Recent beam-beam observations

(... and some more beam-beam basics)

reported by W. Herr

Beam-beam observations, 2 sessions planned

31. October

- **12 bunches per train, 50 ns spacing, stable beams**
- **observation of stable beams, separation scan IP8, damper off**

First significant long range contribution

4. November

- **24 bunches per train, 50 ns spacing, stable beams**
- **observation of stable beams, separation scan IP8, damper off**

Full long range contribution

Beam-beam observations, 2 sessions planned

31. October

- **12 bunches per train, 50 ns spacing, stable beams**
- **observation of stable beams, separation scan IP8, damper off**

First significant long range contribution

4. November no beam !

- **24 bunches per train, 50 ns spacing, stable beams**
- **observation of stable beams, separation scan IP8, damper off**

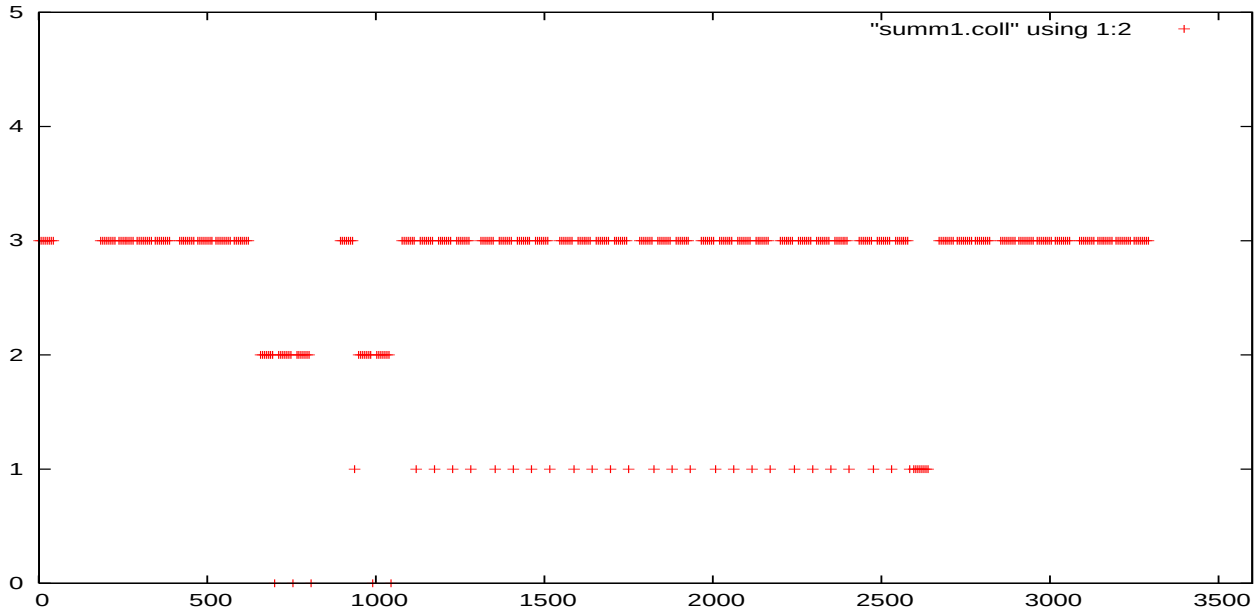
Full long range contribution

The interest for beam-beam:

- Shorter bunch spacing
- Many more long range interactions
- Separation in LHCb to reduce luminosity:
  - Works in ALICE
  - Does it work with many additional LR interactions ?
- Do bunches behave (even more) differently ?

