SRF Linac Commissioning

J. Stovall, D. Jeon, SNS
S. Nath, H. Takeda, L. Young, LANL
K. Crandall, TechSource Inc.

12 February 2002

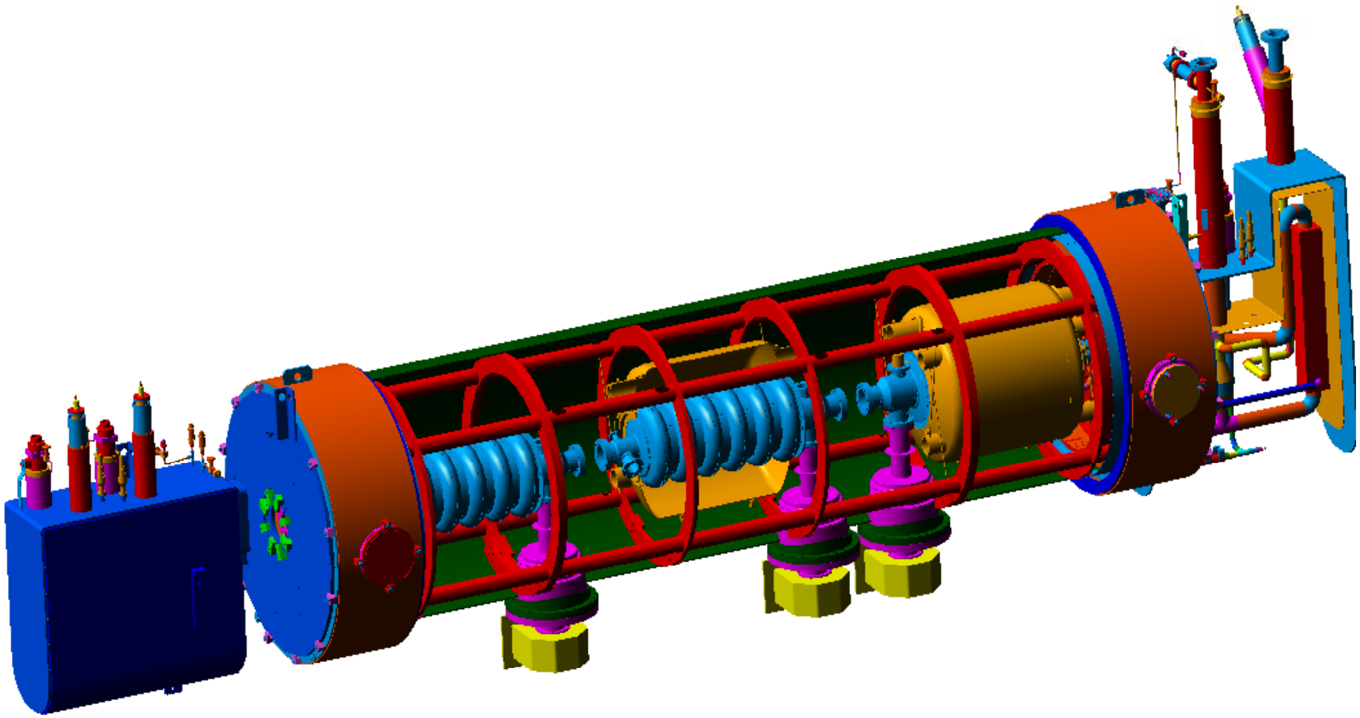
Primary Beam Commissioning Goals Support CD-4 Demonstration

- CD-4 beam current requirement = $1*10^{13}$ ppp
- Primary linac performance goal = $2*10^{13}$ ppp @ 1 GeV
- Example scenario:
  - $I_{peak} \approx 10$ mA
  - $\tau_{macro} \approx 50\ \mu sec$
  - W = 1 GeV $\pm$ 15 MeV
  - PRF $\leq$ 5 Hz
- Debug & integrate all accelerator subsystems
  - PPS, MPS, rf, diagnostics, controls, cooling, vacuum, etc.
- Develop/validate tuning algorithms

Secondary Commissioning Goals are Aimed at Achieving Production Beam Levels

- Production beam ≡ $1.5*10^{14}$ ppp @ 60 Hz
- Linac tuning dump is limited to ≤ 7.5 kW
- Independently demonstrate production beam parameters
  - I_{peak} = 38 mA
  - $I_{chopped}$ = 26 mA
  - τ_{macro} = 1 msec
  - PRF = 60 Hz
  - ε_{rms} ≤ 0.5 π mm-mrad
  - W_{final} =1 GeV
  - Quantify beam halo & beam loss

