Introduction

Karel Melis

June 9th 2017

Settings, Data Runs and other Info

- All stages and all plots are done using **compatible JPP versions (rev), starting from scratch**

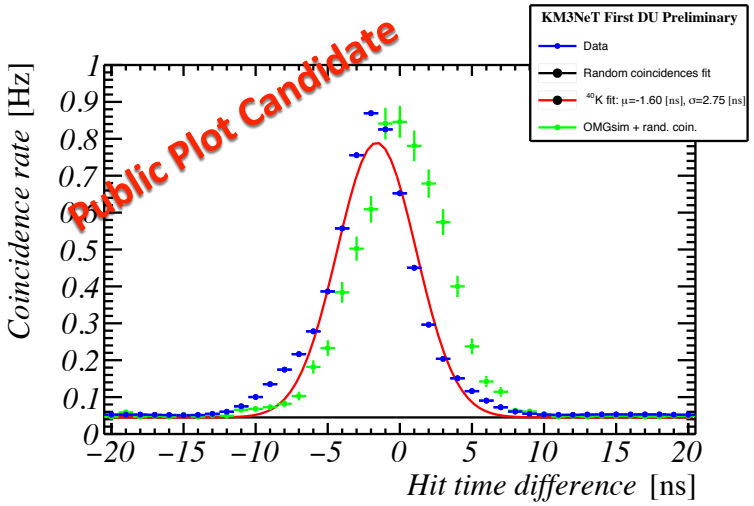
- Runs used are 5009-5046

- Info and details @:
  - http://wiki.km3net.de/index.php/OMGsim_simulations_for_K40_fit
  - http://wiki.km3net.de/index.php/In-situ_calibration
  - http://wiki.km3net.de/index.php/Unofficial_rbr_muon_MC_DU1%2B2

In-situ Fitted Parameters

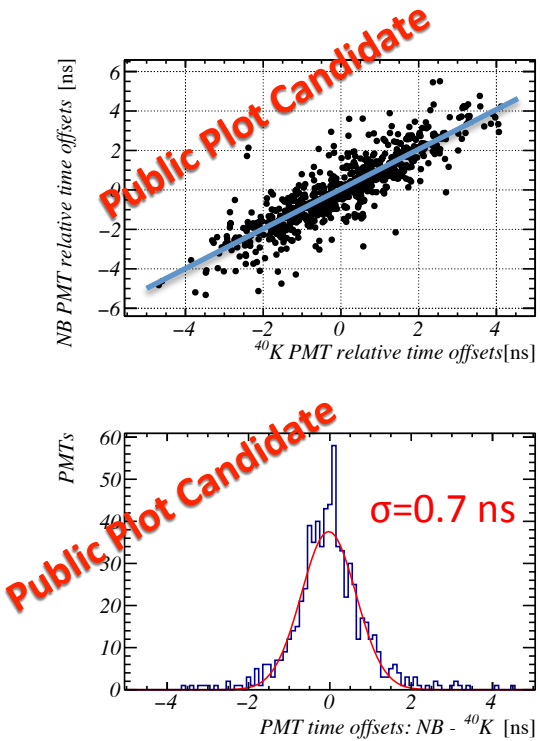
- From data:
  - See back-up slides for details
  - Mean singles rate: 6.7 kHz
  - Mean gain: 1.0 (by definition)
  - Mean gainspread: 0.53
  - Mean TTS: 2.1 ns
  - Inter-PMT time offsets
  - PMT efficiencies (most important)

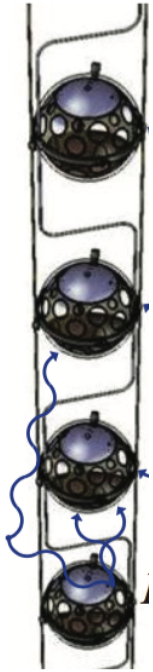
40K Fit



- Background estimated from tails (15-20 ns)
- Model from OMGsim (geant4)
- Simultaneous fit of 465 coincidence graphs per DOM
  - mean -> time offset
  - width -> transit time spread
  - amplitude -> PMT efficiency

PMT Time Calibration Check (2)





- Assuming incident nanobeacon light is plane wave
  - Work by Martijn Jongen
- *Relative* time offset == average time offset set at zero

OMGsim & PMT Efficiencies

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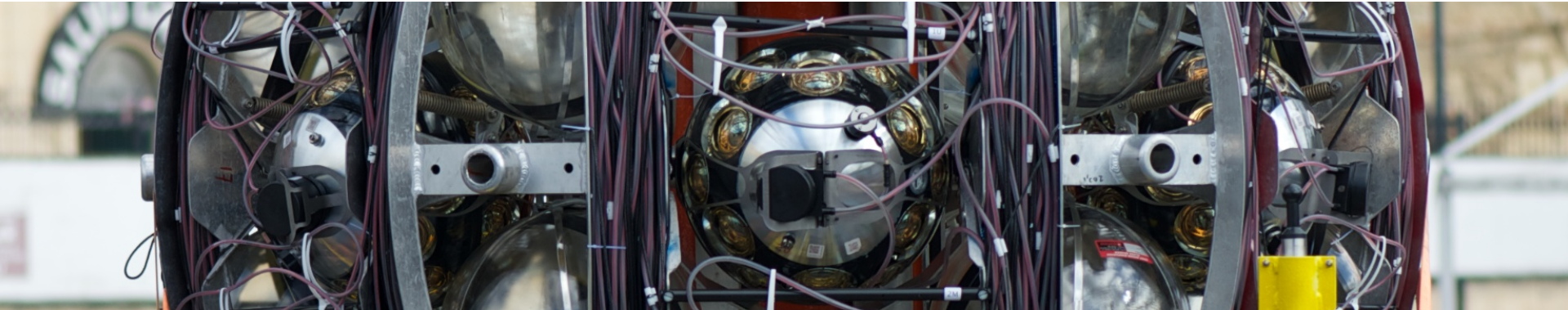

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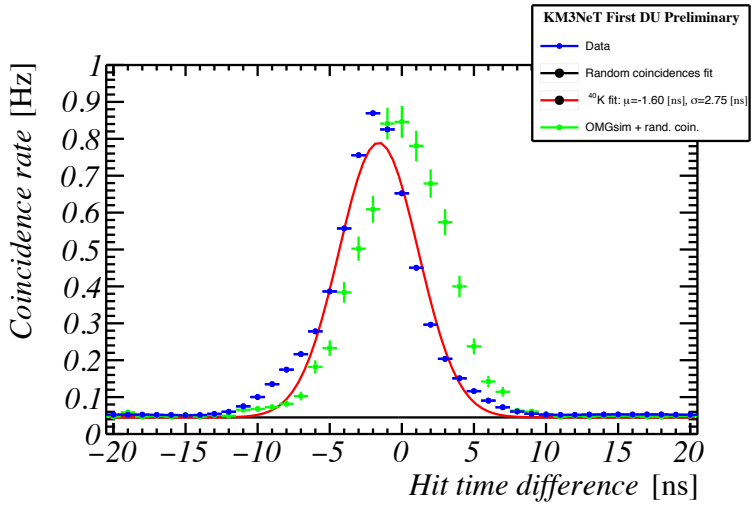

