Preliminary Results on Long Range Wakefield Study in Cold LC

Nicoleta Baboi

- TESLA main linac layout
- Dipole wakefields
- RMS of sum wake
- Bunch dynamics simulations
- Random detuning and interleaving
- Dipole modes in TTF cavities

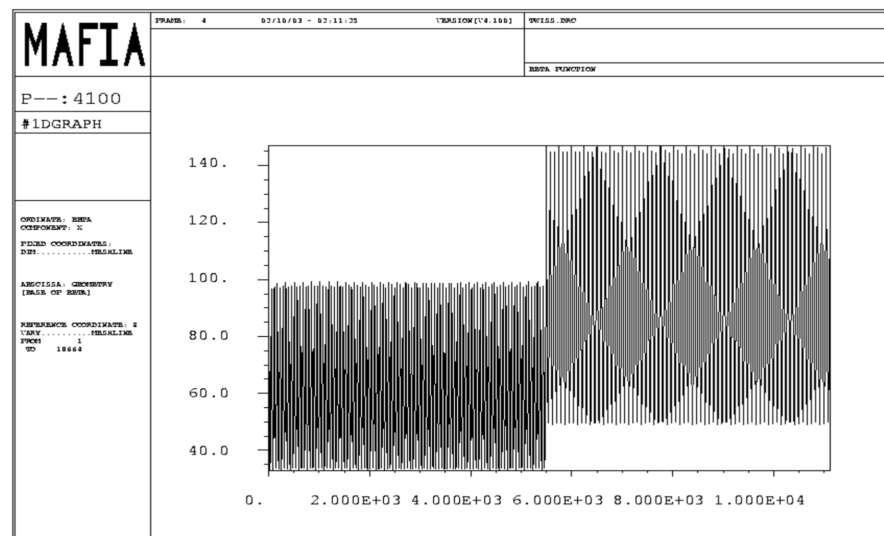
Introduction

- Study various options for minimal long range wakefield effects in TESLA
  - cavity detuning
    - random detuning
    - interleaving: purposely detuning sets of cavities
  - tolerance on misalignment of cavities

- Tolerances
  - systematic errors in frequency
  - beam dynamics simulations
  - study of RMS and standard deviation of sum wakefield

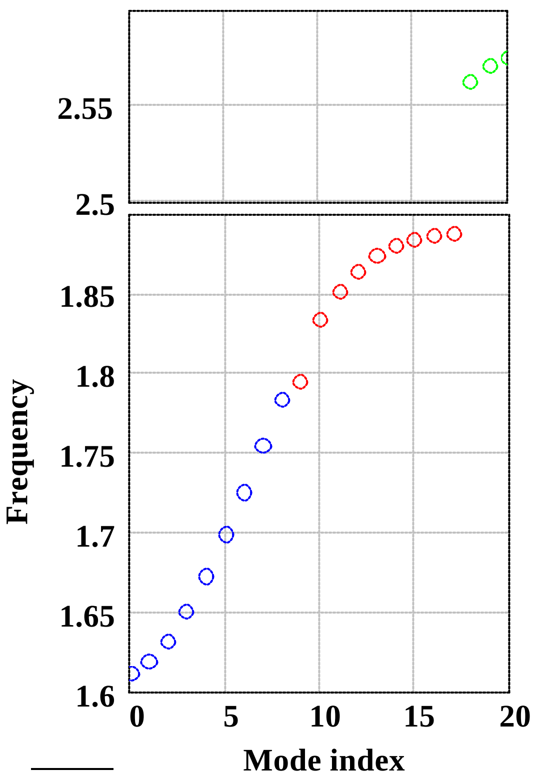
TESLA Linac

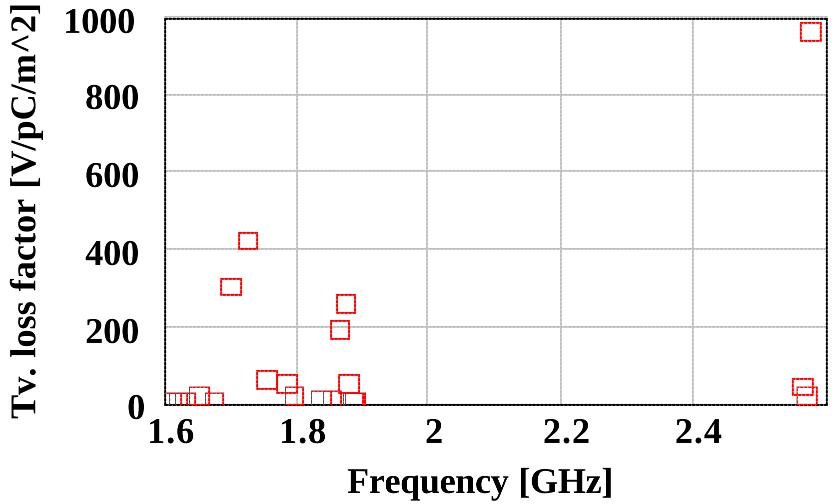
- Based on TESLA500 design
  - 12 1m-long cavities (9 cells/cavity) per cryo-module
  - ~10,000 cavities per linac
  - cavity misalignment 500 μm
  - phase advance per FODO cell: 60 deg
  - 1st section: 4 modules / FODO
  - 2nd section: 6 modules / FODO
- Accelerating mode
  - gradient: <u>**25** MV/m</u>
  - f_0 = 1.3 GHz,
    Q = 3.e6, kloss = 2. V/pC
- Bunch train
  - 2820 bunches, but use only 5-600 (steady state reached)
  - 3.2 nC, 337 ns spacing
  - injection energy 5 GeV

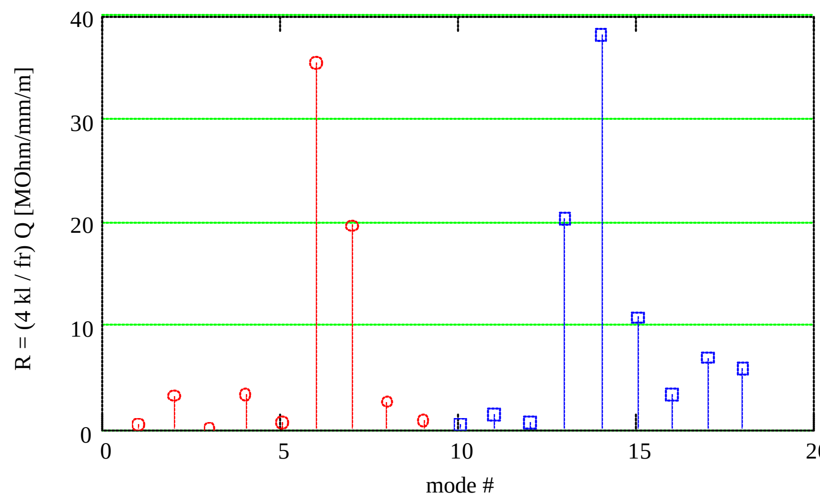


HOMs in TTF Modules

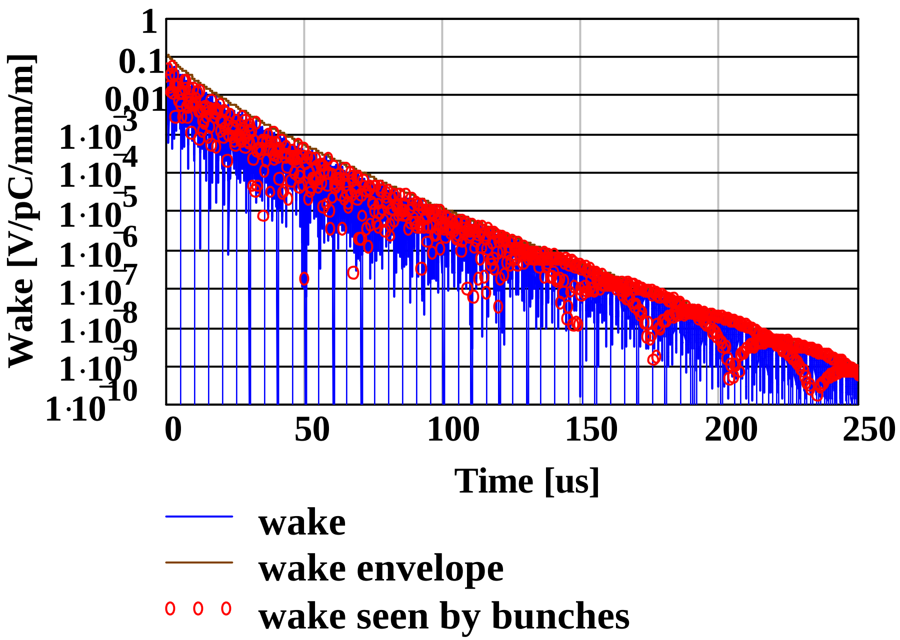
- Consider 14 dipole modes from 1st, 2nd and 3rd dipole passbands, with highest impedance (as measured at TTF1)



