

DOE Lehman Review



Linac Design Status

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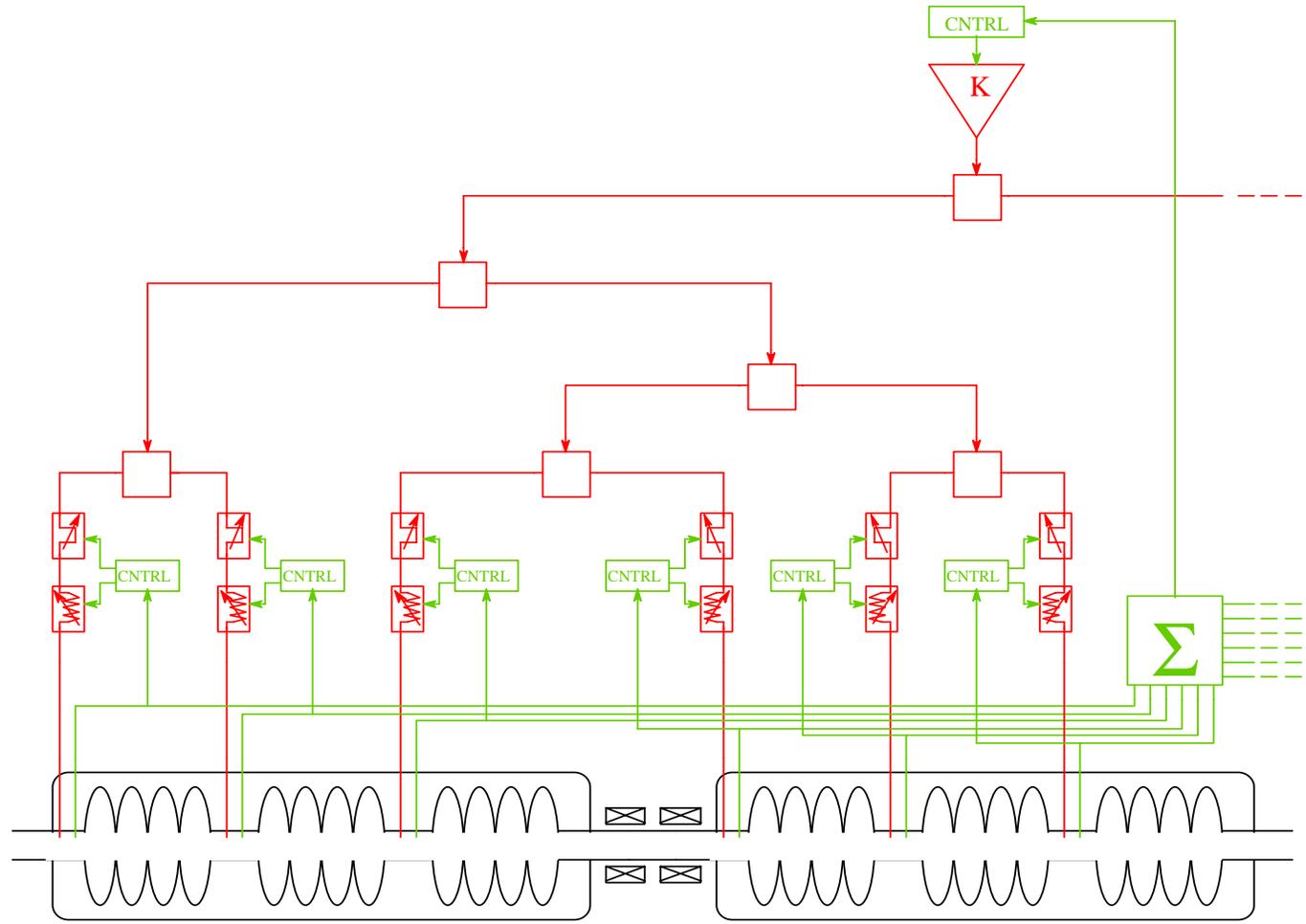
31 October 2000

Outline



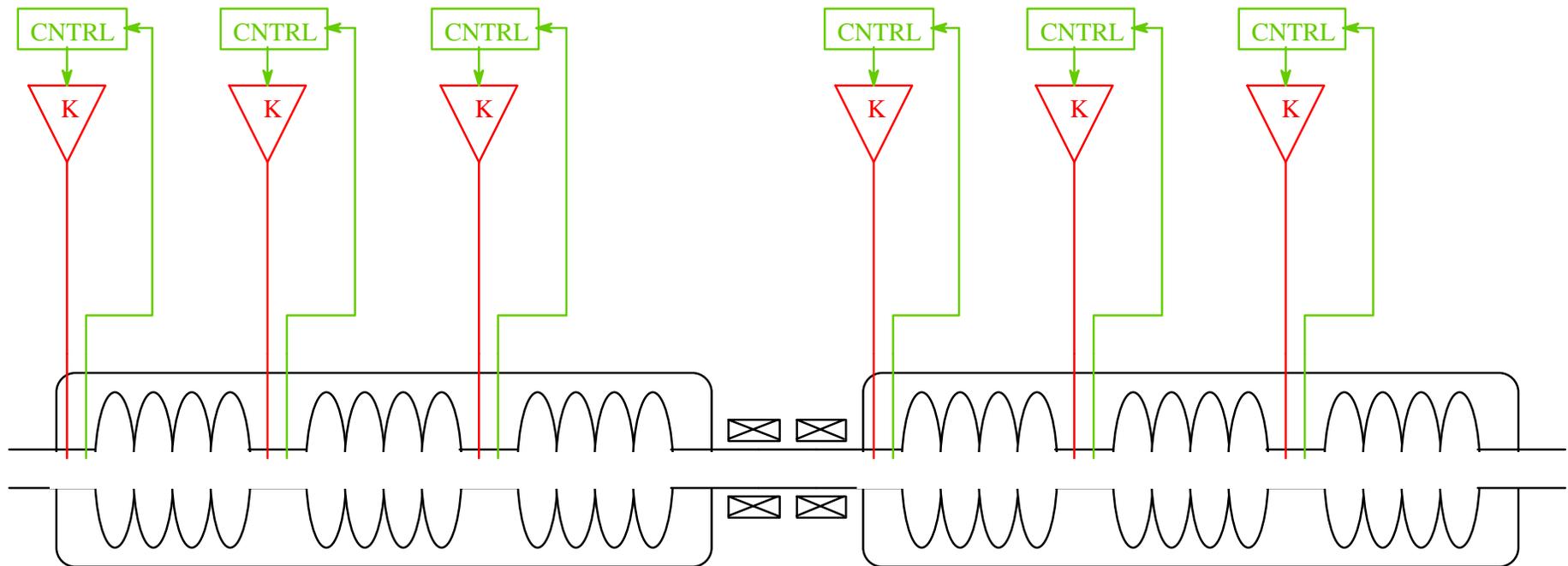
- **SRF Linac design**
- **End-to-end beam dynamics simulations**
- **Cavity physics (Billen)**
- **SRF Beam commissioning (Young)**

“March” Design, 12 Cavities/klystron Individual + Collective Cavity Control



Reference Design

1 Cavity/Klystron Individual Control



Linac Architecture Summary



Structure	W_{final}	Total Length	Cells per Cavity	Cavities per Module	Modules	No of Klystrons	Structure Length
	MeV	m					m
DTL	86.8	36.6	60 to 21		6	6	36.6
CCL	185.6	91.9	8	12	4	4	55.4
SRF I	379.2	157.7	6	3	11	33	64.2
SRF II	948.7	276.0	6	4	15	59	118.4
SRF upgrade	1227.6	323.4	6	4	6	25	47.3

Structure	HVPS	HVPS Power	Transmitters	Klystrons	Klystron Power
		MW			MW
RFQ & DTL	3	10	7	7	2.5
CCL & HEBT	5	10	6	6	5.0
SRF I & II	8	10	16	92	0.55
SRF upgrade	3	10	5	25	0.60



Linac Design is Mature

- DTL Physics design is complete
 - Cavity cold-modeling underway
 - Field stabilization scheme demonstrated
- CCL Physics design is complete
 - Cavity cold-modeling underway
 - Cavity geometry finalized
 - details being incorporated into design
 - Bridge-coupler details under study
 - Hot-model in fabrication
- SRF Reference design is complete
 - Cavity layout is frozen
 - Investigating alternate phase & quad laws



