PHASE 2 TRACKER UPGRADE SIMULATION

Andrés Abreu
On behalf of CMS Collaboration
University of Puerto Rico Mayagüez
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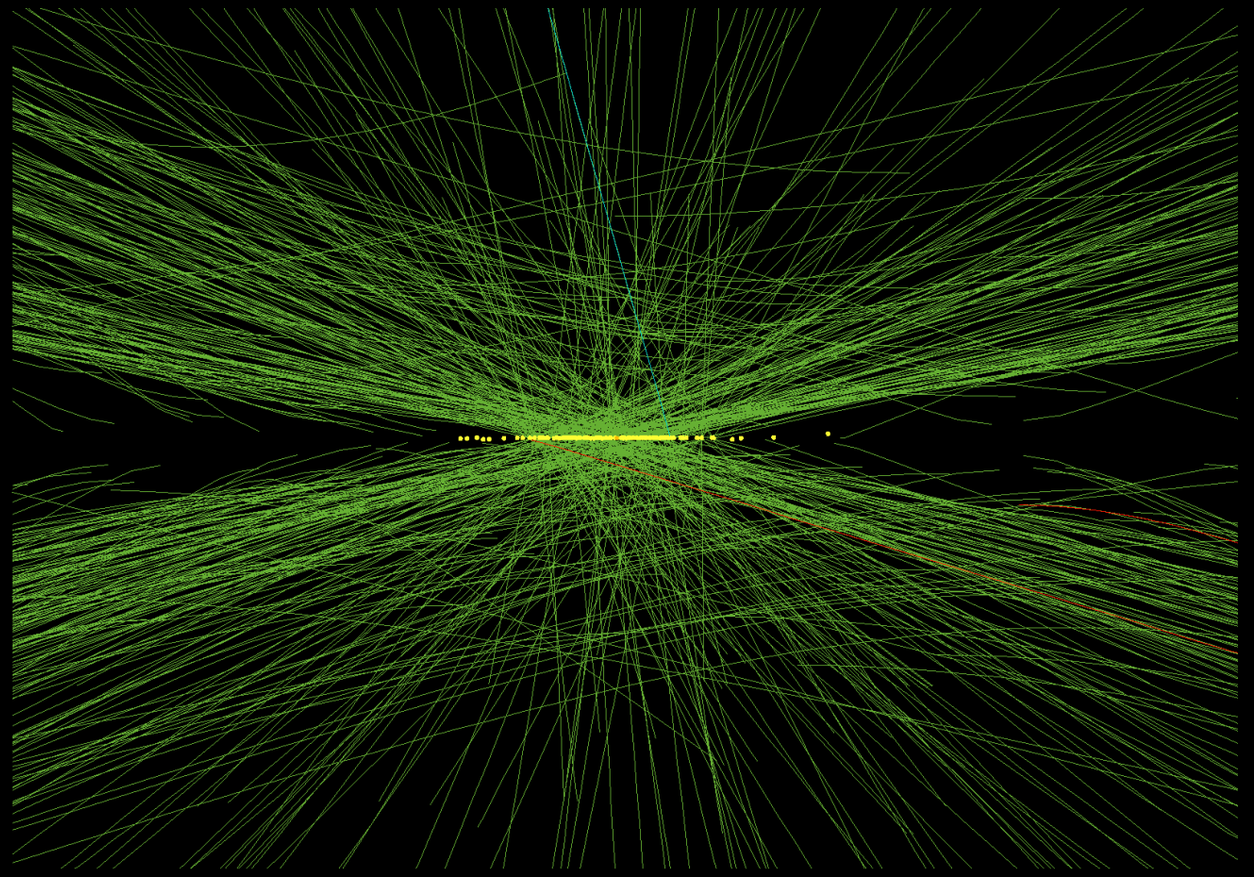
The HL-LHC Upgrade

