Current Status of the Fast Beam Condition Monitor Upgrade at CMS

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ADAMAS Workshop

Beam Condition Monitor

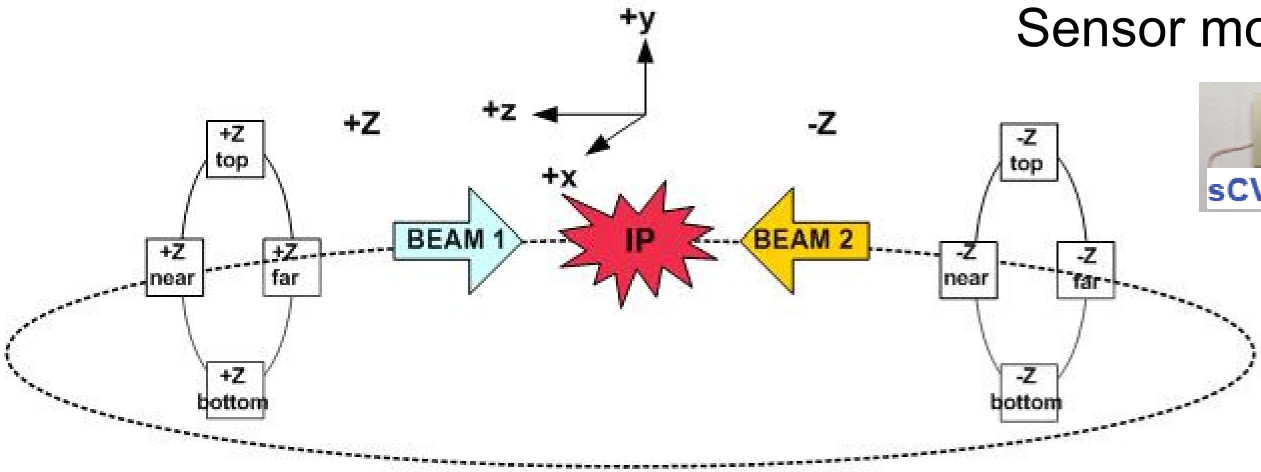
Context

- LHC running at unprecedented beam energies and intensities
- Even small beam losses may cause damage to CMS detector components

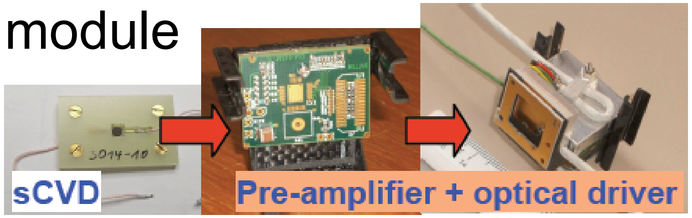
Purpose of Beam Condition Monitor

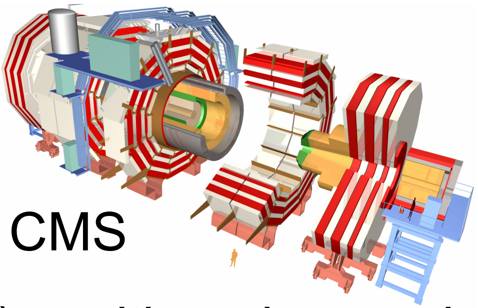
- Monitor particle fluxes near the beam pipe
- Ensure sufficiently low inner detector occupancy for data-taking
- Detect beam loss conditions
- Initiate reactions when necessary (beam abort)

Fast Beam Condition Monitor BCM1F (up to 2012)



Sensor module





8 5mm x 5mm single-crystal CVD diamonds (Element 6) positioned around the beam-pipe, radial distance 4.5 cm, 1.8 m from interaction point

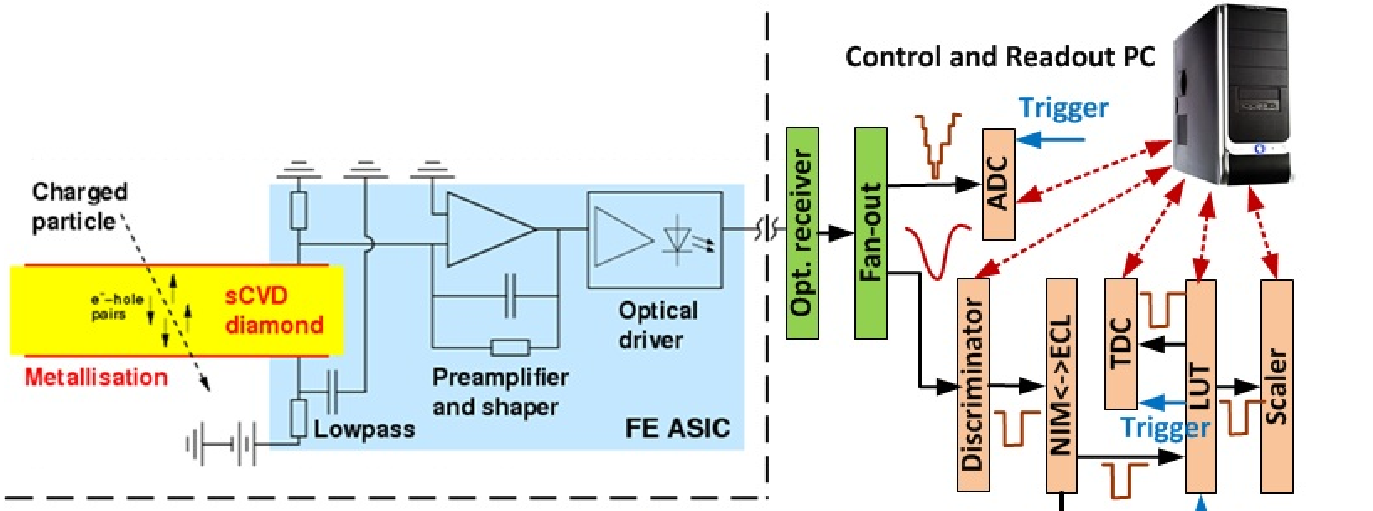
- Diamond → no cooling, robust, radiation-hard
- Sensor module: diamond, radiation-hard preamplifier, optical driver

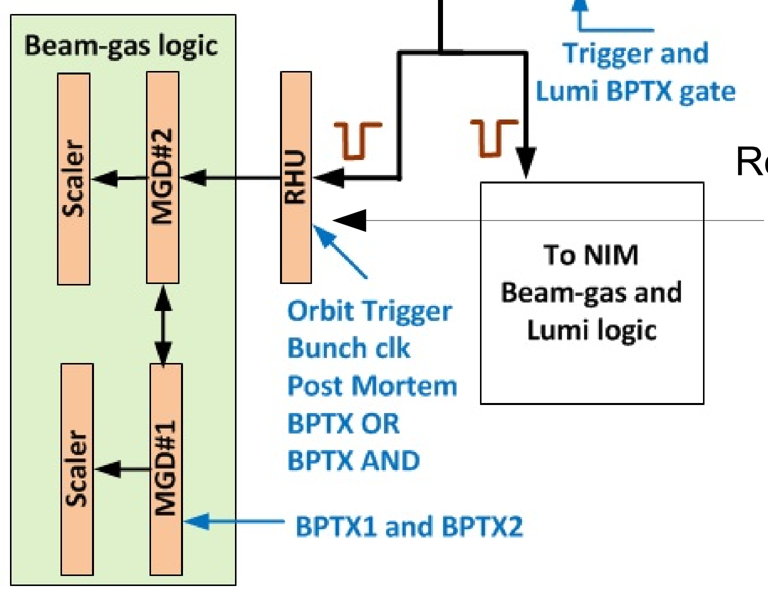
Bunch-by-bunch information on flux of beam halo and collision products

- Monitor condition of beam: ensure low radiation for silicon tracker
- Calculate luminosity

