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Vertical Instability in the Rapid Cycling Synchrotron (RCS) of IPNS of ANL

presented by Shaoheng Wang

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UChicago Argonne LLC

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Coworkers

J. C. Dooling
K.C. Harkay
D. Horan
R.L. Kustom
G.E. McMichael
M.E. Middendorf
A. Nassiri
...

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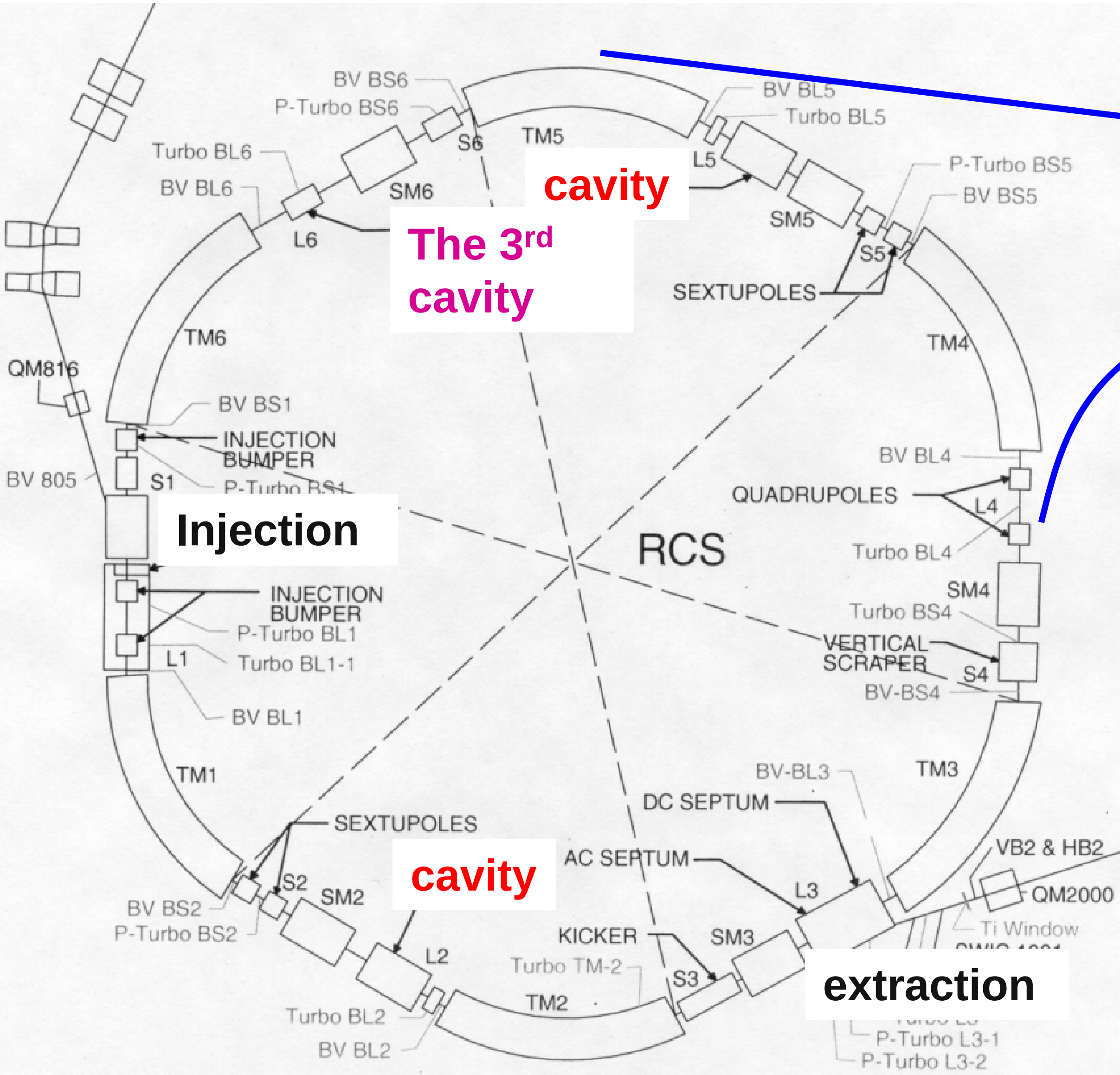
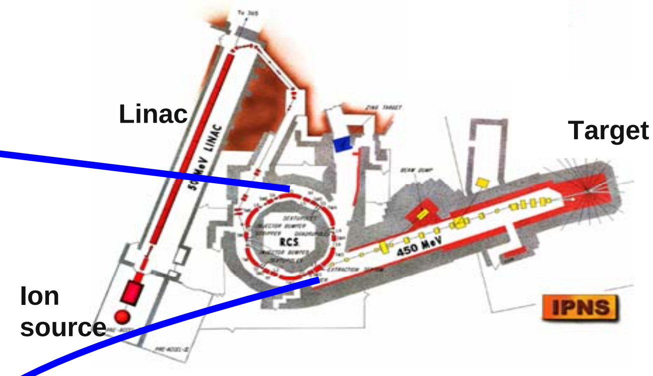
The RCS: Rapid Cycling Synchrotron



Intense Pulsed Neutron Source



Circumference	42.95 m
Injection energy	50 MeV
extraction energy	450 MeV
Revolution frequency	2.21------ 5.14 MHz
tunes	x: 2.21 y: 2.31
Injected pulse length	75 us
Injected charge	3.6e12 H-
Repeat rate	30 Hz
Overall efficiency	88%

The operation of RCS

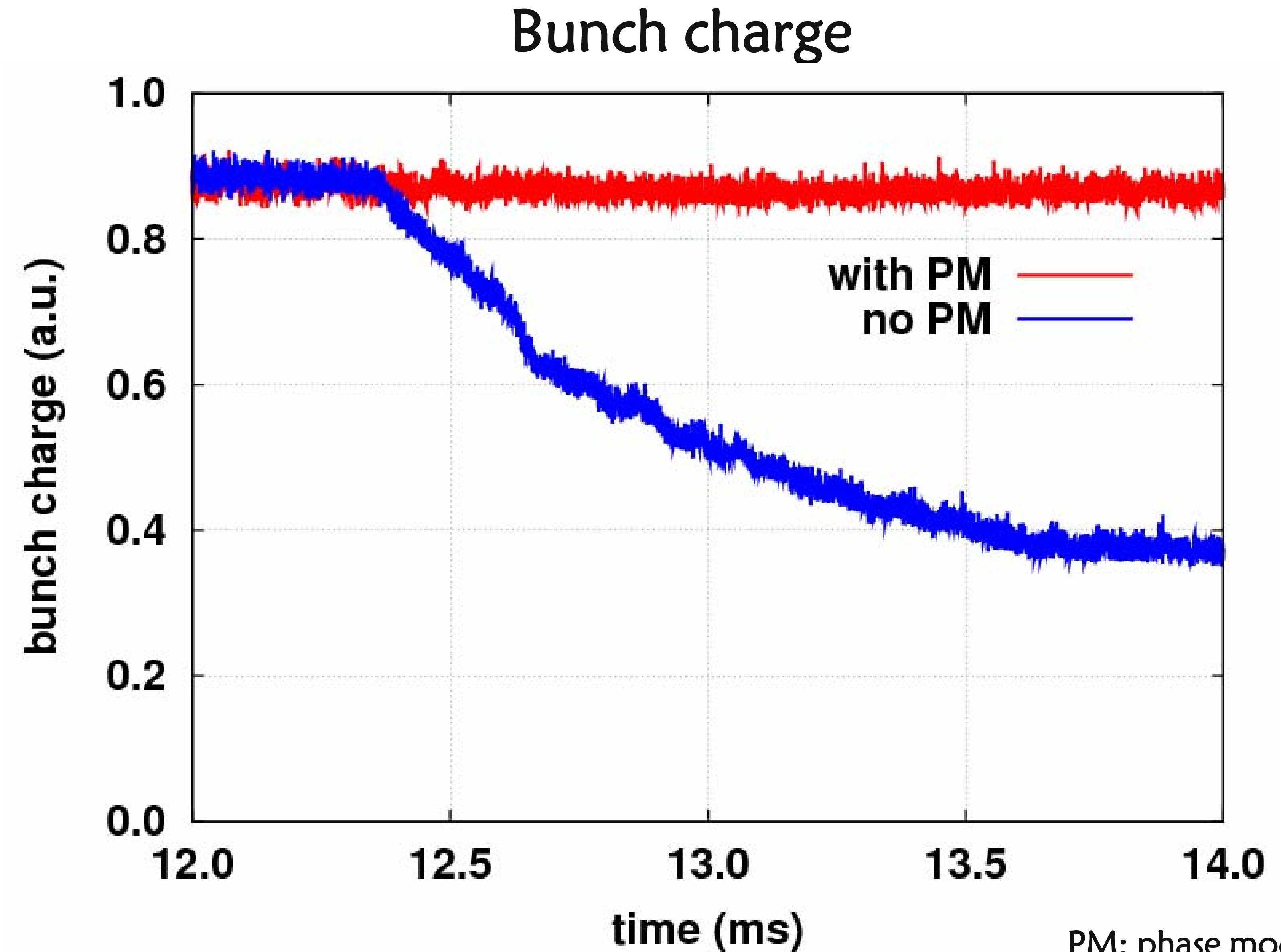
- In the early '80s, a head-tail instability was found. It was cured with the addition of sextupoles.

