Optimization of Cornell L0 injector

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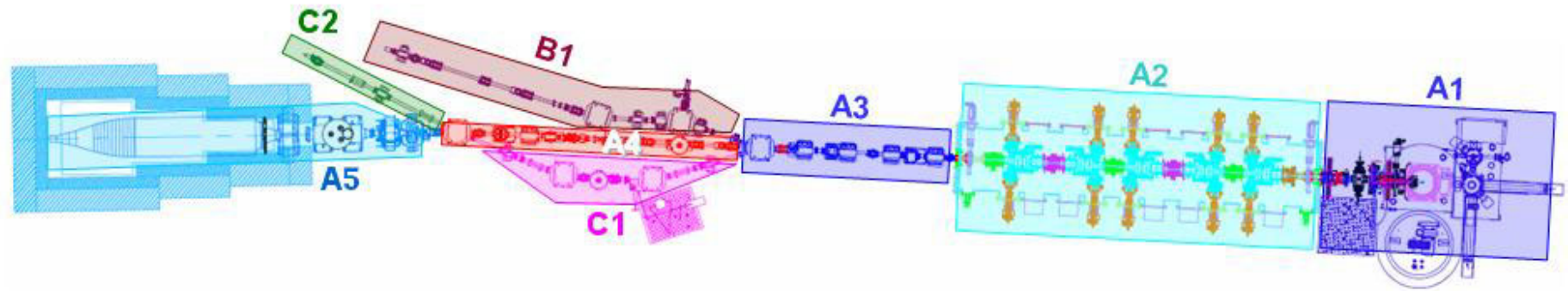
L0 Beam Line



https://wiki.lepp.cornell.edu/lepp/bin/view/ERL/Private/ErlL0Beamline

A1 - Gun Area
A2 - Cryomodule Area
A3 - Four-Quad Telescope
A4 - Straight-Through Chicane Section
A5 - Dump Area
B1 - Merger Line
C1 - Chicane Area
C2 - Offshoot Line Before Dump

- Now constructing…

- Photo cathode DC gun
- 5 SRF cavities
- 4 quadrupoles

- 3-dipoles merger
- Chicane
- Beam dump

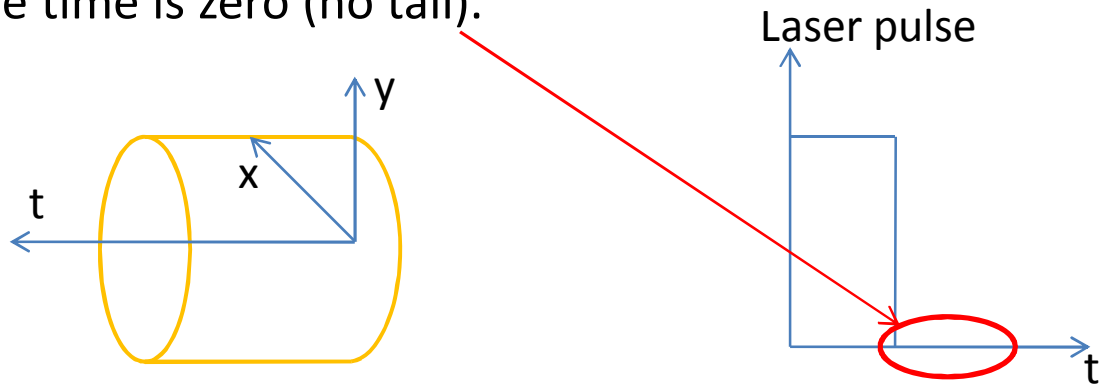
Simulations

- Optimizations of ERL injector
- Modifying space charge program for merger simulation
- Minimum emittance in merger section
- New CSR code in particle tracking simulation
- Optimization of DC gun and SRF gun shapes

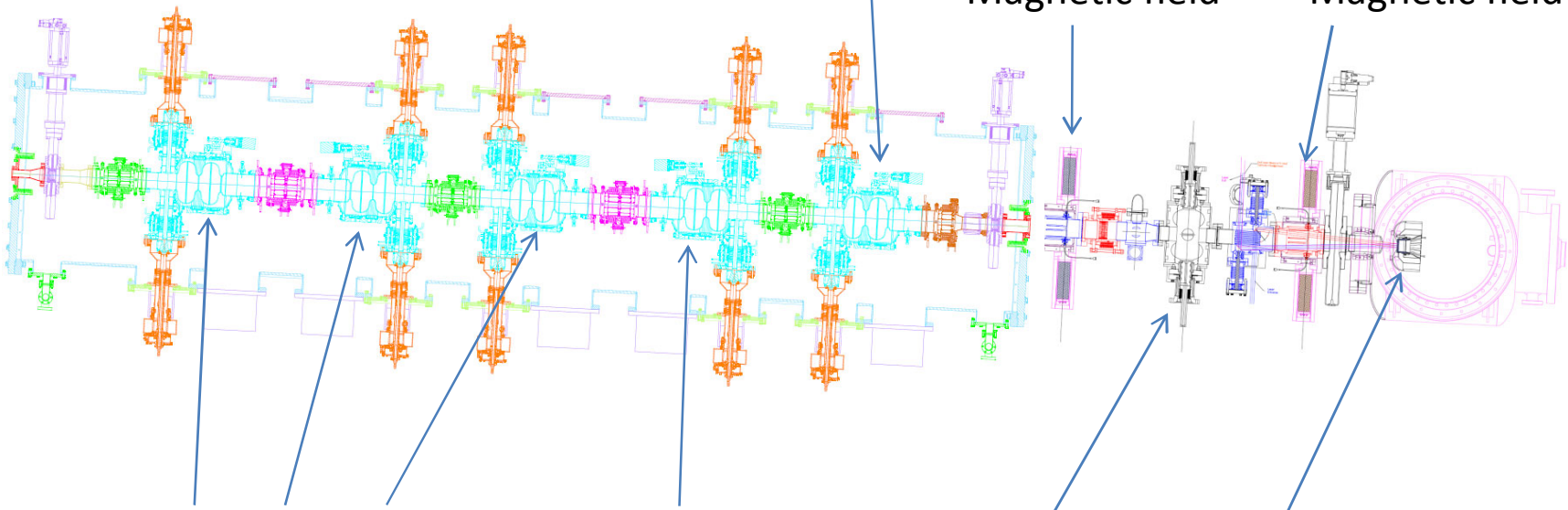
Optimizations of ERL injector

- "Multi-objective method" + "genetic algorithm" developed by I. Bazarov.

- Simulation code: Astra, Parmela and GPT
- Beam line: L0 beam line
  - DC gun
  - Solenoid
  - Buncher
  - Solenoid
  - 2 cell*5 SRF cavities
- Initial distribution: beer-can distribution
- Response time is zero (no tail).



