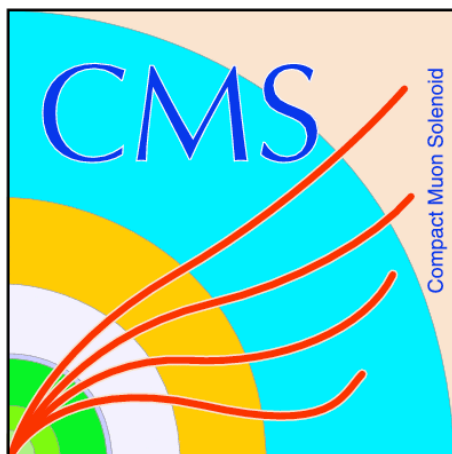




PIXEL LUMINOSITY TELESCOPE: LHC/CMS PILOT RUN

Dean Andrew Hidas
Rutgers / CERN



PIXEL2012

September 3 – 7, 2012
Inawashiro, Japan



The PLT Collaboration

CERN

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Princeton University

Valerie Halyo, Bert Harrop, Phil Hebda, Paul Lujan, Dan Marlow, David Stickland

Rutgers University

Ed Bartz, Christian Contreras-Campana
John Doroshenko, Richard Gray, Eva Halkiadakis,
Dean Andrew Hidas**, Steve Schnetzer,
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University of Tennessee

Mark Foerster, Grant Riely, Stefan Spanier, Zongchang Yang

University of Wisconsin

Jim Cook, Cathy Farrow

Vanderbilt University

Andres Delannoy, Will Johns

Vienna Institute for High Energy Physics

Manfred Pernicka*, Helmut Steininger

Past members

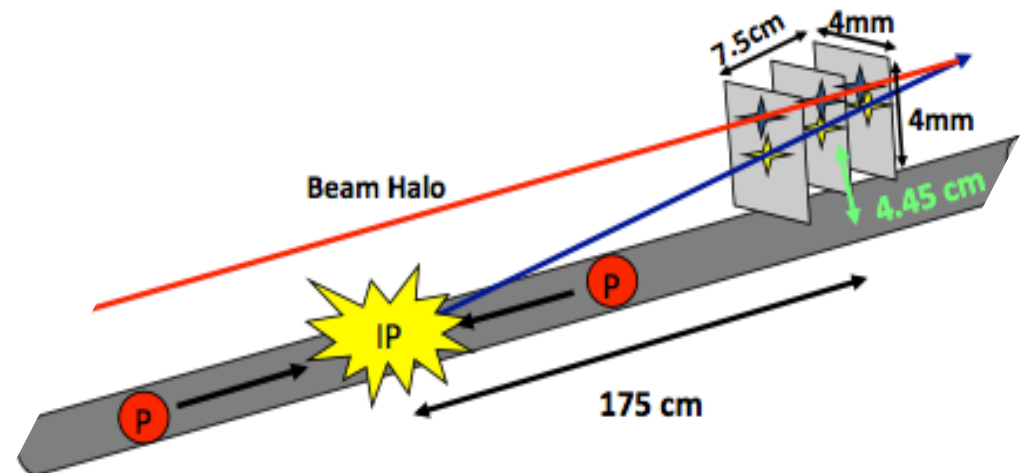
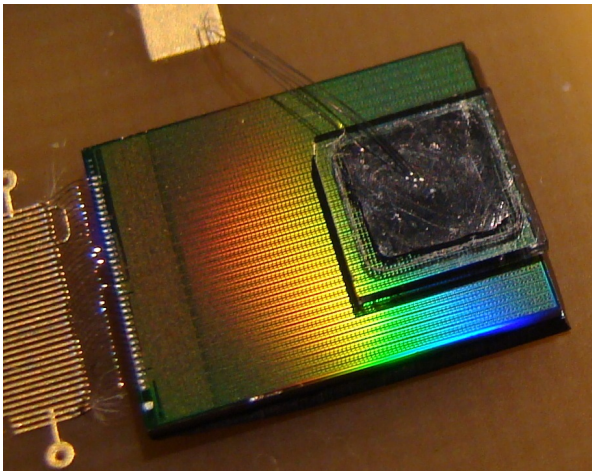
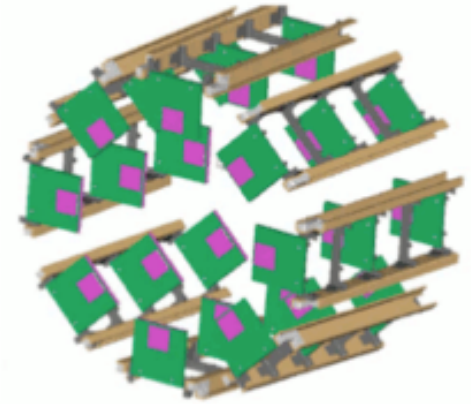
Karen Andeen, Oleksiy Atrementov,
Bill Bugg, Gary Grim, Richard Hall-Wilton,
Dmitry Hits, Richard Lander, Alick Macpherson,
Lalith Perera, Nuno Rodriguez, Bil Gabella,
Matt Hollingsworth

**Also CERN, *Deceased



PLT Overview

- Dedicated stand-alone luminosity monitor for CMS
- High precision bunch-by-bunch luminosity
- Array of 3-plane telescopes each end of CMS
- Single-crystal diamond pixel sensors
- Measure bunch-by-bunch 3-fold coincidence rate
- Pixel readout for tracking and diagnostics





PLT Design

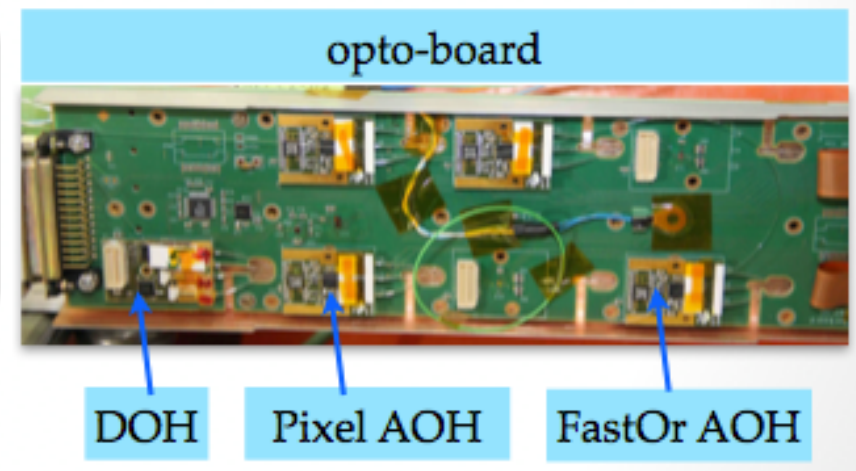
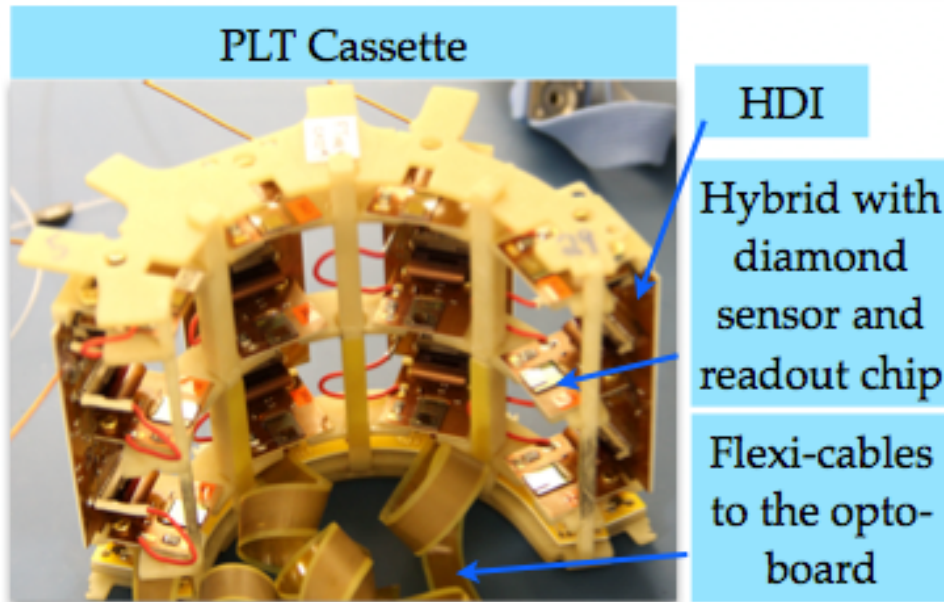
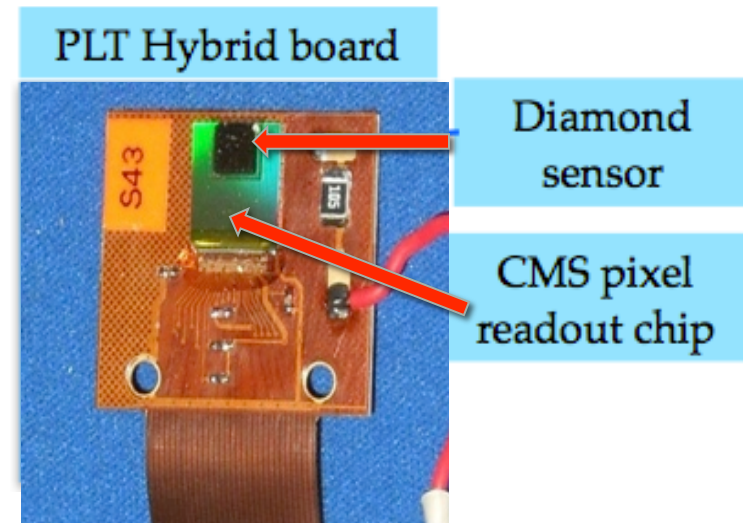
- From simulation expect
 - 0.005 tracks / pp collision / telescope
- For 10^{34} / cm^2 / s
 - 1.6 tracks in PLT per bunch crossing
 - or > 18000 tracks for each of 2835 filled bunches

1% statistical precision on relative bunch luminosity in < 1s
- Additionally, pixel tracking will allow online beamspot measurement



PLT Hardware

- Telescope
 - Made from 3 Hybrid boards (diamond detectors)
- Cassette
 - Self-contained quarter-detector
- Opto-board
 - Control and readout of full cassette

