LHC At 13 TeV: Impressive Progress Climbing a Steep Learning Curve

- Dealing with
- 25 ns Electron Cloud new filling schemes
- Heating at Injection
- UFOs: Declining with Sustained Running
- ULO: Steering

Very Effectively

- 270/pb Run with 2244 Bunches

UFOs 2015

Luminosity Lifetime 48 Hours
Availability for Physics – 25 ns Run

- **Stable Beams**, 32.7%, 455 h
- **Turnaround Time**, 32.5%, 453 h
- **Precycle**, 4.2%, 58 h
- **Downtime**, 30.6%, 426 h

- 22 End Of Fill, 48 dumped due to faults
- Fraction of premature dumps: 48/70 = 68.6%
- Average turnaround (per SB) = 453/70 = 6.5 h
- Average Fault time (per SB) = 426/70 = 6 h
Availability

- 65.3% availability during 25 ns Run (close to 2012)
- Remarkable availability during Ion Run – 81%!
- Cryogenic system is the biggest contributor to LHC unavailability (~25% as ‘child’ due to quench recovery)

Impact on LHC Operation (25 ns Run)

Lost Physics Time: 3 h additional time assigned to each fault dumping while in stable beams (i.e. optimistic turnaround)
Availability

"If you can not measure it, you can not improve it.” Kelvin

• QPS – looking good
  – excellent after card replacement
  – comms issue to be resolved
  – possible usability issues to be targeted
• R2E – is it still an issue? YES!
  – Major success all round
  – no room for complacency (only 4 fb\(^{-1}\) in 2015)
  – power converters – 24 dumps per 35 fb\(^{-1}\) year
• RF – mature system – 300 kW in 2016
Stable Beams Distribution – 25 ns Run

- Average Stable Beams: 6.3 h
- Average - EOF = 9.5 h
- Average - premature dumps = 5 h

Target
Cryogenics

• Cryogenic Run2 (2015) was a success with CM availability at 92.1 %
• New configuration was applied and validated – room for modifications exists
• Main failure – 4.5 K refrigerator – to be repaired in January 2016 plus other stuff
• LS1 consolidations visibly helped
  – (bravo all and R2E!, 0 SEU cases declared in 2015)
• e-cloud thermal effect pushed the LHC cryo to the limits of capacity (over originally installed capacity foreseen for 4.5 - 20 K)
• Triplet movement in 8 – plans?
Operations

Turnaround = time from SB to SB

- **What?**
- Ramp, squeeze, collide – clockwork
- Combined ramp & squeeze recommended
- Injection – biggest scope for improvement
Injection
Incisive critical analysis from Delphine

• IQC has lost its credit
  – warning levels – long discussion – who’s responsible?
• Steering while feeling – 50% of the time
• SPS BQM rejects 20% of nominal
• Wrestle with
  – Cryogenics, TDI.B2, MKI.B2, ADT diagnostics

- Injection is the part of the turnover where we can really gain time
  - Optimize the SPS supercycle length
  - Improve the compatibility between LHC needs and SPS daily operation to allow more setting-up time before beam is requested
  - Optimize the filling schemes to reduce the number of SPS supercycle change, reduce the number of injections and allow for steering while filling.
  - Optimize the time spent for beam measurement
• Feedbacks
  – Good progress – critical – a lot more robust
  – Team work!

• Tune and b3 decay
  – Interesting, interesting...
  – Do we need a pre-cycle?
  – Supplementary question – what can we get away without pre-cycling?
OMC get any beam time they ask for OK.
Wire scanner measurements versus MADX IBS simulations.
emittance evolution in collisions

- emittance evolution for fills with at least 2 OP scans
- horizontal emittance growth, $\sim 0.03 \, \mu m/h$ (crossing plane uncertainty)
- vertical emittance shrinkage, $\sim 0.02 \, \mu m/h$
- convoluted emittance: constant within error bars
  - BSRT sees small shrinkage, difference in horizontal plane

* excluded CMS points for fills with magnet off or ramping
Optimal Fill times for 2016

- **2016 proposed parameters:**
  - $\beta^*=40\ \text{cm in IP1/5}$
  - $410\ \mu\text{rad (11}\ \sigma)$ or $370\ \mu\text{rad (10}\ \sigma)$ in IR1 and 5
  - Similar bunch brightness and bunch length as in 2015 ($1.2\times10^{11}$, 3$\mu$m, 1.3ns)
- **Most probable turnaround time** (based on 2015) of 6-8h (see M. Solfaroli)
- **Using different emittance evolution scenarios** (based on 2015 observations)
  - Long Fills are favorable
  - For 6h prep. Time: 18-20h
  - For 8h prep. Time: 22-24h
  - For 4h prep. Time: 13-15h
UFO Rates 2015 pp Run

Rates of registered UFOs in Arcs and DSs at 6.5 TeV.

Is a ratio of 10 UFOs/hr already the asymptote?
• *Luck seems to be a factor* when it comes to surviving a UFO attack.

