Beam-beam effect with Crab cavity

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MAC2007 for KEKB

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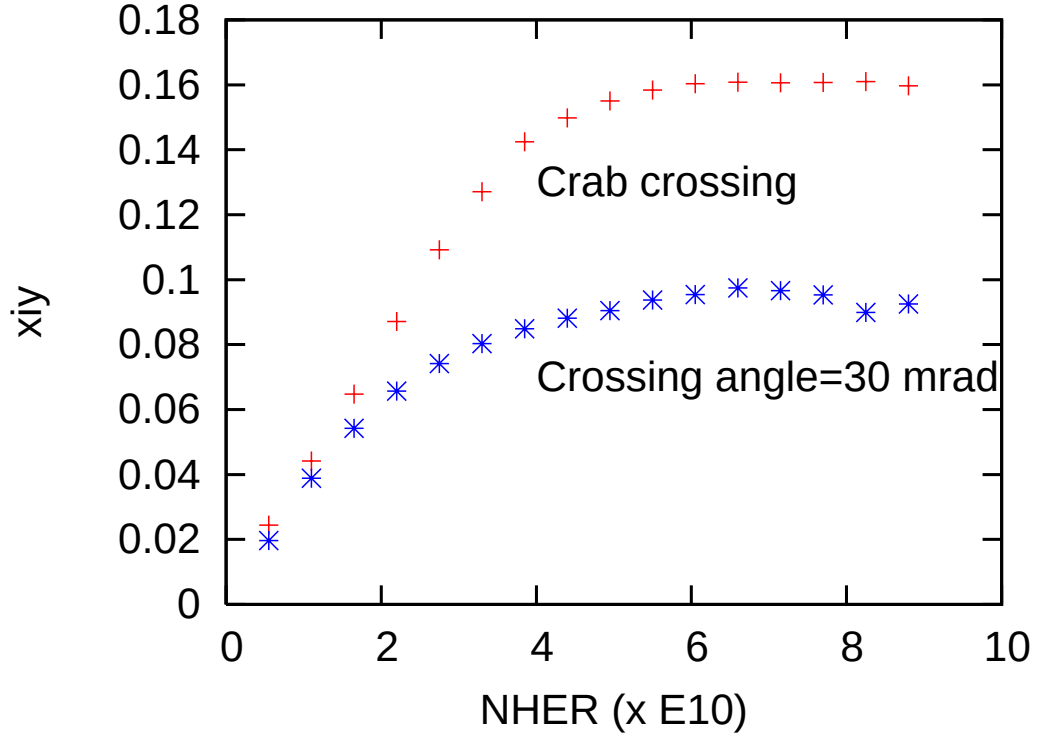
Essentials of crab collision (head-on collision)

- Symmetry of the collision.
- Symmetry breaking, what degrades the luminosity.



Perfect symmetry case

$$N_+\gamma_+ = N_-\gamma_-$$

Our operating condition
Equal tune shift condition

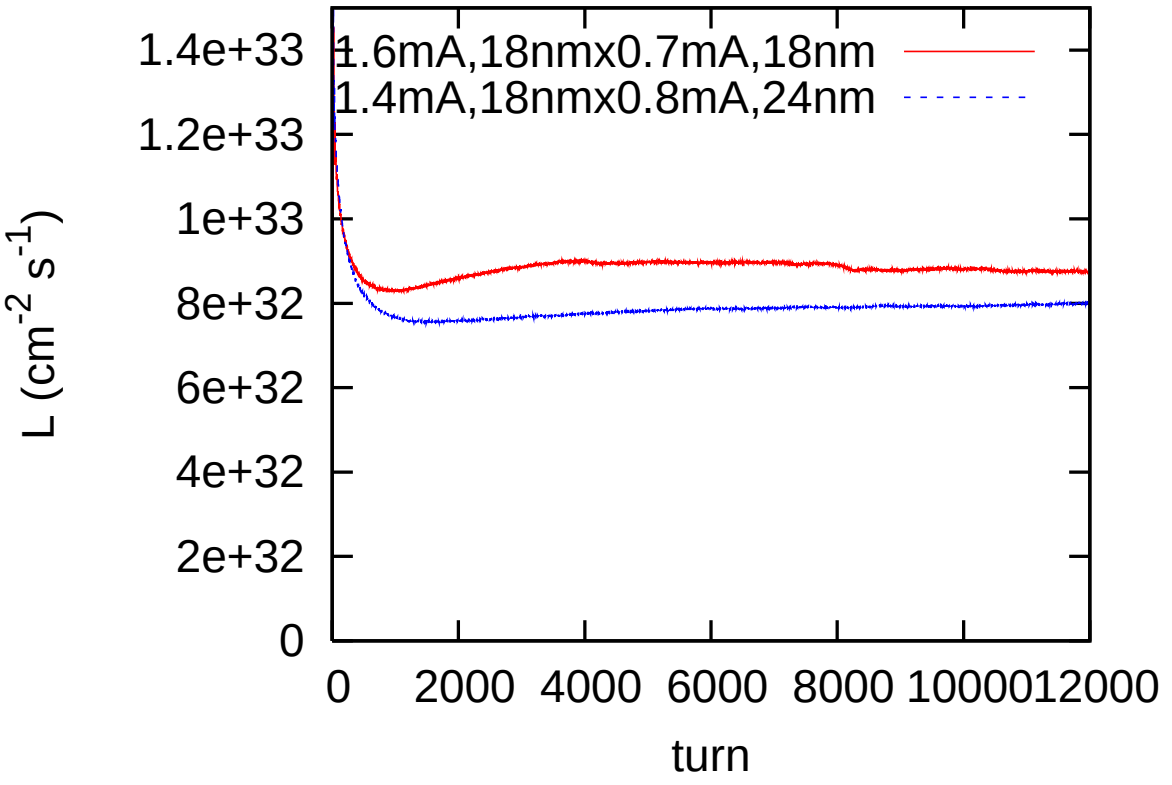
	LER	HER
E	3.5 GeV	8
ε_x	18 nm	24 nm
N	8.66×10^{10}	5.05×10^{10}
I_b Operation	1.39 mA 1.2 mA	0.81 mA 0.67 mA

$$\xi_{y,\pm} = \frac{1}{4\pi} \frac{N_{\mp} r_e}{\gamma_{\pm}} \frac{1}{\varepsilon_{x,\mp} \kappa_{\mp}^{1/2} \beta_{y,\mp}^{1/2} \beta_{x,\mp}^{1/2}}$$

$$\xi_{y,+} = \xi_{y,-} \longrightarrow \frac{N_+ \gamma_+}{\varepsilon_{y,+}} = \frac{N_- \gamma_-}{\varepsilon_{y,-}}$$

Luminosity at the condition

- The emittance compensation is no problem.



