DT STATUS AT THE END OF RUN 2 AND PLANS FOR LS2

(F.R. Cavallo for the DT group)

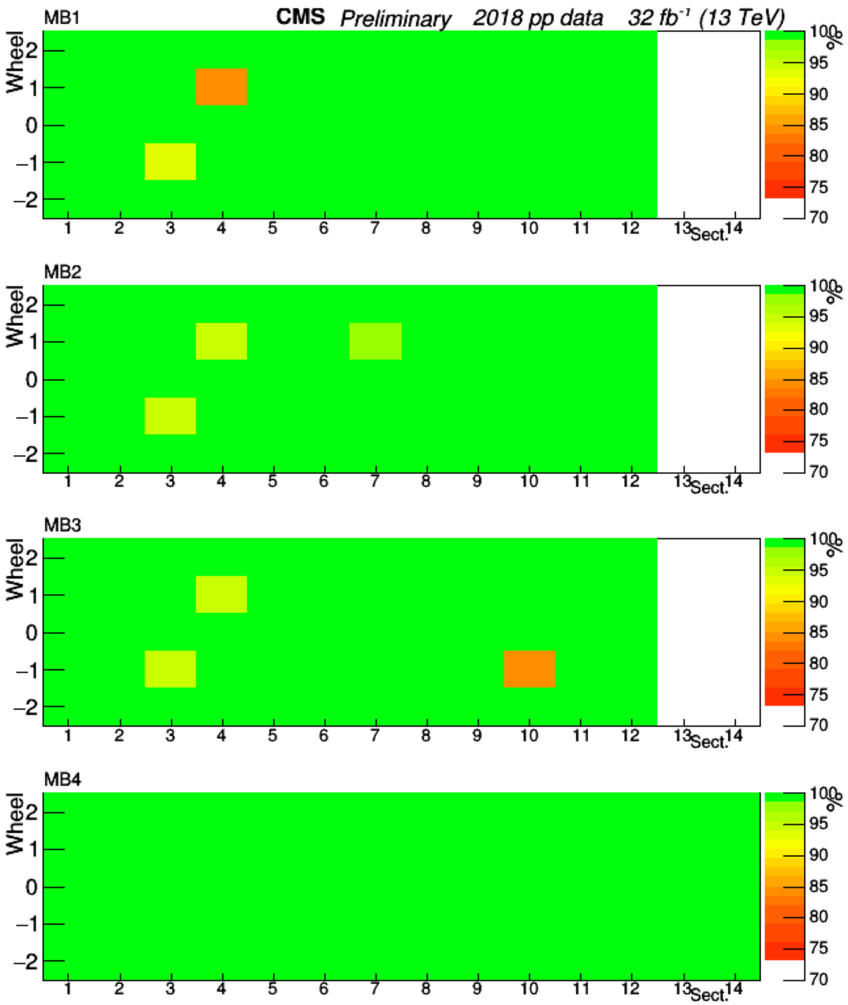
- → DT performance at the end of Run 2
- → DT longevity studies
- → LS2 activities

DT PERFORMANCE AT THE END OF RUN 2

- DT Hit Efficiency at the end of 2018 (dead channels, efficiency by chamber, grand summary)
  Hit Efficiency trends vs Integrated Luminosity
- DT Segment Efficiency at the end of 2018 (efficiency by chamber, φ-η maps, grand summary)
  Segment Efficiency trends with Instantaneous Luminosity, time (run number) and pT
- DT Local Trigger Efficiency at the end of 2018 (efficiency by chamber, φ-η maps)
  DTLT Efficiency trends with Instantaneous Luminosity, time (run number) and pT
- DT Hit Spatial Resolution
- DT time resolution

FRACTION OF WORKING CHANNELS CHAMBER BY CHAMBER

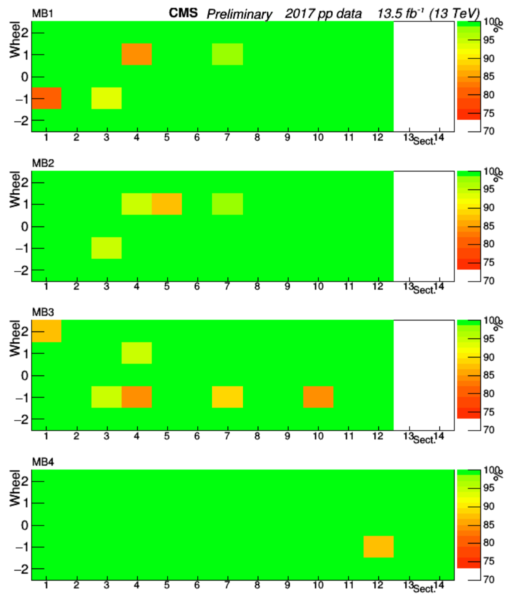
2018



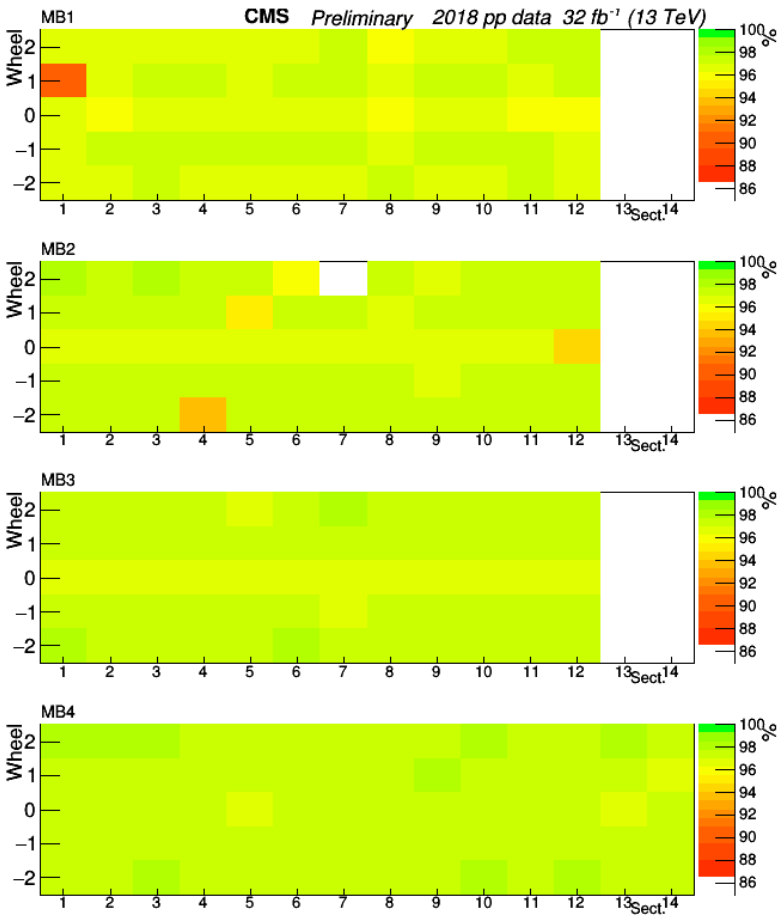
- A not working channel is defined as a channel with zero occupancy (within the considered dataset).
- The fraction of working channels has improved in 2018 thanks to the implementation of the µROS
- Dead channels are discarded in the efficiency computation.
- On the contrary, channels with LOW occupancy (as are e.g. those with malfunctioning HV) are considered inefficient and affect the computed average efficiency of the chamber they belong to.

(see plots in next pages)

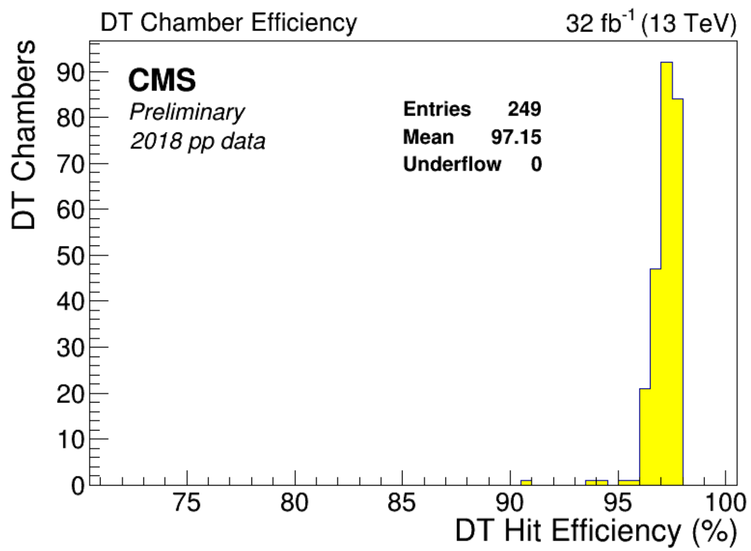
2017



DT HIT EFFICIENCY CHAMBER BY CHAMBER



- The hit efficiency is computed as the ratio between detected and expected hits.
- Expected hits are defined using the intersection of good quality reconstructed segments with the layer under study: the layer is considered efficient if a hit is found within the cell identified by the intersection.
- Segments crossing known dead channels are discarded in the analysis.



Distribution of the efficiency, 1 entry per chamber.
(compatible with last year result).

- *Wheel 2 Sector 7 MB2: full Θ Super Layer inefficient.*
- *YB+1/Sec/1/MB1: SL2, Layer3, ch 1-32 inefficienct*

DT HIT EFFICIENCY TRENDS WITH LHC INTEGRATED LUMINOSITY

✦ Plots in next pages show the trend of Hit Efficiency in time: they make visible any variations, either due to detector ageing or to changes in the detector configuration.

✳ In order to protect the chambers most exposed to radiation from the risk of early ageing, High Voltages were lowered at the beginning of 2017 and again at the beginning of 2018 data taking, as shown in the sketch.

