Current Status of the Fast Beam Condition Monitor Upgrade at CMS

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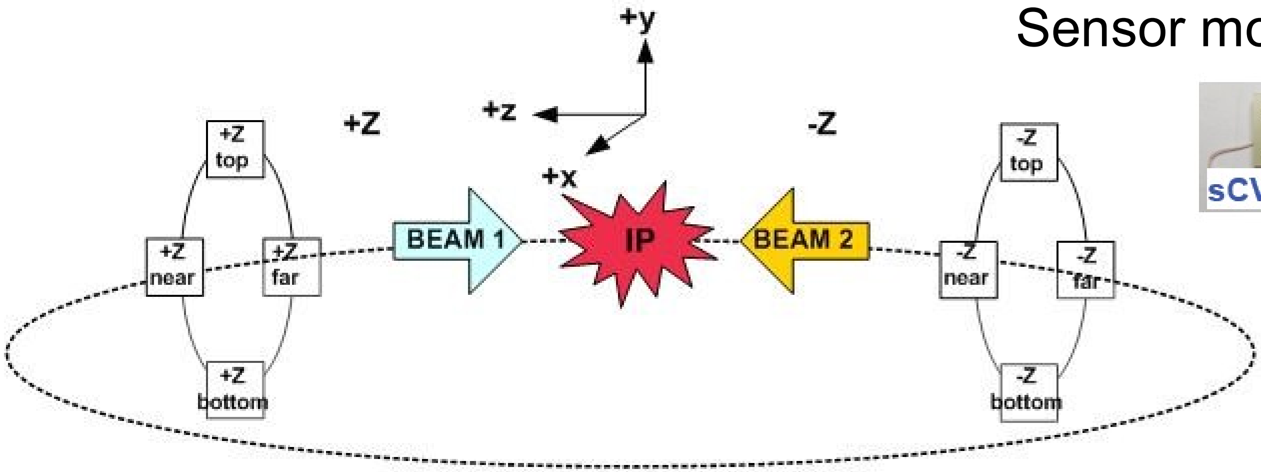
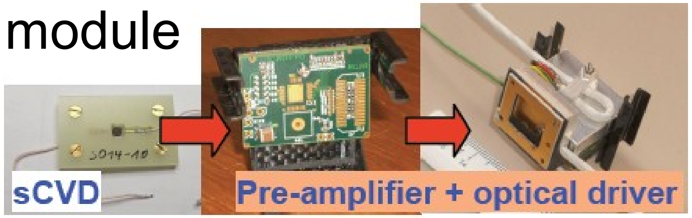
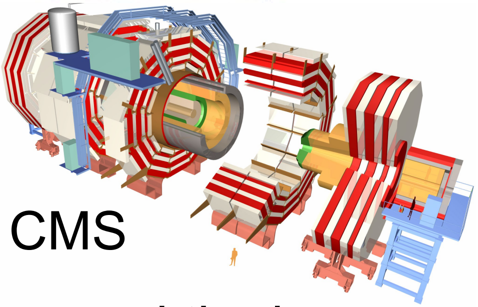
DPG Frühjahrstagung

Fast Beam Condition Monitor BCM1F (up to 2012)



