Novel IBX Experiments

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lenoidal Transport for Drift Compressi

$$\frac{d^2a}{dz^2} = -\left(\frac{B_s}{2[B\rho]}\right)^2 a + \left(\frac{\varepsilon_n}{\beta\gamma}\right)^2 \frac{1}{a^3} + \frac{Q}{a}$$

B_s = solenoidal field

$[B\rho]$ = ion rigidity = $\frac{\beta\gamma Mc}{qe}$

ε_n = normalized edge emittance

Q = effective perveance

a = beam edge radius

e 1: Vacuum $Q_{vac} = \frac{2qe(\lambda\upsilon)}{(\beta\gamma)^3 4\pi\varepsilon_0 Mc^3}$

t ε_n, then equilibrium gives $\lambda = \frac{\gamma\pi\varepsilon_0 qeB_s^2 a^2}{2M}$ ~ independent

cuum Solenoid (continued)

K^+ $\lambda = \left(34\frac{\mu C}{m}\right)B_s^2 a^2$

$= 10T, a = .1m \longrightarrow 34\,\mu c/m$ (any υ)

$\phi \approx \frac{\lambda}{4\pi\varepsilon_0} \approx 306kV$

is looks interesting for compression -

e 2: Neutralize with Electrons

$$Q = -(\beta\gamma)^2 Q_{vac}$$

$$a'' = -\left(\frac{Bs}{2[B\rho]}\right)^2 a + \left(\frac{\varepsilon_n}{\beta\gamma}\right)^2 \frac{1}{a^3} - \frac{(\beta\gamma)^2 Q_{vac}}{a}$$

enerally the perveance term is small

eutralized Solenoid (continued)

ısider $T = 10 MeV \quad K^+$

$\lambda = 34\, \mu C/m$

$B_s = 1.0T$

$\varepsilon_n = 10^{-5} m - r$

$$= a'' = -(.0309)a + \frac{1.8x10^{-7}}{a^3} - \frac{(1.68x10^{-5})}{a}$$

→ $a = \underline{\underline{.0465\, m}}$ Very attractive for compression, <u>if</u> <u>sta</u>

rveance term is small by factor of five in this exampl

ood transport system for large ε_n -

thout neutralization $a = \underline{\underline{.994m}}$

lenoid Science

n we destabilize the breathing mode?

$$a = a_0 + \delta a$$

$$0 \approx -\left(\frac{B_s}{2[BQ]}\right)^2 a_0 + \frac{Q}{a_0}$$

$$\delta a'' \approx -\left(\frac{B_s}{2[BQ]}\right)^2 \delta a - \frac{Q}{a_0^2} sa$$

- $sa \sim e^{-i\Omega z}$

$$\boxed{\Omega^2 = \frac{2Q}{a_0^2}}$$

odulate $B_s(z)$ **with period** $P \approx 2.0m$

$\Omega P \approx \pi \longrightarrow$ **stop band**

$\longrightarrow\; Q \approx \dfrac{\pi^2 a_0^2}{2P^2} = \dfrac{\pi^2 x(.1)^2}{2x2^2} \approx \underline{\underline{10^{-2}}}$

olenoid Science (continued)

eam in vacuum:

$$\frac{\omega_{\rho b}}{v_b} = \sqrt{\frac{n_b e^2}{\varepsilon_0 M v_b^2}} = \sqrt{2Q}/a = \sqrt{2x10^{-2}}/.1 = 1.41m^{-1}$$

interestin

eutralized Beam:

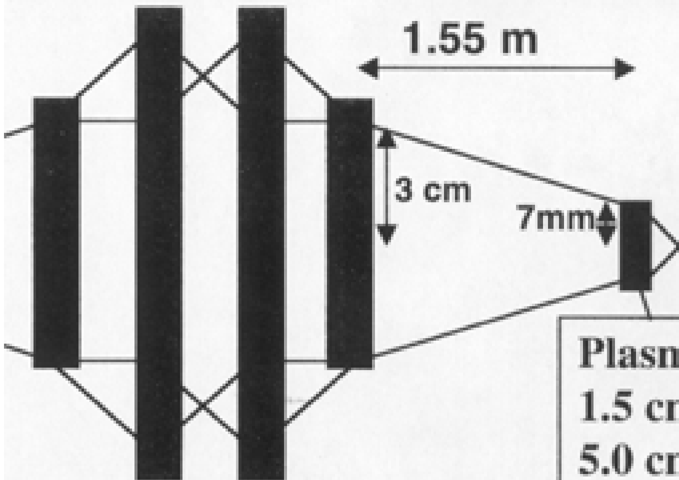
$$\frac{\omega_{\rho b}}{v_b} = \sqrt{2Q}/a = \sqrt{2x10^{-2}}/.0465 = 3.04m^{-1}$$

more interestin

$$\omega_{pe} = \sqrt{\frac{M}{m_e}}\omega_{\rho b} = 5.71x10^9 s^{-1}$$

his would be a simple test bed for stability studies

"double focus" (quads+plasma lens ma
used to reduce spot size to ~0.5 mm)



Radius at final focus ~0.5 mm

Plasma lens
1.5 cm radius
5.0 cm length
400 kA

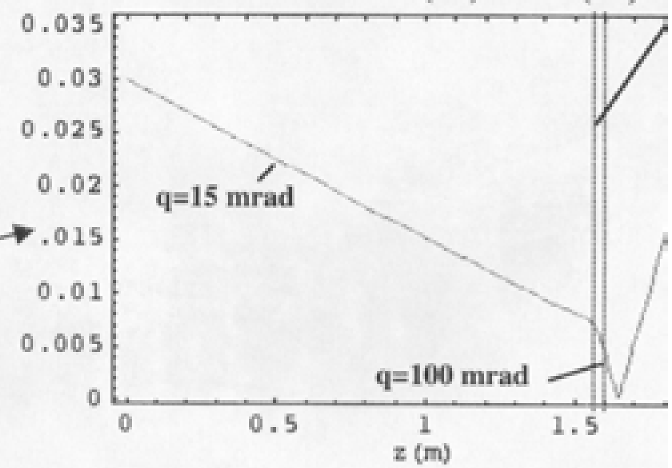
Possible alternative: focus to the null of a high field magnetic cusp

Pl
le

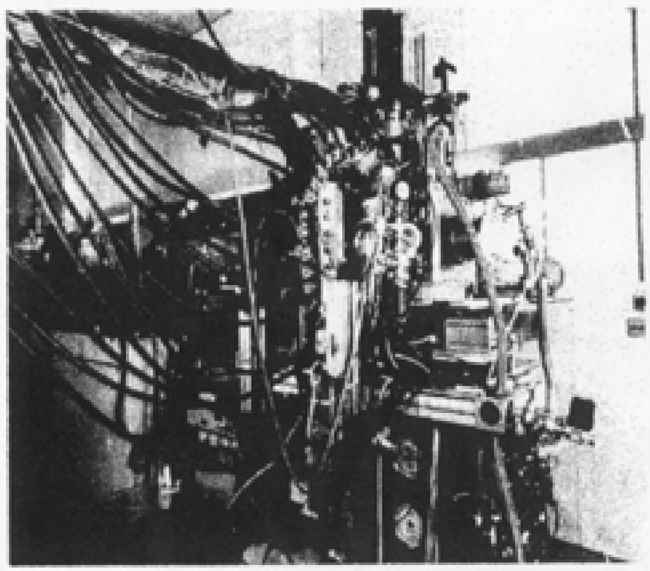
onventional final
ocus using quadrupoles

nvelope plot for T=450 MeV Xe^{+}
nneutralized perveance = 10^{-3}
9.5% neutralized
tripped at plasma lens to Xe^{+26}
ormalized emittance =4 mm-mrad

