Vuvuzela

2020 Simulation Workshop

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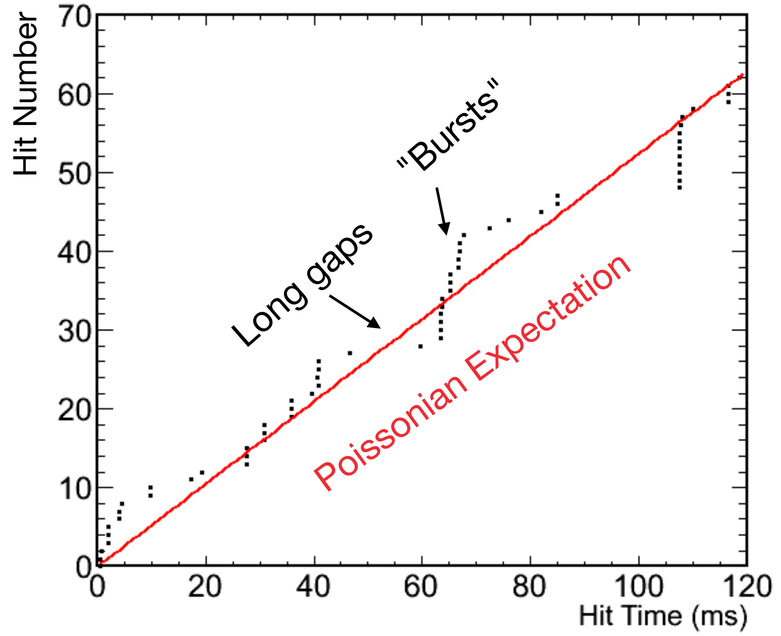
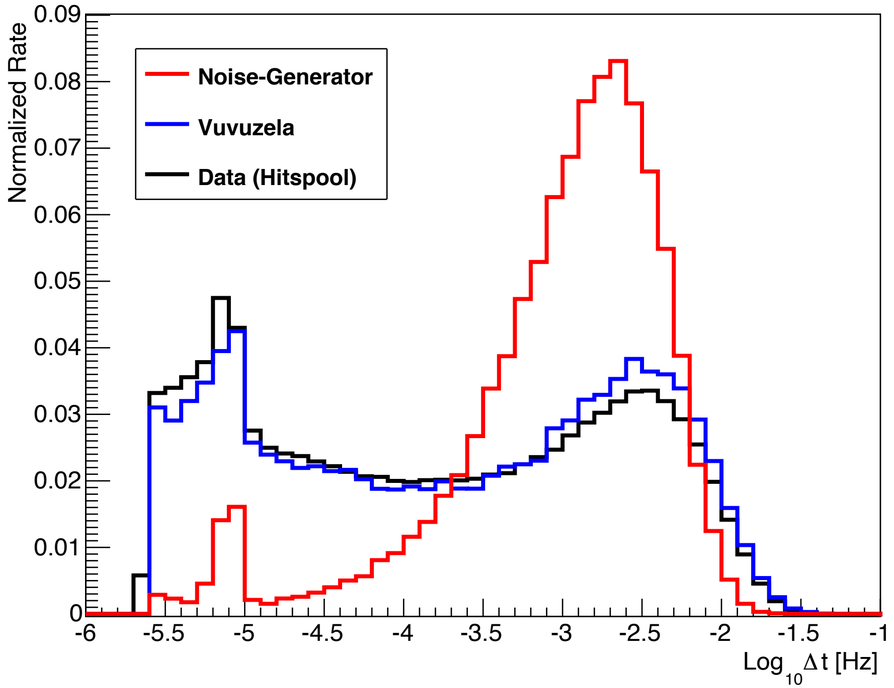
A Brief History of Noise

