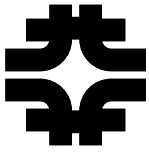


Fermilab

J. MacLachlan, BD/AI

Thursday 25 Sept. 03

Accelerating Lumpy Bunches Through Transition

- bunches observed to be ragged early in cycle (Yang)
- lumpiness causes higher peak currents for given emittance
- strength of most collective instabilities directly proportional to peak current
- Booster already close to NMI threshold for smooth bunches

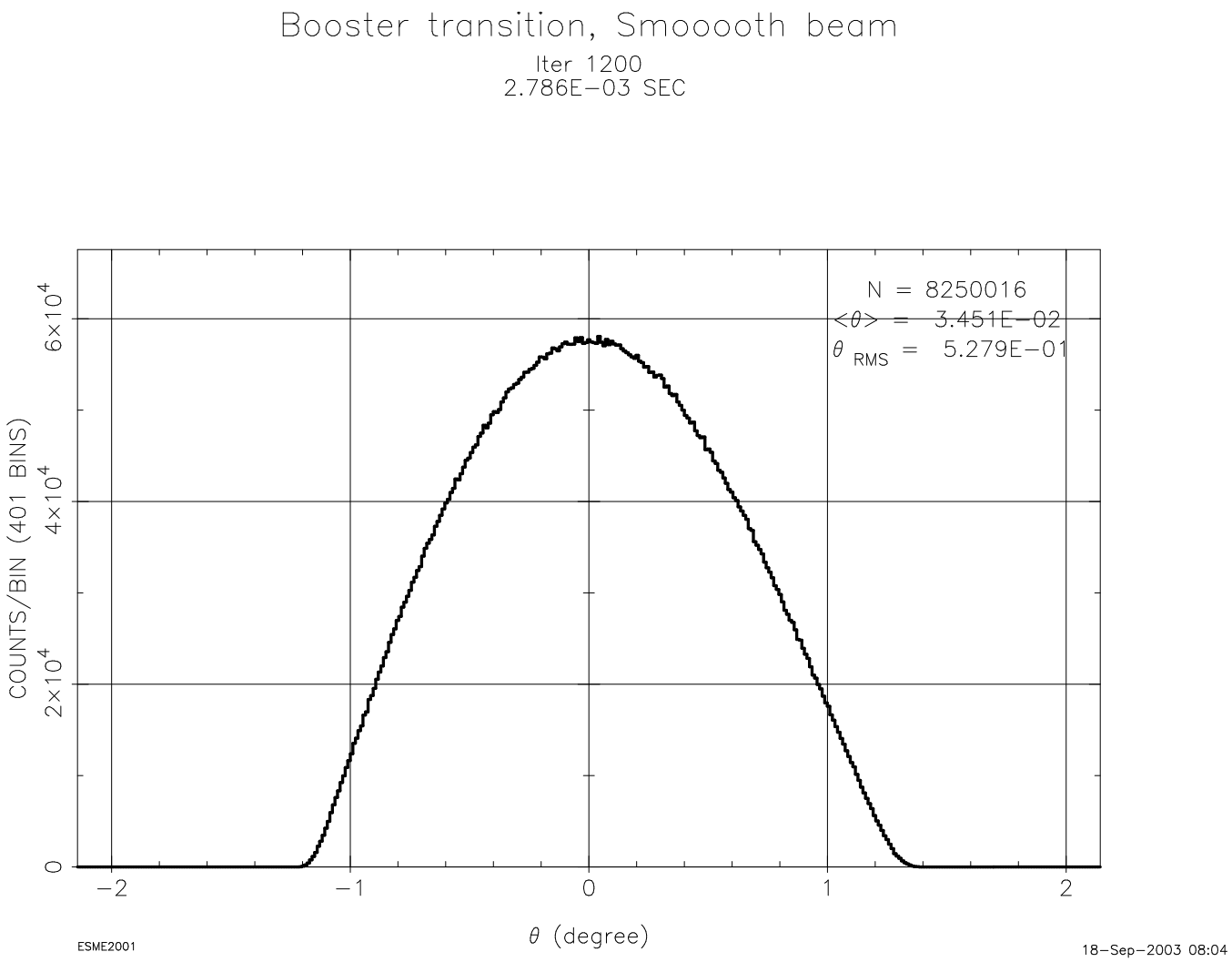
- γ_T jump may be good enough to avoid NMI problem (work in progress)
- A respectable high-brightness injector synchrotron would have a functioning γ_T jump system.

