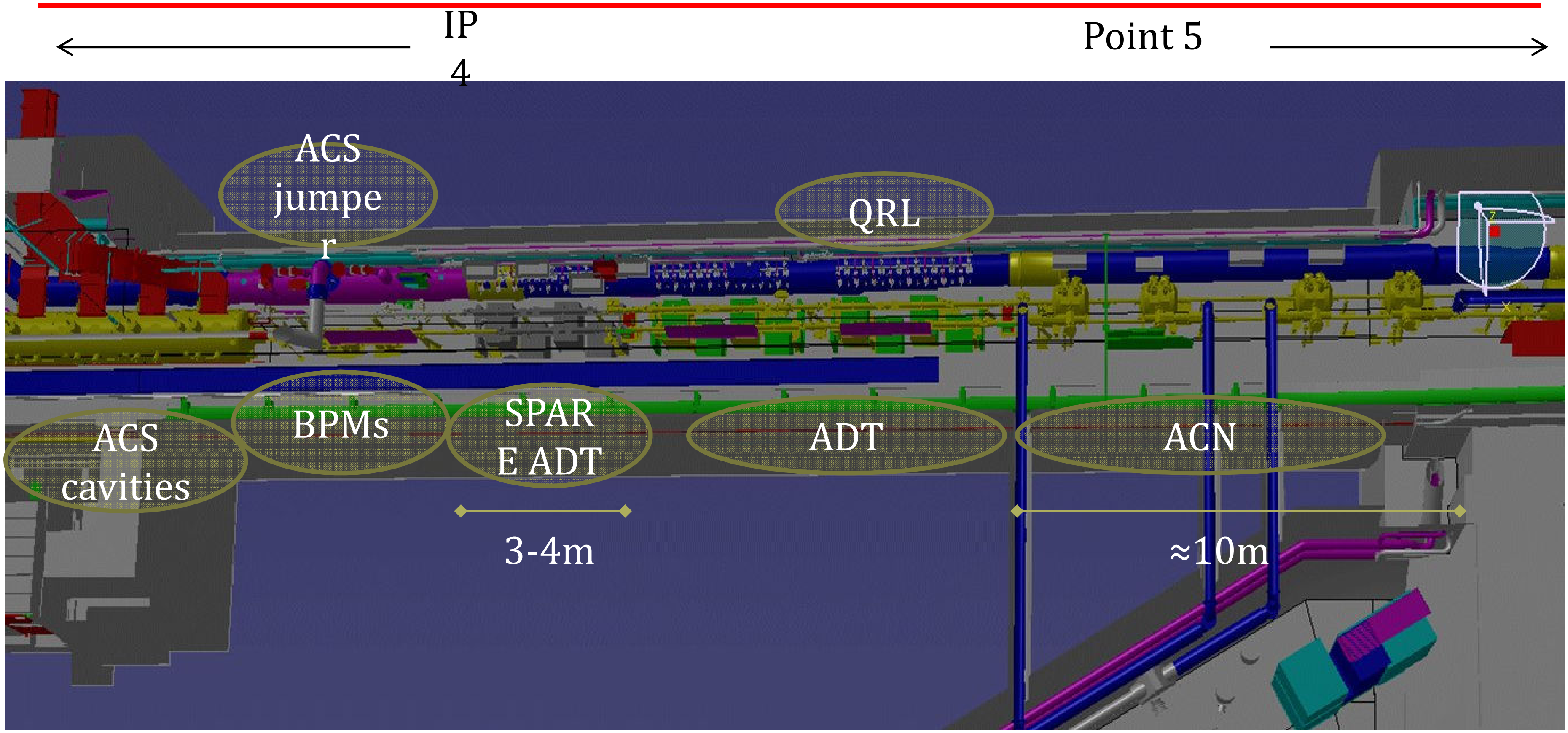
Crab Cavity Integration - Summary

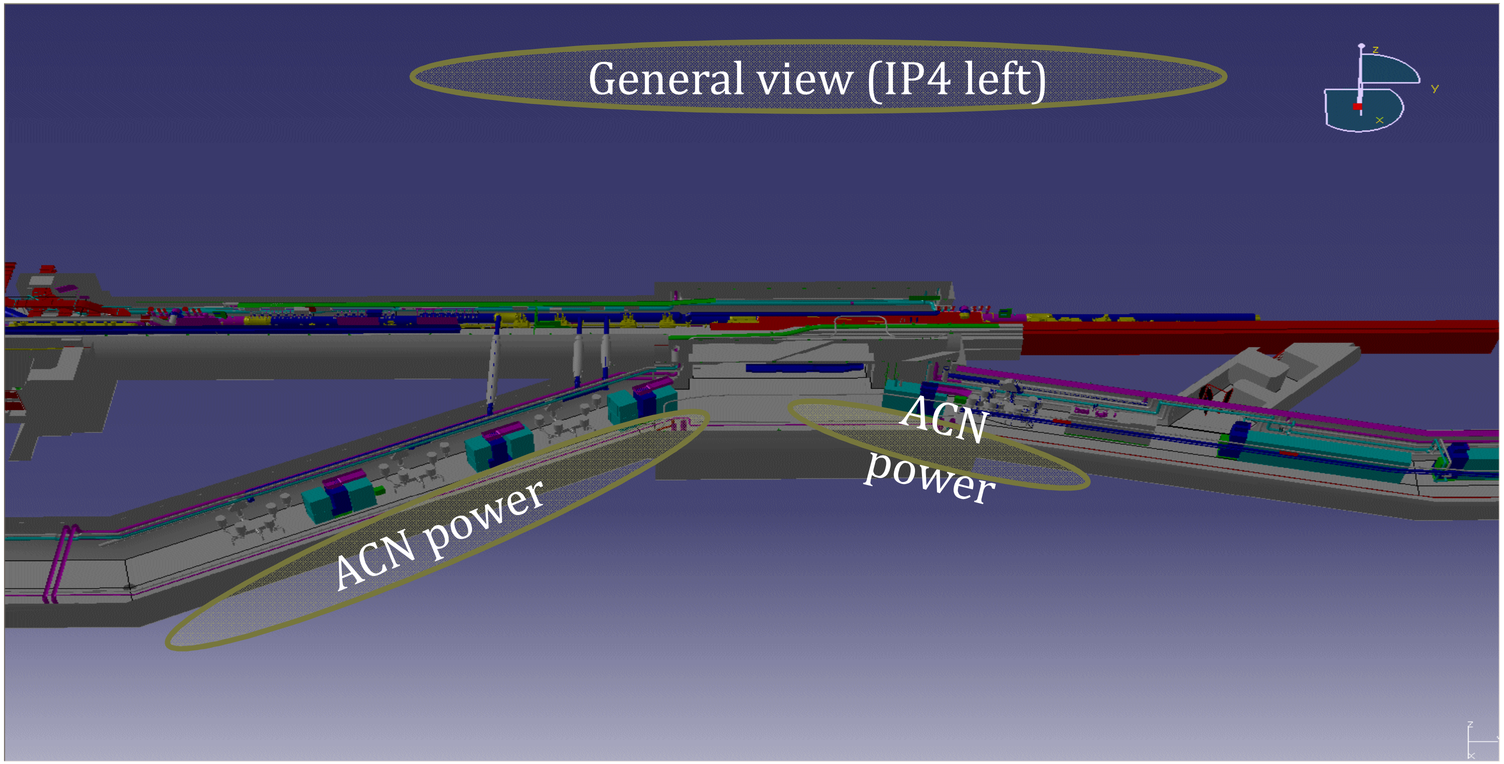
• IP 4 Boundary Conditions	O. Brunner
• LHC Integration and RF Systems.	J. Tuckmantel
• Cryogenics Installation.	B. Vullierme
• Low Level RF and Feedback.	M. Grecki
• KEK-B Instrumentation for Crab Cavity Tuning.	Y. Funakoshi

IR4 layout – Available locations



- Symmetric towards point 3
- Not possible to free space in the ACN cavities region (power lines, RF couplers, access behind the ACN)
- Max 3m longitudinally

Crab Cavity Powering & Layout



CC could be powered by a 60kW RF power station located in the UL's

- Restricted space available in the Ul's (possible conflict with the ACN power stations)

➔Need detailed integration study (very busy area) of:

- the power station + control systems
- LLRF (partially installed in SR4 (surface building))+ RF cabling
- the power lines – waveguide hole sizing
- services (water cooling, electricity (380V),…)

Rough Cost Estimate IP4 Infrastructure & RF Power

Civil Engineering: ≈ 10kCHF
Cabling (controls): ≈ 40kCHF
Water cooling: ≈ 30kCHF
RF cabling: ≈ 150kCHF
RF power lines (50m): ≈ 100kCHF
Interlock & Control system: ≈ 80kCHF
Low Level RF ≈ 125kCHF
Installation: ≈ 90kCHF

Total ~ 620 KCHF not counting Manpower..

