Progress on the LACARA Vacuum Laser Accelerator Experiment

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References:

1) J.L. Hirshfield, C. Wang, Physics Rev. E **61**, 7252 (2000)
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3) S.V. Shchelkunov, T.C. Marshall, J.L. Hirshfield, C-B. Wang, and M.A. LaPointe, AIP Conf. Proc. **647**, 349, Editors C.E. Clayton and P. Muggli, (2002)
4) S.V. Shchelkunov, T.C. Marshall, J.L Hirshfield, C-B. Wang, M.A. LaPointe, AIP Conf. Proc. **877**, 880, Editors M. Conde and C. Eyberger (2006)

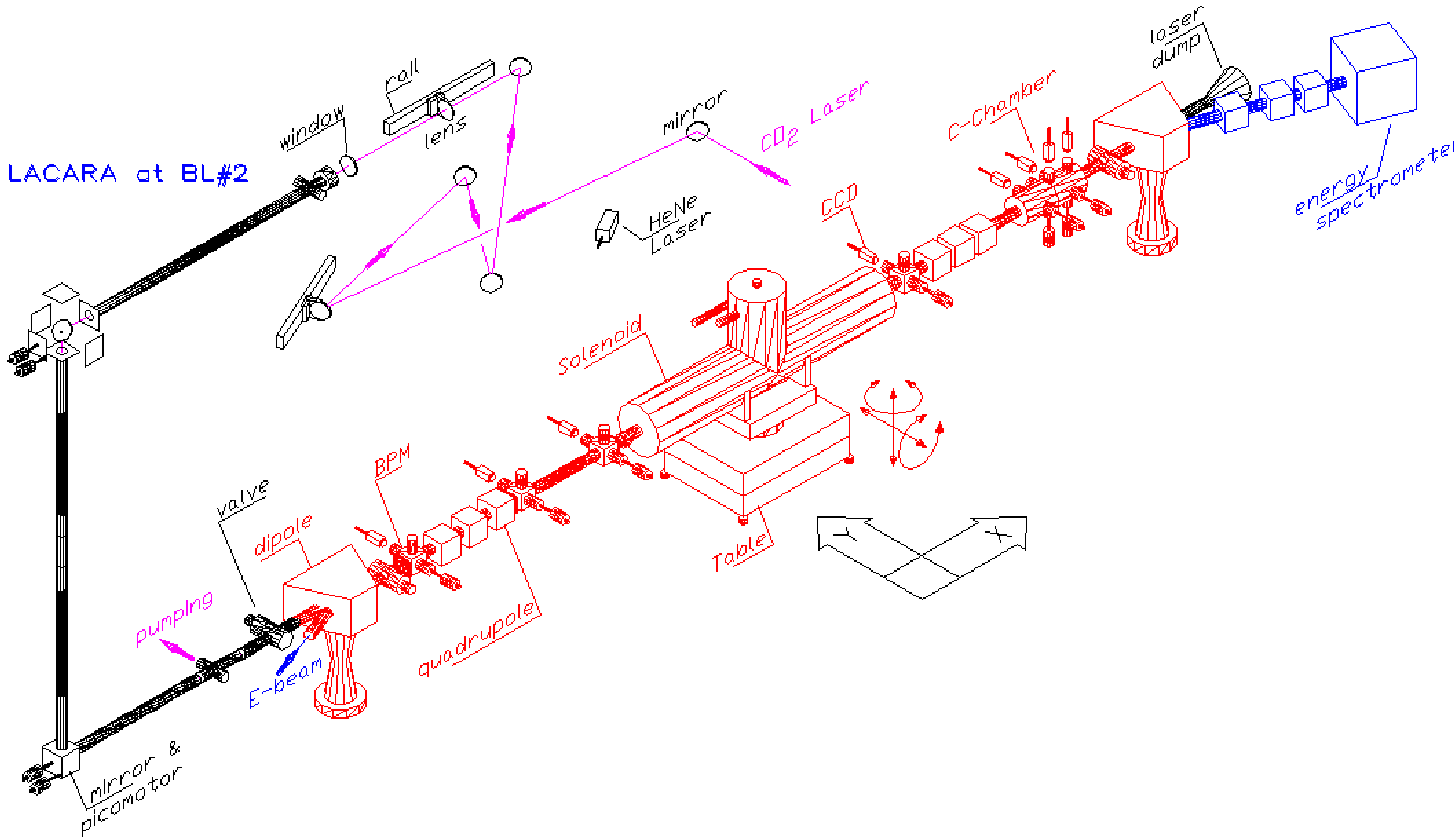


FIG. 1: LACARA (principal layout, not to scale)

(The LACARA will operate at the ATF-BNL experimental floor, BL #2)

LACARA - Laser Cyclotron Auto-Resonance Accelerator

essential parameters:

- * An up-to 6T solenoidal field (length ~1m, provided by a "dry" SC magnet.)
- * A Gaussian CO_2 laser beam ($\lambda \approx 10.6$ μm, Rayleigh Length of ~60cm, Power up to 1 TW, Energy up to 10 J)

expected performance:

- * Accelerate electrons in vacuum using the laser energy in a smoothbore structure
- * Use a un-bunched electron beam (initial test will be for a beam with 100μm waist, and an emittance of 0.015mm-mrad)
- * A 50MeV bunch should gain another 25MeV (initial test plan), i.e. the laser power provides 25 MV/m of acceleration (initial test plan)
- * Acceleration is done by a nearly-gyro resonant interaction, and all the electrons of a bunch undergo the same acceleration

