PRODUCTION OF FLAT ELECTRON BEAMS AT THE FNPL

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Scope

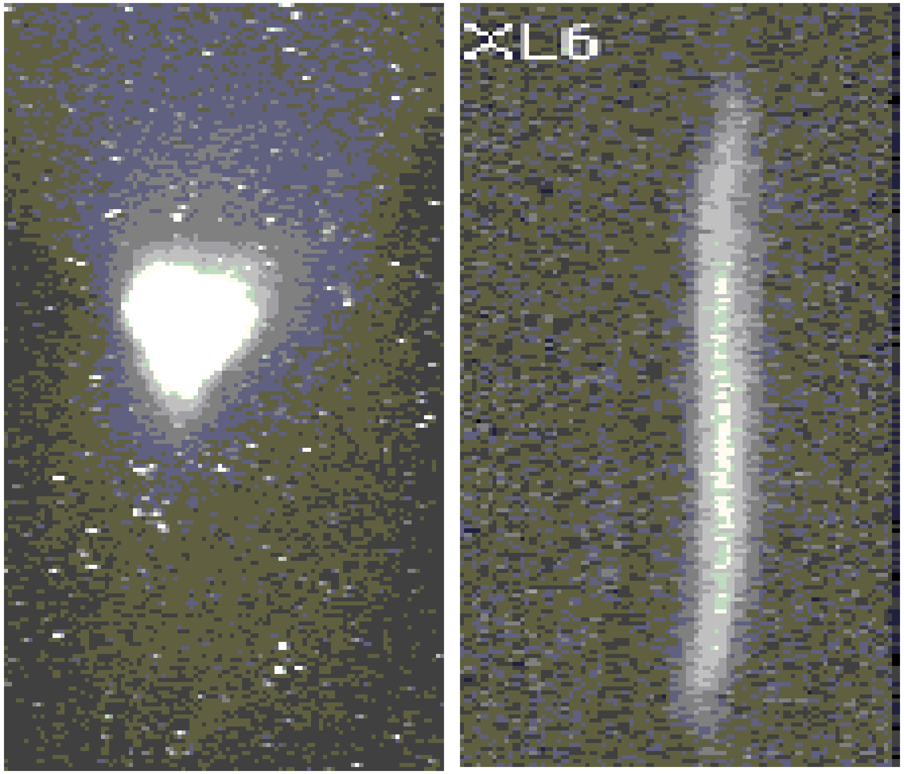
- Introduction
- Theory of operation
- Procedure
- Results and analysis
- Conclusion
- Acknowledgements
- References

Introduction

- A new technique for producing electron beam with high emittance ratio:

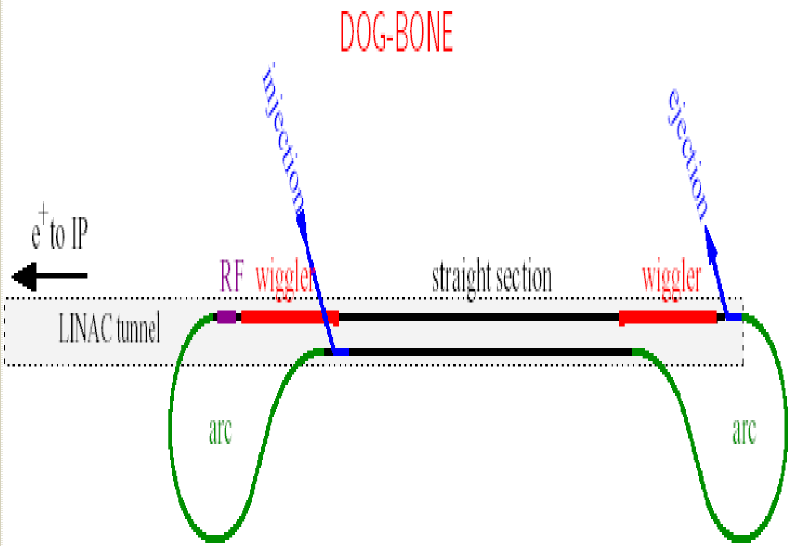
  -Flat beam.

- Electron-positron colliders:
  - small beam to maximize luminosity.
  - better center of mass energy distribution.