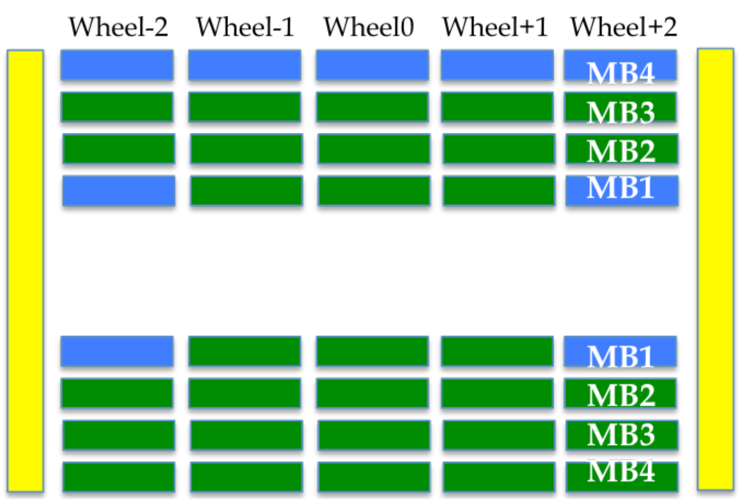
✳ Front End thresholds were also lowered in 2018 in order to recover efficiency.

3600 V

3550 V

FE = 30 mV   3500 V   FE = 20 mV

High Voltage configuration in 2017

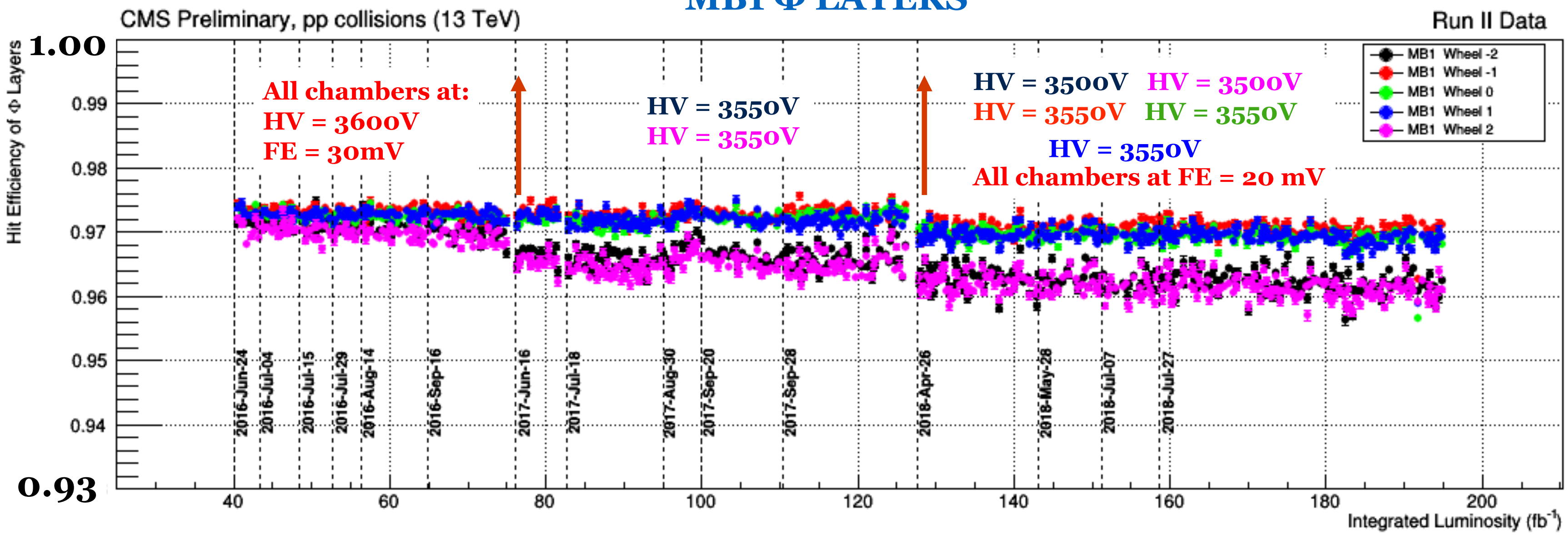


High Voltage configuration in 2018

DT HIT EFFICIENCY TRENDS WITH LHC INTEGRATED LUMINOSITY

✦ The origin of Integrated Luminosity is the start of LHC operation in 2011

MB1 Φ LAYERS



✳ MB1 chambers of external wheels are those most exposed to radiation, hence most at risk of early ageing.

✳ In 2016 all cambers were operated at the nominal value of HV=3600 V: a very mild trend of efficiency loss (< 0.5% for 35 fb^{-1} collected) is visible in the external wheels.

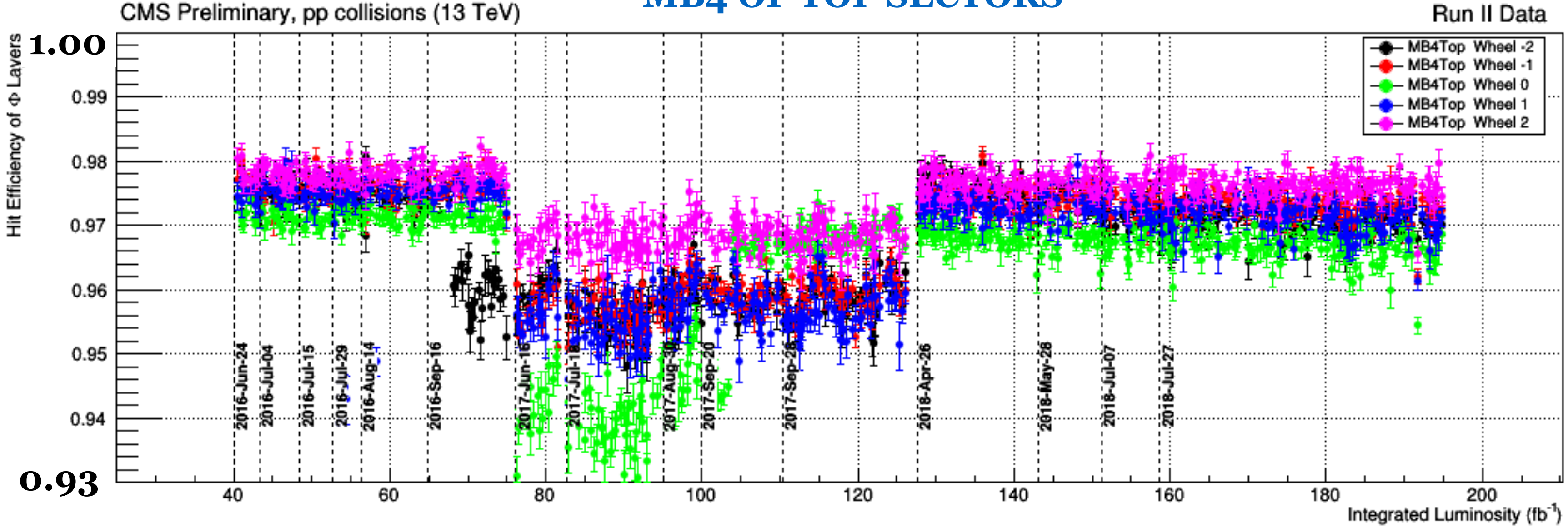
✳ In 2017 the HV of those chambers was lowered to 3550 V, causing a modest step of ~0.5 %, while the trend became flat (no further loss of efficiency was caused by accumulated radiation)

✳ In 2018 the MB1 chambers of external wheels had their HV further reduced to 3500 V, while the 3 internal wheels were brought down to 3550 V. At the same time the FE thresholds were reduced from 30 to 20 mV in order to recover efficiency: in fact the overall reduction of efficiency was small (< 0.5%) and the trend stayed flat throughout the year.

DT HIT EFFICIENCY TRENDS WITH LHC INTEGRATED LUMINOSITY

✦ The origin of **Integrated Luminosity** is the start of LHC operation in 2011

MB4 OF TOP SECTORS



✳ MB4 chambers of top Sectors are exposed to the background produced by interacting thermal neutrons which result from beam collisions and fill the cavern like a gas. Therefore these chambers are also at risk of early ageing.

✳ In 2016 all cambers were operated at the nominal value of HV=3600 V: even though no trend of efficiency was observed so far, several tests were performed to evaluate the effects of HV reduction: the MB4 chamber in Sector 4 of Wheel-2 was the first one to be brought to 3550 V, at the end of 2016: this resulted in ~1% of efficiency loss.

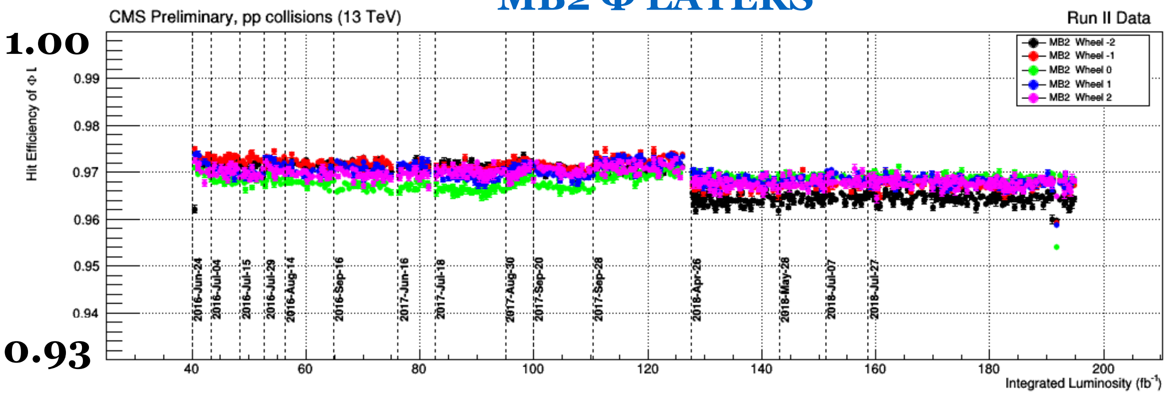
✳ In 2017 the HV was lowered to 3550 V also in the Top MB4 chambers of the other 4 wheels: the largest impact on efficiency was observed in Wheel 0 (~3% loss) where the muon tracks travel the shortest path within the drift tubes and ionize least charge. To recover efficiency in this chamber the FE threshold was lowered from 30 to 20 mV in the Fall: this change fully compensated the change of HV.

