Simulations of Low Energy Acceleration

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Outline

- Modifications to ICOOL
- Longitudinal acceptance
- Modifying linac phase profile
- Transverse linear lattice
- Future work

Modifications to ICOOL

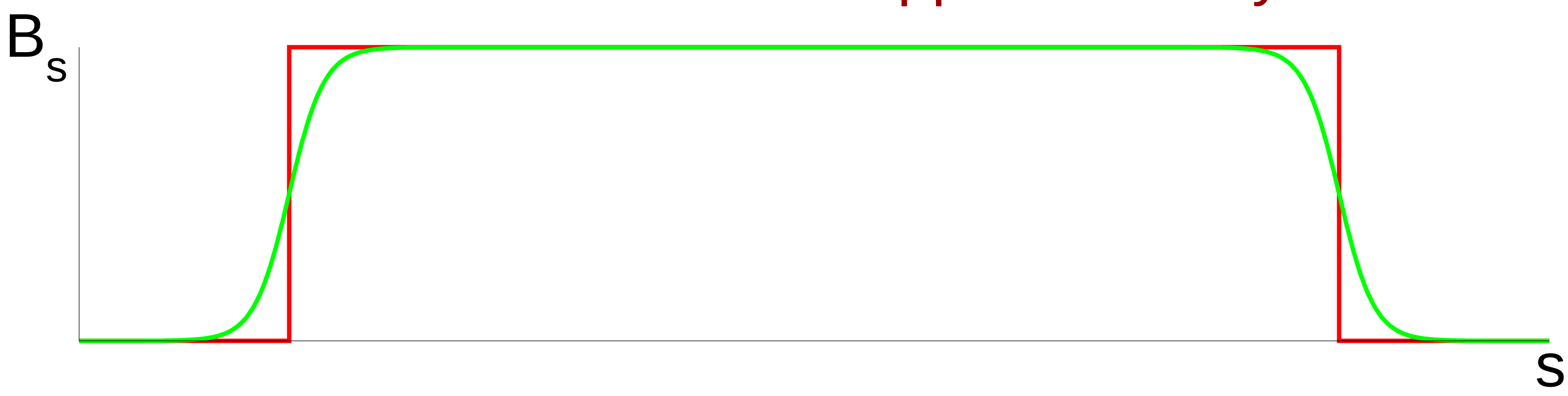
- RF phasing: new phasemodel (2)
  - Really track reference particle to define phase and energy gain
  - Only works in restricted circumstances
- New ACCEL model (13): open hard-edge pillbox cavity
  - Constant longitudinal profile, sinusoidal
  - Has hard-edge focusing on ends (can be turned off for either end)

Modifications to ICOOL (cont.)

- New SOL model (8): hard-edge solenoid
  - Simple fields: runs fast (10K particles in a few minutes)!
  - B_s constant, delta-function B_r on ends (can be selectively turned off)
  - Extra radially symmetric defocusing on ends
    - ⋆ Focusing strength is proportional to B_s^2