  I_{Ave}: 5 uA → 11 uA

- The next threshold appeared to be from a vertical instability. The cure was RF cavity phase modulation (PM) later in the cycle.

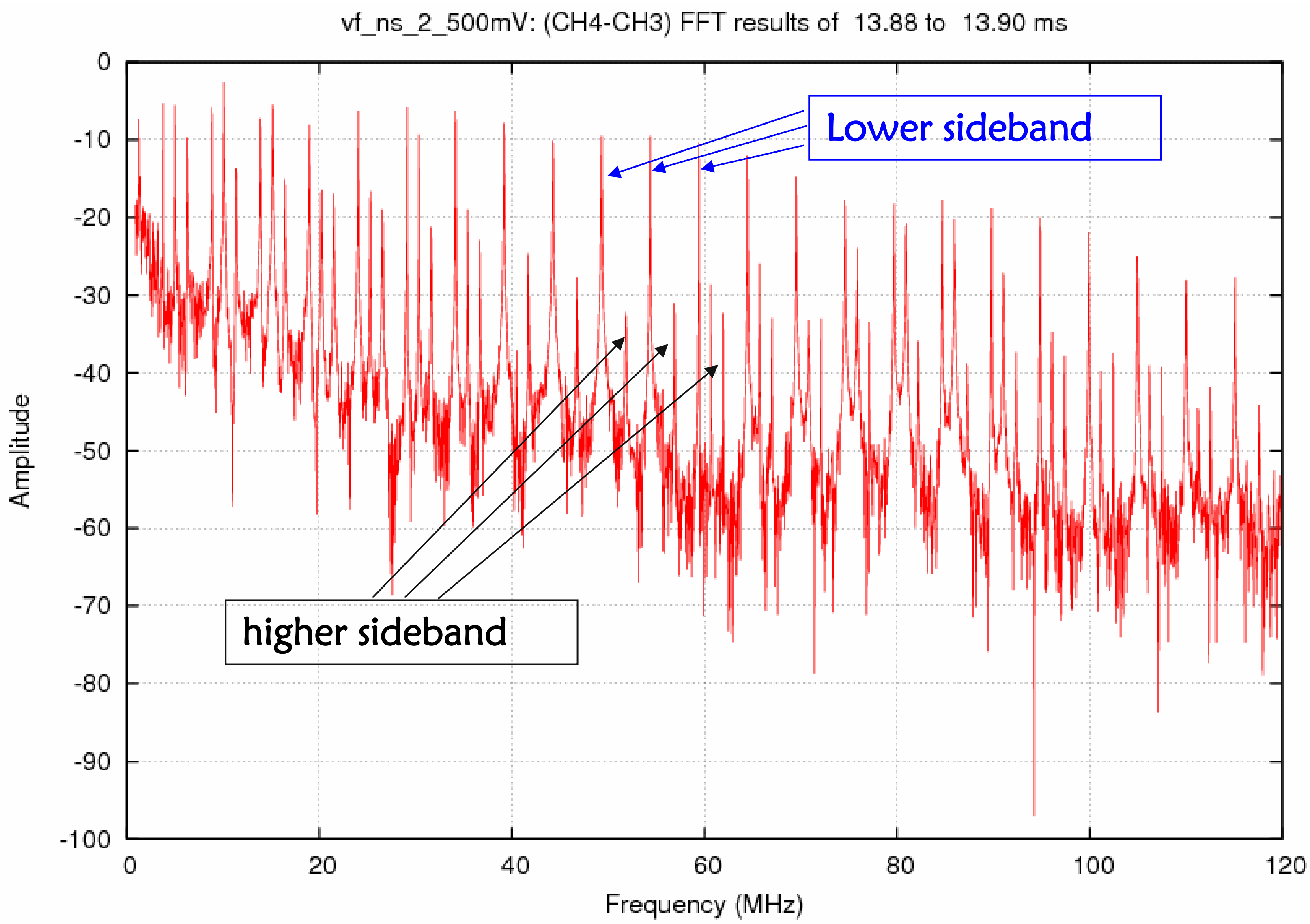
  I_{Ave}: 11 uA → 15 uA

Observation of beam loss with Resistive Wall Monitor



PM: phase modulation

Spectrum with instability

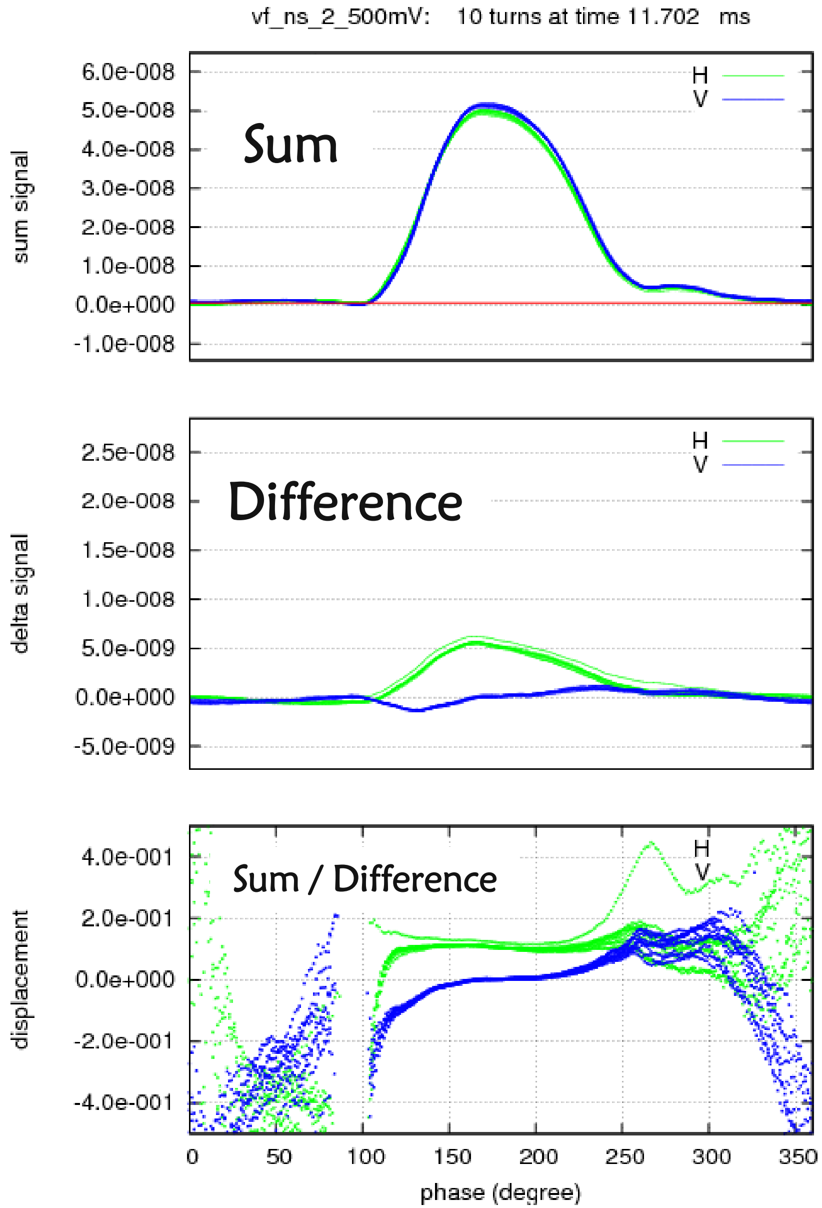