Round Beam Flat Beam

Means of producing flat beam

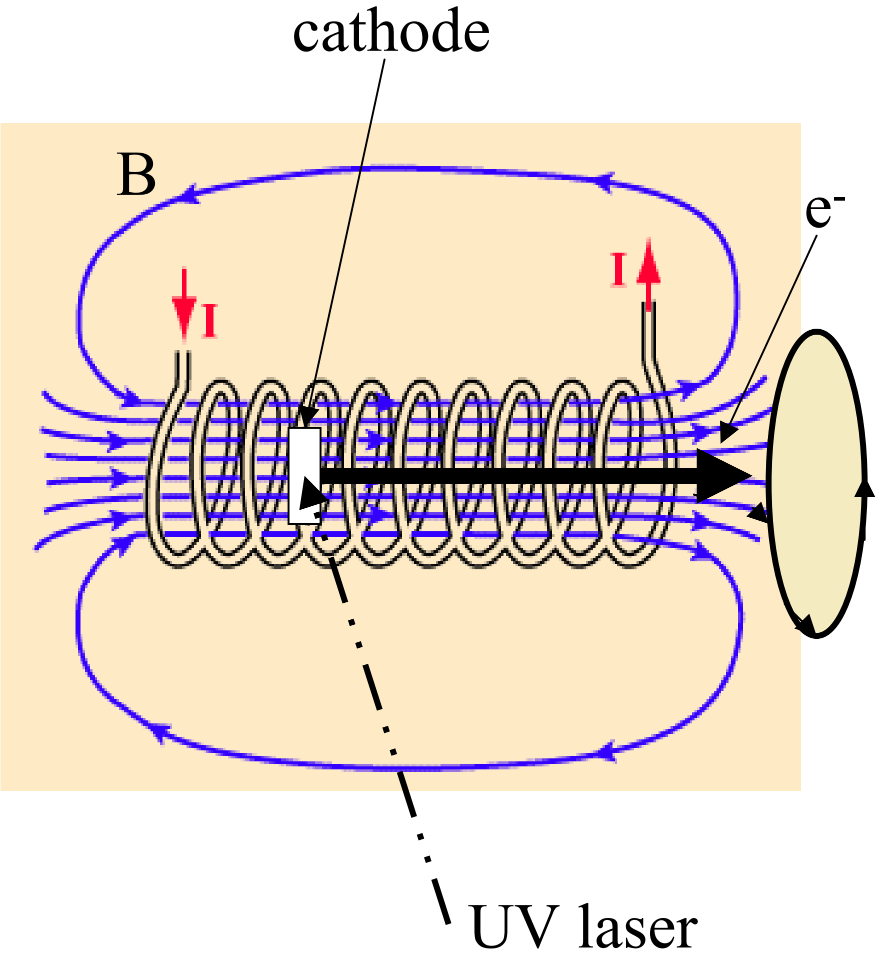


Large damping ring at Tesla

- Large or small damping rings:
  - expensive and cumbersome e.g Tesla ring circumference of about 17 km.
- Electron gun-solenoid arrangement at A0:
  - very easy and less expensive.

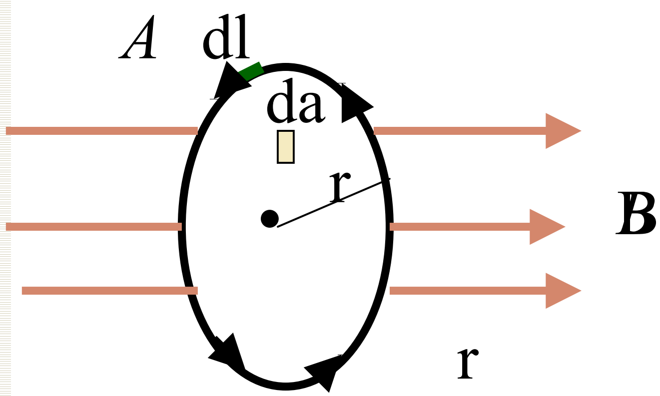
Theory of Operation

- Cathode of an RF gun immersed in solenoidal magnetic field.
- A laser shines on cathode frees bunch of electrons which travels along the solenoid.
- At exit point beams have a net angular momentum.
- Satisfies first step in flat beam production.



