IceTop Muon Calibration

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Cosmic Ray Workshop, Zeuthen, February 23 2010

IceTop Tanks and Stations

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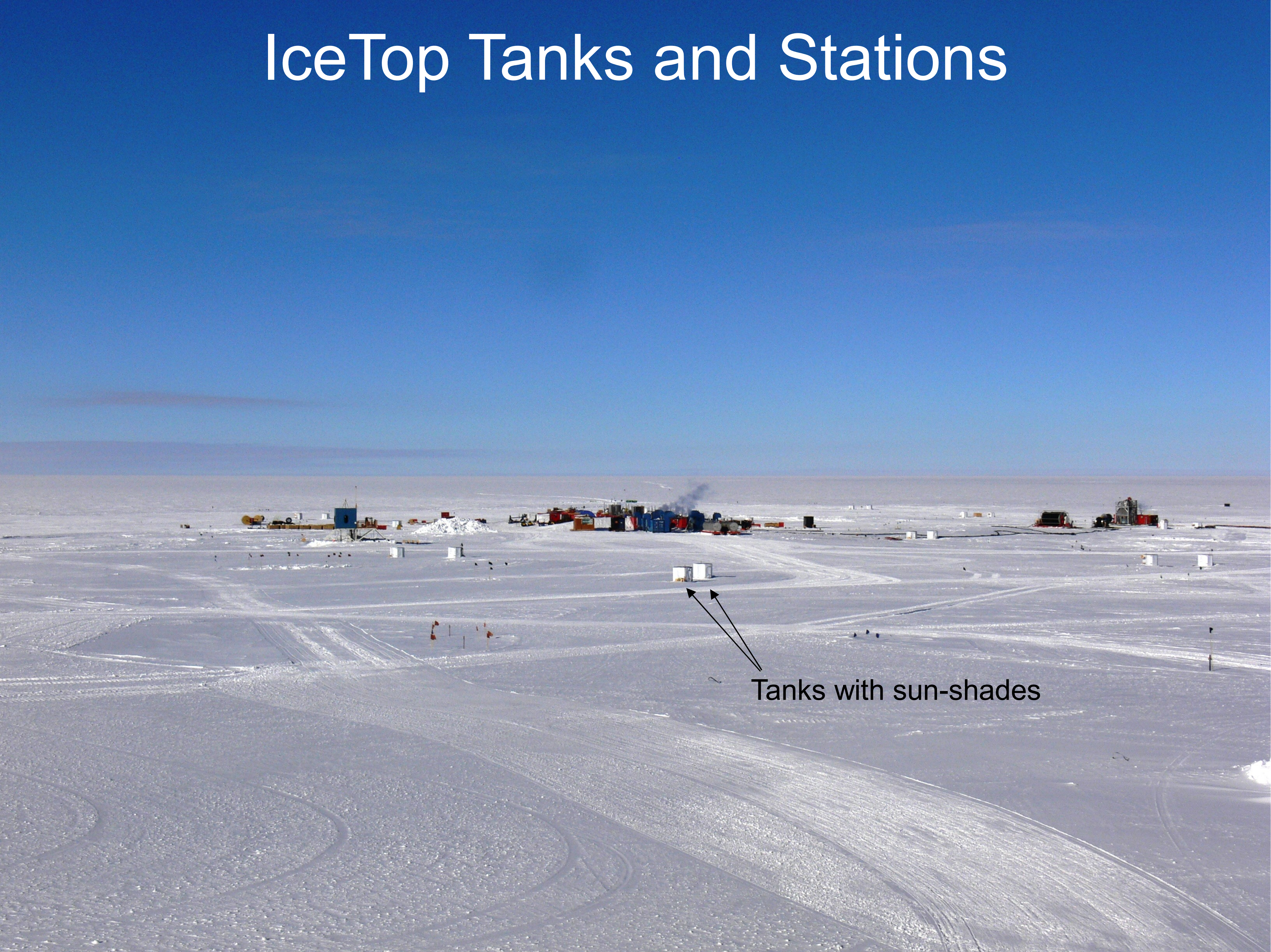

