# Coherent beam-beam effects

Simulation Results for :

- Rigid-Gaussian Model
- Soft-Gaussian Model

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# COMBI

**Goals:**

1) From Original Rigid Gaussian Bunch Model

implementations to enable the selection of the bunches to be kicked and to be observed to **reproduce real tune measurement conditions and spectra**

2) Extension to Soft Gaussian Bunch Model

implementation to multi-particle bunches to **study the effects of particle incoherent motion** (such as Landau damping) **on the coherent spectra**

# 1) Rigid Gaussian Bunch Model

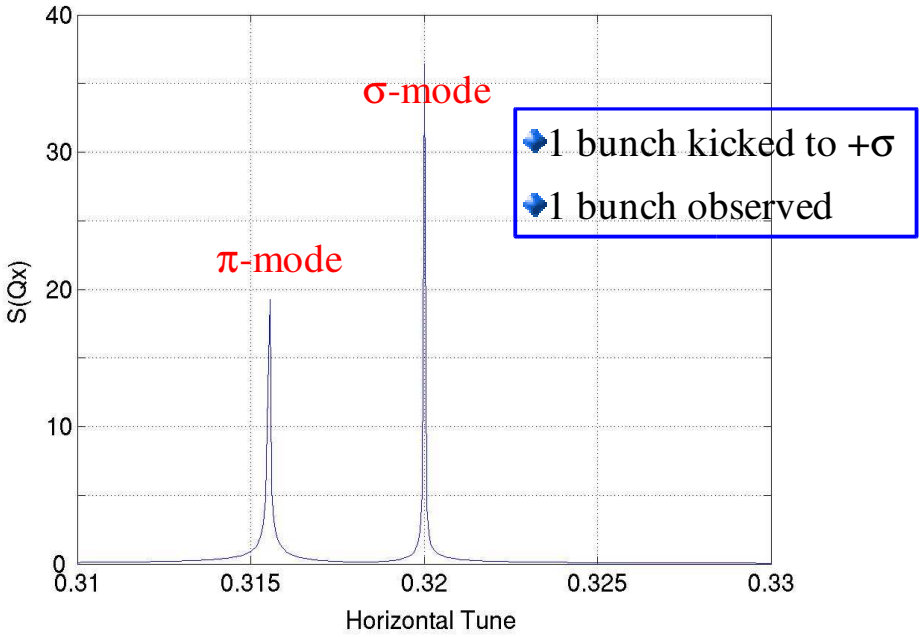
## Additional Program Features:

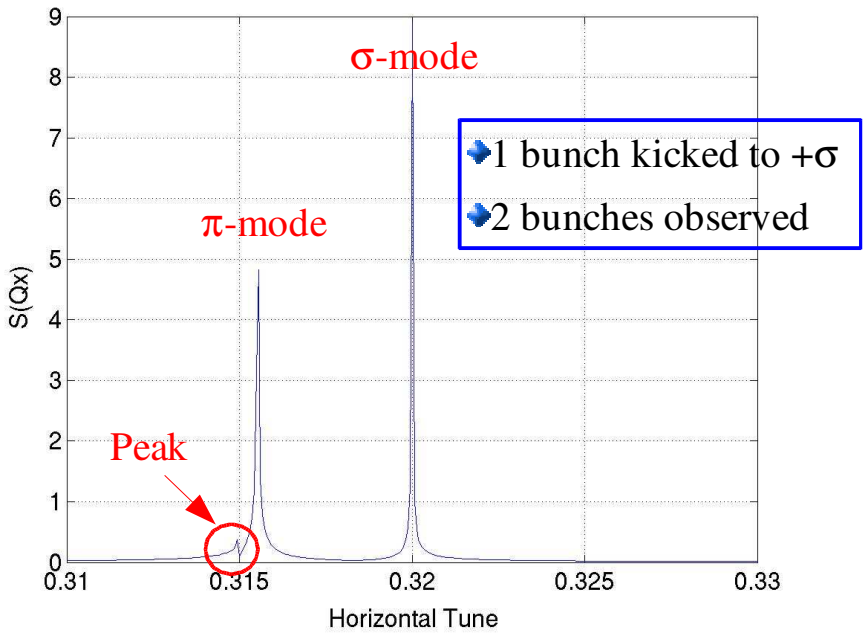
- Observation of a selected bunch and/or range of bunches (average of the output signals of selected bunches)
- Displacement of a selected bunch and/or range of bunches (kick amplitudes defined for the selected bunches can change from bunch to bunch in the beam)