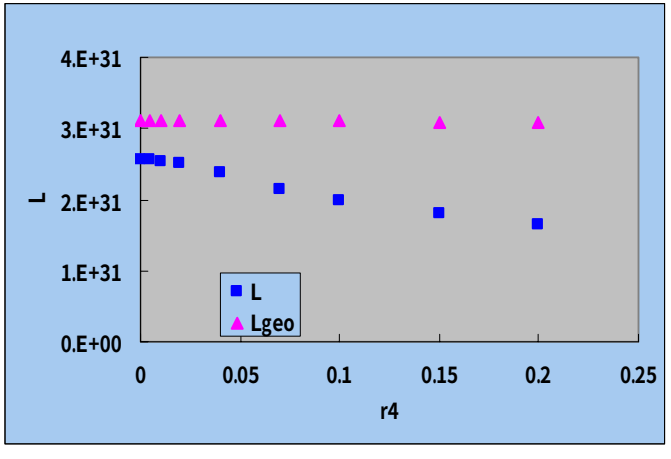
Symmetry breaking source

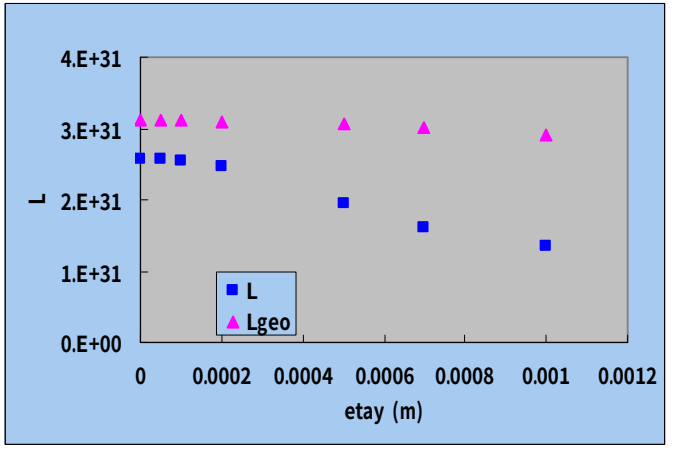
- Optimization with a large number of parameters
- Offset Δx, Δy, $\Delta x'$, $\Delta y'$
- Twiss parameters, β(waist), $R_{i=1,4}$, $\eta_{x,y}$, $\eta'_{x,y}$ of each beam.

Tolerance for twiss parameters

- Tolerance of all parameters are individually in controllable range.

1 unit for KEKB tuning: r4=0.021, η=0.00016

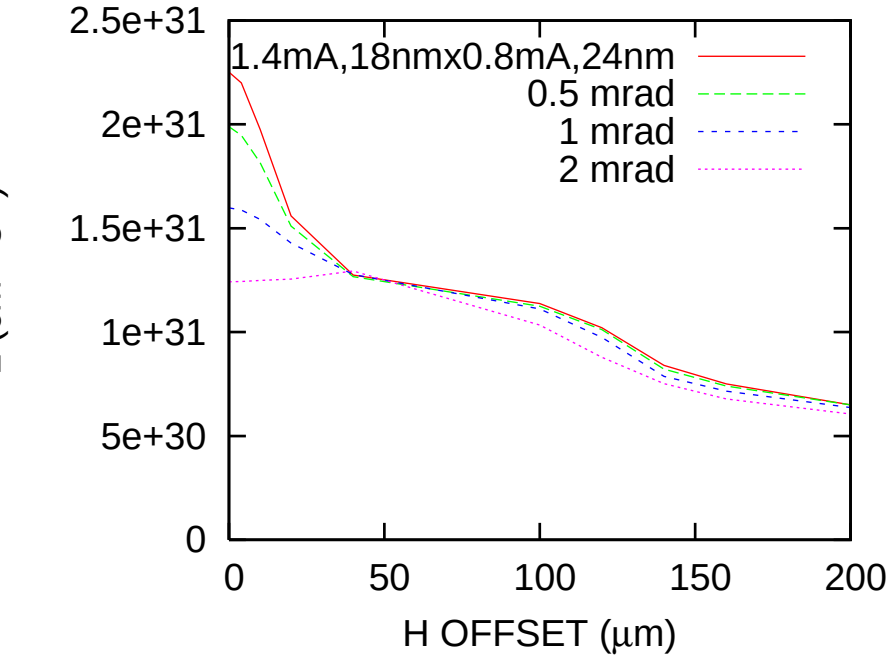




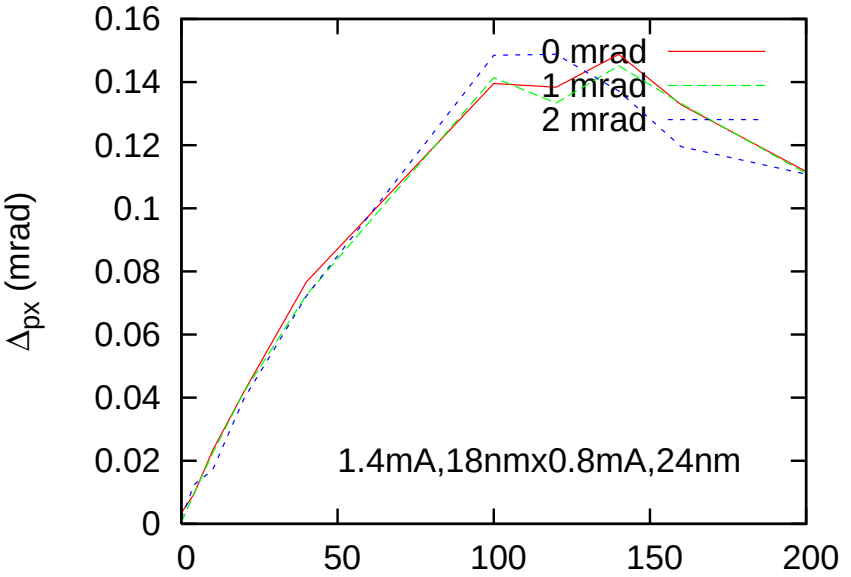
Difficulty for multi-parameters optimization

