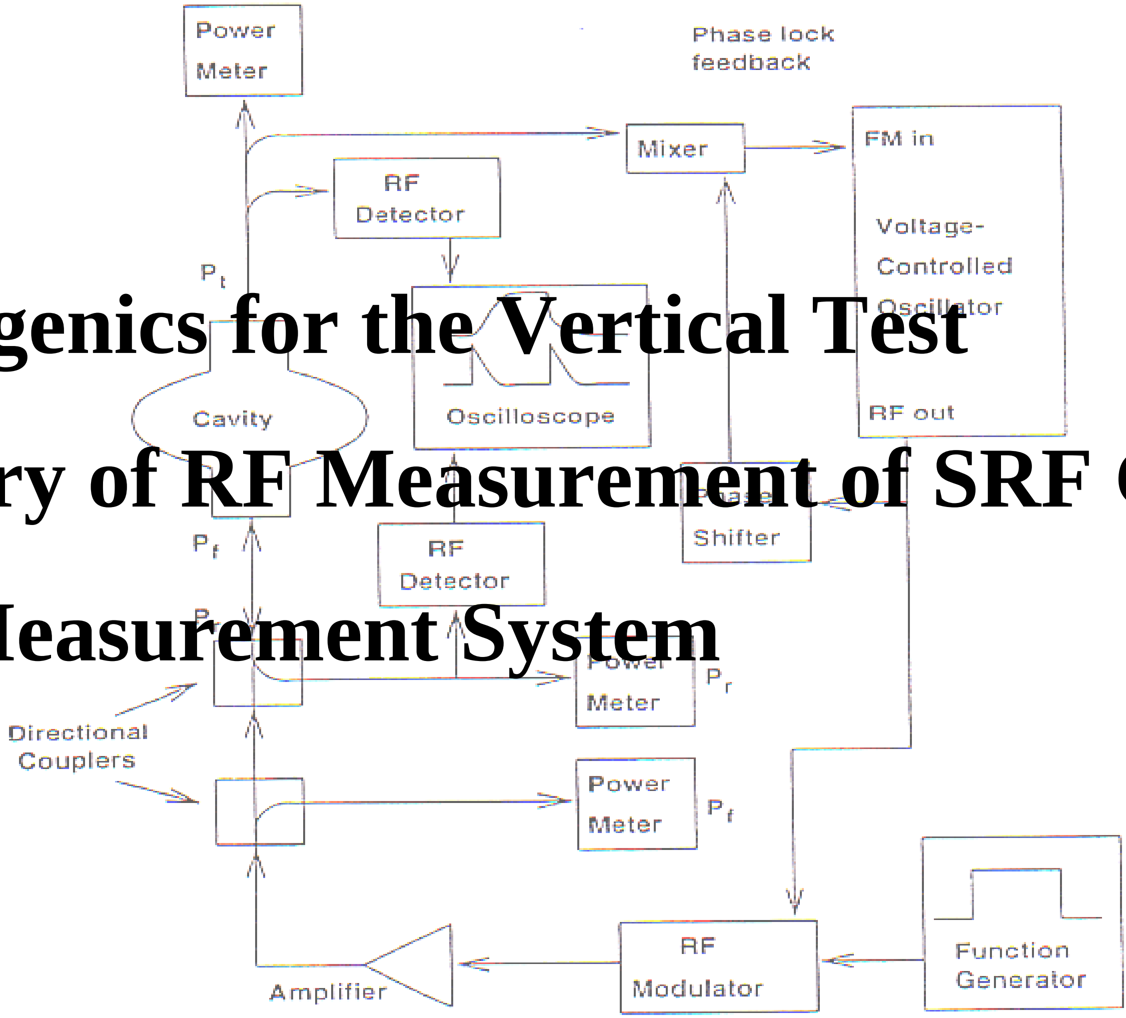
9. Performance Evaluation (Vertical Test)