Feasible

Summary: LHC Integration & RF Systems JT

- For $|\Delta x_0| \leq 200\mu m$ and perfectly tuned (stable) cavity:

  5 kW RF power sufficient —> 80 Hz BW / $Q_{ext}=2\cdot10^7$

- Better choice : 30 kW –> 1600 Hz BW / $Q_{ext} \approx 5\cdot10^5$

  (real world –> 60 kW

Transmitter 'available' SPS 800MHz new IOT based amplifier)

- Add to 'existing' order (on time) 1(2) additional transmitter(s)

  no R&D work, minimal work for installation

- RF power transfer might require a new hole (limestone)

  or (if ACN still absent) some 'RF bricolage'

- 2-cell structure: requires study for feedback (filter !)

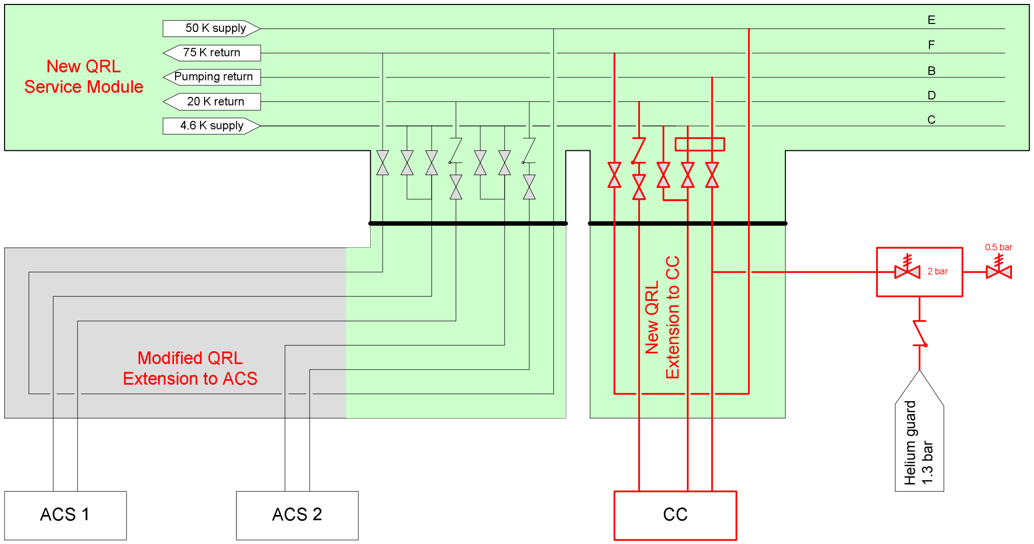
- RF noise is still not completely settled (hadron machine !) CONCERN !

Cryogenics Installation – Summary - BV

- Can not extend existing ACS QRL Extension
- Can not install an additional service module – no space
- Two options..

Cryogenics Installation – Summary - BV

- Option 1) 2K System - Replace existing SM with new design
- CC design pressure: 3.5 bar
- CC operating pressure: saturated helium @ 2 K
- Helium guard required on CC safety (sub-atmospheric) circuits
- Additional cooling power of 50 W @ 2 K is available for CC



Removal and reinstallation of neighboring ACS cryomodules

20 critical cuts and welds on the 5 QRL headers

5 to 6 weeks for dismantling/installation (cryo only)

