Verification of TWR simulation of UHE events

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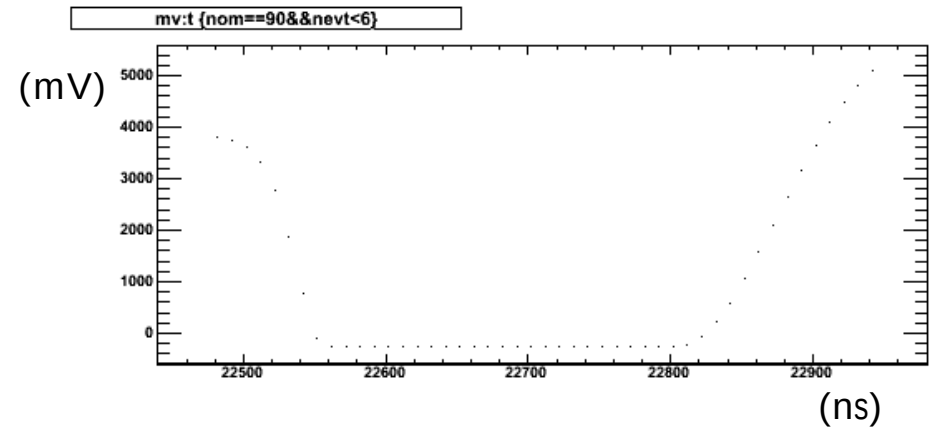
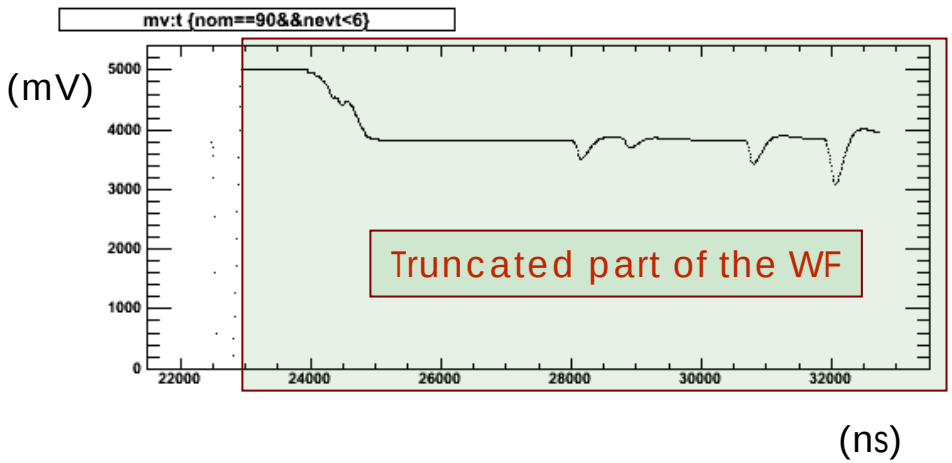
Outline

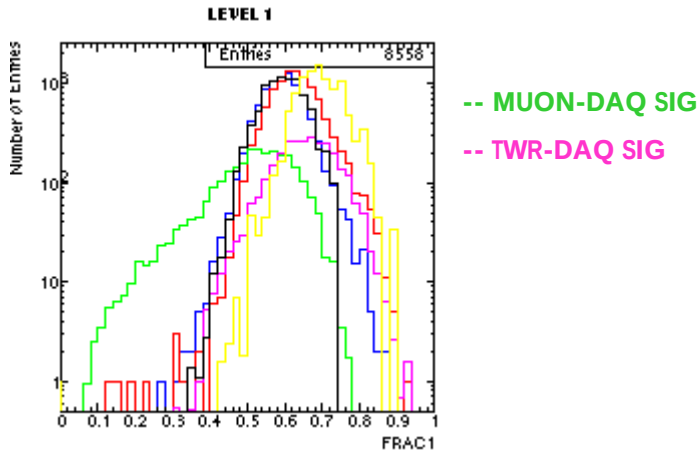
- **TWR experimental data from 2003**:
  - Level-1 of this analysis:
    - **combined streams of L0 filtering + a cut Nhits> 152**
  - Reconstruction Software: current release of Sieglinde
- **MC chain**:
  - **BGR**: CORSIKA + MMC + AMASIM (PTD layered)
  - **SIG**: ANIS + MMC + AMASIM (PTD bulk)
  - AMASIM release "AMASIM version 2.9010 (aluminum) 23/3-06".
- **In the beginning TWR MC showed numerous problems:**
  - WF's were **not** properly simulated
  - ORB's max-voltage outputs were **overestimated**
  - TDC time windows of single OM's were **incorrect**
  - Npe amplitude of single OM's were **incorrectly** calculated
- **Additional problems have been discovered by studying the experimetal data:**
  - Three stable TWR OM's are excellent diagnostic for **very unstable** events
  - combined Muon-DAQ and TWR-DAQ information was a major key **for fixing discrepancies** between TWR DATA/MC
- **TWR MC is now mature and reliable enough to develop a full analysis**

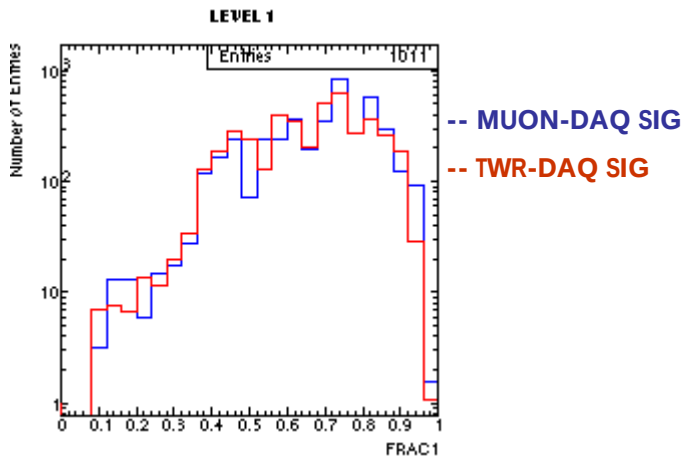
Fixing incorrect WF description

For **bright events WF's** were truncated recording the first pulse only and leaving out the remaining part of the WF. **WF truncation caused by a bug in the fragmentation algorithm.** **All Hit-dependent variables** are automatically effected by this deficit, i.e. **FRAC1**.
MC now generates correctly the full WF, and for bright events the first peak is usually saturated followed by secondary peaks, and afterpulses.

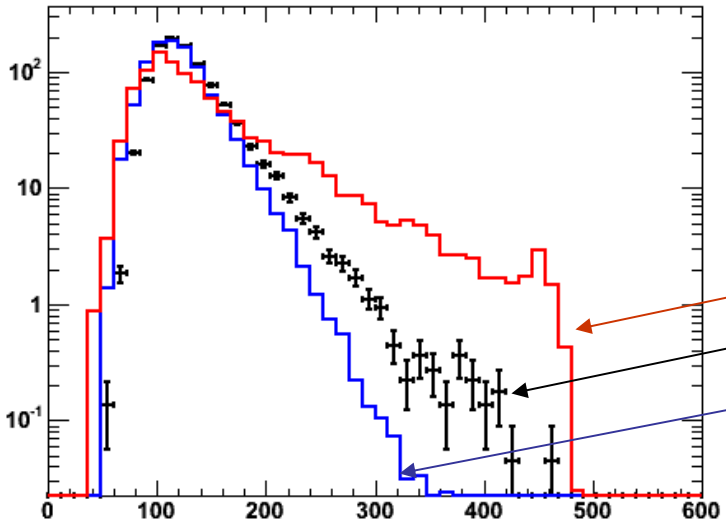








Basic variable disagreement

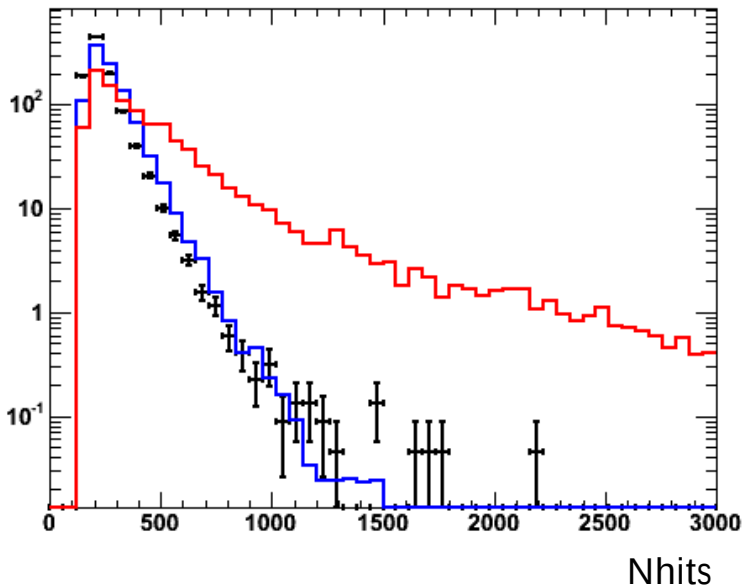


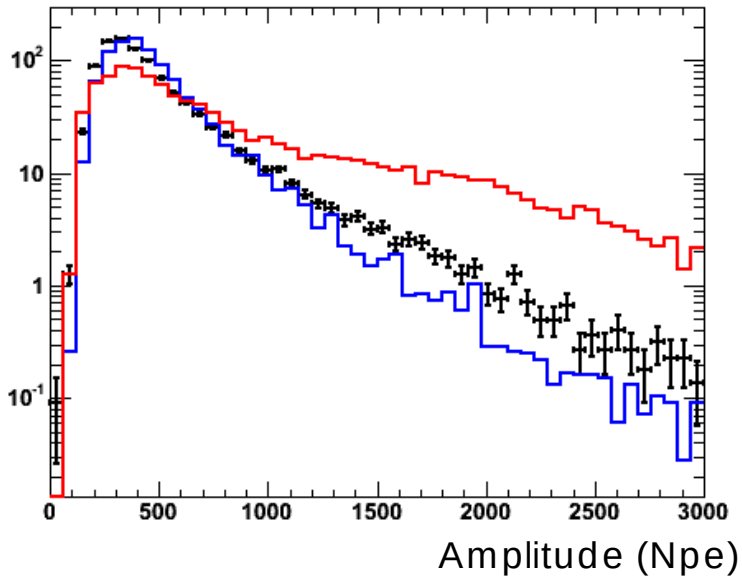
Variable like **NCH, NHITS, and NPE** exhibited a non-linear behaviour. Disagreement in particular observed at the higher values of these variables

