SUMMARY
RF CONTROL AND TESTING

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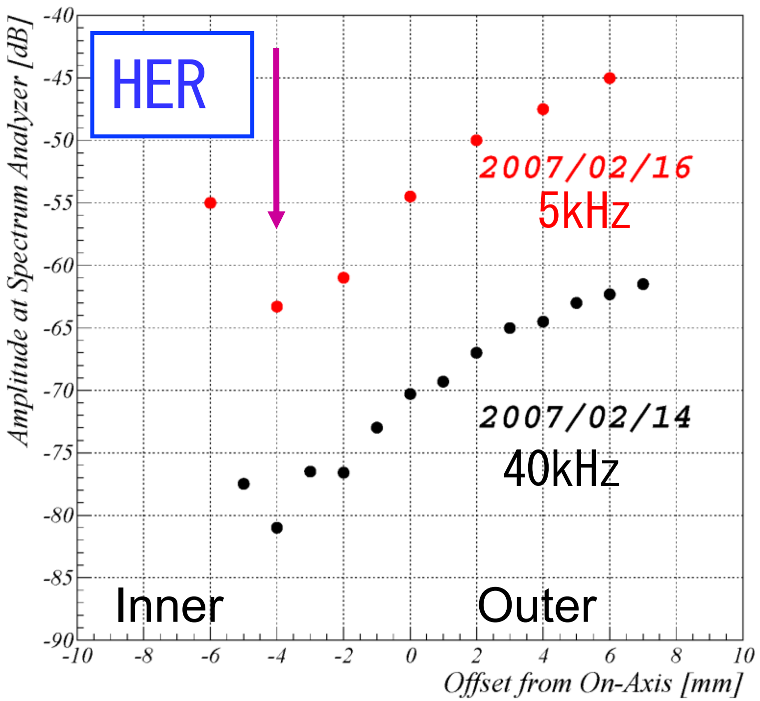
Talks

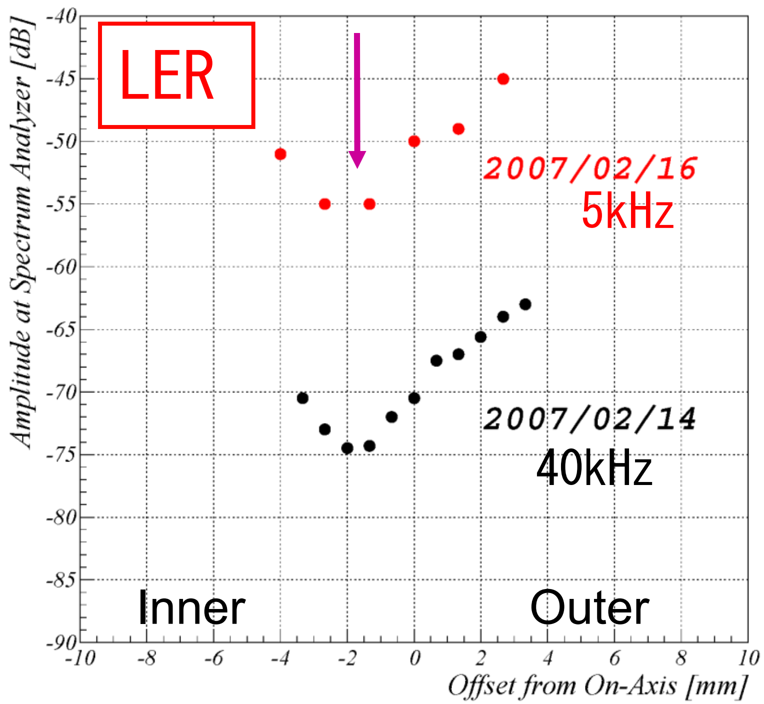
- KEK crab rf architecture & controls (Kota Nakashini)
- SM18 test stand for crabs (Olivier Brunner)
- Cryogenics for SPS, LHC & SM18 (Bruno Vullierme)
- Rf controls for crabs, injection to top energy (Philippe Baudrenghien)

