



Machine Development

6th Evian Workshop, 15 – 17 December 2015

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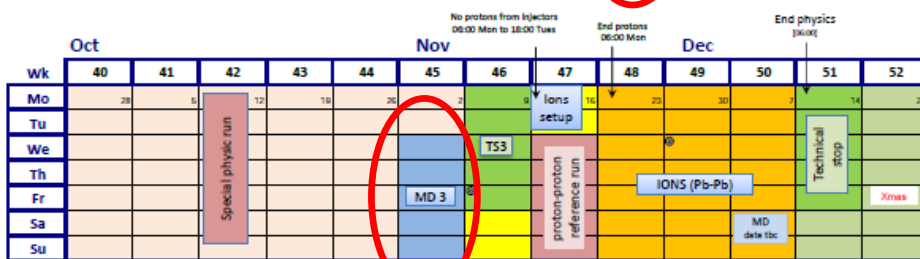
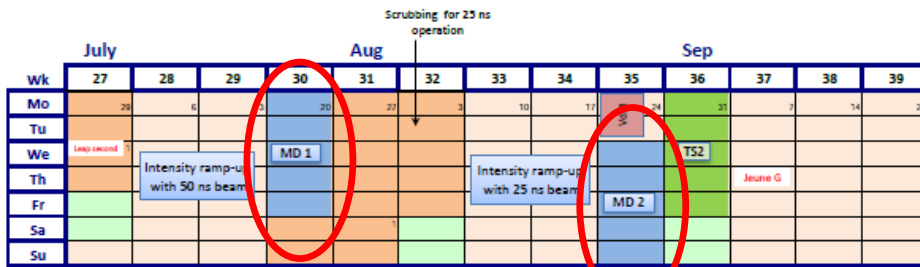
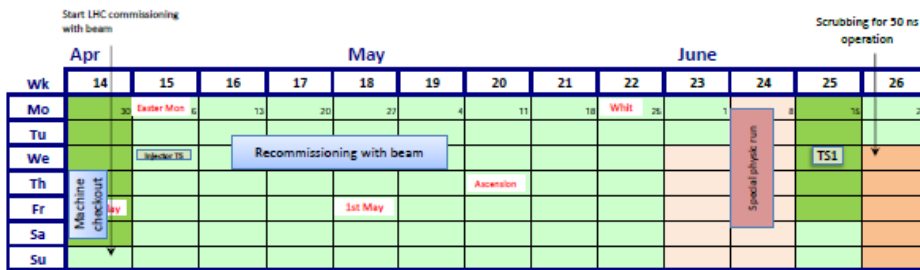
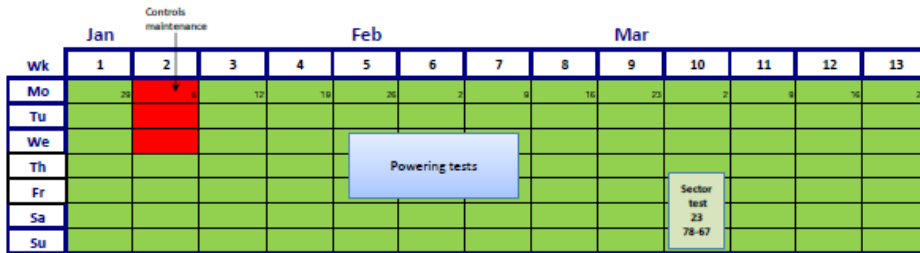
*Thanks to all MD participants,
equipment groups support and OP*

Outline

- 2015 MDs in Numbers and Methods
- End of Fill MDs, Floating MDs, Ion MDs: a Balancing Act
- Some Highlights
- 2016 and Beyond
- Lessons Learned
- Conclusions

