Long pulses at the VUV-FEL

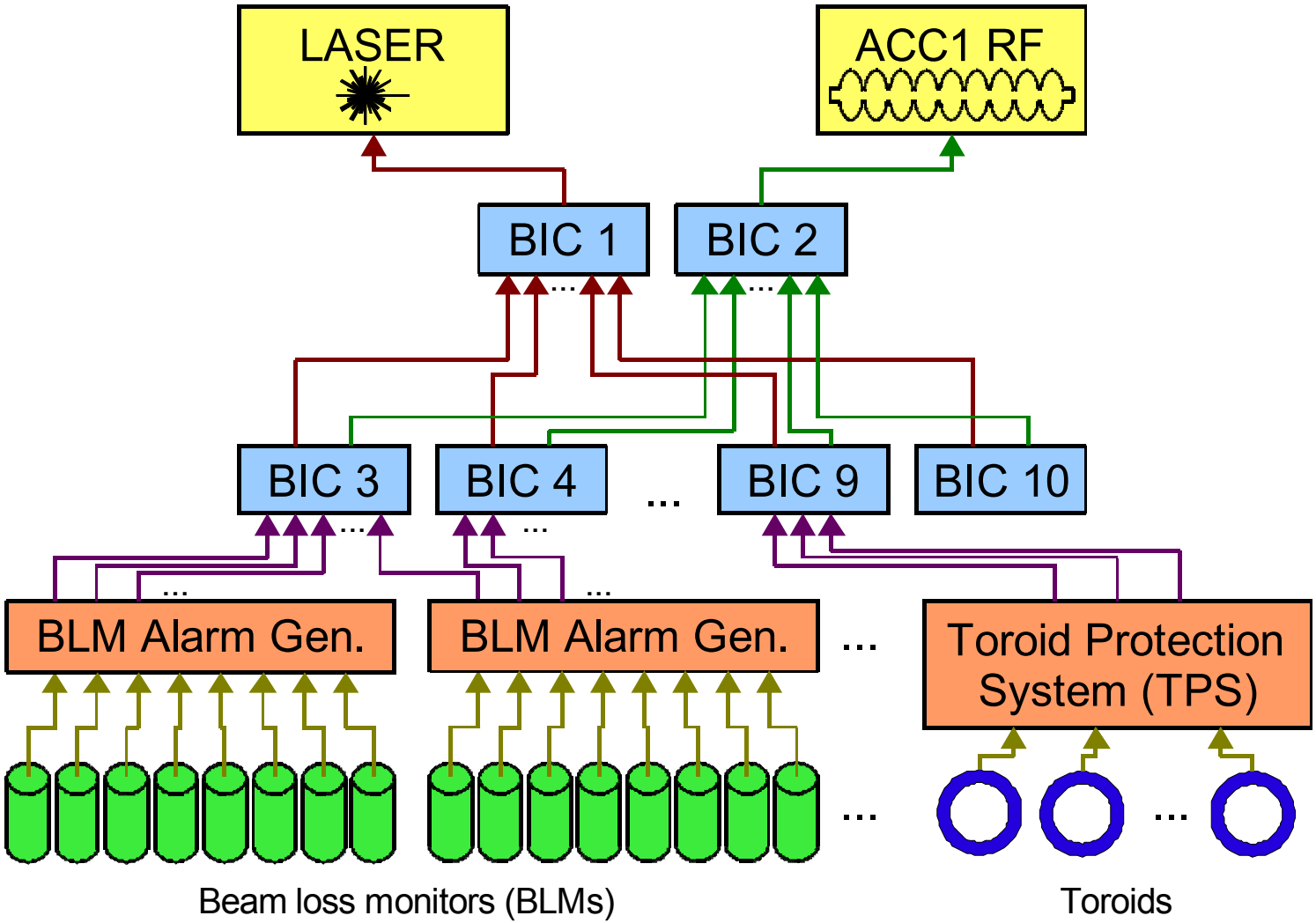
Machine protection system

- Beam loss monitor alarm generators
- Toroid protection system
- Alarm collection with BICs

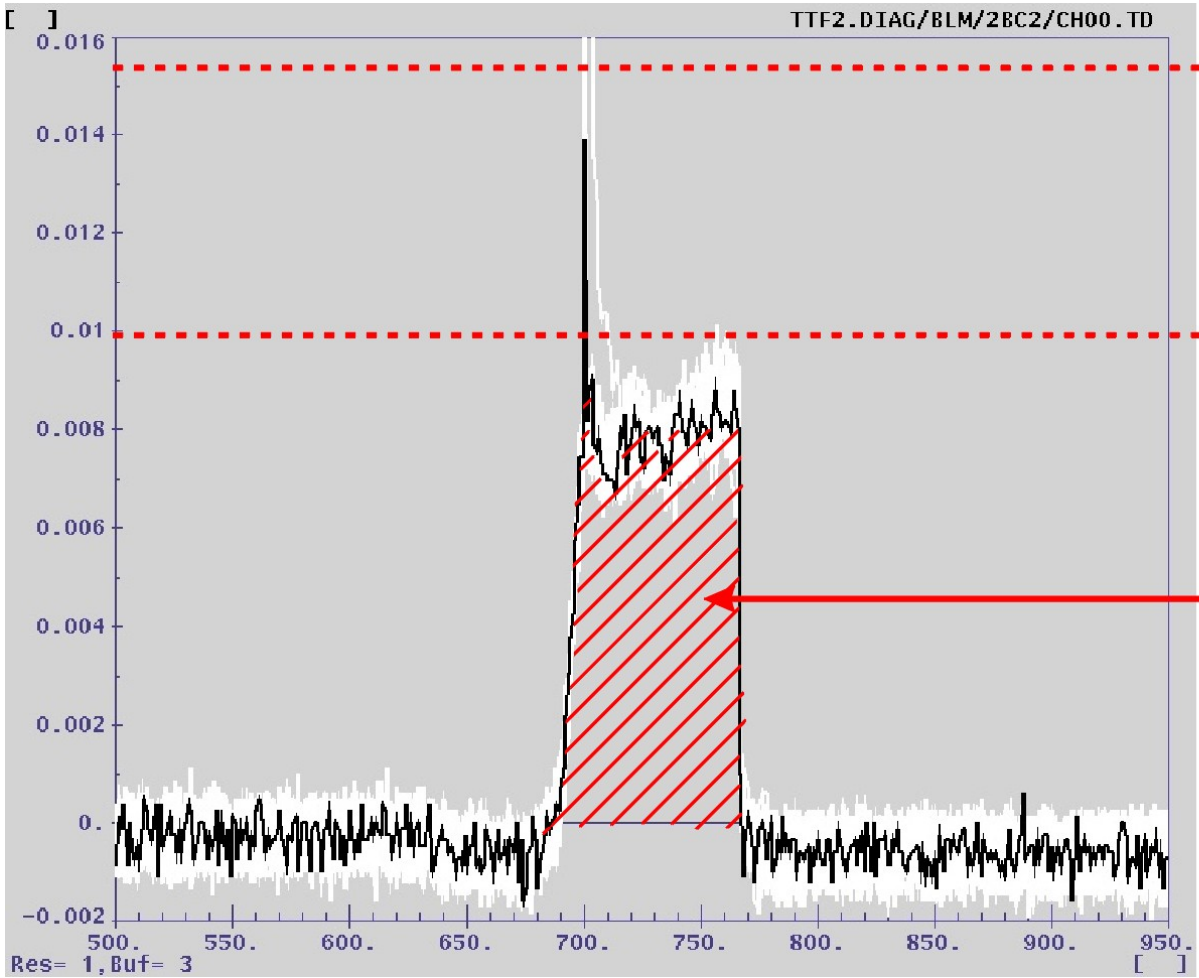
Chronicle of the long pulse studies

- Optimization of transmission (orbit+optics)
- MPS tests
- LLRF tuning
- Finding the dump

Fast protection system



BLM alarm generators (1/2)



"fast high" threshold (single bunch)

