# Some Remarks on the Fast Beam-Ion Instability and the Vacuum

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# Fast Beam Ion Instability

- Ions can be generated from rest gas by
  - collision ionisation
  - field ionisation
- They can be trapped in the beam (F. Zimmermann et al.)

$$4f_i \leq \frac{c}{L_{sep}}$$

- The ion frequency is given by

$$f_i = \frac{c}{\pi}\sqrt{\frac{Q_i N r_e \frac{m}{M}}{3\sigma_y(\sigma_x+\sigma_y)L_{sep}}}$$

- Linear rise time for noise is

$$\frac{1}{\tau_c} = \frac{4}{\sqrt{27}}\left(\frac{N r_e}{\sigma_y(\sigma_x+\sigma_y)}\right)^{\frac{3}{2}}\sqrt{\frac{m}{M}}\sqrt{L_{sep}}\frac{p\sigma_{ion}}{kT}\frac{\beta_y c n^2}{\gamma}$$

- If ions are trapped they increase beam noise at some frequency as

$$\frac{1}{\tau_e} = \frac{1}{\tau_c}\frac{c}{\sqrt{32}\pi L_{sep} n a f_i}$$

# Simplified Formulae

- We rewrite for a round beam

$$\frac{1}{\tau_e} = \frac{p\sigma_{ion}}{kT}\frac{Nnr_ec}{\sqrt{18}(\sqrt{\epsilon_x\epsilon_y}+\epsilon_y)a}\frac{1}{\sqrt{Q}}$$

- For a flat beam

$$\frac{1}{\tau_e} = \frac{p\sigma_{ion}}{kT}\frac{Nnr_ec}{\sqrt{18}\sqrt{\epsilon_x\epsilon_y}a}\frac{1}{\sqrt{Q}}$$

$\Rightarrow$ If ions are trapped, the growth depends on the optics via $a$

- only possibility is to excite different noise frequencies

# Drive Beam

- Parameters are 3564 bunches with 7.8nC each
- We assume that we always trap in the transfer line (25km)

$\Rightarrow$ For $\epsilon = 100\,\mu\mathrm{m}$ and 1ntorr we then find 1.7 e-folding times

- The number can be scaled to the drive beam accelerator
  - 26 times more bunches
  - but shorter

$\Rightarrow$ Required vacuum better than 1ntorr

$\Rightarrow$ Or specific optics to minimise emittance growth, e.g. detuning of the lattice

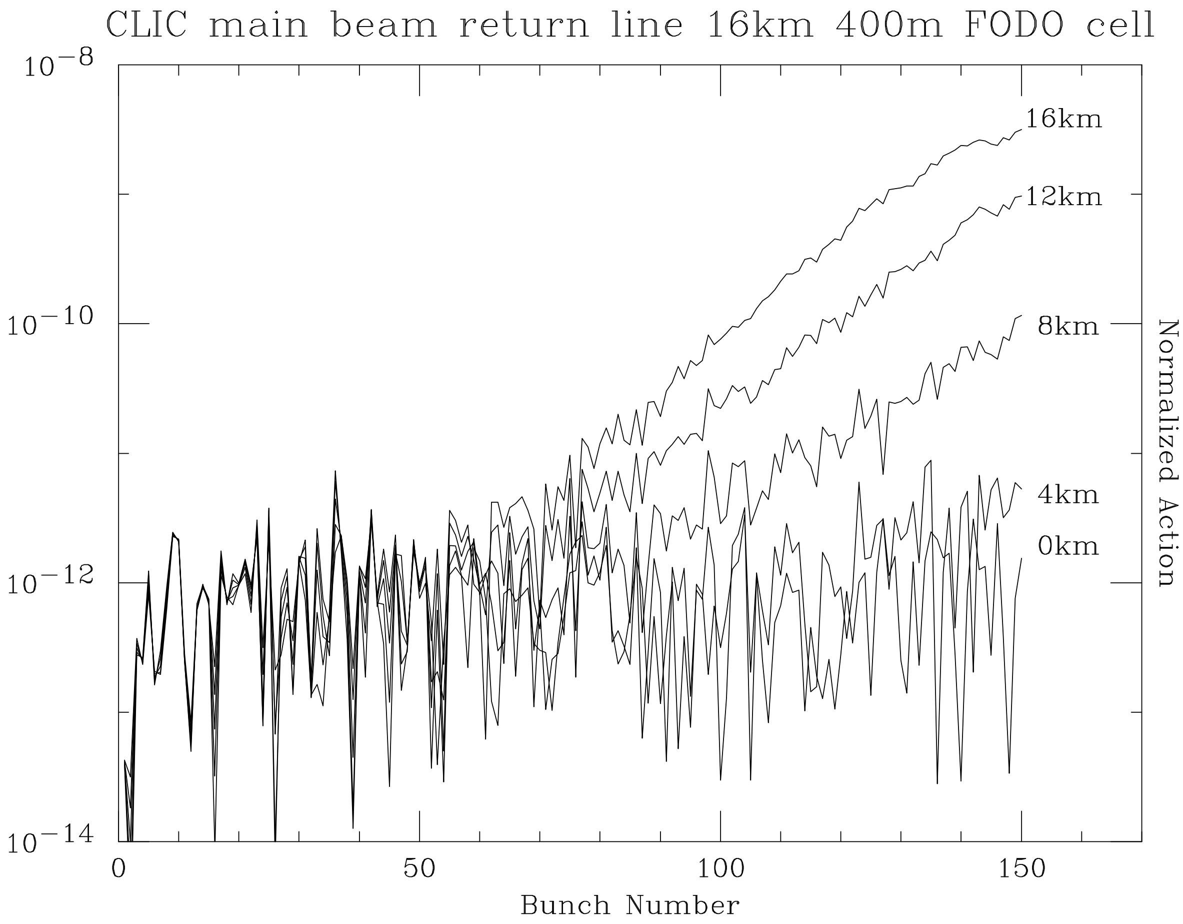
- In decelerator it could be worse by a factor 10
- Need to understand the margin