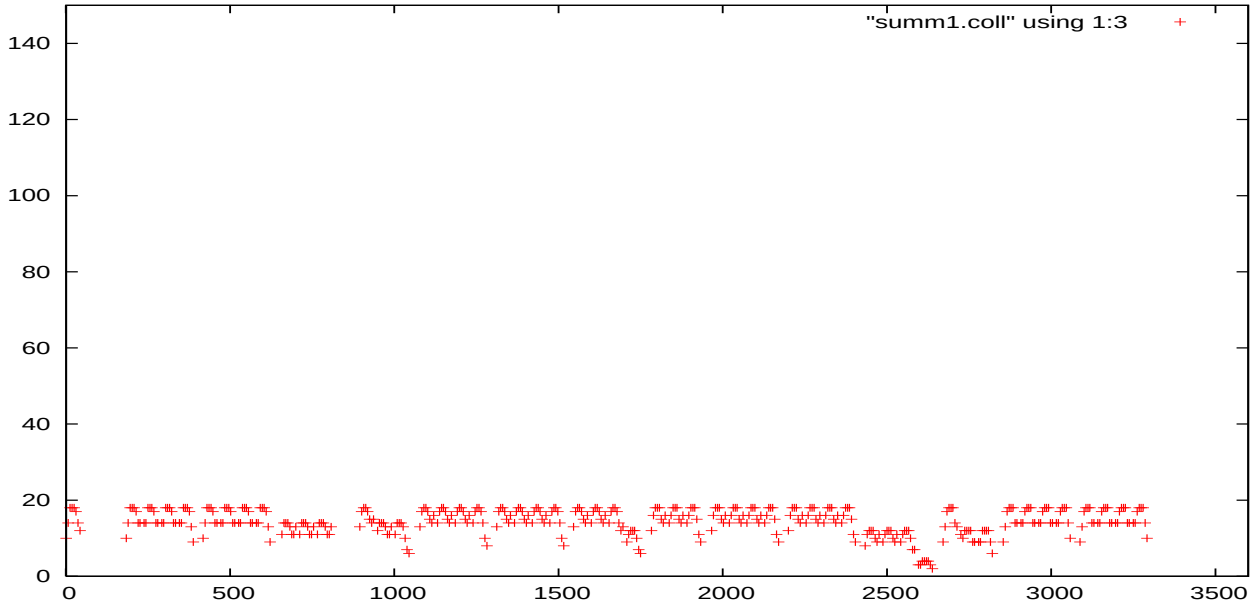
(some numerology first ..)

Numerology - collisions



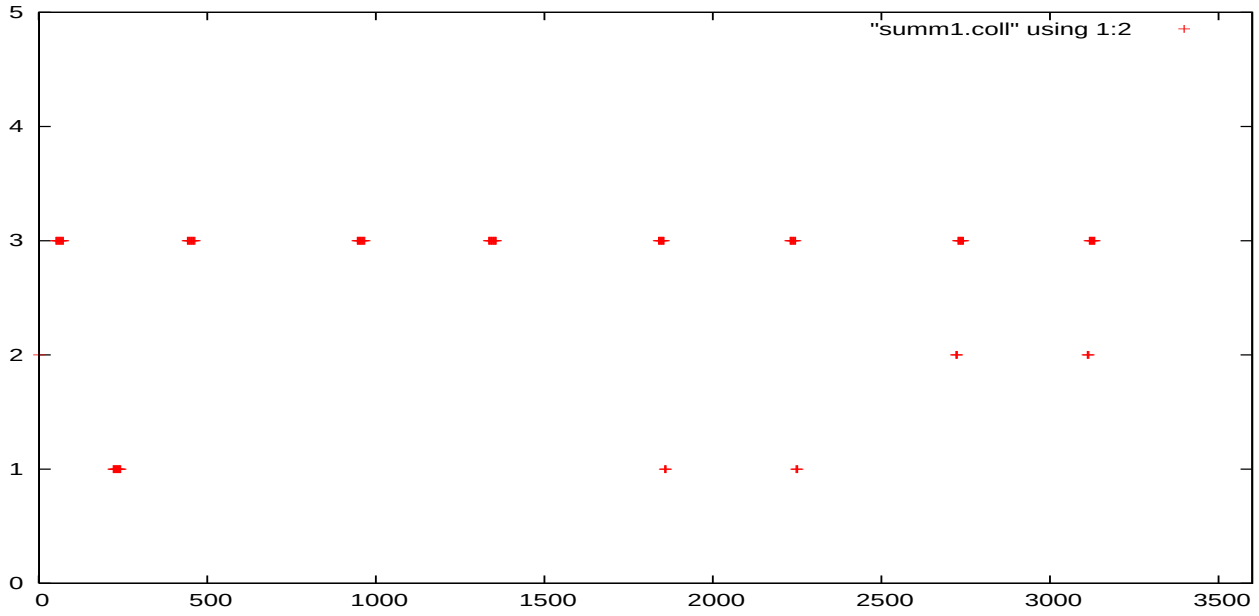
- **150ns spacing, 8 bunches per train, 424 bunches, maximum head-on: 3**

