Longitudinal to Transverse

Landau Damping

A. Burov, ICE mtg, Oct 24, 2012

Dispersion Equation

$$1 = \Delta\Omega \int \frac{F(J)\,dJ}{\omega - l\omega_s(0) - d\omega_s(J) + i0}$$

For HT mode l

Dimensionless units:

$$J \to \frac{Q_{s0} E_0}{|\eta|\,\omega_0 h_{\mathrm{rf}}^2} \;\Rightarrow\; J_{\mathrm{bkt}} = \frac{8}{\pi} \approx 2.54$$

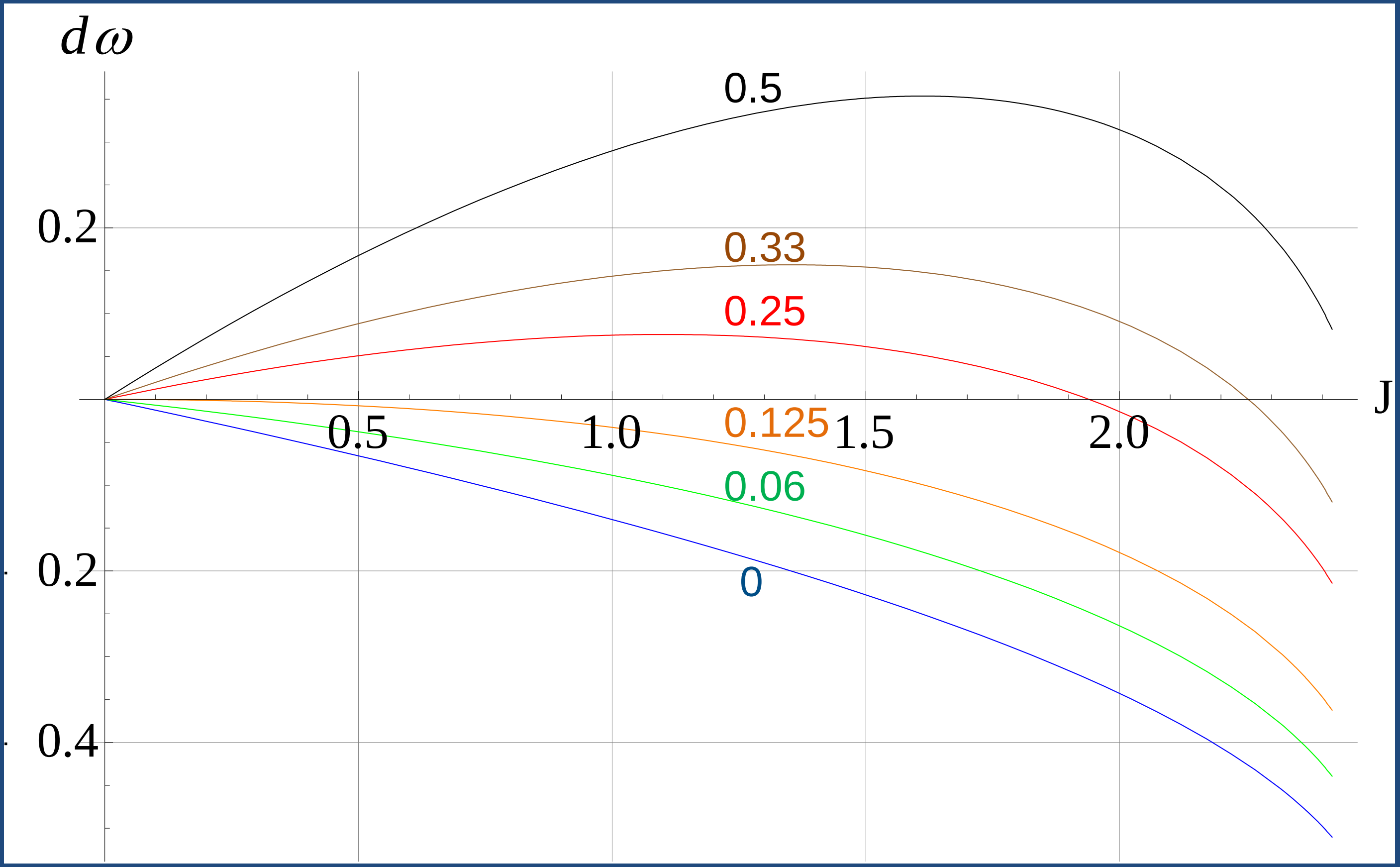
$$\Delta\Omega,\ \omega_s(J) \to \omega_{s0} \;\Rightarrow\; \omega_s \approx 1 - J/8 = 1 - J/(\pi J_{\mathrm{bkt}})$$

