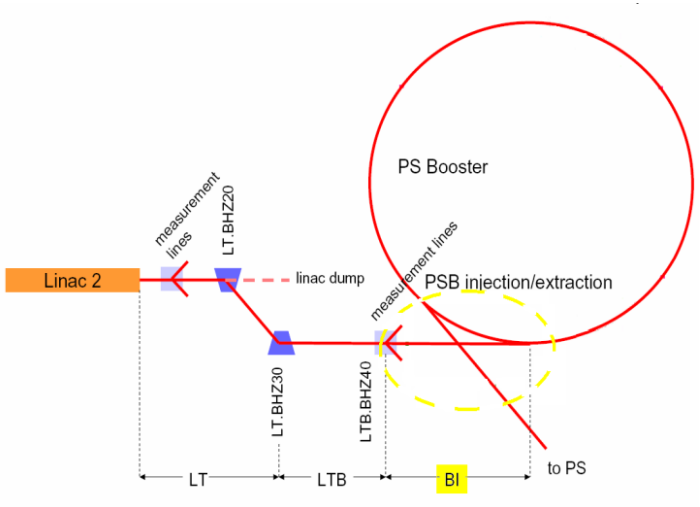


Beam position instabilities in the PSB injection line

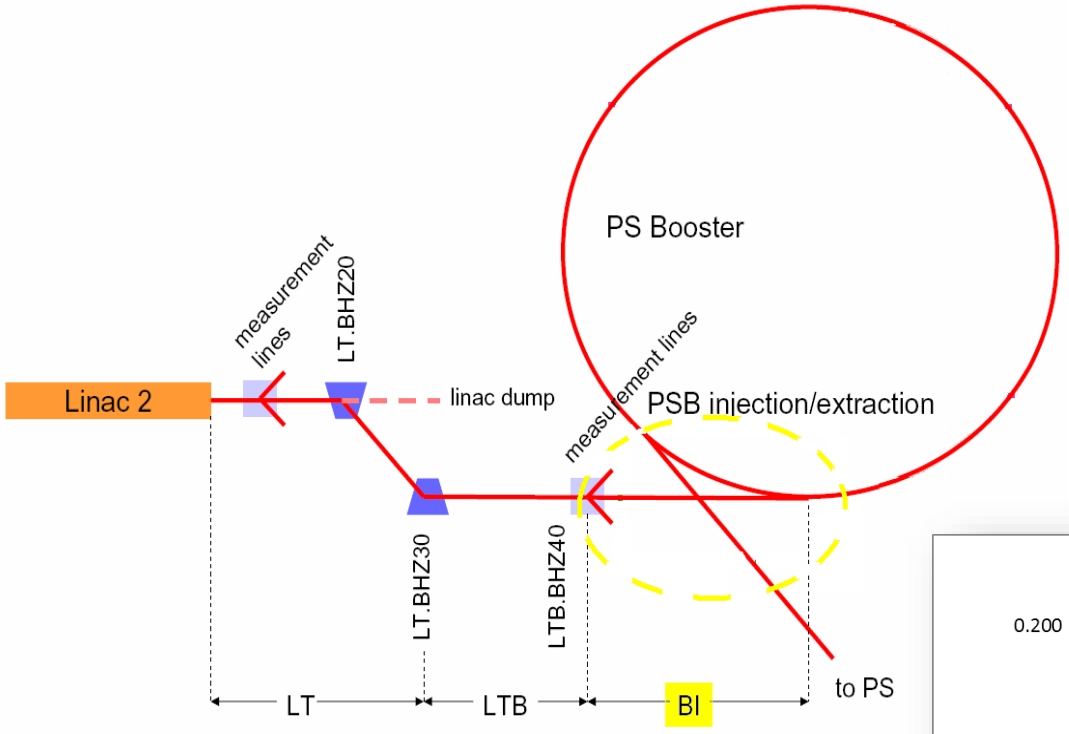
J. Tan, M. Bozzolan, L. Søby, B. Mikulec, G.P. Di Giovanni,
O. E. Berrig, E. Benedetto

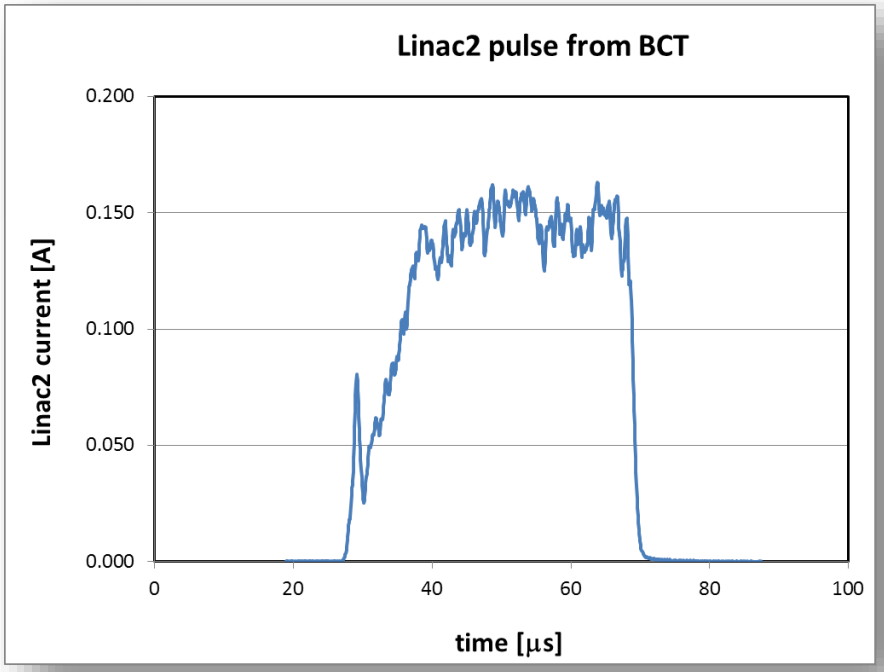
BI Technical Board 17th July 2015

Outline

- The Linac2 transfer line
- The trajectory measurement system
- Position instabilities
- Discussion
- Summary

