Long Pulse Operation

One step towards design parameters

Fast machine protection

- Recap
- Toroid Protection System

FEL studies

- Operation with 800 bunches

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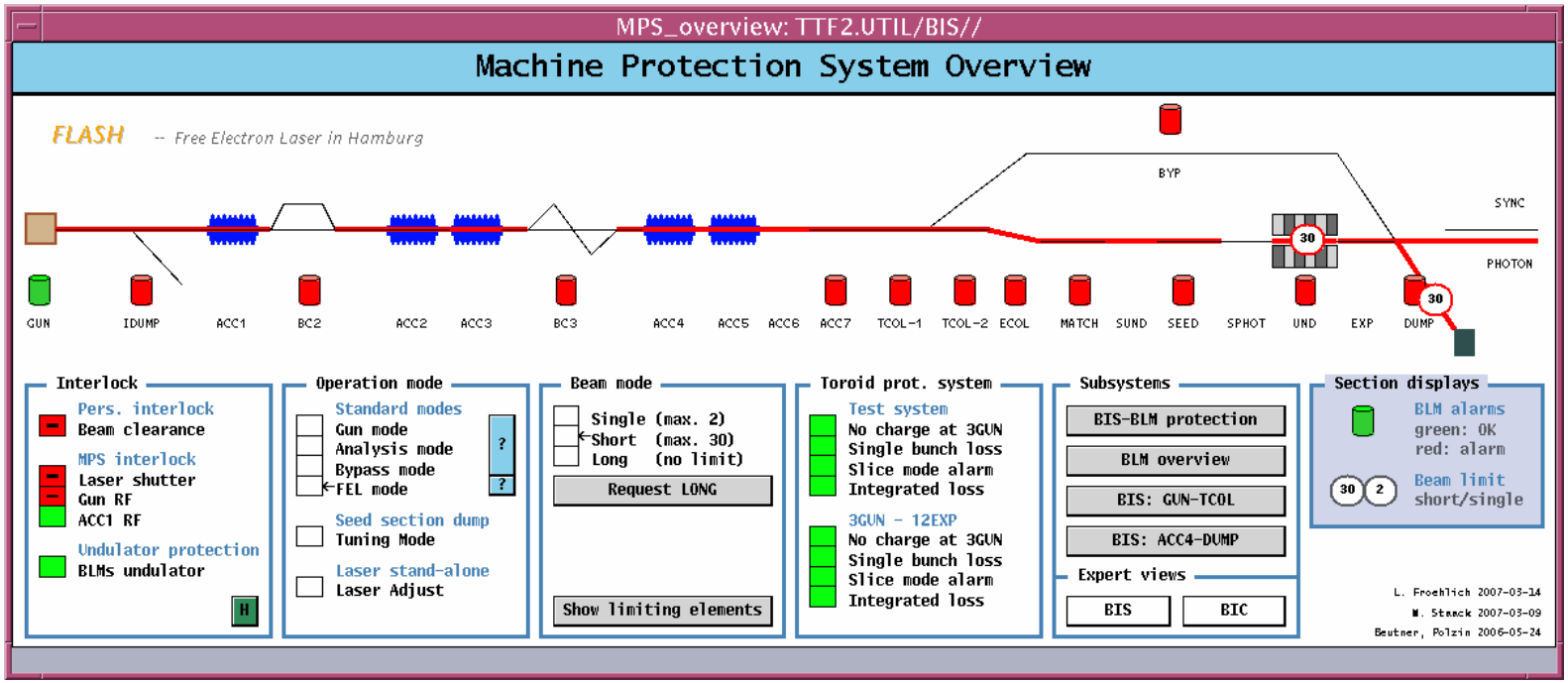
Fast Machine Protection

Lars Fröhlich, MPY

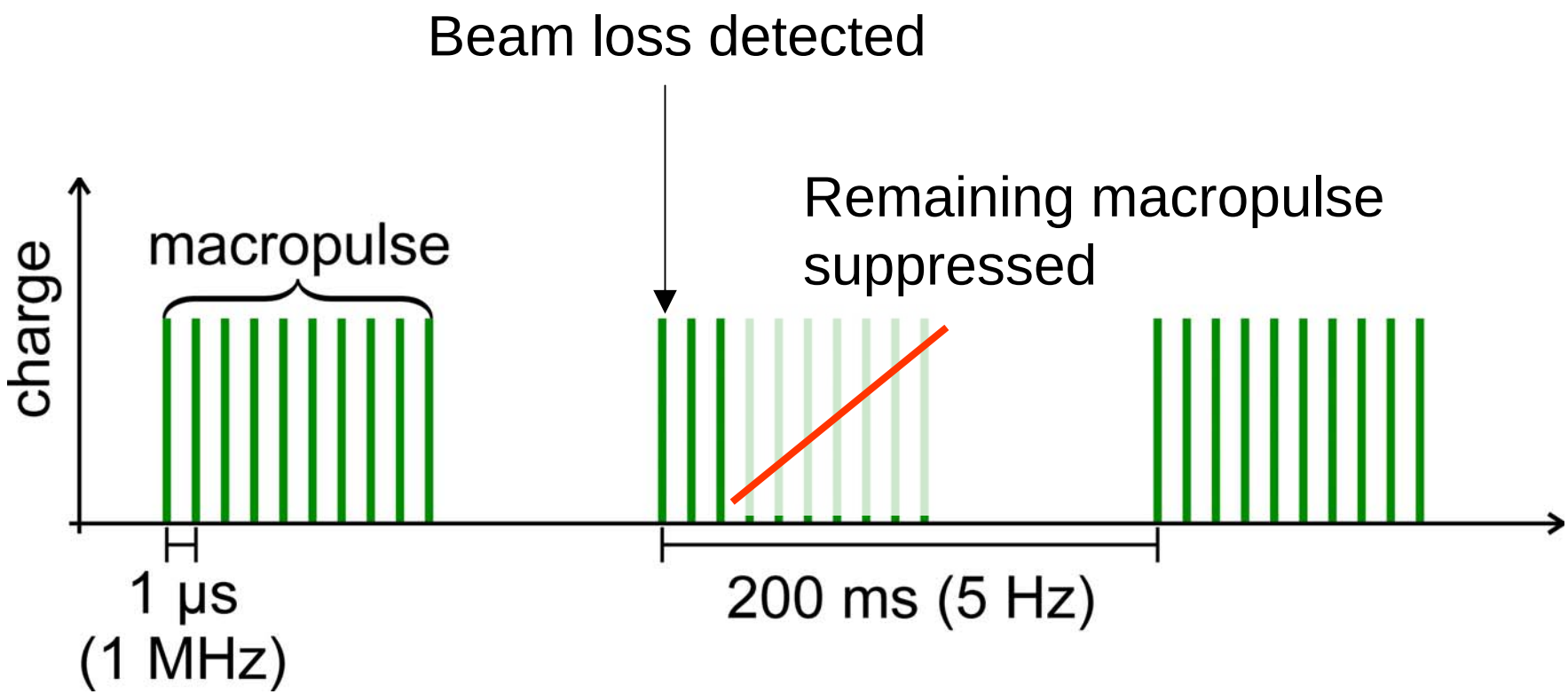
Beam Mode

There are three beam modes:

