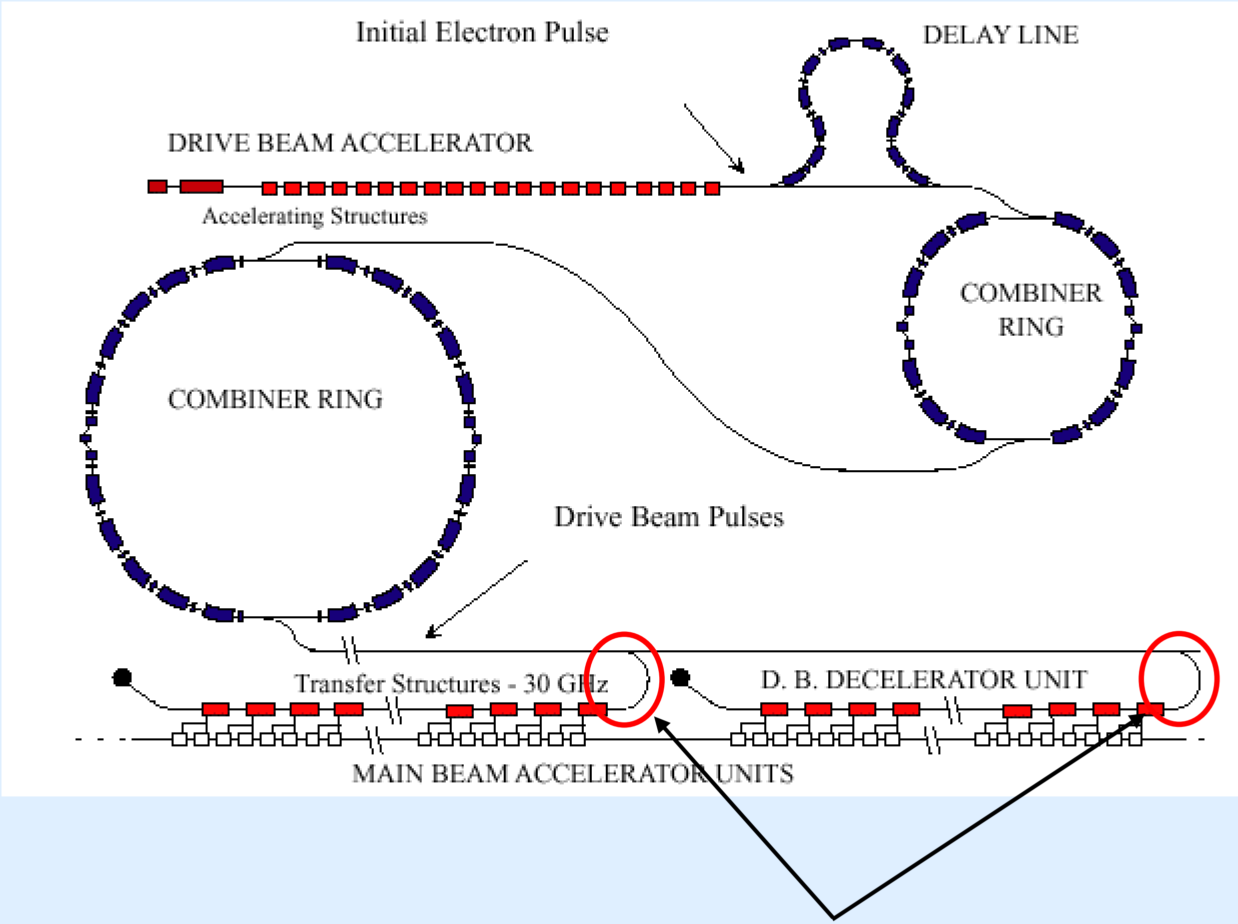
Turn Around Loop, Phase Correction and final Bunch Compression for the CLIC Drive Beam

- Introduction
- Beam Dynamics and Performance of the individual Sections
- Overview of the full Beam Line
- Summary and Outlook

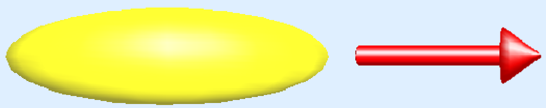
Drive Beam BC, Turn Around and Phase Feed-Forward



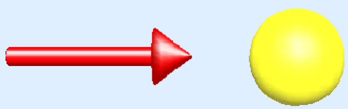
Bunch Compressor, Turn Around Loop and Phase Feed-Forward

Drive Beam BC, Turn Around and Phase Feed-Forward

$$
\begin{aligned}
E_0 &= 2\ \mathrm{GeV} \\
Q_0 &= 10\ \mathrm{nC} \\
\sigma_{\mathrm{s,i}} &= 4\ \mathrm{mm} \\
\varepsilon_{\mathrm{n,x}} &= 100\ \mathrm{mm\ mrad} \\
\varepsilon_{\mathrm{n,y}} &= 100\ \mathrm{mm\ mrad} \\
\frac{\sigma_{\mathrm{E,unc}}}{E_0} &= 2.5 \cdot 10^{-4} \\
\frac{1}{E_0}\frac{dE}{ds} &= -2.5\ \mathrm{m}^{-1} \\
\Rightarrow \frac{\sigma_{\mathrm{E,tot}}}{E_0} &= 1\%
\end{aligned}
$$