Transfer lines LT-LTB-BI

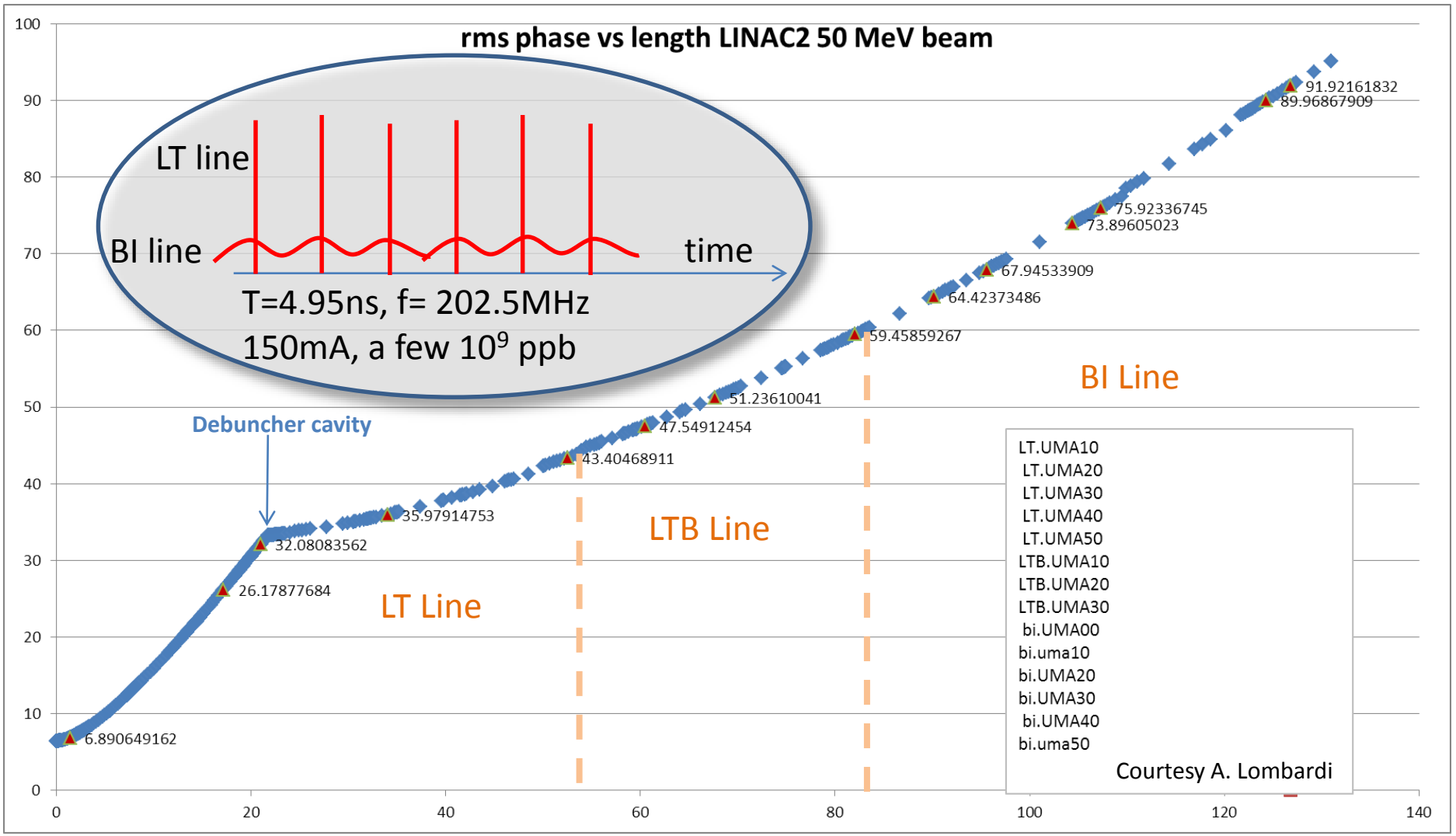




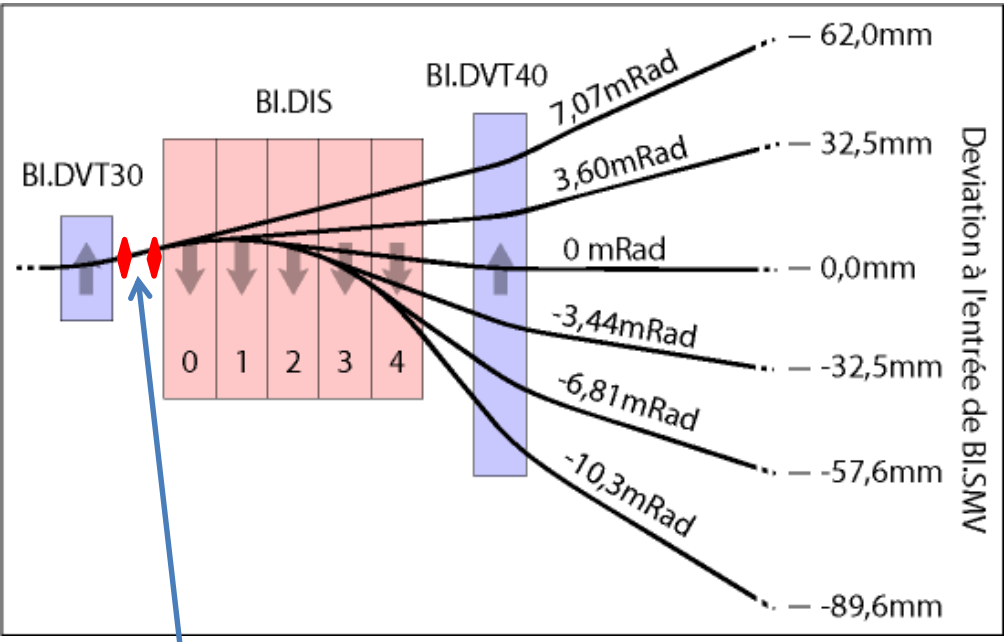
Beam diagnostics devices along 130m long TLs

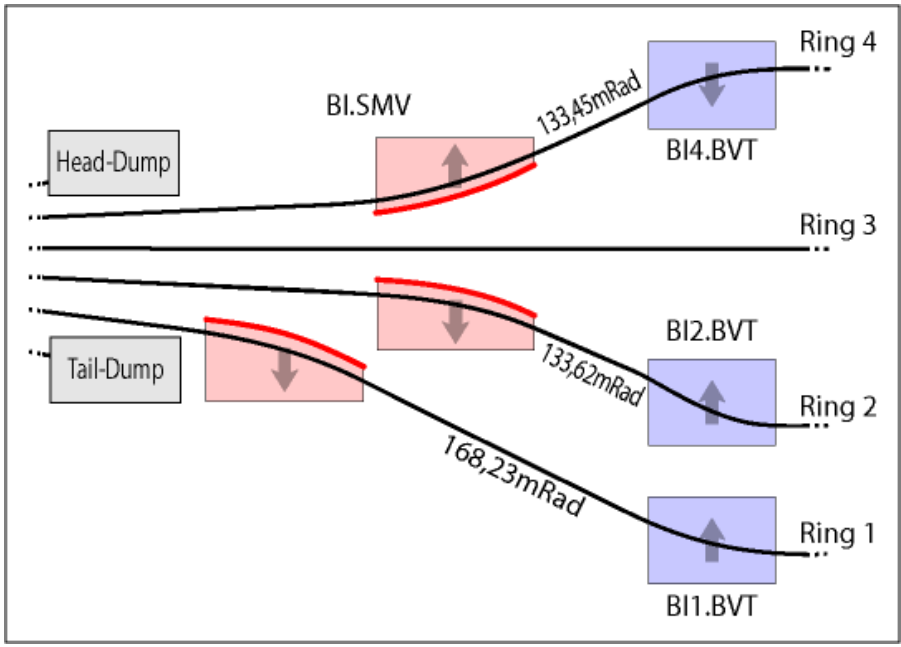
- BPMs
- FBCTs
- BLMs
- Scintillating screens
- Measurement lines for emittance and energy

Longitudinal beam phase



Vertical distribution in BI line

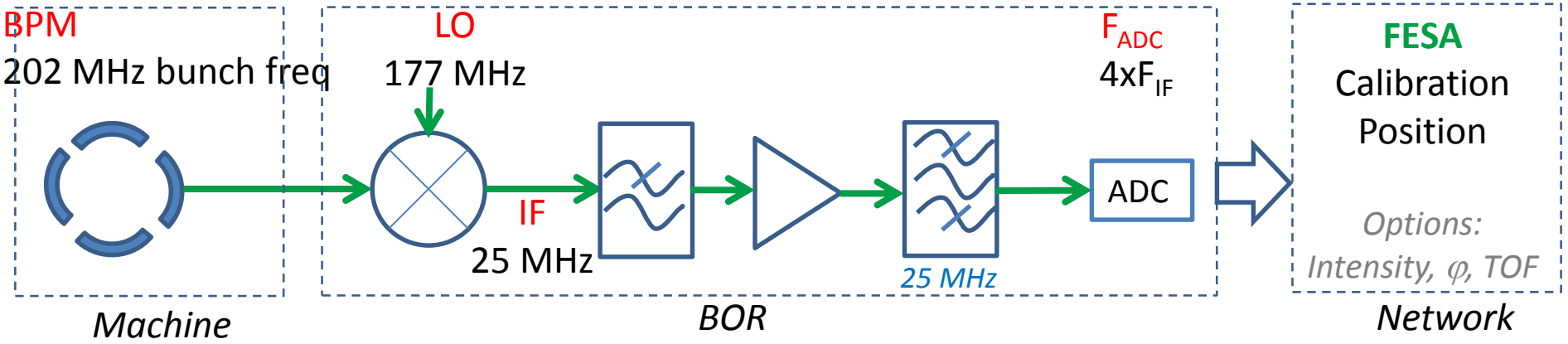




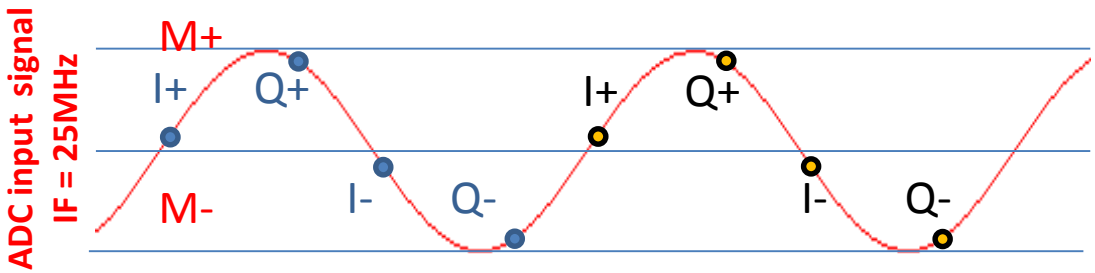
A pair of quadrupoles acting as vertical dipoles

