Measurements Uncertainties in VTS (at Fermilab).

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on behalf of
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Abstract

We discuss source of errors in Q and E measurements during testing of SRF cavity in VTS (at Fermilab, as an example).

Melnychuk's error propagation analysis

SRF2013 THP095 (to follow by expanded paper
O. Melnychuk *"Error analysis for vertical test stand cavity measurements at Fermilab"* , submitted to PRSTAB)
See also Fermilab Tech Report TD-13-010
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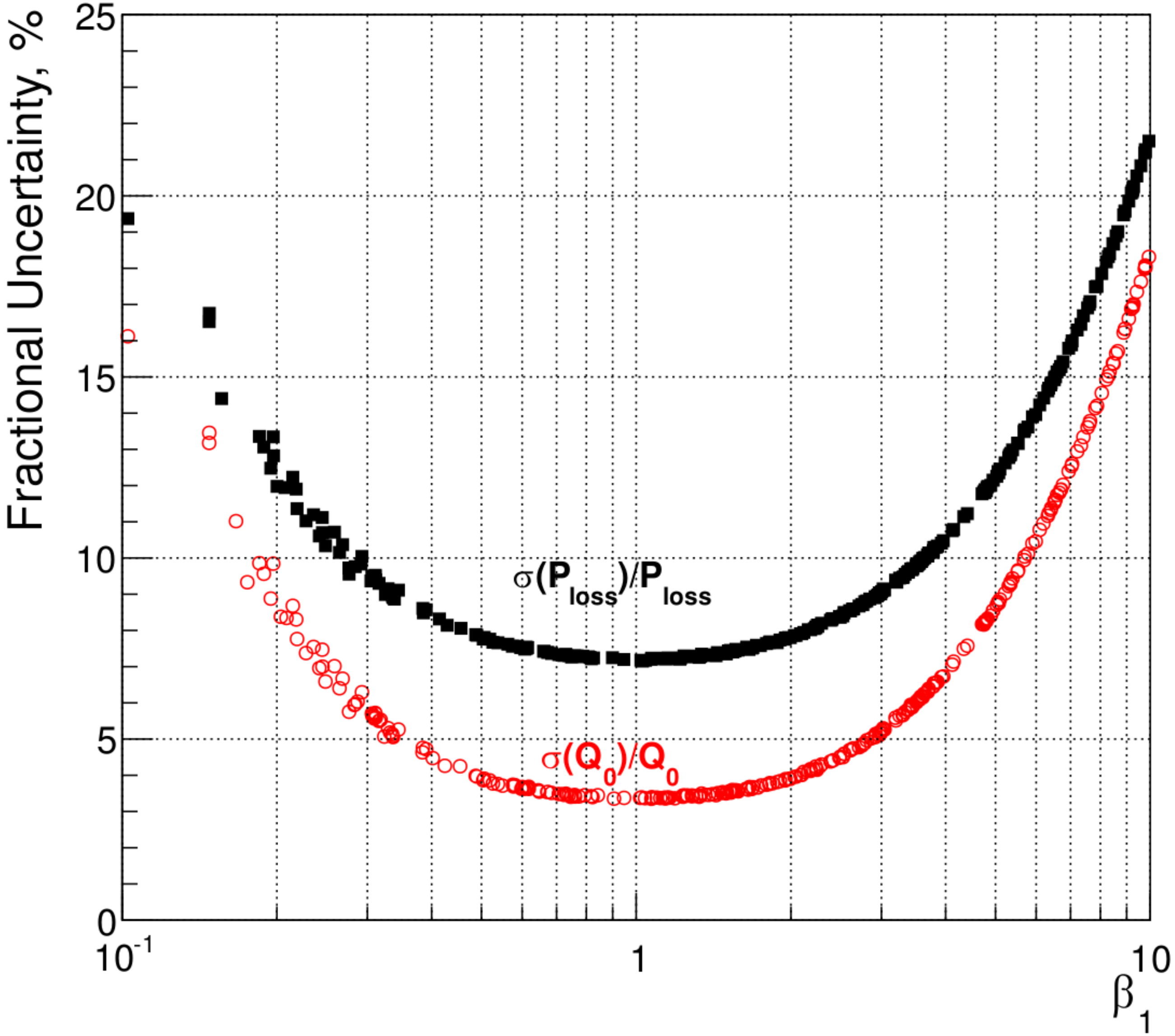
Follows and refines Tom Powers work (see e.g. SRF2011). More careful treatment of correlations between cable calibration, decay measurements, and actual CW measurements.

