Muon rate depth dependence update

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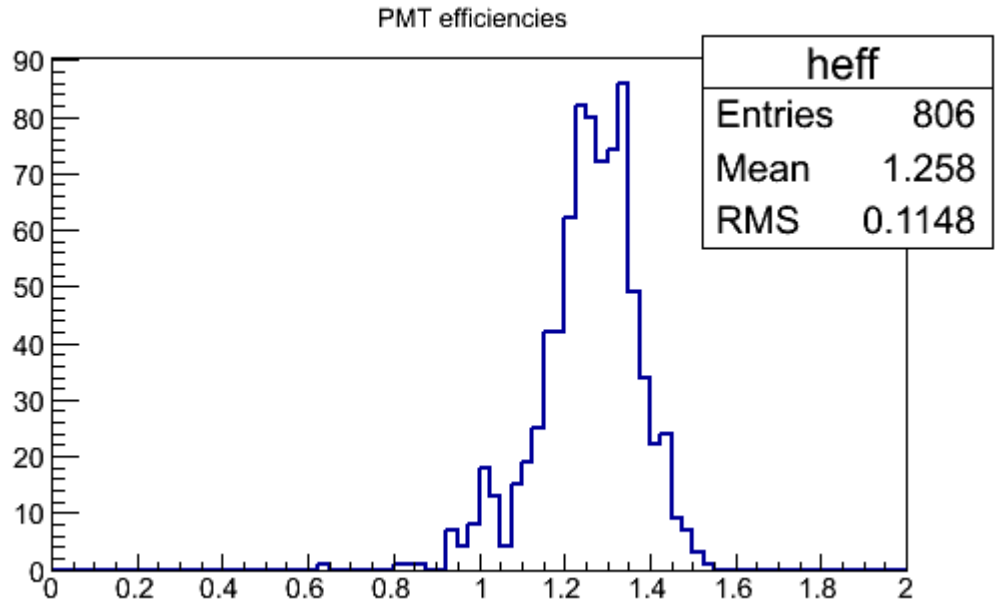
Run selection

- Hand-picked by looking at
  - time streams
  - average PMT rates
  - ToT overview
- Small test sample (7 runs) to base K-40 calibration on
  - 4455-4462 (except 4457)
  - ~14 hours livetime
  - October 19th + 20th
- Extra runs added to get more statistics
  - total 34 runs (last one is 4499, October 23d)
  - 67.5 hours livetime
- Irregularities
  - S2D2 (known to behave strangely)

the **ToTs** for these (and most other) new runs are too low, i.e. the HV tuning is off.

K-40 calibration (Karel)

- PMT efficiencies for the 7 selected runs
  - typically varies ~9% between PMTs
  - variation of PMT efficiency between runs is tiny (no number yet)

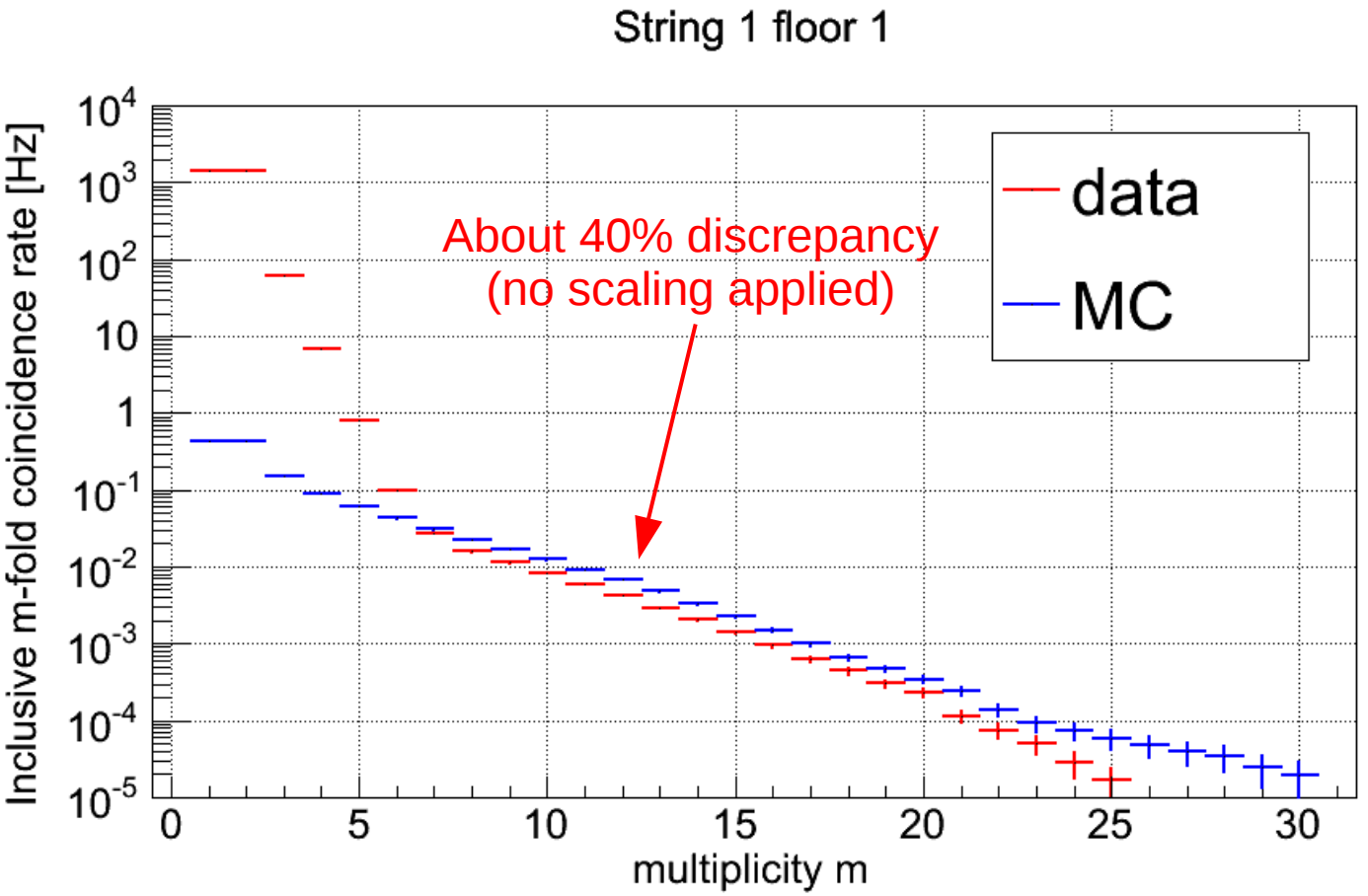


Muon MC (Karel)

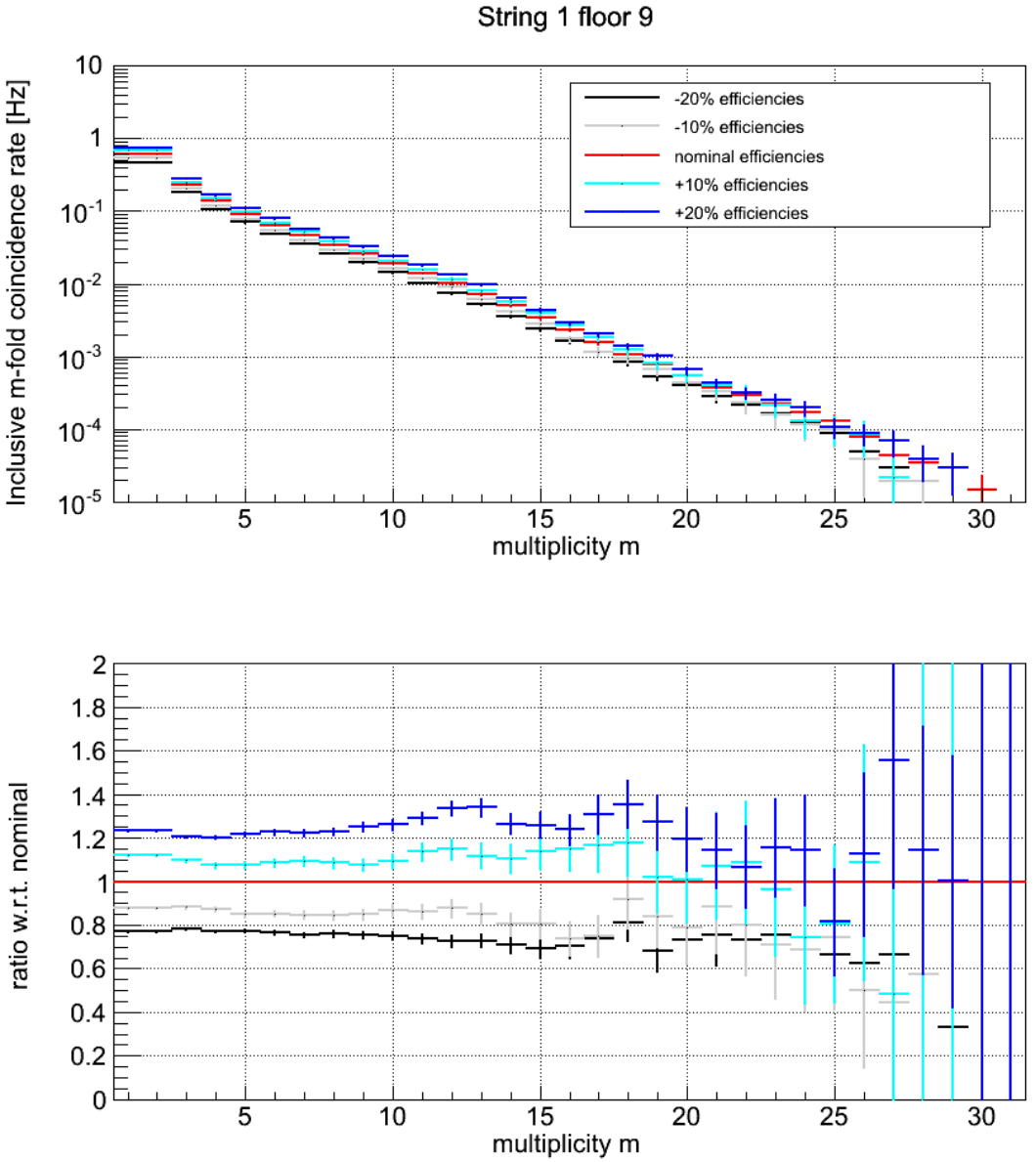
- Atmospheric muons (mupage)
  - ~28 hours of livetime
  - now twice as much is available
  - again twice as much has been produced last night
- Processed with km3
  - photon doubling trick
- JTriggerEfficiency, several times:
  - with “nominal” PMT efficiencies (from K-40 calibration)
  - with nominal PMT efficiencies, scaled by an overall factor
  - with randomly generated PMT efficiencies (Gaussian with **mean 1.269**)

