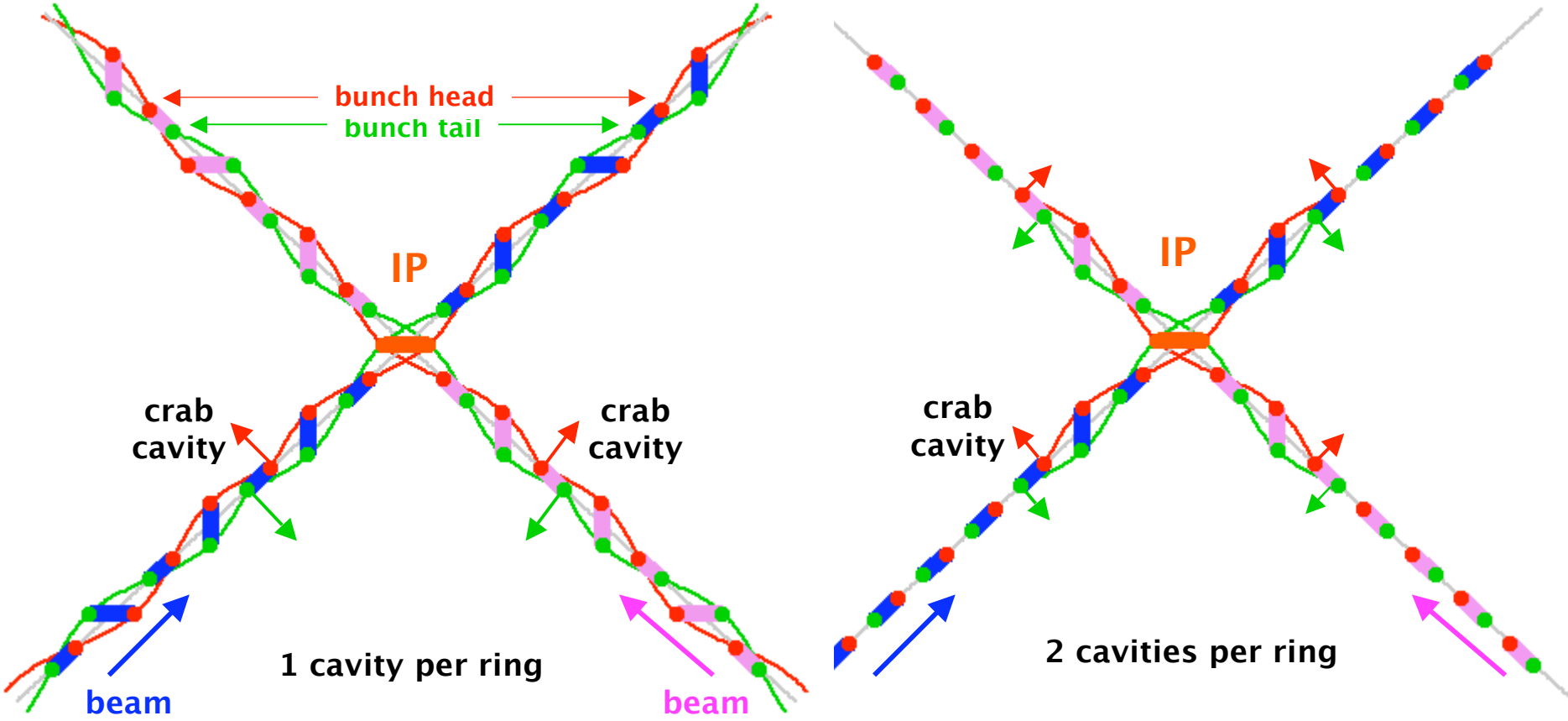
Beam Commissioning with Crab Cavities

12th KEKB Accelerator Review
March 19, 2007
Haruyo Koiso

Crab Crossing

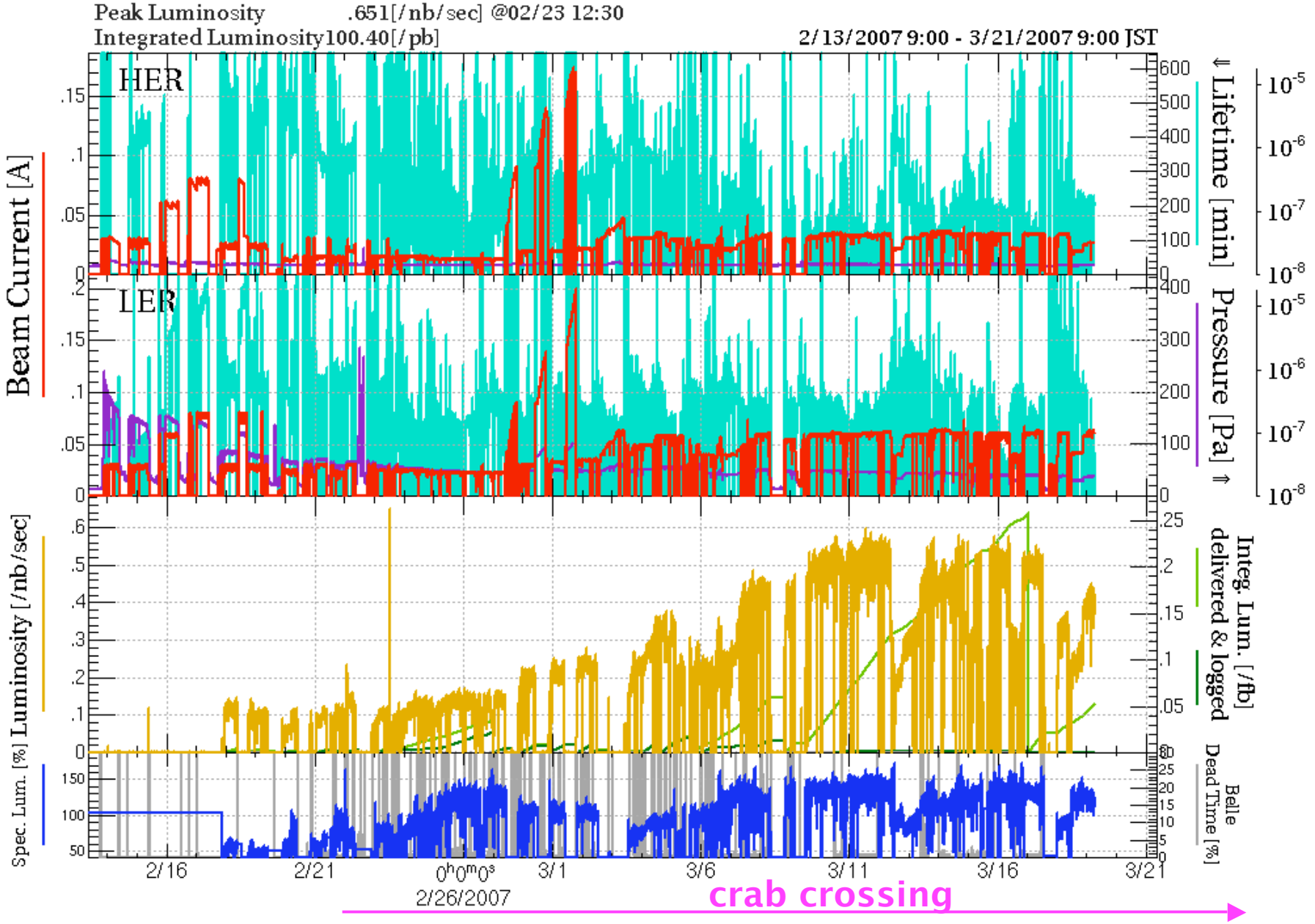


orbits of bunch head and tail

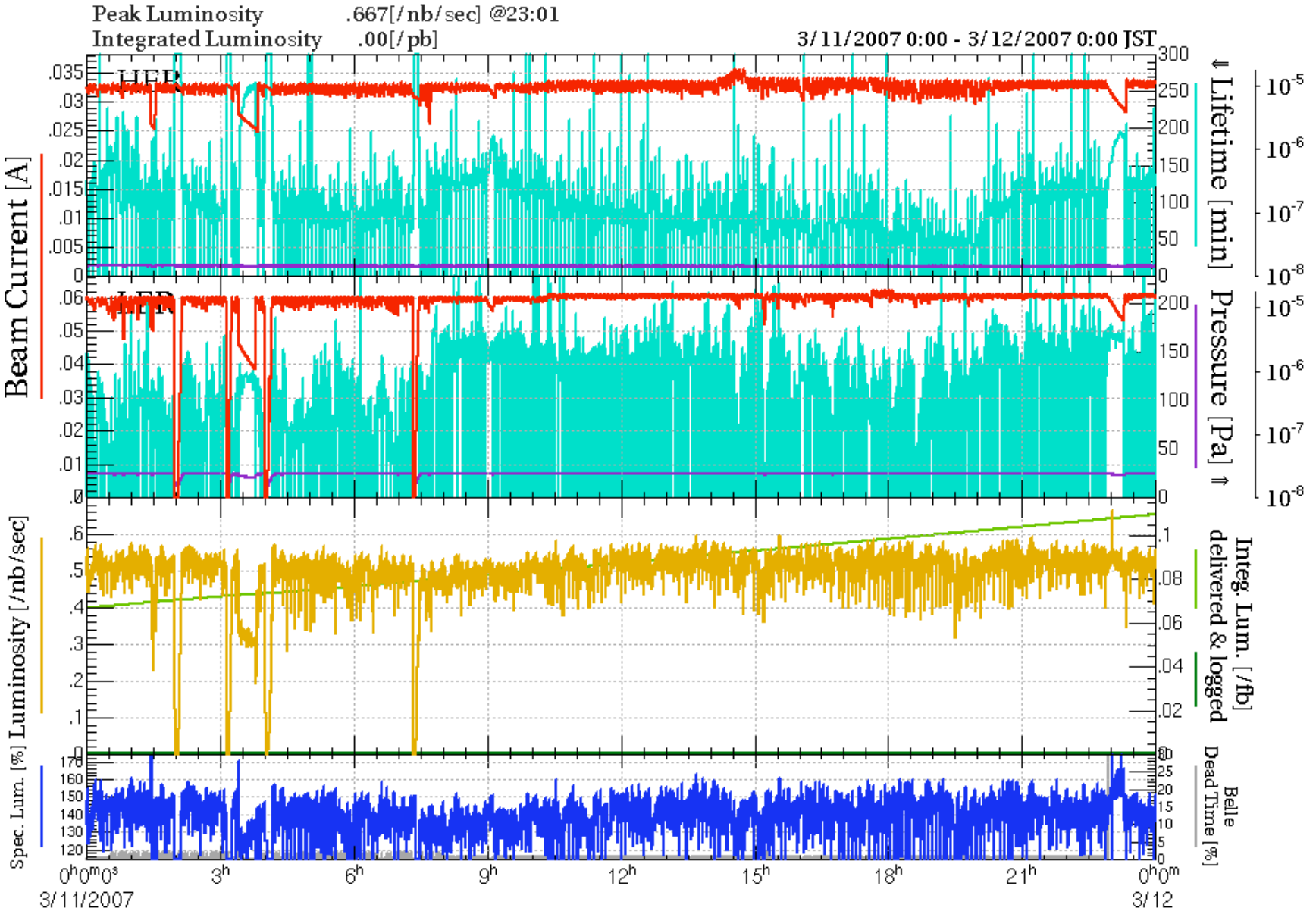
Operation History

- Feb. 13 Beam operation started without crab kicks (Crab OFF).
- Feb. 14– Tuning of SR monitors, streak cameras, etc. Aging of crab cavities without beams.
- Feb. 19 First beam with crab kicks (Crab ON). Crab kicks were observed with BPMs and streak cameras.
- Feb. 21 Crab crossing started.
- Feb. 22– Collision tuning with crab kicks. 30 mA in 31 bunches.
- Feb. 27–Mar. 1 Higher total currents 200 mA (LER) / 174 mA (HER) in 1389 bunches. (no collision)
- Mar. 2– More bunches. Max. currents : 75 mA (LER) / 50 mA (HER) in 51 bunches.
- Mar. 11 Luminosity 0.55/nb/s

2007.2.13 – 3.19


Peak Luminosity .651[/nb/sec] @02/23 12:30