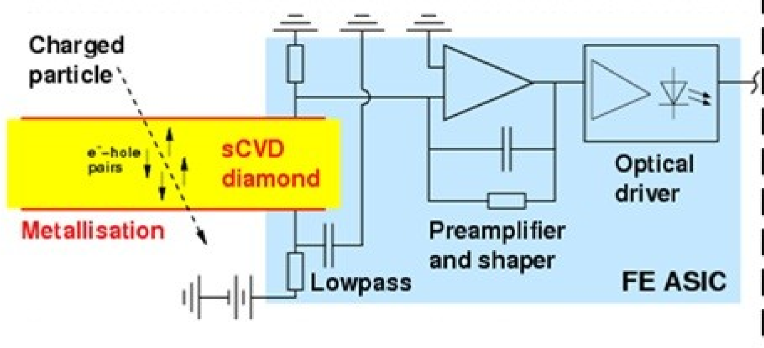
Sensor module

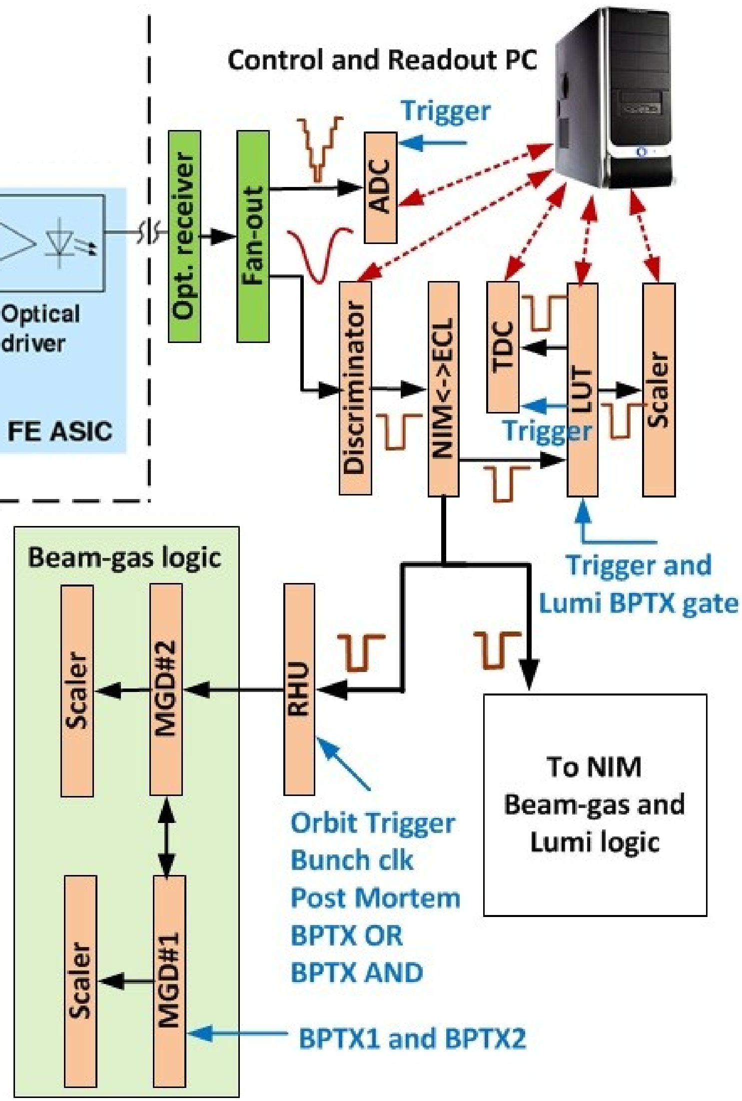


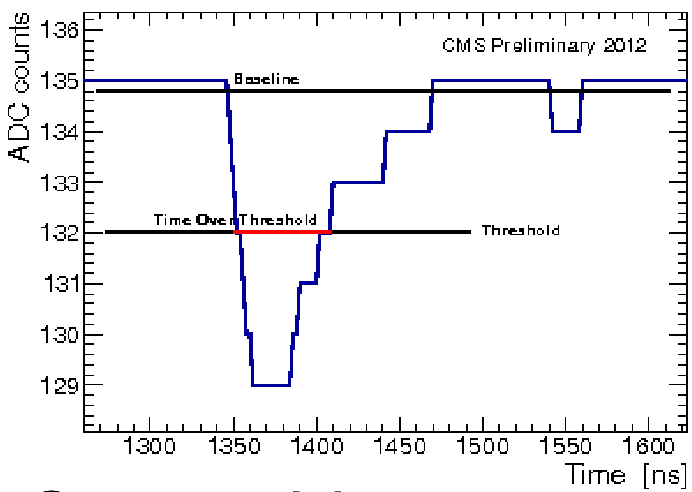


- 8 5mm x 5mm single-crystal CVD diamonds positioned around the beam-pipe, radial distance 4.5 cm, 1.8 m from interaction point
  - Diamond → no cooling, good signal, radiation-hard
  - Sensor module: diamond, radiation-hard preamplifier, optical driver
- Bunch-by-bunch information on flux of beam halo and collision products
  - Monitor condition of beam: ensure low radiation for silicon tracker
  - Calculate luminosity
- Readout independent of CMS DAQ

