Phase and amplitude tolerance - XFEL -

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Amplitude and phase stability for I/Q detection

Phase and Amplitude error:

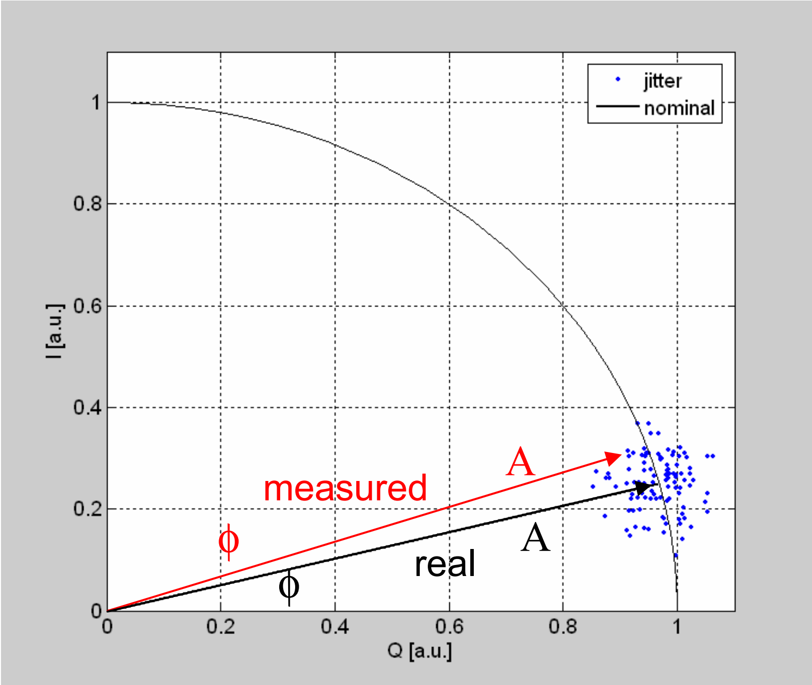
$$d\phi = \phi - \phi$$
$$dA = A - A$$

Is determined by the resolution for I and Q measurements.

But resolution equals $\sigma_I = \sigma_Q$

$\Rightarrow$ $d\phi = dA/A$ or

$\Rightarrow$ $1° \propto 1.75\%$



- To improve the amplitude stability additional detectors are required
- Slow phase drifts in cables and electronics reduce the accuracy
- Good phases reference (LO), e.g. new synchronization eliminates reference drifts

