The 1.6 cell gun correlated energy spread dependence on π and 0 mode amplitude

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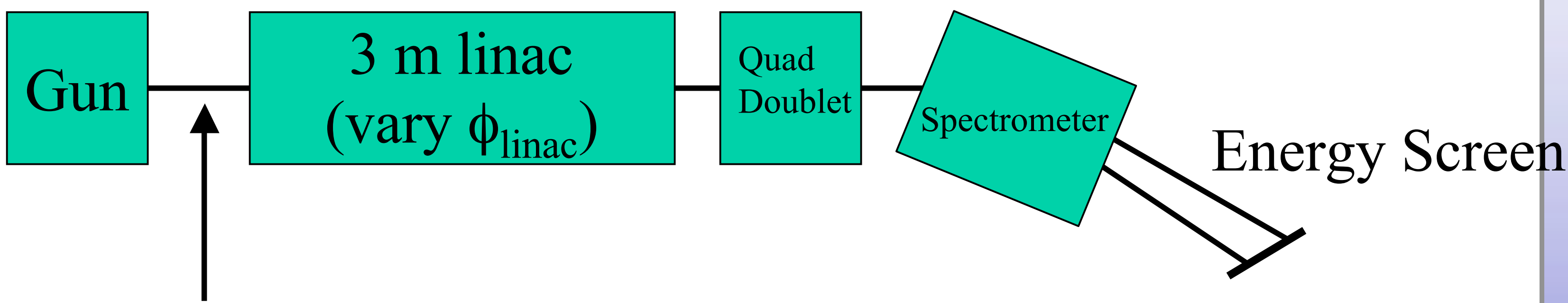
October 11, 2005

- Motivation
  - Measured Correlated Energy Spread
  - Measured Longitudinal Phase Space
- Gun Characterization
  - Frequency Domain
    - Network Analyzer Measurements
    - Bead Drop
  - Time Domain
  - Step Function Response
- 0 mode interaction with π mode
  - Total field in cells
  - Simulated Energy Spread vs Phase
  - Future experiments

Longitudinal Emittance Measurement

Technique analagous to quadrupole scan of transverse emittance



Determine Longitudinal
ϕ-Space at Linac Entrance

Measure Energy Spectra vs linac phase
Linear analysis allows only linear time energy correlations
Fit τ_{11}, τ_{12}, τ_{22}, V_{linac}, and θ_{linac}

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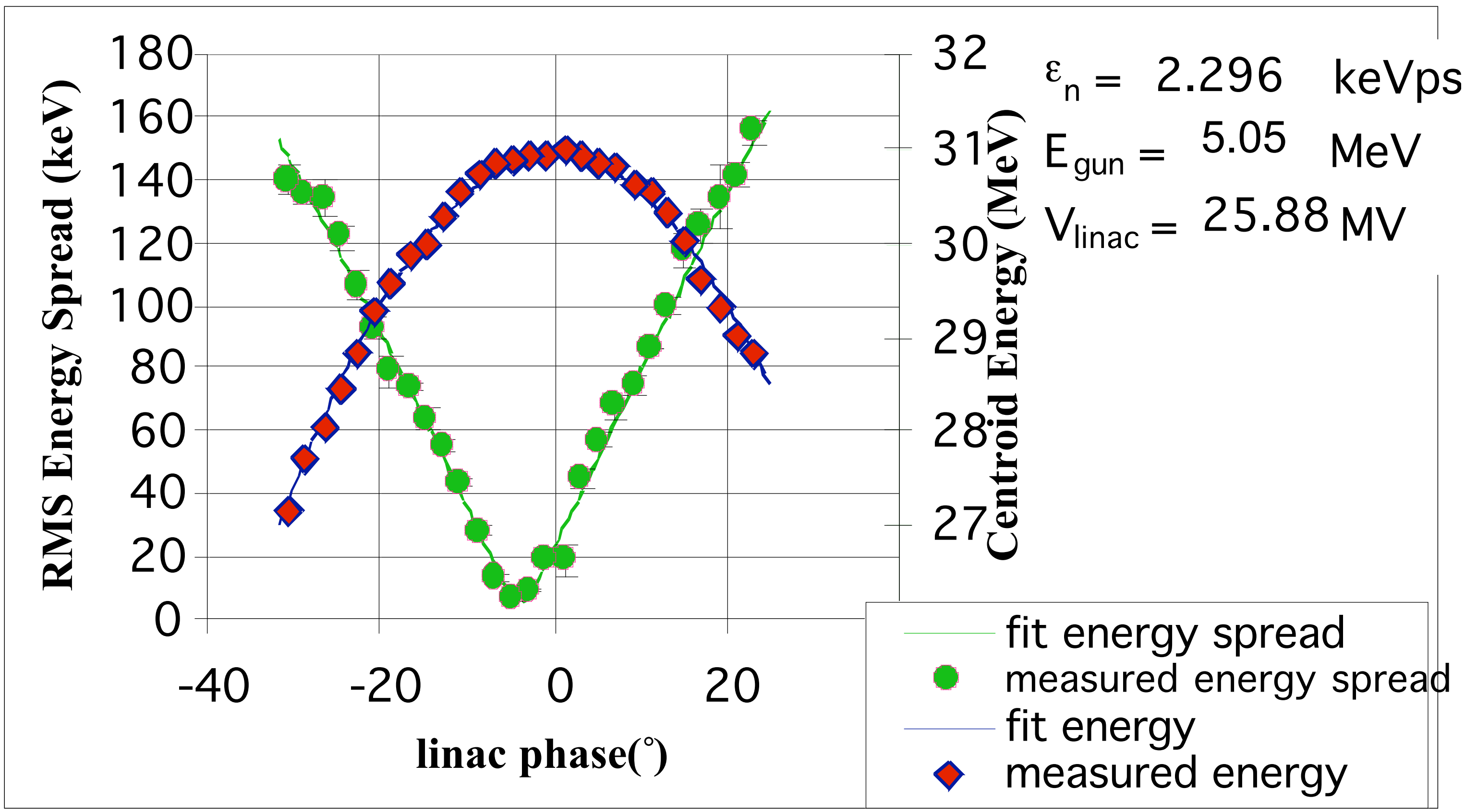
Typical Measurement



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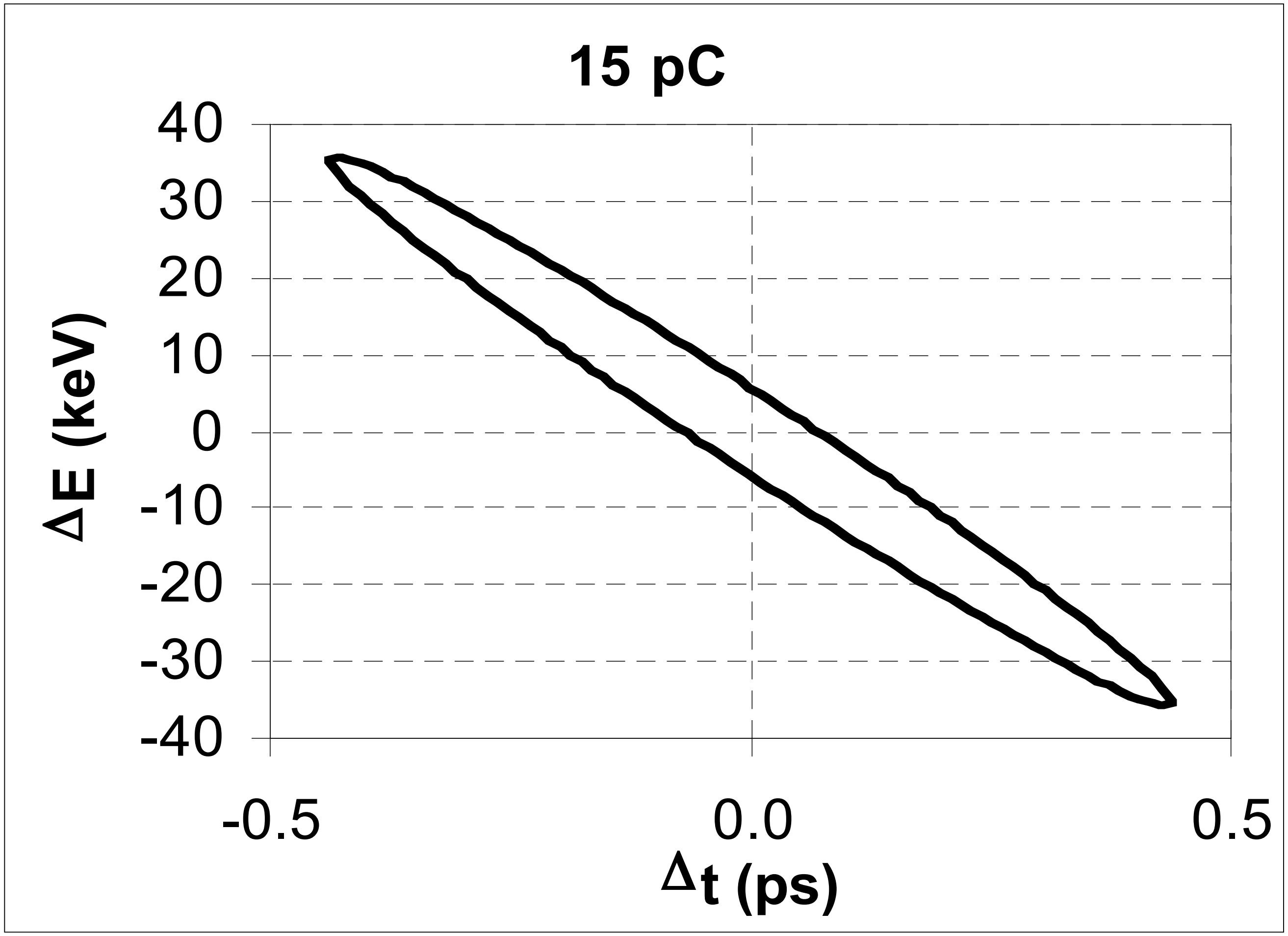
Longitudinal Phase Space at Linac Entrance