Melnychuk's error propagation analysis

Input uncertainties:

- Power meter sensitivity 1 nW
- Power meter precision 4.2%
- Operator error 3%
- Cable loses
  - Forward / Reflected 5%
  - Transmitted 0%
- Decay constant 3%

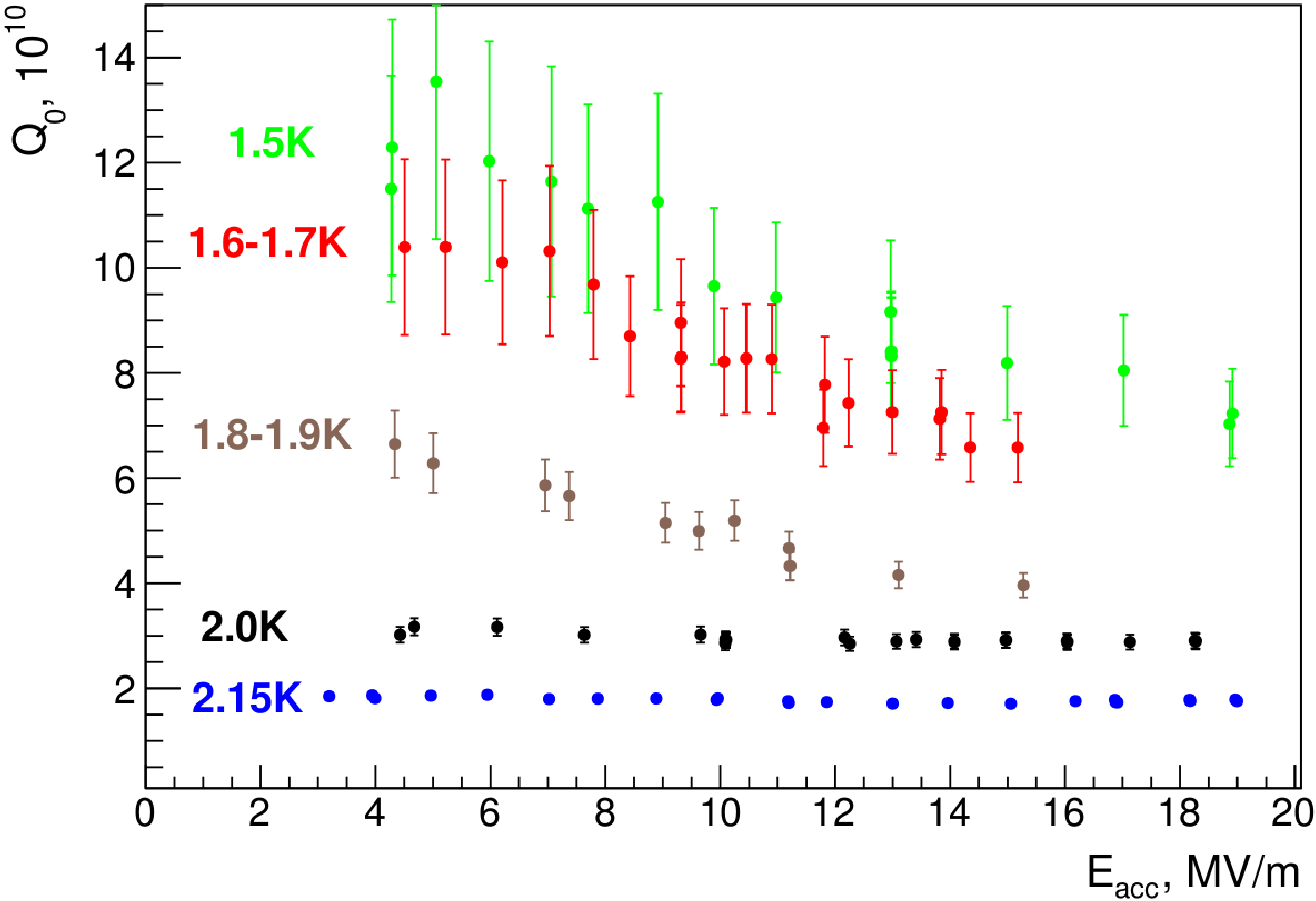
Melnychuk's error propagation analysis



For $0.5 < \beta_1 < 2.5$ $\delta Q/Q$ and $\delta E/E \sim 4\%$ (constant)