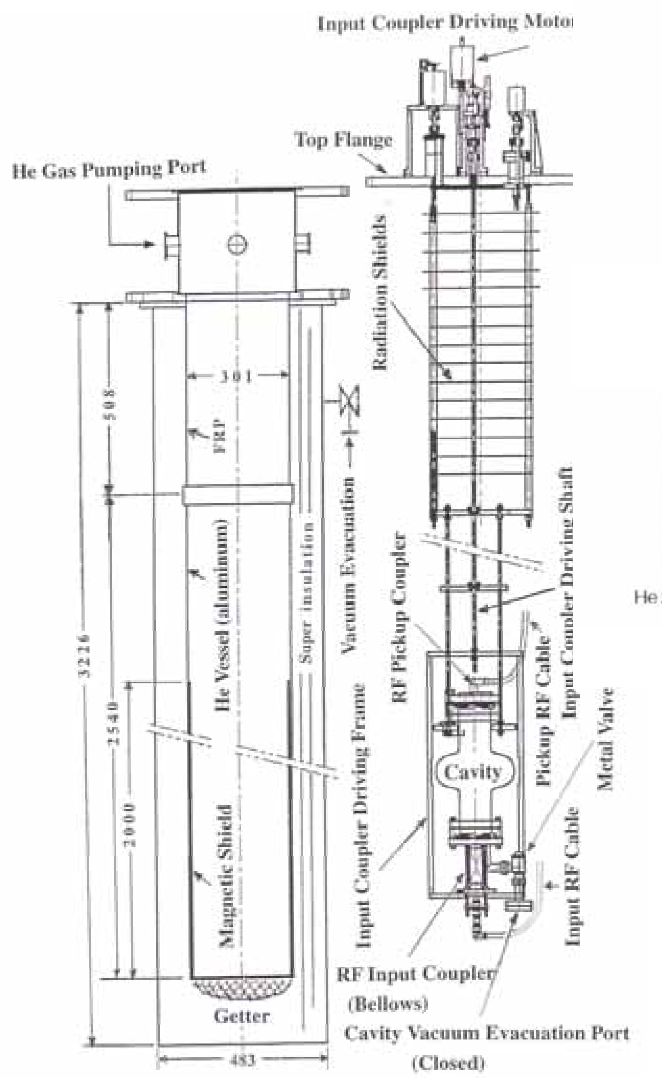


9.1 Cryogenics for the Vertical Test

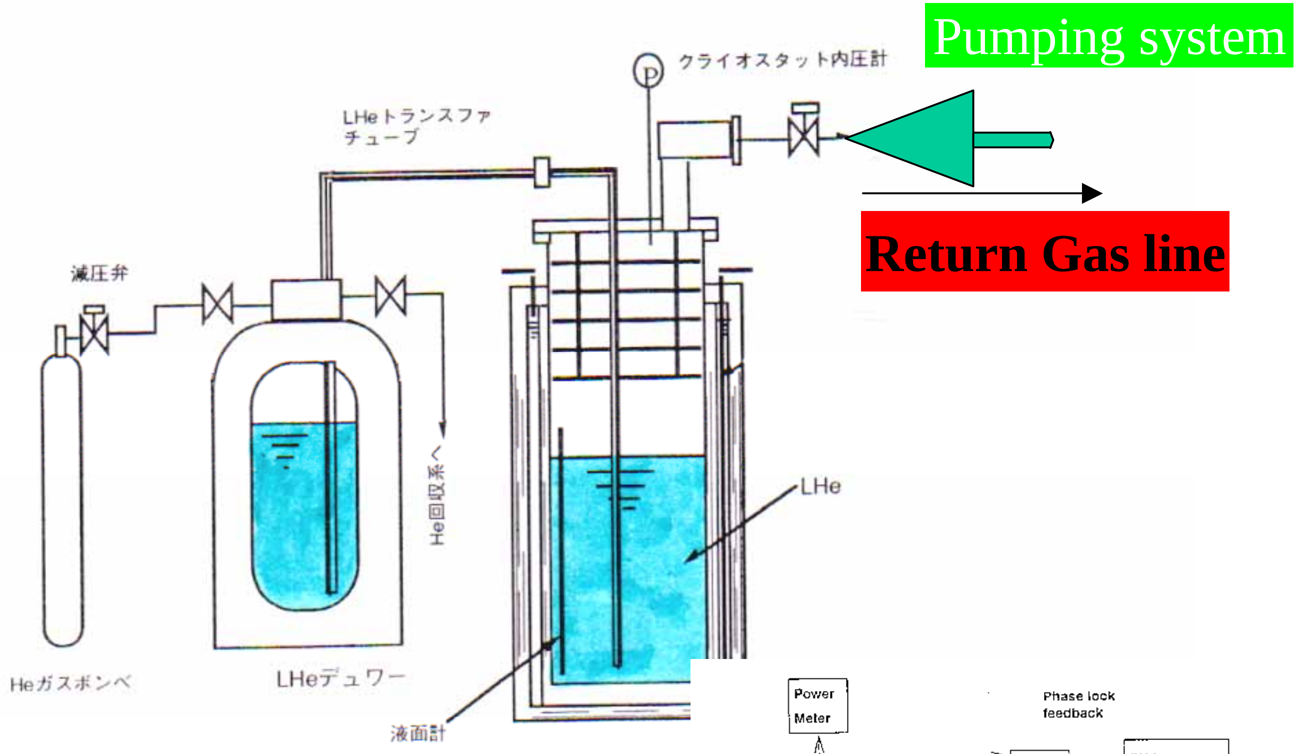
9.2 Theory of RF Measurement of SRF Cavities