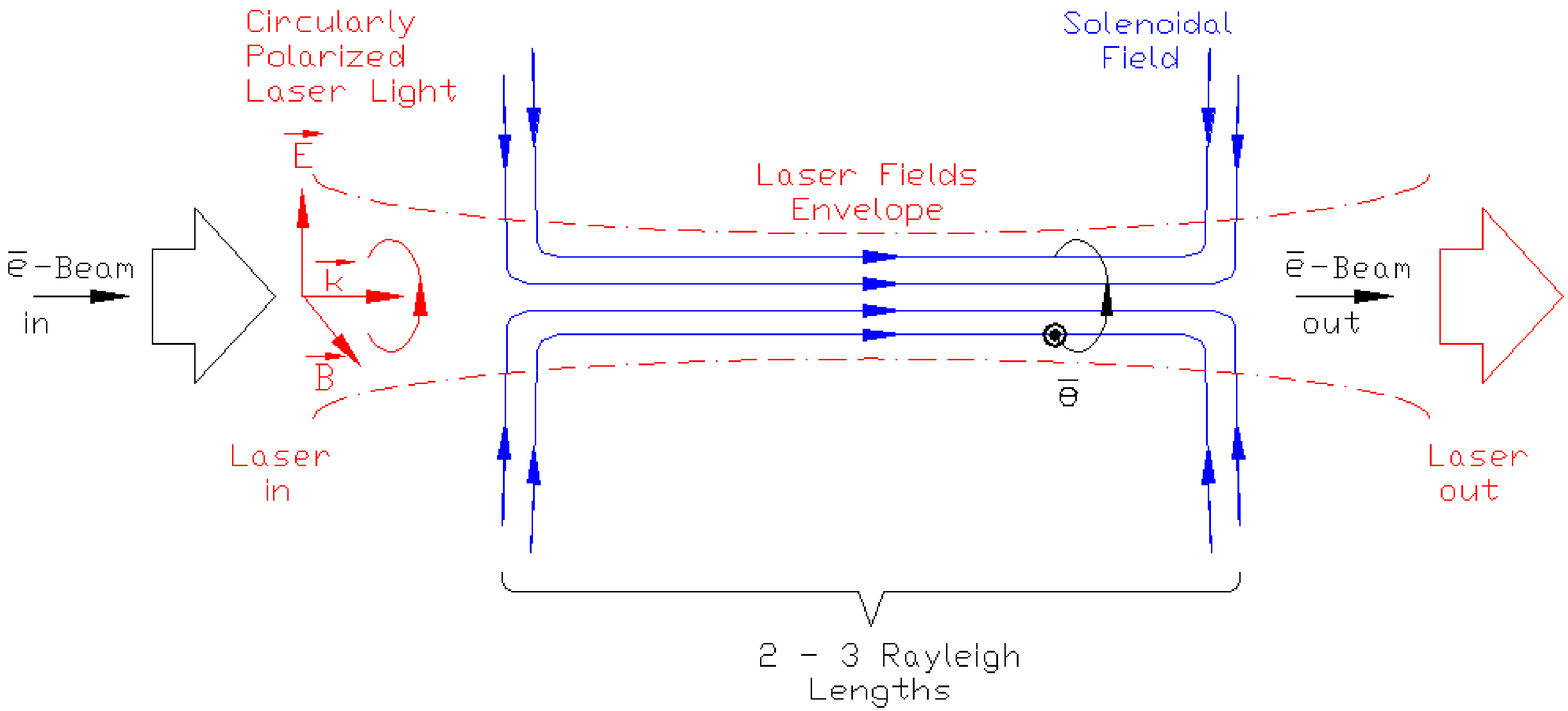
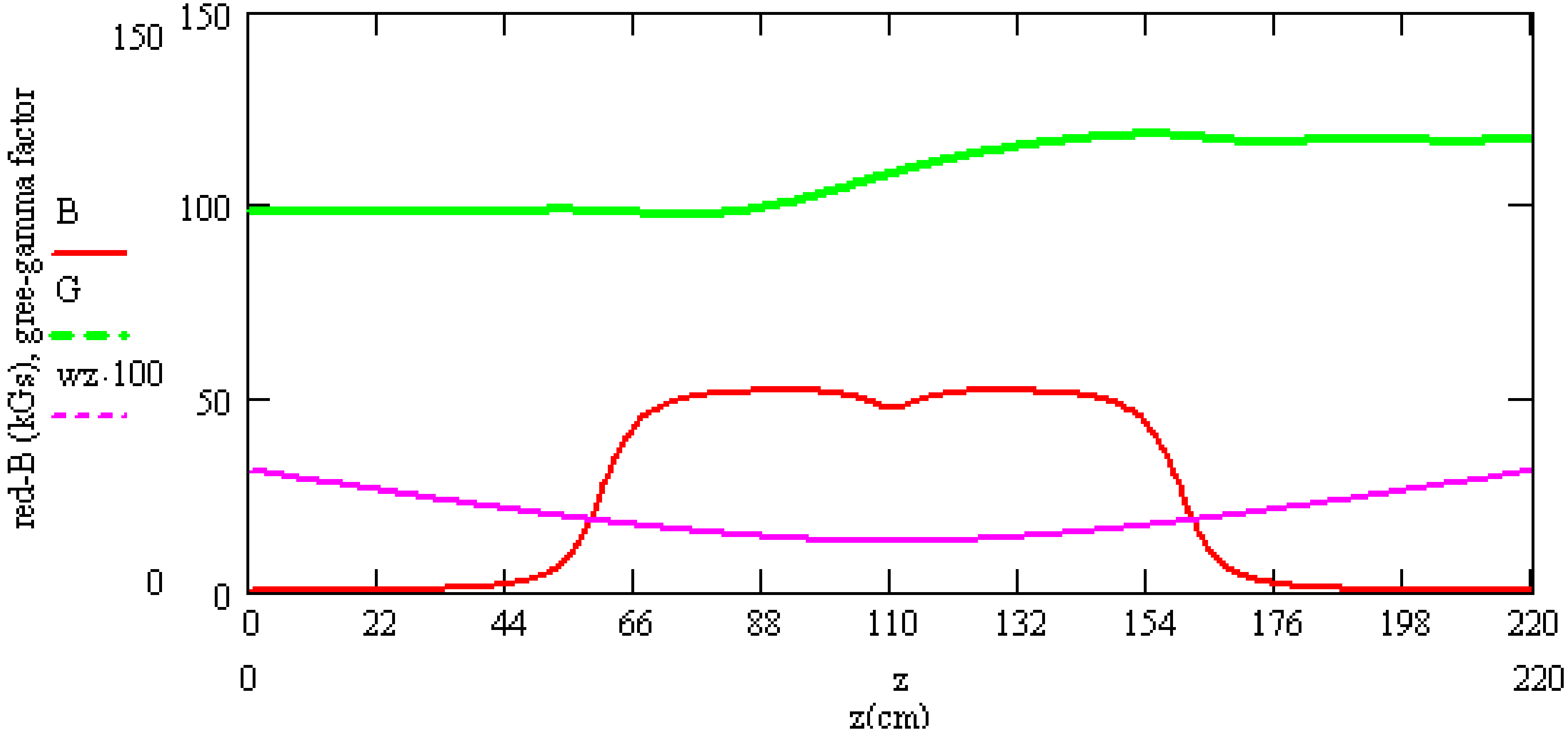