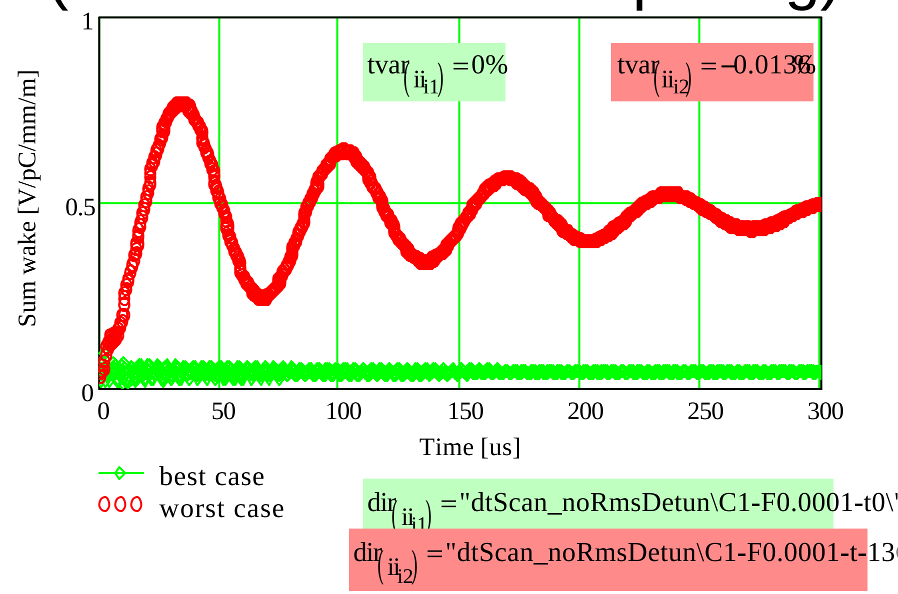




Dipole Wakefield



Sum wake
(for different bunch spacing)

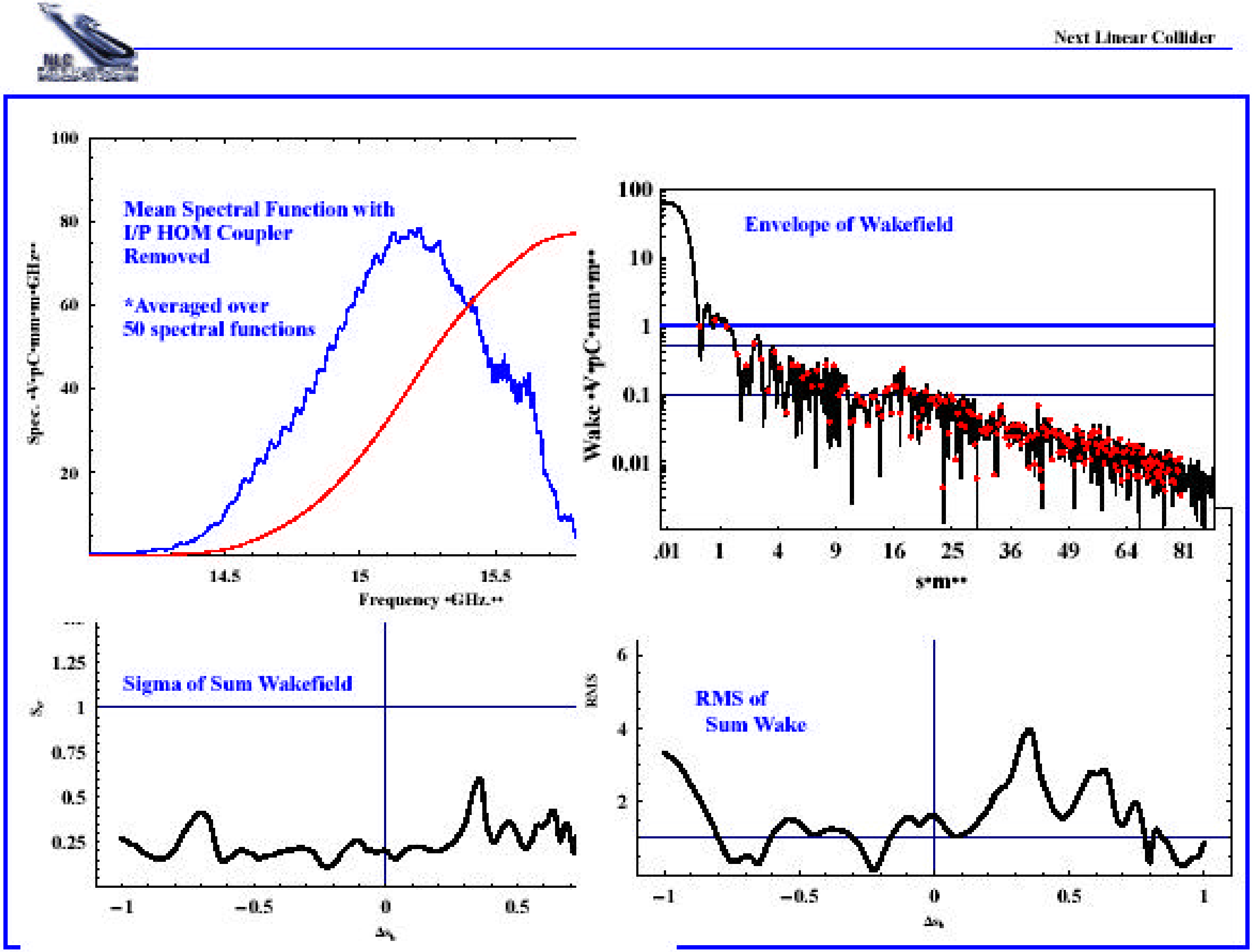


RMS and Standard Deviation of Sum Wake

- For NLC
  - relatively standard tools to measure WF effects

  - 1. the wakefield at the first trailing bunch
  - 2. RMS of sum wake $\rightarrow$ indicator whether BBU will occur
  - 3. StDev of sum wake $\rightarrow$ indicator of alignment tolerances

Example for one NLC Structure



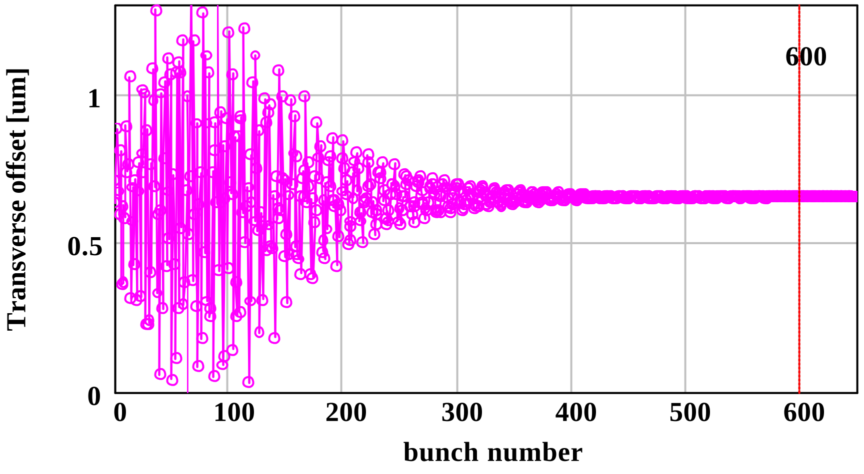
Roger M. Jones (Structures Meeting, SLAC, March 11, 2004)

