FOLLOW-UP OF TRANSVERSE LANDAU DAMPING WITH SPACE CHARGE

Elias Métral

⇒ **After**

- **CERN-GSI bi-lateral working meeting on Collective Effects – Coordination of Theory and Experiments, GSI, 30-31/03/06 ⇒ http://care-hhh.web.cern.ch/care-hhh/Collective%20Effects-GSI-March-2006/default.html**

- **39th ICFA–HB2006 Workshop, Tsukuba, Japan, from 29 May 2006 to 02 June 2006 (after the highlights from FZ)**

  ⇒ http://indico.kek.jp/

GSI (30-31/03/06) (1/5)

TRANSVERSE LANDAU DAMPING WITH SPACE CHARGE

Elias Métral (~10 min, 15 slides)

With F. Ruggiero, CERN-AB-2004-025 (ABP)

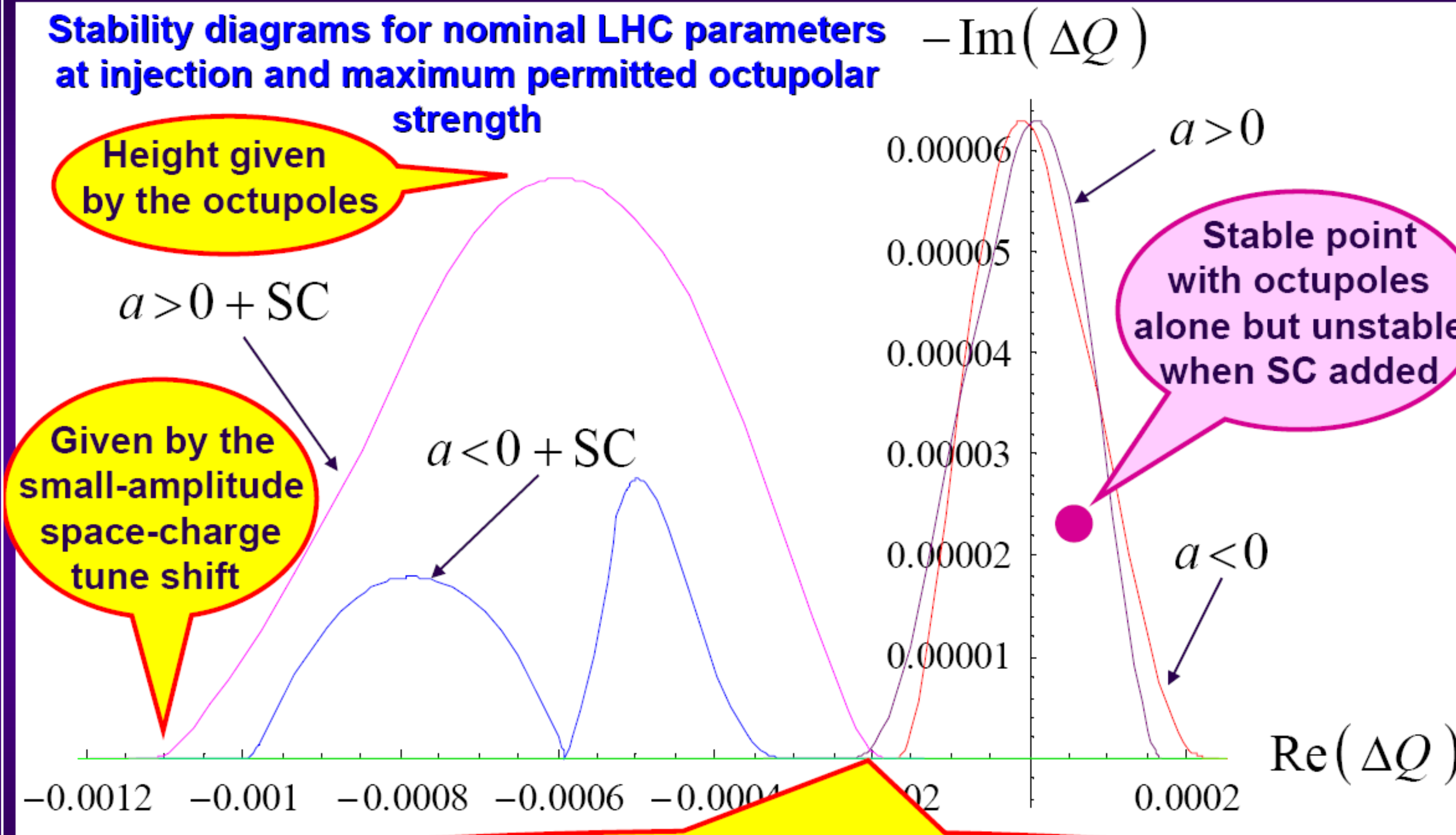
- Introduction and motivation
- Review of our 2004 paper ⇒ Should give a 1st answer to the questions:
  - When can a beam become stable by adding the direct (incoherent) space-charge force?
  - How can a stable beam become unstable (coherent motion) only by adding the direct (incoherent) space-charge force?
  - Why is the decoherence time much longer with space charge (as e.g. in the CERN PS)? ⇒ Same as before
- Conclusions and future work

