Some result from “No-Weights” Corsika simulation.
SD energy resolution/scale changes: an update.

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Two Topics/talks ?

- Related.. Yet, I have meandering (again..)
  - The quantitative calculation of the SD VEM biases in presence of a compromised light collection efficiency in the CWD of SD requires Monte-Carlo.., of low and high energy photons.
  - Interested in testing the new Corsika, which runs on multi-core systems, allowing to truly counts high energy photons with “no weights”
  - Might as well make an attempt at counting muons as well, “event by event”

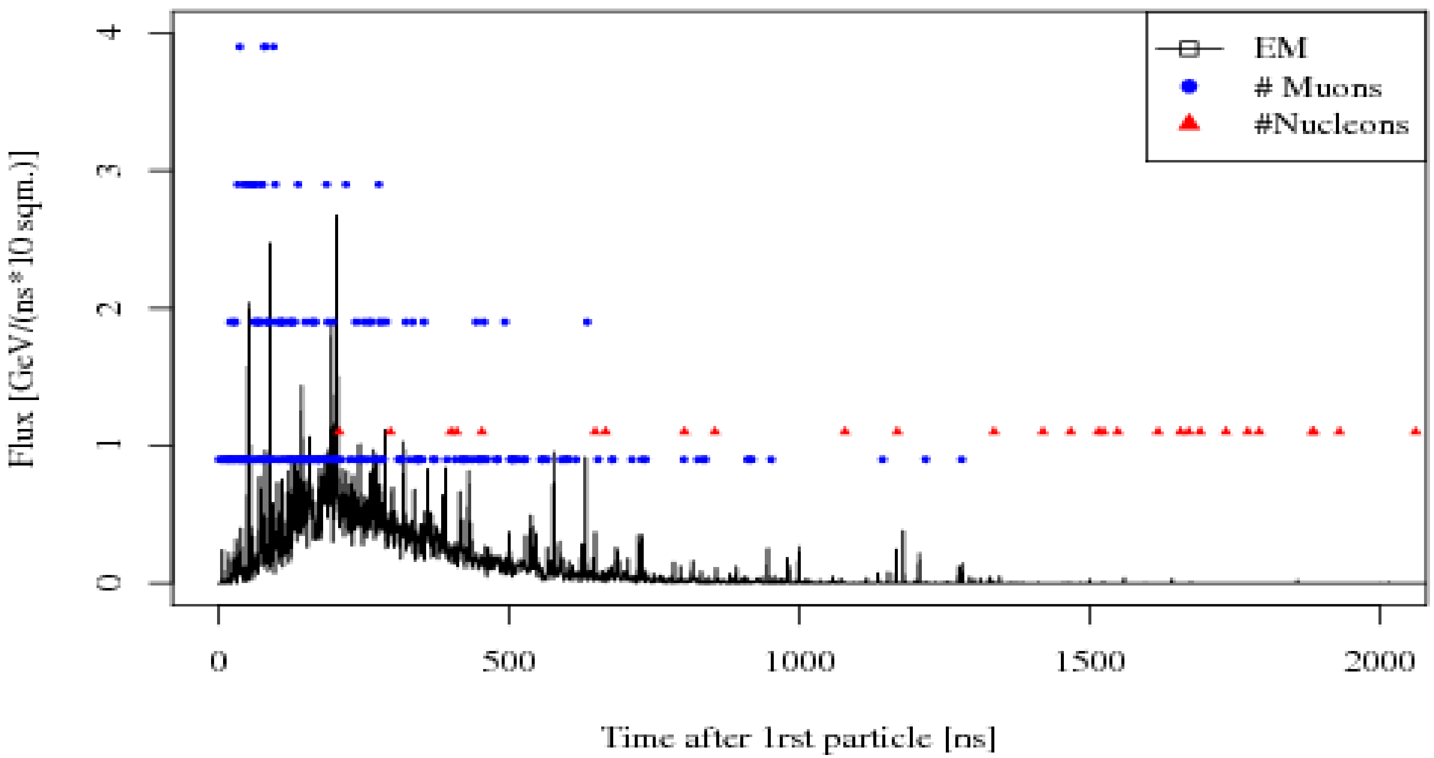
Take Home Message

- The SciDAC initiative gave us the opportunity to study Air Showers with unprecedented accuracy. However, we have to ask for it!.
- SD energy scale/resolution:
  - The EM VEM bias has been defined and quantified..
  - The VEM biases due to non-linearities have been defined, focusing on the FADC saturation in presence of a faster signal collection due to a reduced light collection efficiency and gain adjustments

No Thinning Sims : Scope and Goals

- A new version of Corsika now runs on the mid-size multi-core system, such at the Tev cluster. This work was mostly done to compute the electromagnetic VEM bias.
- Basic feature: No thinning at all! All interactions down to 3 MeV are followed through, until the altitude of 1510 m.
- Performance: about 2 15 EeV showers a day. (zenith angle of 35 degrees)
  - (on good days, i.e., when I have 24, 28 amd-32 core nodes for myself)
- Results:
  - Better estimate of the energy distribution of photons, to be submitted to the Auger Tank Simulator. To be discussed at a later date.
- Side benefits: Evaluation of the so-called “muon excess”, in presence of EM and nucleon background.

