# RF overhead study at FLASH

**DESY Feb.21-27,2012**

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- Study schedule
- RF overhead
- Study results
- Summary

# Study Schedule on Feb., 2012

- PkQl study
- Quench limit study
- ***RF overhead study***

**PROPOSED SHIFT-BY-SHIFT studies plan**

| Shift Ref. | | | Operator | 9mA Study Leader | Primary goals |
|---|---|---|---|---|---|
| 1 | Tuesday (21 Feb) | 07:00–15:00 | Avazyan | | 1. Switch laser to 3MHz<br>2. Switch machine rate to 5Hz |
| 2 | | 15:00–23:00 | Eislage | | 1. Laser setup/optimization for 3MHz / long bunch trains<br>2. Machine startup, preparation for 9mA shifts<br>3. LLRF commissioning for 9mA studies (need list of items) |
| 3 | | 23:00–07:00 | Klose | | 1. Machine tuning, aim for ≥3mA, max. bunches |
| 4 | Wednesday | 07:00–15:00 | Schmidt | | 1. Beam loading compensation setup<br>2. Piezo tuner setup<br>3. Complete measurements of ACC67 quench limits |
| 5 | | 15:00–23:00 | Ayvazyan | | 1. Pk/Ql studies at ≥3mA |
| 6 | | 23:00–07:00 | Eislage | | Machine tuning, aim for >4mAmA, max. bunches |
| 7 | Thursday | 07:00–15:00 | Schmidt | | 1. High gradient studies with light beam loading |
| 8 | | 15:00–23:00 | Ayvazyan | | 1. Pk/QL studies at >4mA<br>2. Preparation for Klystron saturation / RF power overhead studies |
| 9 | | 23:00–07:00 | Eislage | | 1. Machine tuning, aim for ≥6mA, max. bunches |
| 10 | Friday | 07:00–15:00 | Delfs | | 1. Test procedures for performing gradient scans (+/− few %) with 6+ mA and long bunch trains |
| 11 | | 15:00–23:00 | Schmidt | | 1. High gradient studies with light beam loading |
| 12 | | 23:00–07:00 | Ayvazyan | | 1.Pk/Ql studies at 6mA and long bunch trains<br>2. Set up for 8hr stable run with gradients close to quench and moderate beam loading |
| 13 | Saturday | 07:00–15:00 | Delfs | | 8hr stable run with gradients close to quench with moderate beam loading |
| 14 | | 15:00–23:00 | Schmidt | | 1. High gradient studies<br>2. Set up for RF power overhead studies |
| 15 | | 23:00–07:00 | Ayvazyan | | RF power overhead studies |
| 16 | Sunday | 07:00–15:00 | Delfs | | Set up high gradient studies with heavy beam loading<br>High gradient studies with heavy beam loading |
| 17 | | 15:00–23:00 | Schmidt | | High gradient studies with heavy beam loading |
| 18 | | 23:00–07:00 | Ayvazyan | | High gradient studies with heavy beam loading |
| 19 | Monday (27 Feb) | 07:00–15:00 | | | **RESTORE MACHINE TO 1MHz/10Hz** |

# Llrf tuning overhead

- As in RDR, llrf tuning overhead is 16% in power.
- Further suppression of rf overhead is requested.
- LLRF overhead covers such as

  (dynamic) microphonics, fluctuation of HV (klystron), beam current, …
  (static) Pk and Ql tolerance, HV ripple, …

