Transition Crossing

The emittance growth of small bunches passing through transition in the MI is typically about 30 %, where "small" is < 0.25 eVs. Because the coalescing efficiency is strongly dependent on the 53 MHz emittances, it is useful to look for practical means of improvement. A small reduction in bunch area should be quite helpful for coalescing. Work has started recently to take the results from the longitudinal envelope equation (Sørenssen & Hereward, Courant) and the nonlinear single-particle equations (Jie Wei) as guidance in MI-specific numerical modeling.

The object is to look in the short term for optimized curves and to consider for somewhat longer term low-cost expedients (like an inductive insert, for example — an old, old idea).

Early results relate only to the non-linear chromatic effects, *i. e.*, without beam charge. They should be good enough for the antiproton bunches; the resulting parameter curves give < 10 % bunch growth. I want to develop a more detailed model for making estimates of expected dilution including beam current effects.

Figure 1: RMS emittance of a 0.15 eVs bunch during a MI 29 cycle in a single particle (*i. e.*, no beam current) model showing $\sim$ 10 % growth

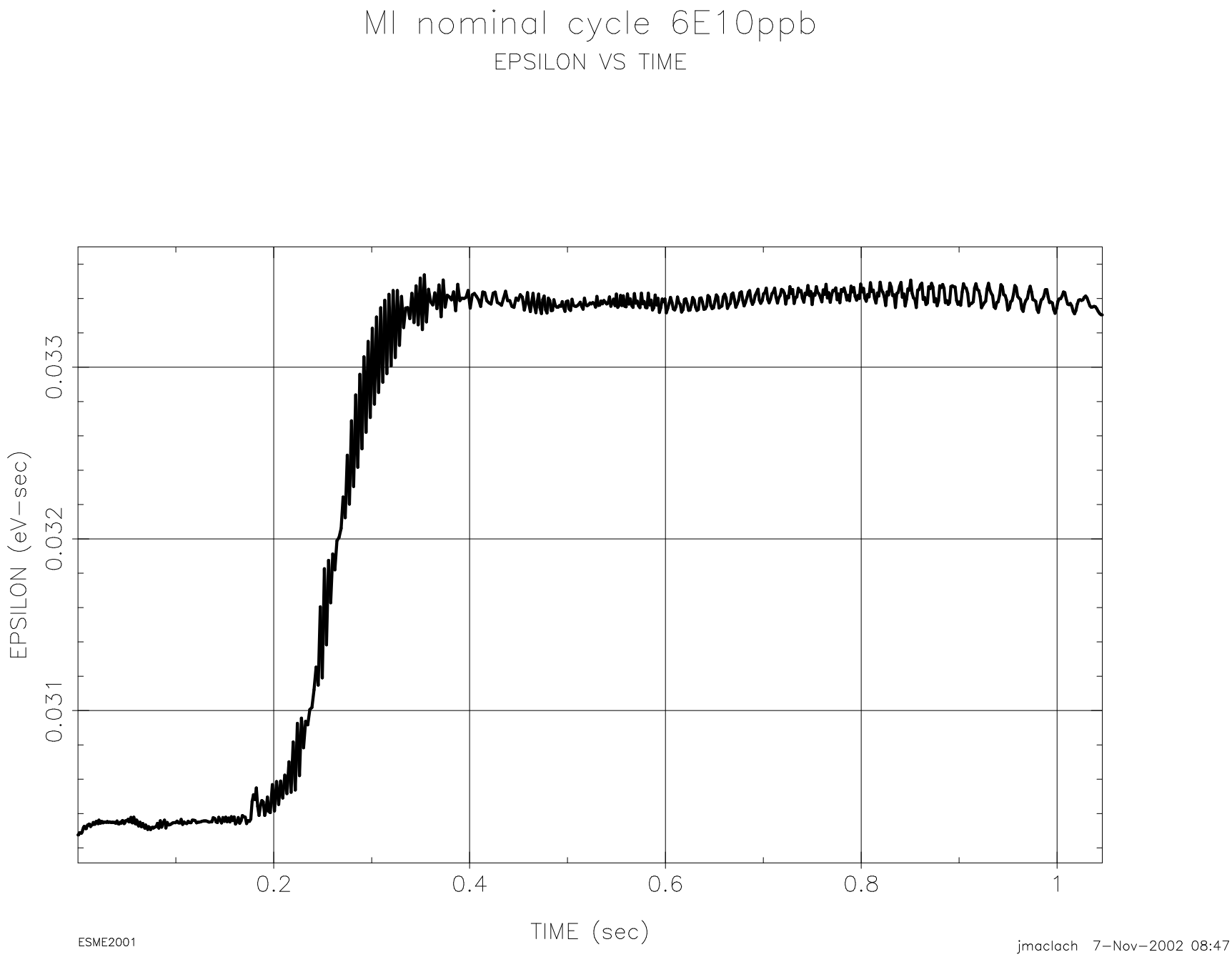
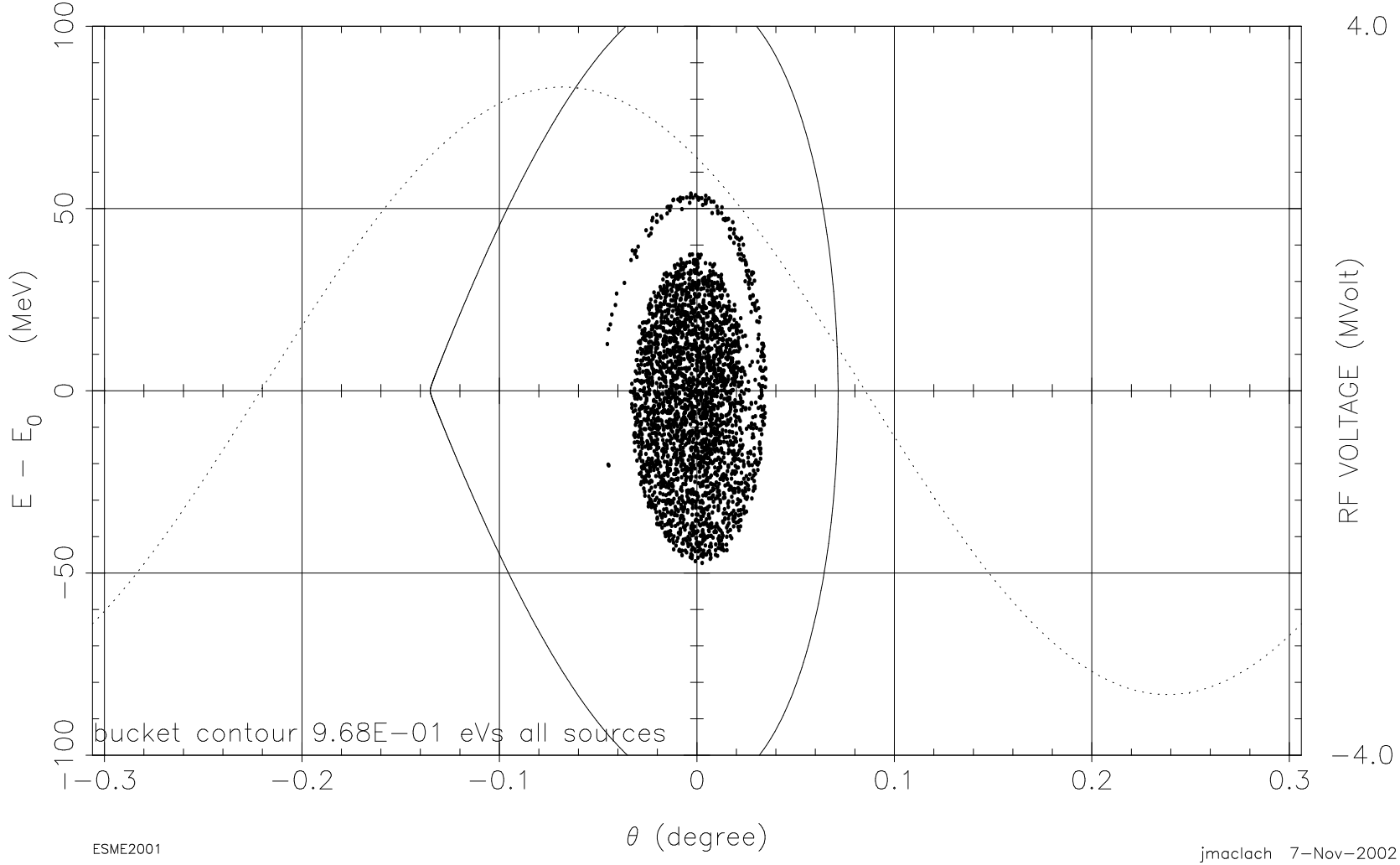