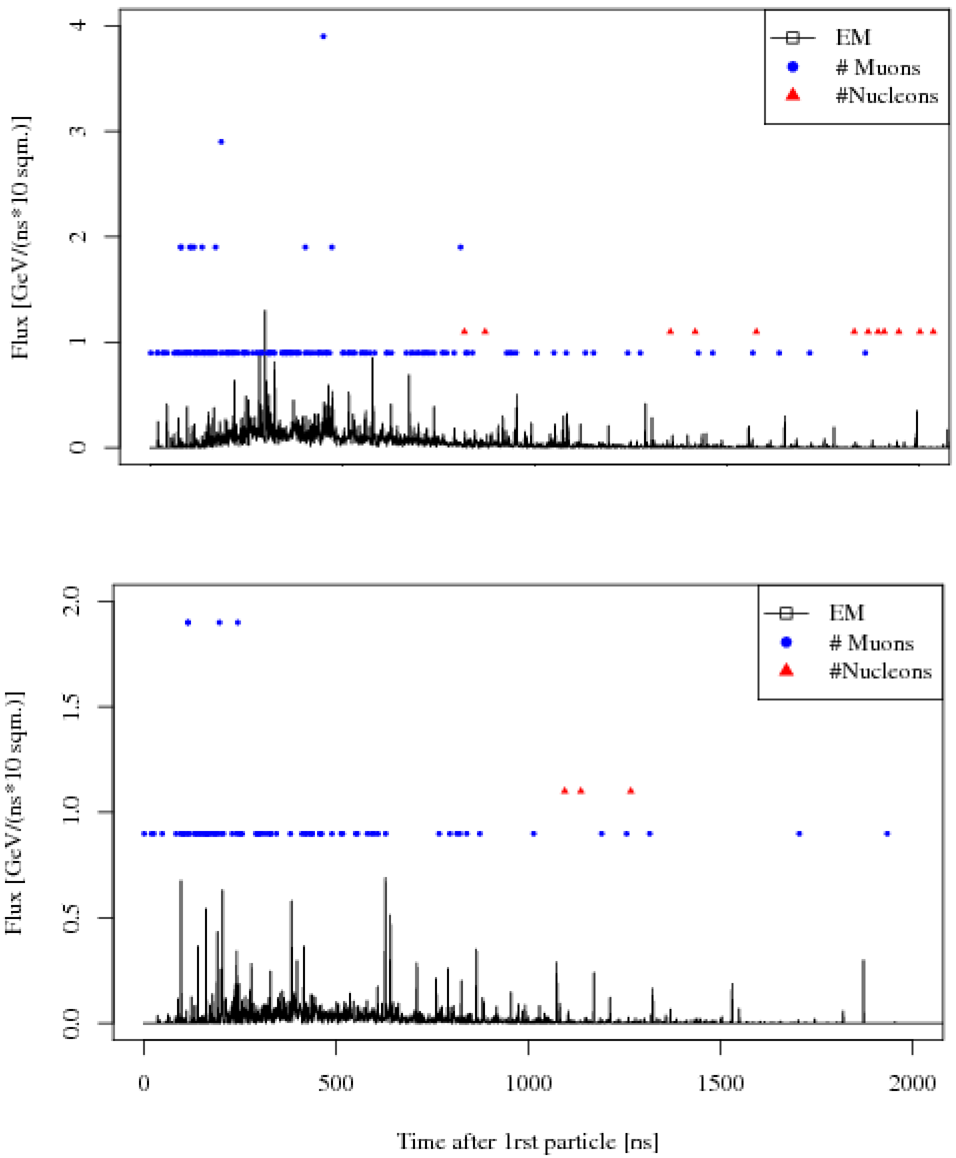
Traces for the station at 650 m.



A bout 300 muons for the stations nearest to the core. ~ 100 (per 9 sq meter!) at 1,000 meters.

But: the EM trace (at 1 GHz) glitchy.

Traces for the station at 990 m.



Key Point:

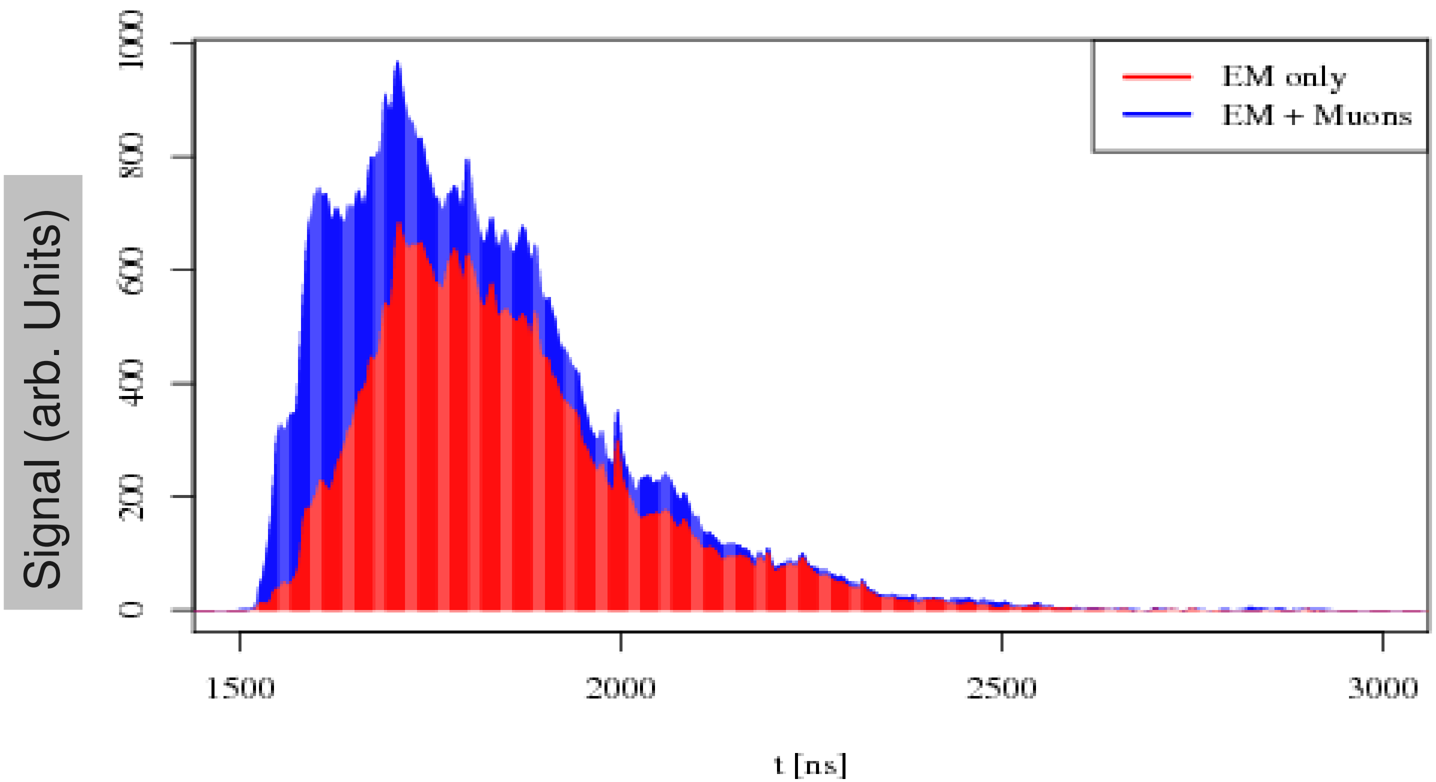
A one GeV photon is worth ~ 3.5 VEM (detailed Tank Simulator results.., Gap Note 2013-065)

So the EM glitch **in near coincidence** with muons are background.

