Requirements from LLRF on operational margin

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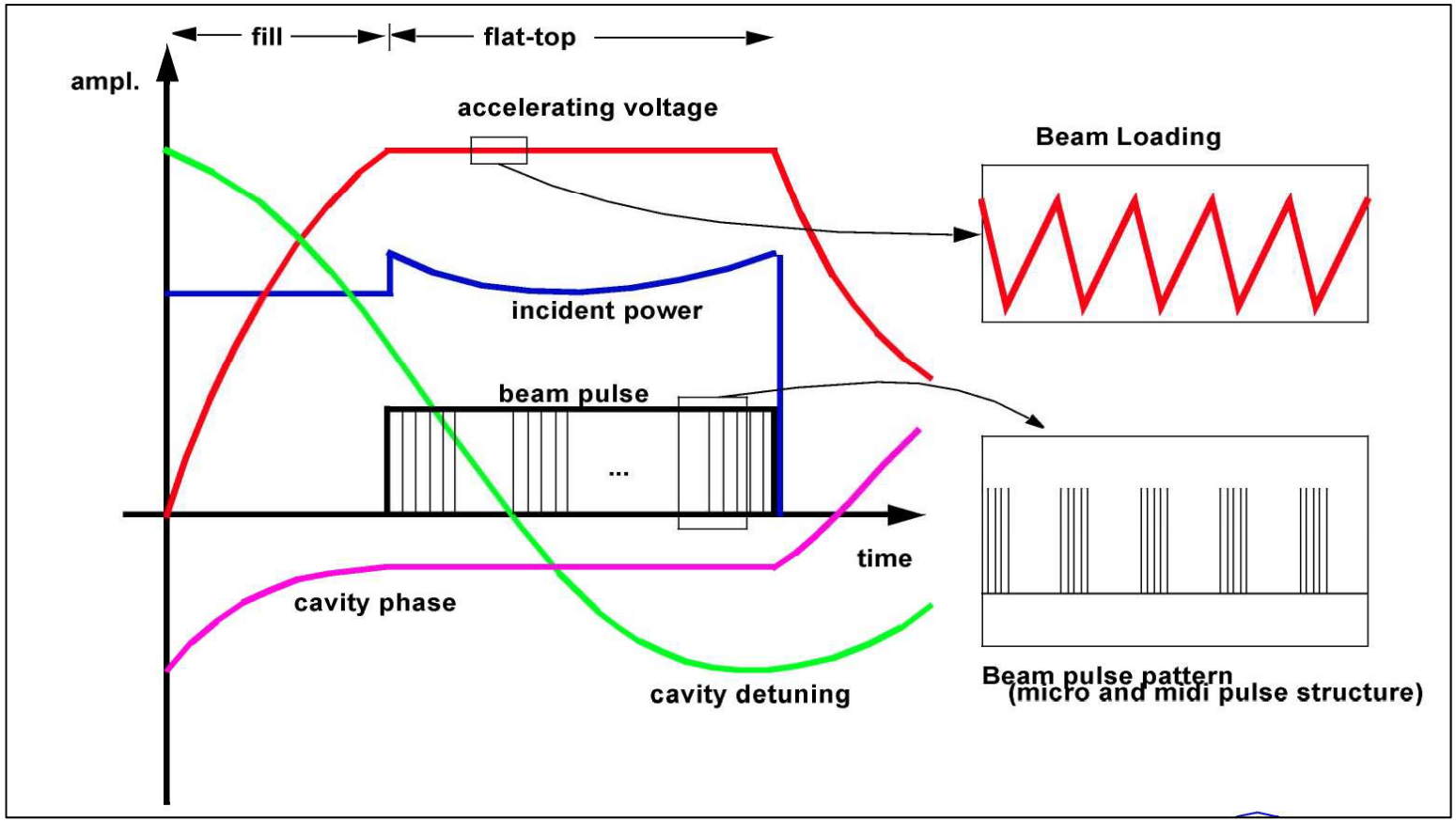
LLRF control



- Various fluctuations are compensated by LLRF feedback system.
- Lorentz force detuning, microphonics, beam fluctuation and so on.

