Status of SPL HOM studies at TRIUMF

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Contents

1 History

- received Dong-o Jeon's code `TALOBBU` transverse&longitudinal HOM (already bench-marked against TDBBU code (only transverse)) Nov 08
- Cern result (J. Tückmantel's paper[a]) received end of Jan 09;
- three tiny notes written – qualitative agreement over first pulse, but seed unknown
- my mistake "h=6" instead of "h=6.1" in text of third note (D.K.) caused J. Tückmantel to think our results were on resonance 1-2 months ago
- received data for fixed seed (HOM freq. and charge jitter dQ) $\sim 10 days$ ago
- nearly exact agreement between the codes last week !

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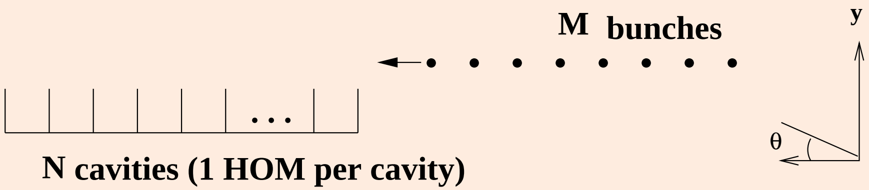
[a] J. Tückmantel, *HOM Dampers or not in Superconducting RF Proton Linacs*

2 Gluckstern's example repeated (dipole mode test for TALOBBU)

Difference equations for M bunches interacting with N HOM cavity modes [a]



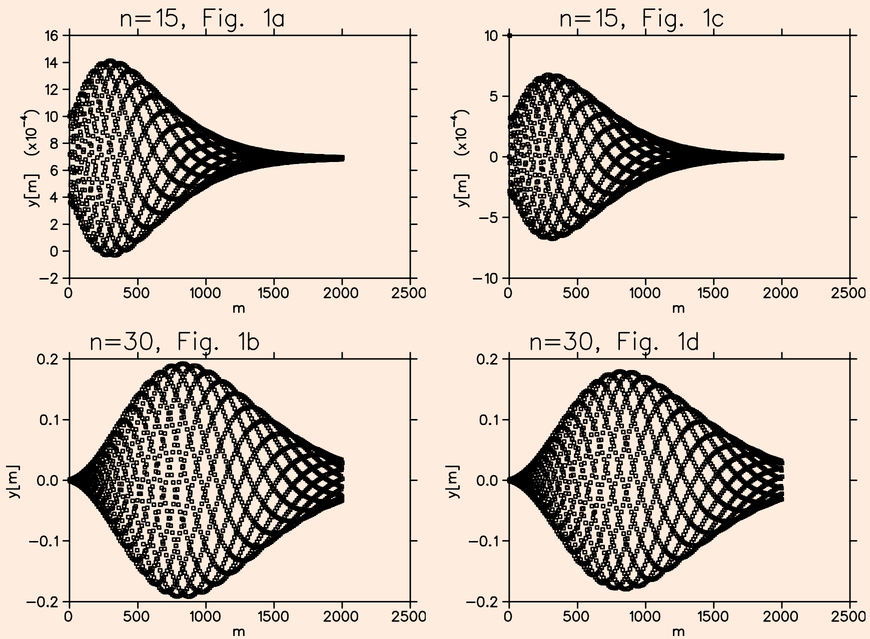
- **single dipole HOM**
- **const. inter-bunch time** τ
- **constant 2x2 transport matrix** M **between cav.**

$$y_m^{n+1} = M_{11}\, y_m^n + M_{12} \frac{\gamma_n}{\gamma_{n+1}} \theta_m^n + r_1 \sum_{l=0}^{m-1} s_{m-l}\, y_l^n; \quad r_1 \equiv M_{12} R/\gamma_n$$

$$\theta_m^{n+1} = M_{21}\, y_m^n + M_{22} \frac{\gamma_n}{\gamma_{n+1}} \theta_m^n + r_2 \sum_{l=0}^{m-1} s_{m-l}\, y_l^n; \quad r_2 \equiv M_{22} R/\gamma_n$$

$$s_k \equiv e^{-\frac{k\ \omega\ \tau}{2\ Q}} \sin(k\, \omega\, \tau)$$

[a] R.L. Gluckstern, R.K. Cooper and P.J. Channell, *Cumulative Beam Breakup in RF Linacs*, Part Acc, vol 16 pp 125-153.



