Welcome to Evian - 2017

R. Steerenberg, BE-OP
8th Time in Evian

- 19 & 20 January 2010
  - Hilton Hotel & Palais Lumière
- 7 - 9 December 2010
  - Hilton Hotel
- 12 – 14 December 2011
  - Hotel Royal
- 17 – 20 December 2012
  - Hotel Ermitage
- 2 – 4 June 2014
  - Hotel Ermitage
- 15 – 17 December 2015
  - Hilton Hotel
- 13 – 15 December 2016
  - Hotel Ermitage
- 12 – 14 December 2017
  - Hotel Ermitage
Evian LHC Operation workshop, Mike’s baby

TRUE STORY: I GAVE MY BABY UP FOR ADOPTION

…and to only thing he gets..

…one bottle for every year..
While he prefers…. 
Change of Physics Coordinators
The Magic Physics Coordinators

Physics coordinator Jamie retires after 2 intense years

He very successfully accomplished his “peacekeeping” mission

Christoph, who was deputy takes over as physics coordinator

The master of filling schemes
New Deputy Physics Coordinator

Brian Petersen

Rende Steerenberg

Evian - 2017
12 December 2017
A quick look back at 2017
2017, ... another eventful year

- **Apr 29**<sup>th</sup> - First 2017 beam
- **May 23**<sup>rd</sup> - First Stable Beams
- **Jun 9**<sup>th</sup> - 1st time 2820 bunches at 450 GeV
- **Jun 3**<sup>rd</sup> - RF full de-tuning operational
- **Jun 5**<sup>th</sup> - 1 week scrubbing run and 1st signs of losses in 16L2
- **Jul 3**<sup>rd</sup> - 7**th** TS #1
- **Jul 20**<sup>th</sup> - Orbit corrector mitigation 16L2
- **Aug 9**<sup>th</sup> - Record Peak Lumi: $1.74 \times 10^{34}$
- **Aug 10**<sup>th</sup> - Planned 16L2 beam screen flushing
- **Aug 12**<sup>th</sup> - 16L2 beam induced Quench
- **Oct 2**<sup>nd</sup> - Switch to high Brightness 8b4e
- **Nov 12**<sup>th</sup> - Xenon ion fill
- **Dec 30**<sup>th</sup> - 45 fb-1 reached
- **Dec 11**<sup>th</sup> - End of 2017 run

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**EYETS**

Rende Steerenberg

Evian - 2017

12 December 2017
2017 Intensity ramp up with BCMS

- Smooth intensity ramp up, increasing the number of bunches
- First dumps on 16L2 losses experienced
16L2, at some point we were all puzzled…

Even the Boss came to turn the knobs 😁
Losing and Reconditioning

- **Variation of number of bunches** during the **“struggle” period**

  - Attempting 2556 bunches
  - Ramp up to 1500 bunches
  - Running with 1500 bunches & frequent dumps

- **16L2 Beam Loss “Signatures”** that result in beam dumps
Cryo Heat Load: BCMS vs 8b4E

8b4e intensity ramp up
8b4e running with 1900 bunches
BCMS 1500 bunches

Total intensity [$10^{13}$ p•]\n
Heat load [W]

Normalized heat load [W/p•]

8b4e

S12
S23
S34
S45
S56
S67
S78
S81
Imp.+SR
Standard 25 ns 8b4e Beam

- 8b4e = 8 bunches + 4 empty buckets

- Due to the gaps in the 25ns bunch trains the electron cloud production is largely suppressed
- Similar scheme as for the 25 ns standard beam
- At 2.5 GeV triple splitting, populating only two first buckets and leaving 3rd empty

8b4e 25 ns: PSB bunches divided by : 2 → 7 x 2 x 2 x 2 = 56
Each PSB bunch divided by 2 leaving 1 bucket empty at h=21
At high energy each bunch/bucket split in 4 → 8b4e
8b4e BCS Beam

• **8b4e = 8 bunches + 4 empty buckets**

• For same LHC bunch intensity PSB bunch intensity and transverse emittance is ~50% of standard scheme

• No longer splitting but batch compression by adding empty buckets

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8b4e 25 ns: PSB bunches only merged: $8 \rightarrow 8 \times 2 \times 2 = 32$