FIG. 2: Inside the solenoid

$$E = E(z, r)$$
$$B = B(z, r)$$

- both are slow functions of z



Red = magnetic field profile; Magenta = laser beam envelope; Green = energy behavior

$\sigma \approx 100\ \mu m$, $\varepsilon_{norm} \approx 1.5$ mm-mrad

Laser power, *GW*	ε_{norm}, final, *mm-mrad*	Energy gain, MeV
30	12.5	0.85
800	19.2	25

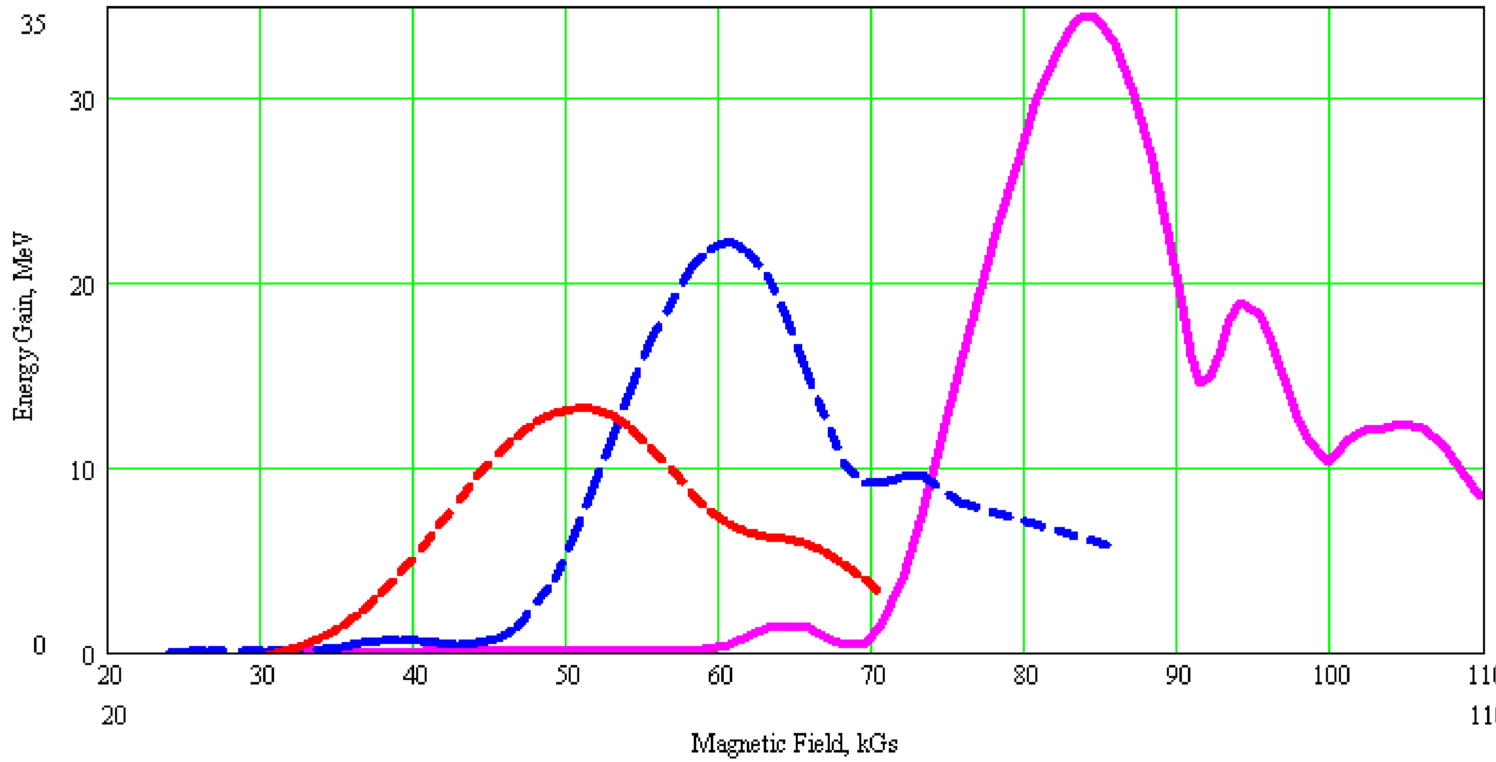


FIG 1: Energy gain (MeV) vs. the maximum magnetic field (kGs) when the laser power is always 0.8 TW (the laser light is focused in the magnet middle plane with *w* = 1.3 mm)
red = initial energy is 65 MeV; **blue** = initial energy is 50 MeV; **magenta** = initial energy is 35 MeV

Initial Energy (MeV)	B (T) when energy gain is max	Width of resonance (kGs) at 75% level of max. energy gain
35	**8.4**	**9.4** / 100%
50	**6.1**	**10.1** / 107%
65	**5.2**	**12.6** / 134%

