



Machine Development

7th Evian Workshop, 13 – 15 December 2016

J. Uythoven, R. Tomas, G. Papotti

Thanks to all MD participants, equipment groups support, @MPP and OP

Machine Development

- 2016
 - Organisation, Highlights & Statistics
 - Lessons & Machine Protection
 - End of Fill MDs
- 2017
 - First inventory of request
 - Does it fit the schedule?
- Conclusions

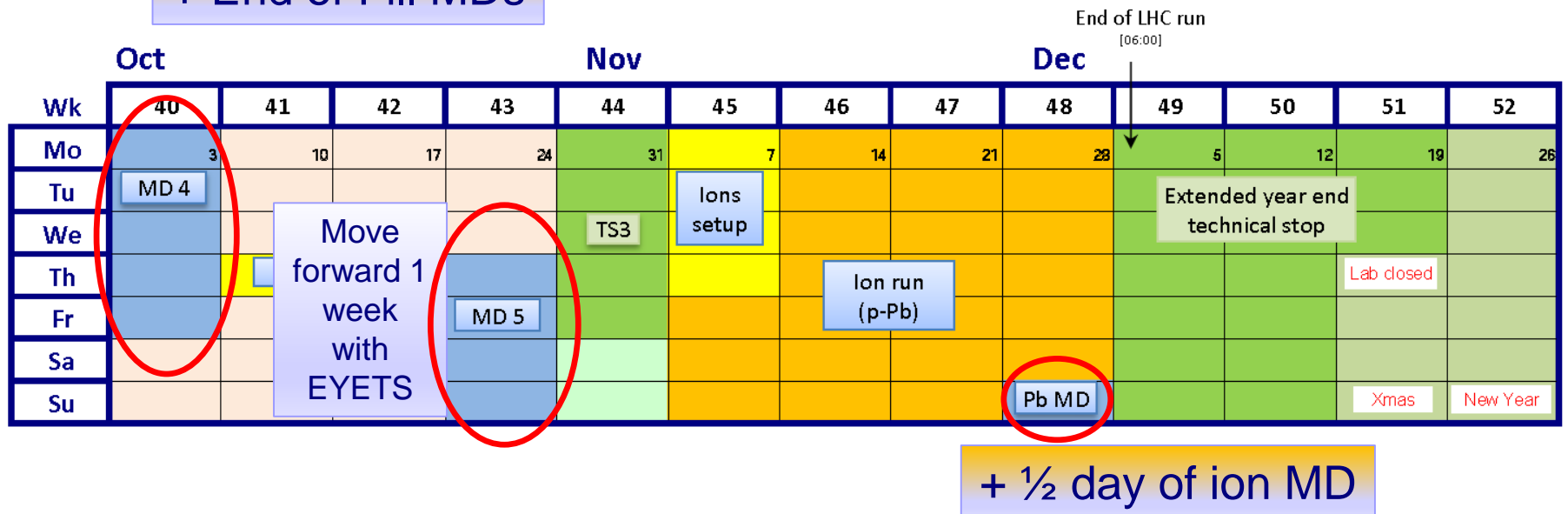
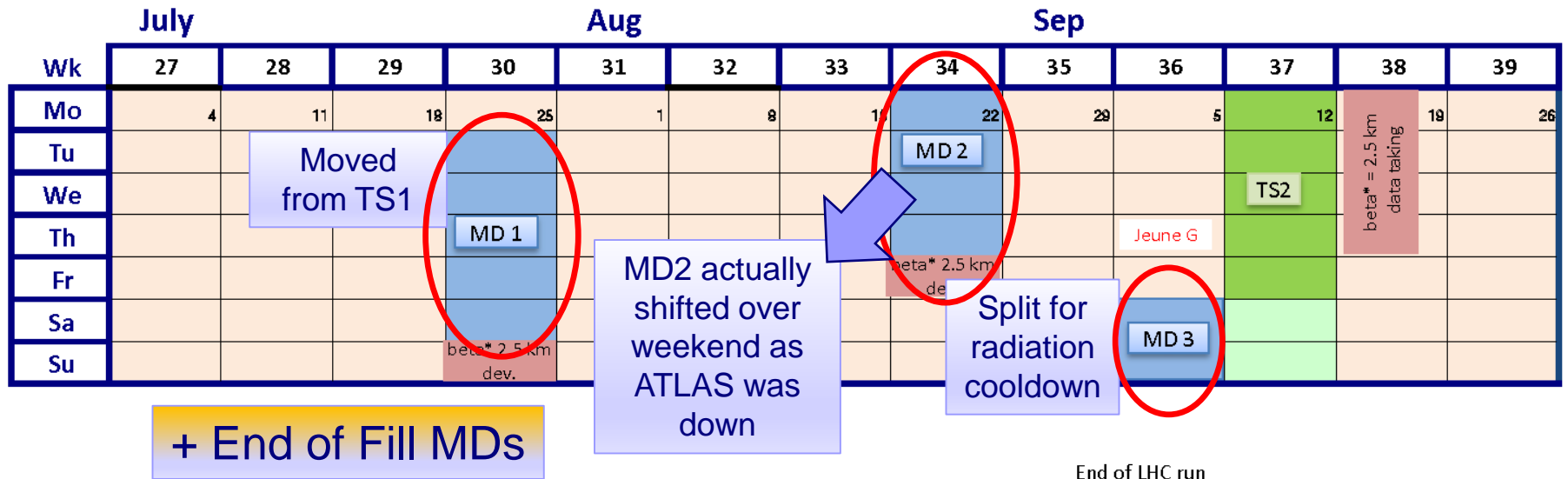
MDs in 2016 – The Plan

