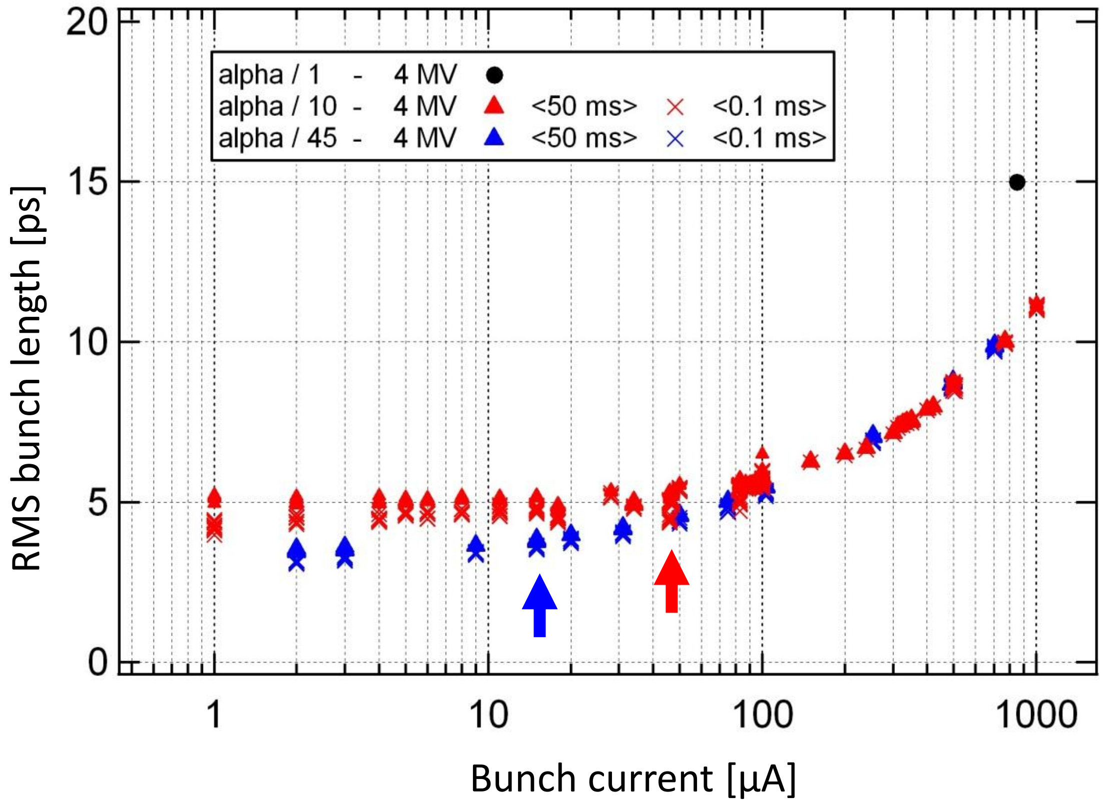
Status of the low-alpha mode at SOLEIL

A. Loulergue
On behalf of the Accelerator Physics Group

- Introduction: bunch length measurements
- Reminder of optics
- Non-linear dynamics
- Low-alpha operation
- On the user side: THz and X-ray short bunch science
- CSR measurement and modeling