$$q'' = Q'' \frac{Q_{s0}}{\eta^2 h_{\mathrm{rf}}^2} \;\Rightarrow\; (Q'' = 7100) \leftrightarrow (q'' = 1/8).$$

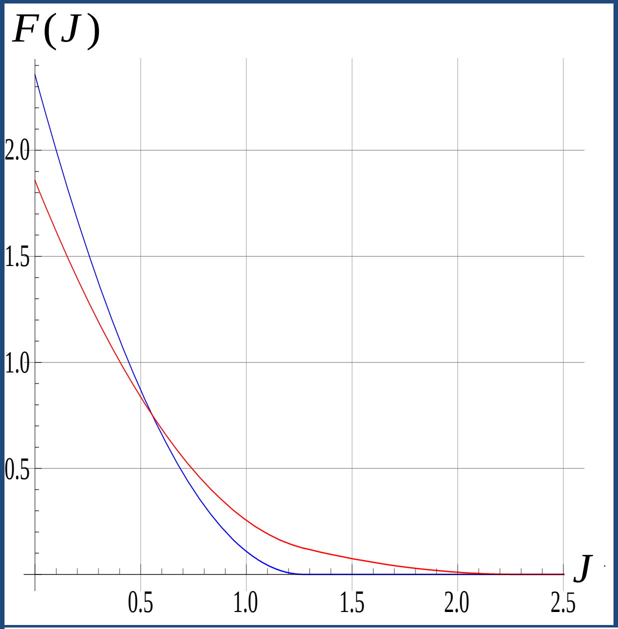
$$d\omega_s(J) = l(\omega_s - 1) + q''\omega_s J \approx J\left(q'' - l/8\right)$$

