Simulation studies for dielectric wakefield programme on CLARA facility

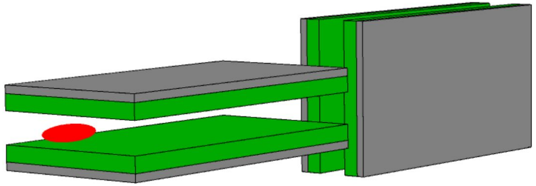
Thomas Pacey

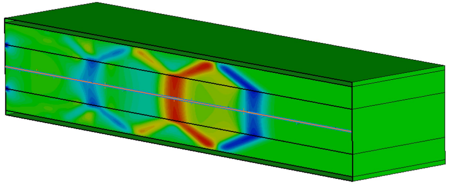
G. Xia, Y. Saveliev

The Cockcroft Institute, STFC ASTeC, The University of Manchester

WG3, EAAC 2017

27th Sept 2017



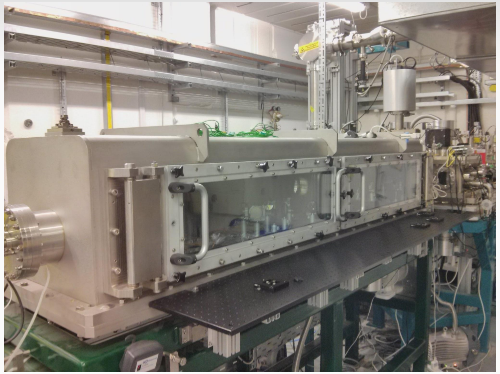


Outline

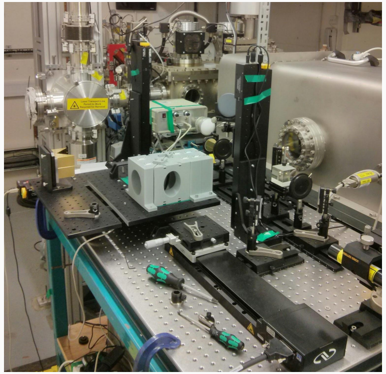
1. Experiment overview
2. Dielectric structure design
3. Simulation studies
4. Summary

Experiment Overview

‘Coffin’ experimental chamber

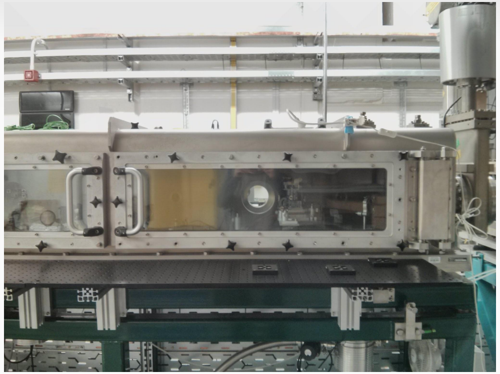


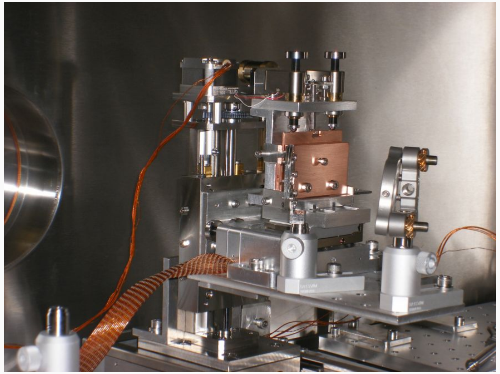
Martin-Puplet interferometer



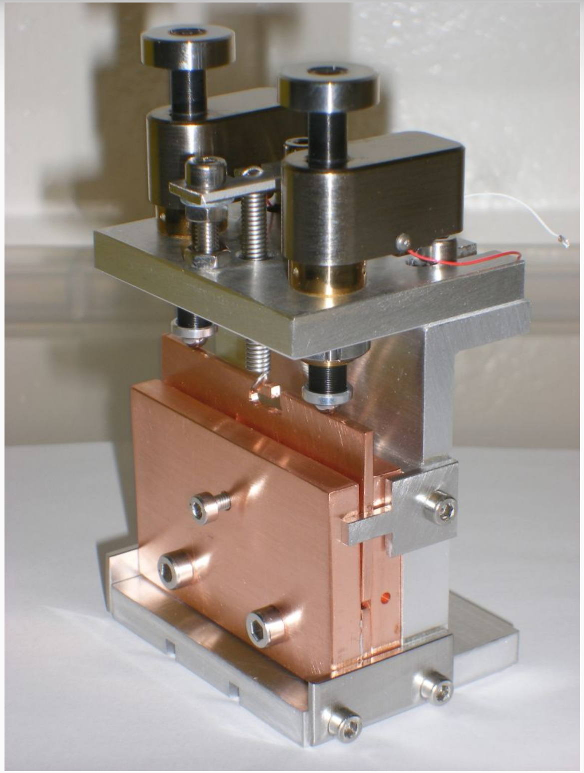
See talk by Y. Saveliev for more information