11 parameters



SRF cavity 1
Electric field
RF phase

Solenoid 2
Magnetic field

Solenoid 1
Magnetic field

SRF cavity 3, 4 and 5
Electric field
RF phase

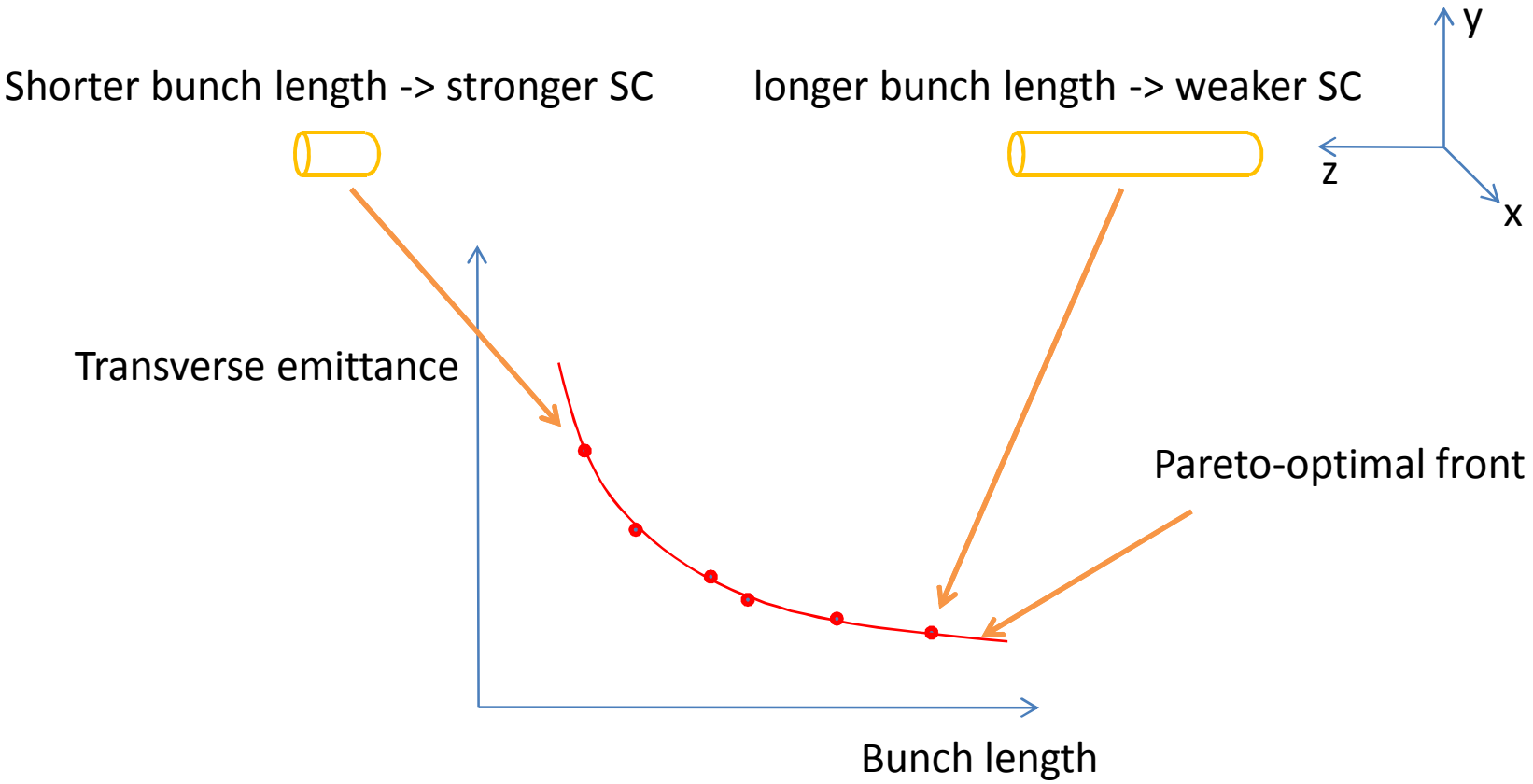
SRF cavity 2
Electric field
RF phase

Buncher cavity
Maximum Electric field

DC gun
Transverse beam size
Laser pulse length

Multi-objective method

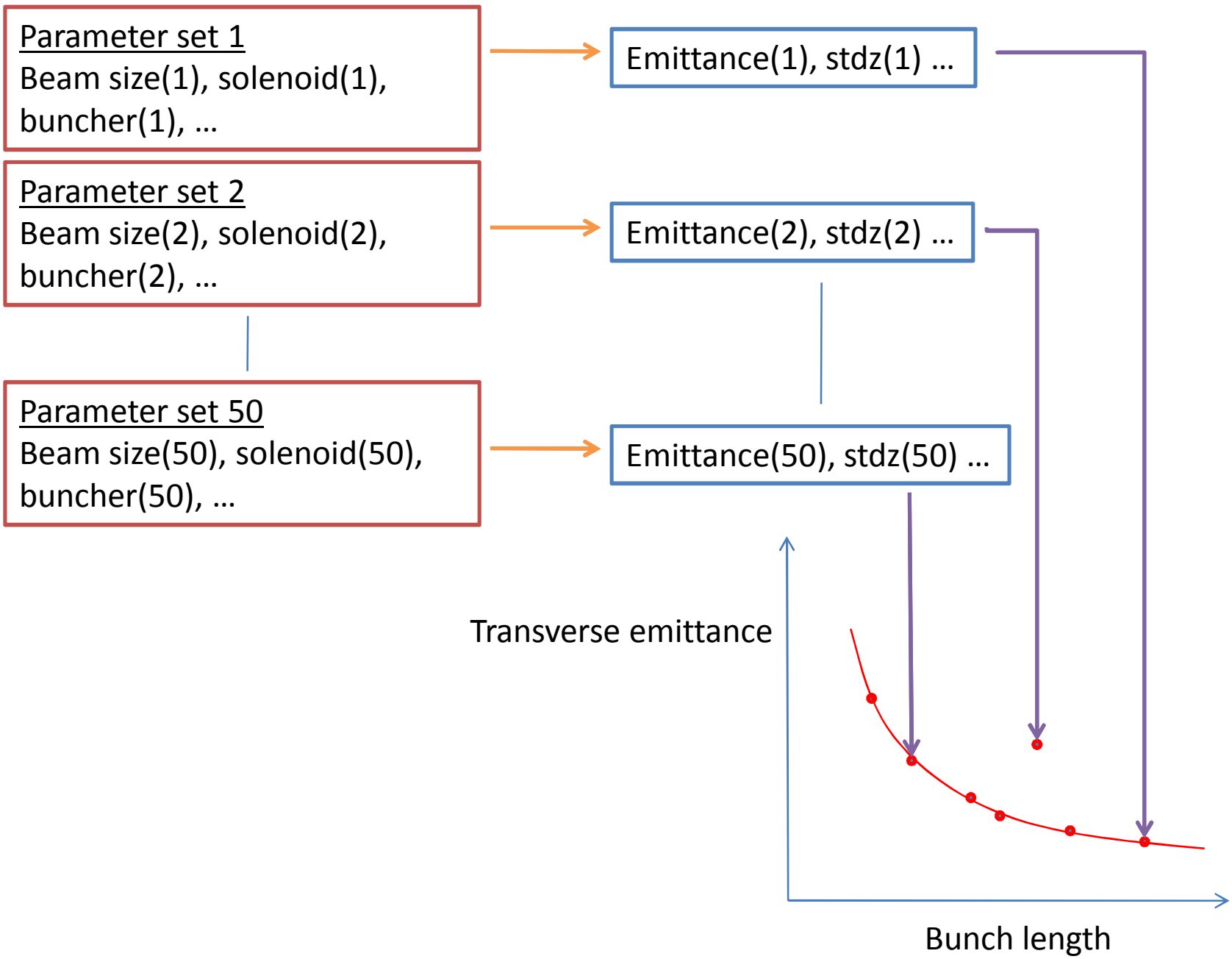
- Two objectives
  - For example, transverse emittance vs. bunch length



Simulation on a cluster computer on LEPP/Cornell

- Simulation code: Astra, GPT
- Cluster computer: “Feynman cluster”
  - OS: Linux
  - CPU: AMD Athlon(tm) MP 2400+ (dual CPU)
  - Number of computers: “compute-0-1” to “compute-0-99” (now, 71 computers are available.)

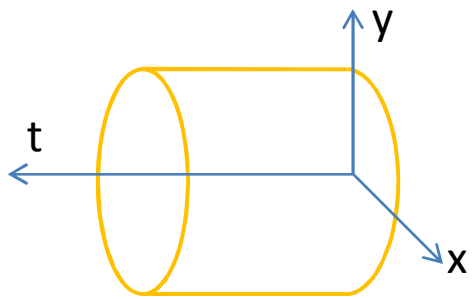
- Settings for multi-objective optimization
  - Number of populations: 50
  - Number of maximum generation: 200
- Example of CPU time
  - Average CPT time per 1 generation: 3.5 min (for nps=2k)
  - Total CPU time: 706 min


Parameter set 1
Beam size(1), solenoid(1), buncher(1), …
Parameter set 2
Beam size(2), solenoid(2), buncher(2), …
Parameter set 50
Beam size(50), solenoid(50), buncher(50), …
Emittance(1), stdz(1) …
Emittance(2), stdz(2) …
Emittance(50), stdz(50) …
Transverse emittance
Bunch length

Initial parameters

- DC gun voltage: 500 kV
- kT = 115 meV
- 77 pC / bunch
- Objectives
  - Bunch length at a slit
  - Transverse emittance at a list

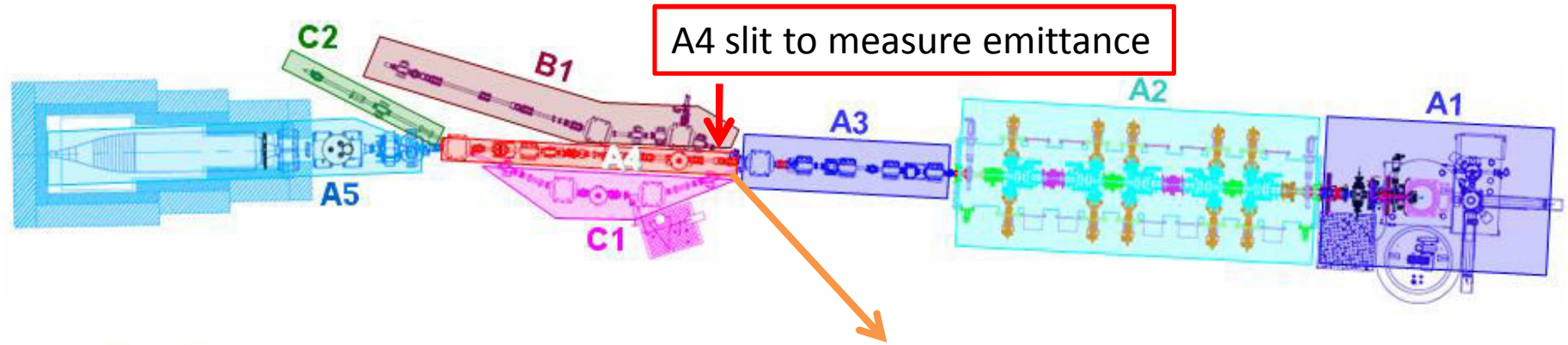
- Initial particle distribution
  - Transverse direction: radial uniform
  - Longitudinal: uniform