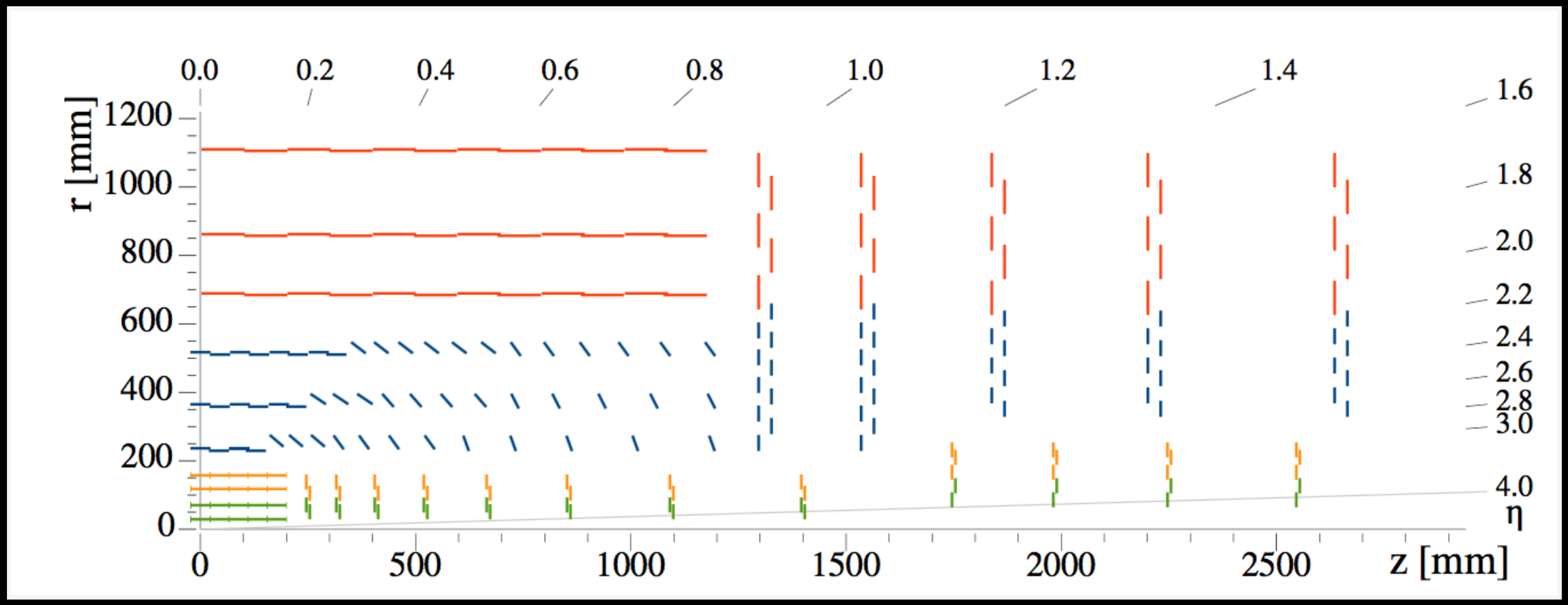
- During the LS3 (2024-2026), the accelerator will be upgraded to enable peak luminosities of up to 7.5×10^{34} $cm^{-2}s^{-1}$ from a value of 1.5×10^{34} $cm^{-2}s^{-1}$ in 2016.

- This will allow CMS to collect integrated luminosities of 300 fb^{-1} per year. In 2016 a total of 41.1 fb^{-1} was obtained.

- Average pileup of 140 - 200 events per bunch crossing are expected.



Tracker Geometry



- The green and orange components constitute the Inner Tracker (IT) and is called the Phase-2 Pixel Detector. The red and blue components constitute what is called the Outer Tracker (OT) and correspond to two types of modules.