Numerology - collisions



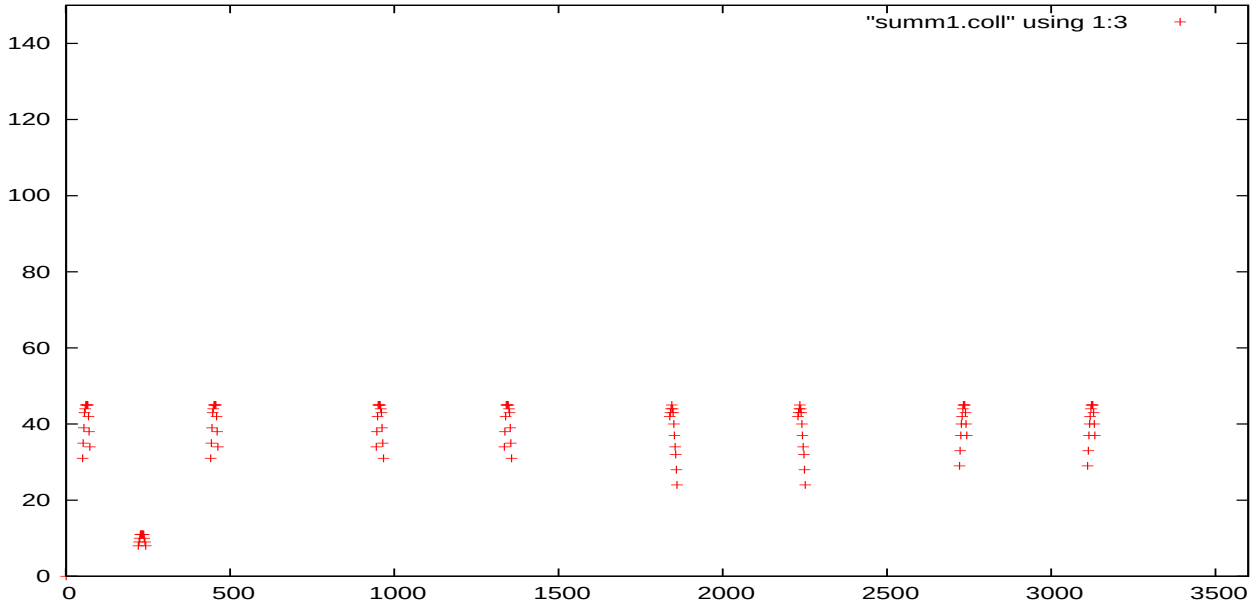
→ **150ns spacing, 8 bunches per train, 424 bunches, maximum long range: 18**

Numerology - collisions



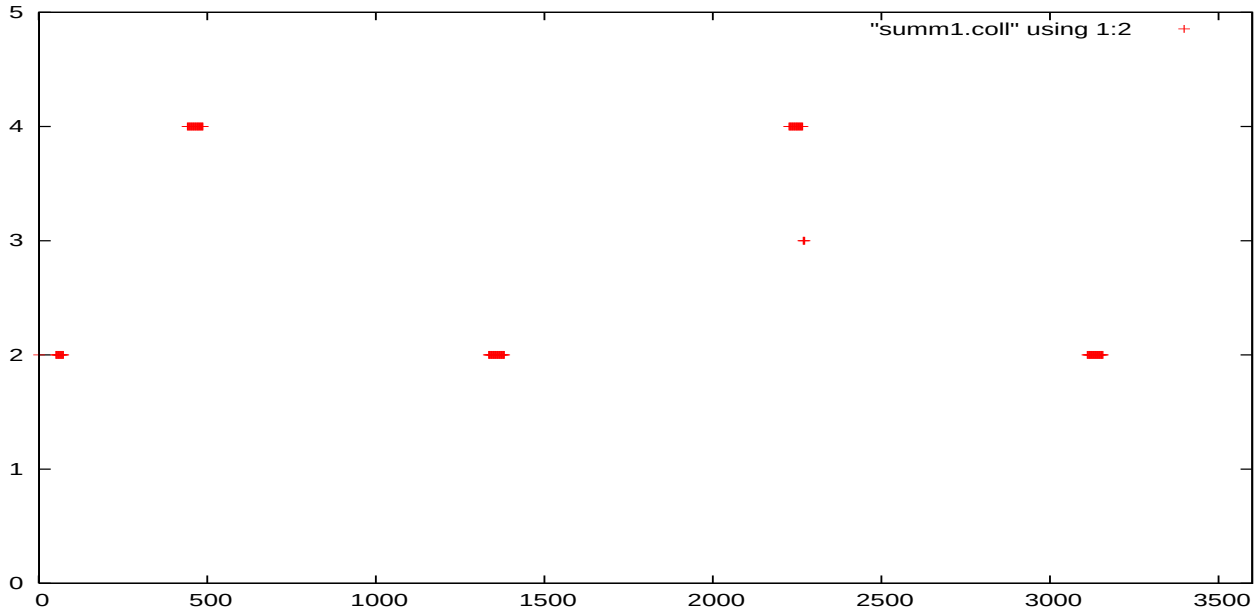
→ **50ns spacing, 12 bunches per train, 108 bunches, maximum head-on: 3**

