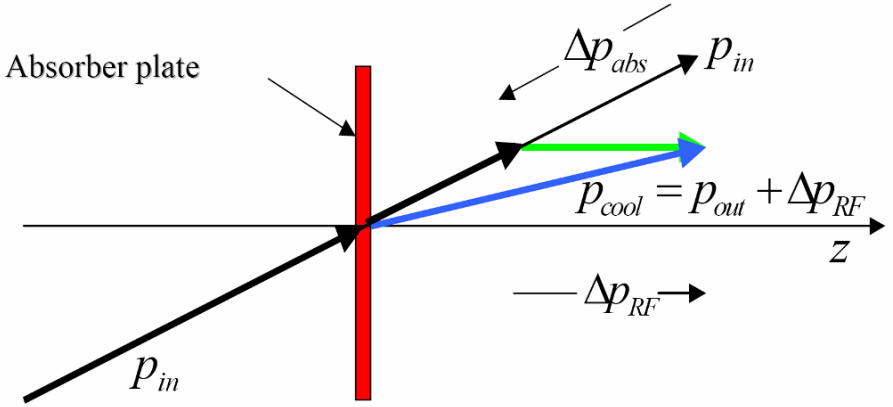
Muons, Inc.
Innovation in Research

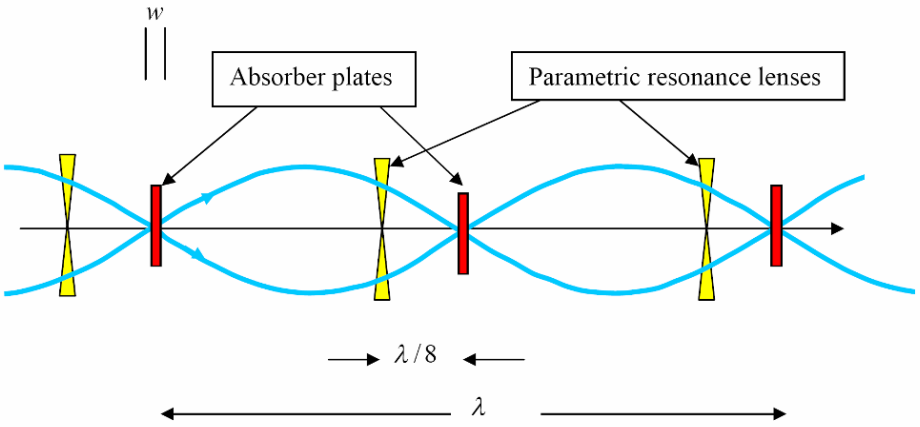
Update on Phase Ionization Cooling using Parametric Resonance

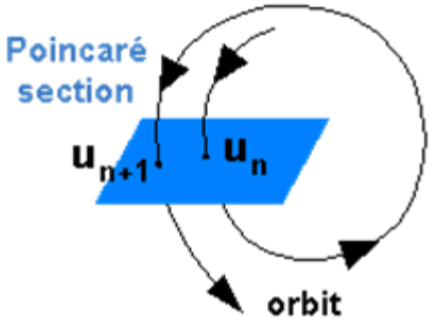
David Newsham
Muons, Inc.

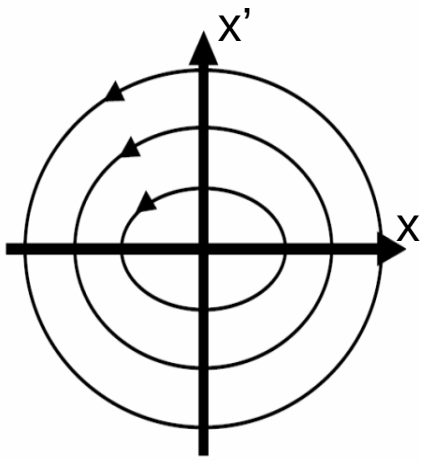
Neutrino Factory and Muon Collider Collaboration Meeting – FNAL
17-20 March 2008

