The CMS Outer Tracker Upgrade for the High Luminosity LHC

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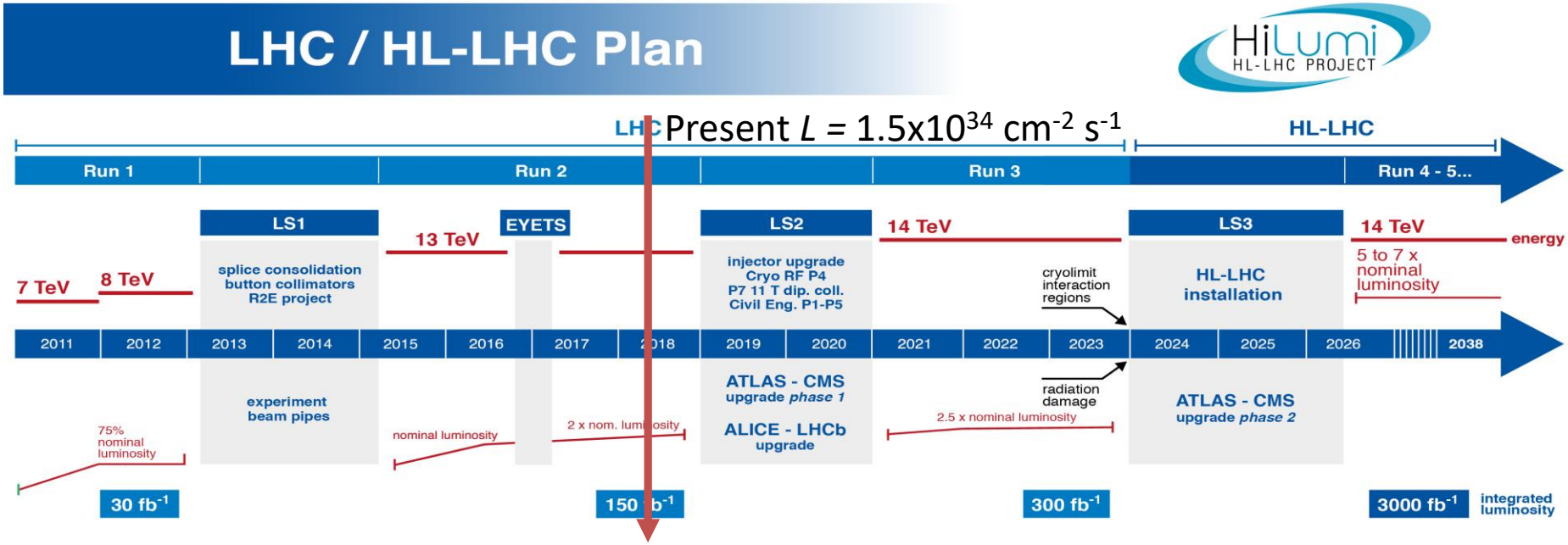
23 October, 2018

Outline

- Phase2 Upgrade schedule and plan
- Outer tracker upgrade project
- New Layout and expected performances
- Level-1 tracking
- Summary

LHC Upgrade schedule



- LHC upgrade is scheduled in 2024 for HL-LHC
- We expect $L = 7.5\text{x}10^{35}$ cm^{-2} s^{-1} and 4000 fb^{-1} by 2039
- Great opprtunity for Physics studies but a challange for the detector design

