OPERATIONS & PERFORMANCE OF THE ATLAS DETECTOR IN LHC RUN II

CANADIAN ASSOCIATION OF PHYSICISTS CONGRESS

MAY 2017

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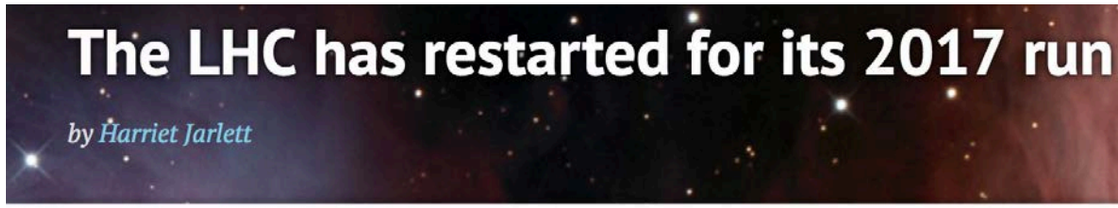
University Of Victoria

OVERVIEW

Updating you on the performance of the LHC and the ATLAS detector subsystems during 2016 data-taking - and looking forward to 2017.

- Large Hadron Collider
  - Outline, schedule and performance
- ATLAS Detector Run II performance
  - Detector operation and challenges
- Looking ahead to 2017 operation
  - Work during technical stop
    - Detector upgrades, software development
  - Current picture with first beam from the LHC



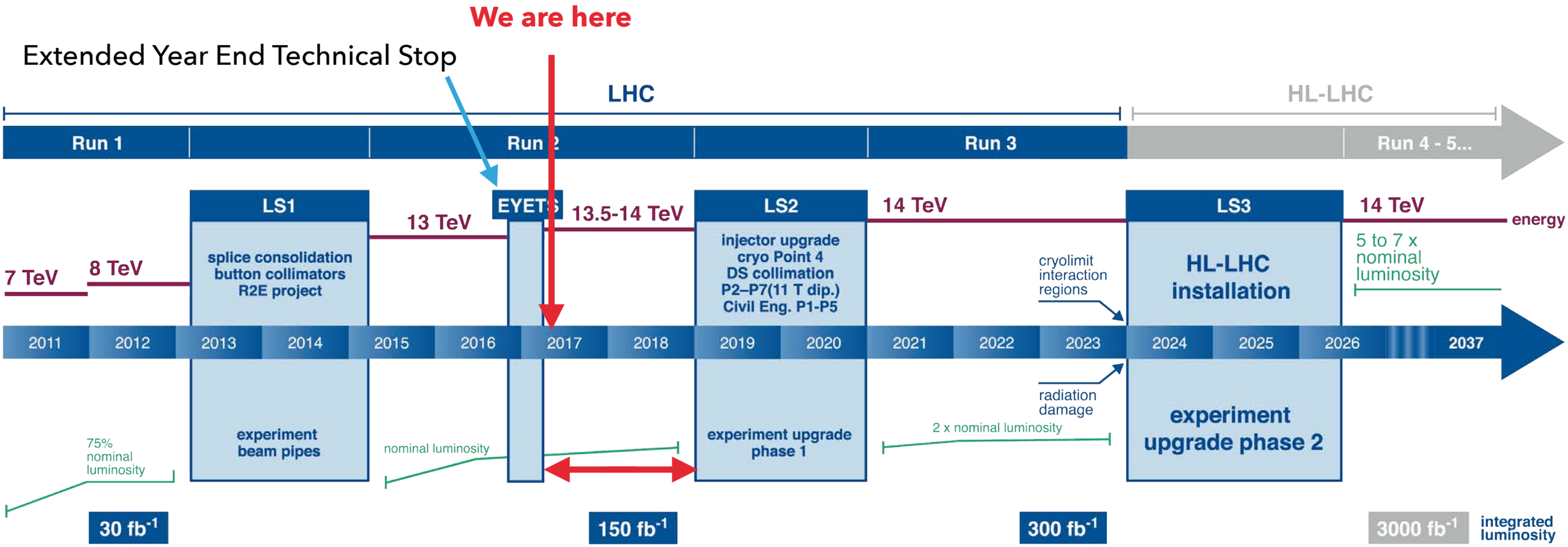
Final tests were performed in the LHC at the end of April, ready for the restart this weekend (Image: Maximilien Brice/ CERN)

THE LARGE HADRON COLLIDER

LHCb
ATLAS
CERN Meyrin
PS 628 m
CERN Prévessin
SPS 7 km
SUISSE
FRANCE
ALICE
CMS
LHC 27 km

E_{cm}= 13 TeV

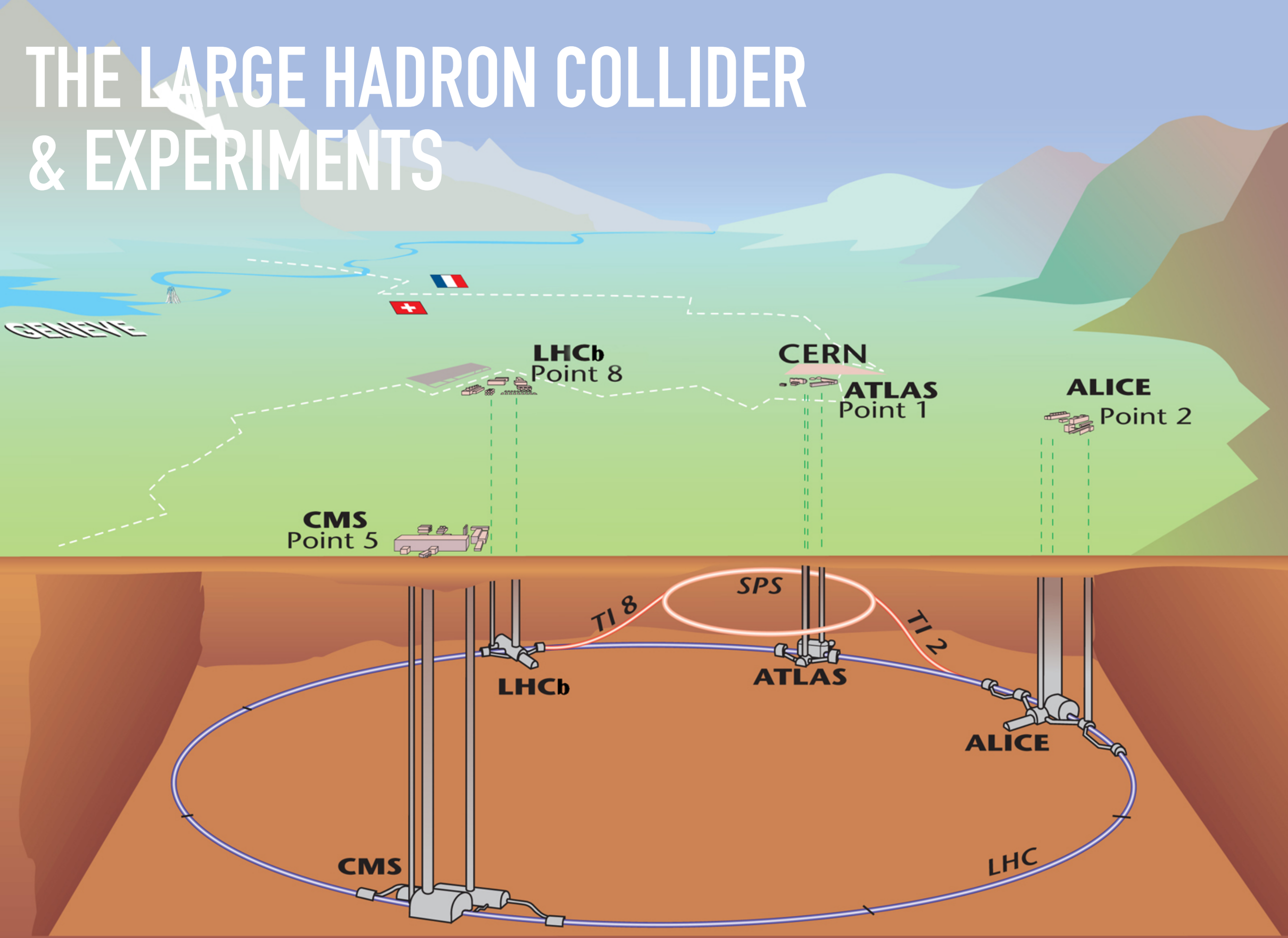
LHC SCHEDULE



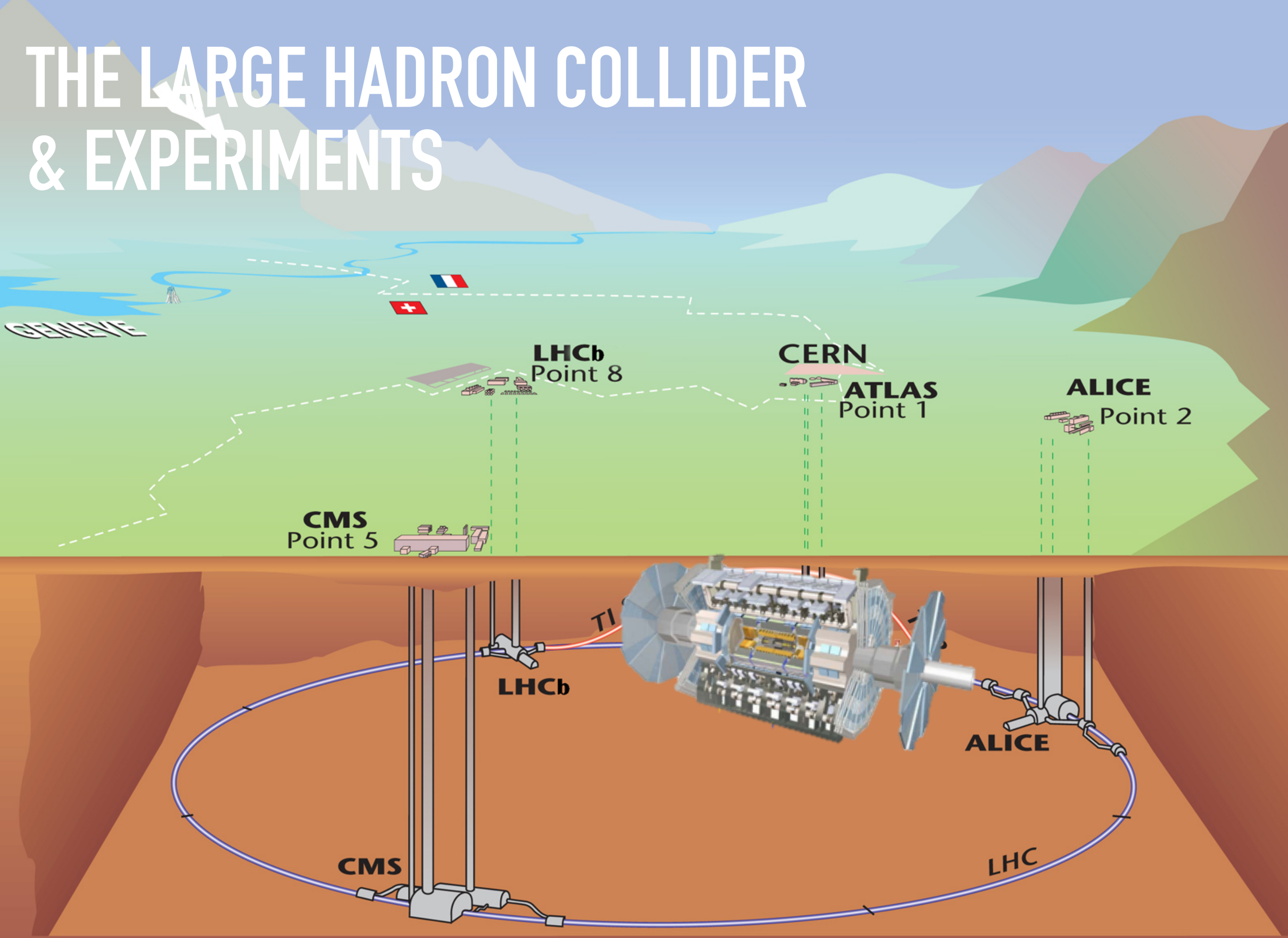
Ramping up for another 13 TeV data-taking campaign

