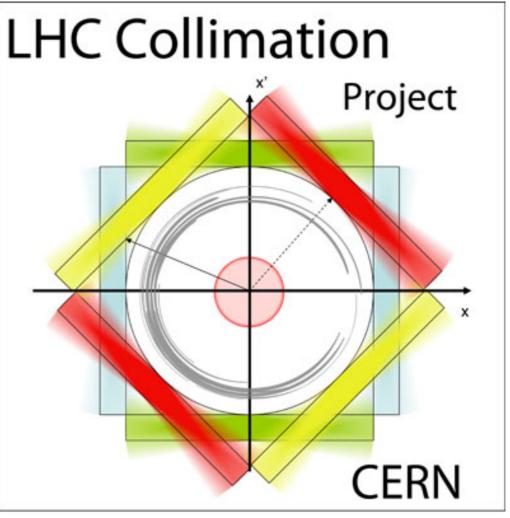
Collimation System



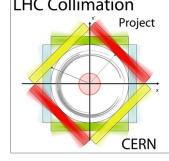
B.Salvachua, R.Bruce, A.Mereghetti, S.Redaelli, G.Valentino, D.Mirarchi, P.Hermes

on behalf of the Collimation Team

12/06/2015 - MPP Workshop



Outline

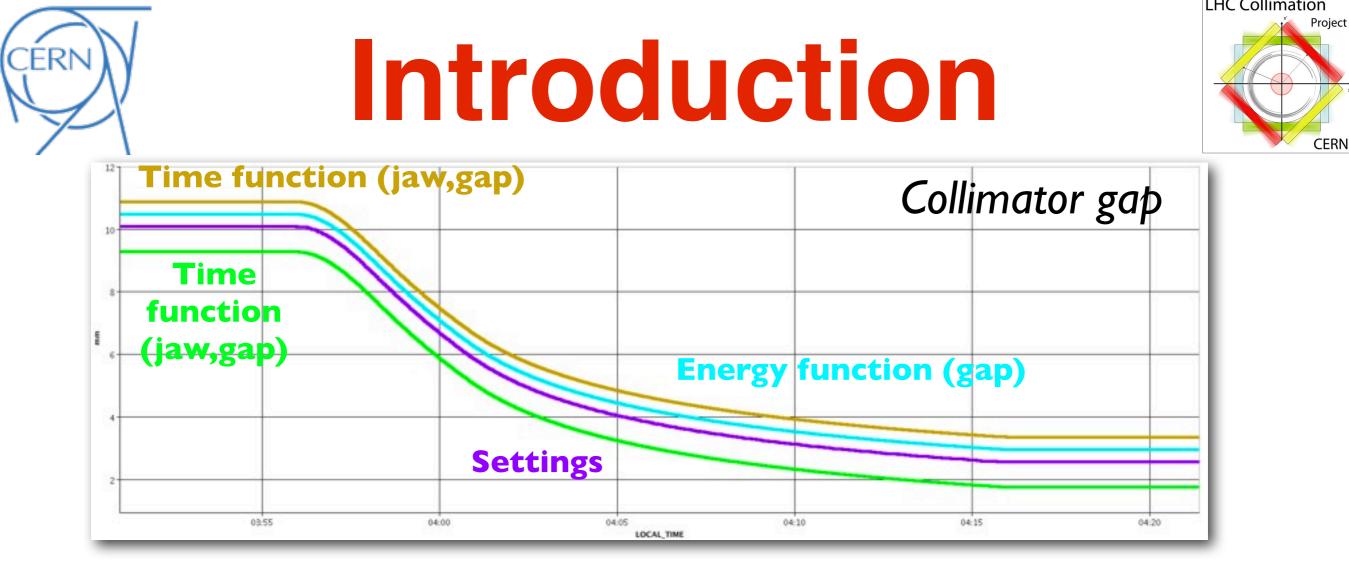


Introduction

Collimators operation:

functions, global aperture and final settings

- Status of MP validation: validation without beam and deployment of operational settings
- Alignment results
- Loss maps validation
- Dump "statistics"

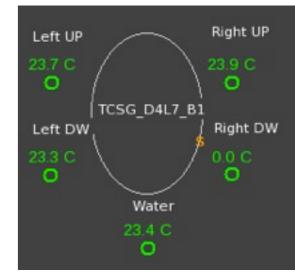


• **POSITION INTERLOCKS**

- Inner and outer thresholds as function of time for each collimator axis and gap (24 functions)
- Maximum gap versus energy (2 functions). *Protection during ramp.*
- Max. and Min. gap versus beta* (4 functions). *Protection during squeeze.*
- TEMPERATURE INTERLOCKS:

Project change: $EN/ICE \rightarrow EN/STI$

- Interlocked temperature sensors in the collimator jaws and cooling water.
- More than 500 sensors that can trigger an interlock.





Changes in LS1:

Collimator movement during OP cycle

- 8 additional collimators
- 18 new collimators with **BPMs**
- new absorbers with additional temperature sensors
- System:
 - 108 movable collimators
 - 93 ring cleaning

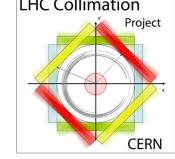
Collimators needed in ALL operational phases. Function-drive motion and precise synchronization



CERN



Global Aperture



- Aperture is the input for collimator hierarchy, many discussions in collimator settings for Run 2:
 - 2014 Evian/Chamonix, R.Bruce
 - 19/01/2014 CWG, R.Bruce
 - 20/05/2015 LMC , S.Redaelli
- LMC endorsement to stay at 80cm beta-star (gives 2σ margin)
- Decided to use the 2σ margin as machine protection to tertiary collimators and triplets in low-β* regions

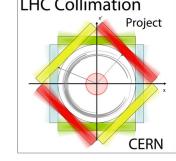
```
Assuming a 3.75μm emittance and 11σ long-range
beam-beam separation, we get:
```

				R.B	Bruce et	al.
14	- TCDQ down	to TCSE	level	,		
	- TCT IR8:	15 (β* =	3 m)			
	- TCT IR2:		-			
Note						
for	a protected	d apertu	re in 1	[R1/5 of	f 15.4	
	TCT1/5	13.7				
	TCDQ	9.1				
	TCS6	9.1				
	TCS7	8.0				
	TCP7	5.5				

What is the aperture at 6.5TeV - 80cm?

