- Proposal - Experimental Investigation of Low Energy Magnetic Bunch Compression at NICADD/A0 Facility

Ph. Piot [1]

Deutsches Elektronen Synchrotronen
Hamburg, D-22603, GERMANY

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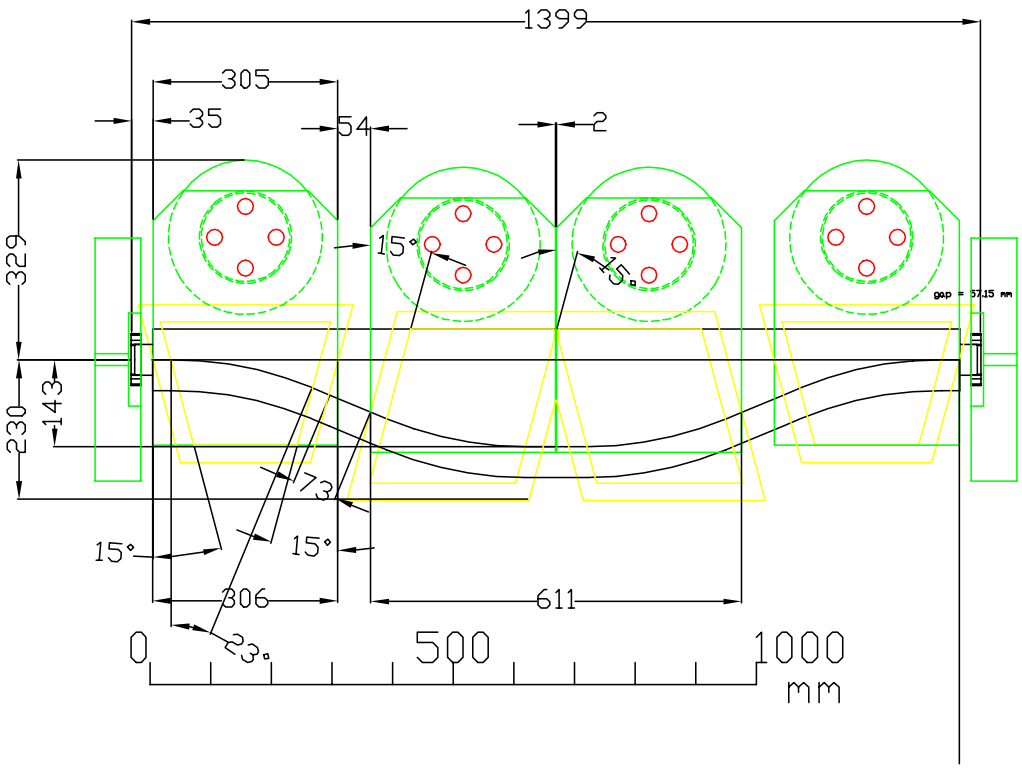
[1] philippe.piot@desy.de

Introduction/Motivation

- learn about compression of high charge low energy beam (up-to-date only few experiments [8 MeV: SPA @ LANL pac'99 p.477-481 (1999), 17 MeV: ISIR @ Osaka NIM A445 p.351-355 (2000)] $\Rightarrow$ but no thorough study
  - quantify and study parametric dependence of energy spread, loss, and transverse emittance
  - study how incoming optics affect emittance
- use the experiment to benchmark available codes/models
- study the compression of flat beam (higher emittance in the bending plane)
- gain some experience with A0 compressor that could be transposed to BC1 compressor at TTF 1.