Introduction: bunch length measurements

Picosecond streak camera Hamamatsu C5680
Resolution: 2 ps fwhm



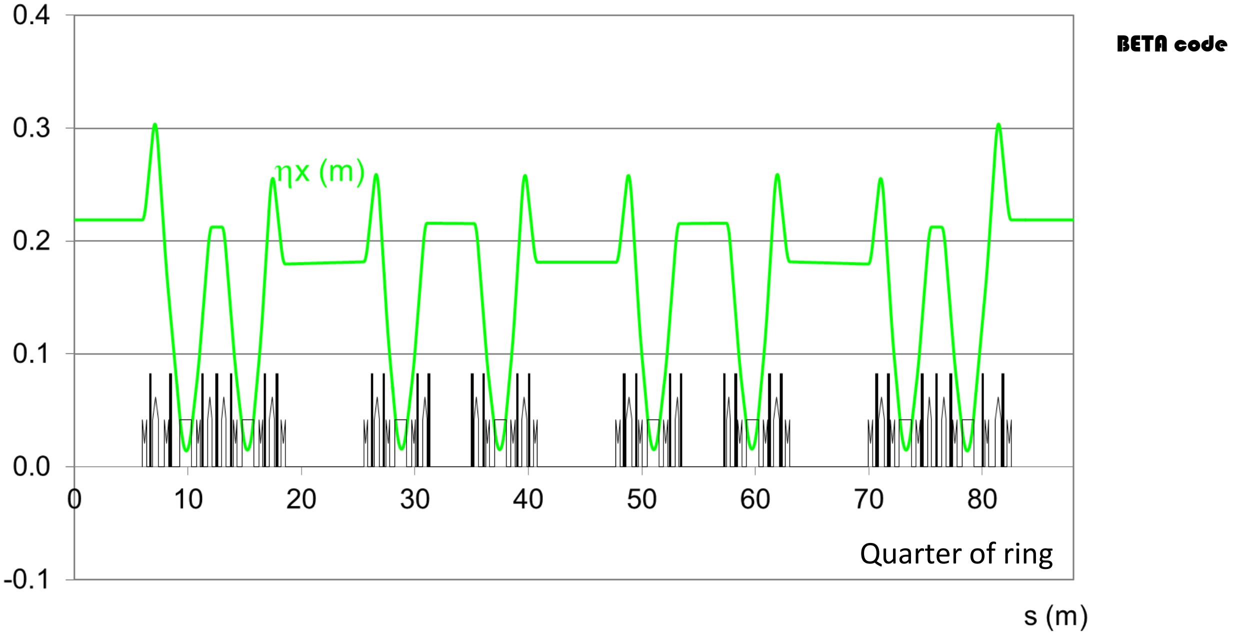
M. Labat
L. Cassinari

Typical bunch lengthening

Reminder of optics

Horizontal dispersion function at nominal α

ε_x = 3.7 nmrad
α_1 = 4.4 10^{-4}



Reminder of optics

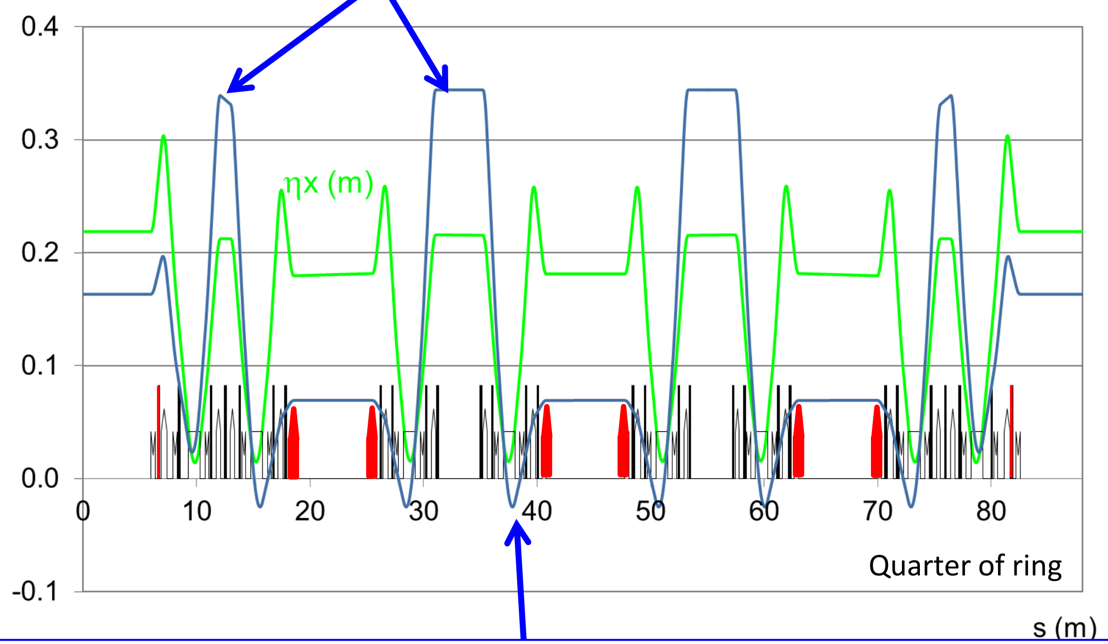
Control of α_2: High dispersion in the focusing sextupoles

Dispersion function at low α_1

ε_x = 8.6 nm.rad

$\alpha_{1\downarrow}$ negative values

Switch in polarity for one Quad. and one Sext. family



Minimization of ε_x: η_x<0 only at the dipole center

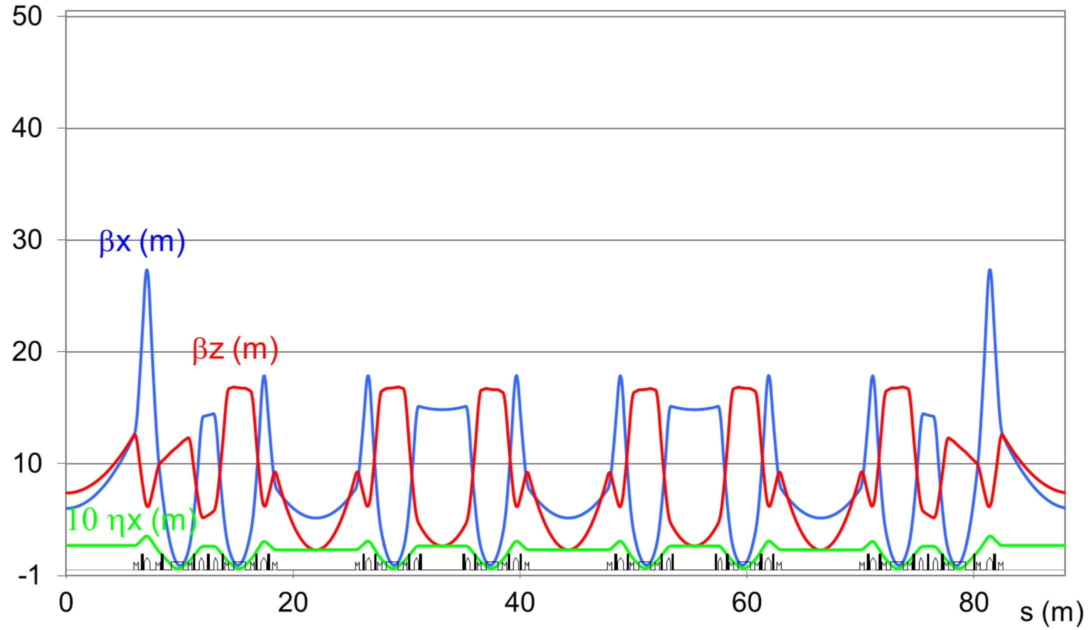
Exception around the injection section to increase β_x

Control of α_1: by varying η_x in the dipole

M. Attal et al., to be published

Reminder of optics

Optical functions at nominal α



BETA code

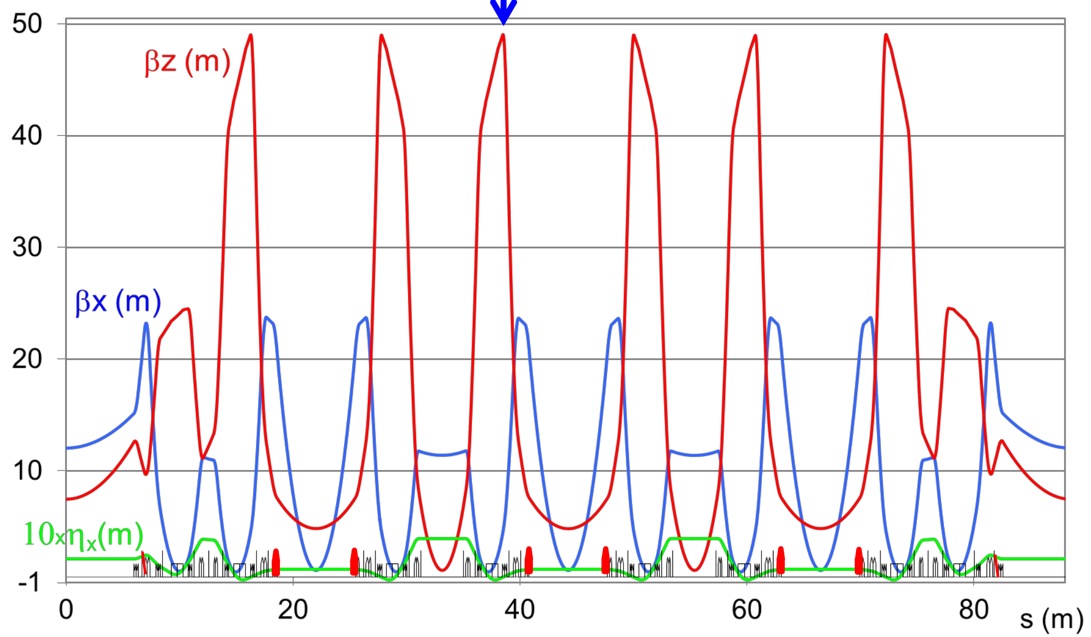
$\nu_x = 18.170$
$\nu_z = 10.234$

Reminder of optics

Control of the chromaticities: High β_z to compensate for the low η_x

Optical functions at low α

ν_x = 20.30
ν_z = 8.40



Optical functions remain unchanged during α_1 control

But..