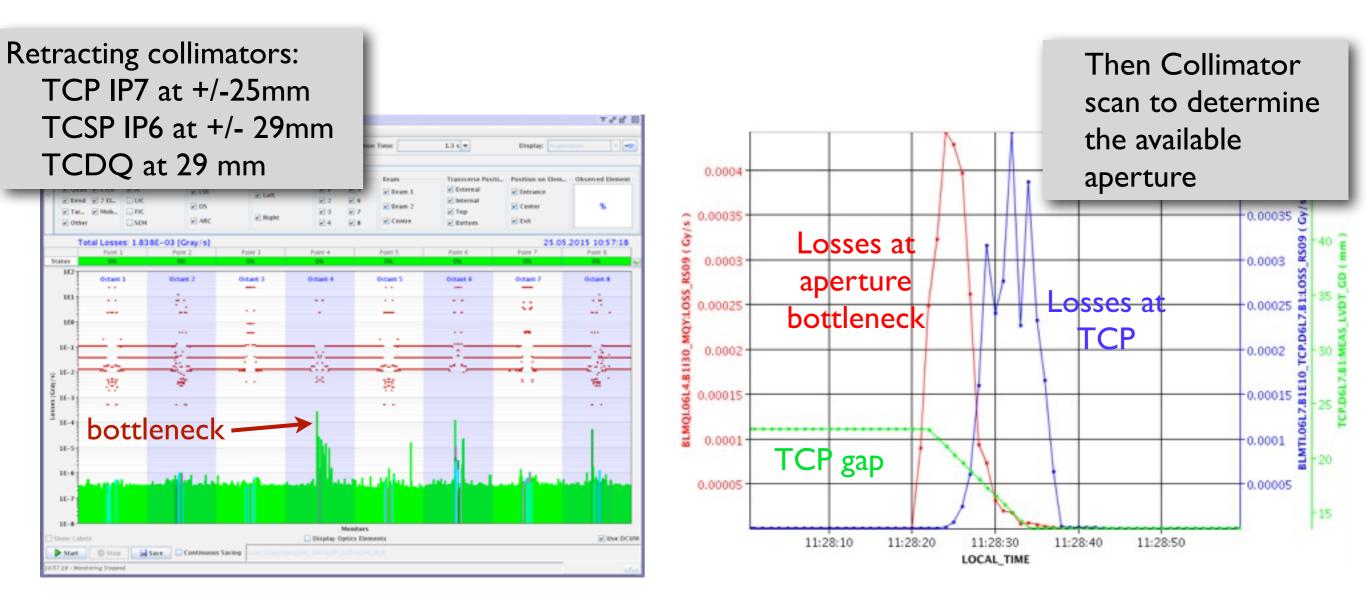


Global Aperture Measurement



The techniques:

- Retract all collimators and identify bottleneck.
- Collimator scan: while exciting the beam with ADT move in/out bottleneck collimators (TCP at injection or TCT at squeeze/colliding).
- Local bump: match a bump with the identified bottleneck and touch aperture after defining beam size with primary collimators.







• Preliminary analysis of the aperture confirms assumptions to calculate margins and beta-star reach.



• Preliminary analysis of the aperture confirms assumptions to calculate margins and beta-

star reach.	Plane	Aperture $[\sigma]$	Bottleneck	
	B1H	17.2-18.2	IR5	
6.5TeV at 80cm β^*	B1V	15.7-16.2	IR1	
assumed 15.4 σ	B2H	16.2-16.7	IR1	
ussumed 15.40	B2V	15.7-16.2	IR1	Pascal D.Hermes



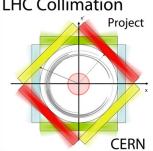
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ussumed 15.40	B2V	15.7-16.2	IR1	Pascal D.Hermes

2015 Collimator Settings

V							
-		0	450 GeV	6500TeV			
	IP7	TCP/TCSG/TCLA	5.6/6.7/10	5.5/8.0/14.0			
	IP3	TCP/TCSG/TCLA	8.0/9.3/12.0	15.0/18.0/20.0			
	IP6	TCSG/TCDQ	7.5/8.0	9.1/9.1			
	IP1 and IP5	ТСТР	13.0	13.7			
	IP2	ТСТР	13.0	37.0			
	IP8	ТСТР	13.0	15.0			
	IP1 and IP5	TCL4/TCL5/TCL6	out/out/out	15.0/15.0/out			





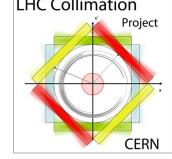


- Functionality of position interlocks:
 - see also talk on 27/03/2015 MPP, G.Valentino
 - Executed 93 x 18 = 1674 sequences in a couple of days, found few issues in BIC connections that were quickly solved.
 - Tests are now in Acc. Testing as sign-only, plan for full functionality in 2016.

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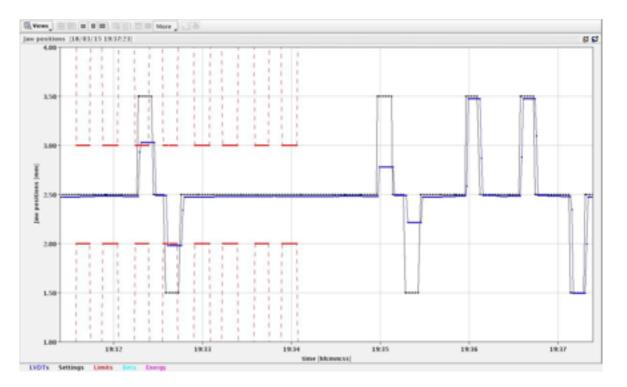


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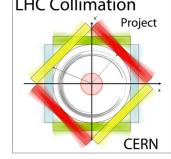
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- not obvious after LS1 to have this functionality back for FESA3 and RDA3.
- during commissioning RBAC roles distributed in a more relaxed manner, is there a common procedure for RBAC lists?