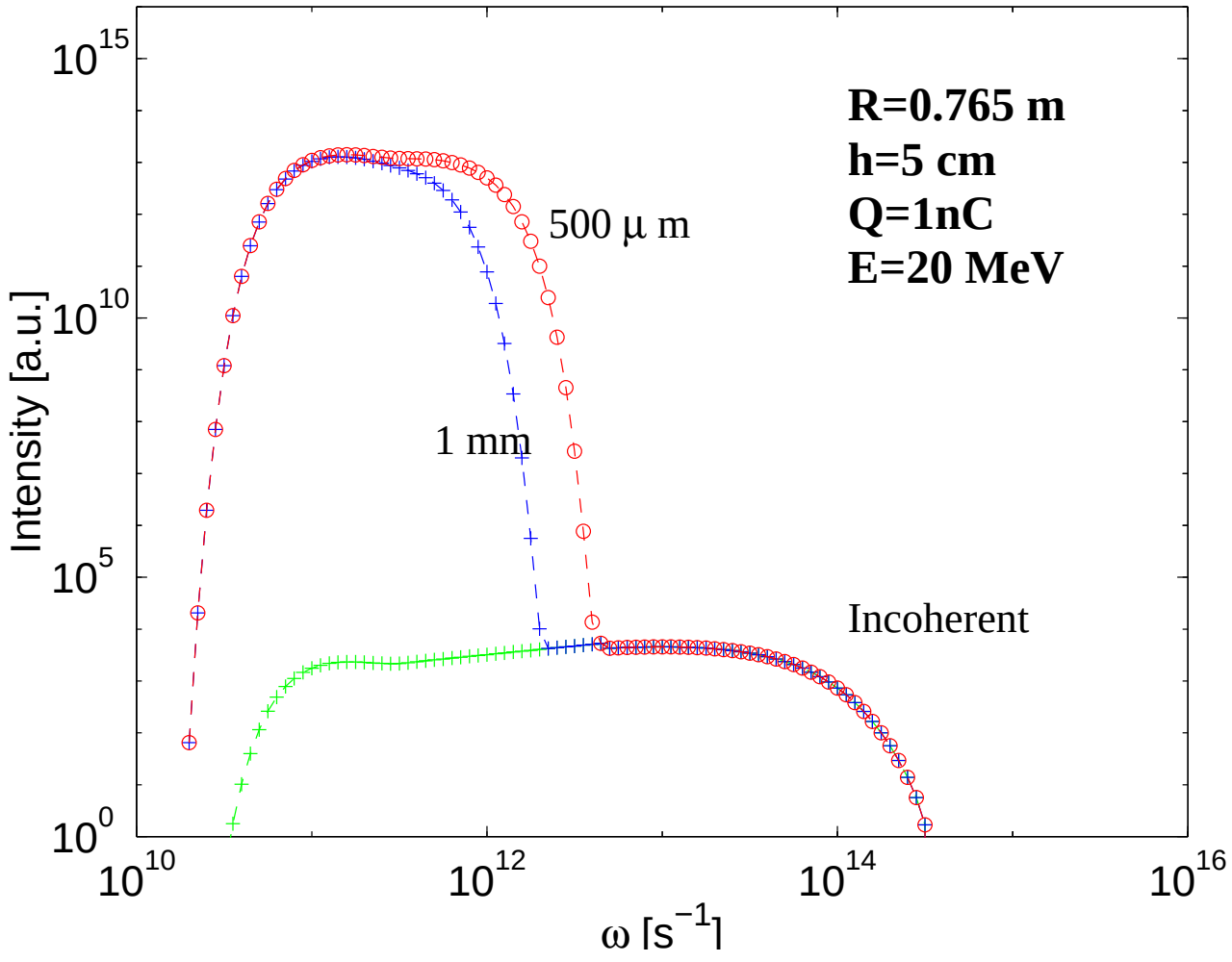
The A0 Magnetic Bunch Compressor



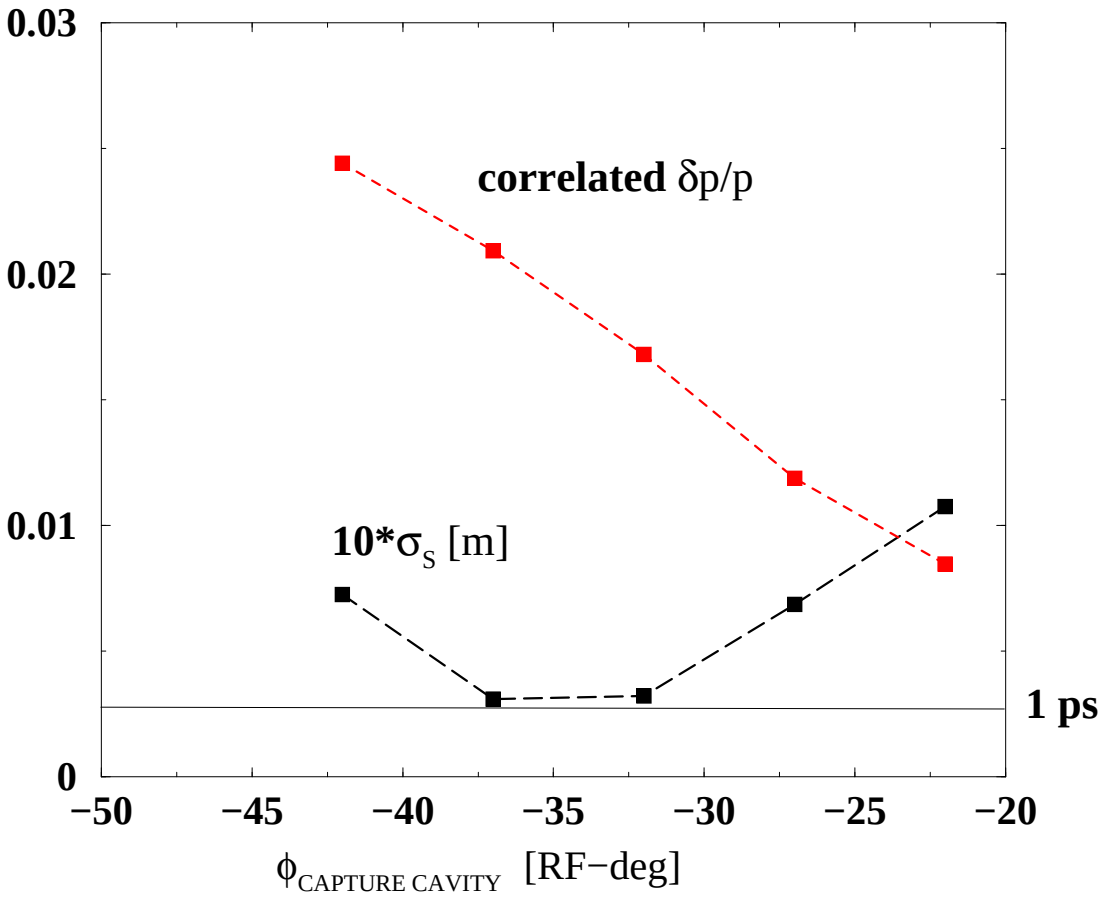
- bending angle $\theta = 0...23°$
- trapezoidal pole faces $\rightarrow$ balance focusing in x/y
- momentum compaction $R_{56} = 0... - 9.6$ cm
- $s - \delta$ correlation provided by the capture cavity
- possible control of beam envelope using upstream doublet (?)

