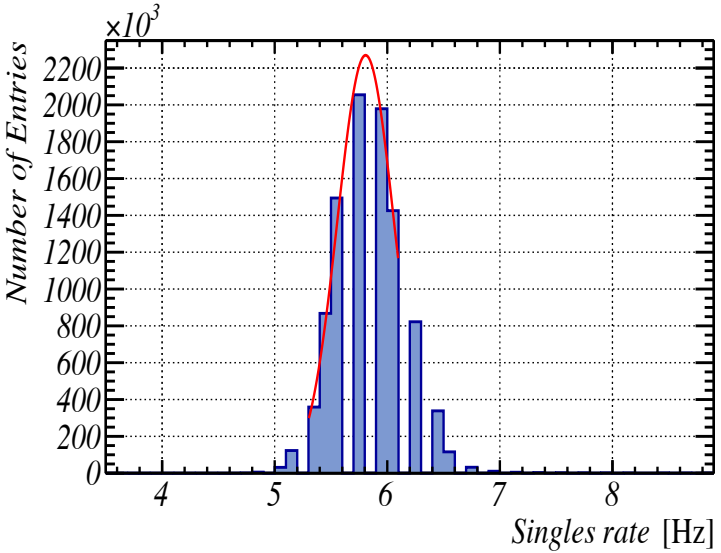
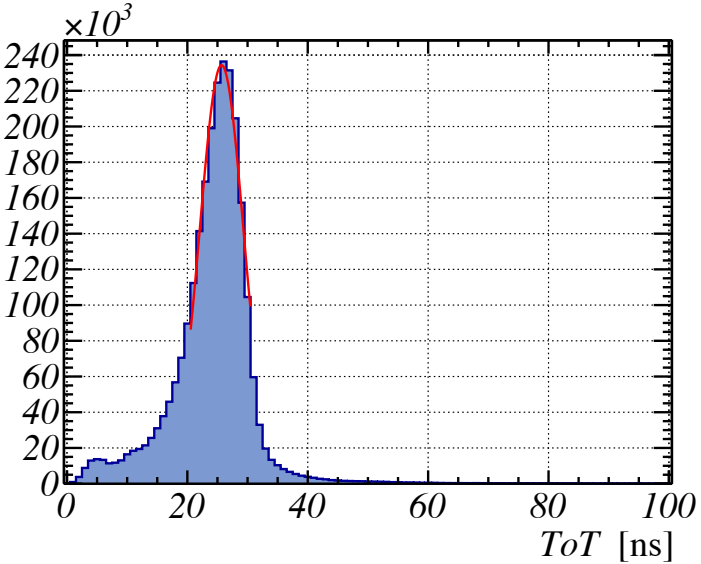
In-situ calibration

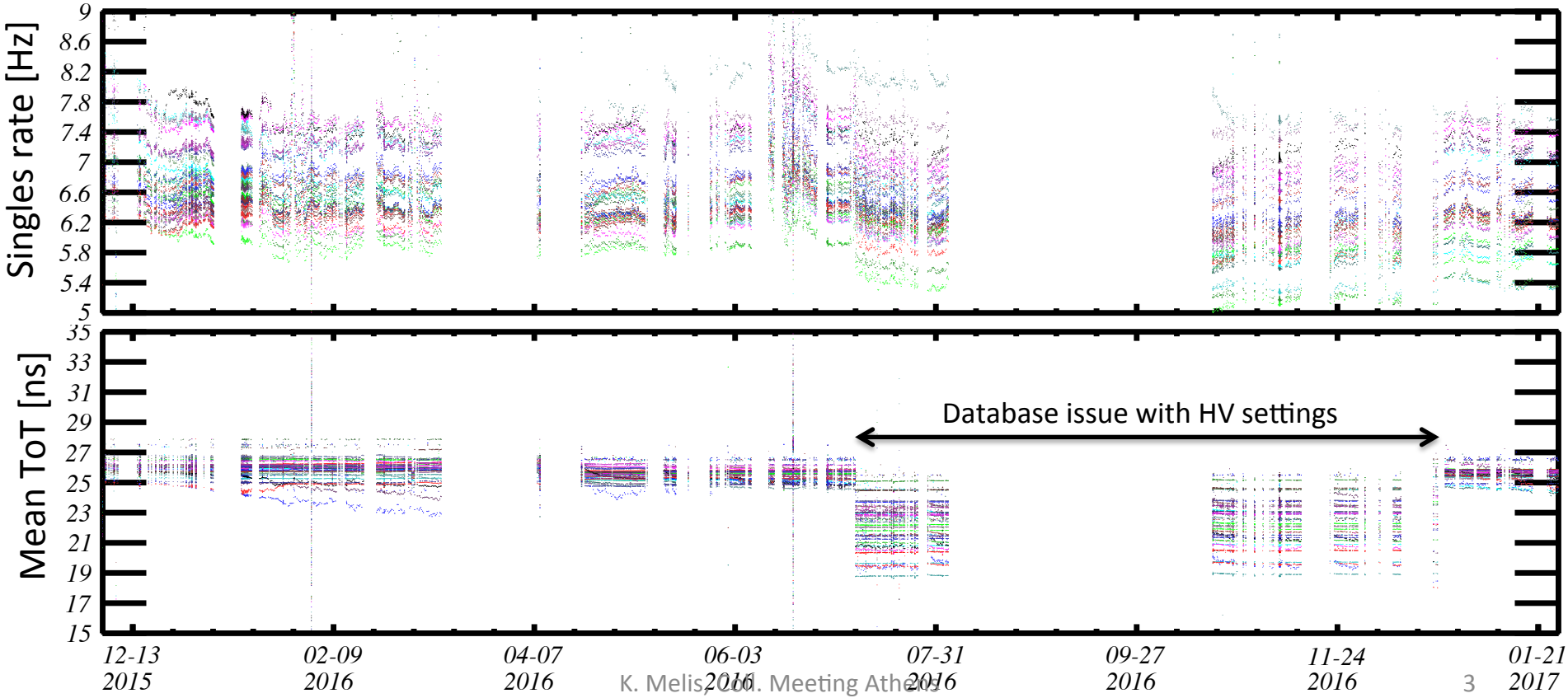
Part I: Basic quanities



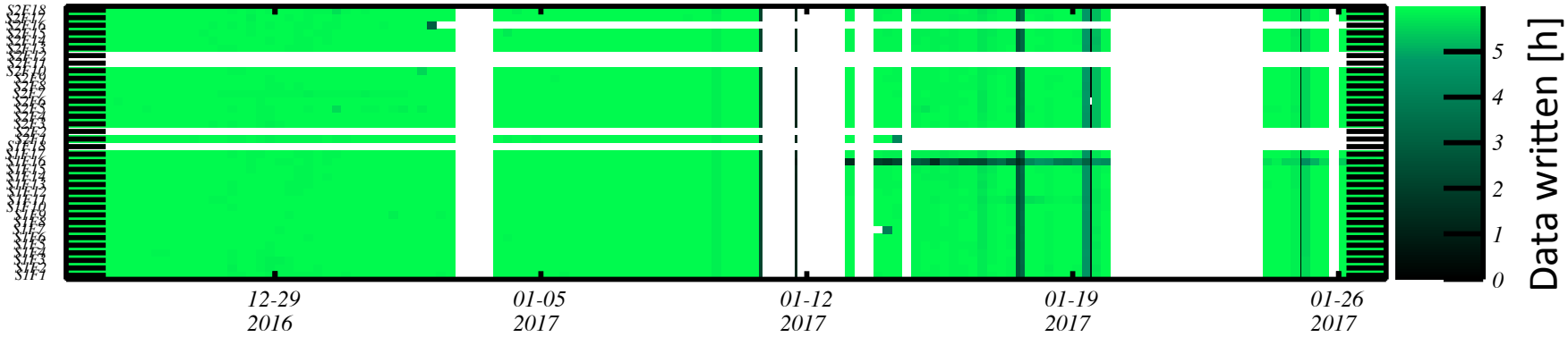


Mean singles rate and ToT from peak fits

Stability


Singles rate [Hz]
9
8.6
8.2
7.8
7.4
7
6.6
6.2
5.8
5.4
5
Mean ToT [ns]
35
33
31
29
27
25
23
21
19
17
15
Database issue with HV settings
12-13 2015
02-09 2016
04-07 2016
06-03 2016
07-31 2016
09-27 2016
11-24 2016
01-21 2017