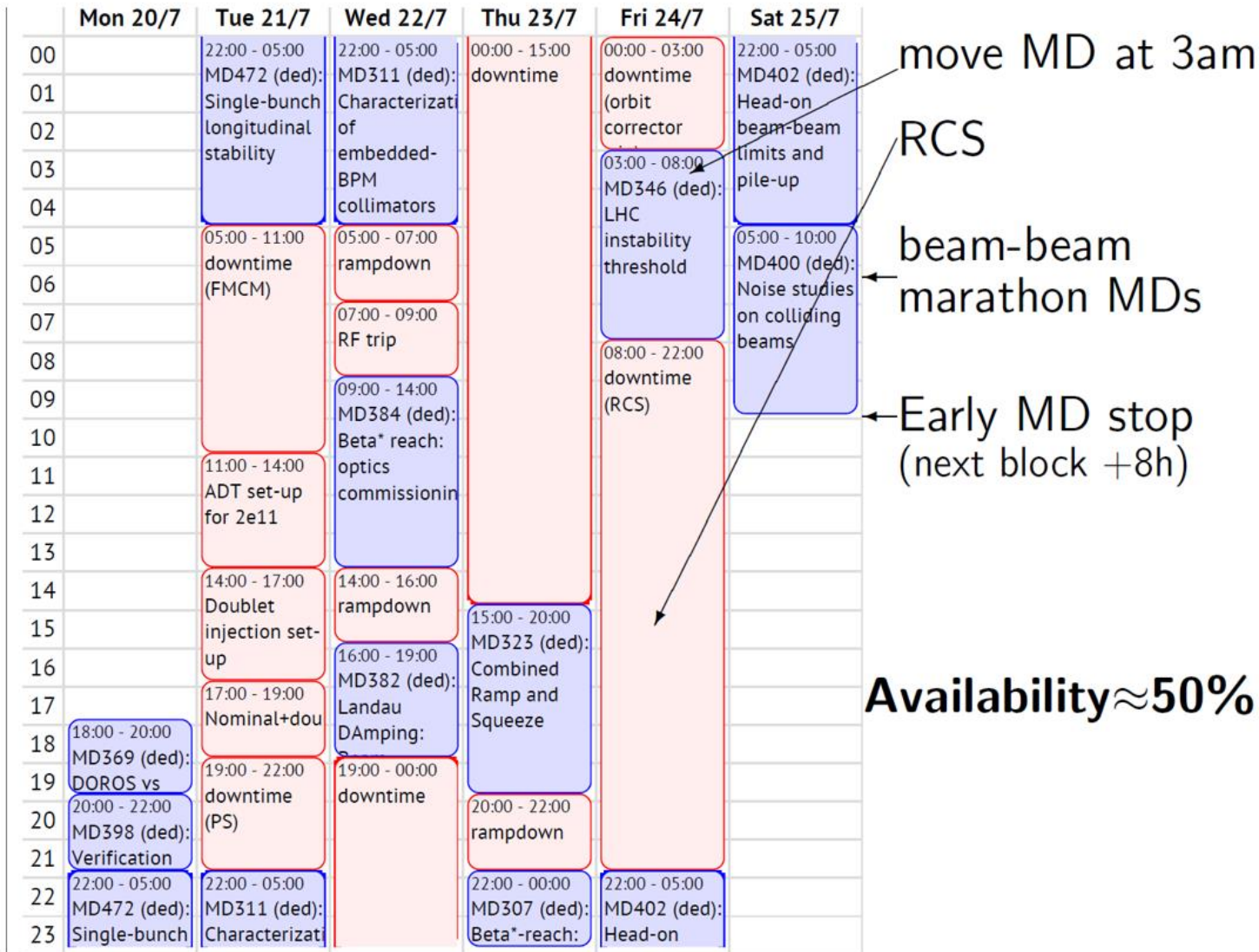


MDs in 2015



- 3 MD blocks of 5 days
 - 4 days lost relative to initial 2015 schedule
- But also
 - 3 x deadline for MD submission
 - 3 x LSWG meetings to prepare
 - 3 x LMC meetings for approval
 - 3 x deadline for procedures
 - 3 x rMPP meetings
 - 5 x LSWG meetings for first results
- But not always written up as MD-note ...