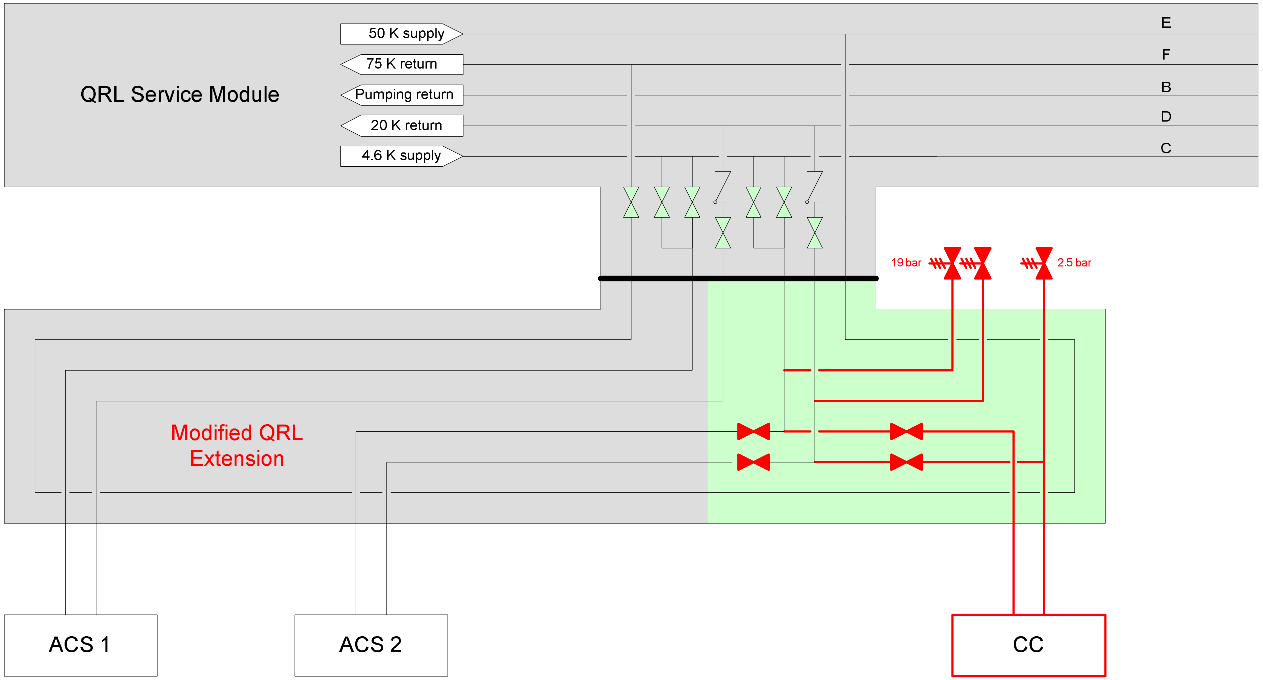
Nearly global pressure tests for both 3-4 and 4-5 LHC sectors

Cost for such QRL modifications : > 1 MCHF

Cryogenics Installation - BV

- Option 2) 4.5 K simple option

The straightforward solution is to finally modify the supply and return lines of the *QRL extension* to one of the two ACS cryomodules, in order to connect the CC in parallel, via an additional set of valves.



Cryogenics Installation – Summary - BV

- Option 2) 4.5 K simple option contd.
  - The present elbow region of the *QRL extension* to the ACS can be cut and replaced by a T-shape part (+ 4 control valves, + safety circuits, + 2 cryogenic lines with bayonets to CC cryostat)
  - **Installation: ~ 1 week**, local pressure and leak tests only, not critical

  - Design pressure of CC helium vessel: 3.5 bar
  - CC helium pressure, temperature: 1. 35 bar, ~ 4.6 K
  - The CC required flow rate of 15-30 g/s of helium at 4.6 K from QRL header “C “ should be available.
  - The flow coefficient of the existing QRL supply and return control valves can be increased (ACS + CC He flow rates). **Concern for Existing ACS !!!**
  - Controls: liquid helium level and pressure controls with dedicated control (and shut-off) valves.
  - Safety: non-return valves to QRL header “D”, possible pressure interlocks (QRL header “C”, QRL header “D”, ACS)
  - Possibility of using an additional circuit for helium return to the Warm Recovery Line via an electrical heater, during magnet quenches (i.e. pressurization of QRL header “D”).

Cryogenics Installation – Summary - BV

	OPTION 1	OPTION 2
Saturated liquid helium temperature	2 K	4.6 K
Heat loads @ temperature	50 W	250-500 W
Removal/reinstallation of ACS cryomodules	Yes (time?)	None
QRL Service Module replacement	Yes, ~6 weeks	None
Installation of *QRL Extensions* to ACS and CC	~2 weeks	~1 week
Nearly global LHC sector pressure tests	Yes (2 x 1 week)	None
Impact on LHC during prototype tests	Marginal	Not critical
Impact on LHC during regular operation	Marginal	Not critical *
Total installation time (QRL cryogenics only)	~10 weeks	~1 week
Cost	> 1 MCHF	~ 150 kCHF