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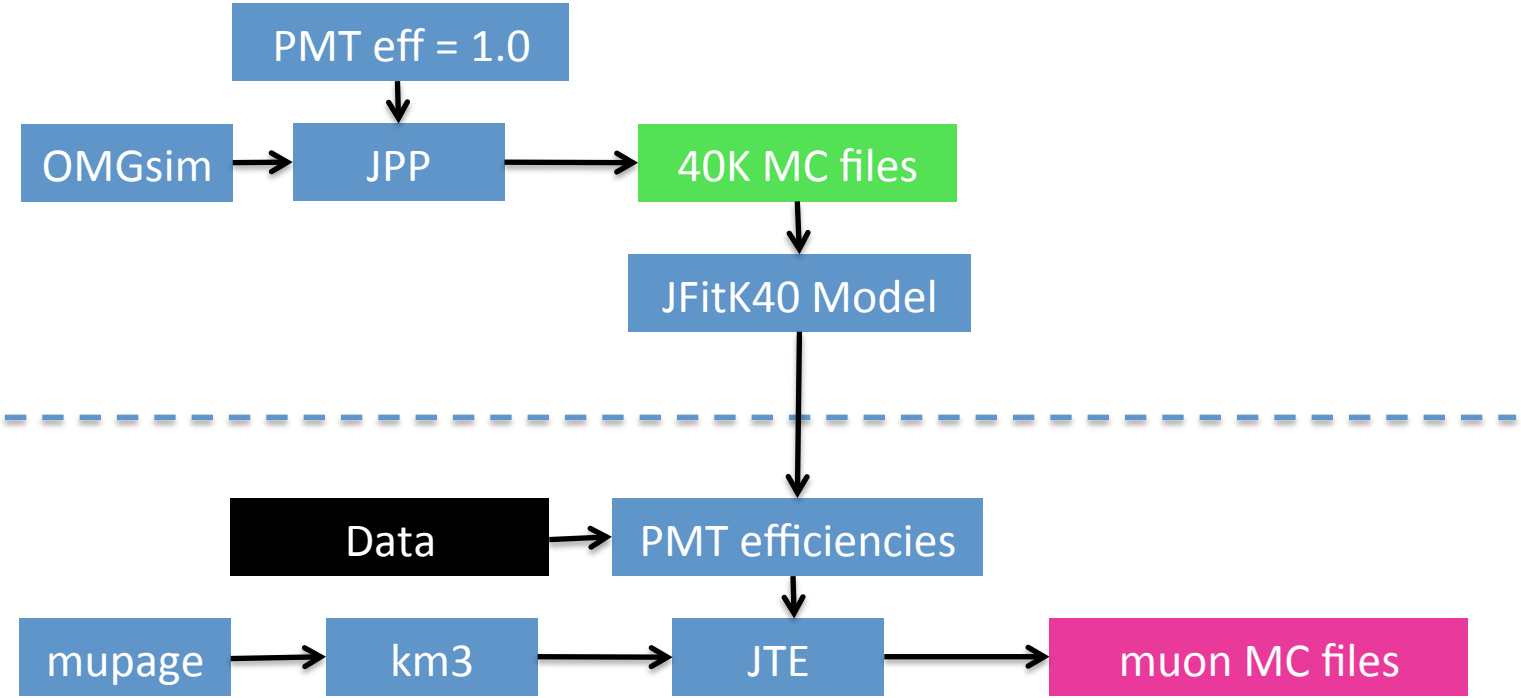
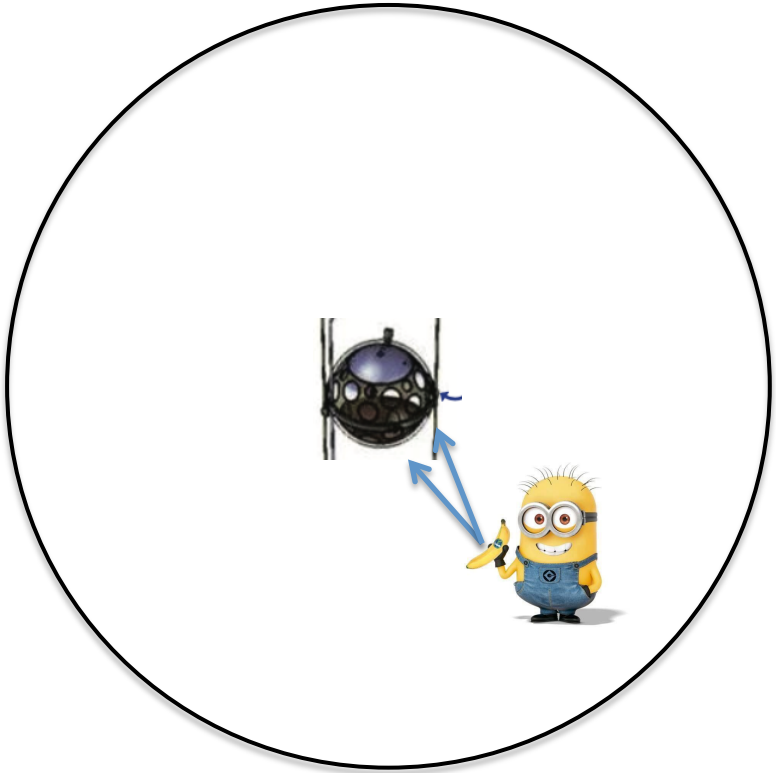
The Big Puzzle

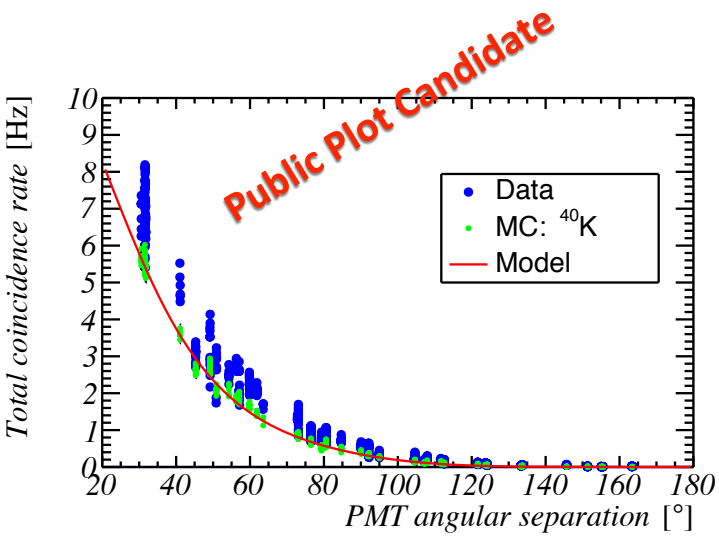


OMGsim



- Wrapper around Geant4
- ^{40}K decays simulated in DOM vicinity (<=10m)
- Detailed model of KM3NeT DOM optical properties
  - However no collar and superstructure
- Livetime from 40K activity and target volume (total ~7minutes)

JFitK40 Model



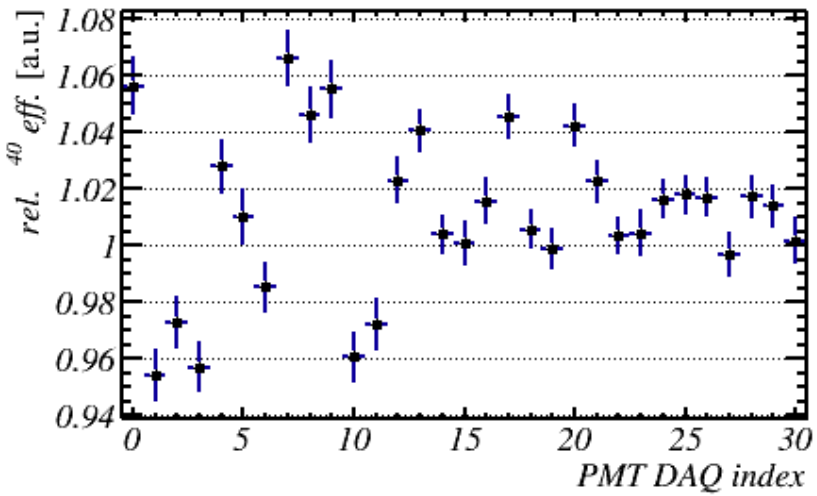
- OMGsim MC is well-fitted by model:

```
/**
 * Get K40 coincidence rate as a function of cosine angle between PMT axes.
 *
 * \param  ct            cosine angle between PMT axes
 * \return                rate [Hz]
 */
inline Double_t getRate(const Double_t ct) const
{
  return Rate_Hz * TMath::Exp(p1+ct*(p2+ct*(p3+ct*p4)));
}
```

```
Rate_Hz: 1
     p1: -1.07061
     p2: 3.17173
     p3: -1.35769
     p4: 1.6885
```