Data written

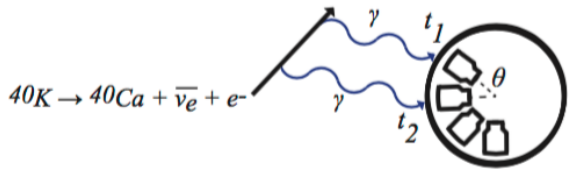


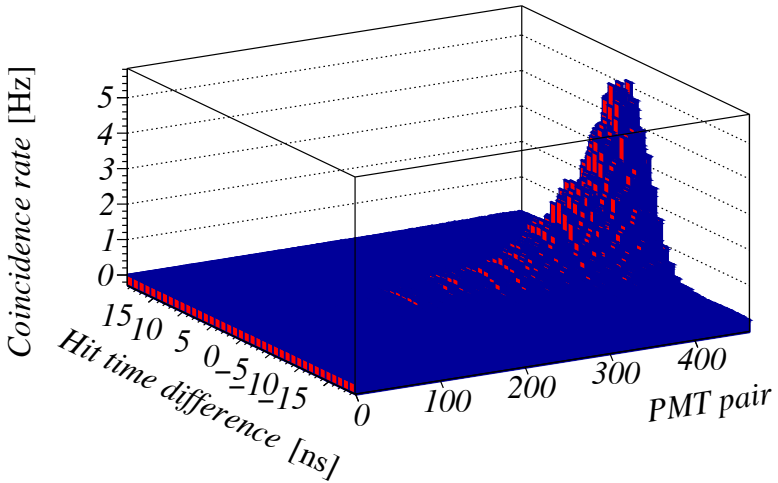
Runs 5009-5170
From 23 Dec. 2016 - 27 Jan. 2017 (=833 h)
261 hours of data written

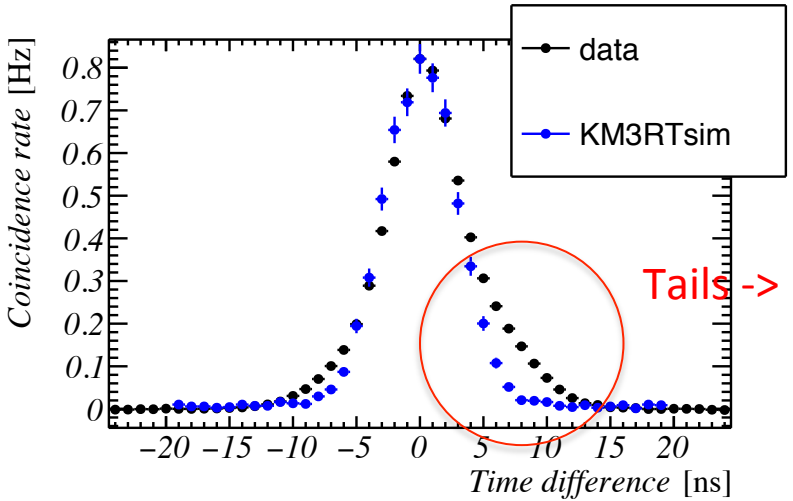
DOMs permanently off:

- S1 F18
- S2 F2, 11 & 12

Part II: Inter-PMT calibration



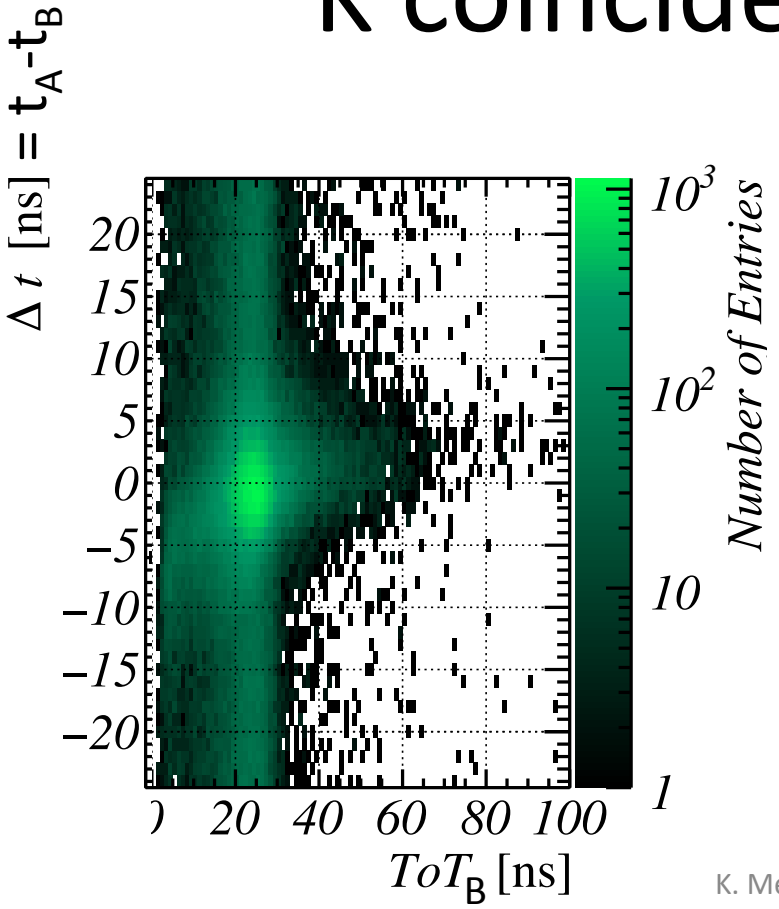




Gaussian fits

Mean	-> PMT time offset
Width	-> (upper bound on) PMT time spread
Amplitude	-> PMT efficiency

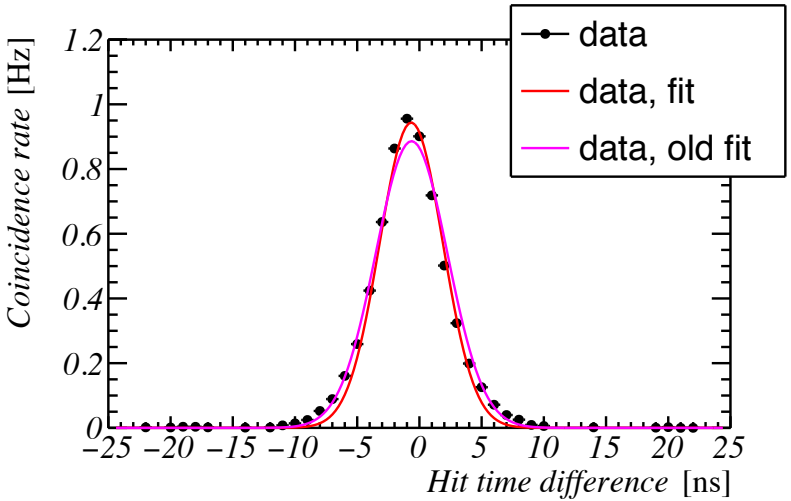
^{40}K coincidence rate vs t,ToT

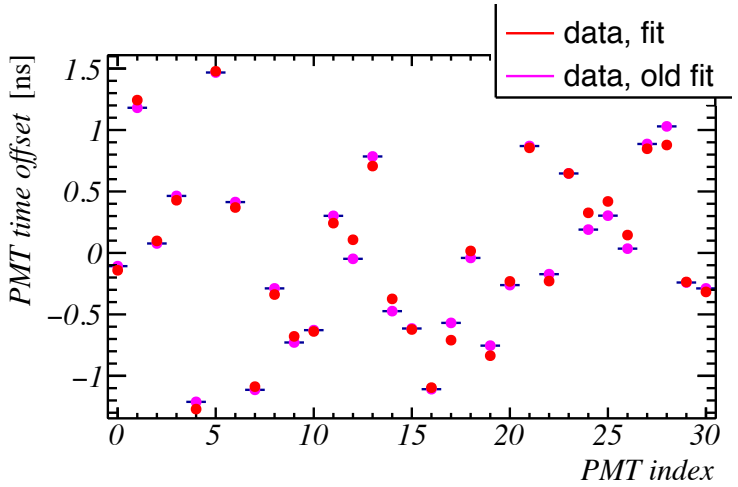


High ToT -> Earlier hits
- combinatorics i.c.w TTS
- time-slewing of leading edge