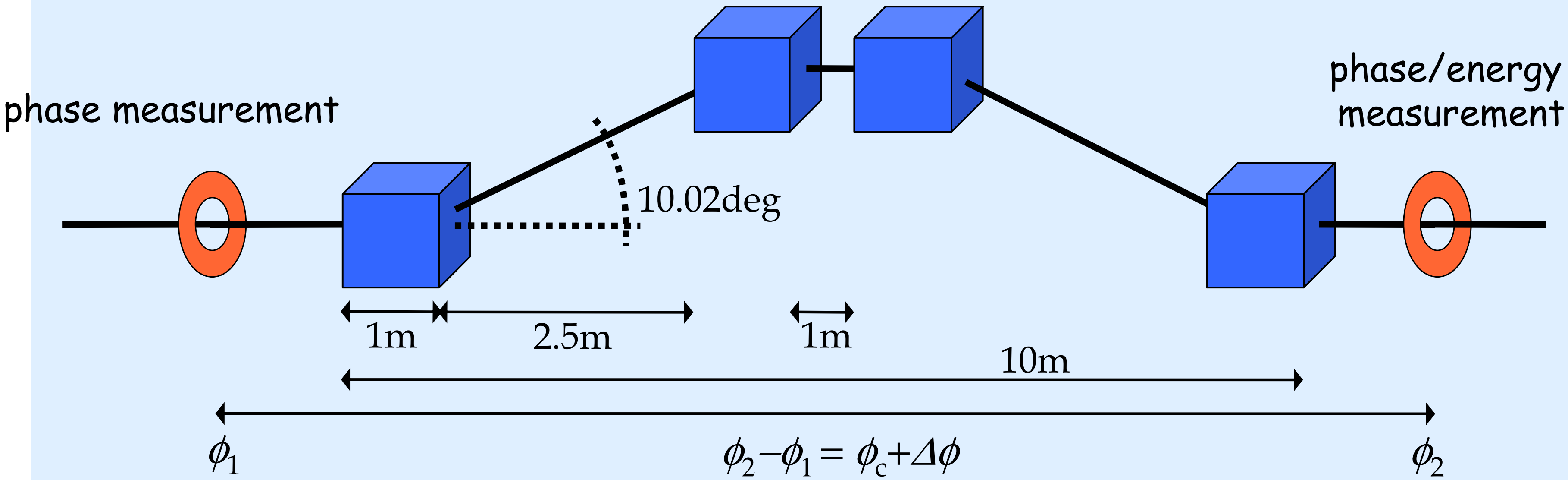


1) first phase-measurement
2) non-isochronous beam line to get a phase error proportional to an energy error
3) second phase measurement to estimate the energy error
4) turn around loop to direct the drive beam into the decelerator
5) bunch compressor chicane
6) phase correction



$$
\begin{aligned}
\sigma_{\mathrm{s,i}} &= 0.4\ \mathrm{mm} \\
\frac{\sigma_{\mathrm{E,tot}}}{E_0} &\le 1\% \\
\varepsilon_{\mathrm{n,x}} &< 110\ \mathrm{mm\ mrad} \\
\varepsilon_{\mathrm{n,y}} &< 110\ \mathrm{mm\ mrad}
\end{aligned}
$$

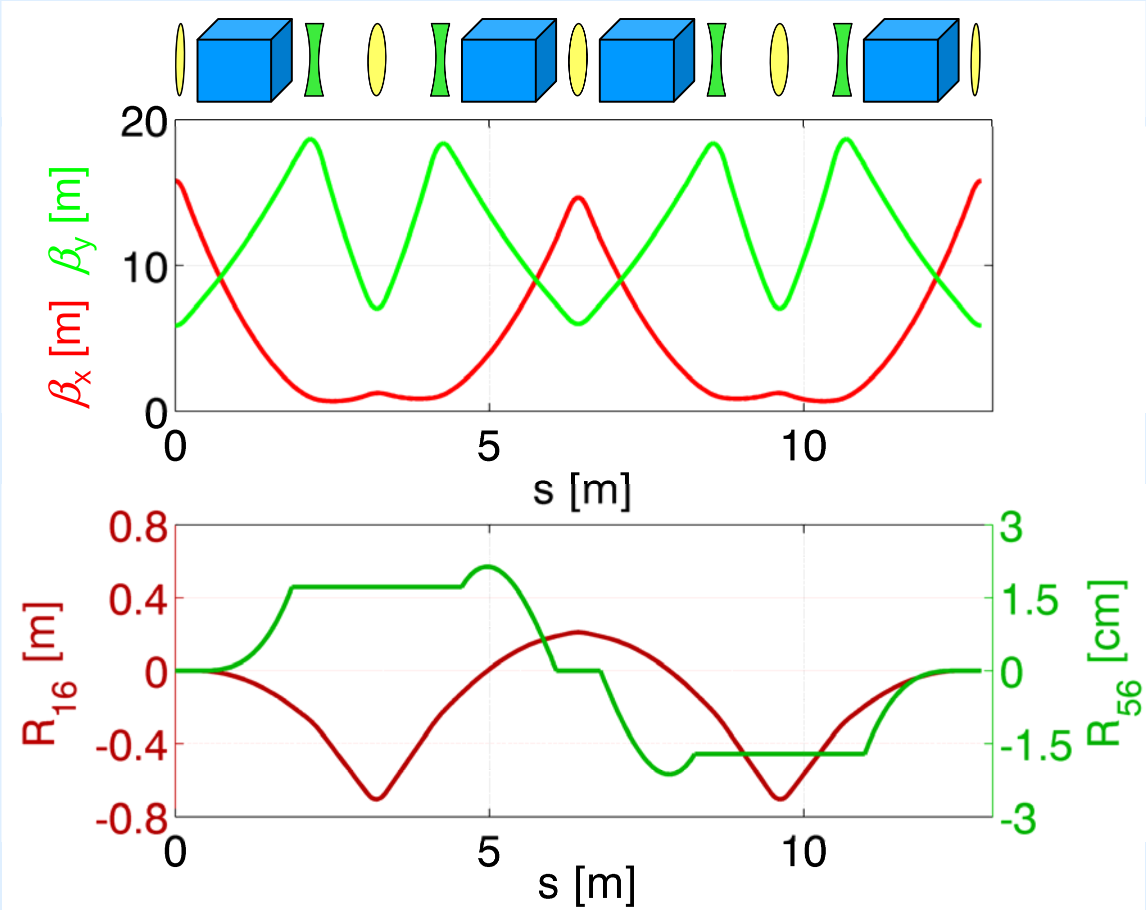
Phase and Energy Measurement



- momentum compaction factor of the chicane: $R_{56} = -0.2$ m
- final bunch length: $\sigma_{s,f} = 2$ mm
- CSR emittance growth: $\Delta\varepsilon_{n,x} < 1$ mm mrad

- energy error $dE/E = 10^{-5}$ => phase error $\Delta\phi = 0.072$deg (30 GHz)