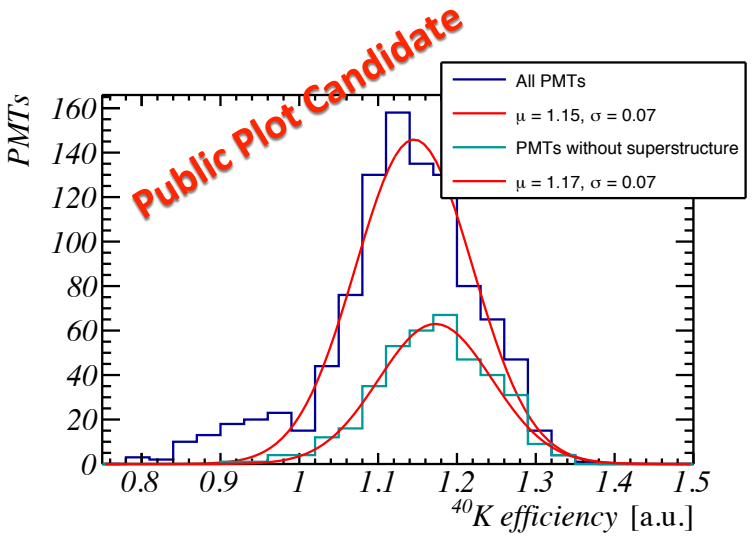
- Data is slightly higher than MC

Check: JFitK40 on MC



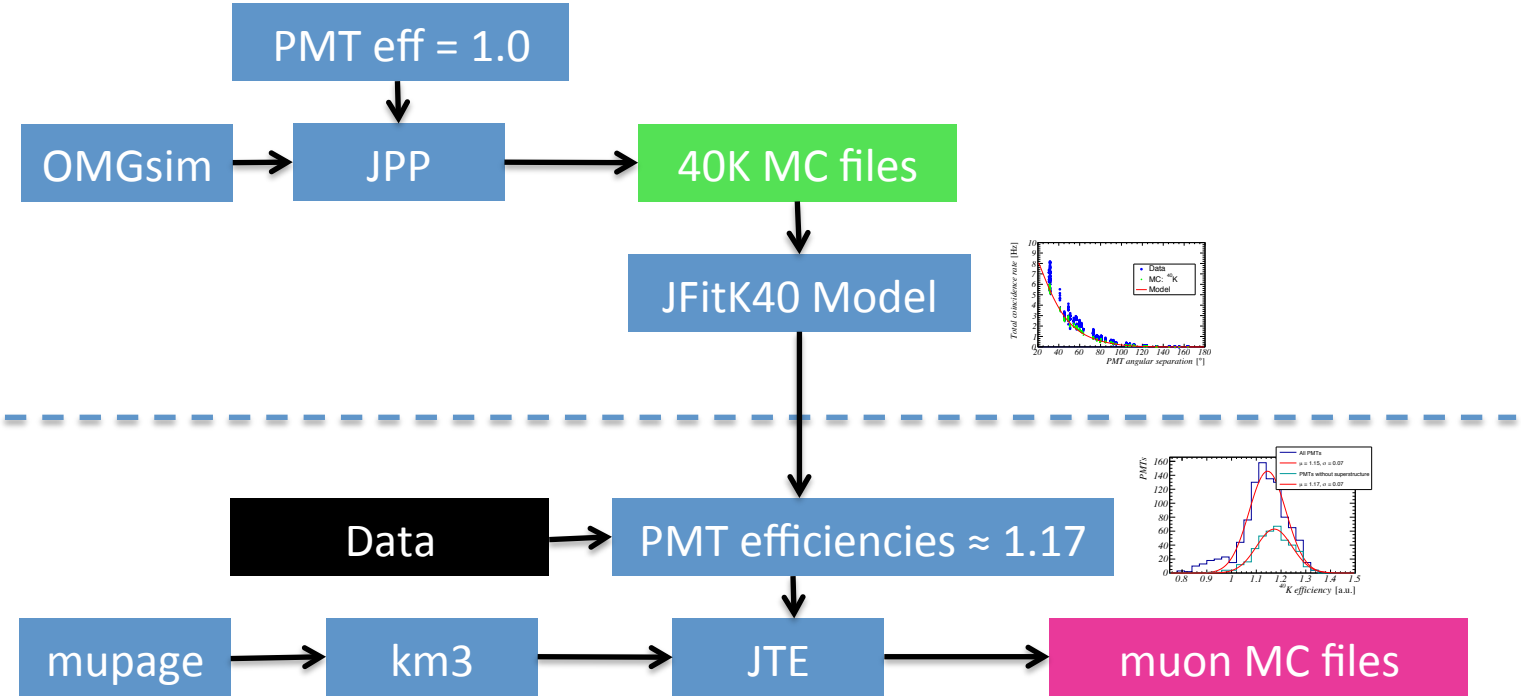
- Fit OMGsim coincidence rates using model from same MC data
  - Should give PMT eff 1.0
- Systematic deviation from 1.0
  - Phase-space effects or wrong fit
  - For now low priority
  - getRate(int index) lookup table rather than parametrisation?

JFitK40 on Data



- Mean PMT efficiency: 1.17
  - Unobstructed PMTs
- Superstructure blocks light -> lower efficiency
- Efficiency >1.0?
  - Efficiency=1.0 means a nominal PMT

The Big Puzzle



Run-by-Run MC

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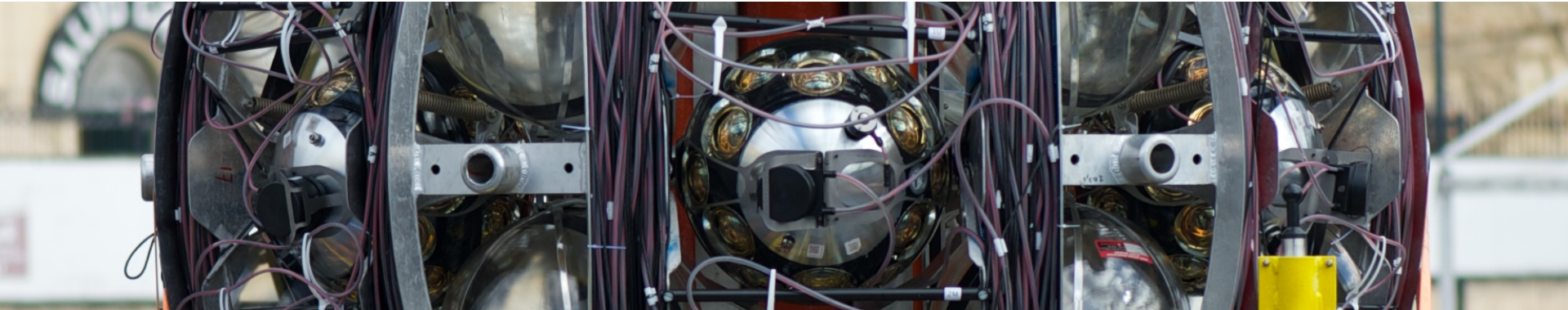
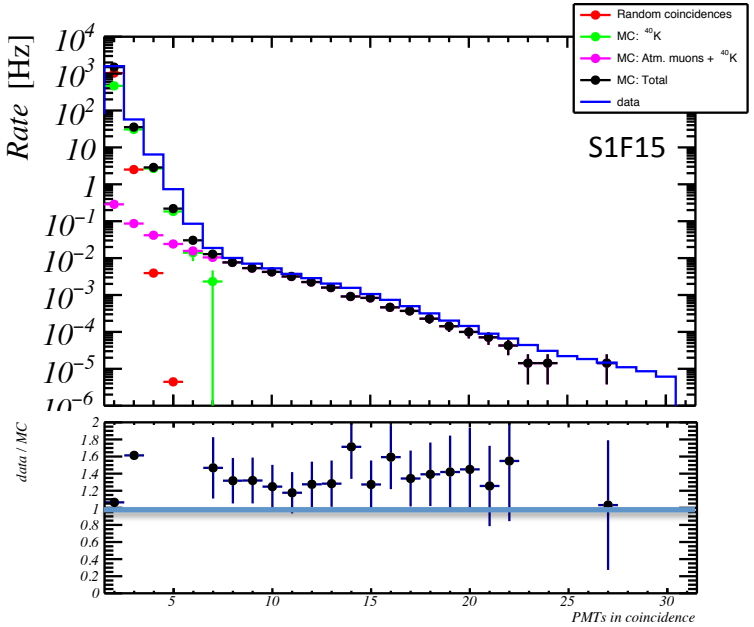