Conversion of beam position monitor signals

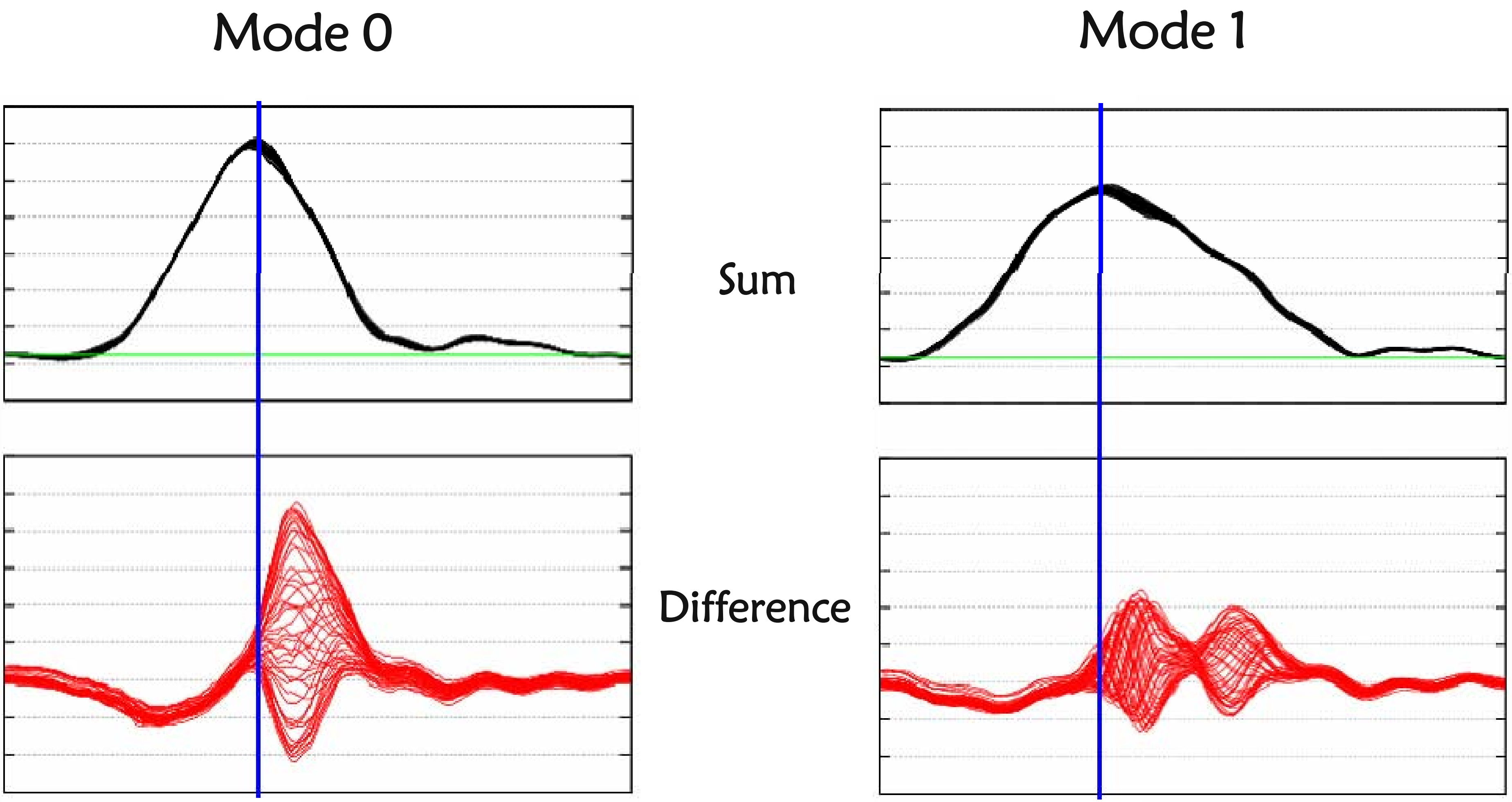
The revolution period shrinks as the bunch's energy steps up.

In order to view the centroid motion on a turn-by-turn basis,

- BPM signals are separated into single turns,
- then for each single turn, BPM signals are converted into rf phase basis,
- then single turn BPM signals can be overlaped.