Low ToT -> Later hits
- time slewing of leading edge

Improved ^{40}K fit (1/4)

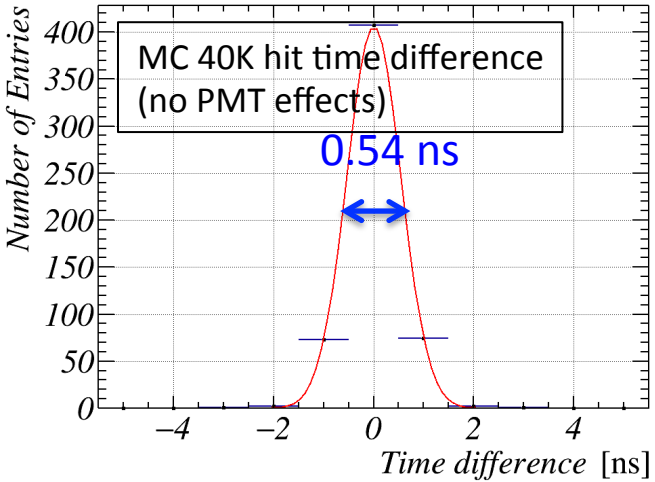


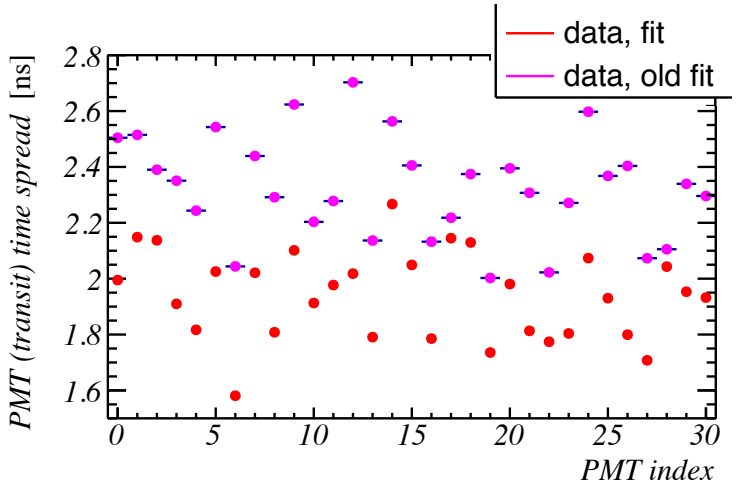


Gaussian fits

Mean **of peak**	-> PMT time offset
Width **of peak**	-> (upper bound on) PMT time spread
Integral of gauss	-> PMT efficiency

Improved ^{40}K fit (2/4)

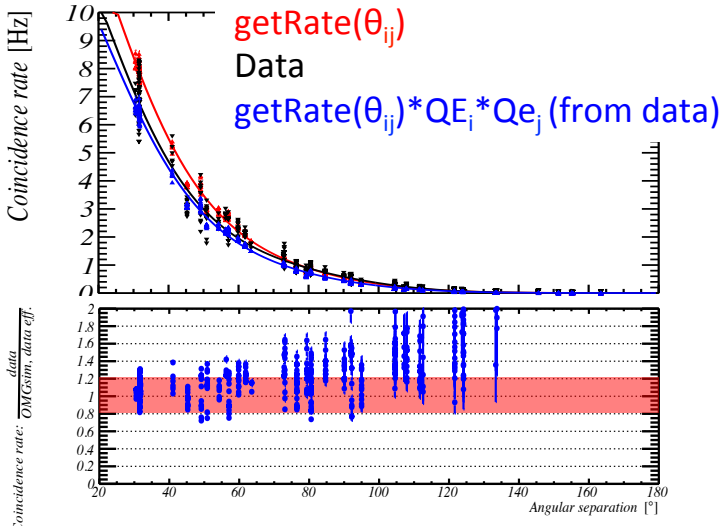


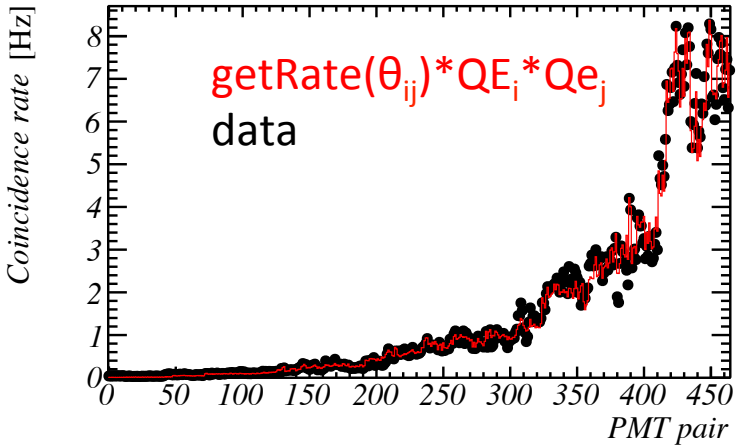


Gaussian fits

Mean of peak	-> PMT time offset
Width of peak **-0.54ns**	-> PMT transit time spread (!)
Integral of gauss	-> PMT efficiency

Improved ^{40}K fit (3/4)





Gaussian fits

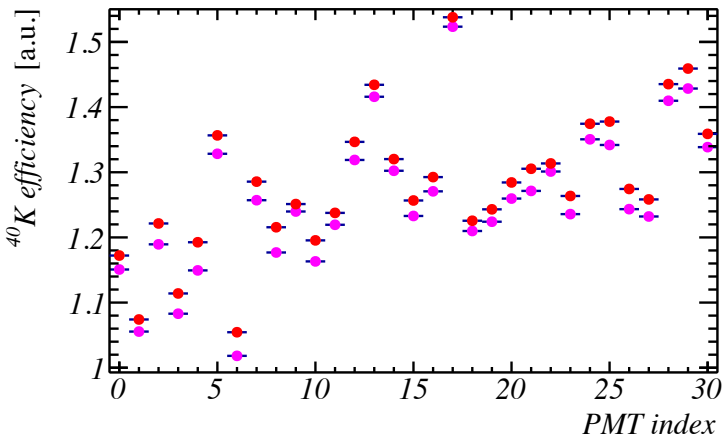
Mean of peak -> PMT time offset

Width of peak -> (upper bound on) PMT time spread

Separate fit

Total coincidence rate -> PMT efficiency

Improved ^{40}K fit (4/4)