Chamber output window





Mounted DLW structure



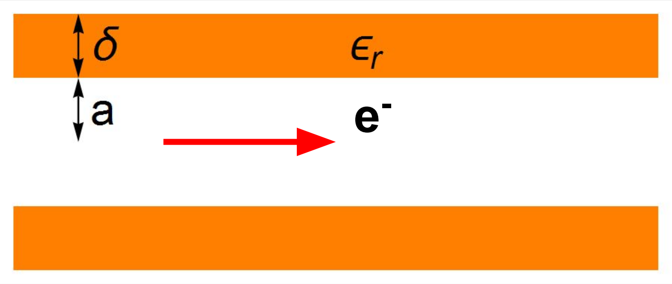
Tunable DLW structure

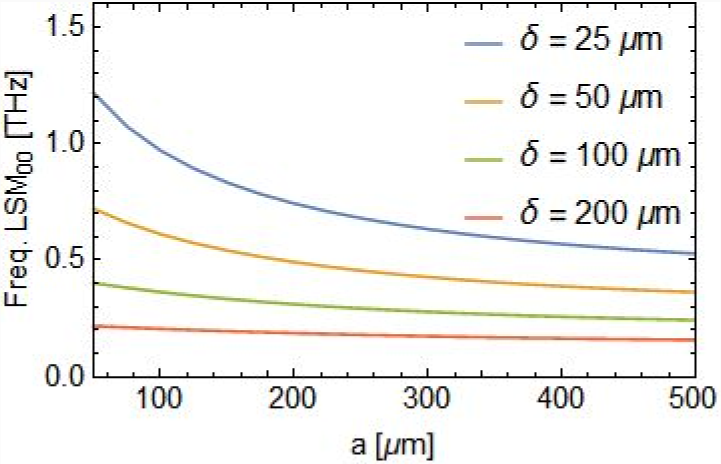
DLW: Structure design

- Quartz wafers used for dielectric.
- Not ideal material, but it is readily available and can be machined to fit required dimensions.
- For all cases ε_r = 3.8 and is non-dispersive and isotropic.
- Analytical wakefield treatment from [1]

[1] Tremaine, A., J. Rosenzweig, and P. Schoessow. , *PhysRev E* 56.6 (1997): 7204.

DLW parameter notation

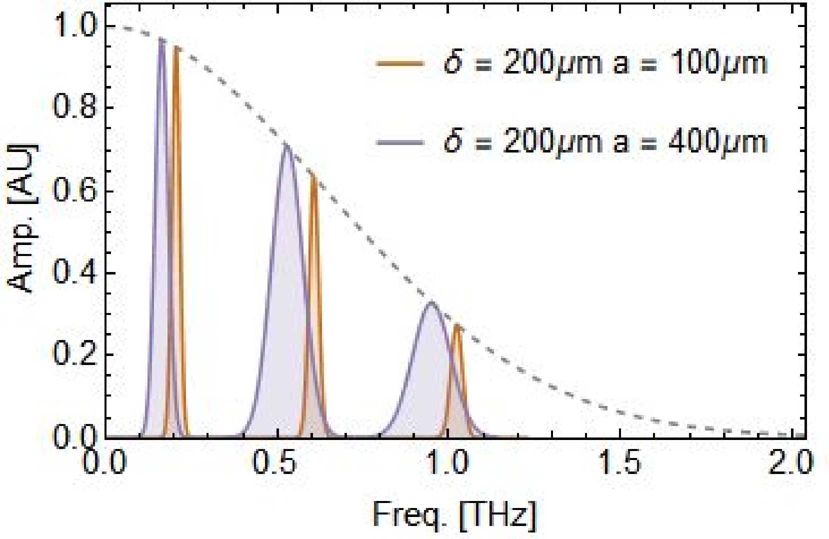




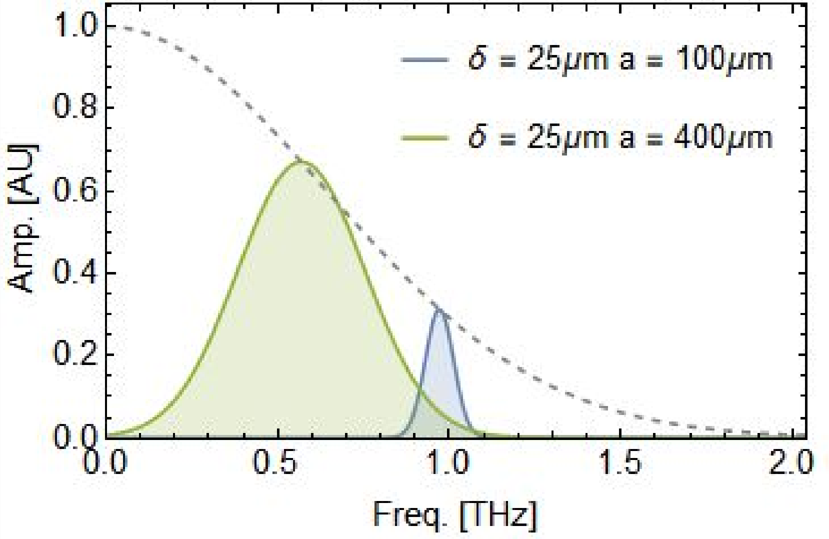
Tunability of fundamental mode for thin dielectric

