Injector Chicane Configuration: $M_{56} = 0.25$ m implications

Arne Freyberger

OPS

February 22, 2010

1. Bunchlength and Energy Spread
2. Intermediate Summary
3. $M_{56} = 0.25$ m Optics
   - $\varepsilon = 125$ ev-radian @ 0L01
   - $\varepsilon = 75$ ev-radian @ 0L01
   - $\varepsilon = 250$ ev-radian @ 0L01
4. Summary

Longitudinal Phase Space

Krafft, Kazimi *et.al.* Linac2000 paper of CEBAF energy spread and bunchlength. The formula presented in the paper for the optimized energy spread in the end-station as a function of the $\varepsilon_{E \cdot l}$ at the end of the injection chicane is as follows:

$$\sigma_E/E = \sqrt{\sigma_{E_{inj}}^2/E^2 + \sigma_\phi^4/2},$$

where σ_E and $\sigma_{E_{inj}}$ are the rms energy spreads at the end of the injector and CEBAF, σ_ϕ is the phase spread (or bunchlength) at the end of the injector.

$$\varepsilon_{E \cdot l} = \sigma_E \times \sigma_{bunchlength} = \sigma_E \times \sigma_\phi$$

For a fixed $\varepsilon_{E \cdot l}$ there is only **one degree of freedom,** $\sigma_{bunchlength}$ **or** $\sigma_{E_{inj}}$**, for a desired energy spread in the hall**.

$\varepsilon_{E \cdot l} = \sigma_E \times \sigma_{bunchlength} = \sigma_E \times \sigma_\phi$

Bunchlength is quantified in degrees, meters, seconds or radians depending on its use. Elegant uses meters, and I'll try to stick to meters when possible.

$$0.2\mathrm{m} = 360^\circ = 2\pi = 6.7 \times 10^{-10}\mathrm{s}$$

or:

$$1^\circ = 5.6 \times 10^{-4}\mathrm{m} = 0.018\mathrm{radians} = 1861\mathrm{fsec}$$

Some numbers from the paper

- $\varepsilon_{E \cdot l} = 6.7 keV^\circ = 117$ ev-rad
- $\sigma_\phi = 0.2^\circ = 1.1 \times 10^{-4}\ \mathrm{m} = 370\mathrm{fsec}$, then $\sigma_E = 34$ keV; This corresponds to dp/p = 0.6% at the 5.5 MeV point.
- $\sigma_l = 200\mathrm{fsec} = 0.11^\circ = 0.6 \times 10^{-4}\mathrm{m}$, $\sigma_E = 61$keV, or dp/p=1.1%. This is not unreasonable.

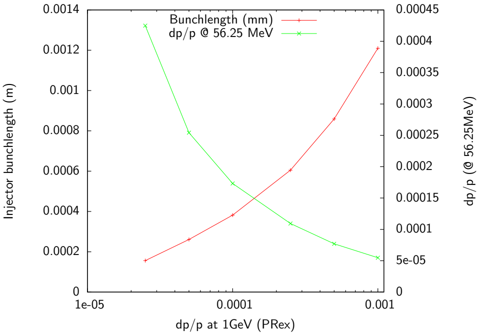
dp/p at one-pass, 1 GeV (PRex)

$$\sigma_E/E = \sqrt{\sigma^2_{E_{inj}}/E^2 + \sigma^4_\phi/2},$$

$$\varepsilon_{E \cdot l} = \sigma_E \times \sigma_{bunchlength} = \sigma_E \times \sigma_\phi$$

- Using $\varepsilon_{E.l} = 117$ ev-radians:
- 370 fsec $= 1.1 \times 10^{-4}$ m, we tend to operate at the small bunch length, large dp/p regime.
- These values are for the minimum dp/p at 1-pass. Obviously we can always configure the machine to deliver large dp/p than the minimum.

For a fixed $\varepsilon_{E.l}$ there is only one degree of freedom, $\sigma_{bunchlength}$ or σ_E, for a desired energy spread in the hall.