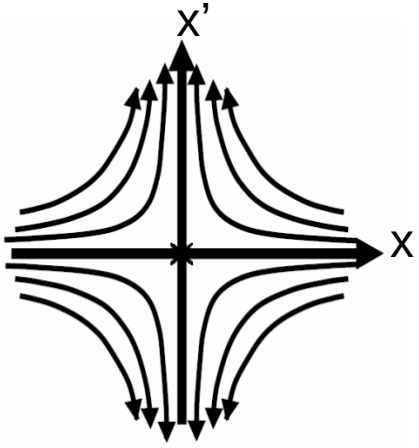
Muon Ionization Cooling & PIC Concept

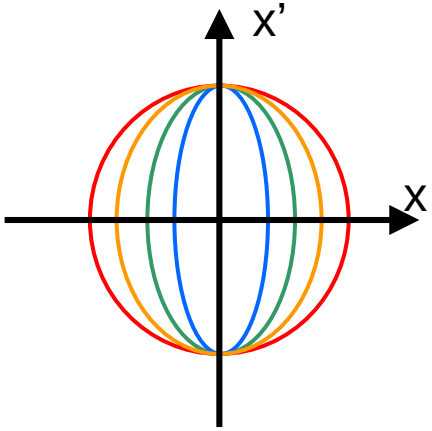






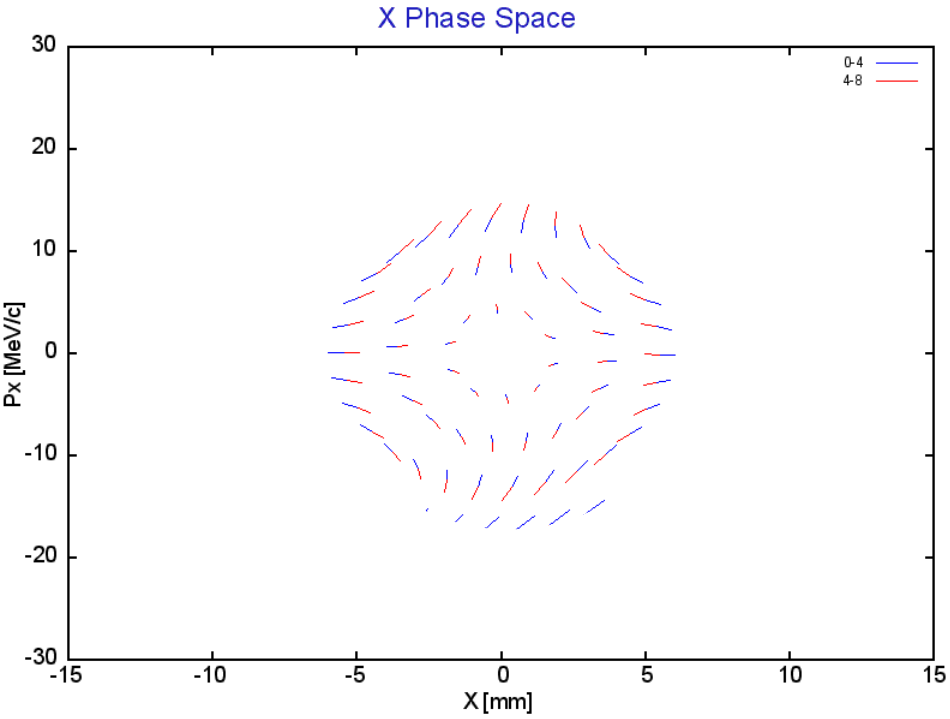




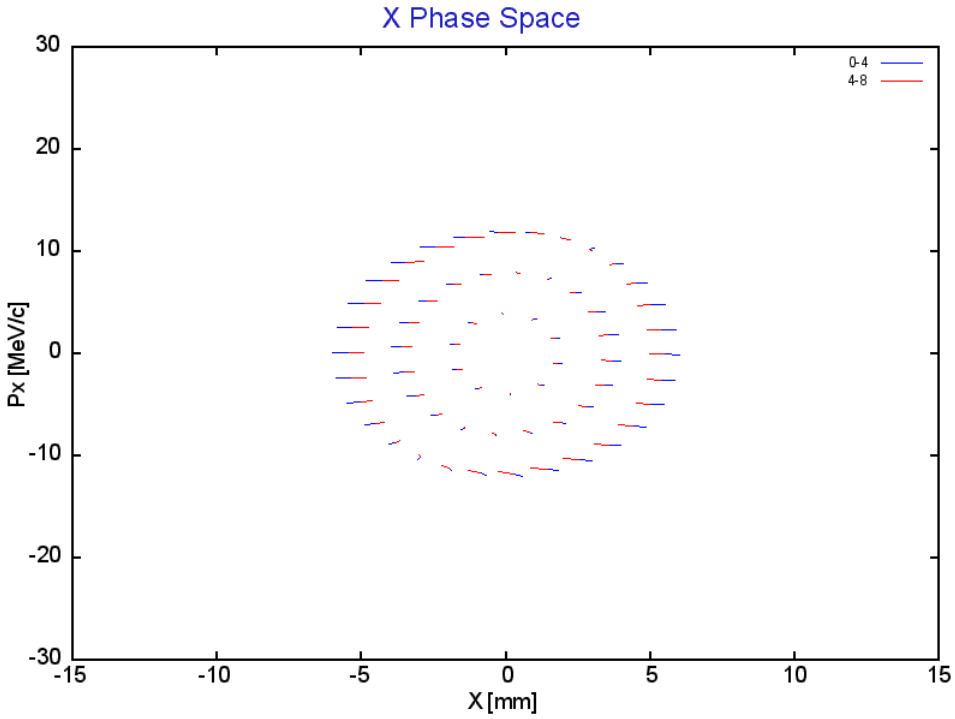


Phase Space Example

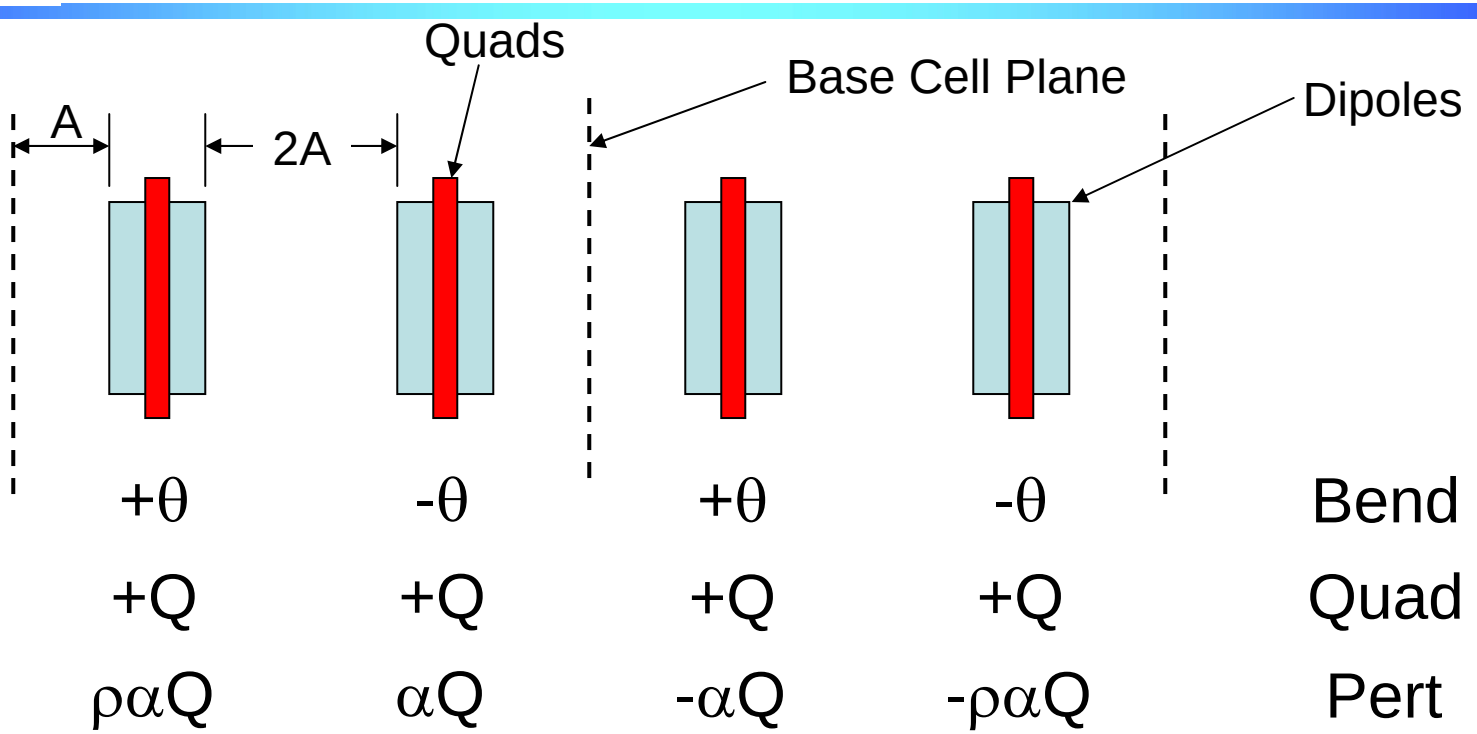
Perturbation Only



Perturbation with Absorber

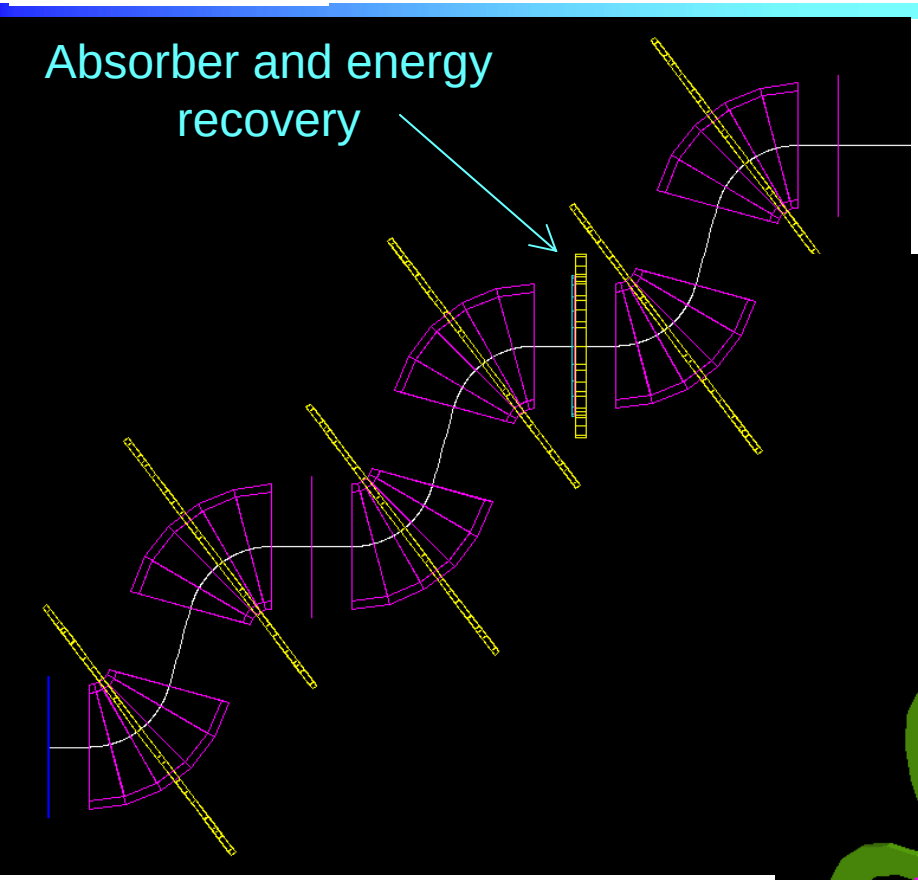


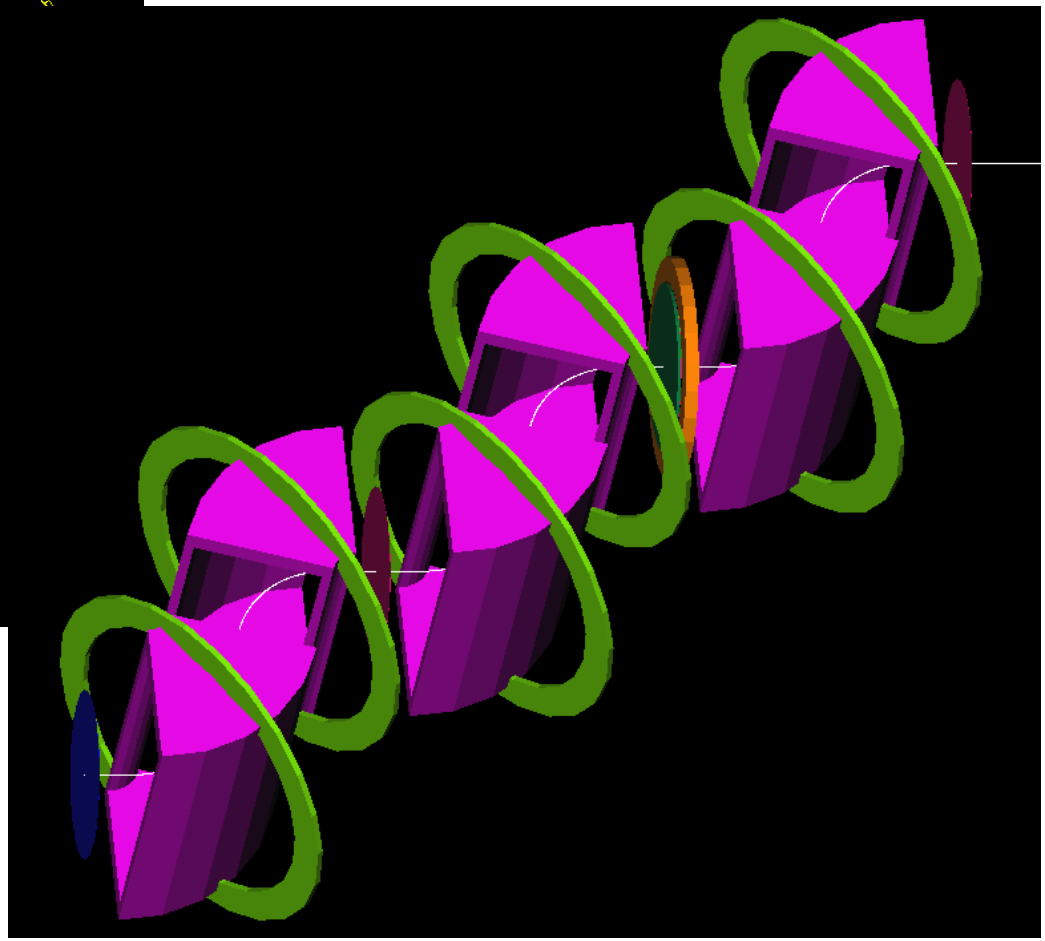
Simplified 2-'Cell' Layout
with Perturbation



- Base cell from 1.6 m to 0.7 m
- Absorbers every alternate base cell ($\upsilon_x=2\pi$, $\upsilon_y=\pi$)
- From matrix analysis ρ = -0.175