DLW: Wakefield mode spectra

Generalised DLW analysis from [2], Gaussian bunch with σ_t = 250fs



Multi-moded operation with low tunability

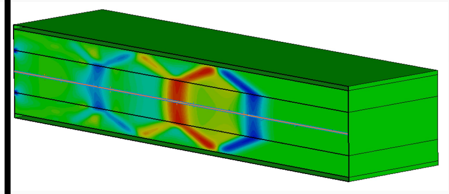


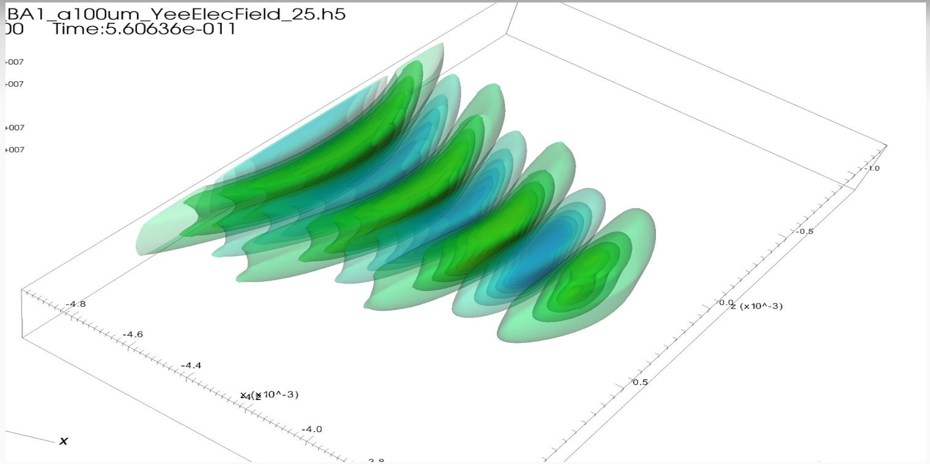
(Quasi-) Single-moded operation with tunability, with bandwidth increases.

[2] Xiao, L., Gai, W., & Sun, X., Phys Rev E, 65(1), 016505.

Field profiles in thin dielectrics

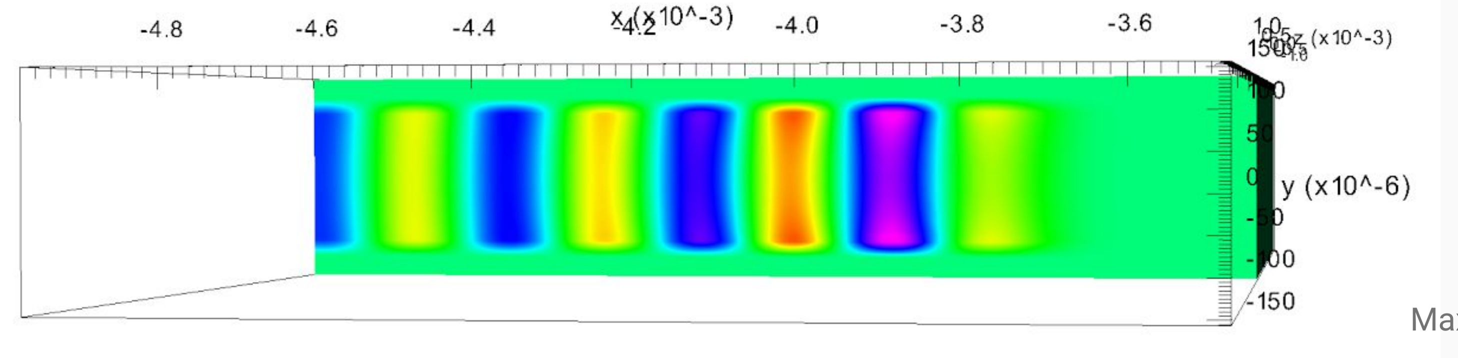
'Classic' Thick Dielectric

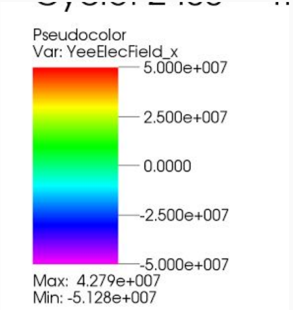




3D Longitudinal E-Field evolution.

Longitudinal E-field profile in DLW centre





Max fields in region of 50 MV/m

Simulations - A tale of two codes

- Impact-T:
  - ES PIC for space charge, with analytic approach to DLW wakefield modelling [3]
  - Free, fast, simple to use, run locally
  - Good for quick parameter scans
  - Longitudinal effects validated against VSim in [3]
  - Fixed weight macros
- Started out here

[3] Mihalcea, D.,et al. *PR:STAB* 15.8 (2012): 081304.

