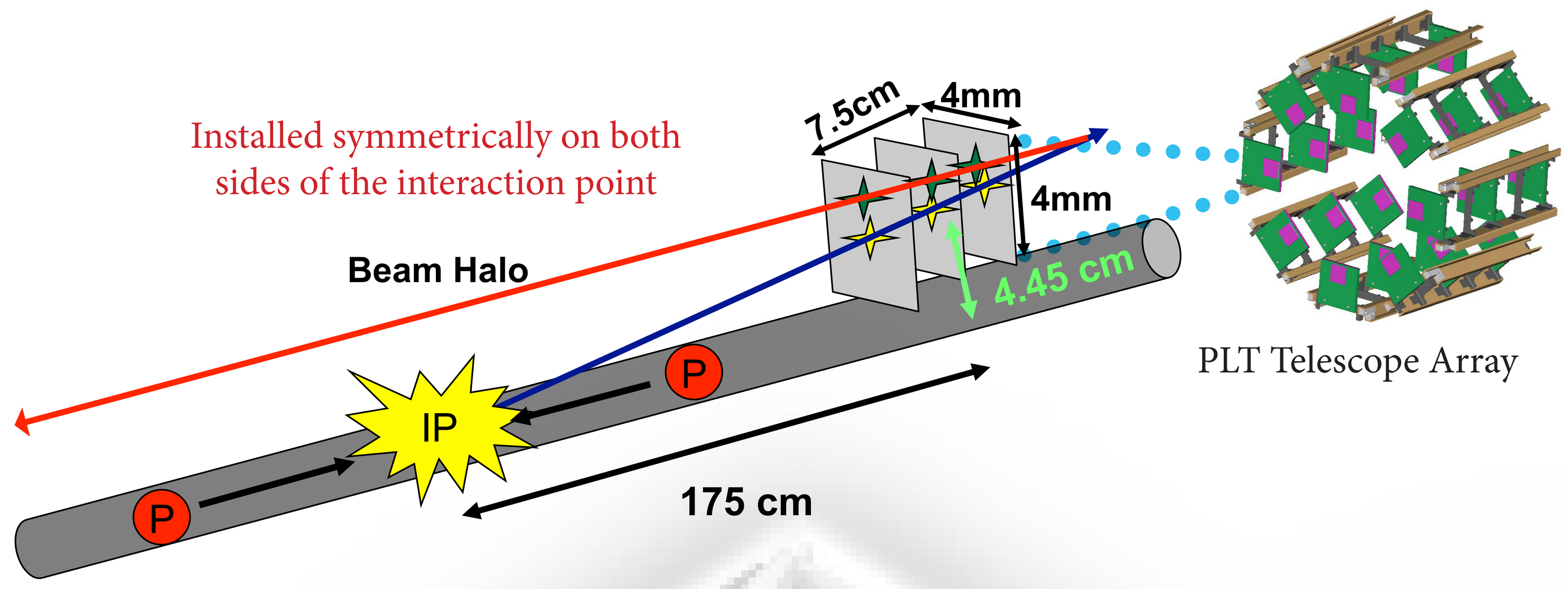
University of Tennessee, Rutgers University, HEPHY-Vienna, Vanderbilt University, Princeton University, CERN

The Pixel Luminosity Telescope: a Dedicated Luminosity Monitor for CMS

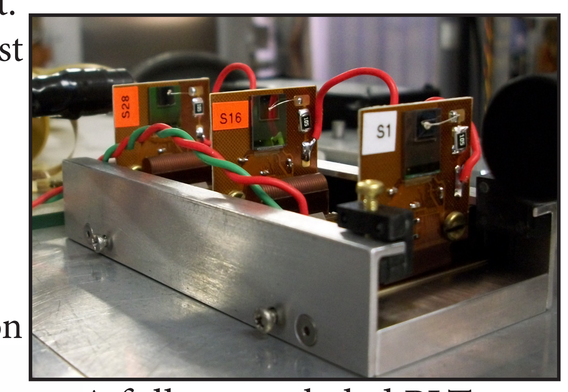
CMS Pixel Luminosity Telescope (PLT)

The PLT is a dedicated luminosity monitor for CMS based on single-crystal diamond pixel sensors. It will consist of two arrays of eight small-angle telescopes situated one on each end of the CMS experiment at CERN. The use of pixel detectors will allow both luminosity measurements as well as measurements of the IP centroid and differentiation of beam gas interactions vs. true luminosity.