**Simulations Setup**:

- 4 equidistant bunches per beam
- 2 symmetric Head-On collisions in IPs 1 and 5
- beam-beam parameter $\xi$=0.0025

# Observation of averaged output signals



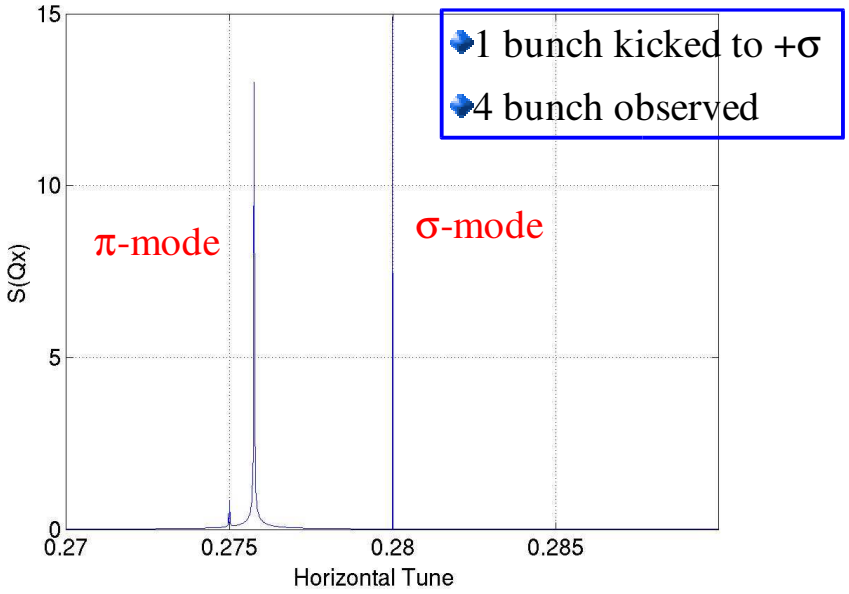



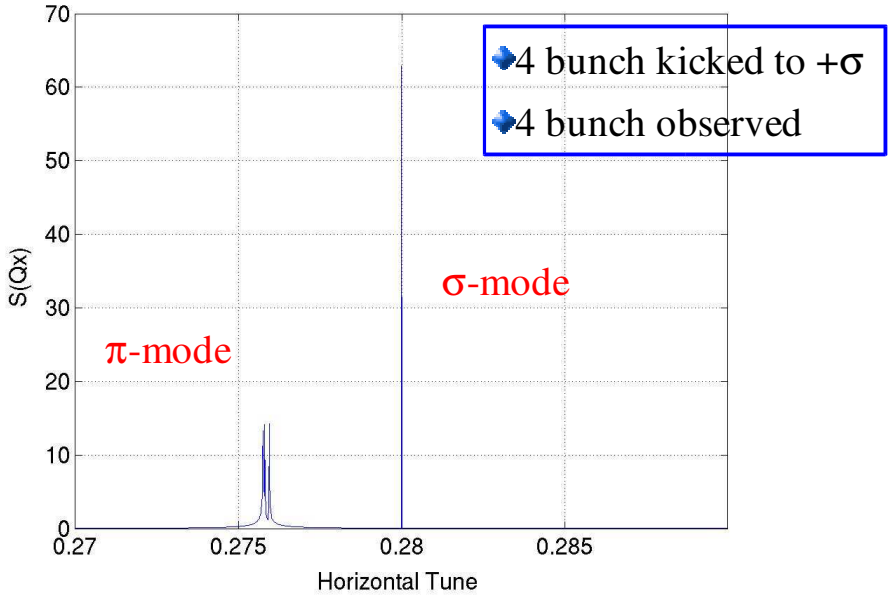

***A lower frequency peak appears if we average signals!***

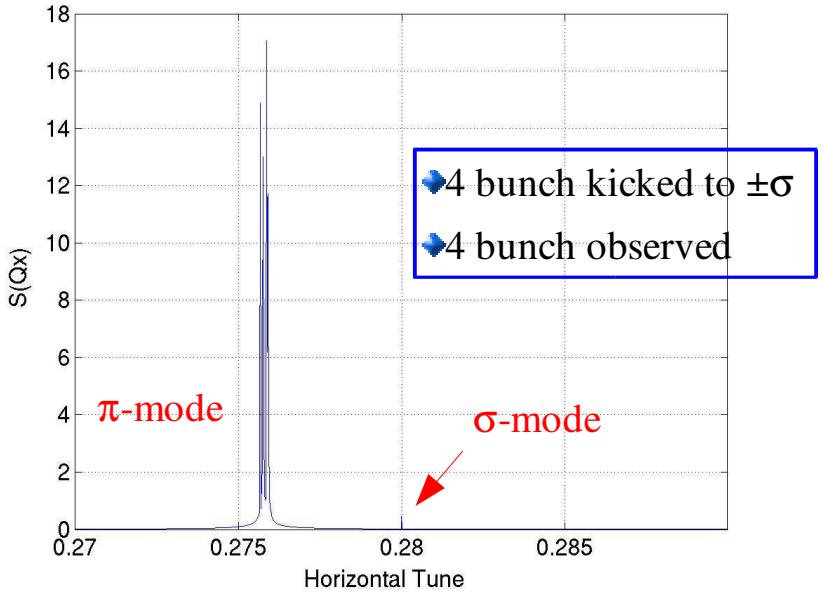
**Explanation:**

- 1 bunch kicked at +/- σ oscillates at amplitude proportional to its displacement
- Other bunches oscillate at smaller amplitudes

# Displacement of selected bunches




## Results

- Tune spectra change depending on the different type of exitations

# Results from Simulations:

- Signal Average gives additional oscillation frequencies
- Peak position depends on bb force amplitude