Linac4-based monitor and Acq. system

Acquition system



FESA Class: I/Q demodulation



$$M_+ = \sqrt{I_+^2 + Q_+^2}$$

$$M = \frac{M_+ + M_-}{2}$$

$$\phi_+ = arctan\left(\frac{Q_+}{I_+}\right)$$

$$\Delta H = \frac{M_R - M_L}{M_R + M_L + M_U + M_D} S \times Cal$$

$$\varphi = \varphi_{beam} - \varphi_{LO}$$

$$I \propto M_R + M_L + M_U + M_D$$

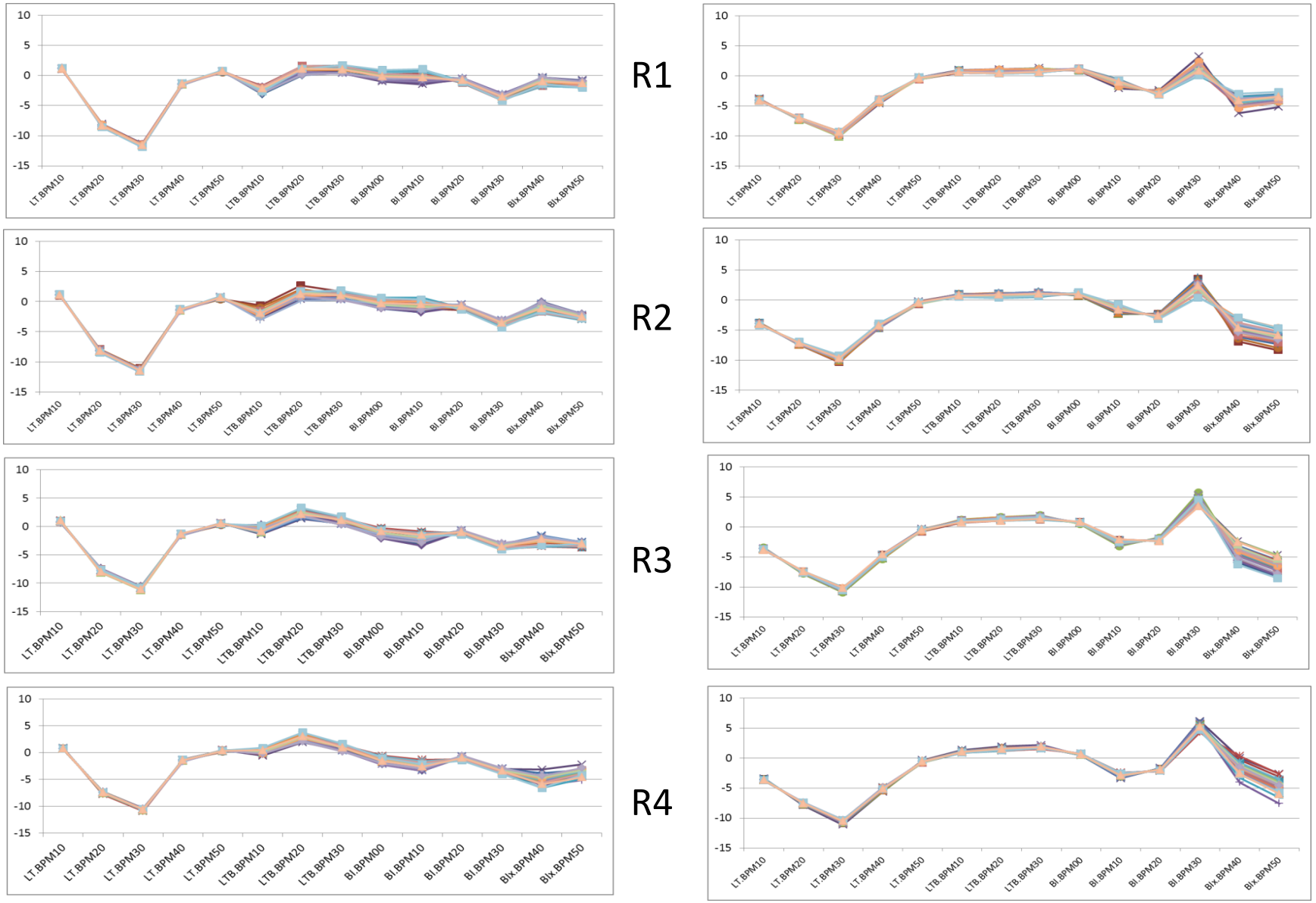
$$TOF = \varphi_{PU2} - \varphi_{PU1}$$

POSITION vs TIME (NOMINAL BEAM)

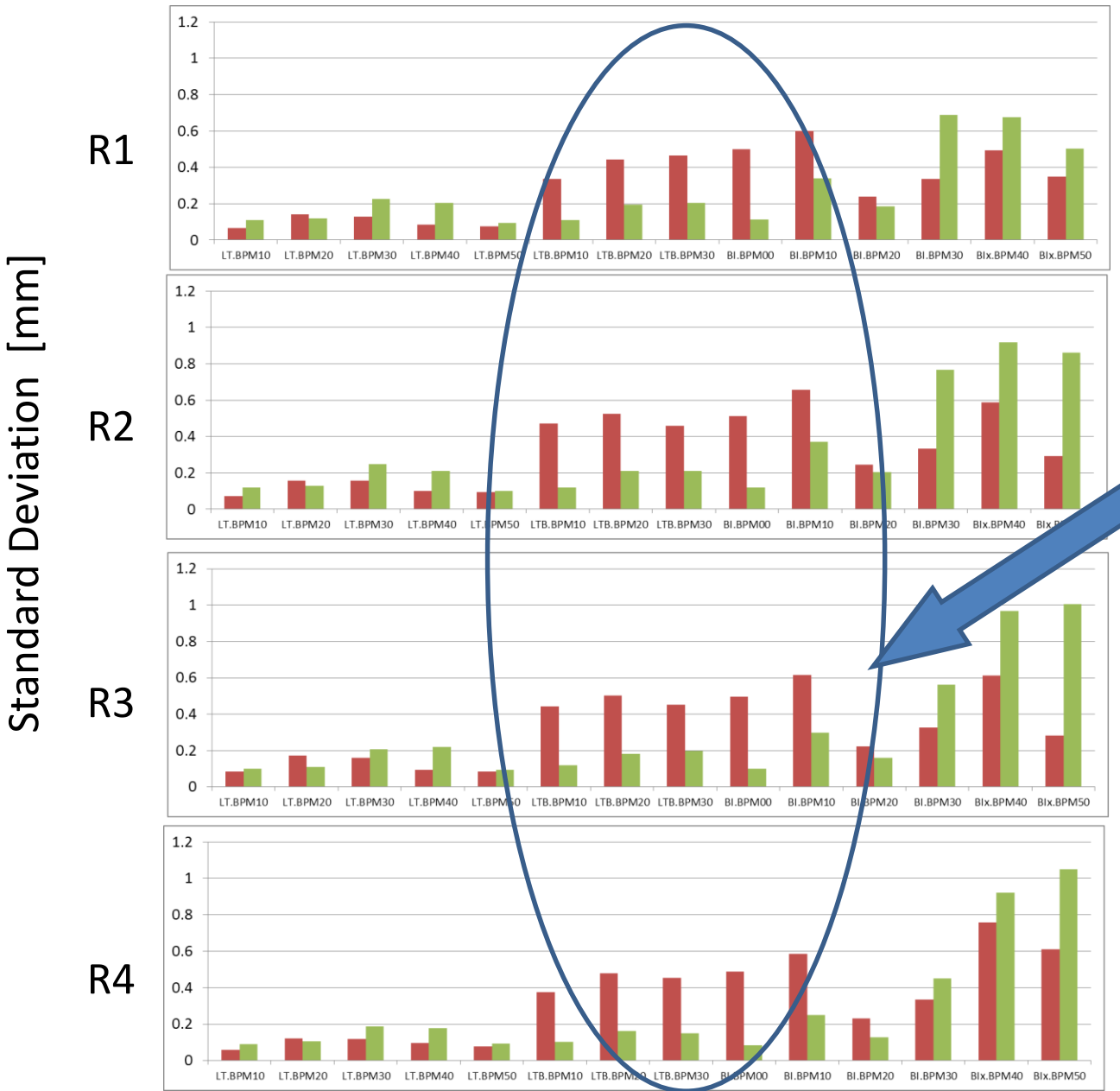
- H PLANE BI LINE BEFORE DISTRIBUTOR
- V PLANE BI LINE BEFORE DISTRIBUTOR
- V PLANE LT LINE: instabilities are present from the Linac2 output.