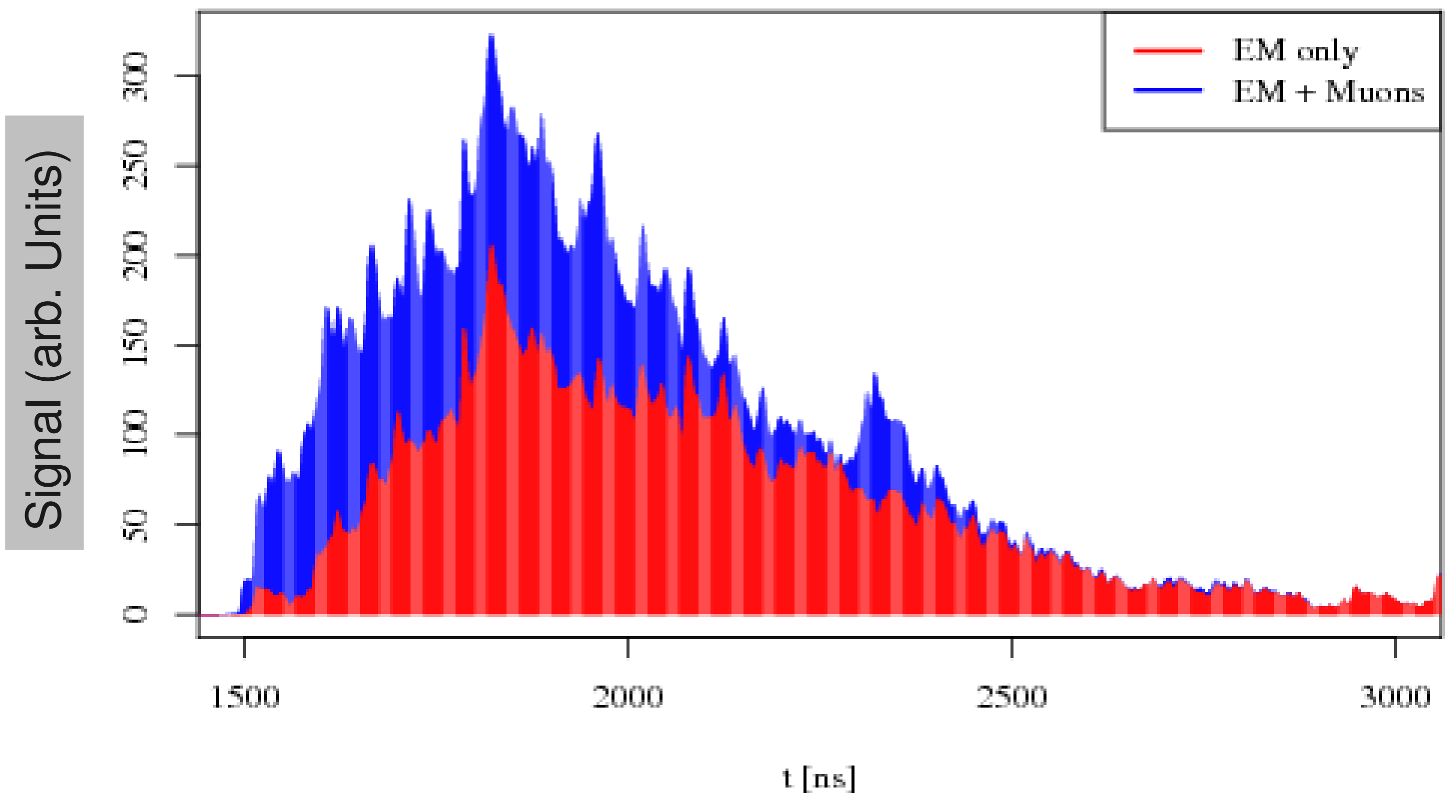
Count the number of such E.M. Glitches

These were plots have little to do with what we measured!

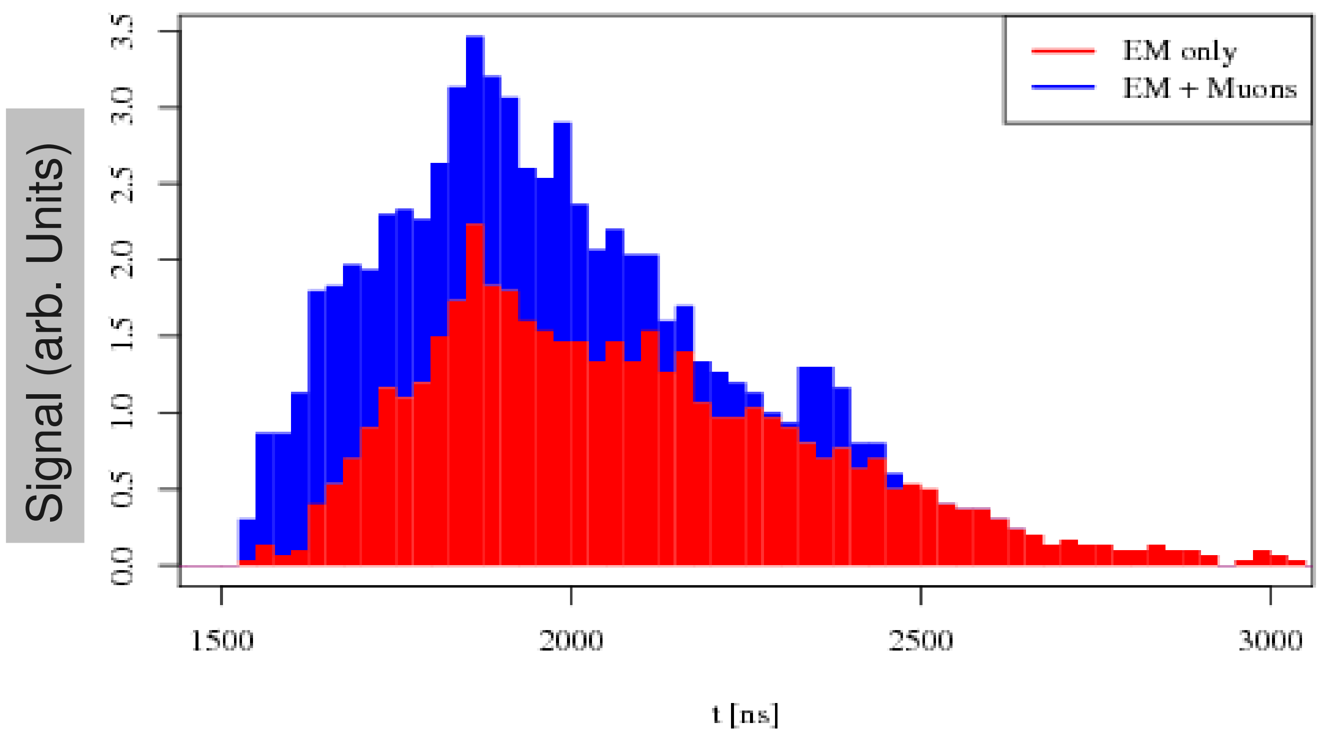
Simulated PMT Signal (sum over 3 PMTs) for the stations at 650 m.