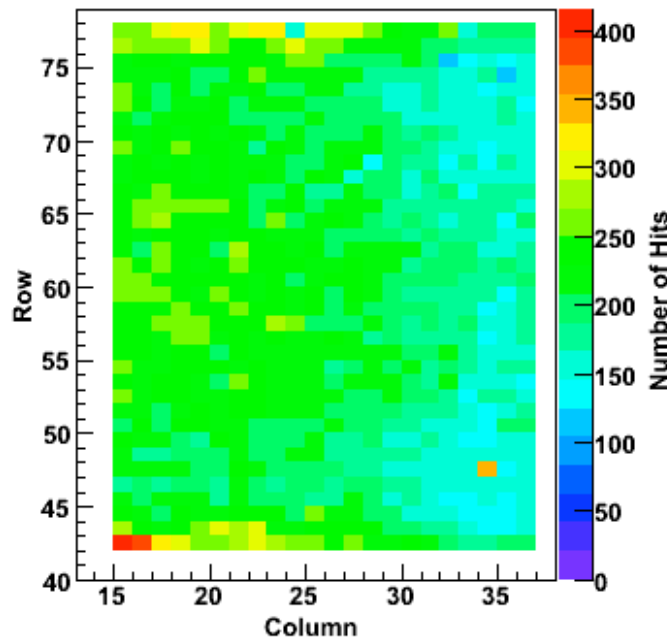




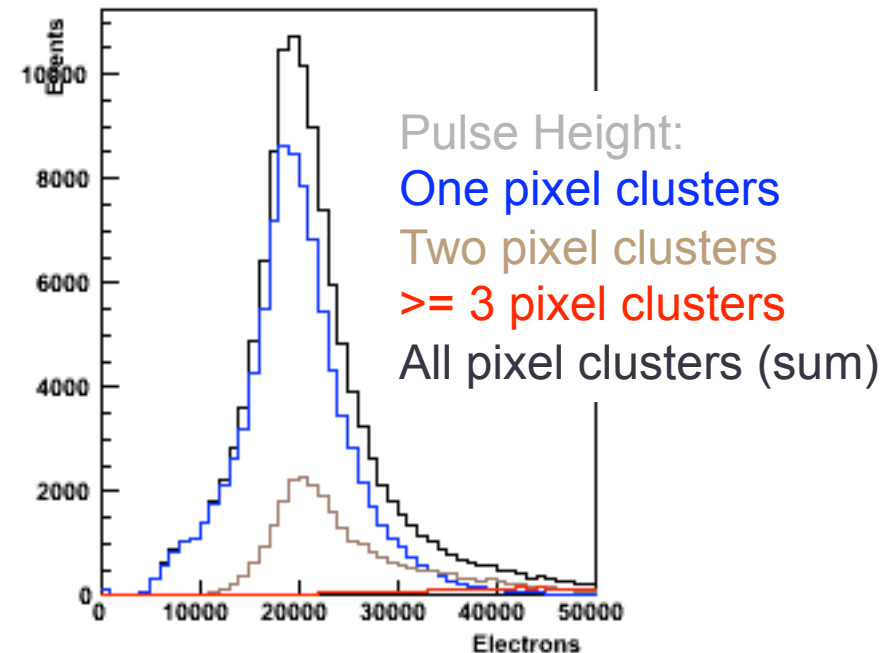
Testbeams

- Several successful testbeams in the last year
- CERN PS (10 GeV protons)
 - Measure charge collection, study tracking, test DAQ

Occupancy Ch23,ROC2



PulseHeight Ch23 ROC2

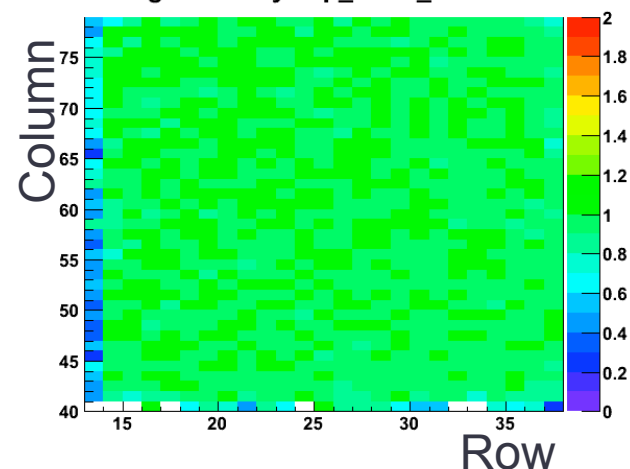




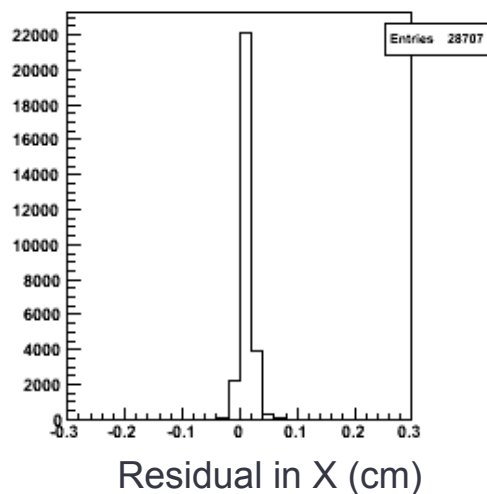
Testbeams

- Uniform hit efficiencies
- Not ideal environment to measure efficiencies (timing, edge effects, etc)
 - But still very high efficiencies

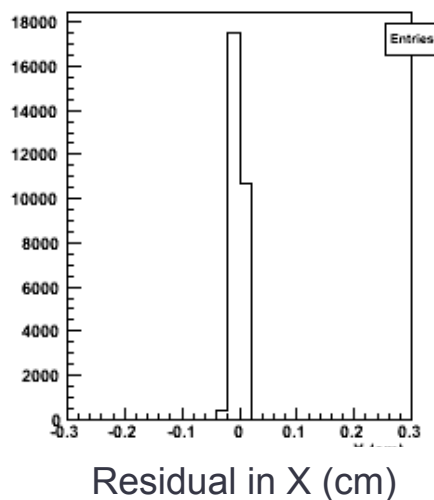
TrackingEfficiencyMap_Ch23_ROC1



Residual_Ch20_12Plane_ROC0



Residual_Ch20_02Plane_ROC1

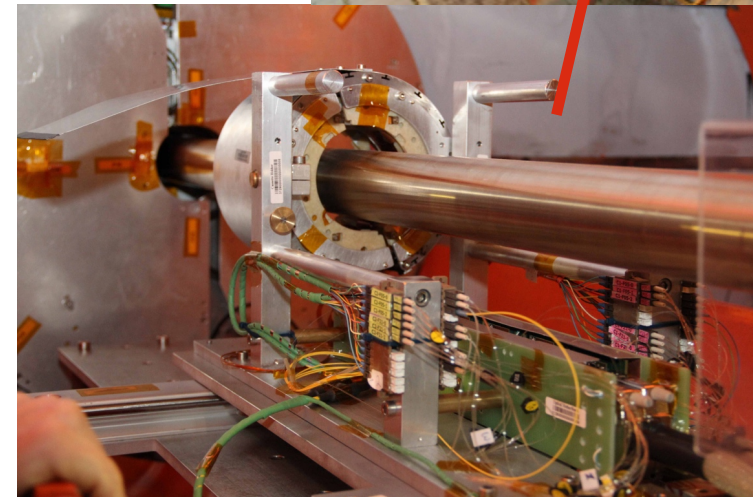


- Raw alignment residuals (no software alignment)
 - ~1 pixel width (~100 μm)
 - Better than expected alignment

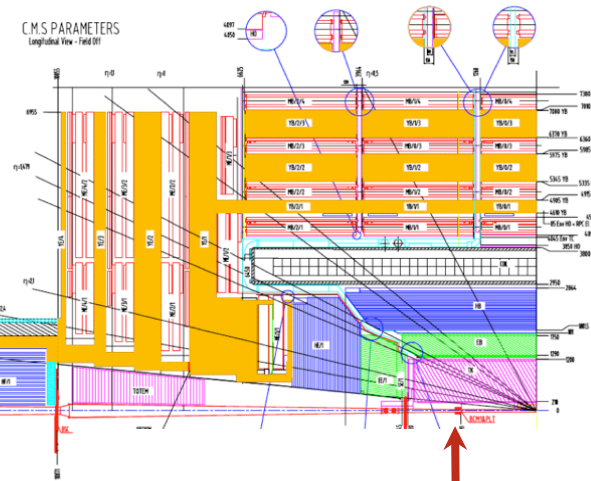


2012 Pilot Installation

- In January we installed 4 diamond telescopes and one with silicon on the +Z castor table in CMS (14.5m from collision point)



CMS PARAMETERS
Longitudinal View - Field Off



**Pilot run
location**

14.5m
 $\eta = 6.4$

**Nominal
location**

1.75m
 $\eta = 4.3$



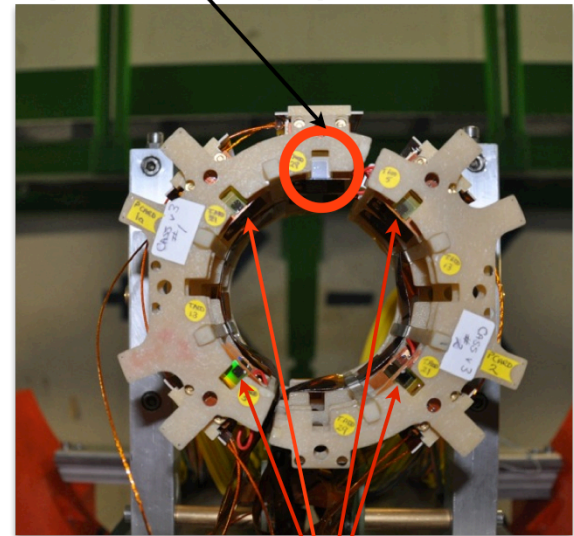
2012 Pilot Run

- First experience with diamond pixel detectors in high rate, high intensity environment
- Check out of full PLT system
- Finalize DAQ, DQM, and control software
- Develop precision software alignment technique
- Develop luminosity publishing tools
- Determine if there is any aging of sensors or electronics with radiation
- Test sensitivity to SEUs
- Test luminosity measurement

Pilot run started in April and will continue for the rest of the run

Pilot run installation configuration

Si pixel telescope



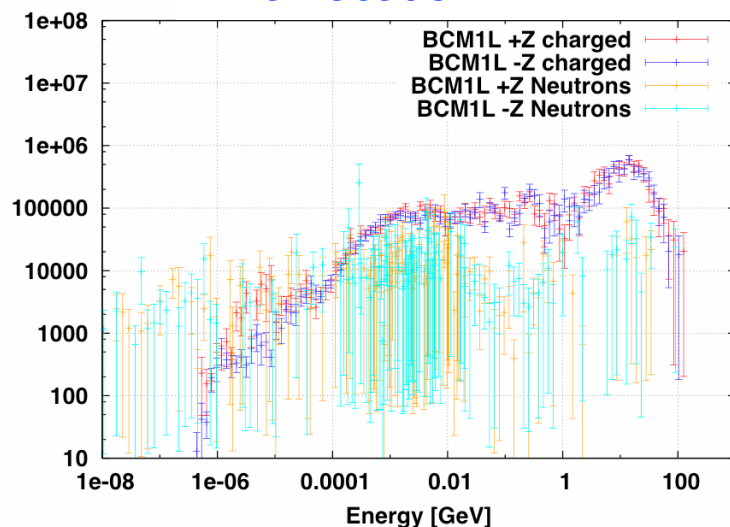
4 diamond pixel telescopes



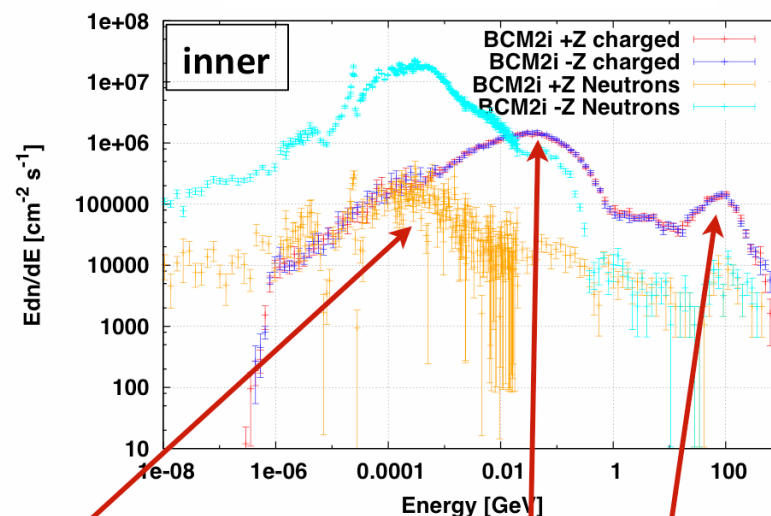
Pilot Run Radiation Environment

- Radiation environment in pilot location is more severe than in the final installation location

