Machine Development - Results from the First Two MD Sessions

R. Assmann

for the LHC MD coordination team

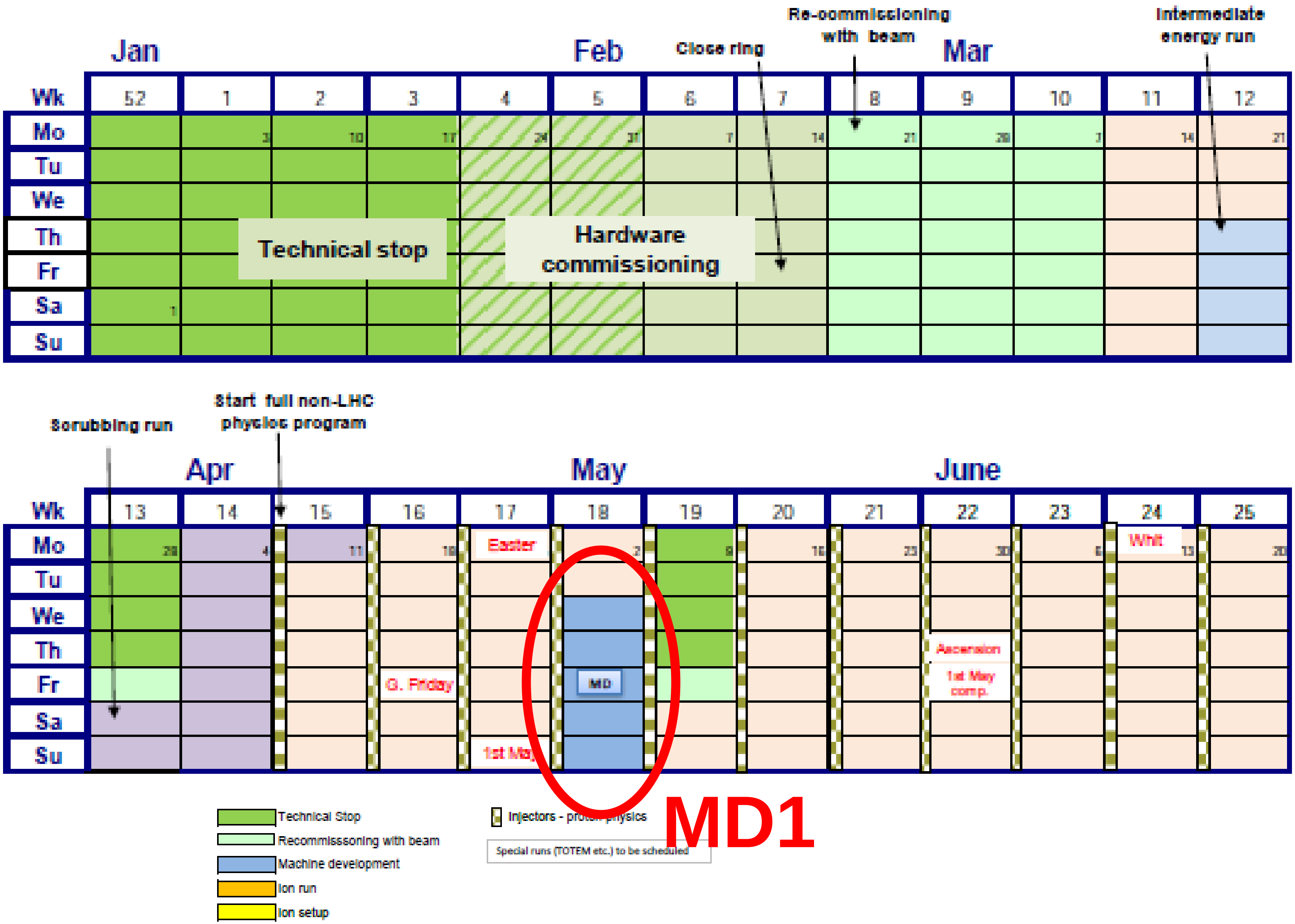
(**R. Assmann, Frank Zimmermann, Giulia Papotti**)

CERN Machine Advisory Committee, 22.8.2011

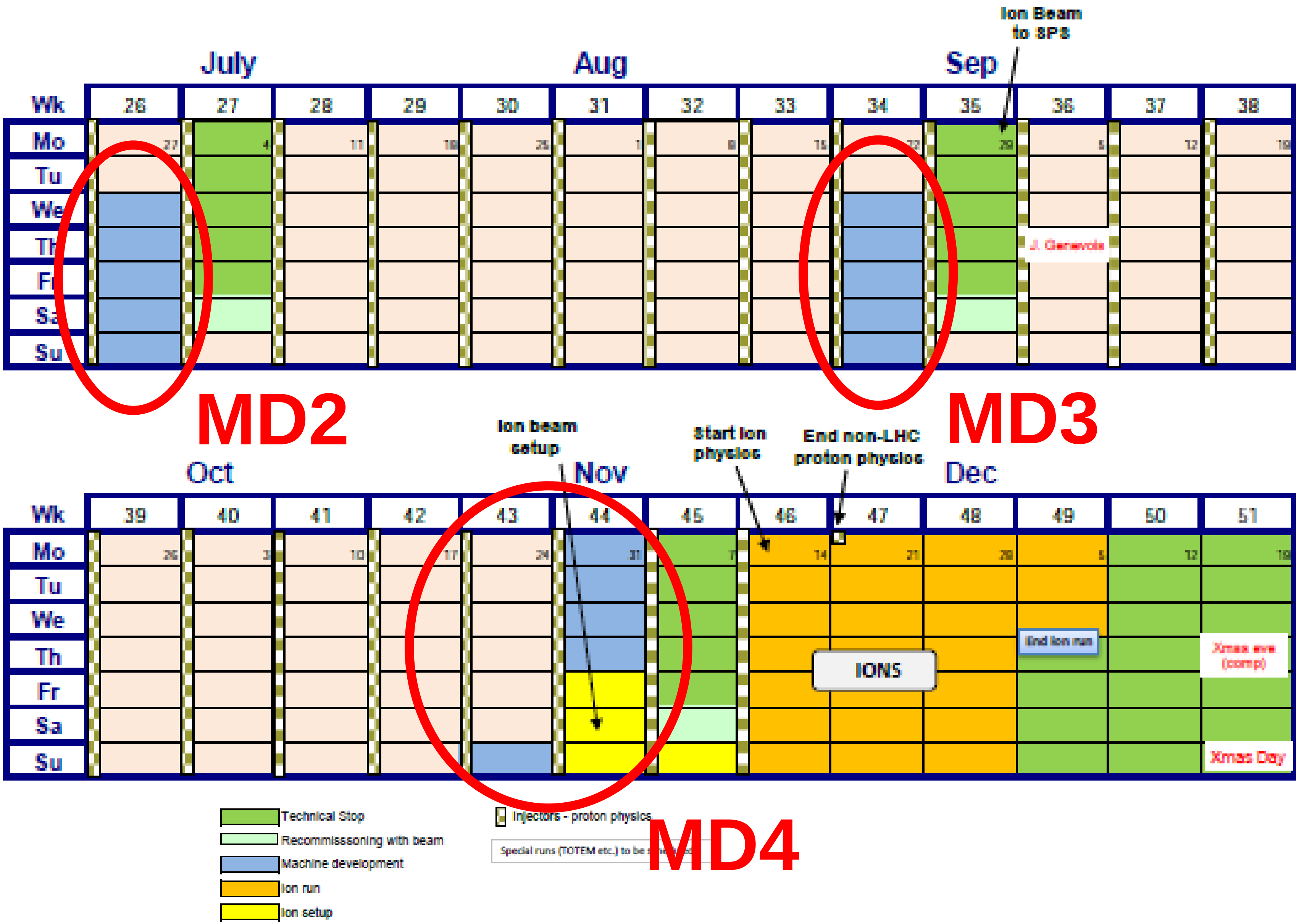
Organization of LHC Machine Time

- The LHC machine schedule includes 4 types of categories.
- Re-commissioning for p, ion setup
  - Set up of agreed machine state (→ Chamonix, Evian)
- Luminosity production
  - Proton luminosity operation
  - Ion luminosity operation
  - Commissioning of new machine states for luminosity production (1.36 TeV, forward physics with high β^*, …)
- Technical stops
- Machine development
  - Machine studies and measurements
  - Improve understanding, test new concepts and ideas, detailed measurements, prepare improvements for higher integrated luminosity, tests for upgrade decisions

LHC Schedule I



LHC Schedule II



R. Assmann

MD Time Available

- 22 days allocated to machine development in 2011.
- Decision to link 4 long MD blocks to technical stops (executed just before):
  - 4 blocks of 5 days ➔ 60 shifts of 8h
  - Plus 2 days of floating MD's, not coupled to technical stops ➔ 6 shifts of 8h
- Total available: 66 shifts ~50-60 MD's
  420 h (with 80% efficiency)

- Well planned organization is needed to make sure that this time is used efficiently and according to the priorities defined and approved by the LHC Machine Committee (LMC).

MD Organization

- MD coordinators appointed by Steve Myers:
  - Ralph Assmann and Frank Zimmermann.
- Helped by scientific secretary and EIC:
  - Giulia Papotti.
- Requests, proposed schedules and results are discussed in the LHC Studies Working Group (LSWG).
- For "critical" MD's formal documents are prepared by MD teams and channeled to Machine Protection Panel for prior safety assessment and approval.
- The LSWG reports proposals of MD program and results to LMC for feedback and approval of priorities.
- In addition coordinate the MD execution, report progress and follow up on the preparation of written MD notes.

http://www.cern.ch/lhc-md

LHC-MD web site holds detailed info, ATS MD notes by the teams, MD requests, LSWG minutes and presentations, ...

Here I will be generic, focusing on issues relevant for this meeting!

Requests per Category (after combining, cutting)

	Time [h]
Beam-beam MD's	144
RF MD's	110
Optics MD's	114
IR MD's	32
e-cloud MD's	72
Injection and injection protection	58
Collimation	64
Passive Protection Stored Beam	16
Impedance	48
R2E	8
Instrumentation MD's	23
Ion MD's	26
Magnet MD's	8
Total	723

Status after analysis of submitted requests in May 2011.

Detailed list at end of talk, as updated by Frank a couple of weeks ago!

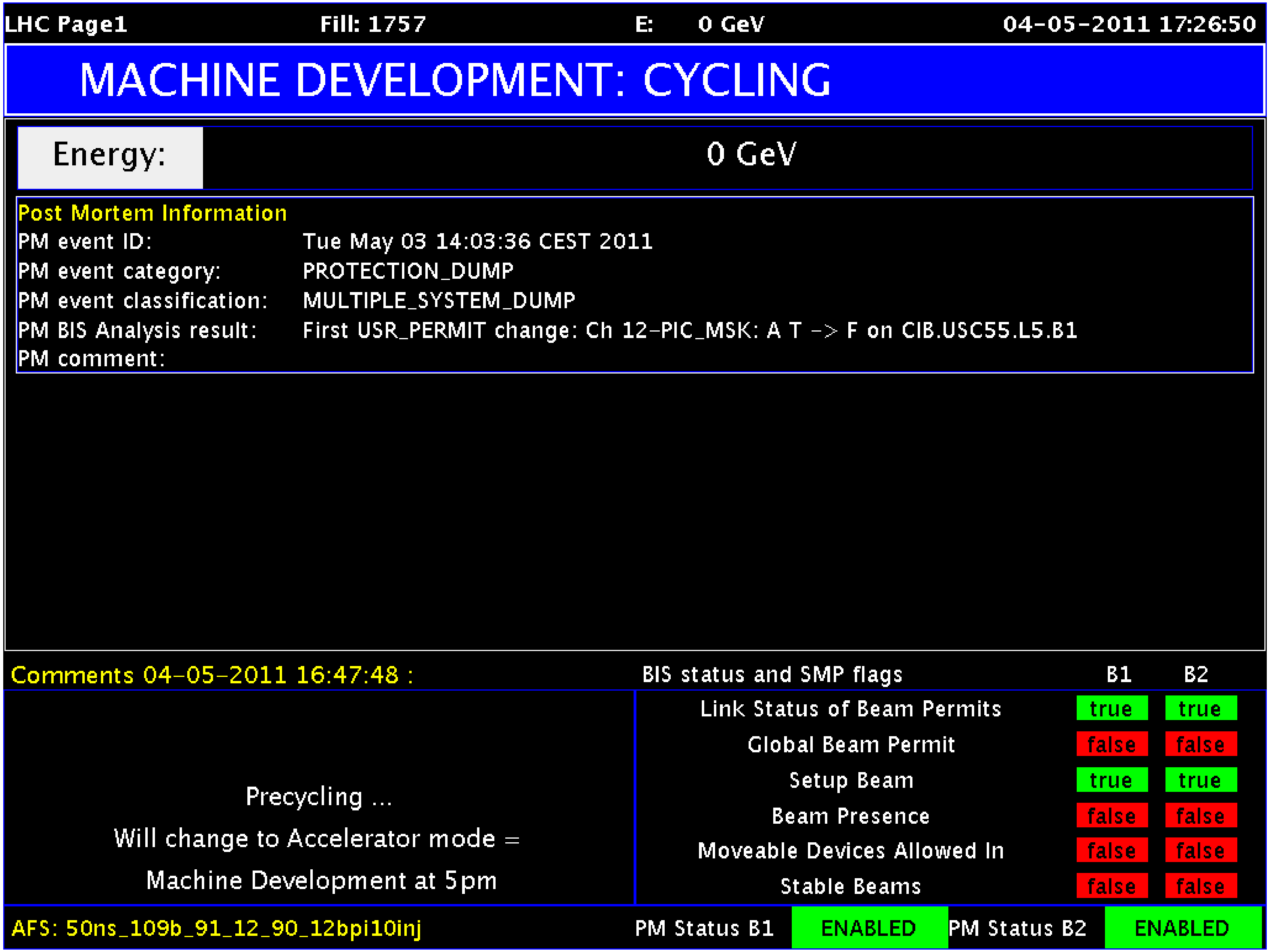
>> 420 h available in 2011

+ additional requests…

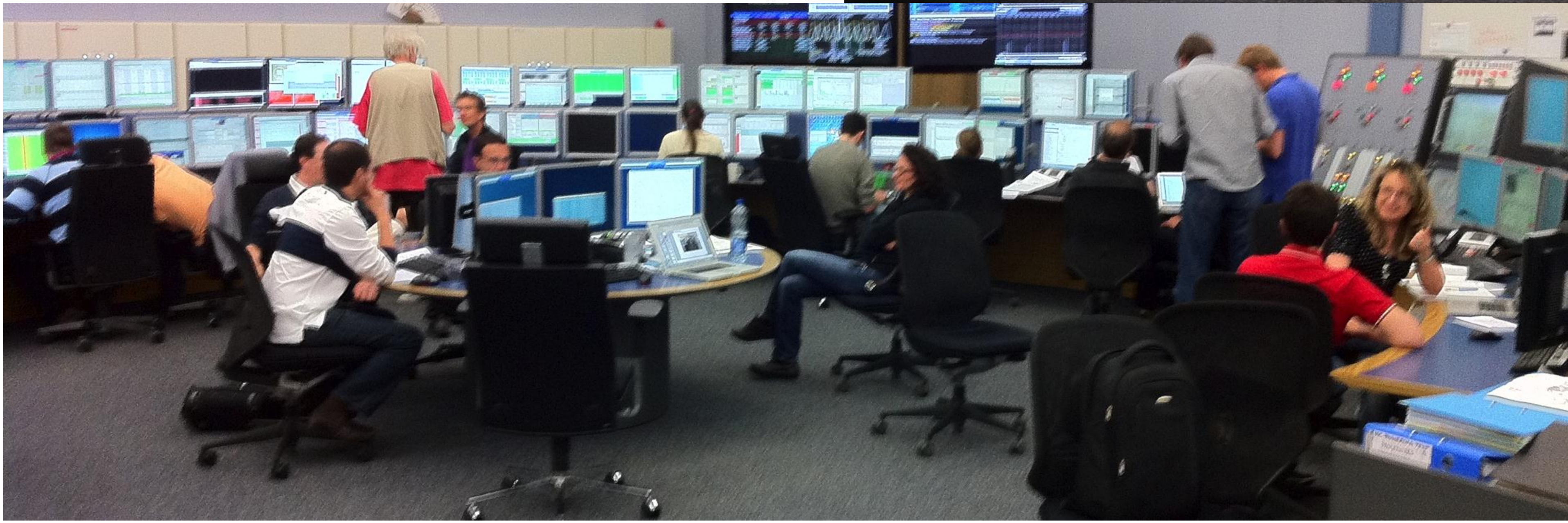
Limiting Time Availability and Priorities

- <u>Not enough MD time to do everything in 2011.</u>
- <u>Combining and cutting of MD's </u>already performed, reflecting some prioritization and overlaps.
- Some MD's moved into end-of-fill MD's.
- <u>Long term priorities </u>defined by allocation to 2011 or 2012 MD time. Reflecting Chamonix/LMC input.
- <u>Short term priorities </u>are defined for each MD. Reflecting also operational issues and needs plus outcome of previous MD's (for MD3 → lower β^*).
- MD time allocation must take availability of teams into account.

1st LHC MD Period: May 4th 2011



Getting busy…



MD Wed – Sat (4.5. – 7.5.)

Day	Time	MD
Wed	**06:00**	**UPS repair, ATS optics checks w/o beam**
	12:00	**Cycle, test ATS optics w/o beam**
	16:00	**0.45 TeV: BPM offset determination for triplet BPMs**
Thu	**00:00**	**0.45 TeV: Alignment TCDQ/TDI and injection losses (other beam)**
	08:00	**0.45 → 3.5 TeV: RF single-bunch instabilities**
	14:00	**Ramp down, cycle.**
	16:00	**0.45 → 3.5 TeV: 90 m optics unsqueeze**
Fri	**00:00**	**Ramp down, cycle**
	02:00	**0.45 → 3.5 TeV: Cross calibration of BSRT/WS/BGI**
	10:00	**Ramp down, cycle**
	12:00	**0.45 TeV: Collision tunes at injection + ramp down, cycle**
	20:00	**0.45 TeV: Beam-beam limit**
Sat	**04:00**	**0.45 TeV: Investigation on CODs**

MD Sat – Mon (7.5. – 9.5.)

Day	Time	MD
Sat	10:00	**0.45 TeV: ATS (including cycle to new injection settings)**
	20:00	**0.45 – 3.5 TeV: Nominal collimation, single bunch tune shift**
	04:00	**Ramp down, cycle**
Sun	06:00	**0.45 TeV: RF multi-bunch instabilities**
	10:00	**0.45 → 3.5 TeV: Coupled-bunch instability rise times**
	18:00	**Ramp down, cycle**
	20:00	**0.45 → 3.5 TeV: Quench test in the DS of IR7**
Mon	06:00	**Technical Stop**
Lost	**6h**	**3.5 TeV: Tune scan – beam-beam optimization, lifetime, losses**

MD Wed – Thu (29.6. – 30.6.)

Day	Time	MD	MP
Wed	*04:00*	*Ramp down, cycle*	
	06:00	No beam: **ATS optics** checks w/o beam	
	08:00	*Ramp down, cycle.*	
	10:00	450 GeV: **Injection 25ns** – different SPS parameters, first look, transverse damper first look (no detailed setup for 25ns)	**B**
	16:00	450 GeV: **RF setup for high bunch intensity**	**A**
	22:00	450 GeV: 450 GeV → 3.5 TeV: **Beam instrumentation** – high bunch intensity, …	**B/C**
Thu	*06:00*	*Ramp down, cycle.*	
	08:00	450 GeV: **Head-on beam-beam limit** – up to 3e11p per bunch, coherent modes. BI parasitically.	**A**
	16:00	450 GeV: **Injecting nominal emittances, MKI & UFO's** – 50ns, blow-up in SPS, SPS scraping and losses, injection into LHC, nominal emittance.	**B**

MD Fri – Sat (1.7. – 2.7.)

Day	Time	MD	MP
Fri	*01:00*	*Switch back to operational injection settings. Verification.*	
	03:00	450 GeV → 3.5 TeV: **RF** – longitudinal beam stability.	**B**
	16:00	*Ramp down, cycle.*	
	18:00	450 GeV → 3.5 TeV: **Long-range beam-beam limit** – lifetime, emittance versus beam-beam separation. Collimation with changing crossing angle.	**C**
Sat	*02:00*	*Ramp down, cycle.*	
	04:00	450 GeV: **Non-linear dynamics** – Dynamic aperture, non-linear chromaticity and frequency map.	**A**
	12:00	*If needed: Precycle.*	
	14:00	3.5 TeV: **Collimation** – combined cleaning, faster setup.	**A**
	22:00	*Ramp down, cycle.*	

MD Sun – Mon (3.7. – 4.7.)

Day	Time	MD	MP
Sun	00:00	3.5 TeV: **ATS** – correction & pre-squeeze.	**A**
	08:00	*Ramp down, cycle.*	
	10:00	450 GeV: **Beam distribution in LHC** – scraping, halo, tails, BLM limits, … (high intensity)	**B**
	14:00	450 GeV: **Quench margin at injection** – observation with special QPS instrumentation, losses from TCLIB collimator, TCDQ checks in parallel	**C**
	22:00	450 GeV: **R2E** – slow controlled losses (1e13p on Q14.R2.B1).	**A**
Mon	**06:00**	**Technical Stop**	

Needs from experiments:

30.6., 08:00 to 16:00 – Luminometers on in ATLAS and CMS

01.7., 18:00 to 02:00 – Luminometers on in ATLAS and CMS

Efficiency and Scheduling (MD#2)

- Available MD hours: **120.0 h**
- Scheduled for MD: **104.0 h** (87% of total time)
- Availability for MD: **92.7 h** (89% of scheduled time) (77% of total time)

→ Scheduling worked: Explicit scheduling of recovery time which was indeed always needed.

- Biggest loss: 4h43 (60% of scheduled time of MD)

- Overall, excellent availability. We could get data for all MD's, even though for some in very limited time!
- Thanks to the HW groups: Cryo, vacuum, PC, magnets, RF, QPS, instrumentation, collimators, BI, kickers, infrastructure, …

MD#1 Notes

#	MD
1	Alignment TCDQ/TDI and injection losses (other beam)
2	90 m optics unsqueeze
3	Collision tunes at injection + ramp down, cycle
4	Beam-beam limit
5	ATS (including cycle to new injection settings)
6	Nominal collimation, single bunch tune shift
7	RF multi-bunch instabilities
8	Quench test in the DS of IR7
9	BPM offset determination by K modulation
10	RF single-bunch instabilities
11	Transverse profile monitors BSRT/WS/BGI
12	Transverse coupled-bunch instability rise times
13	Investigation on CODs

MD#2 Notes

#	MD
1	Injection of bunches with 25 ns spacing
2	Nonlinear beam dynamics tests
3	Longitudinal single-bunch stability with phase-loop on
4	Beam distribution measurements
5	Head-on beam-beam with high intensity & LR-BB studies
6	ATS MD part II
7	IR3 combined cleaning test at 3.5 TeV
8	Improving LHC collimator set up at 3.5 TeV
9	MD on injection quality – longitudinal & transverse
10	MKI UFOs at injection
11	BI studies (draft exists)
12	Quench margin at injection
13	R2E

Achievements MD1

- MD1 proved excellent performance potential of LHC:
  - **No head-on beam-beam limit encountered with 3 times nominal brightness**. Total tune shift: **0.03** with ATLAS/CMS collisions.
  - **ATS** injection optics with **different integer tunes** fine to 3.5 TeV.
  - Collimation system reached **tighter settings with better cleaning efficiency**. Limited by setup accuracy and stability.
  - Collimation system (operational physics settings) **reached 500 kW primary beam loss without quench in dispersion suppressor**.
  - Impedance and **instabilities under control**.
- Operational improvements:
  - **K-modulation** for better orbit and aperture.
  - **90m optics** for ALFA and TOTEM works fine.
  - First test of **bunch blowup with transverse damper**.
  - **Emittance cross-calibration** data collected.
  - Shielding transfer lines for **more tolerant injection**.
  - Data for some suspected dipole correctors.

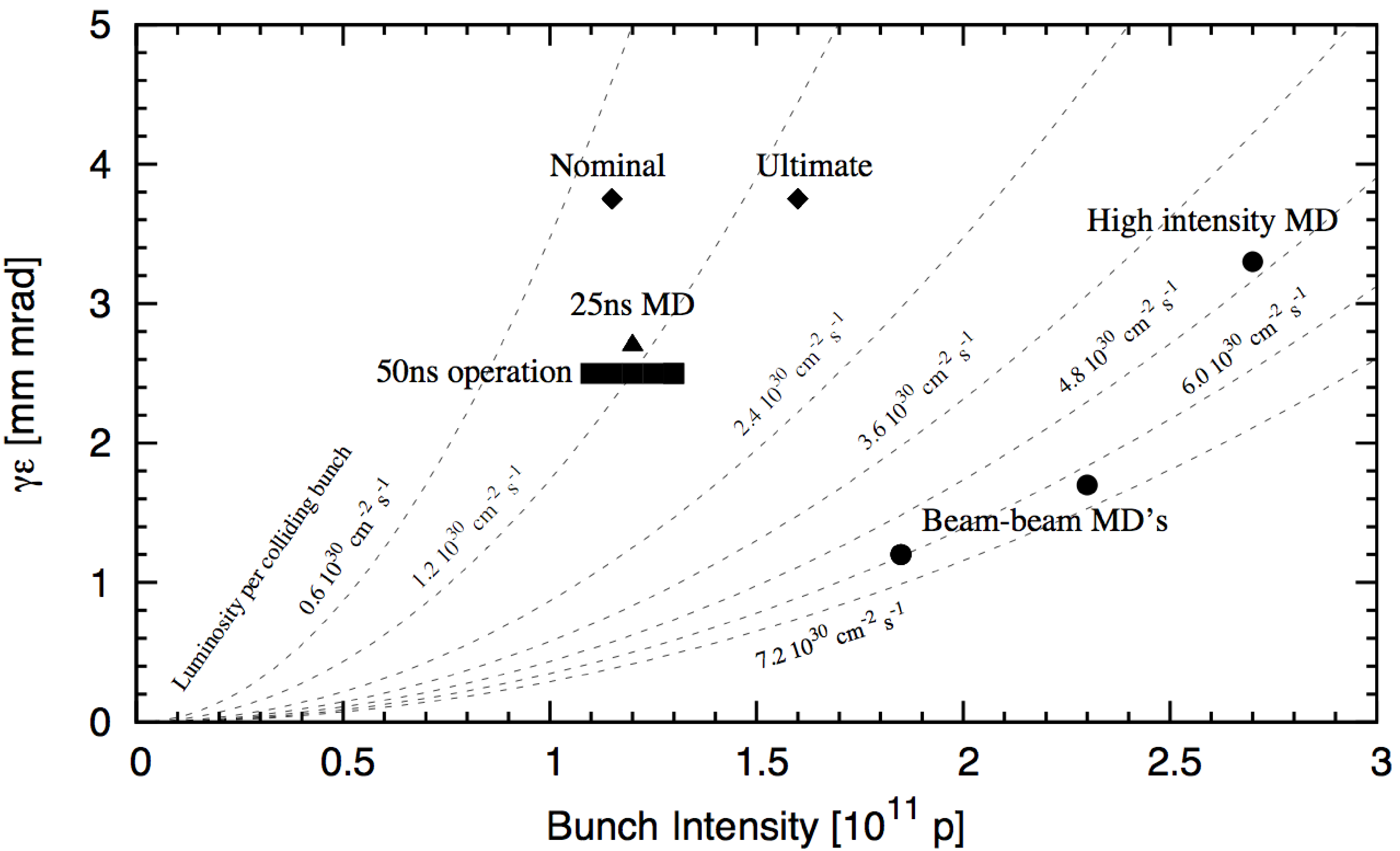
Achievements MD2

- First injection of 25 ns bunch trains with up to 216 bunches.
- Collision of bunches with twice nominal intensity and half emittance, demonstrating 8 times nominal bunch luminosity.
- Injection and storage of even higher bunch intensities with nominal emittance.
- Collision of 50 ns bunch trains with 4-5 sigma separation, demonstrating margin in long-range beam-beam effects.
- First squeeze to below 1.5 m, demonstrating $\beta^* = 0.3$ m with pilot beam, flat machine, no collisions and ATS optics.
- Many, many detailed studies that allow to achieve the above and will make it usable (RF, injection, collimation, quench margins, R2E, optics, BI, …). The devil is in the details!

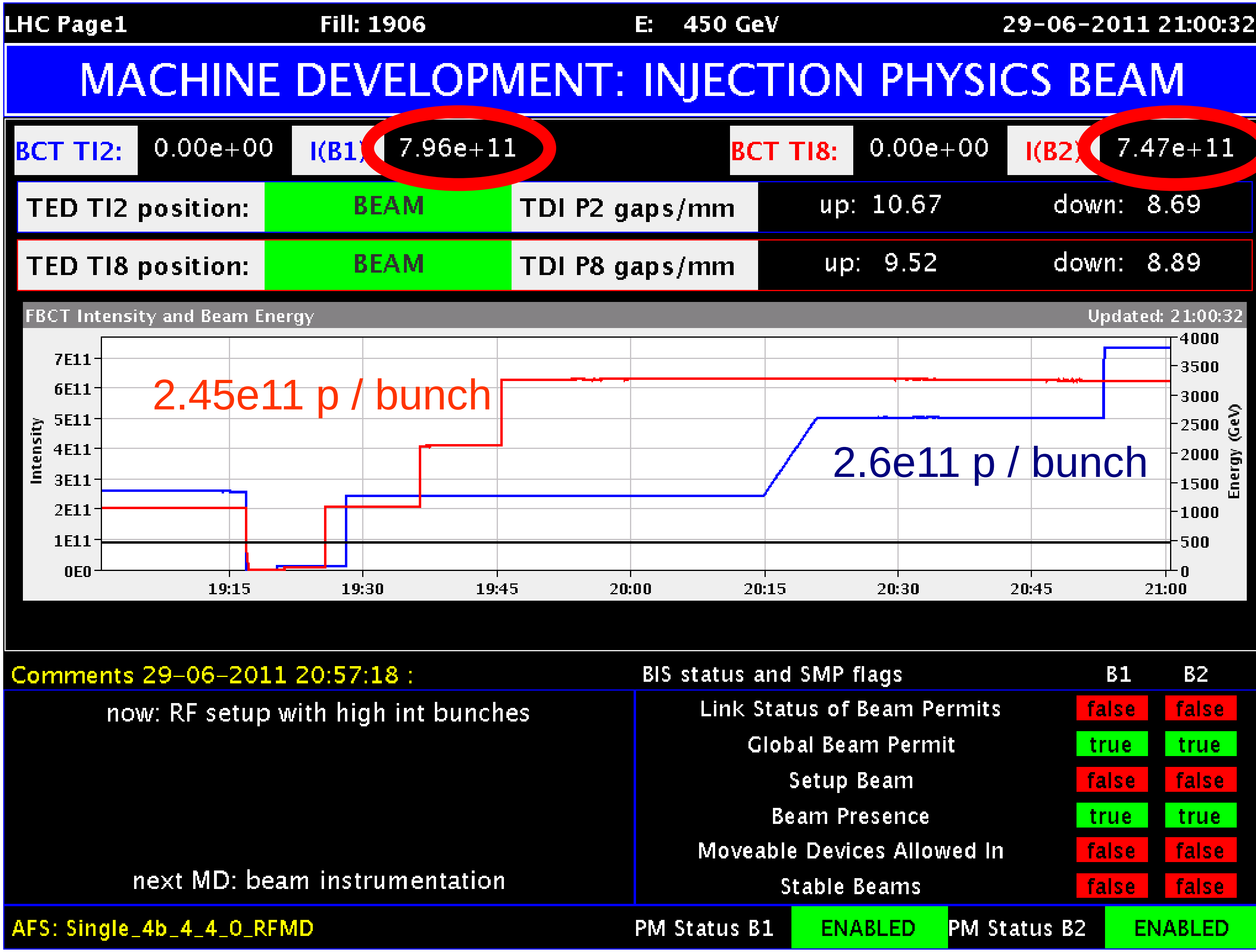
Achievements MD2 in numbers

- High bunch intensity in LHC: N_p = 2.7×10^{11} p/bunch
  excellent beam lifetime $\gamma\varepsilon$ ≈ 3.3 μm
- Colliding beam @ 450 GeV: **N_p = 2.3×10^{11} p/bunch**
  twice nominal intensity, half nominal emittance, head-on & parallel separation OK **$\gamma\varepsilon$ ≈ 1.7 μm**
- Long-range beam-beam for 50ns: **$\alpha_c/2$ = 48 μrad** for $\tau \approx$ 15 h
  crossing angle can be more than halved
- Short bunch spacing → 25ns: N_{bunch} = 216
  24b trains, vacuum ~OK, heat load ~OK, N_p = 1.2×10^{11} p/bunch
  instabilities, better than 50ns at same stage $\gamma\varepsilon$ ≈ 2.7 μm first batches
- Injection: $\gamma\varepsilon$ ≈ 3.5 μm OK for injection
- Tune working point: Q_x/Q_y = 0.47/0.47
  more space in tune diagram for BB footprint
- ATS optics: β^* = 0.3 m

MD Results: Bunch Intensity and Emittance



High Bunch Charge in LHC RF/BI/OP/Injector Teams

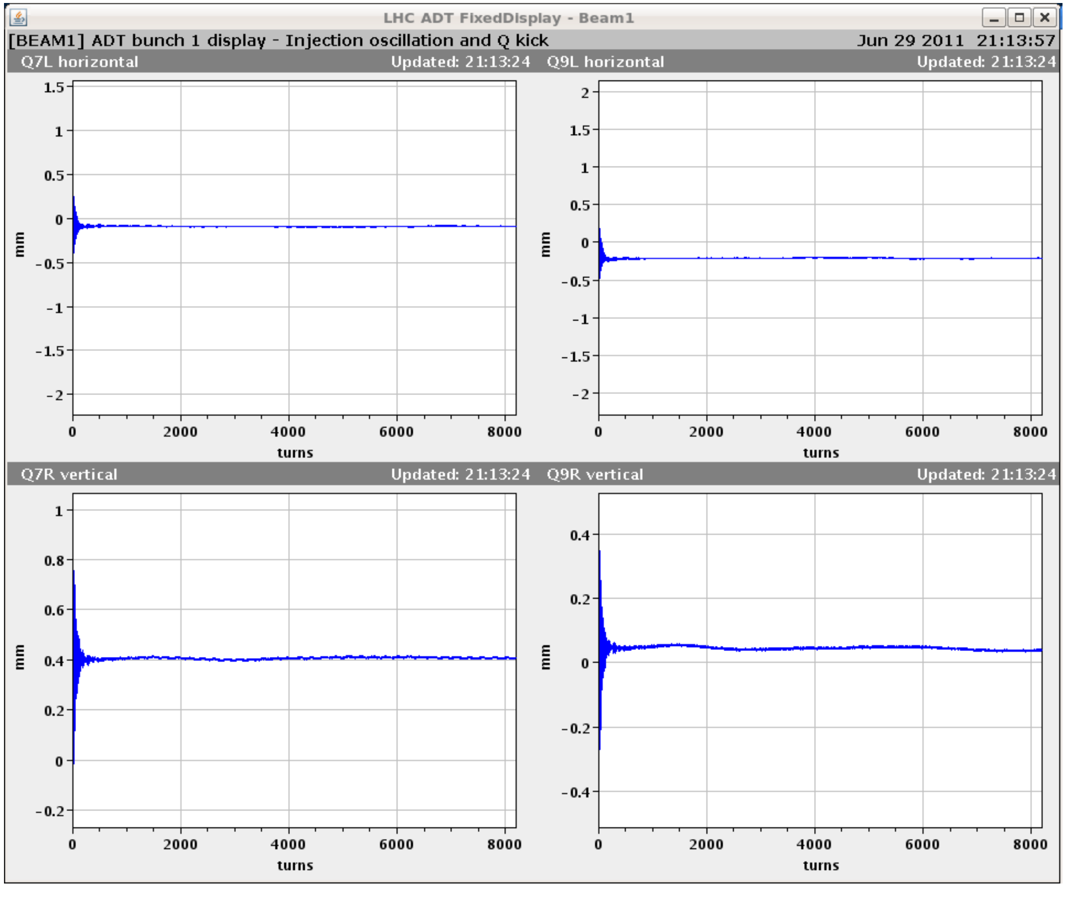


Excellent beam lifetimes: no losses at colli-mators

High Bunch Charge in LHC RF/BI/OP/Injector Teams

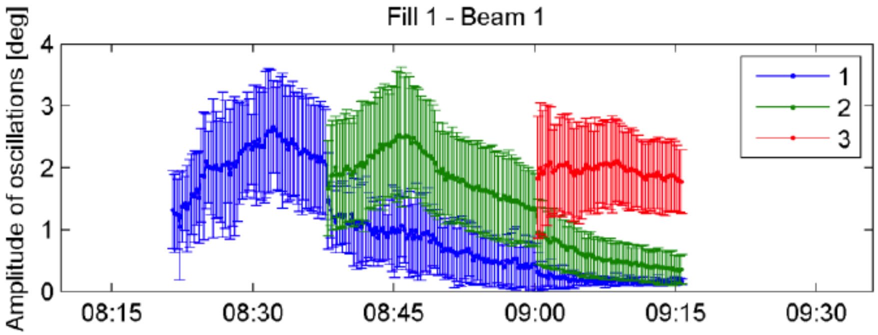
- Emittance in the LHC for 2.6e11 p/bunch:
  - B1H: 3.3, 3.5 μm
  - B1V: 3.1, 3.2 μm
  - B2H: 3.7 μm
  - B2V: 3.9 μm

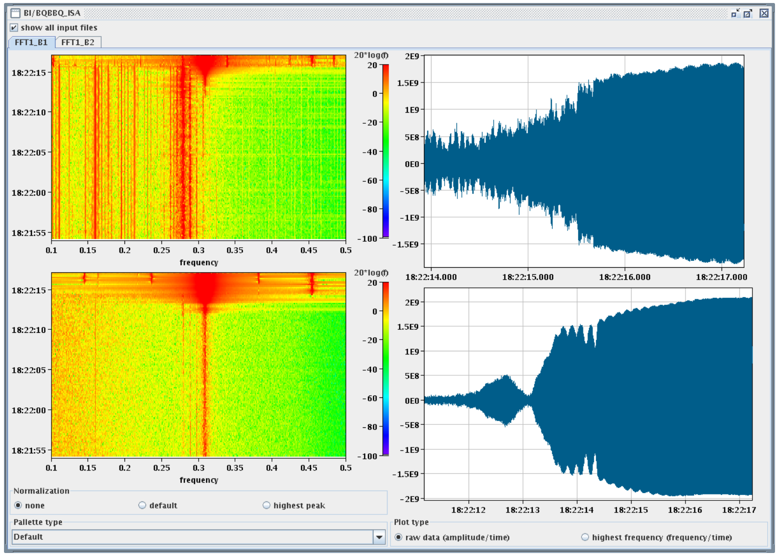
- Injection oscillations:
  - Damper fine…



MD's on Instabilities (ABP/ICE, RF)

- Several MD's performed on single and multi-bunch instabilities. Important subjects behind LHC success.
- Beams kept stable by use of feedbacks, proper working point tuning, octupoles, … Works fine! Very low losses!
- No critical issues here at the moment, therefore details in appendix for the interested…