data, fit
data, old fit

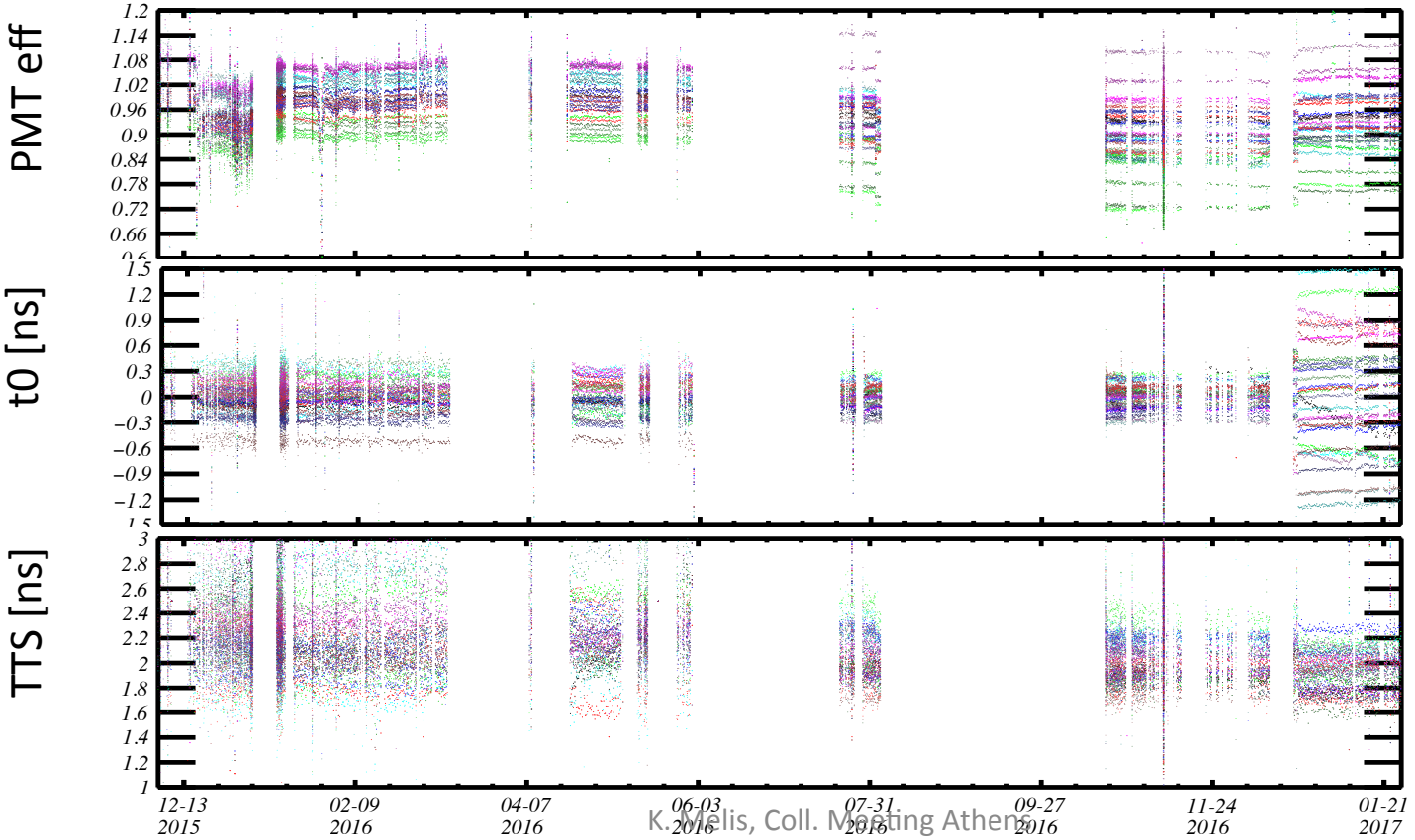
Gaussian fits
Mean of peak -> PMT time offset
Width of peak -> (upper bound on) PMT time spread

Separate fit
Total coincidence rate -> PMT efficiency

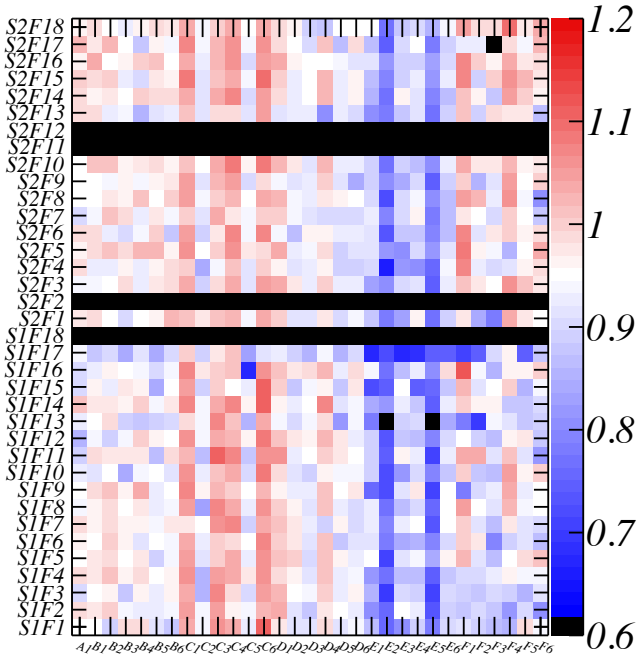
More on KM3RTsim model in software session

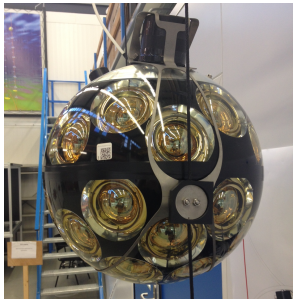
Stability

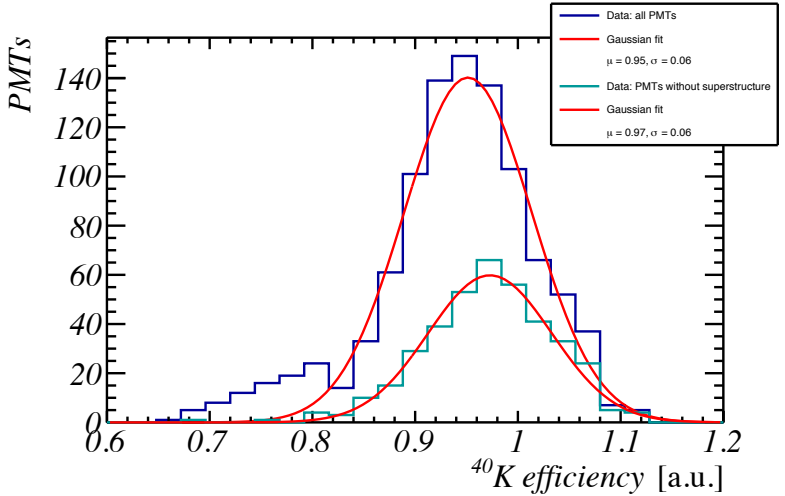
Selected



Systematics: PMT efficiencies



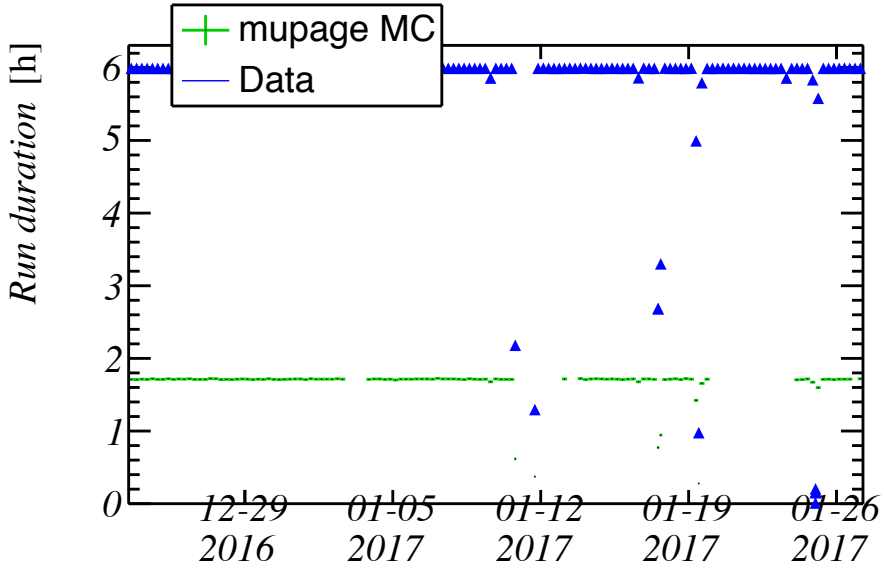




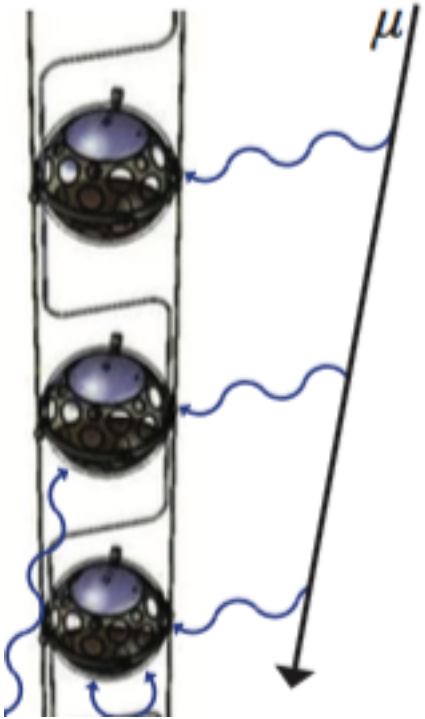
- Clear influence from collar
- PMT efficiency spread: ~6%

Intermezzo: Monte Carlo Simulations

- Atmospheric muons
- mupage + km3 + JTE
- Run by run
  - 30% of data lifetime
  - PMT efficiencies from ^{40}K fit
    - Inactive DOMs are automatically taken into account
  - Same trigger settings
- Trigger rates:
  - Data: 0.54 Hz
  - MC: 0.577 Hz (7% more)