- Peak amplitude depends on kick amplitude
- Peak disappears with linearized bb force
- Very strong effect with bunch trains and long range interactions (Note 356 W.Herr)

**For Tune Measurements**

**preferrable single bunch excitation & observation**

# In parallel: Analytical model
# (for comparisons and cross-checks )

- matrix formalism with linearized bb force
- frequencies of modes calculated from eigenvalues
- presently with multi Head-On collisions and equidistant bunches
- Work ongoing to extend model to long range interactions and bunch train structures (i.e. holes, etc.)

# Next extensions

## Rigid Bunch Model Limitations:

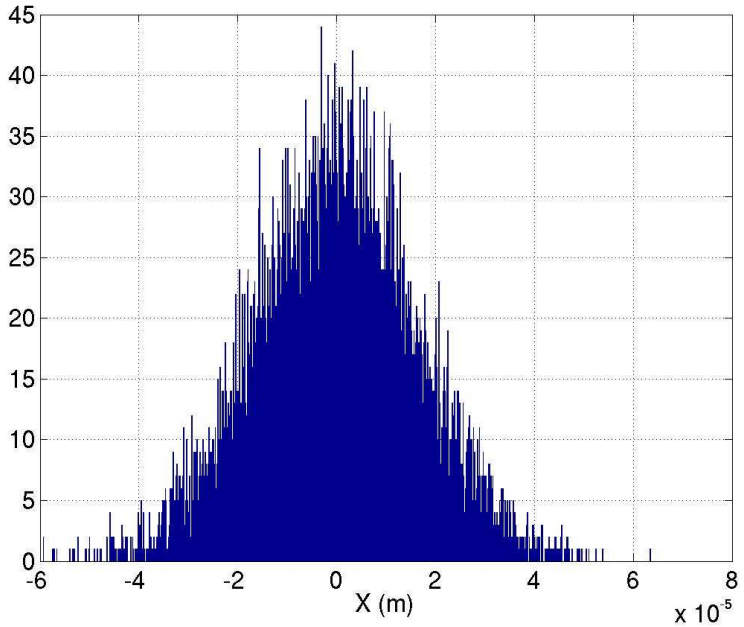
- No Landau damping
- No emittance effects
- No higher order modes