PIC Lattice Mark-IV





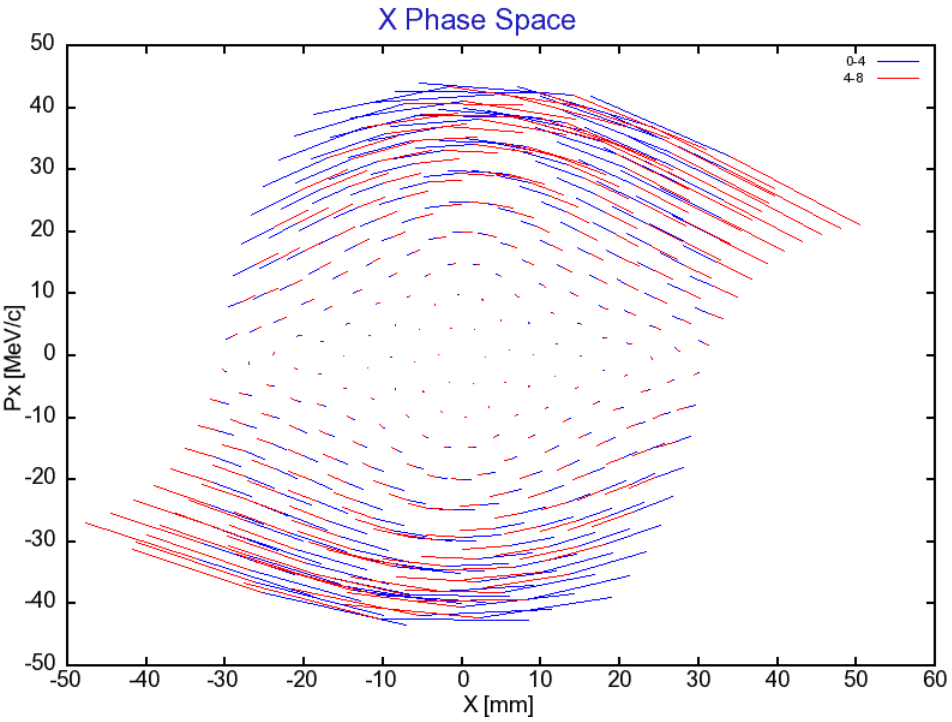
$\theta = 74.6° \Rightarrow B = 2.17$ T

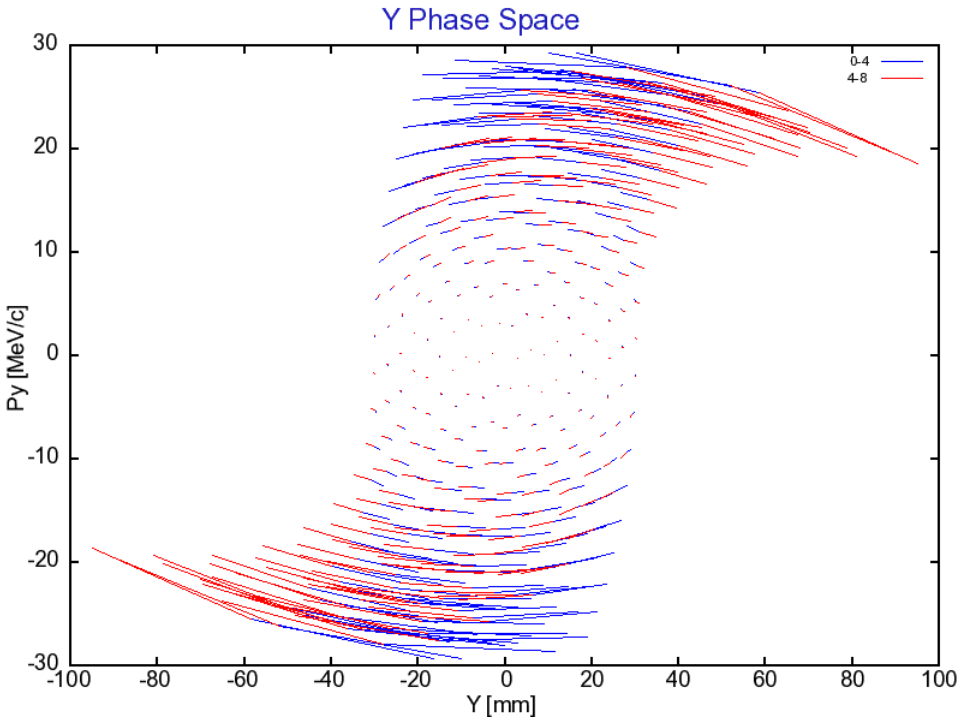
Q ~ -56 T/m (1 cm long)