Large Correlated Energy Spread

- σ_e = 36 keV; -80 keV/ps
- Not predicted by simulations
- Possible sources
  - RF related
  - Space Charge can play a role
- π mode Field Balance
  - Steady State
  - Mode separation (field balance) variation with thermal load
- 0 mode
  - Mode beating
  - Steady State

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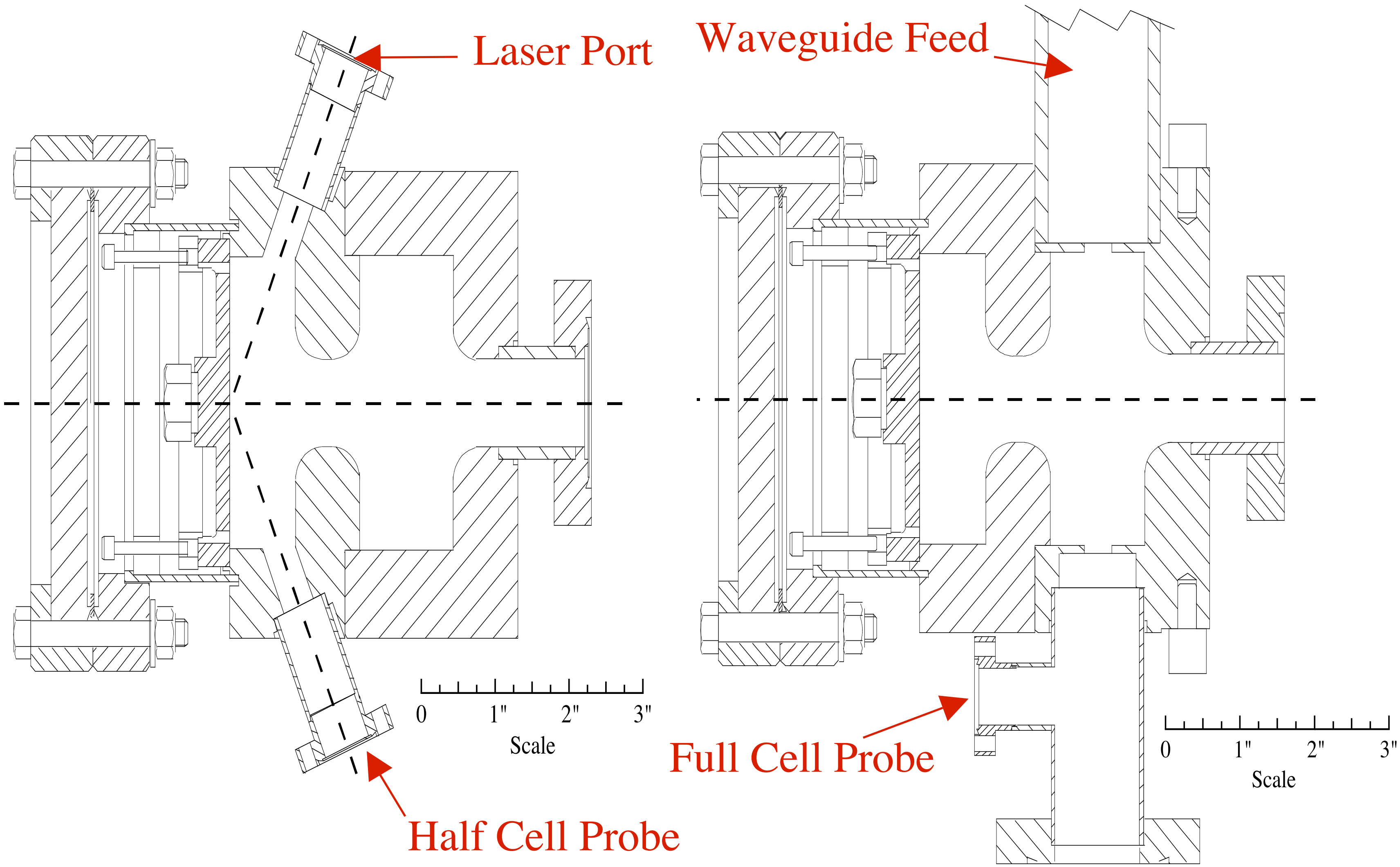
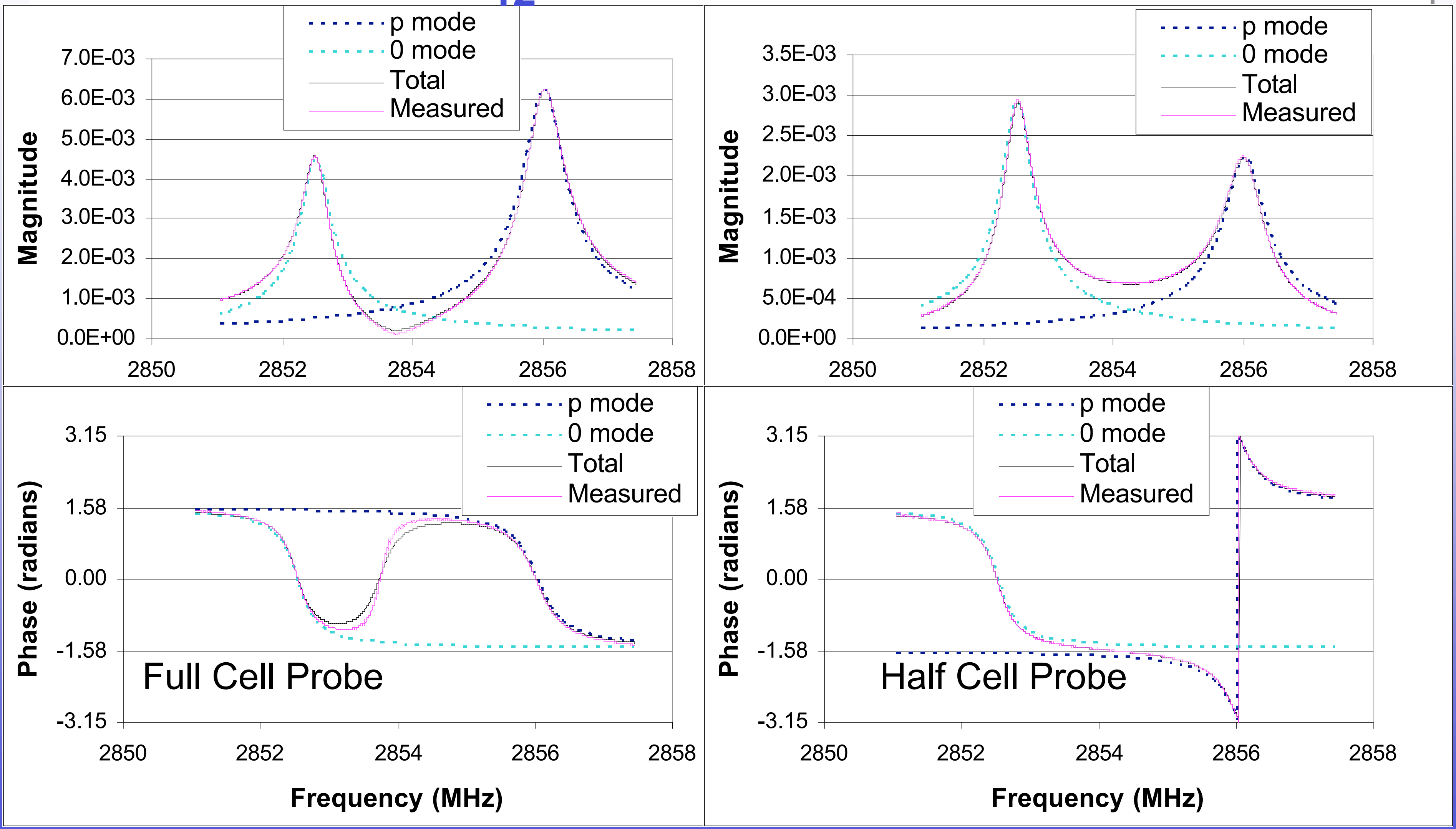
RF Probe Location on GTF Gun