….theory continued

Assume emittance at cathode = 0, then no deflection



Kinetic angular momentum = 0, hence canonical momentum $P = eA$

Magnetic vector potential has angular component obtained by Amperian loop:

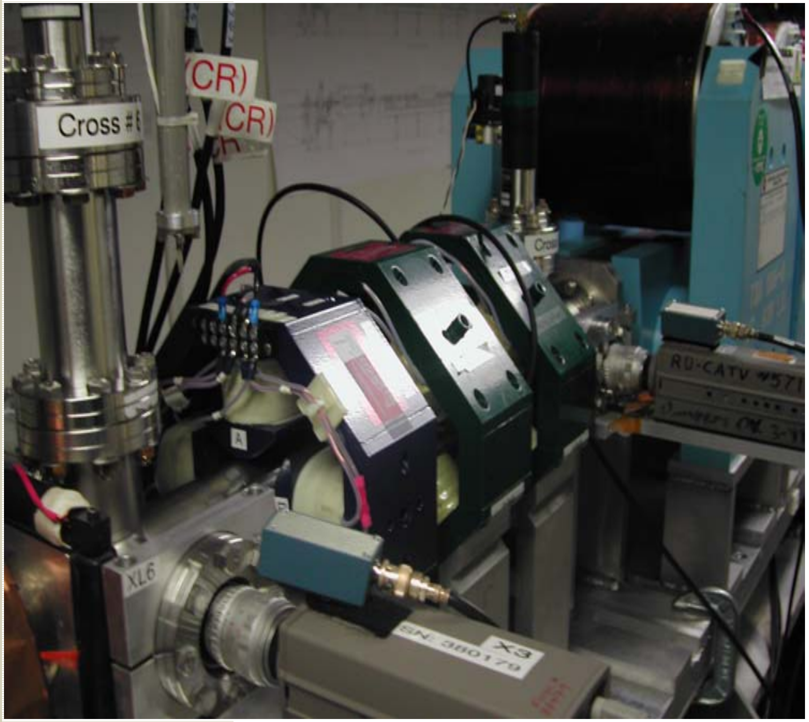
$$\oint A.dl = \int B.da$$

$$A = \frac{B}{2} r$$

Transverse momentum or angular diversion:

$$P_t = \frac{eB}{2} r$$

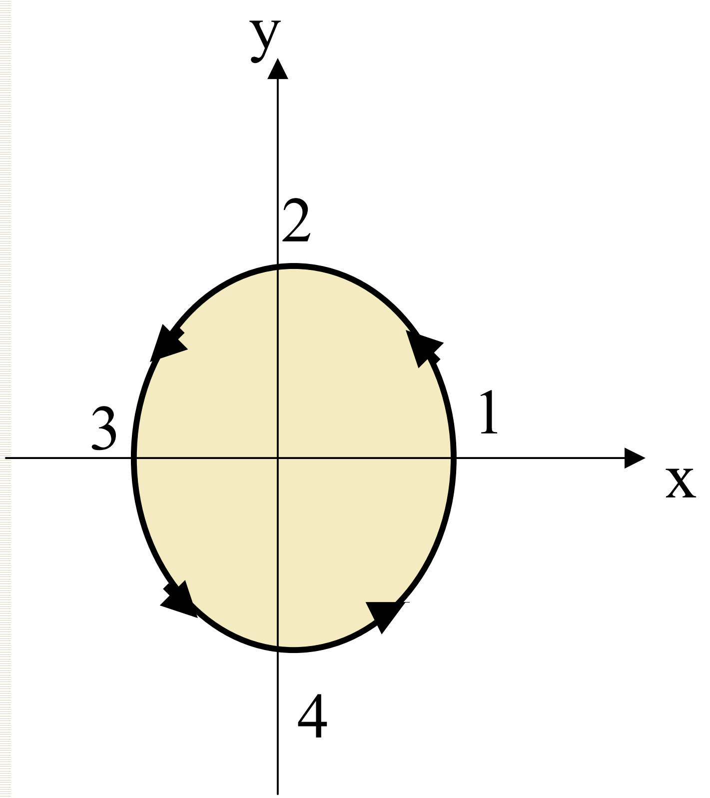
…..theory continued



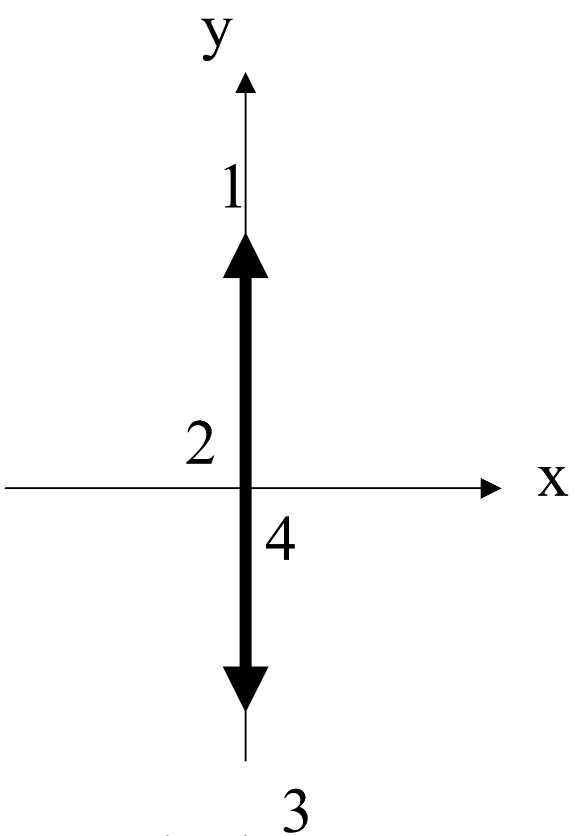
quadrupole channel

- The arrangement of the poles squeezes beam in one direction and stretches in another.
- To flatten beam, pass the beam through an alternating gradient of a quadrupole channel.