IceTop Tanks and Stations

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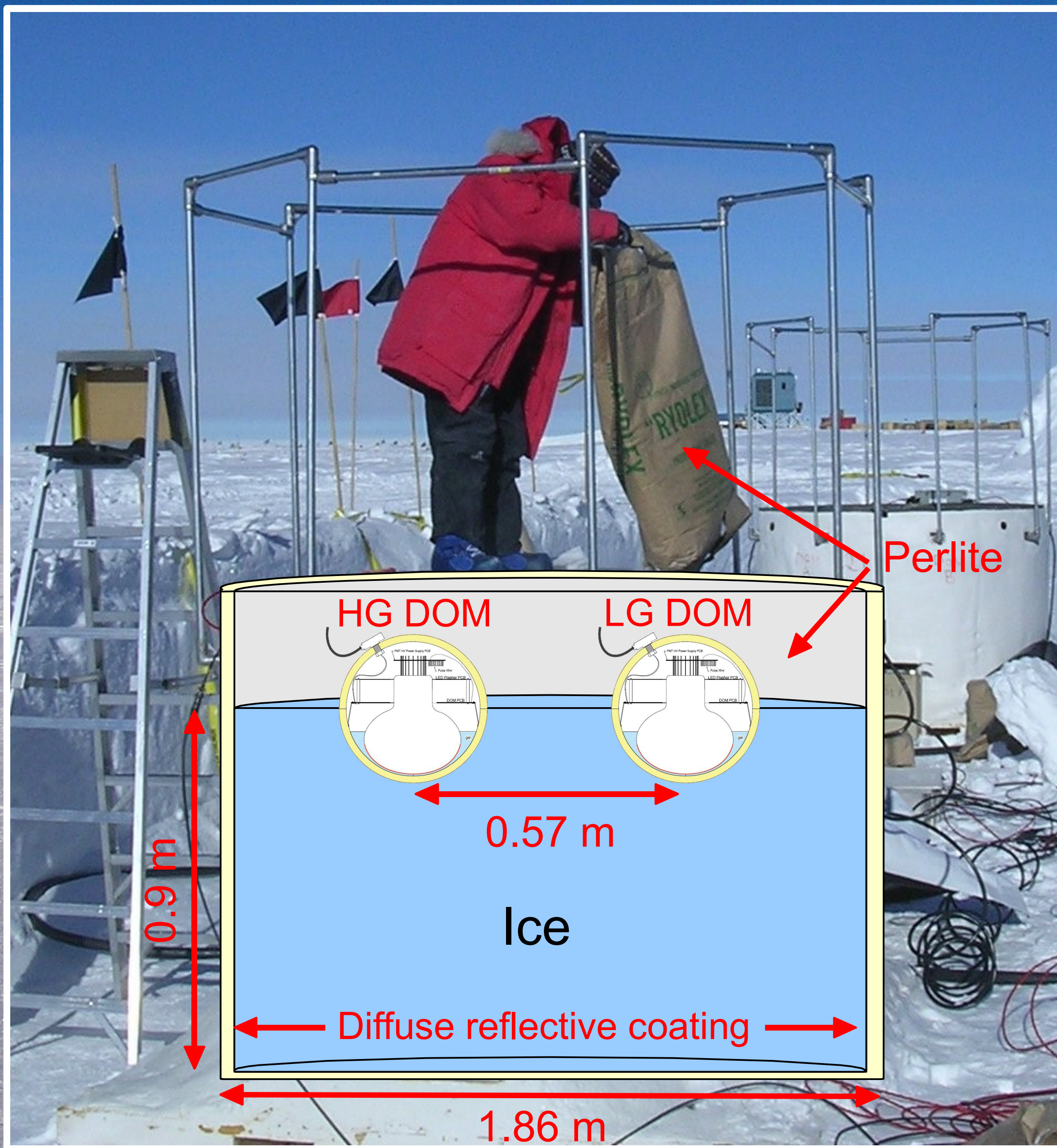
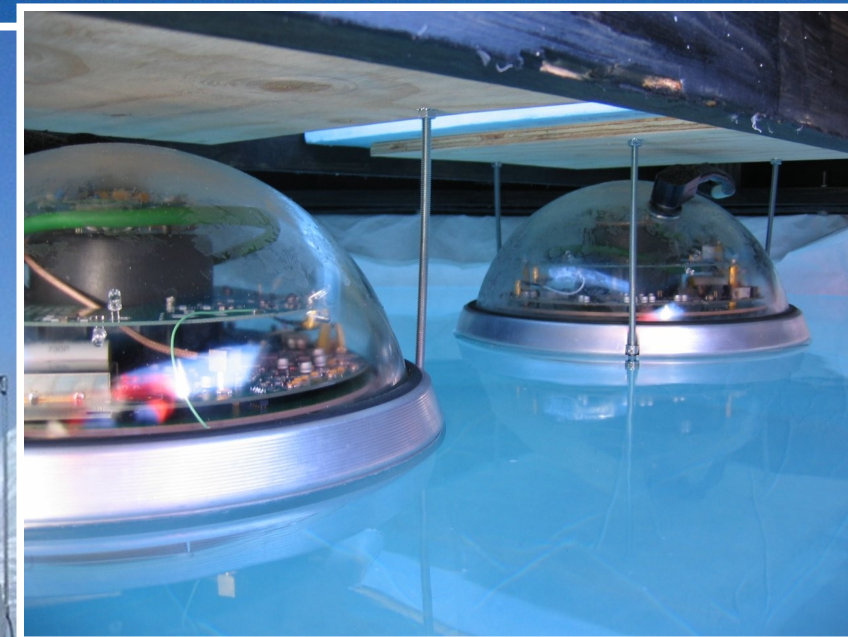
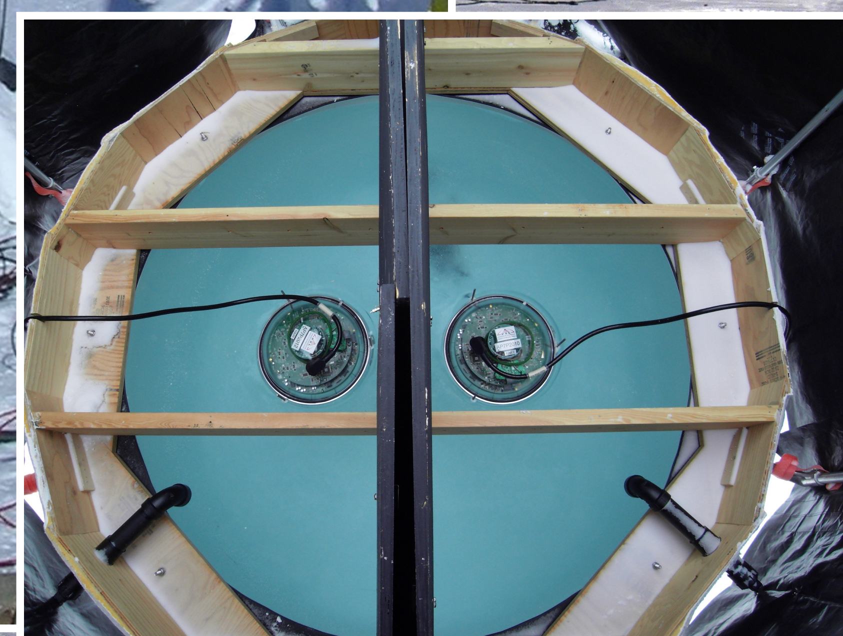
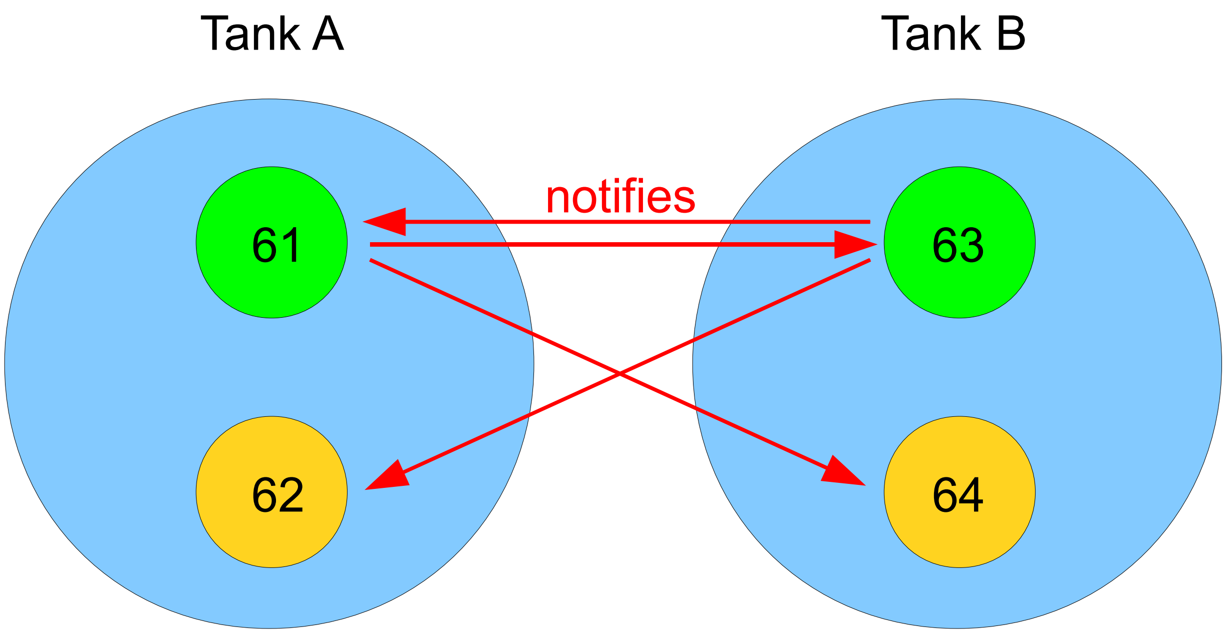






(IceTop) Local Coincidence



LC window: Trigger time +/- 1μs

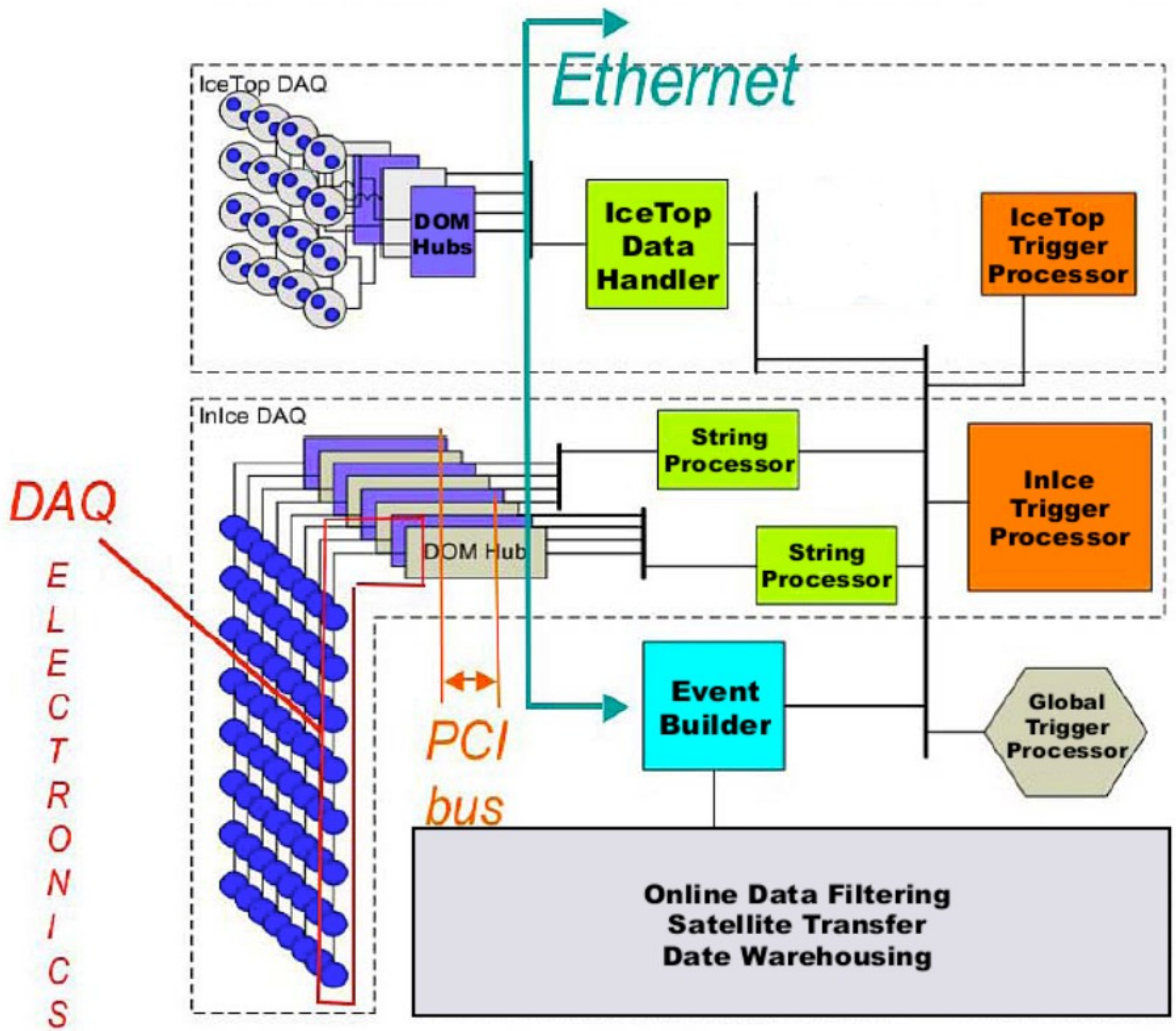
<u>High Gain:</u>

- HV: ~ 1250 V
- Gain: 5E6
- Disc. Thr.: ~ 20 PE
- Disc. Rate: ~ 1400 Hz
- LC Rate: ~ 20 Hz

