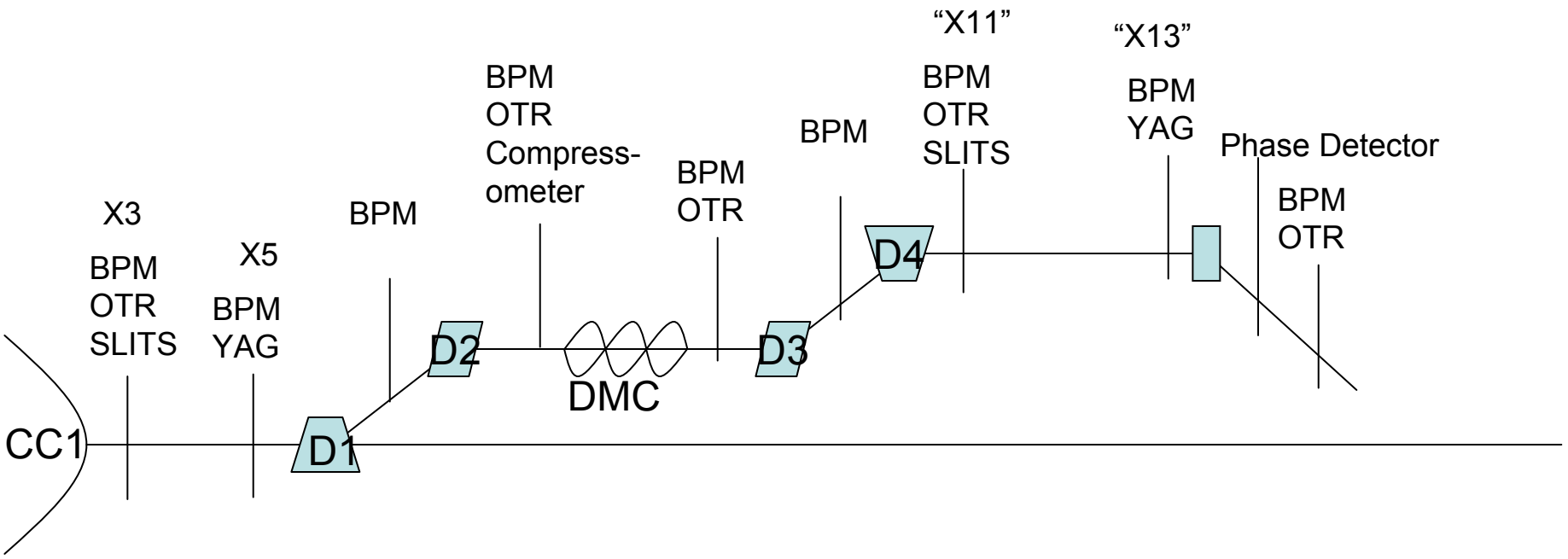


Beam Line Layout

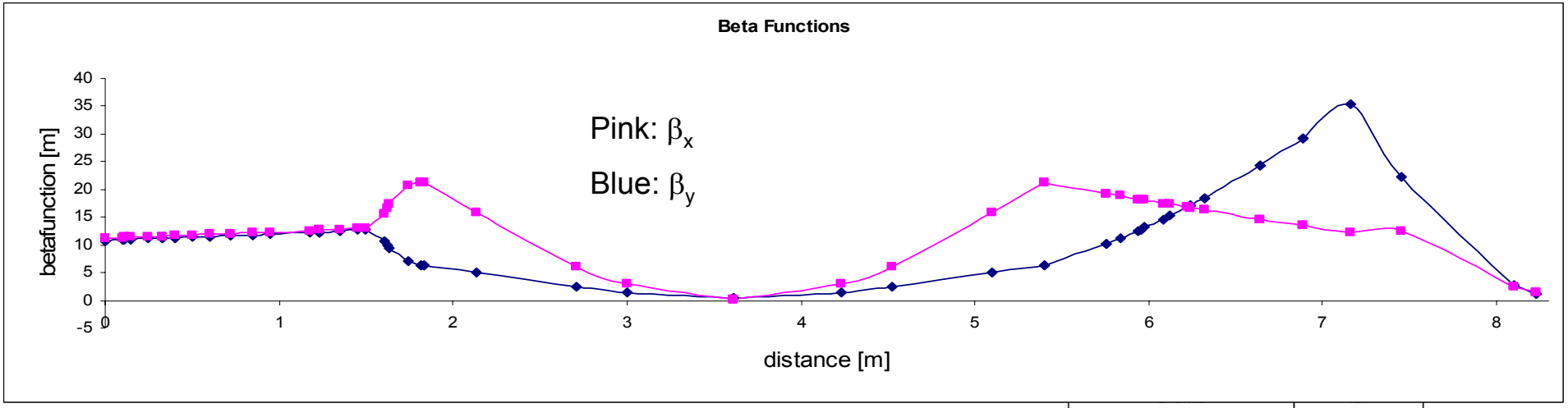


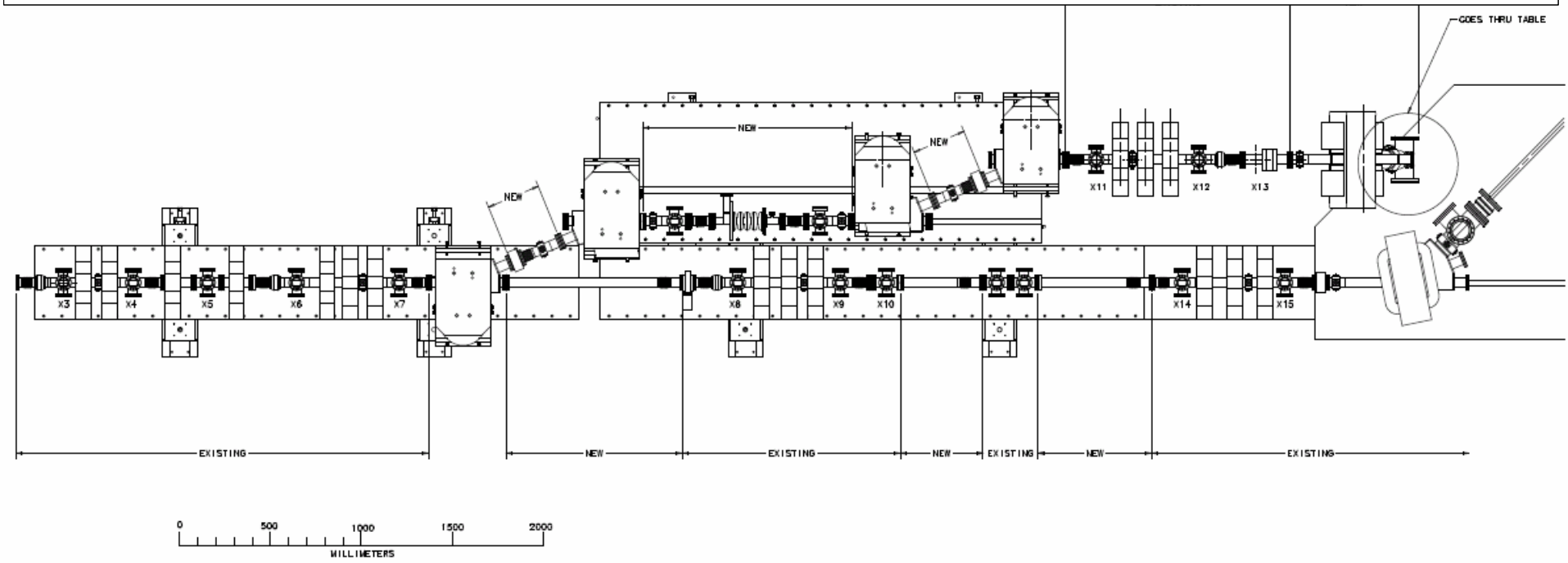