Not clear yet how to convert “K-40 efficiency” from JFitK40 to number to put into JTriggerEfficiency for a km3 simulation

Data/MC comparison



Overall efficiency scaling in MC

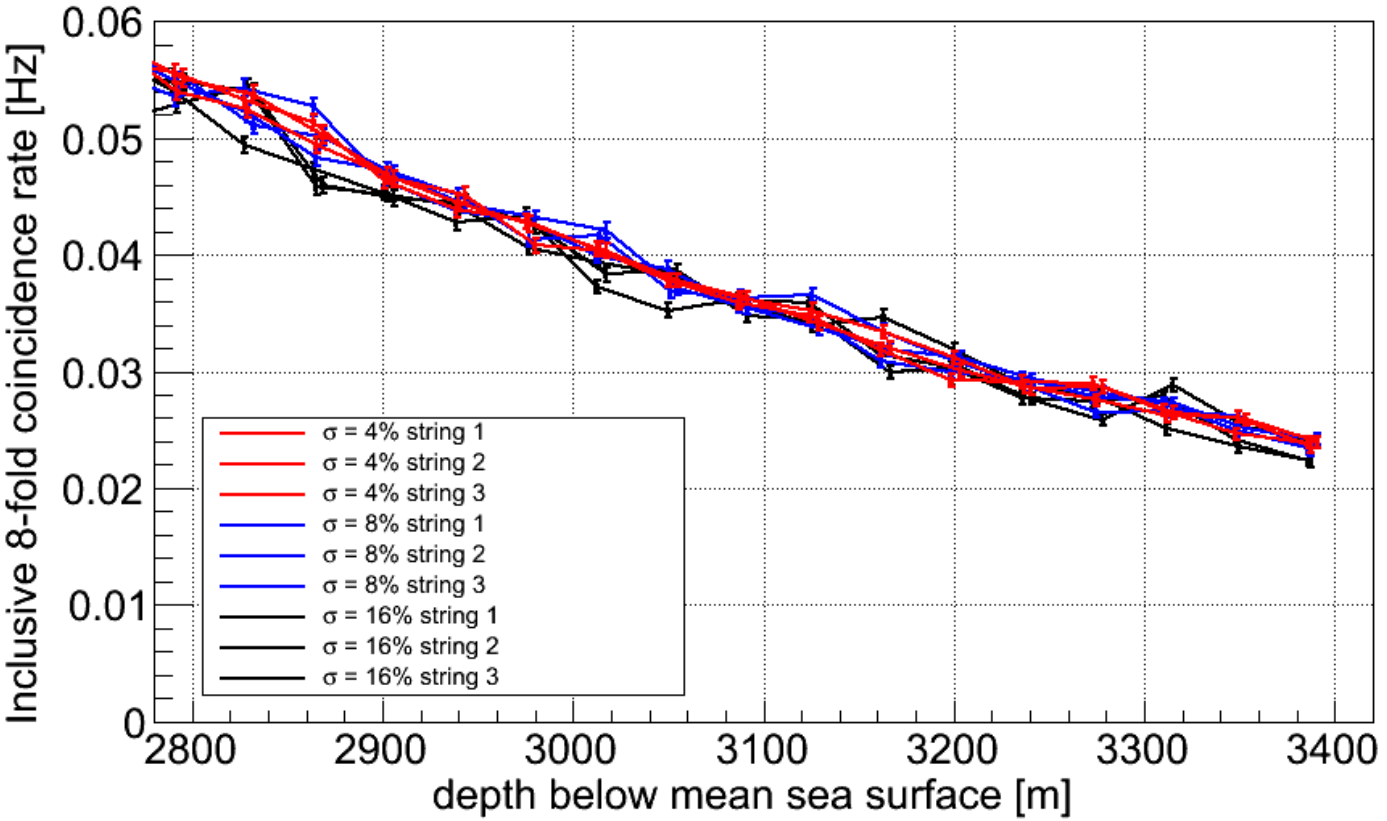


Coincidence rates scale approx. linearly with overall PMT efficiency
(but why?)

- **average PMT efficiency** in the MC is ~1.3 (based on K-40 calibration)
- if we would set the average to 1 in the MC → expected rate decrease of ~25%
- would mean better data/MC agreement

Randomly generated efficiencies

Just to give an indication of the expected size of deviations due to the PMT efficiencies



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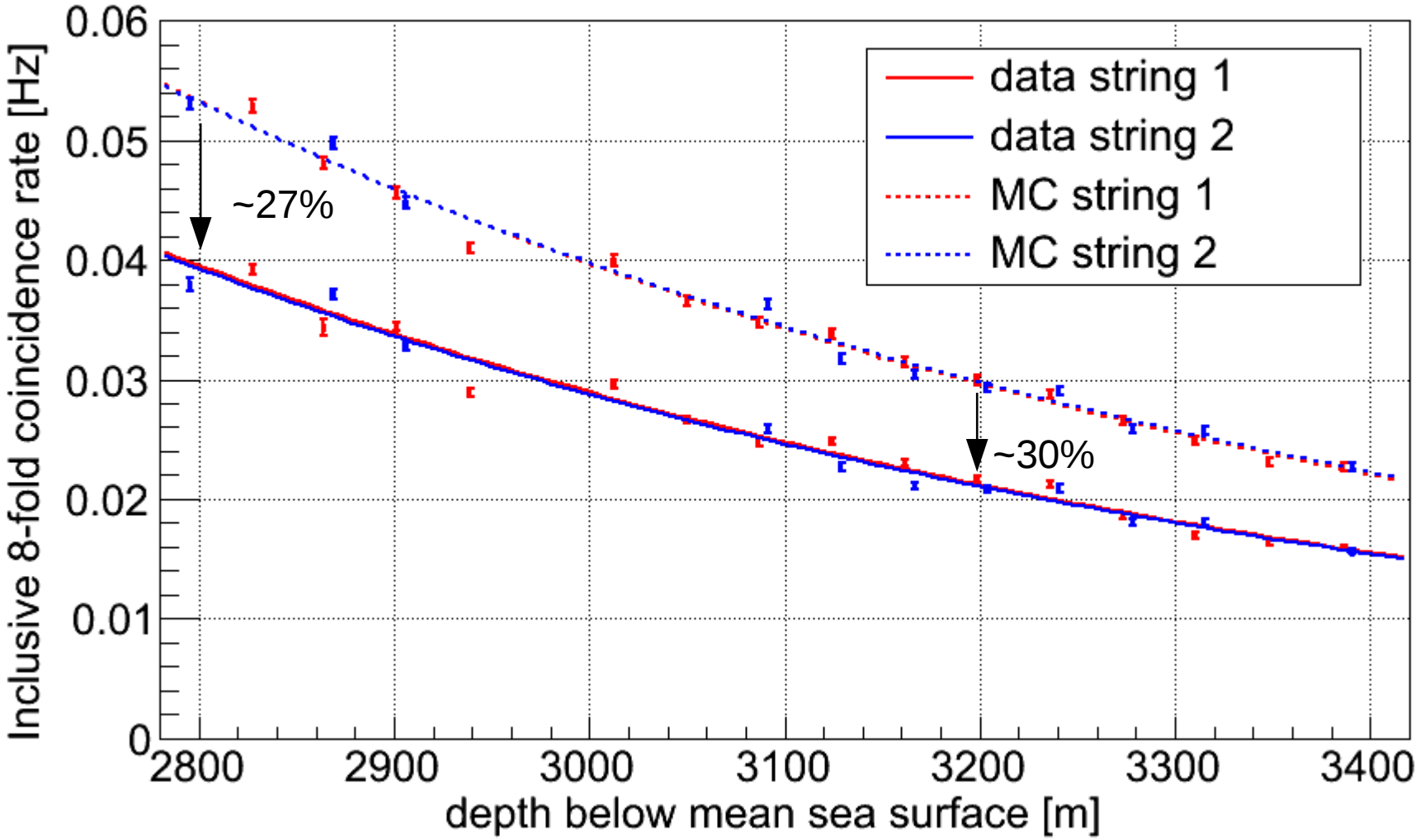