S_{12} Measurements



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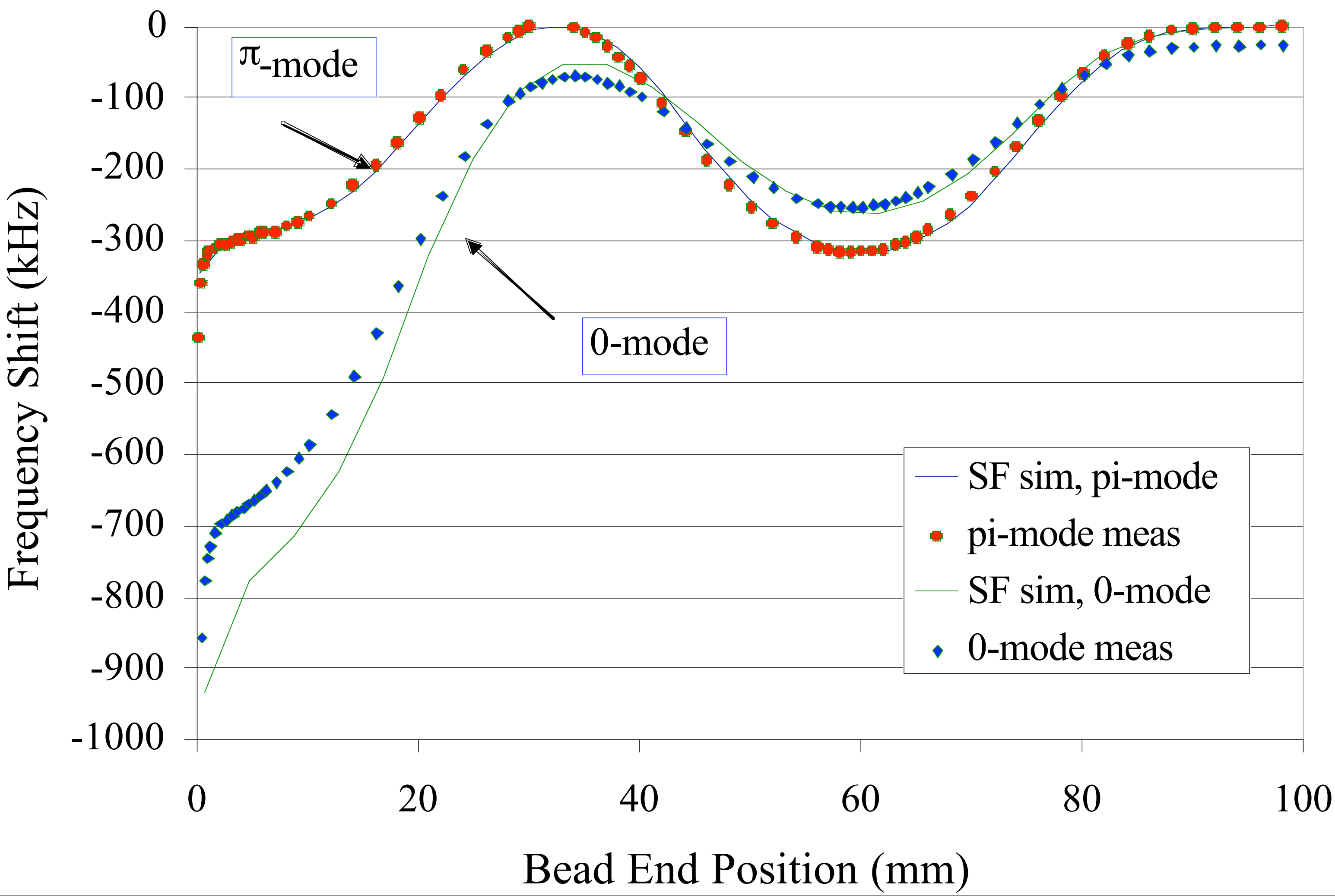
Bead Drop Measurement



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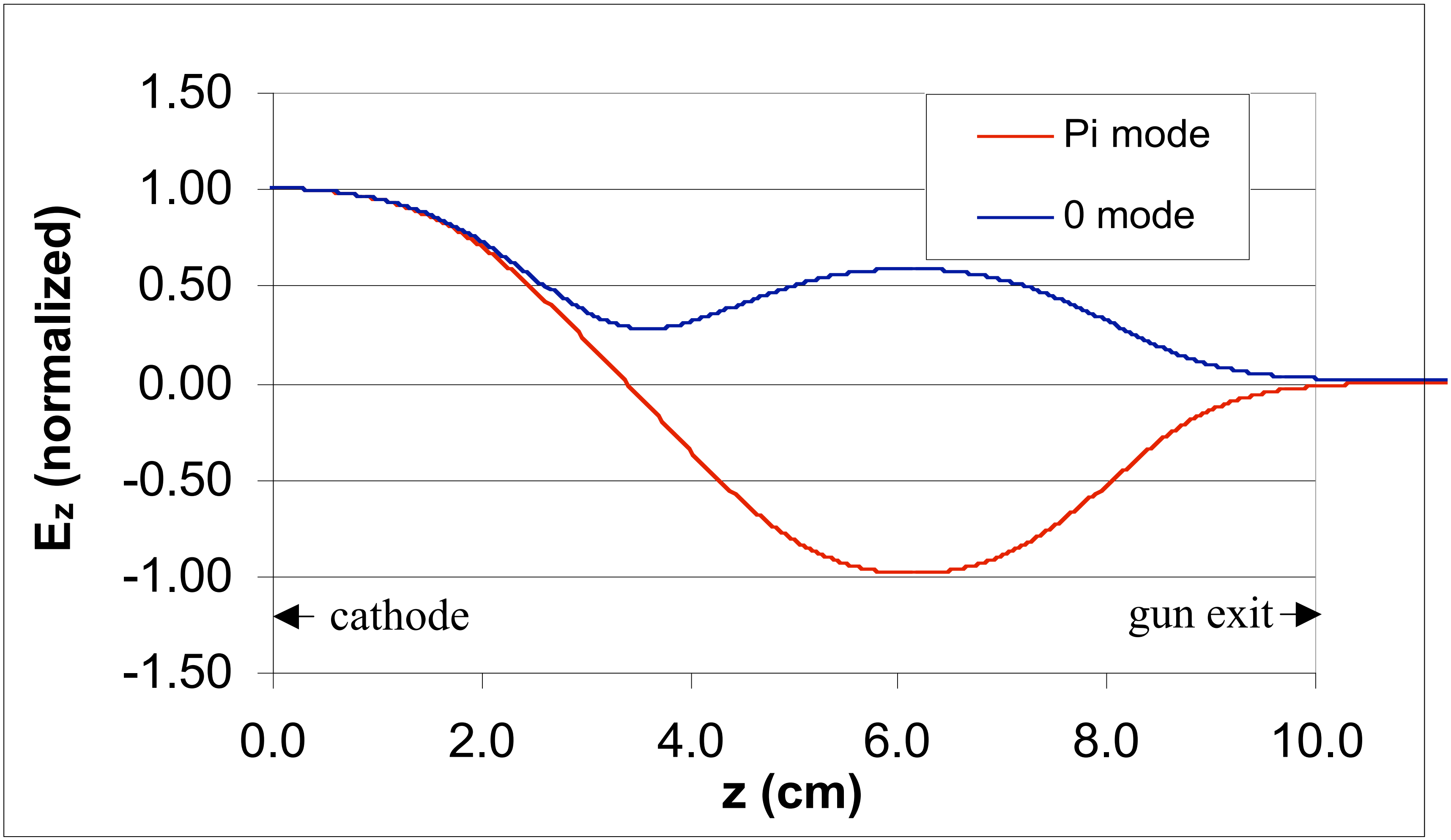
π and 0 mode vs position



