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### **RF** Systems Status and Outlook

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- RF system overview
- RF Fault analysis
- High-Power RF systems
- Status of 2-bunch Operation
- LLRF System Overview and Outlook
- Resonant kickers and Septum
- C- and X-band RF systems in ATHOS



Injector: 7 RF stations routinely in operation 1x S-band RF gun, 4x S-Band TW structures, 1x X-band structures and 1x TDS Linac 1, 2 and 3: 26x C-band RF stations routinely in operation (with a TDS systems shared in S30CB13/14)

35 RF (complex) stations that need to be supervised, maintained, repaired, continuously developed to ensure robust operations  $\rightarrow$  big effort underway for RF section





#### Modulator sum interlock (mainly klystron arcs)



# RF Faults Analysis – 2020





- RF faults at the injectors are mainly due to the klystrons arcs.
- RF faults on the C-band linacs are due to RF breakdown
- We have had a significant improvement in the number of RF faults and their duration



## High-Power RF systems – Overview and outlook

#### Injector

- RF power is limited by the klystron arcs
  - $\circ~$  Several TH2100 Klystron are at CPI for refurbishing. Goal up to 45 MW 1  $\mu s$  RF Stable operation.
  - We installed the first CPI/Thales klystron last summer and it has been working at 35 MW for 2 months and has had only few arcs. Very promising.
  - o Gradual replacement of all S-Band Klystrons
  - We have only 2 spare (old) klystrons until the next delivery of CPI (CPI has just informed us in delivery delays...)
- HV klystron modulator (older modulators, we used them already in WHLA for SITF)
  - Progressively replacing all modulators: mandatory starting the production of 1 or 2 modulators this year (critical funding)

#### C-band linacs

- Some consolidations still pending
- Good news: we are experiencing very low klystron arcs for a couple of months. Trips are mainly due to breakdown in the RF structures
  - RF conditioning at higher RF power could mitigate but we are limited by radiation losses due to dark current
- Warning: in case of severe klystron failure, we do not have prepared klystrons to replace, the RF test stand in WHLA is important for preconditioning of the klystrons



### Status of 2-bunch Operation 2020

- RF tools available for daily operation. Training video: <u>http://i.psi.ch/OqmsO</u>
- Definition of 2-bunch tuning procedure is converging.
  Contributions from many colleagues
- Feasibility study of decoupling of the tuning of two bunches in progress. Global (beam-based) feedback on bunch 2 successfully demonstrated.







## LLRF System Overview 2020

- New RF station expert panels
- Amplitude setting consolidation software RMOD, RLLE, RMSM.
- RF Frontend:
  - C-band new LO Amps (ready to be installed) (A. Dietrich and M. Dällenbach)
  - o EPICS interface uC SW upgrade (A. Dietrich and M. Jurcevic)
- X-band RFFE (prototype) (ready to be installed)
- RF reference channels re-allocation for reliable phase restore – action on the single station
- Timing-relation diagnostics tools (in progress) (Z. Geng) to diagnose if the beam is sitting into right RF bucket









- Commissioning and optimization of Athos stations
- Further consolidation
  - Replace C-band LO amplifiers and X-band RF frontend (SINXB01)
  - o Improve the LLRF rack temperature stability
  - Trigger-race handling with better RF timing certainty (in order to detect or avoid the 60 degrees jumps on the RF stations more complicate with 2 bunches)
  - Improve reference tracking for RF station phase repeatability (based on the RF reference channels re-allocation)
- Long-term R&D (and to be discussed)
  - Fast fiber optical network integration for 100 Hz global beam-based feedbacks
  - Improve DAC (PCB) board output connector (update concept and R&D)
  - Fast HVPS feedback with EtherCAT-based communication with modulator (from 4 Hz to 100 Hz)
  - o RF fault classification and prediction (machine learning)
  - Drift calibration (especially important for the stability of the RF gun)



### **Resonant Kickers and Septum**

✓ Switchyard works without major problems

#### Current tasks

- Resonant Kickers feedback update RKs operators' manual ("Help" file)
  - New way of starting the feedback SW was proposed. The operators' manual should be updated accordingly.
  - Improve description of how to work with the virtual machine.
  - o Minor errors fixing.

#### - Resonant Kickers synchronization – change to general 100 Hz event

There is a request to consolidate the synchronization events system (reduce number of system-specific events). Since RKFeedback monitors/controls timing/state of the RKs as well, it needs modifications.
 The changes have to be tested in a dedicated machine shift before final implementation (to check correct synchronization with beam)



### Resonant Kickers and Septum - Outlook Planning further improvements

- Resonant Kickers tuners upgrade the position readback (relative -> absolute encoder)
  - After each power cycle of the motor controller tuners' position is lost  $\rightarrow$  If that happens and the RKs frequency feedback is activated during normal operation the beam will be lost
  - Possible improvements in the mover system (translation stage and reliable end-stop function of the motor controller)



RKs tuner translation mover

- Resonant Kickers cooling-water flow monitors
  - At the moment there is no way to remotely check if the RKs cooling water flows. Suggested solution: Install water flow monitors and have an early warning if the cooling is lost



## C-Band Systems in ATHOS (SATCB01)

- Software consolidation is nearing conclusion (it is also the test stand for the software of the X-band modulator)
- RF conditioning starts in early February it lasts 6-8 weeks to get the nominal energy gain.
- RF station could be used for BBA before ending the RF conditioning with lower energy gain (>100 MeV)
- *RF* conditioning could have an impact on the operation when breakdowns occur and/or due to radiation losses generated by the dark current
- Under study (R. Zennaro): Beam energy scan (in ATHOS) by introducing phase slippage in the accelerating structures. Dedicated machine shifts are necessary to verify the feasibility.



## PolariX TDS System in ATHOS

- 2 TDS are installed in the tunnel
- Waveguide network will be installed in the spring shutdown (we still have some delays in the production of the RF components at AIK) – we have all the RF components to start with one TDS
- LLRF, Interlock system, KKV (cooling system) are on a good track
- HV klystron modulator:
  - Tank and racks installed in OSFA (Double floor finished)
  - o Transformer Assembly being installed in OSFA
  - Power modules (PPMD) and Boost converter production finished  $\rightarrow$  but Not yet tested (first critical point)
  - o Control system adaptation (from C-band control system) second critical point
  - Preparation of resistive test load and High voltage tests on test load
  - o Installation of klystron and Test in diode mode
  - o Interlock / LLRF connection and Waveguide connection (milestone)
  - o RF startup and RF conditioning (6-8 weeks to full power)



- On-call duty service (24-7)
  - o LLRF and RF trainings have been held and are going on a regular basis
  - From January 2020 there is only one group for LLRF/RF on-call duty service
  - Further effort will have to be made in 2021 to complete the merger between SLS and SF on-call duty (presently common RF on-call duty is ~50%)
- Consolidate the communication channel with the Controls section:
  - To achieve a good understanding of RF/LLRF systems within Controls we should consolidate the exchange of information
  - o and clarify possible synergies between picket groups
  - o and clarify how and if controls is willing to provide support for LLRF/ILK/RMSM/RCON IOCs
- Open a communication channel with Operation, Coordinators and Beam Dynamics to discuss on a regular basis about the RF and LLRF Systems, the related improvement requests and priorities (i.e. see LLRF R&D task list)



#### Wir schaffen Wissen – heute für morgen



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