Gluckstern parameter	value
L dist. betw. cavities	1m
N HOMs	15 or 30
M bunches	2000
Q	1000
$\gamma = const$ coasting	6
$M_{11} = \cos\mu$	1
$M_{12} \equiv L$	1
$M_{21} \equiv -\frac{\sin^2\mu}{L}$	
$M_{22} \equiv \cos\mu$	
$\omega\tau$	$1.846\ 2\pi$
$r_1 \equiv r_2$	$2.88\ 10^{-3}$
μ (no) focusing	0
J of Eqn. 59 Gluck.	0.9986298
($J < 1$ means stable)	

Brute force result, same as TALOBBU result – to be compared with Figures 1a,b,c,d in Gluckstern's paper. Shown are coordinates of 2000 bunches after cavities 15 and 30. Left: all bunches enter at 1 mm. Right: only the first bunch enters at 1 mm

- Brute force means that the values of y are stored in for all n and m (done in Fortran and *Mathematica*), but there is no need to store all m;
- It can be shown that the Gluckstern's difference eqn-s [a] are identical to the recursive procedure in TDBBU, TALOBBU and J. Tückmantel's code [b], namely: Introduce complex V. The m-th bunch passes all cavities. At each cavity the HOM mode voltage V is updated and stored. The imaginary part of V is the HOM kick. The following script does the same as the Brute force:

```
(********  talobbu way in Mathematica ********)
V = Table[0, {NN + 1}];
Do[
  y = 0.001;
  T = 0;
  Do[
    V[[n]] = V[[n]] (Exp[I ot] Exp[-ot/(2.Q)]);
    T = T + Im[V[[n]]]/P ;
    V[[n]] = V[[n]] + R/gam*P*y ;
    y = M11 y + M12 T ;
    T = M21 y + M22 T ,
    {n, 1, NN}],
  {m, 1, MM}]
(********  ********)
```

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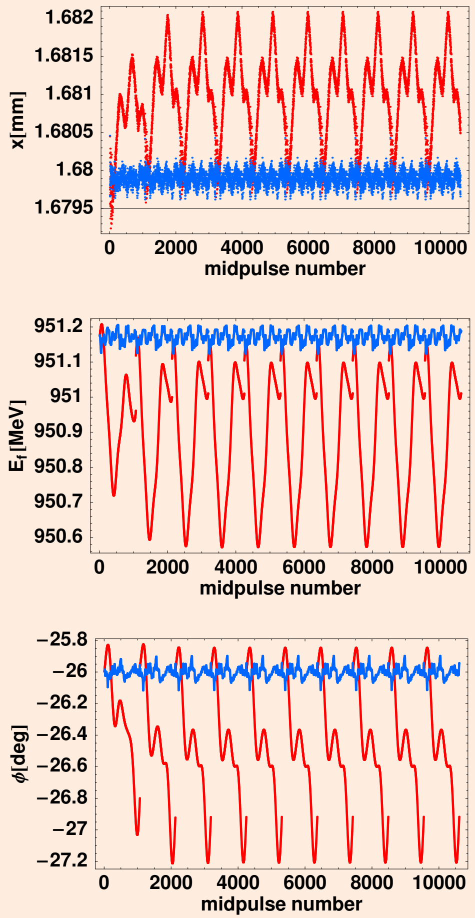
[a] R.L. Gluckstern, R.K. Cooper and P.J. Channell, *Cumulative Beam Breakup in RF Linacs*, Part Acc, vol 16 pp 125-153.