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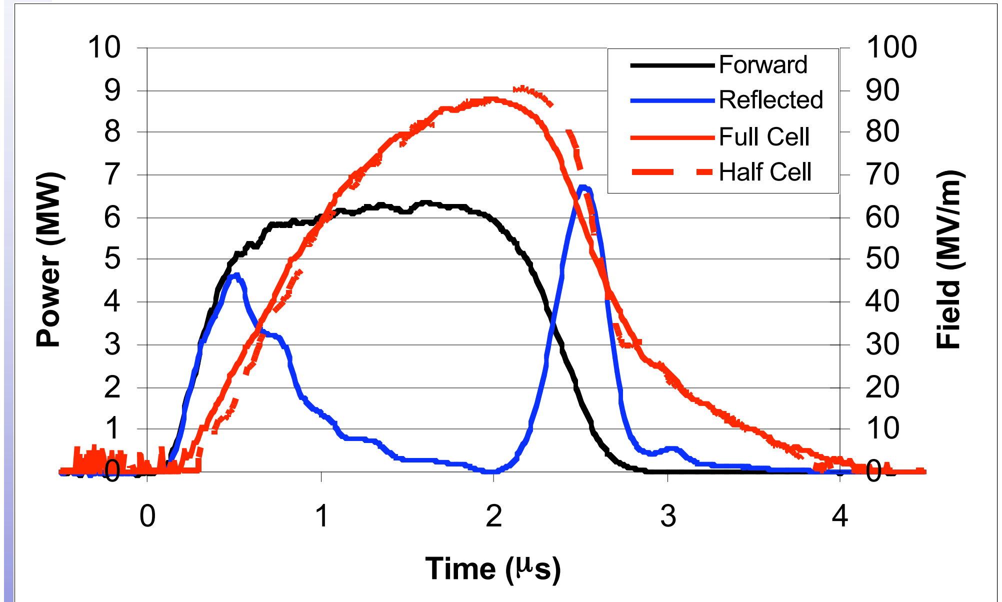
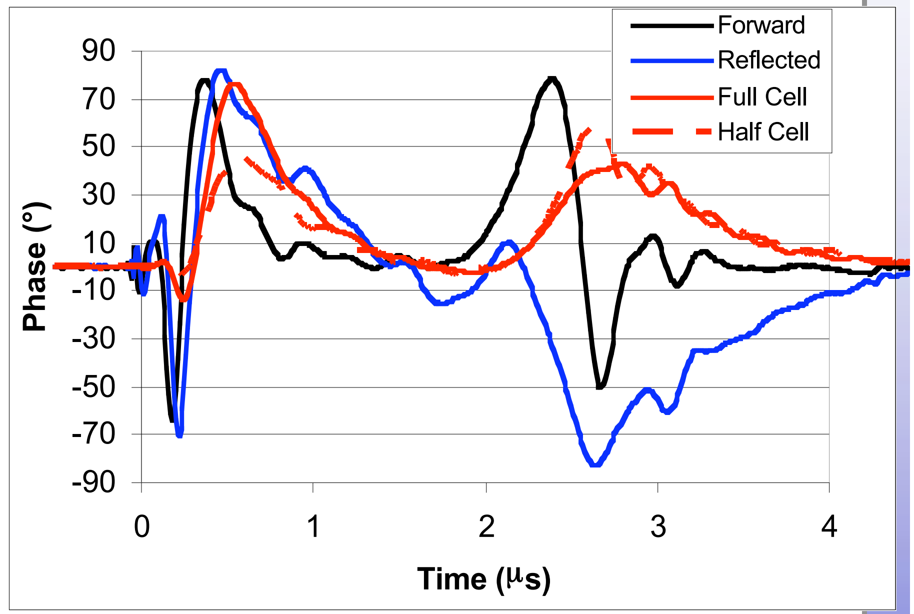
Output Response Equations

π mode only

π and 0 mode

Time Domain Measurement





Temporal Response with ≈ 6 MW incident power

$E_{cathode}$ ≈ 90 MV/m

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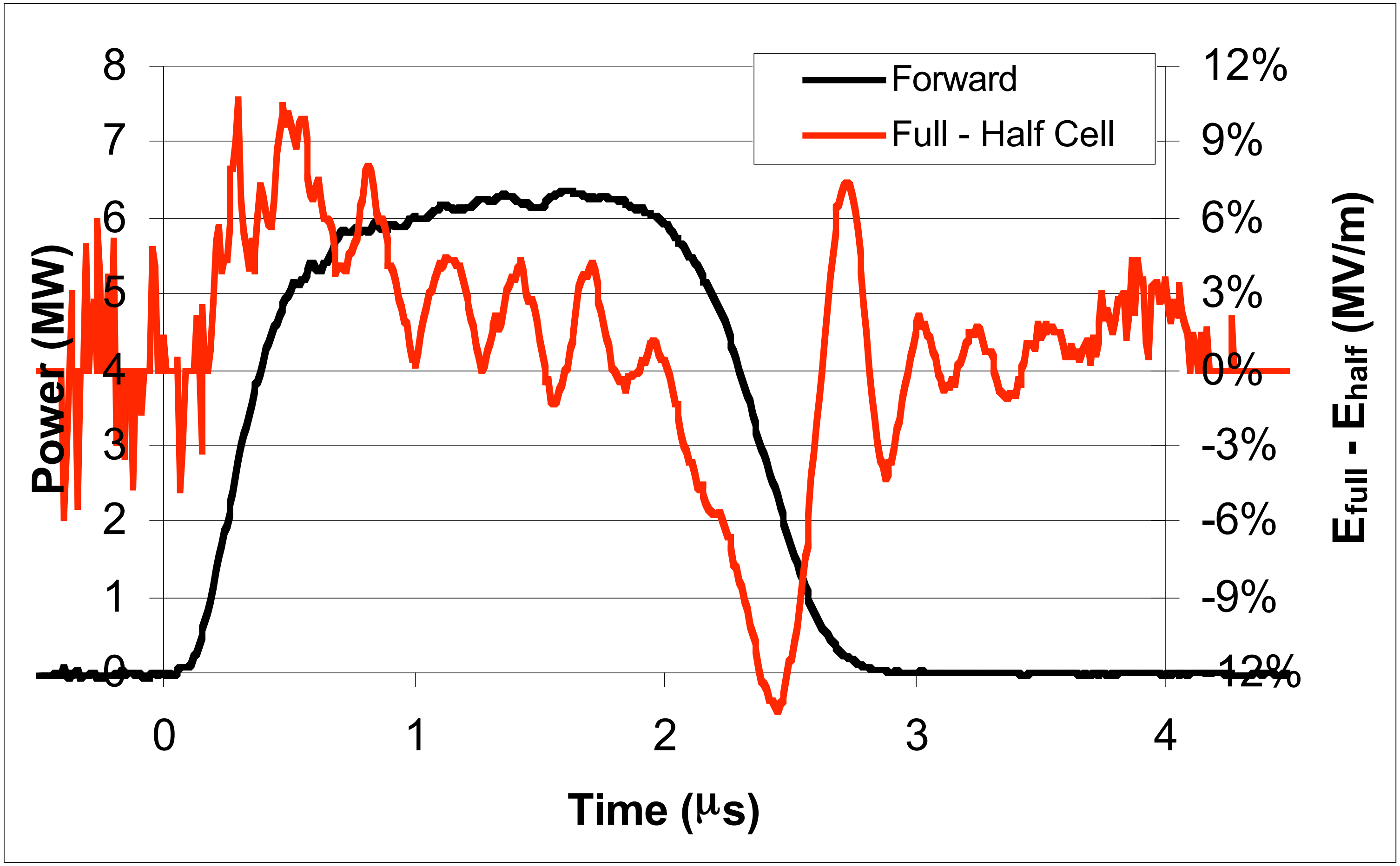
Time Domain Measurement



Temporal Response with ≈ 6 MW incident power

$E_{cathode}$ ≈ 90 MV/m

Field Balance

- **Gun Balanced at low power**
- **Gun Balanced at high power**
  - **No significant field profile variation due to thermal load**
- **Field balance is not the source of correlated energy spread**

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Step Function Response

Steady state response at applied RF frequency

Transient response at resonant frequencies

At a particular z location the fields vary as

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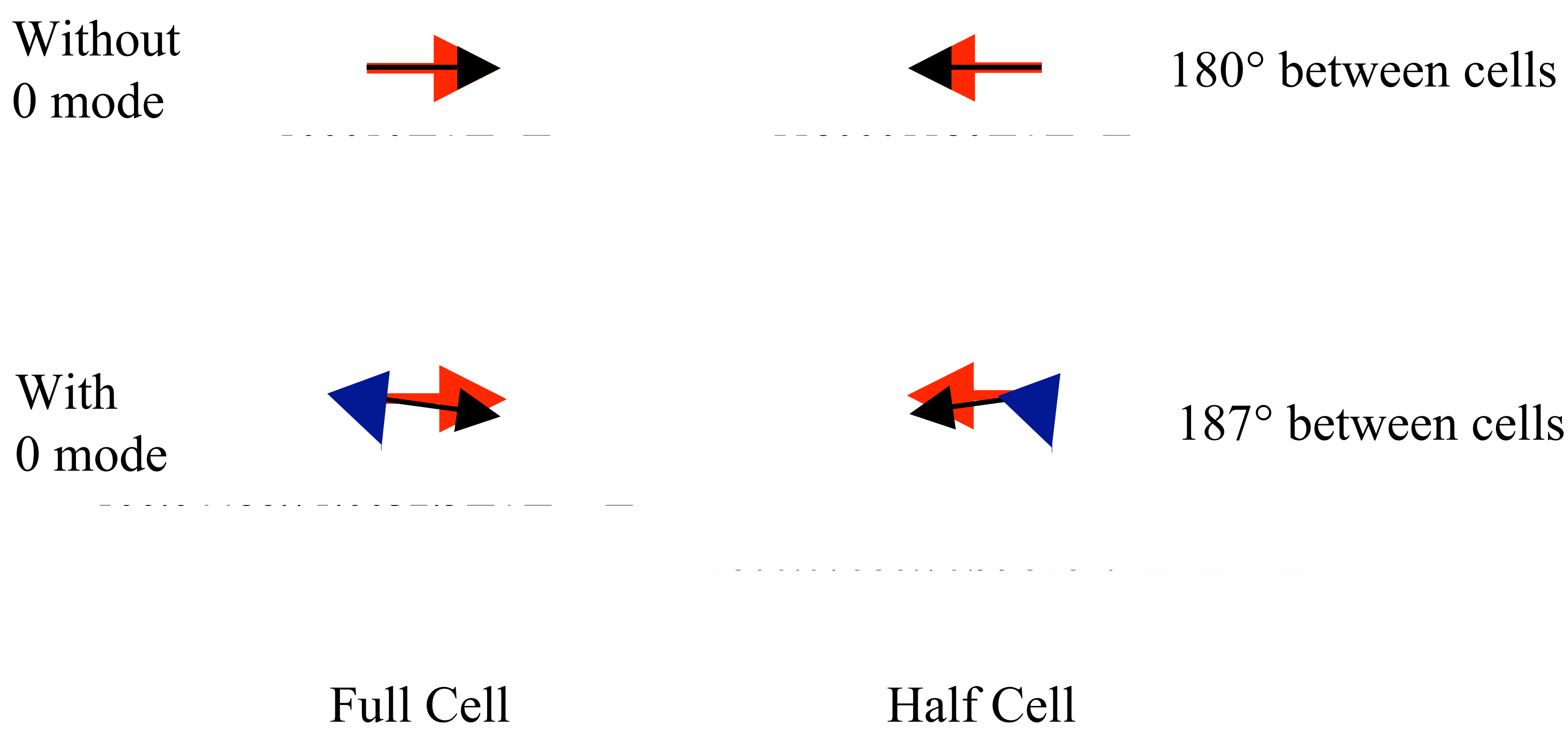
Phasor Representation of the Fields in 1.6 Cell Gun When Excited on π Mode Resonance