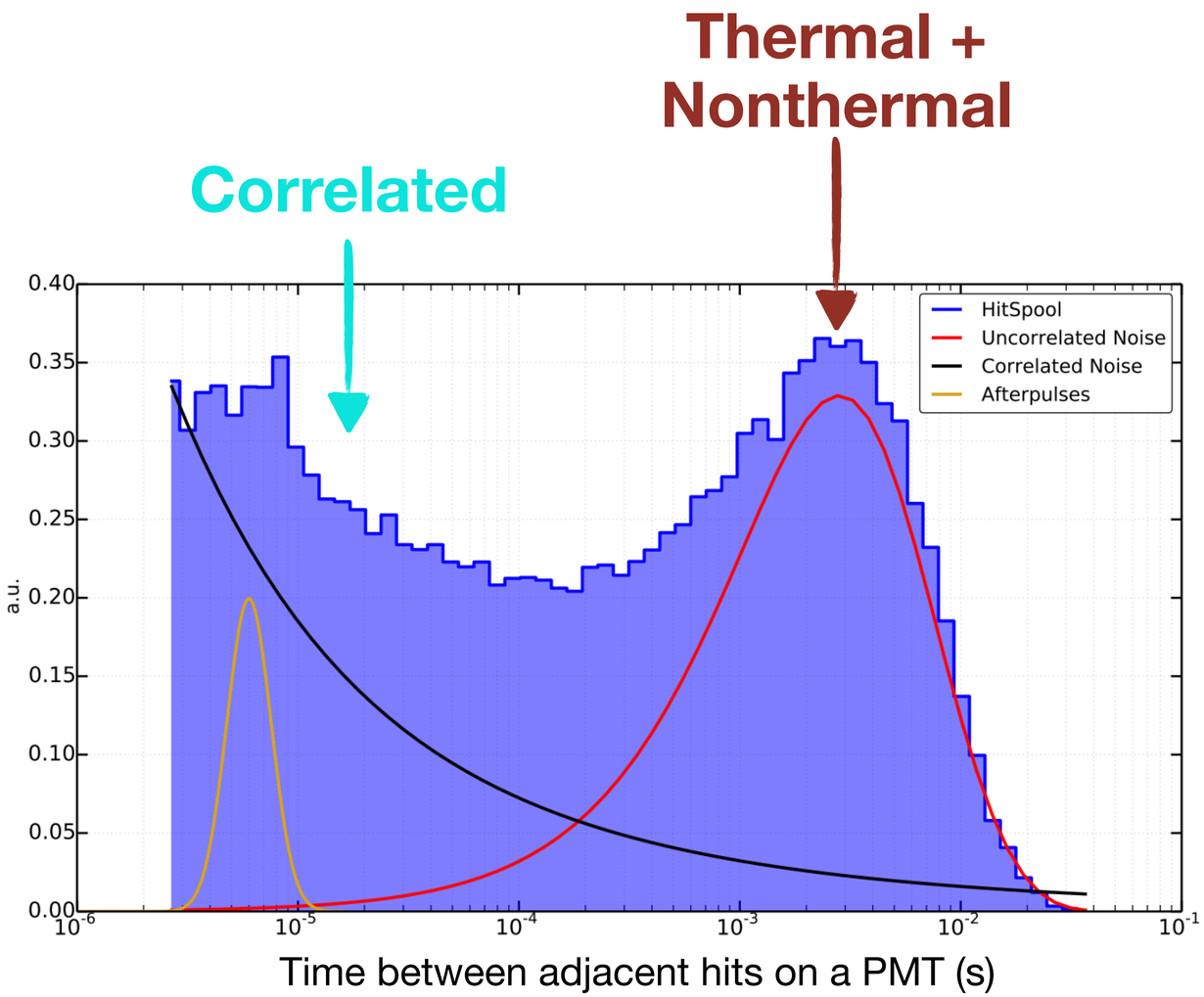
- Noise-generator: Add noise to simulation assuming Poissonian process with per-DOM rates taken from calibration
- IC79, IC86-1 introduce DeepCore's SMT3 trigger + physics analyses
    - Immediate concern: CORSIKA only predicts about half the rate of data for SMT3 + DeepCoreFilter… Large spike of events with HLC nch < 8 discovered in ~2010
    - 2010: Simulation of only noise gives first similar spike at low nch, but rate is too low by at least 2x. SLC hits show especially poor match in data/mc
    - Analysis level rates from GENIE are too high by ~2x
- 2011: Dave Seckel and other show that IceCube's noise appears to have strong non-Poissonian component



