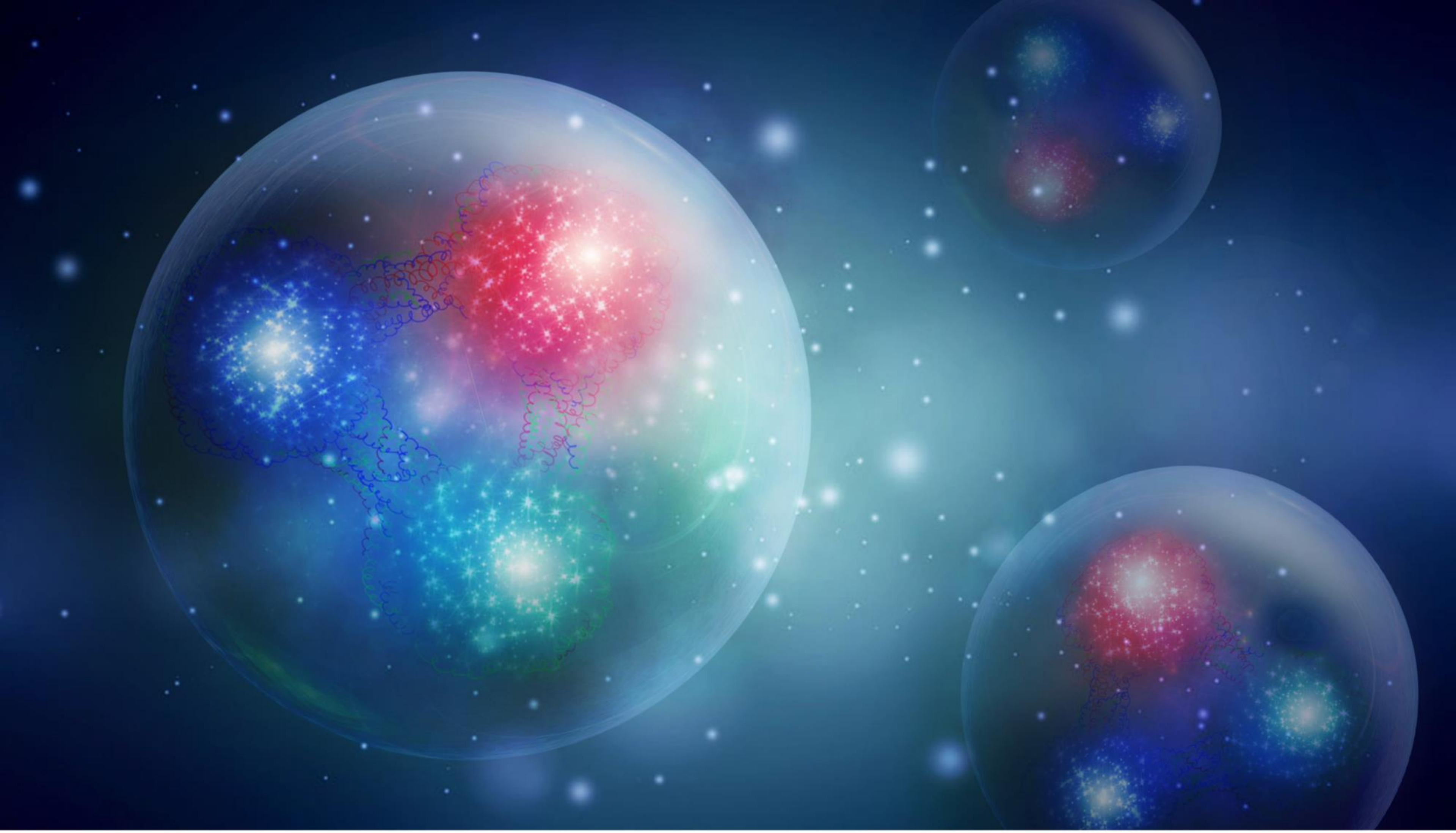


Magnetized Beam Simulations (LDRD)

Fay Hanon

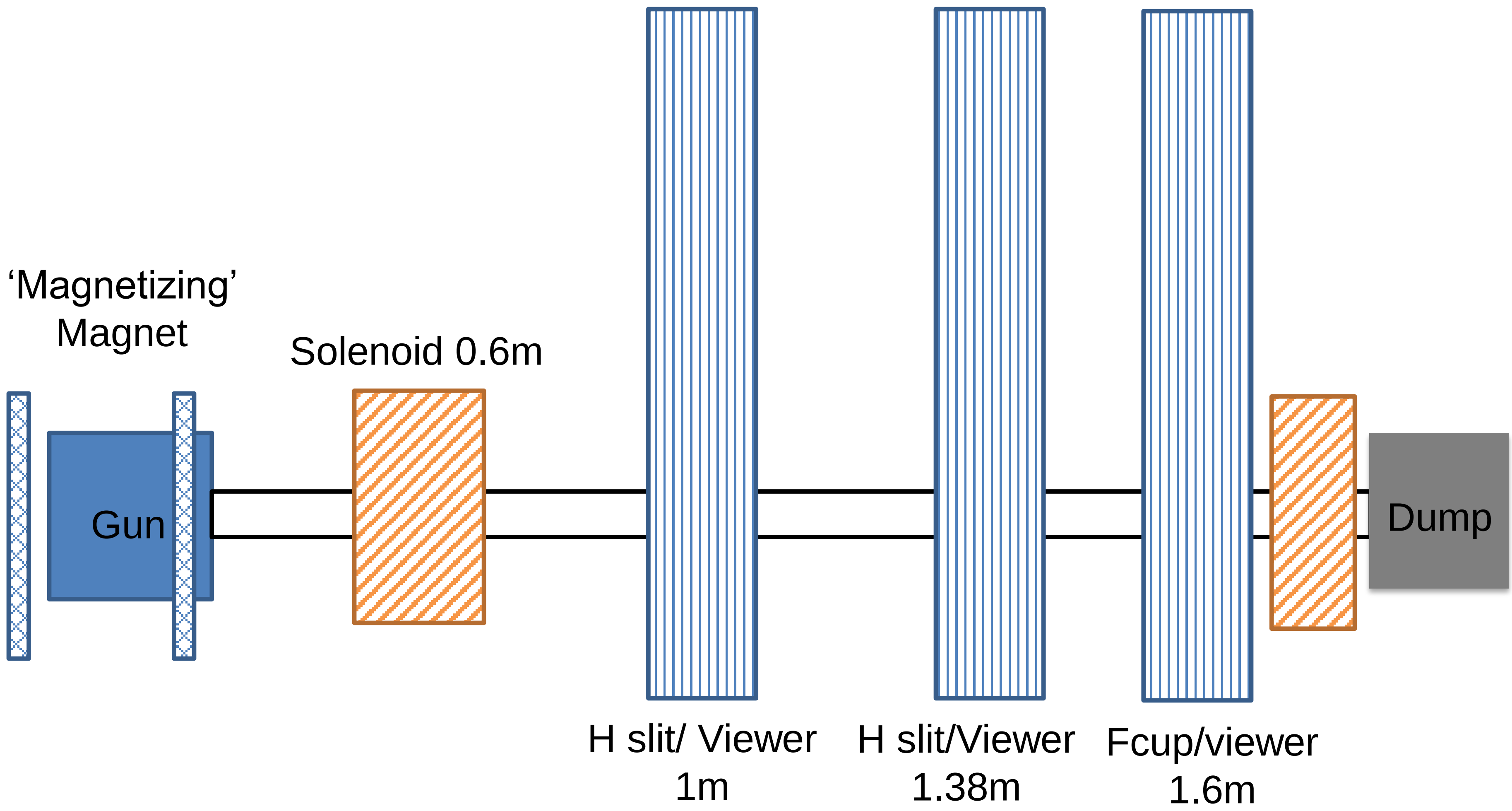
March 29, 2016

OVERVIEW

Goals

- Produce a magnetized beam from a 350kV DC gun
- Measure magnetization
- Measure emittance
- Demonstrate a round to flat transform

Beamline



'Magnetizing'
Magnet
Solenoid 0.6m
Gun
Dump
H slit/ Viewer
1m
H slit/Viewer
1.38m
Fcup/viewer
1.6m

Beamline

diagnostics

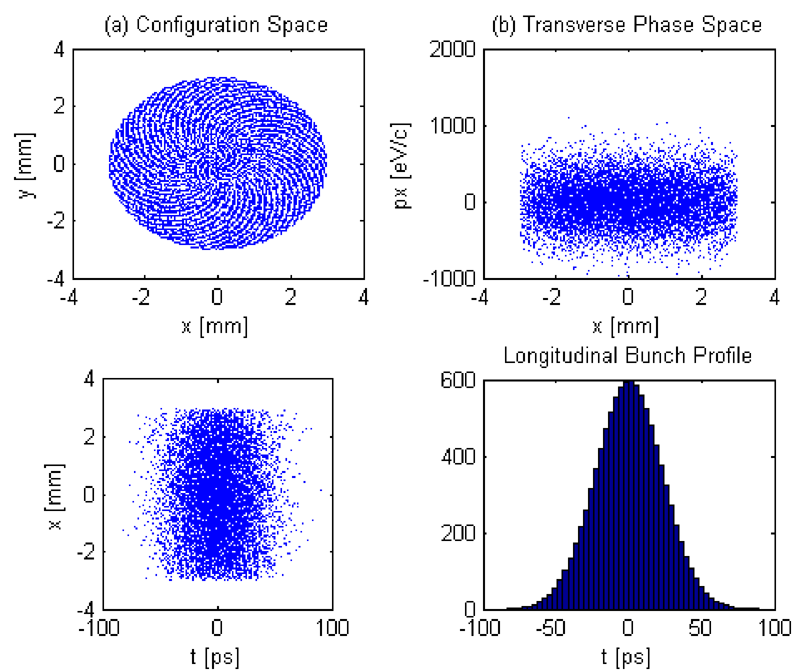
solenoid

Cathode
prep
chamber

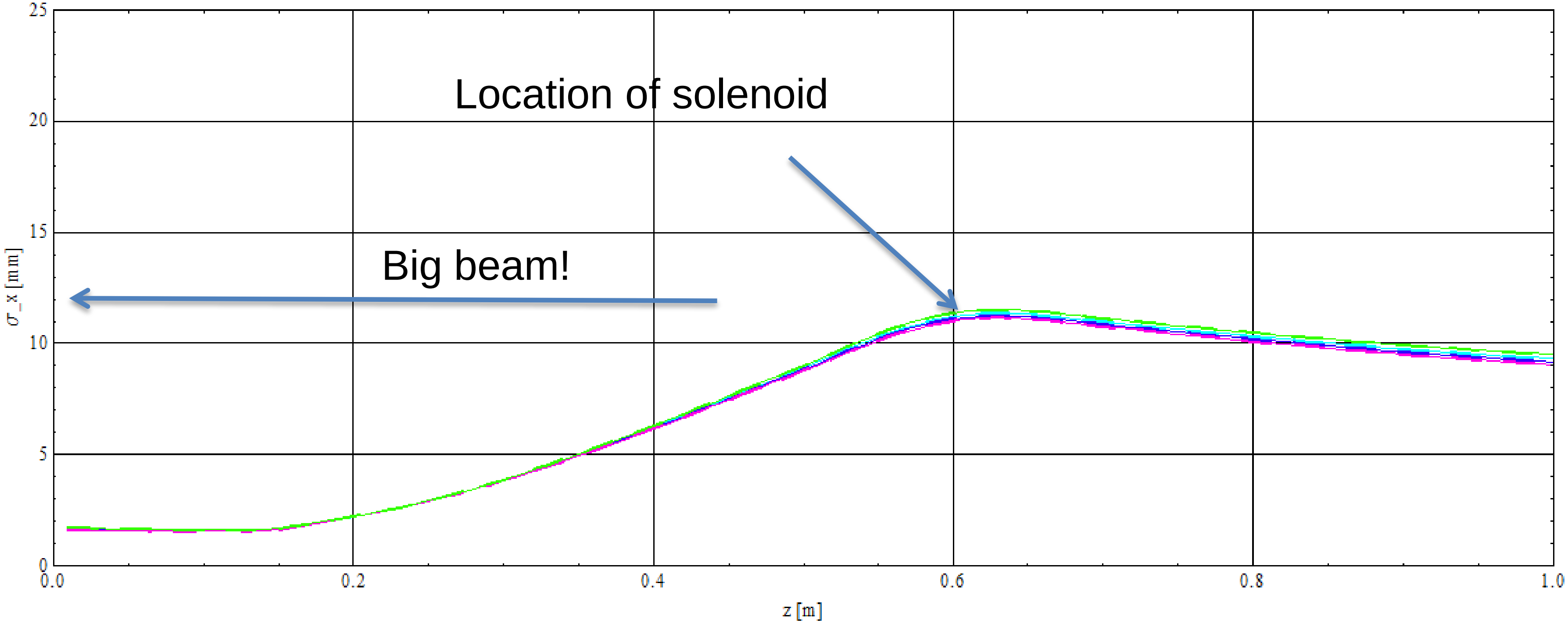
Gun

Beam Evolution

Parameter	
Cathode Bz	0.2T
XY_rms, top-hat	1.5mm
t rms, Gaussian	23ps
Charge	0 – 420pC
Gun voltage	350kV