Horizontal scan

- Luminosity



beam-beam kick

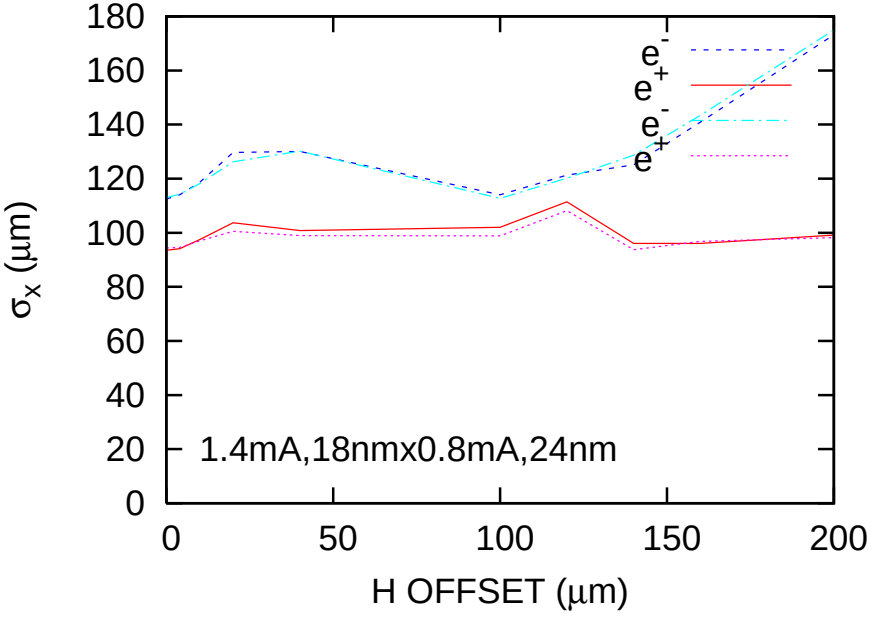


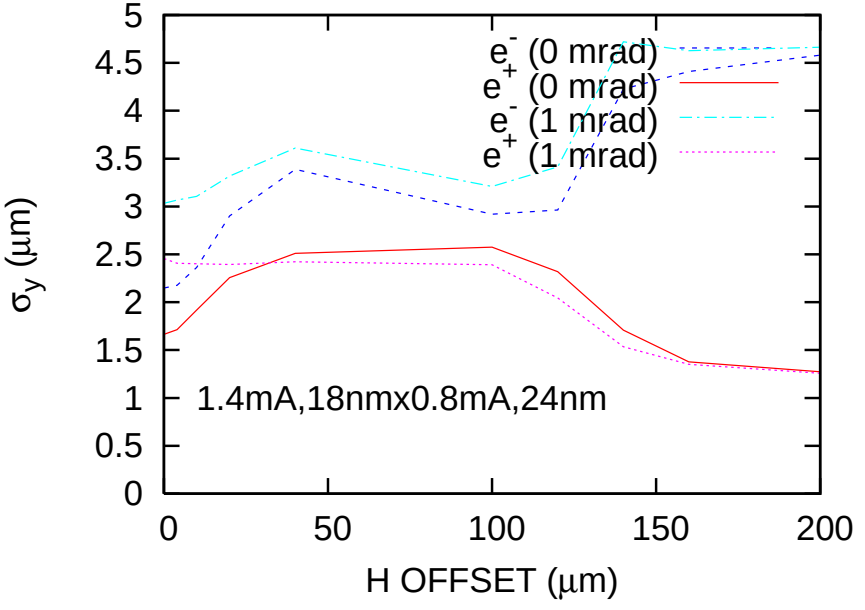
This figure is meaningful.

Even the two parameters, the search of the peak seems to be hard: if residual crossing angle is 2 mrad, we can not realize the existence of the peak.

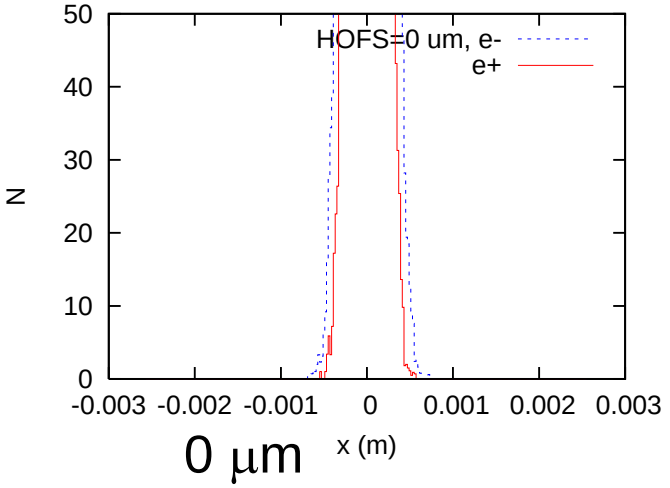
We have to arrive the peak for multi-parameter.