Simulated PMT Signal (sum over 3 PMTs) for the stations at 990 m.



FADC Traces (sum over 3 PMTs) for the stations at 990 m.



More analysis of these virtual stations

- Document more such fluctuations?? (not my focus)
- Study the fall time vs core distance, for the muon and E.M.
  - The fall time is very much related to the distance from the core. More then the rise time, which is dominated by experimental effects.
  - But, as expected, fall time correlates with AoP. => need corrections.

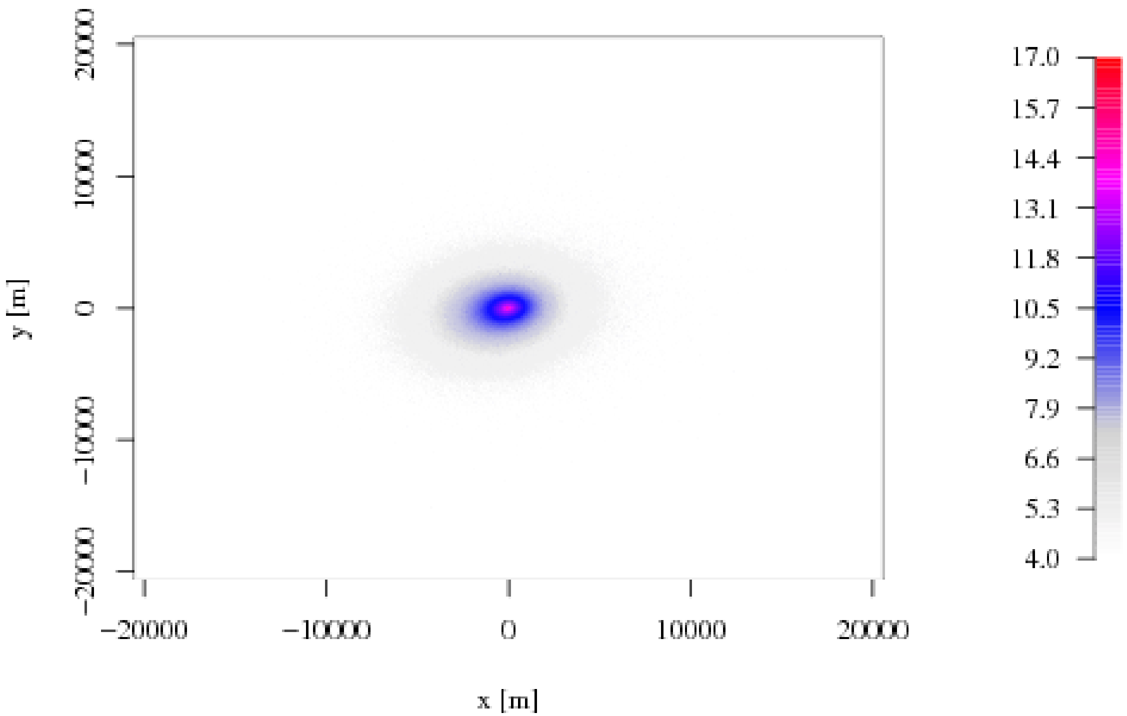
For stations close to the core...

- Fall time are short, of the order of light collection time.
- Stations with a reduced light collection time and running at a relatively higher gain (to compensate for the reduced number of photoelectrons) will FADC saturate more often than high effciency, low PMT gain stations.
- Along with intrinsic PMT non-linearity, and the LDF fit biases, (Fred S. Studies), we now have a solid thesis by which the detector aging influence the SD energy resolutions.

Sparse, 2D histogram Analysis

- ✔ In addition to station data, Corsika// also generates, at ground level a set of 2D sparse histograms, at a resolution of 10x10 m^2
- ✔ Only:
  - EM energy density, (prescaled by 10)
  - Number of muons.