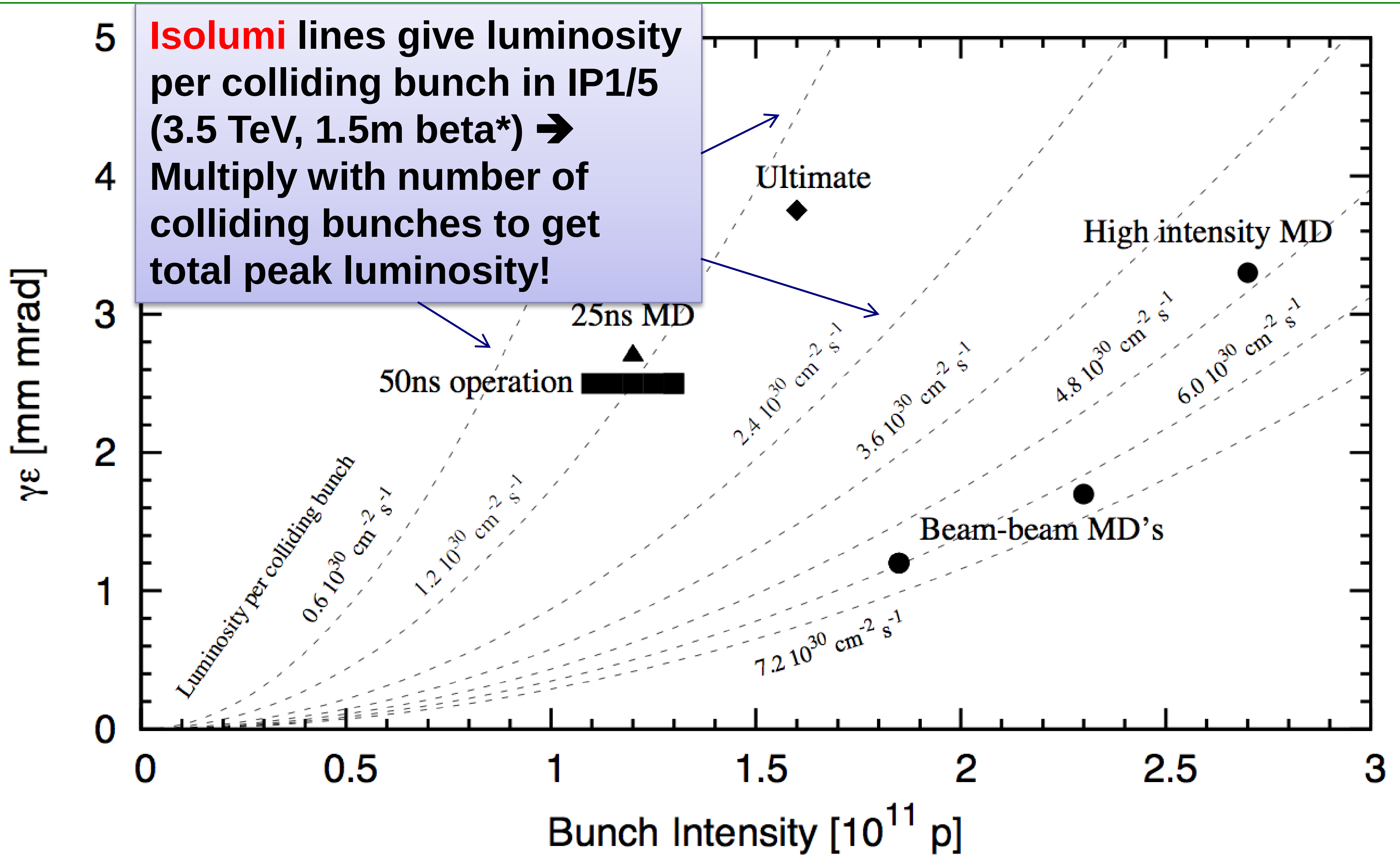




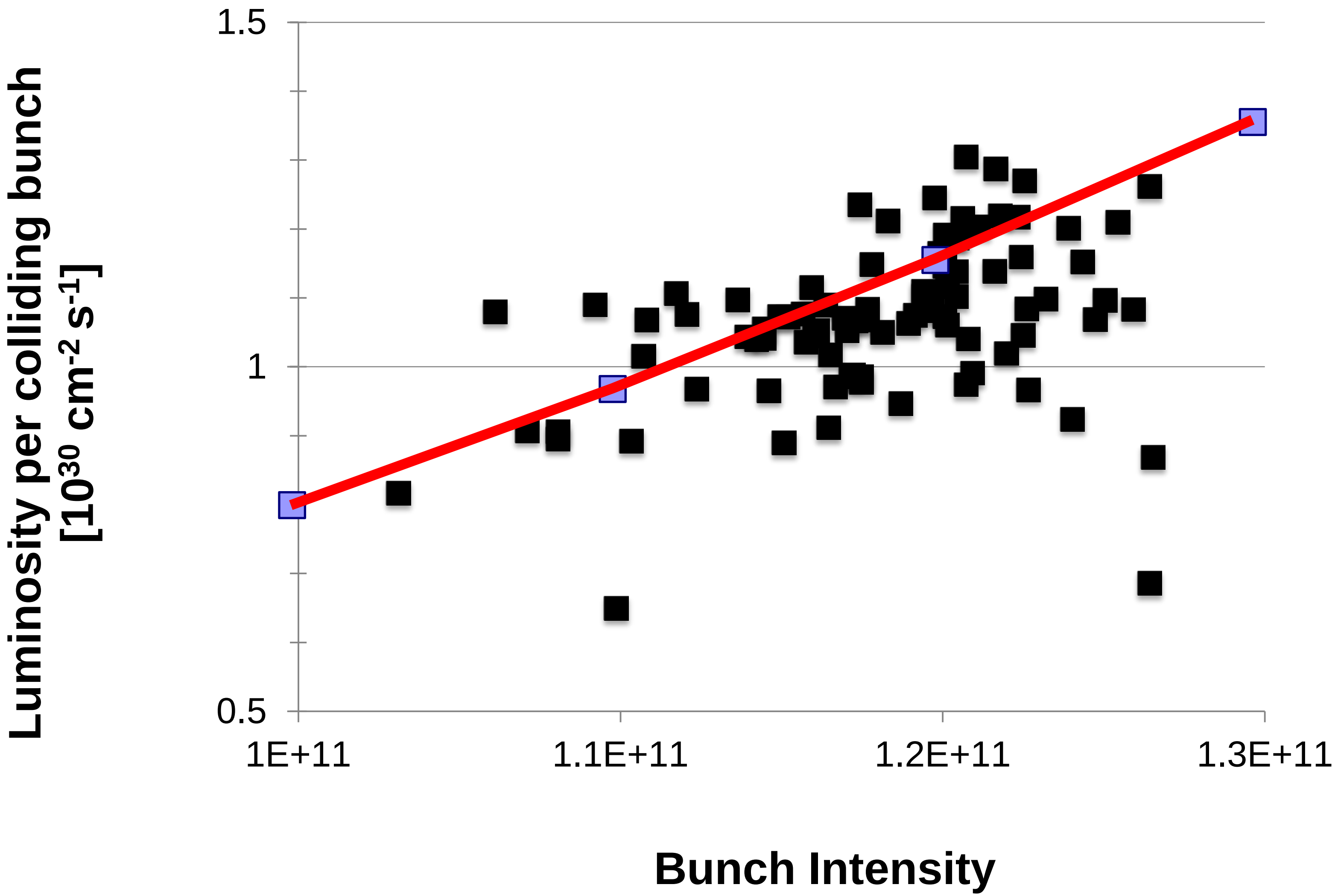
P. Baudrenghien, E. Chaposhnikova, E. Metral and colleagues…

MD Results: Bunch Intensity and Emittance

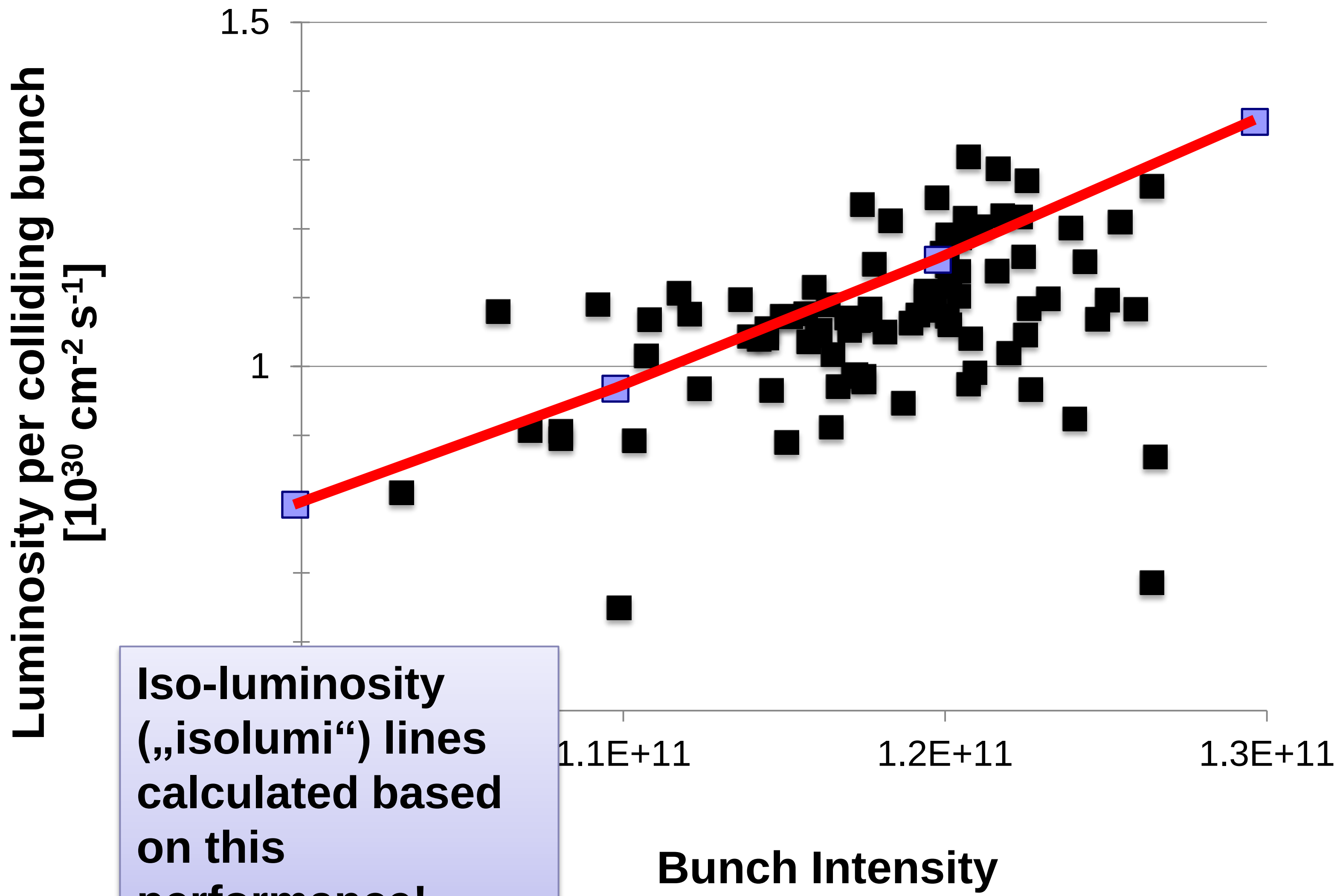
Isolumi lines give luminosity per colliding bunch in IP1/5 (3.5 TeV, 1.5m beta*) ➔ Multiply with number of colliding bunches to get total peak luminosity!



July: Luminosity per Colliding Bunch (IP1/5)

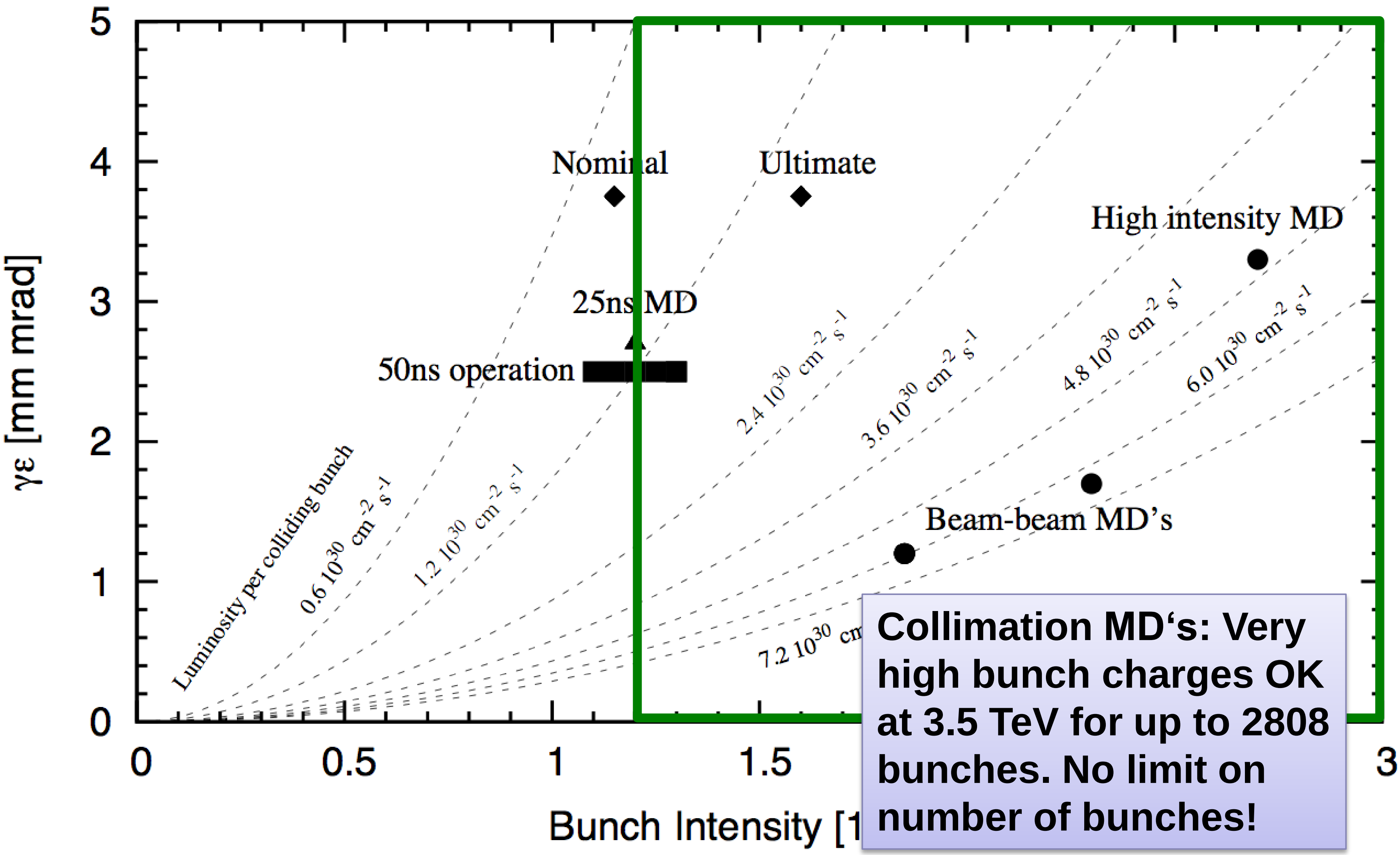


July: Luminosity per Colliding Bunch (IP1/5)



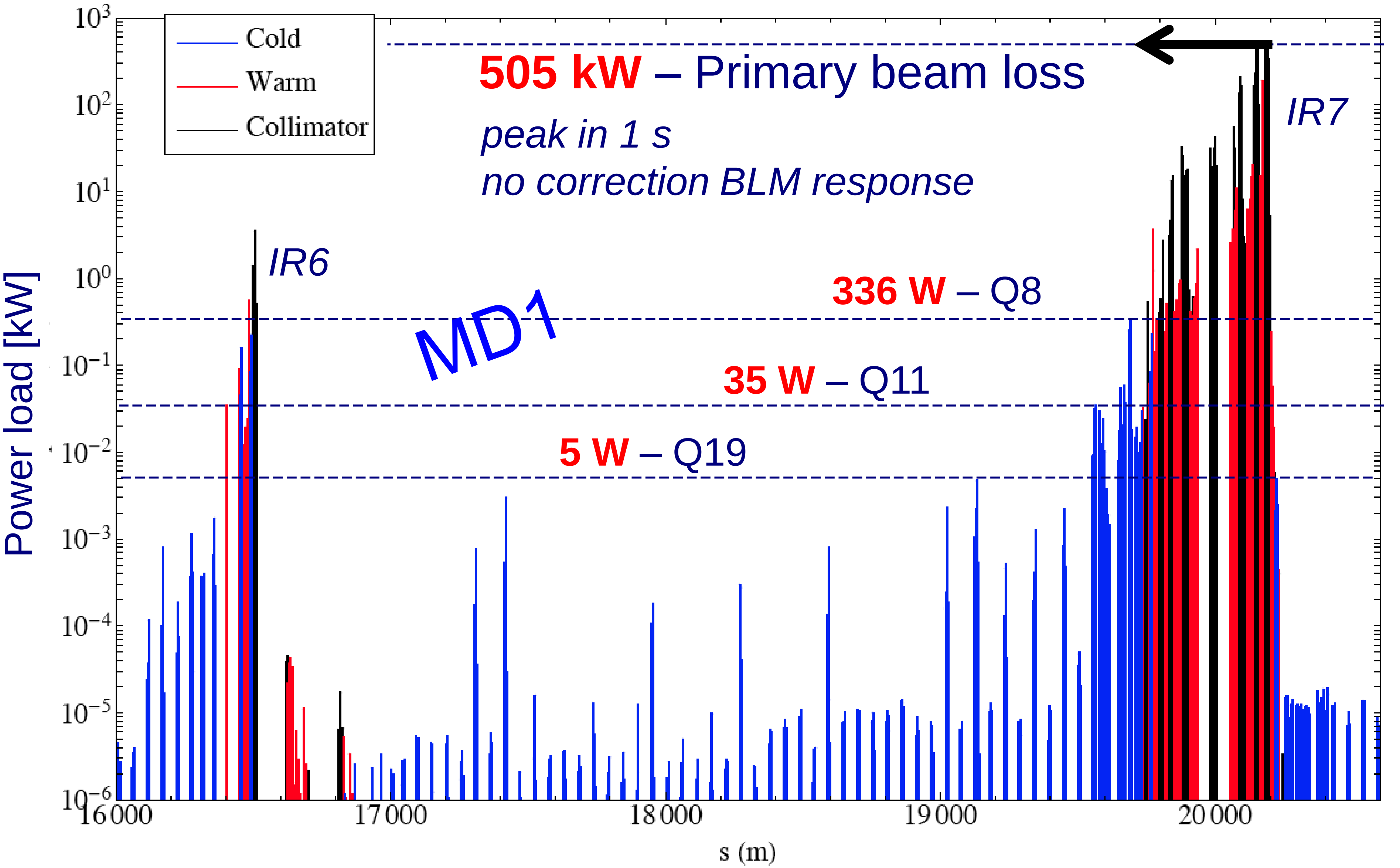
Iso-luminosity („isolumi“) lines calculated based on this performance!

MD Results: Bunch Intensity and Emittance



Collimation MD's: Very high bunch charges OK at 3.5 TeV for up to 2808 bunches. No limit on number of bunches!

Design 7 TeV Power Loss: No quench!



10 x Better Coll. Efficiency *(Coll → SC Magnet)*

LHC Collimation Project CERN

CERN-ATS-Note-2011-036 MD

2011-05-24

Roderik.Bruce@cern.ch
Adriana.Rossi@cern.ch
Benoit.Salvant@cern.ch

Summary of MD on nominal collimator settings

R.W. Assmann, R. Bruce, F. Burkart, M. Cauchi, D. Deboy, L. Lari, E. Metral, N. Mounet, S. Redaelli, A. Rossi, B. Salvant, G. Valentino, D. Wollmann

Keywords: Collimator settings, collimator impedance

MD1

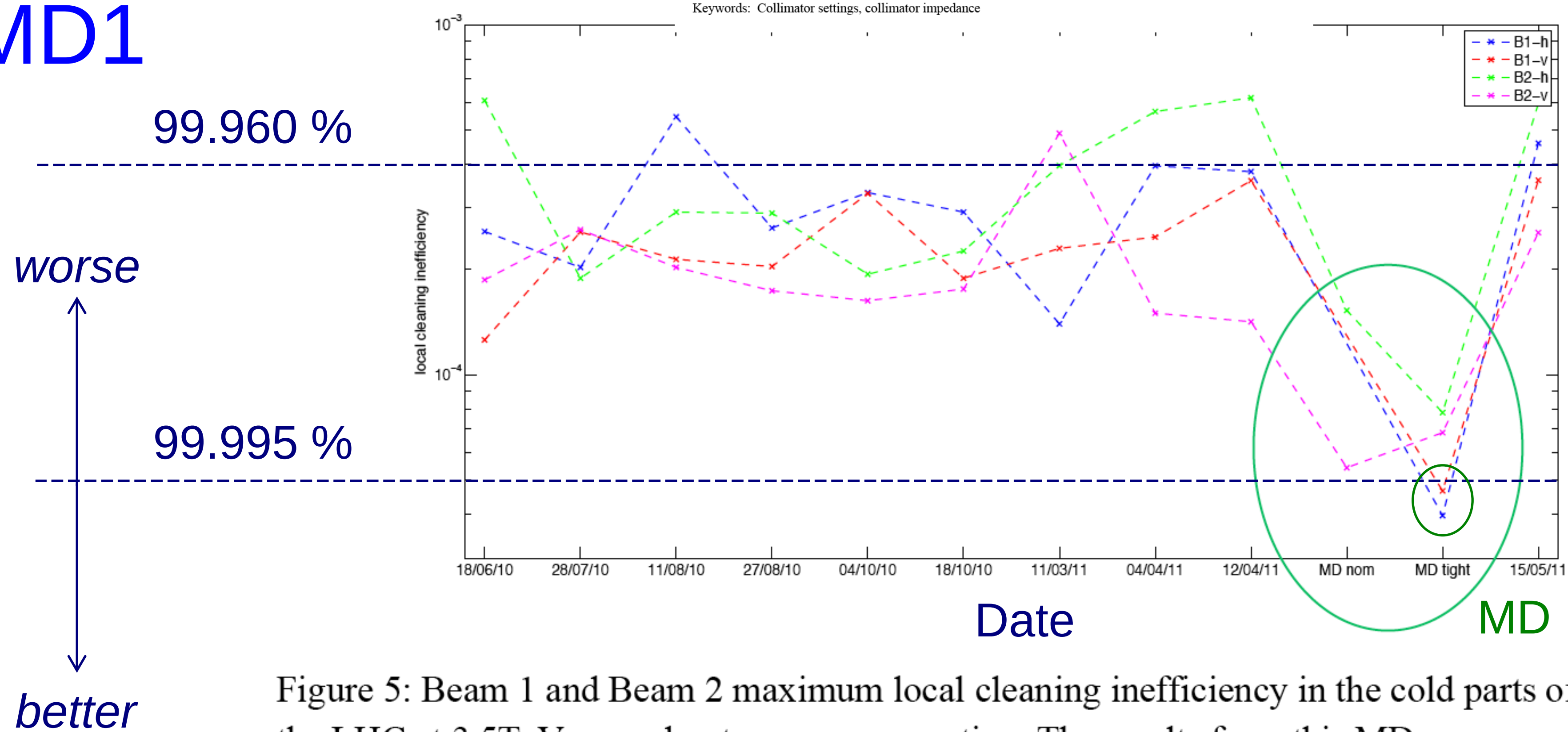
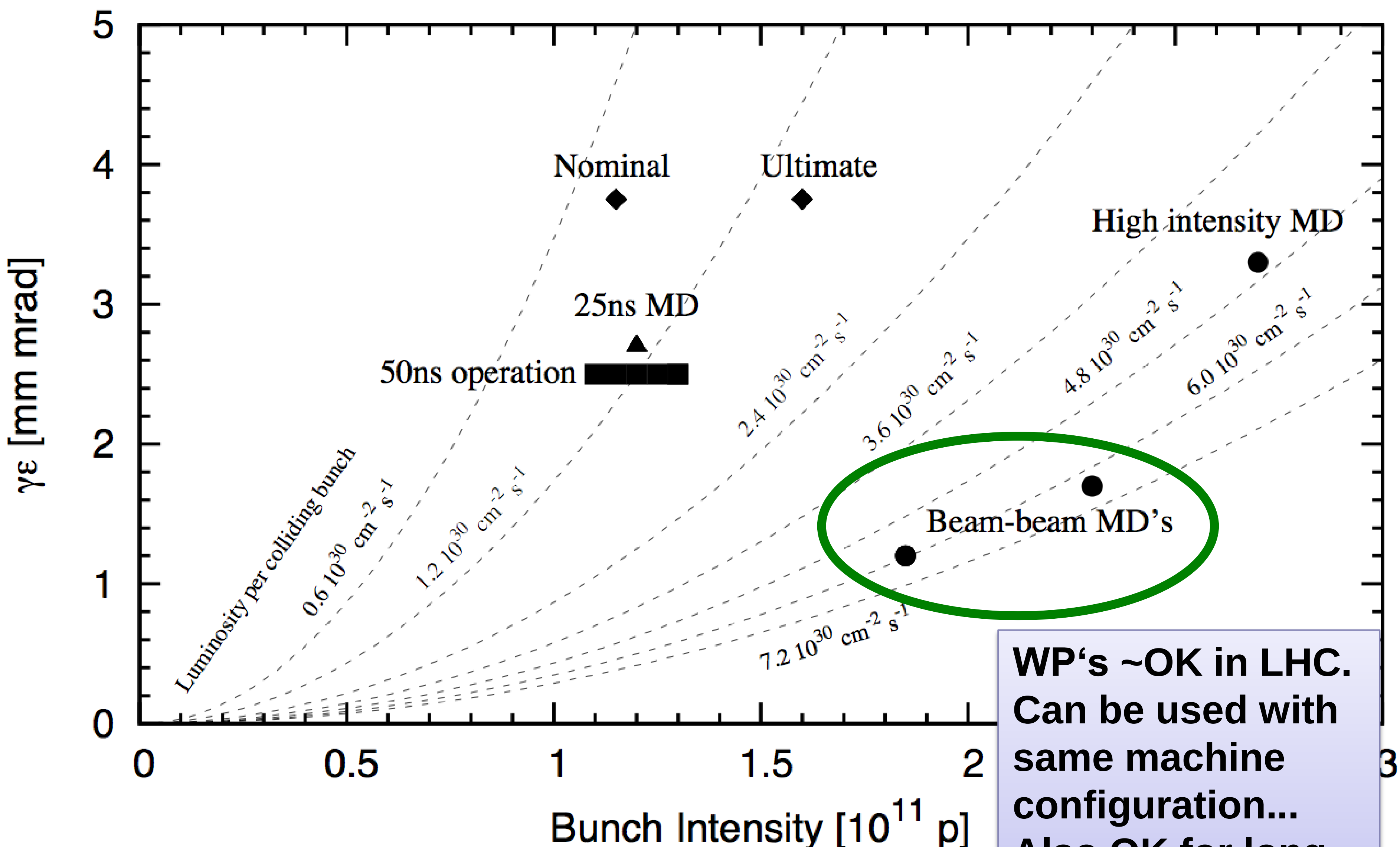


Figure 5: Beam 1 and Beam 2 maximum local cleaning inefficiency in the cold parts of the LHC at 3.5TeV over about one year operation. The results from this MD are contained in the second and third sets of points from the right, where a clear decrease can be observed.

MD Results: Bunch Intensity and Emittance



WP's ~OK in LHC. Can be used with same machine configuration... Also OK for long-range beam-beam!

CERN-ATS-Note-2011-029 MD

19 May 2011

Werner.Herr@cern.ch

tune shifts per IP in excess of 0.015

Head-on beam-beam tune shifts with high brightness beams in the LHC

Participants:
R. Alemany, X. Buffat, R. Calaga, K. Cornelis, M. Fitterer, R. Giachino, W. Herr, A. McPherson, R. Miyamoto, G. Papotti, T. Pieloni, S. Redaelli, F. Roncarolo, M. Schaumann, R. Suykerbuyk, G. Trad
CERN, CH-1211 Geneva 23
S. Paret
LBNL, U.S.A.

<u>No limit found for head-on beam-beam effects for the intensities investigated so far</u>

Keywords: LHC, beam-bear

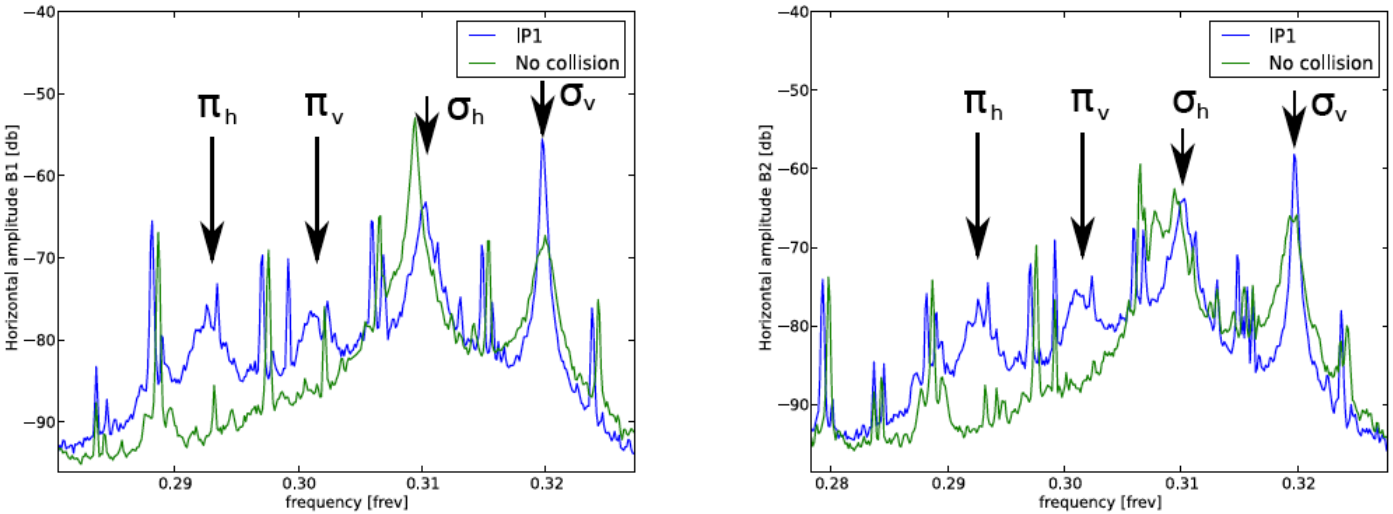


Figure 13: Tune spectra without and with two collisions, horizontal plane for beam 1 and beam 2 (fill 4).

MD2: Head-on beam-beam limit (Werner Herr et al)

- **Twice nominal bunch intensity, half nominal emittance!** Tune-shift and luminosity as expected (~ **0.015/IP**).
- Fill 1:

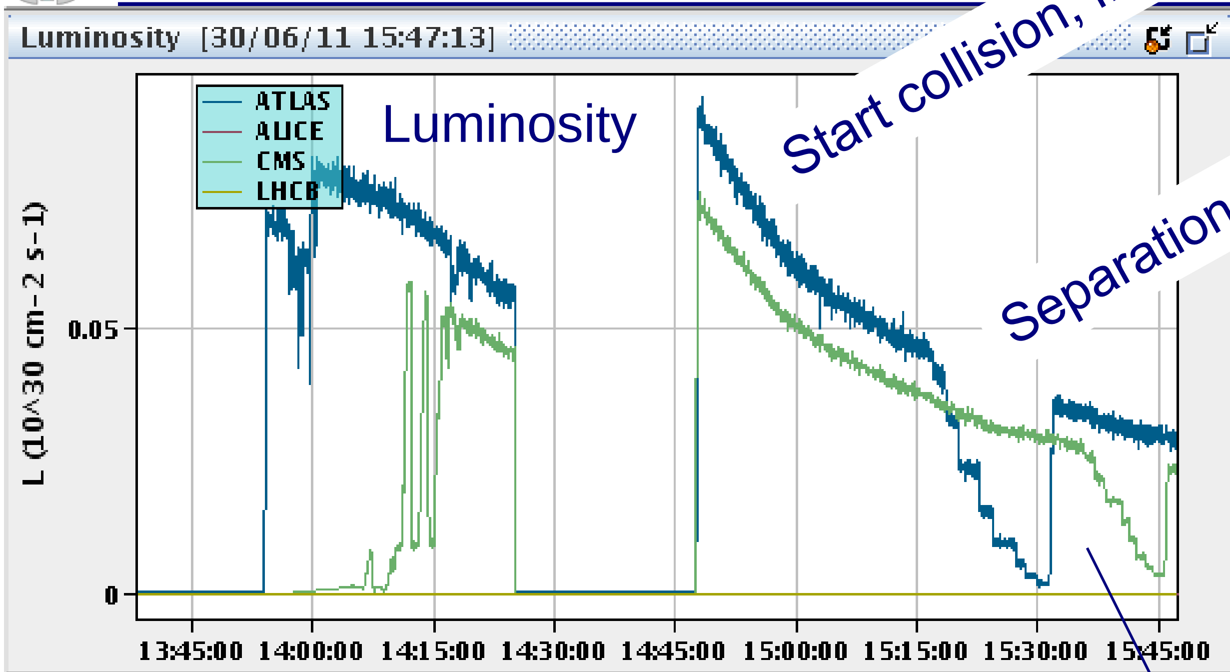
	B1	B2
Intensity per bunch	2.3e11 p	2.2e11 p
Emittance H:	1.6 um	1.7 um
Emittance V:	1.6 um	1.9 um

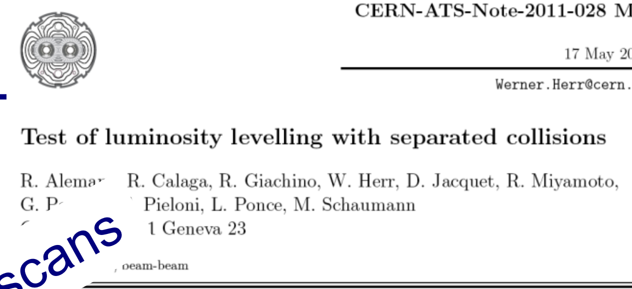
- Fill 2:

	B1	B2
Intensity per bunch	2.2e11 p	2.3e11 p
Emittance H:	1.9 um	1.9 um
Emittance V:	1.7 um	2.1 um

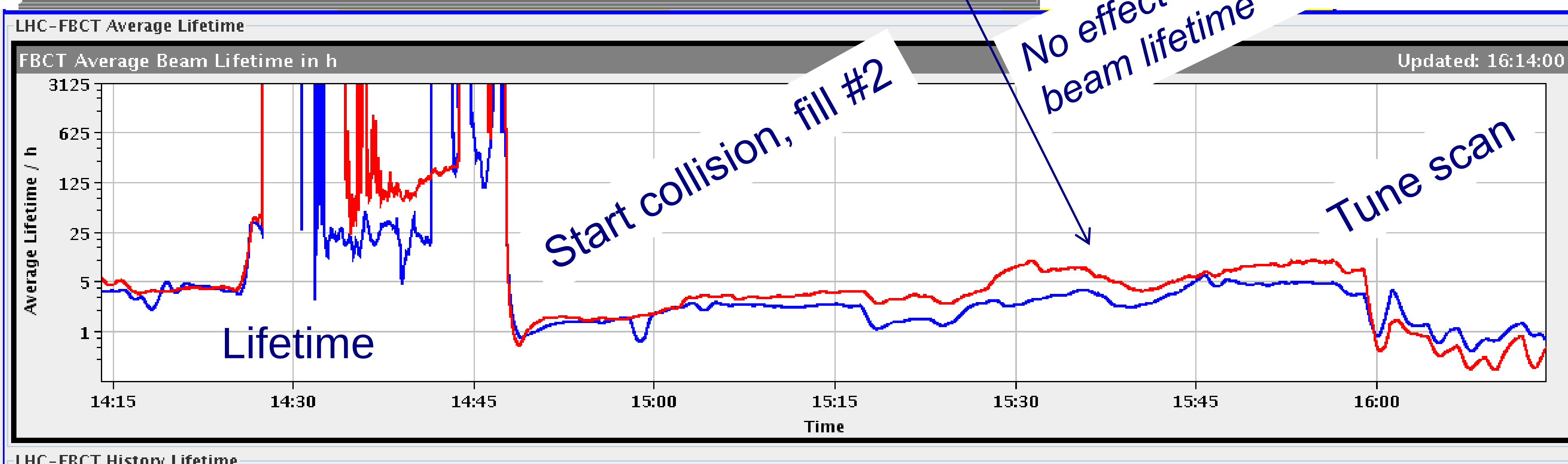
- Highest bunch intensities as achieved in LHC (2.7e11) still to be tested
  - Will have somewhat higher emittance

Luminosity and Lifetime





Twice nominal bunch intensity, half nominal emittance!

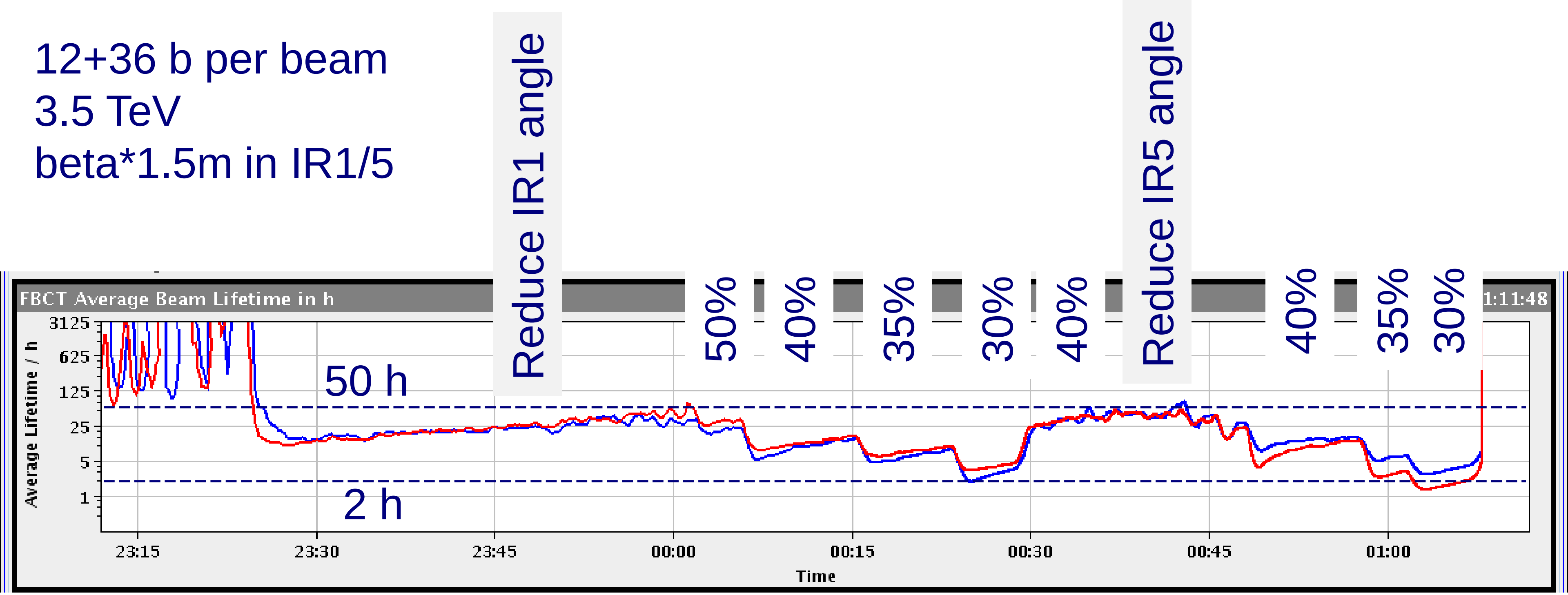


Long-range beam-beam *(W. Herr, BB team, coll team)*

- One ramp with 12+36 bunches per beam to 3.5 TeV, beta*1.5m in IP 1/5.
- Reduced crossing angle in steps from 120 μrad to 36 μrad and recorded losses.
- Tertiary collimators following the changed orbit.
- First losses observed at separation of 4-5 sigma, reduced lifetime.
- Strong correlation of losses with number of long range interactions (PACMAN effects).
- Detailed analysis will be done.

Reduction crossing angle IR1 (V) and IR5 (H)

12+36 b per beam
3.5 TeV
beta*1.5m in IR1/5



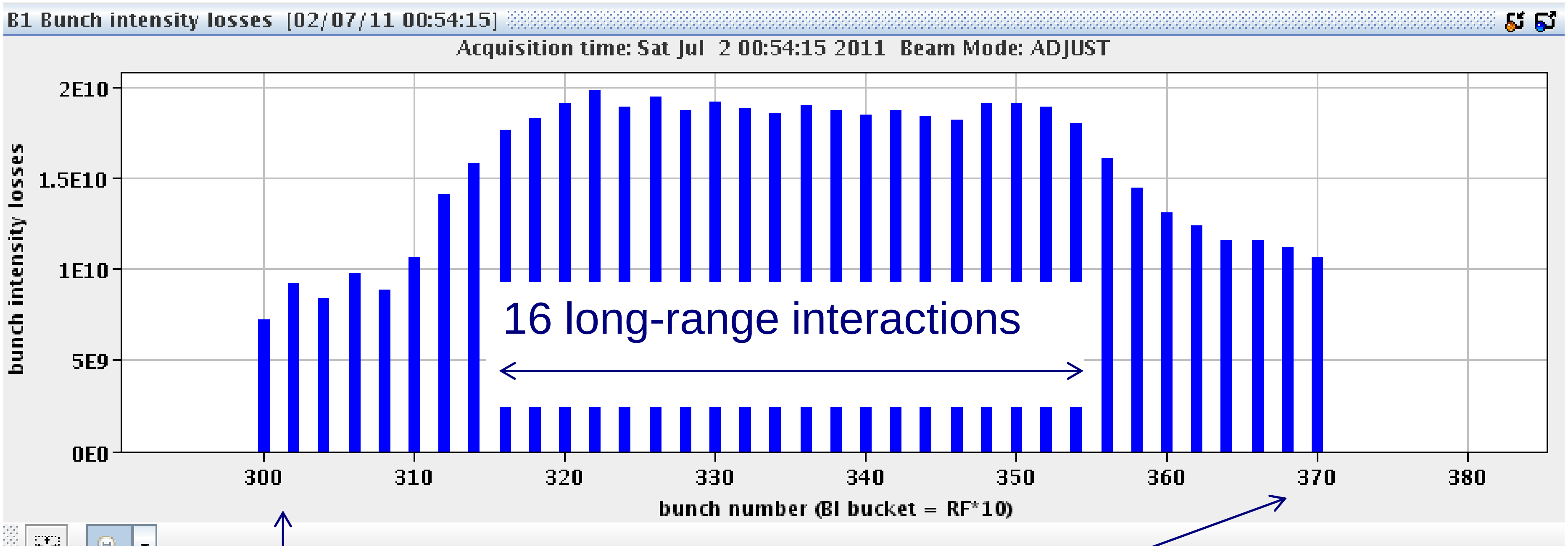
Crossing angles in IR1 and IR5 <u>reduced in steps of 5 – 10 %.</u>

TCT's following changed orbit.