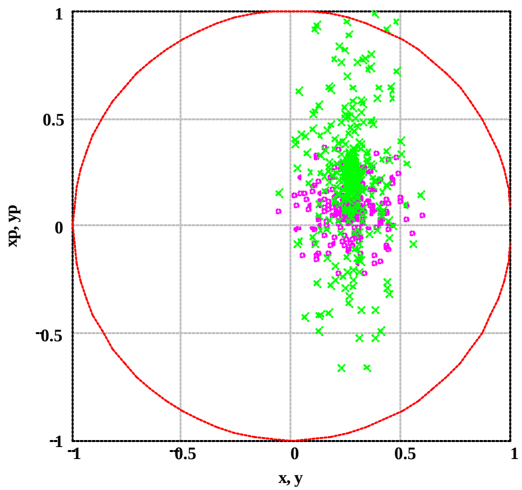
7 (of 18) March 11, 2004 2:55 pm, T:\RMJ\Common Work + Home Files\FrameMaker\H60VG3_Structures_3_04.fm

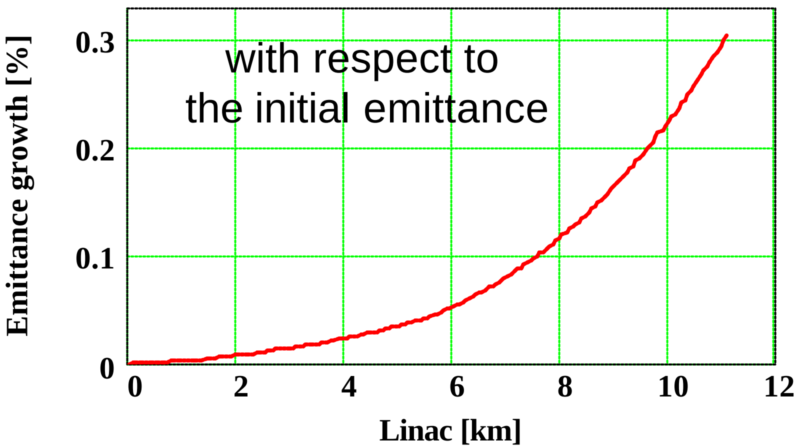
Beam Dynamics Simulations with MAFIA-L

- Assumptions
  - No beam loading
  - No detuning
  - No short range wakes

  - no misalignment of cavities
  - 4 µm injection offset (σ ~ 18µm)



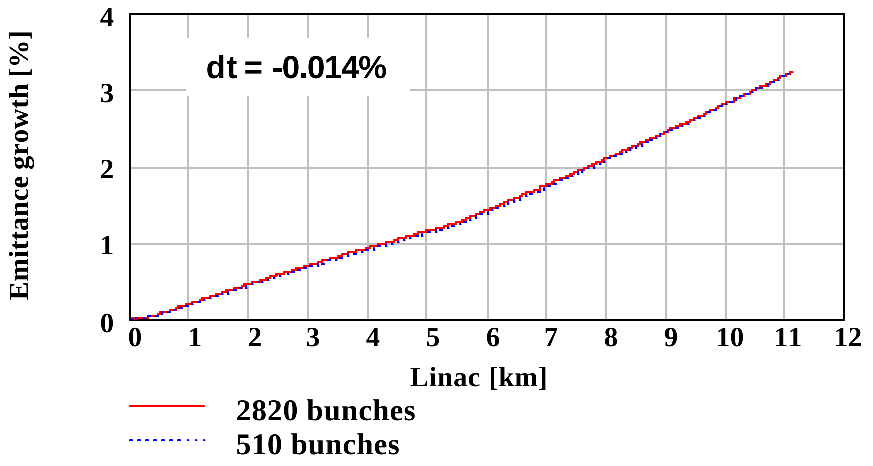


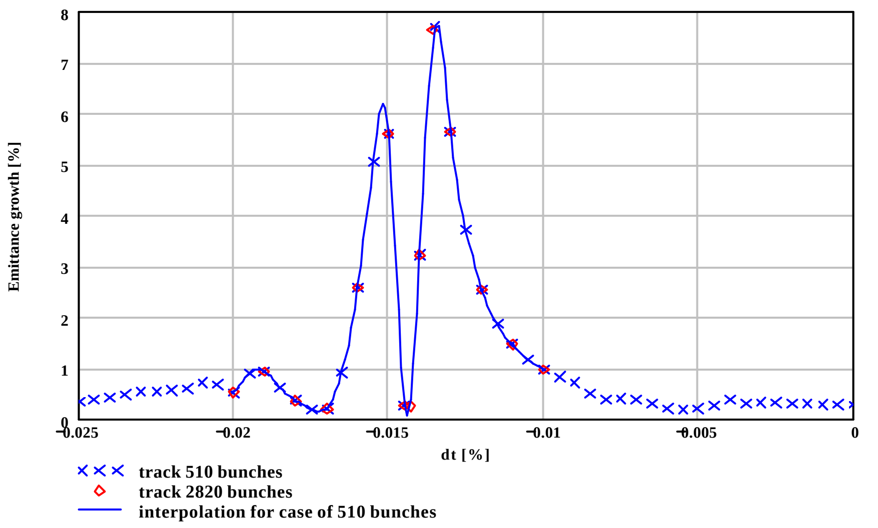


Simulation with Full and Truncated Bunch Train

- Compare tracking with
  - 510 bunches (then normalize emittance to full train)
  - 2820 bunches
- Simulation
  - no cavity misalignment
  - 4 μm injection offset

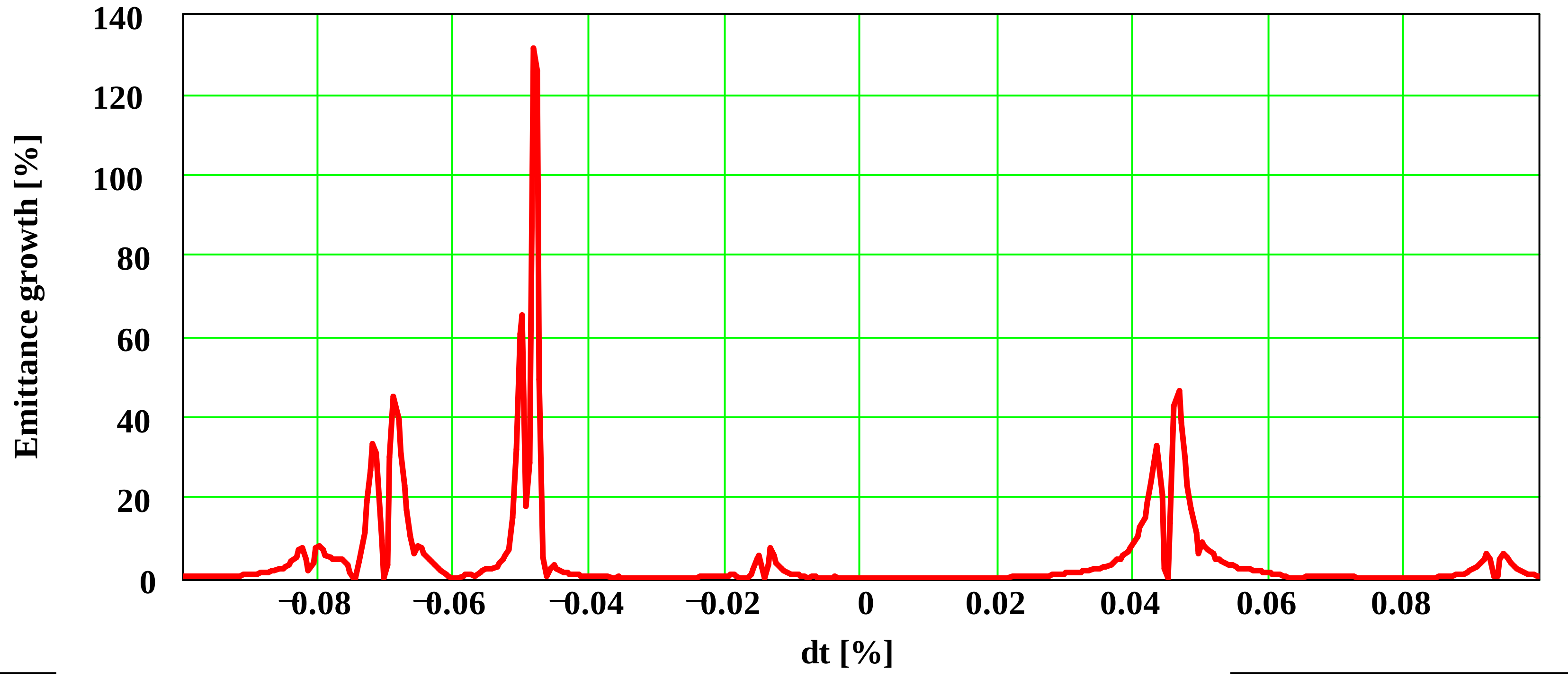
- ⇒ it is sufficient to track 5-600 bunches down the long linac then normalize to full train