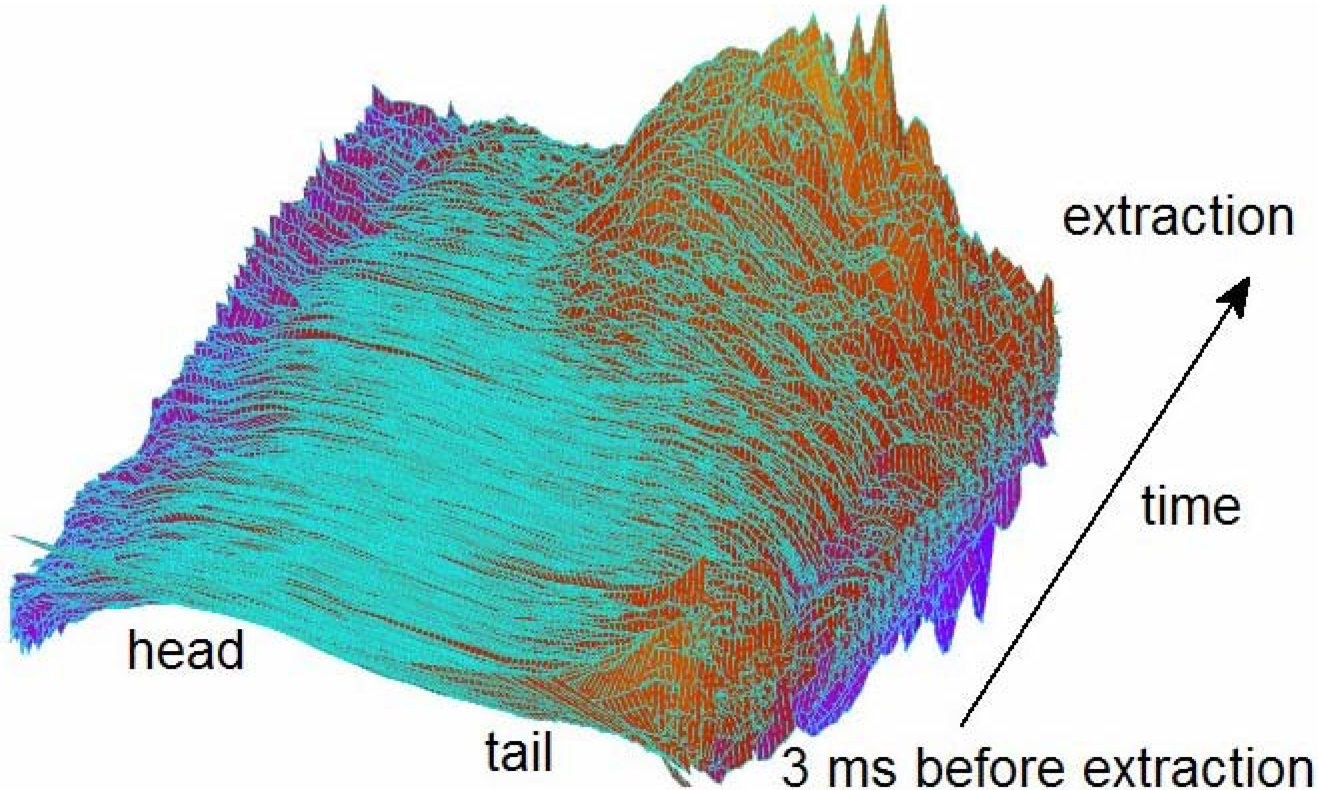


In the vertical plane, instabilities in tail only, 2 modes



50 turns BPM signals are shown

The oscillation starts from the tail

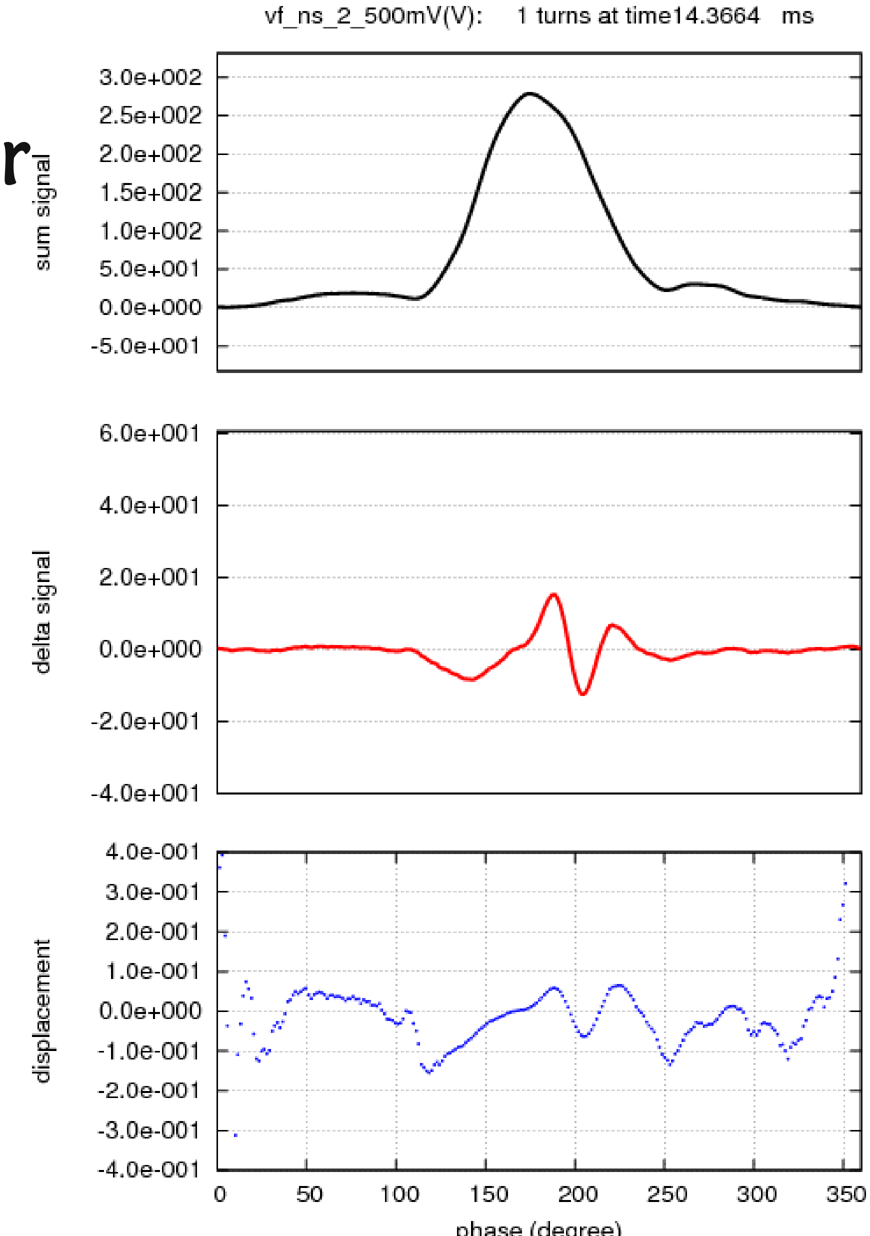


Vertical Centroid Oscillation in the Tail

Beam Position Monitor (BPM) sum signal

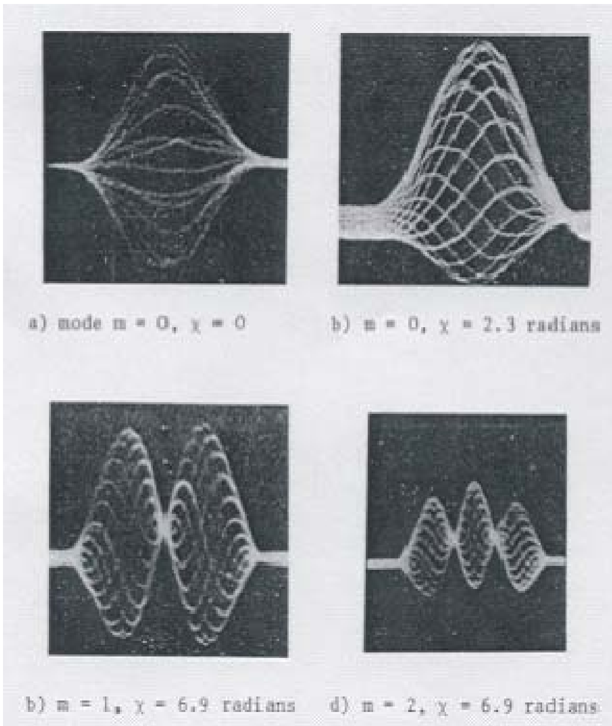
BPM difference signal

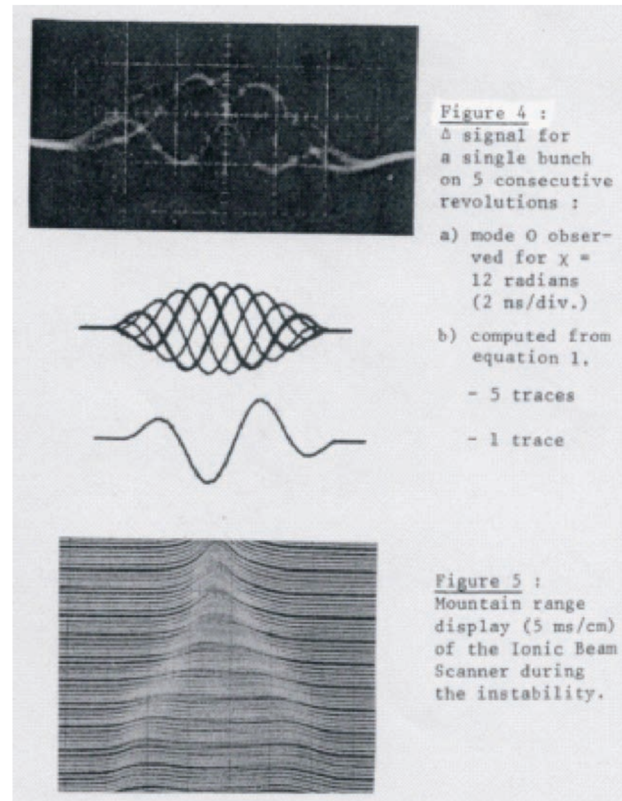
Sum/difference



Classical Head-Tail behavior (Garyete and Sacherer)

