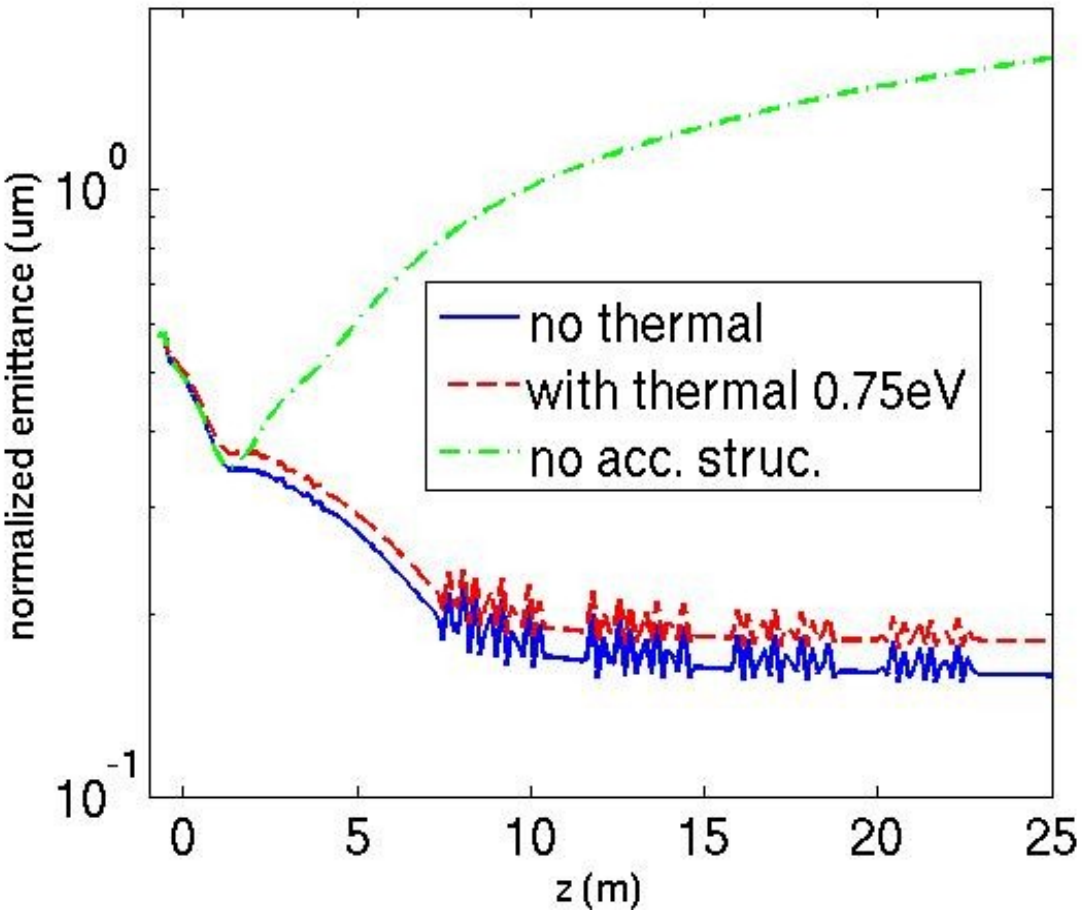
The ITS Photo-Cathode Gun Beam Simulations

Yine Sun
Accelerator Systems Division
Photo-Injector Physics Meeting
September 24, 2013

Gun/Solenoid Optimized for the LINAC at 150MeV – minimize emittance at 50pC



Run pC50z6347

Optimization was done with 0.75 eV thermal energy included (~ 1mm mrad/mm)

Copper cathode measured thermal emittance (266 nm UV drive-laser) is about 0.7-0.9 mm mrad/mm.

Compare optimization results with and without thermal emittance included.

Without accelerating structures, the emittance reaches a minimum at the entrance of the 1st acc. structure and then grows.

Contributions to the Emittance from the Residual Magnetic Field on the Cathode

Beam envelope equation: $$\sigma'' - \frac{K}{4\sigma} - \frac{\varepsilon_u^2}{\sigma^3} - \frac{\mathcal{L}^2}{\sigma^3} = 0,$$

where σ is the transverse rms size, $K = \frac{2I}{I_0\beta^3\gamma^3}$ is the generalized perveance, I is the absolute value of the instantaneous beam current, and $I_0 = 4\pi\epsilon_0 mc^3/e \approx 17$ kA is the Alfvén current, ε_u is the uncorrelated transverse rms emittance, and $\mathcal{L}$ is related to the average canonical angular momentum $\langle L \rangle$ (see Section 2.2) and the longitudinal momentum p_z of the beam via

$$\mathcal{L} = \frac{\langle L \rangle}{2p_z}. \qquad (2.2)$$

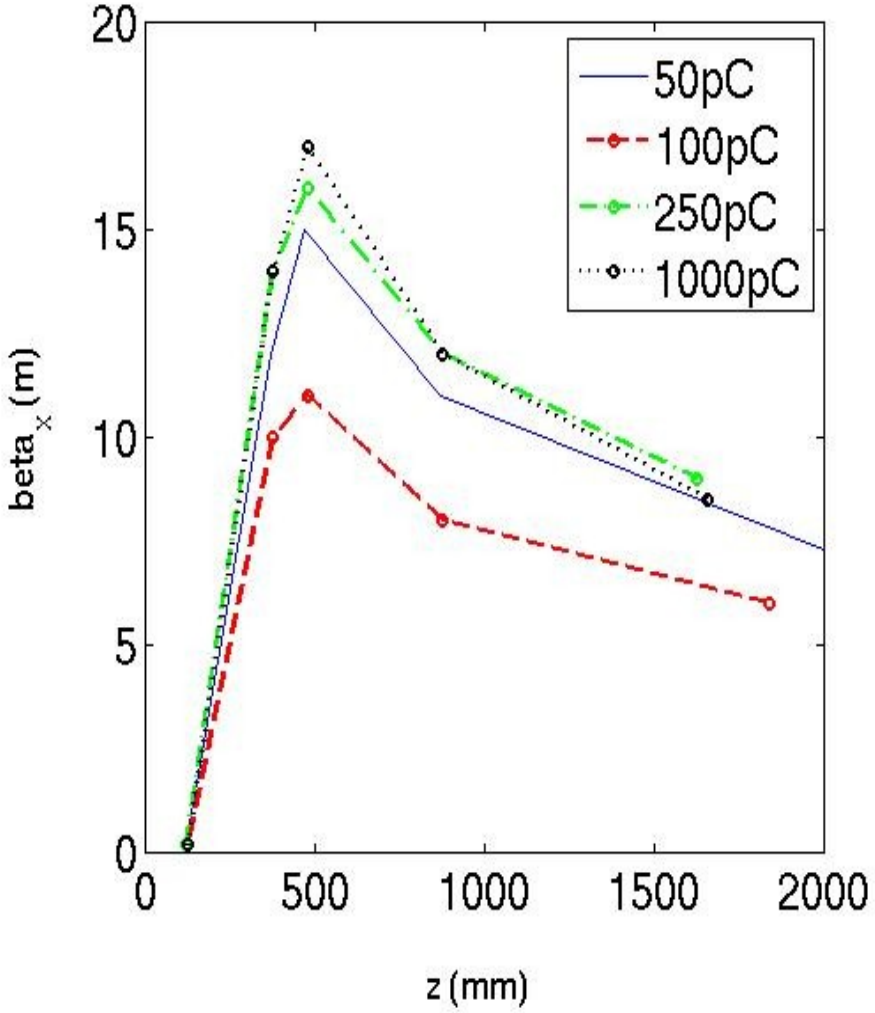
On the cathode, $$\langle L \rangle = \frac{1}{2} eB_0 \langle r^2 \rangle = eB_0\sigma_c^2,$$