π mode in red, 0 mode in blue, total field in black

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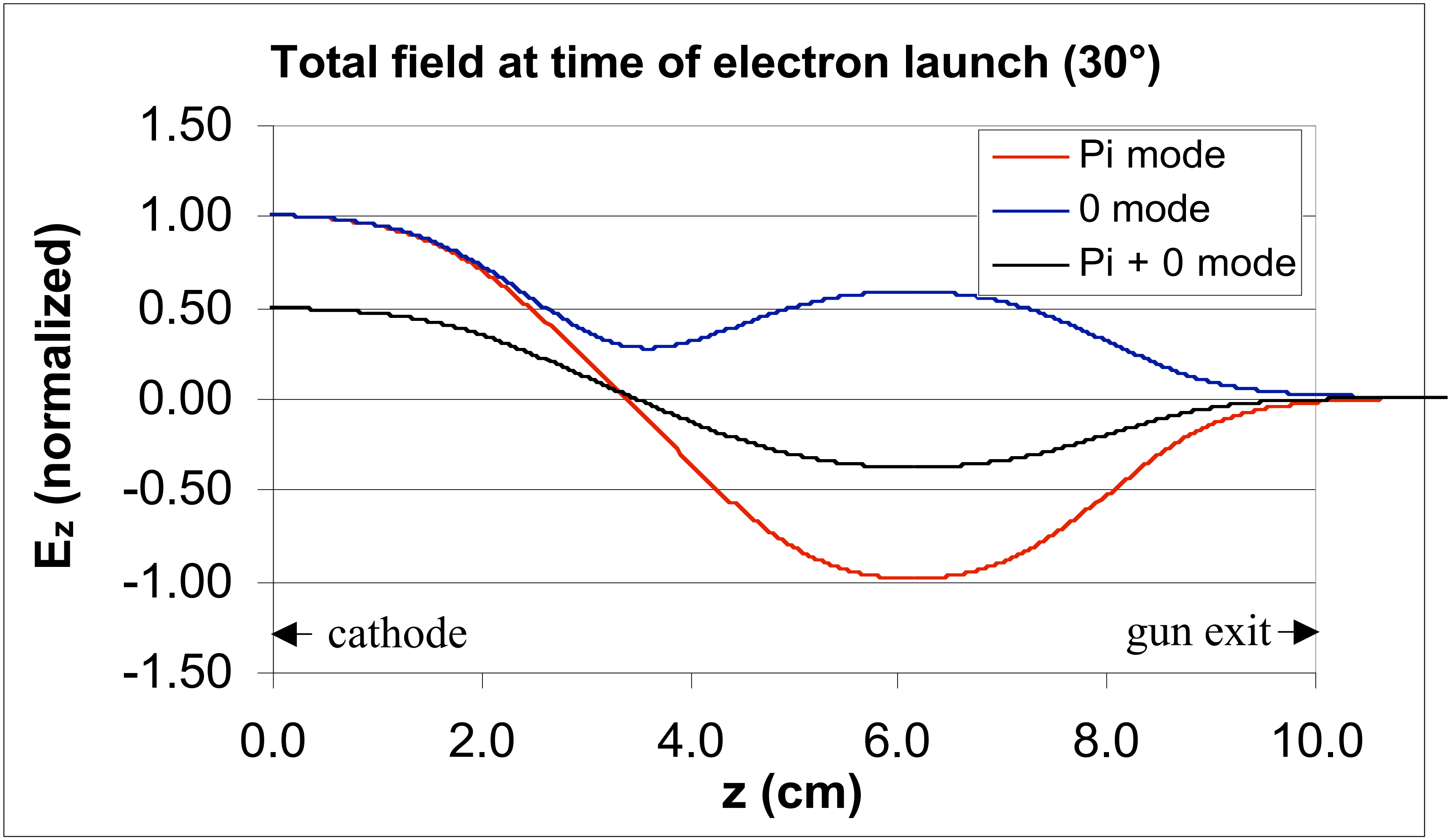
Total Field vs position



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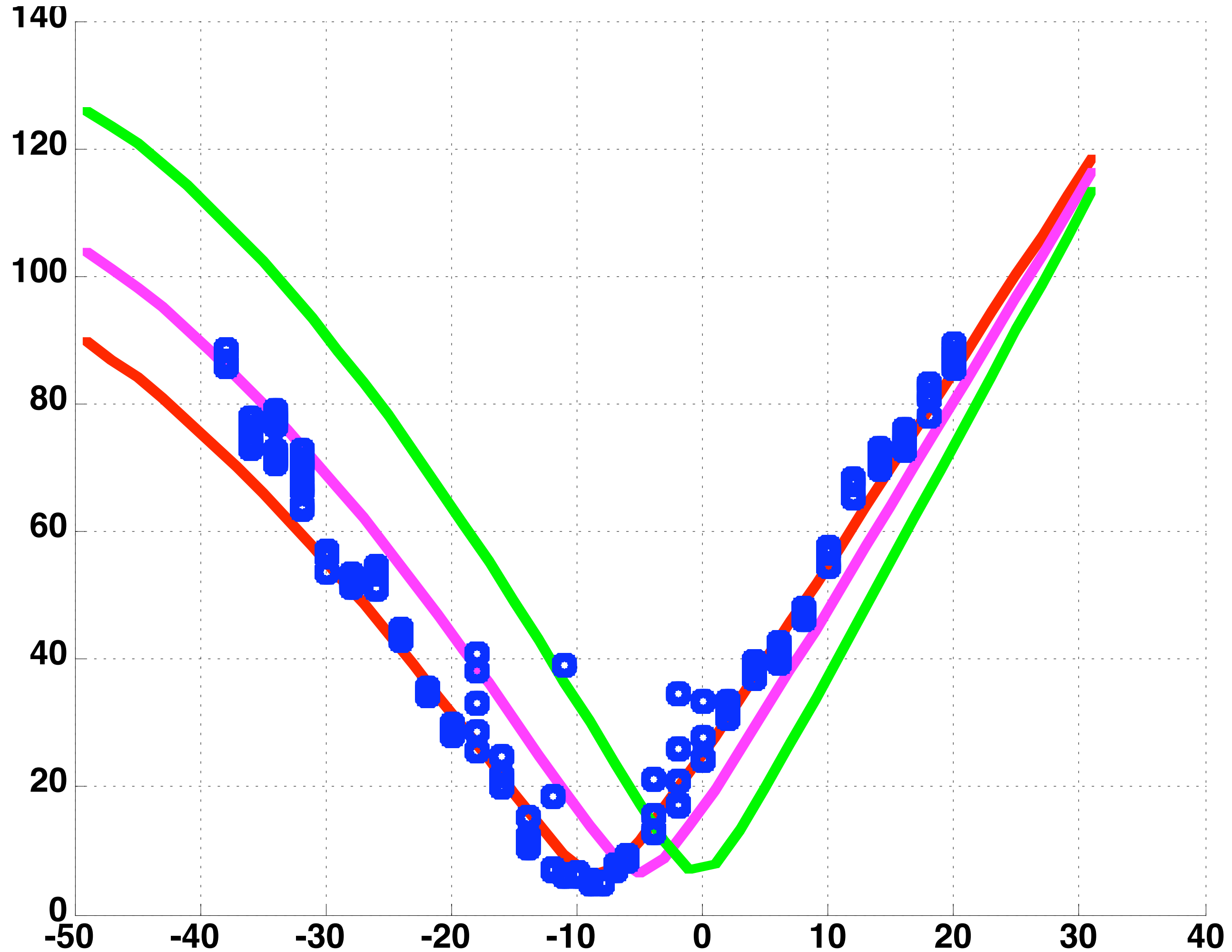
GPT Simulation