Booster Parameters by guess and by gosh

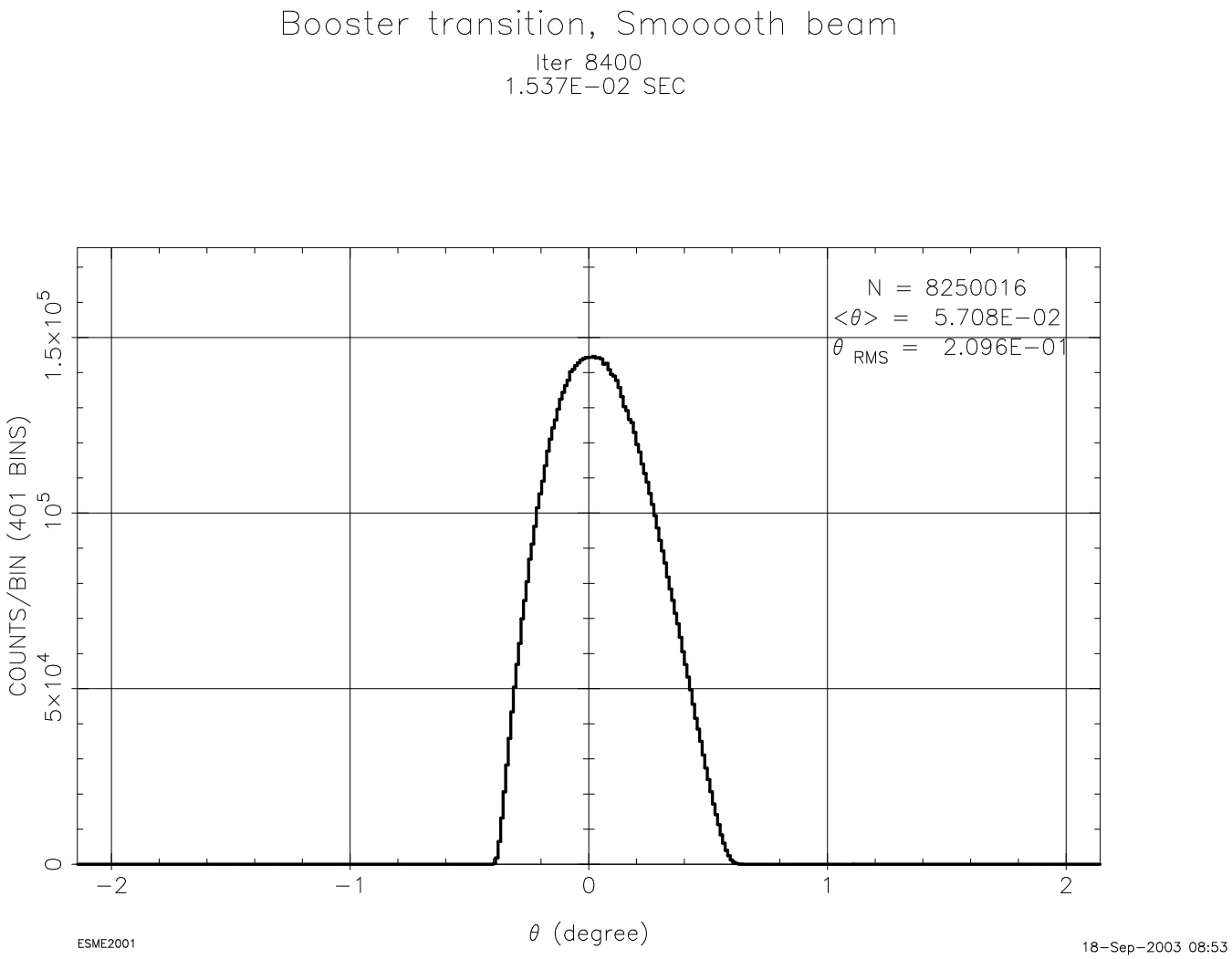
ring radius	75.47	m
injection energy (kinetic)	400.	MeV
extraction energy	8.0	GeV
γ_T	5.446	
ε_ℓ, initial	0.0947	eVs
harmonic number	84	
max. rf volts	1.2	MV
rf frequency	37.9 – 52.8	MHz
sinusoidal ramp	15	Hz
maximum $\dot{p}$	374	GeV/c/s
number of protons	$5 \cdot 10^{12}$	

Transition Parameters analysis

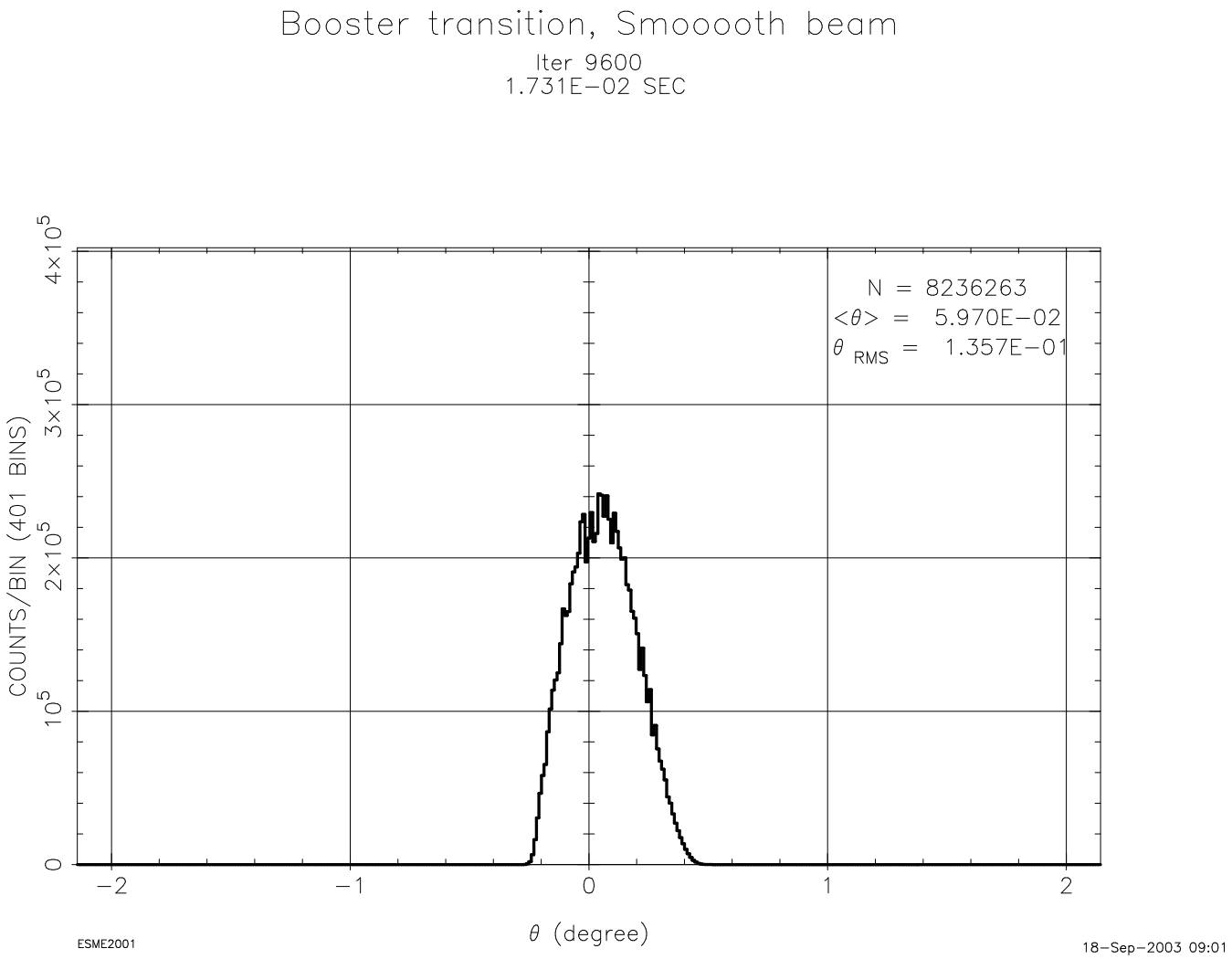
γ_T	5.446	
$\dot{\gamma}$	419.2	s^{-1}
α_1 (ESME)	0.0	
rf amplitude	690.	kV
bunch area	0.0947	eVs
particles/bunch	$6 \cdot 10^{10}$	
harmonic number	84	
Transition energy	5.110	GeV
v/c at transition	0.9829	
rf frequency	52.20	MHz
circulation period	1.609	μs
$\dot{E}$	393.3	GeV/s
ϕ_s	1.161	rad
rms bunch length	0.5445	ns
geometric factor	4.515	
nonadiabatic time	0.2572	ms
nonlinear time	43.30	μs
$\eta_\circ(0)$ (Sorrenssen)	0.5107	
harmonic for $g_\circ/2$	23708	
fastest mode	13688	
“worst” mode	7903	
NMI threshold param.	1.372	
appx. peak current	6.696	A
$\lvert Z_\parallel \rvert$	29.19	Ω
$\frac{\Delta\varepsilon}{\varepsilon}$ (Jie Wei)	0.1280	



