

Time Calibration in DU1/DU2

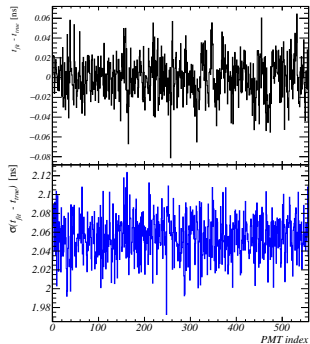
Nikhef



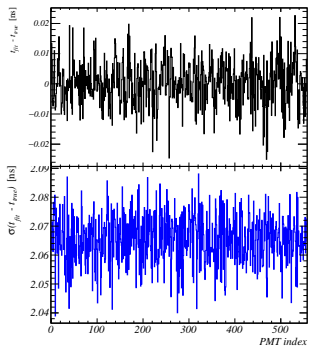
K.W. Melis
Nikhef group meeting
November 10, 2015

Recap: Inter-PMT calibration

15 minutes:



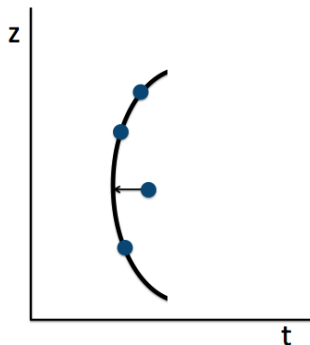
2 hours:



Stable PMT calibration after 15 minutes, ~ 2 ns resolution

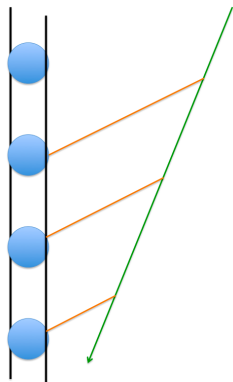
Recap: Inter-DOM calibration

Principle:

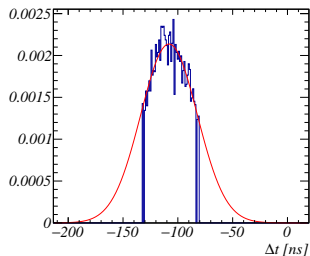


- ▶ Iterative fit excluding hit DOMs
- ▶ Proper fit only if DOM t_0 's are close to true
- ▶ Precalibration required

Inter-DOM precalibration



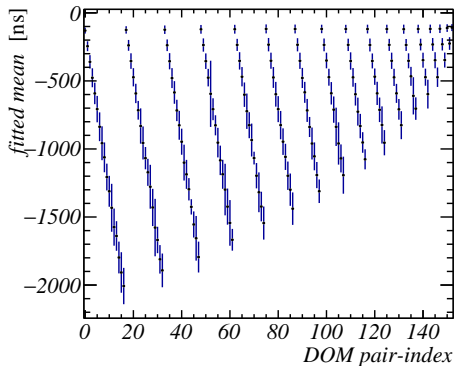
For each DOM-pair L1 hit time distribution:



Fit gaussian using bins with $> 0.5 \cdot \max$

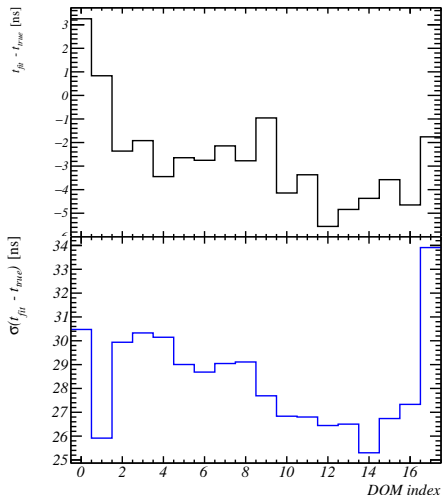
Inter-DOM precalibration

Fitted means for all DOM-pairs:



- ▶ Can be done for (MC) model and data
- ▶ Probe for DOM t_0 's
- ▶ Analytical solution
 - ▶ Robust & fast

Inter-DOM precalibration: resolution



Good estimate of DOM t_0 's after 47 hours

Intermezzo: Analytical solution

- ▶ Each DOM-pair gives a L1 hit time distribution

- ▶ Maximise $\sum_i \sum_{j \neq i} \left[\frac{\mu_{i,j} - \tilde{\mu}_{i,j} + t_{0i} - t_{0j}}{\sigma_{i,j}} \right]$

μ ; $\tilde{\mu}$: fitted mean, measured resp. model

t_0 : DOM t_0

$$\frac{1}{\sigma_{i,j}^2} = \frac{1}{\sigma_{i,j,model}^2} + \frac{1}{\sigma_{i,j,meas}^2}$$