<u>Low Gain:</u>

- HV: ~ 750 V
- Gain: 1E5
- Disc. Thr.: ~ 200 PE
- Disc. Rate: 30 - 100 Hz
- LC Rate: ~ 7 Hz

The IceCube DAQ System



IceTop:

- Simple Majority Trigger
  - 6 LC hits (HG or LG) within 5 μs
  - Rate: ~ 22 Hz (for IT59)
  - Readout window: +/- 10 μs
- MinBias Trigger
  - Random trigger (prescale 10000)
  - Rate: ~ 0.2 Hz (for IT59)
  - Readout window: +/- 10 μs
- Calibration Trigger
  - Single minimum bias hits
  - Rate: ~ 22 Hz (for IT59)
  - Readout window: +/- 1 μs

InIce:

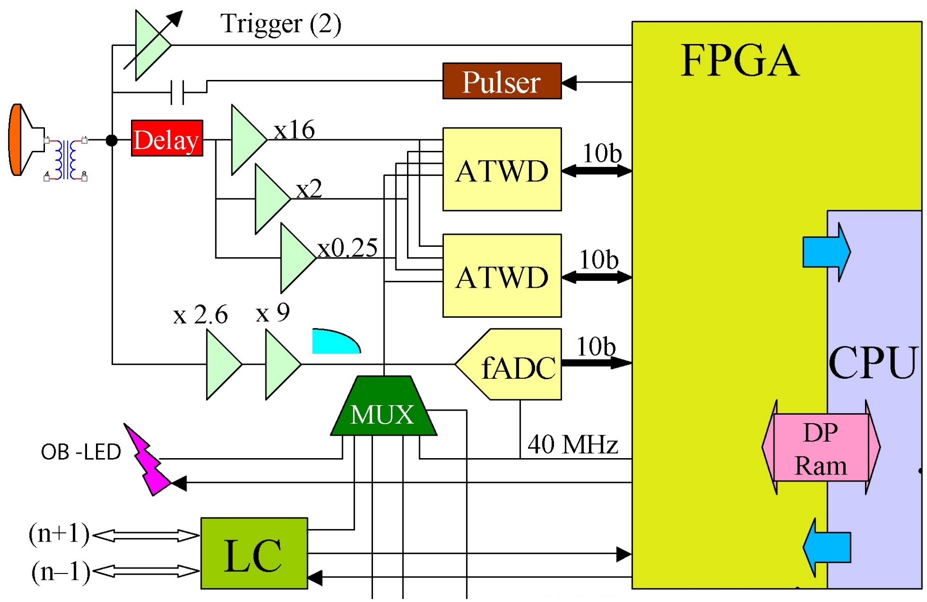
- Simple Majority Trigger
  - 8 LC hits within 5 μs
  - Rate: ~ 1850 Hz (for IT59)
  - Readout window: [-4 μs, +6 μs]
- Various other triggers ...

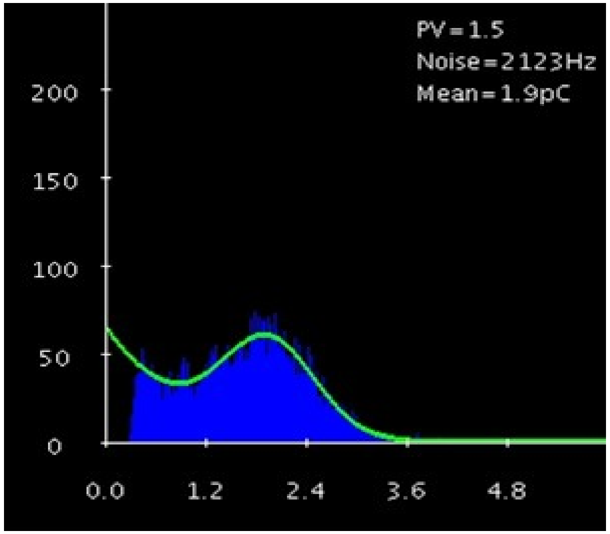
IceTop gets always read out when IceCube triggers and vice versa.

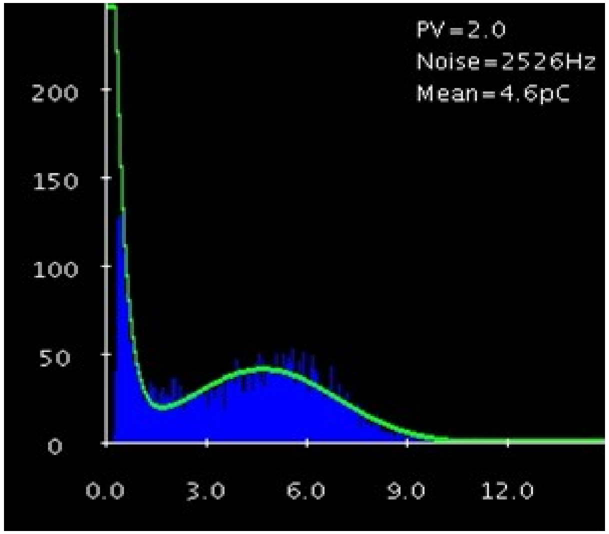
DOMCal

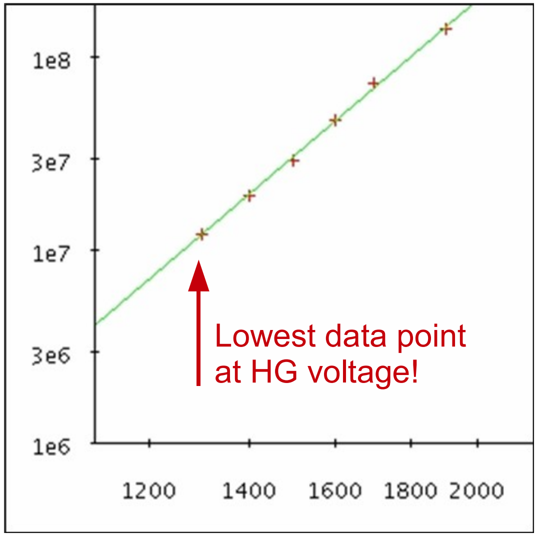
<u>DOMCal calibrates (once a month):</u>

- ATWD
  - Voltage
  - Sampling frequency
- FADC
- Channel Gains (Amplifiers)
- PMT gain (→ Charge to PE)
- Transit time









→ IceTop muon calibration on-top of DOMCal (PE → VEM)

Challenges for the Muon Calibration

- LC suppresses single muon hits
- LG DOMs cannot resolve the muon peak and their thresholds are also too high
- LG gain calibration not very reliable
- Matching of HG and LG signals

Old method:

- Use different DAQ (TestDAQ) which can operate without LC condition
- Operate LG DOMs at HG voltage (and trust the gain calibration from DOMCal)
- Correct the LG calibration by cross-calibration with HG DOM
- Manually perform these special procedures once a months

Disadvantages:

- TestDAQ data needs to be processed differently to standard physics data
- Physics data taking (of the whole detector) has to be interrupted for special muon runs
- Muon calibration of LG DOMs not very reliable because the operating voltage is below the DOMCal validity range
- Everything is done manually

Automated Muon Calibration

1. Pass a full waveform readout (only HG) after every 8192th local coincidence to the string hub (if it doesn't satisfies LC, otherwise take next non-LC hit)
2. Form a calibration trigger for these "minimum bias" hits and pass them to the online processing and filtering (PnF) farm.
3. Process minimum bias hits as usual physics data and store them in compact data container for satellite transfer.

South Pole

4. Checking for new data and launching of histogramming and fitting procedures by daily cron-jobs.
5. Weekly generation of calibration xml-files and plots for muon calibration web-page.
6. Visually inspect calibration results once a week and insert them in database.