SRF Cryomodules are Installed in Parallel with CCL



15% of the 2 Years Linac Commissioning is Devoted to 90% of the Machine

• DTL tank 1	Feb 03	31+ weeks
• DTL tanks 2-6	Dec 03	17 weeks
• CCL modules 1-4	May 04	13 weeks
• **SRF cryomodules 1-24**	**Oct 04**	**11 weeks** **>1/day**
• Beam ready for injection	Dec 04	

"Beam Commissioning" Assumes all Subsystems have been Commissioned

- Prerequisites:
  - rf systems tested at full power and duty factor
  - cavities are under vacuum, cold & rf conditioned
  - diagnostics tested from transducer to display
  - controls tested from console to cavity/magnet
  - tuning beam dump is certified
- Beam commissioning involves 3 activities:
  - Steering
  - Transverse matching
  - Establishing correct rf ϕ & amp. for each cavity

SRF Cavity 1-81 Beam Commissioning

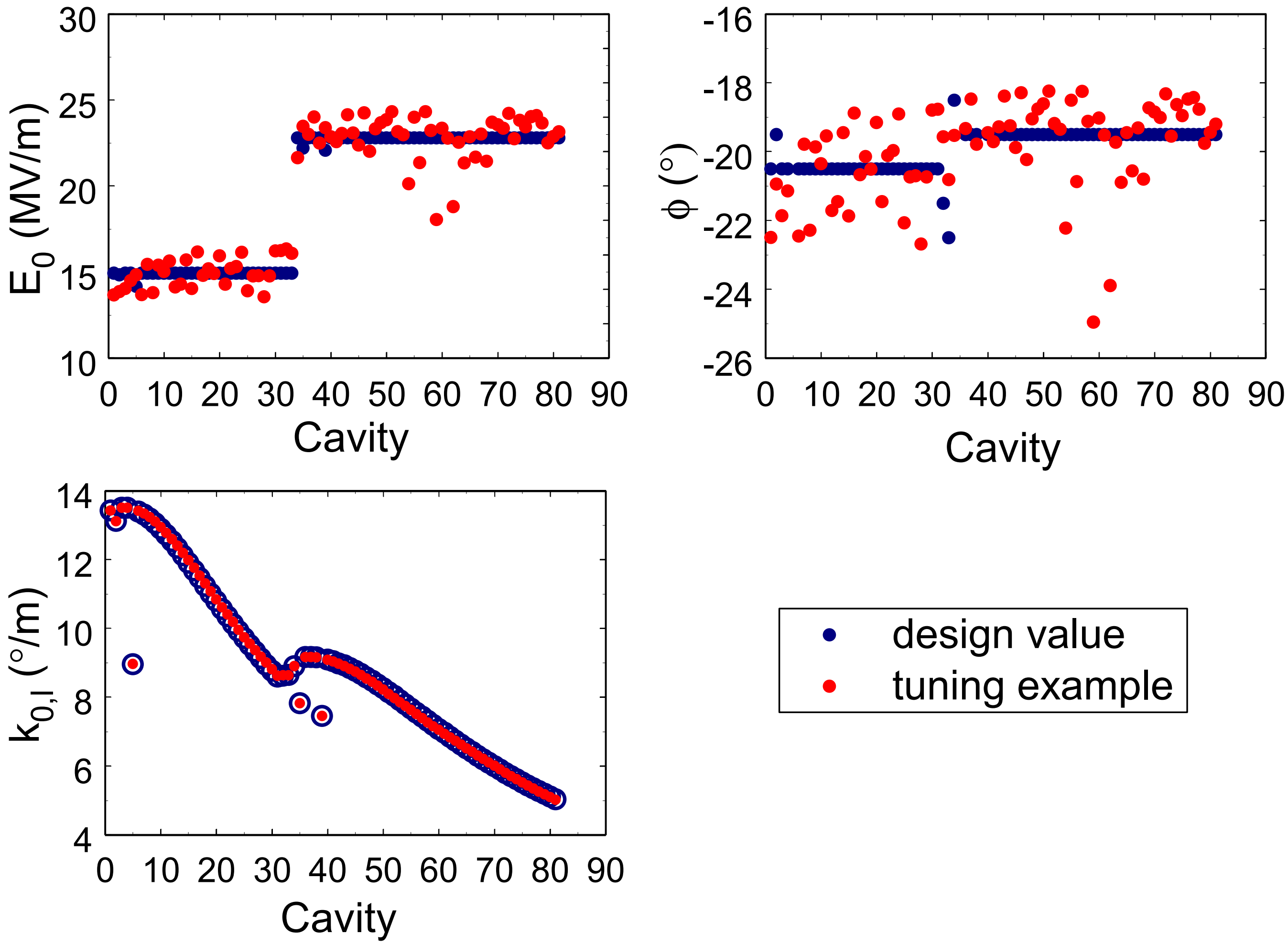
Measurement	Technique	Diagnostic
rf ϕ & amp.	drifting beam loop calibration	BPMs & BCMs
W	time of flight	BPMs
transverse matching	minimize envelope breathing	WSs
steering	minimum steering	BPMs & BLMs
measure halo	x & y profiles	WSs & BLMs
transverse jitter	profile edge	WSs
estimate $\varepsilon_{x\&y}$	derive from multiple profiles	WSs & fast Faraday cup