- VSim:
  - Full EM-PIC solve for beam-structure dynamics [4]
  - Flexible code, add additional physics
  - More accurate over wider range of bunch parameters
  - Moving simulation window improves speed
  - Fixed or variable weight macros
- Focus of future work

[4] Nieter, Chet, and John R. Cary. , J COMPUT PHYS,196.2 (2004): 448-473

Expected Bunch Parameters

Idealised case, 6D Gaussian Beam:

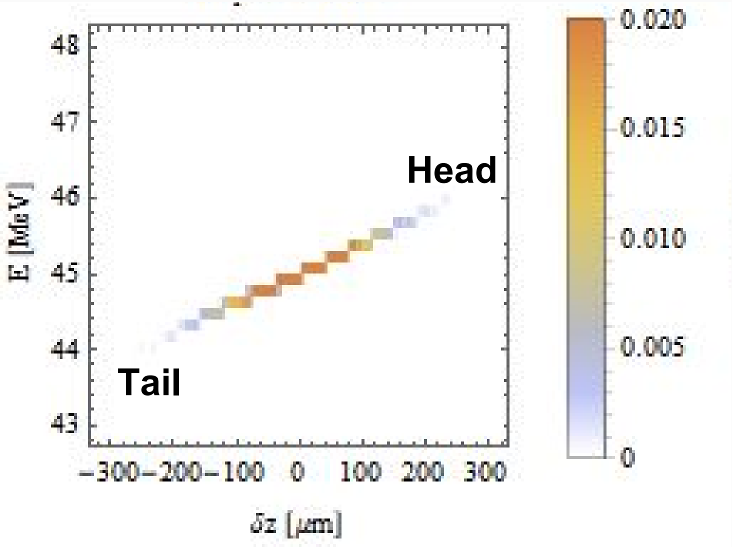
E = 45 MeV

σ_t = 250 fs

$\sigma_{x,y}$ = 100 μm

σ_E = 1% - Linear Chirp, dogleg compression

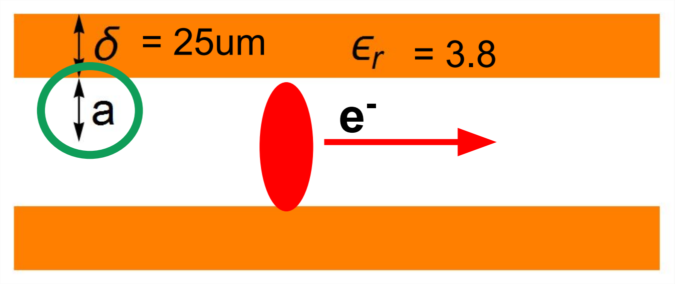
$\varepsilon_{x,y}$ = 10 μm



Example LPS for CLARA BA1 beam

Results

- Comparison of codes
    - Validation of transverse effects in ImpactT
    - Transversely cold beams
- Looking at both longitudinal & transverse effects
- Vary structure aperture
- Focus on what is measurable