Integrated Luminosity100.40[/pb]
2/13/2007 9:00 - 3/21/2007 9:00 JST
HER
LER
Beam Current [A]
⇓ Lifetime [min] Pressure [Pa] ⇑
Spec. Lum. [%] Luminosity [/nb/sec]
Integ. Lum. [/fb] delivered & logged
Belle Dead Time [%]
2/16
2/21
0h0m0s
2/26/2007
3/1
3/6
3/11
3/16
3/21
crab crossing

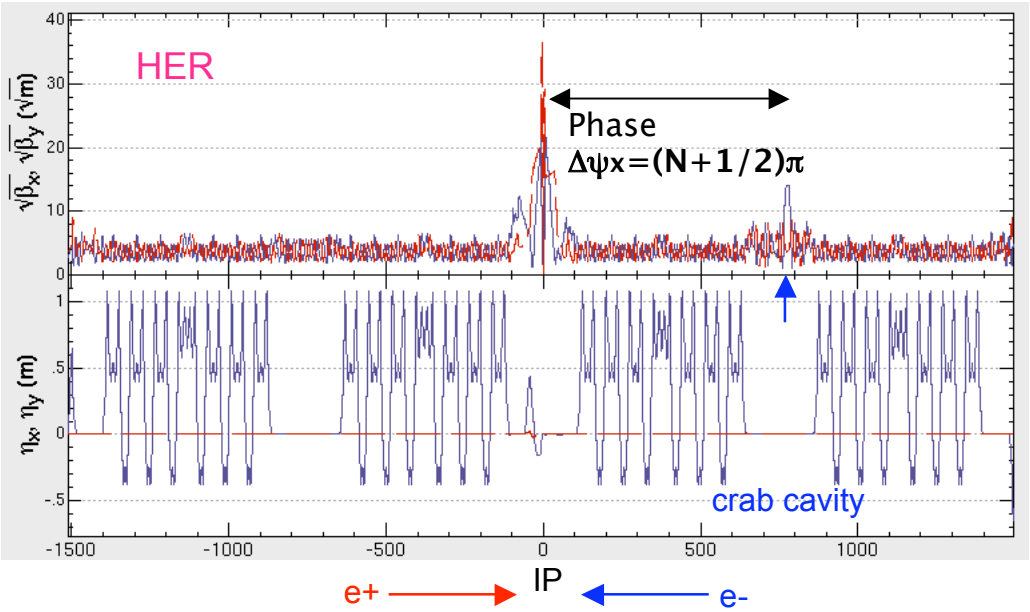
One Day History 3.11

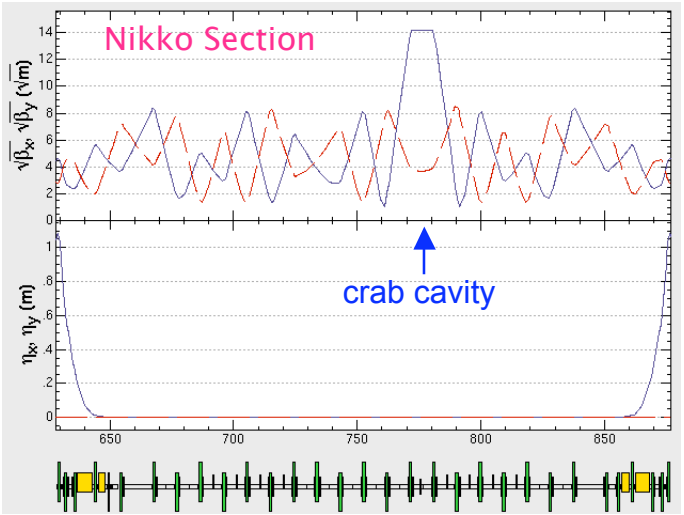


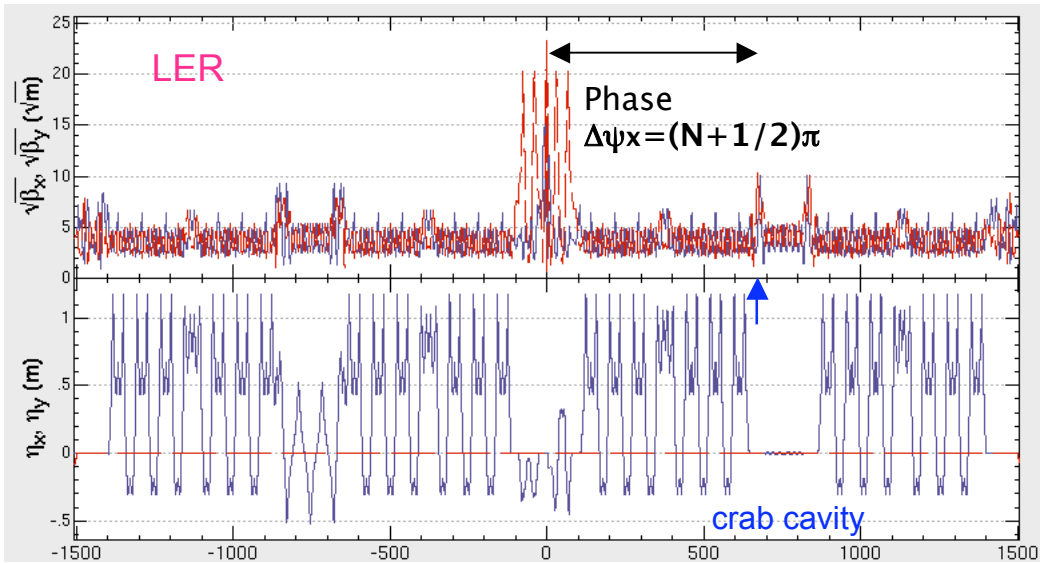
Machine Parameters

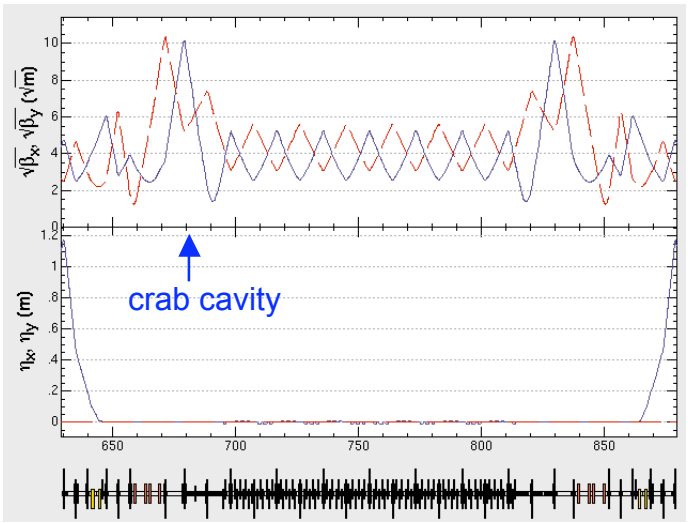
- Crab optics
- Horizontal emittance : LER 18 nm, HER 24 nm
- Tune : LER (45.508, 43.585), HER (45.509, 43.585)
- β_x^* : LER 0.59→0.84 m, HER 0.56→0.80 m
- β_{xcrab} : LER 40→ 74 m, HER 200→174 m
- V_{crab} : LER 0.9–1.0MV, HER 1.4 MV
- Currents
  - 75mA(LER)/50mA(HER) in 51 bunches (collision mode)
  - 200mA(LER)/174mA(HER) in 1389 bunches (aging mode)
- Luminosity : 0.55/nb/s ($\xi y \sim 0.078$ preliminary)

