



# Bunch Compression Experiment in VUV- FEL BC3

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# Overview

- Introduction
- Simulation Methods
- Beam Dynamics in BC3
- Beam Transport to LOLA
- Proposed Experiment



# Introduction

Coherent Synchrotron Radiation in the  
Bunch Compressors distort the Beam.

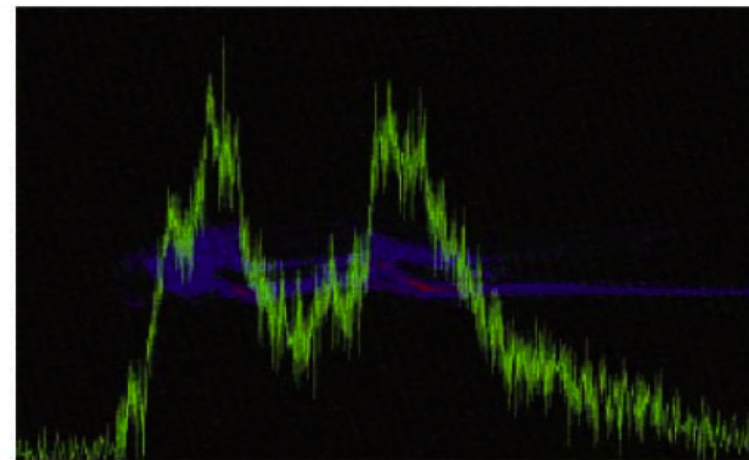
Our Goal is to use LOLA to observe CSR  
effects on the beam.

Both CSR and SpCh forces contribute to the  
final Beam which makes a clear  
identification of CSR effects difficult.

# Introduction

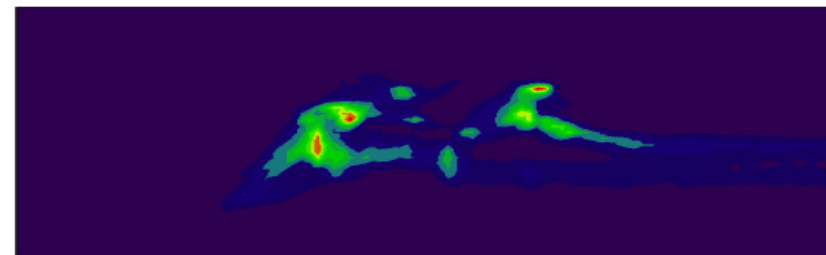
Furthermore bunch compression in both compressors leads to complicated particle distributions.

To keep the situation as simple as possible we decided to use only one Bunch Compressor (BC3).



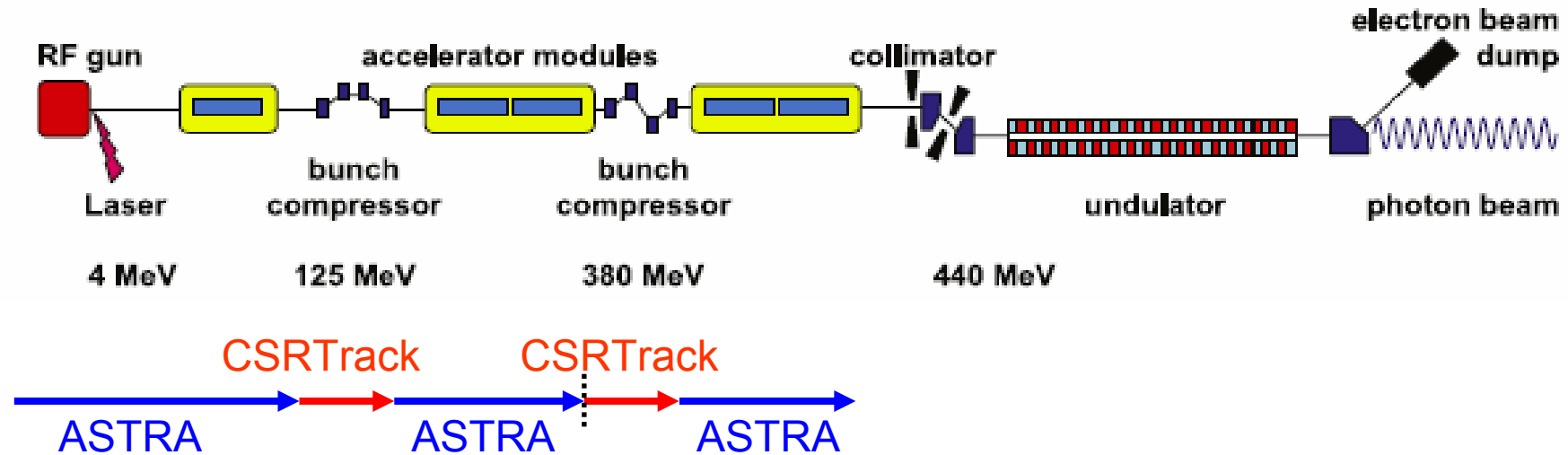
← 1 picosecond →

1 picosecond



M. Dohlus

# Simulation Methods



ACC1 : on crest

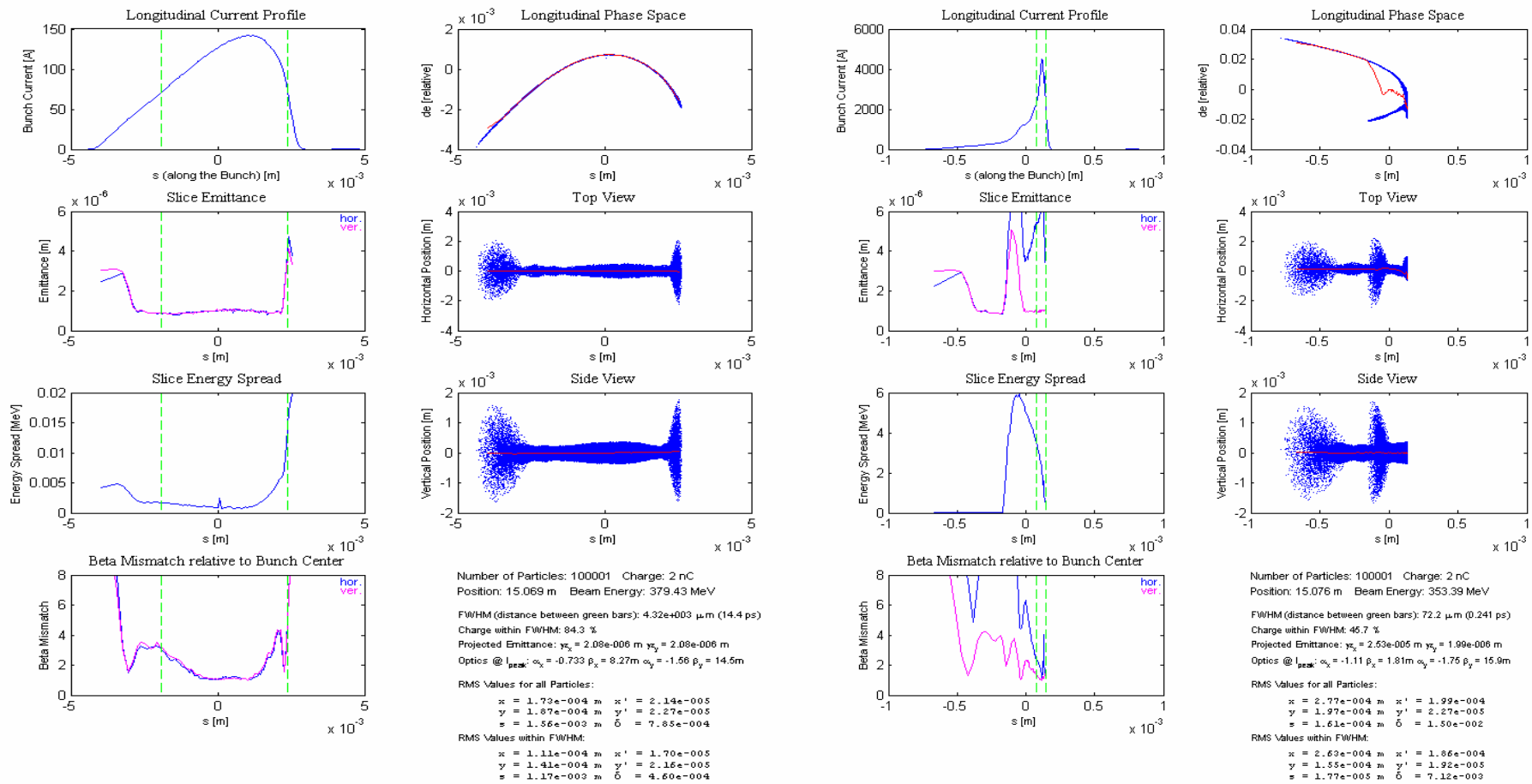
ACC23 : (maximum Compression ~ -28deg)  
 -40deg/-35deg/-30deg/  
 -25deg/0deg

