

# Automation in the SPS and LHC and its effect on operator skills

The past 20 years have seen great advances in the CERN accelerator control systems. Low level operation skills have been largely replaced by sophisticated sequencers and feedback loops. At the same time, a drive for greater efficiency, a tendency for more complex accelerator operations and a need to reduce the risk of "human error" have rendered these tools essential. The effect of this controls evolution on operator skills will be analyzed in the context of SPS and LHC accelerator operations at CERN.

Guy Crockford, BE/OP/LHC, CERN

#### Talk Content

- The CERN Accelerator complex
- Brief history of accelerator controls at CERN,
   A progressive evolution towards greater automation
- Automation tools in the SPS and LHC
- How to manage automation tools without eroding operator understanding





# The CERN Accelerator Complex





#### 1959 PS commissioning





#### 1976 SPS Startup, 400 GeV

- First fully distributed control system.
- Front end mini computers joined in a network to the control room.
- Application software written with "Nodal" interpreter.
- Operations Group taking an active role in application software development.



#### 1983 SPS P-Pbar collider. W, Z Boson





- Stochastic cooling key to producing intense antiproton beams
- Need for automatic countdown sequence of checks before extracting the precious Pbar stack
- 1988: prepare the SPS as the injector for the future Large Electron Positron collider, LEP
  - •UNIX workstations running "C" code application software
  - •High level software, physics parameter trims with full trim history

#### 1990s LEP operation up to 200 GeV





- Database driven settings management, trim incorporation
- Greatly improved reproducibility of the machine

# 2012 LHC operation at 4 TeV /beam



- Intensities ~4x10<sup>14</sup> @ 4TeV. Automation tools essential for safe beam control and fast turnaround between physics fills.
- Big advances in computing power and application software by now written in Java language.
- Well established sequence of tasks to drive the machine via Sequencer tool.





Achieve 10 fb<sup>-1</sup> Integrated luminosity by 4<sup>th</sup> August 2012

# Automation today in the SPS



 SPS providing beams to many users
 Fixed Target, Neutrino, various MD cycles, beams to LHC

- Need for frequent and rapid cycle changes (LHC fills).
- Tools to quickly check and optimize beams.





Π

#### Injector Chain: Cycle Management



- Allows rapid cycle editing through timing tables
- All machines linked together through same timing system
- Around 30 cycles resident in front end, ready to be "played"
- 20 years ago, an SPS cycle change would take at least 2 hours