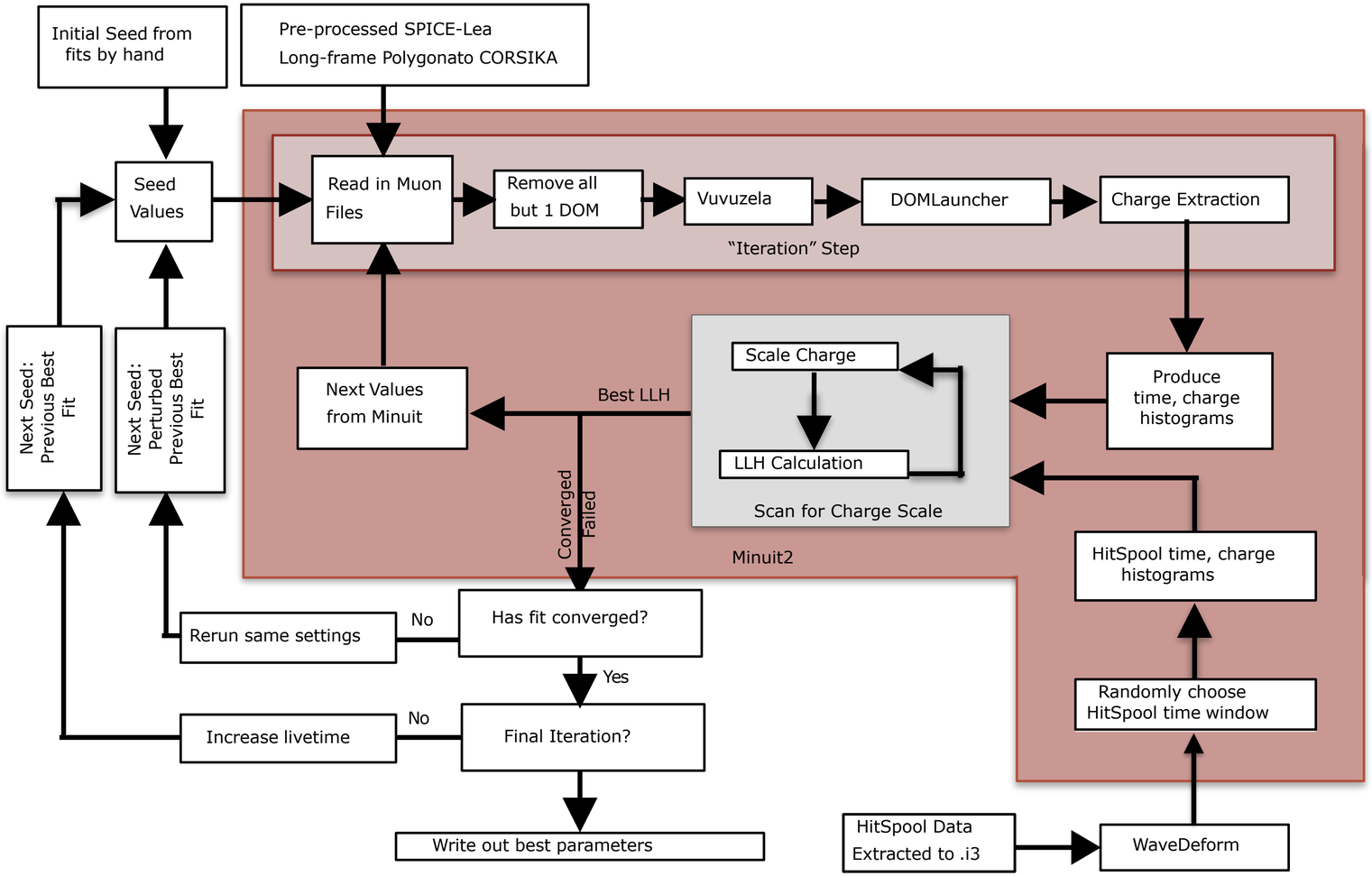


Vuvuzela's Noise Model

- Assume noise is made up of three components:
  - "**Thermal**" Poissonian noise (1 parameter)
  - "**Nonthermal**" Poissonian noise (radioactivity, 1 parameter)
  - "**Correlated**" noise (scintillation, 3 parameters with empirical log-normal distribution)
- Model assumes that the nonthermal radioactivity triggers a burst of "correlated" noise pulses on microsecond timescales
- Scintillation efficiency is ~4-10 photons/ radioactive decay