100% = 120 μrad = 12 σ beam-beam separation for ε~2.5μm!

50% fine (no reduction in lifetime), <u>40% (5 σ b-b) still OK</u>, 30% too low!

PACMAN Effect: Beam Loss vs Bunch Number

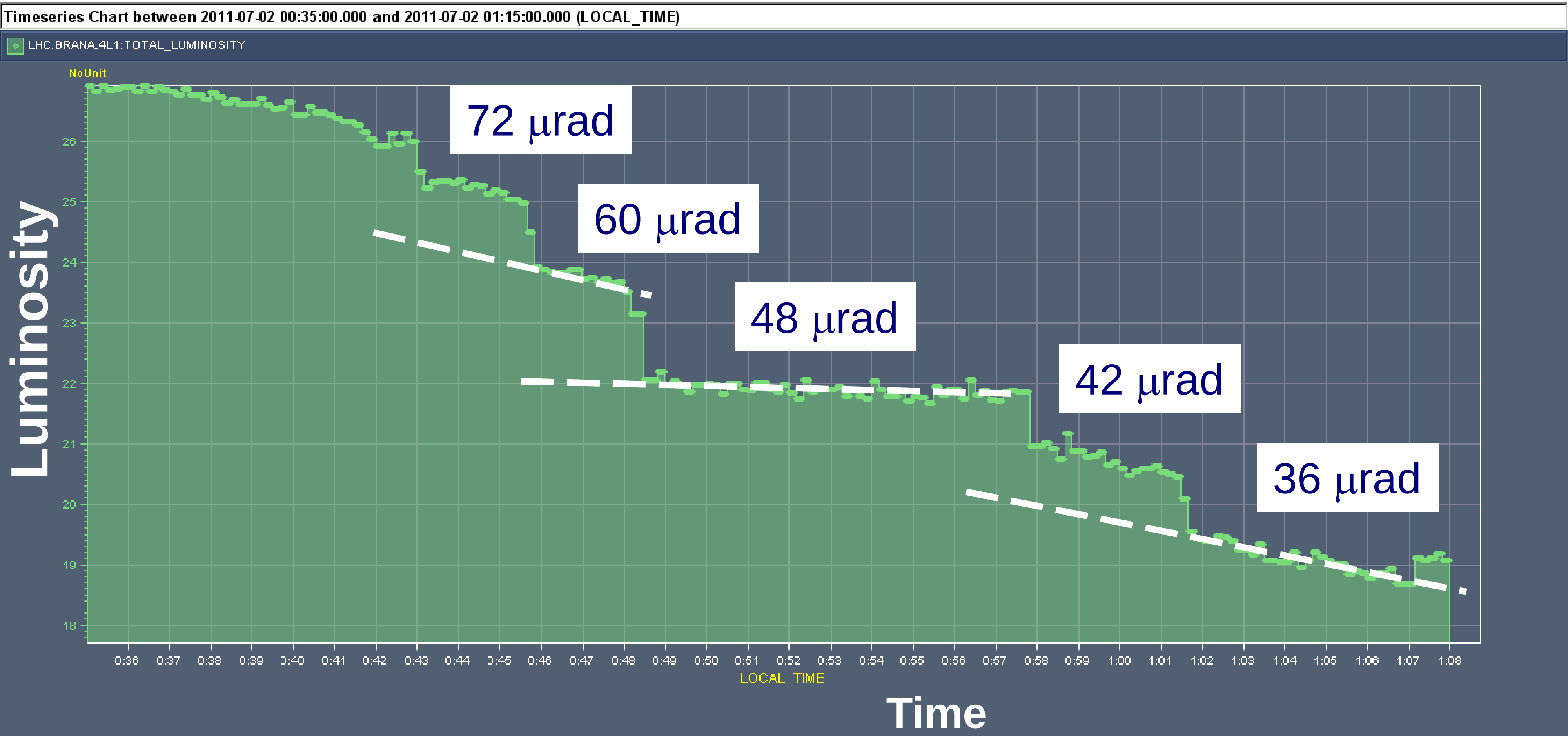


7-8 long-range interactions

R. Assmann

IR1 Luminosity During IR5 Adjustments

IR1 cross. angle at 48 μrad (~5σ sep) constant. IR5 cross. angle being reduced.

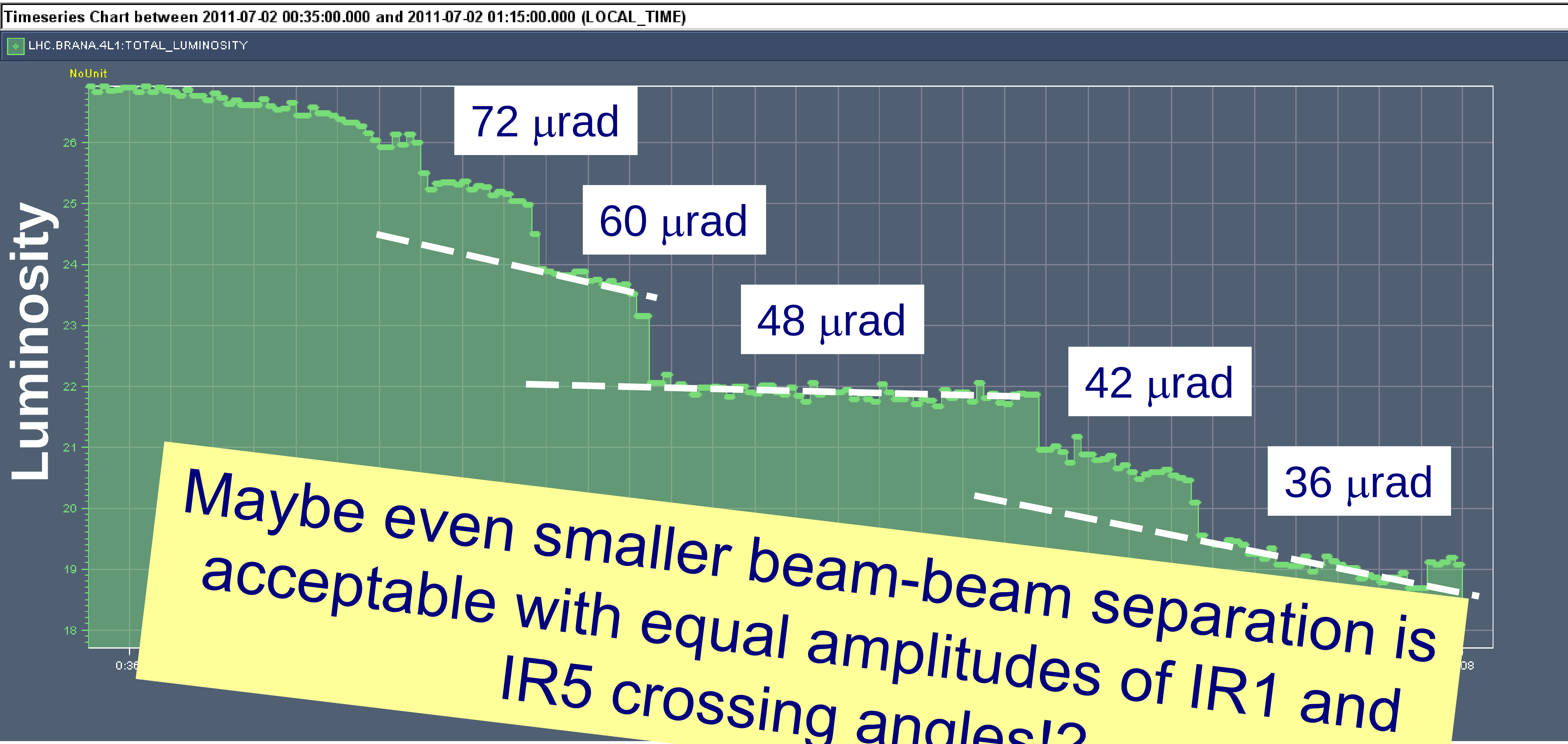


Equal crossing angle amplitude in IR1/5 best for diffusion!

Compensation of LR beam-beam effects in IR1 and IR5…

IR1 Luminosity During IR5 Adjustments

<u>IR1 cross. angle at 48 μrad (~5σ sep) constant</u>. IR5 cross. angle being reduced.



Maybe even smaller beam-beam separation is acceptable with equal amplitudes of IR1 and IR5 crossing angles!?

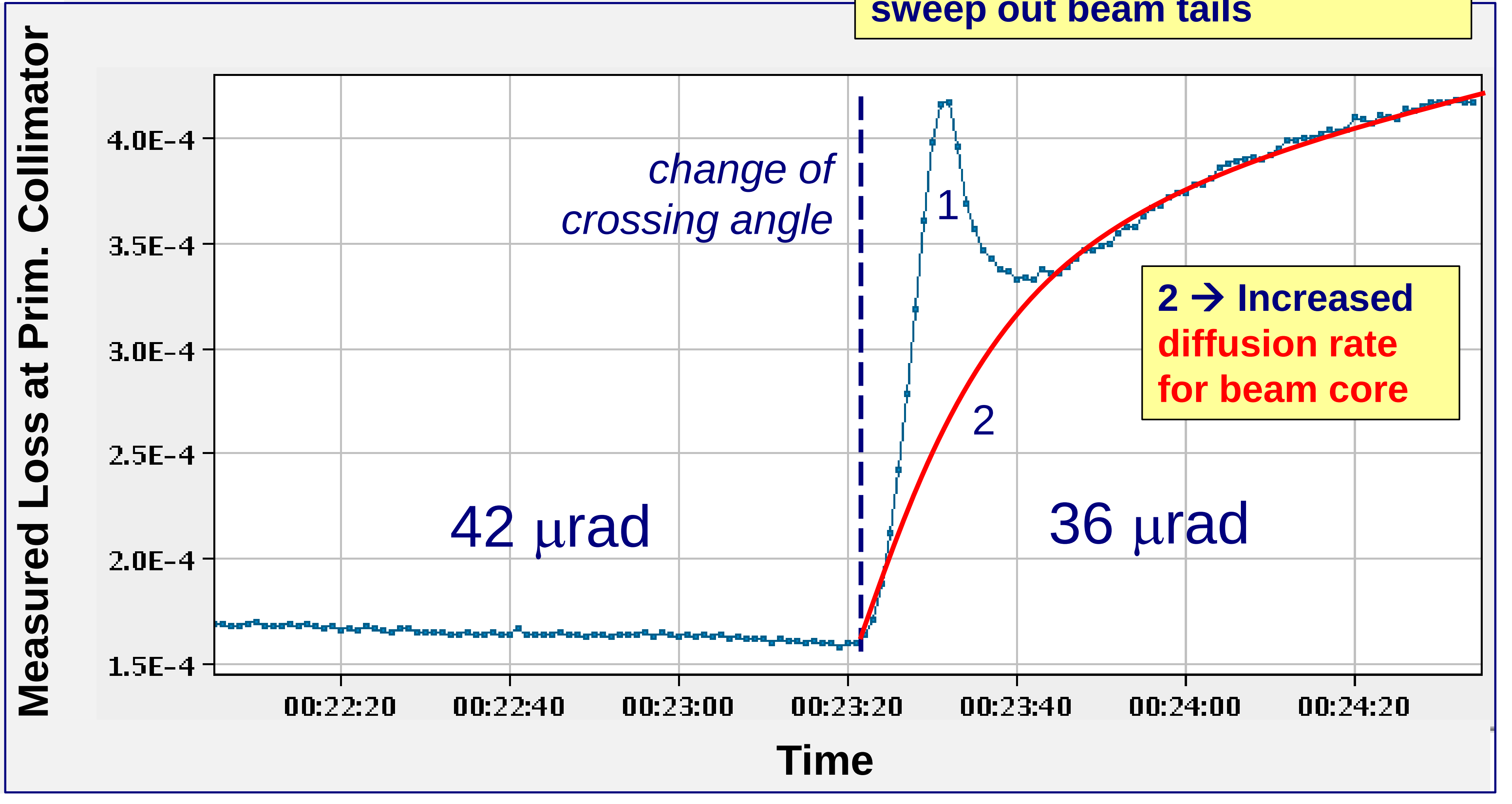
Equal crossing angle amplitude in IR1/5 best

Compensation of LR beam-beam effects in IR1 and IR5…

Losses at Collimator: Dynamic Aperture and Core Diffusion

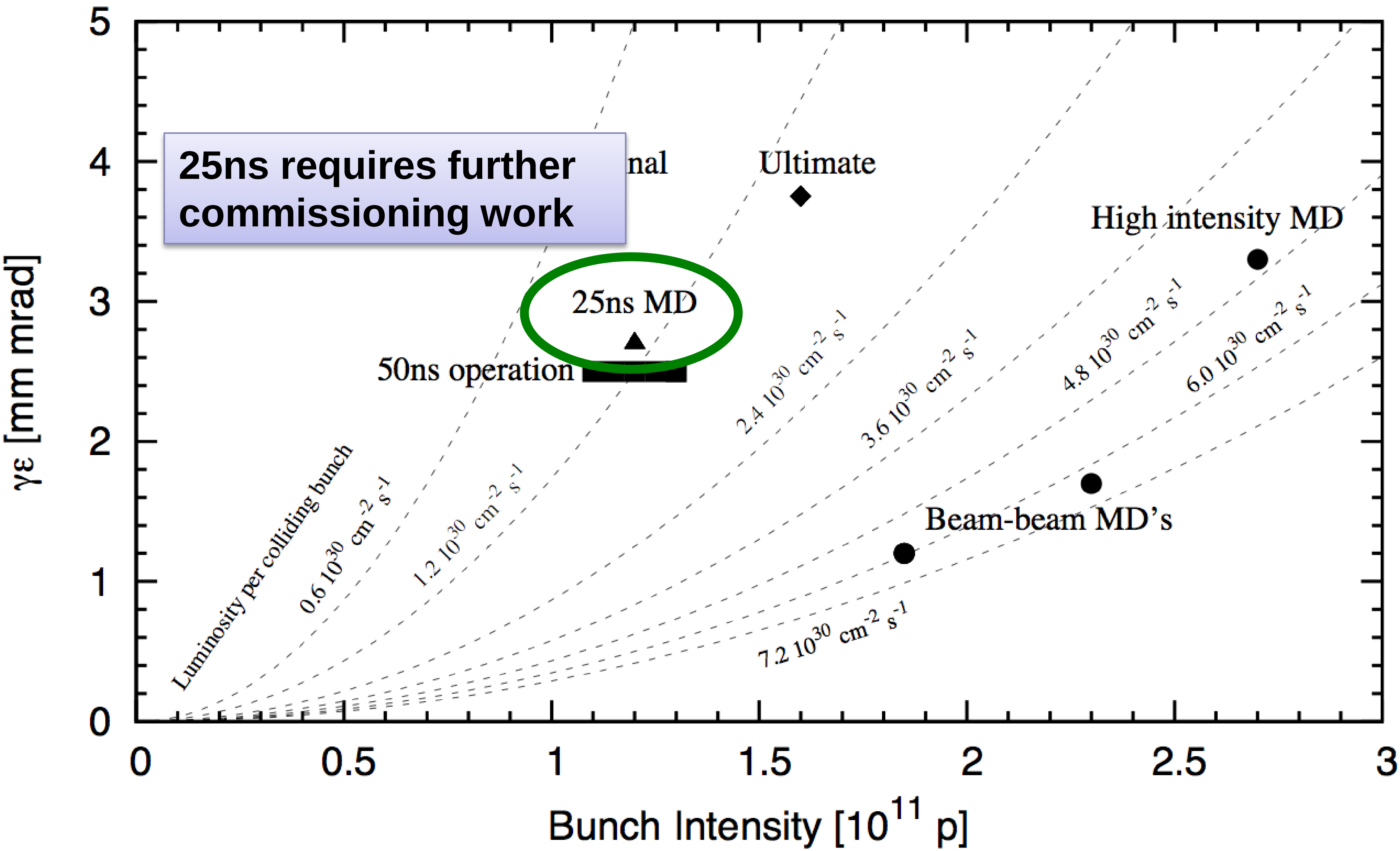
Two processes seen after change of crossing angle → beautiful acc. physics

1 → Reduced dynamic aperture: sweep out beam tails



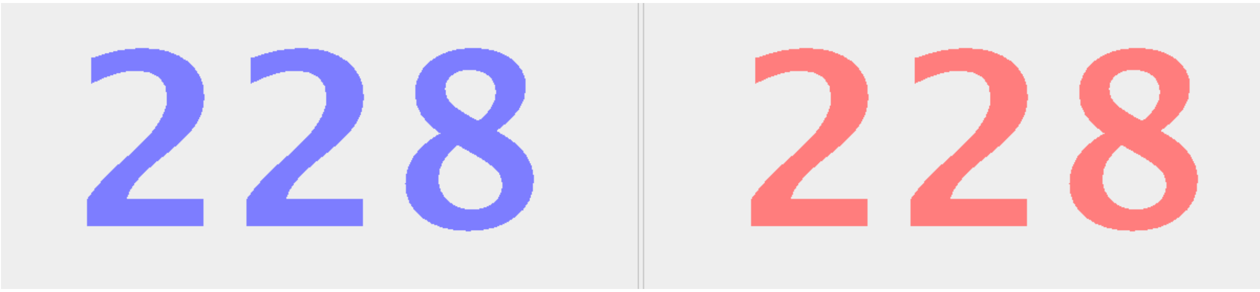
R. Assmann

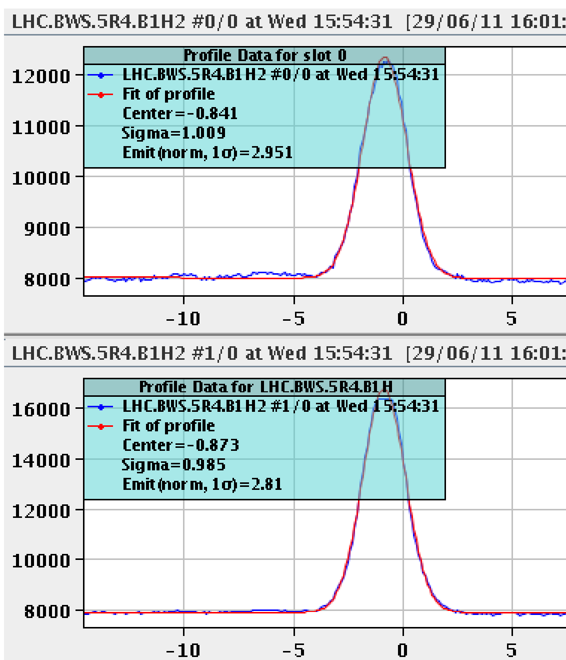
MD Results: Bunch Intensity and Emittance

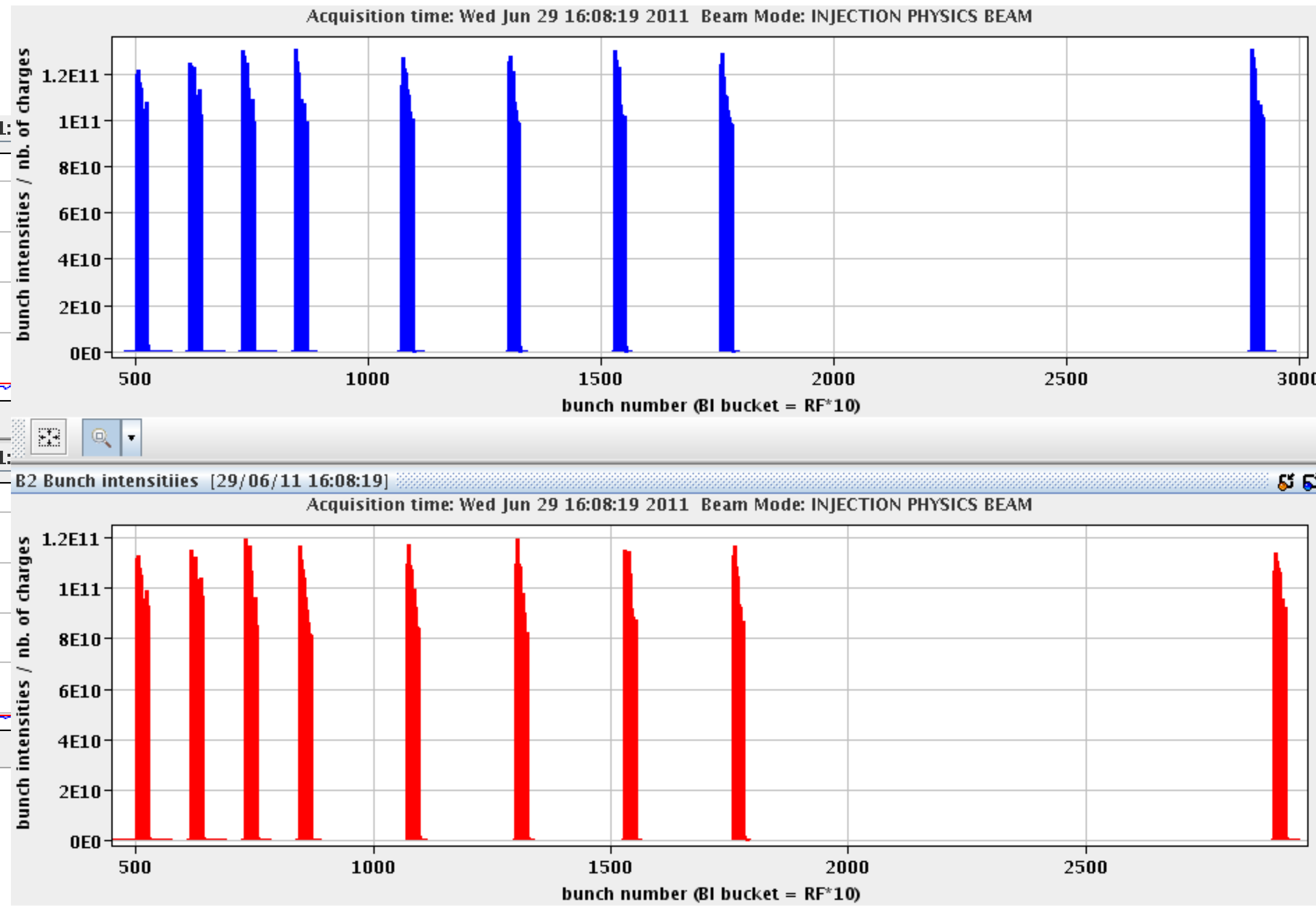


R. Assmann

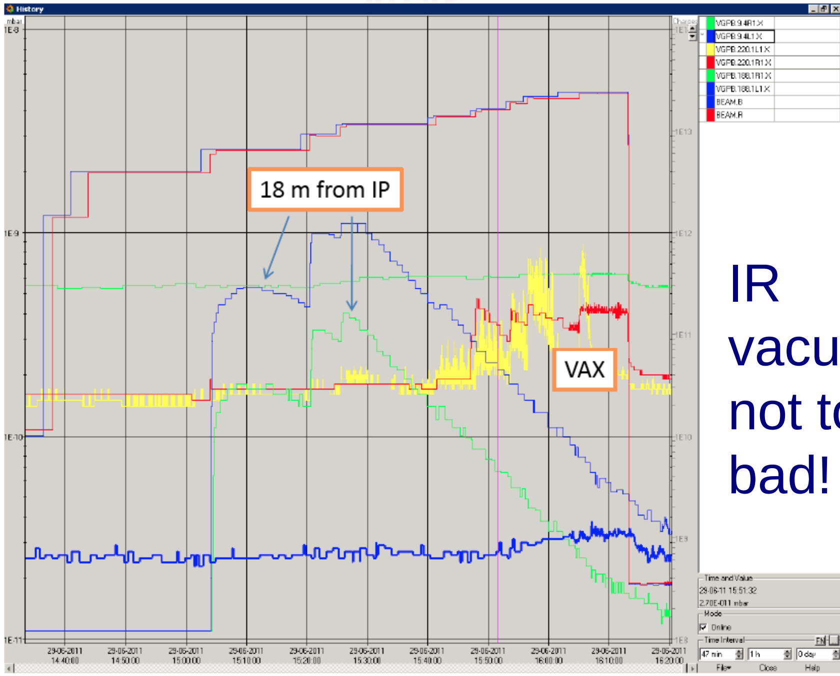
First 25 ns Injection Test (B. Goddard et al)



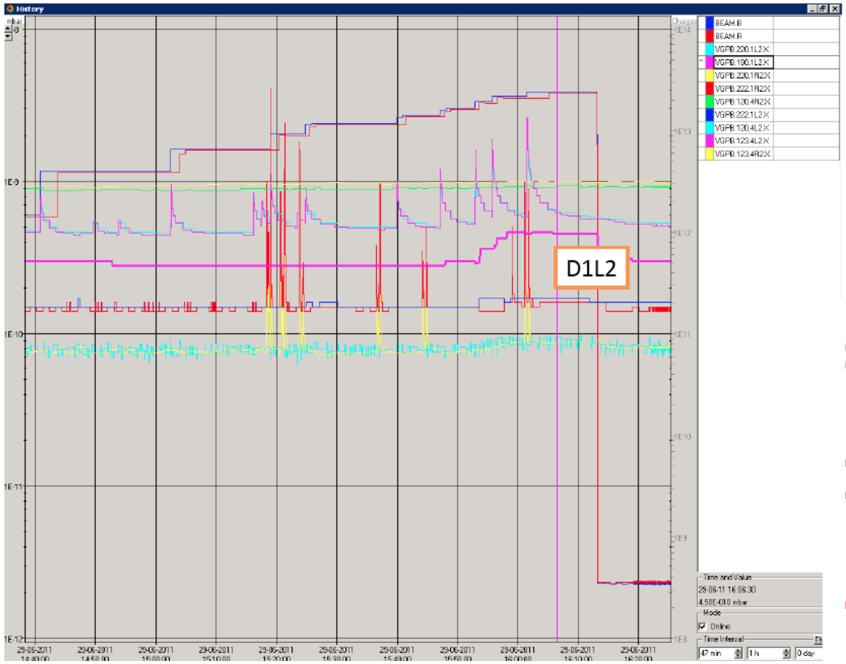




ATLAS

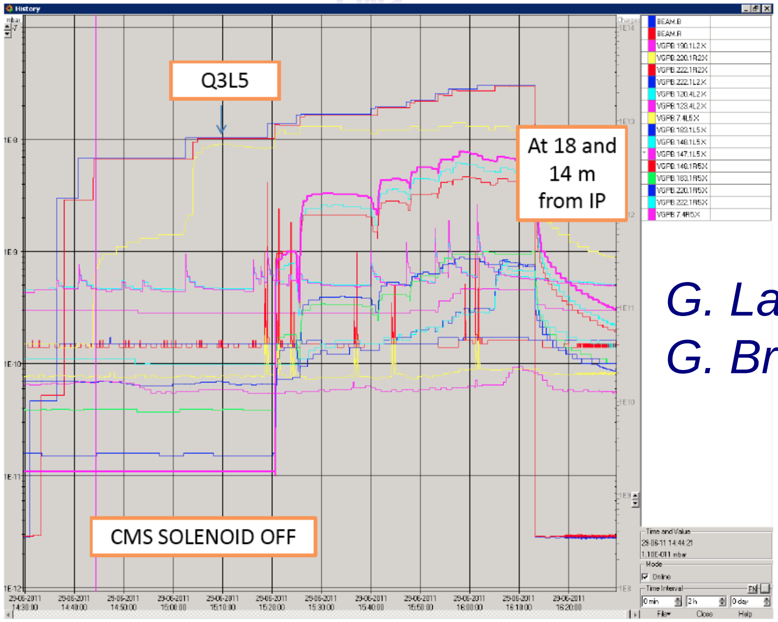


ALICE

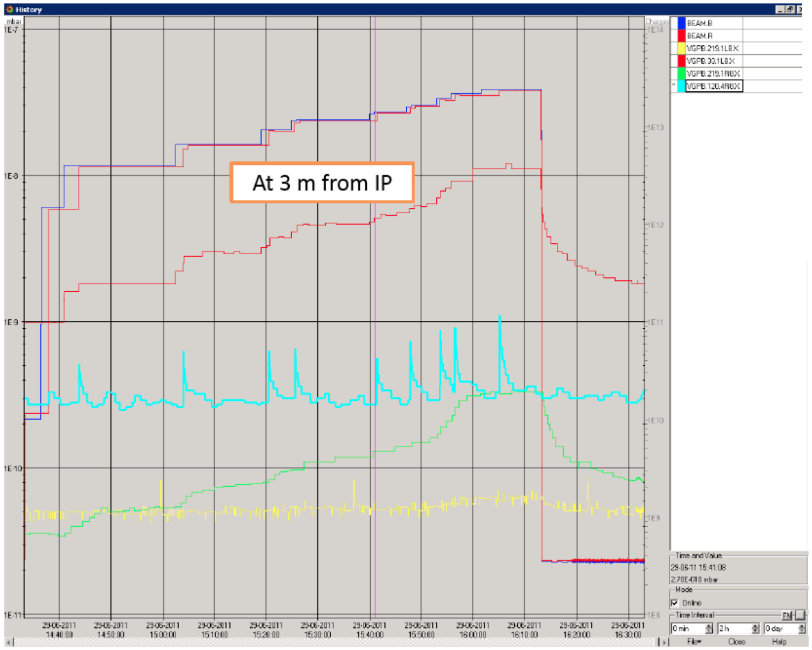


IR vacuum not too bad!

CMS



LHCB

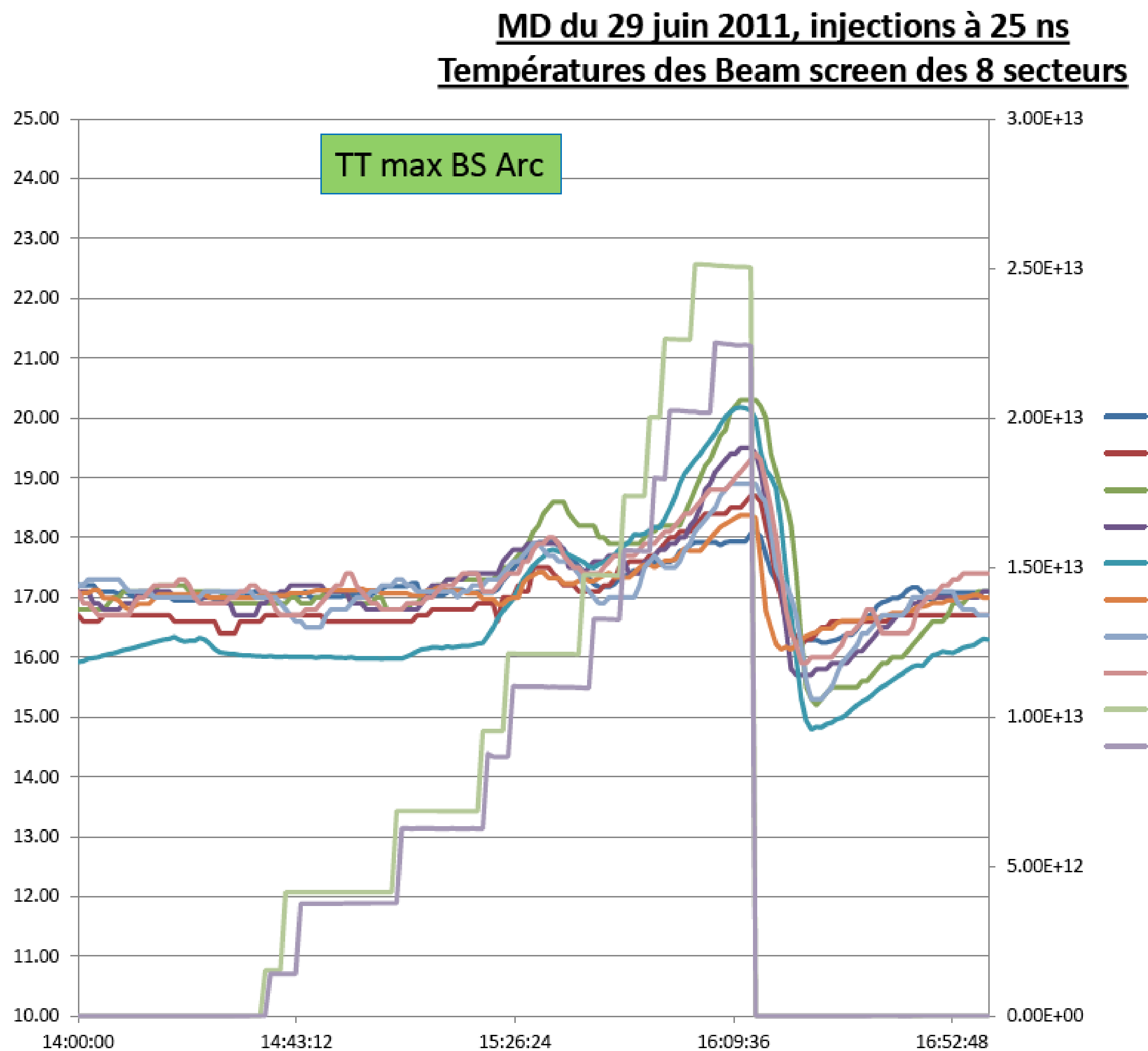


G. Lanza, G. Bregliozzi

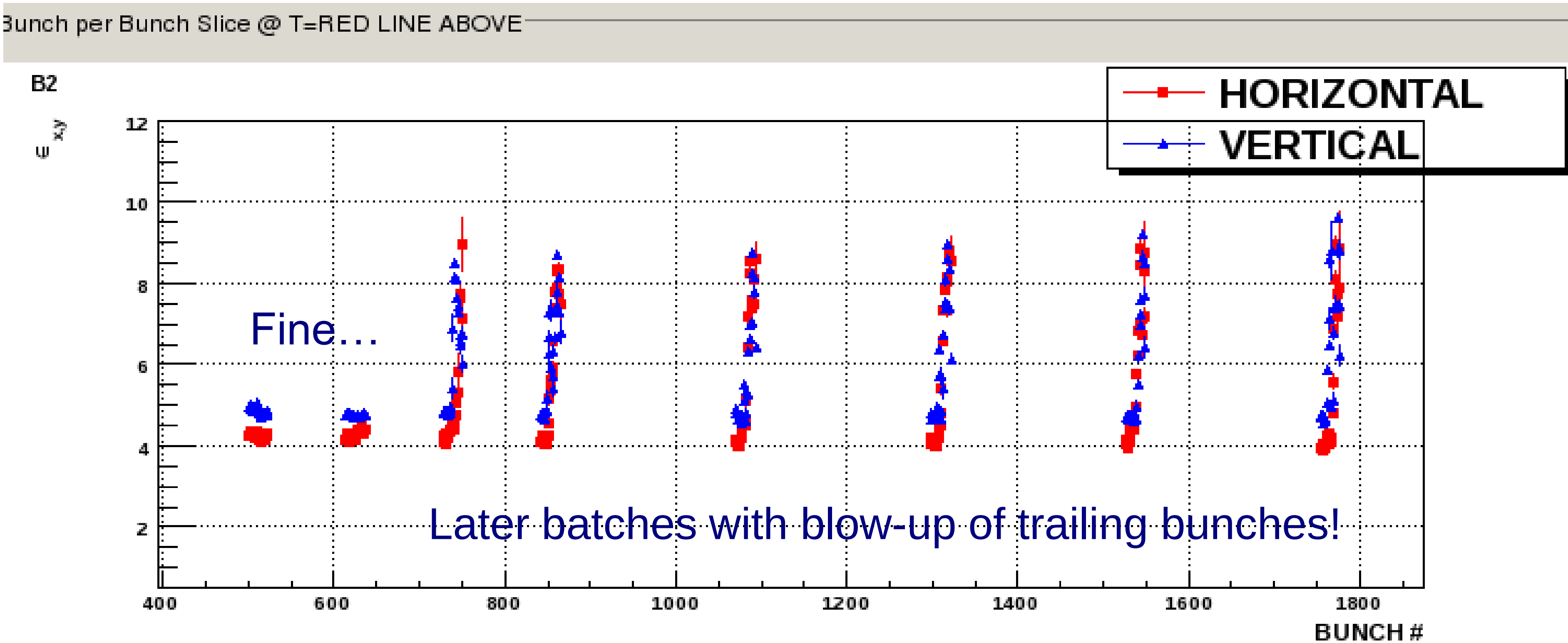
All e-cloud solenoids off!

Injection 25ns – Heat Load

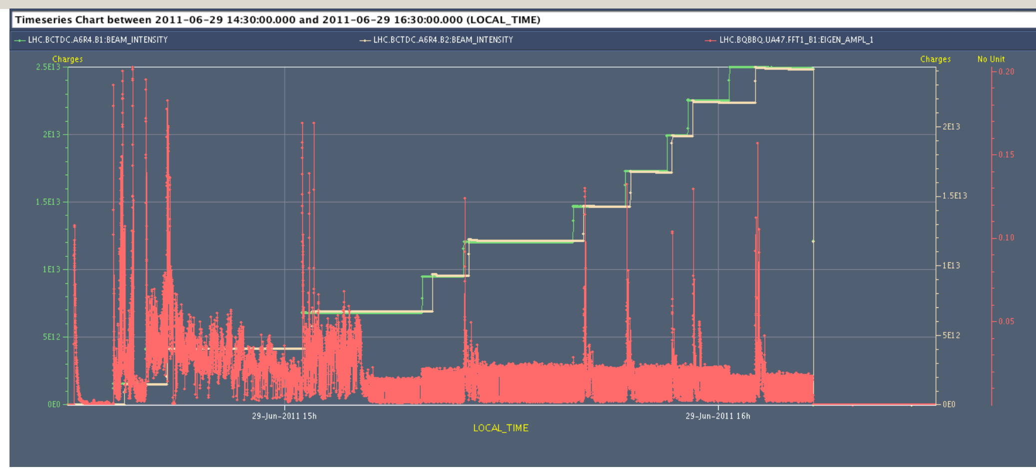
- Beam screen temperatures (S. Claudet):
  - "From operations point of view nothing dramatic has been observed.
  - T_{max} arcs only at about 20K, so nothing serious
  - For triplets very smooth tempe-rature bump, maxi L1 probably due to ATLAS field down."