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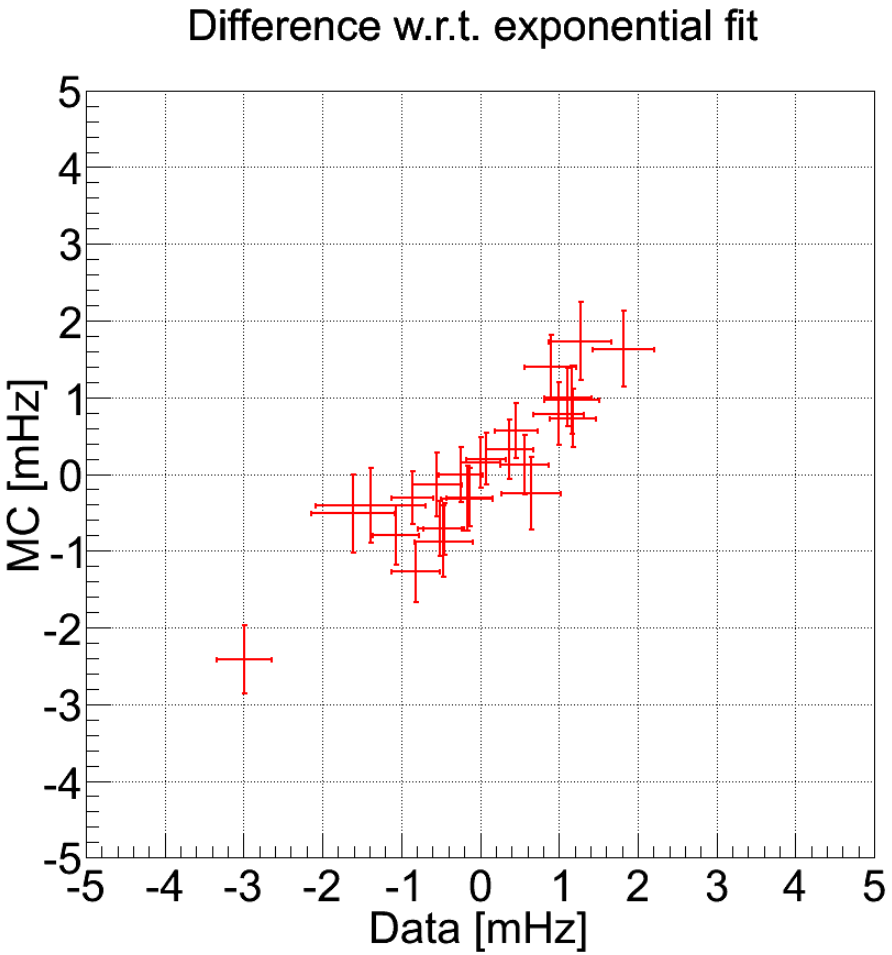
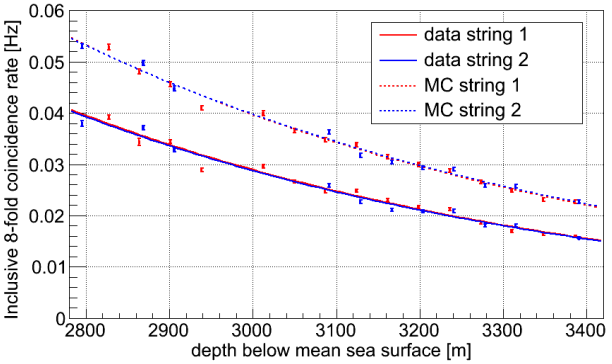
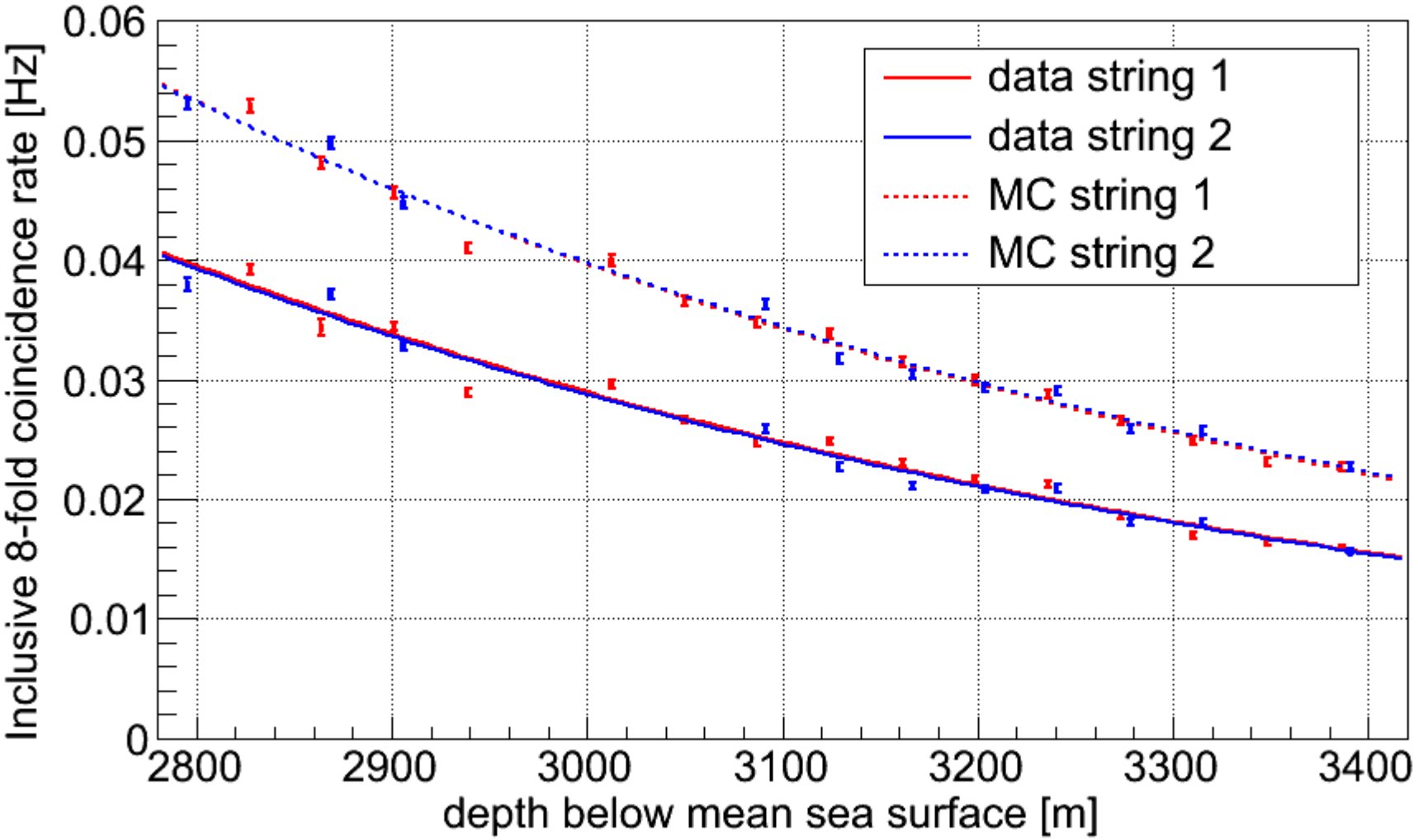




Deviations from exponential behaviour in data and MC are strongly correlated!