Main difference from Tom Powers' work:

- $\delta E/E$ does not depend on E
- $\delta Q/Q$ is about 2x smaller



Test of `te1nr005` cavity on March 2013 on VTS1 at Fermilab.
$\beta_1 \sim 2$ @2.15K, ~ 10 @1.5K

Directional coupler issues

Instigated by Warren Schappert (warren@fnal.gov). Still work in progress.

Directional coupler

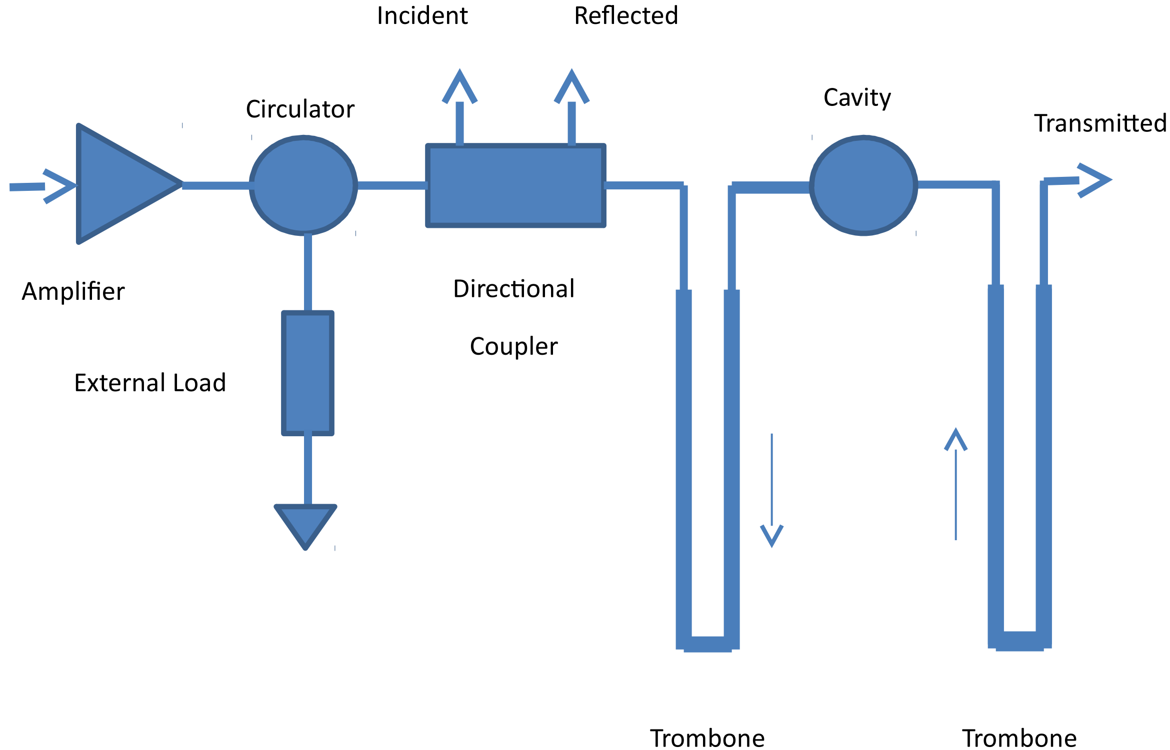
- Coupler directivity is a measure of cross-talk between the forward and reflected signals
- Trade-off between frequency response and directivity
  - Wide bandwidth => low directivity
  - High bandwidth => narrow bandwidth
- Coupler directivity can be modeled as linear mixing between the forward and reflected signals