Madison

Fitting the Muon Spectrum

non edge-clipping muons

Landau peak position and width

$$f(x) = p_0 \cdot \left[\frac{1.85}{p_1} \cdot \frac{1}{\exp\left(\frac{x-p_1}{p_2}\right)+1} + Landau(x, p_1, p_2) \right] + p_3 \cdot \exp(p_4 \cdot x)$$

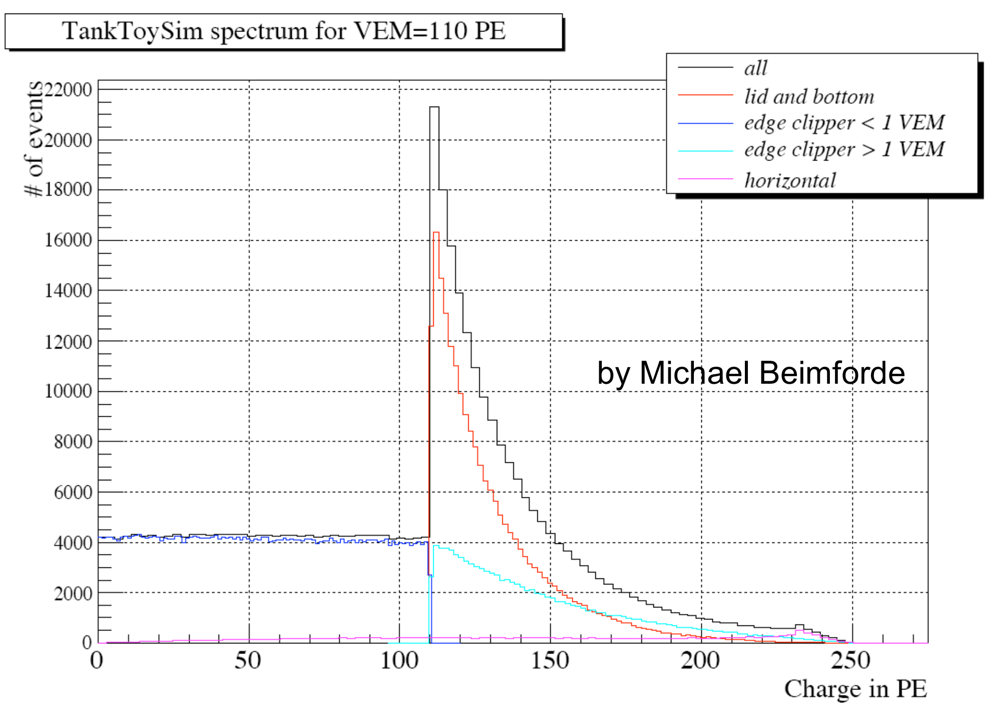
edge clippers

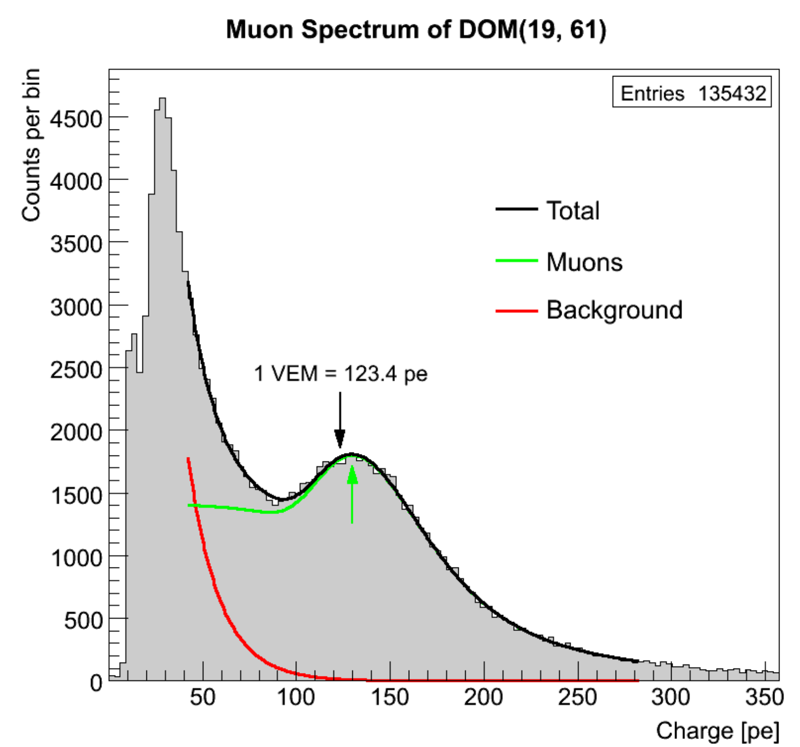
"vertical" muons

