



### **OMC** activities during the beam test

# T. Persson on behalf of the OMC-team



Date	Shift	Team				
10/21/2021	1					
	М	OP/RF/BI	Injection, threading, parasitic splashes			
	М	OP/RF/BI	Injection, threading, parasitic splashes			
	Α	OP/RF/BI	Closed orbit and RF capture, tune, Q' ,coupling, BI setup			
	Α	OP/RF/BI	Closed orbit and RF capture, tune, Q' ,coupling, BI setup			
	Ν	OP	Orbit corrector & BPM polarity			
	Ν	OP	Orbit corrector & circuit polarity			
10/22/2021	2					
	М	OP	Reference orbit with probe, energy matching to SPS			
	М	OP/BI	Orbit & tune FB commissioning, BI setup, AC dipole			
	Α	OP/BI	Orbit & tune FB commissioning, BI setup, AC dipole			
	Α	COL	Coarse setup for probes			
	Ν	OP	Kmodulation - triplet BPM offsets			
	Ν	OP	Kmodulation - triplet BPM offsets			
10/23/2021	3					
	М	OP	Splashes			
	М	OP	Splashes			
	Α	OMC	AC dipole, optics at injection			
	Α	OMC	Optics measurement & correction			
	N	OMC	spare			
	Ν	OP	FMCM tests			
10/24/2021	4					
	М	RF	Cavity phasing and ADT setup			
	М	RF	Cavity phasing and ADT setup			
	Α	ADT	ADT setup with probes, ADT excitation			
	Α	OMC	Optics measurement & correction			
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	Ν	OMC	spare			

10/25/2021	5		
	М	COL	Collimator setup, global injection aperture
	М	COL	Collimator setup, global injection aperture
	Α	ABT	Injection and dump aperture
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	Ν	OP	Feedback tests
	Ν		
10/26/2021	6		
	М	MPS	BLM dump trigger tests
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	Α	ABT	Kick response line + ring, MKI2 waveform
	Α	ABT	14/15 kickers knob
	Ν		
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	Ν		
	Ν		

Do the essential checks of equipment and software

Note that the dates are likely to shift. Already starting day could potentially be 2 days ahead of schedule!!







- The first thing is to excite with the AC-dipole and record with the BPMs
  - In 2015 there were some issues with the phasing of the BPMs
  - New multiturn and changes to the AC-dipole potential source of issues
    - Could be 5 min but could also be days
  - ADT-AC dipole
  - K-modulation
  - MKQ, MKA (without changing setting in the tunnel)
- Important checks at injection
  - 3D-excitation





### New software and functionalities

2		LHC Multiturn 5.1.21		+ _ D		
File Help						
🔯 C Ihcop 🔻	BP: Simulation Mode	Optic: Simulation Mode optic IDLE				
Acquisition BEAM1 ×	Acquisition BEAM2 ×					
BEA	M1 1	xciters				
Flag status		ACDipole MKA/MKQ LHC 3D Excitation	Panel			
Beam Presence	Setup Beam					
		AC Dipole Status				
KICK Group		Kicker H	Kicker V			
(No Group Acti Se	elect Active group	NOT READY		NOT READY		
Measurement Environ	ment			-		
Feedback state		H: LOADED		V: LOADED		
Orbit feedback ON			Open Control Panel			
RadialLoop feedbac	k ON	HORIZONTAL SETTINGS	VERTICAL	SETTINGS		
Tune feedback state	,	Kick enabled	ings Kick	enabled expert settings		
B1 H	81 V	Excitation amplitude (%)	Excitat	ion amplitude (%)		
92.0		1	1			
Tunes set-up						
0.31 A	cquire QH	Tune deltas	Tune d	eltas		
0.32 A	cquire QV	start 0	start	0		
Auto rup apalvois		start nat top 0	start n	lat top		
Auto-run analysis		end nat top 0	end tra	at top		
Harpy		ena	end			
_ narpy		Start Excitation tune	Start E	xcitation tune		
Concentrator settings		0.31	0.32			
Bunches		Excitation width	Excitat	Excitation width		
1		From Meas nb of turns	Fro	m Meas nb of turns		
Turne		O Manually set nb of turns	🔾 Mar	nually set nb of turns		
lums		0		· · · · · · · · · · · · · · · · · · ·		
0000						
Acquire with ACD	pole excitation					