Crab Optics since September 2005







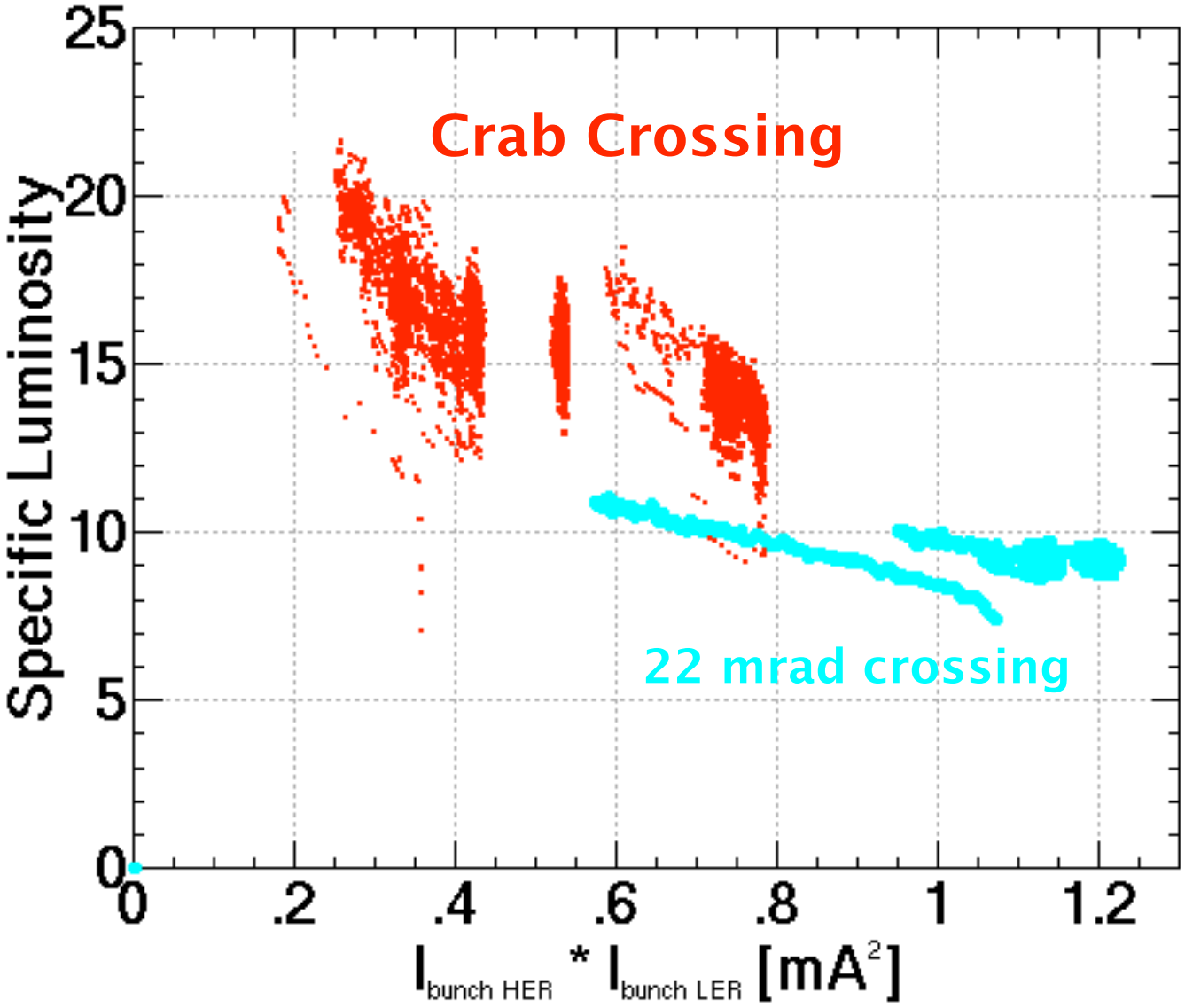


Machine Parameters (preliminary)

Date	**3/11/2007**		**11/15/2006**		
	LER	**HER**	**LER**	**HER**	
Current	0.061	0.033	1.65	1.33	A
Bunches	50+1		1388+1		
Bunch current	1.20	0.66	1.19	0.96	mA
Spacing	29		1.8–2.4		m
Emittance ε_x	18	24	18	24	nm
β_x^*	84	80	59	56	cm
β_y^*	0.65	0.59	0.65	0.59	cm
Hor. size @ IP	123	139	103	116	μm
Ver. size @ IP	1.4	1.4	1.5	1.5	μm
Beam-beam ξ_x	0.112	0.108	0.061	0.040	
Beam-beam ξ_y	0.096	0.078	0.094	0.052	
Luminosity	0.55		17.11		/nb/s

K. Oide

Specific Luminosity



Tuning items for crab crossing

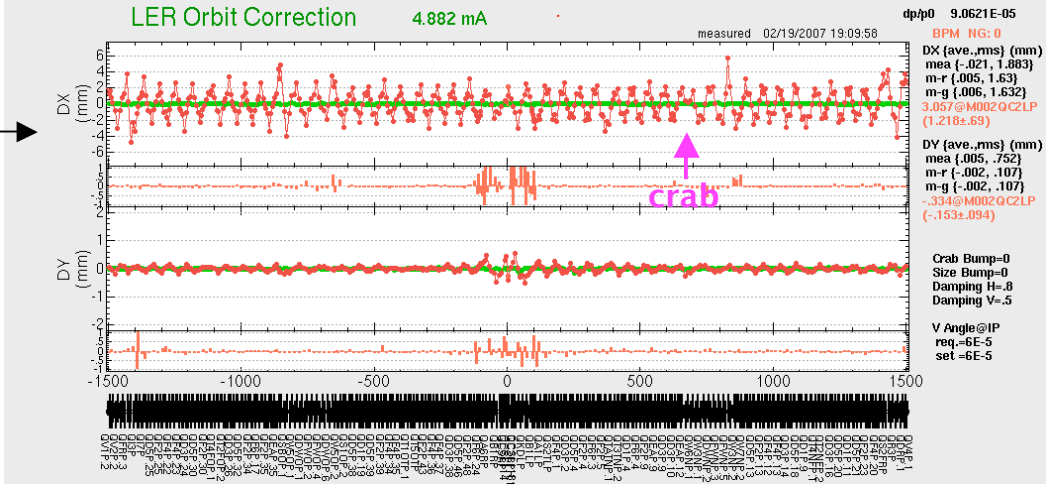
- Observation of beam tilt with streak camera (H. Ikeda, et al.)
- Adjustment of crab phase
- Adjustment of crab angle (crab voltage)
- Horizontal orbit feedback at crab cavities

- Adjustment of horizontal offset to keep head-on collision precisely
- Adjustment of head-on condition in the vertical plane
  - Reduction of vertical crabbing

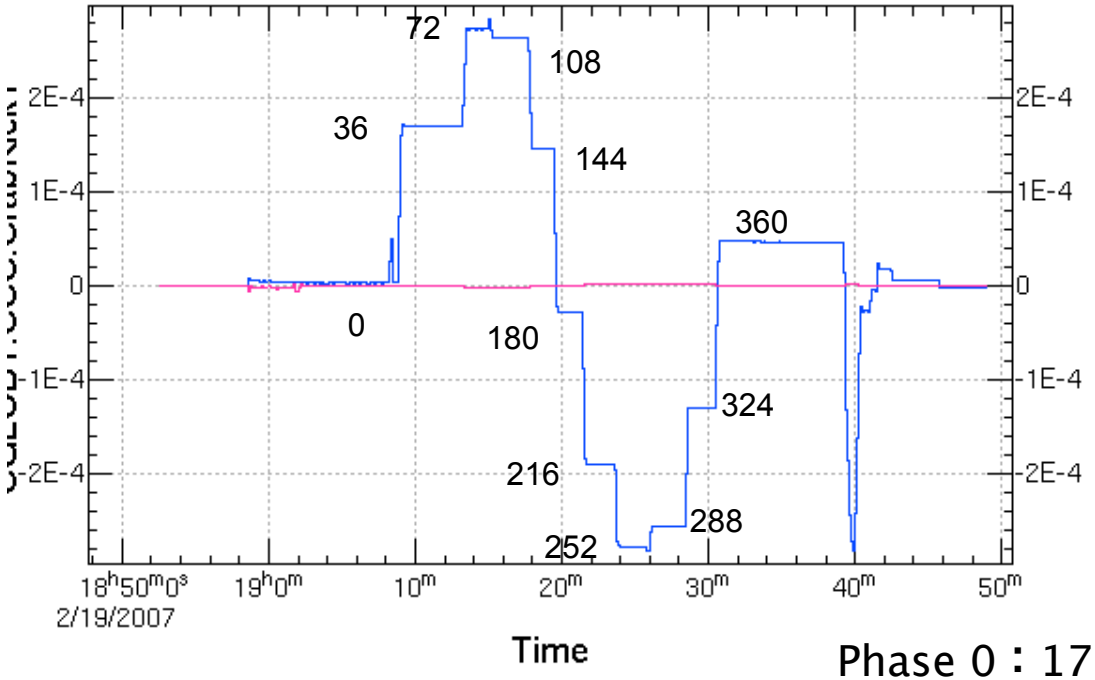
- Adjustment of beam optics
  - β_x^*, $\beta_{crab,}$ horizontal emittance
- Luminosity tuning
  - tunes, orbits, couplings, vertical dispersions, waists, chromaticities

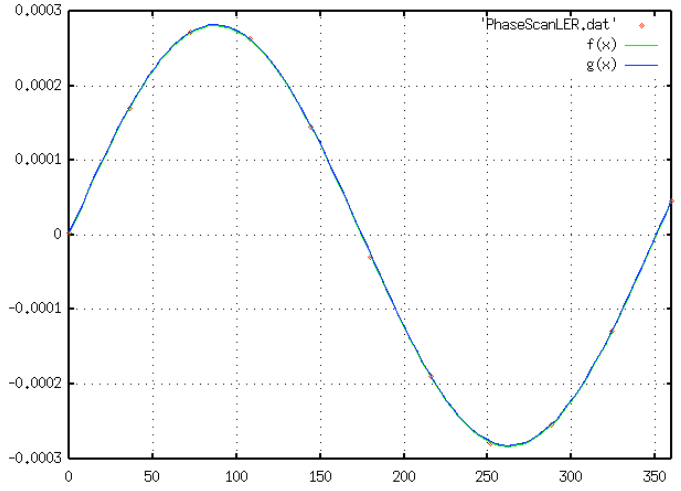
Crab Phase Scan (LER)