$$L \int_0^L B_s^2 ds < \left(\int_0^L |B_s| \, ds \right)^2$$

    - ⋆ Difference concentrated on ends: approximate by thin lens



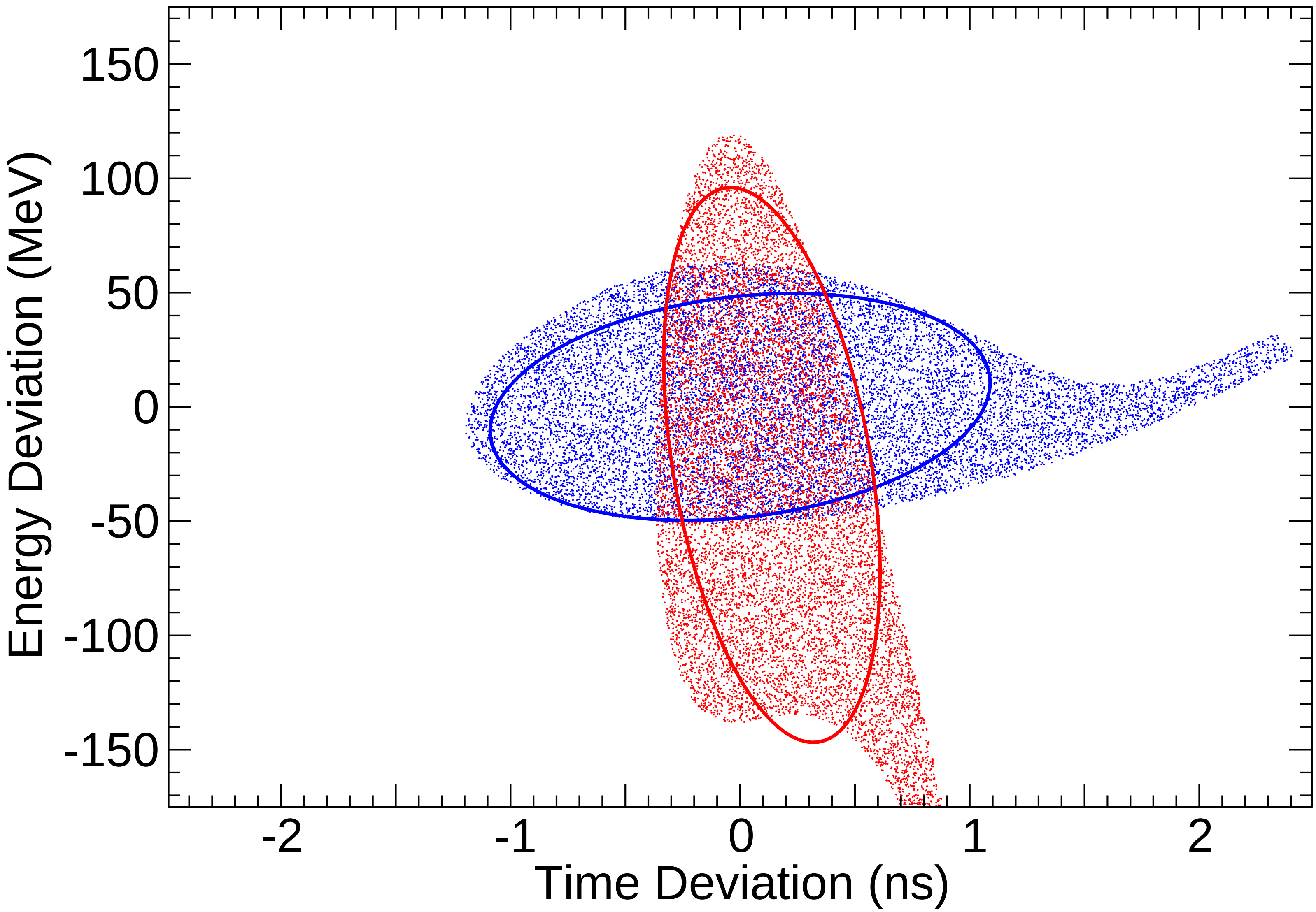
General Comments on ICOOL Run

- Matches Alex's computation, with one exception: I use finite length cavities
  - Lower transit time factor at low energy
  - Slightly lower energy gain
  - Will have other effects (see soon)

Longitudinal Acceptance

- Start with a wide uniform longitudinal distribution
- Track to end, keeping only particles within 1/2 bucket of ref particle
- Plot: particles that make it to end (red), same particles at beginning (blue)
- Ellipses: 150 mm acceptance, orientation computed through cuts

