CLIC Crab Cavity Phase and Amplitude Stability

Dr G. Burt, Lancaster University

And

Dr I. Shinton, Manchester University

ILC and CLIC Parameters

- ILC bunch - 554 nm horizontal x 3.5 nm vertical x 300 μm axial size at IP
- CLIC bunch - 45 nm horizontal x 1 nm vertical x 44 μm axial size at IP

Kick voltage needed for crossing angle

$$V_{crab} = \frac{\theta_c E_o c}{2\omega R_{12}}$$

	E_0 (TeV)	crossing (θ_c, mrad)	V_{crab} (MV)
ILC	0.5	14	1.3
CLIC	1.5	20	2.4

Loading by offset beam

$$P_b = \frac{r\, q\, f_{rep}\, \theta_c\, E_o}{2\, R_{12}}$$

	Bunch offset at CC (r=σ_x, μm)	bunch charge (q, nC)	bunch repetition (f_{rep}, MHz)	R_{12} (m/rad)	Crab peak power (kW)
ILC	300	3.2	3.03	16.4	0.621
CLIC	163	0.6	2000	25.0	116

Amplitude stability requirement

$$\frac{\Delta V}{V} < \frac{2\sigma^*_x}{\sigma_z \theta_c}\sqrt{\frac{1}{S^2}-1}$$

Phase stability requirement

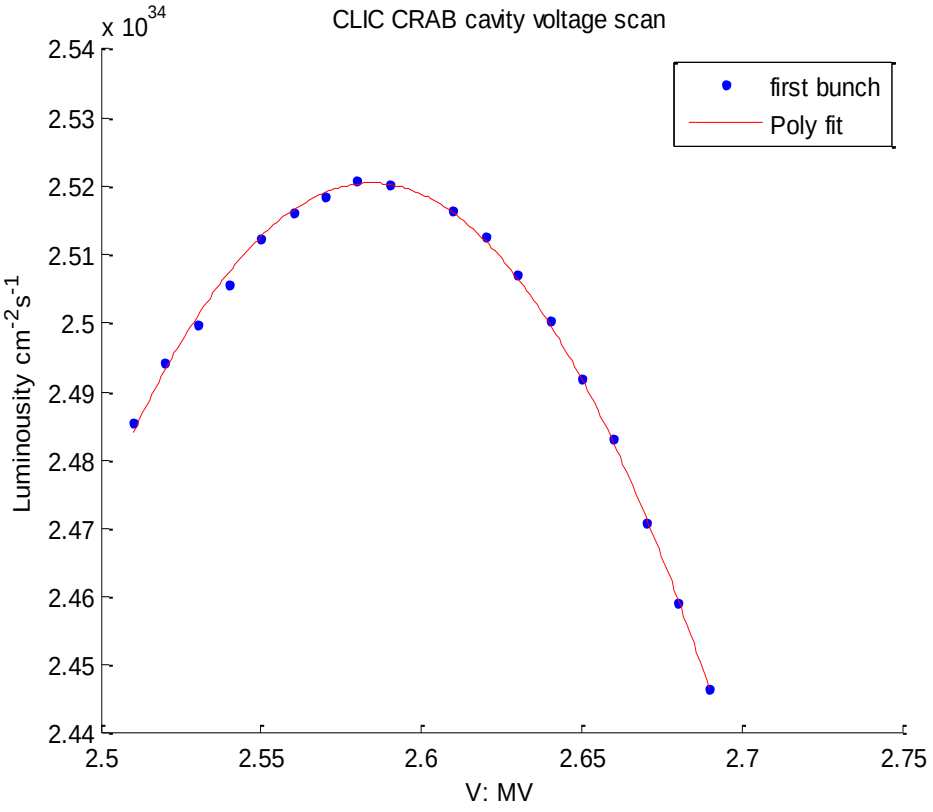
$$\Delta\Phi < \frac{4\omega_{rf}\sqrt{\sigma^*_x \ln(1/S)}}{c\,\theta_c}$$

	S	ΔV/V (%)	Δϕ (mdeg)	Δt (fs)
ILC	0.98	5.36	105	75
CLIC	0.98	2.1	18	4.2

Tracking Simulations

- Bunches are tracked from start of the BDS in PLACET (BDS.match.linac4b.collspoiler)
- Crab Cavities were implemented in PLACET some time ago. They are not exact but are fairly good approximations
- In order to calculate luminosity loss with beam-beam effects the bunch is passed into Guinea-Pig
- As GP doesn't allow for crossing angles we introduce a co-ordinate transform in PLACET_Octave to rotate the bunches by 10 mrad at the end of the BDS.