[b] J. Tückmantel, *HOM Dampers or not in Superconducting RF Proton Linacs*

3 Run with SNS setup provided by D. Jeon: monopole and dipole mode

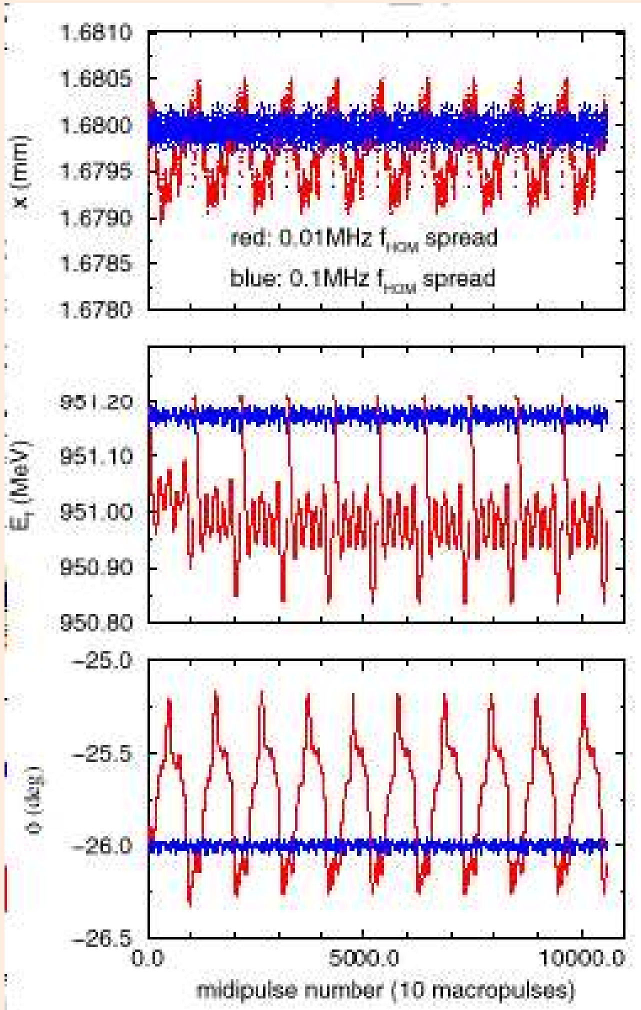


TALOBBU parameters to reproduce [a]

TALOBBU variable	value	definition
particle	H-	
CRRNT	50	current, mA
FREQB	402.5	bunch frequency, MHz
FREQF	805	fund. mode freq., MHz
EI	185	initial energy,MeV
DFHOM(D)	0.1(blue)	spread (uniform)
	or 0.01 (black)	

[a] D. Jeon , L. Merminga , G. Krafft , B. Yunn, R. Sundelin, J. Delayen, S. Kim, M. Doleans, *Cumulative beam break-up study of the spallation neutron source superconducting linac*, NIM A 495 (2002) 85-94.