Final location



Pilot location



Order of magnitude more neutrons
peaked at about 200 keV

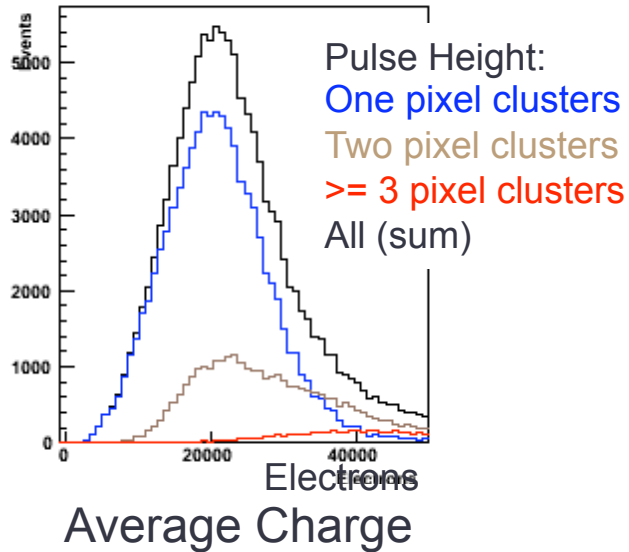
Large number of e^+e^- from showering in beam pipe
peaked at about 20 MeV

About 5 times fewer particles from IP



First LHC Measurements

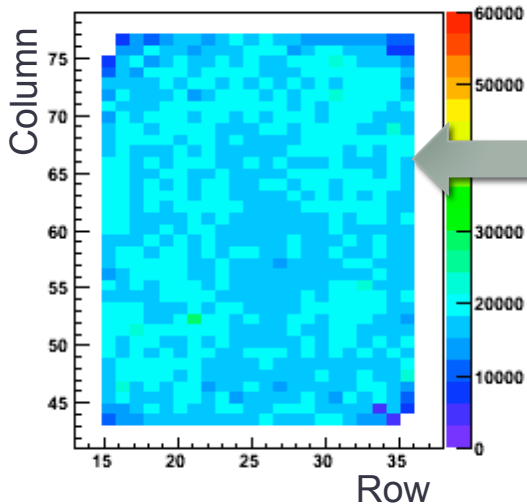
Charge Collection



We see high rates of background on castor table (likely e^+e^- showering from beampipe)

Meaning: This year, much more challenging than years to come

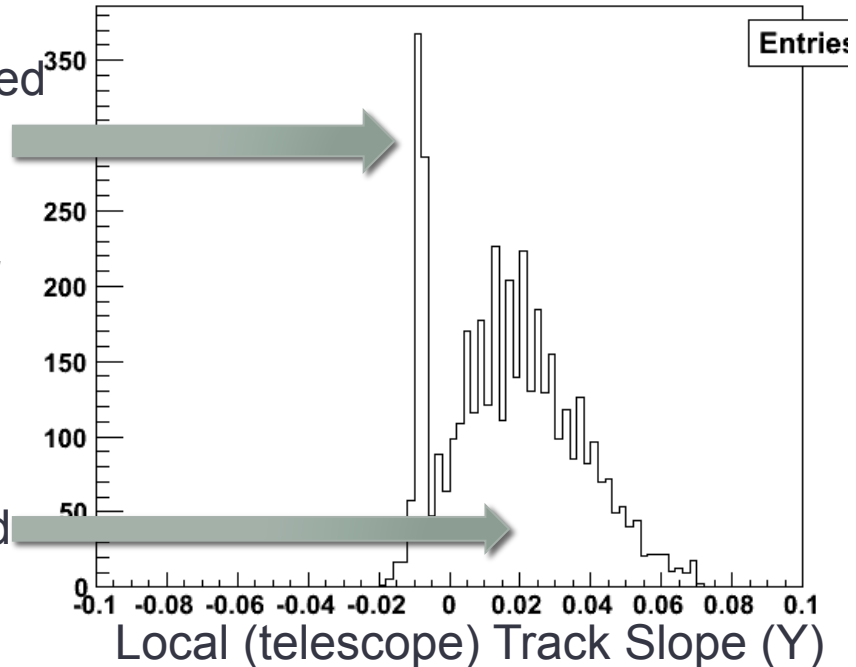
Charge collection during collisions



Example of uniformity in diamond

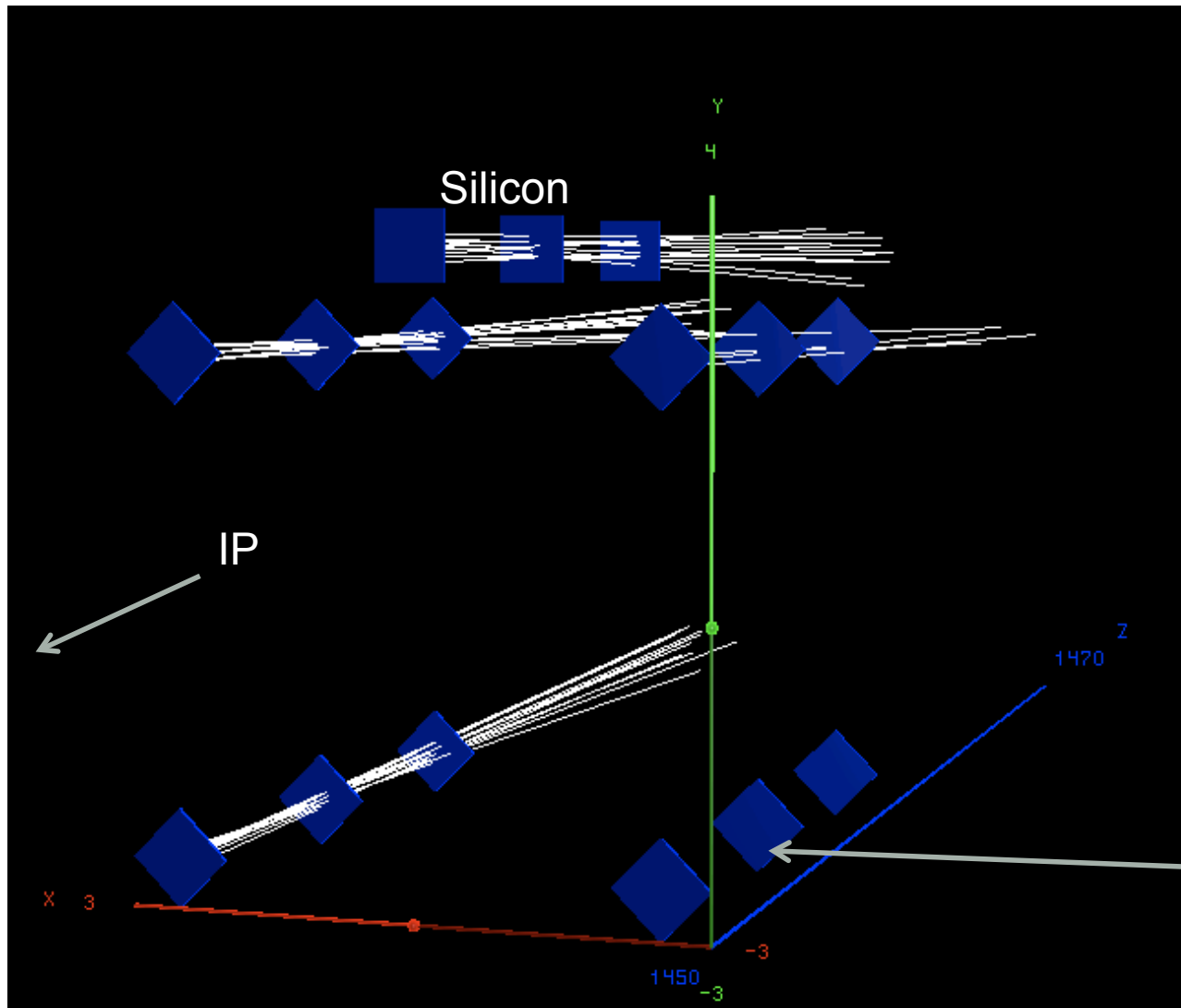
Background

Expected from IP





First Tracks



First Tracks seen
with the PLT from
LHC beam

4 Diamond
telescopes and
one silicon
telescope

One known
missing HV.
Has been
fixed



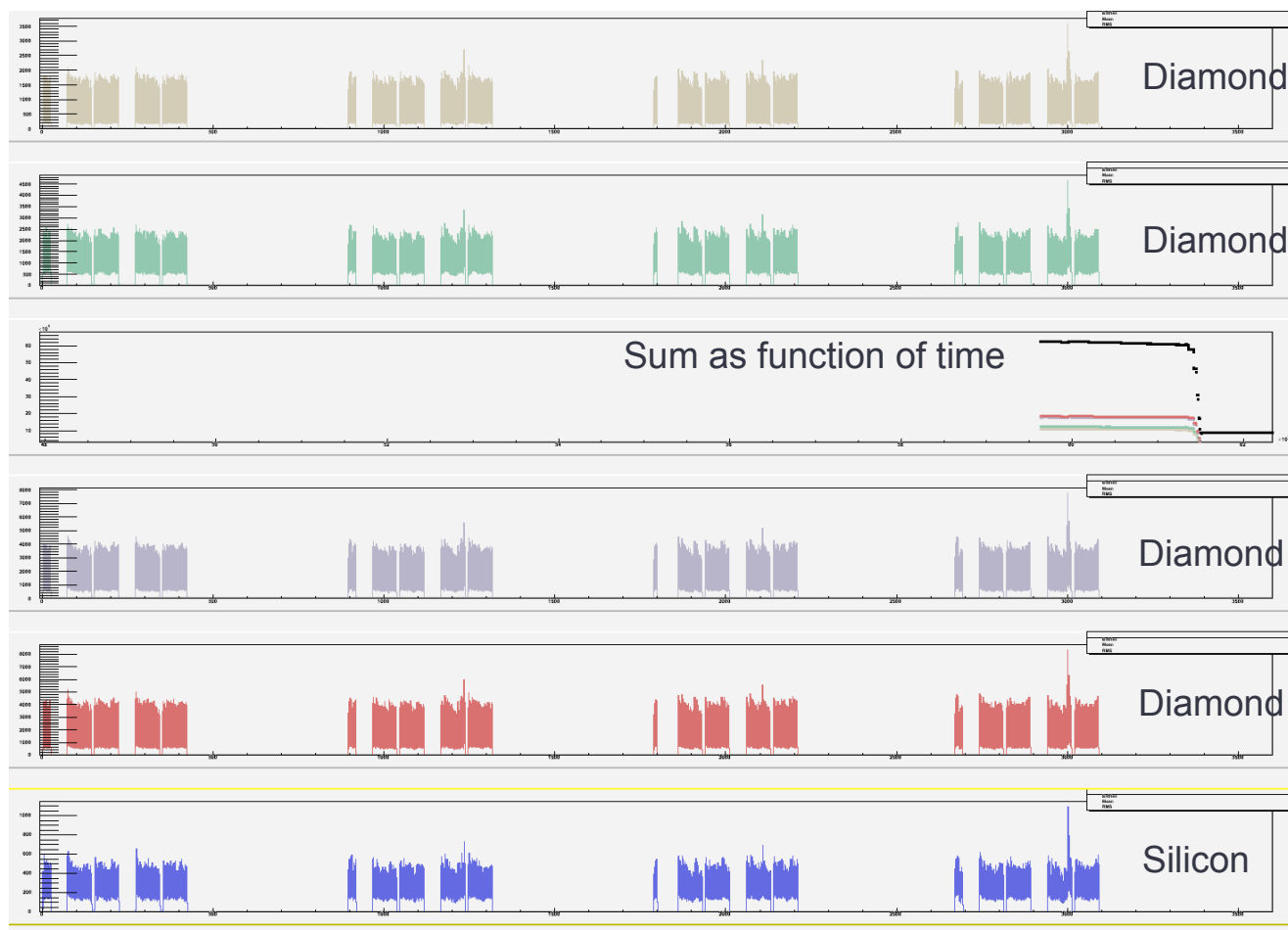
First LHC Measurements

- LHC Bunch structure as seen with PLT

“Histograms” of 3-fold coincidences allow us to measure the luminosity in each 25ns LHC bucket

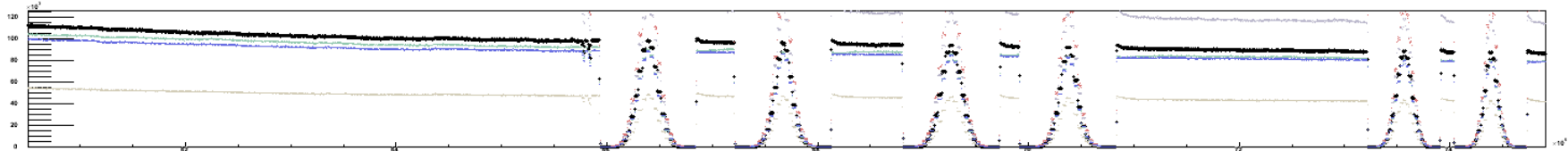
Sum “total” used to visualize instantaneous luminosity

Installed one silicon telescope (without cooling).