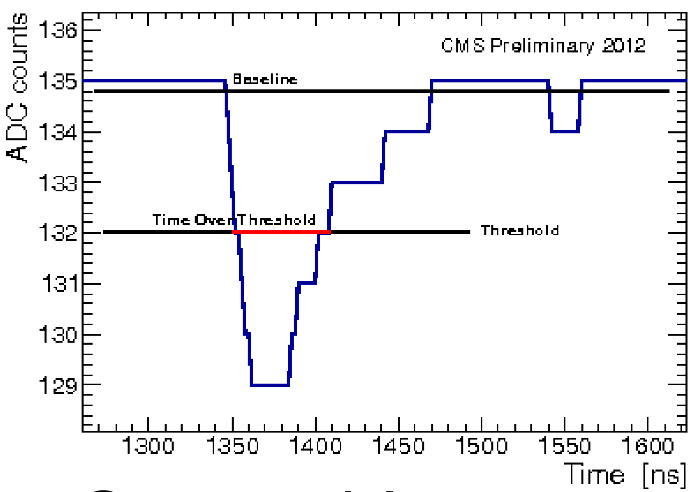
Readout independent of CMS DAQ

BCM1F Electronics



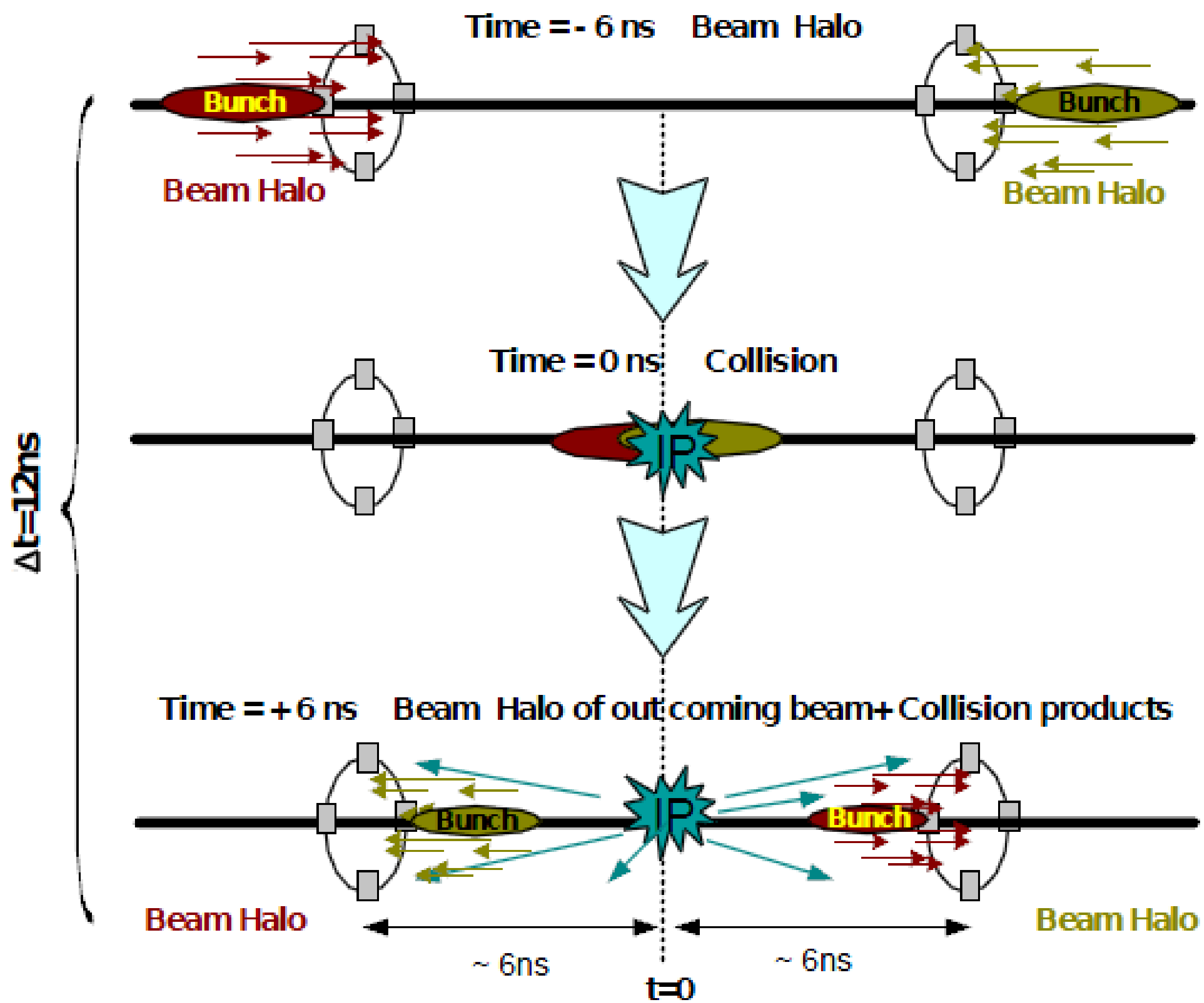


Readout
Histogramming
Unit (slide 13)



Output: hit rates

Beam Arrival Times



Small geometric acceptance: only “see” small fraction of bunches

BCM1F Upgrade

Implications of LHC upgrade for BCM1F

- Radiation: Luminosity 10^{34} cm^{-2}s^{-1} $\rightarrow$ BCM1F charged particle flux ~3×10^{7} cm^{-2}s^{-1}
- 25 ns bunch spacing
- High hit rate

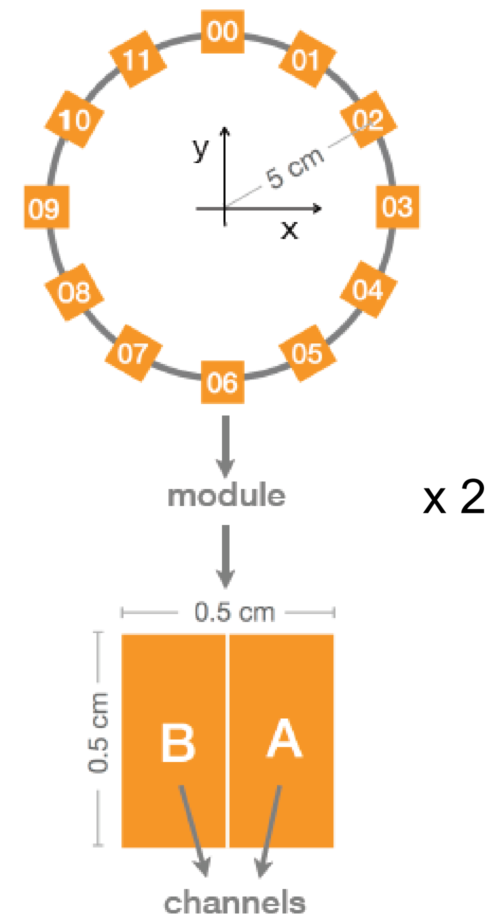
24 diamonds x 2 metallization pads per diamond = 48 channels for higher dynamic range

Minimize and deal with radiation damage

Scale up full system from 8 channels

Faster electronics

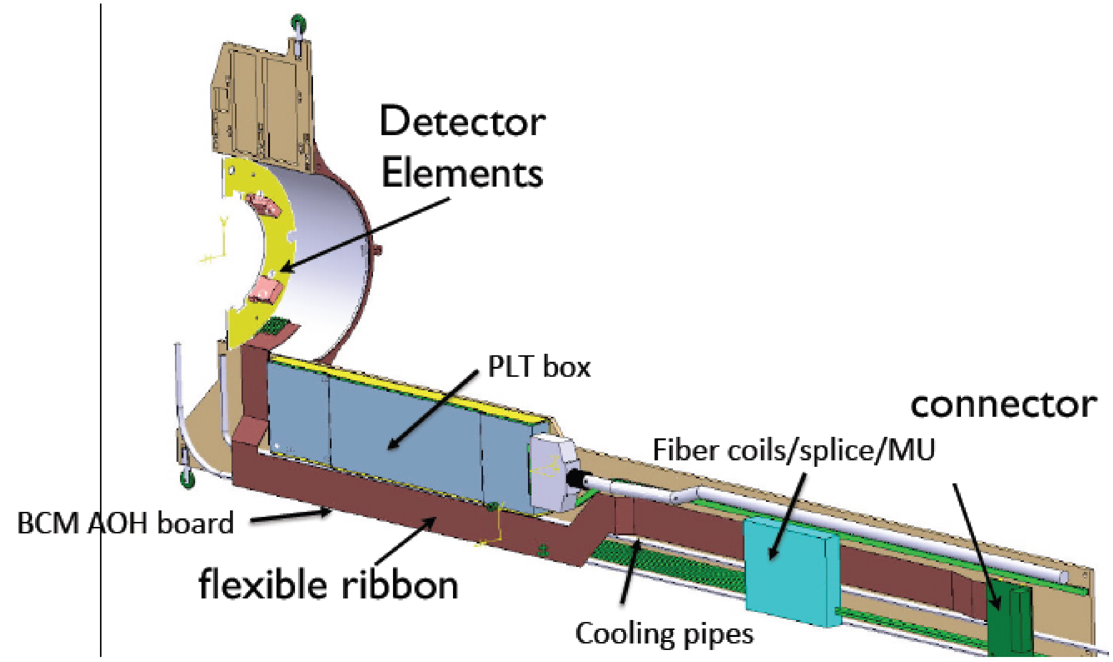
Integrate readout with other luminosity subsystems