……theory contd



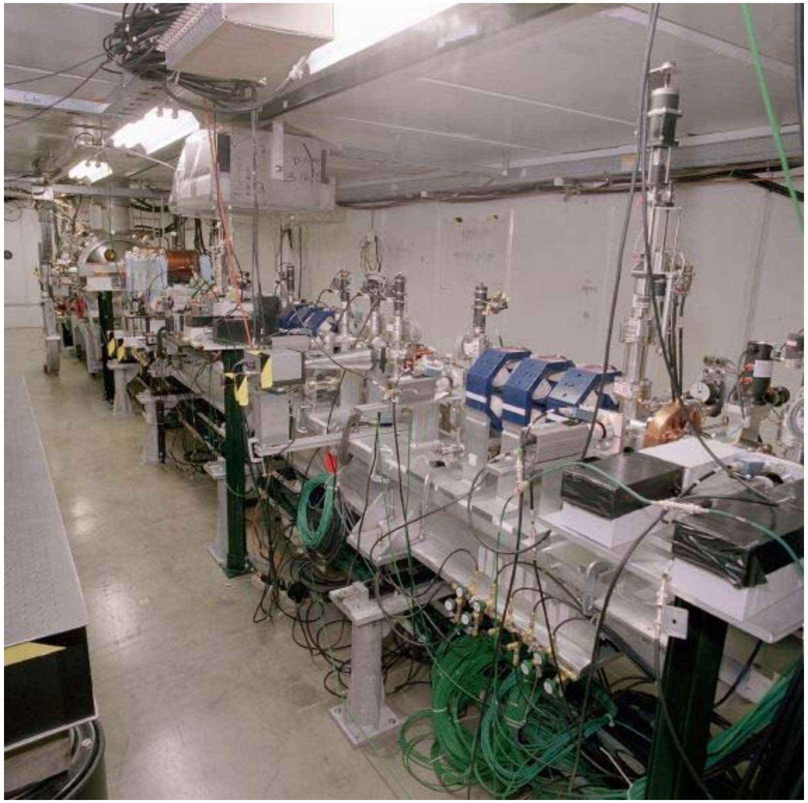
Vortex beam



Flat beam

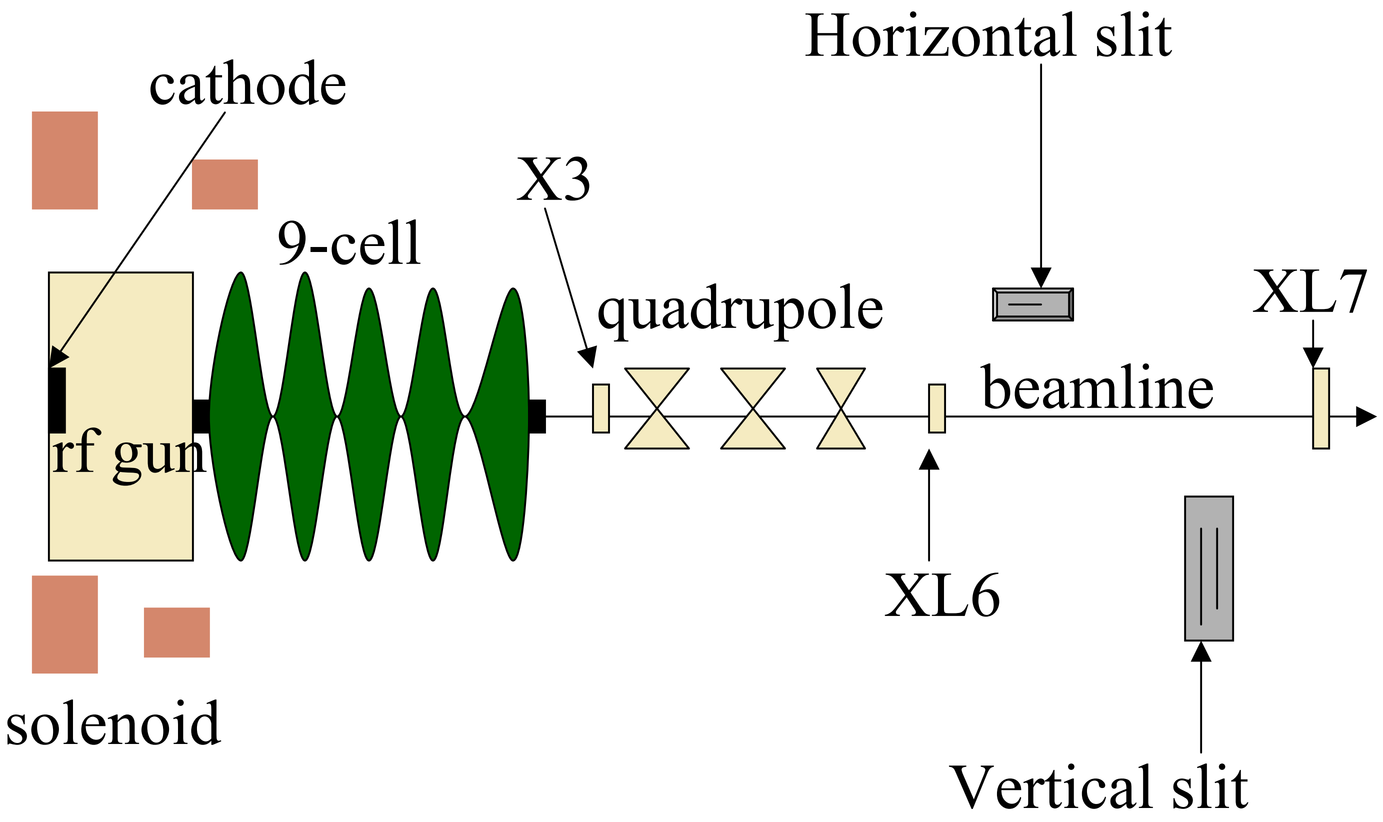
Procedure

- Experimental method:
  - experimental set up
  - beam imaging
  - emittance measurement.
- Simulation method:
  - Use of Astra and correlation matrix
  - The quadrupole channel
  - Determine final emittance.