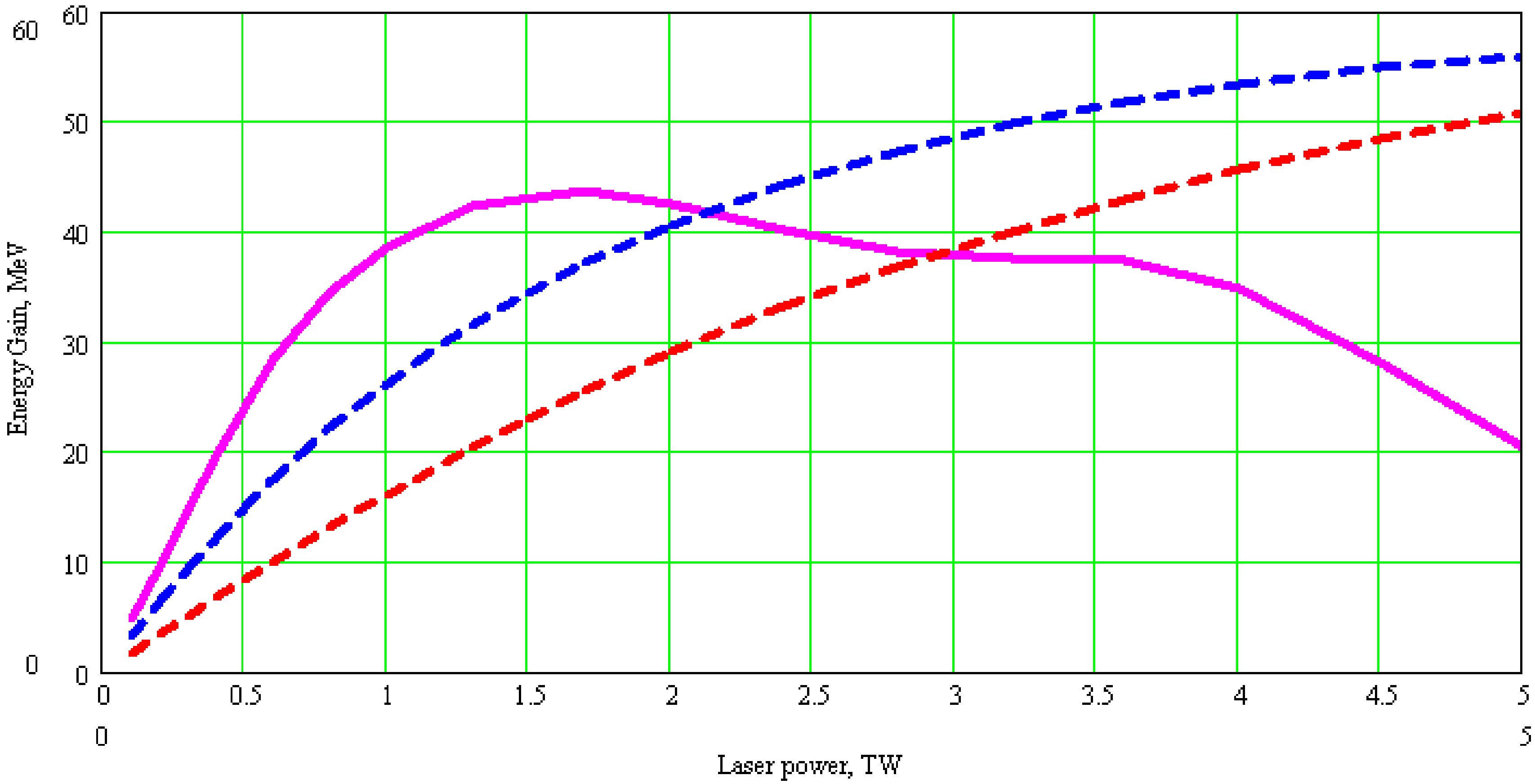


FIG 2: Energy gain (MeV) vs. the laser power (TW) when the magnetic field is always constant (the laser light is focused in the magnet middle plane with *w* = 1.3 mm)
red = initial energy is 65 MeV and B_{max} = 52 kGs ; **blue** = initial energy is 50 MeV and B_{max}= 62 kGs ;
magenta = initial energy is 35 MeV and B_{max} = 84 kGs

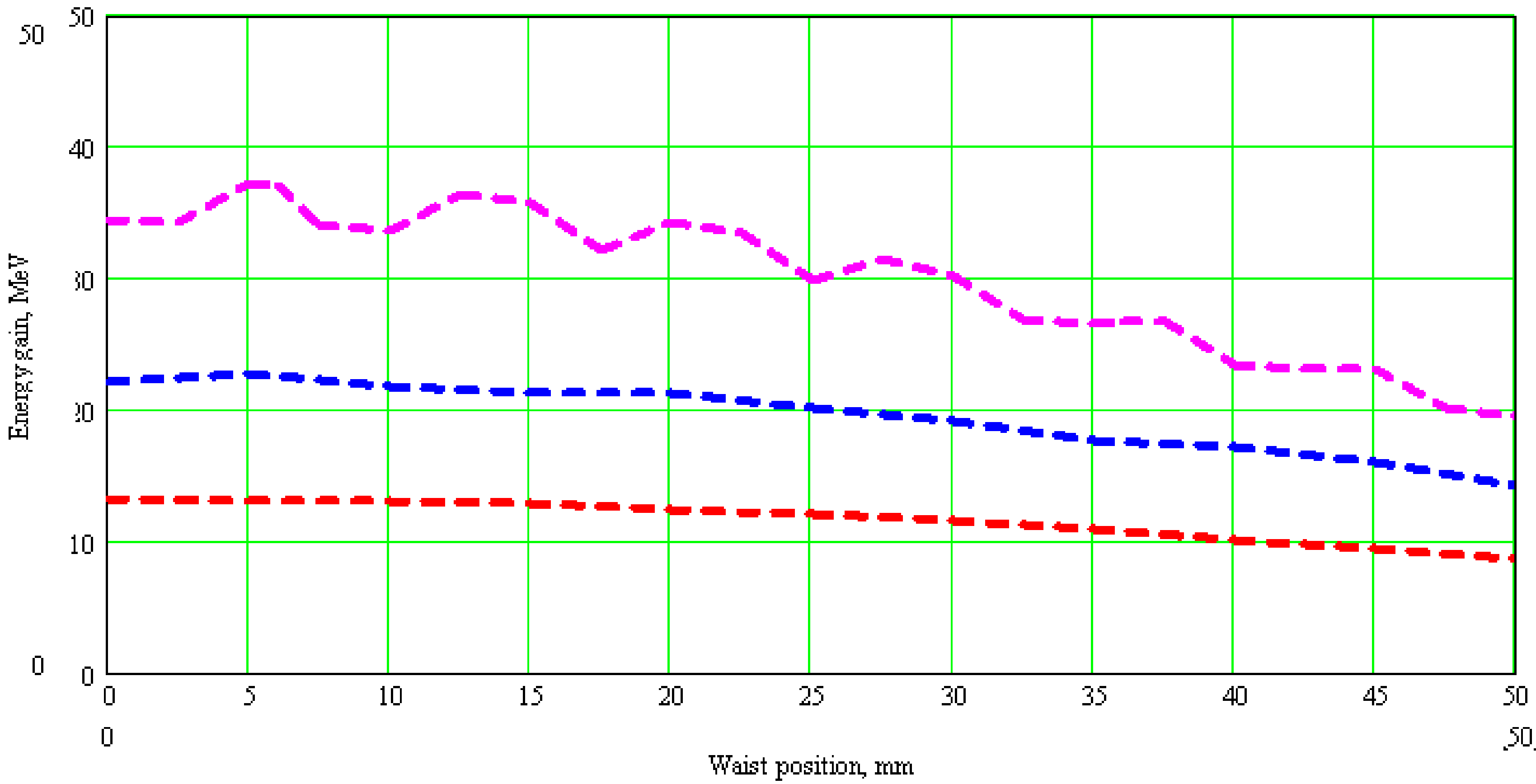
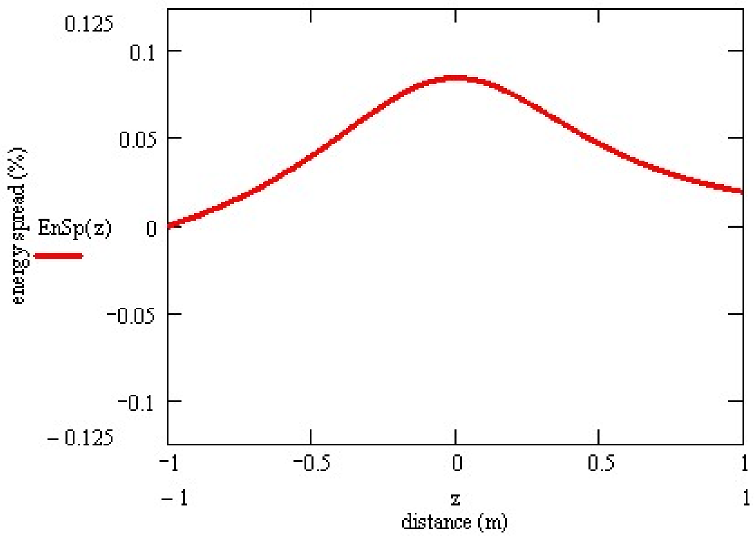
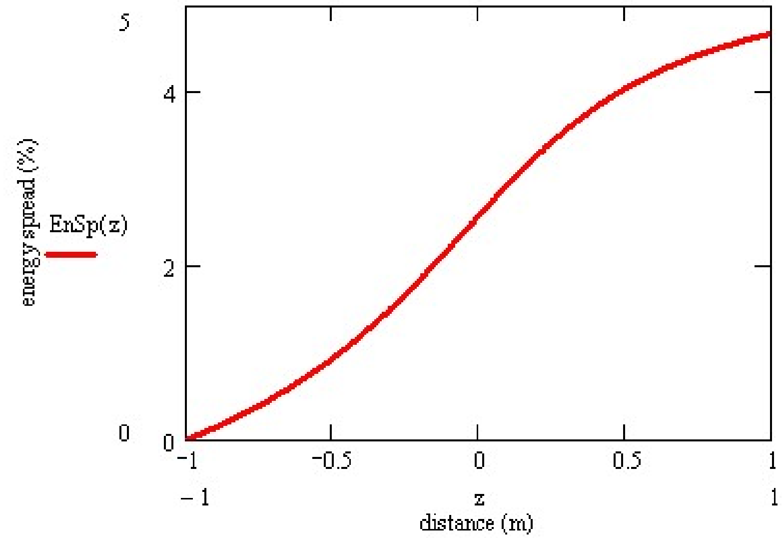