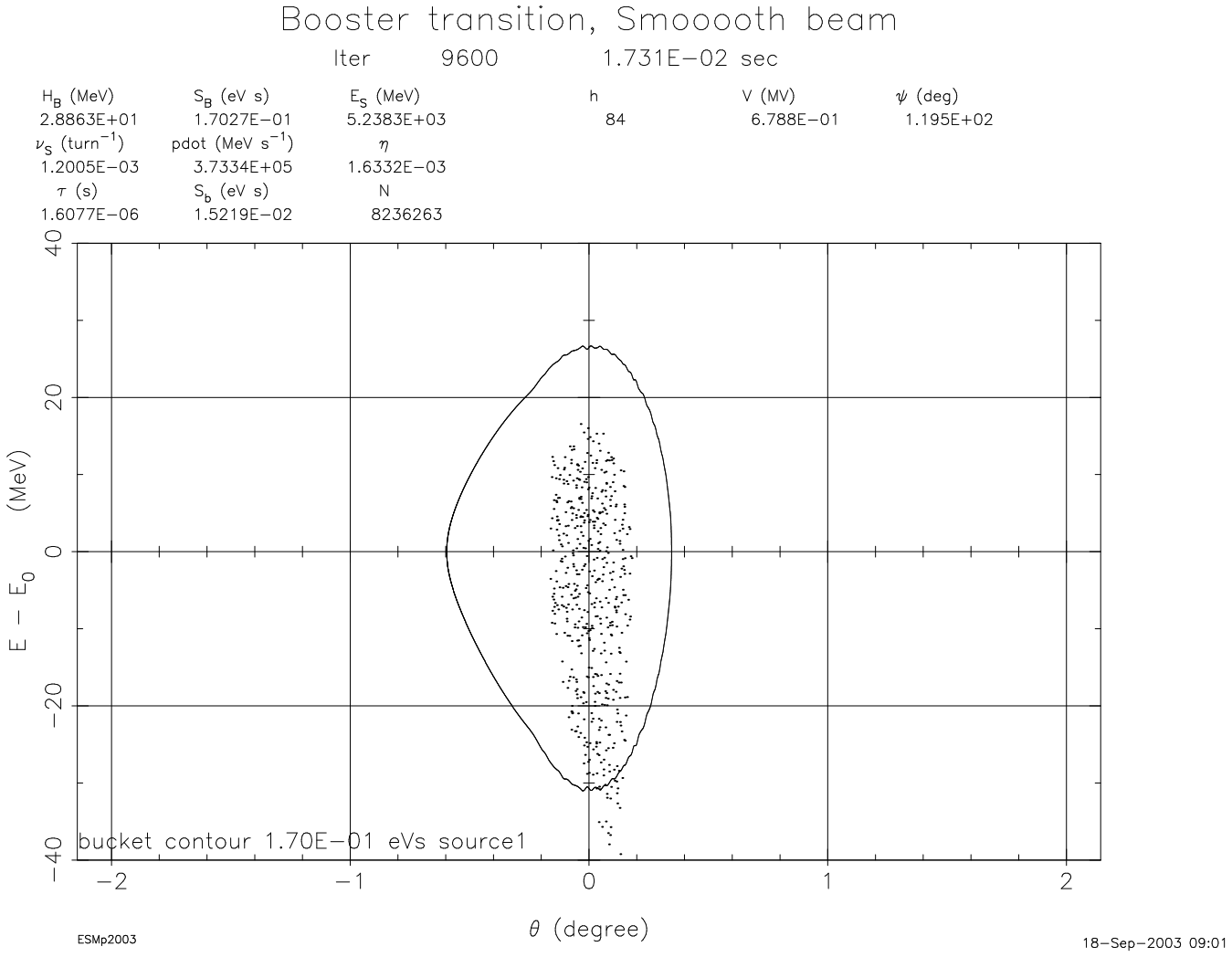
charge profile for smooth bunch of 0.0947 eVs with $6 \cdot 10^{10}$ protons using 8.25 M macroparticles early in Booster cycle