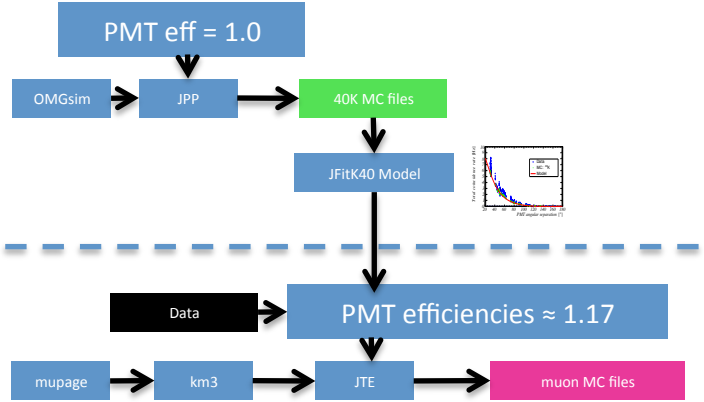
Introduction

- Mupage-km3 chain:
  - Settings from data, or 'on the safe side'
    - Large CAN
    - Low muon E threshold (1GeV)
    - Nominal DOM positions
  - Simulated time proportional to run duration
- JTE inputs:
  - Singles rate background: 6.7 kHz
  - Gain and gainspread: 1.0, 0.53 resp.
  - PMT efficiencies: from fit on run-data
- One MC file per run, fluctuation between runs automatically taken into account.
- **This Monte Carlo production is not the official one, please see Rosa's talk for the investigation of the differences.**

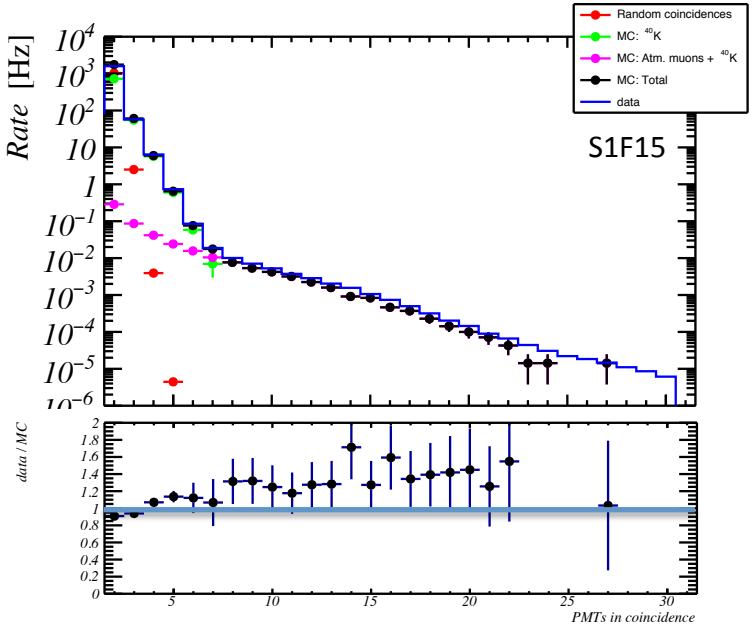
Coincidence Graphs



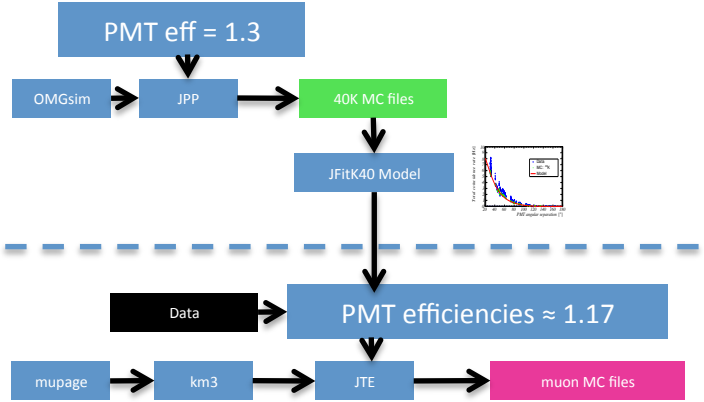
- Monte Carlo 'out of the box'



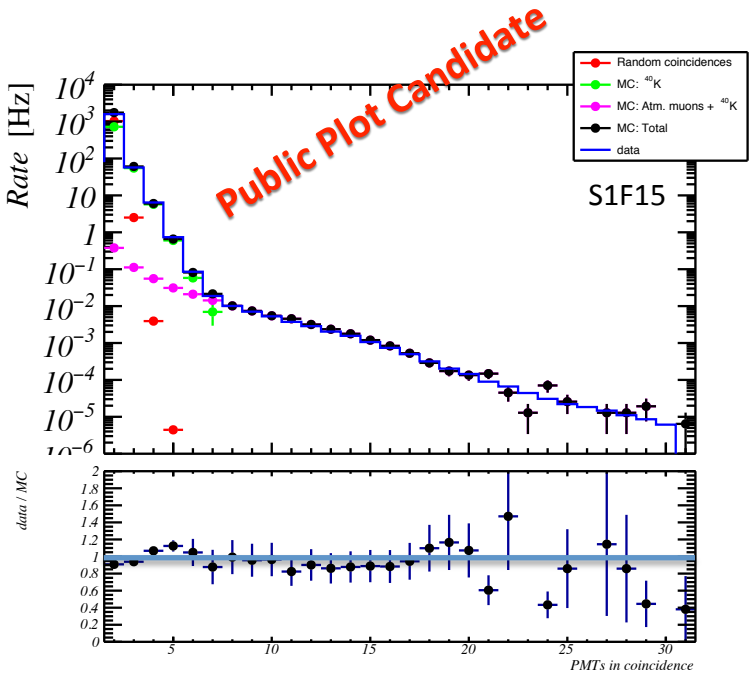
Coincidence Graphs



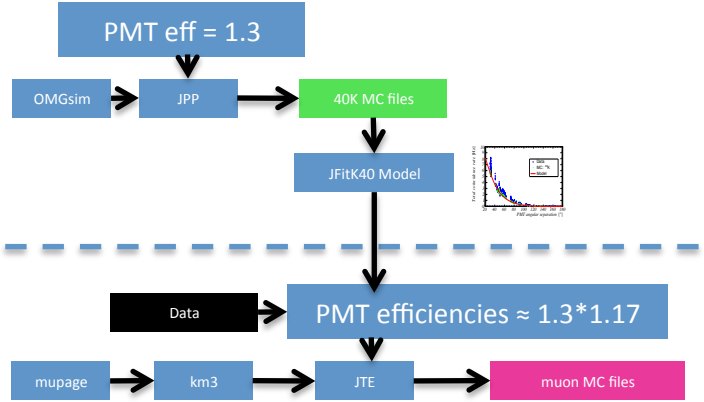
- OMGsim PMT eff = 1.3
- Mupage PMT eff = 1.17*1.0



