17GHz ELECTRON BUNCHING IN HIGH GAIN RELATIVISTIC KLYSTRONS AND RESEARCH ACCELERATORS

Work supported by the US Department
of Energy SBIR Program

HAIMSON RESEARCH CORPORATION

During this presentation:

- Show the results of high gain performance with a 17 GHz klystron - but the detailed design features will be left for discussion in the RF working group.

- Discuss the generation and measurement of short RF bunches obtained with a 17GHz linac and a fast time domain diagnostic.

Acknowledgements:

HRC: Bev Mecklenburg
G.Stowell
B.Ishii

The devices were installed and are operational at the MIT Plasma Science and Fusion Center

R.Temkin I.Mastovsky
S.Korbly
A.Kezar

The LC demands for higher peak power at shorter λ

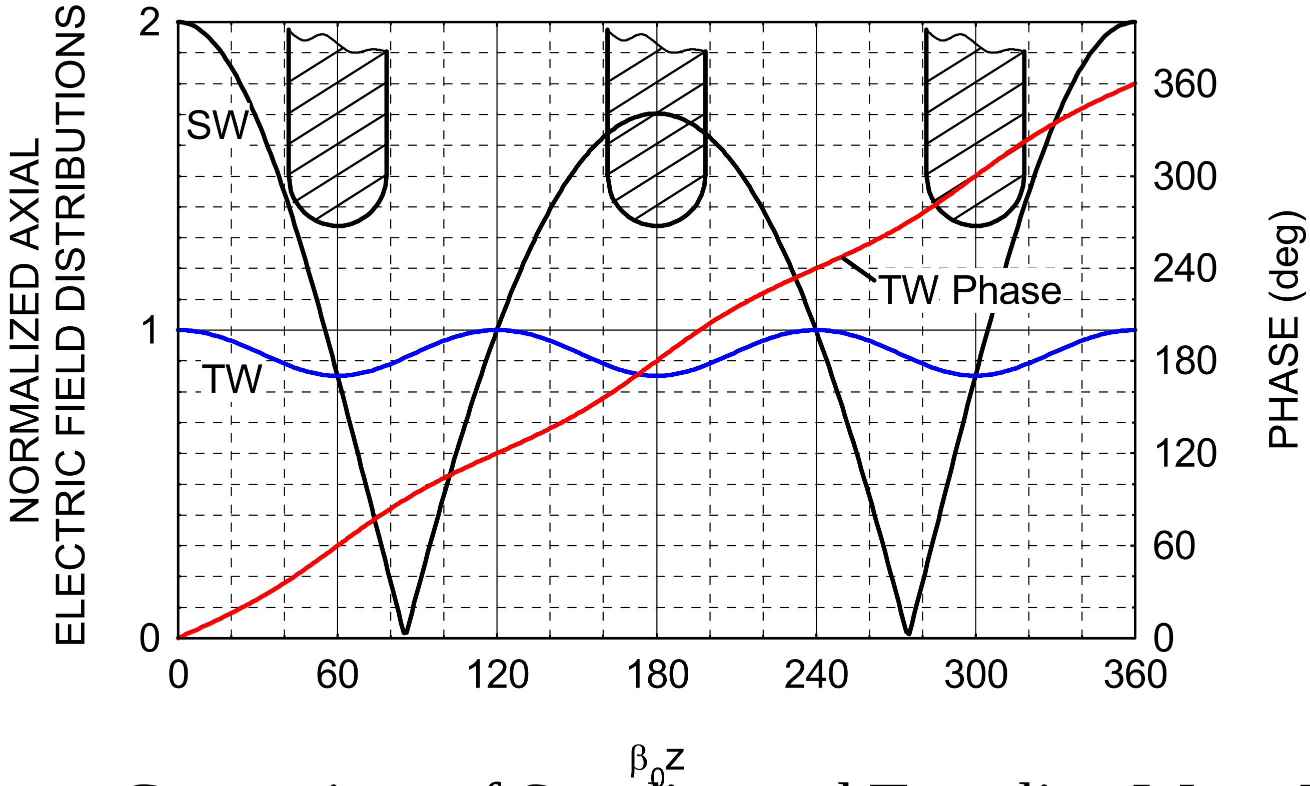
have resulted not only in higher RK beam energy densities (250 to 400 joules/cm^2) - but more significantly - in RF bunch charge densities of

40 – 50nC/cm^3

The associated space charge field gradients are approaching the limit of circuit field containment and

it is unlikely much further increase of the presently achieved RK efficiencies (52 – 56%) will be possible….at least with single beams.

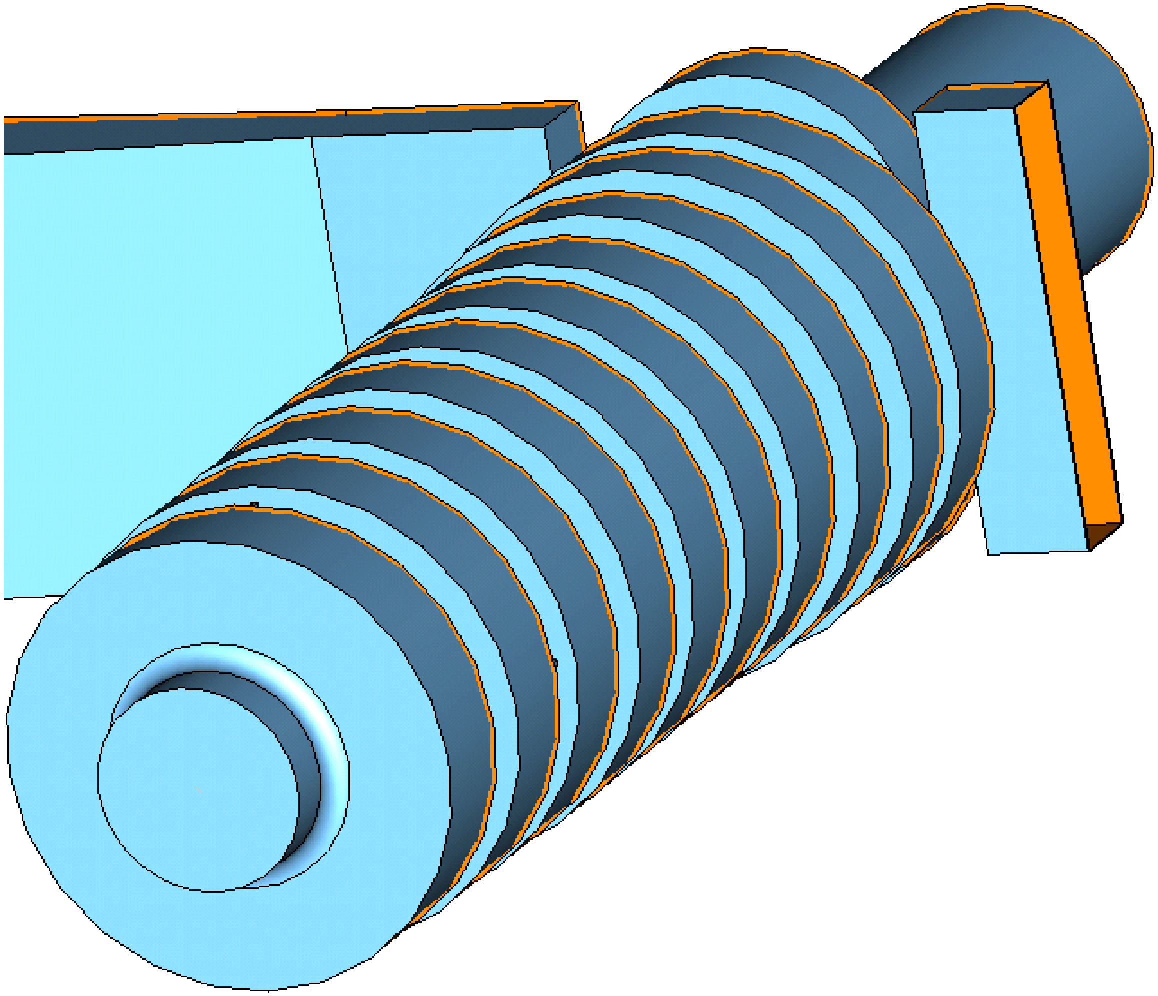
Because TW coupled cavity circuits are more effective in counteracting high space charge debunching forces than SW cavities, a $2\pi/3$mode,asynchronously operated, disc loaded output circuit was chosen for the high gain experiments.