Data/MC comparison



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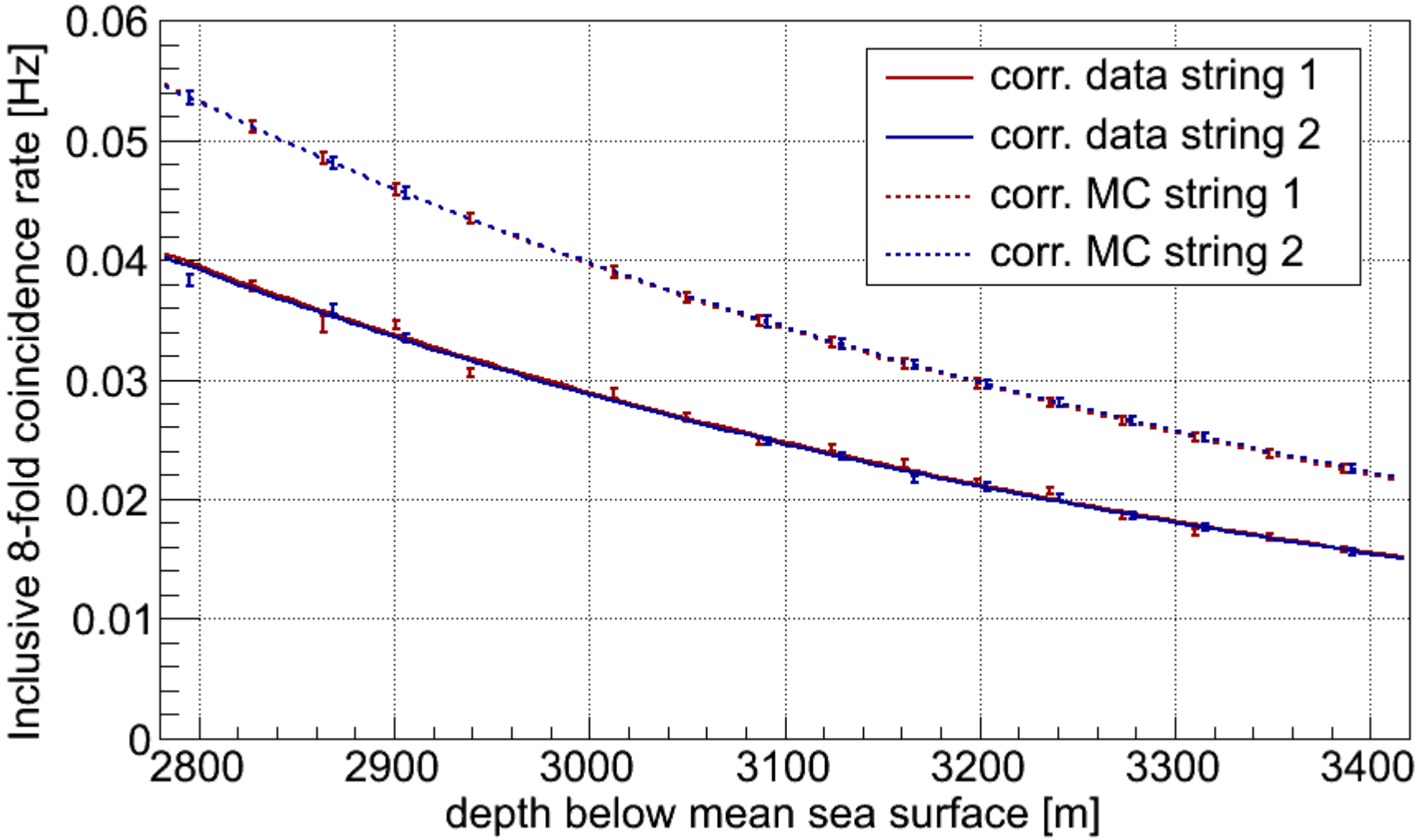
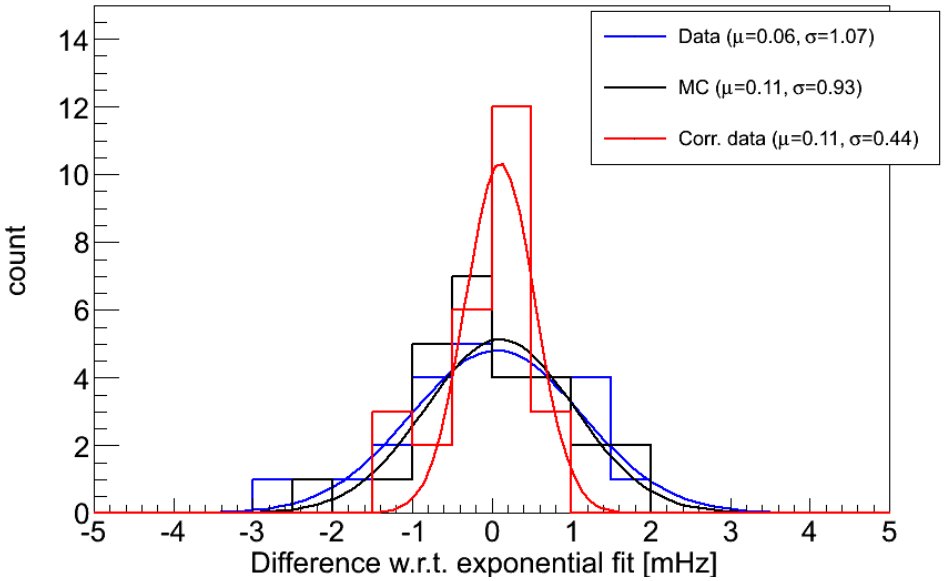


Data/MC comparison

- Fits to **uncorrected** data
  - chisq S1 = 150.468, ndf = 13, prob = 1.65895e-25
  - chisq S2 = 79.9661, ndf = 9, prob = 1.64139e-13
- Fits to **corrected** data
  - chisq S1 = 40.7489, ndf = 13, prob = 0.000104647
  - chisq S2 = 13.3297, ndf = 9, prob = 0.148246

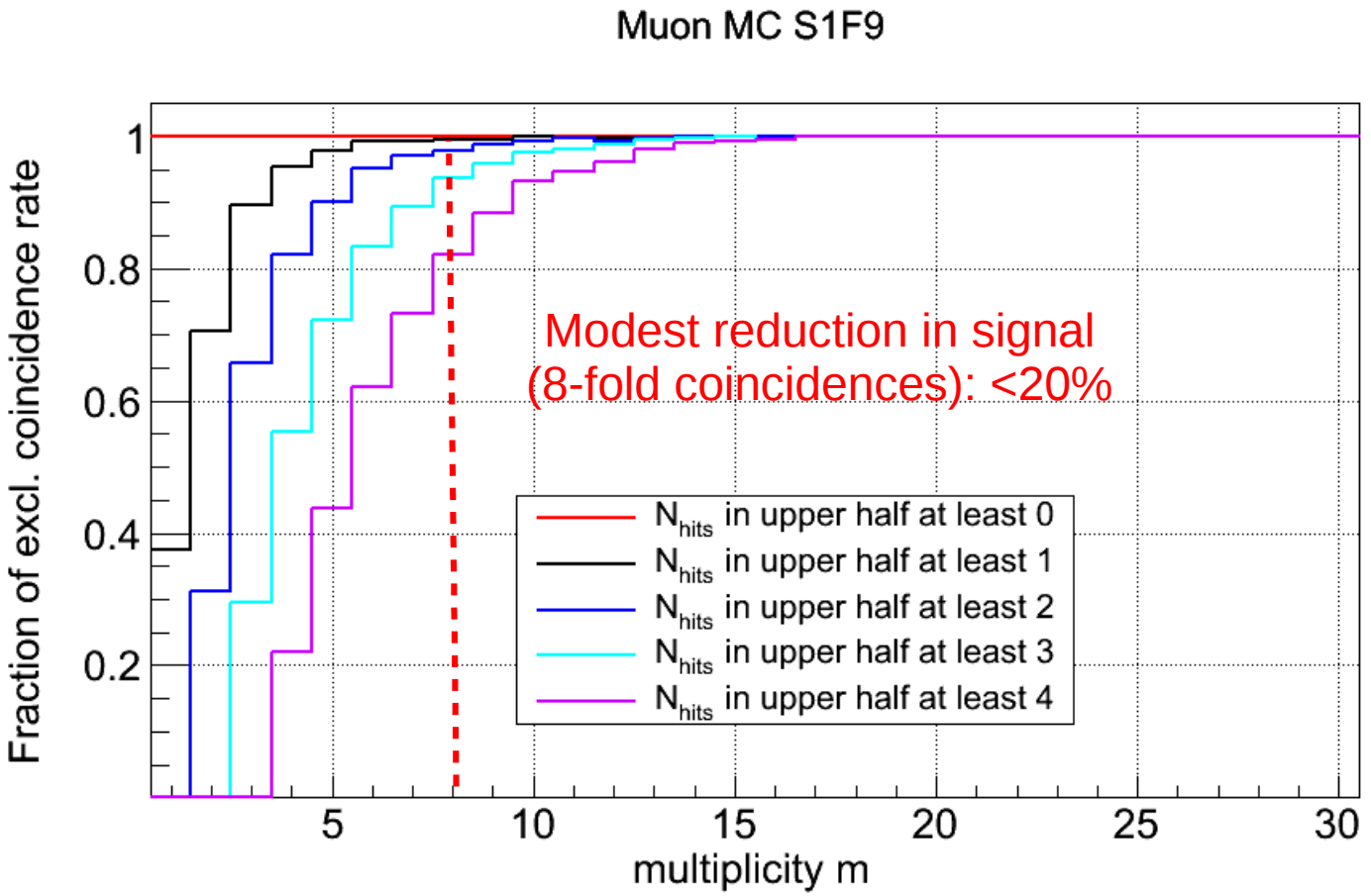
Note:
Uncertainty on correction factor itself is not taken into account!