Beam Line Diagnostics



Twiss Parameters

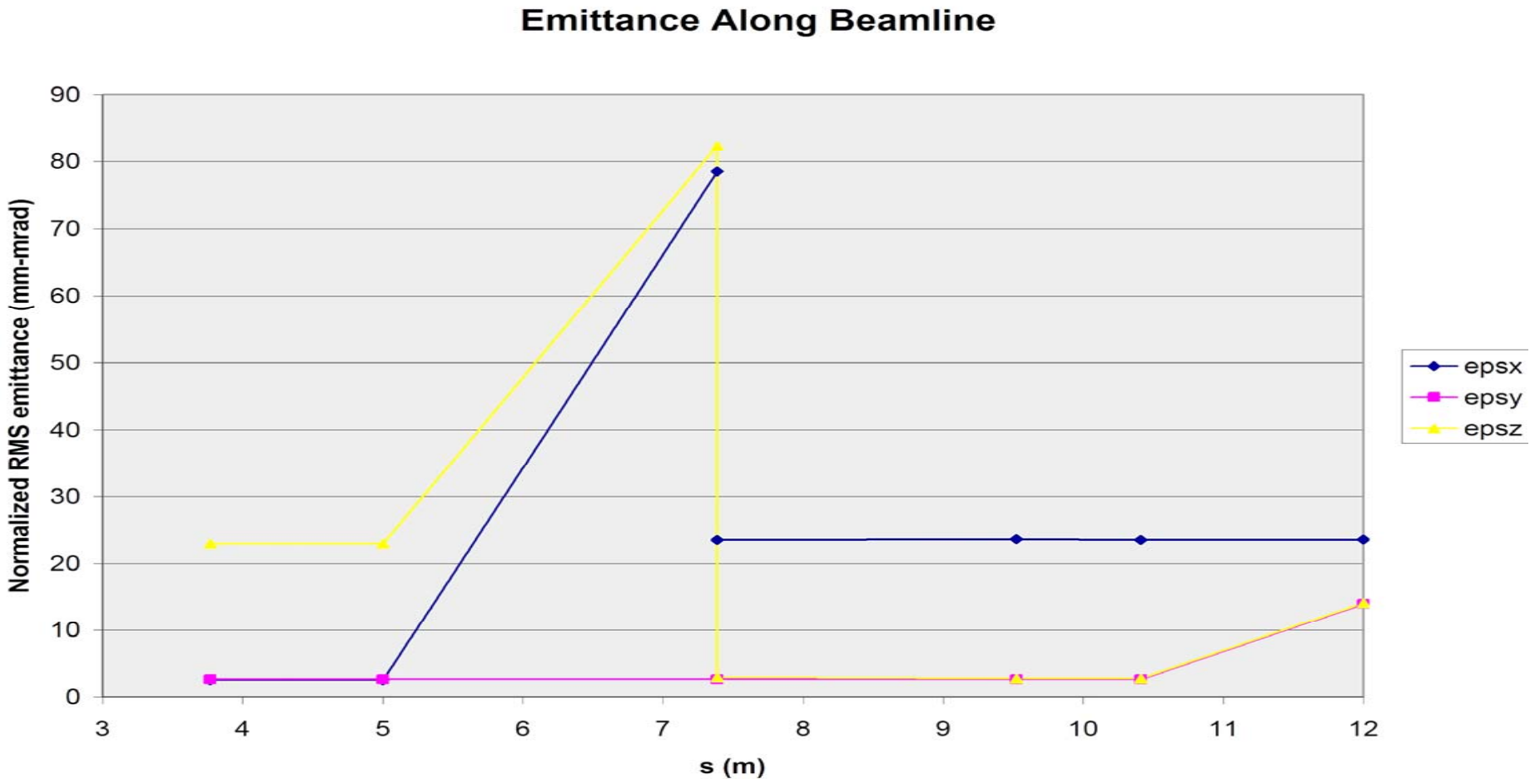




Beam Line Simulations

ASTRA models the beam line from the cathode to the exit of the 9 cell superconducting cavity.

ELEGANT is used from the output of the 9-cell to the dump.