## Combi Extensions:

- Soft Gaussian Bunch Approximation
- Field Solver (i.e. HFMM)
- Parallelization (Message Passing Interface)

# 2) Soft Gaussian Bunch Model

- Np macroparticles per bunch ( Np≥10000 )
- Gaussian distribution for initial coordinates X, X', Y, Y'
- BB force kick computed from bunch size (recalculated at each interaction)
- Each macroparticle treated independently




Initial particle horizontal positions distribution

Presently run at LHC@HOME

# Validation

Simulation Setup:

- 2 equidistant bunches per beam
- 2 symmetric HO collisions in IPs 1 and 5
- $\xi$=0.003476 (for rigid bunch model)
- 1 bunch kicked and 1 observed

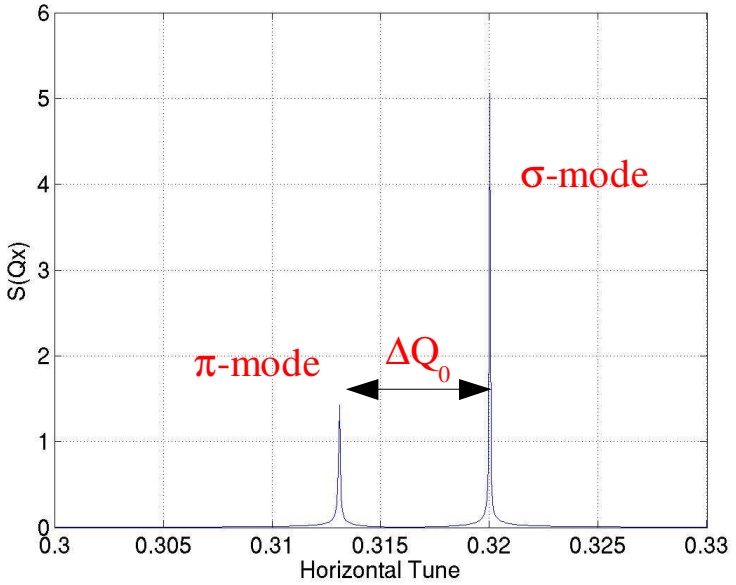
**Rigid** $\Delta Q_o = 2\xi$

**Soft** $\Delta Q_1 = 2(\approx 1.1 * \xi)$

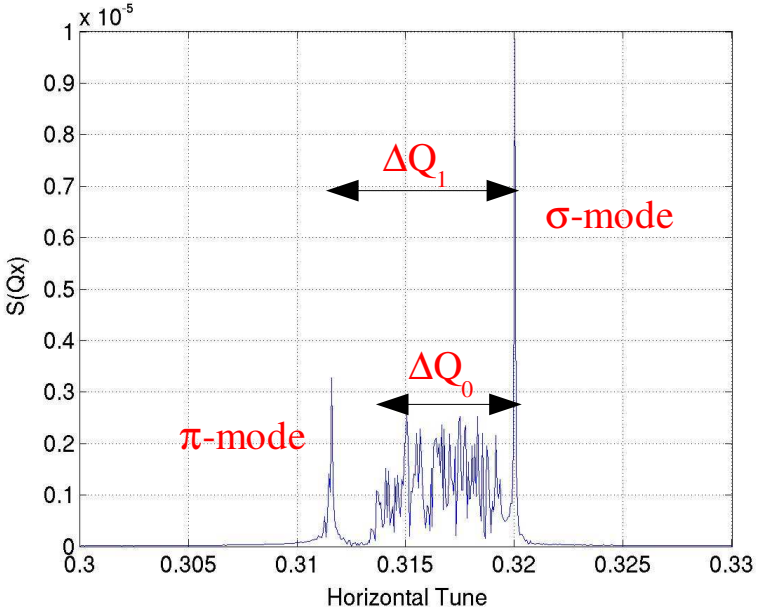
The incoherent spectrum goes from the $\sigma$-mode tune to $\Delta Q_o = 2\xi$