Ratio: edge-/non edge clippers

muon signal

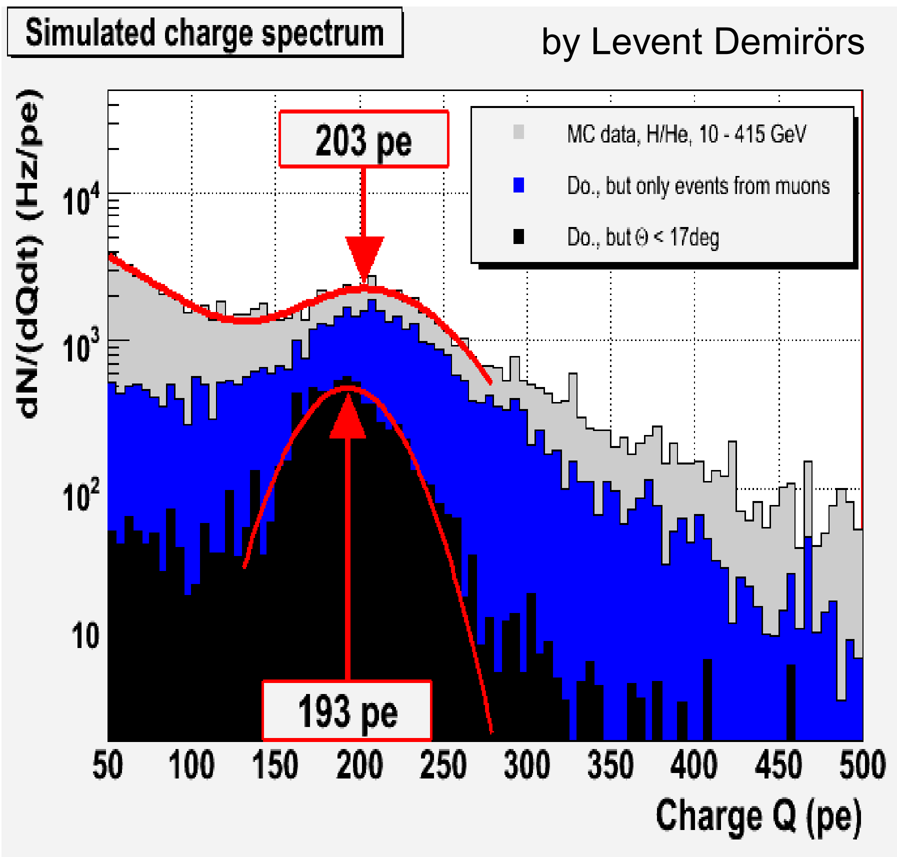
e.m. background



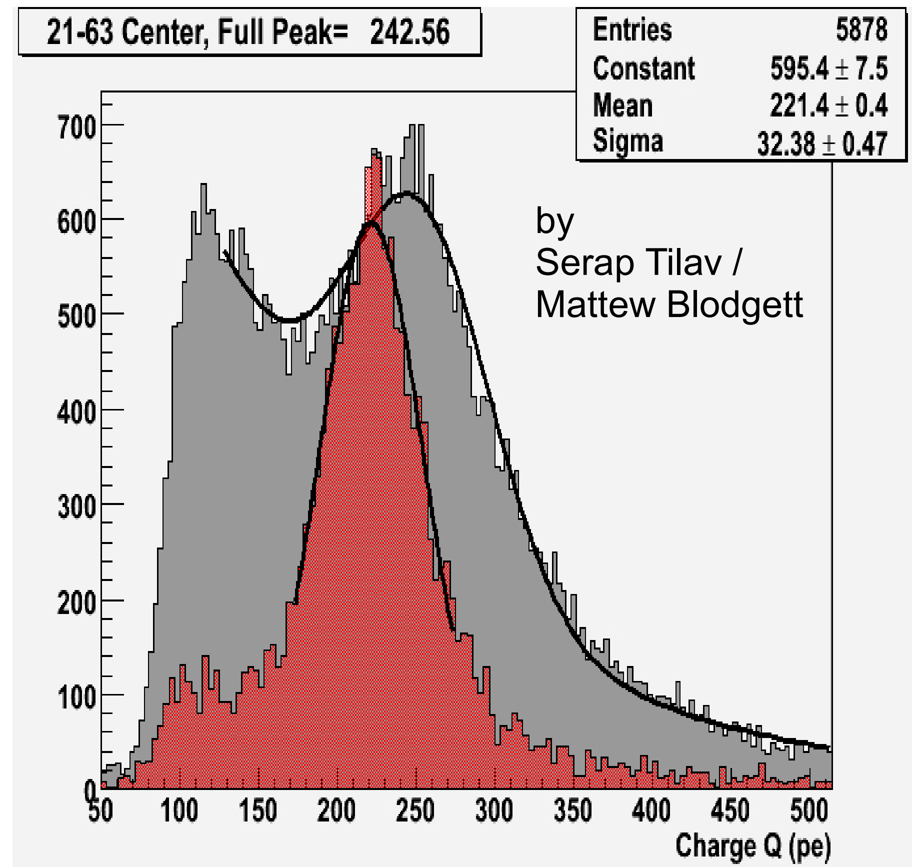


VEM Definition

GEANT4 based simulation

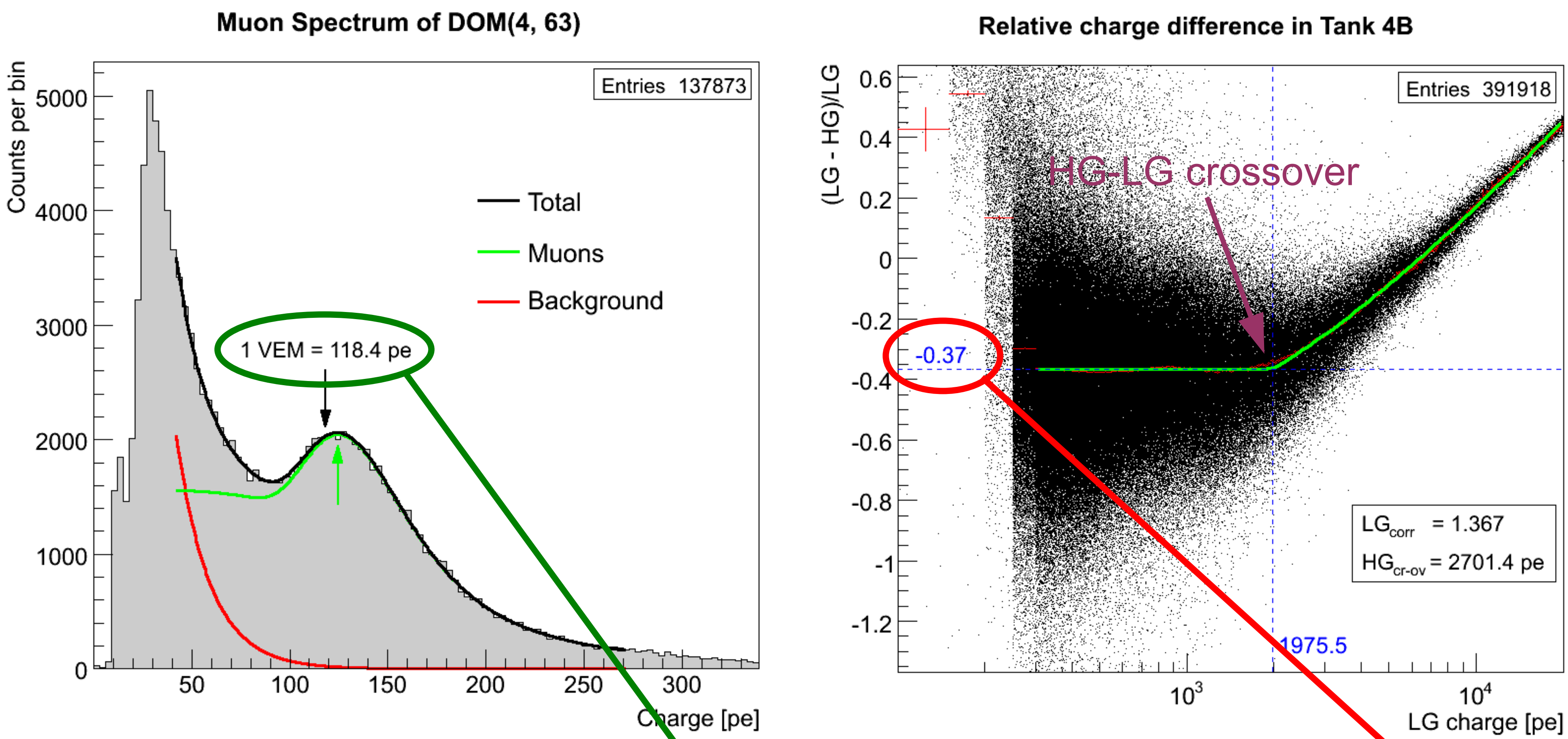


Muon-tagger measurement



$$1\,VEM := 0.95 \times Q_{peak}$$

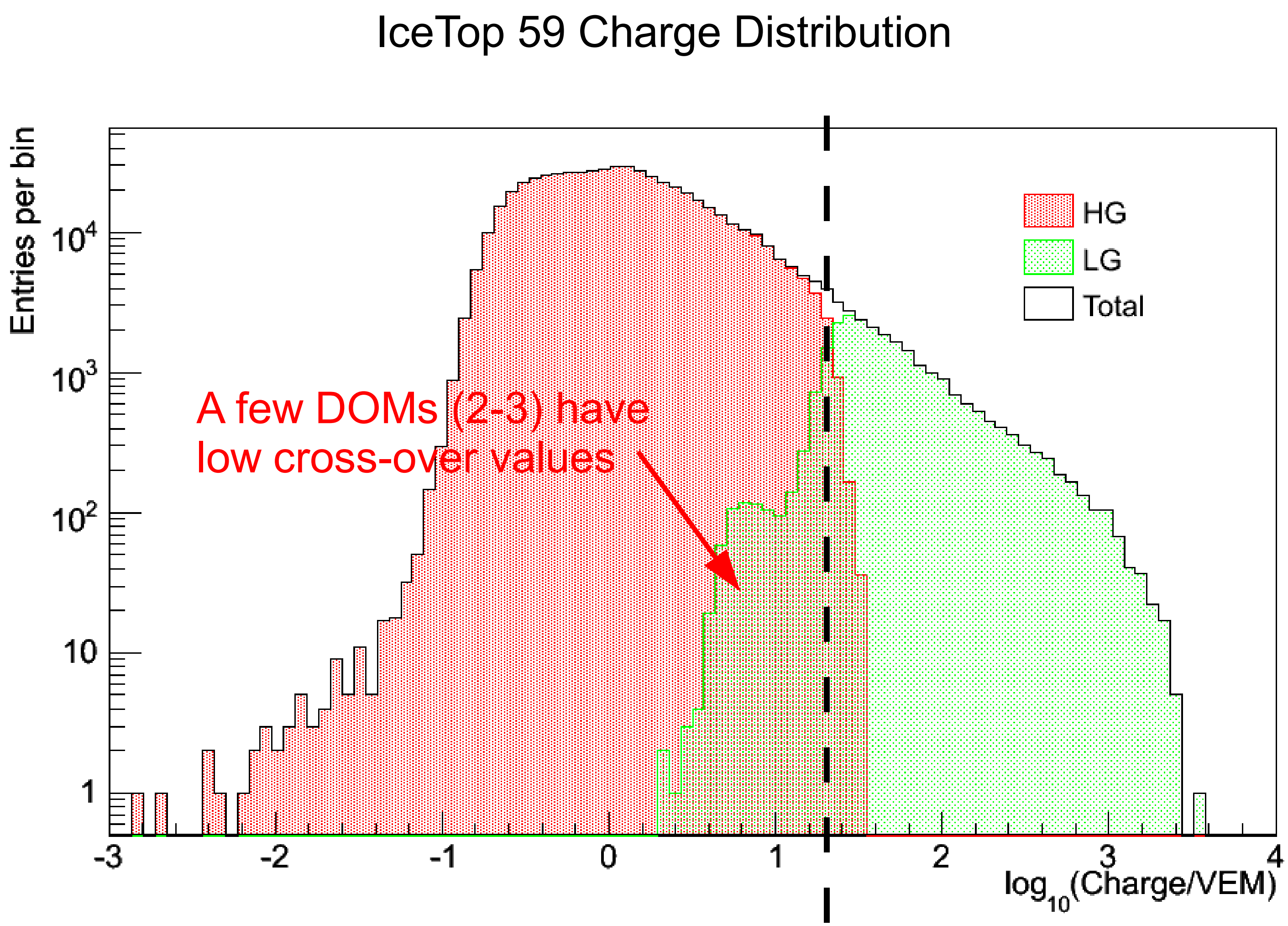
LG Cross-Calibration



