

SPLinac

**simulation of Realistic
sc. Linac RF Systems with Beam**

Joachim Tückmantel

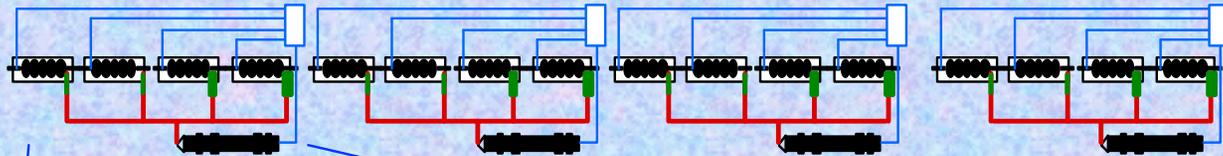
CERN, Geneva

Split up the 'problem':

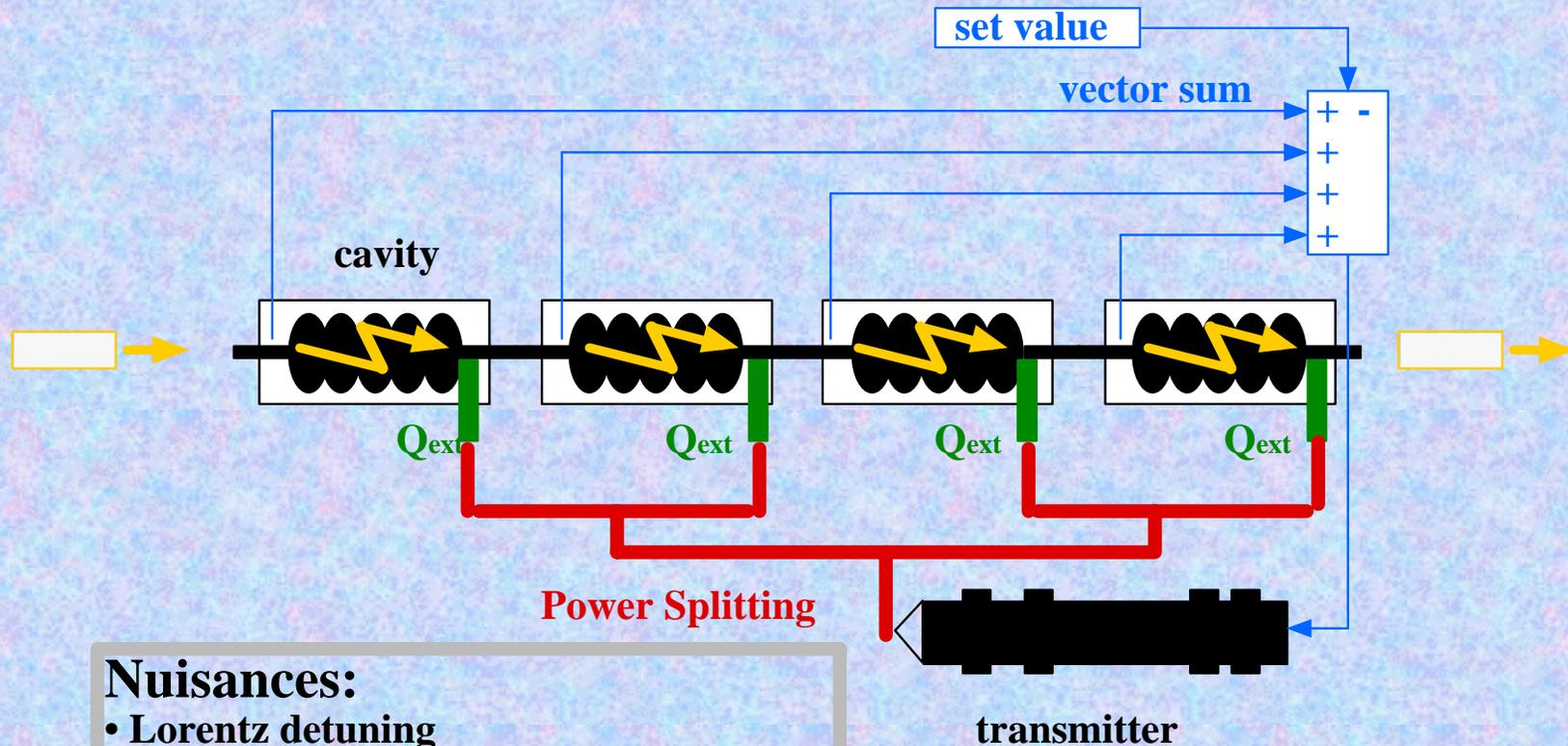
Linac made of different sections



Section made of equivalent 'families'



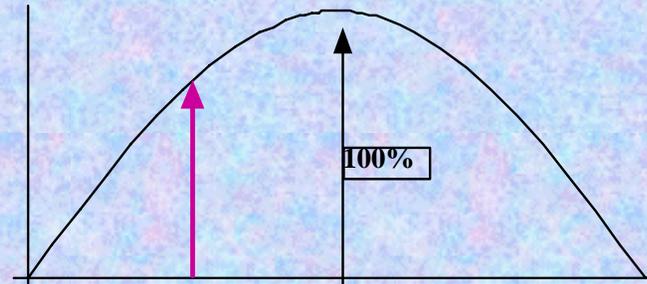
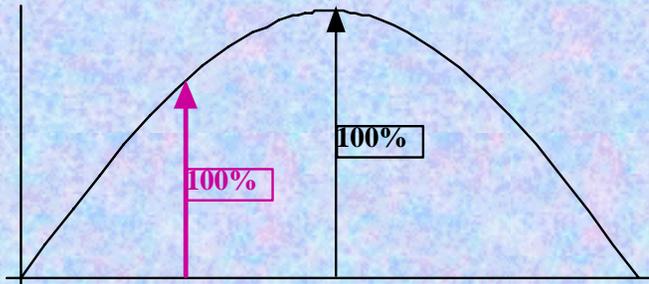
**Family: One transmitter supplies several (or 1) cavities
cavity voltage vector sum controls transmitter**



Nuisances:

- Lorentz detuning
- externally driven cavity vibrations
- errors in vector sum
- errors in power splitting
- scatter in Q_{ext}
- beamloading 

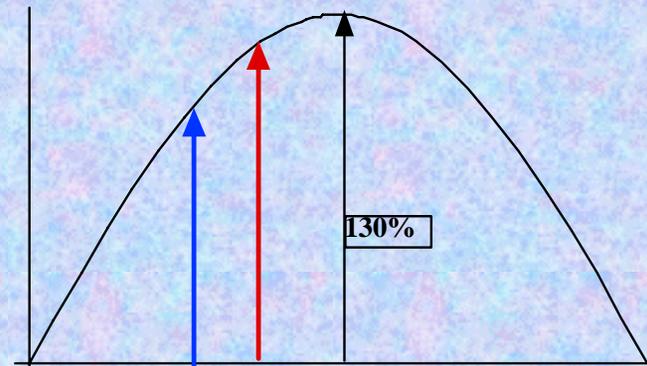
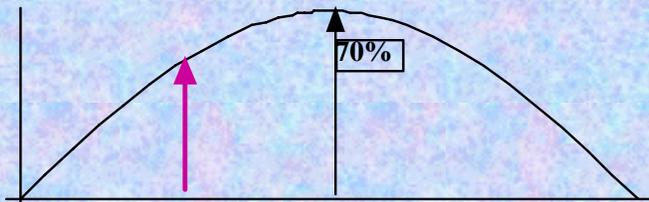
2 cavities: 100%+100% excitation: perfect situation



At cavity 1 all particles see nominal voltage: nominal speed

At cavity 2: nominal phase angle for $\beta=1$ and $\beta<1$: 100% + 100% = 200%

2 cavities: 70%+130% excitation: same (vector) sum: looks OK



At cavity 1 all particles see lower voltage: $\beta<1$ lower speed, $\beta=1$ same speed

at cavity 2: nominal phase angle for $\beta=1$: 70% + 130 % -> 200 %

at cavity 2: larger phase angle for $\beta<1$: 70% + 150 % ->

220%

SPLinac:

The main panel

Global specs:

$(f_0, T_{\text{pulse}}, \langle I_b \rangle, \dots)$

What to do:

Active sections:

Plot scalings

proton electron Global Title

basic freq [MHz] 352.20900
pulse rate [Hz] 75.00000
pulse length [ms] 2.20000
RF rise time [ms] 2.00000
<pulse current> [mA] 11.00000
Inj. energy [MeV] 120.00000
±bunch dt (inj) [ns] 3.50000e-02
±bunch dE (inj) [MeV] 0.14000
RF clock tick [ns] 496.86408
mech. clock tick [ms] 1.00000e-01

Beamloading Feedback delay

Active show

<input checked="" type="checkbox"/> beta = 0.52	<input type="checkbox"/>
<input checked="" type="checkbox"/> beta = 0.7	<input type="checkbox"/>
<input checked="" type="checkbox"/> beta = 0.8 (a)	<input type="checkbox"/>
<input checked="" type="checkbox"/> beta = 0.8 (b)	<input type="checkbox"/>
<input checked="" type="checkbox"/> beta = 1.0	<input type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/> test bed	<input type="checkbox"/>

Frame 500 : 375 plots/page 1
 movie save fr. Overlay mode
✓ Joachim TuckmanteIN/SL
 auto run wait sec. 0.
 Hardcopy All Sound on

Pulses # pulses 20 Dot HC
shots/pulse 5 PhSp HC
 hold at end of shot
 dt, dE along Linac HC
 Full bunches # 250
 PhSp along Linac all .. cav 1 HC
 plot also Vacc max plot shots 1
 periodic Lorentz force

Diagnostic: show TTs HC
sect. 0-9 2 transm. 0 define traces
 RF #pts 1789 all 15 ticks HC
#plots 1 RF test pulsing test beamIdg

clock seed 8578453
 regul. bunch rings 3
 paint bun chose col.

 nPix 3
Plot dt (min) [ns] -1.00000e-01
Plot dt (max) [ns] 1.00000e-01
Plot dE (min) [MeV] -20.00000
Plot dE (max) [MeV] 20.00000
Plot V (min) [MV] -2.00000
Plot V (max) [MV] 2.00000
Plot P [kW] 1000.00000
Plot ±df [Hz] 20.00000

Save specs Revert Cancel GO

RF section panel

modules in section

Cavities / module

Mechanical positioning

Cavity specs:

f_0 , (R/Q), Q_{ext} , Δf , V_{acc} , ϕ_0 , ...

Cavity external vibr.

Lorentz detuning data

Transmitter data

Vector loop data

RF system error data

beta = 0.8 (a)

group # 2





# modules	6
# cavities/module	4
dist cav-cav [m]	2.5
dist cent.cav -flange [m]	2.63

	beta nom.	0.8
# cavities/transm	4	
f0 [MHz]	352.209	
Q0	3e+09	
Qext	3e+06	
R/Q [circ.ohm]	191.8	
static df/f0	0	
V.peak [MV]	15.3	
sync. phase [deg]	-20	
beta/V (1)	0.71	6
beta/V (2)	0.86	8.9
beta/V (3)	0.9	8.76

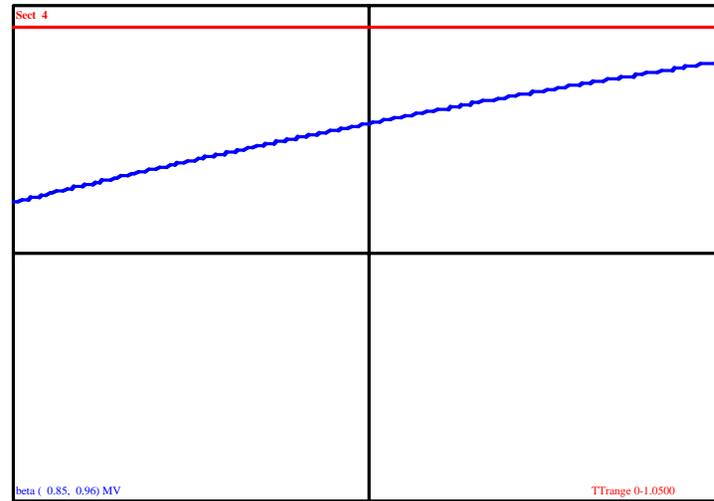
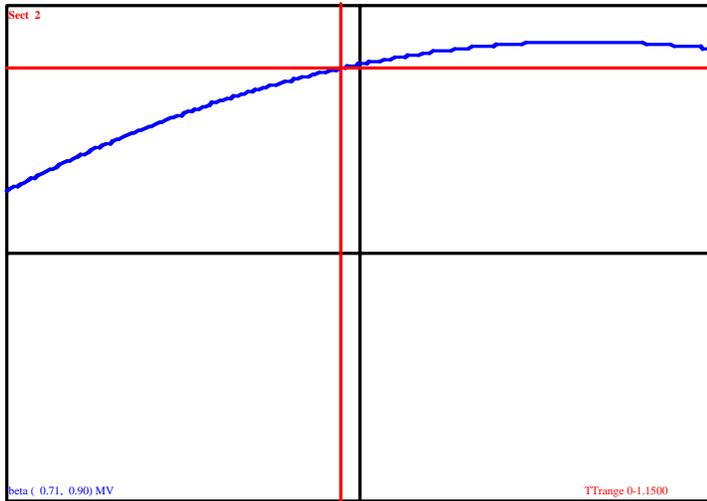
Plim transm. [kW]	1000	<input type="checkbox"/> force nom.
BW transm. [MHz]	1.2	<input type="checkbox"/> FB off

ampVibr [RF-Hz]	20
<input type="checkbox"/> distr. vib. Ampl.	
fVibr [Hz]	35.5263
$\pm dfVibr$ [Hz]	20
<input type="checkbox"/> distr. vib. freq	
psiVibr [deg]	0
<input checked="" type="checkbox"/> distribute vib. phi	
<input type="checkbox"/> vibr. freeze	
LorConst [Hz/MV^2]	-0.75
$\pm scatter$ [Hz/MV^2]	0
<input type="checkbox"/> distribute LorConst	
f0.mech [Hz]	100
$\pm f0$ scatter [Hz]	3
<input type="checkbox"/> distr. f0.mech	
Q0.mech	38
<input checked="" type="checkbox"/> Lorentz freeze	

<input checked="" type="checkbox"/> Vector Sum error	field error %	5
<input checked="" type="checkbox"/> Power split error	field error %	5
<input checked="" type="checkbox"/> Qext error	%	10

loop gain (re)	100
(im)	0
<input checked="" type="checkbox"/> adjust setvalue by (1+g)/g	
FB delay [ns]	200

ignore all dyn. detuning



Transmitter 74 Cav[74,77]