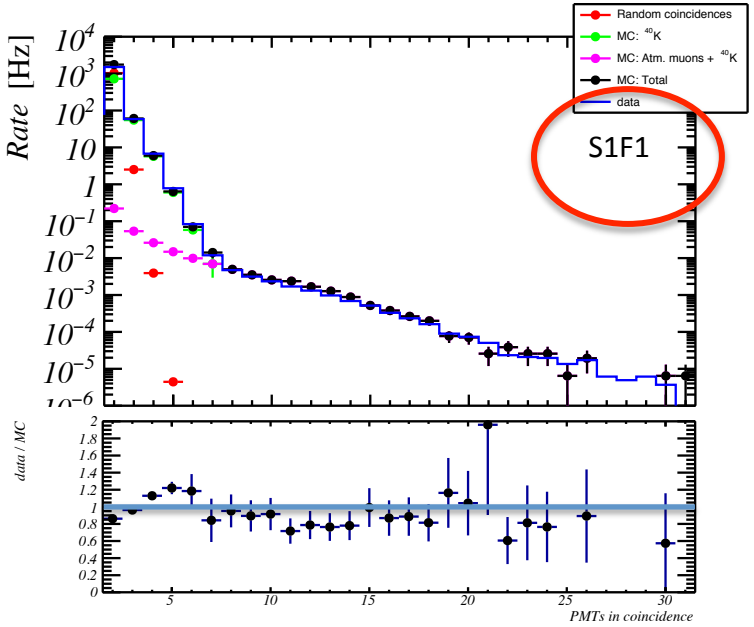
Coincidence Graphs



- OMGsim PMT eff *= 1.3
- Mupage PMT eff *= 1.3



Coincidence Graphs

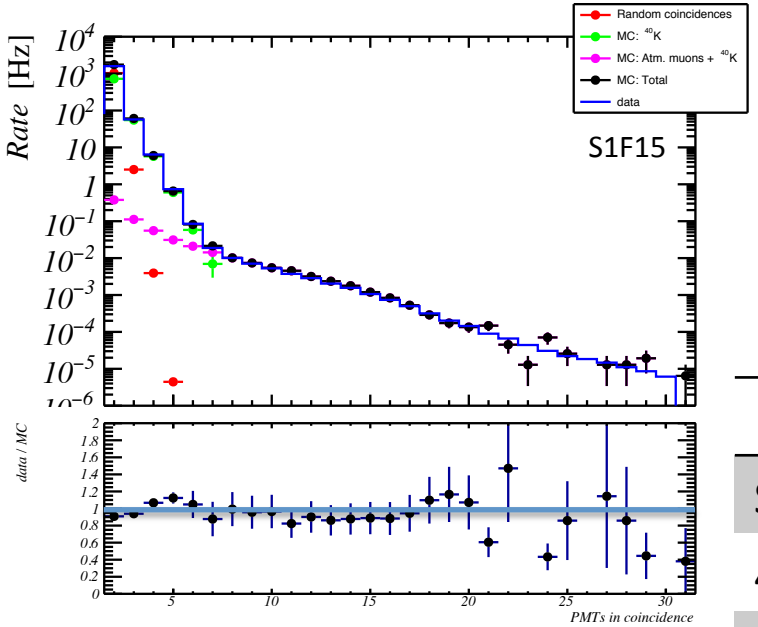


- OMGsim PMT eff *= 1.3
- Mupage PMT eff *= 1.3

- Very good agreement!
  - Personal bold opinion: Apparently Antares felt OK working >10yrs with a factor 2 data-MC disagreement, let's try to get it right in KM3NeT from the start.

- **We're underestimating the PMT efficiencies (in OMGsim and km3) by a factor of 1.3**

PMT Efficiencies *= 1.3



- Absorption length?
- PMT QE/collection efficiency, angular acceptance?
- (Overall flux?)

	L_{abs}	QE
Singles rate k=1	e^{-L}?	linear
40K coin. k=[2; 6]	independent	Log-slope
Muon coin. k>7	e^{-L}?	log-linear

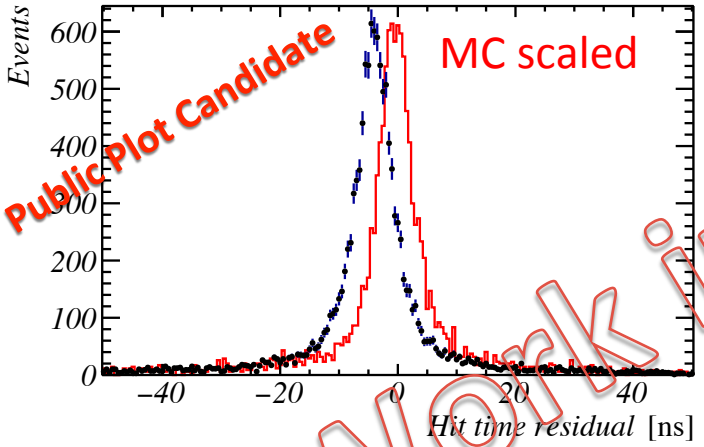
Inter-DOM Time Calibration

Karel Melis

June 9th 2017

Hit Time Residuals

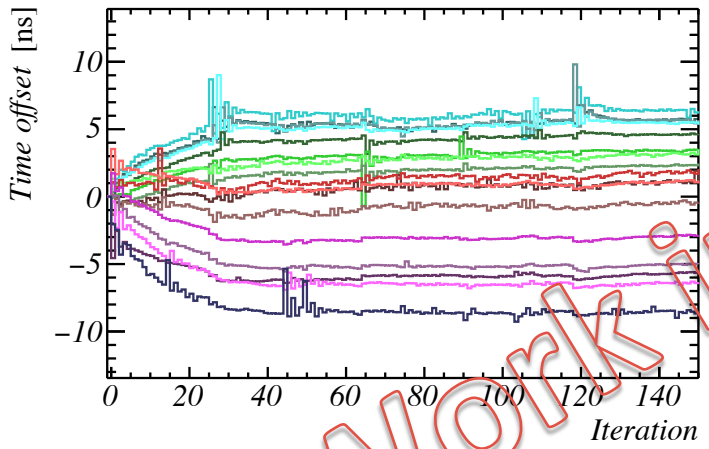
Before calibration:



- Jprefit+JSimplex with hits on same DU
  - No Inter-DU time calibration
  - +JGandalf doesn't make sense at this stage
- Excluding hit on DOM i
- Measured hit time minus expected from fit

Work in progress

Repetitive Fits

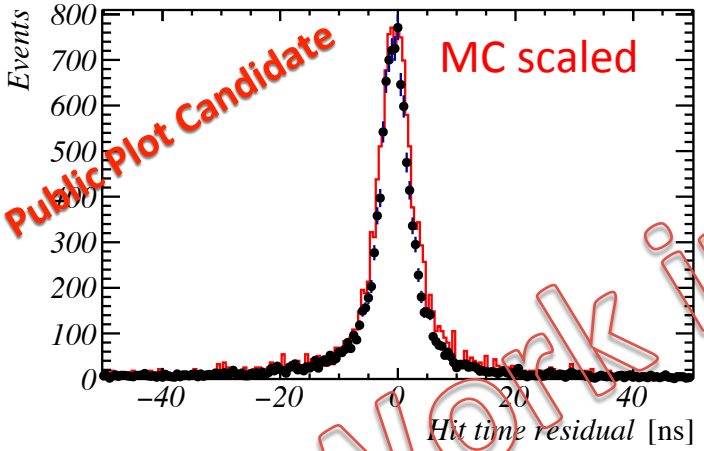


- Every iteration:
  - Fit tracks + monitor HTRs
  - Find best matching DOM time offset
  - Change all DOM time offsets
  - Repeat
- Convergence after ~ 50 iterations
- Final result depends heavily on position calibration

Work in progress

Hit Time Residuals

After calibration:



- Very good data-MC agreement in distribution
  - Working on normalization
- Time calibration machinery is in place

Work in progress

Conclusions

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Calibration

- Most of the **most important PMT parameters can be fitted in-situ**.