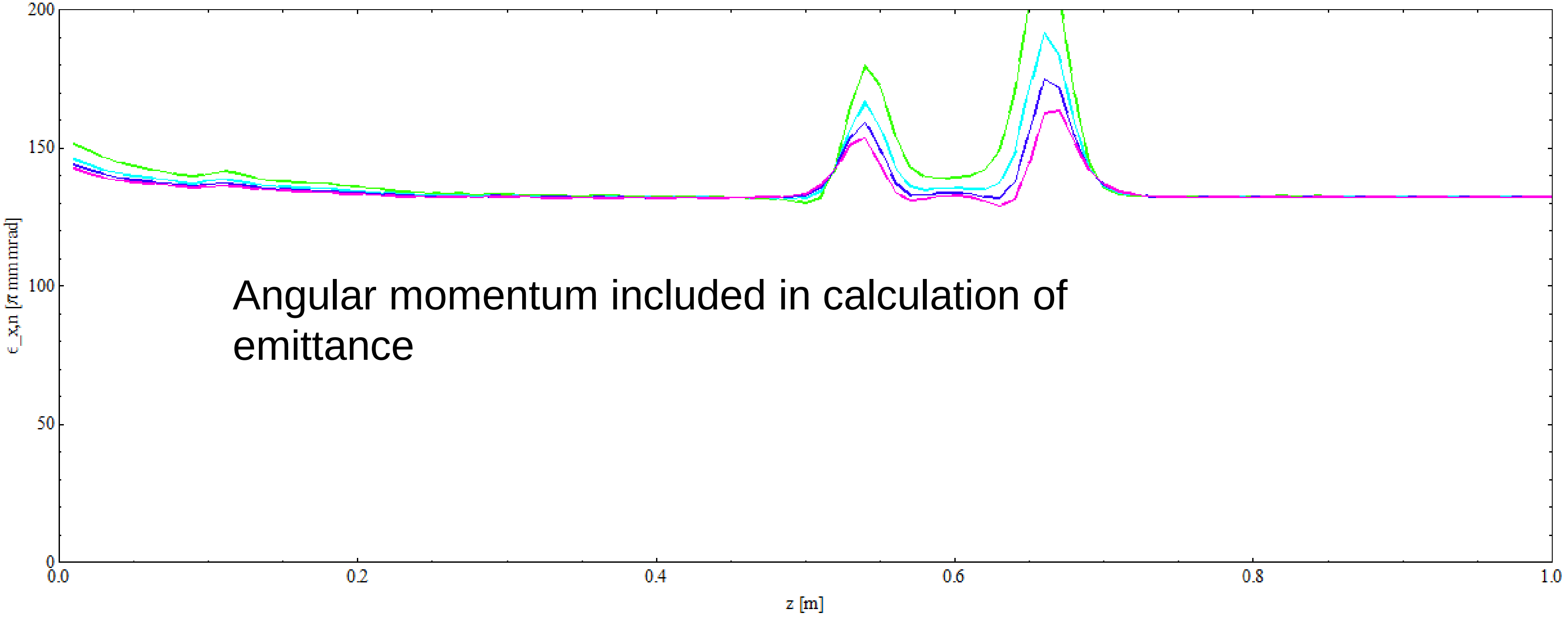
Transverse rms beam size



20pC, 100pC, 210pC, 420pC

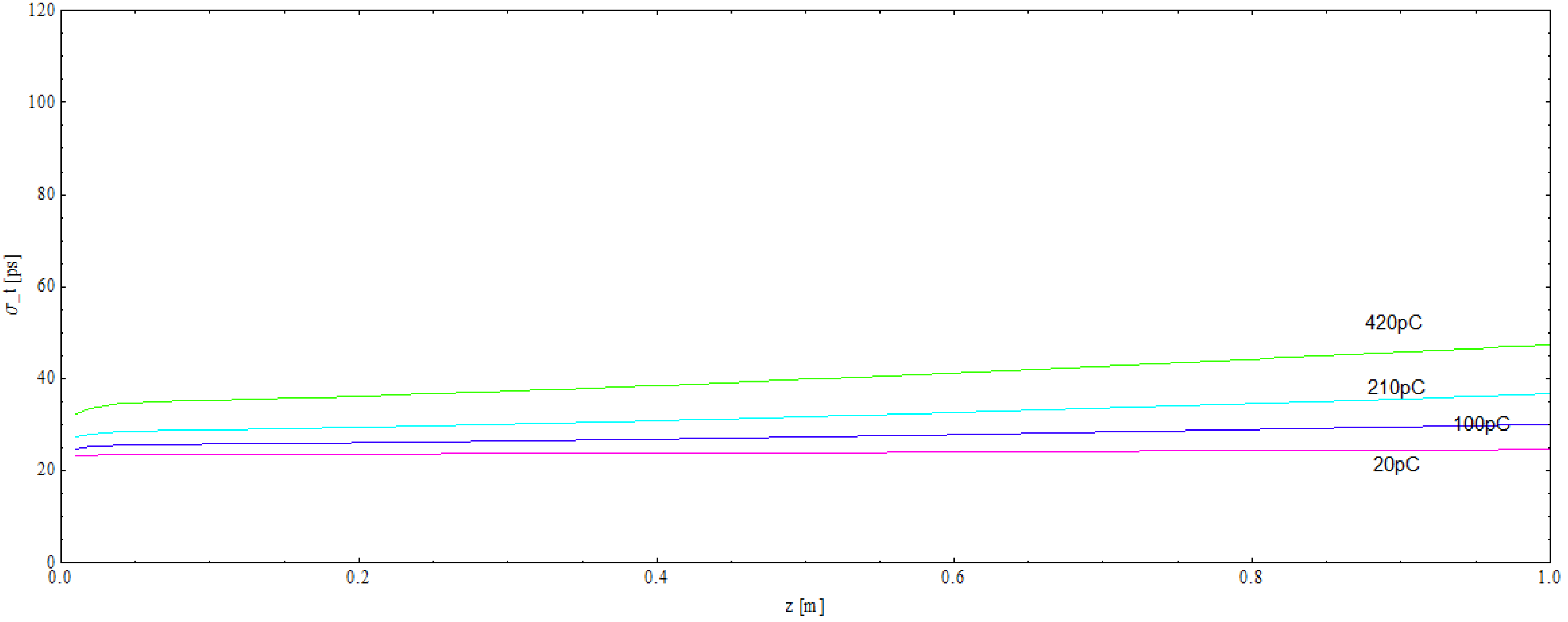
TRANSPORT THE SAME: DOMINATED by canonical angular momentum!

Transverse normalize trace-space emittance



Angular momentum included in calculation of emittance

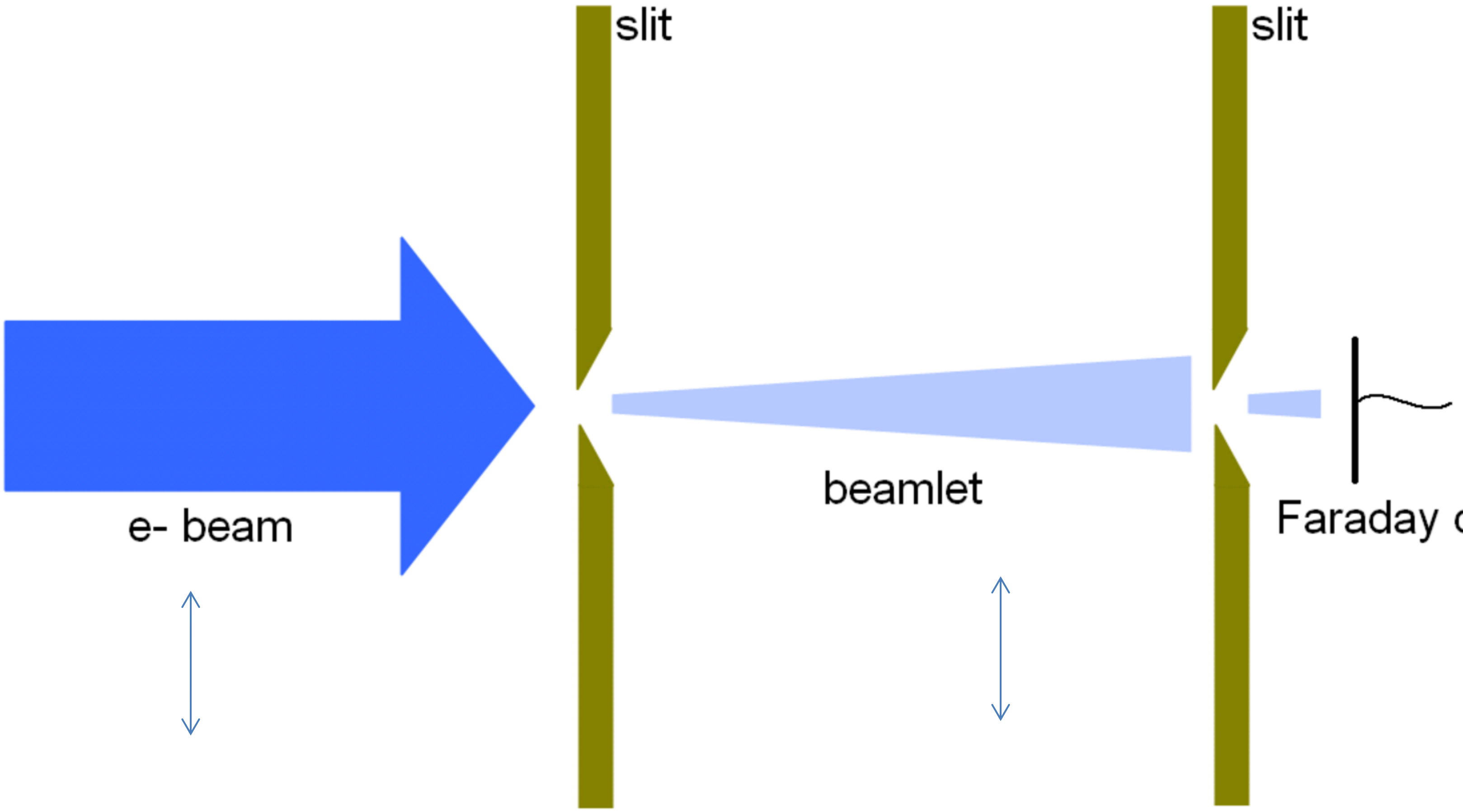
Bunch length rms



Longitudinally we see space charge as usual.

MEASUREMENTS
- EMITTANCE

Double slit emittance measurement

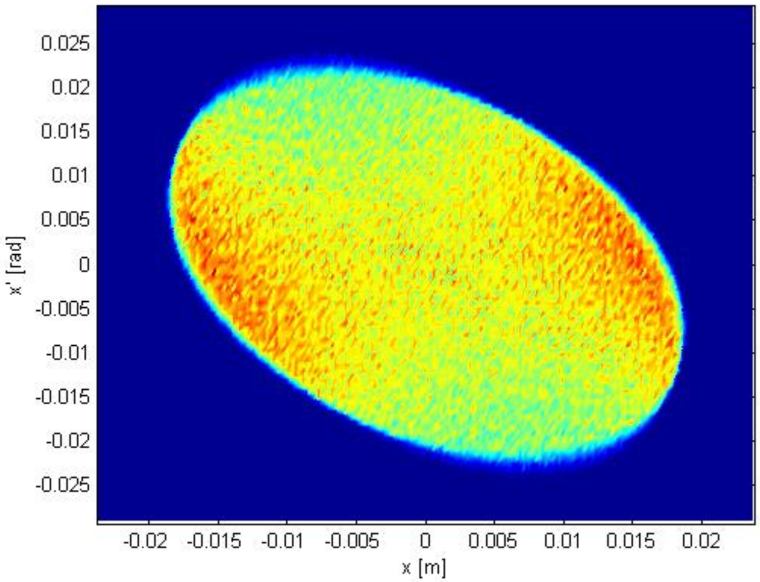


Double slit virtual experiment

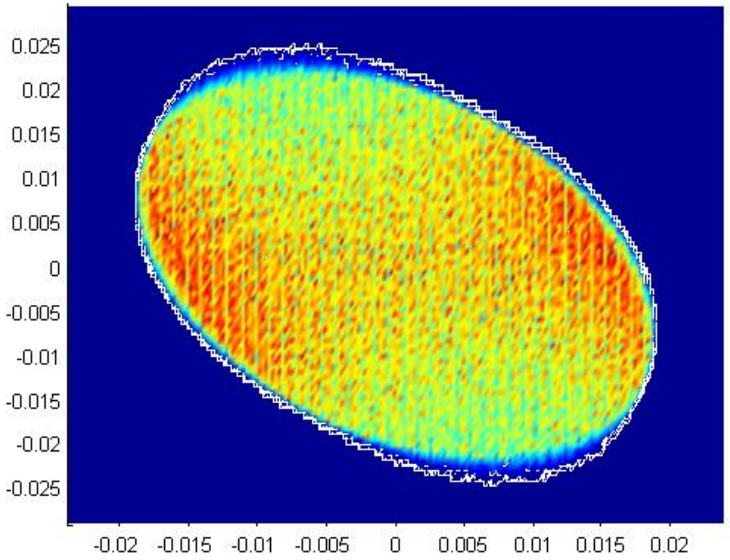
- At the diagnostic, break the beam up into beamlets transversely to simulate the beam scanning over the slit
- Let the beamlet particles drift to the second slit location (removing any that intercept the diagnostic)
- Break the beamlet up into more beamlets
- Count particles in each sub beamlet
- Produce phase space