- **Single** pulse mode (up to **2** bunches, no fast protection)
- **Short** pulse mode (up to **30** bunches, no fast protection)
- **Long** pulse mode (**unlimited** bunches, fast protection **active**)

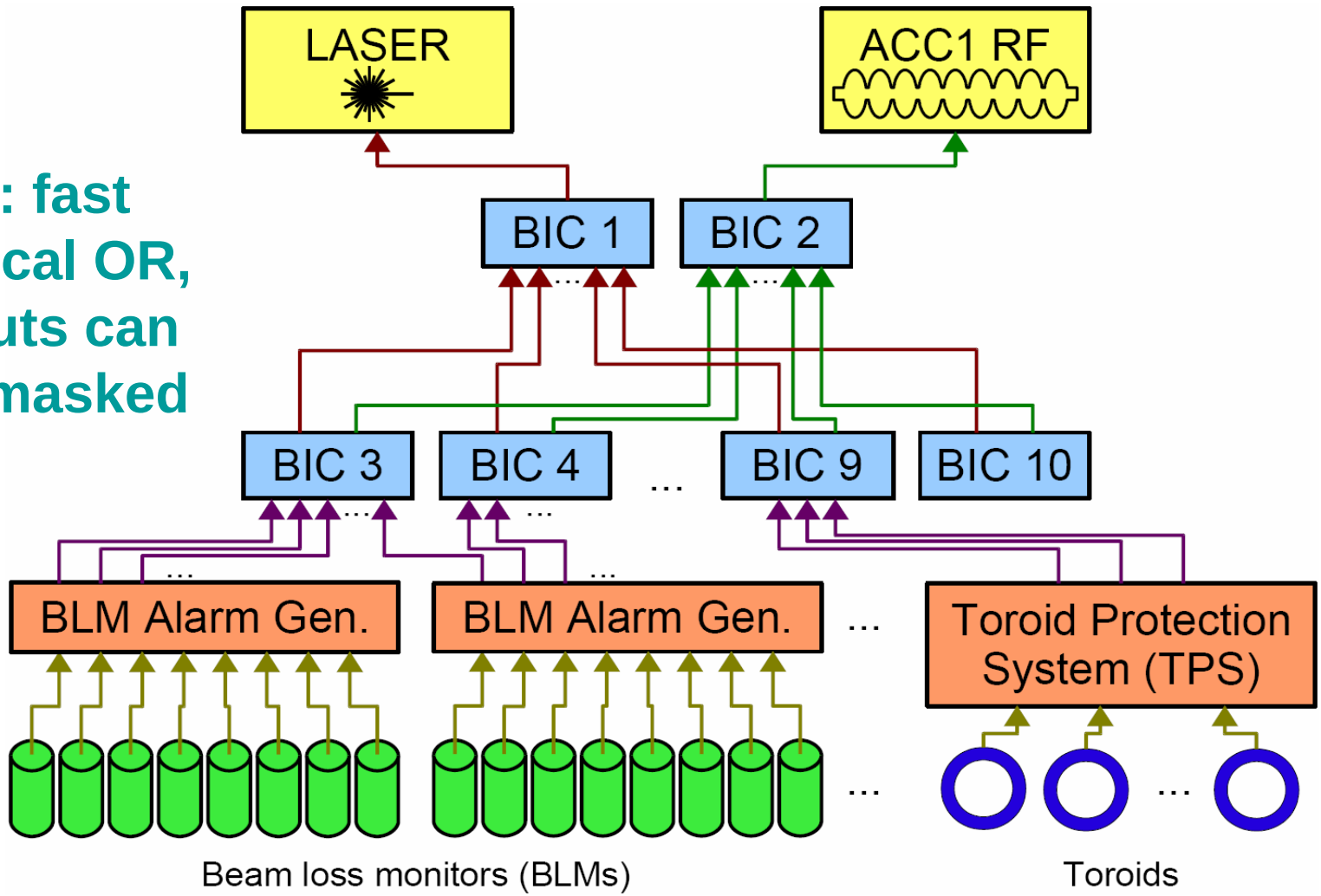


Fast Machine Protection



Beam Interlock Concentrators

BIC: fast logical OR, inputs can be masked



Toroid Protection System (1)

The TPS monitors the charge difference between two points in the machine.

Inputs

- 9 MHz machine clock
- bunch gate
- 2x analog toroid signal

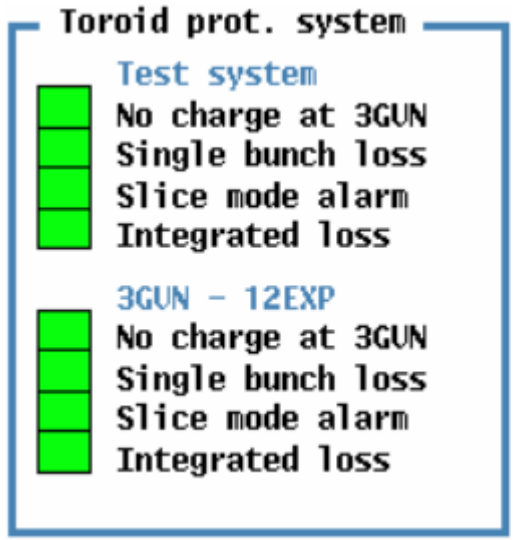
Features

- fully digital signal processing
- response time << 1 µs
- independent of control system

Toroid Protection System (2)

The TPS generates 4 types of alarms:

- **Charge validation:**
  There is no charge on the upstream toroid.
- **Single bunch:**
  One bunch has lost more than 25% of its charge.
- **Slice mode:**
  More than 6% loss over a sliding window of 30 bunches
- **Integration mode:**
  Total loss of more than 20 nC