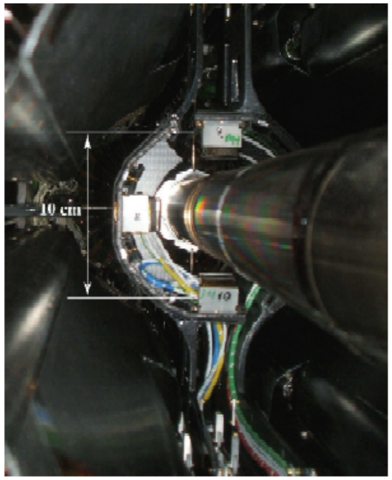
Upgrade sensor layout

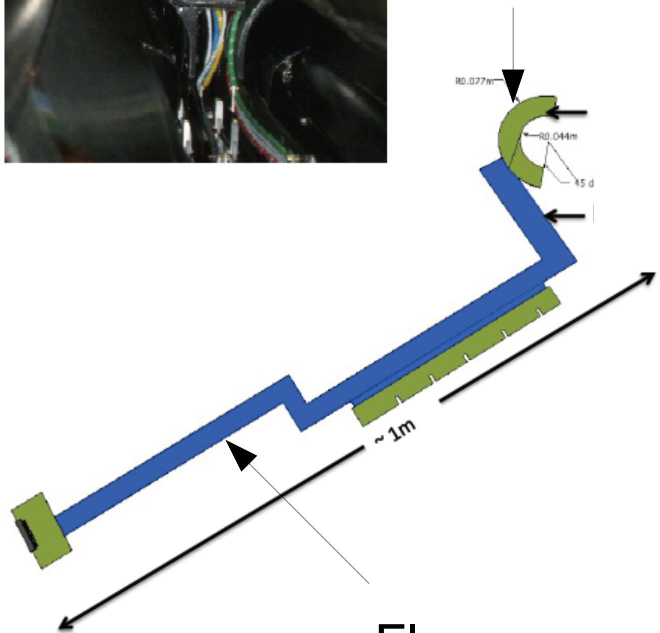
Upgrade Carriage Design

One piece semi-rigid PCB



Old carriage

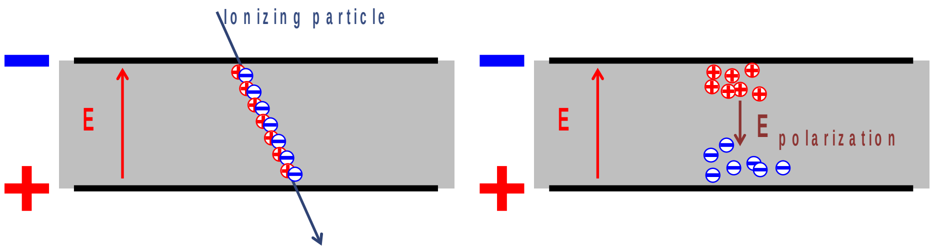




BCM1F Diamonds for Upgrade

Significant issue in Run I: radiation damage

- Effect: diamond polarization decreases efficiency

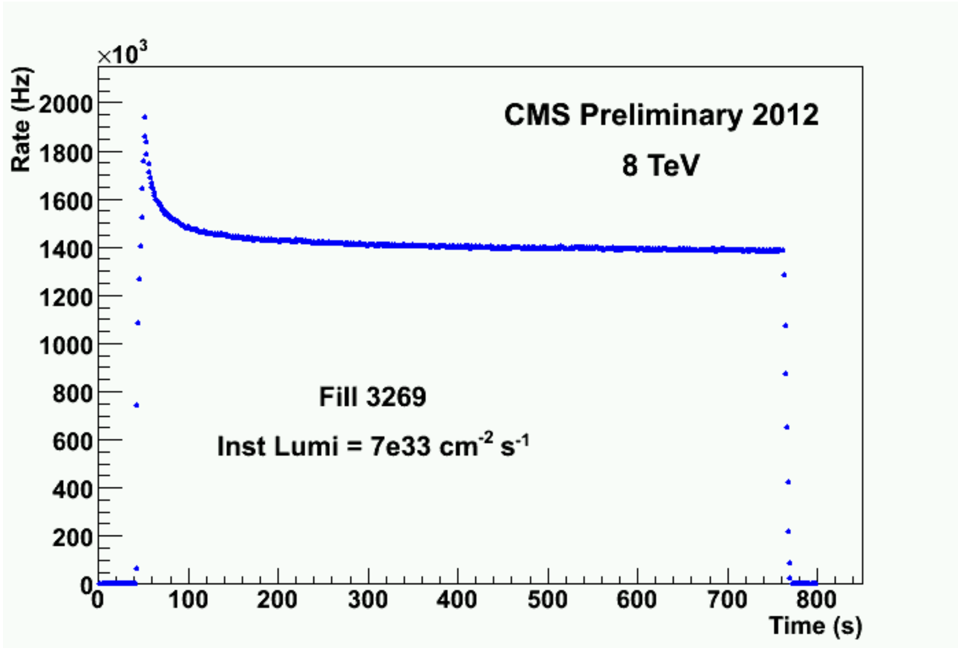


Primary line of defense: higher HV

Other possibilities

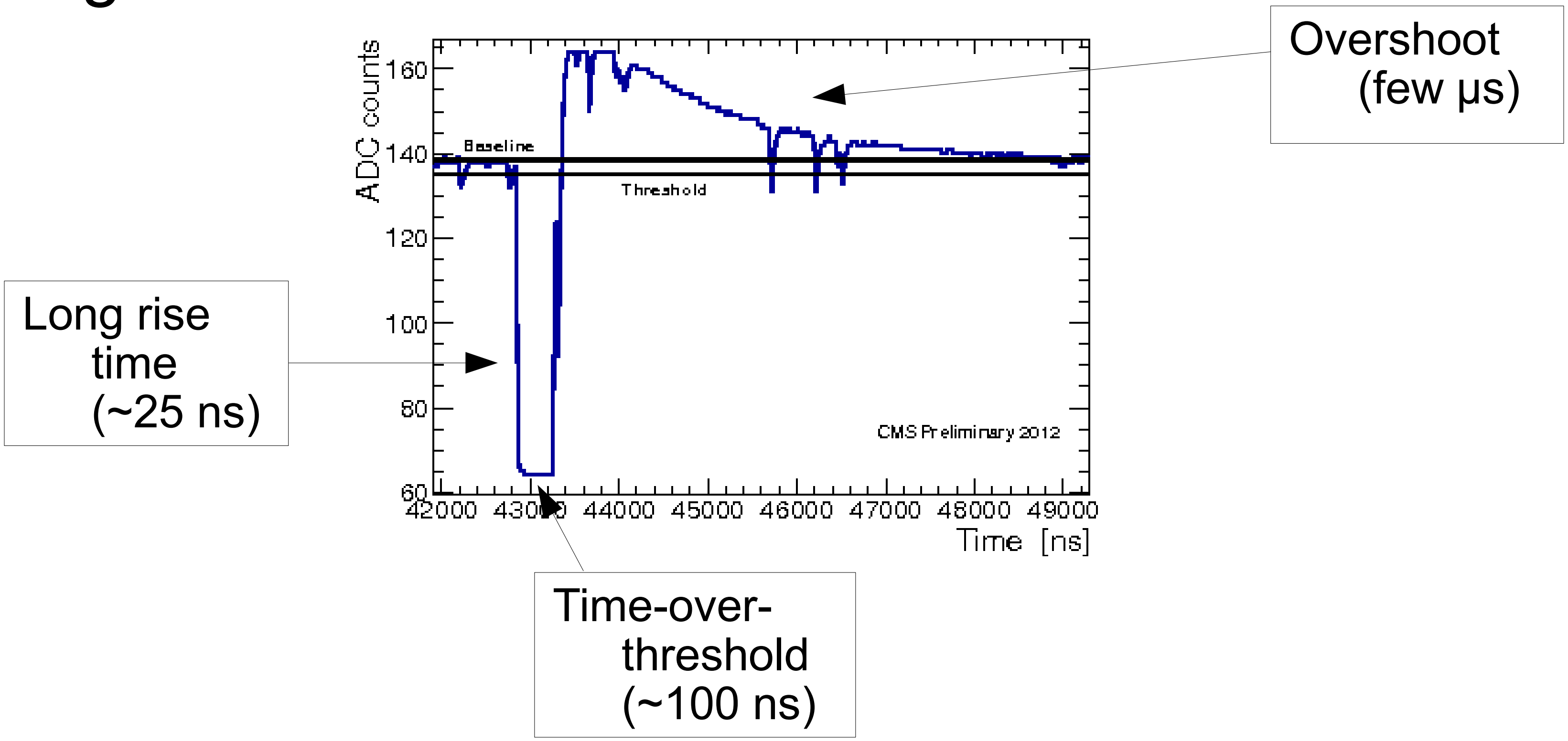
- Red light illumination
- Alternating voltage polarity

Old and new diamonds recently characterized with split metallization (talk from Maria Hempel)



Improving Front End Electronics

Several sources of inefficiency in front-end electronics, especially for (rare) high-amplitude signals