- Decisions

Decision variable	range
Initial laser pulse width	2 to 30 ps
Initial Transverse beam size	0 to 2 mm
Solenoid 1	0 to 0.1 T
Solenoid 2	0 to 0.1 T
Buncher field	0 to 10 MV/m
First cavity field	10 to 30 MV/m
Second cavity field	10 to 30 MV/m
Third to fifth cavity field	10 to 30 MV/m
First cavity offset	-60 to 10 degree
Second cavity offset	-60 to 10 degree
Third to fifth cavity field	-30 to 10 degree

Transverse emittance at a slit



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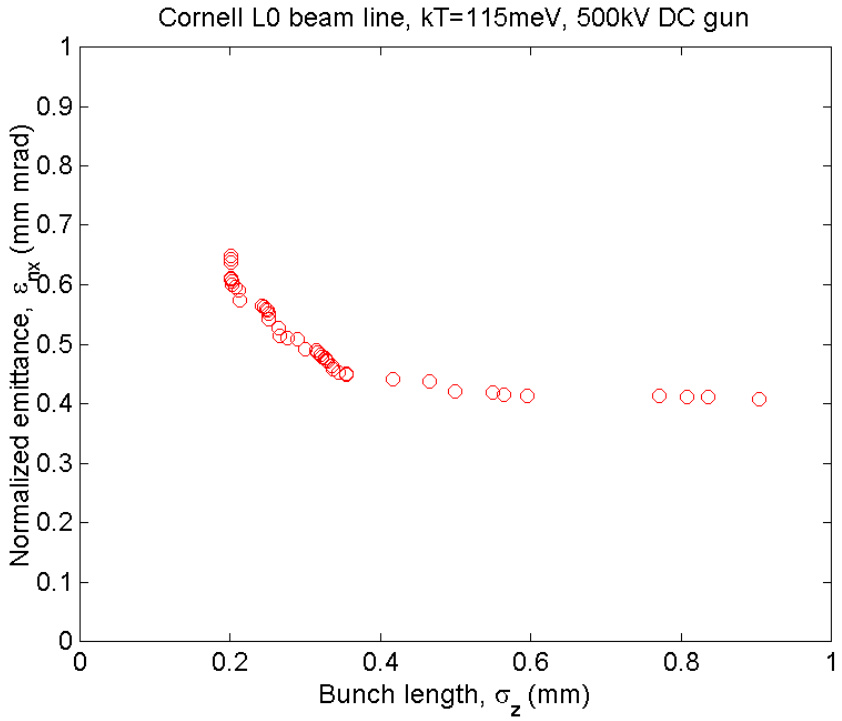
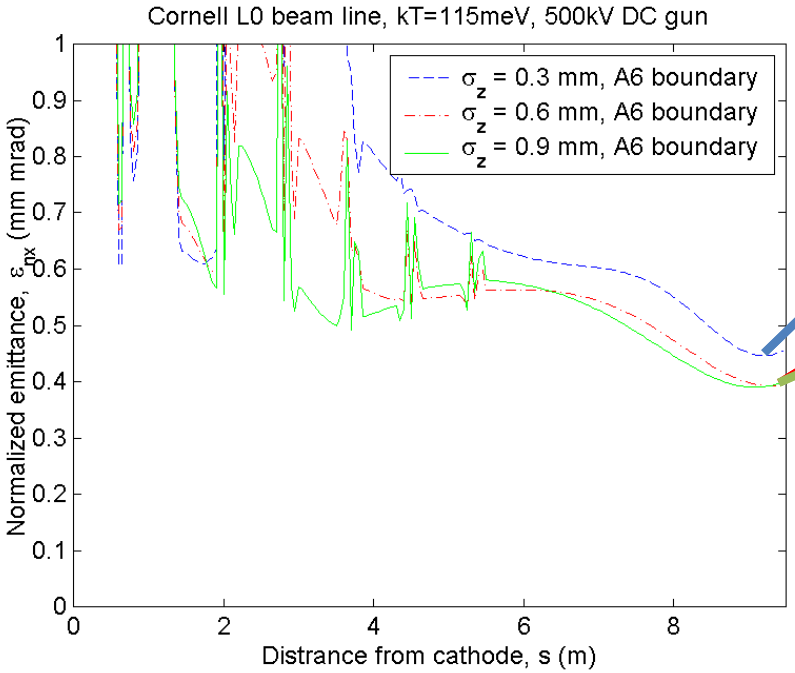
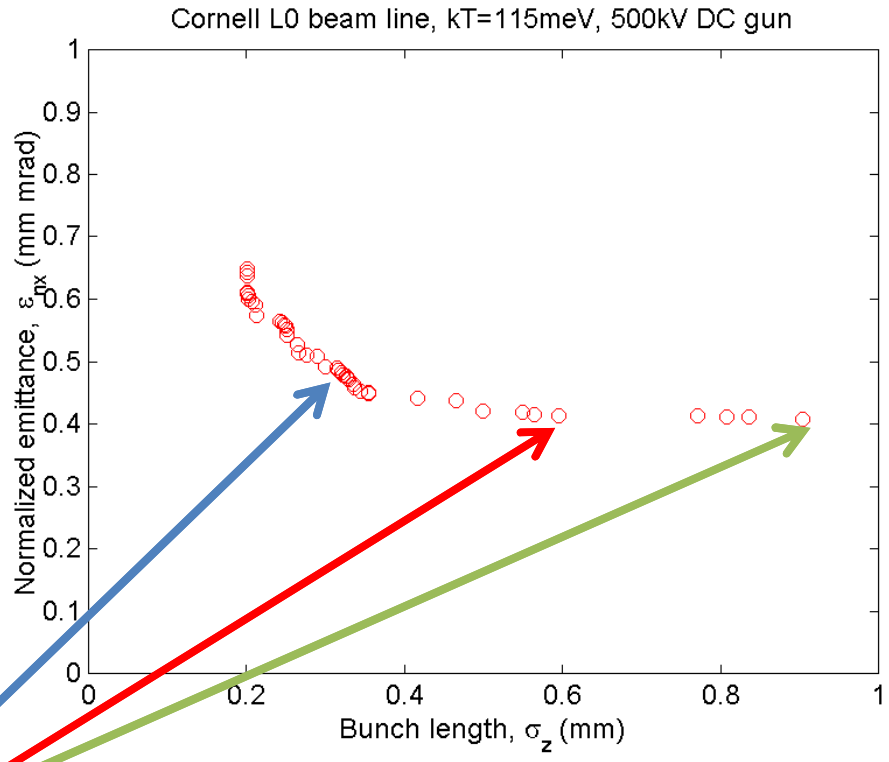


