BCM1F as an online luminometer for CMS

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Outline

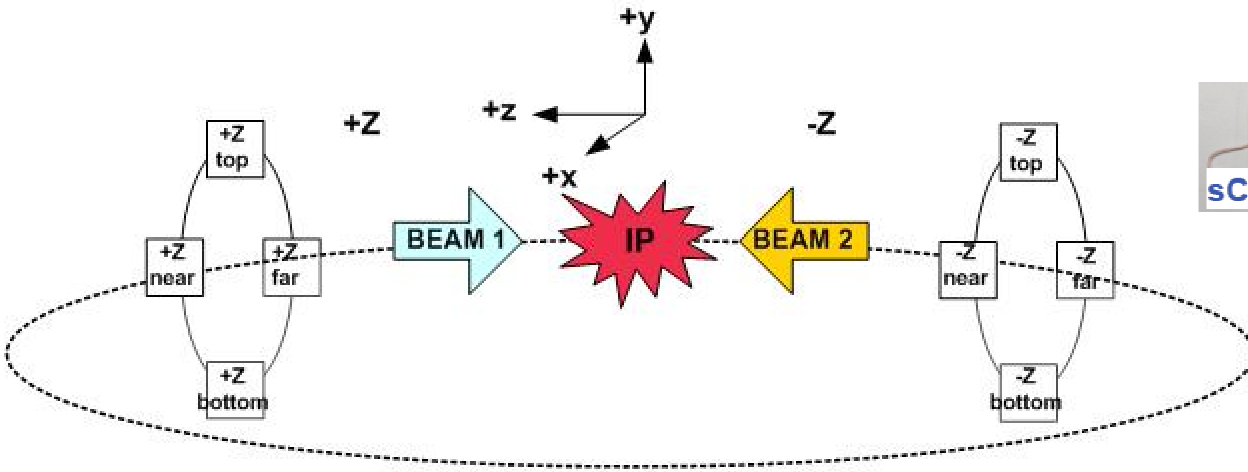
Fast Beam Condition Monitor BCM1F

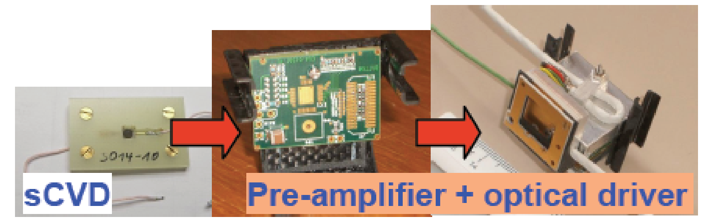
Results of luminosity measurement with BCM1F in 2012