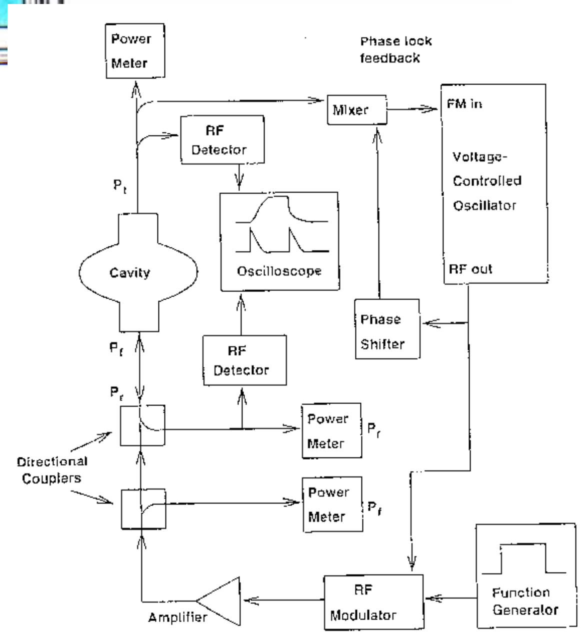
9.3 RF Measurement System

9.1 Cryogenics System for Vertical Test

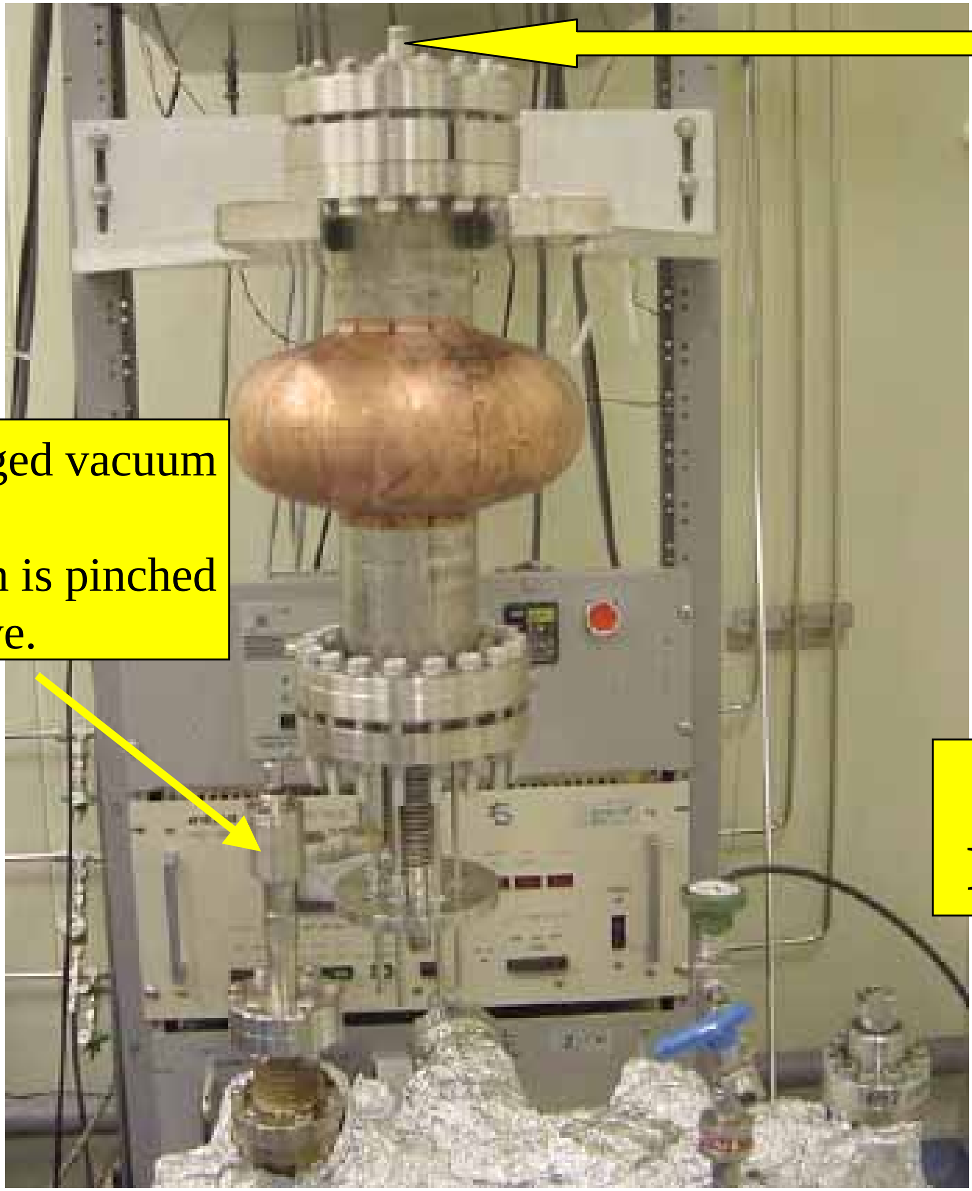


Vertical Cryostat   Vertical Test Stand





SRF Cavity (a Nb/Cu clad cavity)

