Gun-4.1: Q estimations using RF signals from 10MW in-vacuum directional coupler

M.Krasilnikov,

PPS 02.03.2010

Tuning of Gun 4.1 and 4.2

Sakhorn Rimjaem, PITZ Physics Seminar, April 3, 2007

1. Different between tuning temperature (T_{room}) and operating temperature (T_{op}) $\rightarrow \Delta T$
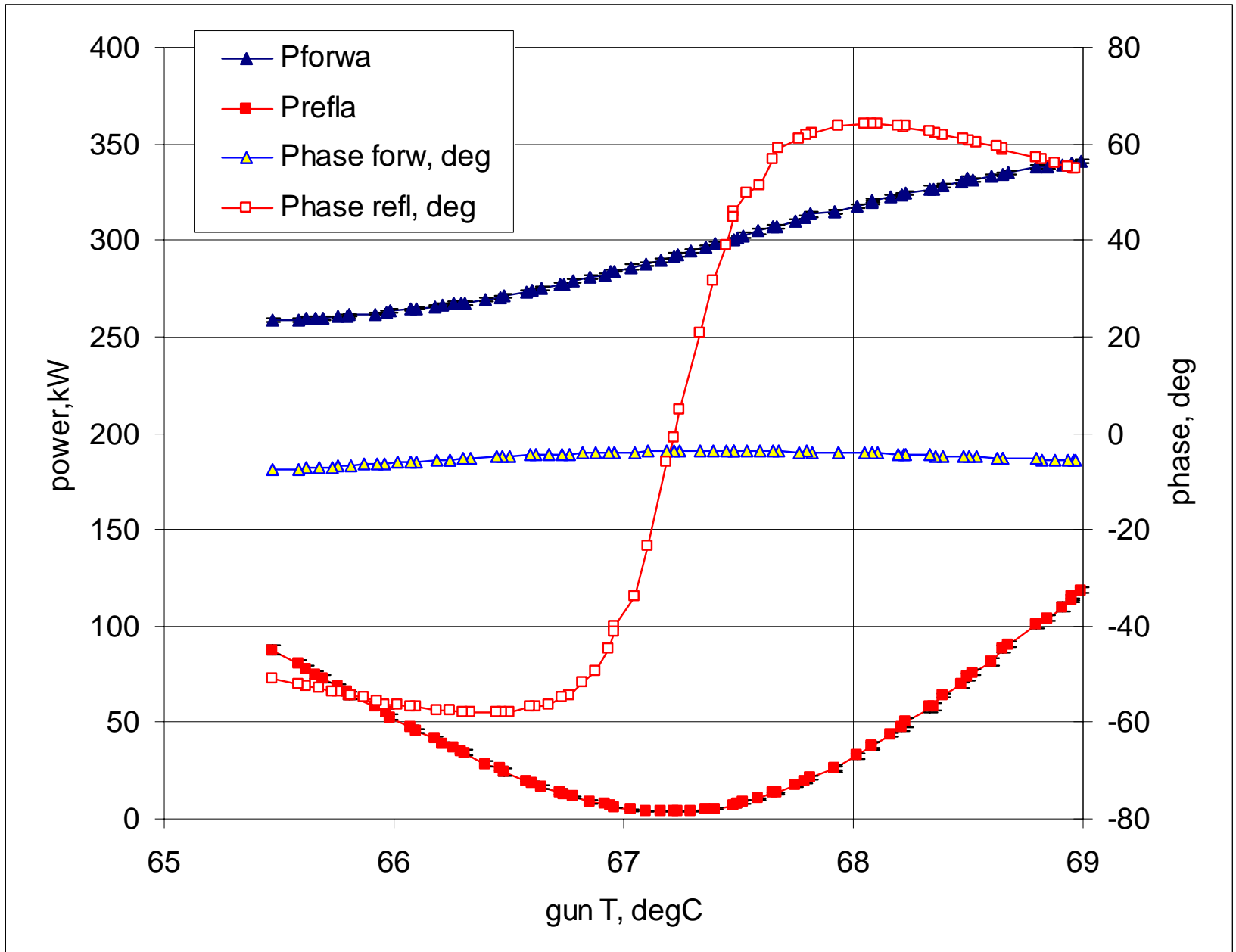$\Rightarrow$ leading to frequency shift df/dT~ -22 kHz/K