RF tolerance for XFEL
- chirp only induced upstream BC1 -

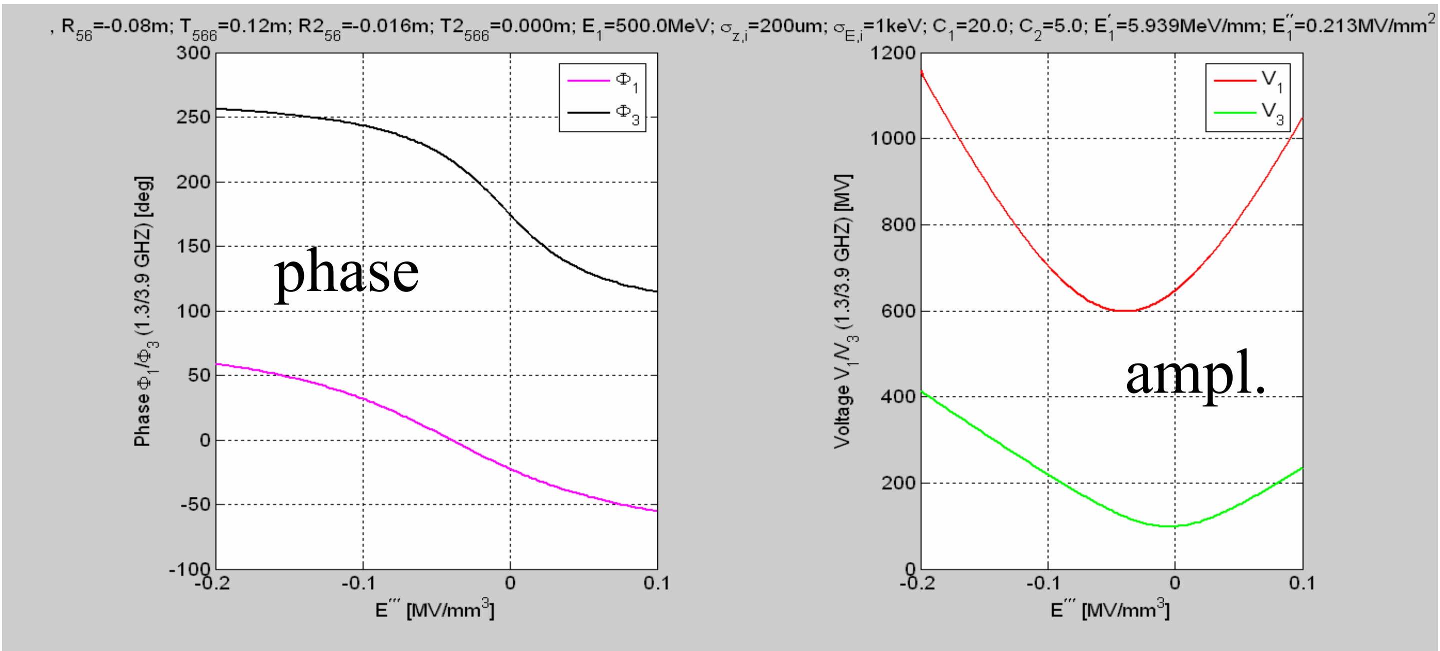
- RF

$$\begin{aligned} V(\phi) &= V_1 \cos(\phi + \phi_1) + V_3 \cos(3\phi + \phi_3) \\ \phi &= \omega_{rf} \cdot t = k_{rf} \cdot z \end{aligned}$$