Searching Field Center in Crab Cavity

Field Center Search for HER Crab Cavity

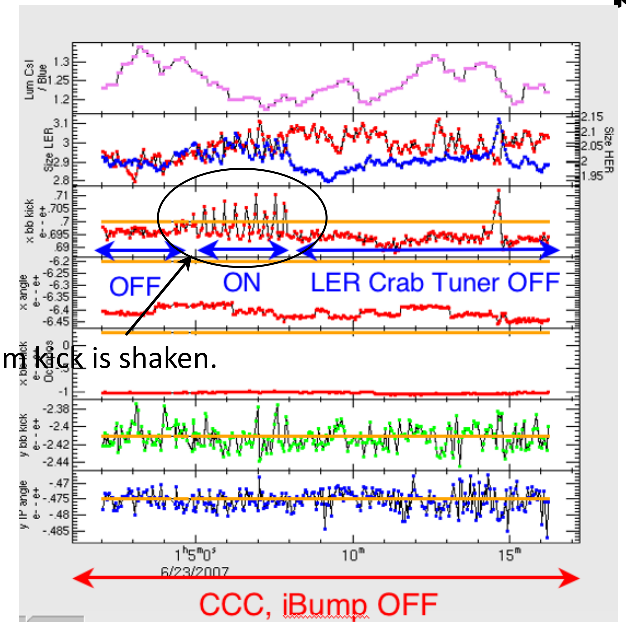


Field Center Search for LER Crab Cavity

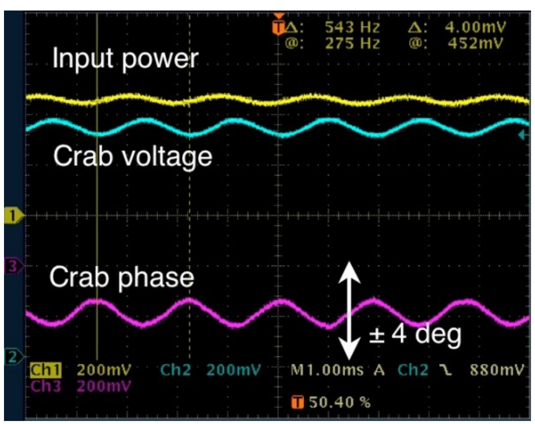


- Field center was searched by measuring the crabbing mode amplitude excited by a beam with the crab cavity detuned. Two measurements with different detuning frequencies agreed to each other.
- A local bump orbit was set to make the beam aligned on the field center.