For the LHC + oct polarity, Qx”=8000/100A, Qy”=-3300/100A

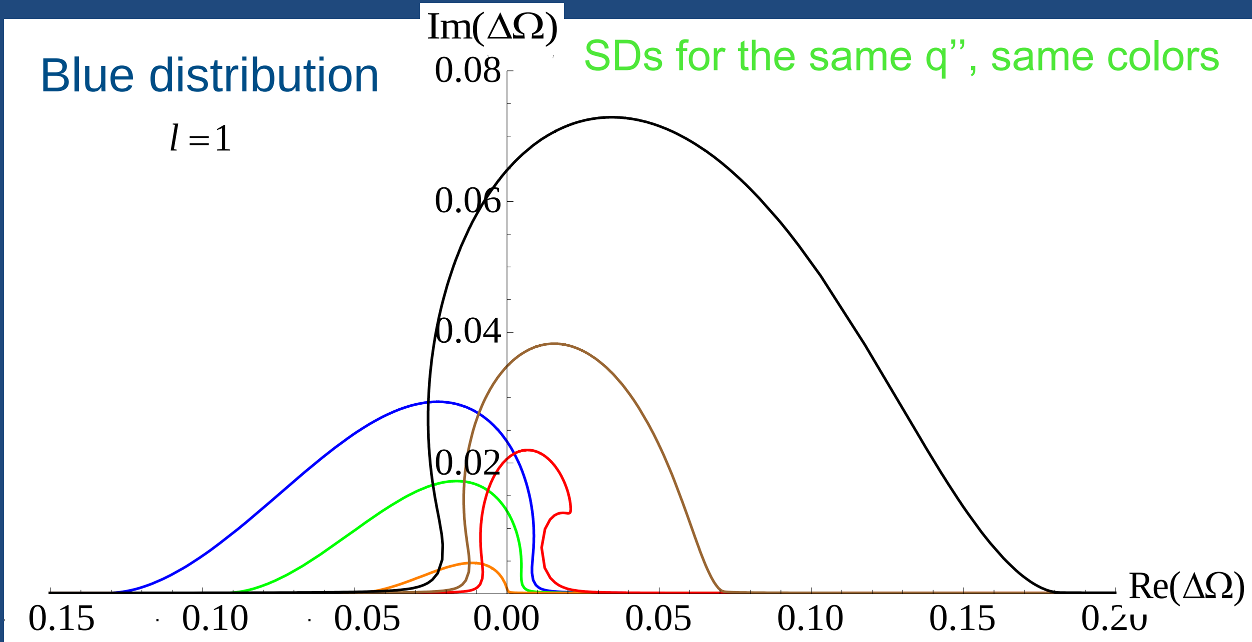
Incoherent spectrum

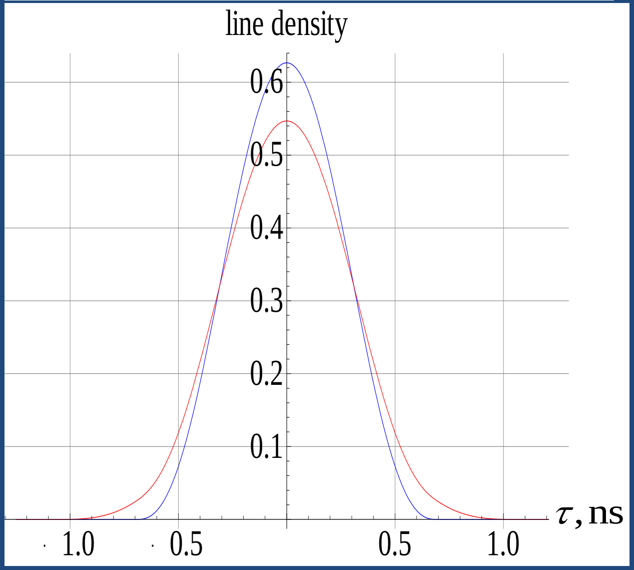


Incoherent spectrum for HT mode l=1 and shown q''=0, 0.06,…, 0.5



LT-Stability Diagrams