Elias Métral, CERN-GSI bi-lateral working meeting on Collective Effects – Coordination of Theory and Experiments, GSI, 30-31/03/06 1/15

GSI (30-31/03/06) (2/5)

REVIEW OF OUR 2004 PAPER (10/10)

- **Analytical stability diagrams derived in the approximate case**



Given by the large-amplitude space-charge tune shift + octupoles
⟹ Will move to the right with longitudinal motion

Elias Métral, CERN-GSI bi-latera… 13/15

GSI (30-31/03/06) (3/5)

NONLINEAR LANDAU DAMPING
(DECOHERENCE)

incoherent tune spread
due to nonlinearities:
- nonlinear space charge
- external nonlinearities (octupoles)

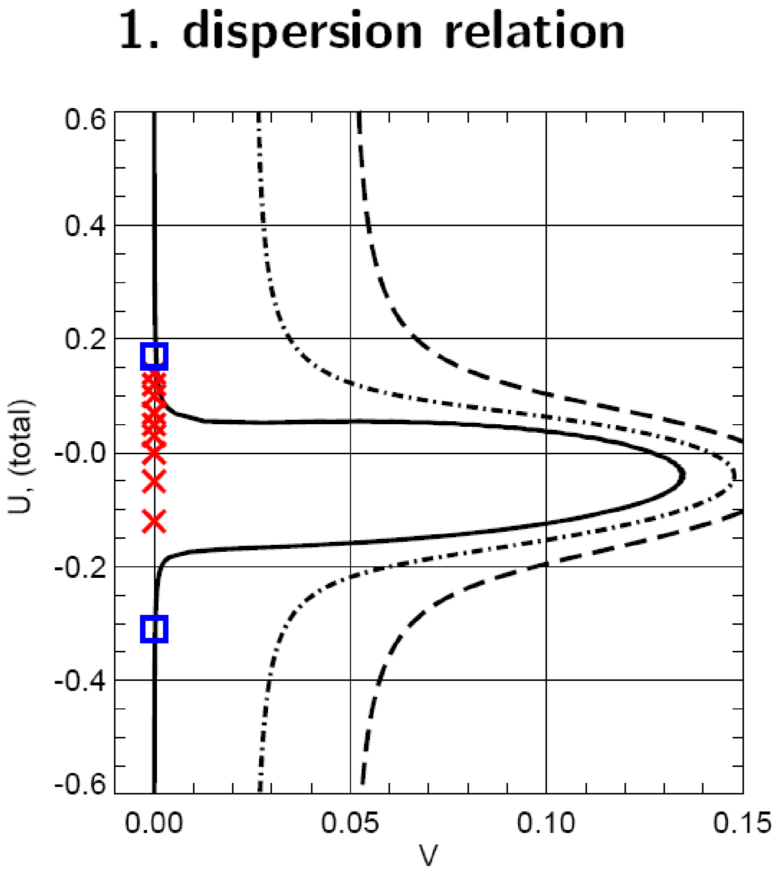
\+ complex interplay between them

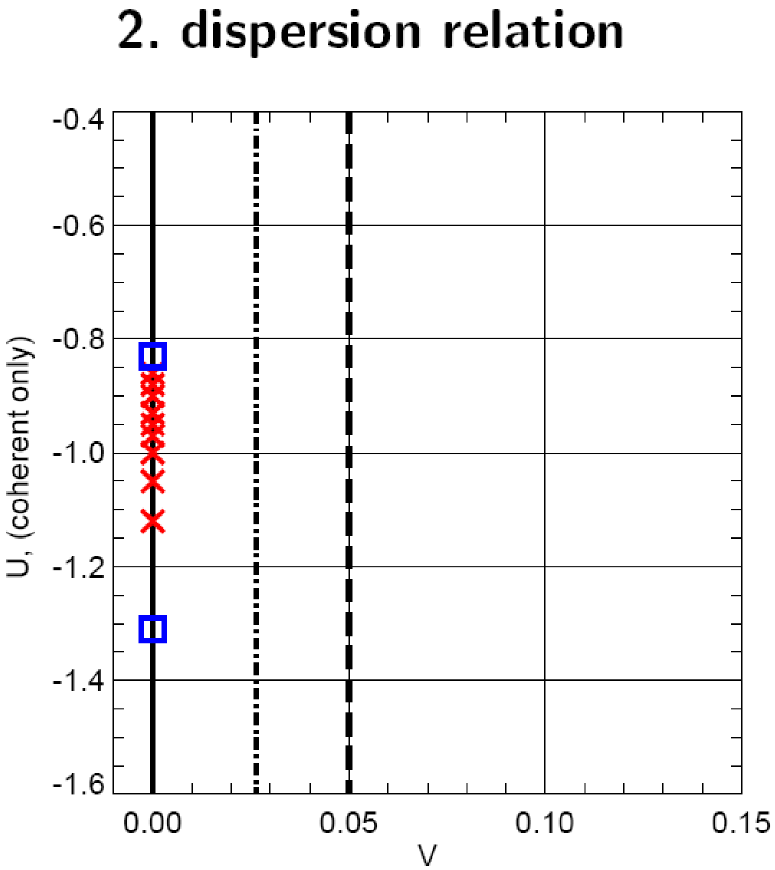
CONTROVERSIAL ATTITUDES

1.	2.
J.L. Laclare, 1985 H.G. Hereward, 1969	D. Möhl, 1974
dispersion relation ⇓ nonlinear space-charge effect produces damping (stability)	dispersion relation ⇓ <u>no</u> stability due to nonlinear space-charge

GSI (30-31/03/06) (4/5)

NONLINEAR SPACE-CHARGE EFFECT ONLY





□ $\mapsto$ no damping

× $\mapsto$ $\overline{x}(t)$ damped

GSI (30-31/03/06) (5/5)

GSI

SUMMARY

- damping mechanisms of collective instabilities are essential for the Design Verification and Impedance Budget definition
- damping (decoherence) due to nonlinearities can be decisive for GSI synchrotrons SIS 18/100
- substantial (qualitative!) differences between the 1. (Laclare) and the 2. (Möhl) dispersion relation
- simulations using the PATRIC code for nonlinear damping mechanisms and their combination
- comprehensive trilateral comparison supports:
  - ★ the 1. dispersion relation
  - ★ damping due to the nonlinear space-charge effect

HB2006 (29 May 2006 to 02 June 2006) (1/3)

GSI

NONLINEAR LANDAU DAMPING

current understanding:

CONTROVERSIAL APPROACHES

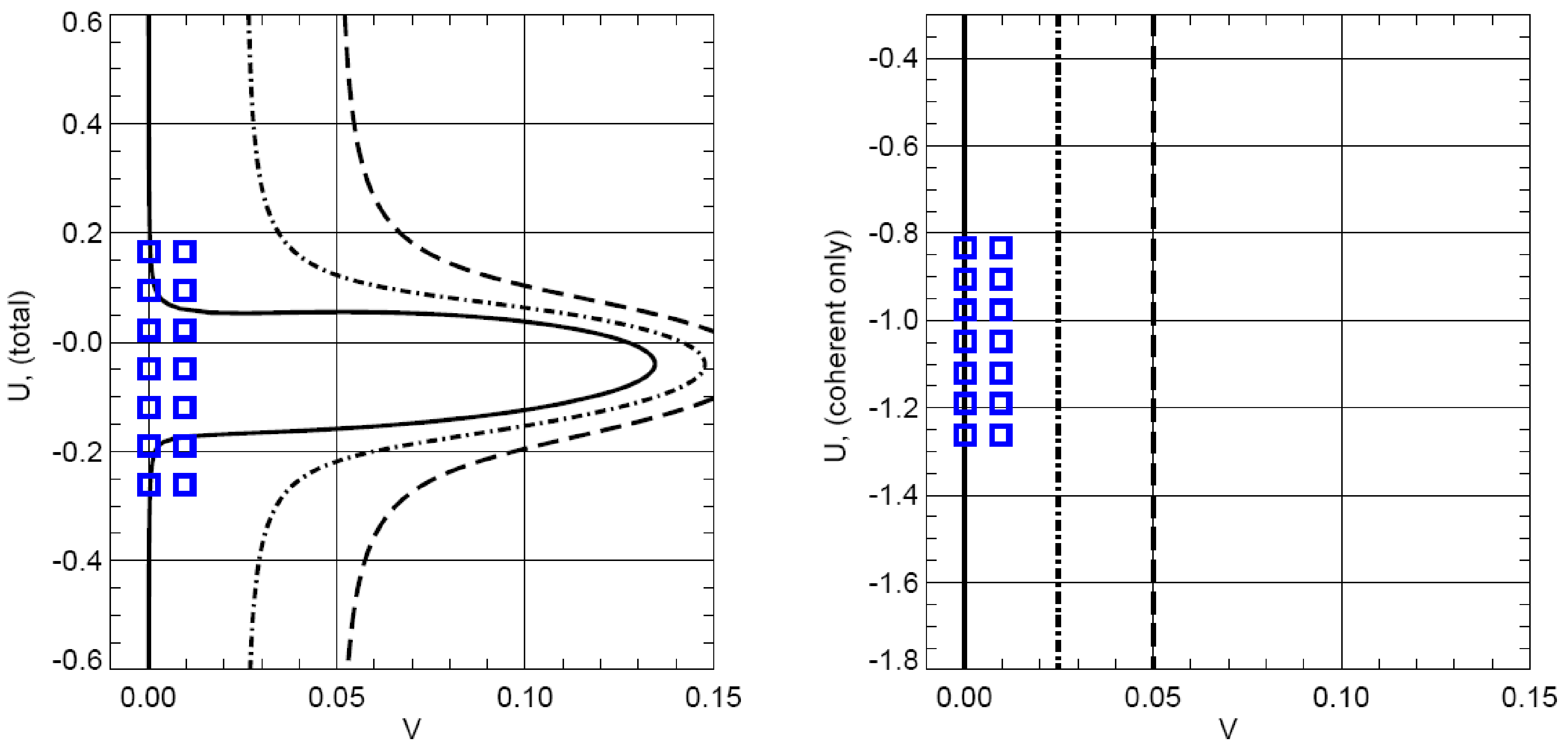
1.	2.
J.L. Laclare, 1985 H.G. Hereward, 1969	D. Möhl, 1974
“1st” dispersion relation	“2nd” dispersion relation
⇓	⇓
nonlinear space-charge effect produces damping (stability)	no stability due to nonlinear space-charge

this work:
clarify and learn more using particle tracking simulations

HB2006 (29 May 2006 to 02 June 2006) (2/3)

NONLINEAR SPACE-CHARGE ONLY

1st dispersion relation | **2nd dispersion relation**



PATRIC **simulations:** □ $\mapsto$ **no damping**

× $\mapsto$ $\overline{x}(t)$ **damped**

HB2006 (29 May 2006 to 02 June 2006) (3/3)

GSI

SUMMARY

- two controversial analytical approaches to describe the damping induced by internal/external nonlinearities
- series of simulations for the internal-nonlinearities-only case using the PATRIC code support:
  - ★ the 2nd dispersion relation
  - ★ no damping due to the nonlinear space-charge alone
- combination of internal and external nonlinearities enhances strongly the stability at small $\mathcal{R}e(Z^{\perp})$ (agreement dispersion relation $\leftrightarrow$ simulations)
- quantitative disagreement in threshold $\mathcal{R}e(Z^{\perp})$ between the dispersion relation and simulations for the case of combination of nonlinearities

CONCLUSION (1/2)

- **Interesting new PATRIC simulations by V. Kornilov et al. seem now in good agreement with Mohl&Schonauer1974 theory (which we extended with FR) ⇒ End (at least qualitatively) of a long-standing problem…**

- **What is in addition in the extended theory and not (yet) in the previous simulations**

  - **2-dimensional betatron tune spread ⇒ In the absence of space charge the stability diagrams from Berg&Ruggiero are recovered**

  - **2 stability diagrams in the presence of both space charge and octupoles: same or opposite sign of the detuning with amplitude ⇒ See next slide**