Upper half hit requirement

- True muons come from above
  - Very likely that the top PMTs are hit
- K40 coincidences depend on inter-PMT distance
  - Lower half has more PMTs, which are closer together
- Requiring a minimum number of upper half hits can help improve signal/BG
  - We might be able to use lower-multiplicity coincidences (m<8)

Upper half hit requirement



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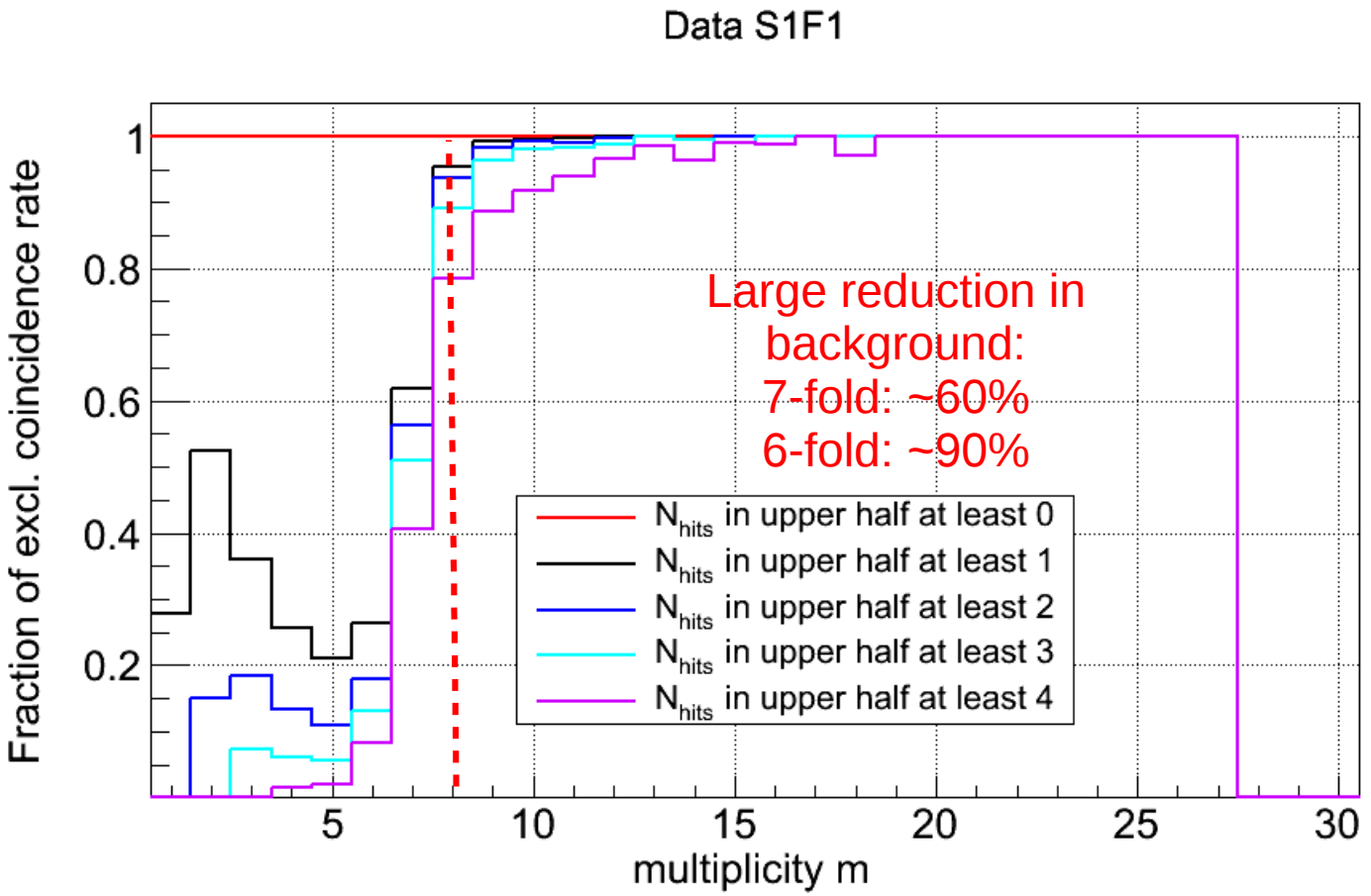
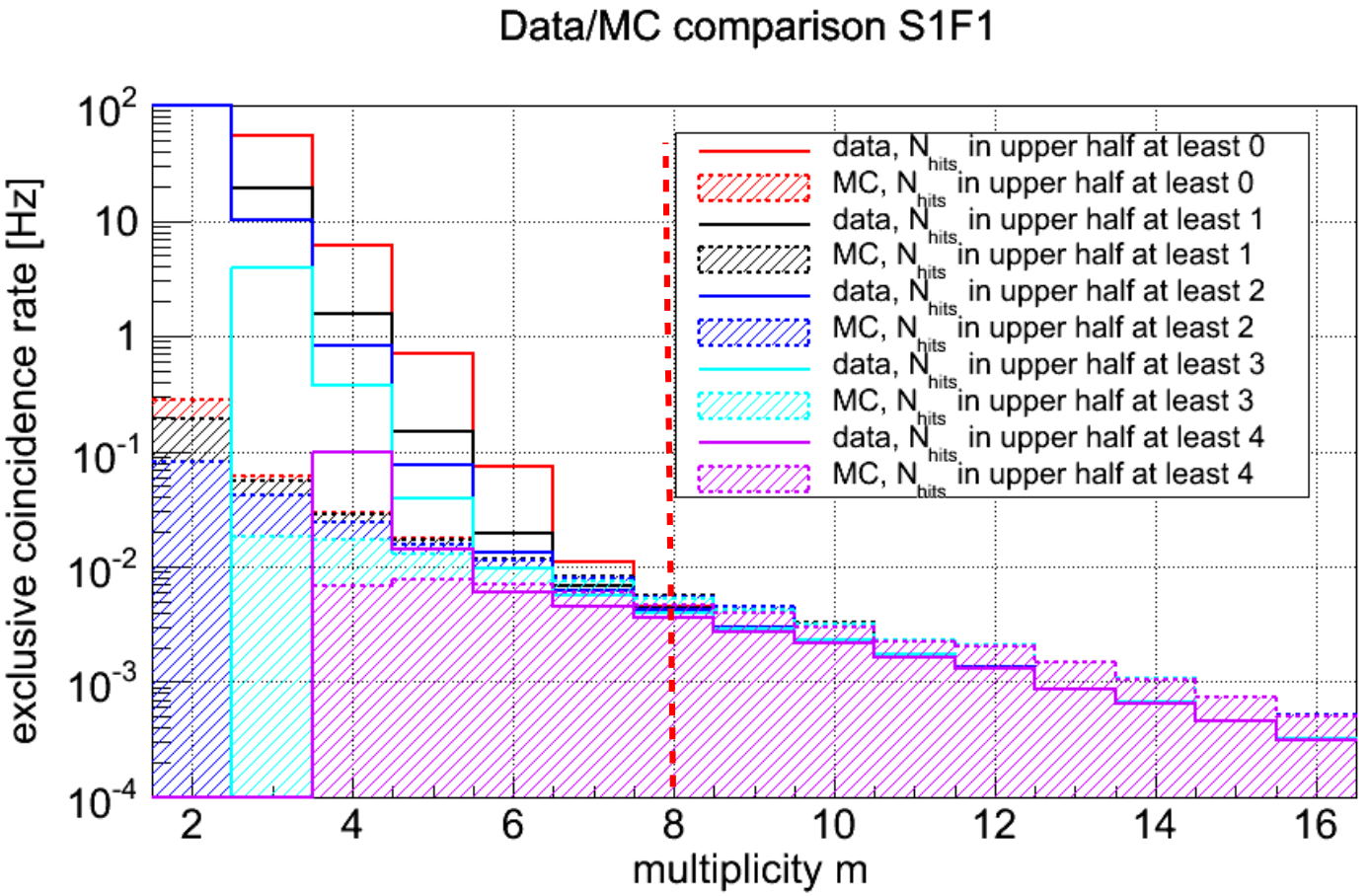
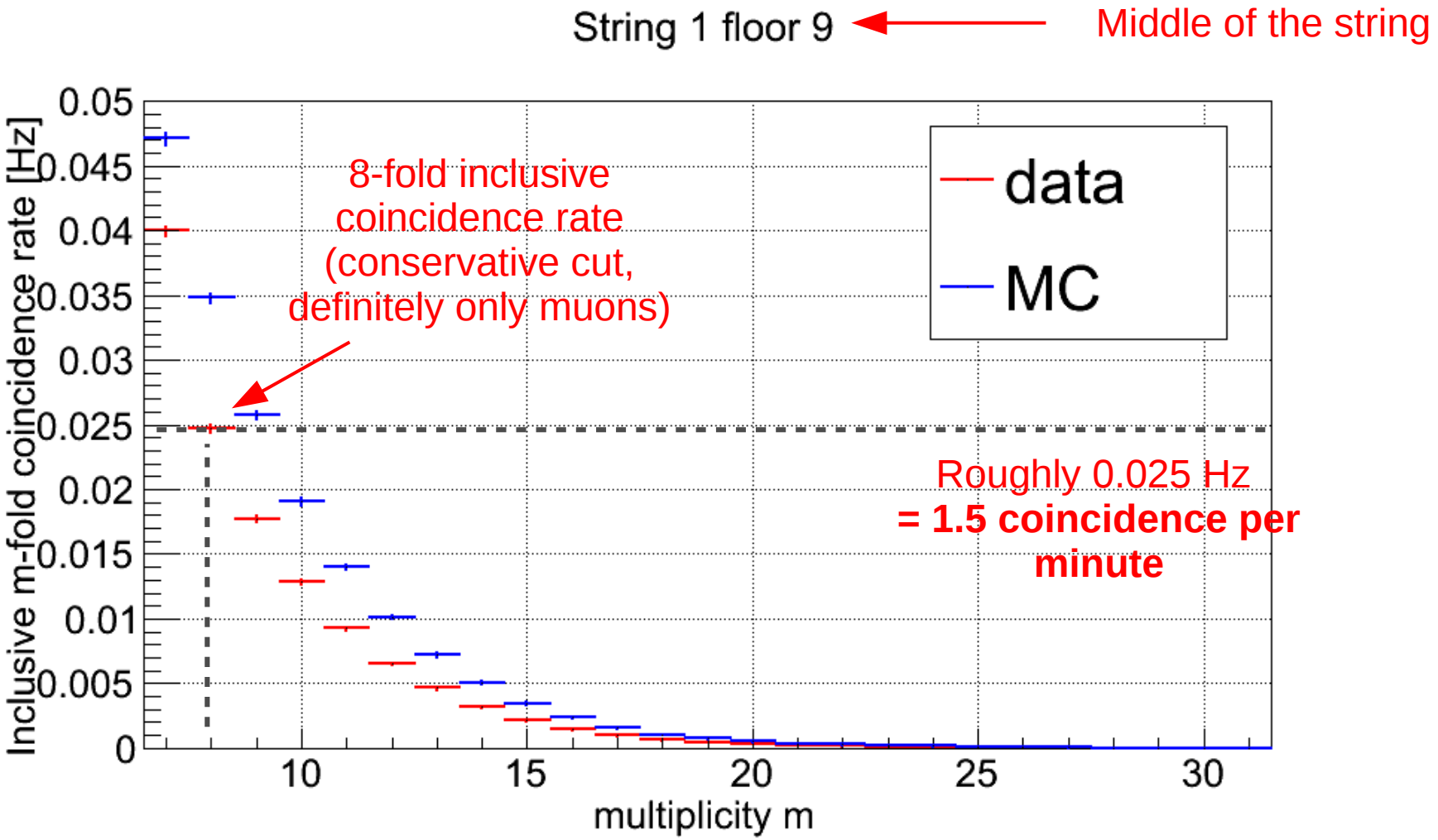