EM density plot from sparse 2d histogram



E = 30 EeV

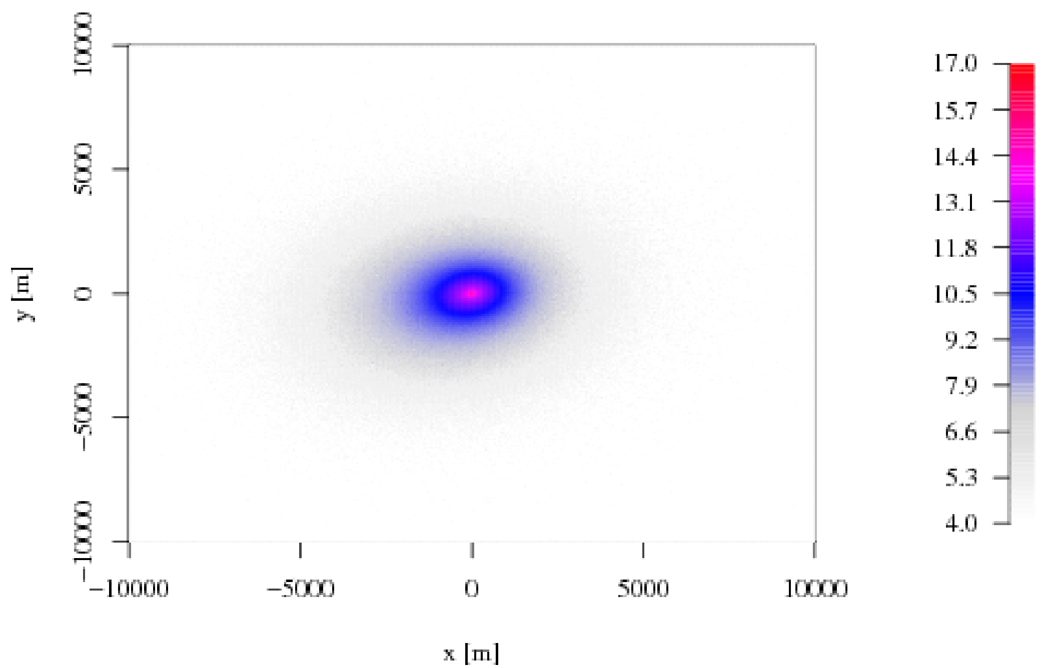
Zenith: 35°

Azimuth : 22°

Resolution: 10 x 10 m

Color coding on a log10 scale, Units are eV/m^2

EM density plot from sparse 2d histogram



E = 30 EeV

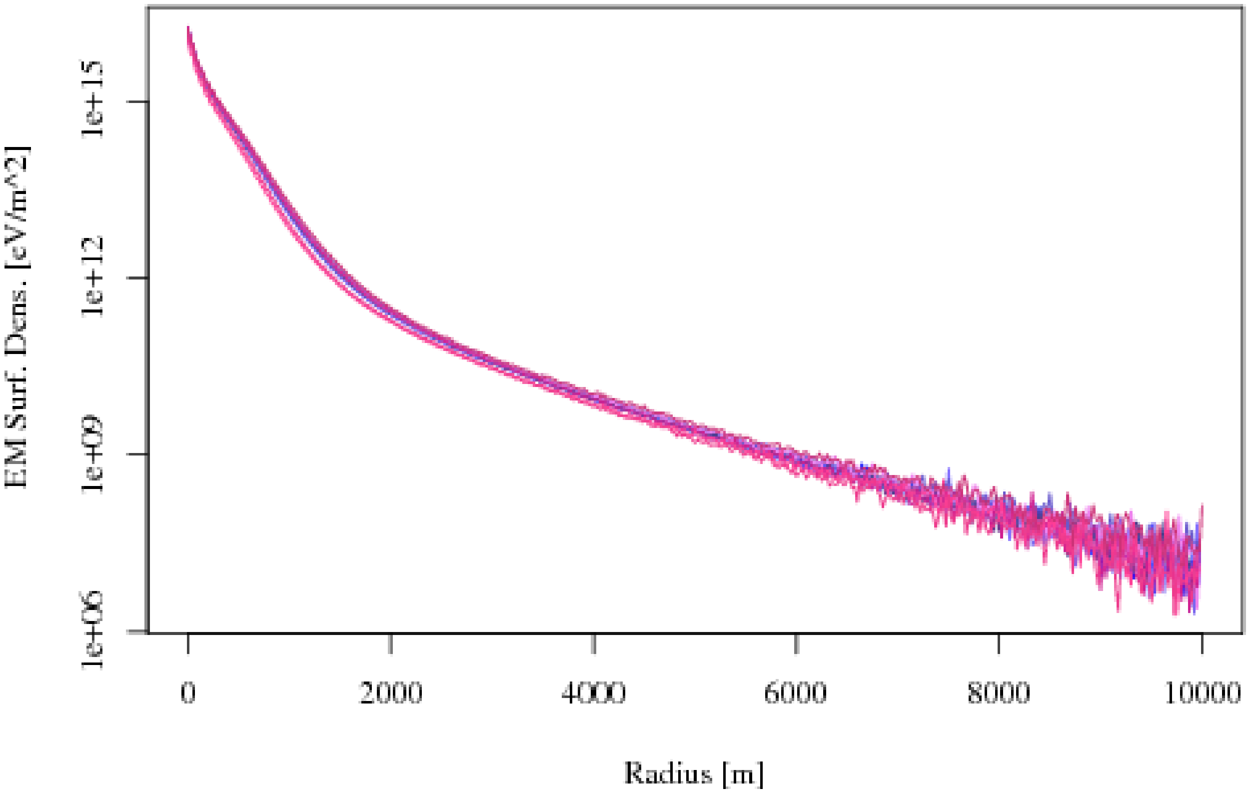
Zenith: 35°

Azimuth : 22°

Resolution: 10 x 10 m

Color coding on a log10 scale, Units are eV/m^2

LDF, integrating over all azimuth.



E = 15 EeV

Zenith: 35°

Azimuth : 22°

Resolution: 10 x 10 m

10 runs, with different MC seeds ==> different shower evolution.

Note:

a. The r.m.s. of S1000, for these simulated (sample of 10..) is around 26% ... not ~ 12%.
This might not be inconflict with FD/SD hybrid calibration data, as the FD and SD, to some extend, see the same shower fluctuations..

b. These LDF, even at a moderate energy of 15 EeV, show a rapid evolution close (~tens of meters) away from the core,a shape that do not fit very well the NKGFermiFunction used in the offline.

c. At a zenith of 38^{o}, the azimuth dependence of the LDF is quite pronounced. In our SD reconstruction code, this is only corrected for via the CIC correction. But only to 1rst order.. Perhaps there is something to be gained..

Finally, more information could be extracted from these runs...

Regarding SD energy determination.

- ✔ Detailed (Corsika no-weight + full Geant4 calculation) of the VEM bias in presence of a reduced light collection efficiency:
  - Analyze data taken in April/March 2013 on Gianni Navarra. Build a (rather drastic) model where there is a reduction of light by a factor ~2.5 for muon, due to a change in the water absorption length (a change in the Tyvek reflectivity coefficient could also explain the loss of light, but such model were favored by the data).
  - Compute the EM VEM bias....

SD energy & EM VEM Bias

- The bias we introduce when we calibrate on muons, re-calibrate on shower (Hybrid), globally, while each stations reports a slightly different ratio of photon to muon integrated signal.
- Geant4 Sims, ~ 5 % (GapNote 2013-065) P. Billoir estimated ~< 3.5 %. Probably based light collection model less drastic than the ones I settled on Gianni Navarra.
- More should be done on the experimental part of AoP, on the new test tank MUON, determination of the absorption length of water in the lab, based, for instance on Thermal Lensing Spectrometry method(s), determination of the aging of TyVek, etc... An other topic of discussion...

Non Linear VEM Bias, First

- PMT have a finite linearity range. Significant non-linearity (~20%) have been observed for signal of ~ 2000 to 3000 VEM. A possible scenario for a bias goes as follow
  - The reduced amount of light get compensated by an increase in the PMT gain, when the station gets calibrated. Thus "bright" stations run at a lower gains the "murky" ones.
  - This means that the PMT non-linearity might be significant higher for murky stations than for bright ones.
- Introduces different CIC calibration curves. But difficult to see this in data, as it mostly introduces a resolution term.

