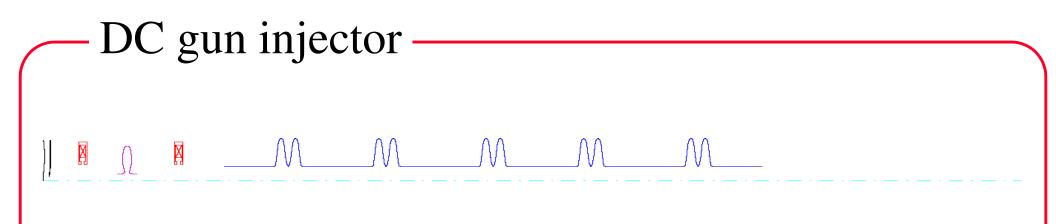# USPAS Course on
Recirculated and Energy Recovered Linacs

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Computer Class: Space Charge in DC Gun ERL Injector

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DC gun injector

Injector Parameters:

Beam Energy Range	5 – 15 MeV
Max Average Beam Current	100 mA
Max Bunch Rep. Rate	1.3 GHz

Accounts

Use Exceed to connect to the following computers:

```
vis11 lnx6114 (2x2.6)
vis12 lnx51    (2x3.2)
vis13 lnx227   (2x2.8)
vis14 lnx614   (2x2.6)
vis15 lnx615   (2x2.6)
vis16 lnx618   (2x2.6)
vis17 lnx4171 (2x2.6)
vis20 lnx5113 (2x2.6)
vis21 lnx5116 (2x2.6)
    use the password you see on the board
```
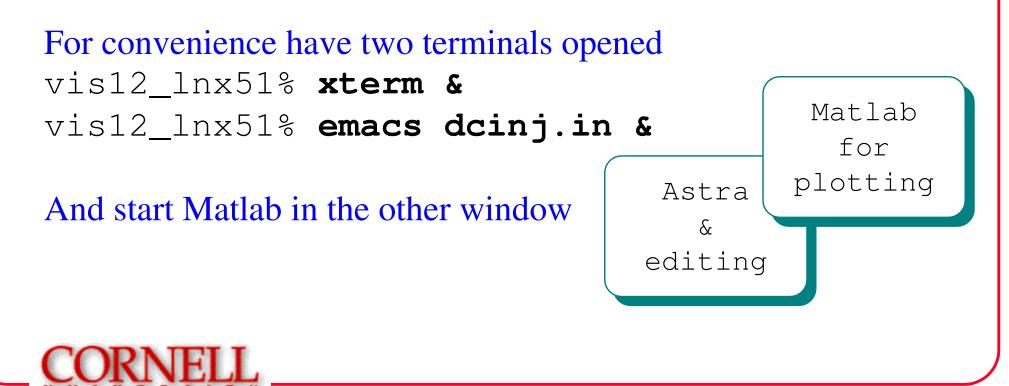
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Commands

```
vis12_lnx51% cd ~/dcinj    - working directory
vis12_lnx51% cleanup       - deletes old Astra files
vis12_lnx51% Astra dcinj   - runs space charge code
vis12_lnx51% matlab        - starts matlab (for gui)
```

For convenience have two terminals opened
```
vis12_lnx51% xterm &
vis12_lnx51% emacs dcinj.in &
```

And start Matlab in the other window

```
Matlab
for
plotting
```

```
Astra
&
editing
```

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Astra input

```
&NEWRUN
  Head='Cornell DC gun injector'
  Distribution='dist/1K.dist'
```
initial distribution

other choices:

uncomment corresponding mesh size

'dist/2K.dist'
```
    4K.dist
    7K.dist
    14K.dist
    28K.dist
    mini.dist
```

```
&CHARGE
 !Nrad=35, Nlong_in=75 !28K
 !Nrad=25, Nlong_in=53 !14K
 !Nrad=18, Nlong_in=38 !7K
 !Nrad=28, Nlong_in=13 !4K
 !Nrad=9,  Nlong_in=20 !2K
 Nrad=7,  Nlong_in=14 !1K
```