4 Blocks, *22 days*, evenly spread



MDs in 2016: What Happened

20 days in 5 blocks over 14 weeks



Example of MD5 juggling

Thu 27/10	Fri 28/10	Sat 29/10	Sun 30/10	Mon 31/10	Thu 27/10	Fri 28/10	Sat 29/10	Sun 30/10	Mon 31/10
00:00 - 07:00 MD1434 (ded): Head on beam-beam limit separation levelling and pile-up	17:00 - MD1878 (ded): Operat	20:00 - 04:00 MD652 (ded): Coupled bunch stability with smaller emittance (all HOM)	22:00 - 06:00 MD979 (ded): Beta-beating correction on colliding beams	00:00 - 06:00 MD1850 (ded): Linear couplings dependence on intensity and a next step towards a feedback	00:00 - 03:00 RF problems etc.	17:00 - MD1878 (ded): Operat	22:00 - ATLAS	21:00 - 04:00 MD979 (ded): Beta-beating correction on colliding beams	00:00 - 06:00 MD1850 (ded): Linear couplings dependence on intensity and a next step towards a feedback
	01:00 - 03:00 ramp down					01:00 - 03:00 ramp down			
	03:00 - 08:00 MD1826 (ded): Measurement of Quench Heater vertical kick	04:00 - 06:00 ramp down			03:00 - 07:00 MD1434 (ded): Head on beam-beam limit separation levelling and pile-up	03:00 - 08:00 MD1826 (ded): Measurement of Quench Heater vertical kick		04:00 - 06:00 MD1787 (ded): Rise time versus chroma and	
		06:00 - 10:00 MD1787 (ded): Rise time versus chroma and damper settings at injection energy	06:00 - 12:00 MD1900 (ded): Measuring the beam halo population via SR	06:00 - 08:00 MD1388 (ded)=			05:00 - ramp down	06:00 - 13:00 MD1900 (ded): Measuring the beam halo population via SR	06:00 - 08:00 MD1388 (ded)=
07:00 - 09:00 ramp down	08:00 - recovery			06:00 - preparation for access	07:00 - 09:00 ramp down	08:00 - recovery	06:00 - Linac and cryo Linac	06:00 - 13:00 MD1900 (ded): Measuring the beam halo population via SR	06:00 - 08:00 MD1388 (ded)=
		10:00 - 20:00 MD1257 (ded): ATS	12:00 - 22:00 MD1879 (ded): Crystal Channeling in Dynamic Operational Phases		09:00 - 15:00 MD1814 (ded): Calibration of all transverse beam profile monitors: WS, BSRT, BGV, LHCb beam gas vertex reconstruction, ...	09:00 - 15:00 MD1266 (ded): Injection of "high performance reach" 80b 25 ns beam		13:00 - 22:00 MD1879 (ded): Crystal Channeling in Dynamic Operational Phases	
09:00 - 15:00 MD1814 (ded): Calibration of all transverse beam profile monitors: WS, BSRT, BGV, LHCb beam gas vertex reconstruction, ...	09:00 - 15:00 MD1266 (ded): Injection of "high performance reach" 80b 25 ns beam						10:00 - 20:00 MD1257 (ded): ATS		
15:00 - 17:00 ramp down	15:00 - 20:00 MD1405 (ded): Short term dynamic aperture with the AC-dipole and resonance driving terms				15:00 - 17:00 ramp down	15:00 - 19:00 MD1405 (ded): Short term dynamic aperture with the AC-dipole and resonance driving terms			
		20:00 - 22:00 ramp down			17:00 - 01:00 MD1878 (ded): Operation with primary collimators at tighter settings	19:00 - 21:00 access for ROS			
17:00 - 01:00 MD1878 (ded): Operation with primary collimators at tighter settings	20:00 - 04:00 MD652 (ded): Coupled-bunch stability with smaller emittance (all HOM)	22:00 - 06:00 MD979 (ded): Beta-beating correction on colliding beams	22:00 - 00:00 ramp down			21:00 - ROS trip again	20:00 - ramp down	22:00 - 00:00 ramp down	
						22:00 - 01:00 ATLAS	21:00 - 04:00 MD979 (ded): Beta-beating correction on colliding beams		

Motivated physicist using the change to wintertime to recuperate some MD time

Organisation

An 11-Step Approach for each MD block

1. MD requests submitted at <https://md-coord.web.cern.ch>
2. Selection made by MD coordination, presentation of MDs at the LSWG
 1. Small fraction of MDs rejected
 2. First feedback on MDs, modifications
3. Approval of topics in the LMC
4. Written procedures submitted → *to be done at least 2 wks before MD*
5. Beam requests to the injectors (FOM) → *to be done at least 2 wks before MD*
6. Procedures reviewed by @MPP, Class C presented at rMPP meeting and for approval in EDMS
7. MD schedule
8. MD
 1. Procedures on the table
 2. No shuffling of MDs
9. LSWG to present results
10. Summary of LSWG in LMC
11. ATS-MD note written

Practically very difficult
towards the end of the year:
high pile-up of MD events