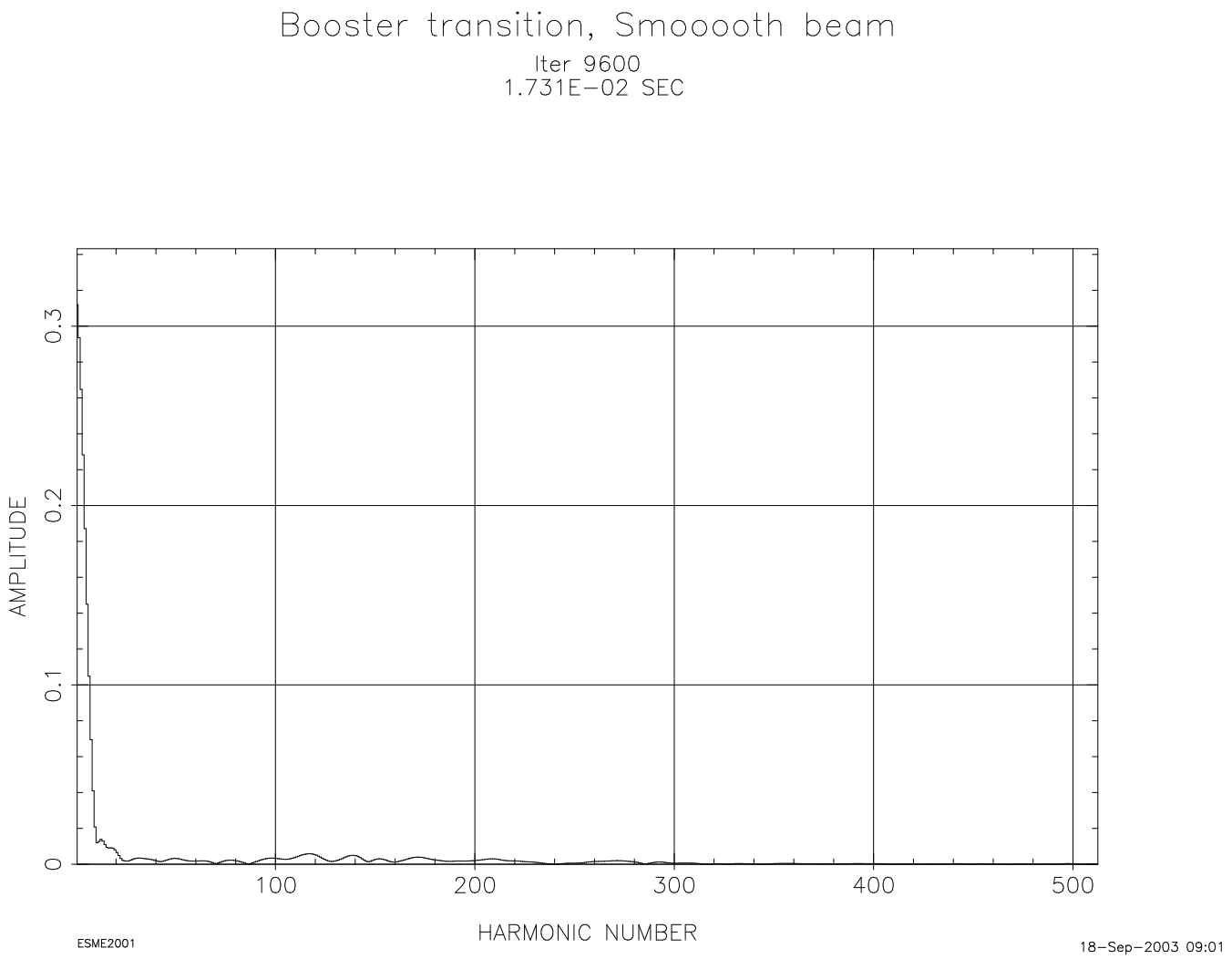
as above at 15.4 ms into cycle



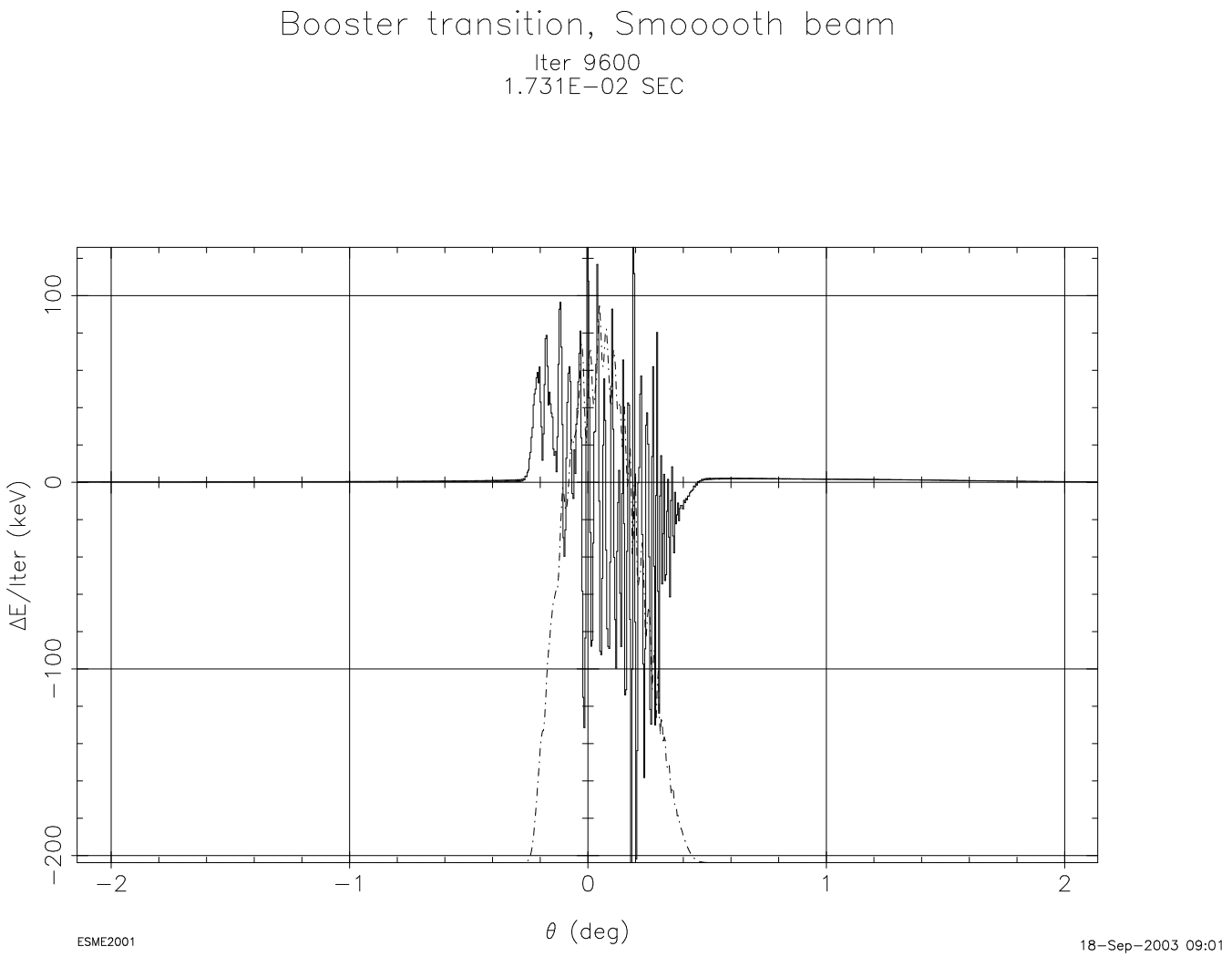
same as above at 17.3 ms — just after transition