-- TWR-DAQ SIG

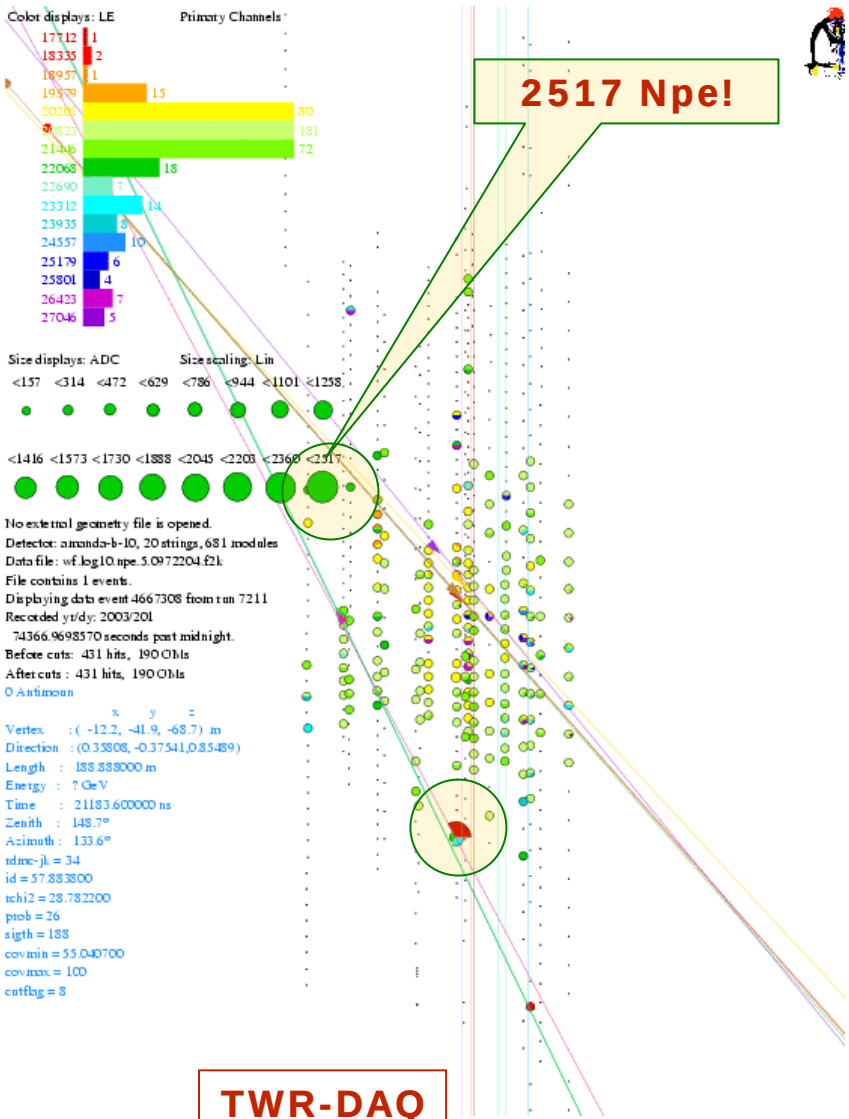
-- TWR-DAQ DAT

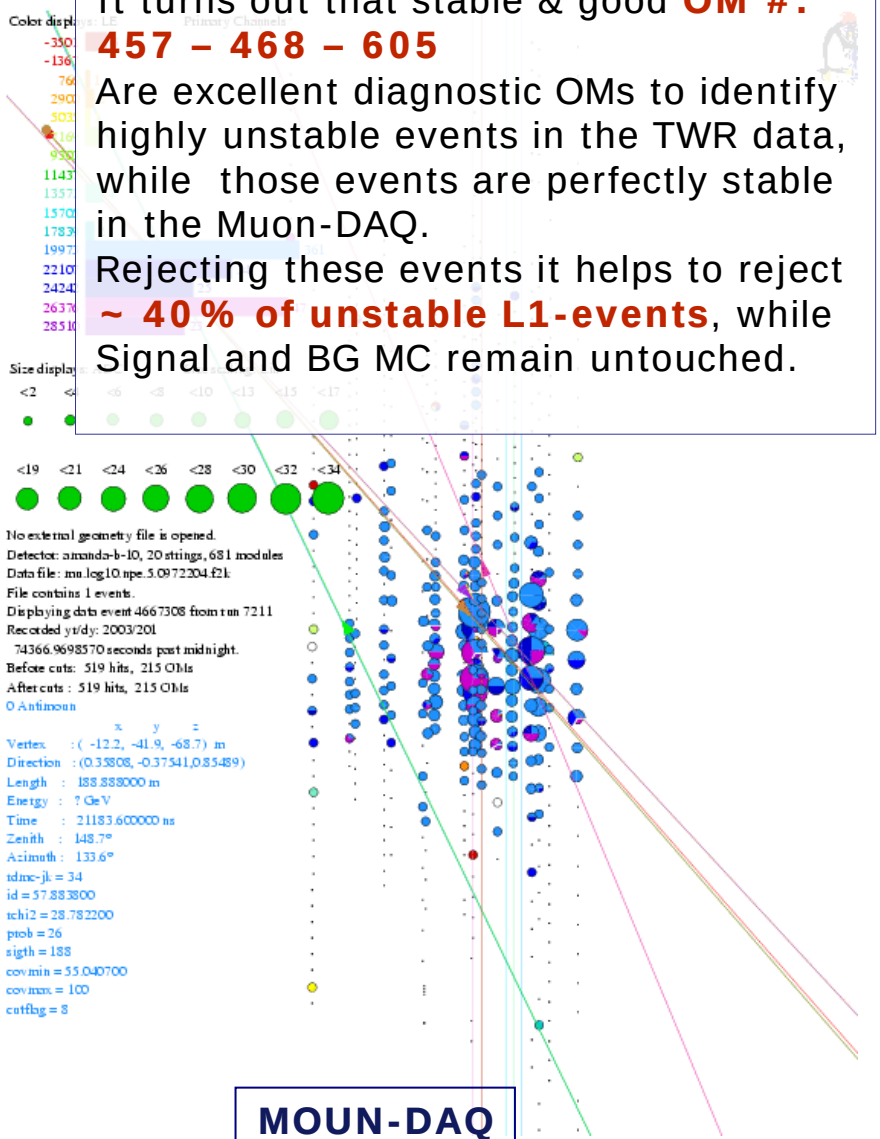
-- TWR-DAQ BGR





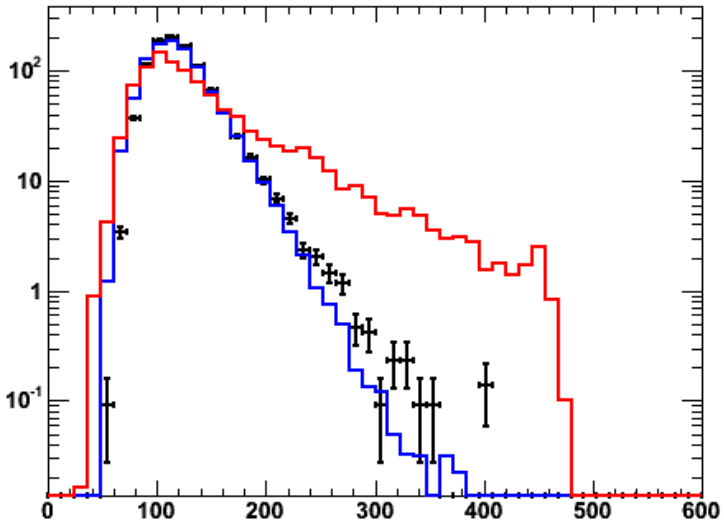
Three stable-diagnostic TWR OMs



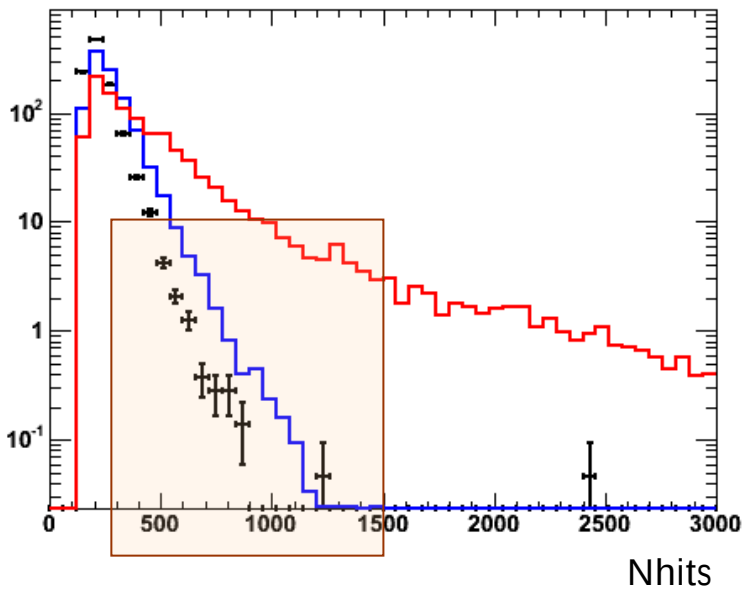


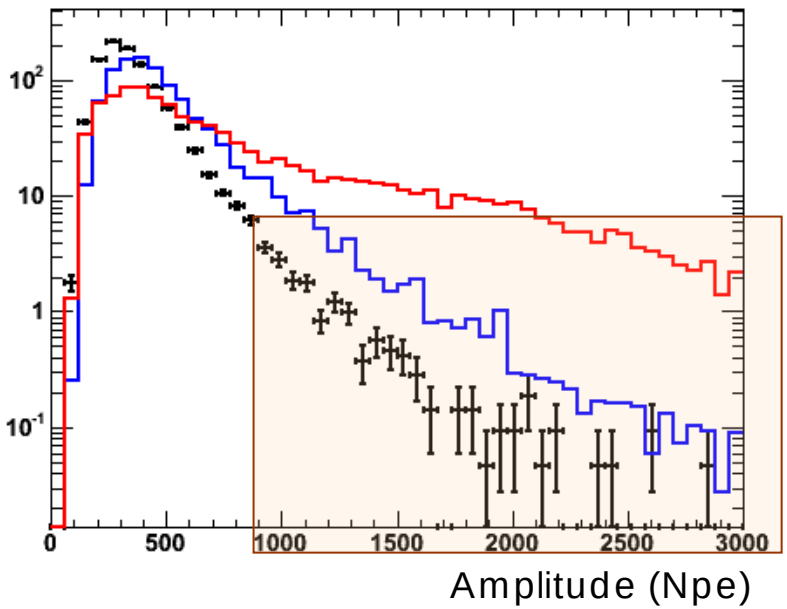
It turns out that stable & good **OM #:**
457 – 468 – 605
Are excellent diagnostic OMs to identify highly unstable events in the TWR data, while those events are perfectly stable in the Muon-DAQ.
Rejecting these events it helps to reject **~ 40% of unstable L1-events**, while Signal and BG MC remain untouched.

Fixing one problem discovering a new one

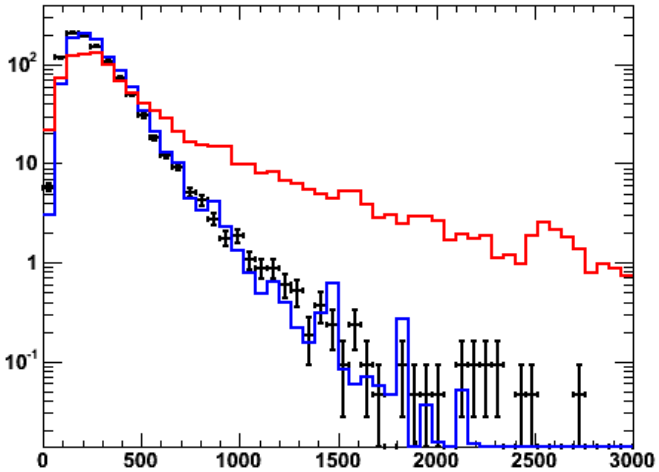


After removing the **"unstable TWR events"** the **NCH** agrees better with MC, while the **data-NPE distribution** and **NHITS** exhibits now a deficit compared to BGR MC.



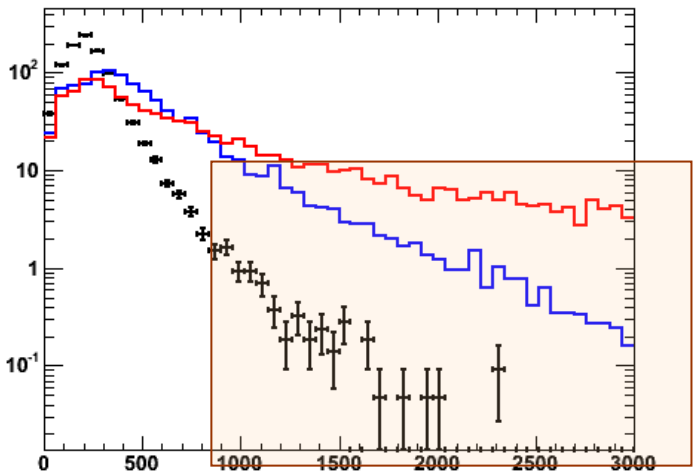


Splitting in three detectors

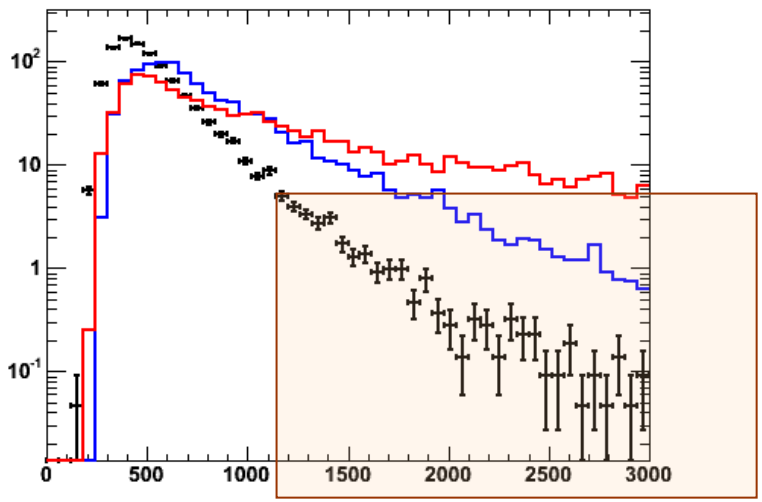


Electrical Amplitude (Npe)

Investigating the **NPE-distribution** for the sub-detectors "**electrical**", "**optical**", and the "**full array**", it turns out that the disagreement had to be accounted to the **optical channels** MC simulation.