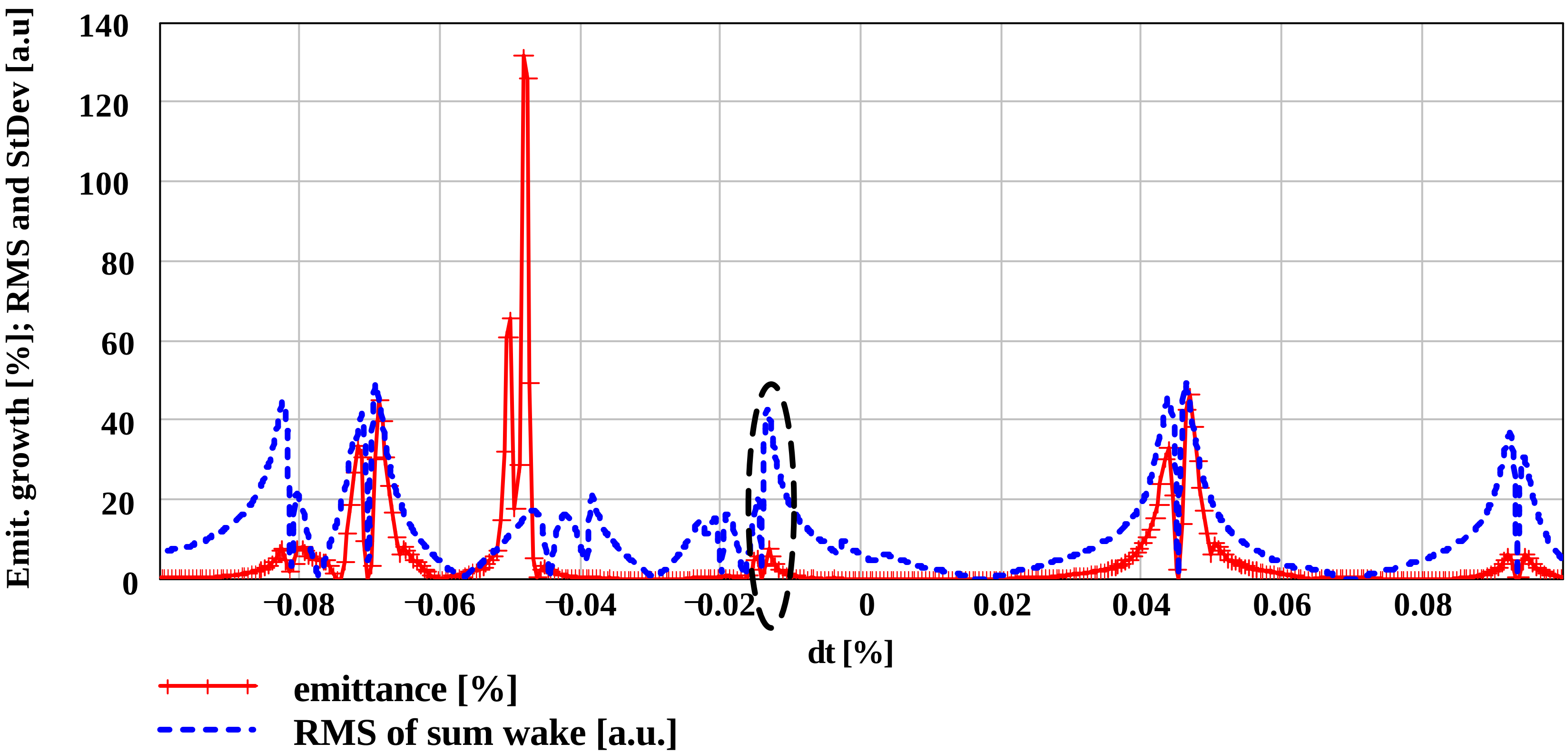
Emittance Scan

- Simulate systematic error in cavity detuning by varying bunch spacing
  - $t_b = t_{b0}\,(1 + dt)$
  - no misalignment of cavities
  - 4 μm injection offset