Virtual result

Directly from simulation



Reconstructed via 2 slit method



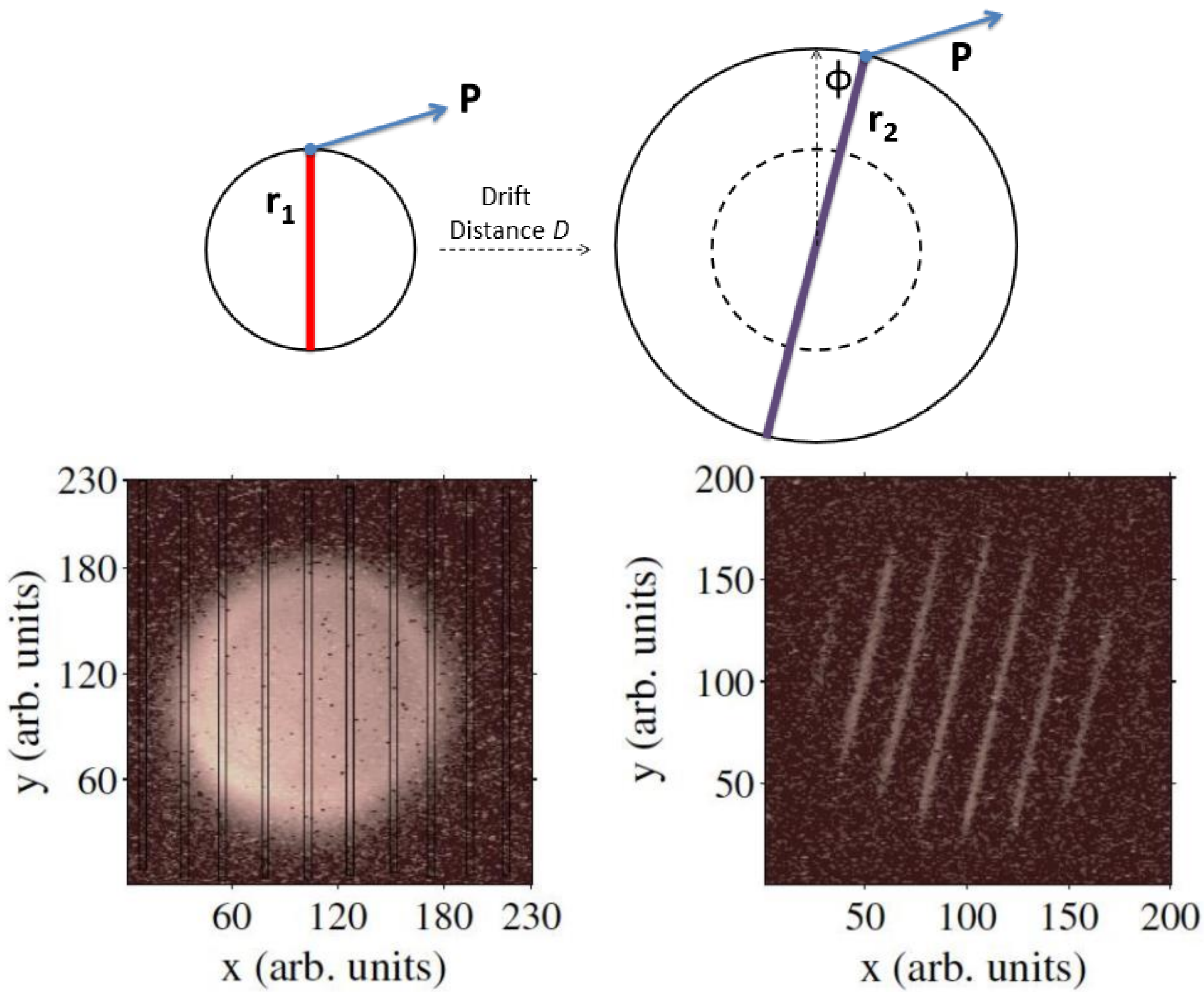
Can change slit size and spacing to get best design

MEASUREMENTS
- MAGNETIZATION

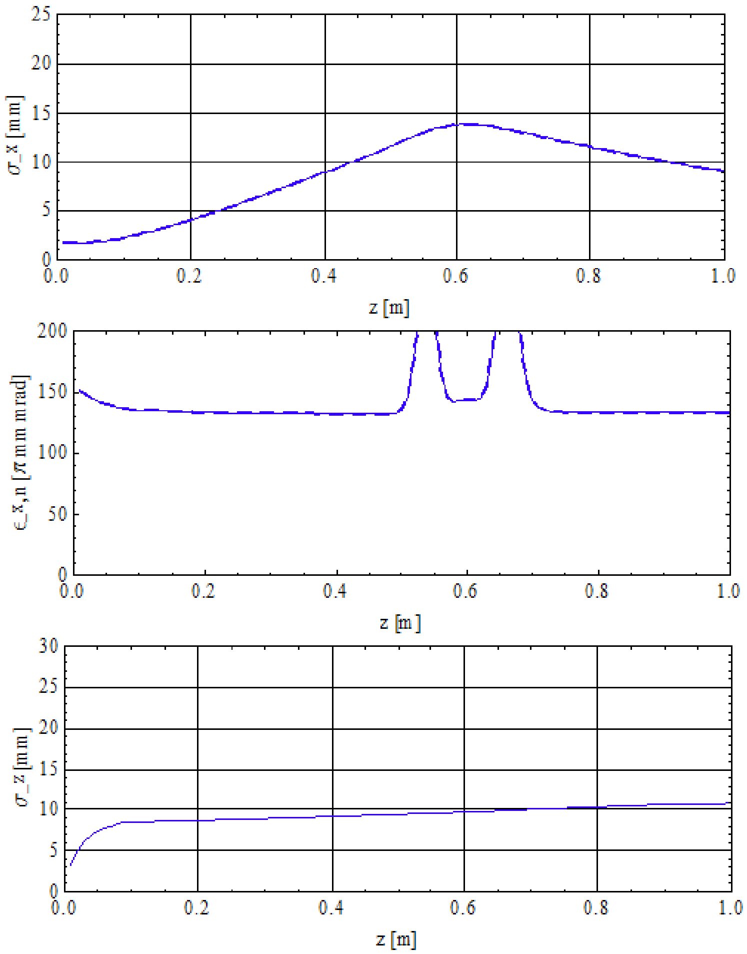
Magnetization/Angular momentum

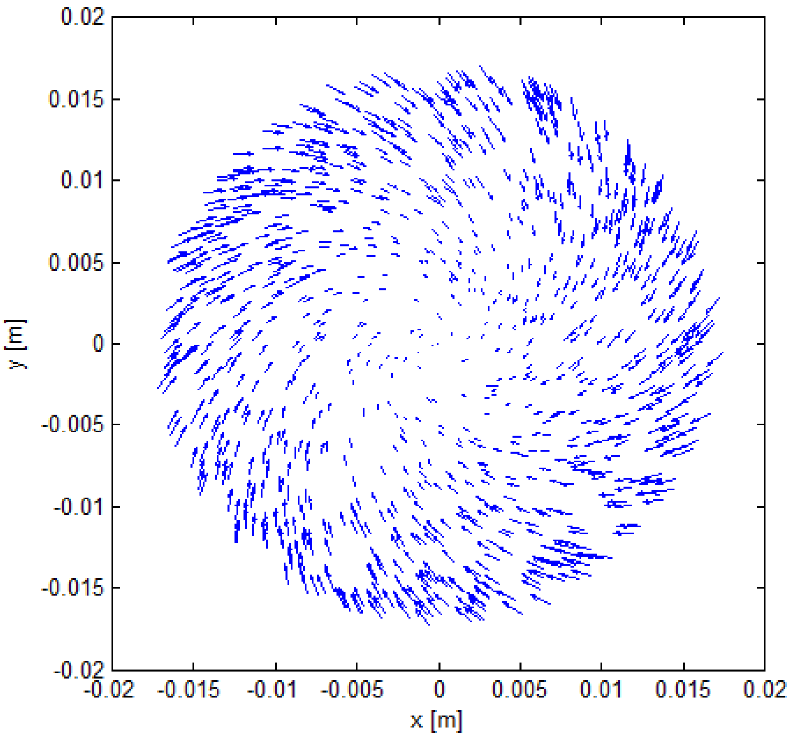
- Insert a slit into the beamline to select an emittance-dominated beamlet.
- Let the beamlet drift to a screen and image it.
- $< L >= \frac{2p_z\sigma_1\sigma_2 \sin\theta}{D} = B_z e {a_0}^2$
  - σ_1: beam rms at diagnostic cross 1
  - σ_2:beam rms at diagnostic cross 1
  - D: drift between diagnostics, θ: angular rotation, pz : longitudinal momentum

Fermilab experiment

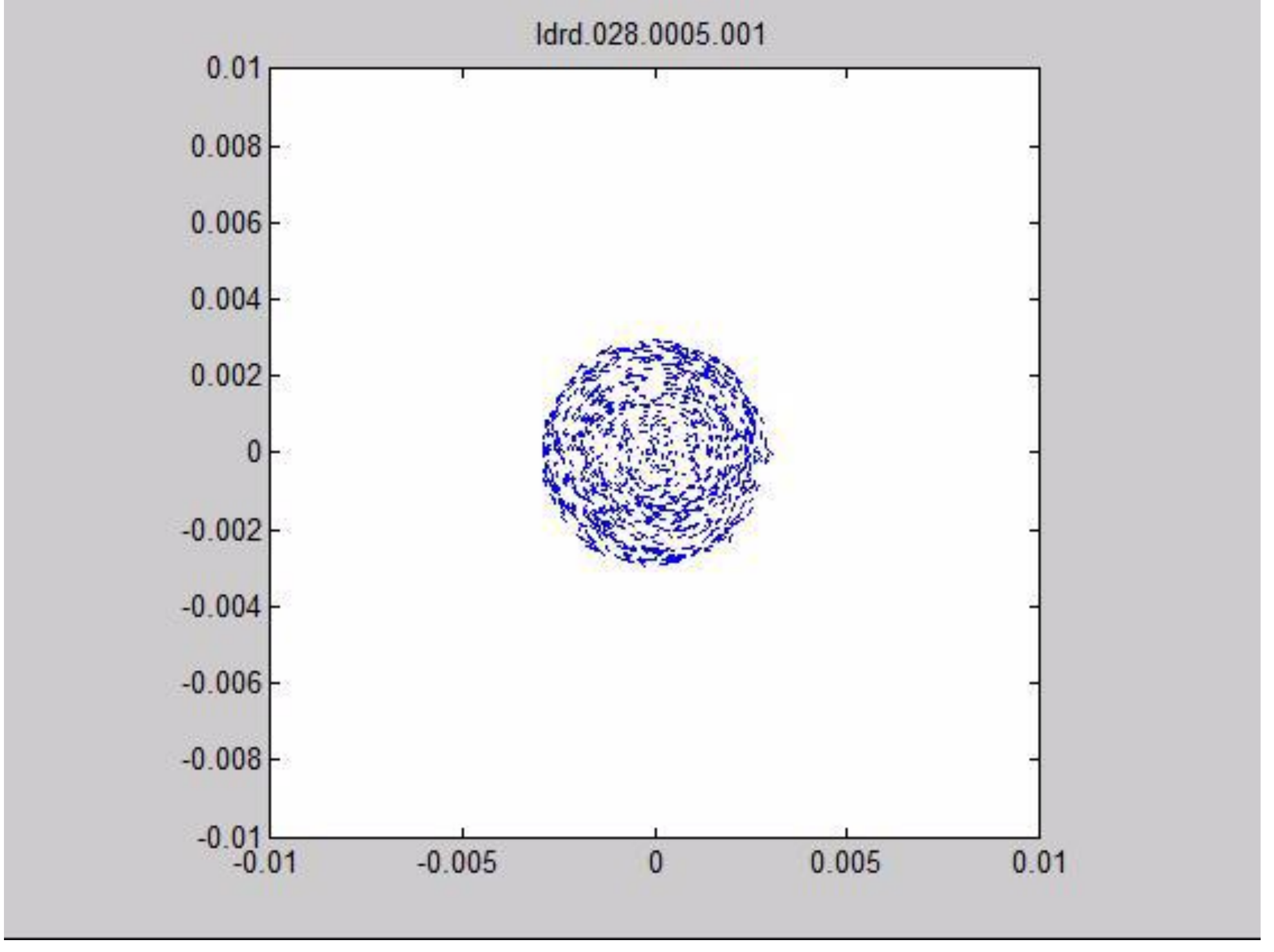


Example beam





Movie

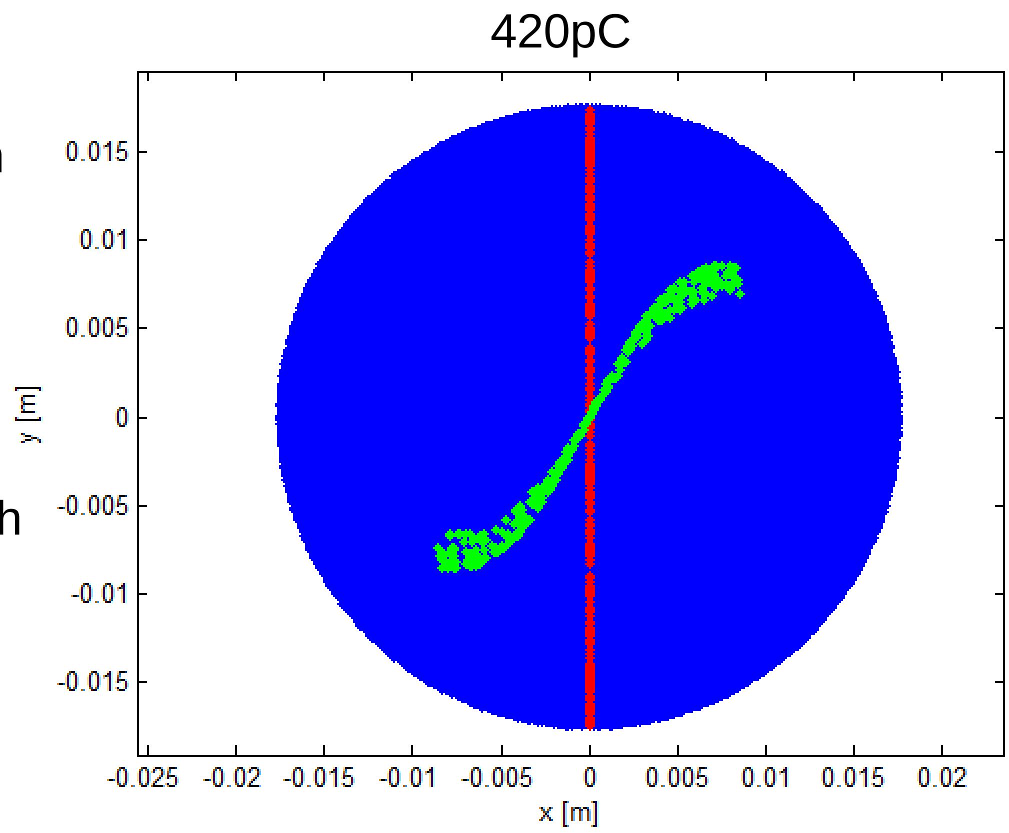


ldrd.028.0005.001
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
-0.01
-0.005
0
0.005
0.01