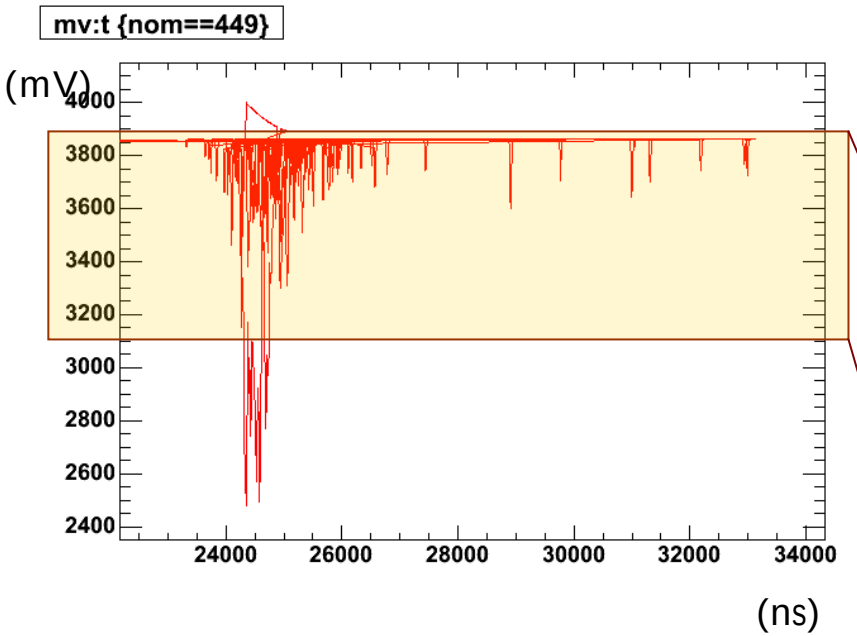


Optical Amplitude (Npe)

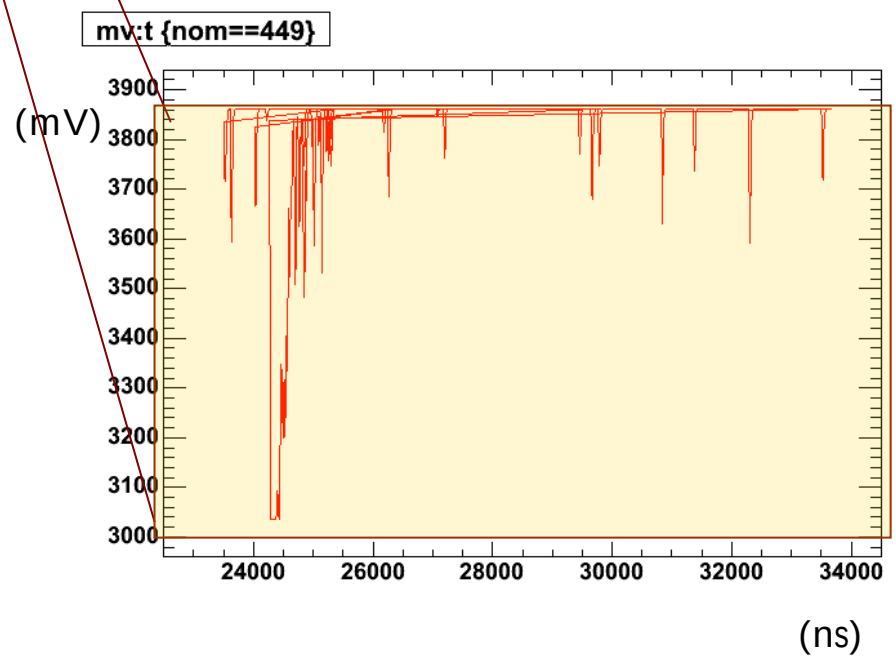


Global Amplitude (Npe)

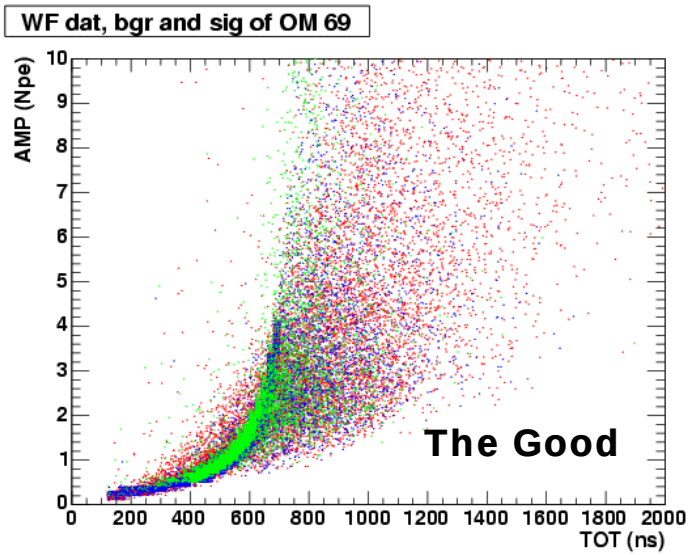
ORB's simulation problem

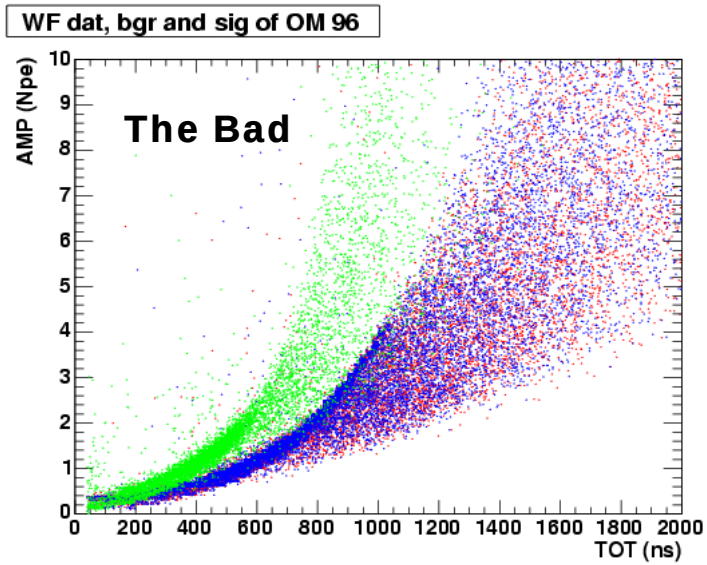


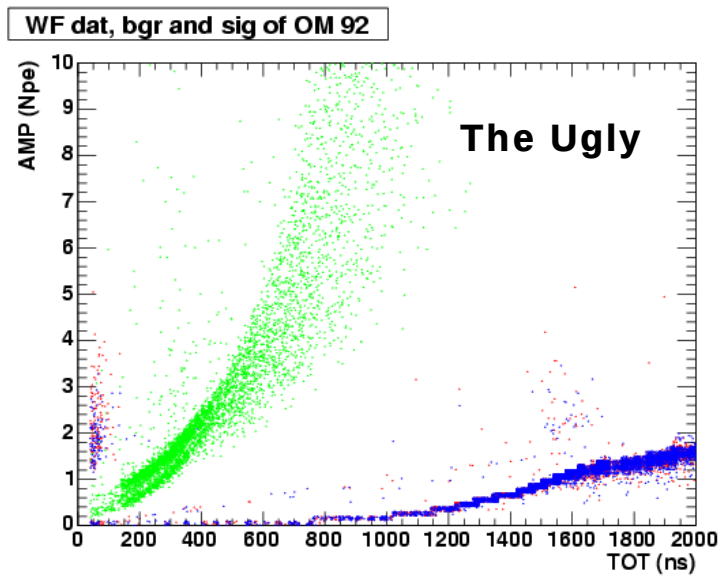
Input **MC ORB's information** was way overestimated. In particular most of the optical channels had a max-voltage values set **up to a factor 5 larger**



The Good, the Bad and the Ugly: X-talk problem?







DAT is GREEN **BGR is BLUE** **SIG is RED**

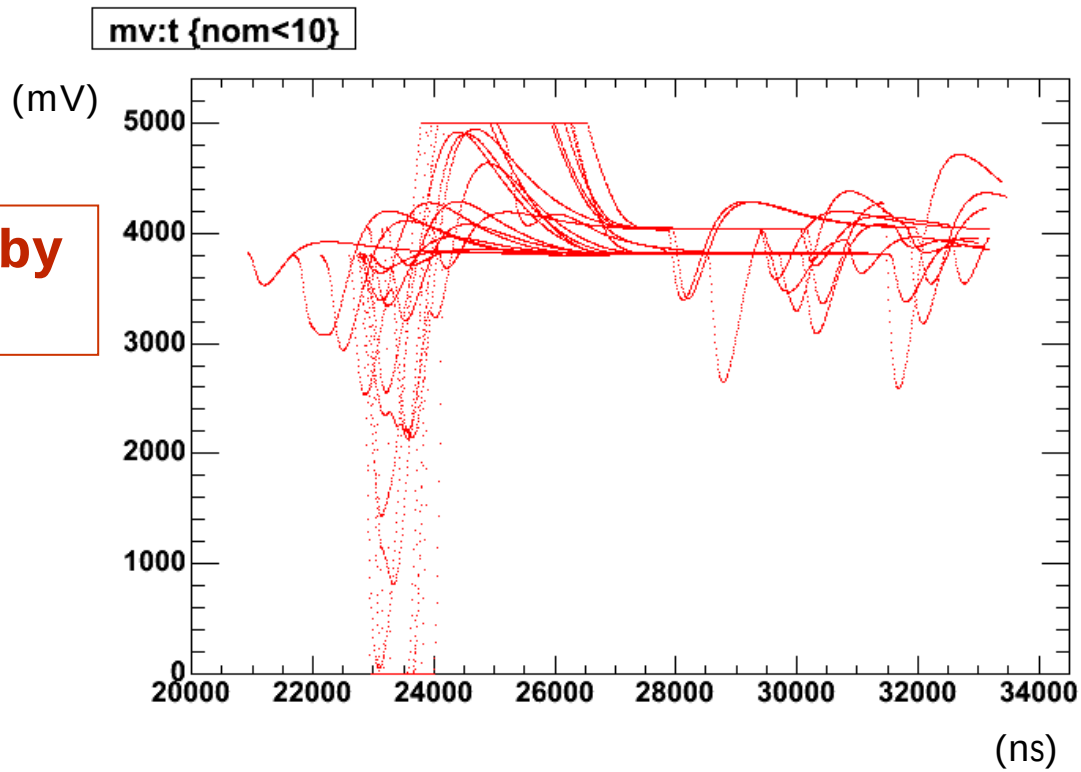
Three examples of OMs for the correlation of the Npe-amplitude vs. TOT. A standard way to identify potential x-talk problems. **However**, we still have serious problems of simulating correctly many OMs for these fundamental variables.

Can we really blame overshoots for X-talk?

- An example of **SIG** waveforms extracted for the first 10 OMs. The MC easily generates overshoot and saturated WFs due to the limited capability of maximum voltage response of the TWR system.