Currently ~36 fb^{-1} proton-proton data to analyse at 13 TeV

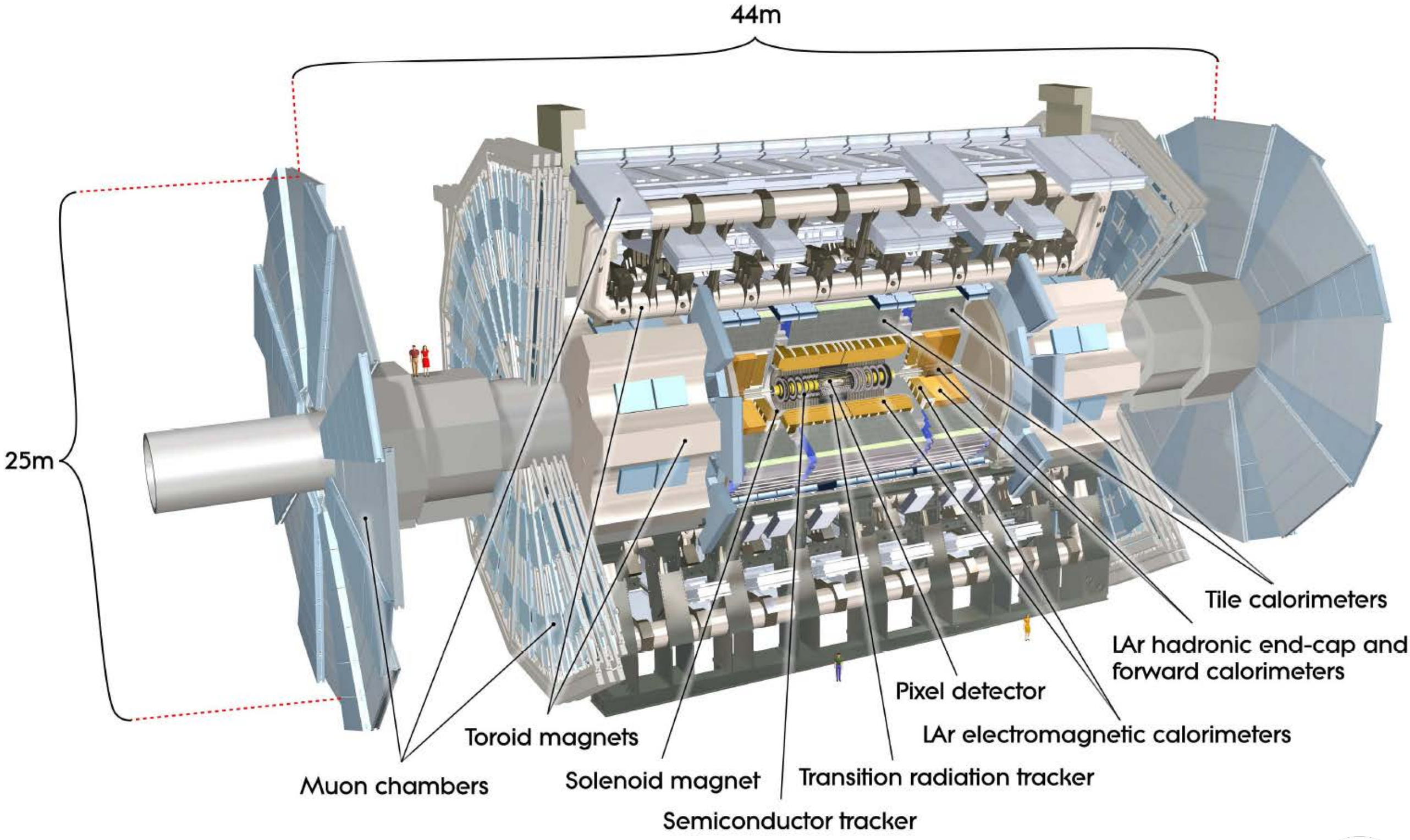
THE LARGE HADRON COLLIDER & EXPERIMENTS



THE LARGE HADRON COLLIDER & EXPERIMENTS

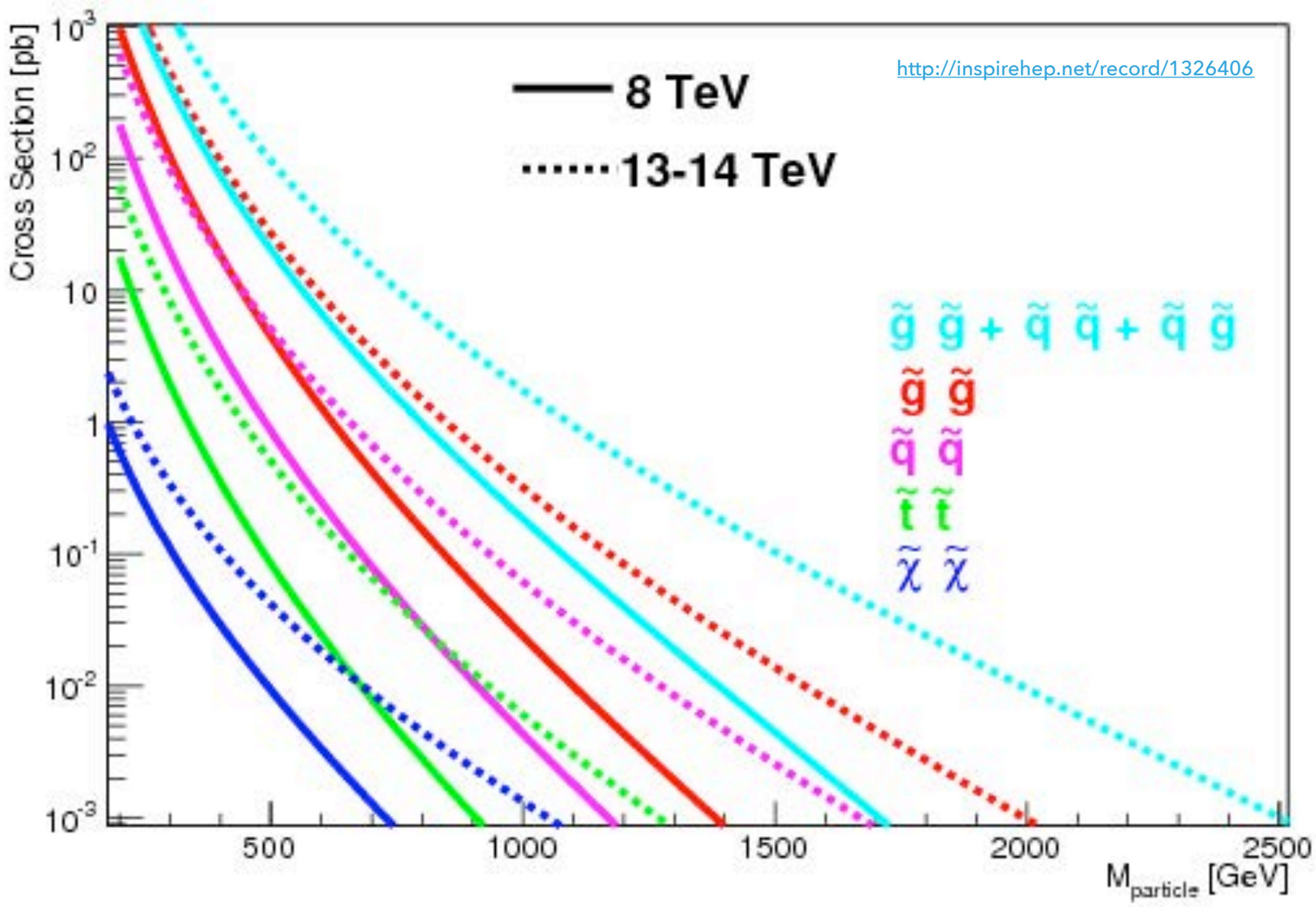


THE ATLAS DETECTOR



THE MOVE FROM 8 TEV TO 13 TEV

- Large gains to be had in terms of new physics discovery potential moving from 8 to 13 TeV
  - Significant increase in squark & gluino production cross-section



Potentially gaining up to a factor 30 in rate for large particle masses!

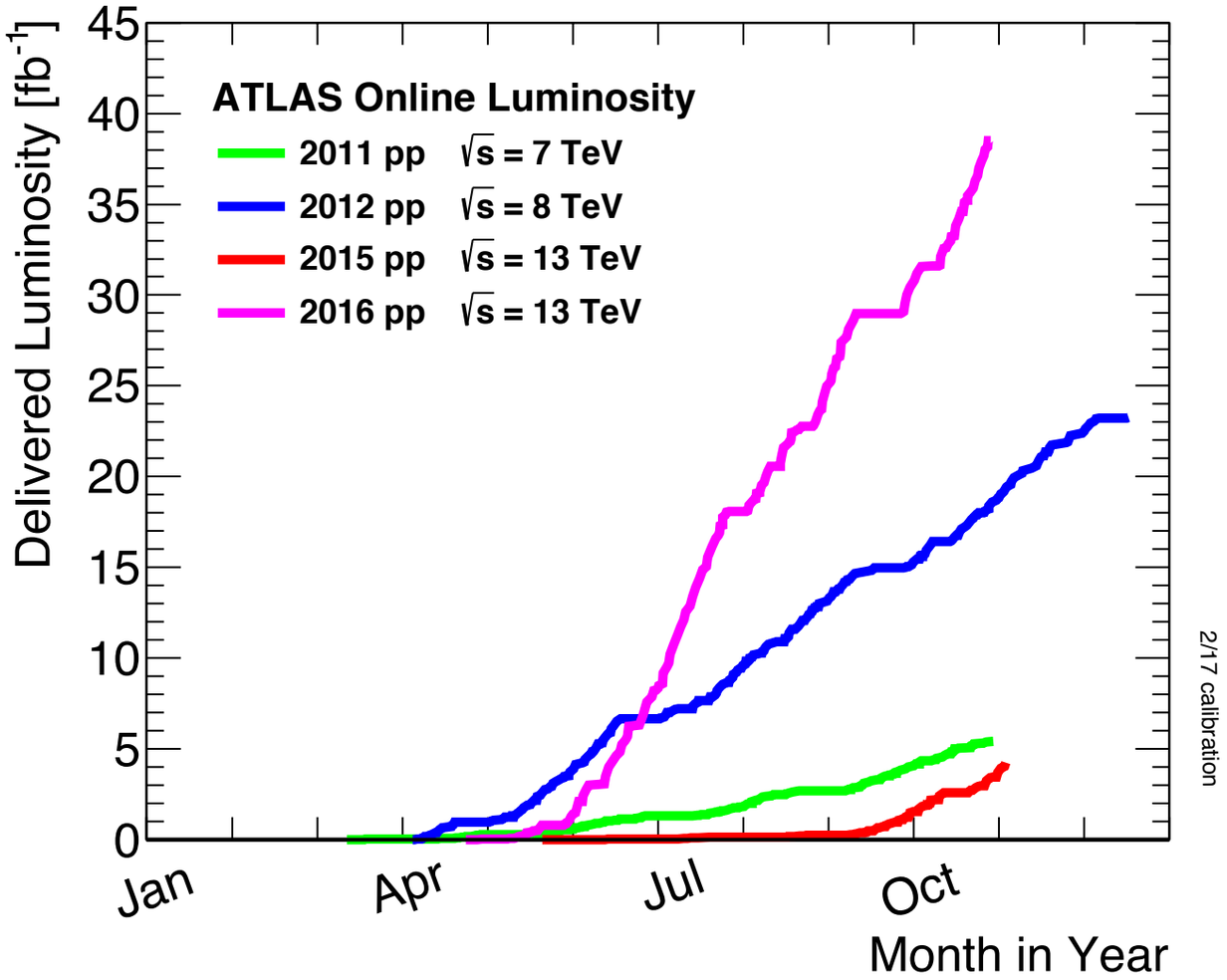
THE MOVE FROM RUN I TO RUN II

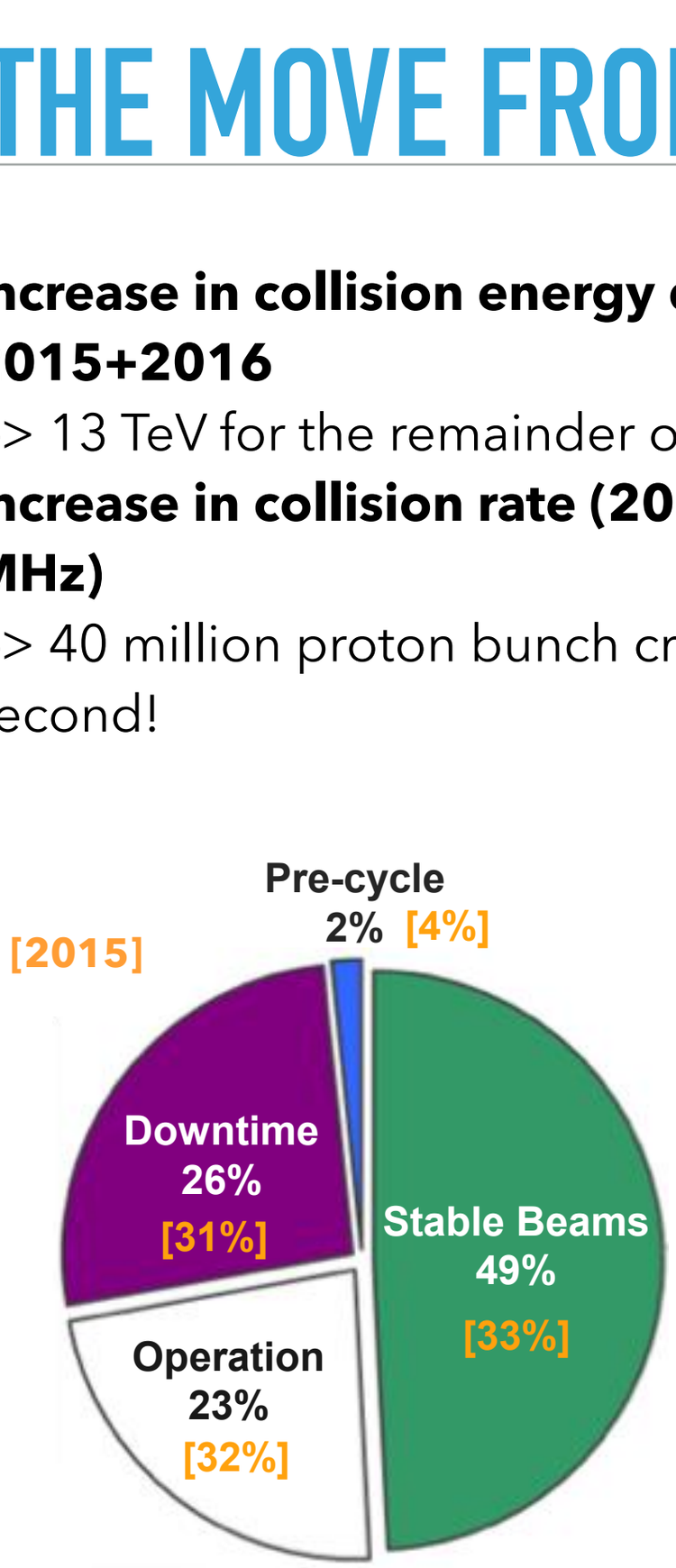
Increase in collision energy during 2015+2016