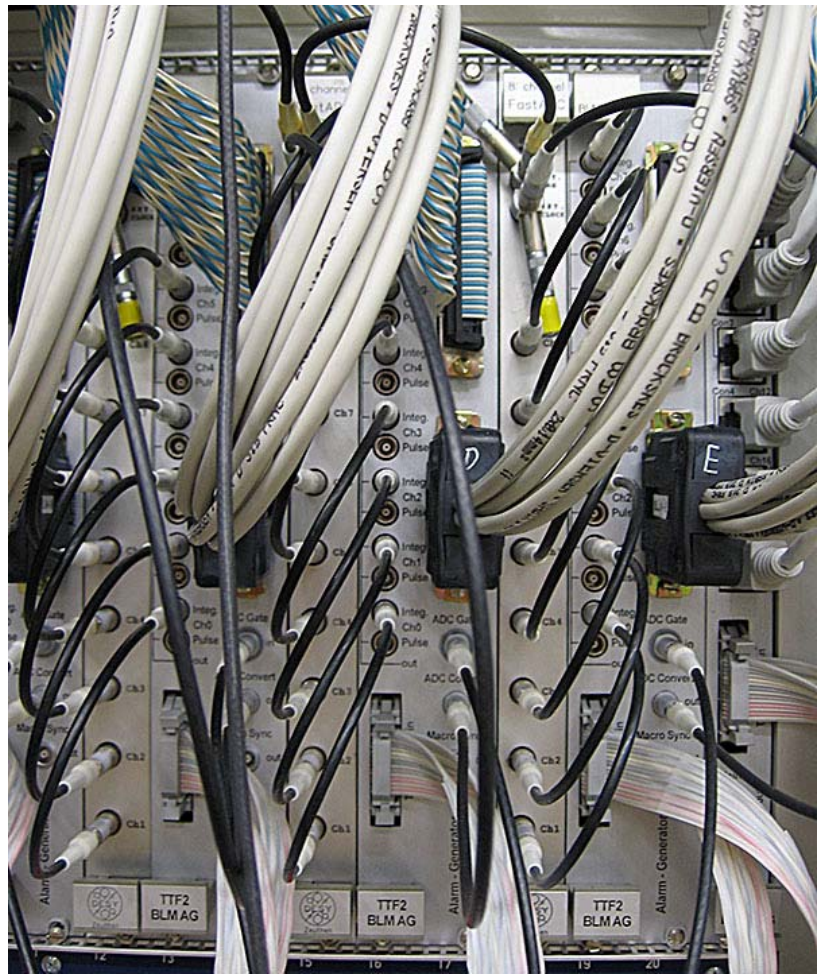
"fast low" threshold (several bunches)

integration threshold (over RF gate)

BLM alarm generators (2/2)

Other alarm types:

- high voltage failure
- supply voltage failure
- wrong result (negative integral)
- coincident alarm
- test alarm



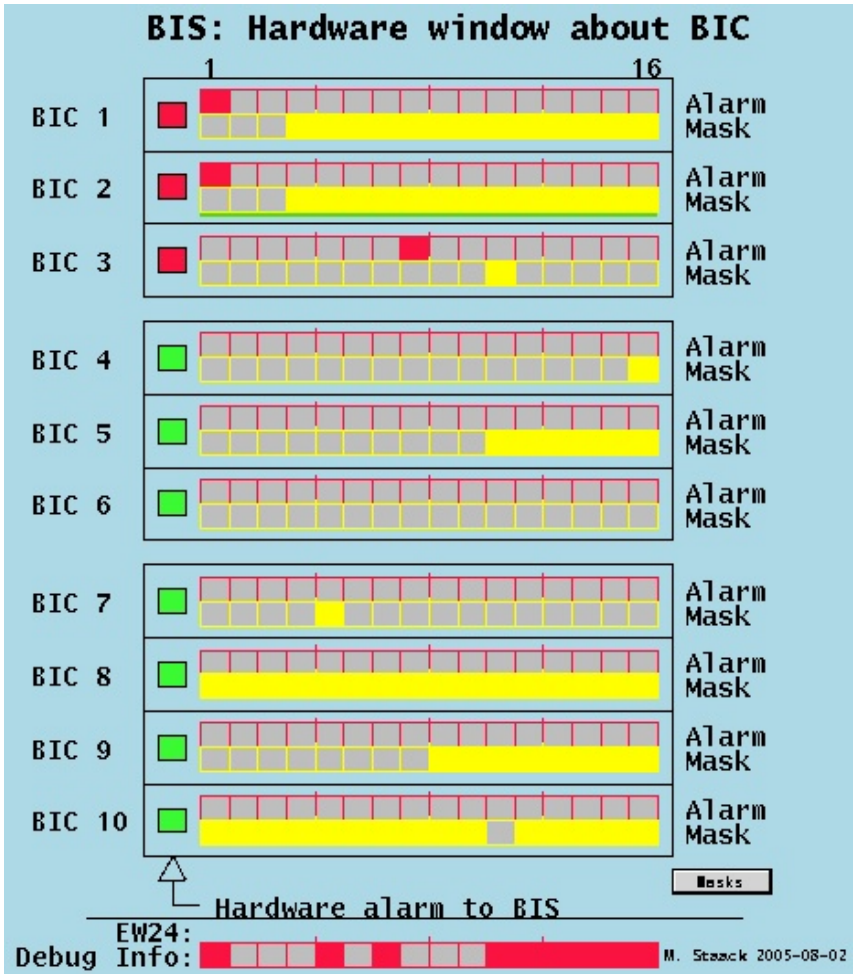
Toroid protection system

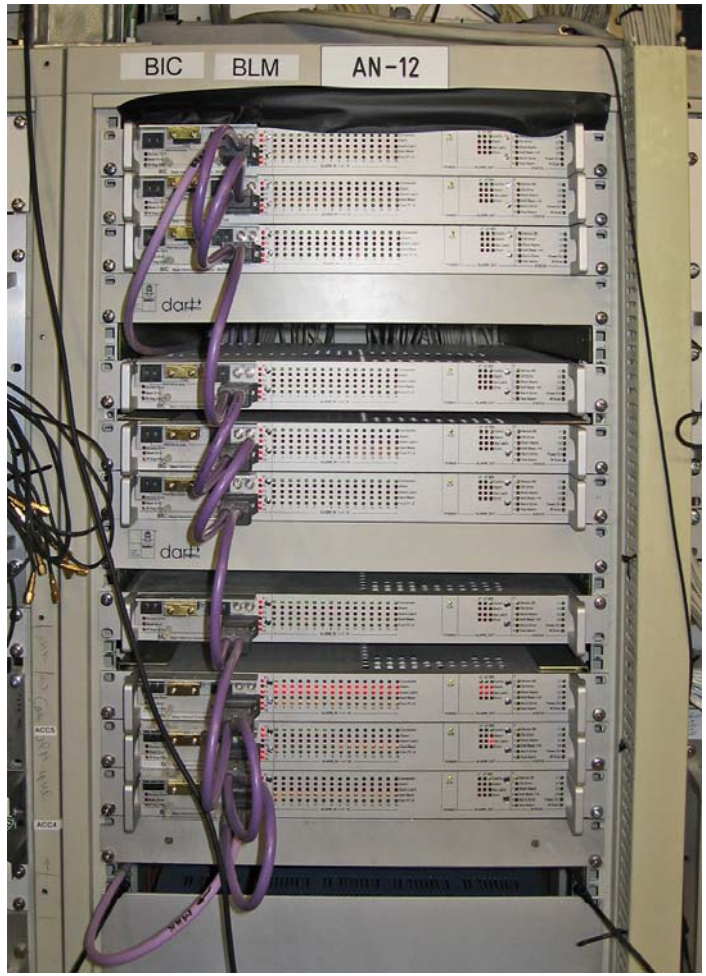
Alarm types:

- charge validation (3GUN < 0.3 nC)
- single bunch mode (transmission < 75 % for 1 bunch)
- slice mode
  (transmission < 90 % for 10 bunches)

Alarm collection with BICs

The fast protection is configured by the BIS, but it works independently.





Long pulse studies

Chronicle of the long pulse studies

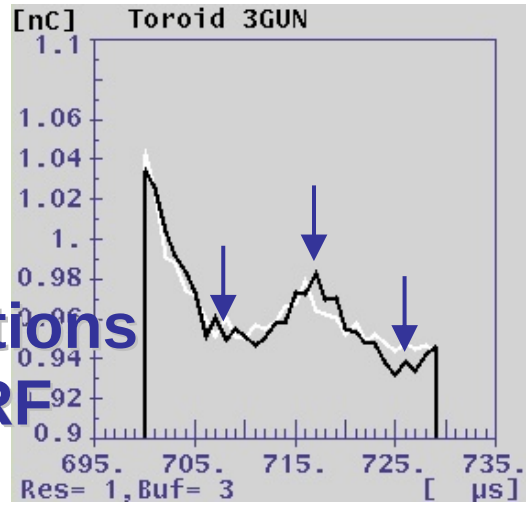
- Optimization of transmission (orbit+optics)
- MPS tests
- LLRF tuning
- Finding the dump