# Main Beam in RTML

- For very old parameters
  - 1ntorr should yield 6 e-folding times for the beam transport
  - simulations of T. Raubenheimer confirm this (I would estimate 9 e-folding times from the plot)
- For new parameters about 17 e-folding times per ntorr

⇒ Fast-beam ion instability can be significant in transfer line

  - vacuum of 0.1 ntorr
  - lattice design, dispersion



# Main Linac

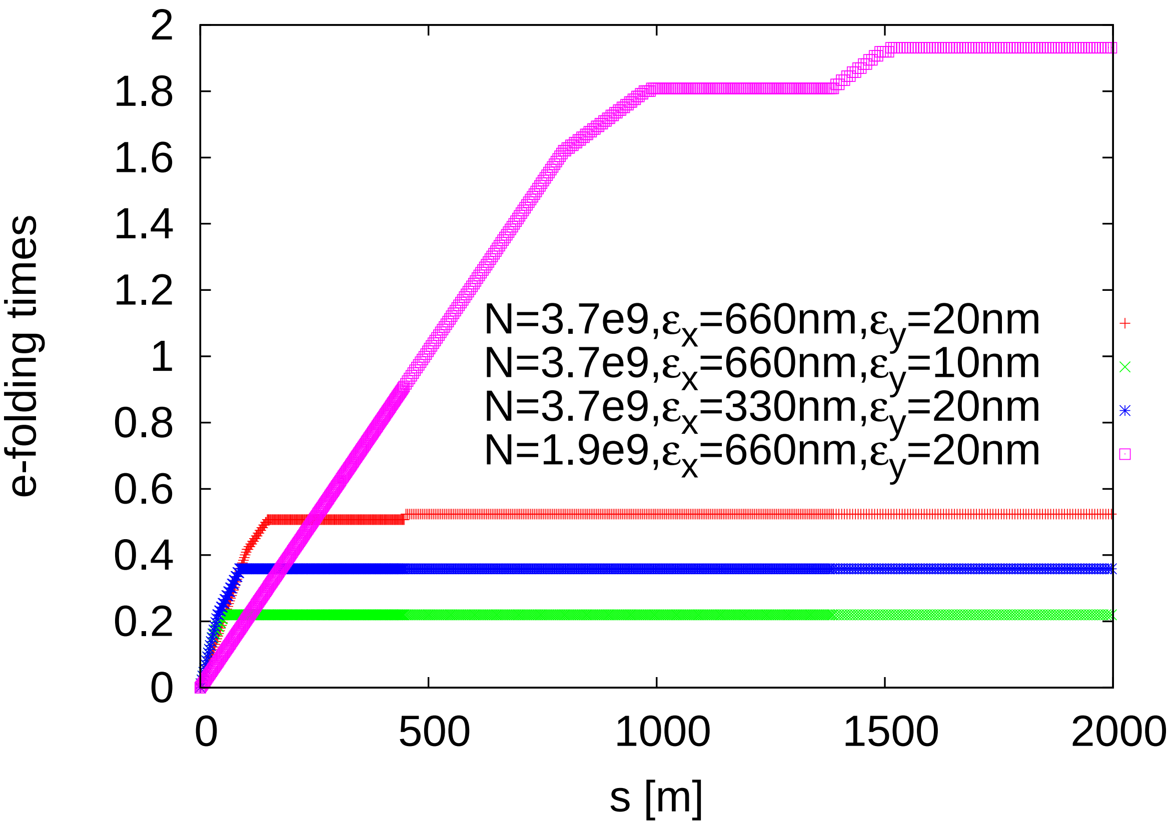
- Growth rate does not depend much on optics, approximately