Horizontal orbit by crab kick



Horizontal kick by crab cavity (rad)
(Estimated from orbits)





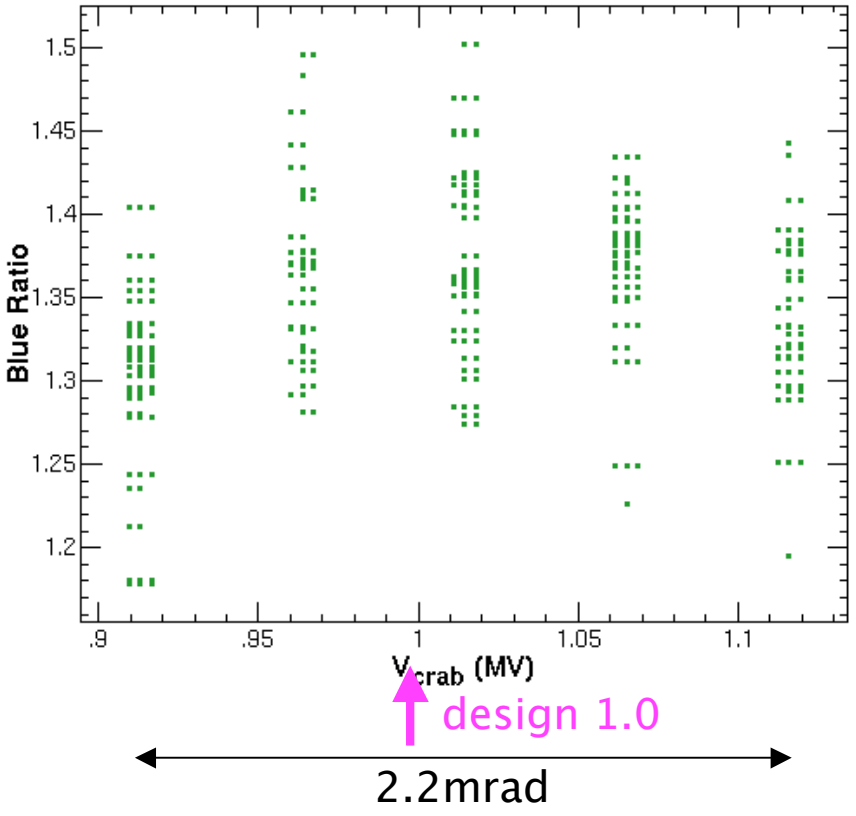
Phase 0：175 deg.
Vcrab set:1.0MV, estimated: 0.987MV

agree very well

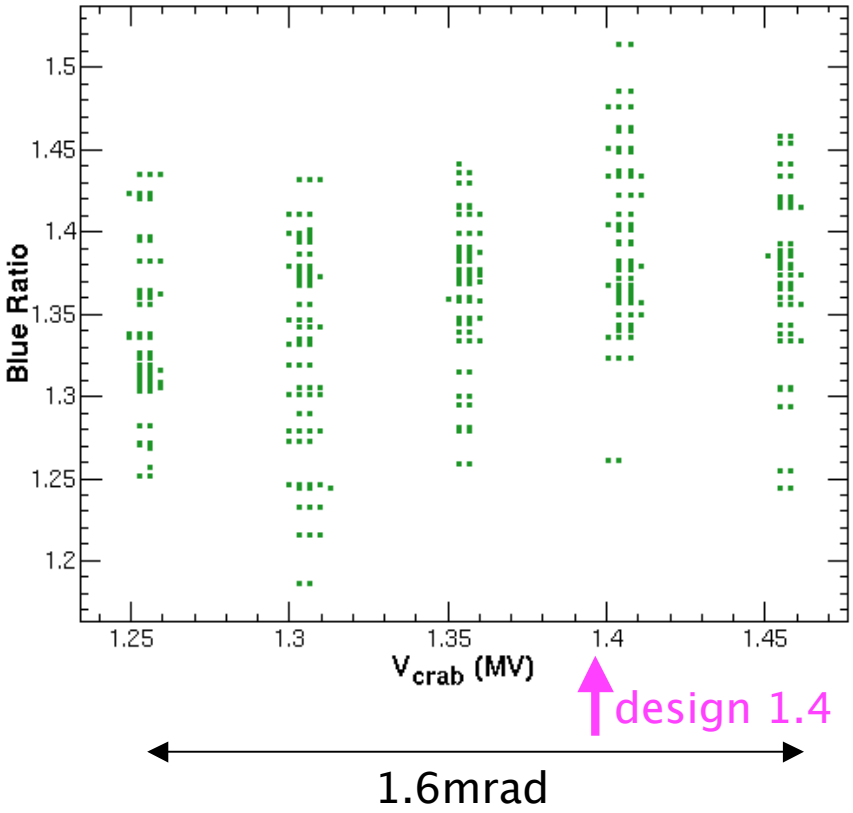
KCG Shift Report 2007_02_19_17

V_{crab} Scan

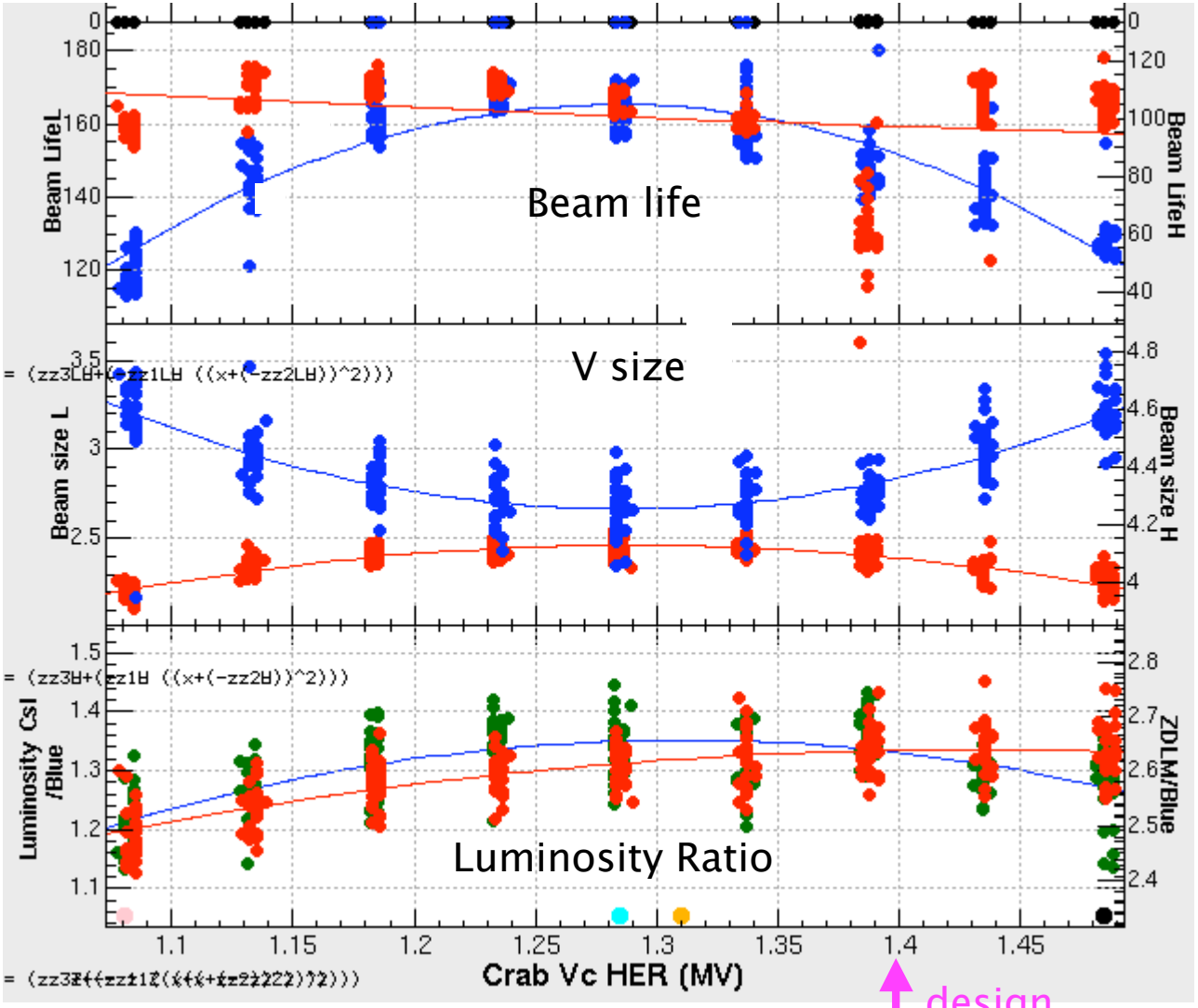
LER



HER



V_{crab} Scan (HER)



3.6 mrad

Working Point of Tunes

Simulations give good guidelines.