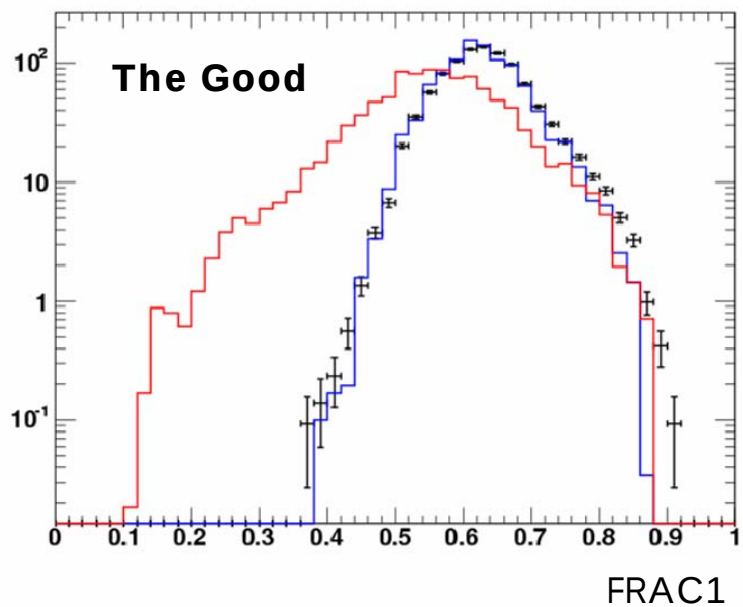
- **Visually inspections of the WFs and an empirical method without correct MC simulation of x-talk events cannot guarantee a robust x-talk cleaning.**

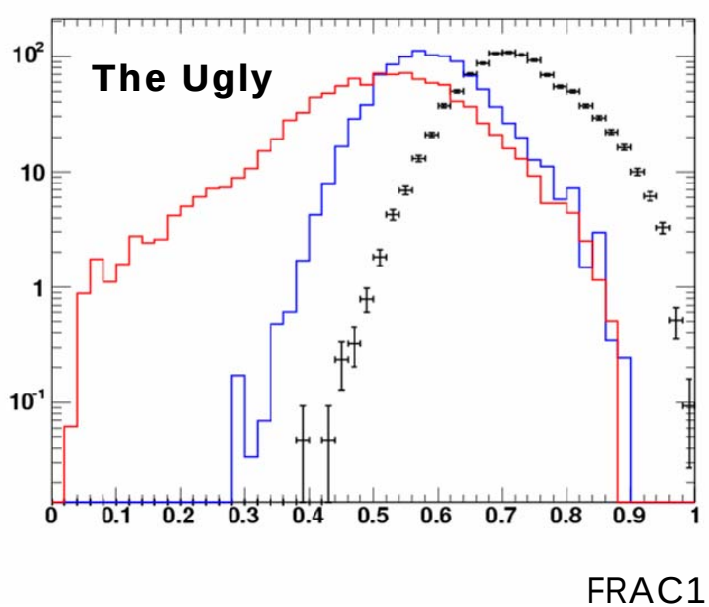
Will this hit be cleaned by x-talk procedure?



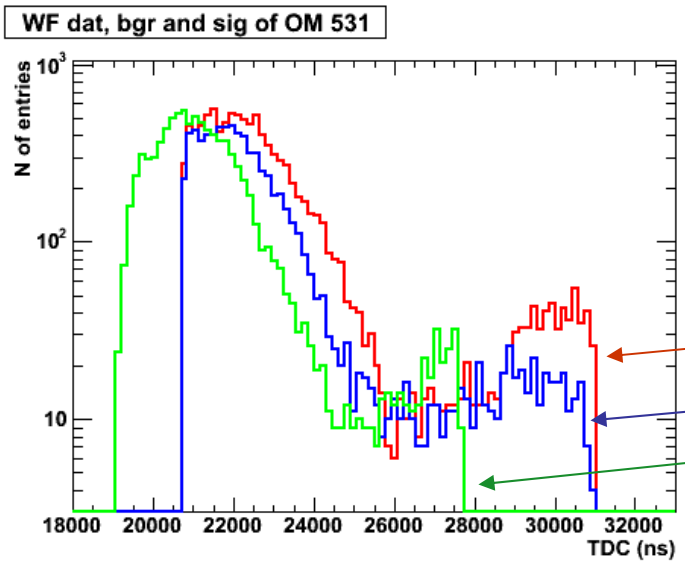
The Good and the Ugly: X-talk problem!

An example of the **FRAC1 (the fraction of OM with one hit only)** plotted with and without x-talk cleaning. It easy to see how badly the FRAC1 distribution get biased due to an incorrect interpretation of x-talk cleaning.





Studying individual OM MC simulation

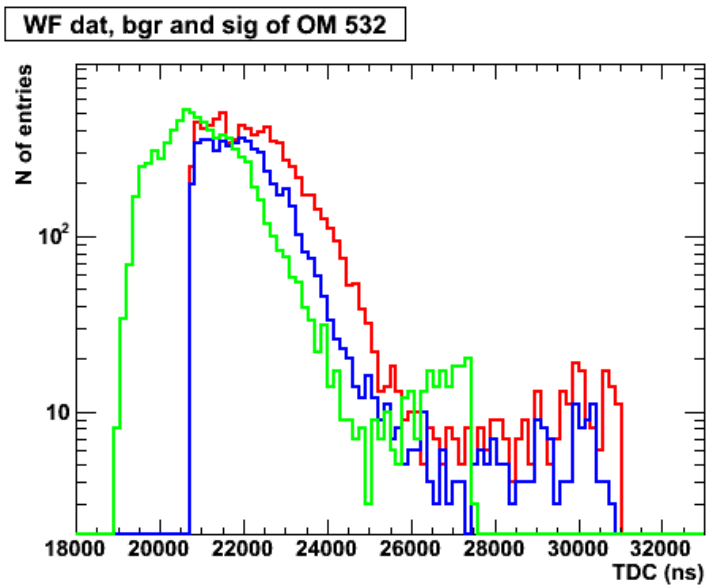


Deepening the investigation to the **single OM MC description**, the TDC time distribution show large disagreement in the simulated **TDC time windows**.

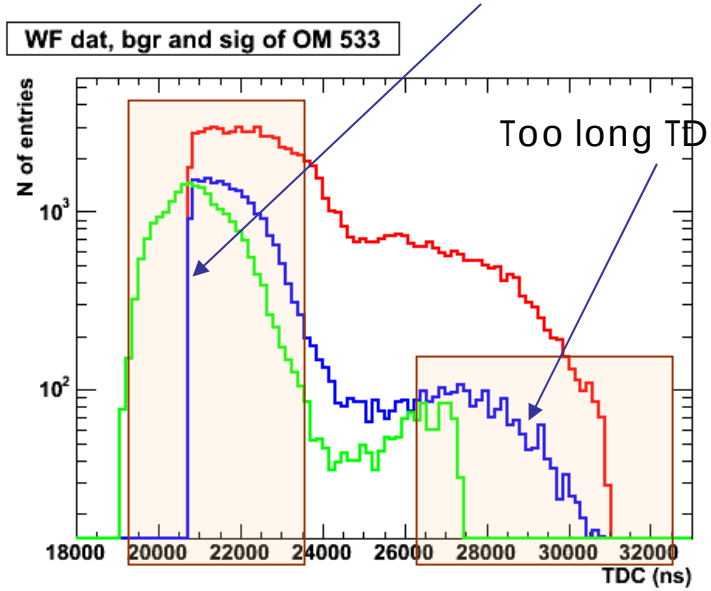
-- TWR-DAQ SIG

-- TWR-DAQ BGR

-- TWR-DAQ DAT

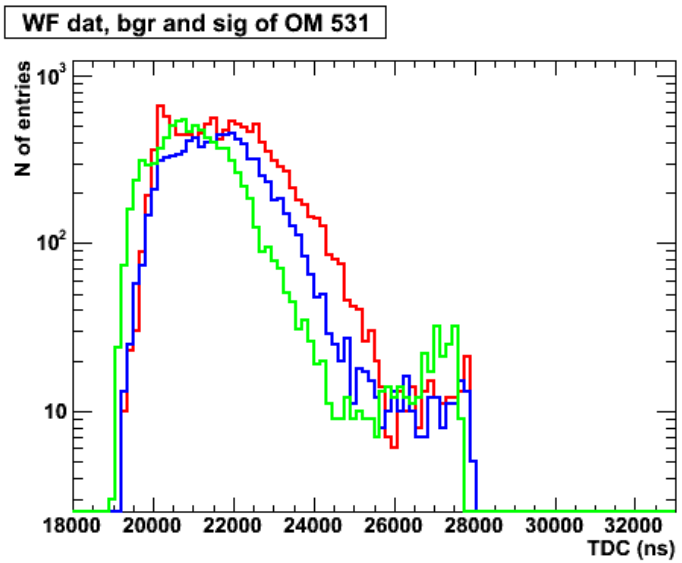


TDC window truncation

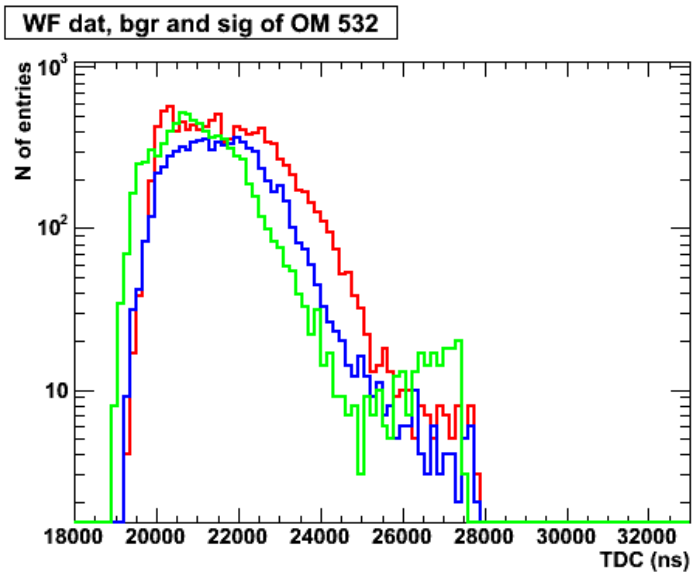


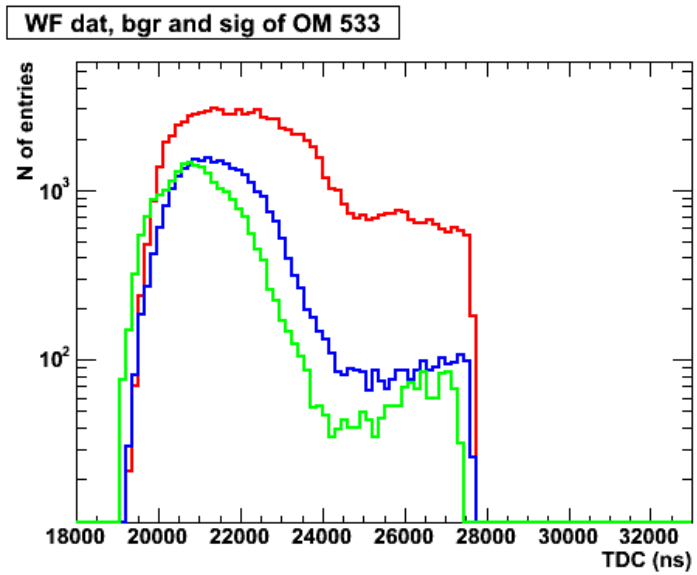
Too long TDC window

Fixing the TDC time first



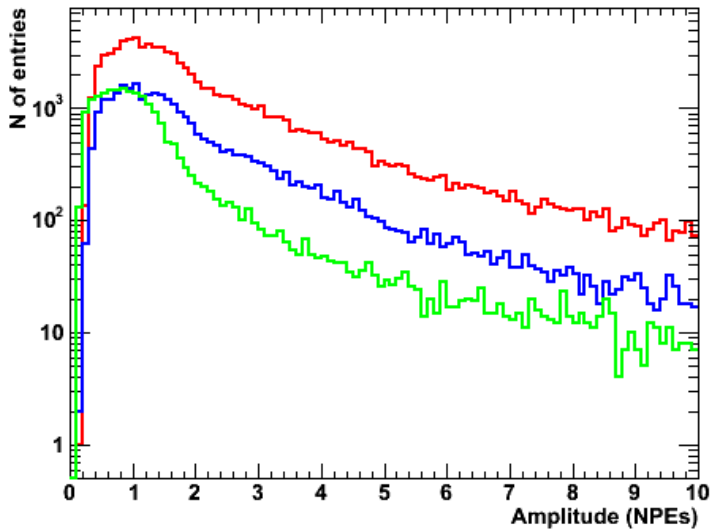
New correct TDC time windows were extracted and implemented into the MC simulation by **running high statistics from experimental data**. Well, still some problems to be solved…