Operating voltage for the CLIC-CRAB calculated from PLACET



SET: ELECTRON LINE PHASE = POSITRON LINE PHASE=0

N_slice=101
N=101
Total particles=10201

Voltage

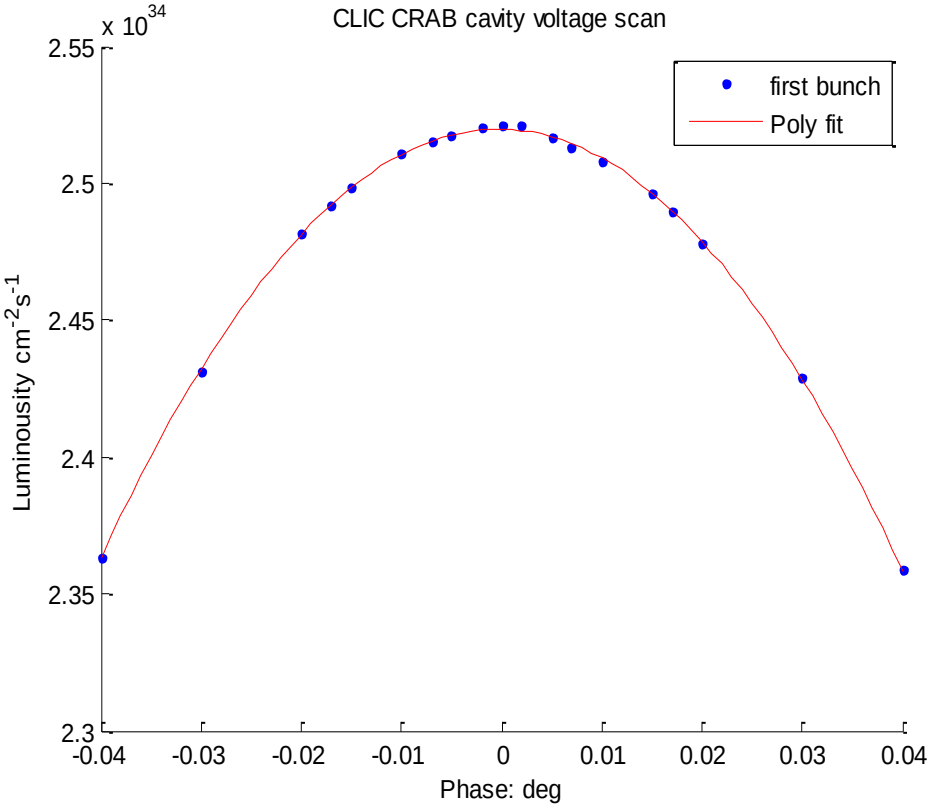
MaxV=2.584MV

Lum=2.5205e34

98% Lum
2.4930<V<2.6710

3.6% almost double analytical estimate of 2.1 %

Differential Phase range for the CLIC-CRAB calculated from PLACET