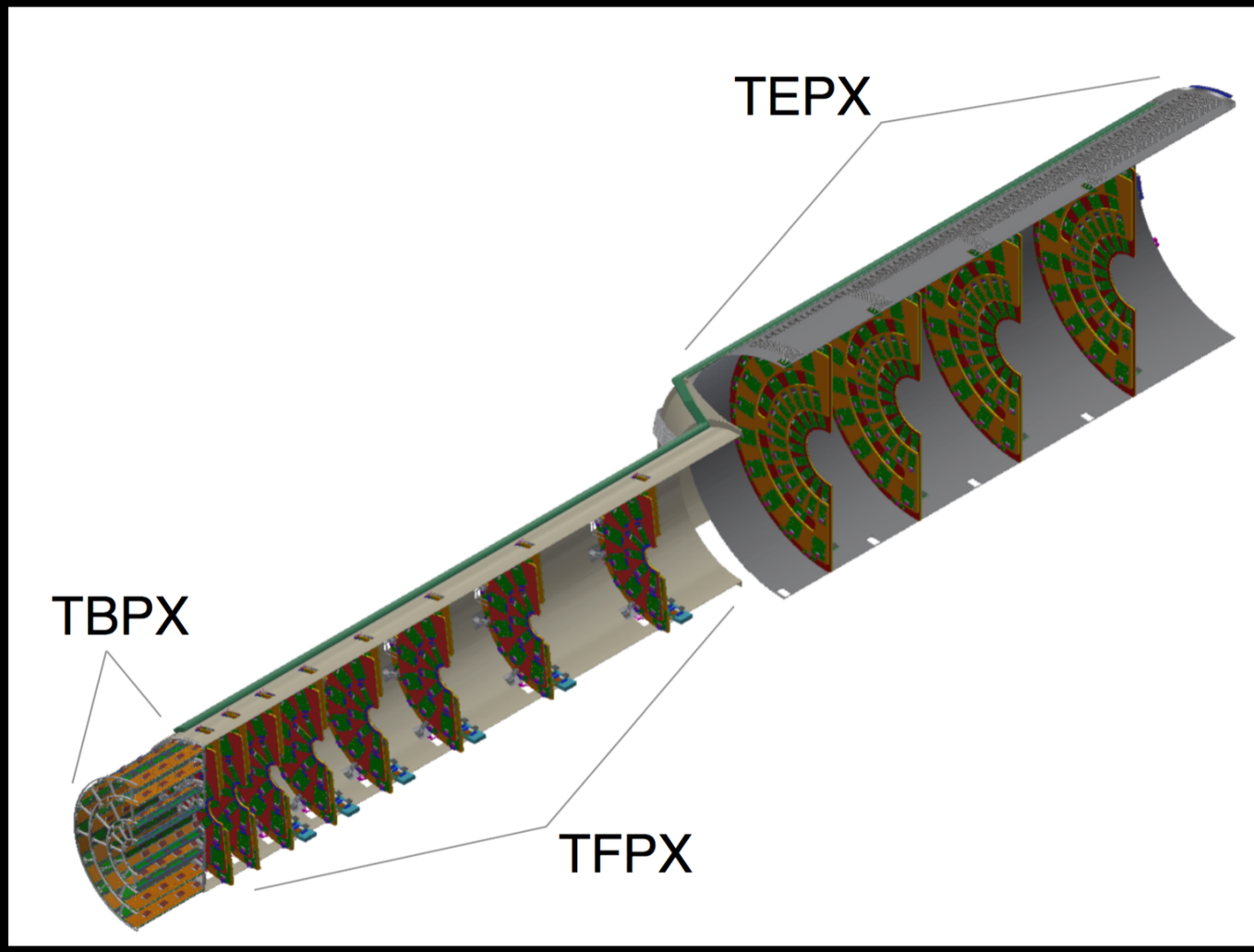
- For the Phase-2 IT we are extending the η out to 4 by including 8 small disks and 4 large in the forward region. We currently have just 3 small disks.

Inner Tracker (IT)

