Update on Modular Driver and Final Focus Study

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Skunk Meeting
4/5/07
at LBNL

Focal System Layout

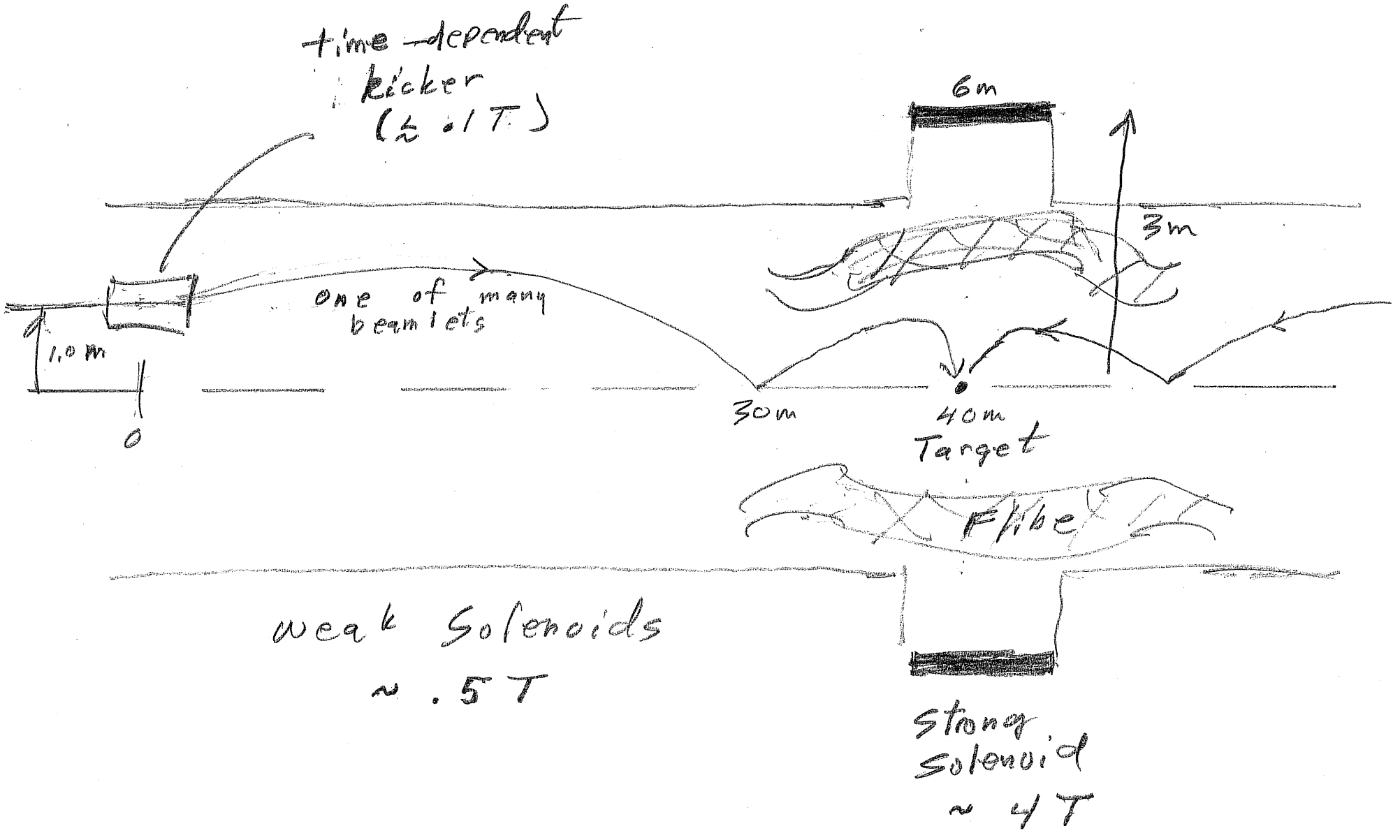
Ion Types + Energies

Improved Dynamics Model

Orbits

Spot Size Sensitivity

Focal System Layout



Ion Types + Energies

Latest Thinking:

		cold carbon range
Ar^{+8}	1039 MeV ± 20%	.1 $\frac{gm}{cm^2}$
Kr^{+8}	500 MeV ± 20%	.006
Xe^{+8}	318.7 MeV ± 20%	.003