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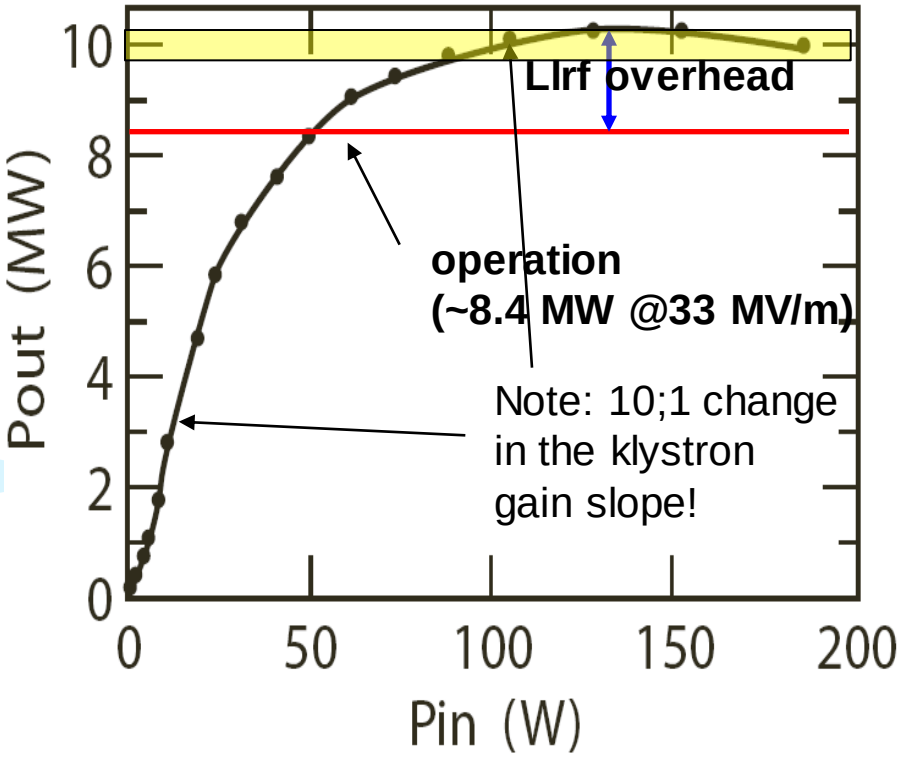
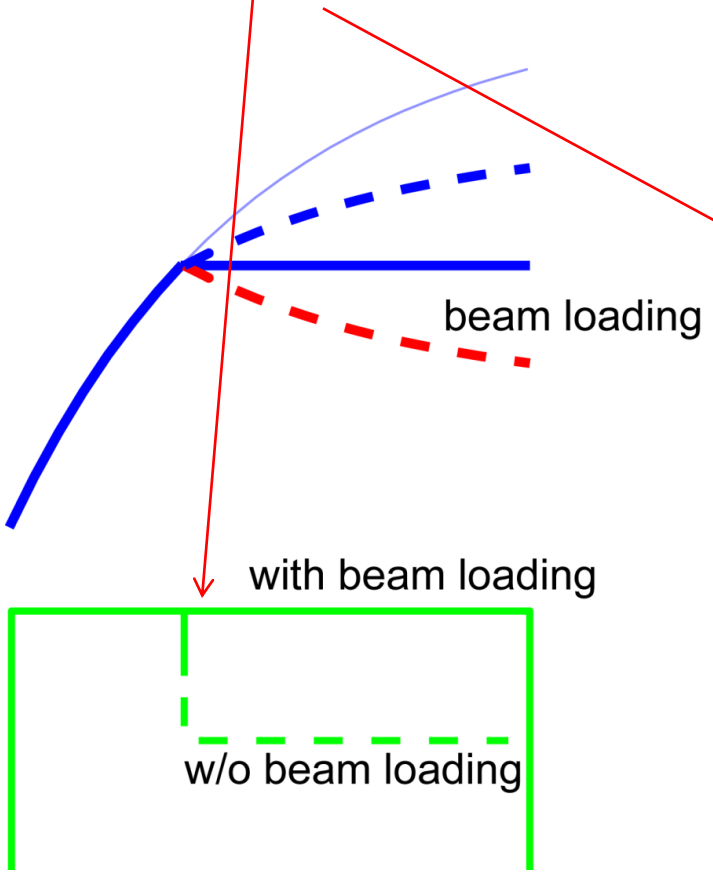
nit parameters.