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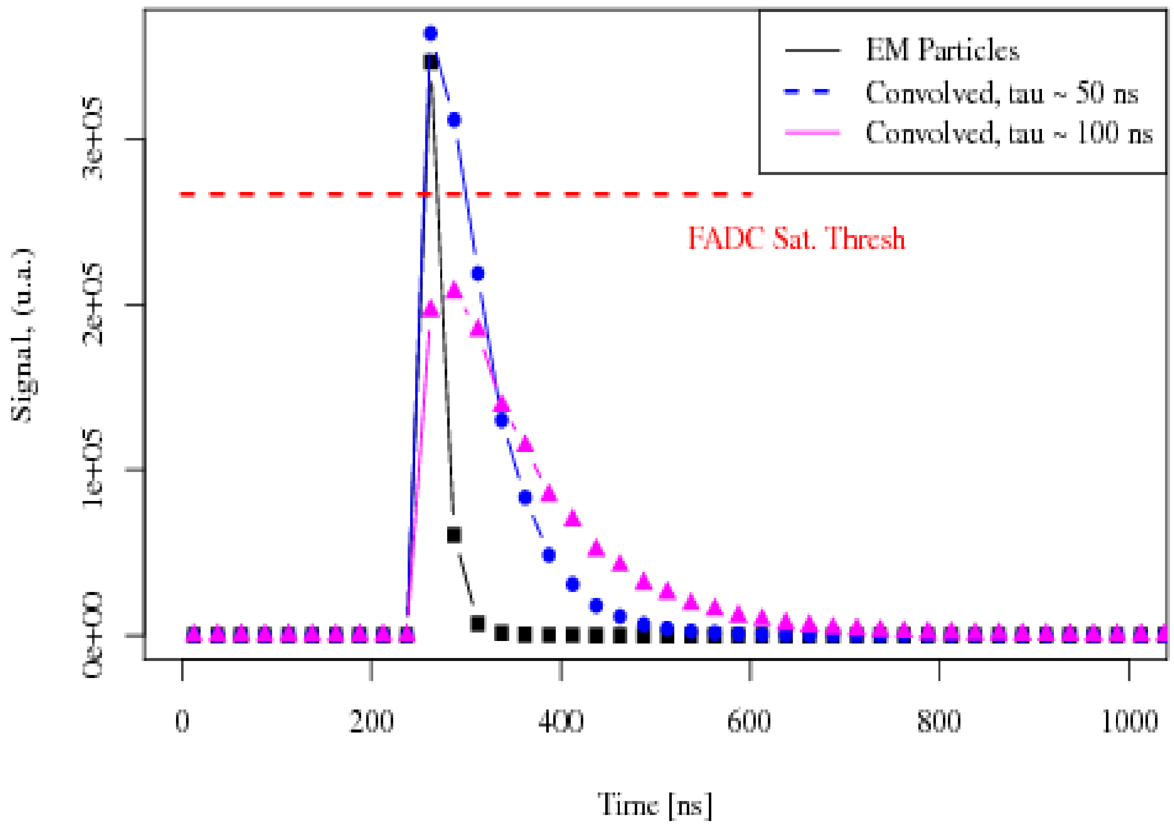
Non Linear VEM Bias, 2nd

- FADC has also a finite dynamic range. At low Zenith angle, too close to the core, particularly at high energy, the low gain channel reaches more than 1023 bits. Recovery is possible, but prone to large (>~ 30%) systematic uncertainties. Other stations are at a distance greater than 1000 => must extrapolate on the LDF, leading to accrued uncertainties on S1000 (F. Sarazin et al).
- If the light collection is reduced, to keep the muon histogram peak and "100 Hz" stable, the gain of the PMT have to increase.
- The pulse duration gets shorter, and, as the intrinsic fall time of the shower front gets shorter (At 1500m, we are at or below Xmax!), the probability to trigger the FADC saturation is higher...

Example: Simulation



30 EeV,
theta 35,
~75 m. from the core

No thinning Corsika
Collect all particles down to 3 MeV
They all come within <~ 25 ns.

Convoluted by the CWD time response

Digitized at 40 MHz.

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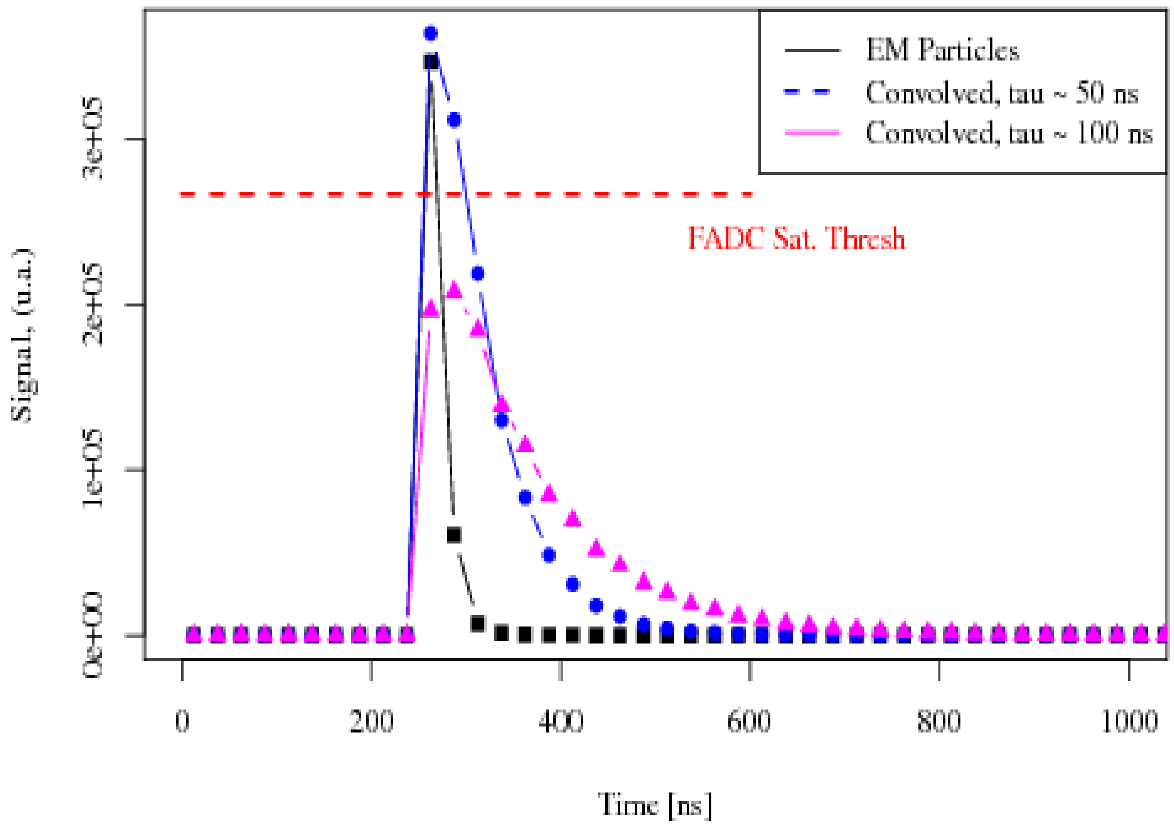