The Fermilab beamline

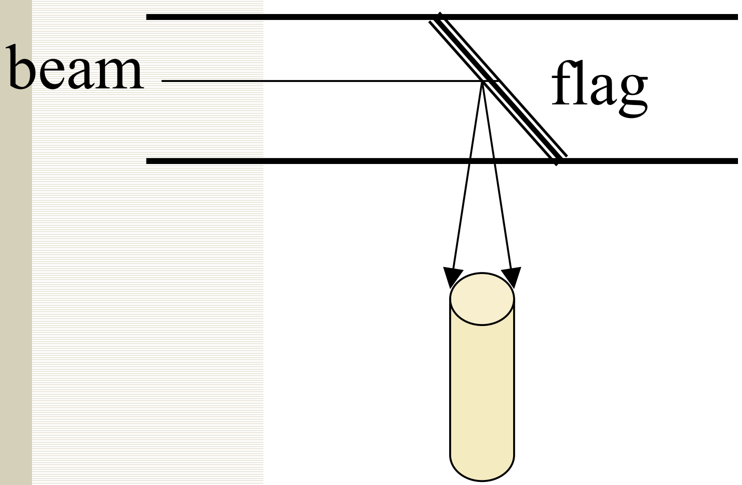
Experimental setup



Schematic diagram of Fermilab A0 layout

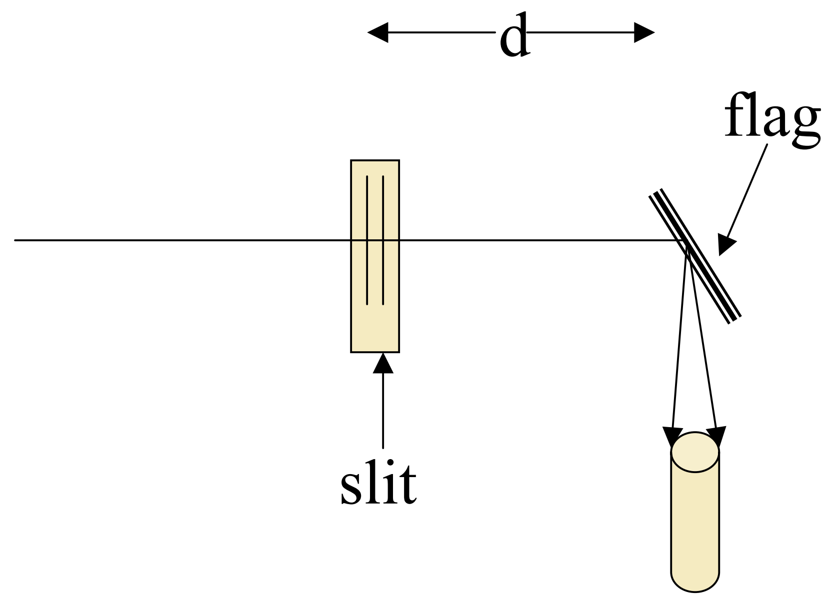
……..setup contd

σ_x obtained



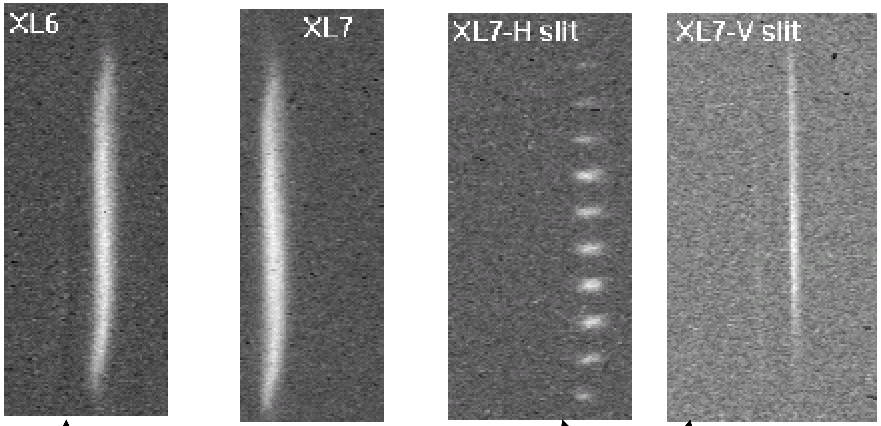
Beam imaging using OTR

$\sigma_{x'}$ obtained



Divergence measurement

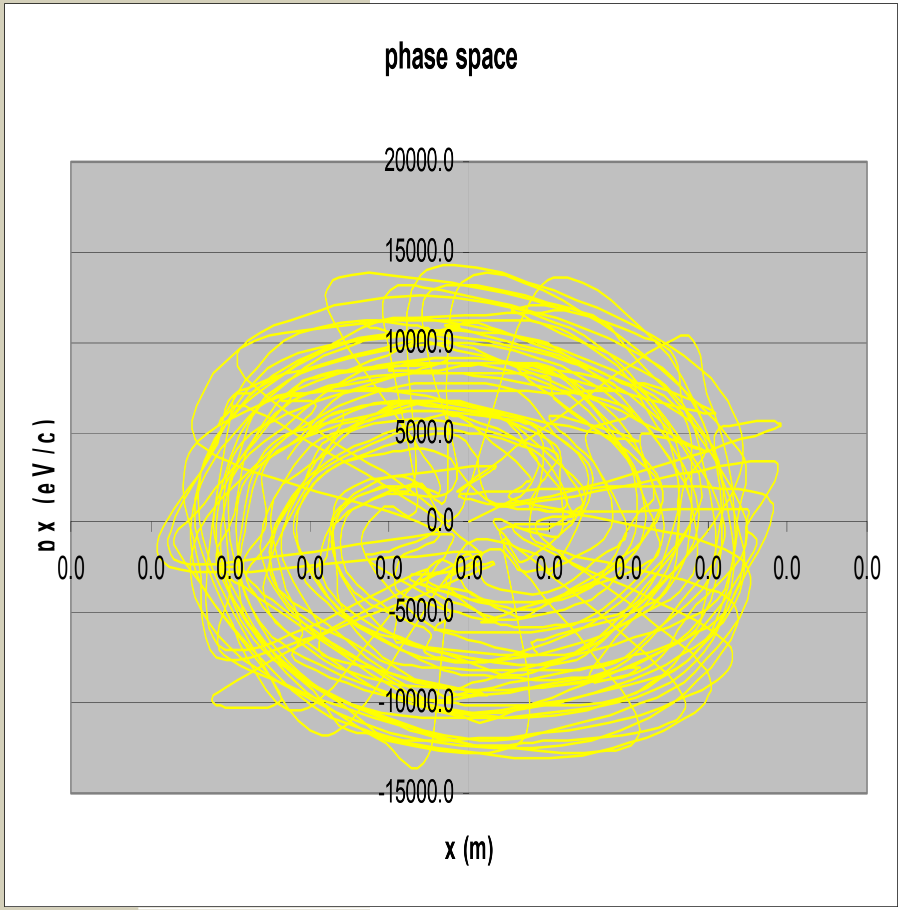
….experimental details



Corrected position images

