Beam physics/Operation and RF

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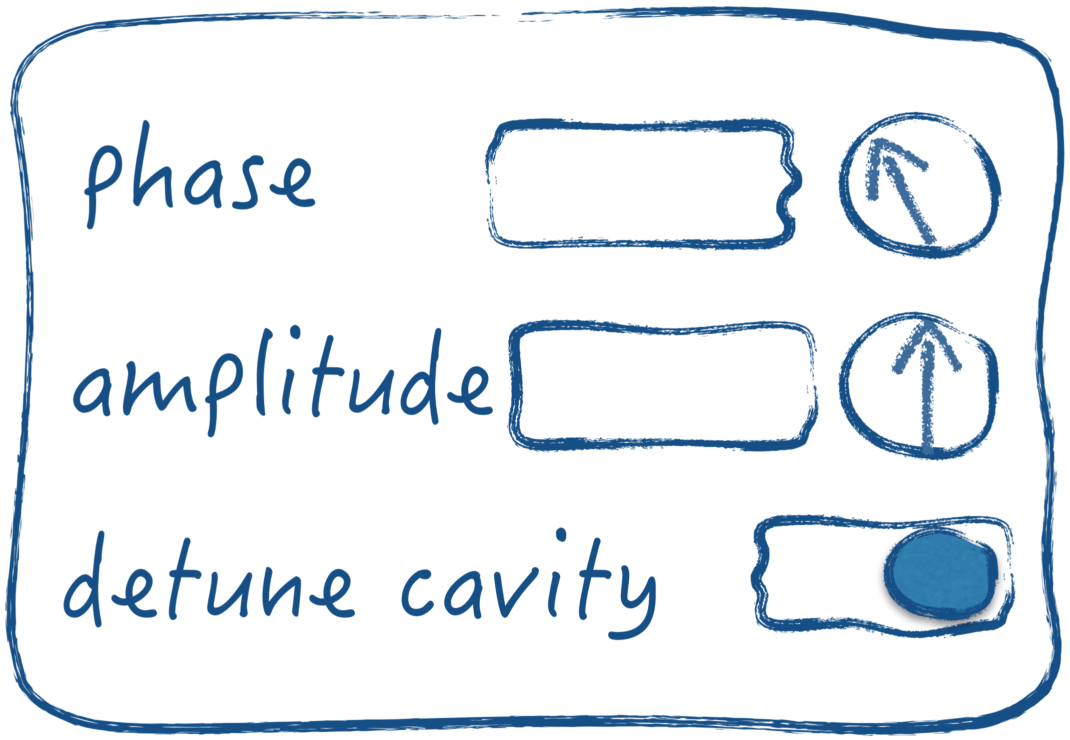
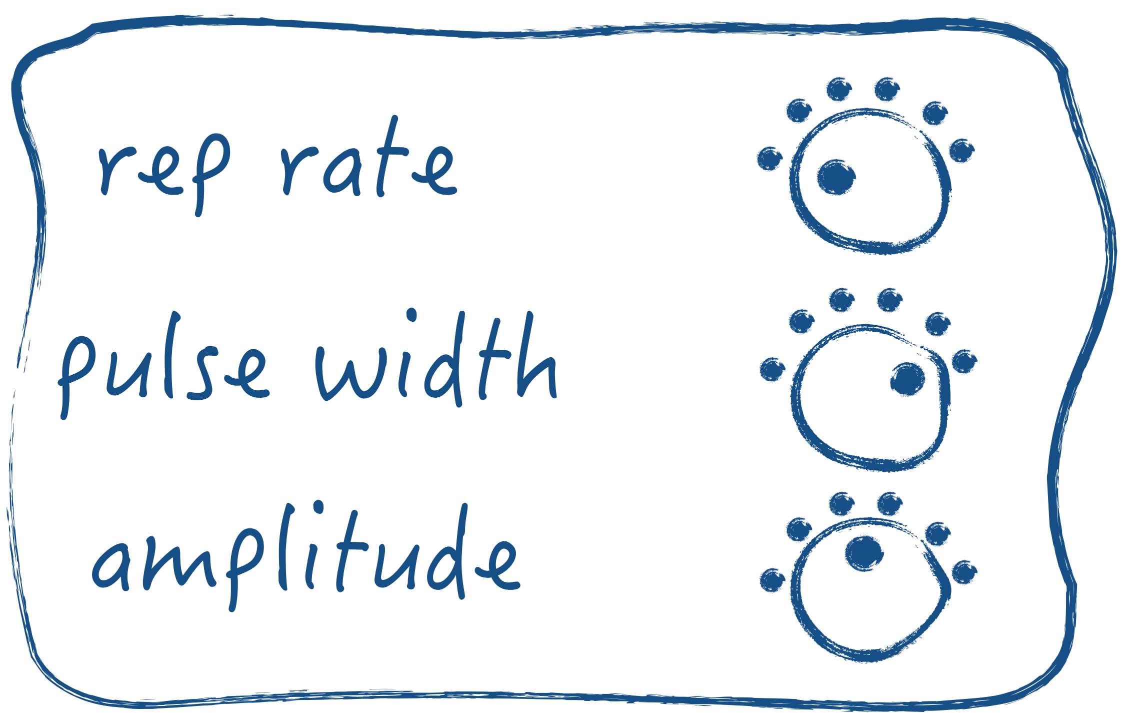
WHAT WE NEED