Spike is present all along the transfer line

Beam Trajectories : 30 x LHCINDIV cycles



Beam Trajectories: Standard Deviations



Horizontal plane

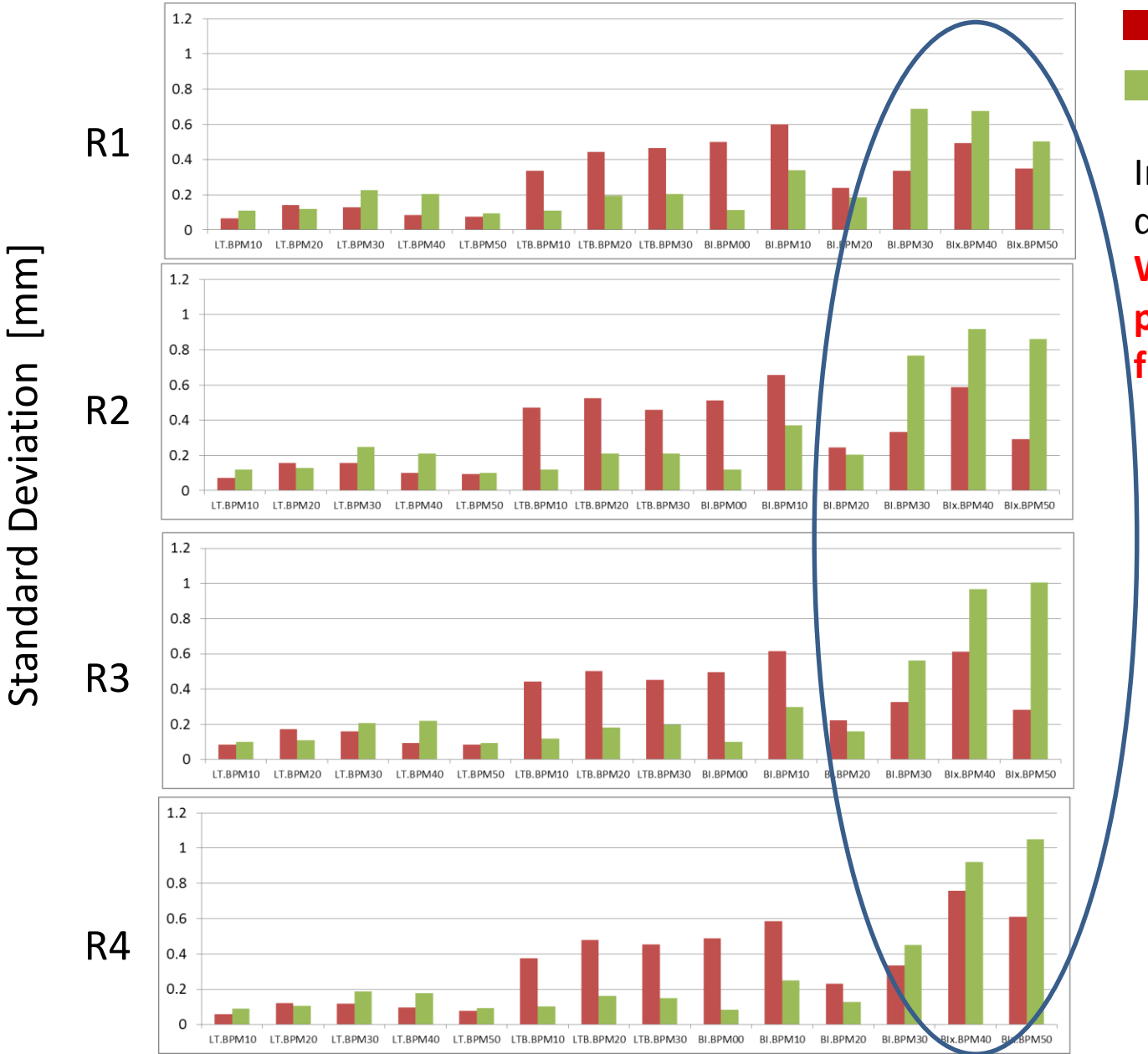
Vertical plane

LTB and part of BI line cross the PS ring.

The 50MeV beam travelling there is perturbed ***horizontally*** by the stray magnetic field of the PS magnets.

Well understood & mitigated **Stray Field Compensation**

Beam Trajectories: Standard Deviations



Horizontal plane

Vertical plane

In BI line where vertical distribution takes place:

We observe large position fluctuations !!

Why?

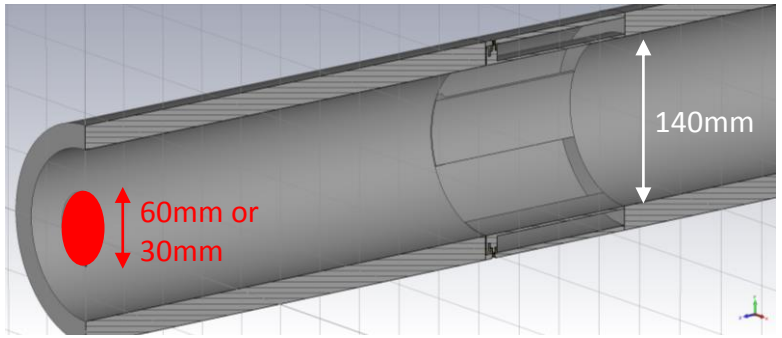
Can we trust the Shorted Stripline?

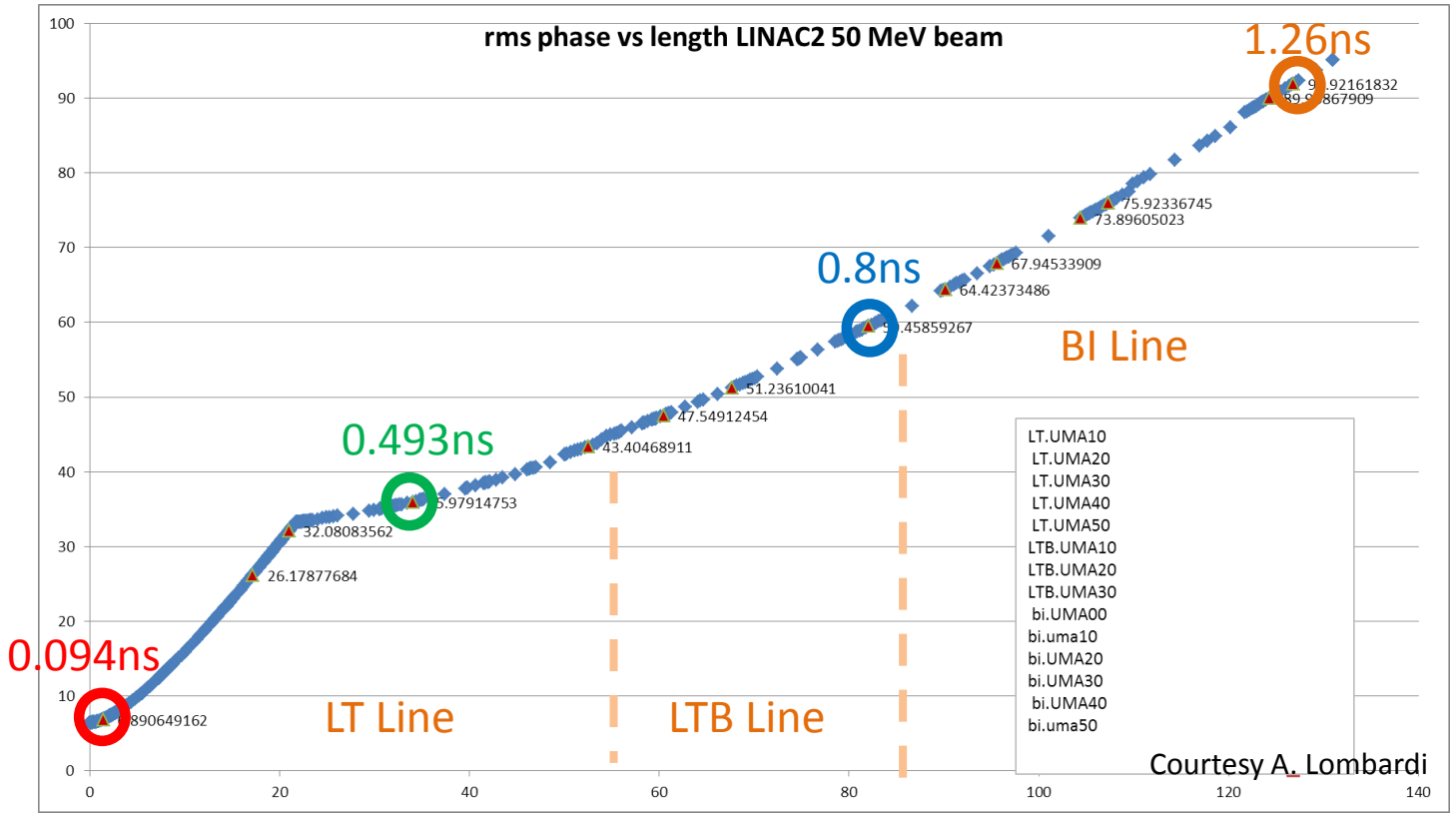
- BPM characteristics are CST-based simulations
- Single bunch and multi-bunch for time domain
- Gaussian distribution: transverse & long.
- Parameters: β, bunch length, transverse beam size, boundary conditions, power dissipation, electrode coupling, geometry
- Lab conditions: stretched wire, step response

Can we trust the Shorted Stripline?