Part III: Inter-DOM calibration



L1 time difference

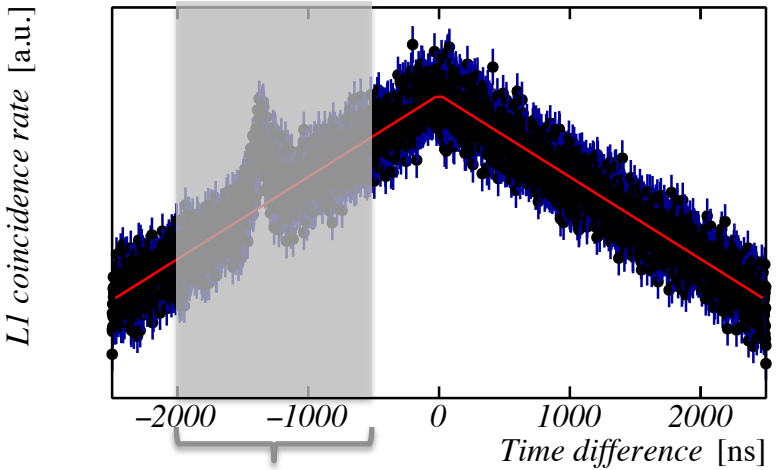
- Time difference between L1 hits on >=2 DOMs

Hit time residuals

- Track reconstruction excluding one DOM
  - Compare measured with expected time

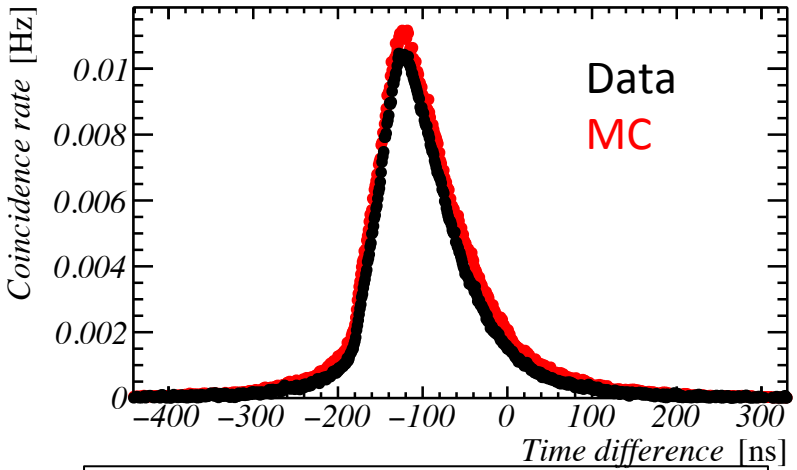
L1 time differences: Method

Random coincidence background



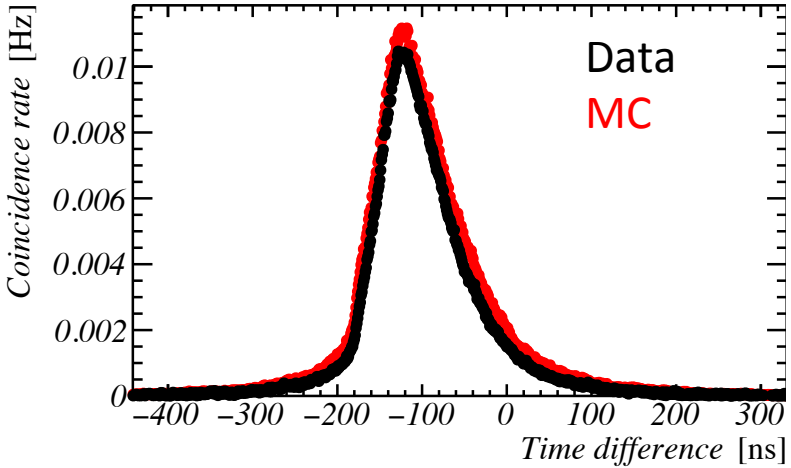
Expected signal region excluded from background fit

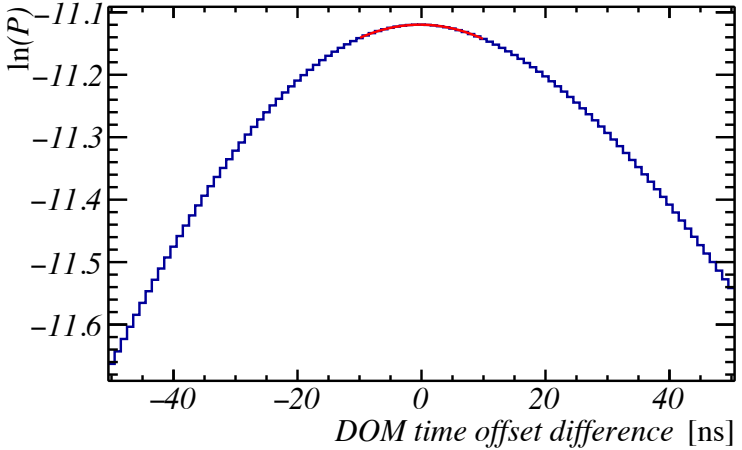
Background subtracted (different DOM pair)



Good data-MC comparison, MC slightly higher ()

L1 time differences: Fit





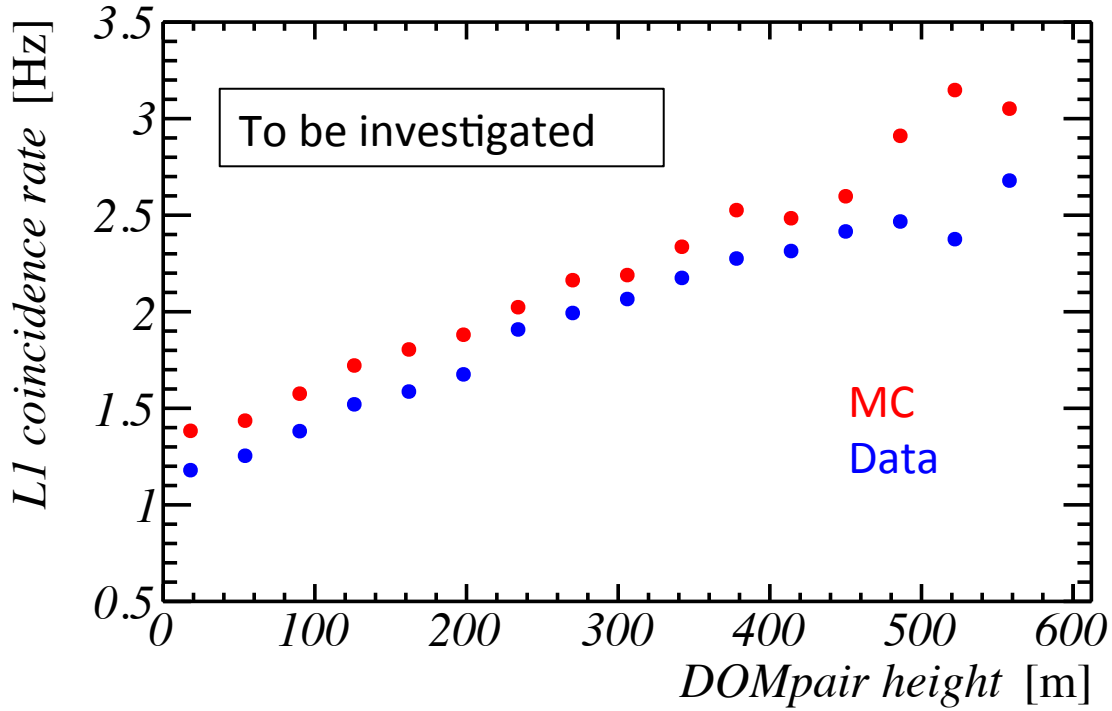
$$P \equiv \prod_{DOMS_{i,j}} \prod_{t} [Poisson(n_{data}(t) \,|n_{MC}(t + \Delta t_{i,j}))]$$

Best fit time offsets:
Maximum of P
(analytical solution)