PkQl control

- In case of the Pk-Ql control near the quench limit condition, the values of Pks and Qls are calculated as followings.

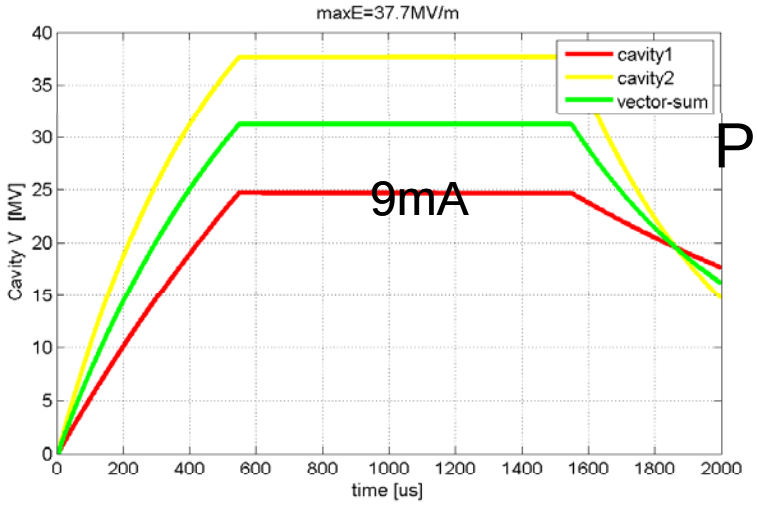
1. Select operational gradient of each cavity (Vcav)
2. Find out the Pk and Ql of each cavity under the specific beam current (Ibeam) and injection timing (Tinj).

$$Igen = Ibeam \cdot \exp\left(\frac{T_{inj}}{\tau}\right)$$

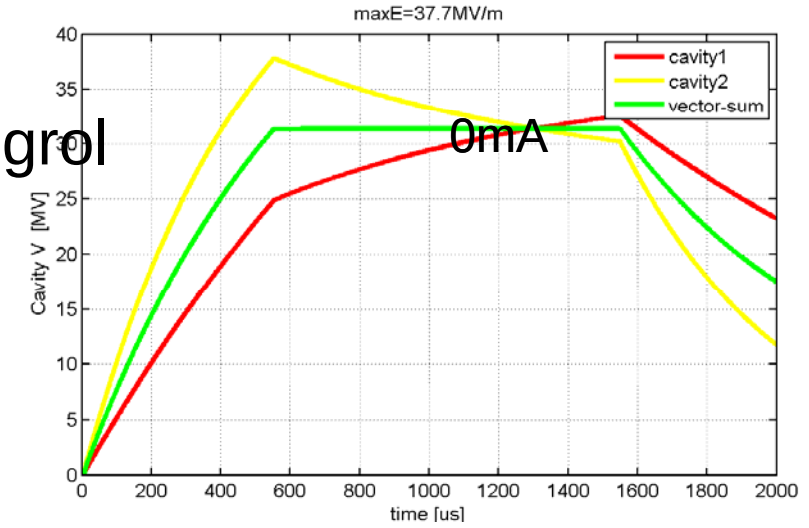
$$V_{cav} = 2\frac{r}{Q} Q_L Igen \cdot \left(1 - \exp\left(-\frac{T_{inj}}{\tau}\right)\right)$$