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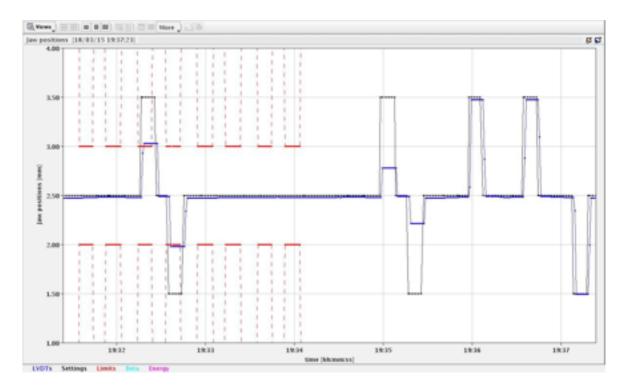
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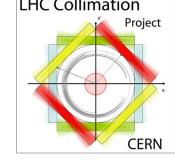
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• Functionality of temperature interlocks

- also checked few sensors disabled







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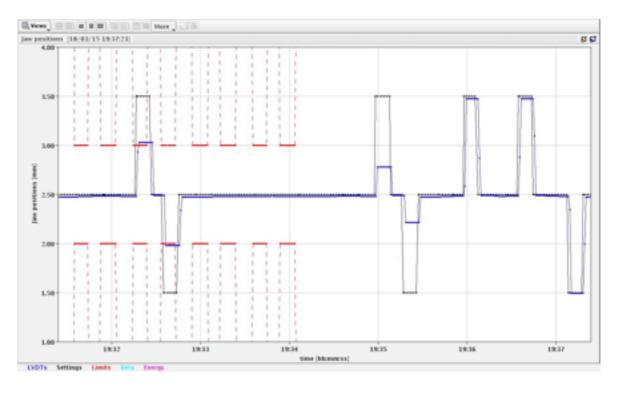
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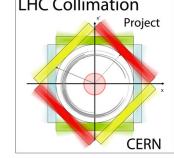
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• Functionality of temperature interlocks

- also checked few sensors disabled
- Other tests: ramp functions reproducibility tests, LVDT signals, triggering of collimator movement (timing), different profile functions, etc...







Functionality of position interlocks:

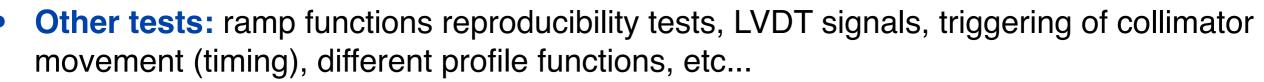
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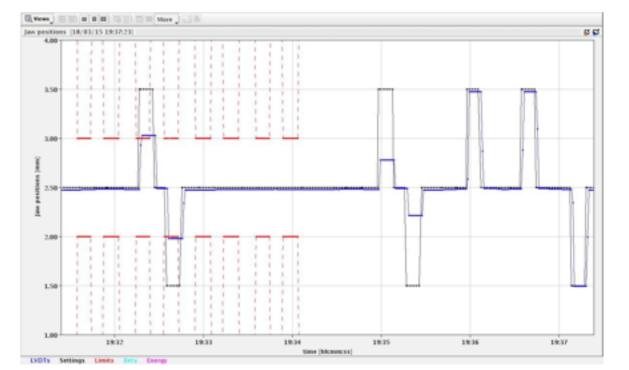
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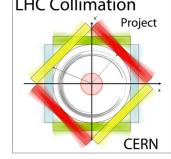
also checked few sensors disabled



Activities started in summer 2014 in order to be ready for start-up



Status deployment Operation



- We have deployed final collimator settings, with tight positions limits and energy depending limits. To be done in the next days the deployment of beta-star (wait to finish with the de-squeeze). Limits ready for the 48 bunches.
- Strategy for commissioning:
 - Coarse settings for pilot ramps (4 collimators/beam ramped) TCSP6/TCP3/TCP7(H/V) 20/30/25σ
 - Less coarse settings for nominal ramps (4 collimators/beam ramped, collimators aligned) 10/15/20σ
 - Final ramp functions (all collimators ramped and aligned)
 - Nominal squeeze/colliding vs special runs:
 - Flat orbit vs Crossing angle settings of the TCTs
 - Squeeze vs de-squeeze

Many OP configurations are already deployed





G.Valentino

Beam Mode:	INJECTION	-	Load LSA Ta	able
Start Date/Time	21-03-2012 1	6:00:00	Load BP D	ata
Stop Date/Time 21-03-20		3:00:00	Load Logging	Data
Select Collimators			Tolerance [um]: 10	
		Start Check!		
Clear: 🗌 LS	A table 📃 Bean	n Process 🗌 Logg	ing 🗌 All	Clear
Collimator	Setup Sheet	Beam Process	Logging	Status
TCL.4L1.82				
TCL.4L5.B2				
TCL 4R1.81				
TCL 4R5.81				
TCL.5L1.B2	1.270	1.270	1.270	1
TCL.5L5.B2	-0.420	-0.420	-0.420	1
TCL 5R1.81	0.308	0.308	0.308	1
TCL5R5.81	-0.050	-0.060	-0.060	1
TCL.6L1.82				
TCL.6L5.82				
TCL 6R1.81				
TCL.6R5.81				
TCLA.6L3.82	-0.410	-0.410	-0.410	4
TCLA.6R3.B1	0.013	0.013	0.013	×
TCLA.7L3.82	-0.100	-0.100	-0.100	4
TCLA.7R3.B1	0.015	0.015	0.015	× .
CLA.A5L3.82 CLA.A5R3.81	-0.458	0.350		
TCLA.A6L7.B2	0.290	0.290		
CLA.A6R7.B1	0.305	0.305		-
TCLA.A7L7.82	0.590	0.590	0.590	1
CLA.A7R7.B1	-0.525	-0.525	-0.525	1
TCLA.B5L3.B2	-1.170	-1.170	-1.170	4
CLA.BSR3.B1	-0.440	-0.440	-0.440	1
TCLA.B6L7.B2	-0.045	-0.045	-0.045	4
	-0.345	-0.345	-0.368	a second
CLAB6R7.B1	0.730	0.730	0.000	
		1.372		
TCLA.C6L7.B2	1.372			
TCLA.06R7.81 TCLA.C6L7.82 TCLA.C6R7.81 TCLA.D6L7.82	0.055	0.055	0.055	1