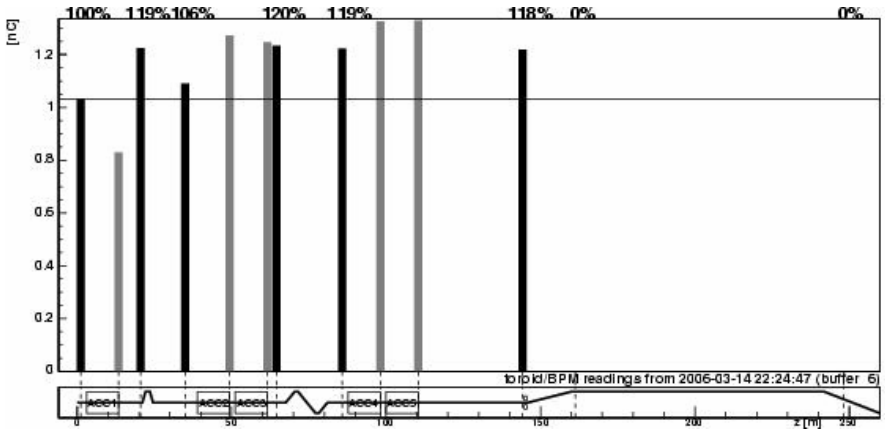
Long pulse studies

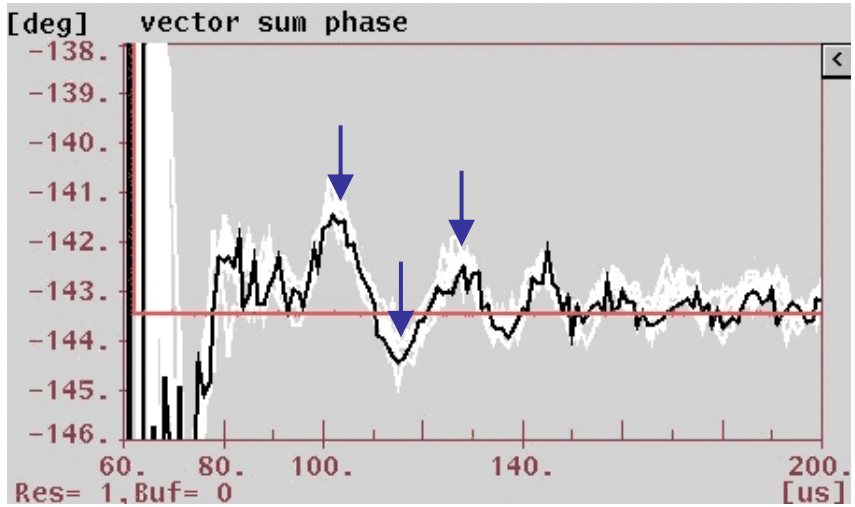
Tue 14.3. afternoon

- startup with new klystron 2
- gun flat top 400 µs
- BC3 off
- transmission to D1BYP

Charge fluctuations due to gun RF feedback







Long pulse studies

Tue 14.3. night

- transmission through bypass

Wed 15.3. morning

- **LLRF: AFF for modules 4/5 adapts FF tables to zero after interlock**
- **LLRF: DSP exception handler cuts RF**
- water: gun water temperature
- RF: kly4 solenoid current, kly3 “coil I compar"
- magnets: broken power supply H10ACC3

→ transmission through bypass lost

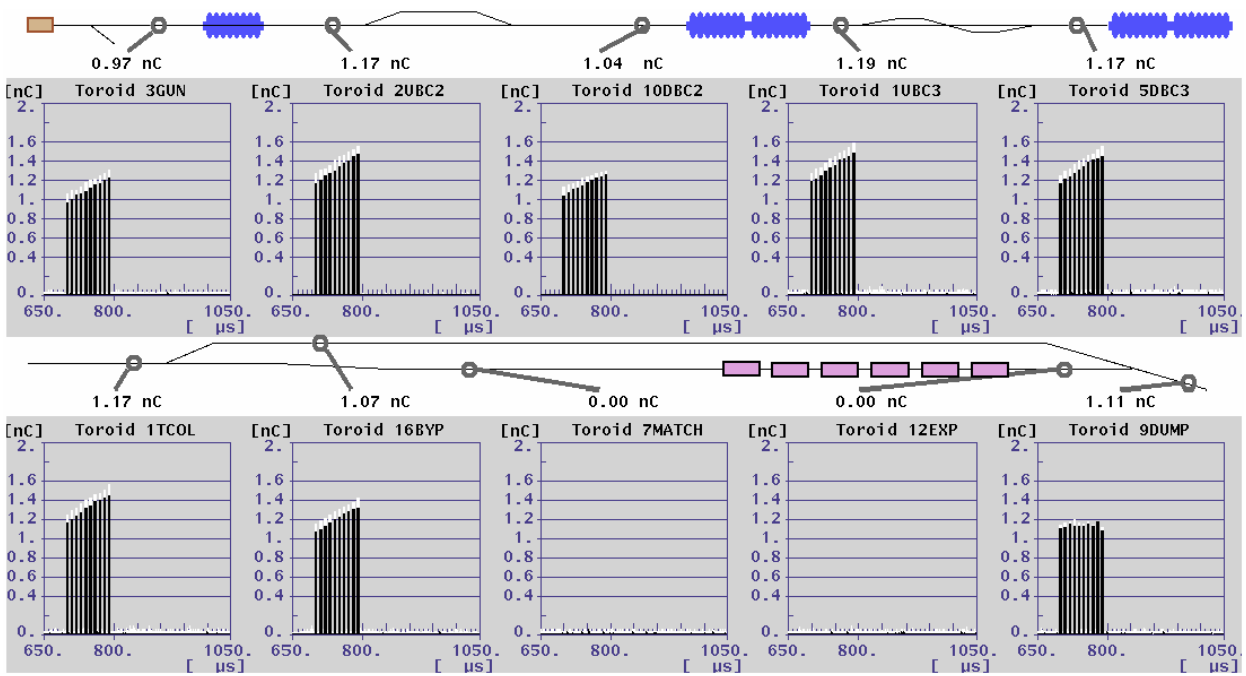
Long pulse studies

Wed 15.3. afternoon

- re-established transmission through bypass

Wed 15.3. night

- 20 bunches at 100 kHz to dump



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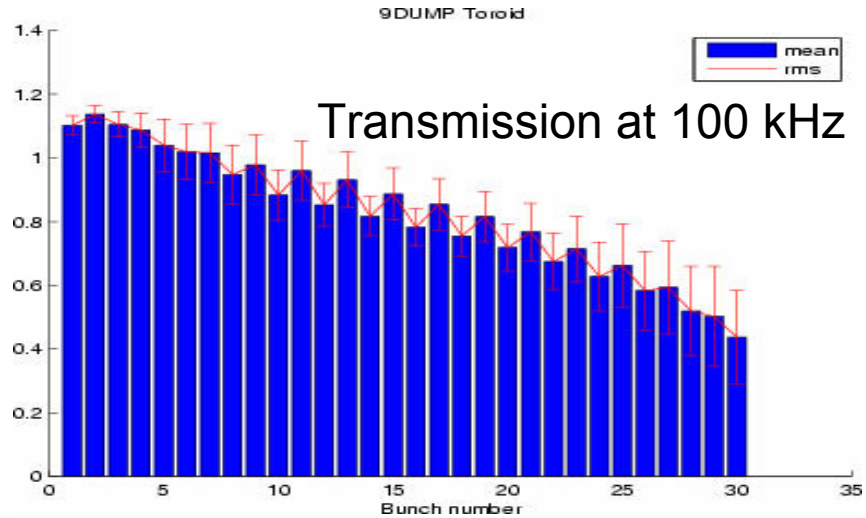
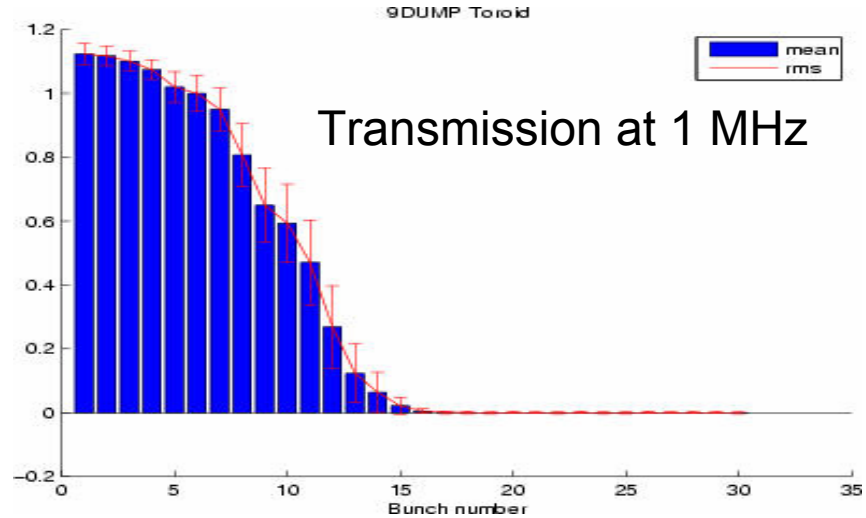
Long pulse studies

Thu 16.3. morning

- TPS calibration
- correlation and stability measurements at various bunch frequencies