Linac Interfaces are Mature

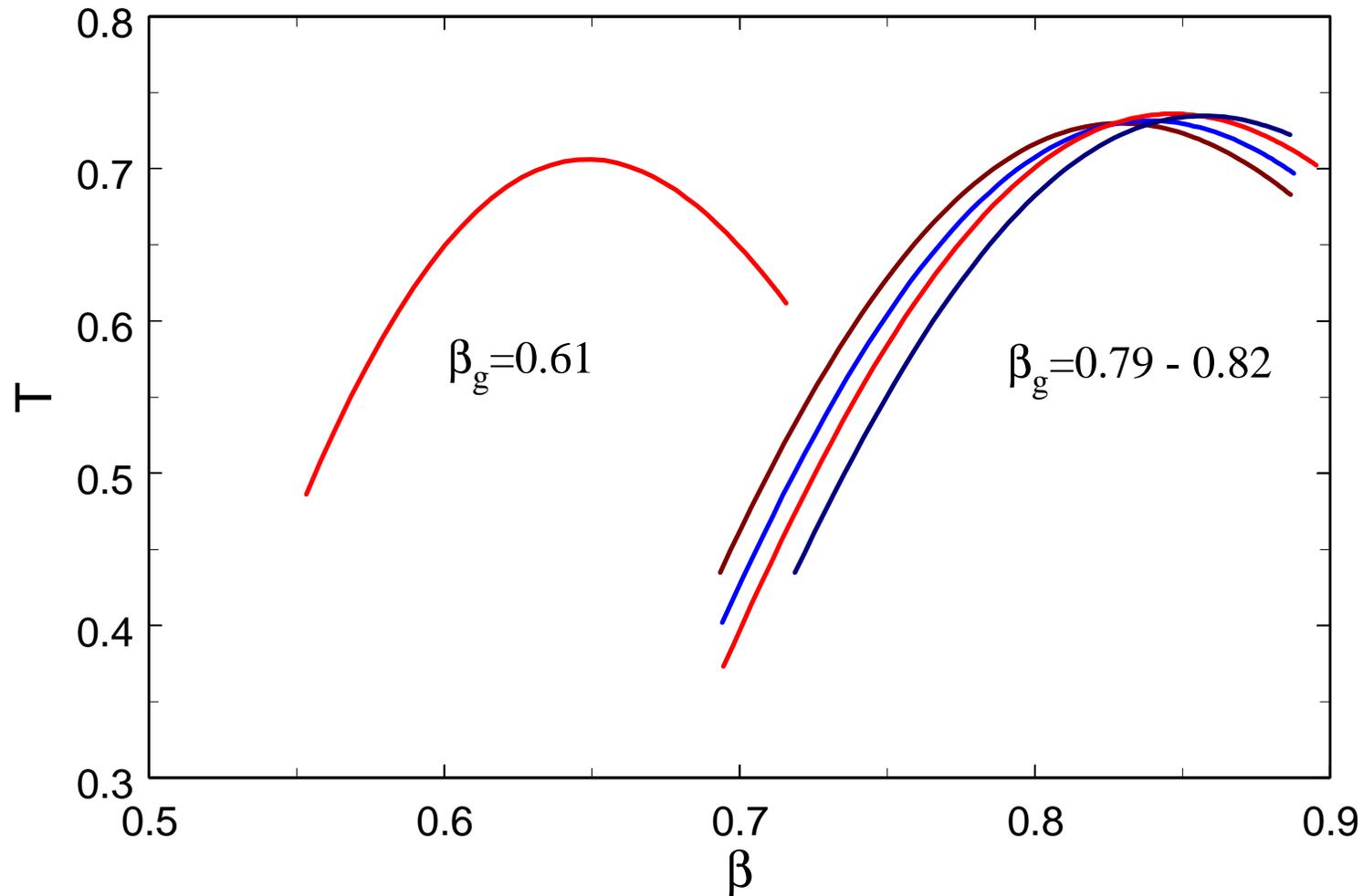
- MEBT-DTL: dimensions are frozen, matching is complete
- DTL-CCL: dimensions are frozen, matching is complete
- CCL-SRF: dimensions are frozen, have a matched solution
- SRF β_1 - β_2 : have a matched solution
- SRF-HEBT: length frozen
 - end-to-end simulations underway
 - energy corrector/spreader cavity-physics design complete
 - HEPT interface workshop in Dec.

SRF Design is Based on 2 Cavity β s

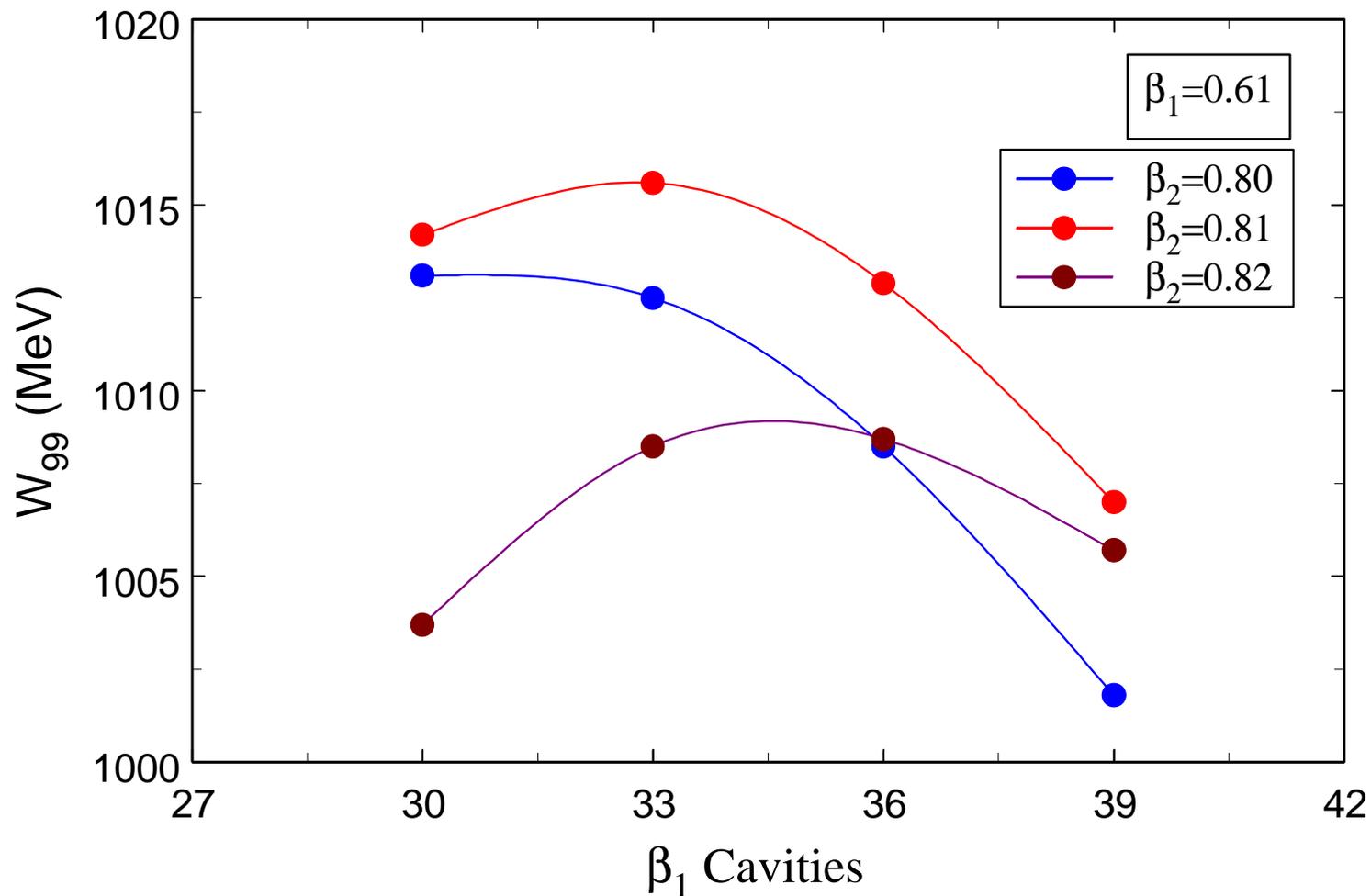


- $E_{\max} \leq 27.5$ MV/m
- Optimized for cost with 2 β cavities
 - a 3rd lower- β cavity would be too numerous & inefficient
- $\beta_1 \equiv 0.61$
 - based on earlier 2-cavity design studies
 - 5 MW CCL modules coarsely quantize initial energy
- $0.74 \leq \beta_2 \leq 0.82$
 - higher β provides more efficient acceleration
 - i.e. higher E_0 , T & L_{cav}
 - if $E_{\max} > \langle E_{\max} \rangle$, higher β supports a higher W_{final}
- Transition energy
 - maximized final energy for fixed cost machine