Magnetization virtual experiment

Blue – beam at the slit (500k, 20um slit)
Red – particles selected by slit
Green – particles tracked to screen 0.26m away

Not linear!
Assumes a solenoid at cathode with 0.2T peak
0.07% particles through slit

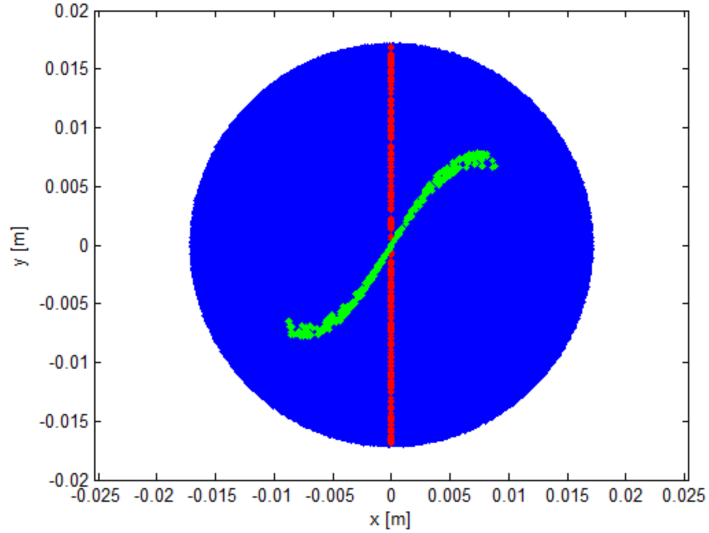


Ldrd.009.0100.001
Nrad=70, Nlong_in=100

Magnetization virtual experiment

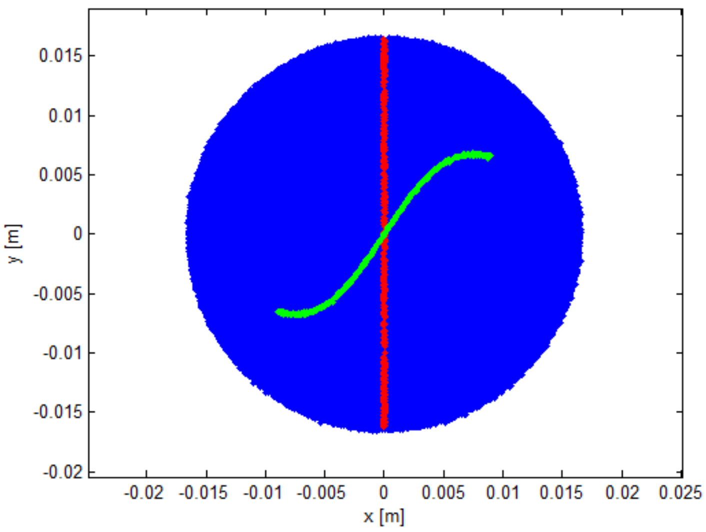
This isn't charge related.

210pC



Ldrd.009.0100.002

20pC

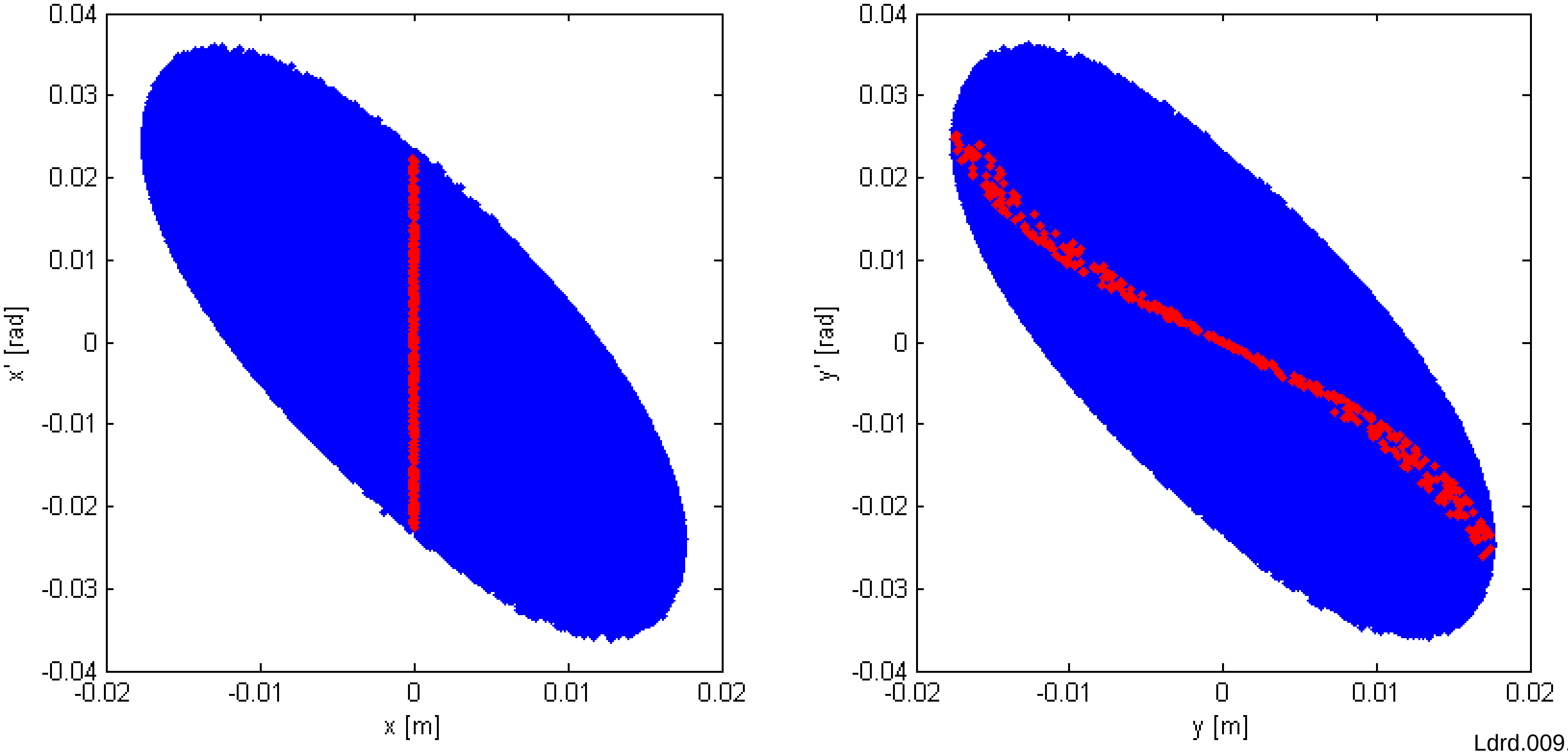


The curve is still evident at 20pC.

Ldrd.009.0100.004
Nrad=70,
Nlong_in=100

Phase space plots

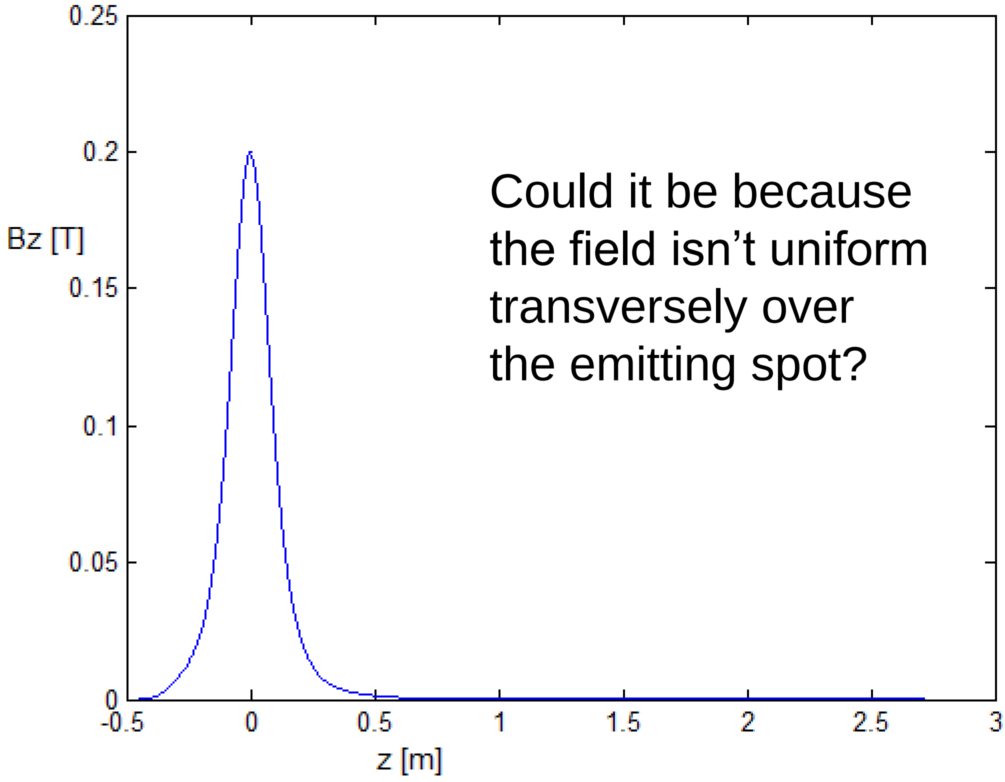
This is what the slit cuts out in phase space



Ldrd.009.0100.001

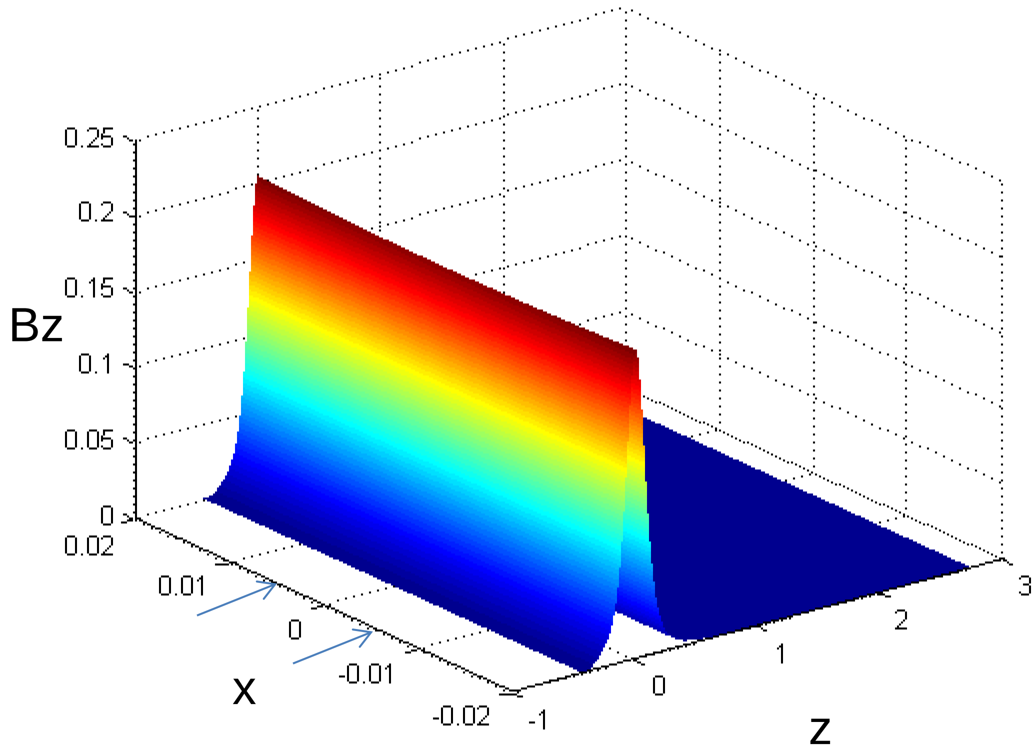
Why is there an ‘S’?