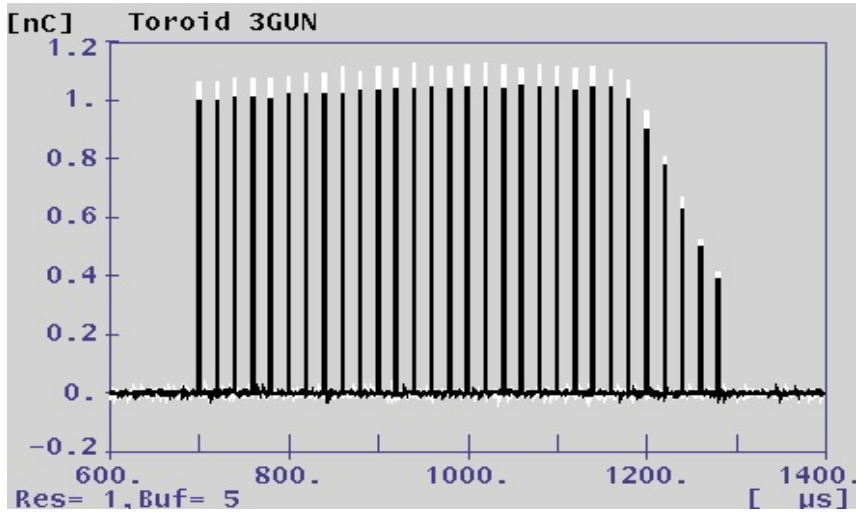




Long pulse studies

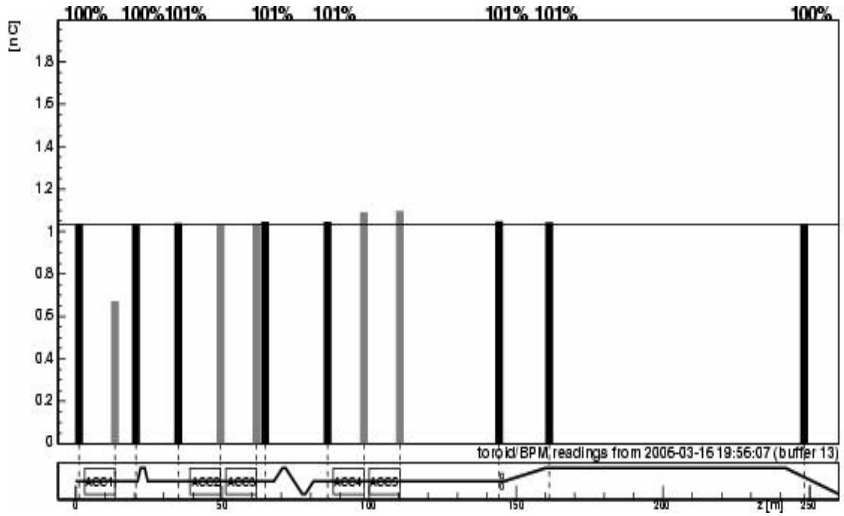
Thu 16.3. afternoon

- minimized losses
- calibration of toroids
- 600 µs flat top length
- 25 bunches at 50 kHz (flashlamps prevented 30)

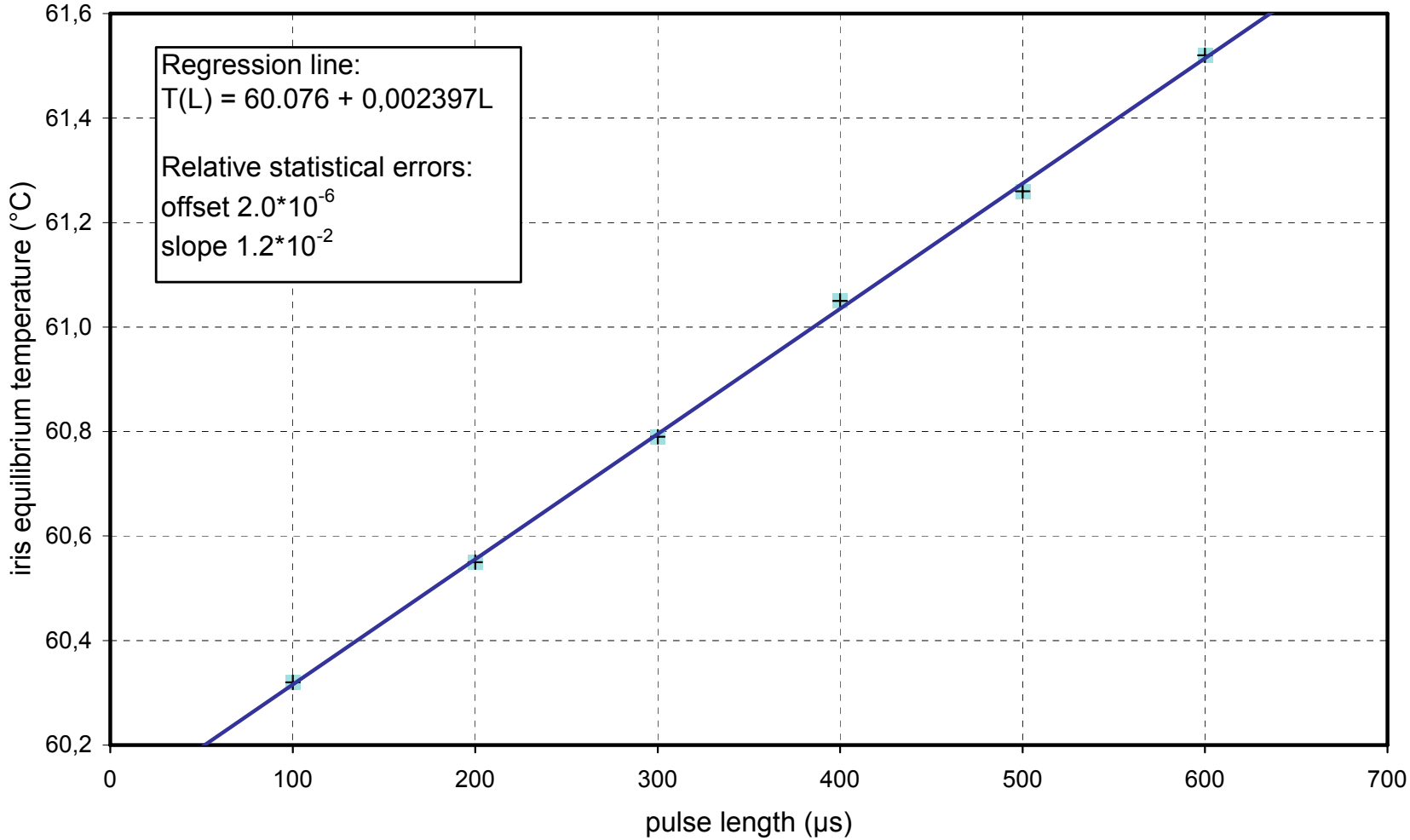


Thu 16.3. night

- quantum efficiency measurements
- iris temperature vs. RF pulse length



Long pulse studies



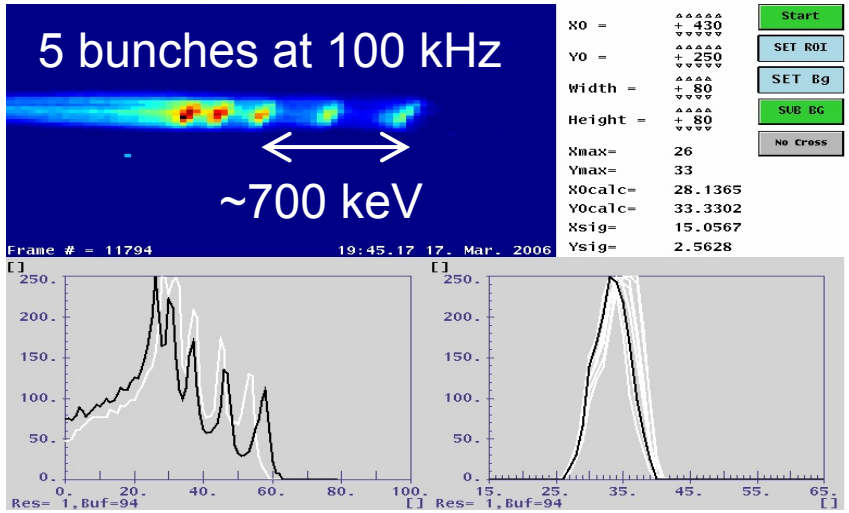
Long pulse studies

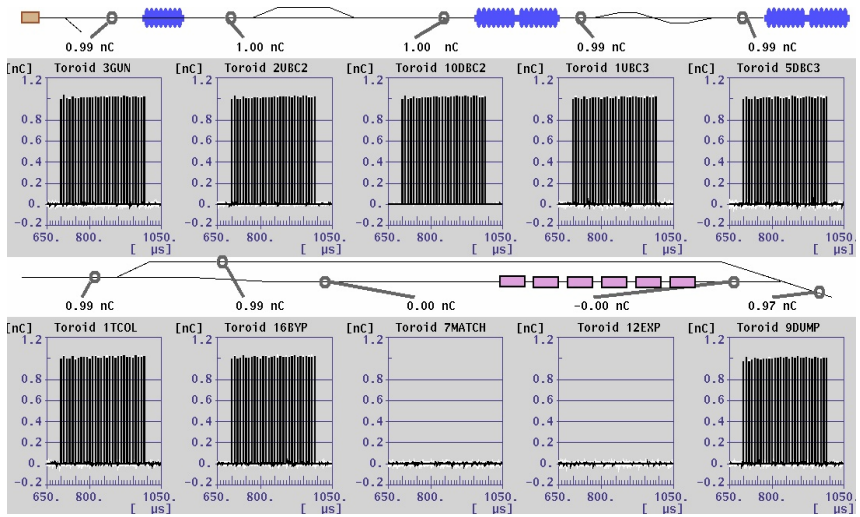
Fri 17.3. morning

- TPS charge validation and single bunch mode tested
- fast machine protection enabled
- back to 300 µs flat top length (window temp.)