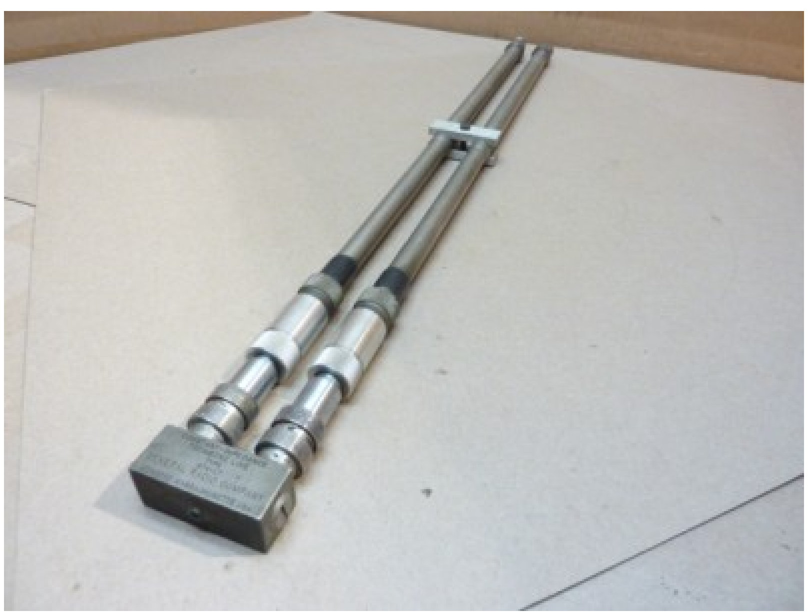
Appendix: Directional Coupler Comparison

	Coupler		
Manufacturer	RF-Lambda	Agilent	Flann
Model	RFDDC1M2G20	776D	11A113
Style	Coaxial	Coaxial	Waveguide
f_{Min}	0.11	0.9	3.30
f_{Max}	2.0	1.1	4.90
Coupling	20	40	20
Insertion Loss	0.5	0.3	
Power	500	50	
Directivity	22	40	50