Transit Time Factors (T_{ave}) for Candidate Cavities Increase With β

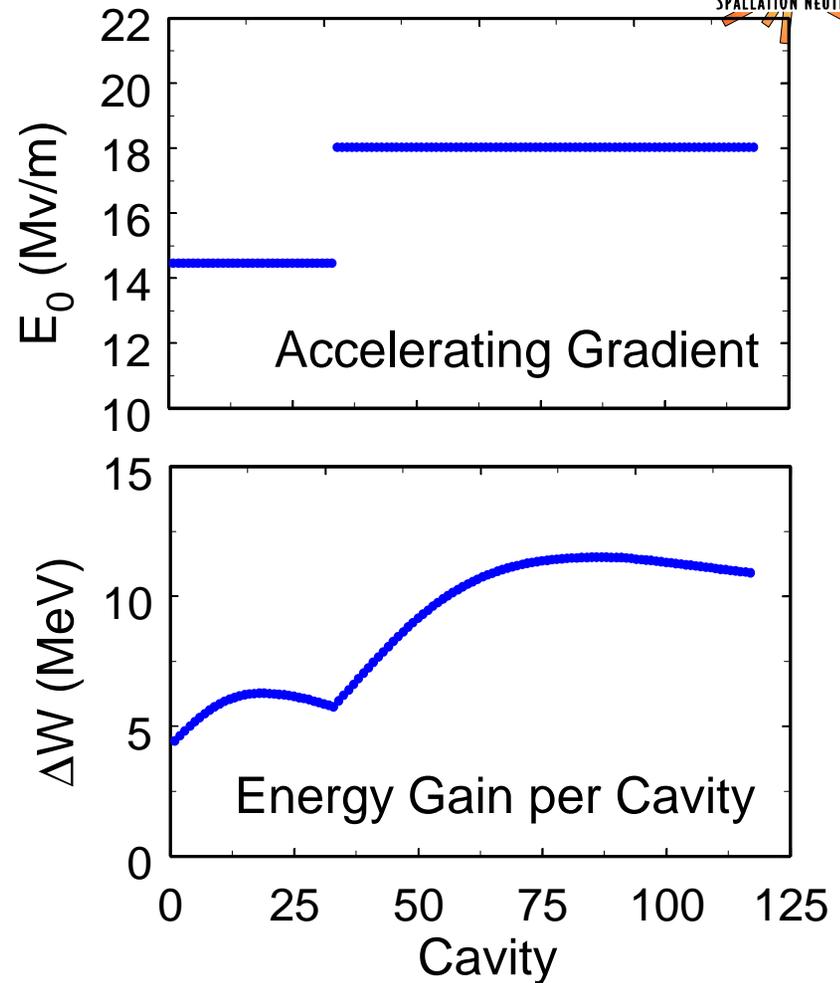
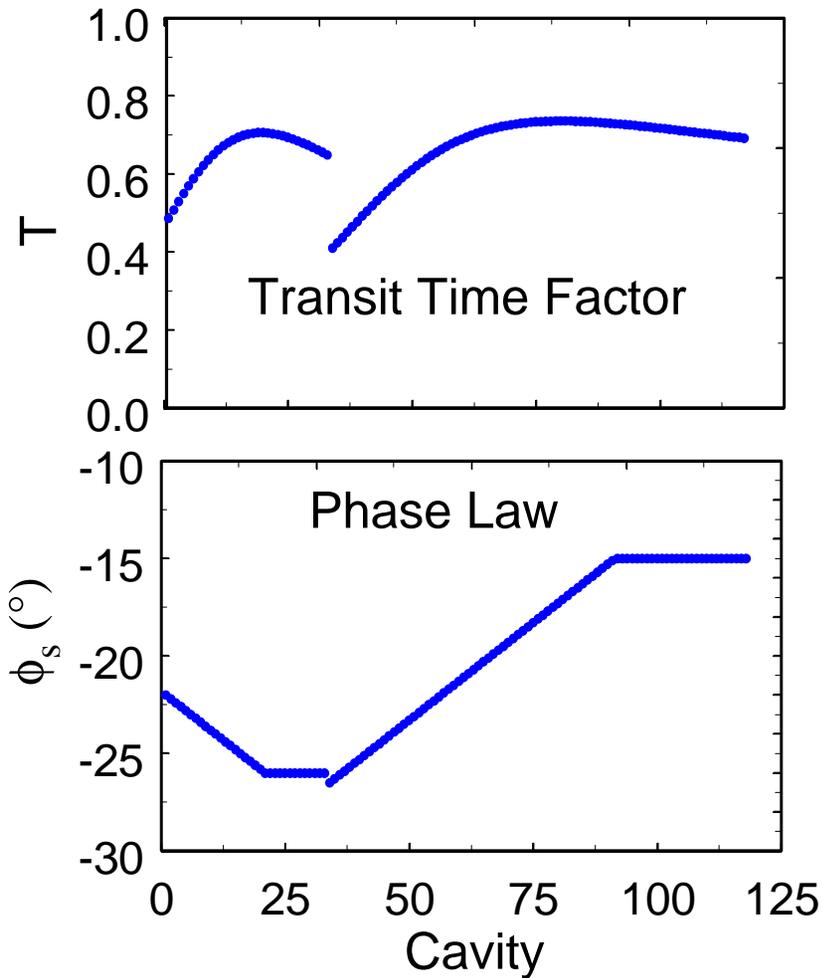