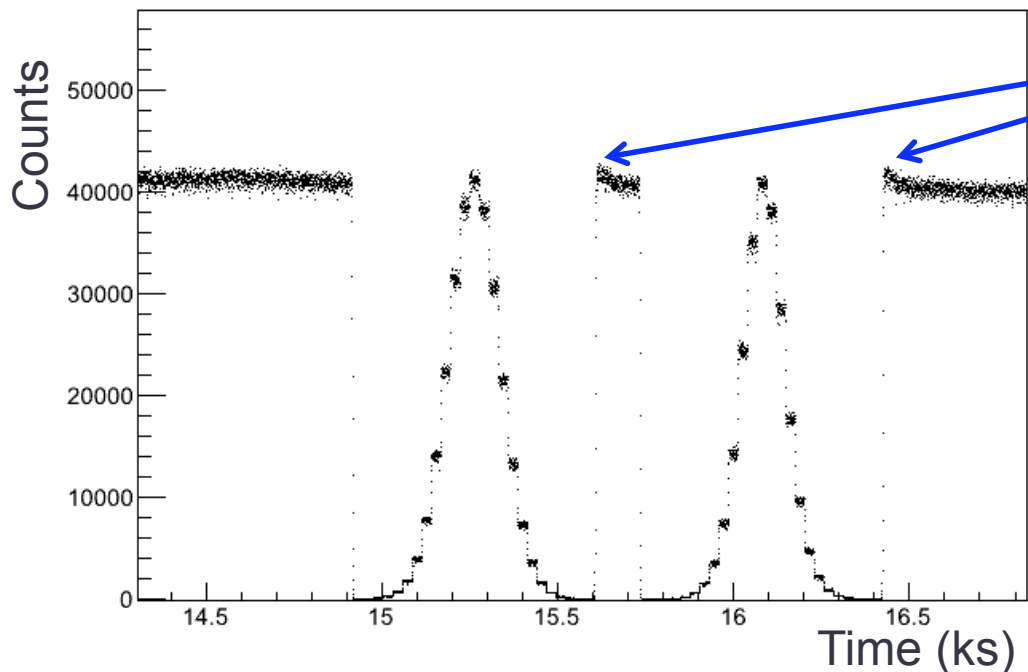




VdM Scan - Luminosity



- Beams are “scanned” across each other in X and in Y
- We measure the rate as a function of beam separation
 - For us this is “counts” in our “fastor” (3-fold coincidence) histograms



See detector effects

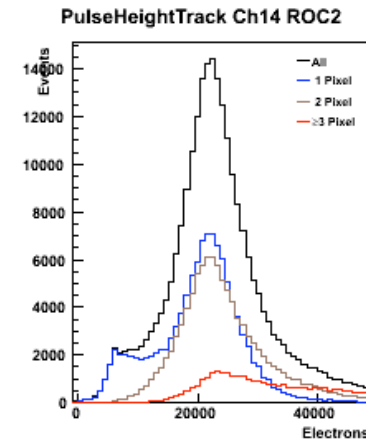
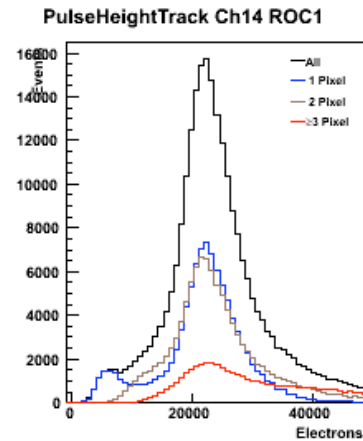
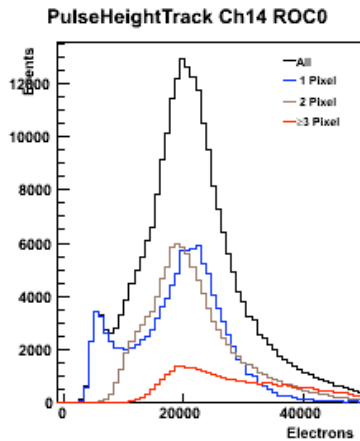
Fit of “counts” vs beam separation give us the luminosity calibration



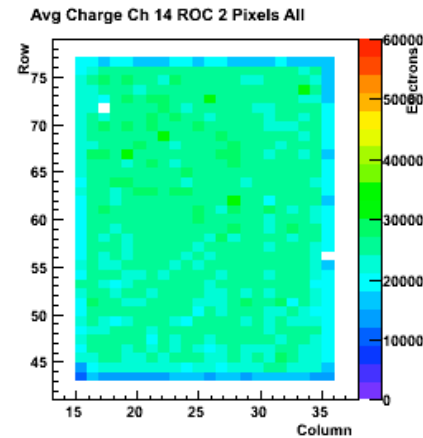
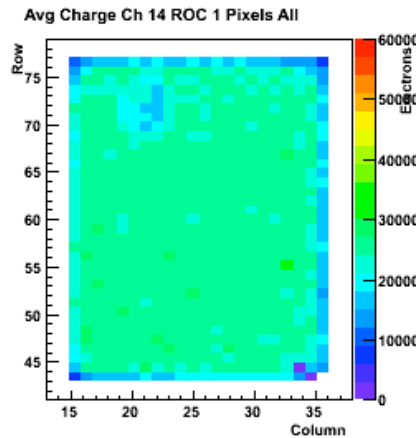
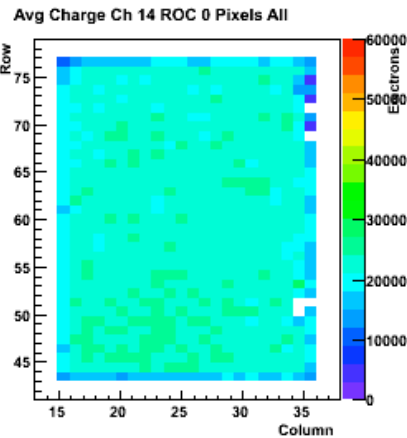
Early Pre-Collision Data

- Mostly beam halo
- Recorded rate is around 200 Hz

20120411.120353



Pulse Height:
 One pixel cl
 Two pixel cl
 ≥ 3 pixel cl



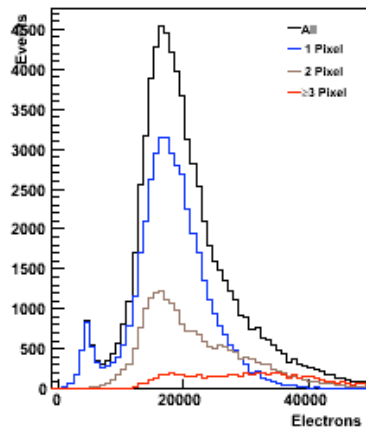
$< 0.1 \text{ fb}^{-1}$



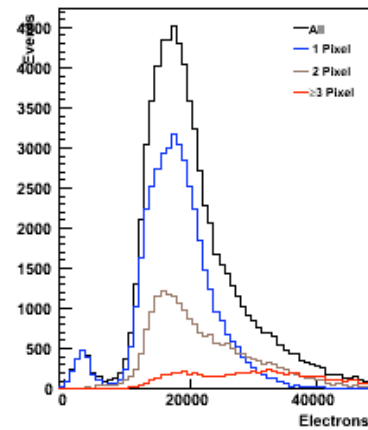
Early Low Luminosity Runs

Recorded rate is 4 kHz per telescope

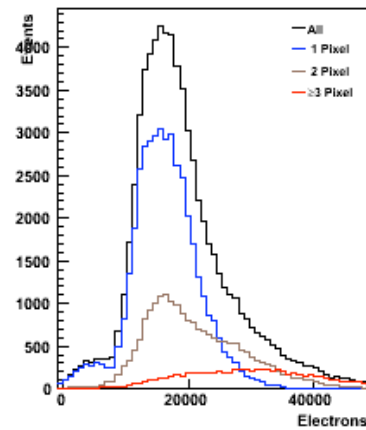
PulseHeightTrack Ch14 ROC0



PulseHeightTrack Ch14 ROC1



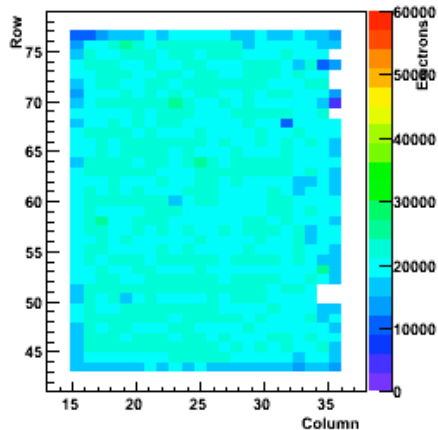
PulseHeightTrack Ch14 ROC2



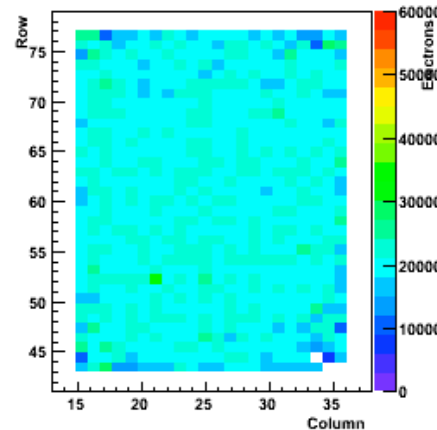
Pulse Height:
 One pixel cl
 Two pixel cl
 ≥ 3 pixel cl

