# A slice-test demonstrator for the upgrade of the CMS Drift Tubes at High-Luminosity LHC

Carlo Battilana[1,2] *on behalf of the CMS Collaboration*

[1] *Università di Bologna* - [2] *Istituto Nazionale di Fisica Nucleare, sezione di Bologna*
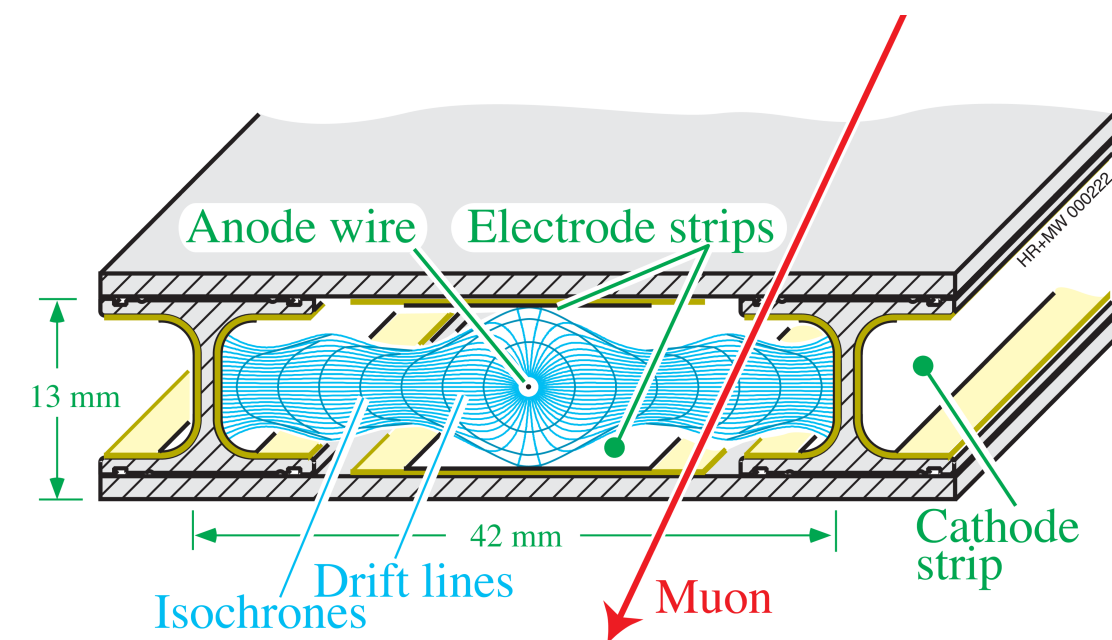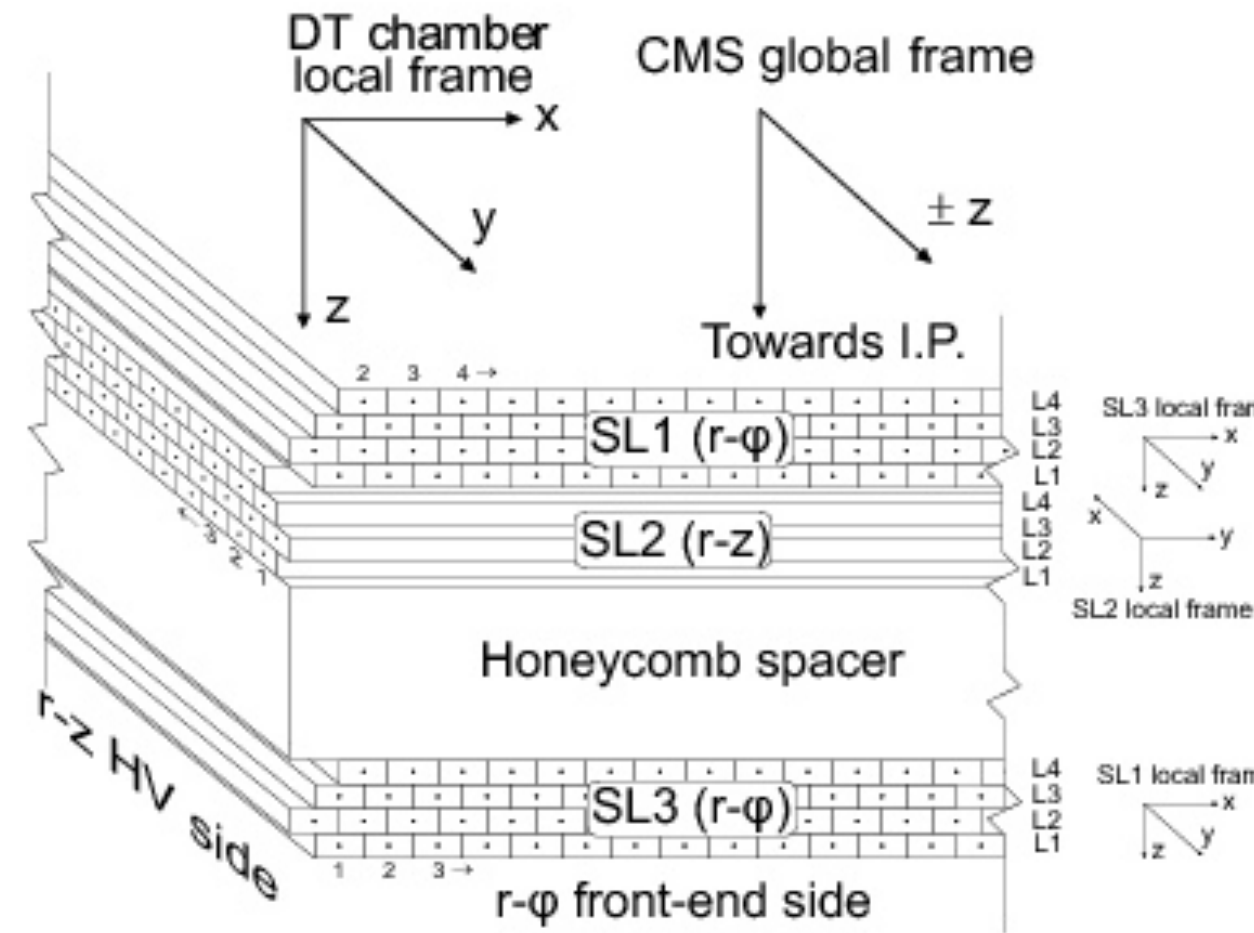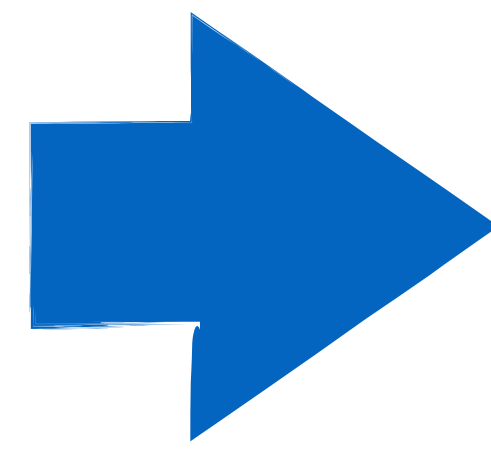
## Overview of the CMS DT system :