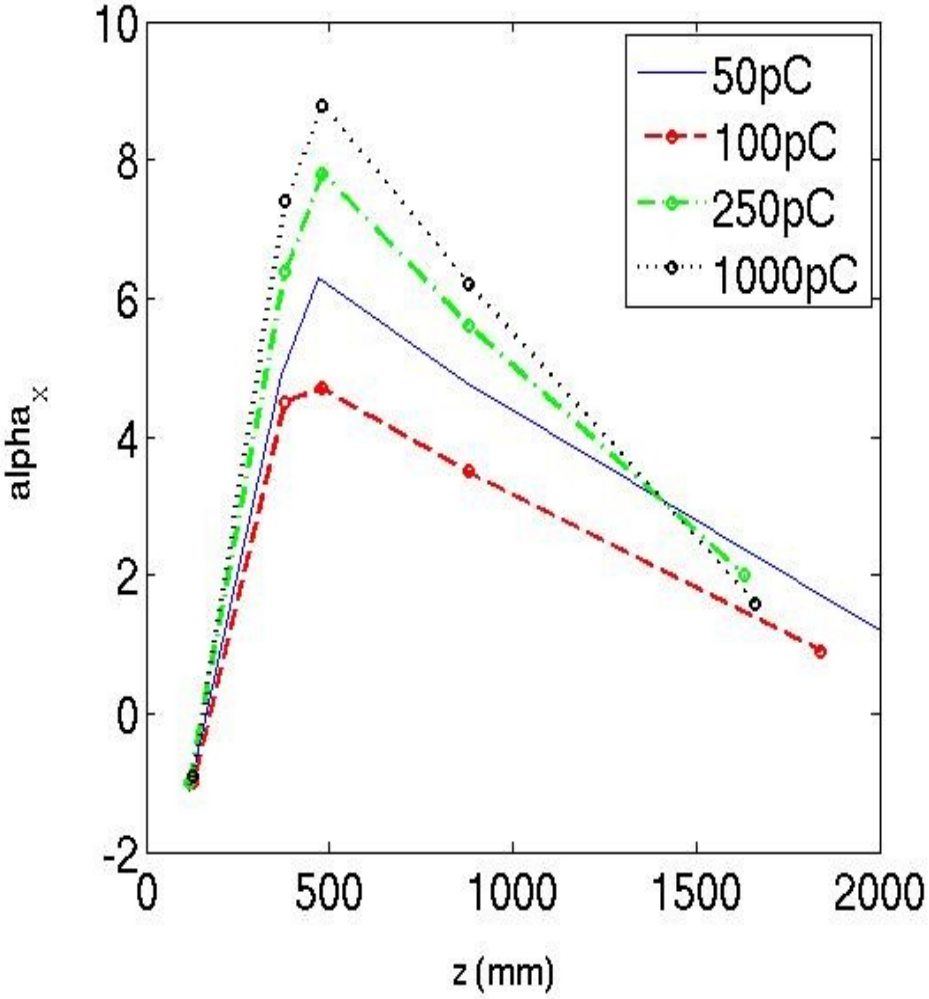
Therefore, $$\varepsilon_{B_0}^n [\,mm\,mrad\,] = \gamma L = 0.03 \mathrm{B}_0 [\,Gauss\,] \sigma^2 [\,mm\,]^2$$

B=20 Gauss, σ=1 mm, Norm. Emit. from B is 0.6 mm mrad; σ=0.1 mm-> emit= 0.006mm mrad.