Beam size and H-offset

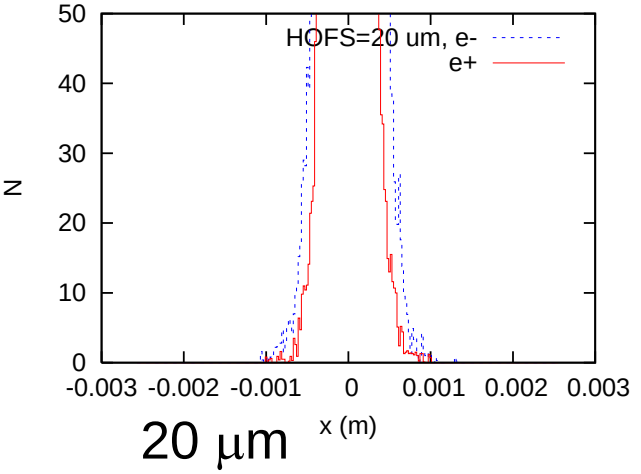




Life time and offset



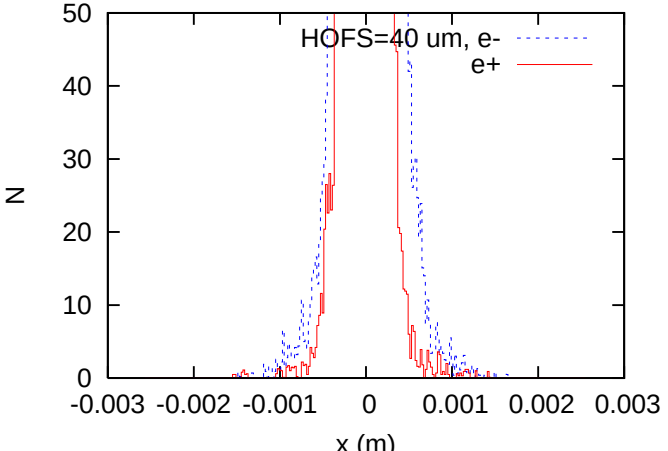
0 μm



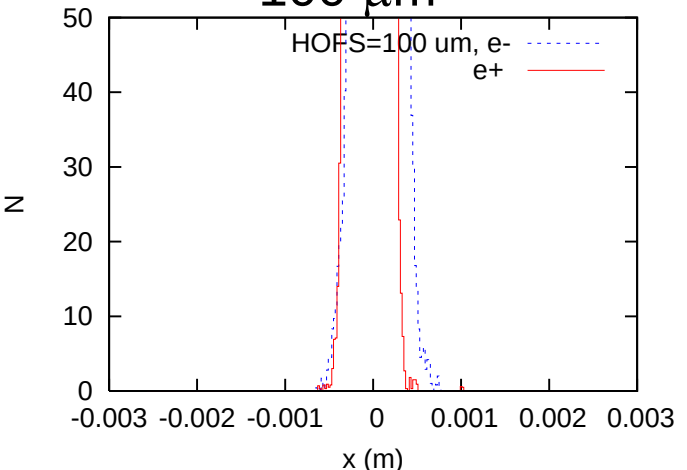
20 μm

- Life time may be short at H-offset 20, 40 μm, Jx=3 μm

40 μm



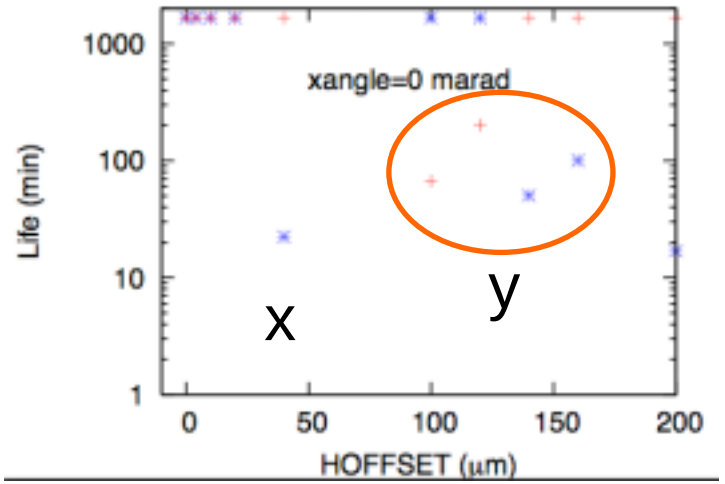
100 μm

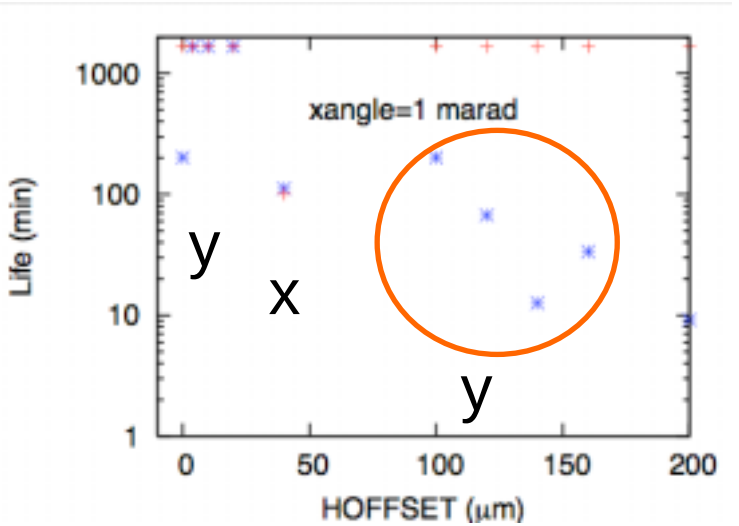


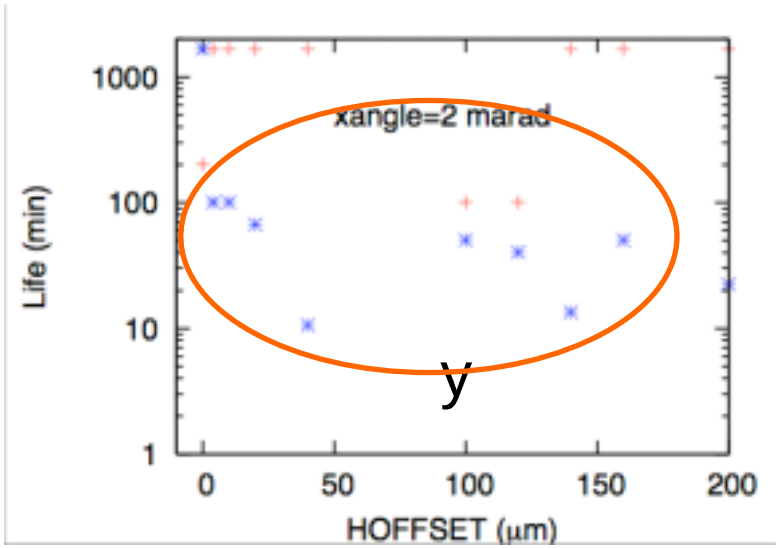
Beam-beam induced Life time evaluation

- Simplified method.
- Count the number of particle outgoing from the meshed area.
- Meshed area, +- 2.5 mm x 0.05 mm.
- Ax=7.8 μm, Ay=0.36 μm.
- Actual aperture Ax~12 μm Ay~1 μm.