–> 13 TeV for the remainder of LHC Run II

Increase in collision rate (20 MHz –> 40 MHz)

–> 40 million proton bunch crossings per second!

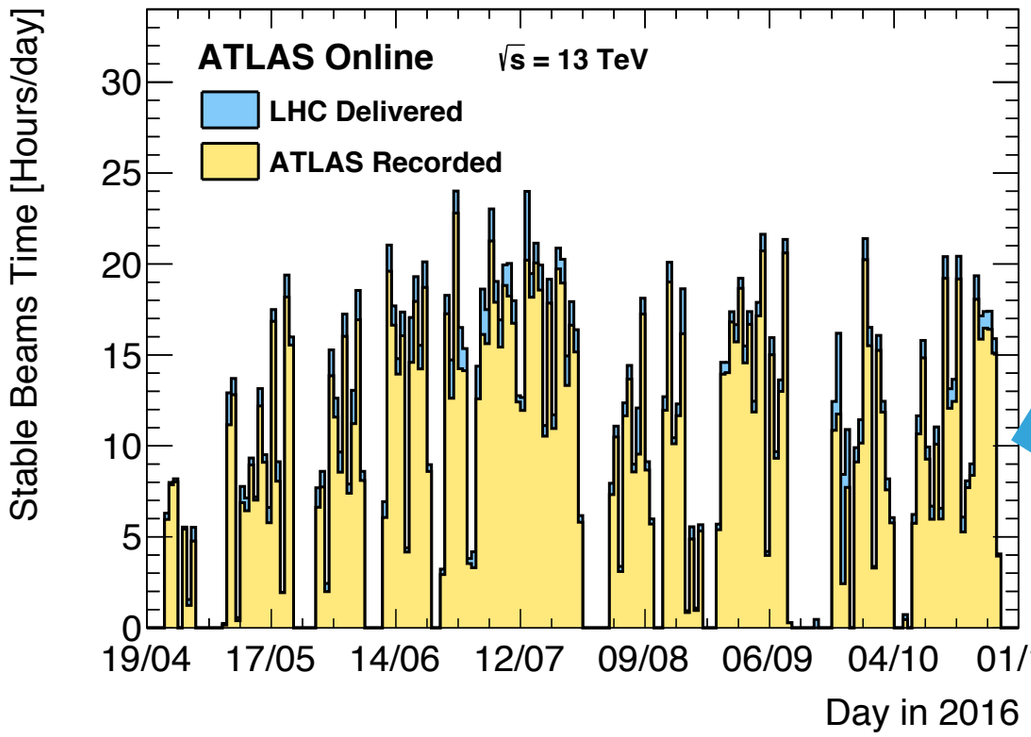




Excellent LHC performance during 2016!

LHC availability ~ 75 %, with ~ 50% stable beam time.

PROTON DATA-TAKING DURING 2016

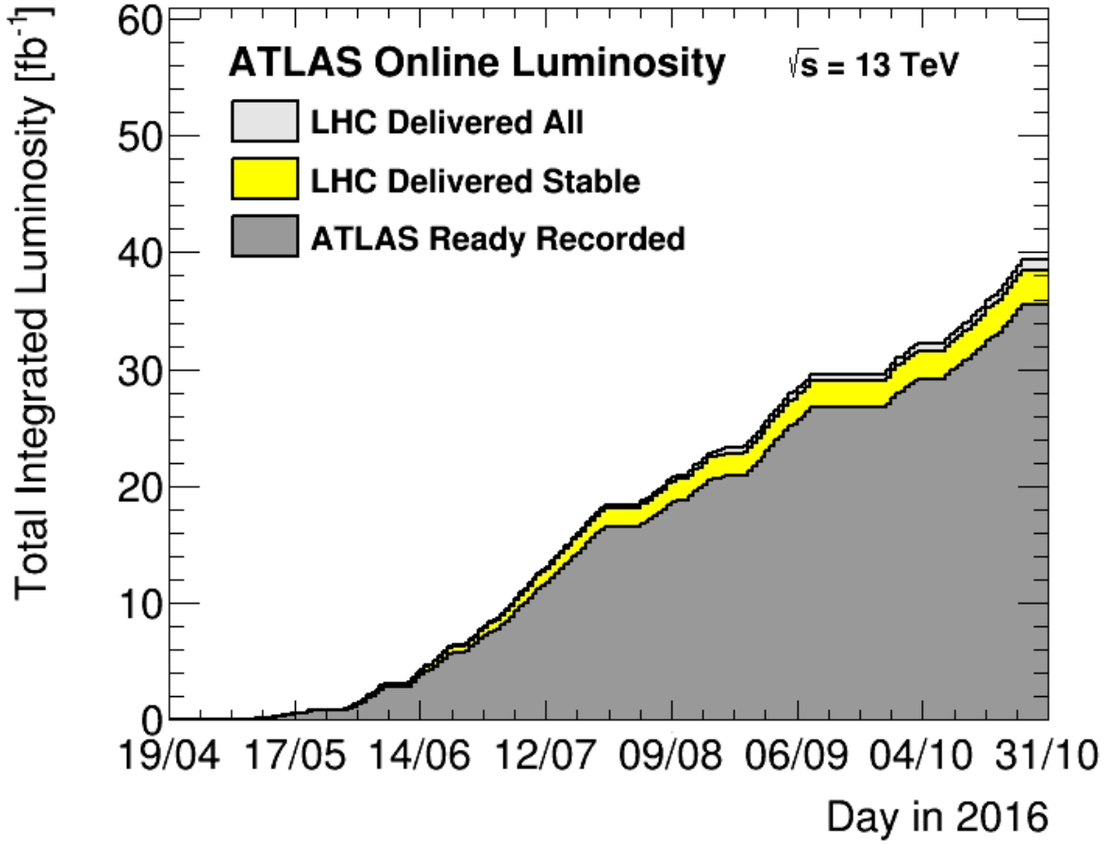


LHC regularly delivering 10-15 hours of stable beams/day!

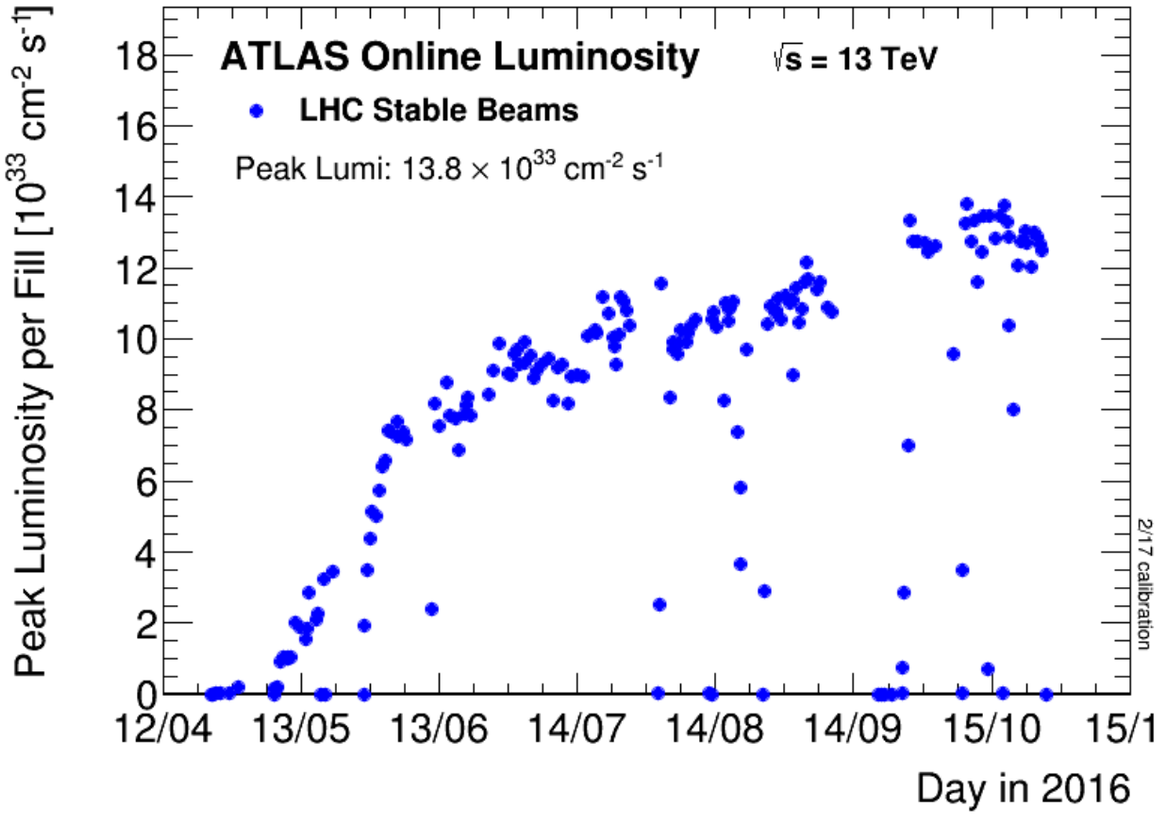
- Large 2016 dataset delivered to ATLAS
  - 38 fb^{-1} delivered
  - 35 fb^{-1} recorded
  - 33 fb^{-1} "good quality" data

36.1 fb^{-1} data from 2015+2016 for physics analysis

92.4% data-taking efficiency
93-95% data quality selection efficiency



RECORDING AT HIGH LUMINOSITY

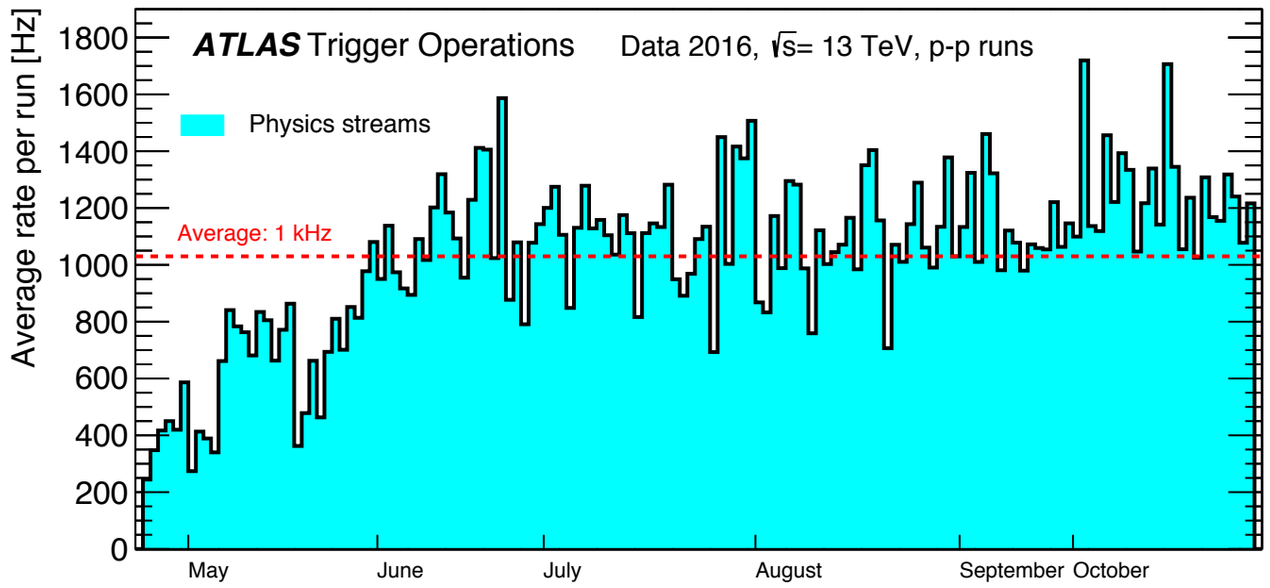


Steady increase in peak instantaneous luminosity during 2016

- Peak instantaneous luminosity up to 1.4×10^{34} cm^{-2} s^{-1}
- Peak interactions per bunch-crossing up to 52
- Writing out 3 GB/s at peak instantaneous luminosity
- Very challenging in terms trigger and detector operations!