Change of resonance
frequency, scale $\pm 20\text{Hz}$

Cavity
loading

Beam
pulse

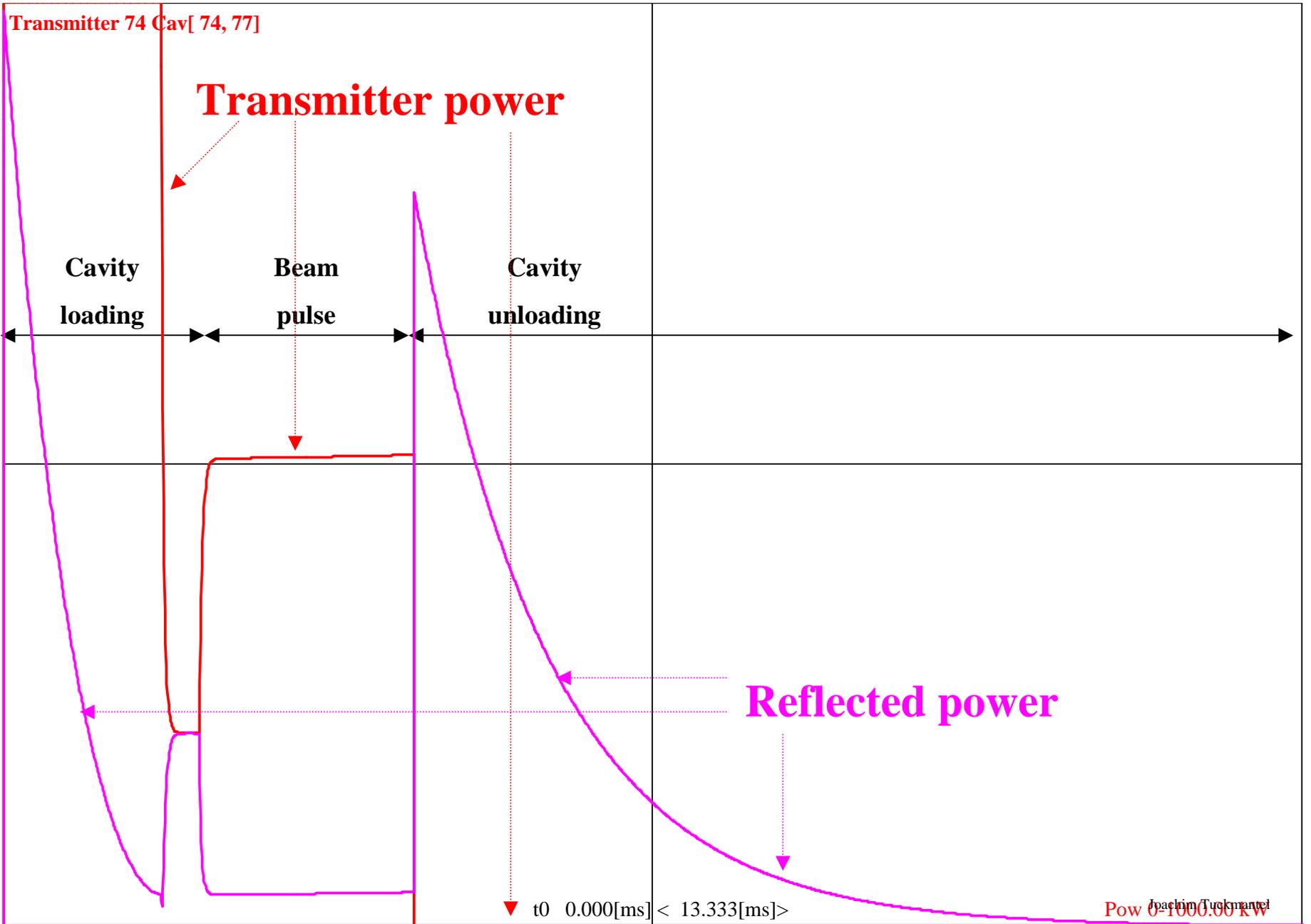
Cavity
unloading

4 cavities
1 transmitter

$\Delta f \pm 20.0 \text{ Hz}$

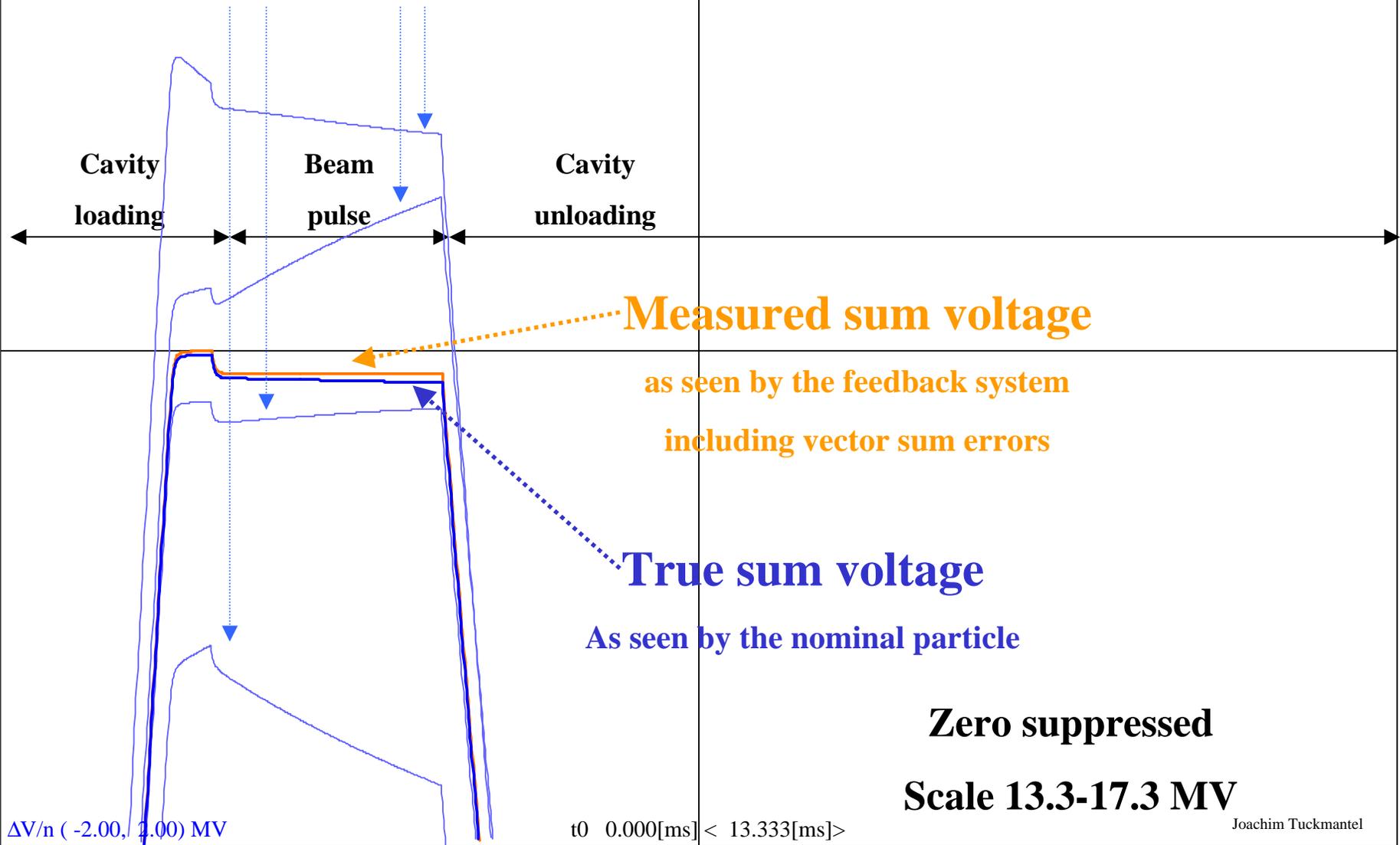
t0 0.000[ms] < 13.333[ms]>

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Real part of voltages

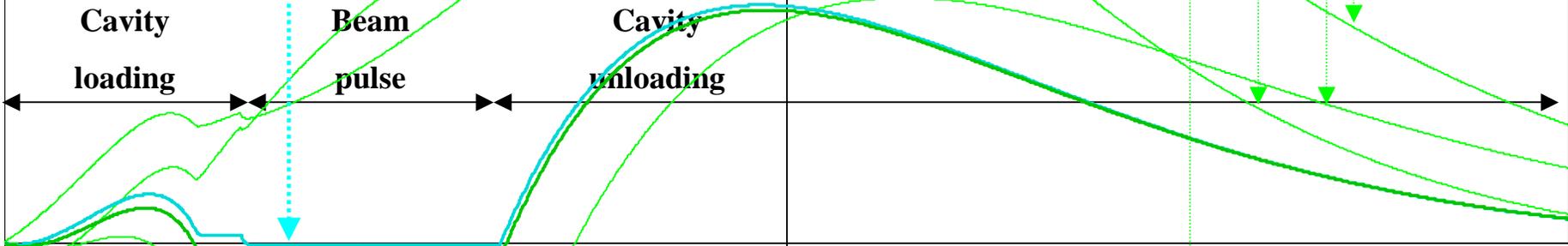