generality lepic		Sequence Editor: Edit BCD /SFTLONG2 - CNGS1 - LHC1 - phase 0/1/2/			
<pre></pre>	e <u>E</u> dit R.Checker Tools <u>Specialist H</u> elp				
Image: space with the problem of the proble		8 B Z Z Z Z Z X X X X X X X X X X X X X X			
A         A         B					
Normal intermediate	lype-				
the construction of the construction o					
Import void line for the fore of t	Selection LELEARLY.2_0->CPS.I_LHC.2_2->SPS.LHCION2.7_3			<b></b>	
<ul> <li> <ul> <li></li></ul></li></ul>	Beam SPS VUSER LHCFAST1 V Preview				
Image:	AND V CPS V USER LHCPROBE V LEI EARLY.2_0				
OP       I	SPS LECTOR2.7_3				
opplie       image: imag	🗴 LEI 🗶 USER "				
Apply       Rest         Apply       Rest             Apply       Rest             Apply       Rest             Apply       Rest             Apply       Rest             Apply       Rest             Apply       Rest             Apply       Rest             Apply       Rest             Apply       Rest       Res       Res       Res					
Apply       Mark         Work ↓       Apply       Mark         Work ↓       Apply       Mark       Apply       Apply       Mark       Apply	Apply Borst				
< 1	Z-Work 🕈				
< 2 >>       1       2       3       4       5       6       7       8       9       10       11       12       13       14       15       16       17       18       9       20       21       22       23       24       25       28       29       30       31       32       33       34       35       36         VIETHING2       VIETHING2 <th col<="" th=""><th></th><th></th><th></th><th></th></th>	<th></th> <th></th> <th></th> <th></th>				
i c c c c c c c c c c c c c c c c c c c	s <-2-> 1 2 3 4 5 6 7 8 9 10	0 11 12 13 14 15 16 17 18 19 20 21	22 23 24 25 26 27 28 29 30 31 3	2 33 34 35 36	
i       i	P SFTLONG2	CNGS1	LHC_NOM		
Ref P       STR0       STR0       SEC       STR0       SEC	\$ SFTLONG2	CNGS1	LHC1		
SFIR0       SFIR0 <t< th=""><th>C &lt;-1→ 1 2 3 4 5 6 7 8 9 10 11</th><th>1 12 13 14 15 16 17 18 19 20 21 22</th><th>23 24 25 26 27 28 29 30 31 32 3</th><th>3 34 35 36</th></t<>	C <-1→ 1 2 3 4 5 6 7 8 9 10 11	1 12 13 14 15 16 17 18 19 20 21 22	23 24 25 26 27 28 29 30 31 32 3	3 34 35 36	
SFTRO       SFTRO       SETTION       LEATE       CAGE       MED       MED       LIC       MED       LIC       MED       EATE       CEATE       EATE       CEATE       CEATE       CROS       CEATE       MED       LIC       LIC       MED       MED <t< th=""><th>P SFTPRO SFTPRO EASTA TOF AD TOF</th><th>AD CNGS CNGS TOF TOF LHC LHC</th><th>LHC LHC TOF AD</th><th>AD</th></t<>	P SFTPRO SFTPRO EASTA TOF AD TOF	AD CNGS CNGS TOF TOF LHC LHC	LHC LHC TOF AD	AD	
1       2       3       4       5       6       7       8       9       10       11       12       13       14       15       16       17       18       19       20       21       22       23       24       25       26       27       28       29       30       31       32       33       34       35       36         SFTMO       SFTMO       NORMCPS       NORM	S SFTPRO EASTE	EASTE CNCS MD9	LHC EASTB	EASTE	
ATTOR       STIPUD       DASTA       OP       D       I       III       IIII       IIII       IIII       IIII       IIII       IIIII       IIIIIIII       IIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIIII					
NAME         NOMINAL         N	P 1 2 3 4 5 6 7 8 9 10 11 12 SFTPRO SFTPRO EASTA NORMER TOT NORMER AD NORMER TOT NORMER AT	2 13 14 15 16 17 18 19 20 21 22 23	24 25 26 27 28 29 30 31 32 33 3 LHC_A LHC_B NORMORE LHC_A LHC_B NORMORE TOT NORMORE AD STAGISO NOR		
TT2_03*     EXTE	SETERO				
1       2       3       4       5       6       7       8       9       10       11       12       13       14       15       16       17       18       19       20       21       22       23       24       25       26       27       28       29       30       31       32       33       34       35       36         NOMINAL LEPROC       NOMINAL LEPROC       NOMINAL LEPROC       NOMINAL LEPROC       EARLY       EARLY <t< th=""><th>TT2_D3*</th><th>TT2_D3 LHC T</th><th>TT2_D3* TT2_D3* EASTB</th><th>EASTB</th></t<>	TT2_D3*	TT2_D3 LHC T	TT2_D3* TT2_D3* EASTB	EASTB	
NOMINAL LIBRAGE         NOMINAL LIBRAGE         NOMINAL LIBRAGE         NOMINAL LIBRAGE         NOMINAL LIBRAGE         NOMINAL LIBRAGE         NOMINAL LIBRAGE         EARLY         EARLY <t< th=""><th>L 1 2 3 4 5 6 7 8 9 10 11 12</th><th>.2 13 14 15 16 17 18 19 20 21 22 23</th><th>24 25 26 27 28 29 30 31 32 33 3</th><th>(4 35 36</th></t<>	L 1 2 3 4 5 6 7 8 9 10 11 12	.2 13 14 15 16 17 18 19 20 21 22 23	24 25 26 27 28 29 30 31 32 33 3	(4 35 36	
NOMINAL LEIRLOC     NOMINAL LEIRLOC     NOMINAL LEIRLOC     EARLY     EARLY     EARLY     EARLY     EARLY     EARLY     EARLY     EARLY     EARLY	E LERLOC LERLOC LERLOC LERLOC	EARLY EARLY EARLY EARLY NOMINAL	EARLY EARLY EARLY EARLY EARLY	NOMINAL LEIRLOC	
	NOMINAL NOMINAL NOMINAL NOMINAL	EARLY EARLY EARLY EARLY NOMINAL	EARLY EARLY EARLY EARLY	NOMINAL	
				- LUNLOC	
28/jul/2012 02:33 USP OPERLIC/MAINSPOP RS CARACTER SOLVER S	28/Jul/2012 02:33	OPERLIC.MAIN.SPSOP	INSISOP37ZCIX V RChecker		
				<u>/</u>	