The program behave as expected

Rigid Gaussian Bunches



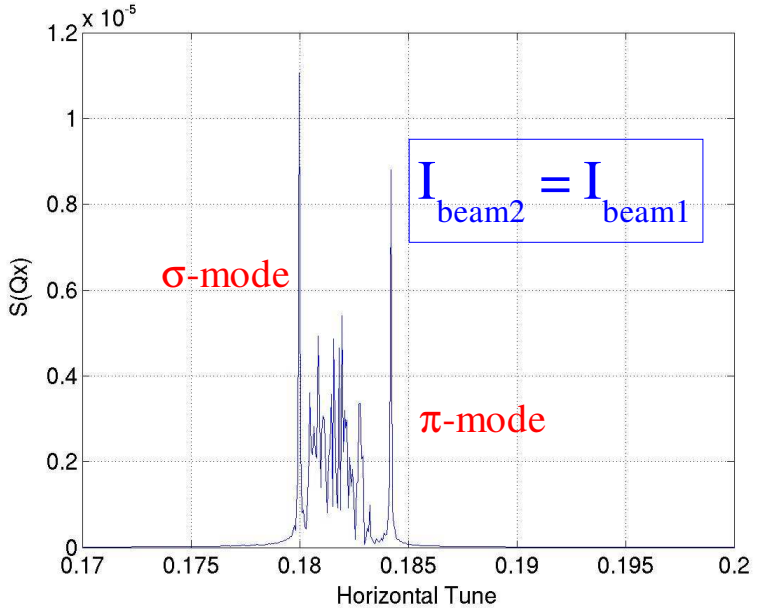

Soft Gaussian Bunches



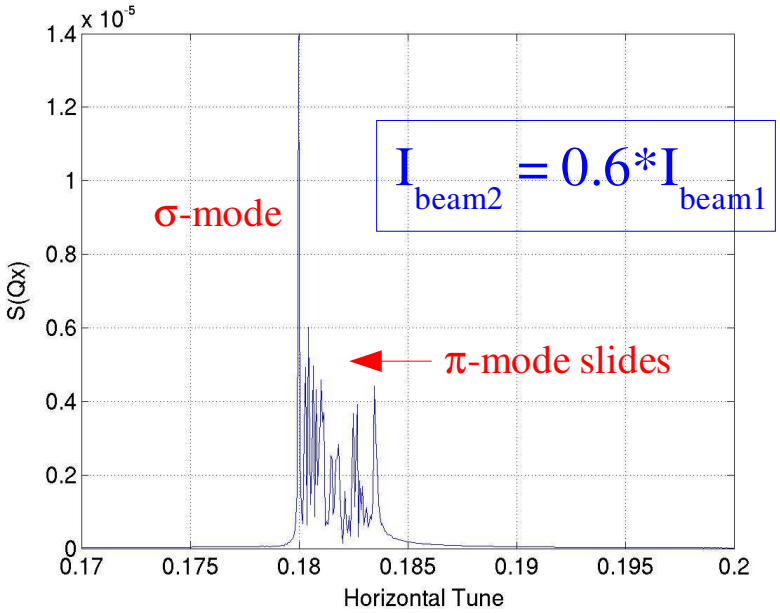
# Dependence on Intensity differences

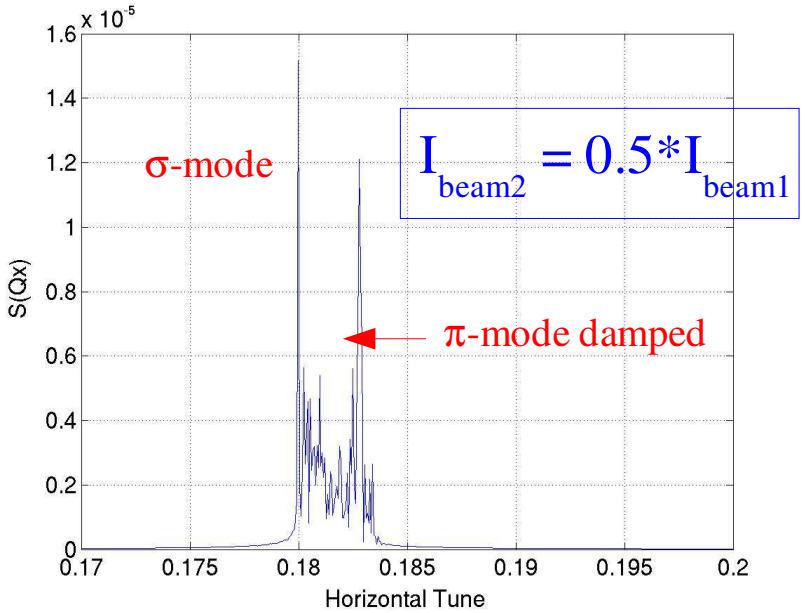
Simulation Setup:

- 1 bunch per beam
- 1 HO at IP 1
- 2**14 turns