BC3: R = 5.3 m  
 alpha = 5.4 deg  
 R56=-0.099369

CSRTrack calculations using  
 'projected' method.

1nC and 2nC Bunches

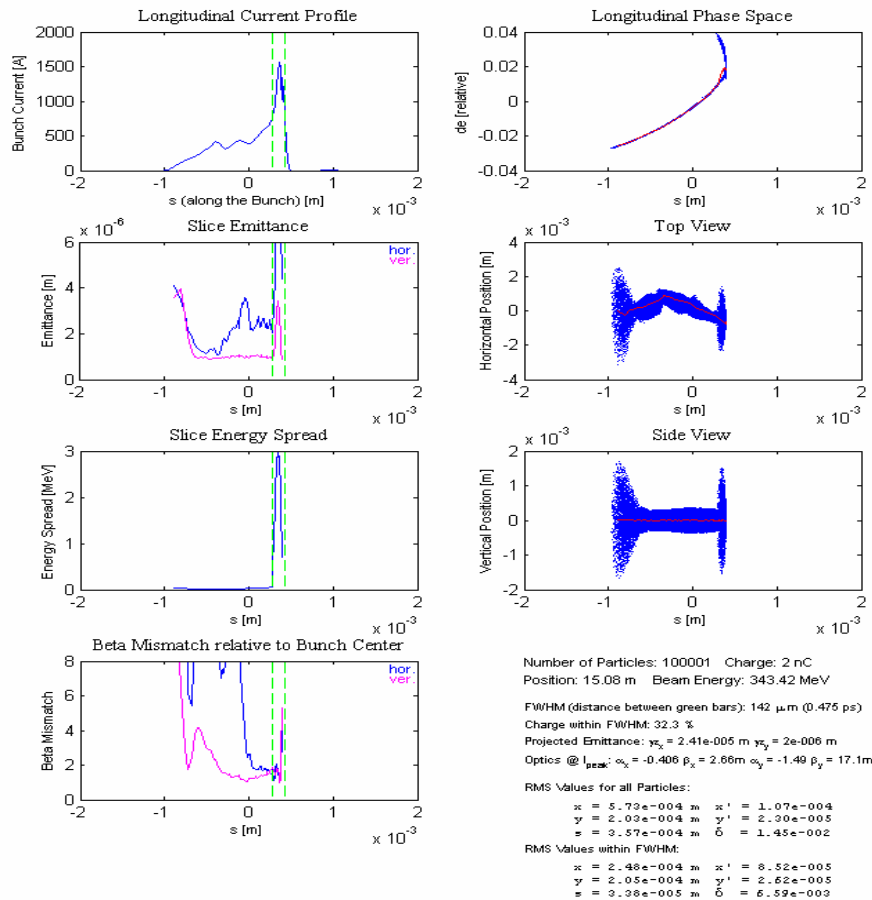
# Beam Dynamics in BC3



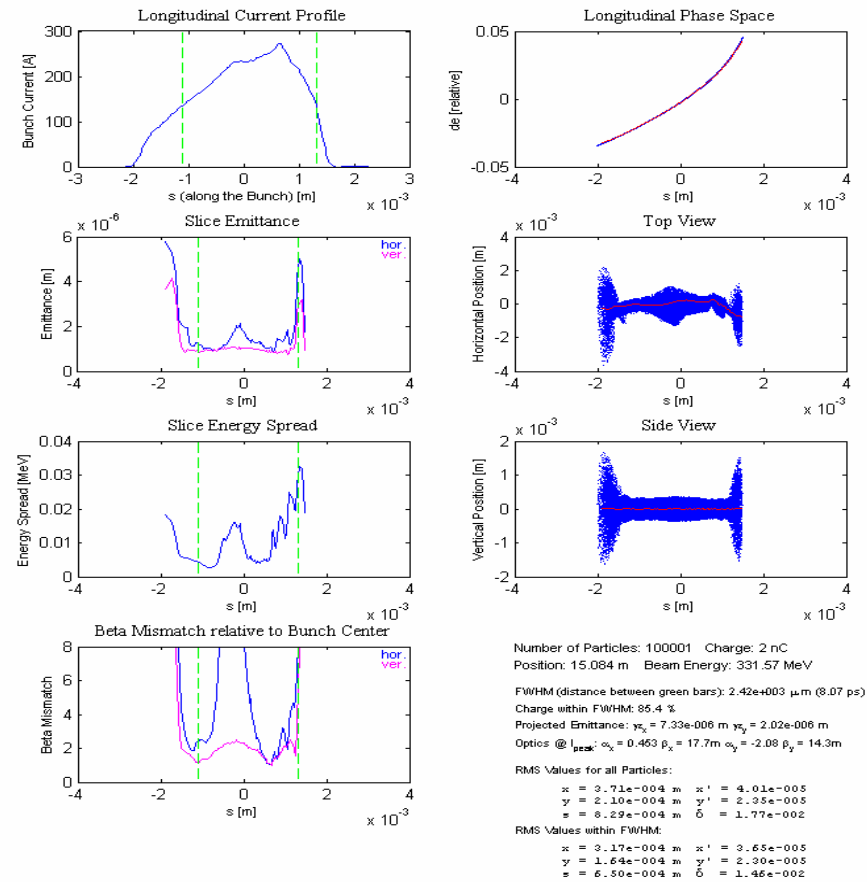
0deg 2nC

-25deg 2nC

# Beam Dynamics in BC3

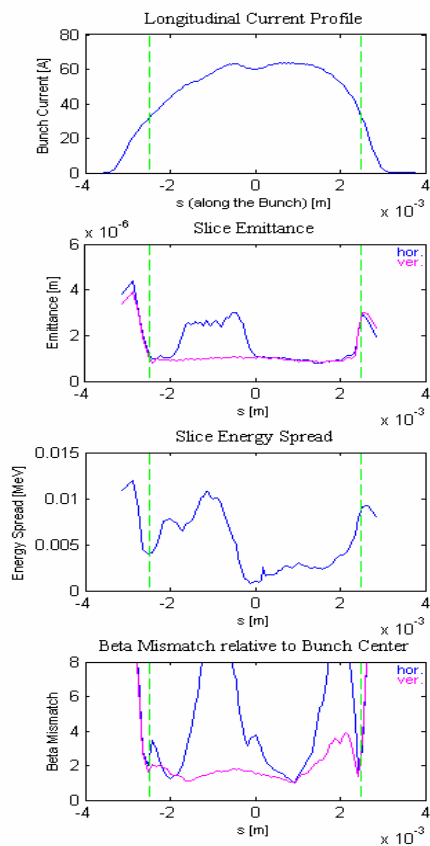


-30deg 2nC



-35deg 2nC

# Beam Dynamics in BC3



Number of Particles: 100001 Charge: 1 nC  
 Position: 15.09 m Beam Energy: 318.17 MeV  
 FWHM (distance between green bars):  $4.99e+003 \mu\text{m}$  (16.6 ps)  
 Charge within FWHM: 92.3 %  
 Projected Emittance:  $\gamma_x = 7.43e-006 \text{ m}$   $\gamma_y = 2.04e-006 \text{ m}$   
 Optics @  $l_{\text{peak}}$ :  $\alpha_x = -1.1$   $\beta_x = 6.27 \text{ m}$   $\alpha_y = -2.24$   $\beta_y = 18.9 \text{ m}$

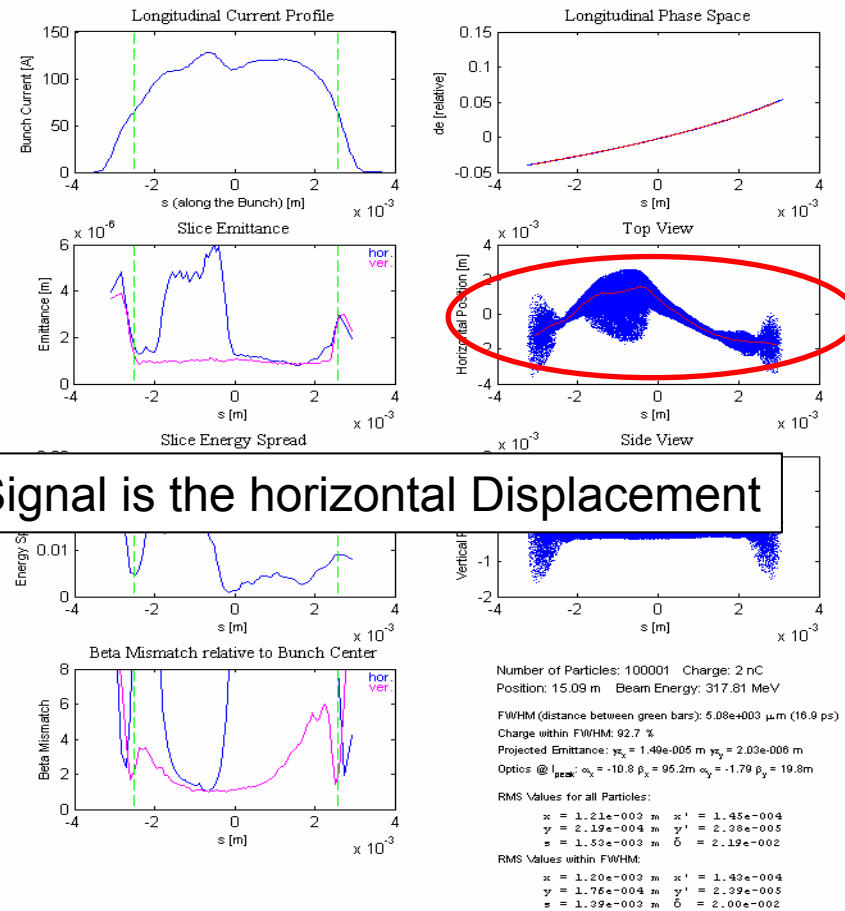
RMS Values for all Particles:

$x = 6.29e-004 \text{ m}$	$x' = 7.49e-005$
$y = 2.19e-004 \text{ m}$	$y' = 2.39e-005$