FIG 3: Energy gain (MeV) vs. the waist position (mm) when the magnetic field is always constant, and the laser power is 0.8 TW (note that "zero" corresponds to the magnet middle plain)
red = initial energy is 65 MeV and B_{max} = 52 kGs ; **blue** = initial energy is 50 MeV and B_{max}= 62 kGs ; **magenta** = initial energy is 35 MeV and B_{max} = 84 kGs





E and B change negligibly over the distance interval occupied by an electron bunch

The example shows the energy spread [%/m] induced by the difference in the electromagnetic force acting on a 5psec (1.5 mm) long e-bunch as a function of bunch position z (the distance along the magnet axis)

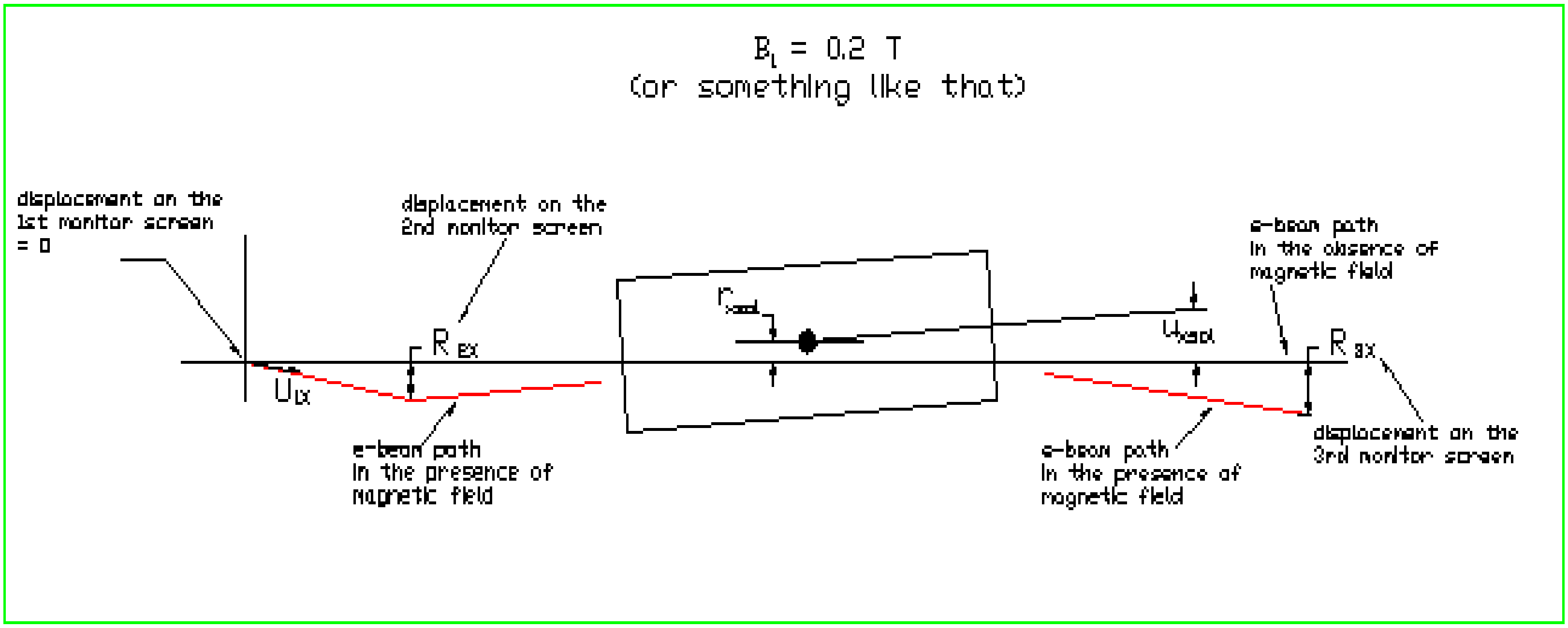
Final energy spread ≈ 0.02%

E and B change with the radius

The example shows the energy spread [%/m] induced by the difference in the ponderomotive force acting on a e-bunch with the initial $\sigma_{x,y}$ = 100μm as a function of bunch position z (the distance along the magnet axis)