✳ Finally in 2018 all the FE thresholds were lowered to 20 mV and the efficiency went up approximately to the initial levels. The trends have been flat or almost flat everywhere (a hint of slope in 2018 may amount to 0.2-0.3 % at most, in 70 collected fb^{-1})

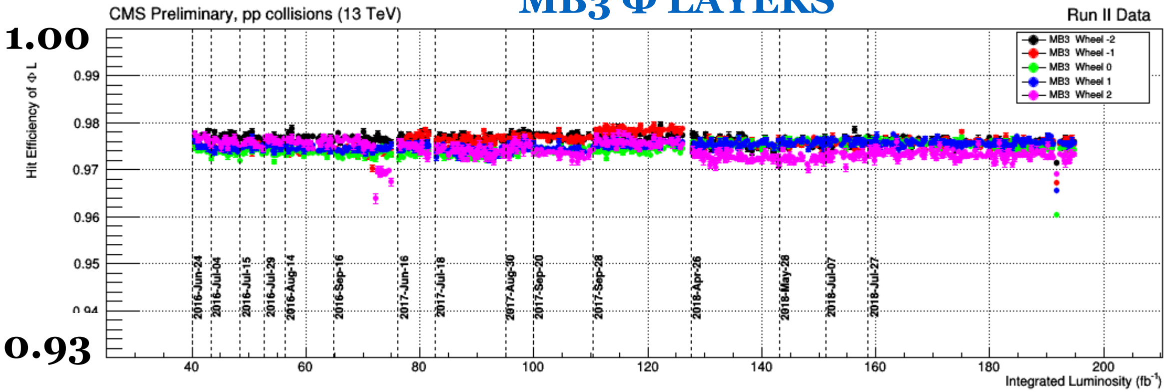
DT HIT EFFICIENCY TRENDS WITH LHC INTEGRATED LUMINOSITY

✦ The origin of **Integrated Luminosity** is the start of LHC operation in 2011

MB2 Φ LAYERS



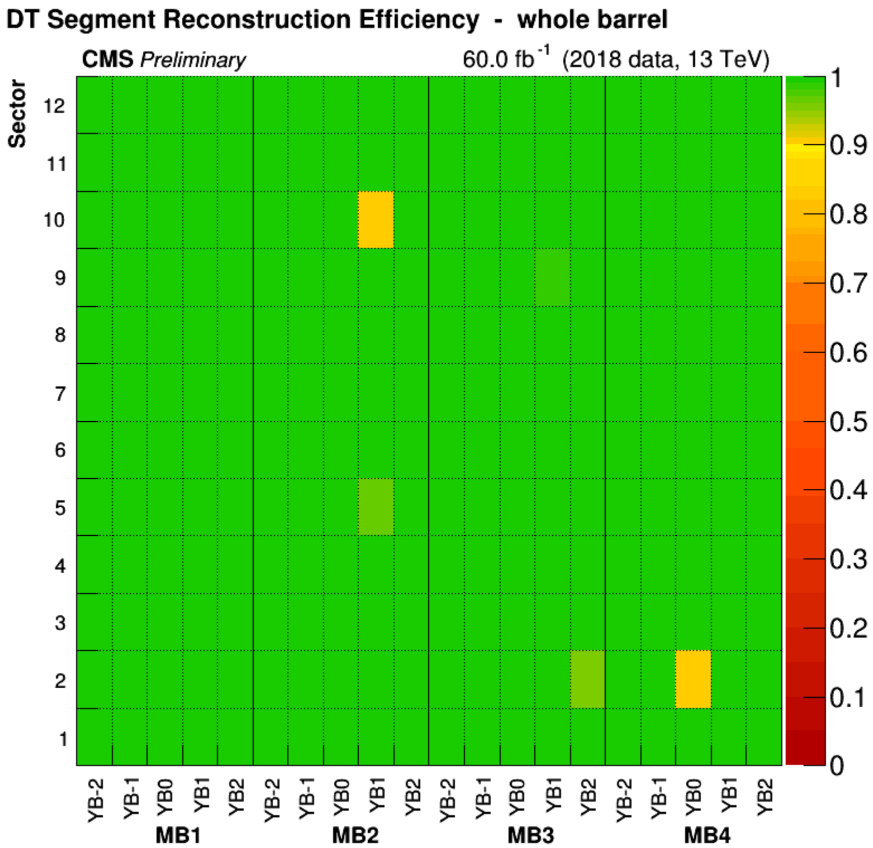
MB3 Φ LAYERS



- ✳ MB2 and MB3 chambers receive much less background than the MB1 ones.
- ✳ Nonetheless the MB2 chambers of Wheels ± 1 and ± 2 and the MB3 chambers of Wheels ± 2 were brought to 3550 V in 2018, while the FE thresholds were reduced to 20 mV.
- ✳ The effects of these changes are visible in the plot, but they are limited to < 0.5%.
- ✳ The trends are flat everywhere.

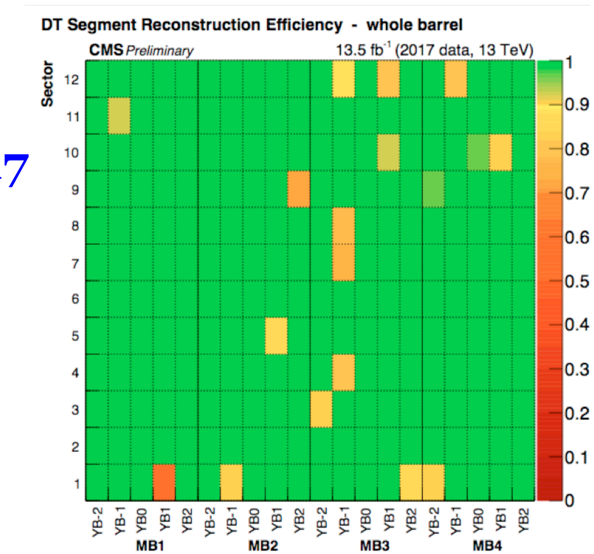
DT SEGMENT EFFICIENCY CHAMBER BY CHAMBER

2018



- The segment efficiency is computed as the ratio between reconstructed and expected segments: these are defined using a Tag&Probe method: events are selected containing 2 reconstructed muons, compatible with the Z mass.
- The probe muon is only required to have ≥ 1 associated segment in a muon chamber different from the one under study and only the information of the tracker is used to extrapolate the muon track.
- A chamber crossed by the probe muon track extrapolation is considered efficient if a segment is found within 15 cm on the RΦ plane.
- While variations of DT hit efficiency of the order of few % don't affect the segment reconstruction efficiency (thanks to the detector redundancy) the recovery of several readout problems, achieved with the implementation of the μROS, visibly improved the segment efficiency, w.r.t. 2017