At high energy each bunch/bucket split in 4 $\rightarrow$ 8b4e
Integrated Performance

- ATLAS / CMS: 50 fb\(^{-1}\)
- LHCb: 2 fb\(^{-1}\)
- ALICE: 19 \(\mu\)b\(^{-1}\)

The total integrated luminosity since the start of LHC is approaching 125 fb\(^{-1}\)

Beyond expectations
LHC Physics Run 2017

- 2556 bunches until early August, despite 16L2 induced beam loss
- Beam screen flushing failed to mitigate 16L2 issue
- Stable operation only with ~1900 bunches of the 8b4e beam
- Despite 16L2 the LHC ran well above design peak luminosity, \(>2 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}\), but no longer visible due to levelling at \(1.5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}\)
Luminosity Levelling & Anti-Levelling

- Initially we level the ATLAS & CMS luminosity down to $1.5 \times 10^{34} \text{ cm}^{-2}\text{s}^{-1}$, using beam separation.
- Once the luminosity burn-off kicks in we apply anti-levelling by reducing the crossing angle and increase the instantaneous luminosity.
LHC Availability & Improvements

- **High machine availability**, resulting in high stable beam time ratio
- The machine availability is high thanks to all the efforts made on all the sub-systems, by all the equipment and support groups
- **Excellent** functioning of **machine protection**
- **HL-LHC methods successfully deployed in LHC**, such as ATS, RF full detuning
- **MDs** were **made operational** scenarios
- Many **enhancements made on diagnostics systems** (ADTObsBox, diamond BLMs, etc.) help to **better understanding** of Machine and beam (Instabilities, coupling, etc.)
Actions From Previous Evian & Chamonix
Cycle Optimisation

- Ambitious estimates to optimise cycles

### Nominal cycle

Further optimization to be pursued – squeezing the pipes

<table>
<thead>
<tr>
<th>Beam Mode</th>
<th>2016 Median</th>
<th>Comment</th>
<th>2017 Median (estimate)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TURN-AROUND</td>
<td>5.2 hours</td>
<td>Tends to be fault dominated. Gain from beam process efficiencies.</td>
<td>4.5 hours</td>
</tr>
<tr>
<td>INJECTION</td>
<td>51.8 min</td>
<td>144b injection. Diagnostics.</td>
<td>40 min</td>
</tr>
<tr>
<td>PRERAMP</td>
<td>4.2 min</td>
<td>Optimise sequencer.</td>
<td>3 min</td>
</tr>
<tr>
<td>RAMP</td>
<td>20.4 min</td>
<td>PPLP ramp</td>
<td>19 min</td>
</tr>
<tr>
<td>FLATTOP</td>
<td>4.2 min</td>
<td>Qchange moves to EoS.</td>
<td>0 min</td>
</tr>
<tr>
<td>SQUEEZE</td>
<td>18.0 min</td>
<td>CRS to 1m. New optics. Qchange.</td>
<td>11 min</td>
</tr>
<tr>
<td>ADJUST</td>
<td>14.1 min</td>
<td>Includes Totem bump. Collide all IPs in parallel.</td>
<td>10 min</td>
</tr>
<tr>
<td>Total</td>
<td>112.5 min</td>
<td></td>
<td>83 min</td>
</tr>
</tbody>
</table>

-30min reduction in sum of beam process

Did we manage? If not why not?

Actions from Evian & Chamonix
LMC 22 March 2017, by Mike Lamont
Time at Injection

- We spend 50% more time at Injection and came up with a set of potential improvements.

Nominal cycle - injection

- Injection process – clearly the area to target

- “50% more time filling than necessary”
  - Diagnostics, automatic tools, stuff to clean up,
  - IQC thresholds should be more consistent with respect to BLM dump thresholds.
  - Better monitoring and management of setting changes through the chain
  - Training
  - Info exchange between accelerators
  - Push diamond BLMs into IQC

Did we manage?
If not why not?
Can/should we further improve?