SET POSITRON LINE PHASE=0
V=Vmax=2.584MV

Differential Phase

N_slice=101
N=101
Total particles=10201

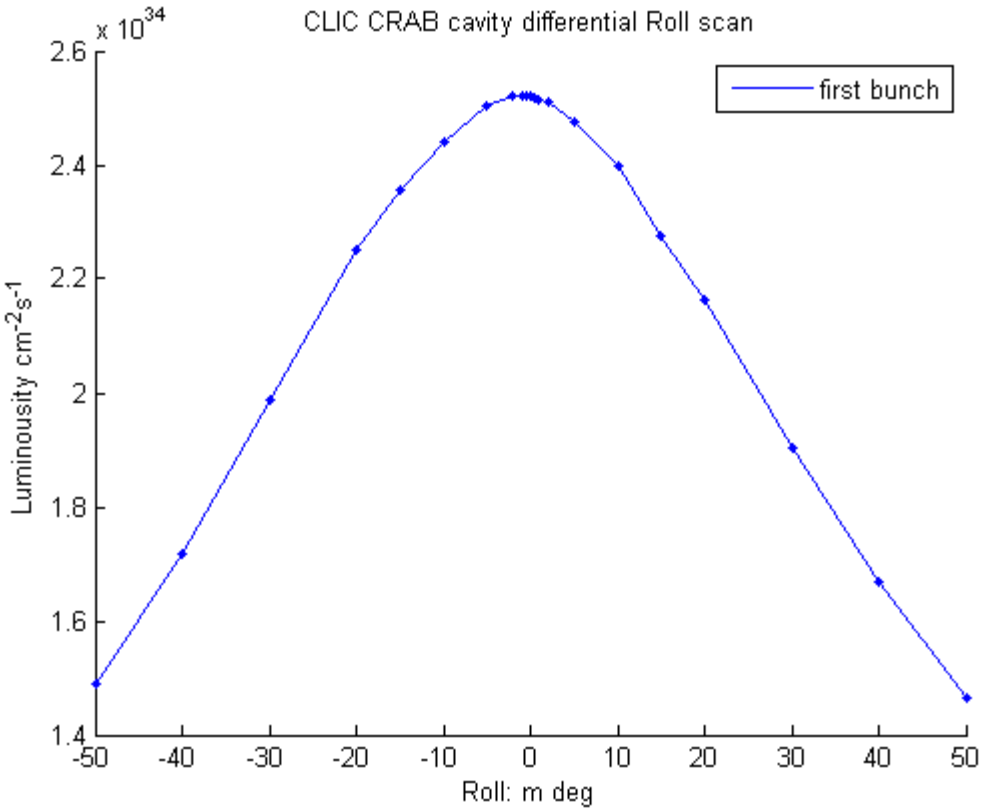
MaxPhase=0deg

Lum=2.5198e34

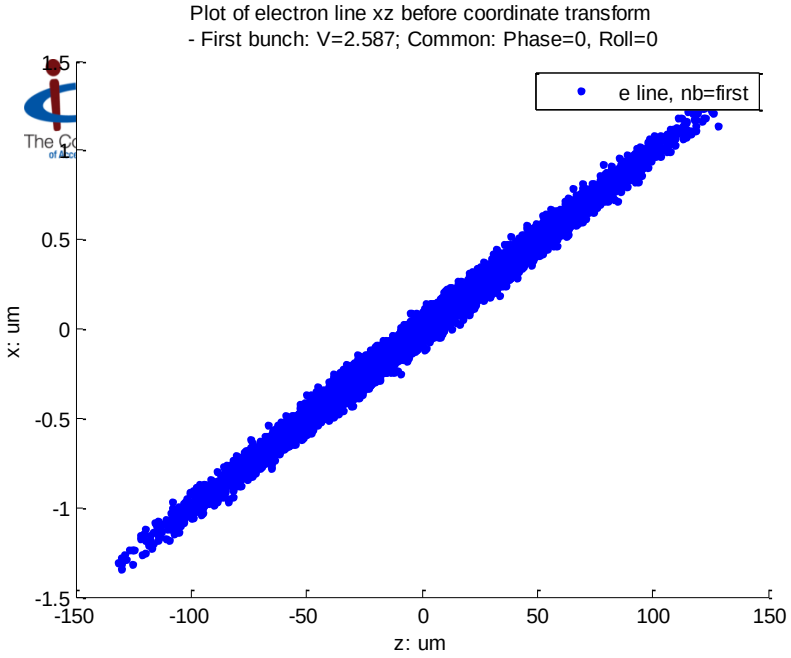
98% Lum
-0.0220<Phase<0.0220

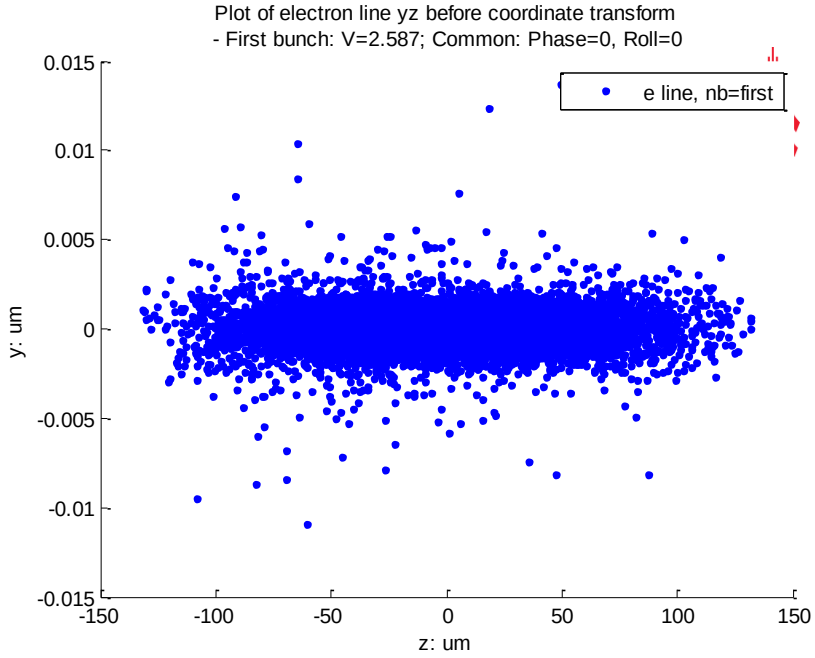
Similar to analytical calculation of 18 mdeg