Diamond Sensors -> stable operation over the lifetime of CMS

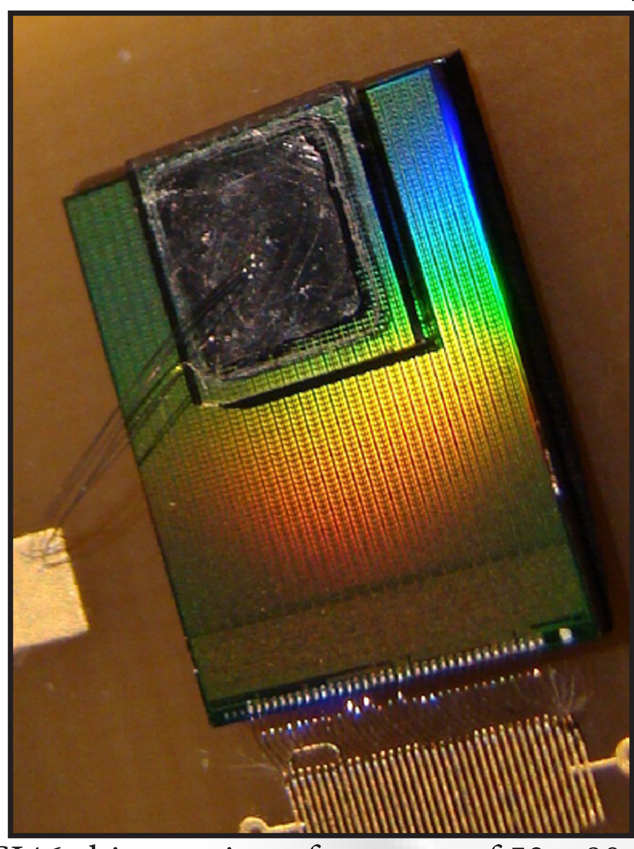
The PLT is designed to provide a high-precision measurement of the bunch-by-bunch relative luminosity at the CMS collision point on a time scale of a few seconds and a stable high-precision measurement of the integrated relative luminosity over the entire lifetime of the CMS experiment. The telescopes consist of three equally-spaced planes of diamond pixel sensors with a total telescope length of 7.5 cm. Their location along the beam pipe is indicated in the figure to the left.