Gun 4.1 (for π- mode):
- f_o after tuning = 1.300465 GHz
- Operating temperature = 60°C (preferable temp.=55°C)
  - $\rightarrow$ still in tolerance of the cooling system limit
  - $\rightarrow$ Gun4 has improved cooling channel design from Gun3
  - $\rightarrow$ higher T_{op} may be suitable with Gun4
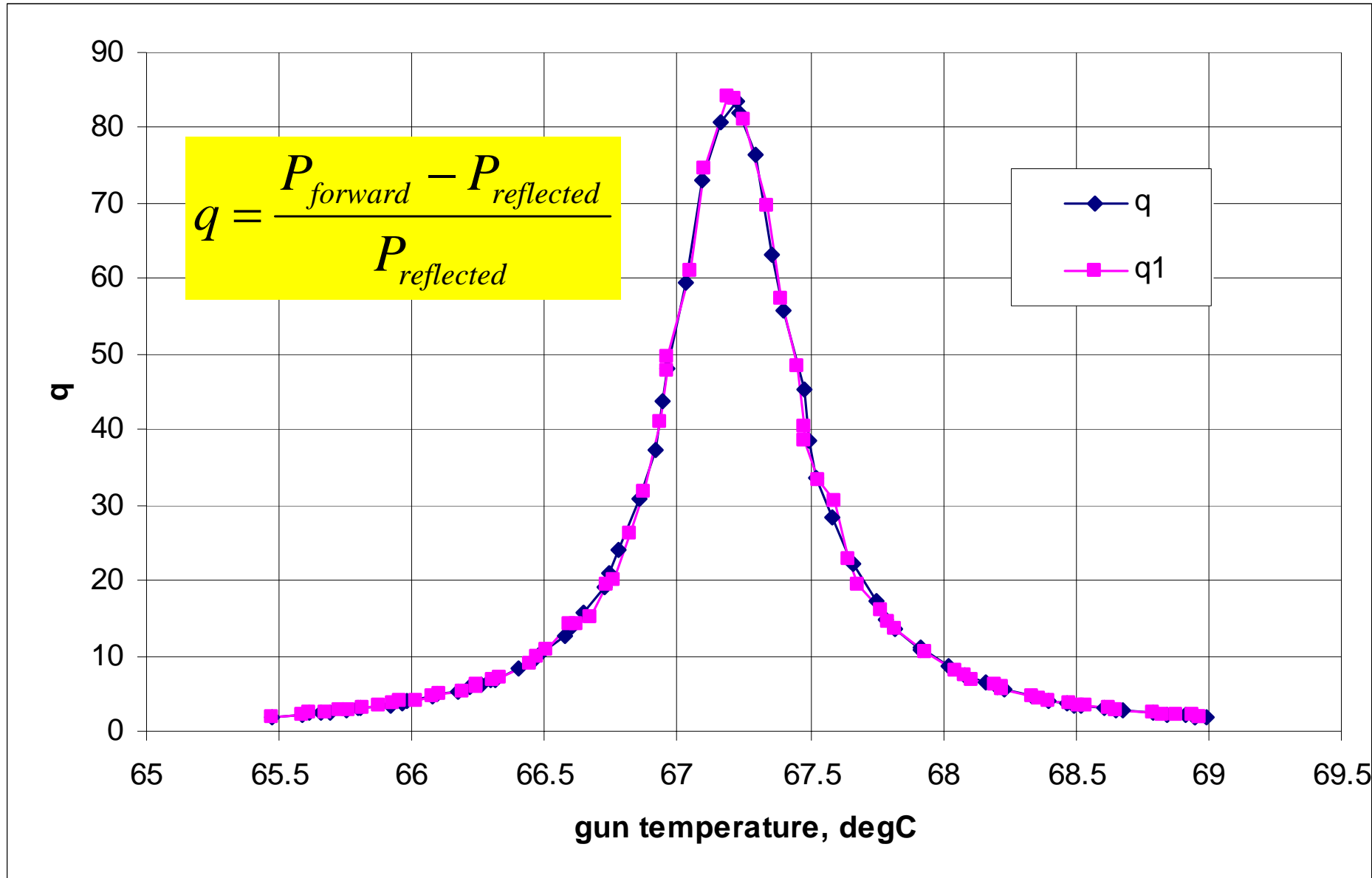   since it will be operated with higher power + longer pulses
- Field flatness = 1.08