Tuning beam must be transported to linac dump

SRF Diagnostics Requirements for SRF Commissioning

Diagnostic	Range	Precision	Beam	τ_{beam}
BPM phase	0-360°	±1°	≥15 mA	≥50 μsec
position	±17.5 mm	±0.4 mm	≥15 mA	≥300 nsec
			1 mA	≥50 μsec
BCM	1-50 mA	50μA		≥300 nsec
WS position	±15 mm	±0.2mm	≥15 mA	50 μsec
FWHM		10%		
BLM	-	0.1 W/m	≥50 MeV	≥50 μsec

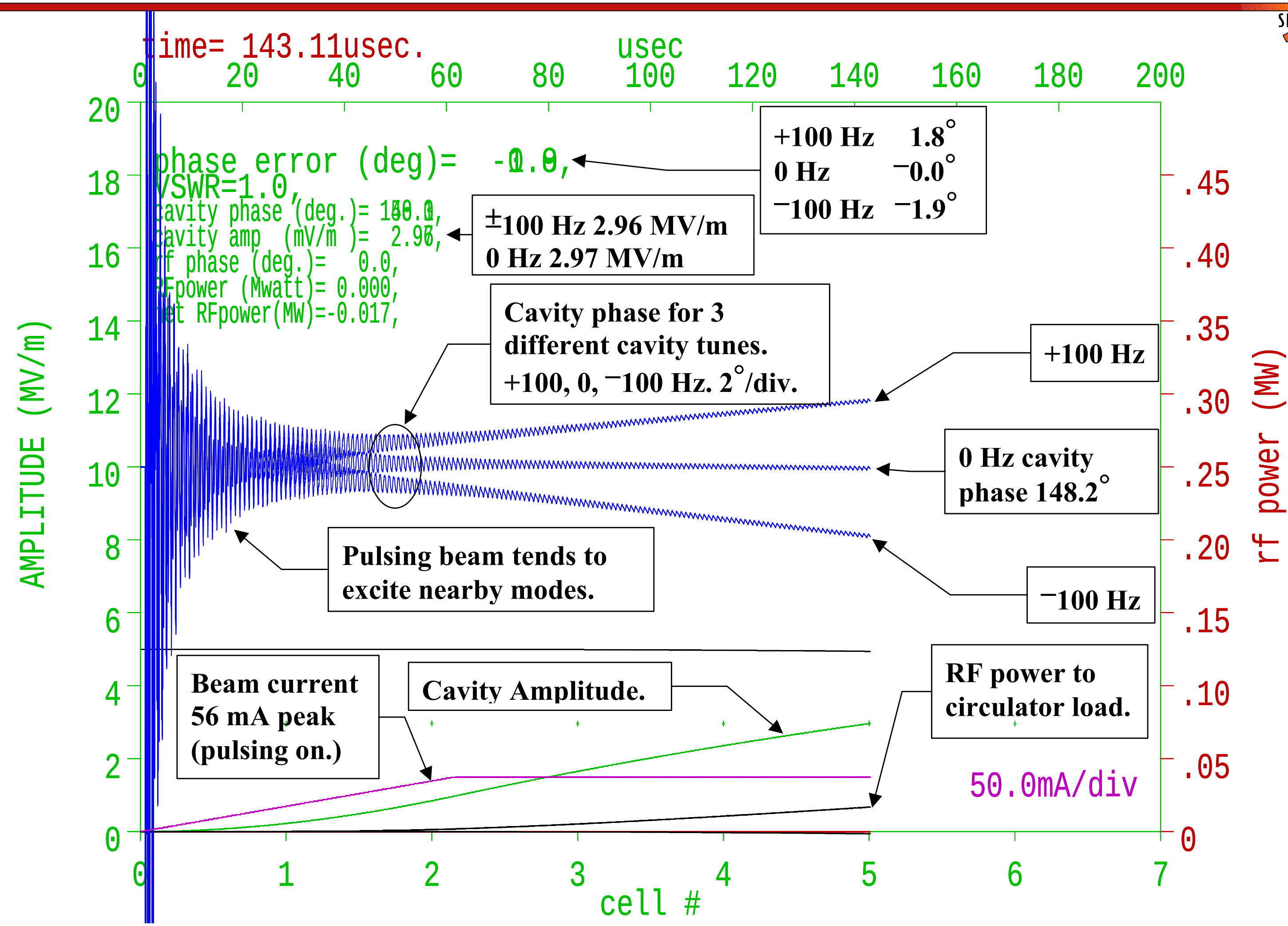
Design Philosophy: Sets $\phi_s = f(E_0)$ for Each Cavity to Preserve $k_{0,l}$