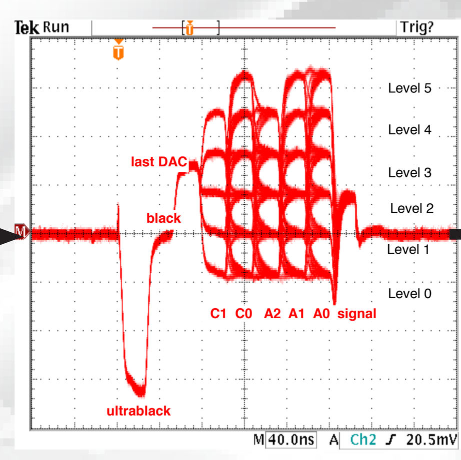


A fully assembeled PLT Telescope

Readout and Assembly

PSI46 Pixel Readout Chip

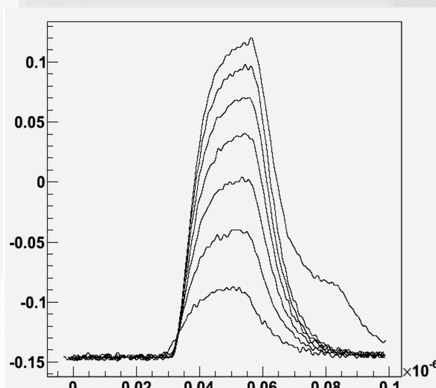


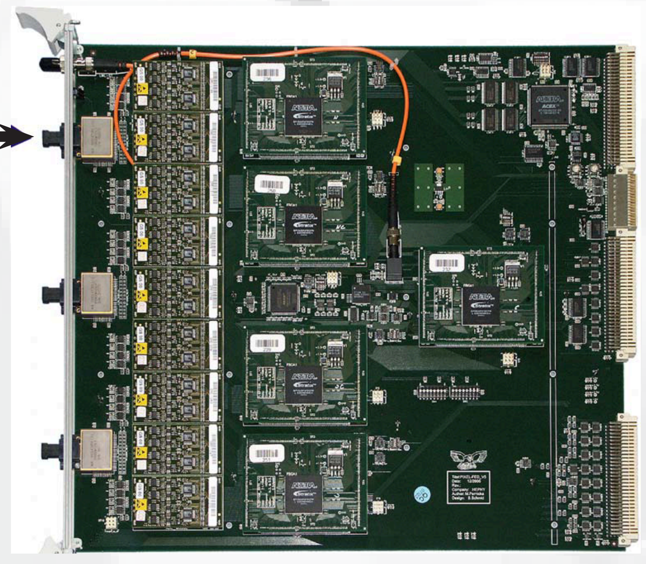


Pixel Hits: Row, Column, Charge deposit

Front End Driver (FED)