Fri 17.3. afternoon

- measured TPS reaction time: < 3 µs (2 bunches at 1 MHz)
- energy measurements with SR camera





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Long pulse studies

Radiation levels in DUMP region

DUMP.1 – tunnel wall

DUMP.2 – dump shielding

1 – ACC1 flat top 800 us, laser on

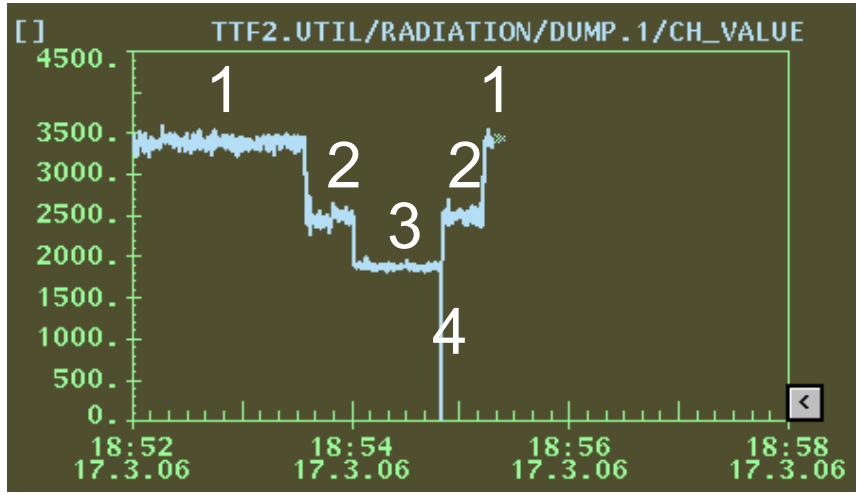
2 – ACC1 flat top 100 us, laser on

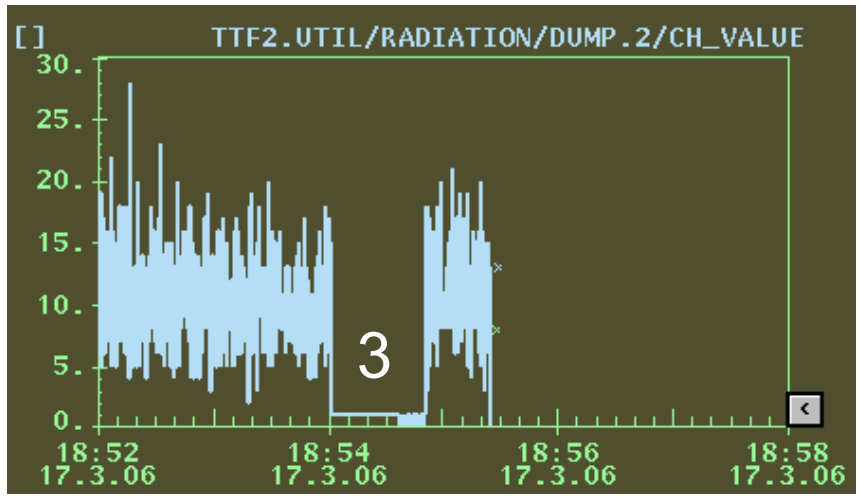
3 – ACC1 flat top 100 us, laser off

4 – gun RF off

Good tuning knobs:

- BC2 collimator
- Q4DUMP
  (aperture: „Hosenstrahlrohr“?)