This is the solenoid field I used…



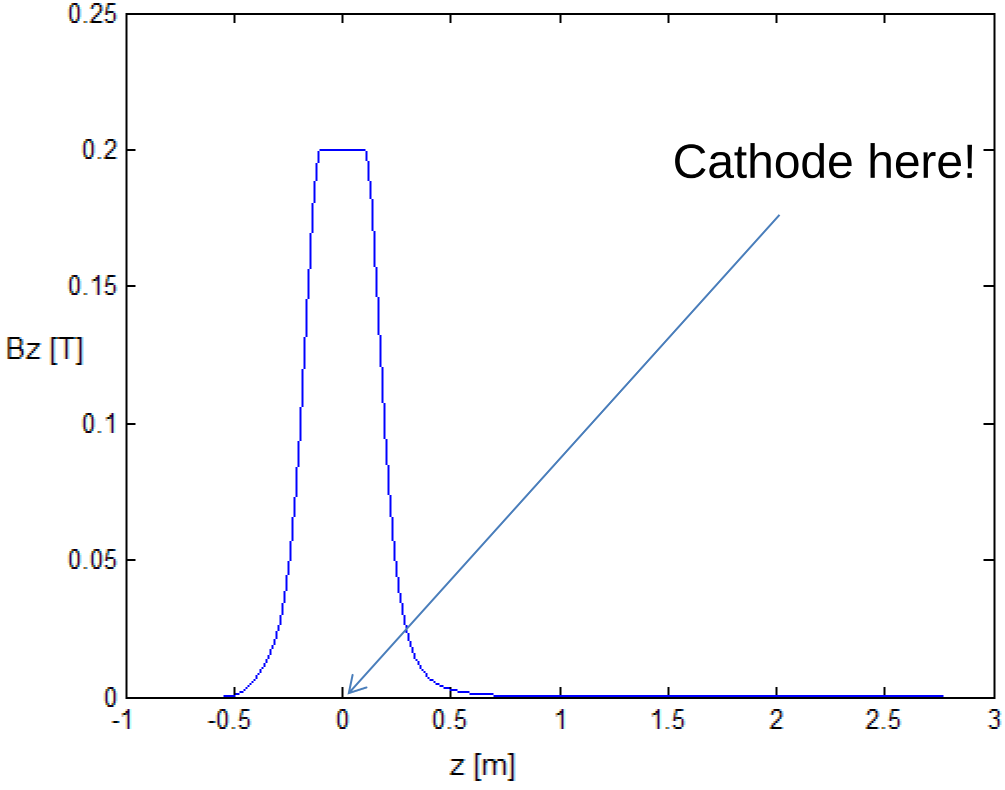
Why is there an ‘S’?

- This is what simulation assumes off axis
- Slight variation



Why is there an ‘S’?

Make fake field map.