MD notes 2016
5 notes / 56 MDs
Not going very strong !
Deadline 16 December



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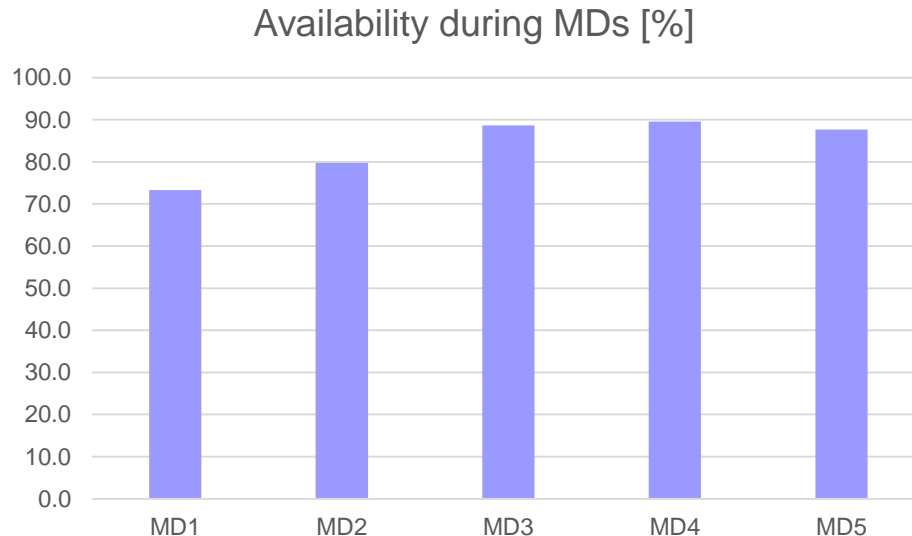
MD Statistics 2016

■ 20.5 days scheduled

- These are 492 h; actually 416 h (85 %) on schedule because of recovery between MDs at top energy
- These 2 hours of recovery give a big psychological advantage
 - Plan for 1 hour between the MDs at injection as of 2017
- 348 hours of Scheduled MD took place in 2016. This is an *average availability of 84 %* (identical to machine availability of the machine between TS2 and TS3)

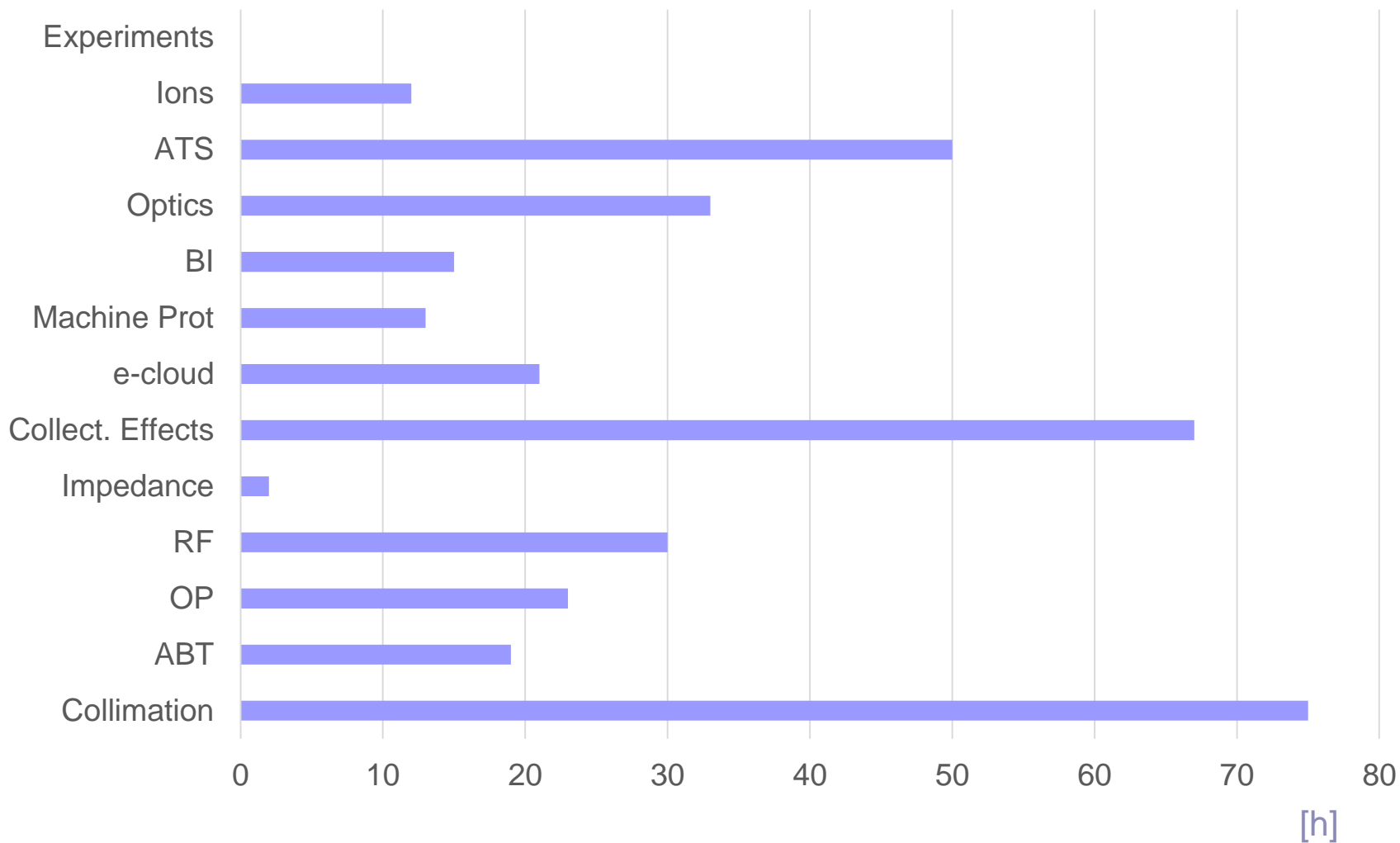
■ Total number of MDs: 56

- With a good machine availability 20.5 days schedule → **14.5 MD days net** which is 70 % of **total** efficiency