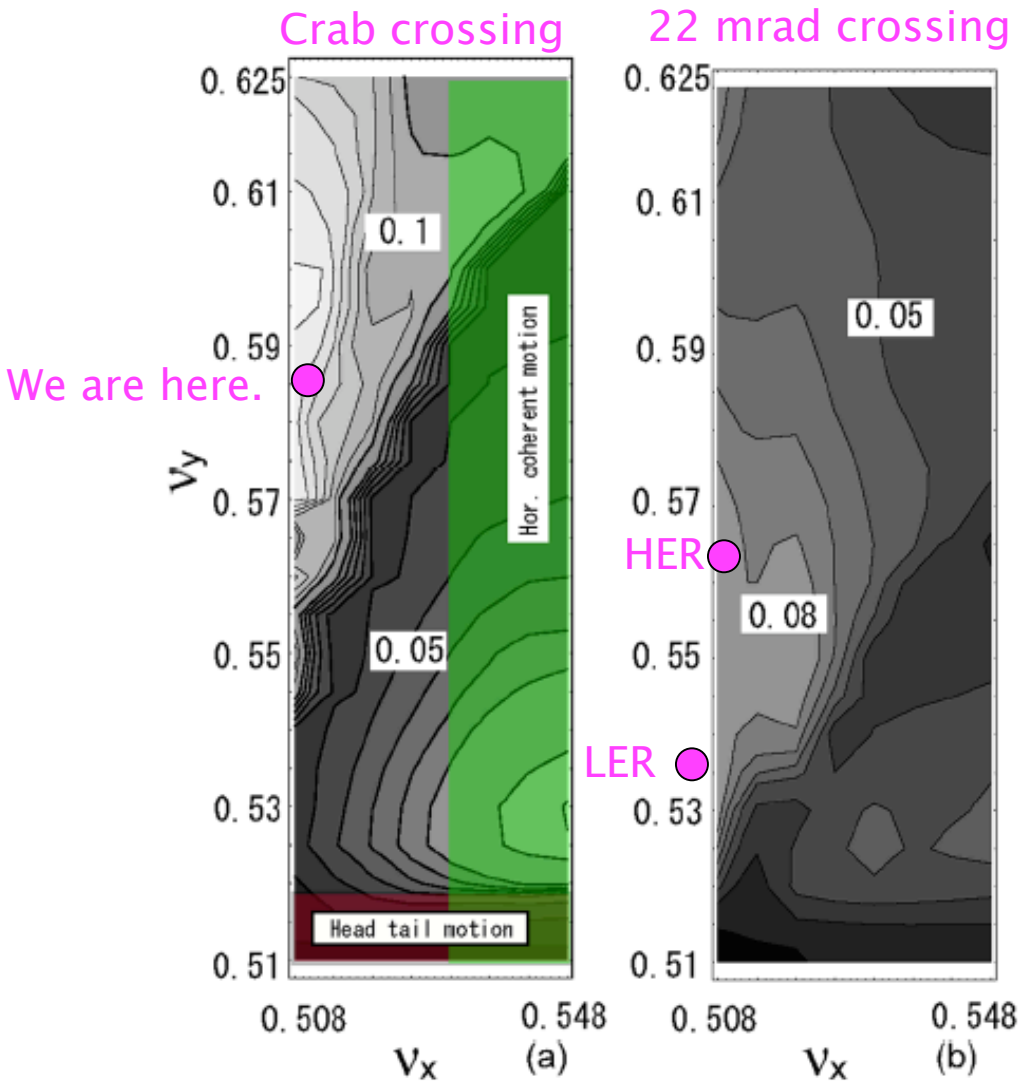
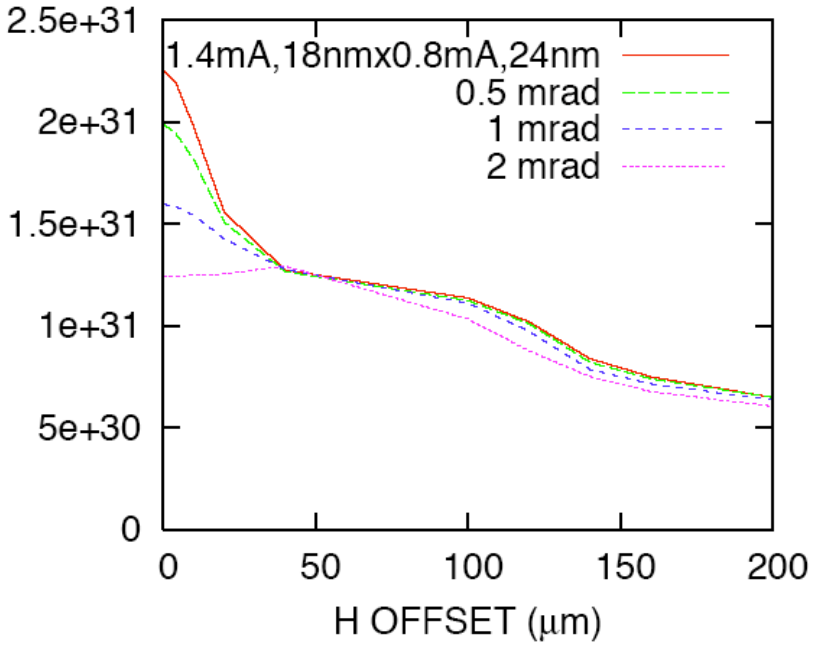


FIG. 6. (Color) Beam-beam parameter ξ_y in x-y tune space. The beam-beam parameter for the crossing angles of 0 and 11 mrad are depicted in (a) and (b), respectively. The contour lines are drawn every 0.01, and lighter gray corresponds to higher beam-beam parameter.

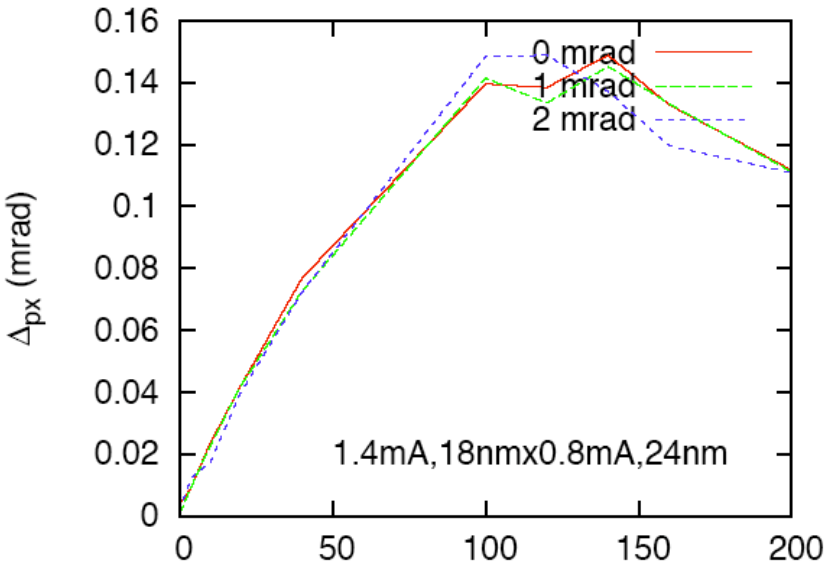
K. Ohmi, et al.
Phys. Rev. ST Accel. Beams 7, 104401(2004)