- New multiturn application
  - Made by LHC-OP
- New functionalities added to the AC-dipole
- New OMC-GUI
- The code to analyse the data is also re-written (OMC3)

Status: The kicker has been pulsed so looks promising

٢	Beta Beating 2021.08	B.15_2300			
🏊 🔄 🔞 <none> 🔻</none>					LHCB
BPM panel Analysis panel Optics Correction					
Active measurement group: Group not selected	File	Bunch ID	Analysis done	Kick group	No. of bad BPMs
Analysis					
Open files Analyse spectra 🗵 Run optics as we	11				
Create Average Remove Turns Split files					
Horizontal plane					
Find BPM     Phase space  Vertical plane					
Find BPM					
Phase space					
Console					
07:24:24 - MainWindow -> Welcome to beta-beating application					
17-24-24 - MainWindow => Welcome to beta-beating application					_





### K-modulation



- New GUI developed in Python by Georges Trad in close collaboration with Michael Hofer to interface our analysis
- Enables the modulation of more magnets including Q2, Q3 and even an entire arc!

#### Status: Has been tested to drive magnets

### ADT AC - dipole

			l tune	lill d	nroma		😤 Dia	agnostic
Coupling measurement with ADT	excitation = options							
LEADY	ack	Last:	B1 REAL proposed		81 RE	EAL Trim		
B1 Tune	B2 Tune	20:56:21	0.0003		4	0.000	*	
0.310 [-0.012]	0.310 [-0.012]	81 [C-] from excitation	B1 IMAGINARY propo		81 IM	AGINARY Trim		-
B1 Tune	82 Tune	0.0014	0.0014	<b>→</b>	4	0.000		
0.320 [+0.010]	0.320 [+0.010]		AD DE N AND AND A					
	0.010 [. 0.010]	B2 JC-J from excitation	B2 REAL proposed	a	82 RE	EAL Trim		-
Bibunch	B2 bunch	0.0030	-0.0025	k	4	0.000		i
476	853		B2 IMAGINARY propo		82 IMAGINARY Trim			
B1 active	B2 active		0.0017		4	0.000		
v								
ews B B B B B B B B B B B B B B B B B B B	Measure	g g sen	ver BEAM2 (11/09/17 20:3	(7:56]	millin		harmit	5
ews a B B B C Coupling History 0.005	More 228 1/09/17 20:57:56	SI SI SIN	rer BEAM2 (11/09/17 20: 0.0035 0.003 0.003 0.003 0.003 0.003 0.003 0.003 0.003 0.003 0.003 0.003 0.003 0.003 0.003 0.005 0.05	77:56]		•	linner <sup>11</sup>	8
Server BEAMI II           ta Viewer Views         22           Coupling History         0.0045           0.0025         0.0025           0.0015         0.0015           0.0015         0.001           0.0015         0.001	Mare Carlos Carl	SI SI Sen 20:52 20:54 20:56	Construction of the second sec	57:56) Mumh 14 20:44	1 20:48	4 2050 2052 2	20:54 2	4 • •

- New protocol to transfer the data
- Using the new code base (OMC3) and <u>different</u> <u>compensation method</u> for the driven motion.

A. Calia, et al "Online coupling measurements and correction throughout the LHC cycle"

Status: Has been deployed and tested with fake data. The ADT class is not yet tested.

### 3D – kicks



- The RF phase is modulated at the same time as the AC dipole excites the beam
  - Can enable measurement of dispersion and chromatic functions during the ramp
  - This is implemented in the Multiturn application

L. Malina

Status: Is implemented but still needs to be tested





### Close collaboration with OP

- The new applications are developed and maintained mainly by LHC OP
  - When it comes to access hardware devices, RBAC etc, this is much more efficient since they have more experience in these area.
  - We still need to collaborate closely since we are the expert on what to expect for many of the applications.
  - A very fruitful collaboration!
- A personal reflection is that the OMC-OP Workshop was very beneficial to increase our understanding of the common challenges
  - In the next slide I will mention one of them