Decreasing the intensity of the second beam the discrete **π-peak slides** into the incoherent spectrum



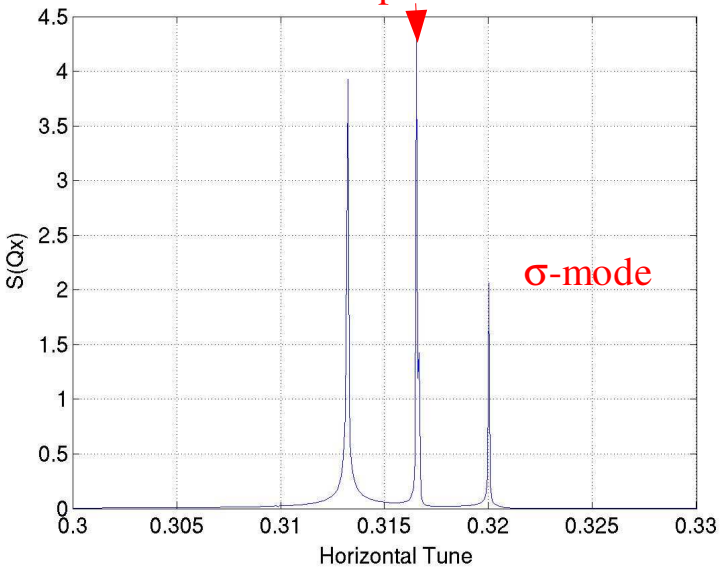



# Dependence on Collision Scheme Symmetries

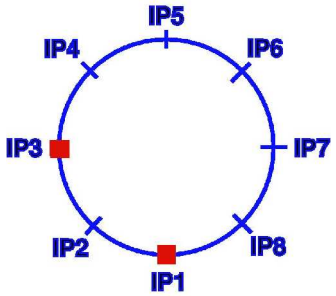
Simulation Setup:
- 4 bunches per beam
- 2**14 turns
- 2 HO (red squares in schemes)