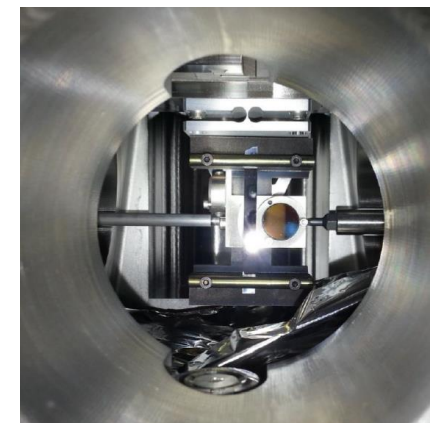
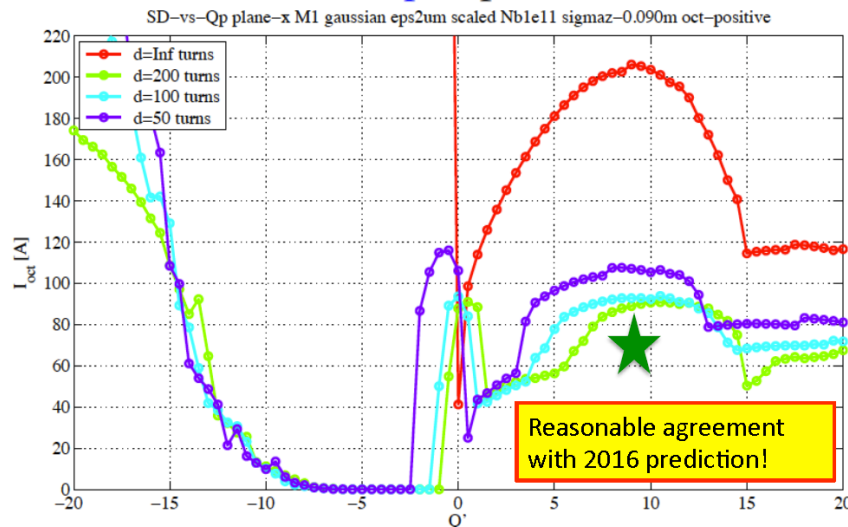
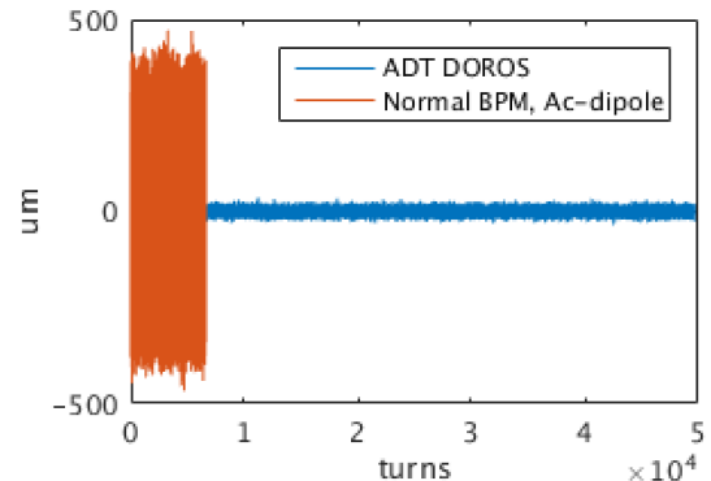
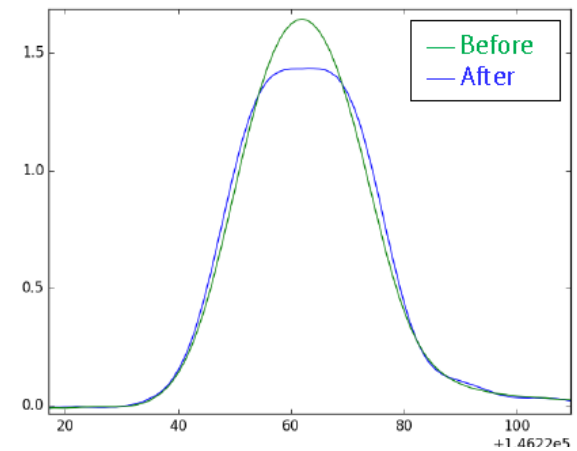
Collimation beats the Collective Effects

Classification of **effective MD hours** per category for 2016



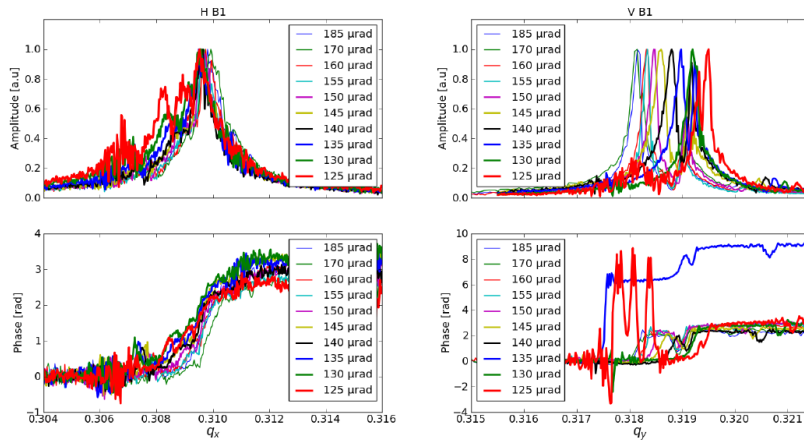
MDs 2016 Highlights

- See many presentation at this workshop
- RF bunch flattening
- DOROS BPMS, used for transverse coupling correction with minimum excitation
- Single bunch instabilities
- Crystal collimation