$s = 1.50e-002 \text{ m}$	$\delta = 2.15e-002$

RMS Values within FWHM:

$x = 6.09e-004 \text{ m}$	$x' = 7.24e-005$
$y = 1.76e-004 \text{ m}$	$y' = 2.39e-005$
$s = 1.35e-002 \text{ m}$	$\delta = 1.94e-002$

-40deg 1nC



The clearest Signal is the horizontal Displacement

Number of Particles: 100001 Charge: 2 nC  
 Position: 15.09 m Beam Energy: 317.81 MeV  
 FWHM (distance between green bars):  $5.08e+003 \mu\text{m}$  (16.9 ps)  
 Charge within FWHM: 92.7 %  
 Projected Emittance:  $\gamma_x = 1.49e-005 \text{ m}$   $\gamma_y = 2.03e-006 \text{ m}$   
 Optics @  $l_{\text{peak}}$ :  $\alpha_x = -10.8$   $\beta_x = 95.2 \text{ m}$   $\alpha_y = -1.79$   $\beta_y = 19.8 \text{ m}$

RMS Values for all Particles:

$x = 1.21e-002 \text{ m}$	$x' = 1.45e-004$
$y = 2.19e-004 \text{ m}$	$y' = 2.38e-005$
$s = 1.53e-002 \text{ m}$	$\delta = 2.19e-002$

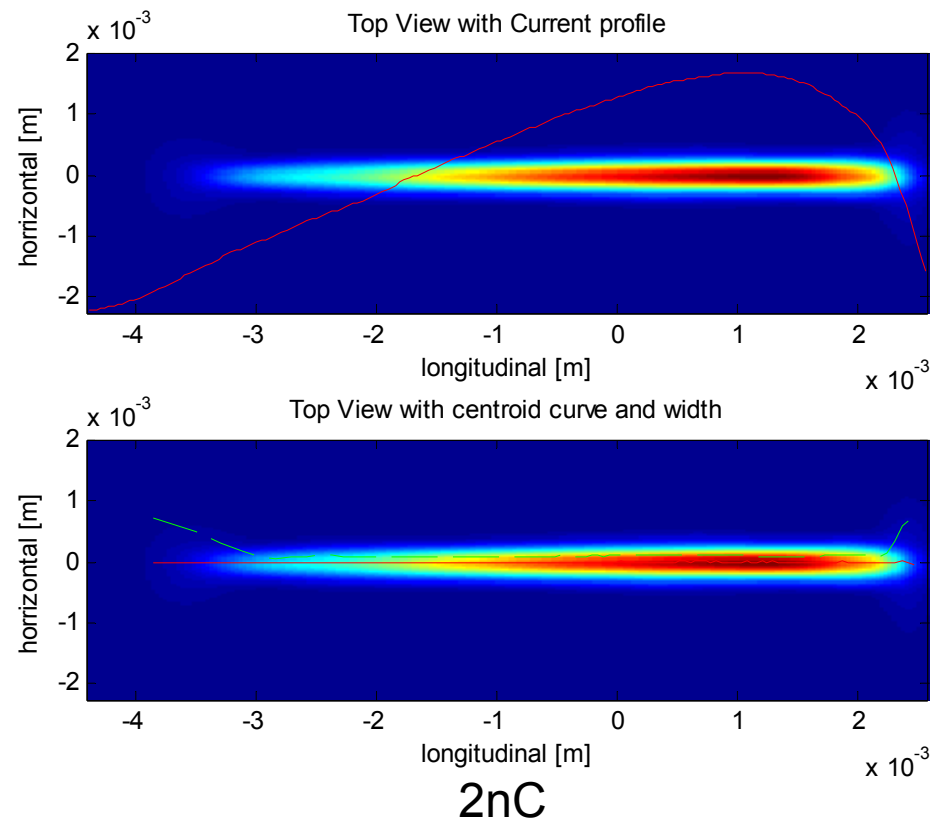
RMS Values within FWHM:

$x = 1.20e-002 \text{ m}$	$x' = 1.43e-004$
$y = 1.76e-004 \text{ m}$	$y' = 2.39e-005$
$s = 1.39e-002 \text{ m}$	$\delta = 2.00e-002$

-40deg 2nC



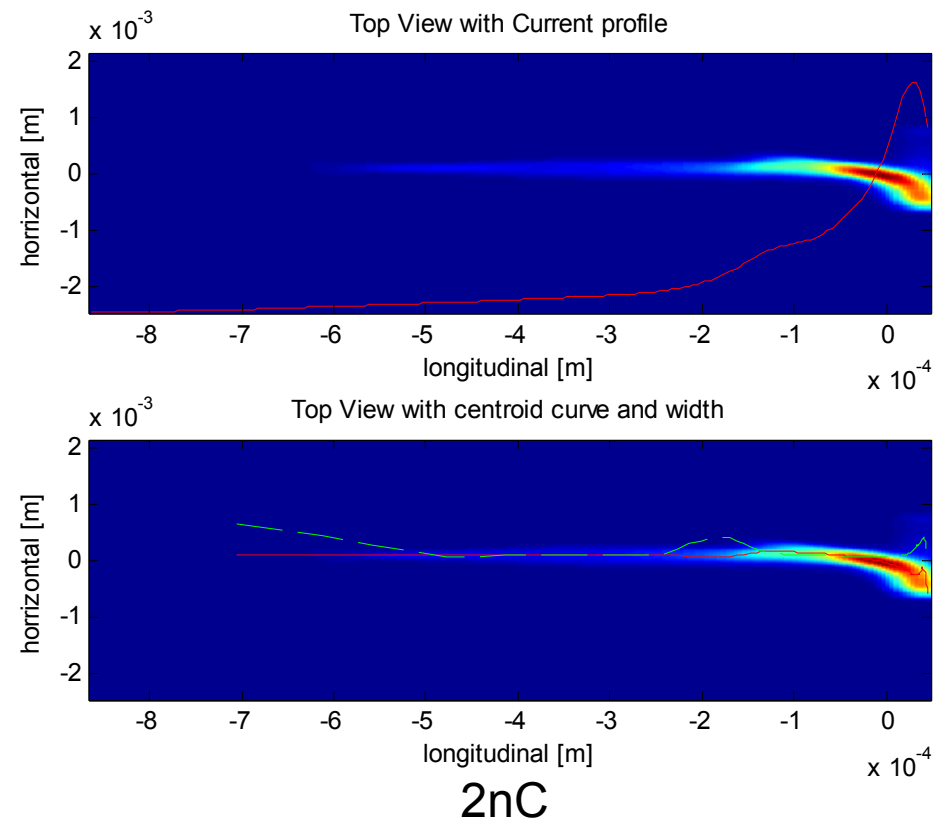
# Beam Dynamics in BC3 0deg



Red solid : Centroid

Green dashed : slice width

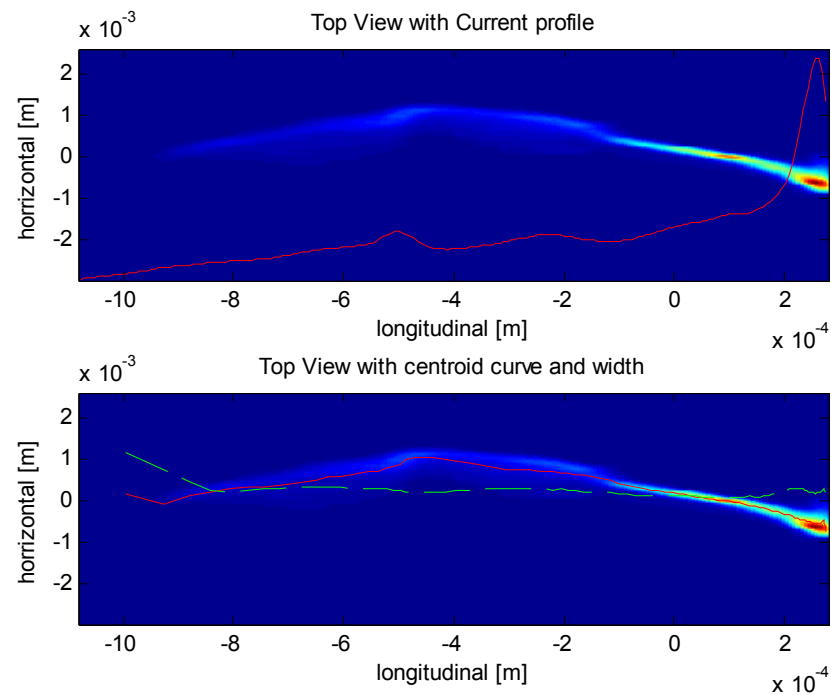
# Beam Dynamics in BC3 25deg



Red solid : Centroid

Green dashed : slice width

# Beam Dynamics in BC3 30deg

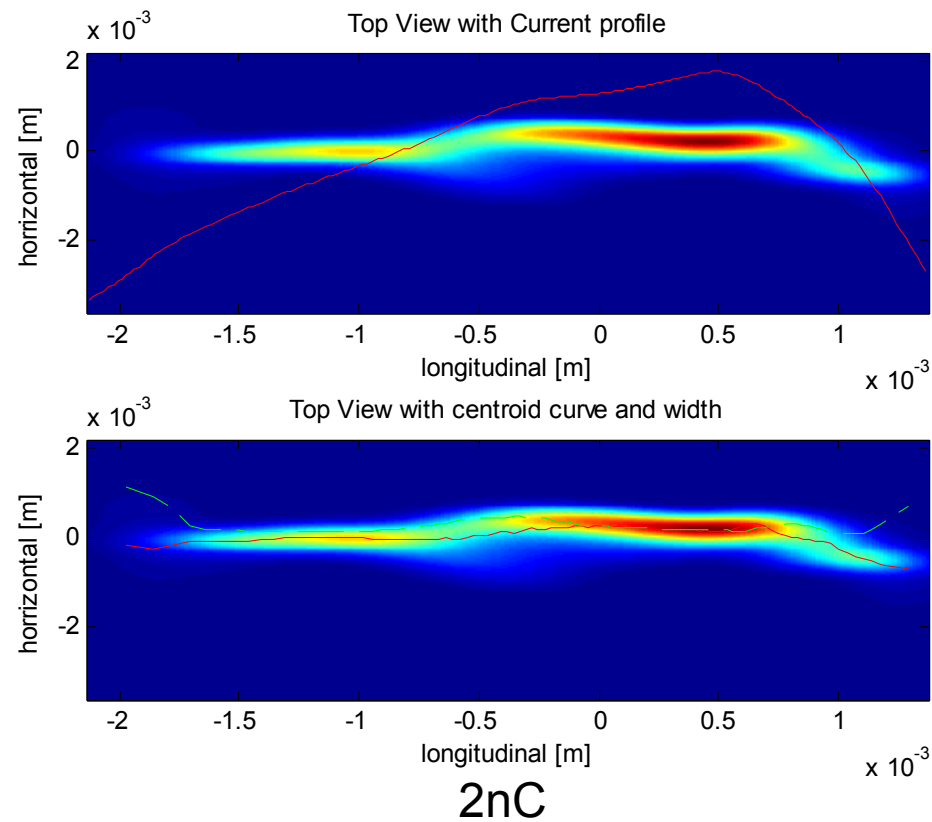


2nC

Red solid : Centroid

Green dashed : slice width

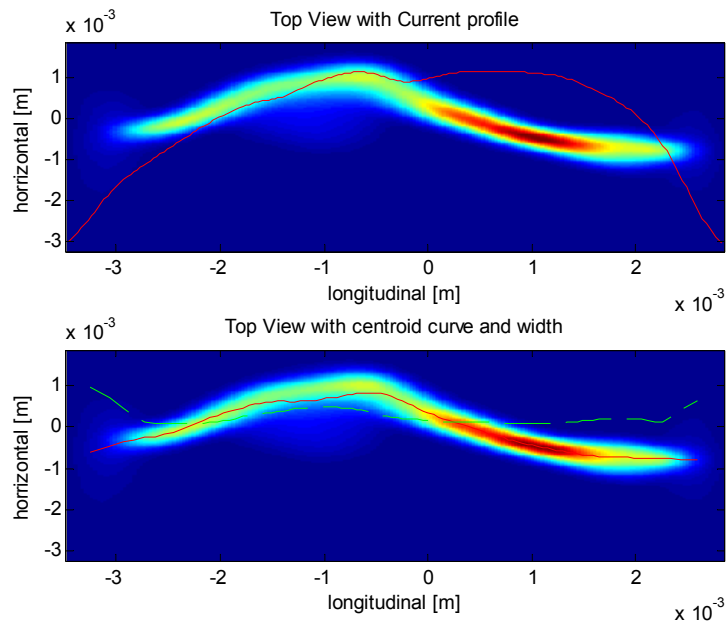
# Beam Dynamics in BC3 35 deg



Red solid : Centroid