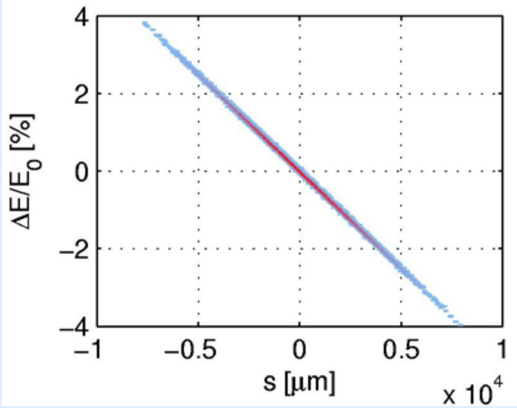
Turn Around Loop, single arc

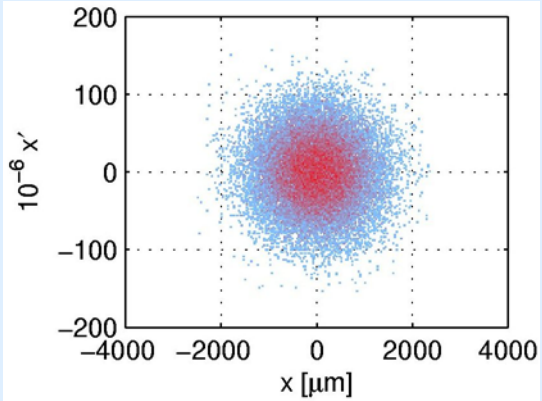


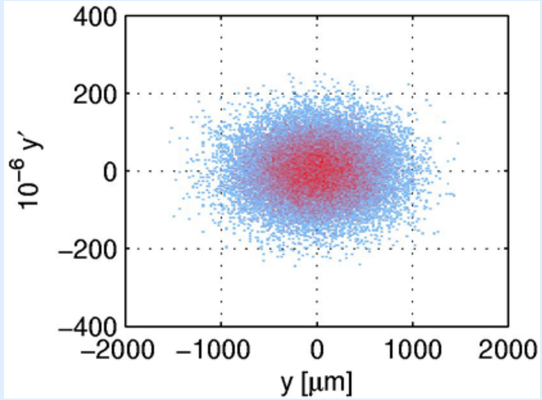
- bend angle per dipole: $\theta = 15$ deg => 60 deg per arc
- each arc is achromatic and isochronous
- CSR emittance growth per arc (5 arcs required!):