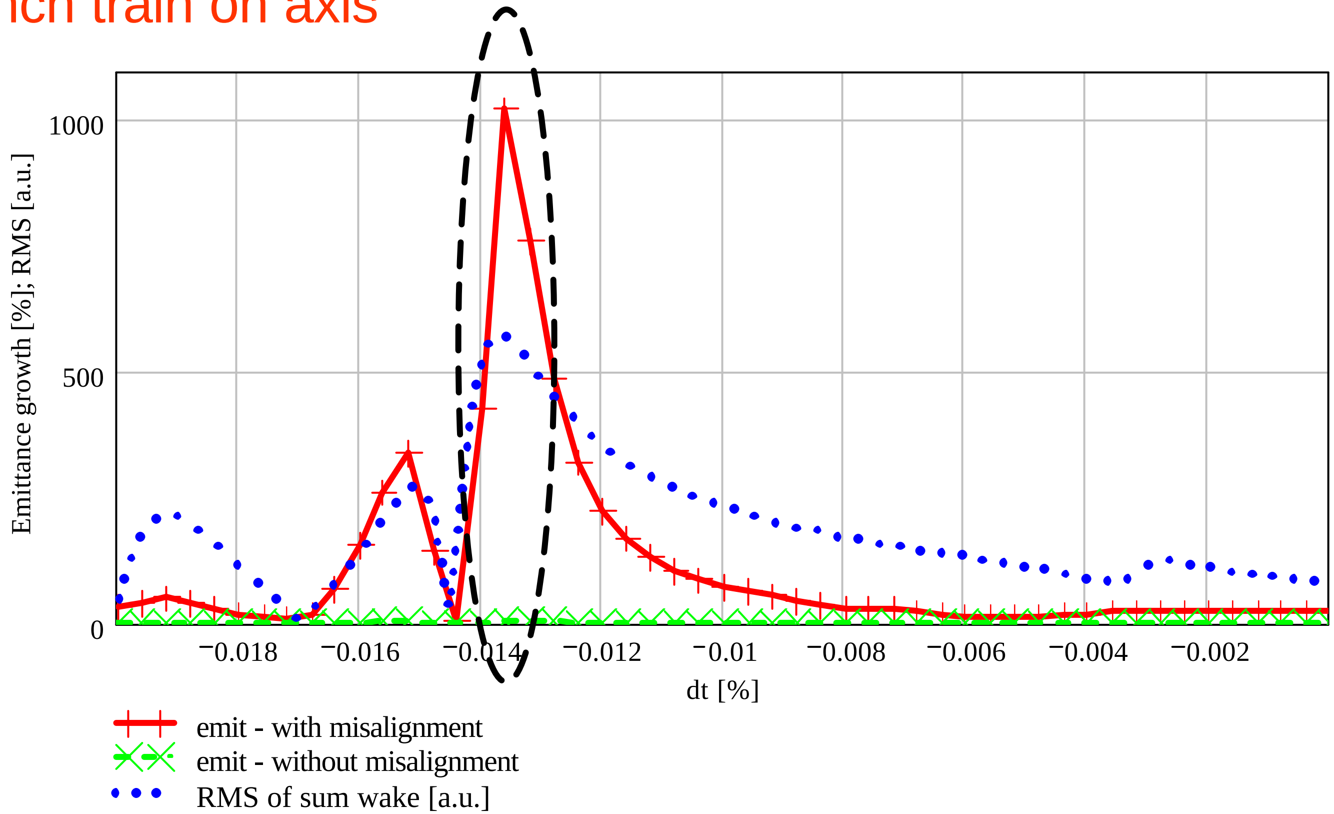
RMS of Sum Wake

- no misalignment of cavities
- 4 μm injection offset



Cavity Misalignment

- Misalign cavities: 500 μm rms
- Inject bunch train on axis

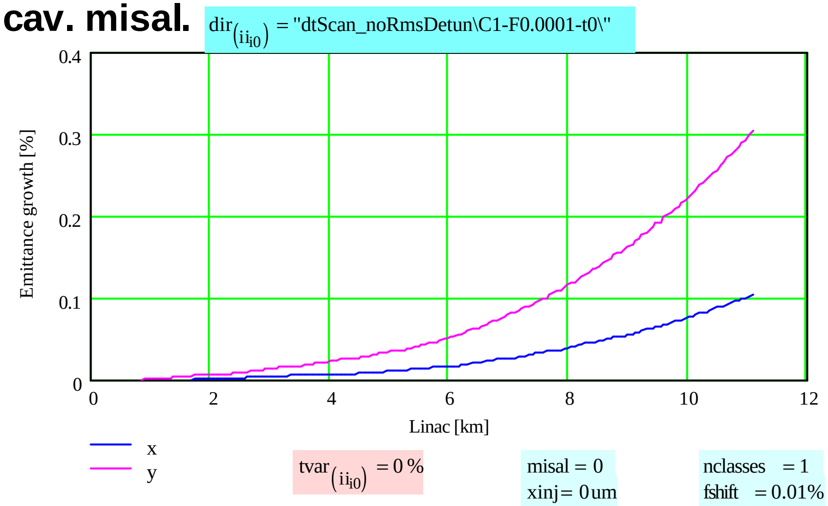


- Even for design bunch spacing: $\Delta\varepsilon \sim 25\%$
- <u>But</u> detuning of cavities has positive effect

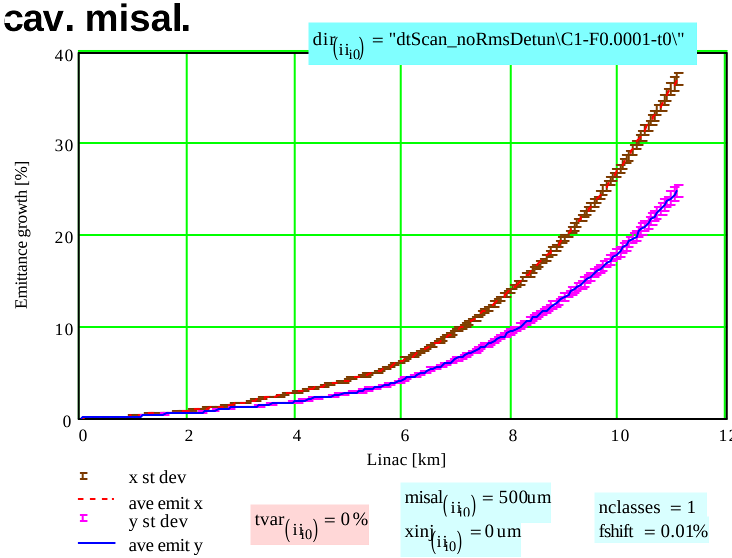
Emittance Growth

dt = 0

no cav. misal.

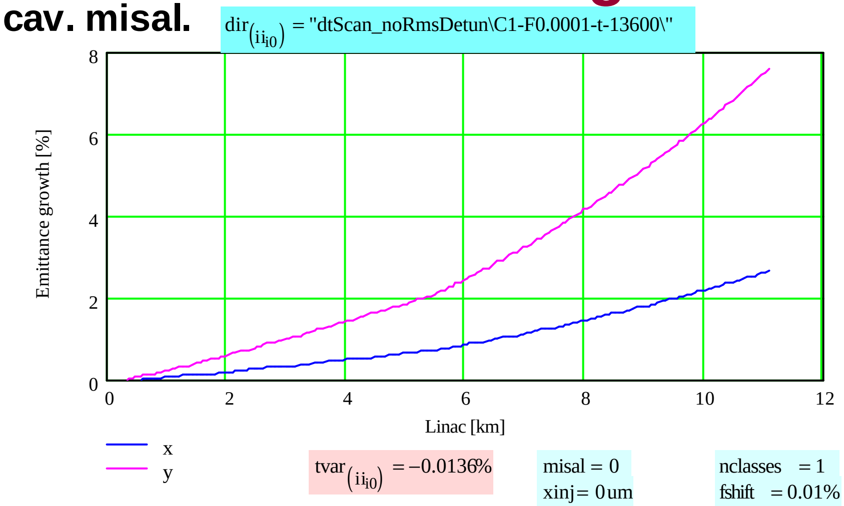


with cav. misal.

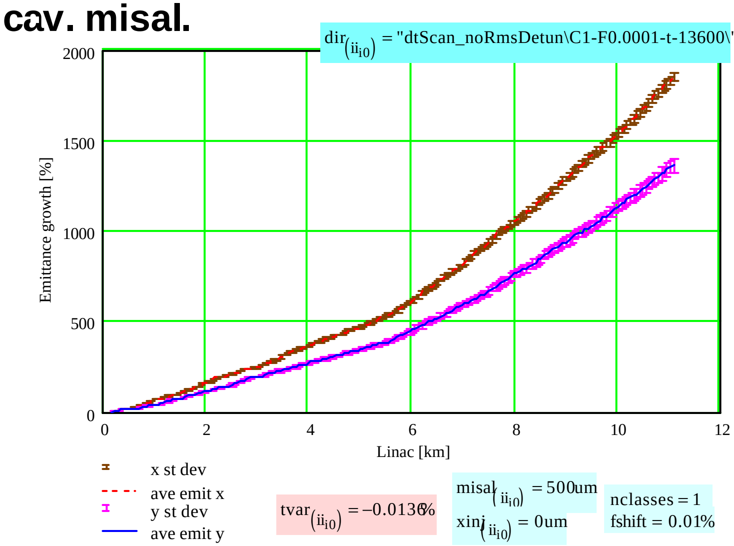


max emittance growth

no cav. misal.

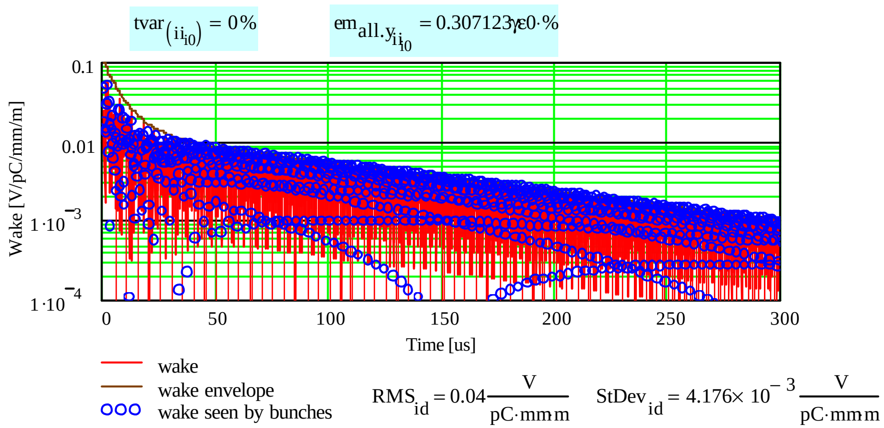


with cav. misal.