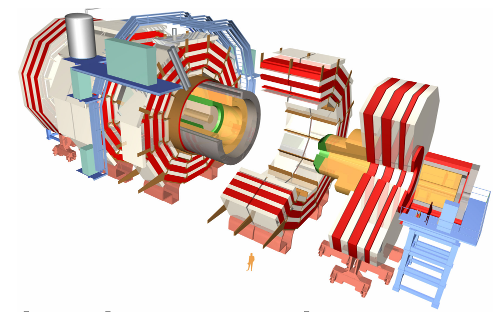
Changes to BCM1F for upgrade

Conclusions

Fast Beam Condition Monitor BCM1F





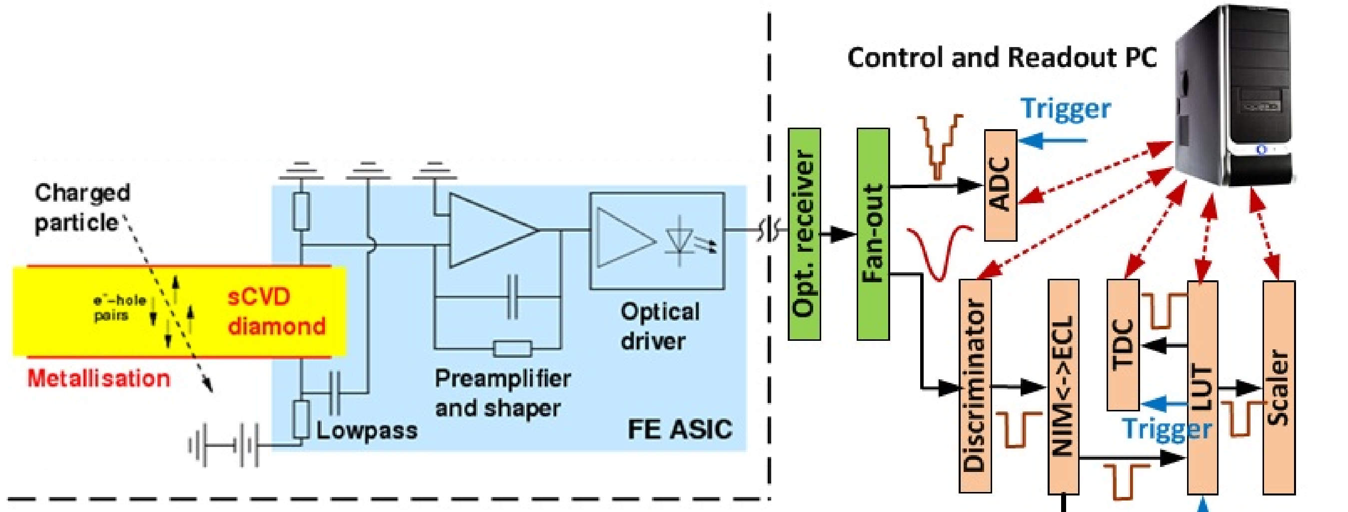


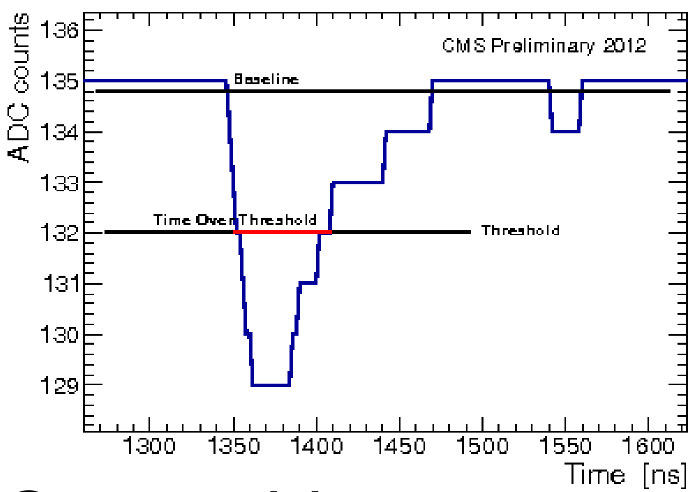
8 single-crystal CVD diamonds positioned around the beam-pipe, 5 mm x 5 mm, radial distance 4.5 cm, 1.8 m from interaction point

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

- Monitor condition of beam
- Measure radiation dose received by detector components
- Calculate luminosity