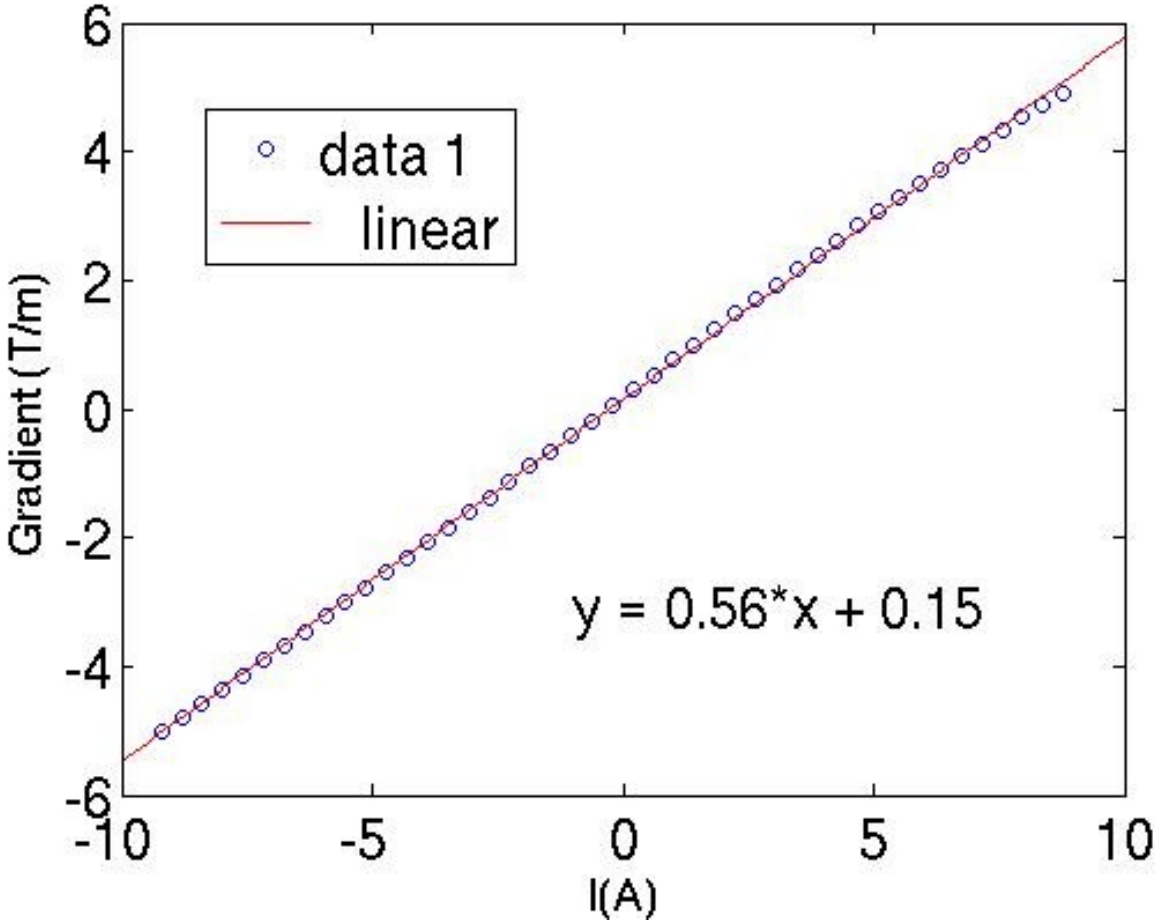
Y. Sun, http://inspirehep.net/record/685388/files/fermilab-thesis-2005-17.PDF

Twiss Parameters Downstream of the Gun





ITS Quadrupole Calibration

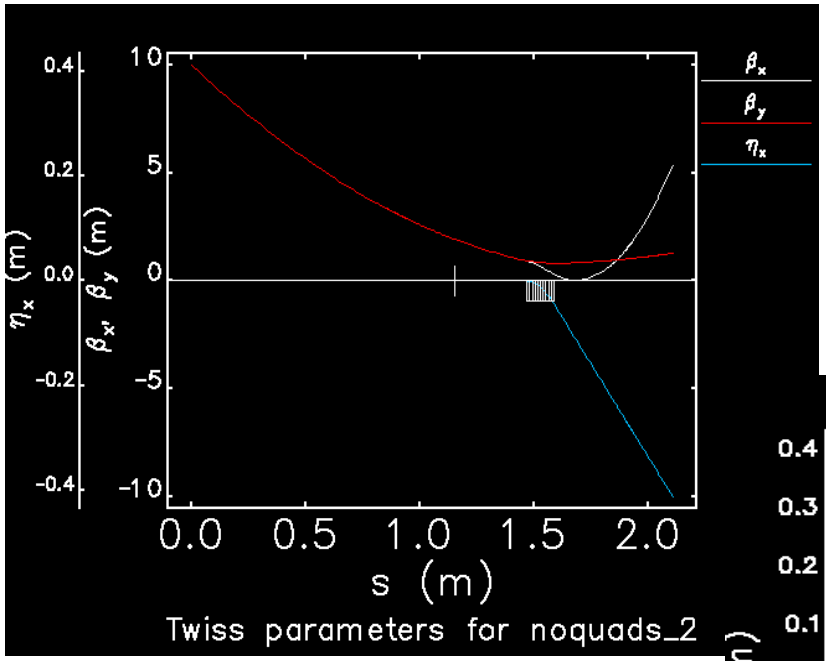


Quad gradient g=0.56T/m/A

For pc=6MeV beam energy,
k[m^-2]=300*g[T/m/A]/pc[MeV]
=300*0.56*I[A]/6=28*I[A]