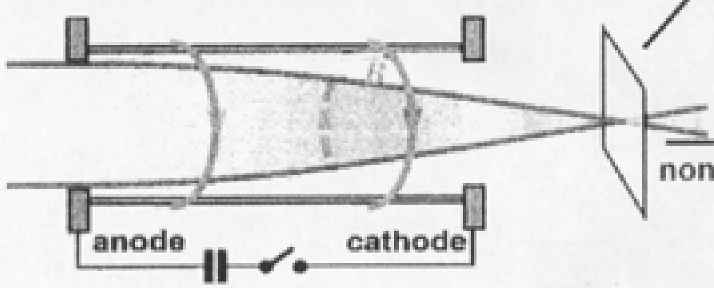
Beam radius (m) vs. z(m)

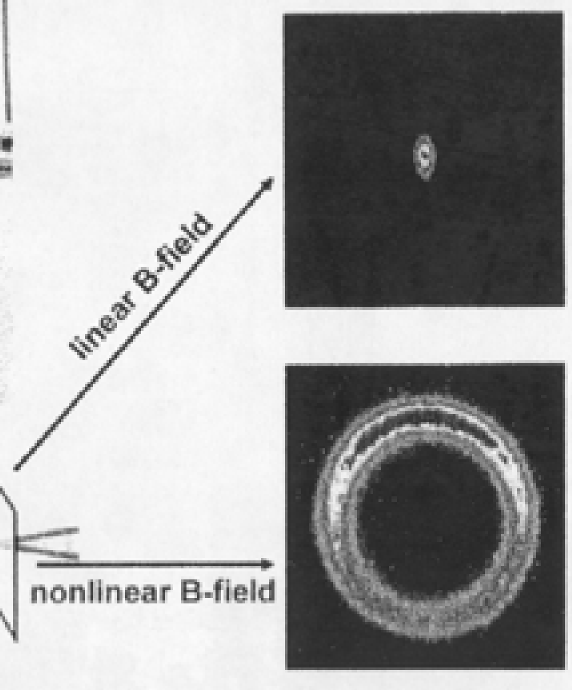


Plasma Lens Focusing of Ion Beams (at GSI)



400 μm focal beam spots
@ 10 π mm-mr normalized
beam emittance achieved





›cusability Factors

›pied Transverse phase space

›pied Longitudinal phase space

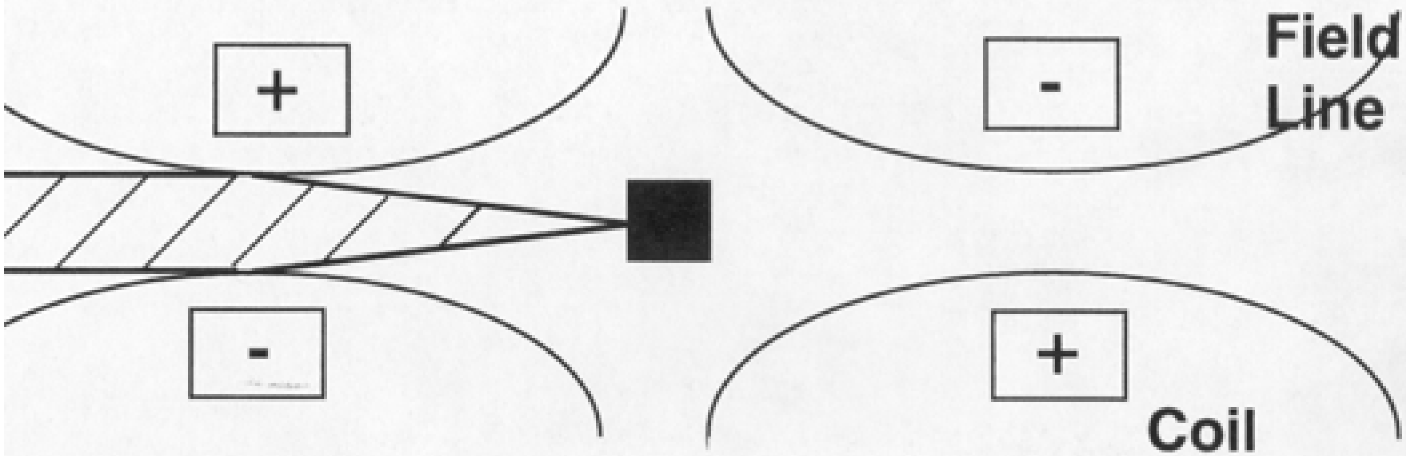
›ralization; look at the dimensionless

›sure of space charge Perveance (*Q*)