Astra input (contd.)

```
&NEWRUN
  ...
  ZSTART=0
  ZSTOP=8.56629      track till this distance (m)
  ...
  Trms=0.011146      initial  pulse width (ns)
  XYrms=0.294907              spot size (mm)
  Qbunch=0.107743            bunch charge (nC)

&CHARGE
  LSPCH=T                    turn on/off (T/F) space
                             charge calculation
```

Astra input (contd.)

```
&CAVITY
    ...  MaxE(1)=-18.9398  ...
    ...  MaxE(2)=2.57122  ...
    ...  MaxE(3)=10.5146  ...
    ...  Phi(2)=225.07  ...
    ...  Phi(3)=18.0733  ...


&SOLENOID
    ...  MaxB(1)=0.08202  ...
    ...  MaxB(2)=0.046955  ...
```

peak field in the gun (MV/m)
in the buncher
field in five (3-7) SRF cavities
buncher phase (deg)
phase in five (3-7) SRF cavities

peak magnetic field in
solenoids (T)

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Astra input (contd.)

```
&SCAN
 LScan=F
 Scan_para='Phi(2)'
 S_min=0, S_max=360, S_numb=181
 FOM(1)='mean energy'
/
```

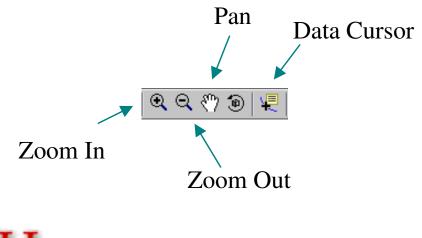if enabled, scans a parameter and records results
of FOM(1) to a file.

Matlab visualization

While in Matlab (should be started through the terminal!)

>> **viewfields** - view all magnetic and electric field maps

>> **viewrms** - display rms beam properties after tracking

>> **viewref** - show single particle trajectory

>> **viewdist** - loop through phase space distrib. dumps

>> **viewscan** - view results of parameter scan

Plot manipulation toolbar

Pan

Data Cursor

Zoom In

Zoom Out

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Exercises

1) Examine field maps, noting the positions of the elements. Examine the gun field. Note the two different regions (corresponding to the cathode and the anode aperture). Analytically estimate focal length from the anode aperture. Compare it with simulations (hint: look at the single particle trajectory). Estimate focal length that corresponds to fields near the cathode. What is total effect (focusing / defocusing) of the gun?

2) Determine the voltage of the gun. Determine the maximum charge per bunch for the given laser spot size and duration (i.e. without changing `XYrms`, `Trms`). Compare it with the simple expression from the lecture. Restore `Qbunch` to its original value.

If the input file becomes corrupted, the original input is available from
http://www.lepp.cornell.edu/~ib38/uspas05/dcinj/

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Exercises (contd.)

3) Examine single particle trajectory (`matlab:viewref`). Comment on transverse projection of the trajectory (x-y plot). Trace how the beam moves on the plot. Estimate Larmor angle and compare your values with those plotted. Correlate (i.e. compare) angles on the x-y plot with Larmor angles. How do they compare?

4) Take a look at rms emittance (`matlab: viewrms`). Note two areas with large emittance 'spikes'. Explain these peaks, estimate analytically their magnitude and compare with simulated values. Also, observe the other two smaller 'spikes' in emittance. Guess where those come from.

5) Examine rms emittance evolution. Take a look at corresponding phase space plots (`matlab: viewdist`). Can you judge on correlated nature of emittance growth (i.e. how much there is correlated vs. uncorrelated emittance growth in the gun, after the buncher, after the cavities at the end of the beamline).

Exercises (contd.)

6) Observe how bunch is being compressed in the injector. Is the 1st SRF cavity being run on crest? What is its off-crest angle (note: angle in Astra input file is absolute corresponding to a 'master clock', i.e. the number there is of little help)? Determine the buncher cavity voltage (i.e. max gain when on crest). Turn off the space charge and set field values in all of the SRF cavities to 0. Observe position where beam goes through longitudinal waist. Compare the result with the formula given in the lecture. Turn on the space charge and restore cavity gradients to their original values. What distance away from the buncher it now takes for the beam to go through its longitudinal waist?

7) Study the effect of the number of macroparticles (and corresponding mesh number and size) on accuracy of the calculation. What happens to emittance at the end of the injector as the number of macroparticles is increased? Give reasons for that change.