Action: OP, BI

Actions from Evian & Chamonix
LMC 22 March 2017, by Mike Lamont
Luminosity levelling

- We wanted to try to make crossing angle levelling a part of operation

**Luminosity levelling**

- It was clear that exploring the potential benefits of levelling is desirable – both for the performance in 2017 – and in order to gain experience for the future.
- The consensus was to try to make crossing angle levelling a part of the operational scenario for 2017.
- Real time dynamic levelling (out of the box) – pick this up again (WIP)

We managed to make this part of routine operation

Otherwise 8b4e pile-up would have been too high in ATLAS and CMS

Actions from Evian & Chamonix
LMC 22 March 2017, by Mike Lamont
Some limitations to be lifted

LHC Limitations

SPS beam-dump
Nb of bunches per injection limited to 96
Total number of bunches: 2200

LHC Injection kickers
Outgassing from ceramic
Bunch population limited to around $1.1 \times 10^{11}$

Electron cloud
Still significant heat-load within cryogenic limits
Dynamics – well handled by cryogenics feed-forward – no impact on operations in the present conditions

UFOs
Frequency has happily conditioned down

Chamonix summary by F. Bordry
Injectors

The performance of the LHC injectors in 2016 was overall a success as confirmed by the production of high quality BCMS beams which allowed the LHC to reach a beyond design peak luminosity.

Availability generally good but major events caused a total downtime of 360 hours for the LHC

Looking forward to:
- Replacement of the SPS internal dump
- Improved fault tracking
- BCMS and further developments
CERN Machine Advisory Committee

Very successfully done

We even did 30 cm

Continuing effort, not e-cloud dominated in 2017

Chamonix summary by F. Bordry

CMAC13 recommendations

Run 2 Operation

R1: Employing the ATS optics as the baseline for 2017 is highly preferable to gain operation experience for HL-LHC. It seems reasonable to start ATS operation at $\beta^*$ of 40 cm with somewhat tighter collimator settings.

R2: Make a plan to go to smaller $\beta^*$ with ATS to gain experience with the telescopic $\beta$ squeeze operation. $\beta^*$ below 33 cm is not preferred by experimenters due to pileup rate unless leveling is routinely used to mitigate.

R3: Continue the intensive study on e-cloud. For e-cloud in quadrupoles, pursue studies including intensity dependence measurement as planned in MD in 2017.

Availability, Technical Infrastructure, Collimation, Machine Protection

R4: Implement those measures that are needed in any case for HL-LHC as soon as possible (e.g.: ATS optics, fully detuned RF, leveling via $\beta^*$)

R5: Reevaluate allocated MD time in 2017 to align with the highest priorities given (Luminosity production & preparation for LS2). If necessary extend.

R6: Investigate the cause of varying electron cloud driven heat loads. Use information gained from warm up of sector 1-2.
## Planned 2017 Parameters

### 2017 scenarios

<table>
<thead>
<tr>
<th></th>
<th>Nominal</th>
<th>BCMS</th>
<th>BCMS+</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beta* (1/5) [cm]</td>
<td>40</td>
<td>40</td>
<td>33</td>
</tr>
<tr>
<td>Half crossing angle [urad]</td>
<td>185</td>
<td>150</td>
<td>170</td>
</tr>
<tr>
<td>No. of colliding bunches</td>
<td>2748</td>
<td>2544</td>
<td>2544</td>
</tr>
<tr>
<td>Proton per bunch</td>
<td>1.1e11</td>
<td>1.2e11</td>
<td>1.2e11</td>
</tr>
<tr>
<td>Emittance into SB [um]</td>
<td>~3.2</td>
<td>~2.3</td>
<td>~2.3</td>
</tr>
<tr>
<td>Bunch length [ns]</td>
<td>1.05</td>
<td>1.05</td>
<td>1.05</td>
</tr>
<tr>
<td>Peak luminosity [cm⁻²s⁻¹]</td>
<td>~1.1e34</td>
<td>~1.7e34</td>
<td>~1.8e34</td>
</tr>
<tr>
<td>Peak pile-up</td>
<td>~28</td>
<td>~48</td>
<td>~52</td>
</tr>
<tr>
<td>Luminosity lifetime [h]</td>
<td>~24</td>
<td>~15</td>
<td>~14</td>
</tr>
</tbody>
</table>

**Achieved with 8b4e → 8b4e BCS**

- Even down to 30 cm
- 140 → 120
- 2556, later ~1900
- 2556, later ~1900
- BCMS: 1.74x10³⁴
- 8B4e: 2.06x10³⁴
- Well beyond 50, hence luminosity levelling