The Challenges

- emittance compensation process not finished
- "standard" space charge
- radiative effect $\rightarrow$ bunch self interaction (CSR and "radiative" space charge)



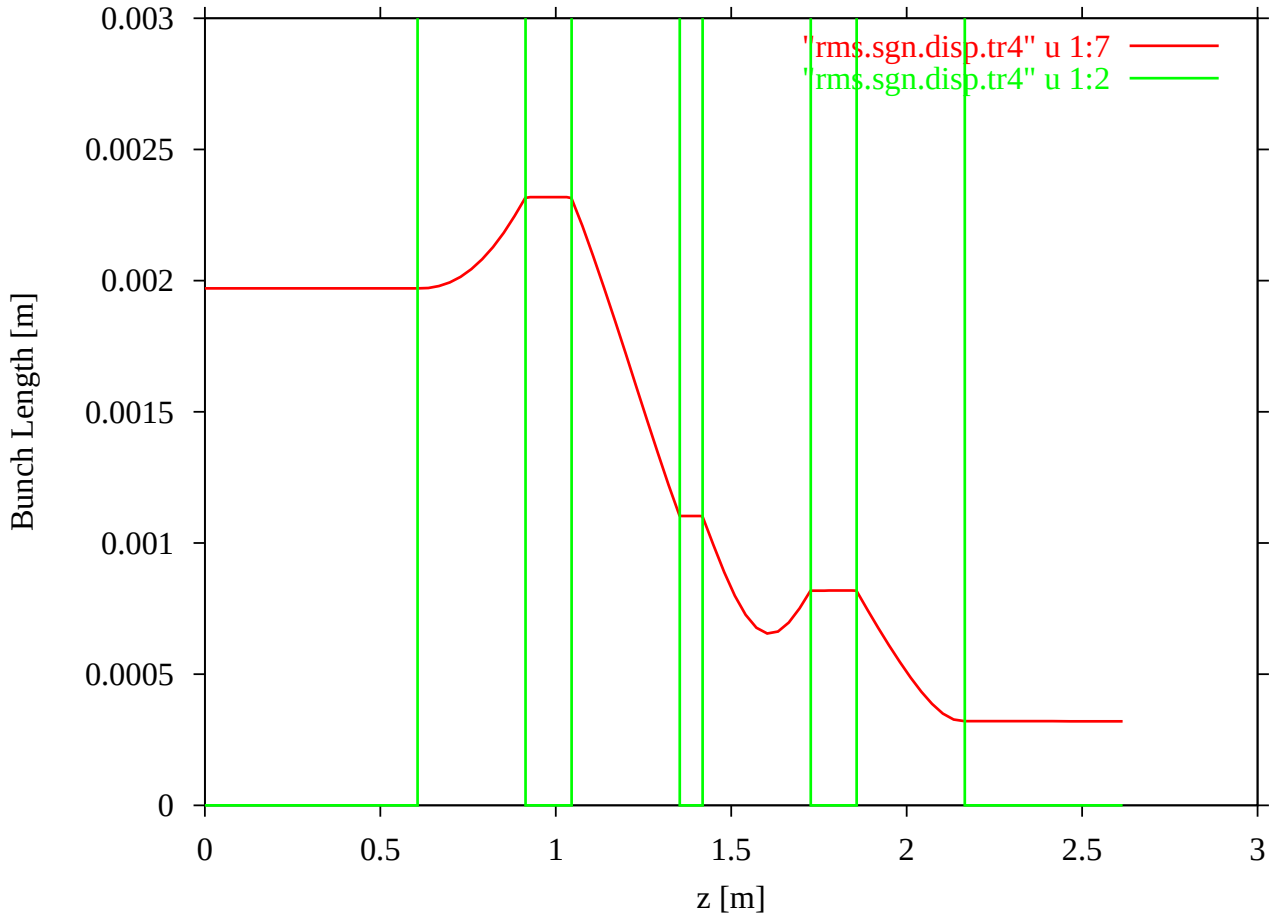
An Example of simulation:



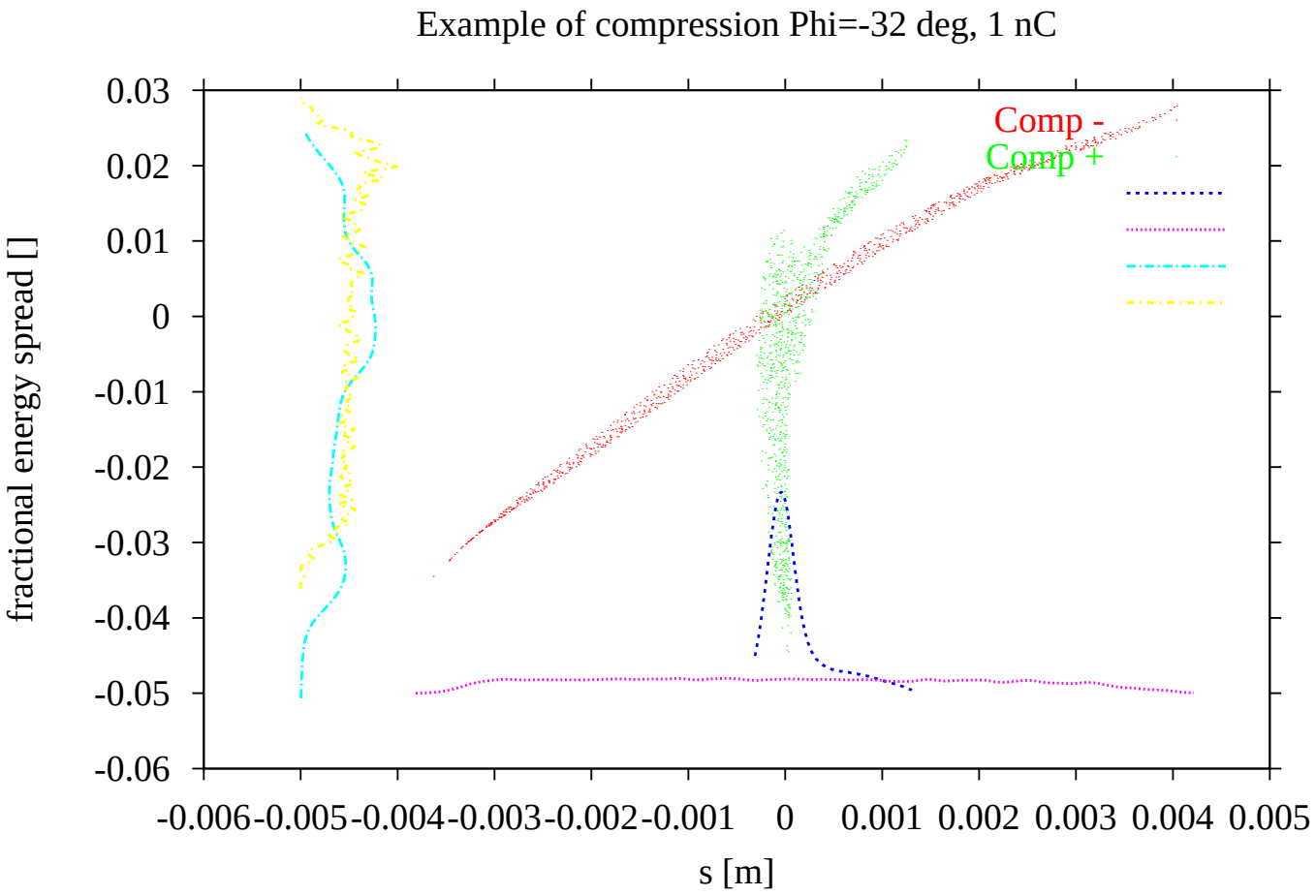
- use ASTRA to simulate injector up to chicane entrance
- pass phase space to TRAFIC^4 to simulate the bunch compressor. Simulation are performed in self consistent mode; using 1000 macro-particle only
- use *long* laser pulse (∼10 ps FWHM plateau with edge of 1 ps)
- study beam parameters evolution versus capture cavity phase