| Parameter | Value | Units |
|---|---|---|
| Modulator overall efficiency | 82.8 | % |
| Maximum klyston output power | 10 | MW |
| Klystron efficiency | 65 | % |
| RF distribution system power loss | 7 | % |
| Number of cavities | 26 | |
| Effective cavity length | 1.038 | m |
| Nominal gradient with 22% tuning overhead | 31.5 | MV/m |
| Power limited gradient with 16% tuning overhead | 33.0 | MV/m |
| RF pulse power per cavity | 293.7 | kW |
| RF pulse length | 1.565 | ms |
| Average RF power to 26 cavities | 59.8 | kW |
| Average power transferred to beam | 36.9 | kW |

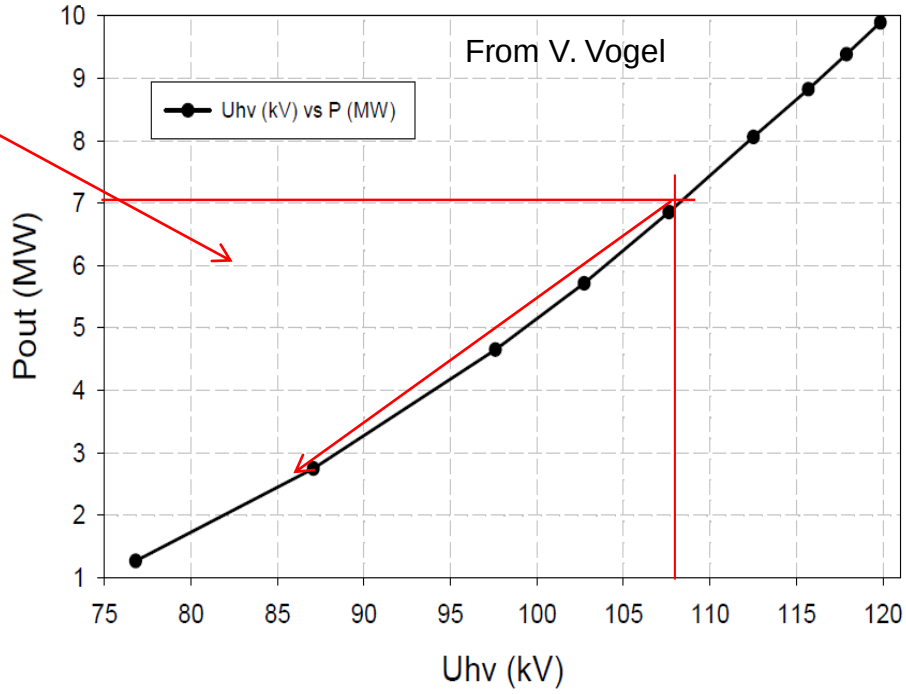


# Preparation for RF overhead study

• Rectangular rf output (not “Step-like”) is required because the rf overhead should be examined at flat-top.
-> high current beam is desired.
-> filling time should be optimized.
• Near saturation operation is required.
-> Lower voltage operation of the klystron