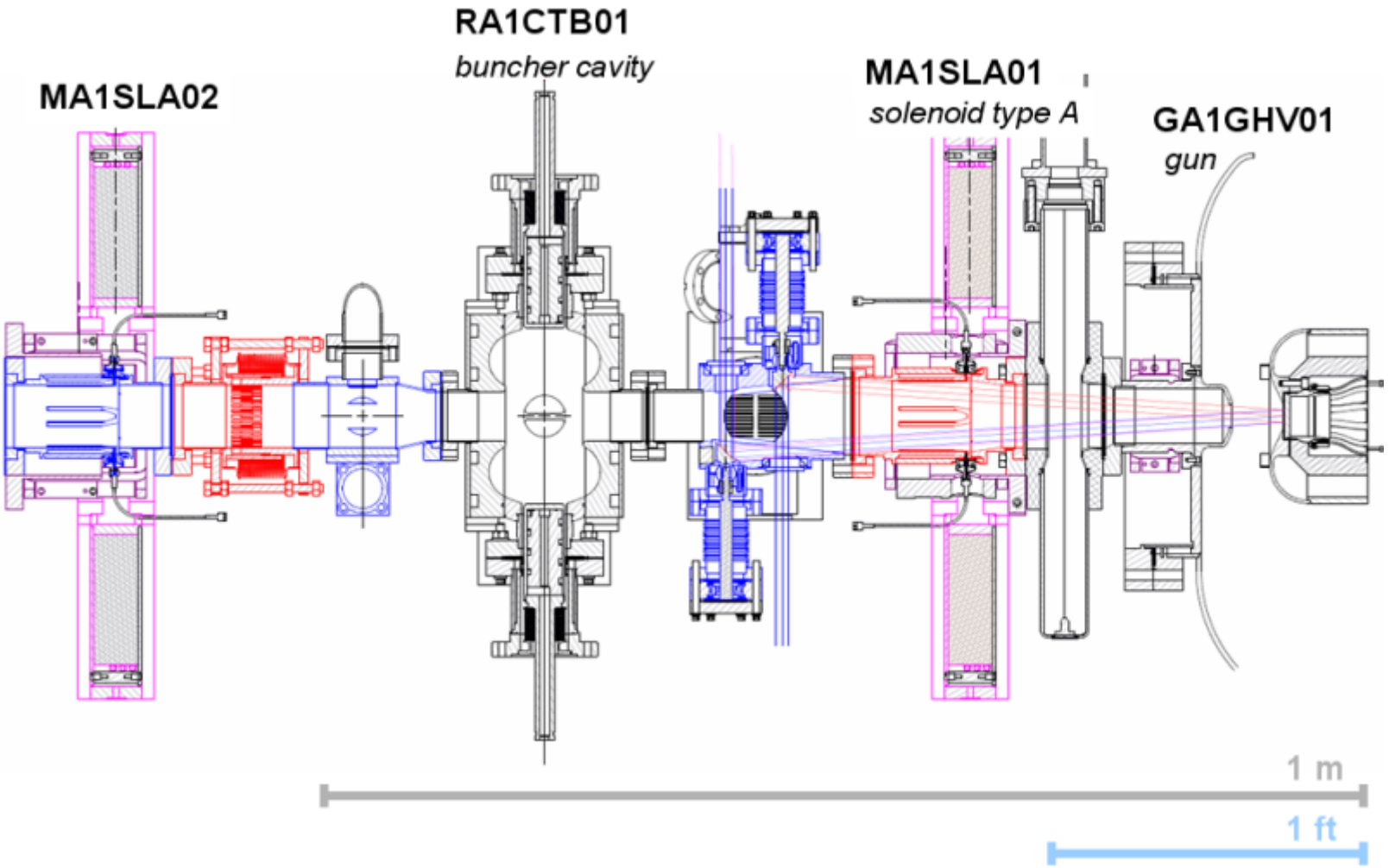
Time evolution of emittance

- Stdz = 0.3, 0.6 and 0.9 mm



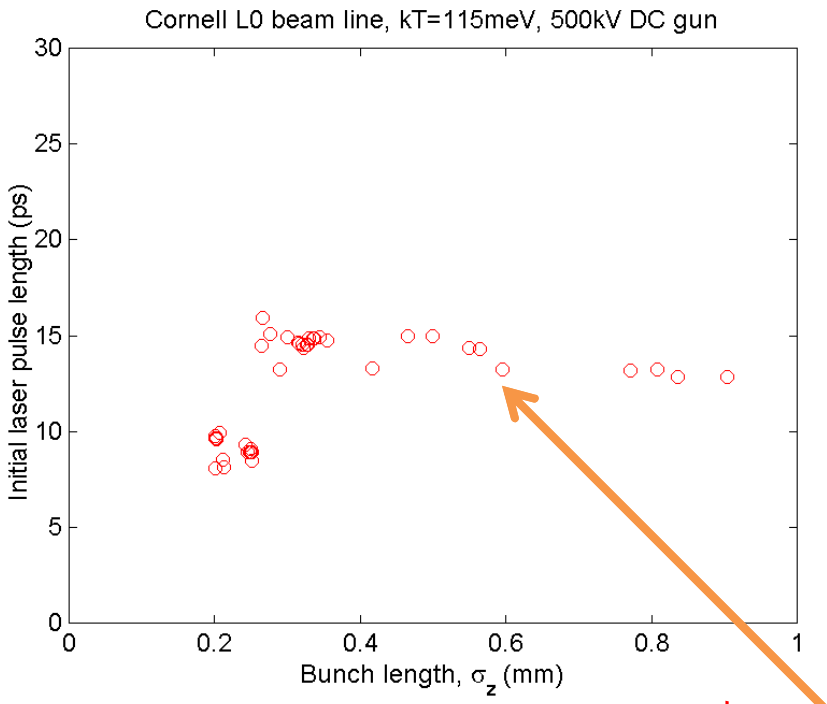


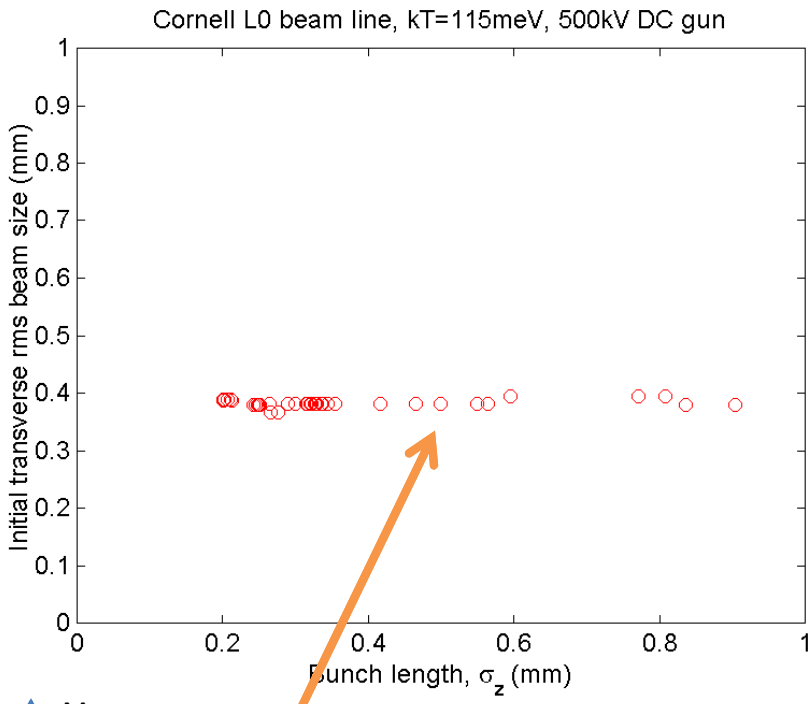
Gun and buncher area

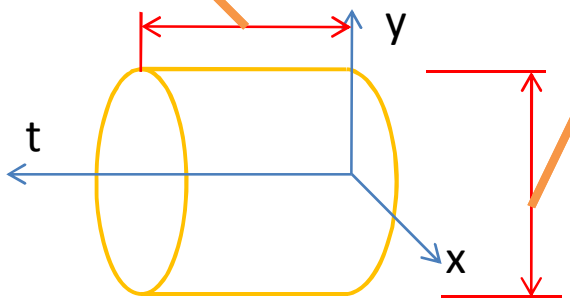


Initial laser pulse and beam size

- Initial laser pulse
  - 2 to 30 ps
- Initial transverse beam size
  - 0 to 2 mm