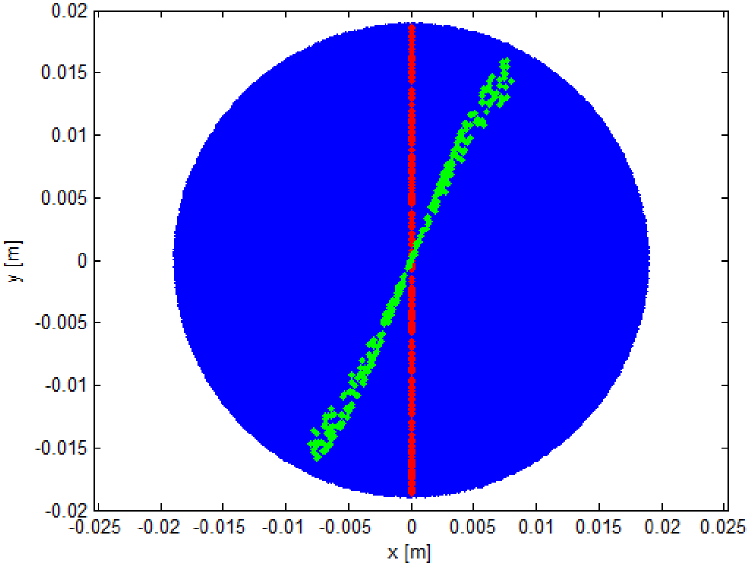


Make fake Helmholz pair field

Compare

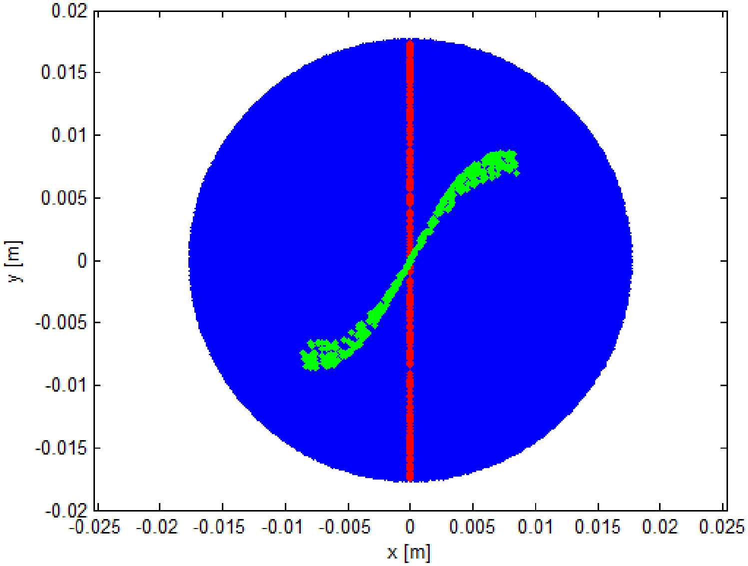
Both 420pC

Fake Helmholtz coil



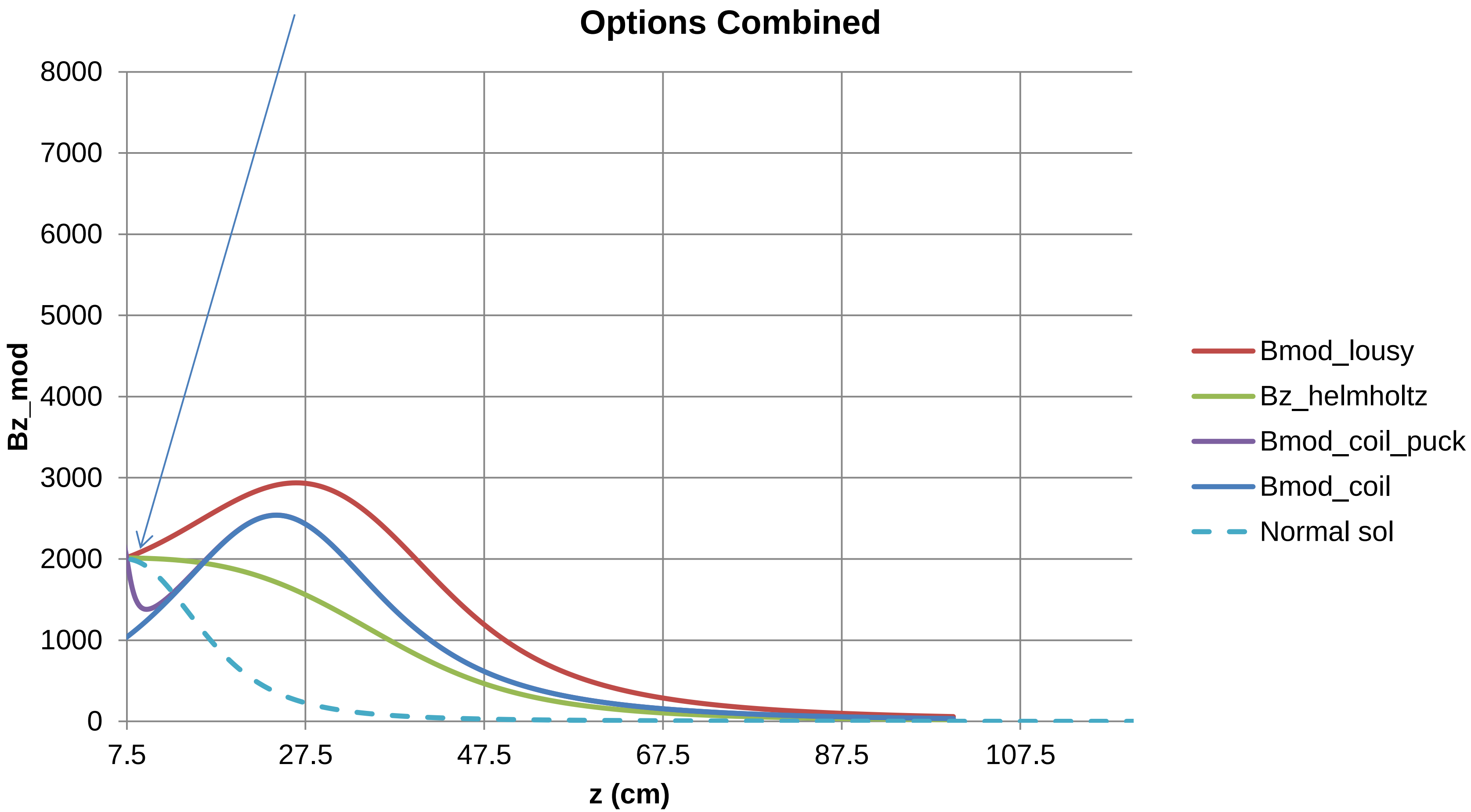
Ldrd.010.001

Standard solenoid

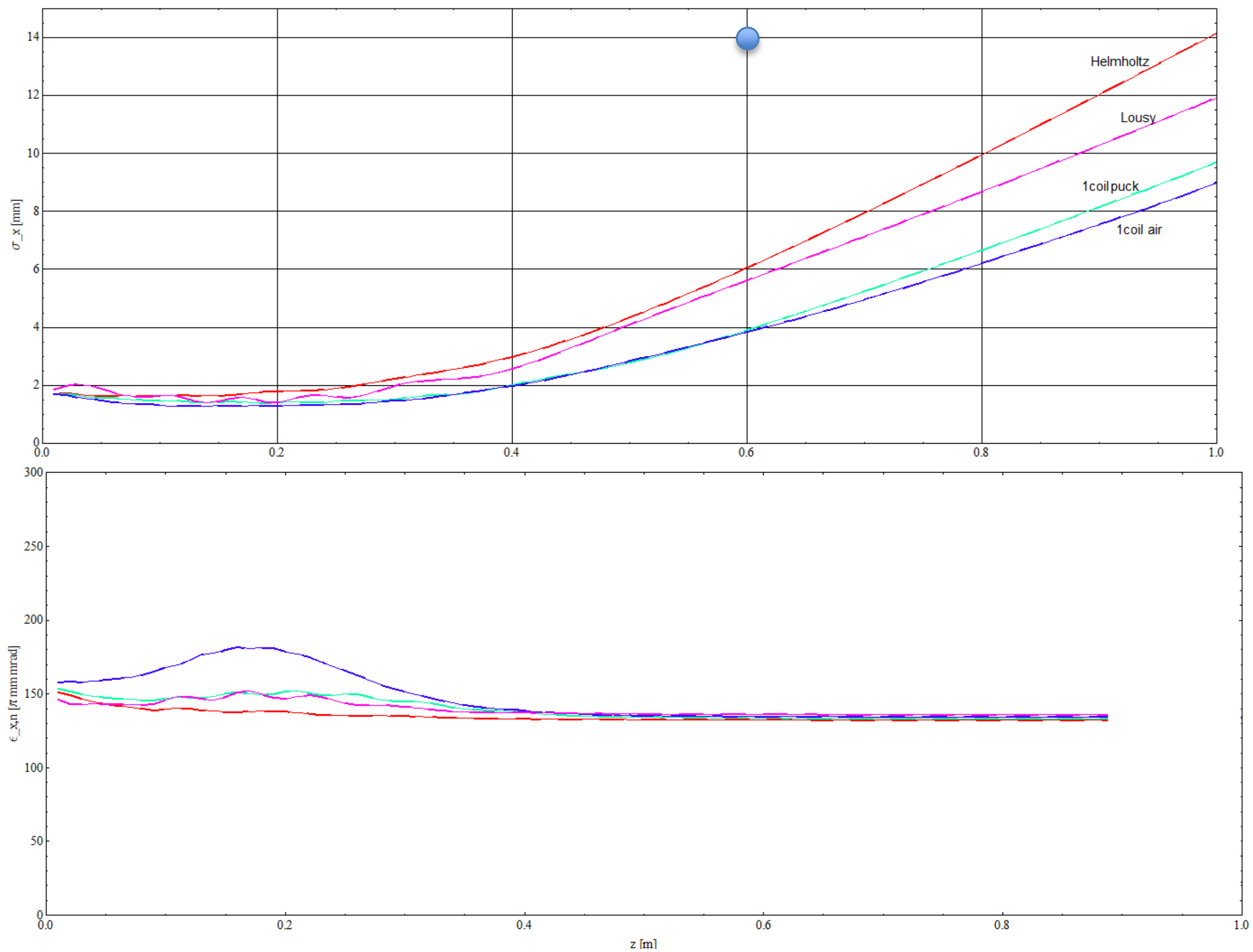


Ldrd.009.001

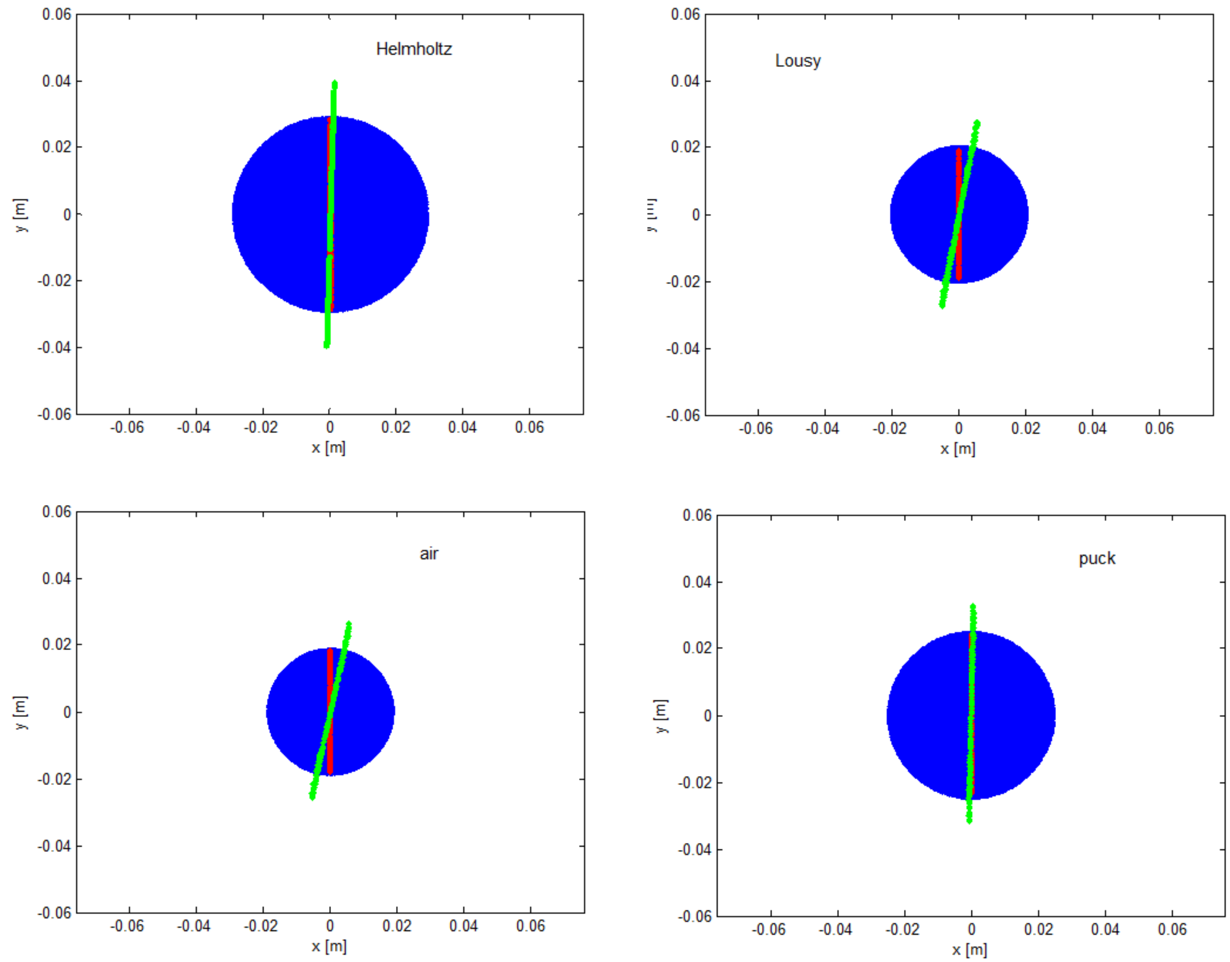
4 real field maps, scaled to give ~0.2T



Transverse beam size, emittance



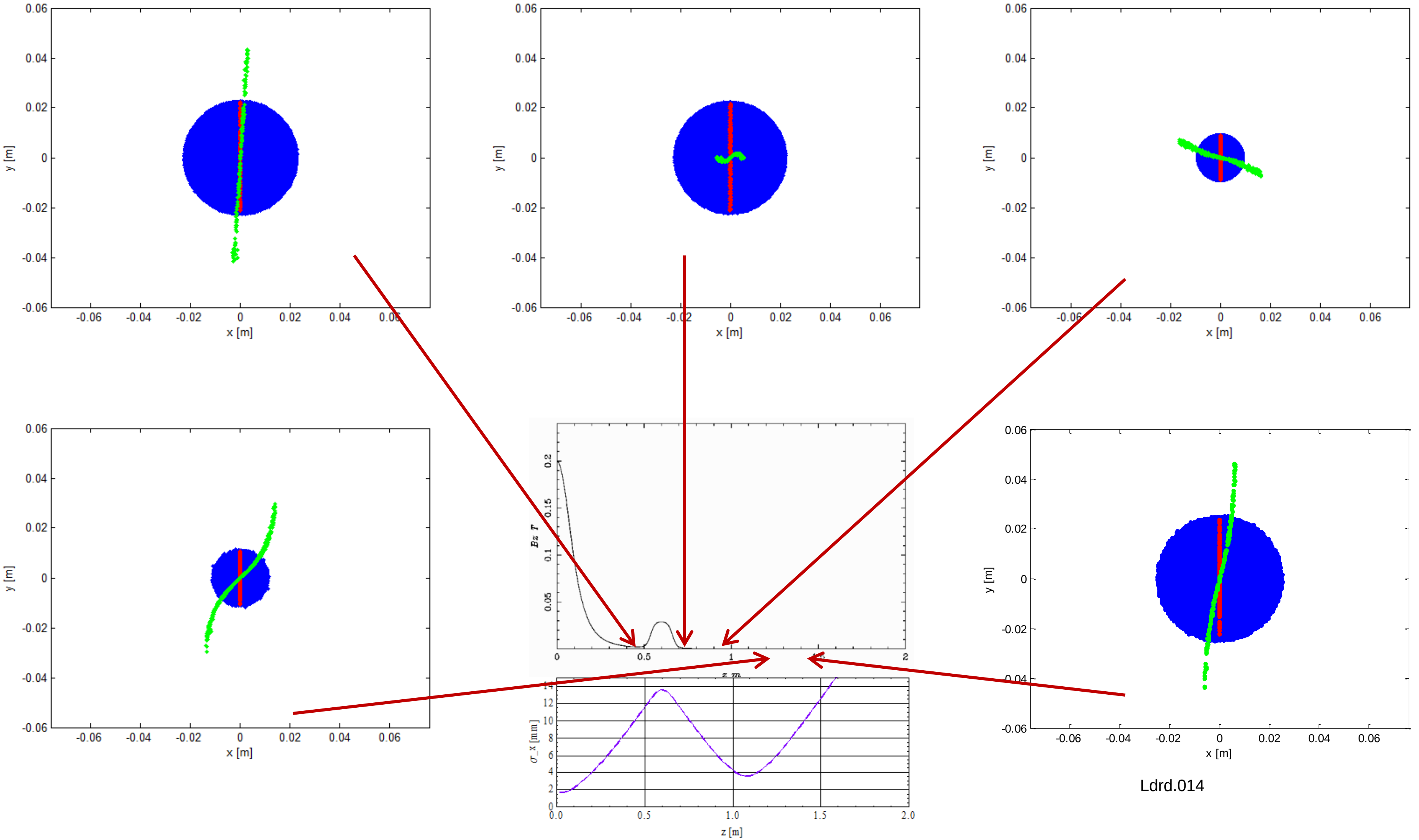
Magnetization virtual experiment



At 1m

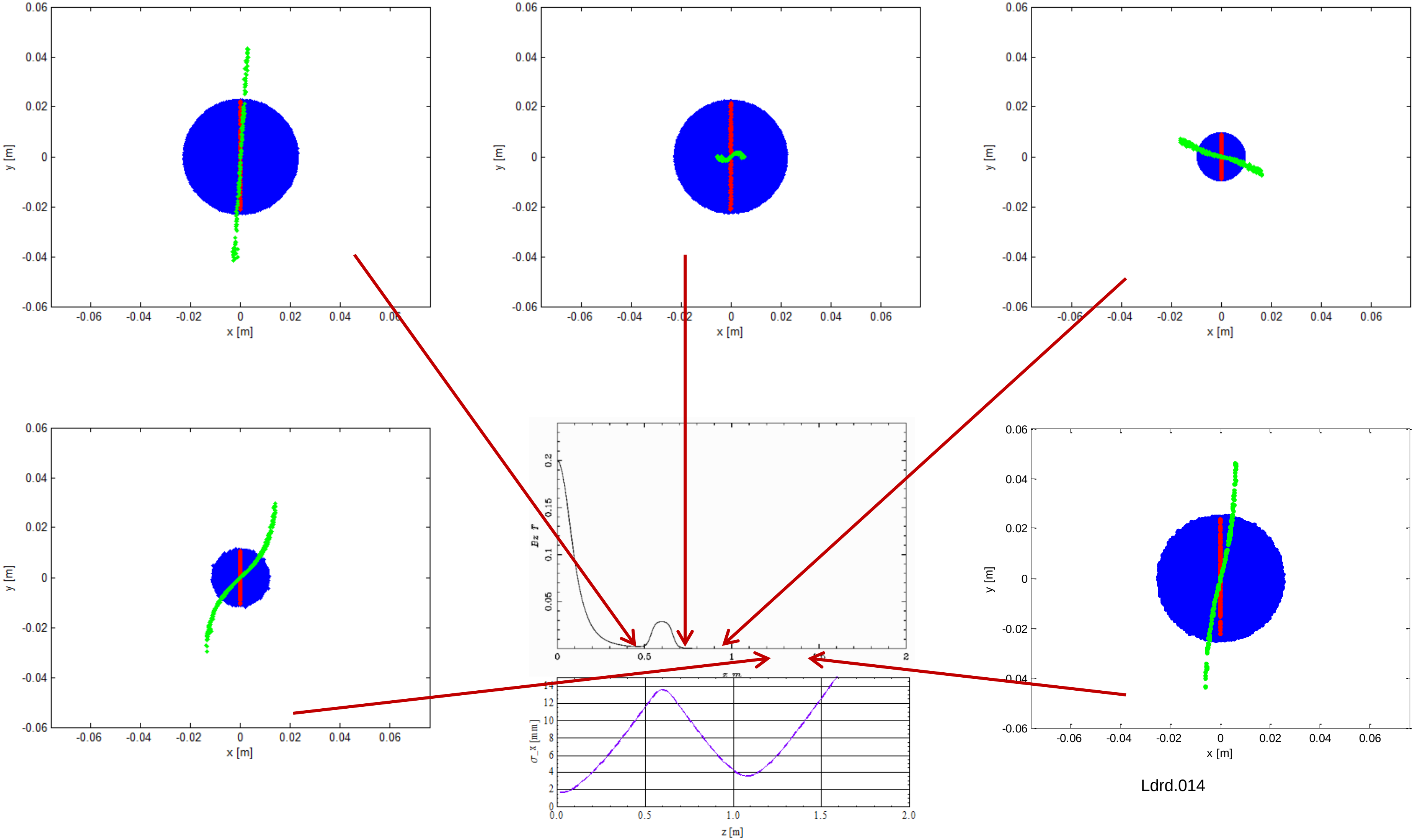
Can't see 'S'
– all seem linear… why is this…

Normal solenoid



Ldrd.014

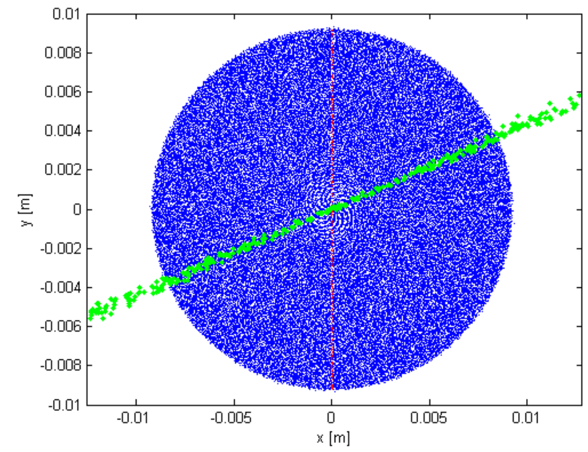
Normal solenoid

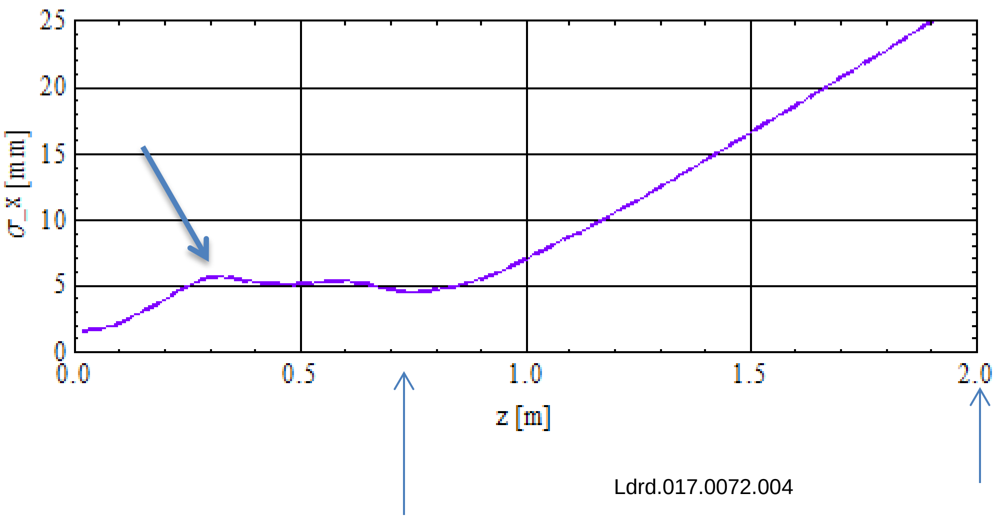


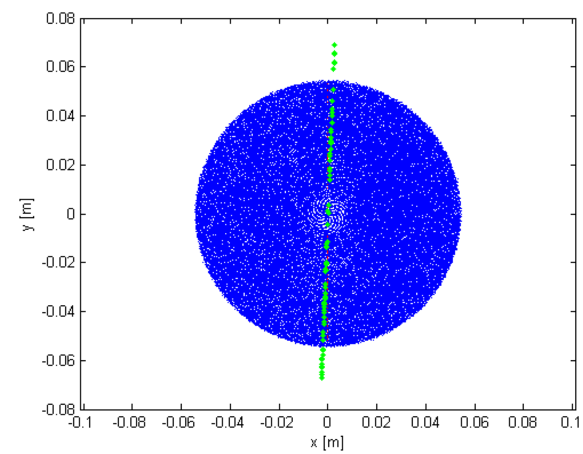
Ldrd.014

Is the trick to keep beam small in beamline solenoids?