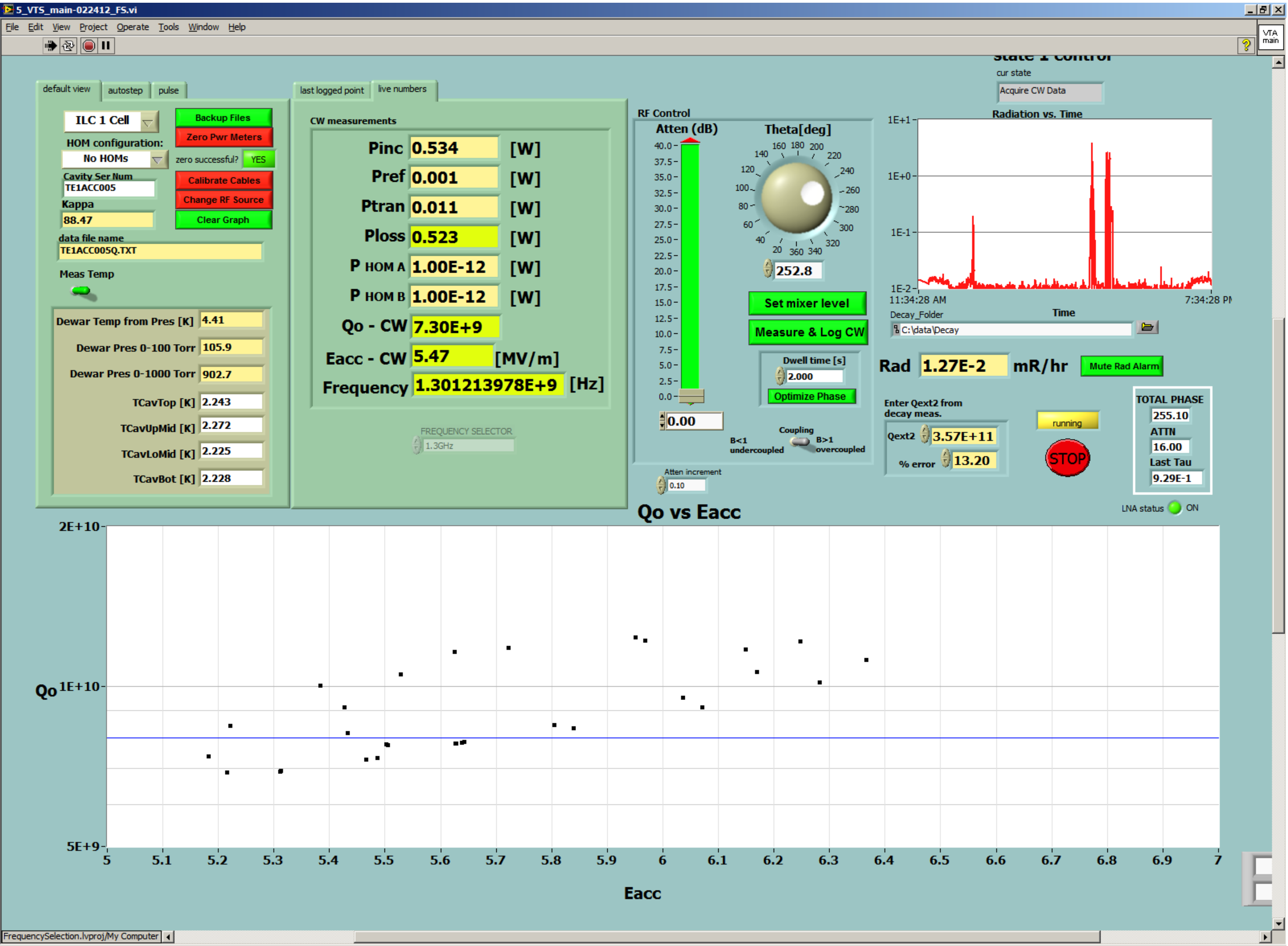
Experimental Setup

- Two back-to-back trombones
- Vary the length of the cable between coupler and cavity
  - Changes relative phase between forward and reflected signals
  - Phase between forward and probe remains unchanged