Upper half hit requirement



Some nice numbers

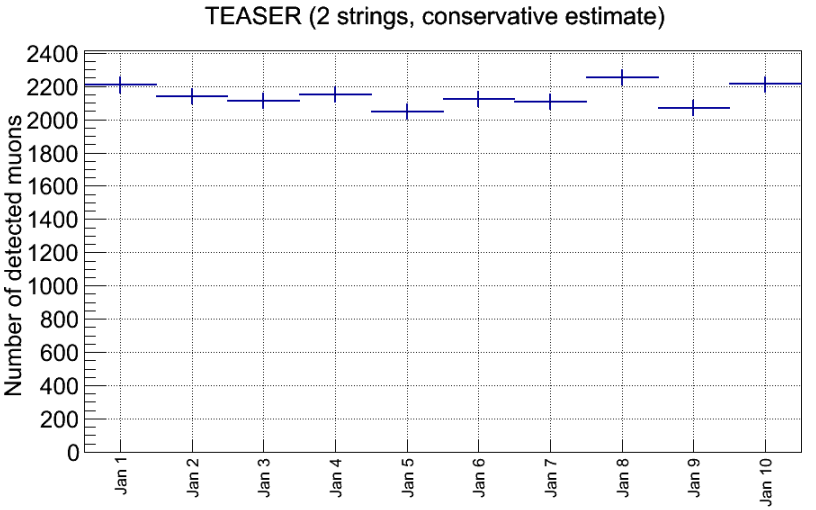


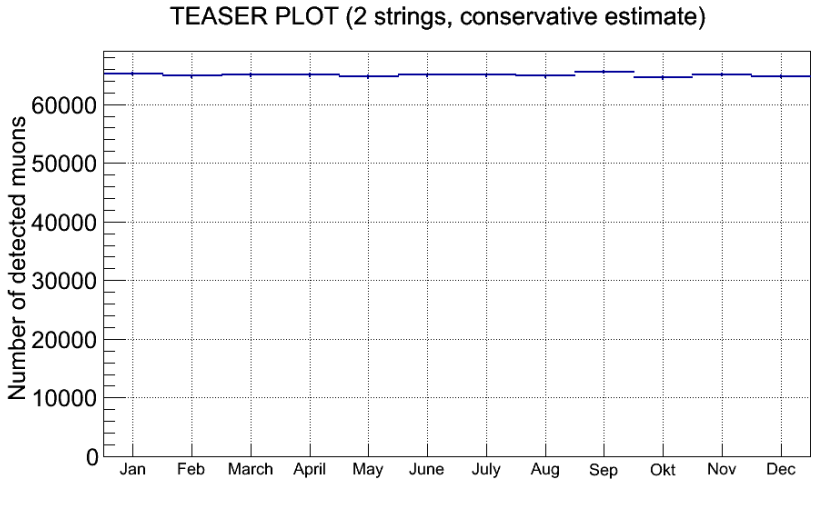
Playing the high statistics game

- **1 week of data** = 10,000 minutes
- 10,000 min x 1.5 μ/min = **15,000 unique high-quality muons per week**
- Current configuration: 2 strings
  - 36 DOMs
  - let's say ~30 are active on average
- Hits:
  10,000 min x 30 DOMs x 1.5 μ/min x 8 hits/DOM
  = **3.6M high-quality muon hits per week**
- For phase 1 (24 DUs) livetime
  - more than **2.2 billion high-quality muon hits per year**
    (15,000 μ/week x 52 weeks x 15 DOMs per string x 24 strings x 8 hits/muon)

What can you do with 15k unique muons per week?

- day-to-day flux variations
  - 15k/7 is approx. 2k
  - 1/sqrt(2000) = 2.2% accuracy
- for 1 year, average muon flux as a function of the hour of the day
  - 15k x 52 / 24 = 32.5k
  - 1/sqrt(32,500) = 0.55% accuracy
- monthly flux variations
  - 15k x 52 / 12 = 65k
  - 1/sqrt(65,000) = 0.4% accuracy



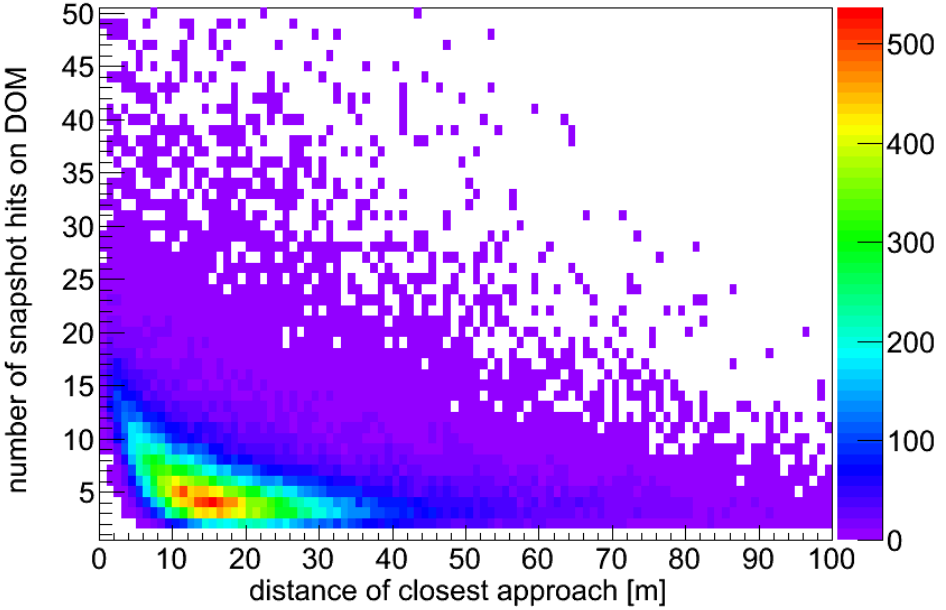


What can you do with 3.6M muon hits per week?

- Azimuth angle-dependent effects
  - e.g. due to DOM structure
  - 1 degree precision: 3.6M / 360 = 10,000 events per bin
  - 1% statistical error

Next steps

- Go to even higher precision
  - more MC is coming
  - simulate pure noise (Karel)
  - aim for great data/MC agreement
- Study MC events
  - what kind of muons are we seeing?
    - energy distribution
    - zenith
    - distance to DOM
    - bundle multiplicity
  - can we constrain some of this stuff from data?