Differential Roll range for the CLIC-CRAB calculated from PLACET

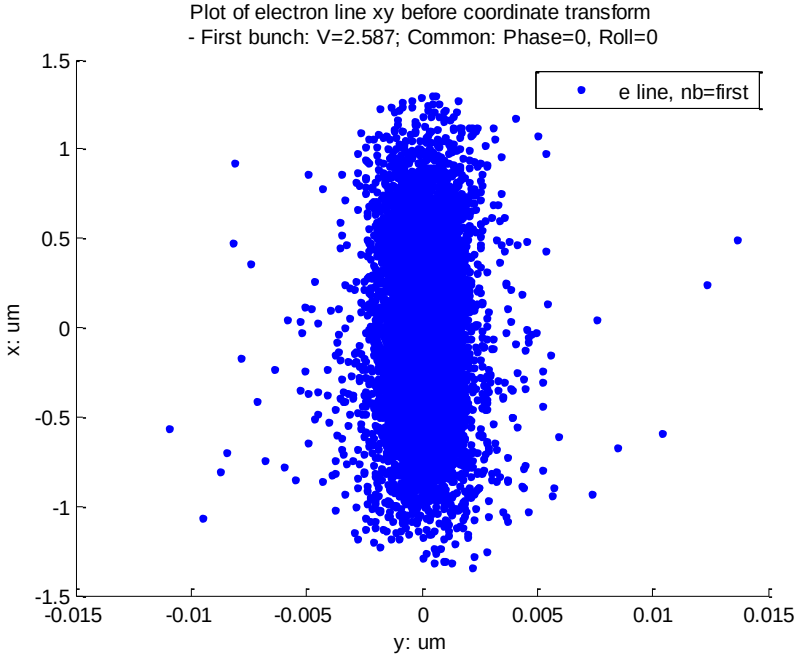


More points required very sensitive to roll



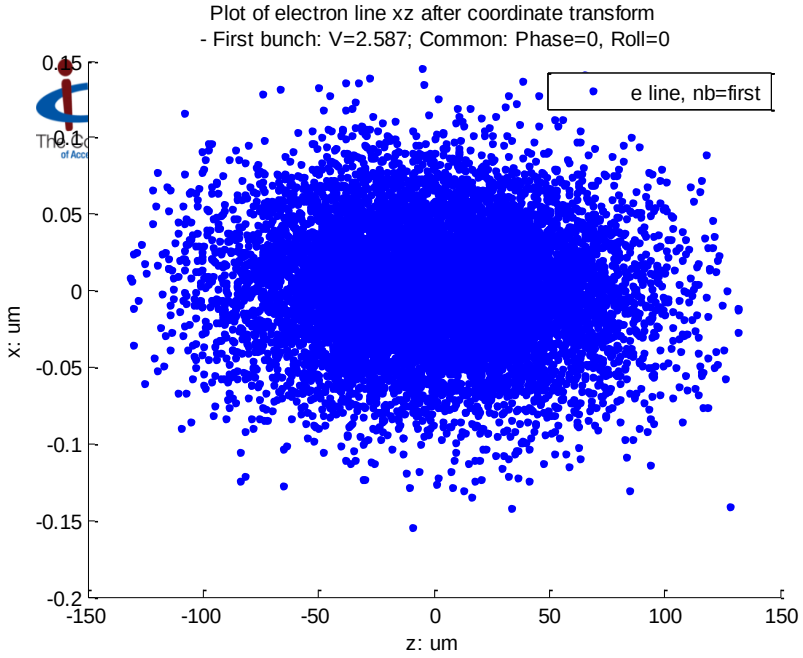


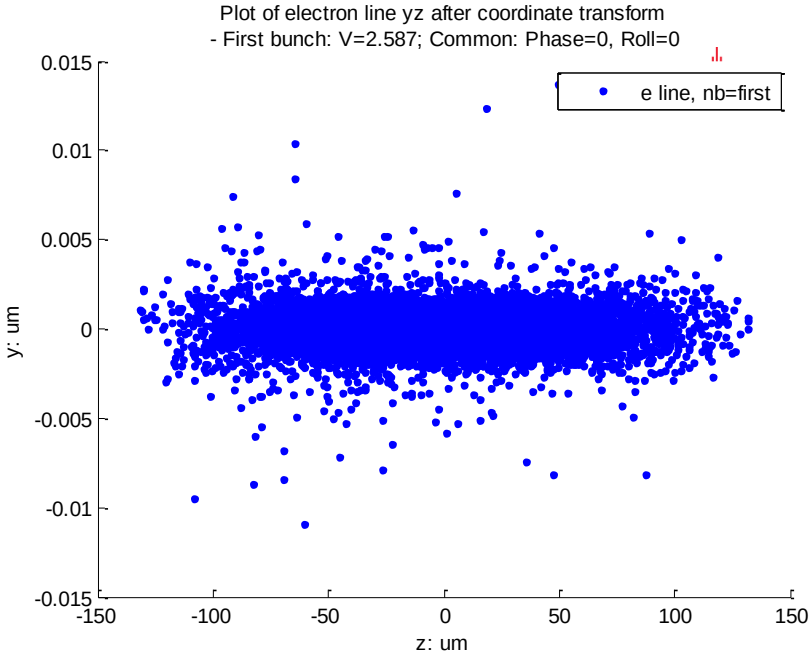
Before Transform – with Crab



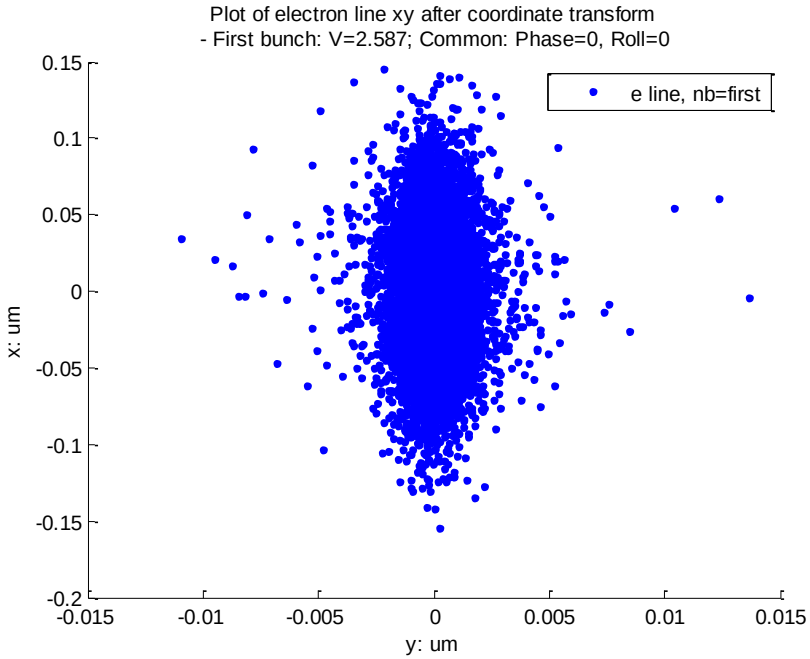