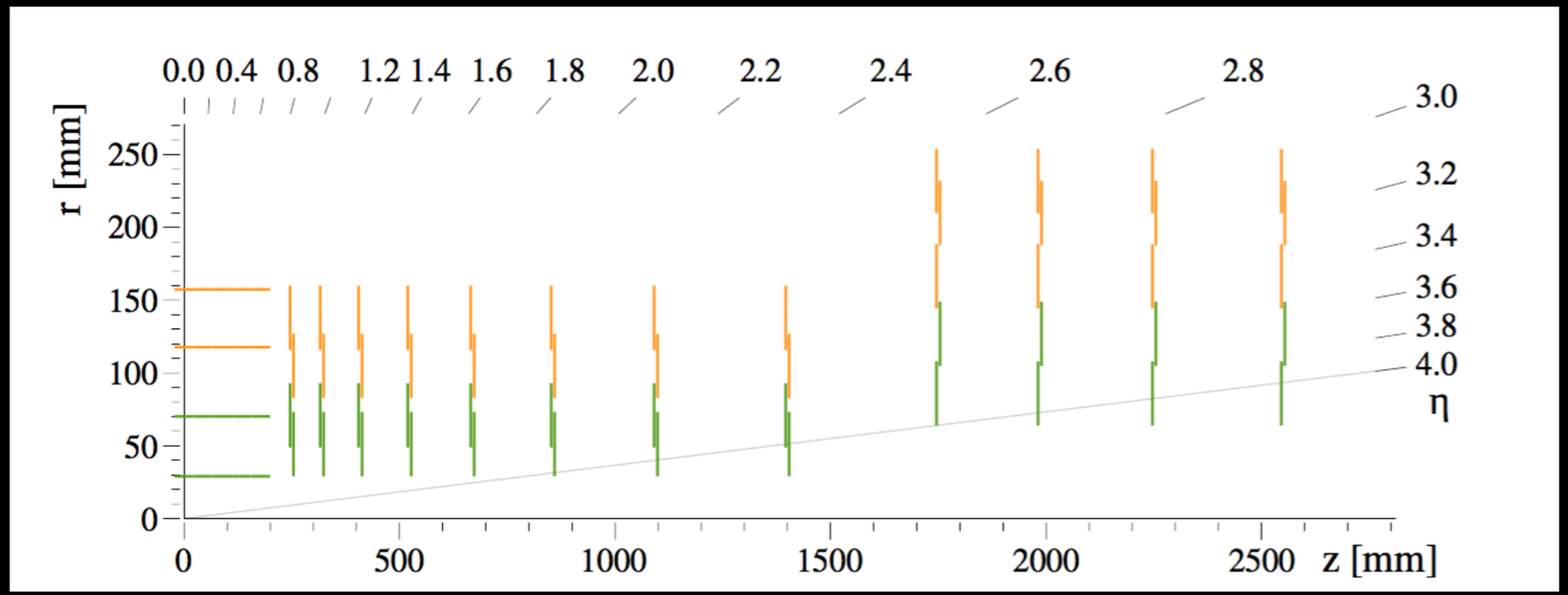
- Resistance to an unprecedented amount of ionizing radiation is a requirement for the new IT as it will have to deal with a radiation dose of up to 1.2 GRad during the lifetime of the detector.

- Higher hit rates are also expected due to the 140-200 pile up. Expected hit rates approaching 3 GHz/ cm^2.

- The new design will allow for the easy exchange of components in the IT.



Inner Tracker sensors



- The green components have two read out chips per module and the orange ones are larger with 4 read out chips per module.
- For the readout chip a 65 nm Complementary Metal–Oxide–Semiconductor Technology (CMOS) (used for integrated circuits) is used and an architecture where a group of channels (referred to as pixel region) shares digital electronics for buffering, control, and data formatting.