Average recording rate of 1 kHz during 2016

- Increased interactions per bunch crossing ("pile-up")
- Increased occupancy
- Dead-time during data-taking



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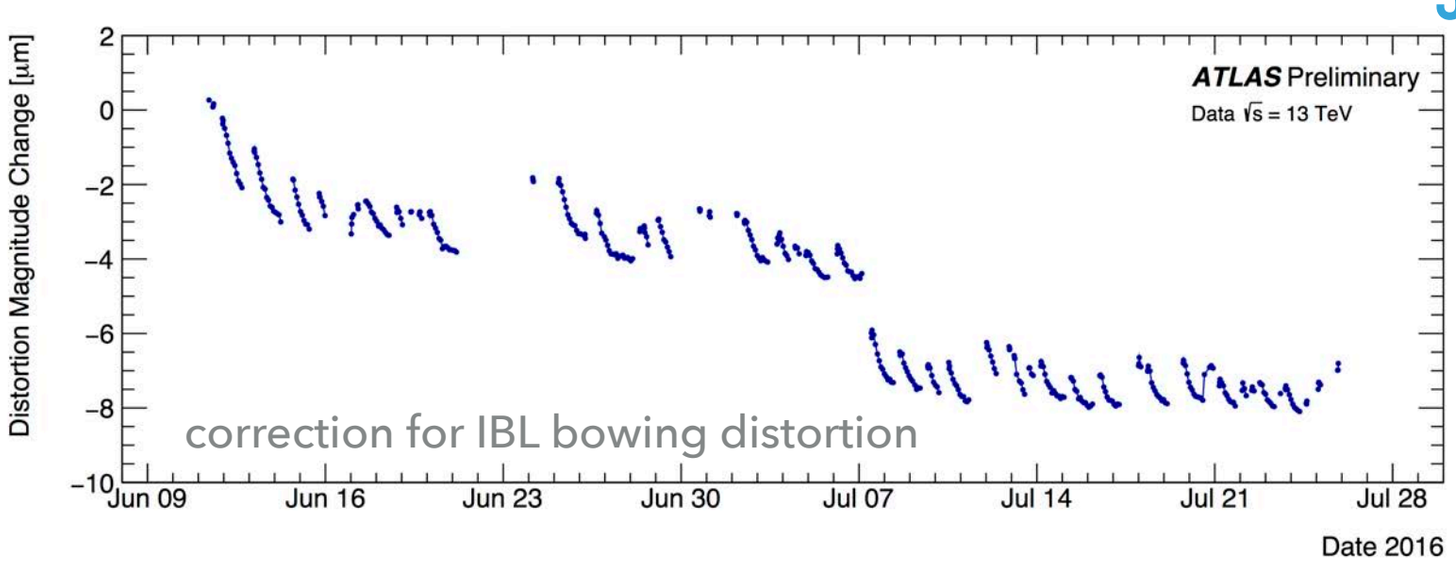
INNER DETECTOR PERFORMANCE

PIXEL DETECTOR

- 98.9% data-quality efficiency during 2016
  - Dynamic alignment as pixels turned on at the start of every fill.
    - Mass in cooling pipes changes as temperature stablises.
  - Insertable B-layer (IBL) inserted for Run II also suffers from temperature variations ("IBL bowing")
    - New alignment scheme to account for this.



TRANSITION RADIATION TRACKER (TRT)

- 99.7% data-quality efficiency during 2016
  - Increasing occupancy and trigger rates.
  - Operating close to read out saturation in 2016.

Work to overcome this during EYETS and beyond.

SEMI-CONDUCTOR TRACKER (SCT)

- 99.9% data-quality efficiency during 2016
  - Relatively trouble-fee operation during 2016.
  - Firmware development resulted in dead time reduction from 0.4% to 0.05%.

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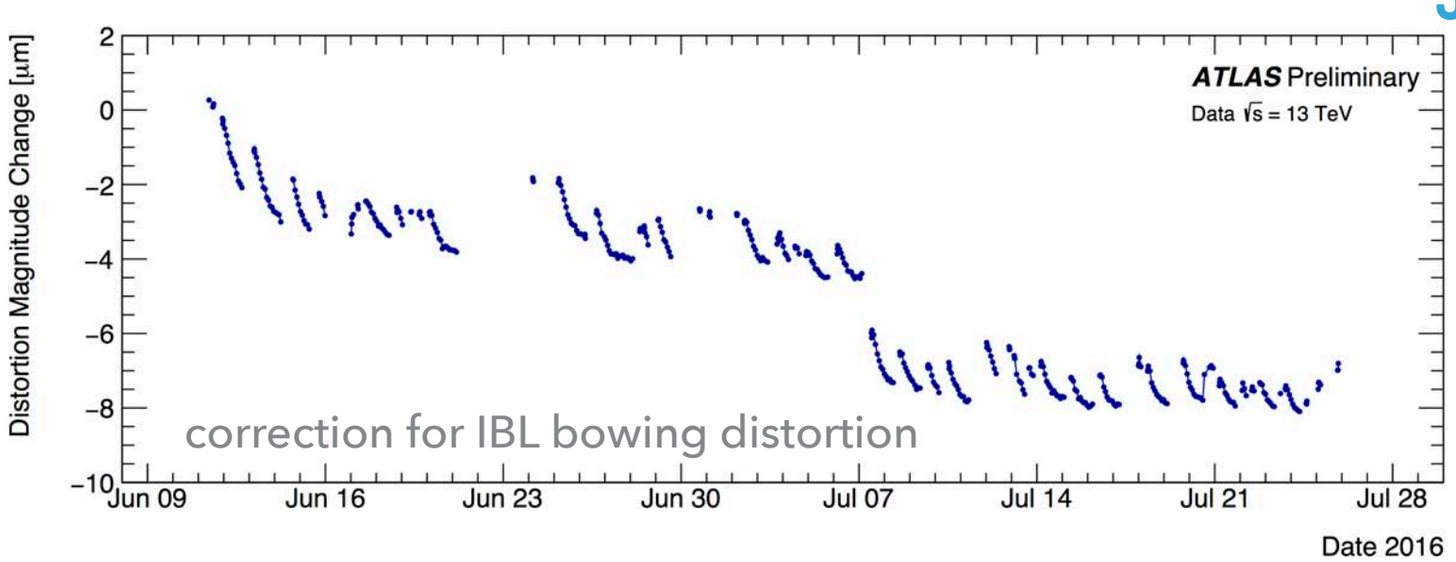

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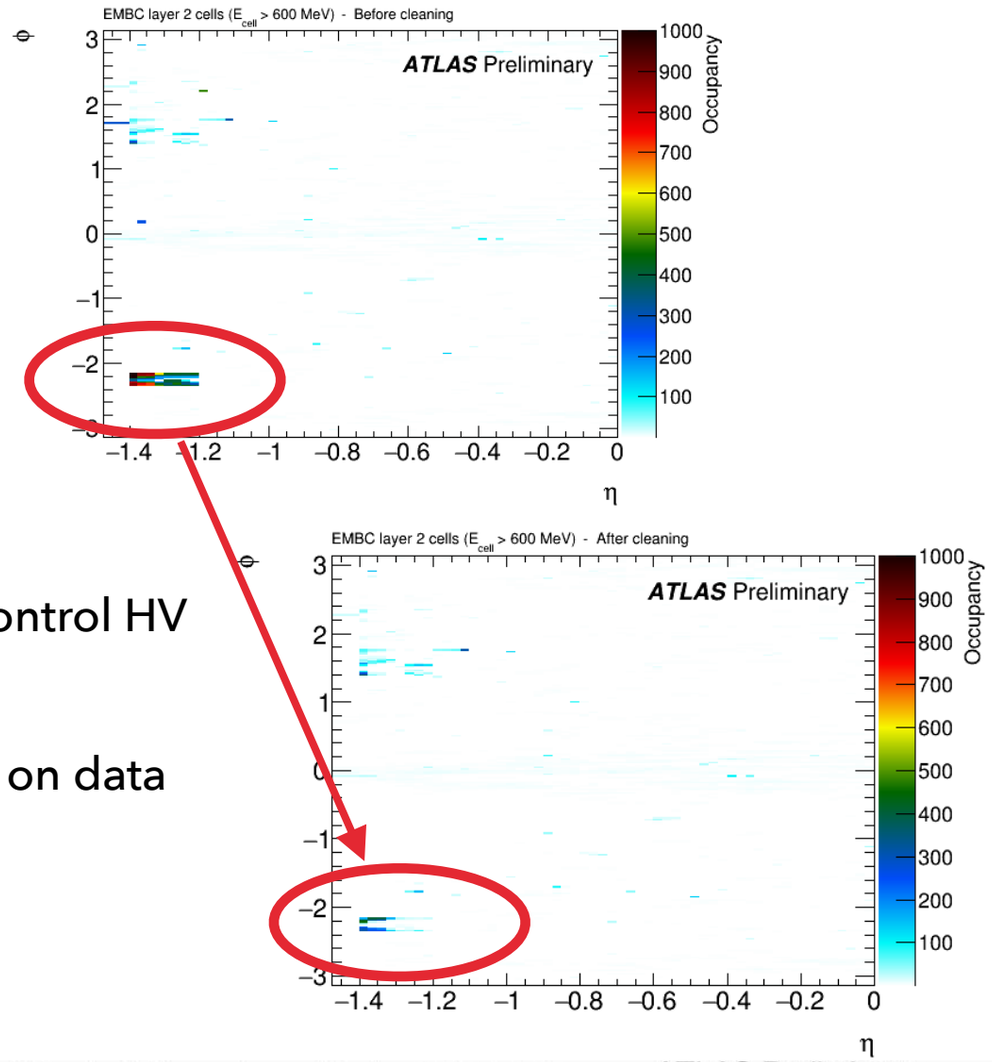
CALORIMETER PERFORMANCE

LIQUID ARGON CALORIMETER

99.3% data-quality efficiency during 2016

- HW problems
  - Cooling leak in May 2016
  - HEC LV power supply issues affected 1/4 of the HEC A-side
    - Fixed during winter shutdown 2016/2017
- Number of HV trips vastly reduced in 2016 due to new current control HV modules

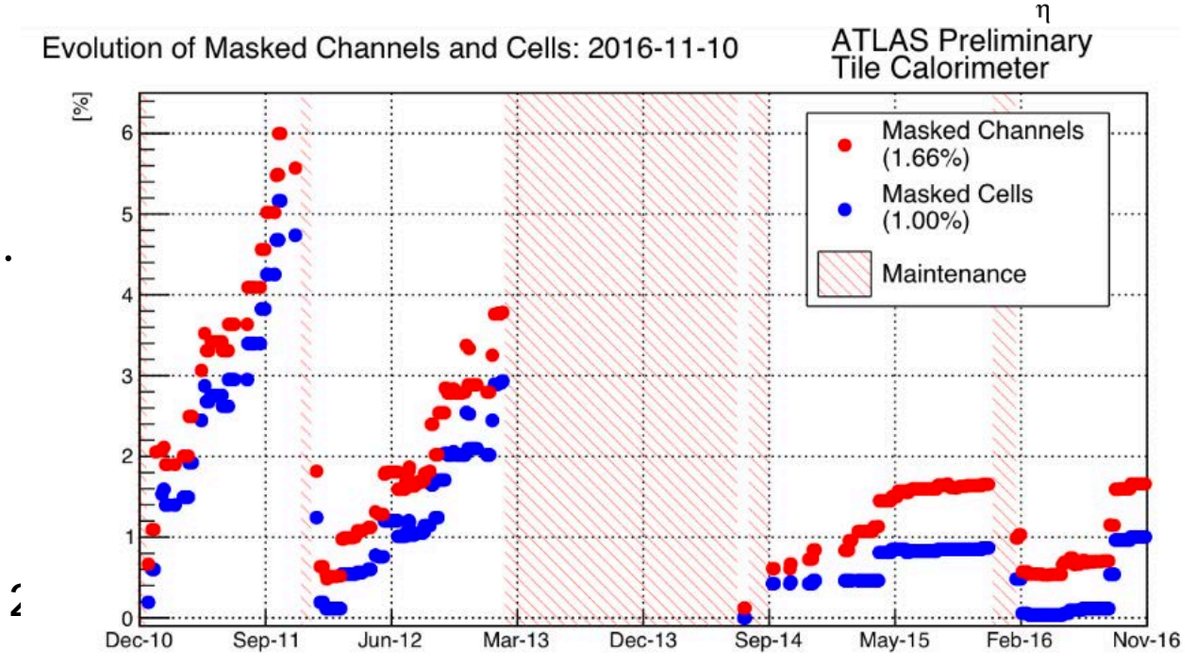
New treatment of detector noise implemented to reduce impact on data quality



TILE CALORIMETER

98.9% data-quality efficiency during 2016

- Cooling leak in August 2016 - isolated to single module
- Fewer noisy channels with respect to previous year operation.
- Good stability of scintillator and PMT.