Oscillation of high-current crabbing beams

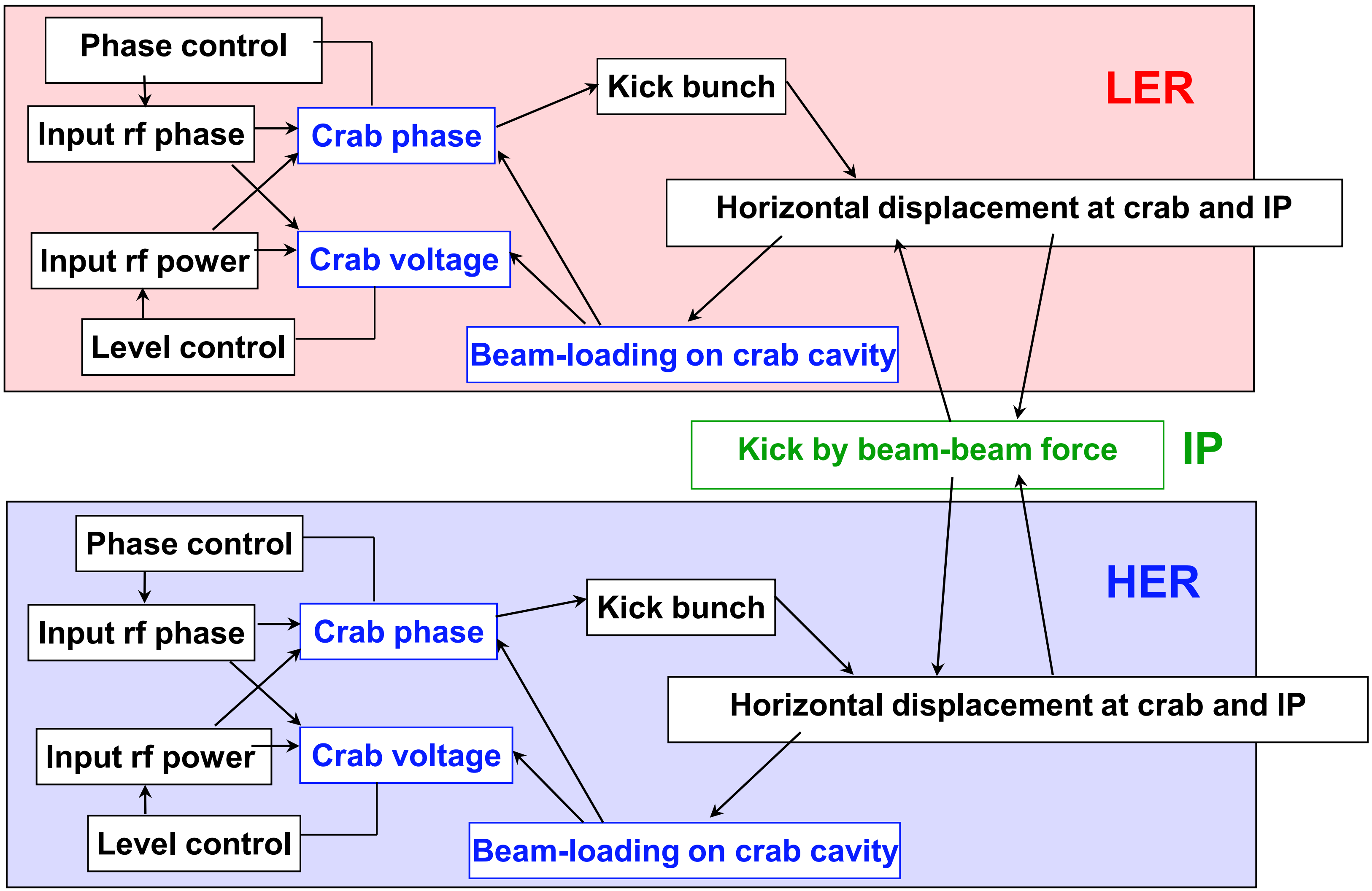


Beam-beam kick is shaken.



- A large-amplitude oscillation was observed in high-current crab-crossing operation in June.
  - It caused unstable collision, short beam life time and luminosity degradation.
  - Crab amplitude and phase were modulated at 540 Hz. Horizontal oscillation of beams was also observed at the same frequency.
  - None of the beam orbit feedback systems is responsible, since their time constants are 1 to 20 sec, much slower than the oscillation.
  - The oscillation occurred when the LER tuning phase migrated to the positive side. This gave us a hint to understand the phenomena.

Possible mechanism of the oscillation



Oscillations in crabbing systems

- Only with colliding beams
- Beams oscillate coherently
- Threshold depends on crabbing phase and tuning phase
- Caused by beam loading and beam-beam interaction at the IP
- Cured by shifting crabbing phase by 10^0 and controlling offset angle

Trips

- Reduced to ~ 1/day or less
- Mostly from couplers
- Weak correlation with current
- Stronger correlation with voltage

Assembly and tests at CERN

- Preparation and assembly
  - ✓ surface treatments (cleaning, electro-polishing, rinsing,..) => upgrade ongoing for SPL cavities
  - ➢ assembly in clean rooms & quality control: upgrade necessary both for SPL and CC
- Low power tests:
  - ✓ four vertical cryostats (2 K & 4.5 K)
  - ✓ can certainly be modified for crab cavity tests
- High power tests:
  - two bunkers
    - Bunker A (4.5K): LHC, HIE Isolde
    - Bunker B (2 K): Linac4, SPL
  - high power area:
    - 352 & 400 MHz high power sources available
    - new high power source (800 MHz?) requires additional space

⇨ ok @ 400 MHz & 4.5 K
difficult @ 800 MHz or/and @ 2 K

Cryogenics for Crab Cavities at SPS

- The KEKB Crab Cavities Cryostat will be connected to the Sulzer/Linde helium refrigerator TCF20 located in BA4.
- New cryogenic transfer lines of length L ~10 m will be required to connect LHe and thermal shield circuits of the CC cryostat to theTCF20.
- Available refrigeration power: 100 W @ 4.5 K.
- The TCF20 control system has to be refurbished.
- Overall cost: ~250 kCHF