20120330.133847

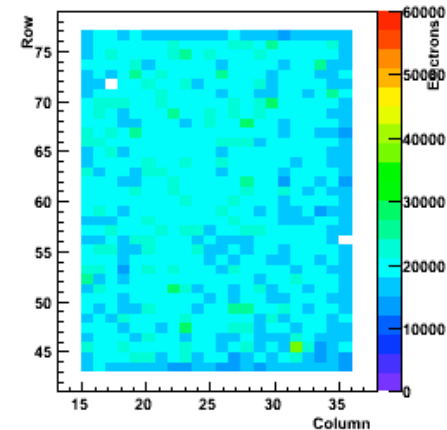
PixelCharge_Ch14_ROC0_All



PixelCharge_Ch14_ROC1_All



PixelCharge_Ch14_ROC2_All



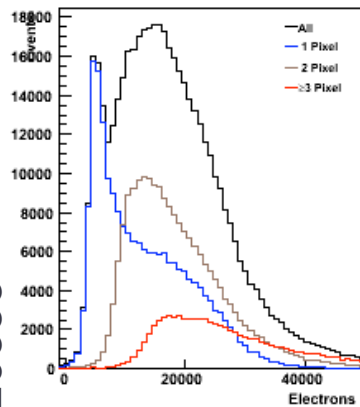
$< 0.1 \text{ fb}^{-1}$



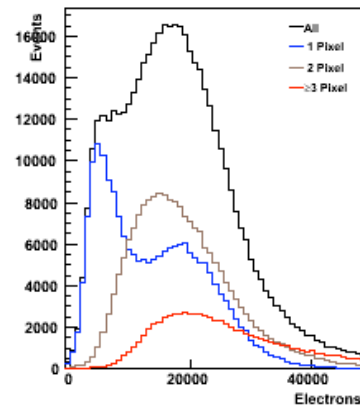
Early High Luminosity Runs

- Recorded rate is 7.5 MHz per telescope

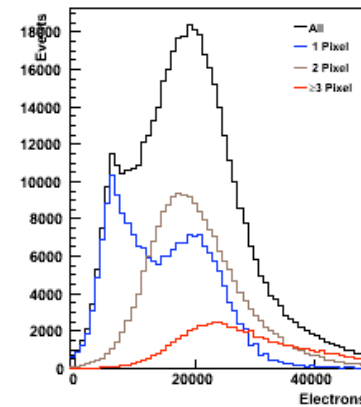
PulseHeightTrack Ch14 ROC0



PulseHeightTrack Ch14 ROC1



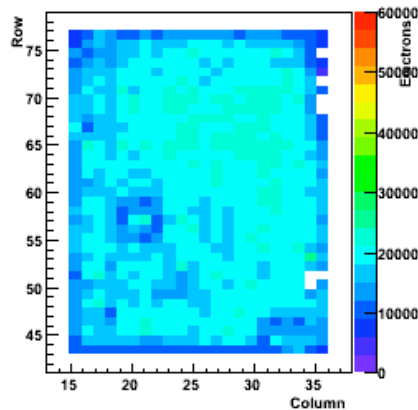
PulseHeightTrack Ch14 ROC2



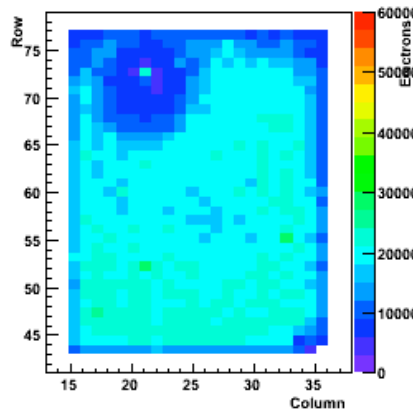
Pulse Height:
 One pixel cl
 Two pixel cl
 >= 3 pixel cl