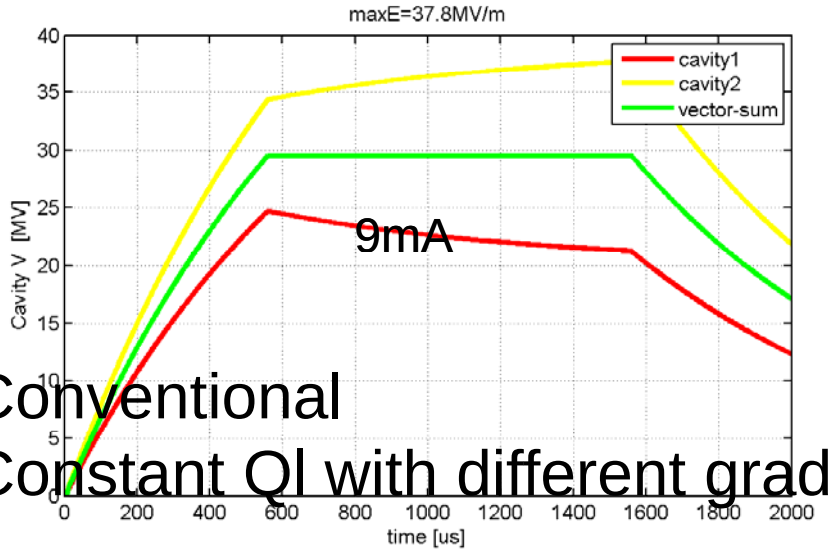
$$\rightarrow \quad Pk = \frac{1}{4}\frac{r}{Q} Q_L (Igen)^2$$

Pk QL control and conventional control

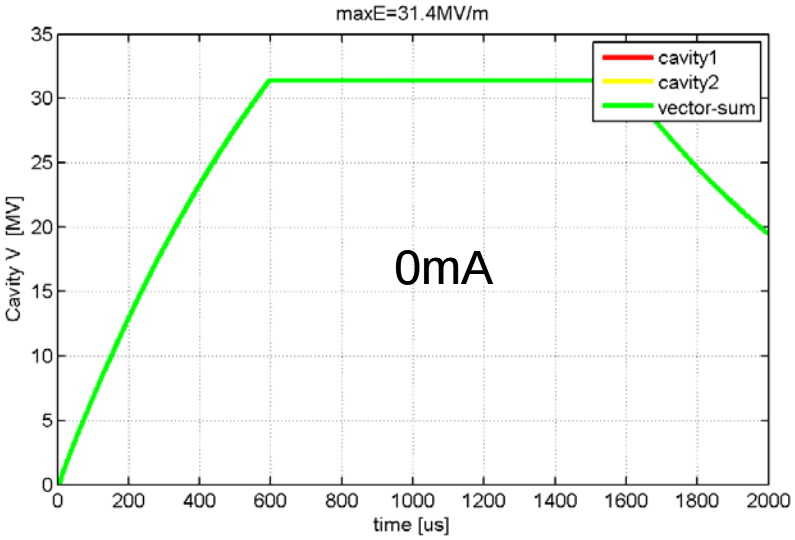


PkQl congrol





Conventional
Constant Ql with different gradients



RF configuration

	Conventional	Pk-Ql control
Ql	constant	Remote change depending on the beam current, gradient
RF distribution (Pk)	constant	Remote change depending on the beam current, gradient
Flatness of each cavity	Flat only if the cavities are operated at same gradient.	Flat if Pk & Ql are changed.
comment		Need study because of its complexity

- Pk-Ql control is one of the candidate. (but rather complex and need more study.)
- If we know the cavity performance in advance, same gradient control of each rf unit is preferable.

Operational margin

- We llrf want to know
  - Operational gradient margin
  - flatness of each cavity (under vector sum)
- Concerning cavity gradient, the margin depends on
  - Availability
  -Detunings of the cavities (microphonics)
  - Lorentz force detuning compensation (reliability of piezo and HV supply)
  - Beam current stability
  - LLRF operational gain (10? 100? 1000?) (The max gain comes from the total feedback loop)

Operational margin (2)

- Operational gradient:

Cavity > Cryomodule > ILC Cryomodule string

- Cavity: qunech limit
- Cyromodule: spread of gradient, gradient tilting
- ILC: Beam fluctuation, high reliability

- Need study (including operability) and simulation under KCS and DRFS configuration with Pk-Ql and conventional control.