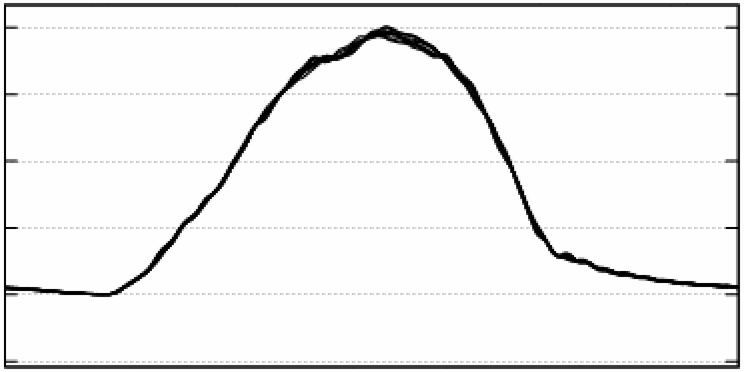
Classical head-tail



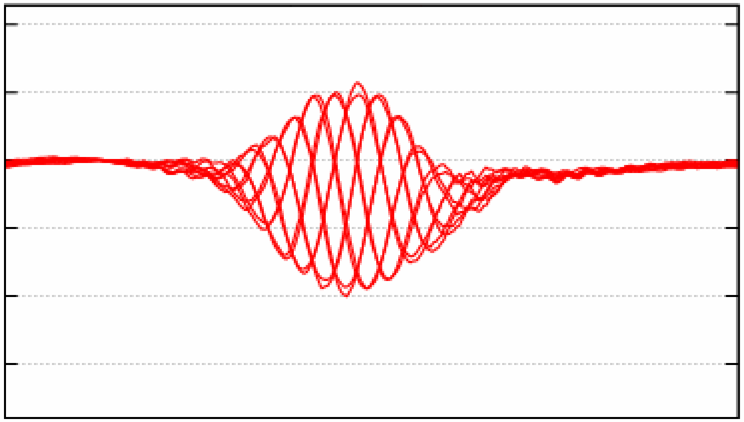


We turned off the sextupole to induce a head-tail at RCS

BPM sum signal



BPM difference signal

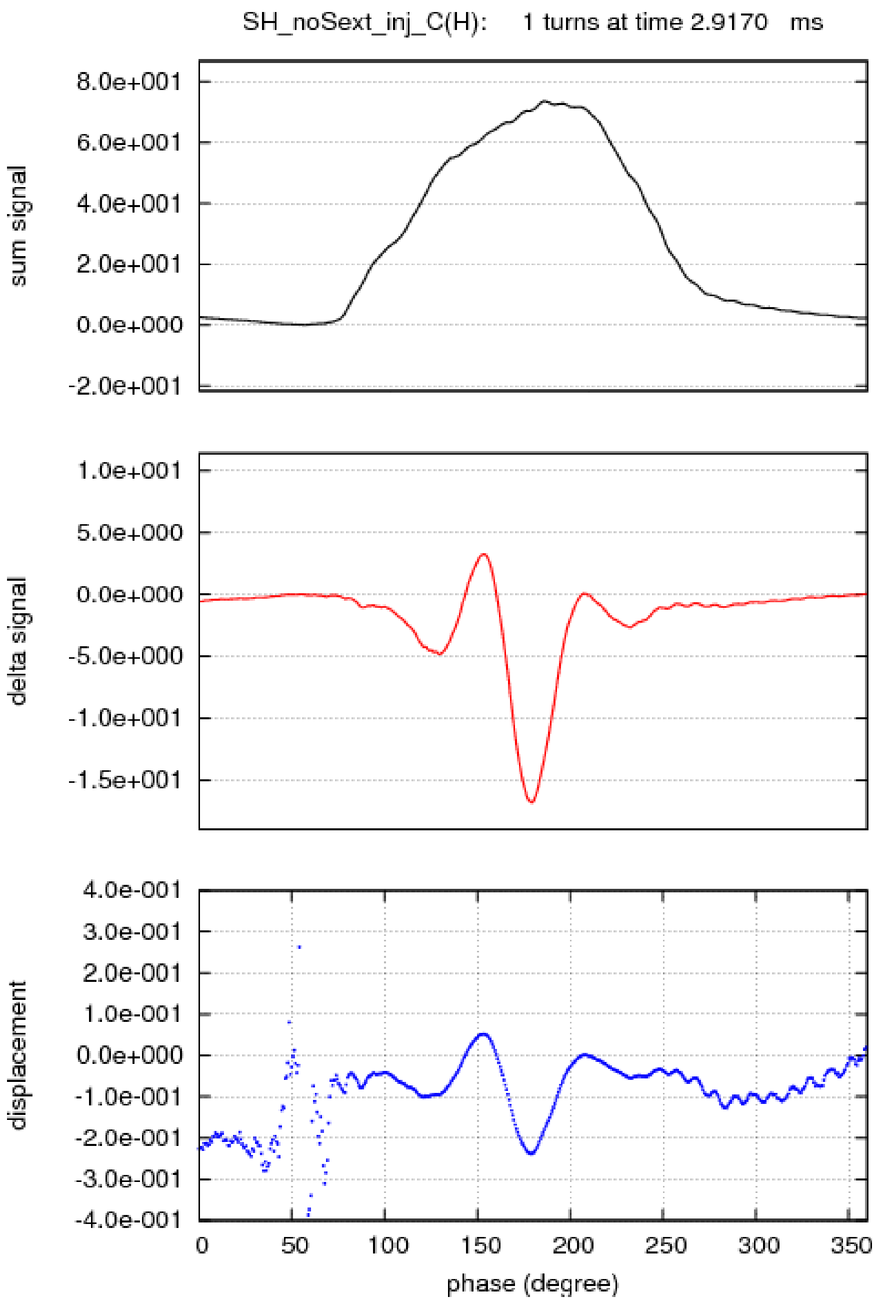