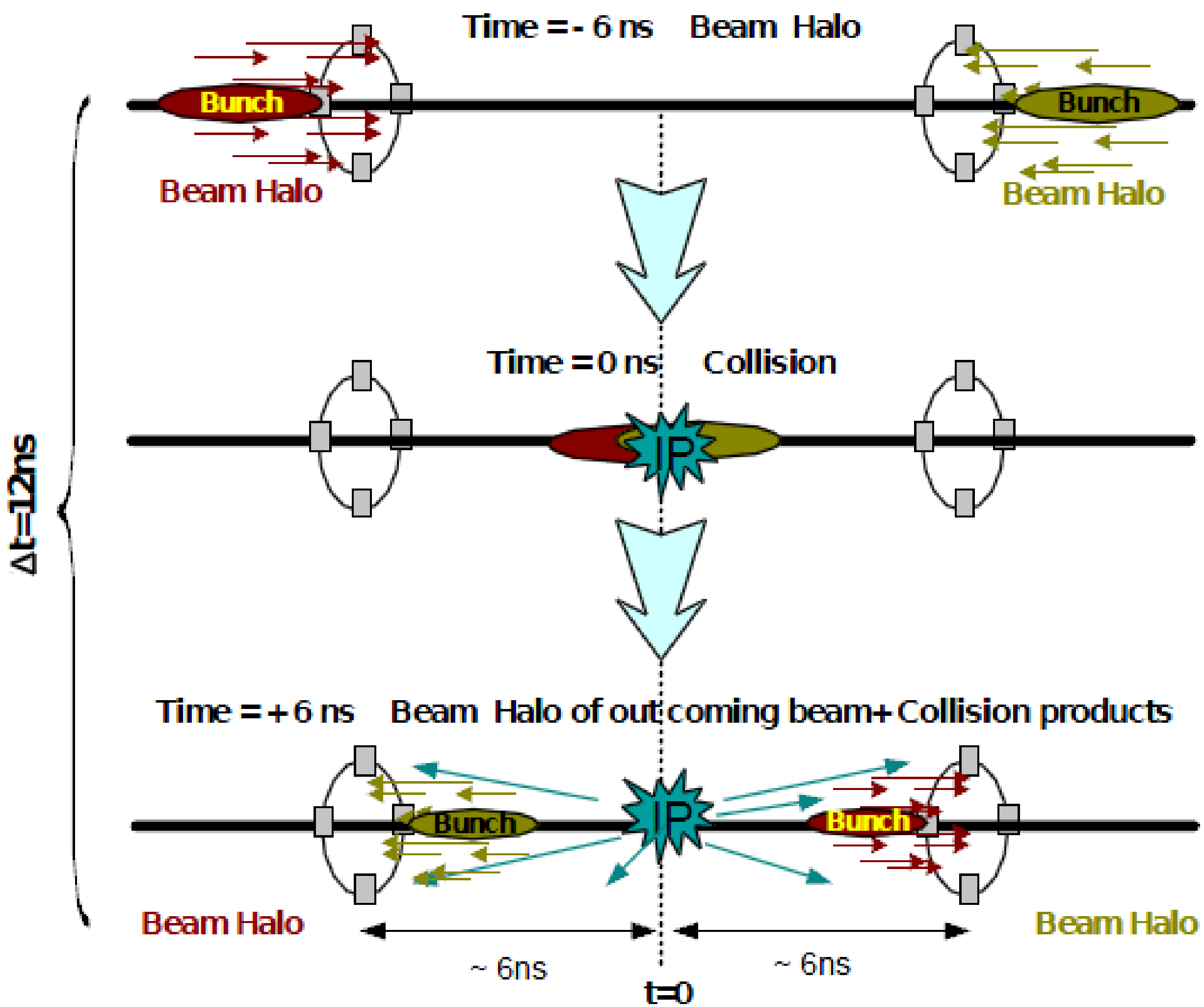
BCM1F Electronics





Output: hit rates

Beam Arrival Times

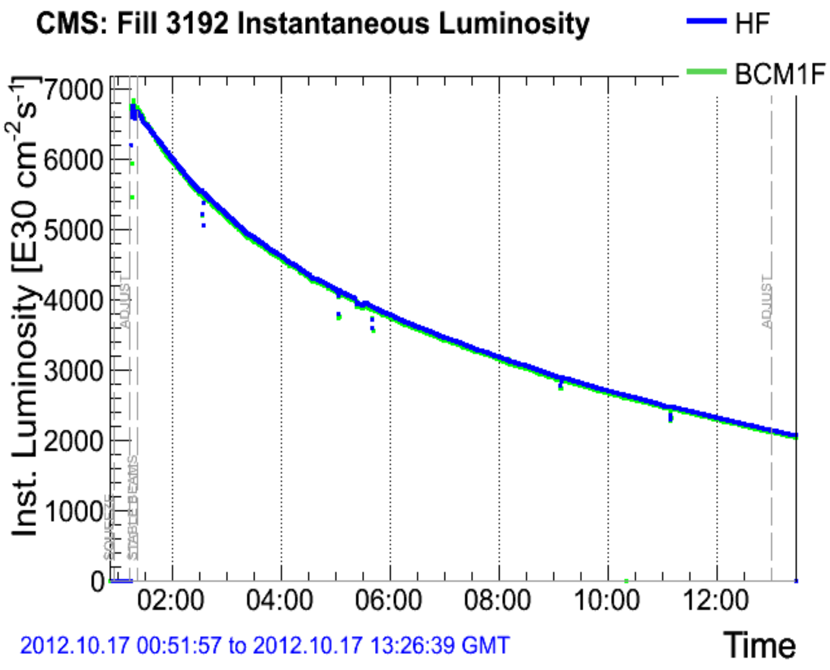


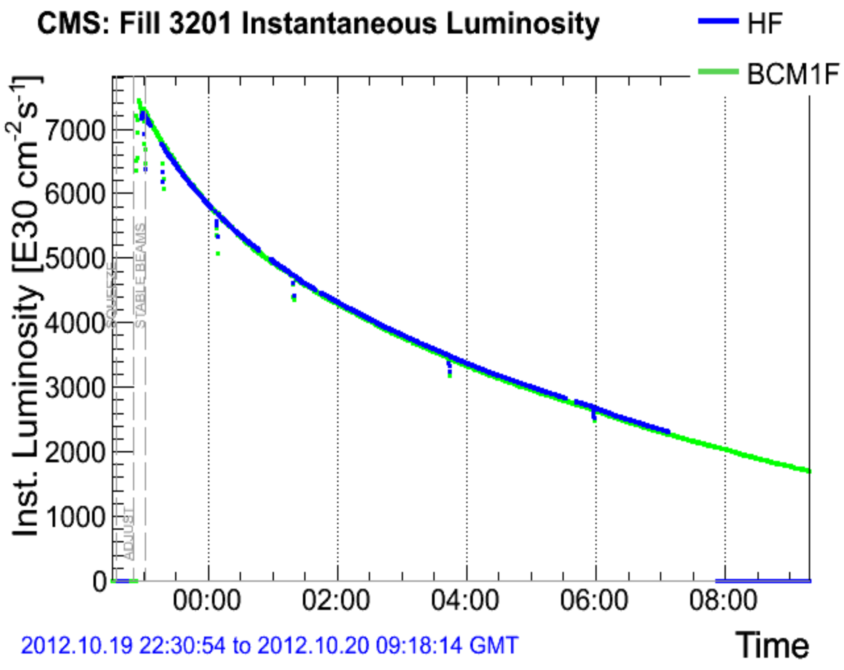
Small geometric acceptance: only "see" small fraction of bunches

BCM1F as Online Luminometer

Demonstrated potential as online luminometer in 2012

- Validation of primary luminosity calculations (HF, pixel)
- Recover missing luminosity in case of glitch in primary calculation