Console

11:07:28 - Error: no data found for: TCTPV.4R8.82 11:07:29 - Logging data loaded!

or an a cogging data reade

11:04:56 - Ready

23/02/2015 - Collimation WG

•

23/02/2015 - Collimation WG

All collimators aligned all cycles.

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Alignment tool reduced more the time spent in alignment (max. 80 collimators around 3 hours)

New alignment tool to check centers in LSA vs alignment result. This was an action from the MPP workshop in 2013

G.Valentino





11:07:28 - Error: no data found for: TCTPV. 4R8.82 11:07:29 - Logging data loaded!

11:04:56 - Reads





ERN

11:07:29 - Logging data loaded! 11:04:56 - Read

11:07:28 - Error: no data found for: TCTPV. 4R8.82

Console

Clean

Collimato

TCLA 6L3

G.Valentino



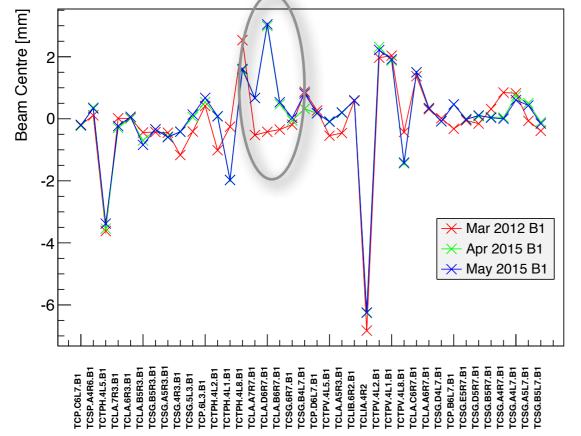
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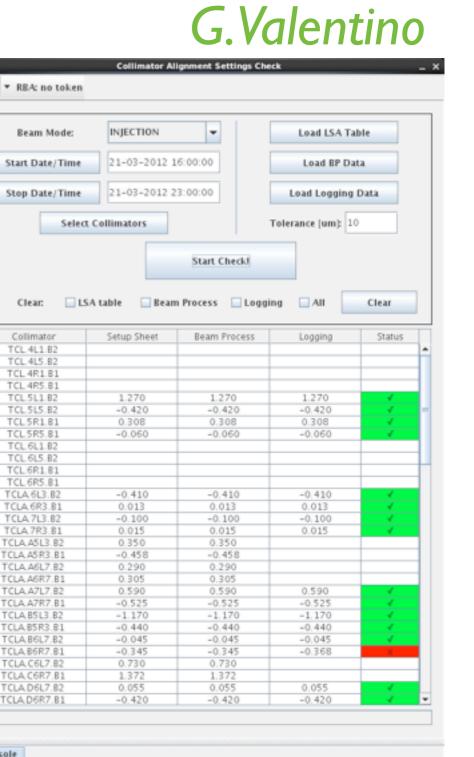
(max. 80 collimators around 3 hours)

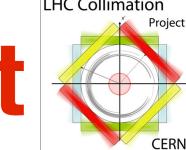
New alignment tool to check centers in LSA vs alignment result. This was an action from the MPP workshop in 2013

Large offset found on TCLA.D6R7.B1.

- I 5mrad tilt observed in LSI
- Corrected but re-measured in May and was 16mrad
- Will be corrected in TS1 and will need to be re-aligned

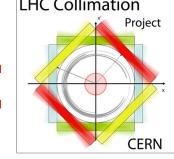








BPM Collimator Alignment

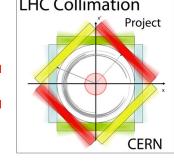


- First alignment tests at top energy with BPMs were also done (in IR1 only). The alignment takes few seconds.
- **Centers compatible with Beam Based Alignment (comparison done without correction** of electronic gains etc.)
- Very promising results, however BPM DOROS electronics to populate the rest of IRs are not yet available. It was foreseen to have them installed during TS1 but the last news from BI were not encouraging.