Corrected slit images

Emittance ε



Emittance = area

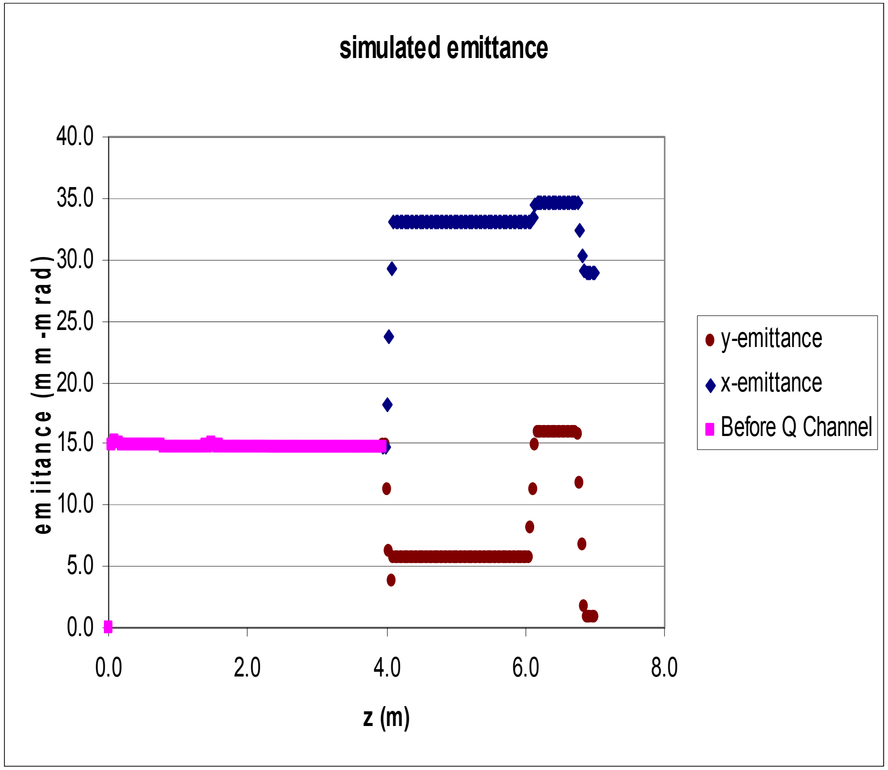
- Measures quality of a beam.
- Area of position and momentum space occupied by beam.
- Small emittance desirable.
- $\varepsilon_x = \sigma_x \sigma_{x'}$ measured in *mm mrad.*
- $\varepsilon_{normalized} = \beta\gamma\varepsilon_x$
- *where* $\beta = \frac{v}{c} \simeq 1$ *and* $\gamma \simeq 30$