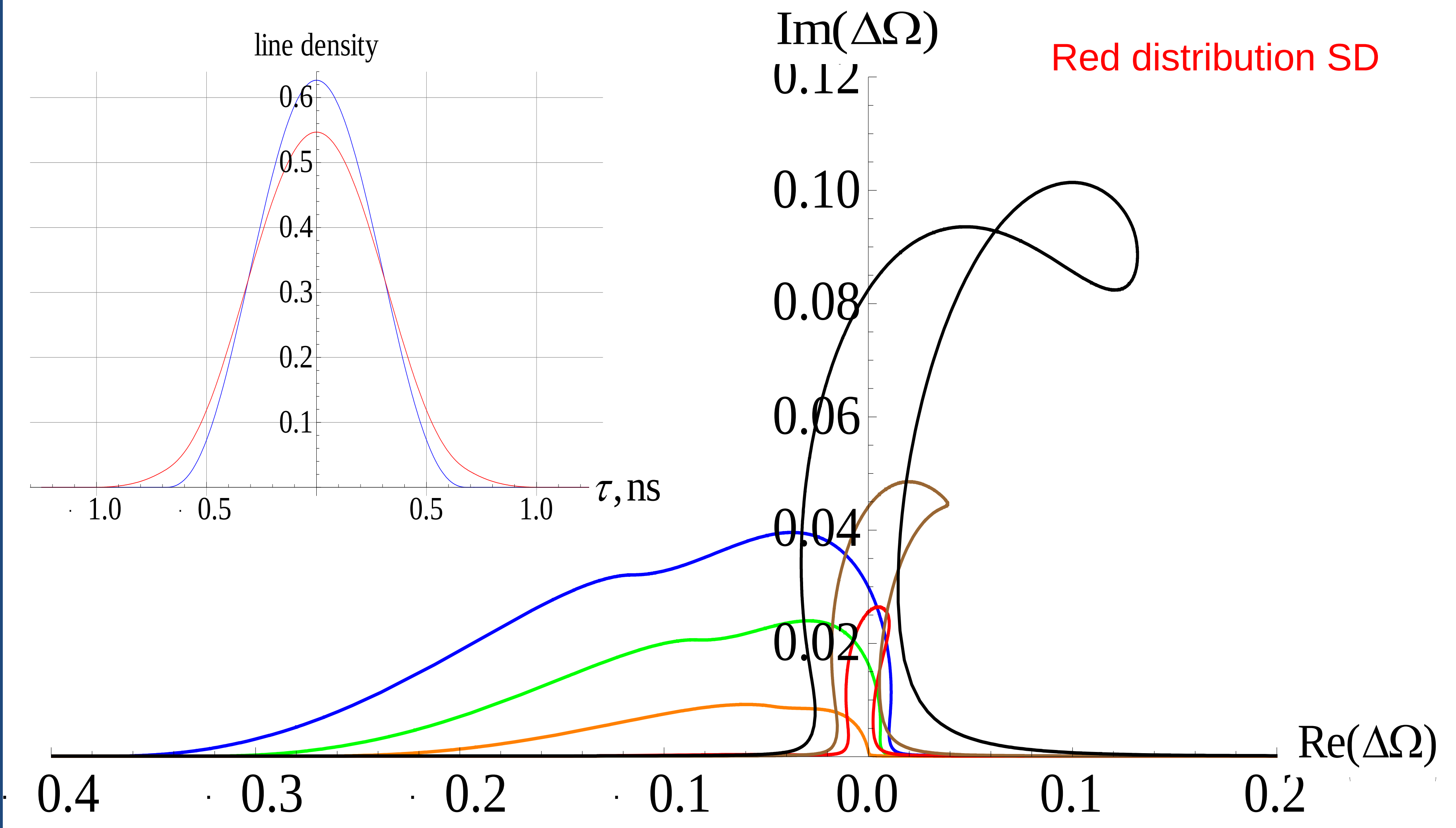


Note the orange SD = the collapse.

Increasing octupoles changes Q'' and thus can result in the collapse.

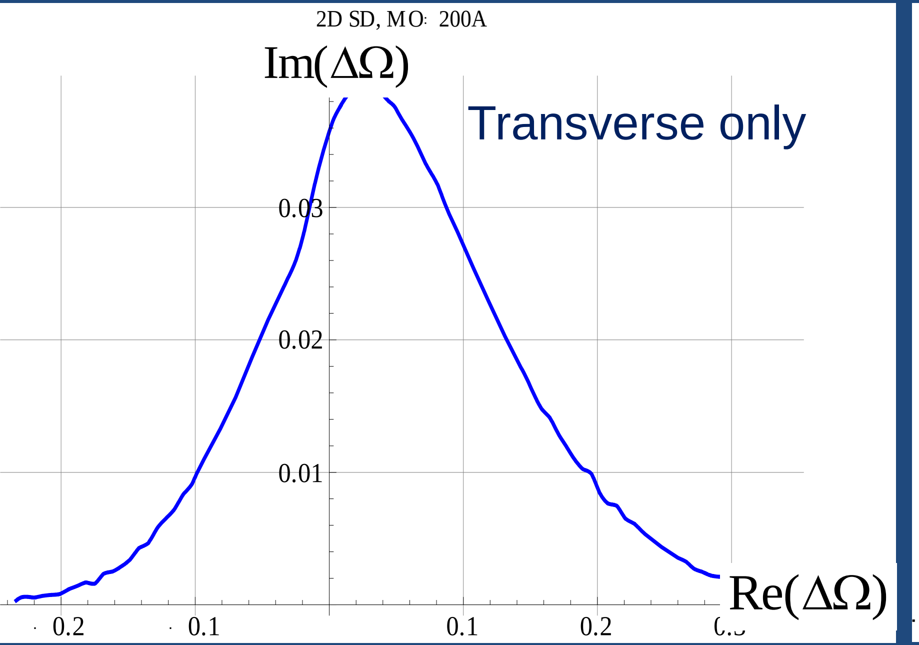
Increasing octupoles can make situation worse!