$$Q_{HG} = f \cdot Q_{LG} \quad \Rightarrow \quad f = 1 - y_{offset}$$

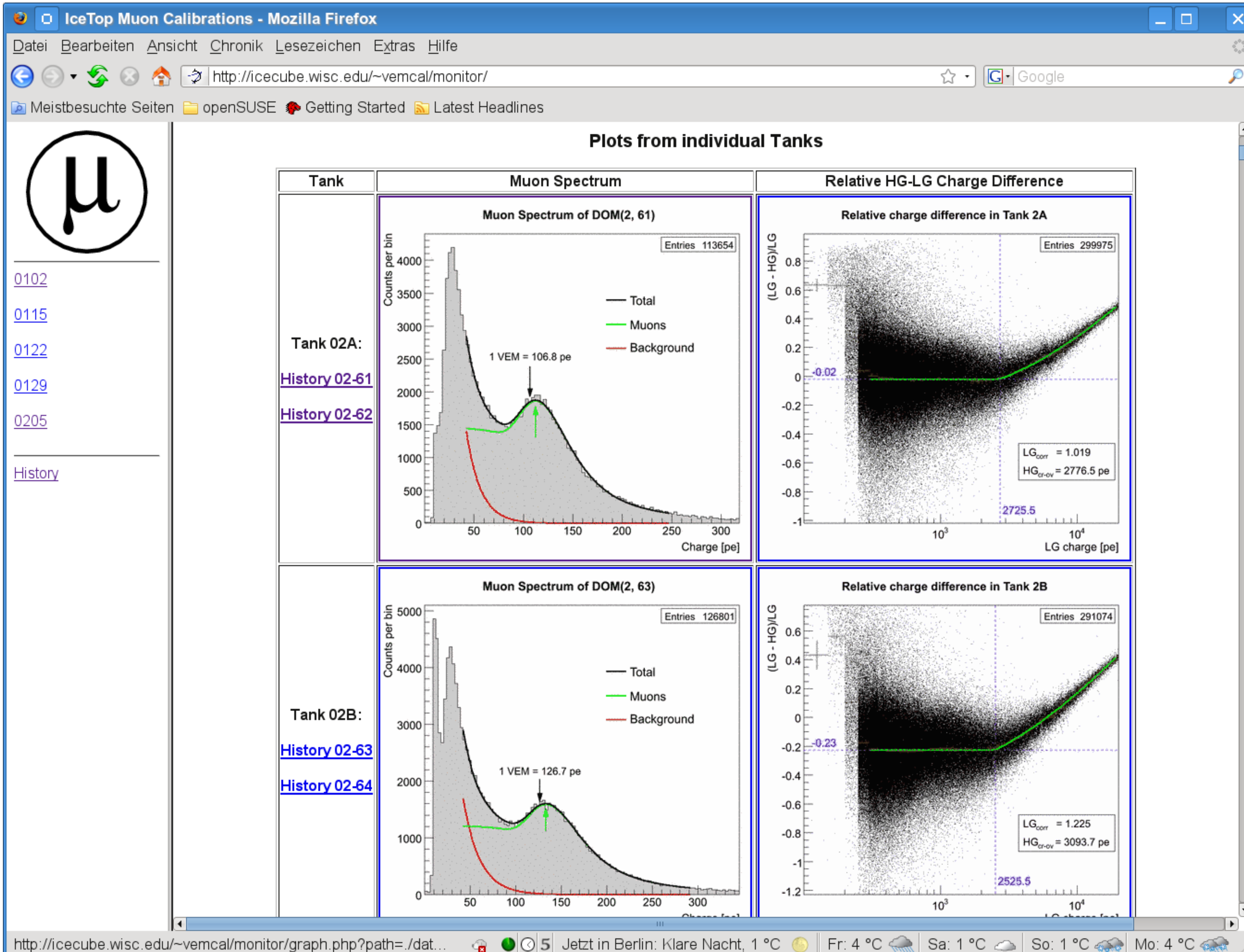
$$VEM_{HG} = f \cdot VEM_{LG} \quad \Rightarrow \quad VEM_{LG} = \frac{VEM_{HG}}{f}$$

HG-LG Crossover

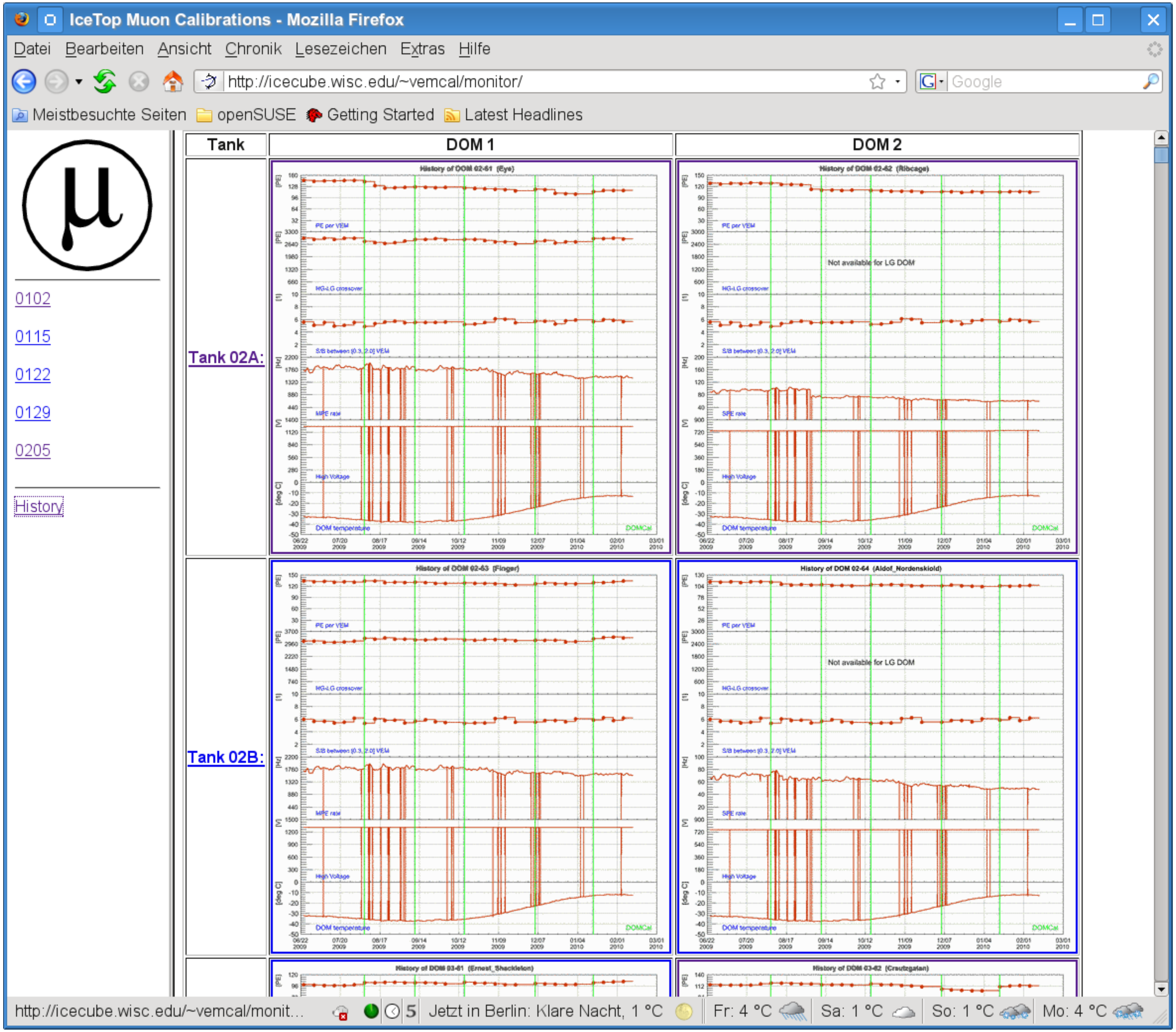


~ 20 VEM (~2500 PE)

Monitoring Web-Page

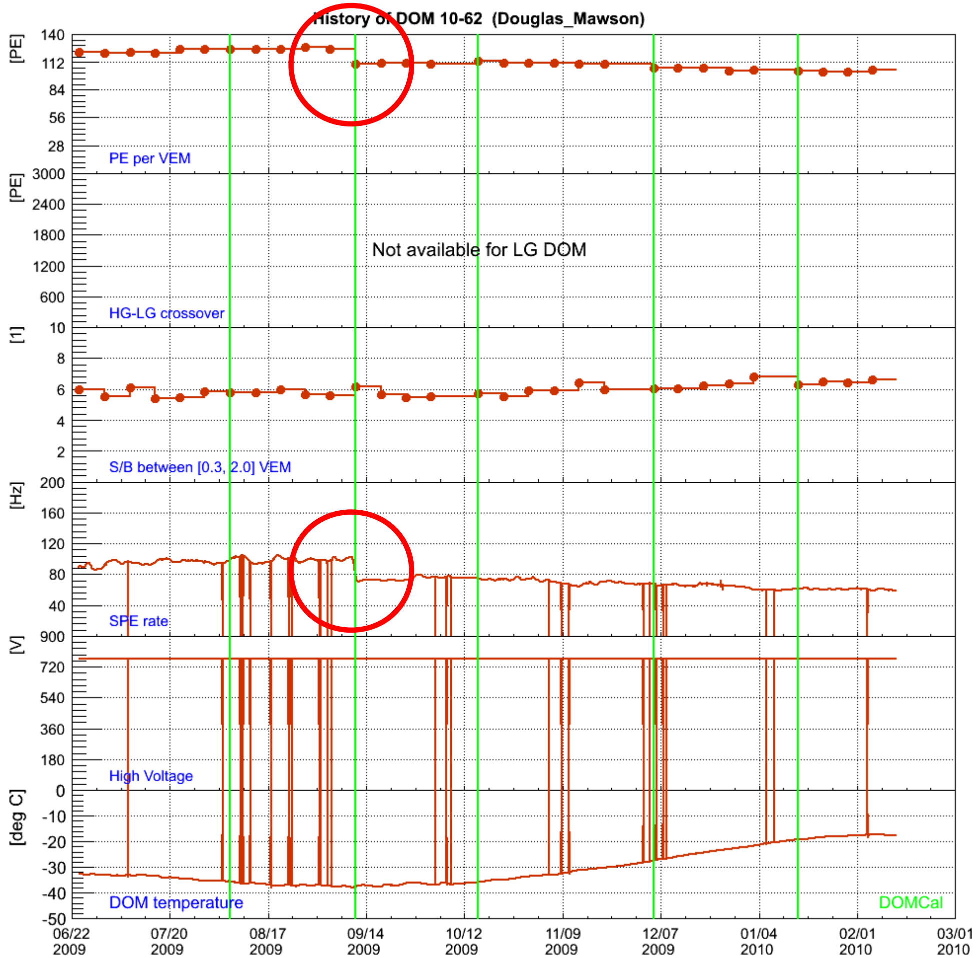


Monitoring Webpage (contd.)