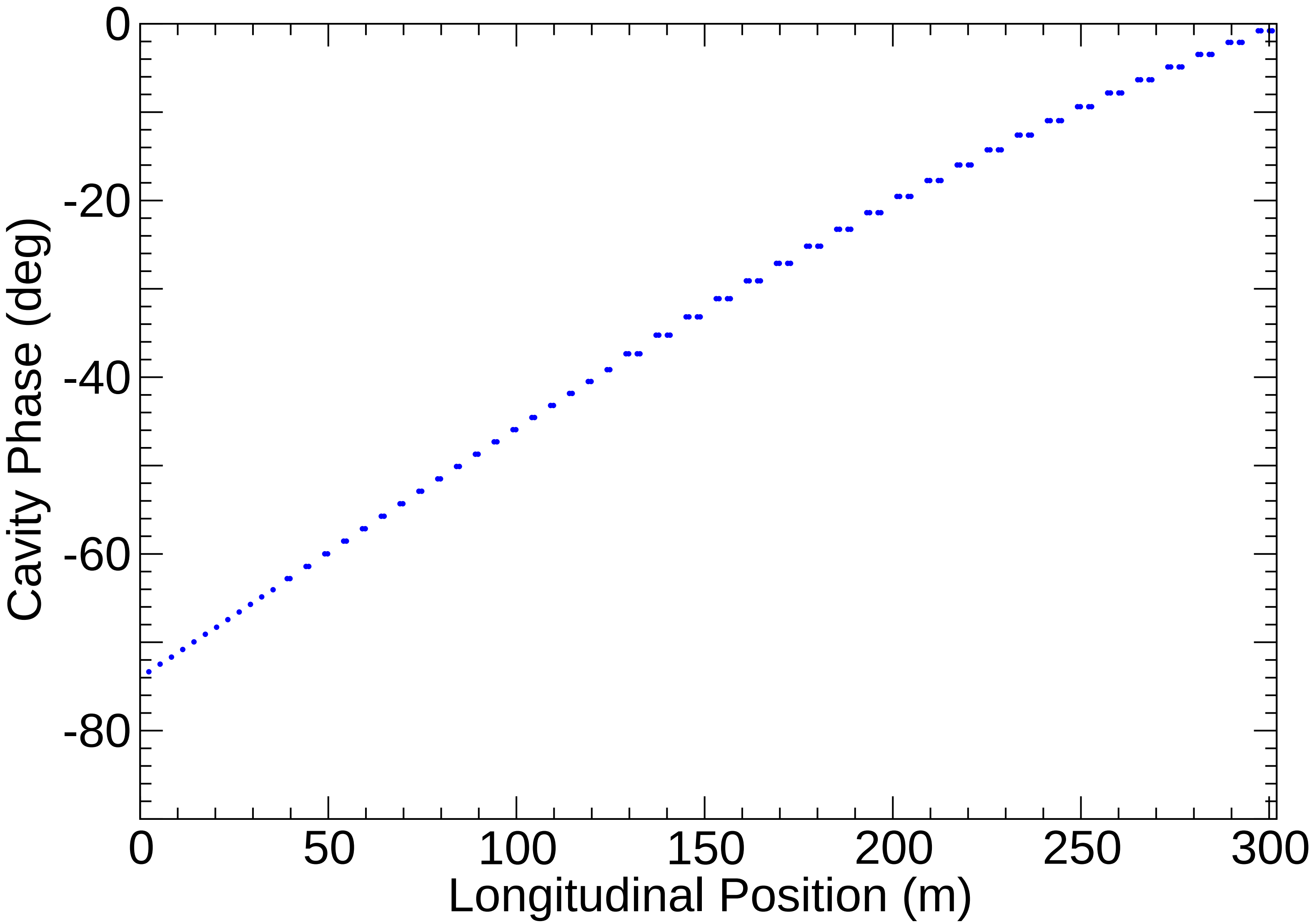
Longitudinal Acceptance



Longitudinal Acceptance

- Don't quite get 150 mm acceptance: close at start, not quite at end
  - Difference from Alex: lower effective gradient at beginning (transit time factor)
  - This is where we need the high cavity gradient!
- Possible cures
  - Start further off crest: but already pretty far off crest (73°)!
  - Better phase profile
  - May be caused by distortion at end on crest!
    - Can check this: take snapshots at different points
    - If so, want to narrow distribution more: can we modify RF phase profile?
  - Tighter lattice: shorter solenoids?
- Average energy is below reference particle energy (about 25 MeV)

Linac Phase Profile



Linac Acceptance vs. Initial Phase

- Smooth approximation to linac
- Accelerate total energy 290 MeV to 1.5 GeV
- Choose phase and gradient as a function of energy
  - Transit time factor depends on energy
  - Length of cryomodule depends on energy
- For this example, assume constant gradient, 4.25 MV/m
  - Lowest real-estate gradient in real linac
  - Include transit time factor in addition to this
- Phase profile (0 is crest)

