Understanding of the CERN-SPS horizontal instability with multiple bunches

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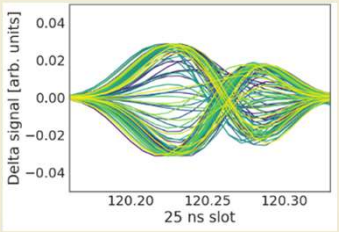
Introduction

First signs of horizontal instability with multiple bunches seen in 2015 at intensities higher than 1.8e11 ppb

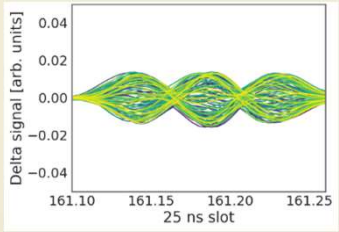
In 2017 horizontal instability observed with 4 x 48 bunches (some bunches in 3rd and 4th batch)

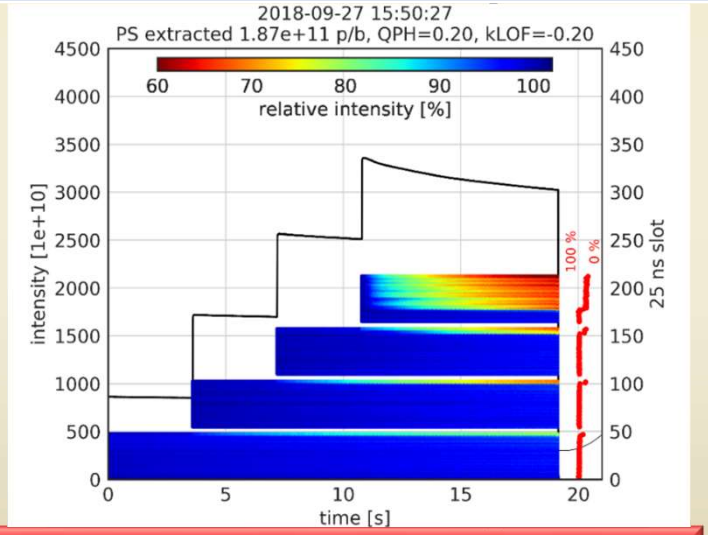
2018 horizontal instability observations
Instability with 4 batches and batch spacing = 200ns
Instability threshold at about 1.8e11 ppb
Instability growth rates versus chromaticity
Instability behaviour versus chroma and octupoles
Instability behavior along the batches
Dependence on batch spacing
Stabilization up to 2.1e11 ppb

$\xi \approx 0.1 - 0.3$



$\xi \approx 0.3 - 0.5$

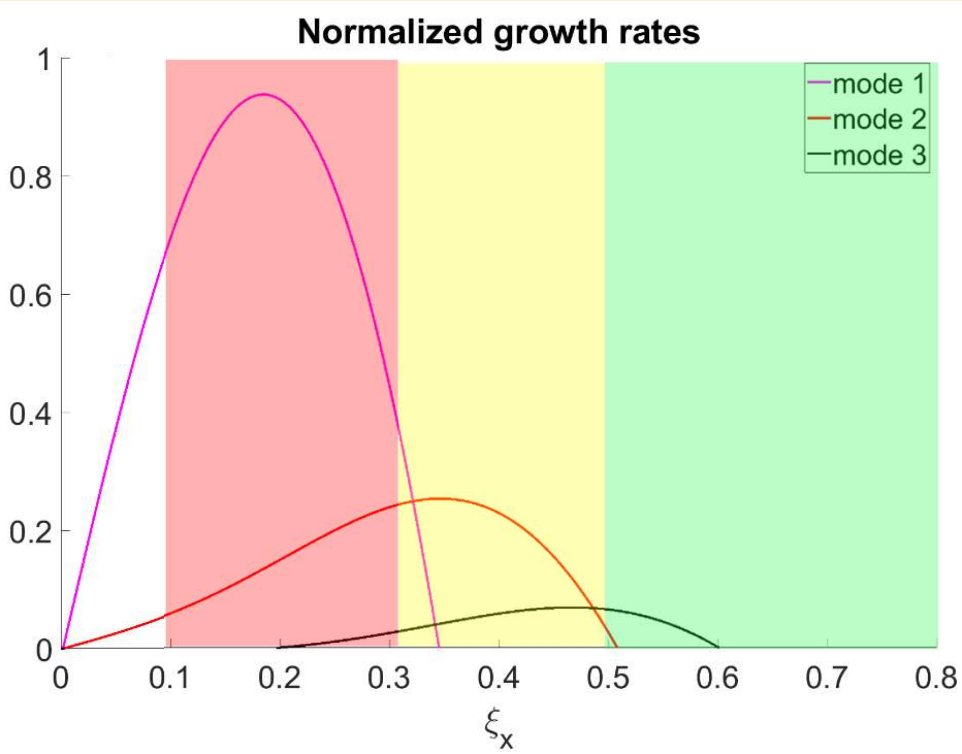




LIU nominal beam 2.6e11 ppb (4 x 72 bunches)