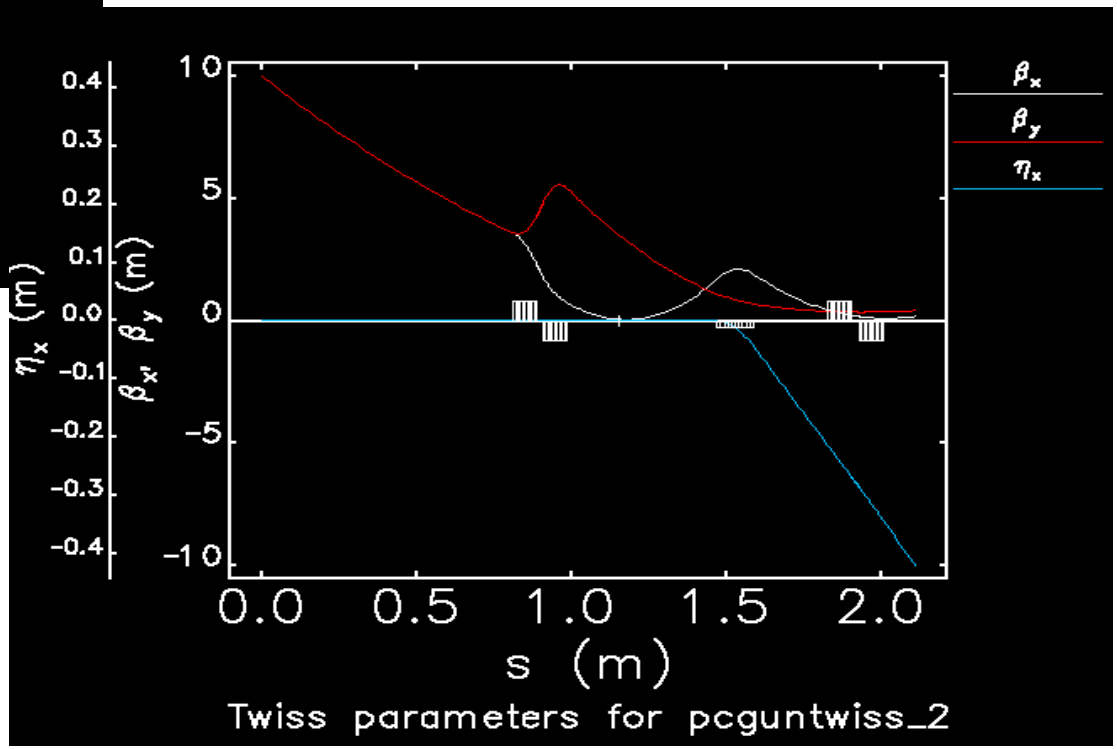
/home/oxygen/OAG/oagData/ITS/magnets/

Beam focusing on the Spectrometer Screen

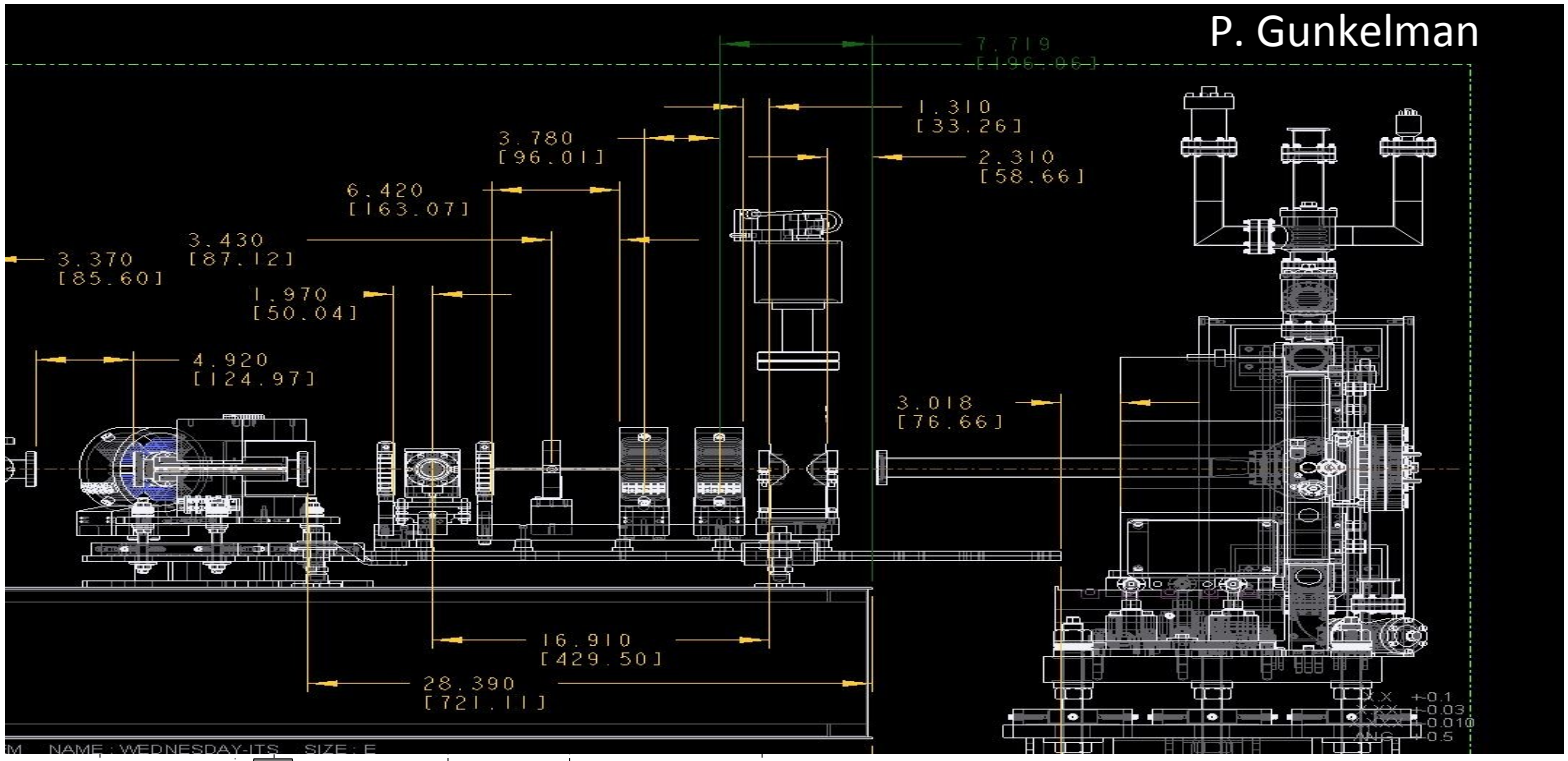


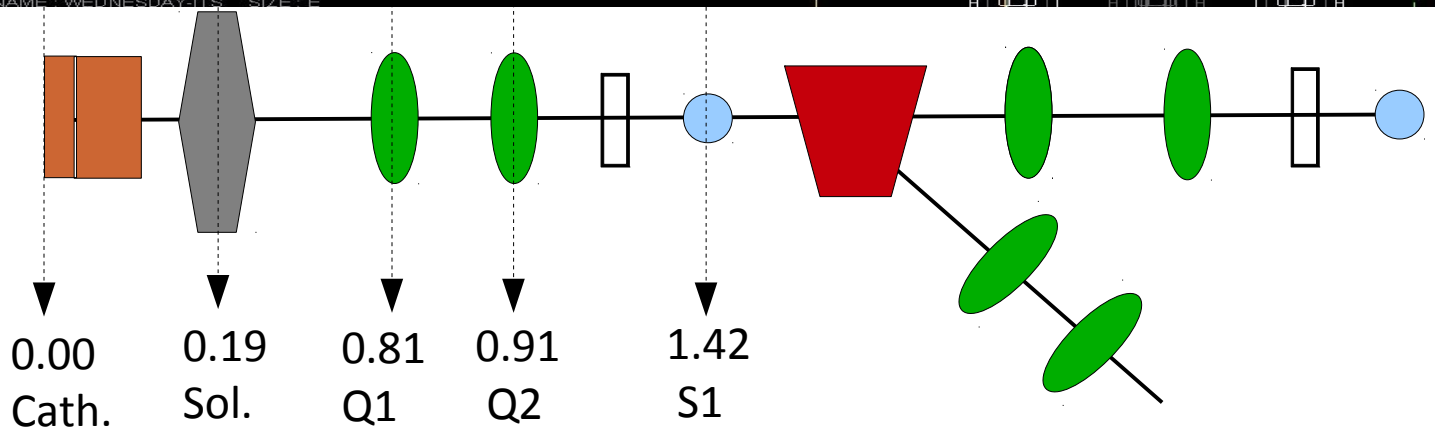
Initial βx=βy=10m; αx=αy=5