MD Block 1: Argggghhh



MD Block 2: Yes !

Wed 26/8	Thu 27/8	Fri 28/8	Sat 29/8	Sun 30/8	Mon 31/8
23:00 - 07:00 postponed to floating MD	17:00 - MD365	00:00 - 02:00 Rampdown and recovery	22:00 - 02:00 MD750 (ded): Towards	17:00 - 04:00 MD239 (ded): Collide and squeeze / b* leveling	21:00 - MD380
	01:00 - 03:00 Recovery	02:00 - 10:00 MD310 (ded): Beta*-reach: Collimation with tighter TCTs	02:00 - 06:00 MD349 (ded): Impedance Localization with AC- dipole		01:00 - 03:00 RQX trip
	03:00 - 06:00 MD377 (ded): Schottky pick-up			04:00 - 06:00 Ramp down and recovery	03:00 - 06:00 MD380 (ded): NONLINEAR ERRORS IN THE LHC
	06:00 - 10:00 MD 307 aborted due to dump		06:00 - 06:00 - MD314 MD751 (ded): (ded): Beta*- Instab reach: thresh IR7 and collim: tune hierarch: shift limit study and with imped: reduce retract	06:00 - 06:00 - MD312 MD333 (ded): (ded): Active Crystal halo collim: contro	06:00 - Prepare
07:00 - 13:00 downtime due to water problem	10:00 - RF trip	10:00 - 12:00 Ramp down and recovery			
	11:00 - 16:00 MD307 (ded): Beta*-reach: IR aperture measurement at small beta	12:00 - 20:00 MD751 (ded): Train Instability Threshold	14:00 - Ramp d		
13:00 - 16:00 MD475 (ded): Calibration of the BSRT			15:00 - 17:00 Cryo problem		
16:00 - Ramp d	16:00 - Ramp d				
17:00 - 01:00 MD365 (ded): Optimum RF parameters at 6.5 TeV	17:00 - 00:00 MD373 (ded): Shaping of longitudinal bunch profile with RF noise and modulation	20:00 - 22:00 Ramp down and recovery	17:00 - 04:00 MD239 (ded): Collide and squeeze / b* leveling	19:00 - 21:00 Ramp down and recover	
		22:00 - 02:00 MD750 (ded): Towards		21:00 - 01:00 MD380 (ded): NONLINEAR ERRORS IN THE LHC	

292/456 moved to
floating MD

long-range MD
385 moved to
intensity ramp-up

Availability=88%!

100 % of the MDs took place !