BCM1F Electronics

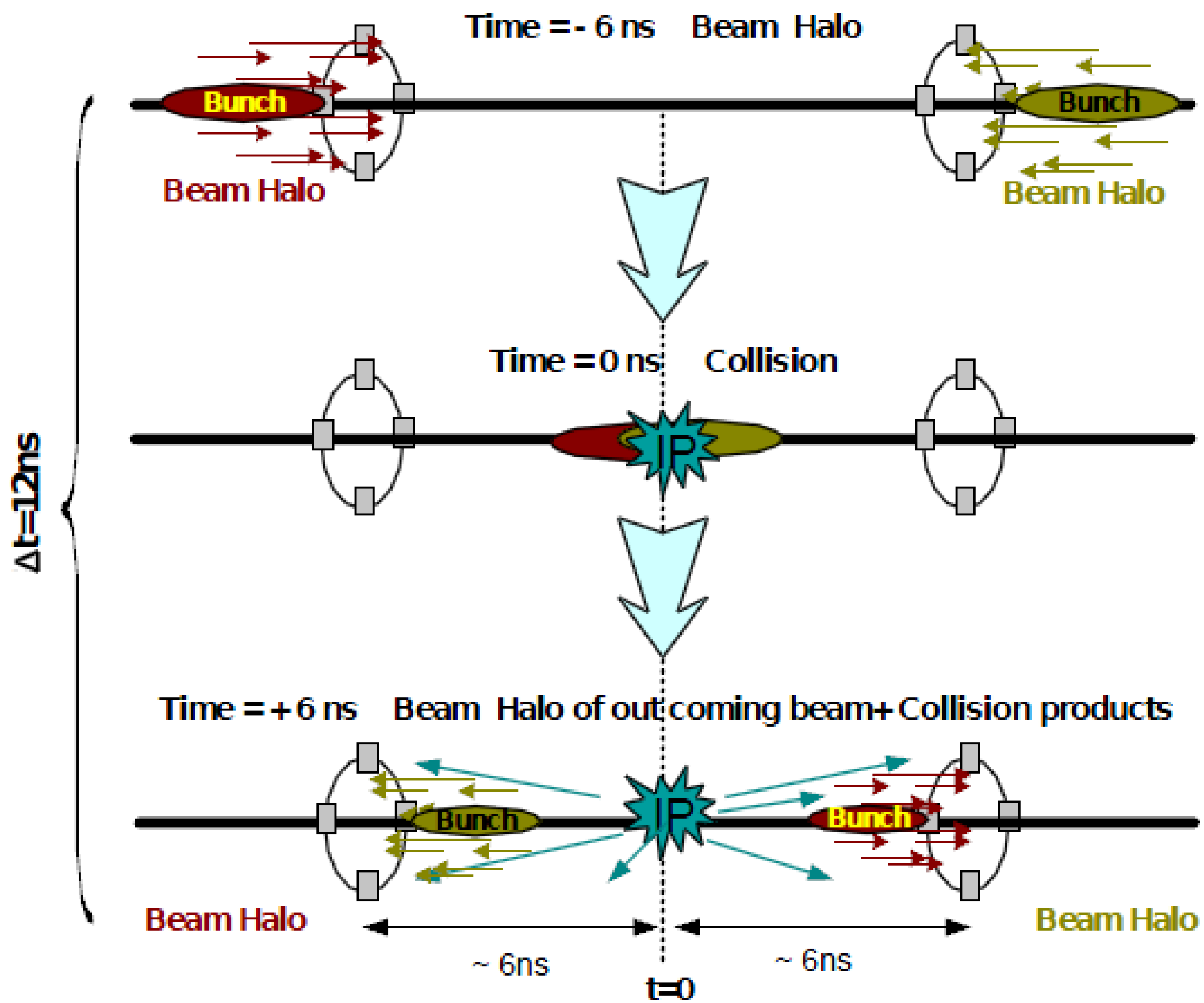






Output: hit rates

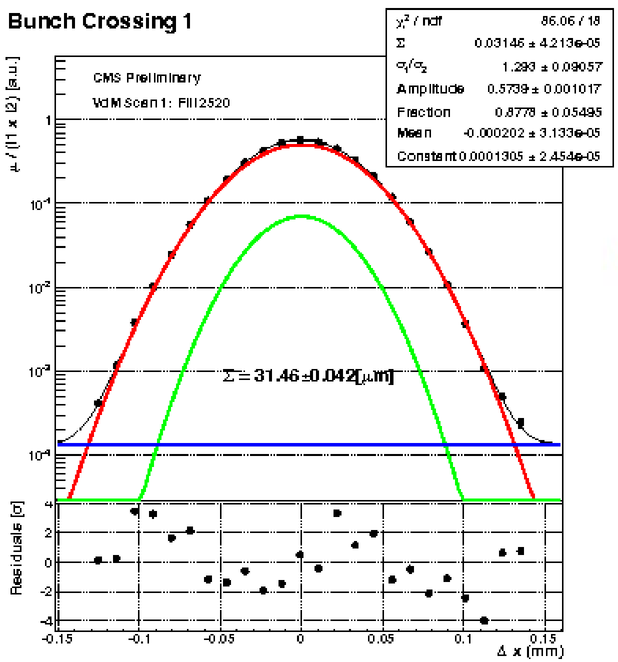
Beam Arrival Times



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

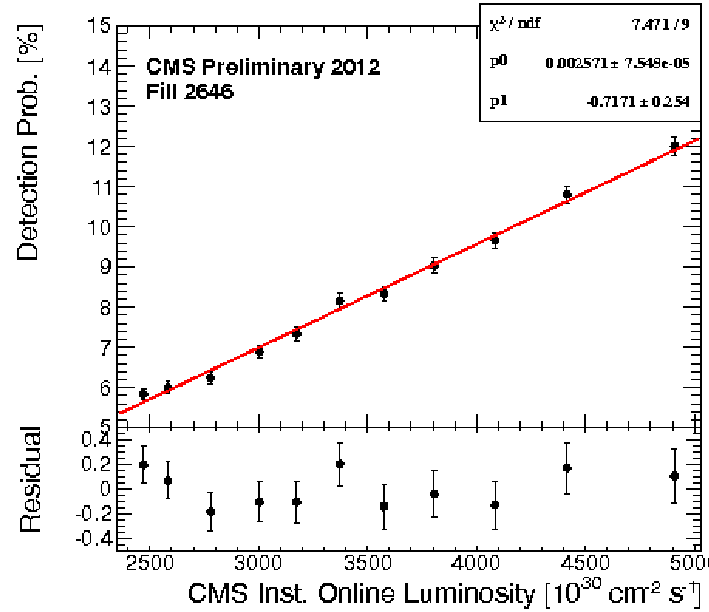
Luminosity Measurement

- Luminosity scales linearly with hit rate
- Non-trivial part: calibration
- Van der Meer scan
  - Scan beams across each other in x,y
  - Measure rate at each separation point
- Width gives calibration constant



$$L = \frac{\mu_{vis} \cdot n_b \cdot f_{orbit}}{\sigma_{vis}}$$

$$L = \frac{f_{rev} N_1 N_2}{2\pi \Sigma_x \Sigma_y}$$



Hit probability: linear extrapolation to higher (upgrade) luminosities reasonable