Operation

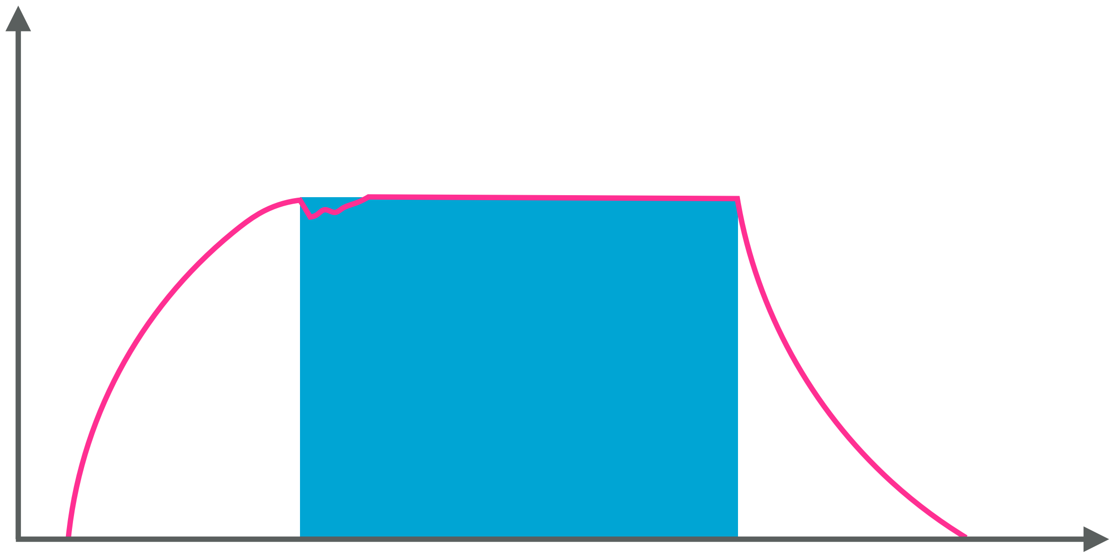


Conditioning and Commissioning



LLRF Needs

- Maintaining the field amplitude and RF phase constant within limits defined in requirements at the presence of errors from other sources
  - Microphonics (low frequency)
  - Beam current variation (not very fast)
  - Klystron and modulator ripple (high frequency)
  - Beam loading
  - …



- Requirements
  - NC linac: 0.2% and 0.2° RMS field and phase jitter
  - SC linac: 0.1% and 0.1° RMS field and phase jitter
    - The limits for the initial first 5 μs, overshoot and undershoot are different

Phase Scan

- Cavity tuning, setting the phase and amplitude of the cavities with respect to the incoming beam is done by a set of phase scans.
  - Each cavity's phase and amplitude will be scanned while a Probe beam (5 μs, 6 mA) beam passes through the cavity
    - from SNS experience we expect that this beam does not cause any beam loading
  - This arrival time or this beam to a downstream BPM or the time difference between two selected BPMs downstream of the cavity under scan will be used to set the phase and amplitude of the cavity
  - This requires the ability to change the phase and amplitude of individual cavities, either directly through EPICS or through an application which does the job automatically
    - For the latter we should make it clear what the format of the data/PV is

- Wish! knowledge of the absolute field in the cavity is a significant plus.
  - This will reduce the range of the phase scan, which will affect both tuning time and the amount of losses in the linac

Other Dependent Measurements

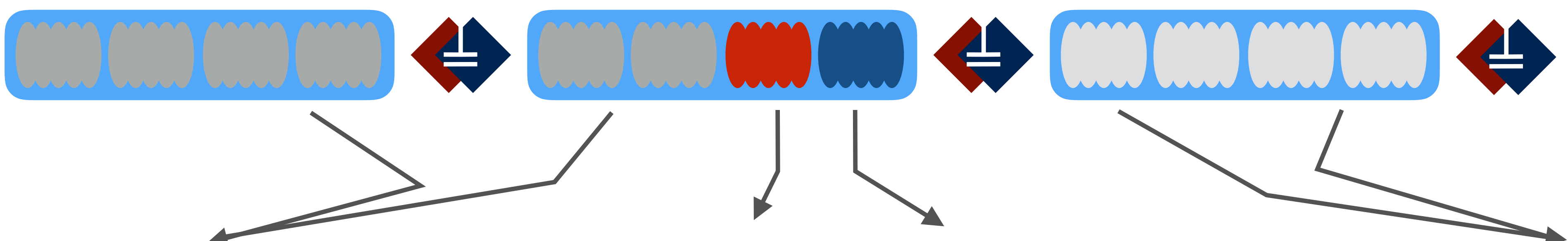
- The accuracy of these cavity tunings depends also on the accuracy of phase measurements using the downstream BPMs,
  - Phase reference line will also be used for measurement of TOF and phase scans
  - Phase reference line requirements*:
    - Phase error between neighbour cavities due to temperature variation: 0.1°
    - Phase error between any two points due to temperature variation: 2°