"Trombone": GR874-LT Constant Impedance Variable Length Coaxial Air Line


5_VTS_main-022412_FS.vi
File Edit View Project Operate Tools Window Help
VTA main
State 1 Control
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Acquire CW Data
default view
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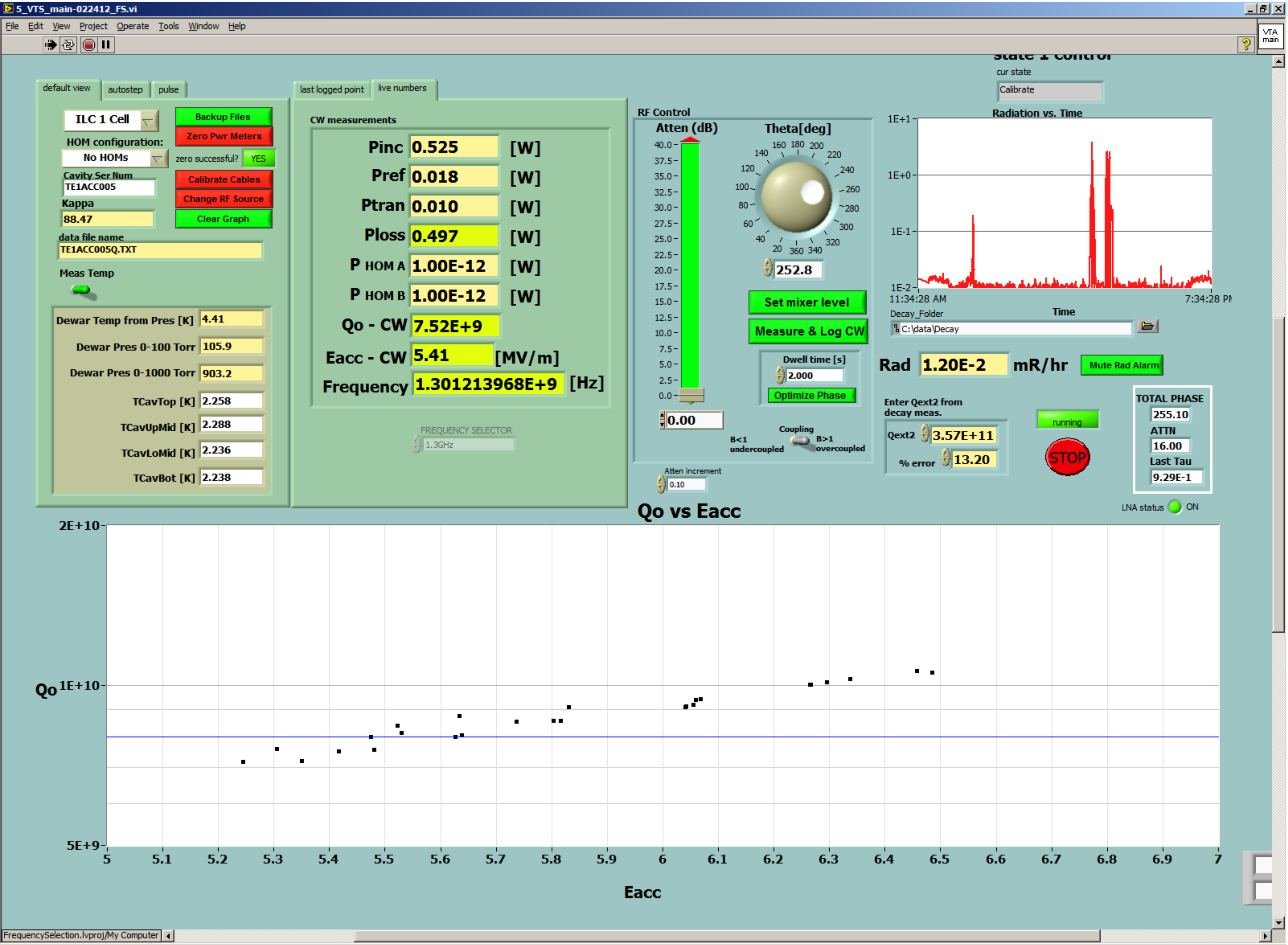
pulse
last logged point
live numbers
ILC 1 Cell
HOM configuration:
No HOMs
Cavity Ser Num
TE1ACC005
Kappa
88.47
data file name
TE1ACC005Q.TXT
Meas Temp
Backup Files
Zero Pwr Meters
zero successful?
YES
Calibrate Cables
Change RF Source
Clear Graph
Dewar Temp from Pres [K] 4.41
Dewar Pres 0-100 Torr 105.9
Dewar Pres 0-1000 Torr 902.7
TCavTop [K] 2.243
TCavUpMid [K] 2.272
TCavLoMid [K] 2.225
TCavBot [K] 2.228
CW measurements
Pinc 0.534 [W]
Pref 0.001 [W]
Ptran 0.011 [W]
Ploss 0.523 [W]
P HOM A 1.00E-12 [W]
P HOM B 1.00E-12 [W]
Qo - CW 7.30E+9
Eacc - CW 5.47 [MV/m]
Frequency 1.301213978E+9 [Hz]
FREQUENCY SELECTOR
1.3GHz
RF Control