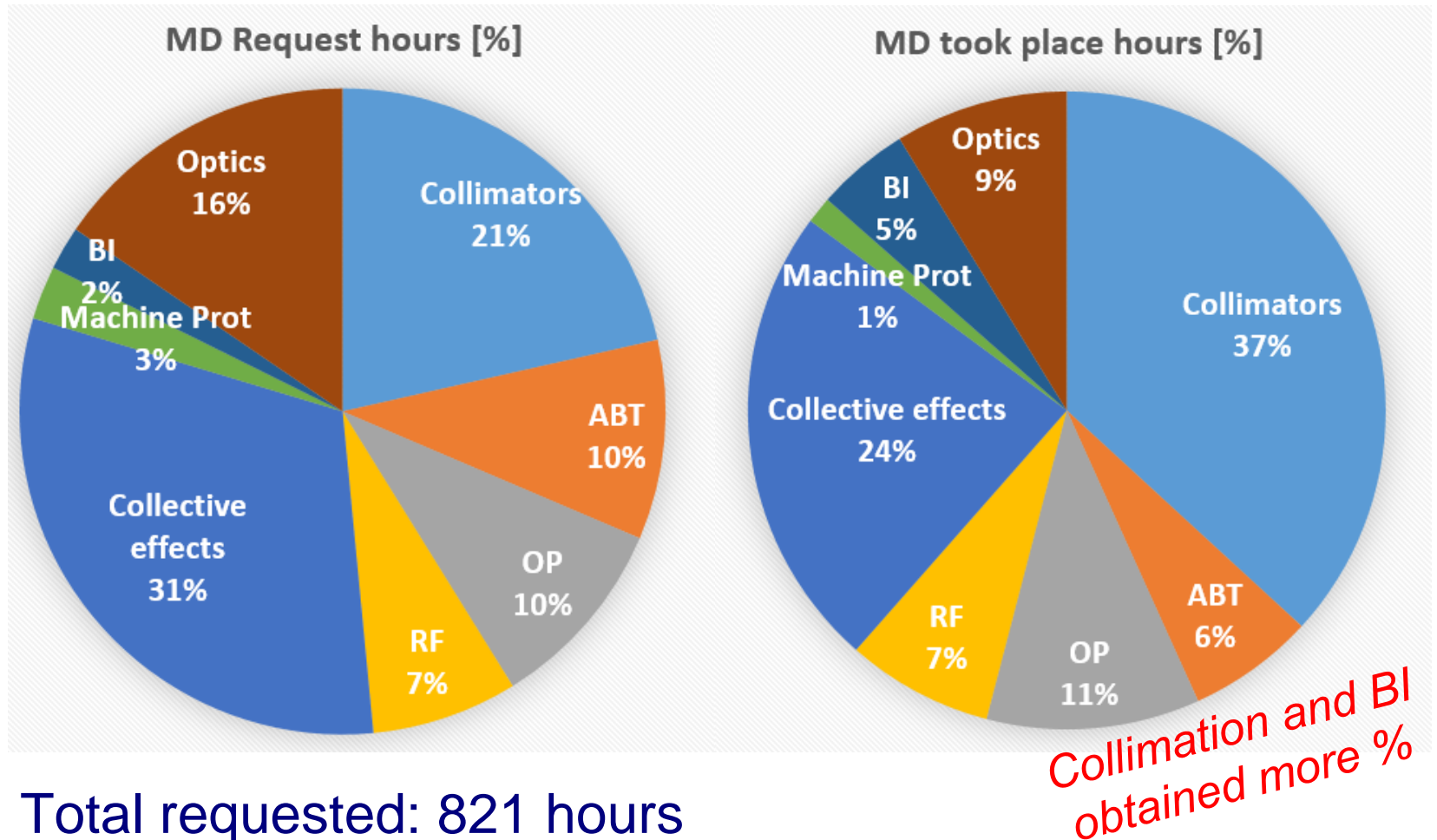
MD Block 3: Average availability but some operational problems



