Expected Beam Performance of the SNS Linac

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20 June 2001

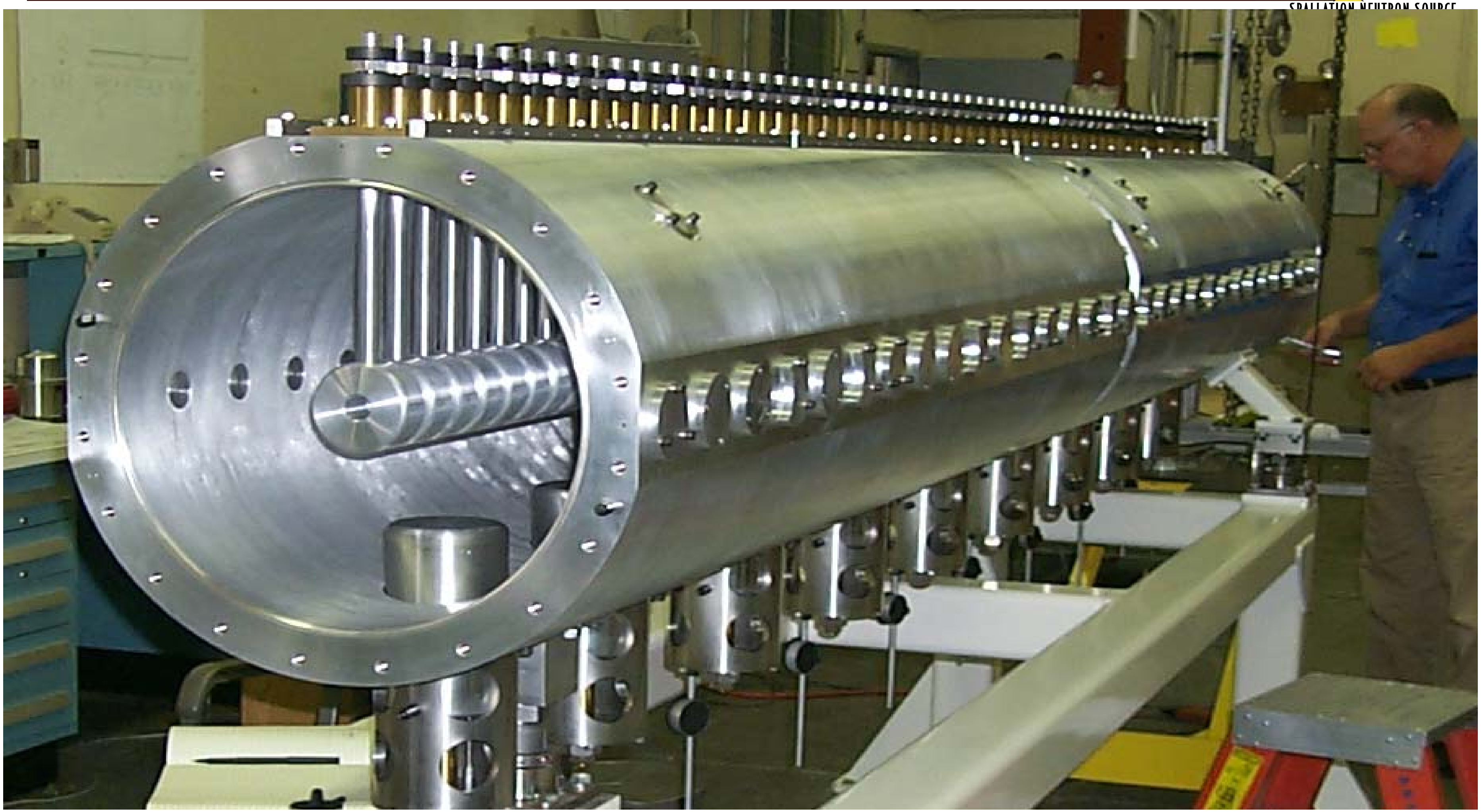
Design Requirements & Constraints

Parameter	Value
$W_{initial}$	2.5 MeV
W_{final}	1 GeV
I_{ave}	1.56 mA
W_{final} stability	$\pm$ 1.5 MeV
W_{final} spread	$\pm$ 0.33 MeV rms
$\varepsilon_{initial,\ rms,norm}$	$\approx$0.27 π mm-mrad
$\varepsilon_{final,\ rms,norm}$	$\leq$0.5 π mm-mrad
Beam loss	$\leq$ 1 W/m throughout
Beam duty factor	6 %
Chopper duty	68 %
SRF cavities	33 ea β=.61, 48 ea β=.
$P_{klystron}$ (SRF)	$\leq$ 550 kW

SNS Linac Contains 4 Linac Sections

Structure	W_{final}	Total Length	Cells per Cavity	Cavities per Module	Modules	No of Klystrons	Klystron Power
	MeV	m					MW
DTL	86	37	60 to 21	-	6	6	2.5
CCL	186	92	8	12	4	4	5.0
SRF I	394	158	6	3	11	33	0.55
SRF II	1000	251	6	4	12	48	0.55

Tank 1 Cold Model Verified Stabilization Scheme



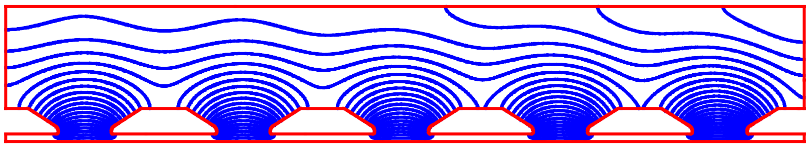
Missing Gaps are Compensated by Adjusting ϕ_s in Adjacent Gaps

- 1-$\beta\lambda$ gaps between tanks represent
  - A missing longitudinal focusing gap &
  - A missing rf defocusing lens
- ϕ_s adjustments in 6 adjacent cells compensate the missing elements
  - Corrects both longitudinal focusing and transverse rf defocusing.
- E_0 increased by ~1% to make up for the lost acceleration.
  - Tank lengths change a few mm.
  - Drift-tube dimensions change only slightly.

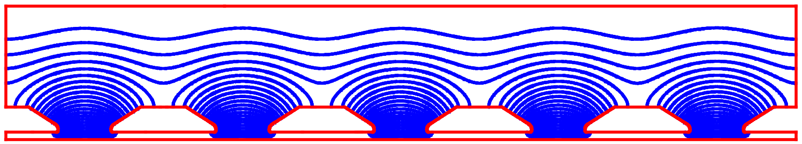
Cell Length Adjustment Does Not Detune the Tank

- Previous methods for shifting ϕ_s moved the gap within a 360° cell resulting in an asymmetry that severely detuned the cell, which causes field tilts if not corrected.
- Present method uses cells a few degrees shorter or longer than 360° to shift the phase.
  - Cells remain very nearly symmetric.
  - Resonant frequency is unchanged.
- With tuned cells, field flatness and frequency are guaranteed as confirmed by multicell SUPERFISH calculations.