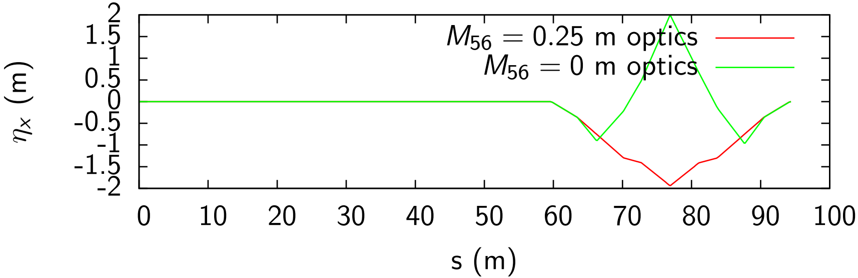
Intermediate Conclusions

- $\varepsilon_{E \cdot l}$ measurements at 5.5 MeV are sparse.
  - 117 ev-radian = 6.7 keV° value used in previous slides, this maybe small?
- σ_l does not need to be that *small*, in fact documented measurements of 200 $\rightarrow$ 250 fs suggest that large bunchlengths are not an issue.
- Relaxed dp/p requirements for remaining 6 GeV program. How can we take advantage of this?

None of this so far explains the Compton background sensitivity to front end adjustments.

Too small σ_l resulting in large $\sigma_{E_{inj}}$ in the injection chicane, causing scraping in the chicane? $dp/p \times \eta_x = 0.001 \times 2\mathrm{m} = 2\mathrm{mm}$. Suppose dp/p increases by a factor of 2 or more due to front end slips??

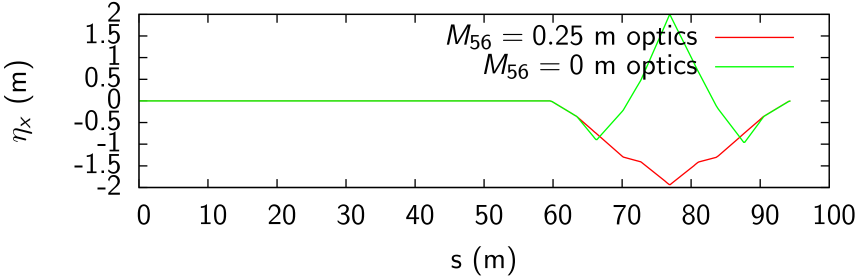
Injection Chicane Optics Choices



Both chicane optics have $\eta_{max} = 2$ m.

$M_{56} = 0.25\mathrm{m}$ optics has $\eta \neq 0$ value at Injector Synchrotron light location, this diagnostic becomes useful as a means of monitoring energy spread of the injector.

Chicane Entrance Parameters for $M_{56} = 0.25\mathrm{m}$

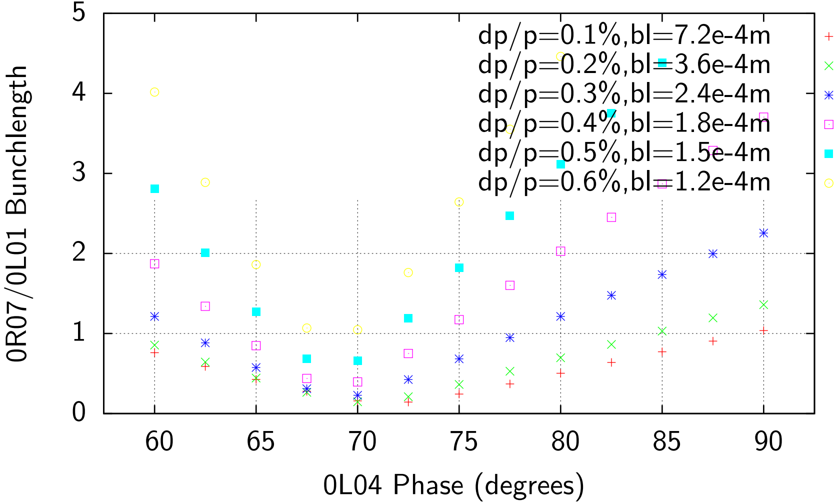


At what chicane input parameters, dp/p and σ_l, makes the most sense in terms of:

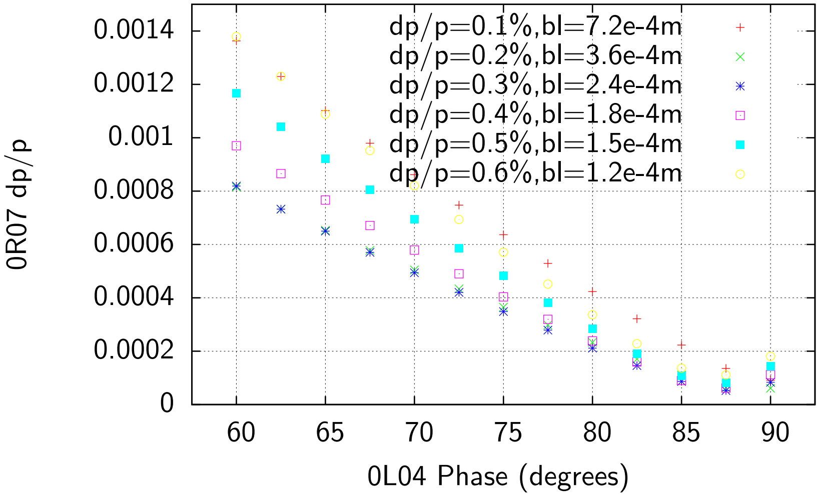
- Final injection σ_l and dp/p
- Reduced sensitivity to 5.5 MeV parameters (σ_l and dp/p).

Explore chicane exit parameters using $\varepsilon_{E.l} = 75, 125, 250\mathrm{ev\text{-}radians}$ at the 5.5MeV point(0L01), where the 125 ev-radian value is nearest the nominal longitudinal emittance value. $E_{inj} = 56.25\mathrm{MeV}$ as for PRex.

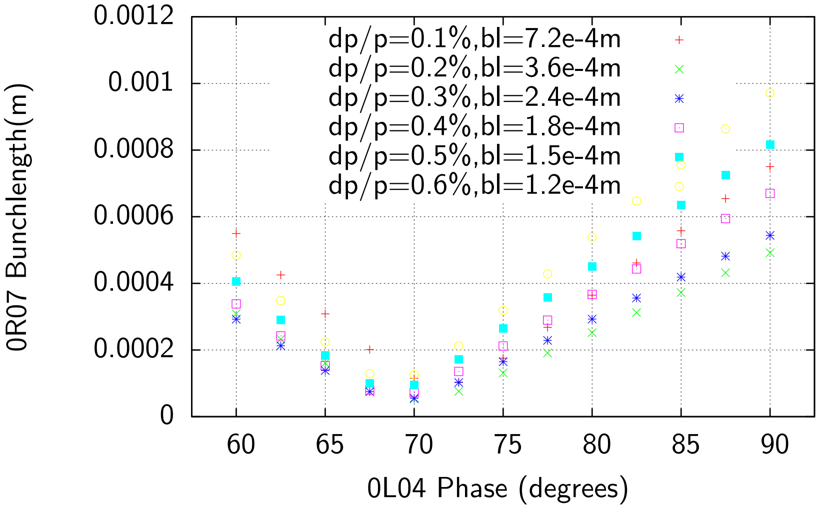
Bunchlength Compression for $\varepsilon_{E \cdot l} = 125$ev-rad



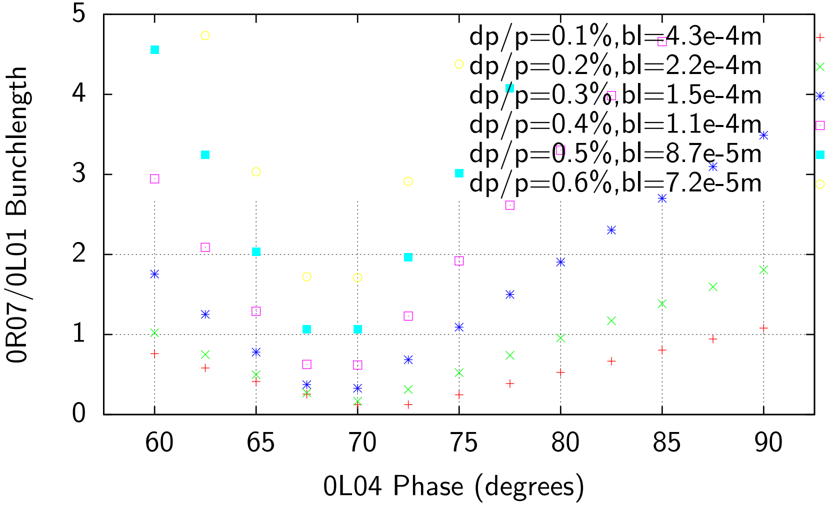
0R07 dp/p for $\varepsilon_{E.l} = 125$ev-rad