This Approach Requires Knowledge of E_0 to Derive ϕ_s

- Calibrate rf field loops of first cavity
  - drifting beam excites cavity
  - corresponding E_0 is defined by TRANS calculations
  - $\phi_{cavity} = \phi_{beam} - 180°$
- Set E_0 set point using calibrated loop
- Derive and set $\phi_{operating}$, cavity phase set point
- Turn on rf & accelerate beam
- Calibrate rf field loops of next cavity
  - set E_0 and $\phi_{operating}$ setpoints of next cavity
  - turn on rf & accelerate beam
- Repeat until all cavities are set
- Periodically check W_{beam} with time-of-flight measurements
- Periodically resteer & rematch beam to minimize loss

Drifting Beam would Excite each Cavity to Calibrate its Field Probe, ϕ & E_0

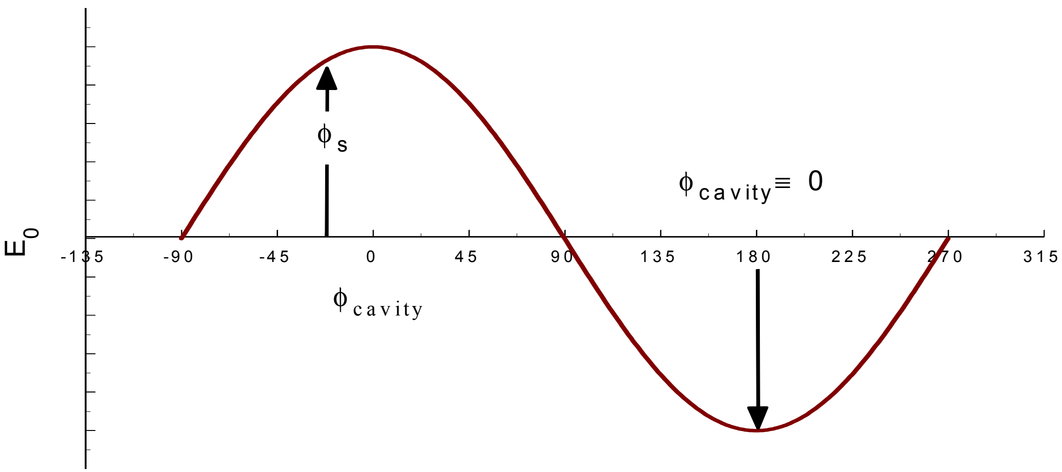


We Propose to Ignore E_0 & Set $\phi_s = \phi_{s,dsgn}$ and Accept Longitudinal Mismatches

