Search for UHE Neutrinos

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What's New Since Lake Geneva

- Search for UHE Neutrinos
- TWR-DAQ data collected in 2003
- Extensive Monte Carlo studies [Fe, p, QGSJET, SIBYLL], 10^6 CPU hours
  - Systematic errors for SIG/BGR MC included
- All-flavors simulated and total ν-Sensitivity, including systematics:

$$E^2\Phi_\nu < 2.18 \times 10^{-7} \text{ GeV cm}^{-2} \text{ s}^{-1}\text{sr}^{-1}$$

$$\text{for } 10^{15} \text{ eV} < E_\nu < 10^{18.7} \text{ eV at 90\% C.L.}$$

- A factor 3 better (per year) than prior UHE analysis
- Unblinding proposal at:
  - http://www.ps.uci.edu/~silvestr/UNBLINDING/Data_2003_Unblinding_Proposal.pdf
- Questions and responses posted on diffuse-wg archive at:
  - http://www.icecube.wisc.edu/pipermail/diffuse-wg

Why TWR is different that Muon-DAQ?

- Why the same analysis cannot be performed by using the Muon-DAQ?
  1. Cleaner analysis by using waveforms data
  2. No X-talk required
     - (more stable ADC%TOT dependency compared to Muon-DAQ)
  3. Diagnose of problems by directly analyzing waveforms
  4. No 8 TDC-edge limitation
  5. More sensitive to timing fluctuation variables
  6. Npe dynamic range is improved

BGR MC

- Biased BGR MC:
  - Energy range: $E_{(lower)} = 8 \times 10^4$ GeV; $E_{(upper)} = 1 \times 10^{11}$ GeV
  - Energy spectrum = E^{-2}
- P + Fe, QGSJET + SIBYLL, 10^6 CPU hours required [SDSC]

TOT-Variables Definition

Def.: $\mu_{TOT}^{opti}(event)$ = the mean of global TOT (Time Over Threshold) tot_i for optical channels, where tot_i is the sum of the individual TOT's recorded in a full waveform of a given channel i for a given *event*. Therefore the sum is computed over hit optical channels.

$$\mu_{TOT}^{opti}(event) = \frac{1}{\mathrm{Nch_{opti}}} \sum_{i=1}^{\mathrm{Nch}} tot_i \tag{3}$$

Def.: $\sigma_{TOT}^{opti}(event)$ = the standard deviation of global TOT (Time Over Threshold) tot_i for optical channels, where tot_i is the sum of the individual TOT's recorded in a full waveform of a given channel i for a given *event*. Therefore the sum is computed over hit optical channels.

$$\sigma_{TOT}^{opti}(event) = \sqrt{\frac{1}{\mathrm{Nch_{opti}} - 1} \sum_{i=1}^{\mathrm{Nch}} (tot_i - \mu_{TOT}^{opti}(event))^2} \tag{4}$$

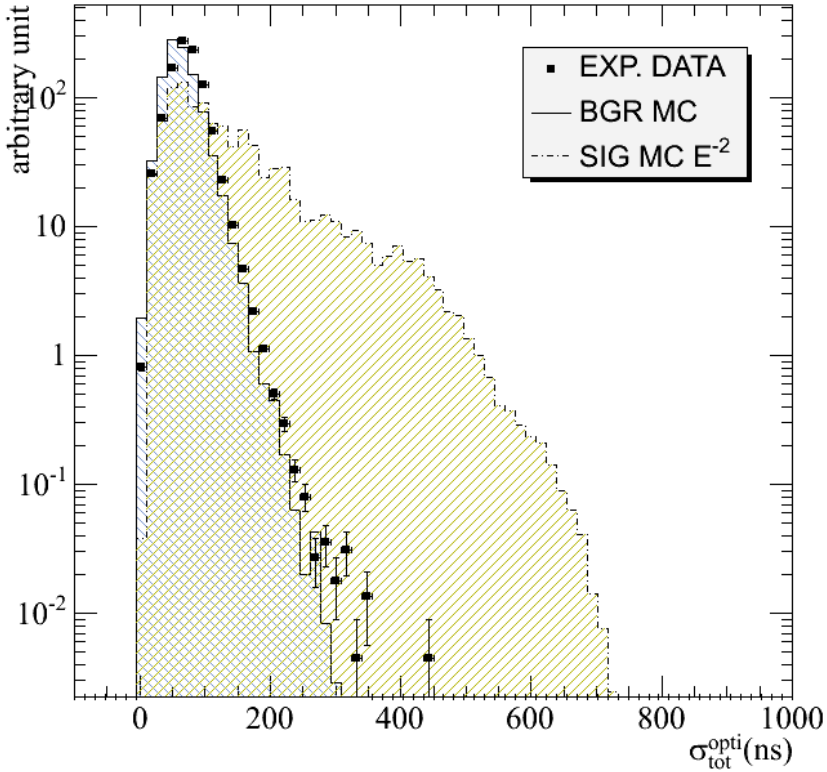
Variables and Selection Criteria

Table 4. Selection criteria of the analysis, and variables used in each single analysis level.