≈ 75 % availability

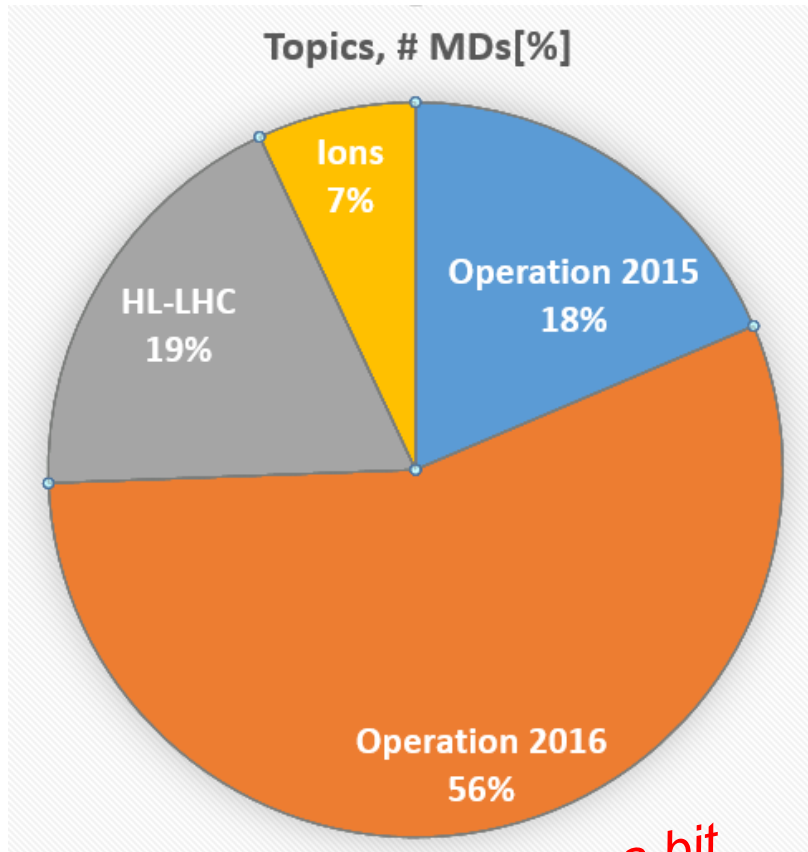
TS3

Hours Requested and Obtained



- Total requested: 821 hours
- Total took place: 296 hours (incl. ions 25 h)
 - This gives overall efficiency around 90 % (2 x 2 ramps/day between MDs accounted for), coherent with previous numbers

Distribution concerning Focus of MD



Classification can be a bit arbitrary ...

- 18 % related to direct operation 2015. Ideally should be less
 - Beam Instrumentation
 - Collimation
- Most of it concerning operation 2016 **and beyond**
 - $\beta^* = 40$ cm related
 - Instabilities, impedance
 - Beam Instrumentation
- Some longer time line, HL-LHC
 - Many related to collimation
 - Quenches
 - Vibrations
- Ions are put separately

More Numbers

- **92** MDs requested
- **50** MDs scheduled
- **43** MDs took place
- **9** MD notes CERN-ACC-NOTE-2015-XXXX
 - Thanks to those who wrote them !
 - The MD-note should not be a final write-up but a record of what took place and a *first* analysis of data
 - Extension “–MD” in reference not possible anymore for some reason.... Difficult to track. Should be better next year ...
 - Rule is to write them in the two months following the MD
 - Final deadline for 2015 is 18th January, extended by 1 week (18th February for ion MDs)
 - *Priority for 2016 MDs will be given to those who write their MD notes !*

A Balancing Act

■ Machine Set-Up

- All MDs which are used for 2015 operation should in principle be part of normal machine time
- Still almost 20 % of MDs for direct 2015 use...
- Typical example is BSRT calibration

■ End-of-Fill MD

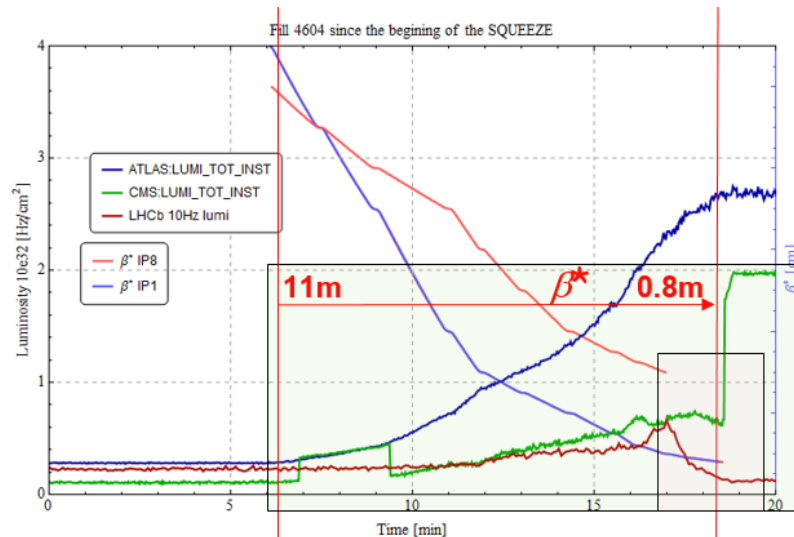
- Very often more time efficient than MD when it needs high intensity beams and Physics conditions
- Typical example: RF stability