Gun 4.2 (for π- mode):
- f_o after tuning = 1.300342 GHz
- Operating temperature 55 (preferable temp.=55°C)
  - $\rightarrow$ agree to preferable operating temperature
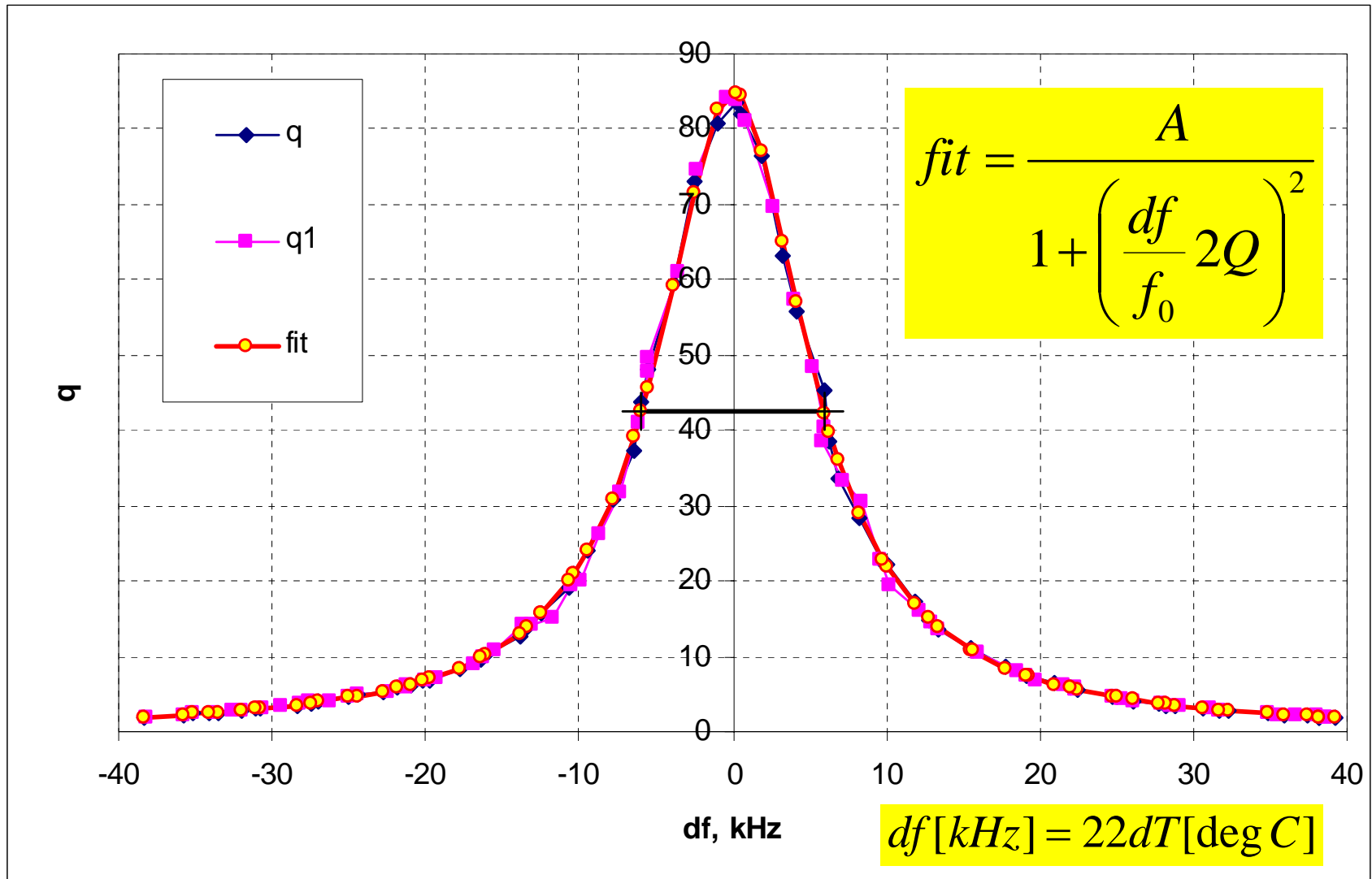- Q-value = 20472
- S_{11} = -38 dB
- Field flatness = 1.06