MI nominal cycle 6E10ppb
EPSILON VS TIME
EPSILON (eV-sec)
0.031
0.032
0.033
0.2
0.4
0.6
0.8
1
TIME (sec)
ESME2001
jmaclach 7-Nov-2002 08:47

Figure 2: The same bunch at 57 GeV showing characteristic development of filamentation arising from shape mismatch after transition

MI nominal cycle 6E10ppb

Iter 30000 3.331E−01 sec

H_B (MeV)	S_B (eV s)	E_S (MeV)	h	V (MV)	ψ (deg)
1.0963E+02	9.6847E−01	5.7132E+04	588	3.315E+00	1.299E+02
ν_S (turn^{-1})	pdot (MeV s^{-1})	η			
2.5231E−03	2.2956E+05	1.8276E−03			
τ (s)	S_b (eV s)	N			
1.1080E−05	3.3118E−02	3000			



ESME2001

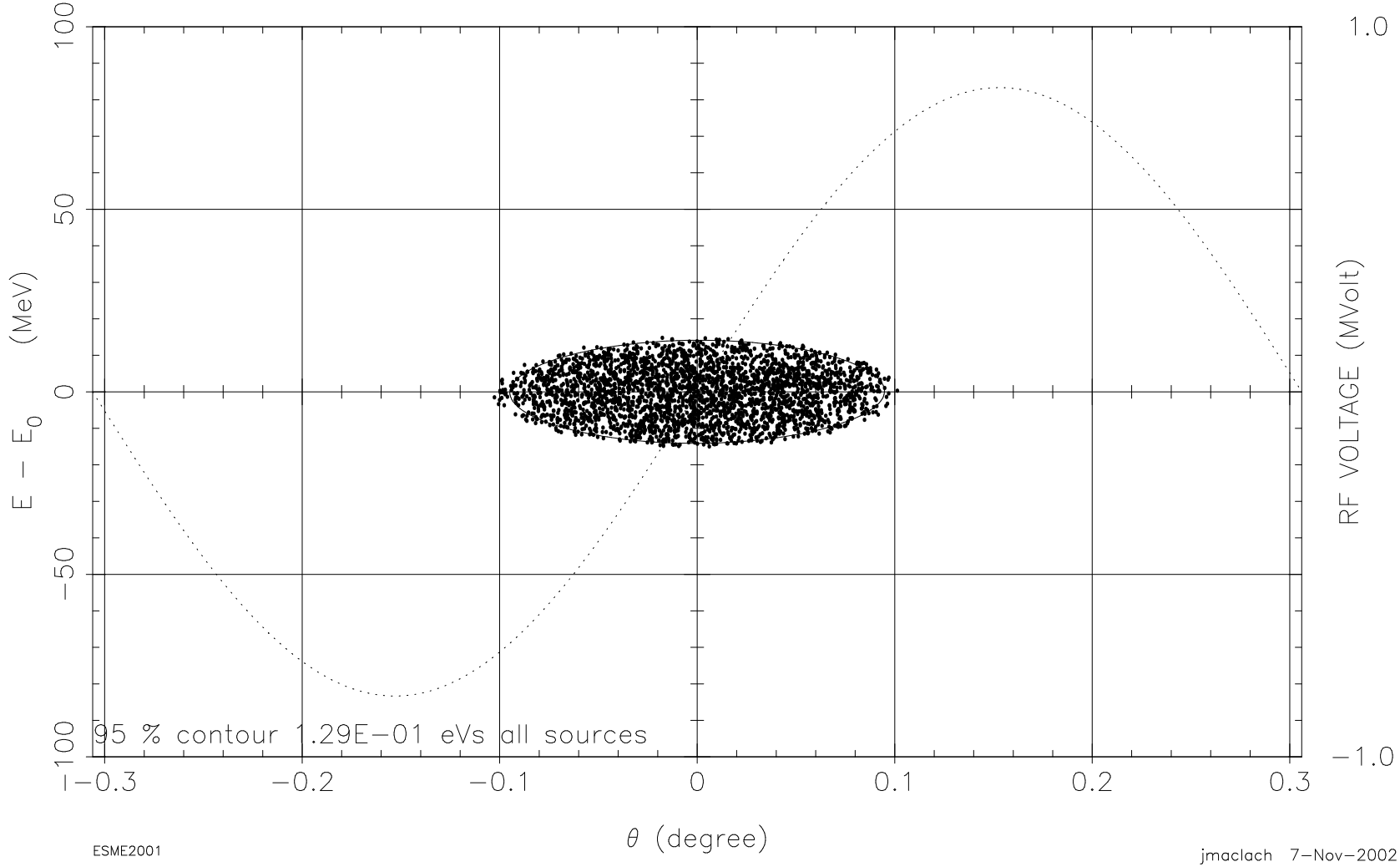
jmaclach 7−Nov−2002 08:44

Figure 3: The original bunch at 8 GeV with a 0.129 eVs contour which encloses 95 % of the particles

MI nominal cycle 6E10ppb

Iter 0 0.000E+00 sec

H_B (MeV)	S_B (eV s)	E_S (MeV)	h	V (MV)	ψ (deg)
3.0196E+01	7.2806E−01	8.9383E+03	588	8.500E−01	0.000E+00
ν_S (turn^{-1})	pdot (MeV s^{-1})	η			
8.9602E−03	0.0000E+00	−8.9219E−03			
τ (s)	S_b (eV s)	N			
1.1140E−05	3.0276E−02	3000			