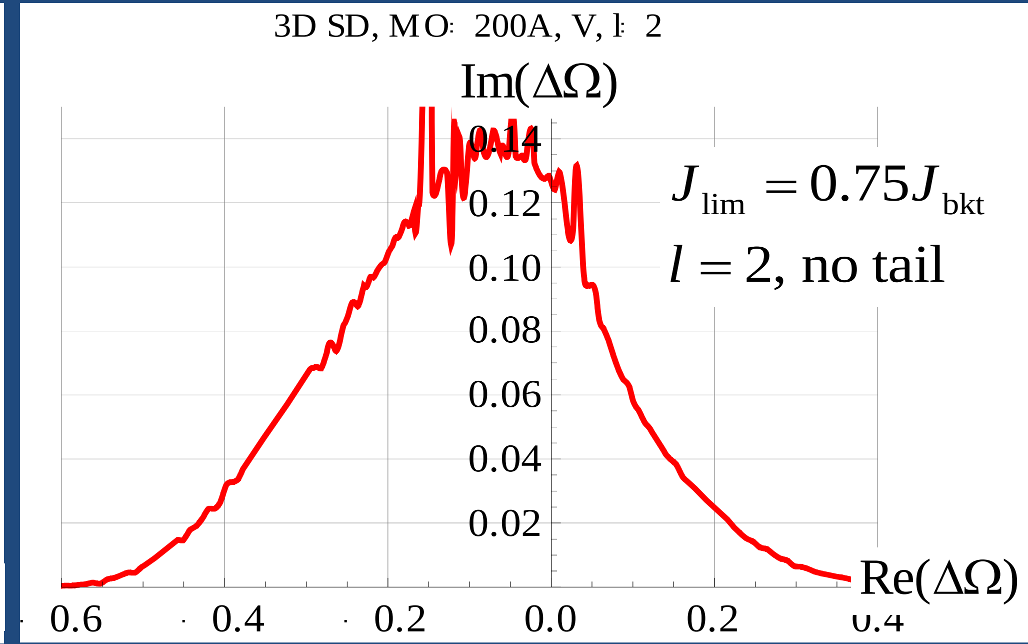
Same + a small tail

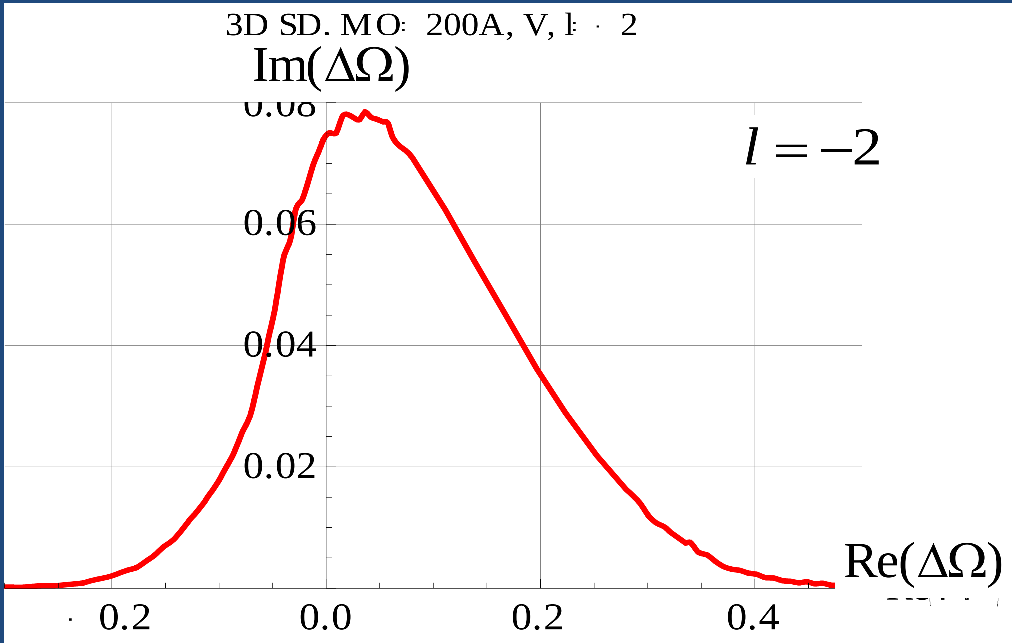