CMS Tracker upgrade for HL-LHC

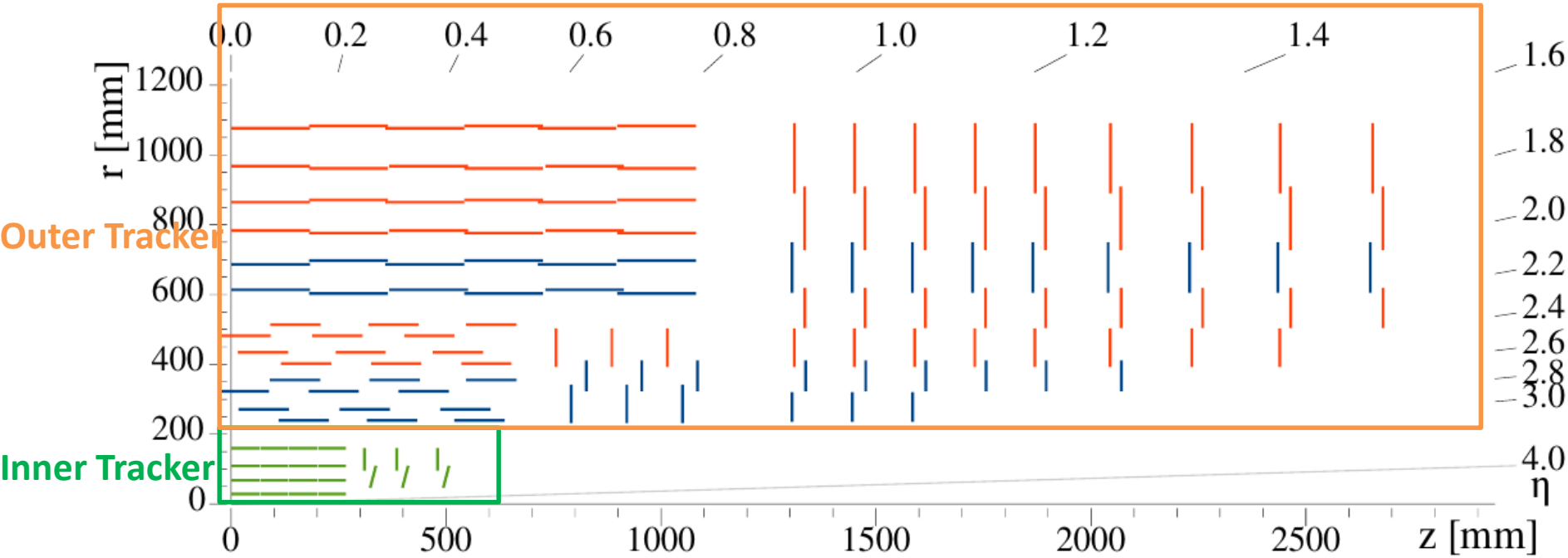
- To retain the excellent performance the CMS Tracker needs to be upgraded

- The new tracker should be:
  - Radiation tolerant
  - Have high granularity
  - Reduction in material budget
  - Participate in L1-Trigger