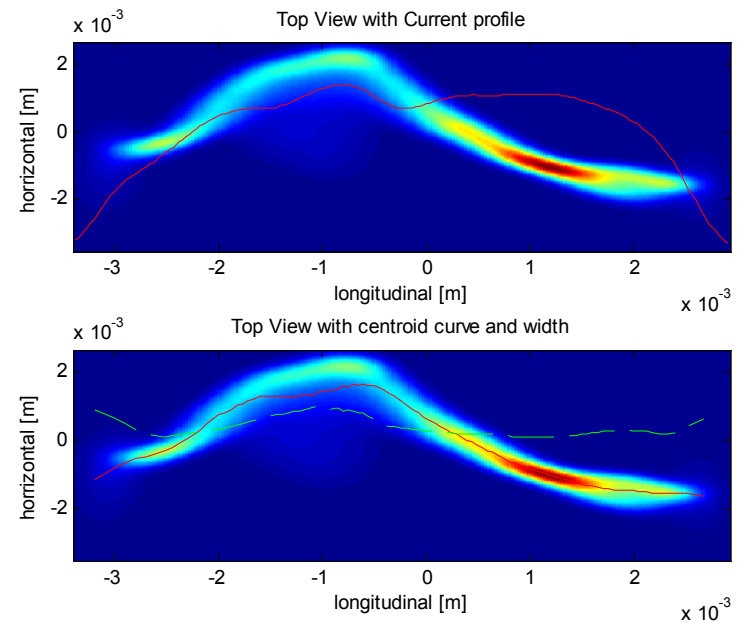
Green dashed : slice width

# Beam Dynamics in BC3 40deg



1nC

Red solid : Centroid

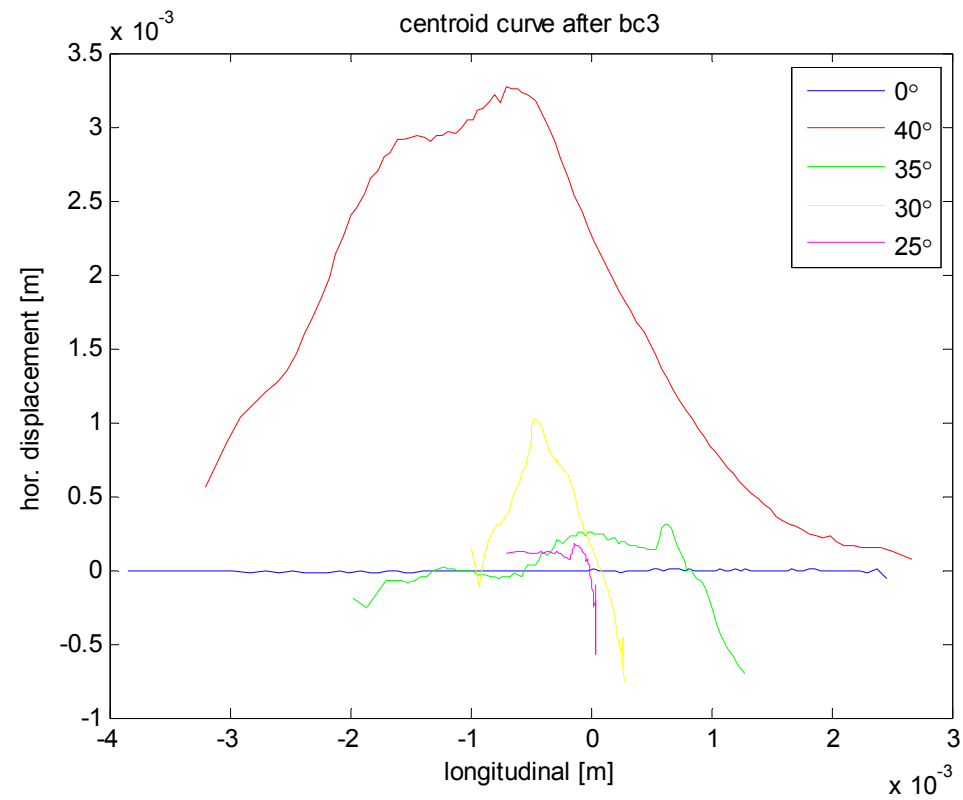


2nC

Green dashed : slice width

# Beam Dynamics in BC3

## Summary of the Centroid curves after BC3





# Beam Dynamics in BC3

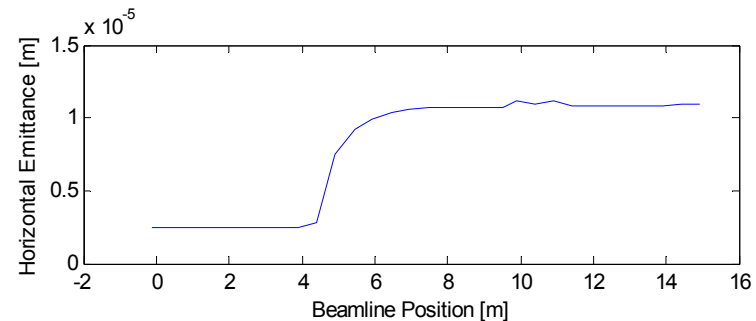
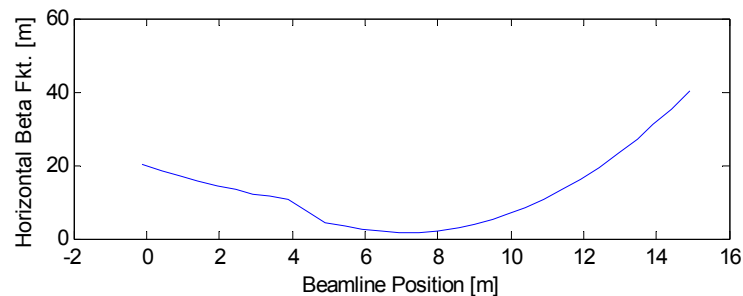
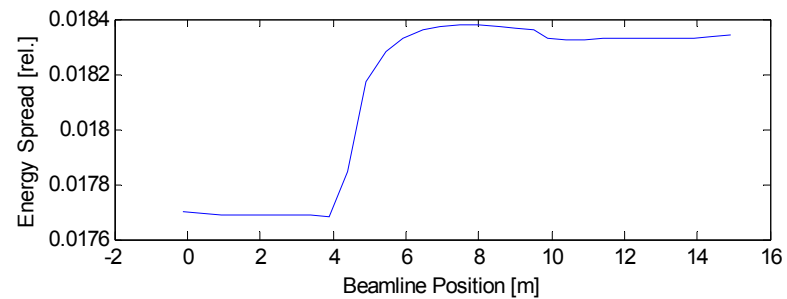
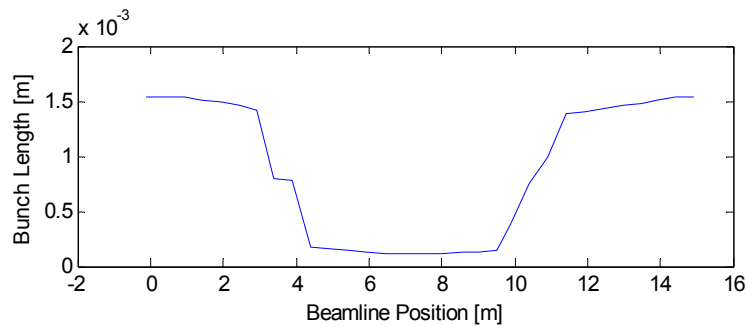
In order to “neglect” space charge forces behind the bunch compressor we focus now on the -40deg case.