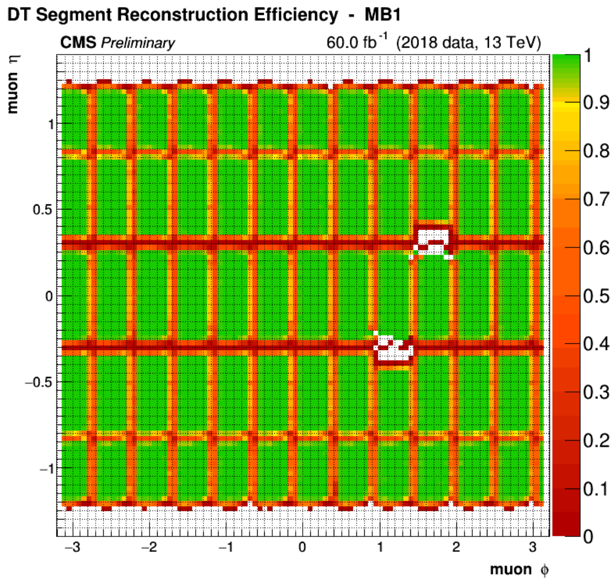
2017

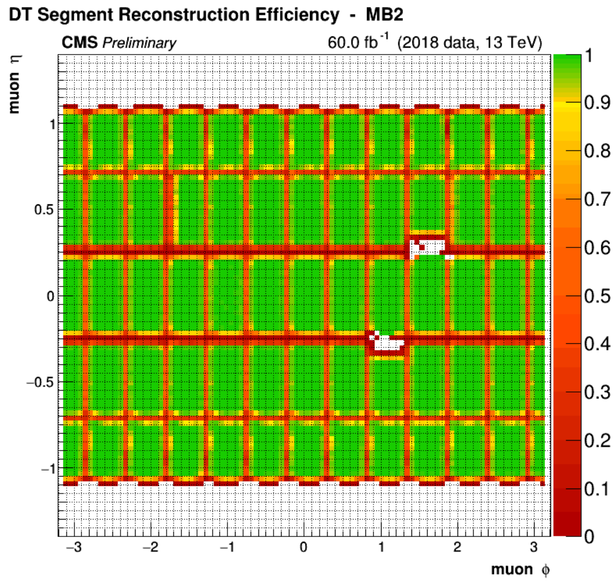


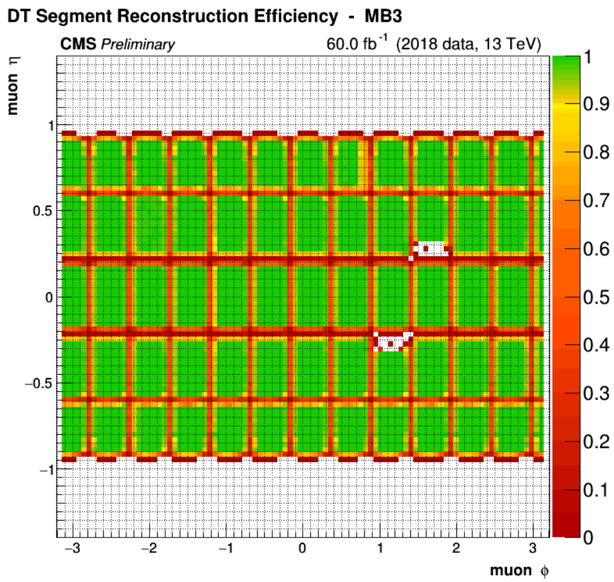
DT SEGMENT EFFICIENCY MAPS

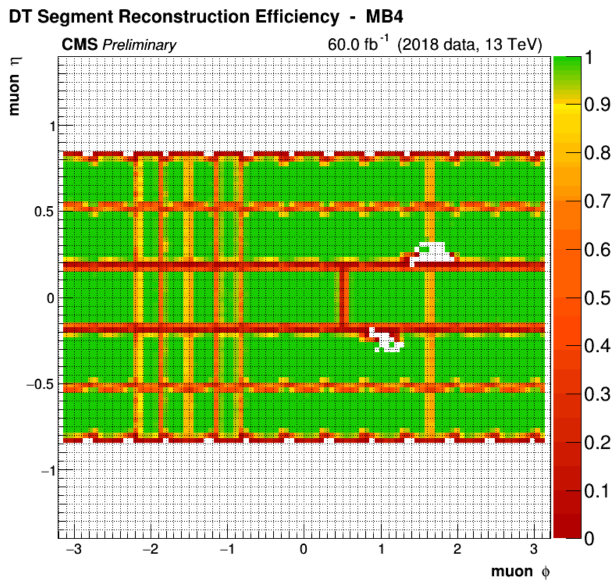
Segment efficiency computed for the 4 DT stations, as a function of the probe muon **φ and η.**

Clearly visible are the dead regions corresponding to "chimney chambers" in Wheel -1 Sector 3 and Wheel +1 Sector 4.



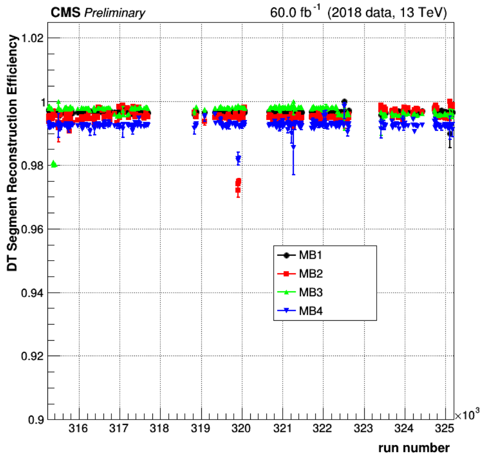


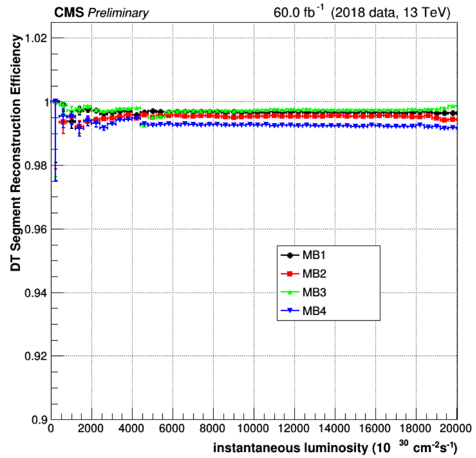




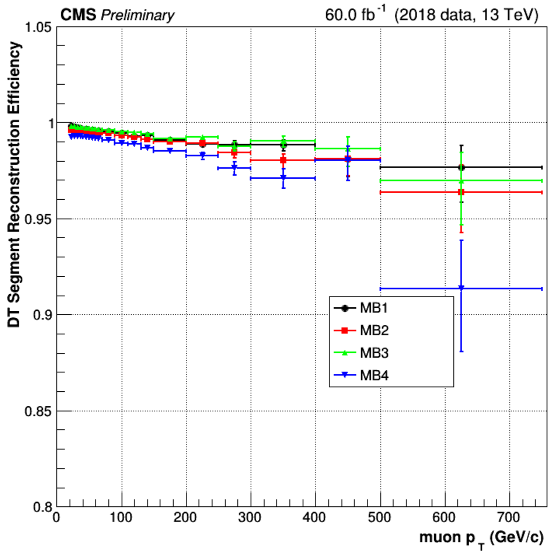
DT SEGMENT EFFICIENCY TRENDS

- ✳ DT segment efficiency is constant **in time** and does not depend on **Instantaneous Luminosity** within the range of available data.
- ✳ The average values are 1-2% larger than in 2017 thanks to the recovery of readout problems in 13 chambers, obtained with the μROS.

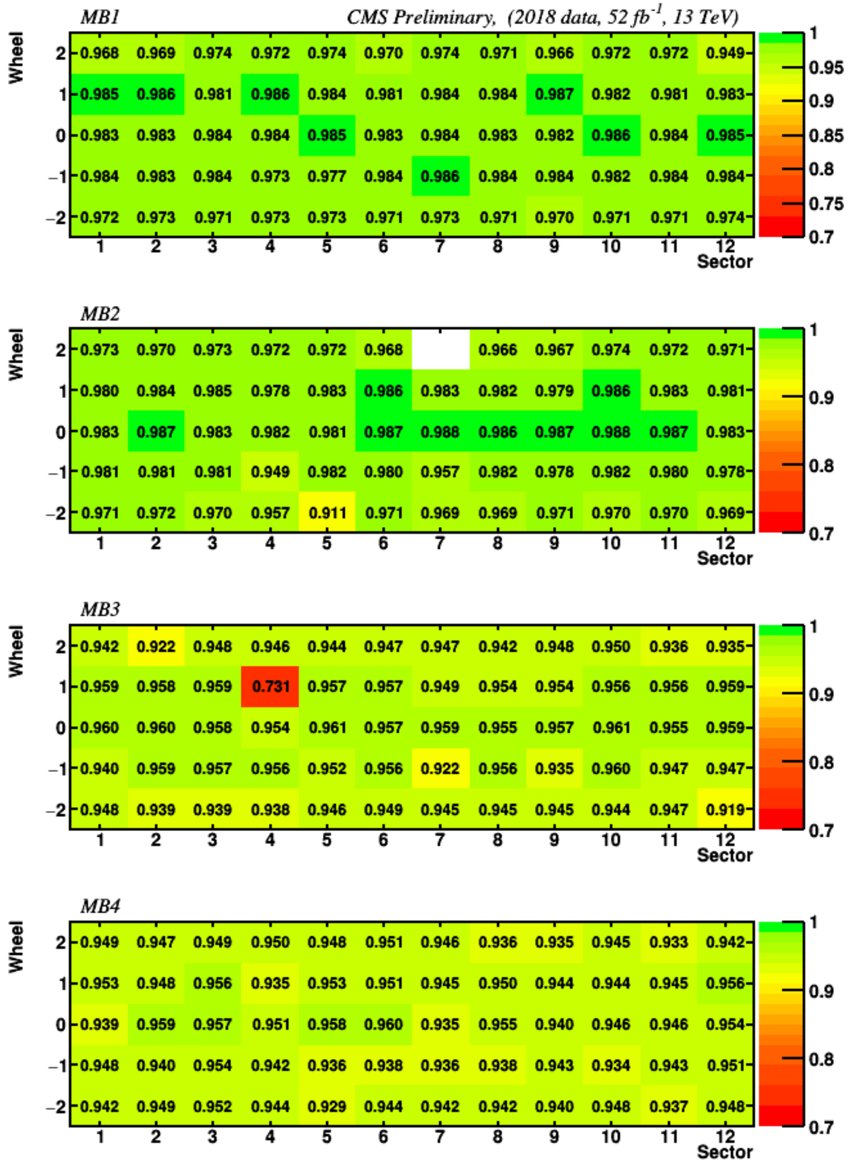




- * The segment efficiency shows a trend at very high **transverse momentum:** it keeps > 98 % up to 500 GeV.