**DTs** equip the **barrel of the CMS muon system** and act as **a tracking detector with standalone trigger capabilities**.



**DT drift cell:**
- rectangular cell, size: 4.2 x 1.3 mm
- gas mixture: 85% Ar - 15% $CO_2$
- almost const $v_{drift}$: ~54 µm/ns ($t_{MAX}$ ~400 ns)

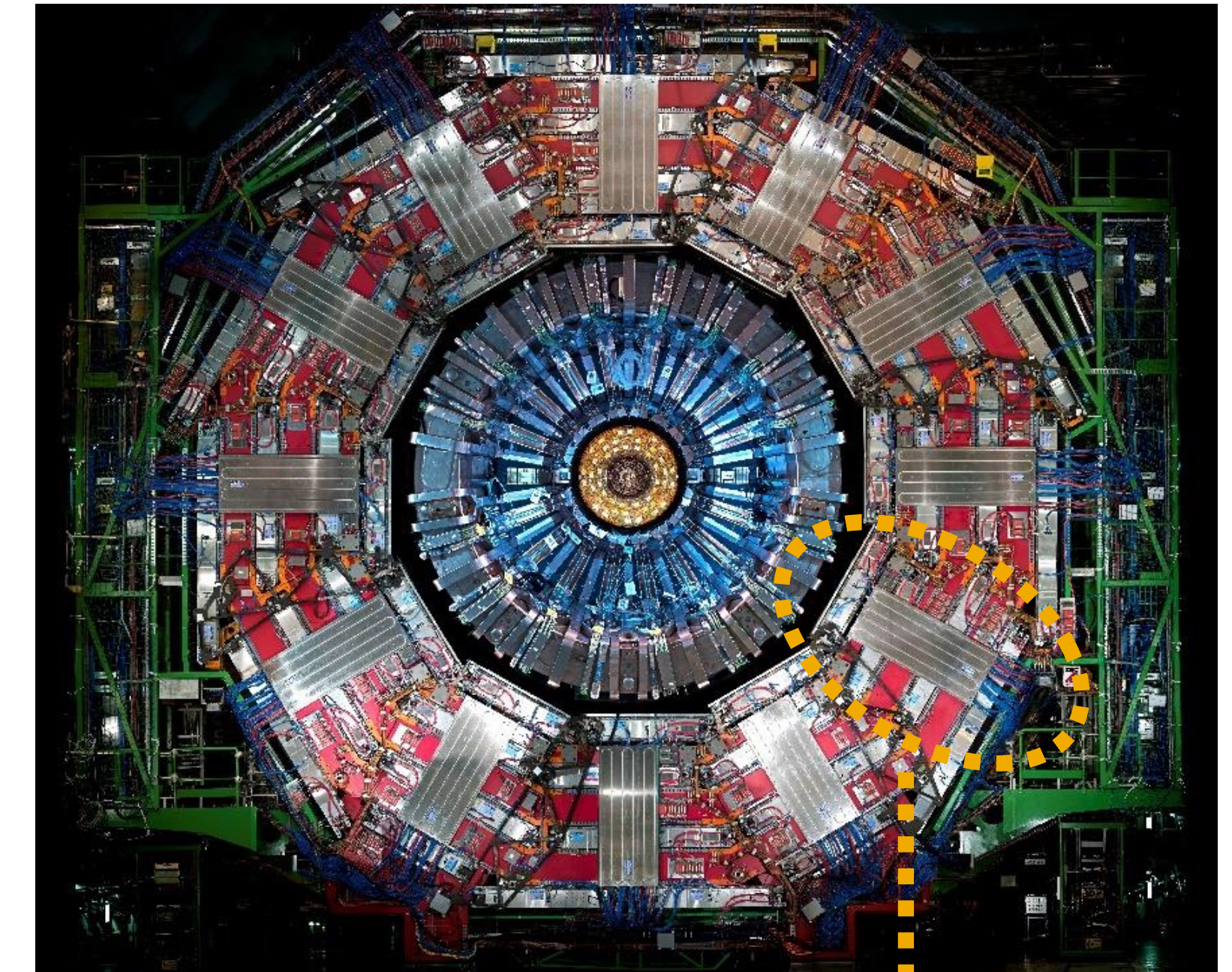**approximately 172000 DT cells in total**

**DT chamber:**
- parallel layers (L) of cells grouped in 4 Ls form a super-layer (SL)
- 2 SLs in r-$\varphi$ + 1 SL r-z (for 3 innermost stations)
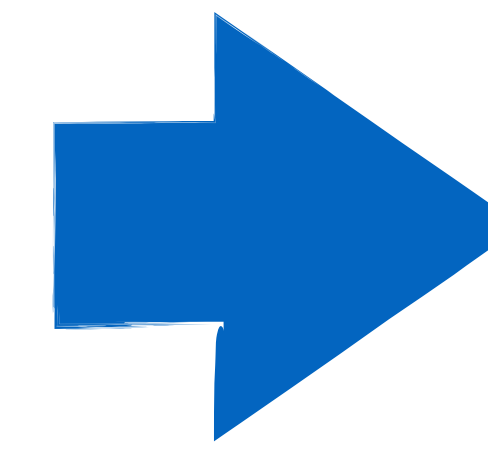
**250 DT chambers in total**
4 concentric rings of stations (MB1 to 4)
12 sector slices (S1 to12)
5 wheels in the CMS muon barrel (YB -2 to +2)