# SPS: Automatic Steering (Autopilot)



#### • Automatic steering of beam on fixed target

OpenYASP V4.99.60/june 12 T2Transfer / SFT LONG L9690 2010 V1 / SPS.USER.SFTLONG2 \_ 0 File Acg&HW Options Status-Control Optics & Model Steering Trim Machine-specials Help Injection SPS.USER.SFTLONG2: 4400-14090 ms Waiting for Data. 🔟 🔻 RBA: spsop Acg SPS.USER.SFTLONG2 oscillations Data Sets Autopilot 17:52:09 - Trying to relogin with policy. LOCATION 17:52:09 - rbac.setup = 'PRO SHARING-T6(-)/T4+T2(+) × Configuration 17:52:10 - RBAC: Attempting SSO login SHARING-T4(-)/T2(+) × Skip acquisitions 17:52:10 - No master or renewable token found Steering 17:52:10 - RBAC: Attempting ping login 17:52:10 - Connected to remote server: "https://rbac-pro2.cem.ch: Read CODs Reloading × Stop when target reached 17:52:10 - RBAC: Ping login succeeded SPLITTER1 × 17:52:10 - RBAC: Attempting SSO login Simulation mode 17:52:10 - Master token found Autopilot × Convenient Client List 17:52:10 - Connected to remote server: "https://rbac-pro1.cern.ch: 17:52:10 - RBAC: SSO login succeeded Stop T2-SYMMETR 17:52:10 - Obtained LOCAL MASTER token: #0xc36fc902 17:52:10 - Obtained APPLICATION token: #0xd0ab3c95 17:52:10 - New RBA Token was set to CMW: RBAToken[serial=0xd0 but may erode 17:52:10 - New subject is set! 17:52:10 - rbac.setup = 'PRO' 18:23:04 - Autopilot starting 🗌 Autosave Simulation 19:25:09 - Autopilot starting operator 20:28:05 - Autopilot starting Status Difference Sub. dp/p 20:34:40 - Autopilot starting 15-07-2012 20:35:14 --> Idle Load Last ability to make YASP DV T2Transfer / SPS.USER.SFTLONG2 / SFT LONG L9690 2010 V1 - 0 × 🔀 Views 🛛 🕀 💷 🛢 📰 🗔 🚍 🖿 🗰 More 🖕 🛃 🖴 P 399.686 GeV/c - SC # 285 - SPS.USER.SFTLONG2 - 15/07/12 20-35-19 o Ø a fully manual -0 957 / RMS = 2 935 / Dn = -1 5871 / Svm = 37.0 / lean 94a 99 / T F10/111 = Mult = 25 H Pos [mm] transfer line \_ -5 SPLITTER1 TT20-TED SPUTTER -10steering 15 5 10 Monitor H P 399.686 GeV/c - SC # 285 - SPS.USER.SFTLONG2 - 15/07/12 20-35-19 ° Ø -1 306 / RMS = 7.657 / Dp = -1.5871 / Sym = 94a - 99 / I [10^11] = 37.0 / Mult = 2.5 Mean = V Pos [mm] -5 TT20-TED SPLITTER1 SPUTTER2 T2 -10-15 ŝ. 10 Monitor V

# SPS: Beam Quality Monitor



- Check of key beam parameters before extraction to LHC
- Check on batches of up to 144 bunches
- Avoids bad quality beam reaching the LHC
- Important fixed display snapshot of each extraction