Measurements (01.03.2010)

Measurements (01.03.2010)

$$q = \frac{P_{forward} - P_{reflected}}{P_{reflected}}$$

Chart legend: q, q1

y-axis: q

x-axis: gun temperature, degC

Measurements (01.03.2010)

$$fit = \frac{A}{1 + \left(\dfrac{df}{f_0} 2Q\right)^2}$$

$$df[kHz] = 22 dT[\deg C]$$
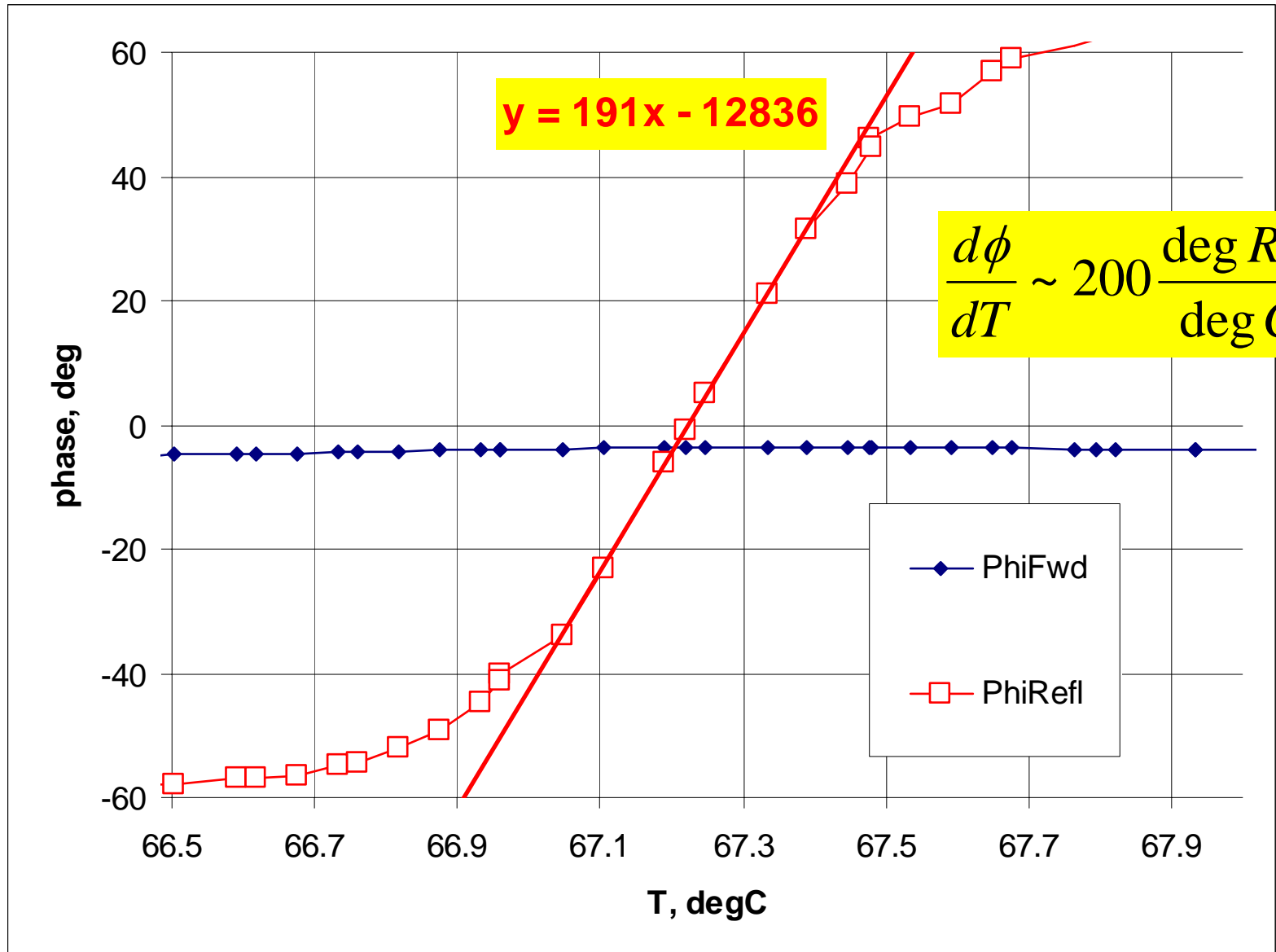
$$A = 85; \quad Q = \frac{f_0}{2df_{fwhh}} \approx \frac{1300000 kHz}{2 \cdot 6 kHz} = 108333$$