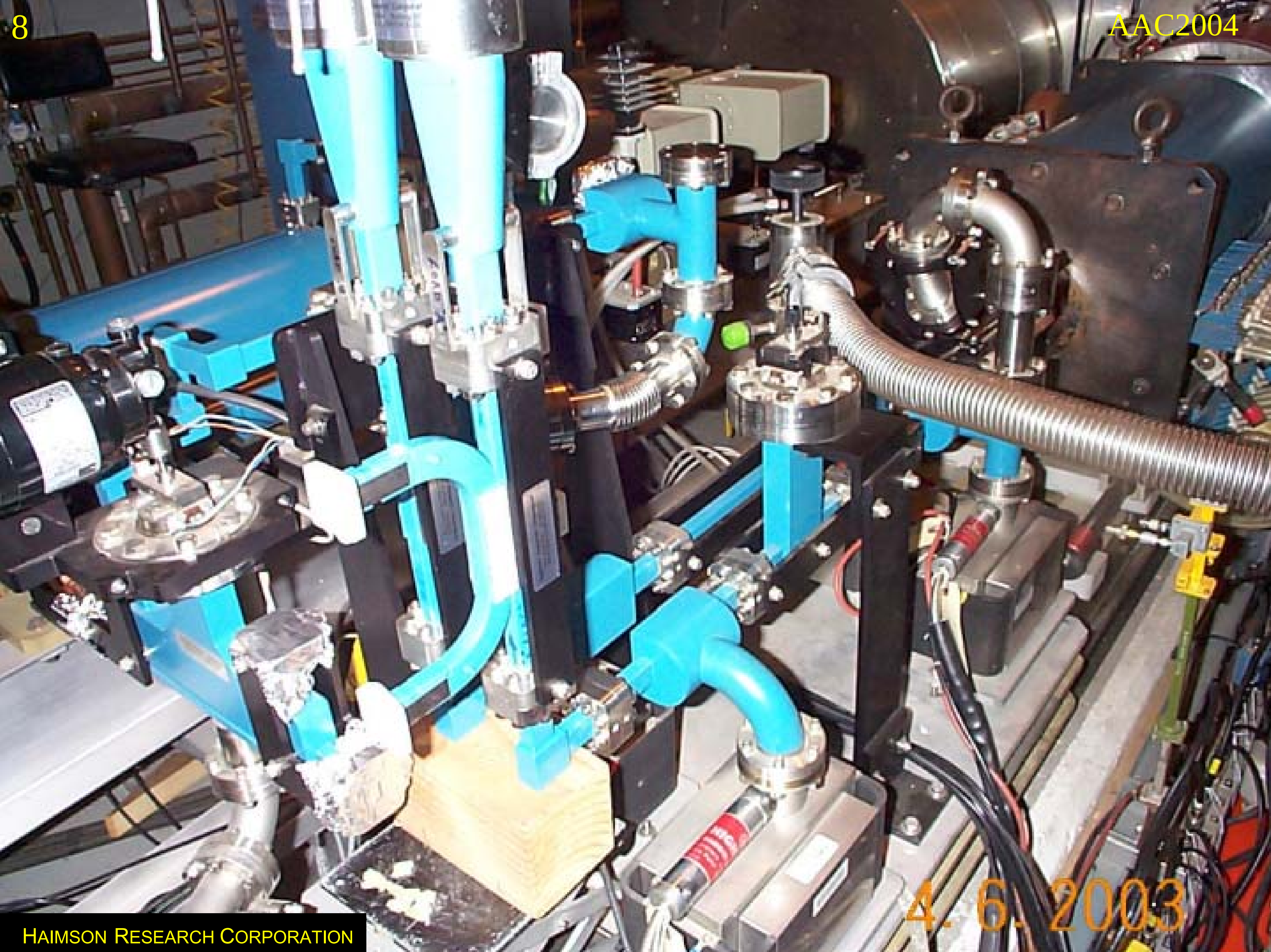
Comparison of Standing and Traveling Wave Field Distributions in a Reduced Phase Velocity 2π/3 Circuit.

SW field amplitudes are reduced to zero and the containment field gradients are reversed twice per λ during circuit traversal.

TW – bunch is maintained in a sp ch opposing field gradient as it travels in near synchronism with the wave.



A 25MW 17GHz TW RELATIVISTIC KLYSTRON STRUCTURE FEATURING A DUAL-FEED RACETRACK OUTPUT COUPLER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17GHz TW MK3 Klystron Performance Characteristics

Collector	89.9	A
Gun Volts	545	kV
Beam Power	49.0	MW
RF Output Power	25.5	MW
Efficiency	51.9	%
Drive Power	1.8	W
Saturated Gain	71.5	dB