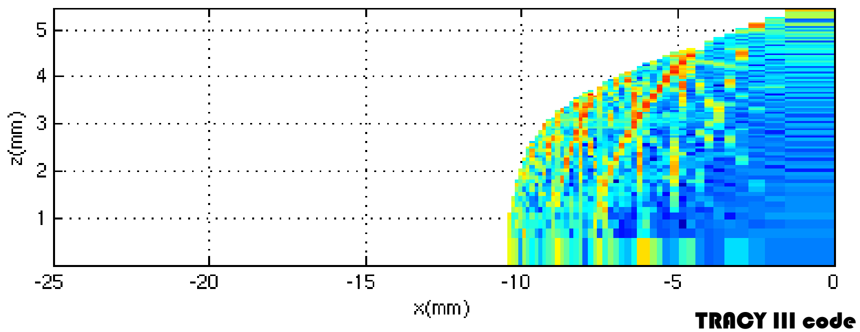
Transverse dynamics is strongly affected..

Non-linear dynamics

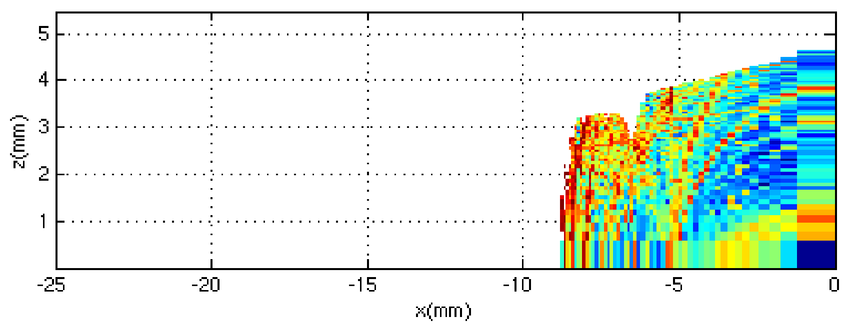
ON momentum transverse acceptance:

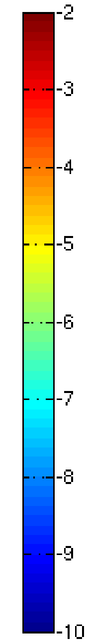
Strongly non-linear dynamics

at nominal α



Example with
α_1=1.8 10^{-5}
α_2=10^{-4}
α_3=8 10^{-2}
(α_{nom} /25)





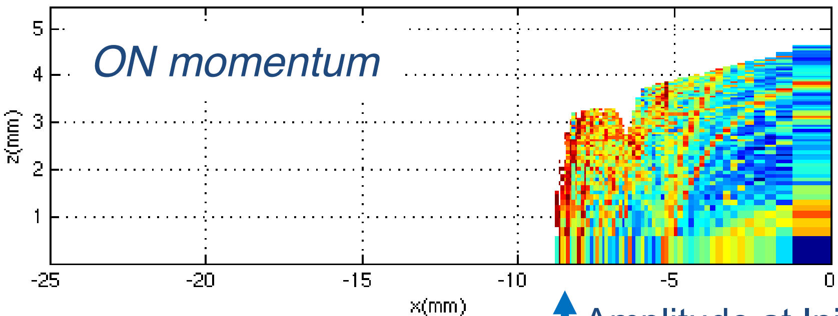
Linear dynamics

Non-linear dynamics

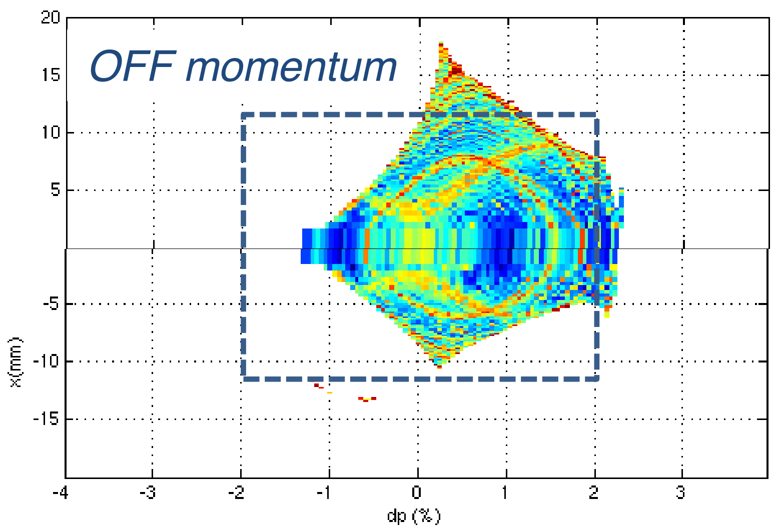
- Injection rate is strongly affected by the reduced ON and OFF momentum transverse acceptances