Collimator Alignment: TCTPH.4R1.82		778
📴 * AE-t; ihesp		
ide Settings Reset. More displays Help EPM		41 82
Jav comers Positions/Angles Increment EEA EPH	(0, News) (11 (11 (11 (11 (11 (11 (11 (11 (11 (Horicontal
Automatic EPM-based Alignment	Beam lovs data (28/05/15 15:36:28) C	
	1 xx	TCP.C6R7.82
Minimum Cap (mm) 10 Milgn	3 48.4	TO DELLAR LESS
	116-6-	TCTPH4R182
Alignment Error (um) 5	§ 206-6	Vertical
Time Interval (s) 2	1 200 6 Brothe High Latie dealer the pilling like or were all	
AUCNED	123408 123428 123448 123588 123528 123548 123688 123628	TCP.D6R7.82
	Jaw positions (28/05/15 15/36/27) C C	TCTPX4R182
	1 16.00 for some of the second s	10110.000
Averaging Average over (s) 1.0	1 Sat	
	5.00	
Impats okay - ready to move!	5.00	
Left Jaw O UP-IN O UP-OUT O DW-IN O DW-OUT	1 - 1440	
	153440 153420 153440 153500 153520 153540 153600 153620	
Right jaw Q UP-IN Q UP-OUT Q DW-IN Q DW-OUT	time (Memory)	
AMI COLL 🔮 BP 🔮 DOWN	Detroit Data (28/45/15.15/36/28) Ø Ø	
Positions readout from the low-level	3 8.40	
LVDT1 - Left UP 8,142 Gap UP 12,429	2.19	
	6 A39	
Left DW 8,343 Gap DW 12,546	8 A.M	
Right UP - \$483 Centre UP - 8.72	6.374	
	Energy Income Income Income Income Income	
Right DW - 9,387 Center DW - 46.482		
Right DW - 9,387 Centre DN - 8,482	time [Mcmacus]	
Bight DW - 9,387 Centre DW - 6,462 Display jam ⊇ Left jaw sticker⊕ ⊇ Bight jaw solik⊕ ⊡ Gap 63000	Erran pretition data (20.01/13.15/30/20) Ø' Ø' I -0.200	
Right DW - 9,387 Centre DW - 6,462 Dirighty jant ≥ Left jan skilcheith ≥ Right jan skillich ⊆ Gap 6100 Perklams: ≥ Set ≥ LVDT = 1,444	Erran presiden data (20.01/35.15.36.28) Ø' Ø' # 4.800	
Right DW -9,387 Centre DW -6,462 Dirighty jant: ≥ Left jan skilole ⊕ ≥ Right jan skilol ⊕ Cap 6100 Positions: ≥ Set ≥ LVDT = ==== Cam = Res = Mot. = E = P	Erran presiden data (24.01/15 15.05.26) Cf Cf • • • • • • • • • • • • •	
Right DW -9,387 Contro DW -6,462 Display jant ≥ Left jan silochen) ≥ Right jan soliki ⊂ Cap 610D Positions: ≥ Set ≥ LVDT = **** LBM = Res = Mot = E = # RLM ≥ RLM 1 = RLM 2 = RLM 1 = RLM 4 = LegY	Erran presiden data (20.01/35.15.36.28) Ø' Ø' # 4.800	
Right DW -5.387 Contro DW -6.462 Display junt: 2 Left juny situation 2 Right juny sould Cap 610D Positions: 2 Set: 2 LVDT - 2 Left Right juny Sould Cap 610D Right 2 RLM 1 - 8LM 2 - 8LM 3 - 8LM 4 - LogY Int, Time: 2 L315 - 8LM2/ms 2 12 Nr - Threshold	Ener [Mcmmcrs] Fram position data (24.01/15 15:36:26) C C 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	
Right DW -9,387 Centre DW -8,462 Display jant ≥ Left jan skickely ≥ Right jan skickel ⊂ Cap 6100 Positions: ≥ Set ≥ LVDT Cam Cam Res Mot E D	Enumportition data (24.01/13) Cf. Cf. 0 -4.390	
Right DW -5.387 Center DW -6.462 Display jant. 2 Left jan siloched 2 Right jan doshid Cap 6100 Pecilizenc 2 fest 2 LVDT Lim - Res - MetE - P RUM 2 RLM 1 - RLM 2 - RLM 3 - RUM 4 - Legy let, Time: 2 L315 - RLM2ns 2 L2 Nr - Threshold	Ener [Mcmmcrs] Fram position data (24.01/15 15:36:26) C C 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	
Right DW -5.387 Contro DW -6.462 Display junt: 2 Left juny situation 2 Right juny sould Cap 610D Positions: 2 Set: 2 LVDT - 2 Left Right juny Sould Cap 610D Right 2 RLM 1 - 8LM 2 - 8LM 3 - 8LM 4 - LogY Int, Time: 2 L315 - 8LM2/ms 2 12 Nr - Threshold	Ener [Mcmmcrs] Fram position data (24.01/15 15:36:26) C C 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	



BPM Collimator Alignment



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- Centers compatible with Beam Based Alignment (comparison done without correction of electronic gains etc.)
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Collimator Alignment: TCTPH.4R1.82		T d' 8
C + REA hesp		
File Settings Reset More-displays Help 87M		45 42
Jav corners Pesitions/Angles Increment EEA EPH	(0, mees) ((((((((((((((((((Horizontal
Automatic EPM-based Alignment	Bram less data (28/85/15 15:38:28)	
	<u><u><u>4</u></u> 5.06-6-</u>	TCP.C6R7302
Minimum Cap (mm) 10 Align	1.00.6	TCTPH4R182
Alignment Error (sm) 5 Stop All	1 200-6-	Vertical
Time Interval (x)	100.6 March all of balance of a balance barrens warred by	
ALICNED	153468 153428 153648 153588 153528 153540 153688 153628	TCP.D6R7.82
	Jaw positions (28/05/15 15/36/27) Ø Ø	TCTPK4R182
Averaging Average over (s)		
Concerning Annuals into (r)	0 1.00- 8 1.00	
Inputs alogy - ready to movel		
	5.00	
eft Jaw 🛇 UP-IN 🔇 UP-OUT 🔇 DW-IN 🔇 DW-OUT	1 - 1640	
ight jaw 🔕 un-in 🔕 un-out 🔕 Dw-in 🔕 Dw-out	1534.00 1534.20 1534.40 1535.00 1535.20 1535.40 1536.00 1536.20 time [Mcmarcia]	
MU COLL Q UP Q DOWN	Dectorede Data (28/95/15 15:38:28) 25 25	
Positions readout from the law-level	F 440	
	2 A.19	
LVDTs • Left UP 6.142 Gap UP 17.629	§ 6.19	
Jaw edges w Left DW 8,343 Gap DW 17,546	0.08*	
	8.17	
Right.0P -5.483 Centry 0P -6.73	15:14:08 15:14:28 15:14:48 15:15:08 15:15:28 15:15:48 15:36:08 15:36:28 Eine [Mcmatcis]	
Right DW - 9.387 Centre DN - 8.482	Beam position data (28/85/35 15/36/28)	
isplay jani 😨 Left Jan Blashedi 😨 Right Jan (solid) 🛄 Gap 61015	I too	
unitions: 2 Set 2 LVDT	£ -0.399 \$ -0.409	
UN REAL DEAL DEAL DEAL DEAL	E -0.600	
	2 -1.800	
et, Timme: 😥 3, 315 🛄 41, 92ms 😥 32 Hz 🛄 Threshold	153400 153420 153440 153500 153520 153540 153600 153620	
PA ELU EN ELD EN EN EN EAN	time [Memarcus]	
O III Options	Tiew plots Seve settings	
No Exception to display		

