Demo study updates: longitudinal emittance using timing planes

In progress

(More) systematic study of longitudinal emittance measurement

- Goal: understand the sensitivity on the z-velocity distribution variations via timing planes

- Simplified setup:

  o Beam: initial parameters from 2025 beam

  o 4 m long solenoid, 1.9 T max on-axis field, radius 25 cm (transmittance >97%)

  o N scoring planes in the field uniformity region (B > 0.95 Bmax, ~3 m)

- Method:

  o Simulate the beam transport, changing the σ(pz) in steps, from 1x initial to 0.5x initial

  o Measure the spread of βz

  o Testing: [6, 10] planes, [10^4, 10^5, 10^6] muons/bunch, [10, 20, 50] ps time resolution

- Procedure:

  o Time-of-arrival (TOA) spread VS z coordinate: $$\sigma(t) = \sqrt{\sigma_{t_0}^2 + z^2 \langle \frac{1}{v_z} \rangle^2 \sigma_{v_z}^2}$$

  o Extract $\langle 1/v_z \rangle$ from the time of flight, fit the above formula VS z and compute the velocity spread

Fitting the TOF and the TOA spread

- Example of TOA spectra for 10^5 muons and 20 ps resolution, at three z planes
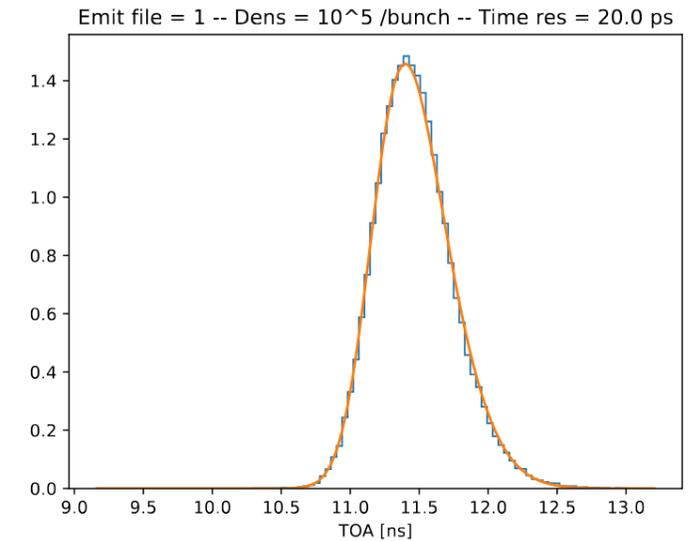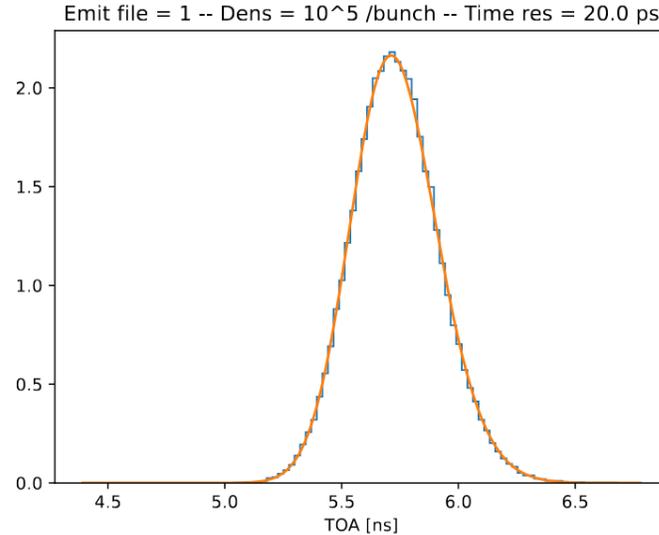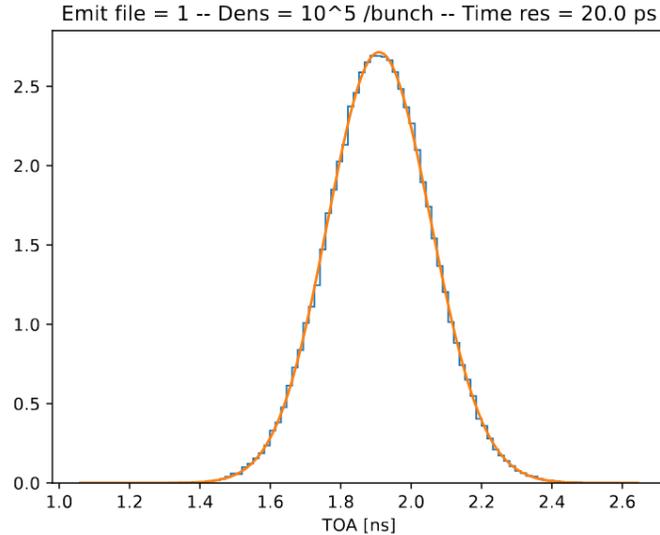
- Gets wider and more "skewed" for increasing z → try a skewed gaussian (unbinned) fit
- Not actually a skewed gaussian, but a convolution of the gaussian t distribution of the bunch and the z/v distribution of time of flight (v is ~ gaussian)
- The skewed gaussian fit is a good model, but the large covariance between σ and α (skew param.) causes large(r) uncertainties and a less reliable σ measurement
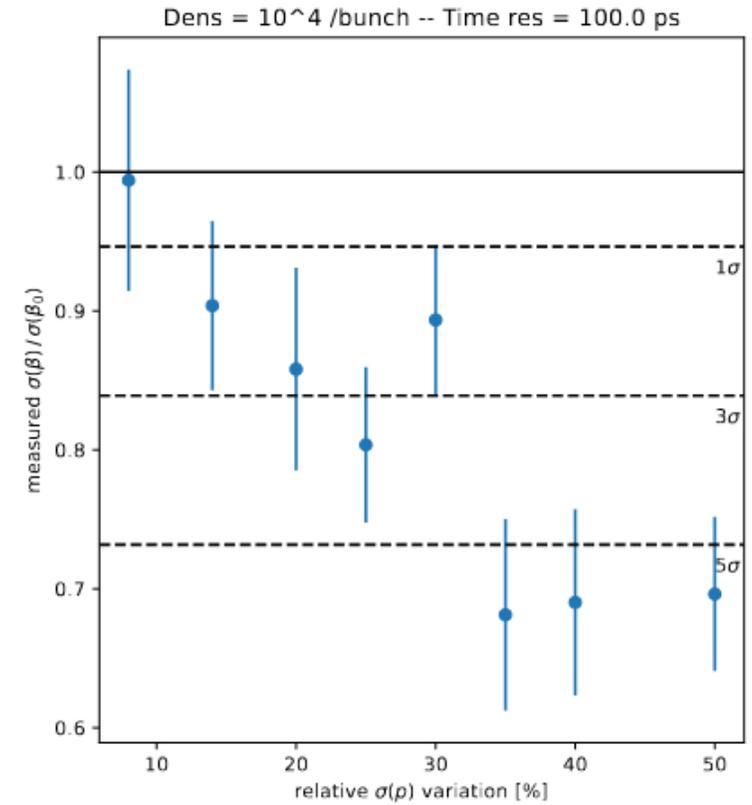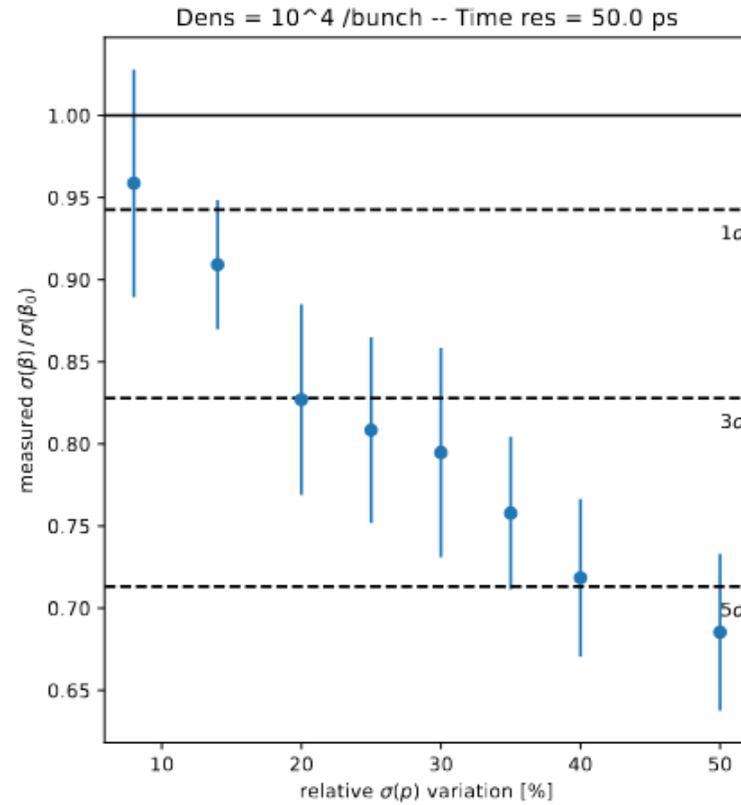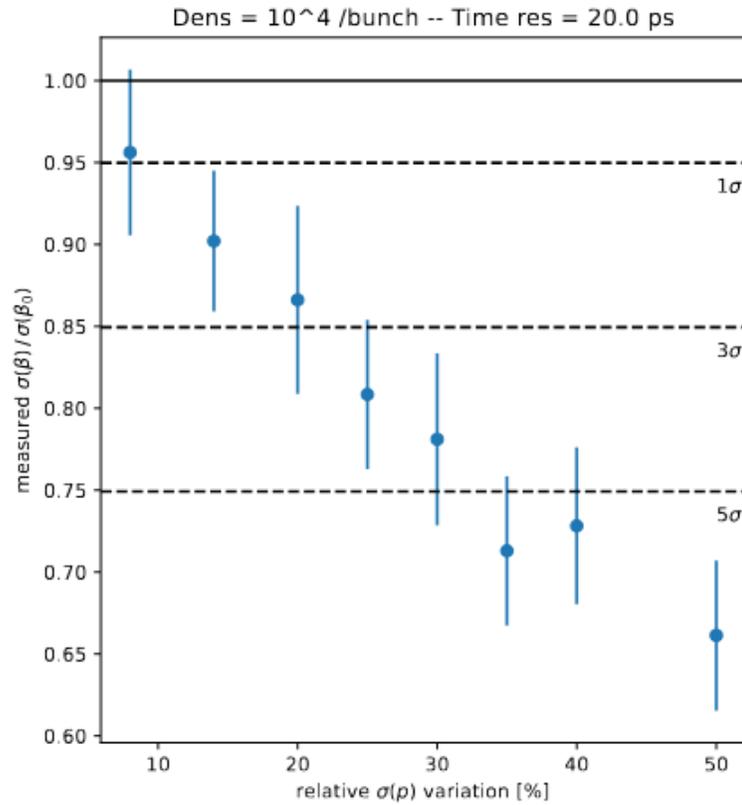- Try also other models (?)