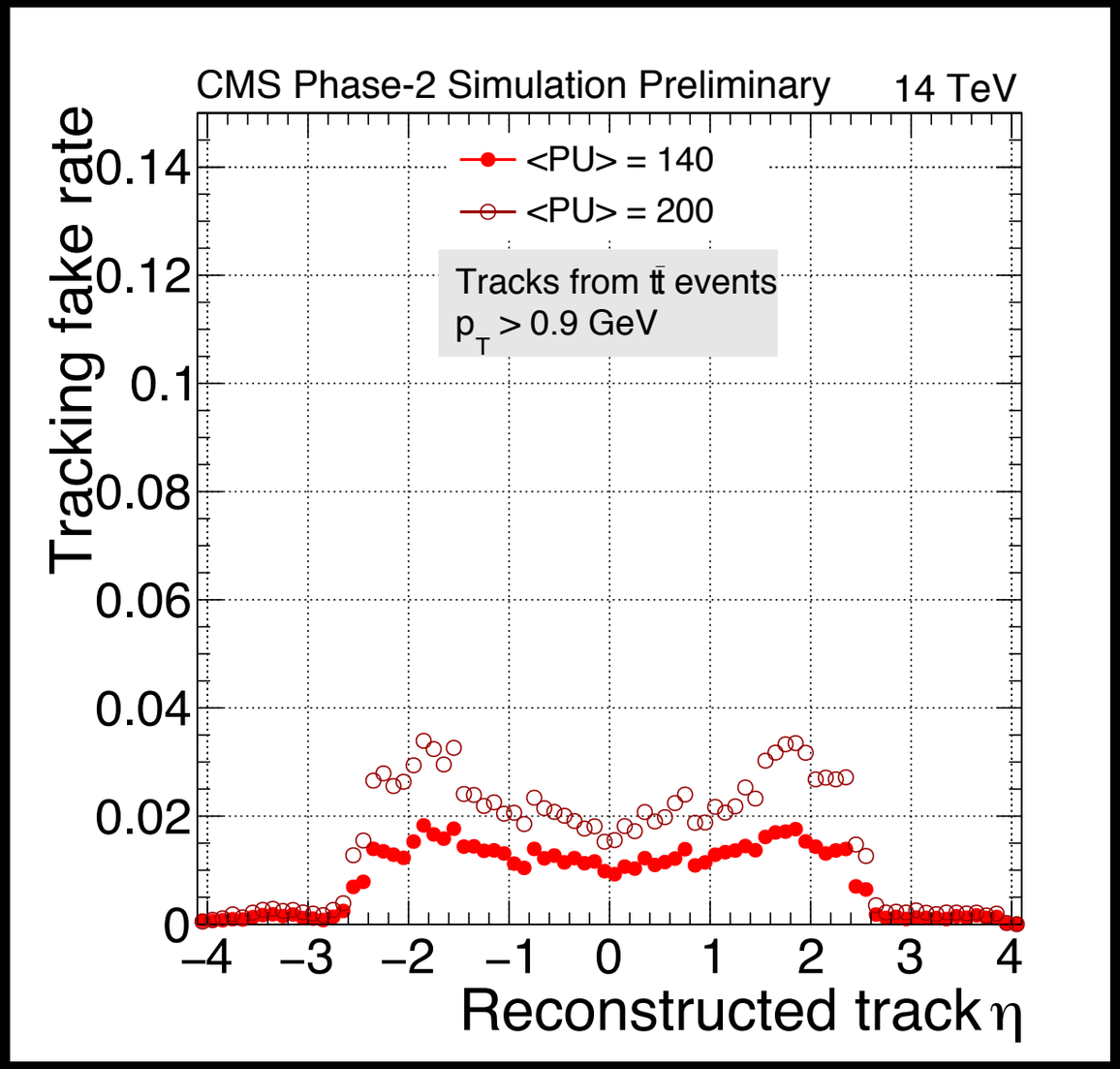
Simulation setup

- A full Monte Carlo simulation of LHC events with high pileup gives the best prediction of the detector performance and overall physics capabilities of the upgraded CMS detector.

- The CMS detector response was simulated using the official CMS software package CMSSW.

- The detector geometry is generated with a design tool for innovative silicon tracking detectors called tkLayout and is exported into the standard CMSSW format along with the materials like sensing silicon elements, electronics and inactive material.