First comparison Squeeze beams

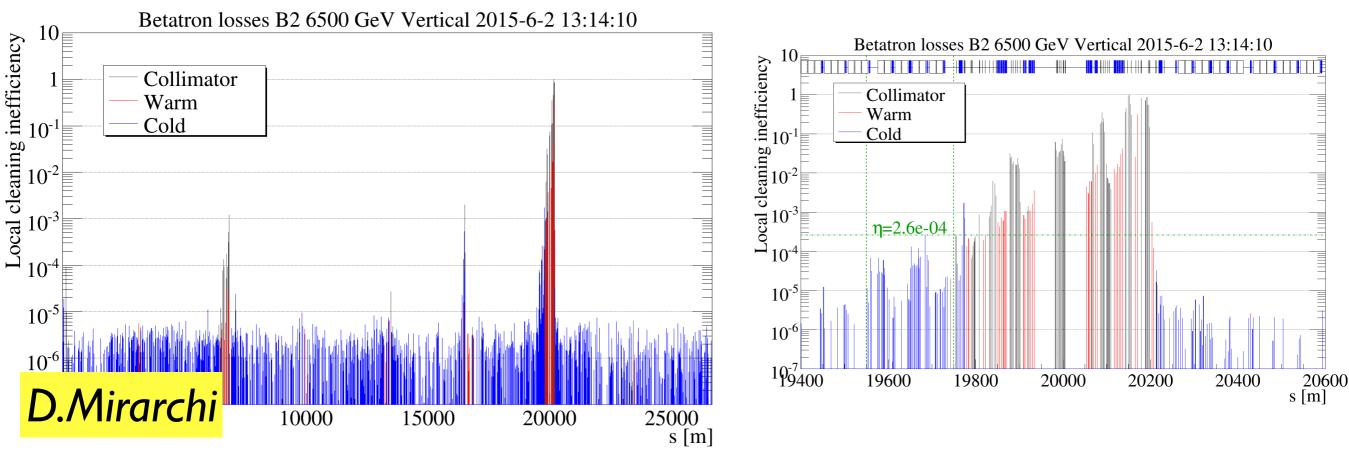
(mm)	BBA	BPM UP	BPM DW	MAD-x
TCTPH.4L1.B1	-0.503	-0.772	-0.367	-0.5275
TCTPH.4R1.B2	-0.843	-1.185	-0.905	-0.865
TCTPV.4L1.B1	1.143	1.050	1.575	1.235
TCTPV.4R1.B2	1.057	1.065	1.175	0.9575



• Collimation hierarchy and cleaning performance is validated through the analysis of loss maps. Minimum validation for start-up:

INJECTION Inj. Prot. IN	BI- H	BI -V	B2-H	B2-V	+500Hz	-500Hz
INJECTION Inj. Prot. OUT	BI-H	BI -V	B2-H	B2-V	+500Hz	-500Hz
Flat Top	BI-H	BI -V	B2-H	B2-V	+500Hz	-500Hz
End Squeeze	BI-H	BI -V	B2-H	B2-V	+500Hz	-500Hz
Colliding all IRs	BI-H	BI -V	B2-H	B2-V	+500Hz	-500Hz