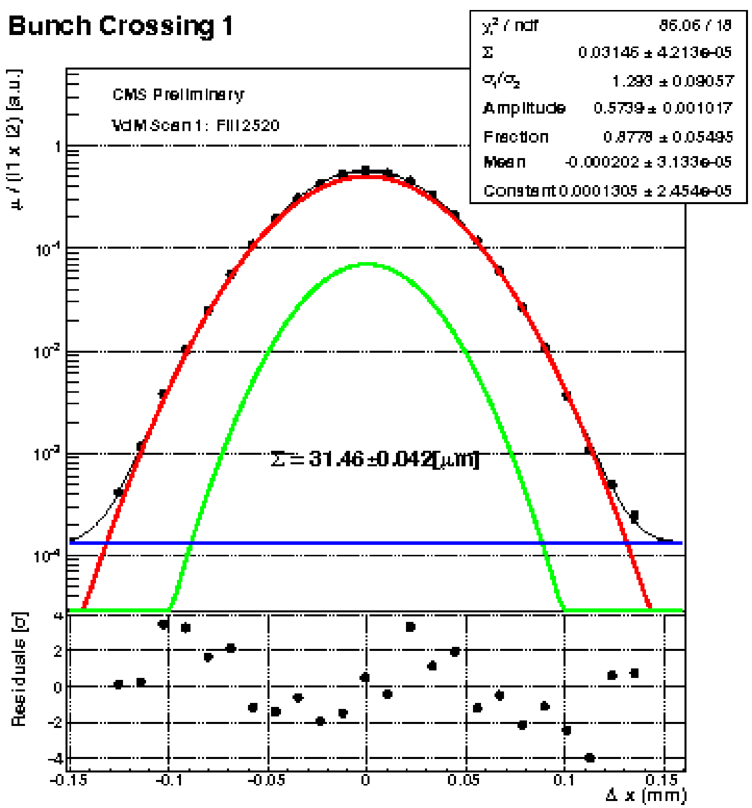


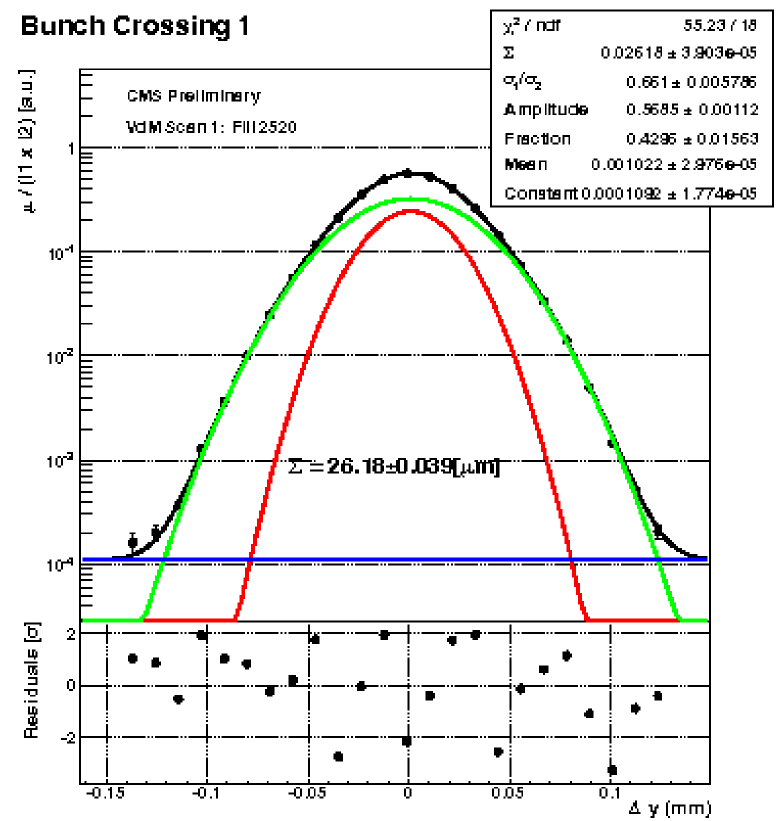


Luminosity Calibration Results

Collision rate as function of beam separation during Van de Meer scan (July 2012)

Measured width gives calibration constant

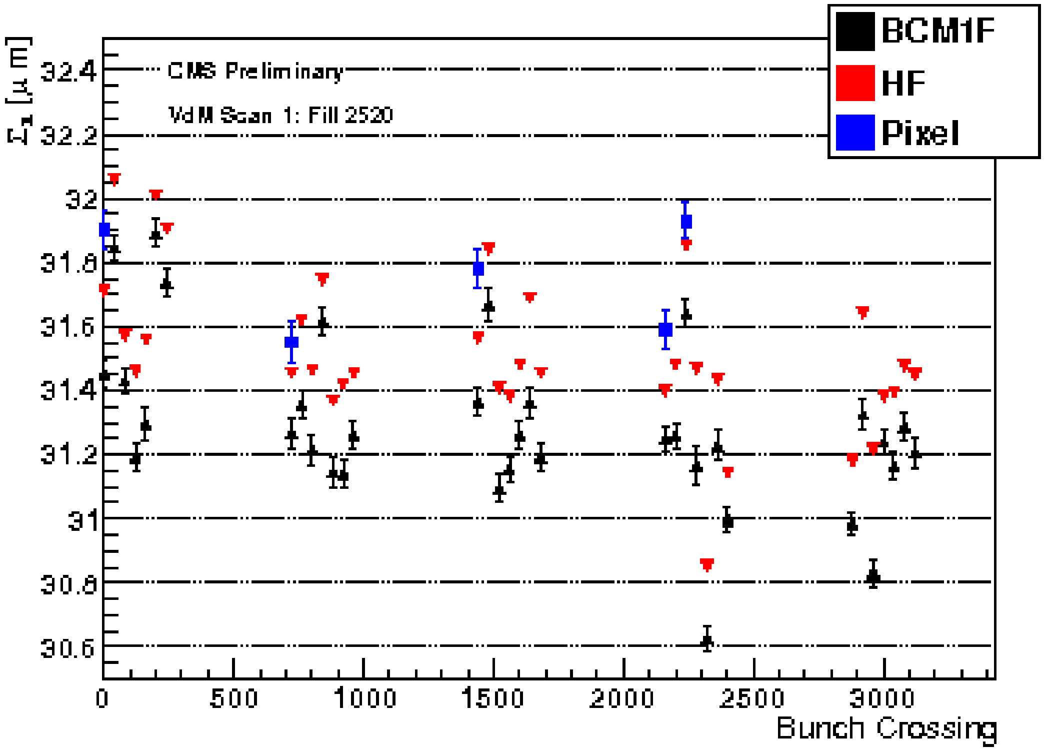




Comparison to Other Subdetectors

Compare bunch-by-bunch measured beam width to that measured by other luminosity subdetectors