- Completely new Layout of the CMS Tracker

- Expected performance

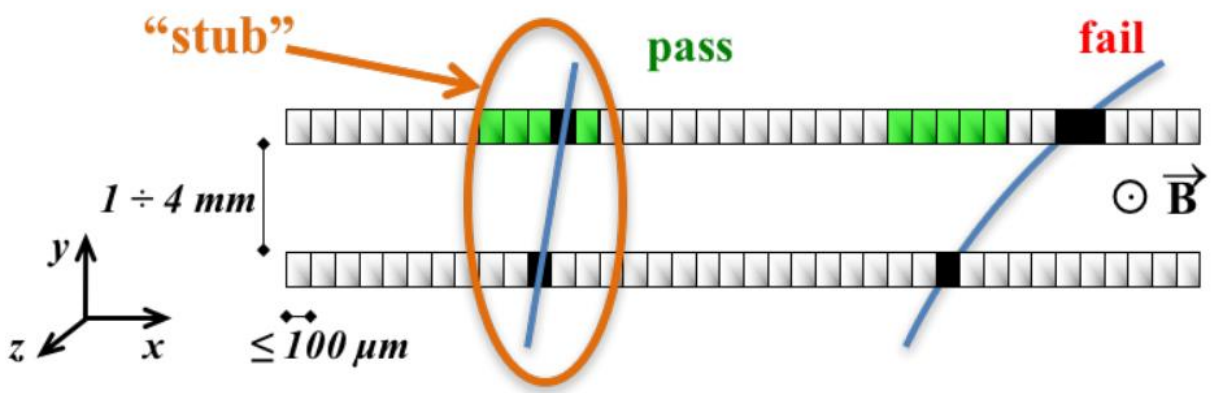
Current CMS Tracker

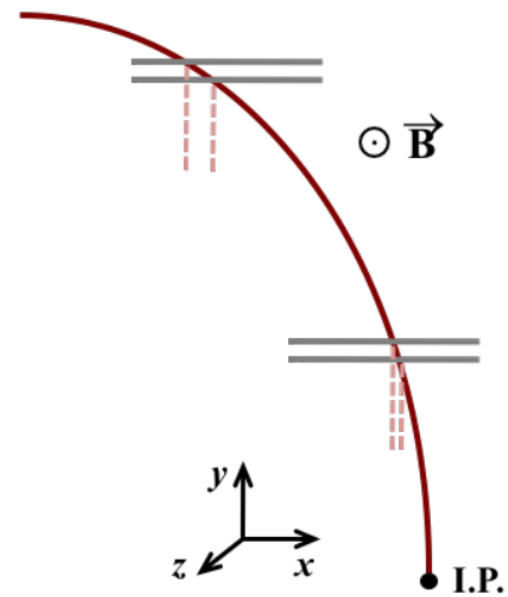


- Sketch of current/present Phase1 CMS Tracking system
- Radiation tolerrance is the main key to the inner tracker
- Outer tracker upgrade is discussed in this talk.

CMS Outer Tracker upgrade

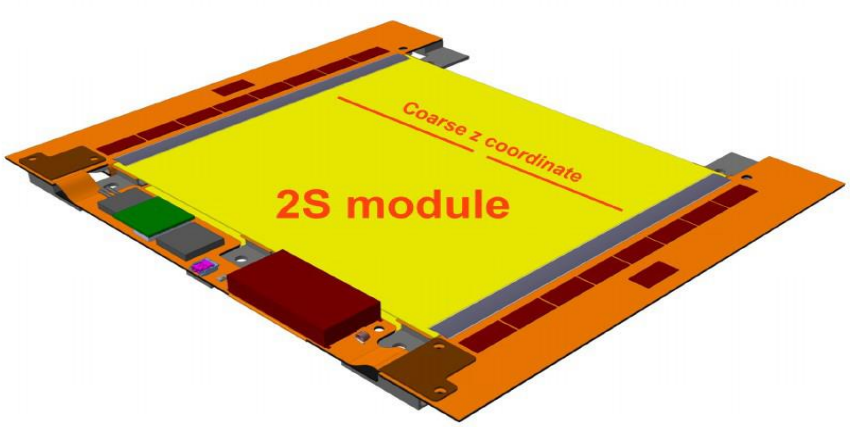
- For L1 triggering data to be sent in each bunch crossing, to reduce data volume p_T criteria used
- High transverse momentum tracks can be selected by correlating hits on two close-by sensors, called "stub"