## The CMS DT Phase-2 upgrade [1] :

Plan to **operate DT chambers throughout HL-LHC**, but **existing electronics** can't:
- face the expected Level-1 trigger rates and latencies (i.e. at ~5 x $10^{34}$ cm$^{-1}$s$^{-1}$)
- withstand the integrated fluences expected at the end of HL-LHC (~4000 fb$^{-1}$)

**Phase-2 DT upgrade strategy:** on-board electronics will be replaced with radiation hard TDCs streaming data to a back-end that will build DT Level-1 trigger stubs exploiting ultimate DT cell resolution (~ 5 times better than in present local trigger).
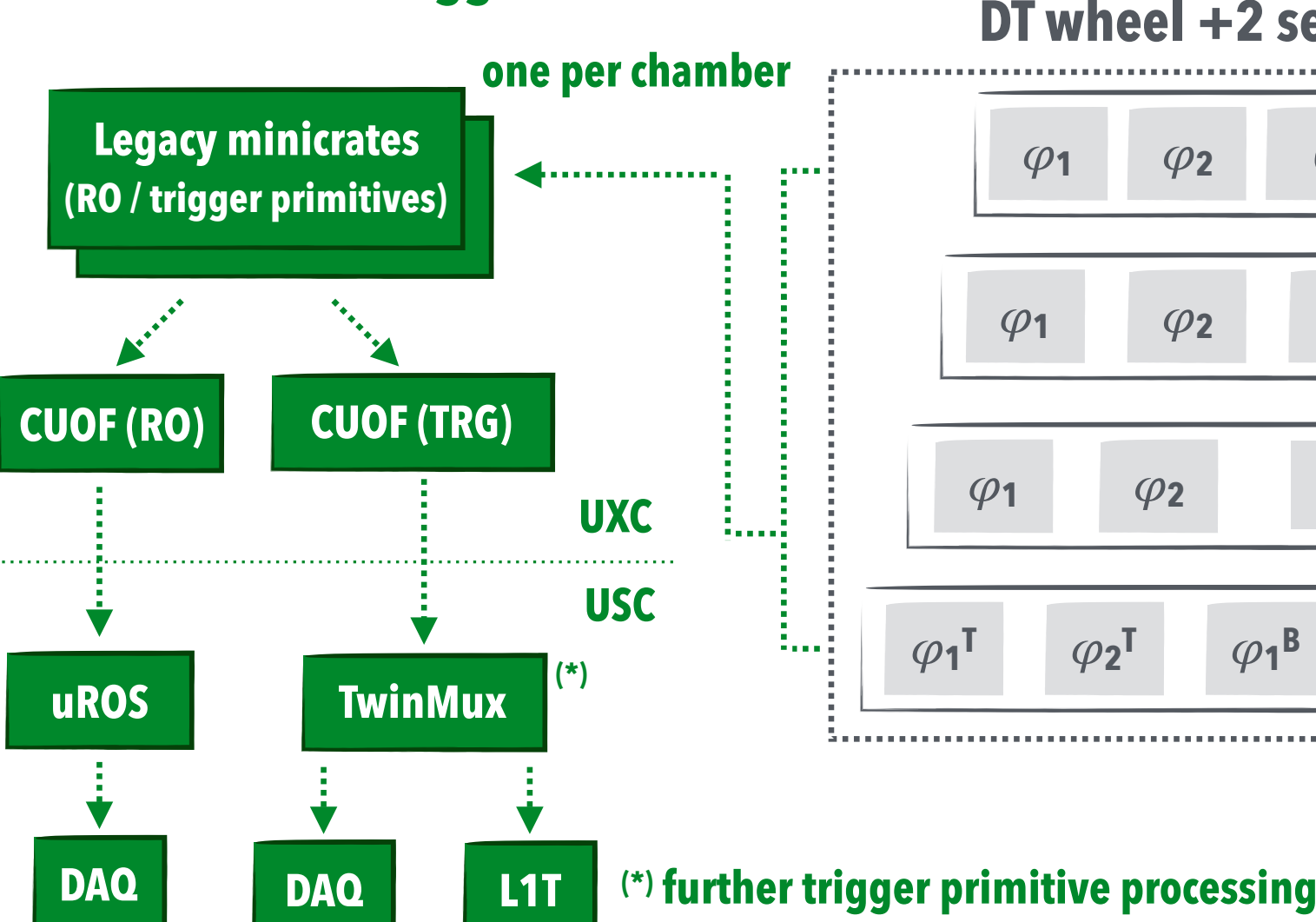
## The CMS DT Phase-2 slice test [2] :

**Prototypes of Phase-2 on-board electronics (OBDT)** installed in a DT sector, in parallel with present system. **Phase-1 backed boards running dedicated firmware** (MOCO, AB7) are used to **prototype Phase-2 DT backend**.
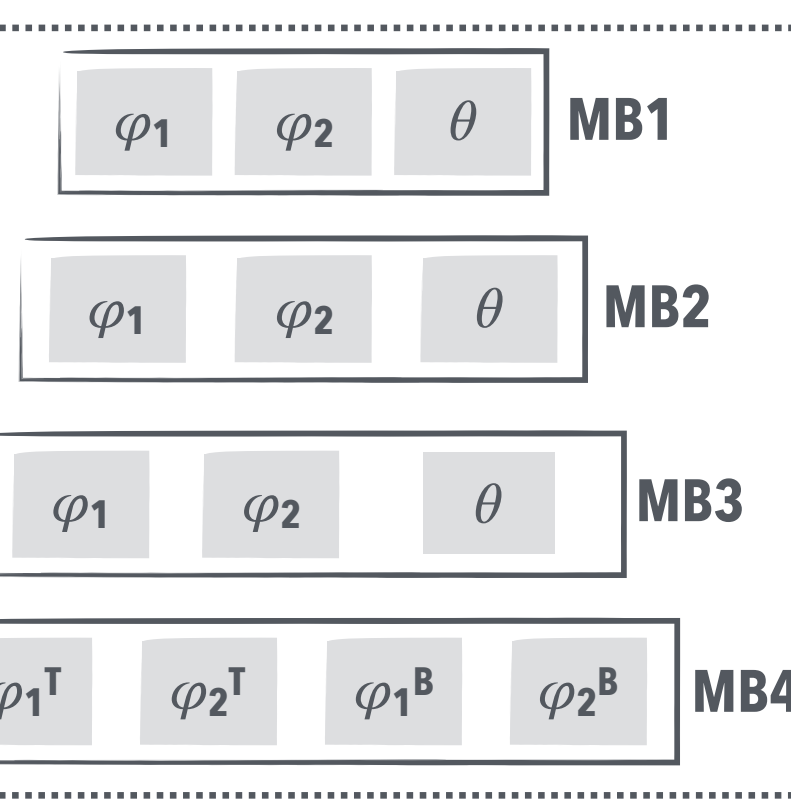
**Used to test mechanics and installation procedures** in view of the complete deployment of the Phase-2 system over LS3.