___done with gentle loss maps technique

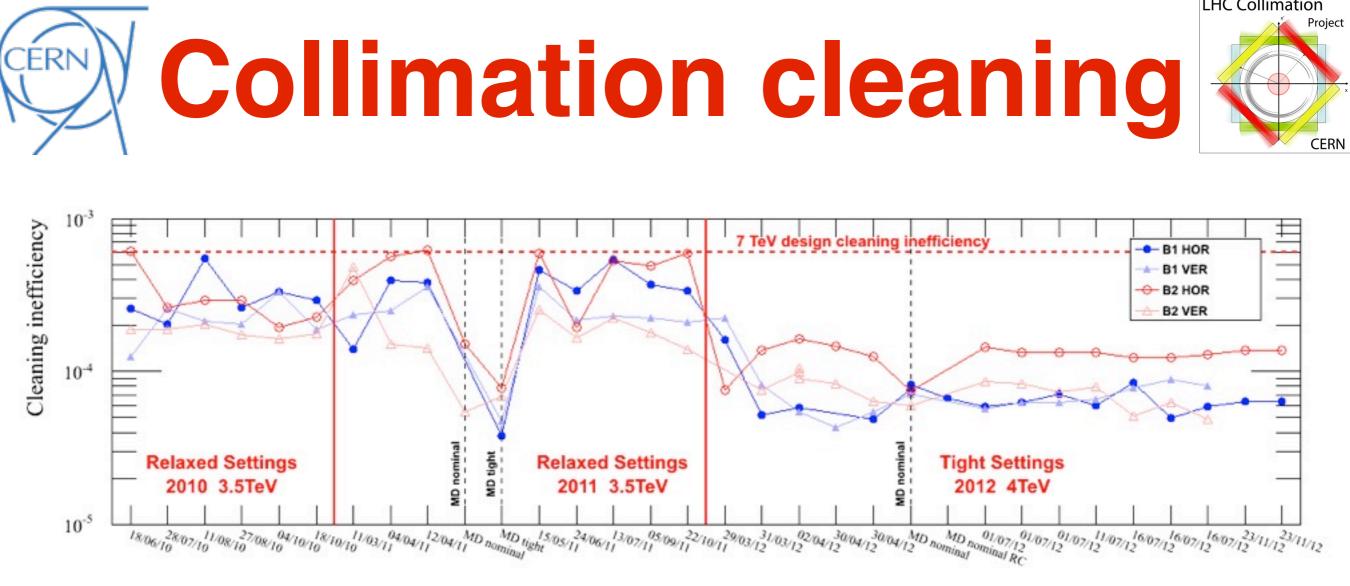


B. Salvachua

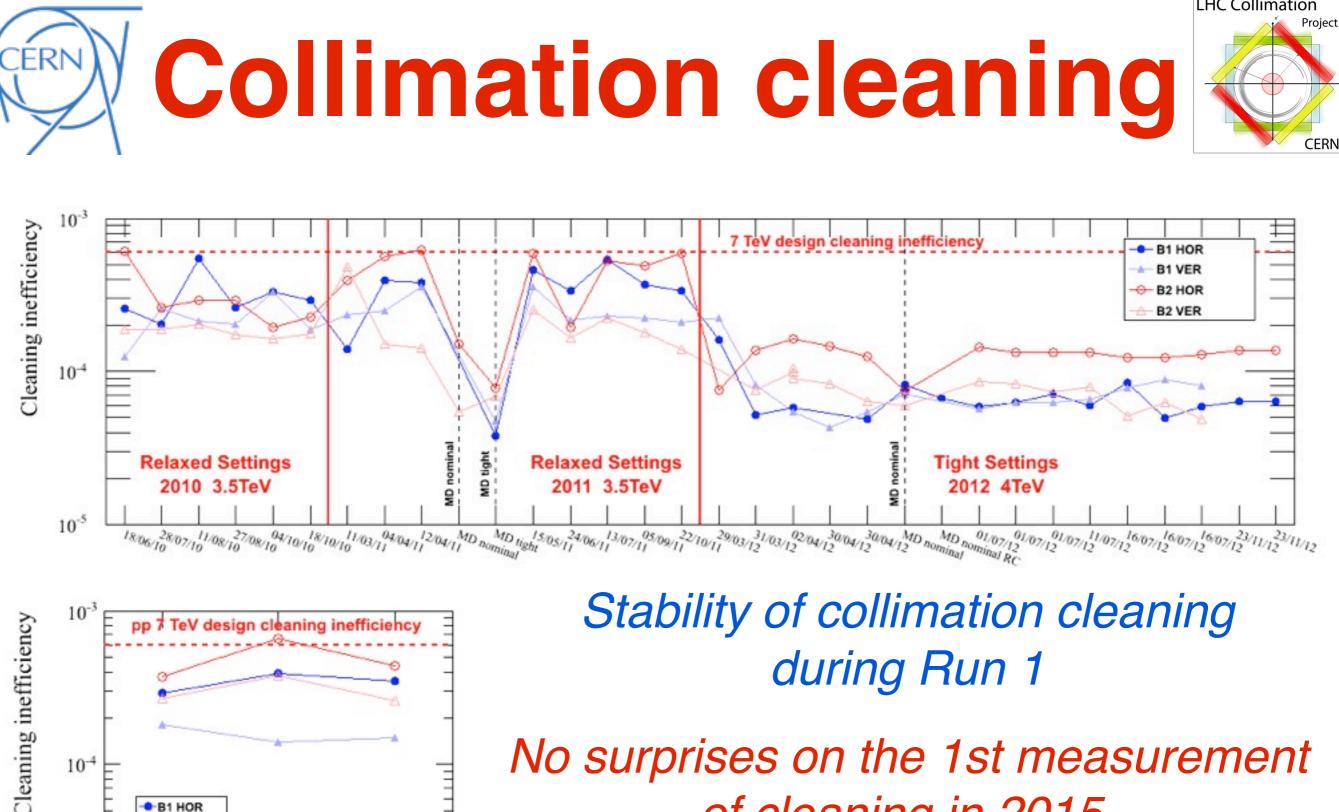
23/02/2015 - Collimation WG

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Stability of collimation cleaning during Run 1



No surprises on the 1st measurement of cleaning in 2015. Machine stability and reproducibility will be shown in the next months

 10^{-4}

 10^{-5}

B1 HOR B1 VER

B2 HOR

5/05/2015

B2 VER

mm-kept 2012

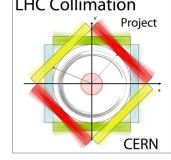
2015 6.5TeV

01/06/2015

2015

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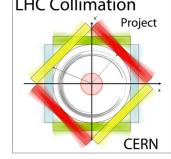
New techniques for loss maps



- Betatron loss maps are done with the ADT transverse damper (H/V and both beams are done in the same fill, even different beam modes)
- However, off-momentum loss maps require 1 fill per side (+/-500Hz RF freq shift)
- New techniques in collaboration with RF (*Ph. Baudrenghien, M.Jaussi, H.Timko*) are being explored. Three paths that could be combined are being explored:
 - blow-up the bunches longitudinally before doing the loss map so that a smaller frequency shift can be done.
 - add an RF noise so that you push the particles from the core to the off-momentum.
 - feedback based on BLM signals to control of the optimal frequency is being prepared.

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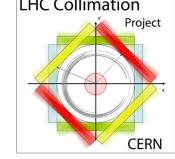
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 - feedback based on BLM signals to control of the optimal frequency is being prepared.

This was partially tested at 450GeV and at 6.5TeV recently. We managed to do 6 off-momentum loss maps in 1 fill but we need a bit more beam time to develop this technique which will later safe time in validation.

