Bunch-by-bunch Luminosity with BCM1F

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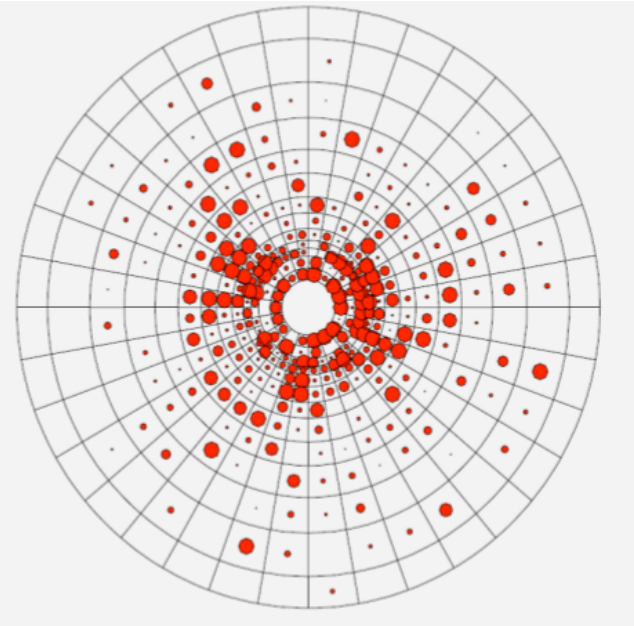
Basic idea for a BCM1F luminostiy measurement

- Isolate colliding bunches
- Determineu BCM1F-measurable quantity that correlates with luminosity.
- Deliver luminosity on a bunch-by-bunch basis.

HF online luminosity measurement



HF characteristics

- Coverage over $3 < |\eta| < 5$ at $z = \pm 5.5$m
- 864 towers
- 11.2 m from IP
- Lumi calibration from Van Der Meers scan

The HF luminosity determination has been done in two ways...

- Zero counting:
  Count the average fraction of empty towers per BX.
  Described in more detail later...
- $\langle E_T \rangle$ per HF tower:
  Scales directly with luminosity.
  To improve linearity, only the inner 4 η rings are used.

Zero counting

Given that the mean number of interactions per bx is,

$$\mu \equiv \frac{\langle N \rangle}{N_{BX}} = \frac{\sigma_{\mathrm{mb}} L}{f_{BX}} \tag{1}$$

the probability of a given number of interactions, n, is poisson distributed,

$$p(n;\mu) = \frac{\mu^n e^{-\mu}}{n!} \tag{2}$$

we can deduce that,

$$\text{for } n = 0 \Rightarrow \mu = -\log[p(0)] \tag{3}$$

This allows us to determine the average number of interactions, and thus the luminosity, by counting the number of crossings with no interaction.

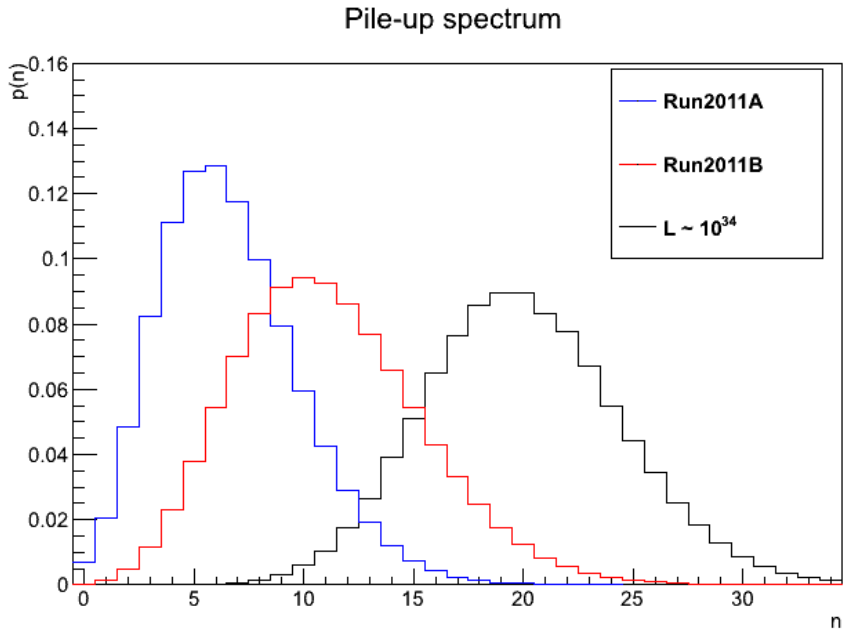
From the perspective of the BCM1F, how do we measure this?