$$\Delta\varepsilon = 1\text{–}2 \text{ mm mrad}$$

Turn Around Loop, single arc







$\varepsilon_{x,ini}$ = 100 mm mrad

$\varepsilon_{y,ini}$ = 100 mm mrad

initial

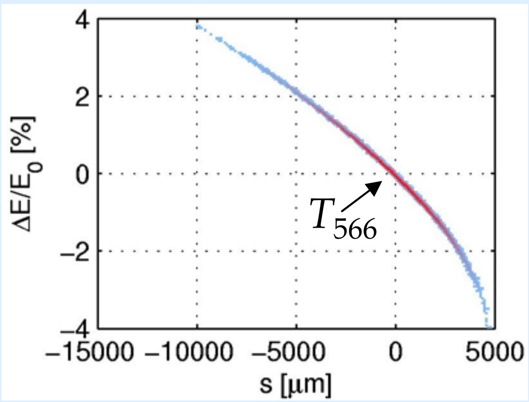
final

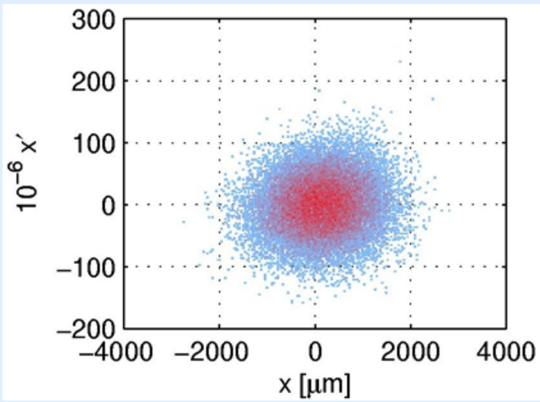
CSR + chromaticity

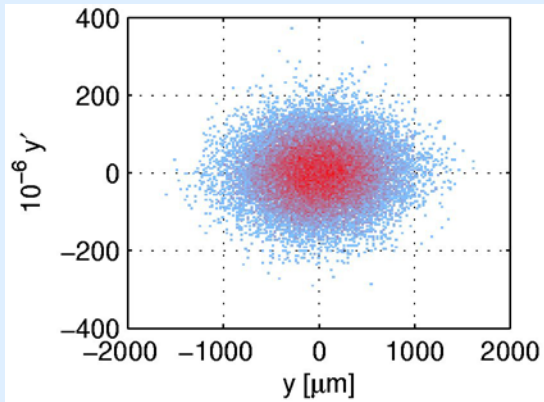
$\varepsilon_{x,final}$ = 104 mm mrad

chromaticity

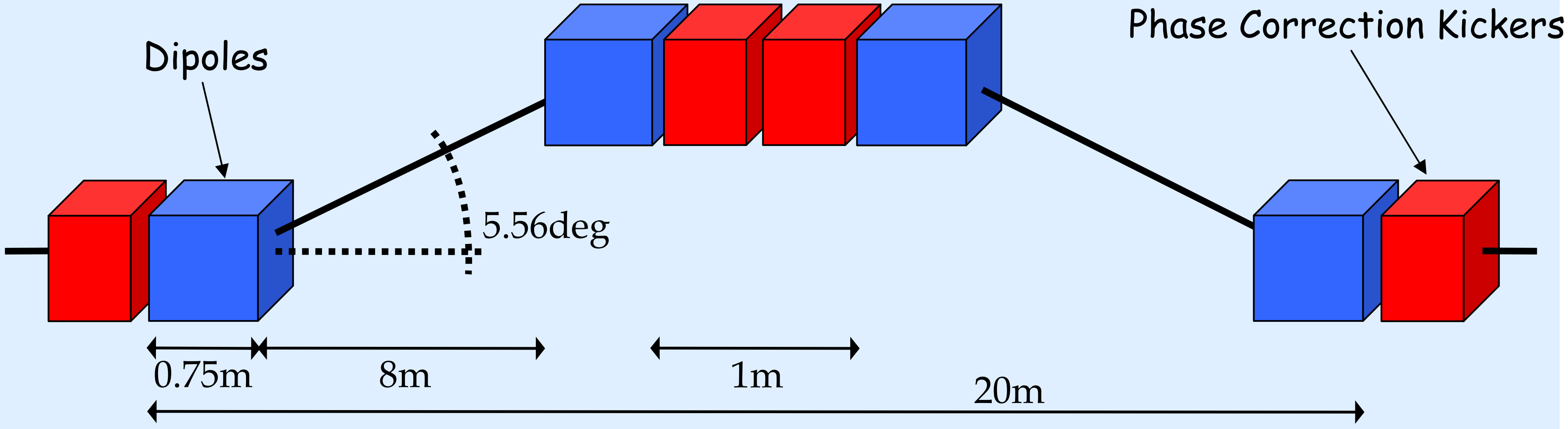
$\varepsilon_{y,final}$ = 103 mm mrad







Final Bunch Compressor and Phase Correction

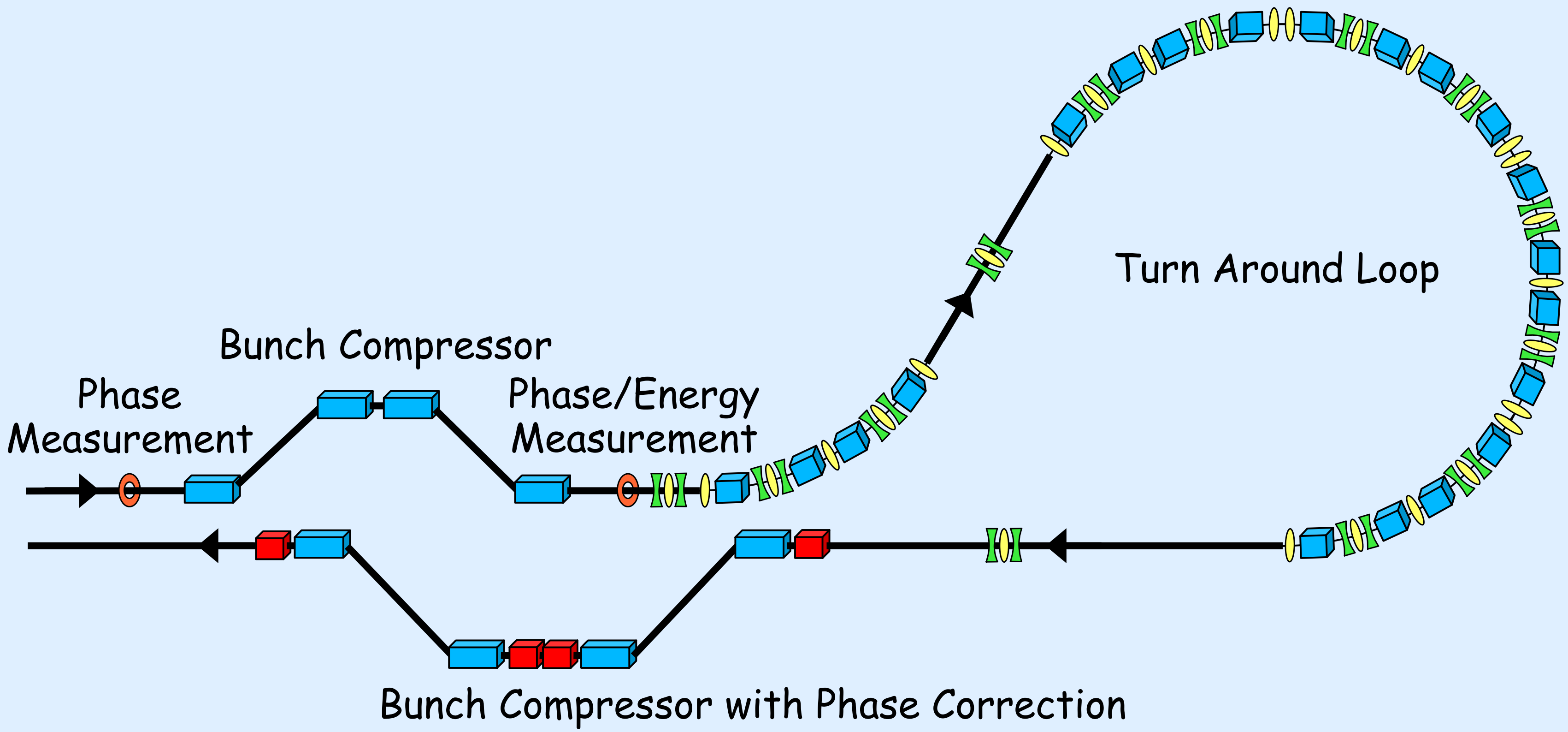


- momentum compaction factor of the chicane: $R_{56} = -0.16$ m
- final bunch length: $\sigma_{s,f} = 0.4$ mm
- CSR emittance growth: $\Delta\varepsilon_{n,x} \approx 3$ mm mrad

- path length tunability: $\Delta l = \pm 100$ µm

  => phase tunability: $\Delta\phi = \pm 3.6$ deg
- required kicker strength: $\theta_{kick} = \pm 60$ µrad
- induced bunch length jitter: $\Delta\sigma_s = \pm 2$ µm

Beam Line Overview



Summary

- To achieve the required drive beam phase stability a phase feed-forward is included in the beam line in front of the decelerator.
- Phase and energy jitter are measured in front of the turn around loop by two phase measurements intersected by a bunch compressor chicane.
- The turn around loop is achromatic and isochronous. Its total length is 76 m <=> 250 ns.
- The phase correction is included in the final bunch compressor chicane behind the turn around loop. The kicker strength required for $\Delta l = \pm 100\ \mu\mathrm{m}$ is $\theta_{\mathrm{kick}} = \pm 60\ \mu\mathrm{rad}$.
- CSR emittance growth in the bunch compressors and the turn around loop is just within the specification of $\Delta\varepsilon_{\max} = 10$ mm mrad.
- Chromaticity in loop is too strong.

Chicanes seem to be o.k.,
but Loop has to be improved!

Outlook

Improve lattice of Turn Around Loop

- reduce chromaticity
- reduce CSR
- reduce T_{566} (if possible...)