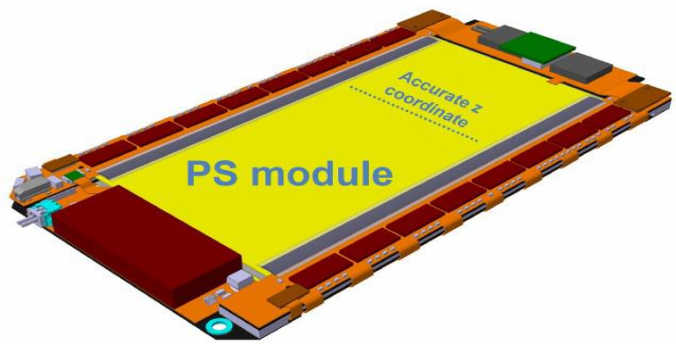




CMS Outer Tracker modules

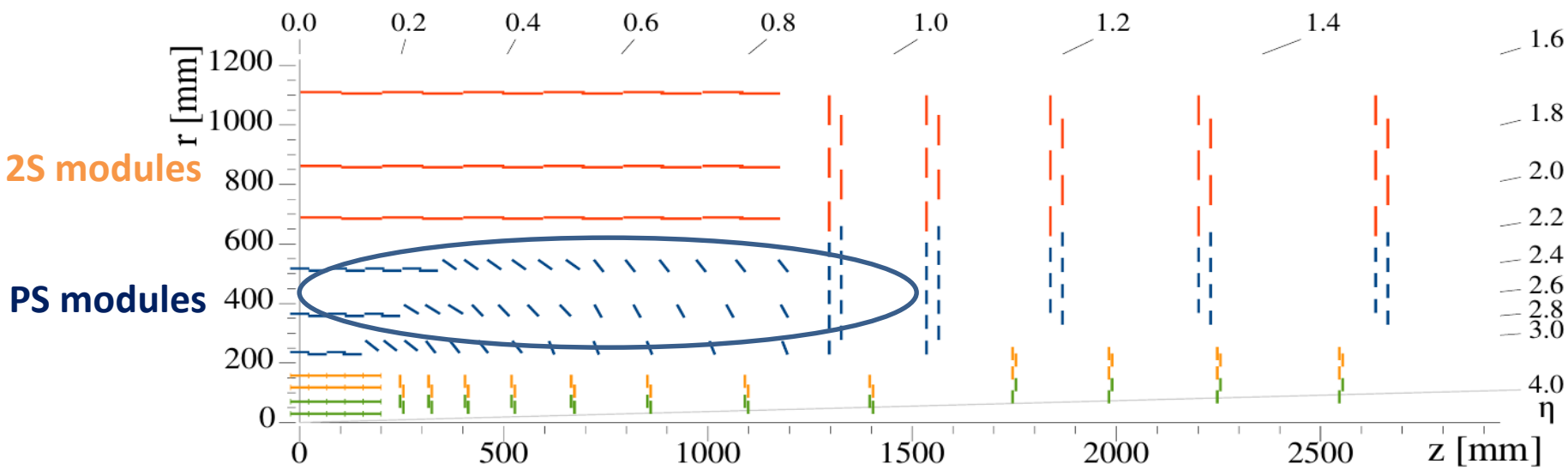
- Outer Tracker modules
  - Planar n-in-p, 200 µm thick sensors
  - Binary read-out chips
  - Zero-suppression and data aggregation at module level
- '2-Strip' Module, PS (Pixel-Strip) modules are used





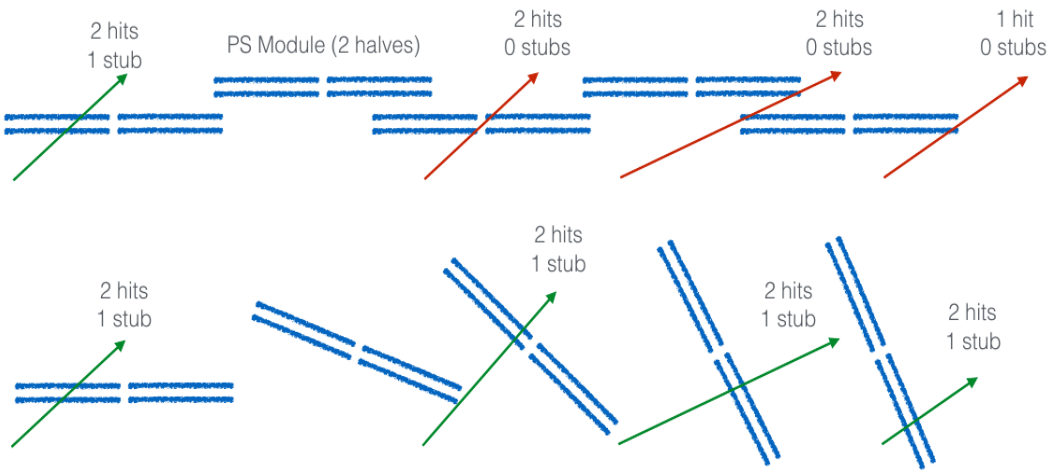
CMS Tracker Layout for HL-LHC

- Tilted barrel modules to optimize the stub efficiency
- Sketch of one quarter of the Phase2 CMS tracking system
- Extended η coverage upto |η|~4