ESME2001

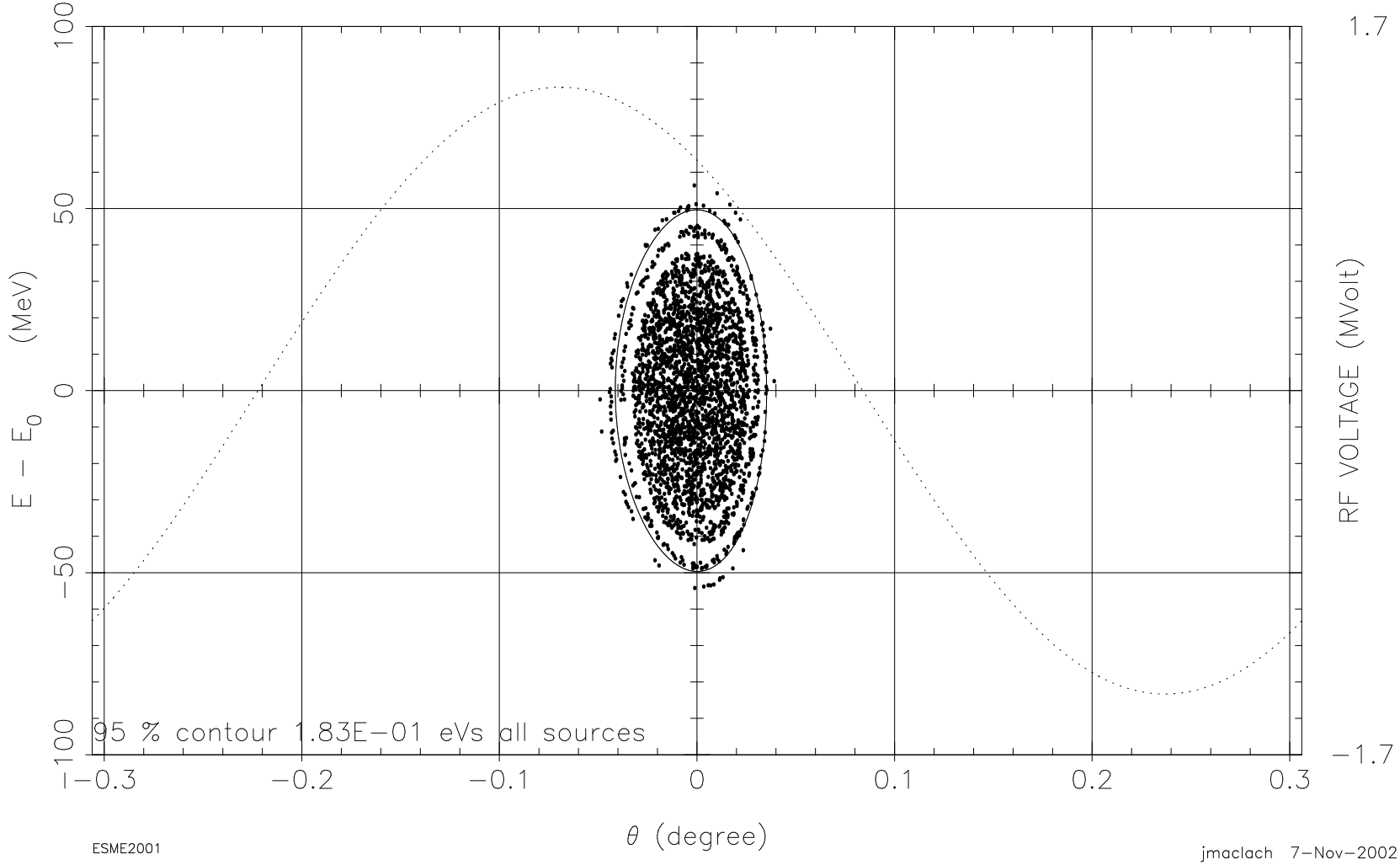
jmaclach 7−Nov−2002 08:43

Figure 4: Still the same bunch, here at 140 GeV, showing the growth of the 95 % contour to 0.183 eVs

MI nominal cycle 6E10ppb

Iter 75450 8.366E−01 sec

H_B (MeV)	S_B (eV s)	E_S (MeV)	h	V (MV)	ψ (deg)
1.0759E+02	9.6864E−01	1.4000E+05	588	1.387E+00	1.306E+02
ν_S (turn^{-1})	pdot (MeV s^{-1})	η			
1.1131E−03	9.5000E+04	2.0524E−03			
τ (s)	S_b (eV s)	N			
1.1078E−05	3.3442E−02	3000			