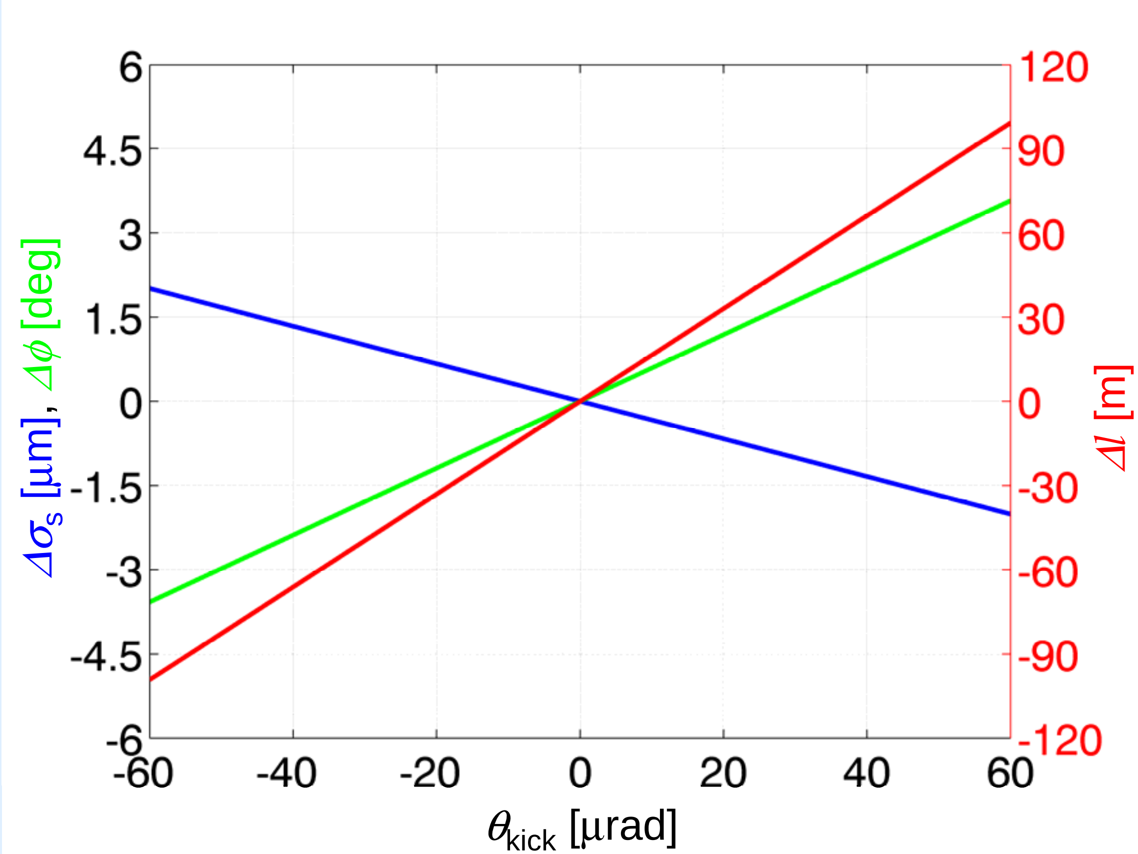
Perform more sophisticated beam dynamics simulations

- use a more realistic charge distribution (incl. RF curvature, non Gaussian profile,...)
- add resistive wall wakes and shielding
- 2D and 3D CSR simulations

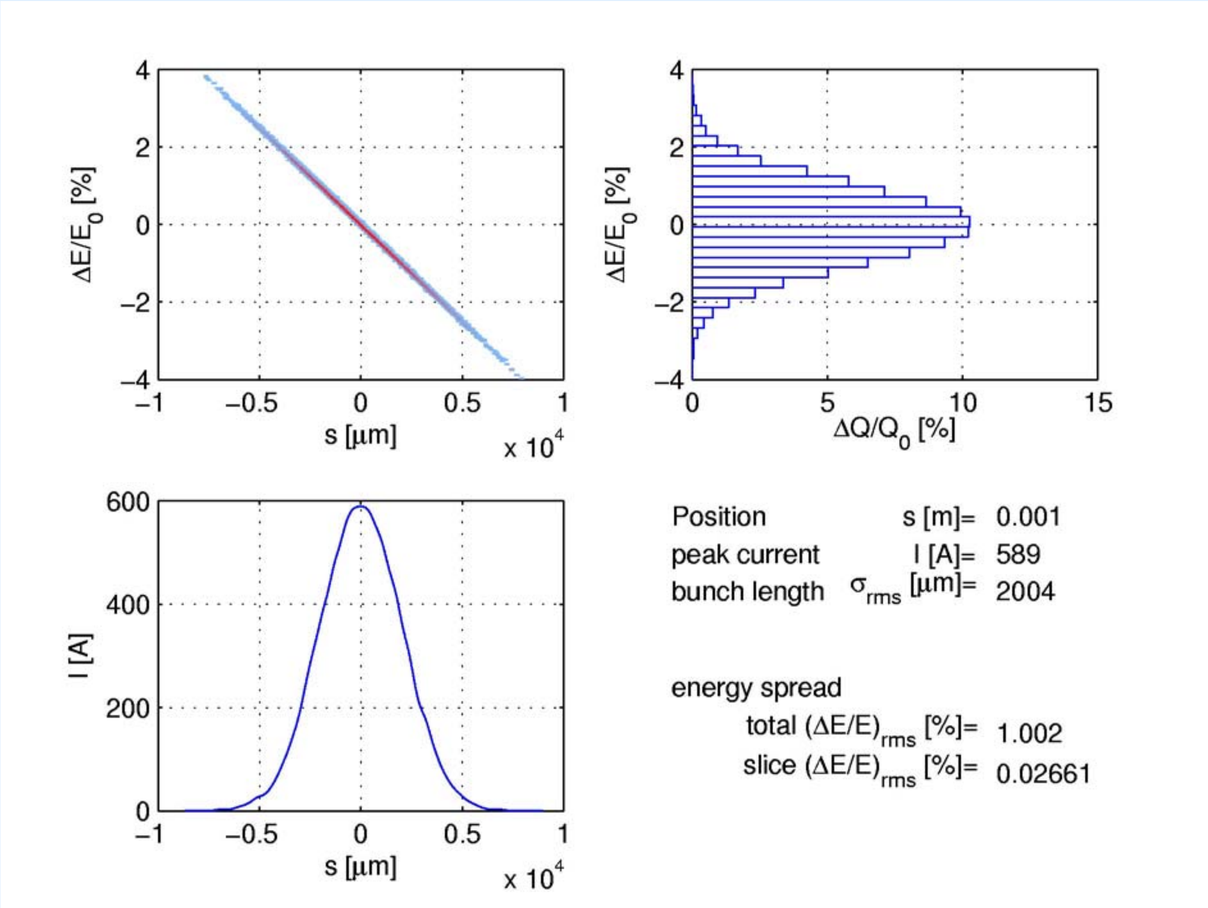
Study flexibility and error tolerances

- change initial bunch length, energy spread (correlated and uncorrelated), change R_{56} of both chicanes
- add jitter of magnet position, roll, tilt and strength
- add RF amplitude and phase jitter