fixed are E_1, $E_1' = -\frac{E_{10}}{R_{56}}\left(1 - \frac{1}{C_1}\right)$

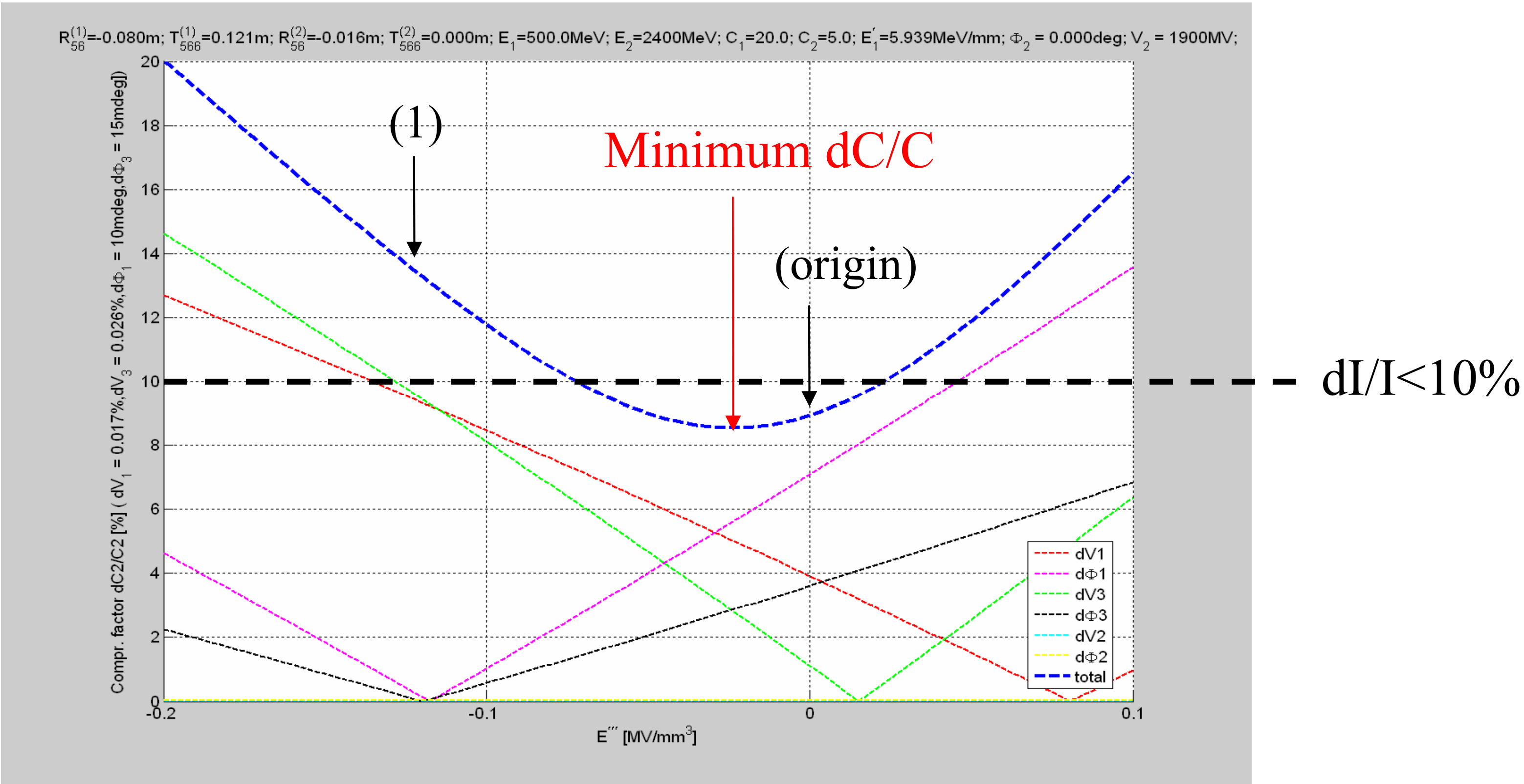
$$E_1'' = -2 \frac{T_{566}}{R_{56}} \frac{(E_1')^2}{E_{10}}$$

- but (M. Dohlus) third derivative (E''') can be chosen
- RF parameter of the 1.3GHz (V_1) and the 3.9GHz (V_3) as fct. of E'''



RF tolerance for XFEL
- variation of compression after BC2 -

- jitter assumptions: $dV_1/V_1 = dV_2/V_2 = 1.7e\text{-}4$ (0.01° L-Band)
  $dV_3/V_3 = 2.2e\text{-}4$ (0.015° at 3.9GHz [not full benefit or higher f])
- variation of E''' allows to operated with distributed tolerance (minimum)
- but relaxed phase sensitivity cause critical amplitude tolerance (1)