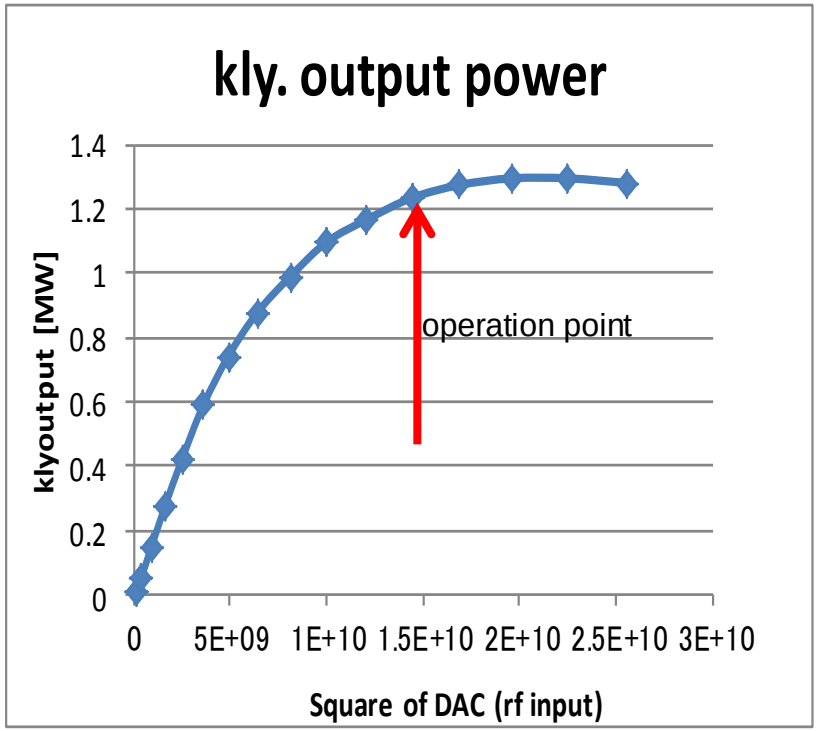


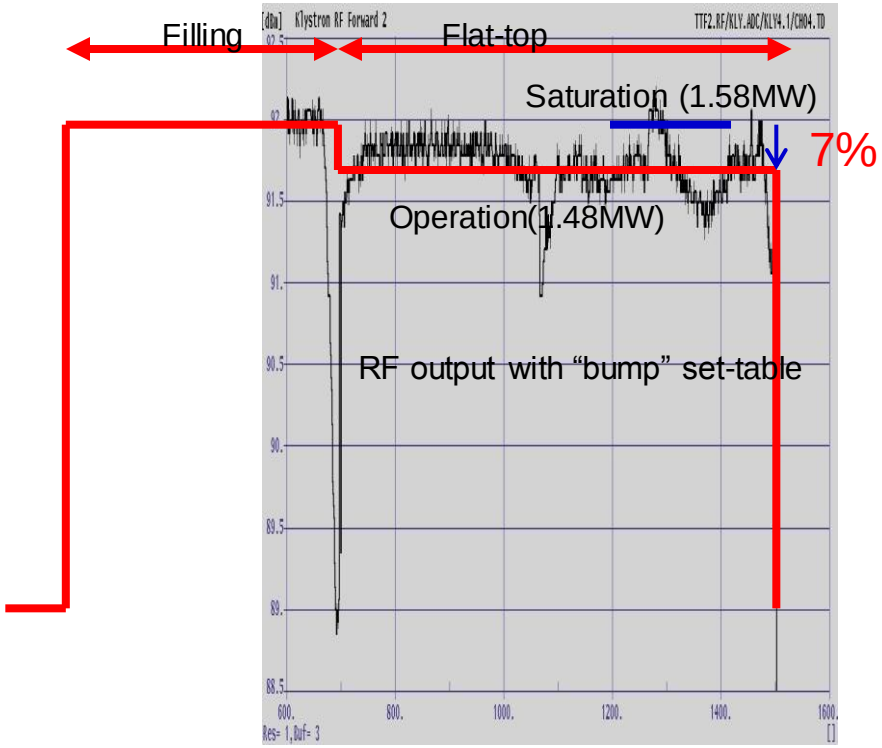

Klystron voltage v.s. rf output



# RF operation condition

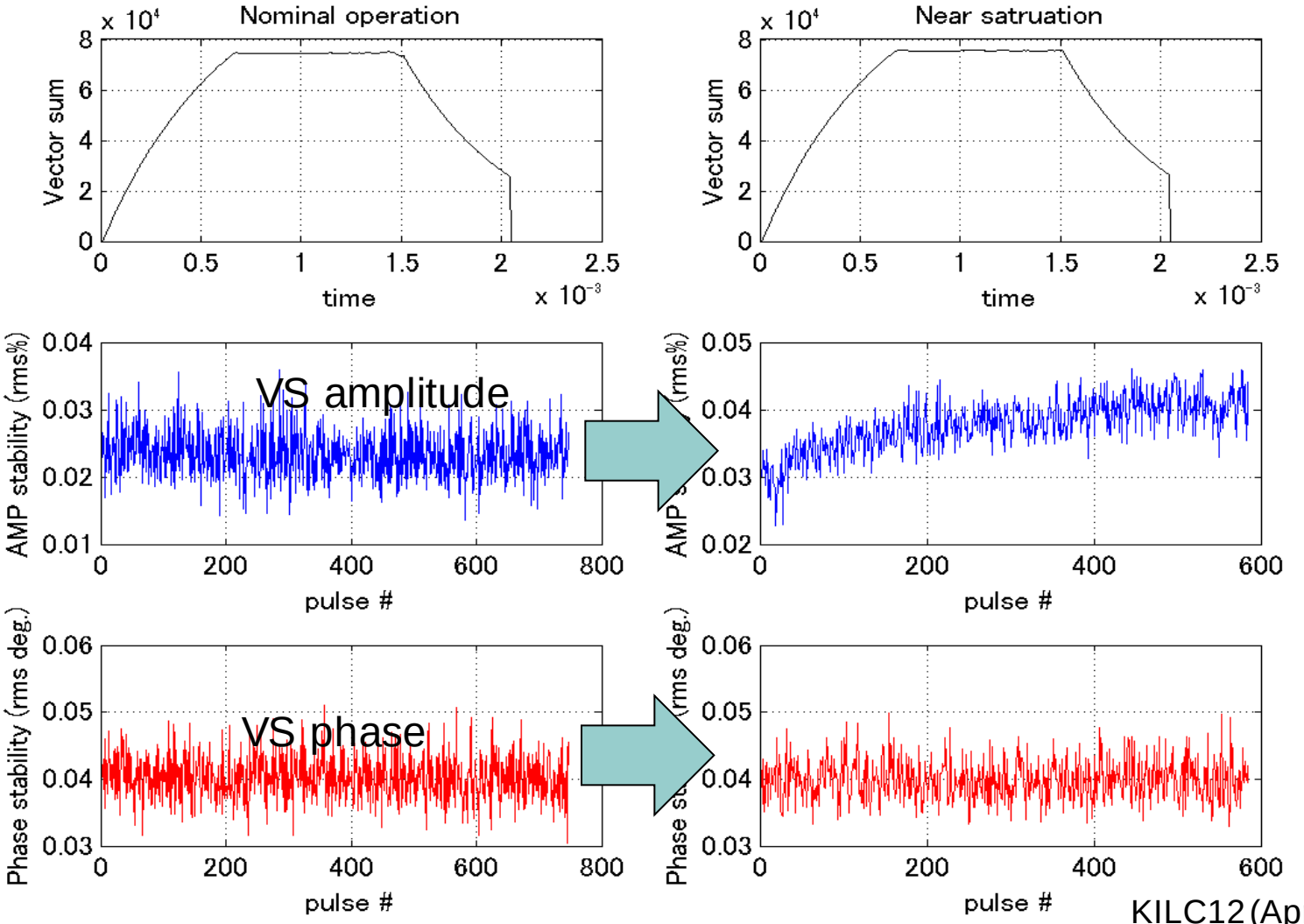
- HV of klystron was decreased from 108 kV to 86.5 kV.
- 4.5 mA beam was used.
- Filling time was adjusted to have ~rectangular output.(500us ->660us)
- Operation point is about -7% (in power) from saturation.



