Analysis of CesrTA Electron Cloud-Induced Tune Shifts with POSINST

Kiel Williams

Cornell Laboratory for Accelerator-based Sciences and Education (CLASSE)

Electron Clouds

- CesrTA beam emits sync. Radiation

Electron Clouds

- CesrTA beam emits sync. Radiation
- Photons hit wall; photoelectrons freed

Electron Clouds

- CesrTA beam emits sync. Radiation
- Photons hit wall; photoelectrons freed
- Free photoelectrons (“primaries”) hit wall; release more electrons (“secondaries”)

Electron Clouds

- CesrTA beam emits sync. Radiation
- Photons hit wall; photoelectrons freed
- Free photoelectrons (“primaries”) hit wall; release more electrons (“secondaries”)
- Beam quality disrupted

Finding Parameters

- ~6 main parameters determine cloud

Finding Parameters

- ~6 main parameters determine cloud
- Hard to measure directly; “guess,” simulate, and compare

Finding Parameters

- ~6 main parameters determine cloud
- Hard to measure directly; “guess,” simulate, and compare
- Look across range of different data sets

Tune Shift

- Beam oscillates (“tune”) in pipe; initial ping + magnet misalignments

Tune Shift

- Beam oscillates (“tune”) in pipe; initial ping + magnet misalignments
- Electron clouds shift tune up for positron beam; typically down for electron beam

Tune Shift

- Beam oscillates (“tune”) in pipe; initial ping + magnet misalignments
- Electron clouds shift tune up for positron beam; typically down for electron beam
- Measure position with BPM’s; find tune with FFT

Tune Shift

- Beam oscillates (“tune”) in pipe; initial ping + magnet misalignments
- Electron clouds shift tune up for positron beam; typically down for electron beam
- Measure position with BPM’s; find tune with FFT
- Compare simulation to measurement

Simulation Technique

- POSINST takes user “guesses,” simulates electron cloud density

Simulation Technique

- POSINST takes user “guesses,” simulates electron cloud density
- Mathematica script finds tune shifts from density

Simulation Technique

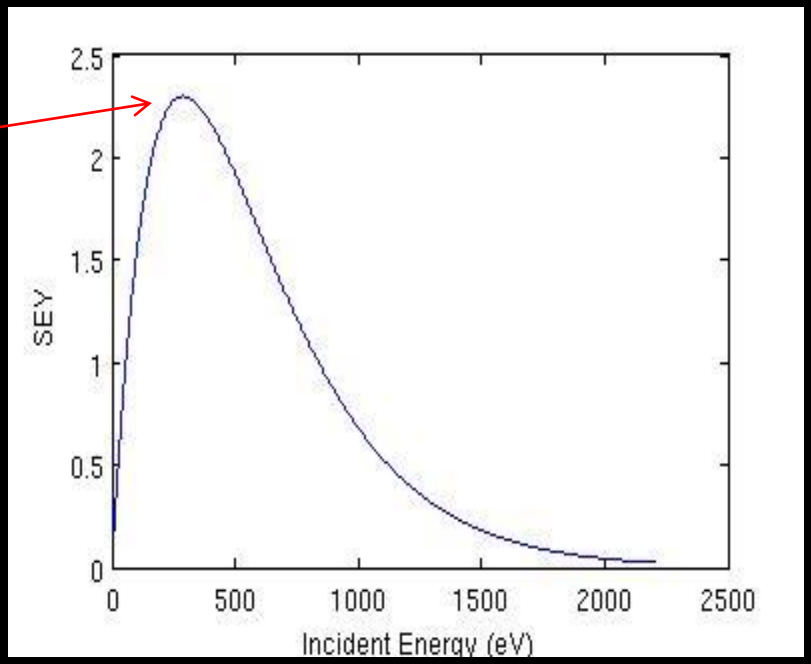
- POSINST takes user “guesses,” simulates electron cloud density
- Mathematica script finds tune shifts from density
- Observe results and iterate