Electron V = Positron V
Electron Phase = Positron Phase = 0

nslice=101
N=101





After Transform – with Crab



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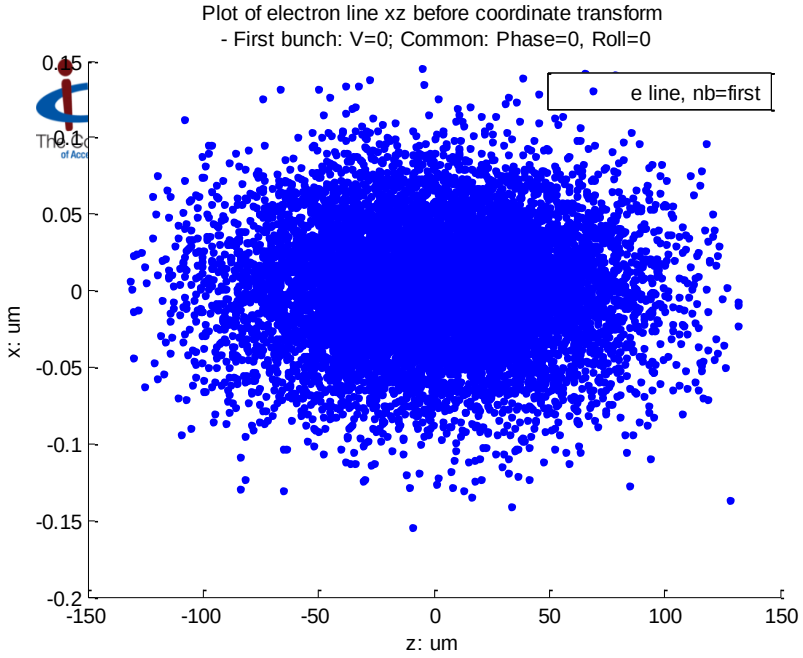
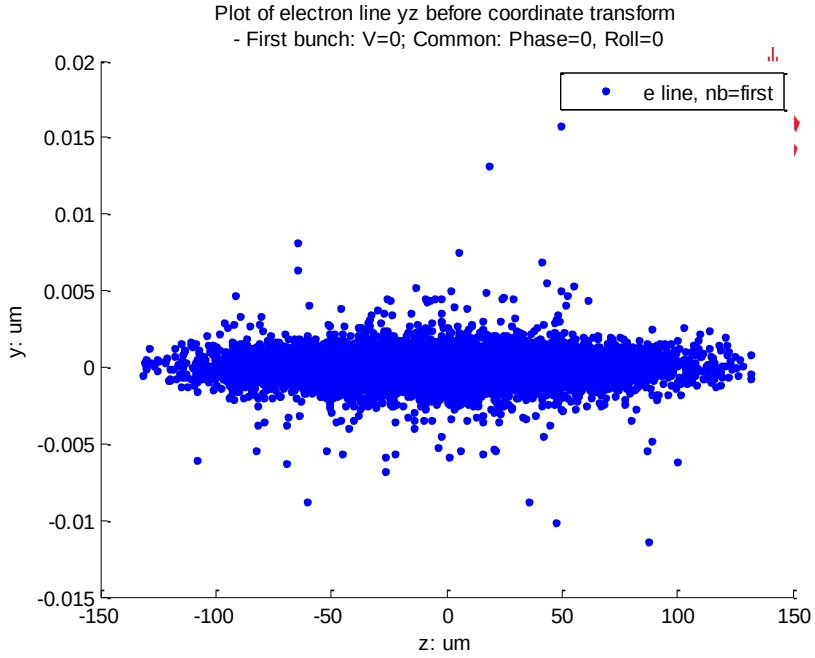
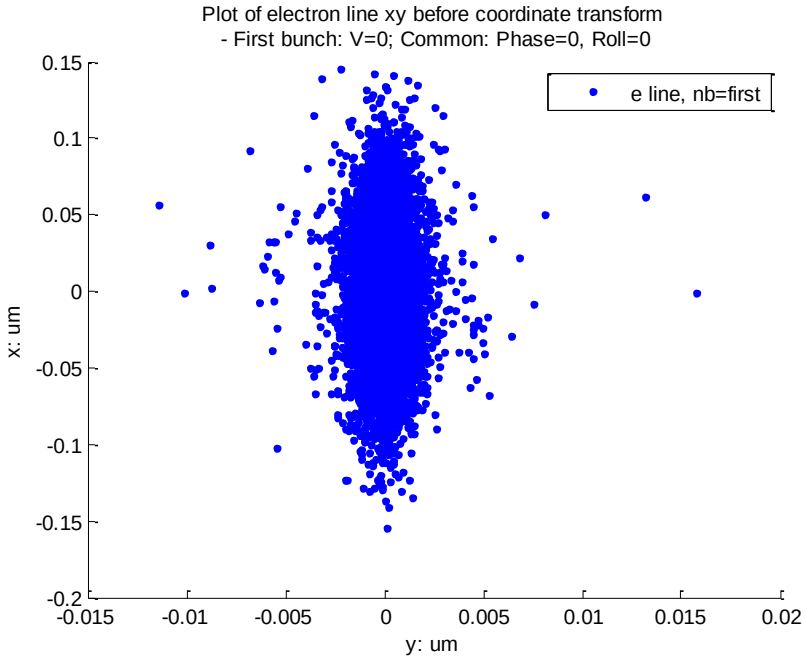
Electron Phase = Positron Phase = 0