MDs 2016 Highlights

Crossing angle scans

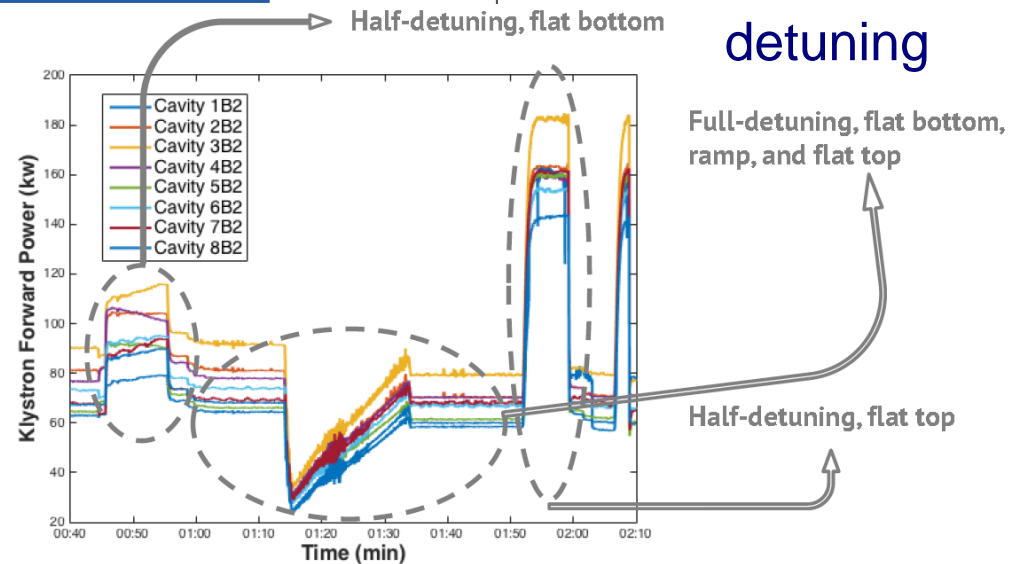
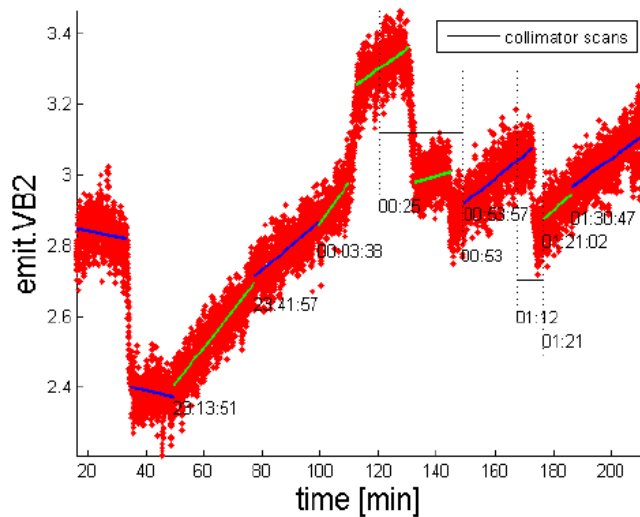