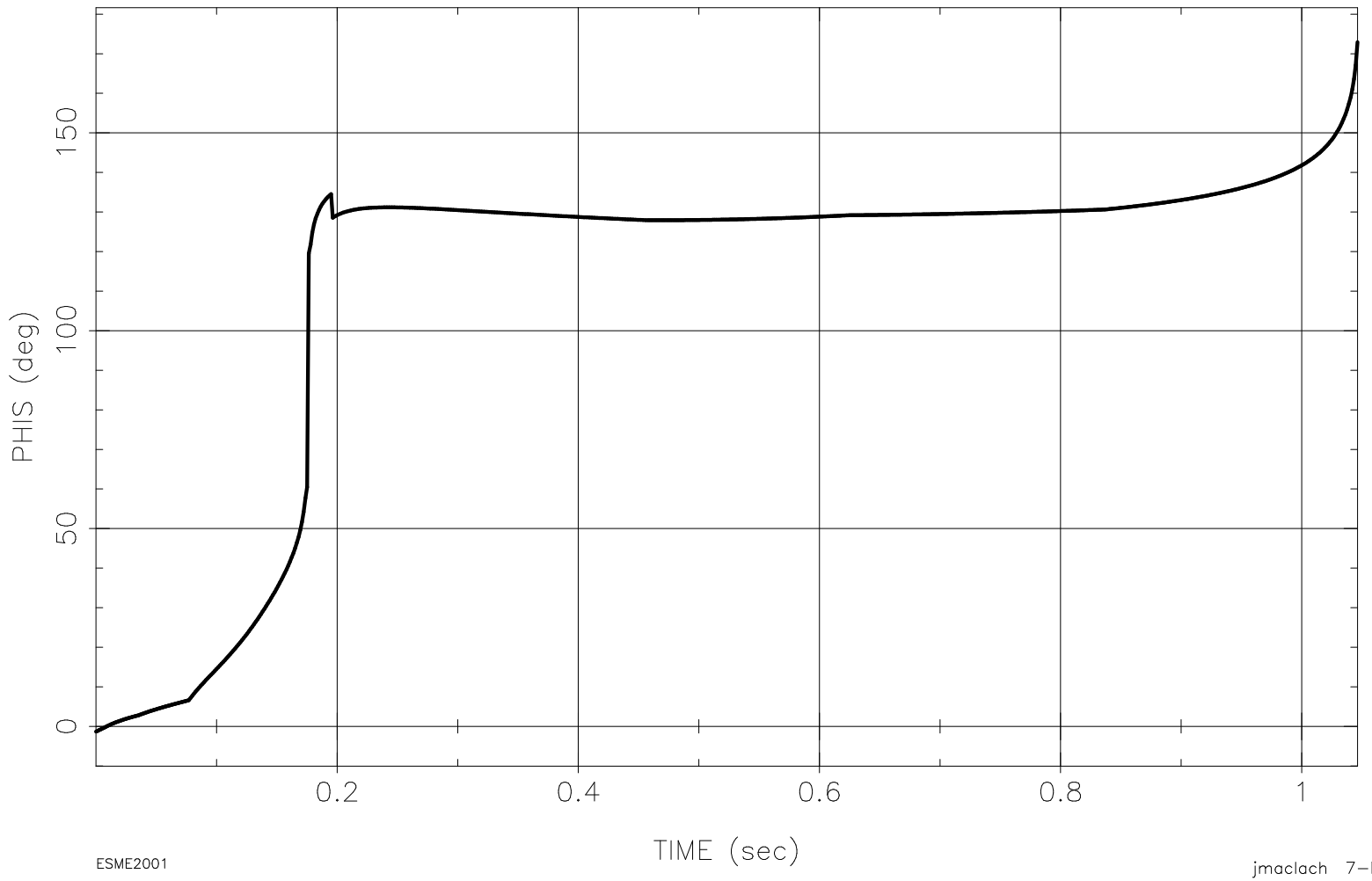
ESME2001

jmaclach 7−Nov−2002 08:46

Figure 5: The synchronous phase curve used for this model which features a continuous change of phase across transition — so-called duck-under There are glitches in this curve and others to follow at 8 Gev and at the end of the $\dot{\gamma}$ = 240 parabola which clearly did not damage the rms emittance by much. There is no problem in improving the aesthetics by removing them.