- Time calibration **methods are available and tested**, waiting for position fit (and working detector) to do inter-DOM time calibration.

Data-MC

- Coincidence rates vs multiplicity provide a very nice handle to check MC.
- We're underestimating the PMT efficiencies (in OMGsim and km3) by a factor of 1.3. The origin of this discrepancy should be traced down.
- For now (ICRC) take this 1.3 factor as granted

Further Reading, Scripts & Data Files

- Wiki+Scripts:
  - http://wiki.km3net.de/index.php/OMGsim_simulations_for_K40_fit
  - /sps/km3net/users/kmelis/OMGsim/README
  - http://wiki.km3net.de/index.php/In-situ_calibration
  - /sps/km3net/users/kmelis/DU_calibration/README
  - http://wiki.km3net.de/index.php/Unofficial_rbr_muon_MC_DU1%2B2
  - /sps/km3net/users/kmelis/DU_MC/README
  - /sps/km3net/users/kmelis/multiplicitystudy/README

- Data:
  - /sps/km3net/users/kmelis/OMGsim/data/
  - /sps/km3net/users/kmelis/data/KM3NeT_00000014_0000*/

Public Plot Candidates

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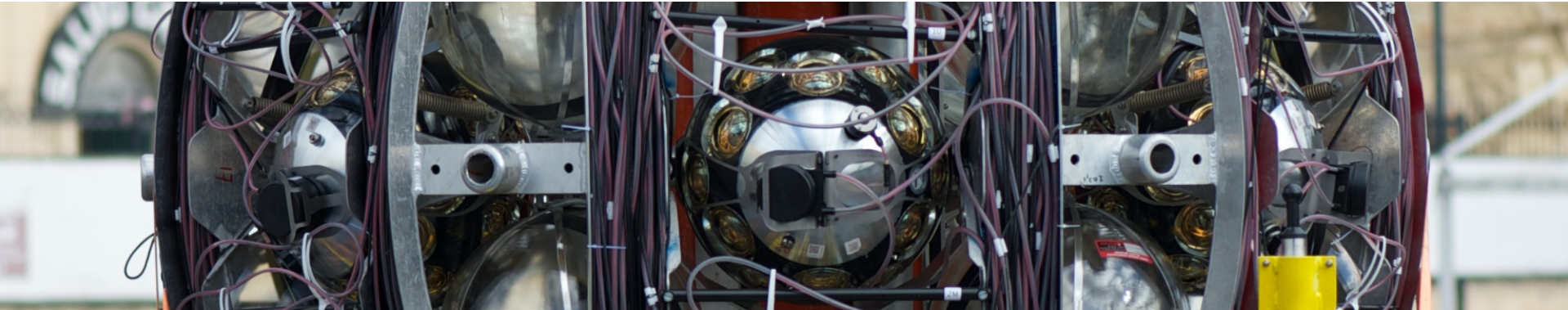
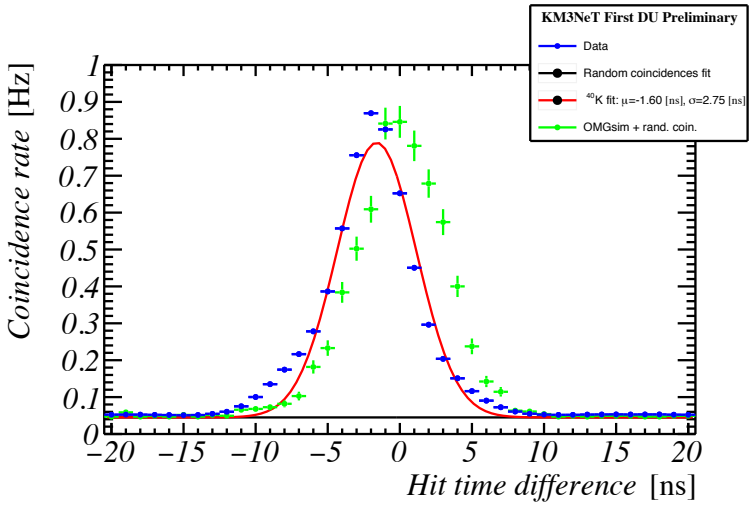


40K Fit



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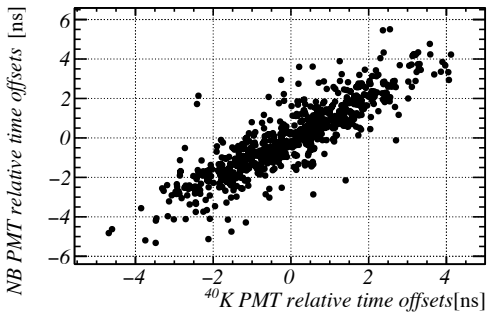
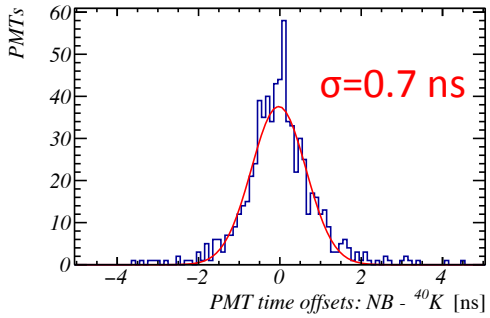
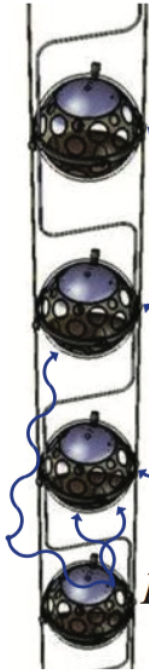
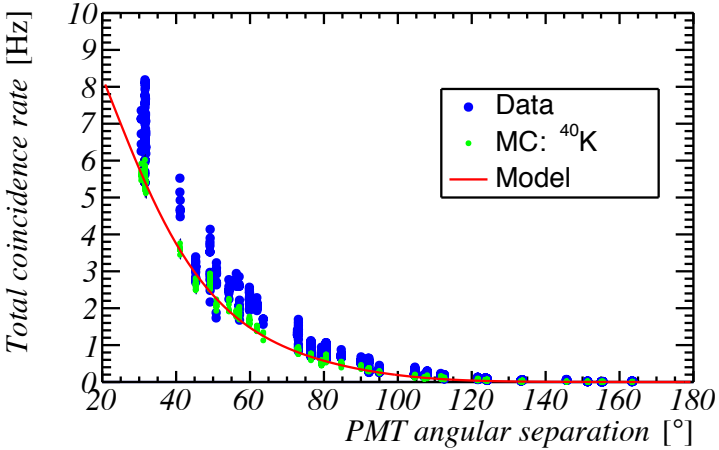






- Assuming incident nanobeacon light is plane wave
  - Work by Martijn Jongen
- *Relative* time offset == difference wrt average of fitted PMT time offsets on DOM