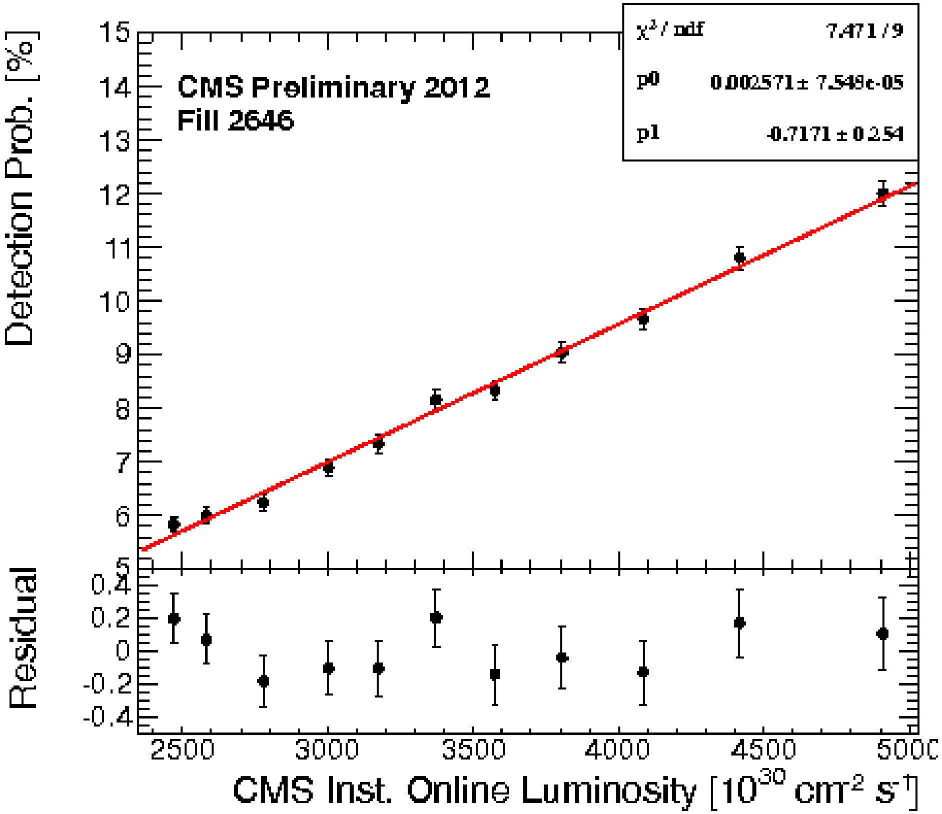
Agreement within 1% on average



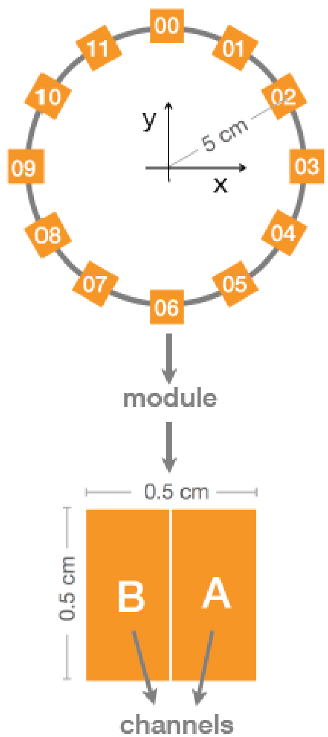
Hit Probability

Single hit probability per bunch (only 1st bunch used: avoid inefficiencies due to front-end performance)

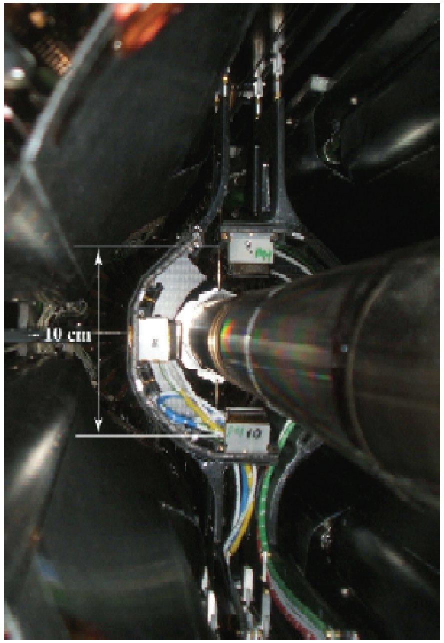
- Insensitive to pileup
- Linear extrapolation to higher (upgrade) luminosities reasonable



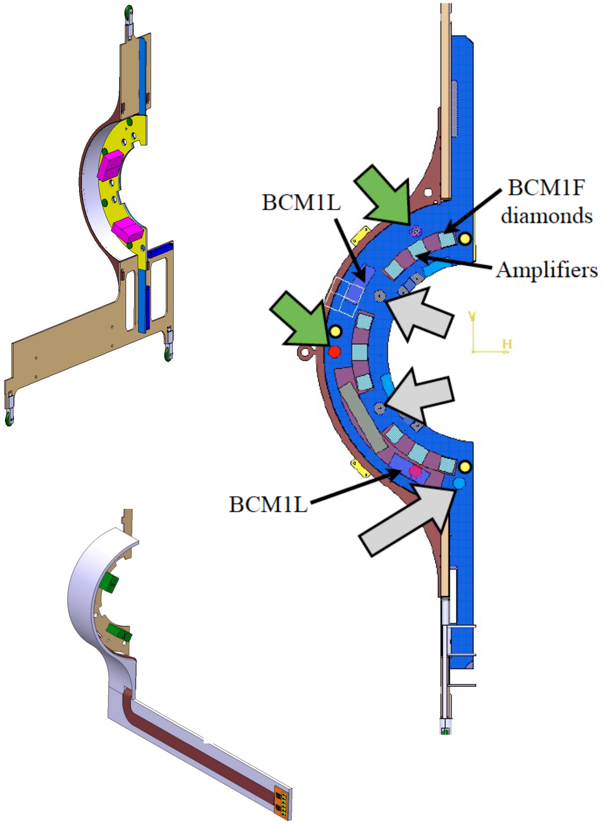
BCM1F Upgrade Concept



Current carriage



Carriage for upgrade



24 diamonds, 48 channels

Laser diodes on carriage arm (lower radiation)

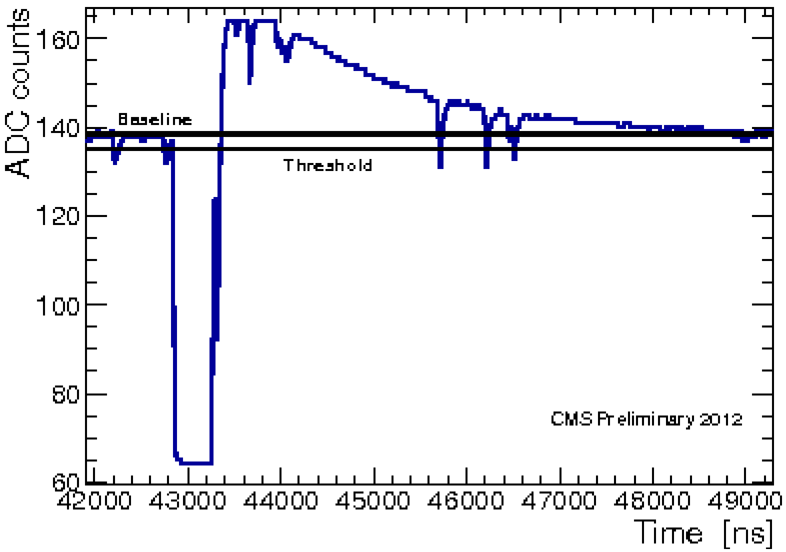
Temperature sensor to account for optical response to temperature