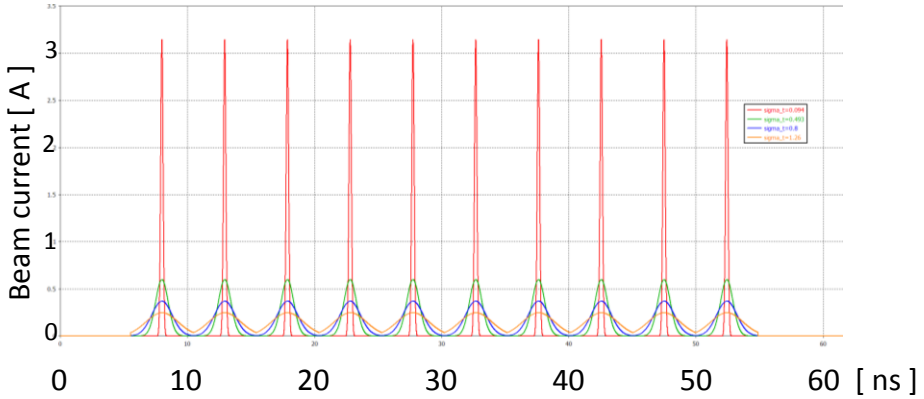
Simulation conditions:

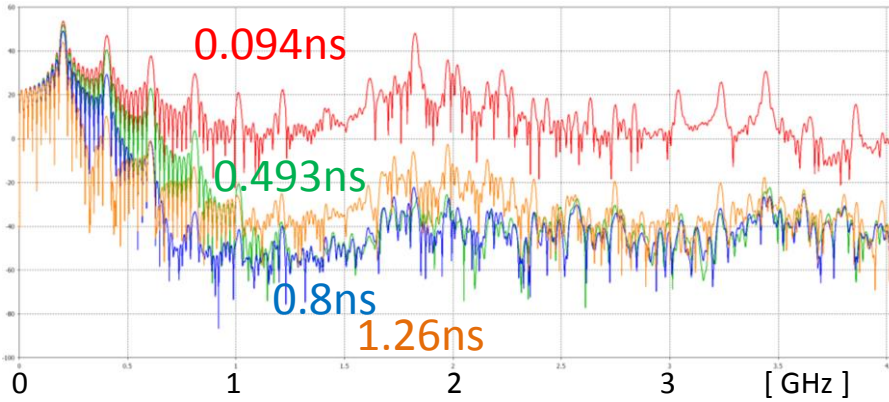
- E_{kin} = 50 MeV
- F_{RF} = 202.5 MHz
- I_{linac} = 150mA
- 10 Gaussian bunches, 5mm off-centered
- Mesh cells: ~ 6.5 M
- *Variables = σ_t and beam size*

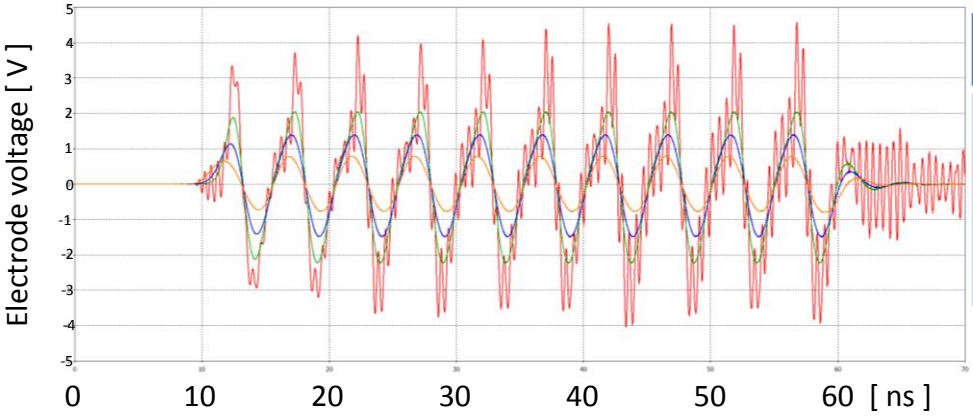




Can we trust the Shorted Stripline?







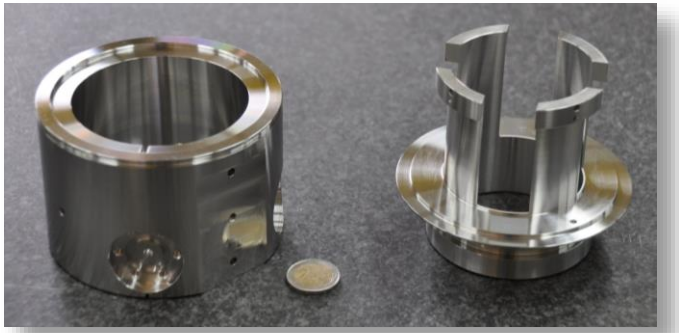
	σ_t [ns]	0.094	0.493	0.8	1.26
S [mm]	60mm beam size	74.399	74.404	74.404	74.406
	30mm beam size	74.396	74.398	74.398	74.399

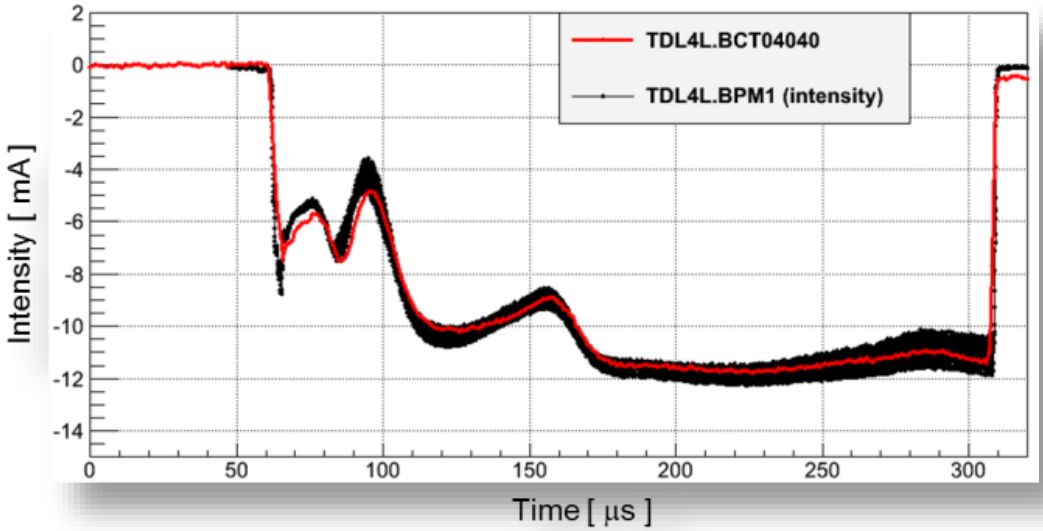
Beam position is not affected by the

- longitudinal beam bunching
- tranverse beam size

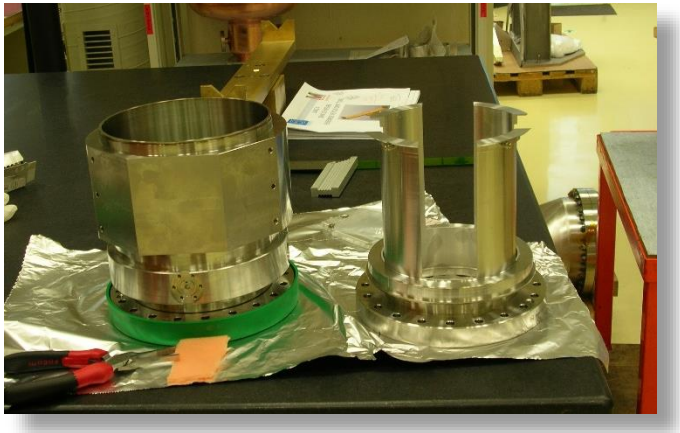
Can we trust the Shorted Stripline?