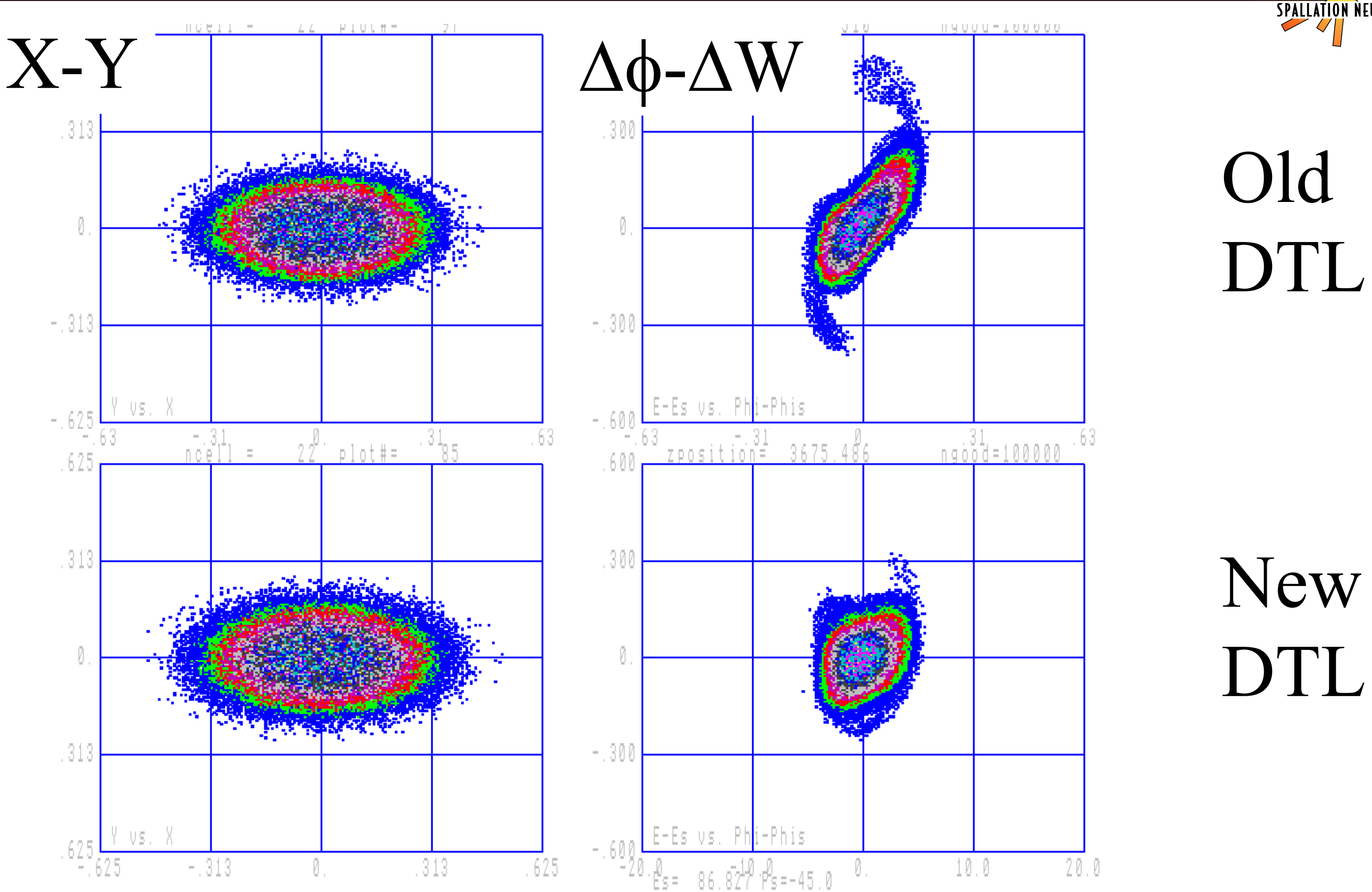
Shifted gaps within cell, 402.1 MHz



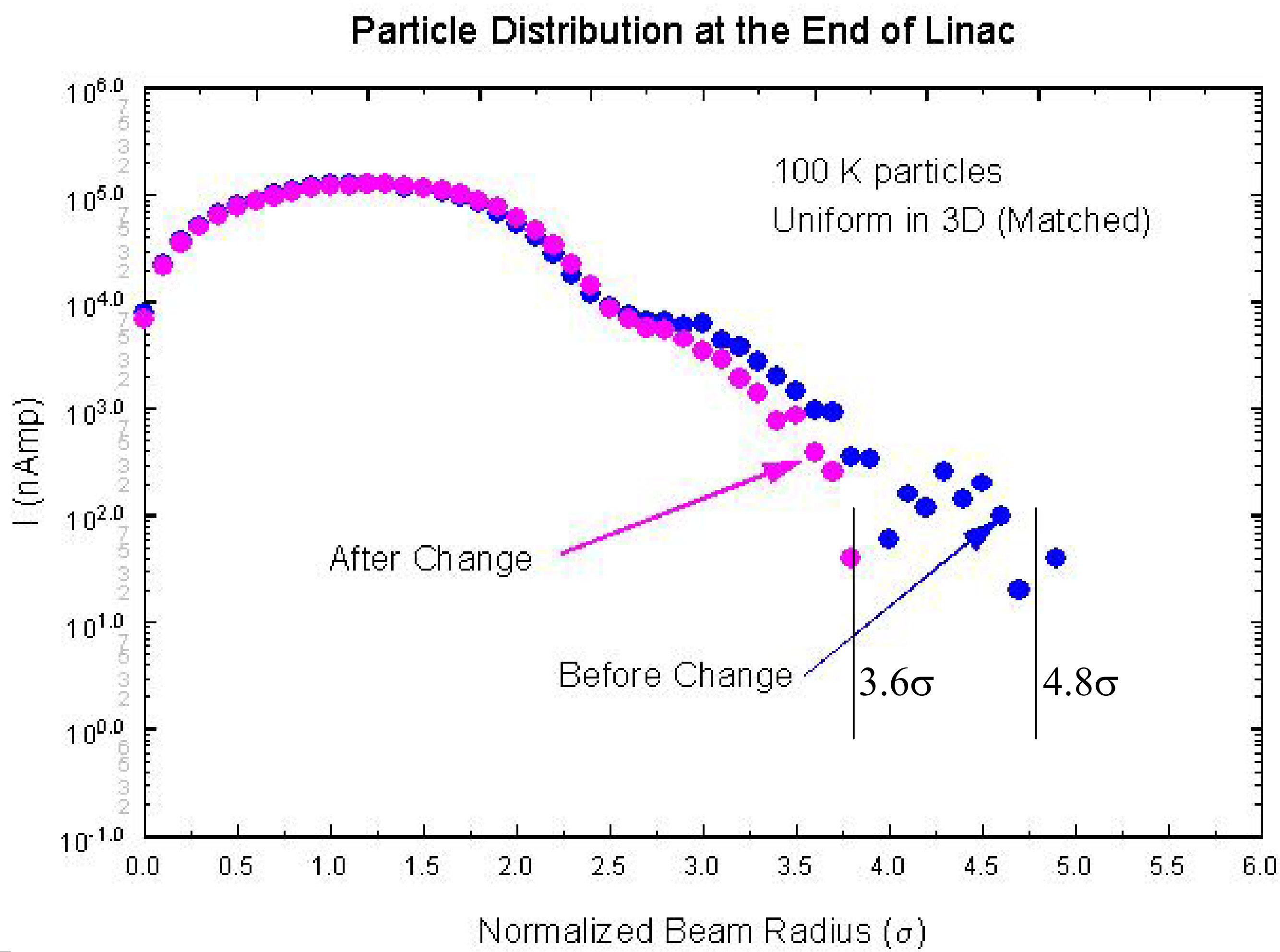
Shorter cells, 402.5 MHz



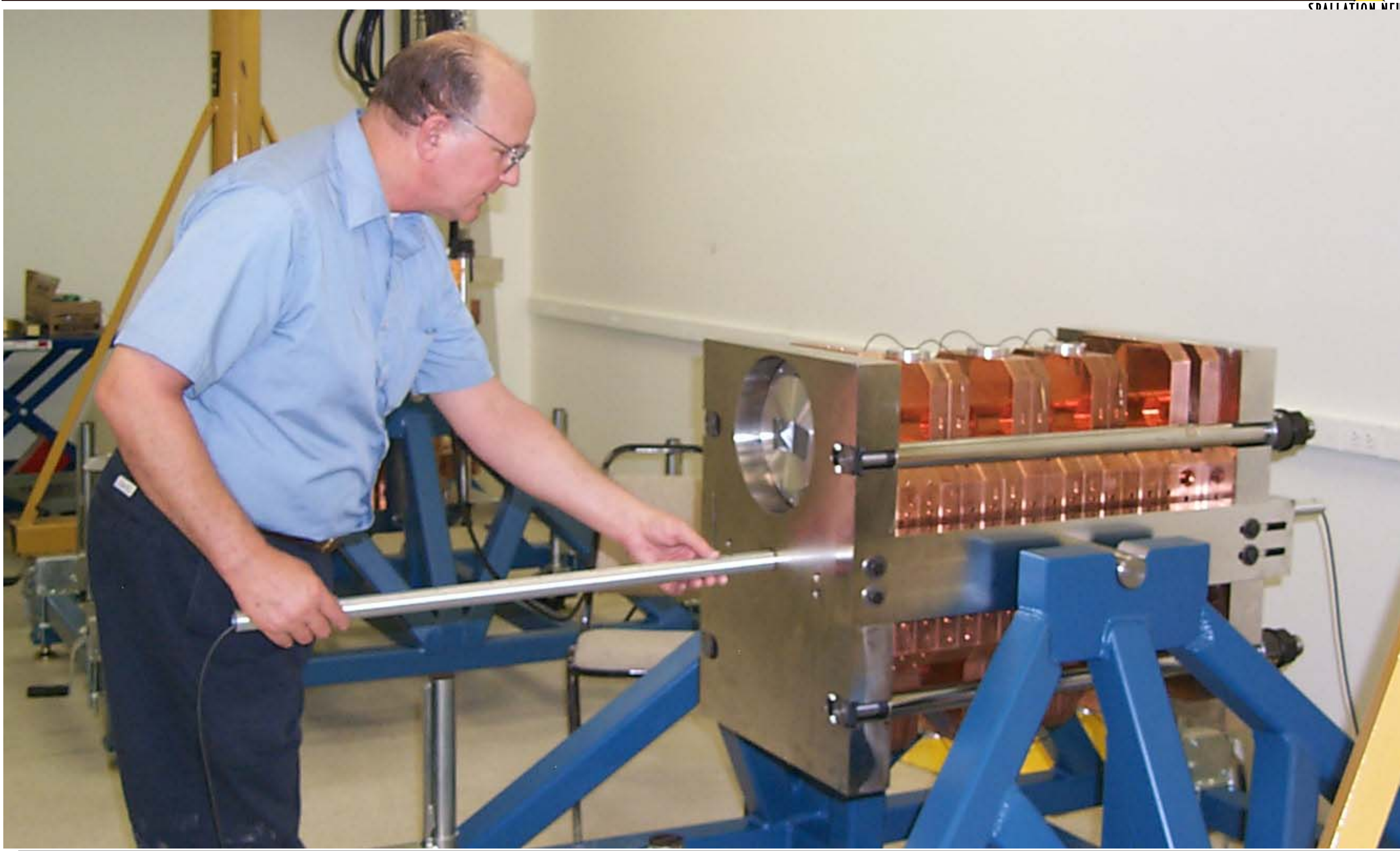
Projections of the Beam Distribution Show Improvement at DTL Exit



Effect of Inter-Tank Matching is Reflected in Radial Distribution at 1 GeV



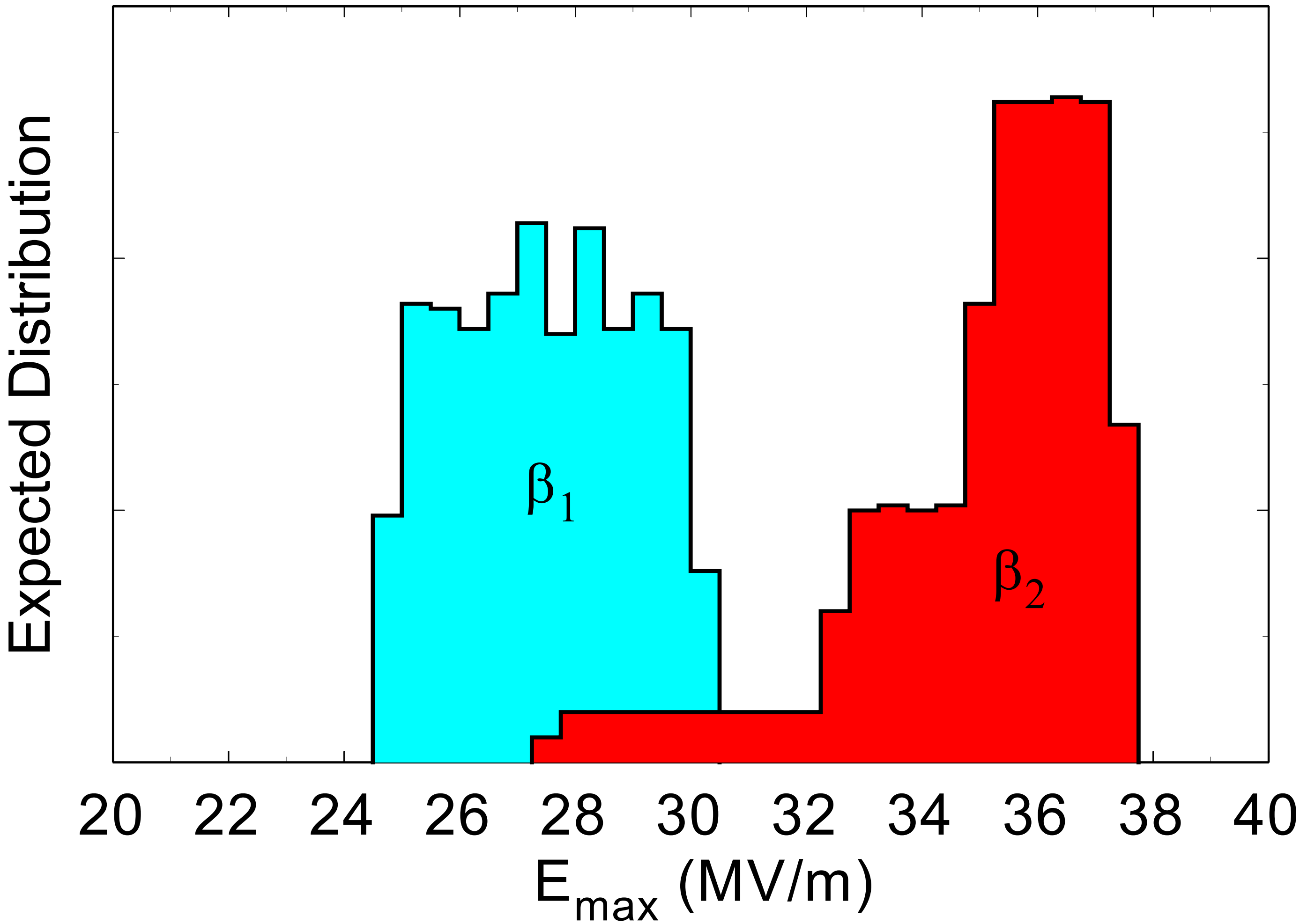
A CCL Hot Model will Verify the Engineering Design & Tuning Plan