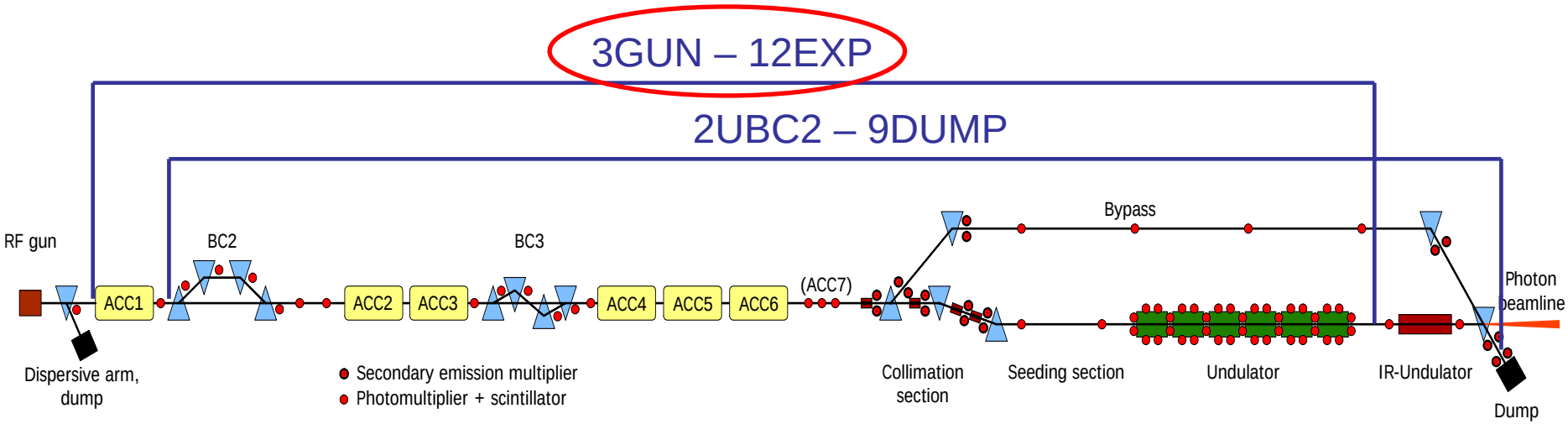
Toroid Protection System (3)

Four independent crates planned:

Two for **FEL mode**

Two for **bypass mode**

Tested and active by default



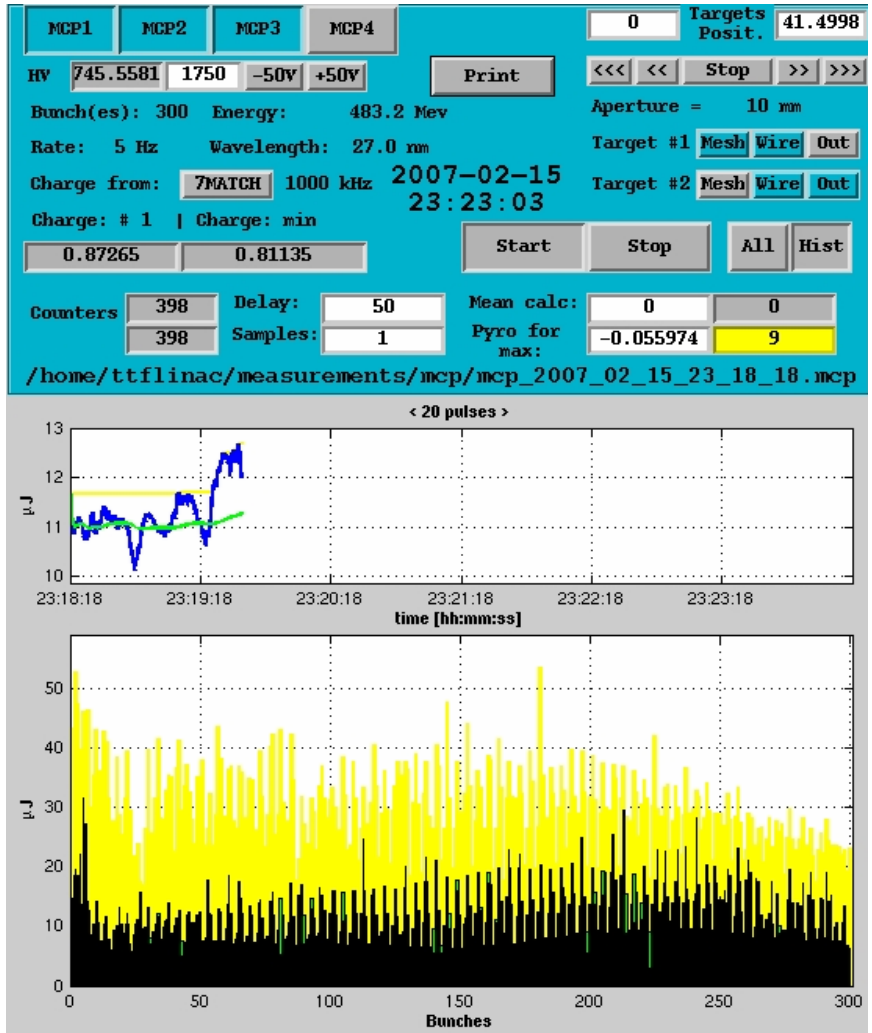
FEL Studies

Feb 15, 18:00 – Feb 17, 3:00

Lars Fröhlich, MPY

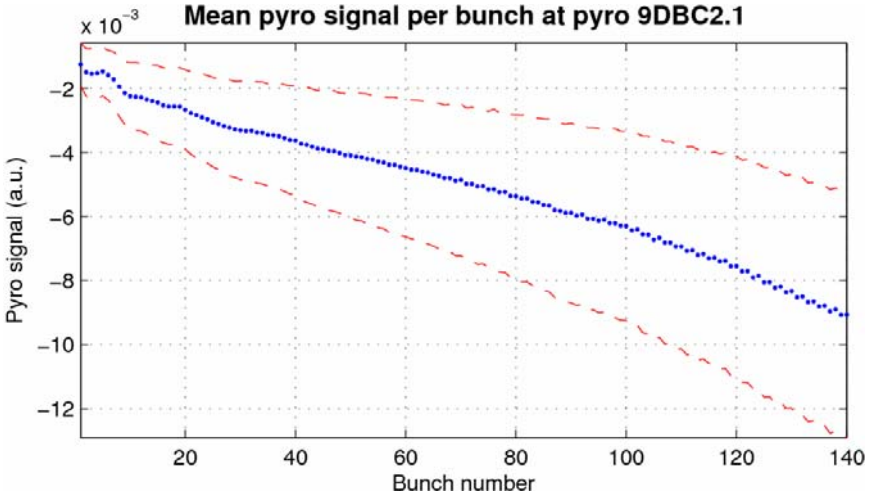
Lasing with 300 bunches

- sacrifice some intensity to reduce losses
- limited by losses in undulators, collimators
- all bunches lasing
- 250 kHz ripple visible in photon pulse energy