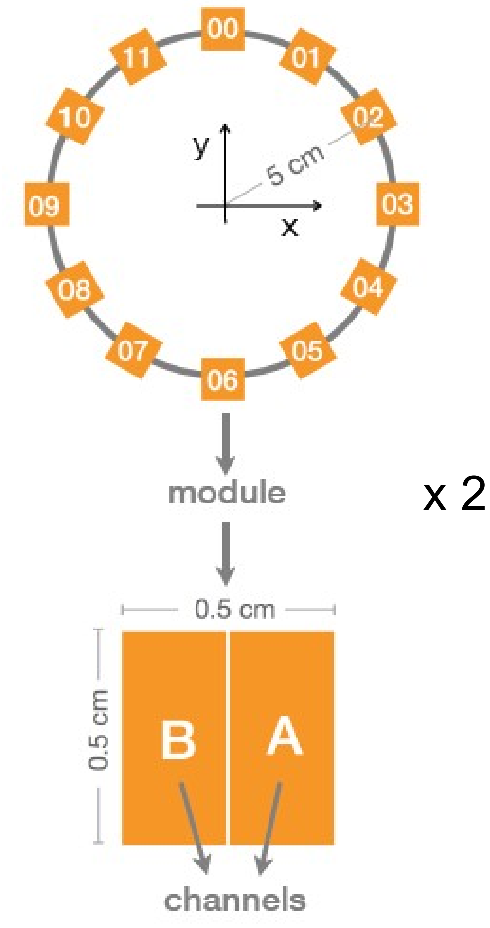
BCM1F Upgrade

Implications of LHC upgrade for BCM1F

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

Strategy

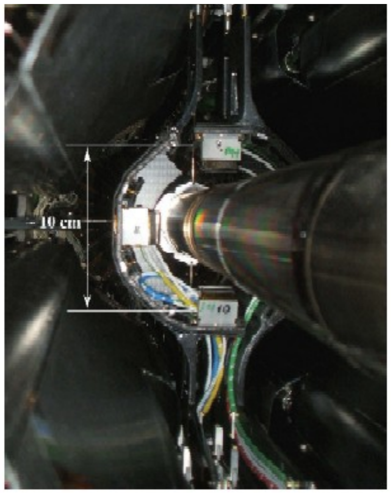
- Higher dynamic range: 24 diamonds x 2 metallization pads per diamond = 48 channels
  - See talk from M. Hempel for diamond specifics
- Scale up full system: 8 → 48 channels
- Faster electronics
- Integrate readout with other luminosity subsystems