- ▶ Maximise $\vec{x}' \cdot \vec{x}$

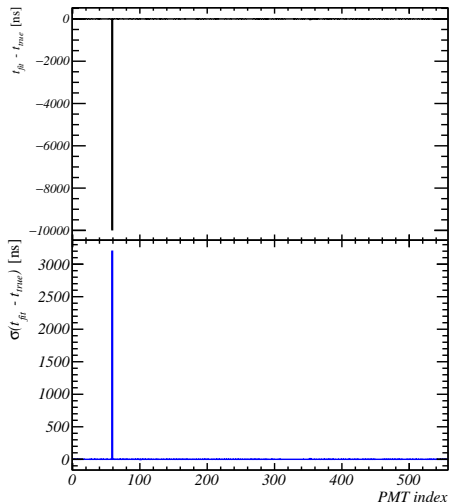
$$\vec{x} = \begin{pmatrix} (\mu_{0,1} - \tilde{\mu}_{0,1}) / \sigma_{0,1} \\ (\mu_{0,2} - \tilde{\mu}_{0,2}) / \sigma_{0,2} \\ \vdots \end{pmatrix} - \begin{pmatrix} 1/\sigma_{0,1} & -1/\sigma_{0,1} & 0 & 0 & \dots \\ 1/\sigma_{0,2} & 0 & -1/\sigma_{0,2} & 0 & \dots \\ \vdots & \vdots & \vdots & \vdots & \ddots \end{pmatrix} \cdot \begin{pmatrix} t_{00} \\ t_{01} \\ t_{02} \\ \vdots \end{pmatrix}$$

$$\vec{x} = \vec{b} - A \cdot \vec{t}_0$$

- ▶ Solution: $\vec{t}_0 = (A' \cdot A)^{-1} (A' \cdot \vec{b})$

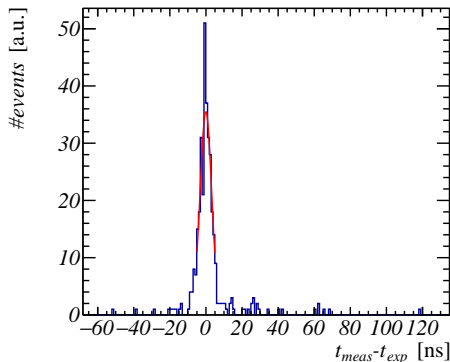
Intermezzo: Analytical solution

- ▶ Test: PMT t0's smeared with gaussian, width 10 ns
- ▶ JMonitorK40 & JFitK40
 - ▶ Fit went berserk →
- ▶ The analytical method can (should) also be used in JFitK40!
 - ▶ Robust & fast



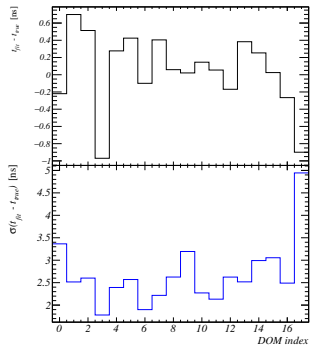

```
exclude one DOM {  
  for events {  
    ▶ JPrefit & JSimplex fit  
      ▶ for  
        (zenith>160° ;  
         zenith+=1°)  
      ▶ Use track if:  
        ▶  $\geq 8$  DOMs hit  
        ▶  $\chi^2 < 10$   
        ▶  $\chi^2 / N_{DOMs} < 2$   
  }}  
}}  
While any DOM  $t_0$   
changes  $> 0.1$  ns
```

Each DOM:

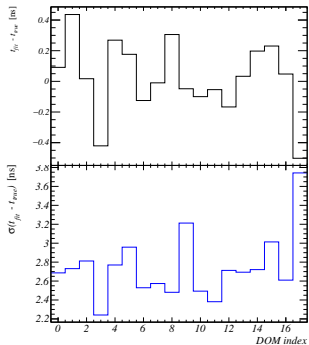


Inter-DOM calibration; fit

23 hours of data:

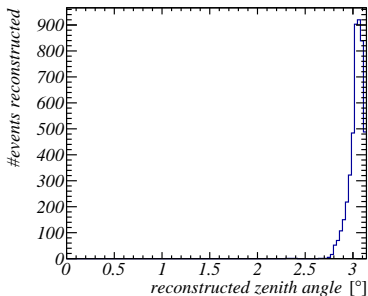


47 hours of data:



Stable DOM calibration after 47 hours, ~ 3 ns resolution

Zenith distribution



- ▶ Inter-PMT calibration
 - ▶ PMT calib (t_0 , $QE_{rel.}$)
 - ▶ Background rate
 - QE_{abs}
- ▶ Inter-DOM calibration
 - ▶ DOM calib (t_0)
 - ▶ Muon rate $\cdot QE_{abs}$
- ▶ Coincidence plot
 - ▶ QE_{abs} ?

Common approach:

- ▶ $\frac{dL}{d[t,r,\theta,\phi]_\mu} = 0$
- ▶ Quality cuts
- ▶ Point source/ Full sky search

New method:

- ▶ $L(\theta, \phi) = \int \int L([t, r, \theta, \phi]_\mu) dt dr$
- ▶ Add likelihood landscapes of all events

- ▶ No quality cuts optional
- ▶ All ν -types
- ▶ No algorithm optimisation for E_μ

Outlook: Reconstruction

Method can already be used in *DU1/DU2*

- ▶ Add $L(\theta)$ distributions of all events