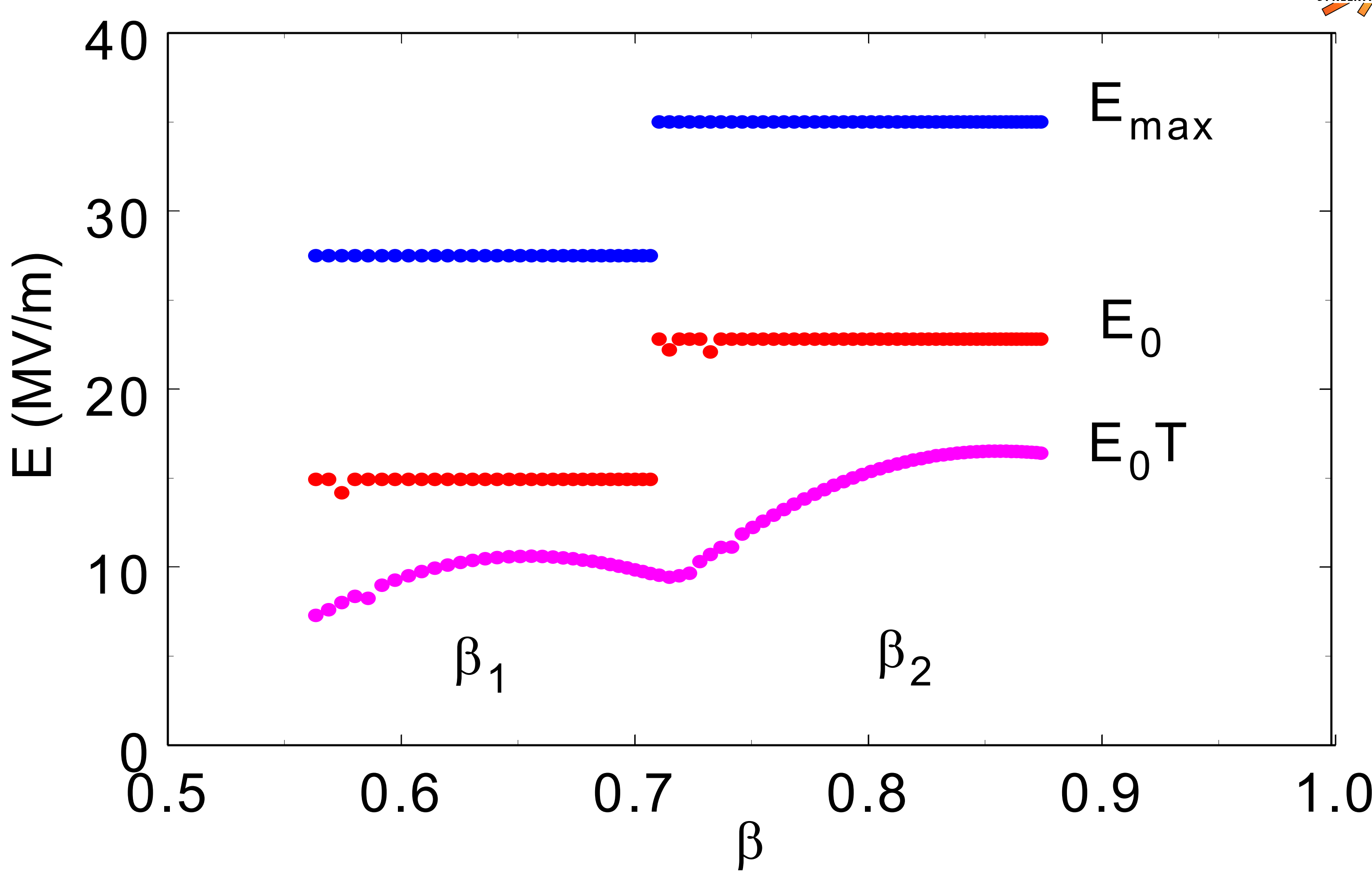
33 β=0.61 Cavities Accelerate the Beam from β=0.55 to 0.70

48 β=0.81 Cavities Accelerate the Beam from β=0.70 to 0.87

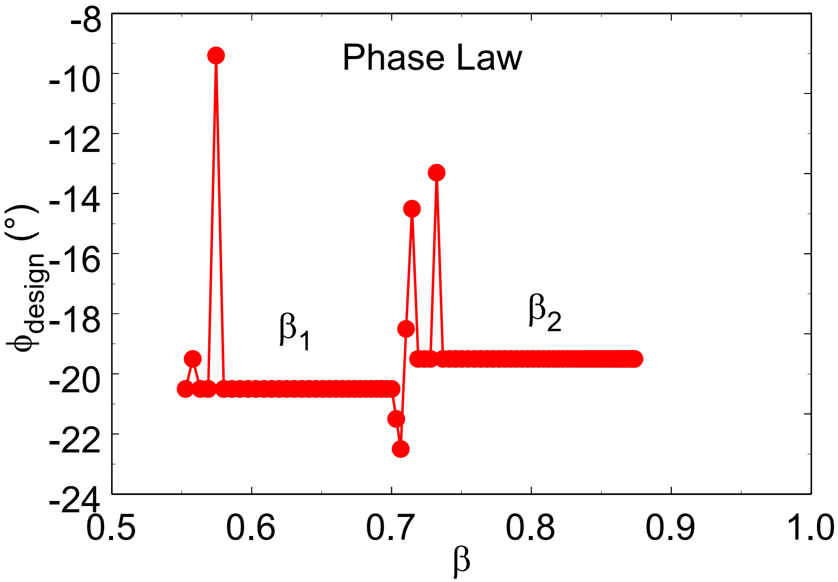
SRF Linac Performance will Depend on Success of Cavity R&D Program