Nominal Key Parameters

- # of freed electrons/photon ("primaries"):
  - ~.1

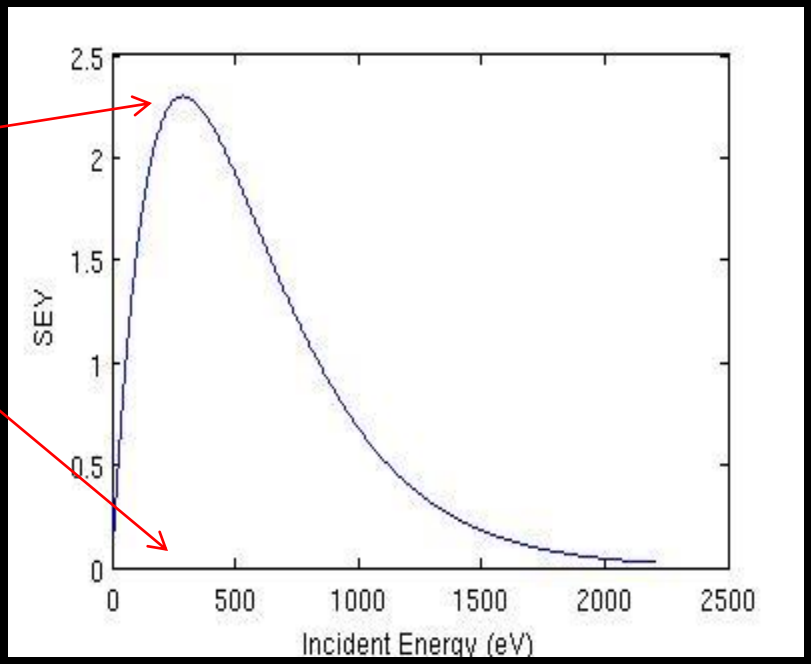
Nominal Key Parameters

- # of freed electrons/photon ("primaries"):
  - ~.1
- # of freed electrons/electron ("secondaries") at peak energy:
  - ~2.0



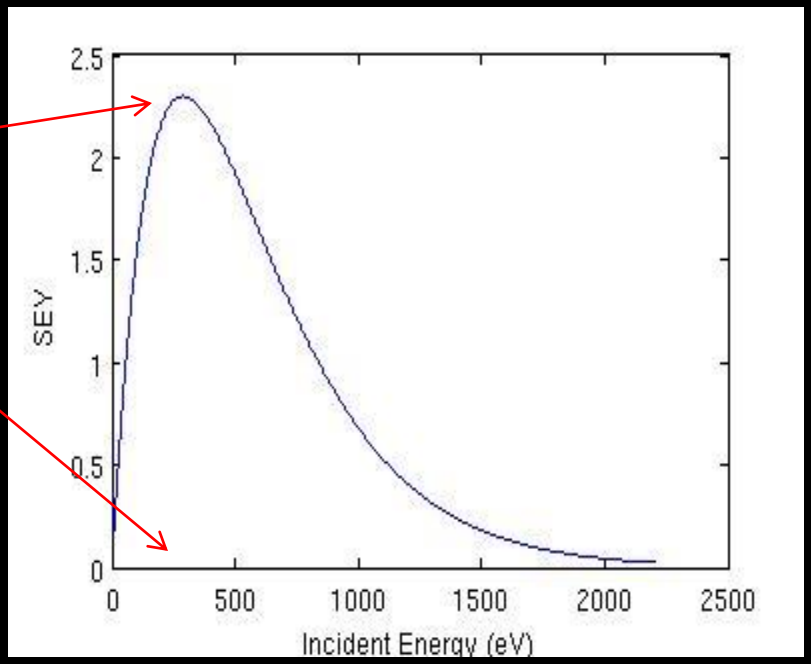
Nominal Key Parameters

- # of freed electrons/photon ("primaries"):
  - ~.1
- # of freed electrons/electron ("secondaries") at peak energy:
  - ~2.0
- Incident energy of peak secondary yield:
  - ~310 eV



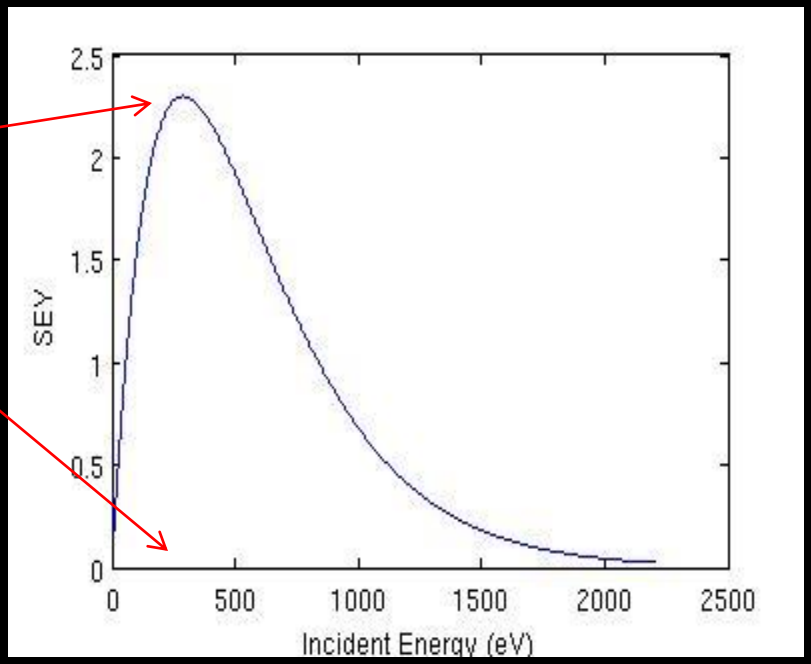
Nominal Key Parameters

- # of freed electrons/photon ("primaries"):
  - ~.1
- # of freed electrons/electron ("secondaries") at peak energy:
  - ~2.0
- Incident energy of peak secondary yield:
  - ~310 eV
- % of electrons elastically scattered from wall:
  - ~50%