Courtesy D.H. Dowell

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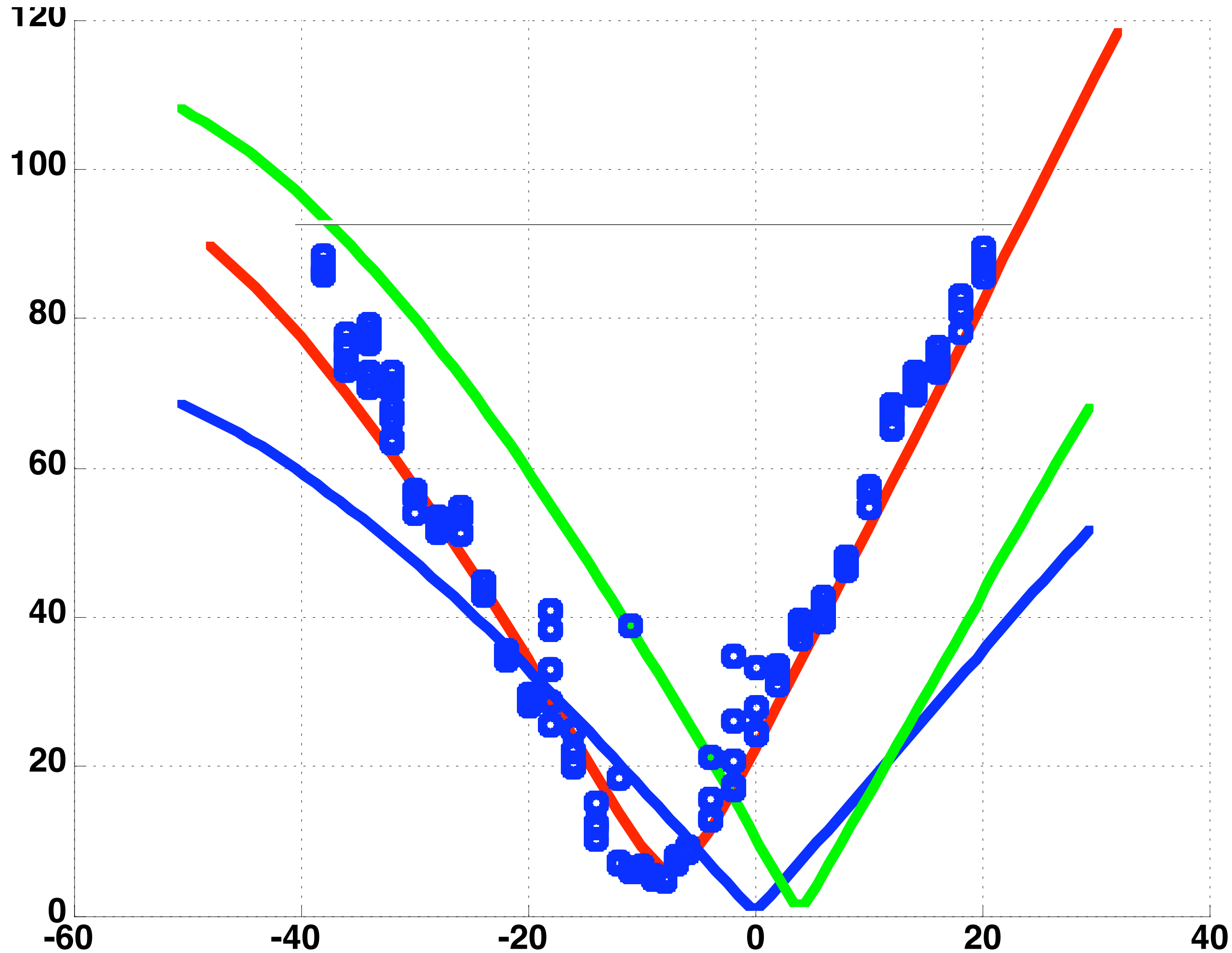
GPT Simulation



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Cancel 0 Mode With Second Applied Frequency

Must phase lock $\omega_{RF2}+\Delta\omega$ to ω_{RF1} for reproducible results

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Summary

- 0 mode produces a measurable 3.5 MHz beating on the gun field
- Always a small steady state 0 mode term
  - Produces a small phase shift between cells in addition to 180° affects longitudinal phase space
  - 0 mode fields at cell to cell iris affect transverse phase space
  - Measured 0° phase (Schottky phase scan) determines phase with respect to total field not π mode field
- Simulations show 0 mode contributes to correlated energy spread
  - Best fit requires 10° phase shift of laser phase
  - Best fit requires 50% larger 0 mode amplitude

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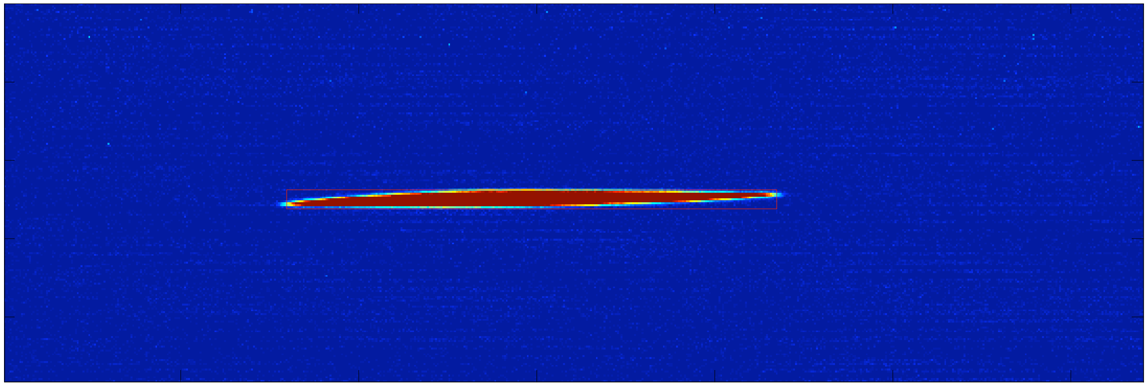
Energy Spectrum at 15 pC



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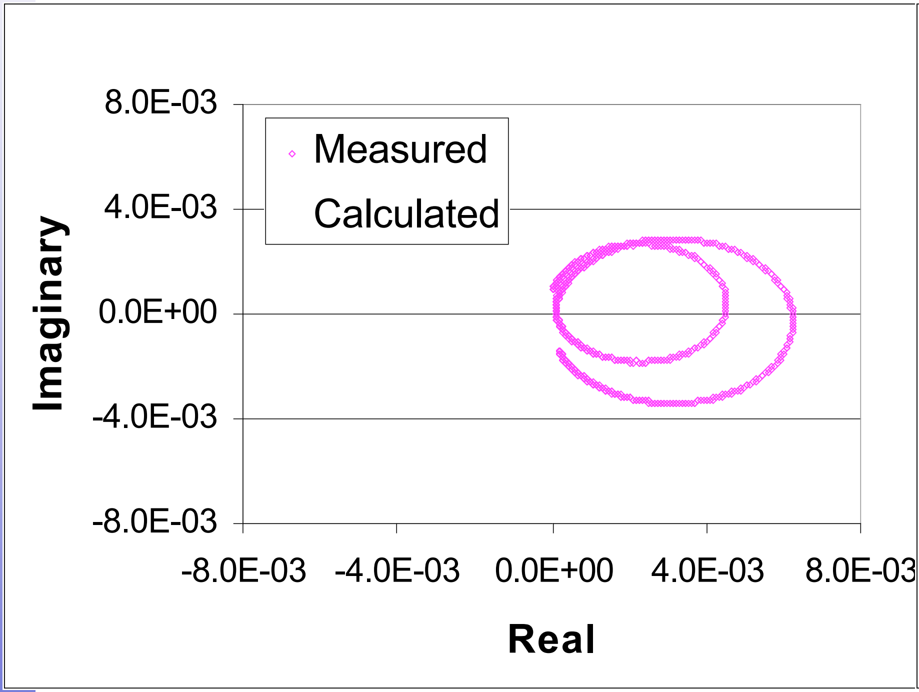
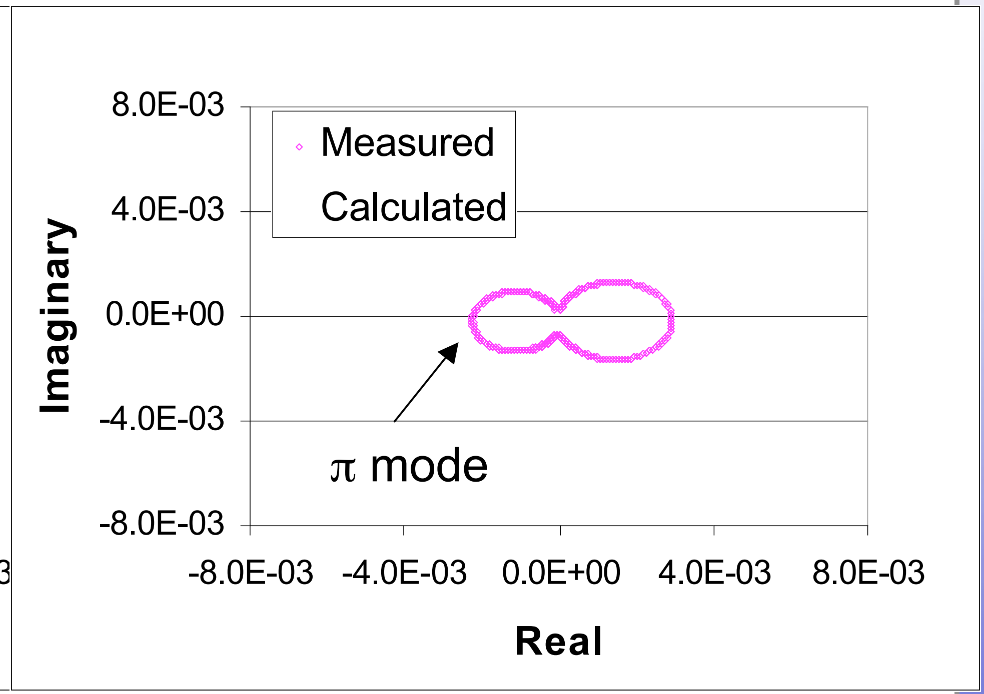
Transfer Function V_{out}/V_{in}