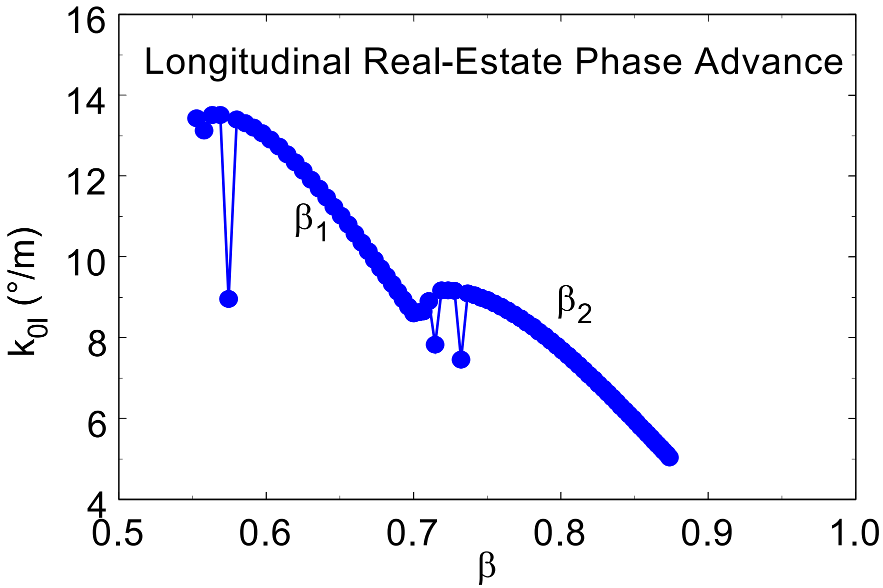


The Reference Design Assumes the Mean Value of the Predicted Cavity Fields

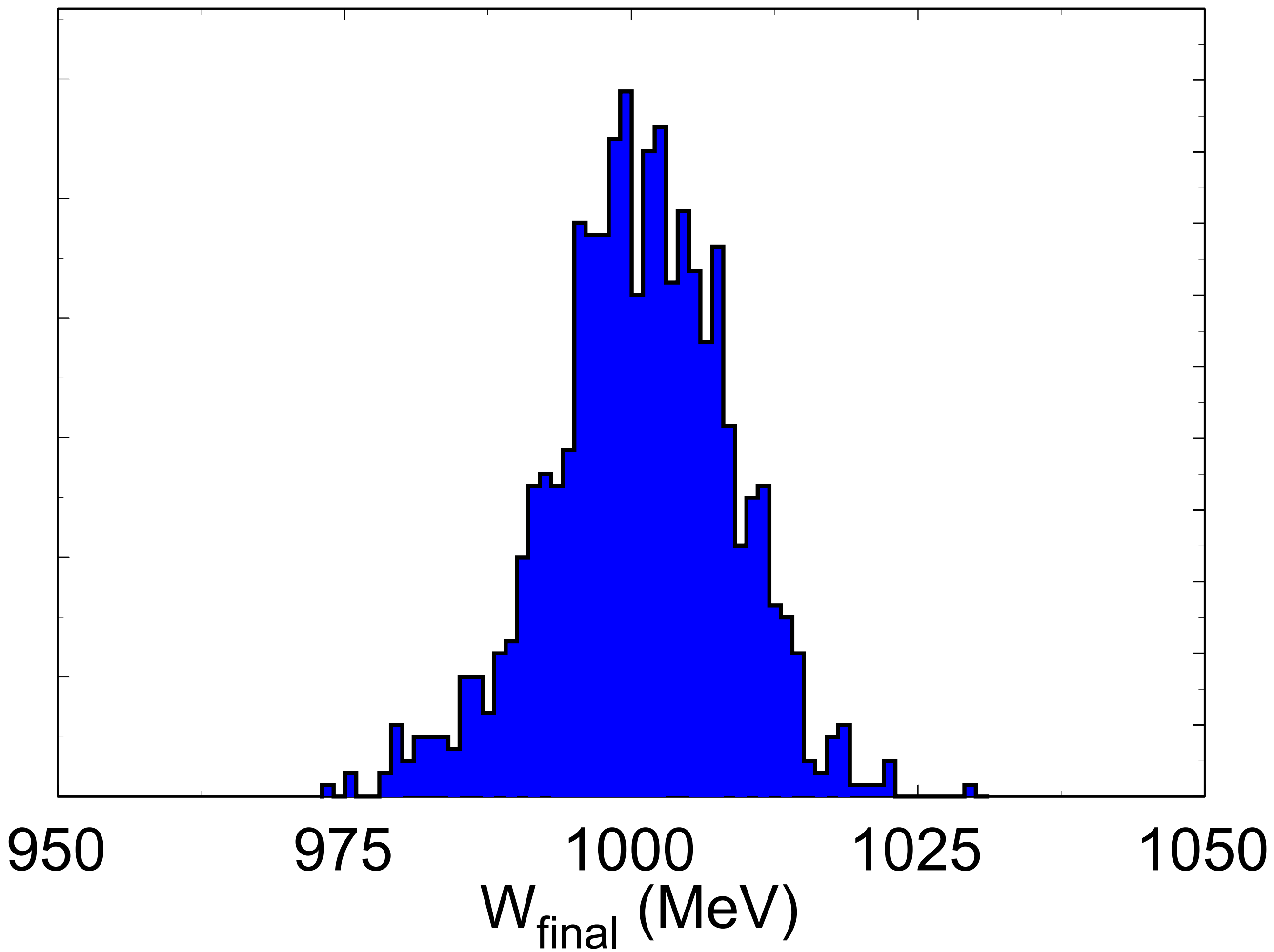


Phase Law Keeps $k_{0,l}$ Continuous but Reduces Longitudinal Acceptance

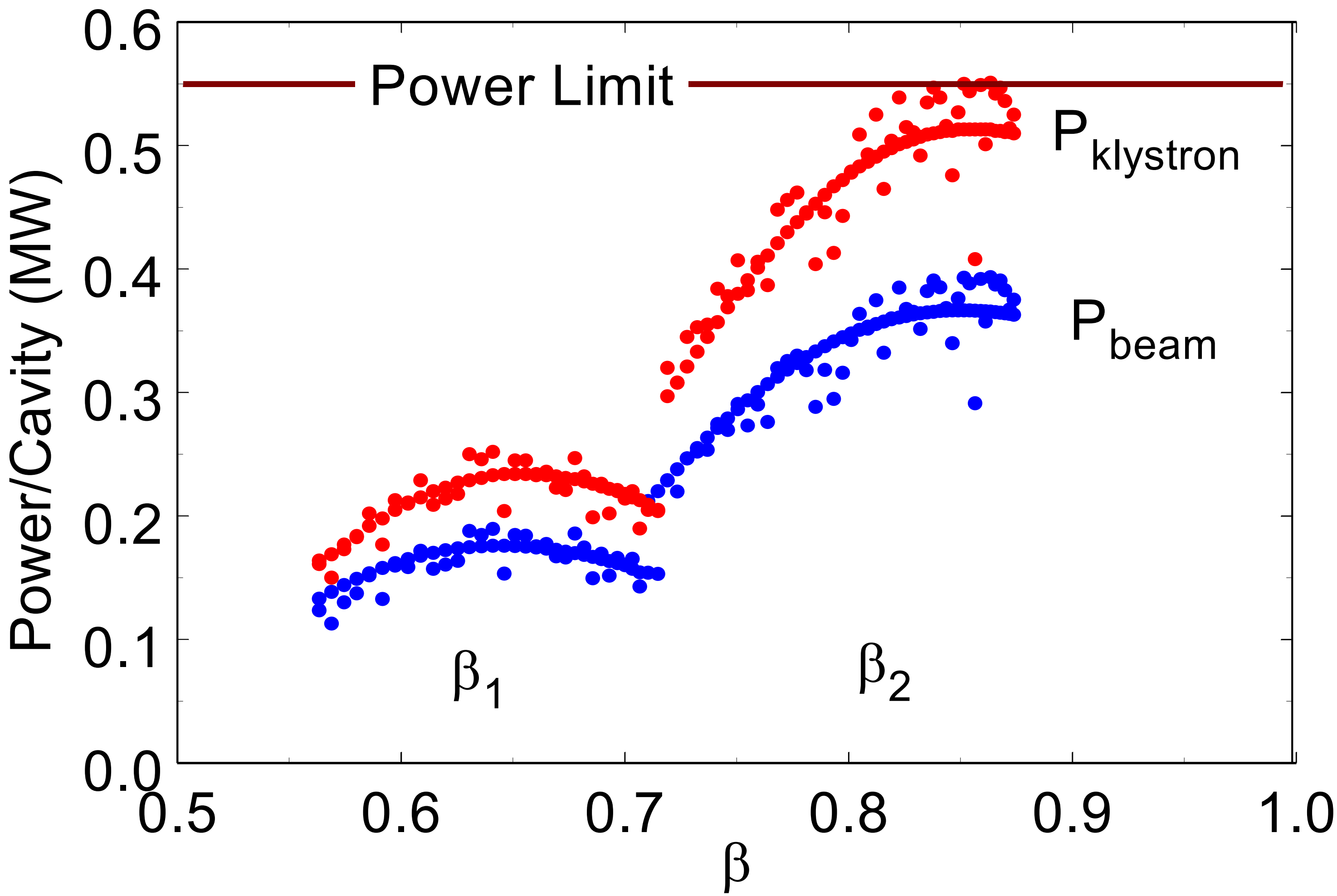




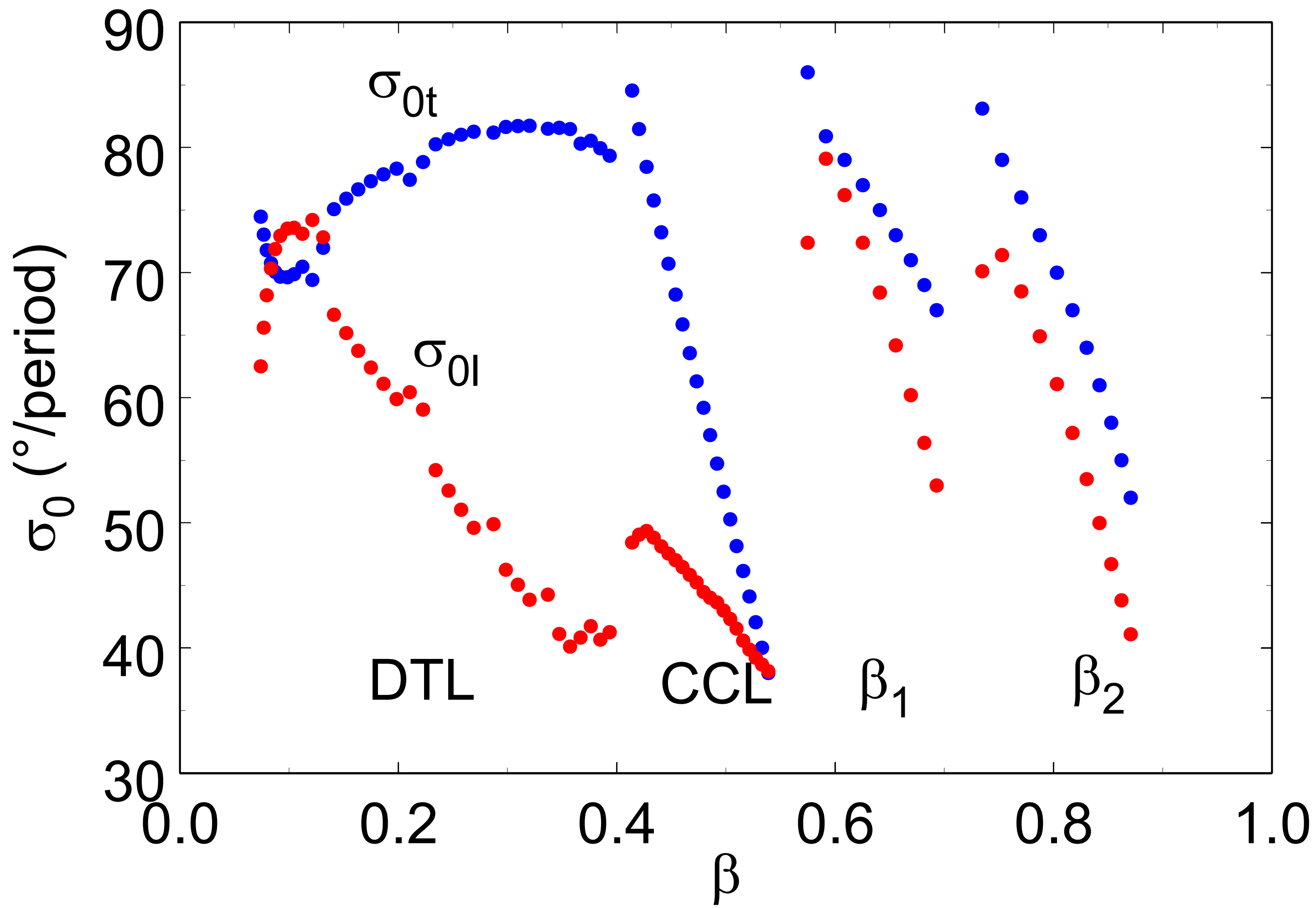
Expected W_{final} = 1 GeV ±15 MeV (±2σ)



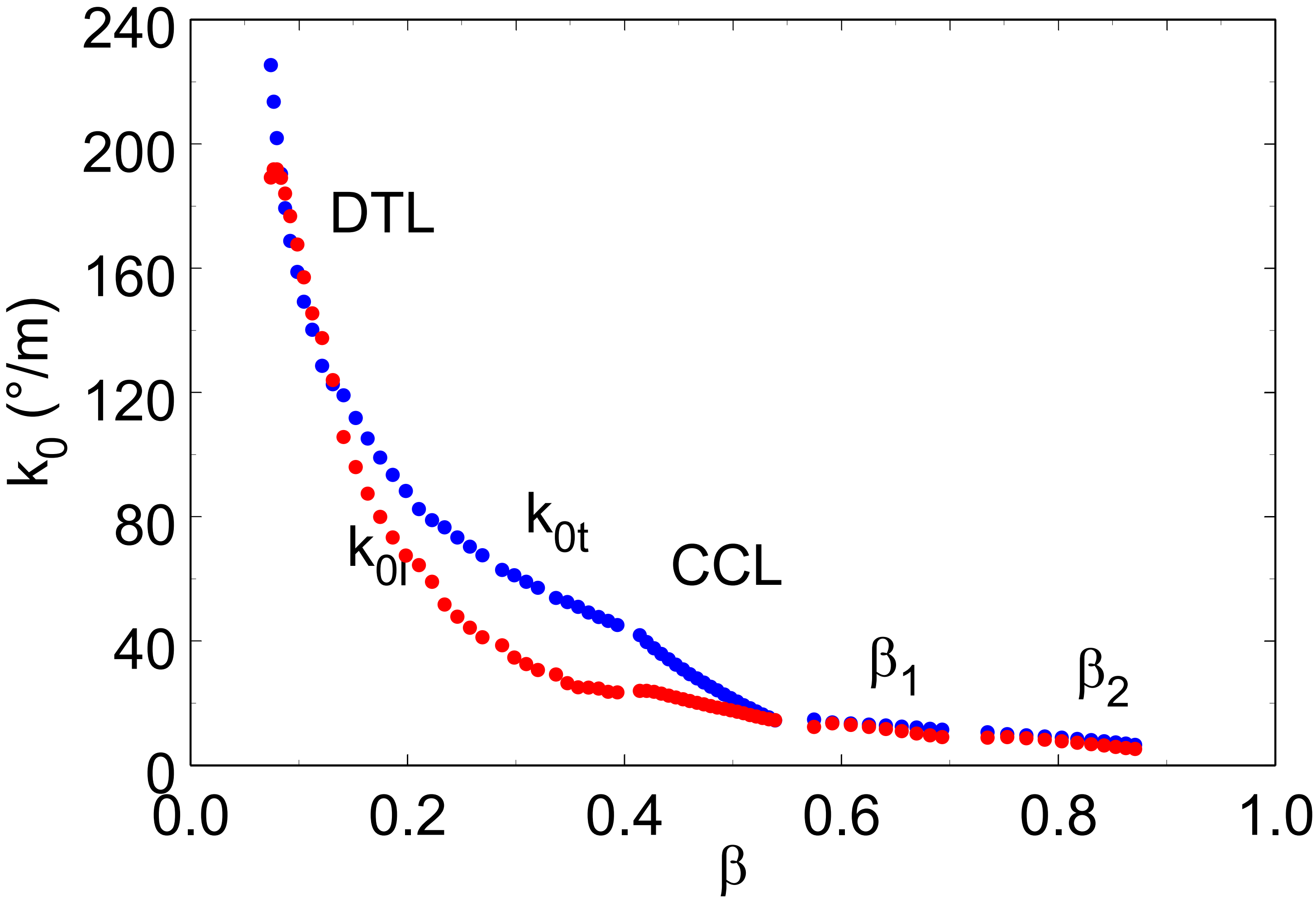
W_{final} is Limited by Cavity Quality, Beam Current is Limited by Klystron Power