Cavity β & Transition Optimization for a Linac Having 99 Total Cavities

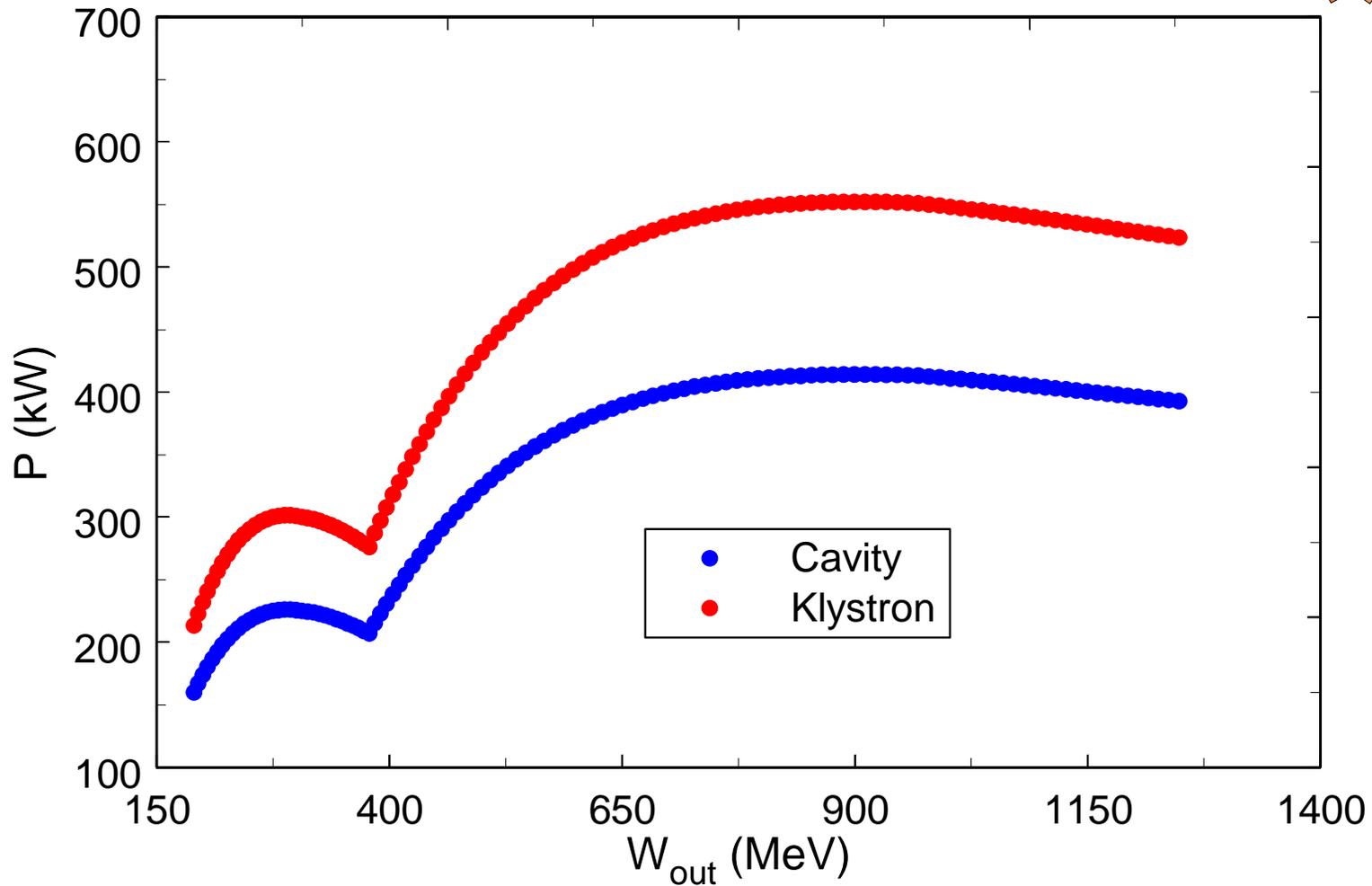


SRF Linac Design Assumes

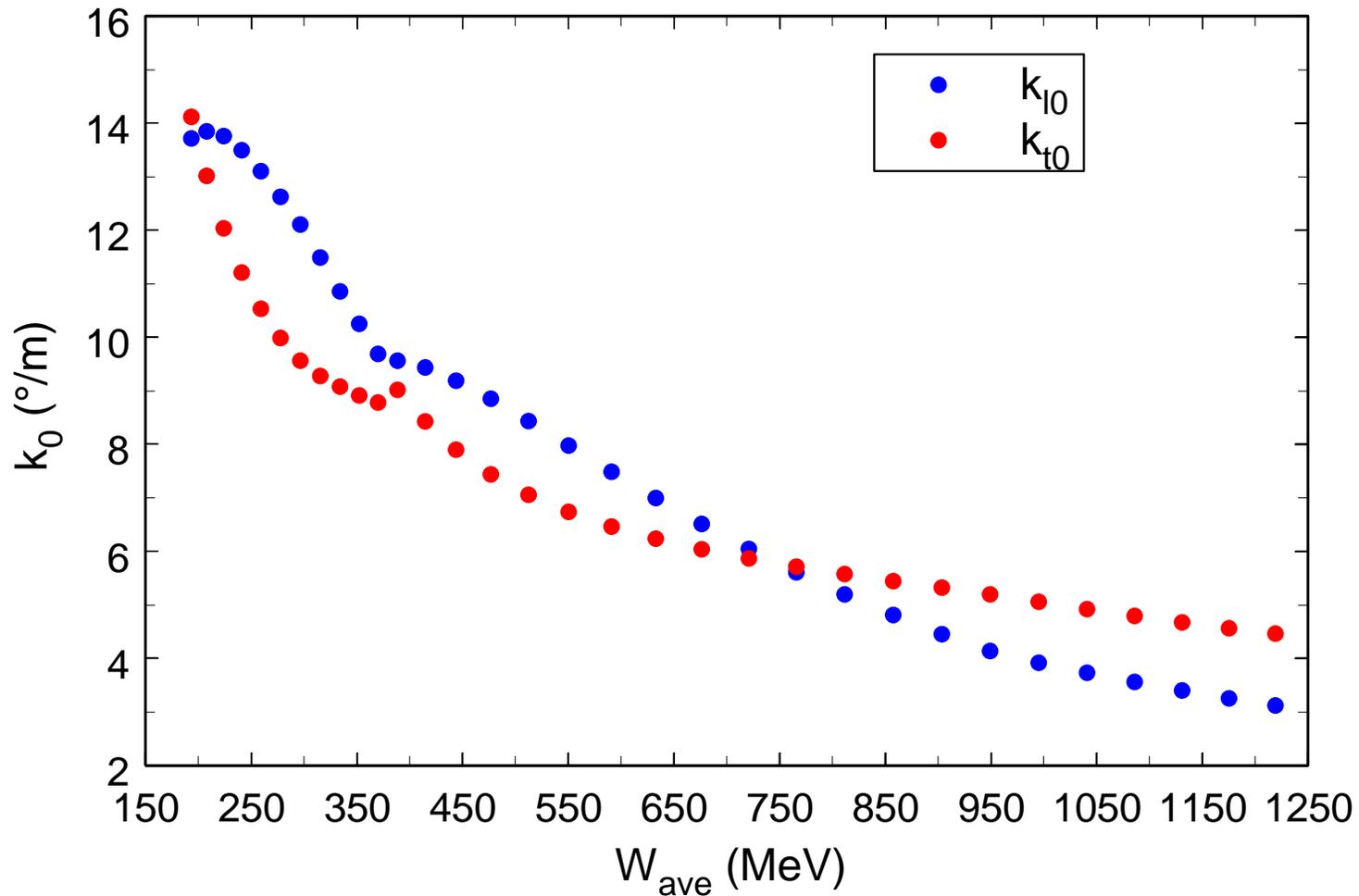
$E_{\max} = 27.5 \text{ MV/m}$



Beam Consumes 75% of Available rf Power



SRF Real-Estate Zero-Current Phase Advance is Smooth & Continuous

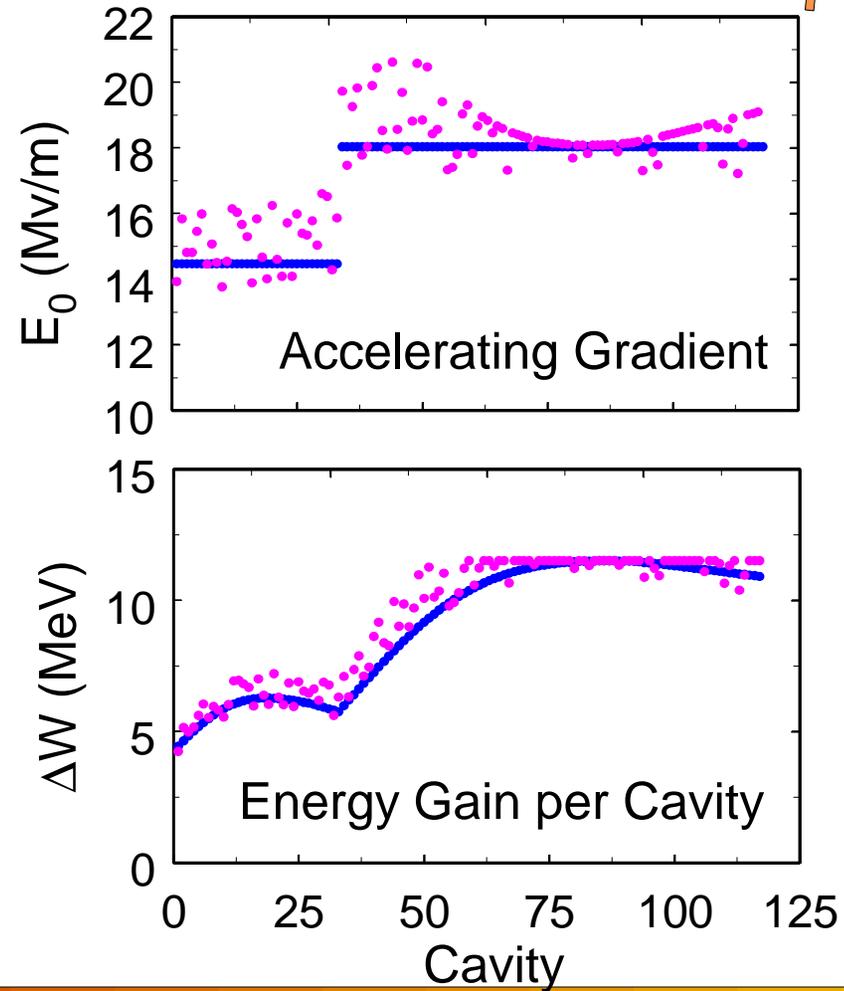
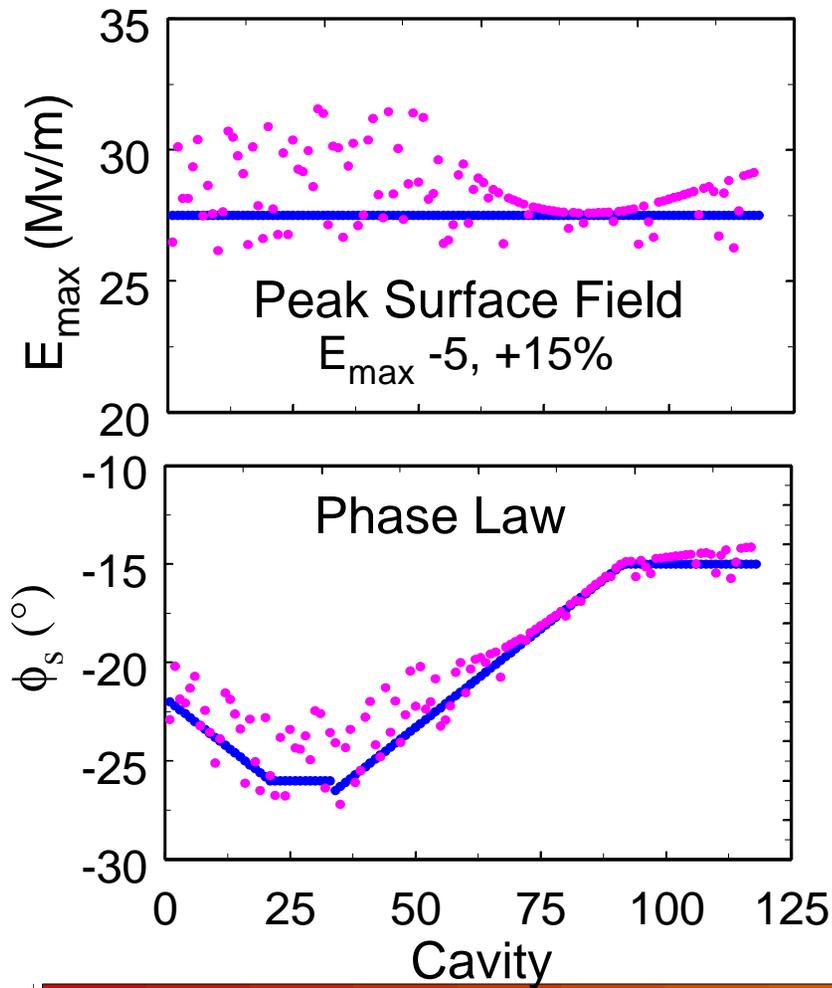


SRF Phase & Amplitude Set-Points Preserve Longitudinal Dynamics



- E_{\max} determined at acceptance for each cavity
 - $\langle E_0 \rangle \approx E_{\text{dsn}} \pm 10\%$
- Calibrate cavity field probes
 - using drifting beam to excite cavities
- $E_{0,\text{operating}}$ established for each cavity
- Corresponding $\phi_{\text{operating}}$ derived for each cavity
 - preserving longitudinal dynamics
 - holding $k_{0,l}$ constant
 - $k^2_{0,l} \equiv E_{0,\text{design}} T(\beta) \sin(\phi_{\text{design}} / \beta^3 \gamma^3)$
 - $\phi_{\text{operating}} = \beta^3 \gamma^3 \sin^{-1}(k^2 / E_{0,\text{operating}} T)$