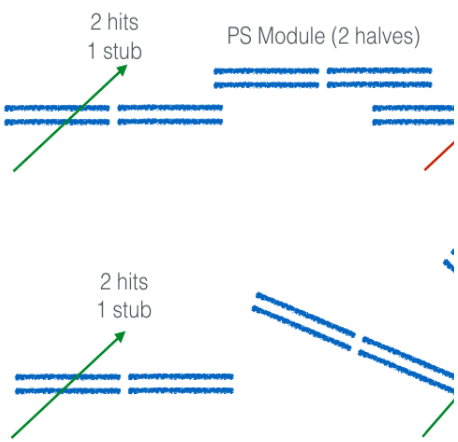
Better performance

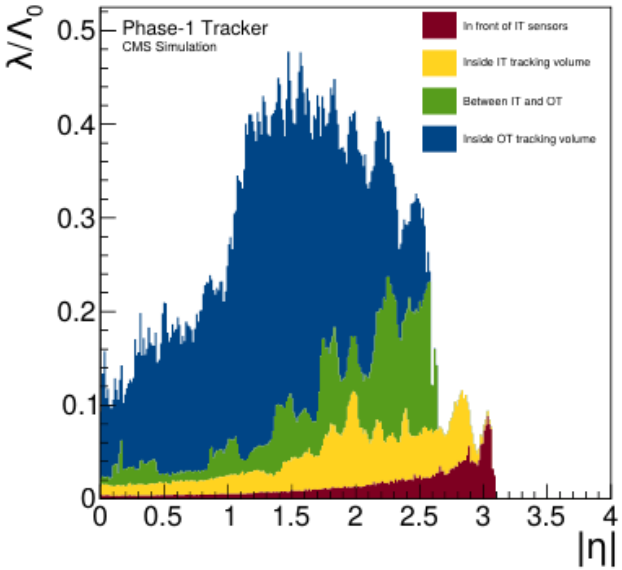
- To get a better stub efficiency we have a tilted geometry in Barrel region

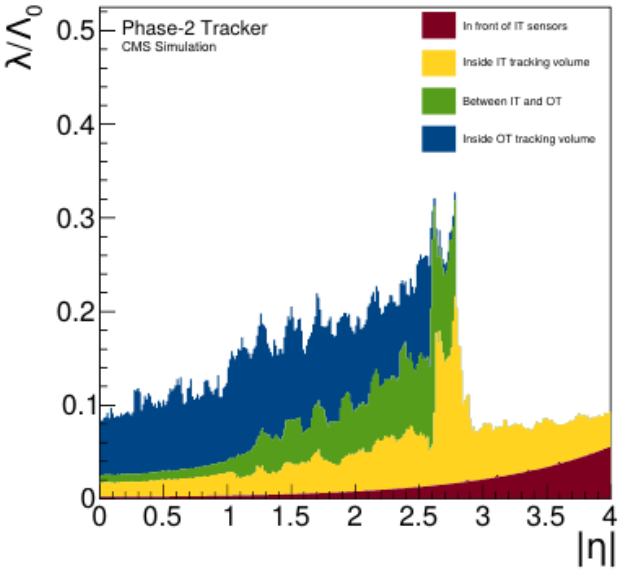


Better performance

- To get a better stub efficiency we have a tilted geometry in Barrel region
- The material budget is also less