DT LOCAL TRIGGER EFFICIENCY CHAMBER BY CHAMBER



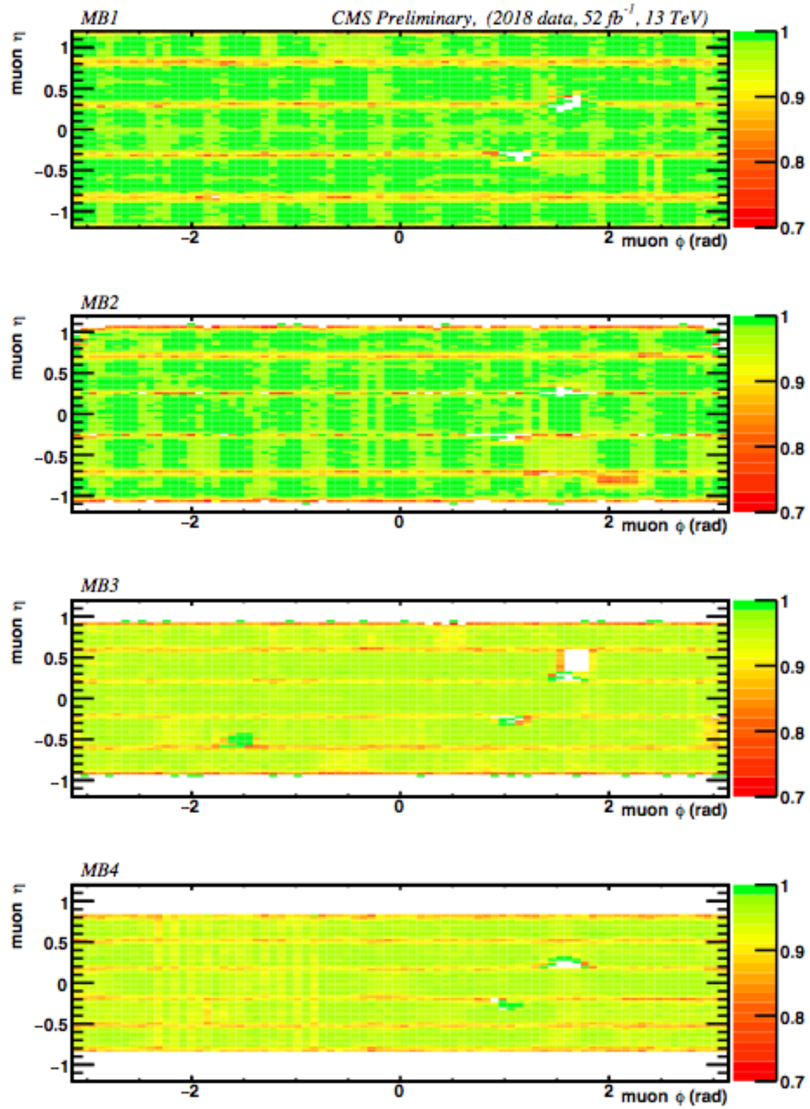
- ✳ The Local Trigger efficiency is computed as the ratio between detected and expected trigger primitives.
- ✳ Expected trigger primitives are defined using the same Tag&Probe method applied to compute the segment reconstruction efficiency.
- ✳ A chamber crossed by the probe muon track extrapolation is also required to have a reconstructed segment matched to the track and reconstructed in both Θ and Φ views.
- ✳ The chamber is then considered efficient if a trigger primitive is found in the chamber at the correct BX.
- ✳ Trigger primitives are read-out at the ouput of TwinMux, so they also exploit the RPC information.
- ➡ In 2018 "RPC-only" primitives were added in the MB1 and MB3 stations (that have two layers of RPC chambers): this addition produced a ~3% efficiency increase in these stations. *(see slide 14)*

The Local Trigger efficiency could not be computed in Wheel 2 Sector 7 MB2, due to lack of information in the Θ view, while Wheel 1 Sector 4 Mb3 has a faulty trigger board.

DT LOCAL TRIGGER EFFICIENCY MAPS

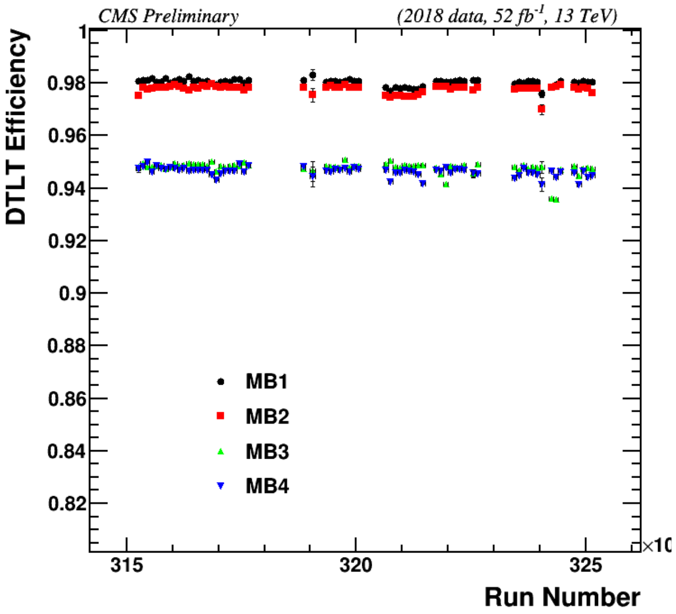
Local Trigger efficiency computed for the 4 DT stations, as a function of the probe muon **φ and η**.

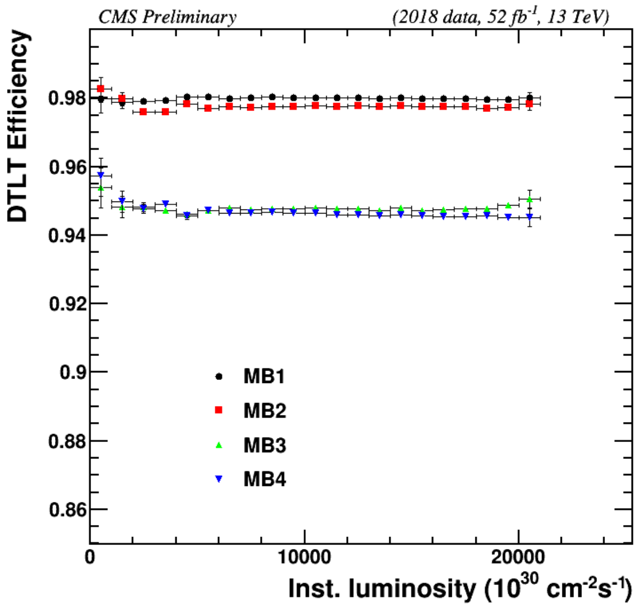
Clearly visible is the effect of the faulty trigger board in Wheel 1 Sector 4 MB3 and those of the dead regions corresponding to “chimney chambers” in
Wheel -1 Sector 3 and Wheel +1 Sector 4.

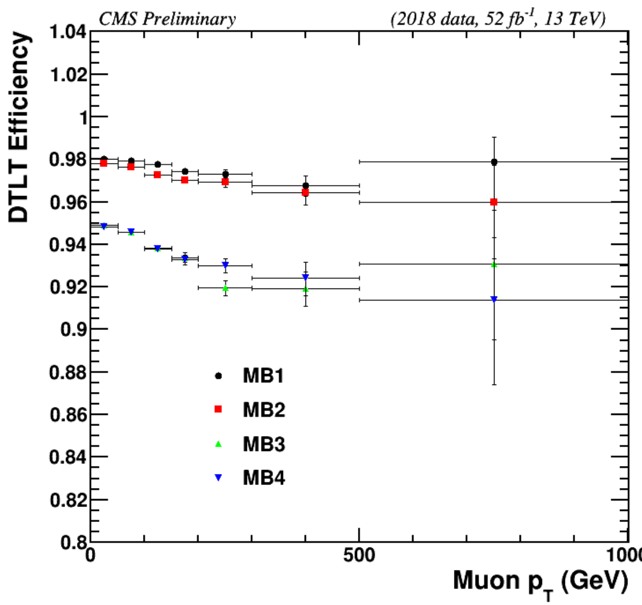


DT LOCAL TRIGGER EFFICIENCY TRENDS

- ✳ The DT Local Trigger efficiency is constant in time and does not depend on Instantaneous Luminosity within the range of available data.
- ✳ Clearly visible is the difference between internal (MB1, MB2) and external (MB3, MB4) stations: this is due to the contribution of RPC-only primitives in the internal stations.
- ✳ In these stations the trend of efficiency with transverse momentum is also milder.







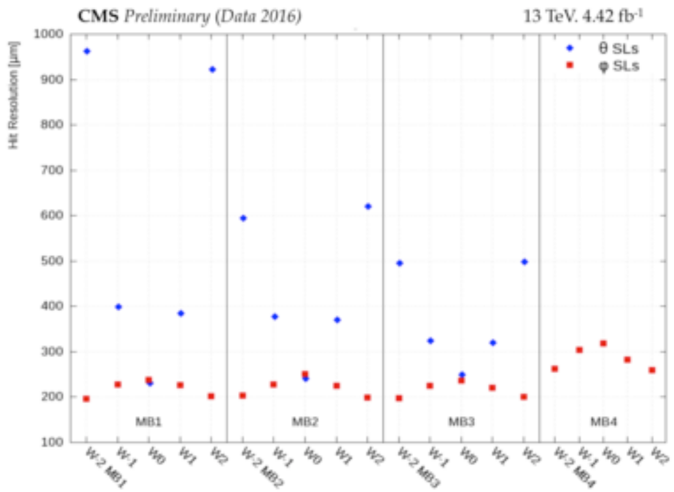
DT HIT SPATIAL RESOLUTION

✳ The spatial resolution is obtained from the widths of residual distributions, i.e. of the distances between each hit and the segment it belongs to.