Nominal Key Parameters

- # of freed electrons/photon ("primaries"):
  - ~.1
- # of freed electrons/electron ("secondaries") at peak energy:
  - ~2.0
- Incident energy of peak secondary yield:
  - ~310 eV
- % of electrons elastically scattered from wall:
  - ~50%
- % of electrons go into wall and reemerge ("rediffused"):
  - ~20%



Early Results

- Nominal values vs. my findings

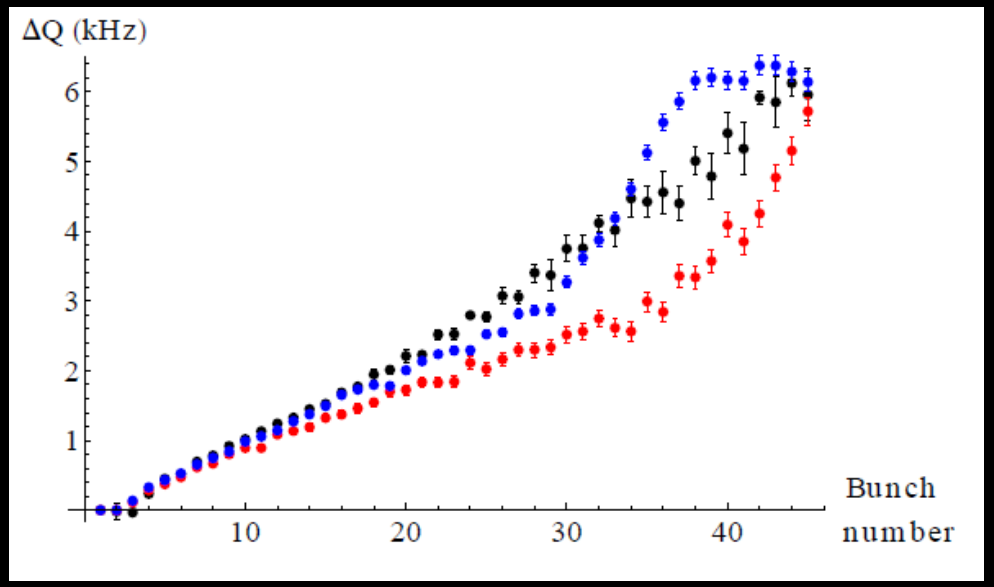
Early Results

- Nominal values vs. my findings

•2.1 GeV, 45-bunch positron beam, .75 mA/bunch, 4ns

•Nominal values

•New Values



Early Results

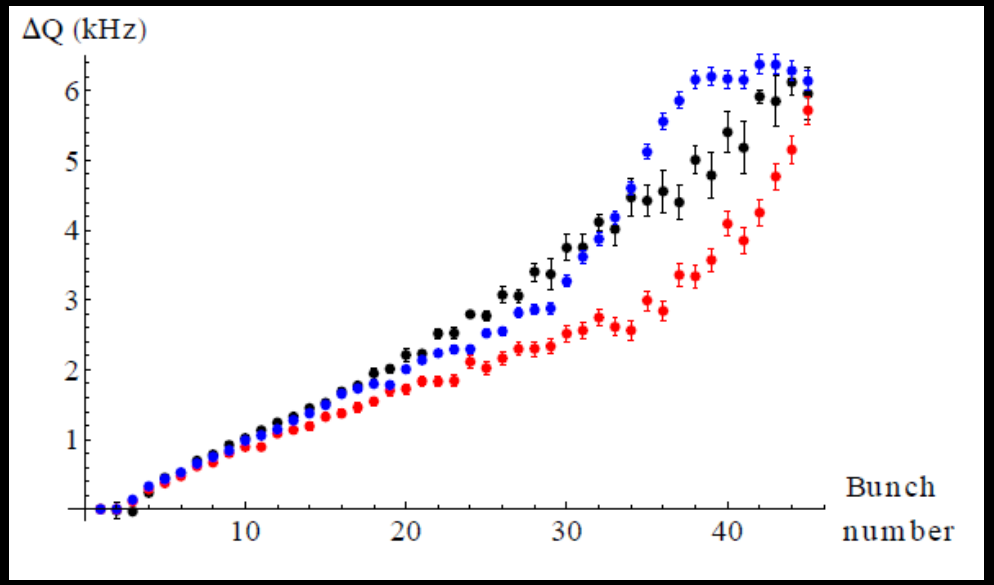
- Nominal values vs. my findings

•2.1 GeV, 45-bunch positron beam, .75 mA/bunch, 4ns

•Nominal values

•New Values

•Peak SEY up from 2.0 to 2.2; peak energy down from 310 to 279 eV



Early Results

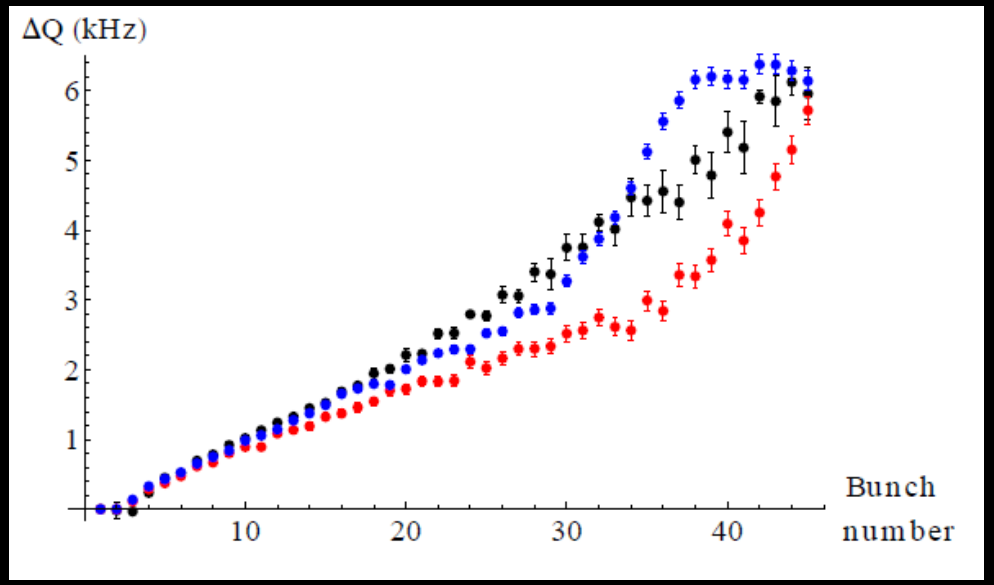
- Nominal values vs. my findings

•2.1 GeV, 45-bunch positron beam, .75 mA/bunch, 4ns