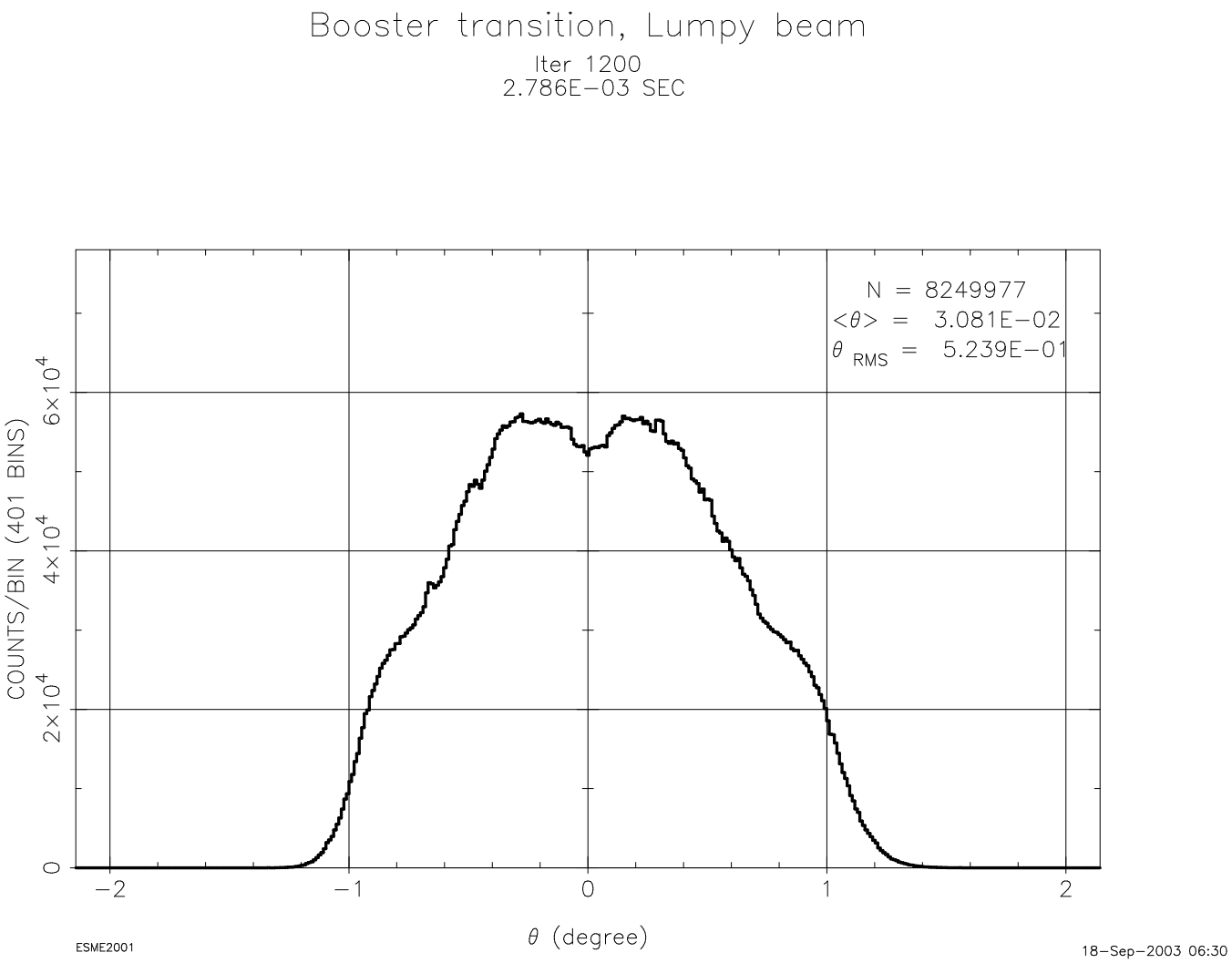
a few of 8.25 m phase space points just after transition — evidence of high collective voltage noticeable on contour. Notice nonlinear single-particle problem(s).