Example with
α_1=1.8 10^{-5}
α_2=10^{-4}
α_3=8 10^{-2}

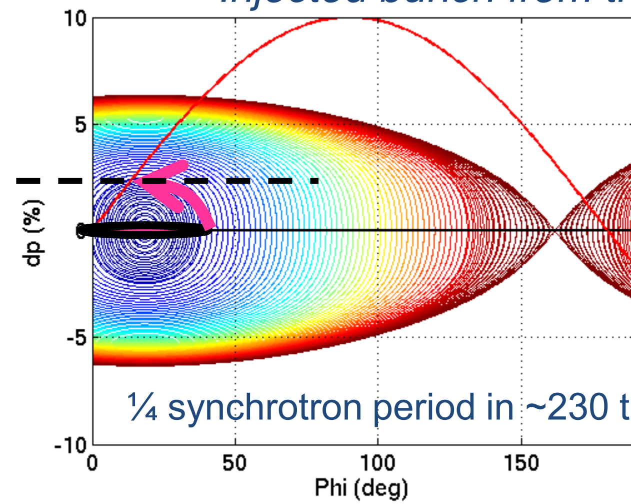
TRACY III code



Amplitude at Injection



Injected bunch from the Booster



Non-linear dynamics

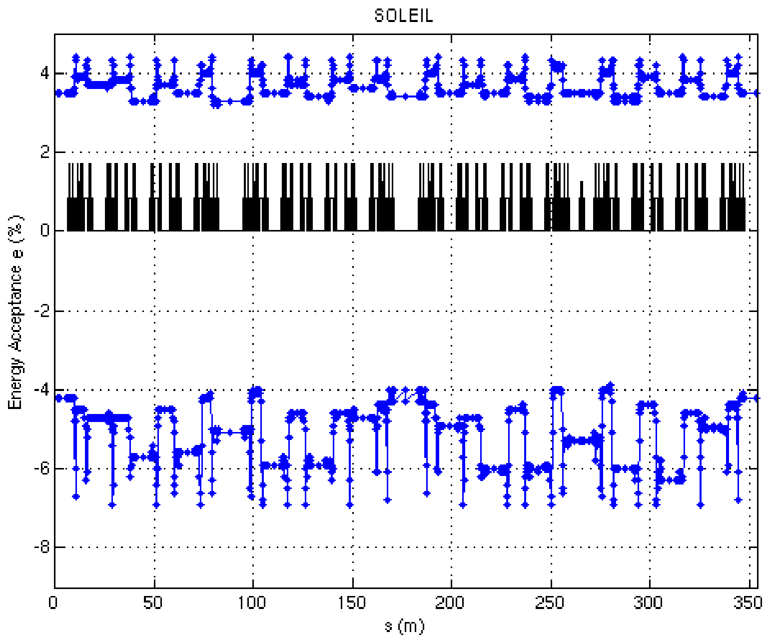
Energy acceptance:

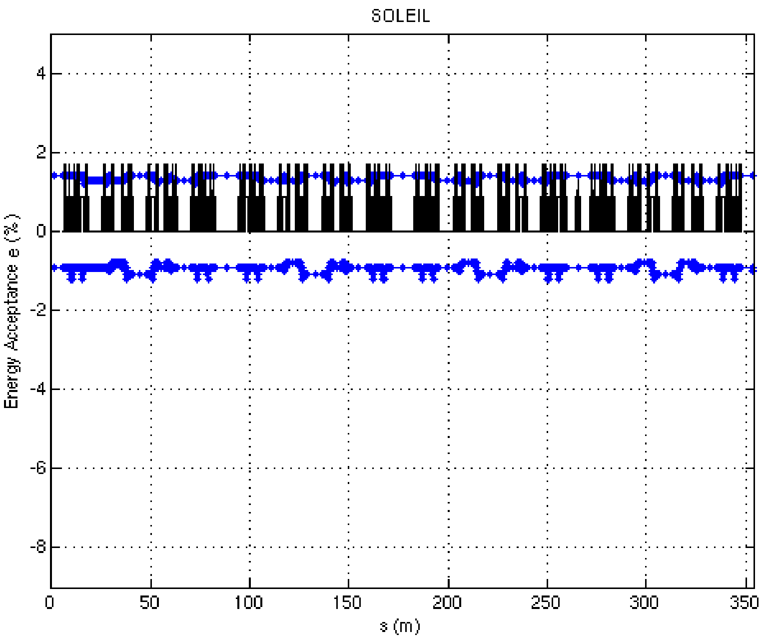
at nominal α

Example with

α_1=1.8 10^{-5} α_2=10^{-4} α_3=8 10^{-2}

(α_{nom} /25)





TRACY III code

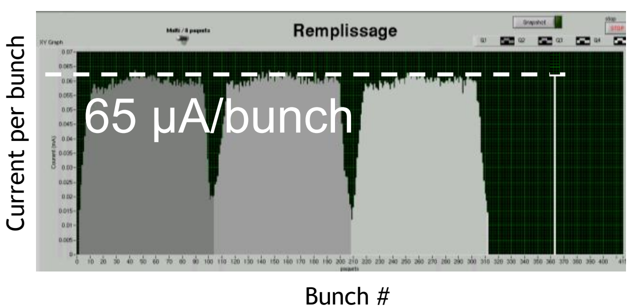
CSR and short bunch operation

On December 10-11th, 2011 the so-called low-alpha mode operation has been delivered to users, which provides:

- The enhanced production of THz radiation for ‘AILES’ **IR beam line**
- Time resolved short X-rays (4.7 ps – 1.9 mm RMS bunch length) for **2 beamlines**

Operation of 2 x 2 days is foreseen for 2012

→ **Hybrid filling mode** *in order to satisfy both* ***time resolved X-ray*** *and* ***Infrared*** *communities*