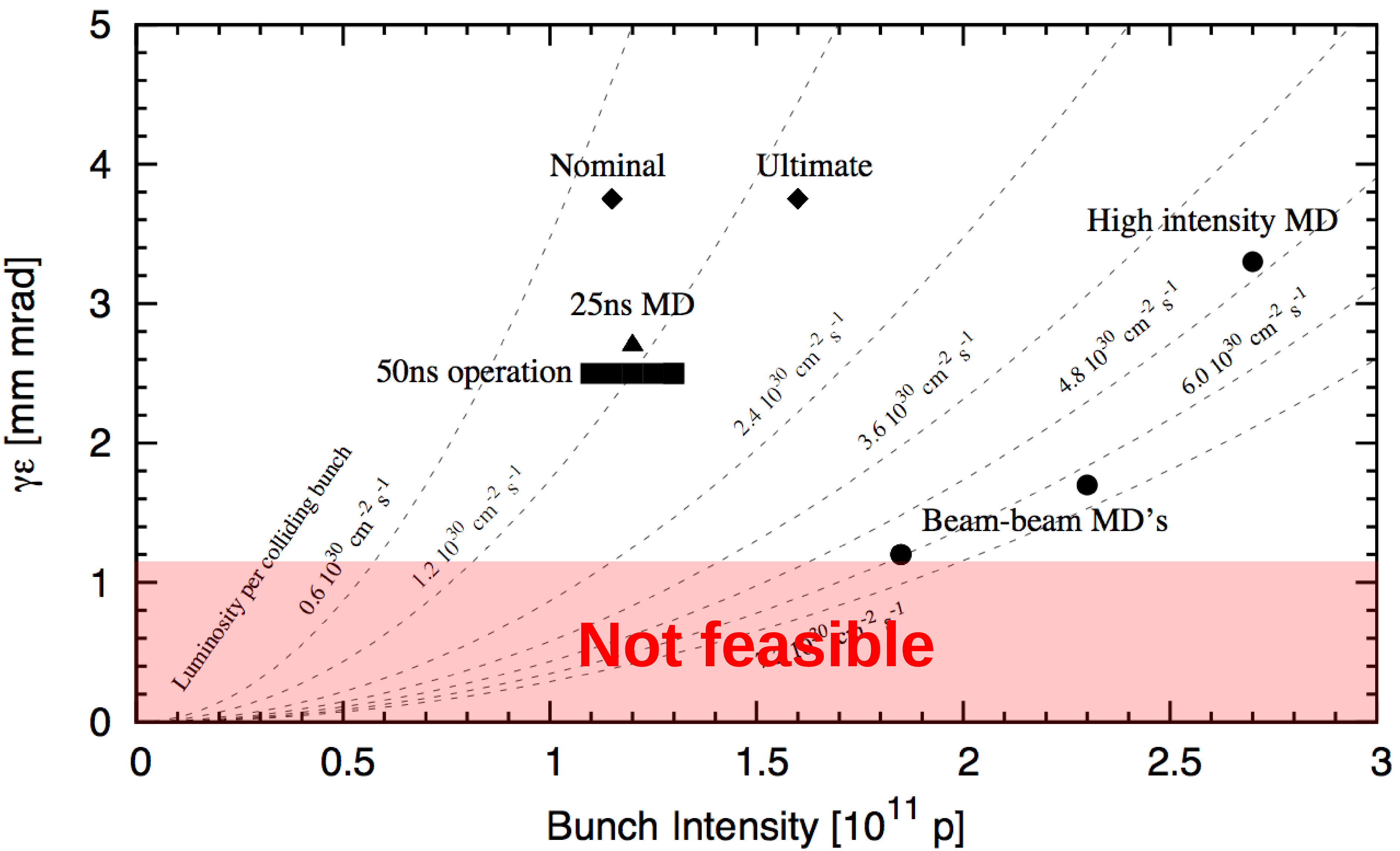
25 ns – Emittance Blowup



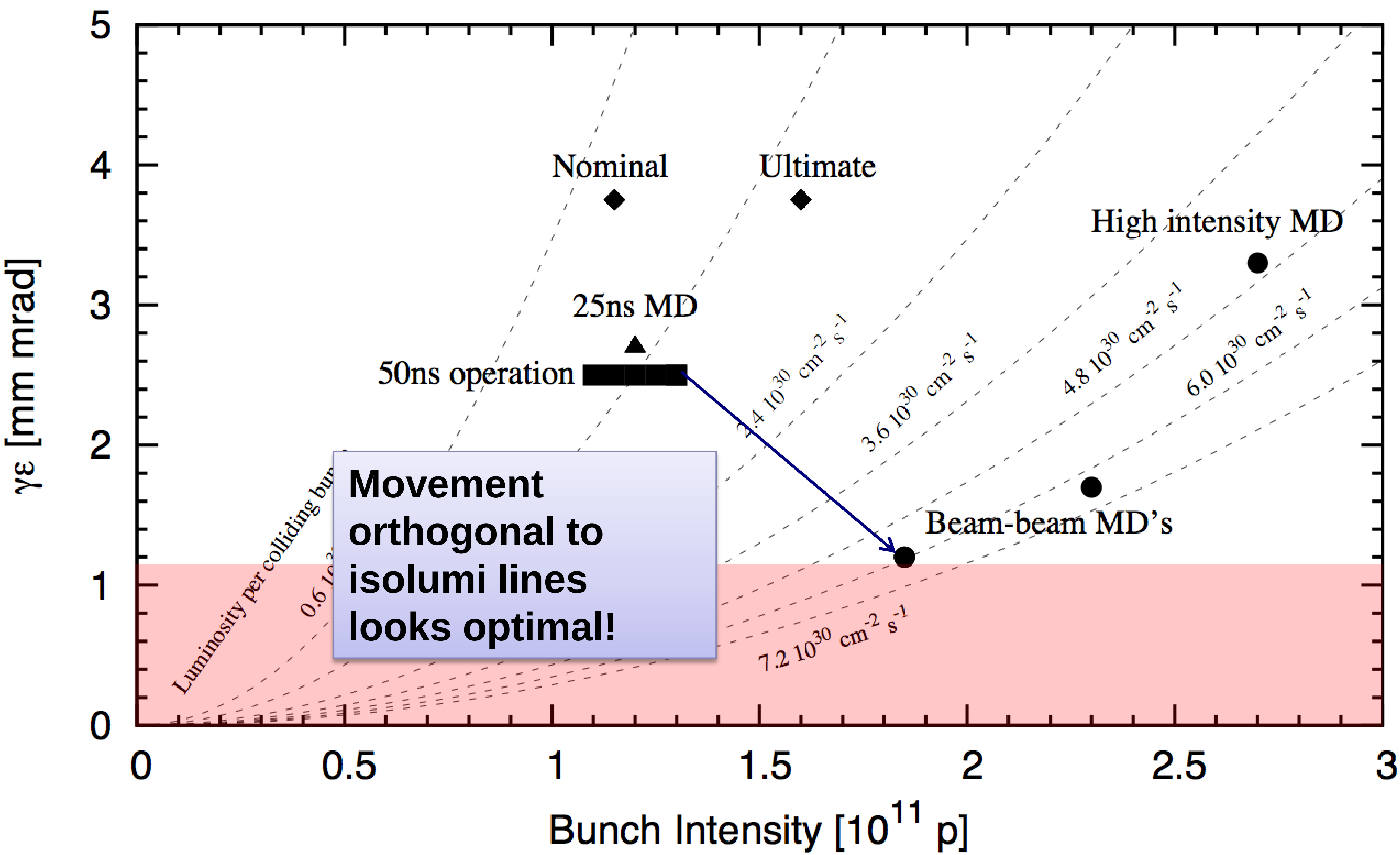
Follow-up for scrubbing need…



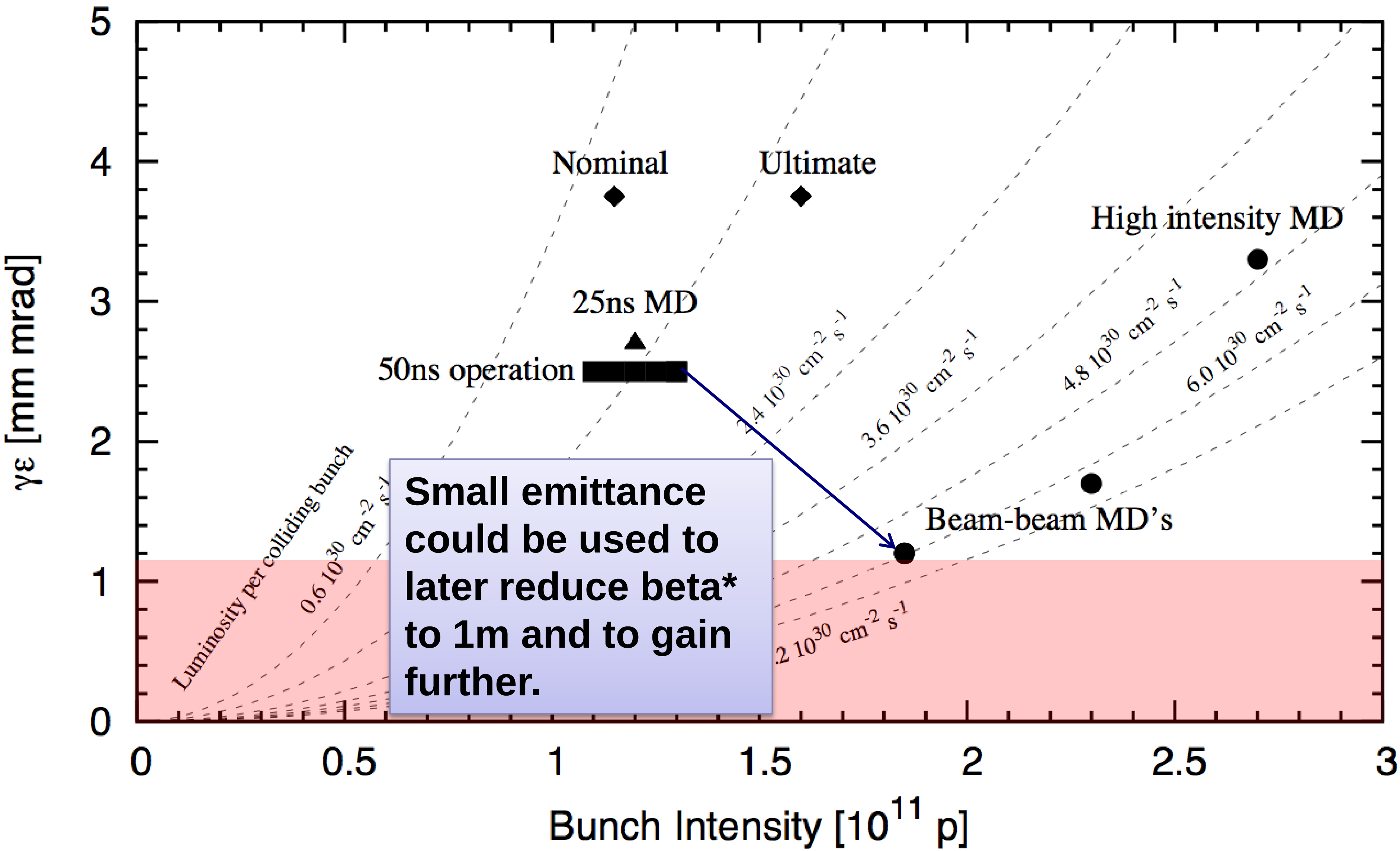
Assume 1.2 mm mrad minimum emittance



Optimal performance improvement

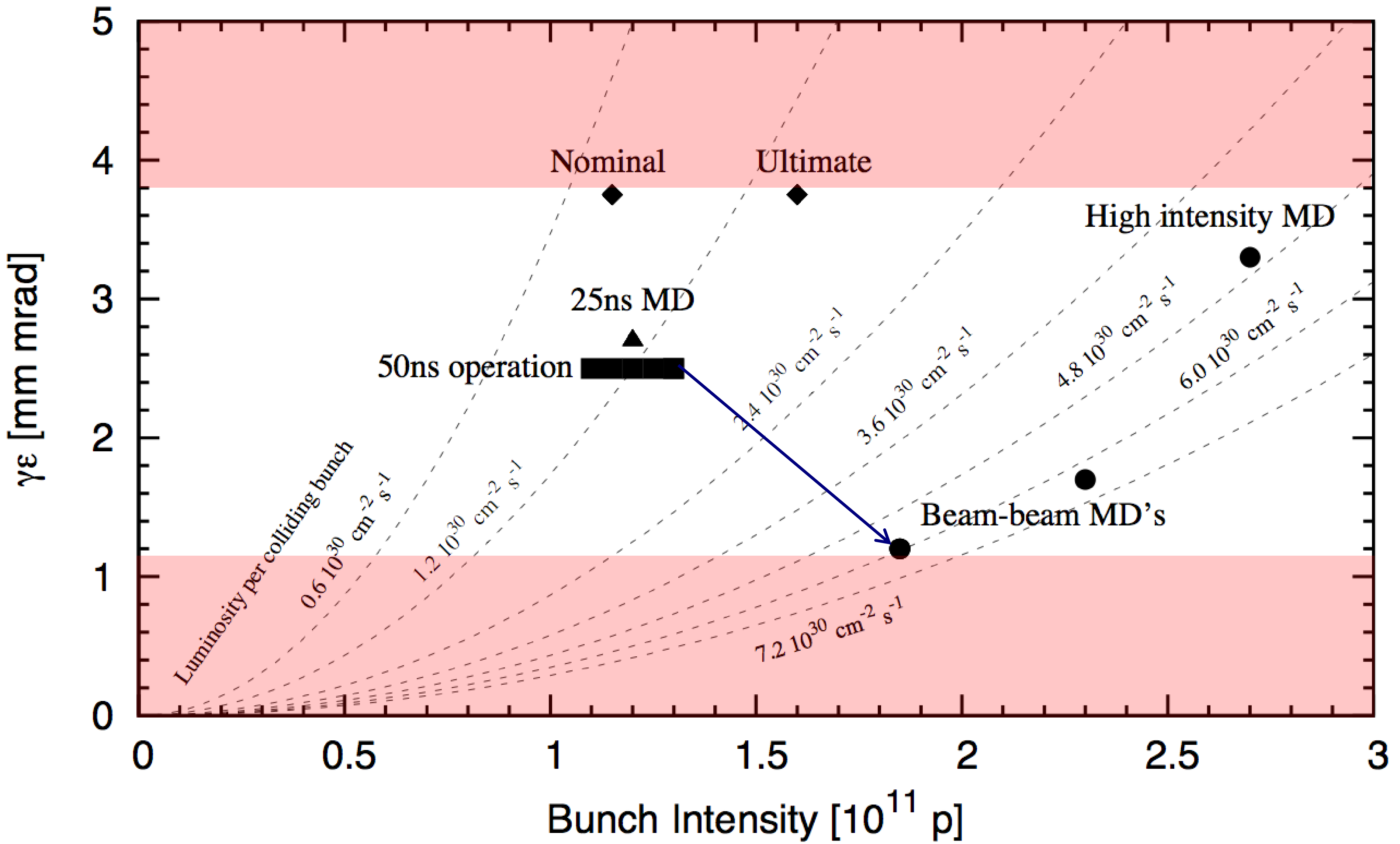


Optimal performance improvement

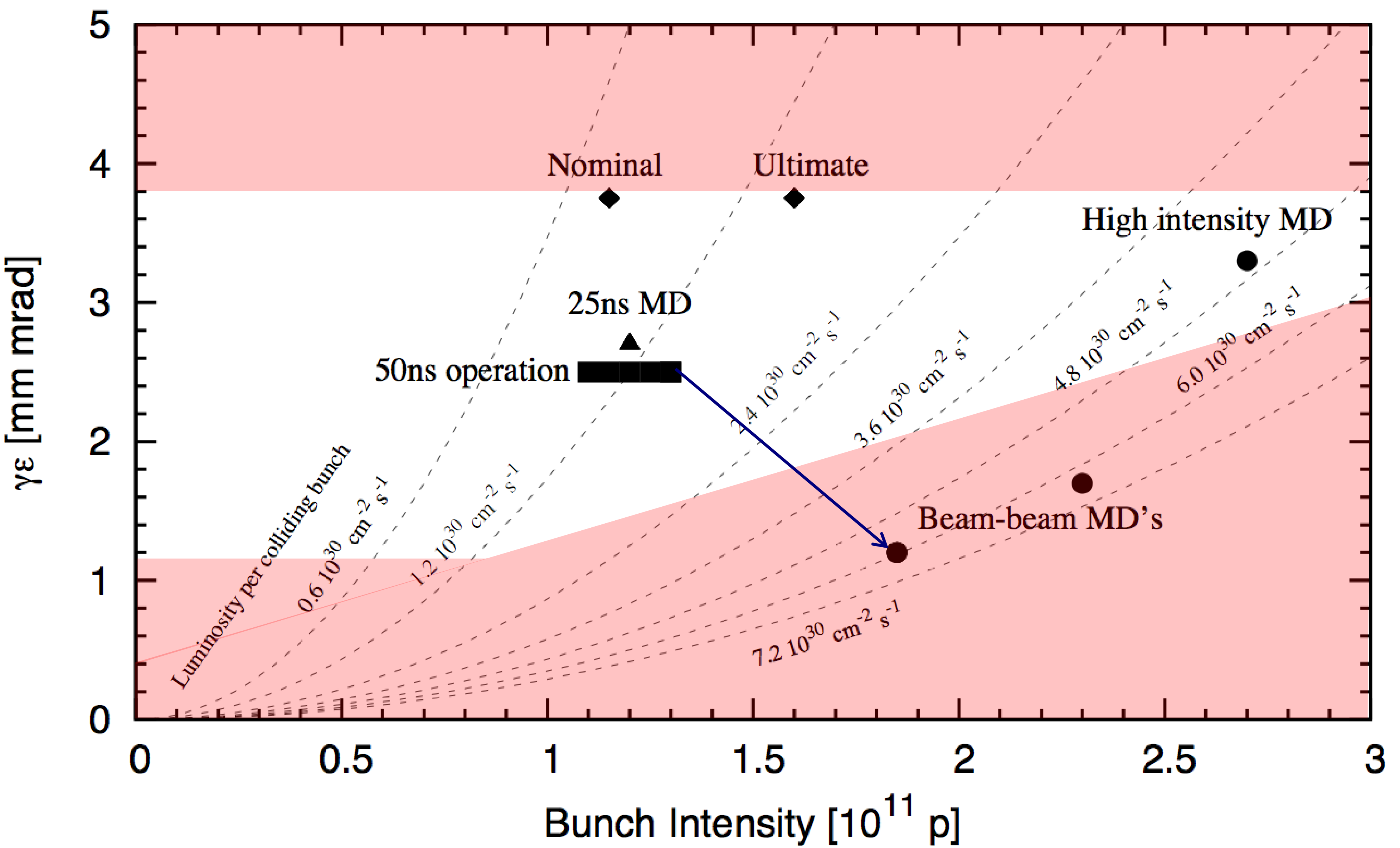


Small emittance could be used to later reduce beta* to 1m and to gain further.

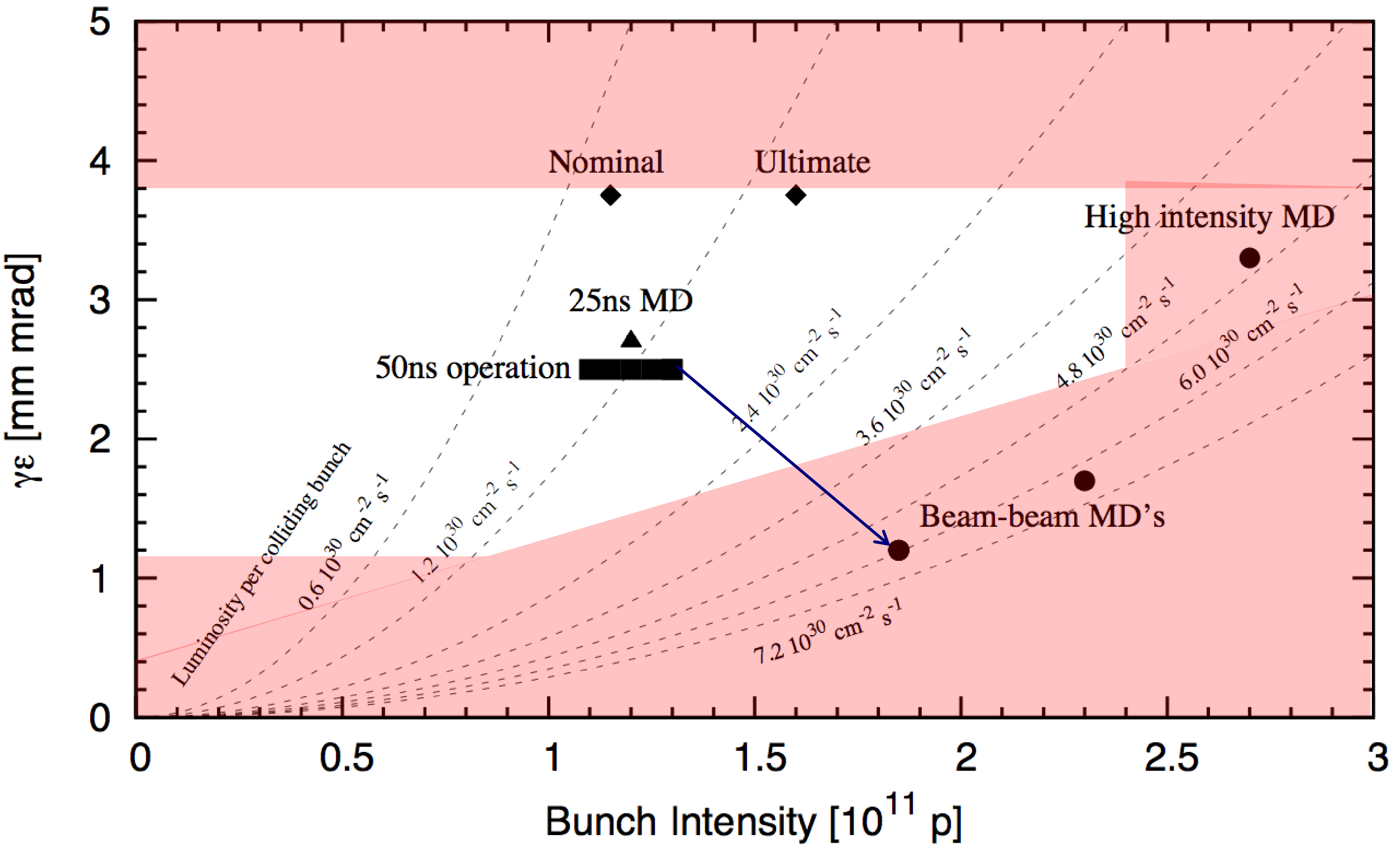
Injection limit on high emittance



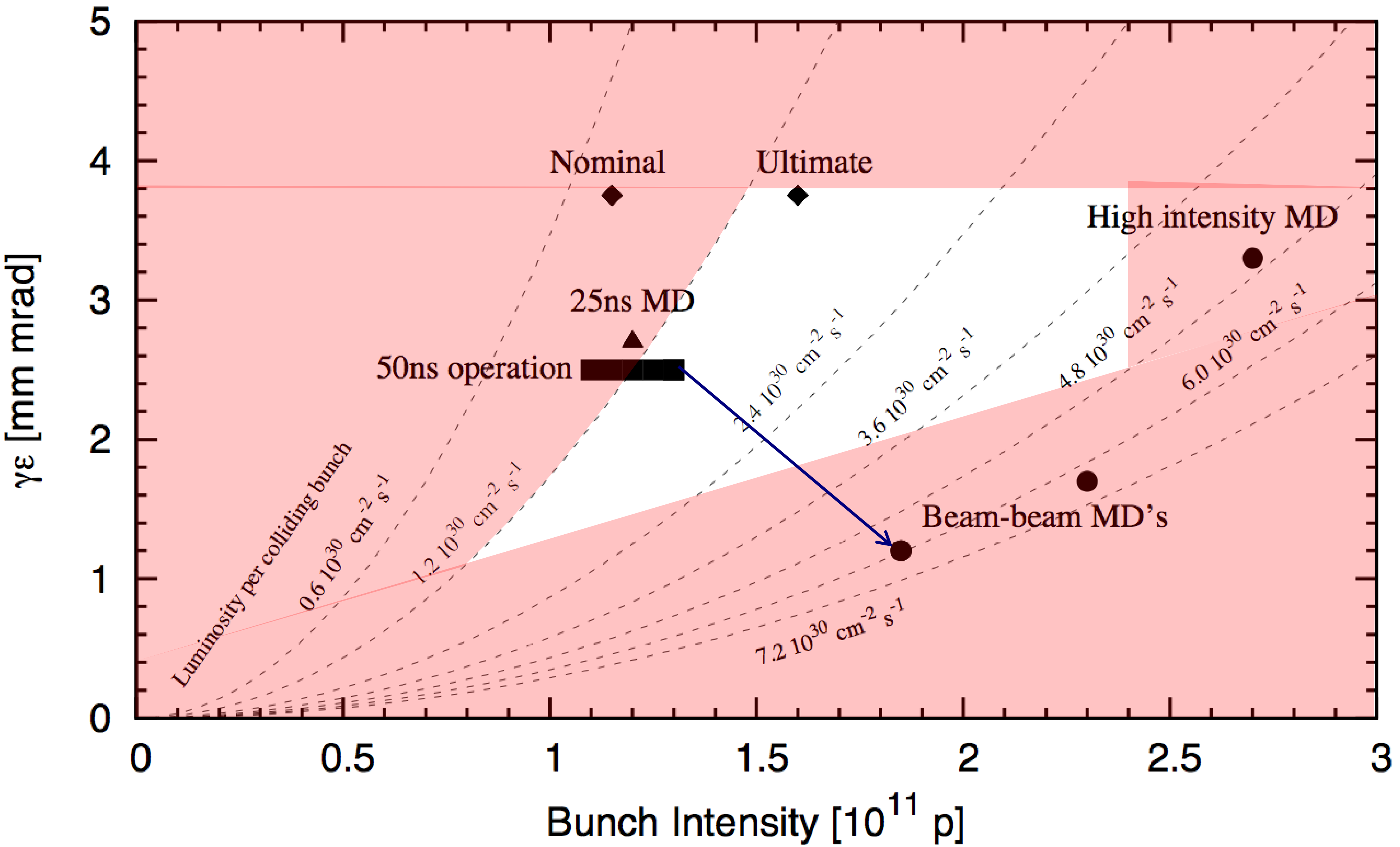
Robustness limit from TCDQ



Intensity Limit for Smallish Emittance

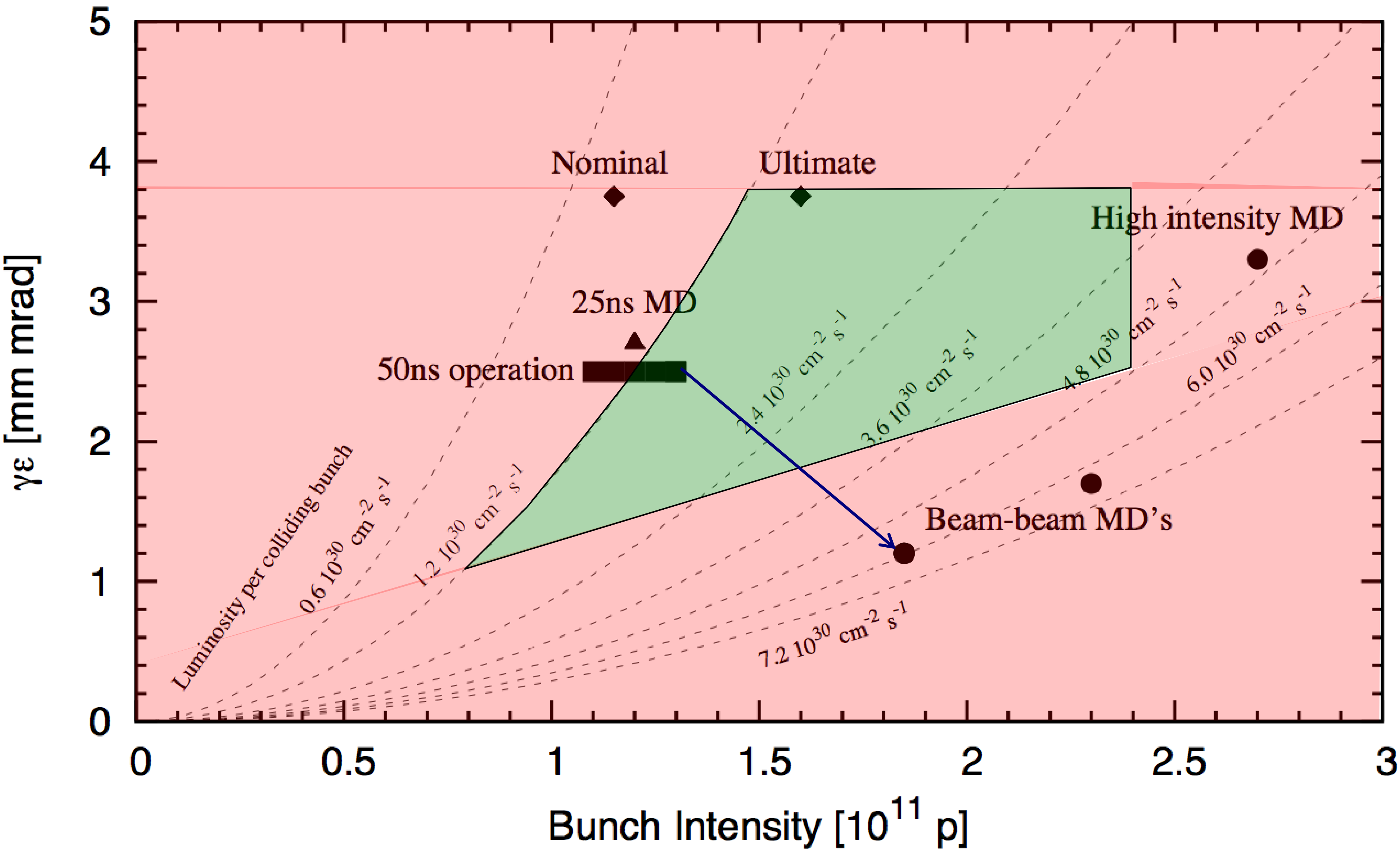


Exclude Region with Lower Luminosity

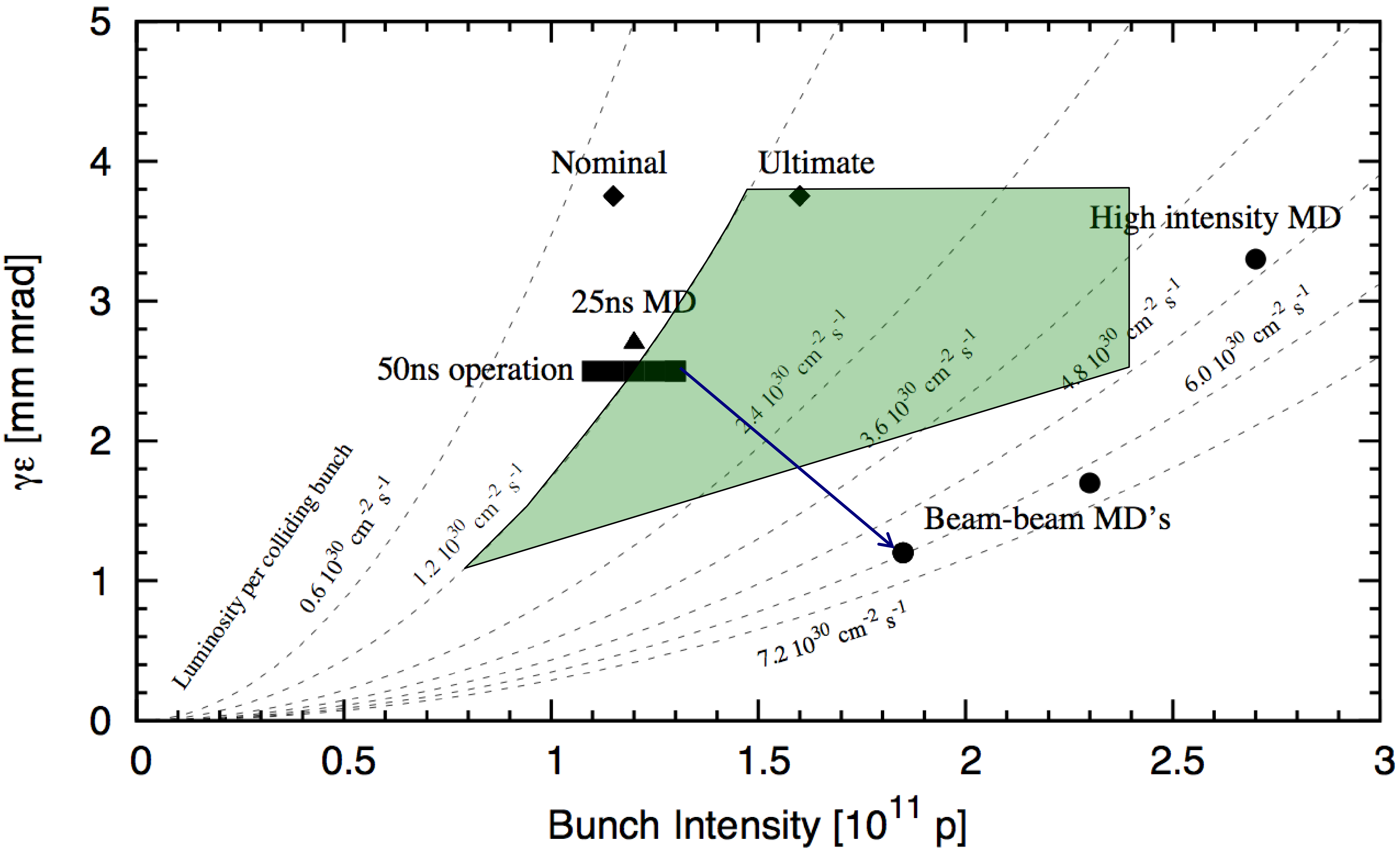


R. Assmann

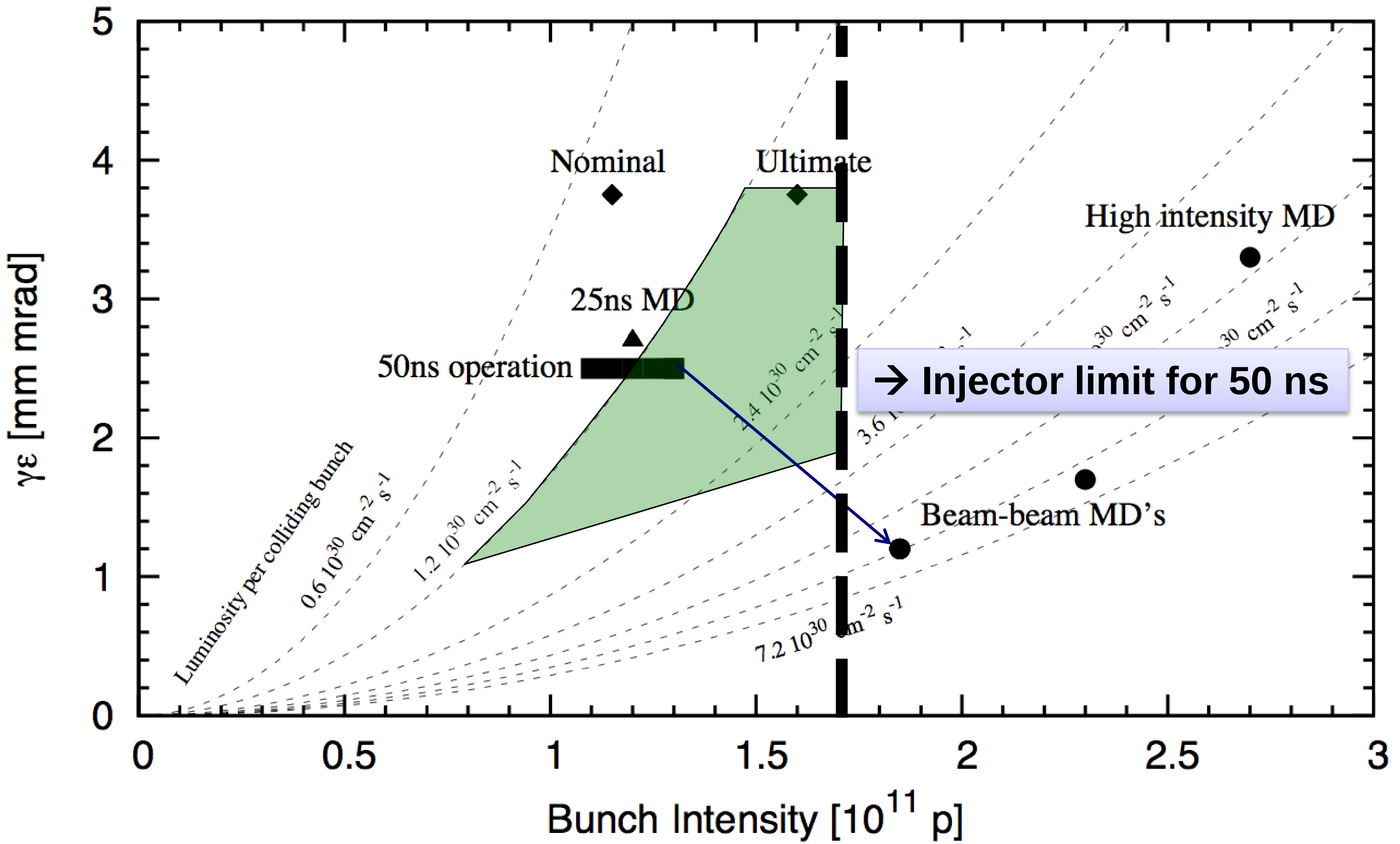
Room for Improvements



Room for Improvements (LHC only)

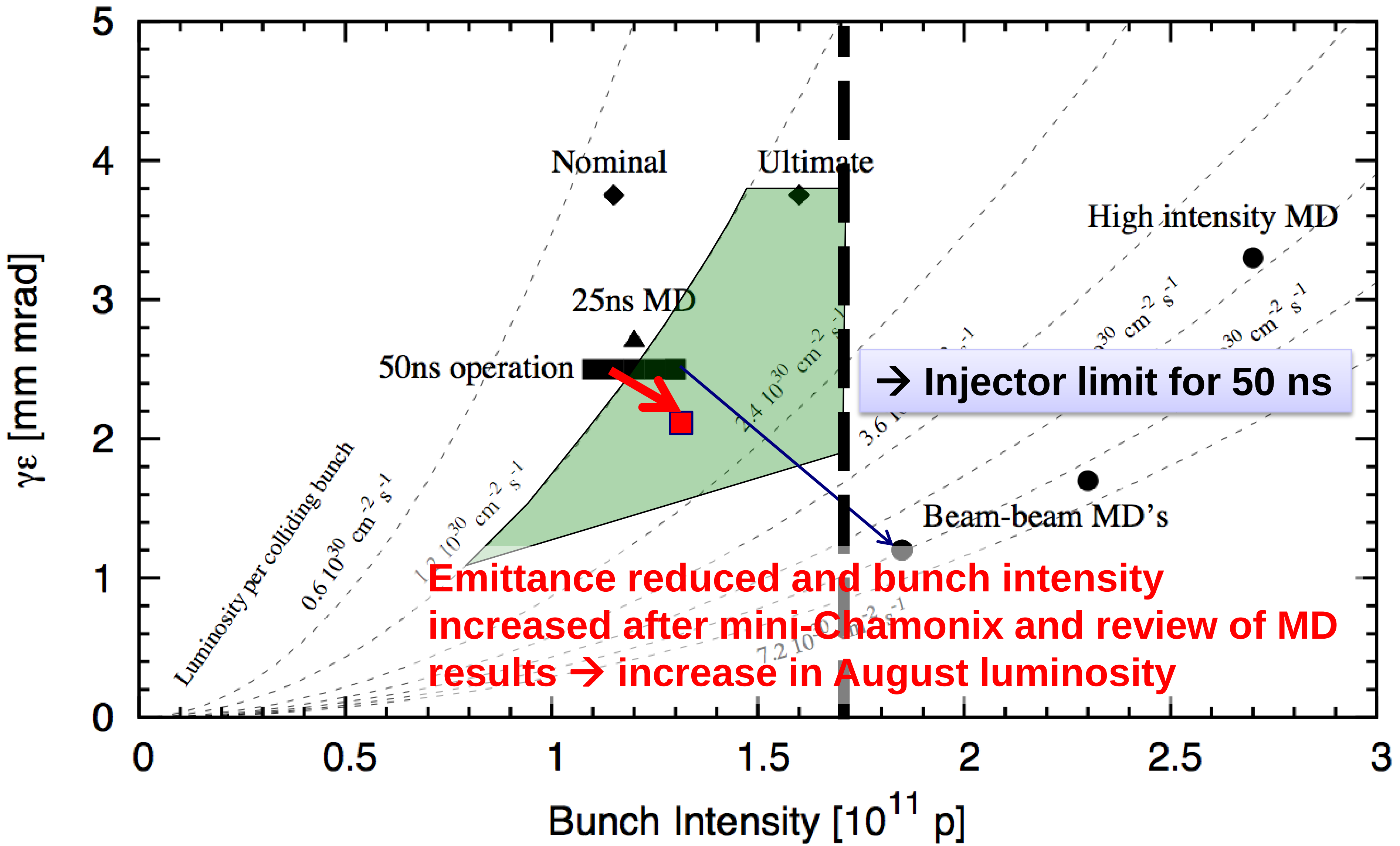


Room for Improvements (with injector limit)



R. Assmann

Room for Improvements (with injector limit)



MD Lessons: Beta*

- Non-linear dynamics MD's (F. Schmidt, M. Giovannozi, …) show well behaved machine (dynamic aperture not critical, non-linear chromaticity can be well corrected). See appendix.
- Optics MD's (90m, ATS) very successful:
  - Demonstrates efficiency in increasing/reducing beta*.
  - Optics errors small and controllable.
  - No major problem from non-linearities even for very small beta* (0.3m with ATS) → reduces overhead for squeezing further.
- Beta* can be reduced to 1m (→ Roderik Bruce) with present, "conventional" optics scheme, limited by coll/prot constraints.
- Smaller beta* requires tight collimation settings:
  - Machine in a different regime (impedance).
  - If successful, could use it as baseline for 2012.