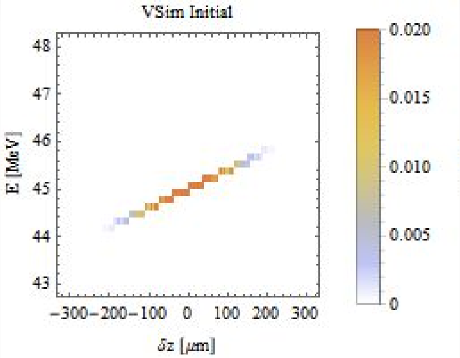


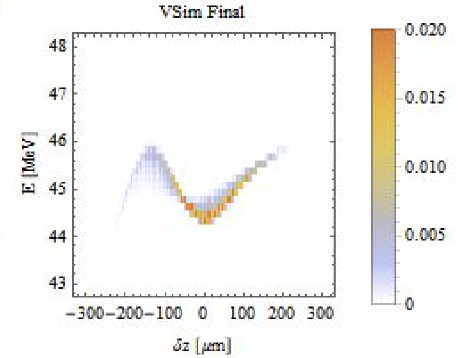
L = 40 mm

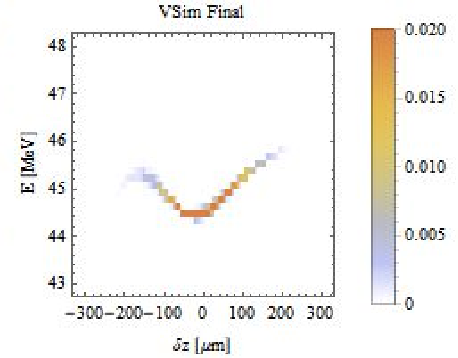
Longitudinal Phase Space change

Initial | **a = 100um** | **a = 250um**

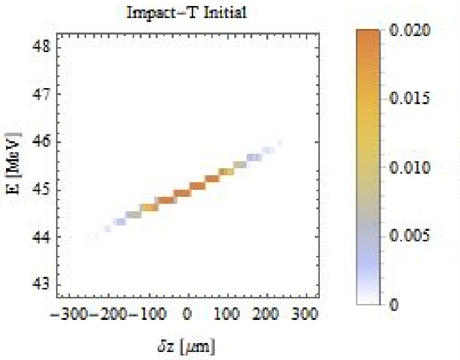
VSim

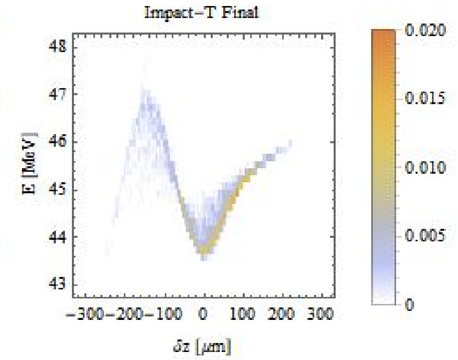


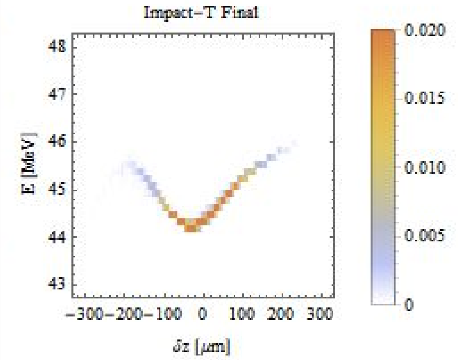




Impact-T







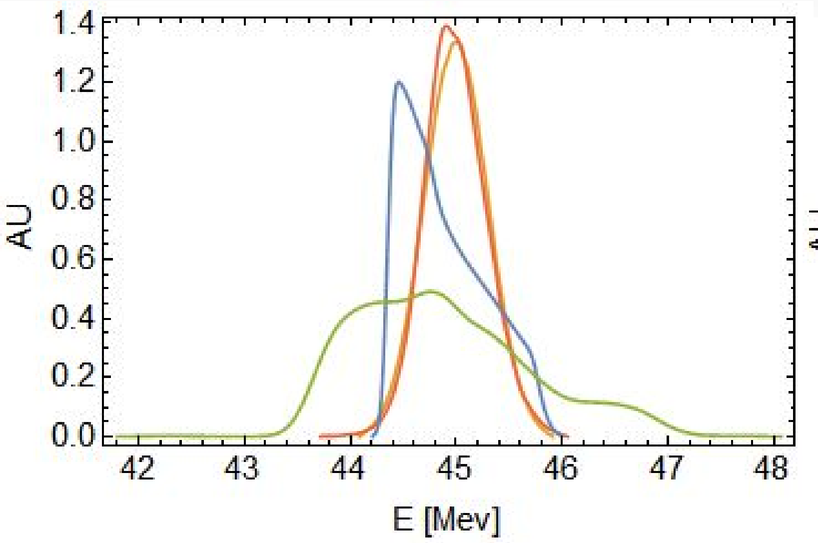
Chirp sign from dog-leg compression

Large acceleration in tail

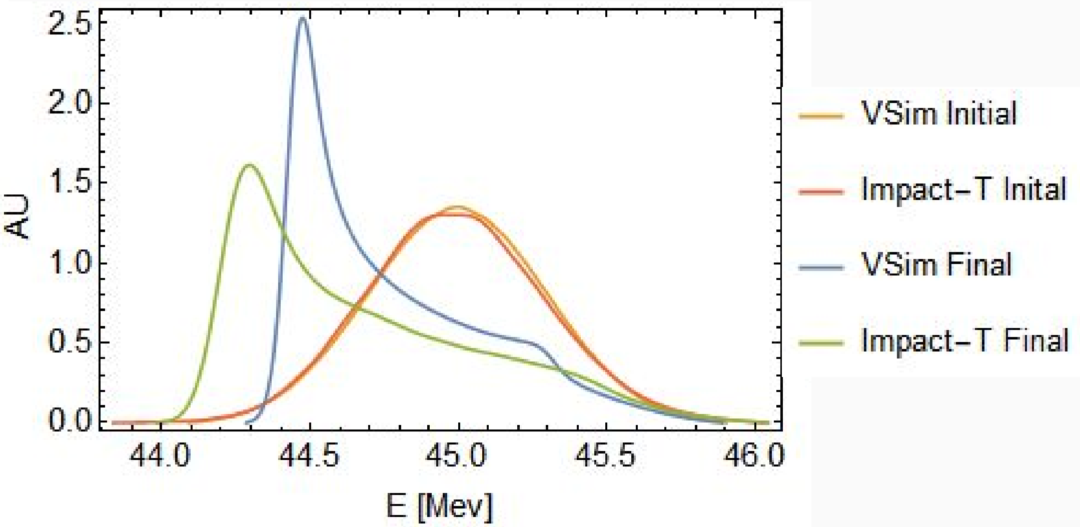
Some flattening of bunch core ‘dechirping’ !