Note the big effect from the small tail!

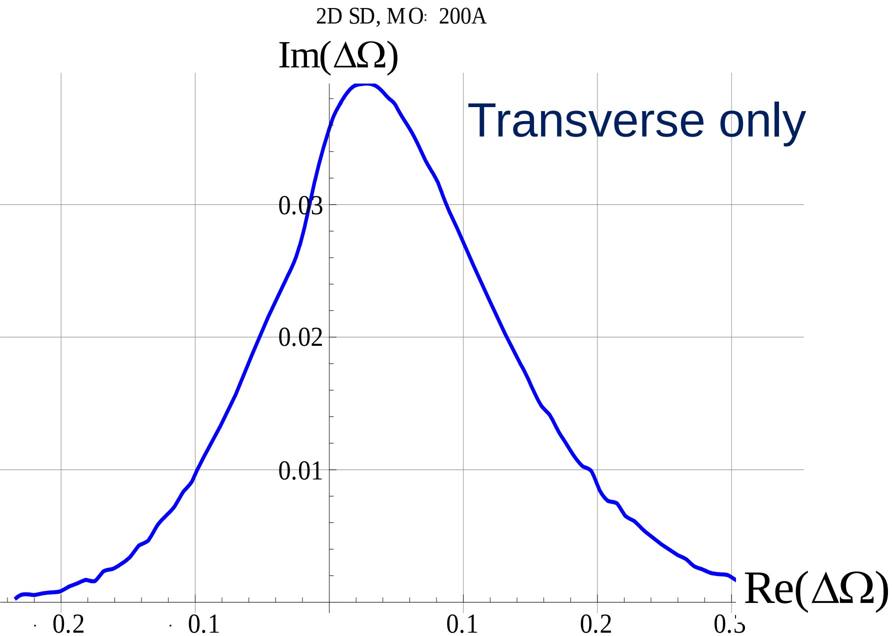
SDs: w/o and with longitudinal contribution