**Operated regularly** over LS2 **to develop and test the Phase-2 system**, as well as to **measure its performance**. Integrated with central CMS DAQ, DCS and offline SW.
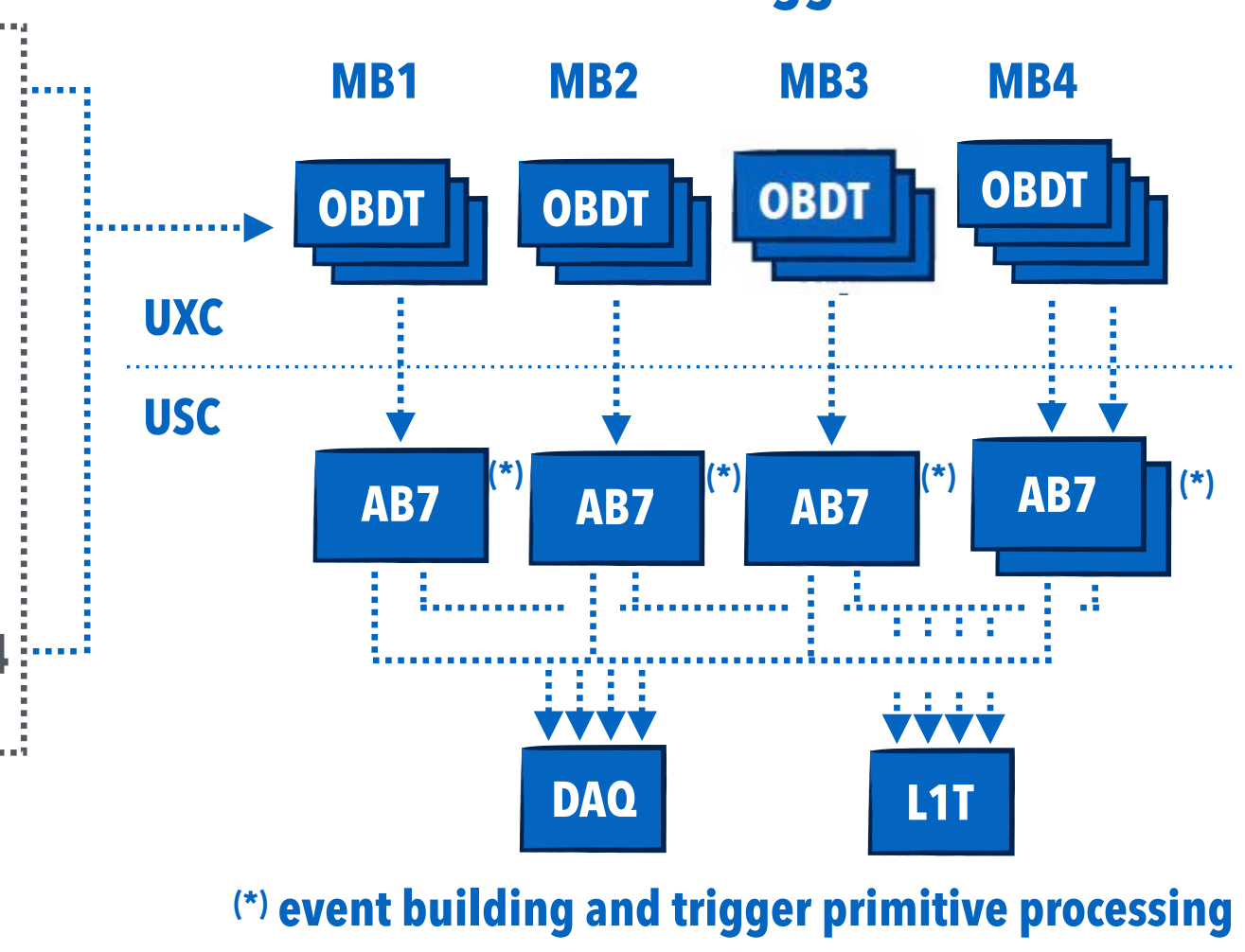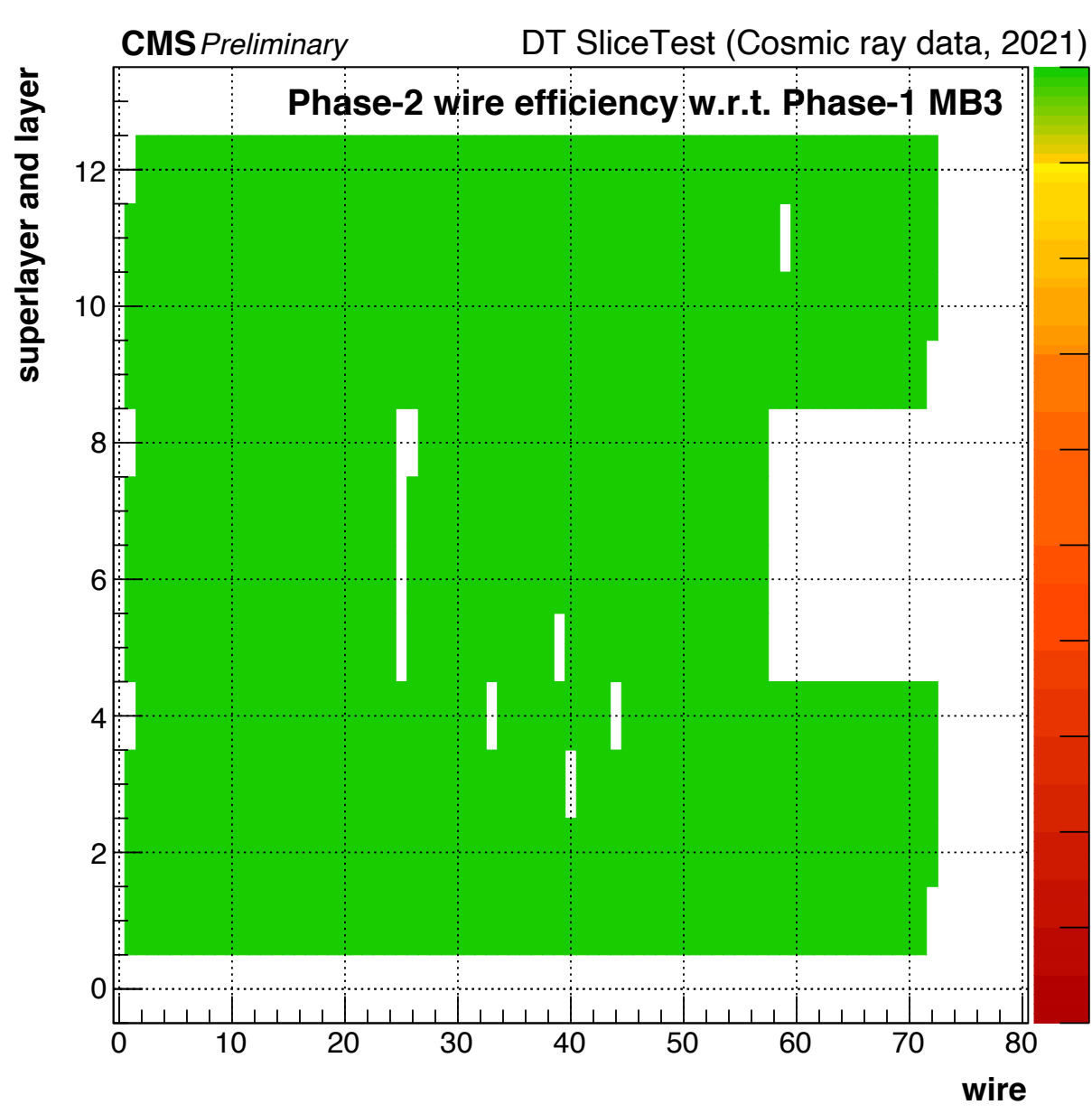