Phase Correction

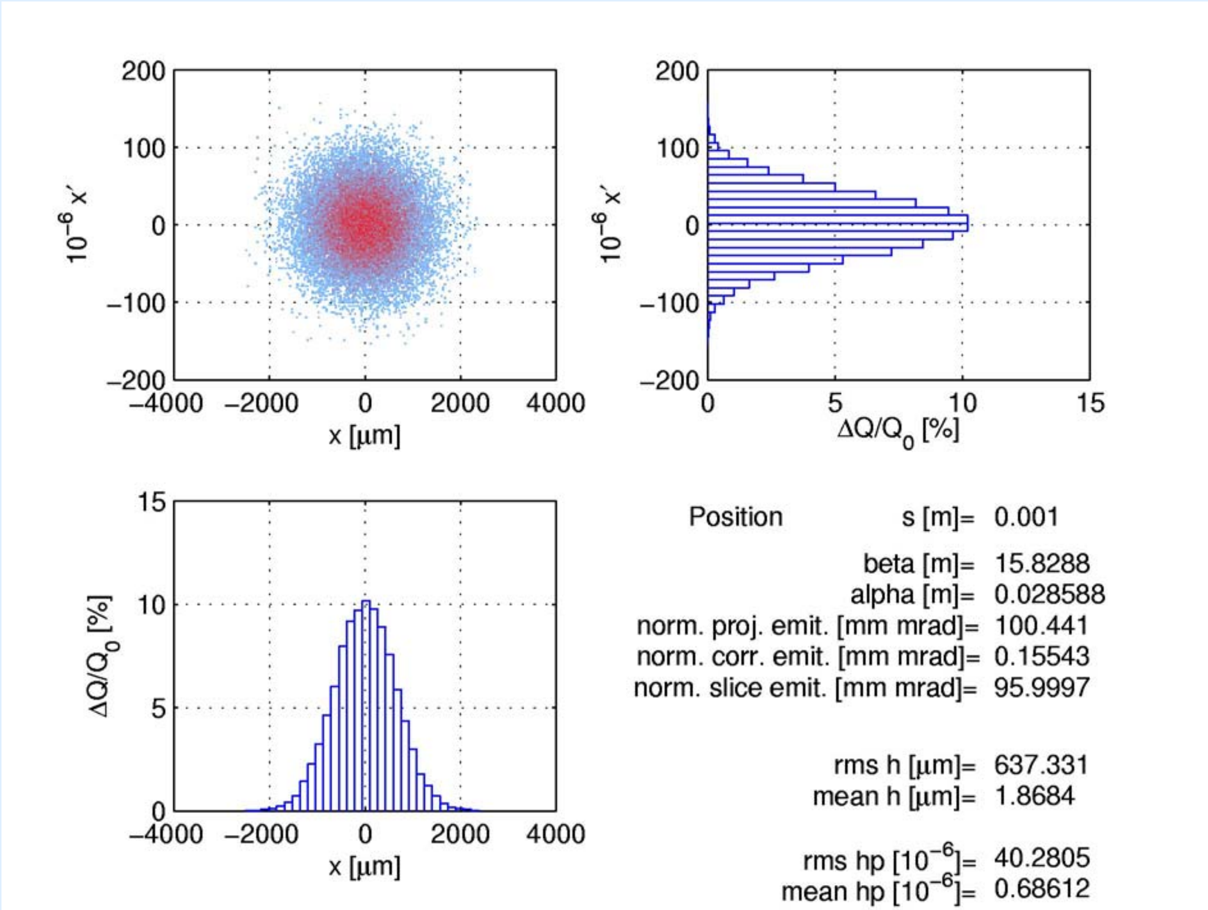


Turn Around Loop, single arc



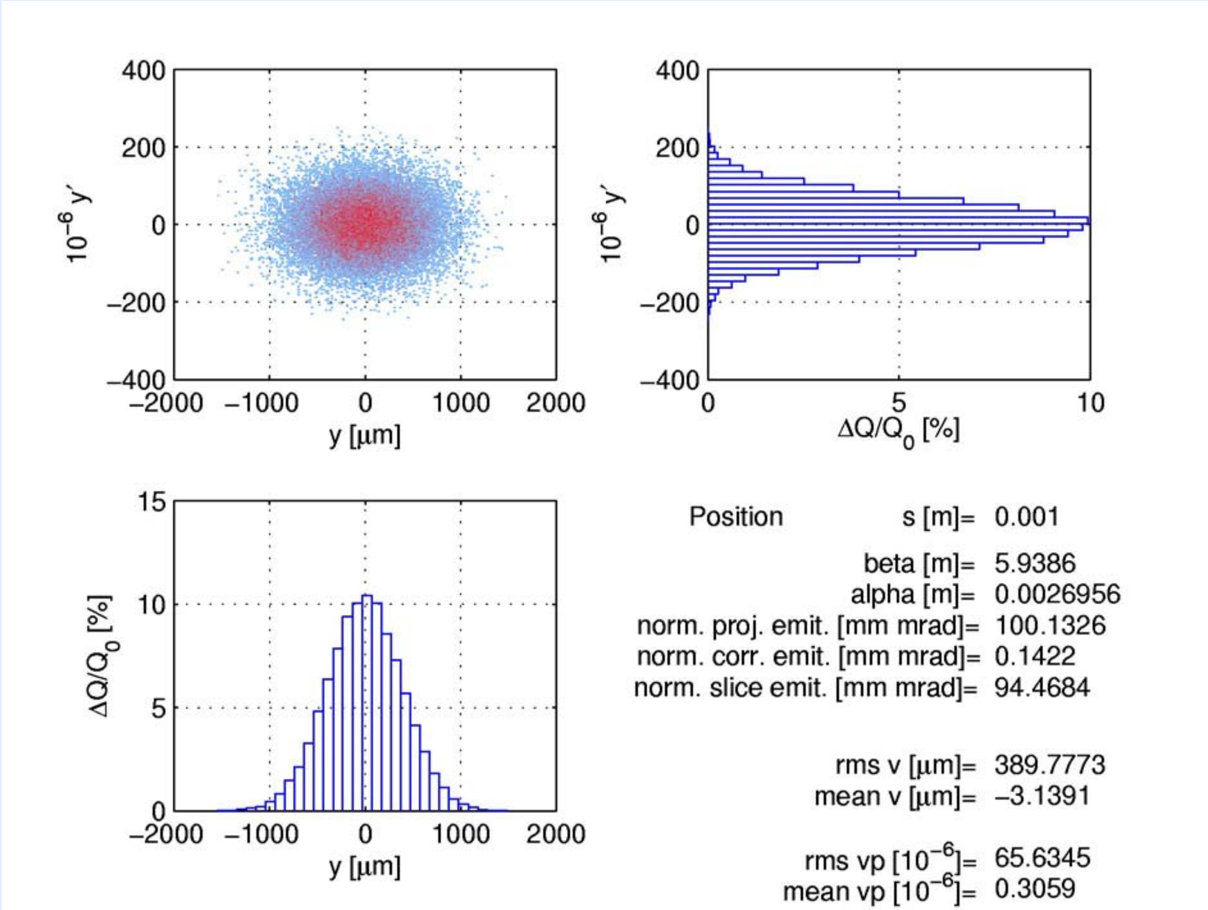
initial longitudinal phase space distribution