Classical head-tail at RCS

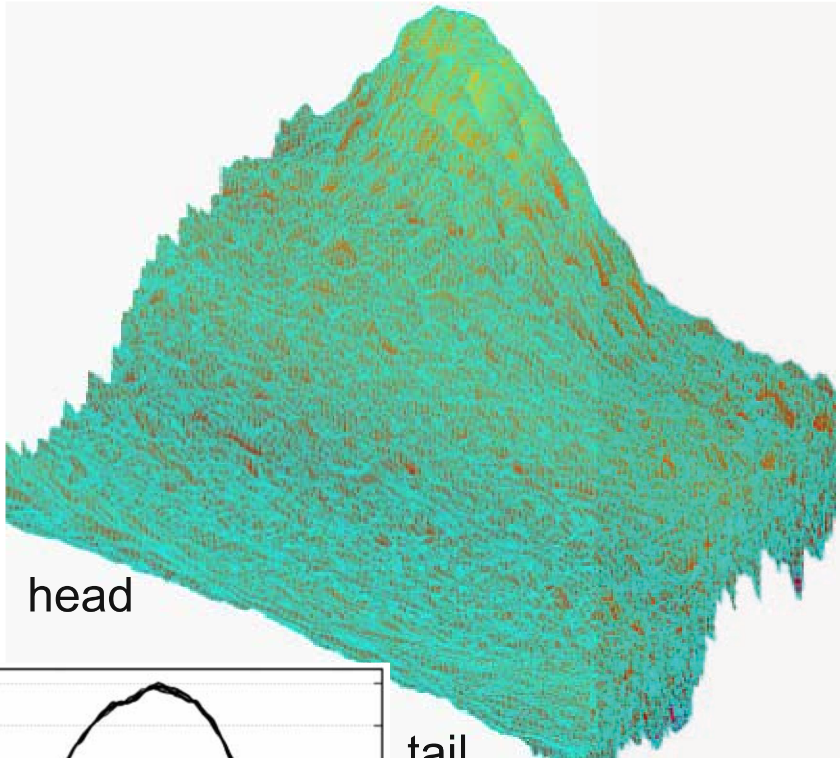
BPM sum signal

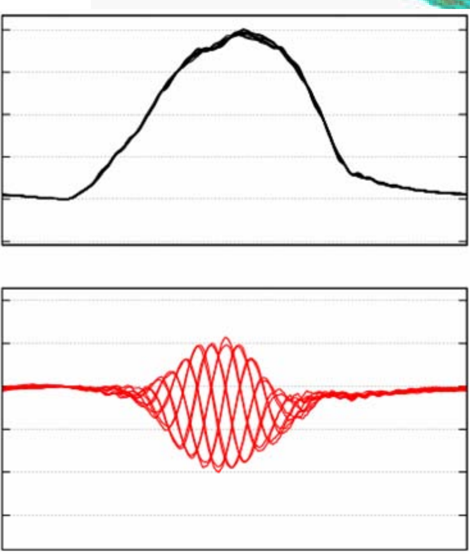
BPM difference signal

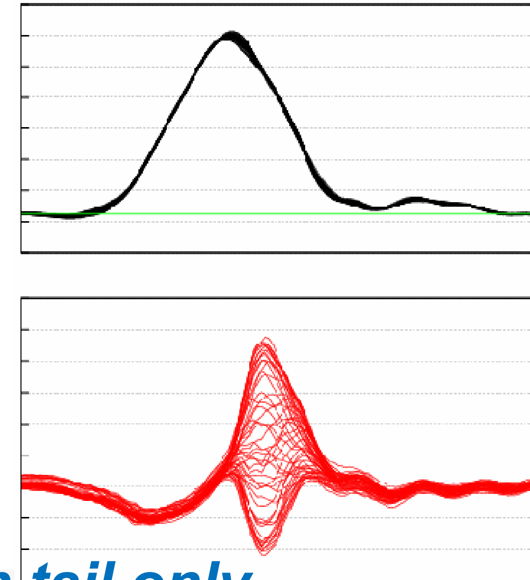
Sum/difference



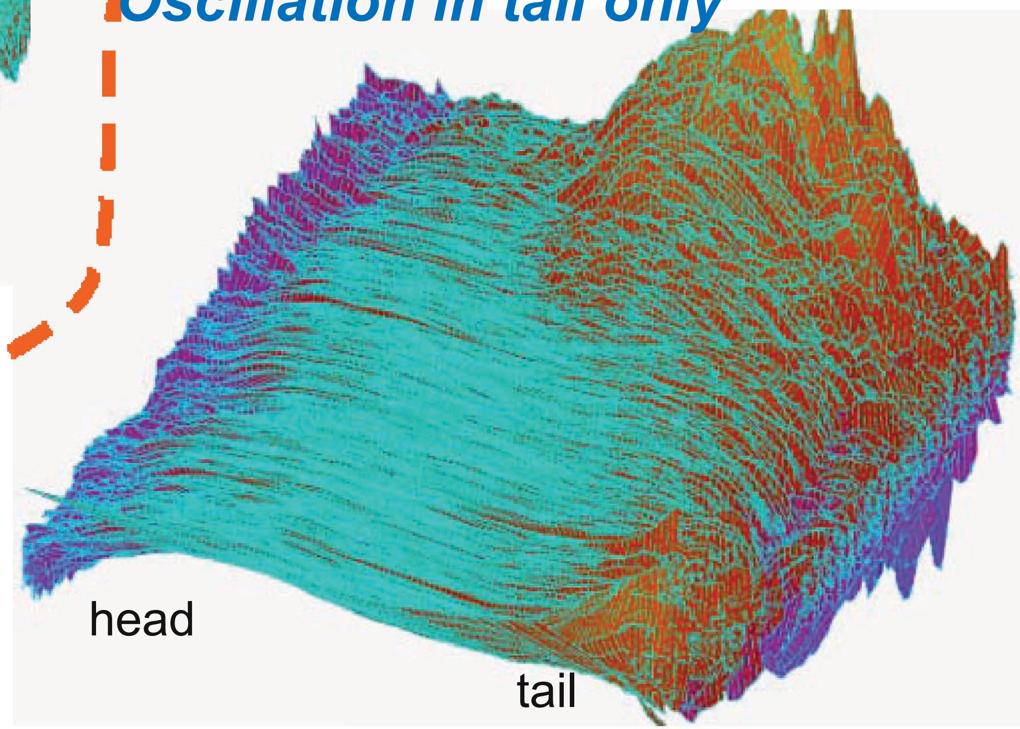
No sextupole, classical head-tail