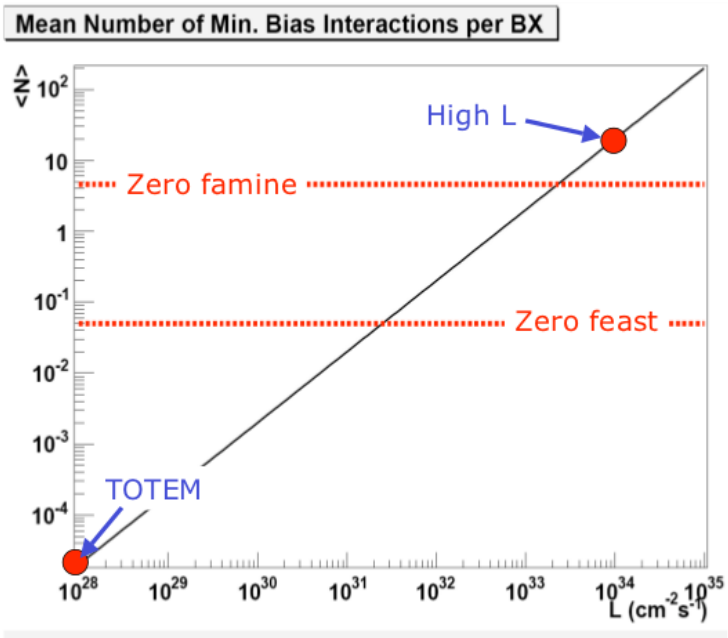
Similar to the case of HF, we can count the average fraction of unoccupied diamonds per bunch crossing. Or given our limited acceptance, the average number of crossings without any hits.

Zero counting (cont.)

Effectiveness of the technique diminishes with increasing luminostiy...

- $p(0) \sim 0.01$ when $\mu \sim 5$
- when $\mu \sim 20$ (expected at design lumi), $p(0) \sim 2 \times 10^{-9}$





Overcome "zero starvation" by measuring fractional BCM1F occupancy.

A rough estimate...

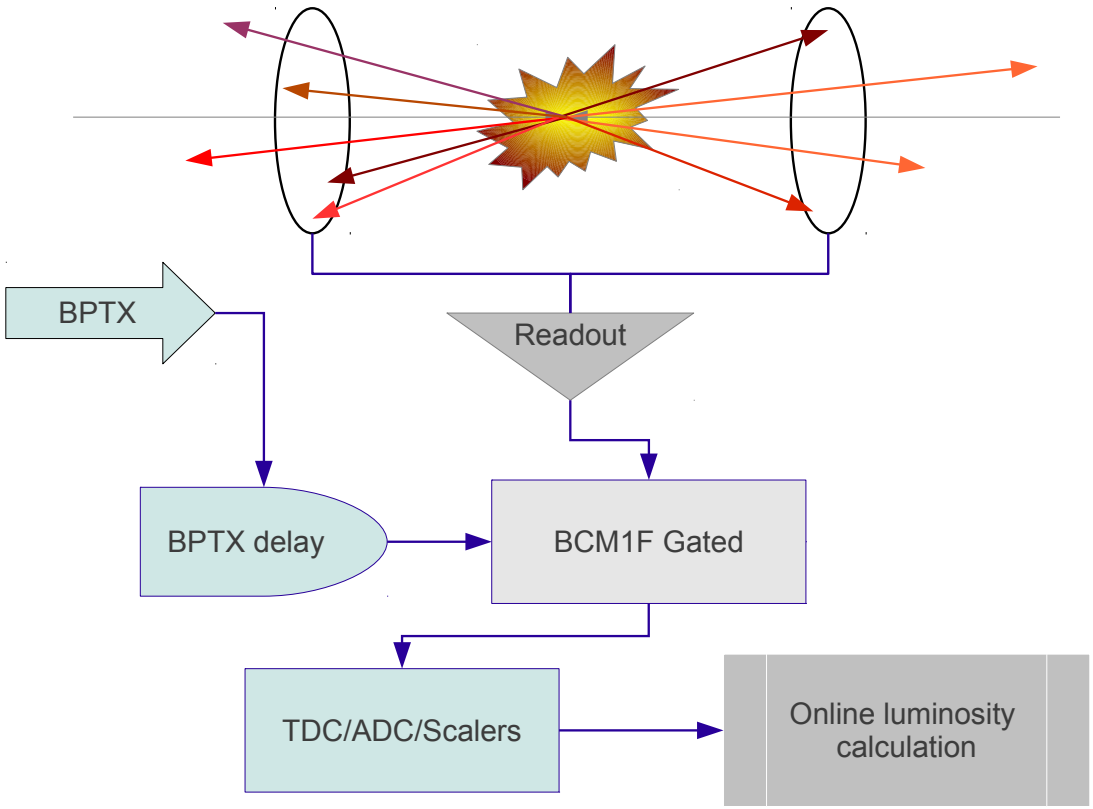
The rate at which we publish data is dependent on how precise of a number we want. That is if we want 1% uncertainty on our published number (per bx), we must first wait to acquire a certain amount of data. Consider the case of $\mu \simeq 20$,