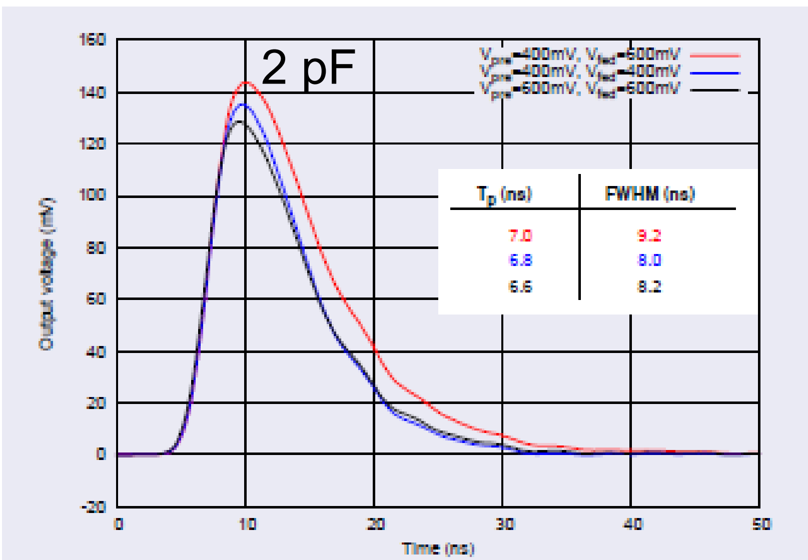
New Fast Front End ASIC

Developed by AGH - Krakow

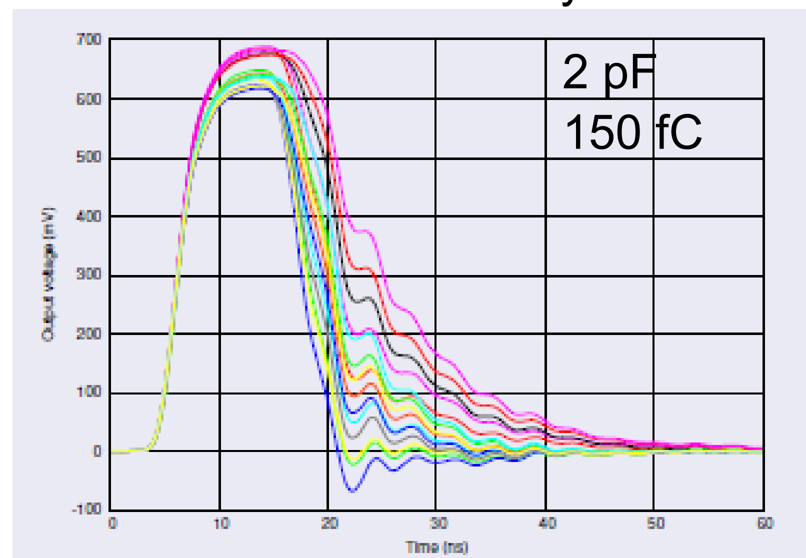
IBM CMOS8RF 130nm technology

~50 mV/fC charge gain, < 1ke- ENC

D. Przyborowski



T_p (ns)	FWHM (ns)
7.0	9.2
6.8	8.0
6.6	8.2



Rise time ~ 7 ns

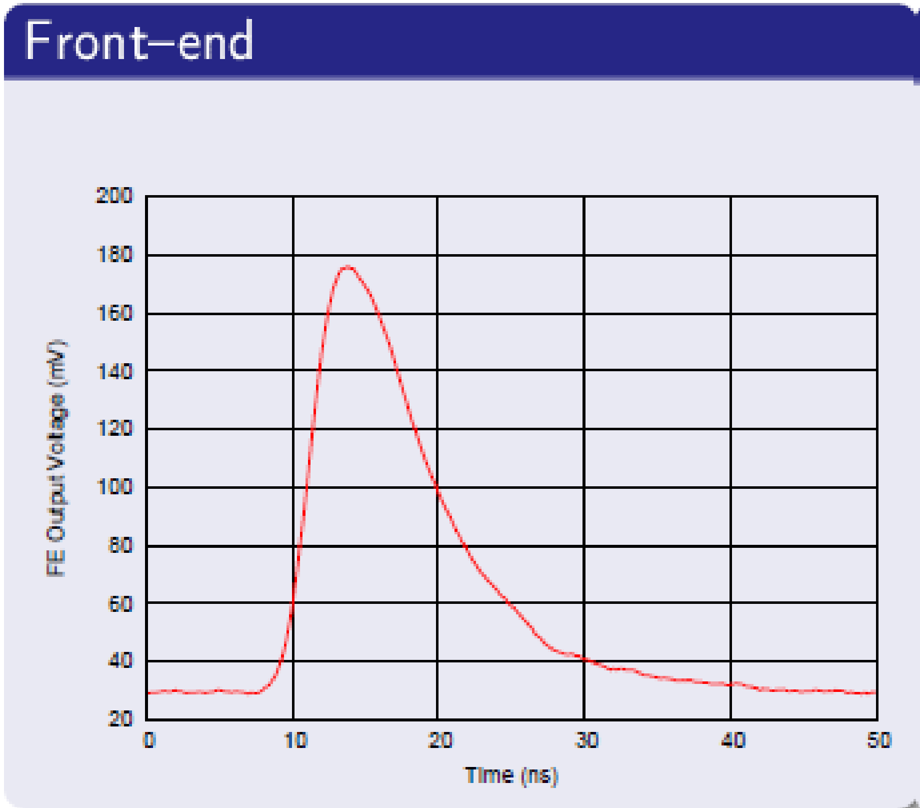
Time-over-threshold < ~30 ns

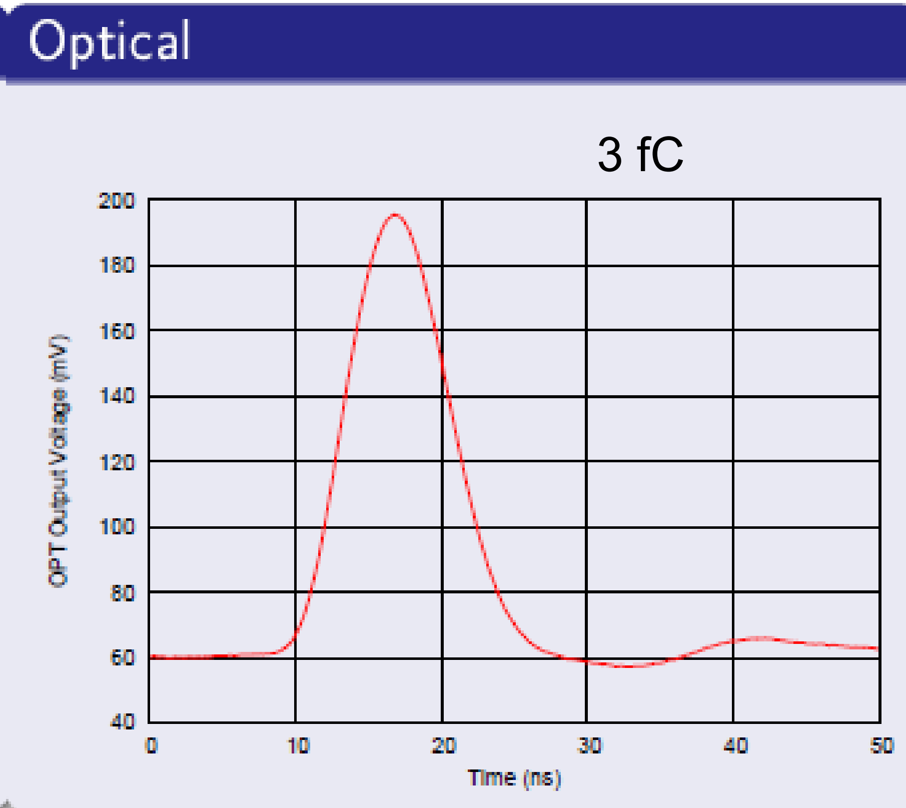
Overshoot time very small

Large improvement in behavior: addresses previous problems

Fast ASIC with Full Chain

Read out test pulses to ASIC with optical transmission board

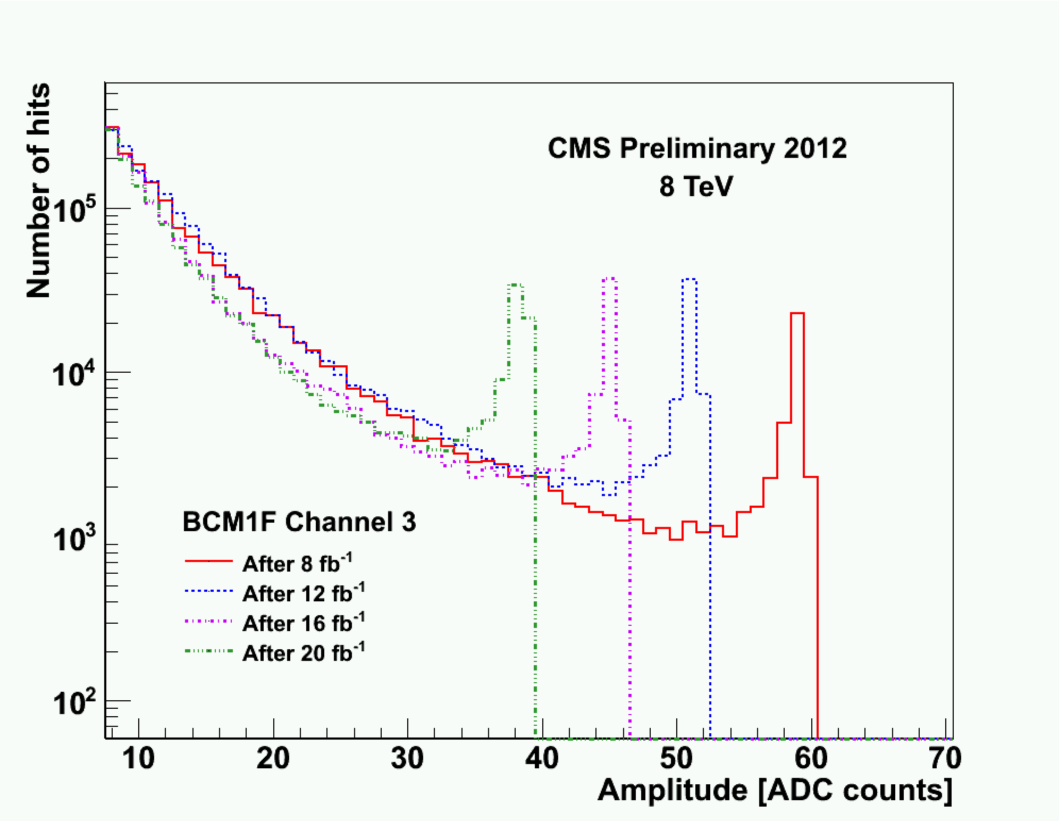




Improving Optical Chain

Radiation damage of laser driver visible in decreasing signal amplitude

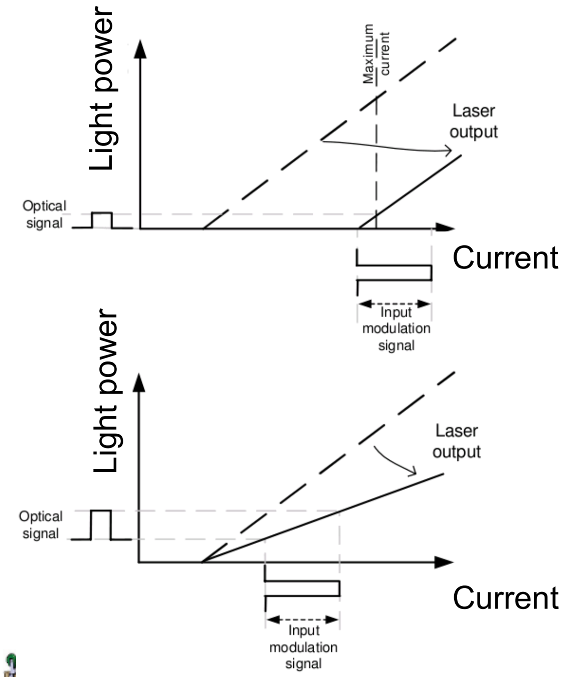
- 25% gain lost in BCM1F optical transmission after 30 fb^{-1}, fluence 8.78×10^{13} cm^{-2} (24 GeV protons)

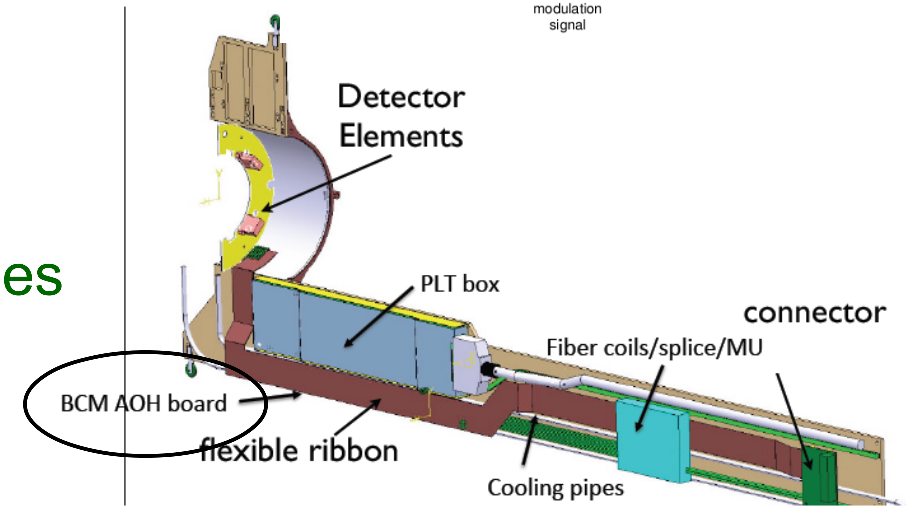