  - **Stability diagrams plotted in the complex tune diagram (instead of the LNS coefficients U and V) ⇒ Much more convenient in practice**

- **Future (collaboration) work: Make the PATRIC simulations for the LHC at injection?**

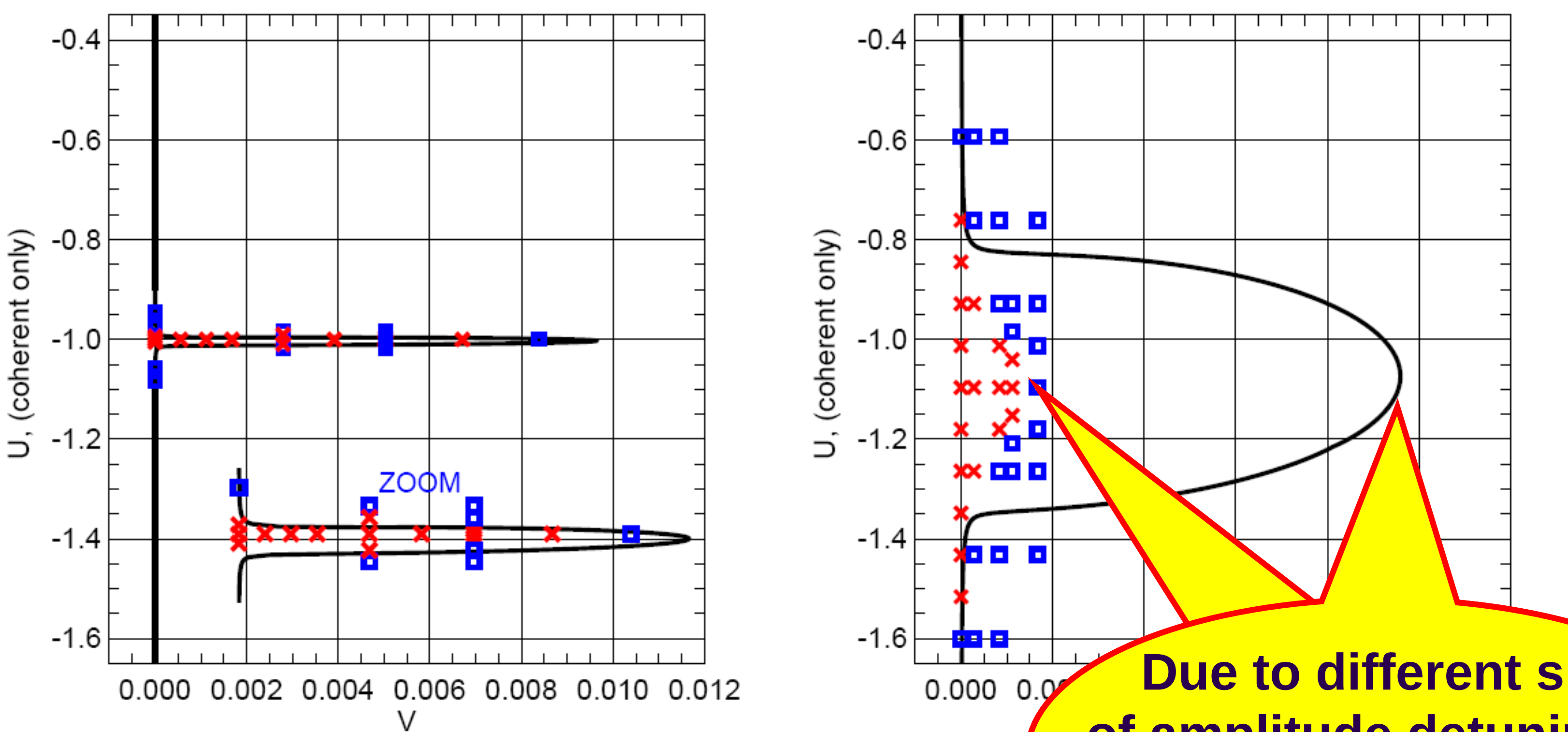
CONCLUSION (2/2)

From HB2006

GSI

COMPARISONS WITH SIMULATIONS

octupole effect only | nonlinear SC + octupole



PATRIC simulations: □ $\mapsto$ no damping

× $\mapsto$ $\overline{x}(t)$ damped

Due to different sign of amplitude detuning as predicted by theory (see page 3)?