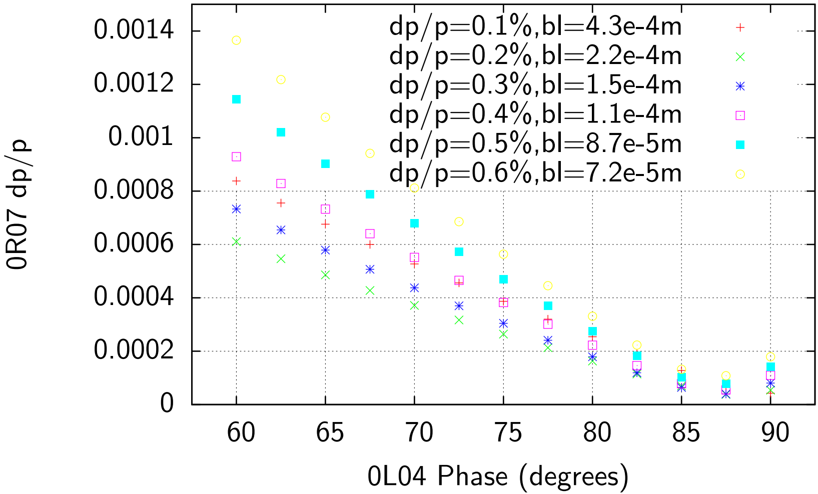
0R07 σ_l for $\varepsilon_{E \cdot l} = 125$ev-rad



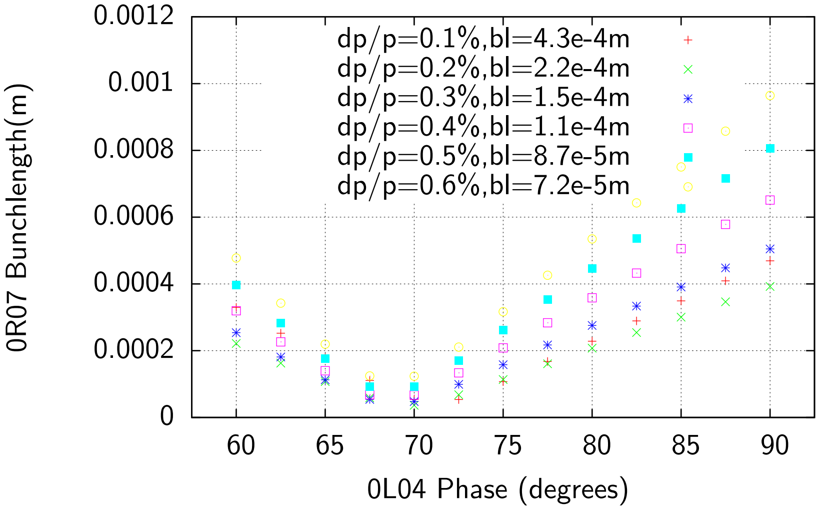
Bunchlength Compression for $\varepsilon_{E \cdot l} = 75$ev-rad



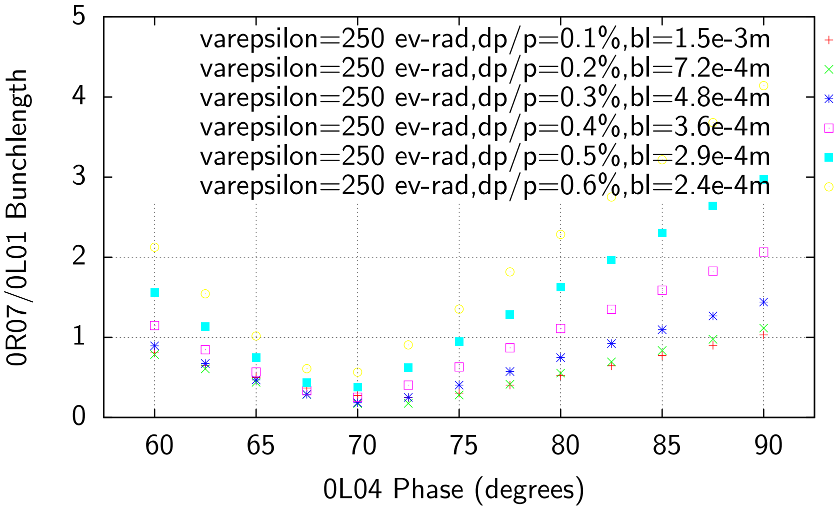
0R07 dp/p for $\varepsilon_{E \cdot l} = 75$ev-rad