Improving Optical Chain

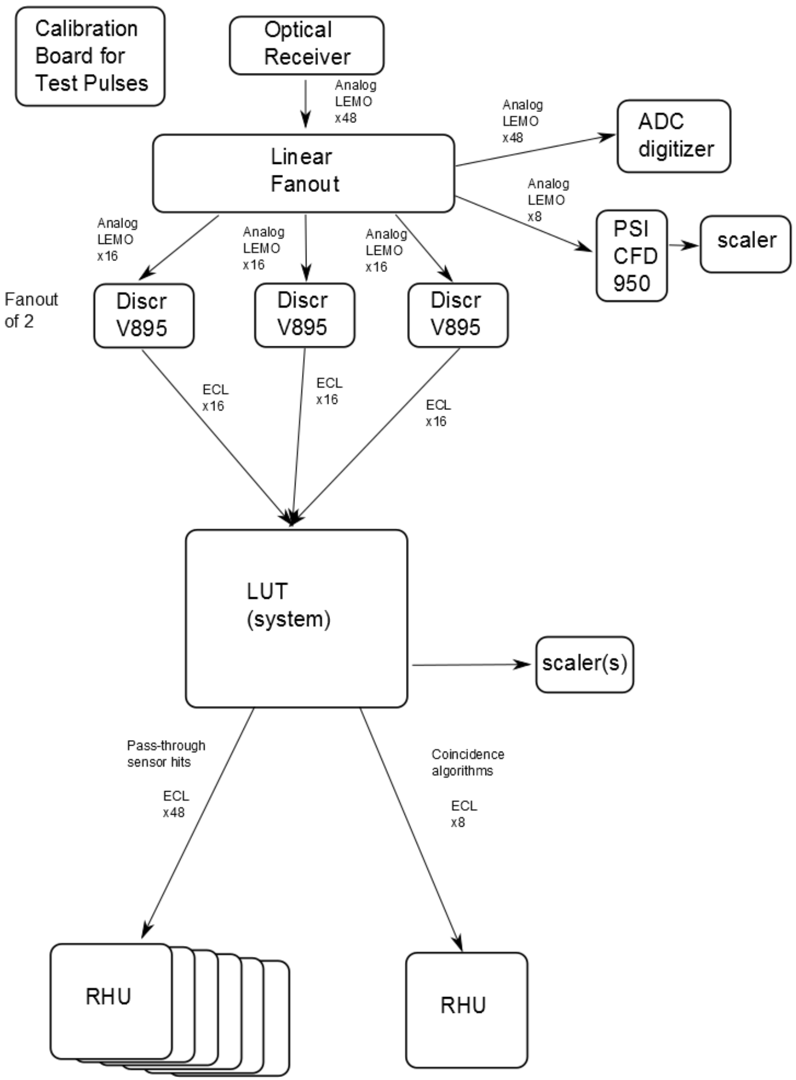
Improvements

- Multi-amplitude test pulse to monitor linearity of response
- Laser diodes on carriage arm (lower radiation)
- Temperature sensor to account for optical response to temperature
  - Bragg grating: wavelength of transmitted light sensitive to temperature changes
- Temperature stabilization (other subsystems)





Backend Concept for Upgrade



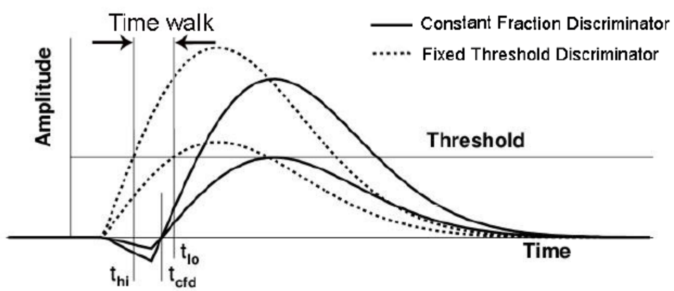
- Use "tried and true" discriminator path for initial running while commissioning digitizer path
- LUT: create coincidences between all 48 channels
- RHU for readout (later slide)

Upgrading Back End Electronics

Two parallel tracks:

<u>Discriminator path</u>

Fixed-threshold vs. constant-fraction

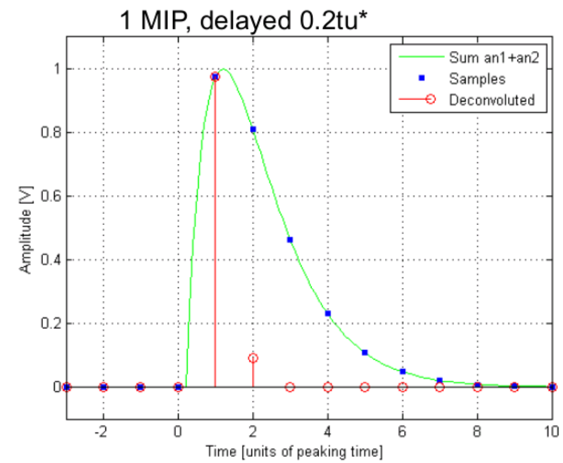


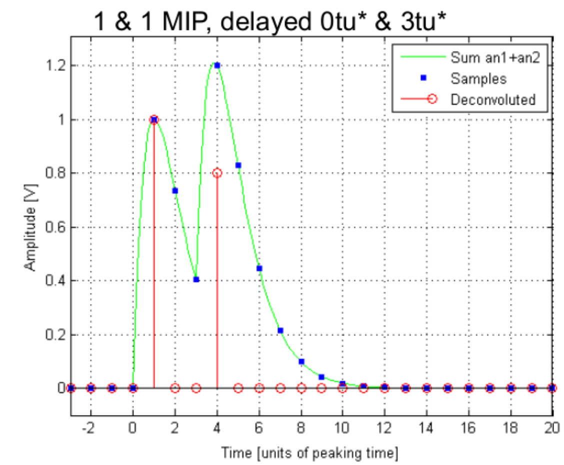
Constant-fraction: better time resolution