<u>e.</u>		SI	PS Beam	n Quality	/ Monito	r - SPS.	USER.LH	IC4							_ 🗆 ×
Eile Reference															
🧐 🕪 🔰 🕨 🖶 💼 🔶 12 Jul 2012 🛛	8:27:42 SPS - LHC4	, 25		LHC4 -	03	🖌 Auto S	elect LHC	Cycle							
Expected Beam Pattern		Results			1,202										
SPS LHC		LHC Mas	tership				55	SC Numbe	r: 21888				20	12.07.12	08:26:54
		Ctature	Cranhe	Viniertie	n Cranhe	Data									
		Time	Grade M	Mastar	Dumm	Data	1 at Da	Ductomath	Dulenat	Du Deelu	Du Deels	Cambrillia	Catallitas	Dettern	Warnings
Bunch Spacing:	650 ns	08:26:54	LHC4	Master	Enabled	Beam	Ist BU	Bu length	Bu Lengt	Bu Peak	BU Peak	. Stability	Satellites	Pattern	warnings
	* * *	08:26:14	LHC4	LHC	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	
Number of Bunches per Batch:	1	08:25:34	LHC4	LHC	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	
	<b>v</b>	08:24:55	LHC4	LHC	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	
	<u>A</u>	08:24:15	LHC4	LHC	Enabled	OK	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	
Number of Batches:	4	08:23:36	LHC4	LHC	Enabled	Ok	Ok	Ok	0k	Ok	Ok	Ok	Ok	Ok	
		08:22:56	LHC4	LHC	Enabled	Error	Ok	Ok	Ok	Error	Ok	Ok	Ok	Ok	
Number of Bunches Total:	4	08:22:16	LHC4	LHC	Enabled	Error	Effor	Ok	Ok	Error	Ok	OK	Ok	Ok	wrong
	¥.	08:21:37	LHC4	LHC	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	
		08:20:18	LHC4	LHC	Enabled	Error	OK	OK	Ok	Error	OK	Ok	OK	OK	
Sattings		08:19:38	LHC4	LHC	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	
second		08:18:58	LHC4	LHC	Enabled	Error	Error	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Wrong
BQM Beam Dump:	Enabled 💌	08:18:19	LHC4	LHC	Enabled	Error	Ok	Ok	Ok	Error	Ok	Ok	Ok	Ok	
Verify Pattern:	Enabled 💌	08:17:39	LHC4	LHC	Enabled	Error	Error	Error	Error	Ok	Error	Error	Error	Error	No bea
Acquisition Full Scale:	1 V 💌	08:17:00	LHC4	LHC	Enabled	OK	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	
, addresses , an even		08:16:20	LHC4	LHC	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	
Bunch Length Min Threshold:	0.95 ns	08:15:40	LHC4	LHC	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	
	**	08:15:01	LHC4	LHC	Enabled	OK	OK	OK	OK	OK	OK	OK	OK	OK	
	A AA	08.14.21	LHC4	LHC	Enabled	Error		OK	OK	Error		OK		01/	
Bunch Length Max Threshold:	1.80 ns	08:13:02	LHC4	LHC	Enabled	Error	Ok	Ok	Ok	Error	Ok	Ok	Ok	Ok	
	* **	08:12:22	LHC4	LHC	Enabled	OK	OK	OK	Ok	Ok	OK	Ok	OK	OK	
Runch Length Standard Deviation:	Ô 5Ô	08:11:43	LHC4	LHC	Enabled	Error	Ok	Ok	Ok	Error	Ok	Ok	Ok	OK	
builen Lenger Stanuaru Deviation.	**	08:11:03	LHC4	LHC	Enabled	Error	Ok	Ok	Ok	Error	Ok	Ok	Ok	Ok	
		08:10:24	LHC4	LHC	Enabled	0k	Ok	Ok	0k	Ok	Ok	Ok	Ok	0k	
Bunch Peak Standard Deviation:	0.430v	08:09:44	LHC4	LHC	Enabled	Error	Error	Error	Error	Ok	Error	Error	Ok	OK	No bea
	***	08:09:04	LHC4	LHC	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	OK	
	â â â â â	08:08:25	LHC4	LHC	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	
BUILTI PEAK MIN INTESNOID:	0.230V	08:07:45	LHC4	LHC	Enabled	OK	OK	OK	OK	OK	OK	OK	OK	OK	Could s
		08:06:26	LHC4	LHC	Enabled	OK	OK	OK	OK	OK	OK	OK	OK	OK	Could r
Bunch Peak Max Threshold:	0.485v	08:05:46	LHC4	LHC	Enabled	Error	Error	Error	Error	Ok	Error	Error	Ok	Ok	No hear
	***	08:05:07	LHC4	LHC	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	
	. 1 .00	08:04:27	LHC4	LHC	Enabled	OK	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	
Bunch Peak Modulation Index Threshold	1: 1.00	08:03:48	LHC4	LHC	Enabled	Error	Error	Error	Error	0k	Error	Error	Error	Error	No bea
		08:03:08	LHC4	SPS	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	
Satellites Intensity Threshold:	15%	08:02:28	LHC4	SPS	Enabled	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	Ok	
	**	08:01:49	LHC4	SPS	Enabled	OK	OK	OK	Ok	OK	Ok	Ok	Ok	OK	
	A A	08:01:09	LHC4	SPS	Enabled	Ok Ok	Ok Ok	0k	Ok Ok	Ok	Ok	Ok	Ok	0k	
Satellites Mid Bucket Threshold:	5%	08:00:30	LHC4	SPS	Enabled	OK	OK	OK	OK	OK	OK	OK	OK	OK	
	<b>v</b> .	07:59:50	LHC4	SPS	Enabled	Error	Error	OK	OK	OK	OK	OK	OK	OK	Wrong <b>v</b>
<b>▲</b>		07.39.10	LINCH	313	Litabieu	CITO	Cirol	OK	UK.	UN	OK	UK	UN	UN	mong (*
Start Monitoring 🔤 Stop	Save Co	ntinuous Sa	ving /use	er/slops/d	ata/SPS_D4	TA/OP_D	AT A/SPSBQ	M							
08:27:10 - Results Ok.															1