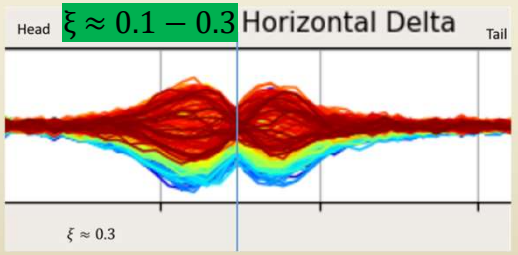
2015 2016 2017 2018 2019

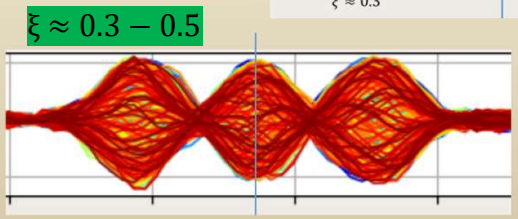
Understanding of the instability behaviour: Sacherer theory

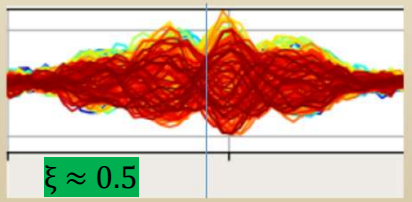


Horizontal instability observations

Chromaticity	Beam Stability
ξ=0.1	Unstable mode1
ξ=0.2	Unstable mode1
ξ=0.3	Unstable mode1-2
ξ=0.4	Unstable mode2
ξ=0.5	Unstable mode2-3
ξ=0.6	Stable