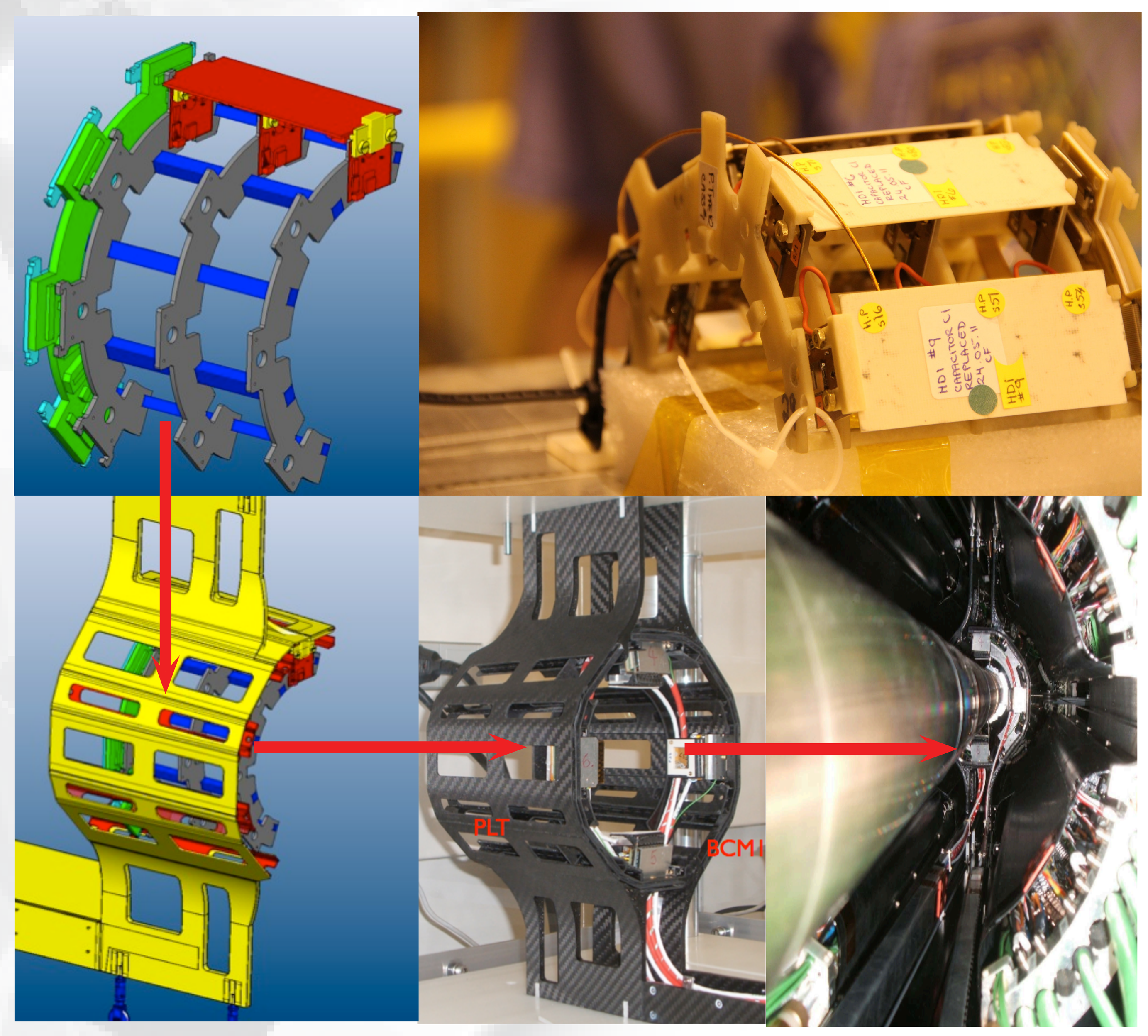
Fast-OR





The PSI46 chip consists of an array of 52 x 80 pixels with a pitch of 150 μm x 100 μm. Each pixel features individual pixel threshold/mask settings, full analog readout of the pixel hit address and charge deposit, as well as a column-multiplicity signal (known as the Fast-OR), which indicates the number of double columns that had pixels over threshold in each bunch crossing. Fast-OR signals are read at the full bunch-crossing rate of 40 MHz clock, while the full pixel information, consisting of the row and column addresses and the pulse heights of all pixels over threshold, is read out at a lower rate of a few kHz.

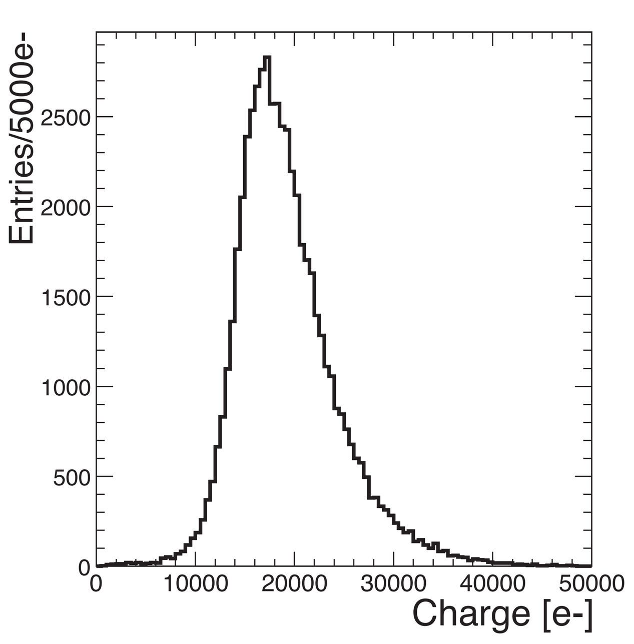
The pixel FED is responsible for digitizing the analog pixel hit information as it is produced. Both the hardware and firmware used for the pixel FED is the same as is used for the CMS pixel system. However, the Fast-OR FED has custom firmware written for the PLT's luminosity measurement.