**Post-YETS Changes**

BLMTWG proposes to

• increase the short Running Sums (RS 1-6) by another factor 2, while reducing the longer Running Sums to conservative values.
  • Monitor factor (MF) from current 0.5 to 0.2.
  • RS 1-6 Master Threshold increase x5.
  • (Possible decrease of long Running Sums in Master Table due to BFPP quench-test result. See Matti Kalliokoski’s presentation.)

• use conservative thresholds next to magnets with heater problems.
• keep this setting (or even increase the MF) provided that UFOs cause no more than ~15 quenches per year.
  • 15 quenches is comparable to expected flattop training, much lower in terms of heater firings than spurious QPS triggers (resets, etc.).
• in short: avoid dumping on UFOs all-together as a strategy to maximize availability.
ULO restriction now?

- Local aperture scan repeated with protons (15/11) and lead beams (10/12)
- Consistent results obtained: *vertical dimension increased*

![Graph showing the results](image)

- Fixed bump of:
  - $H = -3\text{mm}$
  - $V = +1\text{mm}$

- Edge of the object

- What if it keep growing is 2016?
  - Still room to have at least $10\sigma$ in both planes (@ 450 GeV)
  - Possible best *new bump* to be decided based on actual situation

15/12/15

Daniele Mirarchi, Evian 2015
Instabilities

- Transverse instabilities regularly observed during operation.
- ADT gain, Chromaticity and Octupole current increased to mitigate blowup. By the end of November, instabilities were able to be suppressed routinely.
- BCMS fill showed that at injection and during the squeeze, we are quite close to the limit of stability.
- ADT ObsBox will be able to provide more detailed bunch-by-bunch information which will allow us to understand some of the instabilities better.

- Instability measurements show good agreement for operational chromaticities. Further studies required for small and negative chromaticities.
- Threshold was increased by a factor of 5 for bunch train in strong presence of e-cloud. High intensity physics scrubbed the machine at flat top, thereby reducing e-cloud levels and reverting to single bunch instability thresholds.

- Will be challenging again in 2016... defenses very nicely described by Kevin
- Important to continue to validate model and improve understanding...
Scrubbing: Gianni’s proposal for the 2016 start-up

- Arcs will be kept under vacuum → *scrubbing should be at least partially preserved* during the YETS

- Scrubbing *requirements for 2016*:
  - **4 days scrubbing run** should be reasonable to recover high intensities at 450 GeV
  - A few “refresh” scrubbing fills during first 1-2 weeks of intensity ramp up in physics (to avoid problems with deconditioning)
  - Accumulate *further scrubbing in physics*:
    - “aggressive” filling scheme, with up to 288b. per injection, should be used until we hit again limitations from cryo
  - **Doublet test** to be performed when **SEY is sufficiently low** (e.g. after recovering the 2015 situation) to check whether good beam quality can be preserved
    - In case of positive outcome, *first scrubbing stores with doublets*
And please guys – no more sleeping on the job
Beam-beam

• Message
  – We’re in happy place – lower HO, lower LR
  – So happy that high Q’, high oct – not a problem
  – 10 sigma (nominal emittance) is good
  – 370 microrad in 1&5 for beta* = 40 cm
  – 400 urad in ALICE, 2*250 in LHCb

Tatiana Pieloni
Outgassing TDIs should not longer be a problem

Thanks Anton
Hi Benoît,
we have been doing the endoscopy to TDI8 and the surfaces of the HbN are all spoiled, basically there is some spot left of Ti coating. Moreover there are bubbles on the copper coated holder. The contacts and foils look fine.
Here the picture/video: https://espace.cern.ch/be-ice-impedance/Measurements/TDI8%20Endoscopic_2015_12_16.zip
Tomorrow we are going to see TDI2 as it will be available.
With Antonio we preliminary planned the measurements for the first week of January (from 5/01 on).
Ciao

Nicolò and Na
Beautiful - has to be a solution for data storage and robust software solution to exploit the combined systems
Gianluca Valentino

down to 2.2 mm gap in IR7!
Half-detuning (1)

Power transients with a full machine (2244 bunches, fill 4565, 2nd November)

![Graph showing power transients with beam present and absent, and corresponding phase and Q component plots.]

Beam present

Beam absent

Beam present

Beam absent

Helga Timko
Longitudinal beam stability (2)

At the end of long physics fills, Landau damping was lost

- With 2015 end-of-fill beam parameters, coupled-bunch instability not observed, only single bunch instability

Bunch flattening can be used as a mitigation if needed

Loss of Landau damping in the longest fill of the year.