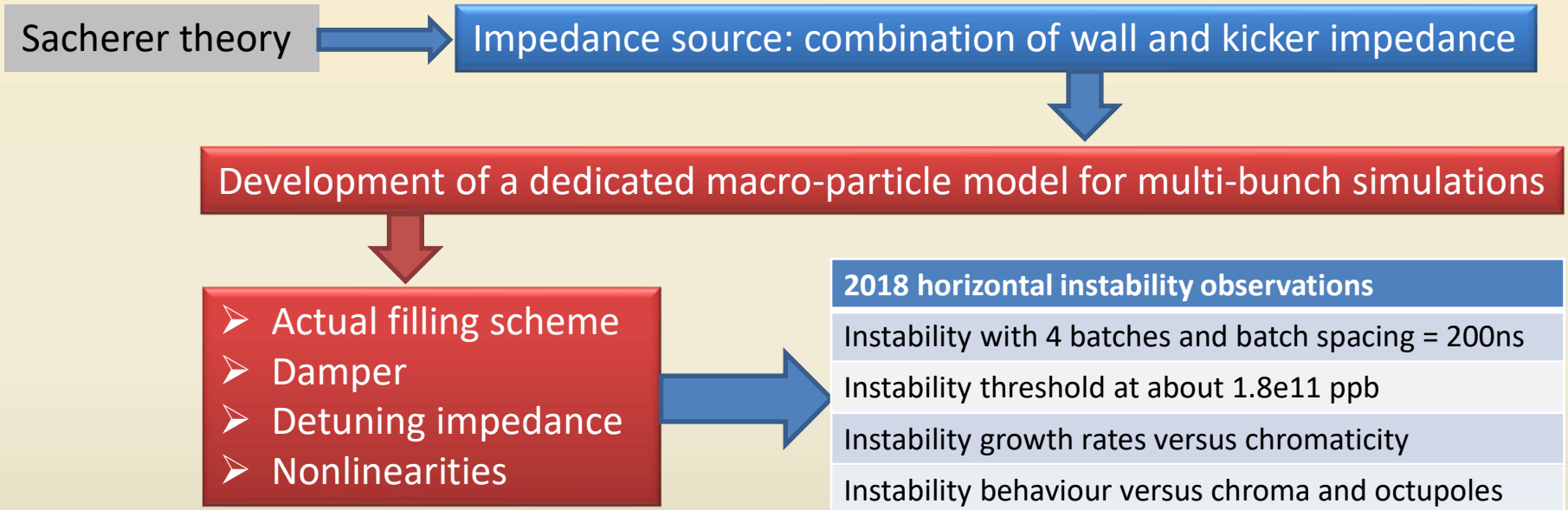




Instability behaviour with chromaticity reproduced with the SPS impedance model

Impedance source: combination of kicker and wall impedance

Understanding of the instability behaviour: macroparticle simulations



Understanding of the instability behaviour: macroparticle simulations

2018 horizontal instability observations
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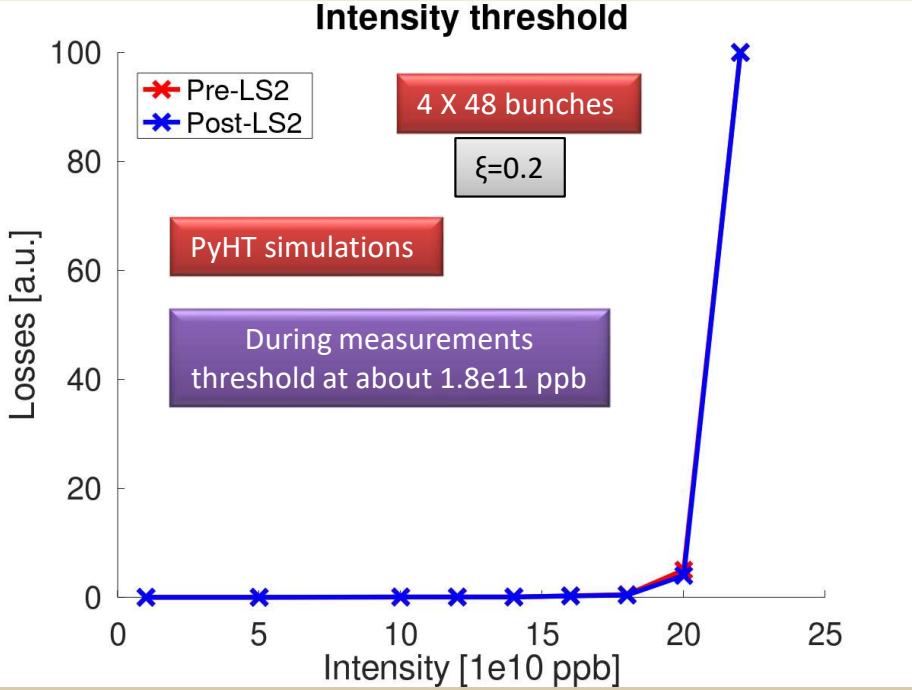
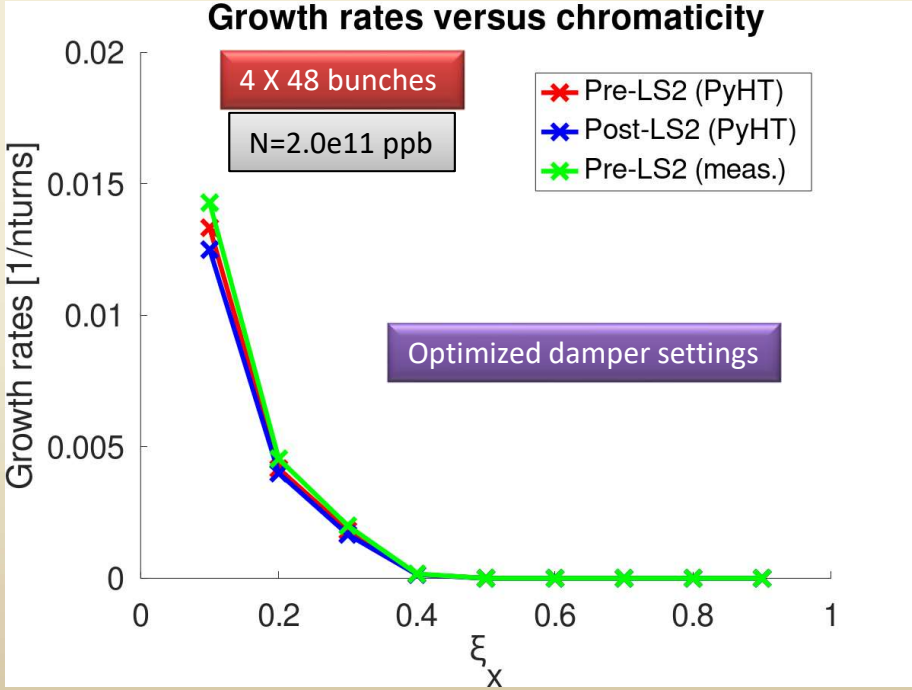
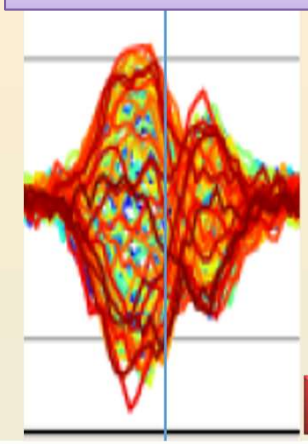
Instability threshold at about 1.8e11 ppb
Instability growth rates versus chromaticity
Instability behaviour versus chroma and octupoles