**DT Phase-2 slice-test architecture as in 2021**

## Performance with cosmic-ray data [3] :



**Hit detection :** tested in several aspects. E.g. efficiency of the Phase-2 readout is probed against the one of Phase-1 for each cell (and vice-versa).
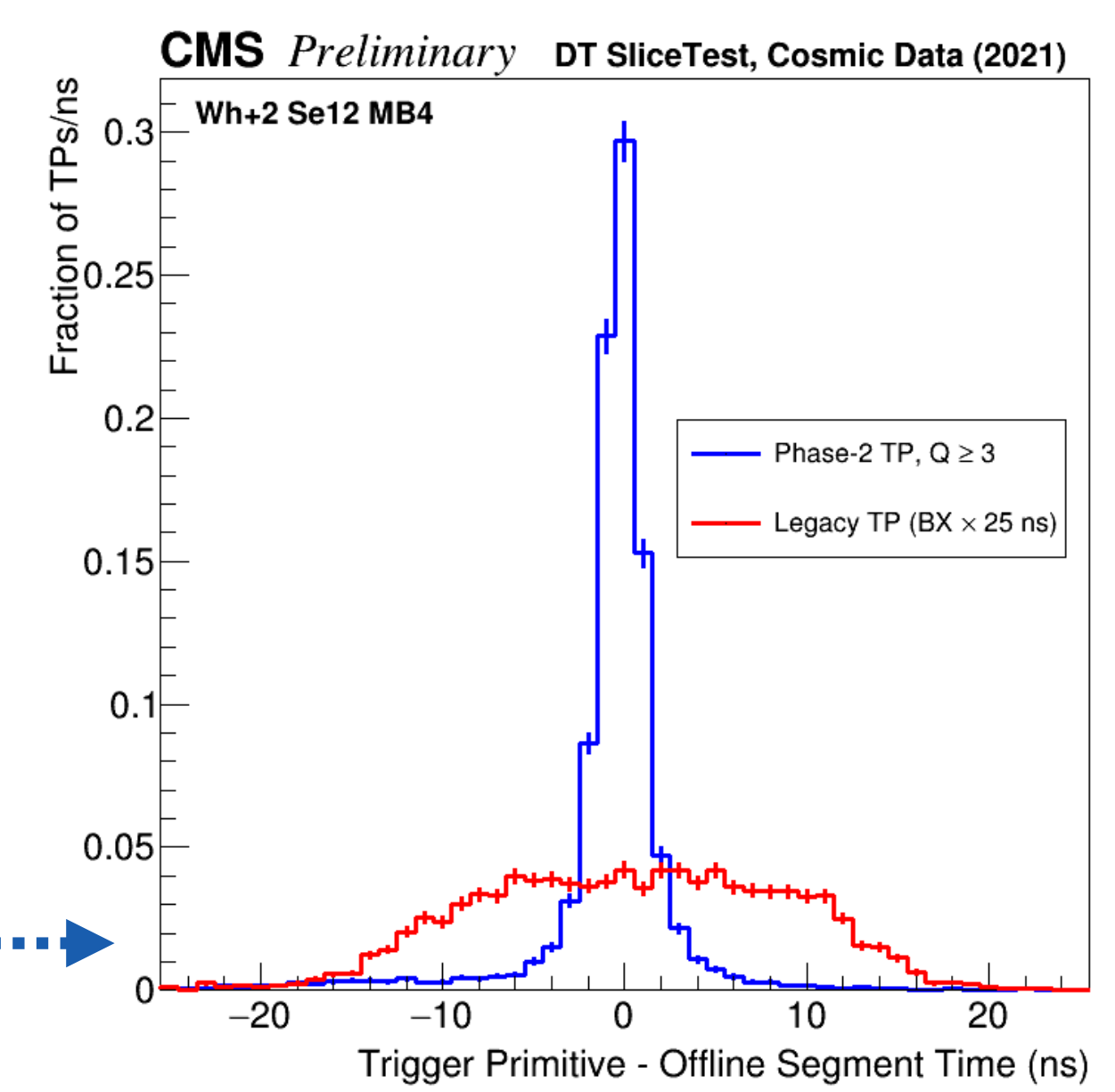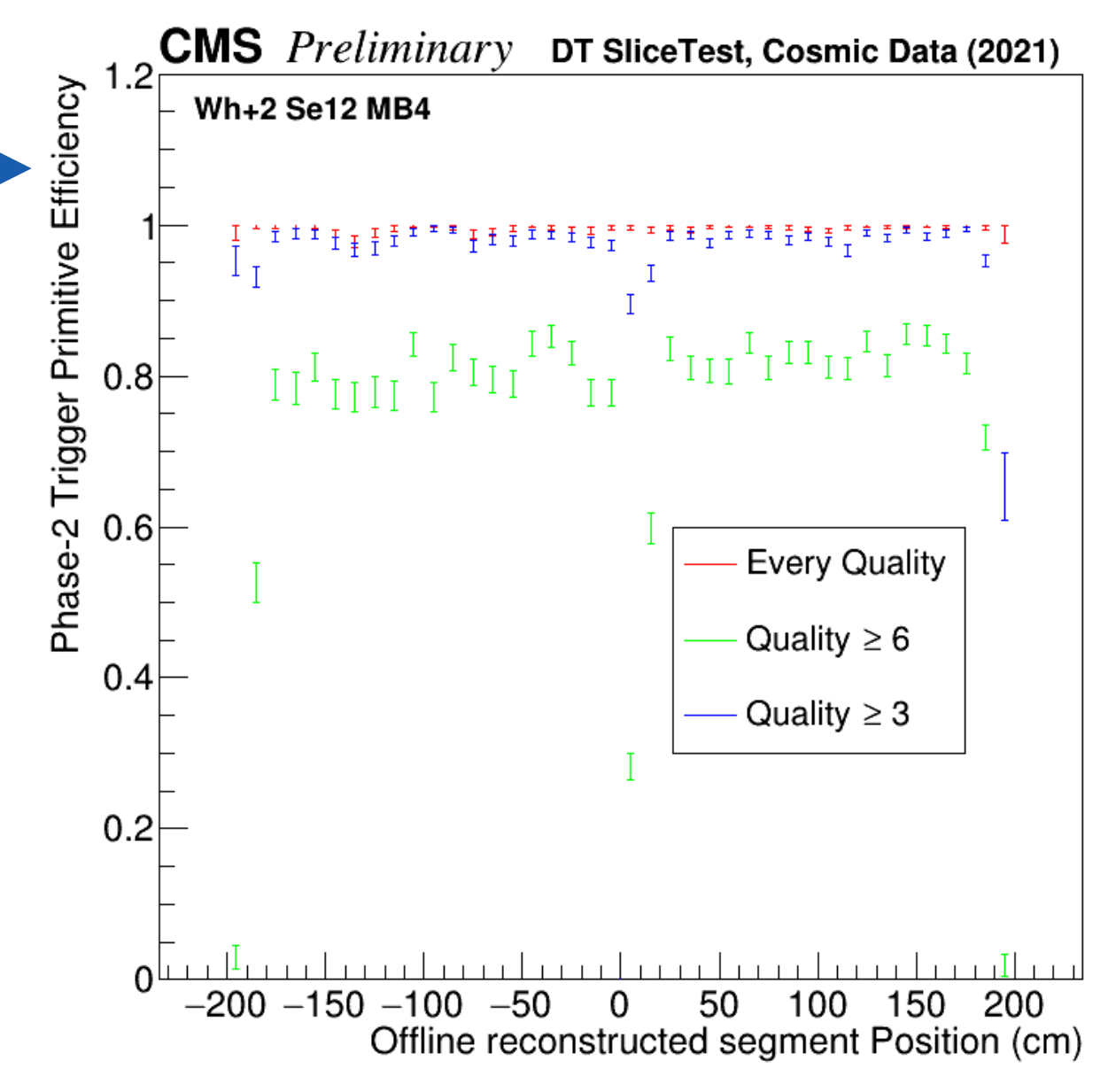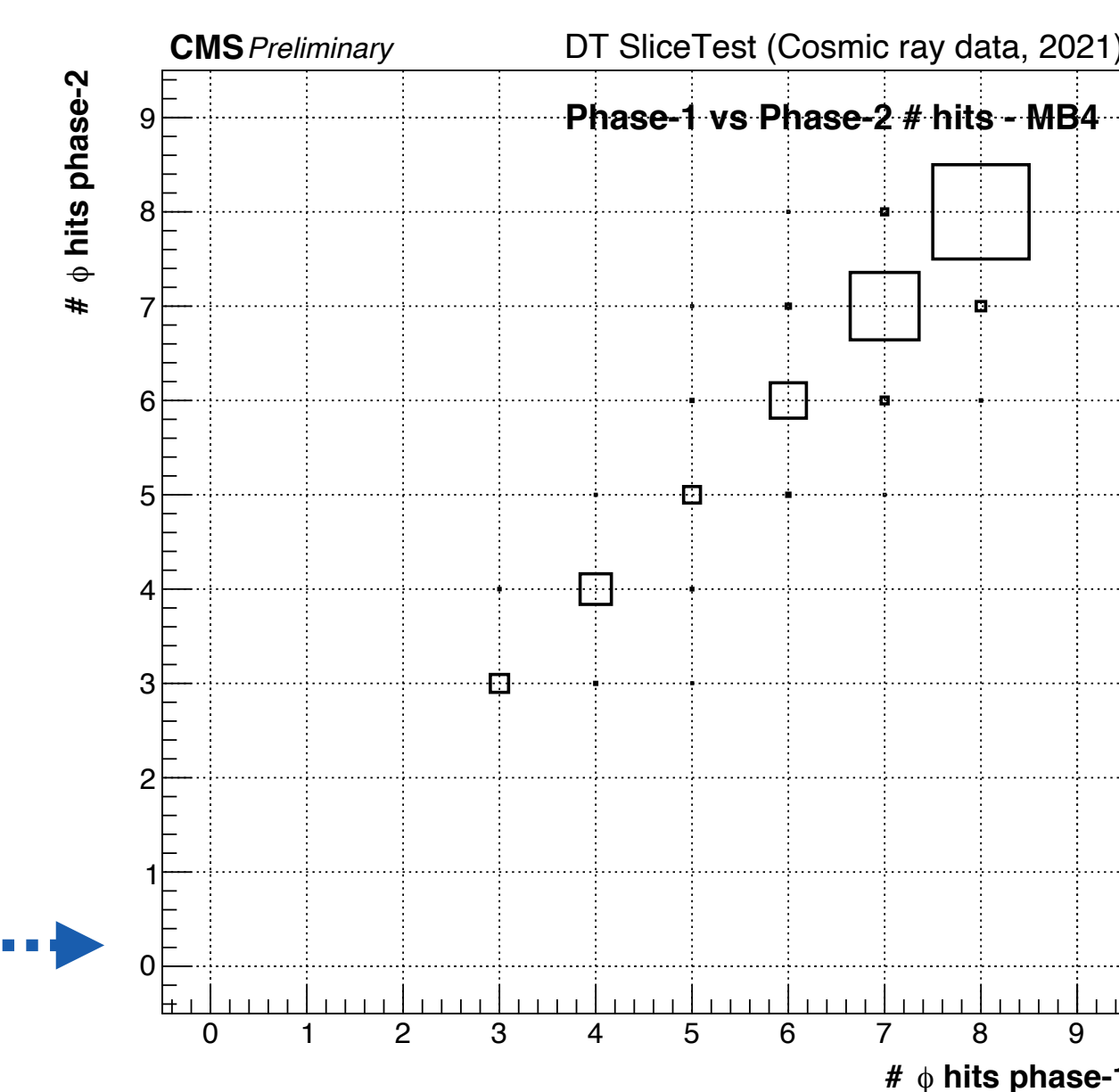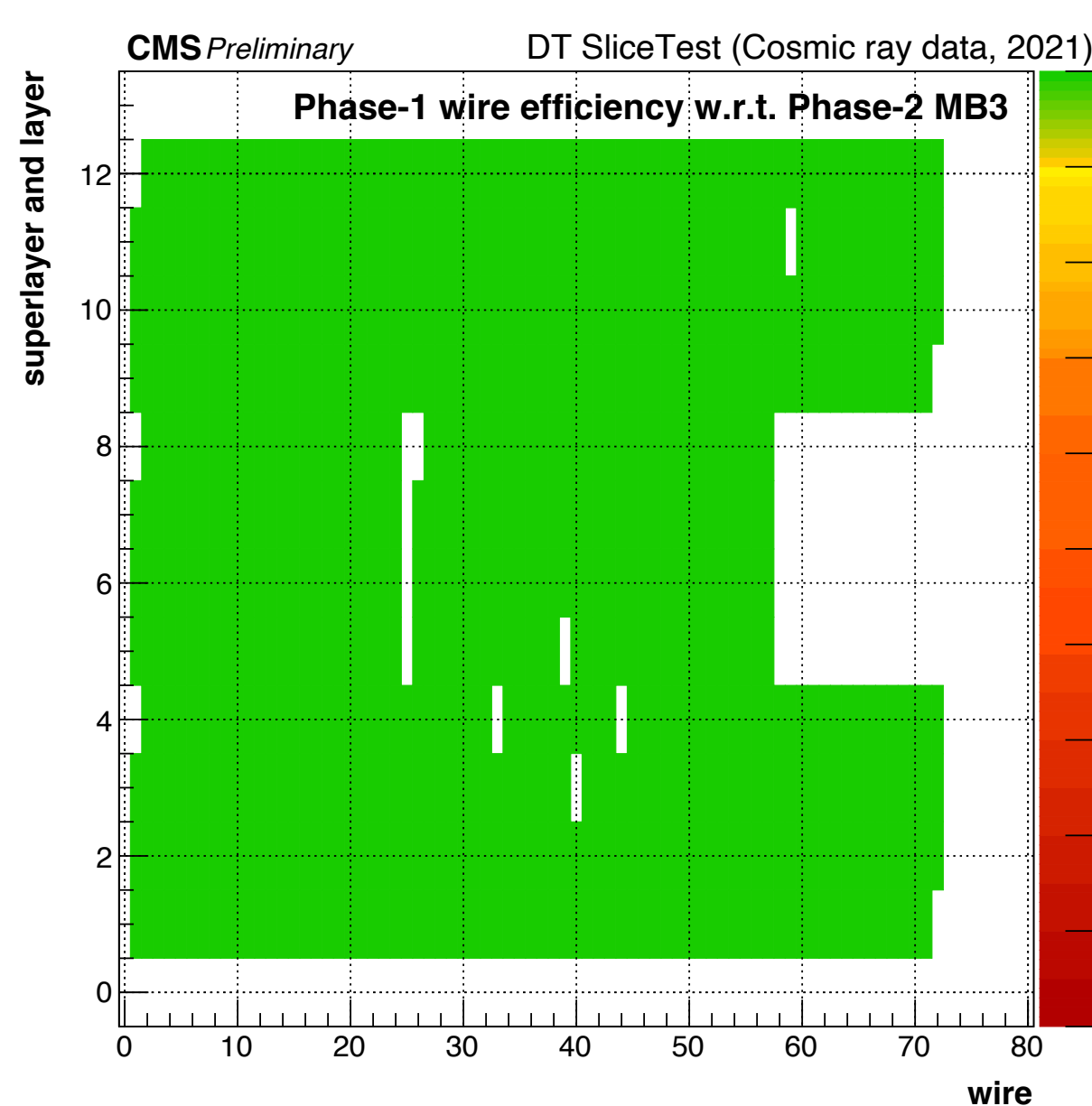
