CMS PHASE-2 hermetic MIP Timing Detector

**Endcap Timing Layer - ETL**

- **Sensor State of the Art**
  - Low gain silicon detectors (LGADs) on HGCAL: noise (Coverage: 3.5 - 3.9)
  - Double disk structure: similar to Tracker TEDD
  - All wafers with embedded cooling pipes (CO2, -30°C)
  - Single layer hermetic coverage: sensors on both disk sides

- **Fill Factor Status**
  - Fill Factor: Active Area / Geometrical Area
  - The fill factor is mainly determined by the inactive gap between sensors
  - Current measured gap size:
    - 70 μm for CMS
    - 50 μm for PH
    - 100 μm for HPK
  - 70 μm gap corresponds to a 9% fill factor

- **Expected Radiation for ETL Life Time**
  - LGAD reach 30 ps time resolution for fluxes up to 5 - 6 × 10^{17} cm^{-2}s^{-1}
  - Low radiation: 50 - 150 cm
  - Medium radiation: 30 - 500 cm
  - High radiation: 100 cm

- **Sensor Strategy**
  - Radiation: Production of 244 sensors → 1620 6-inch wafers
  - Each sensor: 94mm x 94mm with 1548 pads
  - Each pad: 25μm

- **Fill Factor Plans**
  - 90% fill factor corresponds to 93% fill factor
  - CMS, PH, HPK are working towards this result

- **Radiation Effects on Boron-Doped LGAD**
  - Dose dependence of the gain (low to high dose)
  - Increase bias to compensate gain loss → recover good time resolution
  - Splitting the sensors mitigates the gain reduction due to irradiation but reduces the fill factor

- **Time Resolution with Carbon**
  - CMS goal for silicon timing based on CMS Endcap Timing Layer
  - Time resolution between 30 - 60 ps uncharged (8000 R - 15000 R) & charge sharing

- **Physics Impact**
  - **Signal**
    - Detector requirement
    - Analysis impact
    - Physics impact
    - **H → ττ**
      - 30 ps photons and track timing
      - hadron: central signal
      - endpoint: time-zero and acceptance
      - +20% isolation efficiency
      - +30% identification
      - +20% projection mass resolution
      - +20% projection mass resolution
      - +20% precision on cross section
    - **VBF → ττ**
      - 30 ps track timing
      - hadron: central signal
      - endpoint: forward jet tagging
      - hadron: hadron reconstruction
      - +40% isolation efficiency
      - +30% mass resolution
      - +20% precision on mass resolution
      - +20% precision on cross section
    - **HH**
      - 30 ps track timing
      - hadron: central signal
      - endpoint: hadrons in isolation
      - +20% precision on cross section
  - **Leptonic particles**
    - hadron: central signal
    - Endpoint: mass reconstruction
    - +10% mass resolution
    - +20% precision on mass resolution
  - **MTD**
    - Improves the full range of Phase-2 physics