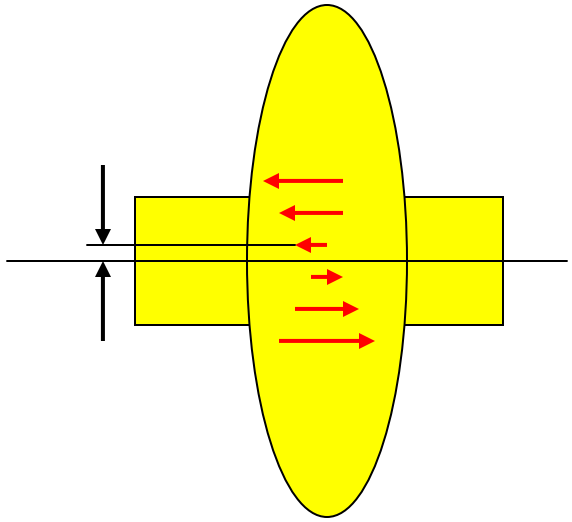
Required off axis Longitudinal E-Field

$$\frac{\Delta E}{E_o} \approx \frac{\Delta p}{p} \qquad \Delta X_{disp} = D\frac{\Delta p}{p}$$

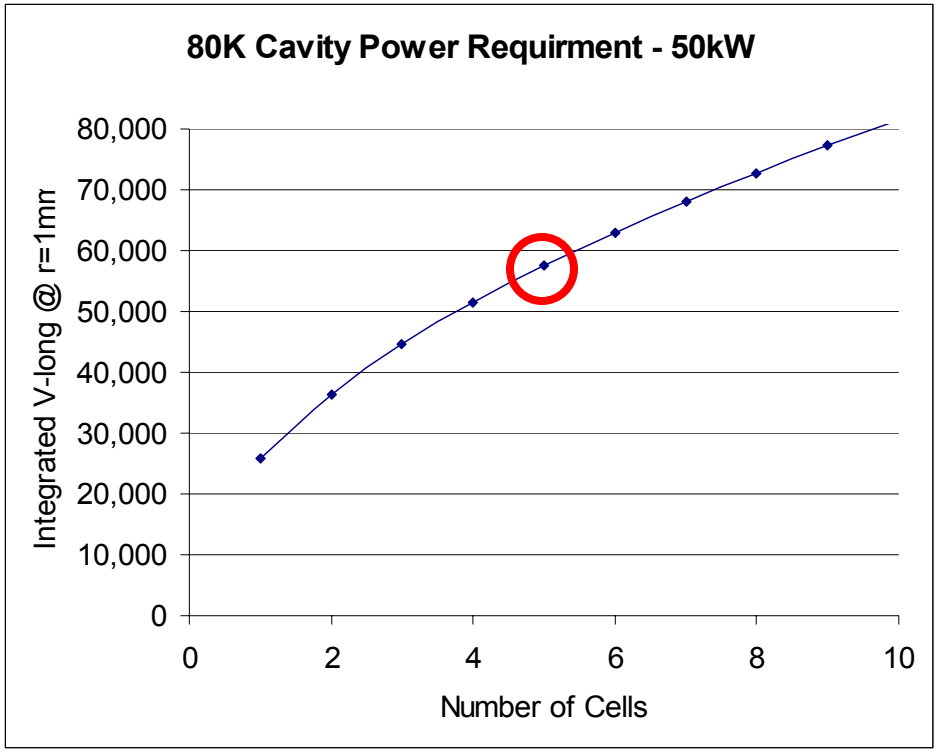
$$\frac{\Delta E}{\Delta x} = \frac{\partial E}{\partial x} = \frac{E_o}{D}$$