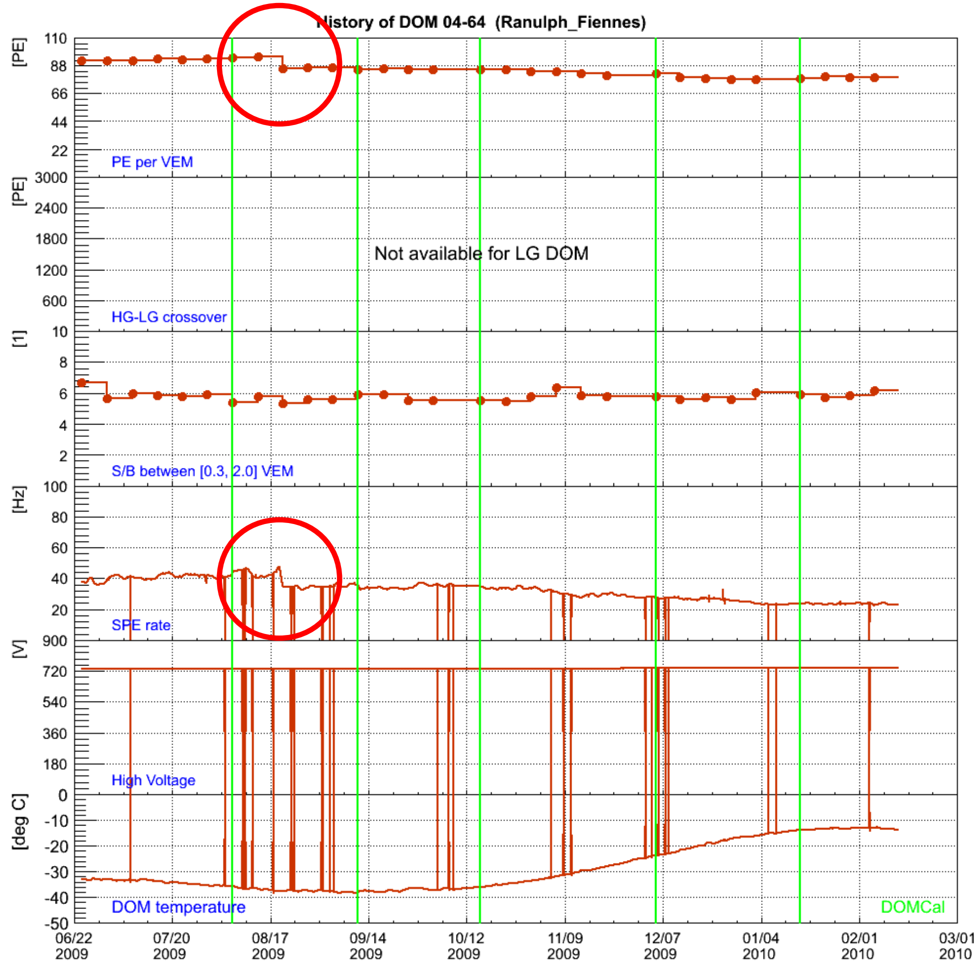


Stability

Changing gain calibration of LG DOM

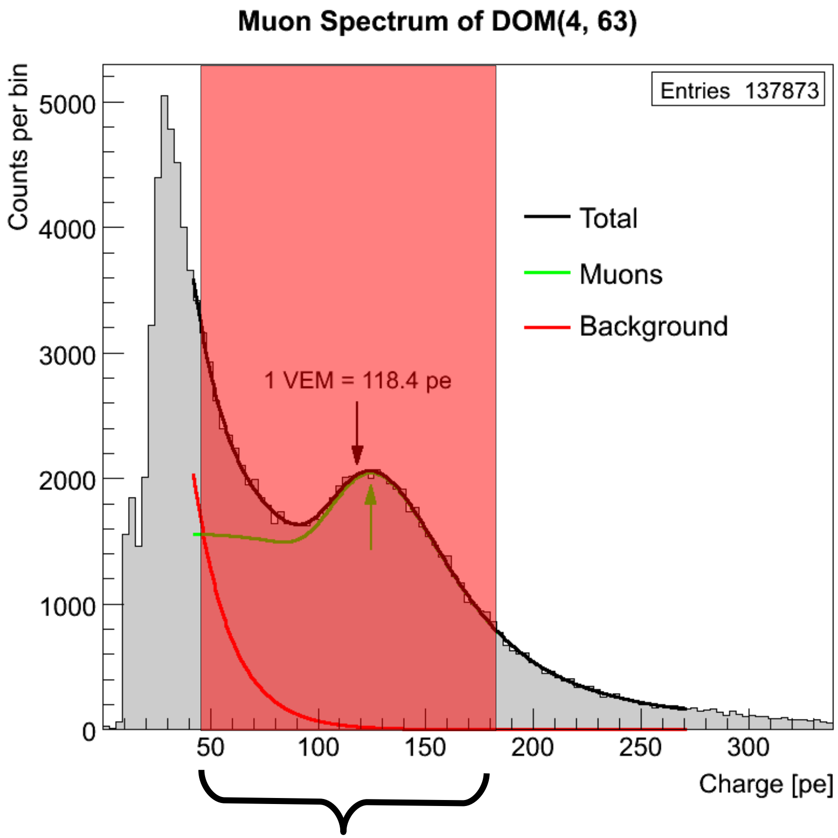


Changing optical properties in Tank ?

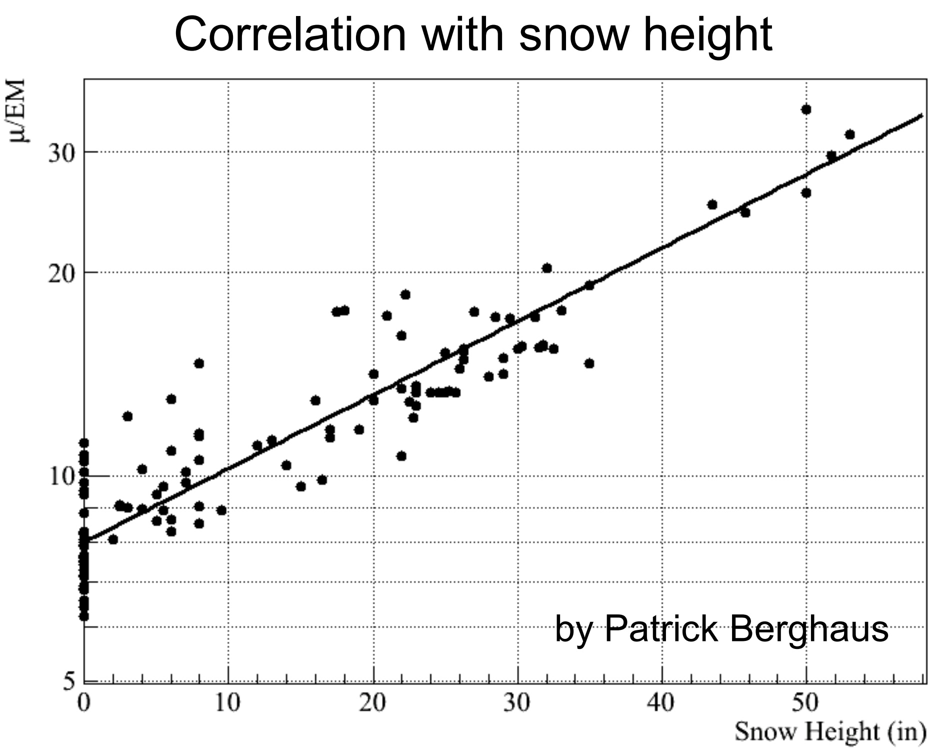


Sensitivity to Snow Depth

Semi-physical fit function allows for separation of muon signal from e.m. background