Phase & Quad Laws Avoid Structure & Parametric Resonances Throughout



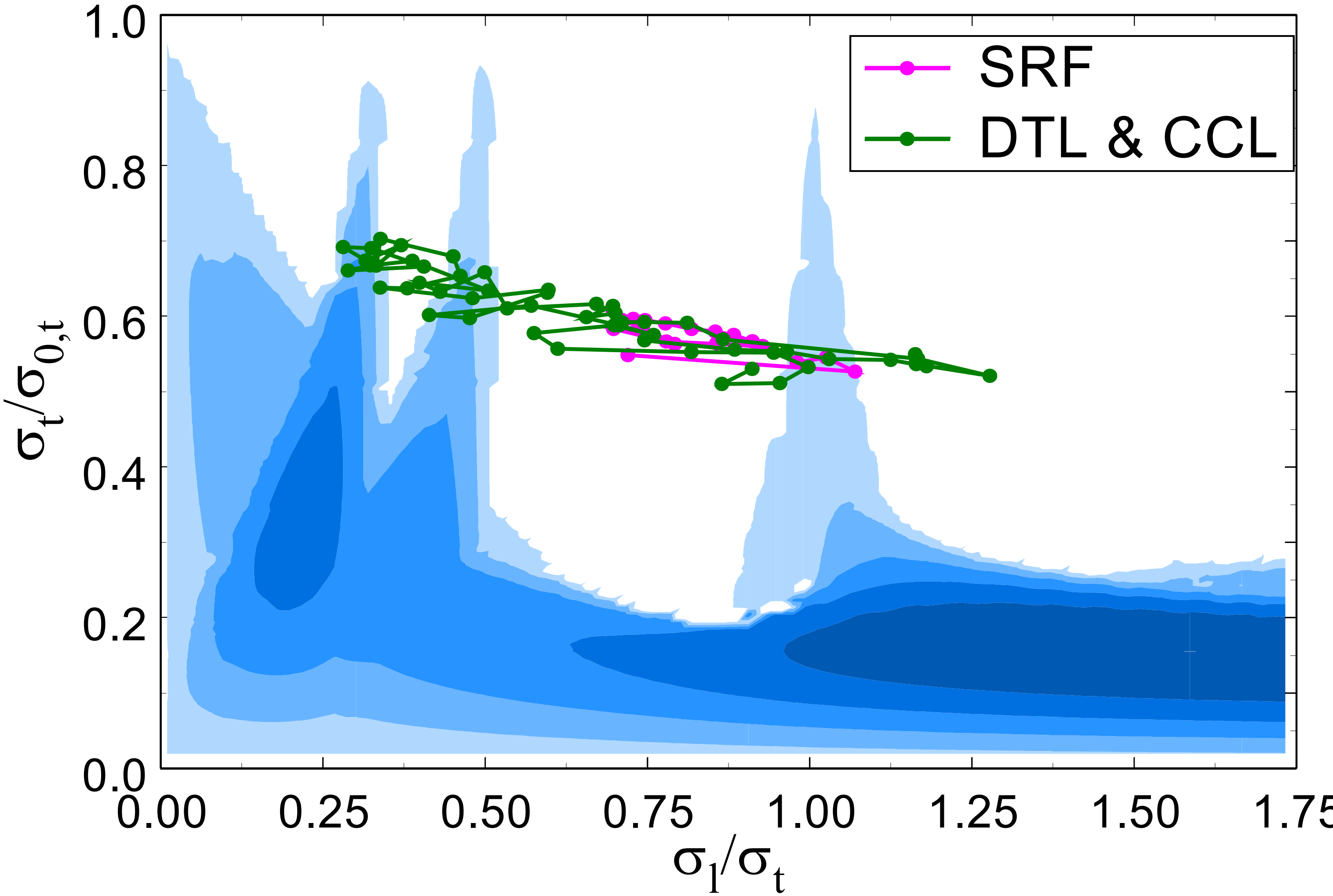
Continuous Transverse Real Estate Phase Advance Helps Current Independence



“Gone in 1.7 μsec”

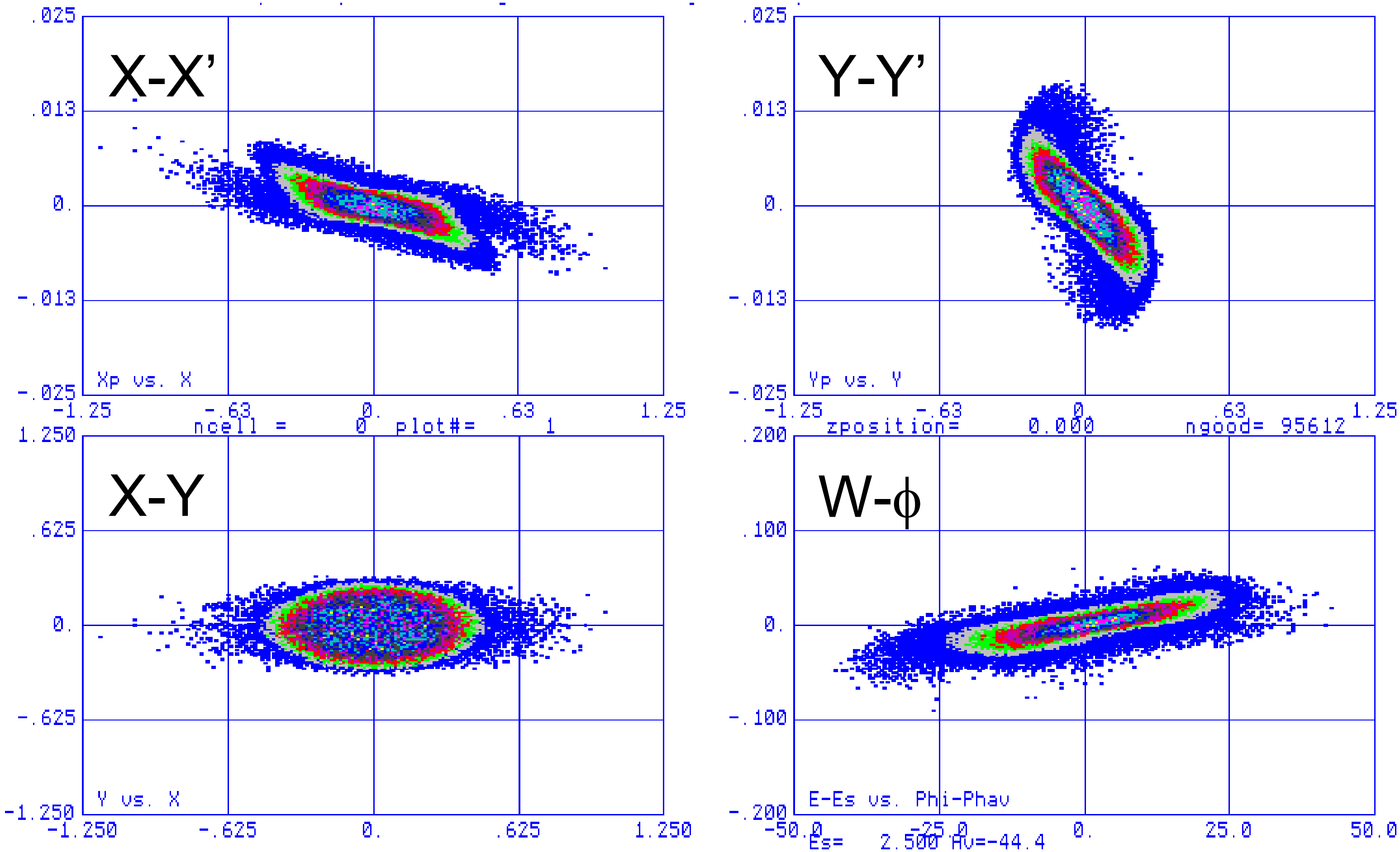
	DTL	CCL	SRF
Accel. Gaps	216	384	486
Lattice periods	37	24	23
Betatron Periods	8	4	4
Transit time (nsec)	552	387	733