Numerology - collisions



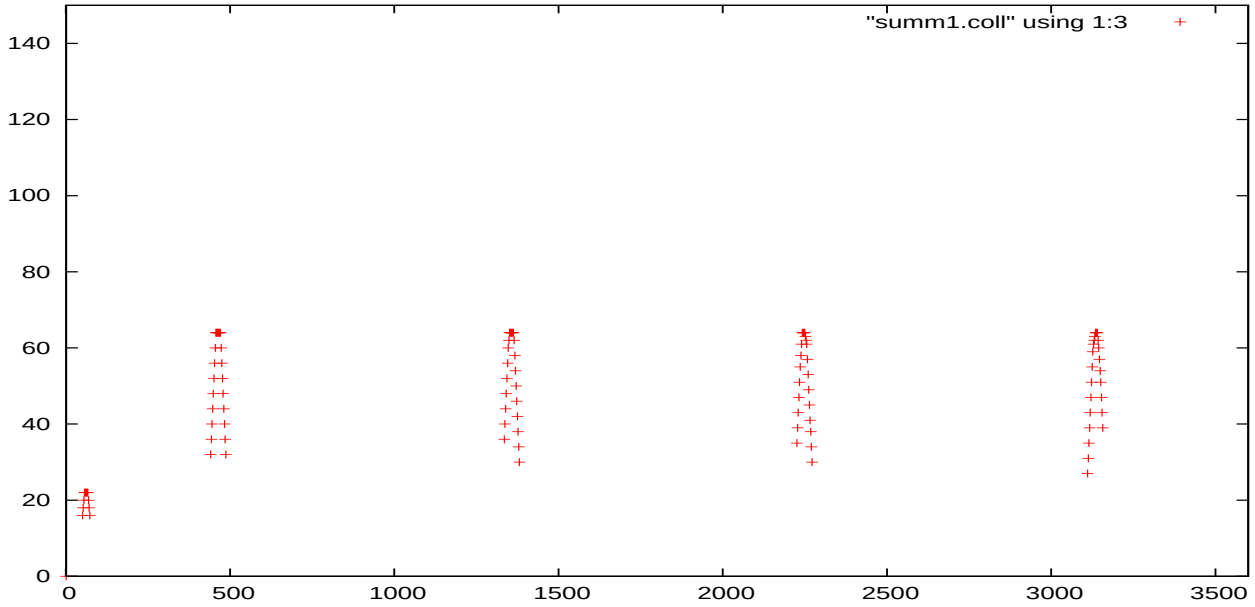
- **50ns spacing, 12 bunches per train, 108 bunches, maximum long range: 45**

Numerology - collisions



- **50ns spacing, 24 bunches per train, 108 bunches, maximum head-on: 4**

Numerology - collisions



- **50ns spacing, 24 bunches per train, 108 bunches, maximum long range: 64**

Numerology - collisions

	150 ns, 8b	50 ns, 12b	50 ns, 24b
Total bunches	424	108	108
Maximum head on	3	3	4
Maximum long range	18	45	64

Observations in stable beam mode (31.10.)

Conditions:

- **About 40% bunch to bunch intensity fluctuations**

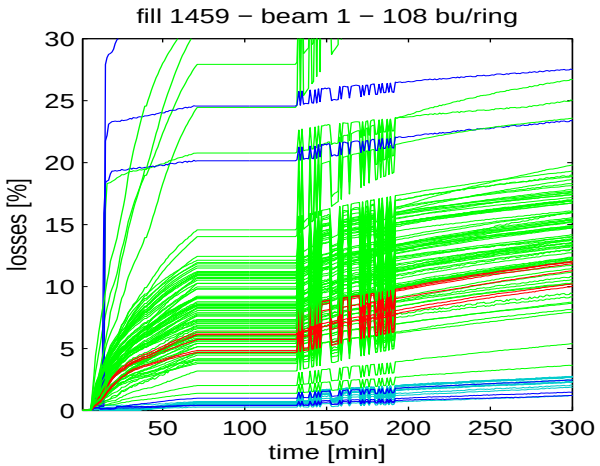
  (reduction along the train)

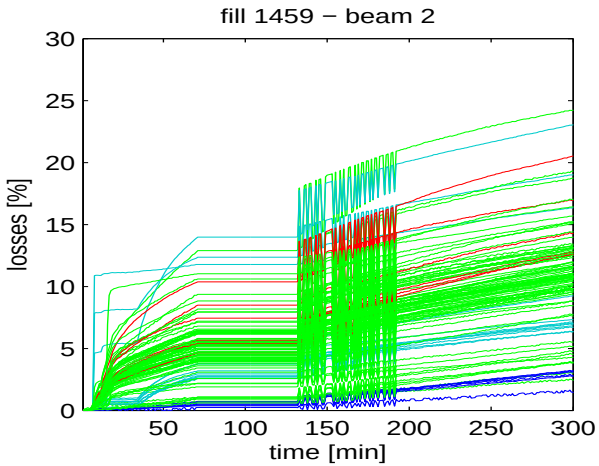
- **Chromaticity unknown (big losses at end of squeeze, cured with ADT)**