Turn Around Loop, single arc



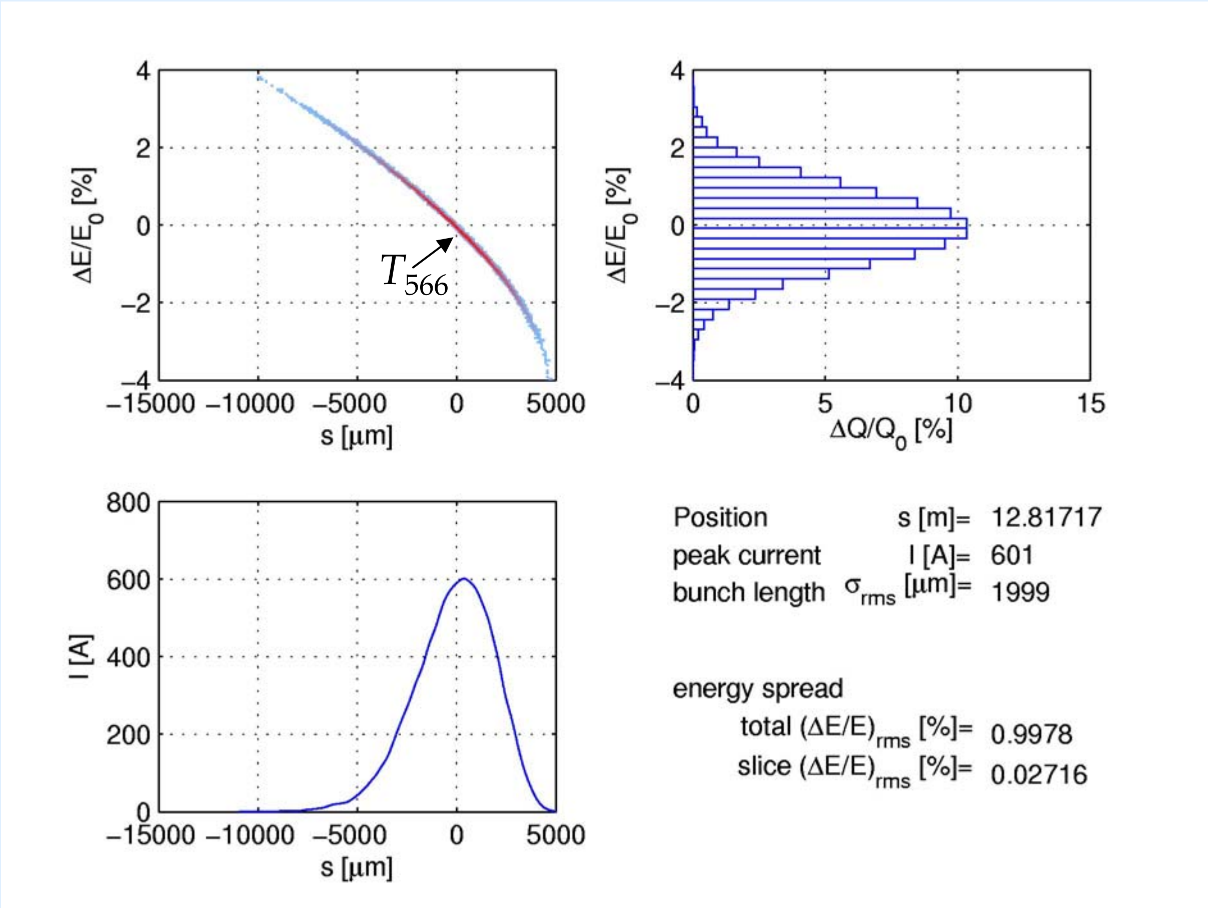
initial horizontal phase space distribution