### Target and Correction

- One of the difficulties with re-create the state of the machine at a given time has been that it is not known from the logging why a setting was change.
  - E.g., The tune knob is changed in LSA: Was this a change of working point or was this simply a correction of the tune back to the nominal?
  - In the OMC-OP workshop different possibilities were discussed but, in the end, the main was to use the two different properties in LSA: Target and Correction.
    - E.g., Target when you want to change the working point and correction when you want to correct the tune back to nominal
    - This is now adopted in the accelerator cockpit application and the idea is to use this principle throughout the run







## Back to the beam test



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10/29/2021 9

Do the essential checks of equipment and software

Calculate the corrections: Local coupling and global beta-beat





corrected

20000

25000

### $\beta$ -beating at injection



- The  $\beta$ -beat at injection has stayed relatively similar between Run 1 and Run 2
- If we measure and correct during beam test we can most probably use the same corrections in 2022





## Local coupling

- The local coupling corrections did not change so much from end Run 1 to Run 2
  - Two data points are not much statistics! Rotations might have changed this time..
  - A rough correction at injection can be made
- Before local correction and arc-by-arc corrections (when needed) are applied the BBQ coupling measurement is less reliable



	Circuit	$\Delta k \ (10^{-4} { m m}^{-2})$				
		2012	2015	2016-2018		
IR1	RQSX3.L1	8.0	8.7	11.0		
	RQSX3.R1	8.0	8.7	7.0		
IR2	RQSX3.L2	-9.0	-16	-14.0		
	RQSX3.R2	-9.0	-16	-14.0		
IR5	RQSX3.L5	6.0	7.0	7.0		
	RQSX3.R5	6.0	7.0	7.0		
IR8	RQSX3.L8	-7.0	-5.0	-5.0		
	RQSX3.R8	-7.0	-5.0	-5.0		

Before and after local coupling correction. Note that the global knobs also have been readjusted.





## If we don't correct the local coupling

- In 2010 (3.5 TeV) the strength of the arc skew quadrupoles were almost maxed out before the local coupling corrections were implemented
  - Local corrections needed for the first ramp and squeeze







# How do we prepare for this?





### Testing in the CCC

#### • Two purposes:

- Finding issues and bugs
- Train new people and remind the rest of us how to use the applications and calculate the corrections
- We already had one session but split into 3 different time slots.
  - We are now in the middle of a second iteration.







### Beta-beat.src and OMC3

- Beta-beat.src was used extensively used in Run 1 and Run 2 so well tested
- OMC3 more flexible but still needs so more testing and still missing some functionalities
  - Will use the beam test to continue testing the OMC while using the betabeat.src as the reference





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MCS, Q" and potentially a re-validation of the corrections if needed

### Counteract the coupling drift at injection





- We change the setting of each of the MCS arc-by-arc
  - Measure the change to C-
  - Stayed constant between 6 months in Run 2.
- Based on this measurement we could potentially have an uneven dynamic b3-compensation

### Measuring Q" and Q""



0.310

0.305 -0.003

-0.002

-0.001

0.000

dp/p

(b) Vertical chromaticity

0.001

0.002

0.003

- Interesting to compare to previous years
  - Help to constrain a beam-based corrections



### Exotic K-modulation

- K-modulation sector-by-sector (4h)
  - Will give an independent measurement of the average beta-function
  - Also try the functionality to trim the Q2 for example







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	N						
			↓				

Potentially the 60 deg phase advance (4 people needed + collimation experts )

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### 60 deg phase advance optics

- Try the 60 deg phase advance optics (8h)
  - Designed for a higher energy LHC (replace every third dipole to 11 T) but would also probe the errors differently and would help to constrain the corrections further
  - Significant different so will also help understand orbit errors
  - Could bring insight into BPM calibration errors as well

### 60 deg phase advance optics

- Would be a different optics with different settings
  - Help identifying underlying alignment and magnetic errors
  - In particular the momentum compaction factor is different