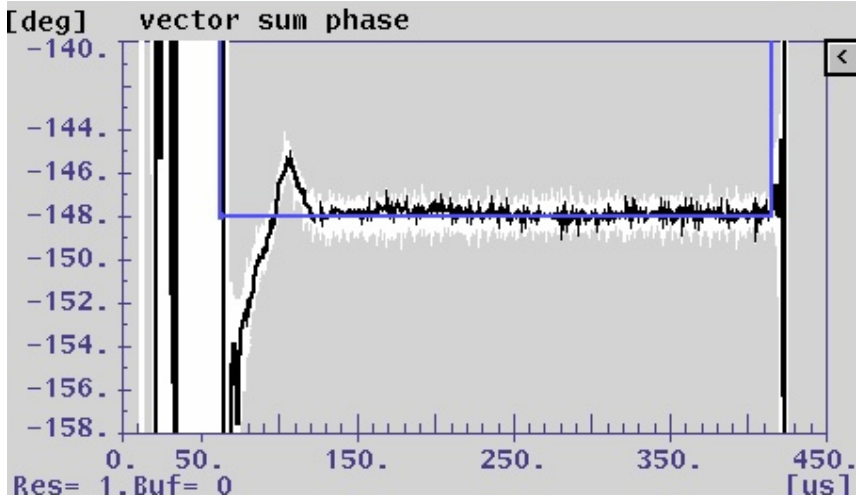
Long pulse studies

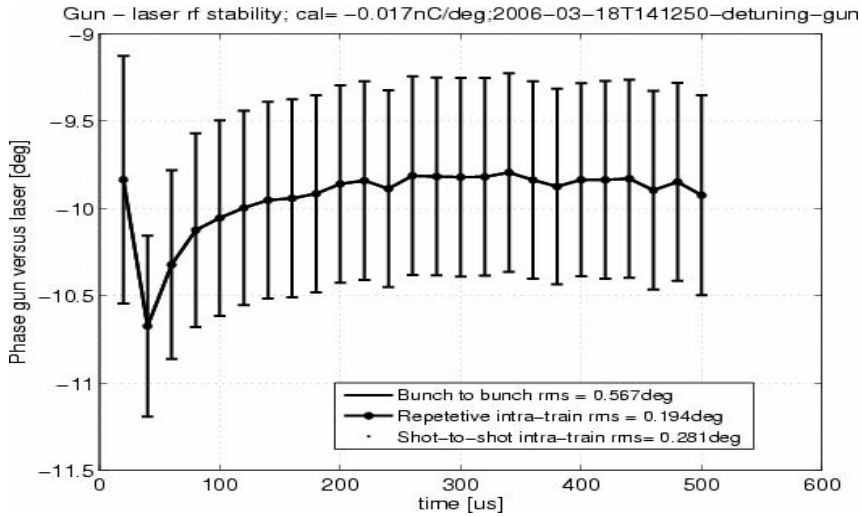
Fri 17.3. night

- straight orbit through bypass
- minimized losses

Sat 18.3. morning

- installation of new SIMCON firmware for the gun

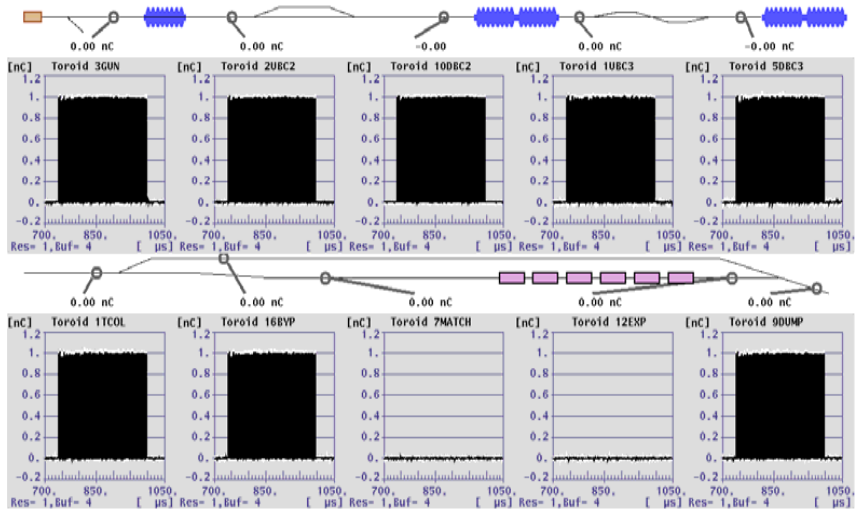


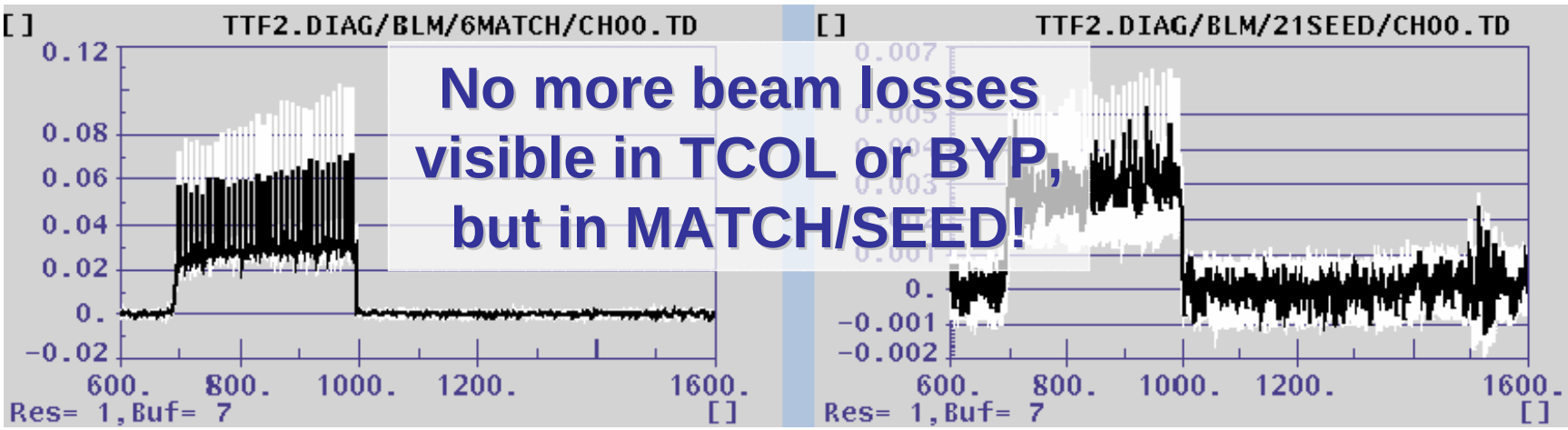


Long pulse studies

Sat 18.3. afternoon

- elimination of beam losses
- switch to long pulse mode
- 65 bunches at 250 kHz
- 100 bunches at 500 kHz



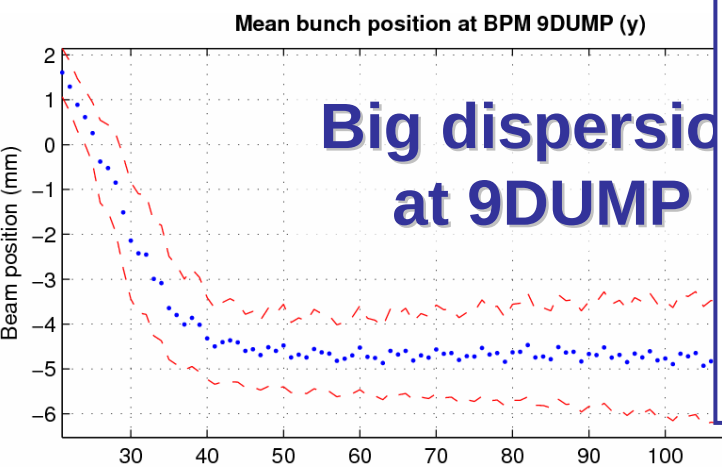


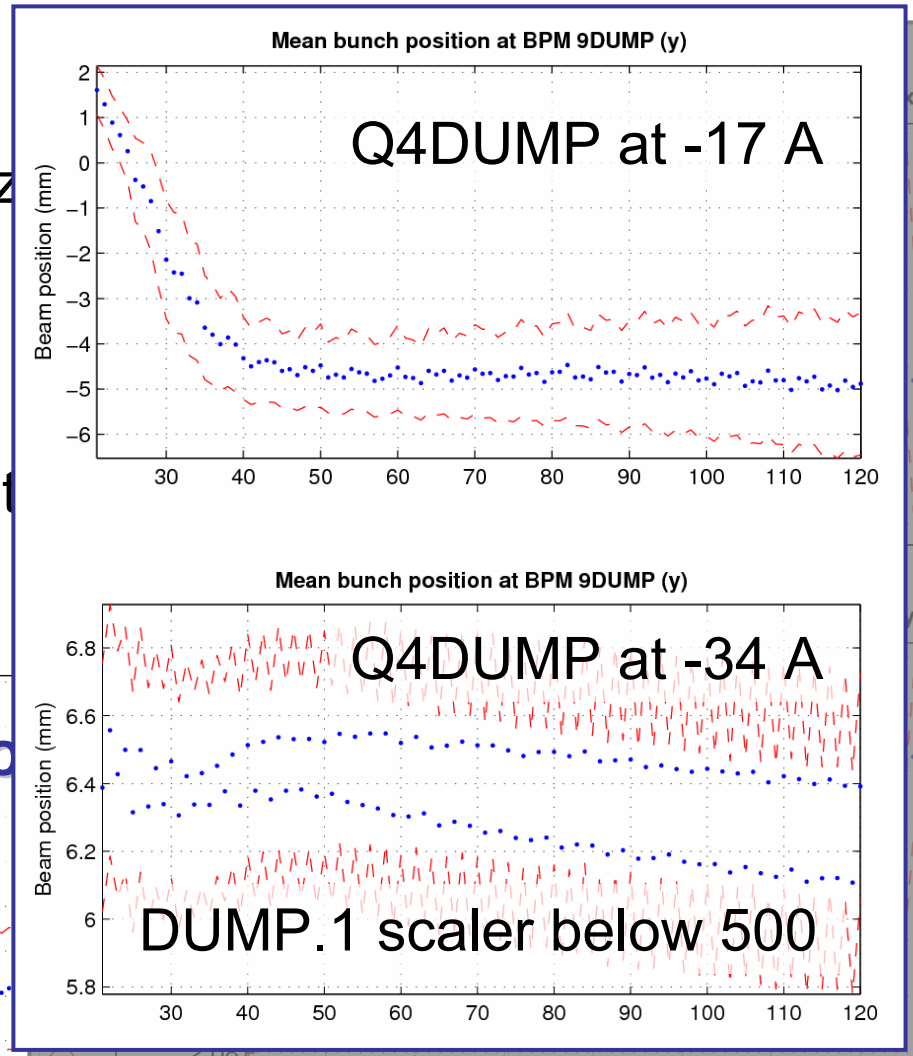
No more beam losses visible in TCOL or BYP, but in MATCH/SEED!

Long pulse studies

Sat 18.3. afternoon

- 100 bunches at 500 kHz
- 250 kHz ripple of the modules visible in the bunch position
- still energy deviation of t first bunches