CERN-ATS-Note-2011-032 MD (LHC)

16 May 2011

Un-squeeze to 90 m

Helmut Burkhardt, Xavier Buffat, Rama Calaga, Sophie Cavalier, Miriam Fitterer, Yngve Levinsen, Alick Macpherson, Ryoichi Miyamoto, Gabriel Müller, Stefano Redaelli, Ralph Steinhagen, Rogelio Tomas, Glenn Vanbavinckhove, Jörg Wenninger

Keywords: optics

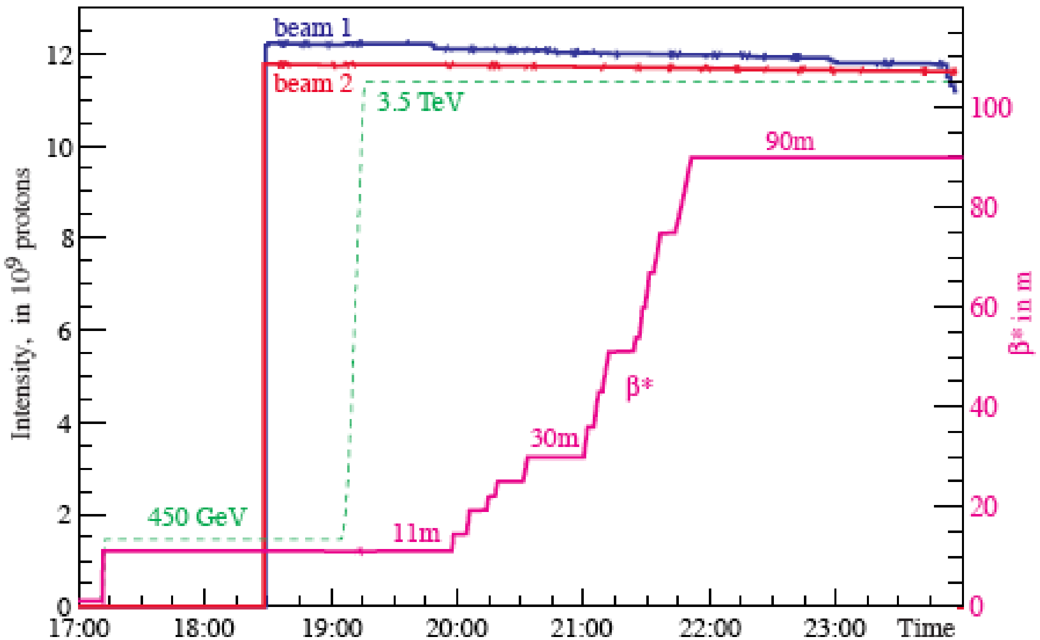
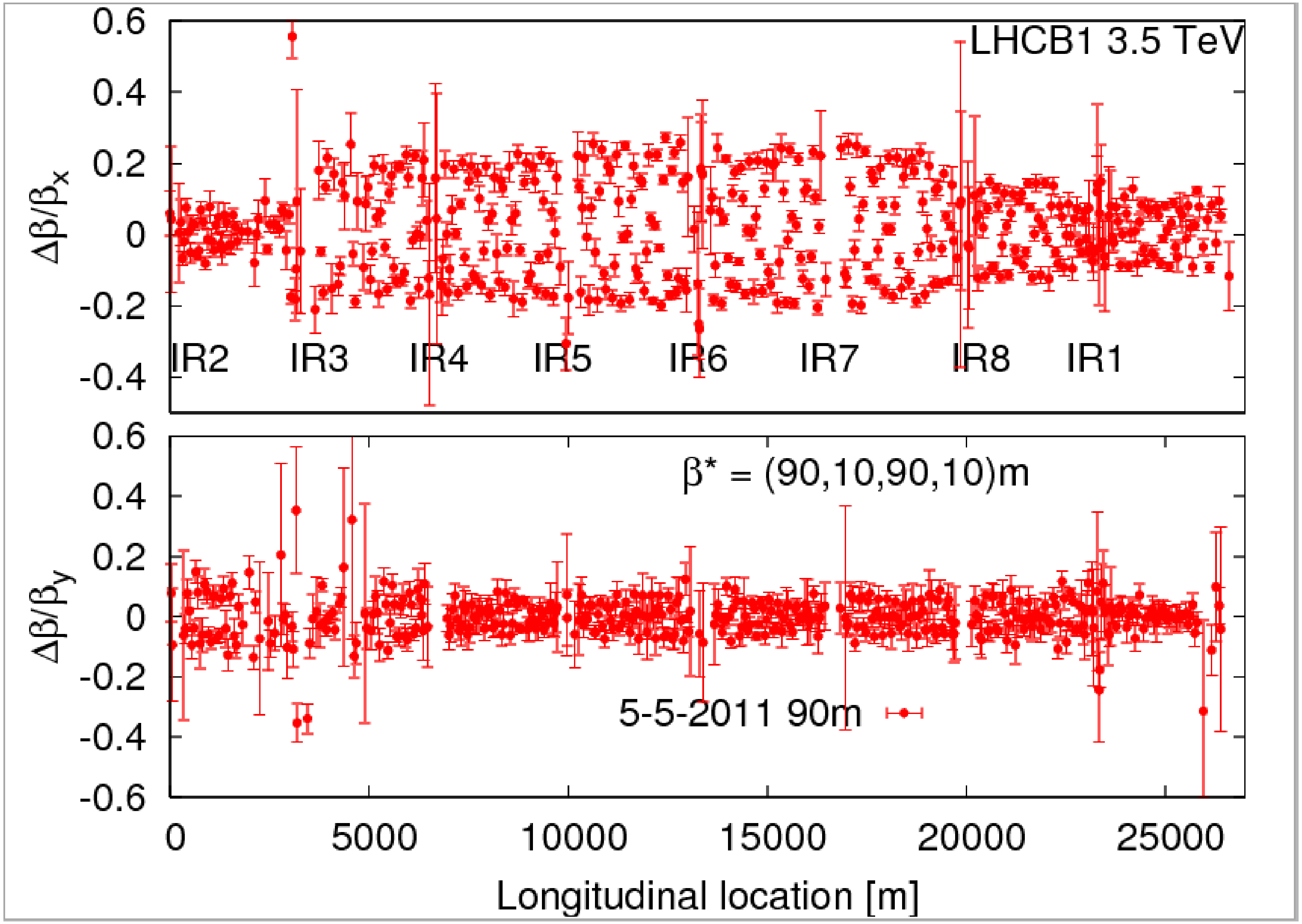


Figure 1: Beam 1, 2 intensities, energy and β^* as a function of time during the machine study on the 5 May 2011 showing that 90 m were reached essentially without losses. Some reduction can be seen for beam 1 towards the very end of the MD at 90 m during measurements with strong beam excitation.

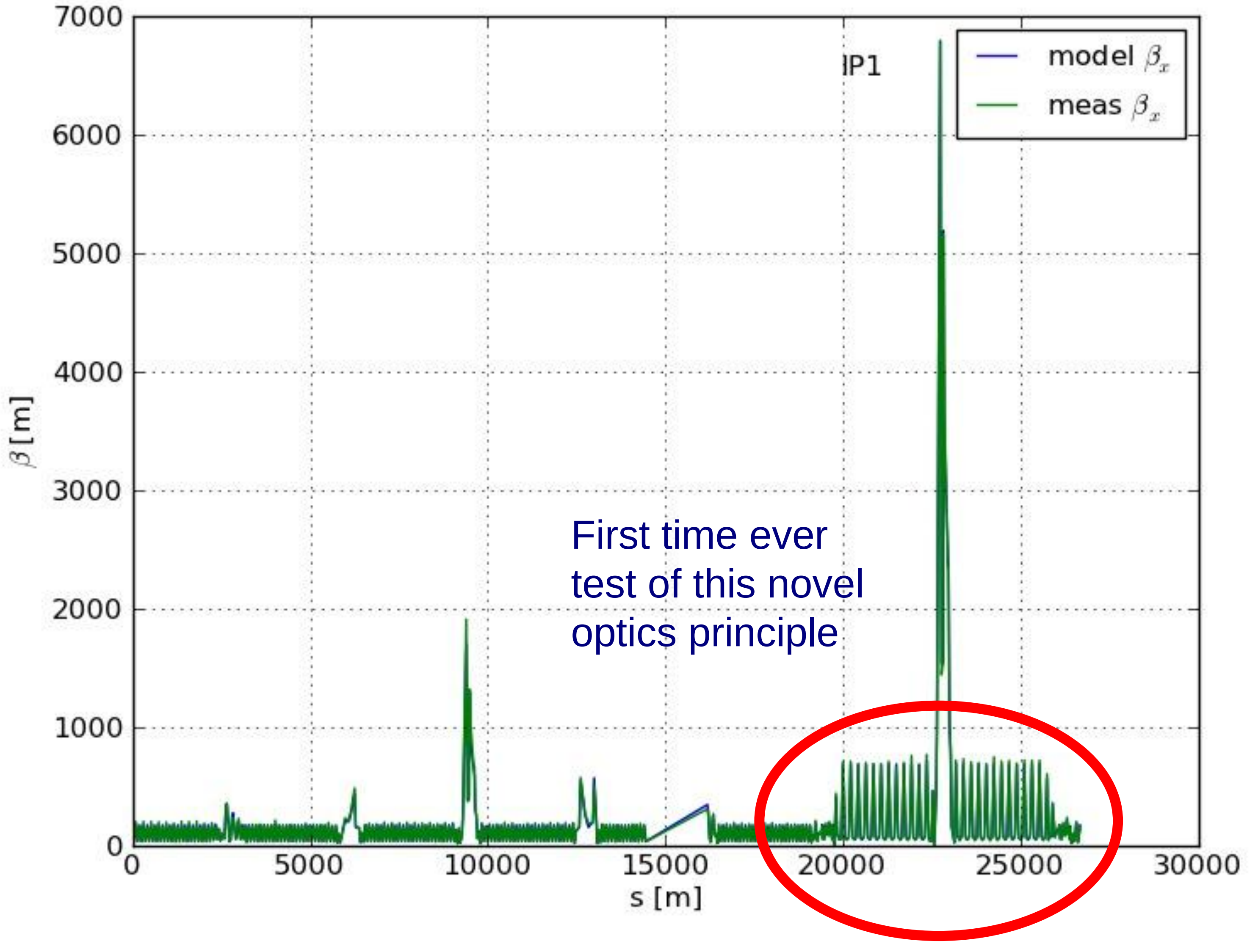
90m Beta Beat



ATS MD (S. Fartoukh et al)

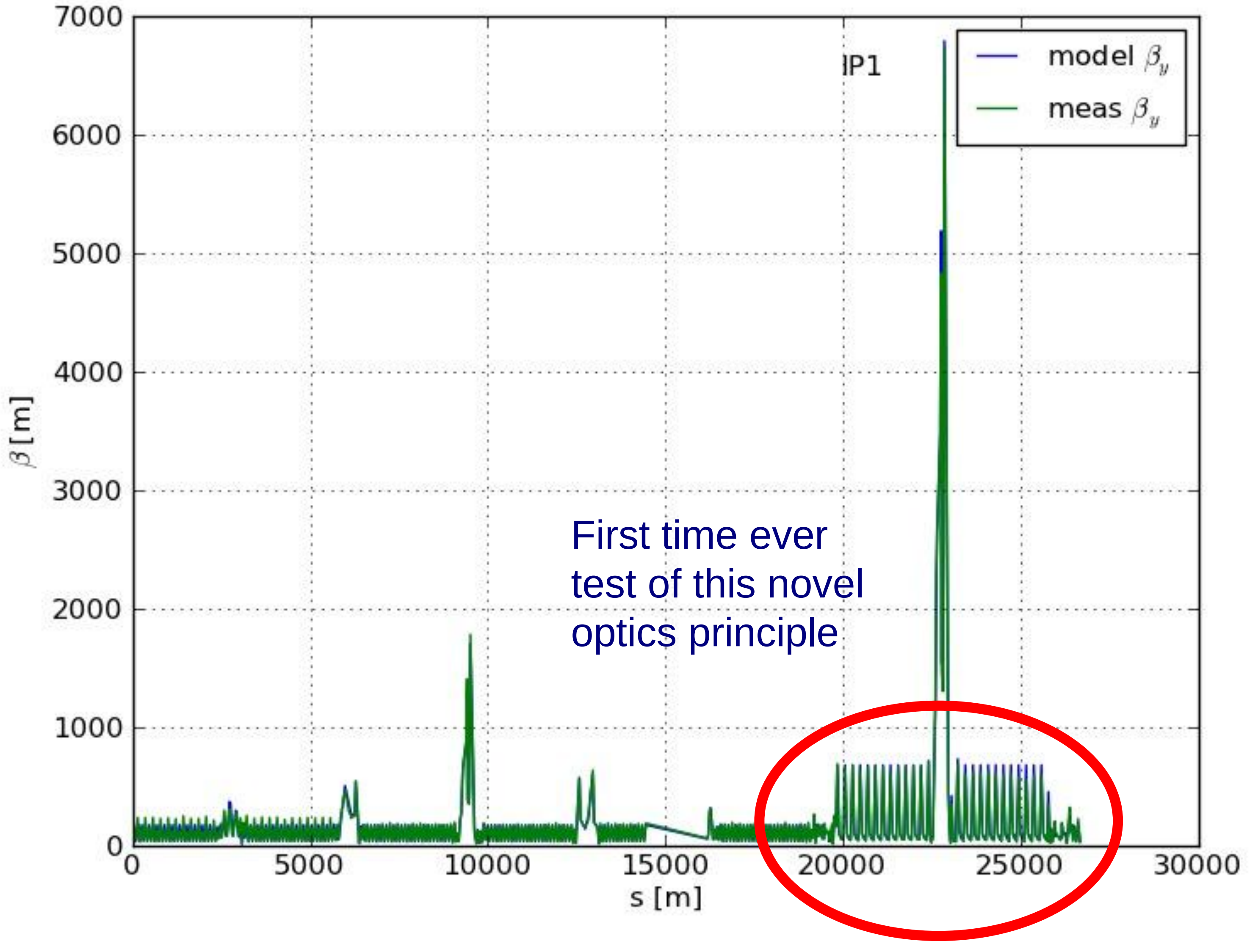
- First ATS MD commissioned optics to high energy.
- Second ATS MD successfully demonstrated the principle:
  - beta*: 30 cm was reached at IP1 while
  - beta* IP5 remained to "pre-squeeze beta* of 1.2 m (already below existing collision beta* of 1.5 m).
  - Chromatic aberrations were well under control during the squeeze (non-linear chroma, off-momentum beta-beating).
  - The on-momentum beta-beating was recorded at beta*=4.4 m, 1.2 m, 54 cm and 30 cm.
  - At 30 cm: peak beta-beating error 15% - 40%, depending on plane and beam, with correction from empirical trims on Q2.R1, Q2.L5 and Q2.R5 (about 10-13 units), as derived for the nominal squeezed optics.
  - This beta-beating error has to be compared to the 400% design beta-beat induced on purpose in sectors 81 and 12 to squeeze beta* by a factor of 4 w.r.t. the pre-squeezed beta* of 1.2 m.
- Note: Pilot intensity → Setup presently not usable for high intensity (collimation & MP issues).

ATS: 30 cm β* in IP1: Measured β_x

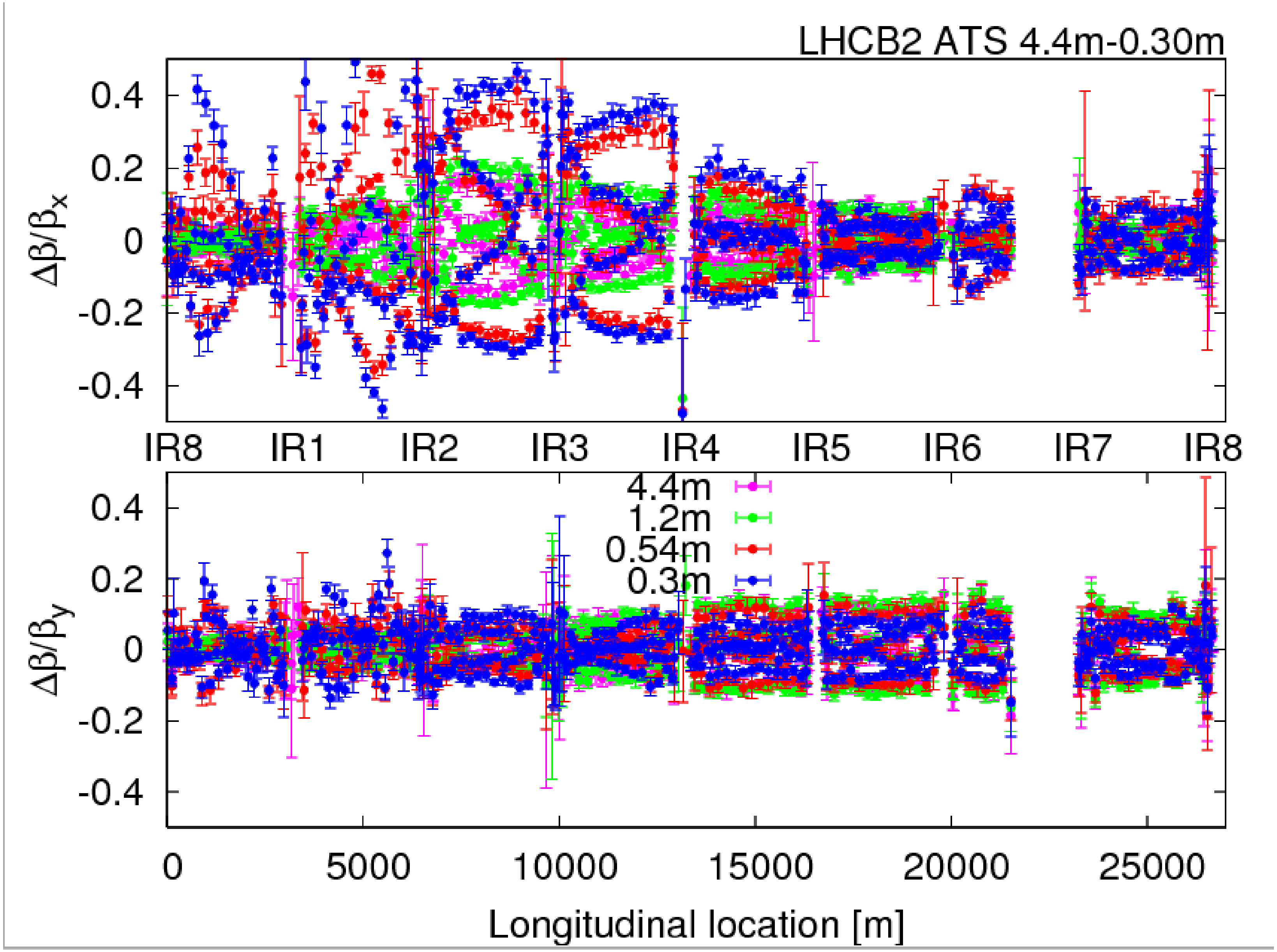


First time ever test of this novel optics principle

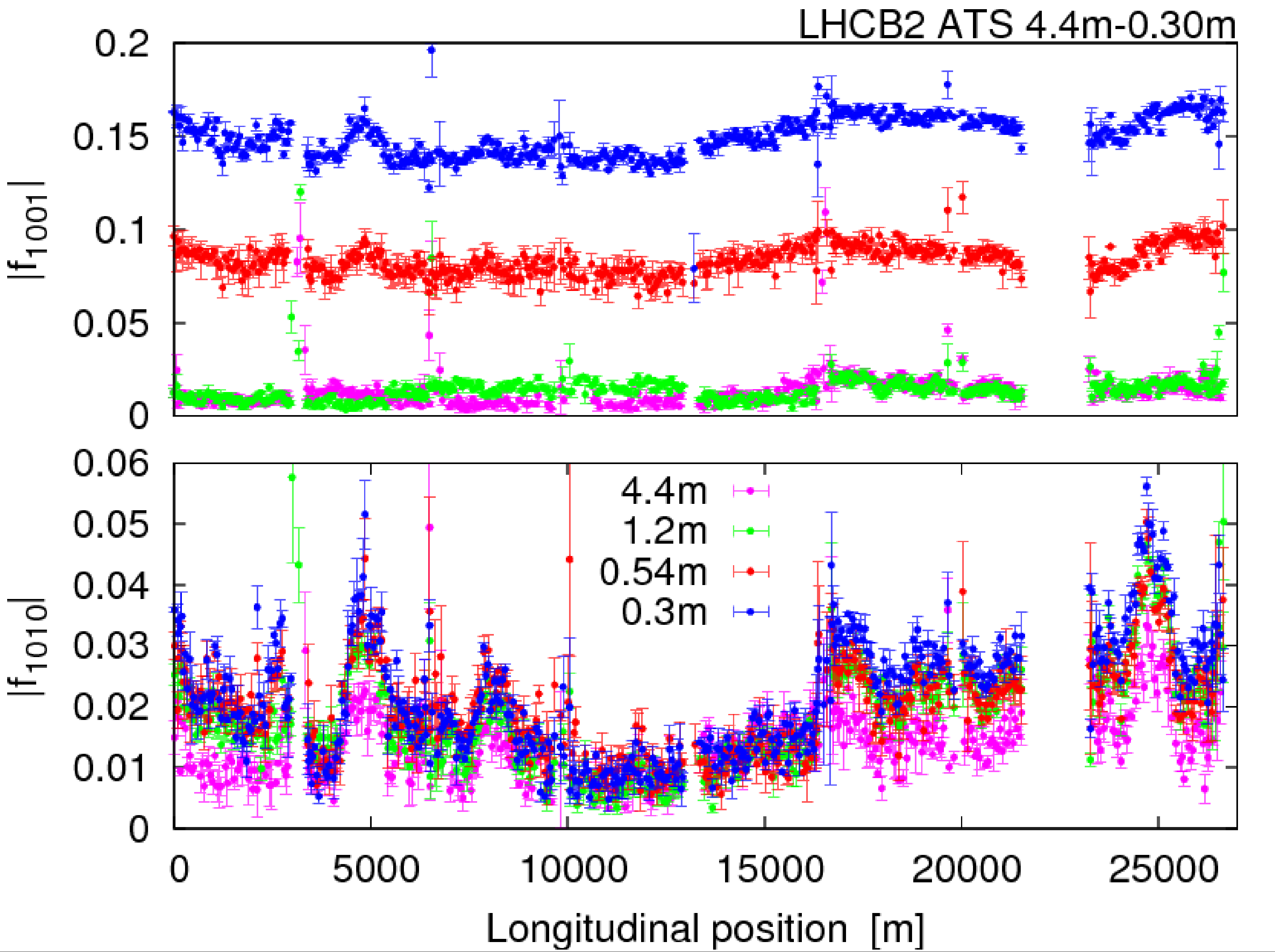
ATS: 30 cm β^* in IP1: Measured β_y



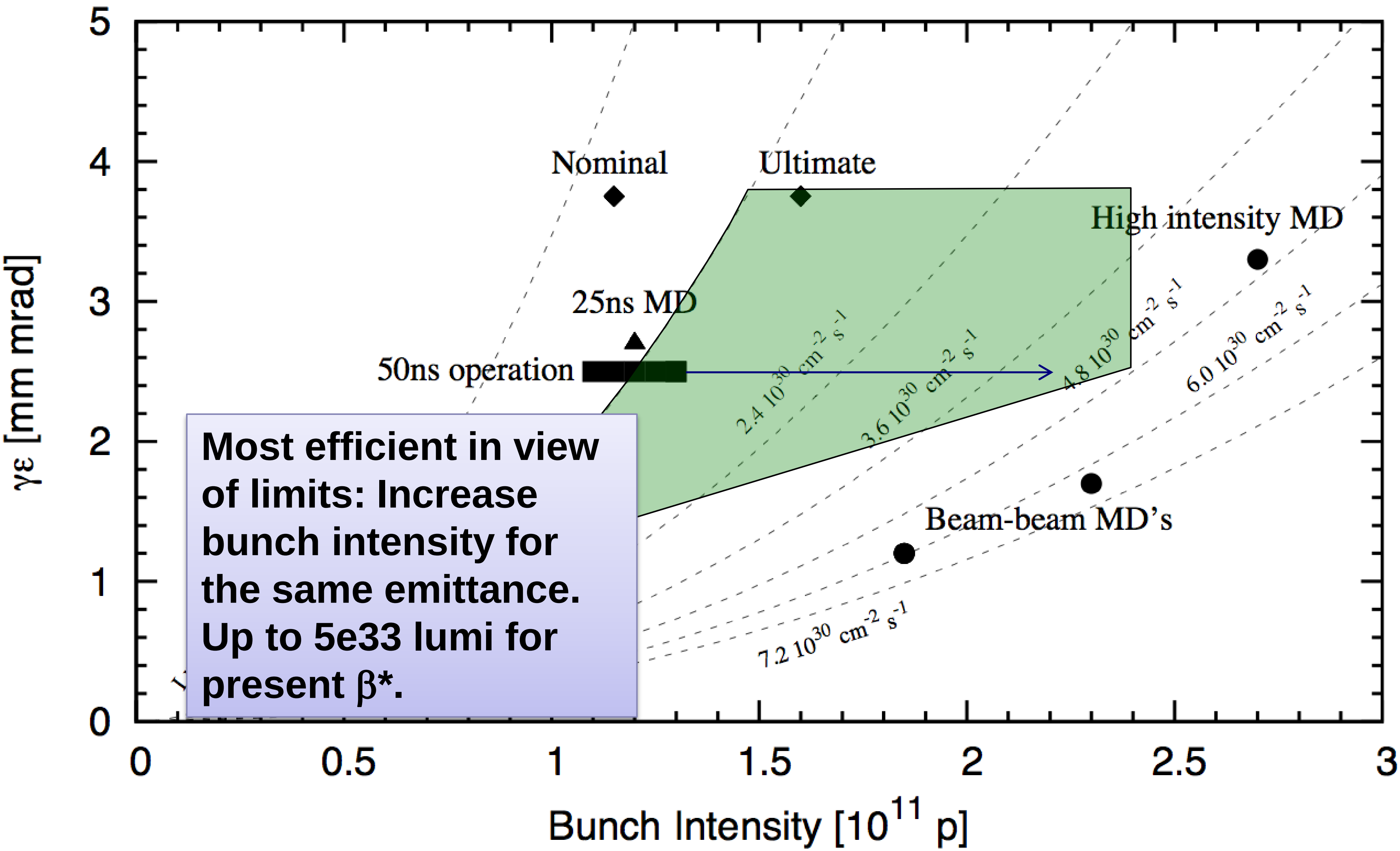
ATS: Beta Beat Err (here B2; B1 even better)



ATS: Coupling Error (here B2; B1 even better)



LHC MD Lessons (LHC only)



Most efficient in view of limits: Increase bunch intensity for the same emittance. Up to 5e33 lumi for present β*.

Conclusions I

- The first 2 LHC MD's worked and made efficient use of beam time, in agreement with LHC priorities. Credits to MD teams, the OP crew and the injectors for the results achieved.
- MD's showed feasibility of WP's with much higher luminosity reach than in design → 8 x design bunch luminosity!?
- The next MD session (this week) aims at lower β* for 50ns (factor 1.5 in luminosity), further exploration of 25ns beams and various other topics.
- We have a full MD list (see appendix) and will continue exploring the LHC accelerator operation and physics.
- Time is tight and we need the allocated 22 days to perform the foreseen program. Start using floating MD's.

Conclusions II

- Based on the results from the foreseen MD's: Can we achieve 6e33 lumi in 2012? → Chamonix & Evian.
- The MD results can also have profound impact on the upgrade plans and directions (Chamonix):
  - Collimation upgrades in IR3 and IR7 less urgent than expected.
  - LHC should prepare on the long term for very high brightness beams → some new collimators and absorbers, feedbacks, …?
  - Success of ATS optics can open path to very small β^*. Can we profit from this optics already before the 2020 IR upgrade?
  - Higher than foreseen luminosity means higher losses and earlier radiation damage and activation problems.
  - Luminosity leveling more important earlier.
- Ion issues will be addressed in last MD of 2011.

Appendix 1 – Updated MD List

Scheduled & not yet scheduled
MD Requests
status August 2011

times in hours
(incl. possible ramp down)
allocated in:
1st MD block
2nd MD block
3rd MD block

beam-beam MD's

MD title	Requester	# MD's	Total time 2010 [h]	Total time 2011 [h]	Energy	Max Intensity	Theme	OP link	
45 degree crossing at LHCb (25ns)	W. Herr and T. Pieloni	2	0	16	3500	physics	LHC nominal	RA, GP	
Beam-Beam Limits	W. Herr and T. Pieloni	5	40	0	450, 3500	5e12	LHC nominal	RA, GP	8+17+16
Crossing Scheme	F. Zimmermann, R. Calaga, W. Herr and T. Pieloni	2	0	24	450, 3500	1.7e13	HL-LHC	SR, RA, GP	
Large Piwinski Angle (LPA)	S. Fartoukh, F. Zimmermann	2	8	8	450	3e11	HL-LHC	SR	8
Transverse noise, coherent beam-beam instability and beam-beam emittance growth	W. Herr and T. Pieloni	1	8	0	3500	5e12	LHC nominal	RA, GP	
Operation tune close to half-Integer	R. Calaga, W. Herr, T. Pieloni, R. Steinhagen	2	0	16	450, 3500	1e12	HL-LHC	RA, GP	1
Tune scan for beam-beam optimization, lifetime and losses	W. Herr, T. Pieloni, R. Assmann, R. Steinhagen	2	8	8	450, 3500	6e12	LHC nominal + HL-LHC	RA, GP	6 (EOF)

total: 134 h

optics MD's

MD title	Requester	# MD's	Total time 2010 [h]	Total time 2011 [h]	Energy	Max Intensity	Theme	OP link	
ATS	S. Fartoukh	6	24	24	450, 3500	1e10	HL-LHC	SR	14+14
Un-squeeze to 90 m	Helmut Burkhardt	1	8	0	3500	1e10	Commissioning leftover	SR	10
Emittance growth. Life-time and emittance dependence on chromaticity at 450 and 3.5 TeV	R. Steinhagen, F.Roncarolo, V.Kain, B. Goddard	2	8	0	450, 3500	2e13	LHC nominal	VK	
Non-linear dynamics studies: various studies. Measurement of single-particle dynamic aperture	F. Schmidt, M. Giovannozzi	3	8	16	450, 3500	1e10	LHC nominal	SR	12
Collision tunes at injection and ramp	R. Tomas	1	6	0	450	1e10	LHC nominal	SR	8
Single beam parameter evolution	G. Papotti	1	4	0	3500	1.15e11	LHC nominal	GP	

total: 98 h

e-cloud MD's

MD title	Requester	# MD's	Total time 2010 [h]	Total time 2011 [h]	Energy	Max Intensity	Theme	OP link
Intensity limitations from electron cloud in the LHC	G. Arduini	1	36	36	450	3e14	Commissioning leftover	x

mC priority

7

total: 36 h

operational MD’s

MD title	Requester	# MD's	Total time 2010 [h]	Total time 2011 [h]	Energy	Max Intensity	Theme	OP link
Combined ramp and squeeze	S. Redaelli	2	6	6	450, 3500	1e10	Commissioning leftover	SR

total: 12 h

IR MD’s

MD title	Requester	# MD's	Total time 2010 [h]	Total time 2011 [h]	Energy	Max Intensity	Theme	OP link	
Movements of the inner triplet with beam at injection	S. Redaelli	1	0	8	450	1e10	Commissioning leftover	SR	
BPM offset determination for triplet BPMs	J. Wenninger	2	16	0	450	1.2e11	LHC nominal	x	**8**
Triplet aperture measurements at 3.5 TeV	S. Redaelli	1	0	8	3500	1e10	Commissioning leftover	SR	**10**

total: 32 h

injection & injection protection MD's

MD title	Requester	# MD's	Total time 2010 [h]	Total time 2011 [h]	Energy	Max Intensity	Theme	OP link	
Beam based alignment issues with long protection devices, injection losses & mitigation in other beam	Wolfgang Bartmann and Chiara Bracco	2	8	8	450	1.2e11 and 1.5e13	Commissioning leftover	VK	8
TCDQ alignment and TCT transmission during asynchronous dump	Wolfgang Bartmann and Chiara Bracco	1	8	0	450	pilot beam (beam 2)	Commissioning leftover	VK	
Injection studies for different SPS beam parameters	Brennan GODDARD	2	16	0	450	1.2e13, 144 bunches at 25 ns	LIU	VK	6+7
Injecting nominal emittance	Lene Drosdal	1	9	0	450	12, 36 bunches	LHC nominal	VK	9
Transverse blow-up, longitudinal blow-up and SPS scraping and injection losses	Verena Kain	1	8	0	450	1.3e11	LIU	VK	
Detailed injection matching studies	Malika Meddahi	2	6	6	450	1.3e11	LHC nominal	VK	
Beam-Based Measurement of the Waveform of the LHC Injection Kickers	Mike BARNES	1	6	0	450	1e10	Commissioning leftover	x	
MKI UFOs at injection	T. Baeer, J. Uythoven	1	8	0	450	up to 1.5e14	LHC nominal	x	(4+)10
sensitivity of injection quality & injection protection to TL steering	Verena Kain, Lene Drosdal,	1	12	0	450	1-12 b at 50 ns, at ~1.2e11	LHC nominal	x	
transfer and injection with SPS Q20 optics	Wolfgang Baartmann,	2	16	0	450	1e10-3e11, single to 36, 1-4 batches	LIU	x	

total: 111 h

collimation MD's

MD title	Requester	# MD's	Total time 2010 [h]	Total time 2011 [h]	Energy	Max Intensity	Theme	OP link	
Scraping scans for beam shape	Daniel Wollmann, Daniel Deboy, Florian Burkart	1	8	0	450, 3500	3e11	LHC nominal + HL-LHC	SR	4
Improving Collimator Setup Speed at 3.5 TeV	Gianluca Valentino	2	8	8	3500	1.2e11	LHC nominal	SR	5
Nominal and tighter collimation settings, single bunch tune shift	R. Assmann, B. Salvant, N. Mounet, E. Metral	2	16	0	3500	3e11	LHC nominal + HL-LHC	SR	10
Feasibility test beta*=1 m	R. Bruce, R. Assmann	1	8	0	3500	pilot	LHC nominal	SR	10
Beta* reach from collimation	Roderik Bruce	2	8	8	3500	1e12	LHC nominal	SR	
combined cleanup		1	5				LHC nominal	SR	5
BLM quench threshold test at 3.5 TeV in the DS of IR7	S. Redaelli, R. Assmann	2	16	0	3500	1e13	LHC nominal	SR	10+10

mC priority

total: 72 h

MD's on passive protection for stored beam

MD title	Requester	# MD's	Total time 2010 [h]	Total time 2011 [h]	Energy	Max Intensity	Theme	OP link
Beam loss measurements with different collimator settings (TCTs, TCLAs, …), TCDQ/TCSG/TCT protection levels and tolerance	Adriana Rossi, Chiara Bracco	2	8	8	450	1.5e11	LHC nominal	VK, SR

total: 16 h

impedance MD's

MD title	Requester	# MD's	Total time 2010 [h]	Total time 2011 [h]	Energy	Max Intensity	Theme	OP link	
Coupled-bunch instability rise times at injection&flat top and stabilization by Landau octupoles, with collimators	N. Mounet, E. Metral, collimation team	3	16	8	3500	6e13	LHC nominal + HL-LHC	SR	**10**
Multi-bunch tune shift at 450 GeV and 3.5 TeV, with collimators	N. Mounet, E. Metral, collimation team	3	16	8	450, 3500	6e13	LHC nominal + HL-LHC	SR	**(5?)**

total: 48 h

R2E MD's

MD title	Requester	# MD's	Total time 2010 [h]	Total time 2011 [h]	Energy	Max Intensity	Theme	OP link
Slow controlled losses for RadMon application benchmark	M. Calviani (EN/STI)	1	8	0	450	1e10	LHC nominal	MP

8

total: 8 h

instrumentation MD’s

MD title	Requester	# MD's	Total time 2010 [h]	Total time 2011 [h]	Energy	Max Intensity	Theme	OP link	
Optimization of BGI parameters	Mariusz Sapinski	4	4	0	450	1e11	Commissioning leftover	x	
BSR studies at 1.38 TeV	F. Roncarolo	2	2	0	1380	2e13	Commissioning leftover	MP	
Continuous beta-beat measurement at injection and squeezed optic	Ralph Steinhagen	1	0	8	450, 3500	7e12	LHC nominal	x	
Quench Test at 1.38 TeV	Agnieszka Priebe	1	5	0	1380	1.2e11	LHC nominal	x	
Quench test with wire scanner	Mariusz Sapinski	1	2	0	3500	1e14	LHC nominal	x	
Cross calibration of BSRT/WS/BGI	F. Roncarolo	2	2	0	450, 3500	>1e10 & <2e13	LHC nominal	MP	**10**
High bunch intensity	F. Roncarolo	1	8		450, 3500		LHC nominal		**10**
direct-dump BLM calibration, new BPM firmware, stripline crosstalk, BCT/FBCT, BSRT. BSRA, Schottky, emittance vs Q'	F. Roncarolo	1	8		4,503,500	1-24 bunches, 0.5e10 to 1.3e11	LHC nominal	x	

total: 31 h

RF MD's

MD title	Requester	# MD's	Total time 2010 [h]	Total time 2011 [h]	Energy	Max Intensity	Theme	OP link	
RF noise induced beam diffusion	E. Shaposhnikova	4	8	8	450, 3500	1e12	LHC nominal + Commissioning leftover	GP	
Synchronous phase shift	E. Shaposhnikova	4	8	8	450	1e13	Commissioning leftover	GP	
Longitudinal beam stability	E. Shaposhnikova	3	8	4	450, 3500	1e12	LHC nominal	GP	8+10
long bunch length	E. Shaposhnikova	1	8	0	450, 3500	1e12	LHC nominal	GP	10
RF feedback optimization with circulating beam	P. Baudrenghien	4	8	8	450, 3500	1e12	Commissioning leftover	x	
Longitudinal damper commissioning	P. Baudrenghien	2	8	0	450	5e12	Commissioning leftover	x	
Voltage (capture/ramp/Physics) and Blow-Up Optimization	P. Baudrenghien	3	12	6	450, 3500	1.3e13	Commissioning leftover	GP	
1-T feedback commissioning	P. Baudrenghien	3	8	4	450, 3500	6e13	Commissioning leftover	x	
Rephasing	P. Baudrenghien	3	8	4	3500	5e12	Commissioning leftover	GP	8
Controlled transverse blowup	R. Schmidt, W. Hoefle, S. Redaellie	1	6	0	450	safe beam	Commissioning leftover	SR	6

as operational development

total: 124 h

ion MD's

MD title	Requester	# MD's	Total time 2010 [h]	Total time 2011 [h]	Energy	Max Intensity	Theme	OP link
Feasibility of p-Pb operation	John Jowett	3	24	0	450	p, ion	LHC ions	x
Wire Breakage with ion beam	Mariusz Sapinski	1	2	0	450, 3500	50 nom ion b	LHC ions	x

not ready?

total: 26 h

experiment MD's

MD title	Requester	# MD's	Total time 2010 [h]	Total time 2011 [h]	Energy	Max Intensity	Theme	OP link
maximum pile up in single bunches	Physics coordinators	1	6	0	3500	2 bunches with ~2e11	LHC nominal	x
25-ns test run with physics	Physics coordinators	1	8	0	3500	a few trains with 25-ns spacing	LHC nominal	x

mC priority 6

in MD block 4?

total: 12 h

magnet MD’s

MD title	Requester	# MD's	Total time 2010 [h]	Total time 2011 [h]	Energy	Max Intensity	Theme	OP link	
Investigation on CODs	Nuria	1	8	0	450	1e11	LHC nominal		6
RQ6.L8 quench limit investigation	Chiara Bracco, Rudiger Schmidt, Matteo Solfaroli	1	8	0	450	1e10, 2e10, 3e10	LHC nominal		
quench margin at injection	Rudieger Schmidt, Brennan Goddard, Mariusz Sapinski	2	8	0	450	3e9-1.2e11	LHC nominal		6+4
Q' decay vs powering history	Ezio Todesco	1	17	0	450, 3500	probe bunch, 1e10	LHC nominal		

not in MD

total: 41 h

EOF studies

MD title	Requester	# MD's	Total time 2010 [h]	Total time 2011 [h]	Energy	Max Intensity	Theme	OP link
Transverse noise, coherent beam-beam instability and beam-beam emittance growth	W. Herr and T. Pieloni	4 EOF	4		3500	5e12	LHC nominal	RA, GP
TCP alignment test for different orbit settings	S. Redaelli	3 EOF	6		3500	4e13	LHC nominal	SR
Halo scraping	Daniel Wollmann, Daniel Deboy, Florian Burkart	16 EOF	8		450, 3500	physics	LHC nominal	SR
Debunched beam following klystron trip	P. Baudrenghien	4 EOF	8		3500	physics	LHC nominal + Commissioning leftover	GP
Emittance from lumi scan (eof, many)	G. Papotti	0	0		3500	physics	LHC nominal	GP
Tight collimator settings for beta*=1 m at high intensity	S. Redaelli	1	2		3500	physics	LHC nominal	

operational development studies

MD title	Requester	# MD's	Total time 2010 [h]	Total time 2011 [h]	Energy	Max Intensity	Theme	OP link
beta*= 1 m w/o beam	M. Lamont?	1	4		3500	no beam	LHC nominal	SR
beta*=1 m with beam	M. Lamont?, R. Tomas?	1	8		3500	pilot	LHC nominal	SR
SPS Q20 extraction to downstream TED (w/o LHC)	W. Bartmann, H. Bartosik	1	8		450		LIU	VK?