- **Emittances $\approx$ 3 μm**

- **No fast BCT logged during the experiments ..**

Beam losses, 12b/train

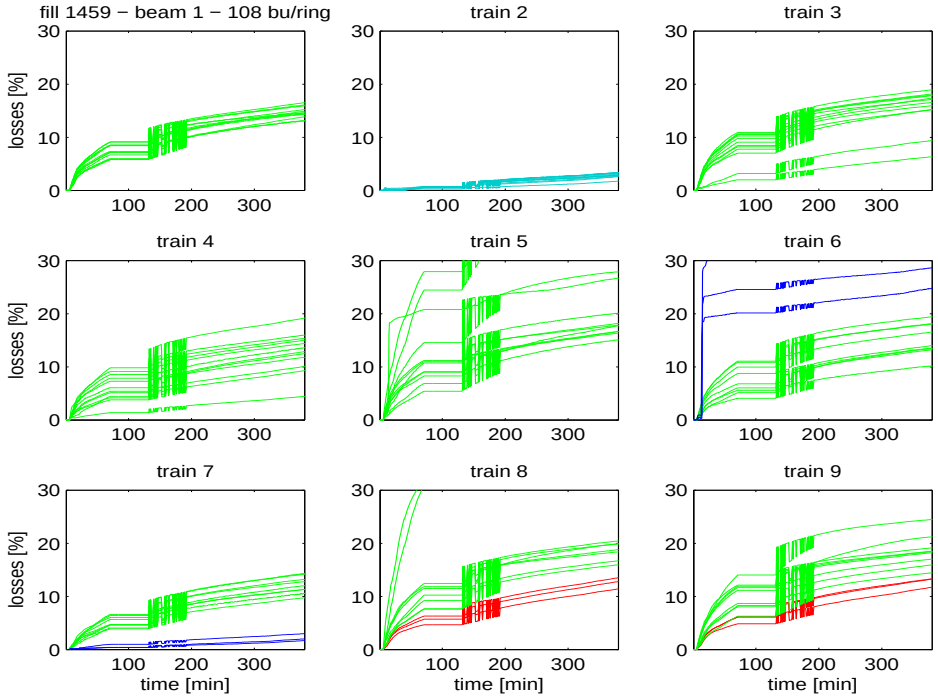




(Prepared by G. Papotti BE-OP-LHC)

→ **Beam losses during the run, strong variation (long range ?)**

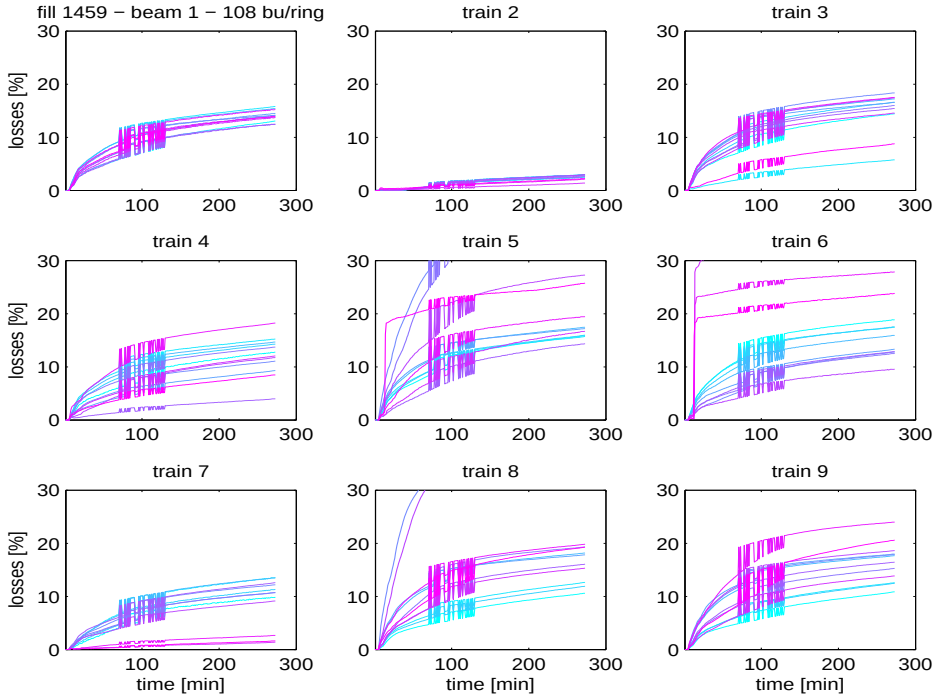
Beam losses, 12b/train



(Prepared by G. Papotti BE-OP-LHC)