Base Cell = 0.7 m

Phase Space

No Perturbation



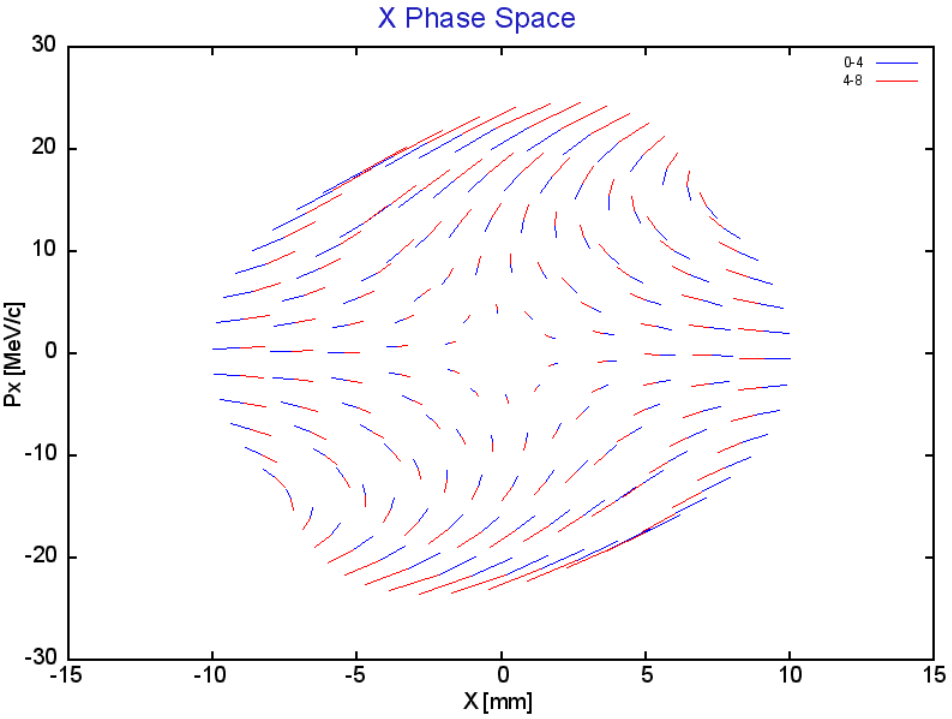


Acceptance limited by physical apertures

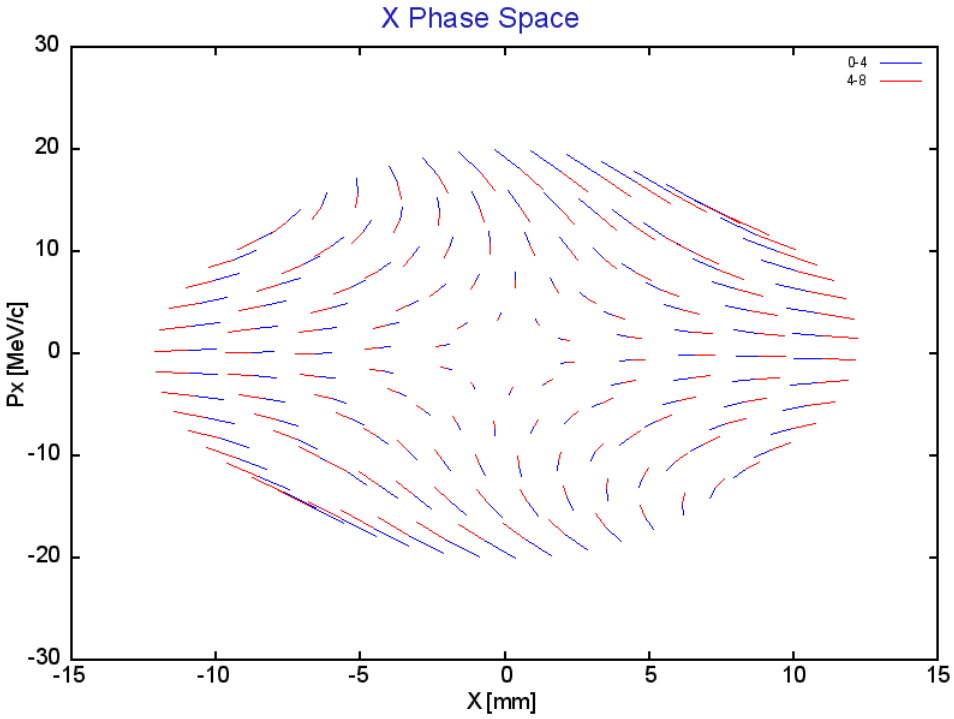
Add Perturbation

No Absorber

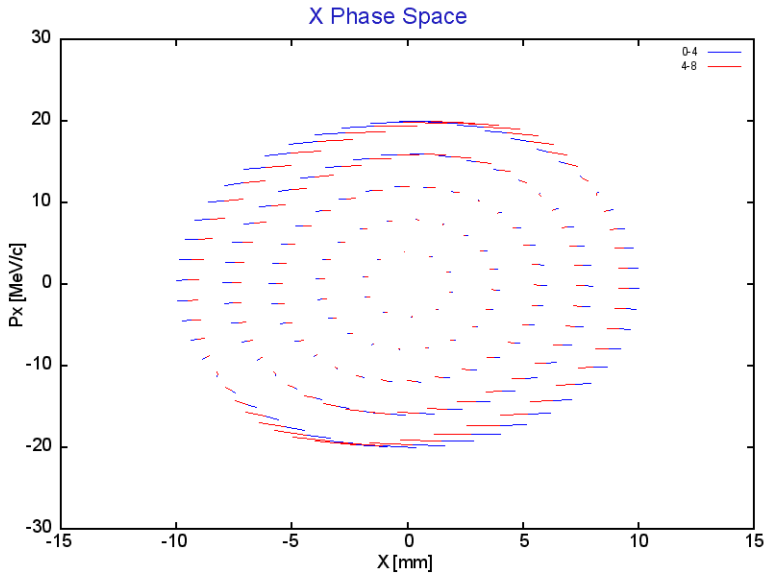
α = +10%



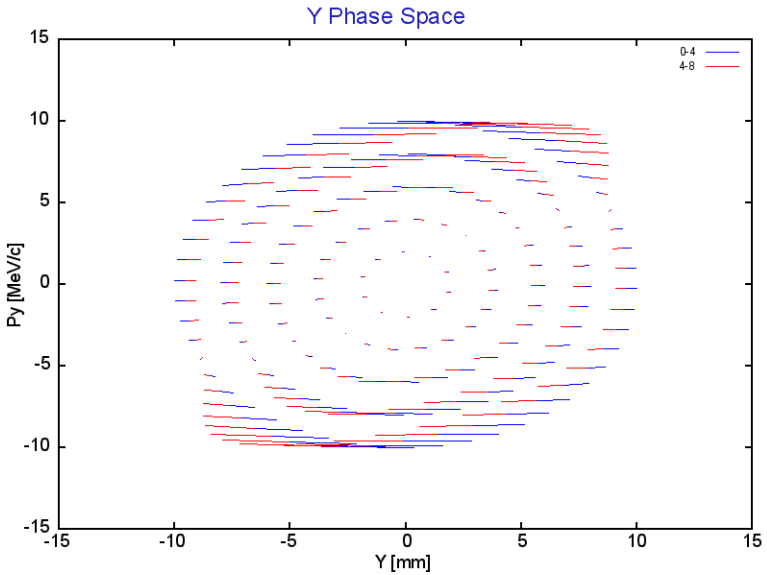
α = -10%

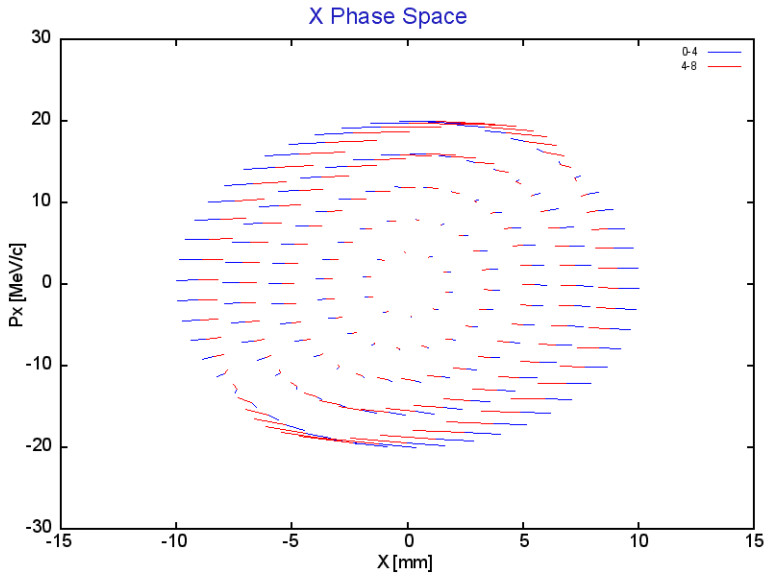


PIC Cooled Phase Space

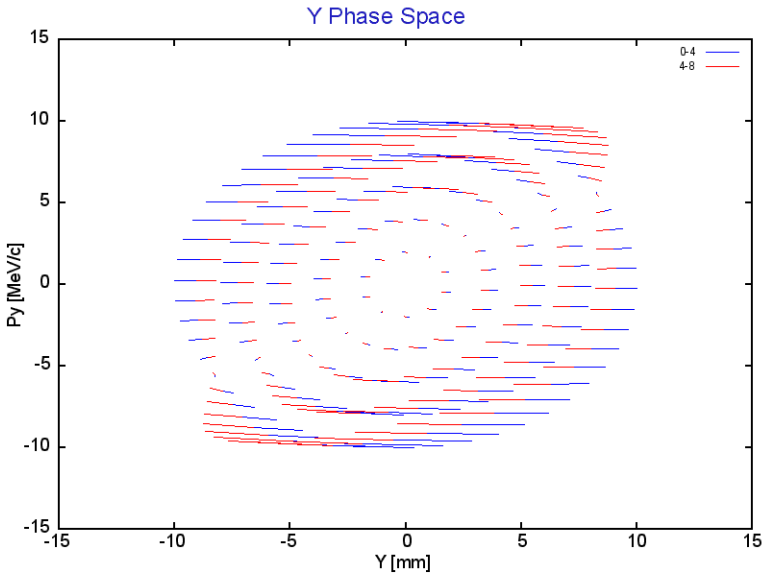


α = 5%
3.5 mm Be

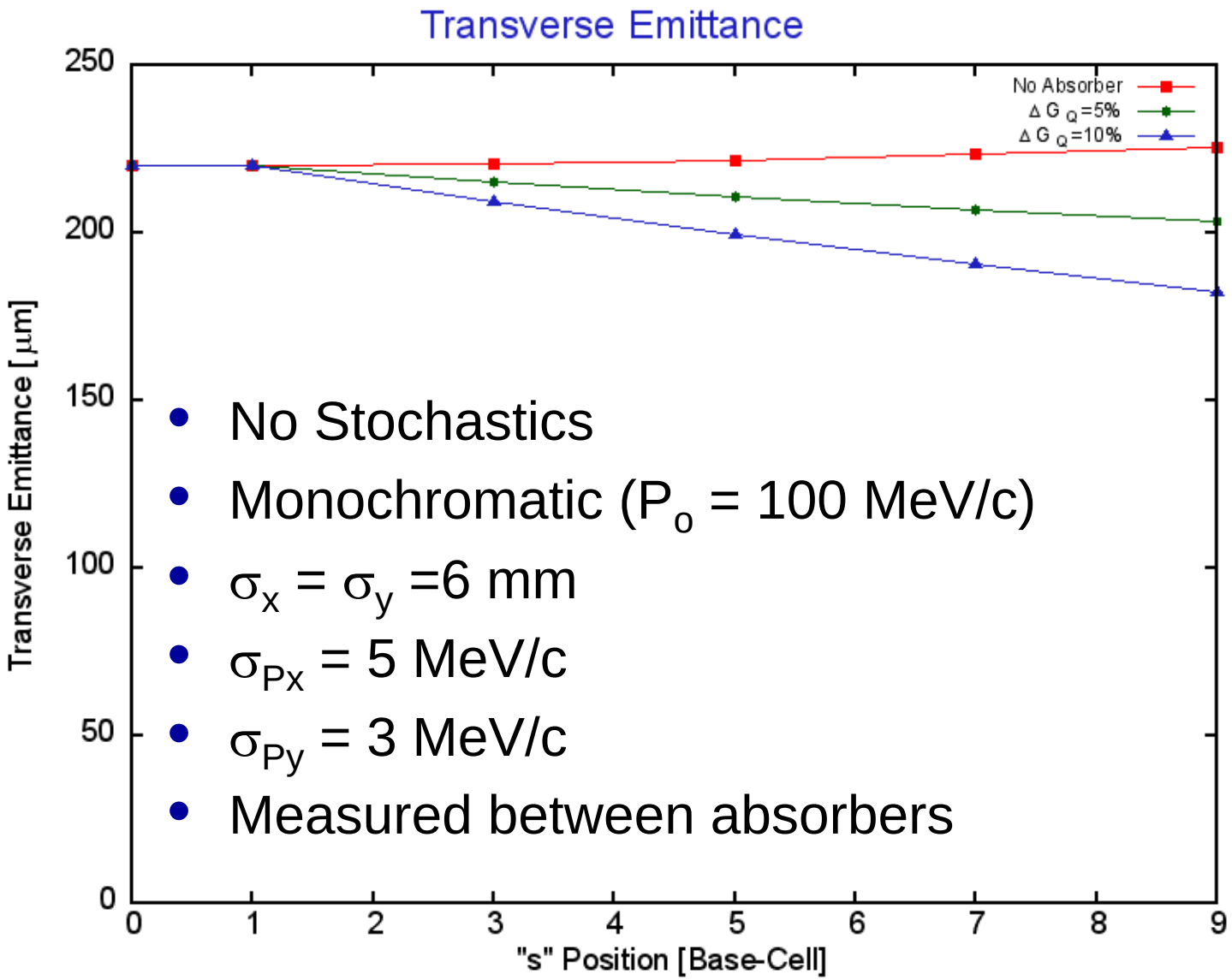




α = 10%
7 mm Be



Emittance



- No Stochastics
- Monochromatic (P_o = 100 MeV/c)
- $\sigma_x = \sigma_y$ =6 mm
- σ_{Px} = 5 MeV/c
- σ_{Py} = 3 MeV/c
- Measured between absorbers

Linear Transfer Matrix

$$x_i = \left(x, \frac{P_x}{P_o}, y, \frac{P_y}{P_o}, t - t_o, \frac{\Delta P}{P_o}\right)$$

$$\tilde{x}_i = \frac{x_i}{x_i^{rms}} \; ; \quad \tilde{M}_{ij} = \frac{\partial \tilde{x}_i}{\partial \tilde{x}_j}$$

$$x^{rms} = y^{rms} = 6\,\text{mm}$$

$$P_x^{rms} = P_y^{rms} = 20\,\text{MeV/c}$$

$$t^{rms} = 0.055\,\text{ns}$$

$$\Delta P^{rms} = 2\,\text{MeV/c}$$

$$\tilde{M} = \begin{pmatrix} 1.0007 & -0.0188 & 0 & 0 & 0 & -7.4\times10^{-5} \\ 0.00021 & 1.0004 & 0 & 0 & 0 & 0.10057 \\ 0 & 0 & 1.0006 & -0.027 & 0 & 0 \\ 0 & 0 & 0.00014 & 1.00078 & 0 & 0 \\ 0.00030 & -0.00667 & 0 & 0 & 1 & -4.59 \\ 0 & -3.1\times10^{-5} & 0 & 0 & 0 & 1.00012 \end{pmatrix}$$