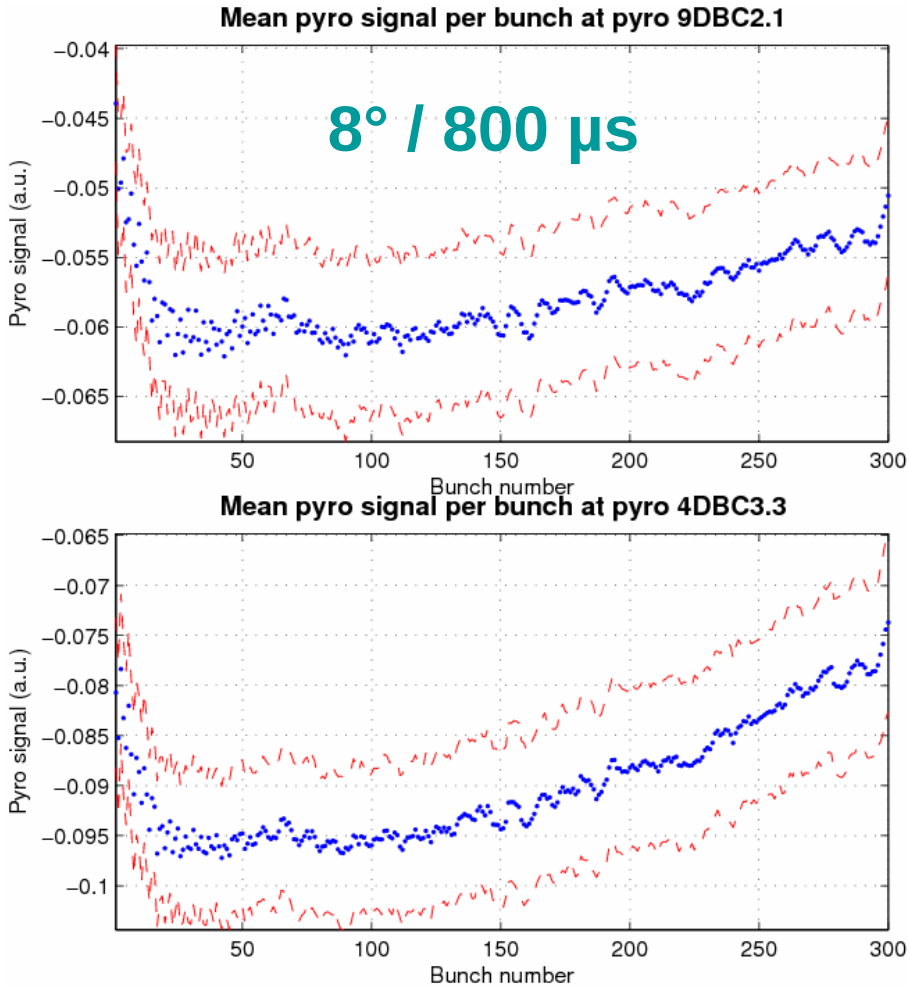


Compression Homogeneity

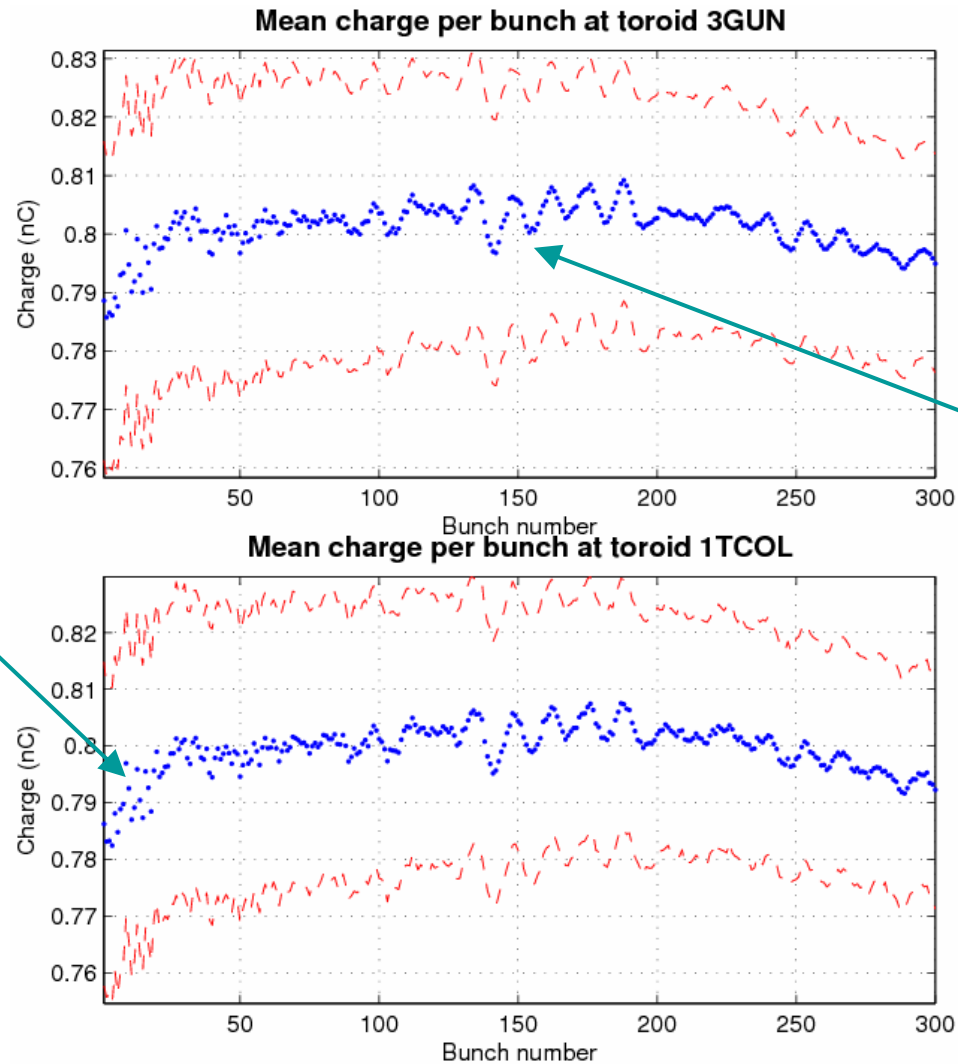
Old status:
strong slope on bunch compression