•Nominal values

•New Values

•Peak SEY up from 2.0 to 2.2; peak energy down from 310 to 279 eV



•Note nonlinear effects

Electron Results

- Electron beam tune shifts smaller, negative

Electron Results

- Electron beam tune shifts smaller, negative
- Saturate at low levels

Electron Results

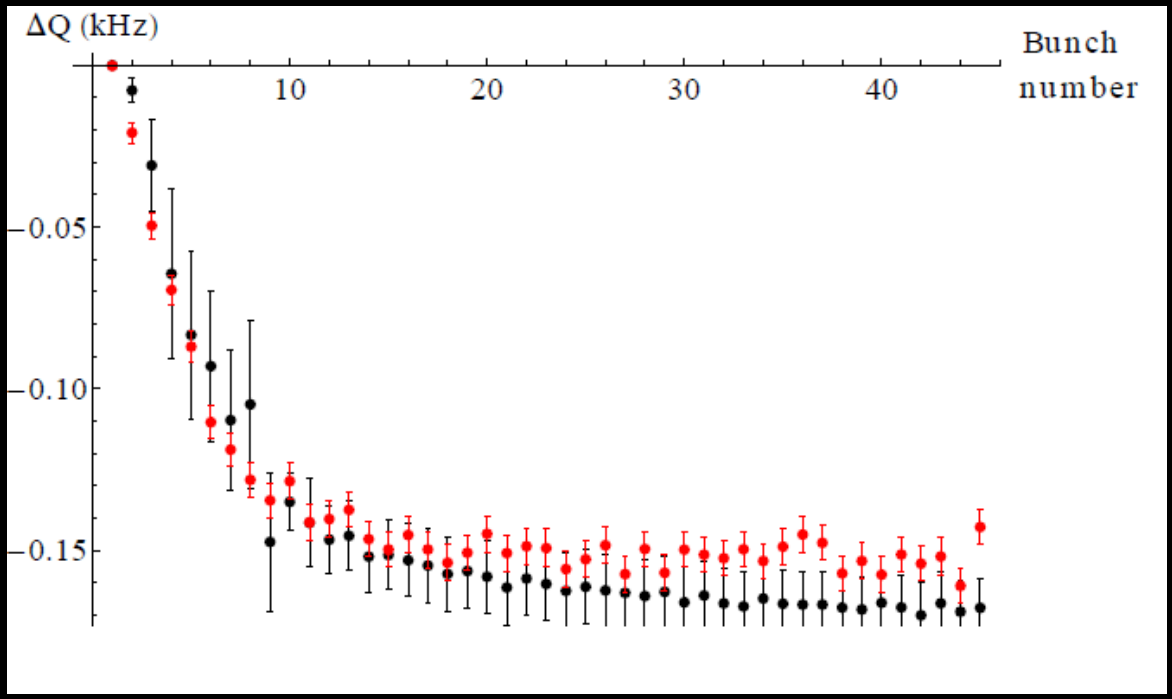
- Electron beam tune shifts smaller, negative
- Saturate at low levels
- Less informative due to small tune shift

Electron Results

- Electron beam tune shifts smaller, negative
- Saturate at low levels
- Less informative due to small tune shift

•5.3 GeV 45-bunch electron beam, 0.75 mA/bunch, 8 ns

•Simulation



Minima in 6-D Space

- 6-D parameter space is *big*

Minima in 6-D Space

- 6-D parameter space is *big*
  - Parameters strongly correlated

Minima in 6-D Space

- 6-D parameter space is *big*
  - Parameters strongly correlated
- Some parameters matter more