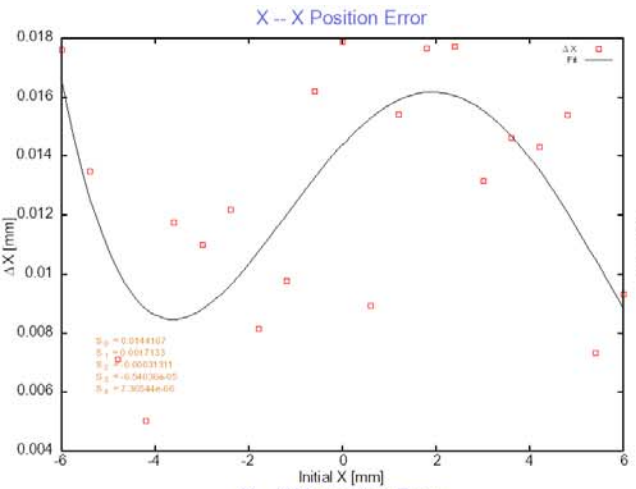
T_{ijk} Aberration Matrix

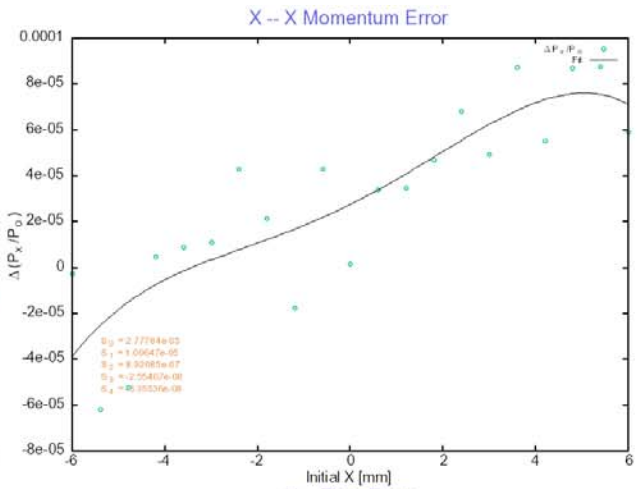
$$\tilde{T}_{ijk} = \frac{1}{2}\frac{\partial^2 \tilde{x}_i}{\partial \tilde{x}_j \partial \tilde{x}_k}$$

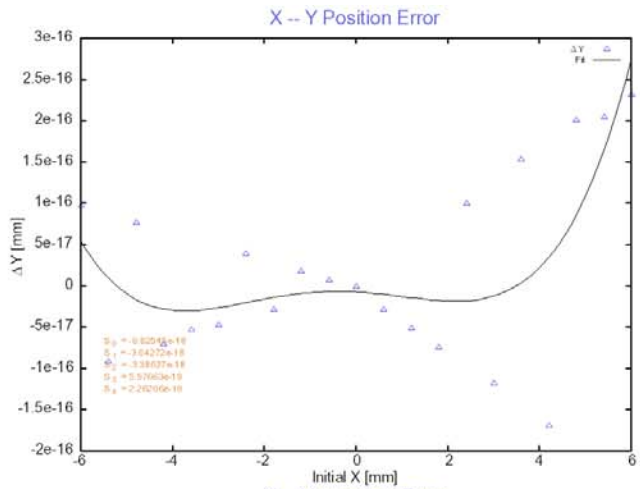
T_{522} = 3.429	T_{511} = 0.079
T_{544} = 2.912	T_{216} = 0.016
T_{144} = -1.027	T_{533} = 0.013
T_{324} = -1.025	T_{414} = -0.011
T_{346} = -0.655	T_{234} = -0.011
T_{126} = -0.590	T_{313} = 0.011
T_{526} = -0.313	T_{423} = -0.005
T_{566} = 0.197	T_{111} = -0.005