In this case the bunch length is the same before and after BC3 (1.53mm). This makes it easy to compare with the on crest case.

# Beam Dynamics in BC3 40deg

The main contribution from CSR forces are in the area of the 3<sup>rd</sup> Dipole.

Max peak current is about 6kA (2nC).



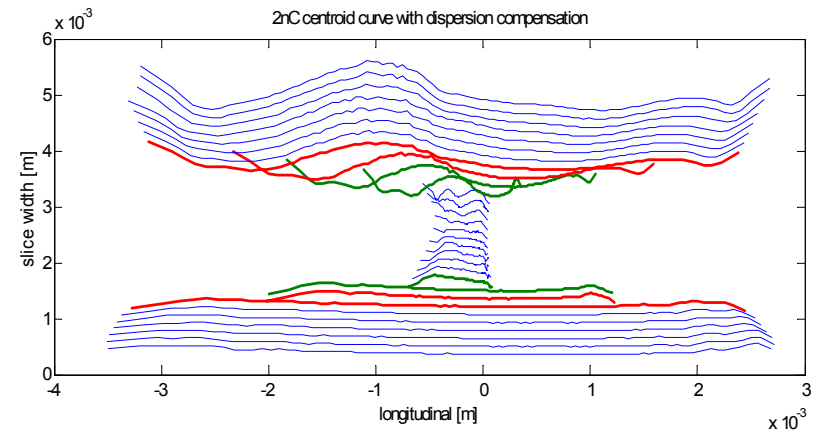
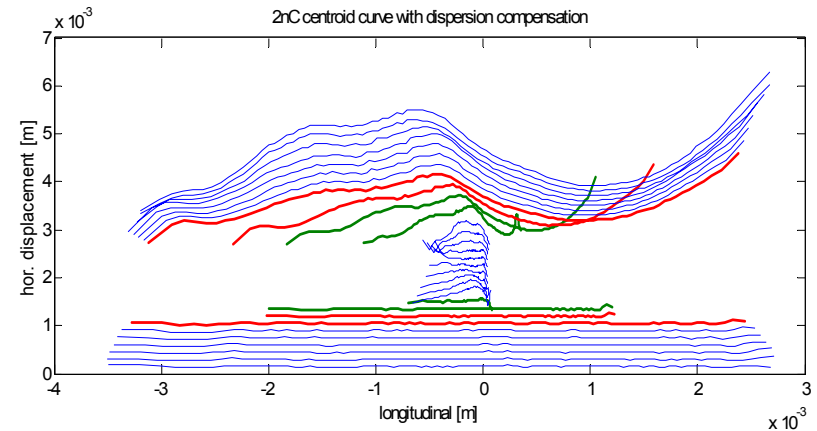
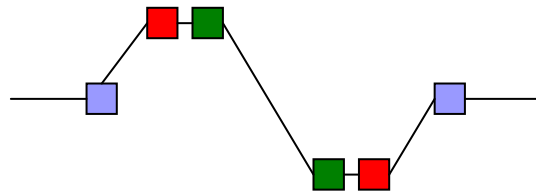


# Beam Dynamics in BC3 40deg

Evolution of the centroid curve and the slice rms width in BC3.

Dispersion is Substracted.

Red and green lines show the positions of the dipoles.