SRF Operating Example for a Representative Set of Cavities

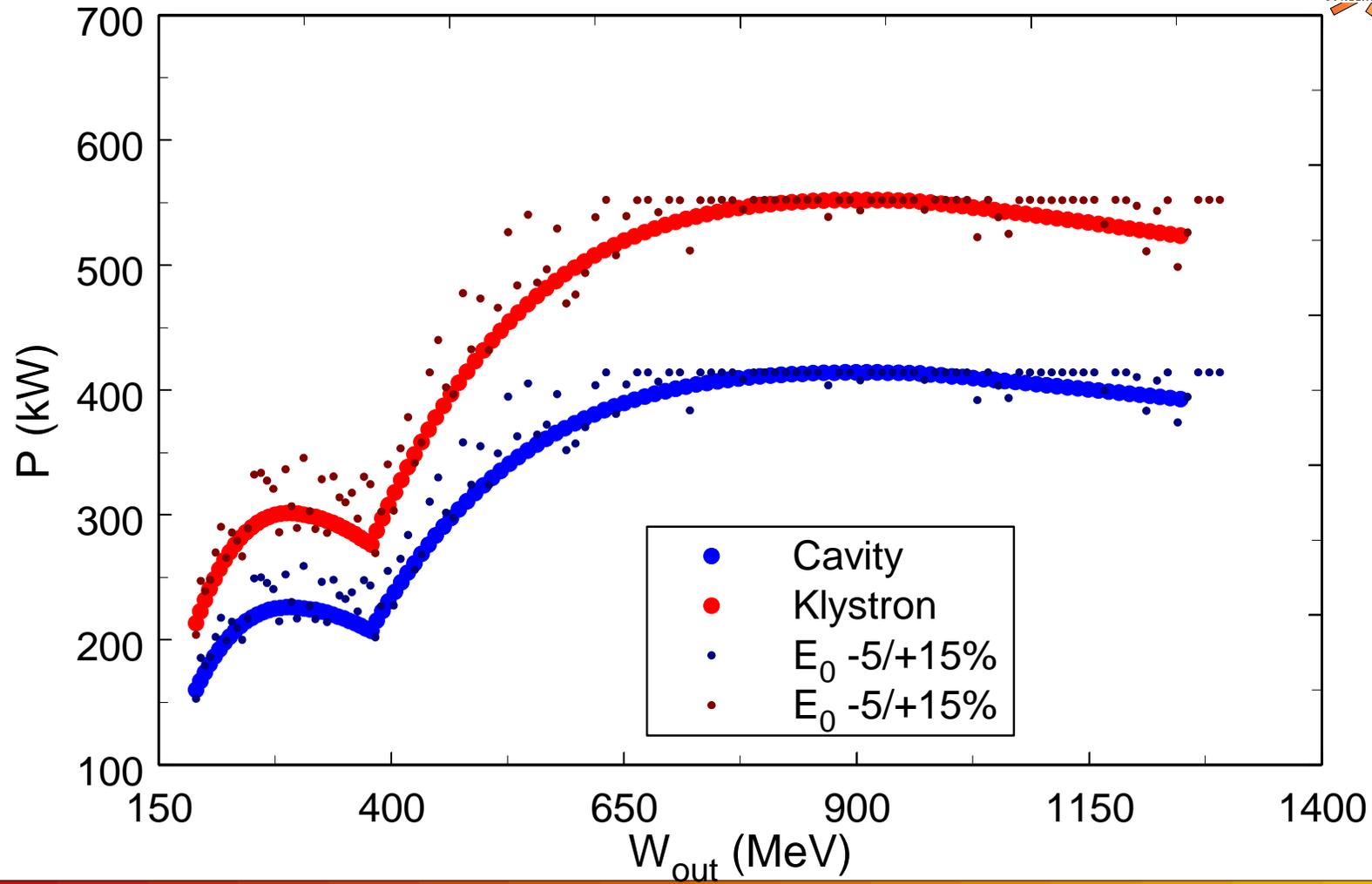


SRF Linac Will Have 184 Static Field Errors Effecting W_{final}



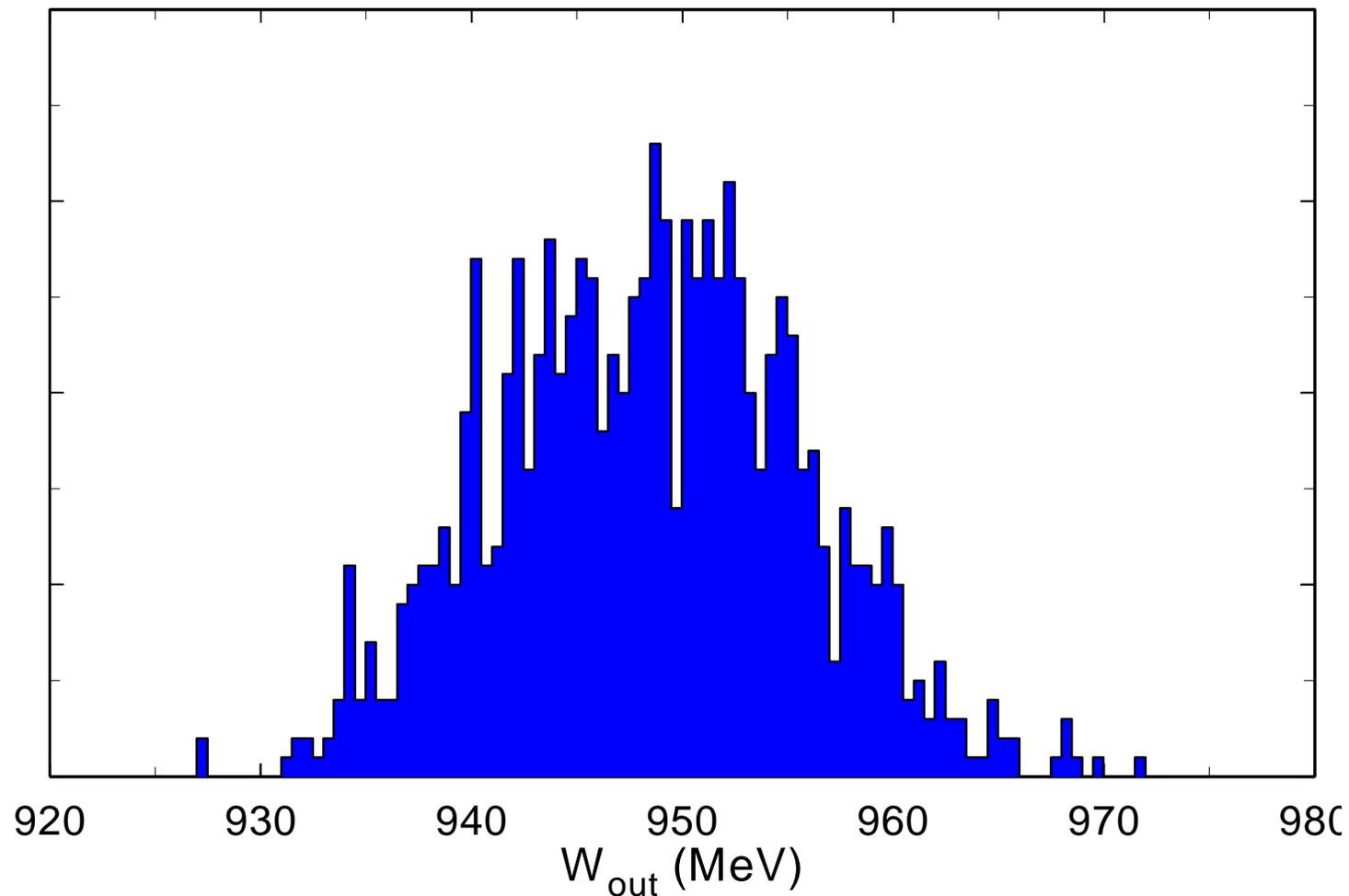
- Design cavity field: $E_{0,\text{design}}$
- Cavity performance varies: $E_{0,\text{operating}} = E_{0,\text{design}} \pm 10\% \text{ nom}$
- Field measurement error: $E_{0,\text{measured}} = E_{0,\text{operating}} \pm 5\% \text{ nom}$
- Design cavity phase: ϕ_{design}
- Phase set-point is derived: $\phi_{\text{setpoint}} = f(\phi_{\text{design}}, \beta, E_{0,\text{measured}})$
- Phase measurement error: $\delta\phi = \pm 2^\circ$
- Actual cavity phase: $\phi_{\text{operating}} = \phi_{\text{setpoint}} + \delta\phi$