Lead to reduction of crossing angle for normal operation in second half to 2016



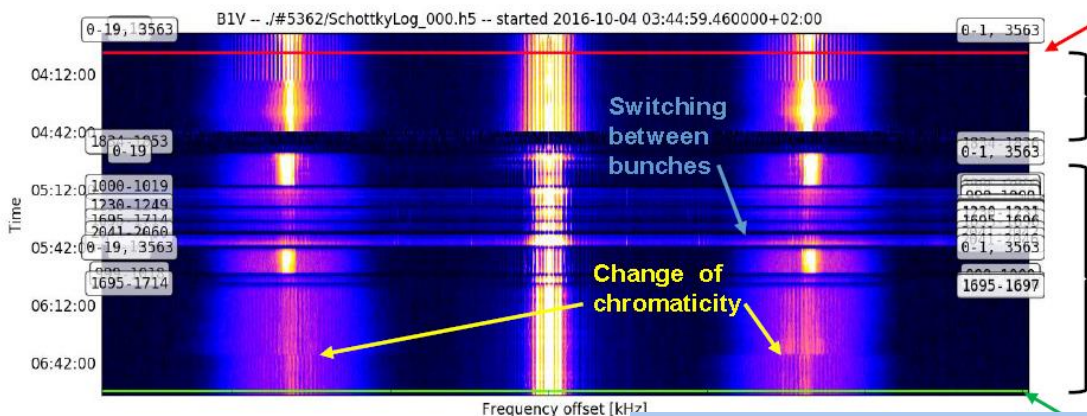
Resonant excitation MD



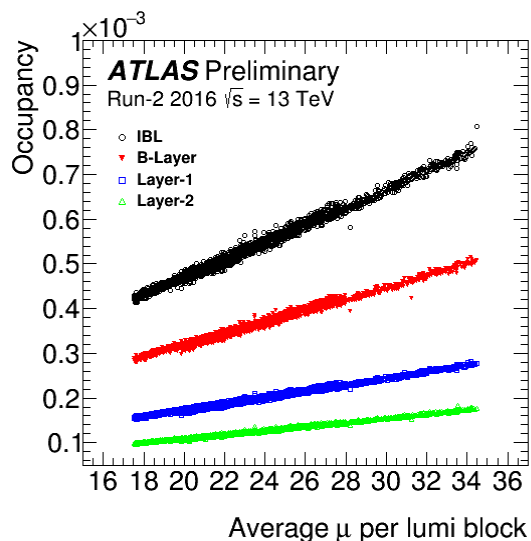


ACS cavities with full detuning

MDs 2016 Highlights



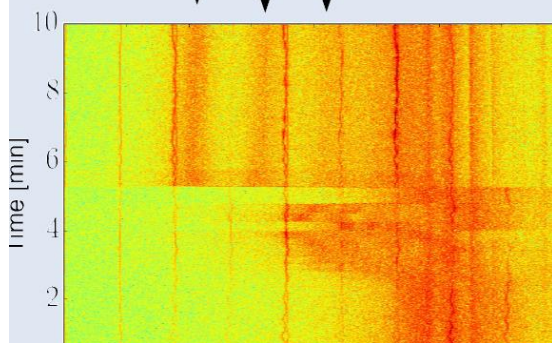
Extract the chromaticity from the measured **Schottky** sidebands



High brightness
 $\Delta Q = 0.018 \pm 0.001$

Intermediate brightness
 $\Delta Q = 0.012 \pm 0.001$

Low brightness :
 $\Delta Q = 0.007 \pm 0.001$



- Tune shift just below 0.02 measured with the BBQ (similar to operation at 4TeV in 2012)
 - Three families of bunches visible
 - High brightness bunches compatible with :
 - Bunch intensity $1.9E11$
 - Emittance $1.5E-6$
 - Bunch Length 9cm
 - Pile up of ~ 160
- Measured pile up (ATLAS and CMS) ~ 90
- The discrepancy cannot be attributed to the lumimeters' non-linearity (W. Kozanecki)
- Yokoya factor could explain $\sim 20\%$
- Dynamic β could explain less than 10%

High pileup fill 5412 gave CMS invaluable information to...

MDs 2016 Highlights

- Clear impact on lifetime observed when changing b_6 corrector strength

MD5 - TCPs at 5.0σ and TCSGs at 6.5σ

- ✓ **Very similar lifetime and transmission** with respect to **standard 2016 physics fill** with TCPs and TCSGs at 5.5σ and 7.5σ , respectively

→ **ATS telescopic optics down to 10 cm with probes**

- Overall mechanics successfully tested down to $\beta^* = 10$ cm
- Optics measurement @ $\beta^* = 33$ cm / 21 cm / 14 cm / 10 cm
- State of the art optics correction demonstrated @ $\beta^* = 21$ cm
- Chromatic properties fully demonstrated @ $\beta^* = 21$ cm

Within reach for 2017, tightening a little bit further the collimation hierarchy !!
(assuming X-angle OK for beam-beam: 9.0σ @ $\beta^* = 33$ cm, $\gamma\varepsilon = 2.2 \mu\text{m}$ & 6.5 TeV)

140 μm

↑
2017 ?

End of Fill MDs & Single Ion MD

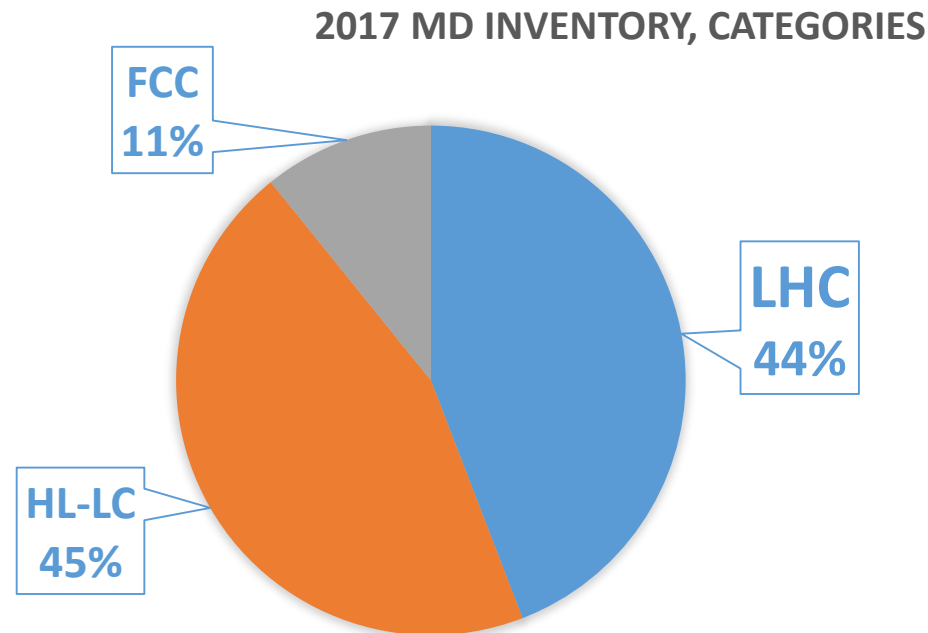
- 15 End of Fill MDs with procedure
 - MD procedures written
 - Checked by ®MPP
 - Good collaboration with OP and Physics Coordinators
 - Extremely useful and efficient use of machine time
 - Sometimes difficult to limit in time ...
- Single 12 h ion MD
 - MD moved **at the last moment** → use of parallel beam not well organised
 - Last minute, 'free' parallel proton beams during the ion crystal collimation MD
 - ***To be avoided for Machine Protection reasons !!***