Bunch length evolution

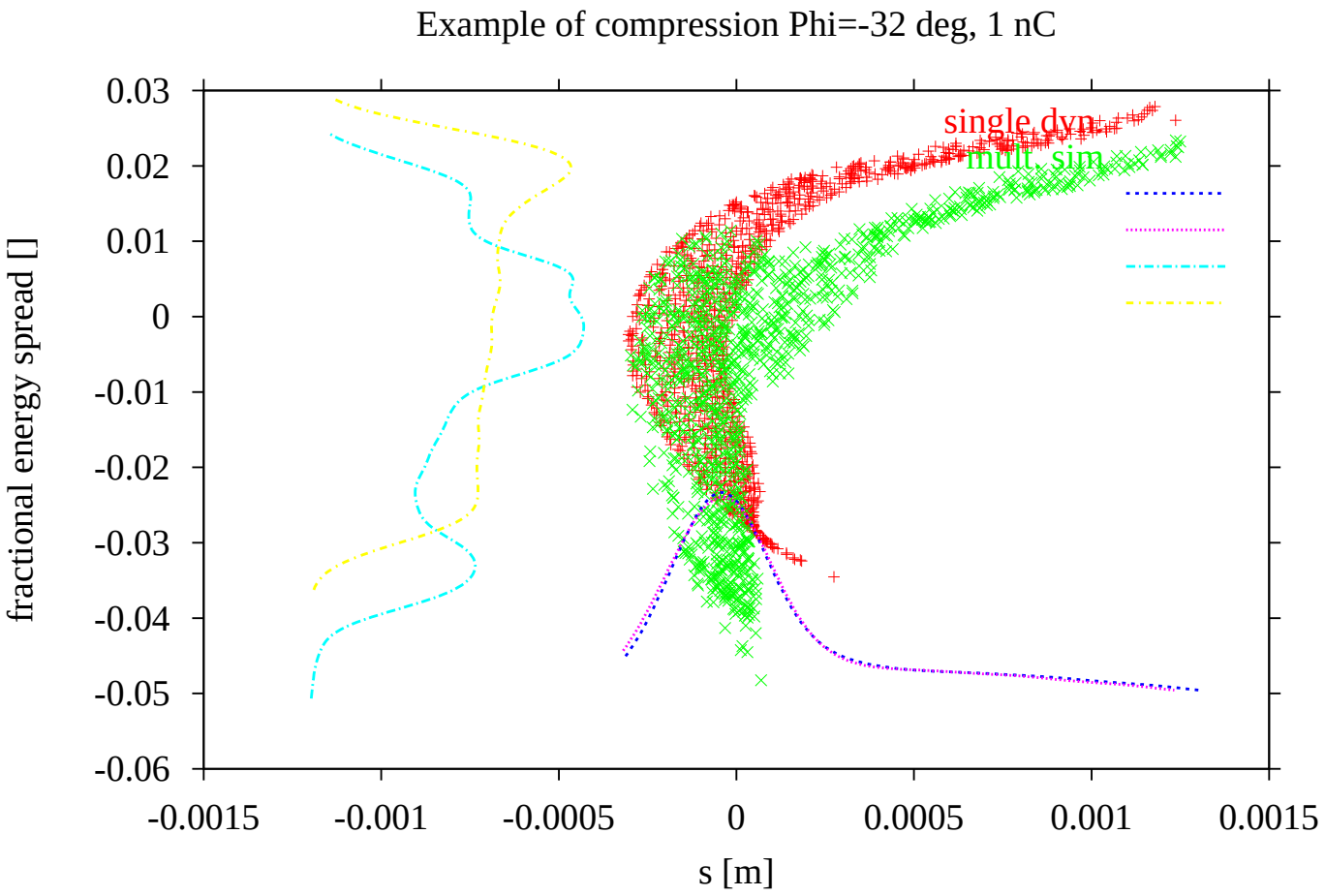
- two modes of operation for the laser *short* (2 ps rms Gaussian pulses) and *long* 4 stacked 2 ps-Gaussian pulses approx 10 ps FWHM)
- here we only restrain to *long* pulse
- example for $\phi_{CAPTURE} = -32°$: bunch compressed from 2 mm down to ~ 300 μm (1 ps)



Phase space evolution during compression (multi-particle simulations)