# LHC Injection Quality Check



2x10<sup>13</sup> per batch @ 450 GeV from SPS

Automatic check of each batch of beam as it is injected

- Kicker pulse
- Beam loss monitors
- RF Bucket and phase check
- Injection oscillations and transfer line beam position



# The LHC Sequencer

- Drive machine through a clear predefined set of sequences.
- Allows for parallel task execution.
- Can run sequences automatically, or manually step through.



•Clear execution status and error reporting.

•Sequences fully maintained by operations group. Convenient sequence editing tool.

# The LHC Sequencer



	Sequencer Execution GUI (PRO) : 2.1.2	
quencer Feedback Help		
▼ RBA: Ihcop		
LHC NOMINAL SEQUENCE (B1_B2) 없		
LHC NOMINAL SEQUENCE (B1 & B2)	PREPARE LHC FOR INJECTION (ALL BUT PCS) - + x	BI CHECKS BEFORE INJECTION -+ x
PREPARE LHC FOR INJECTION (ALL BUT PCS)     INIECTION PROBE BEAM	▼	▽ □ BI CHECKS BEFORE INJECTION
▶	MOVE TO STATE=PREPARATION	CHECK LBDSKICKER B1 IS NOT ARMED
DISABLING BEAM 1 INJECTION AND TOI B1 OU	CHECK HYPERCYCLE 4TEV_10APS_0.6M ACTIVI	CHECK LBDSKICKER B2 IS NOT ARMED
PREPARE RAMP		BPM CALIBRATION
	BI CHECKS BEFORE INJECTION	DC BCT QUICK CALIBRATION     TEST FAST BCT DUMP ACOULSITION CHAIN
CONTRACTOR SOLUTION STATES STA		DC BCT (24-BIT ADC) OFFSET COBBECTION
PREPARE COLLISIONS FROM END OF SQUEEZE A move state prane mode - state prane	CHECK BLM MCS AND START BLM SANI	SET BLM CAPTURE TYPE = IOC
PROGRAMMED DIMP WHEN STABLE BEAMS	BIS PRE-OPERATIONAL CHECKS	RESET INTERLOCKED BPM
RAMP DOWN - PRECYCLE COMBO	SMP PRE-OPERATIONAL CHECKS	B1: RESET BMPD
	E SET BOM TO PILOT SENSITIVITY	B2: RESET BPMD
	PREPARE FEEDBACKS FOR INJECTION	SET BPM SENSIT=PILOT
	EXAMPLE SEND COLLIMATORS FROM PHYSICS TO II	RESET TURN-BY-TURN BPM CONCENTRATOR
	SET OUT THRESHOLDS FOR ROMAN POTS	
	CONFIGURE BEAM CONTROL ACOULSITION FO	
	SEND ADT FROM PHYSICS TO INIECTION	
	SWITCH OFF ABORT GAP CLEANING	
	DRIVE INJECTION CLEAN AND ABORT GAP	
	▶	
	(	
m	PREPARED	PREPARED
REPARED	Run Suspend Step Skip Skip	🕨 Run 🔢 Suspend 🤝 Step 📭 Skip 🔳 Stop
🕨 Run 🚺 Suspend 🤝 Step 📭 Skip 🔳 Stop	Console Details Result	Console Details Result
	user=null]:user=UserPrincipal[name=lhcop, roles=	user=null]:user=UserPrincipal[name=lhcop, roles=
Details Result	[[DIAMON-Operator, SeqLhcOperator,	[[DIAMON-Operator, SeqLhcOperator,
	OP-Daemon, SPS-Operator]]];extra=null]	OP-Daemon, SPS-Operator]]];extra=null]
	SWITCHING TO MODE: MD	SWITCHING TO MODE: MD
	-	
rver logs		
quence prepared : SequenceId = PREPARE LHC FOR INJEC	TION (ALL BUT PCS)@1478@20120729234144943	
quence prepared : SequenceId = BI CHECKS BEFORE INJE	CTION@1479@20120729234303655	=
		Ľ
		C Crockford CEDN