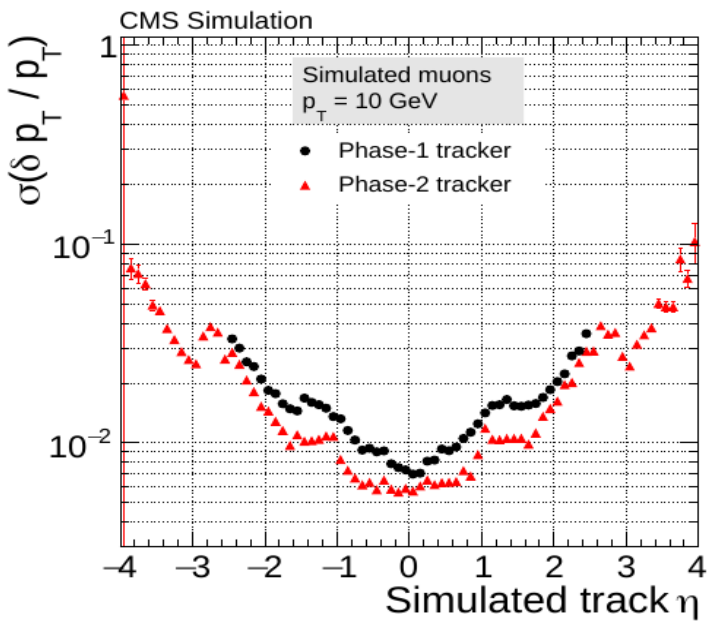


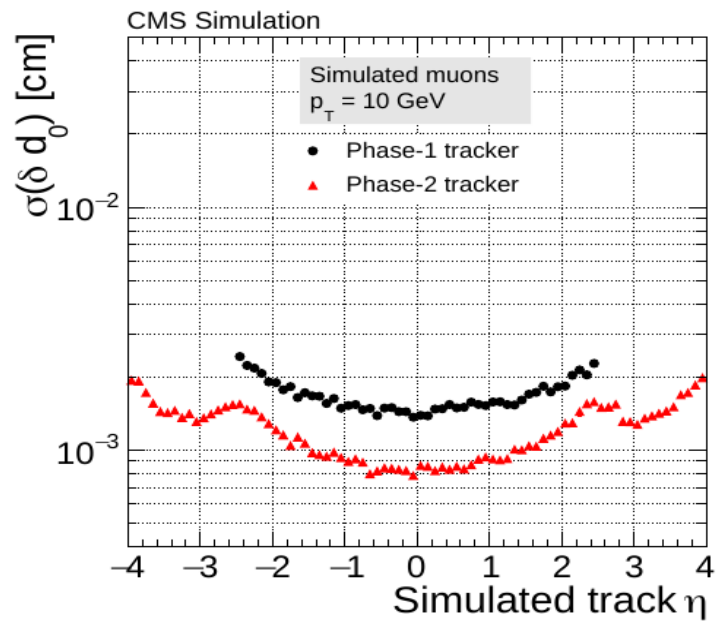




Expected performances

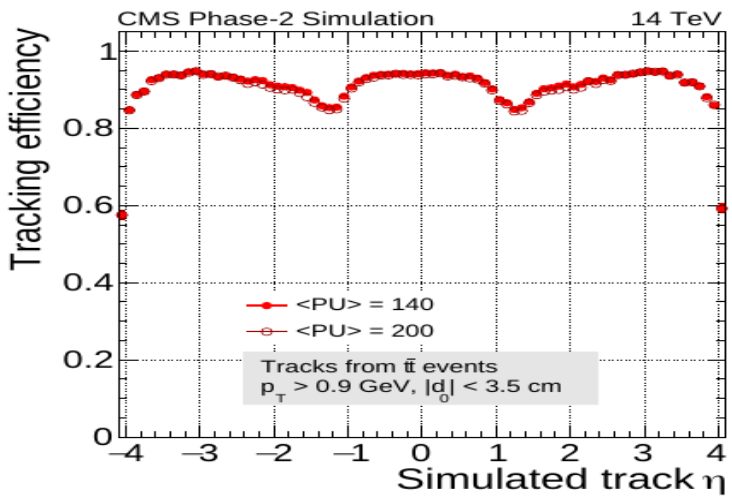
- Full detector simulation is done
- p_T and d_0 resolution is much better than the present Phase1 pixel detector