Final energy spread ≈ 4.7% (scales $\propto \sigma^2$)

ALIGNMENT



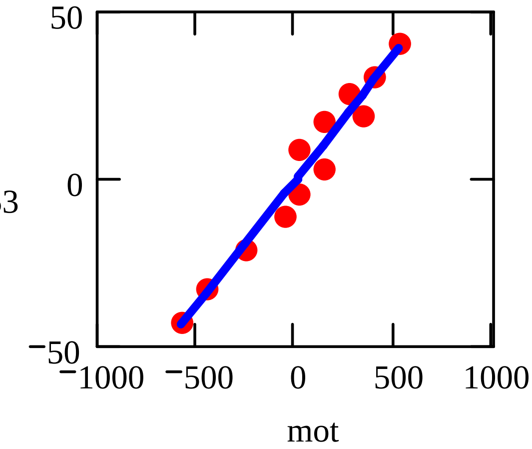
Note: the e-beam path in the absence of the magnetic field coincides with the HeNe path, and is called the axis**.**

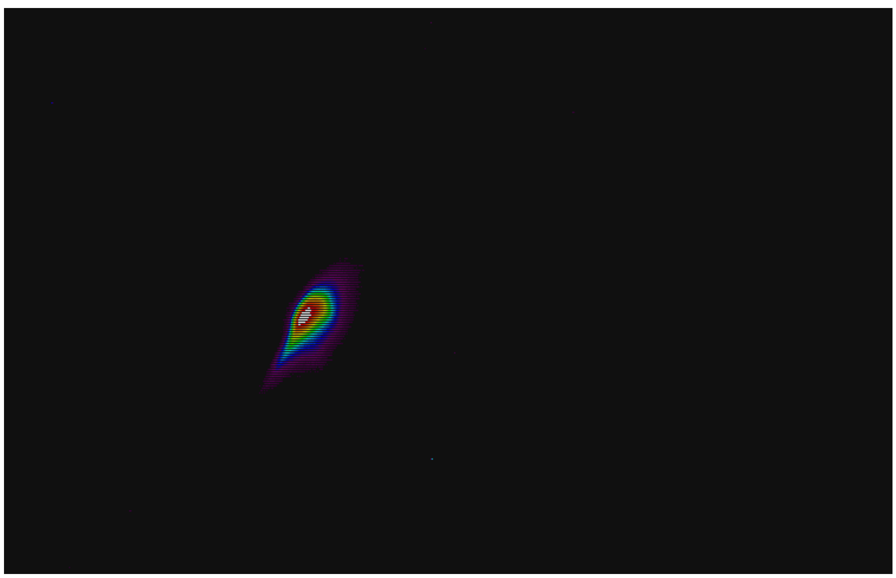
Recipe:

We can accurately determine the position of the solenoid by

1. Keeping the e-beam at the same position on the monitor #1
2. Observing the shifts at two other BPMs: one before the magnet, and another after the magnet
3. Use at least three (3) different values of the magnetic field

$$\begin{pmatrix} R_X \\ R_Y \end{pmatrix} = \begin{pmatrix} \alpha & \beta & \gamma & \Delta \\ -\beta & \alpha & -\Delta & \gamma \end{pmatrix} \times \begin{pmatrix} X \\ Y \\ U_X \\ U_Y \end{pmatrix}$$





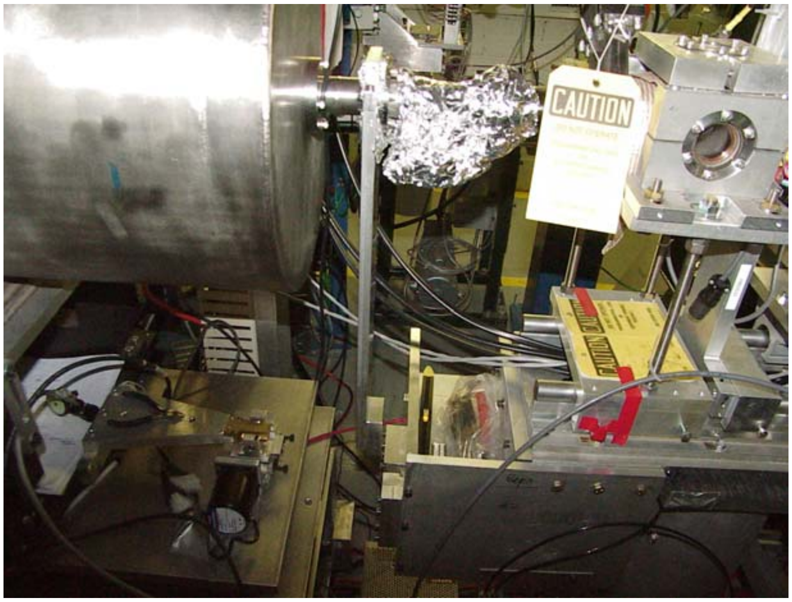
Beam behind the solenoid (at 5.2 T)