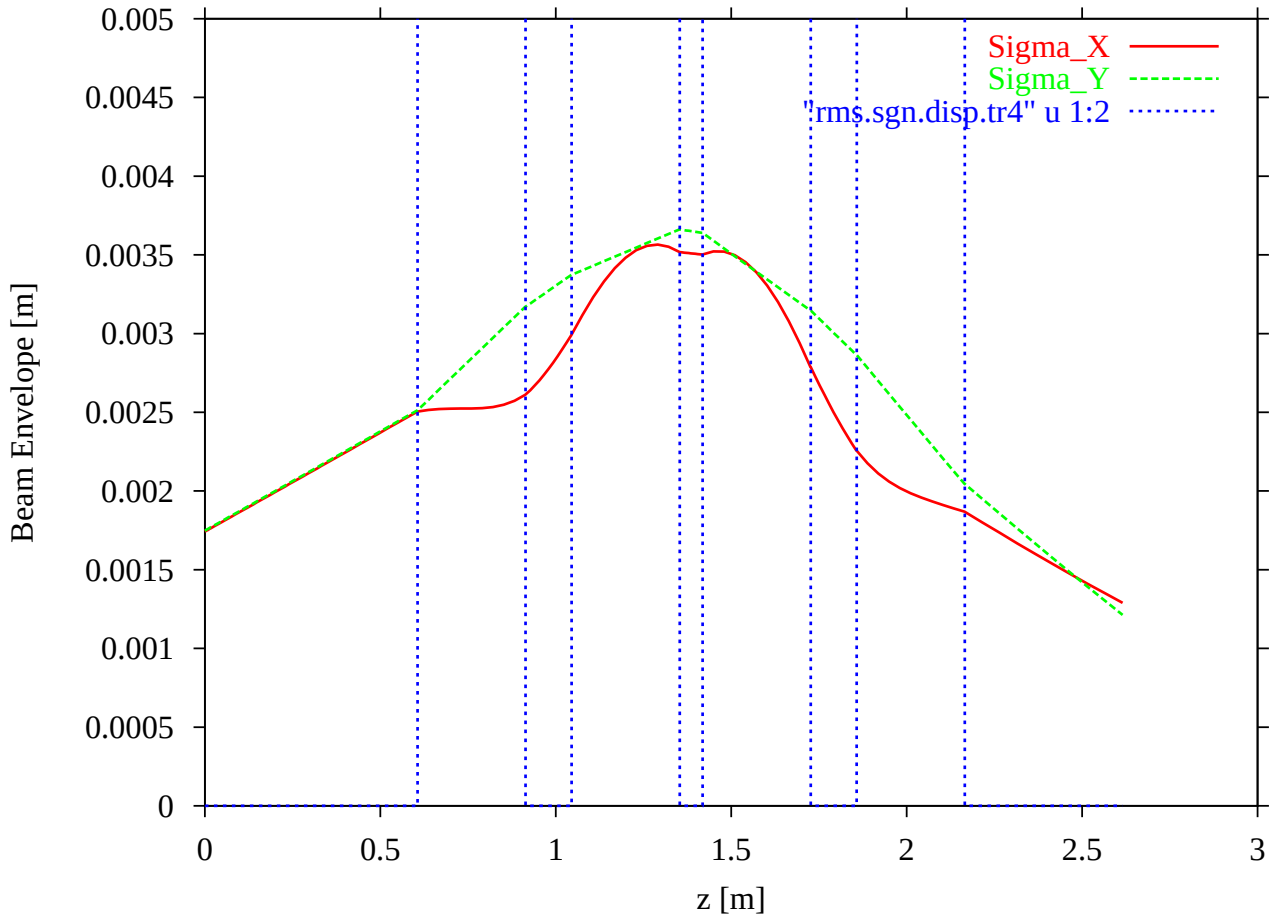


Impact of BC on $s - \delta$ space



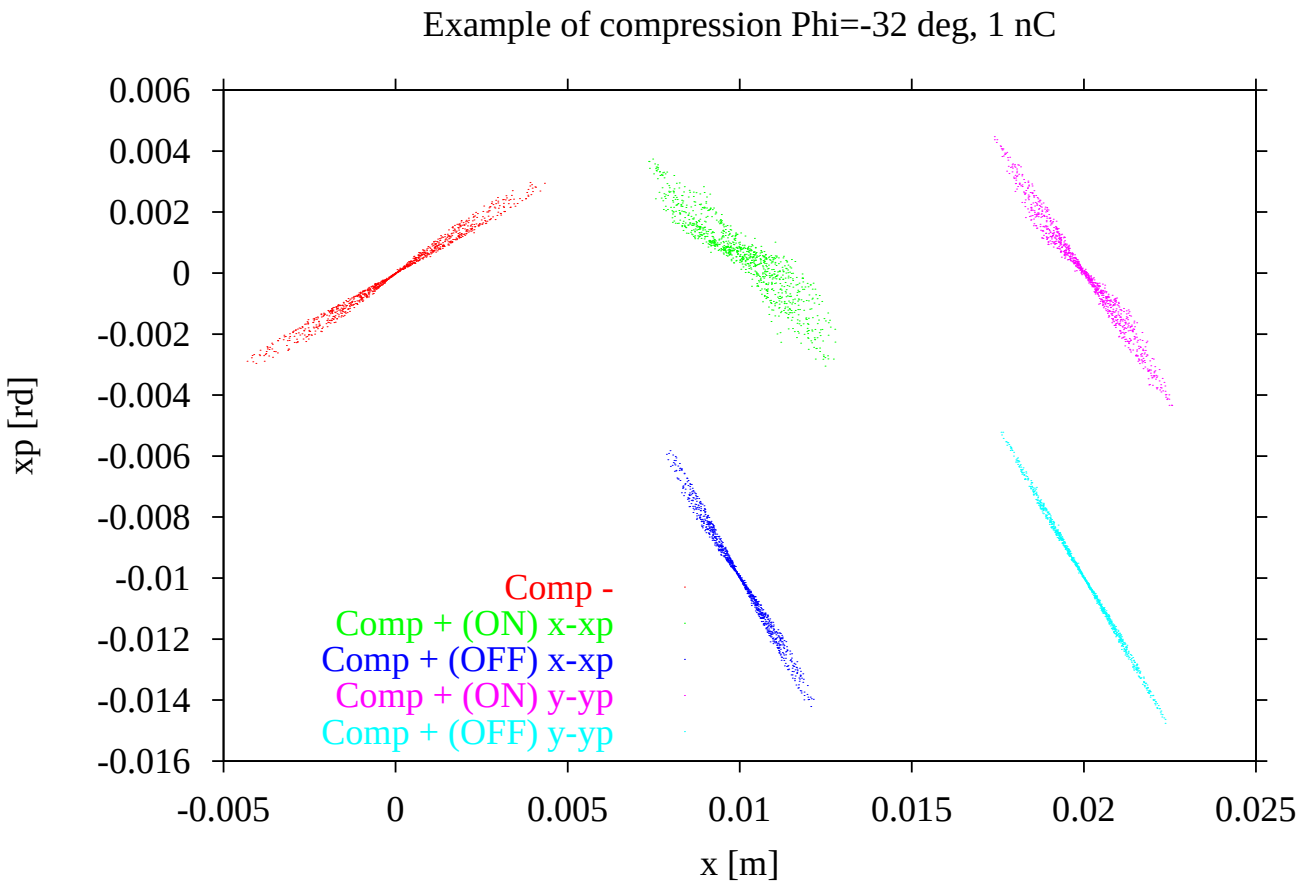
- energy loss
- energy profile strongly modified
- bunch profile unhanged

Beam envelope in the compressor



- upstream doublet is unexcited
- naively would expect $\Delta\tilde{\varepsilon}(z) \sim \beta(z)\langle x'^2\rangle^{1/2}$ so there might be some control of the compressor impact on the transverse phase space