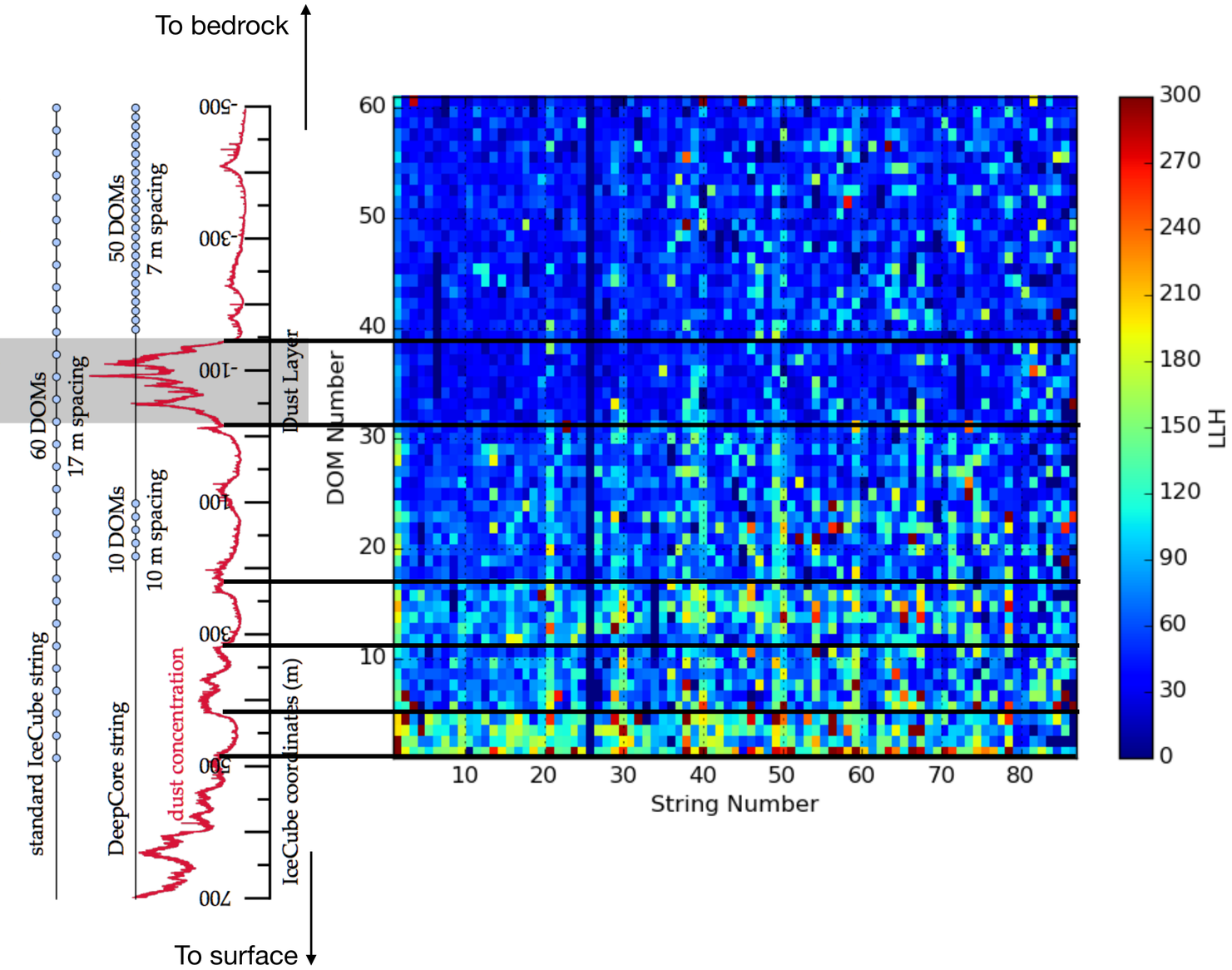


Fitting Vuvuzela



- Model fit to HitSpool data using simulation chain through DOMLauncher, wavedeform
- Fits require special millisecond long-frame unweighted CORSIKA simulation to include muon pulse contributions
- Fitting one DOM requires 2-4 weeks ignoring possible correlations between modules
  - Probably not feasible to redo these fits regularly