W_{final} is Limited by E_{max} & Installed rf Power

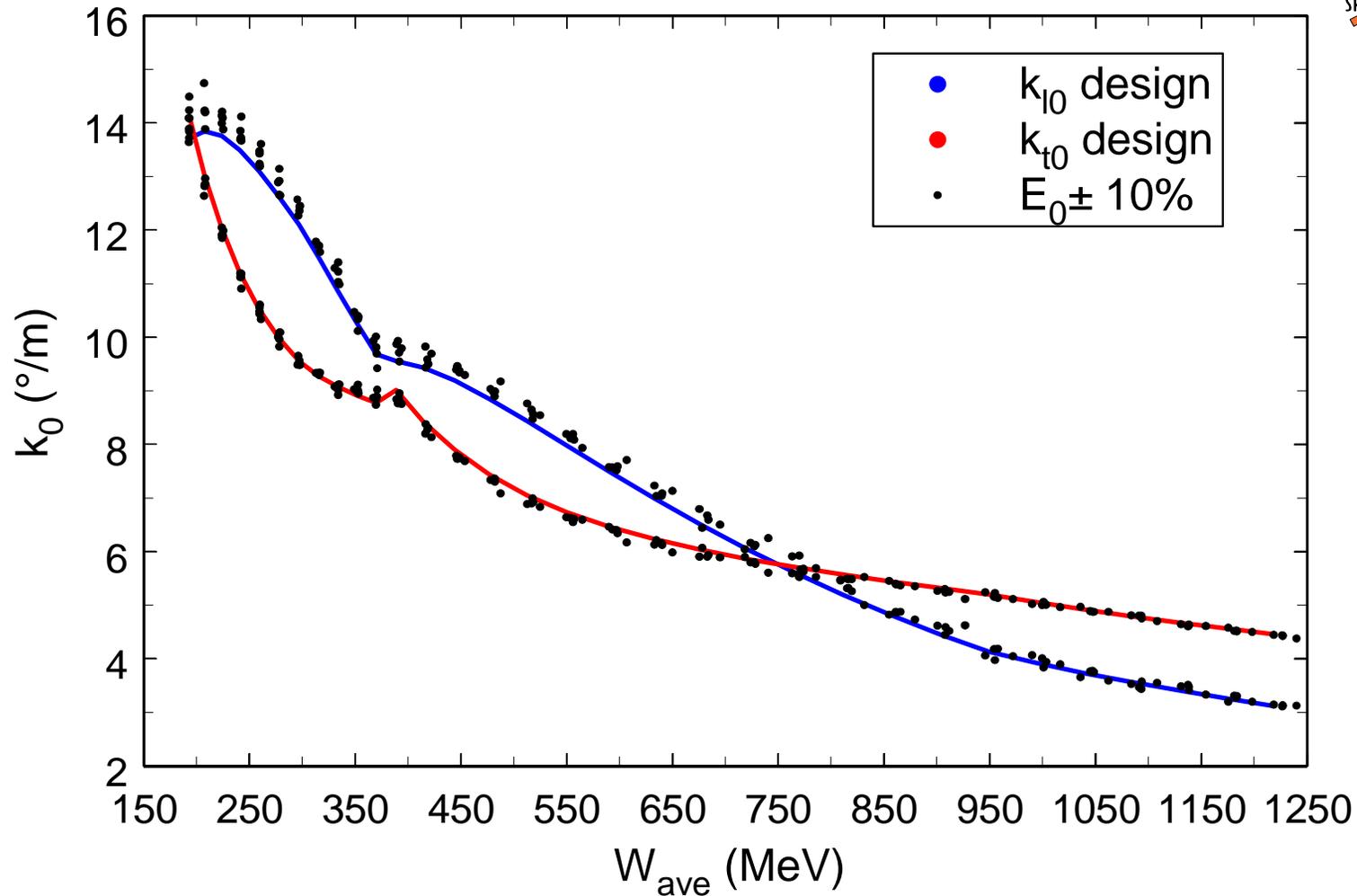


Expected Output Energy

$$E_{\max} = 27.5 \text{ MV/m} \pm 10\%$$



Tuning Philosophy ($k_{0,l}=\text{const}$) Preserves Beam Dynamics



End-to-End Beam Dynamics Simulations



- 4-D “Waterbag” distribution enters the RFQ
- RFQ beam dynamics calculated by:
 - Parmteq: multiparticle space based
 - Toutatis: multiparticle time based
- Linac beam dynamics
 - MEBT, DTL, CCL, SRF & HEBT
 - Parmila is the design code
 - Parmila, Linac & Impact calculate multiparticle beam dynamics
 - LTrace calculates envelope dynamics

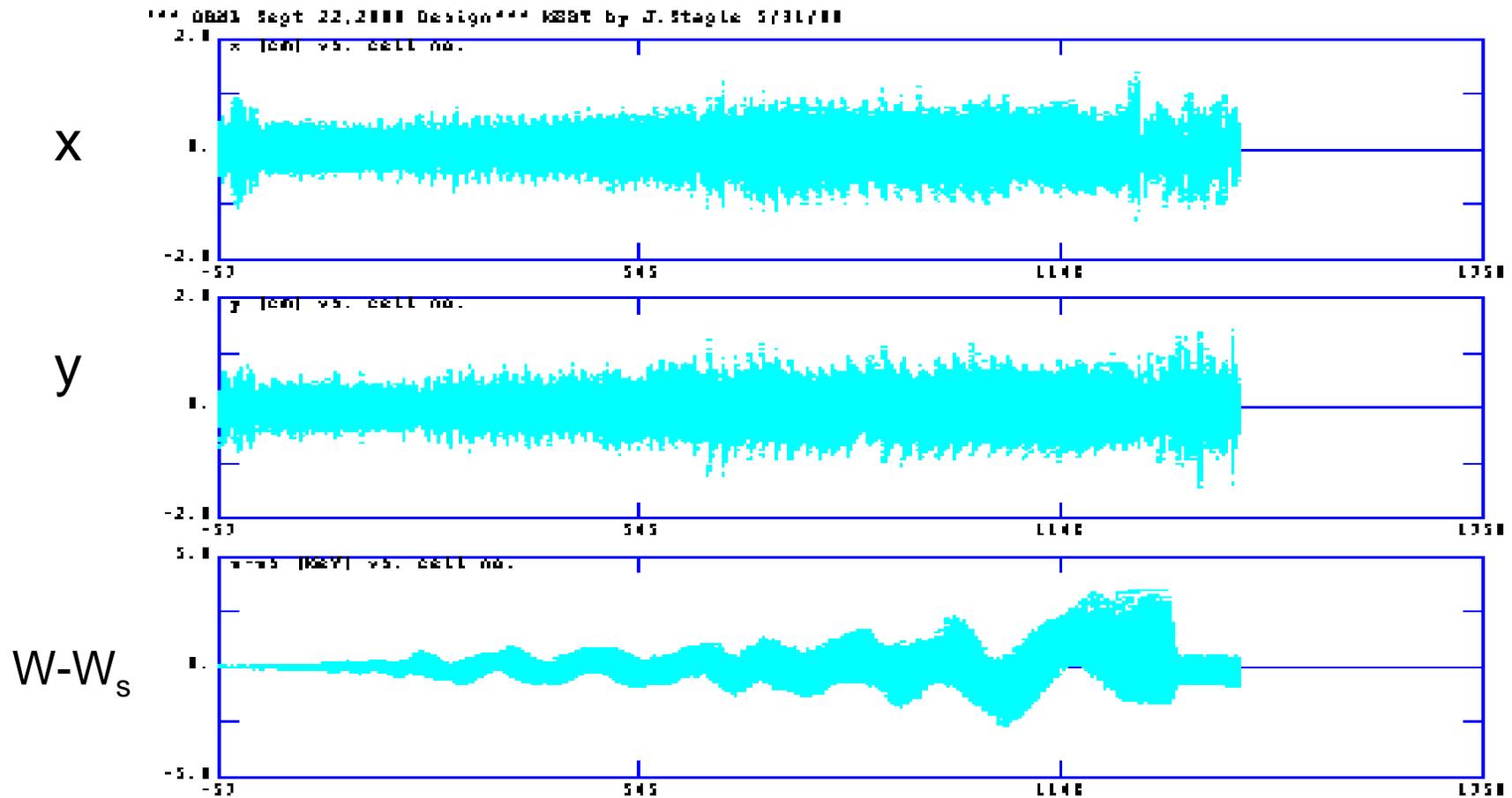
Error Budgets Included in Simulations to Date



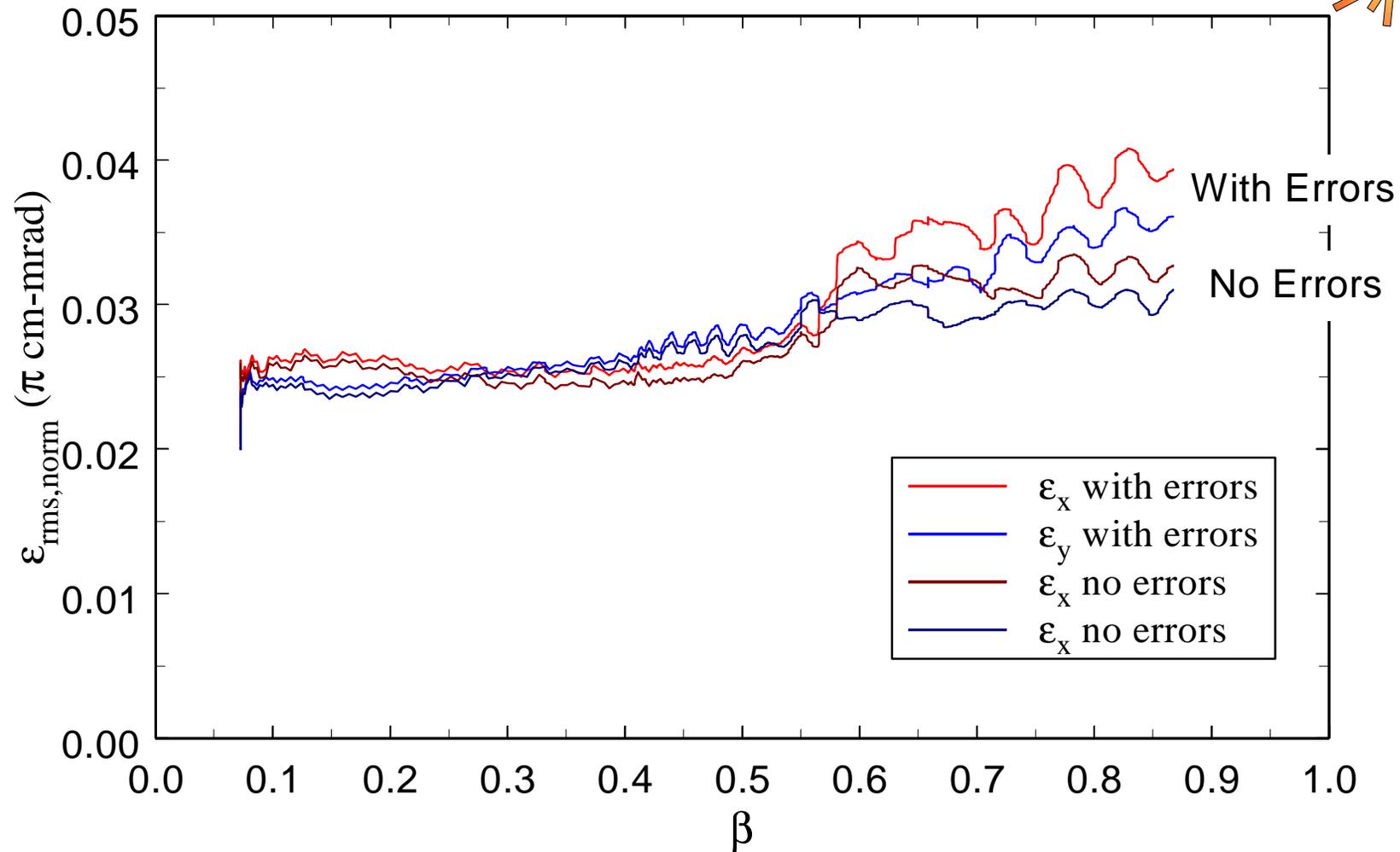
	Units	MEBT	DTL	CCL	SRF
Quad Errors:					
displacement	_cm	--	--	--	--
Pitch & yaw	deg	0.57	0.57	0.57	0.57
Roll	deg	0.25	0.29	0.29	0.29
Gradient	%	1.73	0*	0.5	0.5
Cavity Errors, Static:					
		--	--	--	--
Cavity Errors, Dynamic:					
Phase	deg	0.5	0.5	0.5	0.5
Amplitude	%	0.5	0.5	0.5	0.5
Tilt	%	--	0.1	0.	0.