The simple case: Count BCM1F zero hits

At $L \simeq 10^{33}$, there is a $\sim 2\%$ chance of seeing a hit in a single BCM1F diamond per bunch crossing (within 12 ns window).

- expect an average rate of about 1.6 hits per bx at design luminosity ($L \simeq 10^{34}$ cm^{-2} s^{-1}).
- assuming that the number of hits in BCM1F is Poisson distributed, this makes a probability of 0.20 to get zero hits total.
- Ideally (no deadtime), this means with the requirement of a statistical error on the zero counting of 5%, we can publish at a rate of 1 Hz.

BCM1F lumi datastream



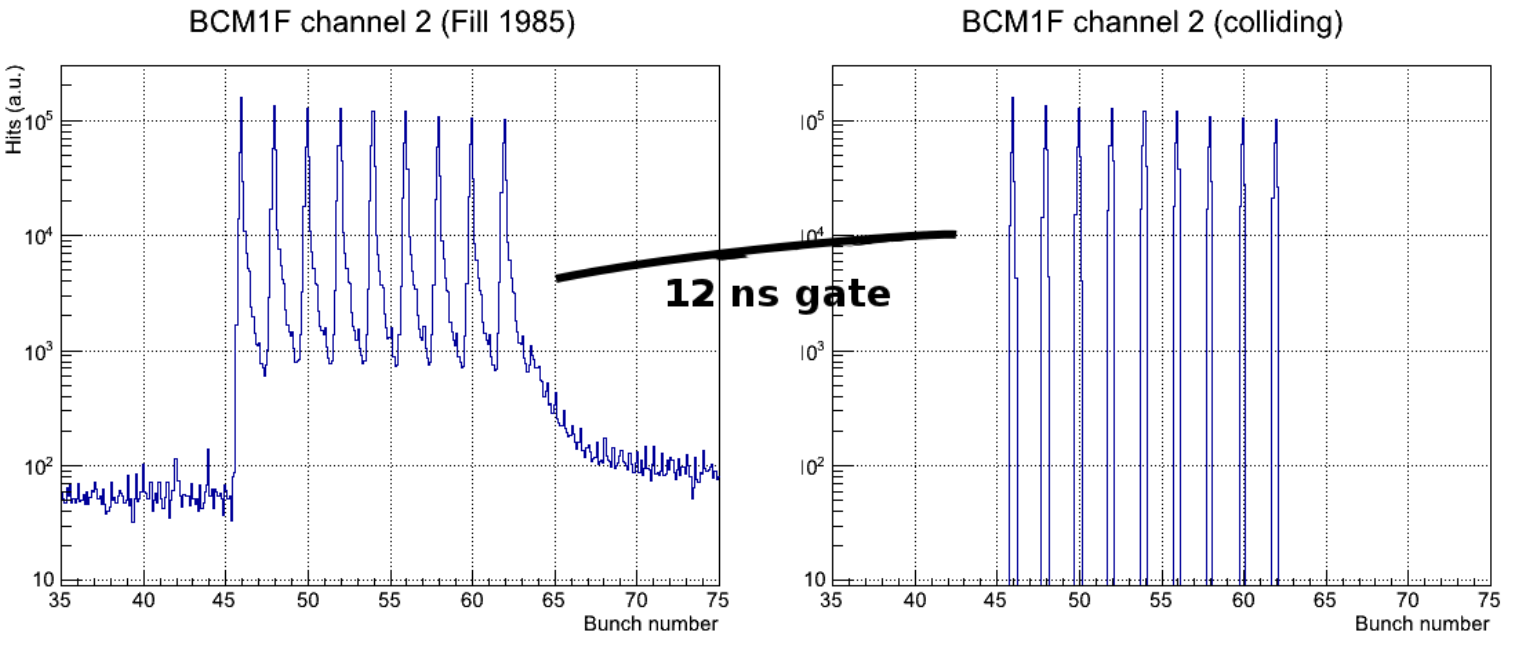
Readout summary:

- outputs from bcm1f and bptx
- bcm1f gating crate
- output to TDC/ADC
- to pc for software analysis and data reduction
- output to several (size of 3653) arrays/histograms for data consumers
  - 1min/10min average

BCM1F gated signals

As in the beam gas measurement, we exploit the BPTX signals to trigger on colliding bunches. This is done by,

- checking for coincidence of bptx1 AND bptx2
- delay by ∼600 ns
- look for BCM1F hits in 12 ns window



For the fill scheme above (1318 colliding), there is a data reduction of about 15%.

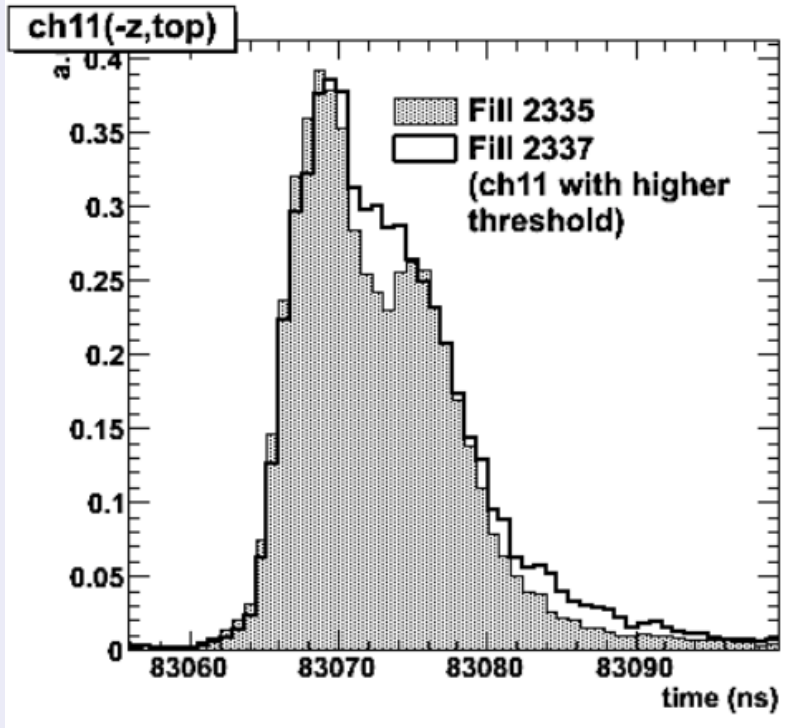
BCM1F TDC

Essential for bunch-by-bunch lumi calculation. Two options...

TDC as a TDC(!)

The obvious choice, but has issues...

- interference effects between TDC and other modules observed
- performance deterioration at higher rates
- extraneous features $\longrightarrow$



Hopefully, work by Zeuthen will resolve many of the issues so that we can utilize a similar setup for the lumi measurement.

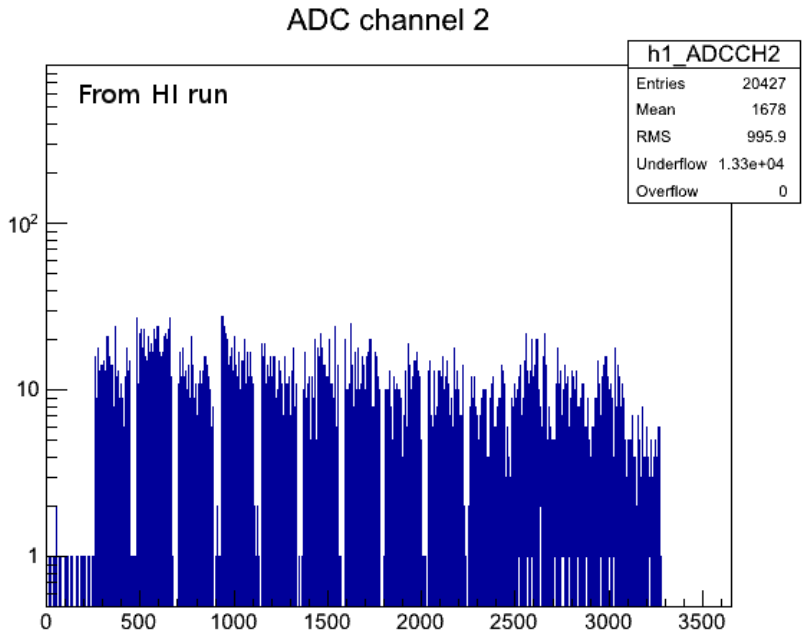
ADC as TDC

A possible alternative is to configure an ADC to run as a TDC. This method has shown some preliminary promise, but still needs work.

