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 $L = 7.5 \times 10^{35} \text{ cm}^{-2} \text{ s}^{-1}$ and 4000 fb$^{-1}$ by 2039
- Great opportunity for Physics studies but a challenge for the detector design

August 23, 2018 VERTEX conference, Chennai
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

August 23, 2018
VERTEX conference, Chennai
• Sketch of current/present Phase1 CMS Tracking system
• Radiation tolerance 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 $\eta$ coverage upto $|\eta| \sim 4$
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 $|\eta| = 1.2$ being addressed, geometry to be optimize (work in progress)
L1 Track finding

• Tracking at L1 trigger level: Challenging task
  ▪ Tracks need to be made within 5 micro-second
  ▪ Two different approaches 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
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