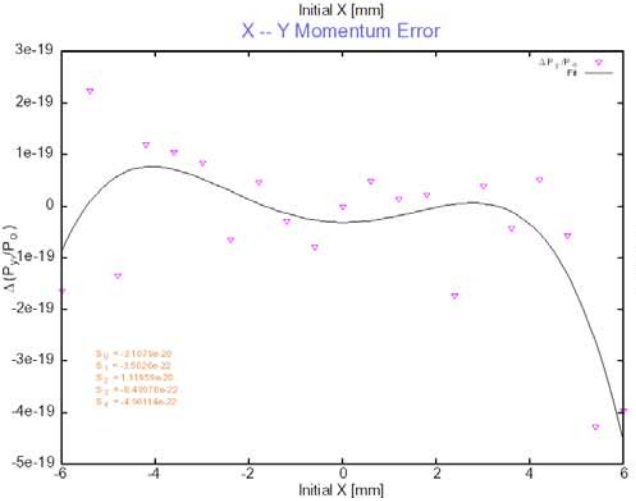
Muons, Inc.
Innovation in Research

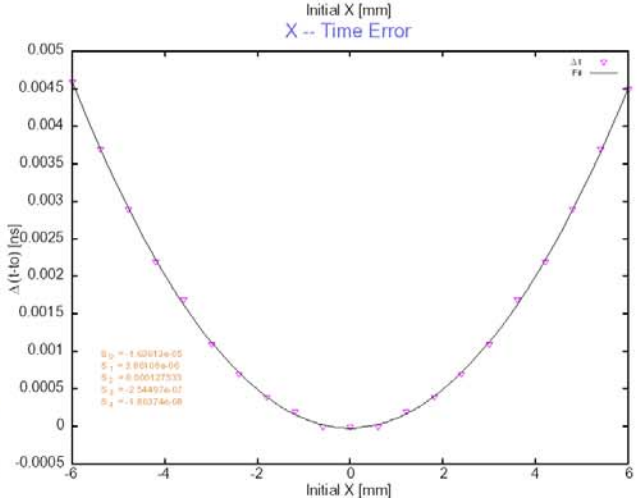
Vary x

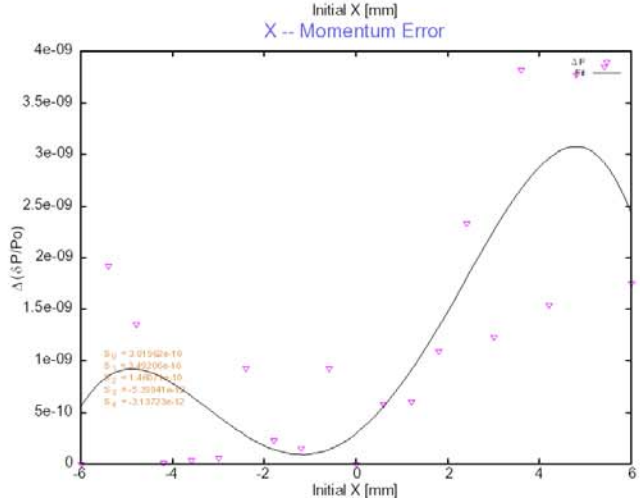






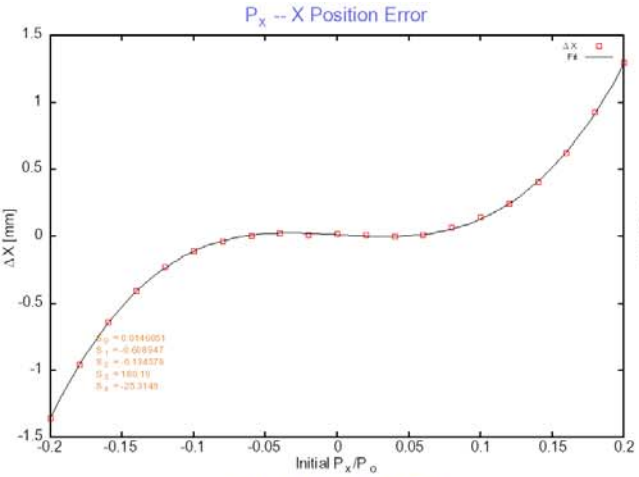


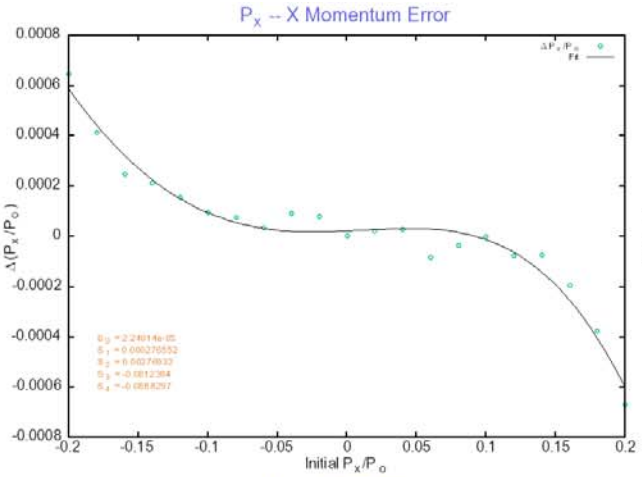


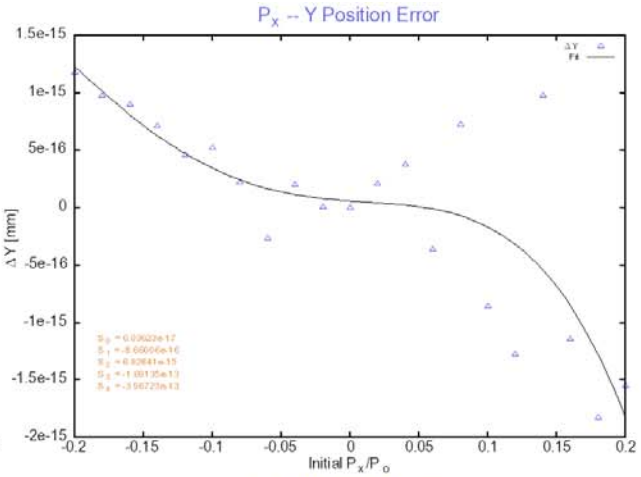


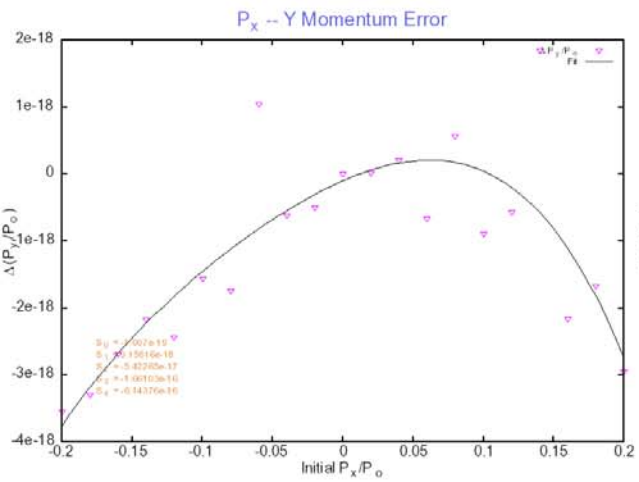
Muons, Inc.
Innovation in Research

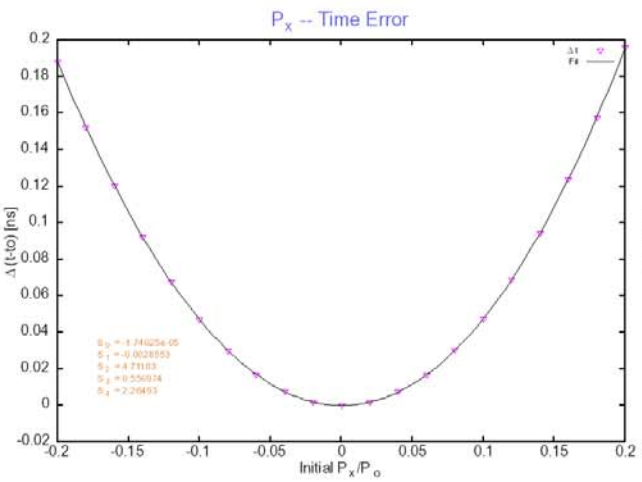
Vary Px/Po

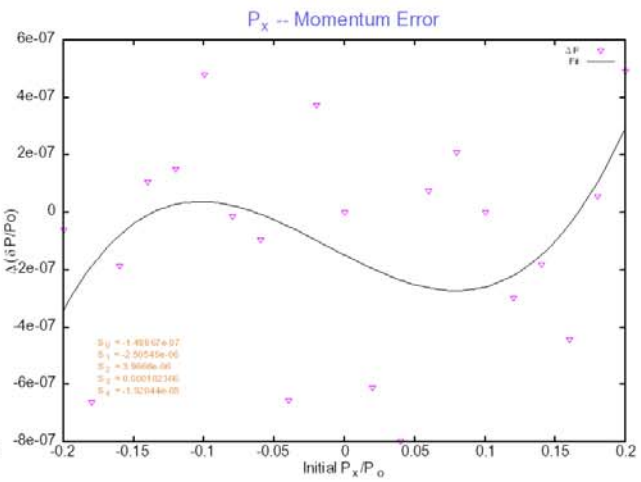




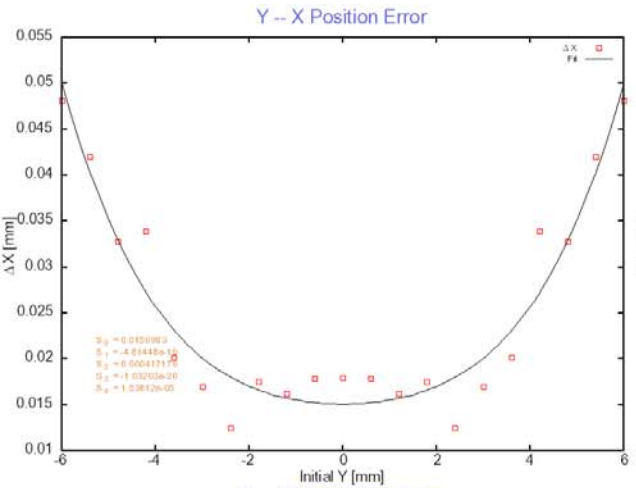


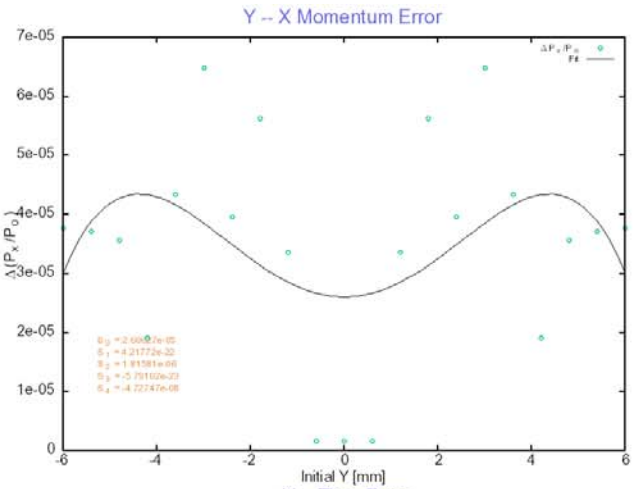


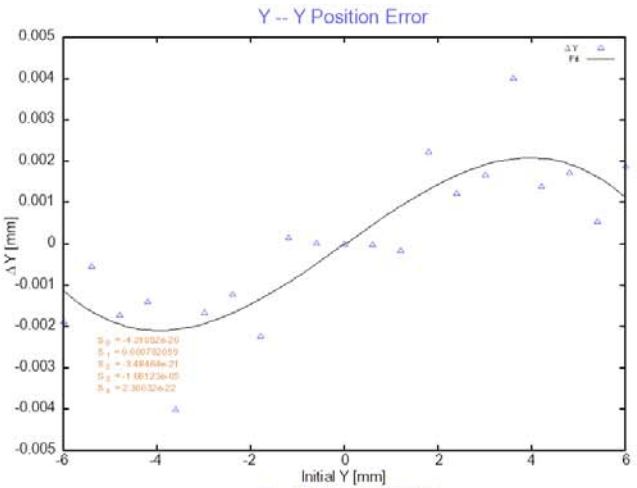


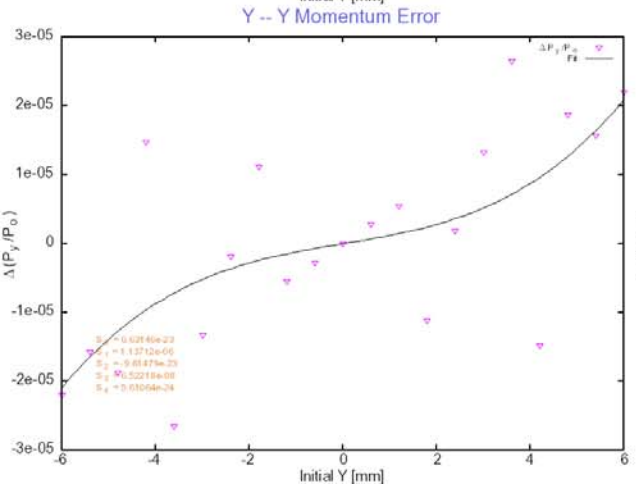


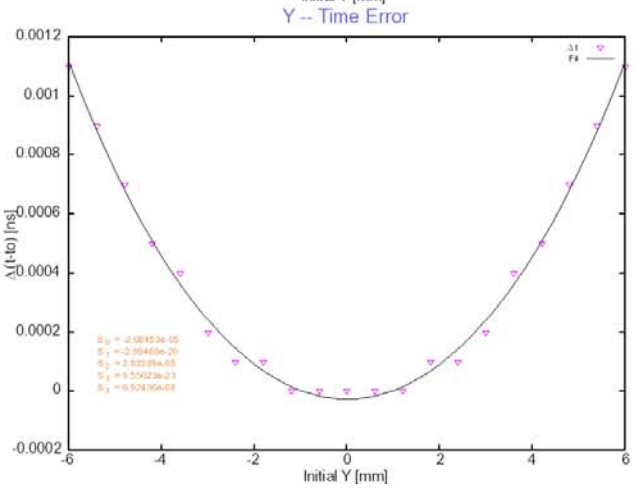
Vary y

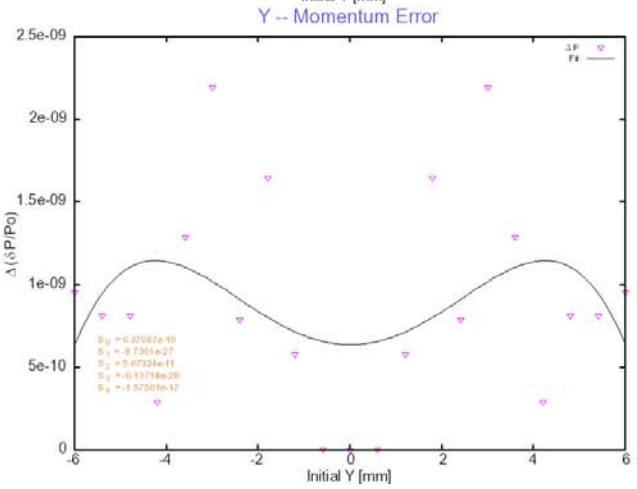

Y -- X Position Error
ΔX [mm]
Initial Y [mm]