Sensor layout for upgrade

Upgrade Carriage Design

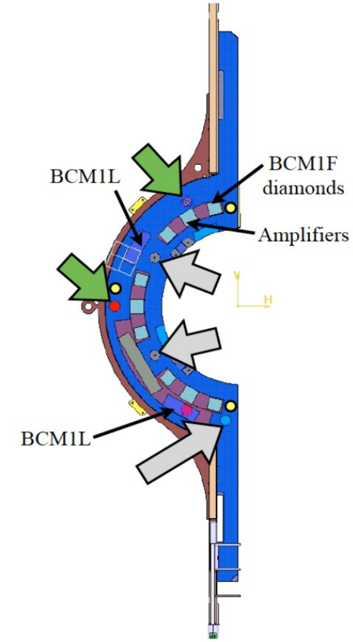
Old carriage

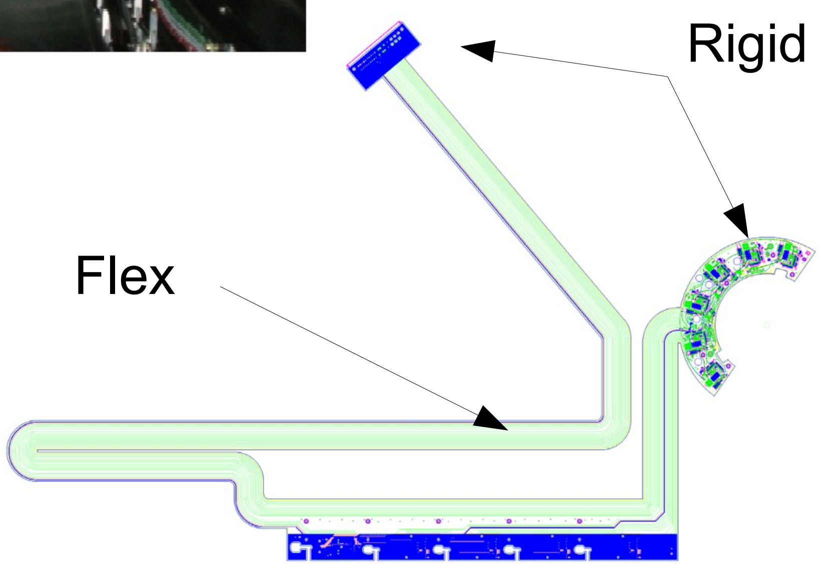


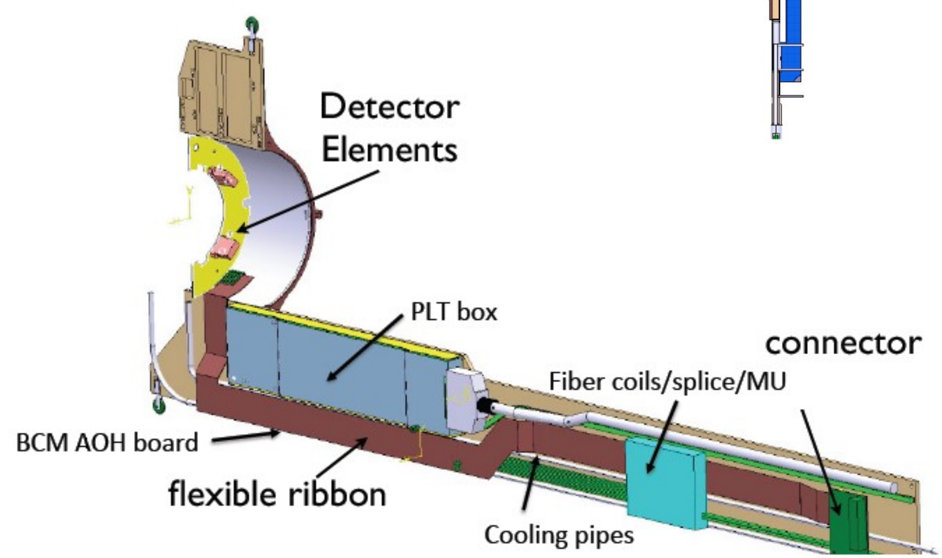
Old: carbon fiber

New: semi-rigid PCB

- Shape allows extended length from single PCB panel
- Currently being produced

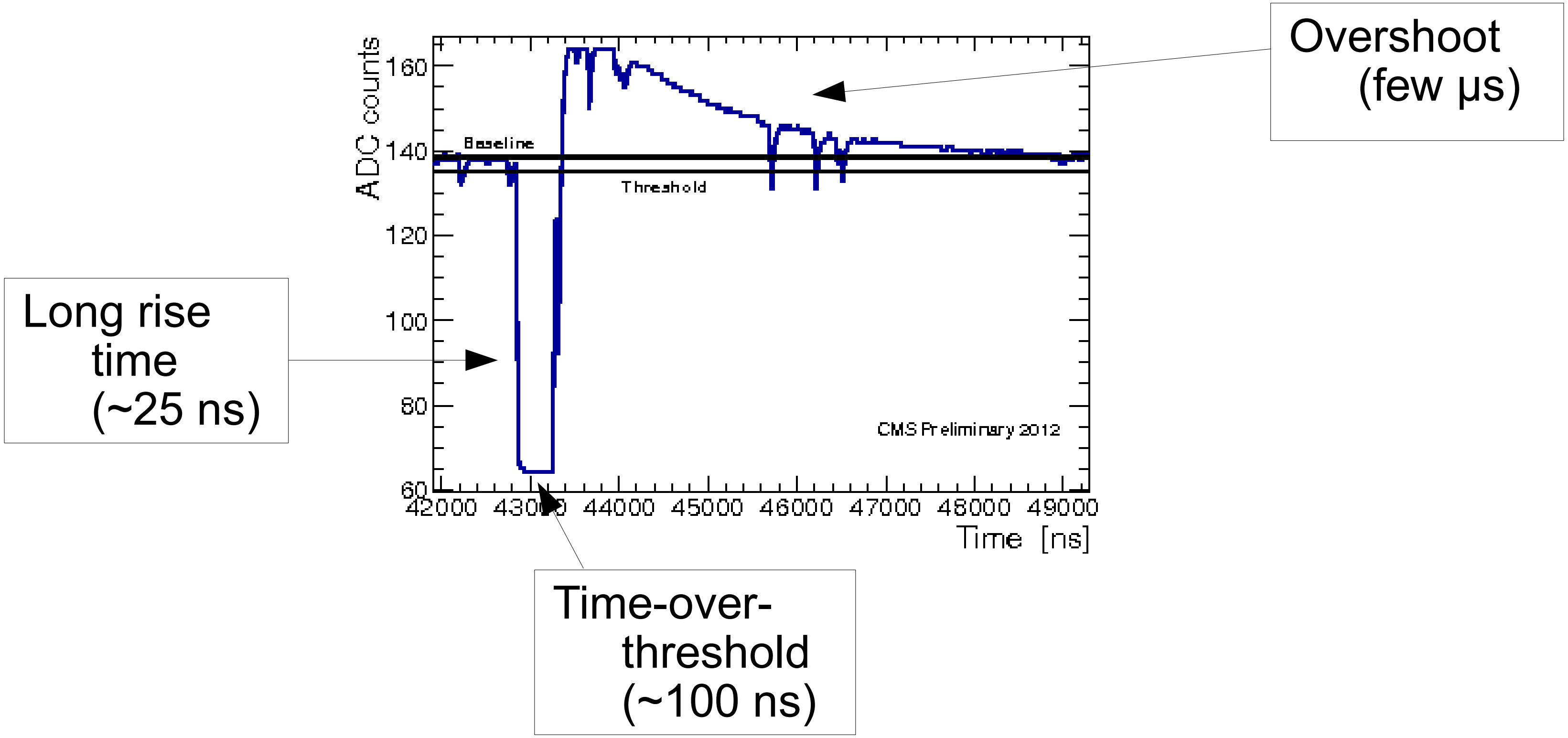






Improving Front End Electronics

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



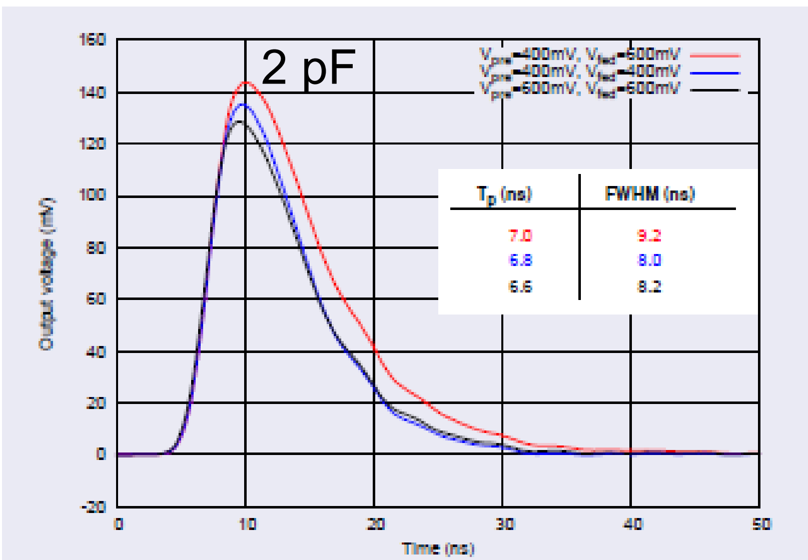
New Fast Front End ASIC

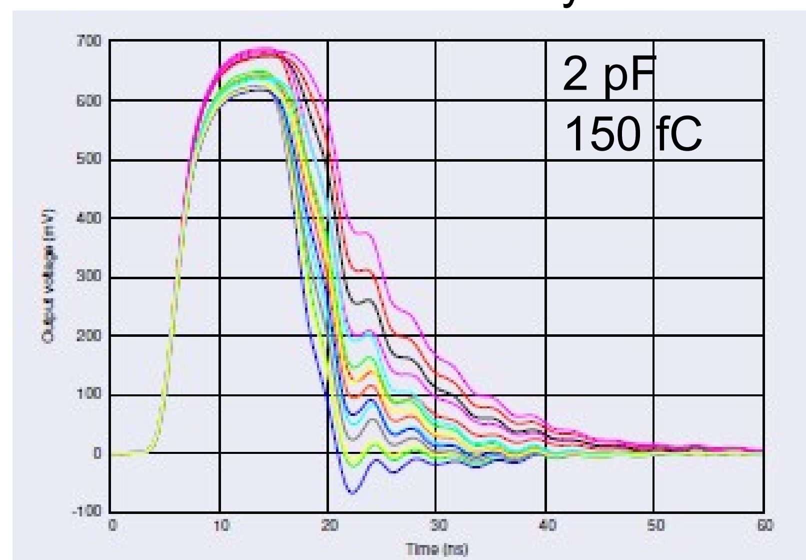
Developed by AGH - Krakow

IBM CMOS8RF 130nm technology

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

D. Przyborowski