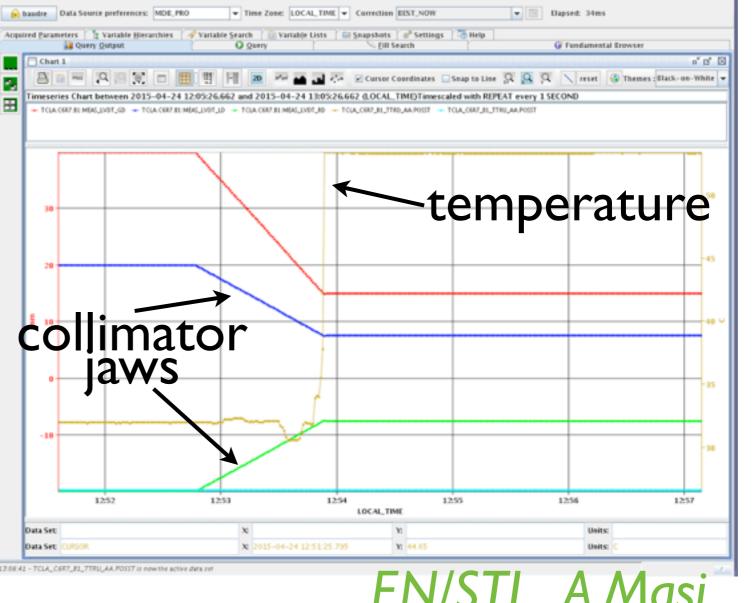




	Injection	6.5TeV
Temperature sensors*	1	
LVDT false reading	1	1

* 1 additional dump at injection during alignment





All temperature interlock reading and logging were tested as part as Machine Protection

collimator is moving (spurious false contact)

It cannot be repaired but an new interlock logic could be set in place to check both jaw sensors (upstream and downstream) before triggering an interlock.

0

0

Left DW

TCSG D4L7 B1

Water

23.4 C

0

Right DW

0 0 C

0



8/93 collimators

still full

monitoring of

temperature due

to redundancy of

sensors



Temperature Sensors

1 dump at Injection on false reading of collimator jaw temperature while

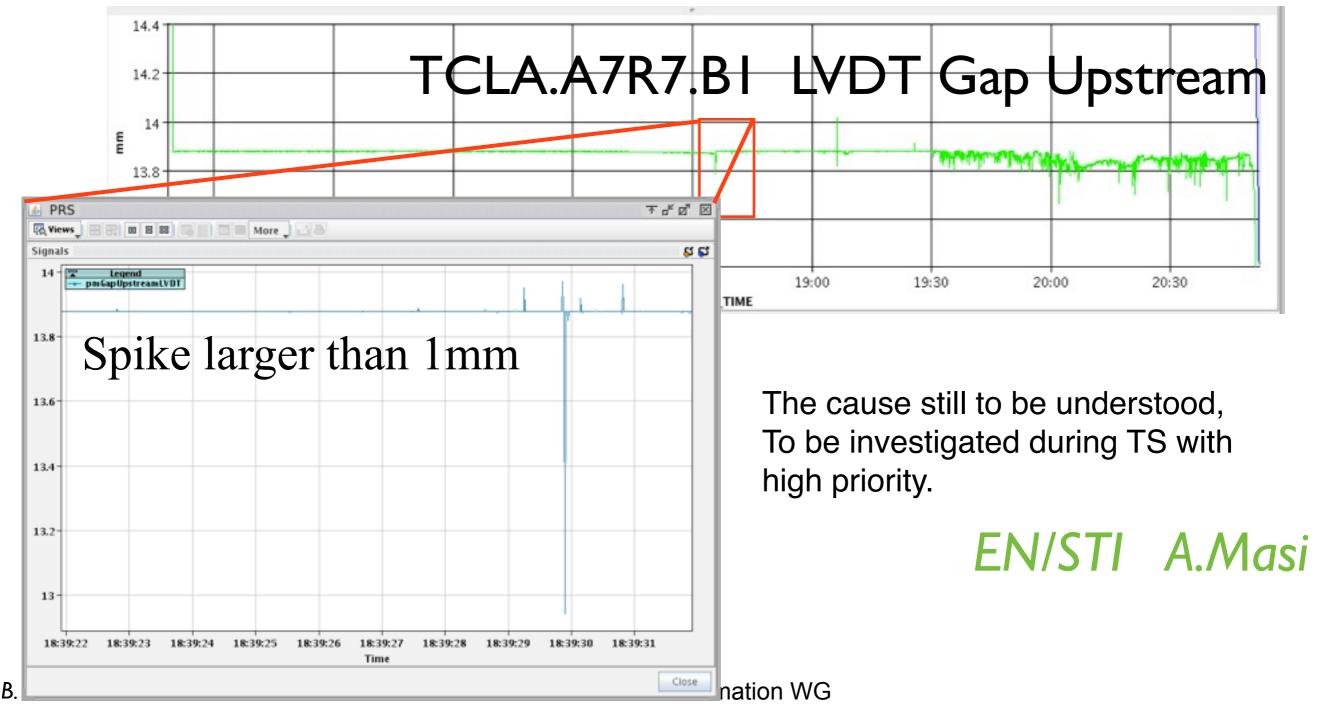






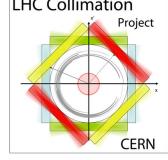


1 dump at injection and 1 at top energy (10-11June)





Summary



- Interlock status: in good shape, only the beta-star are missing and will be deployed in the next days before 48 bunches injection.
- Aperture at 80cm β^* was measured, the preliminary analysis shows agreement with expected aperture (~15.4 σ).
- Collimator settings for 2015 defined, deployed and validated. Beam time is needed to develop the new technique for off-momentum loss maps, this time will be recuperated if the procedure is well established.
- System is ready for intensity steps.