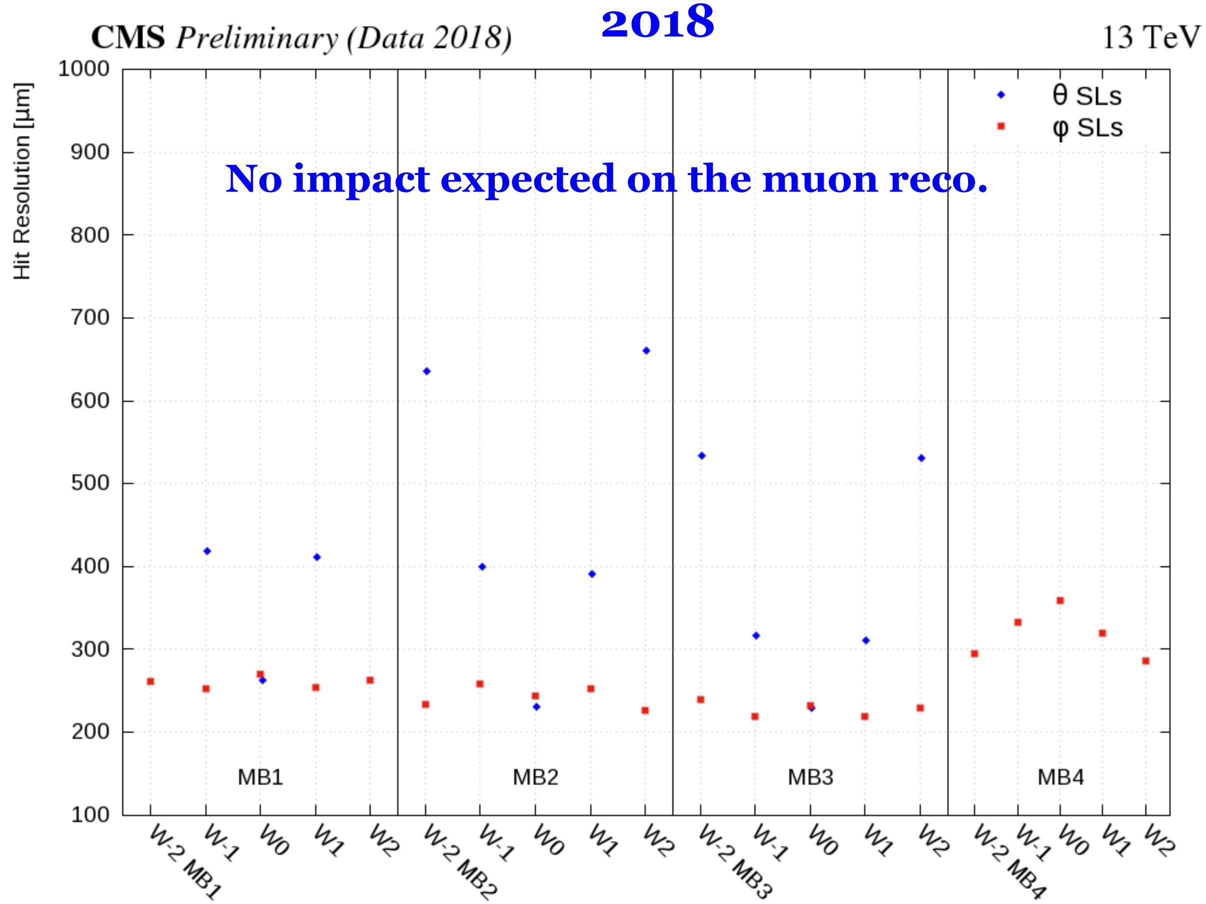
→ A comparison to previous public results show the effects of lower High Voltages:

- * In MB1, MB2 and MB3 the HVs were lowered more in the external than in the internal wheels: this brought the resolution of Φ layers in the external wheels to the same level of the central one, thus compensating the effect of the longer path travelled by muons within the tubes.
- * In MB4 the HV was lowered by the same amount in all wheels so the result was a slight worsening of resolution everywhere, preserving the same trend as a function of **η** (wheel).
- * The resolution of Θ layers of external wheels also slightly worsened as a result of lowering the HV (in particular Wheel-2 MB1 and Wheel+2 MB1 now slightly exceed 1mm)

2016



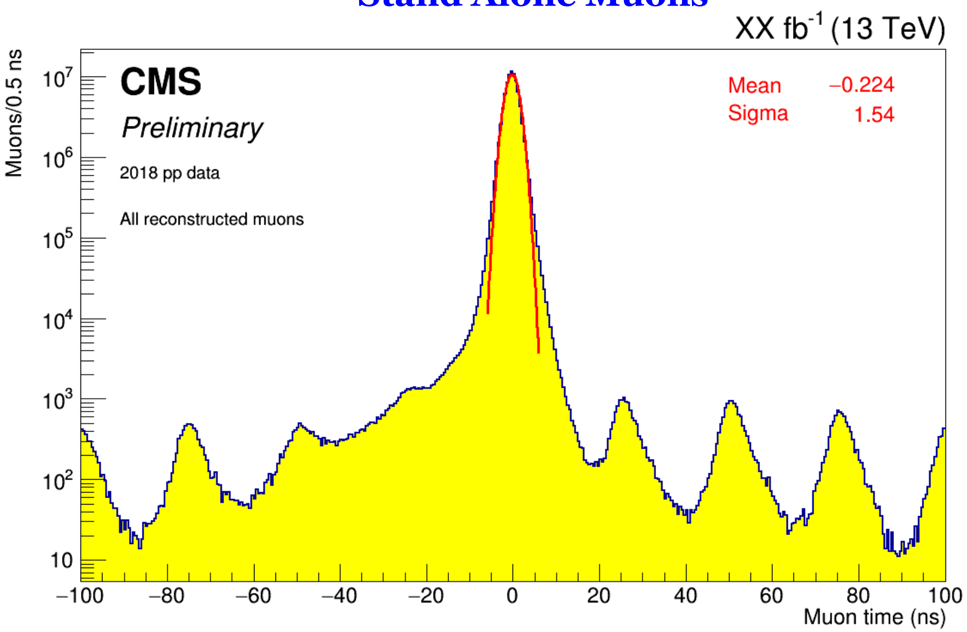
2018



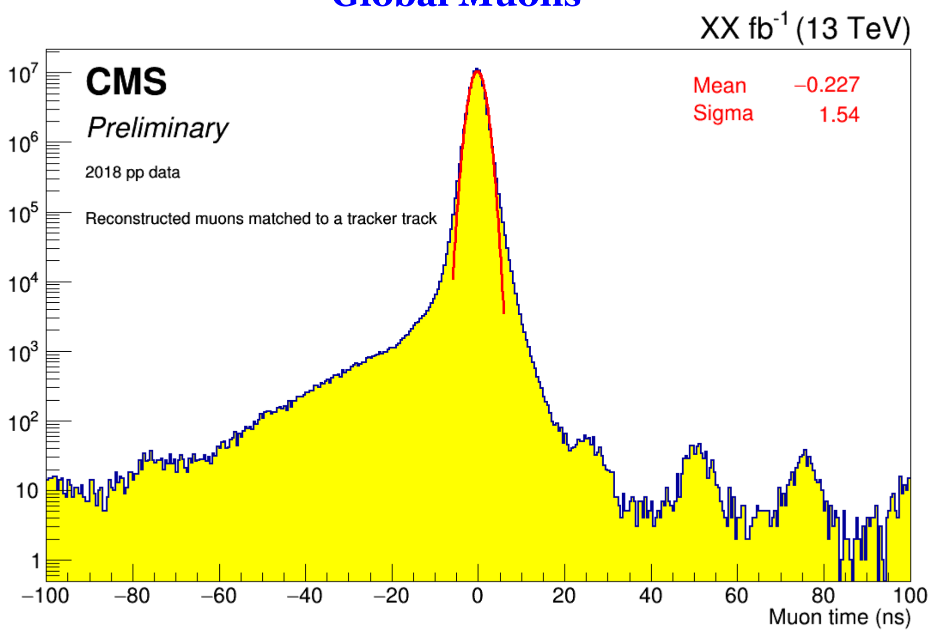
DT HIT TIME RESOLUTION

* The time resolution is obtained from the time distribution of muons reconstructed in the barrel region (only DT time information is used)
* Thanks to a very accurate calibration, it did not worsen as a result of lower HV (it was 1.57 ns in 2017, 1.54 ns in 2018)
* When no matching with the tracker is required, the beam structure is evident in the secondary peaks.

Stand Alone Muons



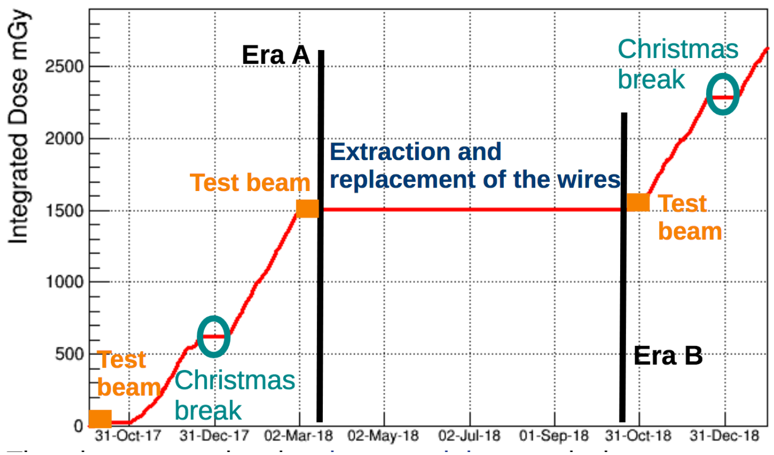
Global Muons

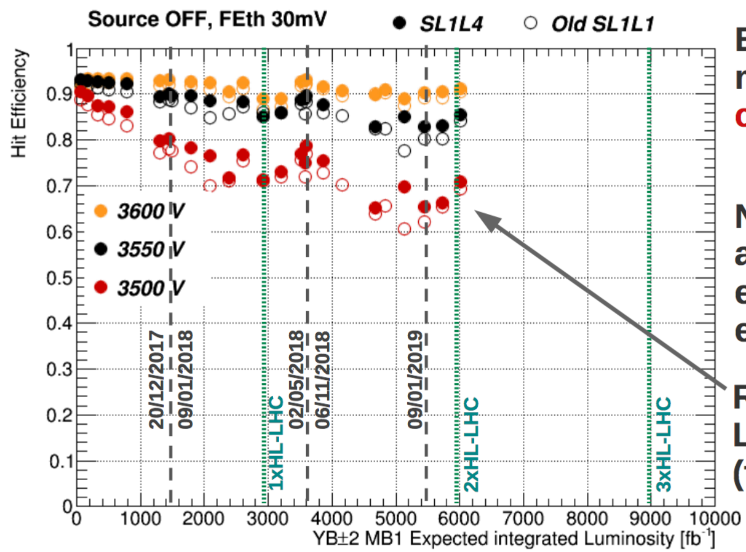


DT LONGEVITY STUDIES: ACTIVITIES AND RESULTS

(Anna M. for the DT Longevity Task Force)