DOM time offsets

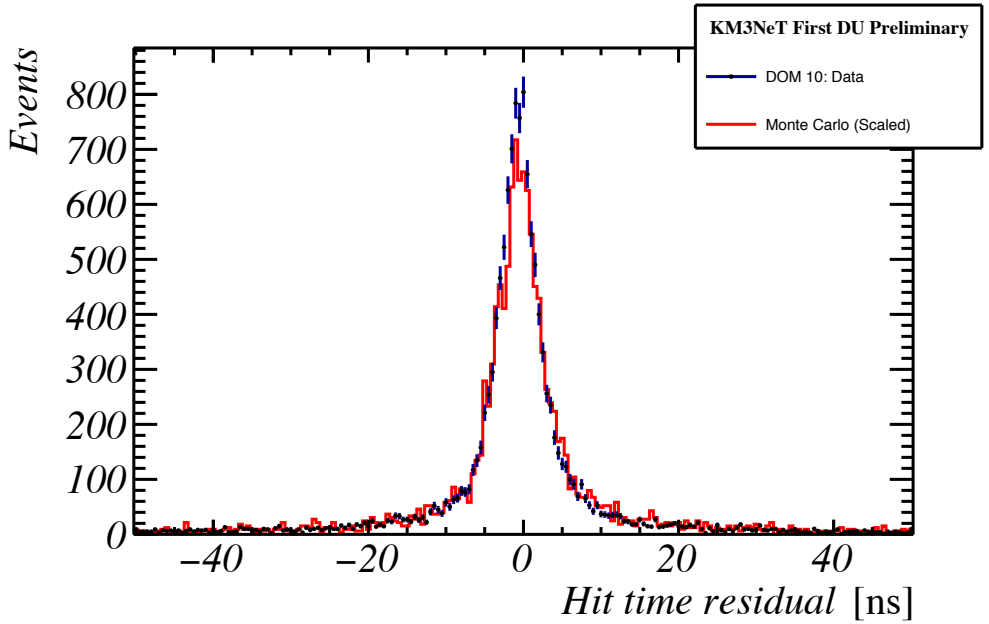
- Fit not working yet ☹
- Inter-DU time calibration ?

L1 coincidence rate vs depth



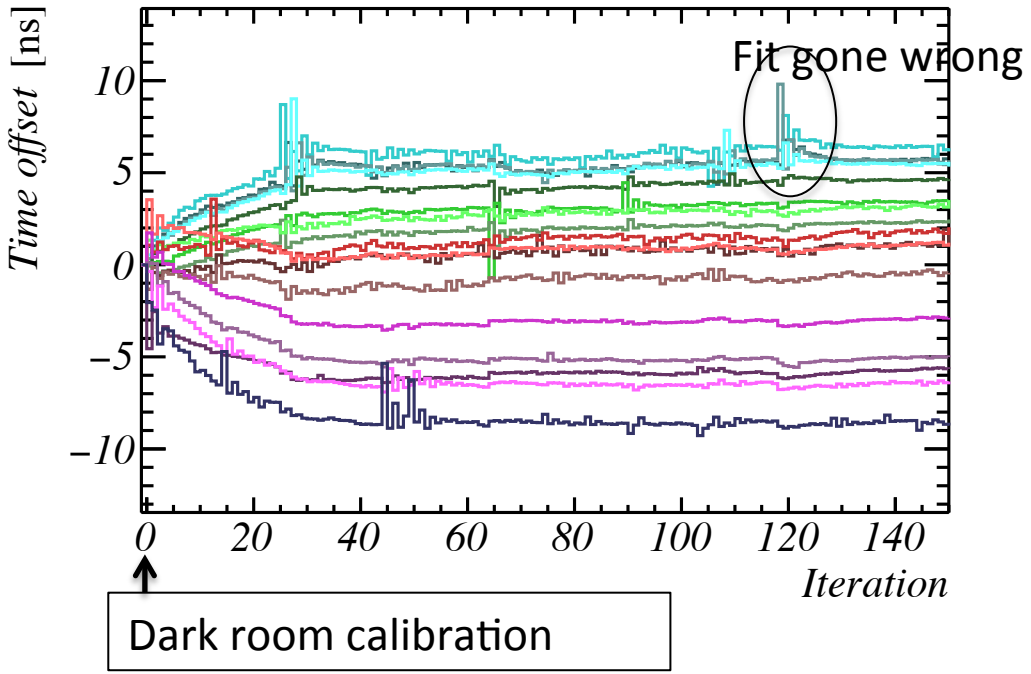
Hit time residuals

```
for each DOM A
  for each triggered event
    select first L1 on each DOM
    remove L1 on DOM A
    fit track if >=5 L1s left
    if cos(theta_fit) > 0.97
      h_HTR.Fill( t_A – t_fit)
```



Inter-DOM time calibration

```
for iteration <= 150
  monitor hit time residuals
  for each DOM
    compare HTR data with MC
    shift DOM time offset
```



Calibration comparison

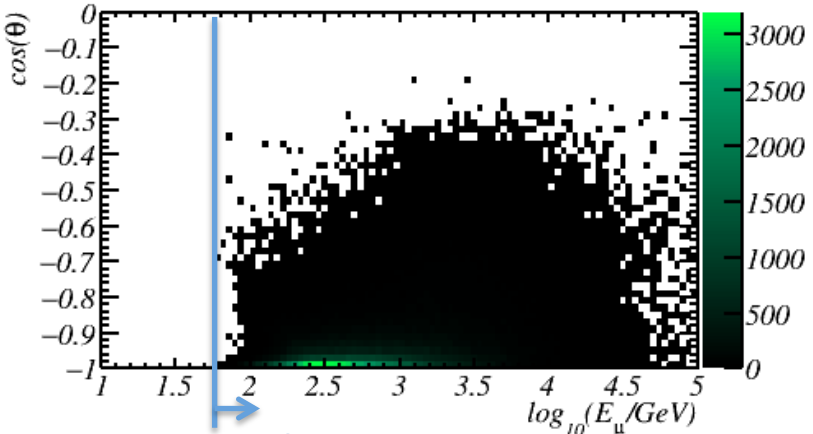
- TODO

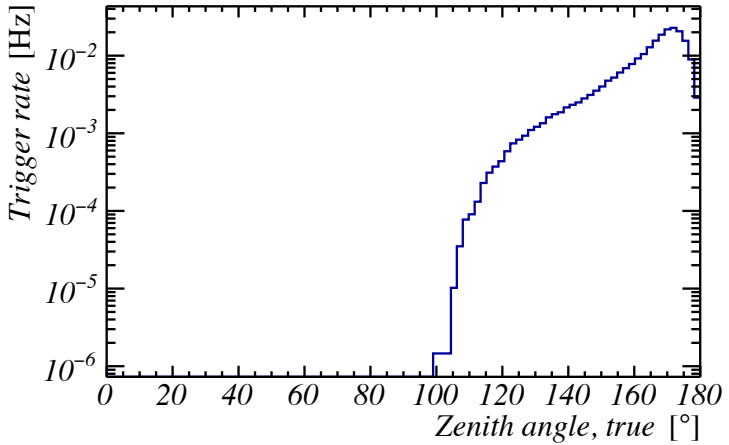
Part V: Reconstruction

- Runs 5009-5170 (…. hours of data)
- Trigger on either DU (numberOfHits=5)
- JPrefit + JSimplex
- One line fit
  - At least 5 L1s on DU
  - Exclude hits on other DU

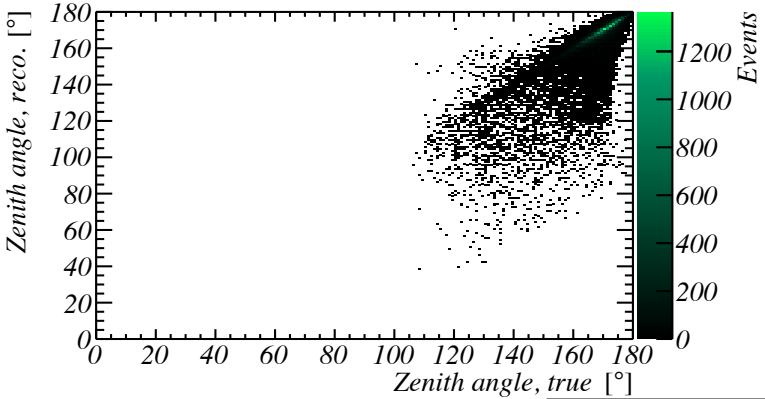
Simulated and Triggered events

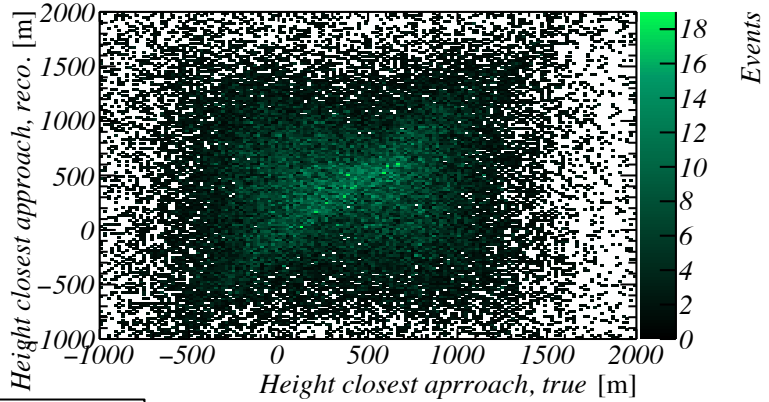
- ~97 million atm. muons generated
- ~400k triggered events (numberOfHits=5)