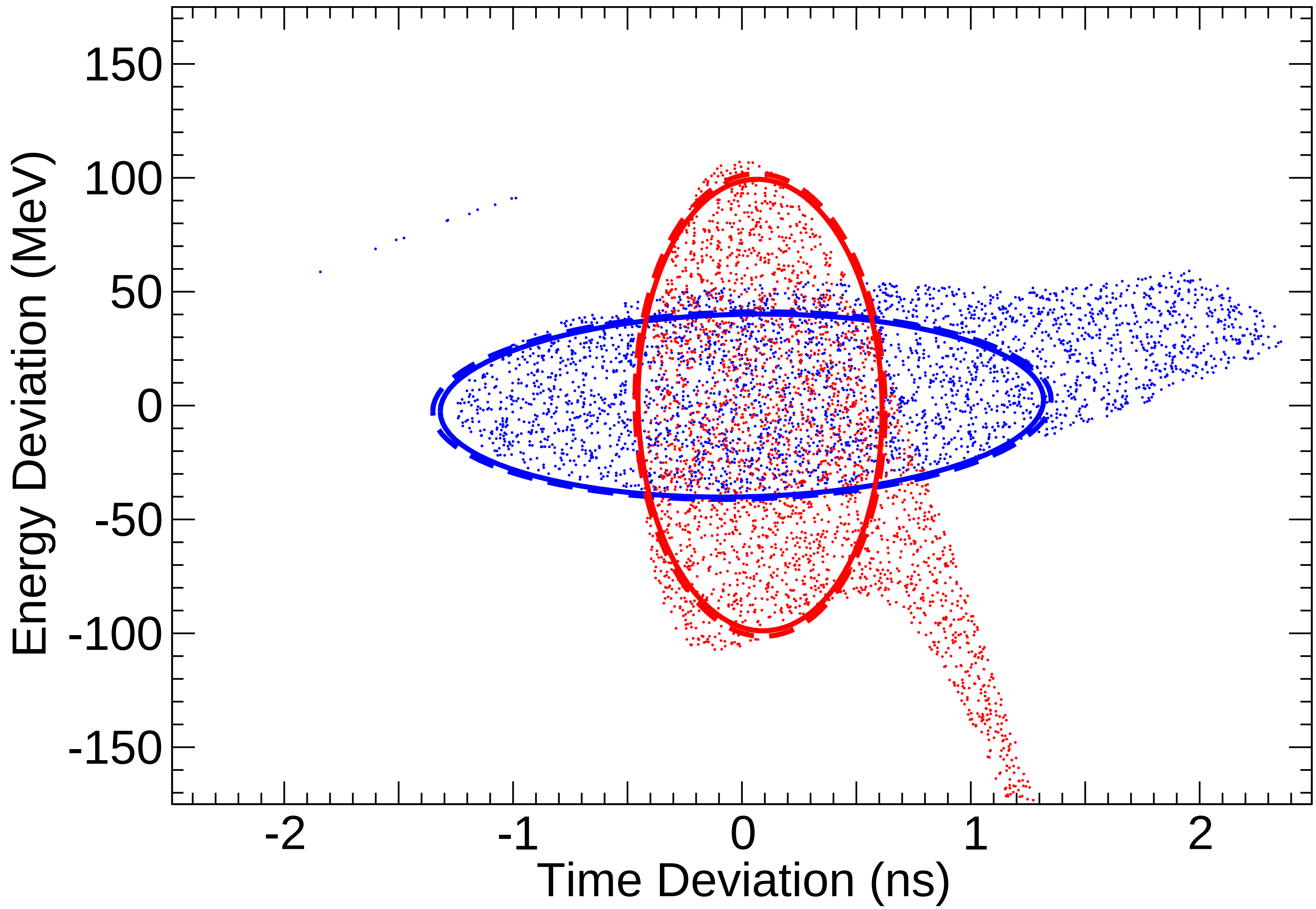
$$\phi(E) = \phi_0 \frac{E_{\text{max}} - E}{E_{\text{max}} - E_{\text{min}}}$$