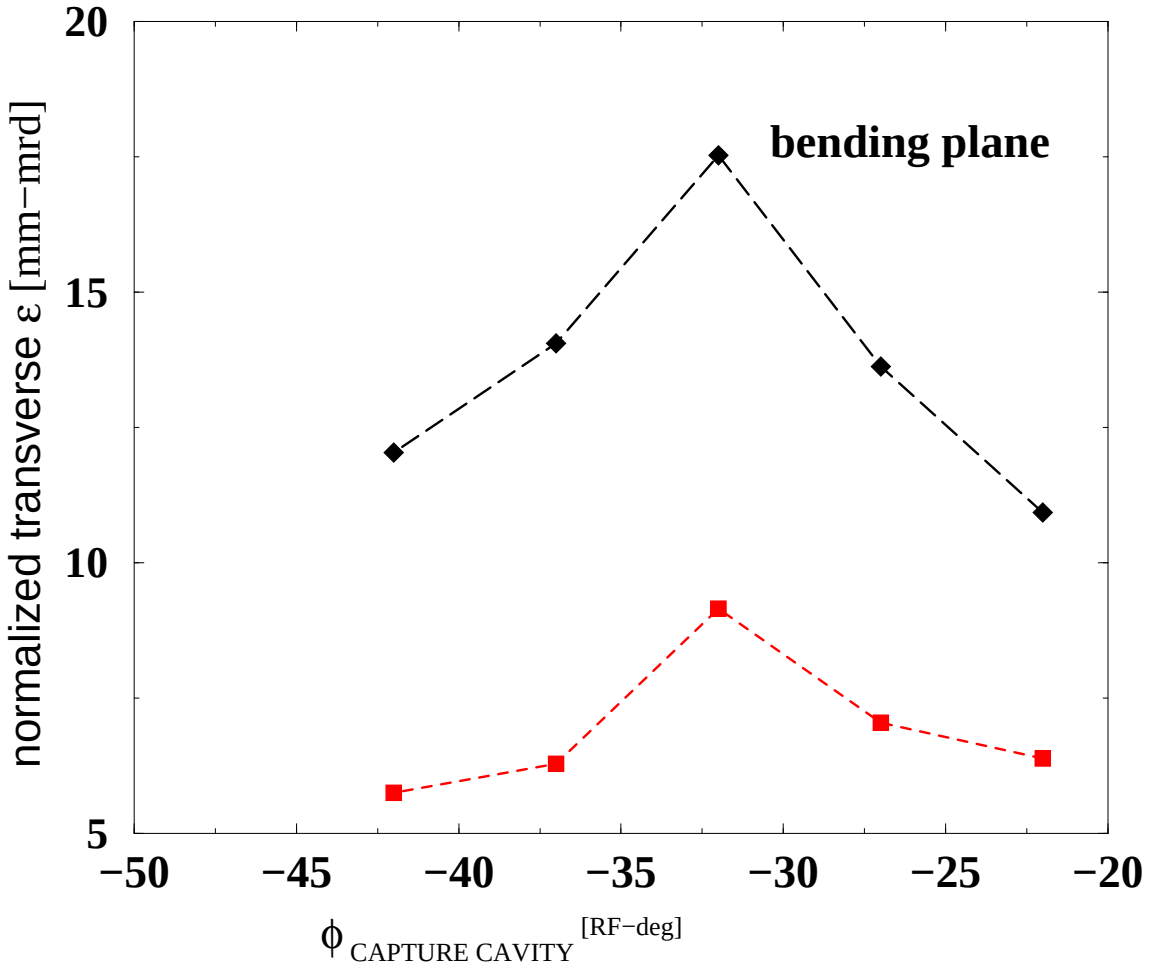
Example of Impact of BC on transverse space



Normalized emittance $\tilde{\varepsilon} = 1/\langle m_e c^2 \beta\gamma \rangle \times \sqrt{\langle x^2 \rangle \langle p_x^2 \rangle - \langle x p_x \rangle^2}$

- $\tilde{\varepsilon}_x$: 5.8339e-06 $\rightarrow$ 1.7529e-05 (200% growth)
- $\tilde{\varepsilon}_y$: 5.9137e-06 $\rightarrow$ 9.1631e-06 (55% growth)

Example of Impact of BC on transverse space (CNT'D)



Case of flat beam

Proposal (still need further work!)

Four independent experiment that can be performed in different time slots.

1. EXPERIMENT 1:
   - **purpose:** beam parameters dependence vs $\phi_{CAPTURE}$, for frozen bending angle.
   - **method:** vary $\phi_{CAPTURE}$, measure $\delta p/p$, ΔE, and $\tilde{\varepsilon}_{x,y}$. Iterate for different charges e.g. 0.25, 1.0, 4.0 nC. Monitor CSR power (and try to correlate). Do all of this for the *short* and *long* laser pulse.
2. EXPERIMENT 2:
   - **purpose:** beam parameters dependence vs bending angle.
   - **method:** vary chicane θ and each time set $\phi_{CAPTURE}$ so that maximum compression is achieved. Measure $\delta p/p$, ΔE, and $\tilde{\varepsilon}_{x,y}$. Iterate for different charges e.g. 0.25, 1.0, 4.0 nC. Monitor CSR power (and try to correlate). Do all of this for the *short* and *long* laser pulse.

3. EXPERIMENT 3:

   - **purpose:** emittance dependence vs incoming optics, for frozen bending angle and $\phi_{CAPTURE}$ (using one of the previous set-up).
   - **method:** measure $\tilde{\varepsilon}_{x,y}$ for different setting of the upstream doublet.

4. EXPERIMENT 4:

   - **purpose:** Impact of the spectrometer on the measurement.
   - **method:** Modify optics between compressor exit and spectrometer entrance. Measure $\delta p/p$, ΔE.

Instrumentation

(x $\stackrel{def}{=}$ bending plane of chicane)
(y $\stackrel{def}{=}$ bending plane of spectrometer so $y \rightarrow \delta$)

- **streak camera:** if possible located in the spectrometer line to directly have some information on the spaces $s - \delta$, $s - x$ [see "nice stuff" from Uesaka et al. NIM A406 p.371-379 (1998)]
- **energy spread:** measurement of $x - \delta \rightarrow$ energy profile, but maybe some info on the correlation between x and δ
- **polychromator device:** Do single shot measurement of CSR bunch spectrum.
- **multislit masks:** perform single shot emittance measurement spectrum.