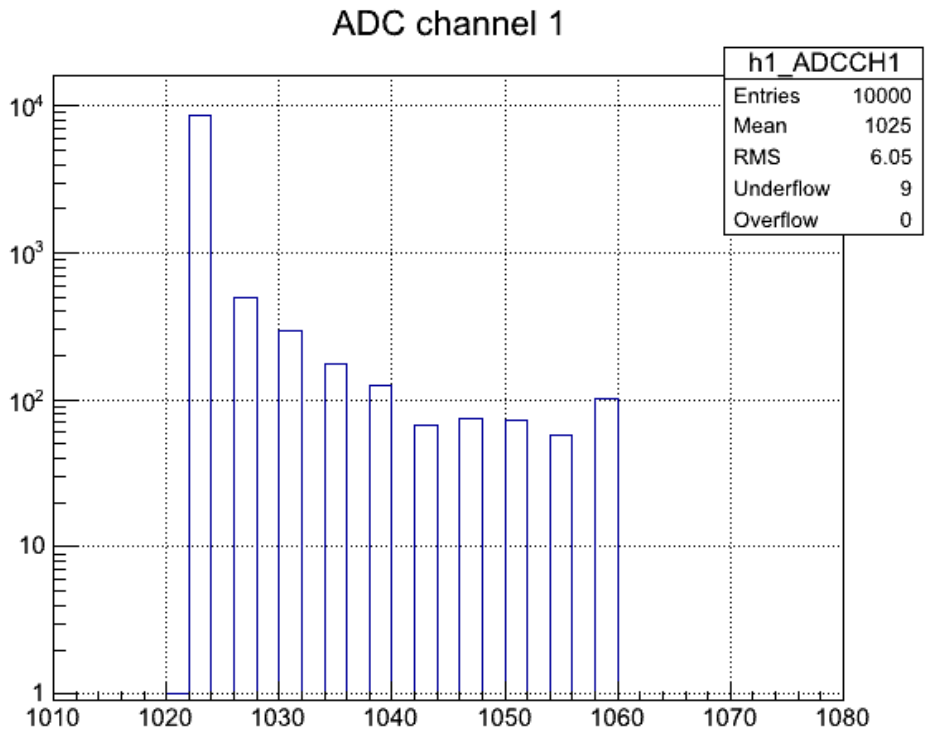
ADC test setup

CAEN V1721 digitizer

- Data reading in Block mode (BLT)
- Trigger on orbit
- Use bunch clock instead of internal clock (needs to be implemented)
- 4800 samples after trigger (likely to change)
- Find minimum of all samples below baseline after trigger



The current configuration is biased towards earlier signals.



Changes for the near term

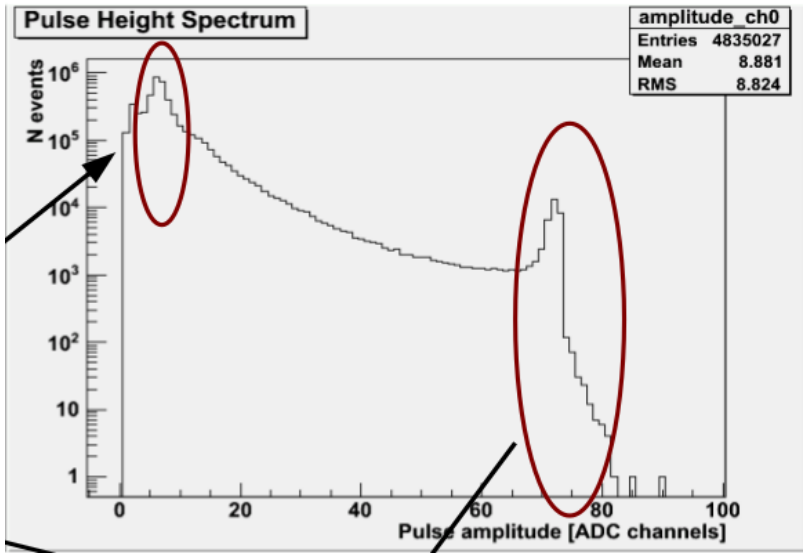
- DAC calibration for flat baseline
- Implement zero suppression
- Consider entire waveform after trigger
- Set software threshold for accepting signal pulse