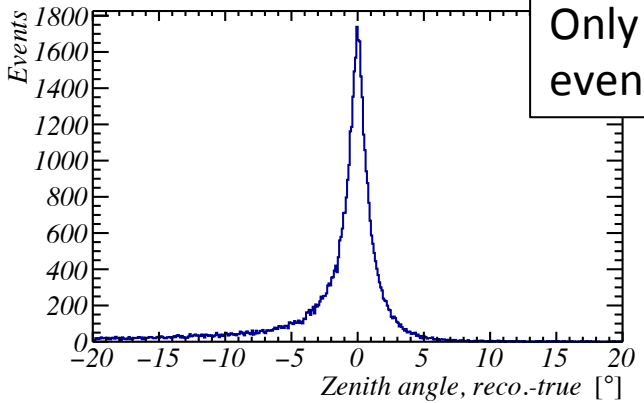


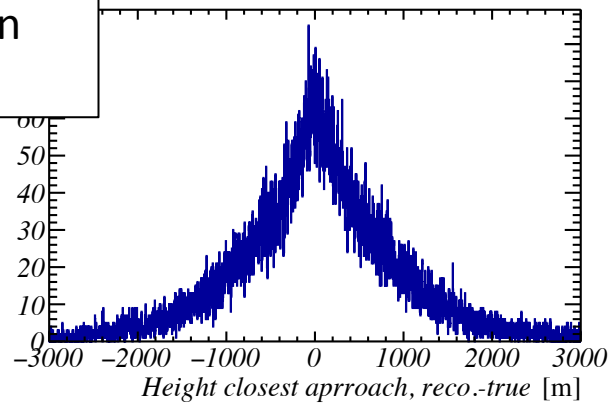
Reconstruction Performance



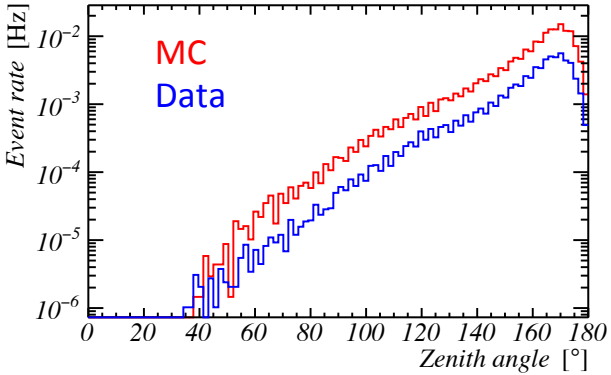


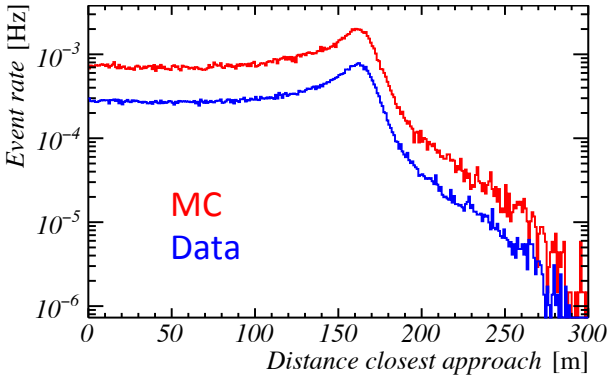
Only single muon events shown

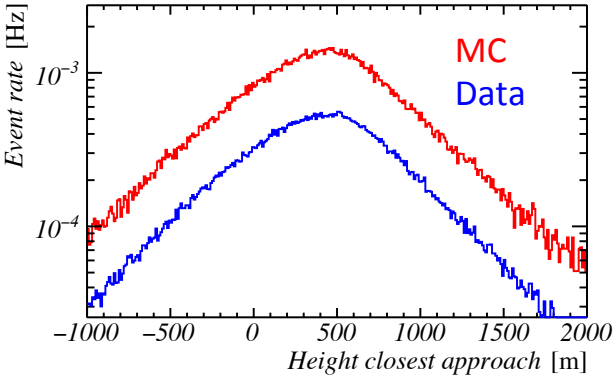




Reconstructed quantities







- No event selection
- Shapes seem to agree well
- Normalization wrong

To be investigated

Conclusions

- Main issues:
  - Normalization data-MC
- Still a lot to do:
  - Hit coincidence multiplicity comparison
  - L1dt fit (inter-DU timing)
  - Calibration comparison
  - More interesting quantities from reconstruction

Backup

Multiplicity

Calibration overview

Inter-PMT

^{40}K

Nanobeacons
Not ideal

Lab measurements
Not feasible

Inter-DOM

Atm. muons L1 time differences

Hit time residuals

Nanobeacons
Done

Lab measurements
Done

Inter-DU

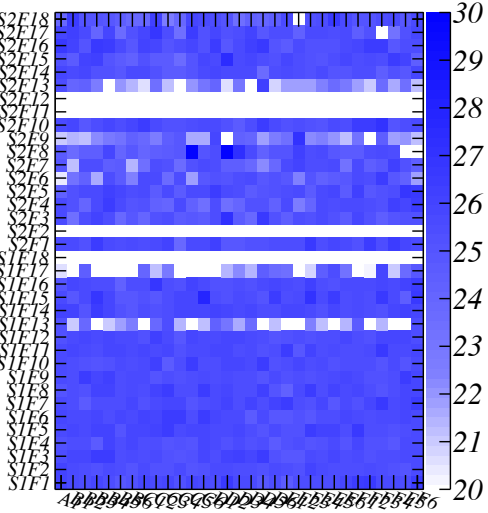
Trigger rates
Done

Hit time residuals
Only 2 DUs yet

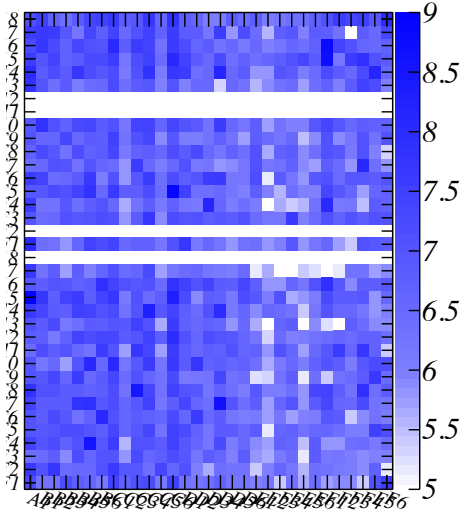
Nanobeacons
Done

White rabbit
Done

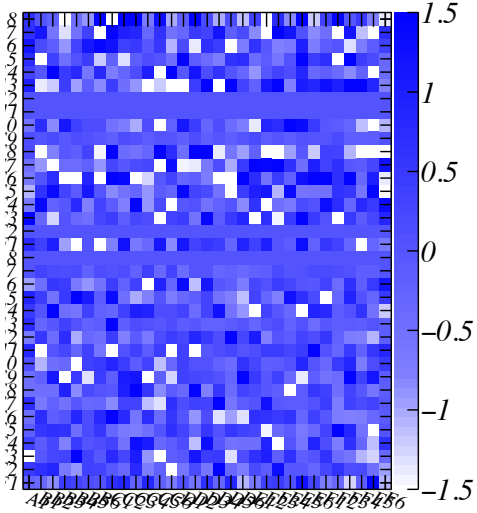
Systematics: others



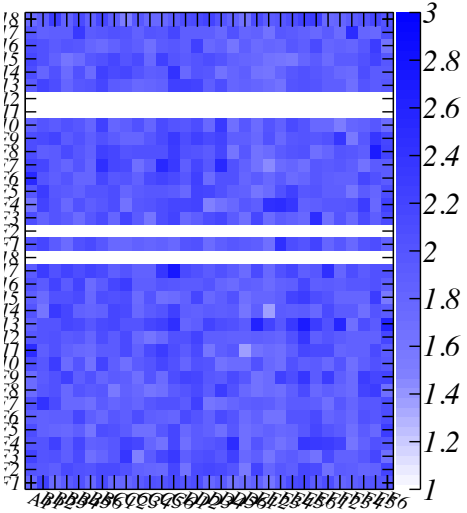
ToT [ns]