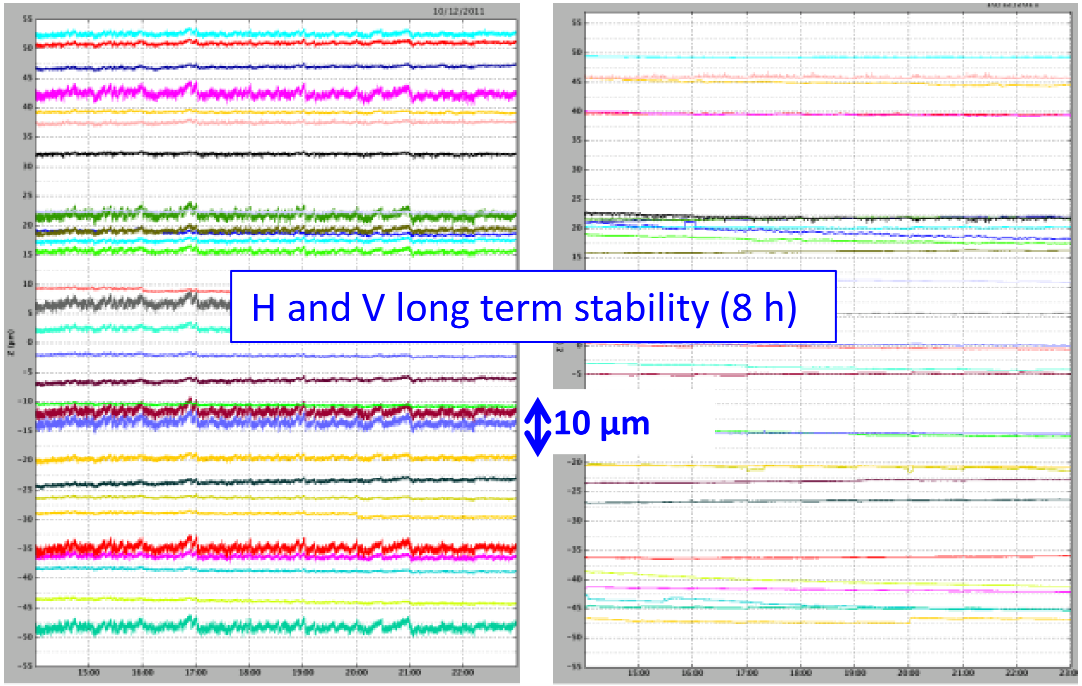


α_1 value	$\alpha_{1\ nominal}/25 = 1.8\ 10^{-5}$
α_2 value	$\alpha_2 = 10^{-4}$
Total current, current per bunch	18 mA, 65 µA
RMS Bunch length	4.7 ps
Horizontal emittance, coupling	8 nm rad, 4 %
Lifetime	20 hours
RF voltage	3.2 MV

- *α_1 and V_{RF} chosen on the basis of THz spectrum optimization*
- *Current per bunch is limited by the micro-bunching instabilities threshold: 67 µA per bunch at α_1 /25*

CSR and short bunch operation: Stability

- Beam current stability:
  - refilling once per hour with 3μA/bunch (tight requirement for THz spectrum stability),
  - injection with shutters open foreseen for the next operation (April 2012), radiation safety tests in progress.
- Source point position stability: Slow and Fast orbit feedback systems effective (slightly deteriorated in H plane with respect to the normal α mode)



α_{nom} /25

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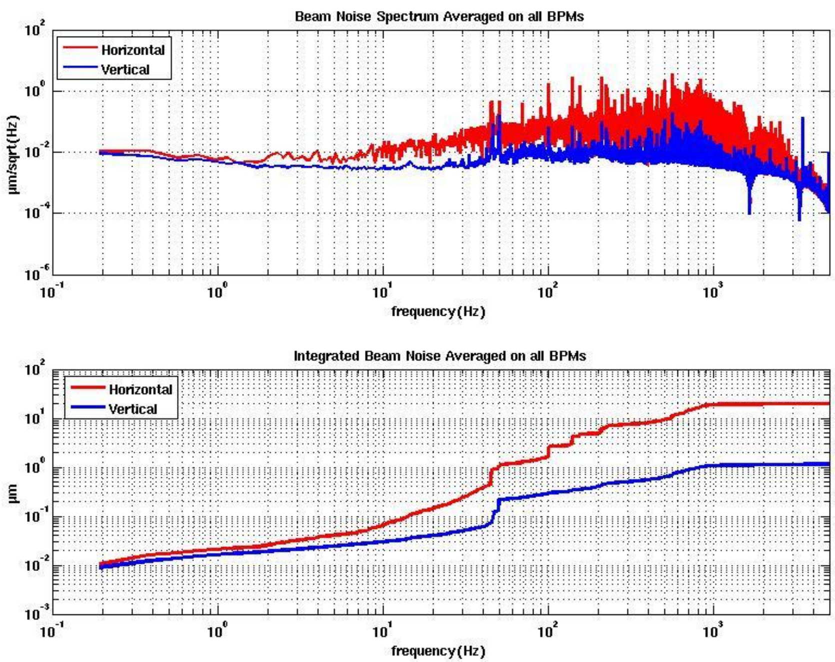
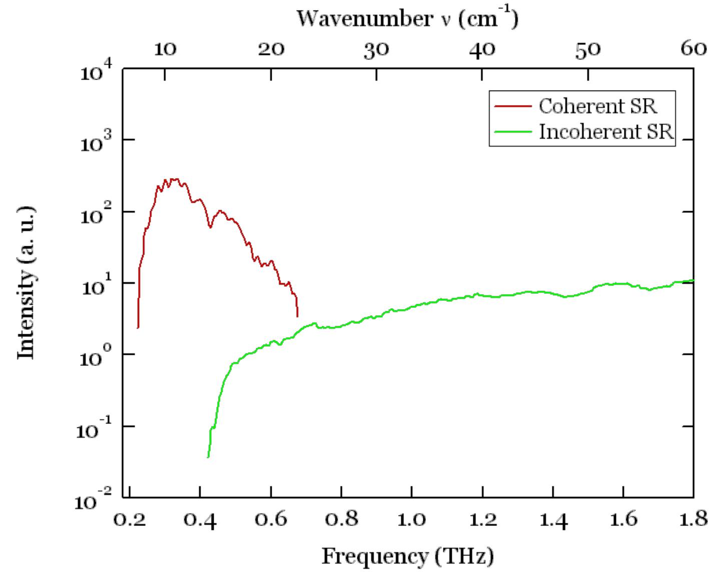


α_{nom} /25

@ 500 Hz:	
H	10 μm
V	700 nm

Science with THz

THz spectroscopy using a Fourier Transform interferometer
→ 3 important criteria:



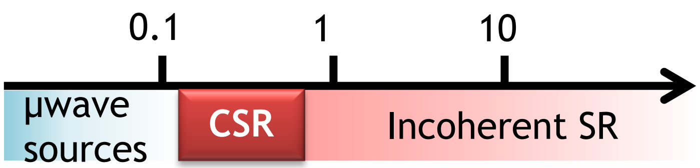
Intensity and brilliance

AILES beamline: highly collimated beam thanks to dipole edge radiation

Confirmed flux gain of ~ 10^4 – 10^5 with CSR

Spectral coverage

CSR fills the "THz gap":