New knob:
force phase slope on gun vector sum



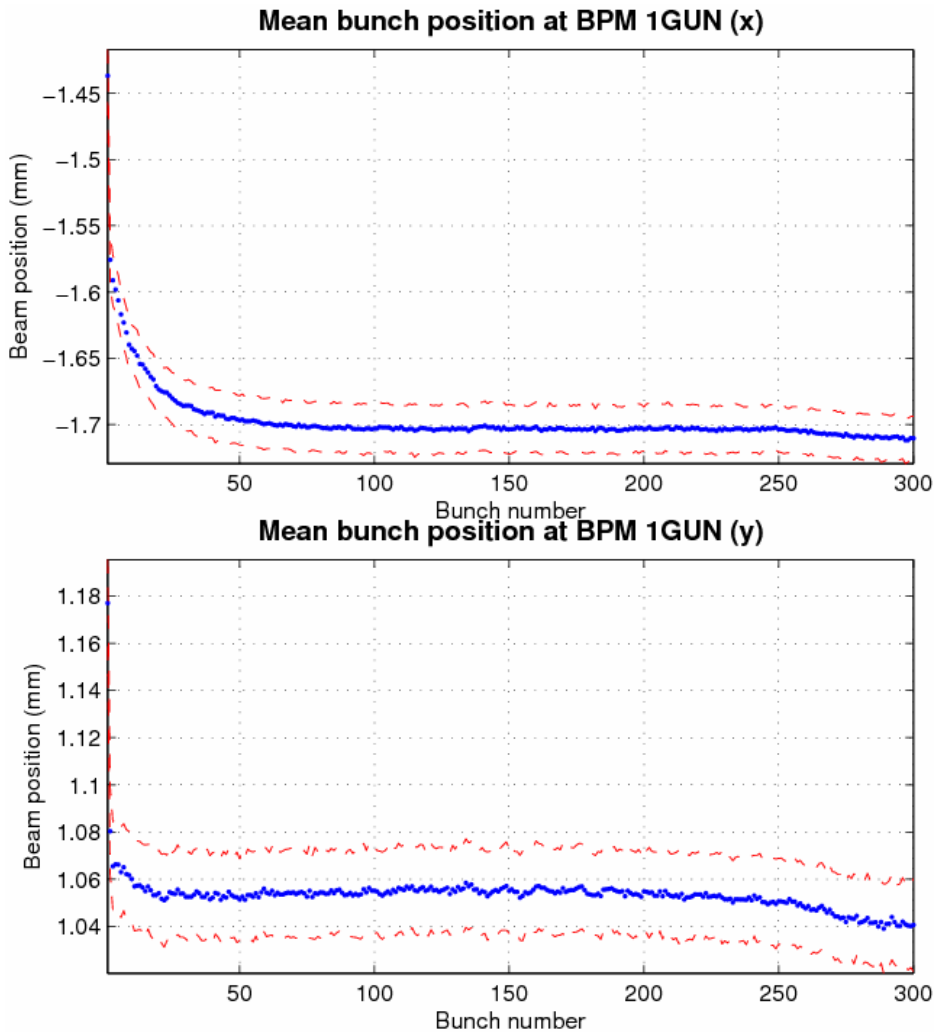
Charge Homogeneity



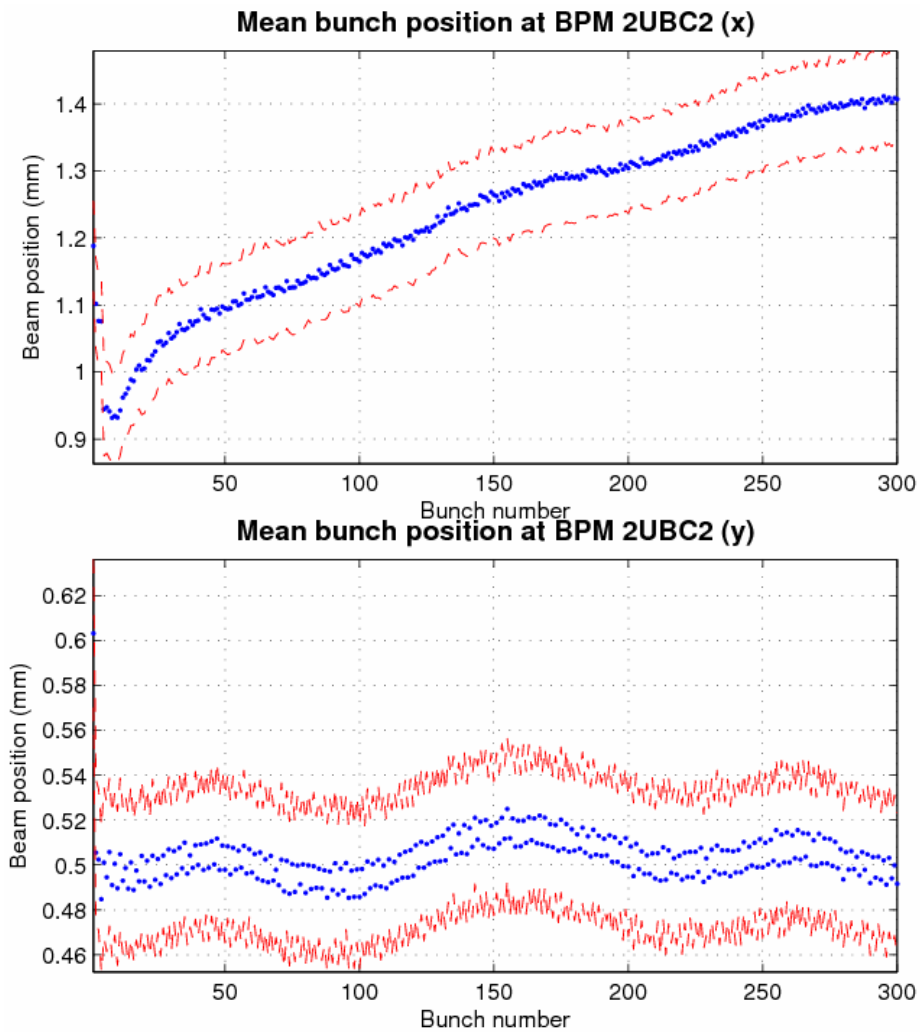
initial slope

oscillations

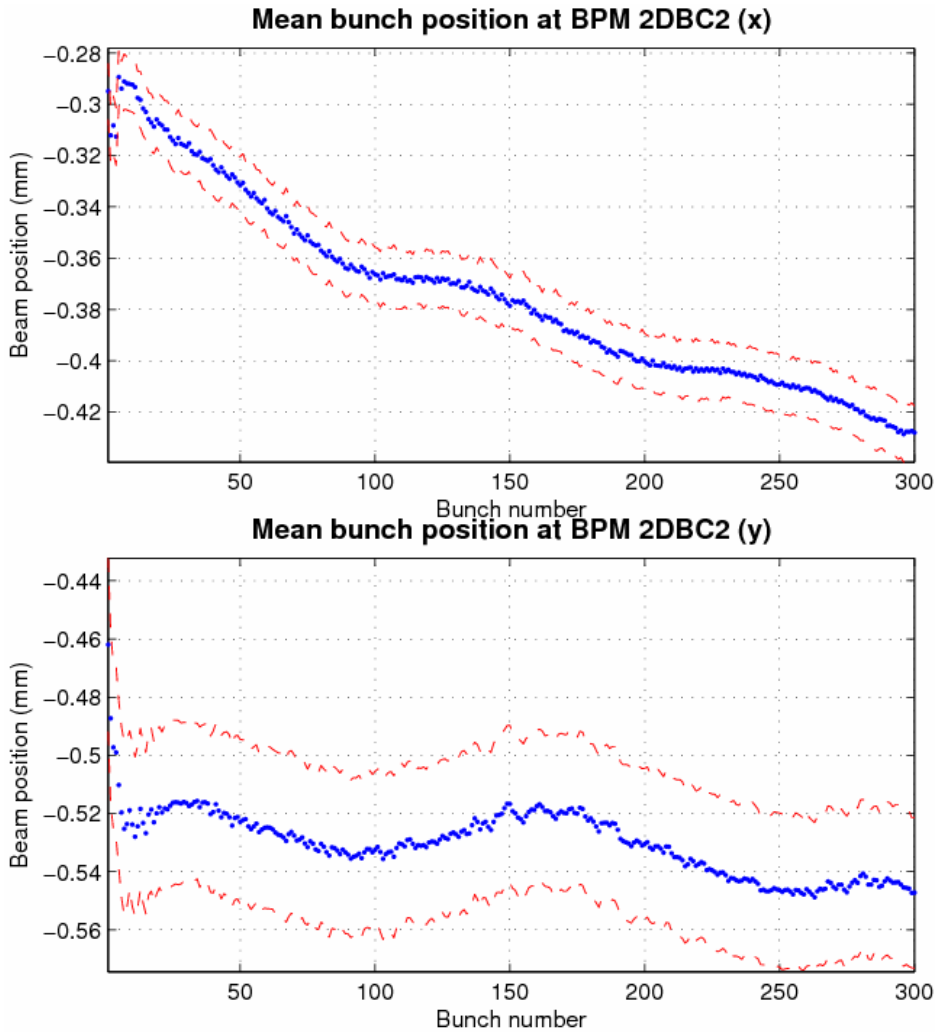
Orbit: 1GUN


Mean bunch position at BPM 1GUN (x)
Beam position (mm)
−1.45
−1.5
−1.55
−1.6
−1.65
−1.7
50
100
150
200
250
300
Bunch number
Mean bunch position at BPM 1GUN (y)
Beam position (mm)
1.18