Luminosity 10^{34} $cm^{-2}s^{-1}$ $\rightarrow$ BCM1F charged particle flux ~3e7 $cm^{-2}s^{-1}$

Improving Timing Performance

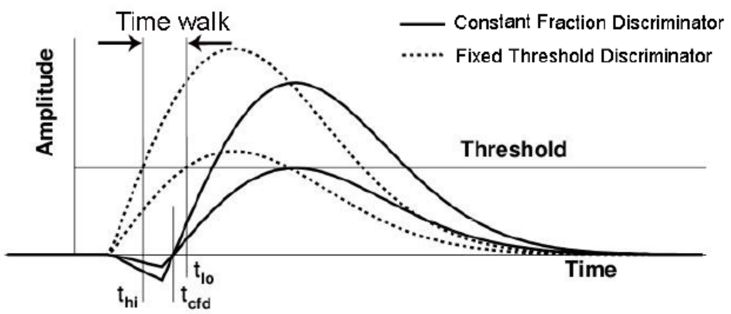
Frontend

- High-amplitude signal saturates front-end electronics (preamplifier) → “overshoot,” inefficiency
- Long rise time (25 ns) and time-over-threshold (100 ns) → inefficiency
- New front-end ASIC designed to improve this behavior



Backend

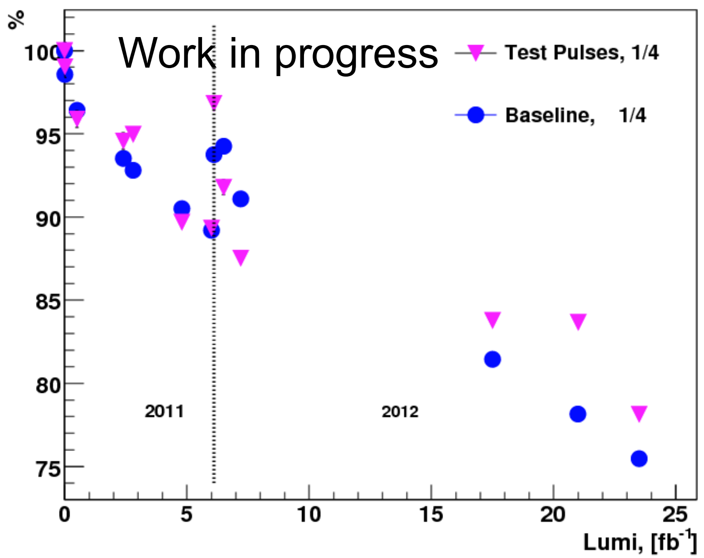
- Fixed-threshold discriminator: “time walk” causes uncertainty, wide single-pulse resolution
- Upgrade to constant-fraction discriminator: eliminates time walk, better single-pulse resolution

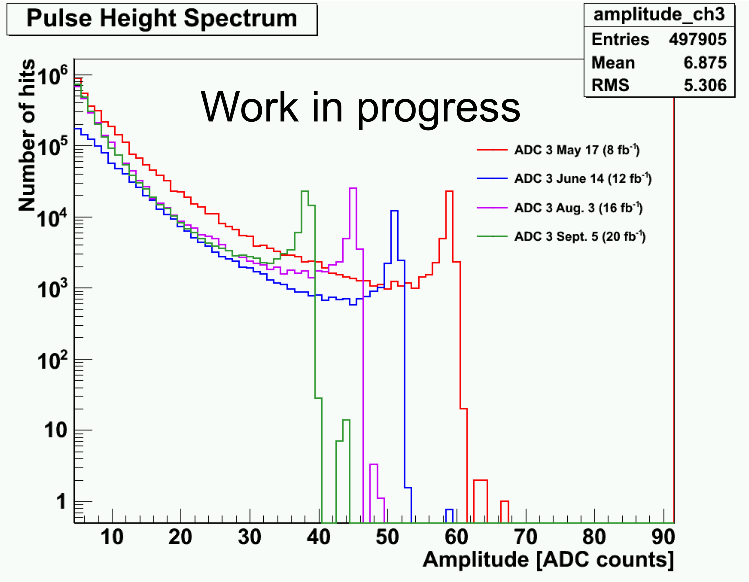


Effects of Radiation: Front-end Electronics

Radiation damage of laser driver visible in decreasing signal amplitude

- 25% gain lost in BCM1F optical transmission after 23 fb^{-1}, fluence 6.73 e13 cm^{-2}





Post-upgrade radiation environment will be even more challenging

Future improvements

- Test pulse of two amplitudes: check for linearity
- Move laser driver to lower-radiation field

Recording Histogramming Unit (RHU)