MUON PERFORMANCE

CATHODE STRIP CHAMBERS (CSC)

- 99.9% data-quality efficiency
  - 3 dead layers due to broken wires

MONITOR DRIFT TUBES (MDT)

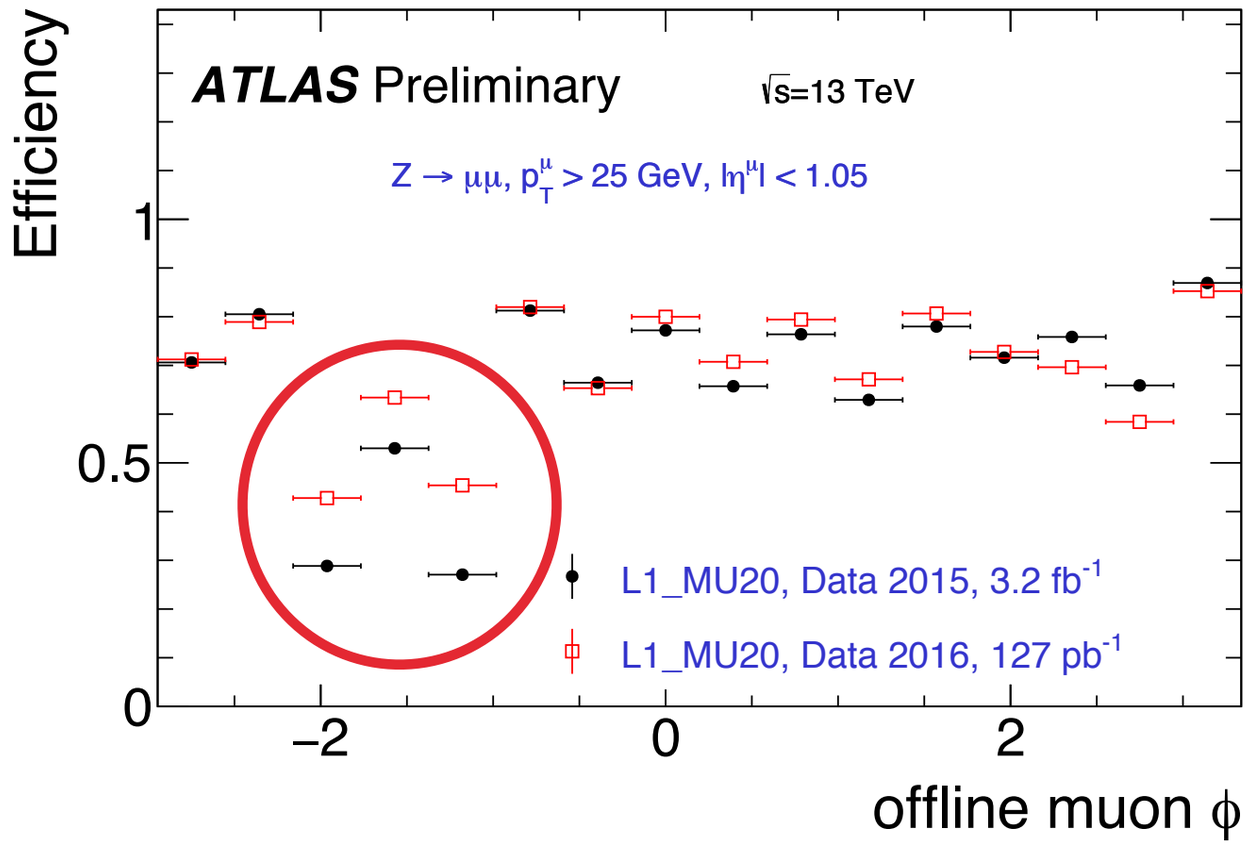
- 99.8% data-quality efficiency
  - Smooth operation

RESISTIVE PLATE CHAMBERS (RPC)

- 99.8% data-quality efficiency
  - New trigger chambers in “feet” region fully operational

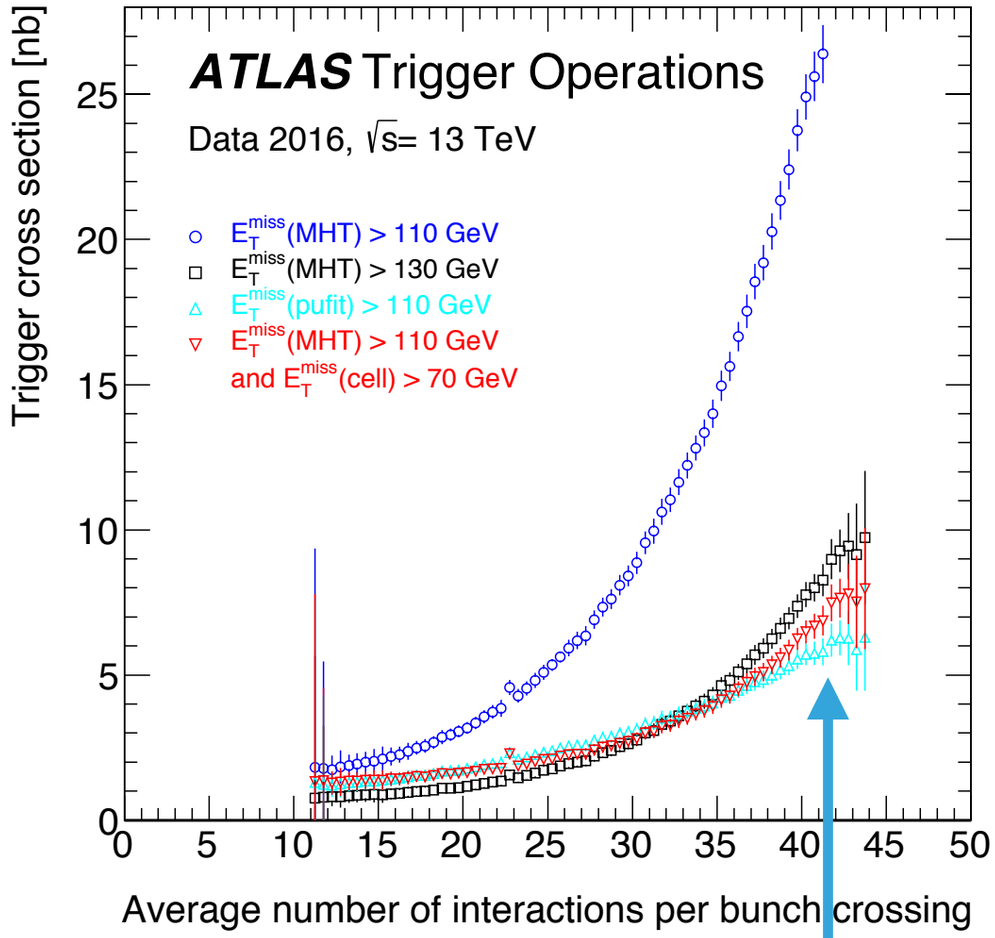
THIN GAP CHAMBERS (TGC)

- 99.9% data-quality efficiency
  - “Noise burst” veto activated in October to reject noise in TGCs.



PILING UP THE TRIGGER

- Extensive work in preparation for new data-taking campaign:
  - Code optimisation (e.g. reduction in HLT processing time of ~20%)
  - Increased/revised thresholds
  - New ideas for triggers
- Exponential pile-up dependence of E_T^{miss} trigger rate
  - Forced to raise E_T^{miss} trigger thresholds in 2016
  - Current trend not sustainable for 2017

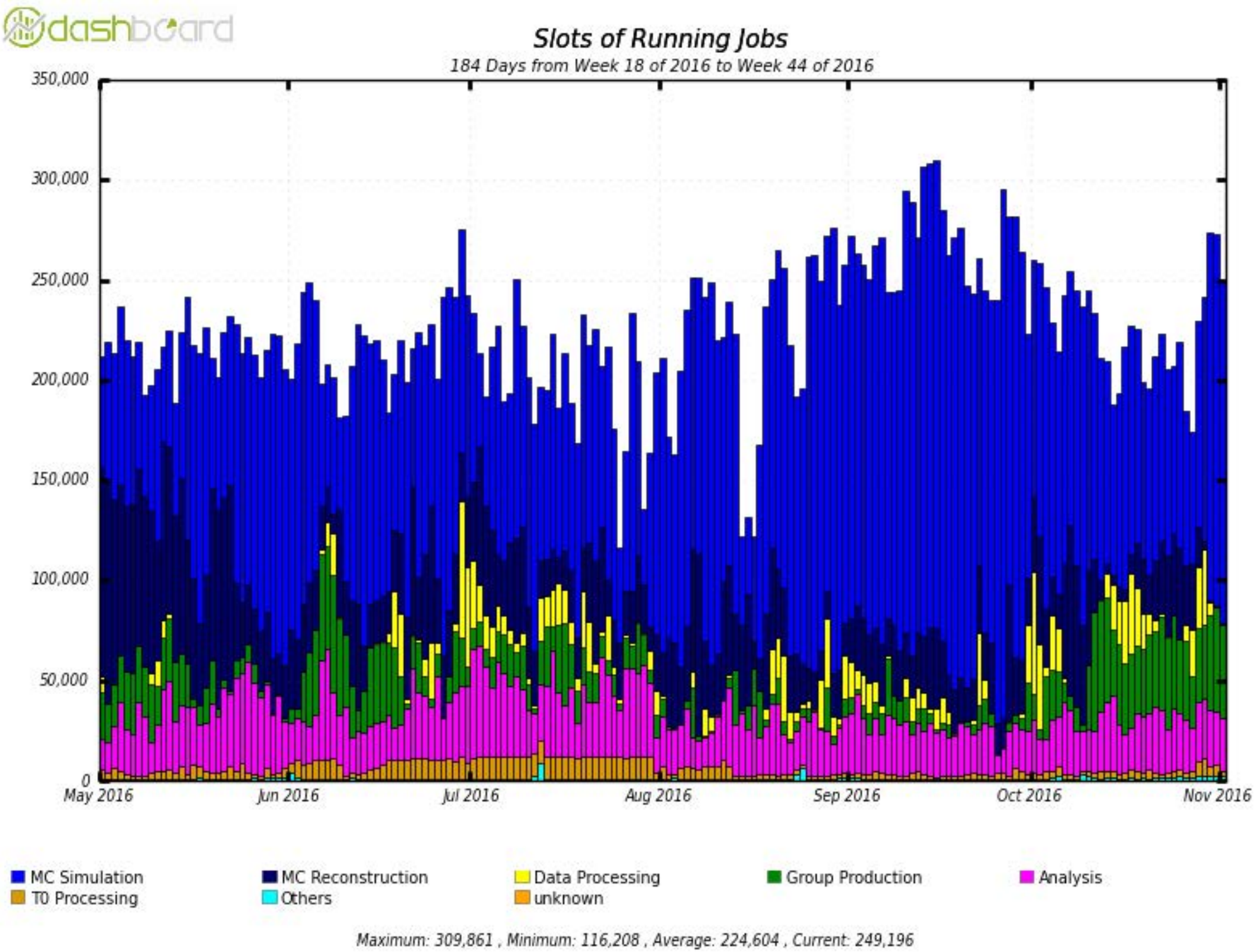


Significant reduction in pile-up dependence

NEW PUFIT ALGORITHM FOR E_T^{MISS} TRIGGERS INTRODUCED FOR 2017 OPERATION

- Calorimeter clusters grouped into "towers", which are deemed to come from pile-up if their E_T falls below a pile-up dependent threshold.
- The fitted E_T values of these pile-up contributions are used to correct the E_T of the calorimeter topological clusters.