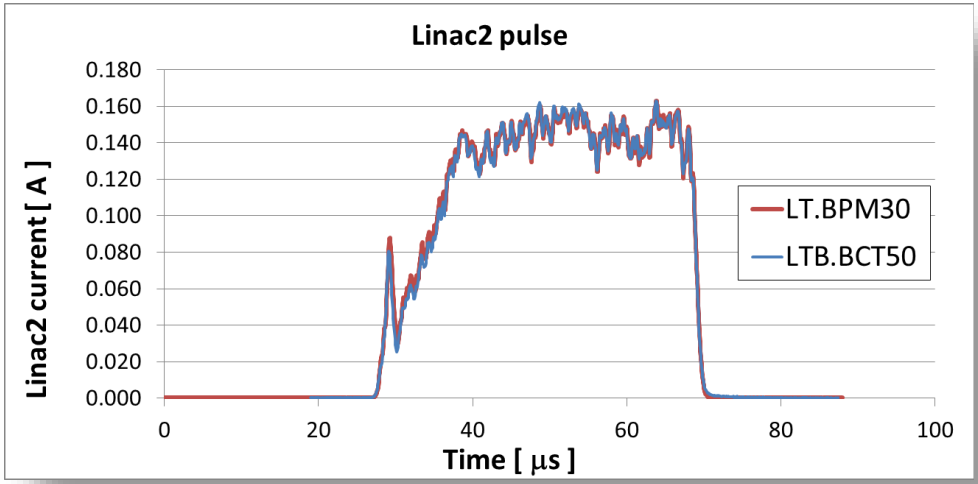
Beam aperture: 67mm, 3MeV H- beams





Beam aperture: 140mm, 50MeV p beams

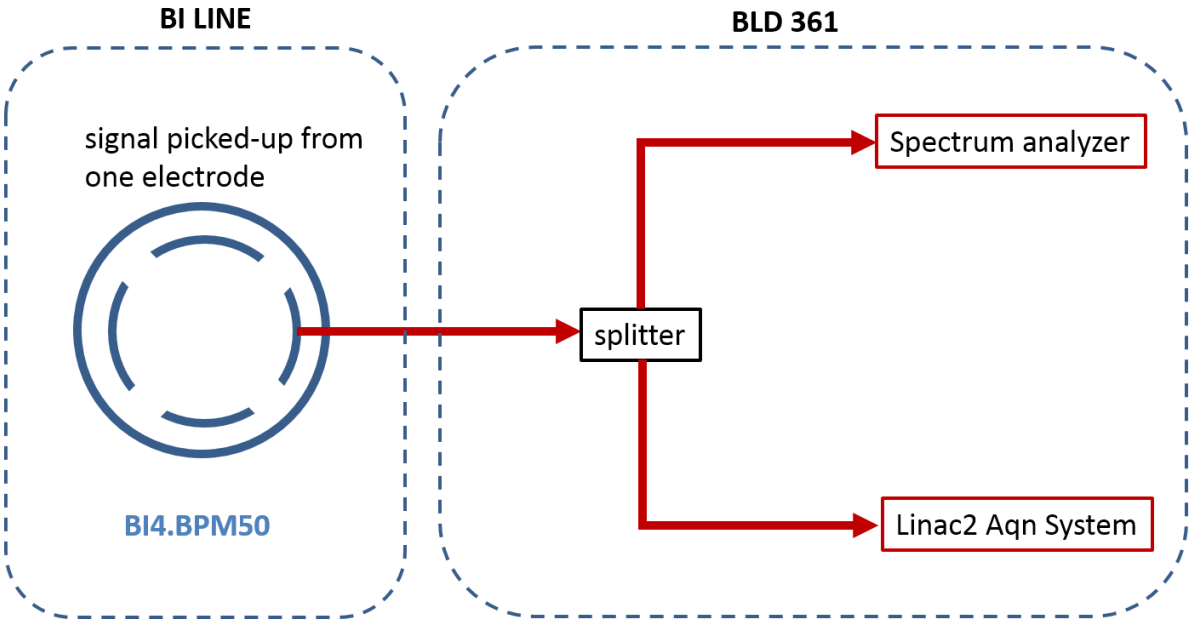




Can we trust the acq. chain ?

- Algorithm
  - Cross check I/Q demodulation with Hilbert transform and RMS processing
  - Amplitude difference between algorithms is within a few per mille.

- Down-mixing board
  - Process data from fast digitizing oscilloscope: same results as with analogue board
  - Cross check with a spectrum analyser



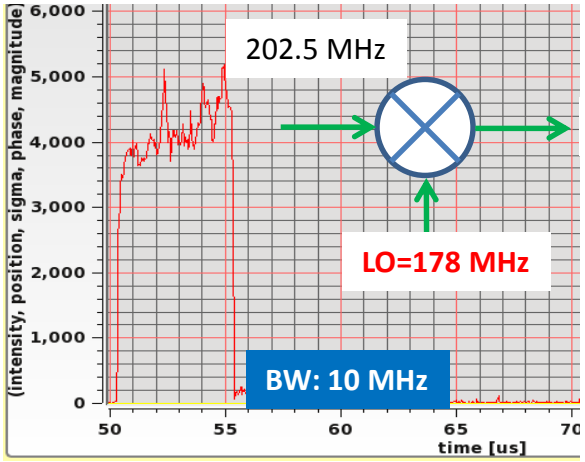
Can we trust the acq. Chain ?

Spectrum analyzer

Linear scale, span 0Hz, trigger

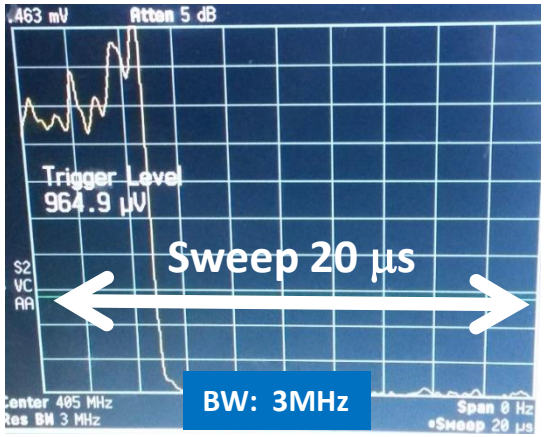
Linac2 aqn chain

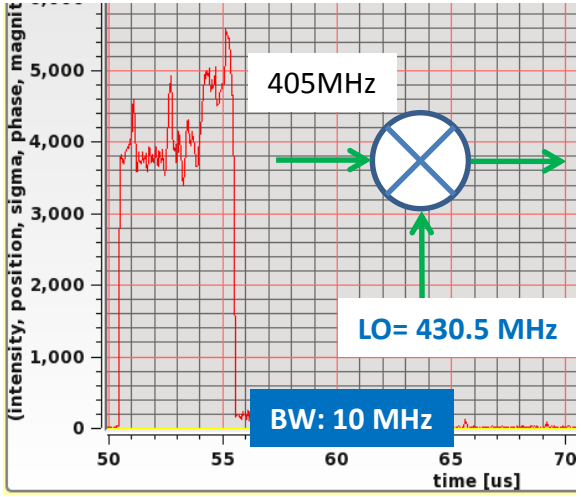
1st harmonic
202.5 MHz



25.5 MHz

2nd harmonic
405 MHz





25.5 MHz

Pick-up sensitivity is frequency-dependent:

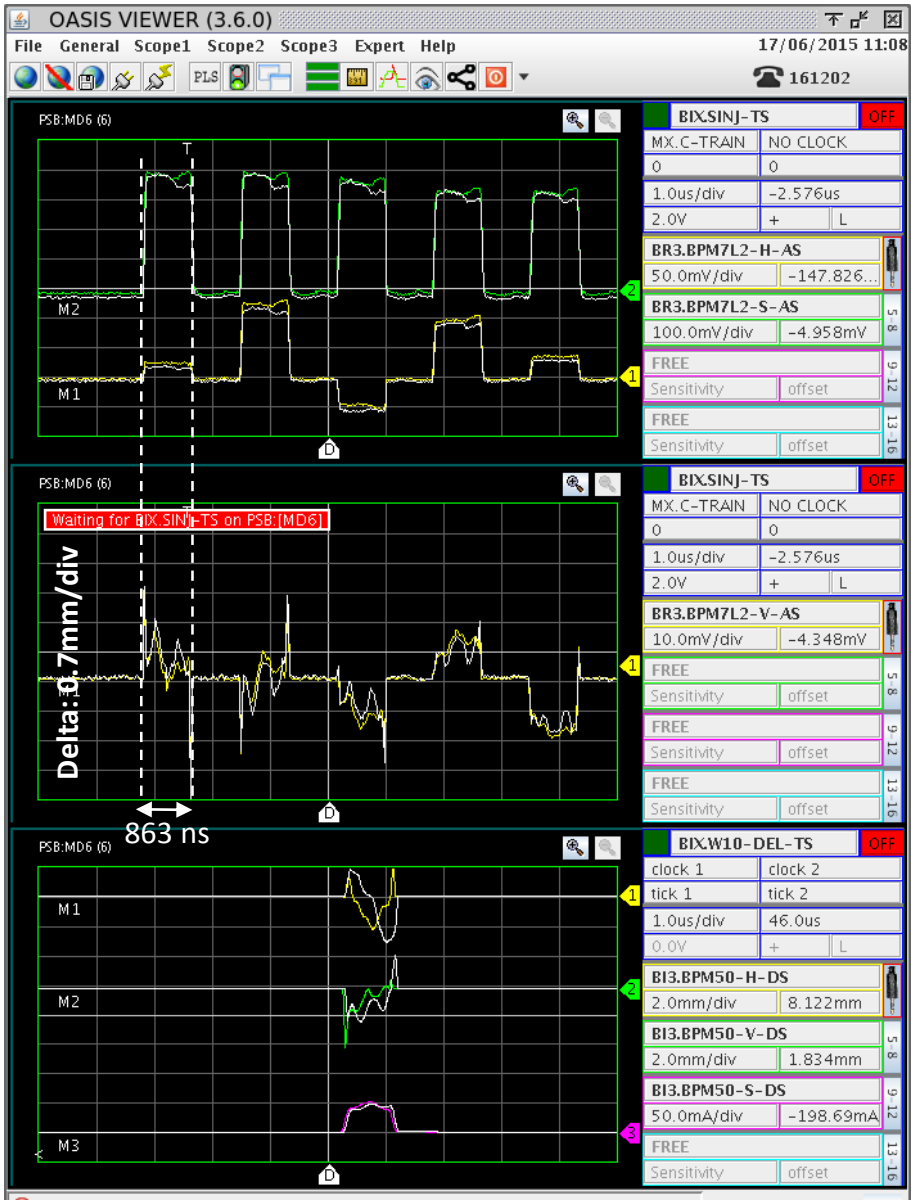
74.4mm @ h1

56.2mm @ h2

Beam positions are the same for both harmonics.