left: Quads off.
Bottom: Quads on LTS:Q1=+1.82A
LTS:Q2=-1.77A

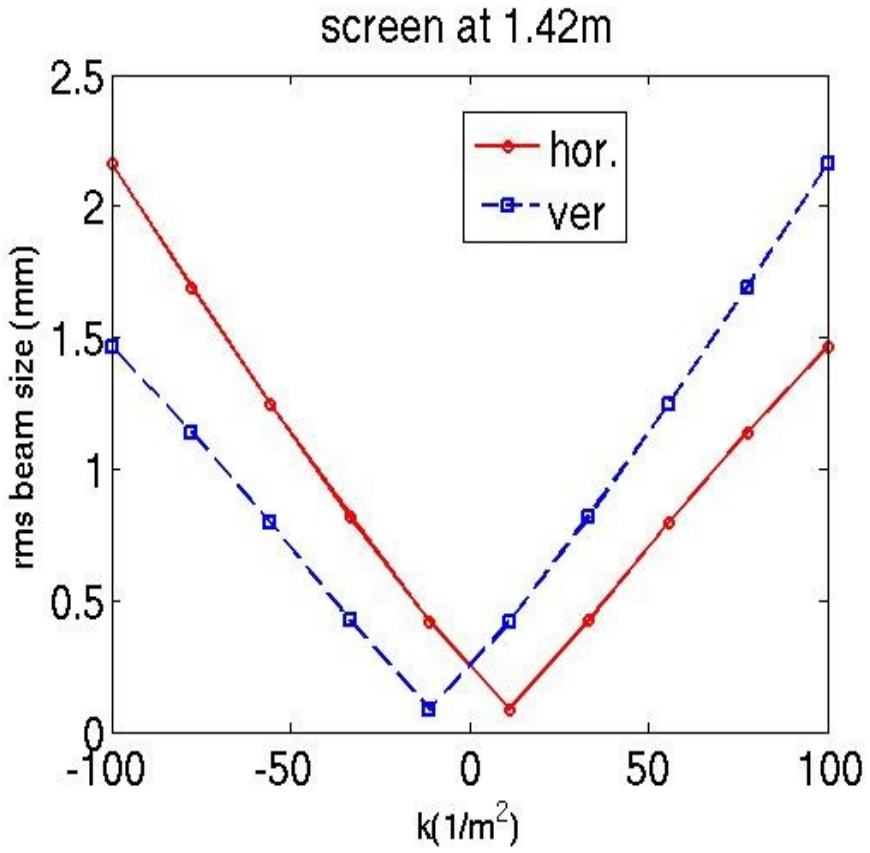


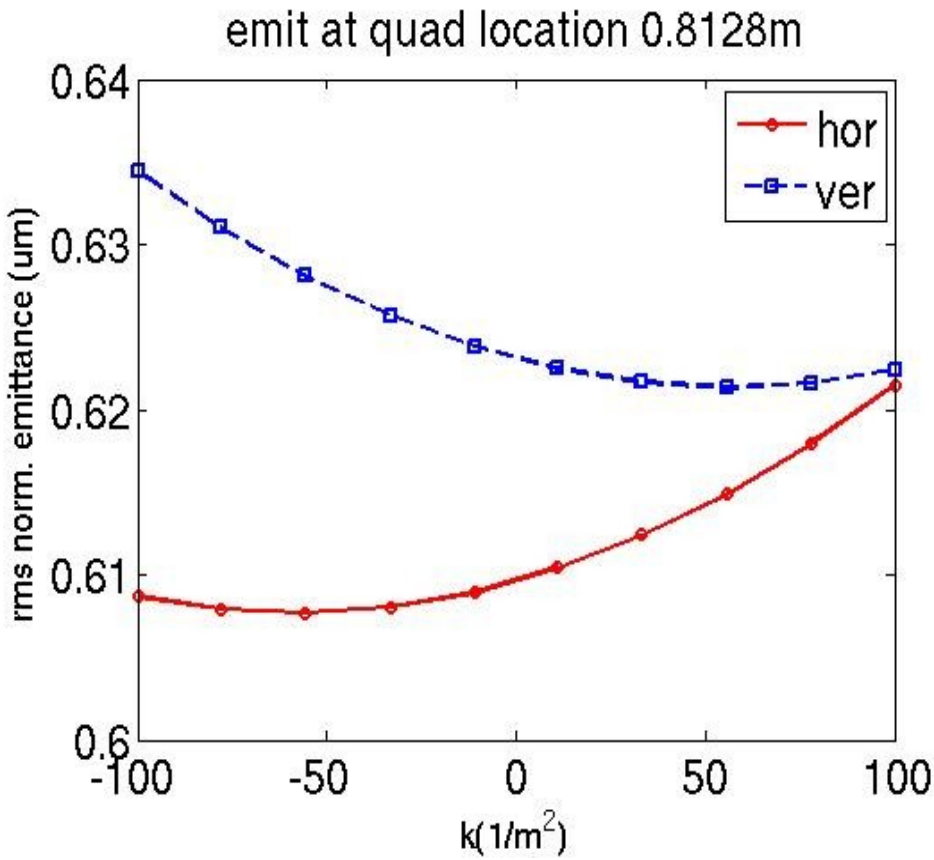
PC Gun in the Injector Test Stand





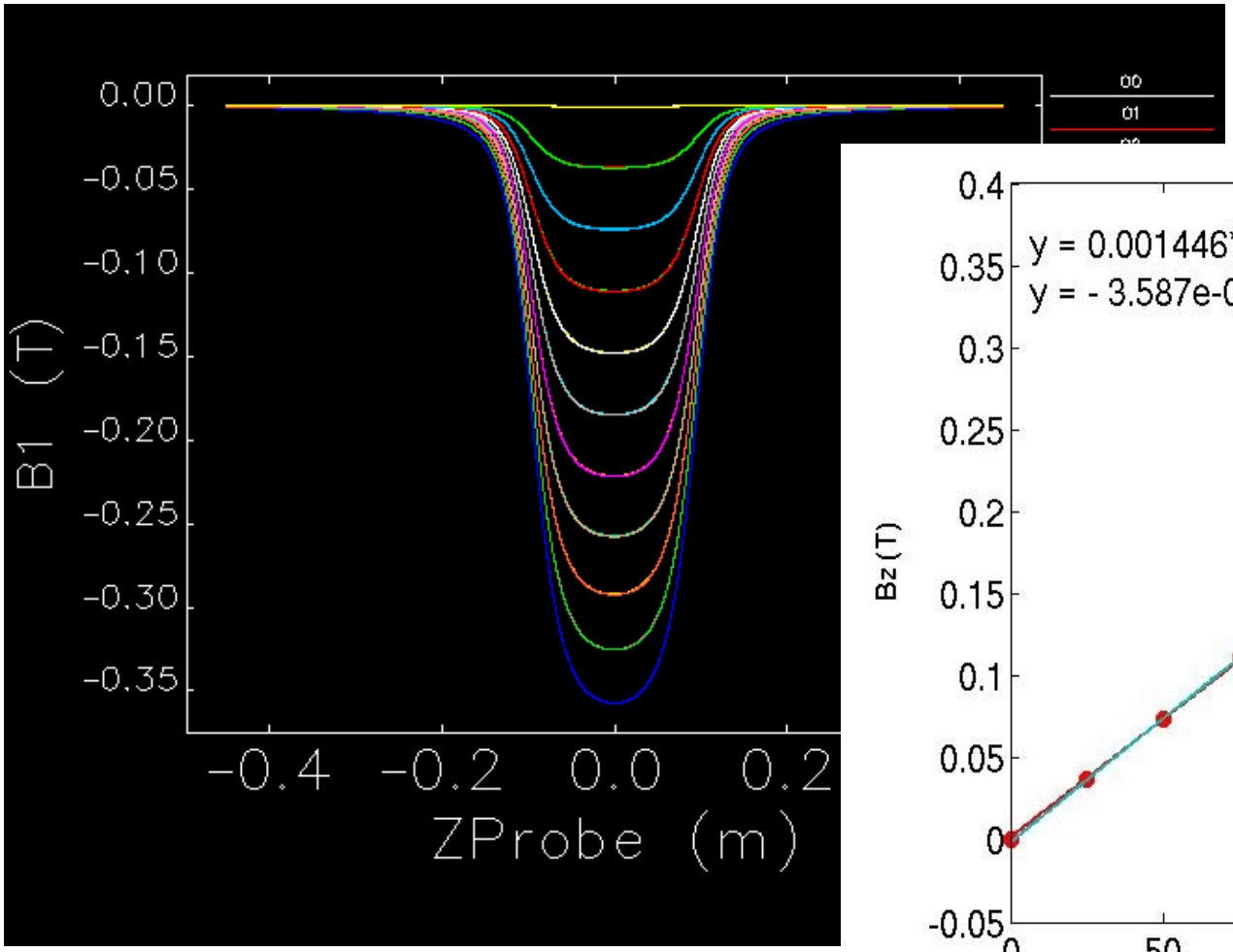