Understanding of the instability behaviour: macroparticle simulations

ξ = 0.2, LOF = -2.2



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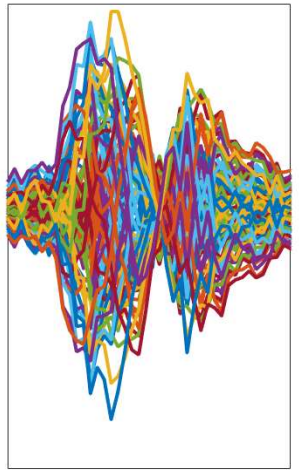
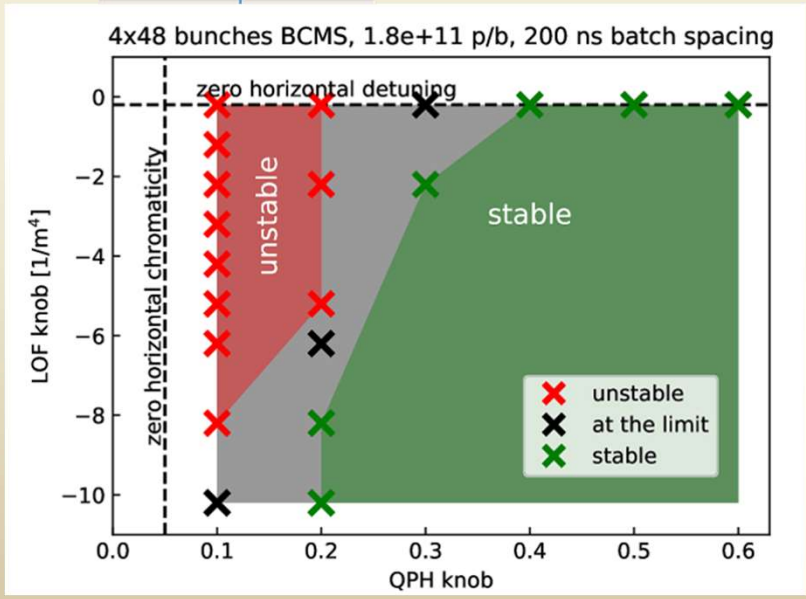
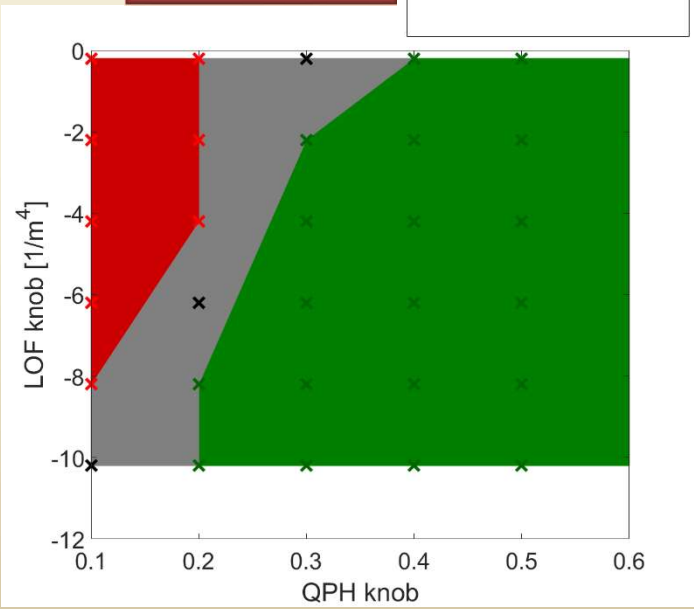