Beam loss feature



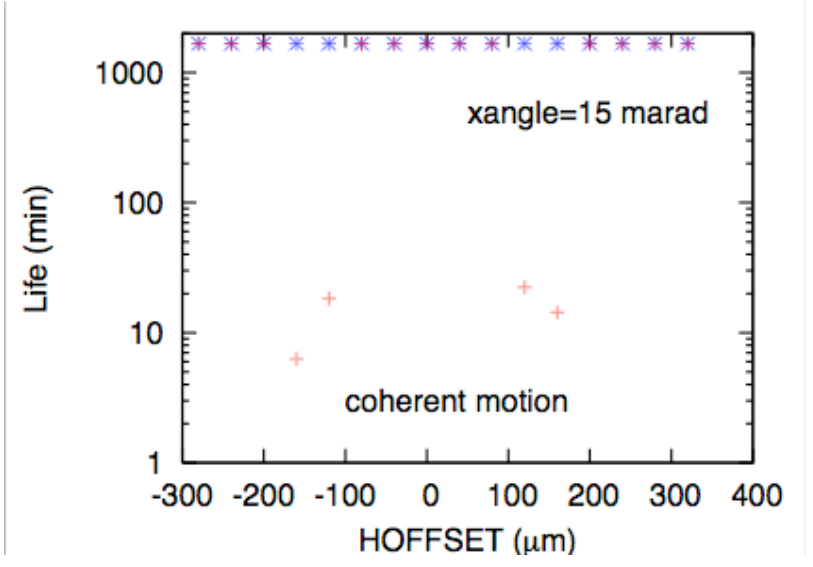


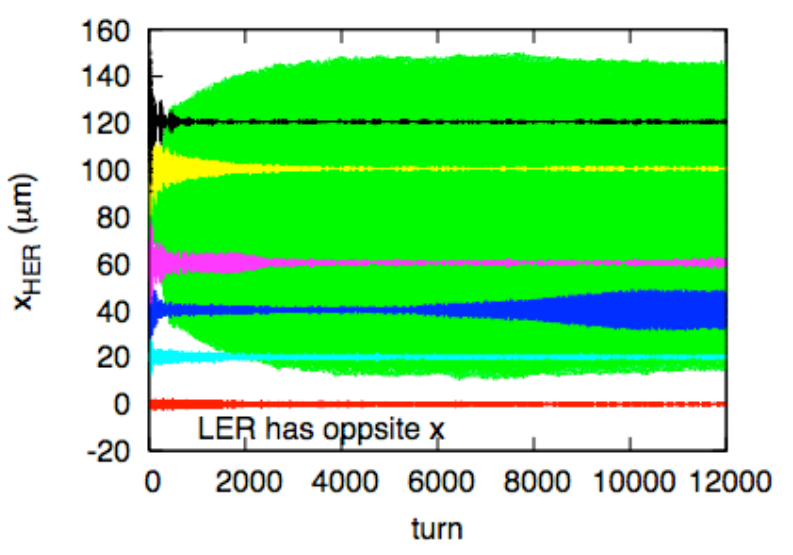


- Beam particles are lost vertical for large horizontal offset.
- Beam particles are lost horizontal for horizontal offset 50 μm.
- Electron beam is easily lost in this condition.

Beam life at 11 mrad crossing

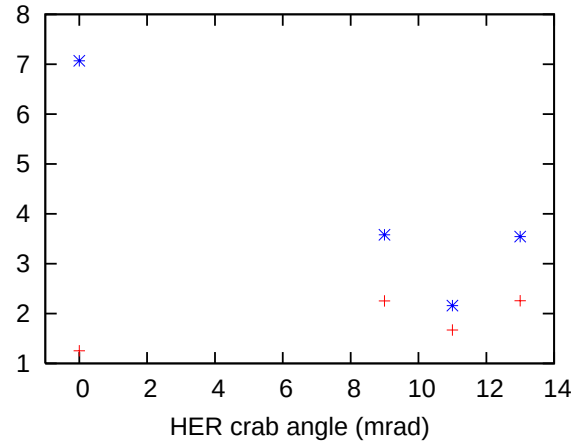
- Life time is no problem, if coherent motion does not occur

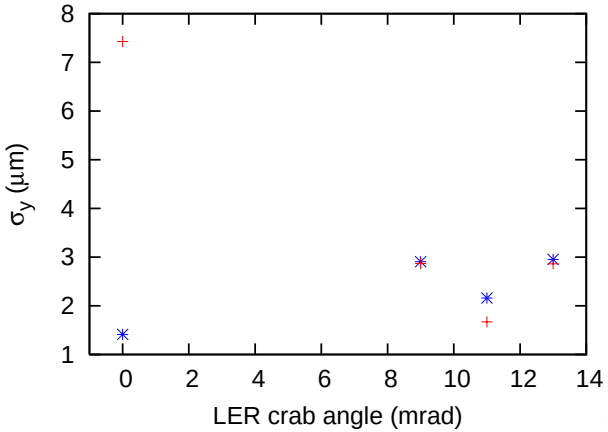


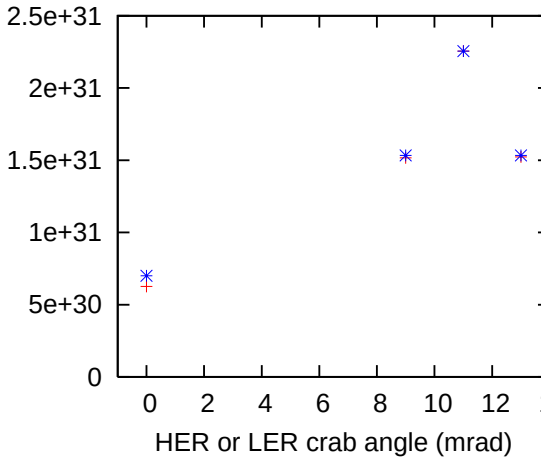


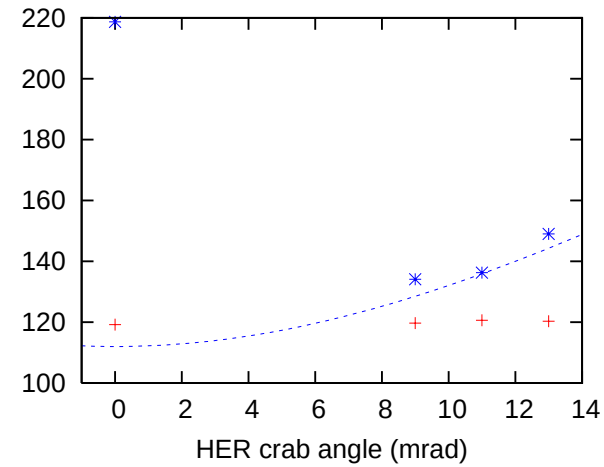
Simulation of the Crab voltage scan

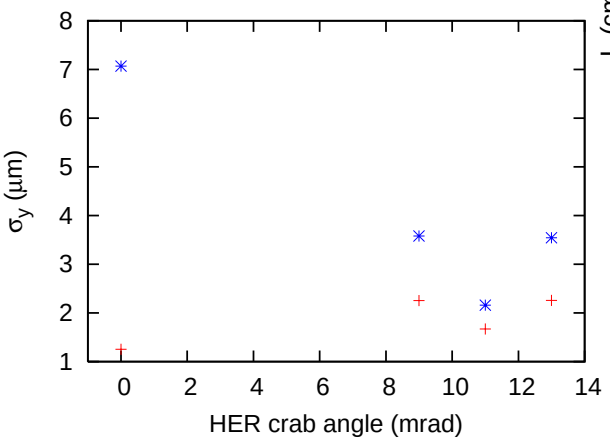
- The size is minimum for no bunch tilt.