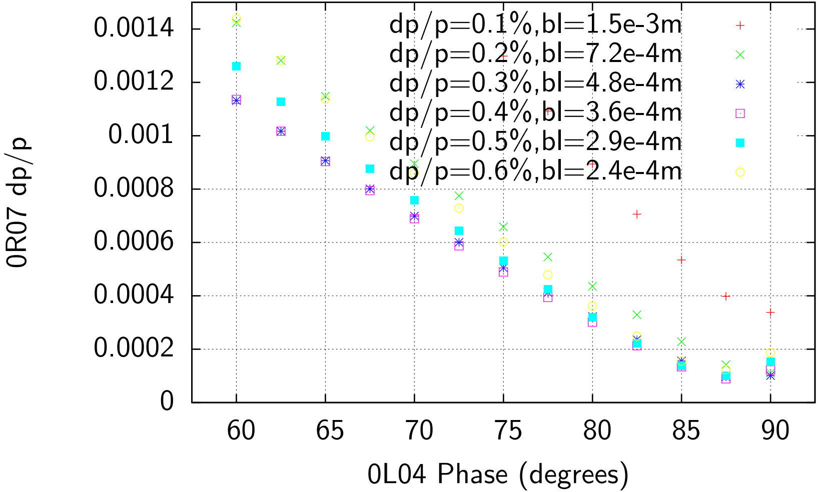
0R07 σ_l for $\varepsilon_{E\cdot l} = 75$ev-rad



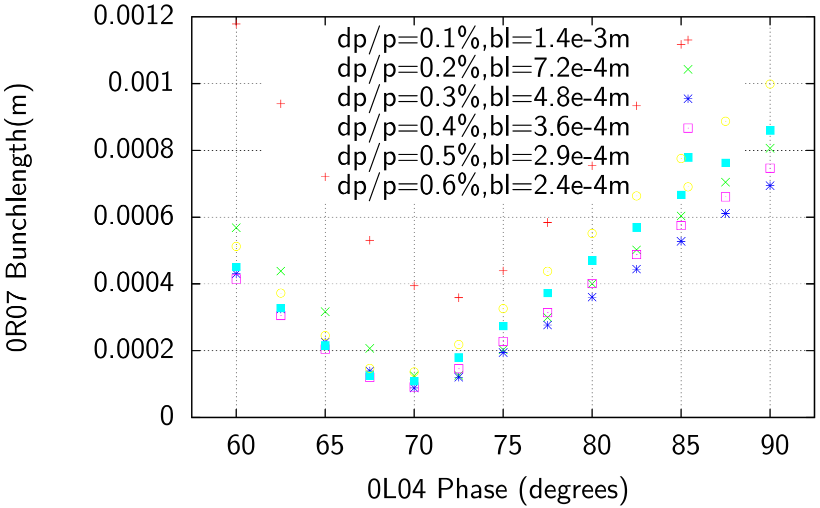
Bunchlength Compression for $\varepsilon_{E \cdot l} = 250$ev-rad



0R07 dp/p for $\varepsilon_{E.l} = 250$ev-rad



0R07 σ_l for $\varepsilon_{E \cdot l} = 250$ev-rad



Summary

The compton background rate is sensitive to something in the Injector.

$M_{56} = 0$m optics, provides a direct line of sight from the Injector warm RF to the endstations.

$M_{56} = 0.25$m injector chicane optics can shield the endstations from changes in the Injector warm RF. But the input to the injection chicane needs to be properly configure.

Beam Parameters at 5.5 MeV Point

- $0.15\% < dp/p < 0.35\%$
- 75 ev-radian ¡ $\varepsilon_{E \cdot l} > 250$ ev-radian
- $1.2 \times 10^{-4}\mathrm{m} < \sigma_l < 1 \times 10^{-3}\mathrm{m}$
- $0.2^\circ < \sigma_\phi < 1.7^\circ$

Injector SRF and Chicane Configuration

- $15^\circ < \phi_{0L04} < 20^\circ$ 0L04 off crest
- $M_{56} = 0.25$ m transport in the chicane.