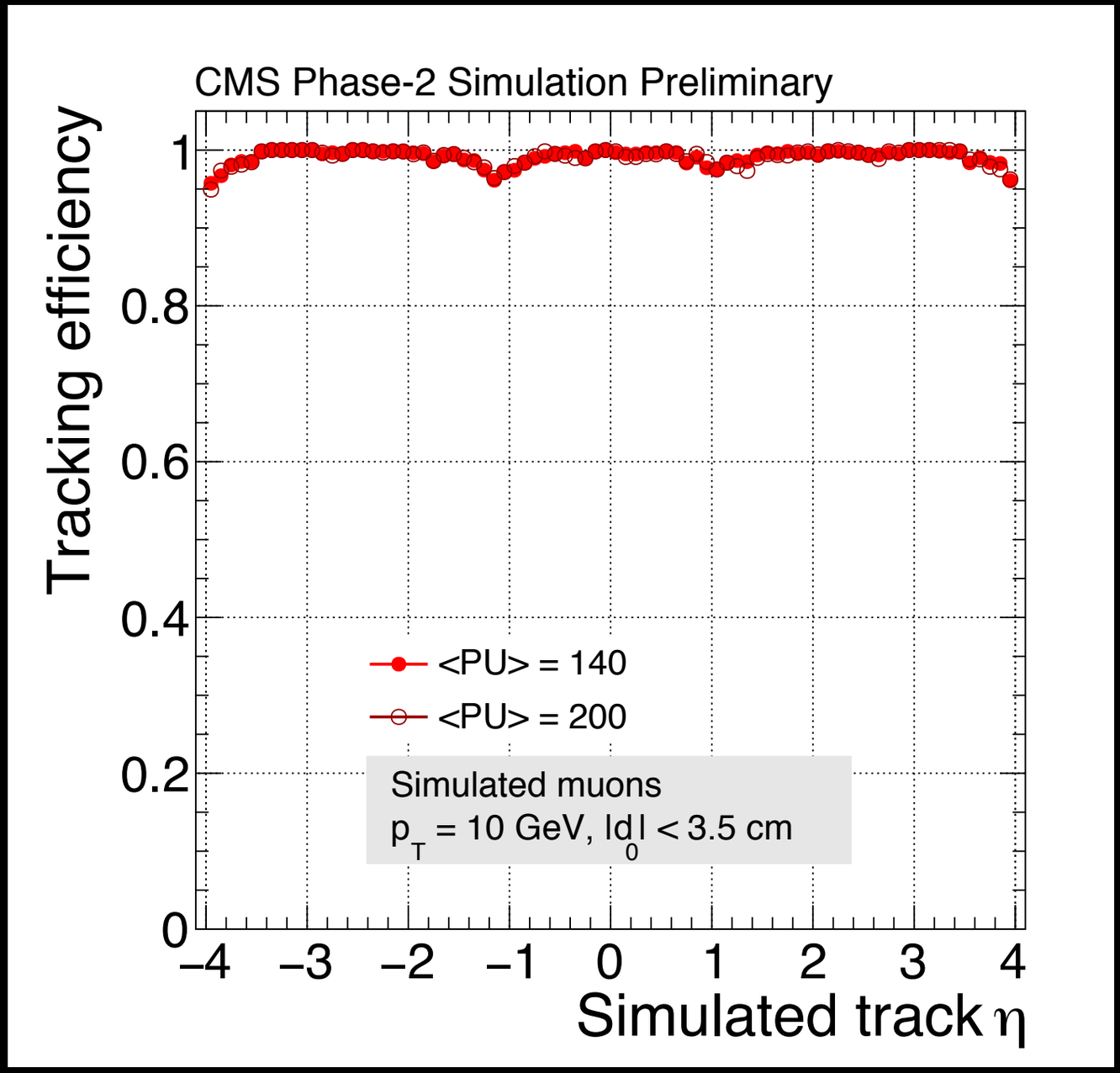
Tracking Fake rate



- A reconstructed track is considered associated to a simulated particle if at least 75% of its hits originate from this simulated particle. If this is not the case, the reconstructed track is considered as a random combination of hits and marked as a fake track.

- The fake rate is the fraction of fake tracks in the set of all reconstructed tracks.

Tracking Efficiency



- The tracking efficiency is defined as the fraction of charged particles associated to at least one reconstructed track.