Canonical Momentum

$$P_\phi = \gamma m r v_\phi + q e r A_\phi$$
$$= 0 \text{ for } \underline{\text{ideal}} \ \underline{\text{ion}}$$

$$\text{Magnetic Rigidity} = \frac{\text{momentum}}{\text{charge}} = 3.69 \text{ T-m } (\pm 10\%)$$

$$\underline{\text{For}} \ \underline{\text{All}} = (B\rho)$$

We can simultaneously use all species

Improved Dynamics Model

Specify Current Layers

$\rightarrow$ $B_0(z)$ = on-axis field

$$B_z = B_0 - \frac{B_0'' r^2}{4} + \frac{B_0'''' r^4}{64} - \cdots$$

$$B_r = -\frac{B_0' r}{2} + \frac{B_0''' r^3}{16} - \frac{B_0'''' r^5}{384} + \cdots$$

Solve Ion Dynamics:

$$x'' = \frac{1}{(B\rho)}\sqrt{1+x'^2+y'^2}\left[x'y'B_x - (1+x'^2)B_y + y'B_z\right]$$

$$y'' = \frac{1}{(B\rho)}\sqrt{1+x'^2+y'^2}\left[-x'y'B_y + (1+y'^2)B_x - x'B_z\right]$$

Include geometric + fringe field aberrations.

+ Vary $(B\rho)$ for chromatic aberration

In[117]:=

```
q = 8;
A = 83.91;
T0 = 500;
T = 500;
βγ0 = ((T0 / 931.5 / A) ^2 + 2 * (T0 / 931.5 / A)) ^.5;
βγ = ((T / 931.5 / A) ^2 + 2 * (T / 931.5 / A)) ^.5;
Brho0 = 3.107 * βγ0 * A / q;
Brho = 3.107 * βγ * A / q;
mu0 = 4 * Pi * (10 ^ -7);

f[S_, R_, x1_, x2_, z_] =
  mu0 * S / 2 * ((z - x1) / ((z - x1) ^2 + R ^2) ^.5 - (z - x2) / ((z - x2) ^2 + R ^2) ^.5);
Bb = -.0;
h = 1.0;
l = 1.0;
zb = .5;

B0[z_] = f[366672.8, 2, 1, 27, z] + f[-91668.2, 2, 27, 37, z] +
   f[-4925701.809, 3, 37, 43, z] + f[-91668.2, 2, 43, 53, z] + f[366672.8, 2, 53, 79, z];
Print["B0[z]"];
Plot[B0[z], {z, -10, 90}];
Plot[B0[z], {z, 30, 50}];

B0p[z_] = D[B0[z], z];
B0pp[z_] = D[B0p[z], z];
B0ppp[z_] = D[B0pp[z], z];
B0pppp[z_] = D[B0ppp[z], z];
B0ppppp[z_] = D[B0pppp[z], z];
Bz[x_, y_, z_] = B0[z] - B0pp[z] * (x ^2 + y ^2) / 4 + B0pppp[z] * (x ^2 + y ^2) ^2 / 64;
Bx[x_, y_, z_] =
  -B0p[z] * x / 2 + B0ppp[z] * x * (x ^2 + y ^2) / 16 - B0ppppp[z] * x * (x ^2 + y ^2) ^2 / 384 -
   Bb * h * y / (x ^2 + y ^2) * If[(x ^2 + y ^2) ^2 / h ^4 ≥ 4 * (z - zb) ^2 / l ^2, 1, 0];
By[x_, y_, z_] =
-B0p[z] / 2 * y + B0ppp[z] * y * (x ^2 + y ^2) / 16 - B0ppppp[z] * y * (x ^2 + y ^2) ^2 / 384 +
   Bb * h * x / (x ^2 + y ^2) * If[(x ^2 + y ^2) ^2 / h ^4 ≥ 4 * (z - zb) ^2 / l ^2, 1, 0];
z0 = -1;
zf = 40;

x0 = 1.00;
xp0 = 0.0;
y0 = 0;
ψ = 1 / Brho * (B0[z0] * (x0 ^2 + y0 ^2) / 2 -
      B0pp[z0] * (x0 ^2 + y0 ^2) ^2 / 16 + B0pppp[z0] * (x0 ^2 + y0 ^2) ^3 / 384);

yp01 = 1 / x0 * (y0 * xp0 - ψ * (1 + xp0 ^2) ^.5);
yp02 = 1 / x0 * (y0 * xp0 - ψ * (1 + xp0 ^2 + yp01 ^2) ^.5);
yp03 = 1 / x0 * (y0 * xp0 - ψ * (1 + xp0 ^2 + yp02 ^2) ^.5);
Print["initial yp to make Pθ=0"];
yp0 = 1 / x0 * (y0 * xp0 - ψ * (1 + xp0 ^2 + yp03 ^2) ^.5)
Print["initial Pθ/qe"];
Pθoverqe = Brho / (1 + xp0 ^2 + yp0 ^2) ^.5 * (x0 * yp0 - y0 * xp0) + B0[z0] / 2 * (x0 ^2 + y0 ^2) -
  B0pp[z0] / 16 * (x0 ^2 + y0 ^2) ^2 + B0pppp[z0] / 384 * (x0 ^2 + y0 ^2) ^3
```