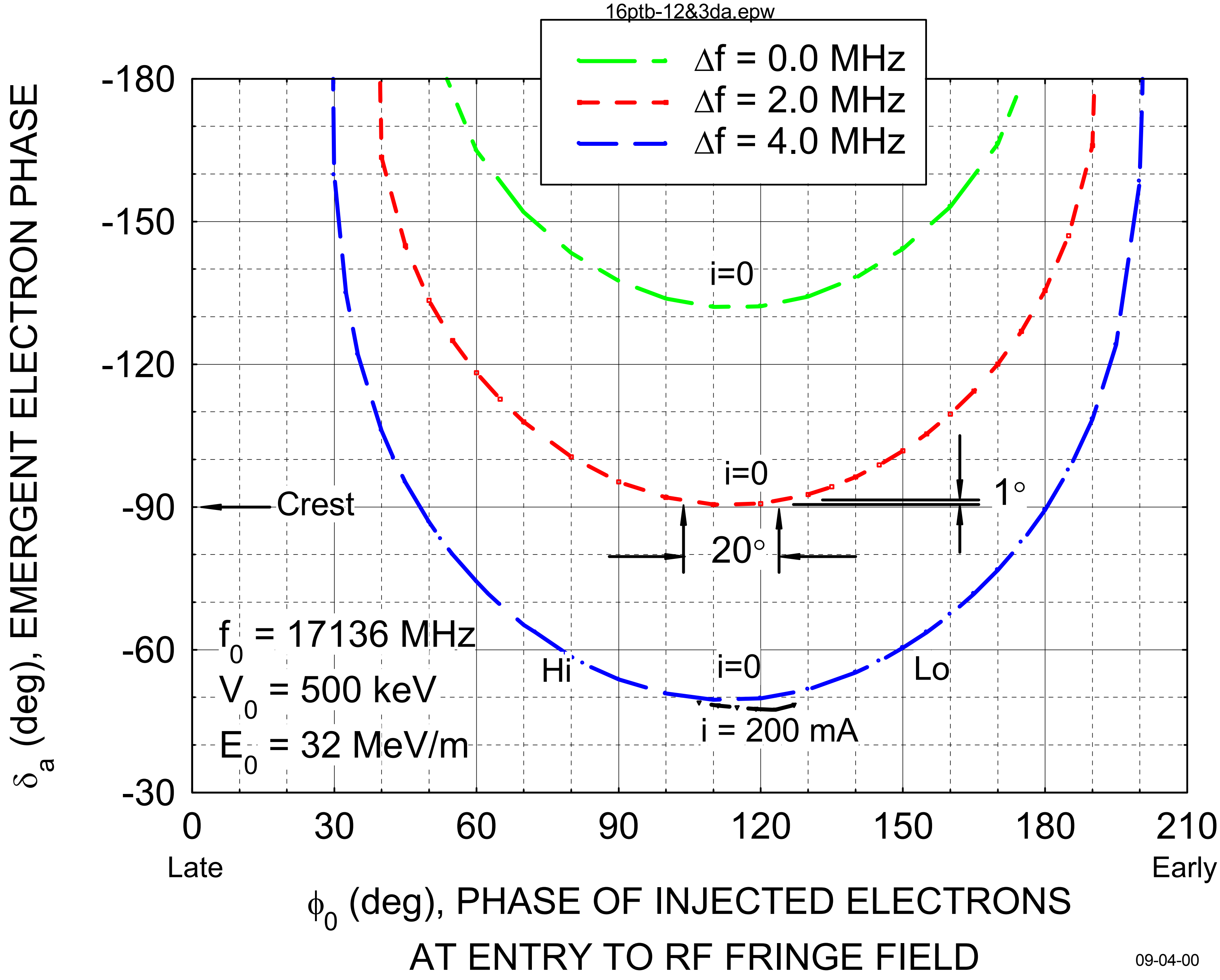
FUTURE GOALS

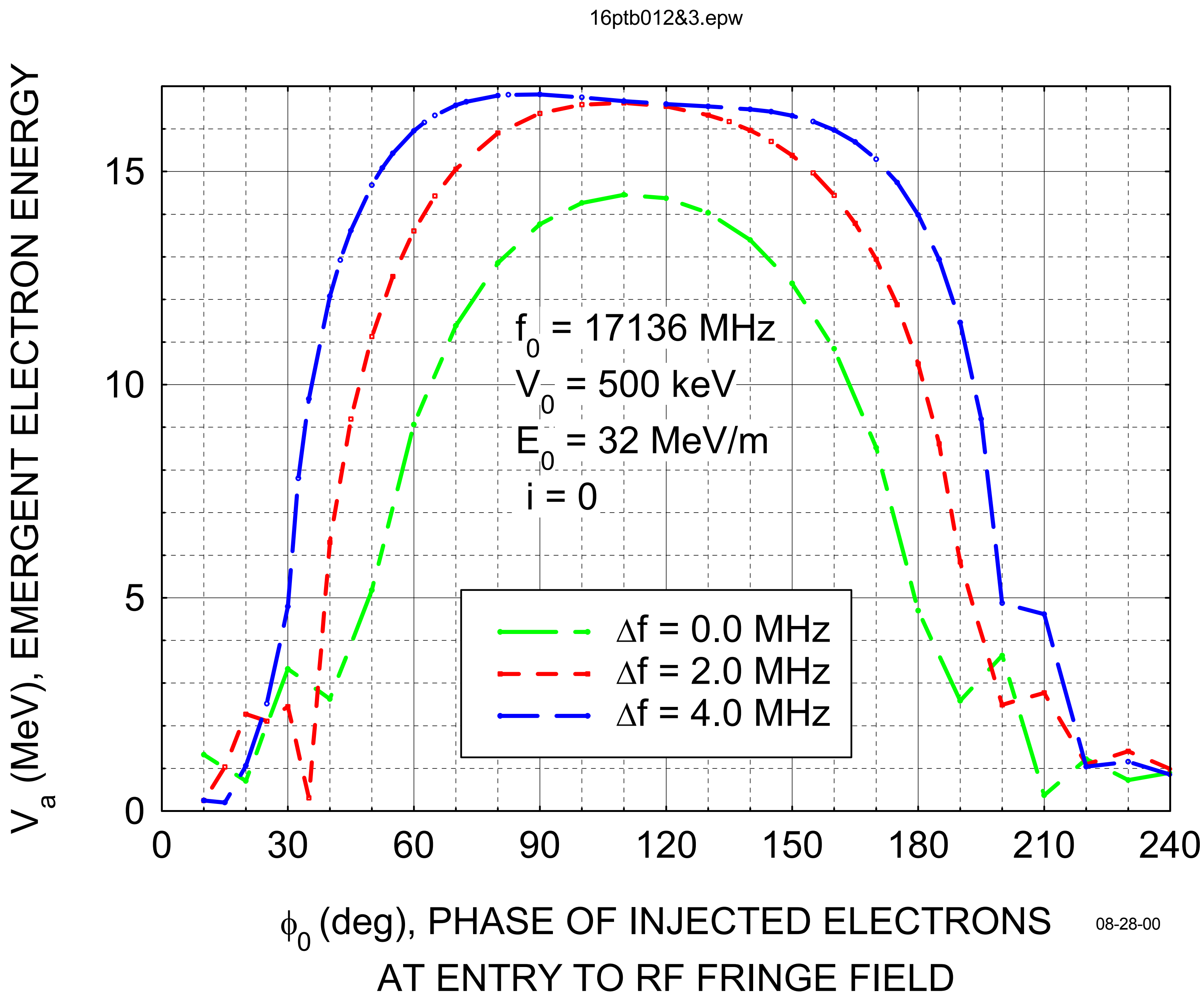
- Demonstrate the Practicality and Economics of Actually Driving a High Gain, High Peak Power Klystron with a Small (3 Watt) Solid State RF Source.
- Develop Distributed Filter Circuits that can be Integrated into the Rectangular Waveguide High Power Output Arms of the TWRK to Ensure Stable Performance Even When Required to Operate into a Mismatched Load of > 1.5 VSWR..

17 GHz LINAC SYSTEM (1° Bunch)

- Pulsed 550 kV 1A electron gun.
- Chopper–Prebuncher assembly injects 15-20° fully gated bunches into the linac.
- 94 cavity, non-uniform impedance TW circuit with a maximum operating gradient of 45 Mev/m.

The 58ns fill time 17GHz linac was designed for steady – state beam operation (1724 RF bunches /100ns) and delivers from 10 to 30 nC/100ns of beam pulse, depending on length of the RF bunch.


16ptb-12&3da.epw
Δf = 0.0 MHz
Δf = 2.0 MHz
Δf = 4.0 MHz
-180
-150
-120
-90
-60
-30
i=0
i=0
i=0
Crest
1°
20°
Hi
Lo
i = 200 mA
f0 = 17136 MHz
V0 = 500 keV
E0 = 32 MeV/m
δa (deg), EMERGENT ELECTRON PHASE
0
30
60
90
120
150
180
210
Late
Early
φ0 (deg), PHASE OF INJECTED ELECTRONS
AT ENTRY TO RF FRINGE FIELD
09-04-00



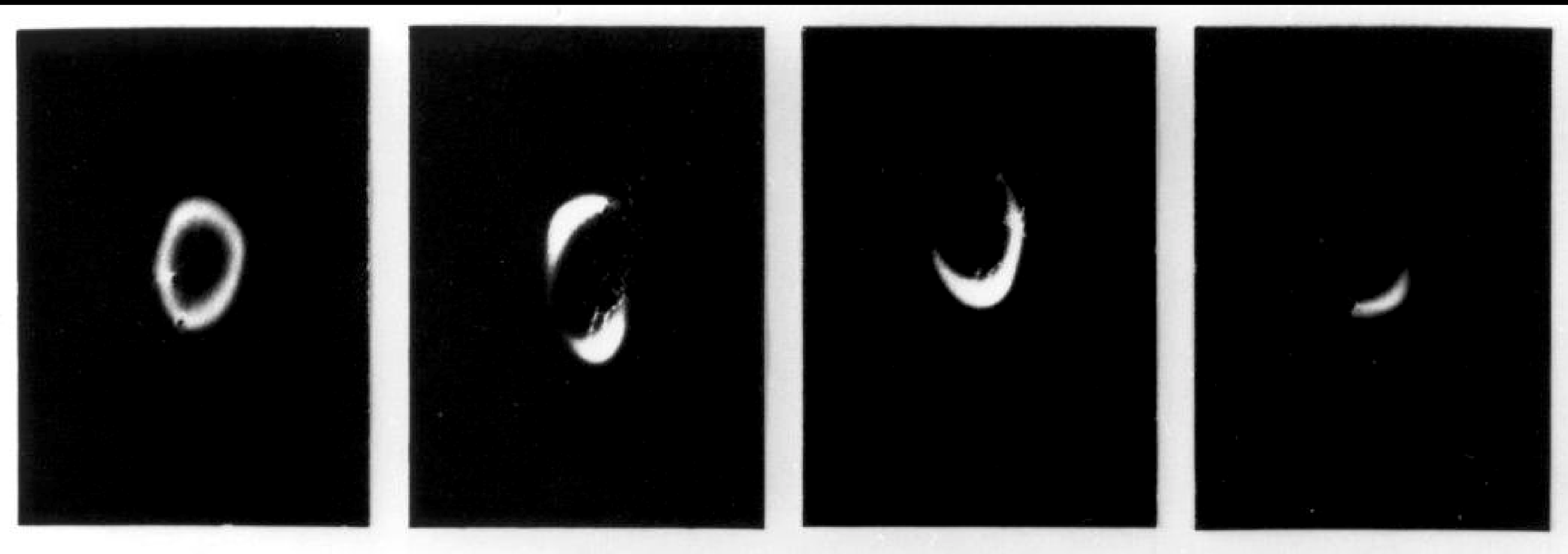
16ptb012&3.epw
V_a (MeV), EMERGENT ELECTRON ENERGY
0
5
10
15
0
30
60
90
120
150
180
210
240
f_0 = 17136 MHz
V_0 = 500 keV
E_0 = 32 MeV/m
i = 0
Δf = 0.0 MHz
Δf = 2.0 MHz
Δf = 4.0 MHz
ϕ_0 (deg), PHASE OF INJECTED ELECTRONS
AT ENTRY TO RF FRINGE FIELD
08-28-00

CIRCULAR

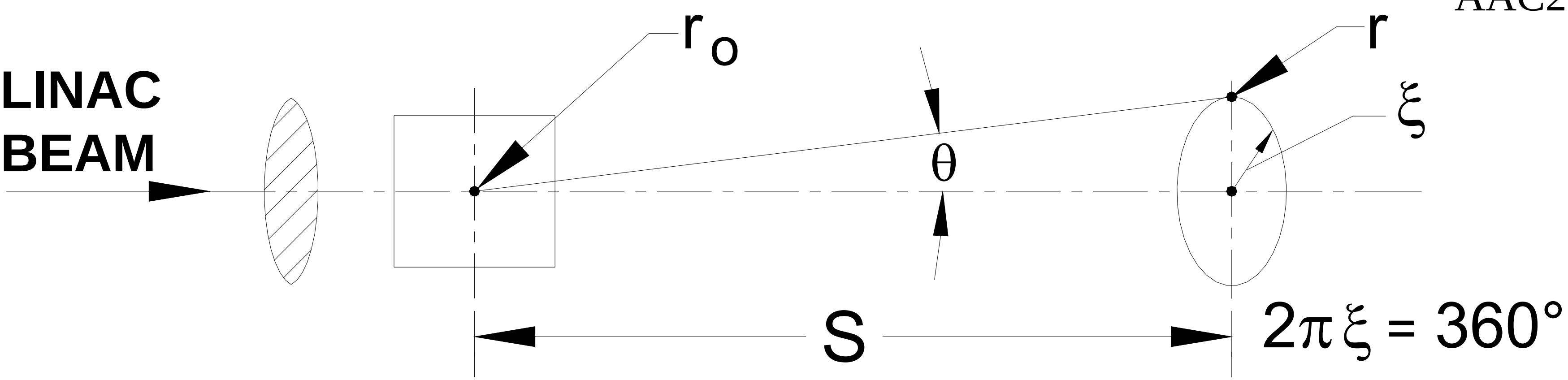
The deflector establishes a constant amplitude deflecting force that rotates at a uniform angular velocity in synchronism with the linac frequency.