Coherent Resonances Pose Little Risk for Emittance Growth

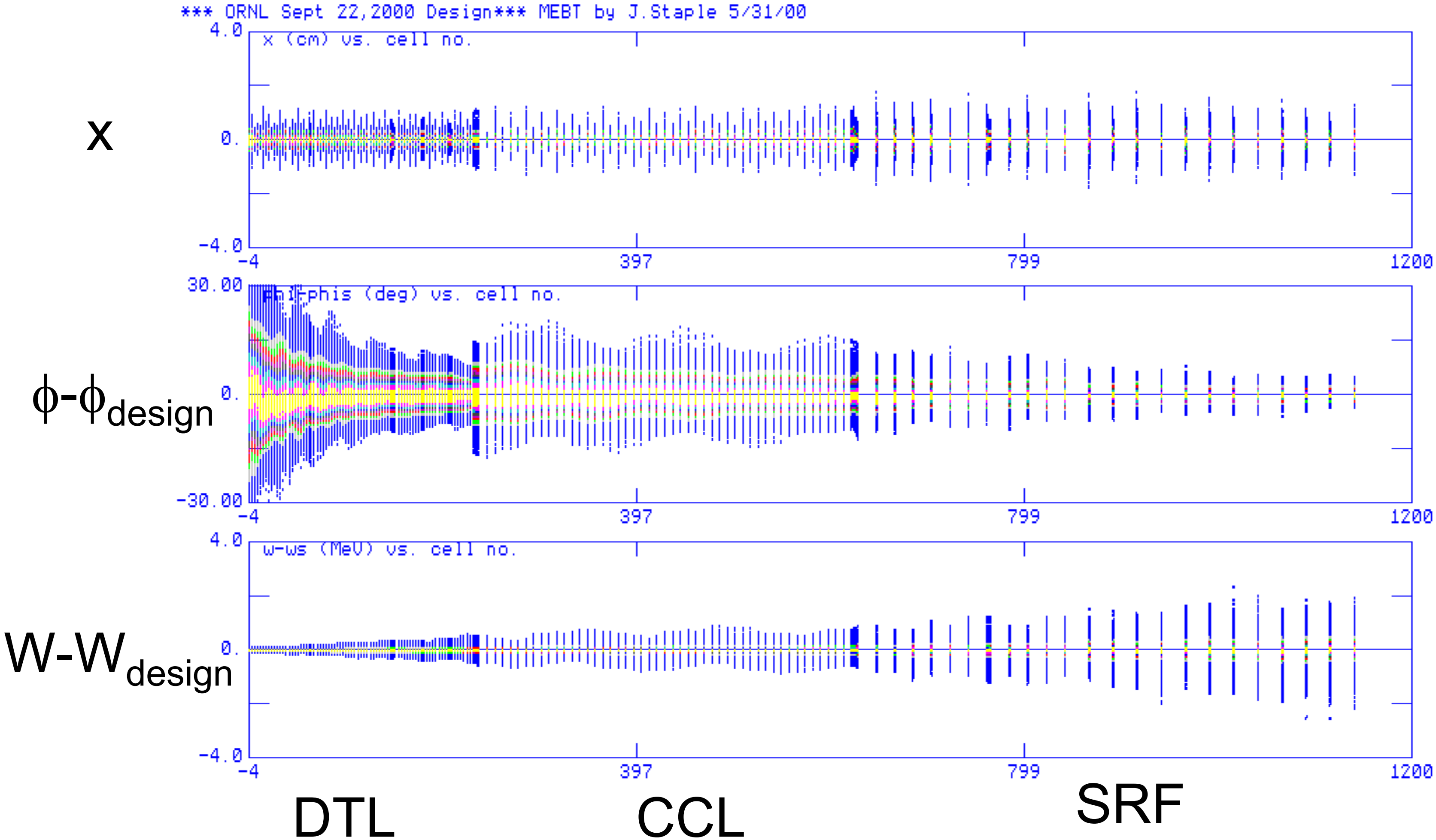


Design Studies Assume a Water bag Distribution Entering the RFQ

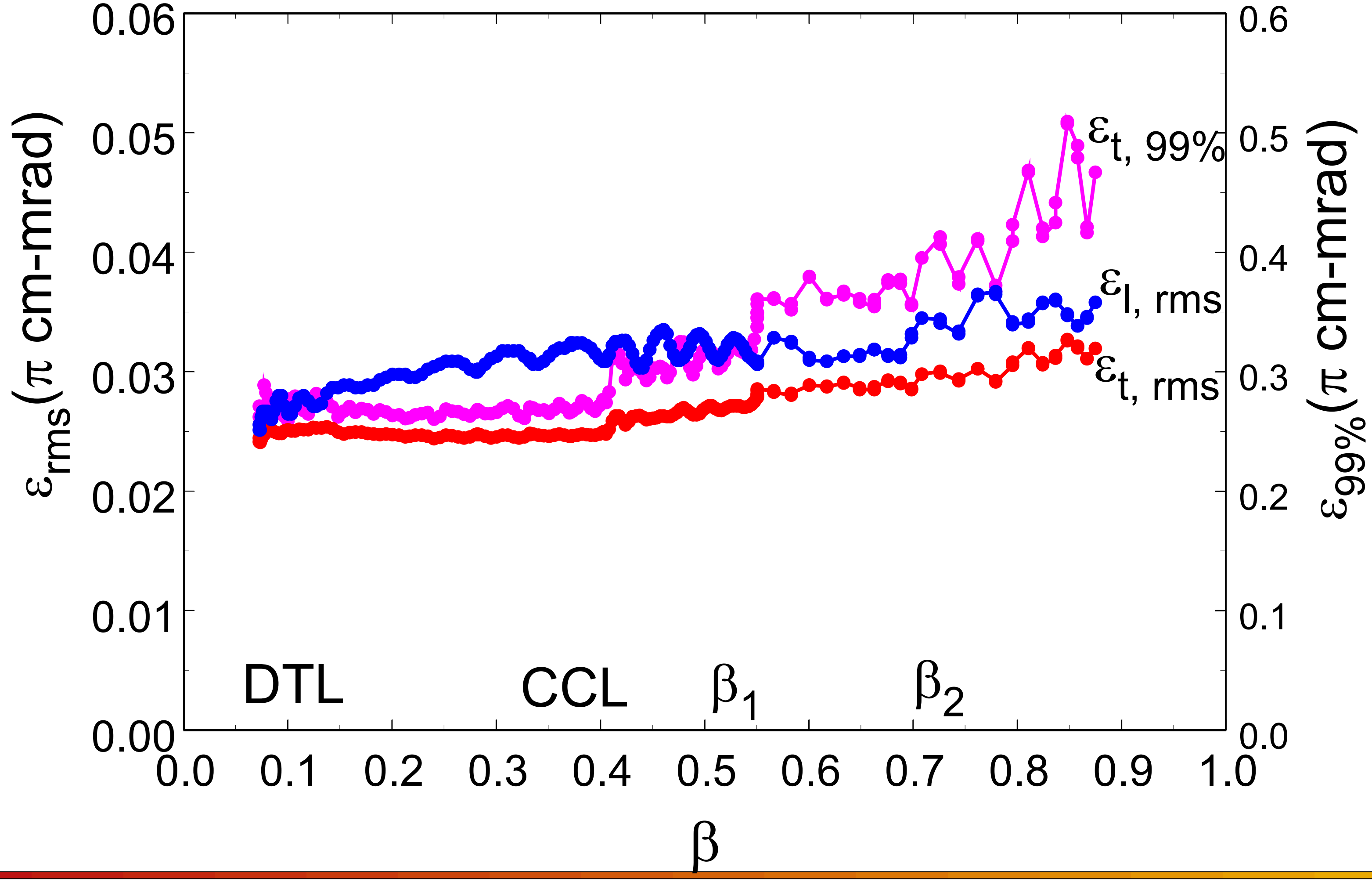
Beam Distribution at DTL Entrance



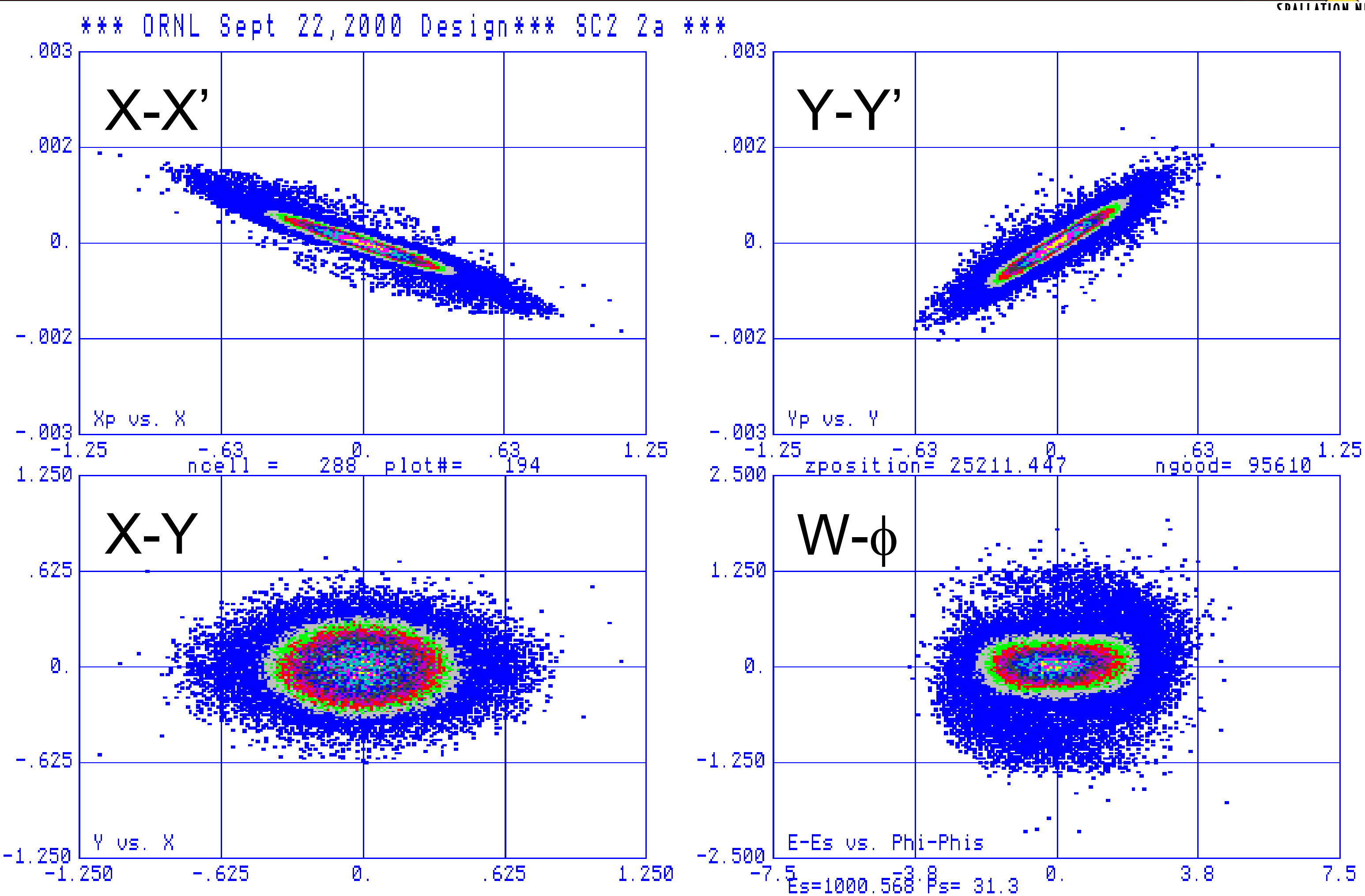
Profiles Show a Matched Beam



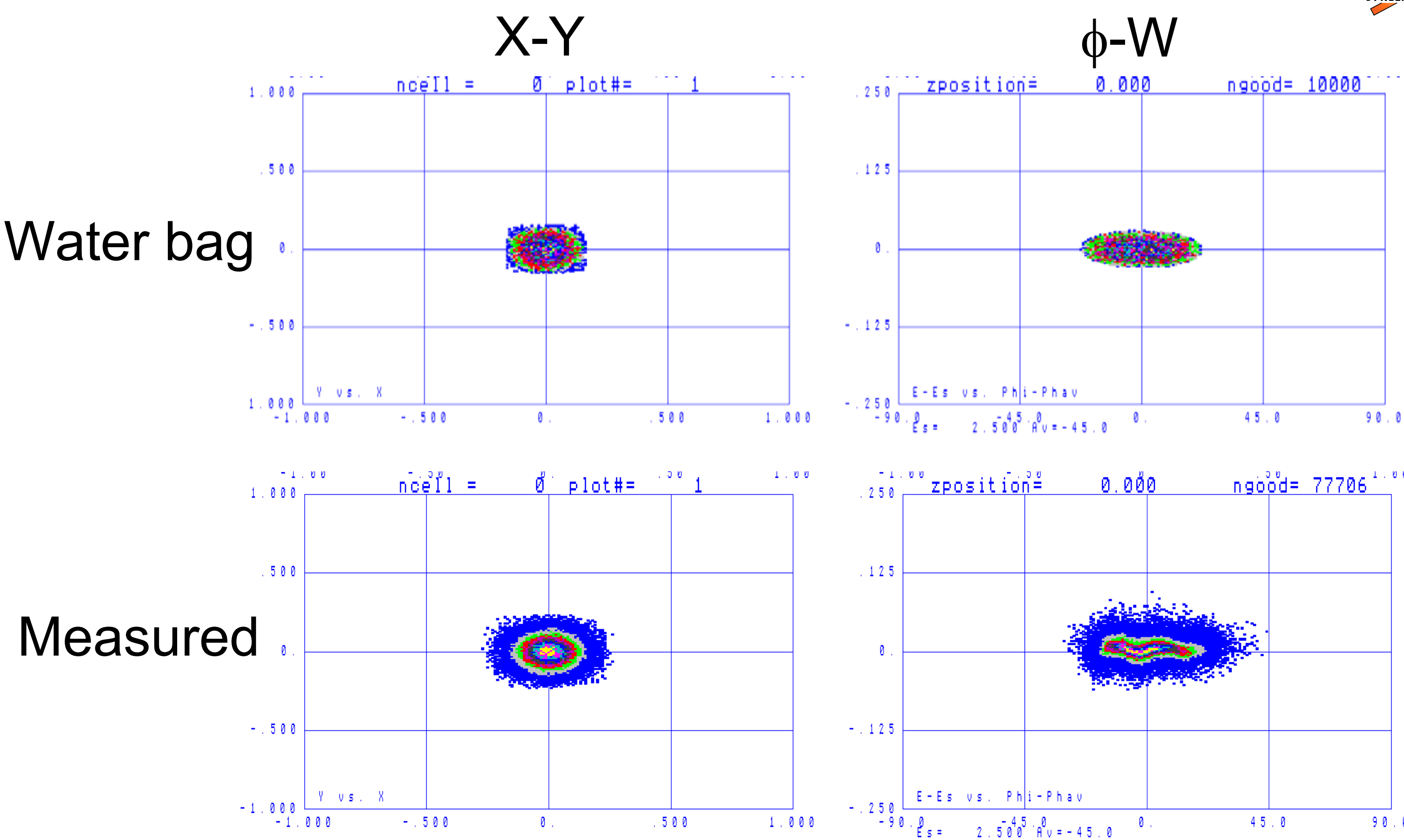
30% RMS Emittance Growth, Without Errors, Meets Design Spec.