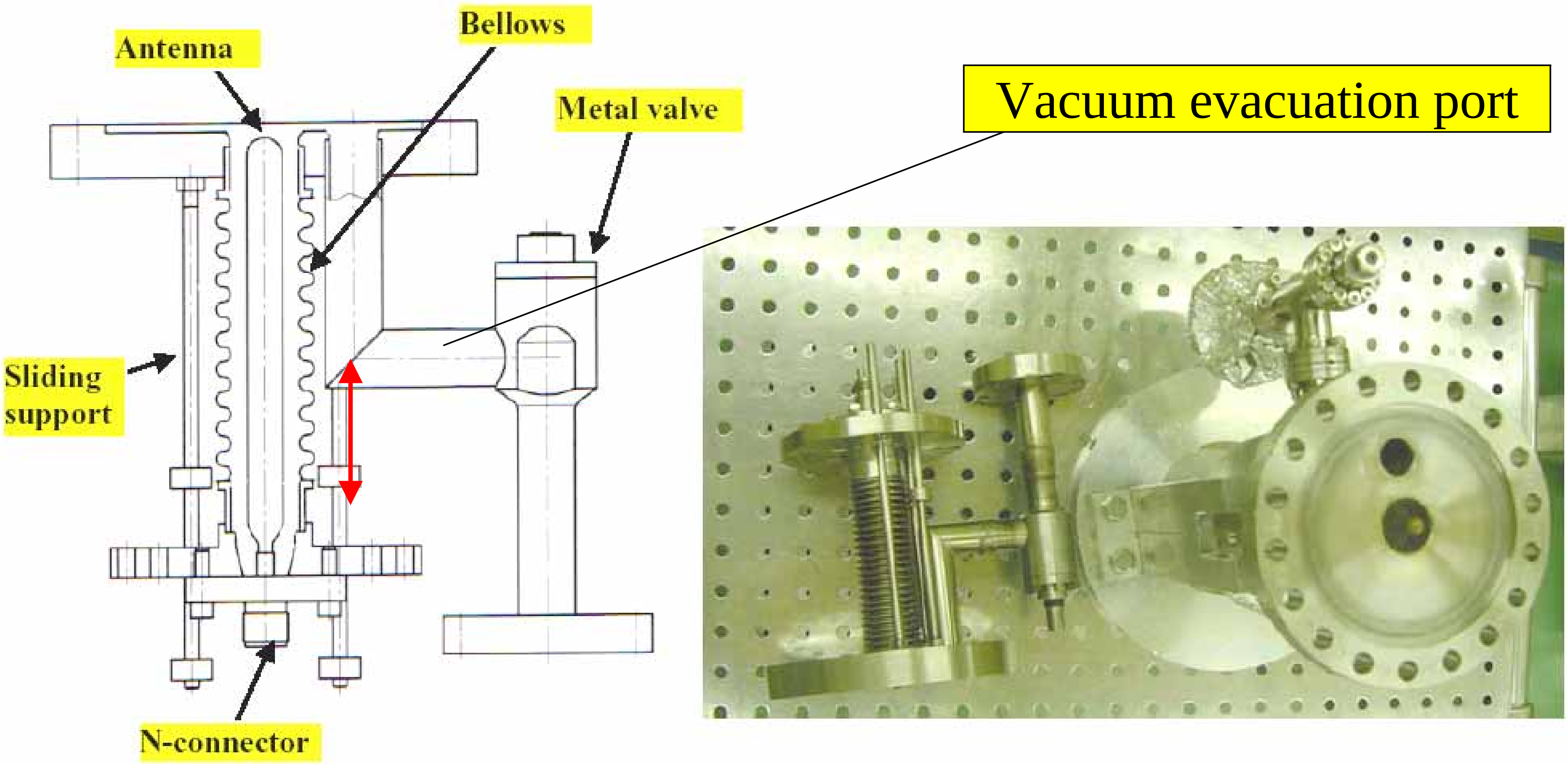


Pickup coupler

A SRF cavity hanged vacuum evacuation stand.
The cavity vacuum is pinched off by a metal valve.

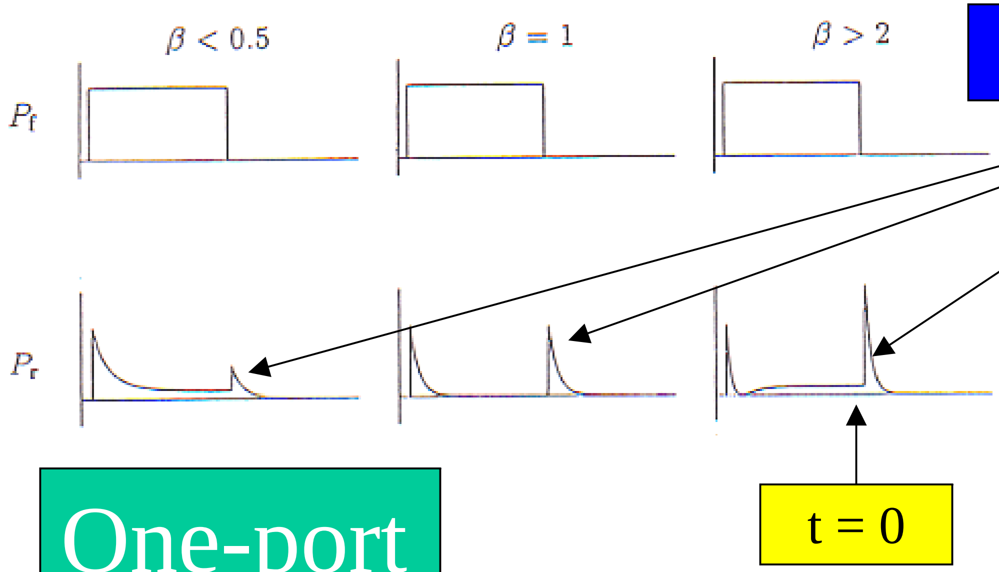
Variable
RF Input coupler

Structure of the Variable RF Input Coupler



Variable input coupler for the vertical test in KEK

9.2 Theory of RF Measurement of SRF Cavities

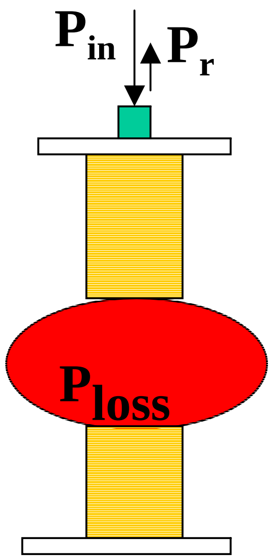


Pulse method

$$P_t(t) = P_o \exp\left(-\frac{\omega}{Q_L}t\right)$$

$\omega = 2\pi f$, Q_L : Loaded Q

One-port



Decatime : $\tau_{1/2}$

$$P_t(\tau_{1/2}) = \frac{1}{2}P_o = P_o \exp\left(-\frac{\omega}{Q_L}\cdot\tau_{1/2}\right)$$