Minima in 6-D Space

- 6-D parameter space is *big*
  - Parameters strongly correlated
- Some parameters matter more
- Variant of Newton's Method estimates how to best change parameters

Minima in 6-D Space

- 6-D parameter space is *big*
  - Parameters strongly correlated
- Some parameters matter more
- Variant of Newton's Method estimates how to best change parameters
- More efficient use of comp. time (and my time)

6-D Newton's Method

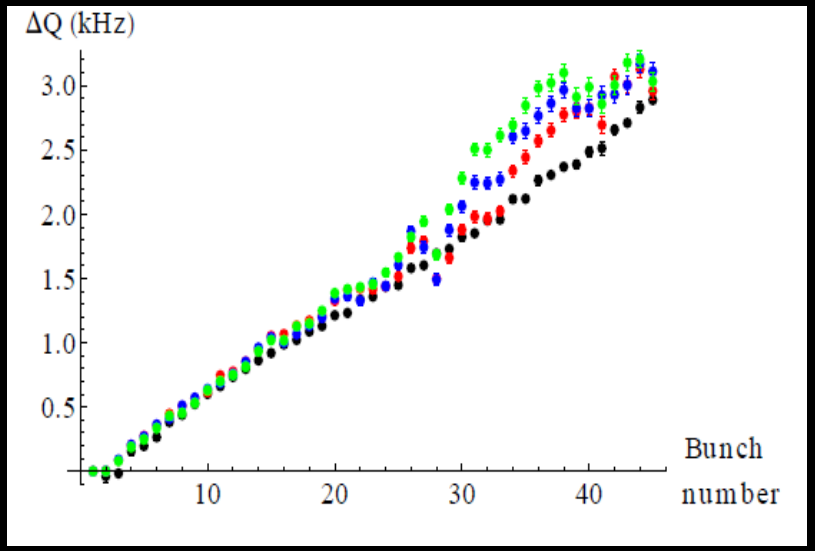
- Linear estimate of Jacobian

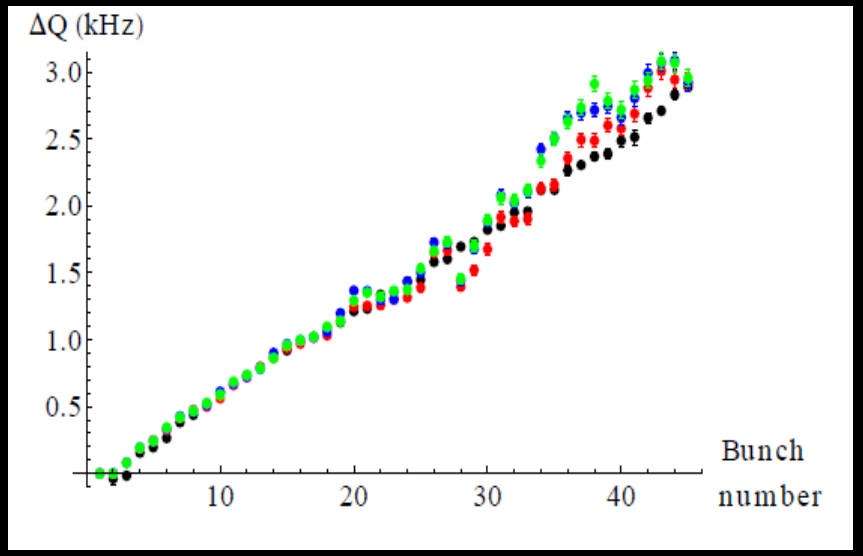
6-D Newton's Method

- Linear estimate of Jacobian
- Give some guessed parameters

6-D Newton's Method

- Linear estimate of Jacobian
- Give some guessed parameters



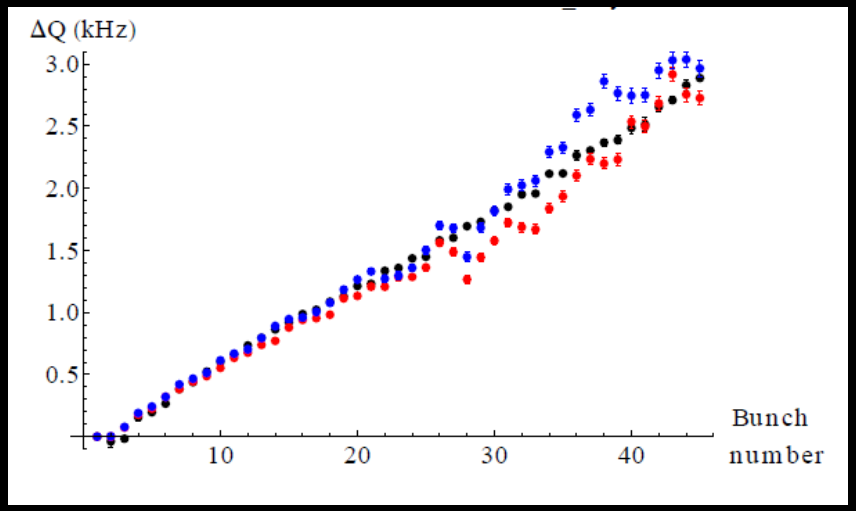