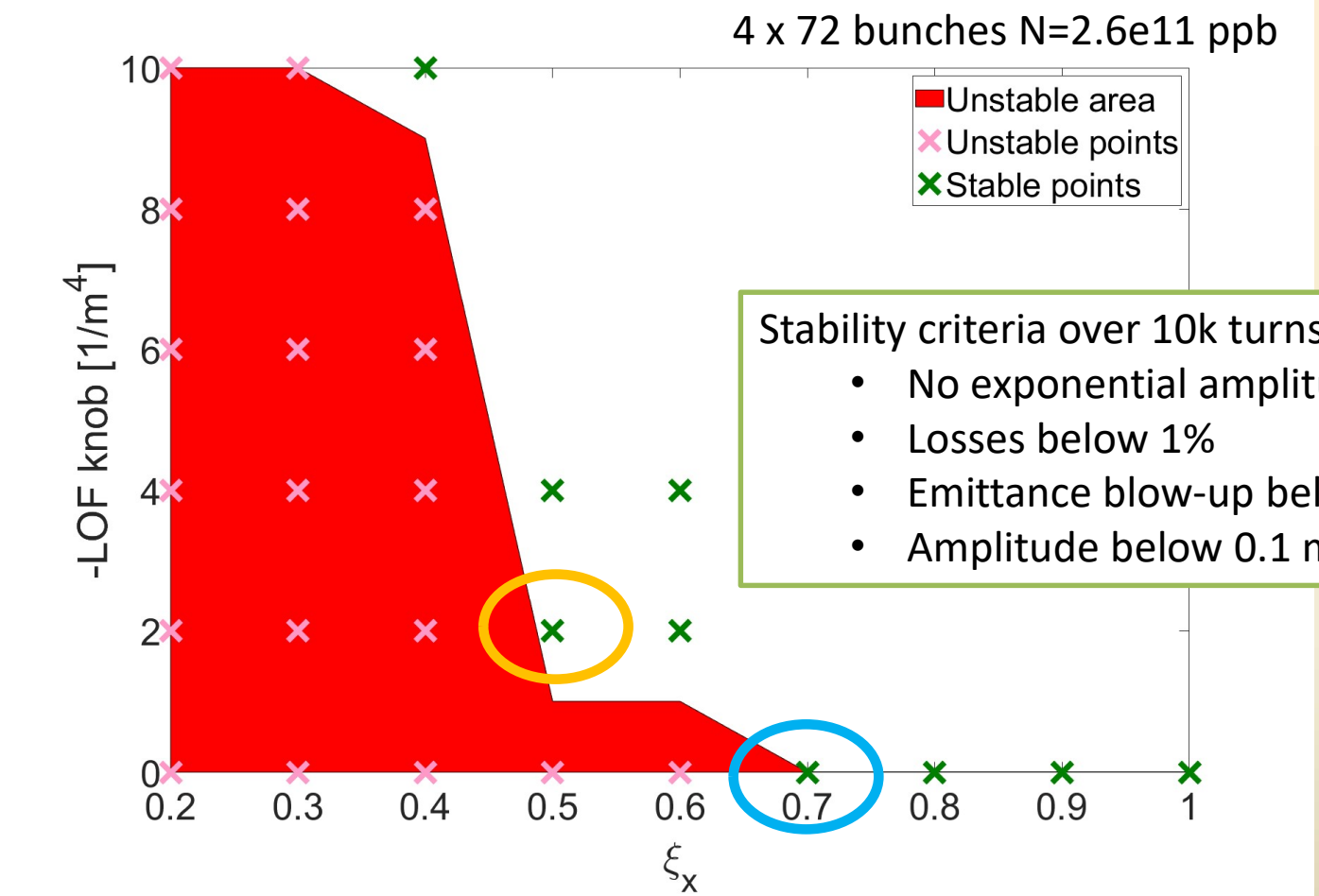
Measurements



PyHT simulations



Prediction for the nominal LIU beam



Stability criteria over 10k turns

- No exponential amplitude growth
- Losses below 1%
- Emittance blow-up below 10%
- Amplitude below 0.1 mm

Without octupoles stabilization at $\xi_x \geq 0.7$

With octupoles (-klof < 10) stabilization at $\xi_x \geq 0.5$

Stabilization strategy

- Operational knobs from simulations
  - **Stabilization of nominal LIU beam for $\xi_x \geq 0.7$ without octupoles**
  - **Chromaticity can be lowered to $\xi_x = 0.5$ using octupoles**

- An alternative mitigation solution could be represented by the employment of a wideband feedback system
  - Prototype demonstrated in the SPS in the vertical plane against TMCI
  - Efficiency against this instability to be demonstrated in simulation
  - System to be designed and deployed in the horizontal plane, possible installation in LS3 if study launched by 2023