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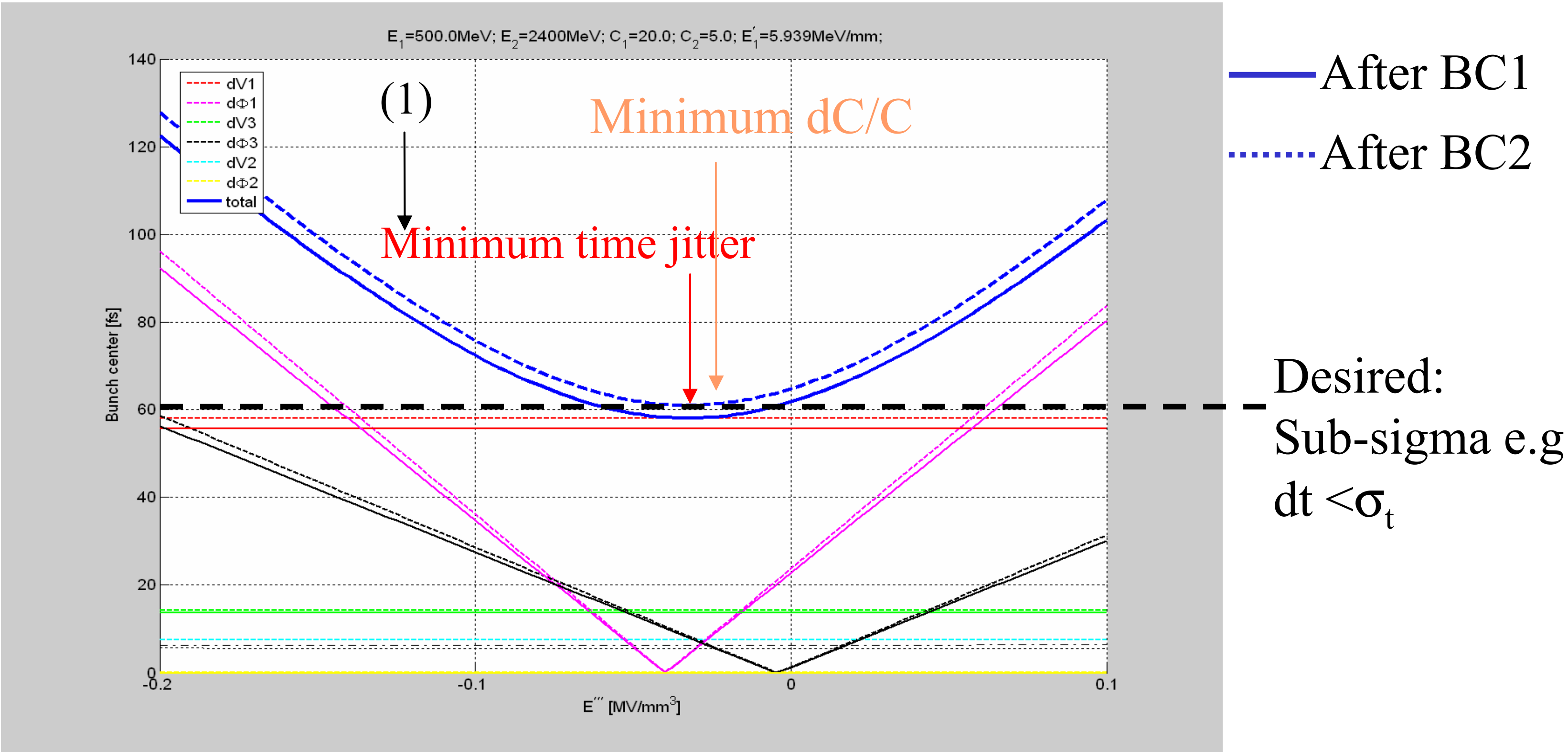
RF tolerance for XFEL
- arrival time jitter -

- most critical is amplitude jitter of 1.3GHz V_1
- phase jitter dominates for larger |E'''| (correlated jitter with $\phi_1 = +3\phi_3$)
- operation point (1): arrival time jitter increased by 40%, ϕ_1 critical



RF tolerance for XFEL
- conclusion -

• variation of E''' allows to select minimum
  - of compression jitter and
  - of arrival time jitter