Turn Around Loop, single arc



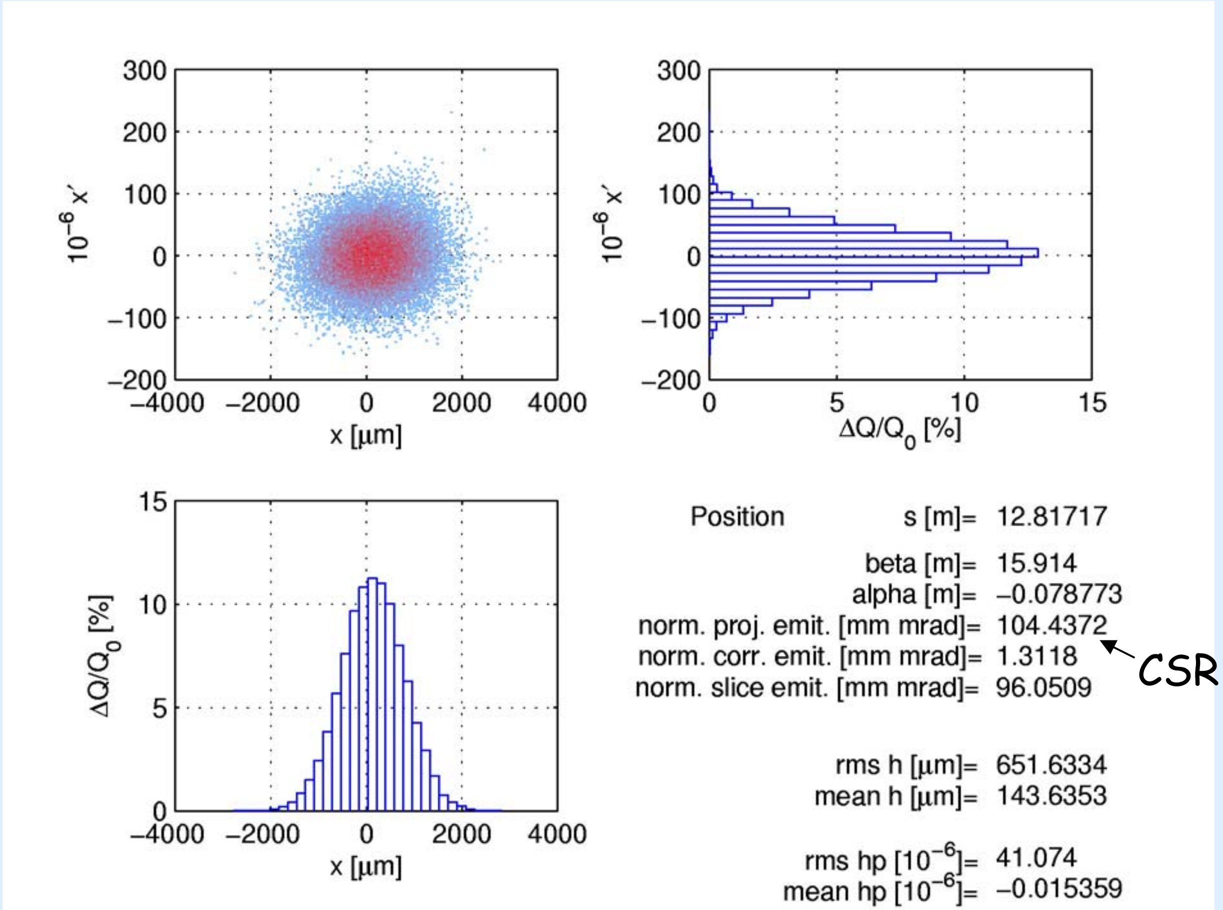
initial vertical phase space distribution

Turn Around Loop, single arc



final longitudinal phase space distribution

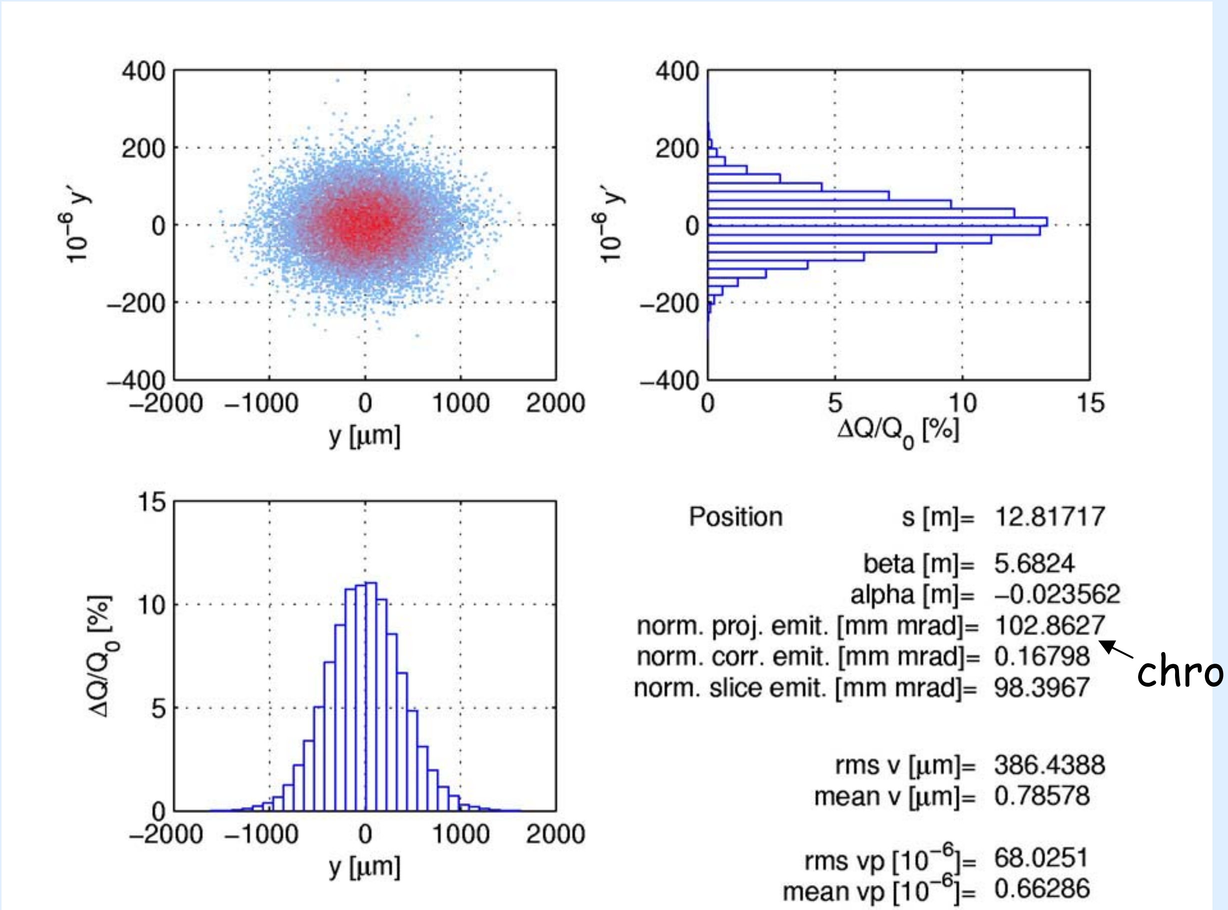
Turn Around Loop, single arc



CSR + chromaticity

final horizontal phase space distribution

Turn Around Loop, single arc



chromaticity

final vertical phase space distribution