MI nominal cycle 6E10ppb

PHIS VS TIME



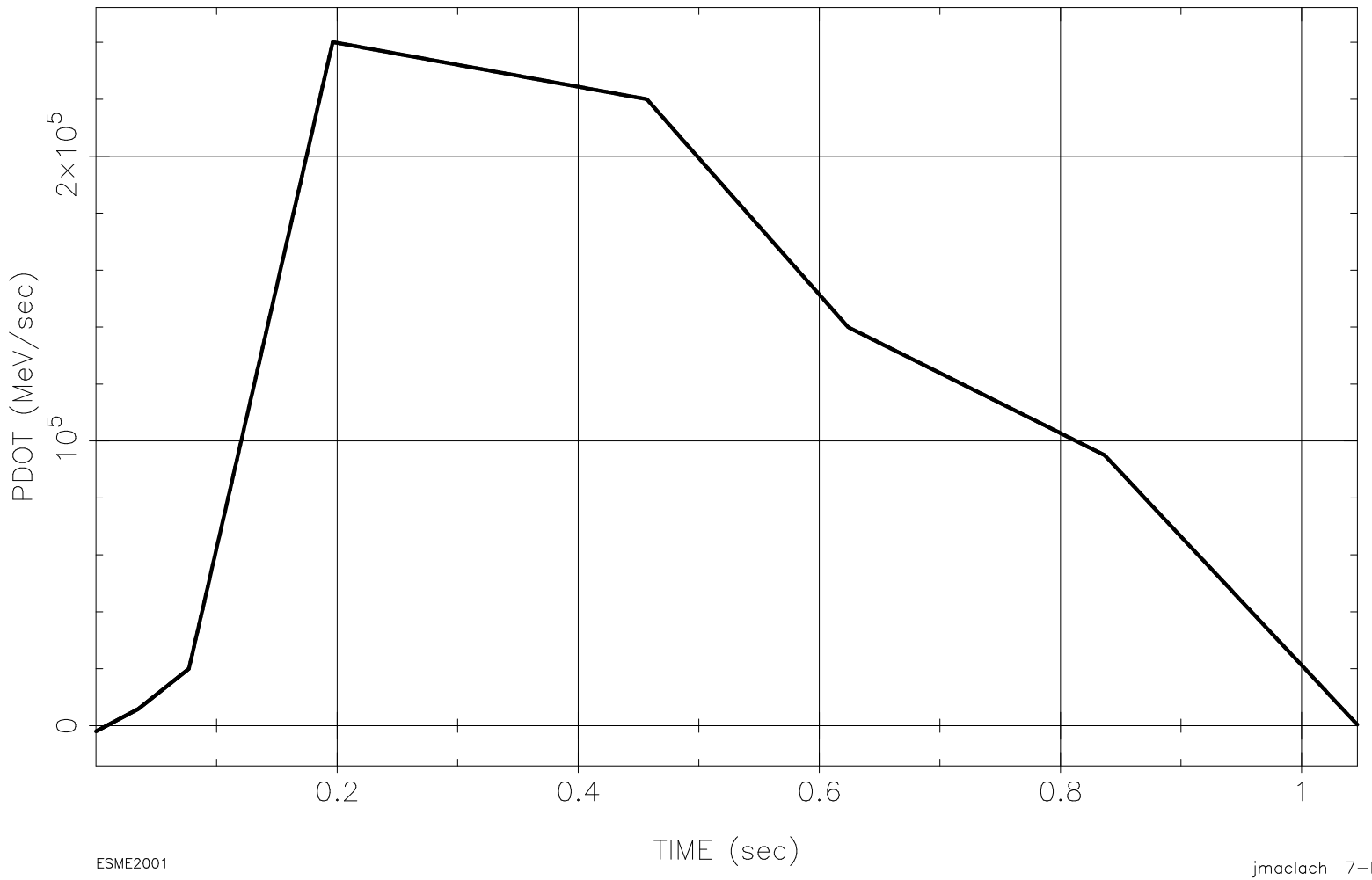
ESME2001

jmaclach 7–Nov–2002 08:46

Figure 6: The $\dot{p}$ curve for the cycle and the root source of the glitches

MI nominal cycle 6E10ppb

PDOT VS TIME



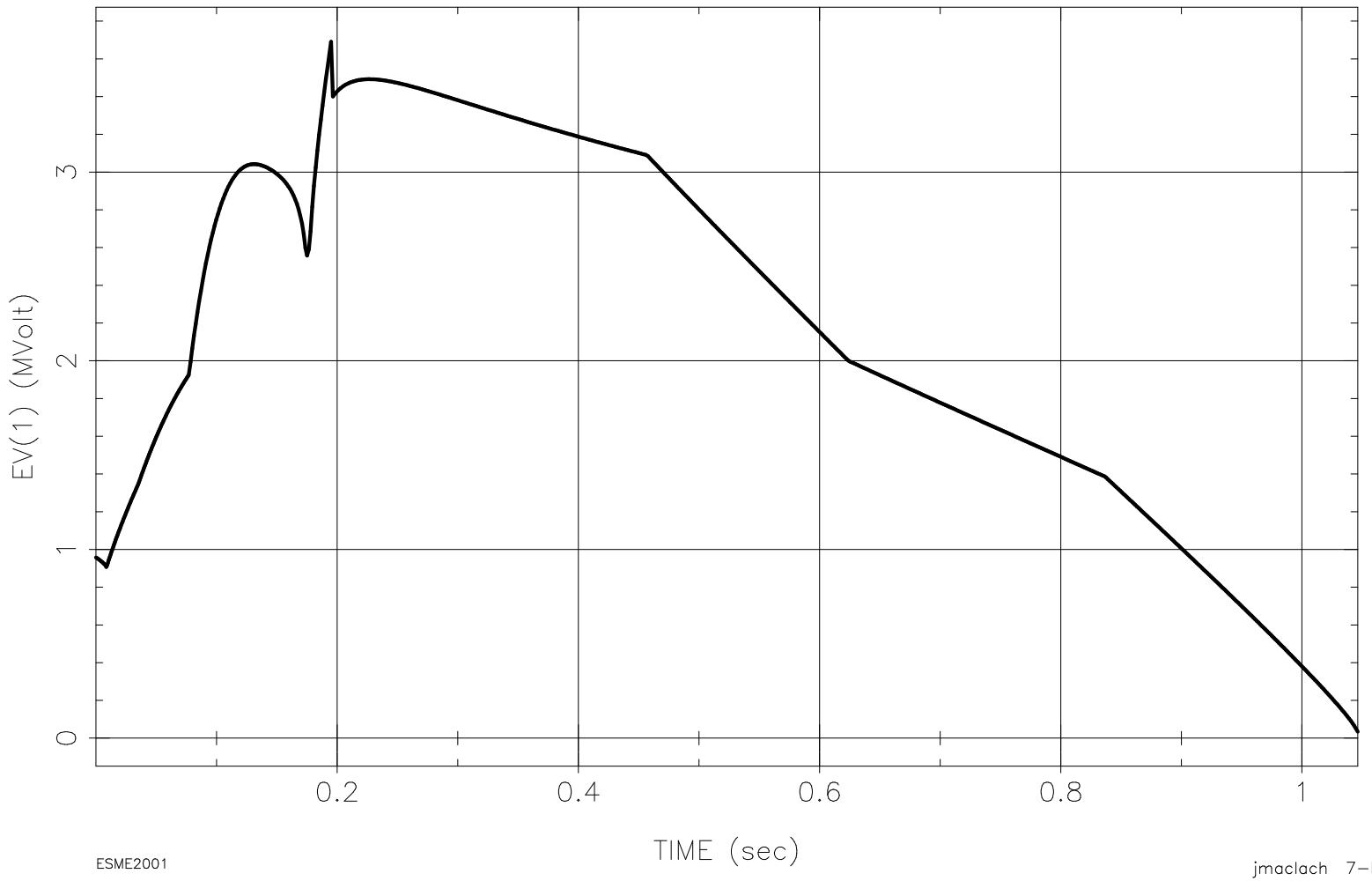
ESME2001

jmaclach 7–Nov–2002 08:46

Figure 8: The voltage curve showing the sharp dip at transition that characterizes the so-called duck-under

MI nominal cycle 6E10ppb