(500 MeV Kr^+)

Pulsed deflection

Magnets

Fringe Field

Ion initial values

$P_\theta = 0$

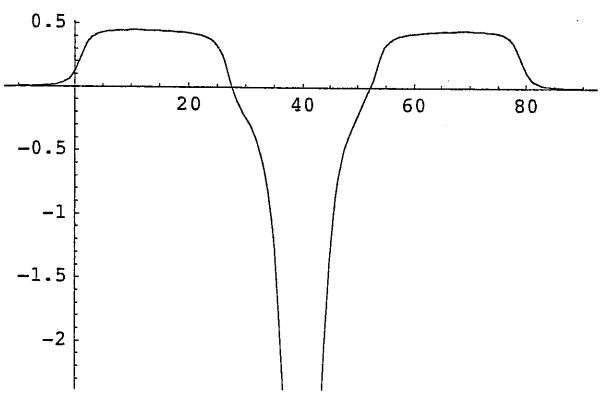
Solve Dynamics

```
aol = NDSolve[{x'[z] == xp[z],
    xp'[z] == 1/Brho*(1+xp[z]^2+yp[z]^2)^.5*(xp[z]*yp[z]*Bx[x[z], y[z], z] -
        (1+xp[z]^2)*By[x[z], y[z], z] + yp[z]*Bz[x[z], y[z], z]), y'[z] == yp[z],
    yp'[z] == 1/Brho*(1+xp[z]^2+yp[z]^2)^.5*(-xp[z]*yp[z]*By[x[z], y[z], z] +
        (1+yp[z]^2)*Bx[x[z], y[z], z] - xp[z]*Bz[x[z], y[z], z]),
    x[z0] == x0, xp[z0] == xp0, y[z0] == y0, yp[z0] == yp0}, {x, xp, y, yp},
   {z, z0, zf}, MaxSteps → 1100000, MaxStepSize → .01];
```

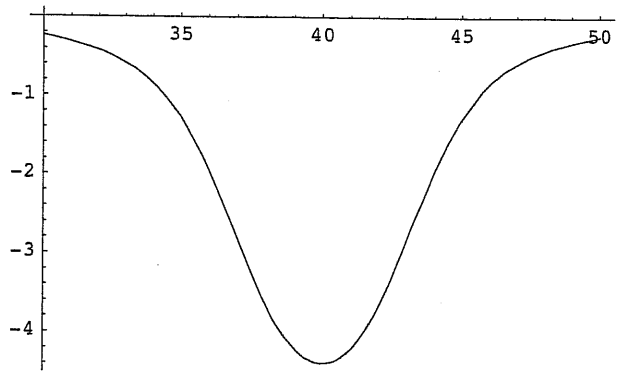
Plots

```
xx[z_] = x[z] /. aol;
yy[z_] = y[z] /. aol;
xxp[z_] = xp[z] /. aol;
yyp[z_] = yp[z] /. aol;
Print["x[z] and y[z]"]
ParametricPlot[{x[z], y[z]} /. aol, {z, z0, zf}];
Plot[{xx[z], yy[z]}, {z, z0, zf}];
Plot[{xx[z], yy[z]}, {z, 39, 40}];
Print["x[40,y[40]"];
xx[40]
yy[40]
r[z_] = (xx[z]^2 + yy[z]^2)^.5;
Print["r[z]"];
Plot[r[z], {z, z0, zf}];
Plot[r[z], {z, 39, 40}];
Print["r[40]"];
r[40]
Print["r'[39.8]"];
(xx[39.8]*xxp[39.8] + yy[39.8]*yyp[39.8]) / r[39.8]
```

B0[z]



On-Axis Field $B_0(z)$



$F_\theta(z)$

initial yp to make Pθ=0

Out[153]=

-0.00822021 — ideal initial y'