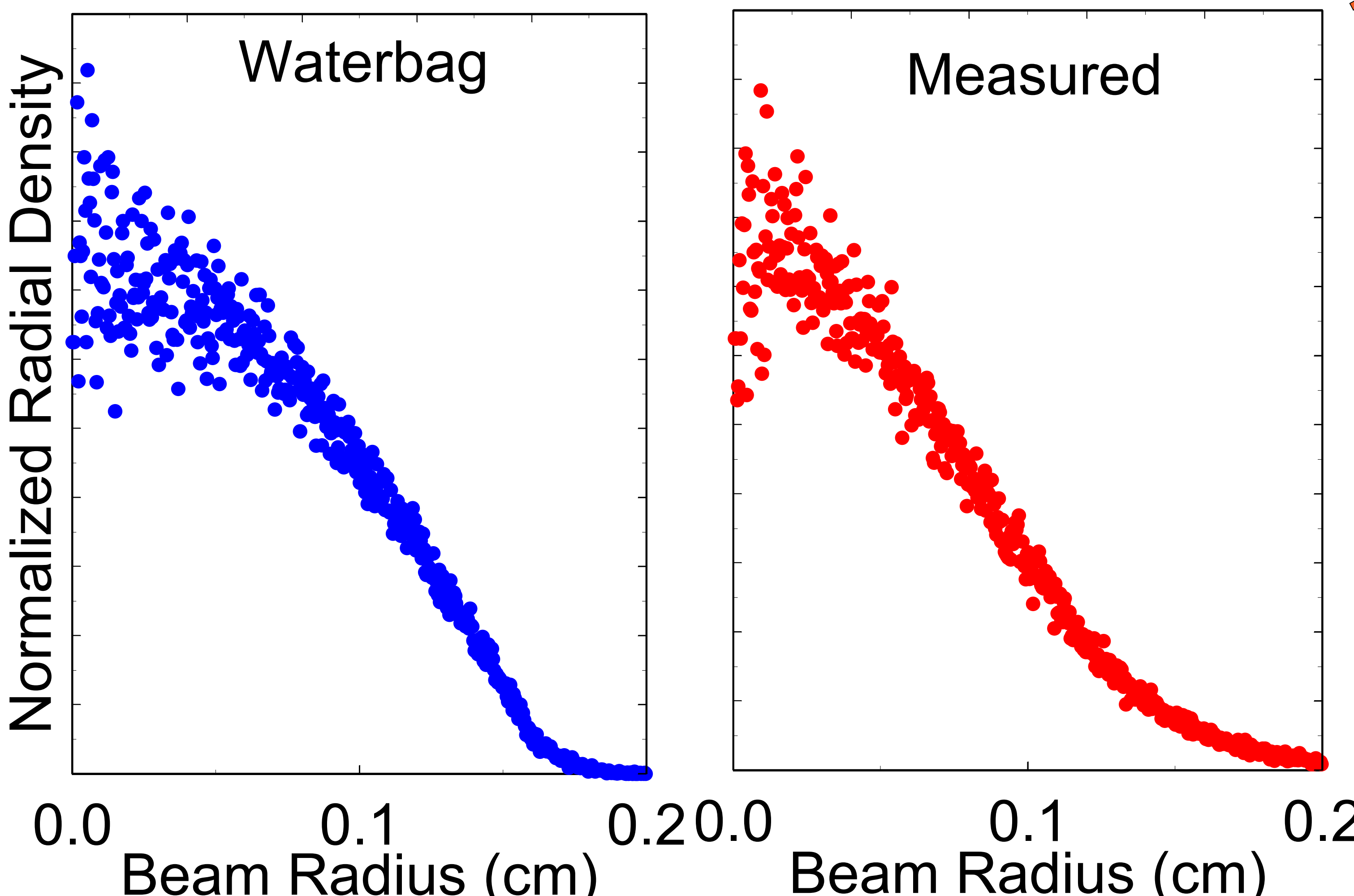
Beam Projections at 1 GeV Show Some Halo



Beam Projections at RFQ Exit Show that Distributions are not Filtered by the RFQ



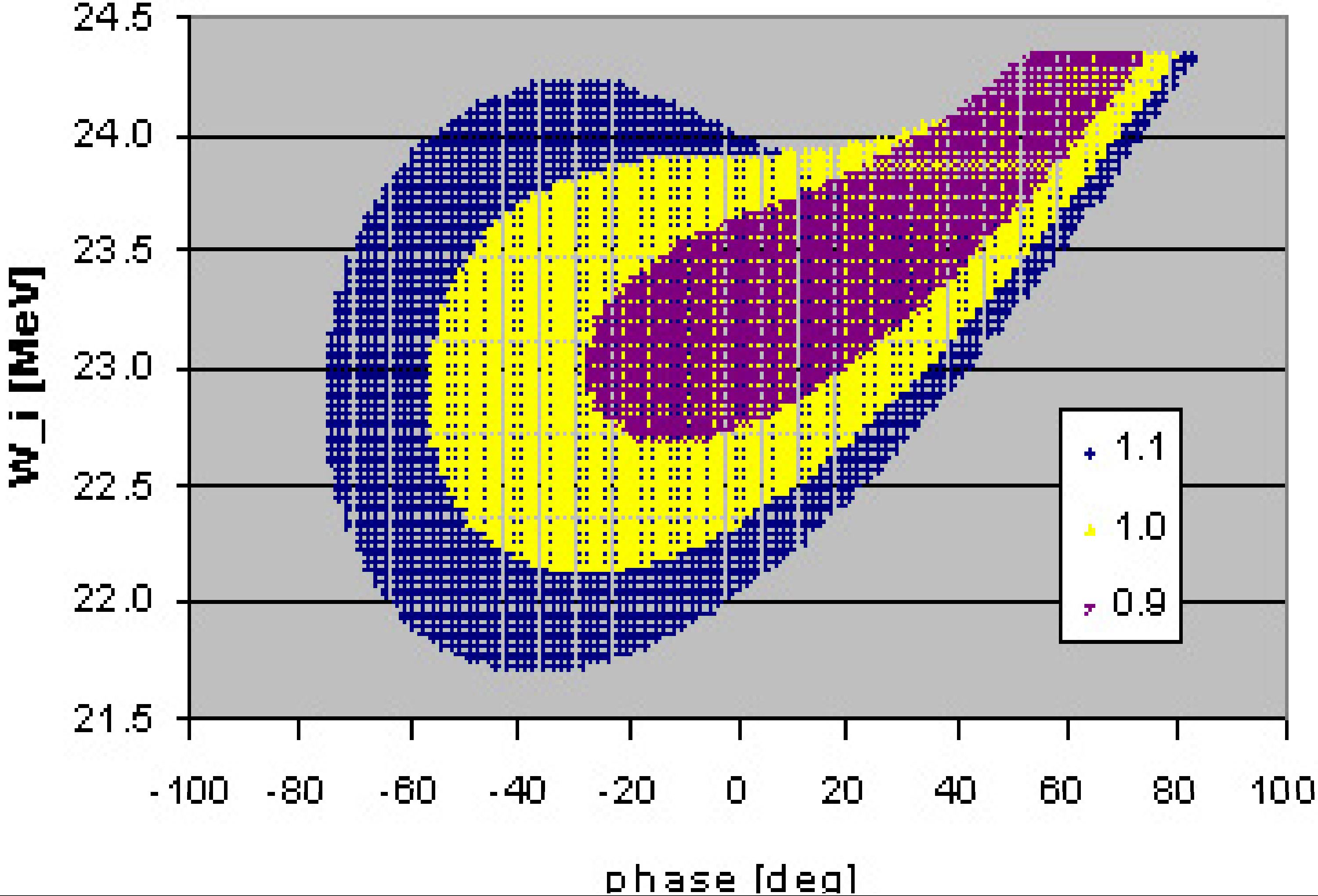
Beams have the Same RMS Properties at RFQ Exit



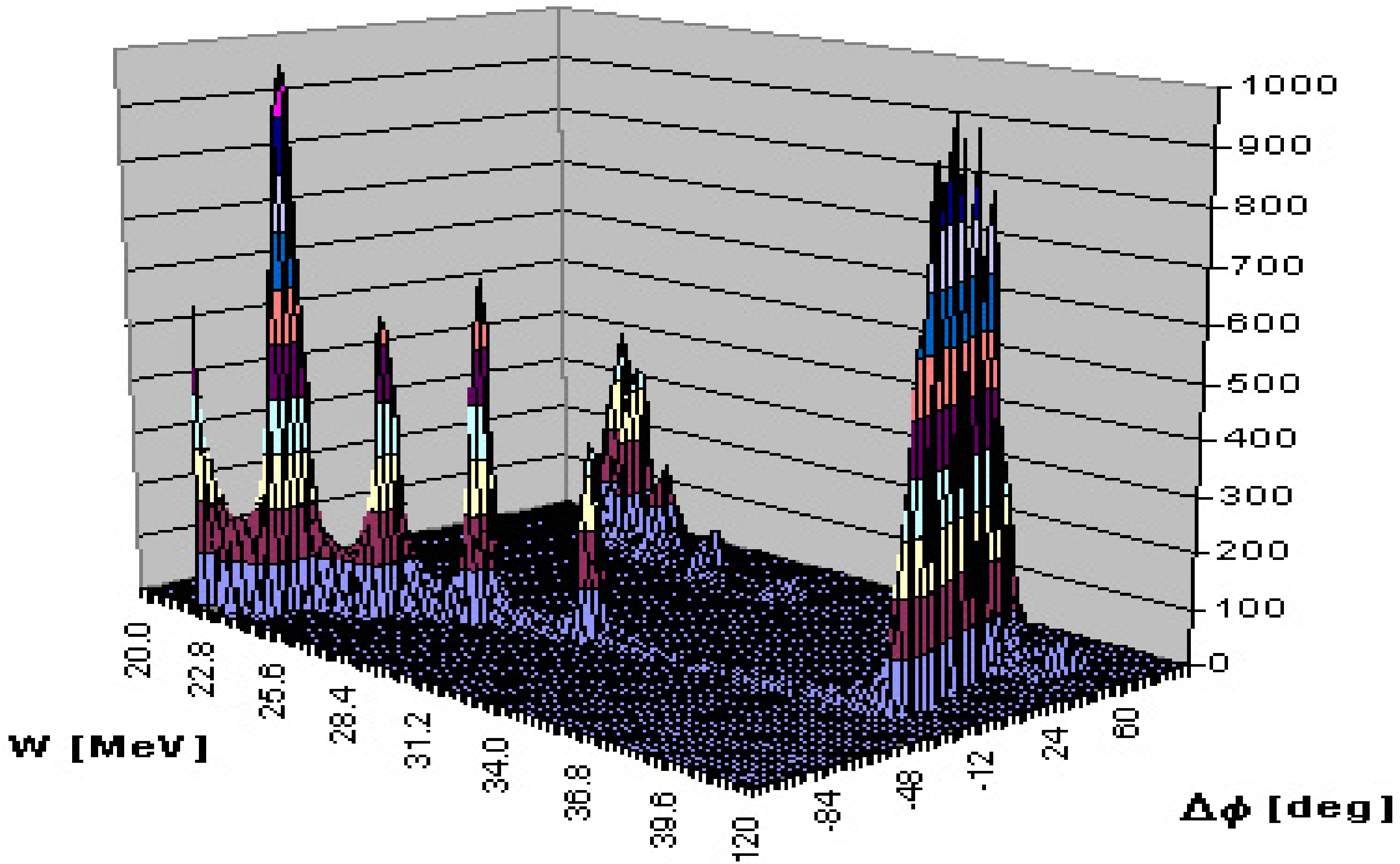
Status of Linac Studies

- Design is “frozen”
- Specifications met for:
  - rms emittance
  - Spatial stability
  - Energy Stability
  - Energy spread
- Error studies are proceeding with “measured” beam distribution
  - Beam loss patterns
  - Distribution on the foil
- Tuning algorithms are under development