Comparison with the “half-turn PU”

- Section 7L2
- Capacitive PU
- S = 27mm (corrected for the gain ratio)
- Head amp. provides Σ and Δ signals
- Acquisition on Oasis



Position fluctuations in the vertical plane are also seen by capacitive PUs !

Investigation on possible causes

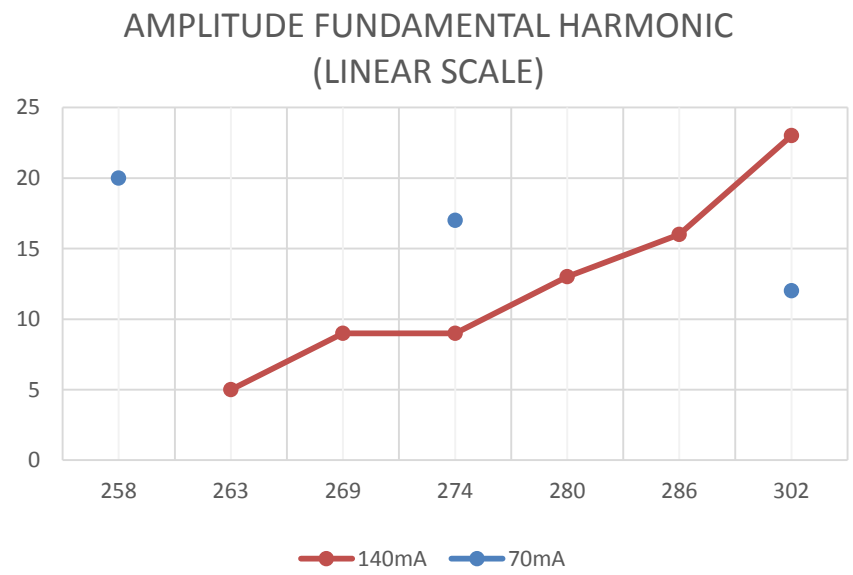
- EMIs: 50Hz, pulsing elements…
  - S/N ratio : 60dB
  - Noise background before and after beam aqc. ~ 2 mVpp, flat
  - Position variations are < 200 ns

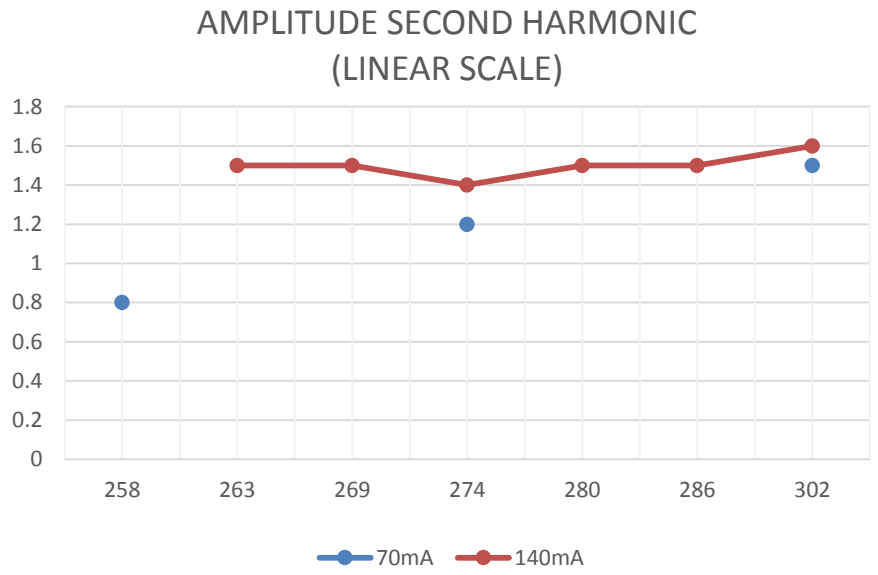
- Vertical distribution scheme:
  - Dedicated MD: All vertival pulsed elements BVTs, DIS, SMV were set “disable”. Only ring 3 travelling straight
  - Beam positions from striplines PUs remainded unstable
  - Beam positions from scintillating screens seems stable

Investigation on possible causes: Debuncher cavity

BI3.BPM50 HARMONICS (MD 27/05/2015)

- 6 DEBUNCHER PHASES WITH THE NOMINAL CURRENT (140mA)
- 3 DEBUNCHER PHASES WITH HALF CURRENT (70mA)

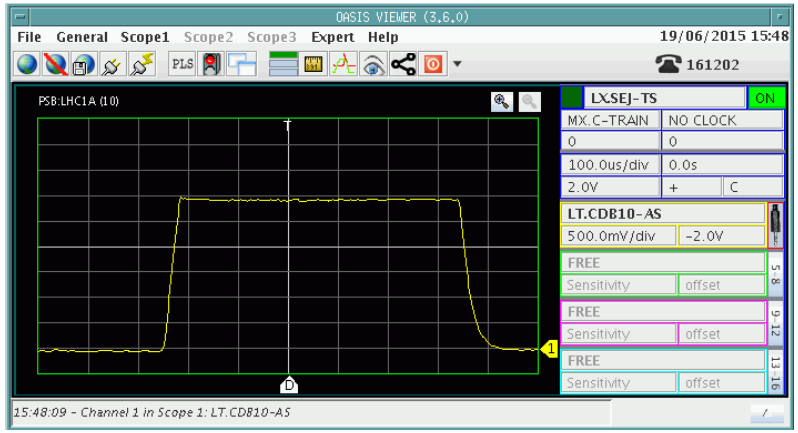




- STRONG RELATION BETWEEN PHASE AND FUNDAMENTAL AMPLITUDE
- SECOND HARMONIC ALMOST CONSTANT
- Extrapolation for Linac4: Lower current 64 mA, higher energy 160 MeV $\Rightarrow$ lower space charge
- Amplitude dependency with debuncher phase is reduced ? To be confirmed.

Investigation on possible causes: Debuncher cavity

Debuncher gap voltage along the pulse is pretty flat, phase value 274.4°



Courtesy R. Wegner

BI.BPM30, and Bix.BPM40/50 debuncher phase (MD 17/06/2015)

Courtesy: GP Di Giovanni

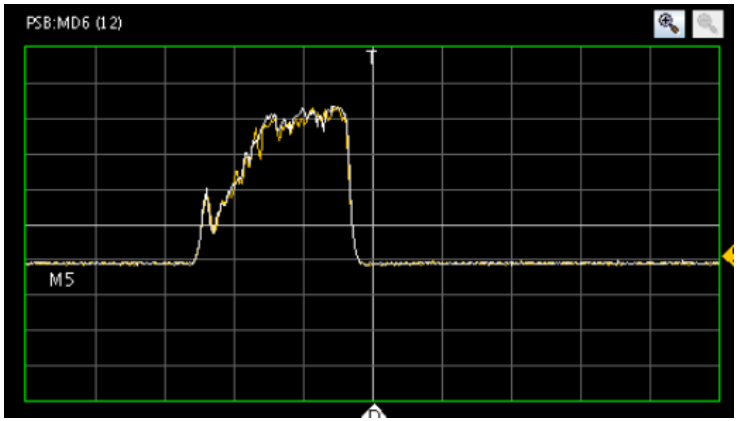
"We noticed that the positions recorded in the BPMs became more and more stable as we increased the debuncher phase (from 274.4 to 285.6 to 302.4 degrees)."

"…This is clearly not a Linac2 issue, as it seems to point out that the BPMs are sensitive to the bunching of the beam." Misleading statement on the beam bunching: a change of debuncher phase means the bunches are either accelerated or decelerated.