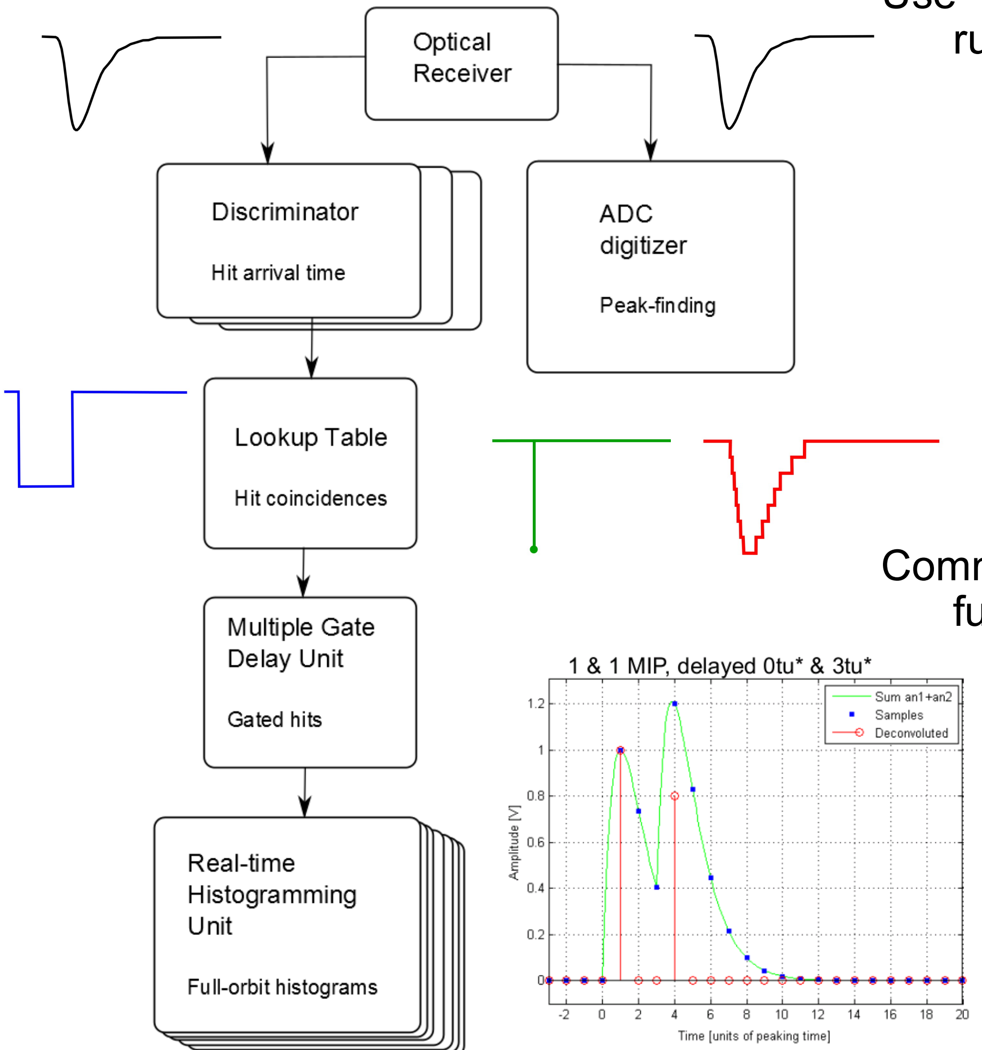
Rise time ~ 7 ns

Time-over-threshold < ~30 ns

Overshoot time very small

Large improvement in behavior: addresses previous problems

Backend Concept for Upgrade: Parallel Paths



*tu – time units

Use "tried and true" discriminator path for initial running (VME)

- Fast low-deadtime discriminator to measure hit arrival time
- Lookup Table (LUT): detect coincidences between channels
- Multiple Gate Delay Unit (MGD): Gated signals to pick out background, collisions
- Real-time Histogramming Unit (RHU) for readout (see next slide)

Commission digitizer with fast peak-finding for future use (uTCA)