True individual cavity voltages



Measured sum voltage

as seen by the feedback system
including vector sum errors

True individual cavity voltages



True sum voltage

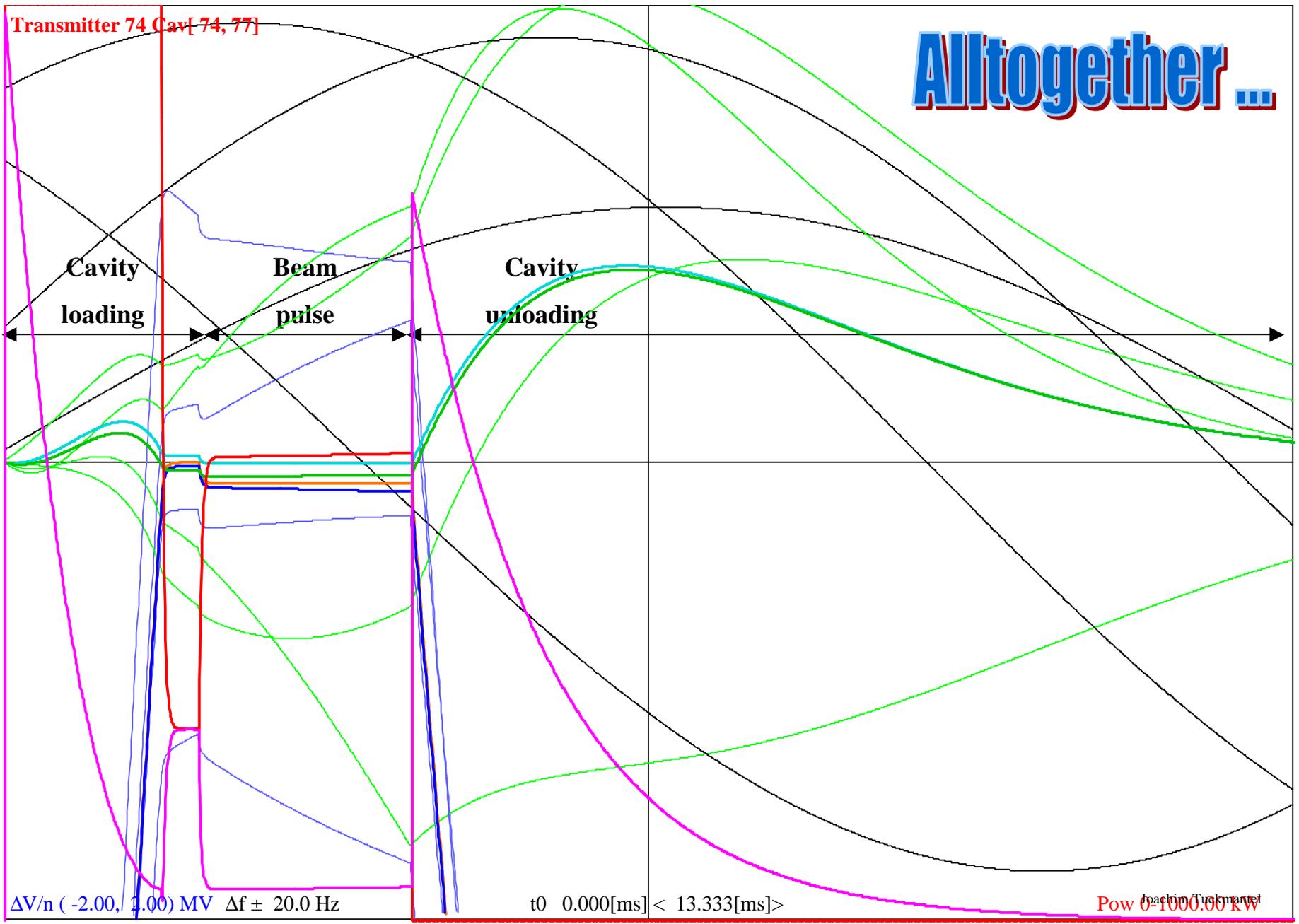
As seen by the nominal particle

Imaginary part of voltages

$\Delta V/n$ (-2.00, 2.00) MV

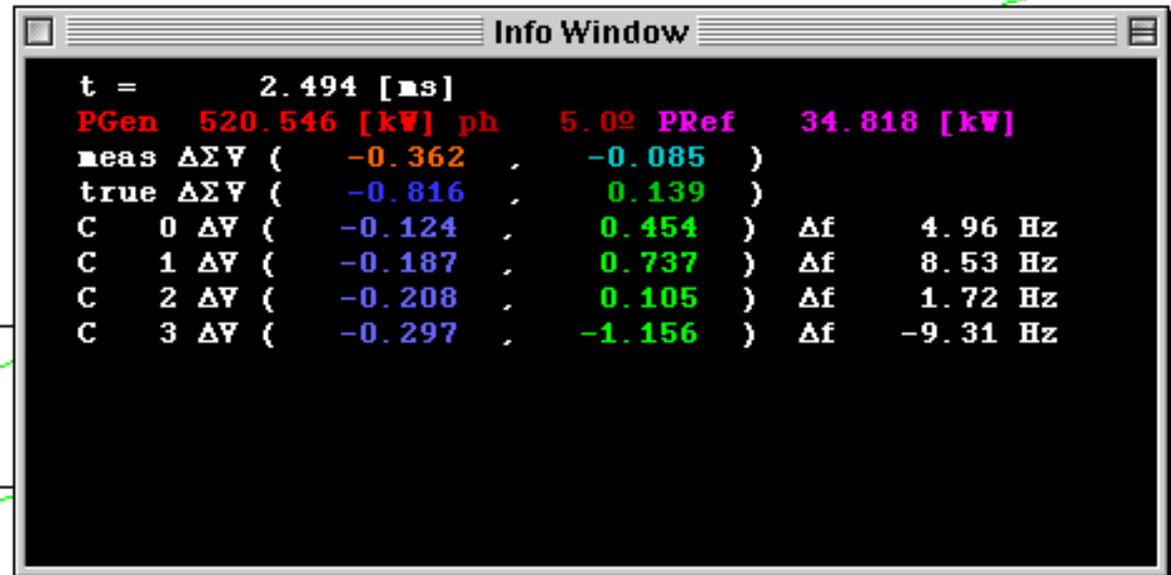
t0 0.000[ms] < 13.333[ms]>

Alltogether ...