BCM1F systematics

The reliability of the delivered number will rely on a thorough understanding of the systematics

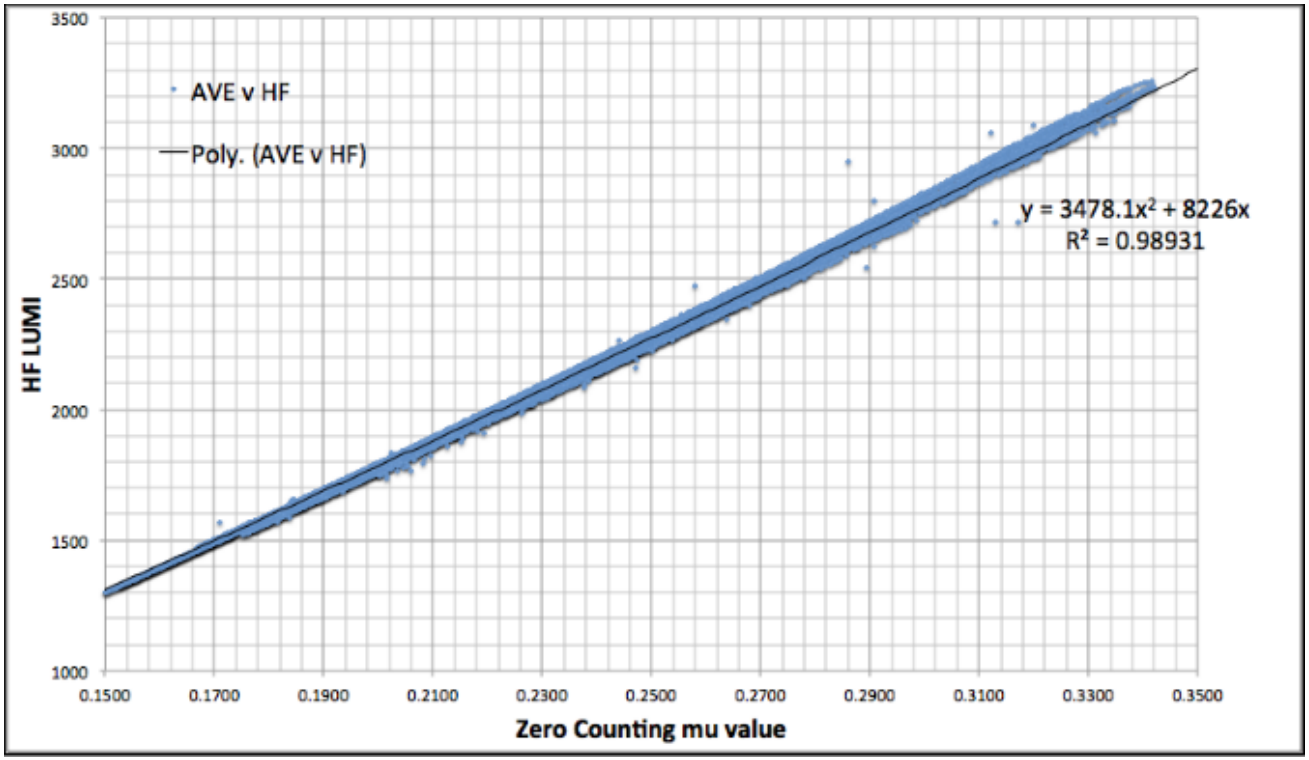
Possible sources of systematics

- Lumi calibration/normalization
- detection efficiency
- Deadtime
  - Saturation of front-end electronics
  - ADC time above threshold
  - Readout
- discriminator threshold
- Albedo
- Beam gas



Results from 2011

We already have some very promising results from the 2011 run.



The available data uses the gated rates of the OR of BCM1F $\pm$z.

- good agreement with HF luminosity
- some deviation from linearity
- limited to OR of +/-z

Conclusions

Making a reliable bunch-by-bunch lumi measurement seems very promising. Plenty of options for improvement.

Things to do before beam...

- Implement both TDC options in lab
  - Optimize configuration
  - Understand limitations
- Establish normalization
- Characterize systematics
- Stress test readout