Atten (dB)
Theta[deg]
252.8
0.00
Set mixer level
Measure & Log CW
Dwell time [s]
2.000
Optimize Phase
Coupling
B<1 undercoupled
B>1 overcoupled
Atten increment
0.10
Radiation vs. Time
11:34:28 AM
7:34:28 PM
Time
Decay_Folder
C:\data\Decay
Rad 1.27E-2 mR/hr
Mute Rad Alarm
Enter Qext2 from decay meas.
Qext2 3.57E+11
% error 13.20
running
STOP
TOTAL PHASE
255.10
ATTN
16.00
Last Tau
9.29E-1
LNA status ON
Qo vs Eacc
Qo
Eacc
FrequencySelection.lvproj/My Computer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TCavTop [K] 2.258
TCavUpMid [K] 2.288
TCavLoMid [K] 2.236
TCavBot [K] 2.238
last logged point
live numbers
CW measurements
Pinc 0.525 [W]
Pref 0.018 [W]
Ptran 0.010 [W]
Ploss 0.497 [W]
P HOM A 1.00E-12 [W]
P HOM B 1.00E-12 [W]
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Last Tau
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Qo vs Eacc
Qo
Eacc
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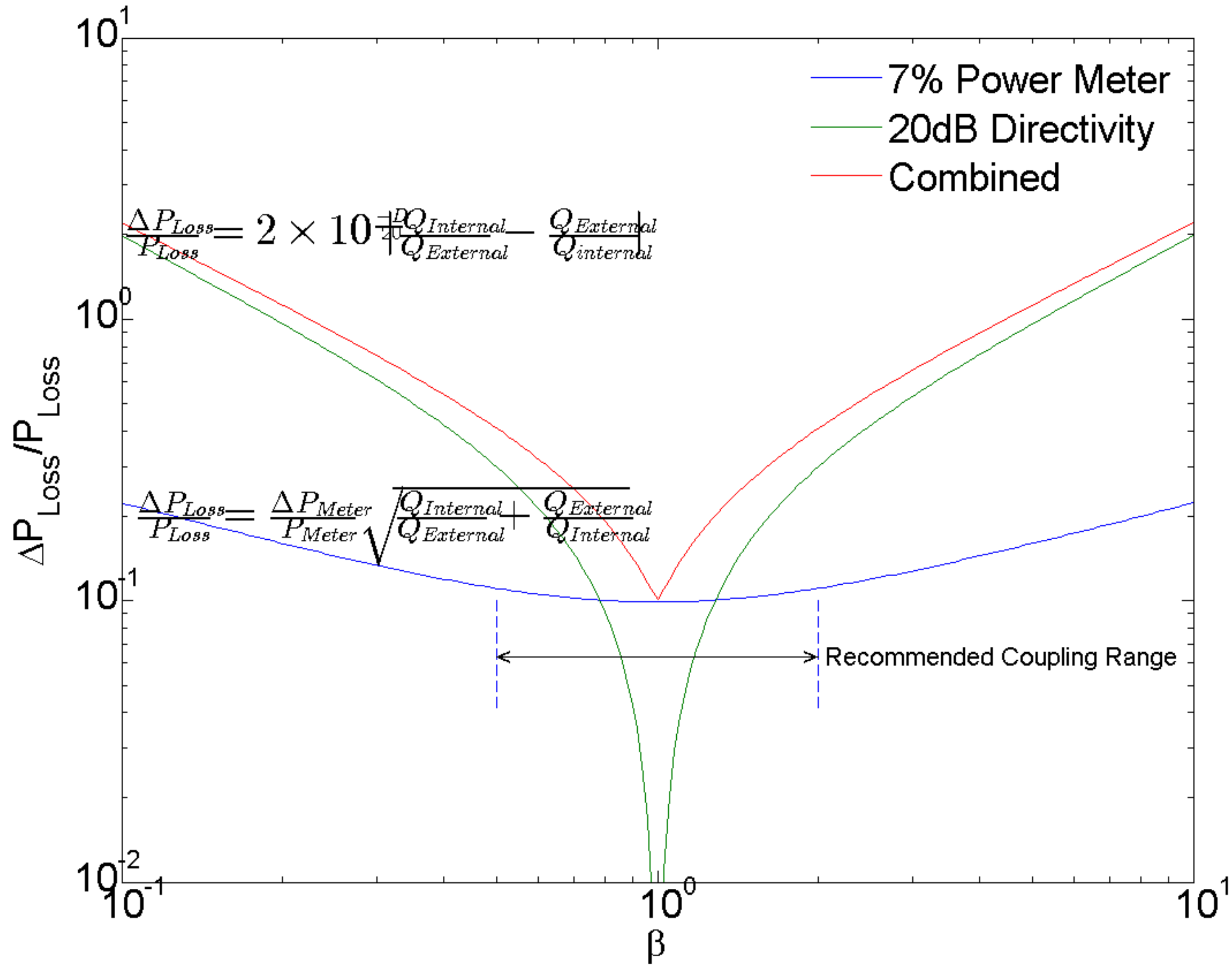
Directivity Errors