• for I/Q detection 1° = 1.7% => both minima close to one another

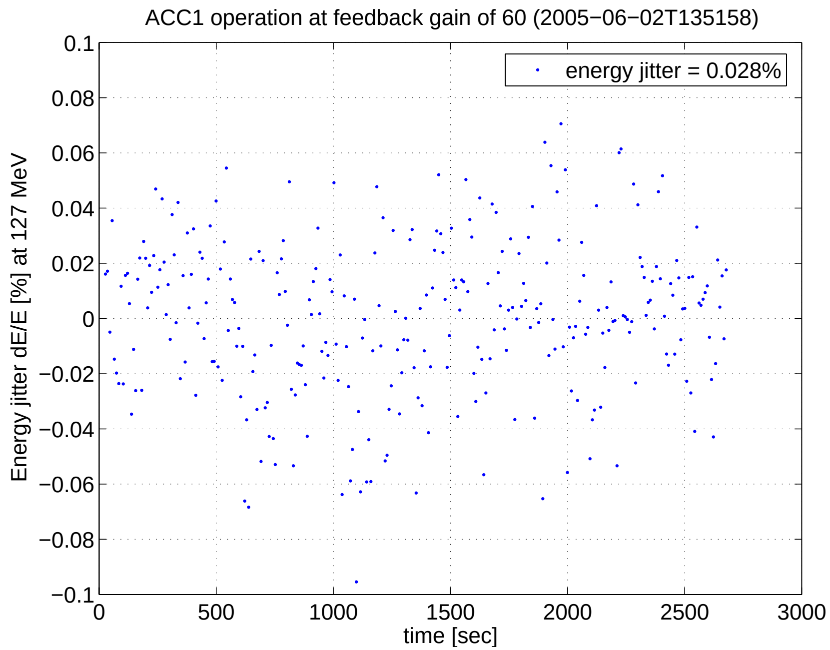
• currently operation point (1) does not provide advantages

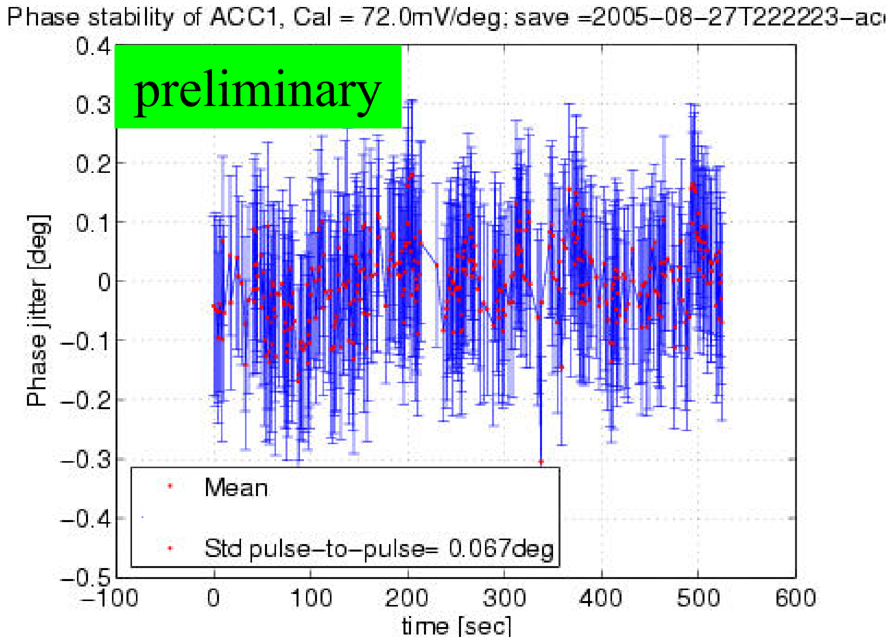
• preferable to develop additional RF amplitude detectors to reduce arrival time jitter and to achieve higher flexibility in the operation point of E'''.

• beam based monitors of the energy, the compression and the arrival timing for FBs are most critical and will dominantly influence the final choice of the machine operation settings.

RF tolerance for XFEL
- achievements at VUV-FEL -

- only measurements shot-to-shot (no detectors available for intra-pulse trains)
- amplitude stability ACC1 (8 cav.) best result $\sigma_A/A = 0.028\%$, typical =0.05%
- phase stability with pyro-detector $\sigma_\phi = 0.067°$ (but laser and gun phase included)





- TTF1: 5 times better within the macro-pulse compared to shot-to-shot
- upgrade of LLRF: DSP -> FPGA, down-converters from 250kHz -> 81MHz
  => high resolution, lower latency and no ripple -> high gain 100-200 possible

σ_A/A = 5e-5 within pulse possible => intrinsic 3 mdeg phase