Quadrupole Scan for Emittance Measurements: vary quadrupole Q1 and measure at Screen S1



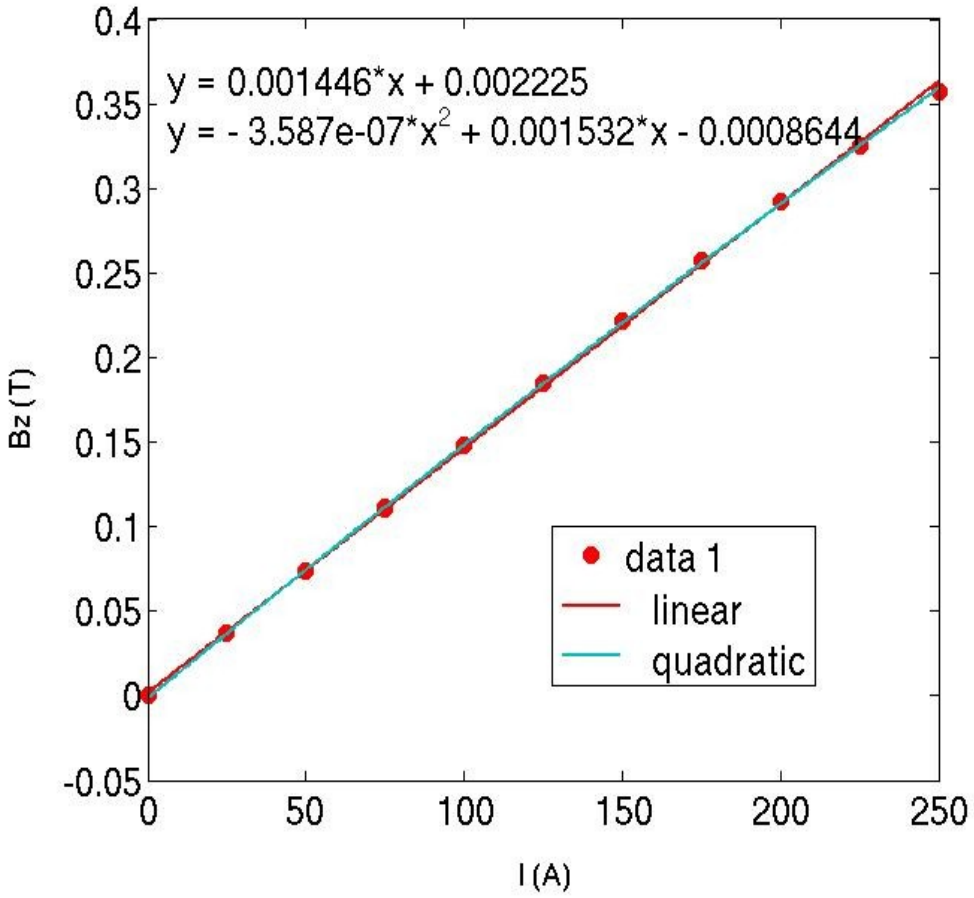


An example of quadscan emittance measurments
@ 50pC, rms size on cathode 0.2mm.