→ **Losses during the run (beam 1), each train separately**

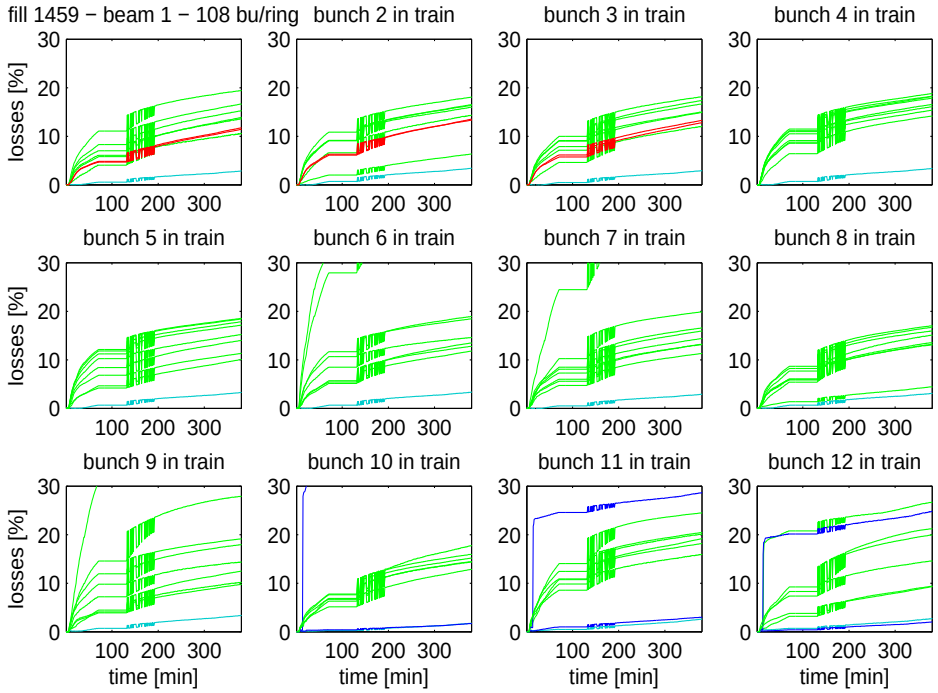
Beam losses, 12b/train



(Prepared by G. Papotti BE-OP-LHC)

→ **Losses, each train separately, bunches sorted**

Beam losses, 12b/train



(Prepared by G. Papotti BE-OP-LHC)

→ **Losses during the run, for bunch position within train**

Observations in stable beam mode

- First physics run with 50 ns spacing, 12 bunches/train
- Loss pattern reflects (somehow) collision scheme
- Clear effect of long range interactions not (yet) visible (but may be there)

→ Study with 24 or 36 bunches per train will improve the picture

→ Single bunch tune measurement would allow to bring it home (available for second session only)

Separated beams in LHCb

- **Purpose: test whether can run with separated beams (reduced luminosity)**
- **Beams were separated slowly up to 6 σ**
- **No effect on life time or tune spectra visible**
- **However: limited long range contribution (only 12 b/train), should be repeated for 24 b/train, otherwise not conclusive**

Transverse damper off

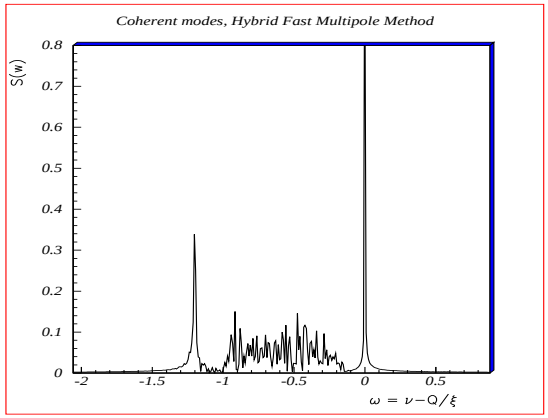
- **Damper (ADT) was turned off to observe effect in frequency spectra**
- **Procedure:**
  - **Reduce gain to half (no effect)**
  - **Switch off completely (beam losses start after $\approx$ 10 seconds)**
  - **Switch on again (beam stable)**
  - **Repeat procedure with tune split between beams 0.005, (beam stable)**
- **Did we observe a coherent beam-beam mode ?**