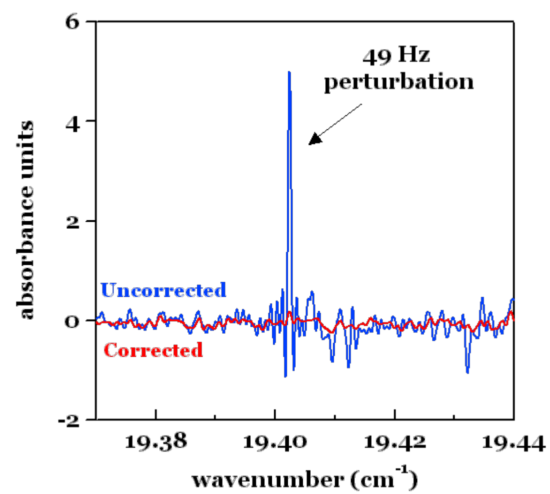
AILES beamline optics dimensioned for long wavelengths (extraction mirror, transport mirrors)

Stability

Ph.D. project: noise correction system (*J. Barros, to be published*)

→ Attenuates the effects of microbunching

→ High spectral resolution: more sensitive to intensity fluctuations

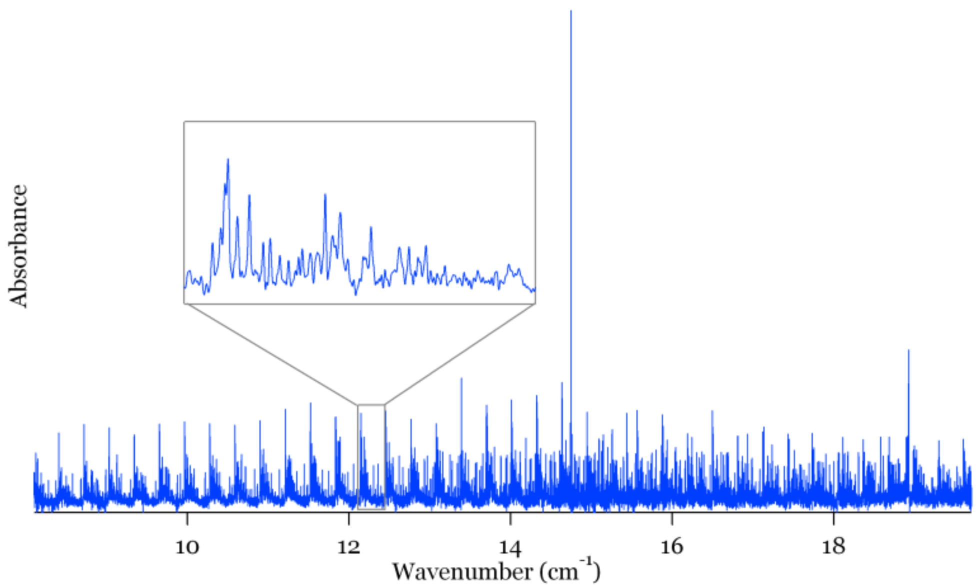


Science with THz

http://www.synchrotron-soleil.fr/Recherche/LignesLumiere/AILES

THz: energy range of (quantified) rotational transitions of molecules in gas phase
→ **High-resolution spectroscopy needed** to detect the corresponding absorption lines

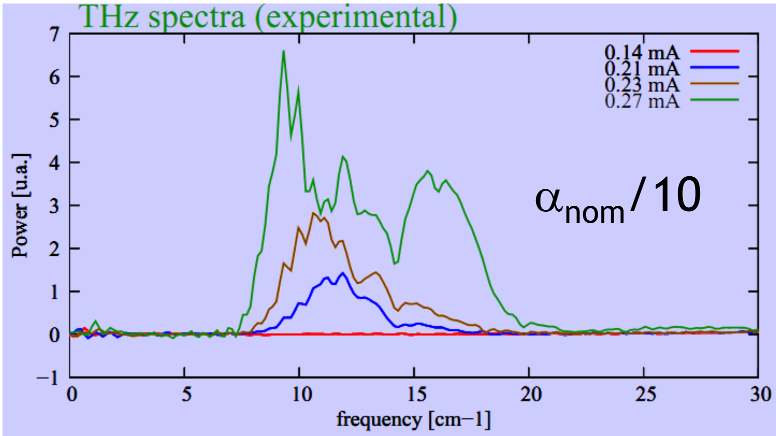
Molecules of astrophysical interest



Normal α:
Too low intensity in this spectral range

Low α :
adapted source

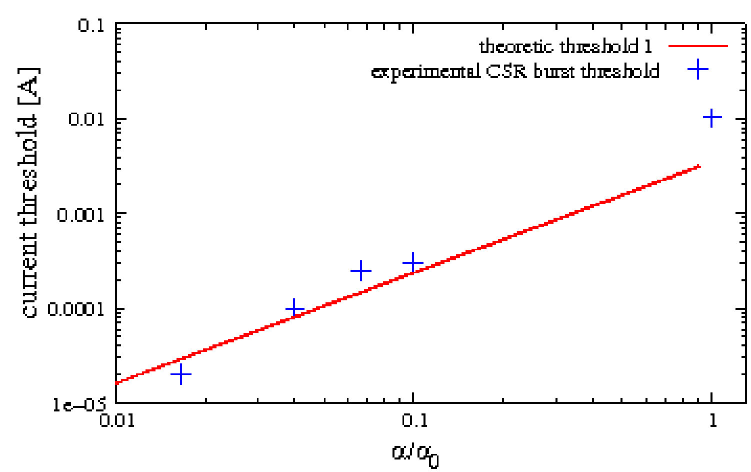
CSR measurement and modeling



- THz measurements on AILES beamline allow to determine the CSR burst current threshold versus α/α_0

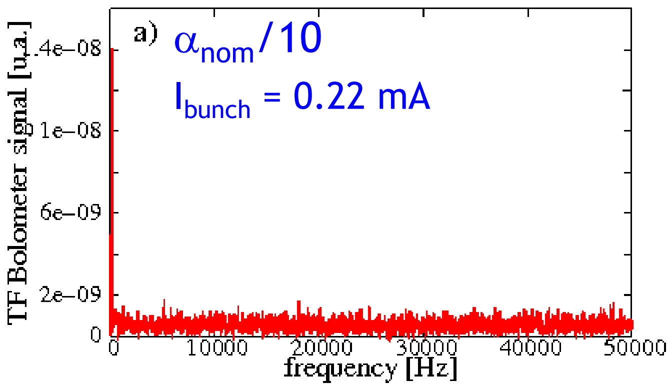
- In good agreement with S. Heifest and G. Stupakov analytical threshold [PRST-AB 5 (2002) 064401]

$$kR < 2\Omega^{3/2} \quad \text{with} \quad \Lambda = \frac{IR}{\alpha\Lambda(\sigma_E/E_0)^2 I_A <R>}, <R> = C/2\pi, I_A = 17.5\ kA \quad \text{and} \quad k = 2\pi/\sigma_{z0}$$