Measurable Longitudinal Effects

a = 100um



a = 250um



Some disagreement between ImpactT and VSim, requires further investigation

Here acceleration of tail reduces energy spread - potential 'positive' dechirper

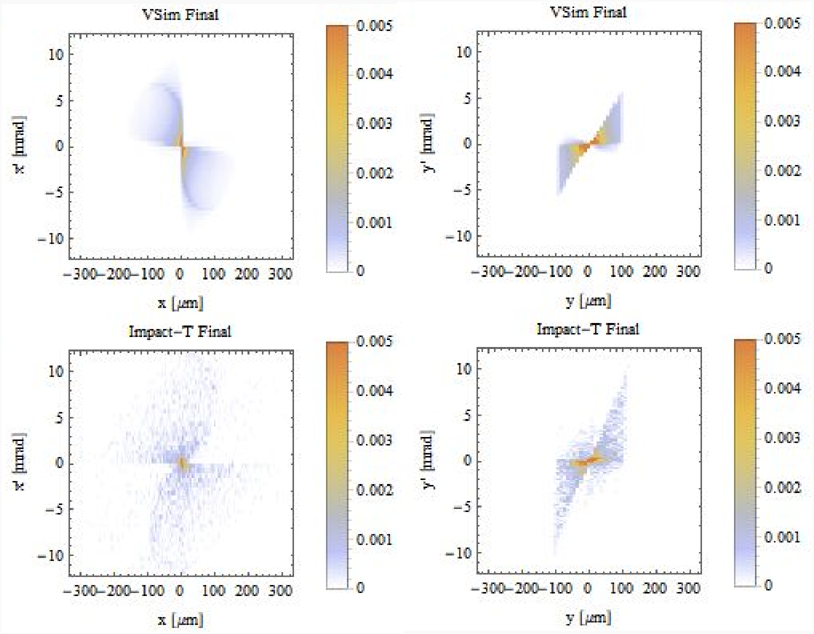
Transverse Phase Space

a = 100um

Horizontal **Vertical**

VSim

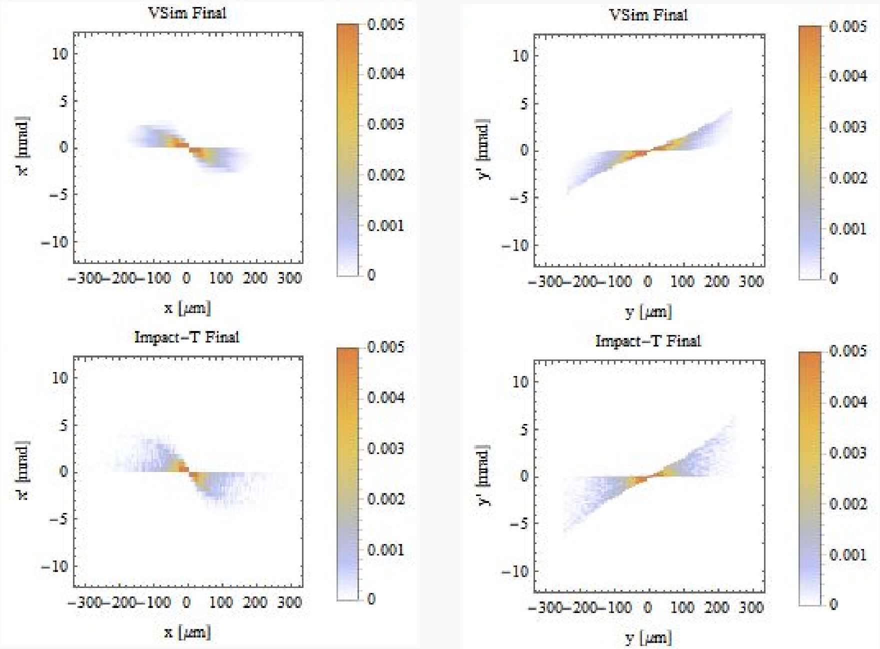
Impact-T



Qualitative agreement, but poor sampling in ImpactT due to fixed weight macro distribution

a = 250um

Horizontal **Vertical**



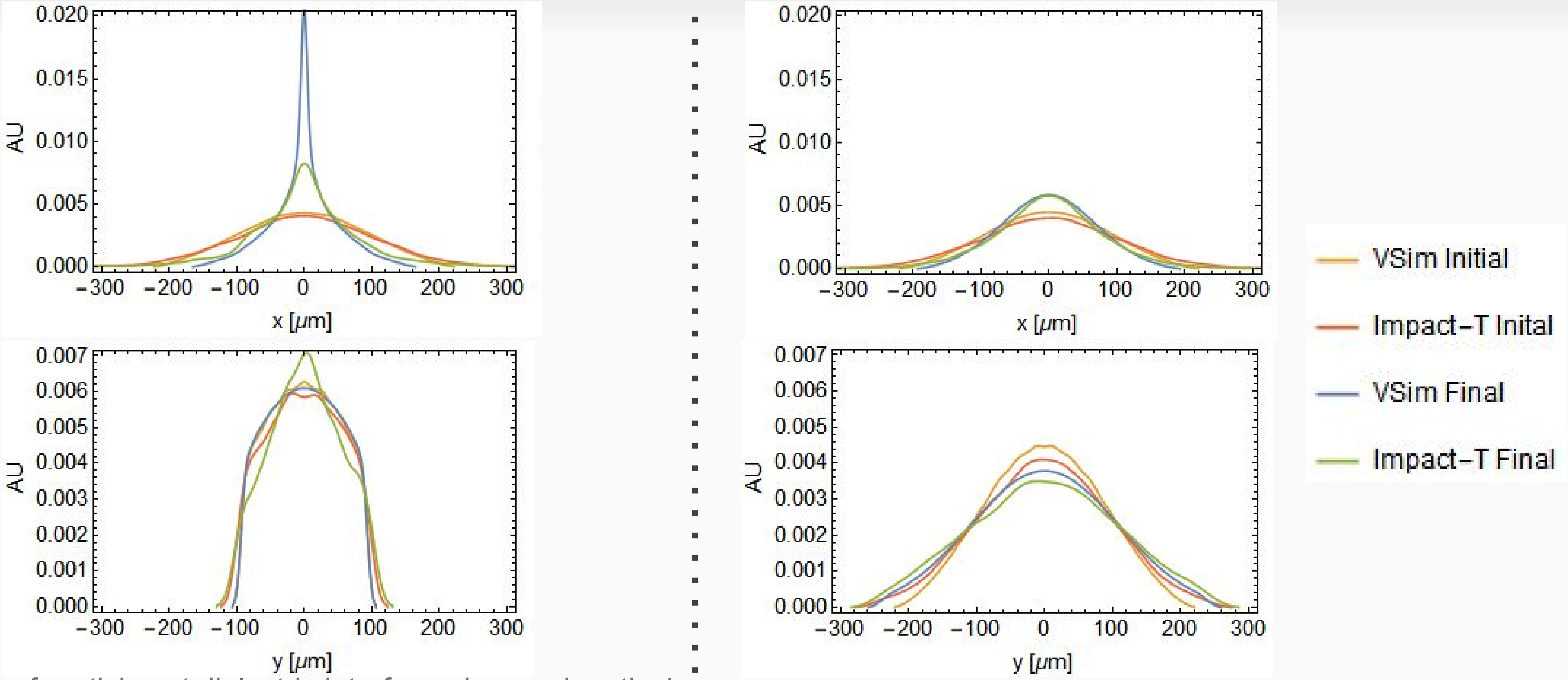
Good qualitative agreement between codes in both transverse planes