Measurements (01.03.2010)

$$y = 191x - 12836$$

$$\frac{d\phi}{dT} \sim 200 \frac{\deg RF}{\deg C}$$

Legend:
- ◆ PhiFwd
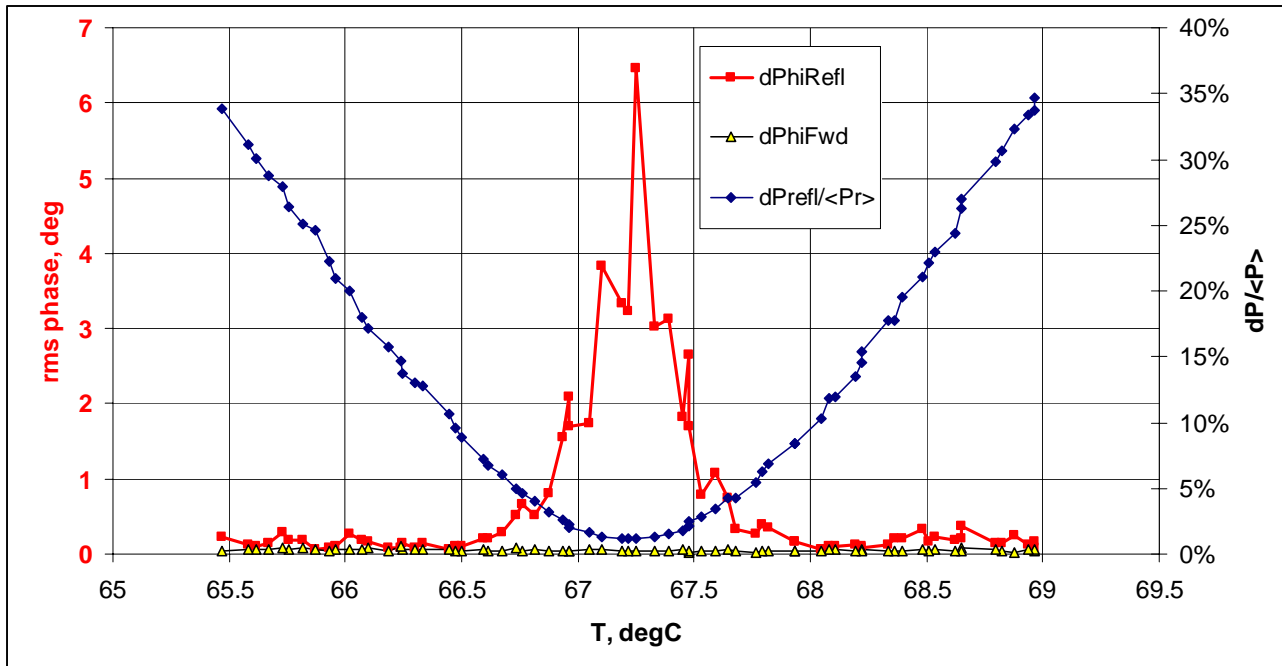- □ PhiRefl

Expectation on the phase slope from cold measurements

$$\varphi = Arctg\left(2Q_0 \frac{df}{f_0}\right) \approx 2Q_0 \frac{df}{f_0}\bigg|_{df \to 0}$$

Gun 4.2 (for π- mode):
- f_o after tuning = 1.300342 GHz
- Operating temperature 55 (preferable temp.=55ºC)
  - → agree to preferable operating temperature
- Q-value = 20472
- S_{11} = -38 dB
- Field flatness = 1.06

$$\frac{2Q_0}{f_0} = \frac{2 \cdot 20470 \, rad}{1300000 \, kHz} \approx 0.031492 \, \frac{rad}{kHz} = 1.8 \frac{\deg RF}{kHz} \xrightarrow{22 \, kHz / \deg C} \sim 40 \frac{\deg RF}{\deg C}$$

Phase fluctuations

LLRF measurements (02.03.2010)