Where E_o is 15MeV and D = 0.330m

$$\frac{\partial E}{\partial x} = \frac{15MeV}{0.33m} = 45.5keV/mm$$



3.9 GHz Power Requirements

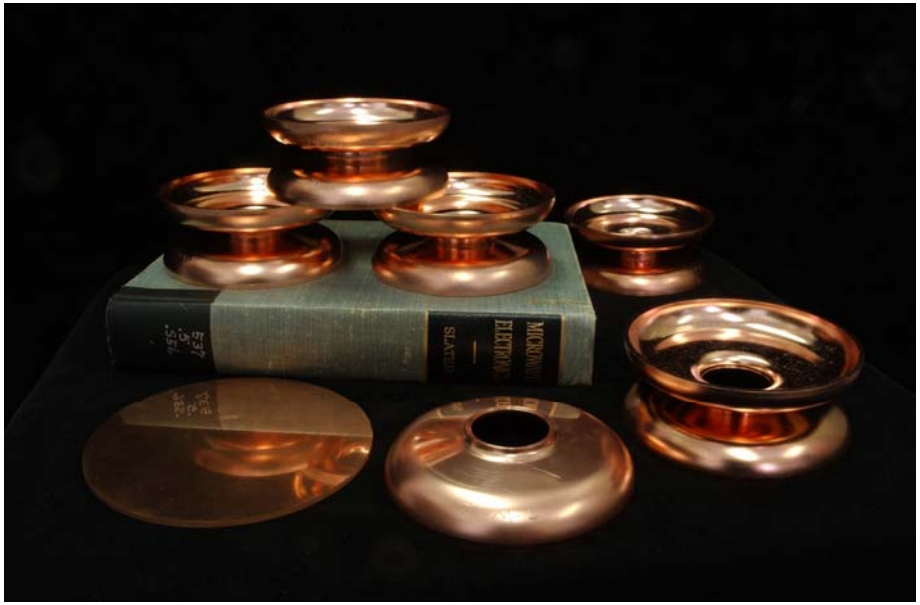


80K Q of 36,000 shows 50 kW is fine

(We will be using an existing 3rd harmonic input coupler)

An 80 kW 3.9 GHz klystron is being installed in A0 for 3rd Harmonic Input Coupler Processing. We will use this for our cavity. Commissioning of the klystron is beginning next week !

TM_{110} Copper Cavity



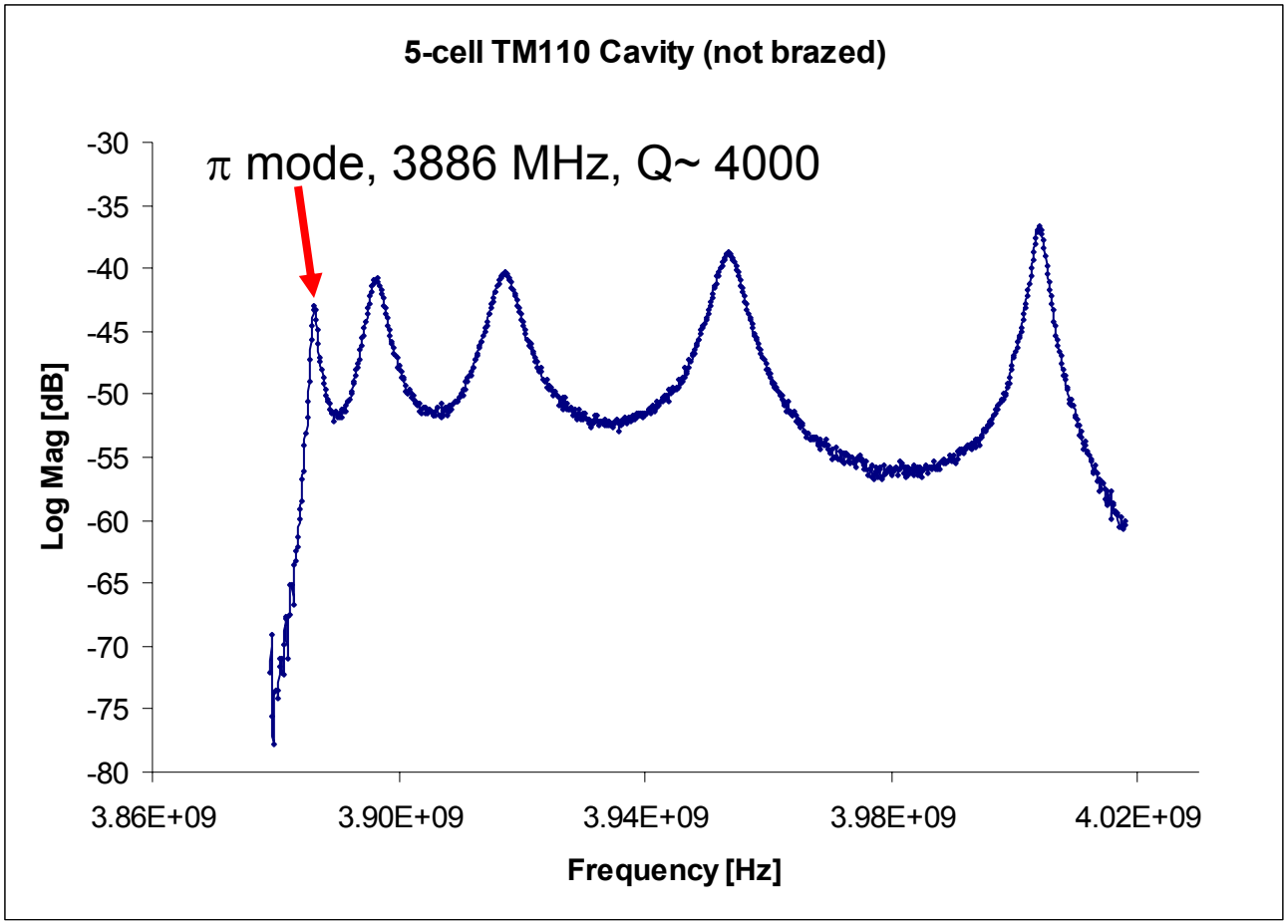
Half cells were punched from 0.093” copper disks at AES.