**Local reconstruction :**
**a.** Phase-1 and Phase-2 raw TDC counts are calibrated (including inter-channel equalisation);
**b.** pedestal-subtracted times are used to build muon track segments in each chamber using Phase-1 and Phase-2 data independently;
**c.** Phase-1 and Phase-2 segments are compared in terms of overall distributions, as well as event-by-event.
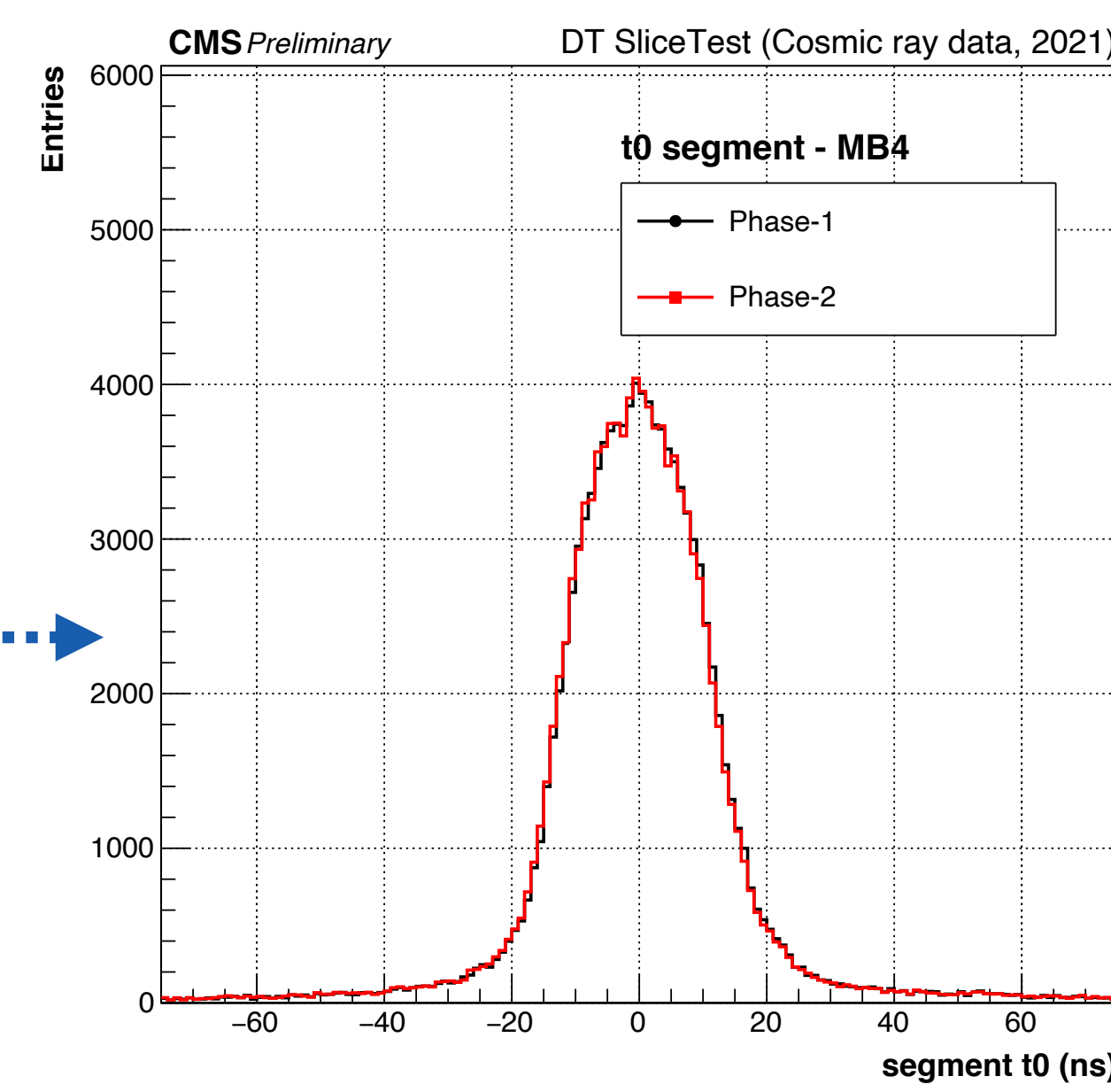
**Local trigger :** wire-by-wire offline Phase-2 calibrations are used to equalise inter-channel response in the AB7 and fully exploit the ultimate DT resolution in the local trigger. Several performance figures are monitored:
**a.** overall distributions are checked;
**b.** trigger segments are compared with offline reconstruction (e.g. to measure efficiency and resolution);
**c.** the output of the local trigger algorithm from the AB7 firmware is compared with the output of an emulator implemented within the central CMS offline software.