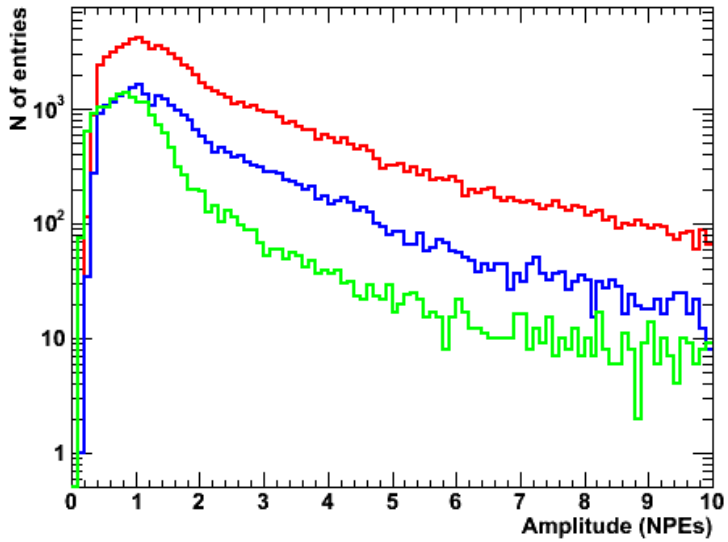
MC Npe disagreement of individual OM

WF dat, bgr and sig of OM 501



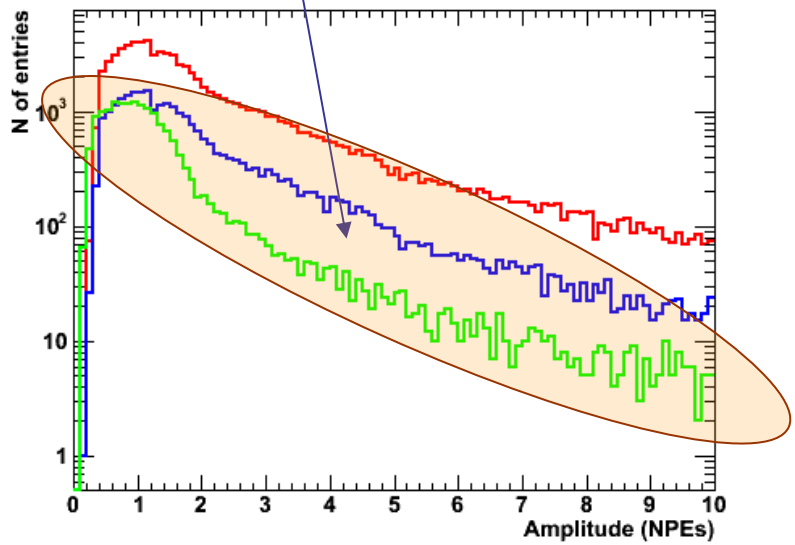
Solving TDC time issues were not enough to achieve the desirable data/MC agreement. OM Npe distribution for MC were exhibiting a higher statistics compared to the data:
Who to blame now, DATA or MC?

WF dat, bgr and sig of OM 503

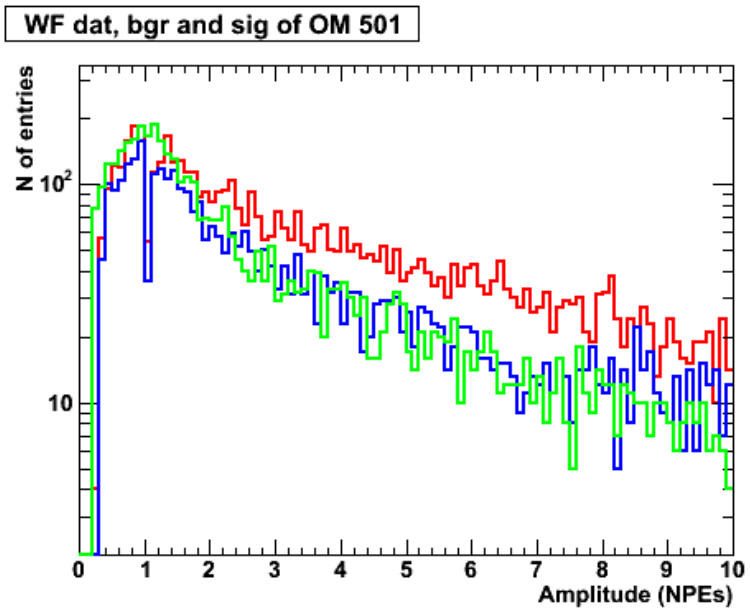


Unexpected excess of **MC pulses ~ 3x larger** compared to exp data

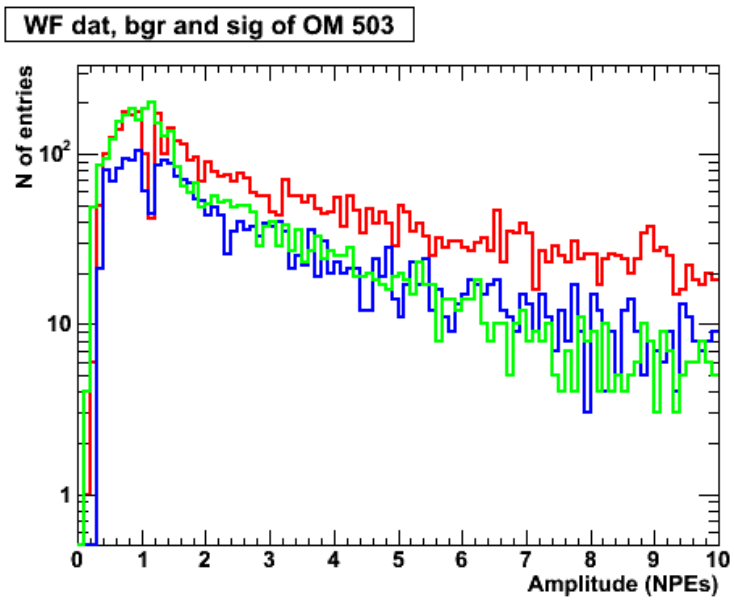
WF dat, bgr and sig of OM 504

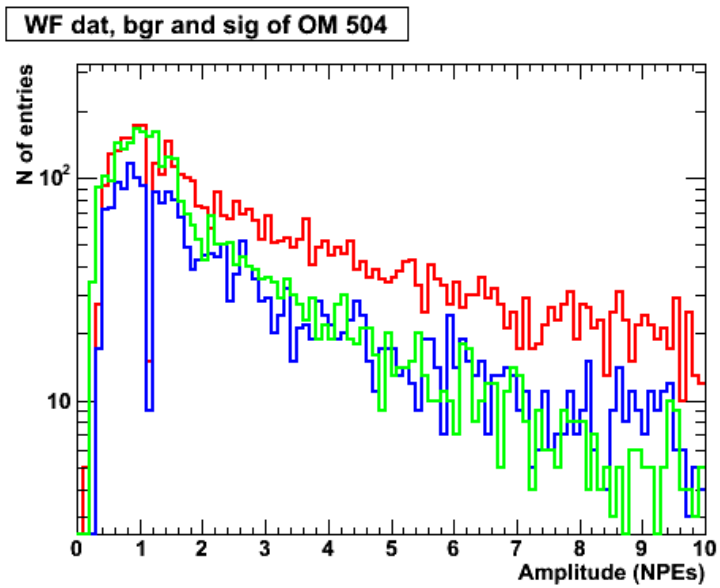


Fixing the Npe issues

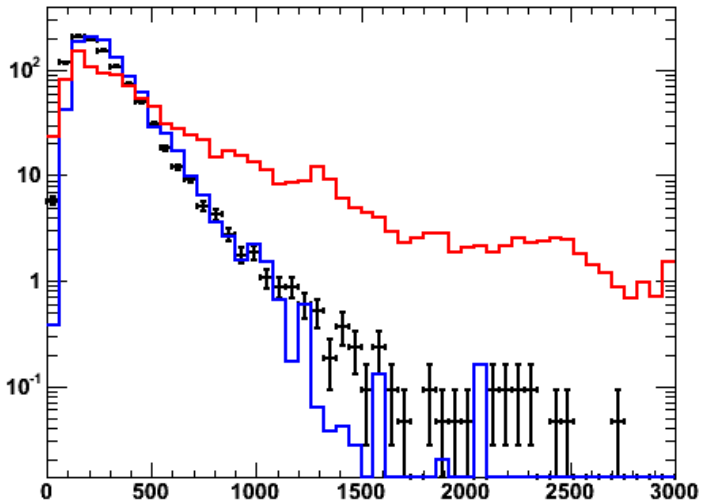


By investigating MUON-DAQ data it seems that experimental TWR-DAQ data was the source of the problem:
"a TWR hardware problem? Scary!"
However, it turns out that "**fortunately**", that it was a software mysterious bug which caused **to count ~ more than 3 times the same MC peak amplitude.**





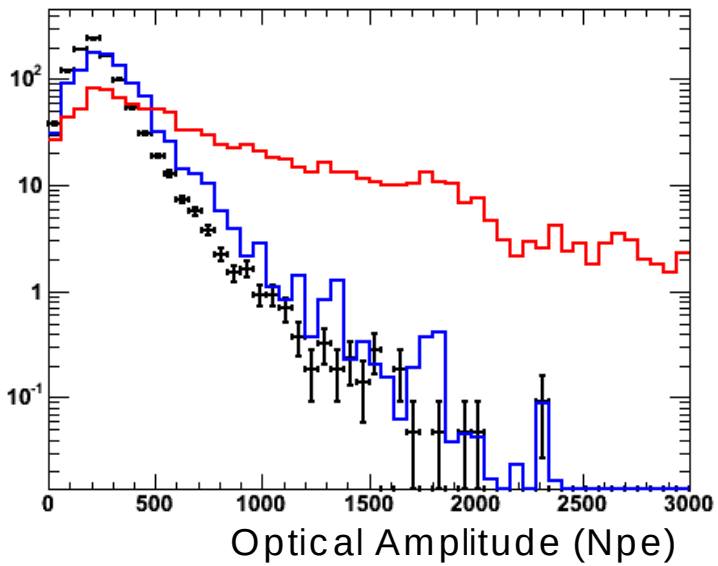
Back to the global behaviour

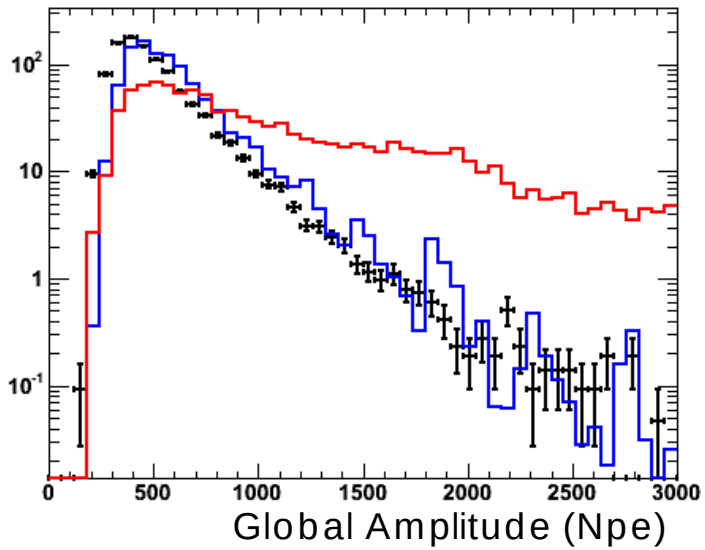


Re-plotting the **NPE-distribution** for the sub-detectors "**electrical**", "**optical**", and the "**full array**", after implementing all MC fixes, the MC now agrees way better.

Green light!:

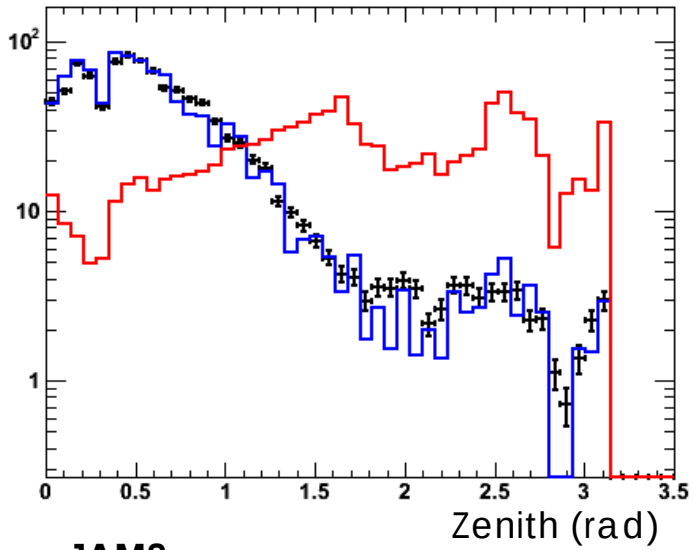
At this stage the TWR MC can be used for further reconstructions, and to develop more complicated analyses, in particular for the UHE search.