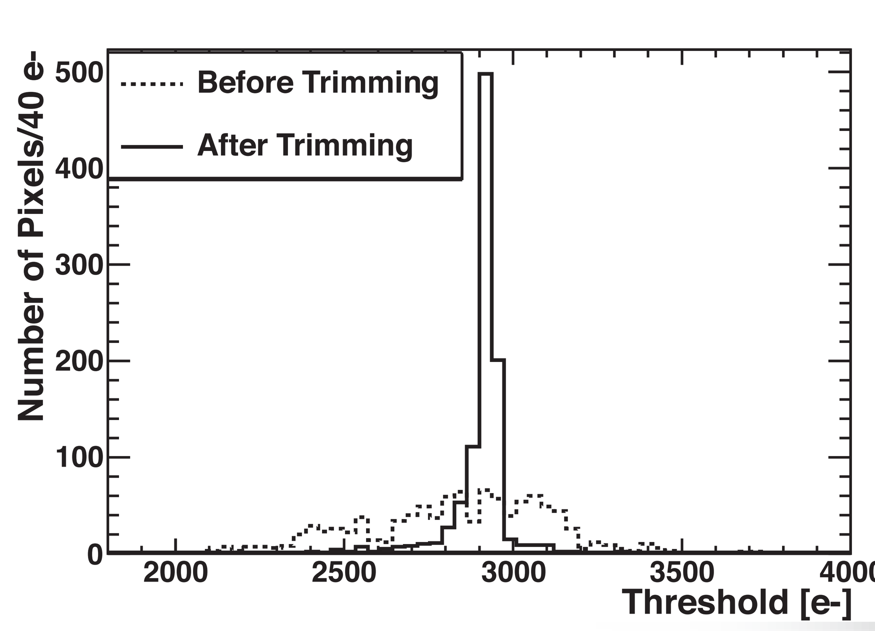


PLT Mechanics

Performance

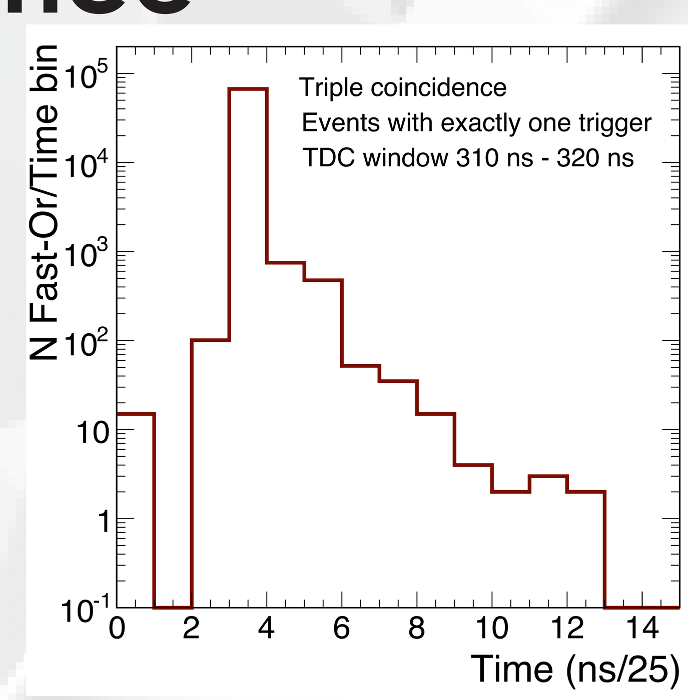
Charge Collection



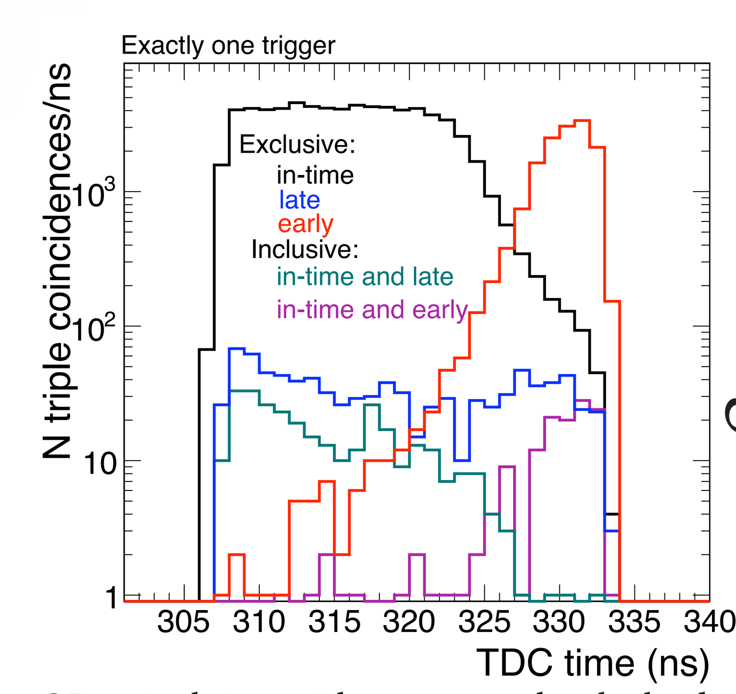


The PLT frontend is capable of reading out actual charge deposit in units of deposited electrons. The left figure shows the charge deposit in one PLT plane, which has a sensor thickness of 500 microns. Each pixel can have its threshold set to provide uniform response at around 3000 electrons by utilizing a process referred to as "trimming". Thresholds for each pixel before and after trimming are shown in the figure on the right.