Developed as data acquisition system for BCM1F upgrade

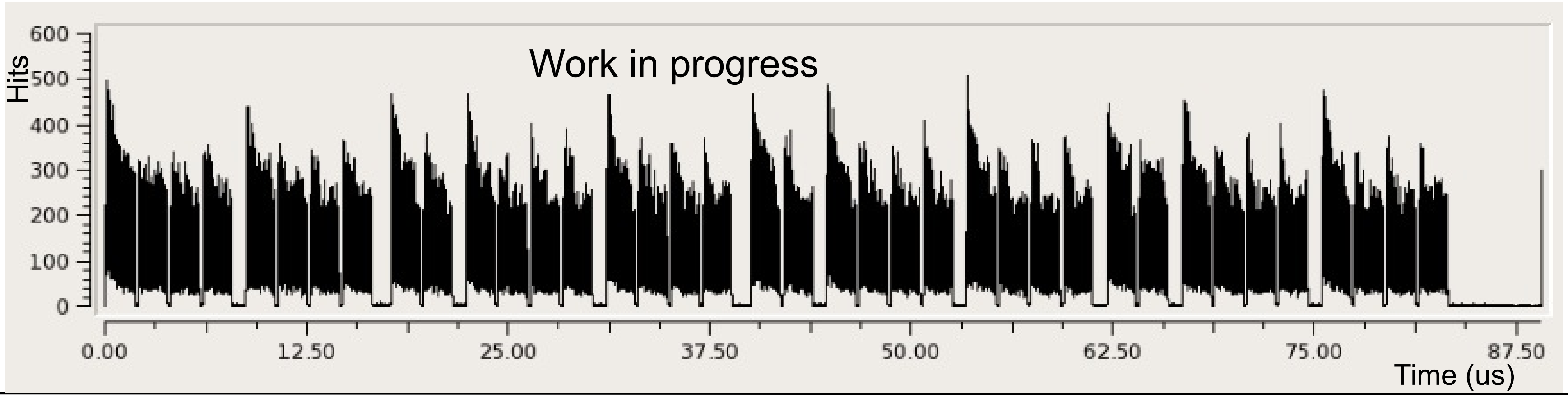
Readout

- Full-orbit count rate histograms
- Post-mortem information

Characteristics

- No deadtime
- Bins of 6.25 ns (4/bunch bucket), 14256 bins/orbit
- Configurable sampling period

Prototype installed September 2012, validation during 2012-2013 running



Conclusions

- BCM1F showed potential as online luminometer in 2012
  - Beam width agreed with other subdetectors to within 1%
  - Hit rate linear over range of luminosities, extrapolation to post-upgrade period reasonable
- Future improvements in the works to increase effectiveness in challenging post-LS1 radiation environment
  - Timing: new front-end ASIC to reduce “overshoot” inefficiency, constant fraction discriminators to improve resolution
  - Radiation damage: lower radiation for laser driver, multi-amplitude test pulses
  - RHU developed for readout of bunch-by-bunch rate counts

BCM1F Diamonds

Sccvd from element six

Improving Timing Performance: Front-End

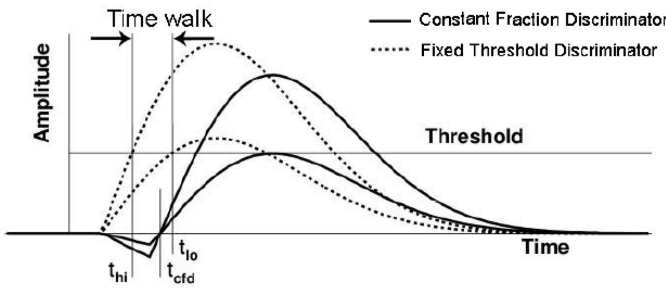
High-amplitude signal saturates front-end electronics (preamplifier) → "overshoot," inefficiency

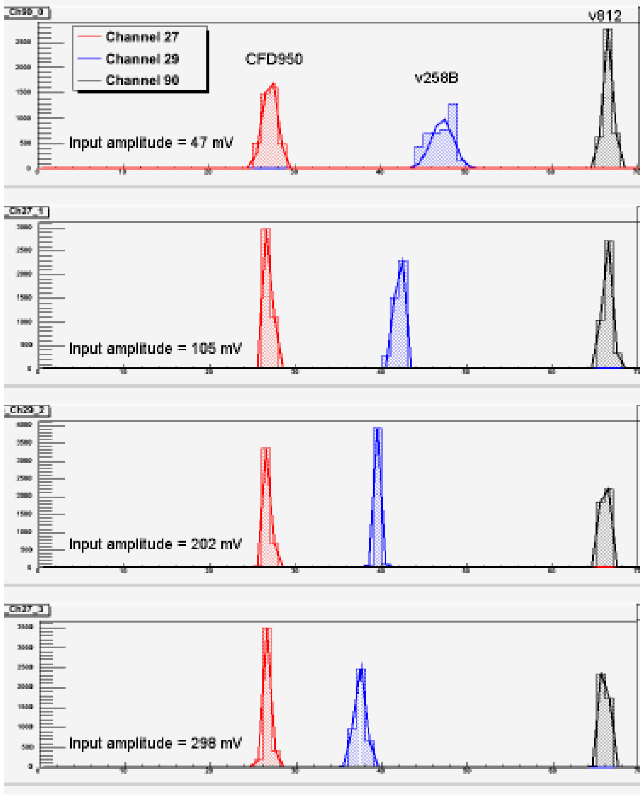
Long rising time (25 ns) and signal time (100 ns) → inefficiency

New front-end ASIC designed to improve this behavior

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





Improving Timing Performance: Discrimination

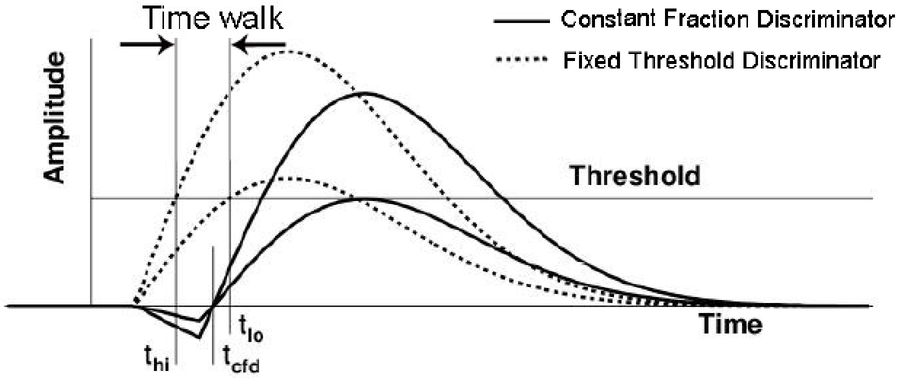
Current discriminator: CAEN v258B fixed-threshold discriminator