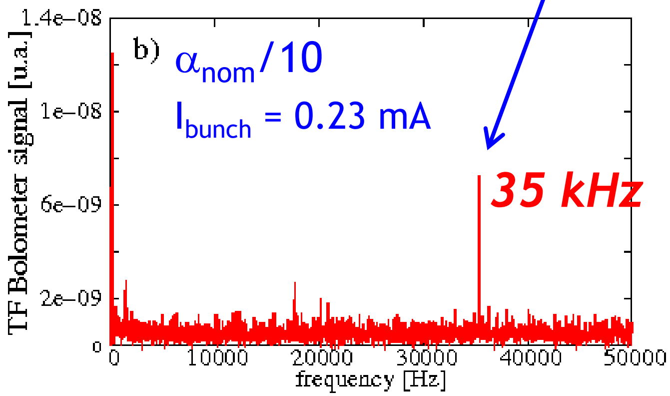


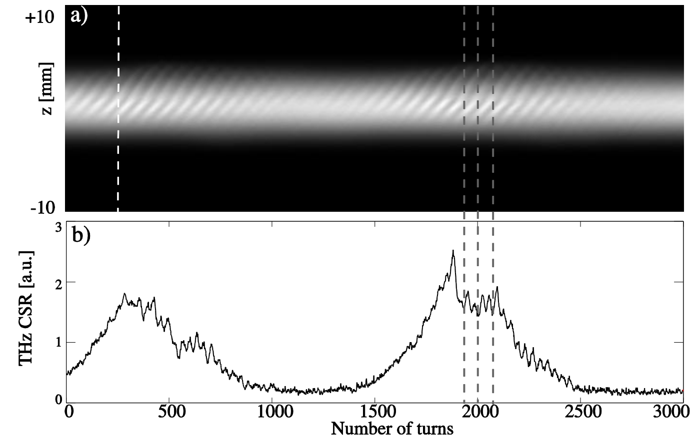
CSR measurement and modeling

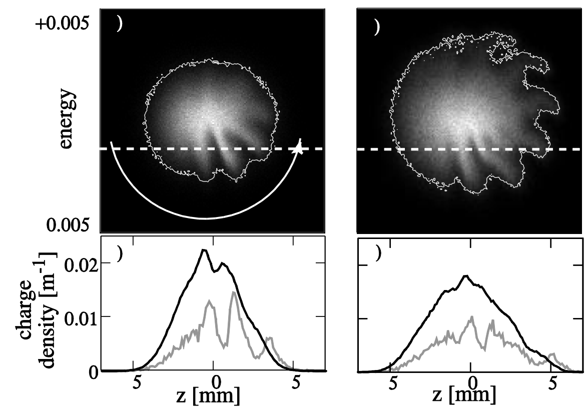
Above a current threshold, appearance of microstructures in the longitudinal charge density



Measurement of a specific frequency







CSR // plates J-B Murphy et al.

In good agreement with simulation (macro-particle code)