20120411.120353

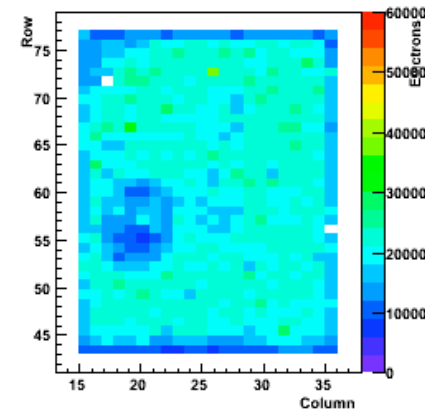
Avg Charge Ch 14 ROC 0 Pixels All



Avg Charge Ch 14 ROC 1 Pixels All



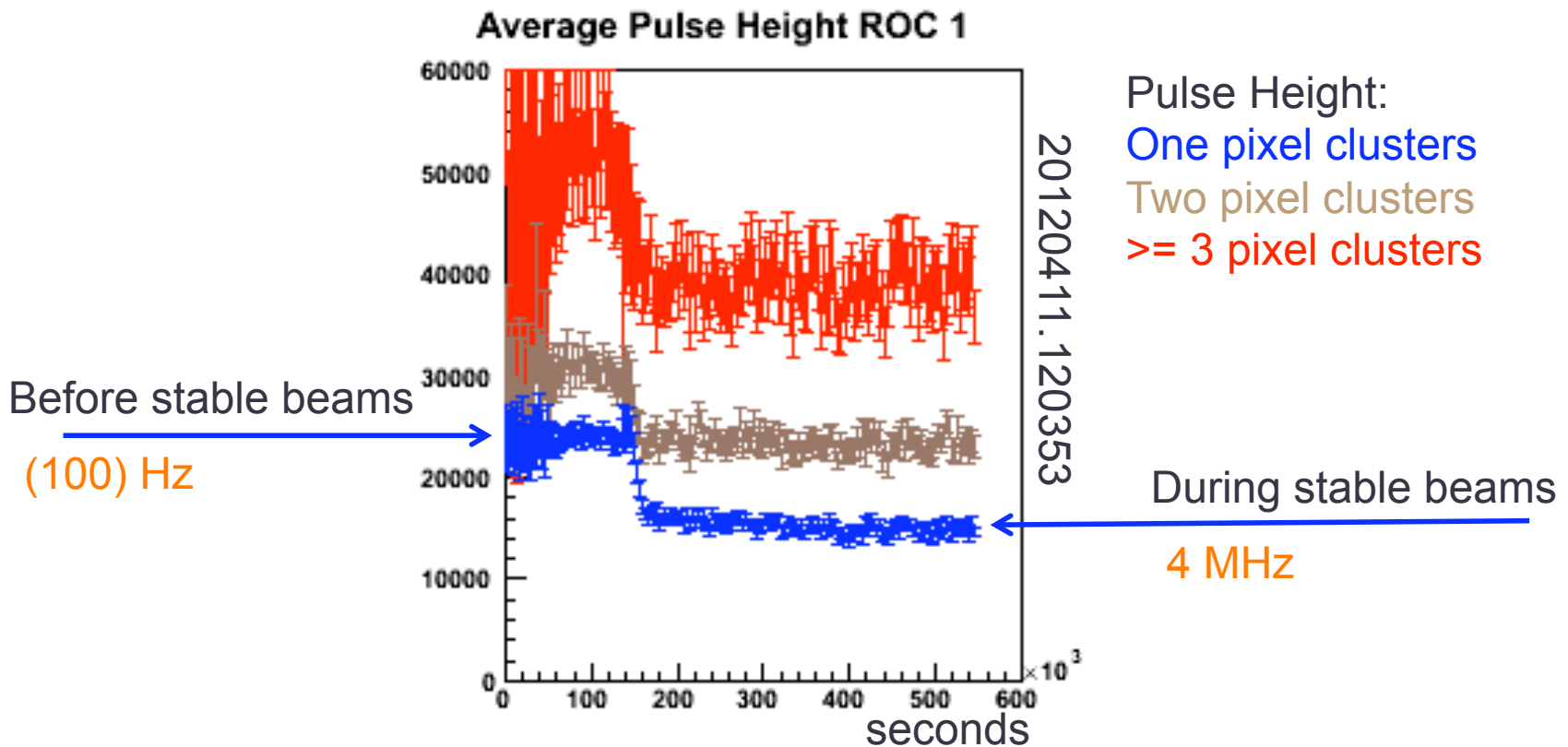
Avg Charge Ch 14 ROC 2 Pixels All



$< 0.1 \text{ fb}^{-1}$



Pulse Height Shift With Luminosity



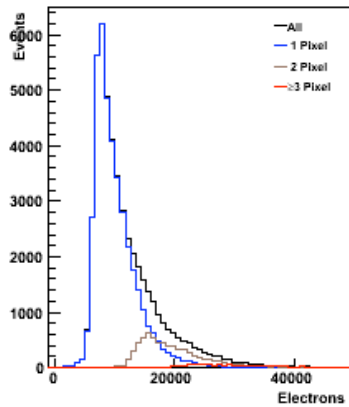


Pre-Collision Data 500V

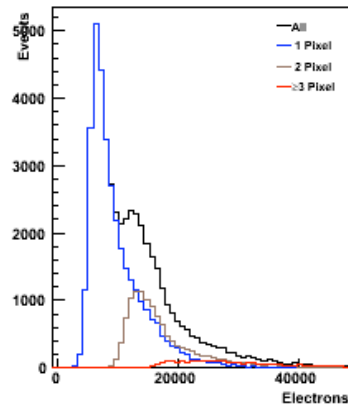
Recorded rate is 150 Hz per Telescope

20120720.041911

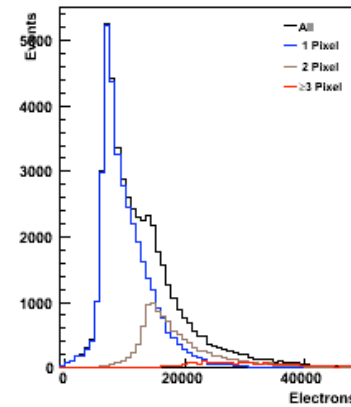
PulseHeightTrack Ch14 ROC0



PulseHeightTrack Ch14 ROC1

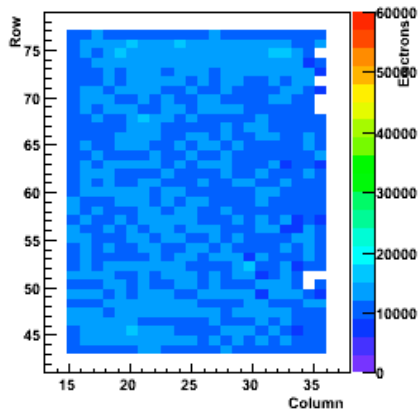


PulseHeightTrack Ch14 ROC2

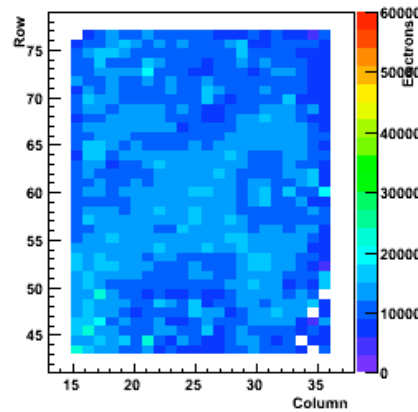


Pulse Height:
One pixel cl
Two pixel cl
>= 3 pixel cl

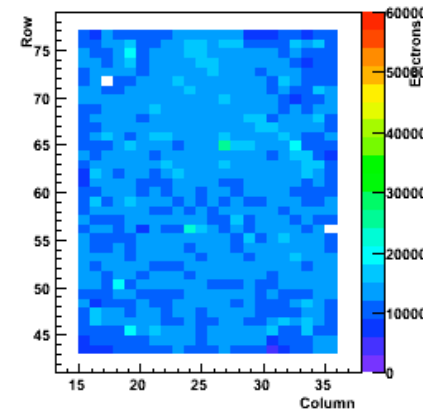
Avg Charge Ch 14 ROC 0 Pixels All



Avg Charge Ch 14 ROC 1 Pixels All



Avg Charge Ch 14 ROC 2 Pixels All



8.5 fb⁻¹

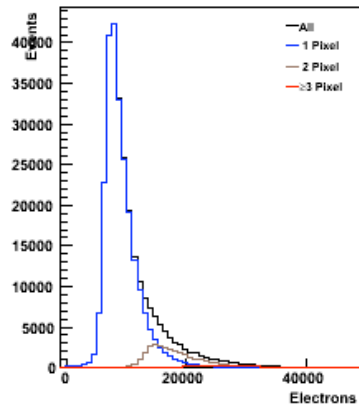


Low Luminosity at 500V

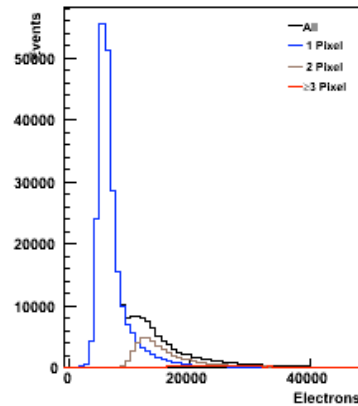
Recorded rate is 3 kHz per Telescope

20120719.184109

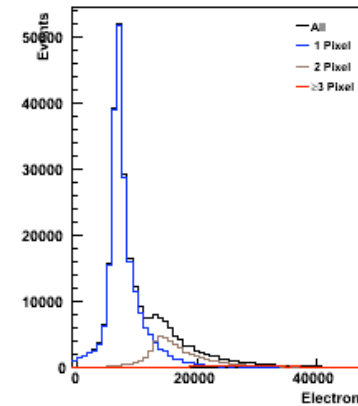
PulseHeightTrack Ch14 ROC0



PulseHeightTrack Ch14 ROC1

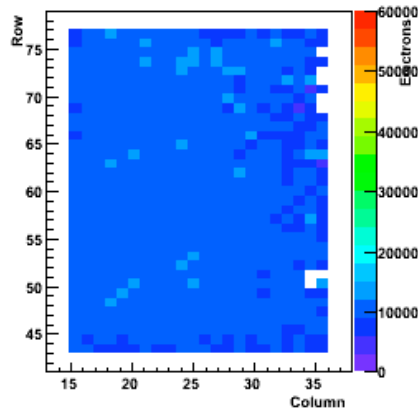


PulseHeightTrack Ch14 ROC2

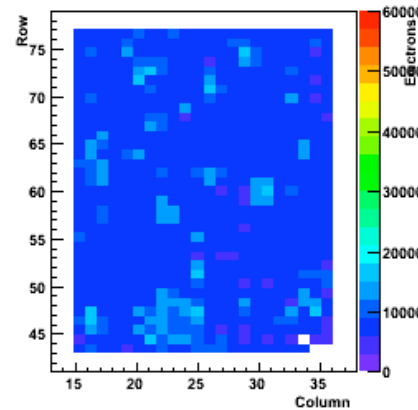


Pulse Height:
 One pixel cl
 Two pixel cl
 ≥ 3 pixel cl

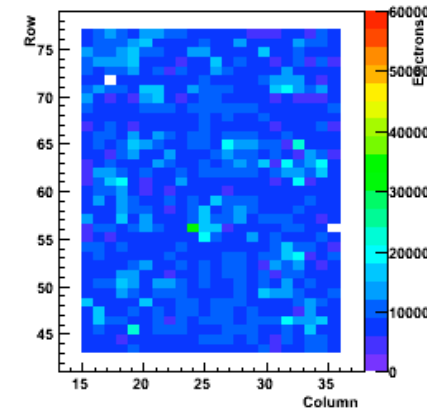
Avg Charge Ch 14 ROC 0 Pixels All



Avg Charge Ch 14 ROC 1 Pixels All



Avg Charge Ch 14 ROC 2 Pixels All



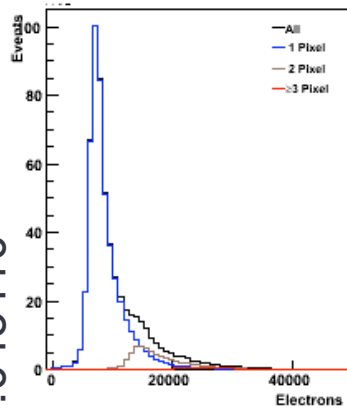
8.5 fb⁻¹



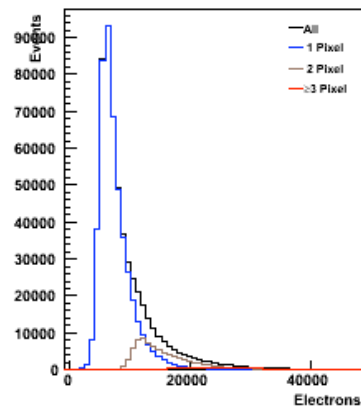
High Luminosity at 500V

Recorded rate is 10 MHz per Telescope

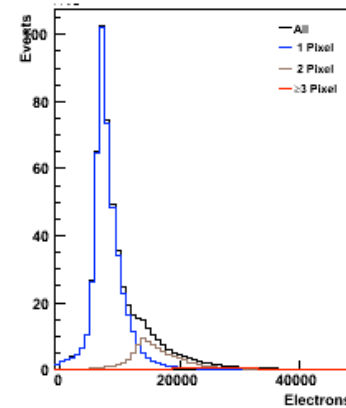
PulseHeightTrack Ch14 ROC0



PulseHeightTrack Ch14 ROC1



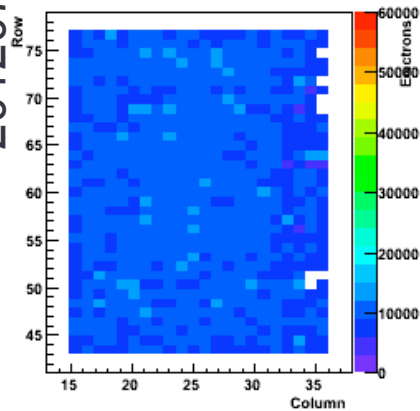
PulseHeightTrack Ch14 ROC2



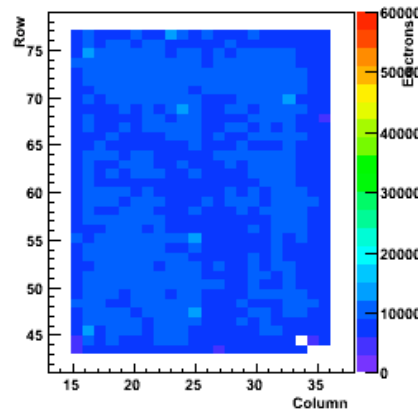
Pulse Height:
 One pixel cl
 Two pixel cl
 >= 3 pixel cl

20120720.045110

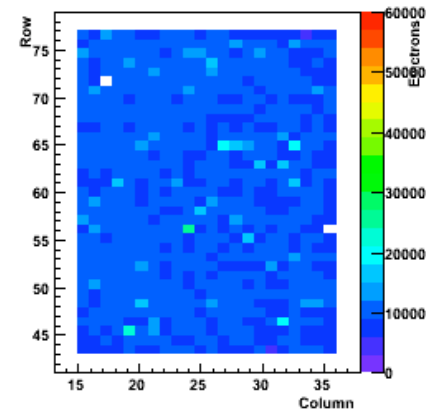
Avg Charge Ch 14 ROC 0 Pixels All



Avg Charge Ch 14 ROC 1 Pixels All



Avg Charge Ch 14 ROC 2 Pixels All



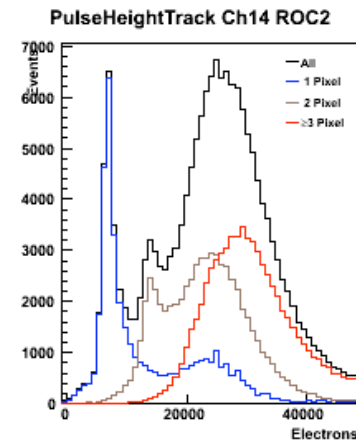
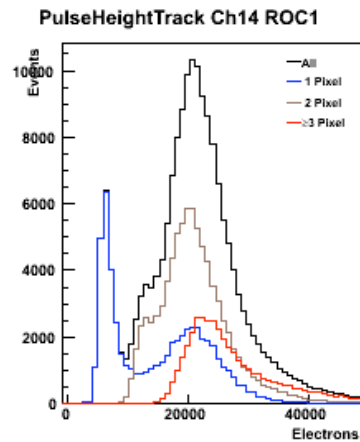
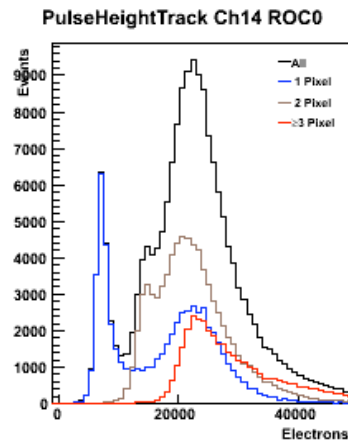
8.5 fb⁻¹



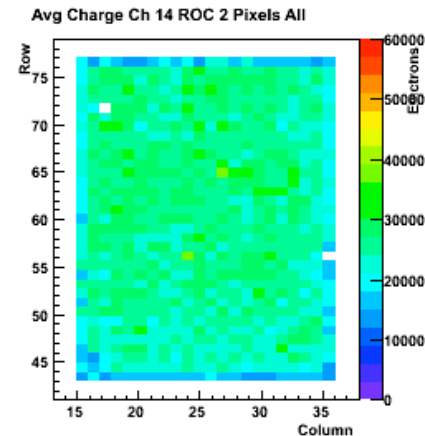
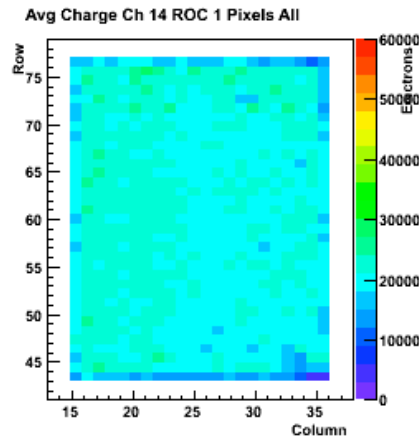
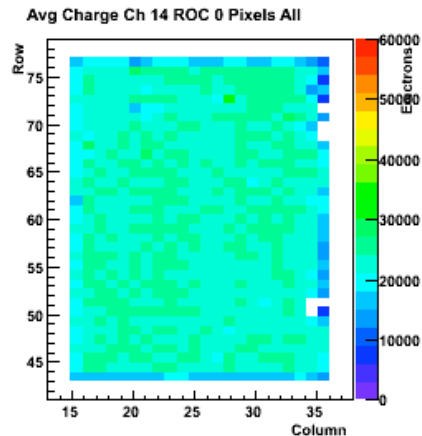
Pre-Collision Data 1100V

Recorded rate is 200 Hz per Telescope

20120617.181245



Pulse Height:
 One pixel cl
 Two pixel cl
 ≥ 3 pixel cl

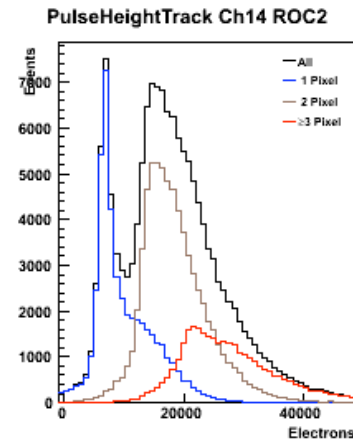
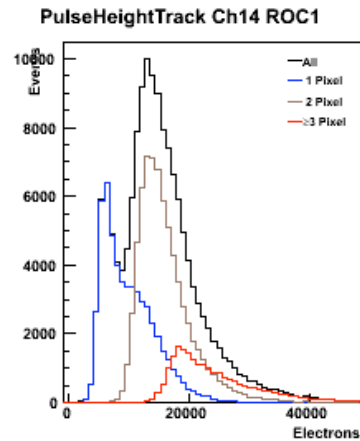
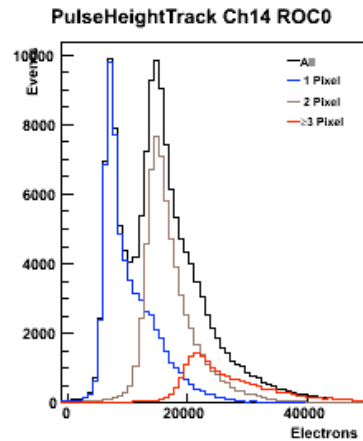