Fit Quality



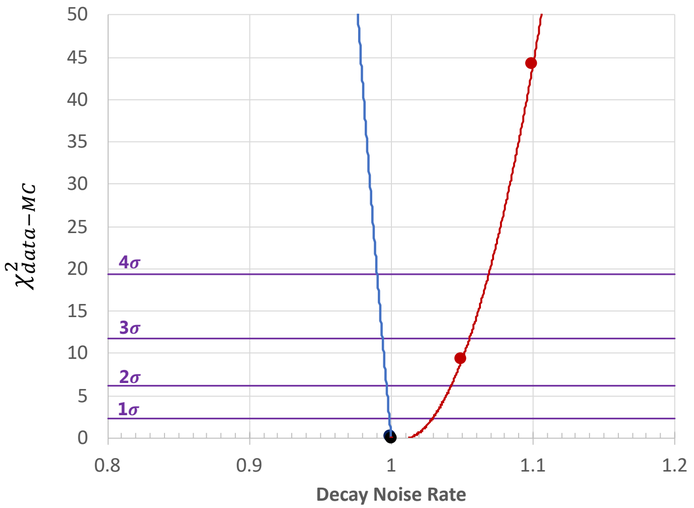
- LLH after fits shows uncertainties are correlated with muon, ice models through the CORSIKA simulation
  - Worst fits at top of detector in regions of low absorption (muons visible)
  - Best fits at bottom of detector or regions of high absorption (muons not visible)
- No absolute scale of uncertainties exists due to large correlations between parameters

Fit Quality

- Estimates by Etienne B. (NBI) put full-detector noise uncertainty at -0/+3%

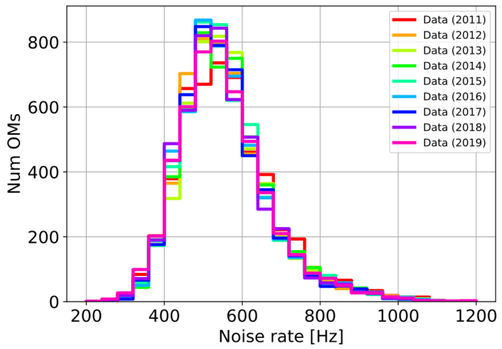
Putting it together:

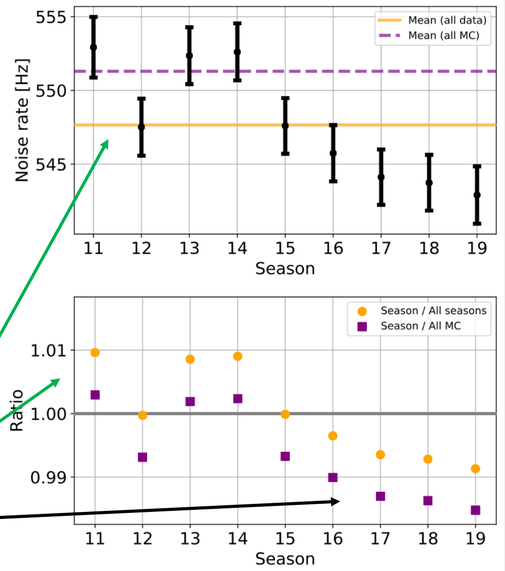
- Showing **Chi2 of the first 2 bins w.r.t data**
- Behaviour is asymmetric (reducing the rate causes more harm than increasing it)
- **1-sigma range:** [~1.0, +3%]
- **2-sigma range:** [~1.0, +4%]