COMPUTING DURING 2016



Simulation

Reconstruction

Data format reprocessing

Data processing

User analysis

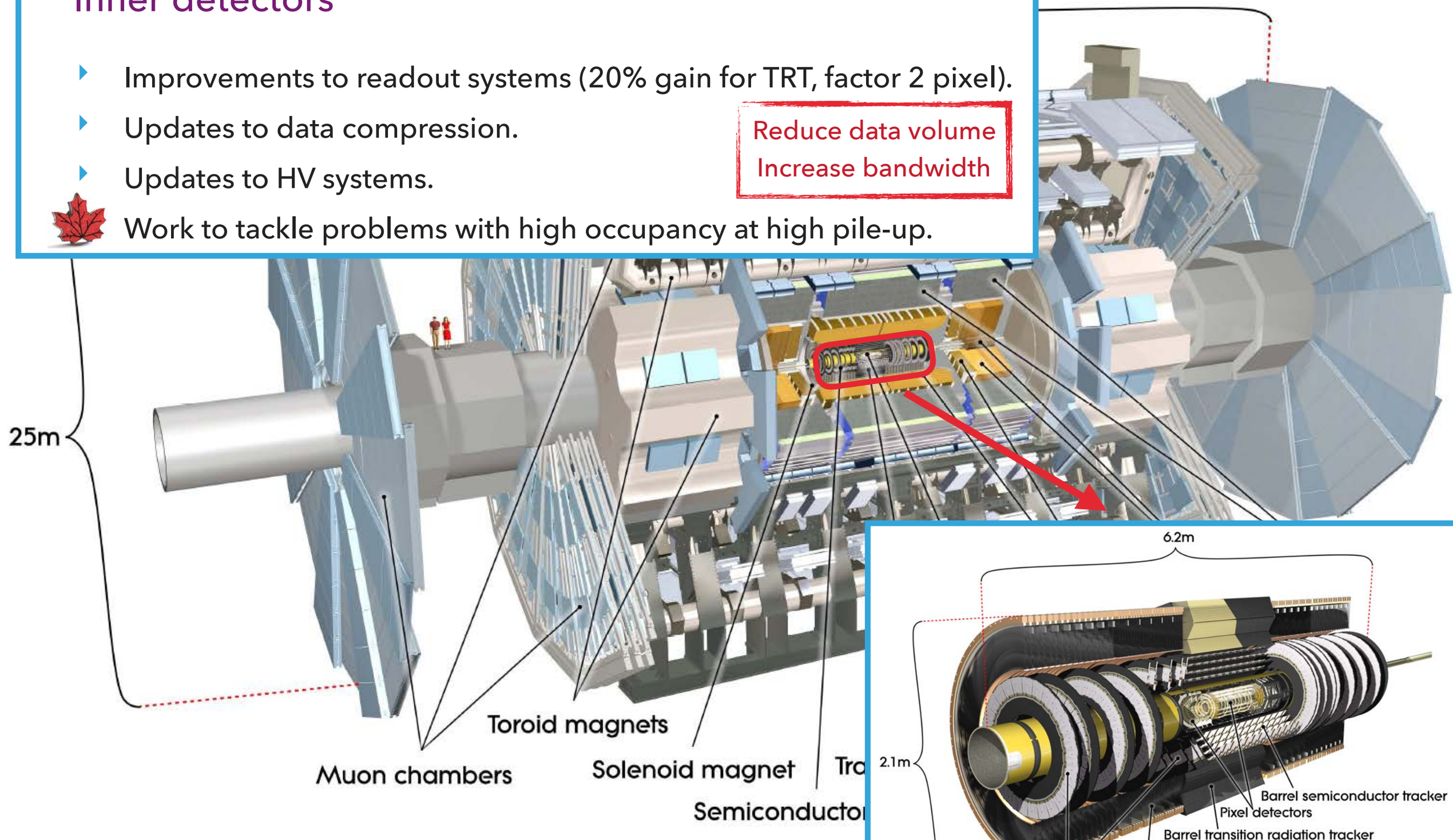
Tier0 cluster size increased over the year - continue to exploit all available resources, including clouds.

DETECTOR READINESS FOR 2017 DATA

Inner detectors

- Improvements to readout systems (20% gain for TRT, factor 2 pixel).
- Updates to data compression.
- Updates to HV systems.
- Work to tackle problems with high occupancy at high pile-up.

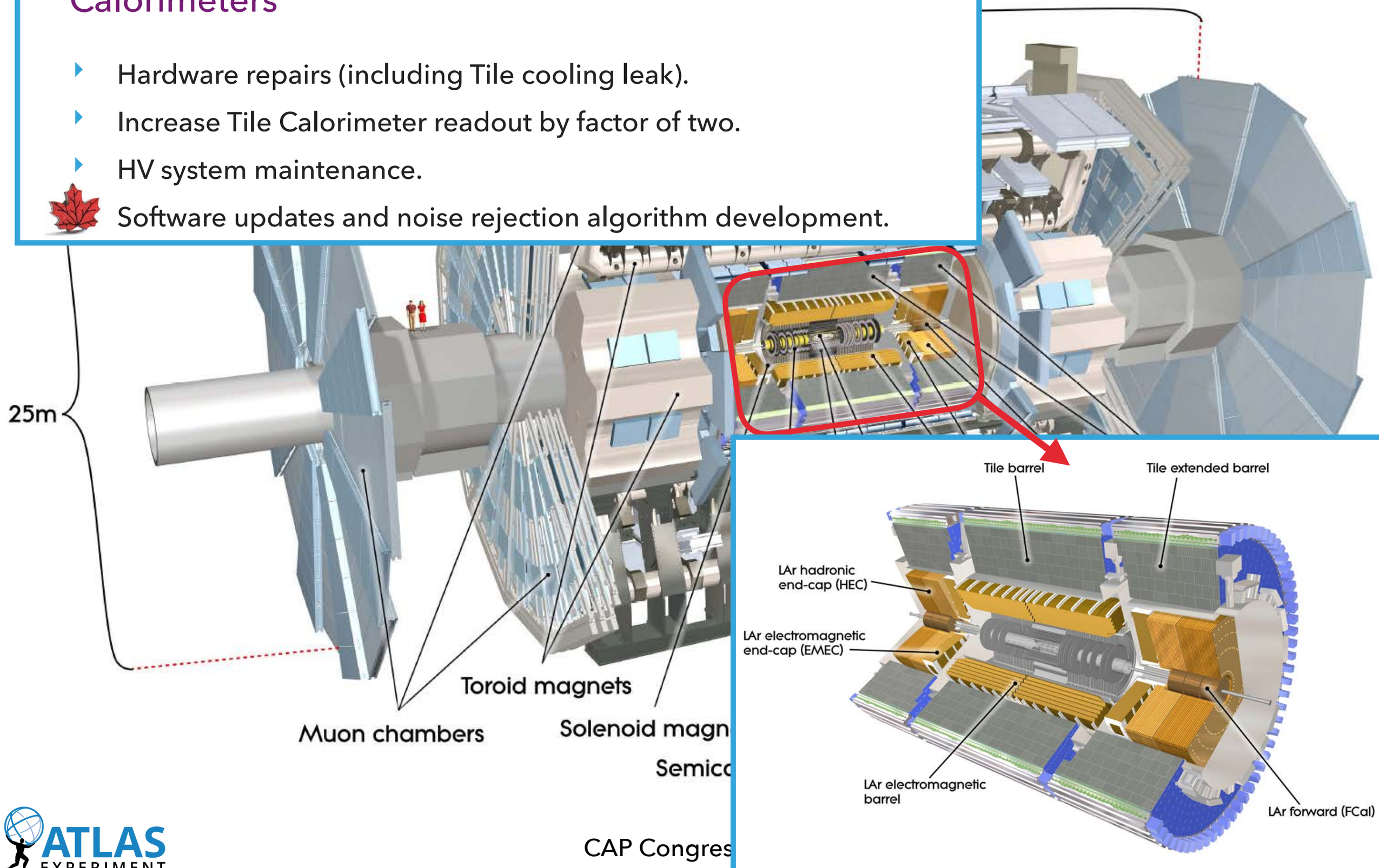
Reduce data volume
Increase bandwidth



DETECTOR READINESS FOR 2017 DATA

Calorimeters

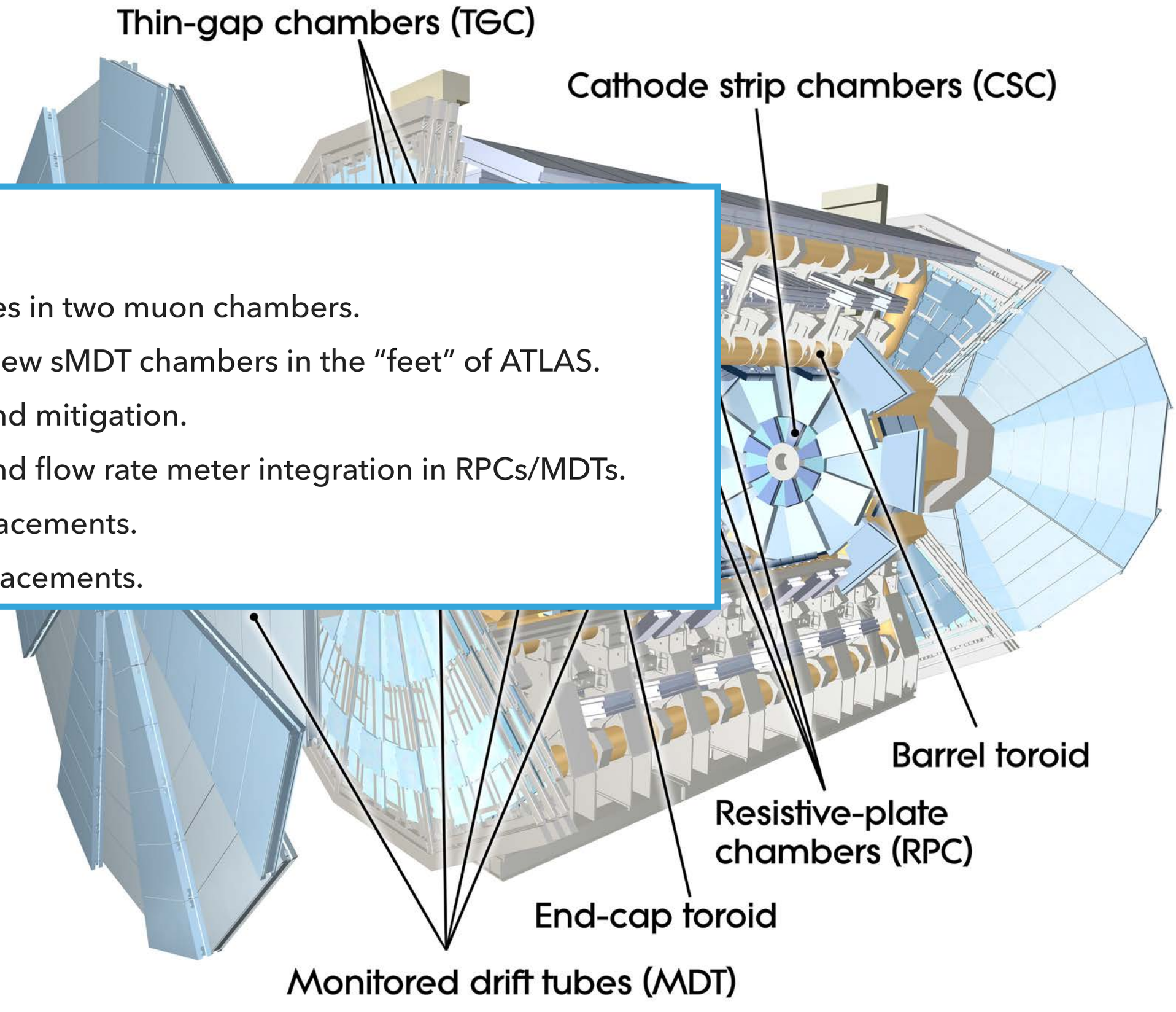
- Hardware repairs (including Tile cooling leak).
- Increase Tile Calorimeter readout by factor of two.
- HV system maintenance.
- Software updates and noise rejection algorithm development.



DETECTOR READINESS FOR 2017 DATA

Muon system

- Repair broken wires in two muon chambers.
- Installation of 12 new sMDT chambers in the “feet” of ATLAS.
- Noise reduction and mitigation.
- Gas leak repairs and flow rate meter integration in RPCs/MDTs.
- Power supply replacements.
- TGC chamber replacements.