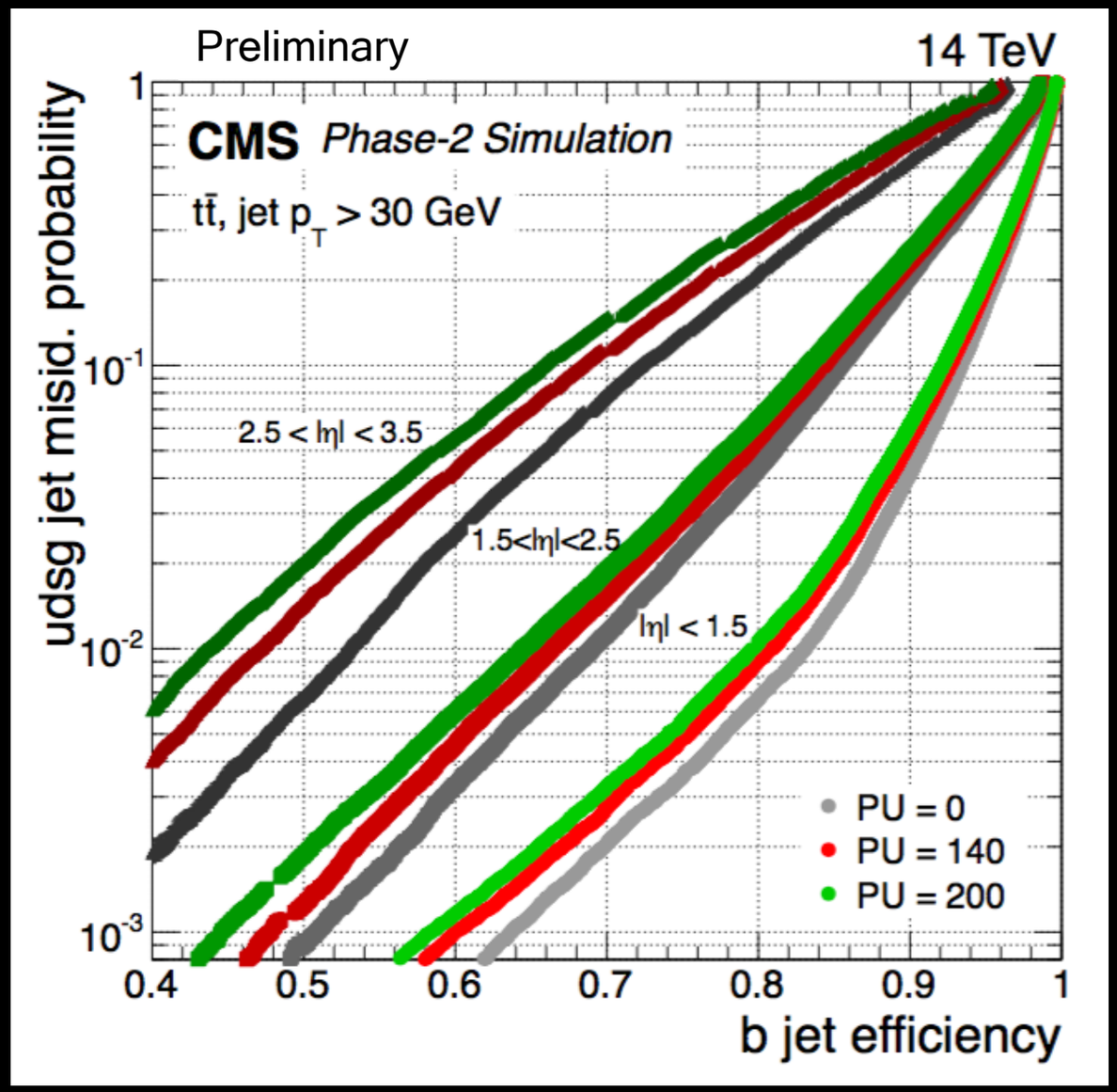
- The plot shows the tracking efficiency as a function of **η** for single muons with p_T equal to 10 GeV, with 140 (full circles) and 200 (open circles) pileup events.

B Tagging

- The ability to distinguish the jets arising from the hadronization of b quarks (b jets) from the ones originating from the light partons.

- Performance of the b tagging algorithms* in simulated ttbar events, expressed as misidentification probability for light jets (udsg) as a function of the b jet tagging efficiency. Jets with p_T > 30 GeV are considered in three |η| ranges: 0–1.5, 1.5–2.5, and 2.5–3.5.

- The extension of the pixel detector provides b tagging capability in the high |η| region (|η| > 2.5).



**The cMVAv2 and DeepCSV b tagging algorithms are used for jet |η| within 0–1.5 and 1.5–3.5, respectively.*

Conclusion

- The new IT coverage is extended to $\eta \sim 4$.
- The IT will be tolerant to much larger doses of radiation.
- The expected performance in terms of efficiency and fake rate for 200 pileup events is consistent with the respective expected performance of the Phase-1 tracker for 70 PU events.
- The b tagging efficiency now extends to the very forward region.
- More details can be found in https://cds.cern.ch/record/2272264?ln=en