- 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

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



Effects of Radiation: Front-end Electronics

Radiation damage of laser driver visible in decreasing signal amplitude

- Test pulses: amplitude steadily decreasing with exposure to radiation
- Data signal height amplitude spectra: saturation at lower amplitude over time

Improvements for upgrade

- Test pulse of two amplitudes: check for linearity
- Move laser driver to lower-radiation field

Recording Histogramming Unit (RHU)

Readout of full-orbit histograms

No deadtime

8 input channels

Additional input signals: orbit trigger, bunch clock, beam abort

Bins of 6.25 ns (4/bunch bucket), 14256 bins/orbit

Configurable sampling period

BCM1F as Online Luminometer

Demonstrated potential as online luminometer in 2012

- Validation of primary luminosity calculations (HF, pixel)
- Recover missing luminosity for glitch in primary calculation

Effects of Radiation: Diamond Sensors

Polarization → Inefficiency, changes with time

Change in response depends on HV, luminosity

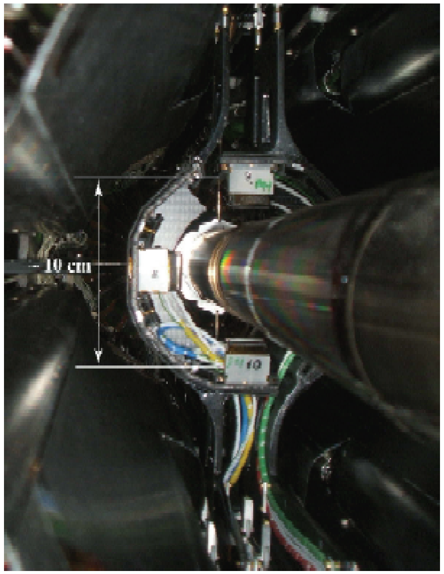
Ongoing investigation

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

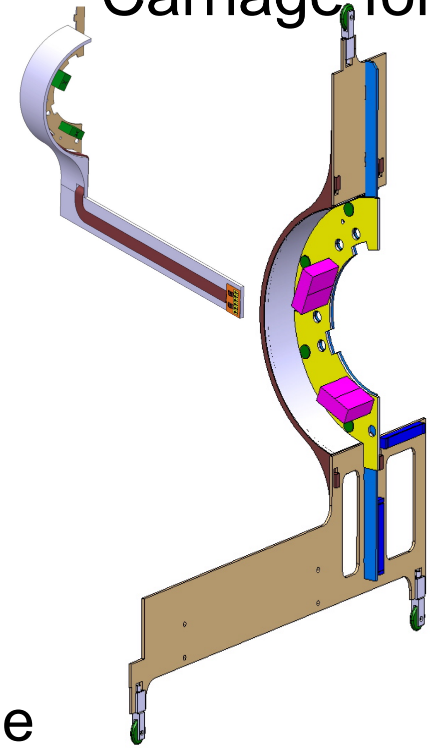
Important to characterize systematic error on luminosity calibration

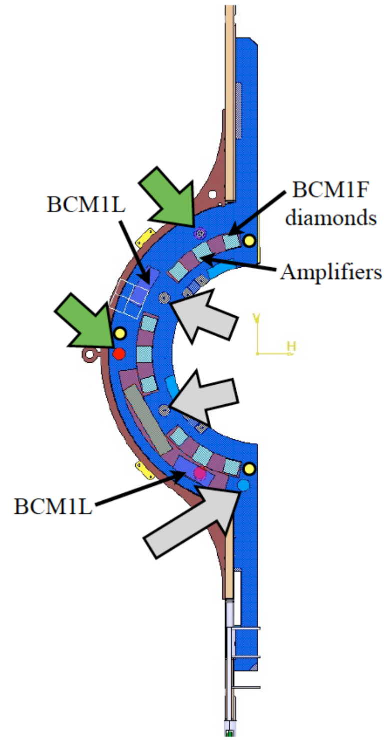
BCM1F Upgrade Concept

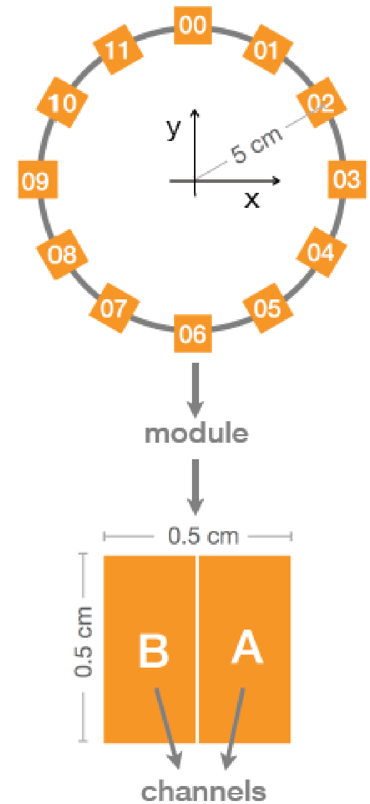
Current carriage



Carriage for upgrade







Carbon fiber carriage

24 diamonds, 48 channels

Laser diodes on carriage arm (lower radiation)

Temperature sensor to account for optical response to temperature

Luminosity 10^{34} cm^{-2}s^{-1} → BCM1F charged particle flux ~3e7 cm^{-2}s^{-1}