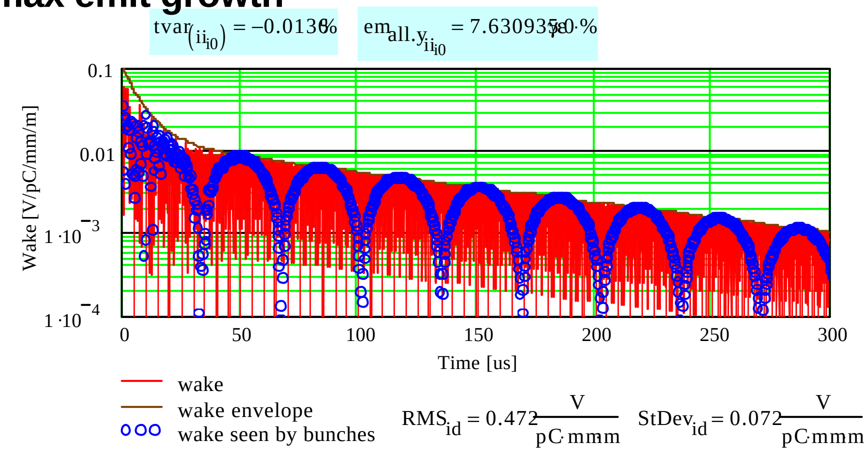


Wake Field and Sum Wake

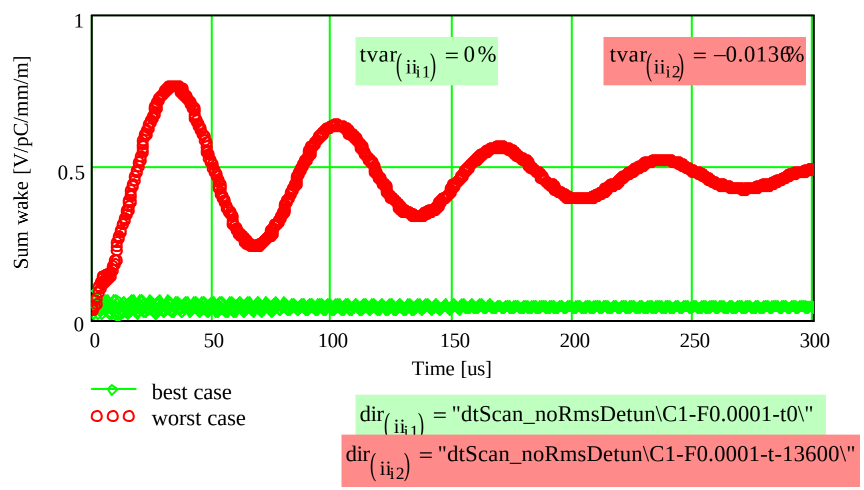
dt = 0



max emit growth



Sum wake



Detuning

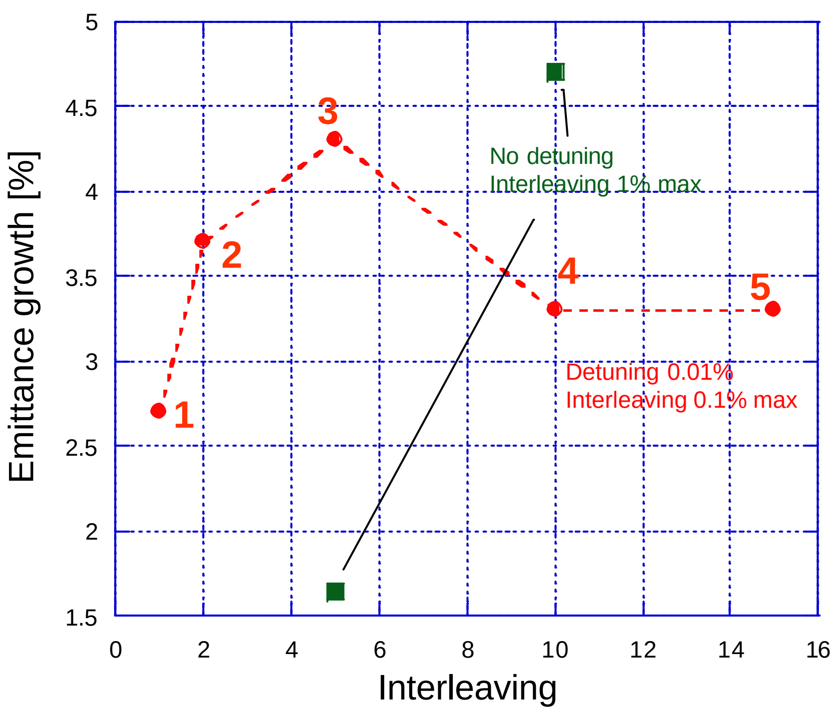
- **Random detuning**
  - from fabrication tolerances
  - TDR: 0.1%

- **Interleaving**
  - n-fold interleaving =
    - ncl = 1 .. 15
  - df_{shift} = maximum detuning range
    - df_{shift} = 0.1 .. 1%
    - In first 3 TTF modules
      - – 0.5 .. 0.6% for 1st band
      - – 0.05 .. 0.2% for 2nd
  - all modes shift with same percentage df ($i=0..n-1$)

$$f_{i,m} = f0_m \cdot \left(1 + i\frac{df_{shift}}{n-1}\right)$$

Emittance with Detuning and Interleaving

- Design bunch spacing



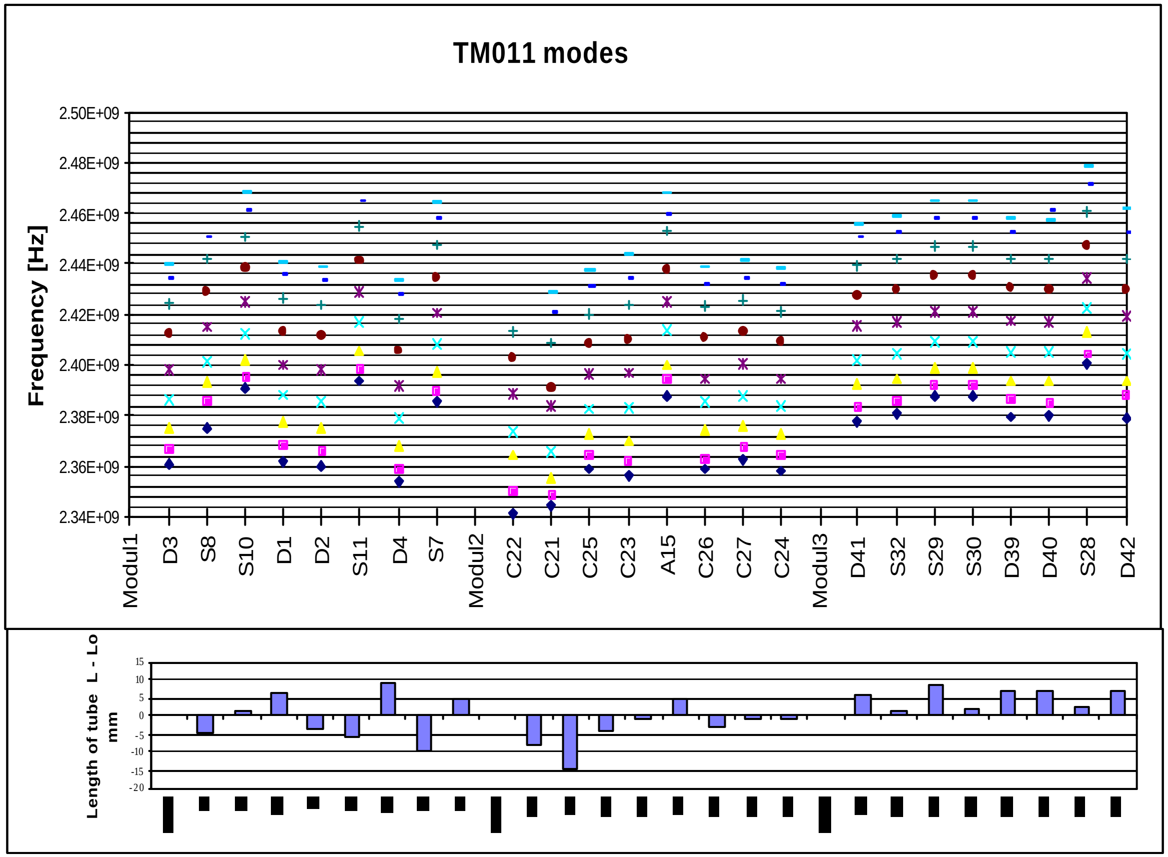
Misalig. (500 mm rms)	Rand detun.	Interl. (max)	Emit. growth [%]
- (#)	-	-	0.3
x	-	-	24
- (#)	-	5 / 1%	0.006
x	-	5 / 1%	1.64
x	-	10 / 1%	4.7
x	0.1%	-	3.7
X(1)	0.01%	-	2.7
X(2)	0.01%	2 / 0.1%	3.7
X(3)	0.01%	5 / 0.1%	4.3
X(4)	0.01%	10 / 0.1%	3.3
X(5)	0.01%	15 / 0.1%	3.3