Half cells are 1st brazed at iris to form dumbbells.

Measure dumbbells & trim to freq.

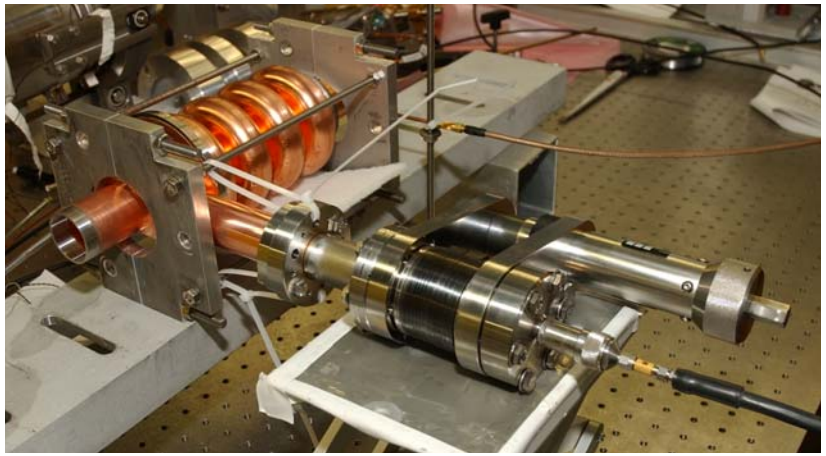
There is close proximity of one end cell, input coupler, and LN2 tank flange. Therefore these parts were machined from a copper block.