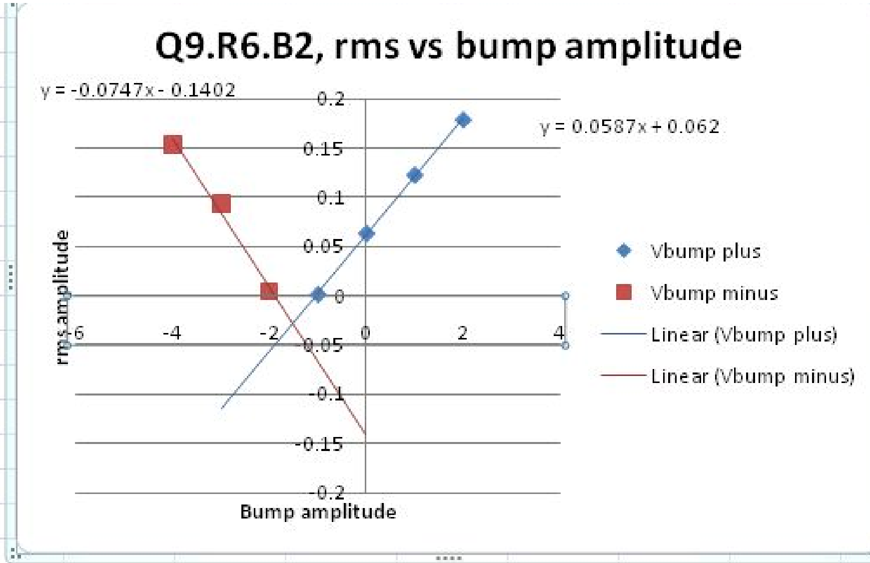
Appendix 2 – Additional MD Results

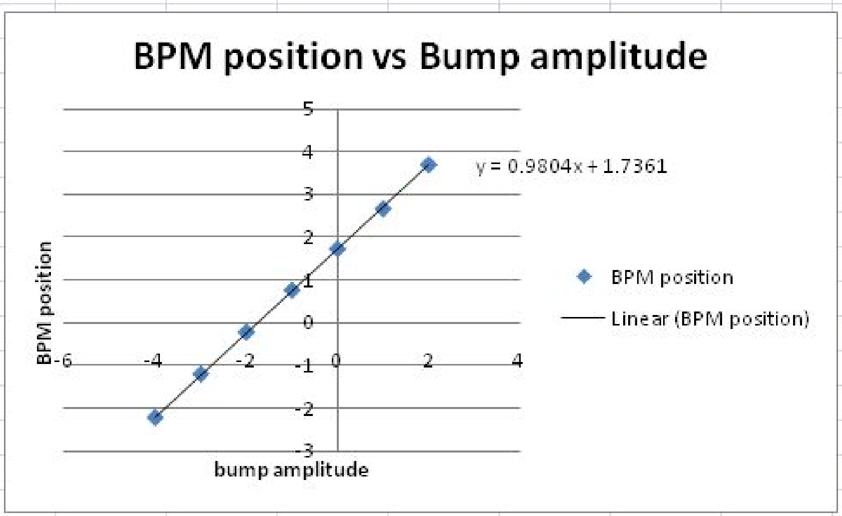
K-Modulation

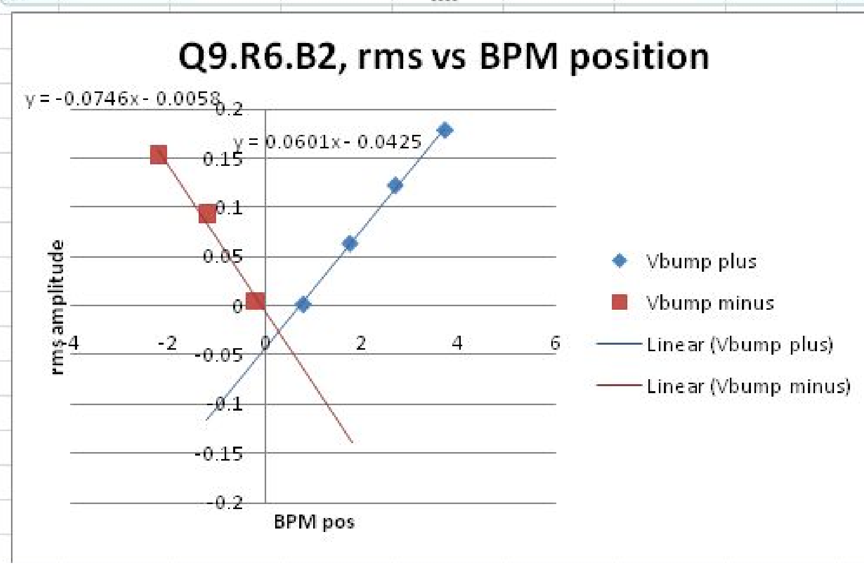
- MD was successful (Jorg, Kajetan, Tobias)
  - lot's of good data was collected.
  - about 3 1/2 hours of efficient MD time.
- We took data for four quadrupoles:
  - Q6.L5B2, Q6.L7B2, Q9.R6B, QX1.L5
- Preliminary analysis was done for Q6.L5B2 and Q9.R6B2 vertical:
  - For Q6.L5B2 we found a very good alignment of the BPM with the quadrupole, while we found that the beam was off-center by -0.2mm, as indicated by the BPM.
  - The preliminary analysis for Q9.R6B2 indicates an **offset between quadrupole and BPM of 0.2mm**, while the **beam was really off-center by about 1.5 mm**!

K-Modulation Result

	rms - amp	amp-error	rms - amp	amp-error			
H-Bump [mm]							
0	0.0634	0.0011	0.012	0.0005		1.74	-0.23
1	0.1222	0.0012	0.0125	0.0005		2.68	-0.23
2	0.178	0.0024	0.0134	0.0006		3.71	-0.23
-1	0.0018	0.005	0.011	0.0002		0.77	-0.25
-2	0.0043	0.0009	0.0006	0.0001		-0.21	-0.23
-3	0.0938	0.0011	0.0102	0.0006		-1.19	-0.22
-4	0.1537	0.0014	0.0113	0.0002		-2.21	-0.23







ATS/Note/2011/040 (MD)

2011-05-18

chiara.bracco@cern.ch

TI8 shielding studies and angular alignment of TDI and TCDQ

Wolfgang Bartmann, Vittorio Boccone, Chiara Bracco, Brennan Goddard, Verena Kain, Annika Nordt.

Keywords: hardware calibration and setup

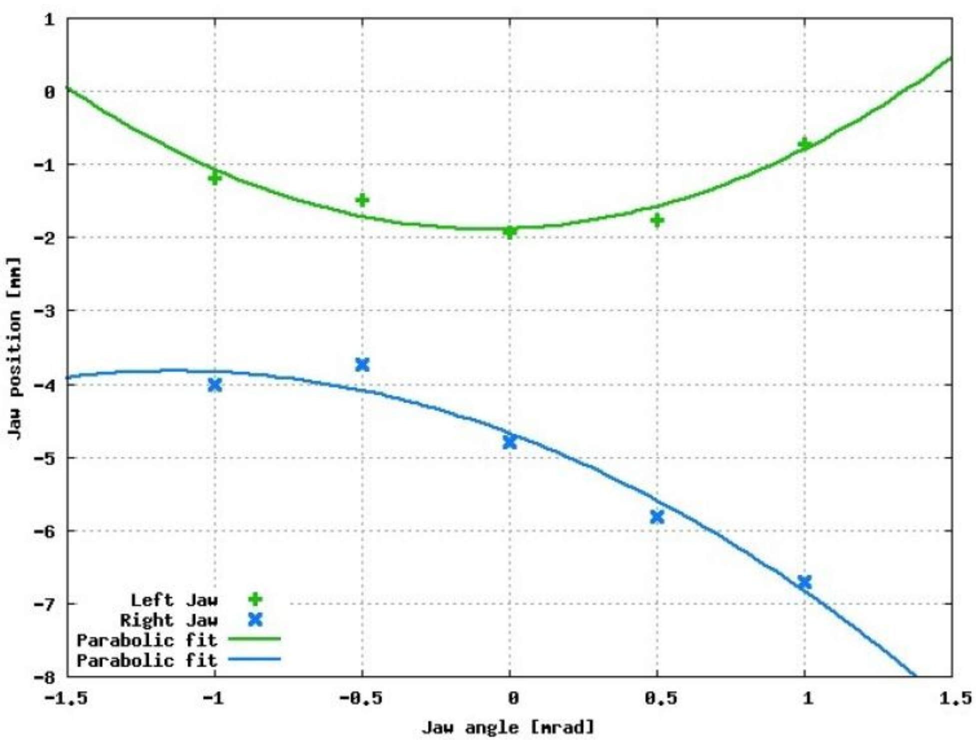


Figure 3 Angular alignment of the B1 TDI. The parabolic fit for the right jaw has to be taken with caution - an additional measurement should be taken at -1.5 mrad

TCDQ angle alignment and TI8 shielding MD

- TI8 shielding studies (Chiara, Wolfgang, Annika):
  - B2, use probe bunch, opened all TCDIs to +/-15 mm
  - for one after the other close left jaw to 3 sig across zero to dump beam on this jaw
  - 3 shots per collimator, analysis to check shielding effect offline
  - Completed successfully.
- TCDQ angle alignment (Chiara, Wolfgang)
  - B1, use probe bunch
  - TCDQ maximum angle corresponding to 2mm discrepancy between up and downstream corner ==> 300 urad
  - measure angle of TCDQ
  - Stopped by problem with an SPS kicker. Not complete. B2 to be done.

ATS/Note/2011/031-MD

2011-05-17

Philippe.Baudrenghien@cern.ch

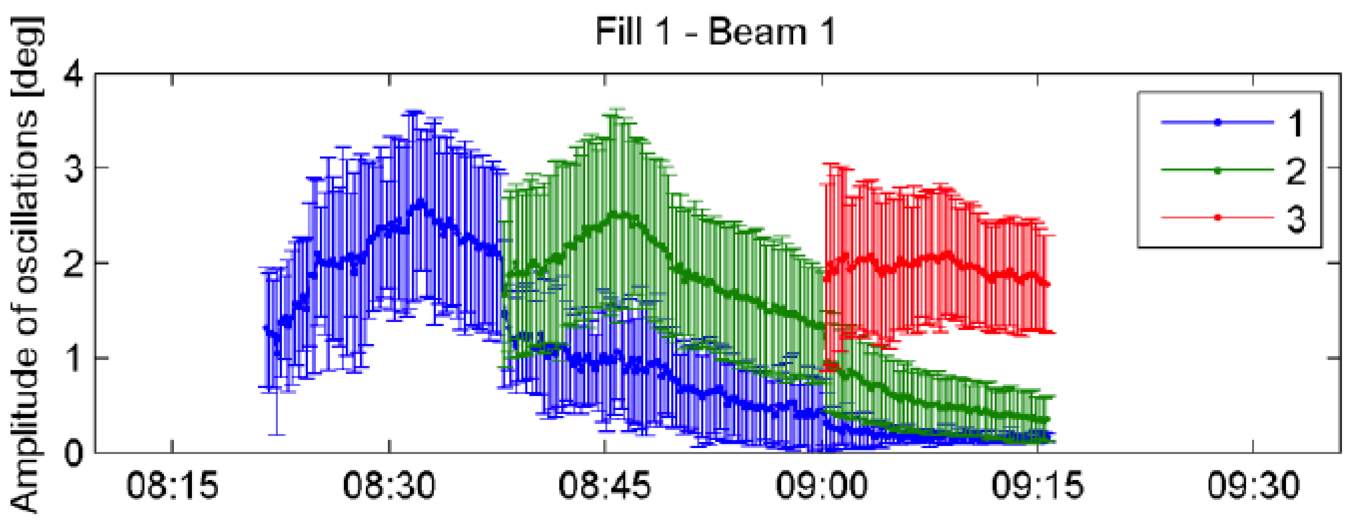
Longitudinal Oscillations with Batch Injection in the LHC

T. Argyropoulos, P. Baudrenghien, T. Mastoridis, J.E. Muller, E. Shaposhnikova, J. Tuckmantel, D. Valuch / BE-RF

G. Papotti / BE-OP

C. Bhat / BE-ABP

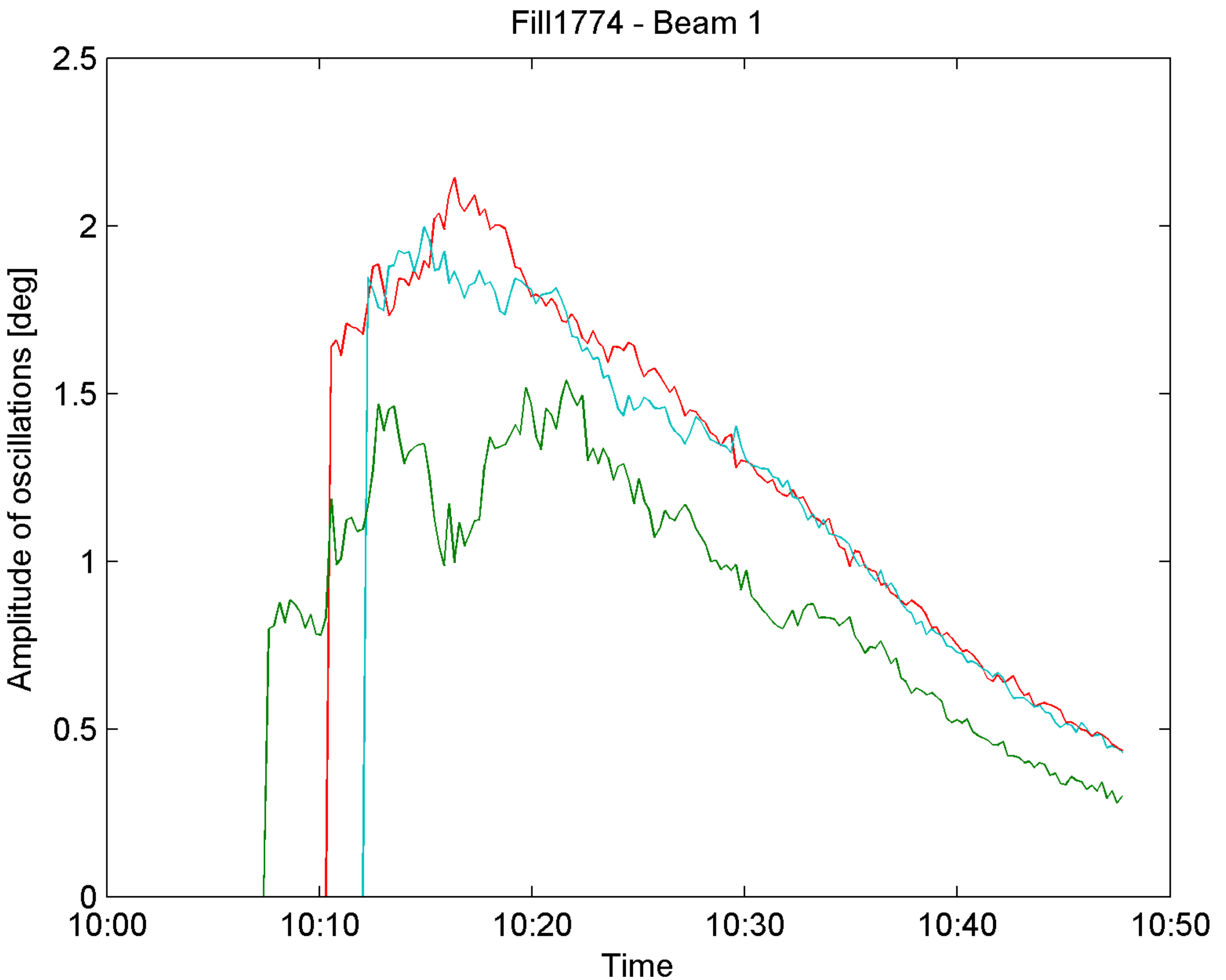
Keywords: LHC , RF , instability, longitudinal, injection, multi-bunch, bunch train



RF multi-bunch instabilities (Philippe et al)

- Studied VERY slowly damped oscillations of bunches at injection. 3 different fillings, all nominal bunch parameters.
- Varied batch spacing and the nbr bunches per batch.
  - Fill1: 12b, then 36b at 0.875 us spacing, then 36b at 0.875us
  - Fill2: 12b, then 36b at 0.875 us spacing, then 36b at ½ turn spacing
  - Fill3: 12b, then 36b at 0.875 us spacing, then 72b at 0.875 us
- Measured:
  - bunch profiles (25 ps/sample) to see whether oscillation is pure dipole or higher-order and the b-by-b stable phase to measure damping.
  - Plot shows damping of the dipole oscillation for fill3
  - The figure is similar for the other fills: an oscillation growing for the first 5-10 min, then damped with a 30-40 min damping time.
  - Further analysis will tell whether batch spacing and nbr bunches/batch have an influence on the damping time. The BQM data will also be analyzed to see whether quadrupole oscillations are present.

RF multi-bunch instabilities (Philippe et al)



damping of the dipole oscillation for fill3:

12b batch (avg over all bunches) in green

36b batch (avg) in red

72 b batch (avg) in blue.

ATS-Note-2011-041 MD
2011-05-16
Elena.Chapochnikova@cern.ch

Studies of longitudinal single bunch stability

T. Argyropoulos, T. Bohl, C. Bhat, P. Baudrenghien, J. Esteban Muller, W. Hofle, G. Papotti, E. Shaposhnikova, J. Tuckmantel, D. Valuch, W. Venturini Delsolaro, U. Wehrle (BE)
Keywords: Beam dynamics, Longitudinal, Instability, RF, LHC

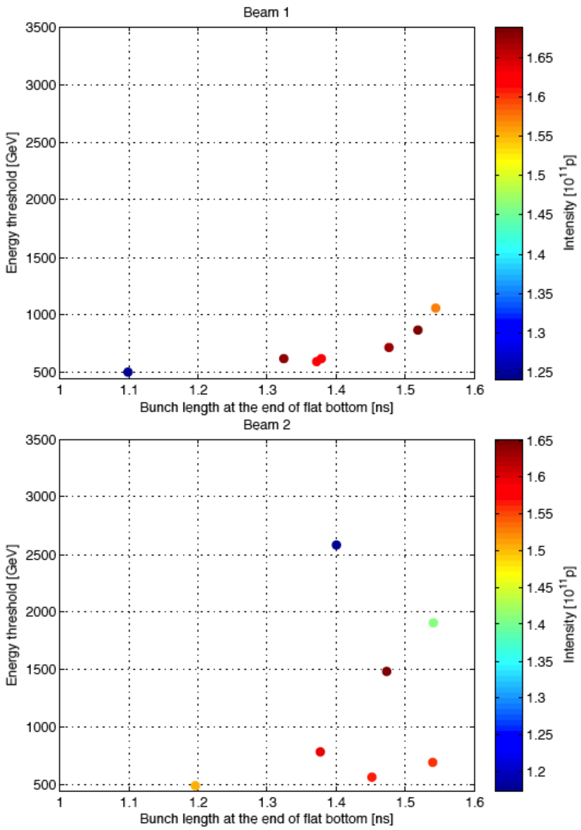
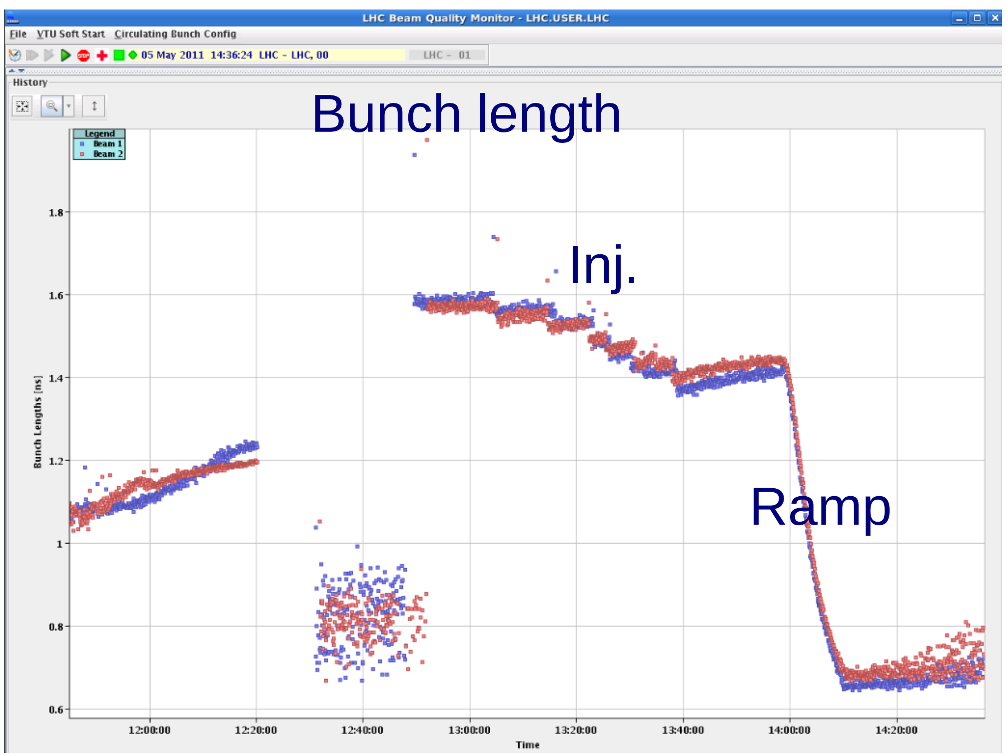


Figure 4: Energy at which the phase oscillations start to grow during the ramp (2nd MD fill) as a function of bunch length at the end of the flat bottom for all 8 bunches in Beam1 (top) and Beam2 (bottom).

RF Single-bunch instabilities MD (Elena et al)

- Loosen limits on interlocked BPMS IP6 and test
- Inject beams with different longitudinal emittances, expect some of them to go unstable during the ramp
- 1.6e11 ppb, .35eVs single bunches are stable in the LHC at injection energy.
- Ramp to 3.5 TeV



“Bunches became unstable on the flat top with phase oscillation amplitude increasing for bunches with smaller injected longitudinal emittance. Beam 2 was more unstable than beam 1. Only the first bunch with injected emittance of 0.9 eVs was stable. To see instability during the ramp (if any) bunch profile data should be analysed.”

Unstable at flat top after a while

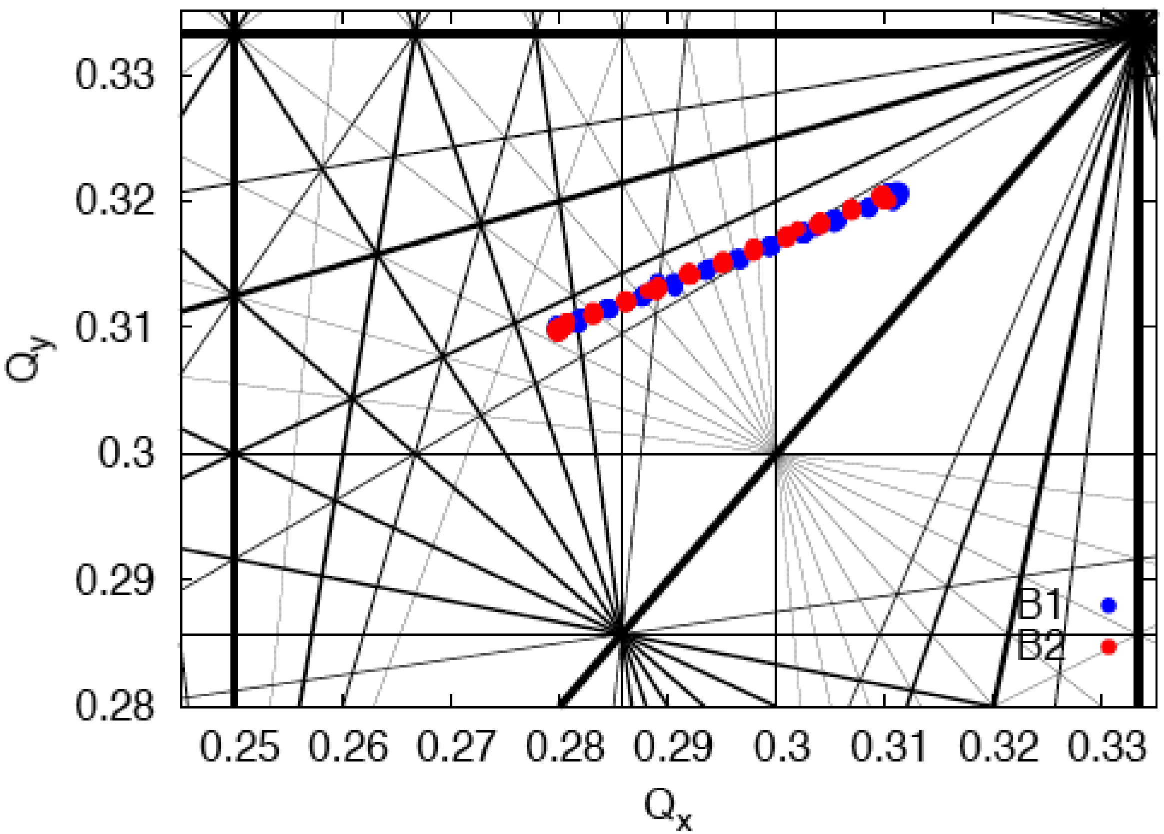
CERN-ATS-Note-2011-034 MD (LHC)

May 23, 2011
Rogelio.Tomás@cern.ch

Collision tunes at injection and ramp

Rama Calaga, Delphine Jacquet, Elias Metral, Ryoichi Miyamoto, Nicolas Mounet, Laurette Ponce, Stefano Redaelli, Benoit Salvant, Frank Schmidt, Ralph Steinhagen, Rogelio Tomás, Glenn Vanbavinckhove, Frank Zimmermann

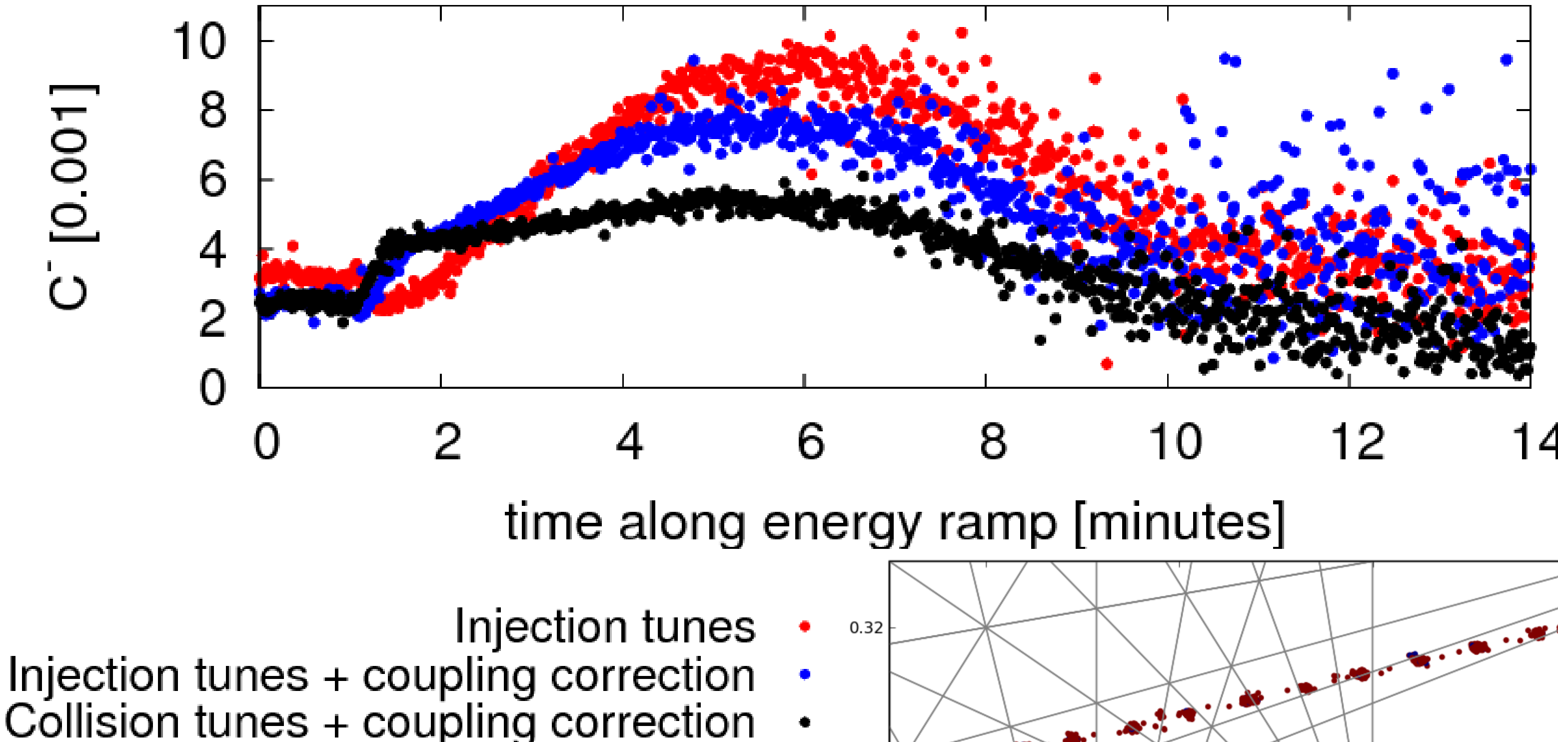
Keywords: optics

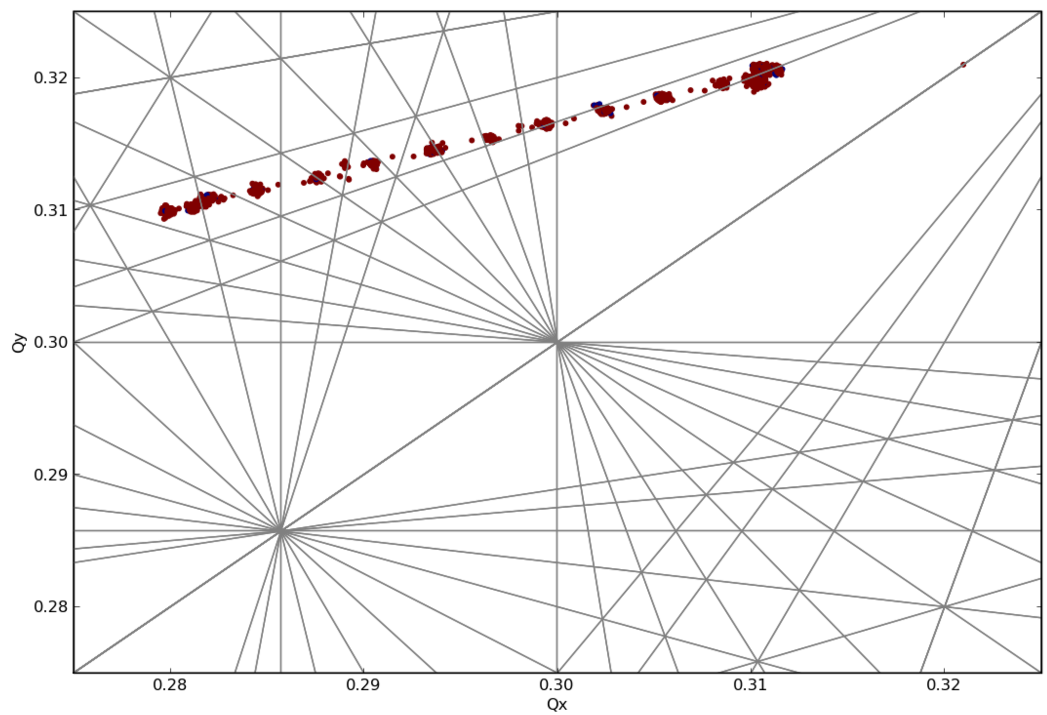


Collision tunes at injection

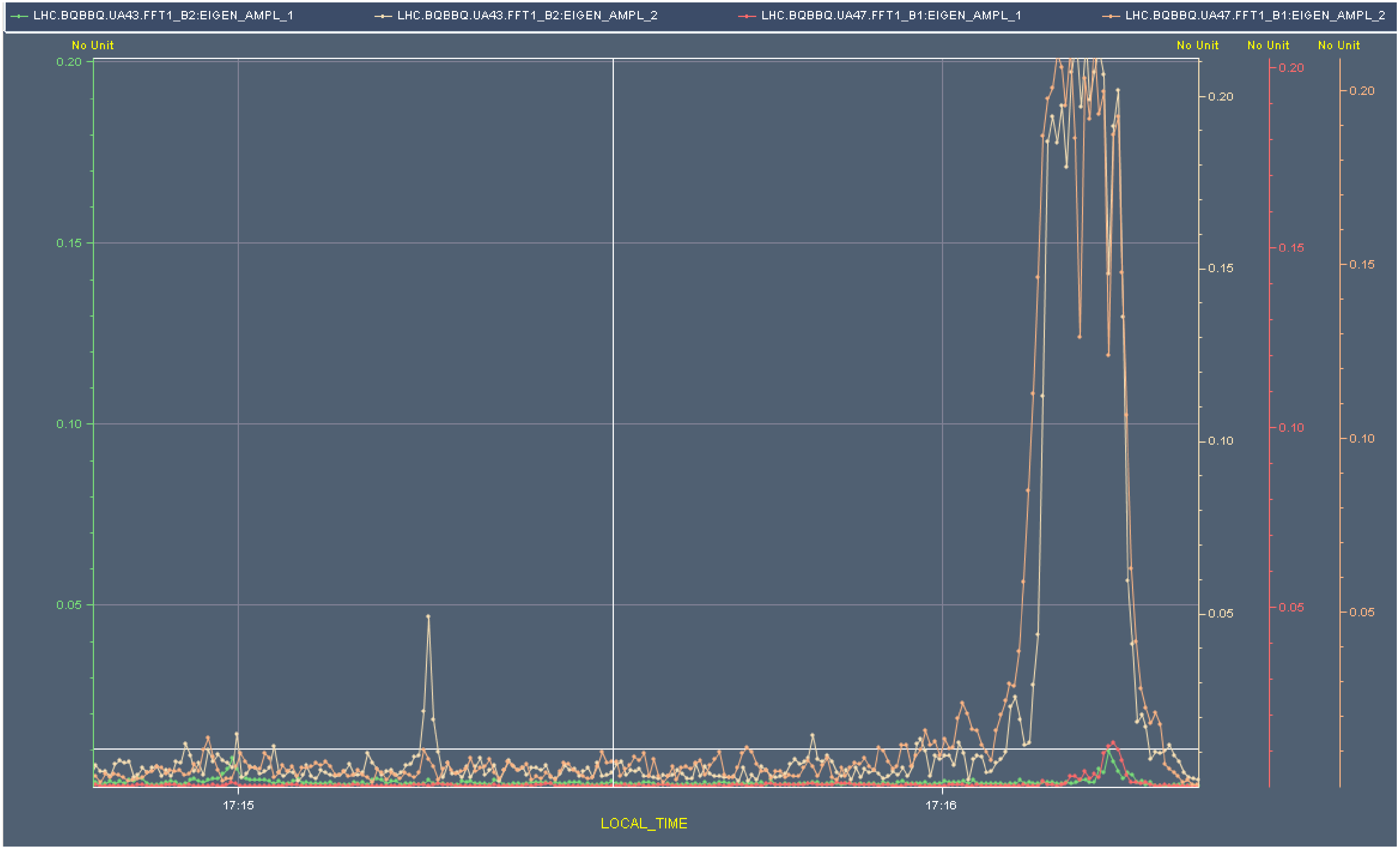
- Local coupling corrections implemented.
- Nominal tunes ramp for further coupling measurement and correction along the ramp with pilot bunch. Fine.
- Tune scan from nominal to collision tunes at injection. No effect on lifetime. Ramped with collision tunes.
- A second ramp: coupling corrections from ramp 1. Improvement of about factor 2 observed in C-. Coupling correction is valid for nominal injection tunes too.
- 3rd ramp nominal bunch, lost half intensity at start of the ramp: chromaticity could be negative. Vertical oscillations 1 minute after start of ramp. Transverse dampers were off.
- No difference in beta-beat for collision and injection tunes.
- Small difference observed in the beta-beat for injection compared with 4-4-2011 (for both beams).

Coupling correction & Tune Scan





Tune Amplitude: Beam Loss Ramp #3



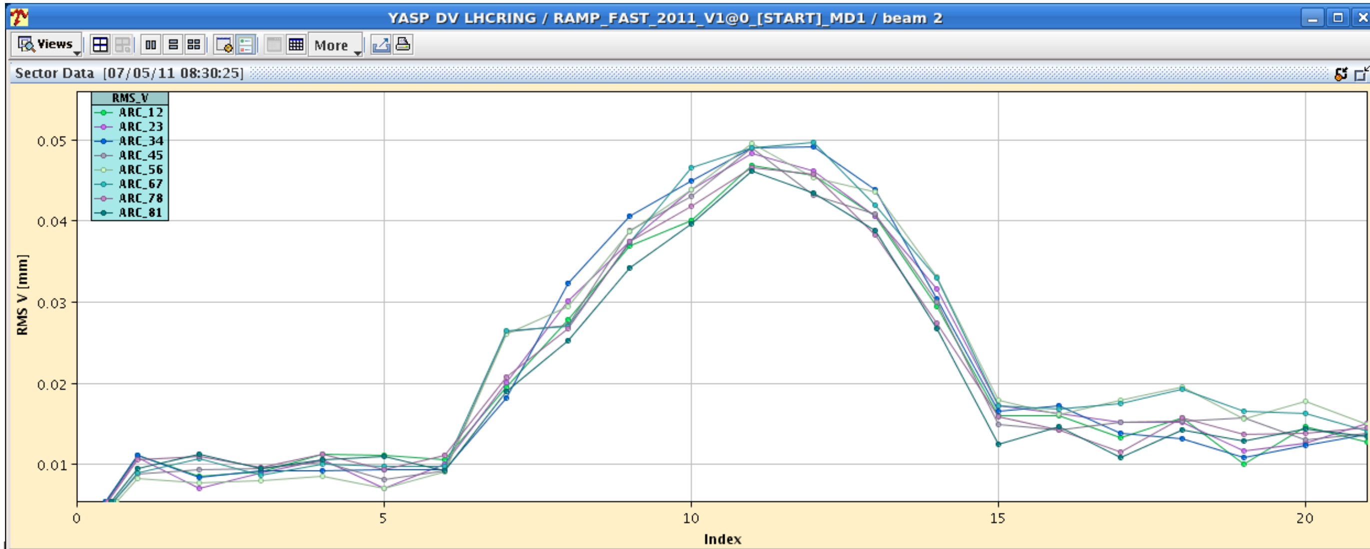
0.45 TeV: Investigation on CODs

Nuria, Matteo, et al

- Investigation done on the following CODS:
  - 1 - RCBYHS5.R8B1
  - 2 - RCBYV5.L4B2
  - 3 - RCBYH4.R8B1
  - 4 - RCBYHS4.L5B1
  - 5 - RCBCV8.L1B2
- Procedure:
  - Bump with each of the correctors observing leakage to machine.
  - Data acquired at 25Hz has to be analyzed online, but some hints suggested good results (especially the corrector 2 showed a large dynamic response).
- Further analysis has been done on correctors 1 and 5 sending a sinusoidal current at different frequency.
- Results to be analyzed. Ongoing.