Y -- X Momentum Error
Δ(Px/Po)
Initial Y [mm]


Y -- Y Position Error
ΔY [mm]
Initial Y [mm]

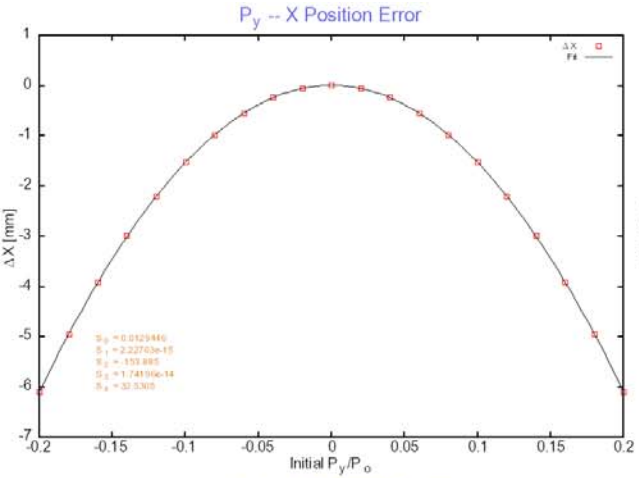

Y -- Y Momentum Error
Δ(Py/Po)
Initial Y [mm]

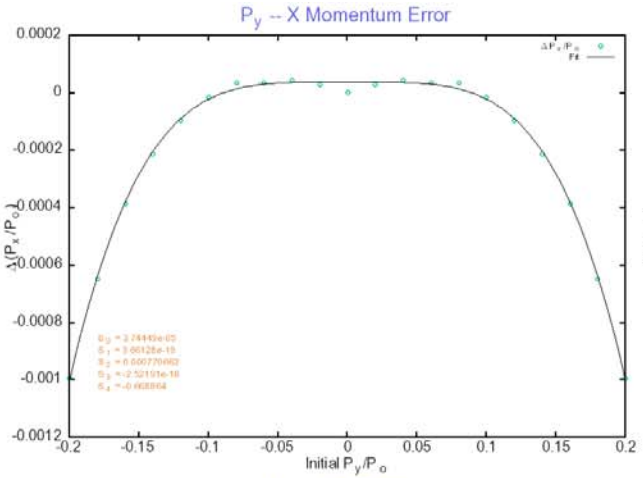

Y -- Time Error
Δ(t-to) [ns]
Initial Y [mm]

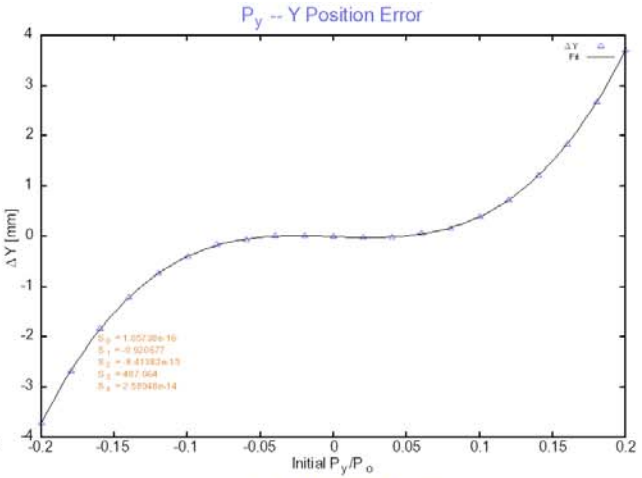

Y -- Momentum Error
Δ(ΔP/Po)
Initial Y [mm]