Thus the bunch phase and energy charge distributions are orthogonally decoupled and presented along azimuthal and radial coordinates.

The First PAC (Washington DC March 1965)



S-Band RF Bunch Measurements Using a Circularly Scanned Beam (2 x TE_{102} Rectangular Cavities With Transverse Magnetic Fields)



and since $r = s\varepsilon/r_o$, $\chi = s\theta$

and $\theta = (\beta_\perp\gamma)/(\beta_D\gamma)$,

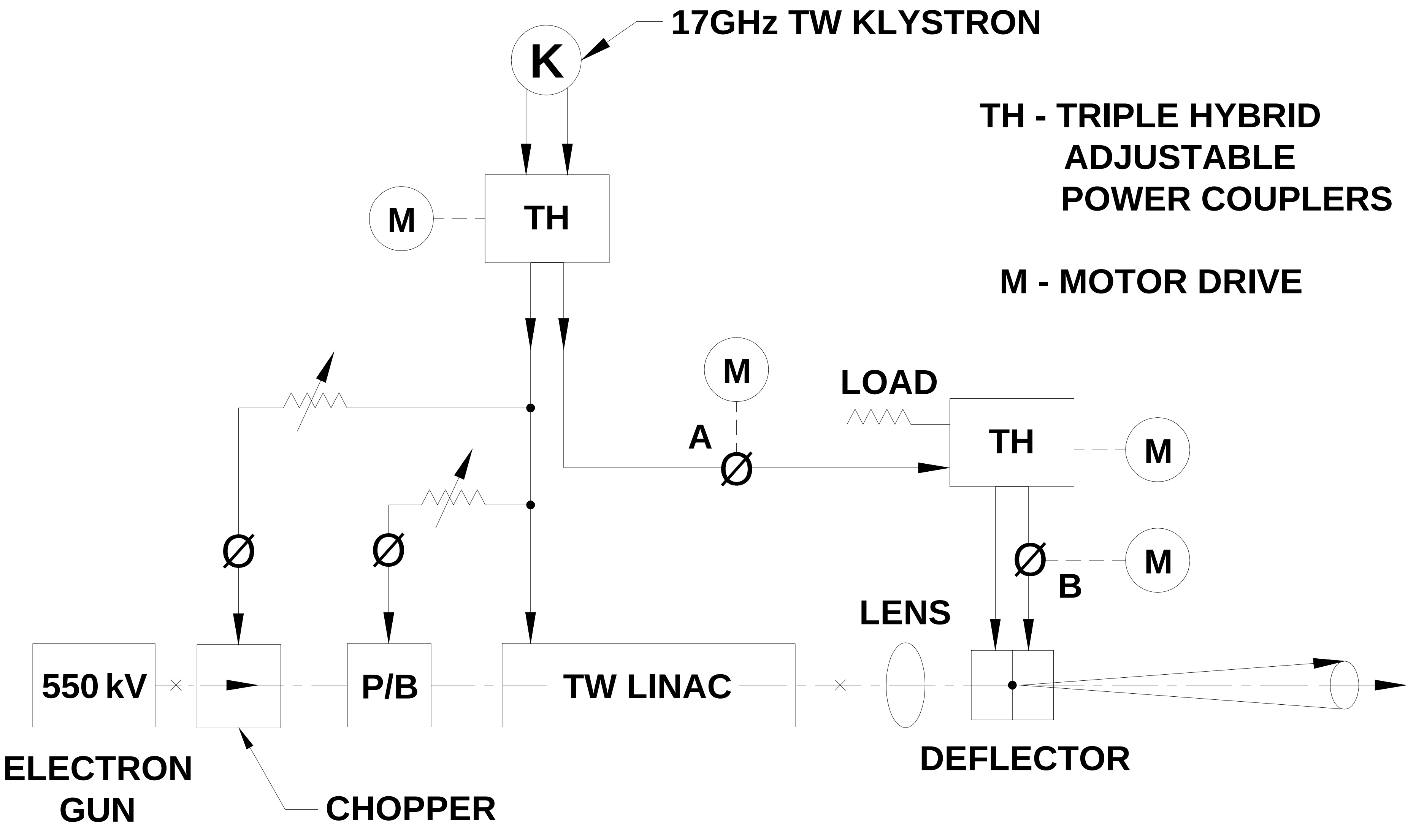
then $\phi_{min} = \varepsilon_n/(r_o\Delta p)$ (1)

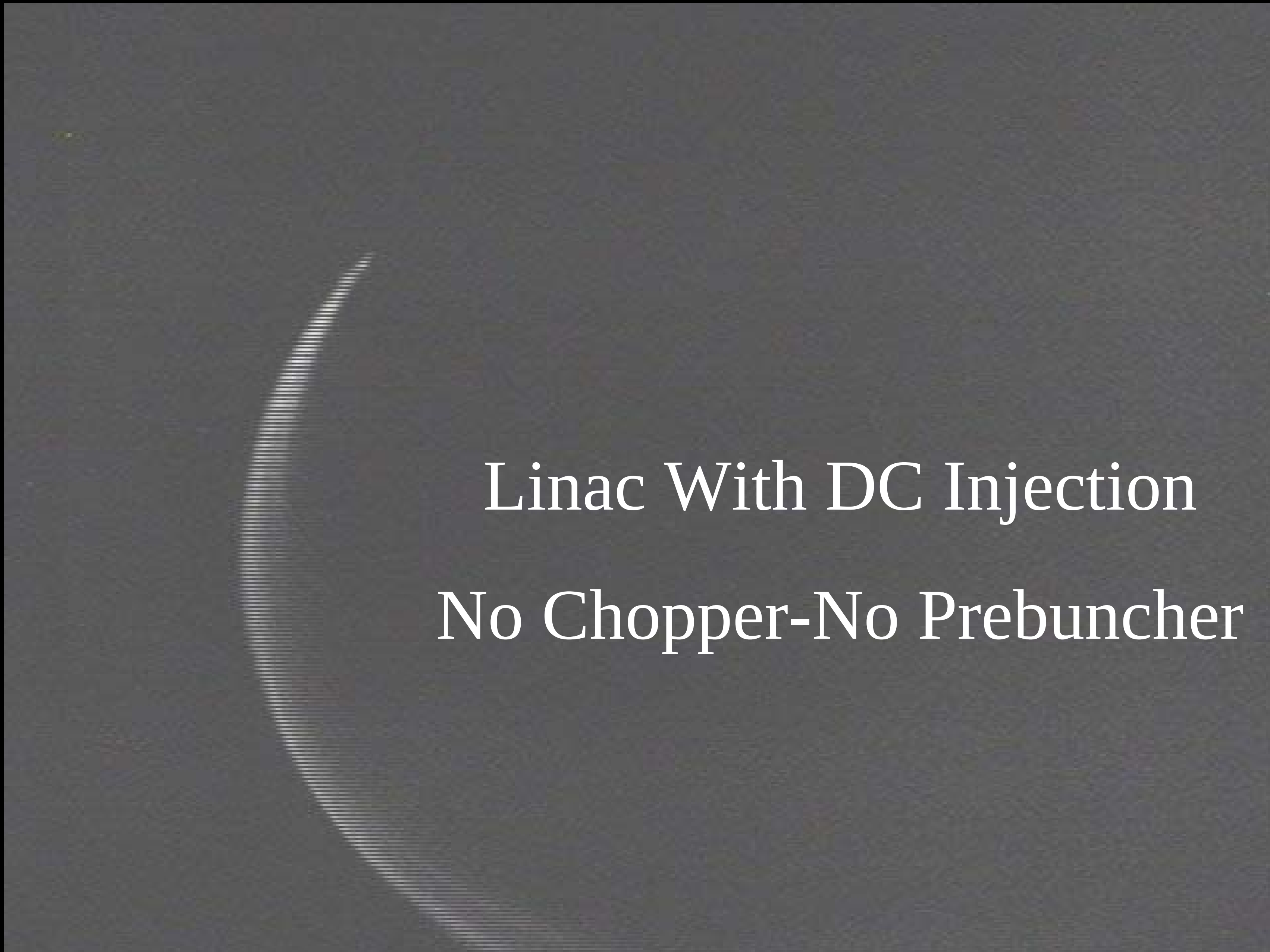
where ε_n = normalized beam emittance

r_o = beam radius at deflector

Δp = transverse momentum kick(m_oc)