ATLAS EXPERIMENT

DETECTOR READINESS FOR 2017 DATA

ATLAS Run-2 Detector Status (from May 2017)

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	92 M	97.8%
SCT Silicon Strips	6.3 M	98.7%
TRT Transition Radiation Tracker	350 k	97.2%
LAr EM Calorimeter	170 k	100 %
Tile Calorimeter	5200	99.9%
Hadronic End-Cap LAr Calorimeter	5600	99.5%
Forward LAr Calorimeter	3500	99.7%
LVL1 Calo Trigger	7160	99.9%
LVL1 Muon RPC Trigger	383 k	99.8%
LVL1 Muon TGC Trigger	320 k	99.9%
MDT Muon Drift Tubes	357 k	99.7%
CSC Cathode Strip Chambers	31 k	96.1%
RPC Barrel Muon Chambers	383 k	94.4%
TGC End-Cap Muon Chambers	320 k	99.5%
ALFA	10 k	99.9%
AFP	430 k	93.8%

Back

21-09-2012
14:29:22

ATLAS	READY	OK
PIX	READY	OK
SCT	READY	OK
TRT	READY	OK
IDE	READY	OK
LAR	READY	OK
TIL	READY	OK
MDT	READY	OK
RPC	READY	OK
TGC	READY	OK
CSC	READY	OK
MUON	READY	OK
CIC	READY	OK
EXT	READY	OK
TDQ	READY	OK
LHC	READY	OK
FWD	READY	OK
SAFETY	READY	OK
DCS BE	READY	OK

Zoom: 100

3D View

All connected

IDE

Back

EVCOOL		
EVC	READY	OK
PIX	READY	OK
BAR	READY	OK
ECA	READY	OK
ECC	READY	OK
PLA	READY	OK
PS	READY	OK
GAS	READY	OK
RAC	READY	OK

MAG		
MAG	READY	OK
COM	READY	OK
SOL	READY	OK
TOR	READY	OK

BCM		
BCM	READY	OK
INF	READY	OK

ENV		
ENV	READY	OK
VOL	READY	OK
HEX	READY	OK
SER	READY	OK
DIP	READY	OK
CAN	READY	OK

TEH		
TEH	READY	OK
ELM	READY	OK
BAR	READY	OK
END	READY	OK
EPS	READY	OK

RAD		
RAD	READY	OK
CAN	READY	OK
PS	READY	OK
SEN	READY	OK

LHC	READY	OK

Stable Beams
Energy 3500.0 GeV
Injection Permit N
ATLAS is beam-safe N
Stable Beams Flag Y
Handshake

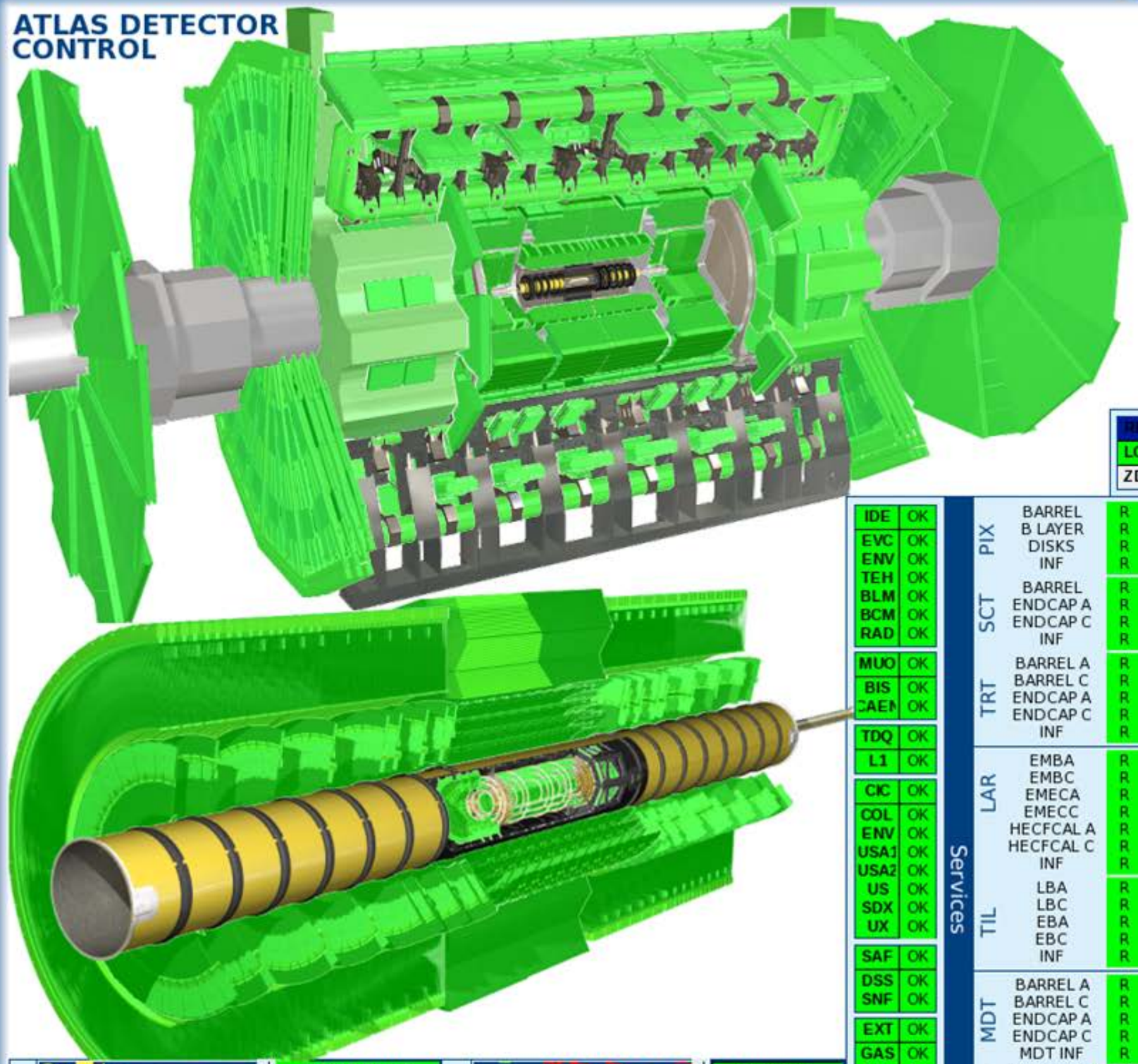
ID		CALO		MUON		SERVICE	
PIX	OK	LAR	OK	MDT	OK	CIC	OK
SCT	OK	TIL	OK	RPC	OK	EXT	OK
TRT	OK			TGC	OK	TDQ	OK
IDE	OK			CSC	OK	FWD	OK
						SAF	OK

S	Object	Time

n/A
W
E
F
D

22

ATLAS DETECTOR CONTROL



FWD		
RPC	OK	
LCD	OK	
ZDC	U	

Services		
IDE	OK	
EVC	OK	
ENV	OK	
TEH	OK	
BLM	OK	
BCM	OK	
RAD	OK	
MUO	OK	
BIS	OK	
CAEN	OK	
TDQ	OK	
L1	OK	
CIC	OK	
COL	OK	
ENV	OK	
USA1	OK	
USA2	OK	
US	OK	
SDX	OK	
UX	OK	
SAF	OK	
DSS	OK	
SNF	OK	
EXT	OK	
GAS	OK	
CAV	OK	
ELC	OK	
VAC	OK	
DBM	OK	
MAG	OK	
7729	A	

Inner Detector			
PIX	BARREL	R	OK
	B LAYER	R	OK
	DISKS	R	OK
	INF	R	OK
SCT	BARREL	R	OK
	ENDCAP A	R	OK
	ENDCAP C	R	OK
	INF	R	OK
TRT	BARREL A	R	OK
	BARREL C	R	OK
	ENDCAP A	R	OK
	ENDCAP C	R	OK
	INF	R	OK

Calorimeter			
LAR	EMBA	R	OK
	EMBC	R	OK
	EMECA	R	OK
	EMECC	R	OK
	HECFCAL A	R	OK
	HECFCAL C	R	OK
	INF	R	OK
TIL	LBA	R	OK
	LBC	R	OK
	EBA	R	OK
	EBC	R	OK
	INF	R	OK

Muon Spectrometer			
MDT	BARREL A	R	OK
	BARREL C	R	OK
	ENDCAP A	R	OK
	ENDCAP C	R	OK
	MDT INF	R	OK
RPC	RPC SIDE A	R	OK
	RPC SIDE C	R	OK
	RPC INF	R	OK
TGC	TGC SIDE A	R	OK
	TGC SIDE C	R	OK
	TGC INF	R	OK

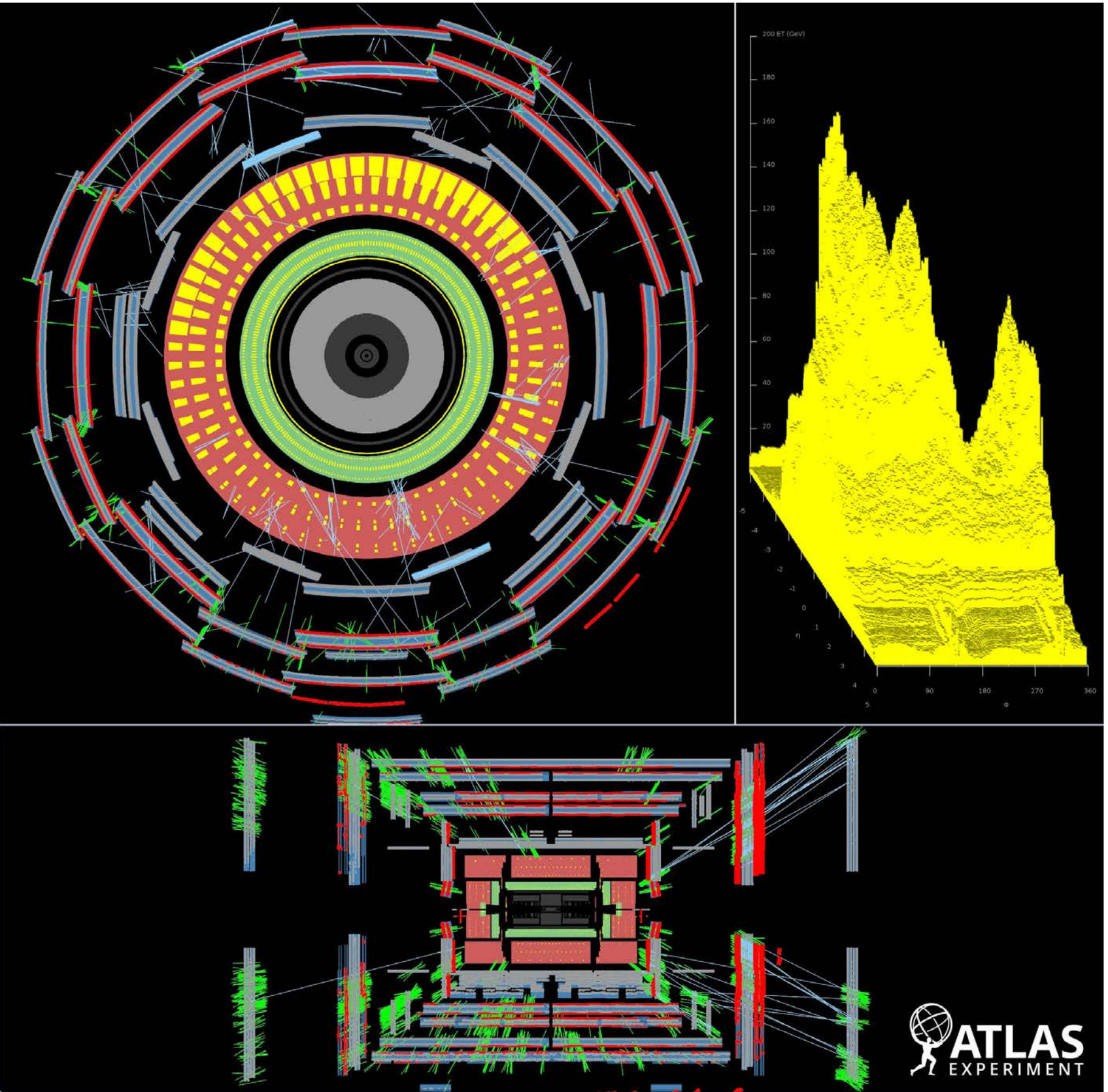
LHC

STABLE BEAMS
Stable Y Permit N
Standby N
B1 2121.4 10^{11}
B2 2121.4 10^{11}
E 3999 GeV
10^{30}

DAQ

RUNNING
Type Physics
Run# 213695
LB# 303
62231 Hz
5468 Hz

FIRST BEAM OF 2017!



BEAM SPLASH EVENT

29 APRIL 2017

Beams return to ATLAS in the first “splash” events of 2017.