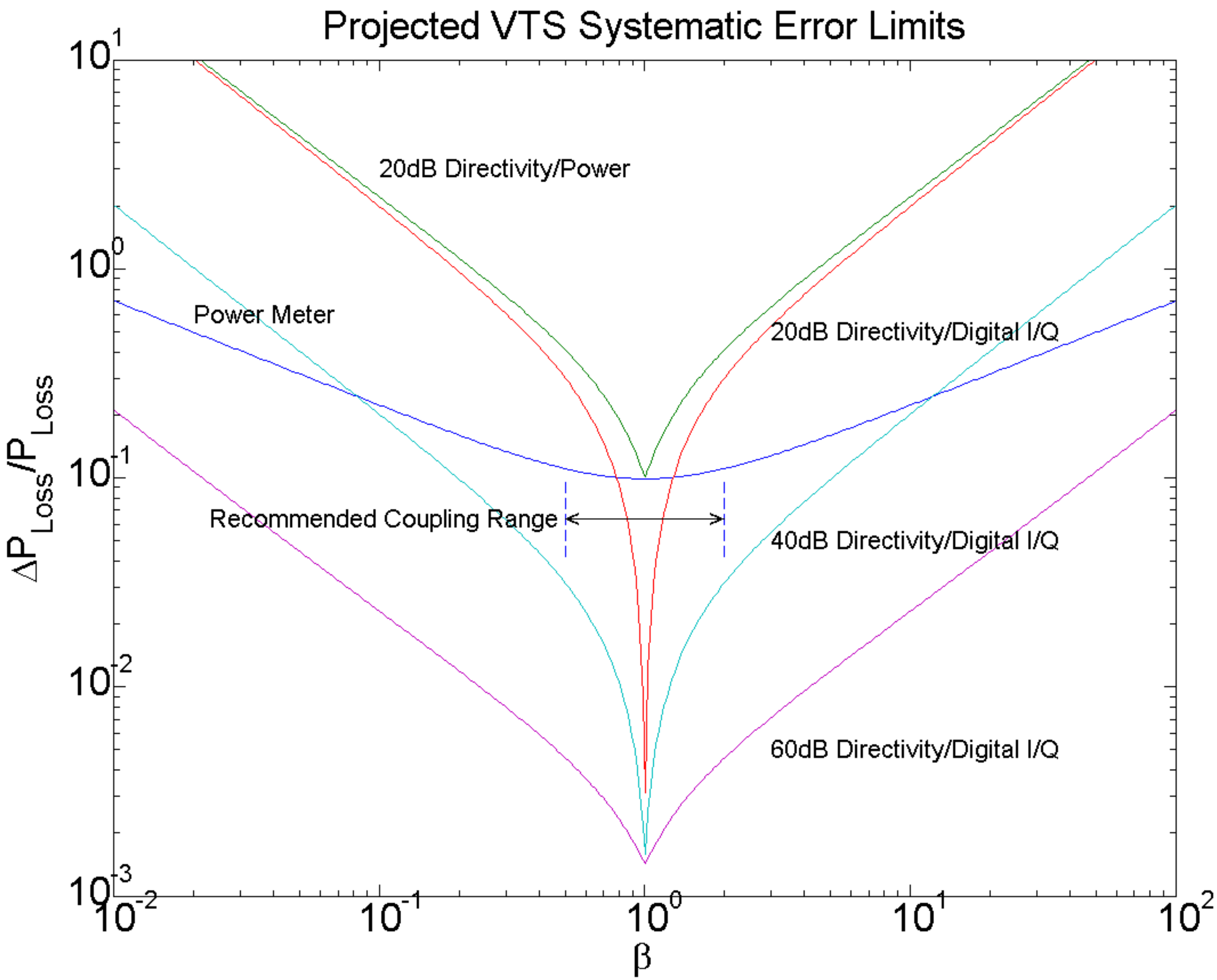
Conclusion (W.S.)

The upgrades to the VTS in order of importance are (in my opinion)
1)A variable power coupler.
2)A high directivity directional coupler
3)A digital I/Q system.

The power coupler is by far the most important.

A high directivity coupler will improve both analog power and complex digital measurements but the power meter limits will still dominate in the analog case
The digital I/Q system in combination with a high directivity coupler provides sufficient information to determine the relative calibration of the forward, probe and reflected signals from the data itself. No measurements of or corrections for cable loss are required. This results in a significant reduction in the systematic uncertainties.

With a poor directivity coupler it is difficult to separate contamination in the coupler from reflections from the circulator even with a digital system. A trombone can resolve that ambiguity.



Projected VTS Systematic Error Limits
20dB Directivity/Power
Power Meter
20dB Directivity/Digital I/Q
Recommended Coupling Range
40dB Directivity/Digital I/Q
60dB Directivity/Digital I/Q
ΔP_Loss/P_Loss
β