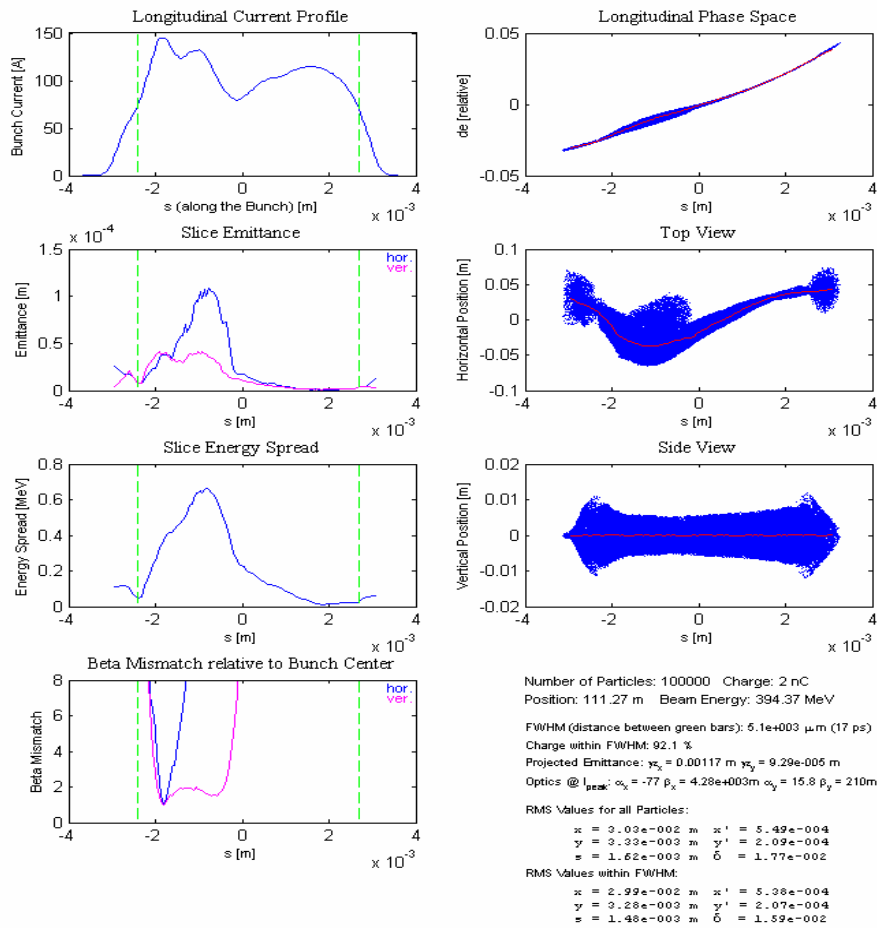
# Beam Transport to LOLA

Beam Transport from BC3 to LOLA with  
ASTRA using Op1 8.8.2005 optics.

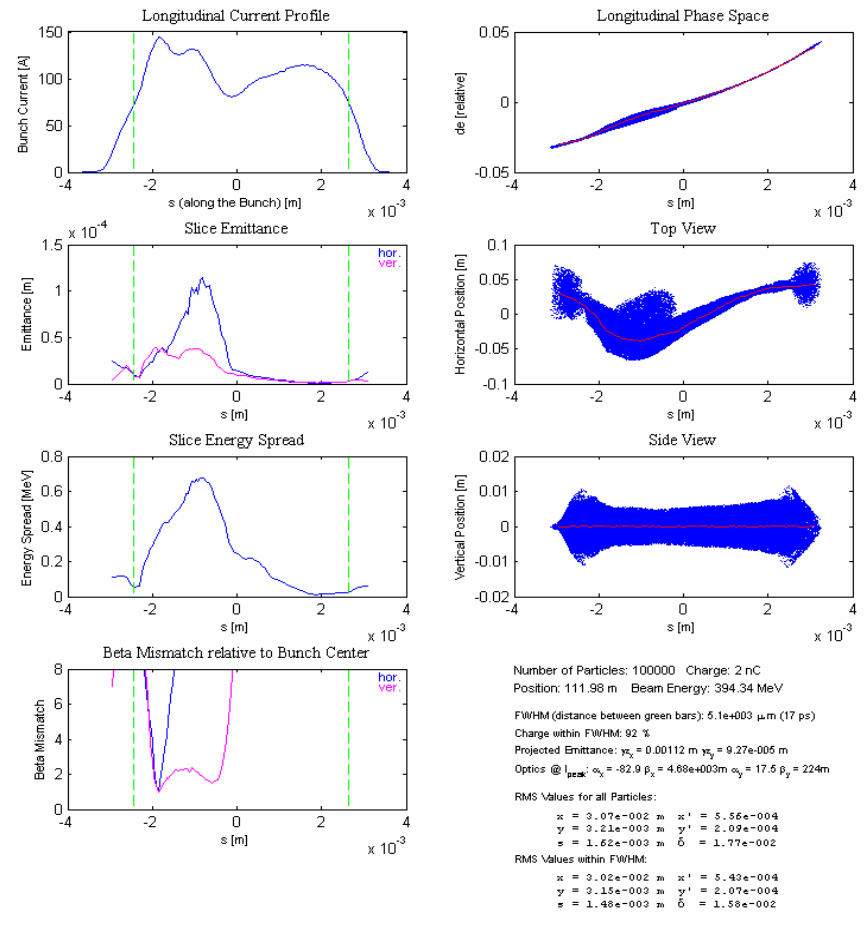
Only small longitudinal alterations from  
space charge forces are expected.

However the optics should have an strong  
impact on the horizontal centroid curve.

# Beam Transport to LOLA



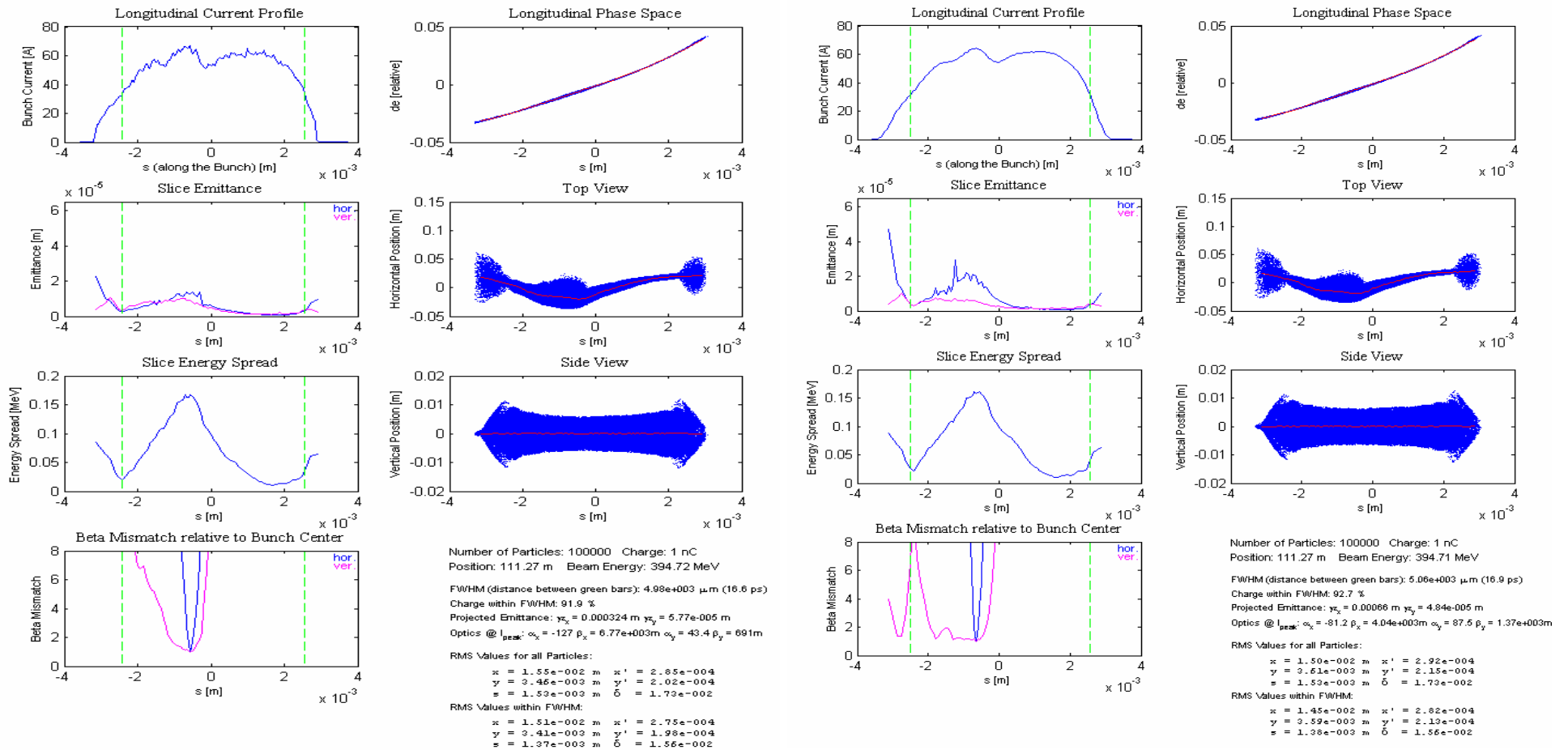
No SpCh 2nC



SpCh 2nC

Almost no difference....