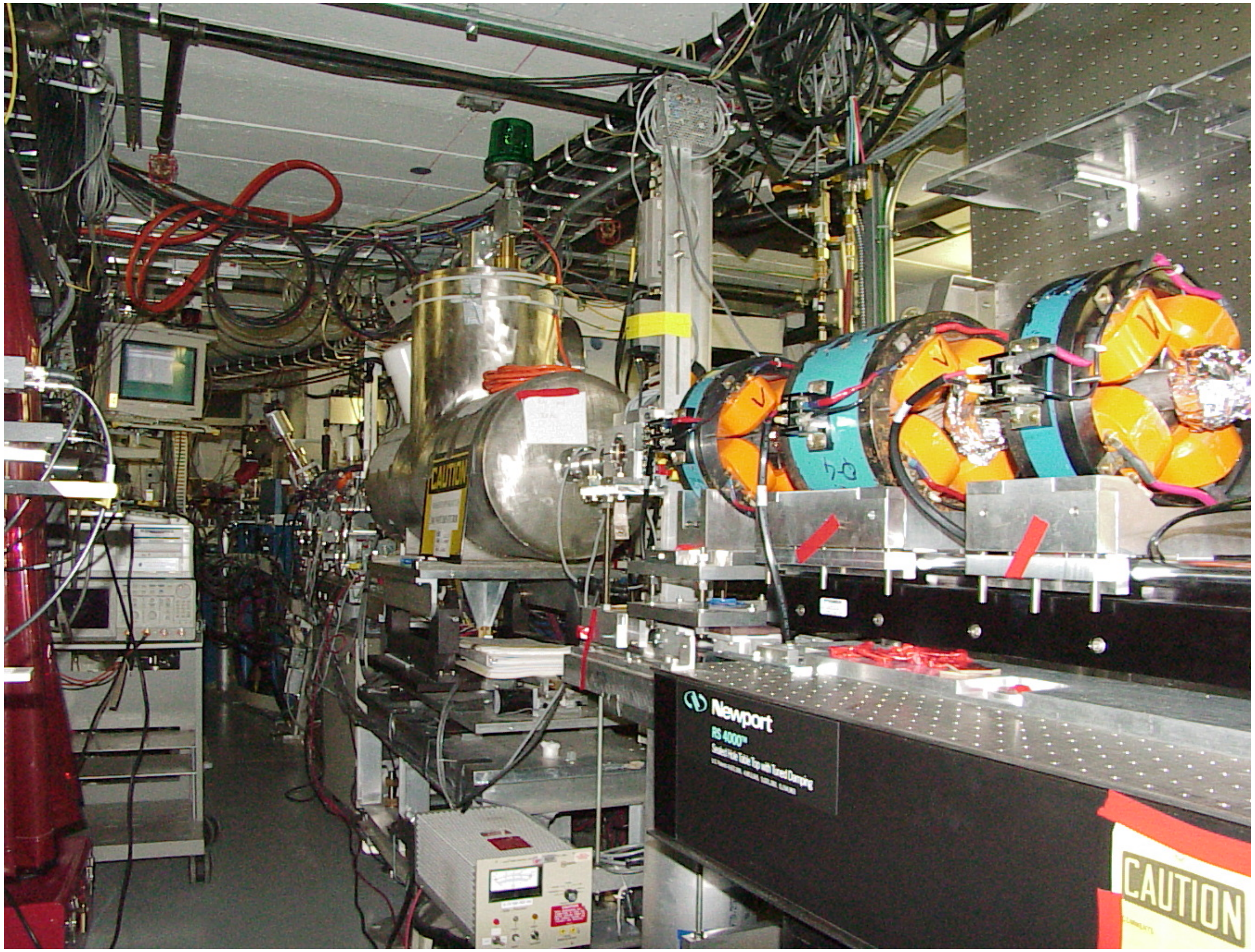
We compared the beam position at 2.5 T and 5 T and discovered that there was a shift which can be explained if the solenoid axis is as straight as ΔY = 150 μm, and ΔX = 500 μm

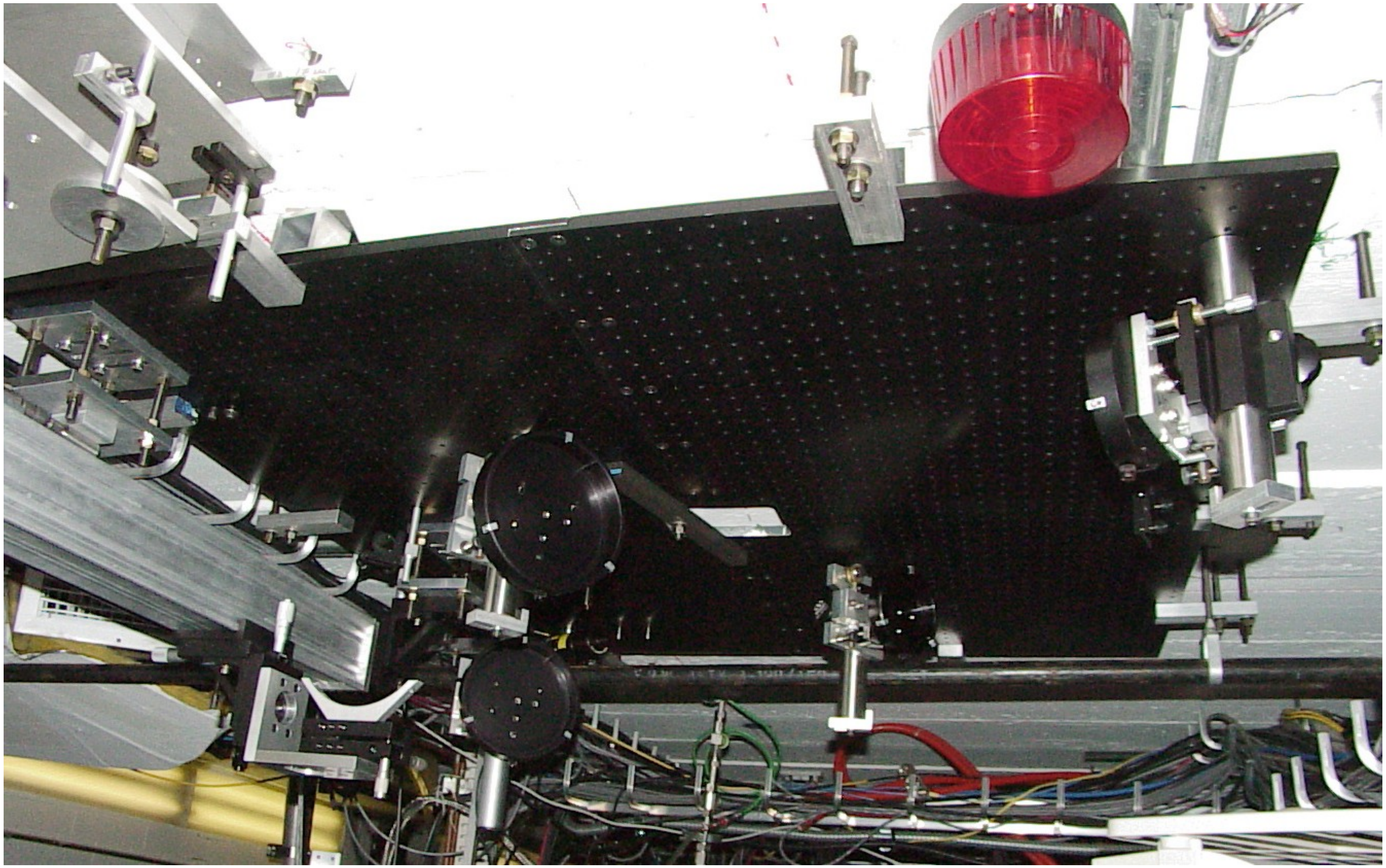
Problems:

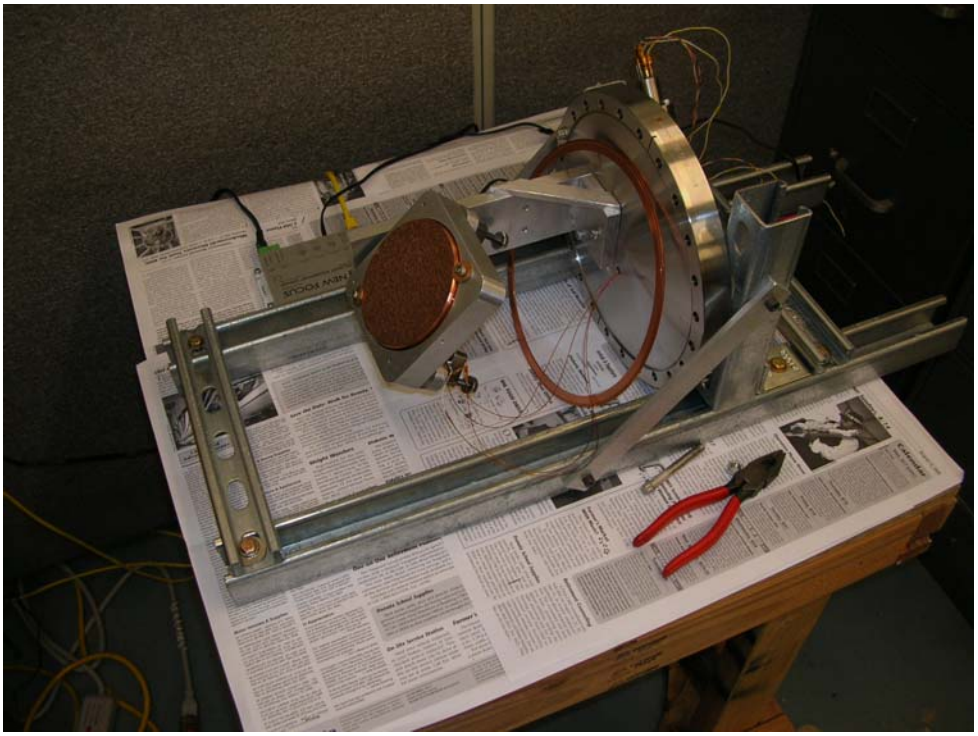
- **The solenoid position presently is determined relative to its support**
- **This support (table) position may change relative to the beam line**
- **The Y-position is not very much sensitive; the X-position is very sensitive.**

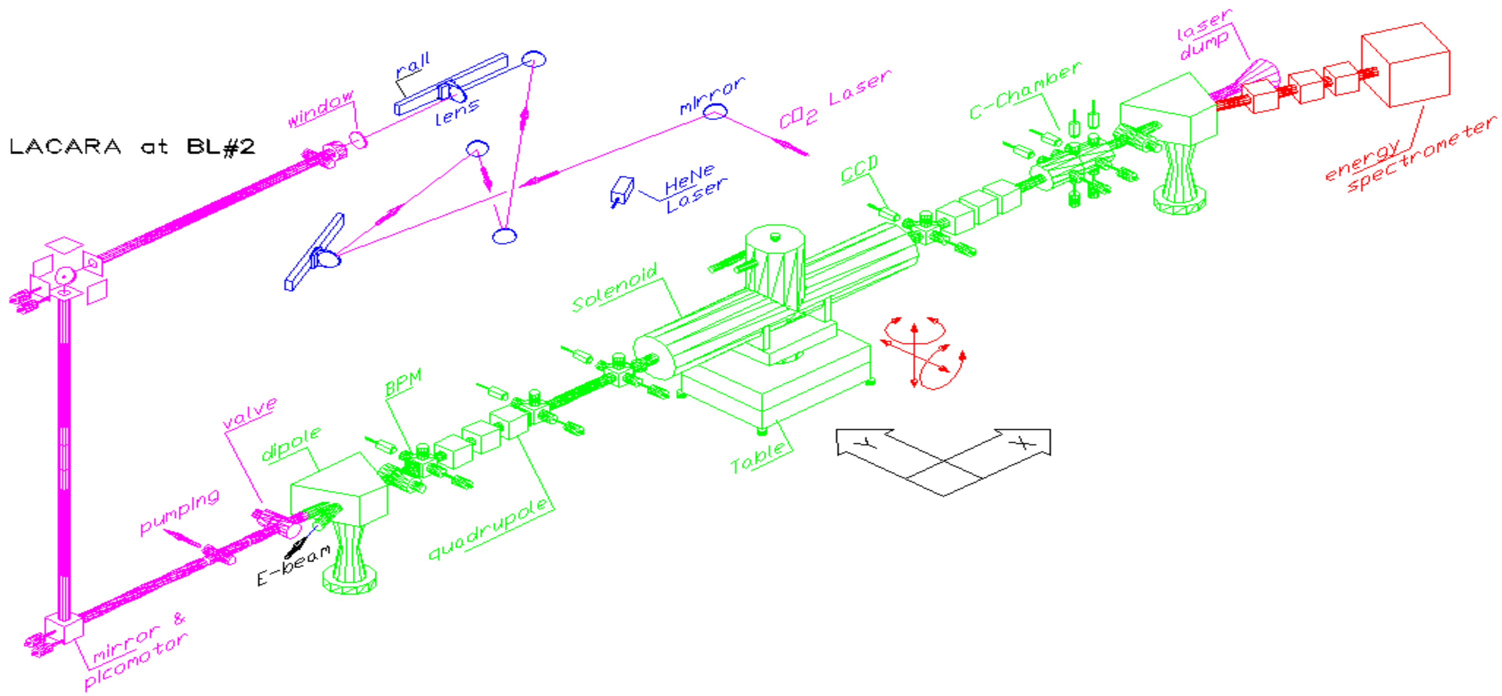
Solution:




CAUTION
Newport
RS 4000
CAUTION







Electron Transport	Already assembled
Solenoid-E-beam alignment	Tested/ almost done
CO_2 focusing optics	April/May
CO_2 transport in-vacuum line	April/May
Demonstrating the CO_2 transport	May/June
Runs	May/June
New Spectrometer	July/October
More runs	July/February