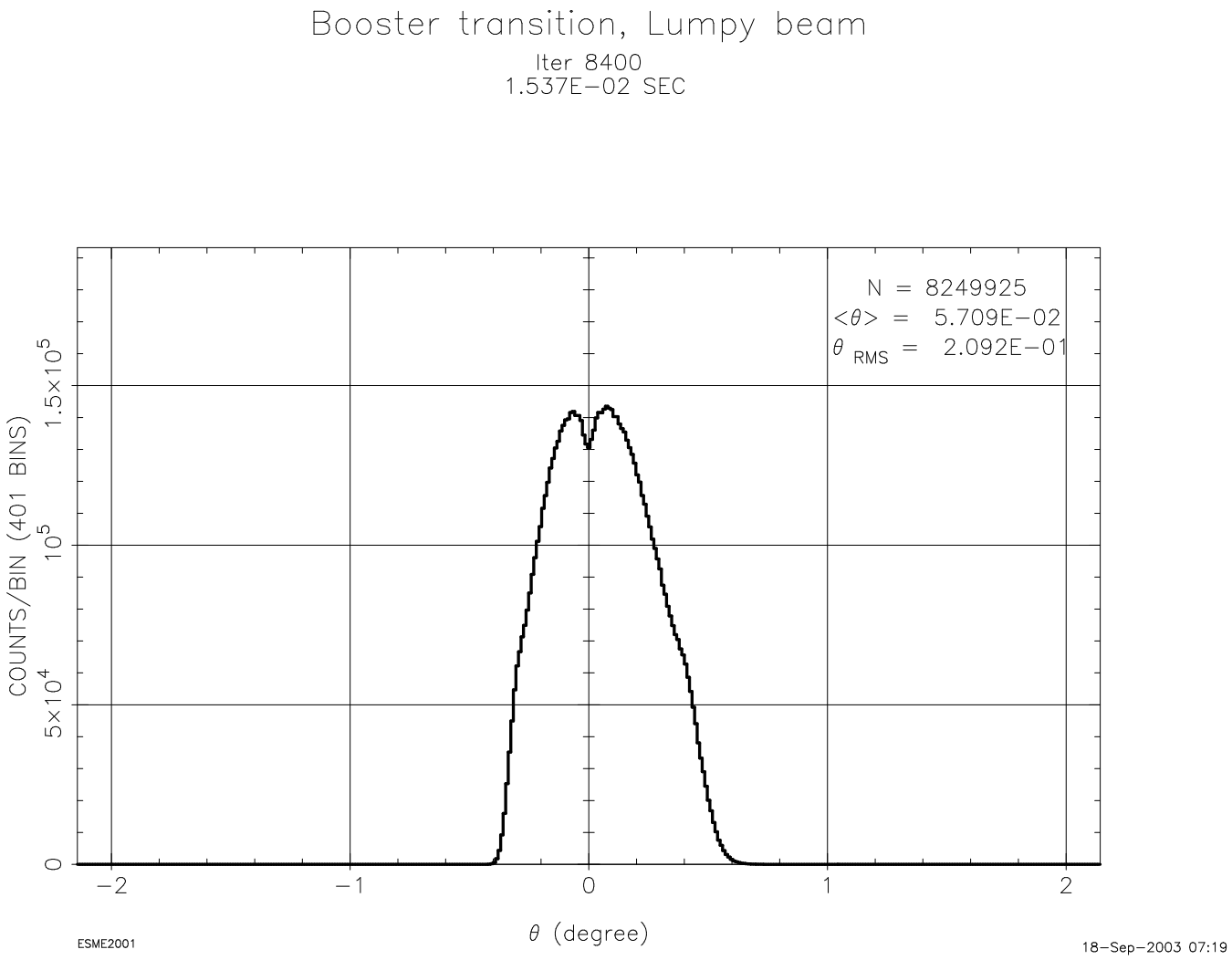
the Fourier spectrum of the beam current just after transition — most excitation below 15 GHz



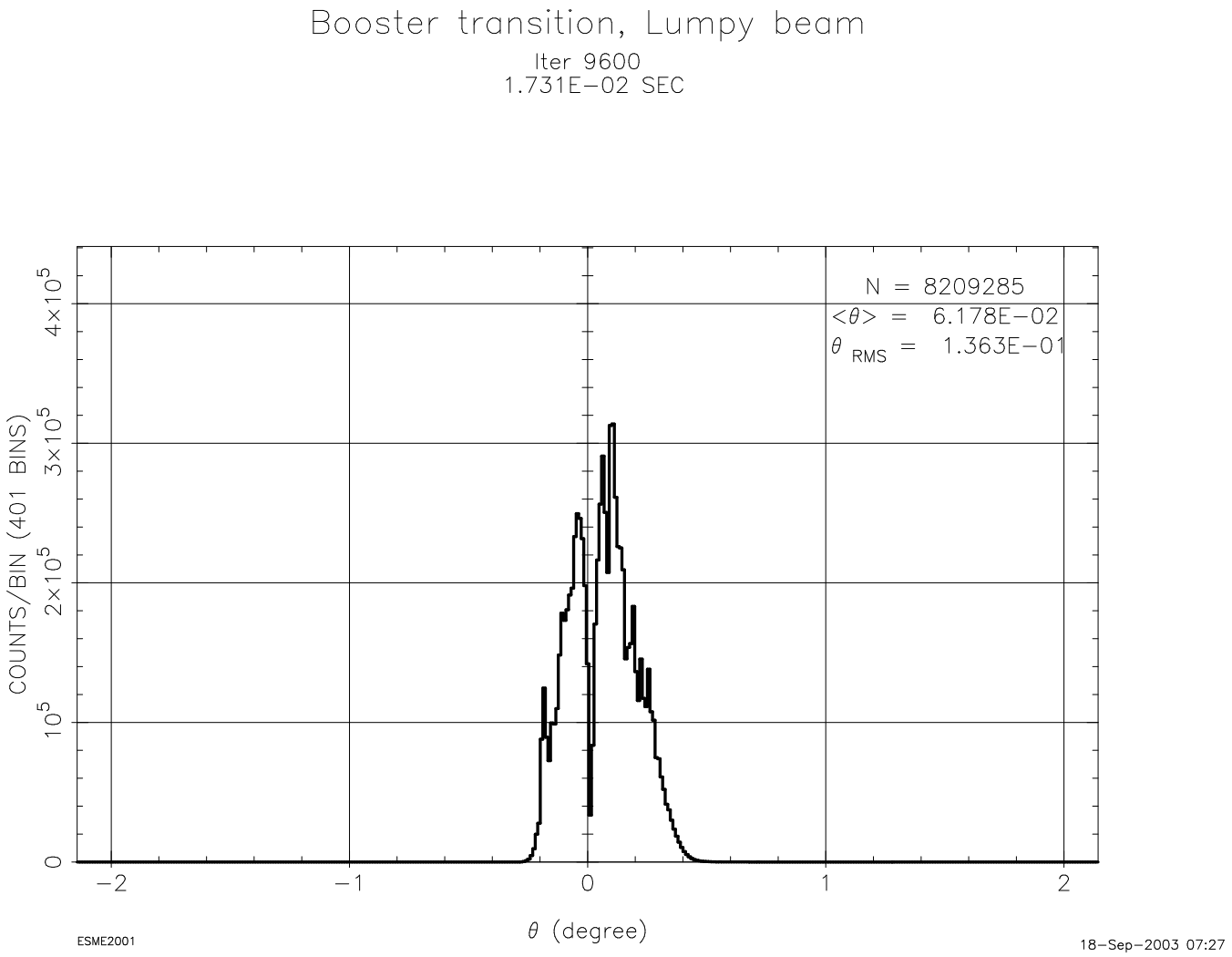
the collective voltage resulting from the previous beam current spectrum — enough to perturb distribution noticeably