Fixed-threshold: lower deadtime

Preliminary conclusion: deadtime outweighs resolution -> use FTD (CAEN V895) for primary path but install CFD to run and test in parallel

<u>Digitizer with fast peak-finding algorithms</u>





*tu – time units

Identify pulse arrival time and peak height, distinguish signals close in time (overlapping)

Development of algorithms ongoing

Current hardware choice: uTCA ADC FMC mezzanine system. Multiple FMC candidates, to be tested

Upgrading Data Acquisition: RHU

Recording Histogram Unit (RHU): Readout of full-orbit histograms

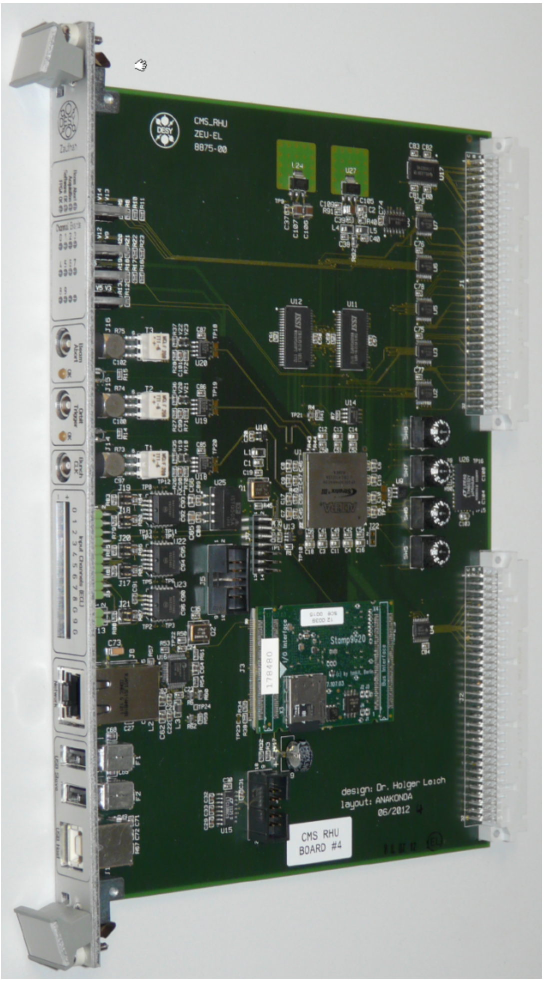
- No deadtime
- 8 histogramming input channels
- Bins of 6.25 ns = 4/bunch bucket (14k bins/orbit)
- Bunch clock, orbit clock, beam abort
- Configurable sampling period
- Ethernet readout

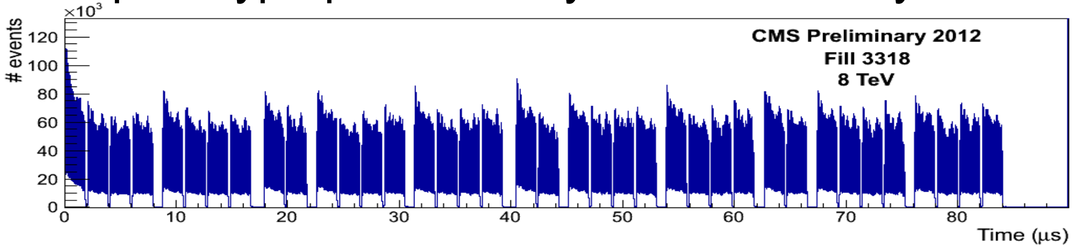
Developed at DESY-Zeuthen

Prototype installed Sept. 2012, validated during 2012-2013 run

Next revision: Optical fiber input (timing signal), ECL input mezzanine connection

Rev. 2 prototype produced by end of January





Upgrading Data Acquisition: LumiDAQ

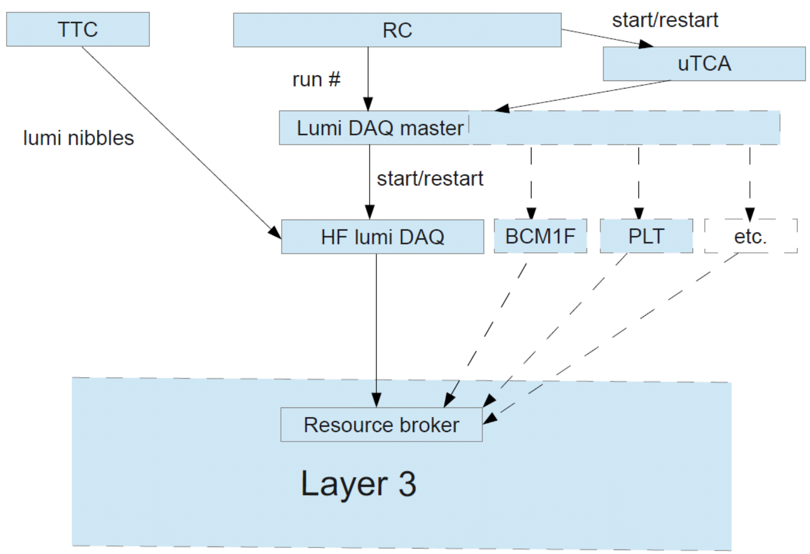
BCM1F output hit rates acquired via LumiDAQ system

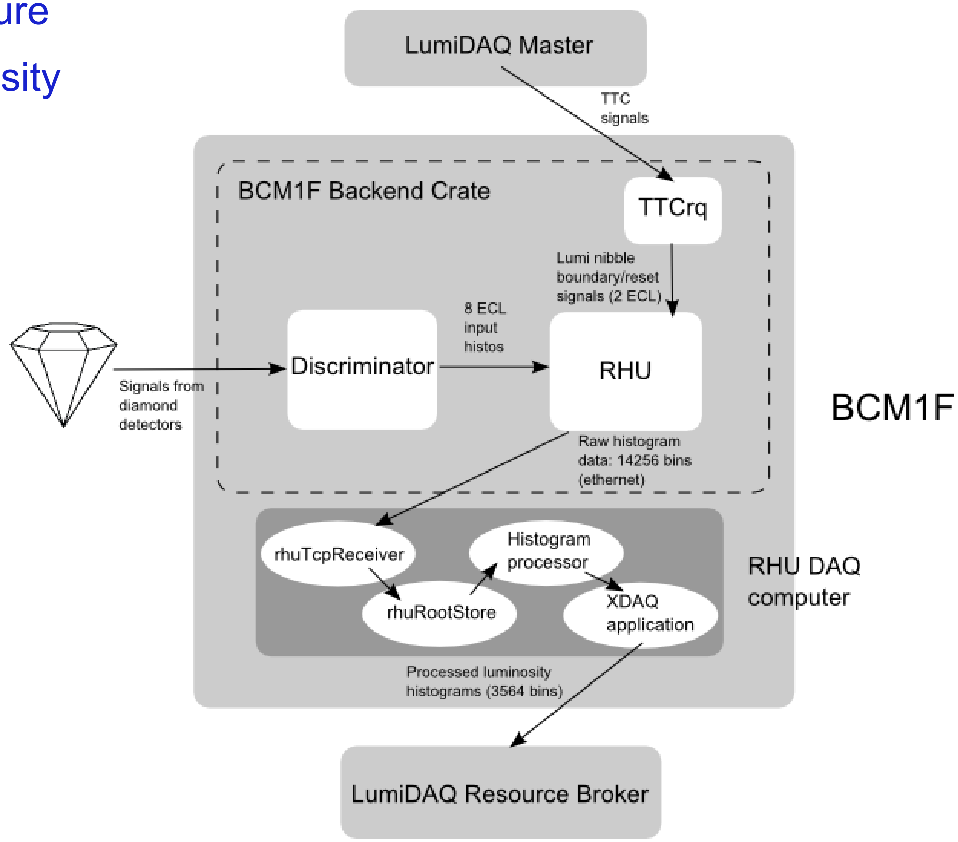
- Expansion of already-existing structure
- Combines data from all CMS luminosity detectors