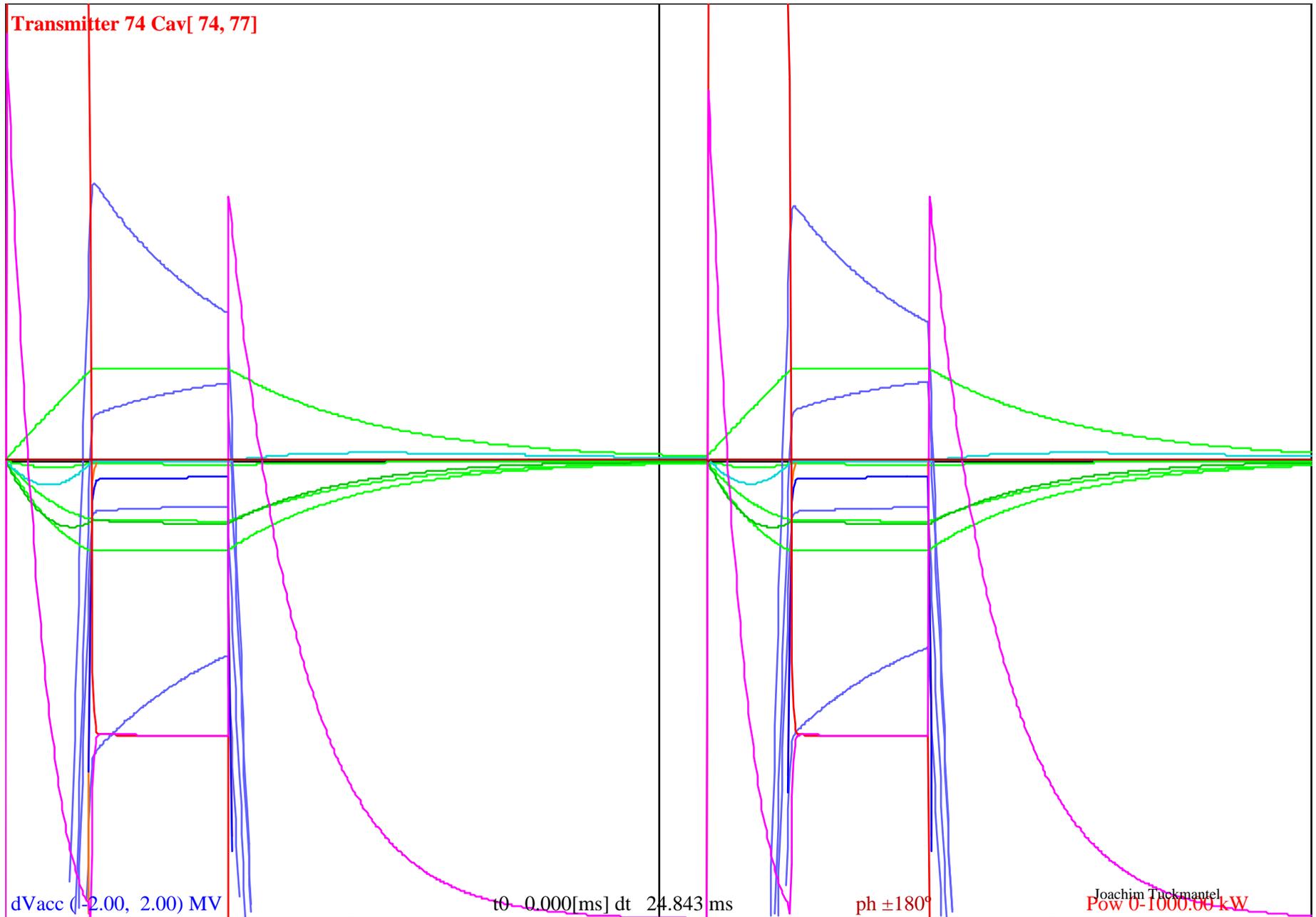
The Info Window (Cmd-I)

Gives data for time-instant of mouse-cursor

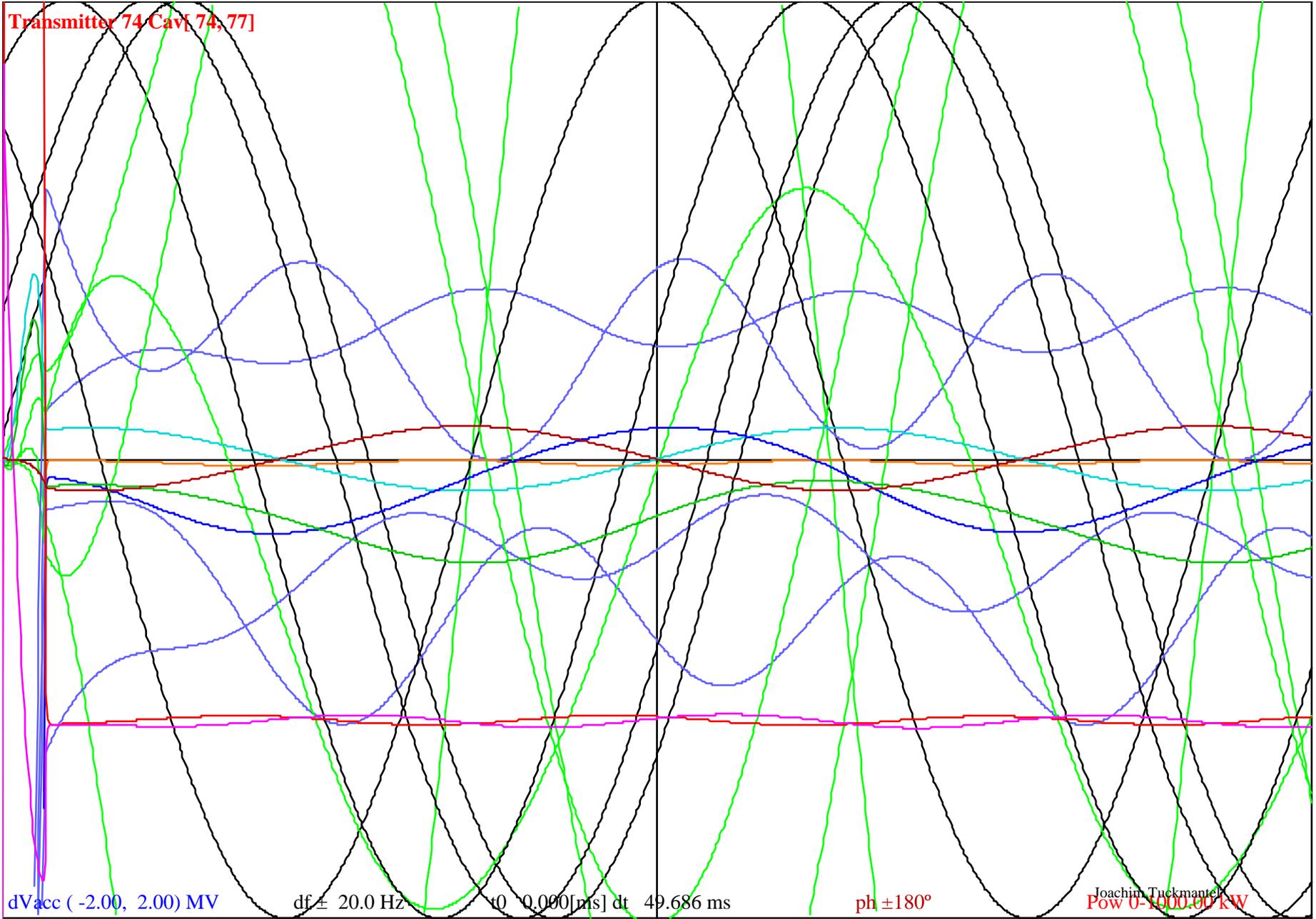


Cmd-T: Tells 'static' data: position in linac, nominal particle energy, vibration frequency phase and amplitude, mech. resonance frequency, nominal beta

'Long term' pulsing and ... (no vibrations)



Transmitter 74 Cav[74, 77]



dV_{acc} (-2.00, 2.00) MV

df ± 20.0 Hz

t0 0.000[ms] dt 49.686 ms

ph ±180°

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Pow 0-100.00 kW

Lorentz detuning: **normal k**

Transmitter 74 Cav[74, 74]

$f_{\text{mech}} = 100 \text{ Hz}$, $f_{\text{rep}} = 75 \text{ Hz}$ **no pre-detuning**