•Each fit perturbs one thing; determines sensitivity of each parameter

Newton's Method Results

- 5.3 GeV 45-bunch positron beam, 0.75 mA/bunch, 4 ns

- Before Newton
- After Newton

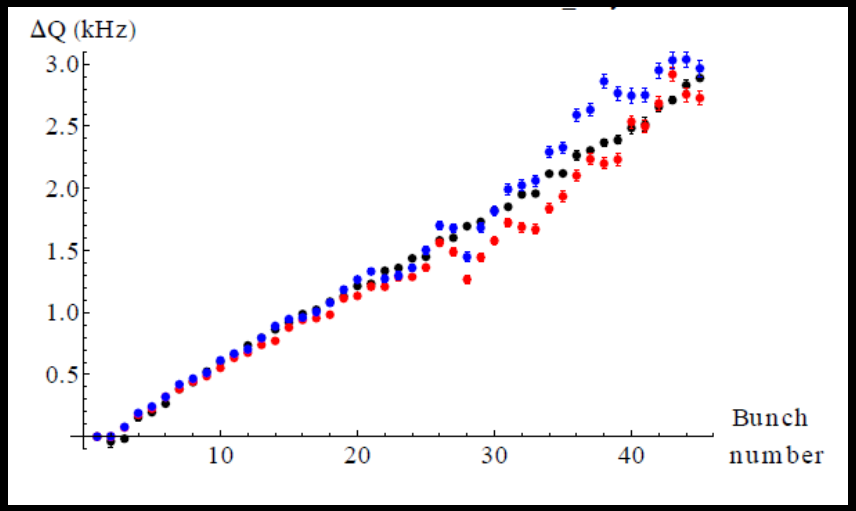


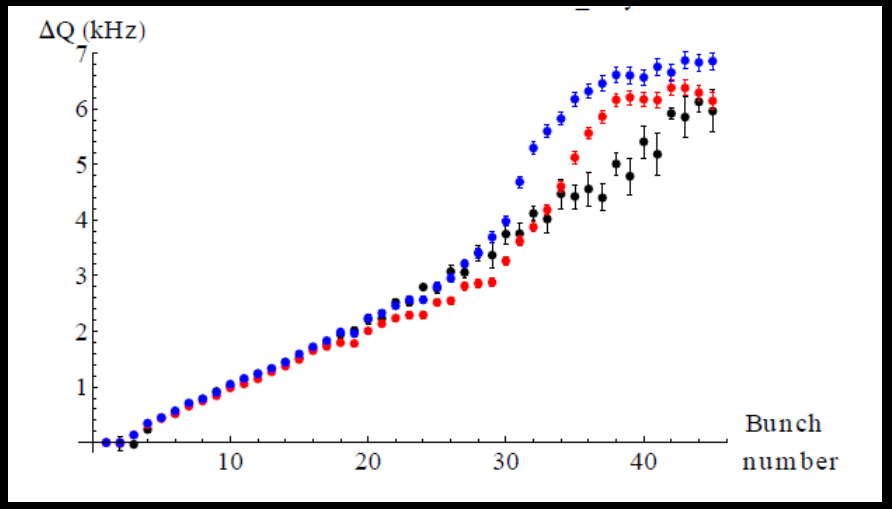
Newton's Method Results

- 5.3 GeV 45-bunch positron beam, 0.75 mA/bunch, 4 ns

- Before Newton
- After Newton

- 2.1 GeV 45-bunch positron beam, 0.75 mA/bunch, 4 ns





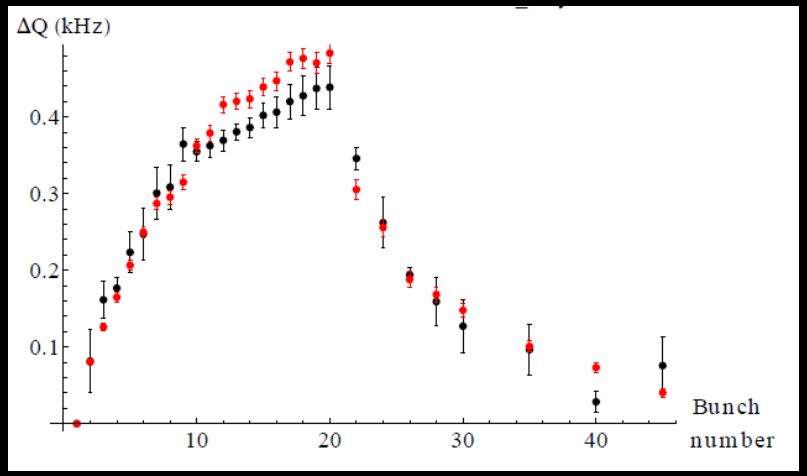
Witness Bunches

- Send bunches after main train to measure cloud decay

Witness Bunches

- Send bunches after main train to measure cloud decay

- 4.0 GeV 20-bunch positron beam, 0.50 mA/bunch, 8 witnesses, 20 ns



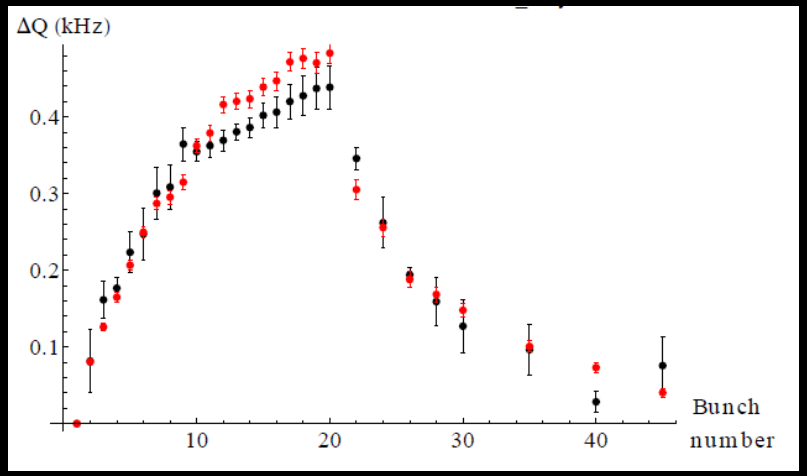
Simulation

Data (black)

Witness Bunches