SPT	FB			Tgun	Phase_fwd	Phase_refl	Pfwd	Prefl	AmpVS^2	PhaseVS	Remark
	on/off	gain	loop phase	degC	deg	deg	kW	kW	kW	deg	
68.15	off			68.15	-4.12	64.10	323.47	43.10	278.97	-25.53	mean
overheated				0.03	1.70	0.16	1.12	1.70	0.88	0.49	rms
				0.04%			0.35%	3.94%	0.32%		rms/mean,%
68.15	on	-180	-13.9	68.15	-3.29	65.06	325.18	43.20	280.94	-24.67	mean
overheated				0.03	1.56	0.27	1.54	1.56	1.26	**0.09**	rms
				0.04%			0.47%	3.62%	**0.45%**		rms/mean,%
67.2	off			67.21	-1.33	0.97	293.29	3.46	233.22	-1.61	mean
resonance				0.02	0.05	3.66	1.03	0.05	0.80	0.43	rms
				0.02%			0.35%	1.42%	0.34%		rms/mean,%
67.2	on	-180	7.1	67.20	-1.52	-3.55	294.11	3.46	233.98	-1.27	mean
resonance				0.02	0.03	4.42	0.75	0.03	0.59	**0.16**	rms
				0.03%			0.25%	0.96%	**0.25%**		rms/mean,%
66.25	off			66.27	-1.31	-53.60	267.38	35.83	183.48	19.16	mean
overcooled				0.03	0.94	0.12	0.79	0.94	1.25	0.28	rms
				0.04%			0.30%	2.63%	0.68%		rms/mean,%
66.25	on	-110	27.5	66.24	-1.32	-53.50	265.74	36.56	181.44	19.45	mean
overcooled				0.02	1.16	0.15	1.00	1.16	0.74	**0.11**	rms
				0.04%			0.38%	3.18%	**0.41%**		rms/mean,%

$$AmpVS = \sqrt{P_{forw}} \cdot e^{j\phi_{forw}} - \sqrt{P_{forw}} \cdot e^{j\left(\phi_{refl} + \delta?\right)}$$

Conclusions and open questions

!NB: The measurements have been done at low power level (300kW)

Possible reasons for the discrepancy:
- **RF measurements (calibration?)**
- **Temperature measurements (67degC instead 60degC?? And the slope?)**
- **22kHz/degC is not correct? (but 100kHz/degC seems too much!)**
- **…???**