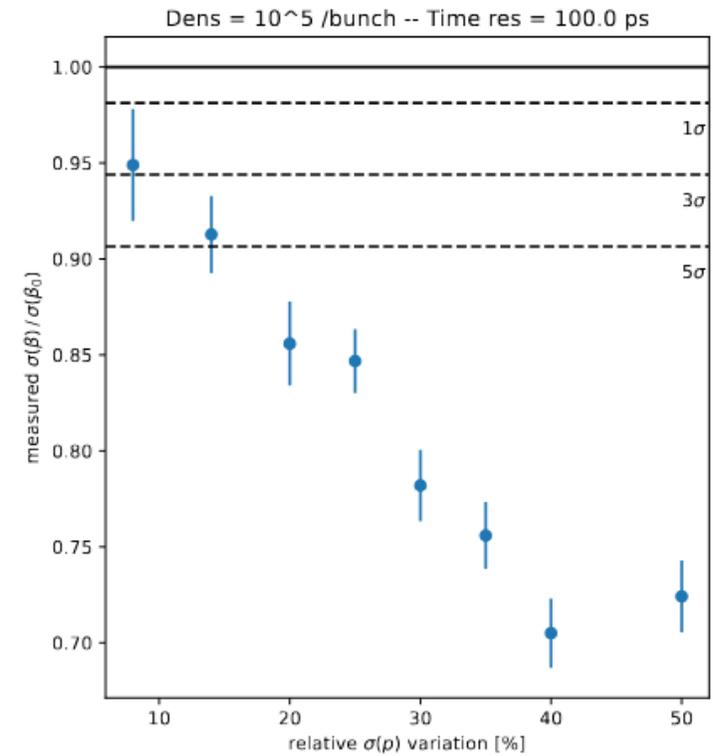# Fitting the TOF and the TOA spread (2)