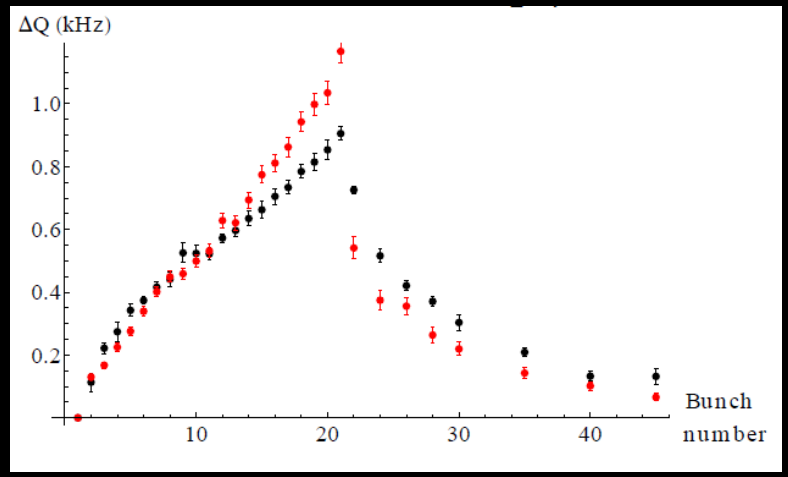
•Send bunches after main train to measure cloud decay

- 4.0 GeV 20-bunch positron beam, 0.50 mA/bunch, 8 witnesses, 20 ns



Simulation

- 4.0 GeV 20-bunch positron beam, 1.00 mA/bunch, 8 witnesses, 20 ns



Data (black)

Remaining Problems

- SEY value higher compared to other methods; 2.3 vs. ~1.5

Remaining Problems

- SEY value higher compared to other methods; 2.3 vs. ~1.5
- Global vs. local minima

Remaining Problems

- SEY value higher compared to other methods; 2.3 vs. ~1.5
- Global vs. local minima
  - Spurious parameter sets possible

Remaining Problems

- SEY value higher compared to other methods; 2.3 vs. ~1.5
- Global vs. local minima
  - Spurious parameter sets possible
- Difficulty with high-current and/or low-energy data