EV(1) VS TIME



ESME2001

jmaclach 7–Nov–2002 08:47

Analytical Results – Various Cycles

Table: Analytical prediction of several important parameters related to transition crossing phenomena for the four examples of a $\dot{\gamma}$ = 240 29-type cycle, a simillar cycle with $\dot{\gamma}$ = 180, a possible uncoalesced $\bar{\text{p}}$ cycle with a 0.37 eVs bunch, and finally, a $\dot{\gamma}$ = 4.2 cycle with a 1.3 eVs bunch accelerated on h=28

	$\dot{\gamma} = 240$	$\dot{\gamma} = 180$	0.37 eVs	h=28	units
Assumptions					
$\dot{\gamma}$	240	180	240	4.2	s^{-1}
bunch area	0.2	0.2	0.37	1.3	eVs
φ_s	53.6	37.1	53.6	47.6	deg
V_{rf}	3.1	3.1	3.1	0.06	MV
Results					
bunch width	1.39	1.20	1.90	17.9	ns
T_{na}	2.00	1.99	2.00	75.4	ms
T_{nl}	0.51	0.78	0.69	14.5	ms
Sorenssen param.	0.24	0.28	0.09	0.11	
Energy spread ($\pm$)	122	106	144	53	MeV
Emittance growth	19	30	26	15	%