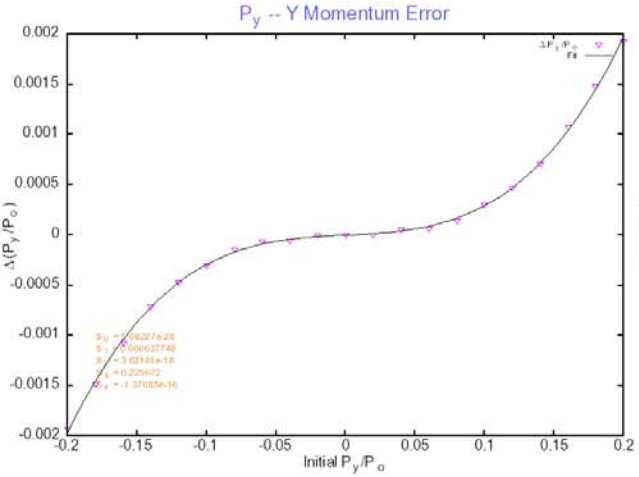
Muons, Inc.
Innovation in Research

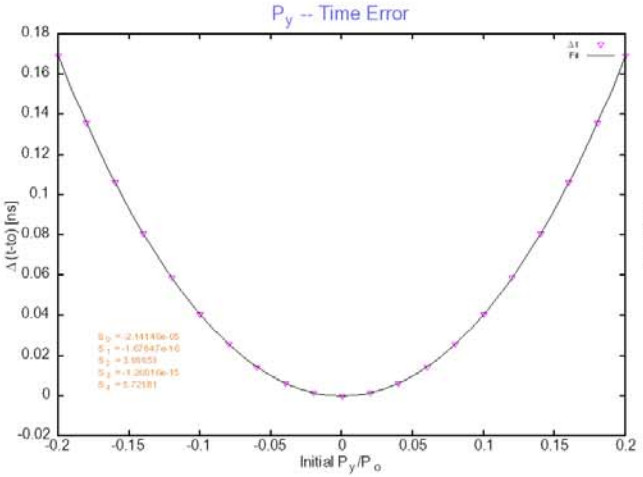
Vary Py/Po

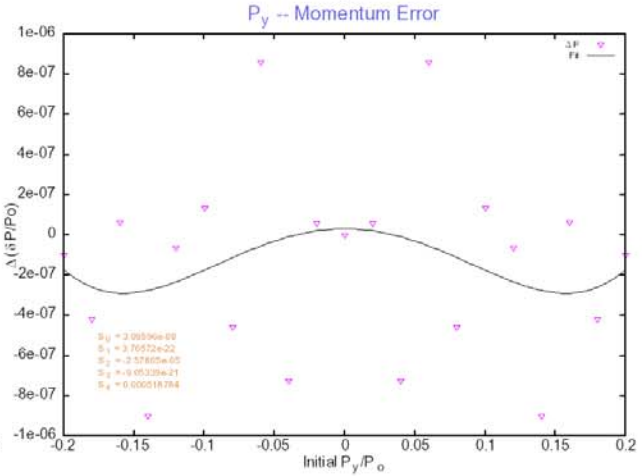






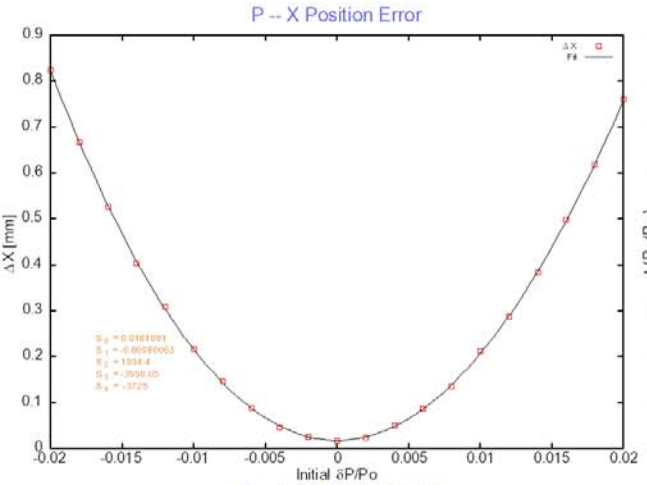


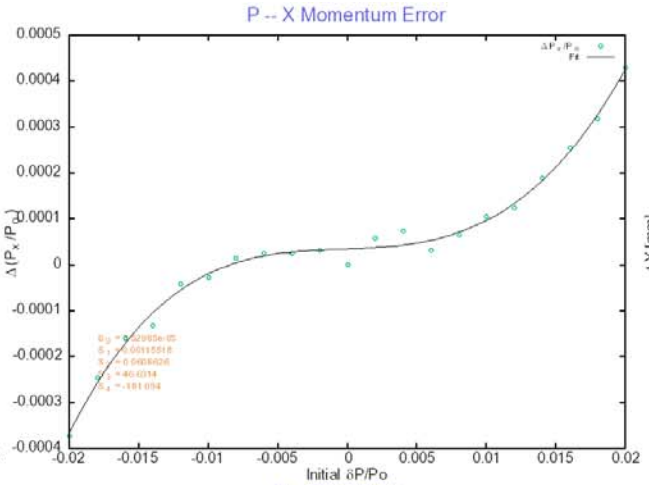


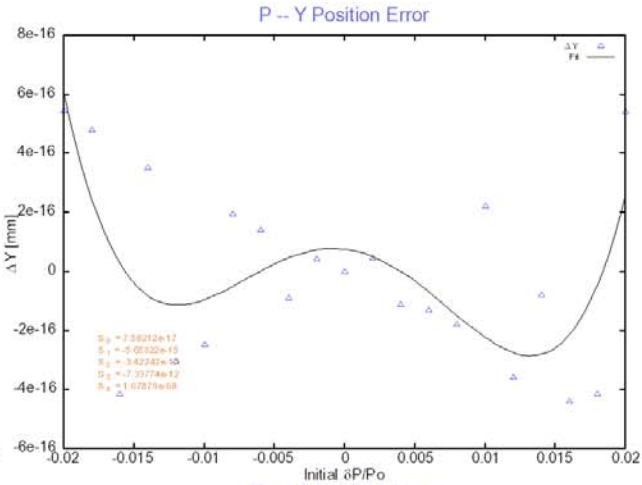


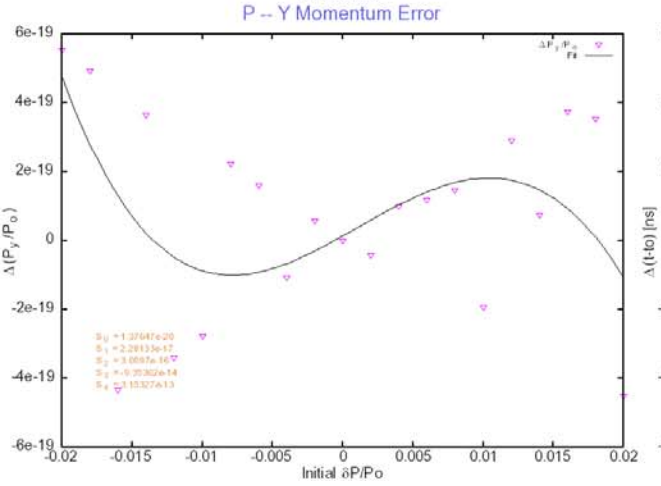
Muons, Inc.
Innovation in Research

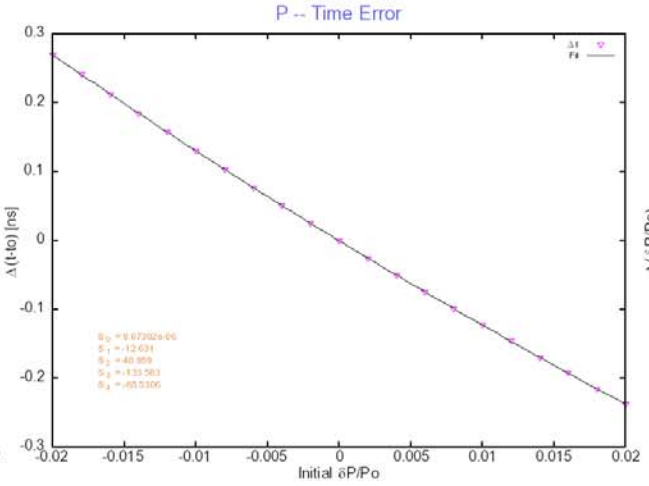
Vary P

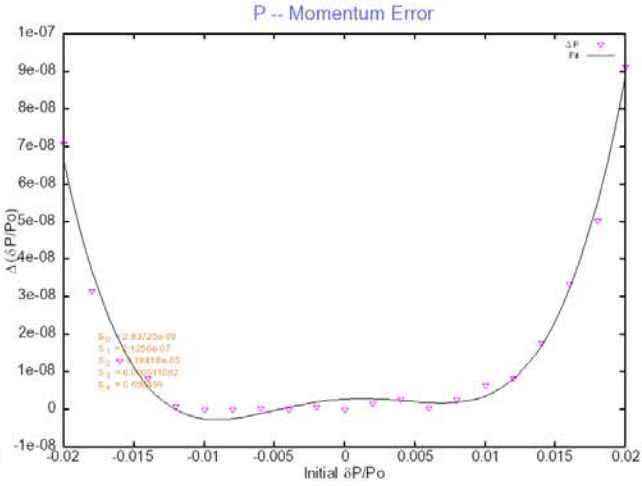






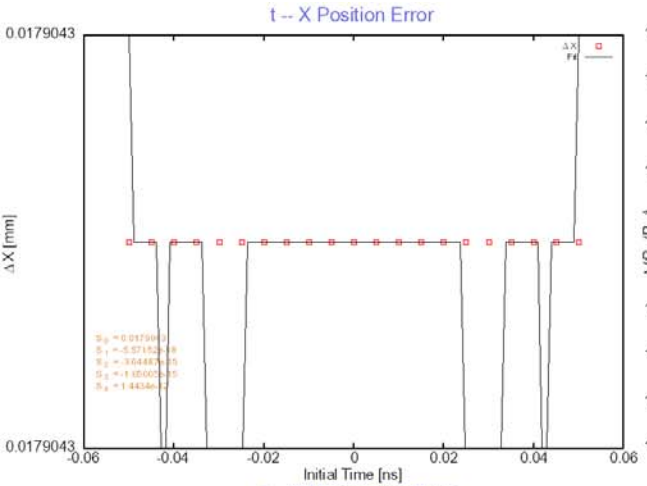


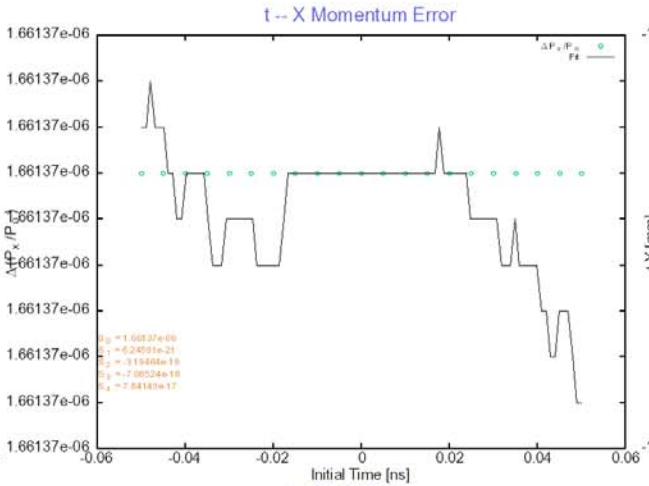


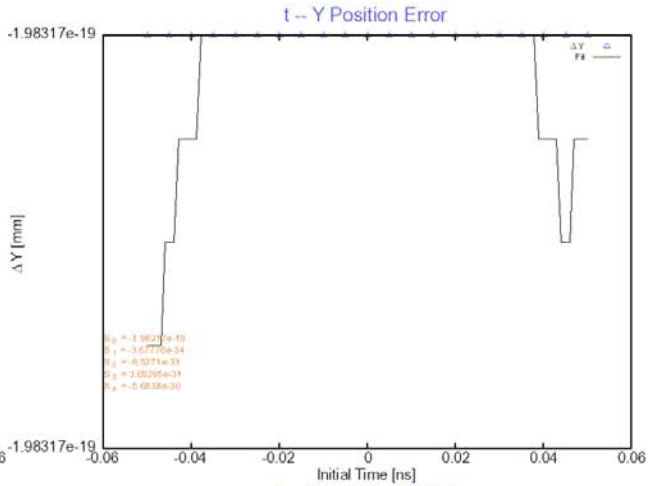


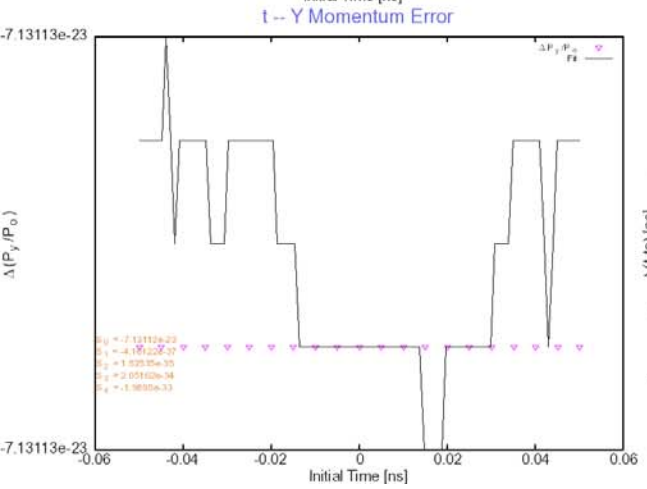
Muons, Inc.
Innovation in Research

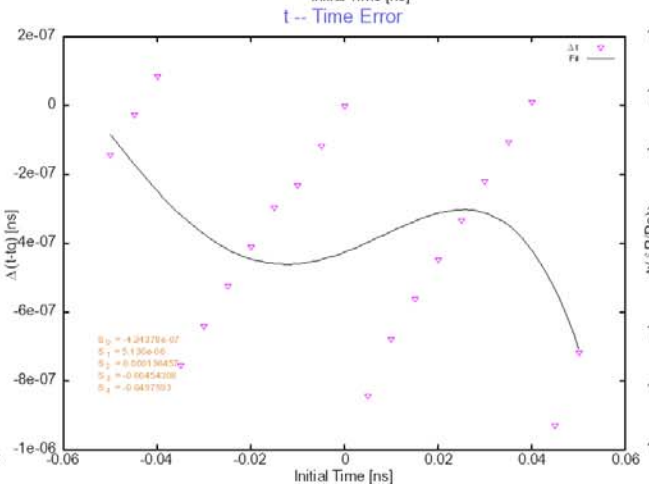
Vary time

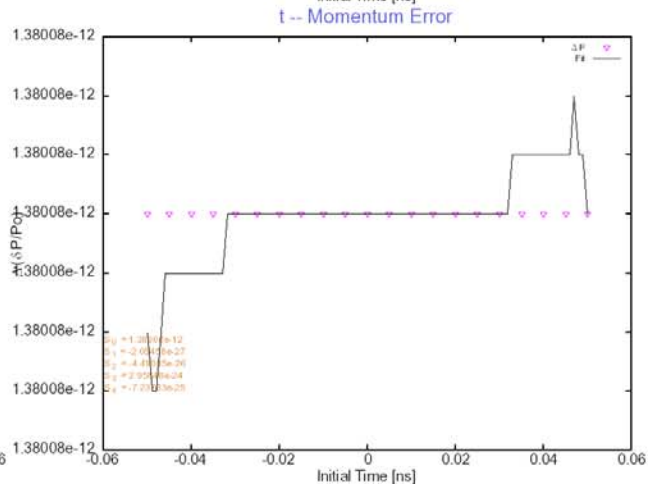












Muons, Inc.
Innovation in Research

PIC with Sextupoles