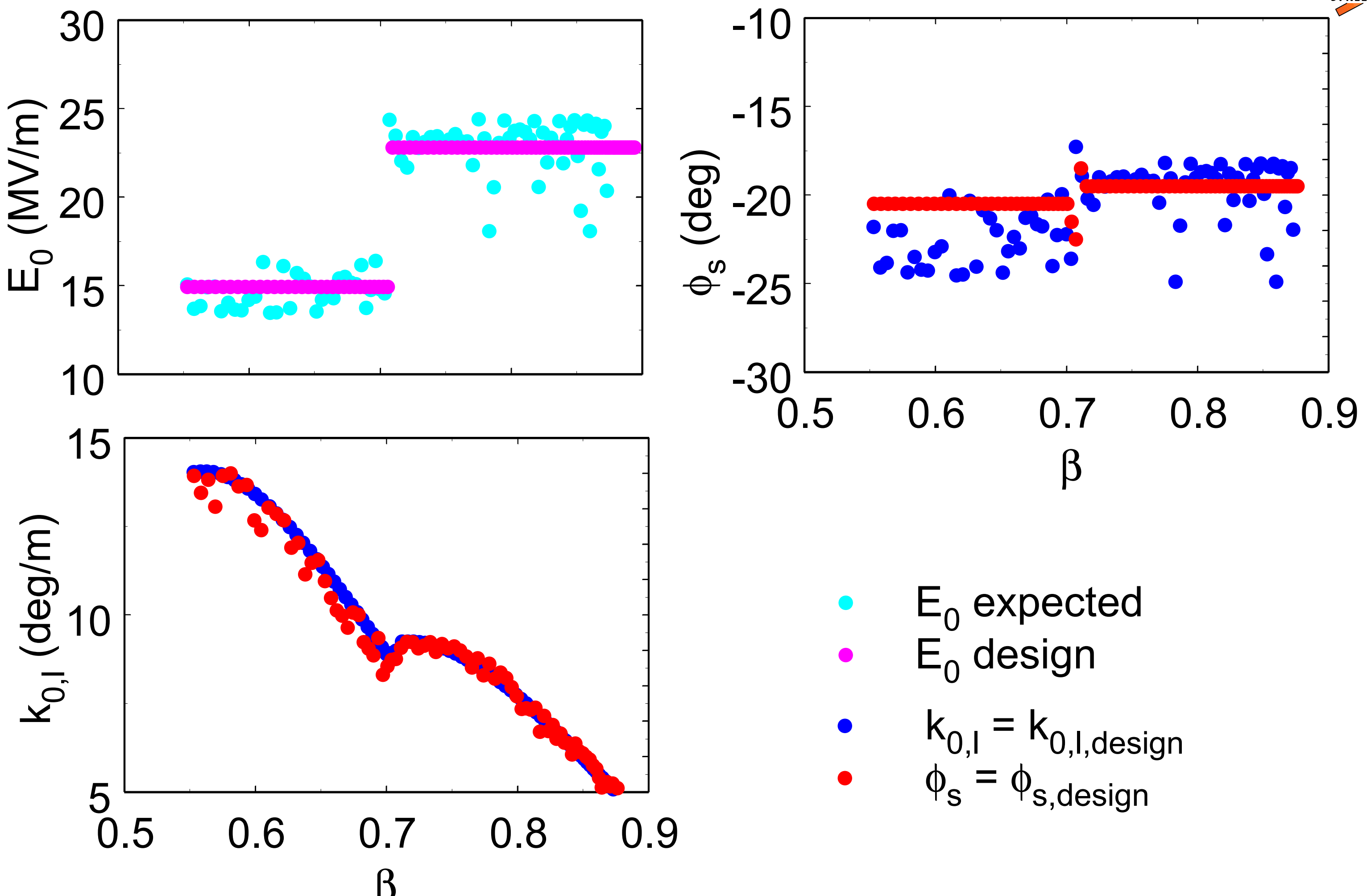
- E_0 will be determined for each cavity by the onset of field-emission
  - We will know its value to ±20% from power measurements
  - We need not further calibrate the field probes for amplitude
- The probes can be calibrated for phase with a few pulses of drifting beam
  - Beam will excite cavity fields to ~10% of nominal
  - The cavity resonant frequency can be tuned by minimizing phase drift during "ring-down" to ±100 Hz
  - Phase error from Lorentz detuning will be very small
  - $\phi_{cavity} \equiv \phi_{beam} \pm 180°$

