

Comparison of proton and carbon in LhARA Stage 1

K. Long (k.long@imperial.ac.uk)

Department of Physics, Imperial College London/STFC

Section 1

Introduction

Focal lengths

Rigidity:

$$\mathcal{R} = B\rho = \frac{p}{q}$$

Kinetic energy of reference particle proton and carbon beams set such that:

$$\mathcal{R}_{^{12}\text{C}^6} = \mathcal{R}_p = \mathcal{R}$$

Solenoid (thin lens approximation)^a

$$f_{\text{sol}} = \frac{4}{e^2} \frac{\mathcal{R}^2}{LB_0^2}$$

So:

$$f_{\text{sol}}(^{12}\text{C}^6) = f_{\text{sol}}(p)$$

Gabor lens (thin lens approximation)^a

$$f_{\text{Gabor}} = \frac{2\varepsilon_0}{e^2 n_e} \frac{P_0^2}{qE_0} \frac{1}{L} = \left[\frac{2\varepsilon_0}{e^2 n_e} \frac{\mathcal{R}}{L} \right] \frac{P_0}{E_0}$$

So:

$$f_{\text{Gabor}}(^{12}\text{C}^6) = \frac{\beta_0^p}{\beta_0^{^{12}\text{C}^6}} f_{\text{Gabor}}(p)$$

Electron density

Equivalent solenoid field strength:

$$B_0 = \sqrt{\frac{2n_e E_0}{q\epsilon_0}}$$

So, n_e obtained from k_{sol} using:

$$n_e = \frac{\epsilon_0}{2} \frac{q}{E_0} B_{\text{sol}}^2 = \frac{\epsilon_0}{2} \frac{\beta_0}{\mathcal{R}} B_{\text{sol}}^2$$

Consistency, therefore, requires that $\beta_0 = \beta_0^{\text{p}}$ when n_e is calculated

Parameter comparison proton to carbon

Proton	
m_p	938.27 MeV
K	15.00 MeV
E_p	953.27 MeV
p_p	168.44 MeV
Brho_p	0.56 Tm
Charge	1

$^{12}\text{C}^6$	
m_C	11174.80 MeV
K	45.61
E_C	11220.41 MeV
p_C	1010.66 MeV
Brho_C	3.37 Tm
Charge	6

Rigidity

168.4433514

168.443351

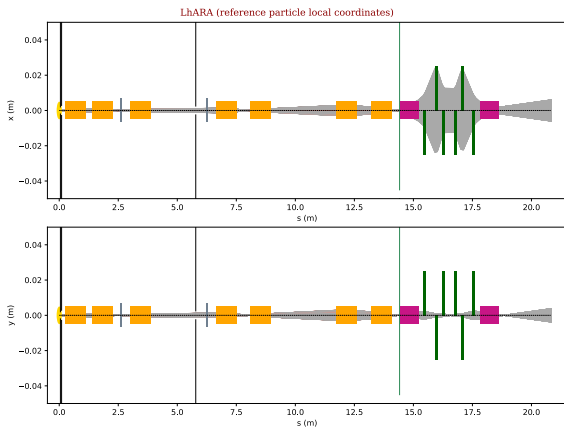
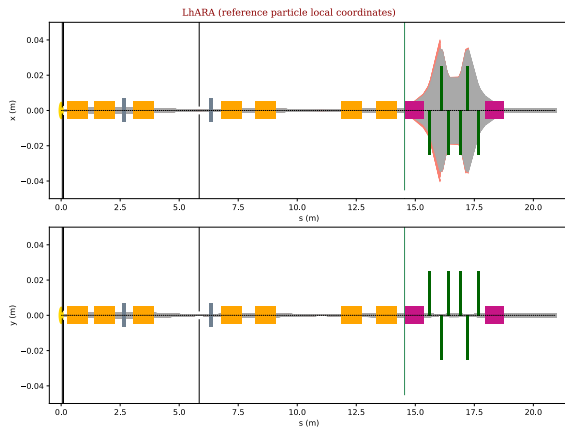
0