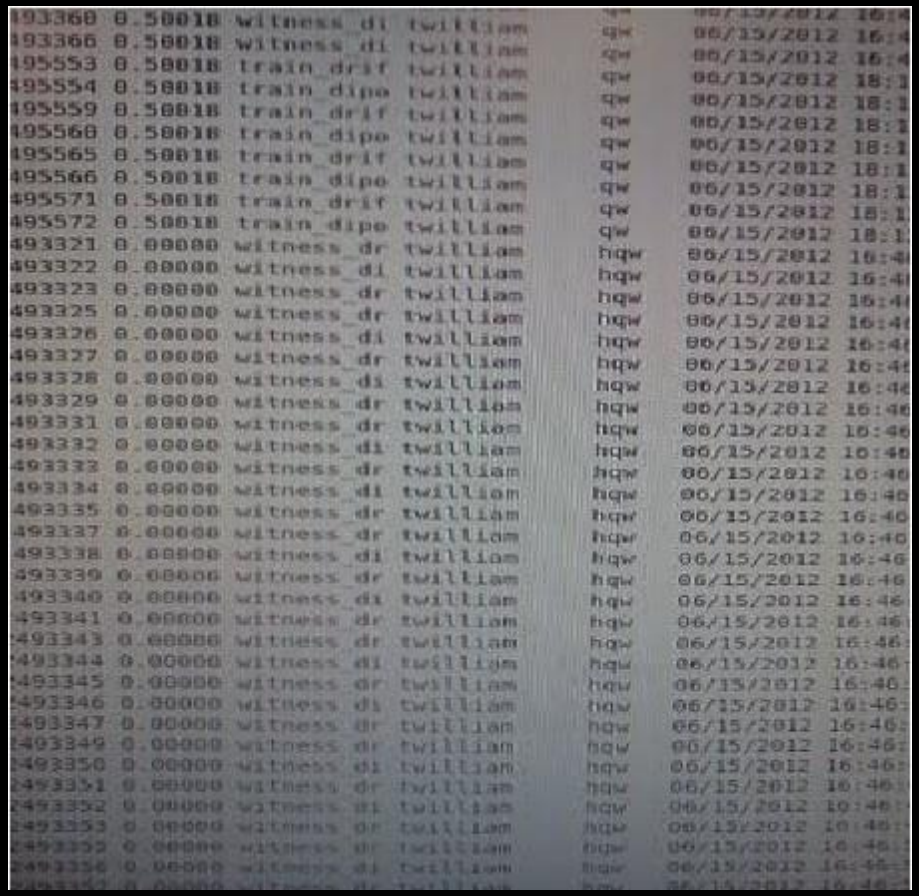
Remaining Problems

- SEY value higher compared to other methods; 2.3 vs. ~1.5
- Global vs. local minima
  - Spurious parameter sets possible
- Difficulty with high-current and/or low-energy data
  - Nonlinearities

Acknowledgements

- Many thanks to mentor David Kreinick
- Thanks to Joe Calvey for help with Newton technique
- Thanks to Gerry Dugan for Mathematica tune shift scripts
- Thanks to the National Science Foundation and Cornell CLASSE REU program for making this experience possible

Questions?


493360 0.50018 witness_di twilliam qw 06/15/2012 16:4
493366 0.50018 witness_di twilliam qw 06/15/2012 16:4
495553 0.50018 train_drif twilliam qw 06/15/2012 18:1
495554 0.50018 train_dipo twilliam qw 06/15/2012 18:1
495559 0.50018 train_drif twilliam qw 06/15/2012 18:1
495560 0.50018 train_dipo twilliam qw 06/15/2012 18:1
495565 0.50018 train_drif twilliam qw 06/15/2012 18:1
495566 0.50018 train_dipo twilliam qw 06/15/2012 18:1
495571 0.50018 train_drif twilliam qw 06/15/2012 18:1
495572 0.50018 train_dipo twilliam qw 06/15/2012 18:1
493321 0.00000 witness_dr twilliam hqw 06/15/2012 16:4
493322 0.00000 witness_di twilliam hqw 06/15/2012 16:4
493323 0.00000 witness_dr twilliam hqw 06/15/2012 16:4
493325 0.00000 witness_dr twilliam hqw 06/15/2012 16:4
493326 0.00000 witness_di twilliam hqw 06/15/2012 16:4
493327 0.00000 witness_dr twilliam hqw 06/15/2012 16:4
493328 0.00000 witness_di twilliam hqw 06/15/2012 16:4
493329 0.00000 witness_dr twilliam hqw 06/15/2012 16:4
493331 0.00000 witness_dr twilliam hqw 06/15/2012 16:4
493332 0.00000 witness_di twilliam hqw 06/15/2012 16:4
493333 0.00000 witness_dr twilliam hqw 06/15/2012 16:4
493334 0.00000 witness_di twilliam hqw 06/15/2012 16:4
493335 0.00000 witness_dr twilliam hqw 06/15/2012 16:4
493337 0.00000 witness_dr twilliam hqw 06/15/2012 16:4
493338 0.00000 witness_di twilliam hqw 06/15/2012 16:4
493339 0.00000 witness_dr twilliam hqw 06/15/2012 16:4
493340 0.00000 witness_di twilliam hqw 06/15/2012 16:4
493341 0.00000 witness_dr twilliam hqw 06/15/2012 16:4
493343 0.00000 witness_dr twilliam hqw 06/15/2012 16:4
493344 0.00000 witness_di twilliam hqw 06/15/2012 16:4
493345 0.00000 witness_dr twilliam hqw 06/15/2012 16:4
493346 0.00000 witness_di twilliam hqw 06/15/2012 16:4
493347 0.00000 witness_dr twilliam hqw 06/15/2012 16:4
493349 0.00000 witness_dr twilliam hqw 06/15/2012 16:4
493350 0.00000 witness_di twilliam hqw 06/15/2012 16:4
493351 0.00000 witness_dr twilliam hqw 06/15/2012 16:4
493352 0.00000 witness_di twilliam hqw 06/15/2012 16:4
493353 0.00000 witness_dr twilliam hqw 06/15/2012 16:4
493355 0.00000 witness_dr twilliam hqw 06/15/2012 16:4
493356 0.00000 witness_di twilliam hqw 06/15/2012 16:4