- Example using simple stat, 6 planes
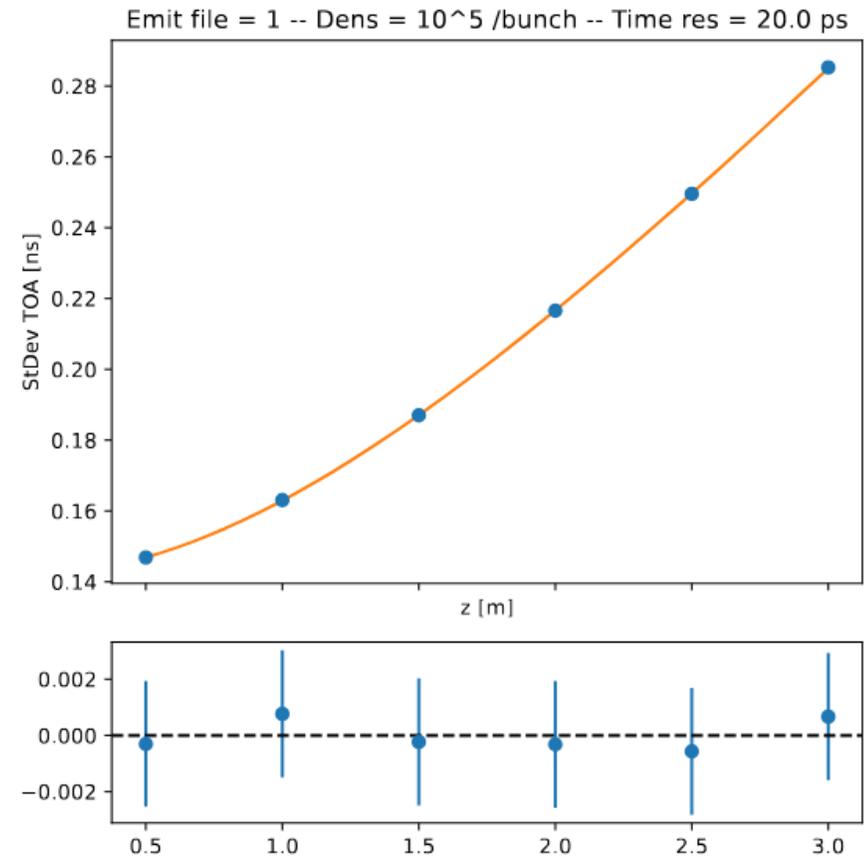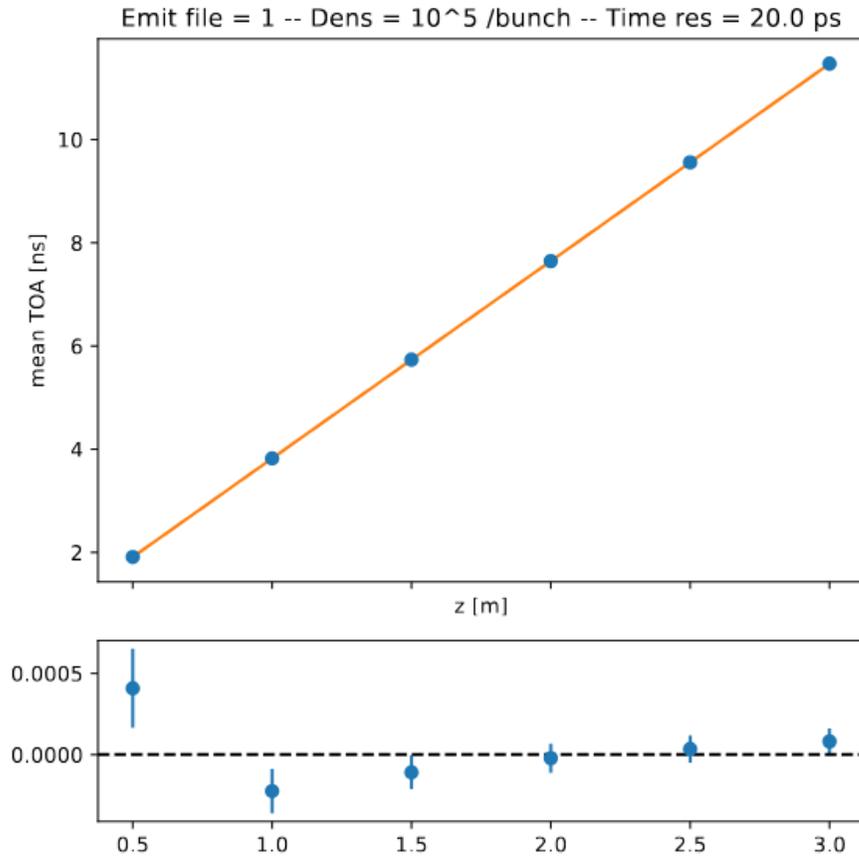