β_0^p	0.17670018	β_0^C	0.09
$k(\text{Gabor})$	1.55		3.04
Ratio	1.00		1.96

Section 2

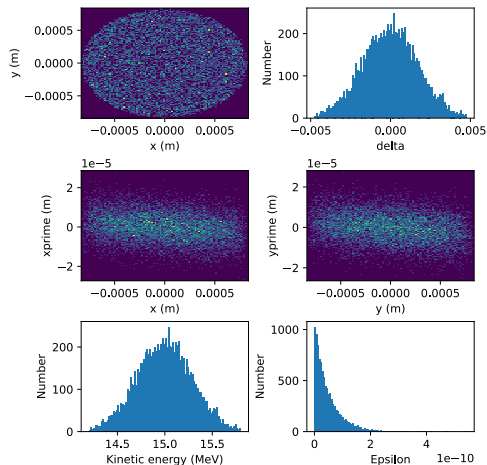
Comparison of Gabor-lens transport

Comparison proton to carbon without chromaticity/dispersion



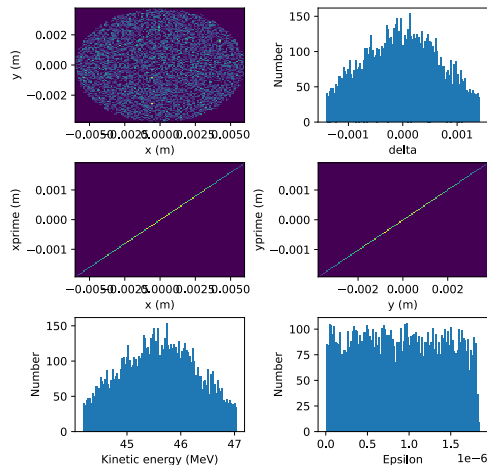
Phase space distributions at the end of the arc

LhARA:1:Arc:Drift:12



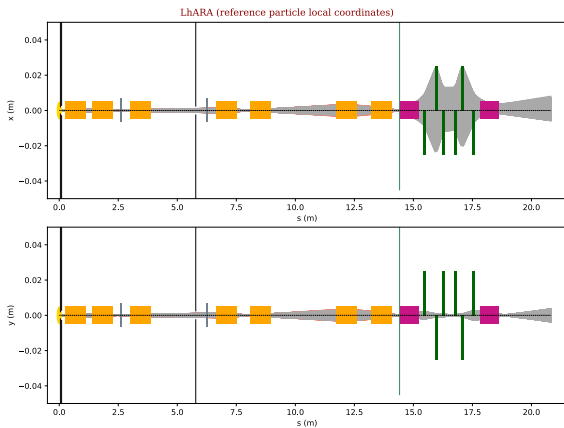
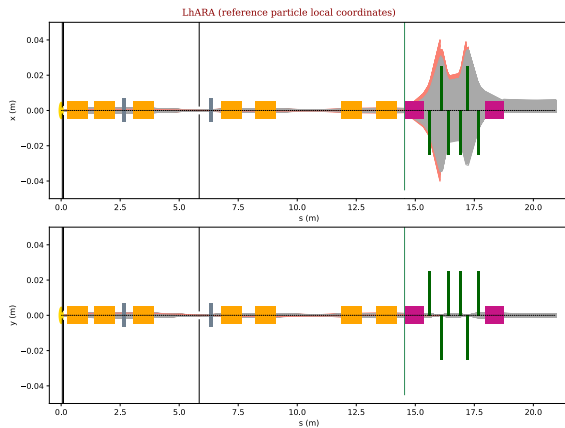
Left: proton (no chromaticity/dispersion)

LhARA:1:Arc:Drift:12



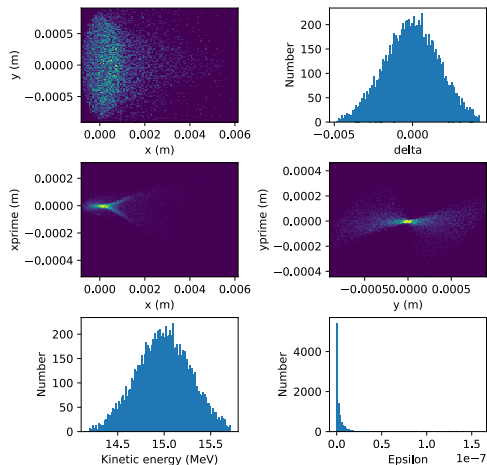
Right: carbon (no chromaticity/dispersion)

Comparison proton to carbon with chromaticity/dispersion



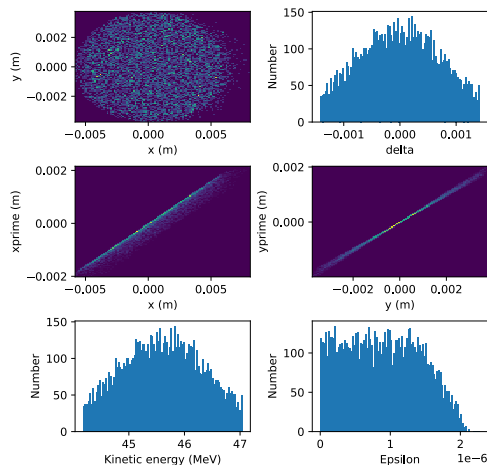
Phase space distributions at the end of the arc

LhARA:1:Arc:Drift:12



Left: proton (chromaticity/dispersion)

LhARA:1:Arc:Drift:12



Right: carbon (chromaticity/dispersion)

Section 3

Needs a study!