- No significant aging effects were observed at P5 so far: slopes of currents vs instantaneous luminosity are constant , from 2012 to 2018. Aging effects at P5 were also studied in 2018 with monotubes at large acceleration factor.
- At GIF++ a spare MB2 chamber
  - was irradiated at an acceleration factor of ~15 times the worst background expected in the MB1 of external wheels at HL-LHC. Only two layers (L1 and L4, SL1), had HV on. From Nov 2017 up to March 2018 the layers integrated 1.2 times the foreseen HL-LHC luminosity, i.e. 3500 fb^{-1} (Era A in the left plot).
  - In summer 2018 the chamber was opened and 8 wires of the irradiated L1 layer were extracted and 7 replaced. Extracted wires were inspected.
  - A second period of MB2 irradiation went from Nov 2018 up to the end of January 2019 (Era B in the left plot) and further ~3000 fb^{-1} were integrated at the same acceleration factor. So the new wires collected 3000 fb^{-1} while the already irradiated wires ("old wires") reached 6500 fb^{-1} (2.2 times the HL LHC).
  - In the last two weeks of January 2019 8 wires of L2 SL1 (never irradiated before) were set with HV on during irradiation.
  - Along the whole period of tests, efficiency measurements were performed every week with cosmic rays and with no irradiation (right plot)
- Tests with different O2 concentrations have been performed on the aged MB1 chamber at GIF++ along 2018 irradiation .





Efiiciency measured with cosmic muons

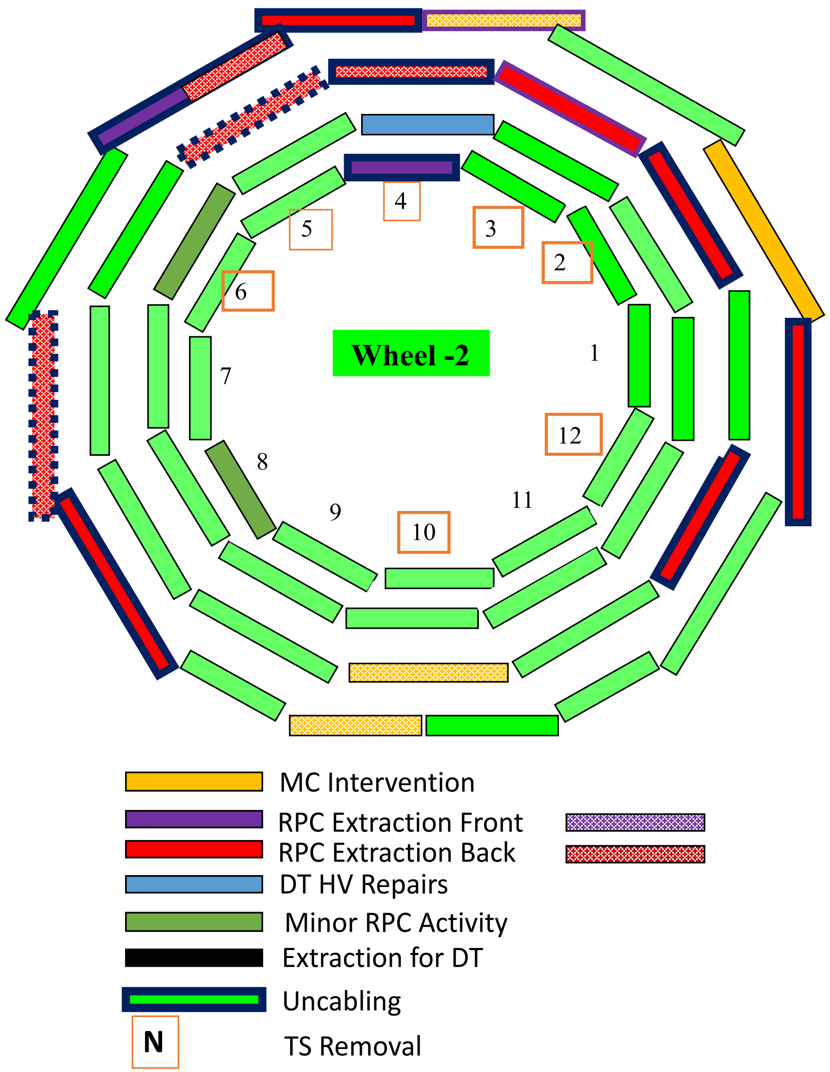
No corrections applied for environmental effects

Reached 2xHL-LHC expected lumi (for a MB1 Wh±2)

TECHNICAL COORDINATION ACTIVITIES: PLANNED INTERVENTIONS

(from Daniele)

- → Final update of the Barrel planning for Spring/Summer is ongoing
- → Collaboration with RPC to identify all interventions
- → Most impacting activity are the back extractions for the RPC leaks. Final number require investigation of the leak with the endoscope and depend on wheel accessibility



Realistic Scenario			
No-IP side Chamber Extraction (RPC thresholds)	IP Side Chamber Extractions (RPC leaks)	Full Chamber extraction (DT problem)	DT chambers to un-cable
14	25	1	60 (25% of the detector)

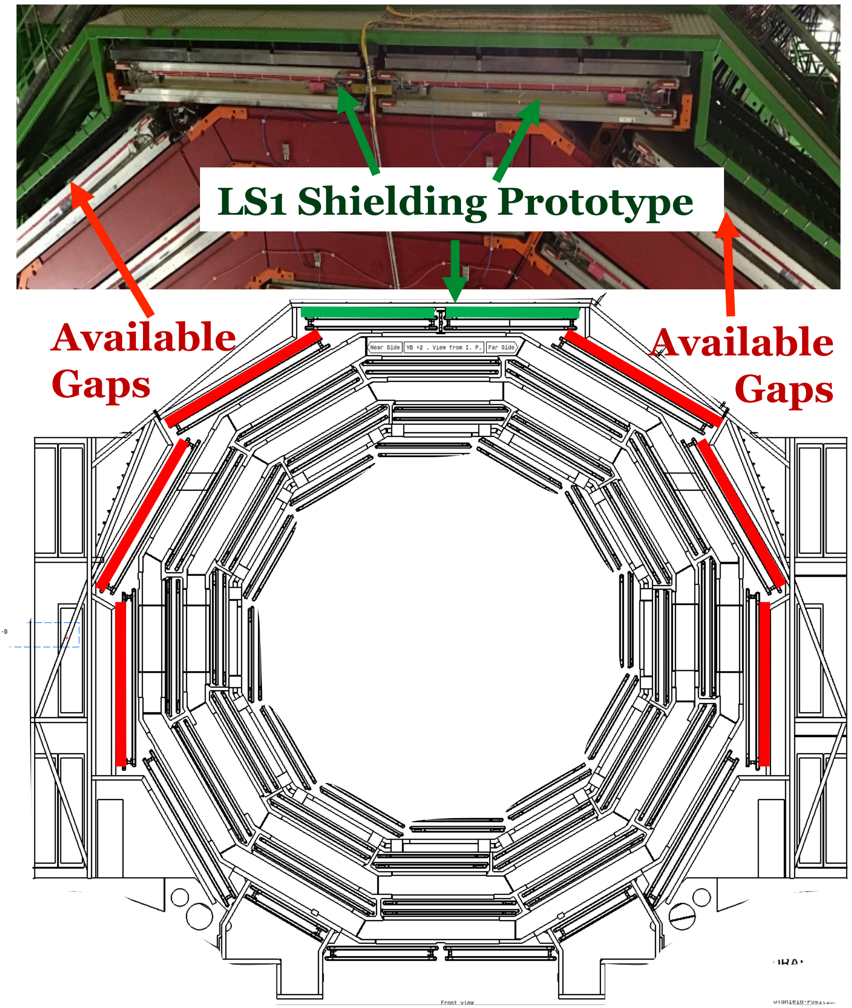
TECHNICAL COORDINATION ACTIVITIES: ALBERTO'S SHIELDING PREPARATION

(from Daniele)

→ Shield production is proceeding well
  * Built cassettes to cover 6 sectors
  * Supporting structure prototypes are being completed

→ TC has requested a trial installation to measure the actual deformation of the green structure
  * Will be performed on S3/5 of an external wheel

→ Ongoing work:
  * Inspection of Wheel0 to determine space available for partial shielding (due to the presence of services)
  * Design support and insertion tool for the vertical sectors (1-7) which will be installed in a later access window.