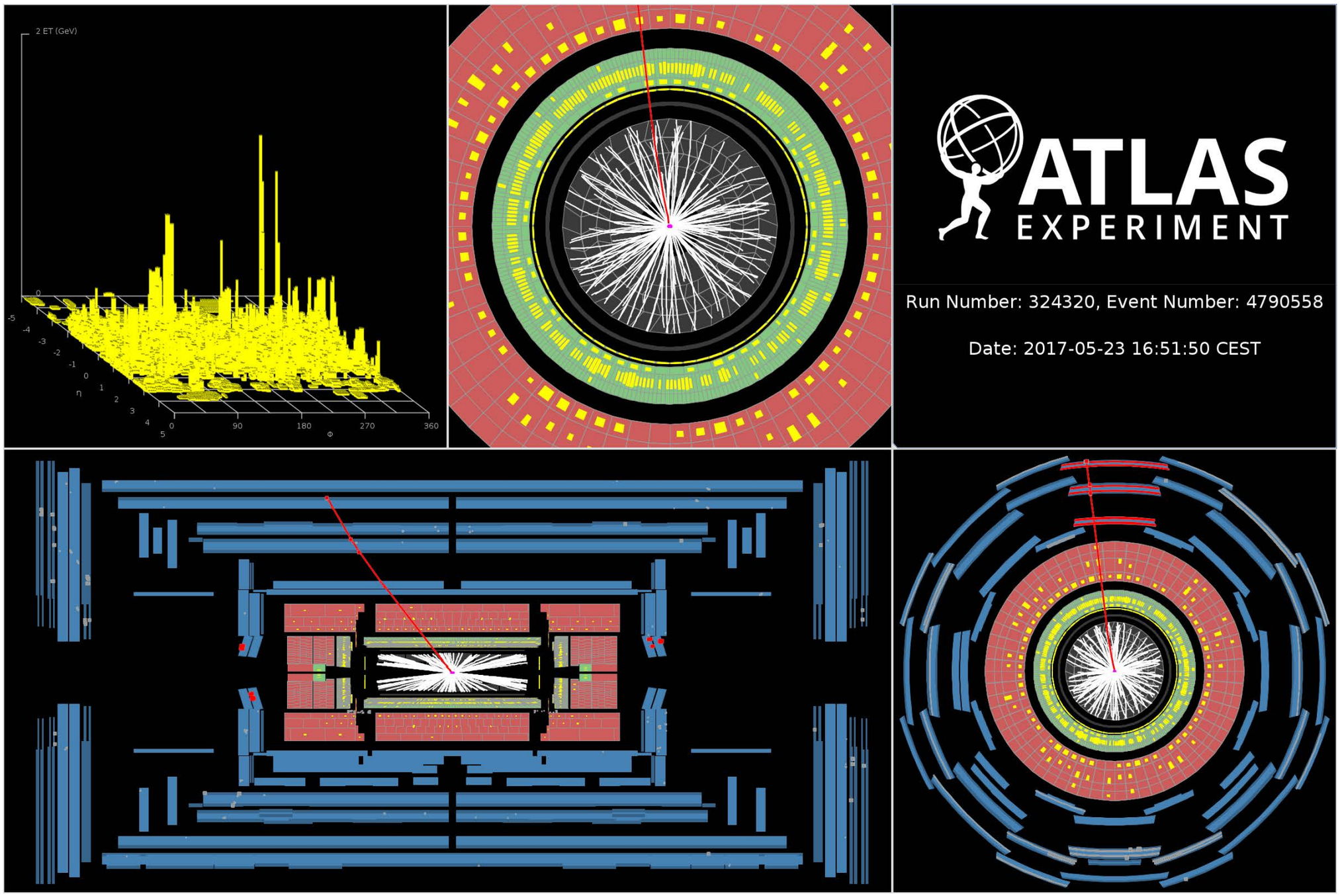
Splashes are generated when protons circulating the collider ring strike collimators downstream from ATLAS.

The resulting spray of particles strike the detector, causing it to light up all the sub-detectors.

University of Victoria

FIRST STABLE BEAMS OF 2017!

One of the early collision events with stable beams recorded by ATLAS on 23 May 2017, with a reconstructed muon candidate.

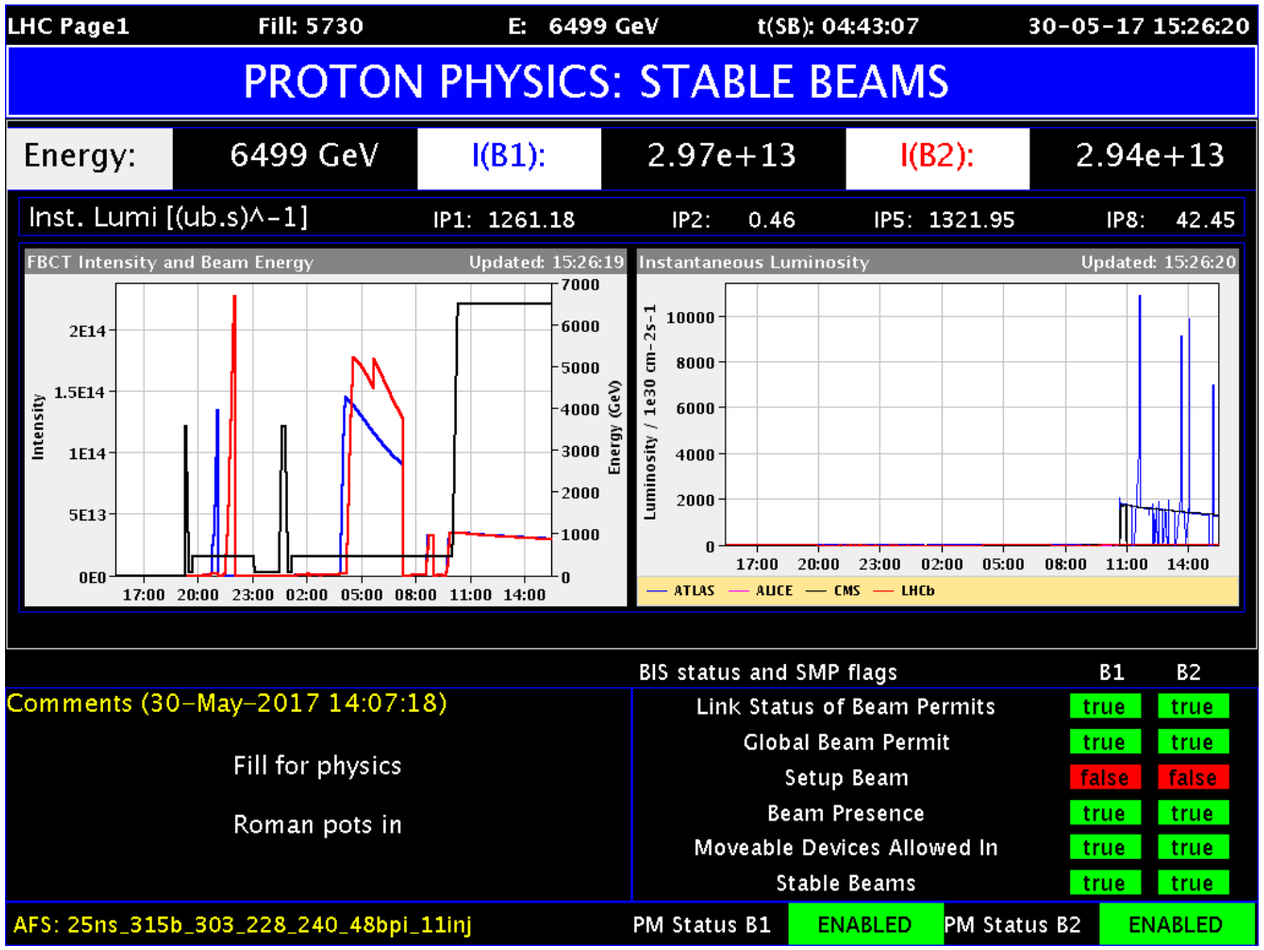


Eta-phi view of the energy deposits in the cells of the ATLAS calorimeters and a transverse view of the inner tracking detectors.

ATLAS in longitudinal cross-section and a transverse view of the whole detector.

SUMMARY

- Excellent LHC availability and performance last year
  - 38 fb^{-1} delivered to ATLAS during 2016
- Increased luminosity and pile-up posed challenges for detector, trigger and computing systems
  - Lessons help to prepare for what's to come in 2017
- Extensive work during EYETS to ready ALTAS for 13 TeV data-taking this year
  - Already starting the 2017 ramp-up

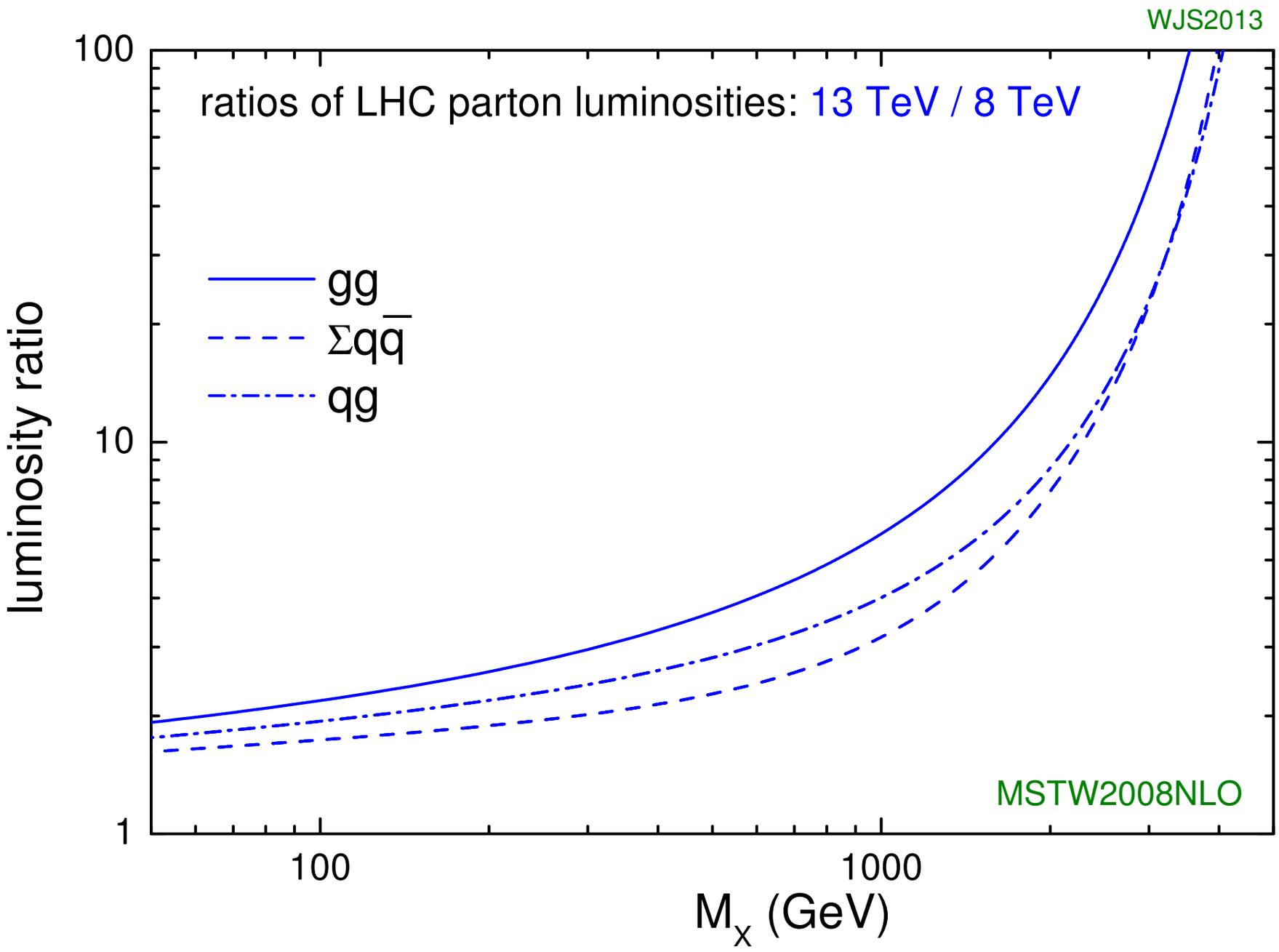


READY FOR SOME NEW PP DATA AT 13 TEV

BACKUP

THE MOVE FROM 8 TEV TO 13 TEV

- Large gains to be had in terms of new physics discovery potential moving from 8 to 13 TeV



Potential gains of > factor 10 for large particle masses.

FORWARD/LUMINOSITY

LUCID

Cerenkov detector

- Upgraded LUCID detector installed end of 2015
- New electronics to cope with 25 ns bunch-spacing.
- Smaller acceptance to avoid saturation.
- Preferred source of luminosity measurement for 2016 operations - also used to monitor non-collision background.

TIMEPIX

Not "forward", but also offers handle on luminosity

- Two silicon Timepix detectors interleaved with neutron converters.
- Active area $2cm^{2}$

ALFA

Total cross-section and luminosity measurement

- Mainly active for high beta* 2.5km runs ($330\mu b^{-1}$).
- Increase in radiation in 2016 by factor ~10 (AFP)
- Increase shielding to reduce impact from radiation during EYETS.

AFP

First AFP arm commissioned during 2016

- Restricted usage due to concerns over ALFA radiation exposure.
- Second arm and time-of-flight detector installed during EYETS.
- Continuous operation planned for 2017 running.