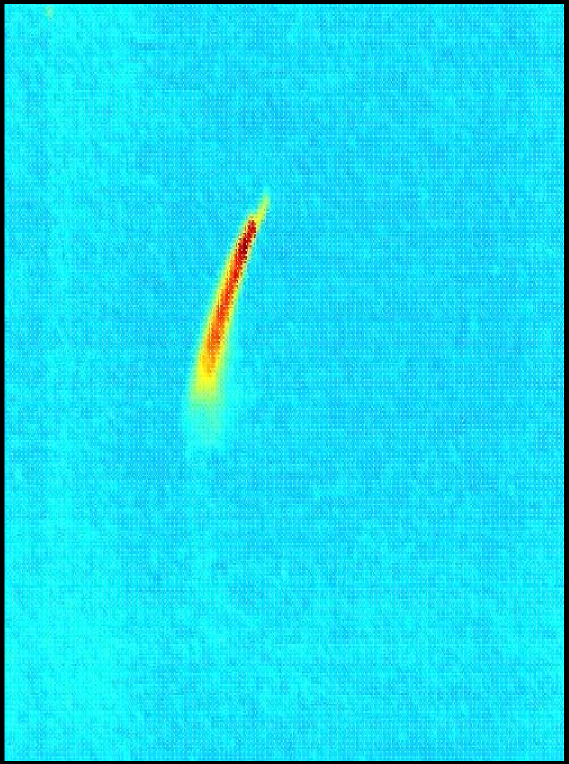
WR62 EVACUATED NETWORK CONFIGURATION FOR THE 17GHz LINAC AND CIRCULARLY POLARIZED DEFLECTOR

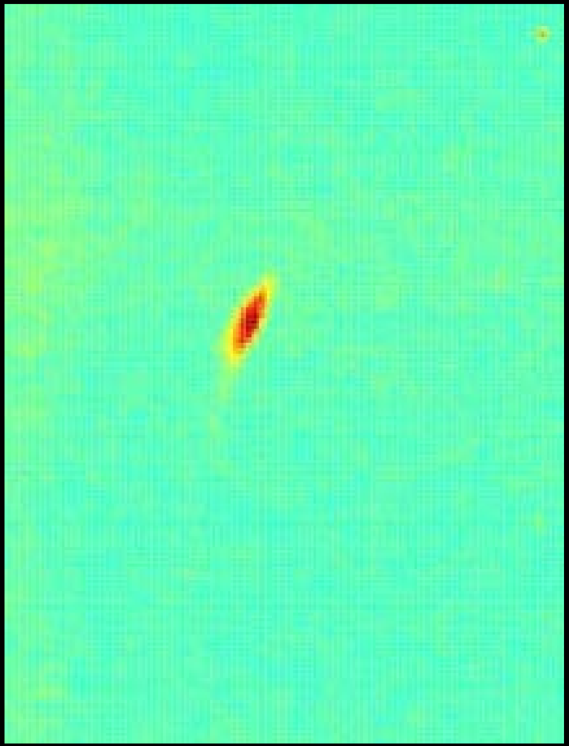



Linac With DC Injection
No Chopper-No Prebuncher

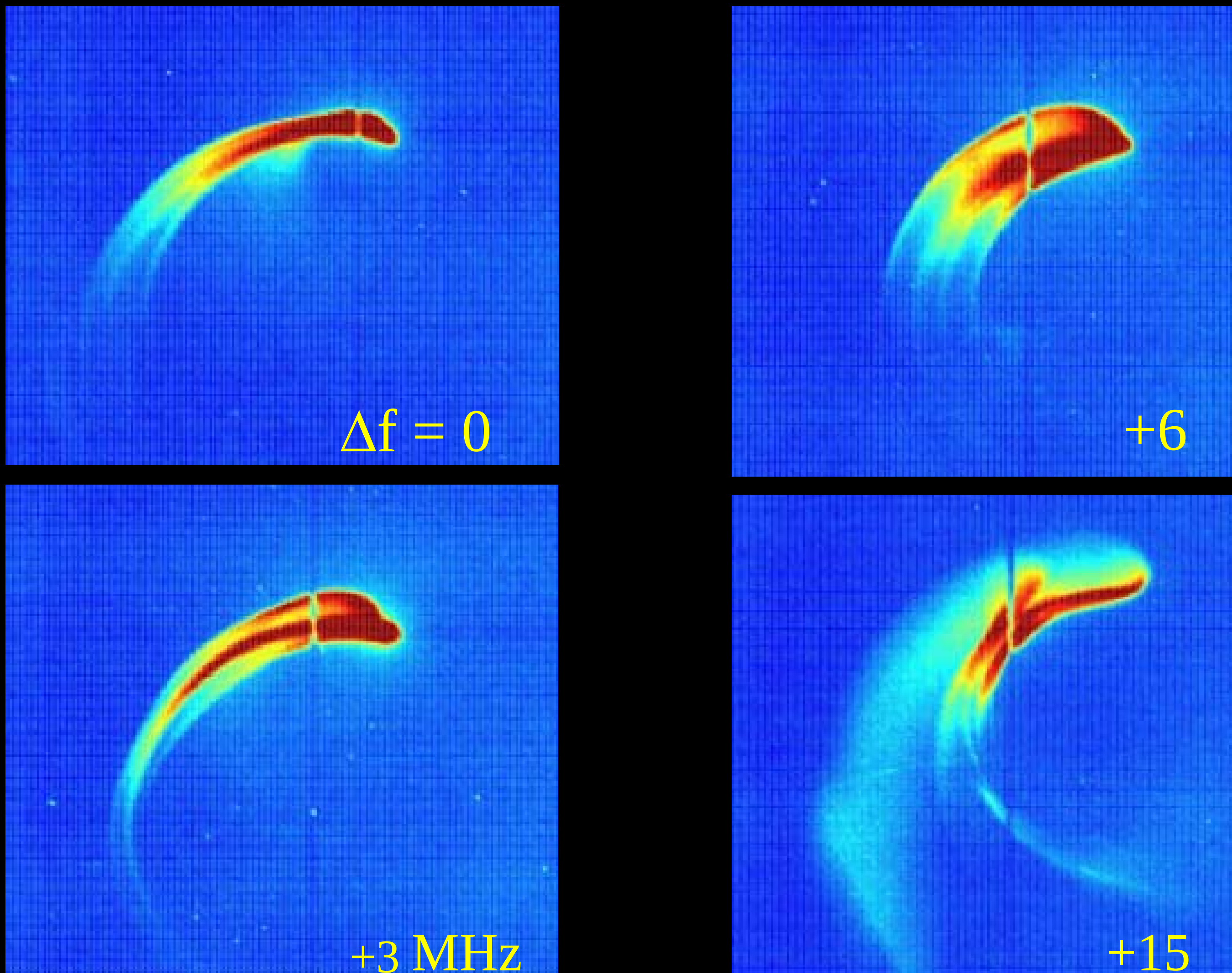
Charge Enhancement With Prebuncher Excitation