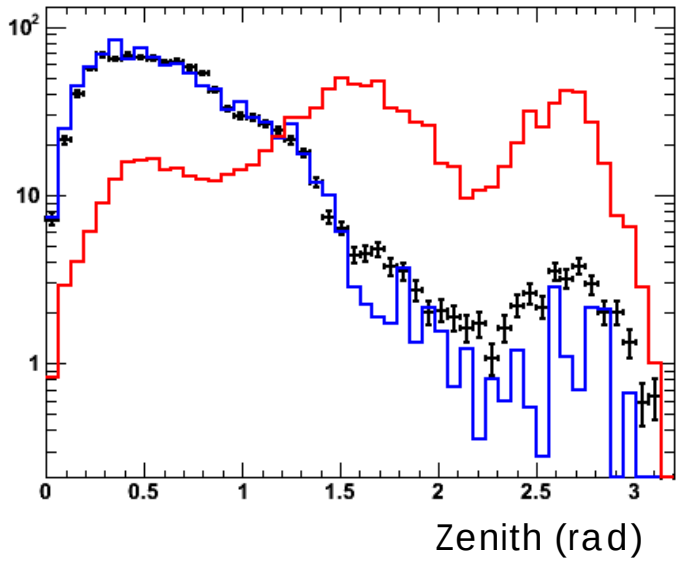
Some important RECO-results

Direct Walk

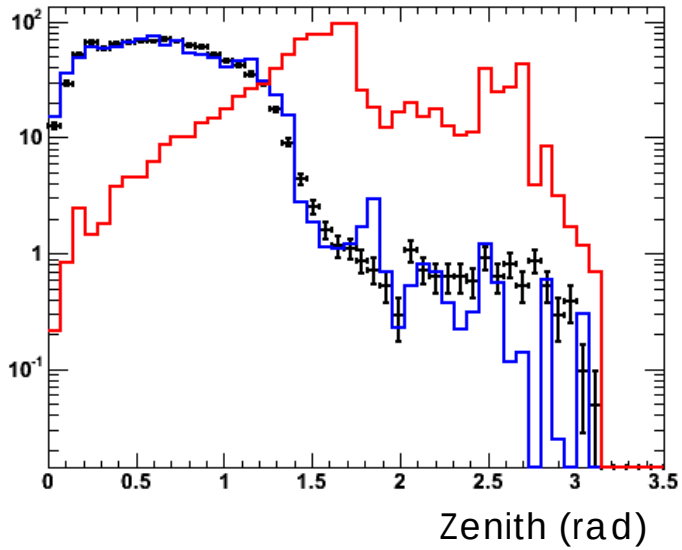


Now reconstruction can be performed:
First guess and likelihood reconstructions shows a very good agreement between **DATA/BGR MC**, and a correct description of high energy **signal**.
However, this reconstruction is still restricted to the first hit-information. **Upgrade including the full WF info is highly desirable!**

JAMS

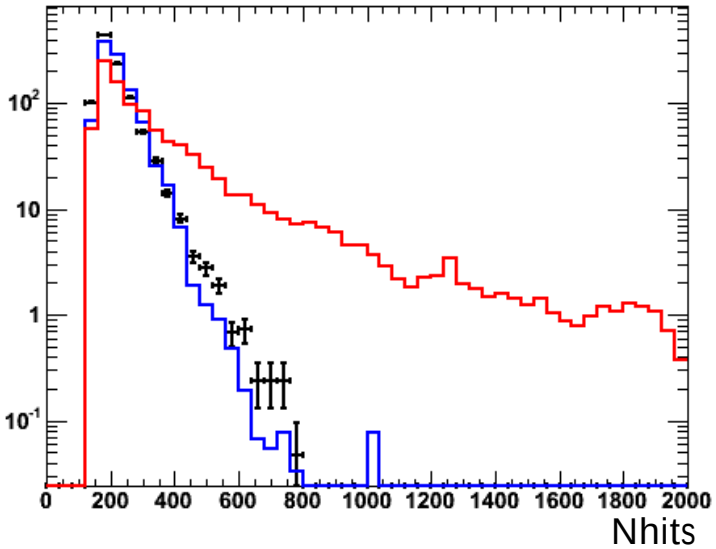


Single Log-Likelihood



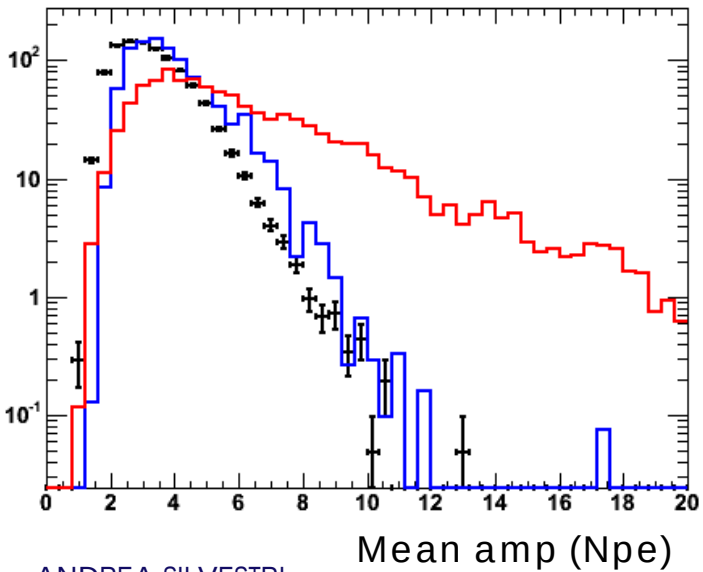
Some classical UHE discriminating variables

NHITS

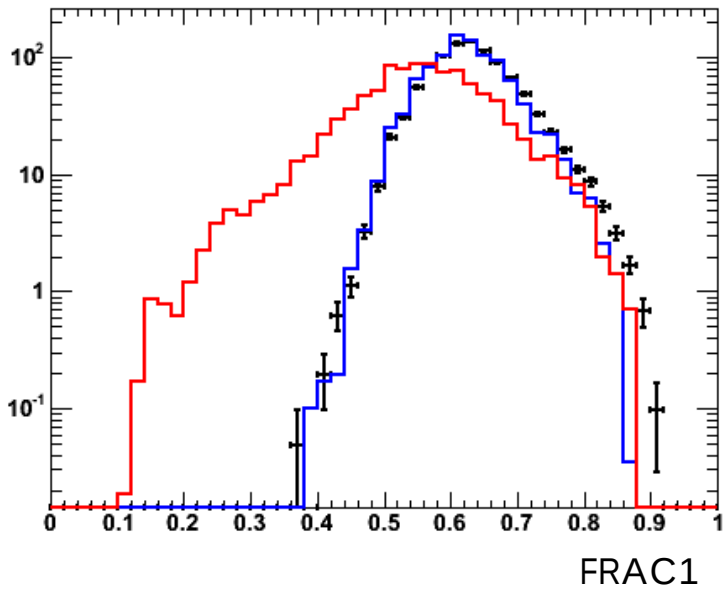


Good description of “classical” UHE discriminating variables: **NHITS, FRAC1 and Mean of electrical Npe**

Mean of electrical Npe amplitude

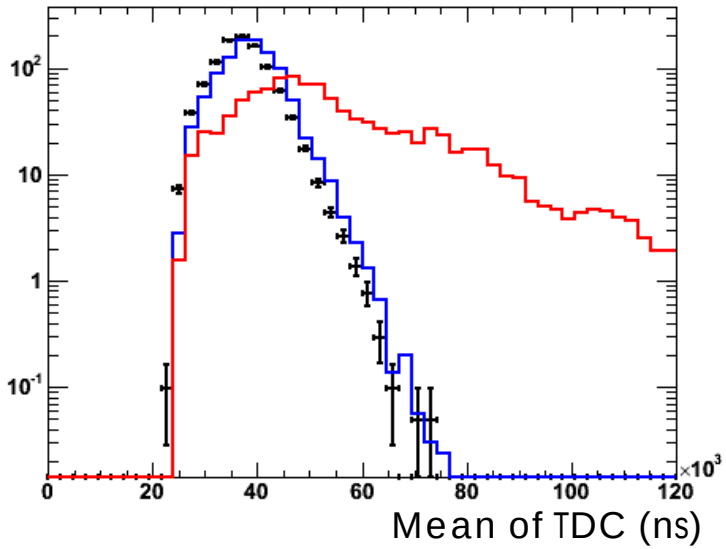


Fraction of OM-1hit



Some NEW UHE discriminating variables?

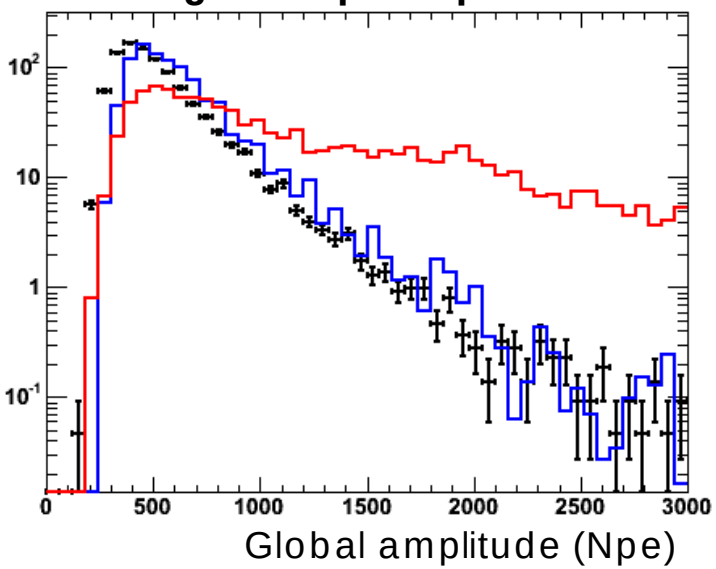
Mean of TDC's



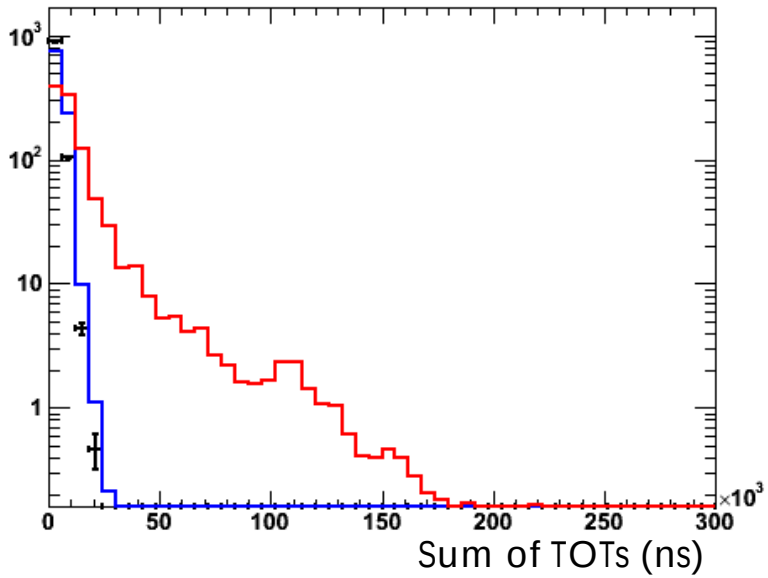
Developing new variables from the full WF information:

Mean of TDC, SUM of all NPEs, Sum of all optical TOTs, …

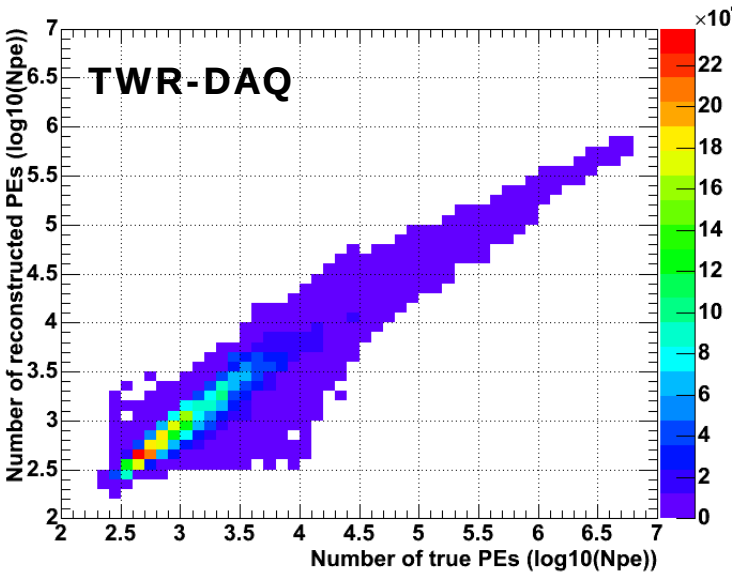
Sum of global Npe amplitudes



Sum of optical TOTs



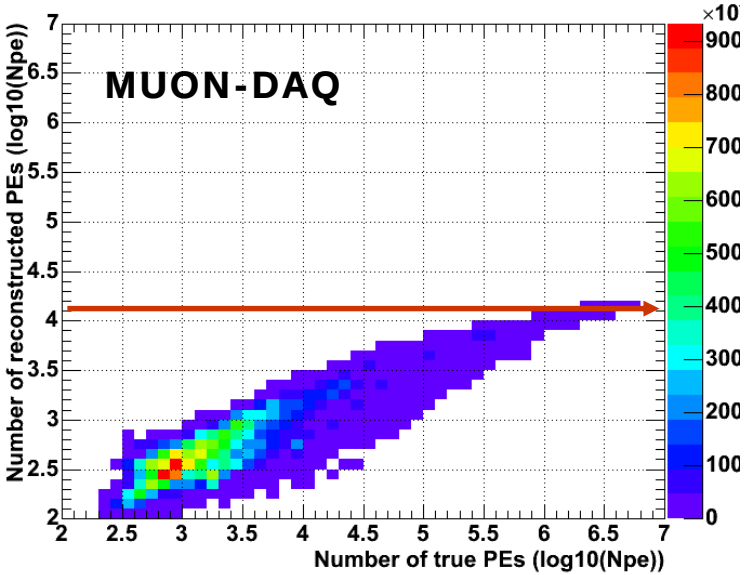
True and Reconstructed Npe

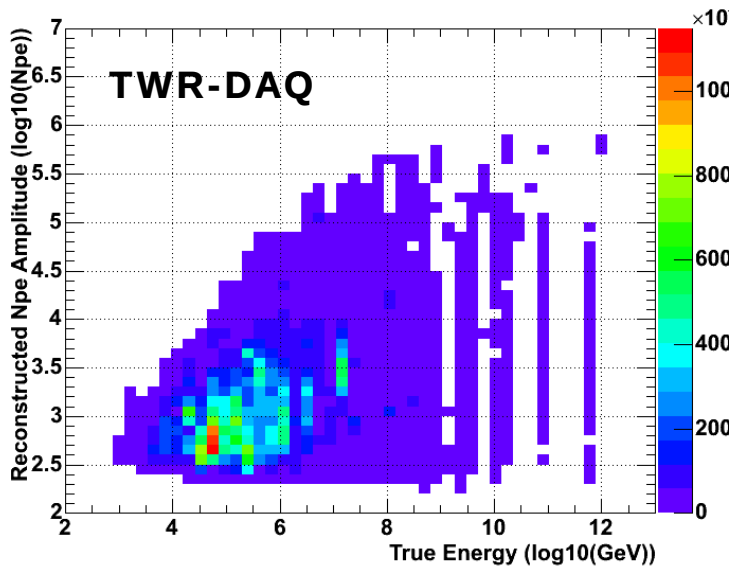


Using After-Pulses TWR Npe amplitude extends over 6 order of magnitudes!!

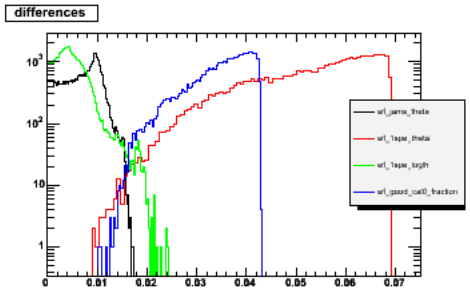
While Muon-DAQ Npe amplitude saturates much quicker at ~ 10,000 Npes

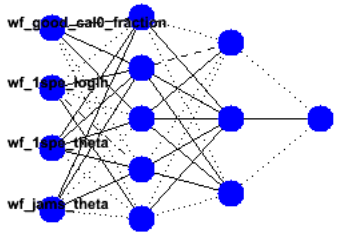
Good agreement between true and reconstructed Npe of the full detector.
However, timing and geometry inputs are necessary to improve the energy reconstruction.
Npe info only for energy is not sufficient.



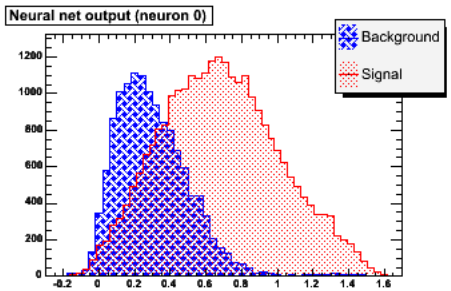


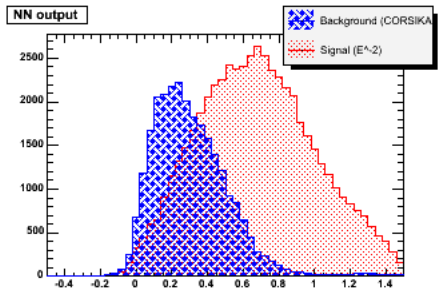
Investigating Neural Networks

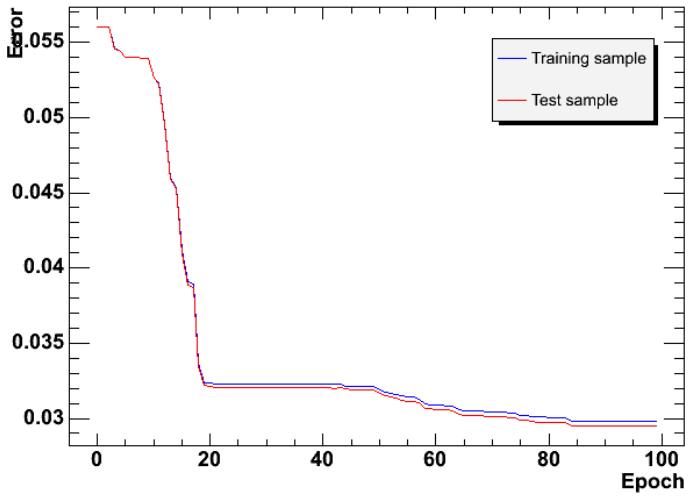


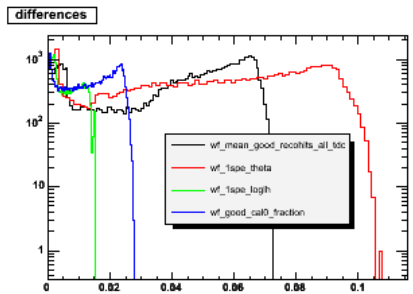


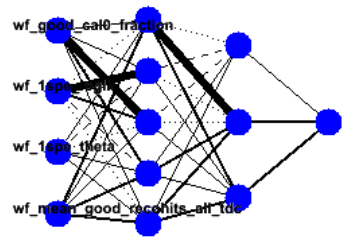
A first analysis using the **Neural Networks** shows that building the NN with new WF's variables (**Mean of TDC and Sum of NPE**) **can improve the BGR-SIG separation** compared to NN's built with standard variables.

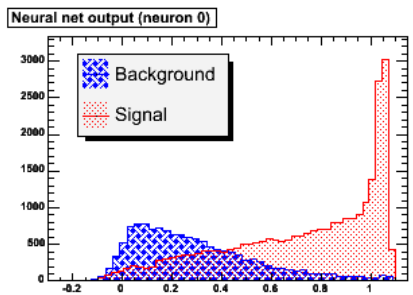


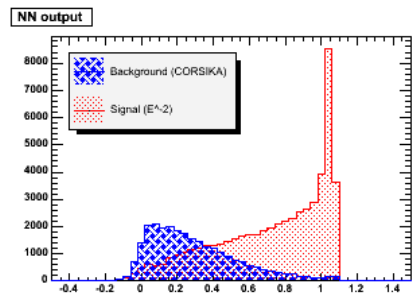












Summary and Outlook

- ☑ **Full 2003 TWR DATA has been merged, processed, and filtered using high performance computers**

  (see A. Silvestri talk in GRID parallel session)
- ☑ Combination of all streams guarantees **~ 80% of SIG at Level-1**
- ☑ **TWR MC studies:**
  - ☑ OLD MC showed numerous discrepancies with DATA
  - ☑ WFs were not properly simulated: **now fixed**
  - ☑ Basic variables NCH-NHITS showed discrepancies: **now fixed**
  - ☑ Overestimated ORB's max-voltage: **now fixed**
  - ☑ Wrong TDC time windows: **now fixed**
  - ☑ Wrong Npe calculation: **now fixed**
- ☑ **TWR MC is now ready for reconstruction and further analyses**
  - ☑ **Changes relevant for TWR simulation 2003-2006**
  - ☑ **If AMASIM imported into IceTray, then changes relevant for IceTray as well**
- ☑ Event Reconstruction needs full WF's information
- ☑ Energy reconstruction needs to be improved
- ☑ **First TWR MC results: correct calculation of Neutrino effective area for the Point Source search**

  (see A. Silvestri talk in Atmospheric Neutrino parallel session)
- Now the analysis can be fully developed for the **UHE search**
- …For questions about 2005 UHE filtering, I have few more slides …

UHE filter for 2005 TWR

Andrea Silvestri
University of California, Irvine

IceCube Collaboration Meeting
October 05-10, 2006 | Zeuthen, Germany

Definition of Variables used

- Global detector variables:
  - **NHITS** :

$$\sum_{j=1}^{Nom} = hits_j$$

  - **Mean of TDC**:

$$1/N_{om} \times \{\sum_{j=1}^{Nom} \sum_{k=1}^{Nhit} = (tdc)_{k,j}\}$$

- Single OM variable:
  - **AMP**: Charge of pulse normalized to 1p.e.
  - **TOT** : Time over threshold

- MC Signal:
  - **SIG** is weighted to E^{-2} for E = 10^{12} eV to E = 10^{21} eV