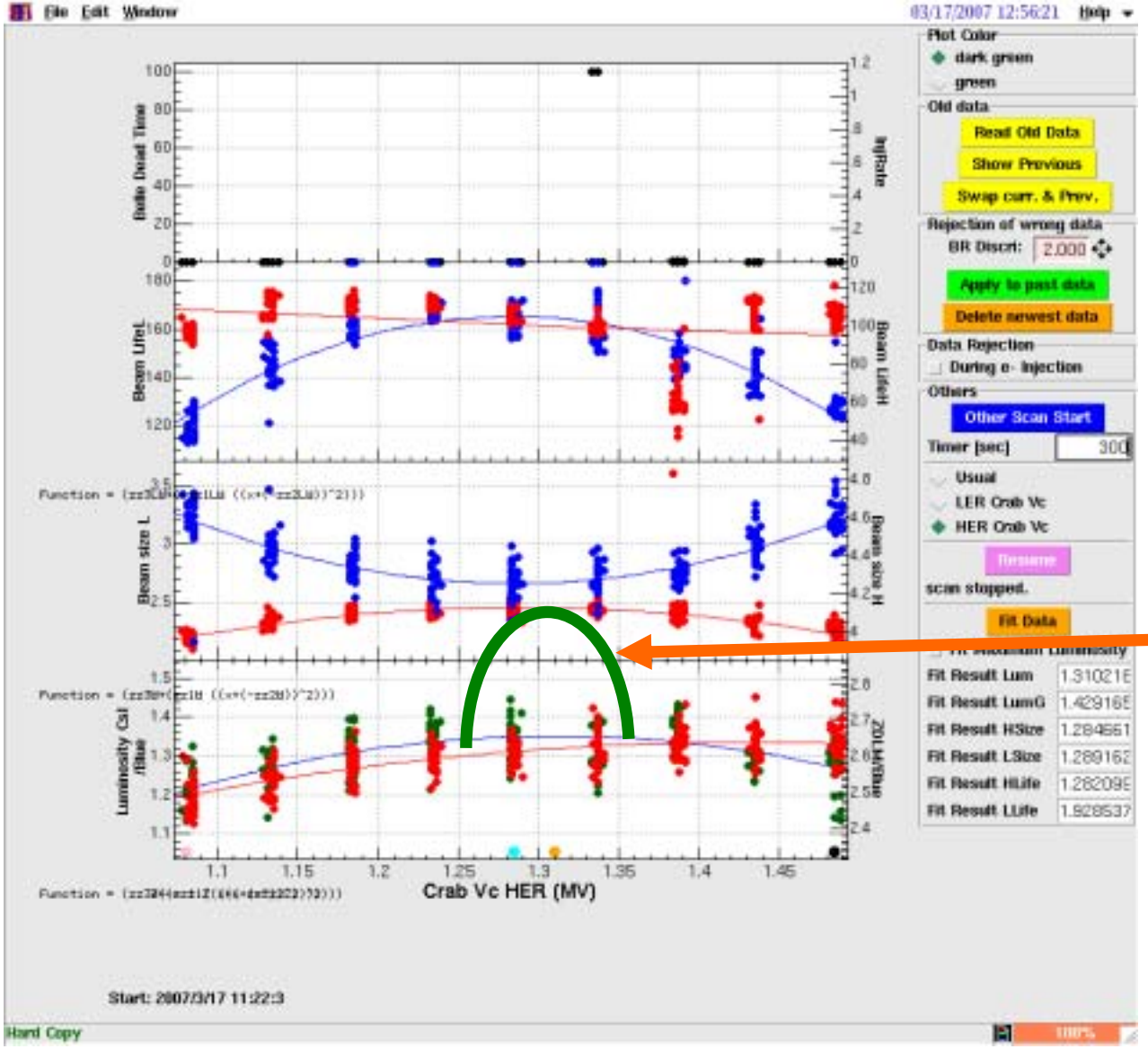








Measurement of HER voltage scan

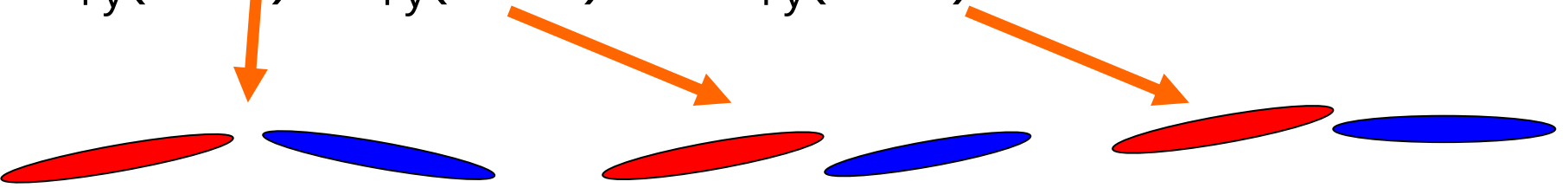


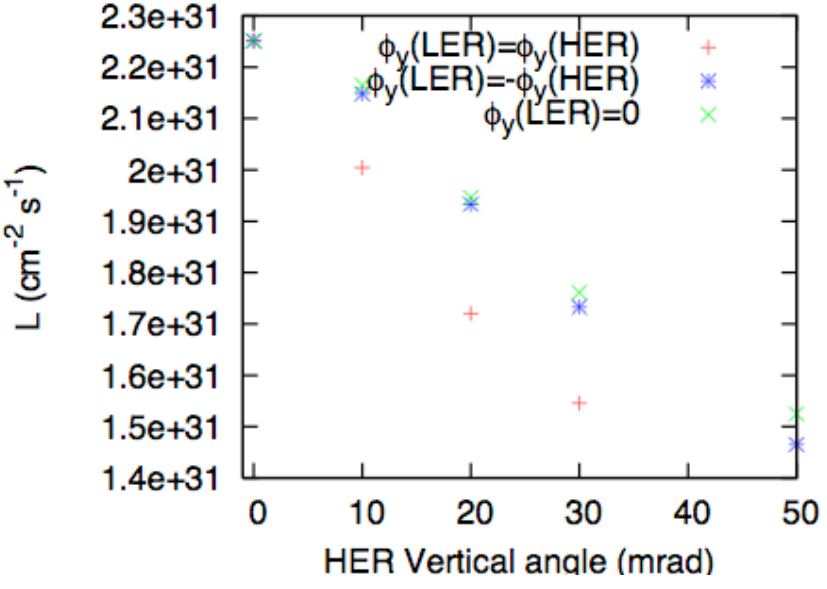
If there is not other errors, we have a shape enhancement.