Measure Stacked Dumbbells

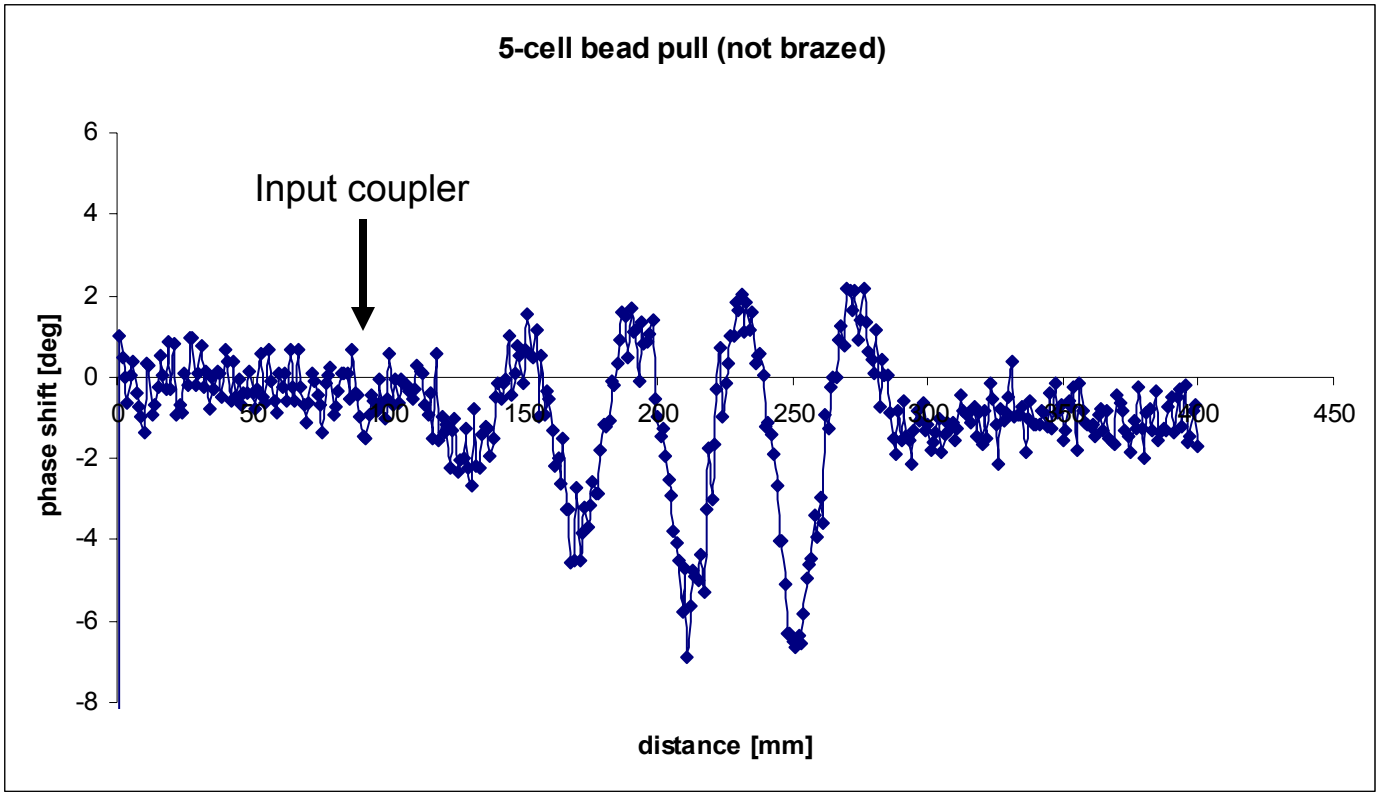


Shows why 5 cells is the upper limit – from mode spacing.