Transverse profiles - immediately after DLW

a = 100um | **a = 250um**

Horizontal

Vertical



Absorption of particles at dielectric interface obscured vertical defocusing effect. Strong horizontal focusing.

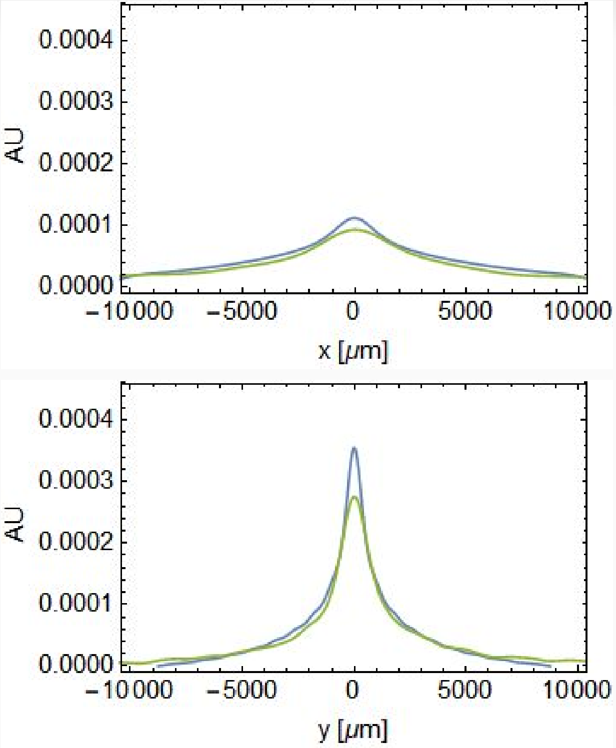
Some vertical defocussing. Reduced horizontal focusing effect