nslice=101
N=101







We wanted to look at keeping the positron line perfect while introducing errors to the electron line.

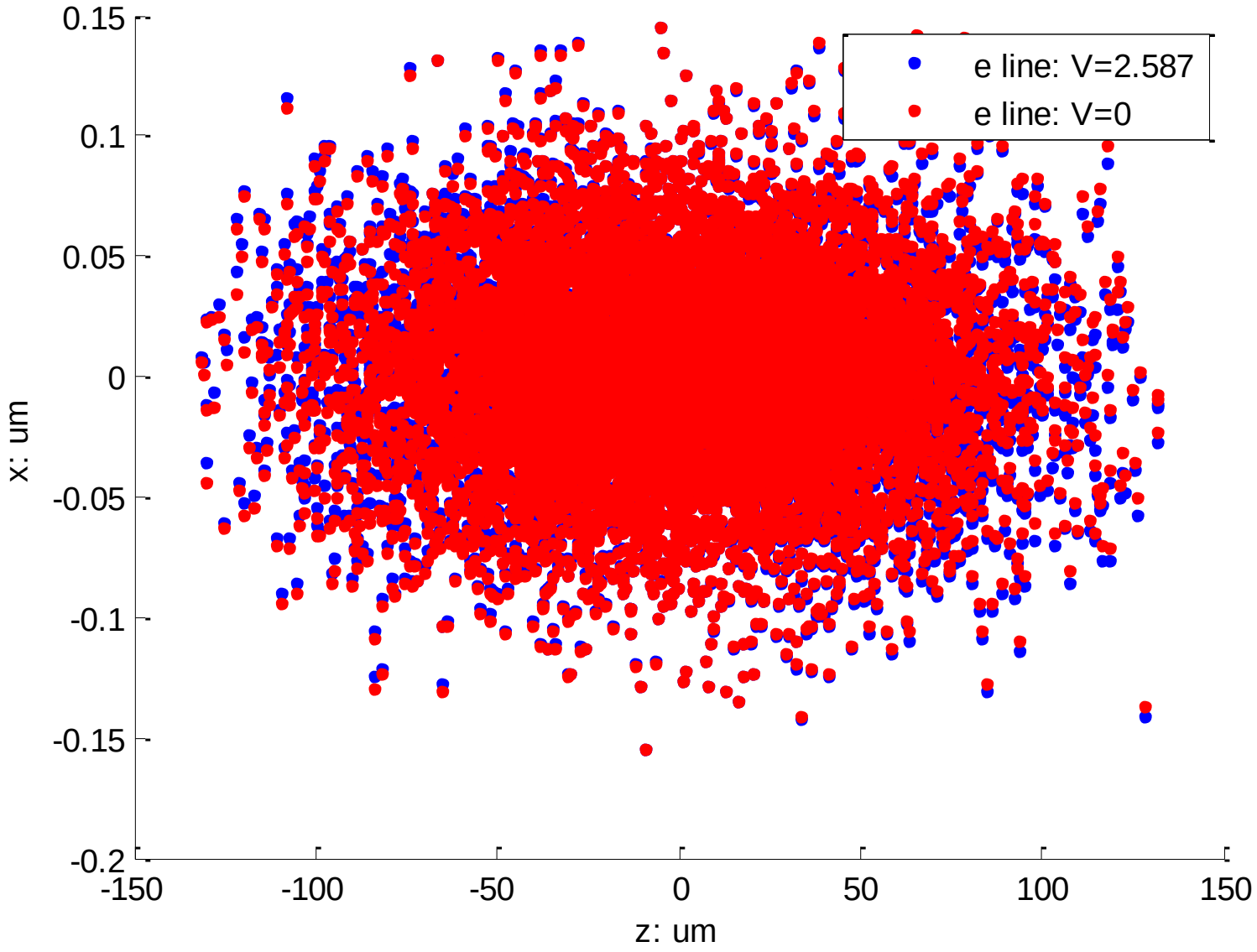
This could be performed by either crabbing then rotating in Octave,