$$\ln(2) = \frac{2\pi f}{Q_L}\tau_{1/2}$$

$$Q_L = 2\pi f \cdot \frac{\tau_{1/2}}{\ln(2)}$$

One-Port Cavity

$$Q_O \equiv \frac{\omega U}{P_{loss}},$$

$$Q_L \equiv \frac{\omega U}{P_{loss} + P_e} = \frac{\omega U}{P_{loss}\left(1 + \frac{P_e}{P_{loss}}\right)}$$ **(for one port)**

$$= \frac{Q_O}{(1+\beta_{in})}$$

$$Q_O = (1+\beta_{in}) \cdot Q_L$$

$\tau_{1/2}$, P_{in}, P_r } Measurement

Calculation Q_L, β_{in}

Equivalent Circuit model

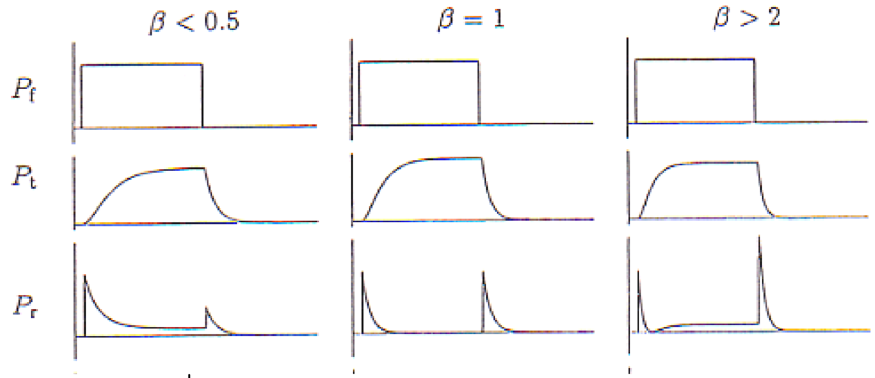
Judgment from Pr

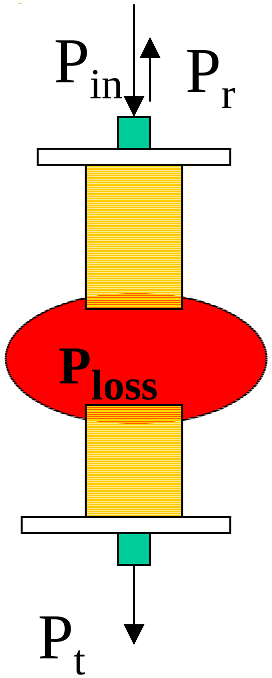
Calculation Qo

$$\beta_{in} \equiv \frac{P_e}{P_{loss}} = \frac{1 \pm \sqrt{P_r / P_{in}}}{1 \mp \sqrt{P_r / P_{in}}}$$ **(over > 1 / under < 1)**

$$R_s = \frac{\Gamma}{Q_o}$$

Two-Port Cavity





$$P^*_{loss} = P_{loss} + P_t$$

$$Q^*_o = \frac{\omega U}{P^*_{loss}} = \frac{\omega U}{P_{loss} + P_t}$$

$$= \frac{\omega U}{P_{loss}\left(1 + \frac{P_t}{P_{loss}}\right)}$$

measurement

$$= \frac{Q_o}{(1+\beta_t)} \quad \because \beta_t \equiv \frac{P_t}{P_{loss}}$$

$$= (1+\beta^*_{in})Q_L$$

measurement

$$\beta^*_{in} = \frac{1 \pm \sqrt{P_r / P_{in}}}{1 \mp \sqrt{P_r / P_{in}}}$$

(over > 1/ under < 1)

$$Q_o^* = \frac{Q_o}{(1+\beta_t)} = (1+\beta_{in}^*)\cdot Q_L$$

$$Q_o = (1+\beta_{in}^*)\cdot(1+\beta_t)\cdot Q_L$$

$$= \left[1+(1+\beta_t)\cdot\beta_{in}^* + \beta_t\right]\cdot Q_L$$

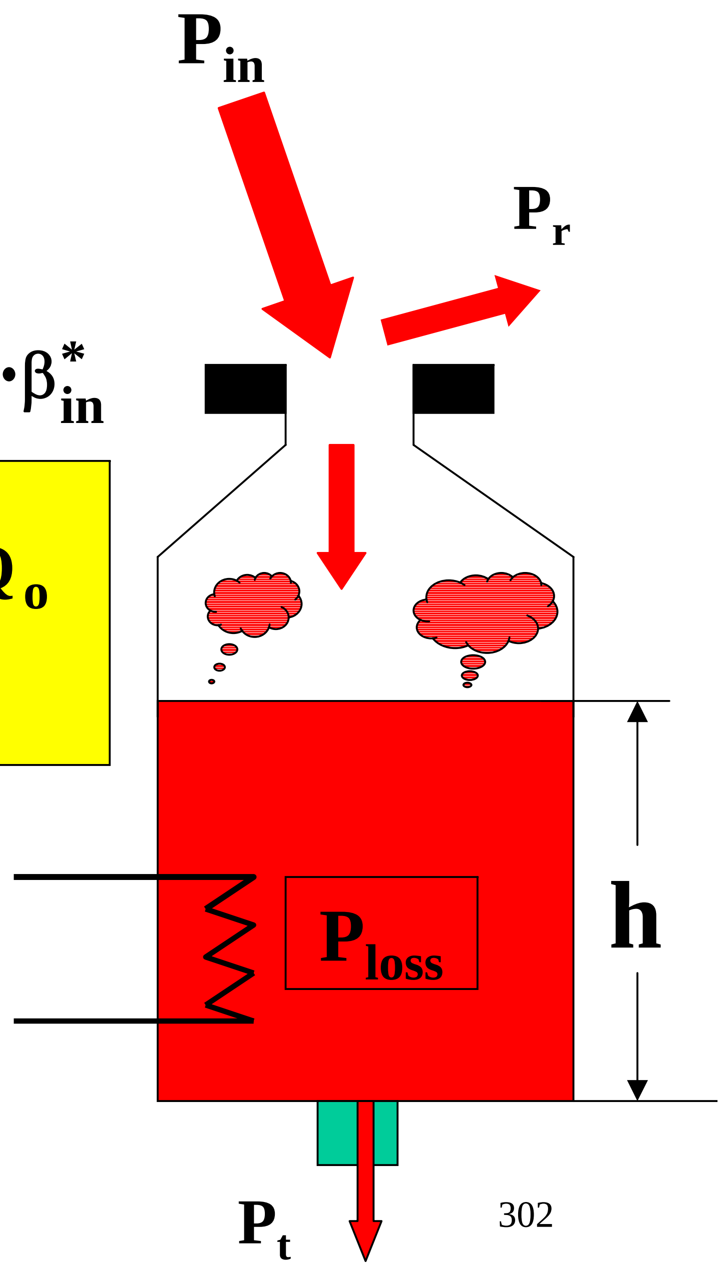
$$= (1+\beta_{in}+\beta_t)\cdot Q_L \quad \because \ \beta_{in} \equiv (1+\beta_t)\cdot\beta_{in}^*$$