* Equivalent to 2% sorted.

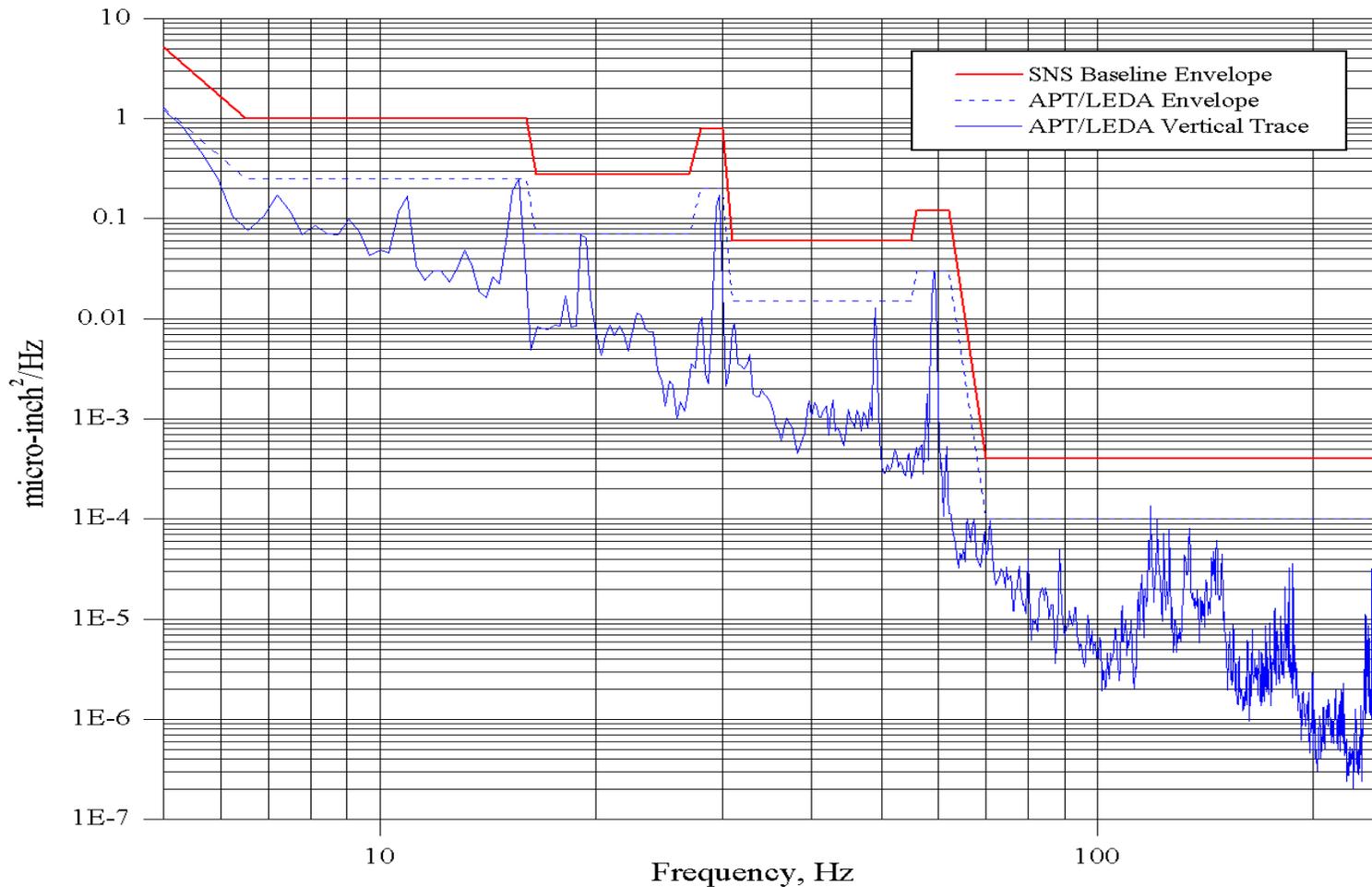
Beam Profiles for Reference Design With Errors



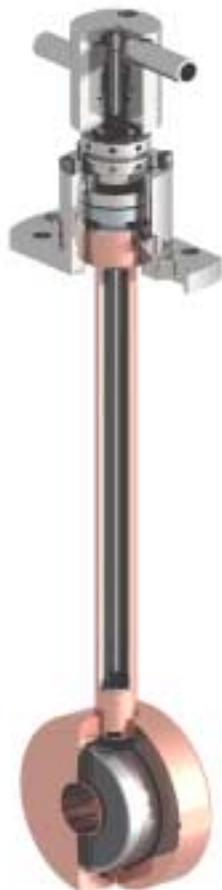
rms Emittance Profiles With & Without Errors