1.16
1.14
1.12
1.1
1.08
1.06
1.04
50
100
150
200
250
300
Bunch number

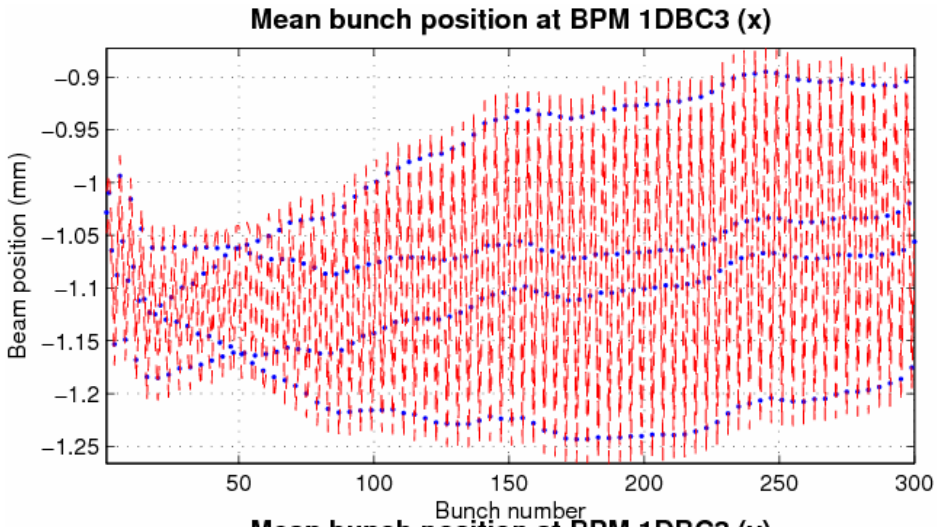
Orbit: 2UBC2

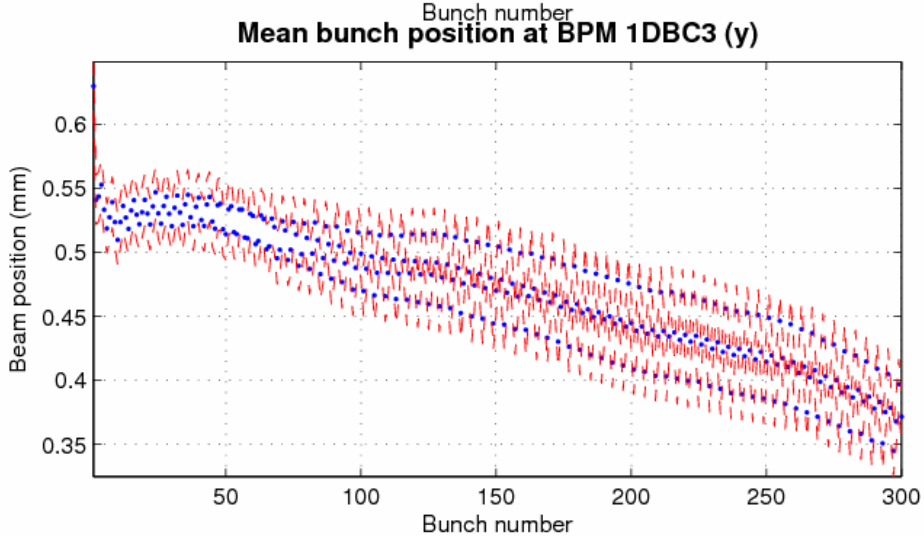

Mean bunch position at BPM 2UBC2 (x)
Beam position (mm)
1.4
1.3
1.2
1.1
1
0.9
50
100
150
200
250
300
Bunch number
Mean bunch position at BPM 2UBC2 (y)
Beam position (mm)
0.62
0.6
0.58
0.56
0.54
0.52
0.5
0.48
0.46
50
100
150
200
250
300
Bunch number