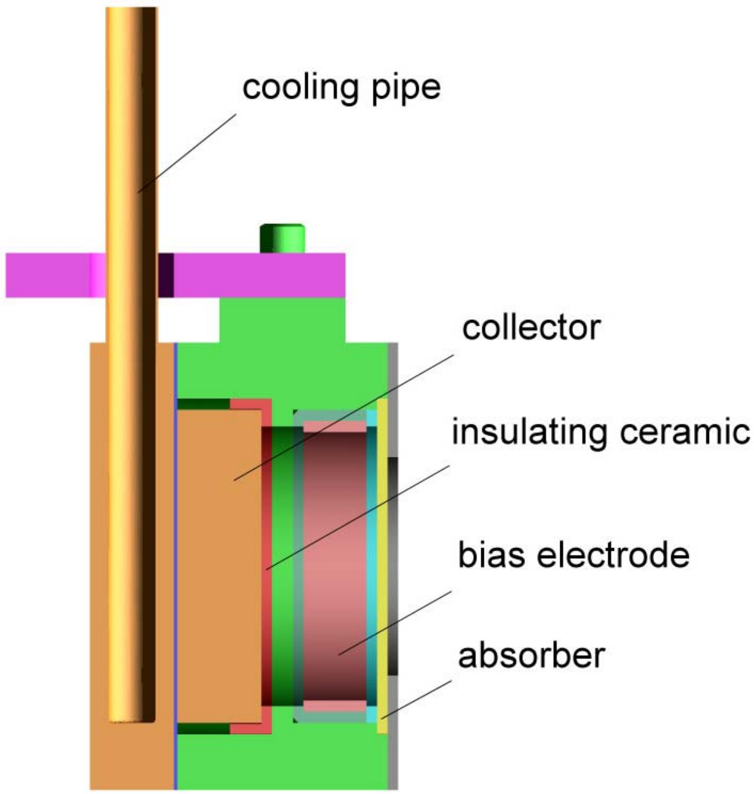
Tank 3 Longitudinal Acceptance For 3 Values of E_0

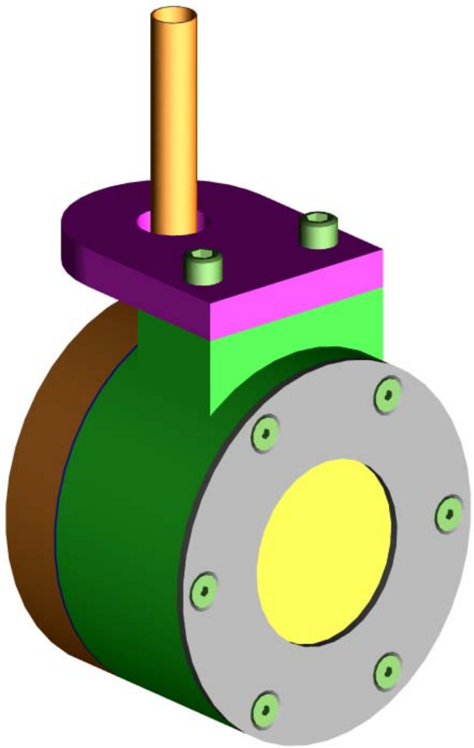


Composite Energy Spectrum During a Phase Scan

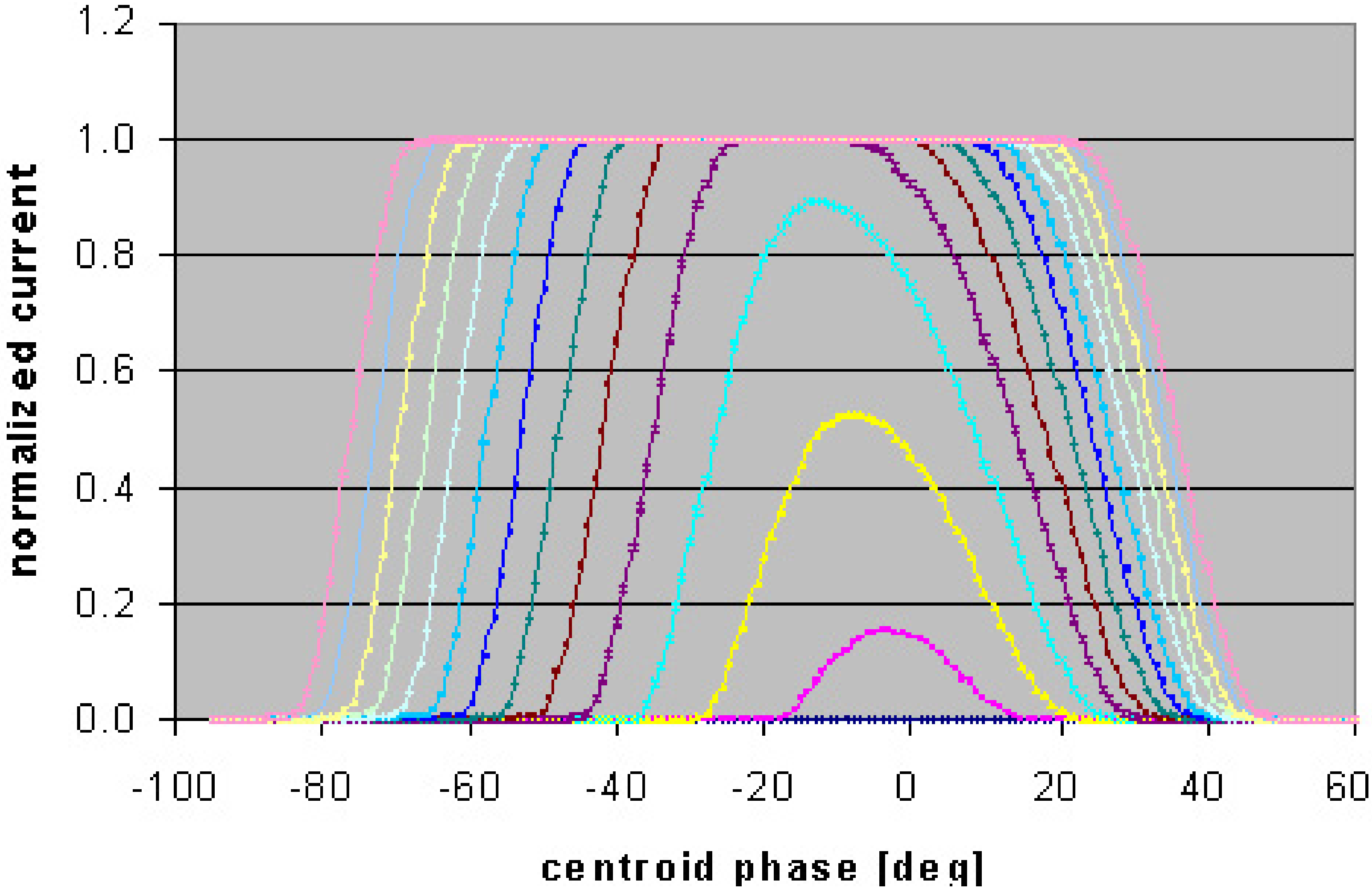


Energy-Degrader/Faraday-Cups Are Located Between Tanks

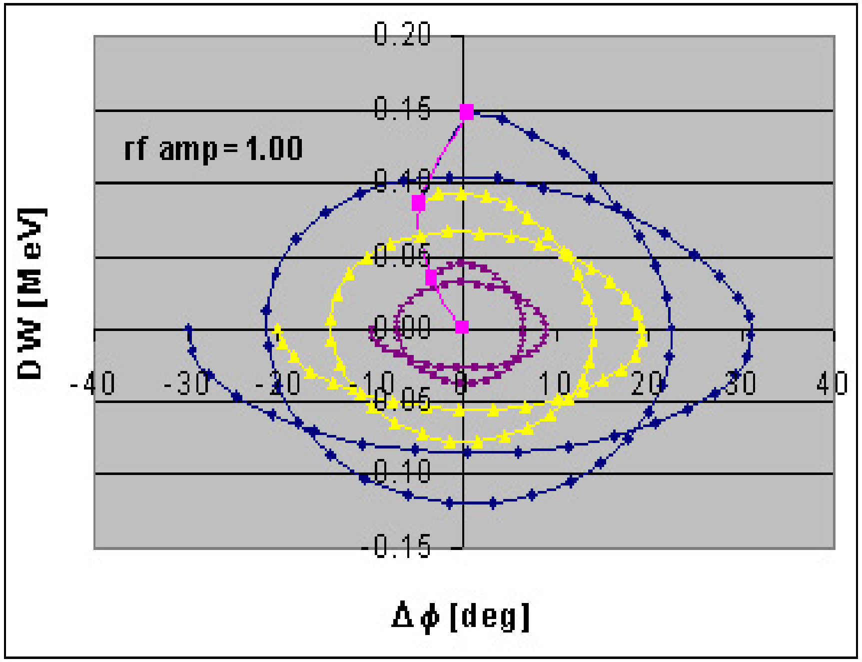


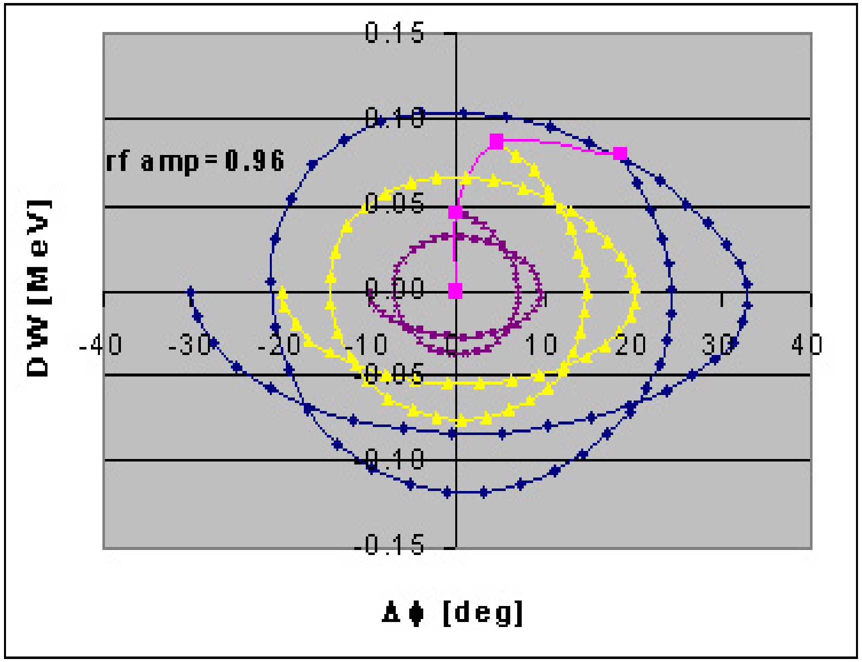


Tank 3 Phase Scan for E_0 = 84-110 % of Design



Longitudinal Motion in a DTL Tank





- Phase advance for 100% and 96% of design

TOF Phase Scan of Tank 2