$$Q = \frac{2ZeI}{(\beta\gamma)^3 Mc^3 4\pi\varepsilon_0} \approx \frac{2Z^2 I_0}{(\beta\gamma)^3 (31x10^6\ Amp) M_{amu}}$$

IRE	Q	Required Neutralization	Spot Temperature
MeV K^+	10^{-2}	99.9%	———
MeV K^+	10^{-3}	99%	100eV for a=2.0n
MeV K^+			150eV for a=1.0n
	10^{-4}	90%	
MeV R_b^+			200+eV for a=1.
	$6x10^{-5}$	50%	
	$3x10^{-5}$	0%	

utralized Cusp Focus



$$'' \cong -\left(\frac{B_s}{2[B\rho]}\right)^2 a + \frac{\varepsilon^2}{a^3} + \cancel{\frac{Q}{a}}$$

Spin is removed at cusp

Use large convergence angle to get to small spot rac

ısp (continued)

ɔread change state < $\pm 10\%$ desired

ırge magnetic field

mple: 4.0 Mev K^{+7}

Coils at R = 5cm

Separation 2ℓ = 10cm

Current = 909 kA

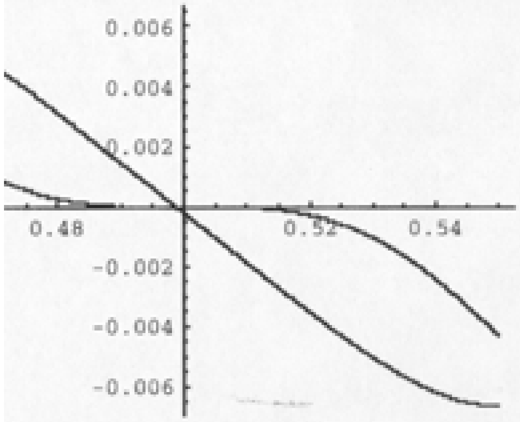
Maximum Field = 10.4T (on axis)

Initial edge radius a_0 = 1.0cm

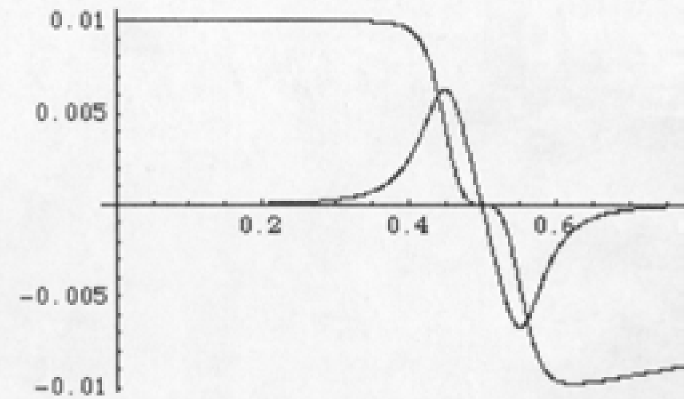
Cone half angle $\Theta \approx$150mr

$$\mathbf{B}z_0(z) = \frac{\mu_0 I R^2}{2}\left\{\left[(z-\ell)^2 + R^2\right]^{-1.5} - \left[(z+\ell)^2 + R^2\right]^{-1.}\right.$$