# Beam Transport to LOLA

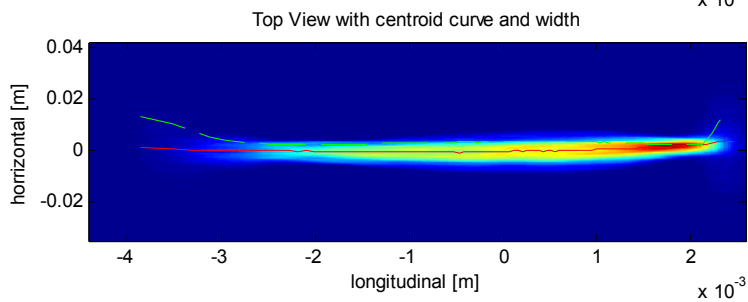
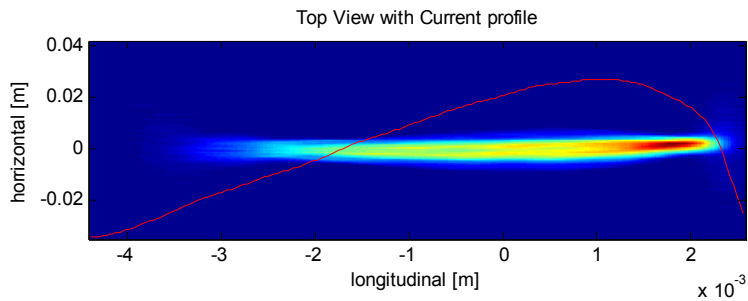


No SpCh 1nC

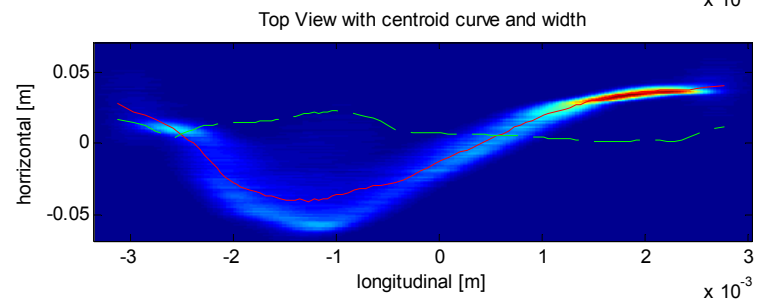
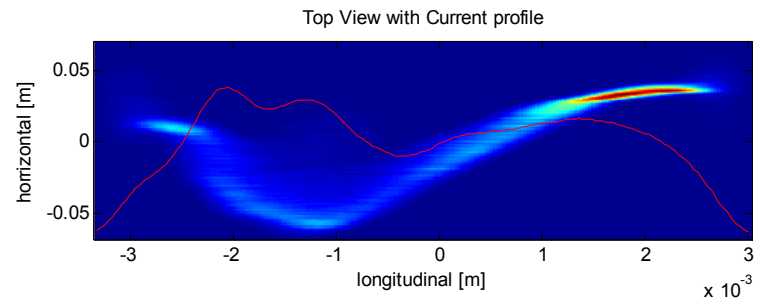
SpCh 1nC

Almost no difference....

# Beam at LOLA 2nC

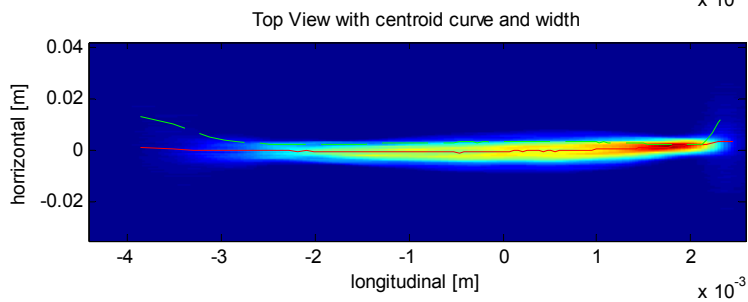
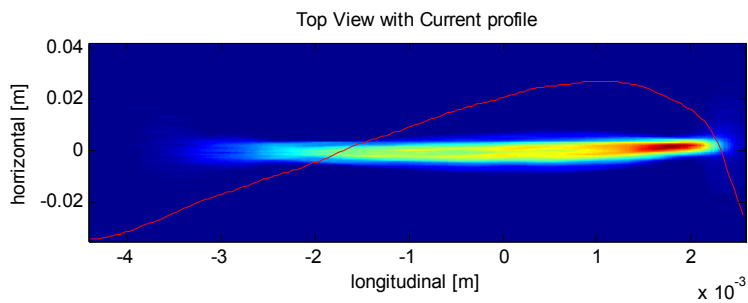


0deg

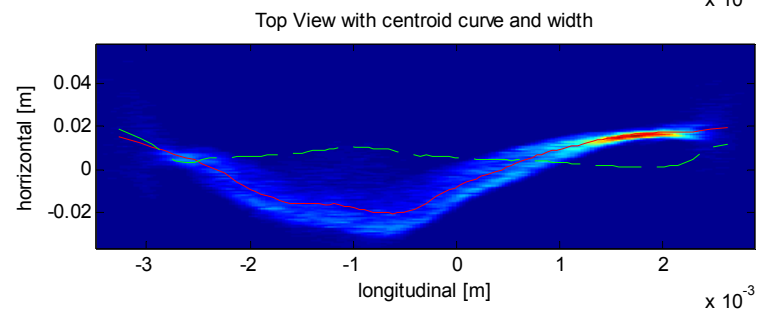
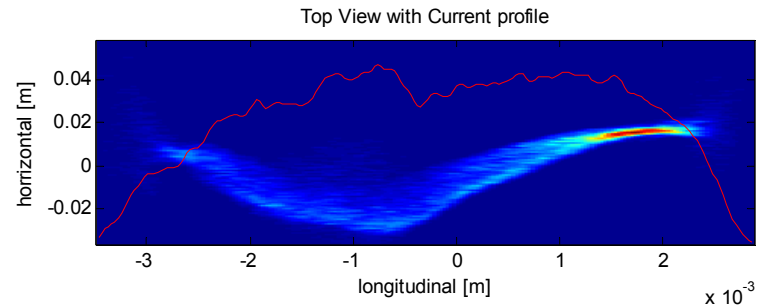


-40deg

# Beam at LOLA 1nC



0deg



-40deg



# Proposed Experiment

## Machine Set Up

Energy after ACC1 = 125 MeV

Phase of ACC1 = 0deg (on crest)

Energy after ACC23 = 380 MeV (on crest)

Phases of ACC23 = 0/25/30/35/40deg



# Proposed Experiment

- Set up machine
- LOLA measurement
  - If necessary optics and orbit adjustments
  - LOLA pictures at different phases (0/25/30/35/40deg) and charges (0.5/1/2nC)
- Optics measurement between BC3 and LOLA for proper tracking of the horizontal centroid curve.





# Summary

- LOLA should see clear CSR effects on the centroid.
- In the 2nC case slice energy spread growth from CSR should be observable.
- In the -40deg case space charge contributions are almost negligible.