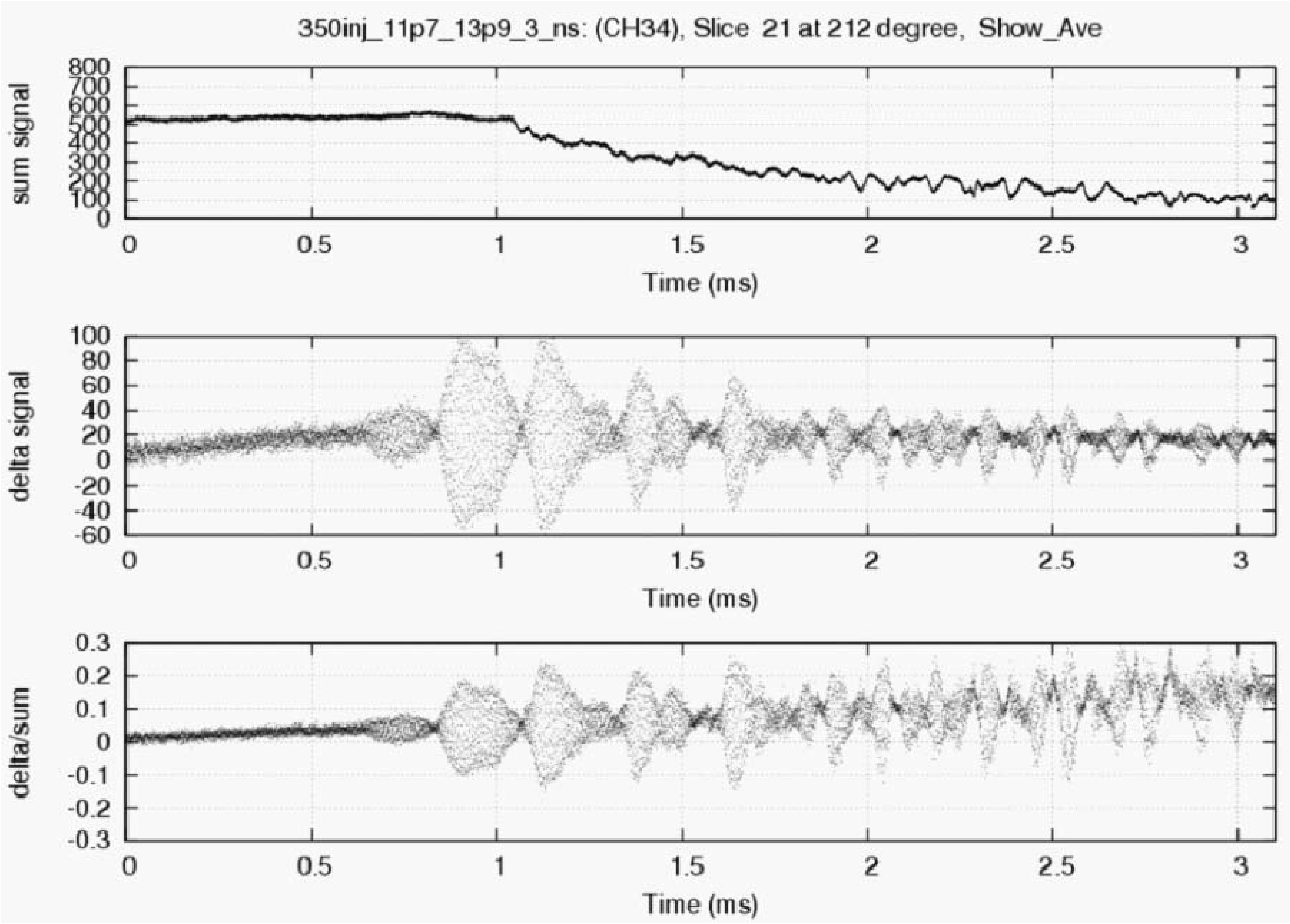




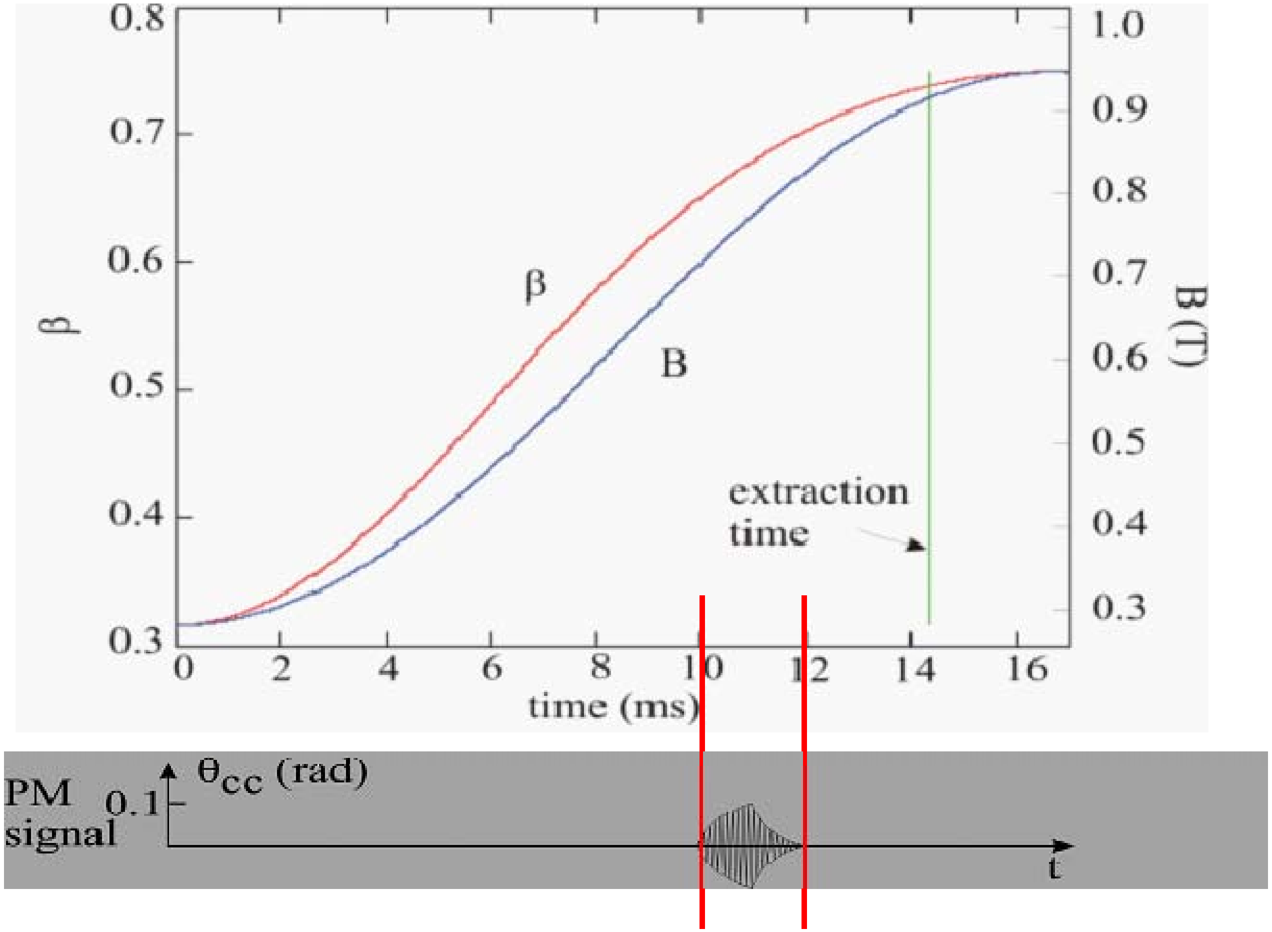
Oscillation in tail only



Tail oscillation starts before beam loss



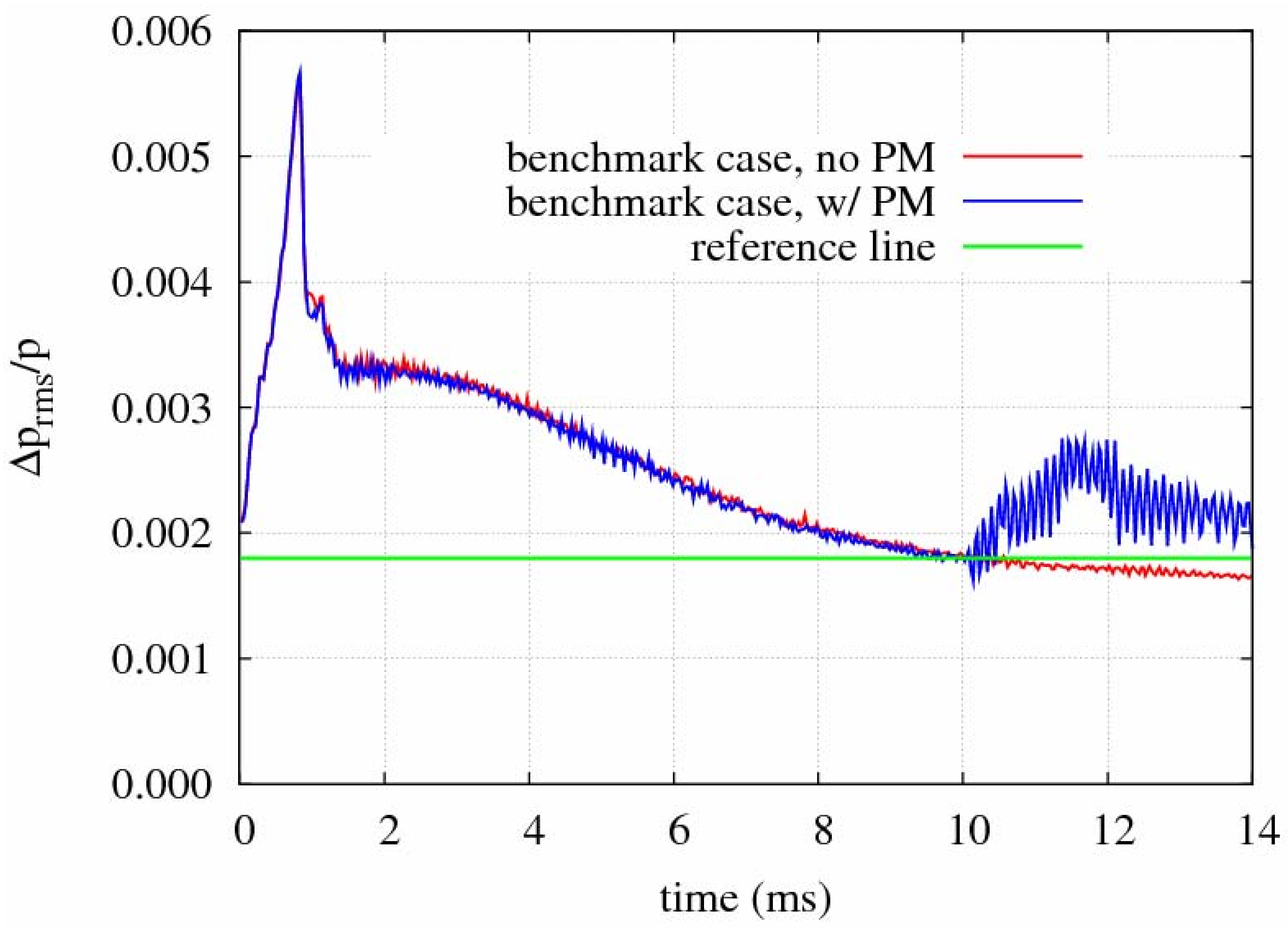
Phase Modulation (PM) at $2f_s$ in the RCS