7 fb⁻¹

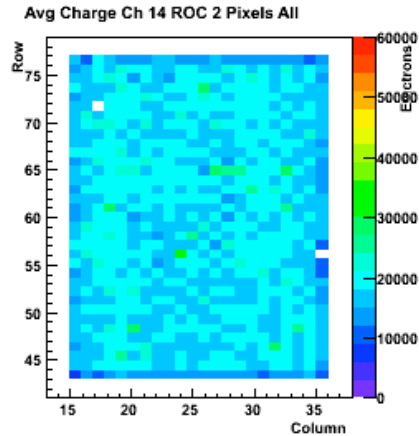
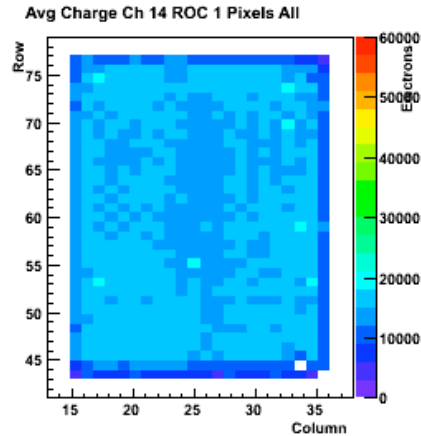
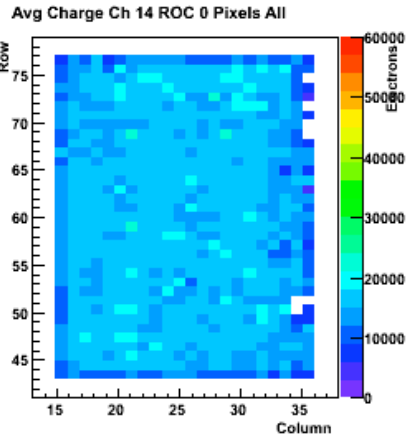


High Luminosity at 1100V

Recorded rate is 10 MHz per Telescope



Pulse Height:
 One pixel cl
 Two pixel cl
 ≥ 3 pixel cl



20120617.193001

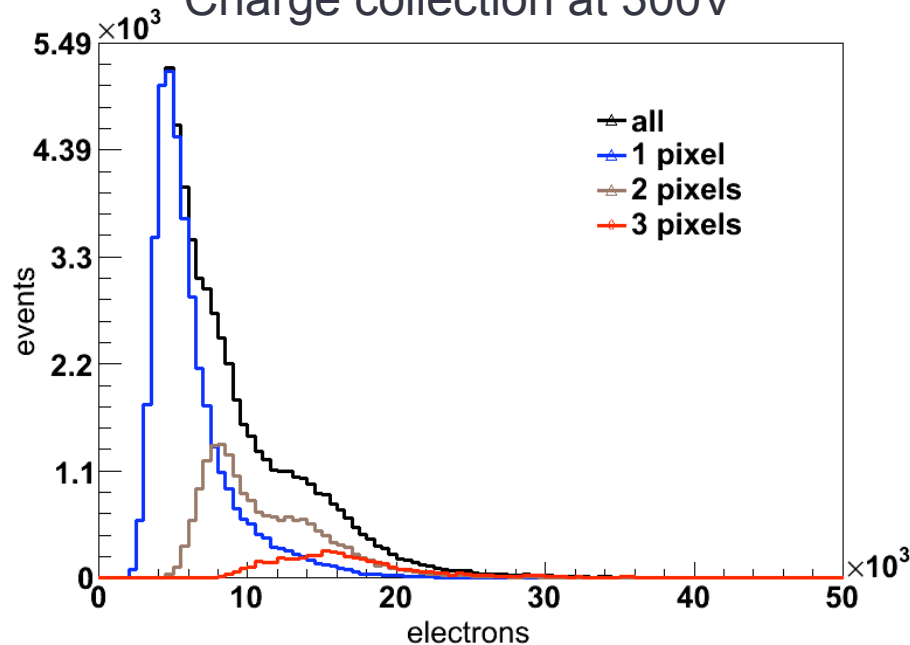
7 fb⁻¹



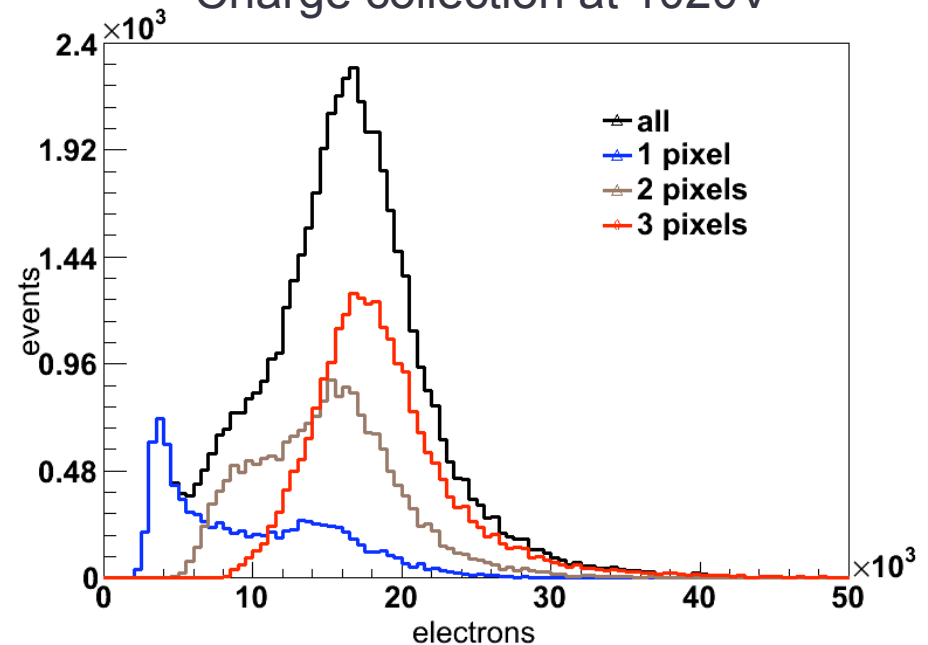
Testing Removed Planes

- We removed 3 planes from Castor after $\sim 7 \text{ fb}^{-1}$
- **Higher voltage dramatically increases charge collection**
 - Both in pilot installation and on test stand with removed planes
- Consistent with what we see (and continue to see) in pilot installation

Charge collection at 300V



Charge collection at 1020V

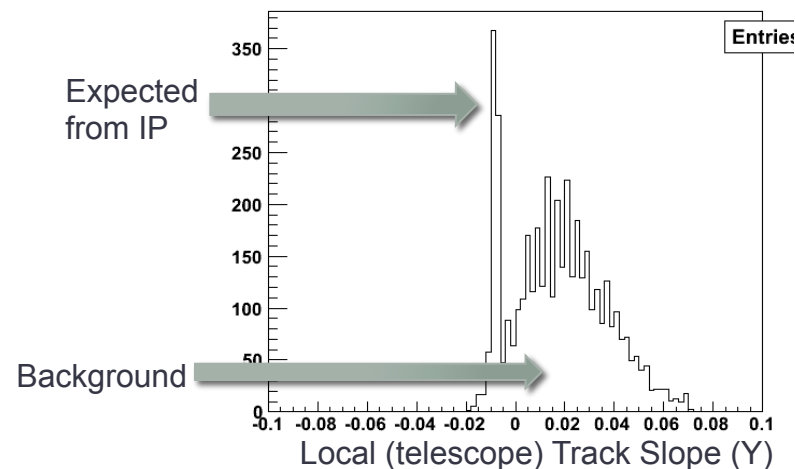
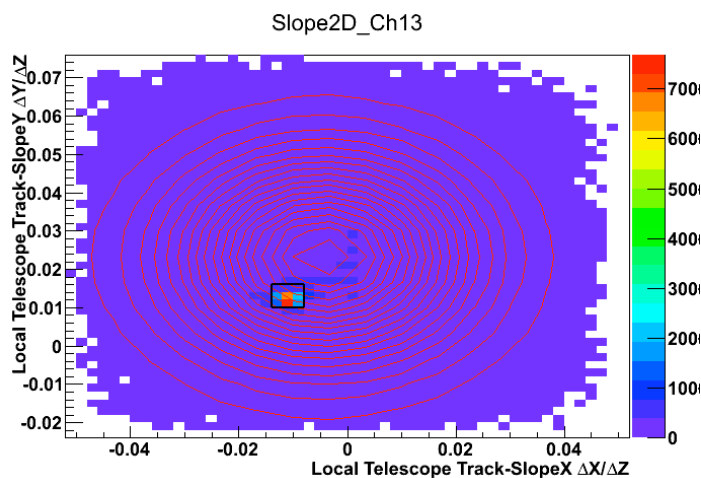


7 fb^{-1}

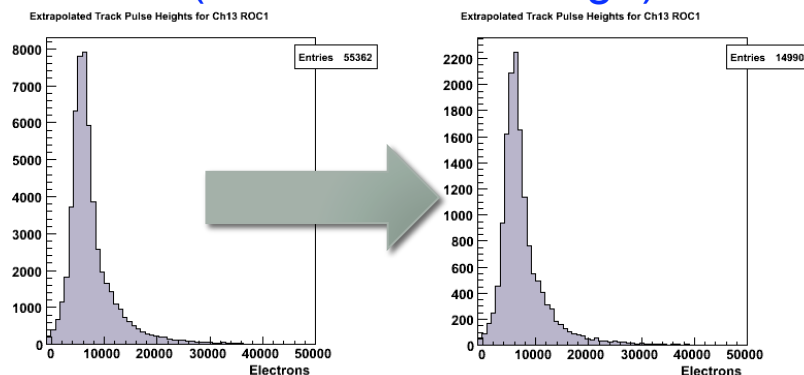


Efficiencies

- Studying the efficiencies in all of the previous cases
 - Make quantitative comparisons
- Need to account for large backgrounds



Cutting on track slope
(PH does not change)



- Fit the background in 2D outside the signal region
 - Estimate background in signal region and subtract



Future Plans

- Study 3 diamonds removed from pilot installation after 7fb^{-1} of LHC collisions
- CERN PS testbeam in October
 - Unirradiated diamonds
 - pilot run (castor) diamonds
 - neutron (Oak Ridge) irradiated diamonds
 - proton (Los Alamos) irradiated diamonds
- Test varying high voltage
- Would like to perform high rate-high intensity tests (up to 100 MHz)
- Study dependence on high voltage
- Long term: Full installation in long shutdown 1 (LS1)
 - Late 2013



Summary

- Successfully built a full detector system
- Promising results from testbeams
- Installation of PLT for pilot run in CMS
- Are continuing to monitor and investigate the degradation in charge collection
- Looking forward to a full installation in the long shutdown

Thank you!