^{40}K Coincidence Rate



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```
Rate_Hz: 1
     p1: -1.07061
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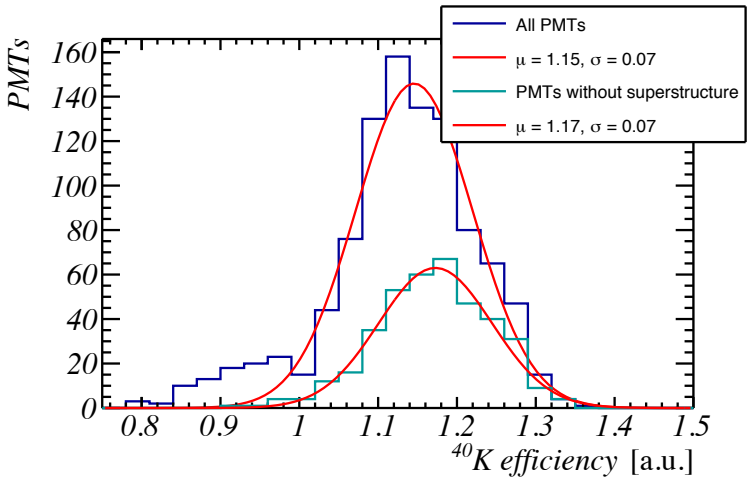
- Data is slightly higher than MC

K40 Fit on Data



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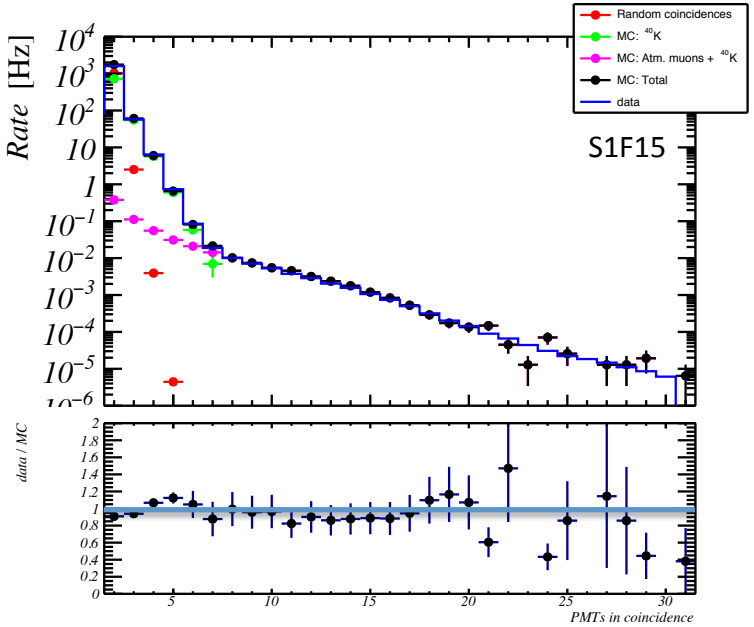

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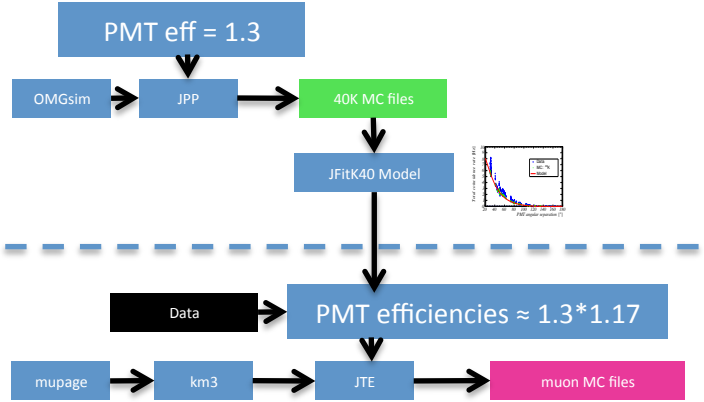
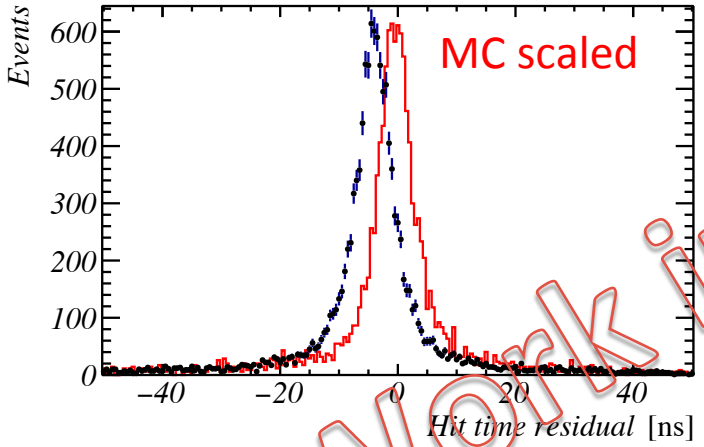


Hit Time Residuals

Before calibration:



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Work in progress

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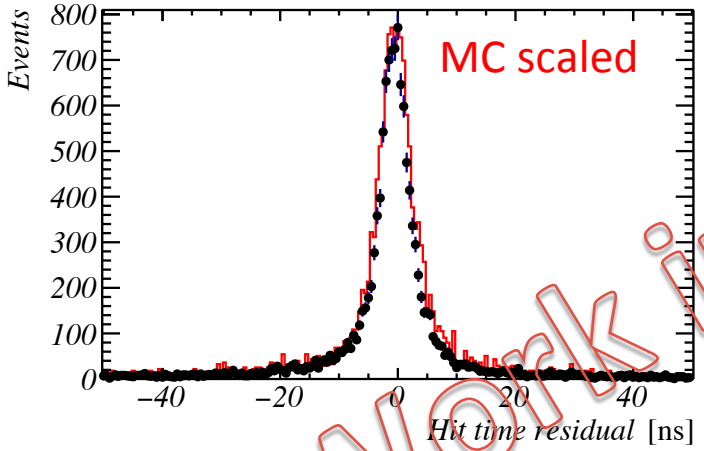

- Very good data-MC agreement in distribution
  - Working on normalization
- Machinery in place, waiting for position calibration (and working detector)

Work in progress

Back-up

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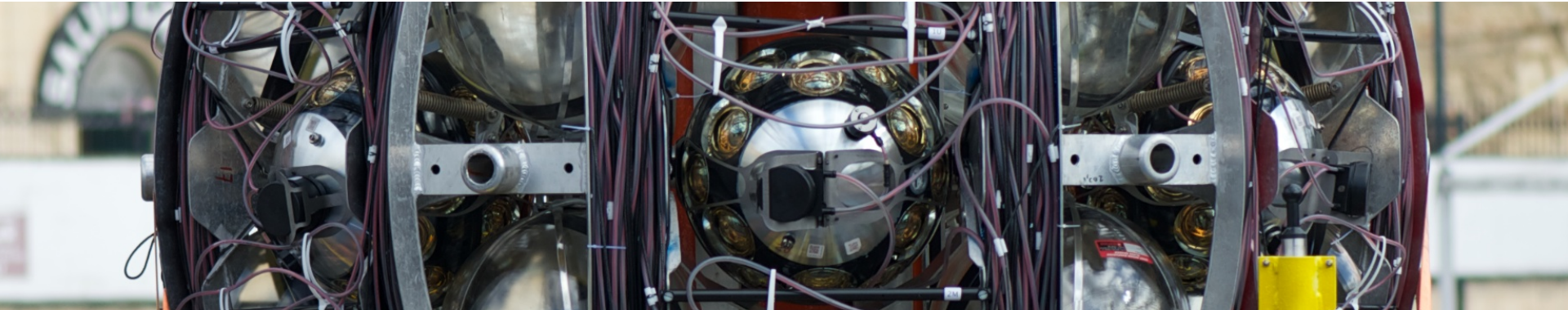
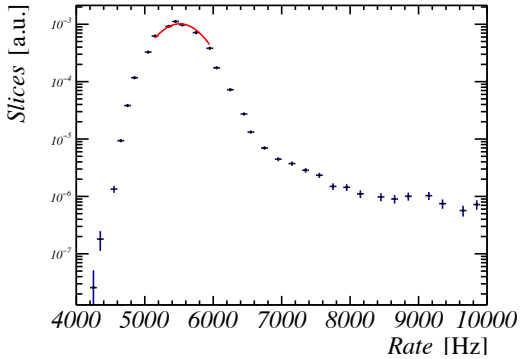
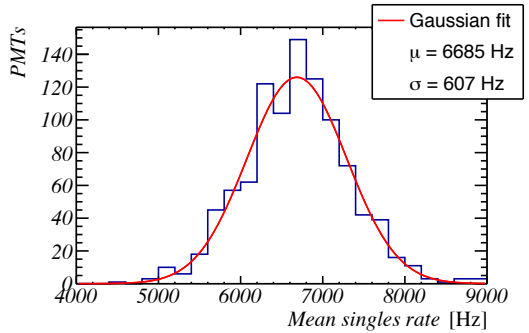