Simulation

- A Space Charge Tracking Algorithm (Astra):
- - Astra generates and propagates 500 particles up to X3.
- - correlation matrix.
- - the quadrupole gradients.
- - the simulated emittances.

.....emittance ratio

- Correlation C used to obtain the quadrupole gradients.
- A graph of the simulated emiitance versus beam axis is obtained.
- Emiitance ratio calculated.



Comparison Table

	δ (mm)	I_p (A)	I_s (A)	i_1 (A)	i_2 (A)	i_3 (A)	ε_x (mm-mrad)	ε_y (mm-mrad)	$\frac{\varepsilon_y}{\varepsilon_x}$
Experimental	0.95	105	180	0.60	0.31	0.22	1.68	27.8	16
Simulation	0.81	117	180	0.82	0.56	0.47	0.86	28.8	33.4

Conclusion

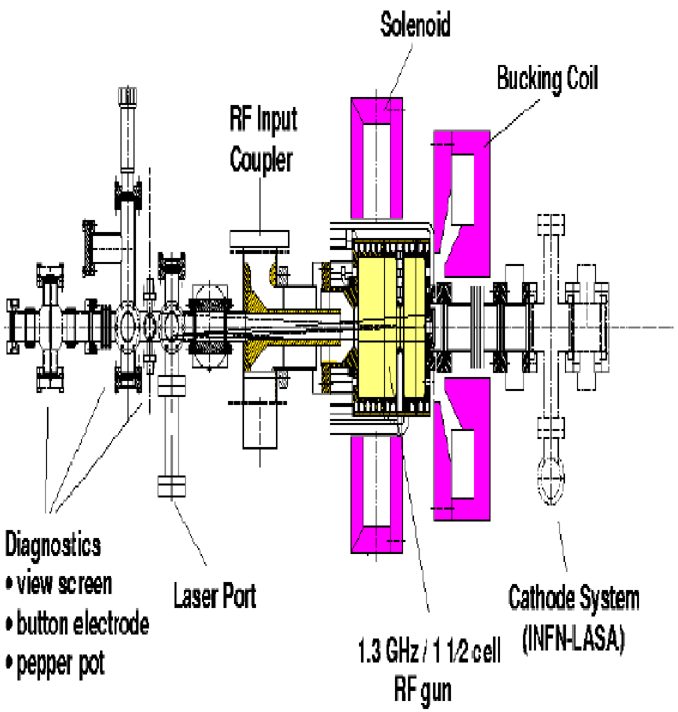
- Round-to-flat beam achieved.
- Experimental ratio 16.0 and simulated ratio 33.4.
- Agreement less than perfect.
- Disparity due to:

  - variation in bunch and space charges.

  - hot spots in the beam spot.

  - experimental errors in measurement.

  -simulation gives higher ratio.



….Thank you

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- A0 Fermilab group.
- SIST Committee.

References

- [1] D. Edwards et al, “The Flat beam experiment at FNAL Photoinjector”, Proceedings LINAC2000.
- [2] D. Edwards et al, “The Flat beam experiment at FNAL Photoinjector”, Proceedings LINAC2001.
- [3] E. Thrane “Flat Electron Beam Dynamics: A comparison of Data with Simulation”, Thesis W.L Prize Competition 2003.