Orbit: 2DBC2

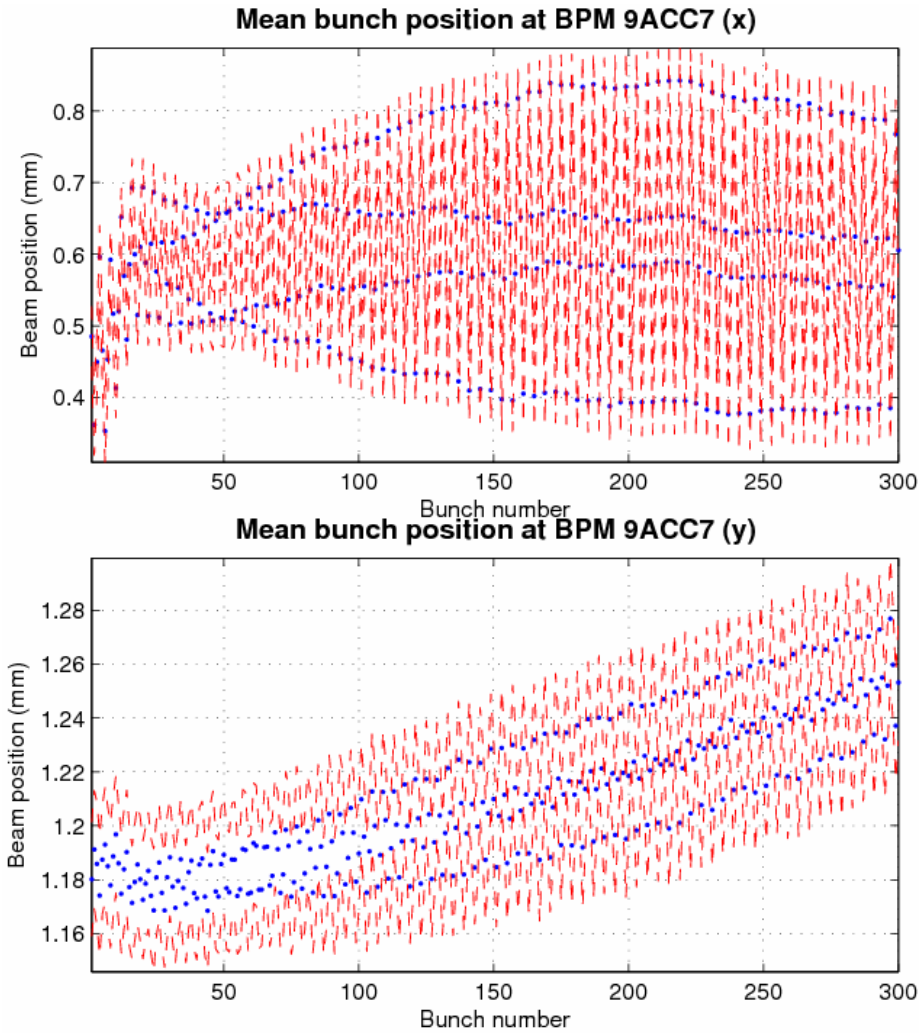

Mean bunch position at BPM 2DBC2 (x)
Beam position (mm)
−0.28
−0.3
−0.32
−0.34
−0.36
−0.38
−0.4
−0.42
50
100
150
200
250
300
Bunch number
Mean bunch position at BPM 2DBC2 (y)
Beam position (mm)
−0.44
−0.46
−0.48
−0.5
−0.52
−0.54
−0.56
50
100
150
200
250
300
Bunch number