Horizontal Offset

- Luminosity



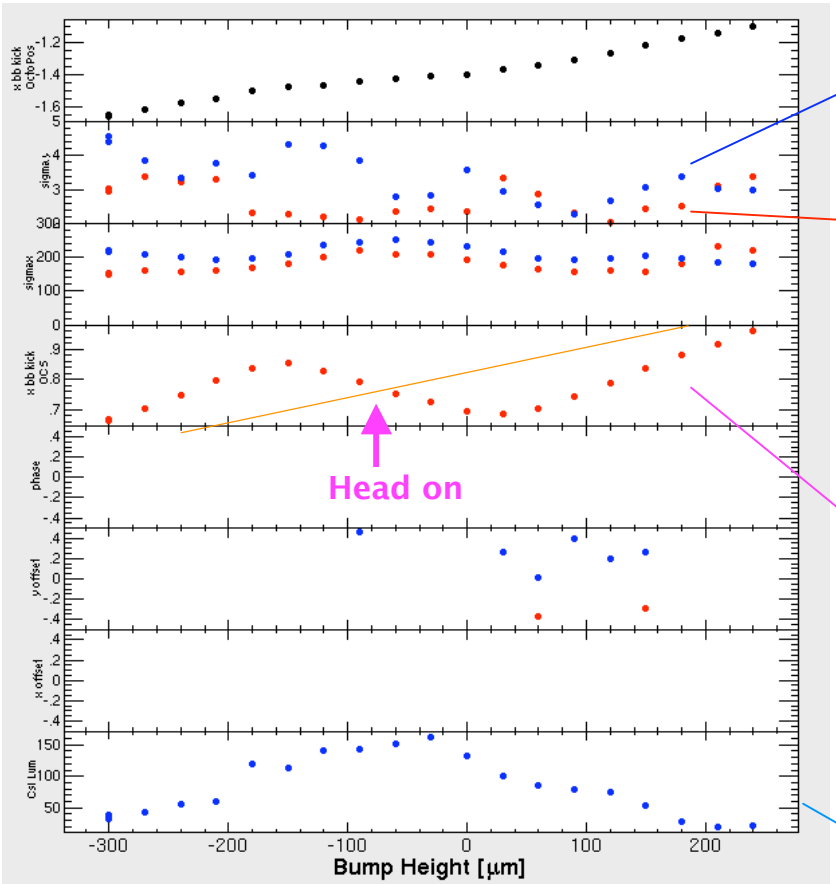
beam-beam kick



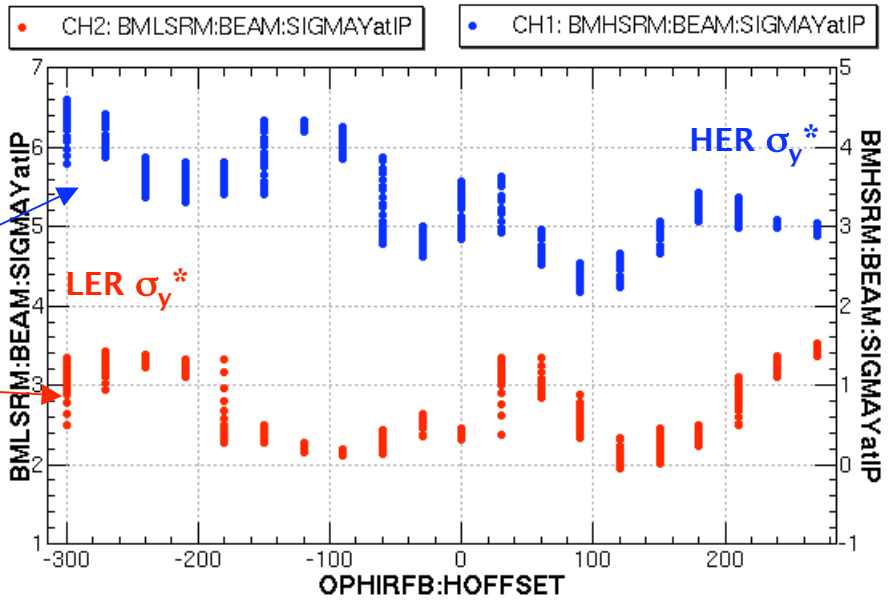
K. Ohmi, 2007/3/5 report

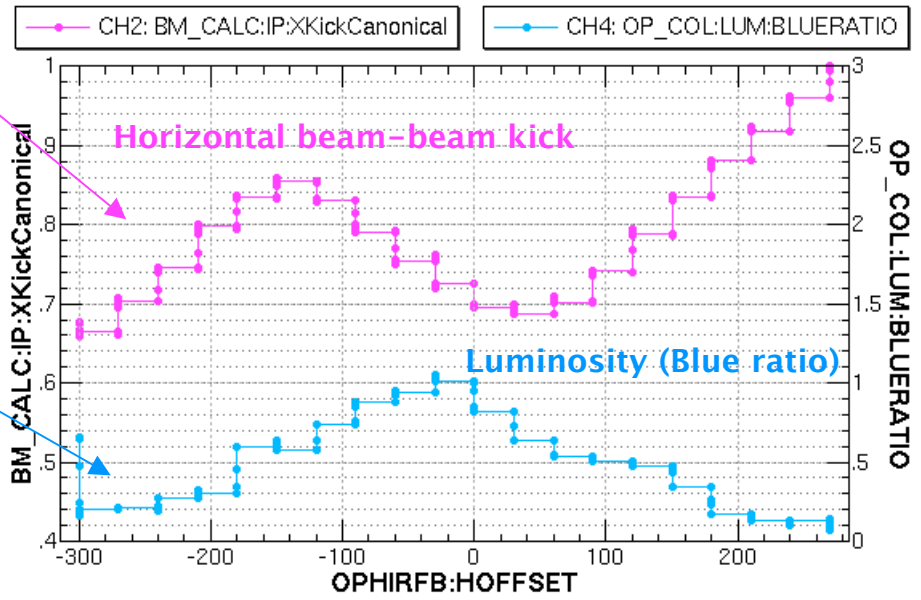
- Luminosity is degraded by small errors in head-on condition, optics, etc.
- H offset must be less than 40 μm.
- H offset is now adjusted by a feedback so as to keep the horizontal beam-beam parameter constant.
- May need more intelligent feedback.

H Offset Scan



Horizontal offset





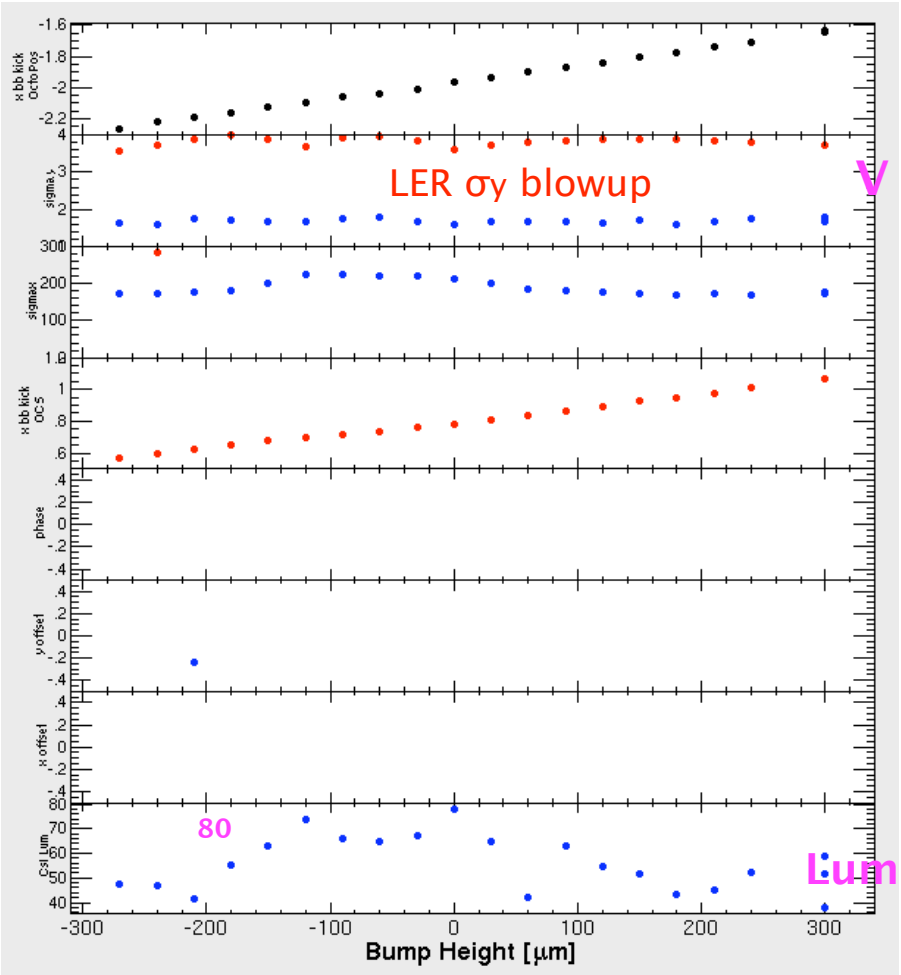
Horizontal bump height (μm)

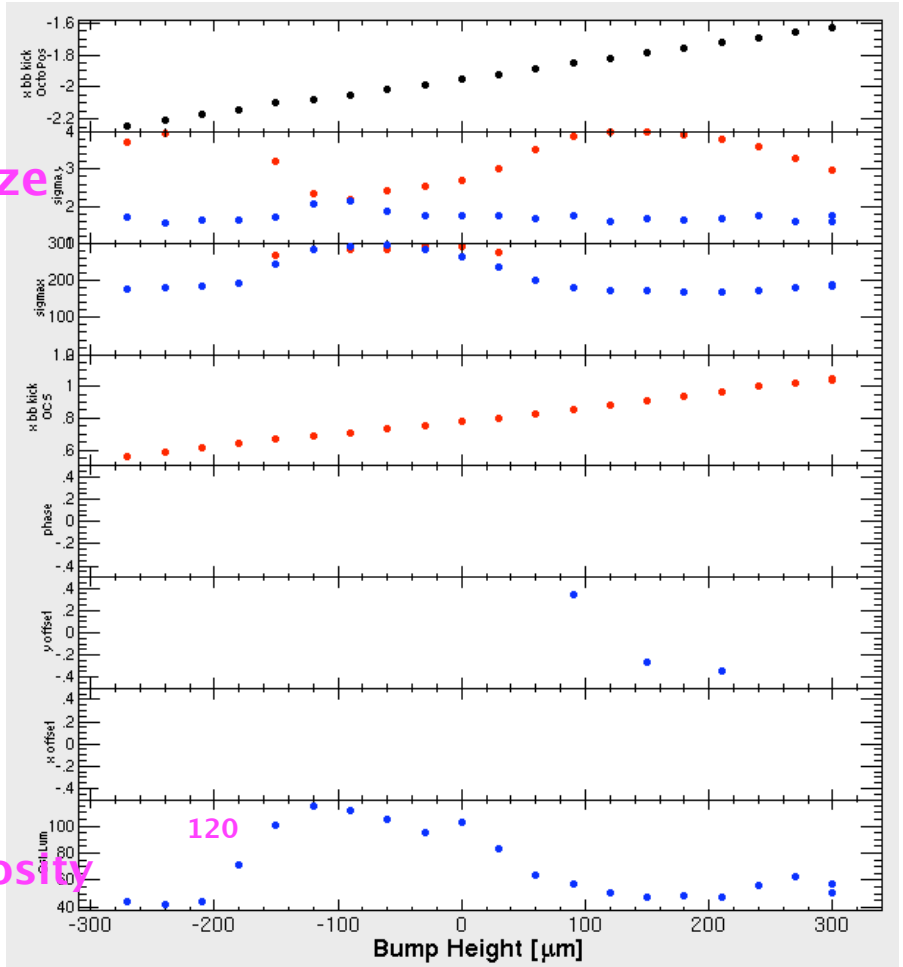
KCG Shift Report 2007_02_26_09

LER: ~0.75mA/bunch

HER: ~0.48mA/bunch

Crab Angle Check (I)