Parameter [Unit]	60°LHC	90°LHC
β <sub>min</sub> /β <sub>max</sub> [m]	63/182	32/177
η <sub>min</sub> /η <sub>max</sub> [m]	2.5/4.1	1.1/2.2
Momentum Compaction [10 <sup>-4</sup> ]	6.9	3.5
Transition Energy [GeV]	40.0	53.6
Natural Chromaticity at 450 GeV	- 60	- 83
Corrected Chromaticity at 450 GeV	2	2
Sextupole Strength at 450 GeV [Tm <sup>-2</sup> ]	56	142
Tune at Injection Optics (H,V)	45.28/44.31	62.28/60.31





### Mom. Comp. Factor Measurements

- Fit of relative energy (momentum) offset over frequency
- Problem: no device in LHC to measure energy  $\rightarrow$  Use TbT measurements





### **Beam Position Monitor Errors**

Measured closed orbit used for momentum offset calculation



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### Beam Stay Clear at 450 GeV



#### At the moment we are only interested in a single pilot bunch





Date	Shift	Team						10/20/2024	0		
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	М	OP	Reference orbit with probe, energy matching to SPS		М	MPS	BLM dump trigger tests		М	COL	Local aperture triplets
	М	OP/BI	Orbit & tune FB commissioning, BI setup, AC dipole		М	MPS	BLM dump trigger tests		М	COL	Local aperture triplets
	Α	OP/BI	Orbit & tune FB commissioning, BI setup, AC dipole		Α	ABT	Kick response line + ring, MKI2 waveform		Α	COL	Selected local aperture checks
	Α	COL	Coarse setup for probes		Α	ABT	14/15 kickers knob		Α	OP	ALICE pol +, Stable beams at injection
	Ν	OP	Kmodulation - triplet BPM offsets		Ν				N	OP	Stable bearns at injection
	Ν	OP	Kmodulation - triplet BPM offsets		N				N		
10/23/2021	3			10/27/2021	7			10/31/2021	11		
	М	OP	Splashes		М	OP/RF/BI	Nominal bunch injection, BI, RF tuning		М	COL	Crystal collimation test
	М	OP	Splashes		м	OP/RF/BI	Nominal bunch injection, BI, RF tuning		М	COL	Crystal collimation test
	Α	OMC	AC dipole, optics at injection		Α	OP	Collision setup with nominal bunches, ALICE to +/+		Α	OP	ALICE 0, Stable beams at injection
	Α	OMC	Optics measurement & correction		Α	OP	Collision setup with nominal bunches		Α	OP	Stable bearns at injection
	Ν	OMC	spare		N	OP/ABT	MKB waveform		Ν		
	Ν	OP	FMCM tests		Ν				N		
10/24/2021	4			10/28/2021	8						
	М	RF	Cavity phasing and ADT setup		М	COL	Collimation setup nominal bunch	II			•
	М	RF	Cavity phasing and ADT setup		М	COL	Global aperture with nominal bunch	Dotonti	ally +	ho 60	dog phaso advanco (4
	Α	ADT	ADT setup with probes, ADT excitation		А	COL	Loss maps	Fotenti	Folentially the oblieg phase advance (4		ueg pliase auvalice (4
	Α	OMC	Optics measurement & correction		Α	RF	ADT setup	people needed + collimation experts)			ollimation experts)
	Ν	OMC	Optics measurement & correction		N	RF	ADT setup	Leepie			
	Ν	OMC	spare		N						

Do the essential checks of equipment and software

If there is interest, we could also try the aperture measurements with the AC-dipole -> Amplitude detuning for free MCS, Q" and potentially a re-validation of the corrections if needed

### Conclusion

- An extensive program ahead of us!
- A lot of modifications have been done during the shutdown
  - The beam test provides a great opportunity to test modifications to system and software
  - Challenging also in the view of our own detraining (not only magnets can detrain)
- The outcome will also depend on the availability of the machines and experts
  - If everything goes well, we could still hope to test the 60 deg phase advance but we need your help for that!







- Most of the change is in the beginning of the ramp before the squeeze
  - -> Effect is coming from the arcs
  - |C-| change up to **0.02**
  - Small changes in the later part even with the squeeze
    - -> The local coupling corrections worked well









### Without local coupling corrections

- No measurements of the coupling as a function of  $\beta^*$  in Run 2 but can use the local coupling corrections to estimate the situation
  - Correct with knobs to |C-| = 0.001 at injection
  - After squeezing to 7m we would have expected a  $|C-| \sim 0.01$