0.45 TeV: Investigation on CODs

Nuria, Matteo, et al

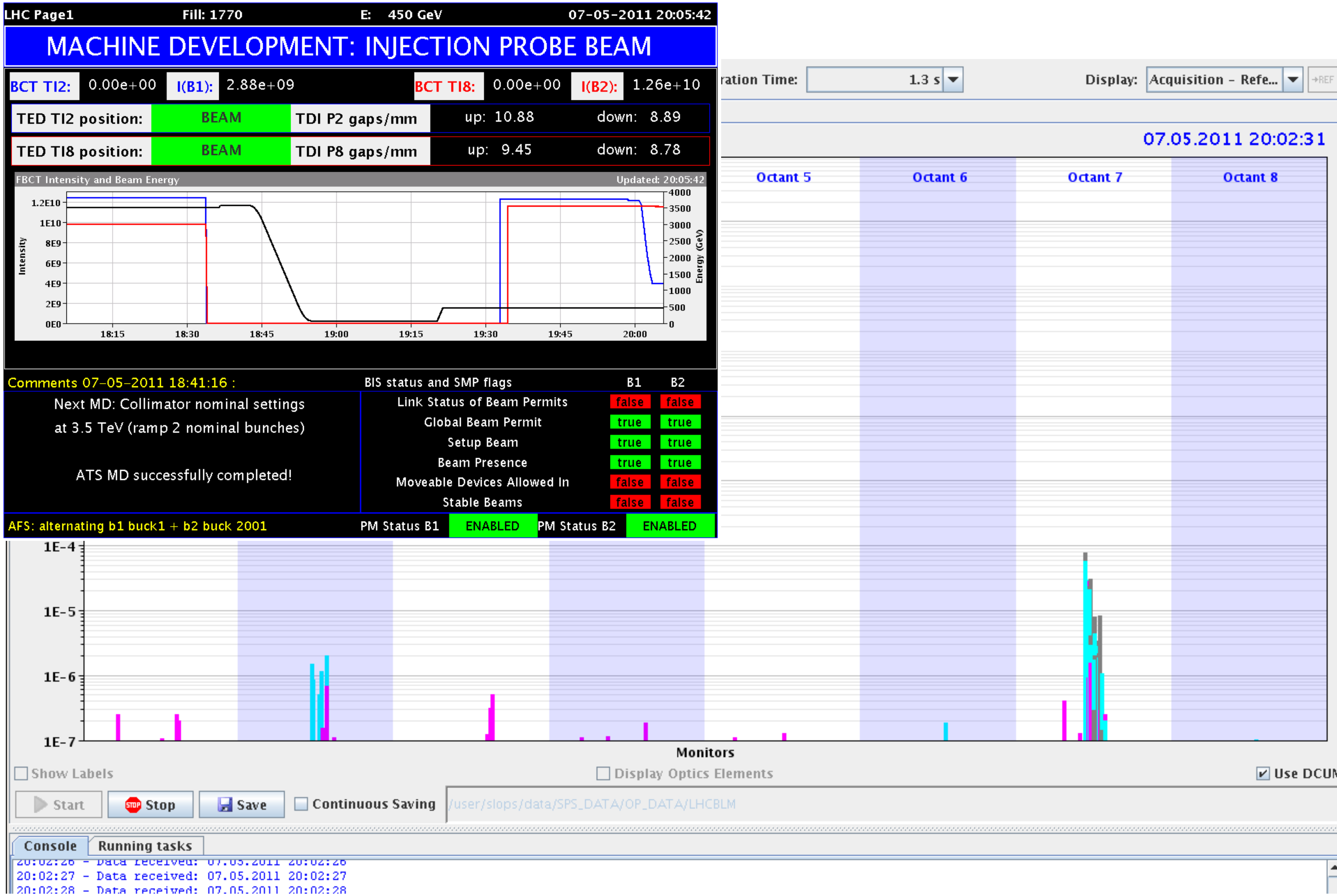


Dynamic orbit effect while ramping bump with correctors.

Nominal collimation, single b tune shift (Coll, Imp.)

- Initial blow-up tests with transverse damper.
- Injection scraping during short delay from injectors.
- Nominal 3.5 TeV collimation settings achieved for b1 &b2:
  - TCP = 5.7 sigma (nom), TCSG = 6.7 sigma (nom)
  - TCLA = 9.7 sigma (nom), IP6 = 7.2/7.7 sigma (nom)
- Octupoles trimmed to 350A for beam 1.
- For b1 moved towards nominal 7 TeV settings. Limited by TCSG losses close to IP7. Valid setup reached:
  - TCP = 4.0 sigma (nom), TCSG = 6.0 sigma (nom)
  - TCLA = 8.0 sigma (nom), IP6 = 7.0/7.5 sigma (nom)
  - Smallest gap: 2.2 mm
  - Beam lifetime: > 100 hours
  - Tune shift measured: ~2e-4
  - Efficiency measured: 3e-5 – 1e-4

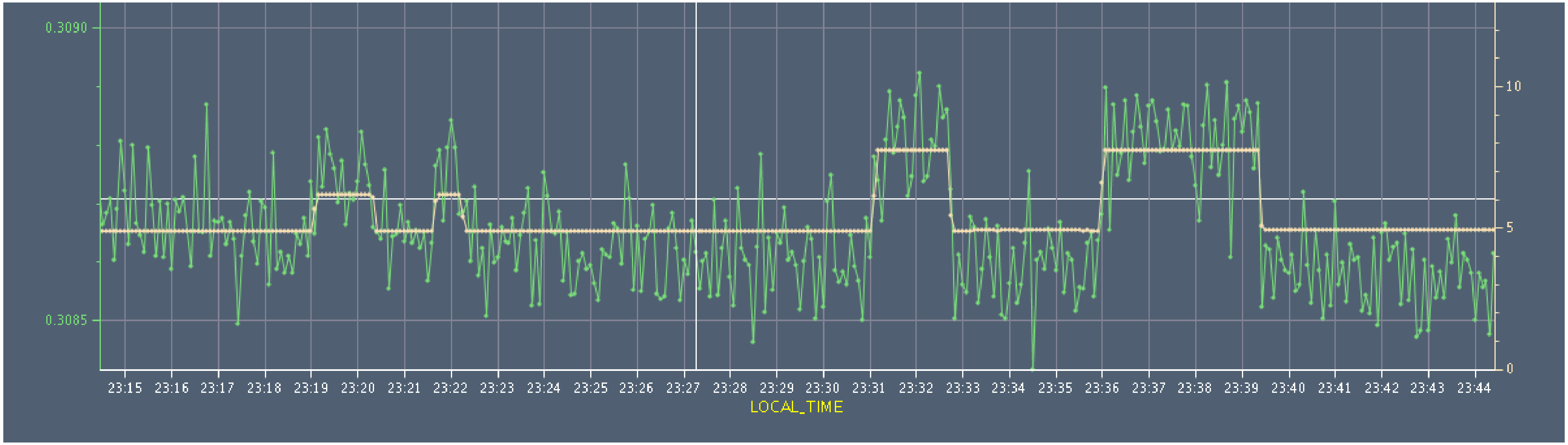
Blowup Test Transv. Damper (Wolfgang, Daniel)



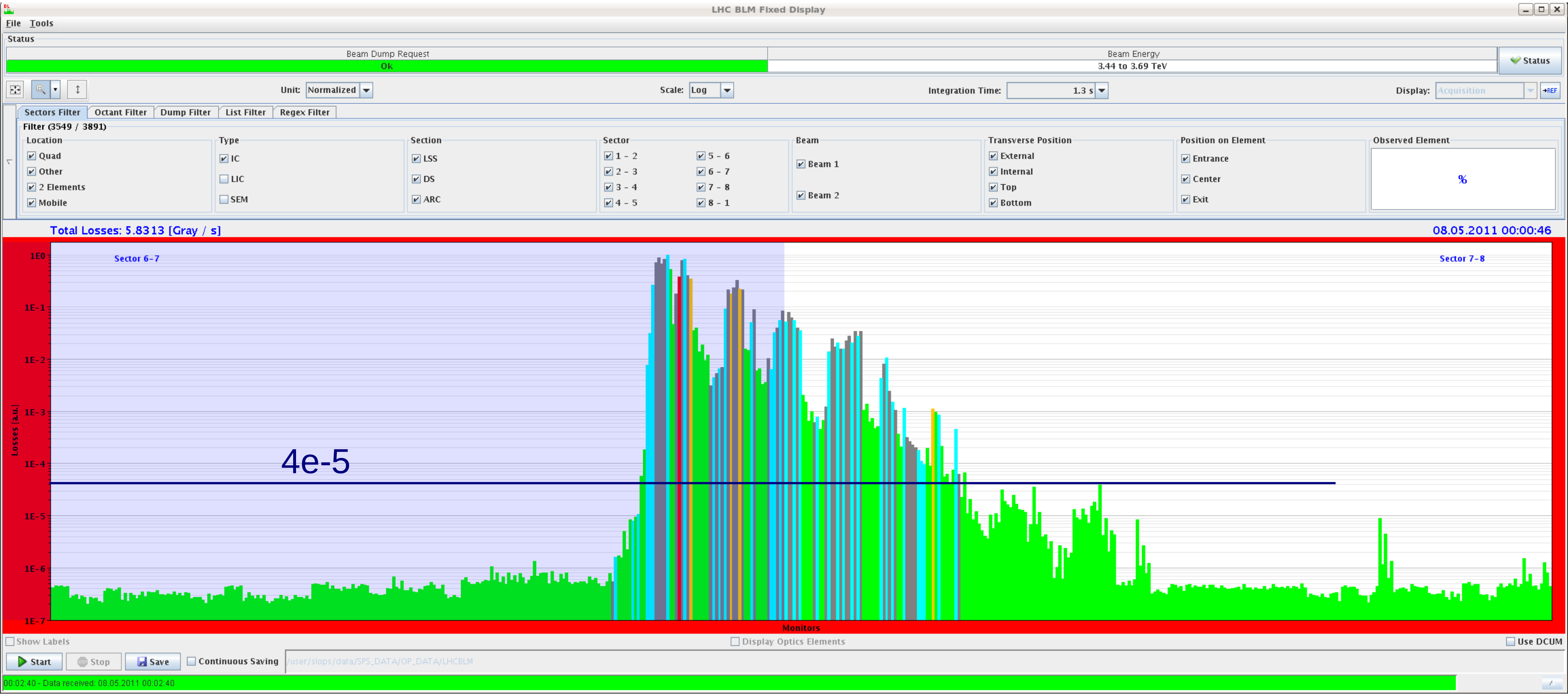
Settings b1 first loss-maps

Vertical tune shift – collimator movement

- Clearly seen in vertical plane when moving collimtors out by 4 sigma and back in, etc…
- Magnitude: ~0.0003



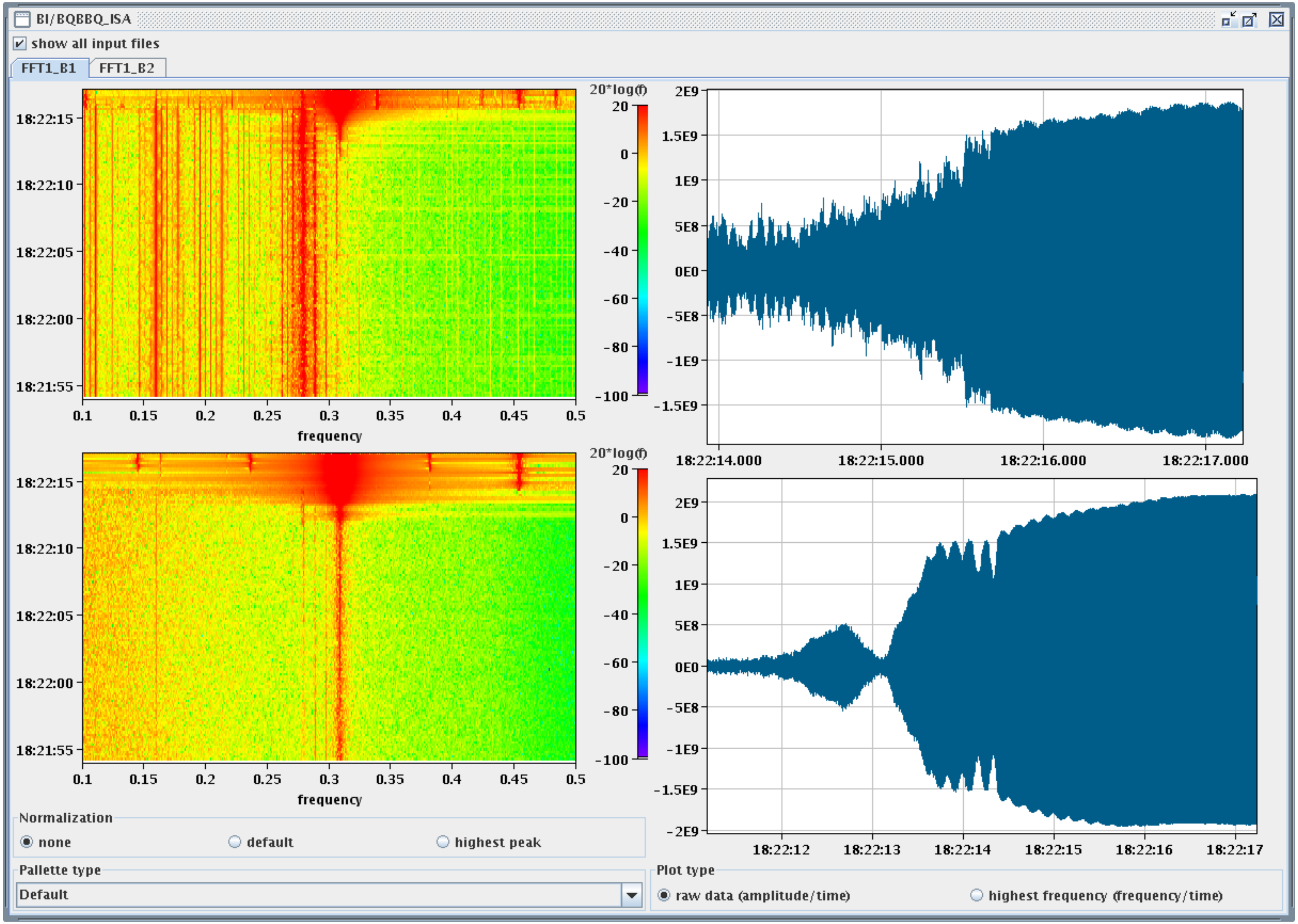
Efficiency measured – here b1, horizontal



Coupled-bunch instability rise times (Elias et al)

- Injection energy, 12+36 bunches:
  - switch off transverse feedback (both planes) for up to 2.5 s, triggering acquisition at the same time on ADT pickups, LHC-BPM and headtail monitor, first for B2 only (up to ~14h00), then for both beams
  - B2: instability visible in the ADT pickups, in vertical only, around 13h18 (Q'H=-1, Q'V=-0.5, feedback off for 1 sec),
  - B1 & B2, both planes: instability visible in ADT pickups and LHC-BPM around 14h46 (chromaticities at 0, feedback off for 2.5sec) and around 15h04 (chromaticities at -1, feedback off for 1.5sec)
- Ramp 12+36 b to flat top, no squeeze, chromaticities ~ 0
  - trim octupoles to 300A, then trim down by step. At each step, we switched off the transverse damper for 1 second. No instability until 100A, then "feedback off" window increased to 3s.
  - Octupoles trimmed down again by steps of 10A. Instability begin visible in B2 vertical at 60A (17h54). We continued to trim down until 0A; no other instability than B2 V was seen, until we dump around 18h23.

Coupled-bunch instability rise times (Elias et al)



Losses in Dispersion-Suppressor (Coll+BLM+MP)

- BLM thresholds adjusted on 120 BLM's, based on old data.
- Created fast (~2 s) beam losses at primary collimators.
- 3 bunches, b2 loss
  - Loss rate: 1.5e11 p/s
  - 20 times below BLM limits, 10 times below assumed quench limit,
- 16 bunches, b2 loss
  - Loss rate b2: 2.5 – 3e11 p/s, 6e11 p/s
  - Reached 505 kW loss
  - Beam dump after damper switched on, b2 still on 1/3 resonance.
- 16b (b1) and 21b (b2):

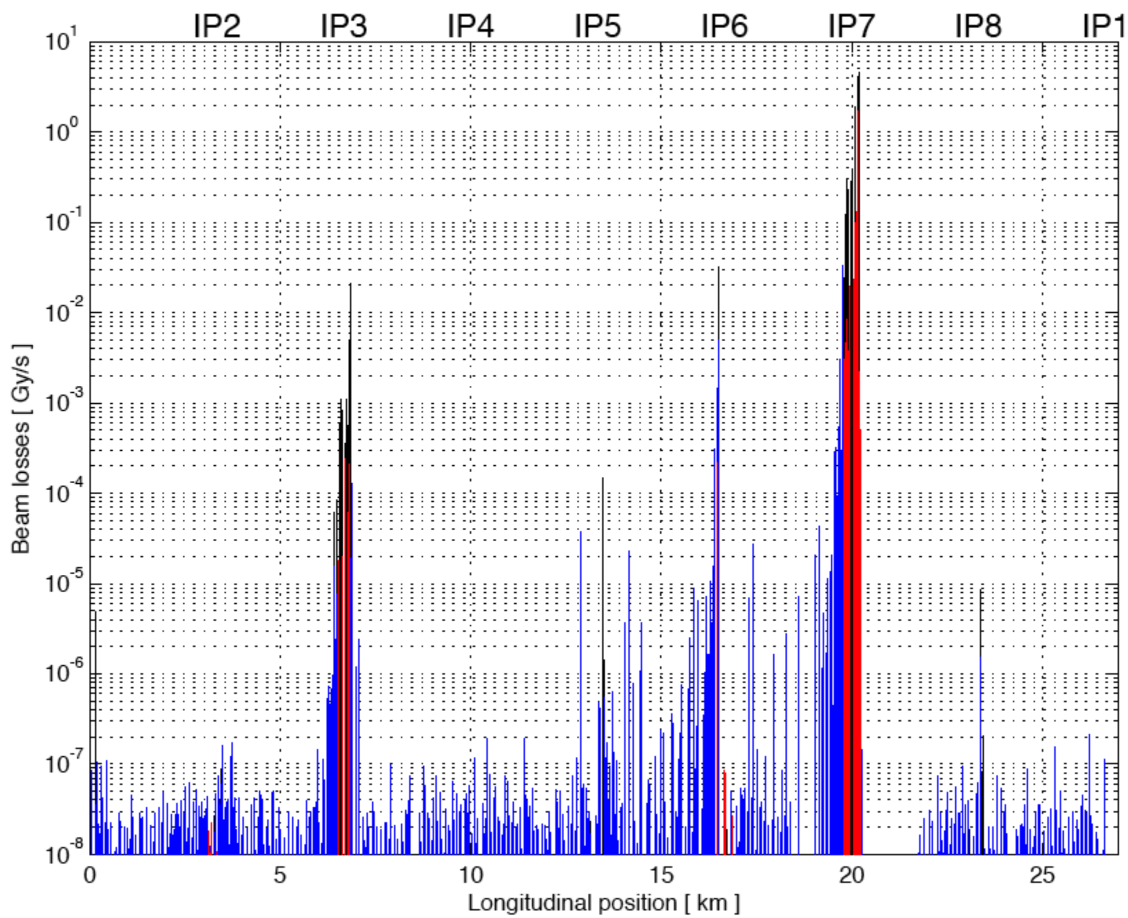
CERN-ATS-Note-2011-042 MD (LHC)

May 24, 2011
Stefano.Redaelli@cern.ch

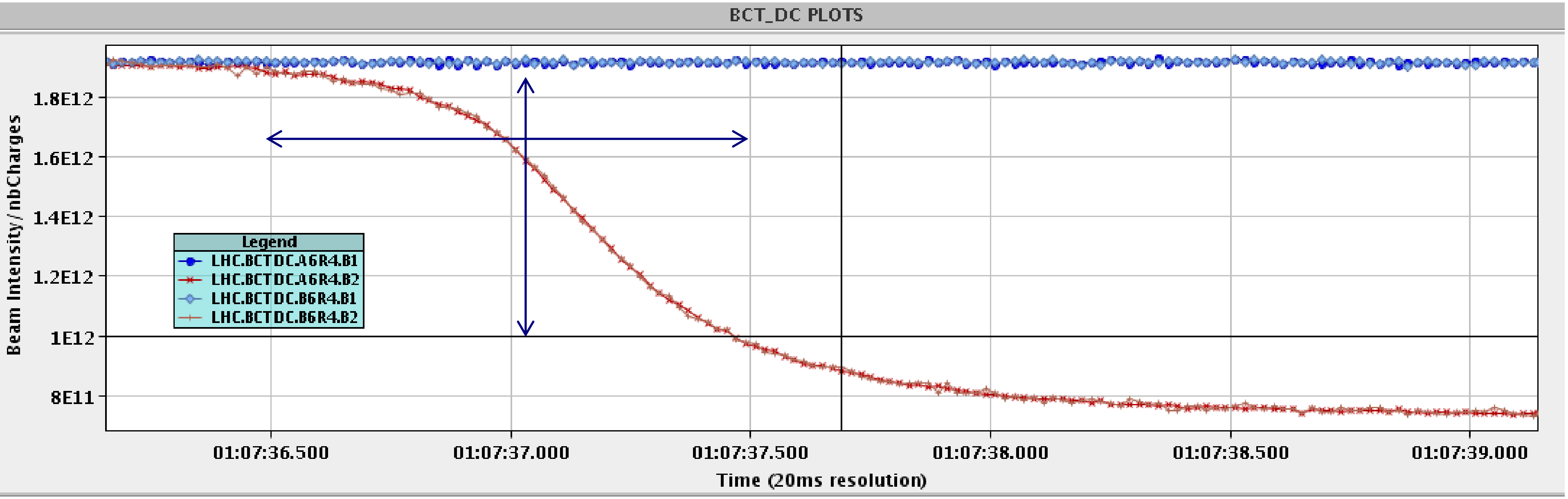
Collimator losses in the DS of IR7 and quench test at 3.5 TeV

R.W. Assmann, R. Bruce, F. Burkart, M. Cauchi, D. Deboy, B. Dehning, E.B. Holzer, E. Nebot del Busto, A. Priebe, S. Redaelli, A. Rossi, R. Schmidt, M. Sapinski, G. Valentino, J. Wenninger, D. Wollmann, M. Zerlauth, CERN, Geneva, Switzerland

Keywords: Collimation, beam losses, quench, dispersion suppressor



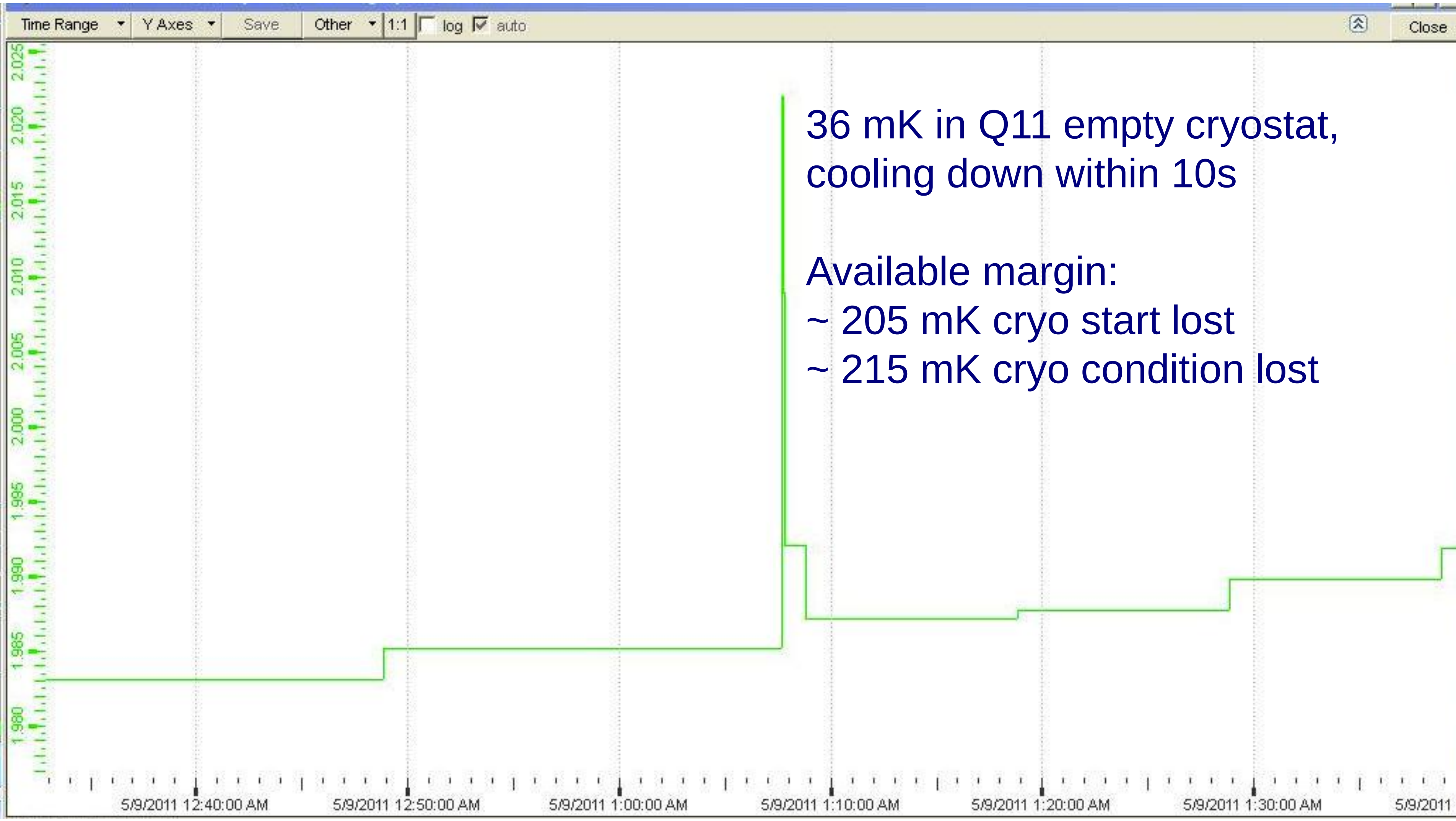
Beam Loss with 16 bunches, 3.5 TeV



Loss rate:

9e11 p/s @ 3.5 TeV → 505 kW

Cryo observation: 505 kW beam loss

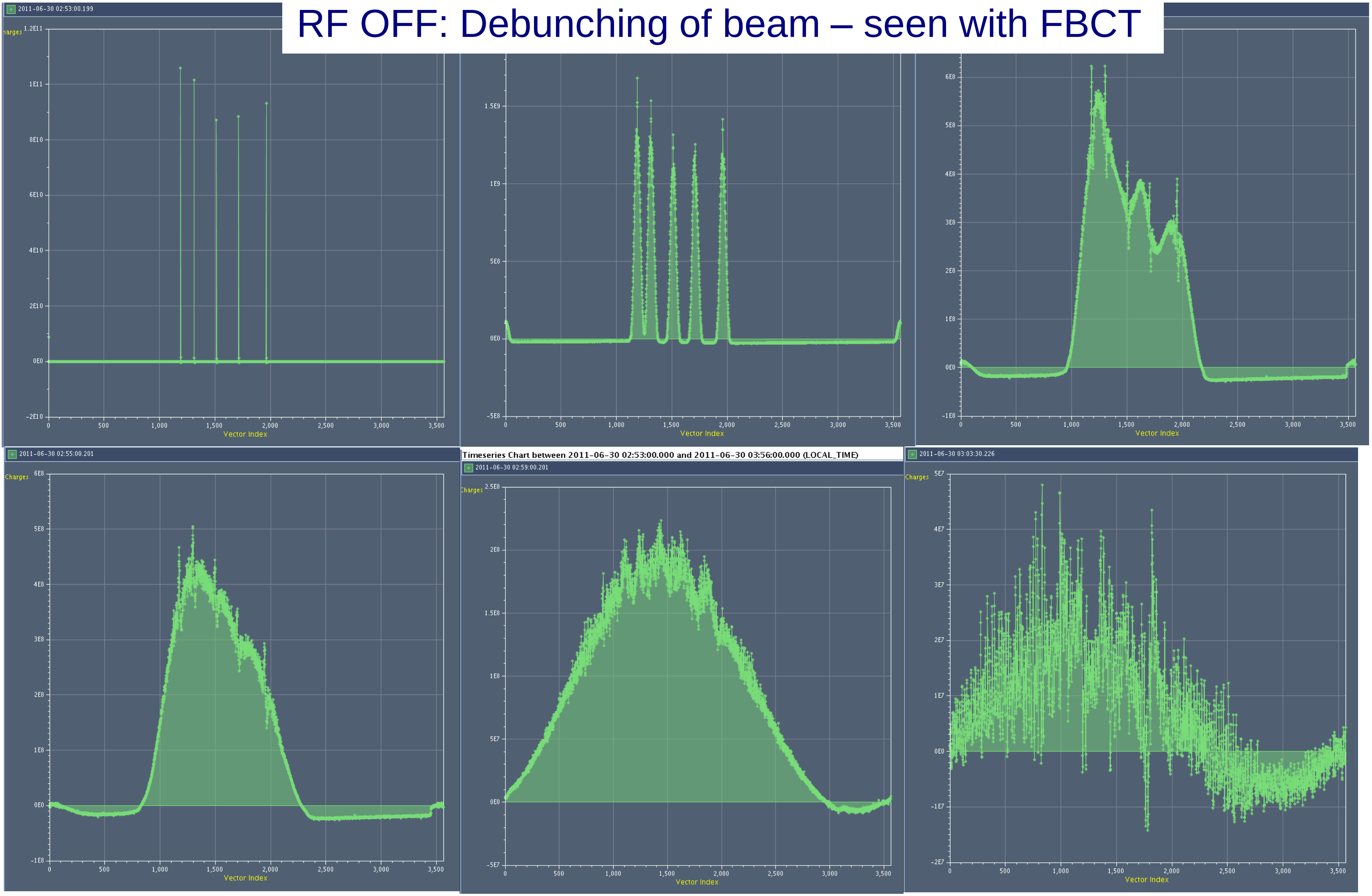


36 mK in Q11 empty cryostat, cooling down within 10s

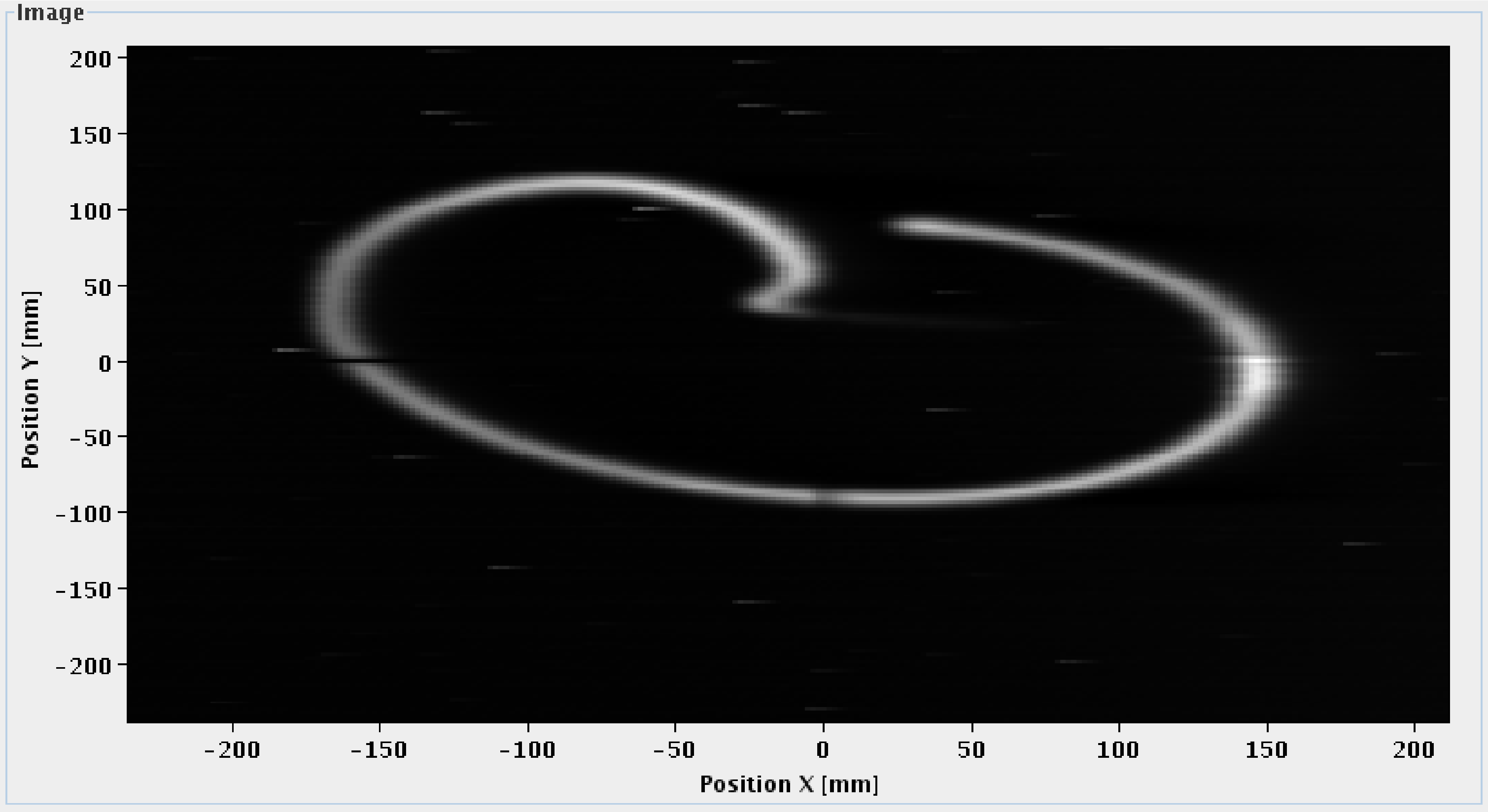
Available margin:
~ 205 mK cryo start lost
~ 215 mK cryo condition lost

Beam Instrumentation F. Roncarollo et al, BI Team

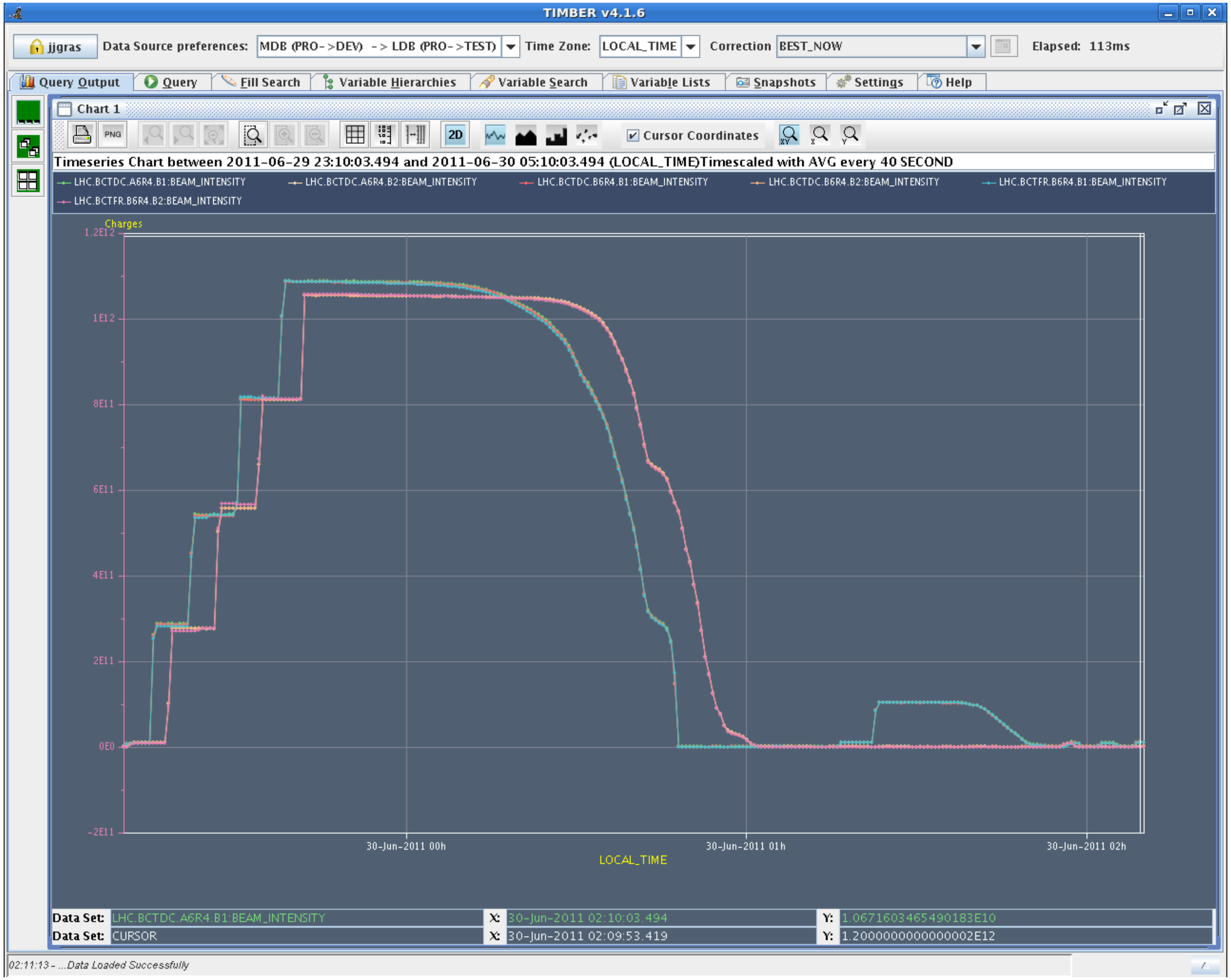
RF OFF: Debunching of beam – seen with FBCT



Beam Instrumentation F. Roncarollo et al, BI Team



BI: Comparison Fast BCT and DC BCT



Disagreement below 1%...

Injecting nominal emittances V. Kain et al

- Longitudinal OK:
  - no significant degradation of injection quality (12 or 36 bunch injections).
- Transverse checks OK:
  - **Inj. emittances of ~ 3.5 um with comparable losses to 2.5 um on TCDIs and nom. scraping (int. loss in SPS due to scraping 10 %).**
  - Injected emittances up to 7.5 um and varying scraping with expected unacceptable losses for physics filling.
  - The TCDIs were kept at nominal settings throughout the test.