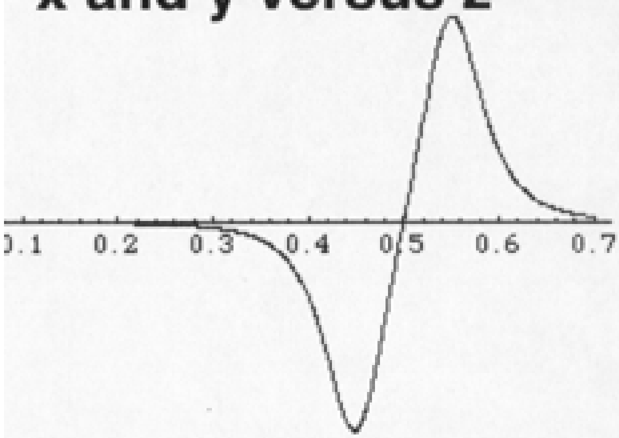
usp Focus Example: 4 MeV K^{+7}



x and y versus z



x and y versus z

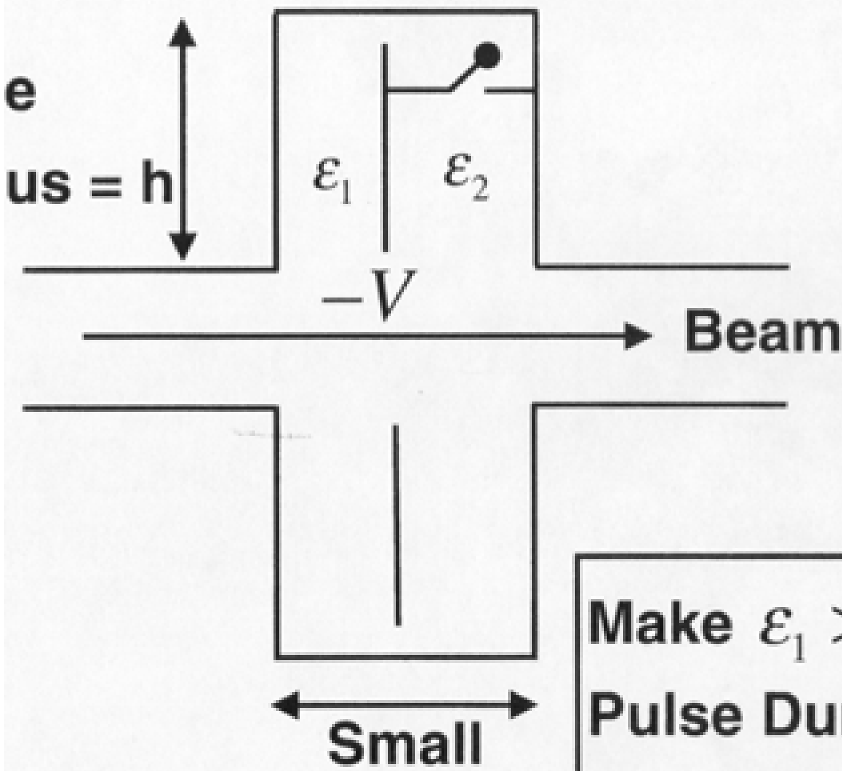


on axis field

electric Wall Accelerator

e

us = h



Structure Repeats
Many Times
(Stacked Capacitors
$\sim 20 \frac{MeV}{m}$ Possibl

Make $\varepsilon_1 >> \varepsilon_2$ (Wave Speed ~

Pulse Duration $\approx \left(\sqrt{\varepsilon_1} - \sqrt{\varepsilon_2}\right) h/$

Example: $\varepsilon_1 = 1000, \varepsilon_2 = 2, h = 5$

$$\tau_p \approx \left(\sqrt{1000} - \sqrt{2}\right) x \frac{5}{3x10^8} = .50$$

electric Wall (continued)

short pulse duration

- Improve with Spiral Line Capacitors?

Very High stored energy per m

[We have $(20\,MV/m)^2$ x large volume x large ε]

- Low coupling impedance
- poor efficiency
- most energy into switch?

ble application at low energy to power an injector?

beam by variable $E(z)$, like an axisymmetric colum