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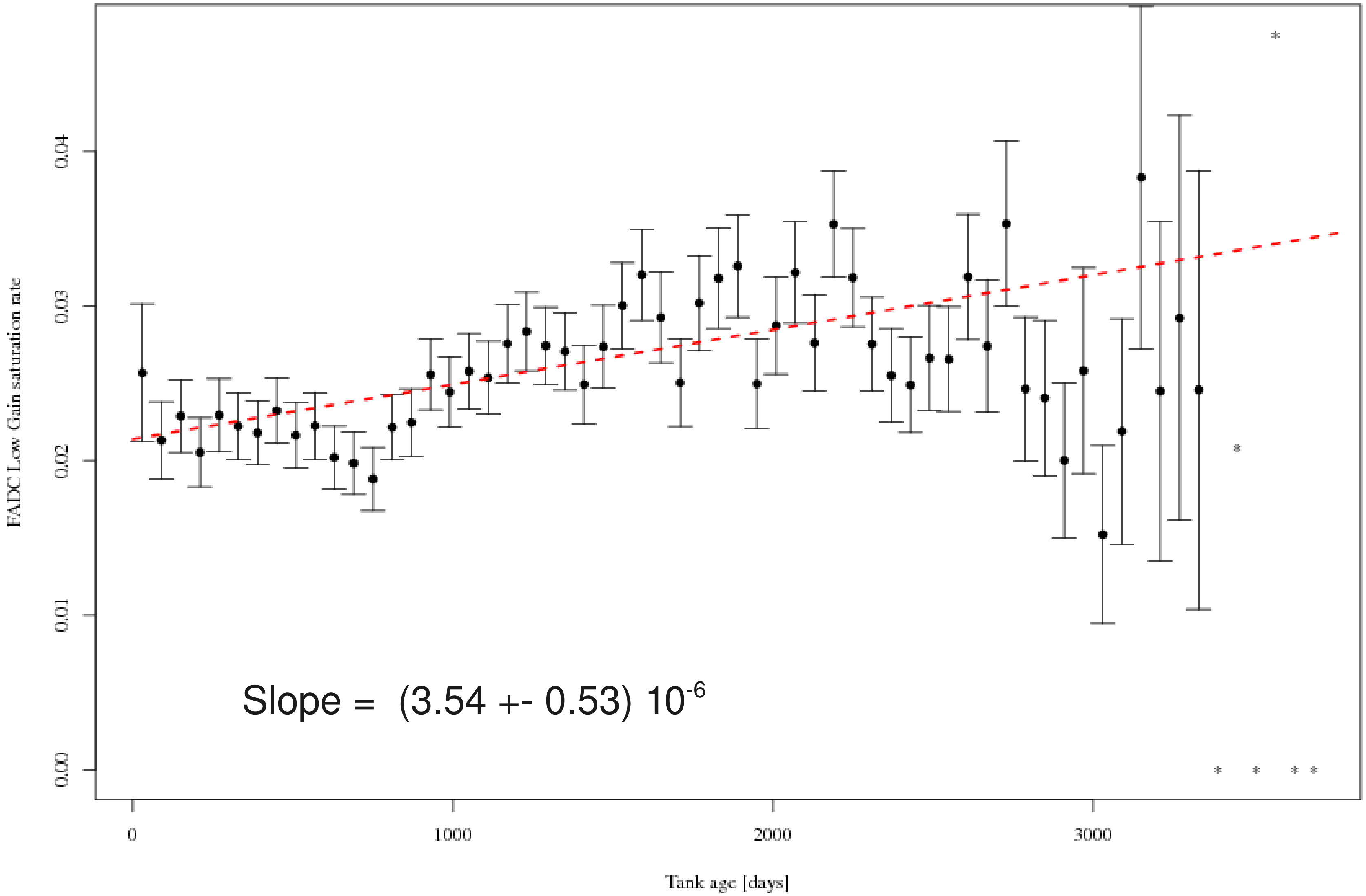
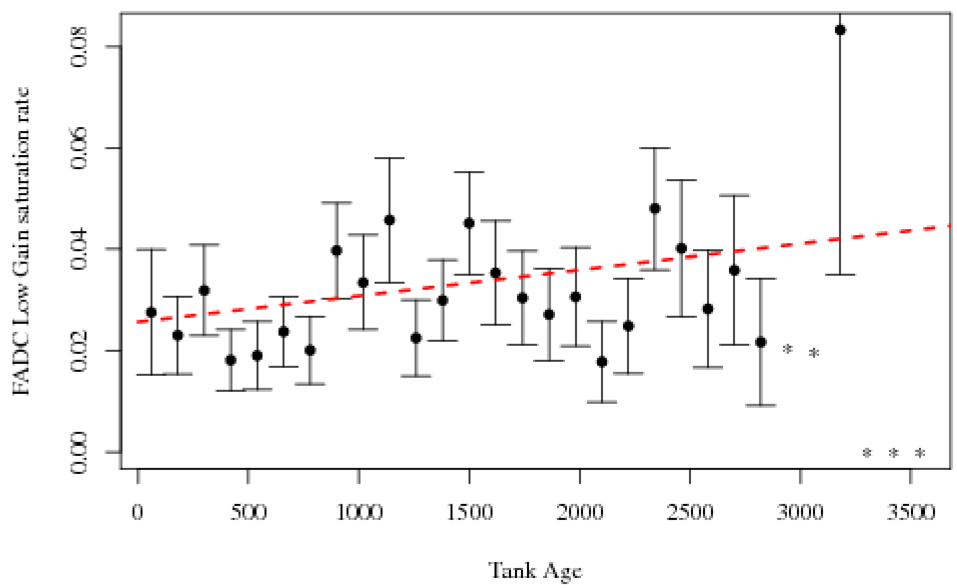
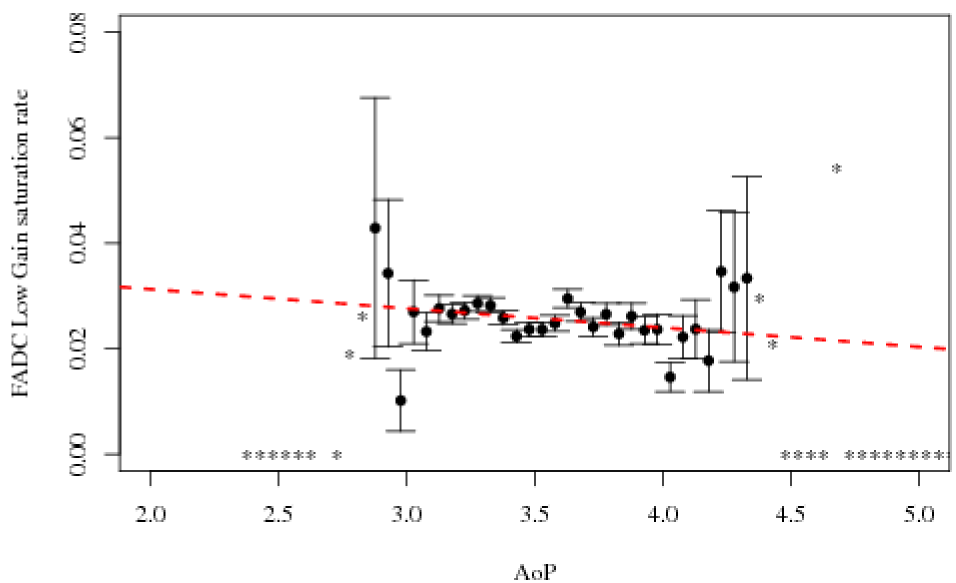
If so, the rate at which the low gain FADC saturates must increase as the SD array is aging. (and/or AoP is decreasing)


FADC Low Gain saturation rate
0.00
0.01
0.02
0.03
0.04
0
1000
2000
3000
Tank age [days]
Slope = (3.54 +- 0.53) 10^{-6}

E> 3 EeV !!