- Identify pulse arrival time and peak height, distinguish signals close in time (overlapping)
- Hardware being evaluated: FMC mezzanine system. Multiple candidates in testing
- Development of FPGA algorithms in progress
- Also will be used as ADC for efficiency studies

Upgrading Data Acquisition: RHU

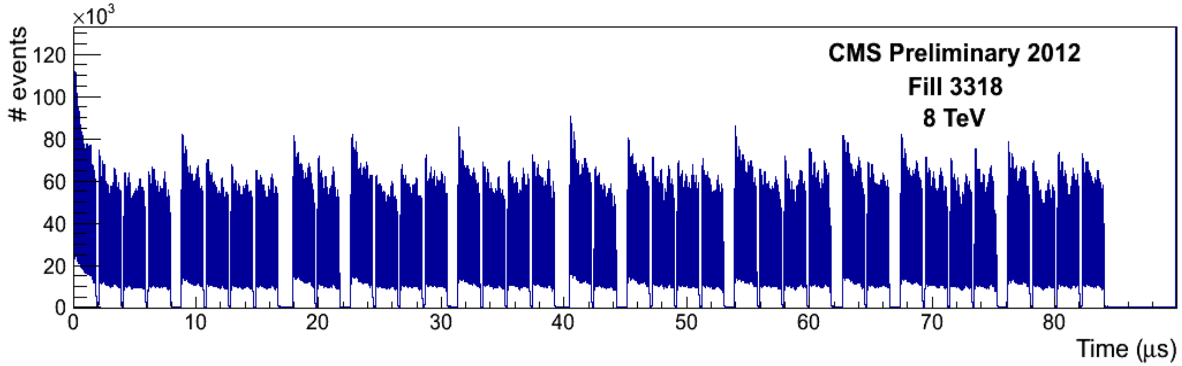
Recording Histogram Unit (RHU): Deadtimeless readout of full-orbit histograms

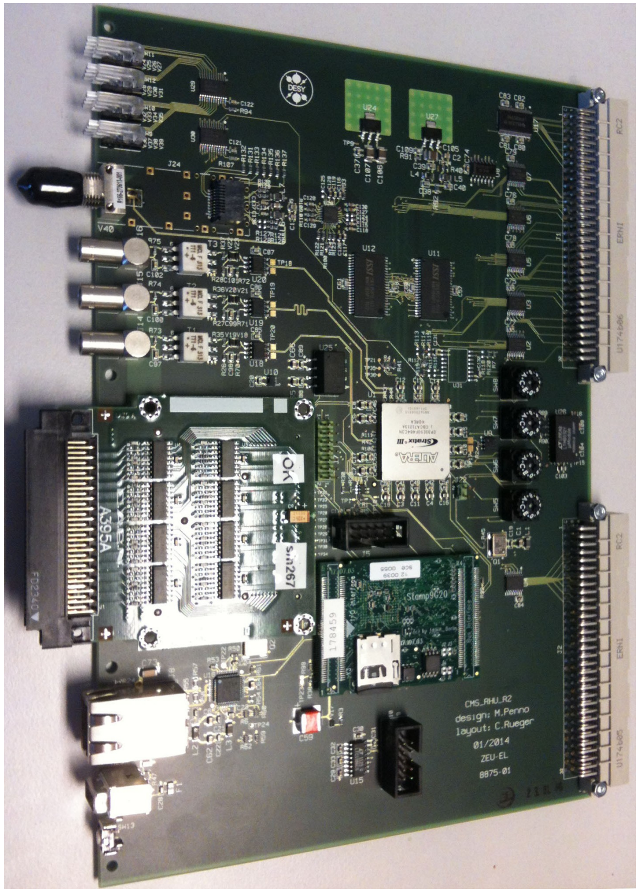
- 8 histogramming input channels: ECL mezzanine
- Bins of 6.25 ns = 4/bunch bucket (14k bins/orbit)
- Bunch clock, orbit clock, beam abort signals (NIM)
- Sampling period from optical timing signal
- 5 Mbit RAM FPGA, on-board embedded Linux system
- Ethernet readout