Sum (full cell) or difference (half cell) of two second order band pass filters



Full Cell Probe



Half Cell Probe

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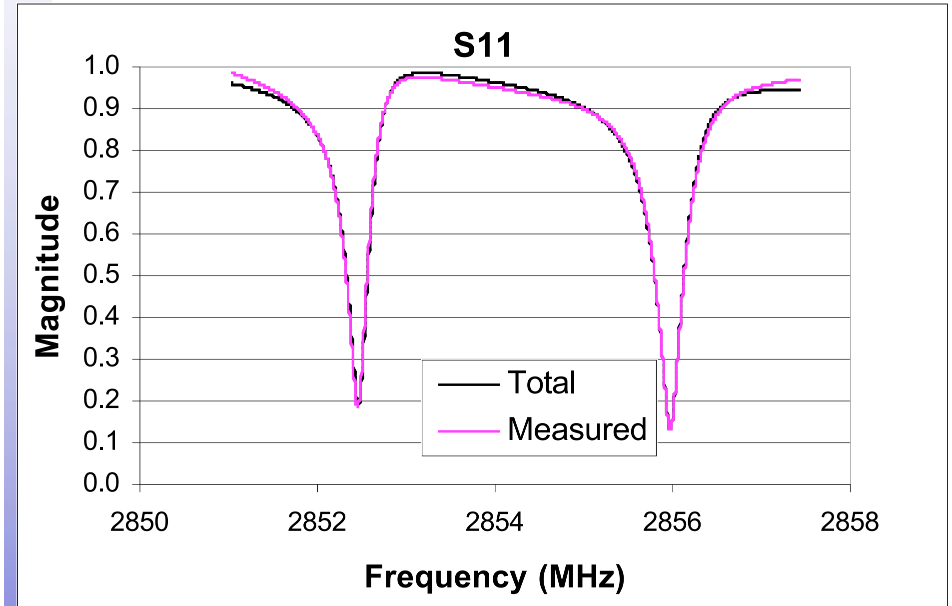
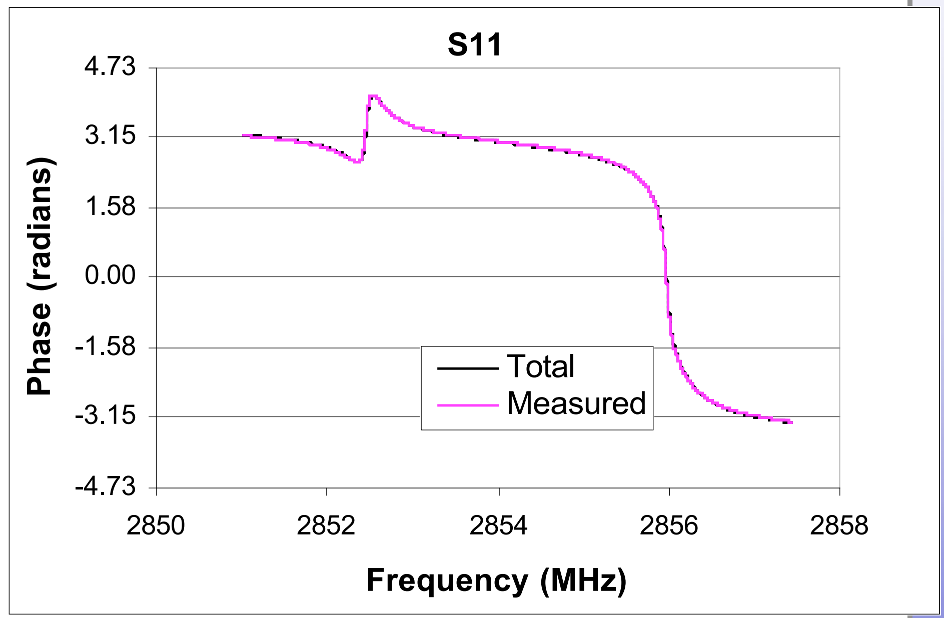
S_{11} Measurement





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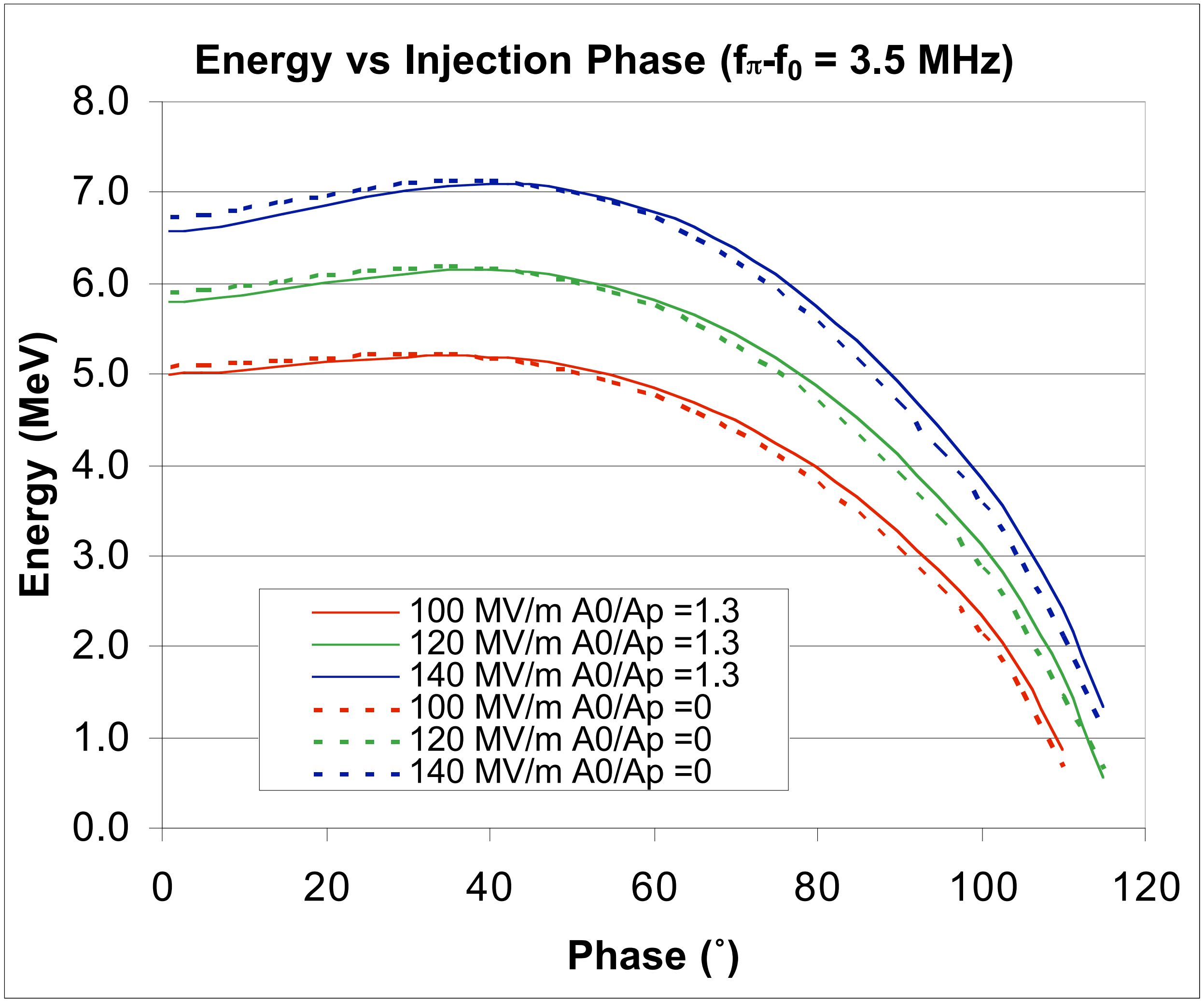
Simulated Energy