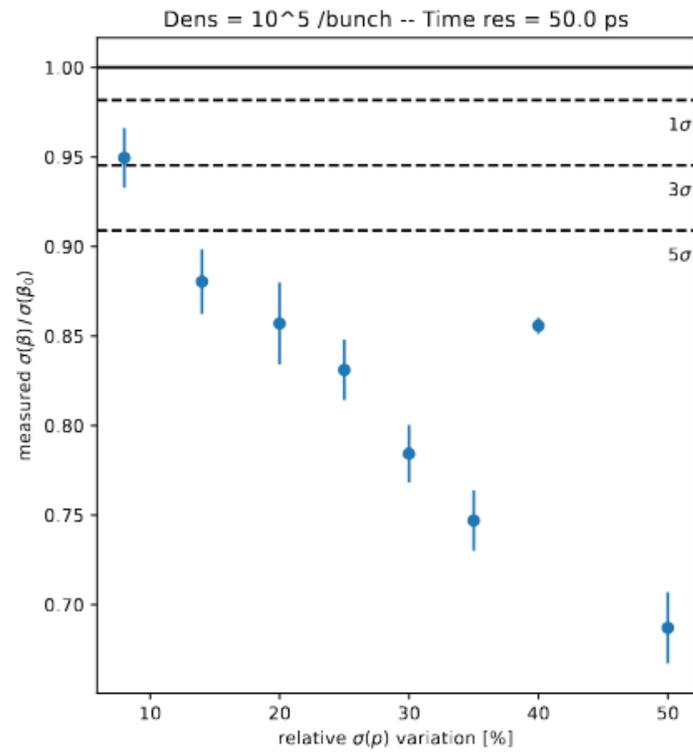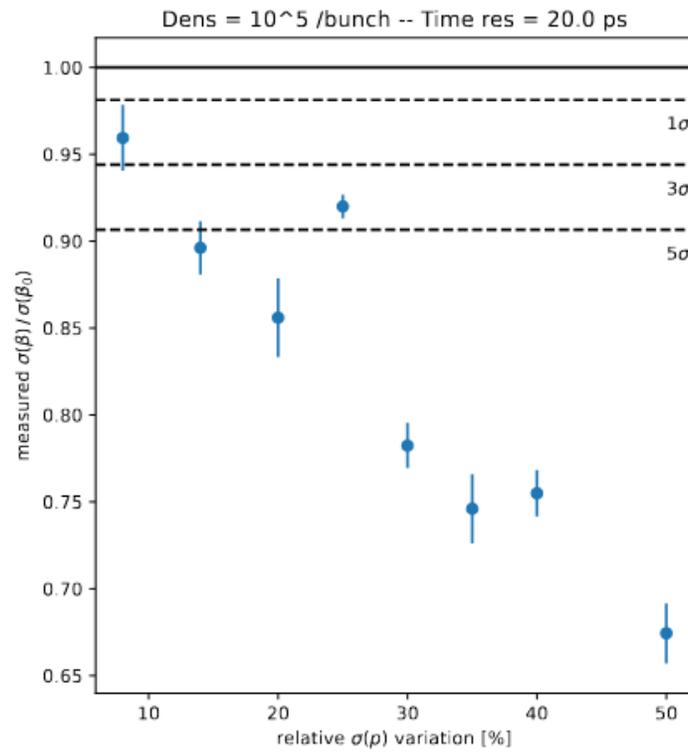# Preliminary plots