Expected Vibration Spectrum in the Linac Tunnel

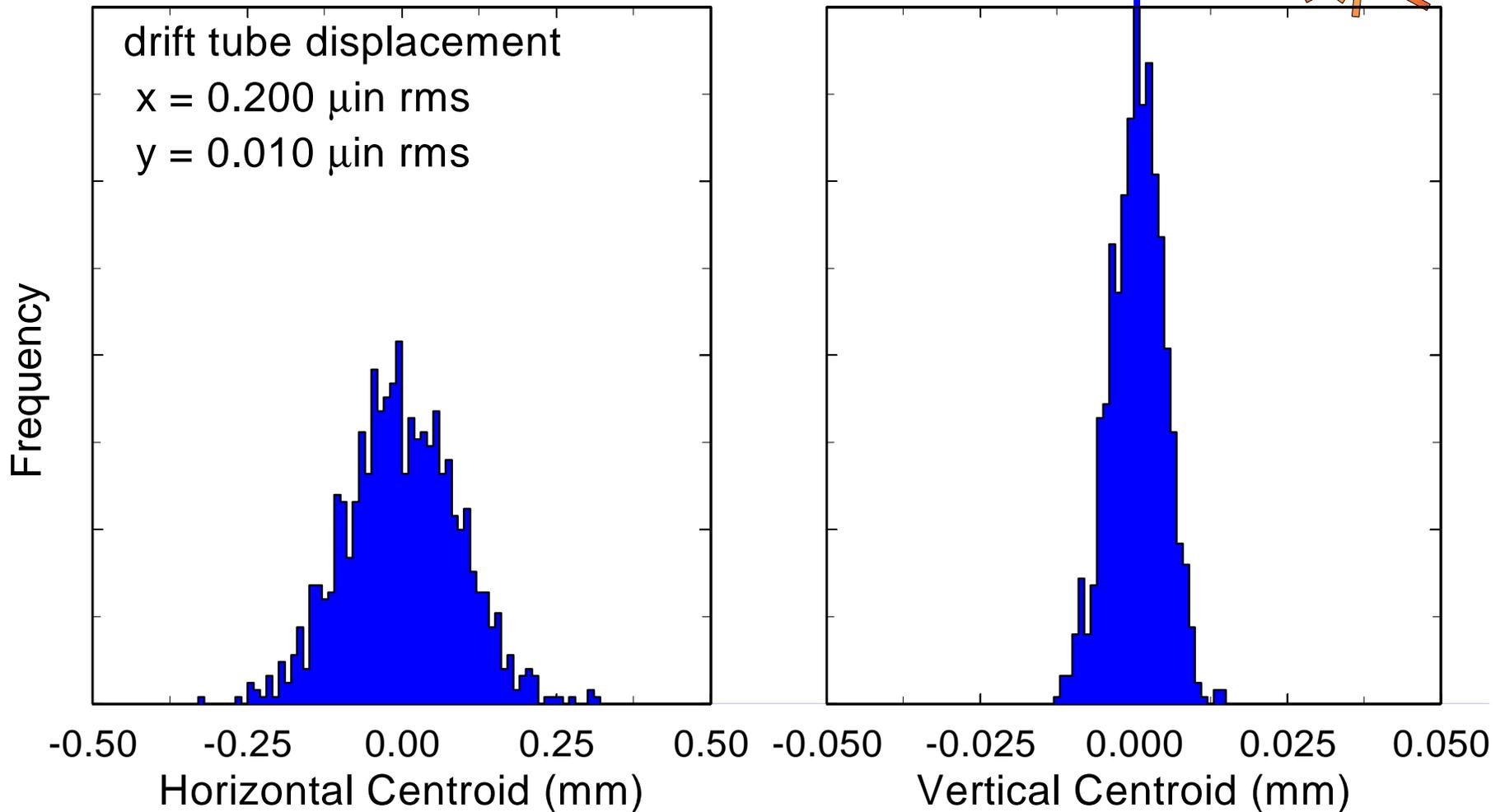


Vibration Amplitudes are Greatest in Tank 2



Drift tube	RMS Displacement		
	x axis	y axis	z axis
first	124 μ -in	24 μ -in	85 μ -in
~ middle	200 μ -in	10 μ -in	85 μ -in
end	148 μ -in	46 μ -in	86 μ -in

Transverse Jitter at the Foil is a Function of Quadrupole Vibrations

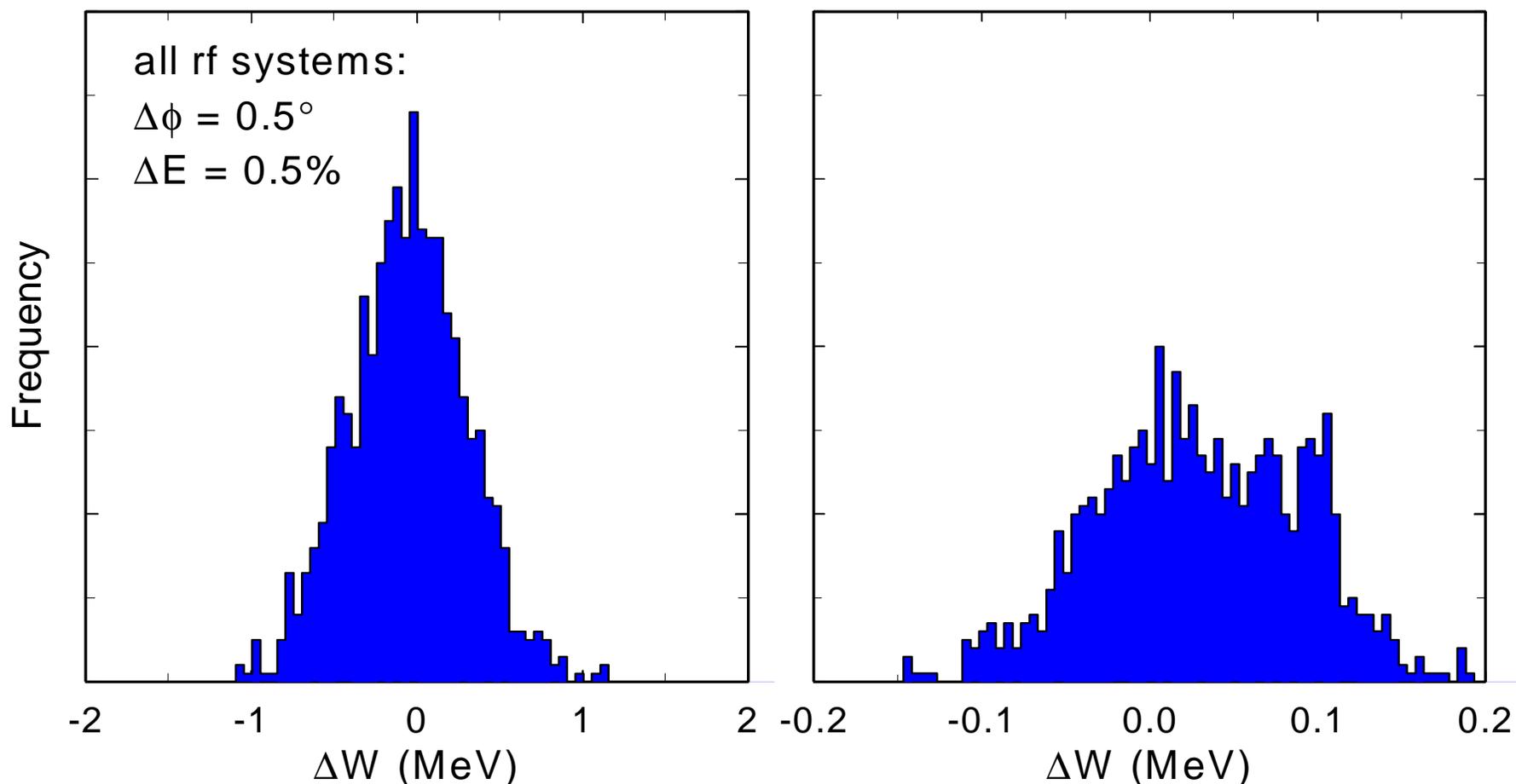


Energy Jitter is a Function of RF Control Tolerances



Linac Exit

Foil

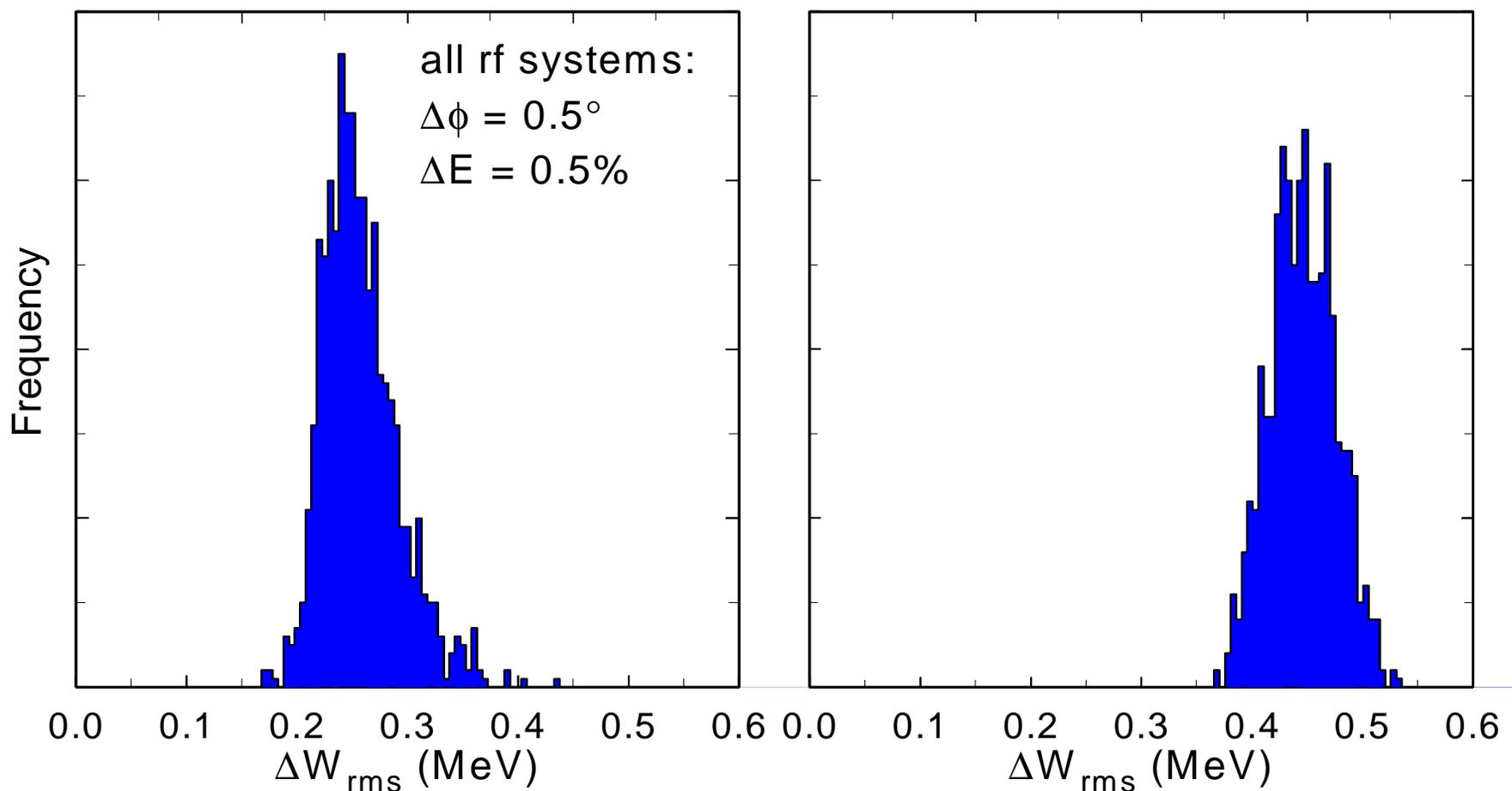


Energy Spread is a Function of Space Charge & Corrector Voltage



Linac Exit

Foil



Beam Phase-Space Projections at the Foil