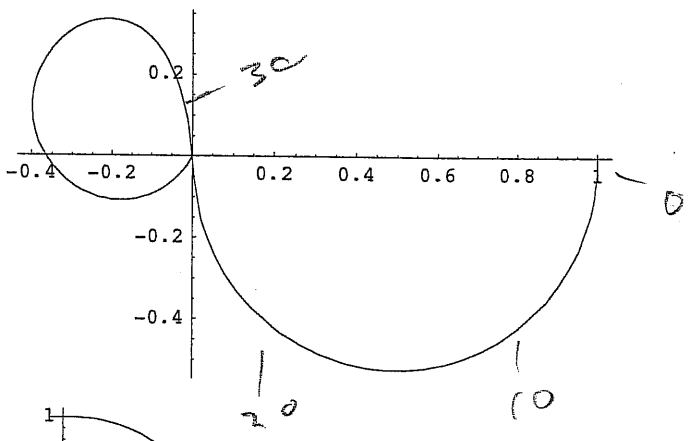
initial Pθ/qe

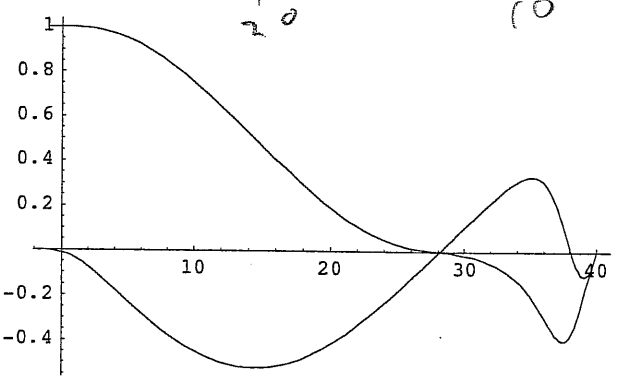
Out[155]=

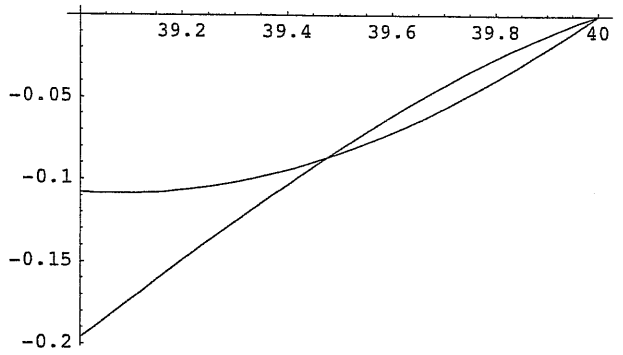
2.83248×10^{-18}

x[z] and y[z]