A Drifting Beam Excites a Cavity at 180°

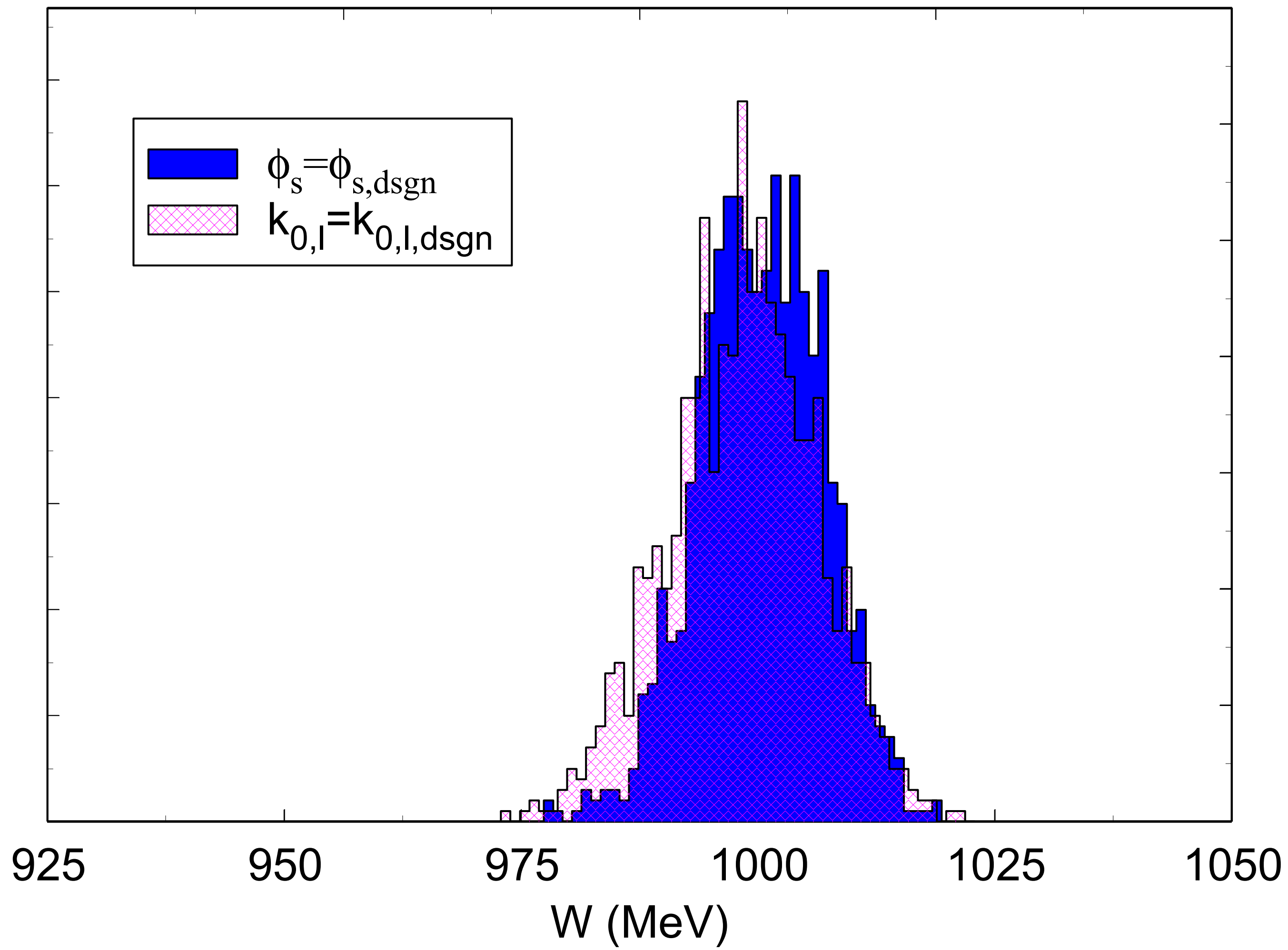
- By definition a drifting beam excites fields in a cavity at 180°
- This defines the cavity phase relative to the beam and to the phase reference line
- The phase is then adjusted to ϕ_s for acceleration
- No BPM phase measurements are required



Constant ϕ_s Results in a Longitudinal Mismatch at Every Cavity



W_{final}, ε_{trans} and ε_{long} are Independent of Phase Law for E_0 ±10%!



Realistic & Simplified Techniques Identified for SRF Linac Commissioning

- Techniques have been developed for
  - Steering
  - Matching
  - Cavity phase & amplitude
- Time of flight energy measurement will require careful calibration of BPMs and will not be routine
- RMS emittance measurements, using profiles are under study