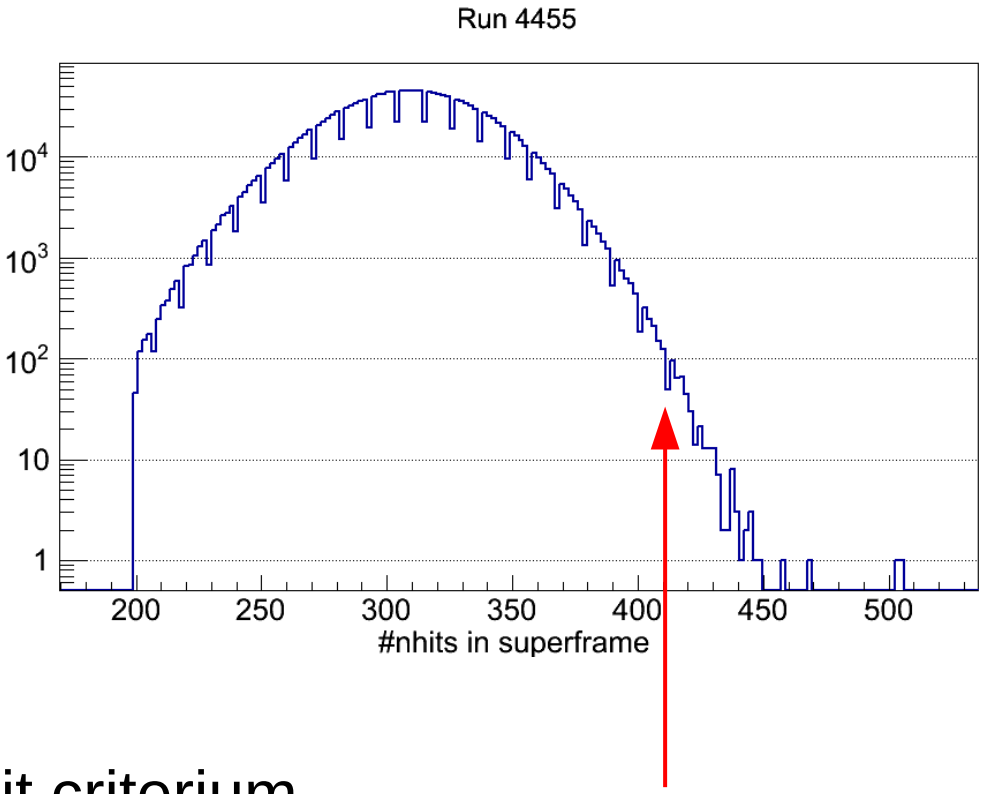


Preliminary result from MC
The number of snapshot hits as a function of the DCA for DOMs with triggered hits

Backup slides

Frame selection criteria

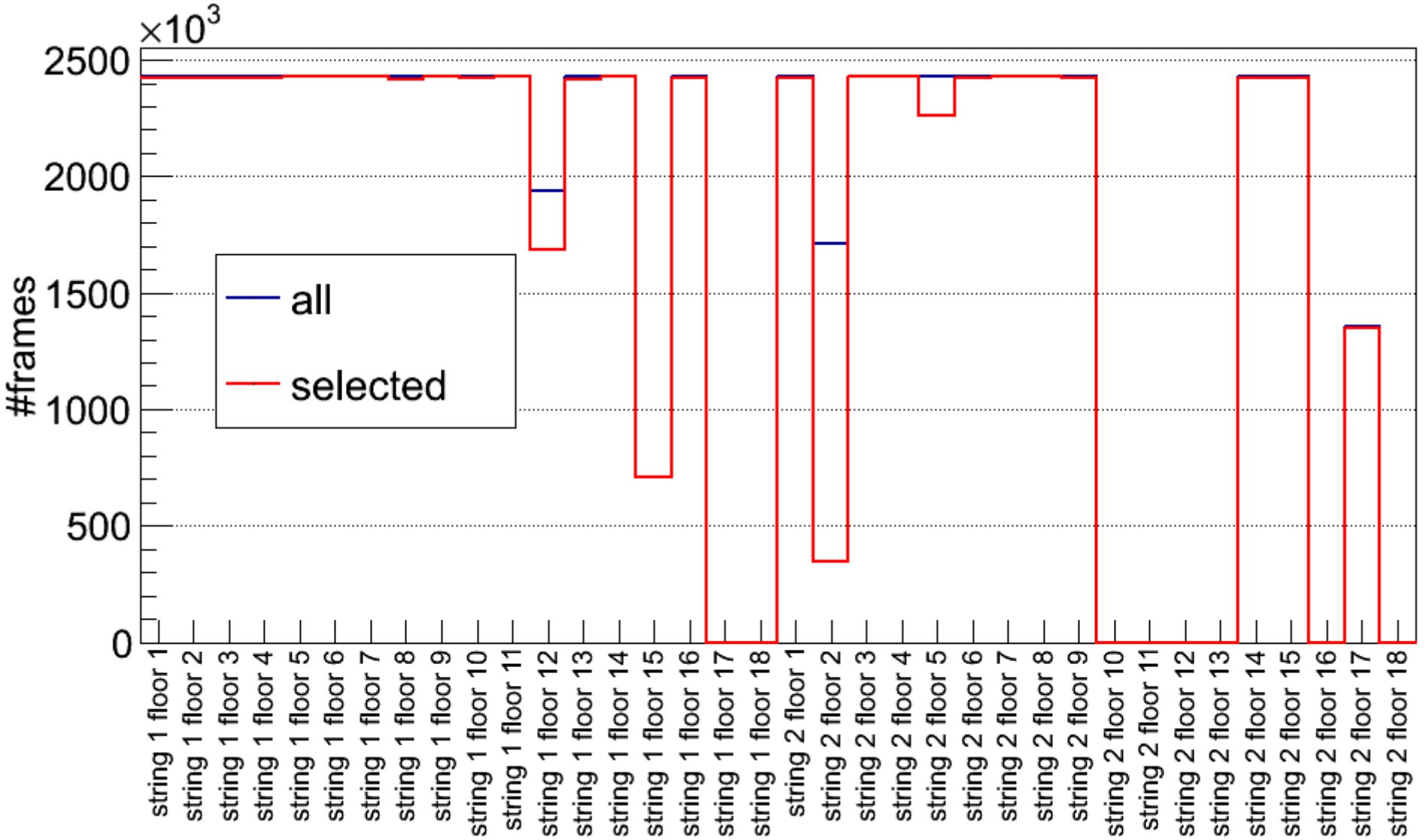
- Criteria
  - >=200 L1 hits
  - <=550 L1 hits
  - all PMT rates <10 kHz
  - no HRV or FIFO full
  - no UDP packet loss
  - all L1 hits match the L1 hit criterium (another hit within 26 ns)
  - no splitting of frames
- Zero tolerance: everything suspicious is thrown out



Don't worry about these, they are just binning artifacts

(bin width is not an integer)

Frame selection



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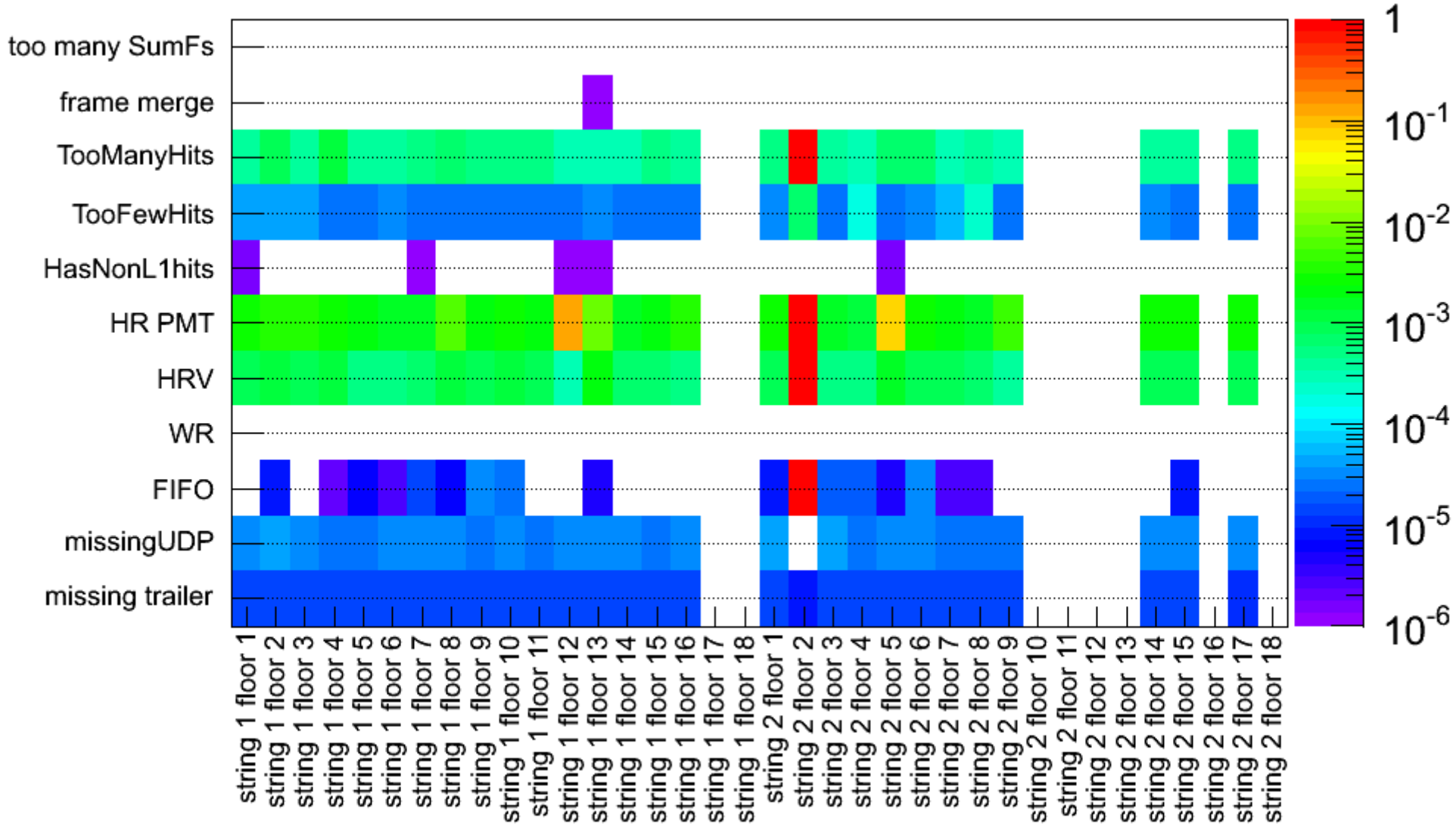