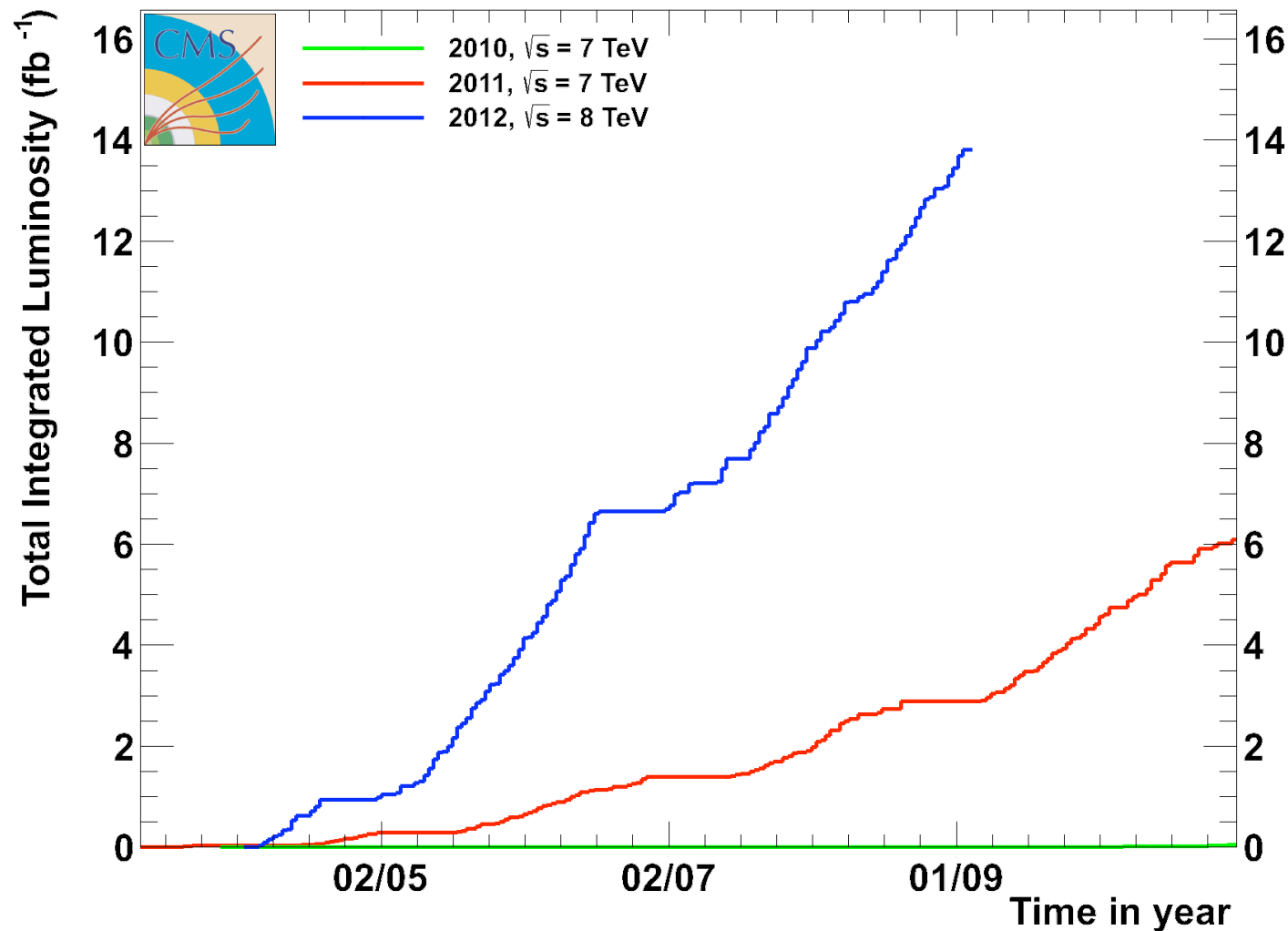


Backup



LHC Luminosity

CMS Total Integrated Luminosity, p-p

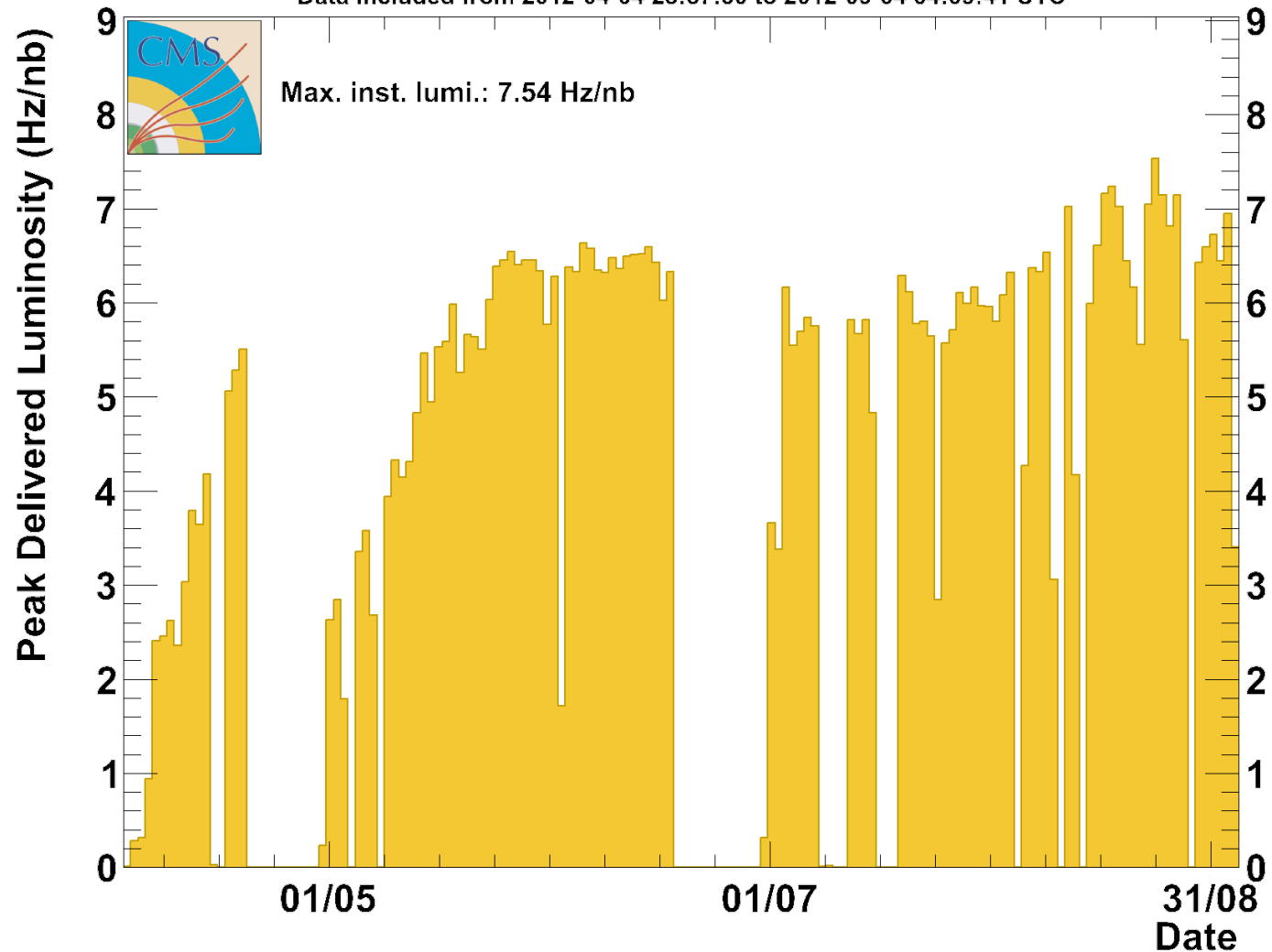




LHC Max Luminosity by Day

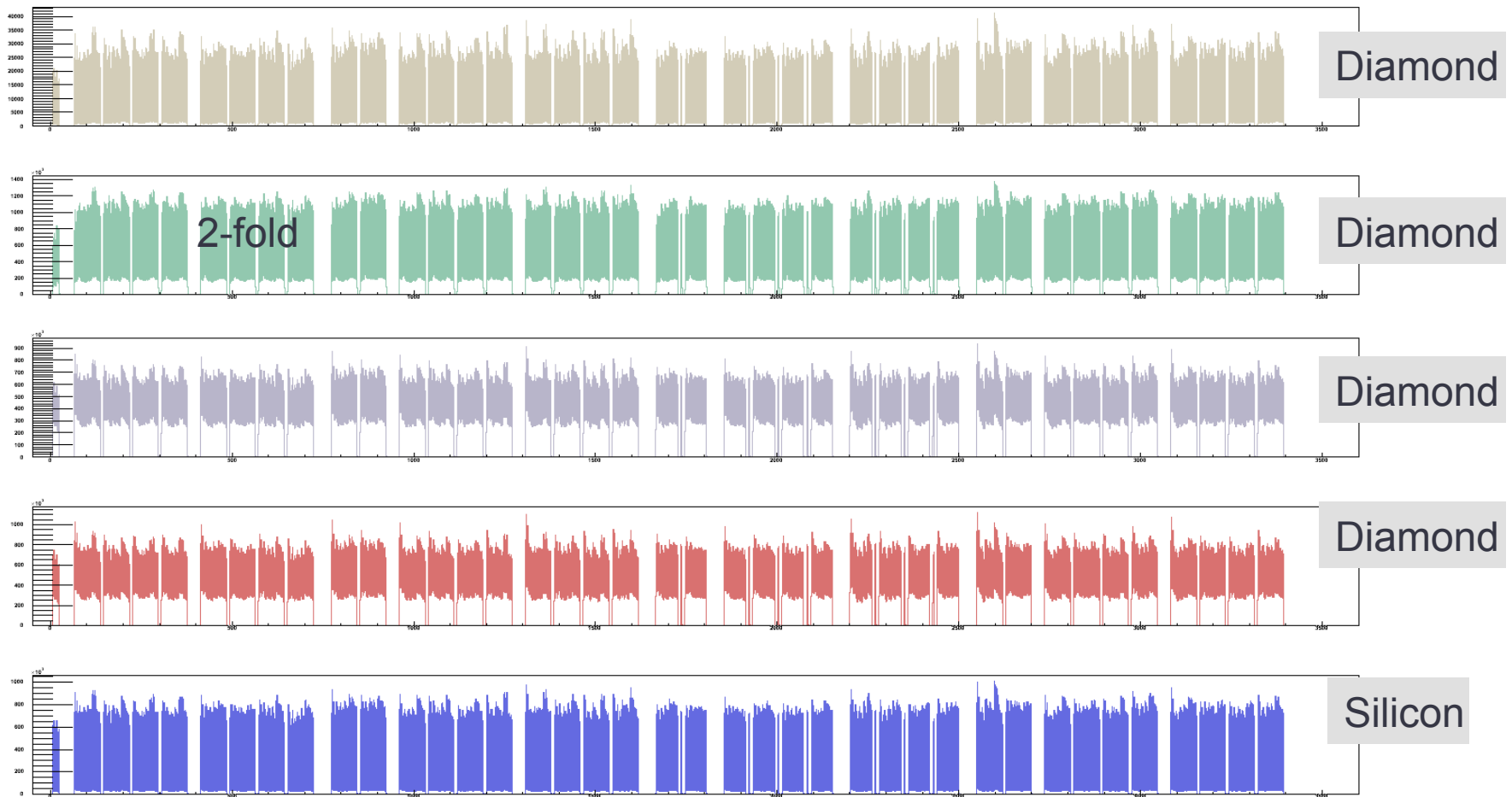
CMS Peak Luminosity Per Day, 2012, p-p, $\sqrt{s} = 8$ TeV

Data included from 2012-04-04 23:57:30 to 2012-09-04 04:09:41 UTC





Full Luminosity





Reference

- The CMS Pixel Chip
 - Allseandro Gaz (Pixel 2012): *CMS Pixel Status*
<https://indico.cern.ch/contributionDisplay.py?sessionId=2&contribId=67&confId=137337>