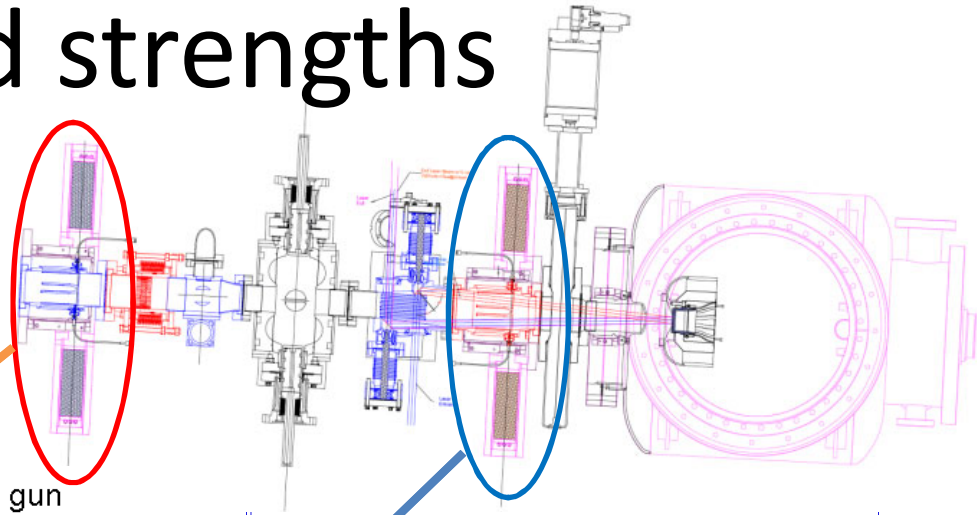


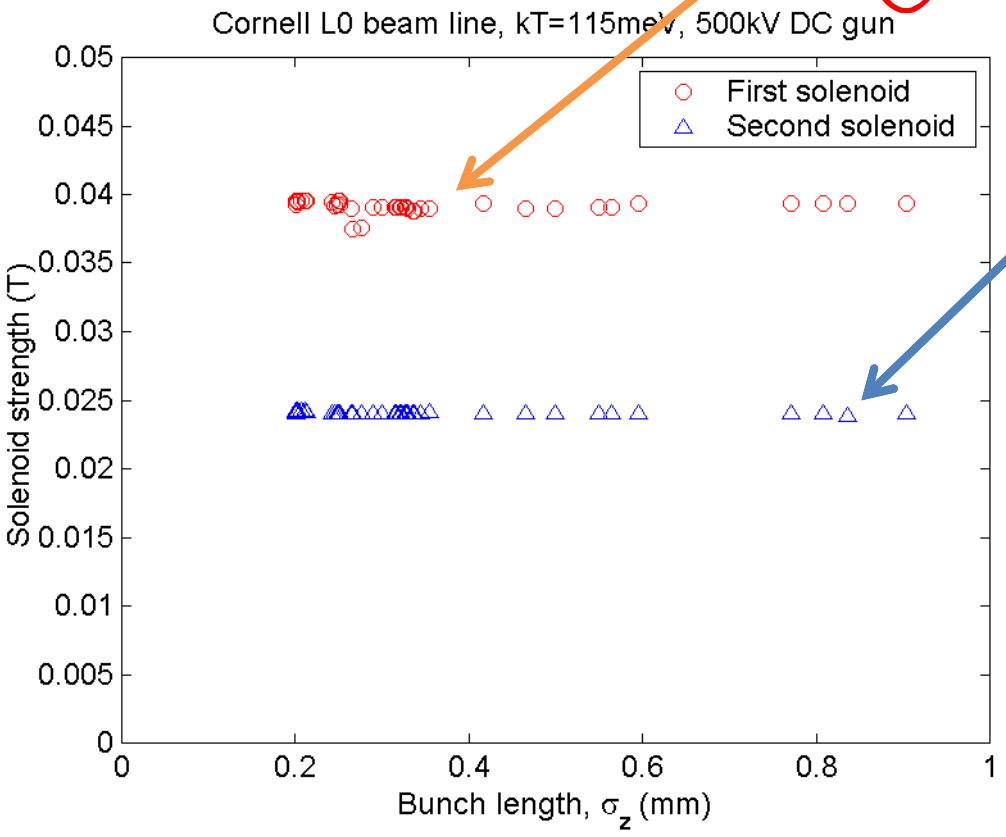


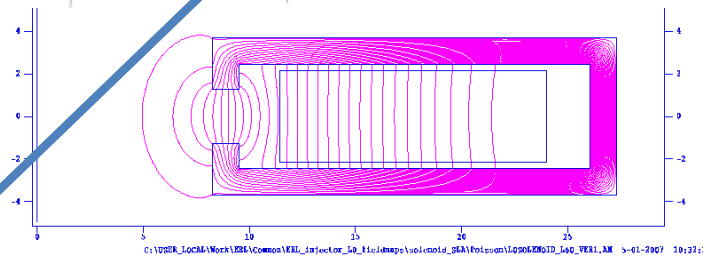


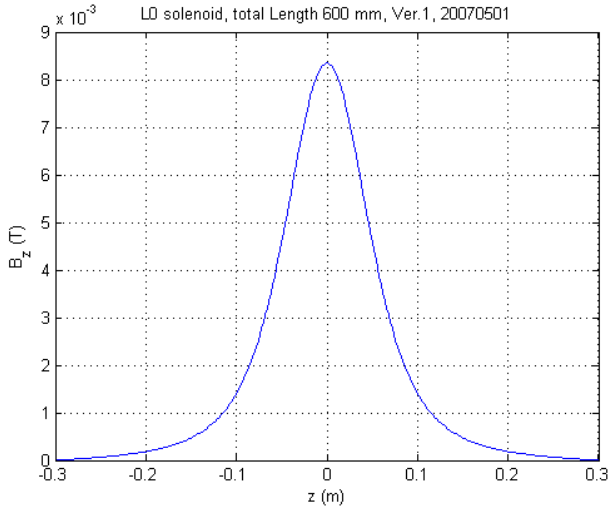
Solenoid strengths

- Solenoid 1 and 2
  - 0 to 0.1 T



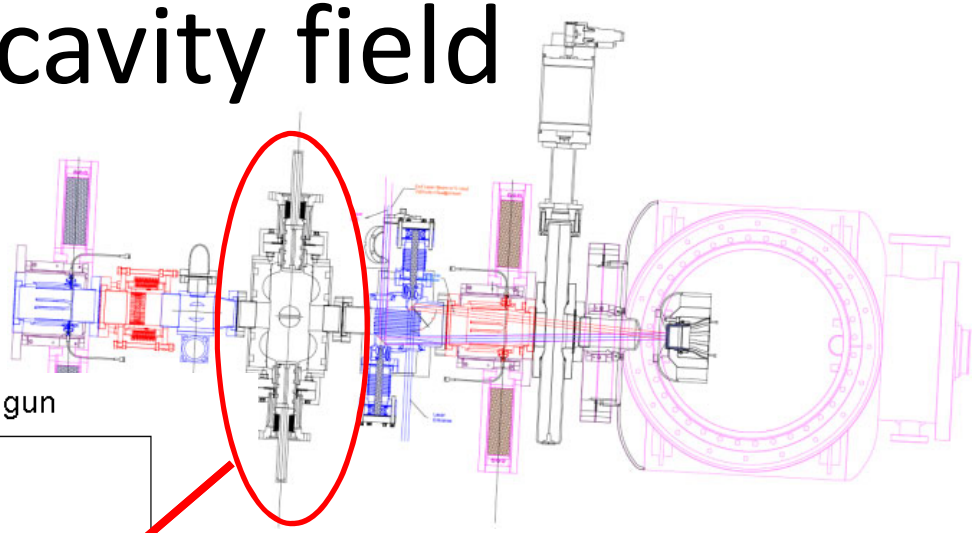


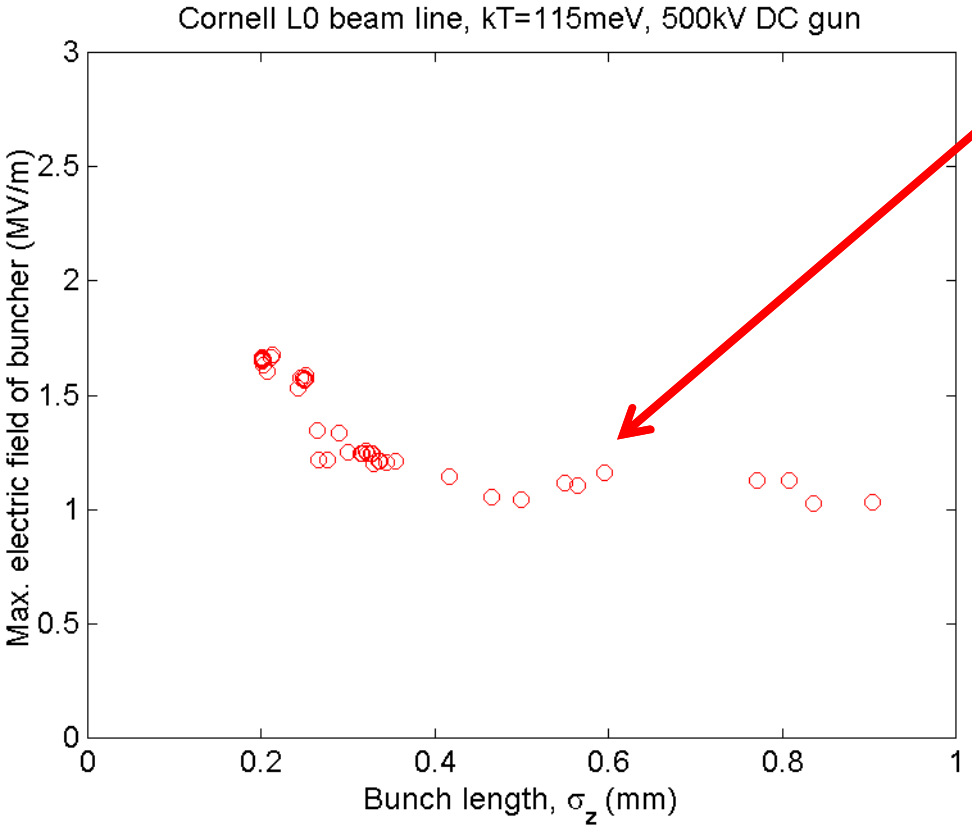