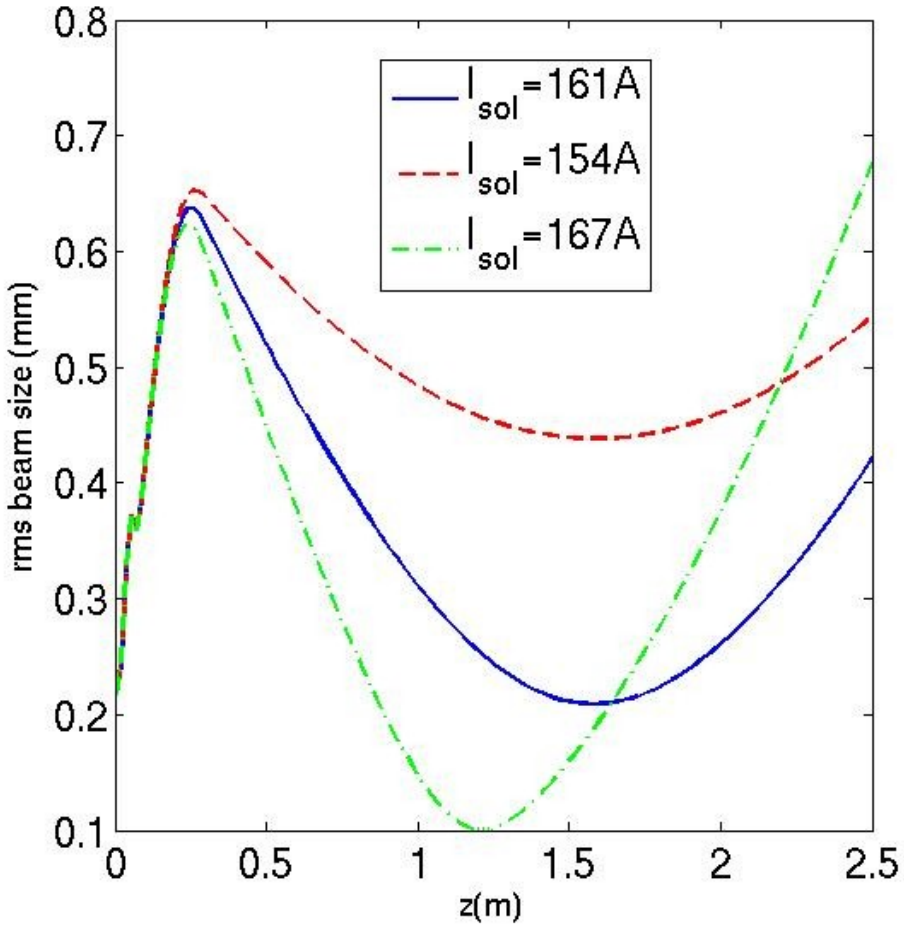
Solenoid Field Map Bz vs z at currents [0, 250]A as measured by Chuck Doose

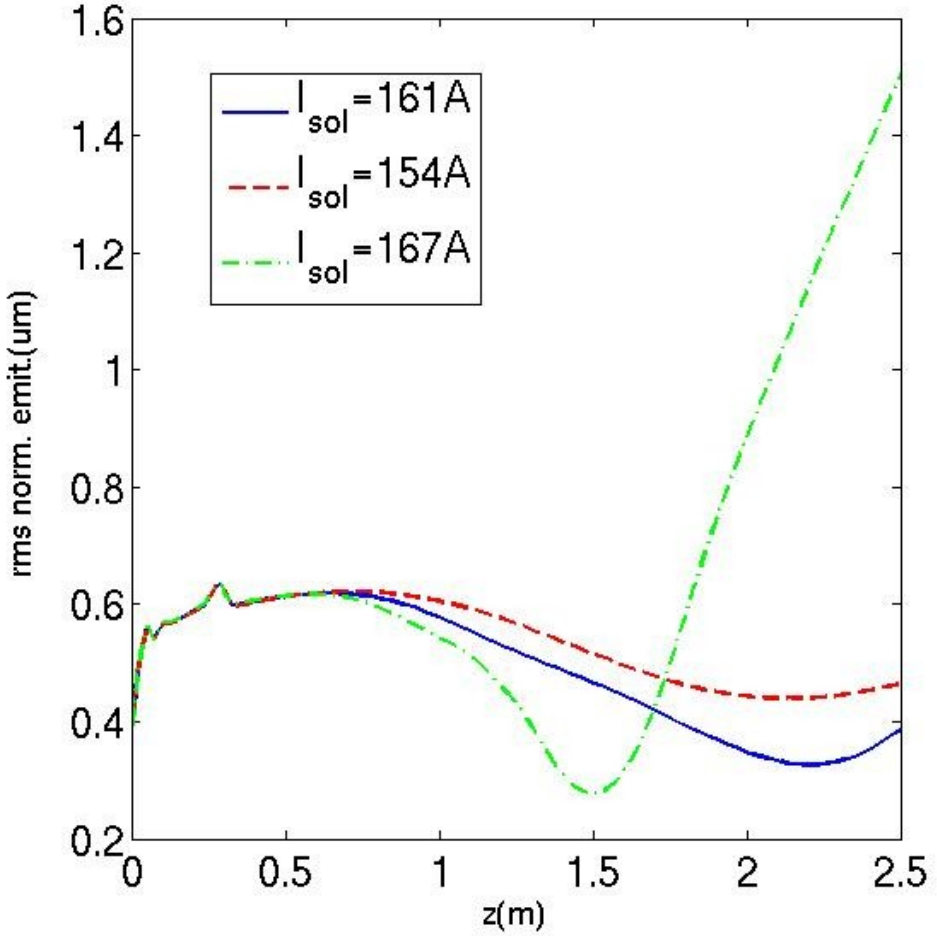


Bmax[T]=0.001532*I[A]