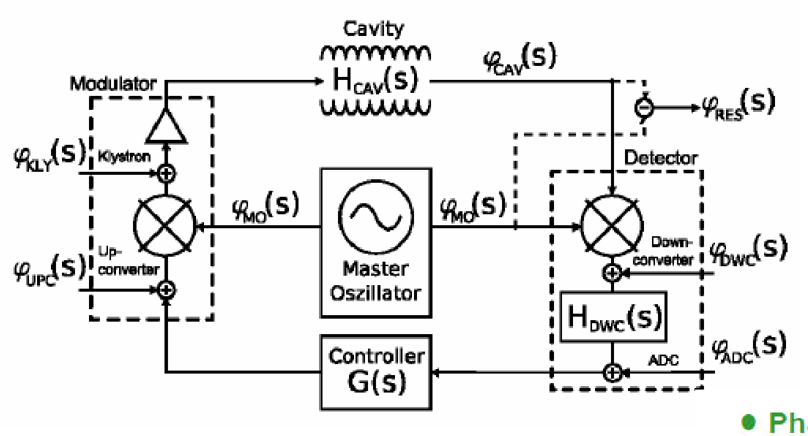
LLRF & Feedback – MG (1)

- Review of LLRF system Layouts, Analog, Digital systems etc.

- Need for LLRF & Feedbacks – beam loading, drive feedback, cavity dynamics, thermal, effects, microphonics, Lorentz detuning, noise sources.
- ATCA based hardware – User Community
- Expert / Adaptive Systems at FLASH
- Aim for high Reliability

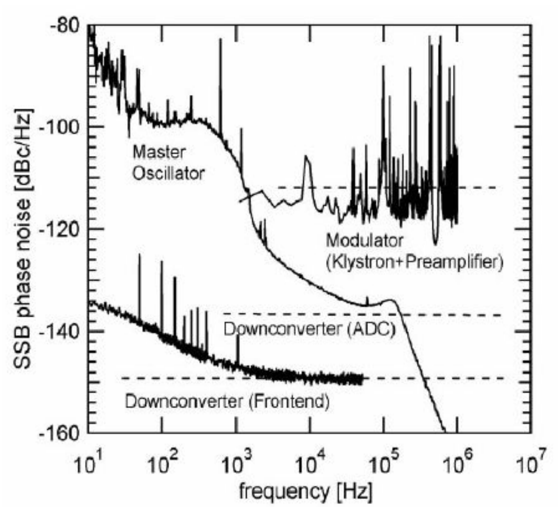
LLRF & Feedback - MG

- Phase Noise Correction at FLASH. 0.01 % amplitude, 0.01 degree

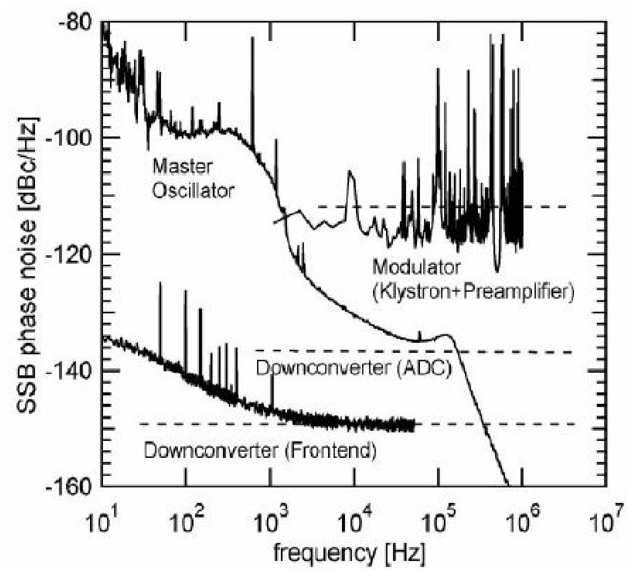


Subsystem	Phase noise [dBc/Hz]	Residual jitter [fs]	Induced jitter [fs]
MO	see Fig.3	14.1	5.5
DWC (Frontend)	−147	1.8	1.8
DWC (ADC)	−135	5.8	5.8
MOD	−110	1.2	1.2