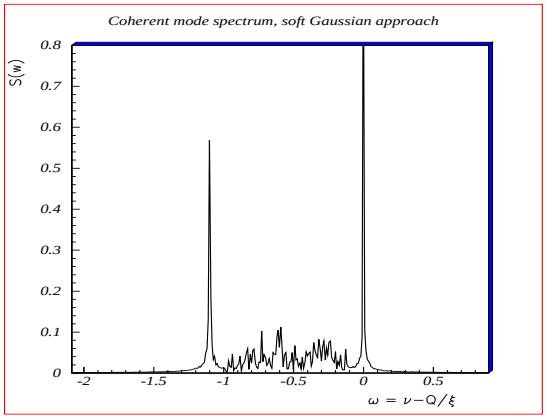
Interlude: coherent beam-beam

- The two beams can couple to coherent beam-beam modes (0-mode, π-mode, higher order)
- Strictly speaking: unstable only near low order resonance
- Oscillation can cause emittance growth or some losses
- Can be cured with feedback or avoided by proper choice of parameters
- Most important for very clean machine: 1x1 bunch

→ How do they look like ?

Beam-beam coherent modes - spectra



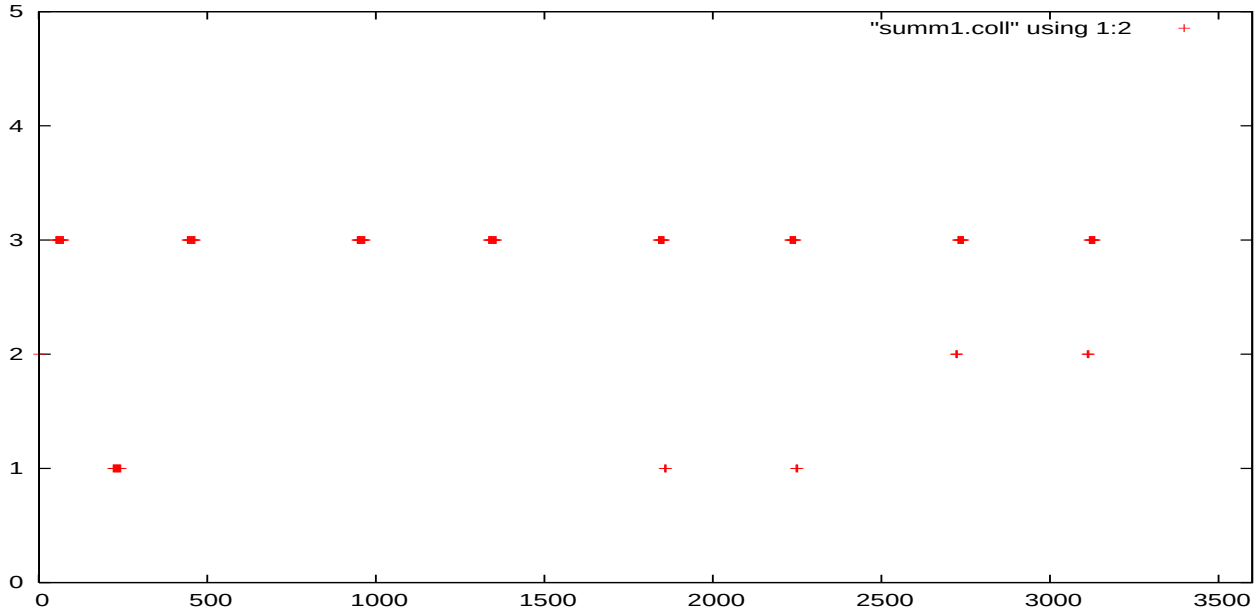


- **Continuum (tune spread), 2 peaks (0- and π-mode)**
- **Soft Gaussian approximation and correct computation**
- **"π"-mode outside incoherent spectrum (i.e. beam-beam tune spread), no Landau damping ..**

Beam-beam coherent modes - cures

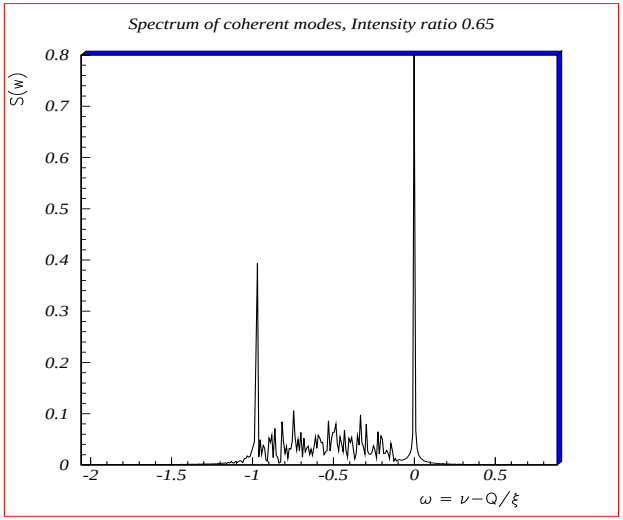
- Breaking the symmetry: moves "π"-mode closer (or into) to incoherent spectrum, Landau damping restored
- Caused by (e.g., there are more ..):
  - → Different tunes (tune split or bunch-to-bunch tune variation)
  - → Different tune shifts (different Intensities, Emittances, collision schemes)
  - → Synchrotron sidebands
- No coherent modes when the machine is dirty enough
- Most important for very clean machine: 1x1 bunch