Control of Linac Bunch Length With Chopper and Bias Adjustment

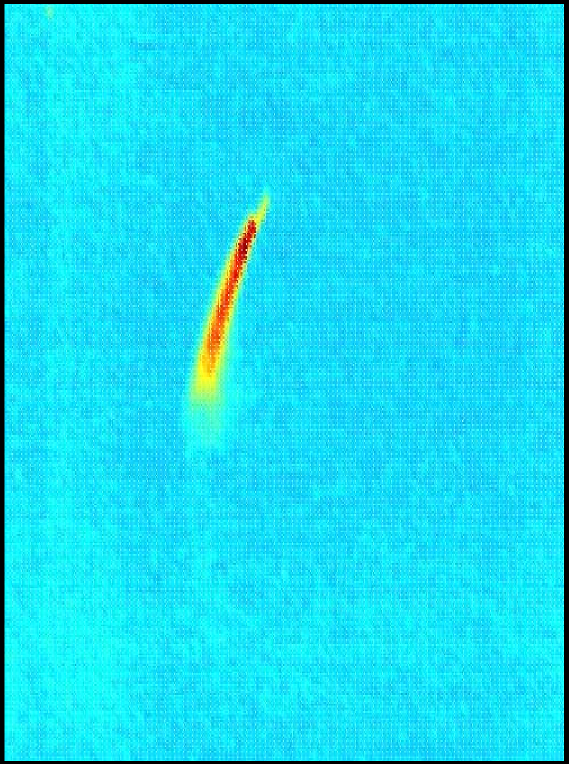


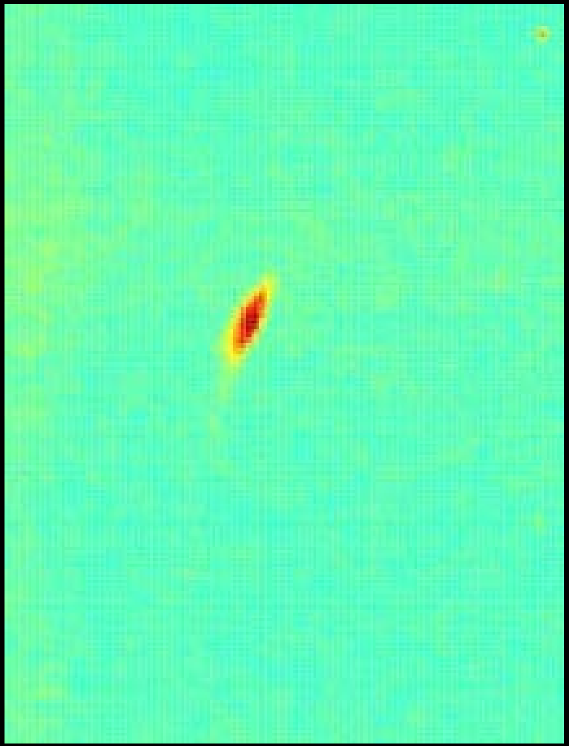


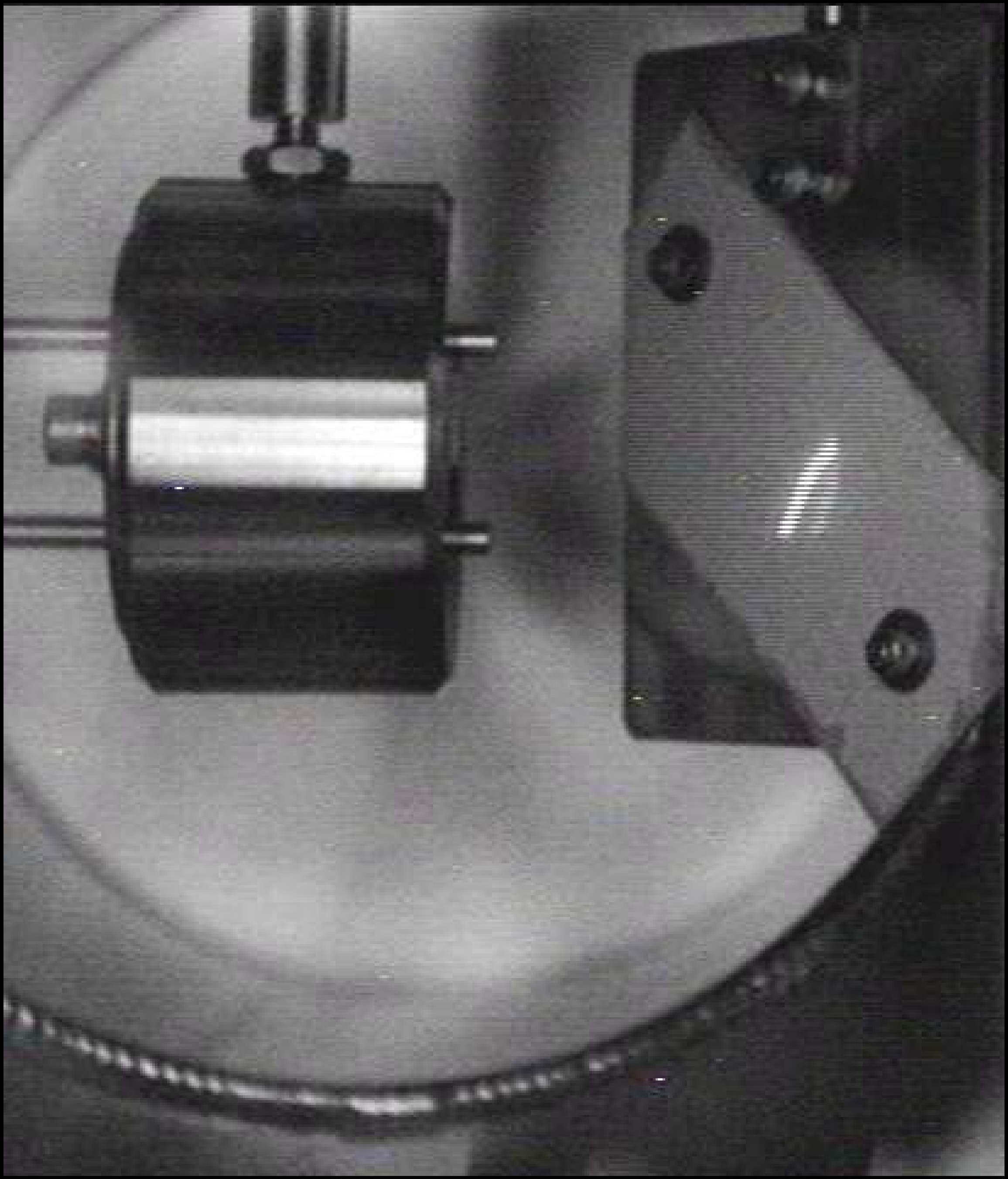
Visualization of Bunch Disruption with Progressively Increasing Linac Frequency



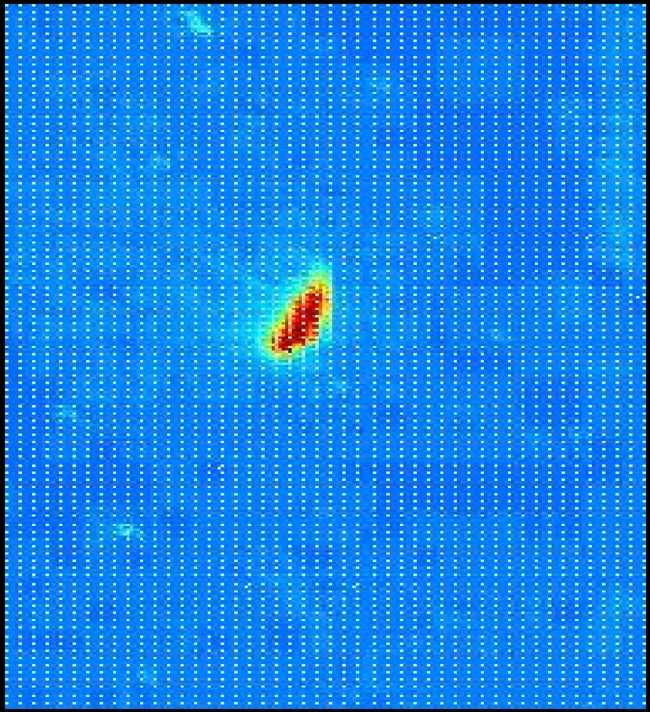
Control of Linac Bunch Length With Chopper and Bias Adjustment