Single-bunch threshold obtained in MDs.
• Very successful year for the beam instrumentation
• Many changes during LS1 requiring some debugging during 2015
• Instrumentation ready for the upcoming production years
• Still a lot of challenges for the R&D systems
• BI can now focus toward HL-LHC
Summary

- **WS:**
  Deep understanding/investigation of the measurement precision in Run II.
  Undergoing software improvements will improve even more the system.
  Accuracy of the beam size measurement (absolute value) is <3 %
  Precision of the beam size measurement (spread around absolute value) <9 %

- **BSRT:**
  Operationally reliable measurements in Run II,
  - Accuracy of the beam size measurement is <6 %
  - Precision of the beam size measurement <5 (% B2 better than B1)
  - At injection, it could replace the systematic WS checks at 1st injection
    => Spare OP time, however would be nice to have routine (monthly) checks
    at injection (<20 min).
  - Dedicated MD time (often confused with “Calibration”) for development
    will be crucial for Hi-Lumi.

- **BGI & BGV:**
  2016 will still be a commissioning year for both instruments.

Lovely talk including timely reminder about the difference between accuracy and precision.
Careful evolution to drive CERN’s accelerators safely into the future
We’ve come some way since LEP
Kajetan: let’s build some bridges

If you only have a hammer, you tend to see every problem as a nail.

(Abraham Maslow)
Losses @ TDI for 144b B1

- 2/3 of losses
- 1/3 of losses

5 ns – 200 MHz
SPS re-captured beam

25 ns – injected beam
MPS ensured safe operation with up to ~280 MJ stored beam energy in 2015

“The condition upon which God hath given liberty to man is eternal vigilance.”

Daniel Wollmann
BLM Thresholds Evolution And 2016 Proposal


BLM Thresholds and Damage Limits for Collimators

R. Bruce, E. B. Holzer, M. Kalliokoski, A. Mereghetti, S. Redaelli, B. Salvachua Ferrando

- Overview of BLM thresholds deployed in 2015, and their updates (debris / operational scaling in IR7 / UFO events in experimental IRs);
- 2016: review of BLM thresholds at collimators:
  - New curve of proton limits at TCPs and scaling factors for non-TCP collimators (already available);
  - Analysis campaign for proton-to-signal conversion factors – focus on metallic collimators and energy dependence (and ions);
  - Lessons learnt from 2015 will be taken into account;
BI for Machine Protection

- Interlock BPMs (IP6)
- Abort Gap Monitoring
- Beam Current Change Monitor: \( dl/dt \)

T. Lefevre on behalf of the people involved in BI and MPE groups
# 2016 Calendar

## January

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- **Year end technical stop**

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- **Powering tests**

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- **Recommissioning with beam**

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- **Scrubbing**

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- **RAMP-UP**
- **"REFRESH" SCRUBBING**
- **Ascension**
- **May Day camp**
- **MD 1**

## June

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- **TS1**
- **Special physic run**

**Notes:**
- Easter Mon: April 18
- G. Friday: May 27

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1st May

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## 2016 Q3/Q4 (v1.0)

### July

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### August

- 27: MD 2

### September

- 25: TS2
- 29: MD 3
- 28: Jeune G

### October

- 3: MD
- 7: Ions setup

### November

- 14: Ion run (p-Pb)
- 5: Extended year end technical stop

### December

- 12: Extended year end technical stop
- 28: Lab closed
- 5: Xmas
- 26: New Year
## 2016 version 1.0

<table>
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<th>Phase</th>
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<td>Initial Commissioning</td>
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<td>Scrubbing: 4 days initially and then as required during ramp-up</td>
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<td><strong>Proton physics 25 ns</strong></td>
<td>152</td>
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<tr>
<td>Special physics runs ([high beta*; 90 m; VdM (19 m)]</td>
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<td>Machine development</td>
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<td>Technical stops</td>
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<td>Technical stop recovery</td>
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<tr>
<td>Ion setup/proton-lead run</td>
<td>4 + 24</td>
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<td><strong>Total</strong></td>
<td>266 days (38 weeks)</td>
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Can we get to $\beta^*=40 \text{ cm}$?

*Provided aperture stays good*
Teamwork

Beam from injectors

Beam performance

Exploitation

Dipole chamber @ 7 TeV

Mitigation

System performance

LHC Eightfold Path

Availability

RF, power converters, collimators, beam dumps, injection, magnets, vacuum, transverse feedback, machine protection, magnets, magnet protection, beam instrumentation, beam based feedbacks, controls, databases, high level software, cryogenics, survey, technical infrastructure, access, radiation protection
Phenomenal

• In a new place – end of first year of operations after a long stop after Run 1.
  – Having got over the hangover...

• Benefits of the feed in of experience gained showing very clearly

• Professionalism, understanding, exquisite level of detail, sophistication, maturity of tools

• Harnessing of 21 century technology

• Resources, talent, imagination and YOOF!!!
Many, many thanks...

• Organization
  – Everything: Sylvia
  – Everything else: Malika & Brennan
  – Technical coordination: Hervé
  – Proceedings: Brennan and Sylvia

• Session chairs – brilliantly done

• Speakers - excellent set of talks!

• Jamie
Happy Christmas!

1. What is the statistical significance of the signal?
2. Is the signal consistent with other data sets?
3. Is there a theoretical framework to describe it?
4. Does it fit in a bigger scheme of new physics?