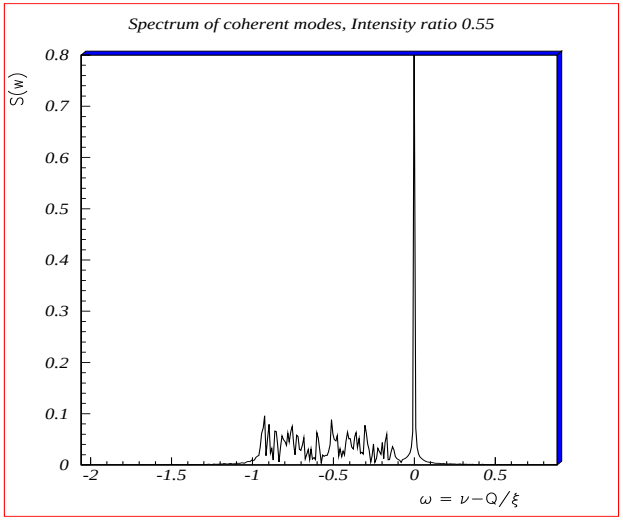
Numerology - collisions



- **50ns spacing, 12 bunches per train, 108 bunches, maximum head-on: 3**
- **clean for some bunches .... !**

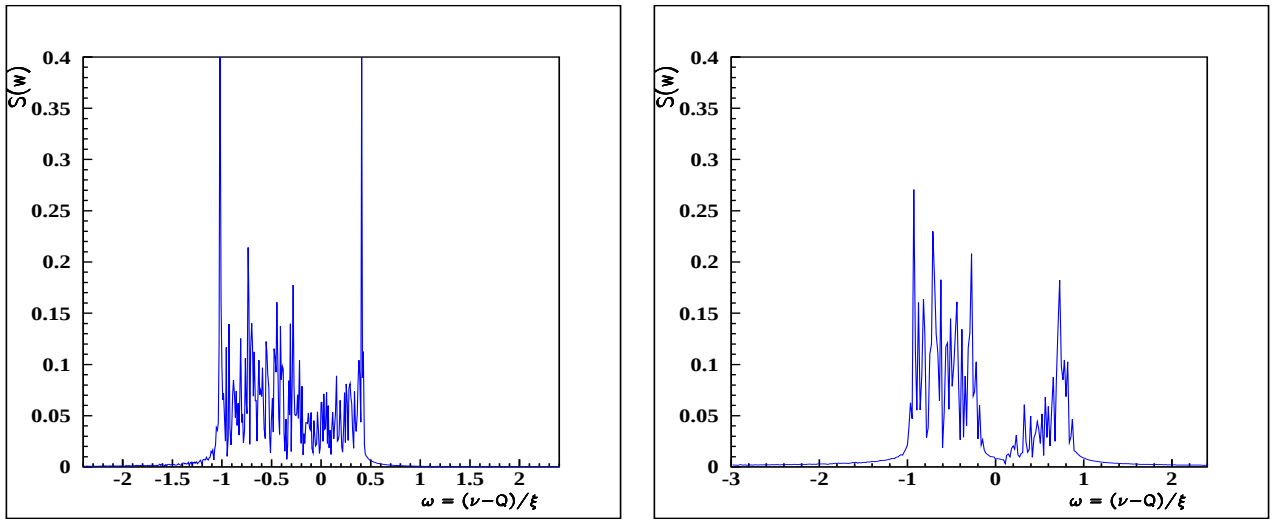
Beam-beam coherent modes





- **Intensity ratio 0.65 and 0.55**
- **π-mode merged with incoherent spectrum**
  - **Landau damped**

Beam-beam coherent modes



- **Tune split: $\Delta Q = 0.002$ and $\Delta Q = 0.003$**
- **π-mode beams decoupled, but ...**

Beam-beam coherent modes

- **Have we observed a coherent beam-beam mode ?**
  - **Maybe, but:**
  - **Experimental conditions not optimal (number of bunches, chromaticity ?)**
  - **Damper already needed before colliding beams**
  - **Diagnostics not optimal (bunch by bunch necessary, should be better now, but ..)**
- **Need more tests with 24 bunches per train (50 ns)**