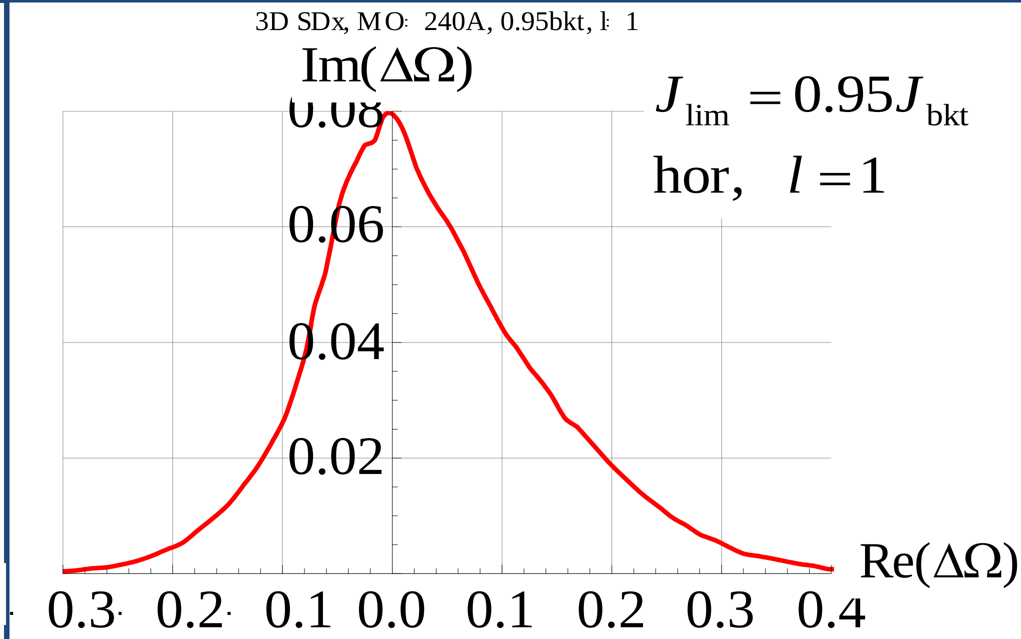


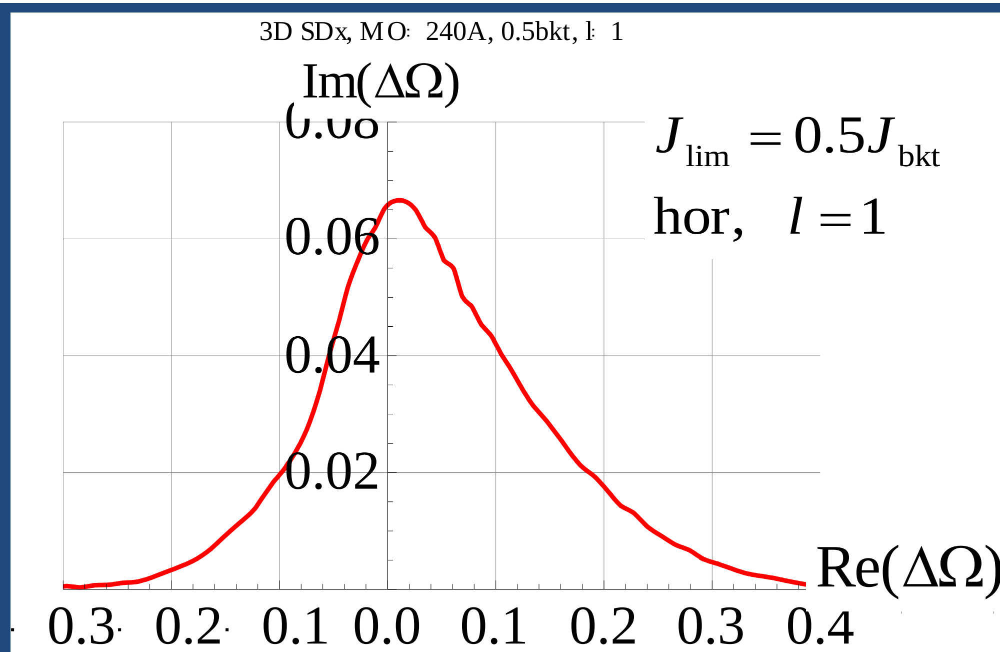




3D SD: Dependence on longitudinal emittance near the collapse

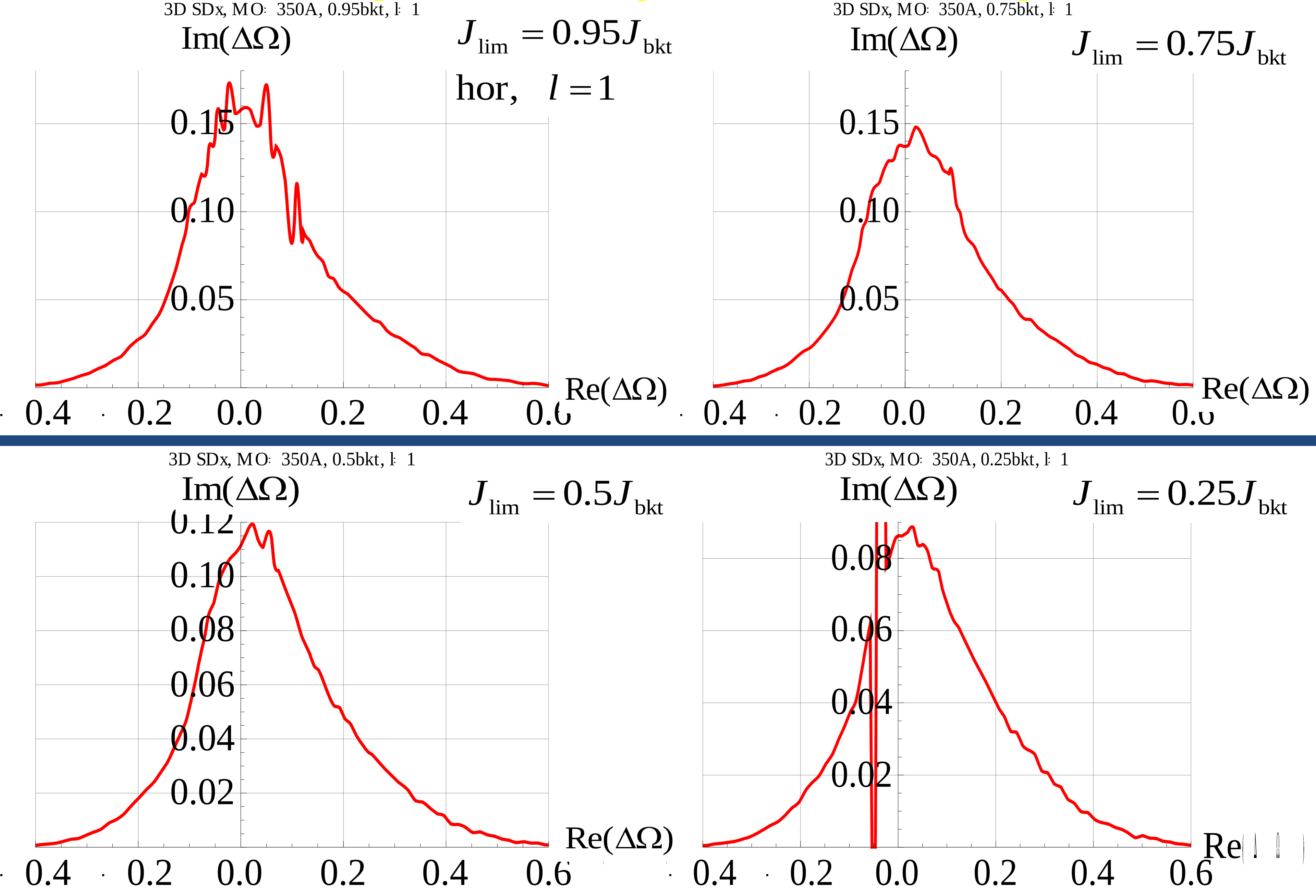






Looks like longitudinal and transverse SD ~ add together. If it is always so, higher filling factor can only help. At worst case, like here, this help is smaller, but still it is there.

3D SD: Dependence on longitudinal emittance for q”=0.5



Conclusions

- Longitudinal to transverse Landau damping (LTLD) can be strongly deformed or eliminated by Q”.

- For HT harmonic l, LTLD collapses at $q'' = 1/8$, being significantly suppressed for

$$q'' \simeq l(0.07 - 0.3)$$

- This effect is sensitive to the potential well distortion.

- Small change of the distribution tails makes a big difference in the SD.

- High volatility of the longitudinal tails could be an explanation for the measured volatility of the thresholds.

- Lower bucket filling factor (reduced RF) can be a powerful tool for the beam stabilization during squeeze and adjust.

Research Program

- Solution of the transverse stability problem in the LHC requires several complimentary directions of research.

- Impedance model (already well-ongoing).

- Beam diagnostics and data processing (tomography) – much more to be done.

- Measuring and improving fill-to-fill reproducibility (Tails are crucial!).

- Further developing of the computational tools – NHT with longitudinal-to-transverse factors taken into account.
  - Generation of sufficiently large family of SDs: SD(MO,l);
  - Parameterization of this family of SDs;
  - Optimization of numerical finding roots;
  - Usage of tomography for the stability analysis, study of tail-sensitivity;

- Explanations, predictions, optimizations...