OR

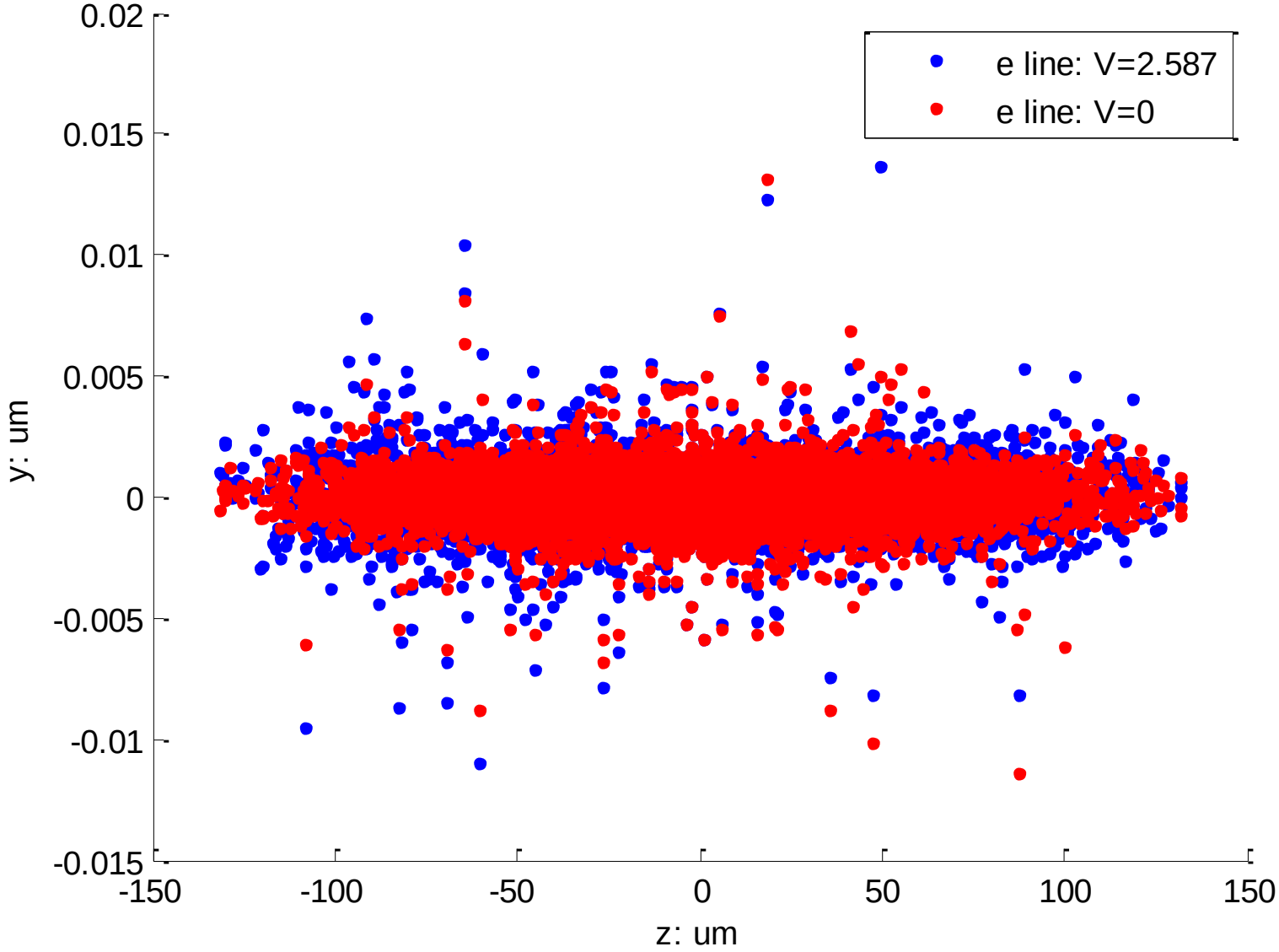
We could simply set the crab cavity voltage to zero and not rotate.