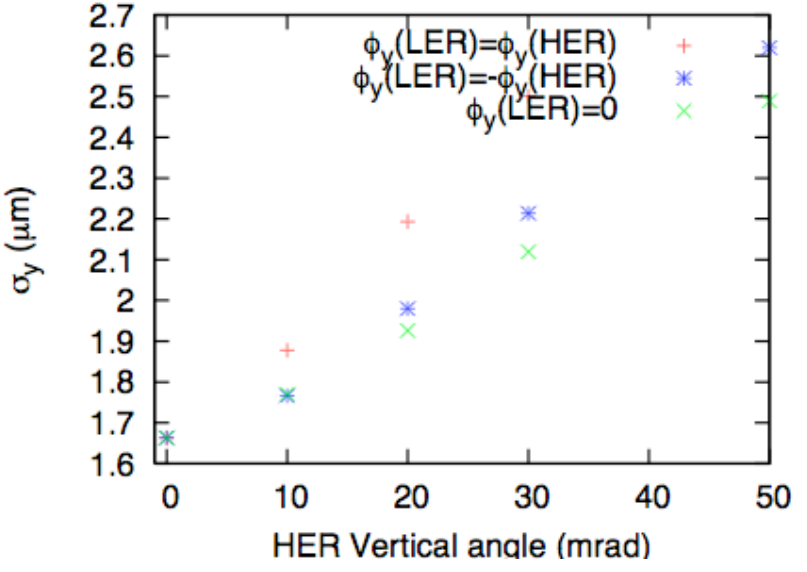
Vertical angle

ϕ_y(LER)= ϕ_y(HER): worst

ϕ_y(LER)= -ϕ_y(HER) and ϕ_y(LER)=0 : better

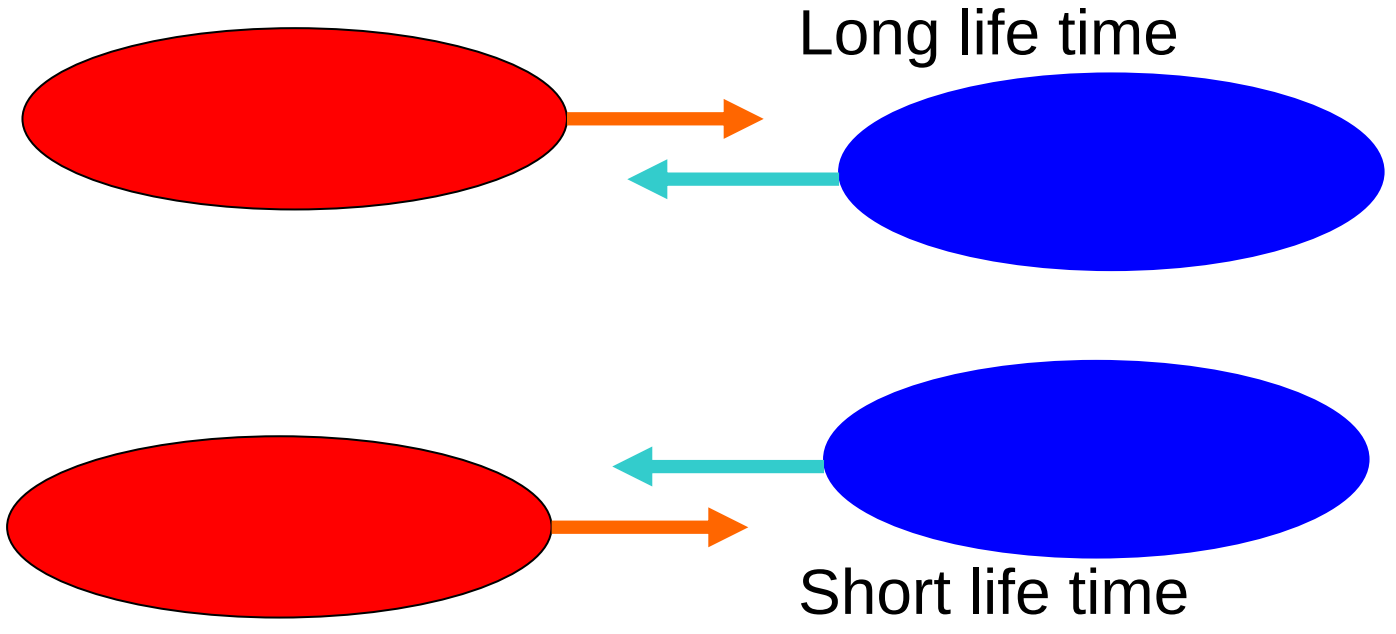






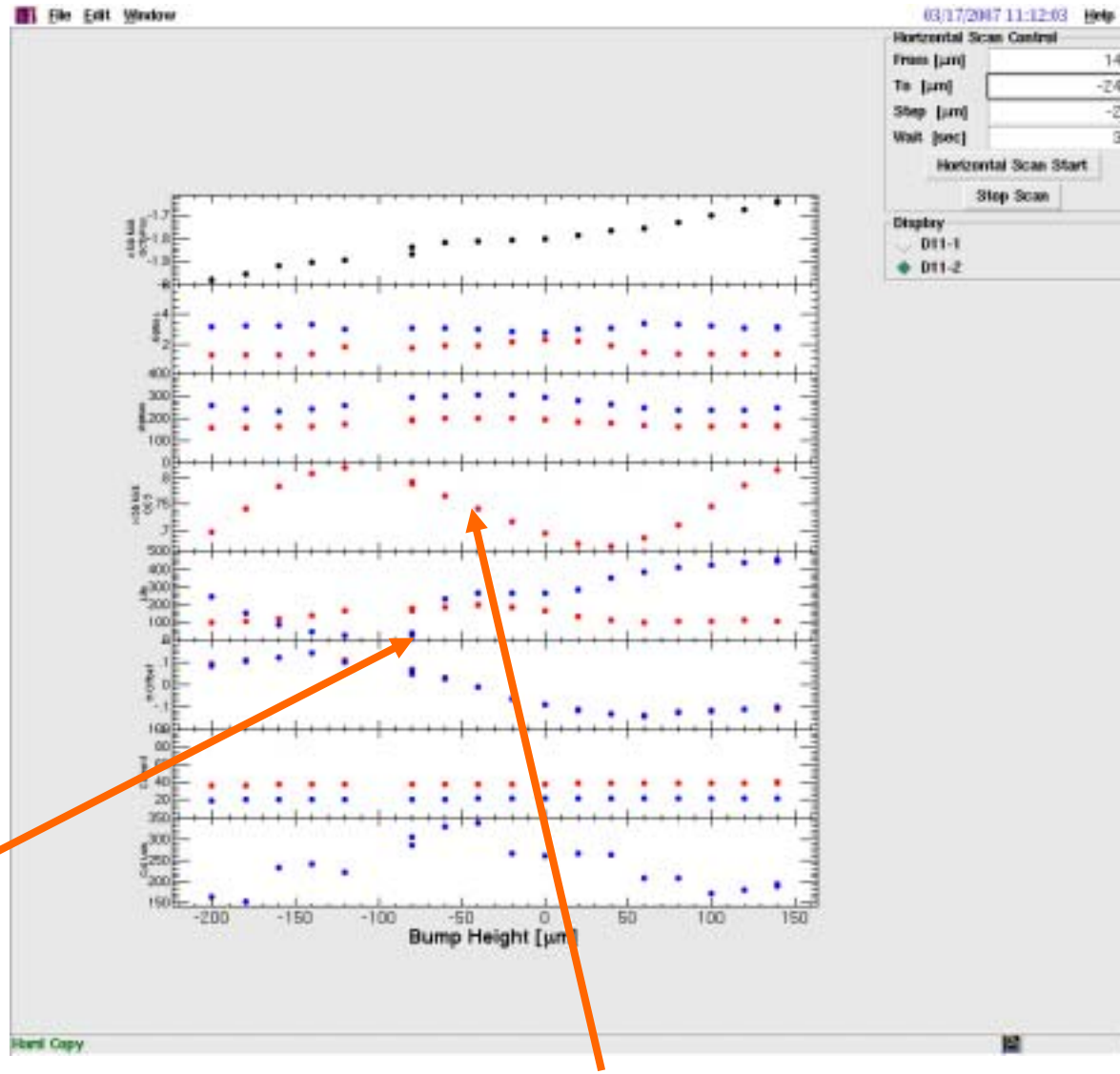
Most serious issue for the crab operation

- Asymmetry for the horizontal offset
- Beam life time is very short in a region of a horizontal offset.
- We still have just like “Egure” effect even in head-on collision.
- This asymmetry can not be reproduced by the simulation.



Horizontal offset scan