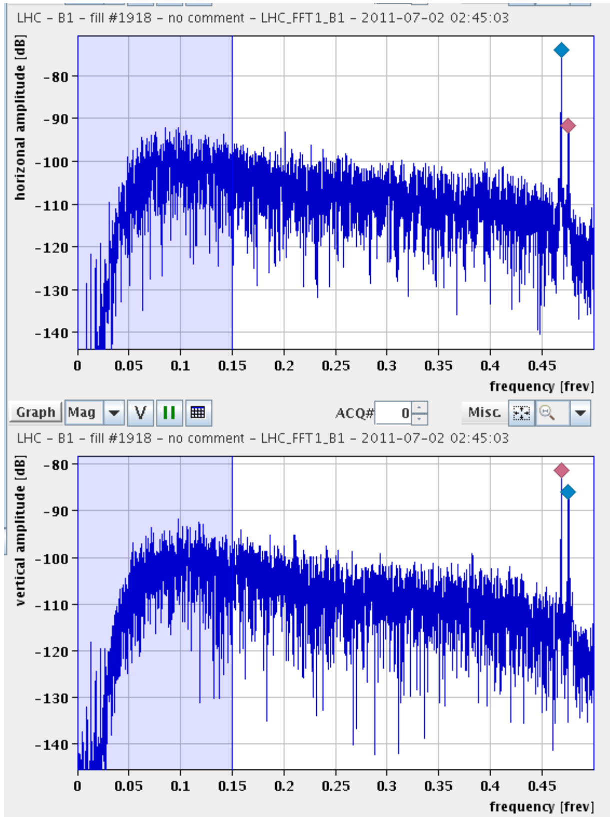
MKI & UFO's J. Uythoven et al

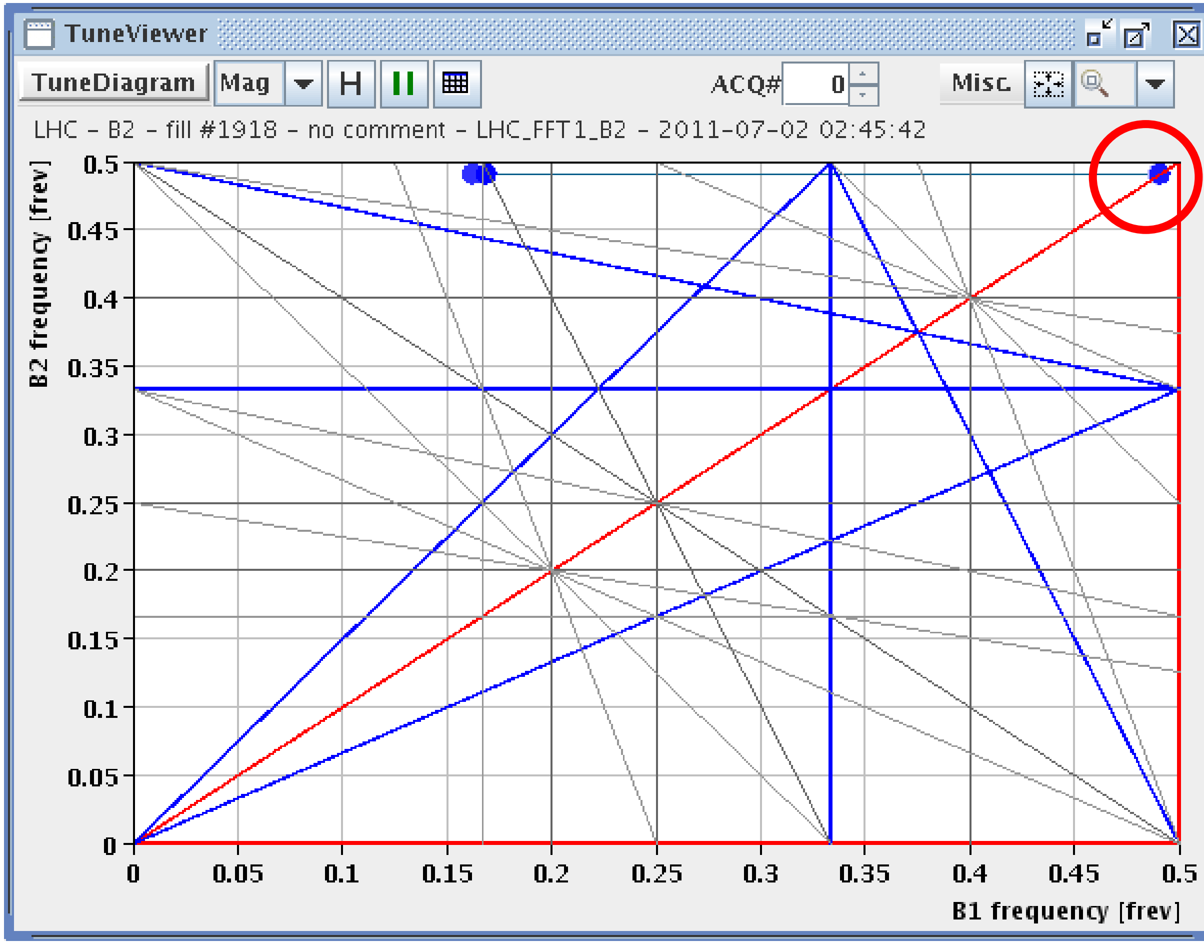
- Data taken for selective pulsing of injection kickers.
- Some initial correlation with UFO's that later disappeared.
- To be followed…

RF MD Results (Philippe, Elena et al)

- Goal: compare thresholds for single and multi-bunch stability.
- Only time to do single bunch studies:
  - Single bunches injected to LHC with nominal (0.5 eVs) and smaller longitudinal emittances extracted from the SPS (down to 0.35 eVs).
  - Intensities were about 1.2-1.4e11 ppb, SPS transverse scraping was disabled for the second part of the MD.
  - Injection phase errors were damped for nominal emittances, but remained undamped for smaller emittances (even slightly growing).
  - The capture voltage changed to 8 MV and 3.5 MV (operational: 6 MV), for different fills (3.5 MV is matched to SPS extraction voltage).
  - The bunches injected in the 3.5 MV were observed to have a longer damping time of the dipole oscillations.
  - One ramp was performed with 8 bunches per ring: observed different energy onset of instabilities for bunches with slightly different long. emittances. Data acquired and will be analysed in detail.

Tune WP Close to Half Integer (B1 shown)





LHC - B1 - Fill#1918.0
2011-07-02 02:45:03
RAW&FFT: 8192 turns@2.5Hz
no excitation

Q1 = .468671	Qx = .469943
Q2 = .475733	Qy = .474461
|C-| = .005427	E = 450.1 GeV
Q'x = ???	
Q'y = ???	

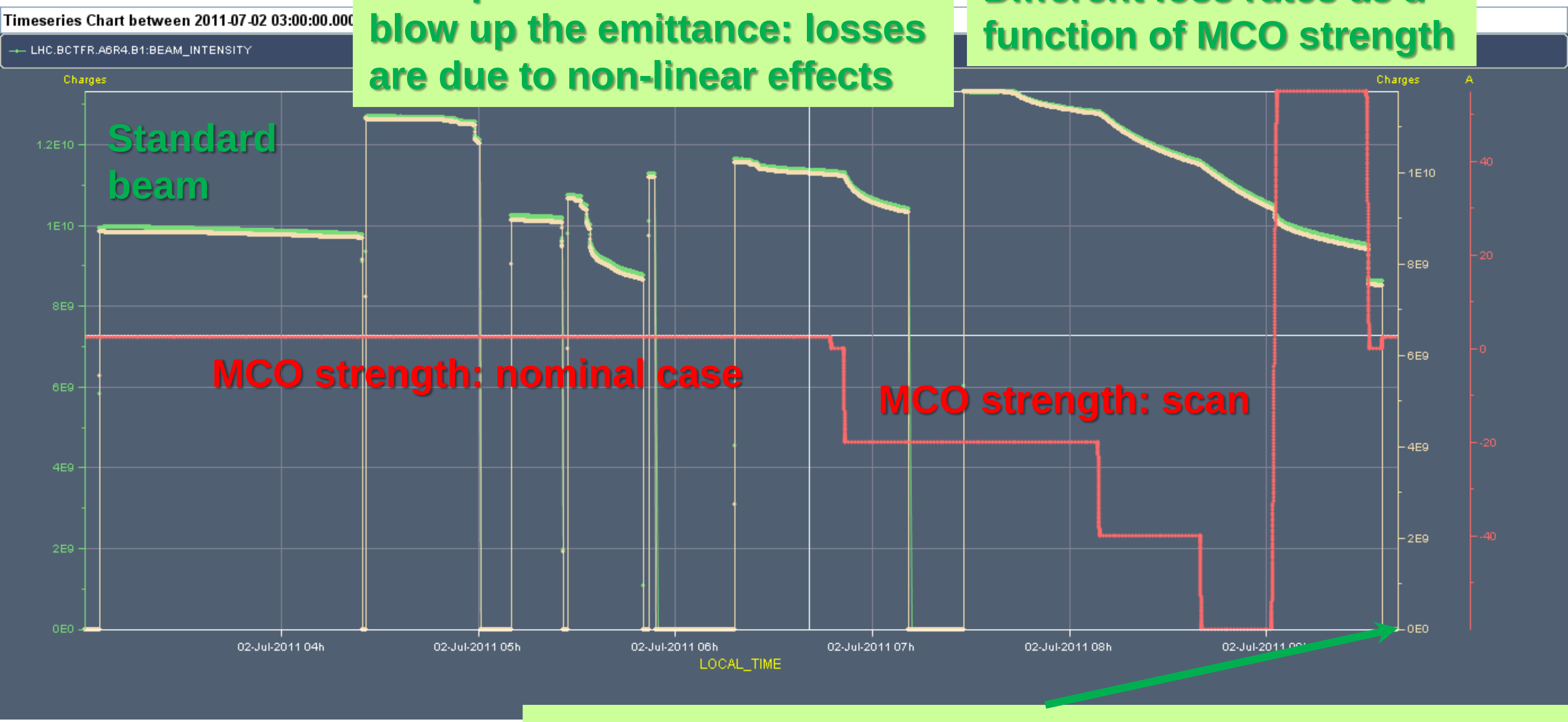
M. Giovannozzi, F. Schmidt et al

Non-Linear MD: DA measurement

DA estimate could be obtained by off-line analysis of intensity decay: analysis in progress.

The aperture kicker is used to blow up the emittance: losses are due to non-linear effects

Different loss rates as a function of MCO strength

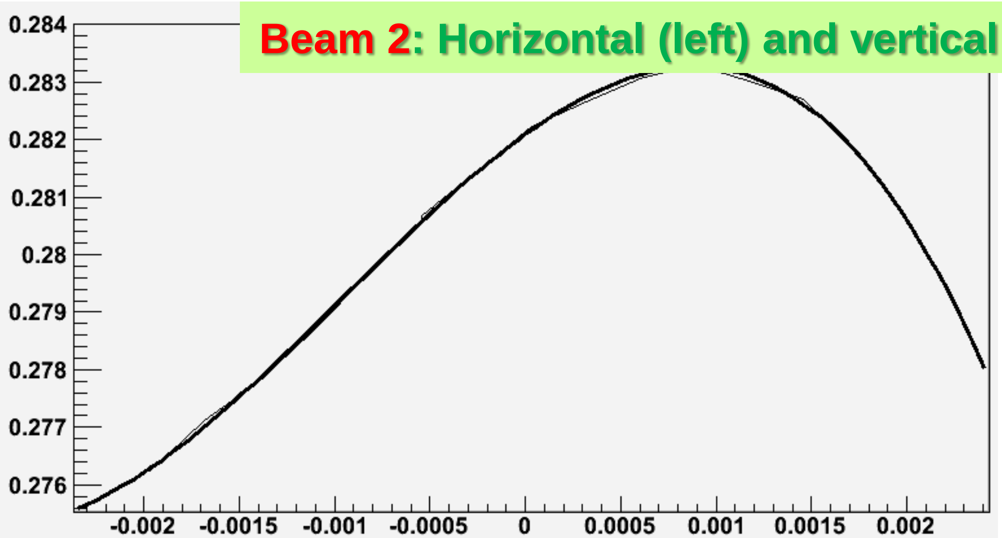


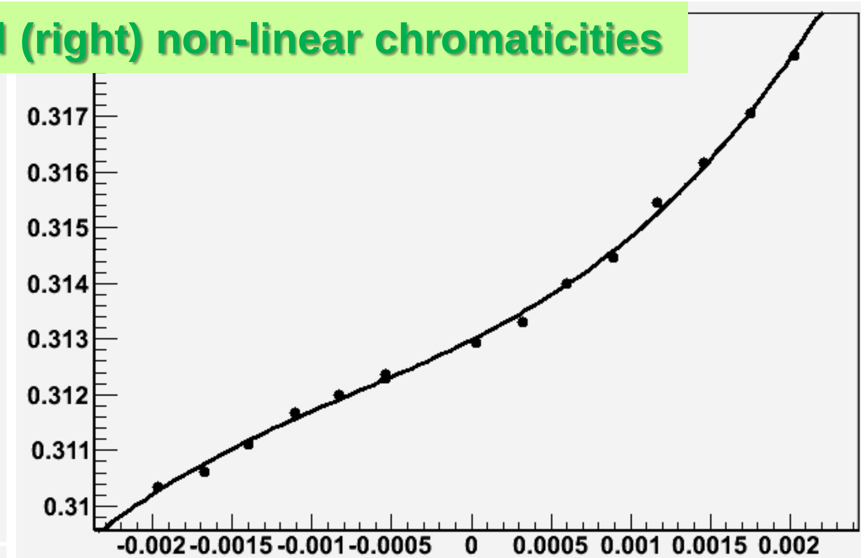
No more Beam 1 as from 10 am due to BTEs problem at the SPS: MCD scan dropped (problem solved after end of MD). Additional time will be requested.

M. Giovannozzi, F. Schmidt et al

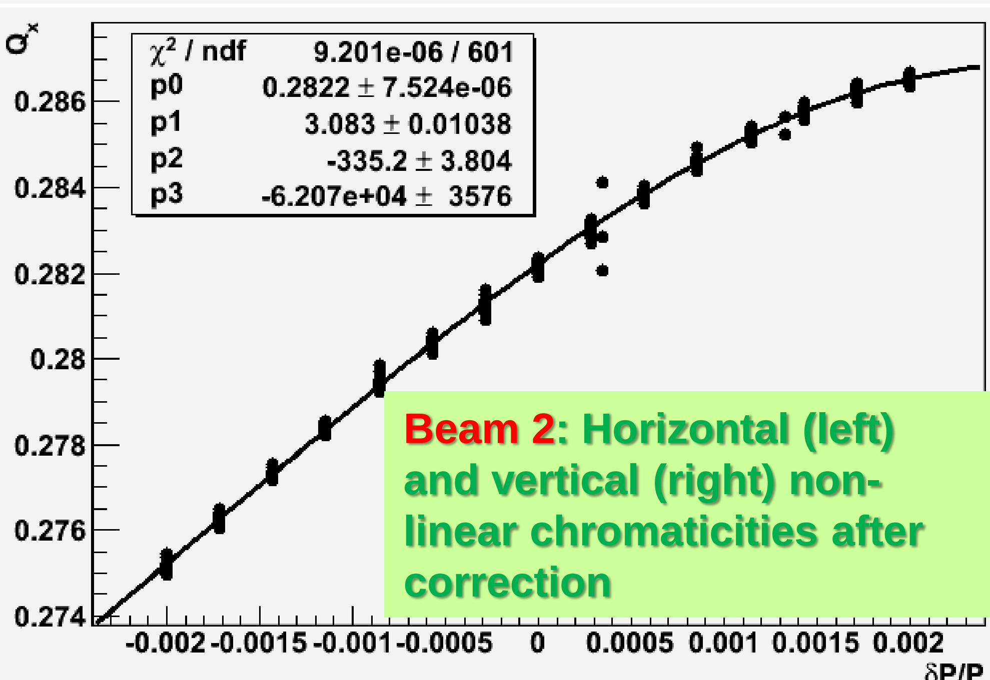
Non-linear MD: Chromaticity before and after Correction

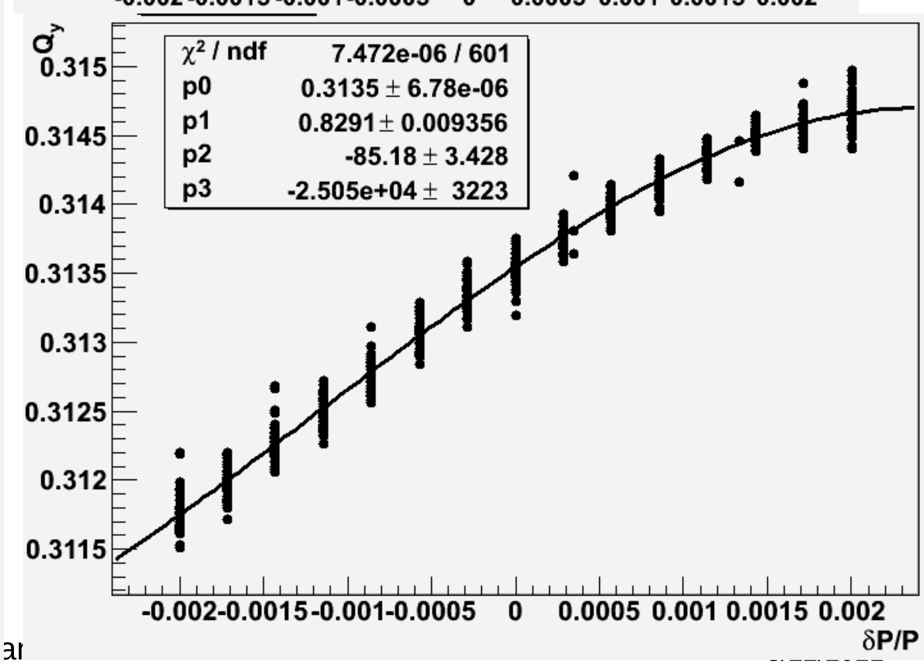
Beam 2: Horizontal (left) and vertical (right) non-linear chromaticities





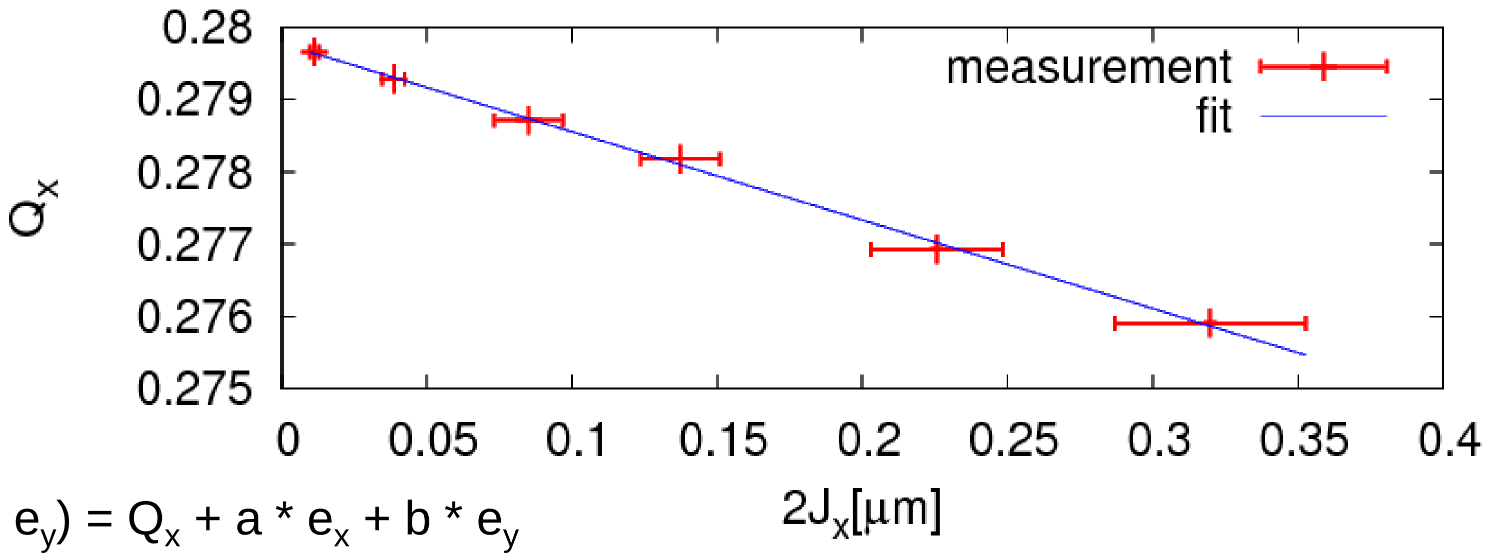
Beam 2: Horizontal (left) and vertical (right) non-linear chromaticities after correction



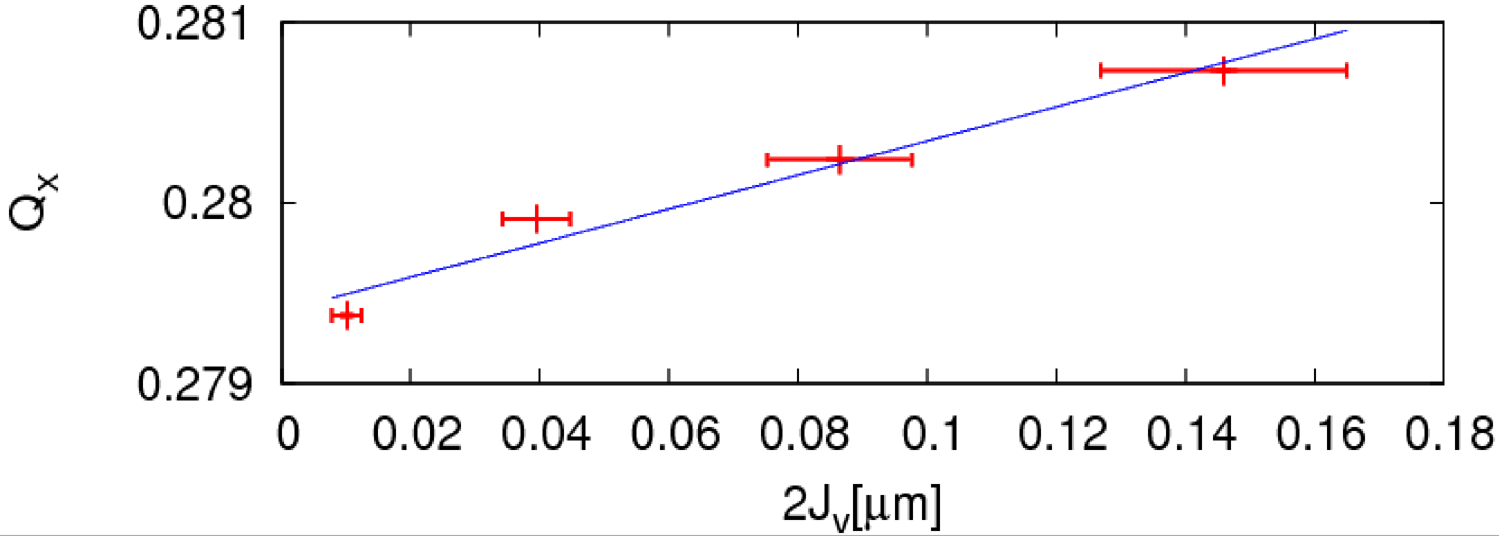


M. Giovannozzi, F. Schmidt et al

Non-linear MD: Detuning with amplitude including crossterm



$Q_x(e_x, e_y) = Q_x + a * e_x + b * e_y$



Collimation MD *G. Valentino et al*

- New alignment of collimators in IR3 for b1 and b2.
  - Centers of collimators within 100 μm from previous values, but for TCSG.5L3.B1 (230 μm difference) ➔ Excellent news!
- In parallel, tested new automatic collimation setup.
- Setup combined H betatron cleaning in IR3 for B2:
  - IR3 collimators moved to 5.7 (TCP),6.7 (TCSG),10 sigma (TCLA).
  - IR7 H and skew opened. IR7 V collimators left at relaxed settings.
- Test of system with B2 horizontal loss map
  - Note that also TCTV in IR1 and IR8 were above dump thresholds (cleaning inefficiency ~ 1to 2%).
  - Cleaning inefficiency downstream IR3 (cold regions) 5e-4
  - To be compared with simulations.

Collimator Settings B2: H Cleaning in IR3

LHC Collimators | Beam: B2 | Set: HW Group:LHC COLLIMATORS

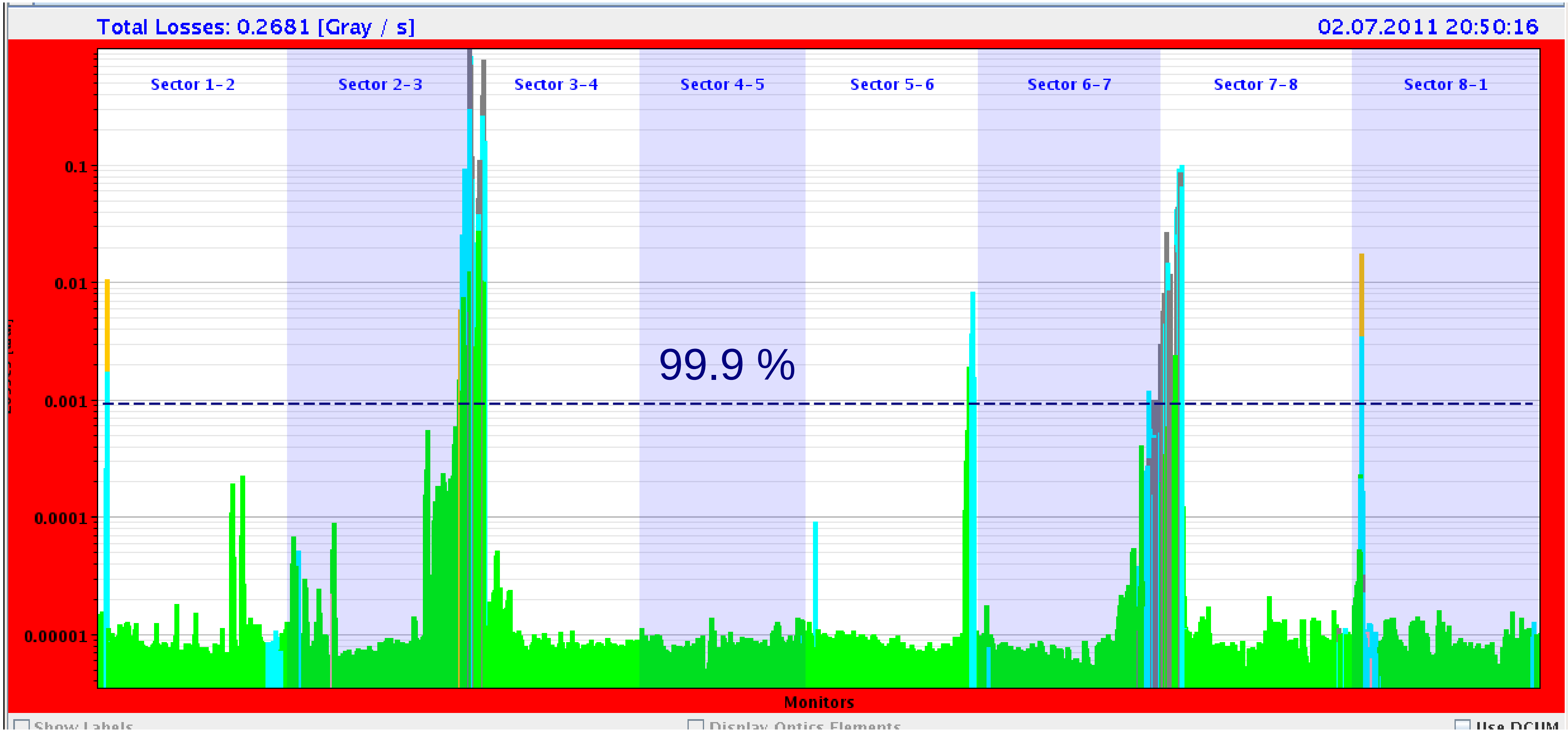
LHC Collimators | Beam: B2 | Set: HW Group:LHC COLLIMATORS 02-07-2011 20:38:30

L(mm) MDC		PRS R(mm)
	IP1	
8.2	TCTVA.4R1.B2	-6.02
9.26	TCTH.4R1.B2	-10.92
25.32	TCL.5L1.B2	-24.67
	IP2	
3.72	TCTVB.4R2	-7.77
4.84	TCTH.4R2.B2	-6.1
	IP3	
2.38	TCLA.7L3.B2	-2.66
2.89	TCLA.6L3.B2	-4.03
2.3	TCLA.B5L3.B2	-5.22
4.34	TCLA.A5L3.B2	-3.78
1	TCSG.B5L3.B2	-2.01
0.72	TCSG.A5L3.B2	-1.97
0.62	TCSG.4L3.B2	-1.42
1.32	TCSG.5R3.B2	-1.66
2.38	TCP.6R3.B2	-1.6
	IP5	
24.56	TCL.5L5.B2	-25.44
7.38	TCTVA.4R5.B2	-6.9

10.32	TCTH.4R5.B2	-9.88
	IP6	
6.44	TCSG.4L6.B2	-6.63
7.23	TCDQA.A4L6.B2	
	IP7	
6.66	TCLA.A7L7.B2	-5.53
6.11	TCLA.D6L7.B2	-5.72
7.4	TCLA.C6L7.B2	-5.94
9.36	TCLA.B6L7.B2	-9.19
4.01	TCLA.A6L7.B2	-3.55
11.97	TCSG.6L7.B2	-11.61
9.01	TCSG.E5L7.B2	-8.25
8.46	TCSG.D5L7.B2	-8.8
9.42	TCSG.B5L7.B2	-7.69
6.72	TCSG.A4L7.B2	-8.18
7.07	TCSG.A4R7.B2	-7.96
7.13	TCSG.B4R7.B2	-8.69
1.86	TCSG.D4R7.B2	-2.44
9	TCSG.A5R7.B2	-7.72

8.6	TCSG.B5R7.B2	-7.78
6.69	TCSG.A6R7.B2	-7.01
5.07	TCP.B6R7.B2	-6.34
6.48	TCP.C6R7.B2	-7.01
2.2	TCP.D6R7.B2	-0.87
	IP8	
24.92	TCLIB.6L8.B2	-24.98
25.01	TCLIA.4L8	-25.01
6.29	TCTVB.4R8	-5.24
20.05	TDI.4R8	-20.04
0.7	TCTH.4R8.B2	-10.25
	TI8	
1.08	TCDIH.87441	-2.05
6.53	TCDIV.87645	0.24
6.03	TCDIV.87804	1.89
1.55	TCDIH.87904	-2.17
2.64	TCDIH.88121	-3.74
7.31	TCDIV.88123	-3.8

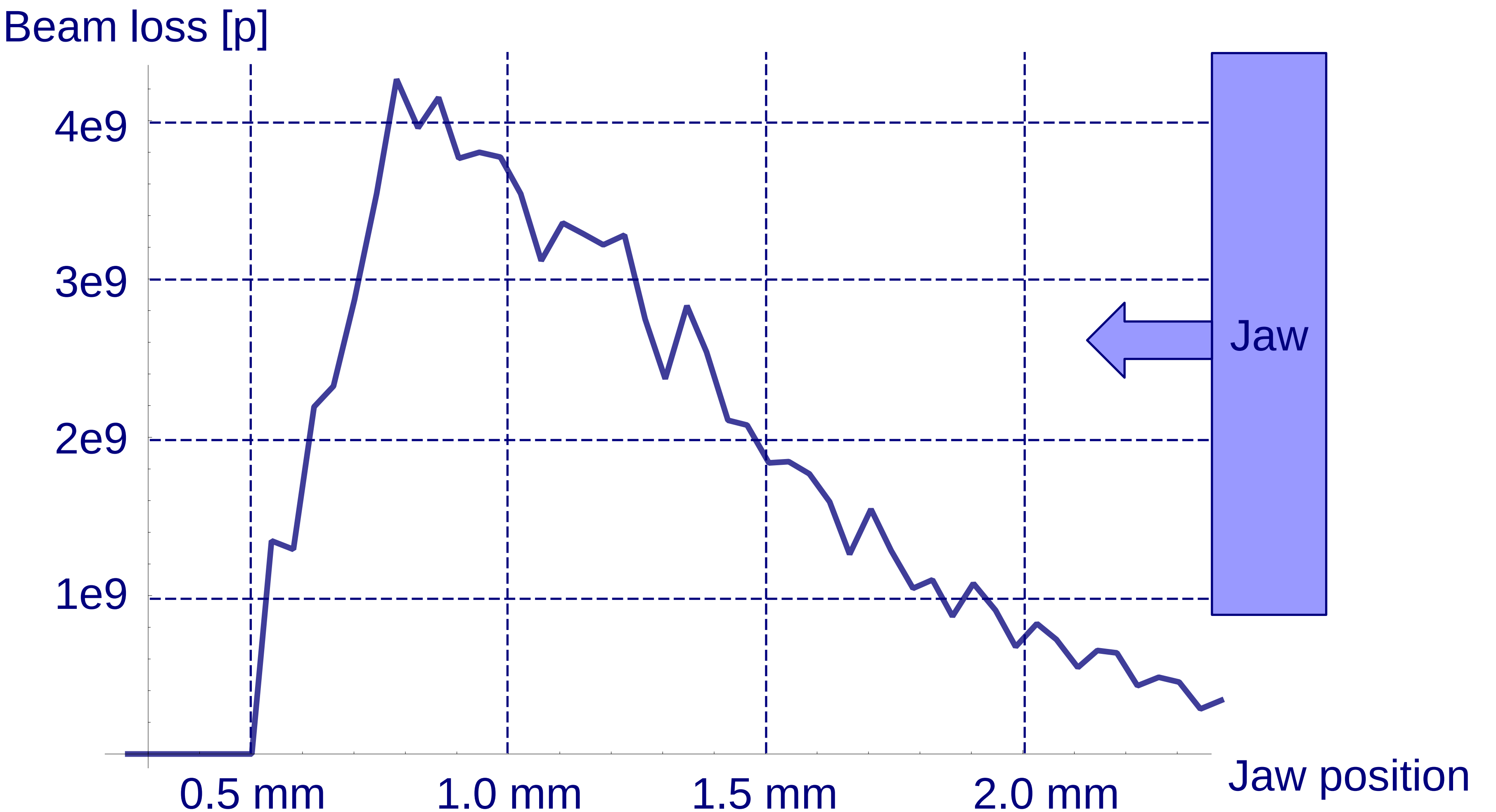
Loss Map Combined H Betatron Cleaning



R. Assmann

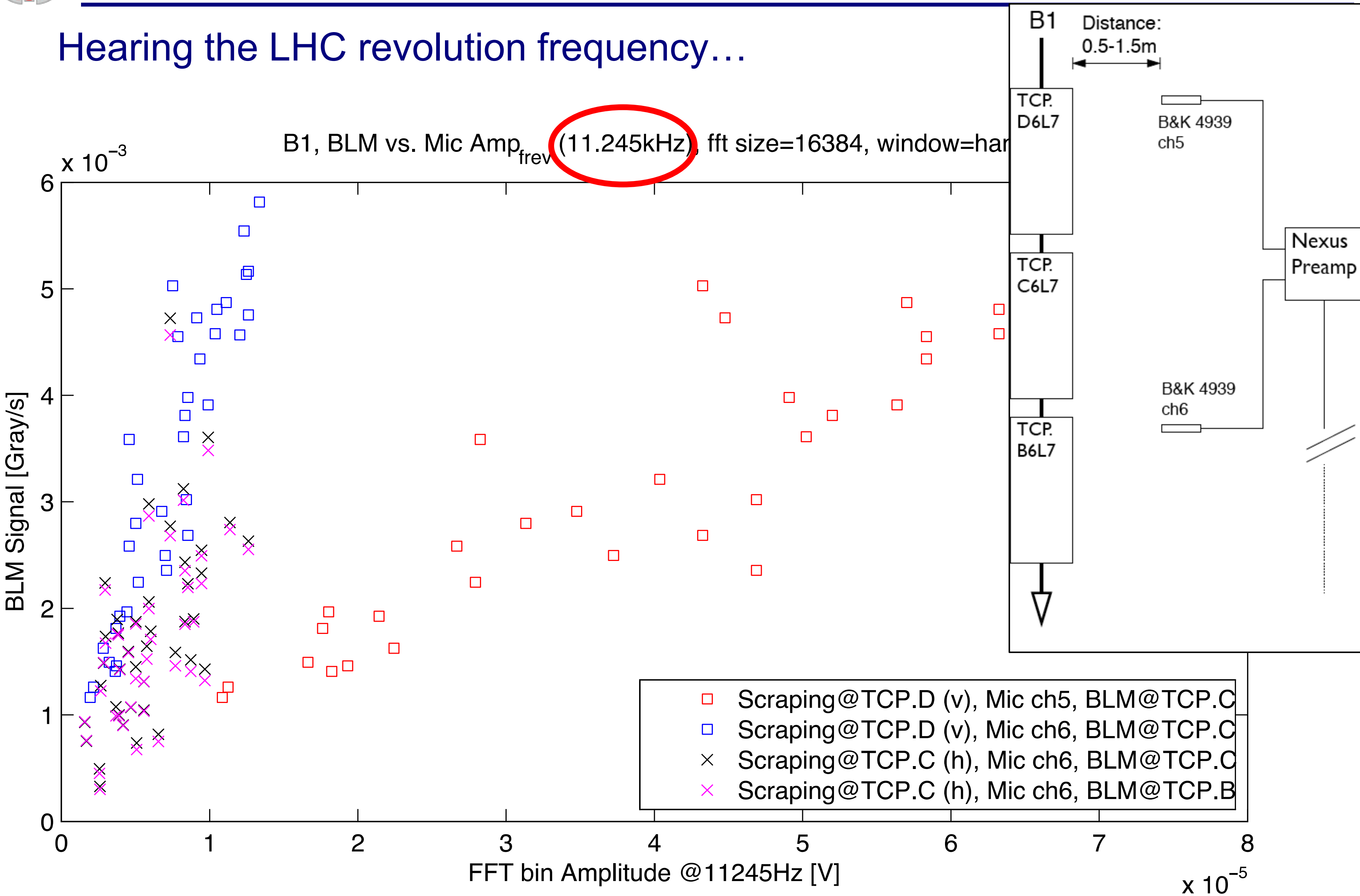
Transverse Beam Distribution *F. Burkart et al*

450 GeV: H, V, skew scraping to determine 2D bunch distribution



Scraping: Sound at Microphone *D. Deboy et al*

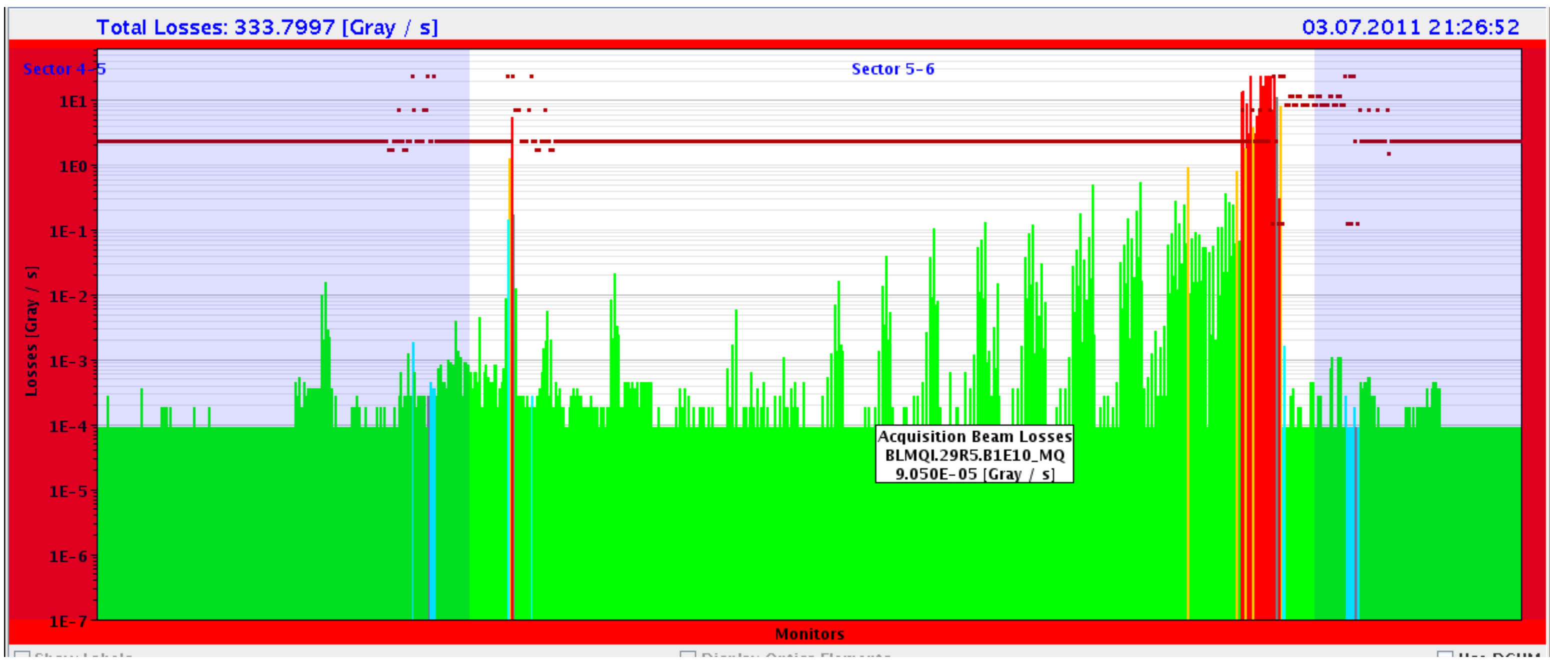
Hearing the LHC revolution frequency…



Quench Margin at Injection C. Bracco et al

No quench, even with 2e10 p per bunch
10 times above BLM threshold
To be analyzed

```
22:03:36 - Warning on: BLMQI.06L8.B1E20_MQML, integration time: 40 us, losses = 6.800170E-01, threshold = 1.745383E00, ratio = 39%
22:03:36 - Warning on: BLMQI.06L8.B1E20_MQML, integration time: 80 us, losses = 5.887478E-01, threshold = 1.527233E00, ratio = 39%
22:03:36 - Alarm on: BLMQI.06L8.B2I10_MQML, integration time: 40 us, losses = 2.360168E01, threshold = 2.316800E00, ratio = 1019%
22:03:36 - Alarm on: BLMQI.06L8.B2I10_MQML, integration time: 80 us, losses = 1.778379E01, threshold = 2.316800E00, ratio = 768%
22:03:36 - Alarm on: BLMQI.06L8.B2I10_MQML, integration time: 320 us, losses = 6.307431E00, threshold = 2.316800E00, ratio = 272%
22:03:36 - Alarm on: BLMQI.06L8.B2I10_MQML, integration time: 640 us, losses = 3.162166E00, threshold = 2.316800E00, ratio = 136%
22:03:36 - Warning on: BLMQI.06L8.B2I10_MQML, integration time: 2560 us, losses = 7.939452E-01, threshold = 1.066401E00, ratio = 74%
22:03:36 - Warning on: BLMQI.06L8.B2I10_MQML, integration time: 10 ms, losses = 1.989893E-01, threshold = 2.666003E-01, ratio = 75%
```



R2E M. Brugger et al

- Data collected for better predictions of radiation to electronics effects.