Timing

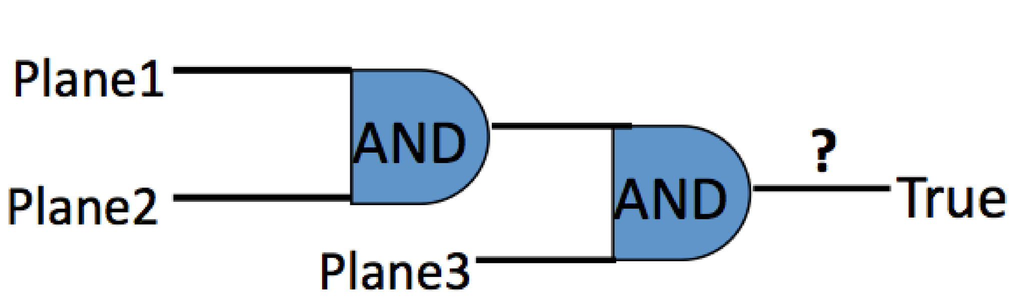


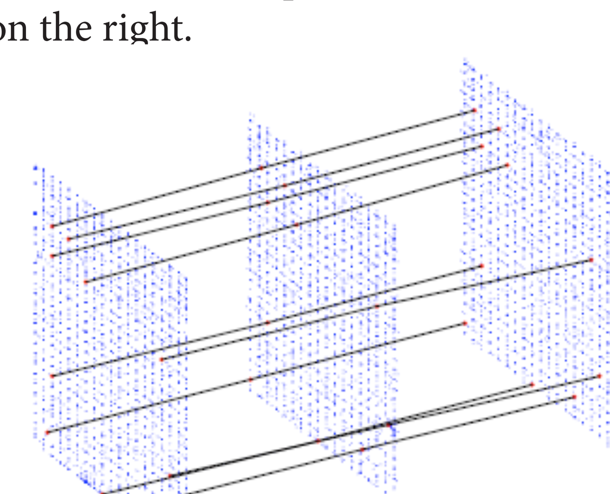
Arrival time of Fast-OR signal in the FED for all events within a TDC time window of 10ns about 5ns before the next clock cycle. In-time events occur in time-bin 3. Everything to the left of this bin is termed "early" and everything to the right is termed "late".



Fast-OR arrival time with respect to the clock edge. The Fast-OR signals have been divided into in-time (solid line), early inclusive and exclusive (long dashed line), and late inclusive and exclusive (short dashed line) signals.