OBDT PROTOTYPE STATUS

(from Sandro)

→ On Dec 19th first batch of prototypes received at Cern

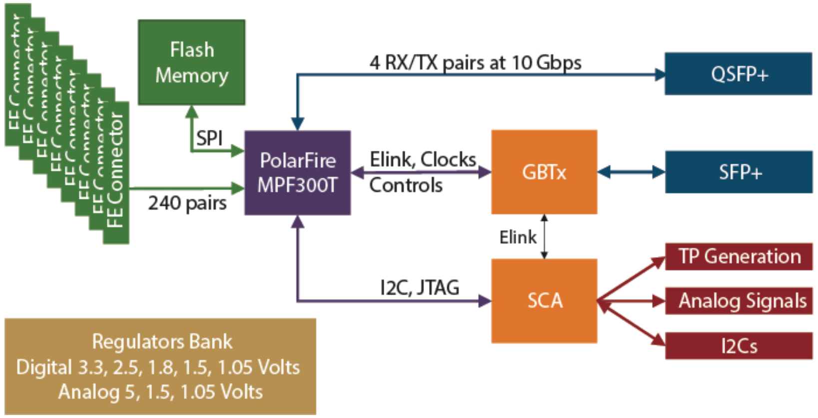
→ During Christmas break three boards have been powered and "newborn" issues worked out

→ Extensive tests ongoing to validate the board and give green light to the assembly of the full batch

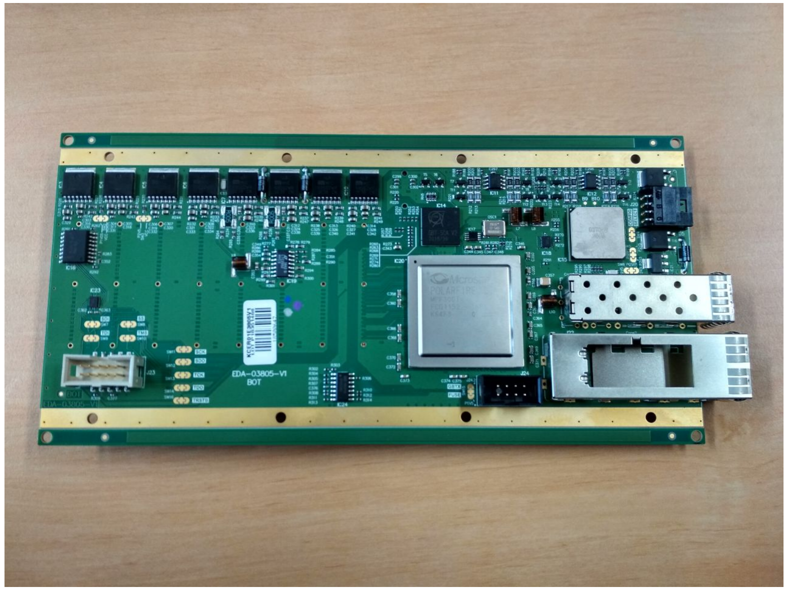
→ Tested up to now (both LNL and Ciemat):
  - Power distribution
  - FPGA
  - Most of the input channels
  - QSFP+ links at 4.8Gb/s
  - SFP+ and GBTx (in Madrid)

→ Boards being integrated on a chamber (SX5 and LNL)

OBDT Architecture



OBDT Prototype



SLICE TEST PREPARATION

(from Ignacio)

1- SX5 setup has been evolving after last CMS week to resemble the architecture we will have in the slice test.

* Data is taken with miniDAQ :
  - FRLs and TCDS as well as the Phase 2 (AB7) and Phase 1 (uROS, TwinMux) backend electronics are in USC, same as will be used in slice test

* TDC Hits from the surface chamber are pushed to the AB7 where the trigger is generated and separately readout by the legacy FEDs reading the positive wheels.
  - CuOF system put in place last December and GBTx emulator part recovered this January thanks to the Torino team.
  - Very useful for parallel offline development, will resume data taking as soon as cooling allows.

* One OBDT board is being integrated in the setup and could be read in parallel to the currently used evaluation board.

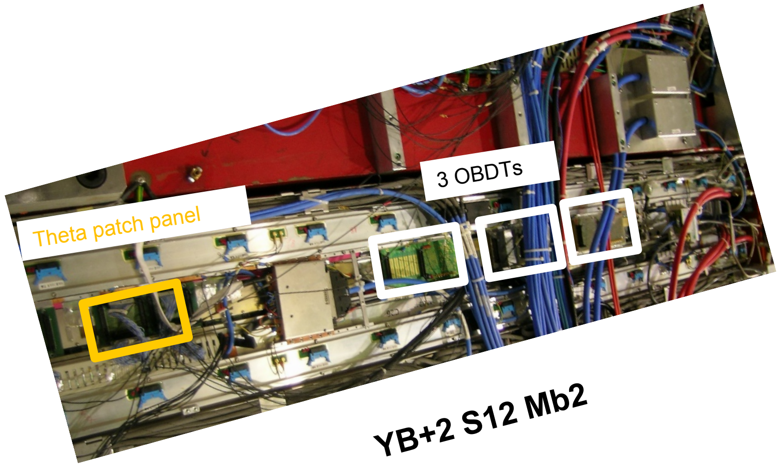
2- Preparation of slice test installation proceeding well

* Clearance to MABs was checked to be >15 mm in S12

* Mechanical mockup boards on MB2 installed by Vincenzo, Vittorio and Lorenzo recently, next iteration in 2 weeks.

* Production of cables advancing
  - MB2 FE cables done, power cables will be available

* As an installation test, a MB1 minicrate was extracted and will be replaced by a legacy minicrate hosting OBDT boards.



Goal is to have infrastructure and offline tools ready when the tested OBDTs with operational FW are ready during the summer access window.

SUMMARY

→ DT behaved very well along the whole of Run 2.

* HV reduction, applied to preserve chambers from early ageing, did not result in any significant degradation of performance

→ GIF++ data are being analyzed

→ LS2 activities have started:

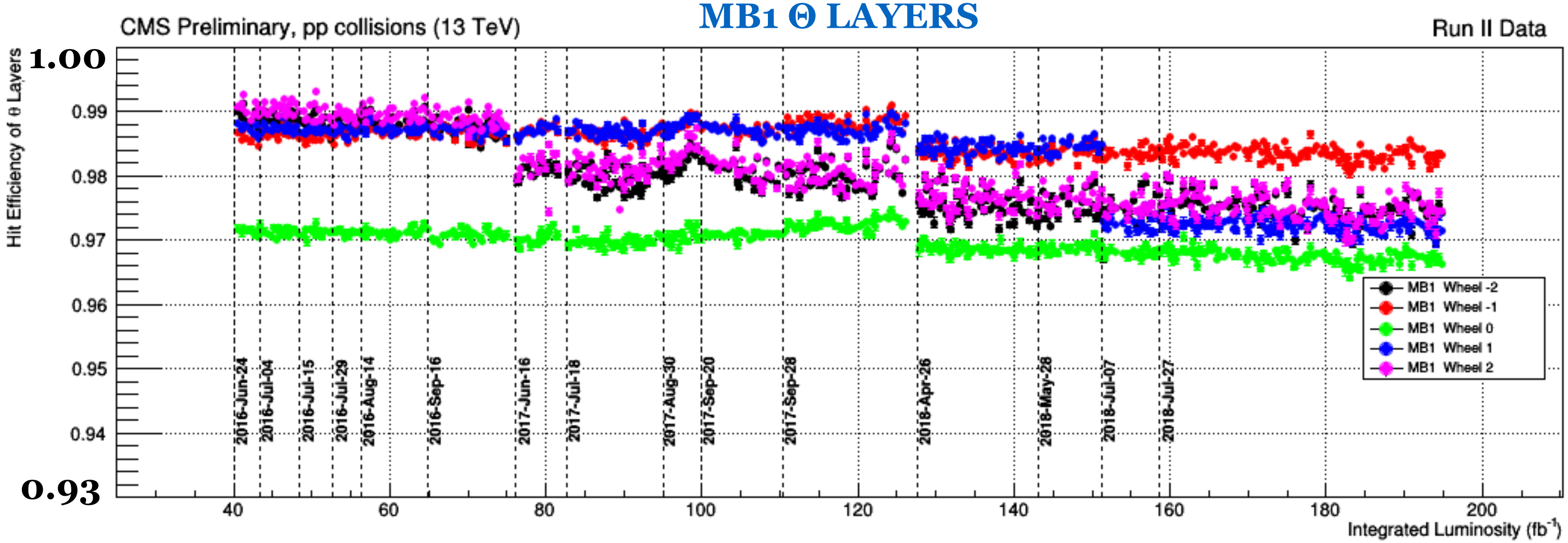
* RPC + DT repairs
* Shield installation
* Slice test preparation

BACKUP

DT HIT EFFICIENCY TRENDS WITH LHC INTEGRATED LUMINOSITY

✦ The origin of Integrated Luminosity is the start of LHC operation in 2011

MB1 Θ LAYERS



✳ In every stations, Θ Layers of Wheel 0 show lower efficiency than other wheels: this is due to the loss of hits caused by the tube walls that act as a dead volume. This effect is larger for tracks impinging orthogonally to the wire layers.

✳ In 2016 all cambers were operated at the nominal value of HV=3600 V

✳ In 2017 the HV of MB1 chambers of external wheels was lowered to 3550 V, causing a step of ~1 %,

✳ In 2018 the MB1 chambers of external wheels had their HV further reduced to 3500 V, while the 3 internal wheels were brought down to 3550 V. At the same time the FE thresholds were reduced from 30 to 20 mV in order to recover efficiency: in fact the overall reduction of efficiency was small (< 0.5%) and the trend stayed flat throughout the year.

✳In the second half of 2018, the new problem, appeared in the MB1 chamber of Wheel+1 Sector 1 and already discussed on page 3, caused the observed loss of 1.2% in the average efficiency of Θ layers of MB1 chambers in Wheel+1.

DT SEGMENT EFFICIENCY GRAND SUMMARY

Distribution of the efficiencies shown in previous plot: 1 entry per chamber.

While variations of DT hit efficiency of the order of few % don't affect the segment reconstruction efficiency, thanks to the detector redundancy, the recovery of several readout problems, achieved with the implementation of the μROS, visibly improved the segment efficiency in 13 chambers, w.r.t. 2017