- Trying not to have different B.dl over transverse direction.



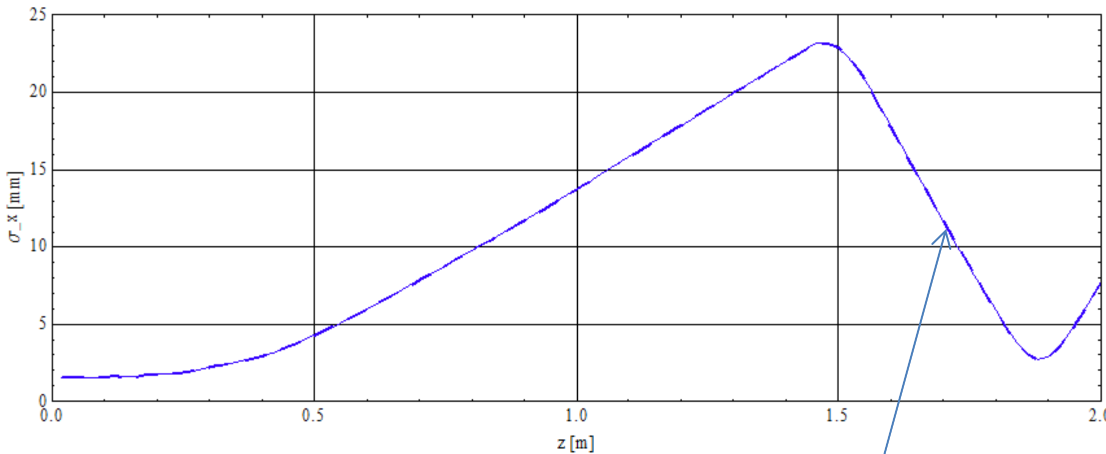


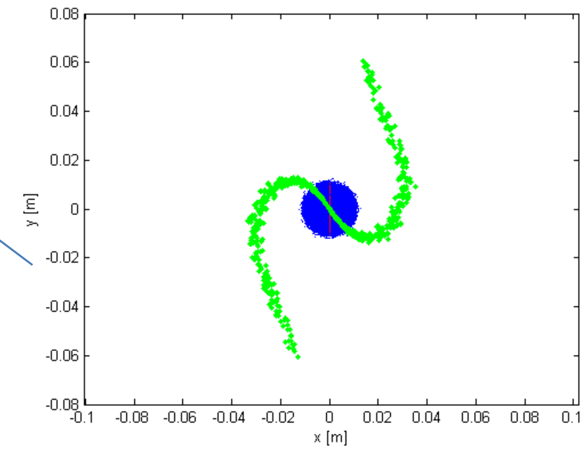


Ldrd.017.0072.004

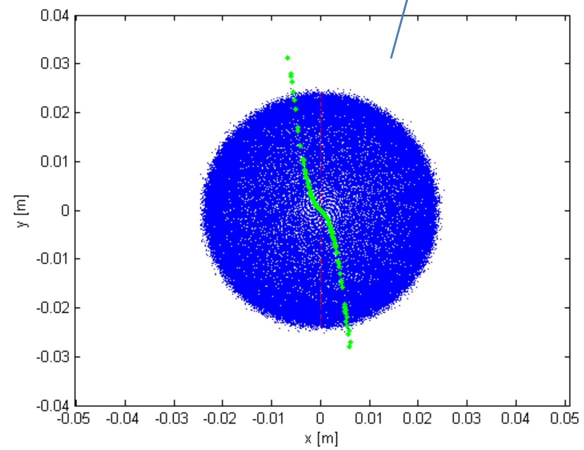
Fay Hannon

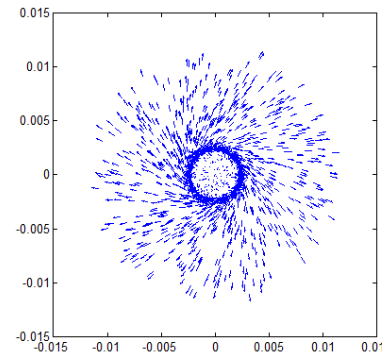
Let beam get big and then focus





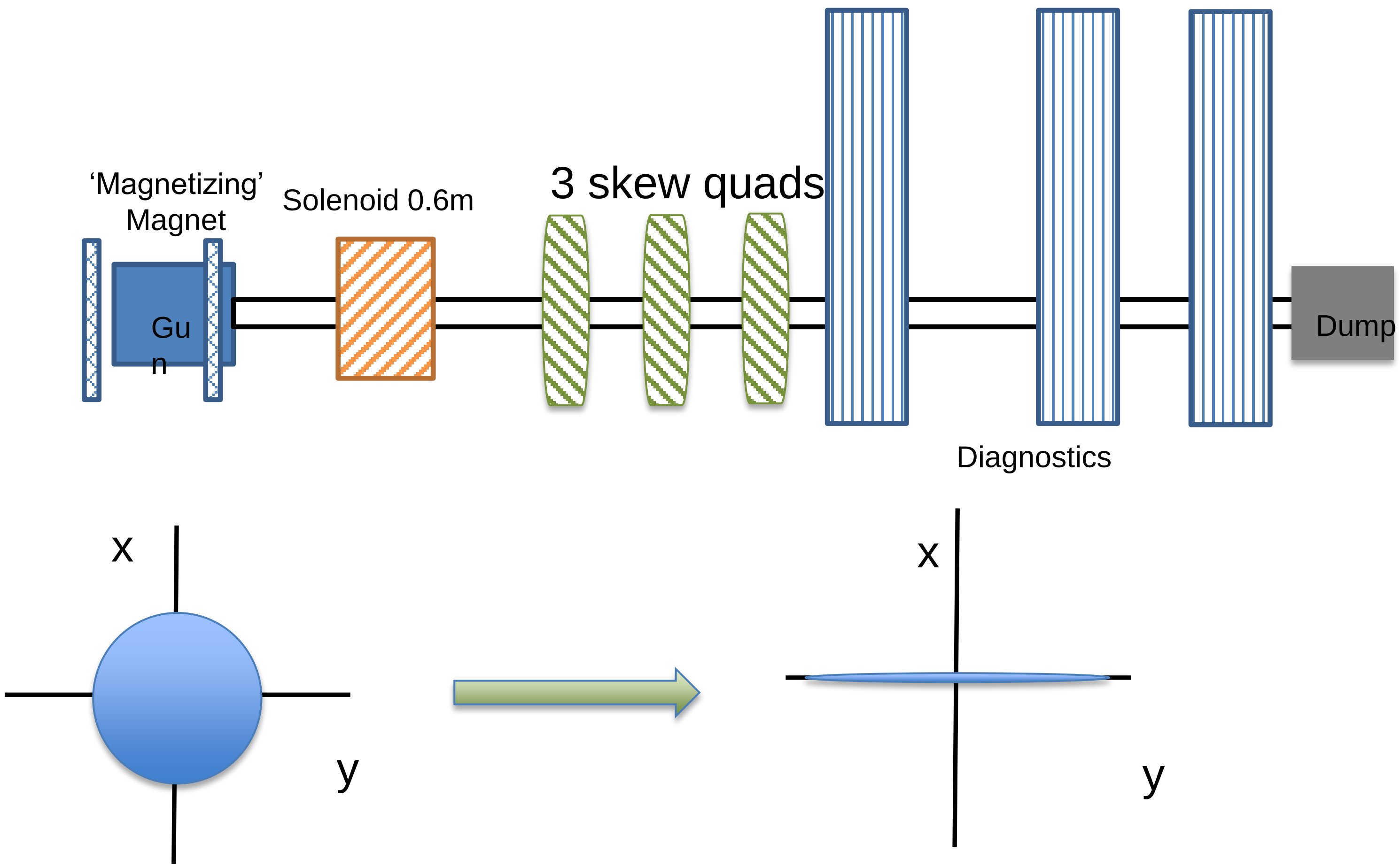
So even with good Helmholtz field it can become distorted!





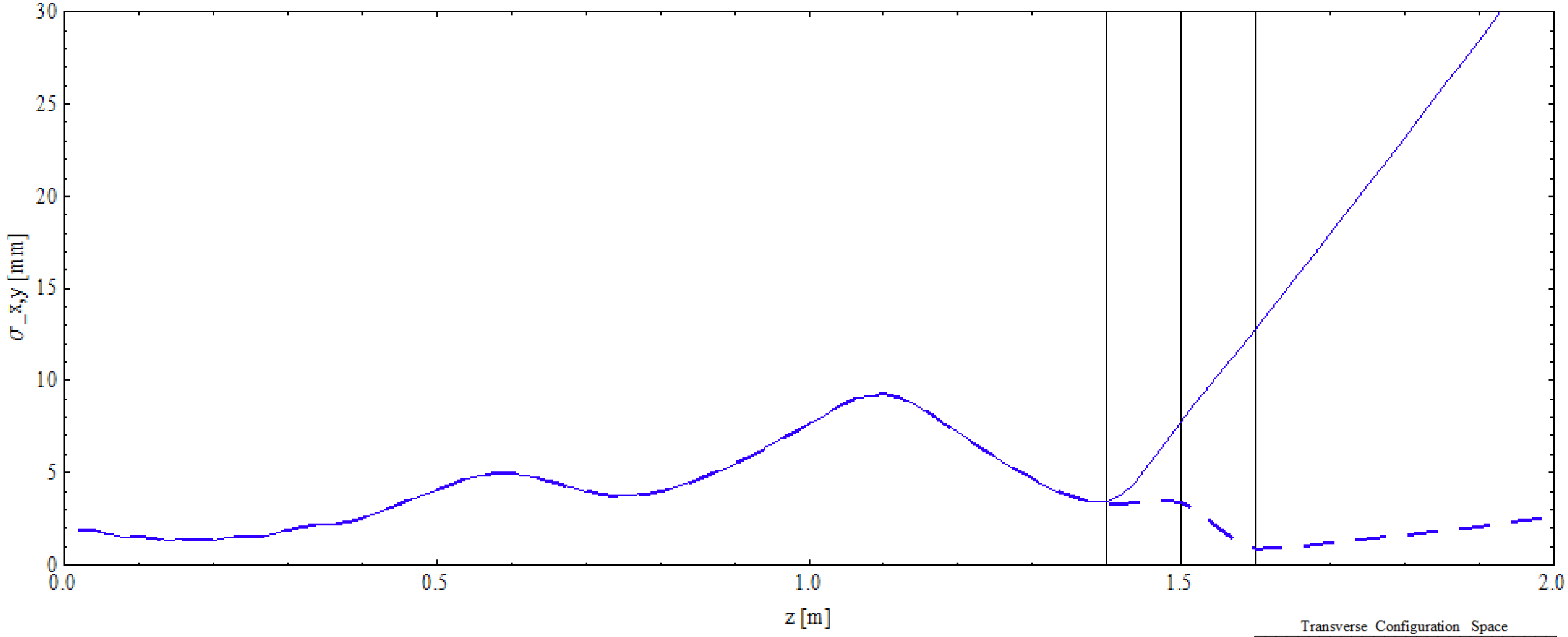
MEASUREMENTS
- ROUND TO FLAT TRANSFORM

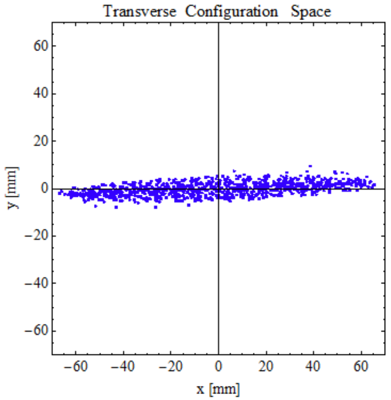
Modified beamline



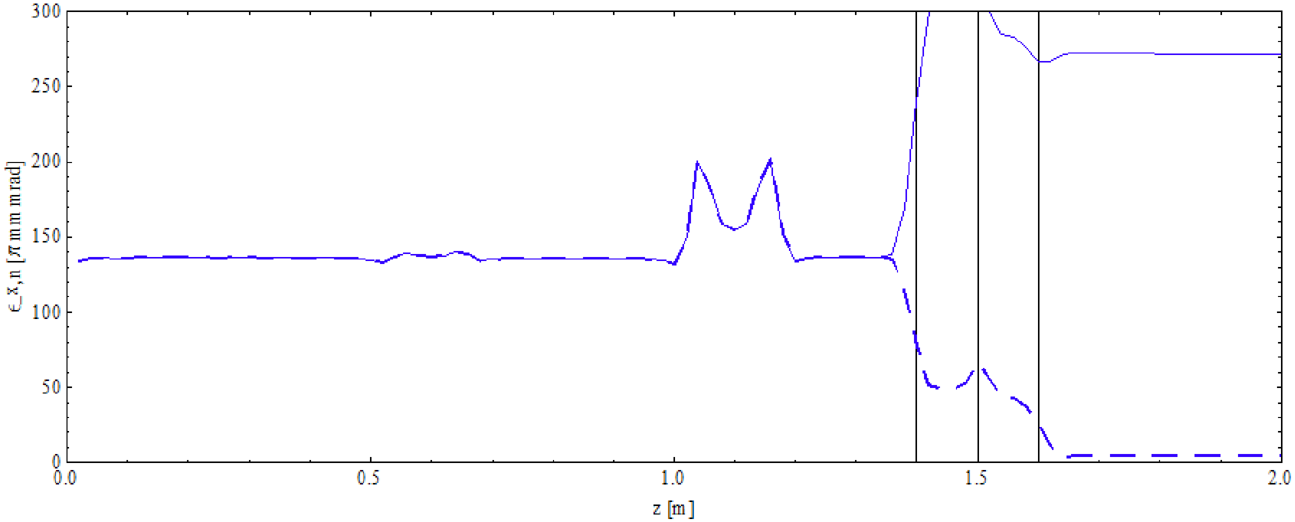
Emittance splits into a large and small component