TestSeparationStability.doc	22/10/2016 10:09
MDXXX_TuneShiftatFlatTop.doc	21/10/2016 12:37
HighPileupTestFill-Procedures.pdf	13/10/2016 17:33
MD-XingAngle-Scans-IR15.docx	12/10/2016 21:45
EOF249_ACSCavityVoltagePhaseModulat...	12/10/2016 13:33
MD-end_of_fill--TCT_closure.doc	11/10/2016 15:43
MD1291_Halo-Scraping-Diffusion_v2.doc	04/07/2016 10:18
MD1279 Bunch flattening v2.doc	13/06/2016 16:21
MD1224-VACUUM-BKGD-TEST-v2.docx	08/06/2016 15:42
MD1291_Halo-Scraping-Diffusion_v1.doc	10/05/2016 13:51
MD1483 procedure.IRNL.EoF.pdf	29/04/2016 17:41
MD1224-VACUUM-BKGD-TEST-v1.docx	26/04/2016 13:59
MD1280 single bunch longitudinal stabili...	19/04/2016 14:29
MD1228_EOF_SingleBunchInstability.doc	15/04/2016 16:33
MD1213_OPscan.doc	04/04/2016 14:53

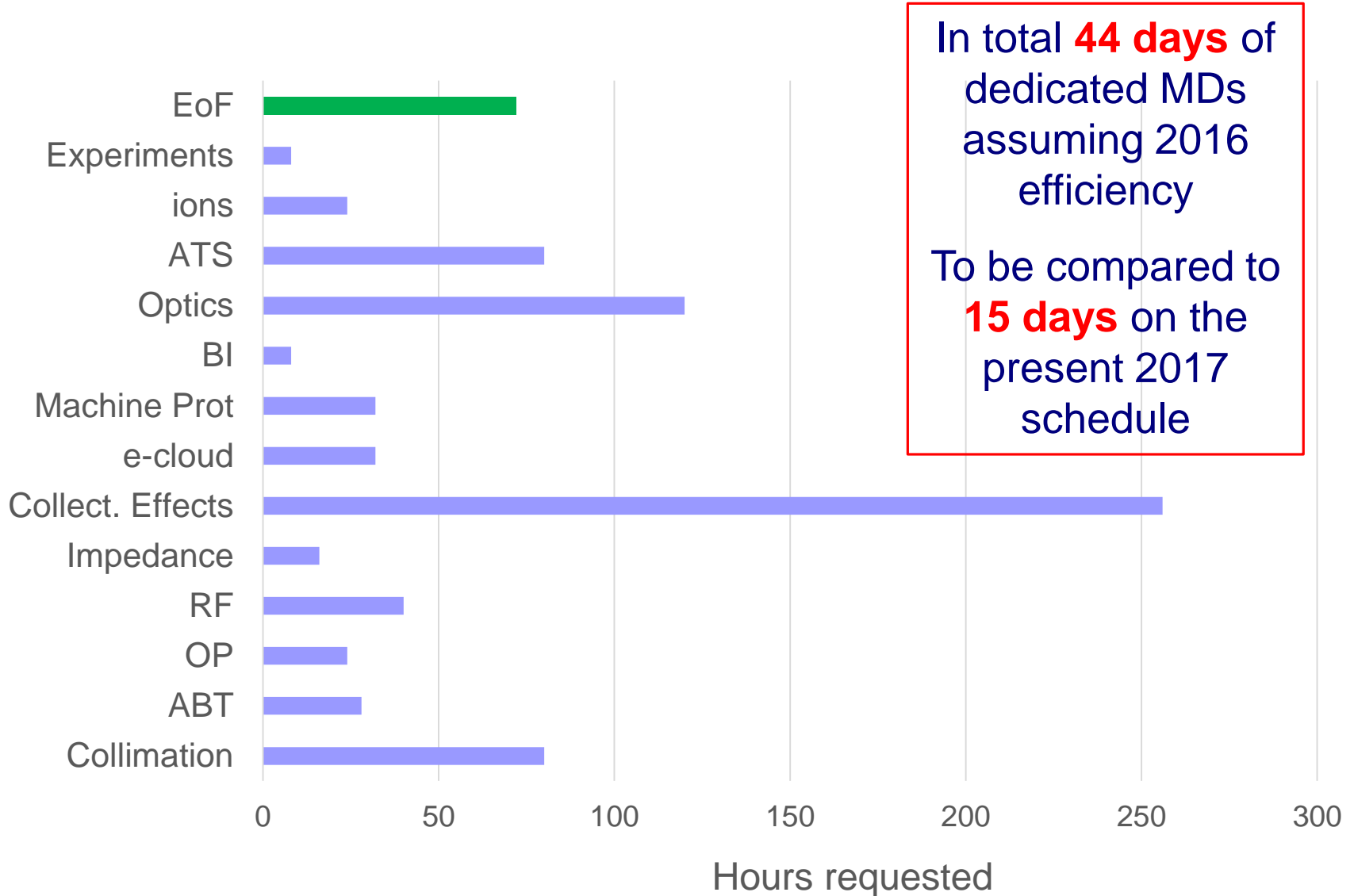
EoF and parallel MDs highly encouraged for 2017, but staying with standard flow: MD-Coord → ®MPP → OP

Do you want any MDs in 2017?