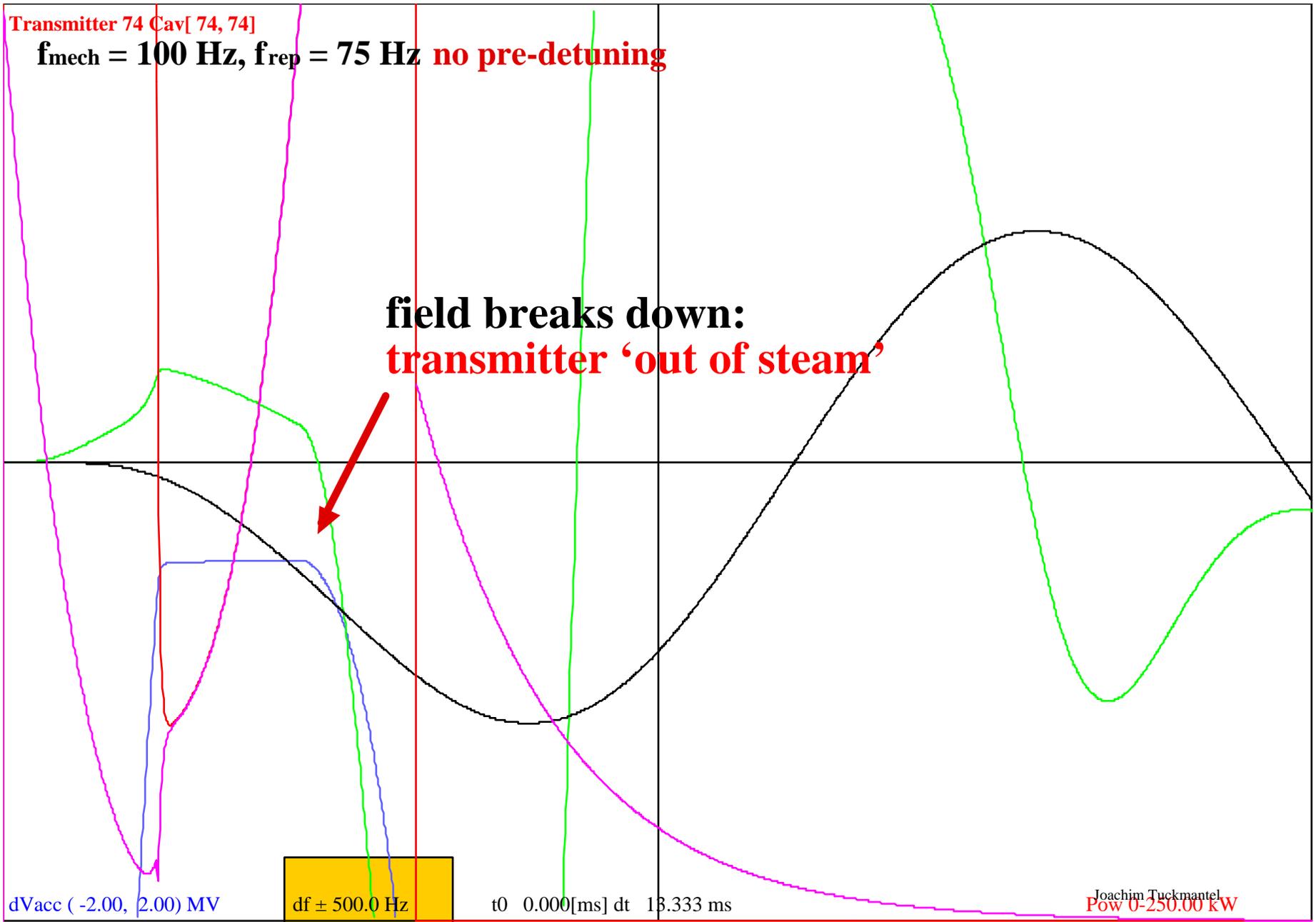
**field breaks down:
transmitter 'out of steam'**

