Abstract: The Large Hadron Collider will undergo a luminosity upgrade targeting a peak instantaneous luminosity ranging from 5–7.5×10^{34} cm^{-2}s^{-1}. The ambitious goal of the High Luminosity LHC is to achieve a total of 3000–4000 fb^{-1} of proton-proton collisions at a center-of-mass energy of 13–14 TeV by 2029. To cope with such challenging environmental conditions, the outer tracker of the CMS experiment will be upgraded using closely spaced silicon sensors (pixels and strips) to provide tracking information at the Level-1 trigger. A PS module, composed of both a pixel and a strip sensor, was tested at the Fermilab Test-Beam Facility to evaluate its ability to provide accurate tracking information, \( P_z \) discrimination capabilities, and optimal performance at the irradiation levels expected after being exposed to the harsh conditions of the High Luminosity LHC. The results of the test and the comparison of the module performance before and after irradiation will be presented in this poster.

High Luminosity LHC (HL-LHC)
- Increased instantaneous luminosity to 5–7.5×10^{34} cm^{-2}s^{-1} [1]
- High pile up of 140-200 at 750 kHz L1 trigger rate
- Benefits:
  - Improve precision of standard model measurements
  - Improve direct searches for new and rare phenomena

Irradiation of PS Module at Fermilab
- 400 MeV protons, 8 pulses per minute across the 4 highlighted areas (sandwich of PSs + MPAs)
- Target radiation fluence: 1.4 × 10^{15} n_{eq} cm^{-2}

Pixel Efficiency
- # of hits on the detector matched to the pointing track within a window 200um
- Pixel cell pitch = 100um x 1467um
- Punch through and grounding rails are part of the pixel structure and the cause of the lower efficiency in the corresponding areas [4].
- These plots are made with data collected when the module was perpendicular to the beam. The inefficient areas are reduced when the angle \( \beta \) between the beam and the module is increased.

Fermilab Test Beam Facility
- 120 GeV proton beam [2], ranging from 1 to 300KHz
- Each spill lasts for 4 seconds every minute and delivers ~ 40k protons
- The telescope [3] consists of 12 strip planes and 4 pixel planes
- Telescope resolution is 7 \( \mu \)m

Efficiency and Noise Occupancy as function of threshold
- Noise Occupancy = \frac{Number of hits in xoan cell}{Number of triggers}
- After the irradiation, it is expected that the noise occupancy should increase due to damage in the silicon bulk.
- According to the requirements, the noise occupancy should be ~ 10^{-2}.
- The conversion between digital threshold DAC \( V_{ech} \) units to electrons has been obtained with a linear fit of the measured average \( V_{ech} \) as a function of the injected \( V_{cal} \) on the detector.

Stub Efficiency
- The relative stub efficiency is calculated with respect to having a cluster in both the pixel and the strip sensors.
- The conversion can mimic the performance of a module with sensor spacing 1.6mm and placed at distance \( R = 0.372 \) m inside the 3.8T magnetic field of CMS experiment as shown below in the p. plots.
- The efficiency was measured for three different strip cuts.

Summary
- Preliminary studies of PS module efficiencies:
  - Not Irrad: pixels = 99% and strips = 99.6%
  - Irrad @ 1.4 × 10^{15} n_{eq} cm^{-2} fluence: pixels = 98.5% and strips = 98.6%
- Stub efficiencies w.r.t angle and \( p_{z} \) are consistent with geometrical window cut

References