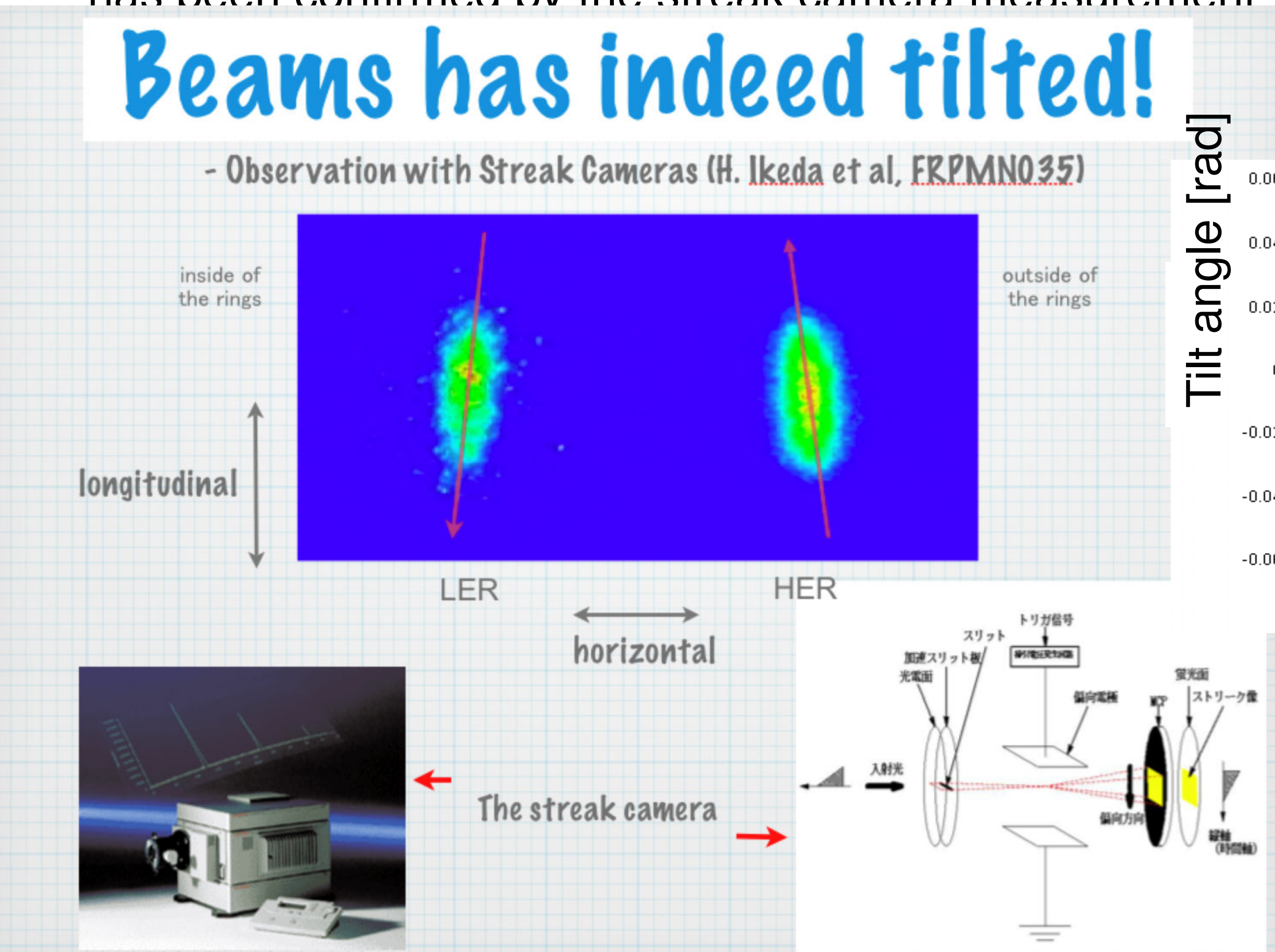
- Phase noise measurements :

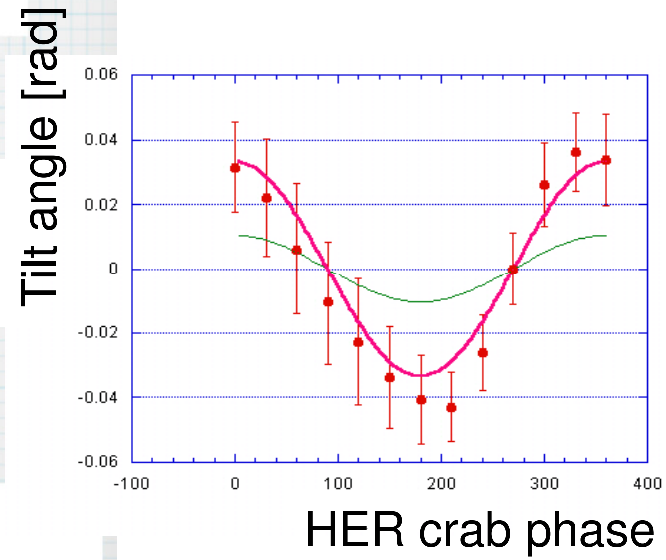


- Phase noise measurements :