Common timing signal distributed via optical fiber

- Hit count integration interval
- Synchronization important

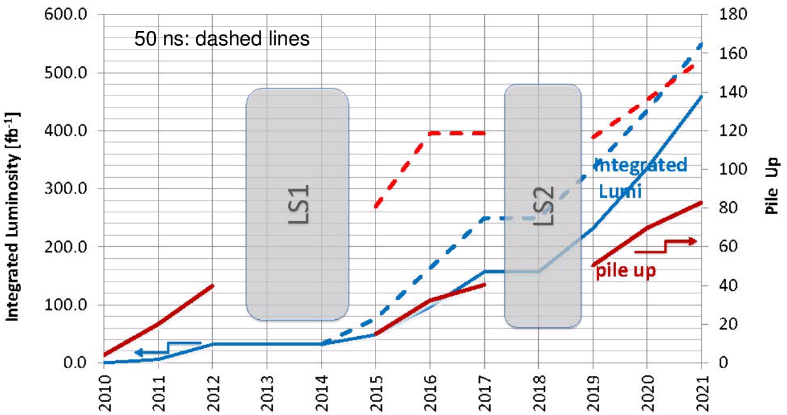
Common data format: 3564 bins



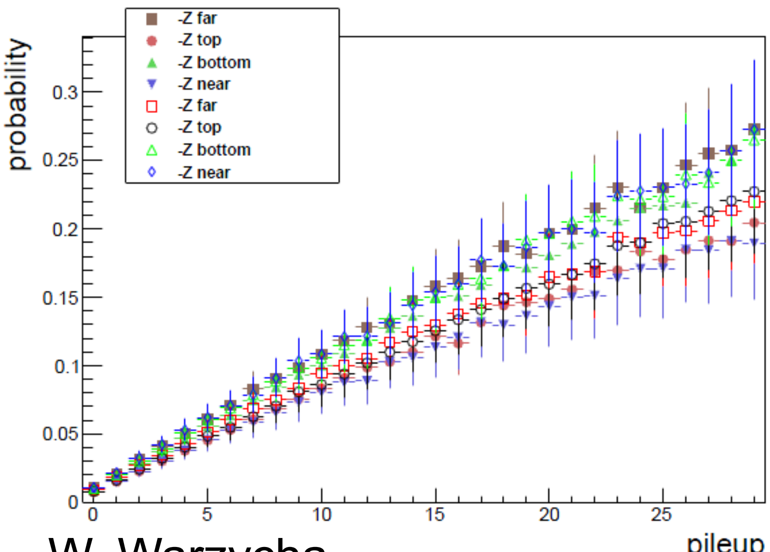


Luminosity Algorithms for Upgrade

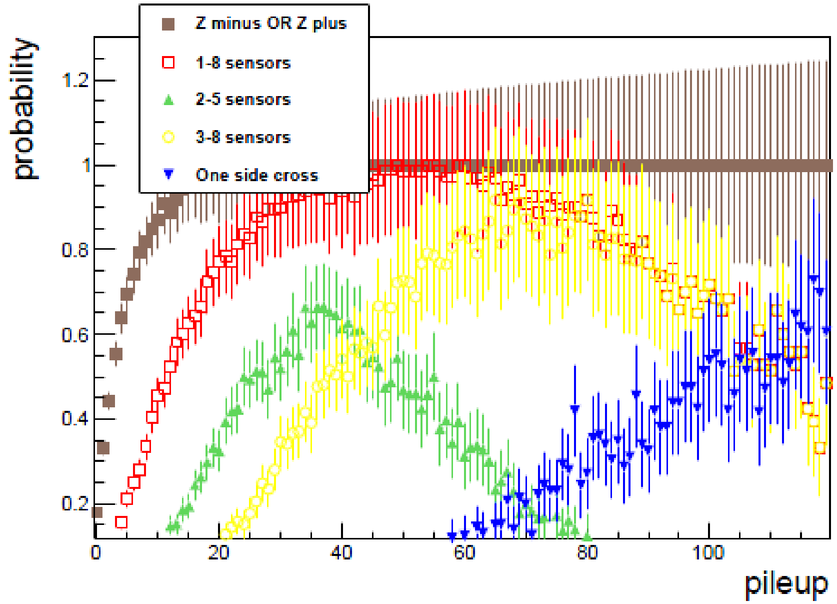
- Simple combinations of sensors used to measure luminosity in Run I
  - Saturation at high pileup levels foreseen post-upgrade



- New algorithms needed, development via simulation



W. Warzycha



Conclusions

Many improvements in the works to increase effectiveness

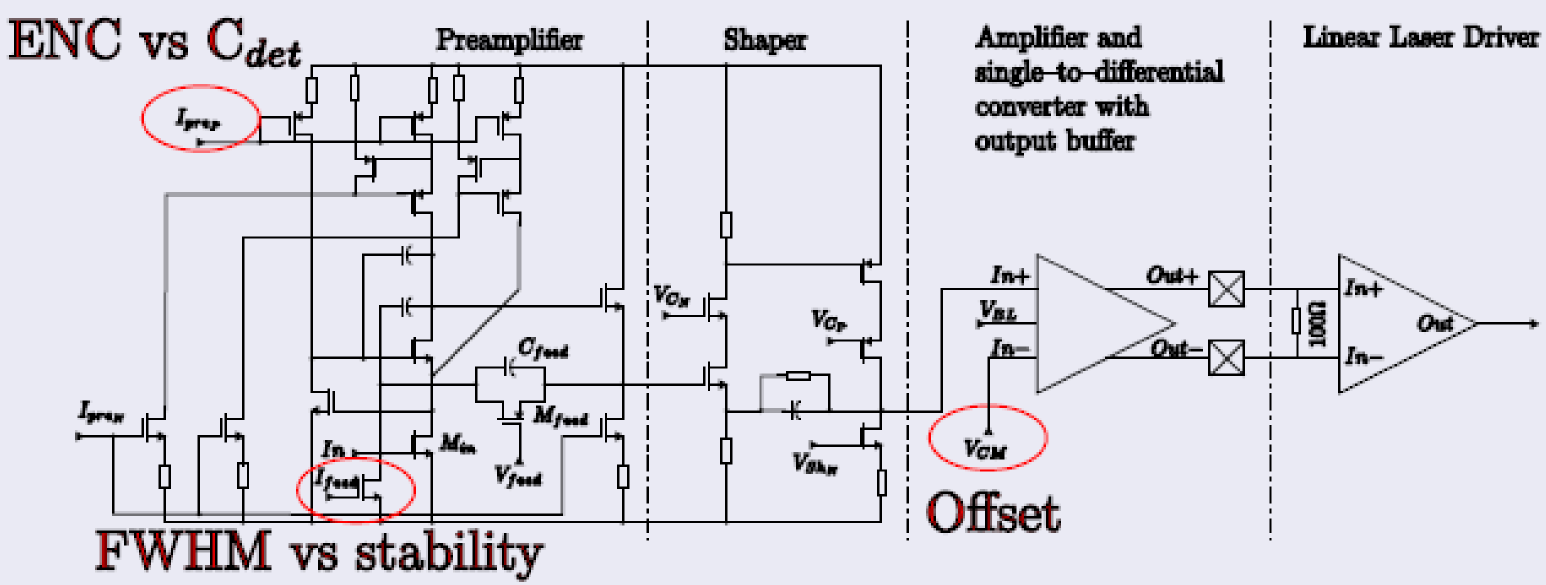
- Carriage: 48 channels, single PCB
- Diamond sensors: minimize effects of radiation damage using higher voltage
- New fast front end ASIC to reduce inefficiencies
- Optical chain: lower radiation for laser driver, multi-amplitude test pulses
- Back end: Discriminator path in parallel with digitizer peak-finding
- RHU, LumiDAQ for collection of hit rates
- Algorithms for luminosity measurement

Future plans

- Full sensor chain to be tested in January at test beam
- Synchronization of readout electronics within timing/LumiDAQ framework