$$Q_o \equiv \frac{\omega U}{P_{loss}}, \quad Q_t \equiv \frac{\omega U}{P_t} = \frac{\omega U / P_{loss}}{P_t / P_{loss}} = \beta_t \cdot Q_o$$

$$\omega U = Q_o \cdot P_{loss} = Q_t \cdot P_t$$

$$P_{loss} = P_{in} - P_r - P_t$$

Stationary state : h = const ⇐ U const



Calculation of Gradient

Exercise VIII.

$$R_{sh} = \frac{V^2}{P_{loss}} \quad \because\ V = E_{acc} \cdot d_{eff}$$

$$= \frac{(Eacc \cdot d_{eff})^2}{P_{loss}}$$

$$Eacc = \frac{1}{d_{eff}} \cdot \sqrt{R_{sh} \cdot P_{loss}} = \frac{\sqrt{R_{sh} / Q_O}}{d_{eff}} \cdot \sqrt{Q_O \cdot P_{loss}} = Z \cdot \sqrt{Q_O \cdot P_{loss}}$$

$$= Z \cdot \sqrt{Q_t \cdot P_t}$$

$$\because\ Q_O \cdot P_{loss} = Q_t \cdot P_t$$

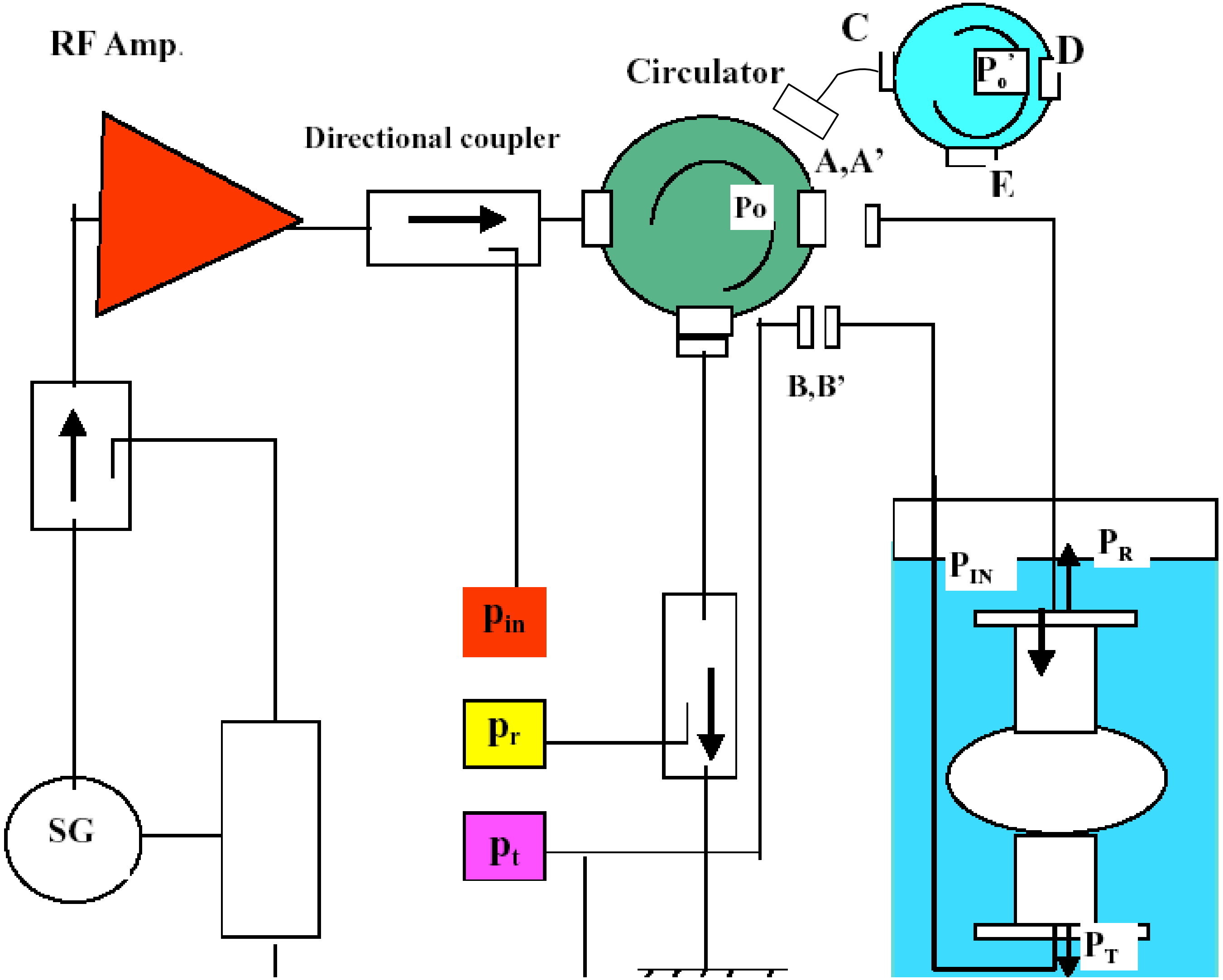
Once measured the Q_t, you can calculate Eacc directly from P_t and Q_t.
Q_O is also directly calculated from them.
You don't need to measure the decay time for every gradient.