(0.4, 1.5) VEM



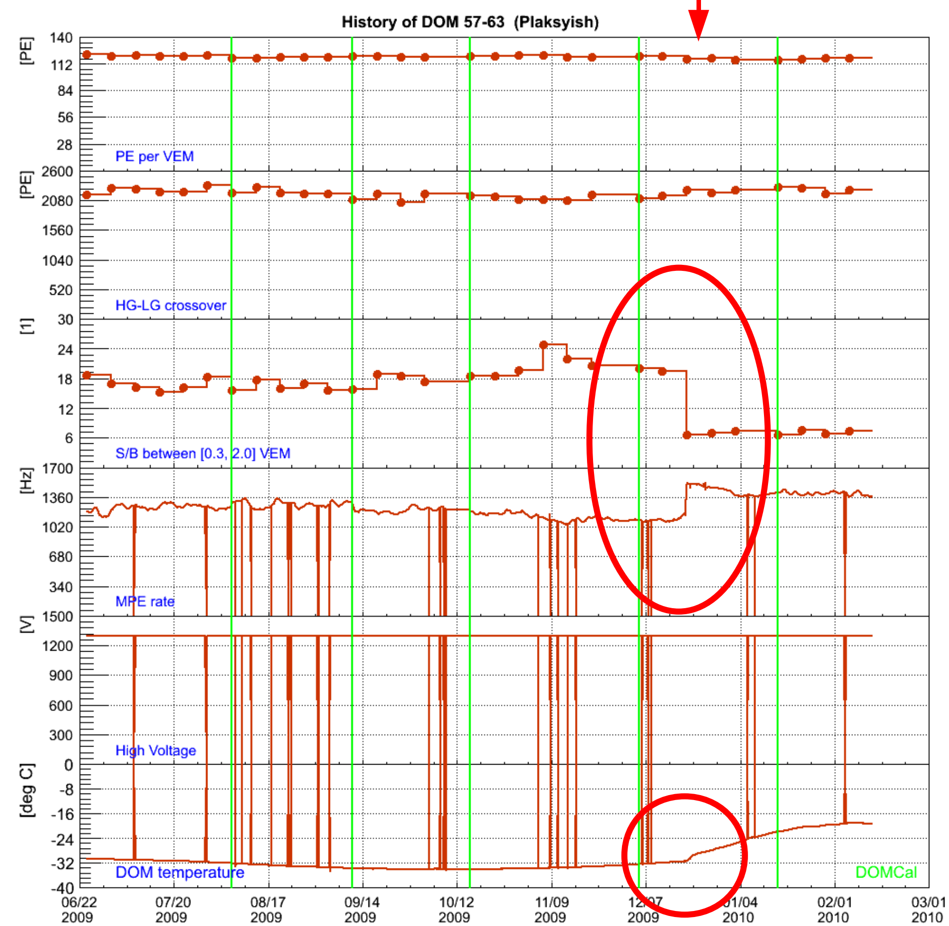
Integration of muon signal S and e.m. background B → S/B

Future: Determination of snow height via Muon/e.m. ratio ?

Sensitivity to Snow Depth (contd.)

Removal of ~ 0.7 m of snow at Station 57

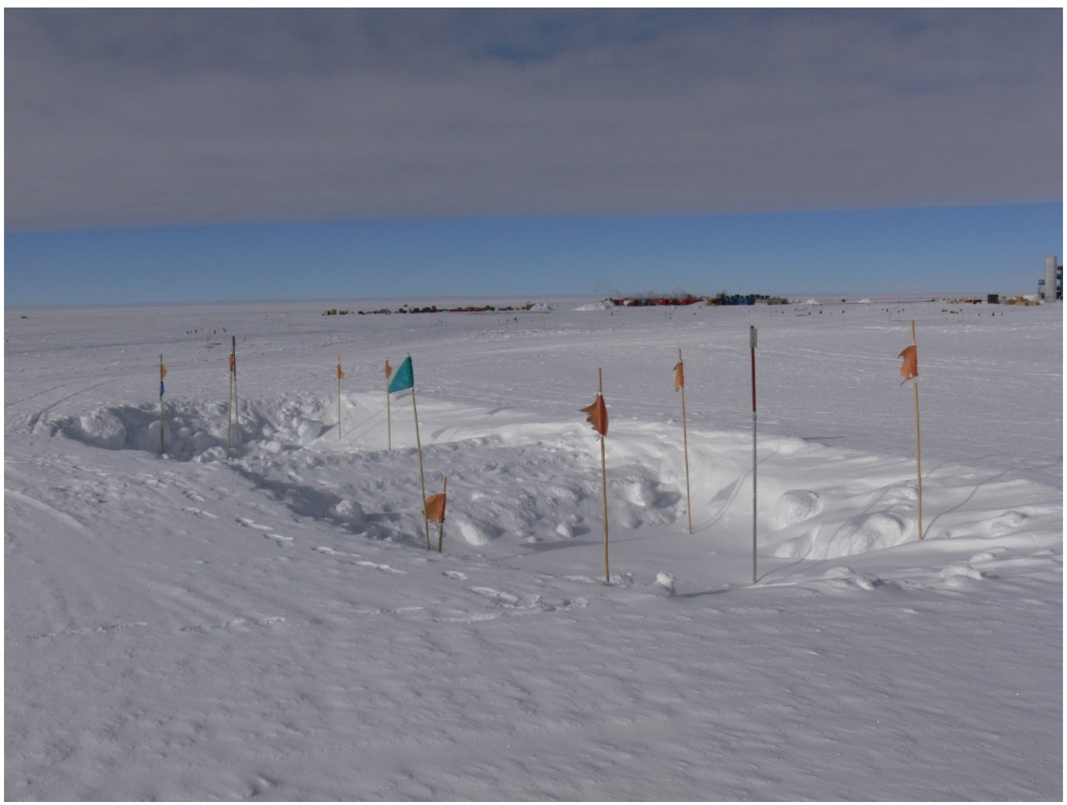
Muon peak unaffected!

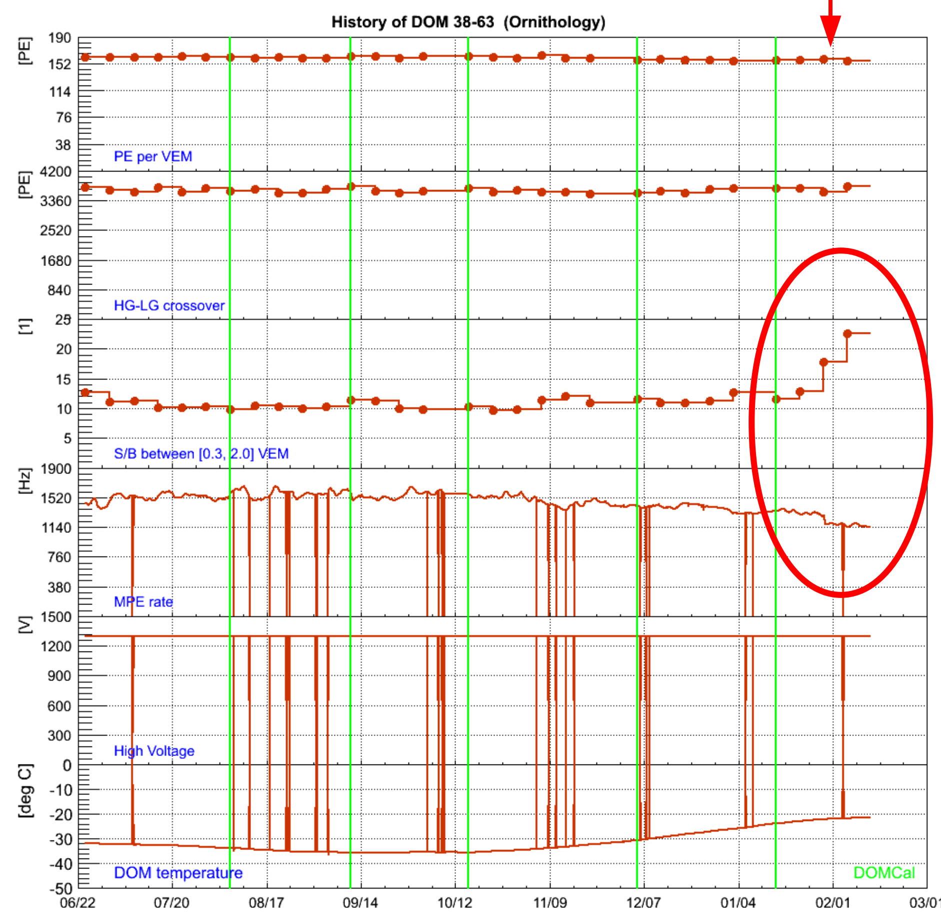


Sensitivity to Snow Depth (contd.)

Back-filling with ~ 0.7 m of snow at Station 38

Muon peak unaffected!





Summary

- Automatic muon calibration operational since start of IC59 (May 20, 2009)
- Advantages:
  - No detector downtime due to muon runs
  - Regular muon calibrations on a weekly basis
  - Intrinsic usage of the correct DOMCal values
  - In-Situ calibration at exactly the same HV-settings as in data taking (→ getting independent of gain calibration)
  - Identical processing chain for muon calibration and physics data
- Muon/e.m ratio sensitive to snow coverage → determination of snow depth?