PM frequency 10 kHz,

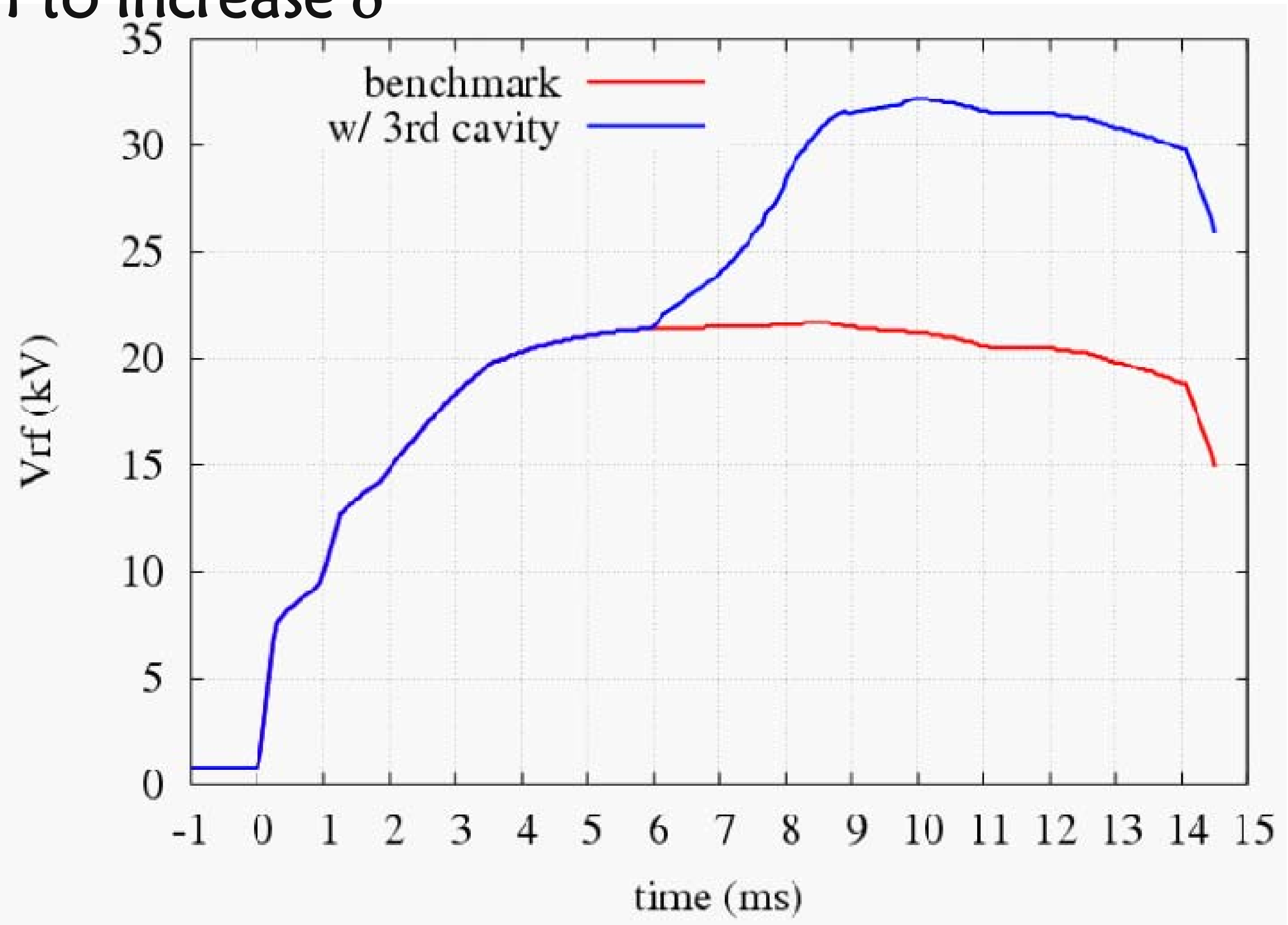
PM amplitude 4.3 degree

Simulation, PM increase Δp/p



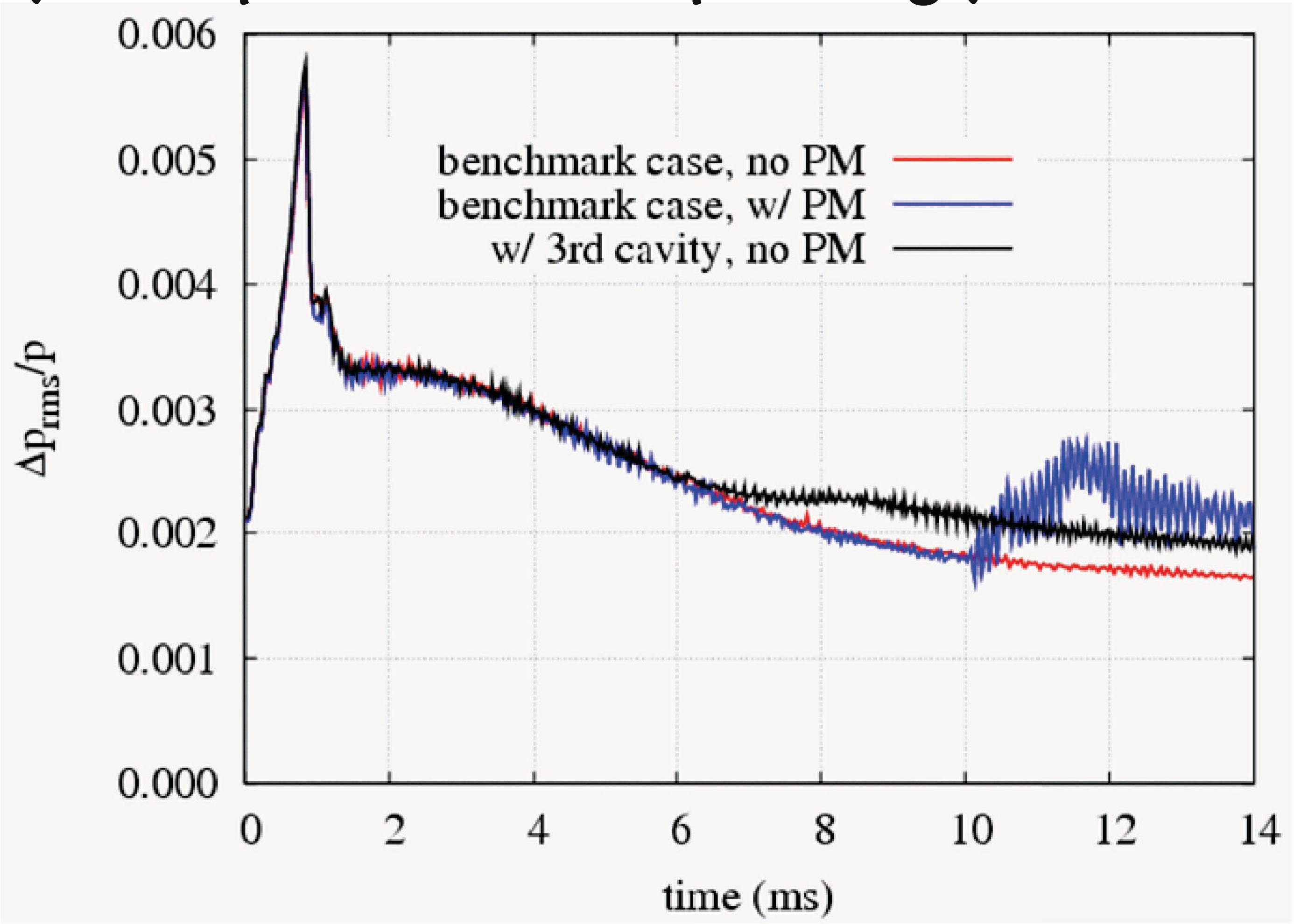
Utilize the 3rd cavity

We can utilize the 3[rd] cavity to increase the total Vrf to increase δ



Simulation, higher Vrf increase Δp/ p

We can see that the increase of Vrf in the later cycle improves δ correspondingly



Summary:

- The vertical instability is limited in the tail
- The characteristics of classical HT instability is different from our observation
- Investigating to use 3rd cavity to increase threshold
- Investigating electron cloud effects in RCS

The end

Thank you