■ Floating MD

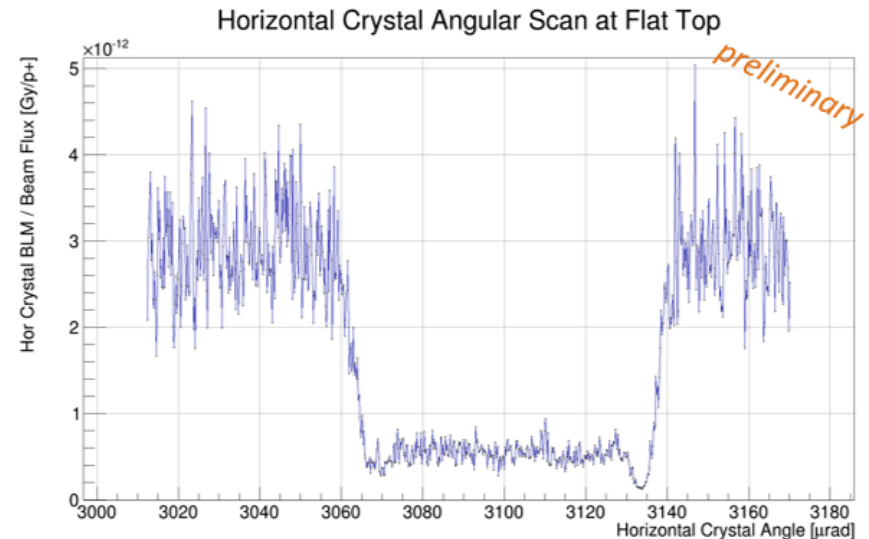
- Can be very time efficient from MD point of view; availability of experts, time for preparation
- However, was again hard to schedule in 2015
- Is it more disruptive for physics (Machine vs. MD coordinator)?

Some MD 2015 Highlights I/II

- $\beta^* = 40$ cm fully probed and ready for operation in 2016
- Ramp and squeezed commissioned and already used for the 2.51 TeV run
- β^* leveling and collide & squeeze fully demonstrated
- Crystal channeling observed at 6.5 TeV
- We quench with ions and more difficultly with protons



No pauses during collide and squeeze

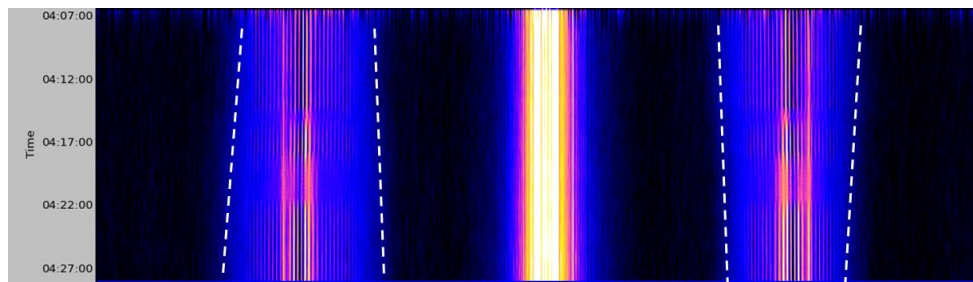


Strategy for next scans: use a nominal bunch and/or increase ADT window

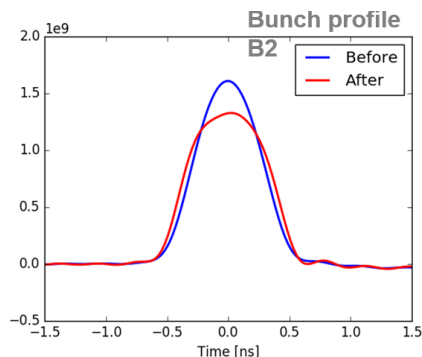
First time Crystal channeling at 6.5 TeV