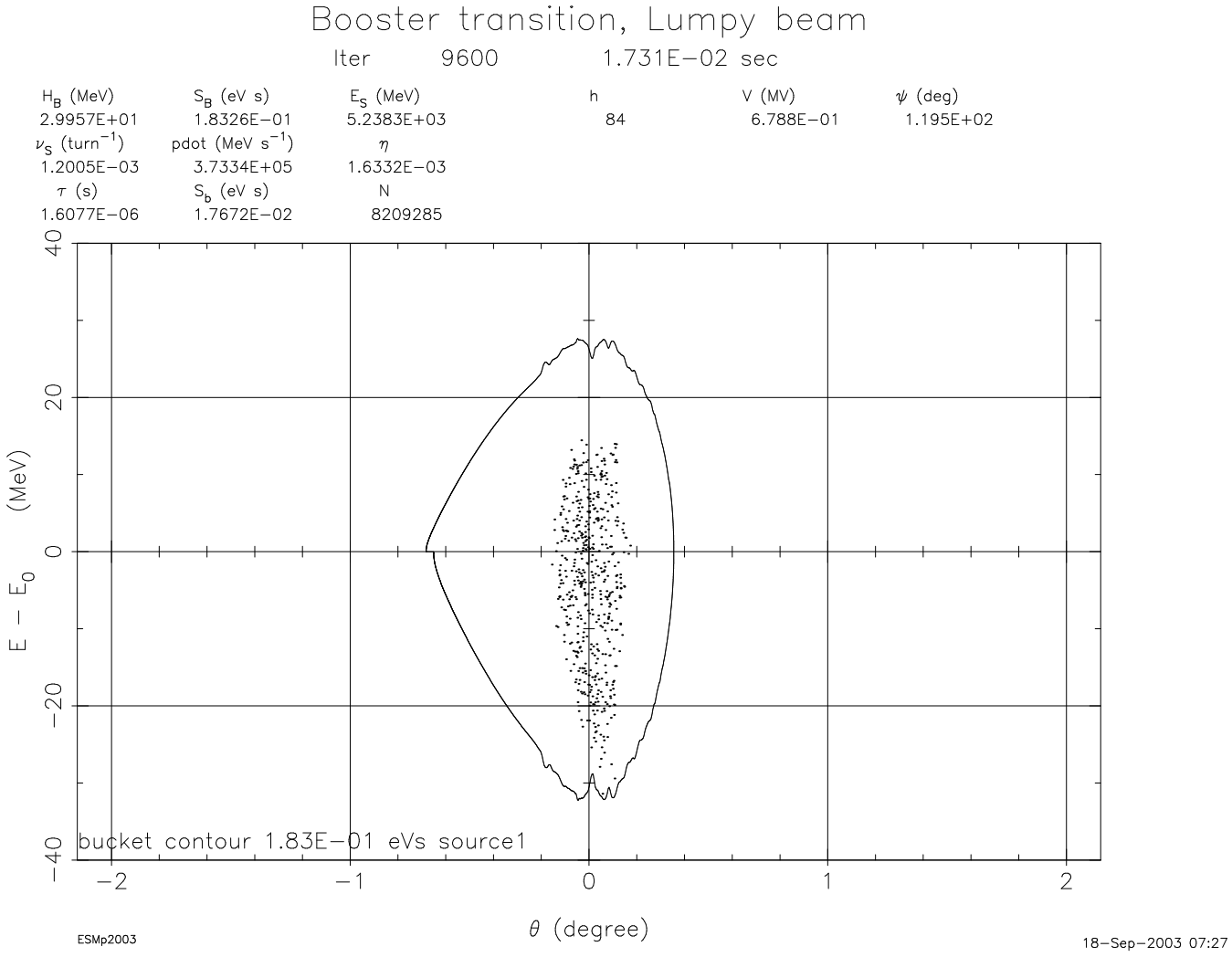
charge profile for lumpy bunch of 0.0947 eVs with $6 \cdot 10^{10}$ protons using 8.25 M macroparticles early in Booster cycle