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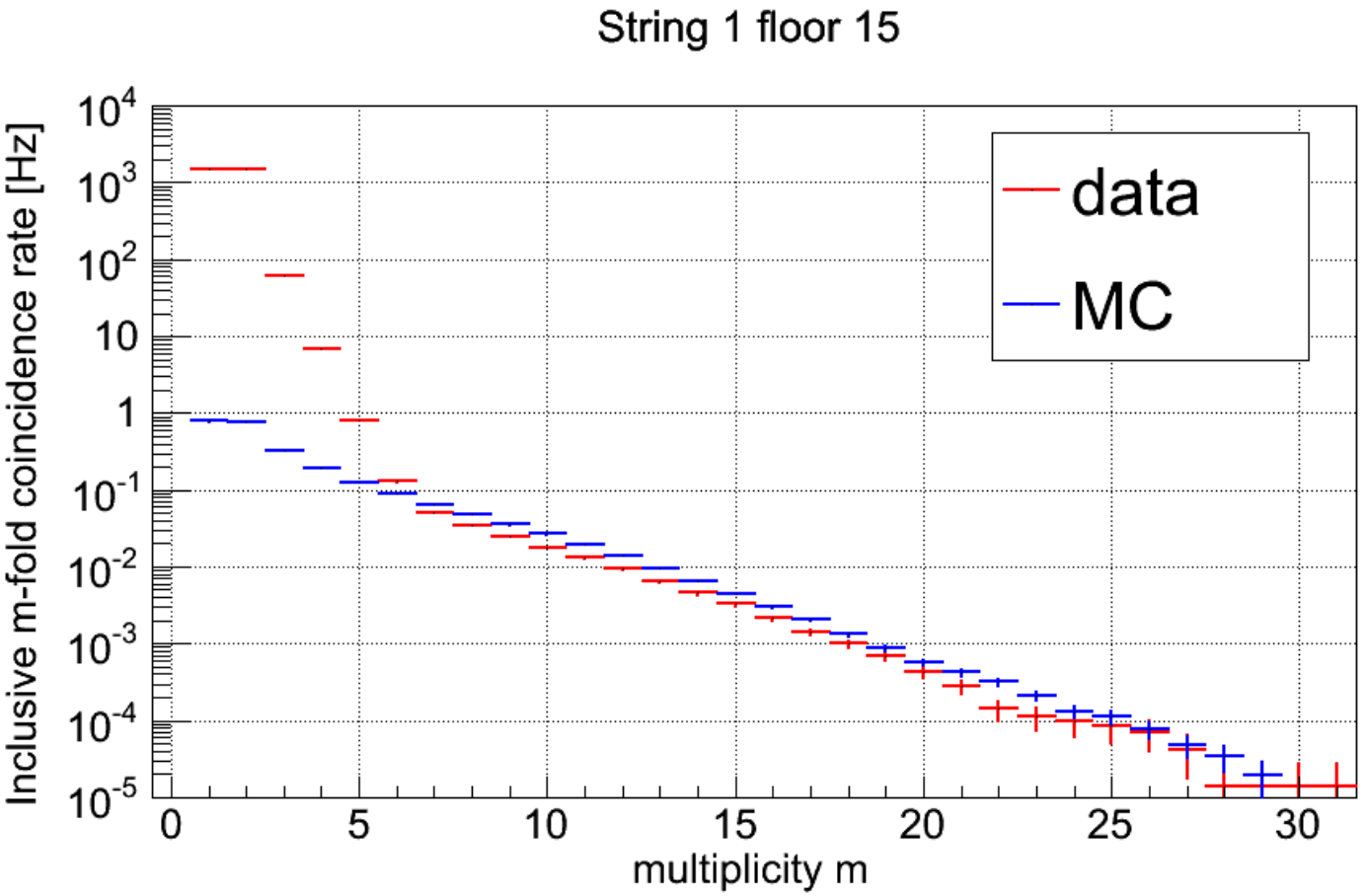

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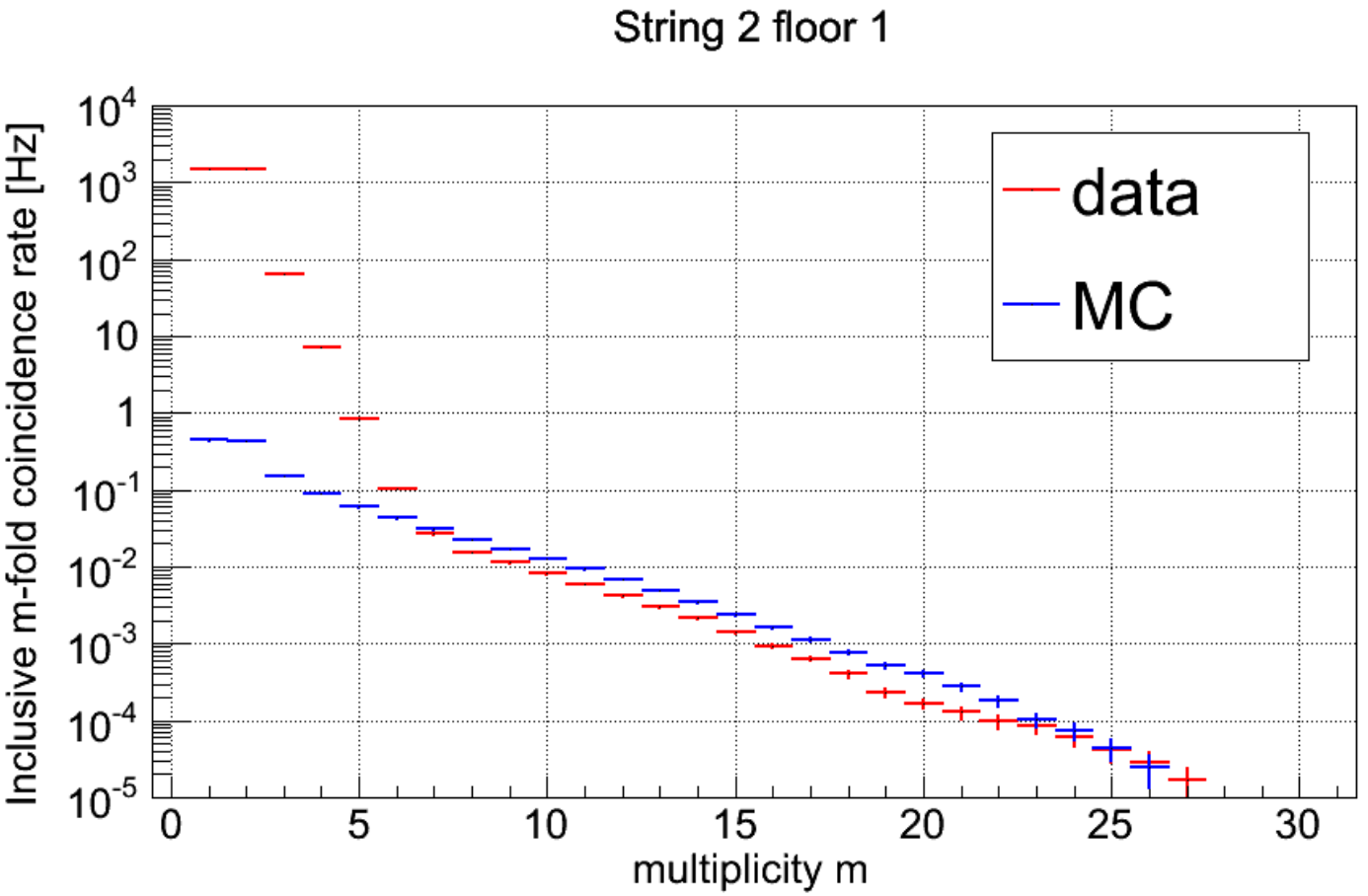

Data/MC comparison