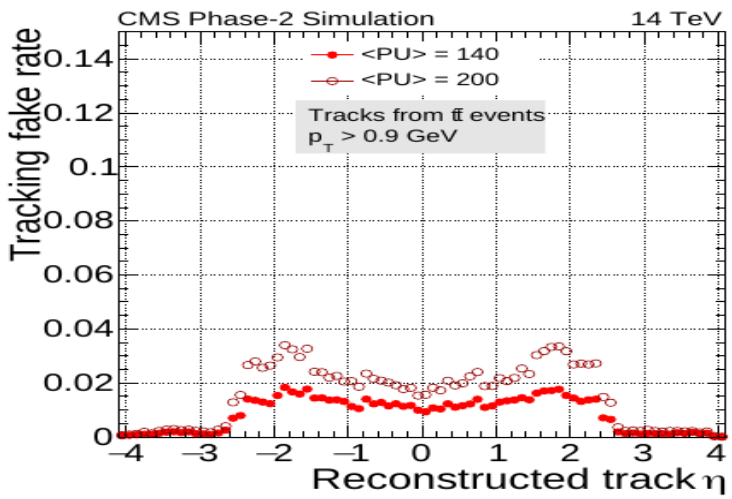




Expected performances

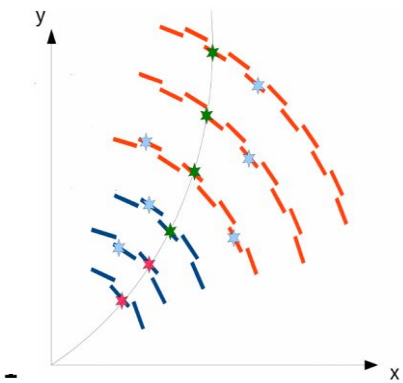
- 90% tracking efficiency for the tracks from tt-bar events with less than 2% fake rate
- The efficiency dip at |η| = 1.2 being addressed, geometry to be optimize (work in progress)



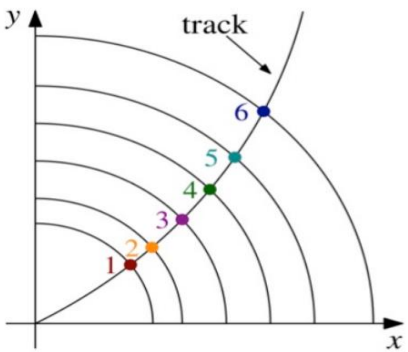


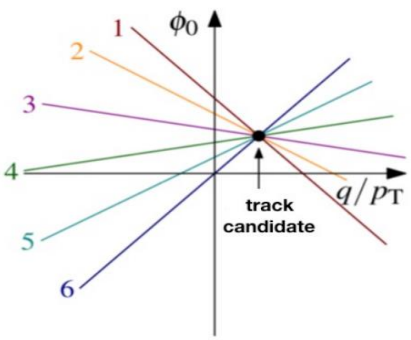
L1 Track finding

- Tracking at L1 trigger level: Challengining task
  - Tracks need to be made within 5 micro-second
  - Two different apporaches considered with FPGAs
- Tracklet approach:
  - “Tracklets” formed from stubs in adjacent layers
  - Extrapolate to tracks, minimize chi² (Kalman Filter)
  - Remove duplicates



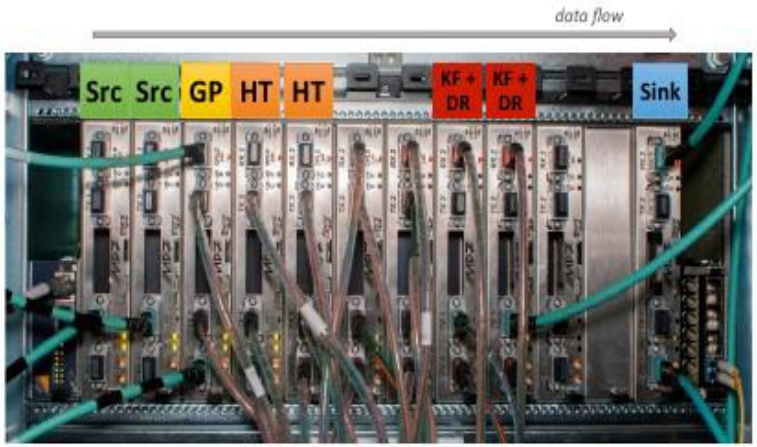
- Hough Transformation approach:
  - Select track candidate through Hough transform
  - Minimize chi² (Kalman Filter)
  - Remove duplicate