Cable Correction

Exercise VII.

p_{in}, p_r, p_t : measured in the measurement room

P_{IN}, P_R, P_T : Power at the cavity (cooled), $P_{IN} = c_{in} \cdot p_{in}$, $P_R = c_r \cdot p_r$, $P_T = c_t \cdot p_t$



p_{in}, P_O at A,

p_r: short A

p_t : connect B to A

P_O/p_{in}, P_O/p_r, P_O/p_t

P_O' at E : connect A and C , and short D

p_{in}' at E : connect D to A'

p_t' at E : connect D to B'

$C_{in}=(P_O/p_{in}) \cdot (p_{in}'/P_O')^{1/2}$

$C_r=(P_O/p_r) \cdot (P_O'/p_{in}')^{1/2}$

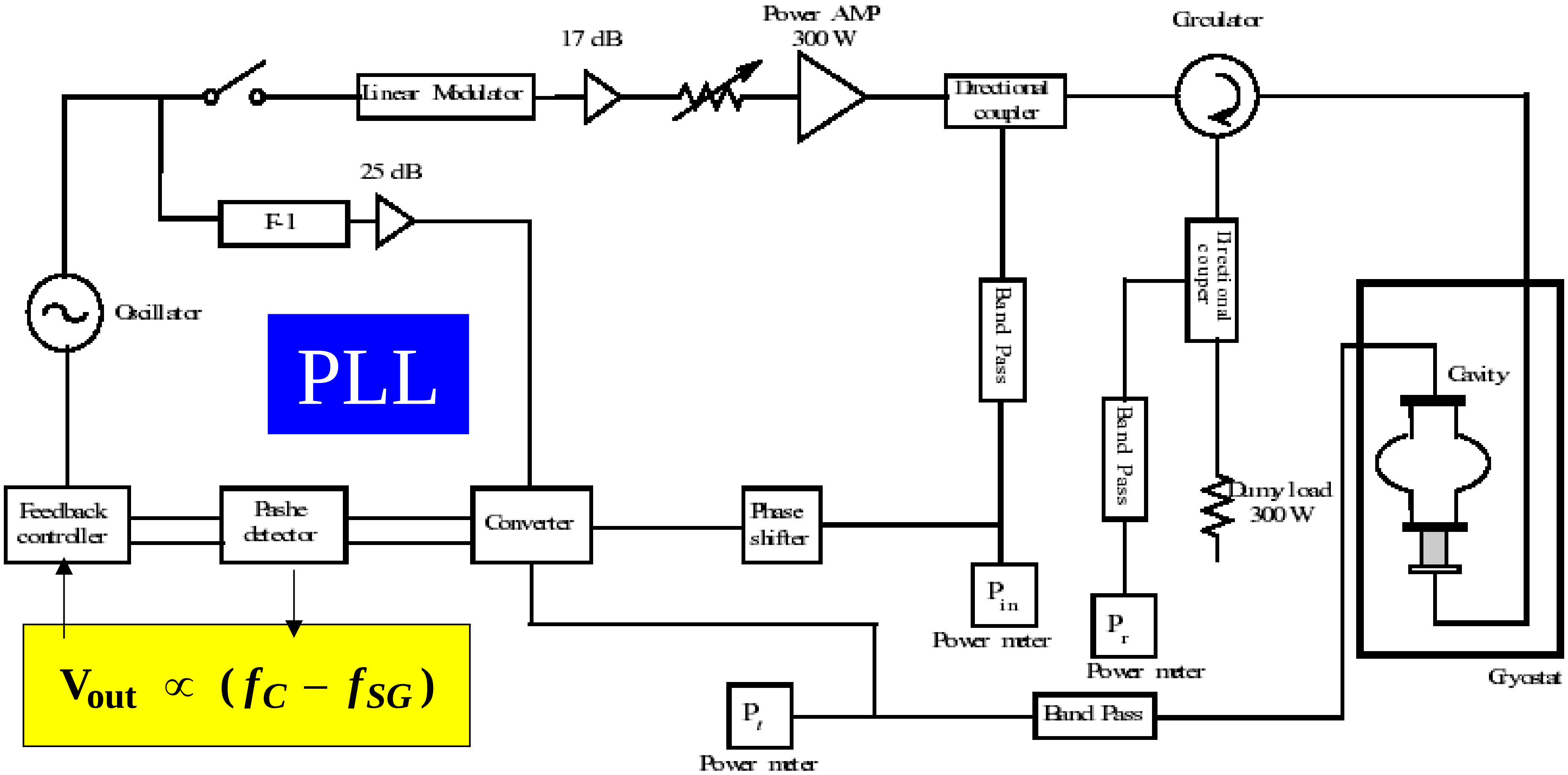
$C_t=(P_O/p_t) \cdot (P_O'/p_t')^{1/2}$

$P_{IN} = c_{in} \cdot p_{in}$

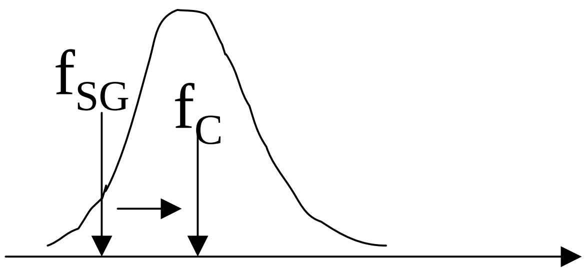
$P_R = c_r \cdot p_r$

$P_T = c_t \cdot p_t$

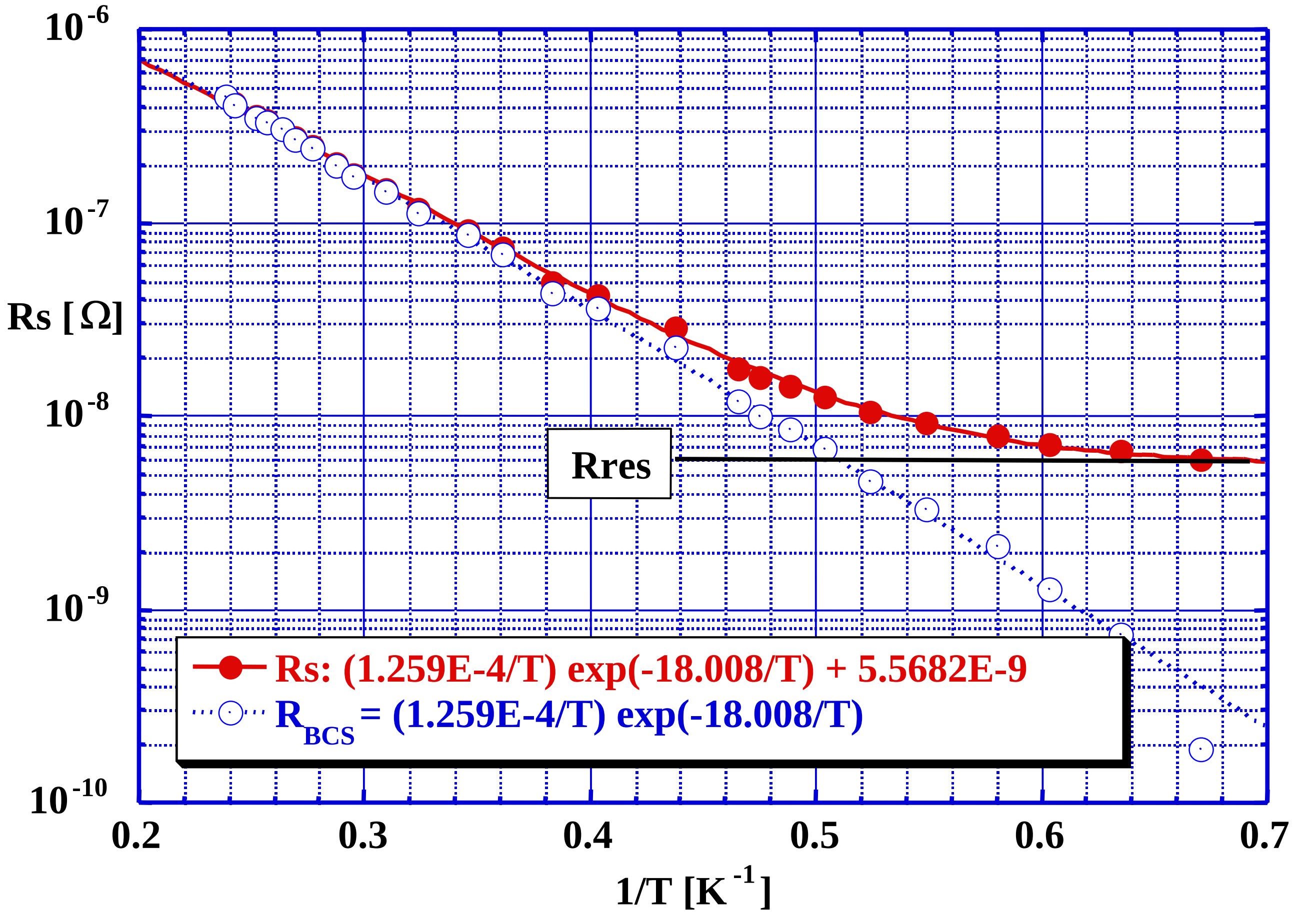
9.3 RF Measurement System



$$V_{out} \propto (f_C - f_{SG})$$



Measurement of Surface Resistance



$$R_s - \text{fit}: R_s(T) = \frac{A}{T} \cdot \exp\left(-\frac{B}{T}\right) + R_{res}$$

$$B = \frac{\Delta}{k_B}$$

High Gradient Measurement Qo-Eacc curve