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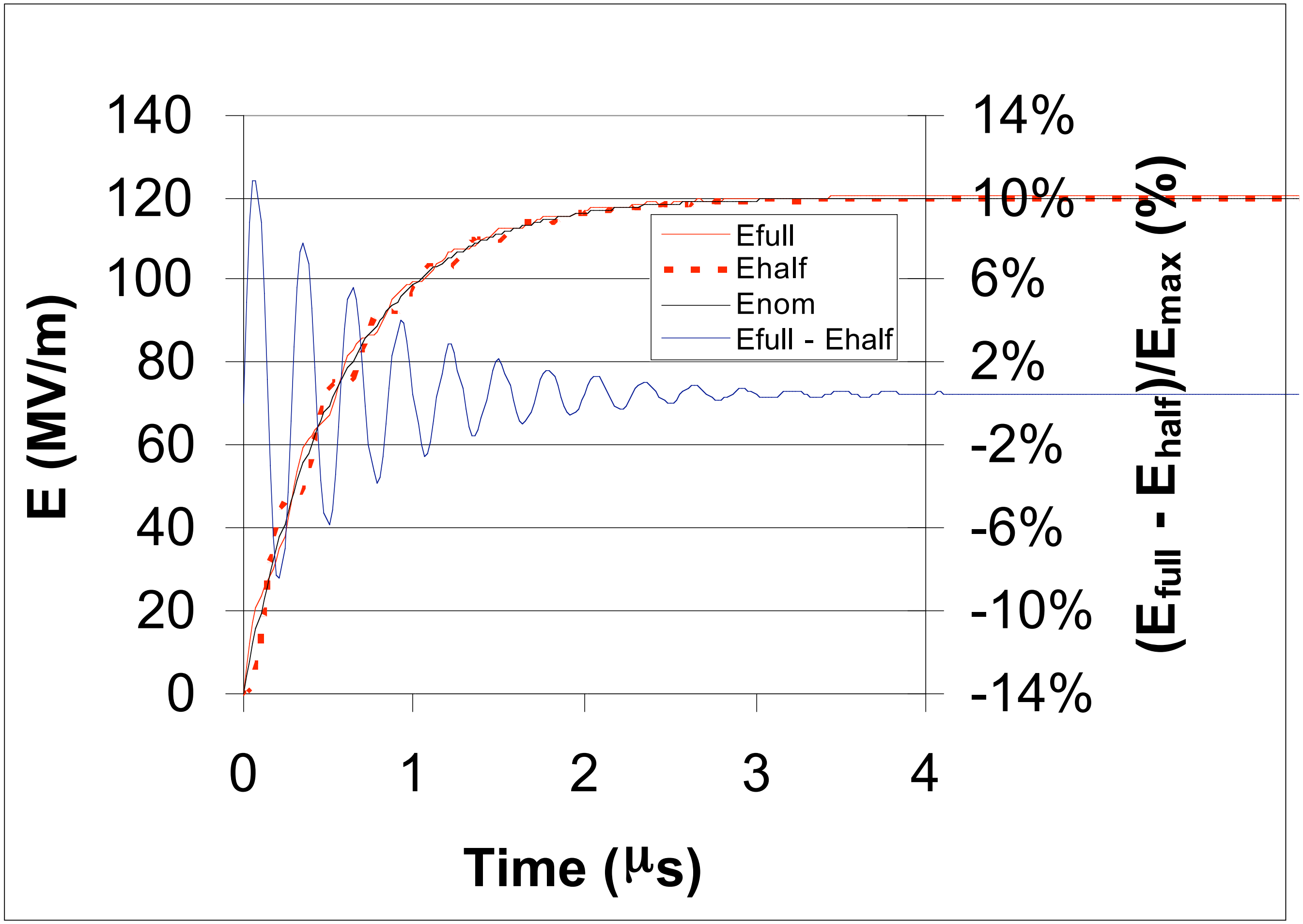
Multiple Modes

- 2 modes with different resonant frequencies and different longitudinal field profiles.
  - $f_\pi - f_0$ = 3.5 MHz on GTF gun
  - Beating observed during gun filling time (transient effect)
- Measure each mode
  - Measure in time or frequency at a particular longitudinal position (RF probes)
  - Measure as a function of longitudinal position averaged over time (bead drop)
- Presence of 0 mode affects e-beam
  - Longitudinal phas space modified since phase shift between cells not exactly 180°
  - Additional transverse fields in the cell-cell aperture affect transverse phase space

Transient Response Including 0 Mode



GTF

f = 2856.00 MHz

f_π = 2856.03 MHz

f_0 = 2852.53 MHz

$Q_{0\,\pi}$ = 11856

$Q_{0\,0}$ = 11823

β_π = 1.30

β_0 = 0.69

τ_π = 576 ns

τ_0 = 779 ns

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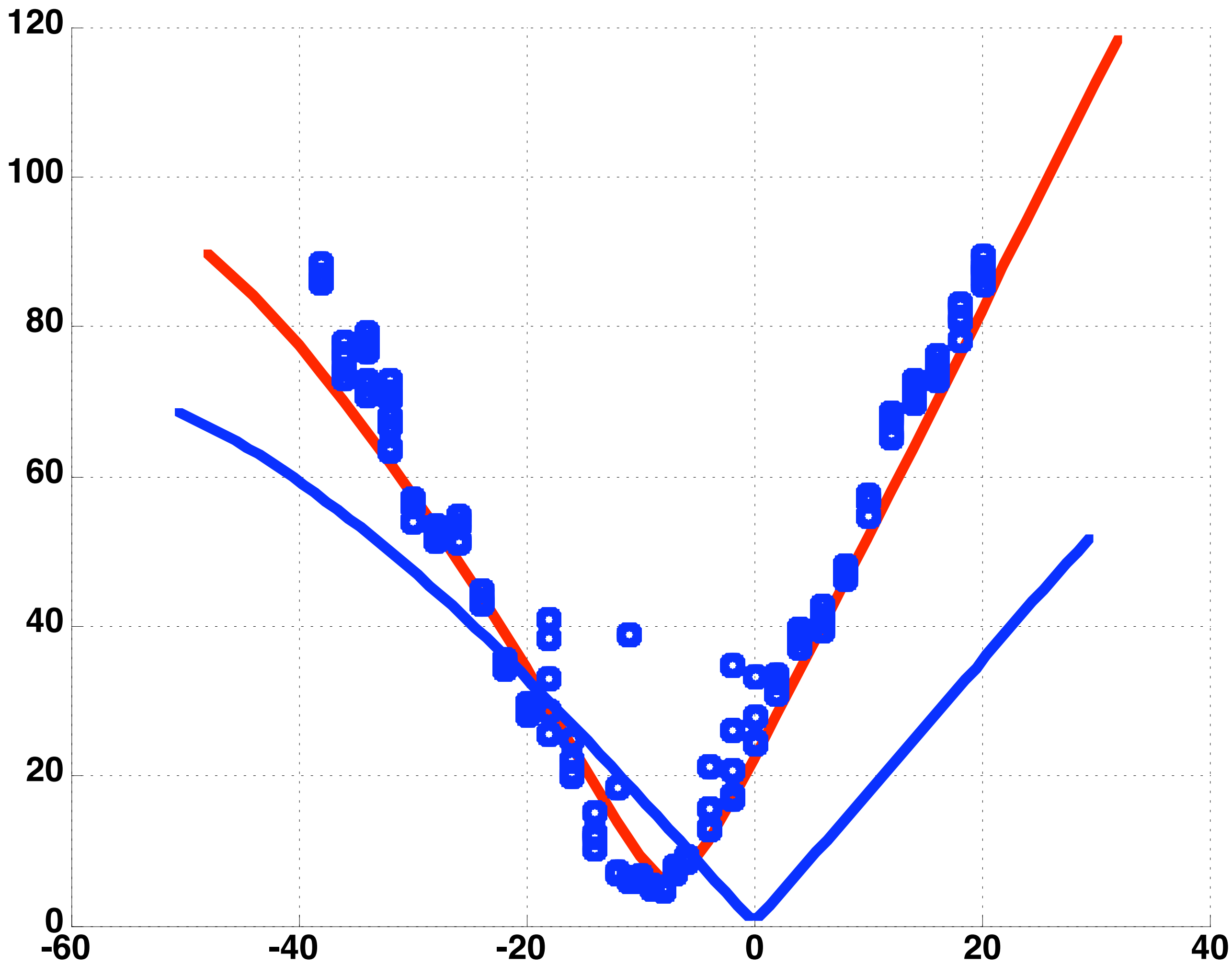

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