Transverse Profiles: Drift transport to YAG @ 1.5m

a = 100um

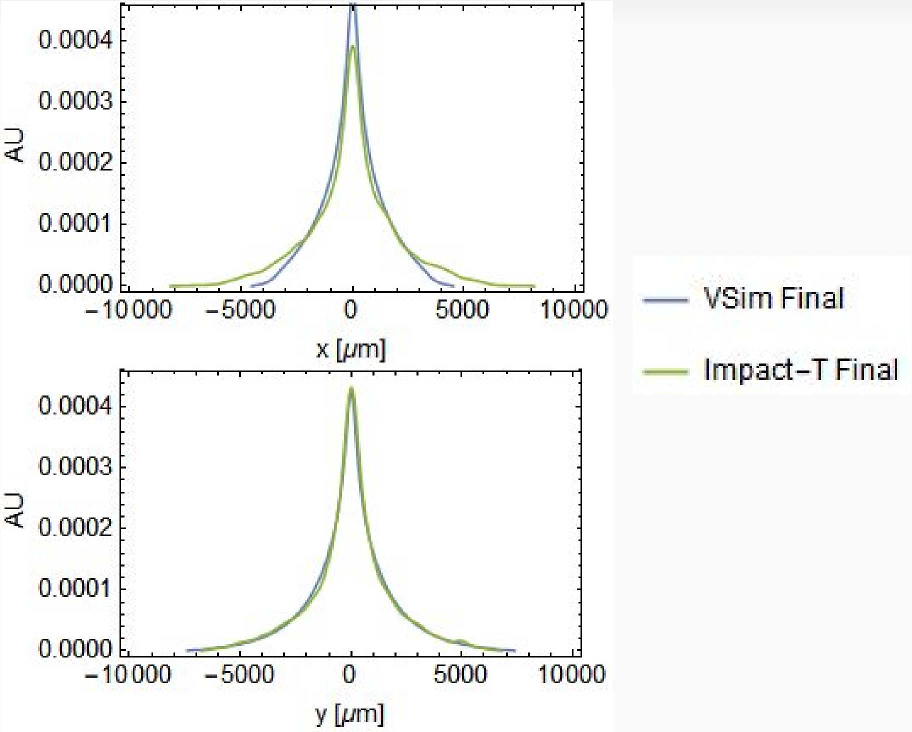
Horizontal

Vertical



Focusing in x dominates defocus in y for narrow aperture

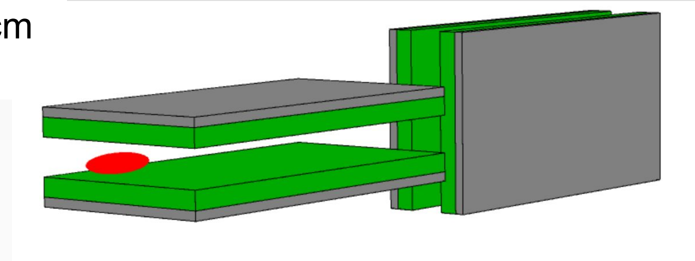
a = 250um



Clear measurable difference between two apertures

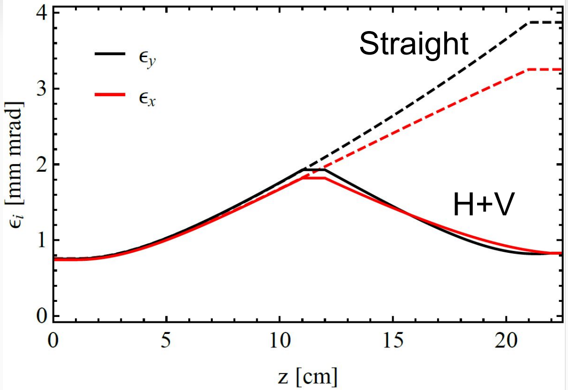
The future: Dechirper for CLARA

L = 10 +10 cm
a = 0.6 mm

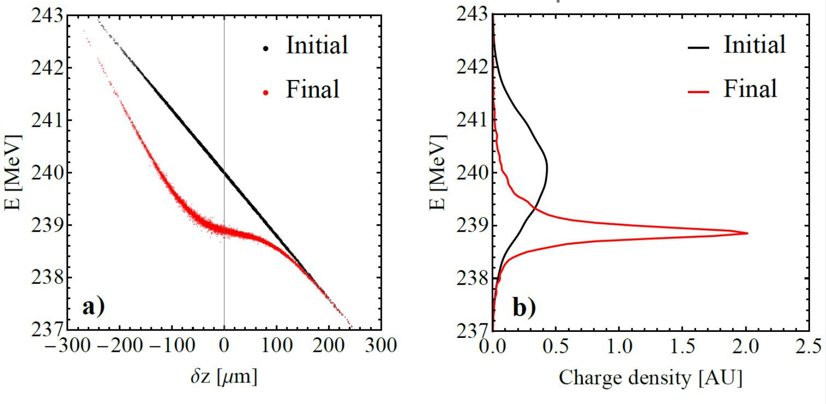


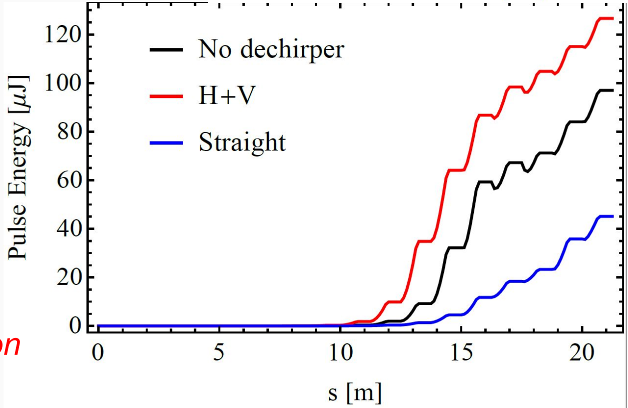
H+V dechirper drawing

Projected emittance preservation with H+V setup



Effect of dechirper on bunch core





GENESIS sim. for CLARA, showing 30% power increase with H+V dechirper

T. Pacey et. al., *"Phase Space Manipulation of Sub-Picosecond Electron Bunches Using Dielectric Wakefield Structures"*, IPAC17.

Acknowledgement

Thanks to:

D. Mihalcea at Fermilab and J. Qiang at LBNL for their assistance in running Impact-T and the DLW wakefield package

&

J. Smith at Tech-X for assistance with VSim and HPC

Summary

- Thin dielectric layers will allow us to study wakefield tunability
- Possibility to experimentally test a ‘positive’ dechirper
- Good qualitative agreement between two codes
- Need to verify transverse effects for CLARA dielectric dechirper

WG Summary Slide

- We are very close to starting DWA experiments at CLARA at Daresbury.
- Use thin dielectric layers in a tunable rectangular structure.
- This will maximise tunability, allowing investigation of changes in
    - Wakefield frequency spectra
    - Longitudinal dynamics
    - Transverse dynamics
- Reasonable parameter space gives us lots to investigate in terms of drive beam dynamics for an accelerator, or passive components like a dechirper for FELs.