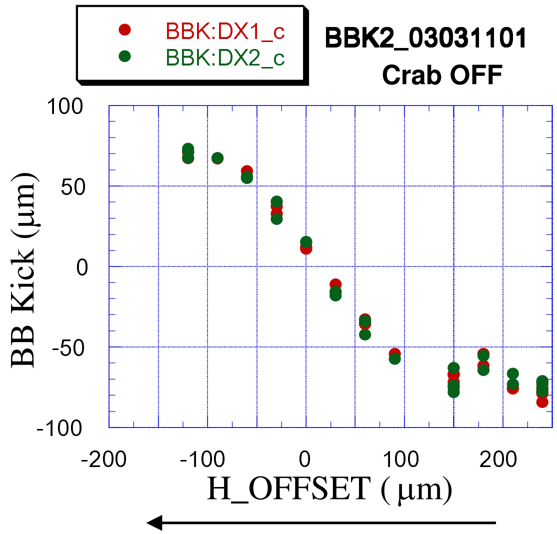
- The crabbing motion of the beam with a single crab cavity scheme has been confirmed by the streak camera measurement



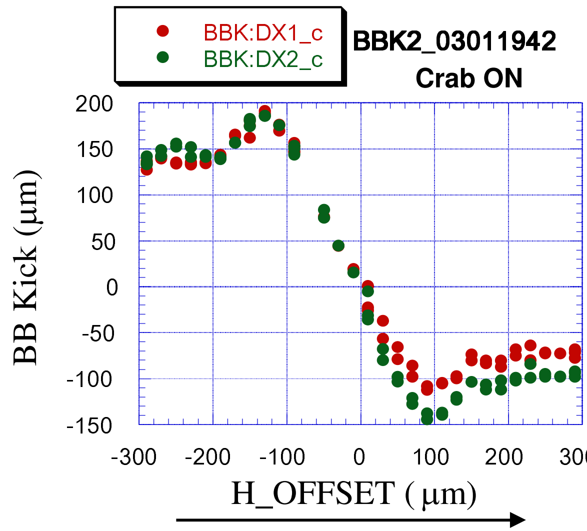


- Effective head-on collision was confirmed by the measurement of the beam-beam deflection.

Crab ON (Vc = 1.31/0.92 MV)



Bunch Current: 0.73/0.42 mA



Bunch Current: 0.64/0.47 mA

$\Sigma_{x\_x'=11}$=230 +/- 3 μm (OFF) → $\Sigma_{x\_x'=00}$=167 +/- 3 μm (ON)

- Horizontal effective size at IP reduces to 72% by the crab.

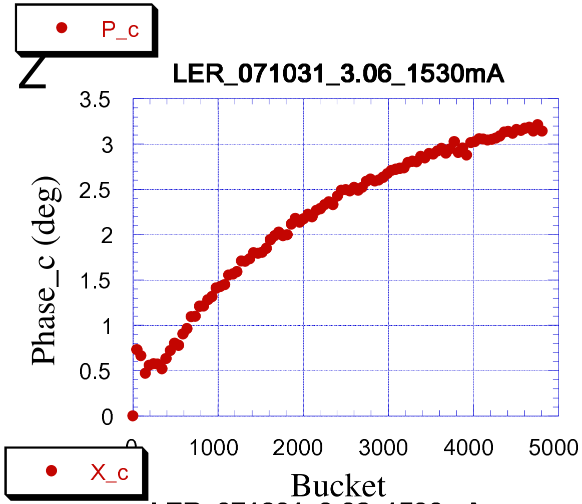
Ratio of Slope:

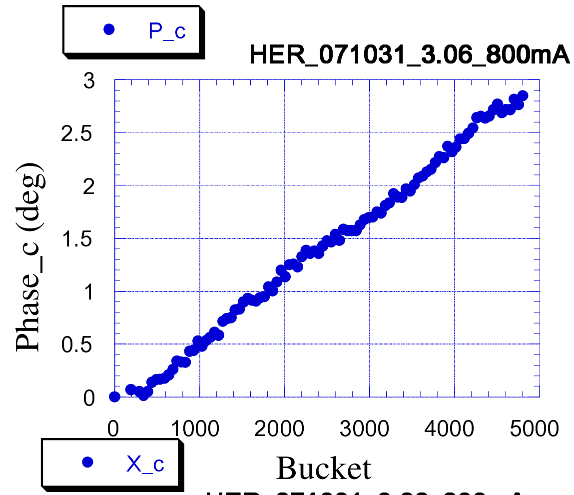
$$\frac{\left.\frac{\Delta k}{\Delta x}\right|_{x'=0}}{\left.\frac{\Delta k}{\Delta x}\right|_{x'=11}} = 2.14$$

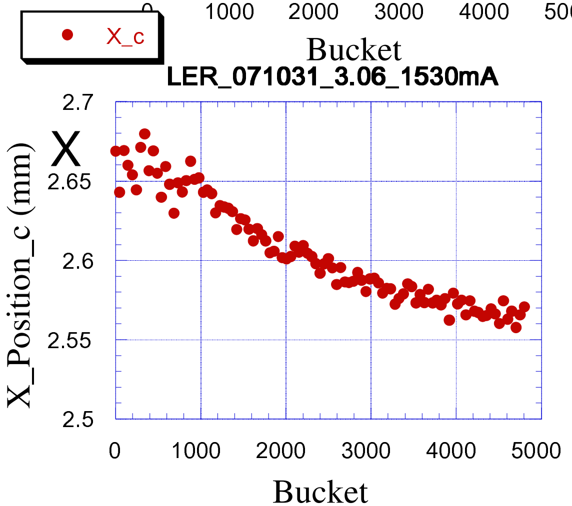
- HER current was lost from 15 to 13.5 mA during scan.

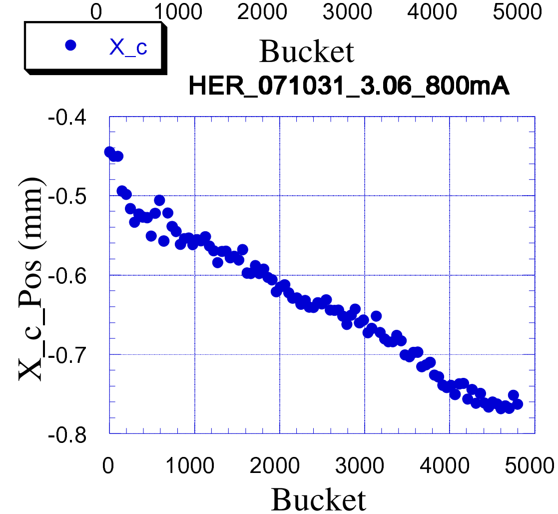
KEK-B Instrumentation for Crab Cavity Tuning - Y. Funakoshi

- The synchronous phase shifts along the train from the transient beam loading have some size at KEKB. However, their impact on the luminosity is very small owing to the cancelation of the effect between the two rings
- CRAB ON/OFF similar ..(ON shown)









KEK-B Instrumentation for Crab Cavity Tuning - Y. Funakoshi

- Almost no harmful effects due to the crab cavities or the single crab cavity scheme (global crab cavity scheme) from the viewpoint of the beam dynamics.
  - Dynamic aperture, synchro-betatron resonance (yesterday's talk)
  - Bunch current dependent tune shift, loss parameter, bunch lengthening, coupled bunch instabiity

- Crab Vc is determined so as to maximize the luminosity in the real beam tuning situation at KEKB.
- Scanning techniques to get optimum Vc, Phase and Orbit Centre

- The phase errors of the crab cavities are much less than the allowed level of the errors obtained from the beam-beam simulations

N=1585

KEK-B Instrumentation for Crab Cavity Tuning - Y. Funakoshi

- At KEKB, the dynamic beam-beam effects (emittance enlargement and the beta-beating) are very important, since the horizontal tune is very close to the half-integer.

- Due to this problem, physical aperture around the crab cavity limited the ring acceptance. After solving this problem, we could increase the bunch current (of HER) and the luminosity.

- In autumn this year, we will operate KEKB for about 2 months. There is possibility that it will be the final opportunity to operate the crab cavities at KEKB.