FE ASIC specs

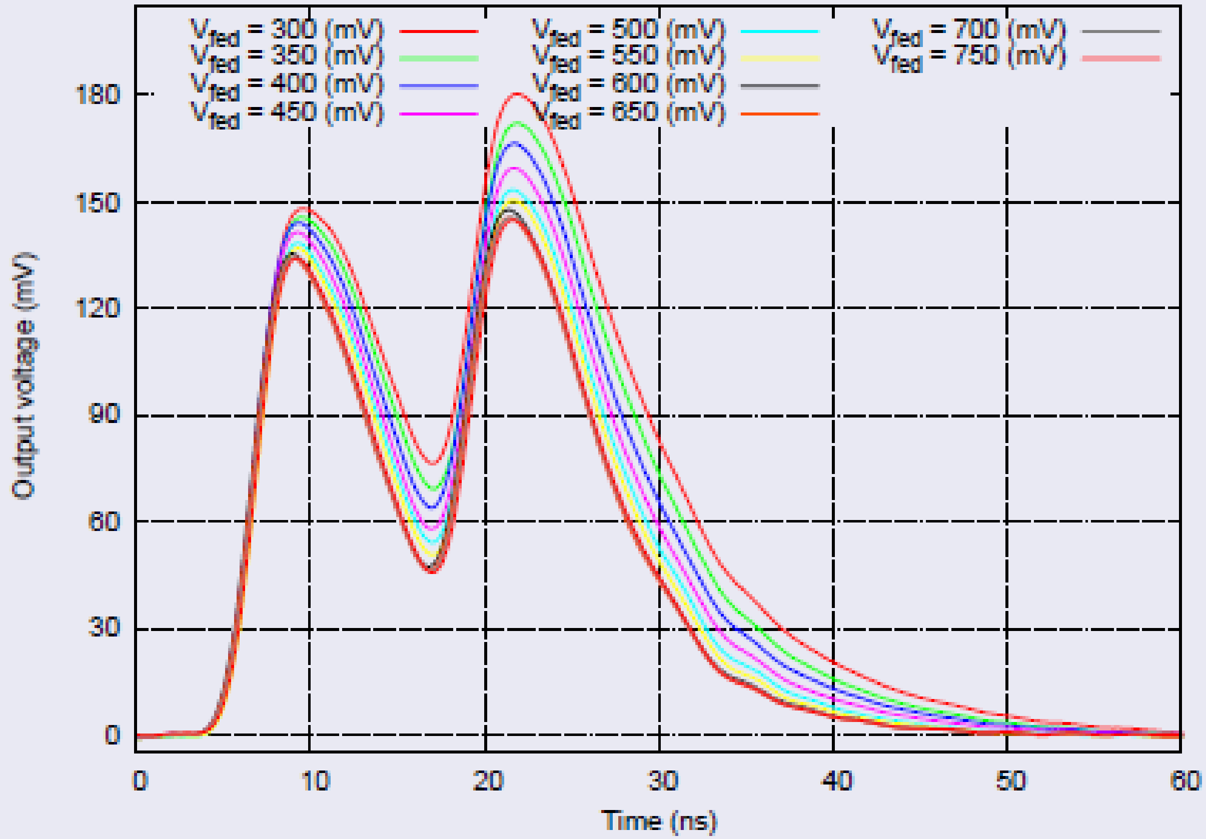
Schematic diagram of BCM1FE channel



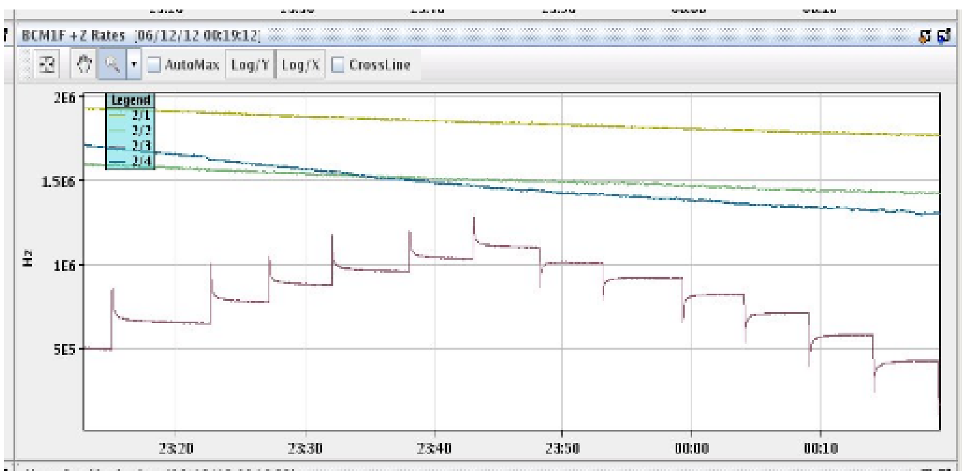
- IBM CMOS8RF 130nm technology
- 2.5 V power supply (high voltage enabled design)
- Power consumption ∼ 11 mW/ch (10mW of output buffer)

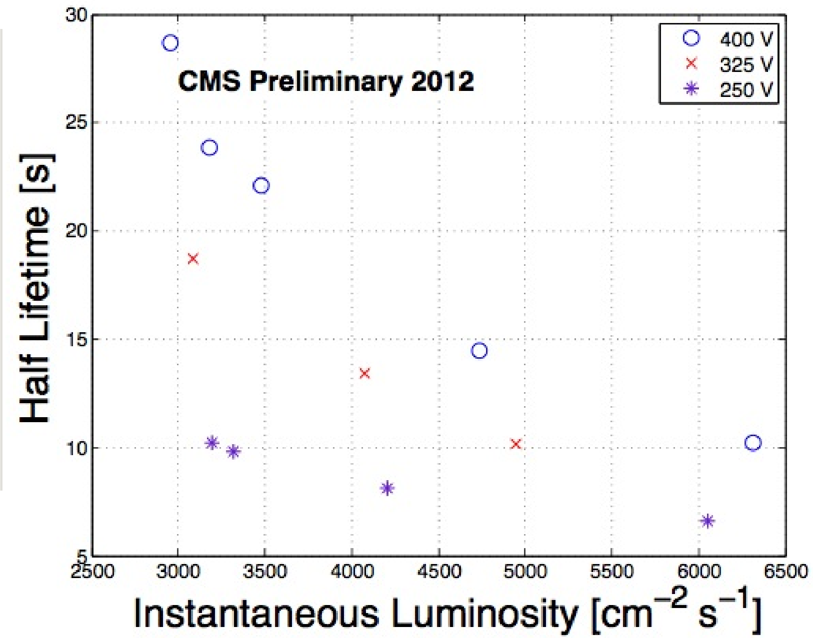
FE ASIC Fast MIPs

Distinguishability of MIPs wi 12.5 ns interval



Effects of Radiation: Diamond Sensors



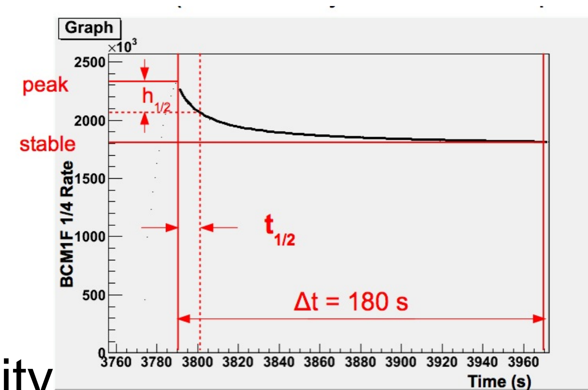


Polarization → Inefficiency, changes with time

Change in response depends on HV, luminosity

Ongoing investigation

– Recent study: thinning diamond appeared to improve polarization, more study needed

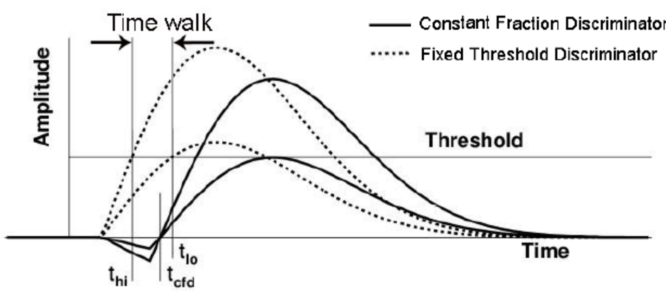


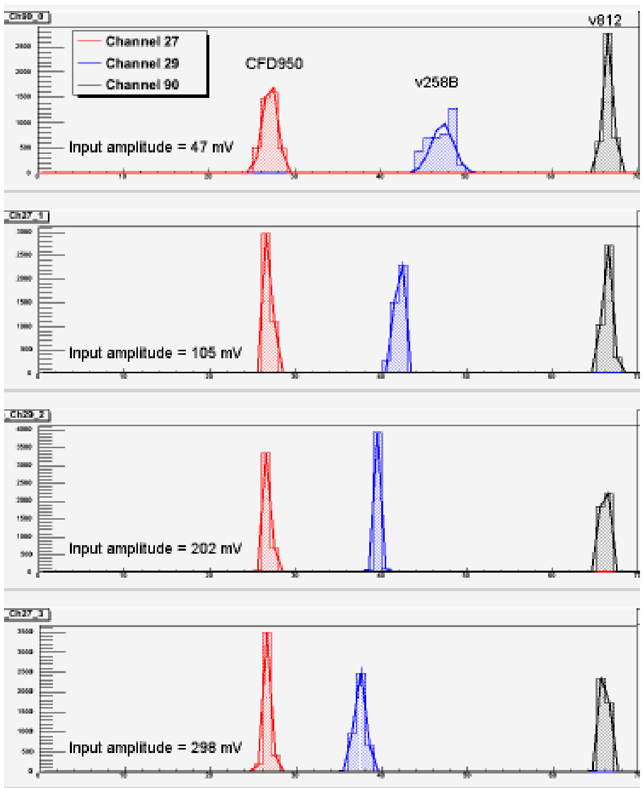
Important to characterize systematic error on luminosity calibration (TIE IN SLIDE WITH DIAMOND STUFF)

Improving Timing Performance: Discrimination

- Current discriminator: CAEN v258B fixed-threshold discriminator
  - Does not discriminate pulses closer than ~12 ns: deadtime causes loss of consecutive signals
  - Triggers pulses of different amplitudes at different times: “time walk” ΔT ~12 ns
- CFDs significantly improve on FTD time walk
  - v812: better time resolution for trigger of single pulse
  - CFD950: better resolution between consecutive pulses

(TIE IN WITH UPGRADED BACKEND SLIDE)





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Current discriminator: CAEN v258B fixed-threshold discriminator

- Does not discriminate pulses closer than ~12 ns: deadtime causes loss of consecutive signals
- Triggers pulses of different amplitudes at different times: "time walk" ΔT ~12 ns

Tested two constant-fraction discriminators: CAEN v812, PSI CFD950

Both CFDs significantly improve on FTD time walk

- v812: better time resolution for trigger of single pulse
- CFD950: better resolution between consecutive pulses