  - Look at different values of ϕ_0

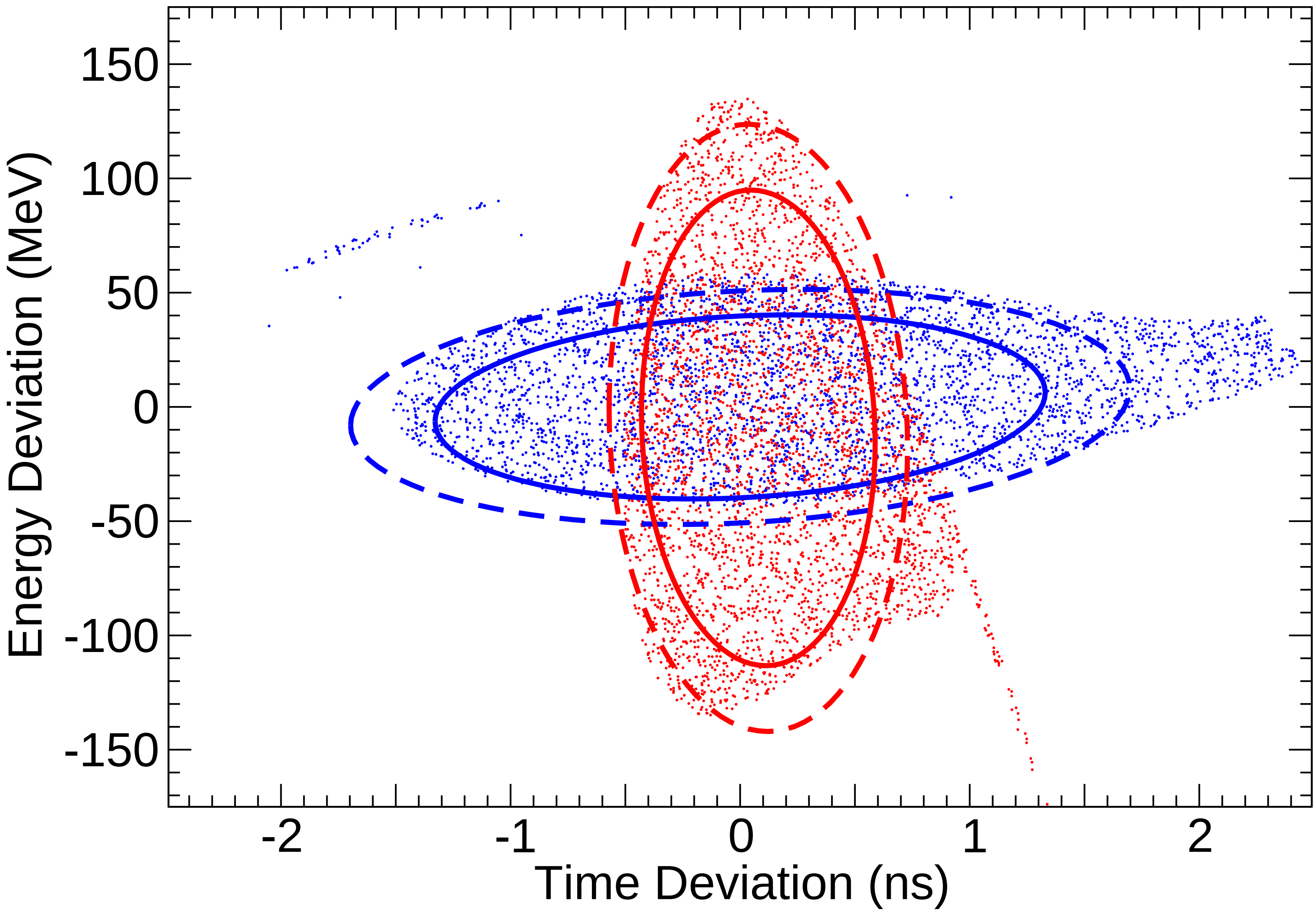
Linac Acceptance: Analysis

- Bunches transported down linac
  - Dashed line is approximate acceptance
  - Solid line is 150 mm acceptance
- Do well even at 75°
  - Since phase is linear in energy, not position, phase increases more slowly at low energy. Better capture.
- Cost of larger acceptance: longer linac
  - Can't compare these numbers to real linac. . .
- Gain levels off at higher phase