4 dipole and 1 monopole HOM in each med- and high-beta cavities



to be compared with Fig. 9 from [a] for **unknown random seed**

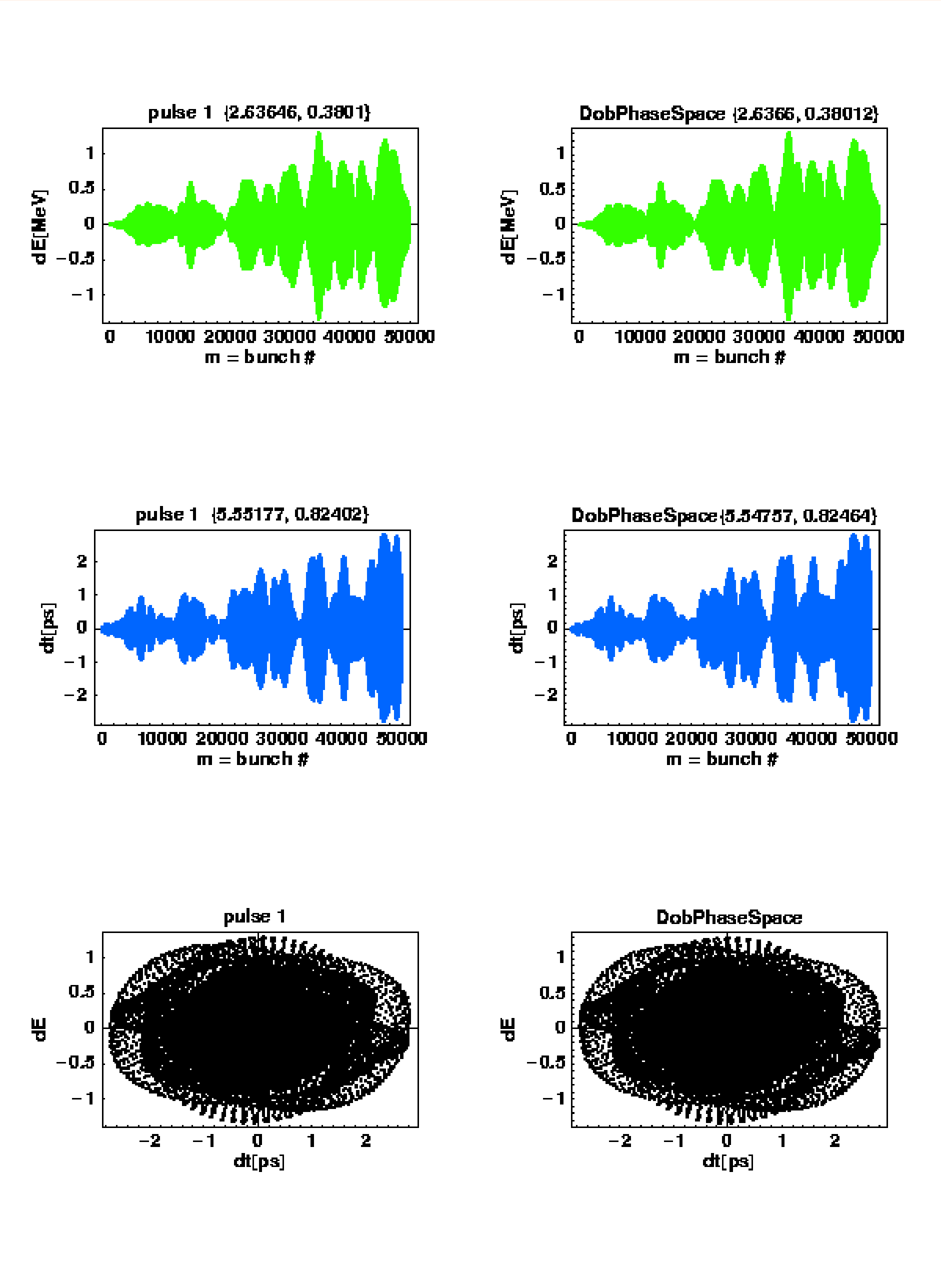
4 Modifications of `TALOBBU`

- random generator changed to `ranmar`
- added random Gaussian charge jitter dQ
- (minor) *The complex HOM voltage V of a cavity HOM is such that the first bunch (m=1) enters this cavity at zero local time. The first bunch (m=1) should pass all cavities unaffected. In the original code the first bunch already experienced small time shifts. I have changed this (DK) and it did not affect the results.*

5 Agreement with the Cern code, monopole mode, first pulse

TALOBBU variable	value	definition
CRRNT	400	current, mA
FREQB	352.2	f_b, bunch frequency, MHz
FREQF	704.4	fundamental mode frequency, MHz
EI	150	initial kin. energy,MeV
NMICRO	50000	$\equiv M$, numb. of bunches for 1 ms pulse
NCAV_MED	150	$\equiv N$, number of cavities
VTTF(I), i=1,...,N	20.7	acc. volt. of all cavities
PHSNOM(I), i=1,...,N	-15	acc. volt. phase of all cav,deg
CALL DRIFT(X,1.75)	1.75	drift len. betw. cav.,m
(R/Q)	50	Ω
Q_{ext}	10^8	Ω
$< f_h >$	2283.83	$= 6.48445 \times f_b$, MHz
DFHOMM	0.1	r.m.s. of frequency f_h spread, Gaussian
dQ	0.1	r.m.s. of charge jitter Q, Gaussian

5 Agreement with the Cern code, monopole mode, first pulse



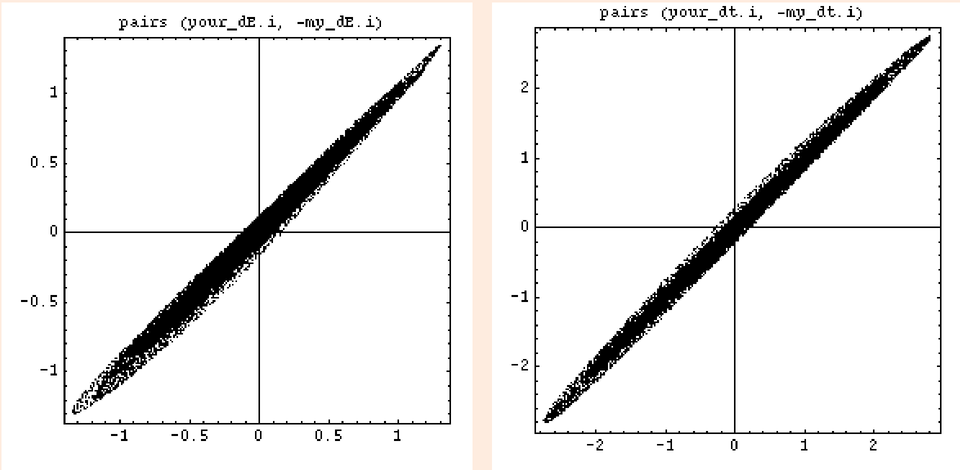
Here: $E \equiv X_5$, $t \equiv X_6$,

$dE = E - E_0$, $dt = t - t_0$.

Left: TALOBBU run with the 150 f_h values and 50000 dQ values sent as two .dat files

Right : Cern code result sent as file `DobPhaseSpace.dat`

A scatter-plot, a 2D plot with pairs (your_dE_i,my_dE_i) for $i = 0, 50000$ *and similar for dt. For perfect agreement we would have all points on a straight line with slope 1*



Left:

(your_dE_i,my_dE_i)

Right:

(your_dt_i,my_dt_i)