More MD 2015 Highlights II/II

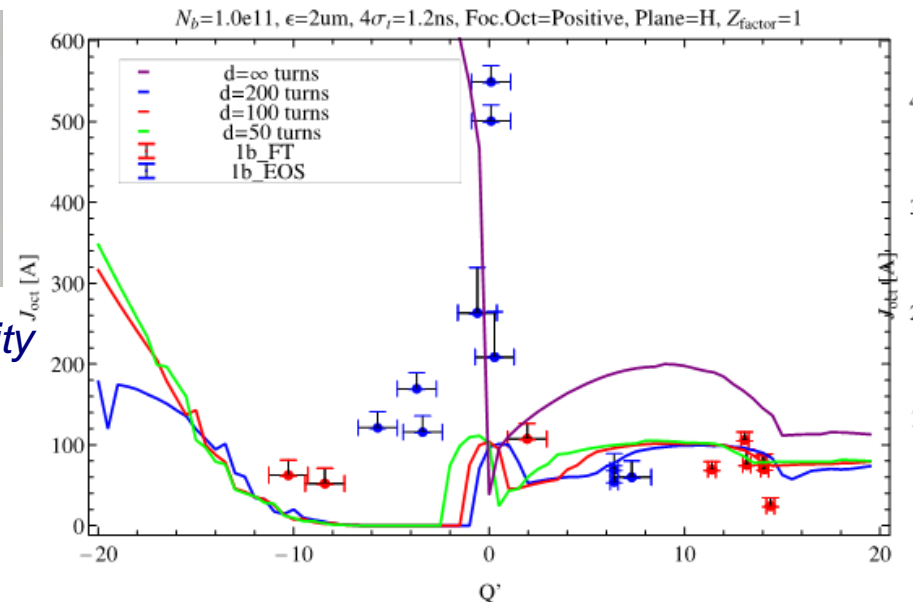
- Longitudinal bunch flattening developed and operational
- New or developed instrumentation: DOROS, BTF, ICT/WCT, Schottky, BSRT, Diamond detectors (inj. losses !)
- Achieved beam-beam tuneshifts of 0.04
- Instability threshold tracked during 2015 and observed to improve with scrubbing



Width of Schottky sidebands varies with chromaticity



Shaping of longitudinal bunch profile



Single Bunch Instability Thresholds

MDs in 2016 and Beyond

- 2016 LHC programme (prel.)
- 2015: $3 \times 5 = 15$ days + ions
- 2016: $4 \times 5 + 2 = 22$ days + ions
- Special LSWG on 18th January @ 14:00

□ <https://indico.cern.ch/event/464617/>

□ Report and more details at the Chamonix workshop; presentation by Rogelio

Trigger the right MD requests that will make a difference in LHC, HL-LHC and future colliders and establish approximate MD priorities for 2016

ML

LHC Schedule 2016

Approved by the Research Board, December 2015

December 12, 2015
V1.0

	Jan					Feb					Mar				
Wk	1	2	3	4	5	6	7	8	9	10	11	12	13		
Mo															
Tu															
We															
Th															
Fr															
Sa															
Su															

	Apr					May					June				
Wk	14	15	16	17	18	19	20	21	22	23	24	25	26		
Mo															
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	July					Aug					Sep				
Wk	27	28	29	30	31	32	33	34	35	36	37	38	39		
Mo															
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	Oct					Nov					Dec				
Wk	40	41	42	43	44	45	46	47	48	49	50	51	52		
Mo															
Tu															
We															
Th															
Fr															
Sa															
Su															

MDs 2016 and Beyond

Anticipating the LSWG of 28/1/2016

- Looking for really new ideas
 - ATS optics
 - Expect recurrent MDs throughout the year
 - Crystals will be back – higher intensities? rMPP...
 - Collimation with one jaw only to reduce impedance
 - Trains of 80 bunches from the PS
 - Flat optics
 - Beta-beating correction on colliding beams...
 - Try in operation for real with larger beam intensities
 - FCC study of snapback effects for very low magnetic fields: injection at 225 GeV / deceleration of beam