**SNS requirements were used at ESS*

- The signal from Beam Loss Monitors, BLMs, and some other beam diagnostic devices could be affected by the RF field, as well as by the beam.
  - We should be able to create and send an RF pulse, at the full field amplitude, for BLM calibration, in the absence of the beam

Blanking

- blanking (not sending rf to a specific cavity, or range of cavities without detuning them for certain pulses)



Functional:	Nonfunctional:	Scanning:	Blanked:
Tuned	Detuned	Tuned	Tuned
RF on	No off	RF on (phase scan)	No off
Beam on	Beam on	Beam on	Beam on

- SNS experience shows that upon failure of a cavity, retuning and phase scan of the cavities could be done without detuning the downstream cavities
  - This would increase the speed the machine gets operational after a failure

COMMISSIONING

- Different beam pulses with no rapid changes (procedural changes a la LLRF)
  - different pulse length
  - different current
    - The feedforward tables are loaded automatically depending on the beam mode.
    - How the feedforward tables get populated? and who does it?

	x µs	y µs	z µs
i mA	xi	yi	zi
j mA	xj	yj	zj
k mA	xk	yk	zk

Beam mode	Maximum Pulse length	Maximum Current	Rep rate	Notes
Probe beam	5 µs	6 mA	1 Hz	First beam through a particular section; non-damaging even in the case of total beam loss; used to verify that machine configuration is not grossly incorrect
Fast tuning	5 µs	62.5 mA	14 Hz	Limited beam loading; used for fast scans to rapidly determine/verify RF setpoints and measure beam profiles with wire scanners.
Slow Tuning	50 µs	62.5 mA	1 Hz	Longest pulses that allow operation of invasive proton beam instrumentation devices like wire scanners; long enough beam pulses to diagnose and monitor RF feedback and the onset of beam loading; used to perform more precise single-pulse measurements
Long Pulse	2.86 ms	62.5 mA	1/30 Hz	Only used when machine reasonably tuned to the tuning dump or the target; slowly-increasing pulse lengths are used to tune RF feedforward, verify beam loading and Lorentz force detuning compensation, and tune for low beam losses.
Production	2.86 ms	62.5 mA	14 Hz	Production

- How timing systems handles the communication of the beam mode information between beam physics and RF?

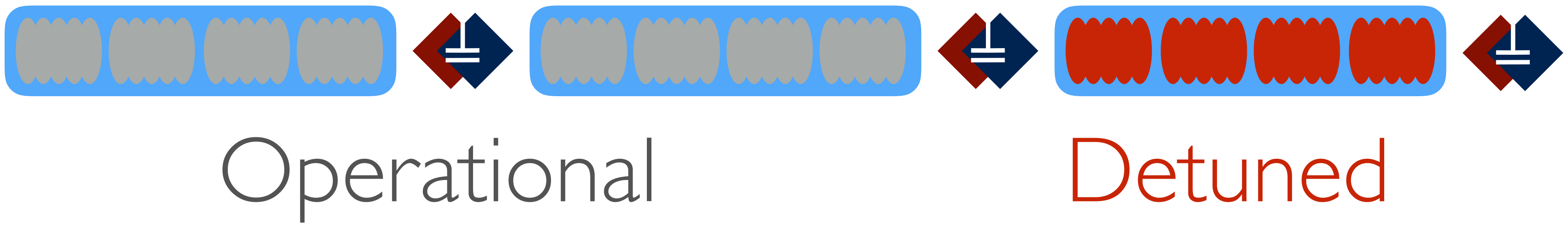
CONDITIONING

- Having the capability to change the rf pulse-width, amplitude and rep rate of the RF stations per cavity or per groups of cavities programmatically
  - This will speed up and enhance the conditioning (and reconditioning) of the cavities, couplers, …

- How do we assure that the cavity/coupler/… being (re-)conditioned are protected from damages?

Tuning

- Mechanical detuning of nonfunctional cavities.
  - When a cavity is not functioning, or is out of operation for any reason, we should be able to detune the cavity by more than 5 bandwidths:
    - This is to assure than the beam is not affected while passing through the cavity
    - Also to make sure that the beam does not cause any excitation in the cavity (same phenomenon, different effect)



Operators needs

- Clear procedures (OPMs) for basic operations of RF sources and cavities
- Simple, easy to understand panels
- List of main candidates:
  - Starting/stoping RF sources (IOTs, Klystrons, Solid State …)
  - Resetting a RF source after a fault
  - Identifying a faulty RF source
  - Setting the phase and amplitude for a cavity
  - LLRF status and faults

EUROPEAN
SPALLATION
SOURCE

Thank you!