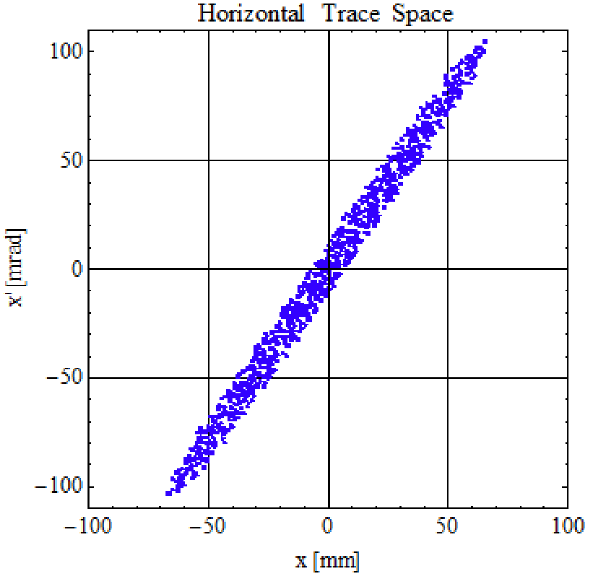
Beam evolution

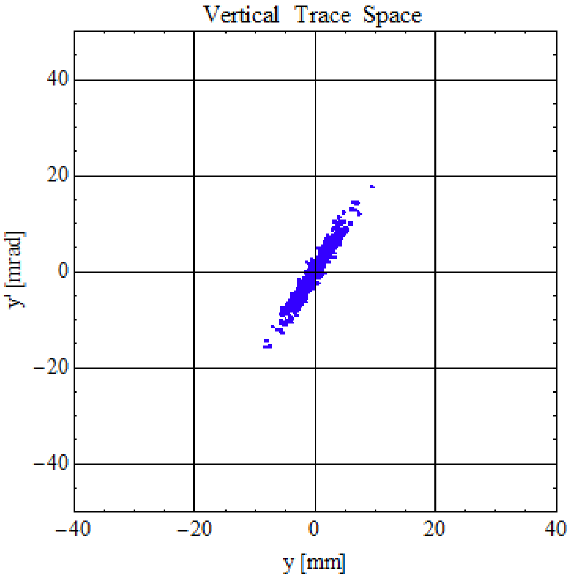




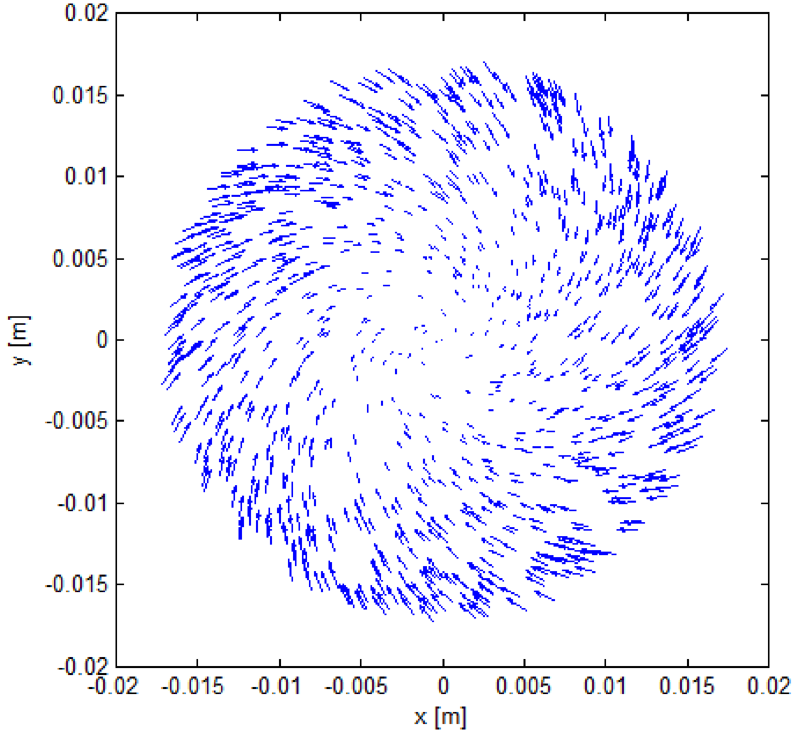
Beam evolution

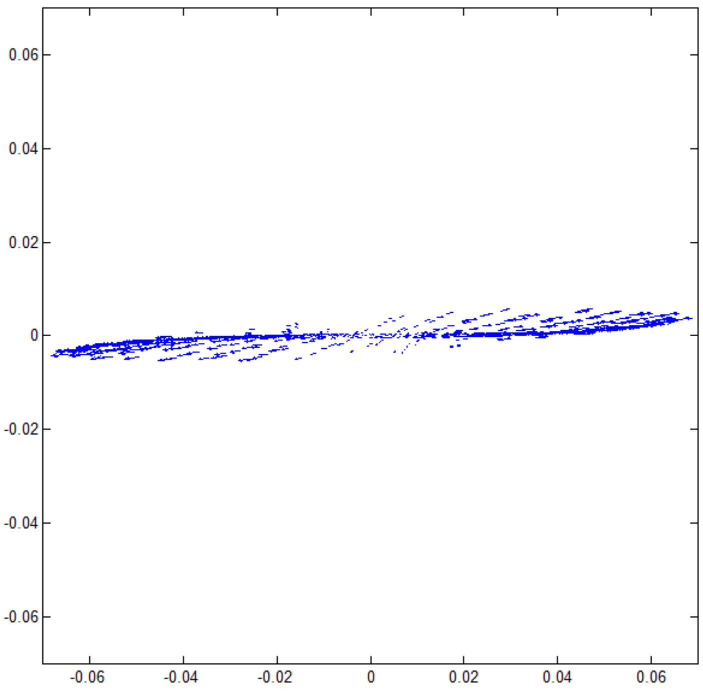






Beam evolution

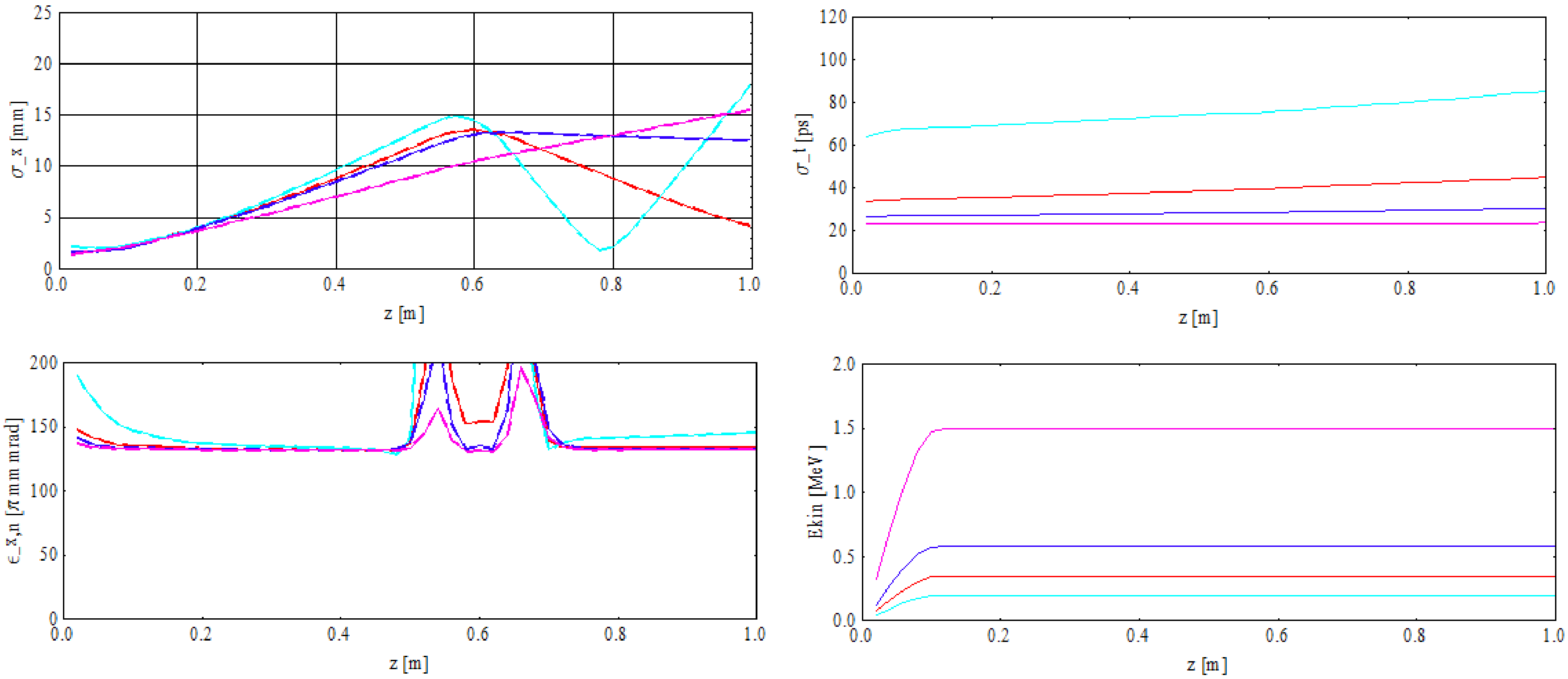




CONCLUSIONS

- Simulations show we should be able to demonstrate measurement of angular momentum dominate beams
- Space charge does not effect transverse transport much
- Should try to keep transverse size small
- Round to flat possible with low energy beam

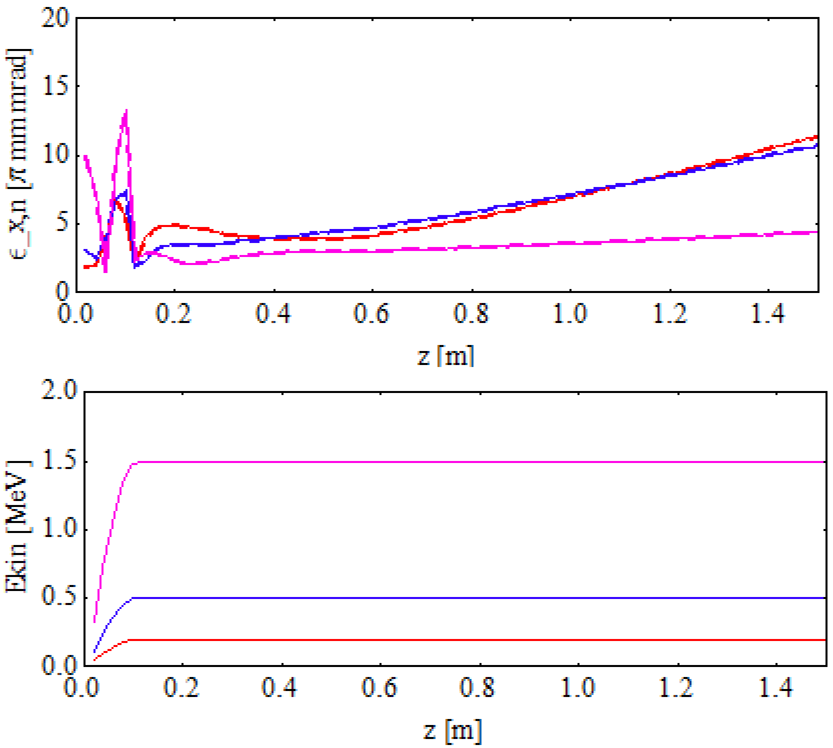
Increase gun voltage



CAM dominated

So what does the emittance look like

Remove the contribution from angular momentum. Calculate the angular momentum from a correlation in the x, px phase space and subtract prior to the emittance calculation.



Field calculation

- In astra – off axis fields calculated from the on-axis field profile derivatives polynomial expansion

- $Bz(r)=Bz,0-(r^2/4*Bz'')+(r^4/64*Bz'''')$…etc
- $Br(r)=-r/2*Bz'+(r^3/16*Bz''')$… etc

- Flatter the profile, less variation in Bz off axis.