PPS – Precision Proton Spectrometer

RUN II – brief review

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On behalf of CMS – TOTEM collaborations
2 horizontal pots equipped with RF shields hosting 10 planes of micro-strip silicon detectors with edgeless technology (TOTEM tracking detectors)

First time diamond detectors installed at LHC

Strip efficiency limited
- by large amount of multi-track events due to high pile-up
- by radiation damage

L ~ 6/fb
PPS – Year 2016

Establish procedure for:

- RP insertion in high luminosity fills
- RP alignment
- Optics determination

(First) Observation of proton-tagged, central (semi) exclusive production of high-mass lepton pairs in pp collisions

JHEP 1807 (2018) 153
6 planes of “slim-edge” silicon pixel detectors with 3D technology

Pixel size: 100 μm × 150 μm;
Track resolution ~20 μm

Designed for high-luminosity → multi-track capability
Sensor radiation hardness: good till \(\sim 100 \text{ fb}^{-1}\)

Readout chip radiation damage due to non-uniform irradiation

The effect appears after an integrated luminosity \(\sim 8 \text{ fb}^{-1}\). To mitigate the impact on the data quality, the tracking stations were lifted to shift the occupancy maximum away from the damaged region.
PPS – Year 2017: timing

TOF measurement to reduce background from pileup (uncorrelated proton tracks)

Diamond sensors:

3 planes of CVD with macro-pixels of varying size to match the proton occupancy as a function of the distance from the beam

single-plane resolution: ~80 ps

Intrinsic radiation hardness → to withstand overall integrated flux of $5 \times 10^{15}$ p/cm$^2$

Ultra-Fast Silicon Detectors:

1 plane based on LGAD technology

single-plane resolution in test beam: ~30 ps

Precise clock distribution (few ps jitter) is obtained with a design adapted from the “Universal Picosecond Timing System” (optical network) or with RF-feedback with low-loss coaxial cable.
Detailed study of the time resolution of the entire system with LHC data is in progress.
PPS – Year 2017: luminosity

88% of luminosity recorded

Alignment, optics determination completed
PPS – Year 2018 : new setup

Tracking

2 RP equipped with 3D pixel sensors

Detailed study of efficiency is in progress
Timing

2 double diamond + 2 single diamond per RP

Two scCVD sensors installed back to back and connected in parallel to the same amplifier channel

Time precision evaluated in test-beam showed an improvement of 1.6 with respect to single crystals (50ps)
92% of luminosity recorded

Alignment, optics determination, proton kinematic reconstruction is ongoing

Large complexity due to the luminosity leveling: continuous crossing angle and $\beta^*$ tuning
Several analyses ongoing:

Central (semi)exclusive production of high mass lepton pairs
Anomalous Quartic Gauge Couplings
Central production of $\gamma\gamma$, $WW$, $ZZ$, $\gamma Z$, $t\bar{t}$
Missing mass searches
Search for axion-like particles

PPS has demonstrated the feasibility of studying forward proton-tagged events at high luminosity
Continuation of the PPS program has been approved for LHC Run 3 (2021-2023) at $\sqrt{s} = 14$ TeV: goal 300/fb

New detectors needed, to replace current ones damaged by radiation

**Tracking**: new 3D silicon pixel detectors

- technology very similar to existing one
- same geometry/granularity
- new detector package with internal movement system, to cope with the non-uniform radiation damage

**Timing**: double diamond sensors to be installed in two Timing stations per arm

Run II is just over and only a small part of the data has been fully analyzed
Looking forward to new results and future challenges!