 # - injection offset 4 mm

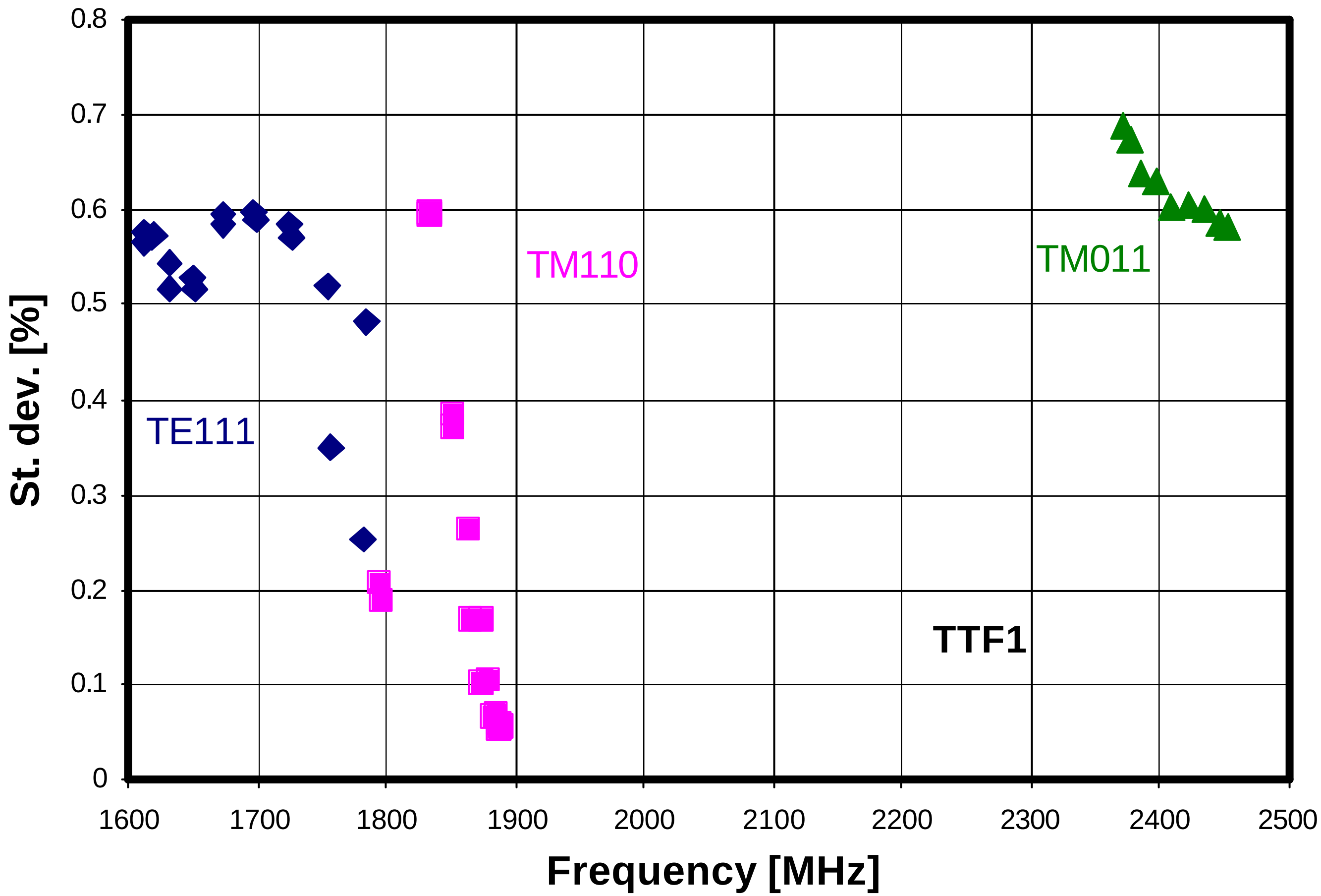
X – 500 mm random misalignments (no injection offset)

Geometrical Spread in TTF1 Cavities

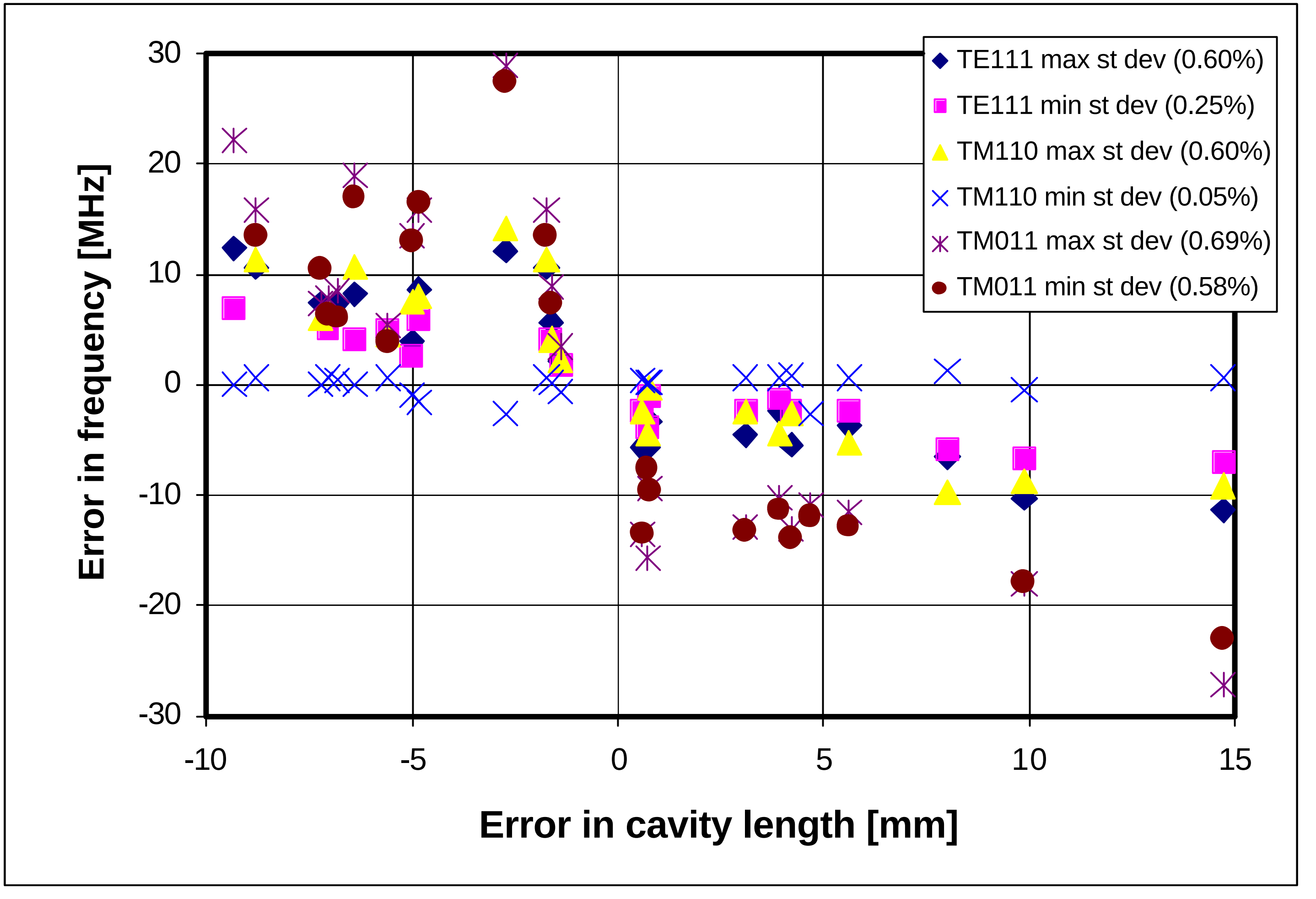
- 24 cavities
- St. dev. of cavity length:
  6.3 mm → 0.6%
- St. dev. of frequency of first monopole mode
  16 MHz → 0.7%