#### LHC: The State Machine

- Checks that all mandatory tasks have been performed at key breakpoints in the sequence
- Gives "green light" before proceeding to a new BEAM MODE
- Handshake with experiments

30-Jul-2012 02:37:	56			Beam Mod	le: SETUP
	INJECTION	ADJUST	BEAM DUMP	TI2 SETUP	TI8 SETUP
LHC Handshakes	READY	STANDBY	STANDBY	STANDBY	STANDBY
ATLAS Handshakes	READY	VETO	VETO		
ALICE Handshakes	READY	VETO	VETO	VETO	
CMS Handshakes	READY	VETO	VETO		
LHCb Handshakes	READY	VETO	VETO		VETO
OTEM Handshakes	READY	VETO	νετο		





#### LHC Software interlock + Announcer

- Software surveillance and interlock on machine critical systems and states.
- Latches an interlock beam dump or injection kicker inhibit.
- Compliments hard wired beam interlocks.
- Same system in both SPS and LHC.
- The Announcer is separate system based on the same software (separate logic tree).
- Monitors various systems to announce warning messages according to equipment state.



#### LHC Tune Feedback



- Tune (and orbit) feedback essential on LHC ramp
- Care needed to achieve a reliable measurement
- Real-time trims need to be checked carefully and end ramp

# LHC Luminosity scan and leveling





IPS Lumi Leveling: Move BEAN1 of 0.8 µm and BEAM2 o IPS Lumi Leveling: START MOVING BEAMS of 1.5 [µm]

IP8 Lumi Leveling: Leveling disabled by the IP8 Lumi Leveling: LEVELING ALGORITHM END

a certain range

LHCb leveling

#### LHC: Post mortem viewer





WAO 2012

# Coping with Automation



Train new operators on beams where they have freedom to make trims and optimize

- Involve crews in non-standard operations and MD studies (which involve switching back to manual operation) where ever possible
- Make crews the stakeholders in automation processes. Software development and sequence maintenance
- Avoid "Black Box" systems. Provide a display and interface







- Automation today in the SPS and LHC has evolved over many years through the experience gained from various accelerator projects, and made possible by technical advances in computer controls.
- Ever more ambitious and technical accelerator projects require a larger degree of automation to operate safely and efficiently.
- Operator workload today implies a higher degree of multitasking. A larger number of tasks must be performed both quickly and efficiently.
- Operations should also be involved in automation process development and maintenance.
- Handling intense beams at high energy in the LHC leave no room for operator error. Automation becomes an imperative.

#### Thanks for your attention!





WAO 2012