Singles Rates

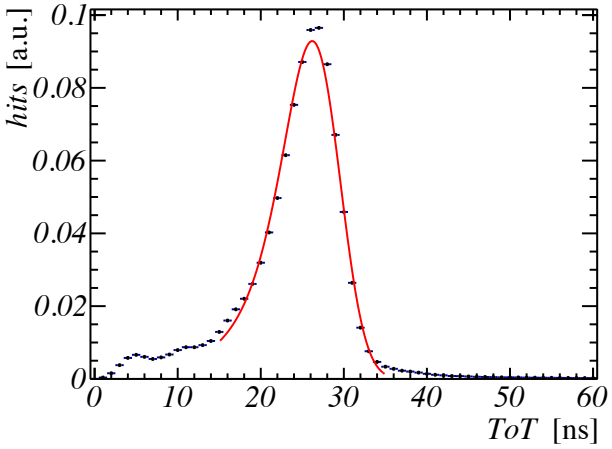




- Genuine (40K) hits and dark count
- Monitored in summary data
- Fit peak with gauss
- Mean singles rate: 6.7 kHz

```
JMonitorSinglesRates -a <detfile> -f <datafile> -o monitor.root
JFitSinglesRates -a <detfile> -f monitor.root -o fit.root -p 0.3
  -p: peakfraction
```

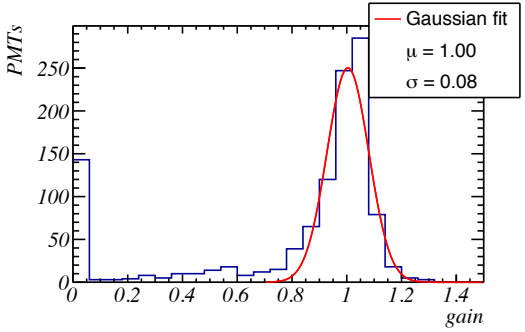
Gain and Gainspread (1)

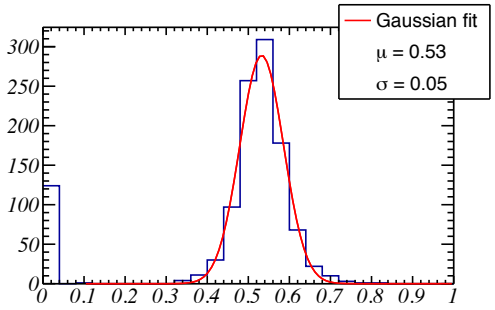


- Single photon peak
- dP/dToT = dP/dnpe*(dToT/dnpe)$^{-1}$
  - dP/dnpe = Gauss(**gain**, **gainspread**)
  - ToT(npe) = (26.2ns +npe*7ns)*sqrt(1.0-0.3/npe)

```
JMonitorToT -a <detfile> -f <datafile> -o monitor.root
JFitToT -a <detfile> -f monitor.root -o fit.root -L -w -t 15+35 -P <gainfile>
  -L: use reasonable range for parameters to be fitted
  -w: write the fits to the ouput file
  -t 15+35: ToT-range to fit
  -P: JTE-compatible output txt file with fitted values
```

Gain and Gainspread (2)



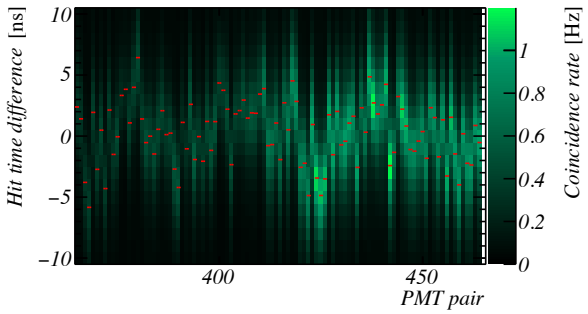


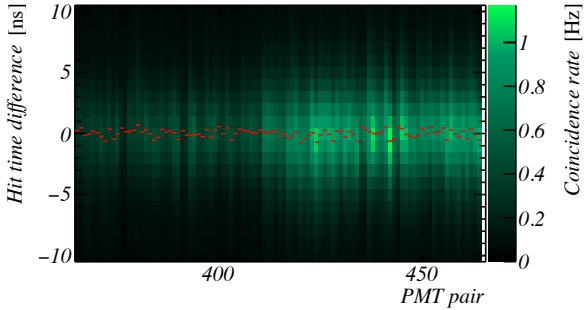
- Mean gain: 1.0 (by definition)
- Mean gainspread: 0.53

- dP/dnpe = Gauss(1.0, 0.53)
- In simulations, 9.3% of hits do not pass the threshold (0.3)

```
JMonitorToT -a <detfile> -f <datafile> -o monitor.root
JFitToT -a <detfile> -f monitor.root -o fit.root -L -w -t 15+35 -P <gainfile>
  -L: use reasonable range for parameters to be fitted
  -w: write the fits to the ouput file
  -t 15+35: ToT-range to fit
  -P: JTE-compatible output txt file with fitted values
```

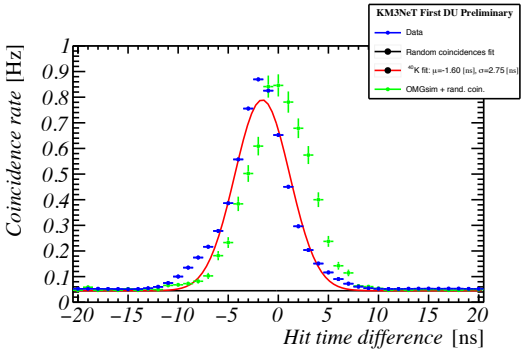
PMT Time Calibration Check (1)

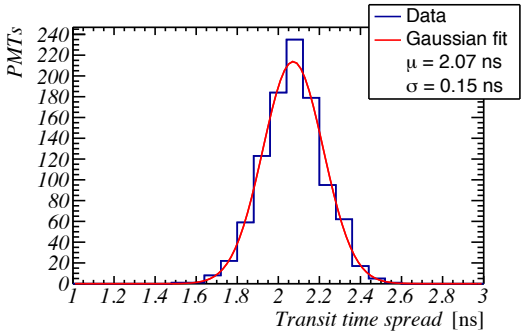




- Uncalibrated PMT time offsets
- Using fitted PMT time offsets
  - Peaks nicely aligned at zero
  - Fit did what it's supposed to do

PMT Transit Time Spread





- $\sigma_{ij}^2 = TTS_i^2 + TTS_j^2 + 0.57^2$
- 0.57 ns from OMGsim model

- Mean TTS: 2.1 ns
  - Assuming gaussian PMT transit time distribution