$$\frac{1}{\tau_e} = \frac{p\sigma_{ion}}{kT}\frac{Nnr_ec}{\sqrt{18}\sqrt{\epsilon_x\epsilon_y}a}\frac{1}{\sqrt{Q}}$$

O(100) e-folding times for 10ntorr

- But for small beam dimensions ions are not trapped

$\Rightarrow$ in plot stop growth when traping condition is not fullfilled any more



- Uncertainty is large
  - tunneling can increase ion production rate (one to two orders of magnitude in CLIC)
  - ions outside the beam can still affect it
  - beam parameters are important (e.g. small $N$)

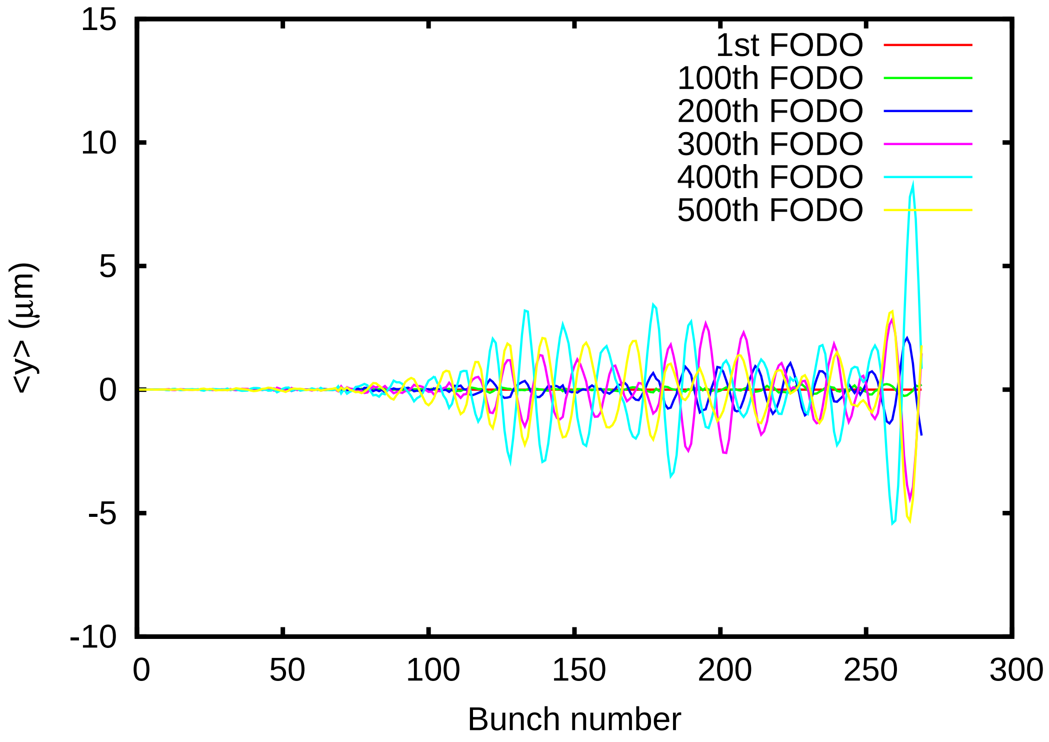
# Simulation Studies

- New code has been developed by G. Rumolo
- Seem to confirm analytic formulae
- Simulations for $1\,\mathrm{ntor}$ ($CO$ and $H_2O$)

⇒ pressure is too high

⇒ need more studies to cross check simple calculation

- This will allow to address main linac problem



# Conclusion

- The fast beam ion instability is more important for the main than for the drive beam
- Expect to need good vacuum for drive beam (1ntorr)
  - need to explore lattice detuning
- We need very good vacuum in the main beam tranfer lines
  - maybe optimised lattice
- In the main linac we avoid the problem by not trapping the ions
- But it is worth checking that the simple estimates are good enough
- Parameters may change
- The ions could affect the feedback systems

⇒ Should be able to simulate ions

- simple programs exist

⇒ We need to integrate this