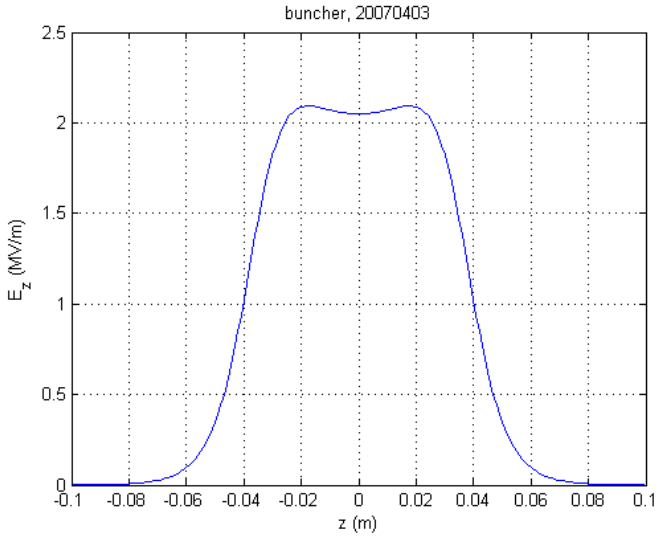


Buncher cavity field

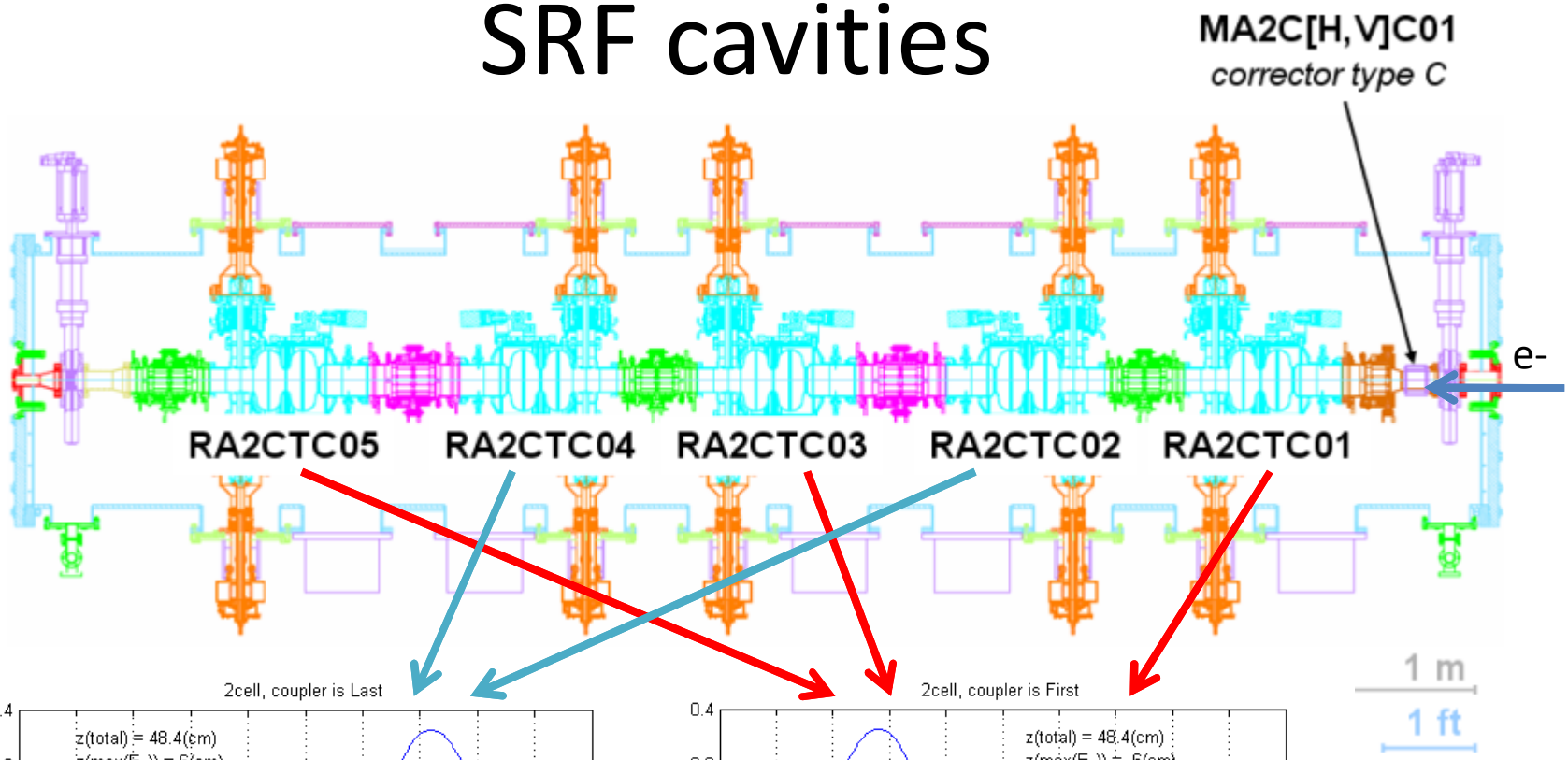
- Buncher
  - 0 to 10 MV/m

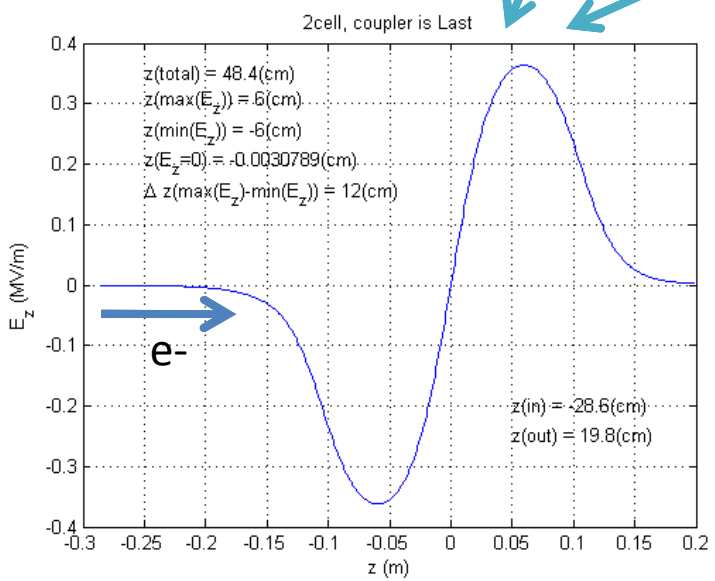


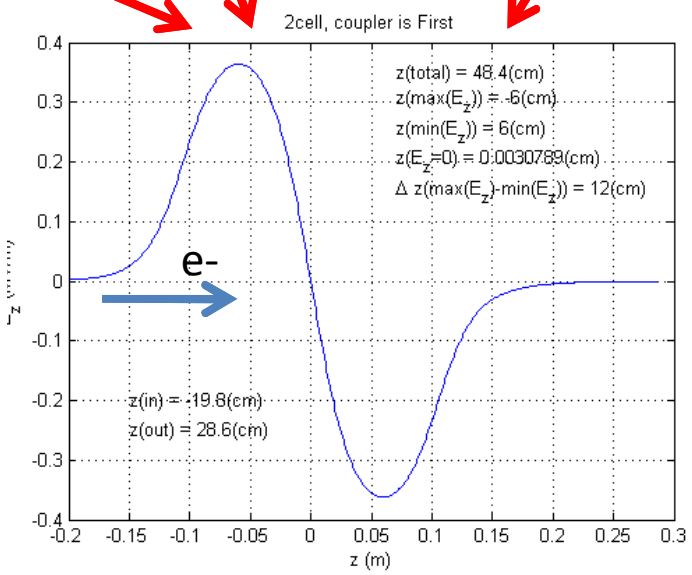




SRF cavities

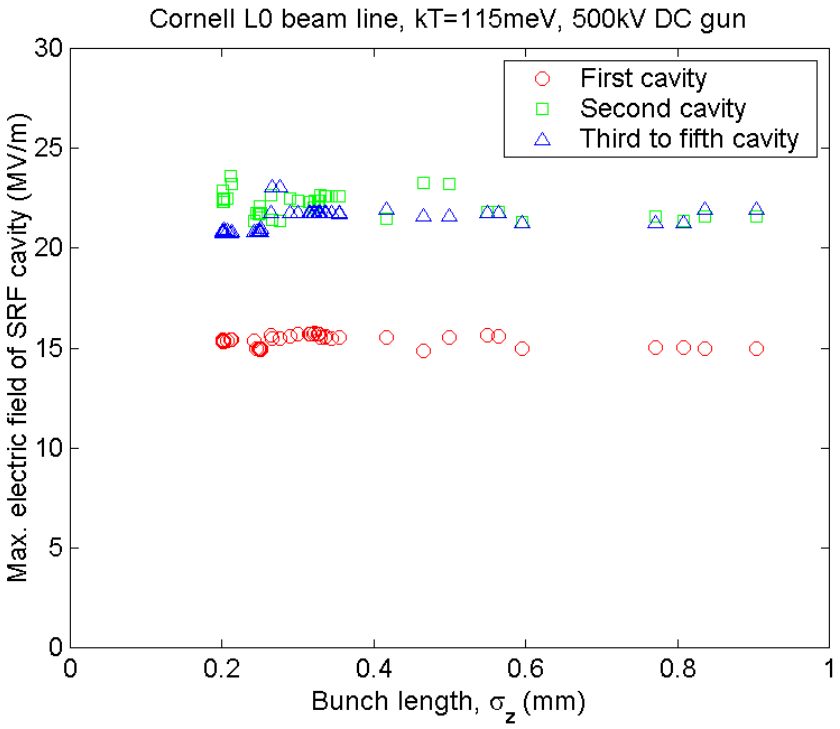


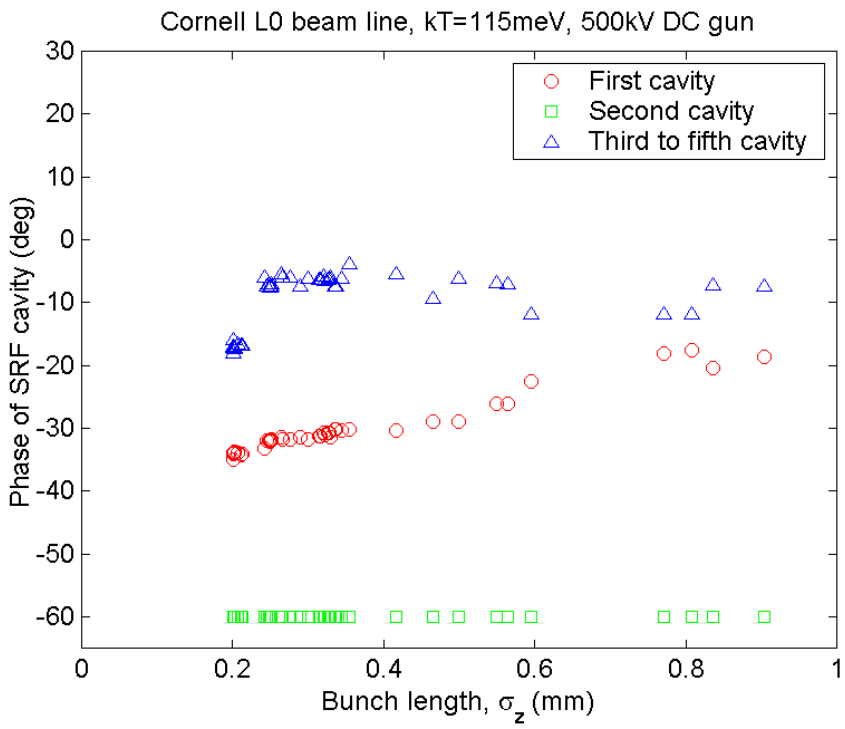