Tuning of Gun 4.1 and 4.2

Sakhorn Rimjaem, PITZ Physics Seminar, April 3, 2007

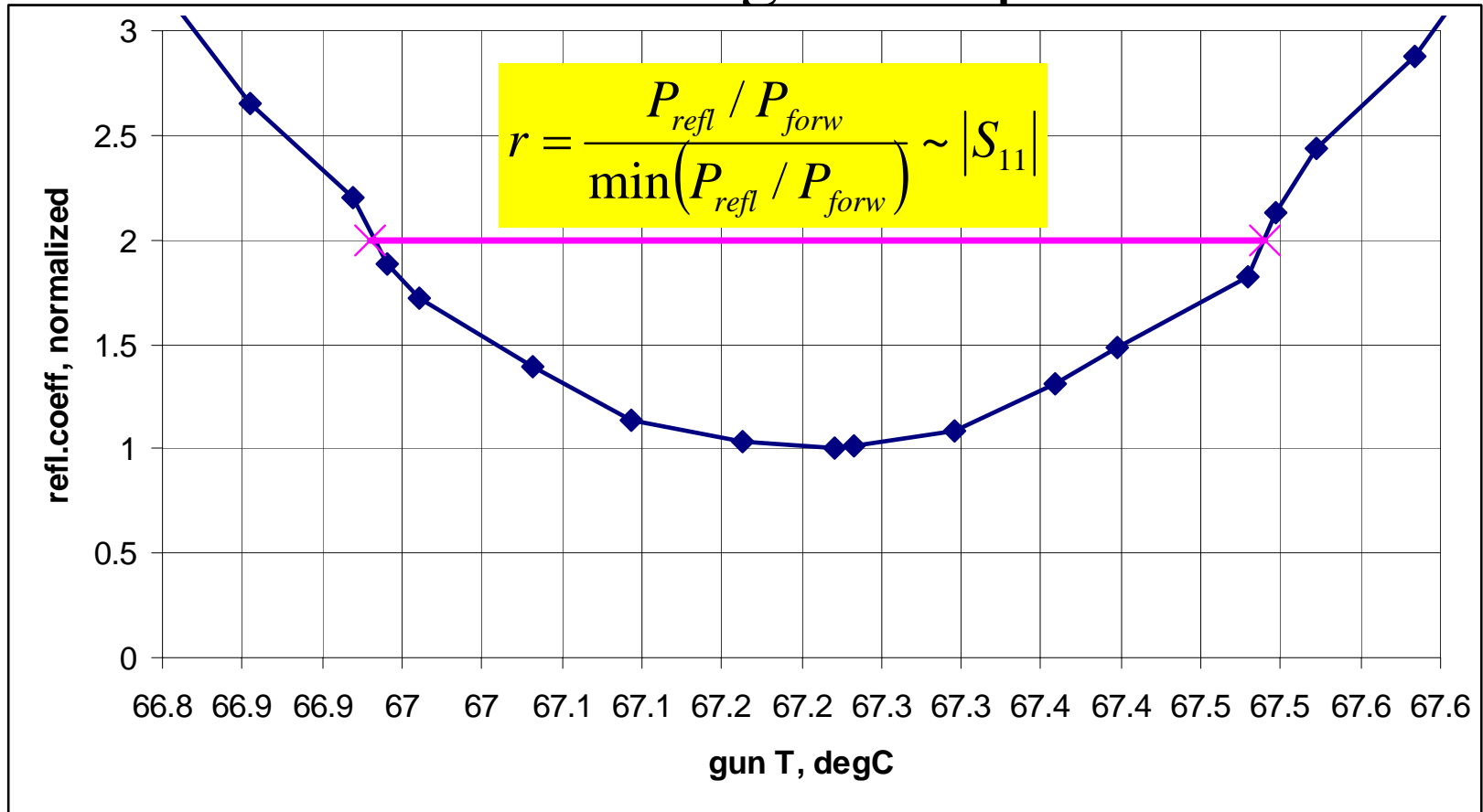## Comparison of RF measurements of all existing gun cavities before and after tuning*

Gun No.	T_{room} (°C)	mode	f_{air} before tuning (MHz)	S_{11} (dB)	$\Delta f_{0\pi}$ (MHz)	field flatness	T_{room} (°C)	f_{air} after tuning (MHz)	S_{11} (dB)	$\Delta f_{0\pi}$ (MHz)	Q_0	field flatness	T_{op} (°C)
1	23	π	1299.435	-	5.3	0.90	21	1300.289	-	5.0	-	1.05	52
		0	1294.169	-		0.49		1295.275	-		-	1.76	-
2	22	π	1298.862	-	5.2	0.97	22	1300.242	-21	4.9	22532	1.22	51
		0	1293.685	-		0.49		1295.341	-12		14056	1.48	-
3.1	21	π	1299.412	-	5.2	-	22	1300.323	-	5.0	24299	1.08	54
		0	1294.230	-		-		1295.300	-		-	-	-
3.2	24	π	1301.338	-	5.0	1.18	24	1300.315	-26	5.1	21316	1.03	56
		0	1296.339	-		1.58		1295.173	-9		14078	1.88	-
4.1	21.5	π	1300.880		-	1.09	21.5	1300.465	-	-		1.08	60
		0	-			-		-	-				
4.2	22	π	1300.655	-34	5.2	1.02	22	1300.342	-38	5.2	20472	1.06	55
		0	1295.468	-10		-		1295.183	-10		13684	-	-

S_{11} is the calibrated amplitude of the reflected power signal
$\Delta f_{0\pi}$ is the frequency difference between π and 0 mode
Q_0 is the unloaded quality value (π-mode: $Q_0 \sim 2Q_l$, 0-mode: $Q_0 \sim Q_l$)

Gun reflection vs. gun temperature

$$r = \frac{P_{refl} / P_{forw}}{\min\left(P_{refl} / P_{forw}\right)} \sim |S_{11}|$$

$3dB \rightarrow r = 2$

$$Q = \frac{f_0}{\Delta f} = \frac{f_0[kHz]}{22[kHz / \deg C]\Delta T[\deg C]} \approx \frac{1300000}{22 \cdot (66.93 - 67.49)} = 105520$$