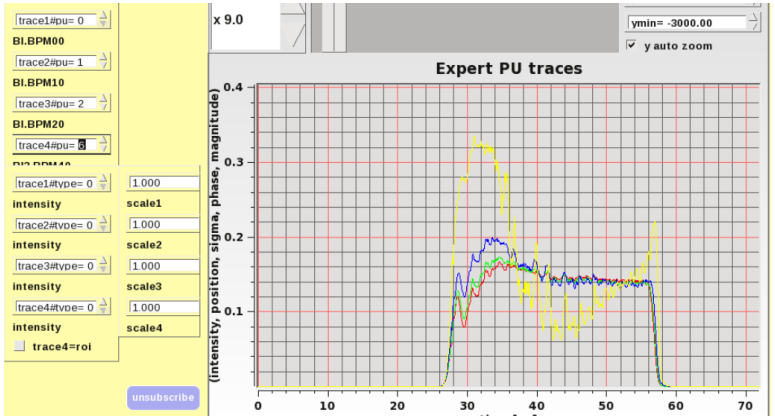
Investigation on possible causes: Debuncher cavity

INTENSITY TRACES COMPARISON @ 140mA

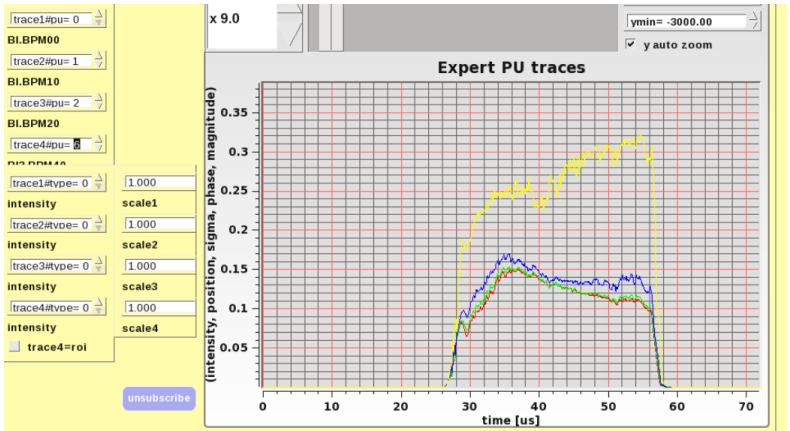
BI3.BCT2 (@ALL PHASES)



BPMs SUM SIGNAL (@274°)



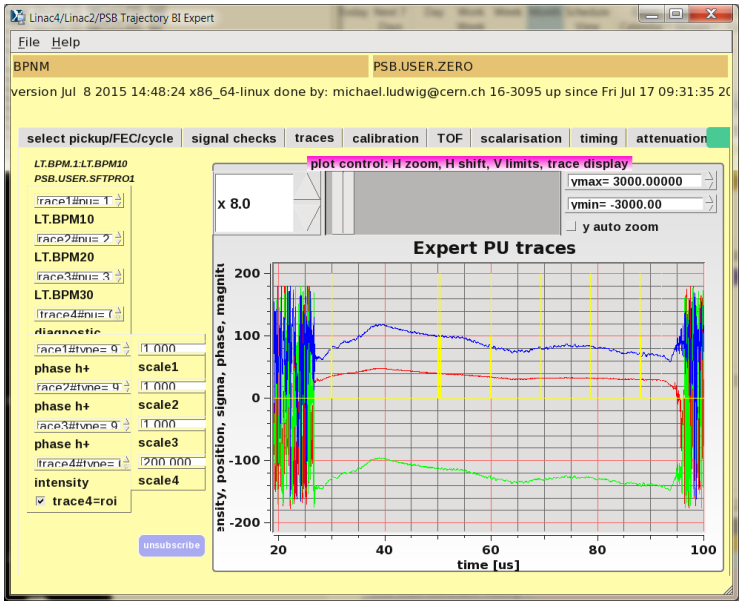
BPMs SUM SIGNAL (@302°)



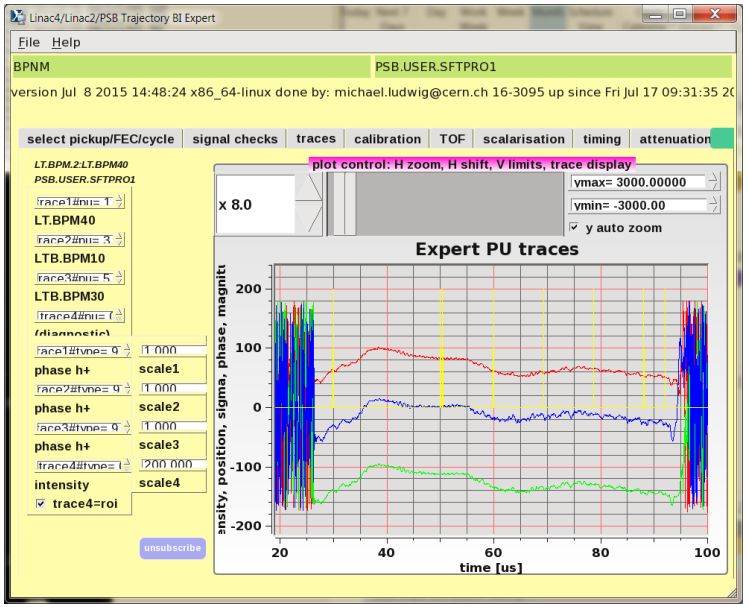
Beam phase

Nominal debuncher phase @ 274 deg.

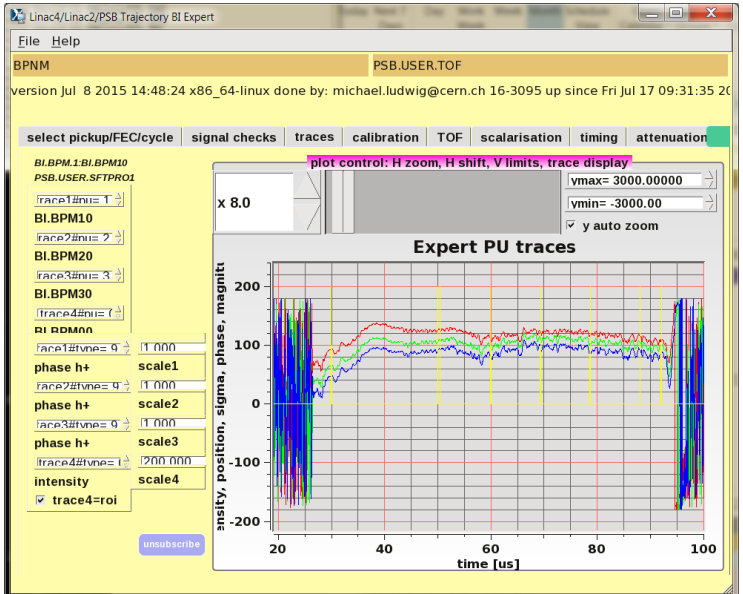
LT line



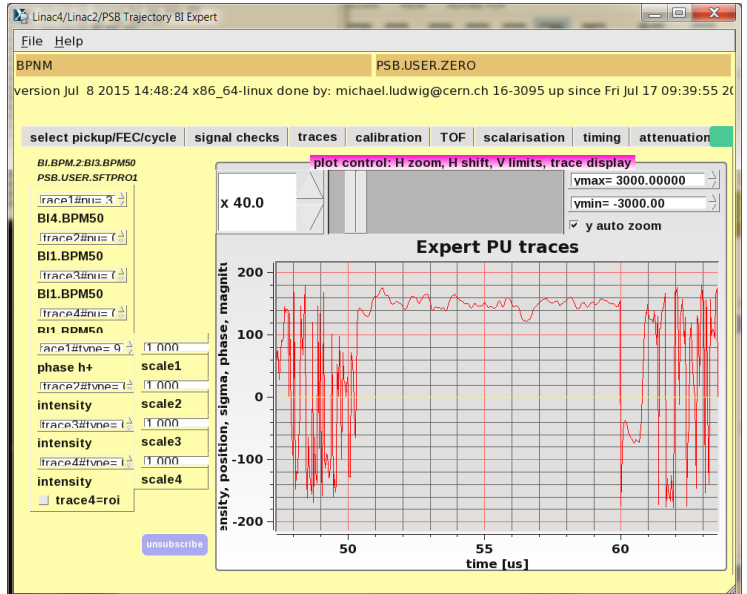
LT + LTB lines



BI lines



BI.3.BPM50



Summary

- Vertical transverse instabilities exist, and have never been measured before.
- Stripline BPM data consistent with
  - Spectrum analyzer
  - FBCTs, with some boundary conditions
  - Half Turn (electrostatic) BPM
- Yes, we can trust the new beam trajectory system
- MD sessions have ruled out
  - Vertical distribution scheme
  - EMIs
- Transverse instabilities
  - Are present from L2 and amplified along the transfer line
  - Dependencies: debuncher phase setting and L2 intensity
- Forthcoming actions
  - ABP's simulations on resonances, instabilities and machine impedance
  - Perform a full Linac2 intensity scan
  - Understand the debuncher phase dependency
  - Simulate the Linac4 debuncher action on the beam

Acknowledgement

- PSB supervisors & OP crew

- ABP: R. Wegner, R. Scrivens, J.B. Lallement

- BI: S. Burger, E. Bravin