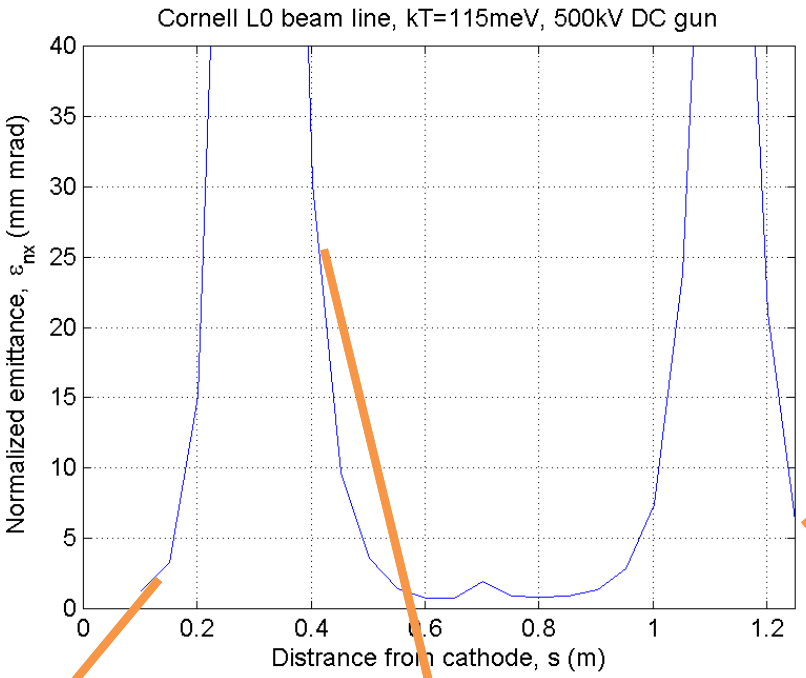
SRF cavity fields and phases

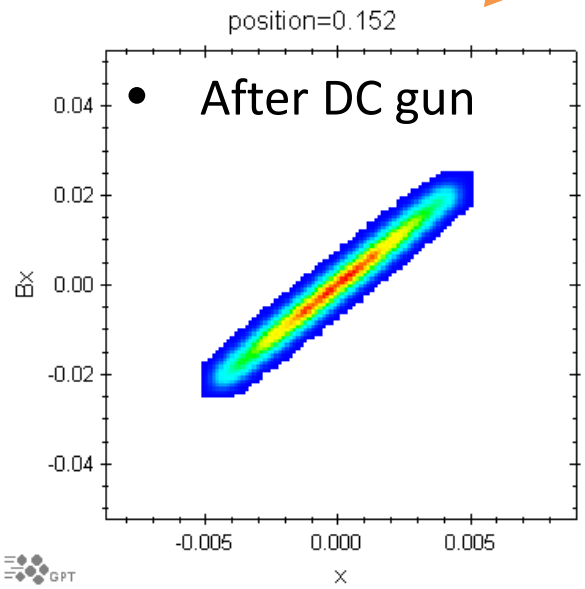
- Maximum fields
  - 1st cavity: 10 to 30 MV/m
  - 2nd cavity: 10 to 30 MV/m
  - 3rd to 5th cavity: 10 to 30 MV/m
- Phase offset
  - 1st cavity: -60 to 10 degree
  - 2nd cavity: -60 to 10 degree
  - 3rd to 5th cavity: -30 to 20 degree