Time dependence of noise rates

- Can also use method to check noise rates consistency between seasons
  - We implicitly assume this in our analyses since we use a single MC set





Consistent noise rates vs season (all within 1.5% of mean)
Evidence of declining noise rates in later seasons

- Tests by Tom Stuttard (NBI) shows average rates agree between data/mc to within 1.5%
- Evidence of noise rates settling over time, but effect is small

Vuvuzela for the Upgrade

- New modules need a new set of noise simulation parameters
- mDOM noise simulated in Geant4 by Martin Unland (Munster)
    - Overall, similar structure as Vuvuzela model, but intra-DOM correlations visible
    - Cherenkov light from radioactivity found to be missing from Vuvuzela's model
- Probably not feasible to run months-long calibration fits for each new module….

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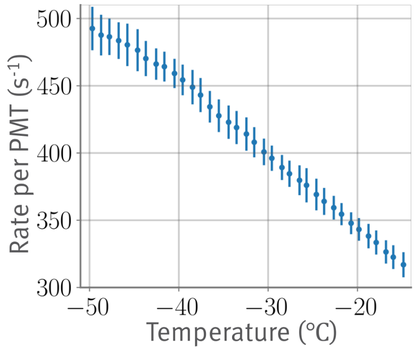
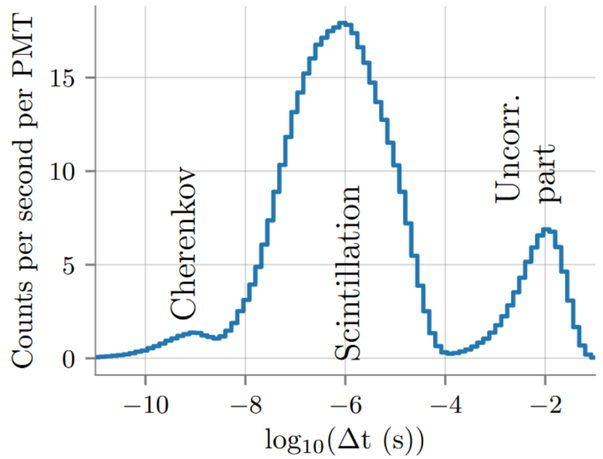
Geant4 results for single PMTs in mDOM





- Results were fitted for Vuvuzela in this talk
- Problems:
    - No local coincidences between PMTs
    - No parametrization of Cherenkov (charge histogram with too low MPE pulses)
    - Vuvuzela assumes hits per decay are Poisson distributed

Vuvuzela for the Upgrade

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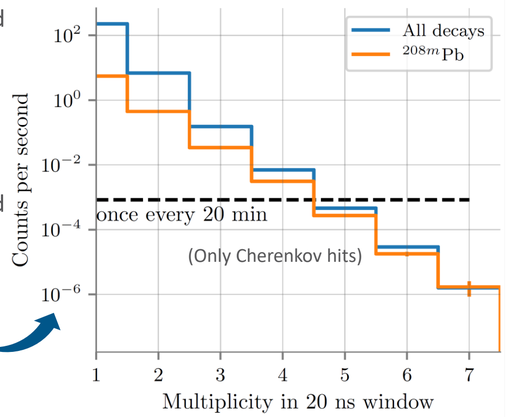
Random sampling instead of modeling

- Parametrization is probably doable but takes time (depending on how good it has to be)
- Simulation is not perfect. Scintillation parameters of glass still under study
  → Any parametrization has to be changed later

- Quickest alternative: random sampling from file with simulated background (20 minutes of mDOM background here)
- **To keep in mind:** events rarer than 1/20min probably not in data set
- More data easy to simulate, but ~ 10k floats and ~ 10k integers per simulated second
- Real detector data can be used after deployment