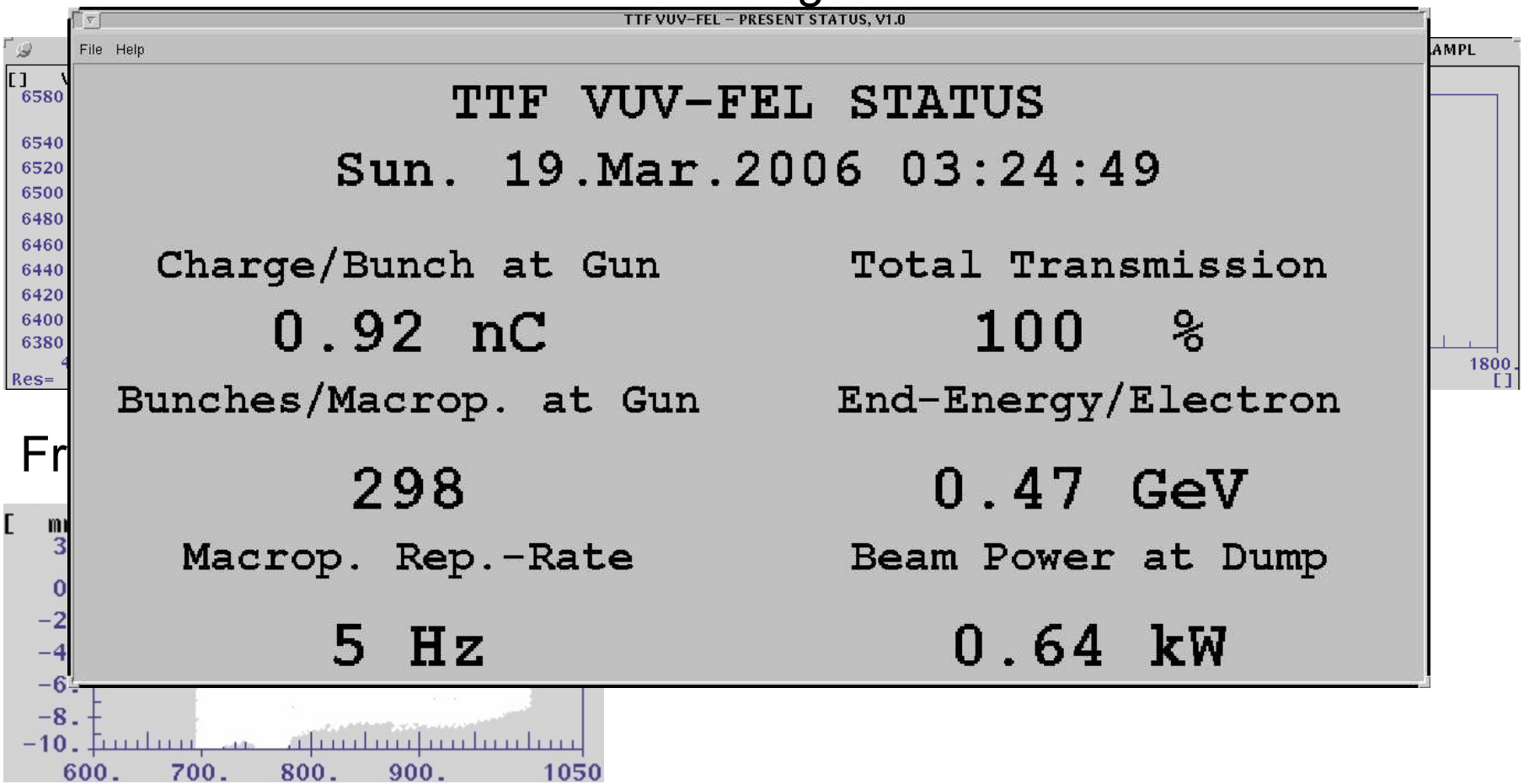




Long pulse studies

Sat 18.3. night

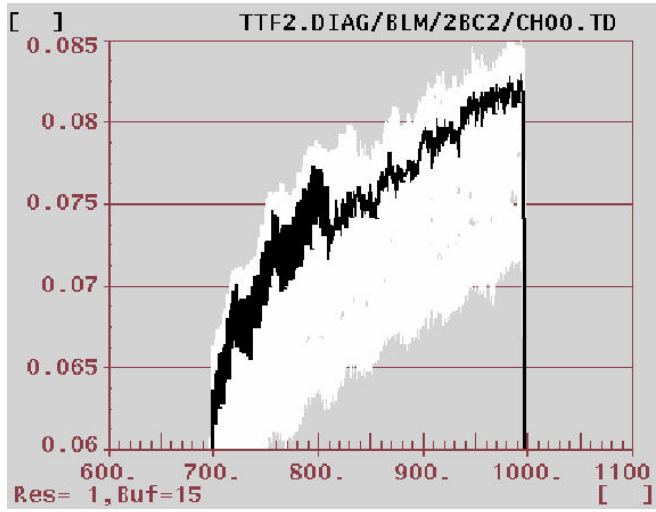
50 bunches at 1 MHz: beam loading is visible



Long pulse studies

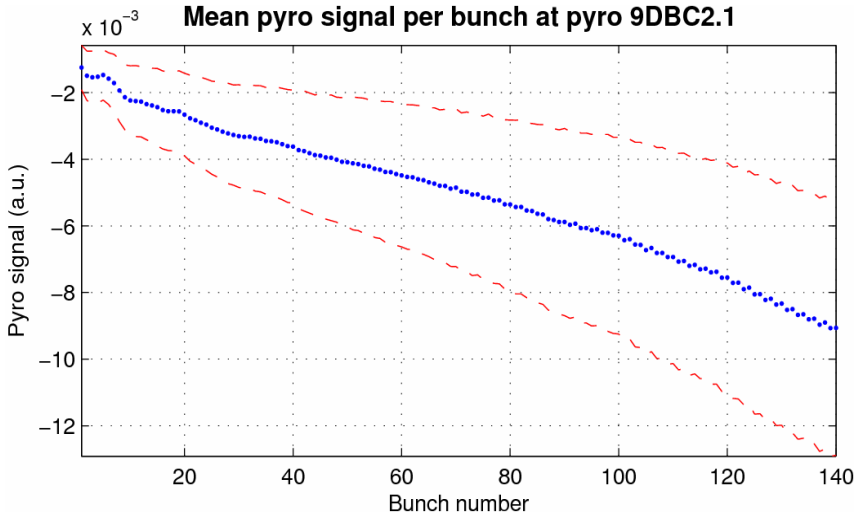
Sun 19.3. morning

- transient measurements ACC1



Sun 19.3. afternoon

- quenches in ACC1
- re-establish transmission
- eliminate beam losses



Sun 19.3. night

- 6° off-crest in ACC1
- small beam losses tolerated

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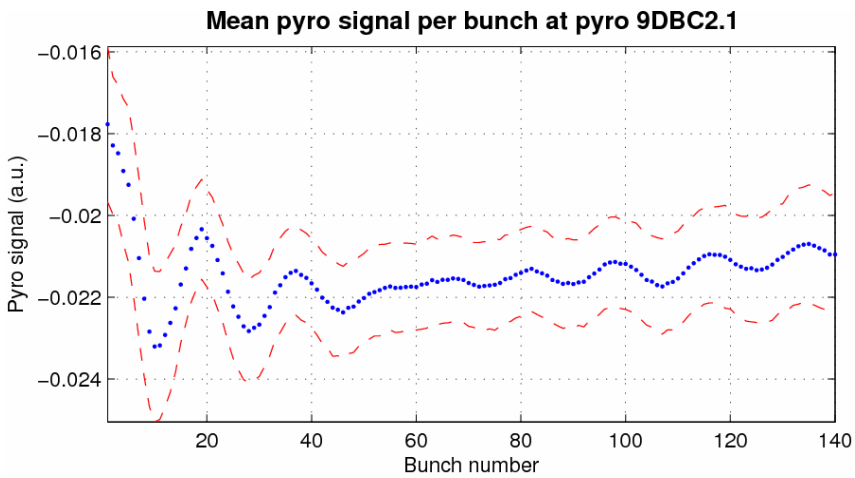
Long pulse studies

- 10° off-crest in ACC1
- strong beam losses in ACC1



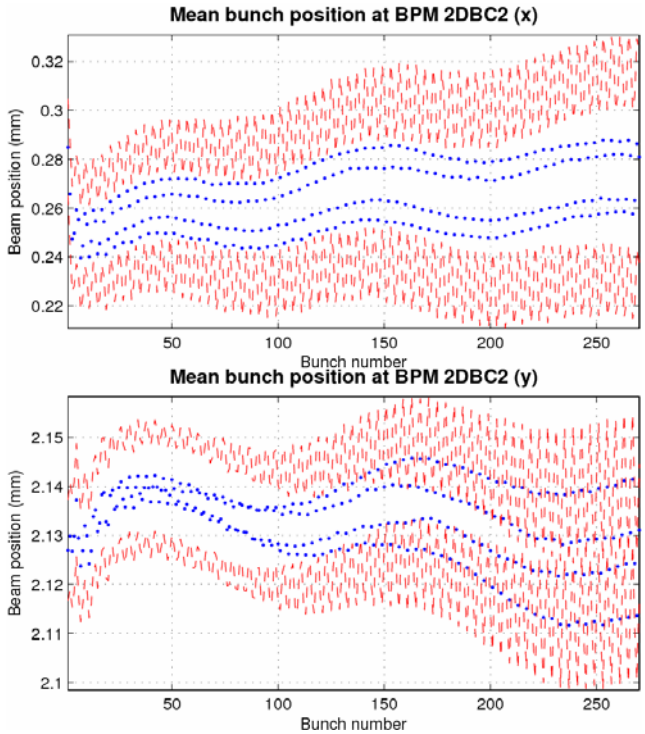
Monday 20.3. morning

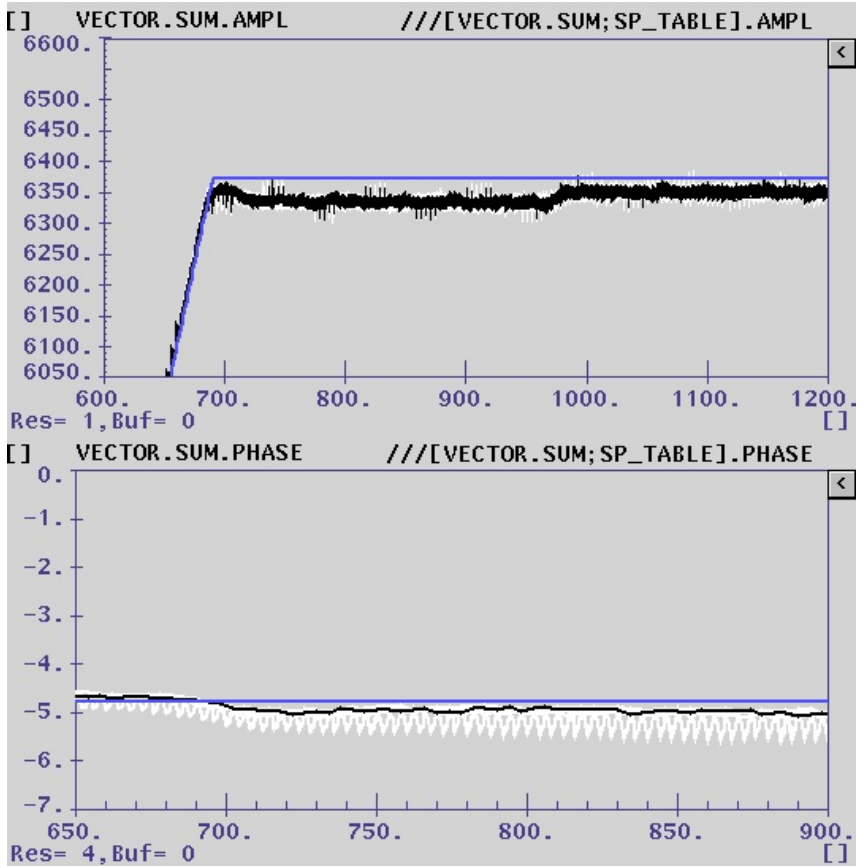
- various technical problems
- other measurements