- Question asked to 2016 key MD players about 10 days ago. This resulted in an inventory of
 - 85 Different MDs
 - Estimate of 748 hours of MD time → **44 Days of MD** assuming 2016 efficiency
 - Plus 72 hours of End of Fill MD



Rough MD Inventory for 2017



2017 DRAFT SCEDULE

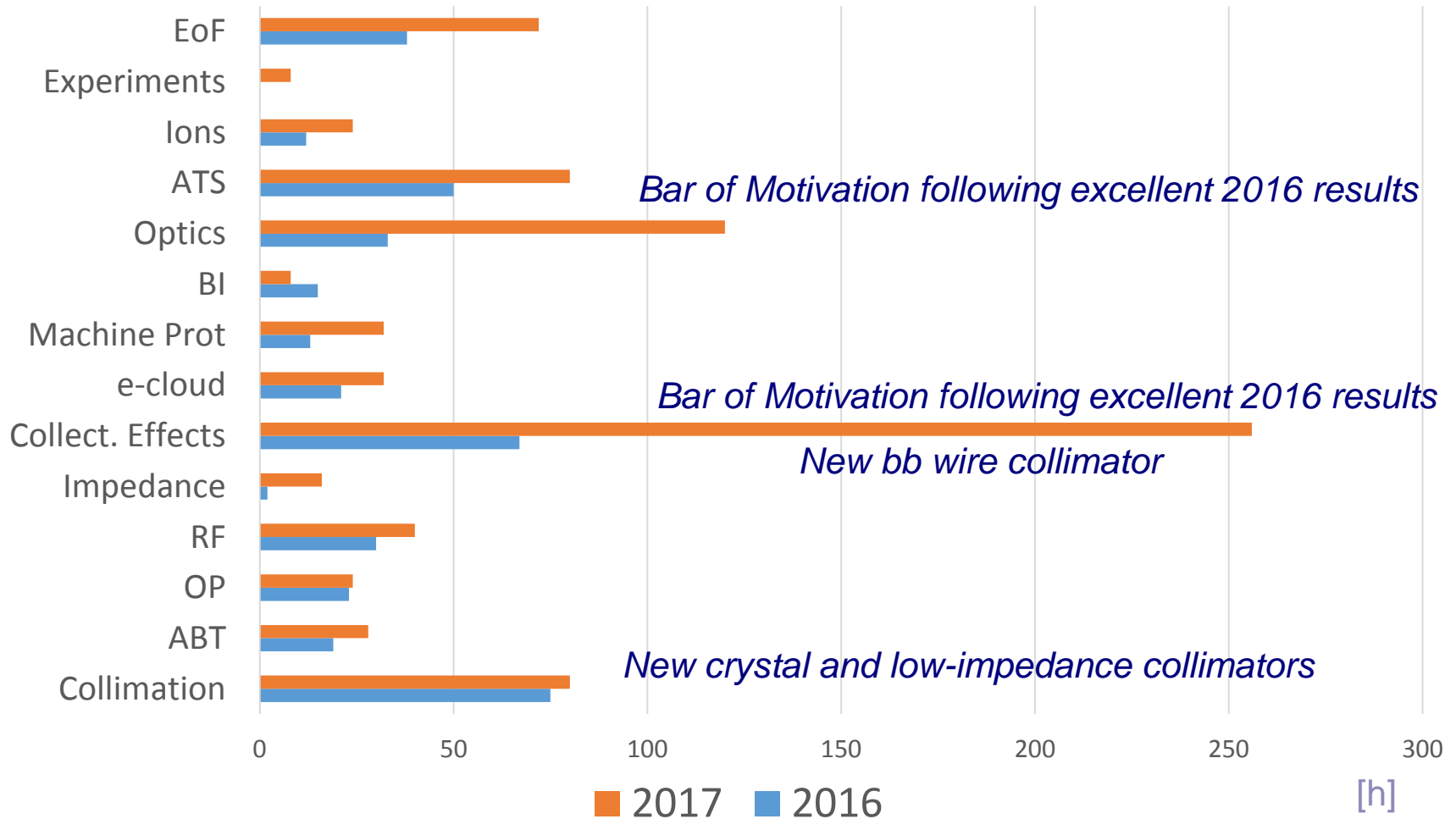
	Jan			Feb				Mar					
Wk	1	2	3	4	5	6	7	8	9	10	11	12	13
Mo													
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	Apr			May				June					
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Wk	40	41	42	43	44	45	46	47	48	49	50	51	52
Mo													
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Fr													
Sa													
Su													

Comparing 2017 requests to 2016 done



Conclusions

- 2016 was an extremely successful LHC year, also for MDs
 - See many presentations at this Evian workshop reporting on great results
 - Important for LHC operation and future machines
 - Difficult due to high MD pile-up towards the end of the year
- Recovery & Settings clean up can be improved
 - Need to be even more explicit in procedures?
 - Responsibility of OP to carefully follow this up and roll-back
- Short MD blocks are easier to manage for MD participants and also for MD coordination
- 2017 rough MD inventory made
 - 44 days of dedicated MDs requested vs. 15 on schedule:
THIS SEEMS TO BE BELOW THE MINIMUM if one wants to keep up the excellent work, investing in the future for LHC, HL-LHC and FCC
 - **Request 3 days of floating MDs on top of present schedule**
 - One should again use EoF and parallel MDs as much as possible, inventory of 72 hours EoF; stick to MD-coordination → @MPP → OP