Orbit: 1DBC3

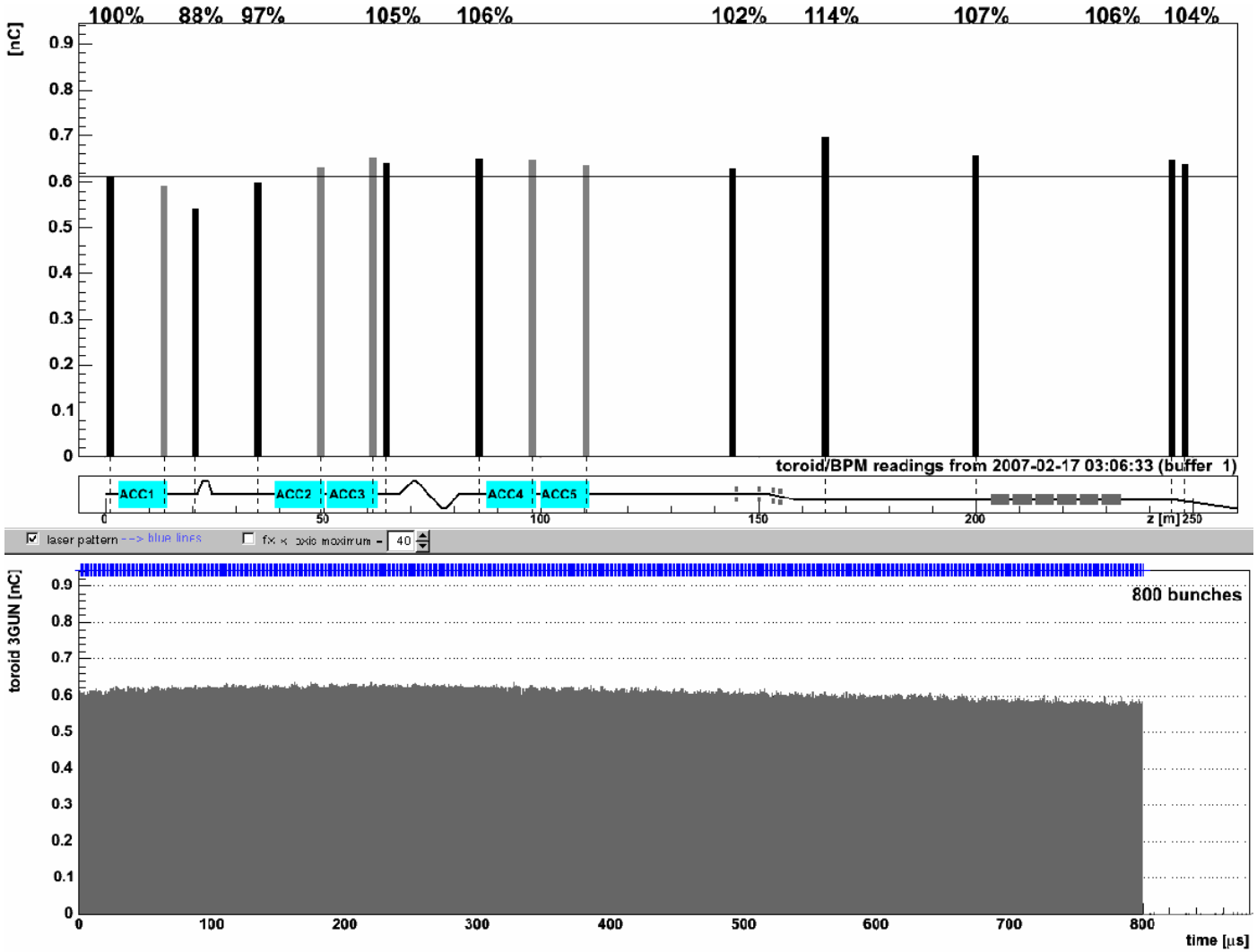

Mean bunch position at BPM 1DBC3 (x)
Beam position (mm)
−0.9
−0.95
−1
−1.05
−1.1
−1.15
−1.2
−1.25
50
100
150
200
250
300
Bunch number


Mean bunch position at BPM 1DBC3 (y)
Beam position (mm)
0.6
0.55
0.5
0.45
0.4
0.35
50
100
150
200
250
300
Bunch number

Orbit: 9ACC7


Mean bunch position at BPM 9ACC7 (x)
Beam position (mm)
0.8
0.7
0.6
0.5
0.4
50
100
150
200
250
300
Bunch number
Mean bunch position at BPM 9ACC7 (y)
Beam position (mm)
1.28
1.26
1.24
1.22
1.2
1.18
1.16
50
100
150
200
250
300
Bunch number

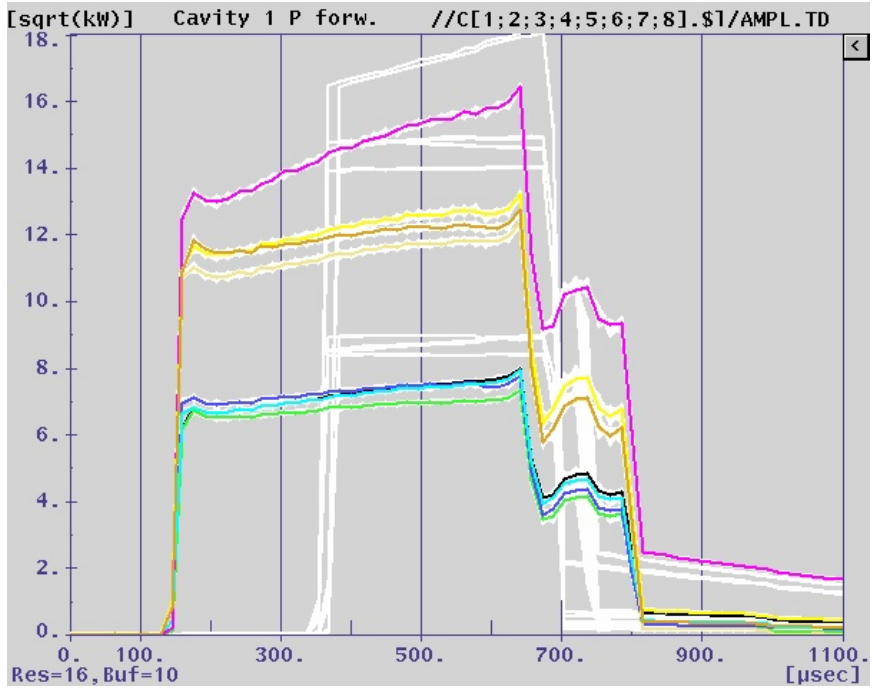
Transmission of 800 Bunches



Problems (1)

Coupler interlocks during MPS cuts of the ACC1 RF pulse

- probable reason: faulty length of BLM alarms (200 ms instead of 2 ms)
- workaround: MPS interlock input for Simcon boards
- debugging of MPS hardware



Problems (2)

Instability towards end of the bunch train

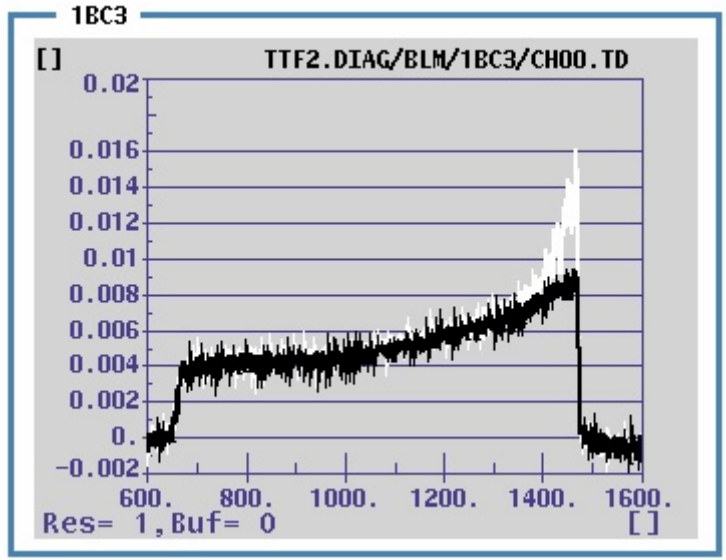
- looks like increasing energy error for the last bunches (but variation of beam energy does not help)

Excluded:

- quenching cavities
- adaptive feedforwards

Suspects:

- RF feedback
- Toroid-based beam loading compensation for ACC1 (?)



Final Remarks

Conclusion

- TPS commissioned and operational
- Operation with 800 bunches/macropulse demonstrated
- Time needed for careful machine setup

- Gun, ACC1 LLRF no longer limiting flatness of lasing (instead: injector laser, ACC2-5)
- Bug in MPS hardware – work in progress
- Investigation needed for end-of-train instability