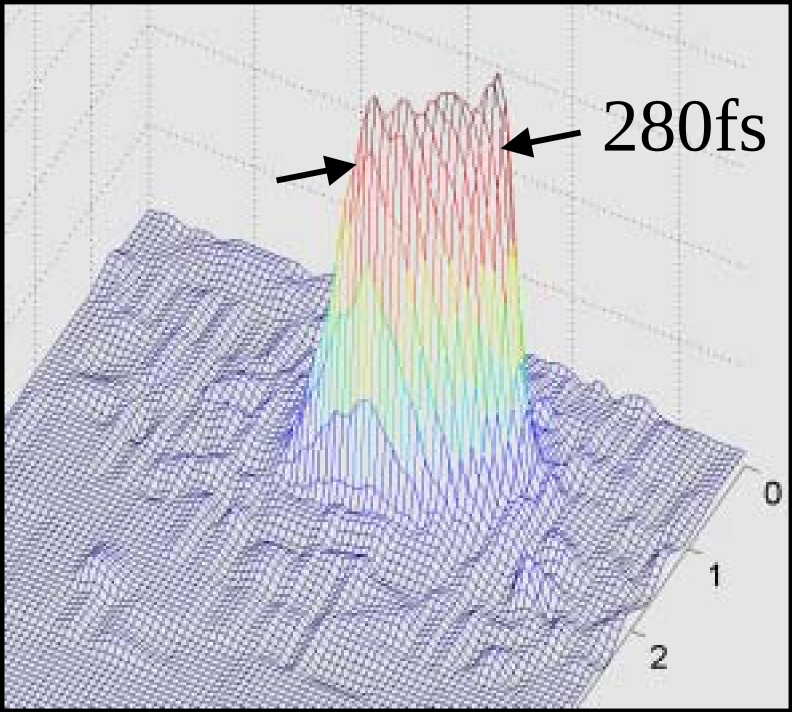






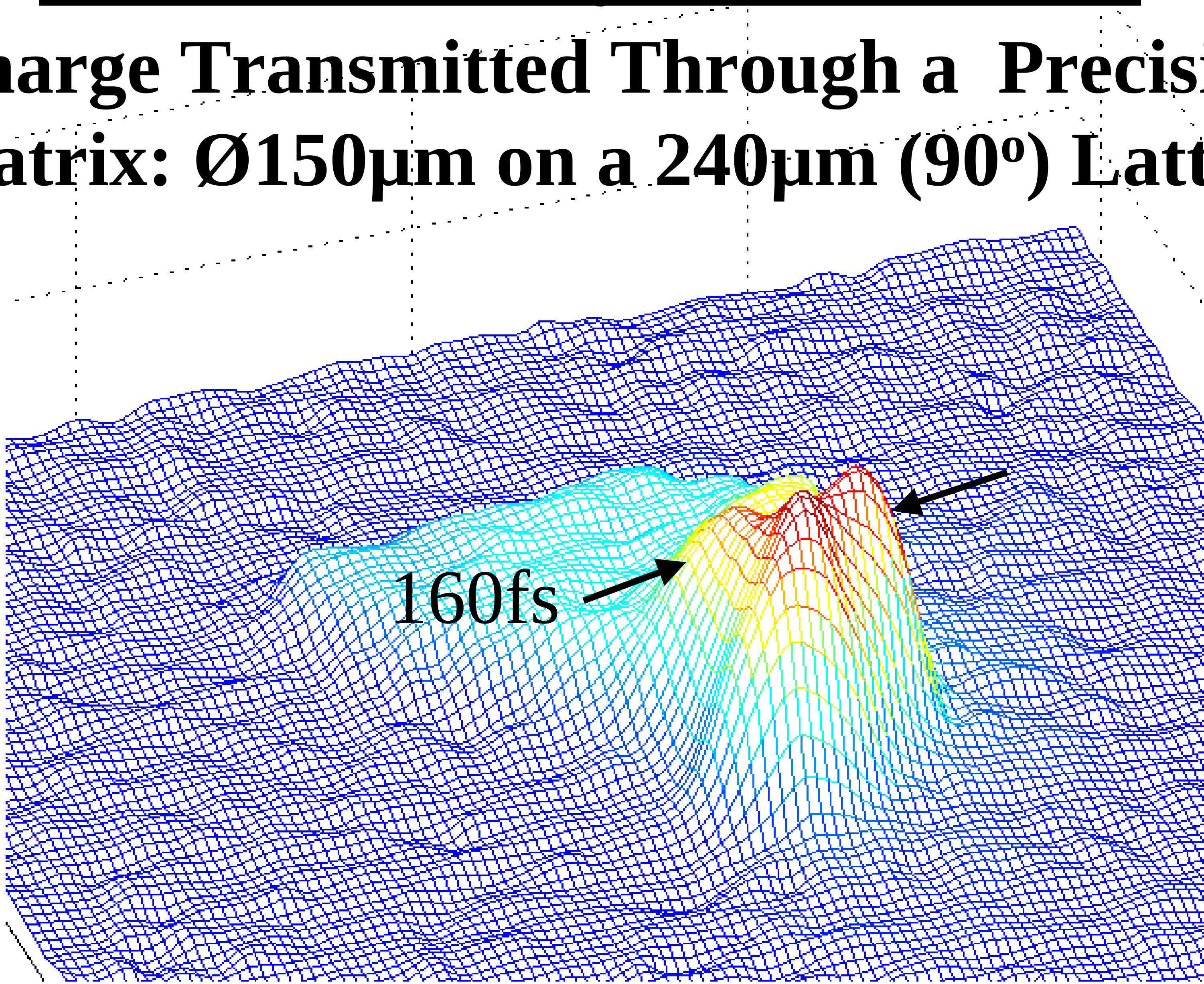
15 MeV, 1.7° Linac Bunch After Circularly Polarized Deflection and Transmission Through a Matrix of Precision Collimators



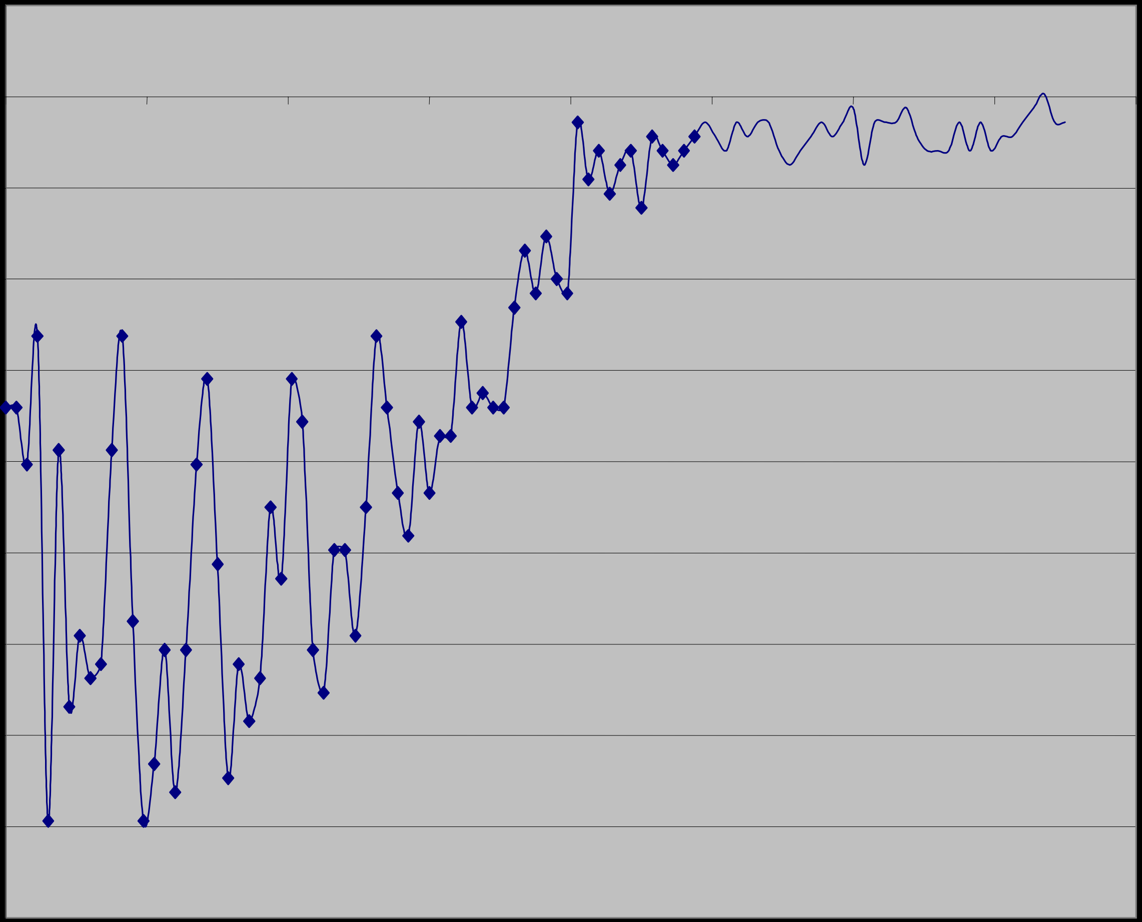


17GHz Circularly Polarized Scan

Charge Transmitted Through a Precision Matrix: Ø150μm on a 240μm (90º) Lattice



Head to (almost) Tail Charge Distribution of a Short RF Bunch obtained with 150μm analyzing slits scanned across the circularly polarized deflected electron beam.



FAST DIAGNOSTIC FOR RF BUNCH ANALYSIS

BRIEF SUMMARY

ON-LINE AND REAL TIME VIEWING.

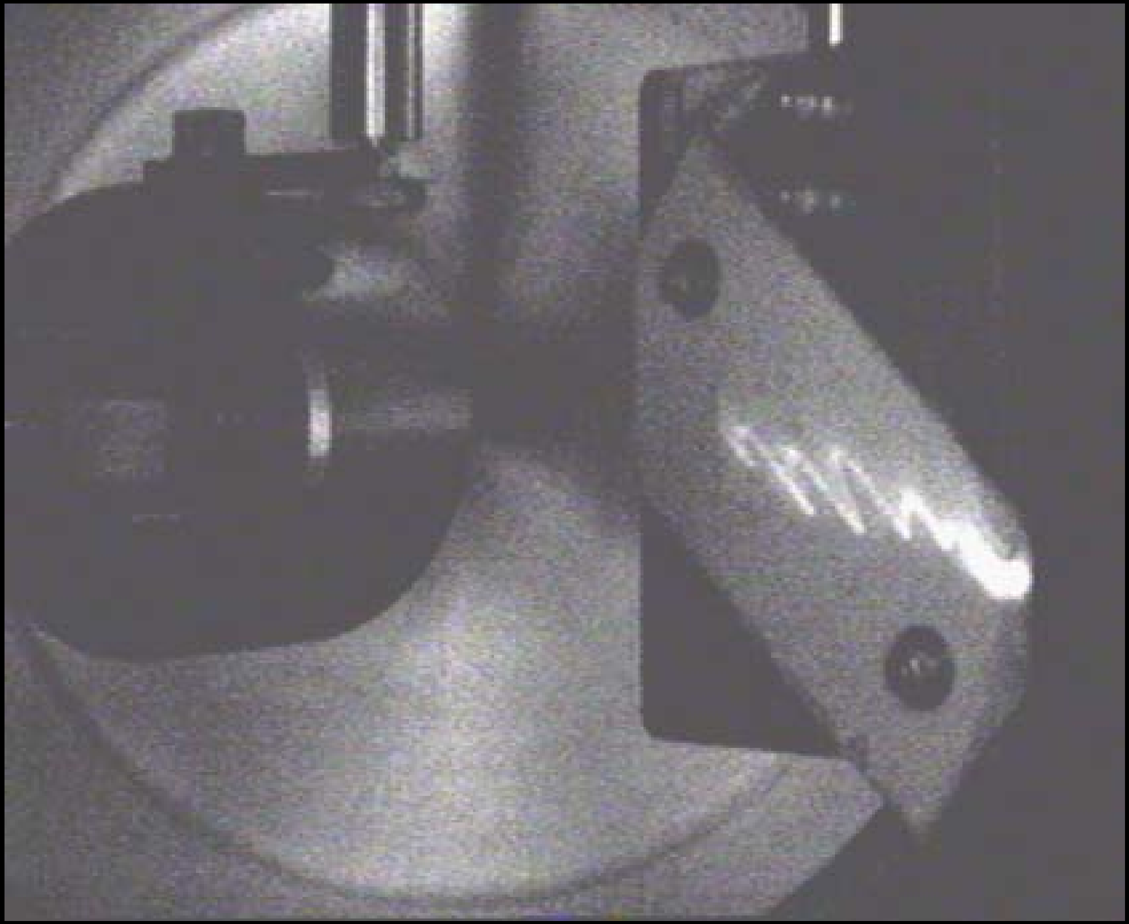
DIRECT AND SIMPLE CALIBRATION.