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Chamonix summary by F. Bordry
Plans for 2017

We used mainly 8b4e
We even did 30 cm
Reached > $2 \times 10^{34}$ cm$^{-2}$s$^{-1}$

Chamonix summary by F. Bordry

2017 plans

- Keep pushing performance and **availability (~50%)**
- **BCMS beams** (Smaller emittance though cycle; lower electron cloud heat load; faster intensity ramp-up; lower total beam current; lower losses; better for R2E... pile-up ?) => *maximize integrated luminosity*
- Starting with **ATS optics**; $\beta^* = 40$ cm and later towards 33 cm
  (would deploy HL-LHC optics and open up the exploration of its possibilities)
  => expect to reach 1.7 to $1.9 \times 10^{34}$ cm$^{-2}$s$^{-1}$ (inner triplet cooling limit ?)

- Look forward to HL-LHC without compromising present performance: ATS, beta* levelling, RF full de-tuning, electron cloud,...
- Look forward to the post-LS2 LIU era and how to exploit the potential.
Requested Performance

LHC schedule 2017

**a new production year at 13 TeV**

**Goal 45fb⁻¹**
keeping the LHC availability close to 50% (stable beams)

Initially 15 days of MD; later during 2017 according integrated luminosity : + 3 days ?

Special runs: VdM scans,... and ... LHCC recommendations

Chamonix summary by F. Bordry
Requested Performance

We did it!!

Congratulations!

Chamonix summary by F. Bordry
The Evian 2017 Programme
8th Evian LHC Operations Evian Workshop
12 – 14 December 2017, Hotel Ermitage - Evian

• **Chair:** Rende Steerenberg
• **Co-Chair:** Jorg Wenninger

• **Editor of Proceedings:**
  • Theodoros Argyropoulos
  • Sylvia Dubourg
  • Georges Trad

• **Informatics & Infrastructure:**
  Hervé Martinet

• **Workshop Secretary:**
  Sylvia Dubourg

**Programme Committee:**

• Wolfgang Bartmann
• Enrico Bravin
• Massimo Giovannozzi
• Wolfgang Höfle
• Elias Métral
• Stefano Redaelli
• Rende Steerenberg
• Jorg Wenninger
• Markus Zerlauth
Principal Aims of the Workshop

• Review the 2017 LHC operation, performance and availability;

• Perform a critical review of individual system performance;

• Take lessons learned and identify areas of improvement;

• Exam beam related issues and develop an operational scenario for 2018, including machine developments and studies to be completed before LS2;

• Prepare input for the 2018 Chamonix LHC performance workshop.
<table>
<thead>
<tr>
<th>Sessions</th>
<th>Talks</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
<td>25’ + 5’</td>
</tr>
<tr>
<td>1. Availability &amp; System Performance</td>
<td>8</td>
<td>135’+ 35’</td>
</tr>
<tr>
<td>2a. 2017 Operation &amp; Performance</td>
<td>5</td>
<td>85’ + 25’</td>
</tr>
<tr>
<td>Guided discussion</td>
<td>-</td>
<td>35’</td>
</tr>
<tr>
<td>2b. 2017 Operation &amp; Performance</td>
<td>3</td>
<td>55’ + 15’</td>
</tr>
<tr>
<td>3. Injectors &amp; Injection Process</td>
<td>5</td>
<td>75’ + 25’</td>
</tr>
<tr>
<td>4. LHC Emittance Preservation</td>
<td>4</td>
<td>70’ + 20’</td>
</tr>
<tr>
<td>5. Machine Developments</td>
<td>4</td>
<td>70’ + 20’</td>
</tr>
<tr>
<td>Guided discussion</td>
<td>-</td>
<td>45’</td>
</tr>
<tr>
<td>6. Operational Scenario for 2018</td>
<td>7</td>
<td>115’ +35’</td>
</tr>
<tr>
<td>Guided discussion</td>
<td>-</td>
<td>30’</td>
</tr>
<tr>
<td>Wrap up</td>
<td>1</td>
<td>25’ + 5’</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>38</strong></td>
<td><strong>655’ + 295’</strong></td>
</tr>
</tbody>
</table>