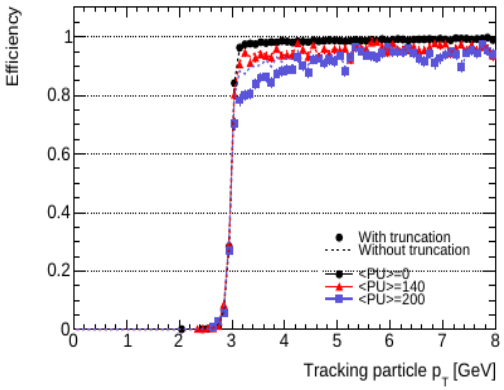
L1 Track finding

- Demonstrators were set-up for both approaches
  - Simulated event used as input
  - Similar results obtained
  - Tracks produced within timing constraints

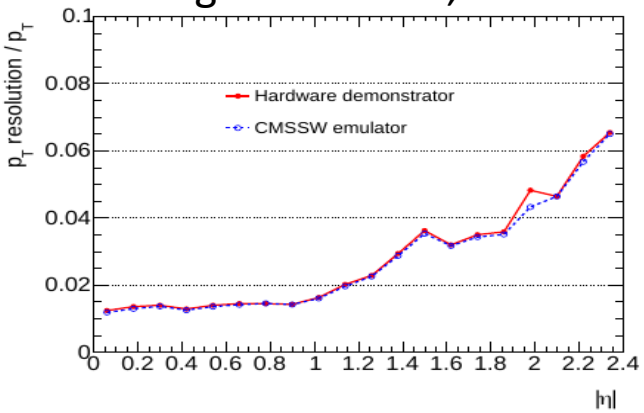


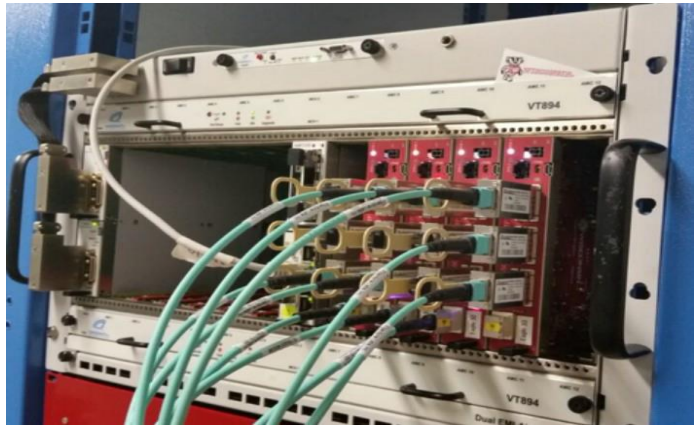
- Work being done to merge approaches

Tracklet



Hough transform, 200PU





Conclusion

- The Phase-2 tracker upgrade is necessary in order to maintain the optimal detector performance
- The new design will allow to good tracking performance under a high pile-up and high radiation environment
- Track information will be used at L1 trigger
- The detector design is well advanced and for the details, link to TDR: https://cds.cern.ch/record/2272264?ln=en

THANK YOU

CMS Tracker Upgrade References

- The Phase-2 Upgrade of the CMS L1 Trigger Interim Technical Design Report:
  - https://cds.cern.ch/record/2283192?ln=en
- RD Collaboration Proposal: Development of pixel readout integrated circuits for extreme rate and radiation
  - https://cds.cern.ch/record/1553467?ln=en