INHERENT PHASE SYNCHRONIZATION.

MINIMUM RESOLUTION – 50 TO 100 fs RANGE

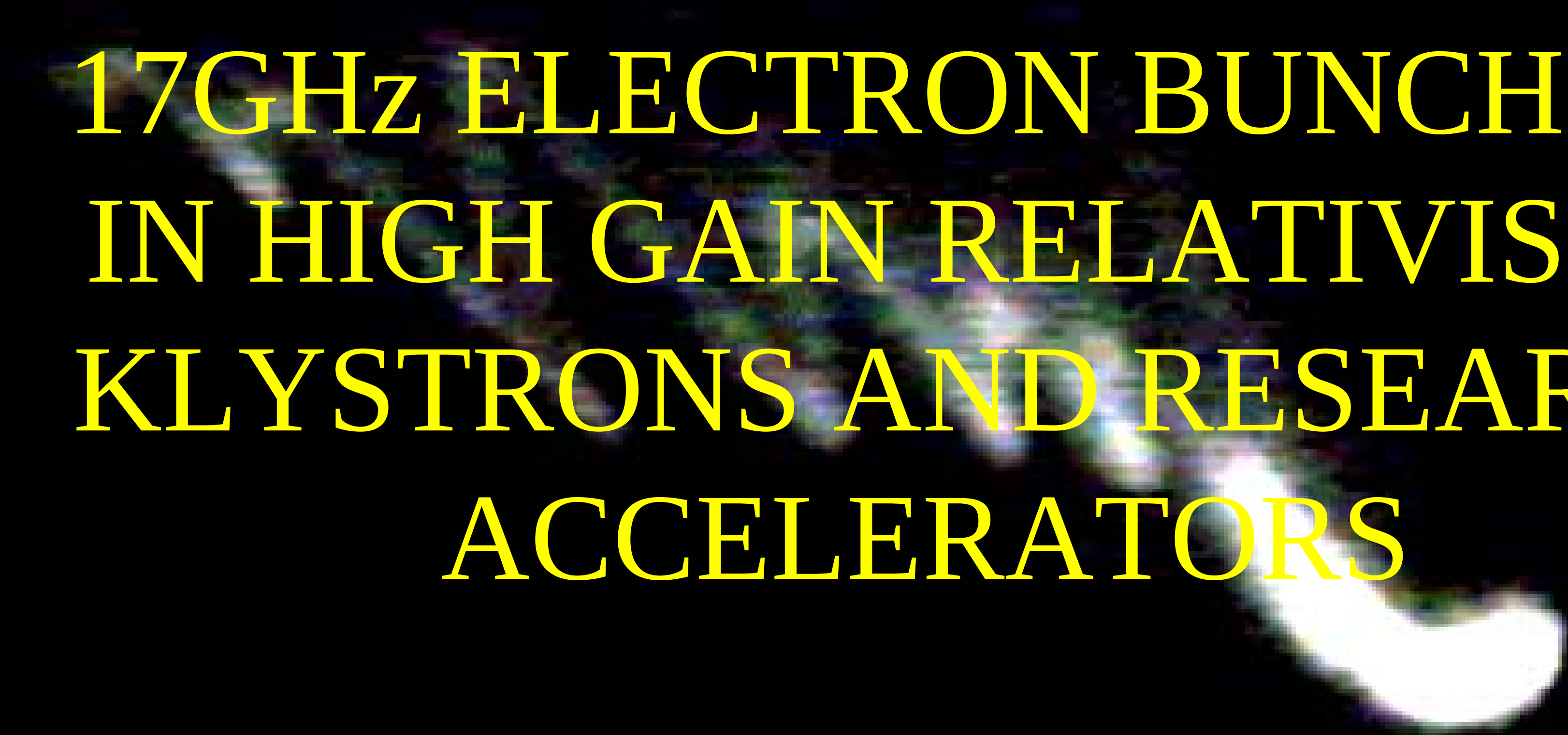
ESPECIALLY SUITED FOR BEAMS OF VERY LOW EMITTANCE AND SHORT RF BUNCHES.

ULTRA-FAST PERTURBATION OBSERVED ON THE LONGITUDINAL PHASE SPACE IMAGE OF THE 17GHz LINAC ELECTRON BUNCH



RESOLVES > 10THz

During final rf processing



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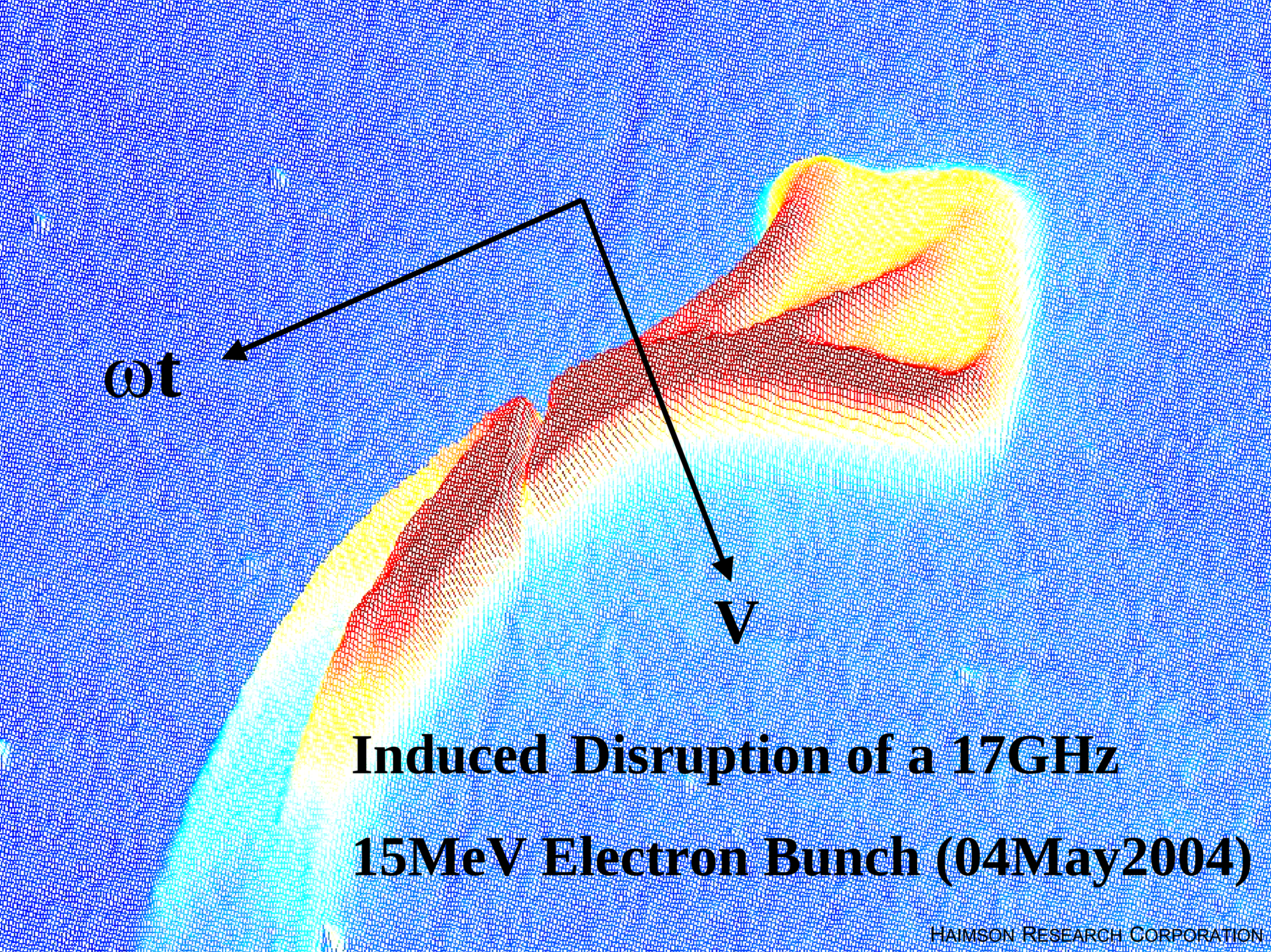
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V
Induced Disruption of a 17GHz
15MeV Electron Bunch (04May2004)
Haimson Research Corporation

Linac Operating Condition During Bunch Measurements

Frequency at 21.5°C . . . . 17139 MHz

Beam Energy . . . . 15 MeV

Steady State Beam Pulse Length . . . . 100 ns

Pulse Current Range . . . . 50 to 200 mA

Charge/Bunch (Nominal) . . . . 6 pC

Charge/Pulse . . . . 10 nC

Normalized Edge Emittance (ε_n) . . . . . . 2.8π mm mrad

(Implied ε_n rms . . . . < 1.0π mm mrad)