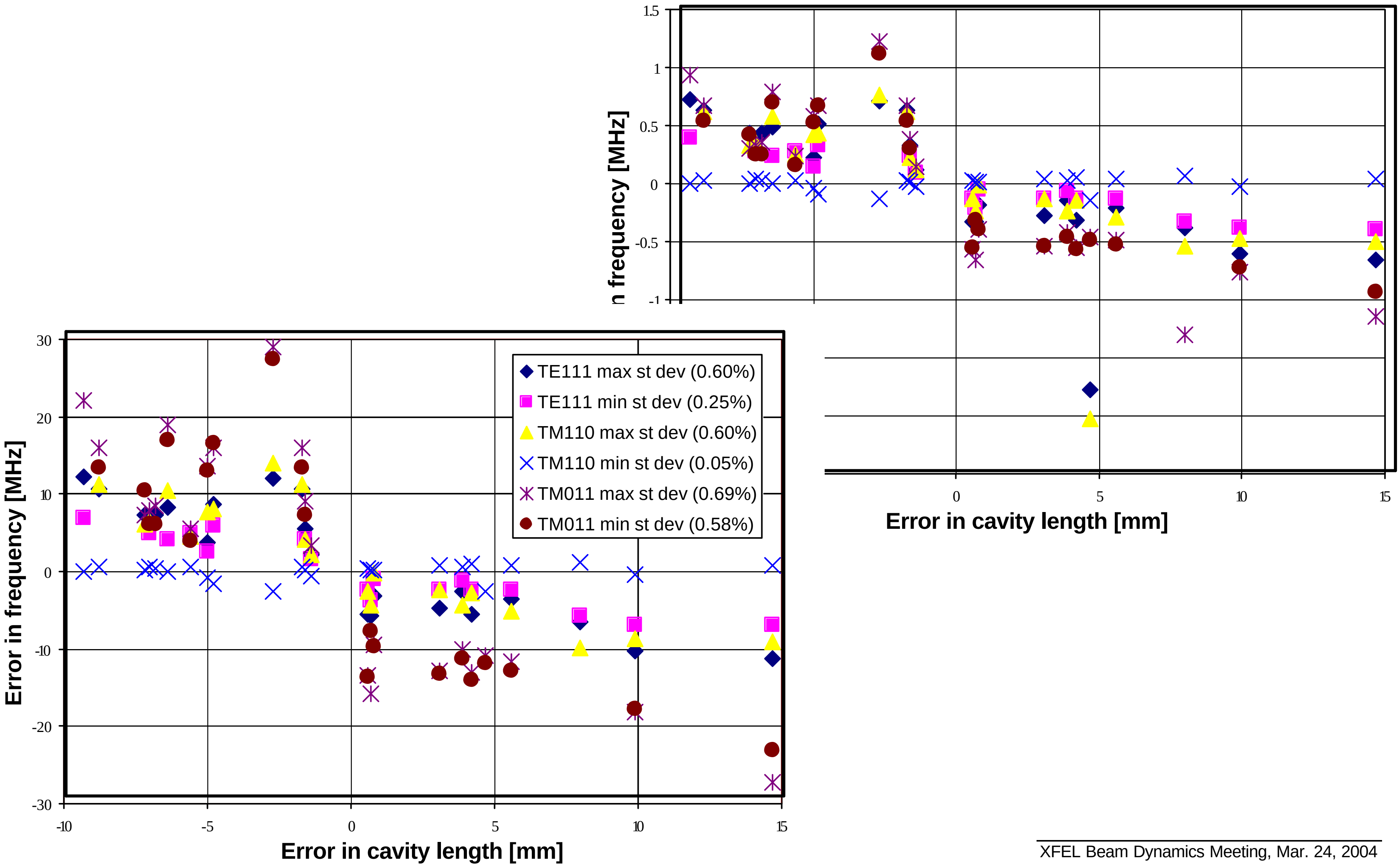
Frequency Errors in TTF1 Cavities



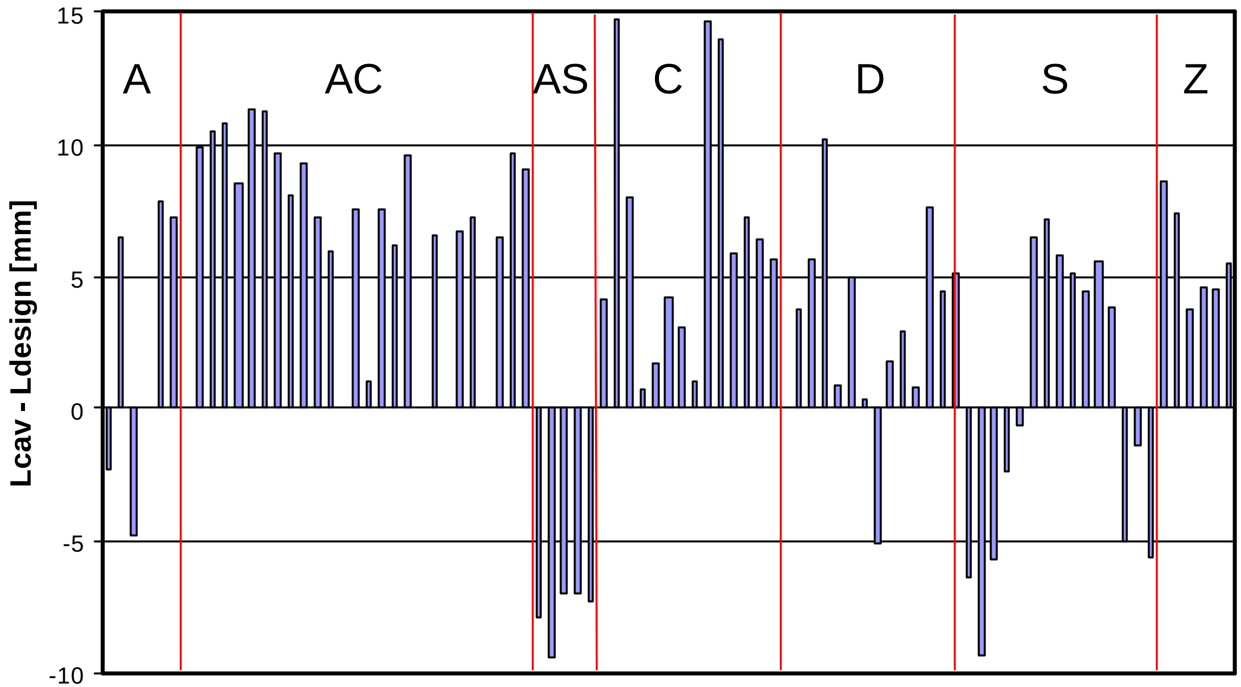
Correlation between Frequency and Length Errors (TTF1)



Correlation between Frequency and Length Errors (TTF1)



Length of TTF Cavities



- Cavity length:
  - average: +4.16 mm
  - st. dev.: 5.74 mm (0.45%)

Length of TTF Cavities by Series

Series	# cav	Ave [mm]	Ave_diff [mm]	Stdev [mm]	Stdev [%]	fabricated between	
C	14	1282.72	6.52	4.82	0.38	07-Mar-95	19-Jan-04
D	12	1279.37	3.17	3.93	0.31	24-Aug-95	19-Sep-03
S	15	1276.32	0.12	5.61	0.44	30-Jul-96	22-Apr-02
AS	5	1268.48	-7.72	1.01	0.08	24-Apr-97	14-Dec-01
A	6	1279.07	2.87	5.95	0.46	19-Mar-98	01-Jul-03
AC	27	1284.38	8.18	2.32	0.18	06-Jul-00	05-Mar-04
Z	6	1281.91	5.71	1.87	0.15	07-Aug-00	19-Mar-03

Outlook

- Study various options:
  - interleaving:
    - 2-fold up to 10-fold
    - various frequency range
  - random detuning
    - various detuning range

- For each case study tolerances on fabrication

- Use information from newest TTF cavities