C. Evain et al., submitted to EuroPhysics Letters

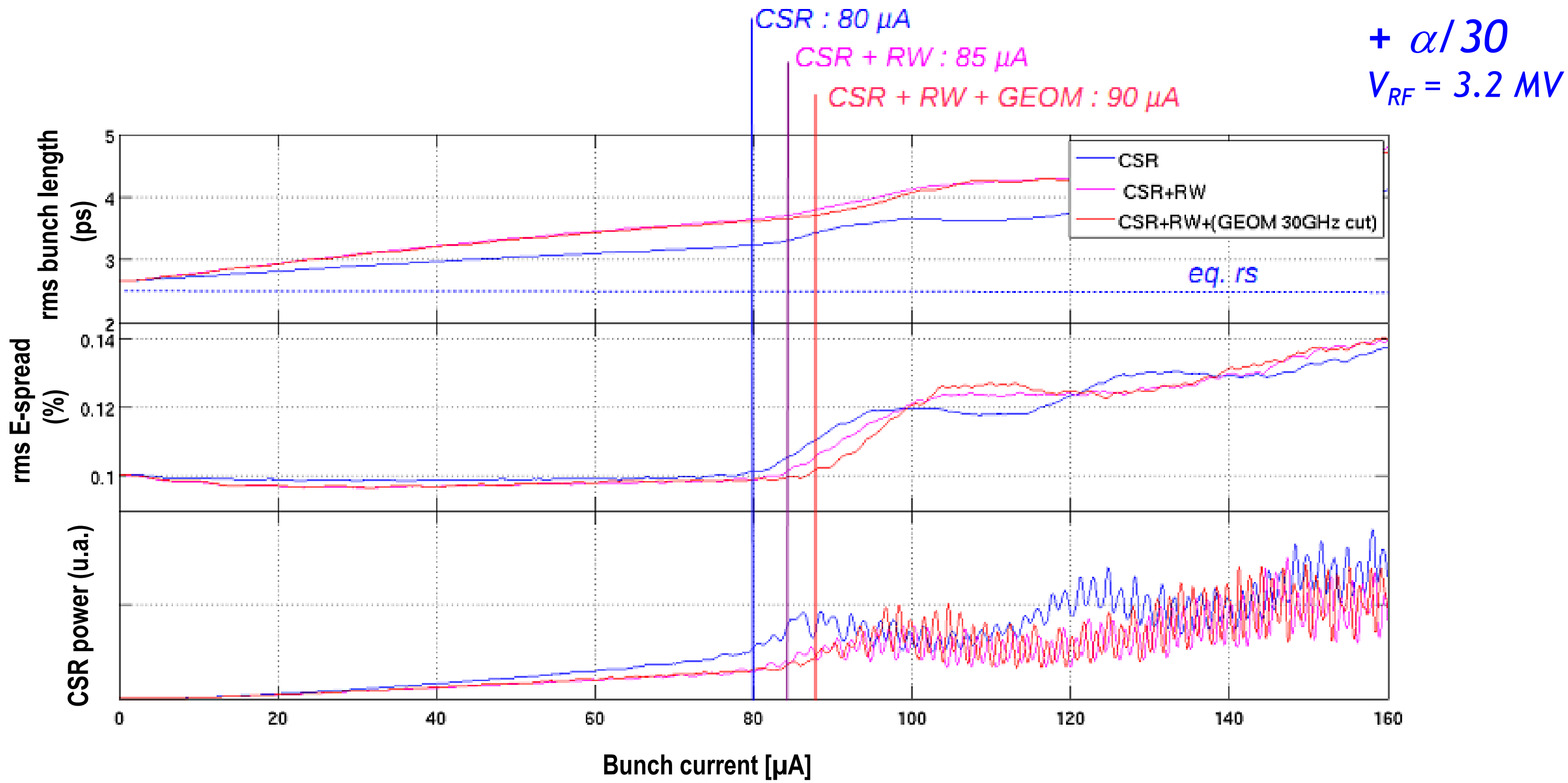
CSR measurement and modeling

Simulation : CSR, Resistive Wall and geometric impedance wakes

J-B Murphy, K. Bane, GdfidL

Bunch current scan over 10^4 turns (τ_{RS} ~2800 turns)

RW and geometric wakes lengthen further the bunch and slightly shift the burst threshold.



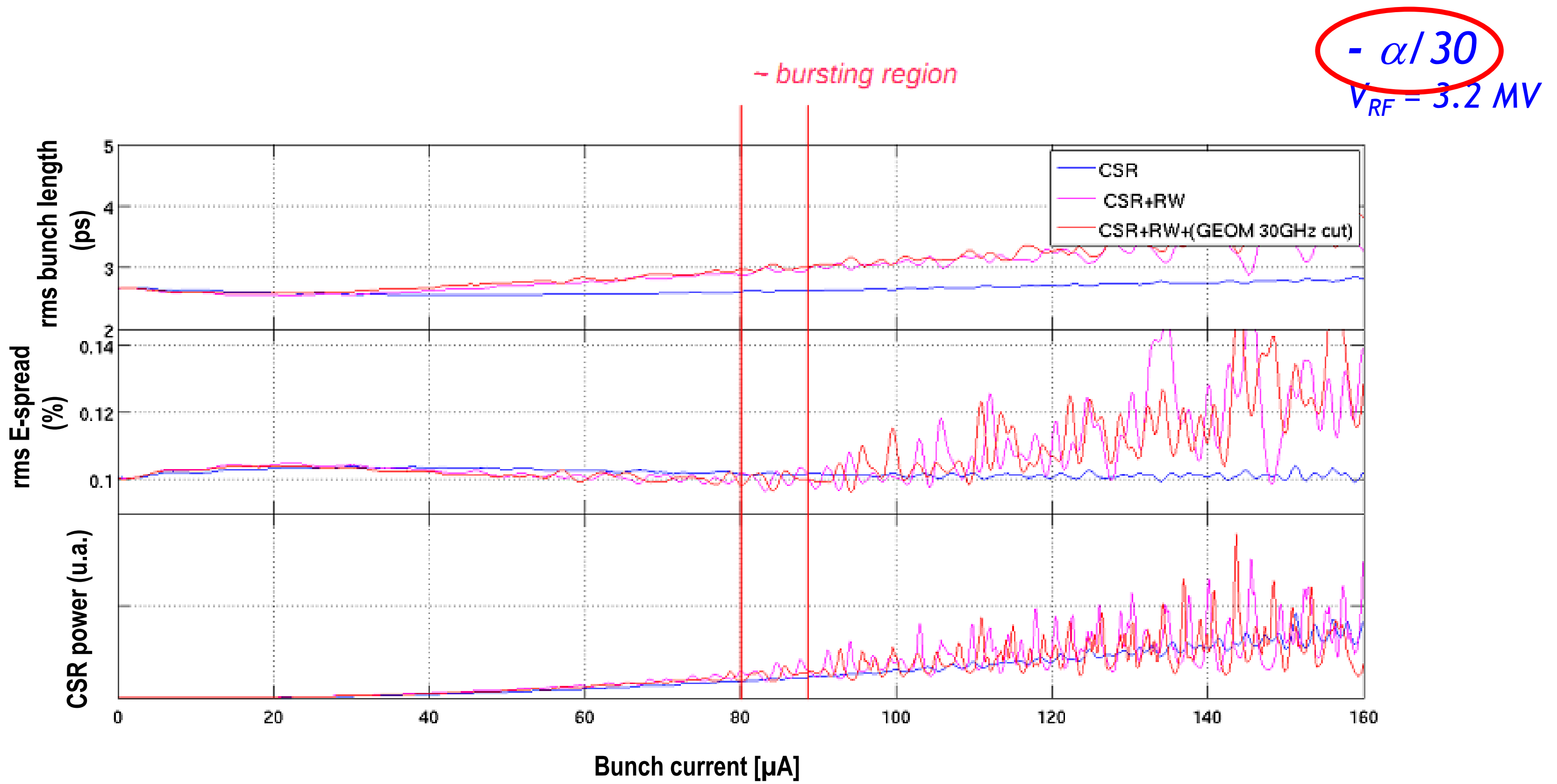
CSR measurement and modeling

Simulation : CSR, Resistive Wall and geometric impedance wakes

J–B Murphy, K. Bane, GdfidL

Bunch current scan over 10^4 turns (τ_{RS} ~2800 turns)

Resistive Wall seems to be the driving term of micro-bunching instability



Conclusion

Get a better injection efficiency

Operate in top-up mode

Test negative alpha mode

Introduction: Storage Ring main parameters

Parameters	Design	Achieved as of Feb 2012
Energy (GeV)	2.75	2.74
RF frequency (MHz)	352.202	352.196
Betatron Tunes	18.20 / 10.30	18.202/10.310
Momentum Compaction α_1 / α_2	4.5×10^{-4} / 4.6×10^{-3}	4.5×10^{-4} / 4.6×10^{-3}
Emittance H (nm.rad)	3.9	3.9
Energy spread	1.016×10^{-3}	1.016×10^{-3}
Coupling, $\varepsilon_V/\varepsilon_H$	<1%	0.7% (w/o corr.) 1% (w/ V dispersion)
Current Multibunch mode (mA)	500	500 (400 for Users operation)
Average Pressure (mbar)	1×10^{-9}	1×10^{-9} @ 500 mA
Beam Lifetime (h)	16 h	20h @ 400 mA / 14h @ 500 mA