Long pulse studies

Monday 20.3. afternoon

- improvements of ACC1 DSP parameters

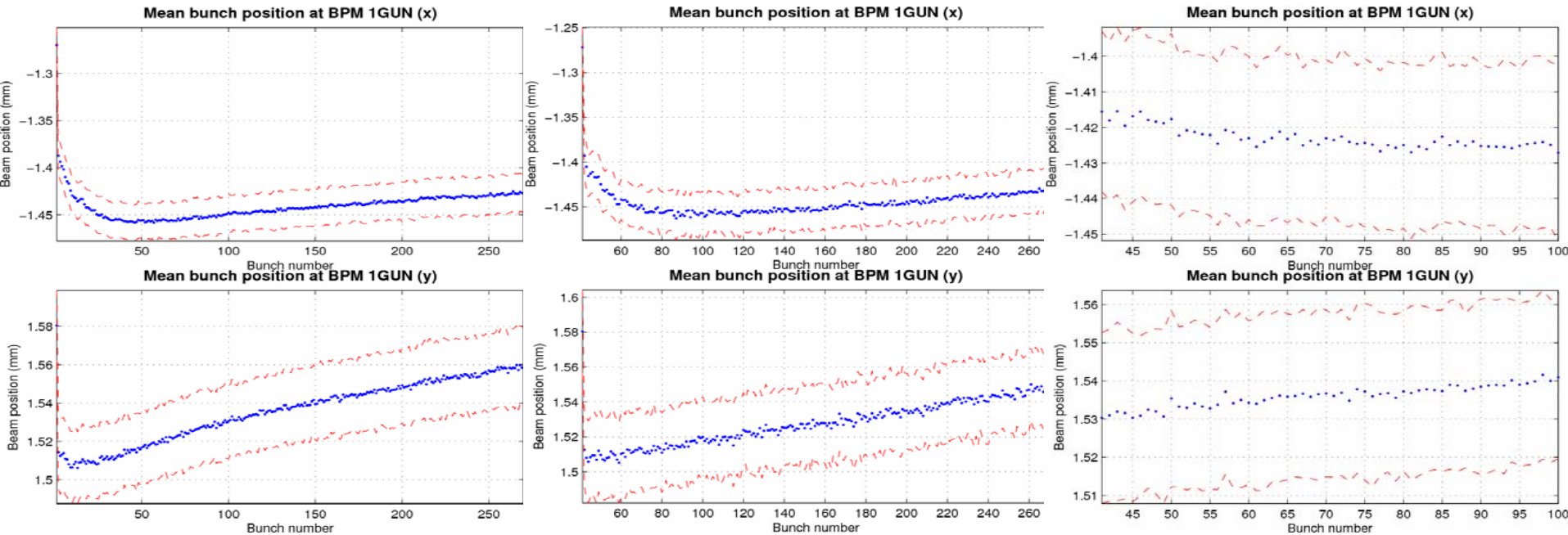




Long pulse studies

Bunch position at the 1GUN BPM

1 MHz	1 MHz	500 kHz
270 bunches	270 bunches	60 bunches
beam start 700	beam start 740	beam start 780



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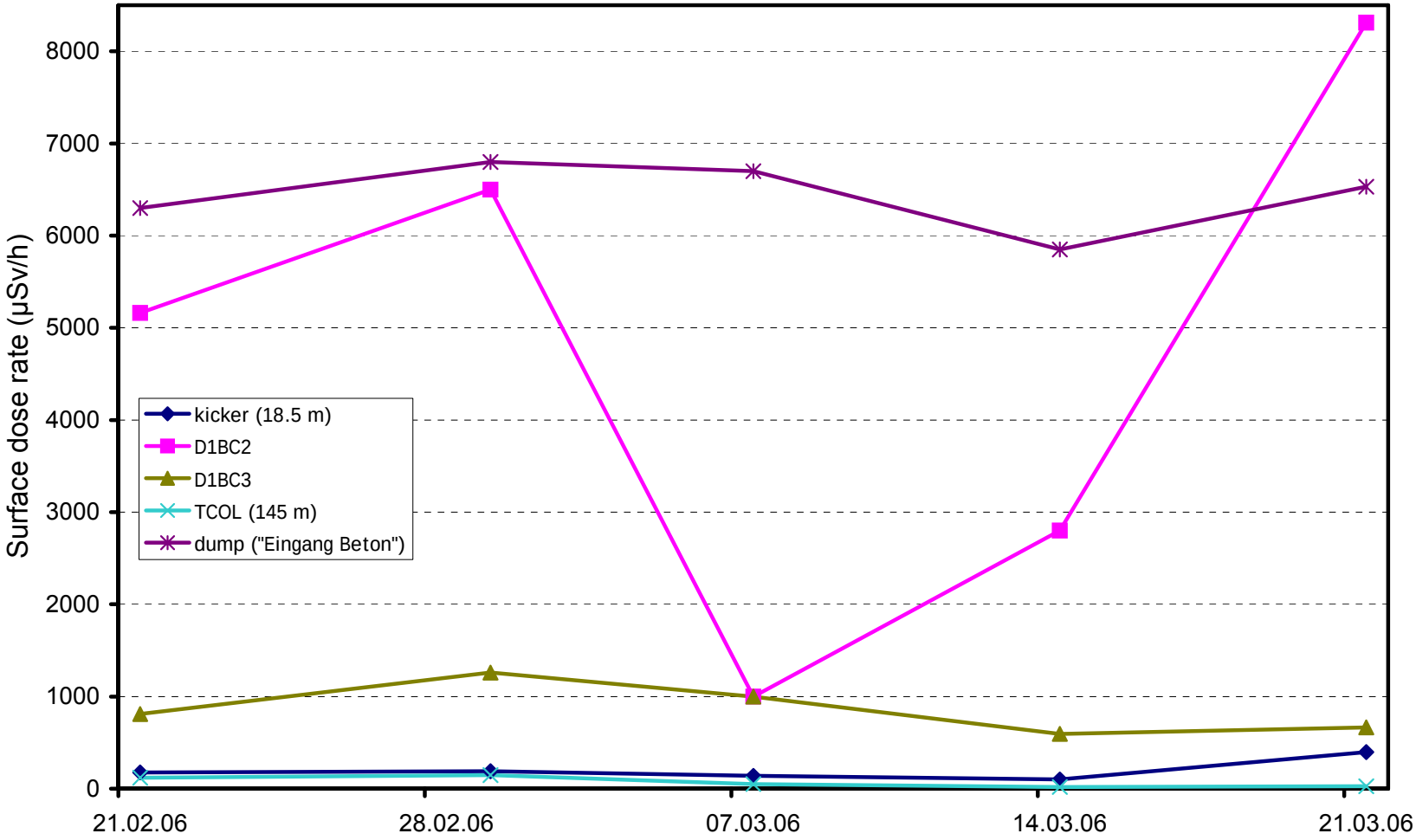
Radiation measurements



Conclusion (1/2)

Machine Protection System

- fast protection works reliably
- Toroid Protection System partly operational
- improvement of user interface necessary

LLRF

- improved vectorsum in gun, ACC1
- DSP beam loading compensation not helpful
- AFF in ACC4/5 helps, but exception handling has to be improved
- major problems: 250 kHz ripple, phase slope after gun/ACC1

Conclusion (2/2)

Operation

- 300 bunches possible
- no fundamental problem visible on the way to 800 bunches
- elimination of beam losses requires lots of tuning
- bypass/dumpline optics unclear

Many thanks to

- the MPS team (M. Görler, A. Hamdi, J. Novo, M. Staack)
- the coordinators (S. Schreiber, E. Vogel)
- the operators (V. Ayvazyan, A. Bolzmann, A. Eckhardt, O. Grimm, J. Haar, V. Kocharyan, V. Miltchev, G. Petrosyan, L. Petrosyan, M. Yurkov)
- the others who helped (Ch. Gerth, H. Schlarb)