dVacc (-2.00, 2.00) MV

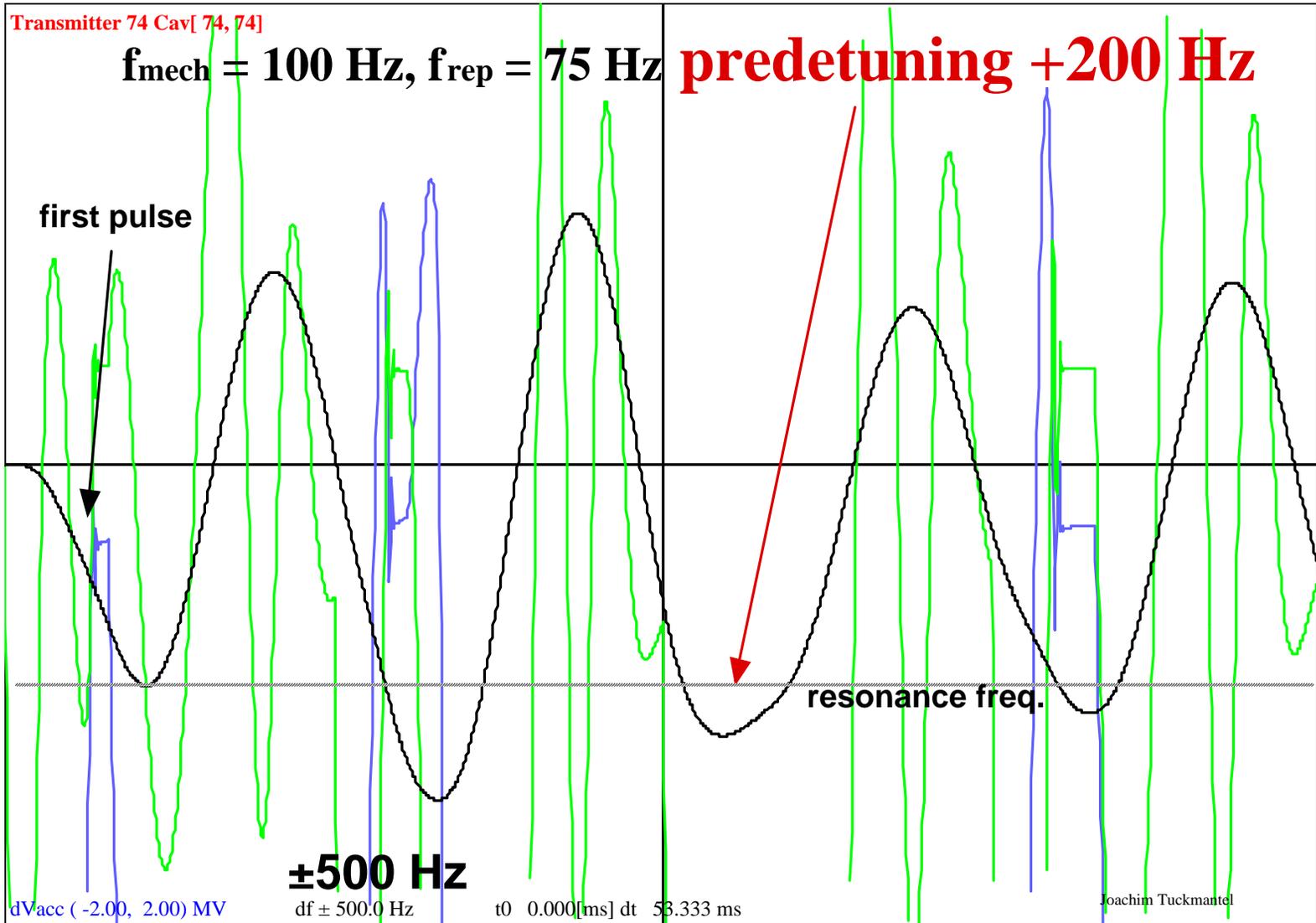
df $\pm 500.0 \text{ Hz}$

t0 0.000[ms] dt 13.333 ms

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Pow 0-250.00 kW



Lorentz detuning: with 'normal' k



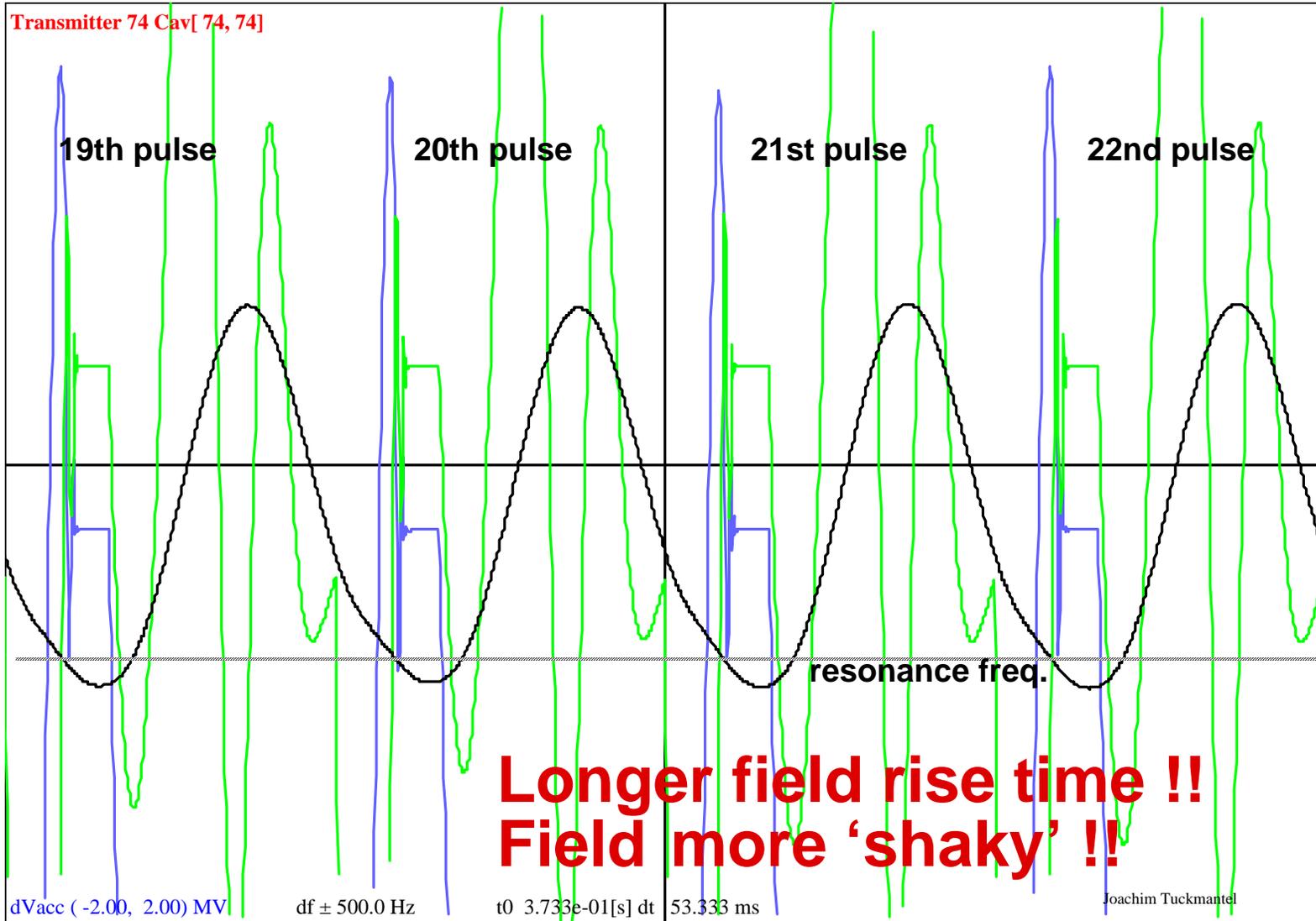
Transmitter 74 Cav[74, 74]