MDs 2016 and Beyond

Continuation of existing MD paths

- Optics
 - Future minimum beta*
 - Crossing / separation beam-beam depending on beta*
- Collimation: biggest block in 2015, related to some of the above
- Collective effects
 - Will try to continue to improve understanding. BCMS beams.
 - In 2015 didn't limit performance, but a better understanding might be required in the future when pushing beta* and intensity
- Impedance
- RF instabilities
- More quench tests, did not quench the last proton quench test
- Beam instrumentation: remains important
- ABT: injection losses, optimisation, 288 bunches, diamonds and sunglasses, kicker waveforms

What should **NOT** be MD in 2016

- Ramp & Squeeze, β^* levelling
 - Now operational, R&S to be used, β^* levelling not required yet ...
- RF bunch lengthening
 - Important for impedance, HL-LHC
 - Run longer periods with increased bunch lengths to check effect on heating and luminosity
 - Will need to be done outside MD period
- Large beta* of 2.5 km for TOTEM & ALFA in 2016
 - To be used for special runs in 2016
 - Very limited aperture...
- BSRT calibration
- Scrubbing and scrubbing checks

Ion MDs

- Performed three MDs during 2015 ion run period
 - For 2016, should we be more formal assigning total available time?
 - Did not really manage to get procedures at the same time as the MD3 block and were finally quite late for rMPP approval of quench MDs
- Ion MDs – 2016 → *no time yet on 2016 schedule*
 - Crystal collimation at top energy
 - Collimation quench tests
 - Proton – lead performance limits, effects of unequal emittances, separation and filling scheme at injection and/or in collision
 - Strategies to minimise losses in operation: larger BFPP bumps, IR7 bumps, TCP jaw movements

MD 2015 Post Mortem I/II

Thanks to G.Domeni
Calgeer, J.Coello de
Portugal and E.Matli

- MD Webpage is great: <https://md-coord.web.cern.ch/>
 - Elaborated from the Injector MDs
 - For submitting the MD requests
 - For making and communicating the MD schedule
- Procedures give final details, not updated 'backwards' to the MD Webpage which can lead to some OP confusion
 - The detailed procedures are useful for rMPP, OP and to make the MD more efficient
- OP contact person was probably taken more seriously for the first two MD blocks
 - Help with making the procedures and check certain things in the machine
 - There is potential to improve, depends on personal initiative of people performing the MD. Give more attention during LSWG meetings?
- A lot of pressure on some teams during the MD period
 - ADT, Collimation support for other MDs
 - Did collimation have too many MDs?



MD 2015 Post Mortem II/II

- Some equipment checks before the actual MD could be beneficial. Example of problems during the last MD block
 - Problems with the luminosity provided by detectors
 - Beams injected in different RF buckets, supercycle problem
 - Forgotten ADT switch
 - Change of the collimator sequence for flat machine
 - Wire scanner intensity interlock
 - ...
- The rMPP approval works
 - **No damage to the machine**
 - DFS for all 50+ MD procedures, then EDMS for 17 MDs for rMPP approval
 - Time between procedure submission – rMPP classification – rMPP meeting and possible changes to be made can be tight in time
 - Will be even more difficult in 2016, as there will be more MDs
- Default will be to not re-schedule MDs according to machine availability
 - No MD priority list once on the schedule
 - Had to deviate from this in the first MD block

Conclusions

- Machine Development 2015 was 'full' and hard work by many teams
- Many very good and interesting results
 - See many presentations at this workshop
 - Some of them already used in 2015 operation, some crucial for 2016 ($\beta^* = 40$ cm) and others HL-LHC related
- Good preparation is half the work
 - Many teams involved, role of OP contact
 - Will be very tight schedule for 2016 MDs
 - Demand for MD time is expected to remain high
- Participate in the LSWG day 18/1/2016 to prepare for even more successful MDs in 2016