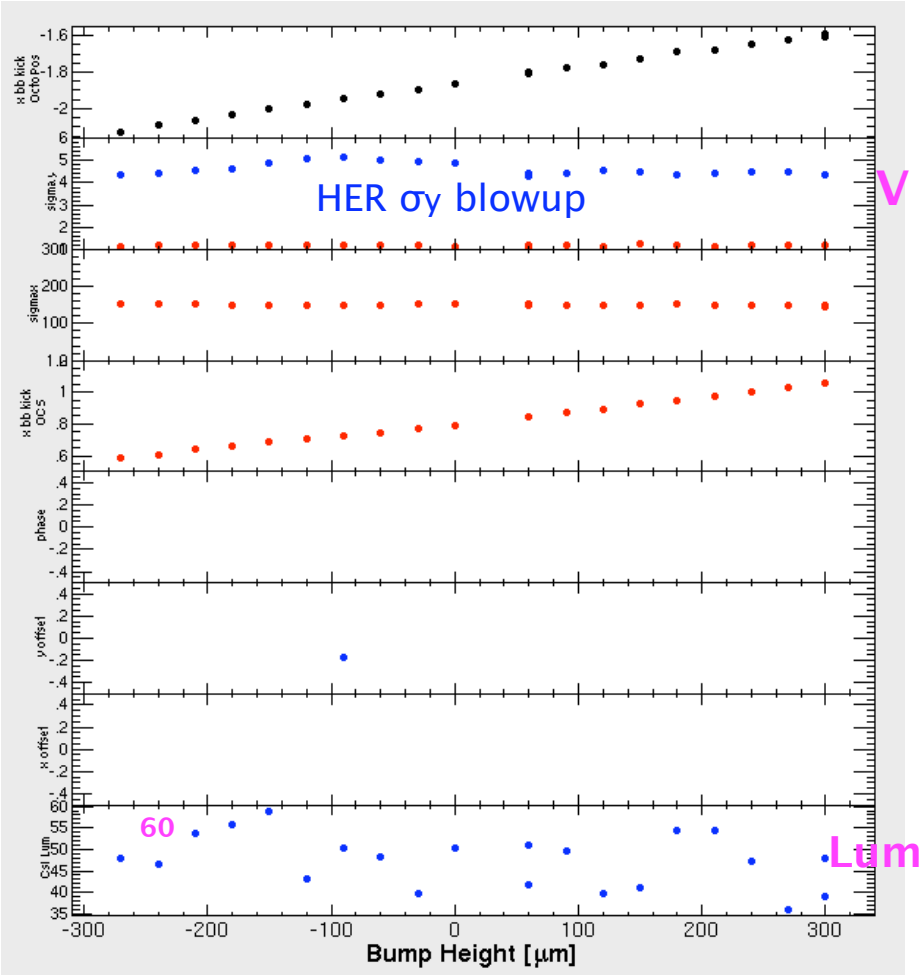


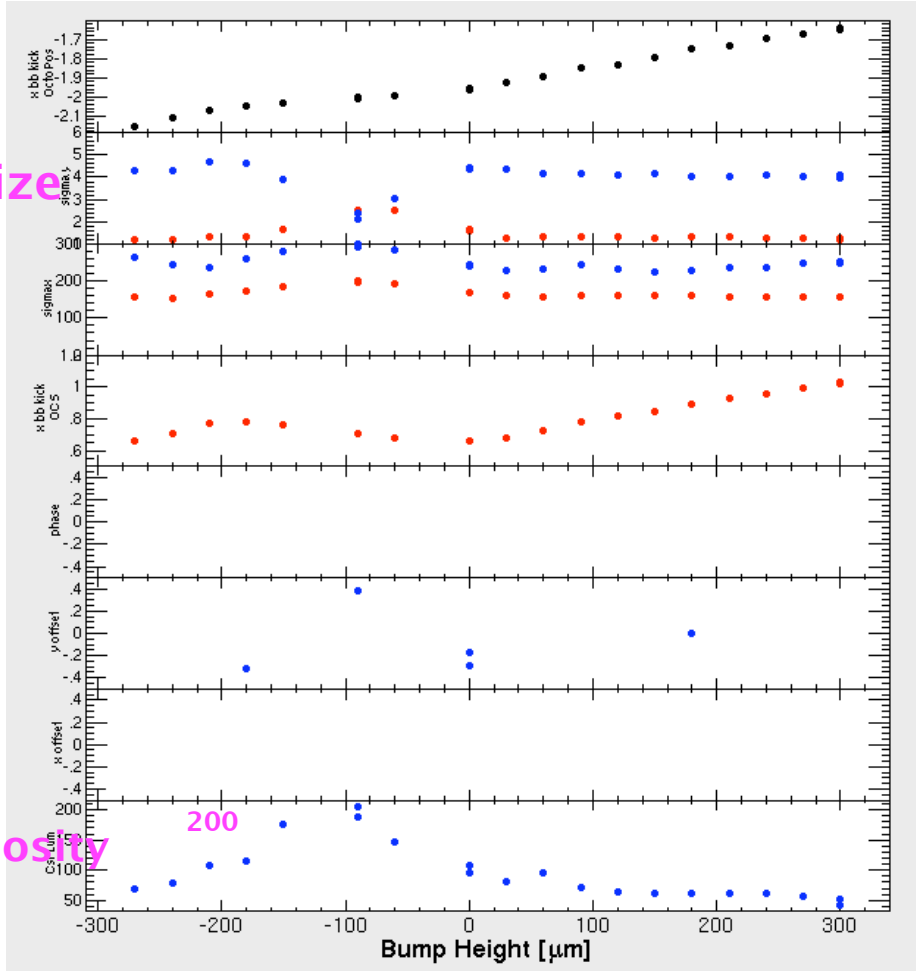


Reversed LER crab angle

Reversed LER & HER

Crab Angle Check (II)

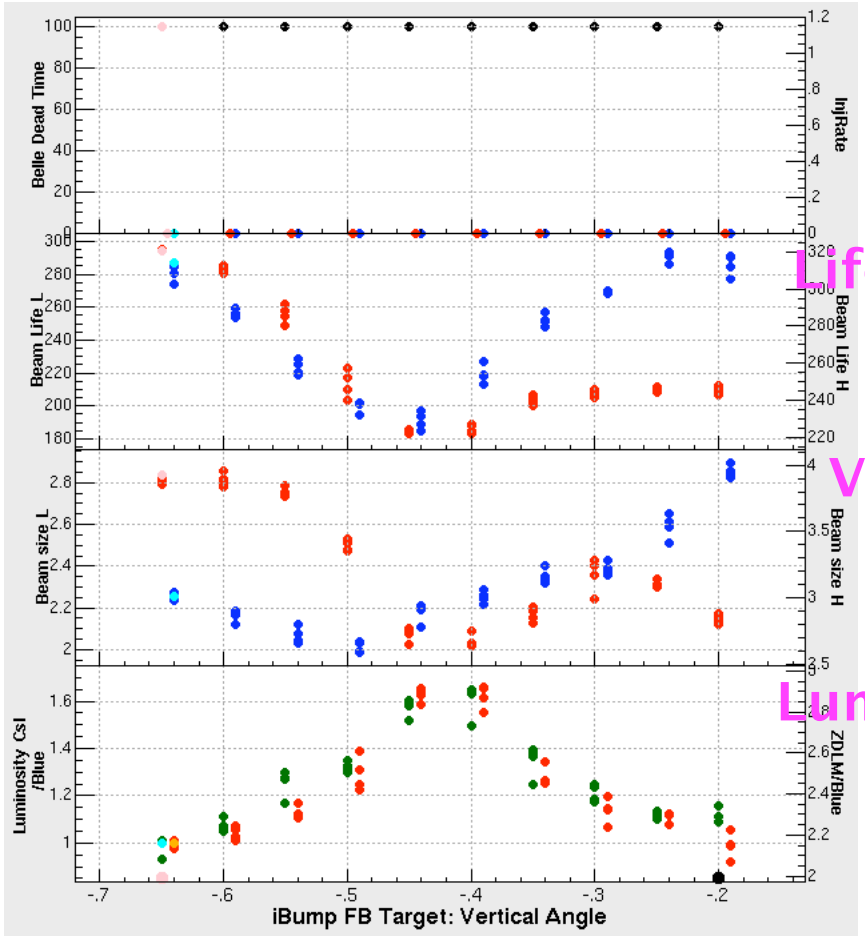




Reversed HER

Original directions

Vertical Crabbing ?

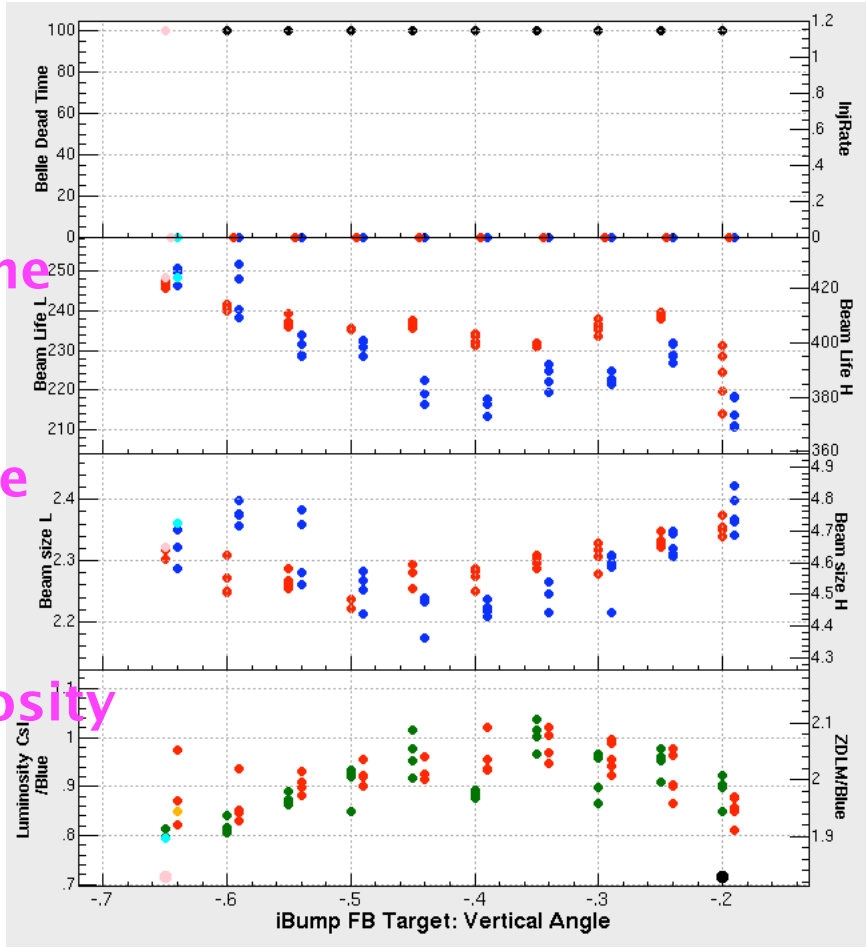


asymmetric

Lifetime

V size

Luminosity



symmetric

V size dependence on the vertical crossing angle should be symmetric at head-on collision.