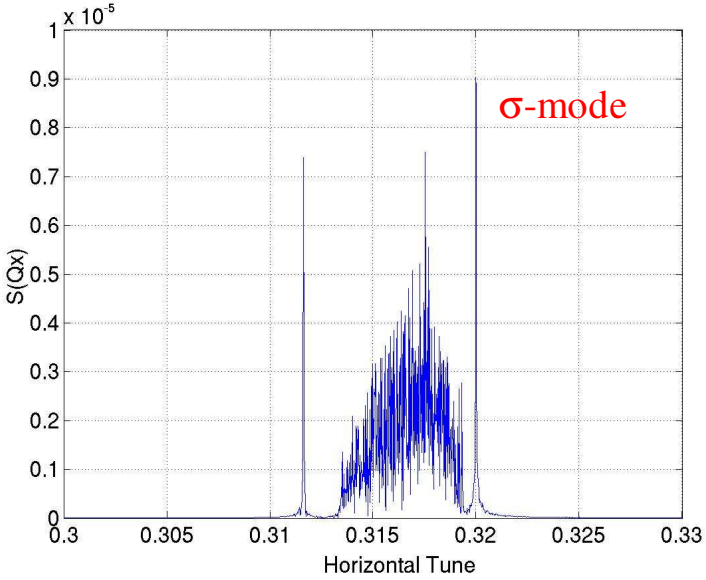
Rigid Gaussian Bunches

Damped mode

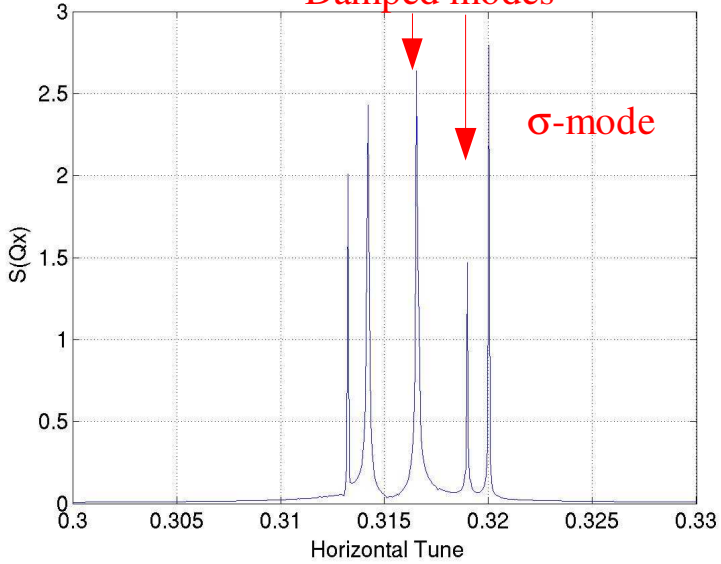



Collision Scheme

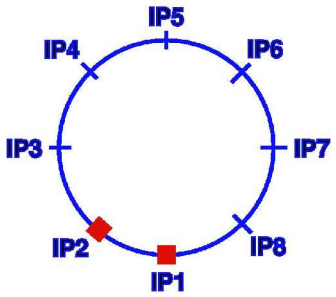


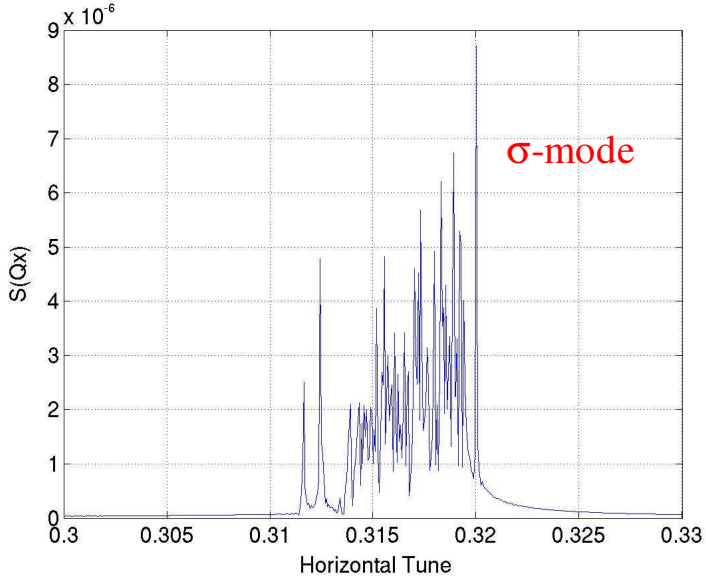




Damped modes




Collision Scheme




Soft Gaussian Bunches

**Damping effects suppress modes in the vicinity of the σ-mode**

# Work in Progress:

## Rigid bunch Model

- kicked/observed bunches at beginning or in the centre of trains?
- study Pacman and Super-Pacman effects

## Analytical model

- extention to long range interactions and beam train structures

## Soft Gaussian bunch model (head-on & long range)

- Simulation campaign to produce tune spectra for different collision schemes and beam structures (i.e. LHC layouts)
- Field solver (HFMM) to get quantitatively correct results (10000 particles per bunch and 2800 bunches per beam)
- Parallelization (MPI) to speed up the field calculations by treating each bunch on parallel machines and retrieve the results