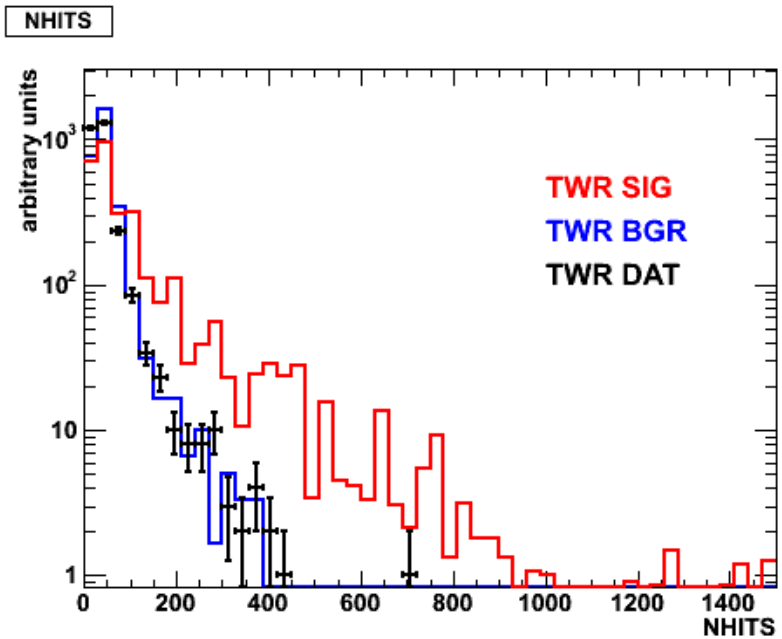
Physics of Variables used

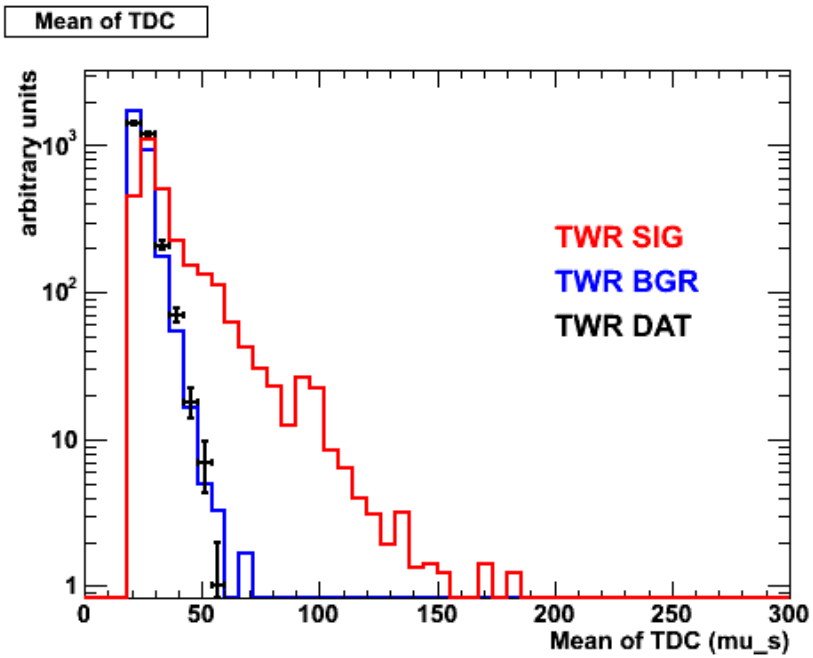
- Global detector variables:
  - **NHITS** and **Mean of TDC** are expected to be correlated for SIG, because bright events from single muons generate a large number of photons generating afterpulses at later times w.r.t. bundle of atmospheric muons, which can produce high value of Nhits in the detector, but are expected to generate much less afterpulses.
  - Therefore:
    - For **SIG**: **NHITS** and **Mean of TDC** should be well correlated
    - For **DAT** and **BGR**: **NHITS** and **Mean of TDC** should be bad correlated
  - A filter based on the combination of these two variables (**NHITS** and **Mean of TDC**) can improve the rejection power of BGR compared to a standard cut based on **NHITS** only.

UHE Filter Variables

NHITS:
is a conservative approach adopted for the MUON-DAQ filtering

MEAN of TDC:
is a new variable based on the full WFs information





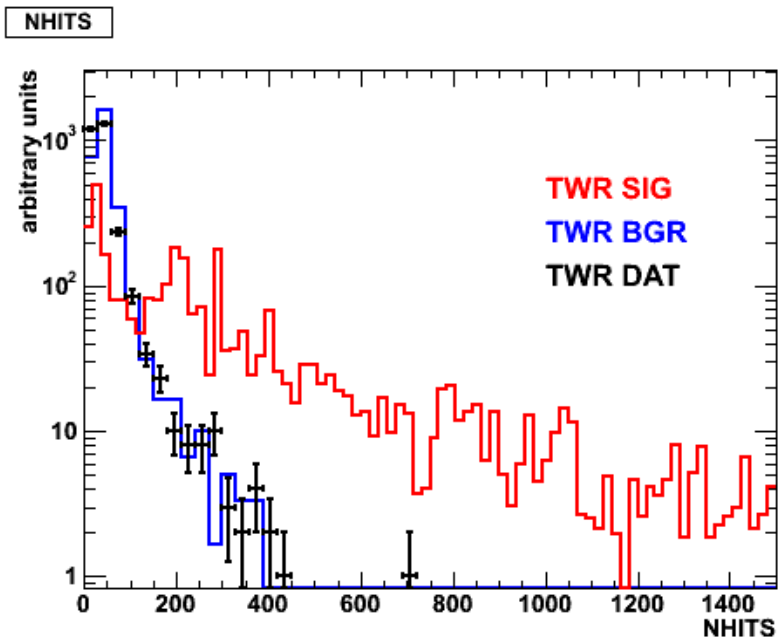
Conservative filter: NHITS > 140
SIG ~ 19% for E =(10^{12}-10^{21})eV
BGR ~ 0.23%

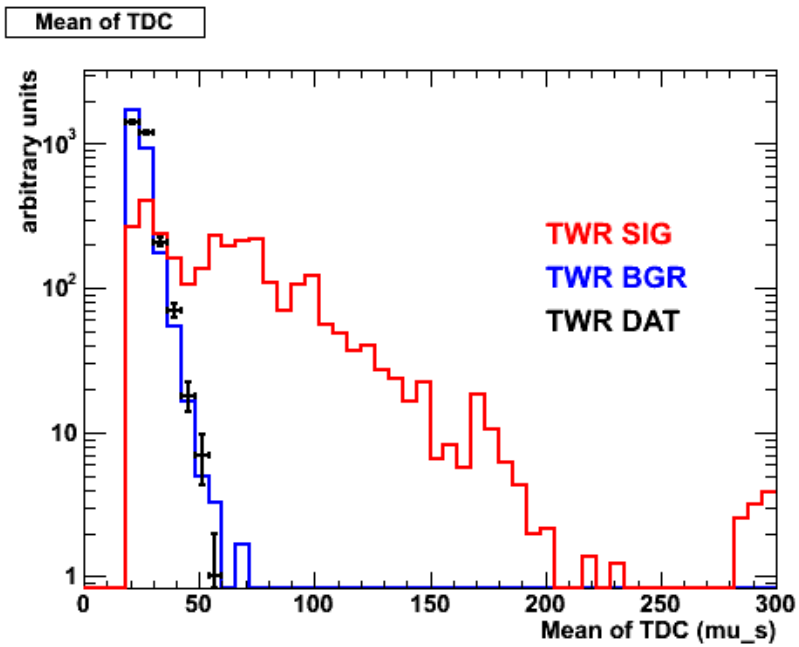
A new filter: Mean of TDC > 36500
SIG ~ 29% for E =(10^{12}-10^{21})eV
BGR ~ 0.25%

UHE filter: Mean of TDC more efficient than NHITS

NHITS > 140
SIG ~ 63% for $E_\nu = (10^{15}\text{-}10^{21})$eV

Mean of TDC > 36.5 μs
SIG ~ 73% $E_\nu = (10^{15}\text{-}10^{21})$eV

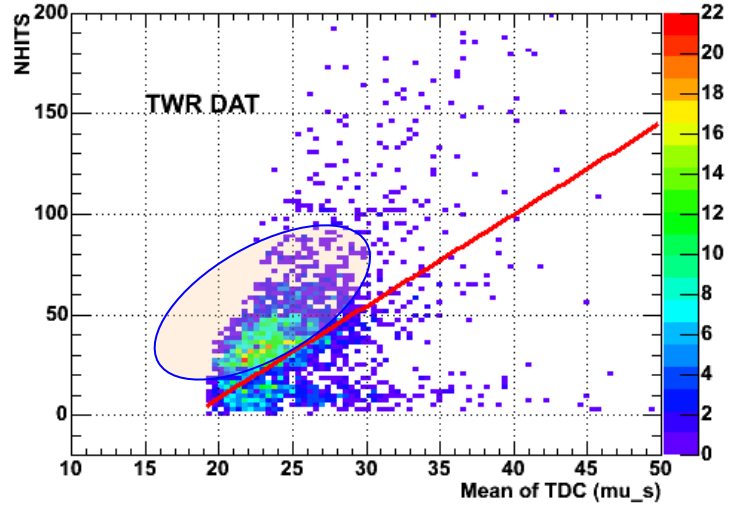




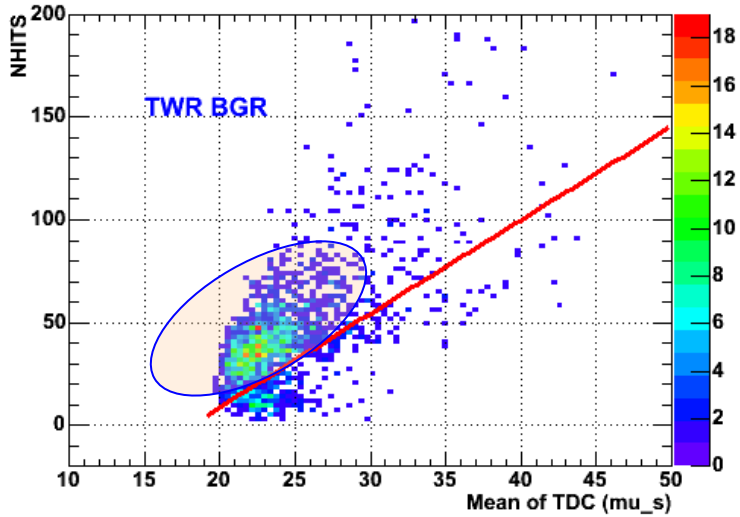
	SIG	BGR	DAT
NHITS>140	0.62	0.0023	0.0030
$Mean_{TDC}$>36500	0.73	0.0025	0.0029

Investigating a new 2D cut

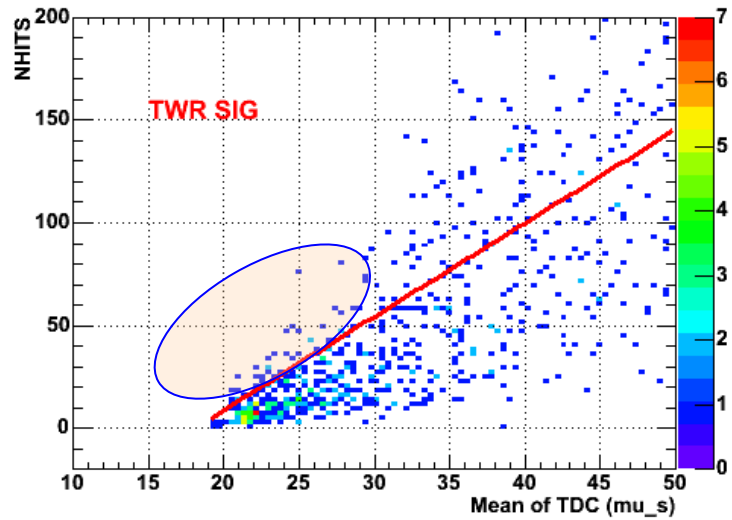
DAT

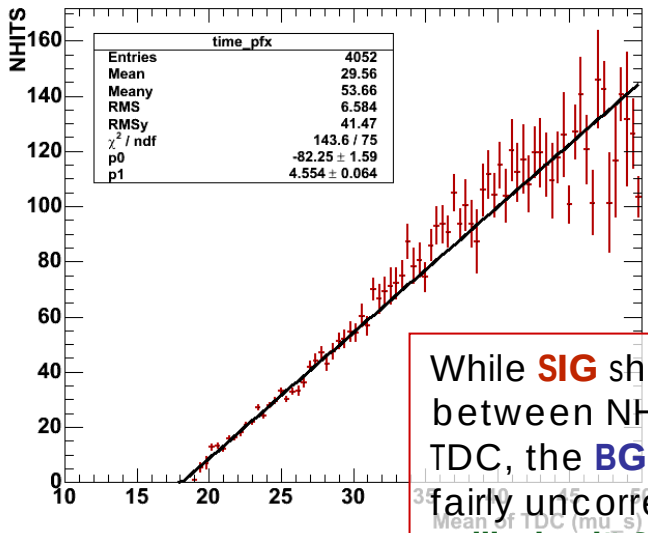


BGR



SIG





While **SIG** shows a correlation between NHITS & Mean of TDC, the **BGR** and **DATA** are fairly uncorrelated. **An „elliptical“ 2D cut could efficiently reject background.**

Summary & Outlook

UHE filter Outlook

- ☑ No X-talk should be applied to the UHE streams, because X-talk cleaning shows disagreement between data/BGR for bright events
- ☑ 2005 TWR filter uses NHITS > 140
- ☑ Mean of TDC shows that we can do better using full WF information
- ☑ Improvement of MC simulation including x-talk description is desirable. This would allow to develop a robust x-talk algorithm without harming good hits from data.