Conclusions

- The available refrigeration power for CC test at SPS will be 100 W @ 4.5 K. The overall TCF20 connection & refurbishing cost will be ~ 250 kCHF. No critical issue.
- Operation at 2 K is not the present baseline for the Crab Cavities of the Global Scheme. A CC cooling power of 2 x ~ 500 W @ 4.5K can be provided with a new RF refrigerator at Point 4 (with redundancy from QRL).
- Operation at 2 K is the present baseline for the Crab Cavities of the Local Scheme. A CC cooling power of 2 x ~ 80 W @ 2 K can be available from QRL at P1 and at P5.
- Cryogenics for CC tests in SM 18, at 4.5 K or 2 K, in a vertical cryostat or in a cryomodule: no critical issue*

** Except LHe availability for concurrent applications in SM18: management of priorities !*

Operational scenario 1/2

This slide has been modified, after the presentation, following very relevant input received during the discussion. Thanks a lot!

- Boundary conditions:
  - During filling, ramping and for physics with crab cavities off, the cavities must be detuned by ½ f_{rev} to keep the beam stable (issue of Transverse Impedance budget)
  - Bringing the cavities from detuned to on-tune can only be done with active RF feedback ON. Else, the beam will be unstable (again…Transverse Impedance)
  - In varying conditions (change of cavity tune) and given the unavoidable fluctuations of key parameters (for example varying cavity tune caused by the fluctuations of the He pressure) the situation can only be controlled if some (hopefully very small !) field is present in the cavity to get on-line "measurements". If it is given measurements, LLRF can do wonder…If the crab kick is provided by a pair of cavities we could use counter-phasing to make the small cavity field invisible to the beam
- Now comes the proposed scenario:
  - During filling, ramping or operation with transparent crab cavities, we detune the cavity by ½ f_{rev} with a small field. Amplitude/phase can be optimized among the cavities of same Beam/IP to minimize effects. The tuning system is ON. The RF feedback is used with the cavity detuned to keep the Beam Induced Voltage zero if the beam is off-centered. This calls for a study: Needed TX power? Higher Q_L not favorable anymore. We can use the demanded TX power as a measurement of beam loading to guide the beam centering
  - ON flat top
    - Reduce the detuning while keeping the voltage set point very small but sufficient to get tune and Closed Loop response measurements. The RF feedback gain/phase must be continuously adjusted as the cavity moves towards tune (easy). The RF feedback keeps the cavity impedance small (beam stability) as the cavity moves to resonance
    - Once the cavity detuning has been reduced to zero, use the functions to synchronously change the voltage in all crab cavities… at will… Any luminosity leveling scheme that ABP can think of…

Operational scenario 2/2

- If a TX or Cavity trips
  - We can trigger the Beam Dump…easy…
  - Or we can think of something more clever. It is not obvious to propagate emergency voltage trims to the other cavities. In the proposed hierarchy these trims can come though the Real-Time channel of the FGCs. This method is very successfully used for orbit and tune feedback in the LHC, with 100 ms update rate. But the response time required here is at least three orders of magnitude faster. An ad-hoc implementation is probably required. To be studied…

Some conclusions

- Compared to the ACS achievements, the RF phase noise budget appears manageable but we must count on a strong RF feedback and that calls for a small loop delay. Layout must be studied: TX and LLRF crate close to the cavities (ex-Lep klystron galleries? SPS test bench?). More detailed studies can be done after selection of TX technology and cavity Q_L
- The integration of the Crab Cavity with the ACS system and with the LHC High-Level Controls appears easy: We propose to use the 400 MHz RF reference from the Beam Control, for the Crab Cavities. The voltage is controlled via the FGCs that would generate voltage set-points used by the RF feedbacks. The proposal to use RF feedback on detuned cavity during filling/ramping must be studied. It may orient the design towards lower Q_L

Answers to charge

- Can compact cavities for the LHC be realized and made robust with the complex damping scheme?
  - Real progress has been made
  - No evidence that the answer would be no
  - Complete set of specifications and requirements needed asap
- Are crab cavities compatible with LHC machine protection, or can they me made to be so?
  - No evidence that the answer would be no
  - Still work in progress
- Should a KEKB cavity be installed in the SPS for test purposes?
  - A real LHC CC would be preferable
  - What questions would that test answer?
  - Would it raise new questions that may not be relevant?