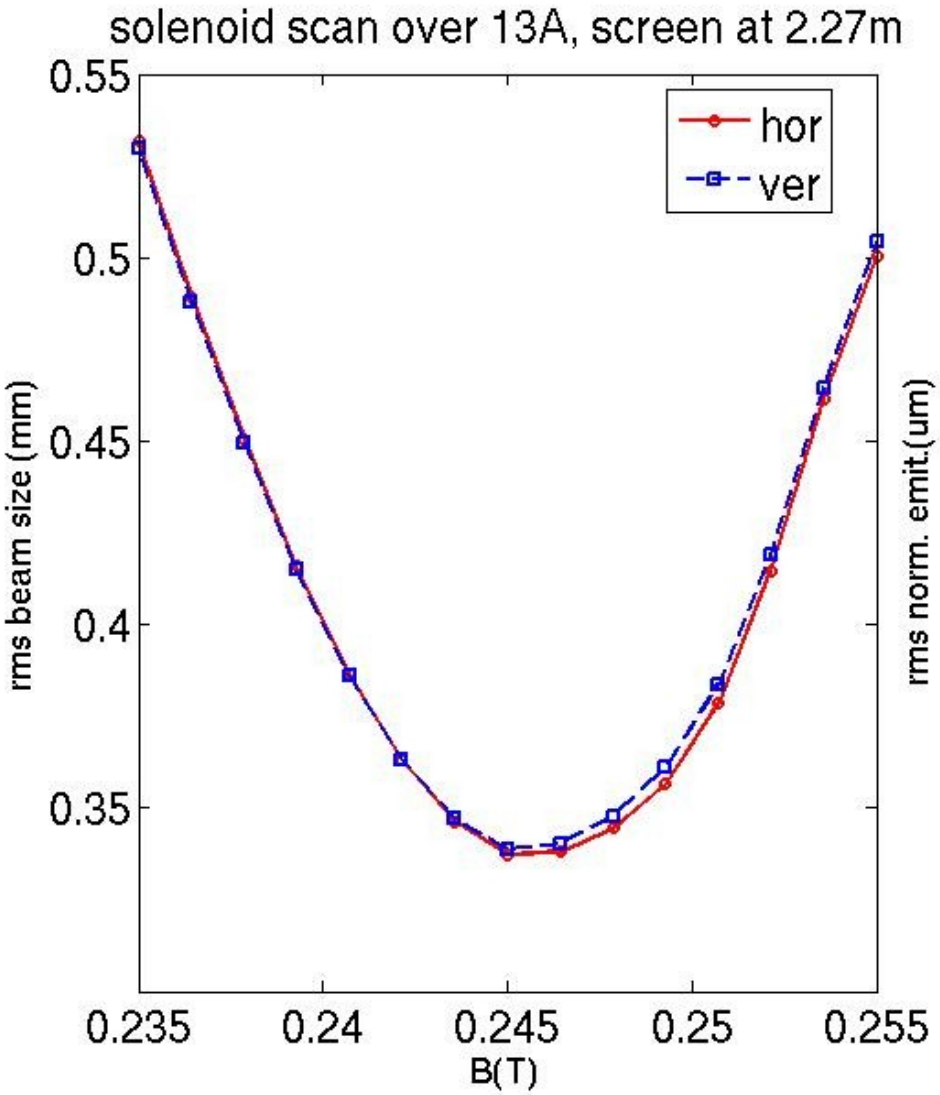
Solenoid Scans

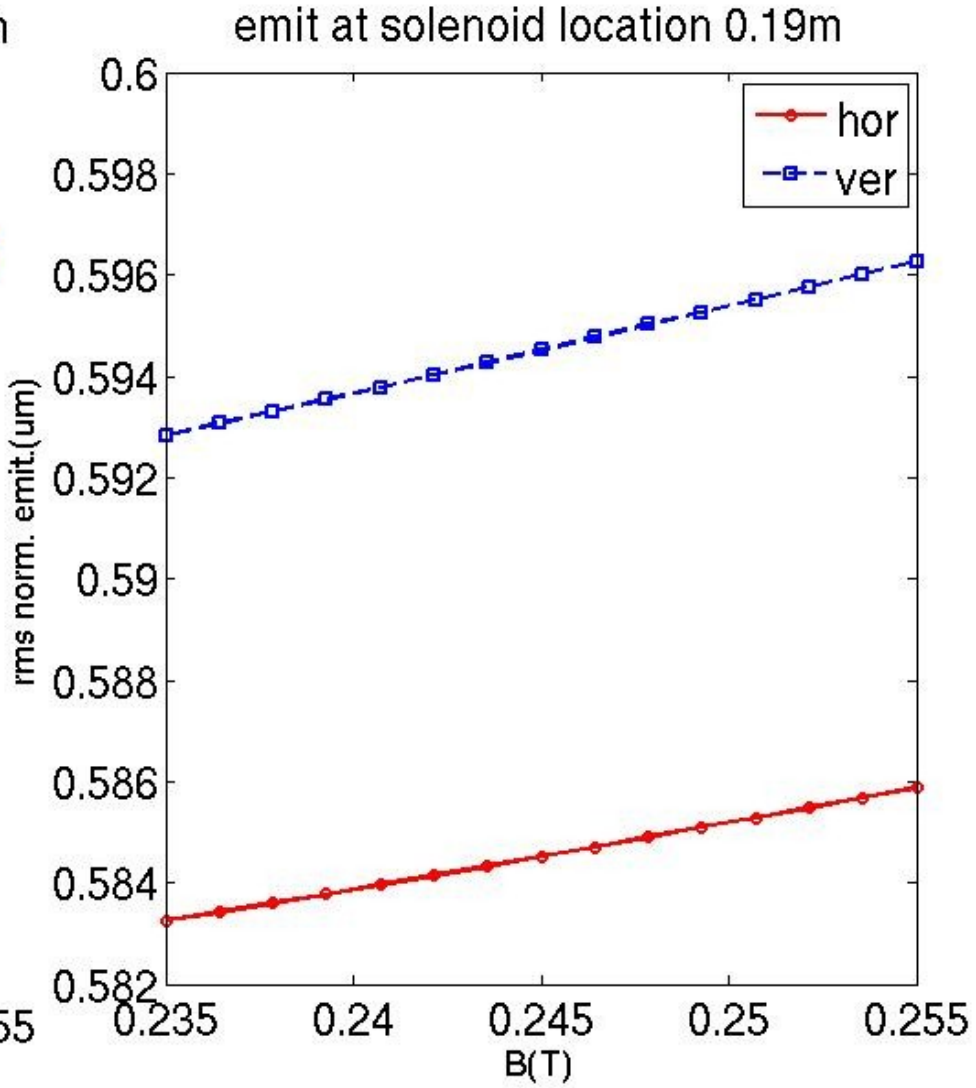




Choose a screen further downstream so that when the solenoid is varied, beam goes through a waist on the screen.

Emittance measurement via Solenoid can





Beam Measurement Planning at the ITS

- Parameters to be measured:
  - Charge (Faraday cup at the end of the straight line, ICT)
  - Beam Size (OTR?)
  - Emittance (quad scan)
    - software
  - Energy and energy spread (spectrometer)
  - Laser UV energy (location? Calibration?)
  - QE
    - Laser UV spot size and location control
- Variables: gun gradient, phase, solenoid strength, laser spot and intensity (for bunch charge, and charge density control).