Singles rate [Hz]

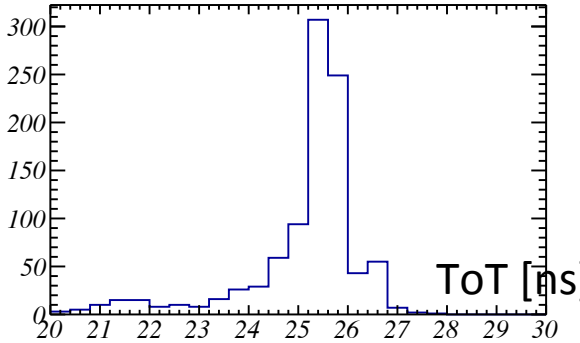


t0 [ns]

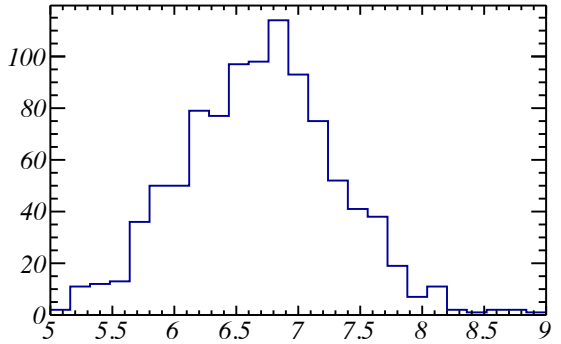


TTS [ns]

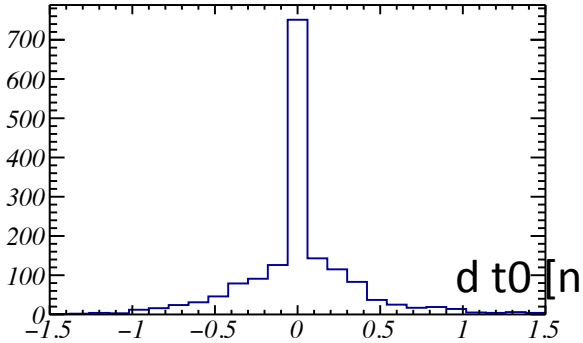
Distributions: others



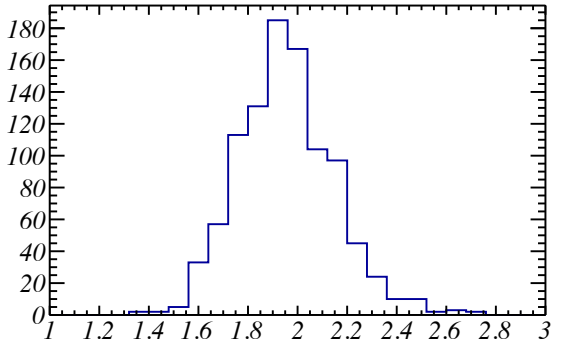
ToT [ns]



Singles rate [Hz]

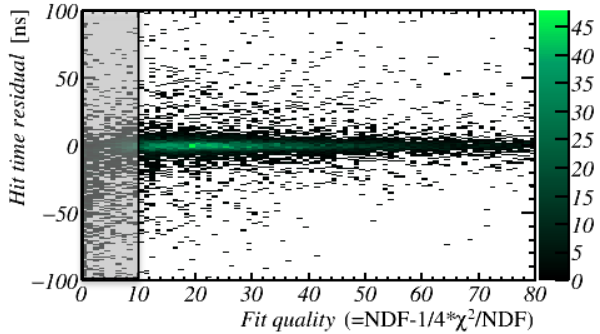


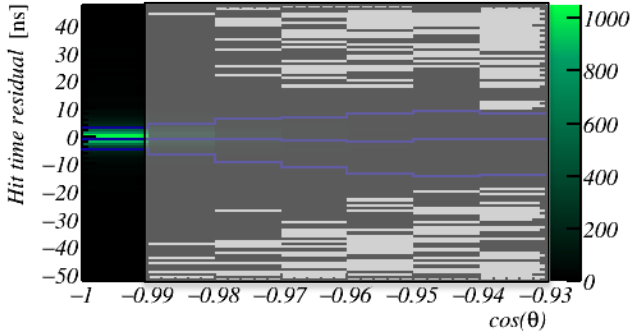
d t0 [ns]



TTS [ns]

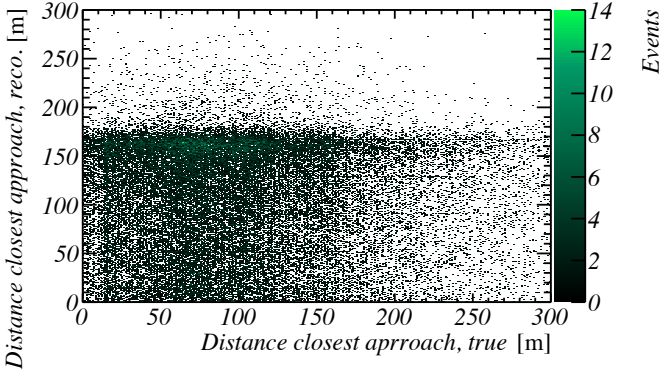
Hit time residuals, high quality tracks

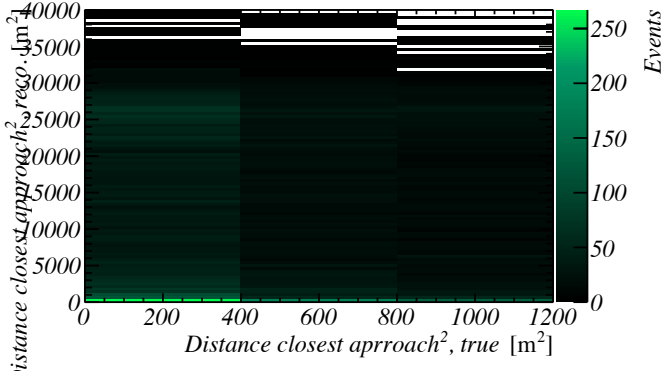


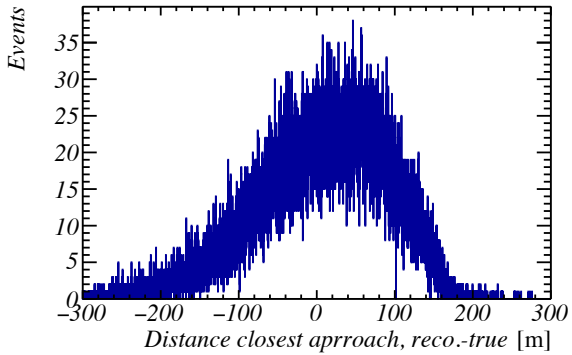


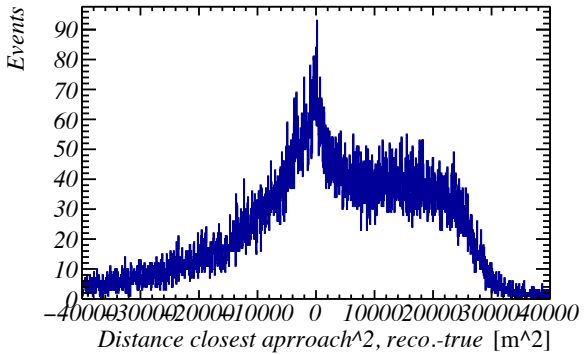
Fit quality > 10
cos(θ) < -0.97

Reconstruction performance









Reconstruction

- Runs 5009-5170 (…. hours of data)
- Trigger on either DU
- Reconstructed if >=3 (L1) hit DOMs on both Dus (>=6 in total)