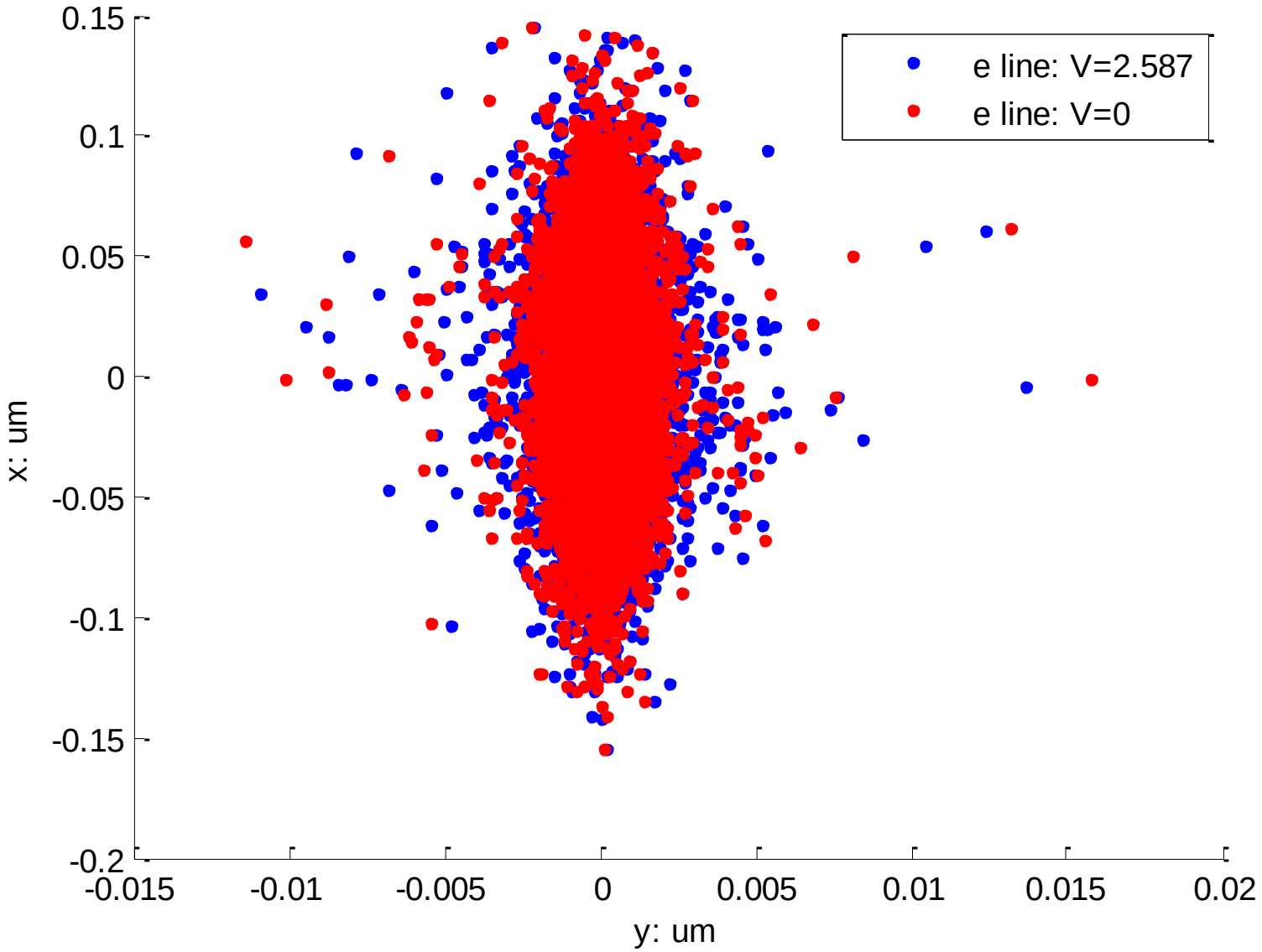
As the crab cavity only provides a kick in PLACET these two should be identical, however we do not find this to be the case.

Plot of first bunch electron lines with and without Crab at IP xz after coordinate transform
- Common: Phase=0, Roll=0



Plot of first bunch electron lines with and without Crab at IP yz after coordinate transform
- Common: Phase=0, Roll=0




Plot of first bunch electron lines with and without Crab at IP xy after coordinate transform
- Common: Phase=0, Roll=0
e line: V=2.587
e line: V=0
x: um
y: um
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.015
-0.01
-0.005
0
0.005
0.01
0.015
0.02

Conclusion

- The head and tail of the bunch seem to have become wider in the y plane (rectangular bunch)
- This is the opposite plane from the crab cavity
- This causes a 5%-10 % luminosity loss
- This could possibly be due to x-y coupling in magnets in the BDS after the crab
- As only the head and tail are affected this seems to be proportional to the particle offset (crabbing)