## Summary of present status and plans for the LHC Run-3:

The **Phase-2 DT slice-test is successfully operated** over the LHC LS2. The performance of hit detection and offline reconstruction is in line with the one of the Phase-1 system (already exploiting the ultimate DT cell resolution). **The capability of significantly improving the Level-1 DT local trigger resolution in the Phase-2 system is demonstrated**.

**Plans for the LHC-Run-3 :**
- **operate the present Phase-2 DT slice-test** setup **at the beginning of Run-3** to test it in harsher conditions
- prototypes of a new (close to final) version of the OBDT electronics were built and a strategy towards their deployment in the slice-test is being defined
- if developments allow, prototypes of the DT Phase-2 backend boards will replace the ones currently used and will possibly connect to Level-1 trigger Phase-2 prototypes

## References:

[1] The CMS Collaboration, "The Phase-2 Upgrade of the CMS Muon Detectors" Technical Design Report, CERN-LHCC-2017-012.
[2] The CMS Collaboration, "The Phase-2 Upgrade of the CMS Level-1 Trigger" Technical Design Report: CERN-LHCC-2020-004.
[3] CMS DT detector public results TWIKI: https://twiki.cern.ch/twiki/bin/view/CMSPublic/DtPublicResults.

**carlo.battilana@cern.ch**