Developed at DESY-Zeuthen

Rev. 1 prototype installed Sept. 2012, validated during 2012-2013 run

Rev. 2 prototype tested and functional, production to begin soon

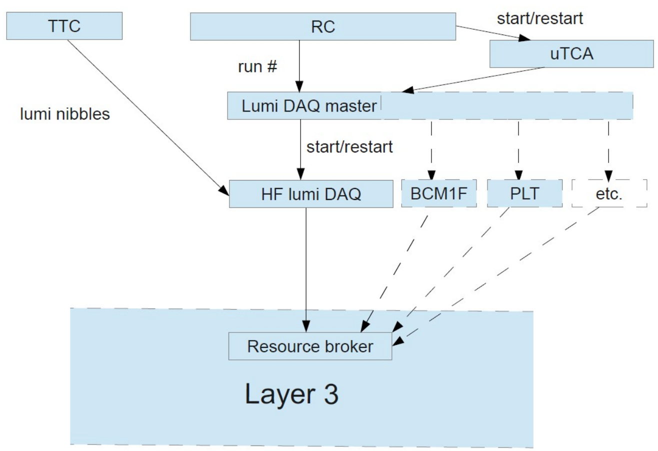


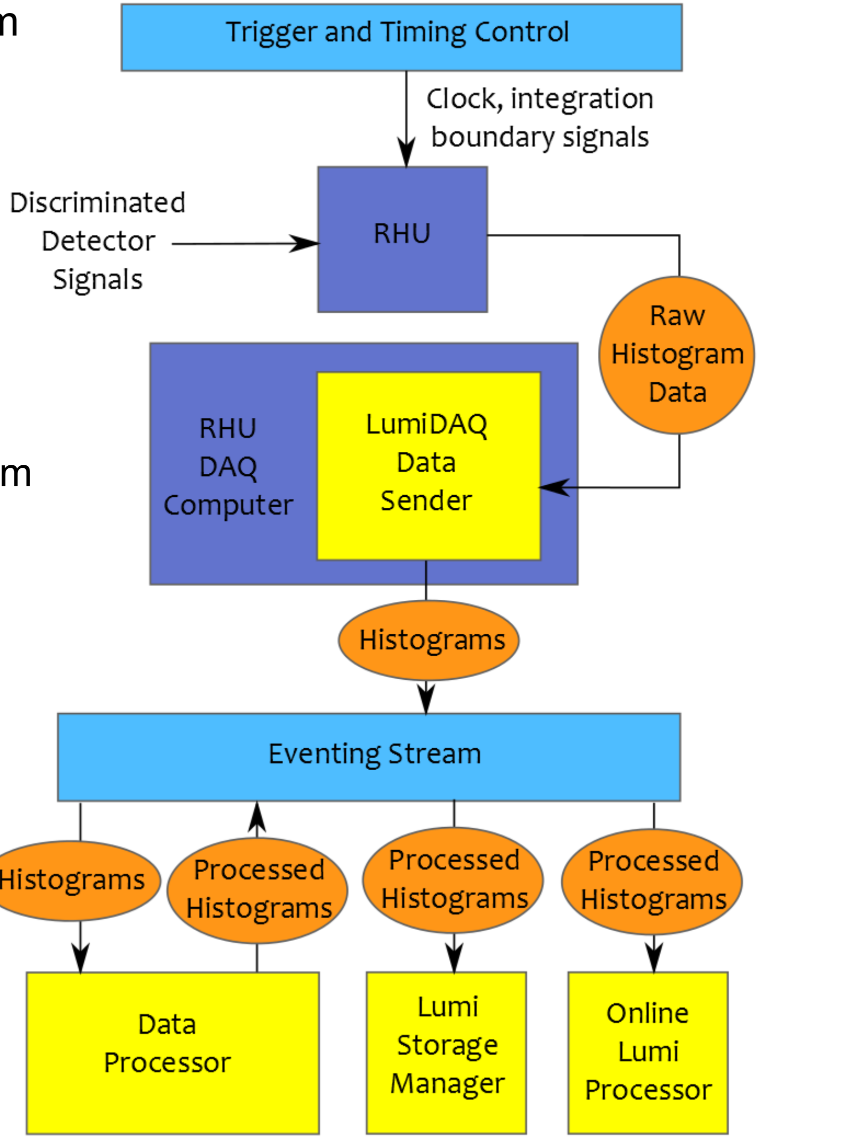


Rev. 2

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
- Eventing stream receives and transmits data to downstream subscribers for processing, storage
- Software framework and components currently being developed





Conclusions

Many improvements in the works to increase BCM1F effectiveness as luminometer

- Carriage: 48 channels, single semi-rigid PCB
- New fast front end ASIC to reduce inefficiencies
- Back end: Discriminator path in parallel with digitizer peak-finding
- Realtime Histogramming Unit for collection of hit rates
- LumiDAQ integration for calculation, publication, and storage of online luminosity values

Future plans

- Produce carriage PCB, RHU boards over next few months
- Synchronize RHU within LumiDAQ framework
- Converge on backend hardware
- Install BCM1F in CMS this fall