19th pulse

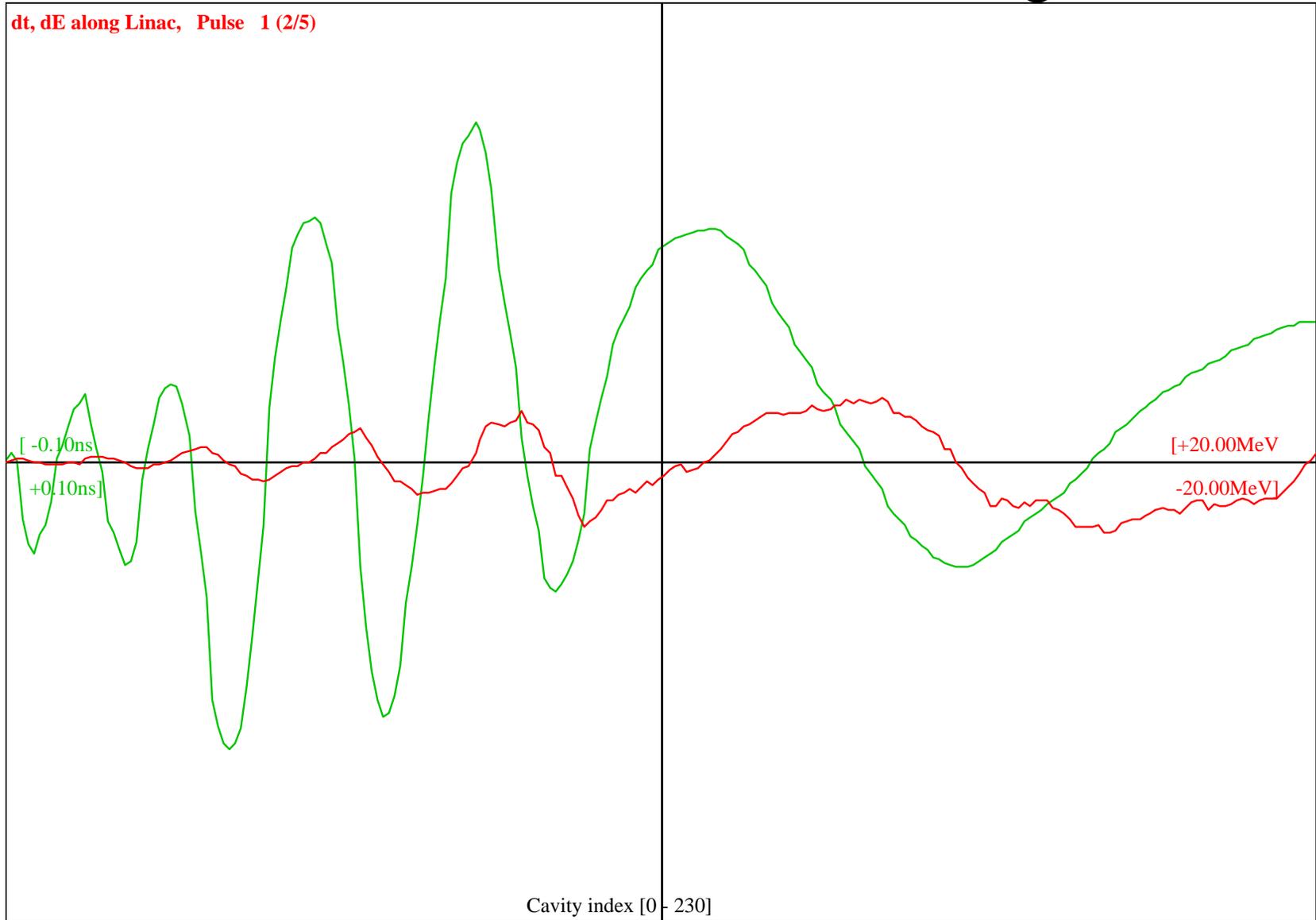
20th pulse

21st pulse

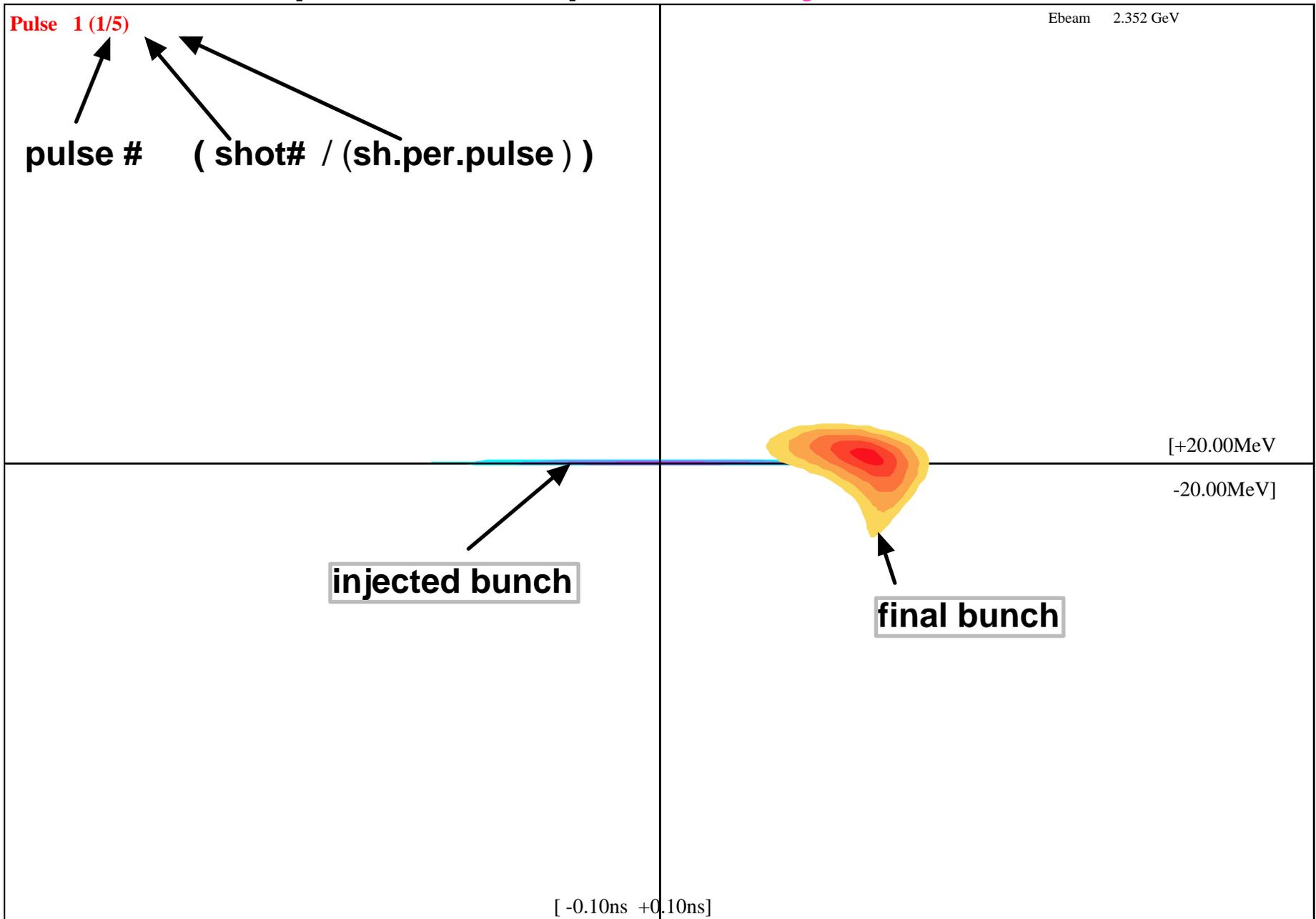
22nd pulse



dt and dE of center of bunch along the linac

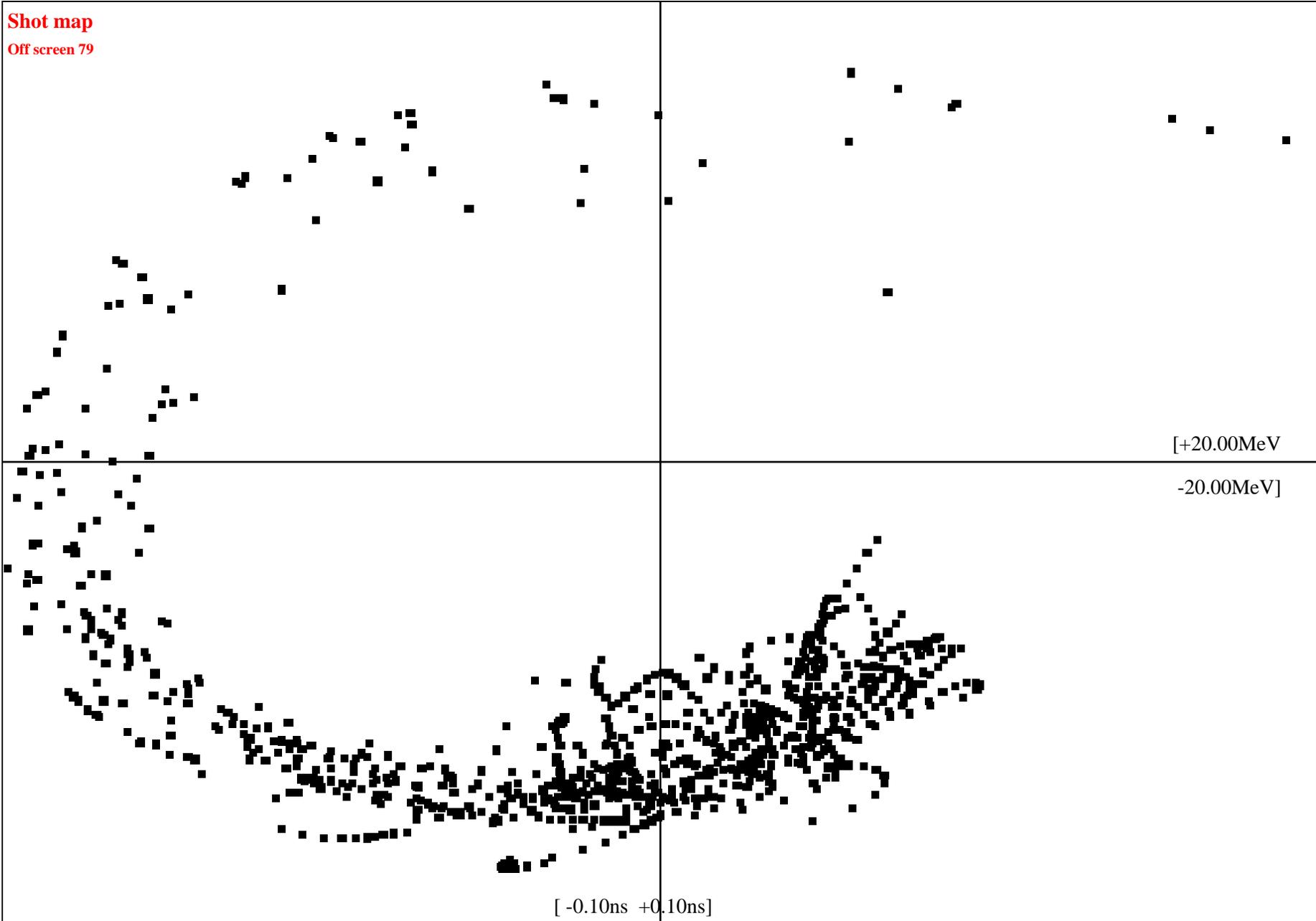


Bunch in phases space, injected and exit



Center of bunches at end of linac, 50 pulses, 5 shots each

Shot map
Off screen 79



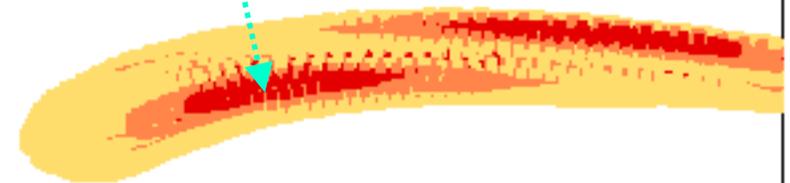
Overlay plot of many phase space images

Overlay: 20 pulses 5 shot/pulse



First 'shot', no beam loading yet

Following 'shots', beam loading established



[+20.00MeV
-20.00MeV]

... or movie
(with QuickTime® )

[-0.10ns +0.10ns]

Joachim Tuckema

SPLinac can simulate RF systems with

- **β -dependent T.T. factor**
- **vector (sum) feedback (opt. with delay)**
- **transmitter power limit and BW limit**
- **microphonics (different modes of perturb.)**
- **Lorentz detuning, mechan. resonance**
- **vector (sum) feedback errors**
- **power splitter errors**
- **Q_{ext} errors**
- **bunch in point or phase space representation**

SPLinac displays phase space plots

- **for each bunch along the linac**
- **for consecutive bunches at the end of the linac**
 - **‘dot maps’ for centroids**
 - **dE, dt along the linac**

**Internal parameters of
each transmitter family**

Precise numbers or

Overlay plots or movies

More information may be found at
<http://cern.ch/joachim.tuckmantel/>

- More detailed program description / user guide
SL-2000-053.pdf
- Application example (for CERN's SPL study)
SL-2000-054.pdf
- Some descriptions of the algorithms can be found in
Download phc07.pdf (*)
- ... and some QuickTime movies

For movie display on Mac or PC:
QuickTime® can be downloaded free of charge at
(careful: Mac or IBM compatible version)

at <http://www.apple.com/quicktime/download/>.

(*)HEACC2001 contribution which describes another program made for LHC but uses partly the same cavity descriptions.

Historically this program is the 'mother', SPLinac the 'child'