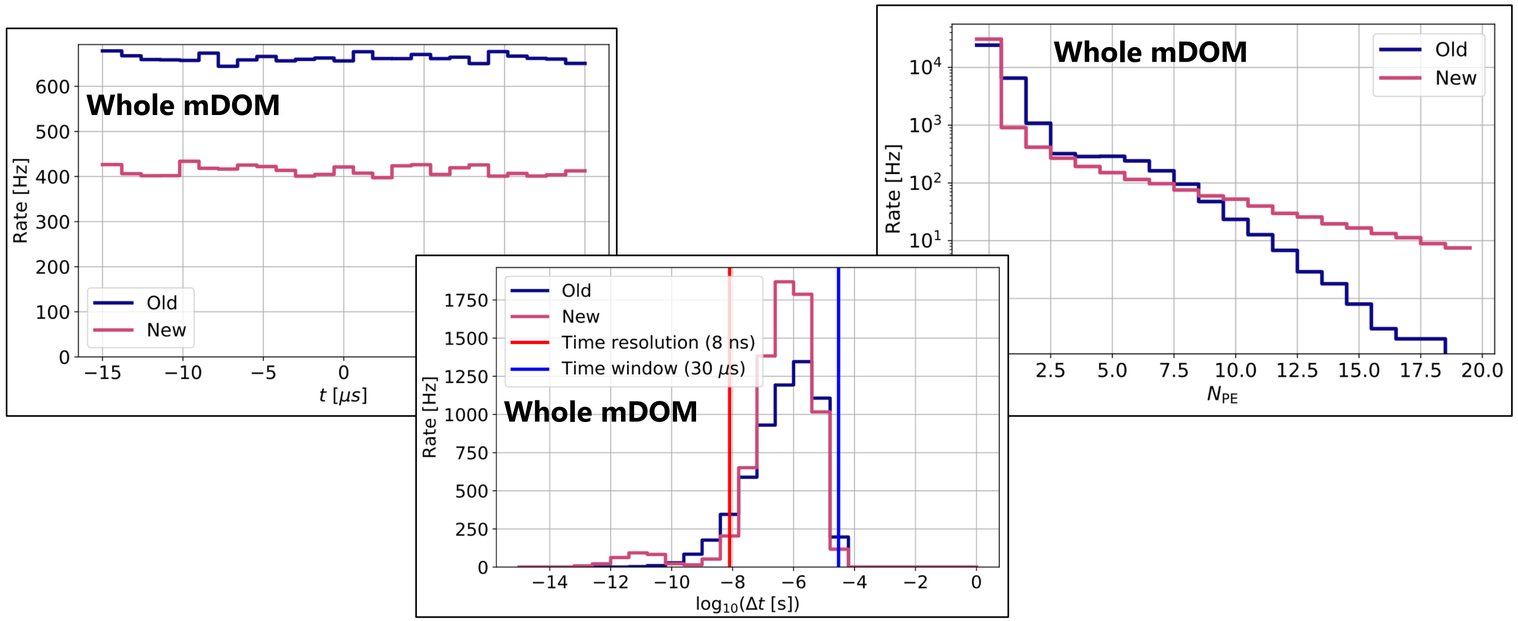
- Simulate a large sample of noise pulse times using Geant4 and sample for each mDOM
  - Automatically get Cherenkov component, intra-DOM noise
- Added to Vuvuzela in late 2019, tested February 2020
- Can replace Geant with HitSpool or other data after deployment
  - Process already used by KM3NeT for noise simulation

Checks on mDOM Noise

- Simulation tests for Geant4 modeled noise look reasonable
- Average rates 20% lower than previous estimates
- Large, potentially important tail of high charge pulses due to new Cherenkov noise
- No comparable DEgg or IceCube PMT timing files yet (?)

Checking whole mDOM

- Get ~consistent picture when looking single PMT or whole mDOM



Conclusions

- Vuvuzela handles our non-Poissonian noise very well for IceCube+DeepCore
- Support available for new modules via old parametrization or Geant4 sampling (needed if testing Cherenkov, intra-DOM correlations)
    - Need Geant4 simulation from DEggs, pDOMs, IceCube DOMs for testing
- Future ambitious goals:
    - Move Geant4 sampling code to C++ for speed
    - Find someone to search for high charge noise pulses as proxy for missing Cherenkov noise component: do we need them for IceCube?
    - Each module is handled totally independently — test case for parallelizing simulation?