- 6 planes, 10^4 μ/bunch

Preliminary plots

- 6 planes, 10^5 μ/bunch

Preliminary plots

- 6 planes, 10^6/bunch (in progress)

Preliminary plots

- 10 planes, 10^4/bunch

Preliminary plots

- 10 planes, 10^5/bunch
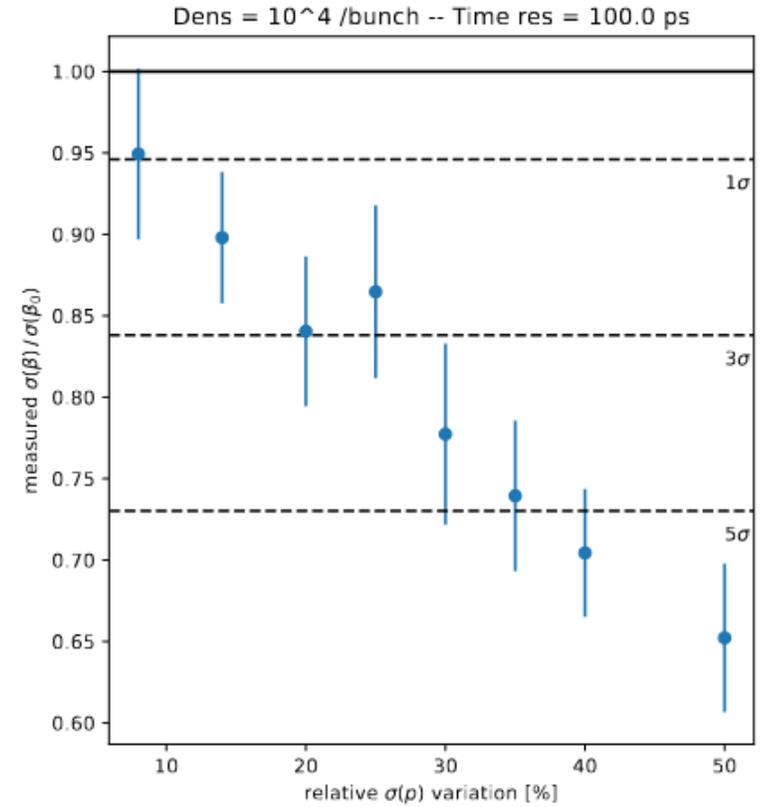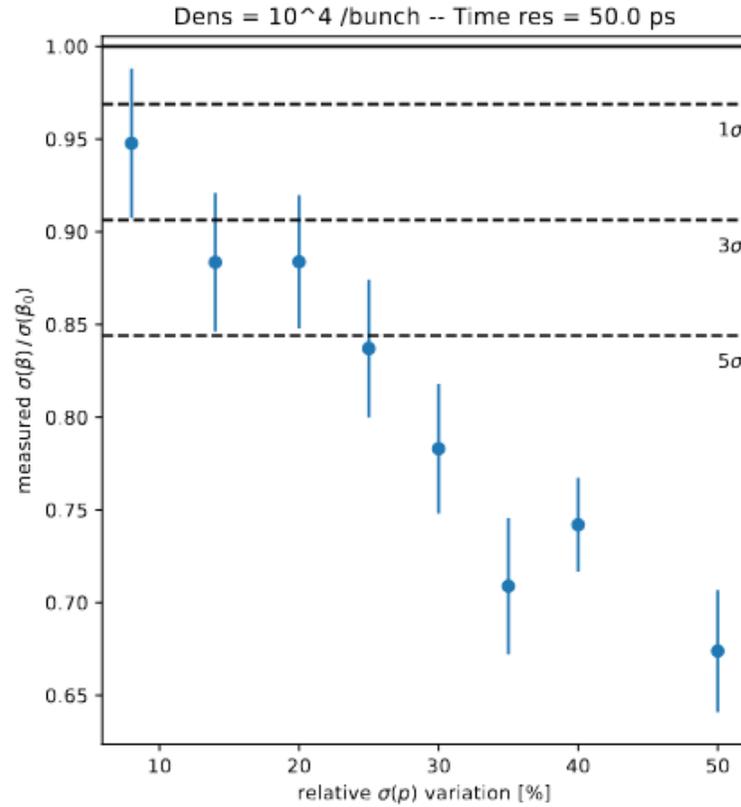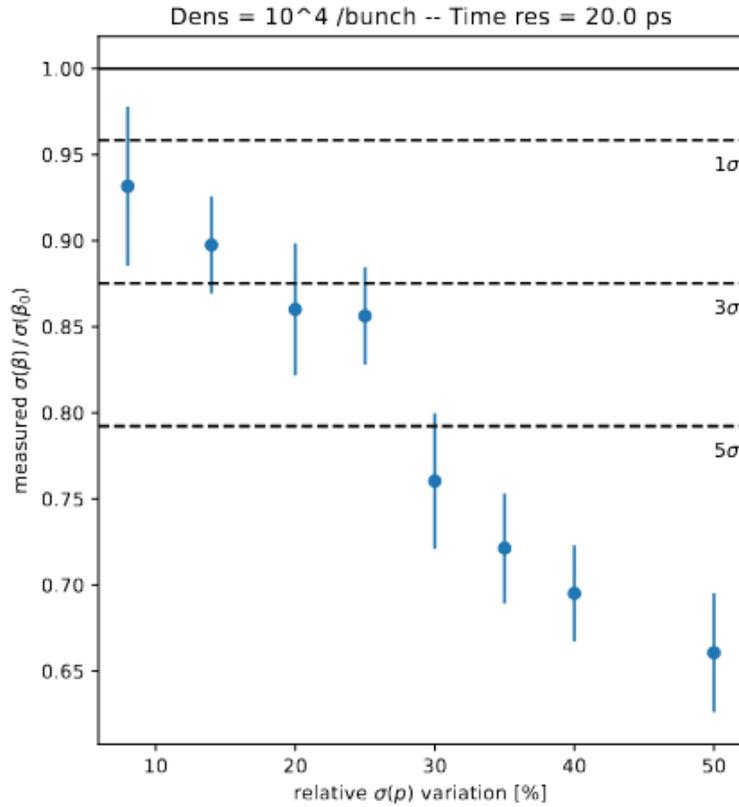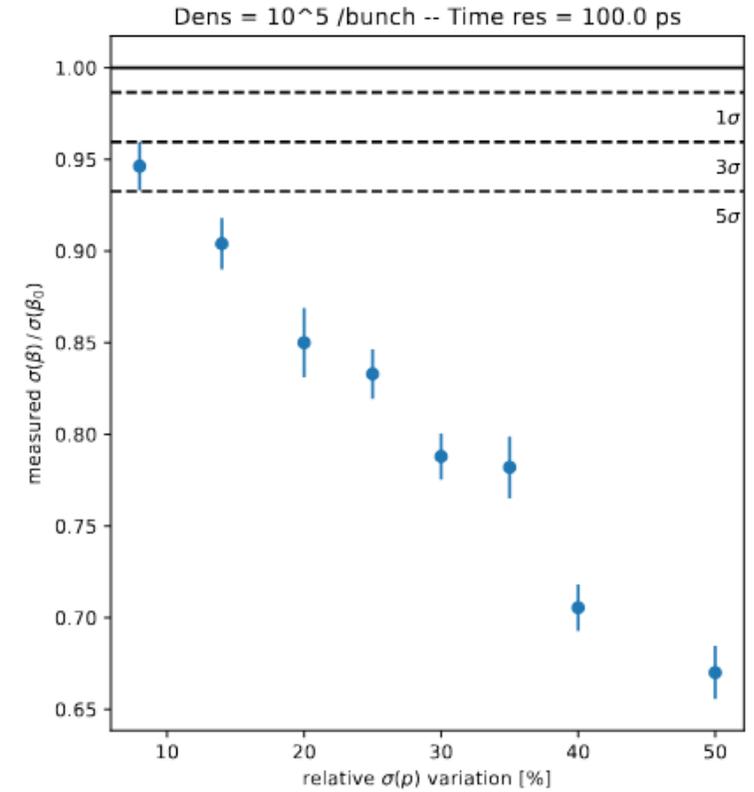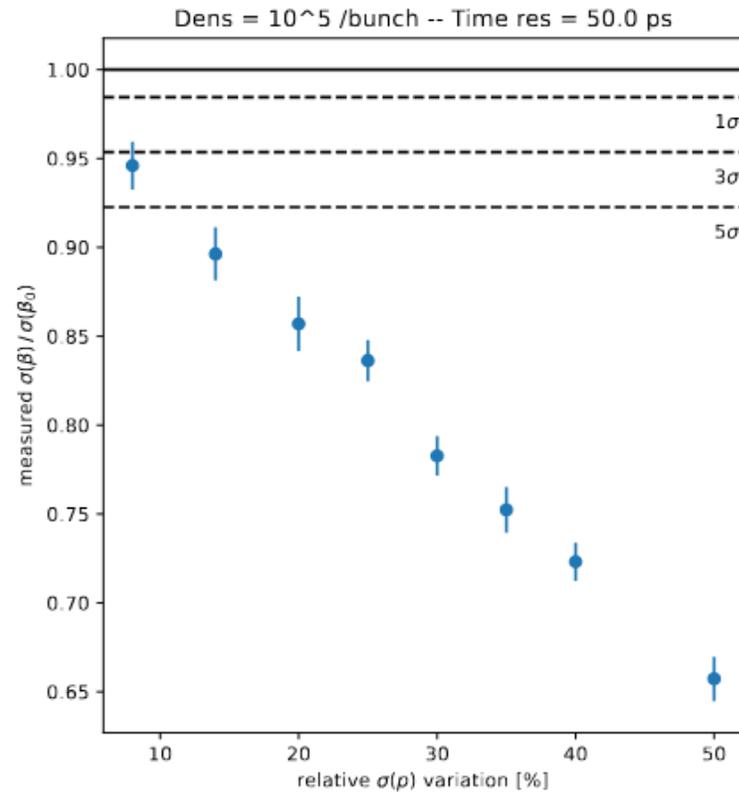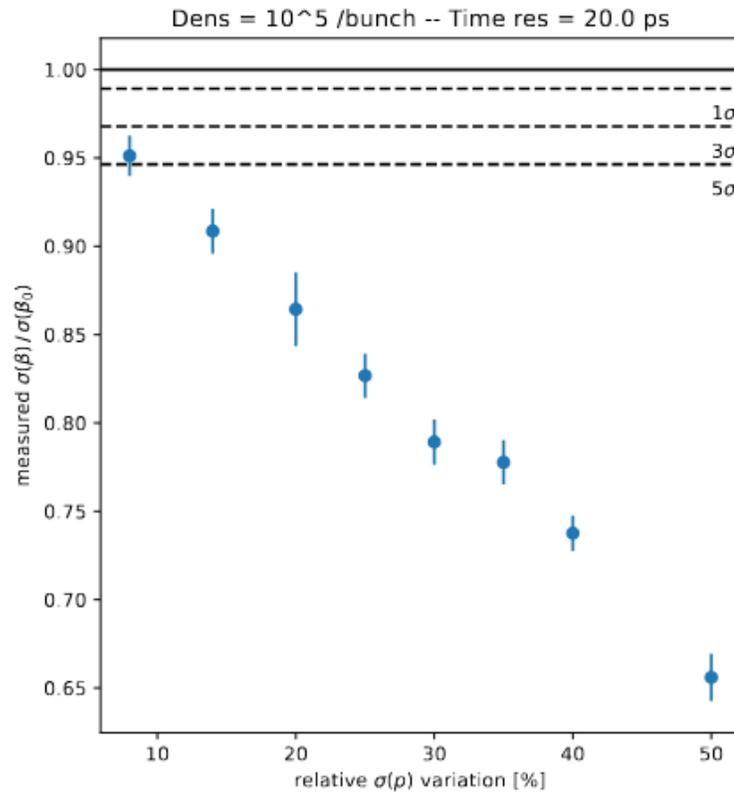
Preliminary plots

- 10 planes, 10^6/bunch (in progress)

Notes on the analysis

- Distributions' parameters are estimated via a skewed-gaussian binned fit, with nbins=$\sqrt{}$nentries and range=[mean-5sigma, mean+5sigma].

- The dispersions of PDFs and their uncertainties are computed using first-order propagation

Both points may introduce systematic uncertainties (not evaluated in this study)

- The detectors are just scoring planes, so matter interaction effects are neglected. However, under the assumption of a O(100 μm) plane thickness, the approximation is ok.

- The length of the detector arm was chosen to limit the bunch longitudinal growth (less than x2). If this condition can be relaxed (e.g. < x3-4), a longer arm results in a more precise measurement or in a more relaxed time resolution requirement (still, a resolution comparable or smaller than the bunch length is recommended, since the measurement of the absolute bunch length is necessary to calculate the full 6d emittance reduction)

- We assume a negligible pixel pileup, condition that may be obtained even at larger bunch densities by reducing the solenoidal field magnitude