IP Coupling

normal

physical

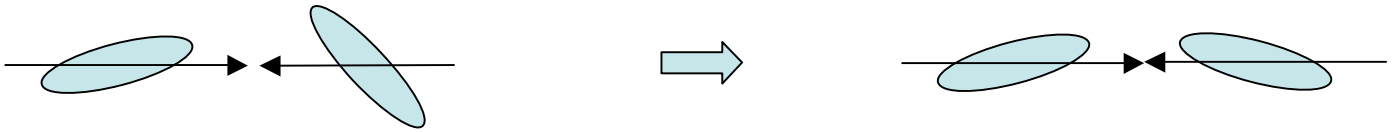
$$\begin{pmatrix} X \\ P_X \\ Y \\ P_Y \end{pmatrix} = \begin{pmatrix} \mu & 0 & -r_4 & r_2 \\ 0 & \mu & r_3 & -r_1 \\ r_1 & r_2 & \mu & 0 \\ r_3 & r_4 & 0 & \mu \end{pmatrix} \begin{pmatrix} x \\ p_x \\ y \\ p_y \end{pmatrix} - \begin{pmatrix} \eta_x \\ \eta_{px} \\ \eta_y \\ \eta_{py} \end{pmatrix} \Delta p$$

$$\mu^2 + \det R = 1$$

	LER (set by IP knob tuning)	HER (set by IP knob tuning)	LER (measured at the optics correction)	HER (measured at the optics correction)	
R1	4.12	4.16	0.01	0.17	mrad
R2	2.01	-3.96	0.001	-0.07	mm
R3	63.90	0	-98.5	72.3	/km
R4	-64.69	128.52	-150.	-23.7	mrad

How to keep the vertical head-on condition

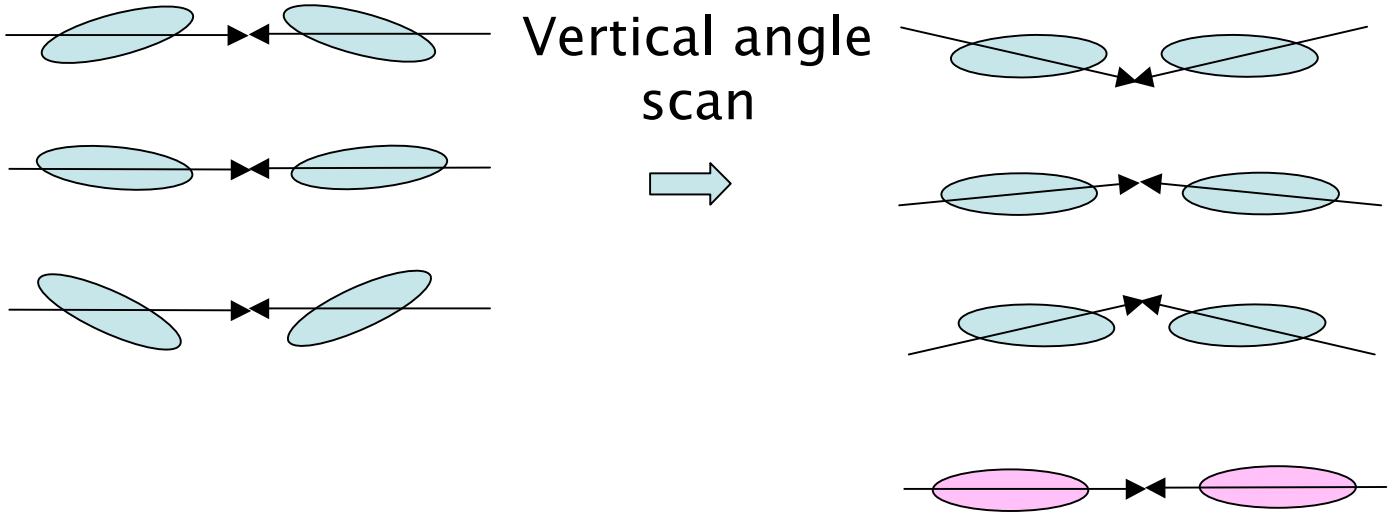
Adjust R1 of one ring at fixed R1 of another ring to find the head-on condition.



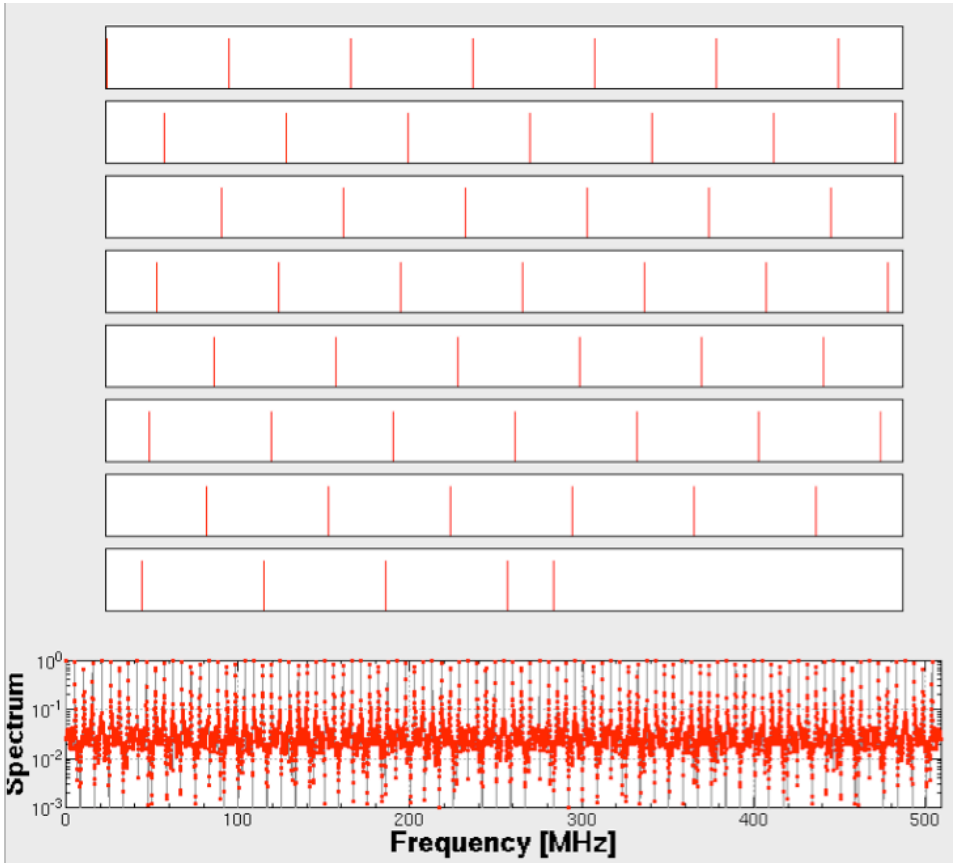
asymmetric

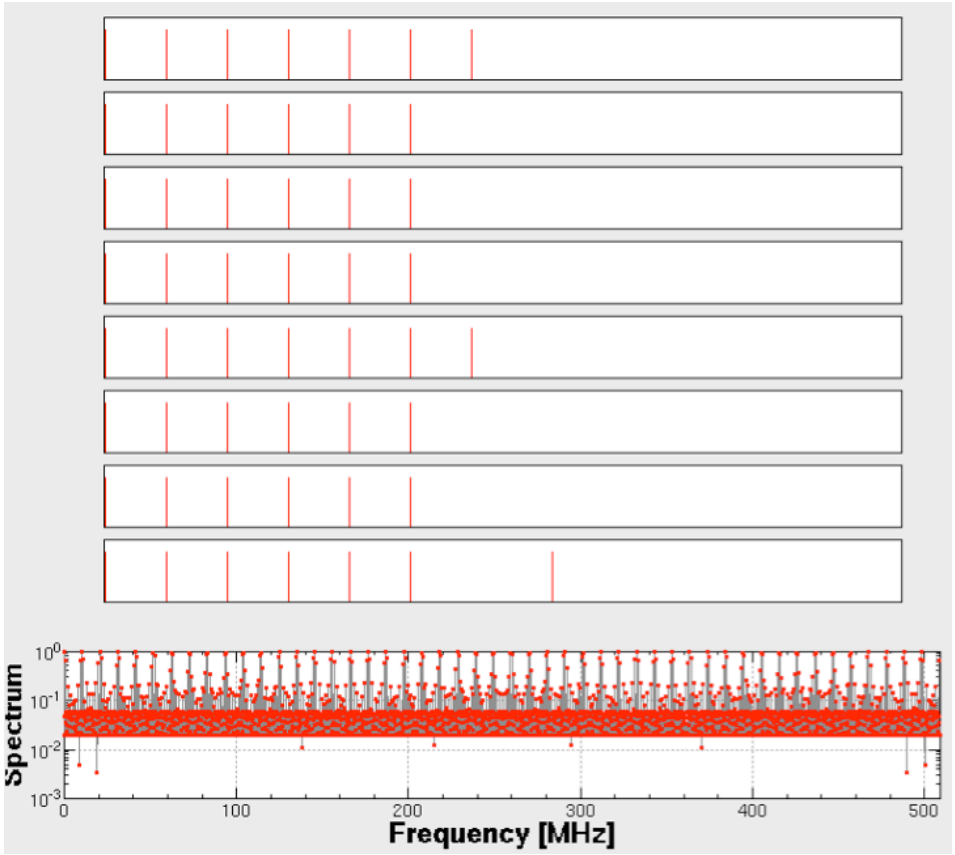
symmetric

Different sets of R1s



Fill Pattern





51 bunches： 98 sp → 49 sp, 8 trains

Plans

- **Step I : Continue machine tuning at low currents (~ 75mA(LER)/50mA(HER), 51 bunches) till advantage of crab crossing is clearly observed, or, our tuning ideas for higher luminosity are run out.**
  - **We have already achieved the vertical beam-beam tune shift parameter of 0.078 in HER, which is higher than our record 0.062 with a correction of the geometric gain.**
- **Step II : Try higher currents for physics run.**