x and y vs z








```
x[40,y[40]
```

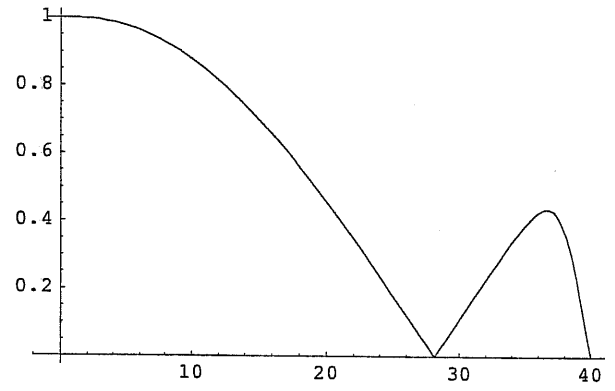
Out[166]=

$\{-6.19893\times10^{-8}\}$

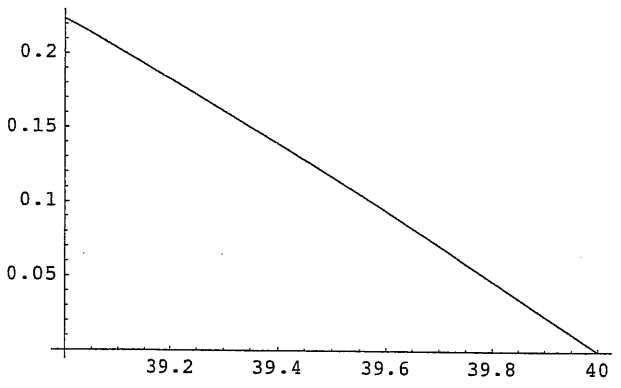
Out[167]=

$\{-1.54166\times10^{-8}\}$

```
r[z]
```



r(z)
ideal ion



r(z)
ideal ion

```
r[40]
```

Out[173]=

$\{6.38776\times10^{-8}\}$

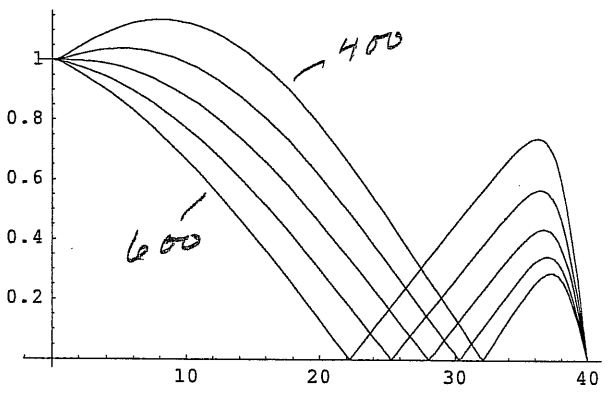
```
r'[39.8]
```

Out[175]=

$\{-0.23635\}$

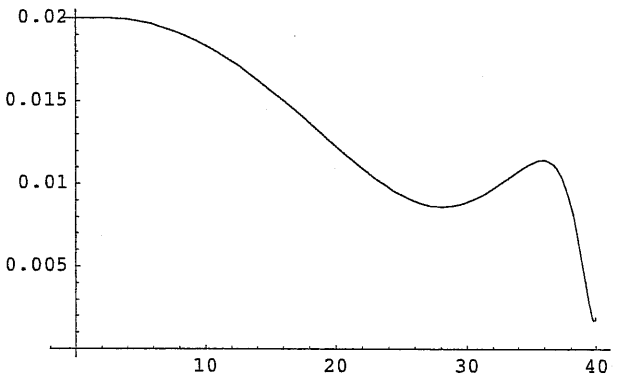
```
u0[z_] = r[z]
{(InterpolatingFunction[{{-1., 40.}}, <>][z]^2 +
    InterpolatingFunction[{{-1., 40.}}, <>][z]^2)^0.5}

u1[z_] = r[z]
{(InterpolatingFunction[{{-1., 40.}}, <>][z]^2 +
    InterpolatingFunction[{{-1., 40.}}, <>][z]^2)^0.5}

u2[z_] = r[z]
{(InterpolatingFunction[{{-1., 40.}}, <>][z]^2 +
    InterpolatingFunction[{{-1., 40.}}, <>][z]^2)^0.5}

u3[z_] = r[z]

{(InterpolatingFunction[{{-1., 40.}}, <>][z]^2 +
    InterpolatingFunction[{{-1., 40.}}, <>][z]^2)^0.5}

u4[z_] = r[z]

{(InterpolatingFunction[{{-1., 40.}}, <>][z]^2 +
    InterpolatingFunction[{{-1., 40.}}, <>][z]^2)^0.5}
```

```
Plot[{u0[z], u1[z], u2[z], u3[z], u4[z]}, {z, z0, zf}];
```



Energy	Kicker
400 MeV	-.1047
450	-.0484
500	0.0000
550	.0504
600	.1043

```
ϵ = 1.0 * (10^-5);
a0 = .02;
ap0 = 0;

bol = NDSolve[{a'[z] == ap[z], ap'[z] == -(B0[z] / 2 / Brho)^2 * a[z] + ϵ^2 / a[z]^3, a[z0] == a0,
    ap[z0] == ap0}, {a, ap}, {z, z0, zf}, MaxSteps → 1100000, MaxStepSize → .01];
aa[z_] = a[z] /. bol;
Plot[aa[z], {z, z0, zf}];
aa[40]
```



Rough Envelope for $\epsilon = 10^{-5}$ m-r ($\epsilon_n \approx 10^{-6}$)

```
{0.00195161}
```

Spot Size Sensitivity

initial energy = ideal + δE

initial x = 1.0 m + δx
" y = δy
" x' = $\delta x'$
" y' = ideal + $\delta y'$

Random δE is very important!
$\pm .1\%$ for 500 MeV K_1^{+8} creats
a spot radius of .7 mm

$\delta x = \pm .02$ m
$\delta y = \pm .02$ m
$\delta x' = \pm .0002$ rad
$\delta y' = \pm .0002$ rad

Typical produce about 10 mm spot radius

→ $\epsilon_n \lesssim 4 \times 10^{-7}$ m-r desired