Less significant at high due to statistics.



The significance for the dependency of AoP vs Low Gain FADC saturation is less pronounced than for tank age..

Besides a reduced light collection efficiency, we may have an other source of a reduced dynamic gain.

Conclusions: No-thinning Corsika

1. It is now possible to generate UHECR showers at E >~ 10 EeV somewhat faster than we can observe them, without thinning

2. No weight correction to apply => less bias in studying timing accurate correlations of time of arrival of various particles.

3. The presence of the ~ GeV photons, along with muons, at a distance of ~1,000 meters from the core is not negligible at all. The are very likely counted in the “jump” methods . Do we really have a “muon excess” problem? Are we counting “jumps” correctly in the simulated data ?

4. To reject EM glitches (and nucleons), need very fine segmentation (~ moliere radius), or many radiation lengths, and a few hadronic abs. Length.)

5. Is the muon count at ground level a robust estimator? (Of what?)

Conclusions: SD energy resolution and energy scale changes

1. The AoP is affecting more than the atmospheric muon line shape. A decrease of the fall time with tank is seen in the data (see backup slides)

2. A reduced (and/or changing vs time) CWD light collection efficiency has implication on the SD energy uncertainties. Two distinct biases in the S1000 estimate have been presented.

3. A change in the rate at which we have low Gain FADC saturation should occur, and it does in the data (6.7 sigma effect).

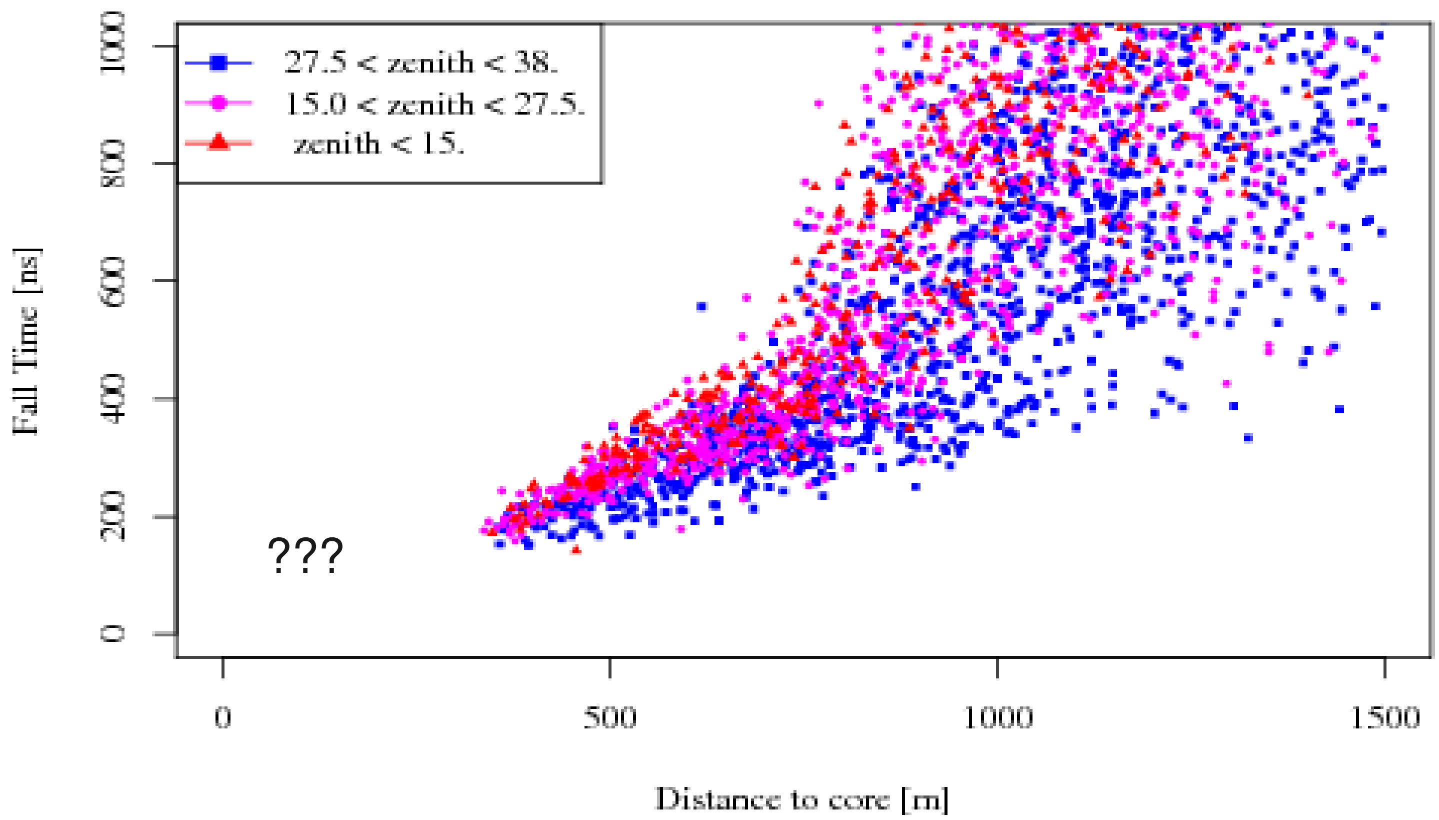
4. An event by event, tank by tank correction seems difficult, as the biases only affect the high energy data, the PMT gains are poorly known. Ultimately, our problem stems from the lack of direct calibration at the highest energies.

5. But a conservative model for the uncertainties can be written..

Moreover, the proposed SDE + small PMT upgrade will definitely improve the situation. A factor of 30 in the maximum signal size that can be measured with a linear response is anticipated. (We still do need to quantify the improvement on the SD energy measurement at ~60 EeV.

Fall time vs Distance to core

2009 -2010 data, E> 3 EeV



Fall time vs tank age.