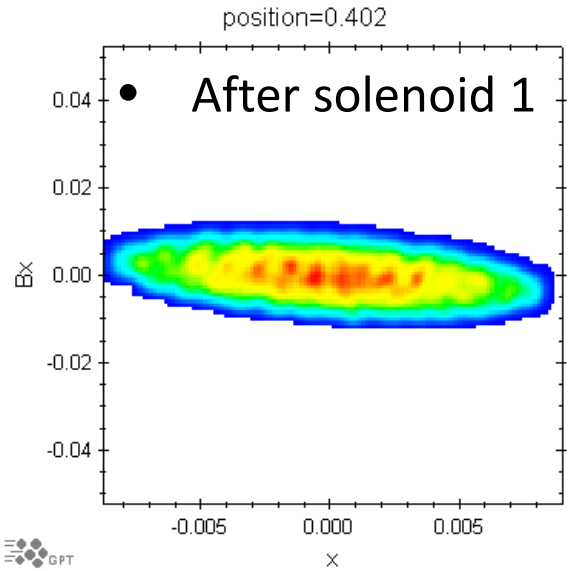


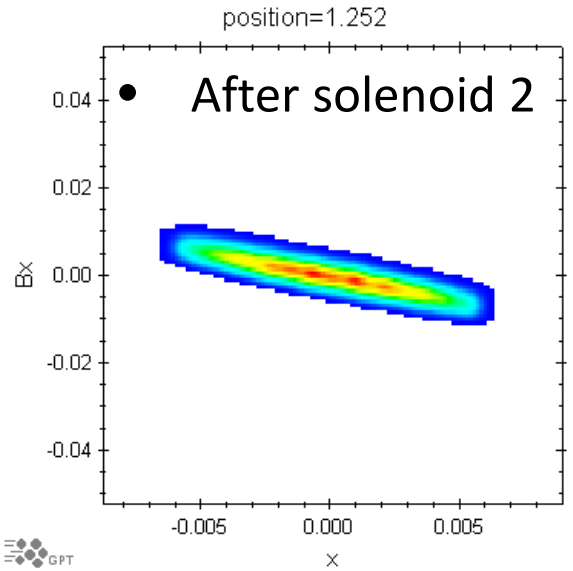


- Stdz = 0.9 mm

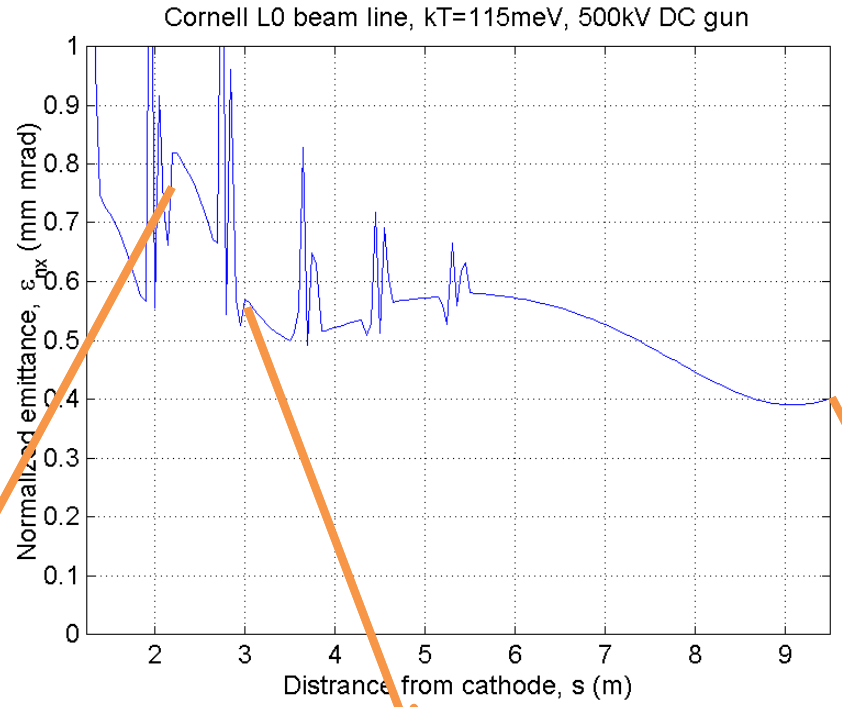

Cornell L0 beam line, kT=115meV, 500kV DC gun
Normalized emittance, ε_{nx} (mm mrad)
Distrance from cathode, s (m)
0
5
10
15
20
25
30
35
40
0.2
0.4
0.6
0.8
1
1.2

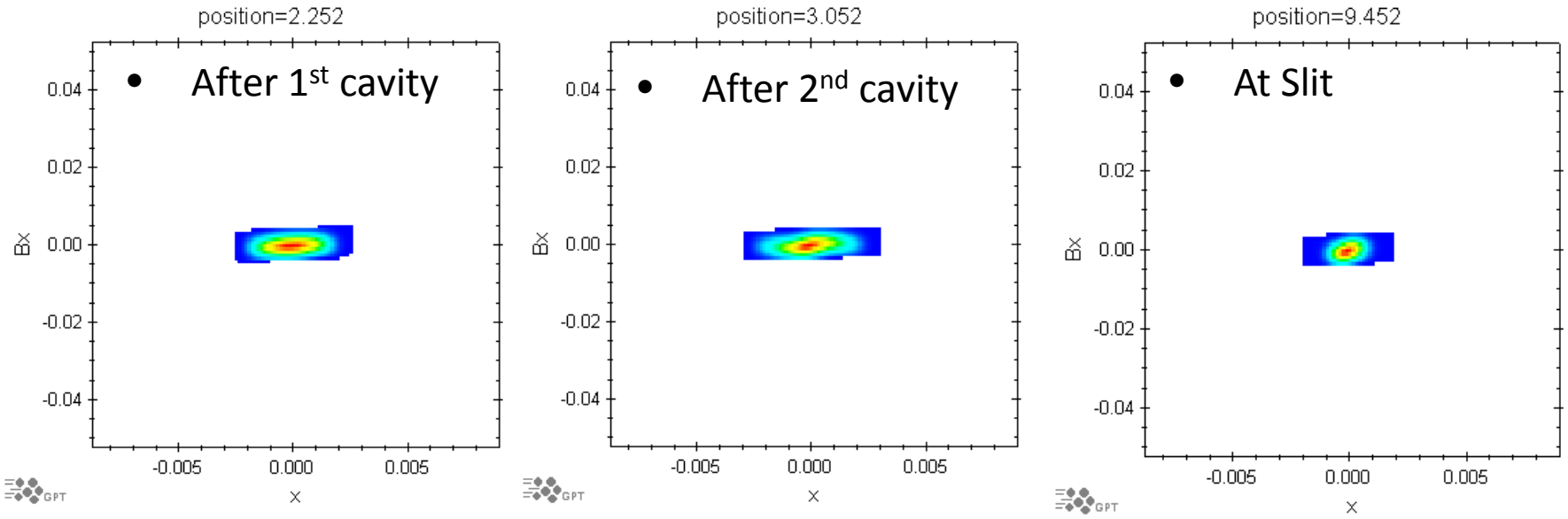

position=0.152
After DC gun
Bx
x
0.04
0.02
0.00
-0.02
-0.04
-0.005
0.000
0.005
GPT


position=0.402
After solenoid 1
Bx
x
0.04
0.02
0.00
-0.02
-0.04
-0.005
0.000
0.005
GPT


position=1.252
After solenoid 2
Bx
x
0.04
0.02
0.00
-0.02
-0.04
-0.005
0.000
0.005
GPT

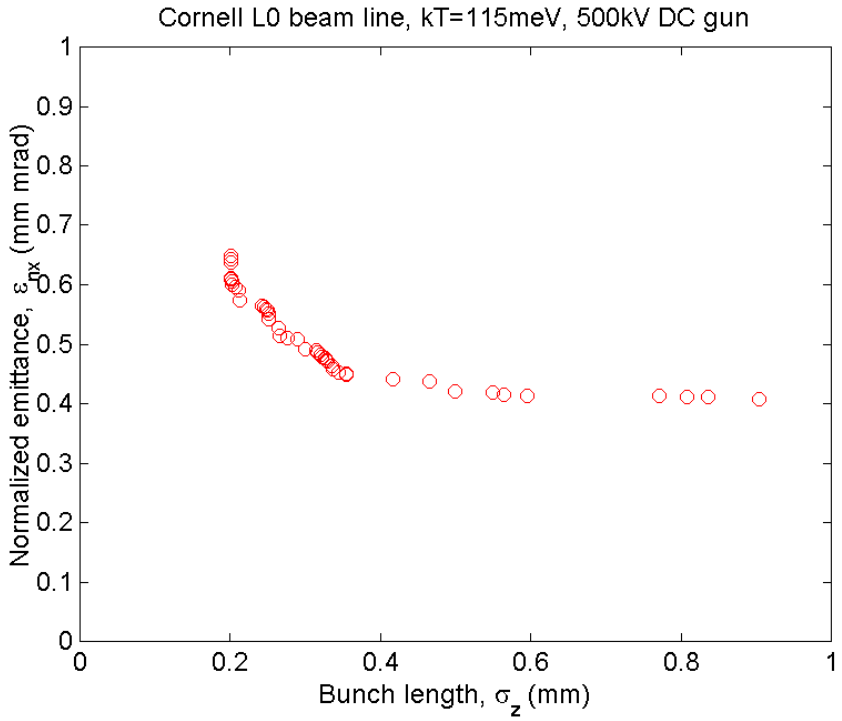
- Stdz = 0.9 mm


Cornell L0 beam line, kT=115meV, 500kV DC gun
Normalized emittance, ε_{nx} (mm mrad)
Distrance from cathode, s (m)


position=2.252
After 1st cavity
position=3.052
After 2nd cavity
position=9.452
At Slit
Bx
x

Optimum parameters for L0 beam line with 500 kV DC gun and kT = 115 meV

- Initial beam size
  - Laser pulse width: 10 to 15 ps
  - Transverse rms beam size: 0.4 mm
- Solenoid strengths
  - 1st solenoid: 0.025 T
  - 2nd solenoid: 0.04 T
- Buncher field
  - 1 to 1.5 MV/m



- 1st SRF cavity
  - Maximum field: 15 MV/m
  - Offset phase: -35 to -20 degree
- 2nd SRF cavity
  - Maximum field: 22 MV/m
  - Offset phase: -60 degree
- 3rd to 5th SRF cavities
  - Maximum field: 22 MV/m
  - Offset phase: -10 to -5 degree