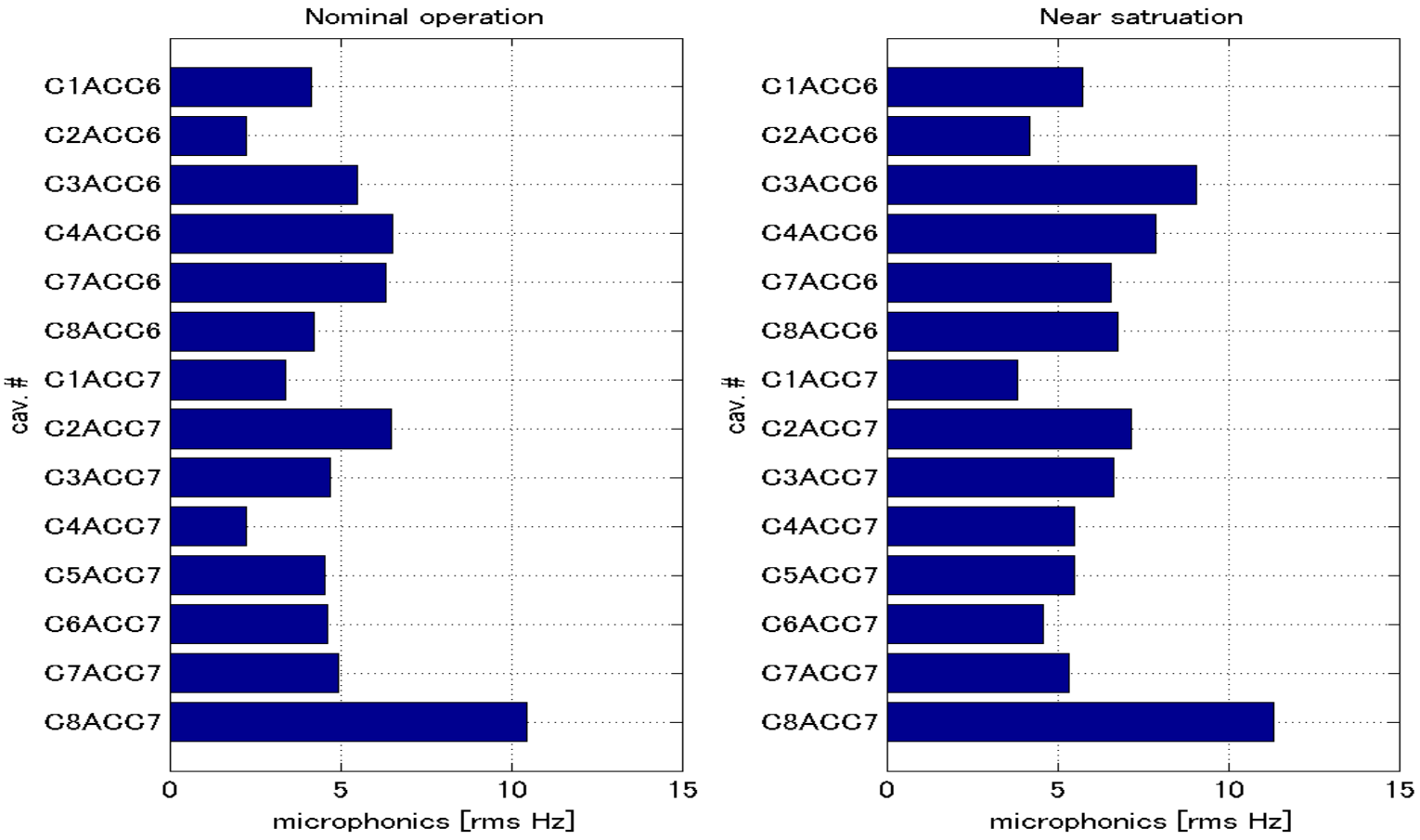
# Stabilities at nominal and near sat.

- Amplitude stability was worse twice at near sat. because of the limitation of rf.
- But 0.05%rms in amplitude can satisfy the requirements (~0.1% in amplitude)
- Phase stability was almost same between nominal and near saturation.



# Detuning (microphonics)

- Microphonics was measured using the phase slope at the end of the rf pulse.
- ~5Hz rms agrees well with the experience.
- These values are almost same between nominal and near saturation.
- The difference in amplitude performance is not related to the cavity itself but rf.



# Summary

- RF overhead was evaluated.
- It is possible to operate near saturation (~7% below saturation).
- The performance (amplitude and phase stabilities) satisfy the requirements.
- Dynamic fluctuations such as
  - Klystron HV fluctuation
  - Beam current fluctuation
  - Dynamic detuning (microphonics+ Lorentz force detuning)

  can be compensated.

Note: Evaluation of static rf losses, which use the rf overhead at all times, should be considered.
- Ql tolerance, Pk distribution tolerance, …