- The beam current seems to be limited by the short life time of the region.
- The region is enlarged for high current.



HER life

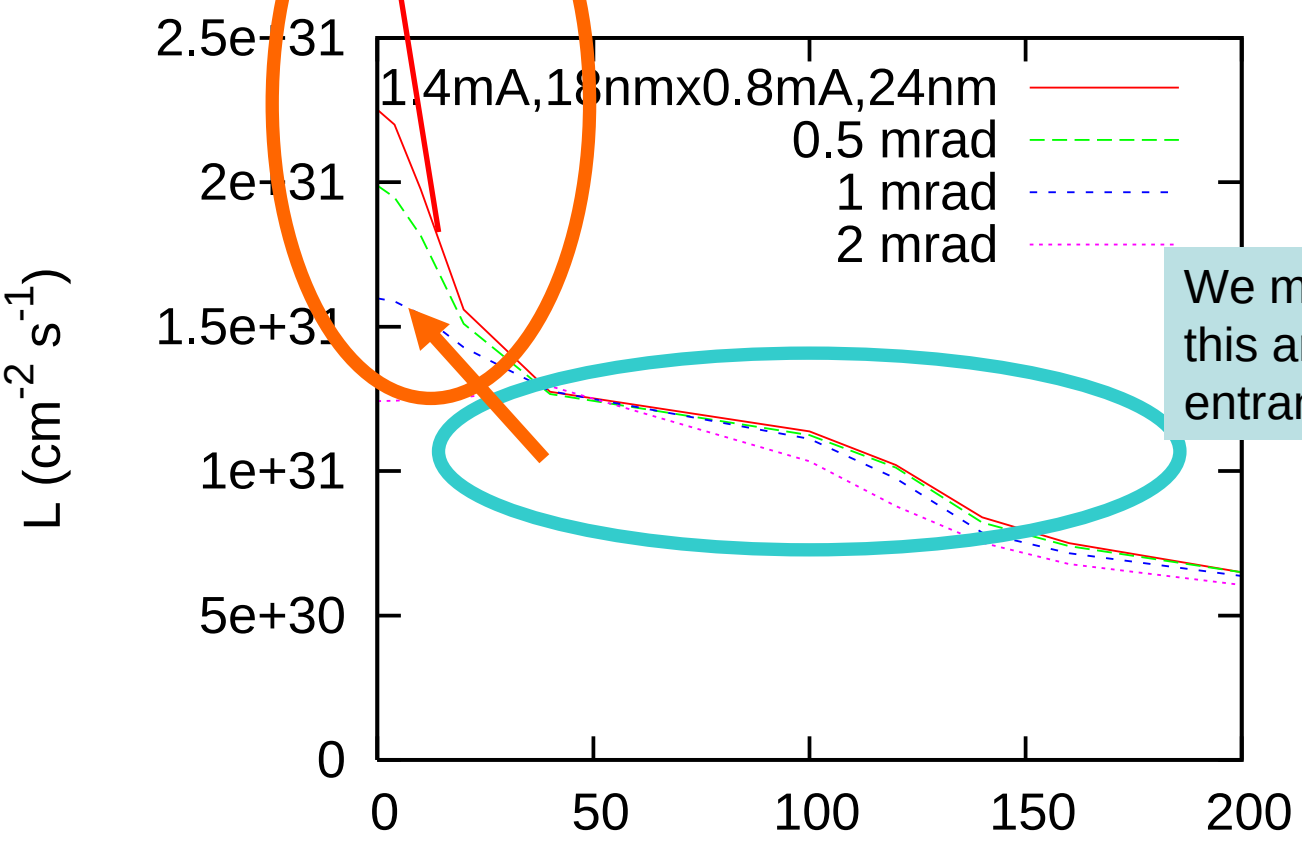
LER life decrases depending on the condition

Collision center given by the beam-beam kick

Beam-beam limit for us

For more sophisticated parameters, the luminosity is higher.

Real world or the kingdom of Heaven?



We may still loiter this area or in just entrance.

and many other parameters, which destroy the symmetry.