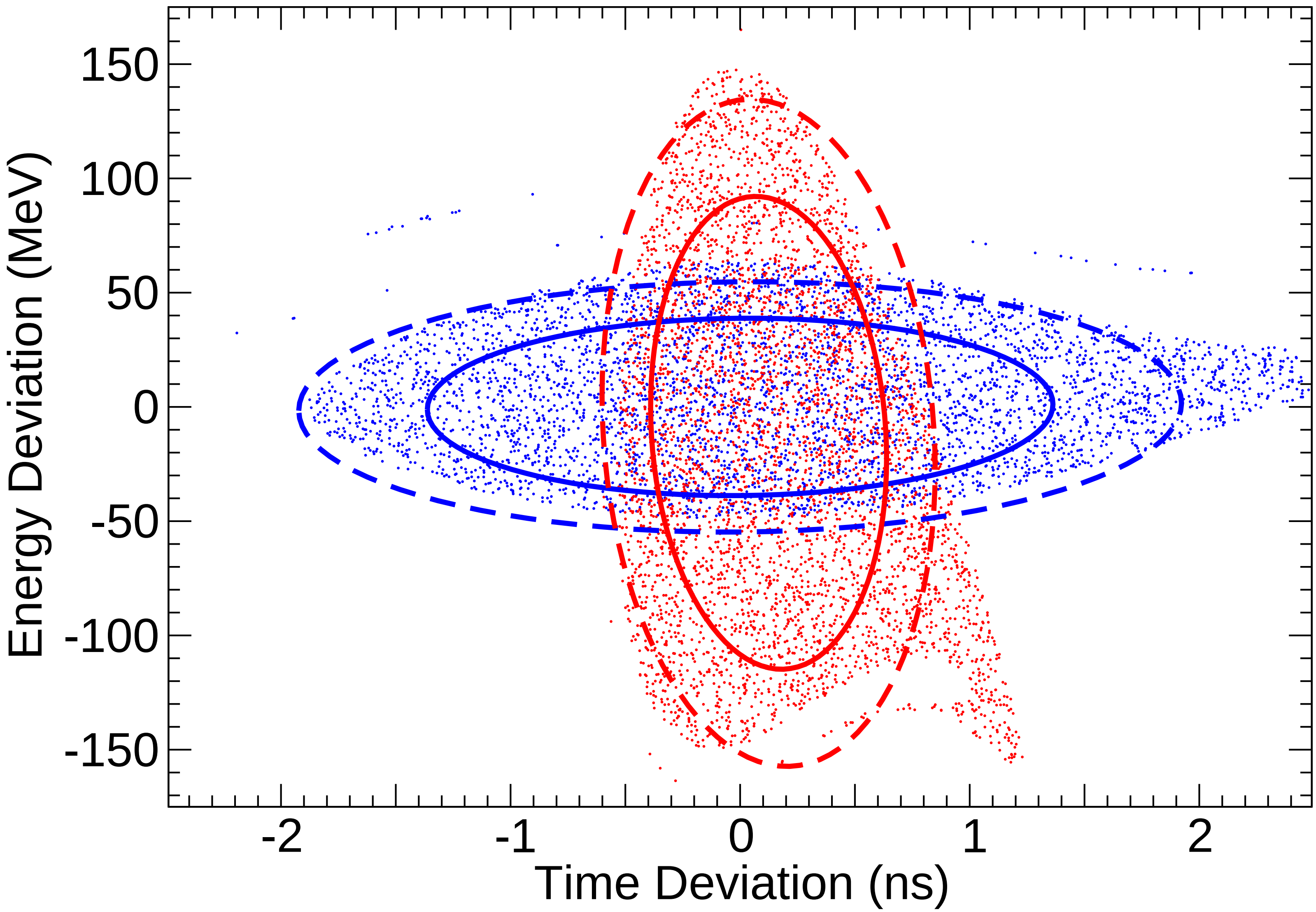
Longitudinal Acceptance: 65°



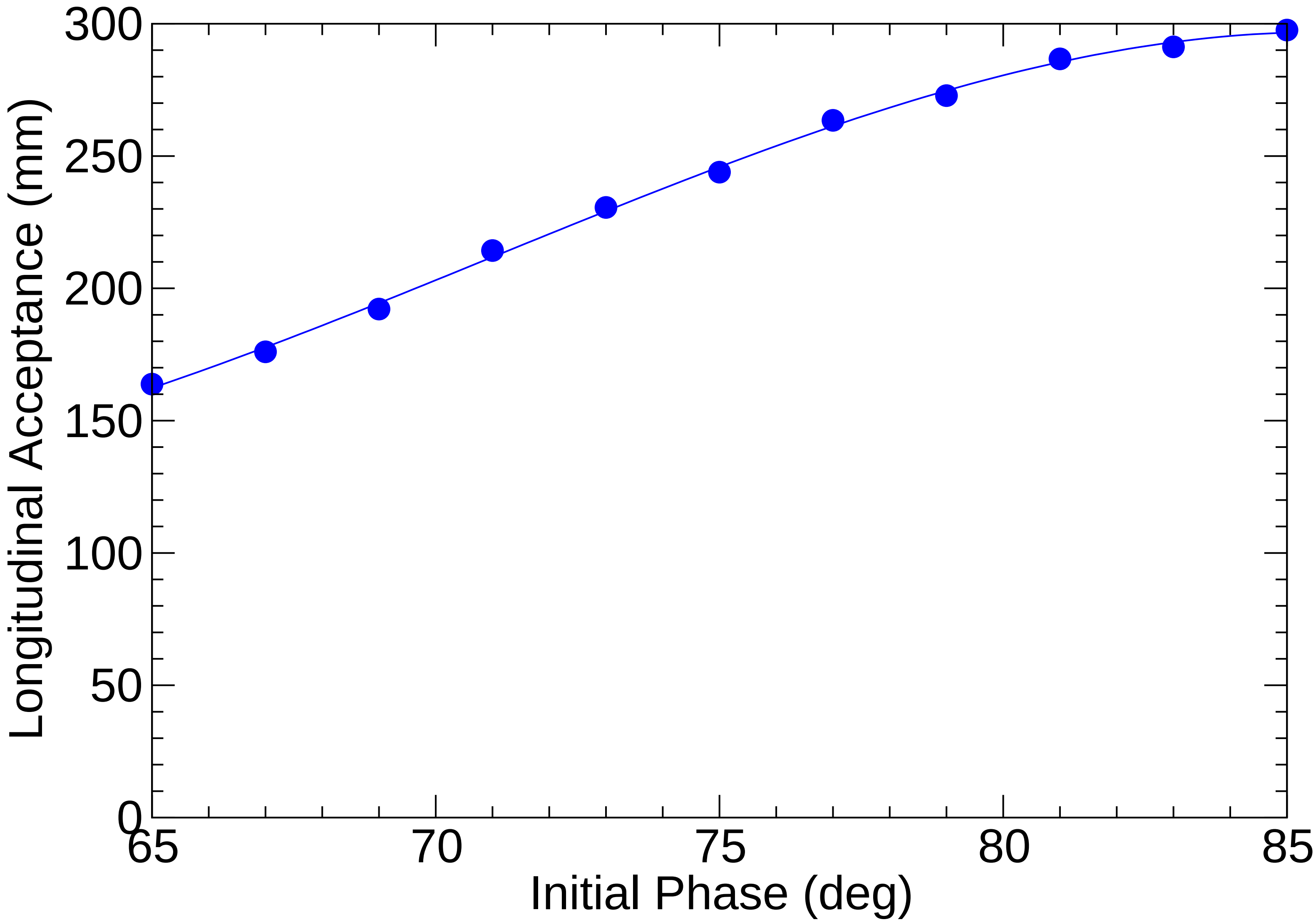
Longitudinal Acceptance: 75°



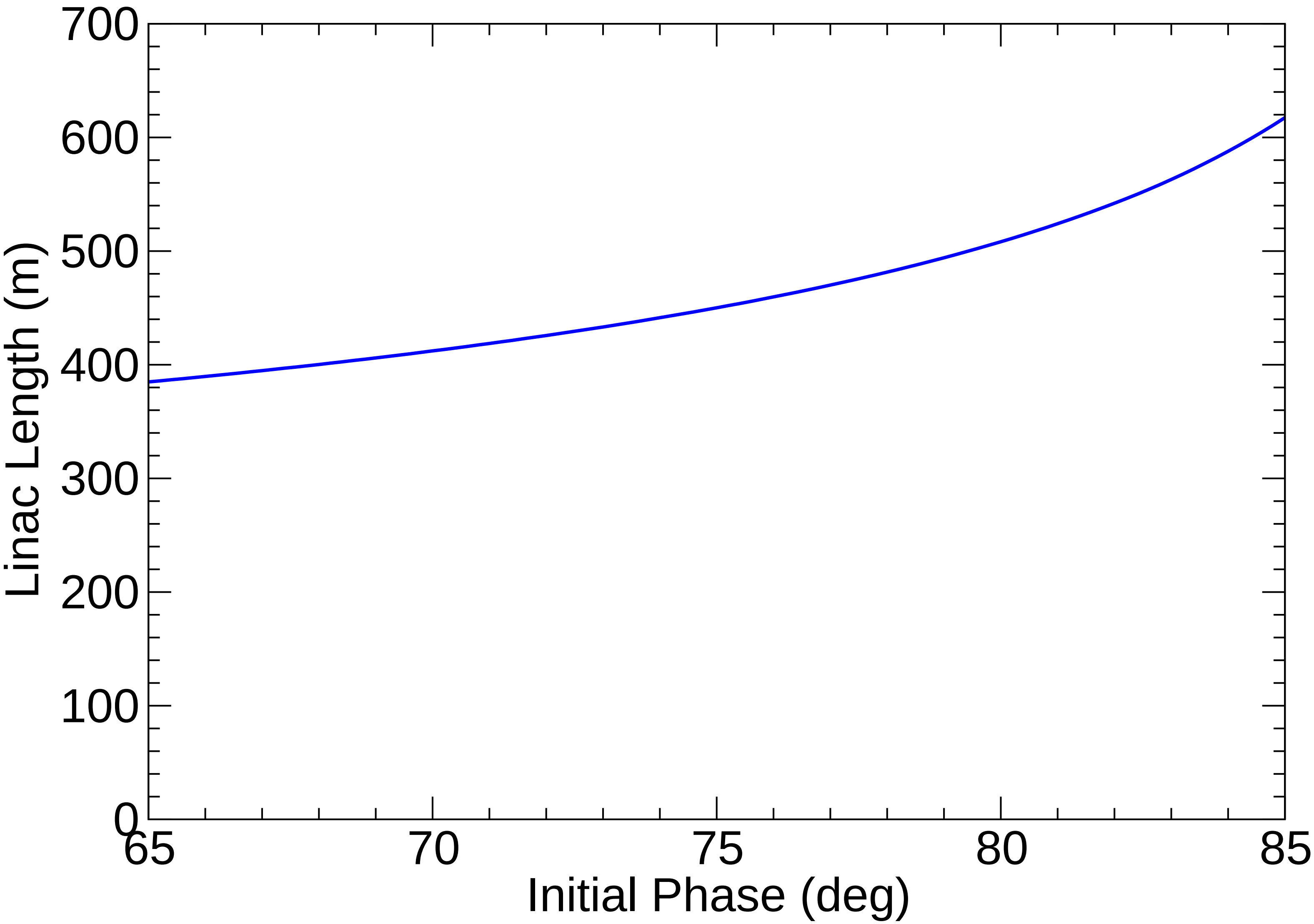
Longitudinal Acceptance: 85°



Longitudinal Acceptance vs. Initial Phase



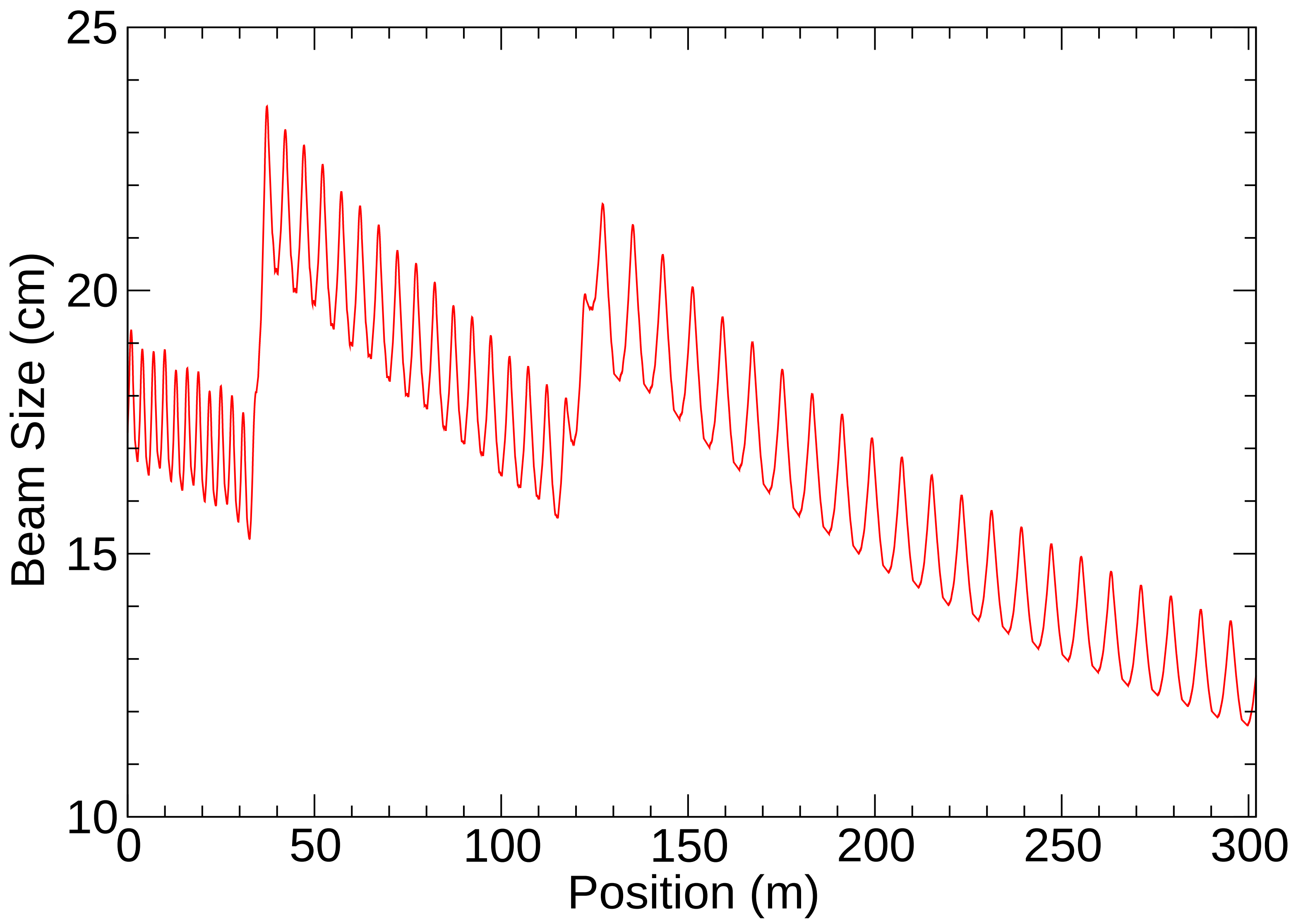
Linac Length vs. Initial Phase



Transverse Linear Lattice

- Send small amplitude particle through ICOOL to compute transfer matrix
- Compute beta functions, beam sizes at acceptance
  - Beginning of second stage is a bit large, but not too bad
  - Plenty of room at beginning of first stage
    - Could start at lower energies
    - Longitudinal acceptance is the issue

Beam Size



Continued Work

- Fix the longitudinal acceptance
  - Or demonstrate that we can live with it (e.g., subsequent systems transmit the distorted phase space)
  - Continue analysis of phase profile modification
    - Look at different types of phase profile (add quadratic)
    - Include increased gradient linacs
    - Optimize against decays
- Check for emittance growth (tracking done, analysis not)
- Use more realistic solenoid model: nonlinearities
- Model remaining components (I have the dogbone linac. . .)