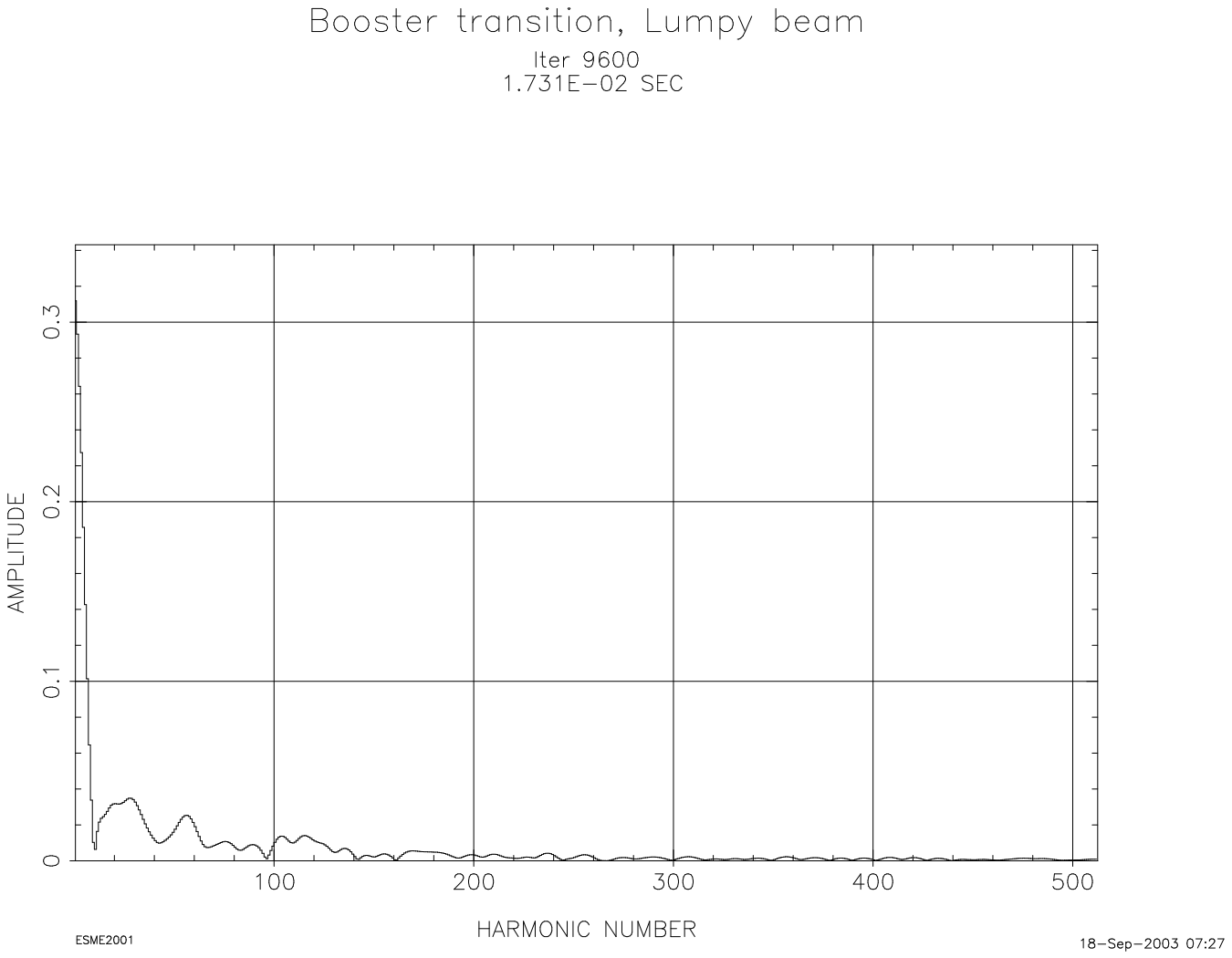
as above at 15.4 ms into cycle



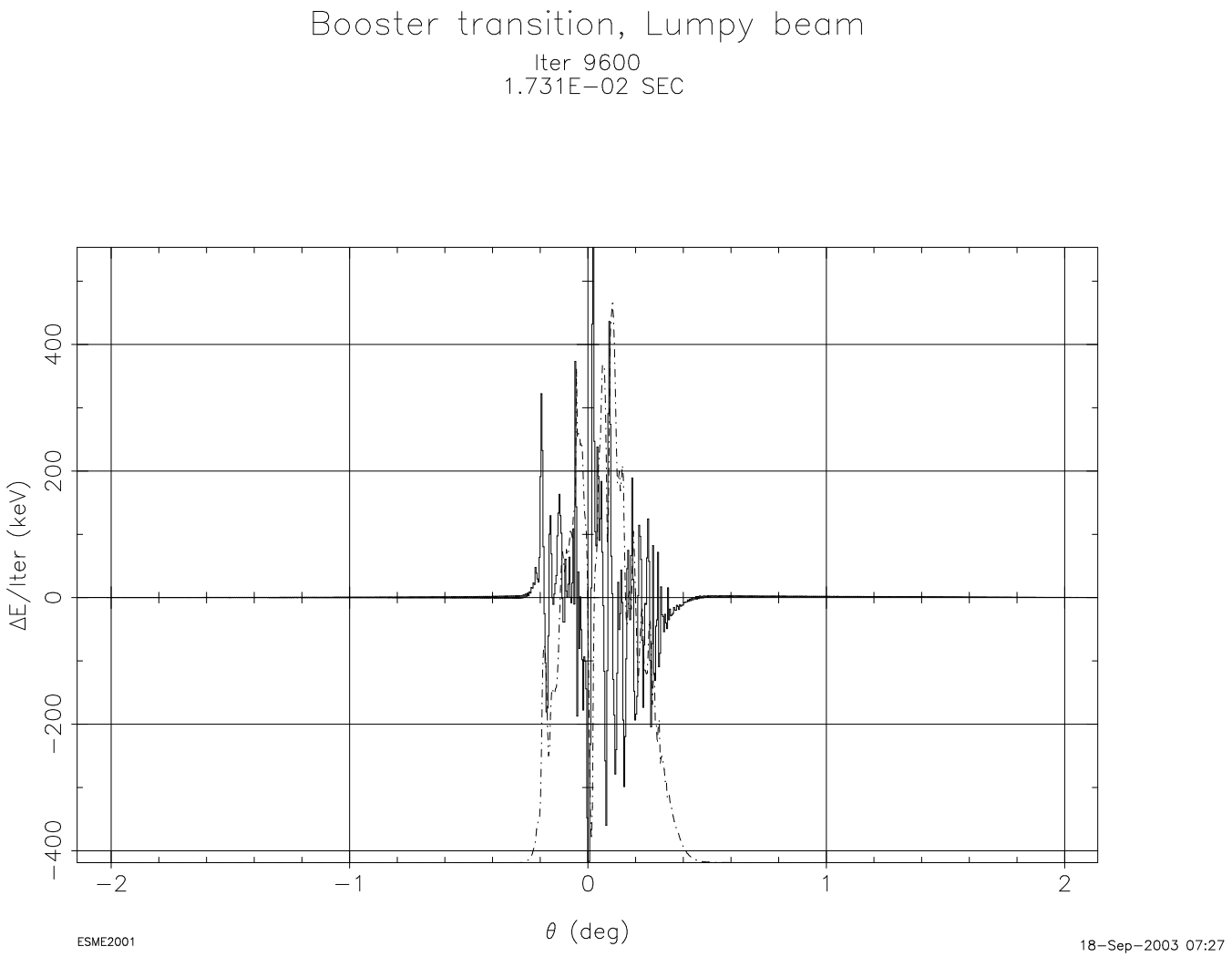
same as above at 1.73 ms — just after transition



a few of 8.25 m phase space points just after transition — marked evidence of high collective voltage on contour. Notice nonlinear single-particle problem(s) also.



the Fourier spectrum of the beam current of the lumpy bunch just after transition — most excitation below 15 GHz, but extending higher at detectable levels



the collective voltage resulting from the lumpy bunch current spectrum — enough to perturb distribution noticeably

Summary and extrapolation

- Ragged bunch profiles obtained by Lucas are in qualitative agreement with observations of Yang.
- The details of injection do matter much later in the cycle.
- Negative Mass Instability is a relevent problem for near term.
- The γ_T jump deserves respectful attention.

Acknowledgement: Thank you Peter Lucas for a beautifully lumpy distribution.