Bead Pull for Field Flatness

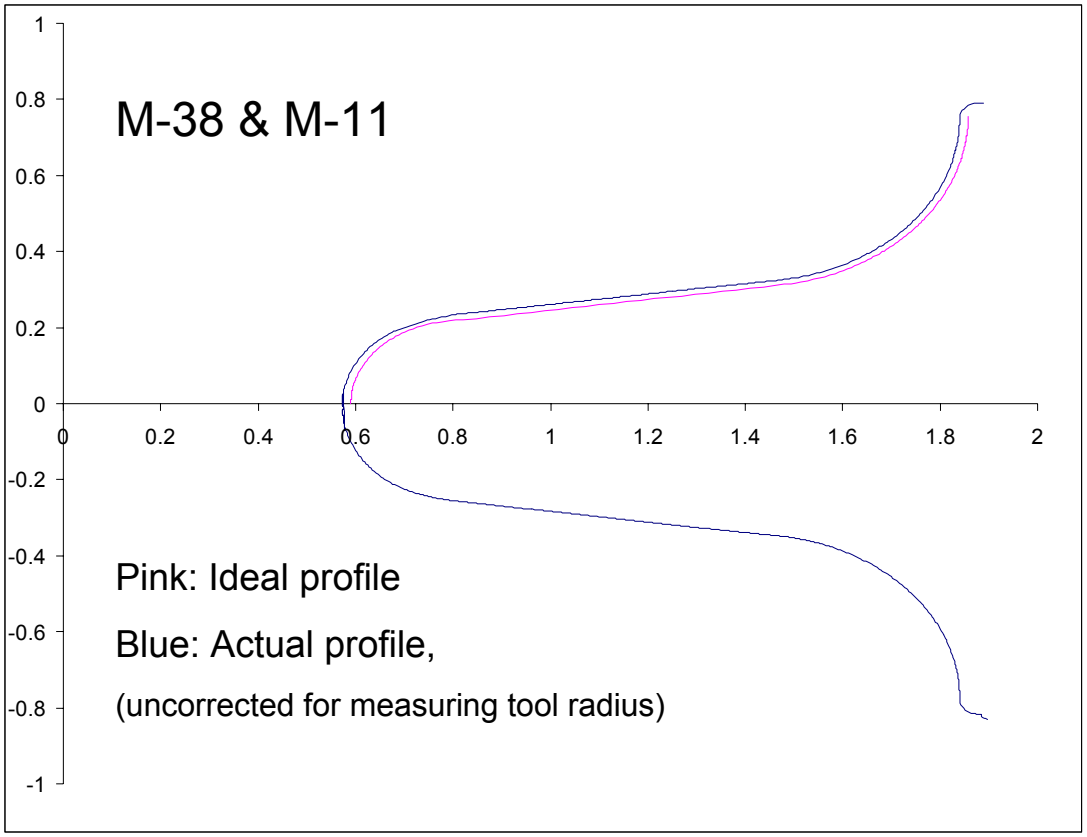


Initial bead pull shows that “solid” input coupler end cell frequency is higher than the others.



Problems:

Input Coupler End (ICE) machined 0.168mm too short (3MHz too high)
Dumbbells shrinkage due to vacuum leak check (0.022 inches, ~ 10MHz low)
Restored initial length, but frequency did not follow
0.014 inches too much trimmed (3MHz too high)
Dumbbells are physically too long by ~ 1mm.
Cavity profile in question → CMM'ing First data taken Monday:



Four radial profiles taken (90 deg increments) on dumbbell M38-M11.

Needs analysis….

Rest are being scanned.

Highlights of Time Line

ID	Task_Name	Duration	Start_Date	Finish_Date	Predecessors	Resource_Names
1	**Preparation**	95.63 days?	Thu 11/16/06	Thu 3/22/07		
7	Remaining Optical design of Beamline	2 wks	Thu 11/16/06	Thu 11/30/06		
9	Design Beamline Vacuum	3 days	Wed 12/6/06	Fri 12/8/06	8	
10	Aquire BPM buttons	4 mons	Mon 11/27/06	Fri 3/9/07		
25	Aquire vacuum components for Tim's Line	6 wks?	Wed 12/6/06	Wed 1/17/07	7,8	
26	Aquire vacuum components for straight line	6 wks?	Wed 12/6/06	Wed 1/17/07	7,8	
27	**Installation Phase I**	23 days?	Wed 1/17/07	Wed 2/14/07	3,26,20	
28	Break Vacuum	1 day?	Wed 1/17/07	Wed 1/17/07		
31	Modify A0 Beamline	2 wks?	Mon 1/22/07	Fri 2/2/07	29	
32	Install Dogleg Dipole 1	1 day?	Fri 2/2/07	Mon 2/5/07	31	
36	Commission new A0 Beamline	2 days	Thu 1/25/07	Mon 1/29/07	35	
37	**Installation Phase II**	32 days?	Thu 3/22/07	Tue 5/1/07	12,25,24,7,8,19,20,22	
38	Break Vacuum	1 day?	Thu 3/22/07	Thu 3/22/07		
39	Install RF cavity	3 days	Fri 3/23/07	Tue 3/27/07	38	
41	Close vacuum	3 days	Fri 4/13/07	Tue 4/17/07	40	
44	Commission Tim's Cavity	2 wks?	Tue 5/1/07	Mon 5/14/07	37	
45	Commission new beamline	7 days	Tue 5/1/07	Wed 5/9/07	37	
46	Commission new interlocks	1 day	Tue 5/1/07	Wed 5/2/07	37	
47	Rad Safety Clearance	1 day?	Wed 5/9/07	Thu 5/10/07	46,37,45	
48	Make Measurment	4 mons	Mon 5/14/07	Tue 8/21/07	47,44	
49	Tim Writes Thesis	6 mons	Tue 8/21/07	Thu 1/17/08	48	
50	Tim Graduates	0 days	Thu 1/17/08	Thu 1/17/08	49	