Efficiency

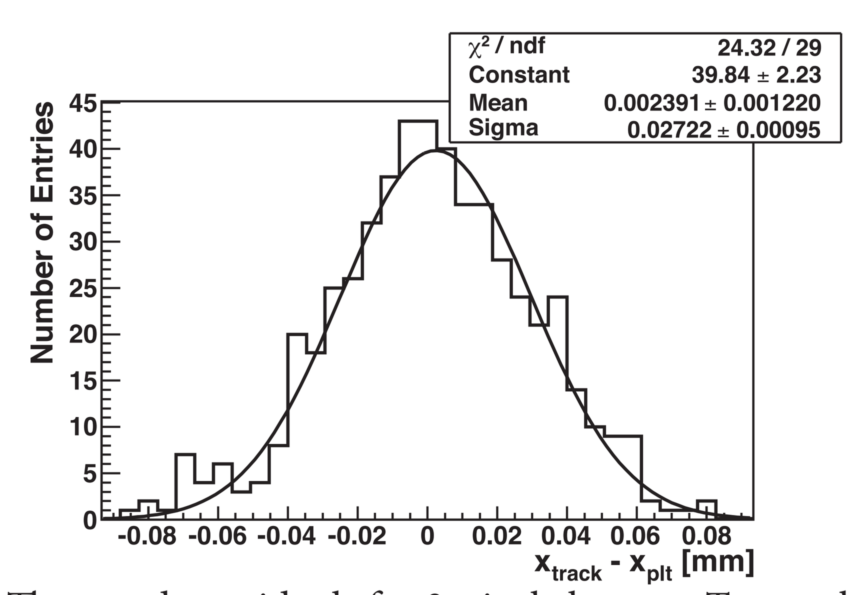


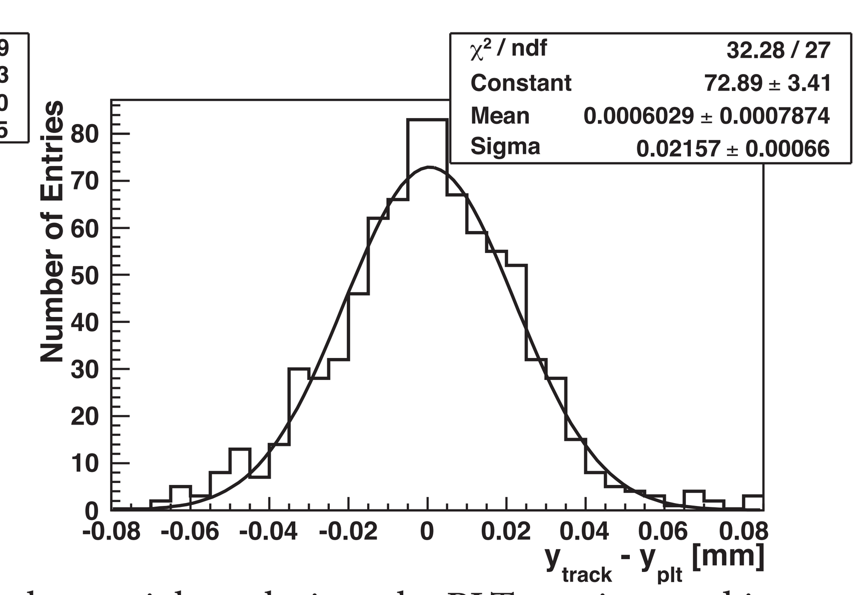


	Plane 1	Plane 2	Plane 3
Efficiency	99.3%	99.6%	99.9%
Dead Pixels	1.8%	2.2%	0.1%

One full PLT telescope was tested to measure the efficiency of each plane relative to a trigger scintillator. Efficiency was calculated by requiring that any events which triggered two planes also triggered the third plane. This measurement is the lower limit of the PLT efficiency as it will perform in the LHC, since no cuts were applied which would guarantee the arrival phase of the particle with respect to the clock--see the discussion on timing above.

Spatial Resolution





The x and y residuals for 2-pixel clusters. To test the spatial resolution, the PLT was inserted into a silicon strip detector provided by then University of Zurich. Residuals for the PLT were defined as $\Delta X = x_{track} - x_{plt}$ where x_{track} is calculated as a linear fit through the strip detector, and x_{plt} is given by the equation $x_{plt} = \frac{\Sigma x_i \cdot Q_i}{\Sigma Q_i}$ where Q_i is the charge in each pixel of the cluster in the PLT, x_i is the column address of the pixel, and the sum is over the number of pixels in the corresponding cluster. The formula for y is analogous to these formulas. The measured resolution is significantly improved over the expected digital resolution of ΔX = 43 μm and ΔY = 29 μm.

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