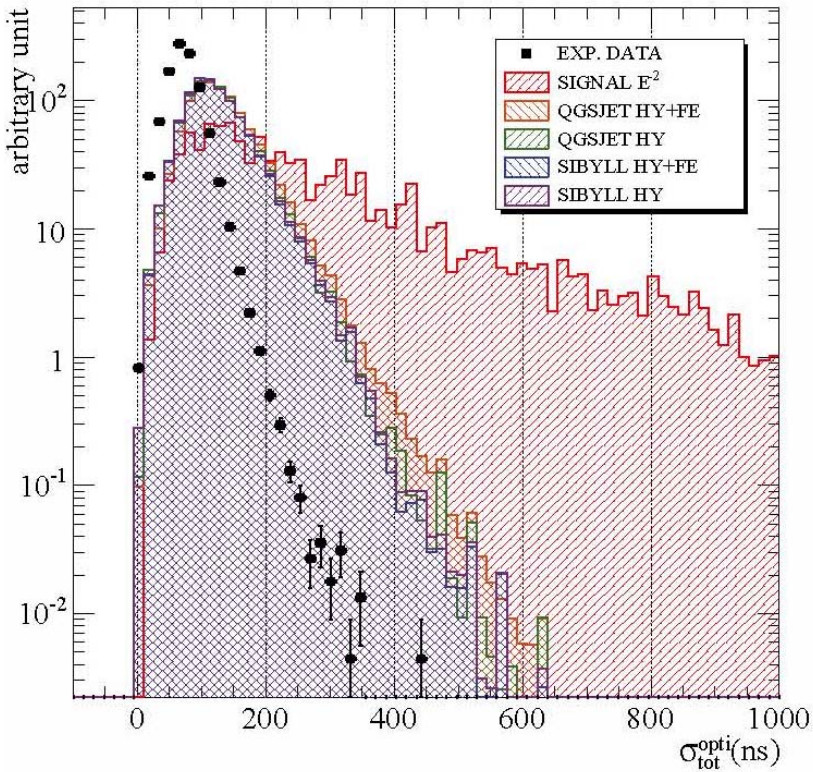
Level	Variables	Selection
Level-0	-	Trigger
Level-1	-	Combined Streams
Level-2	NHITS	NHITS$>$ 152
Level-3	$\mathrm{NN}_1(\rho^2_{latehits}$, F1H, θ, $\sigma^{all}_{TDC})$	$\mathrm{NN}_1 > 0.65$
Level-4	NN_2(F1H, σ^{elec}_{Npe}, μ^{all}_{TDC}, $\sigma^{opti}_{TOT})$	$\mathrm{NN}_2 > 0.78$

Data-BGR improvement

NEW



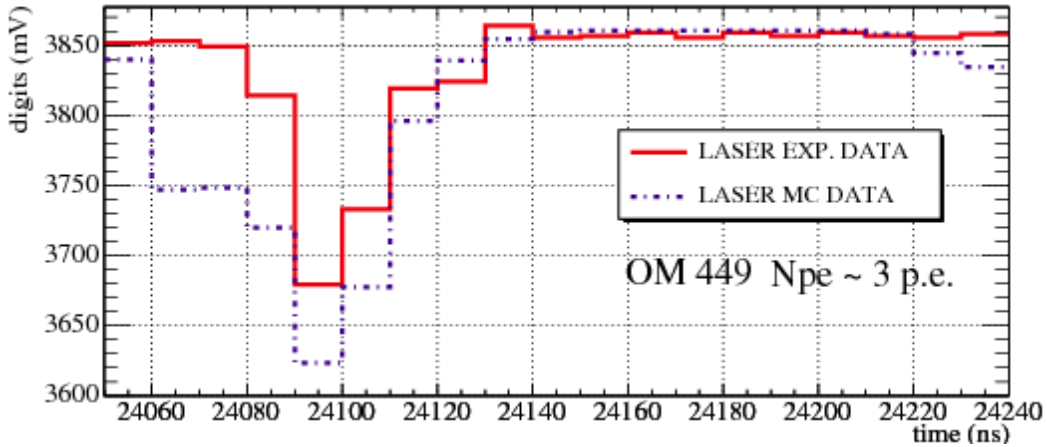
OLD

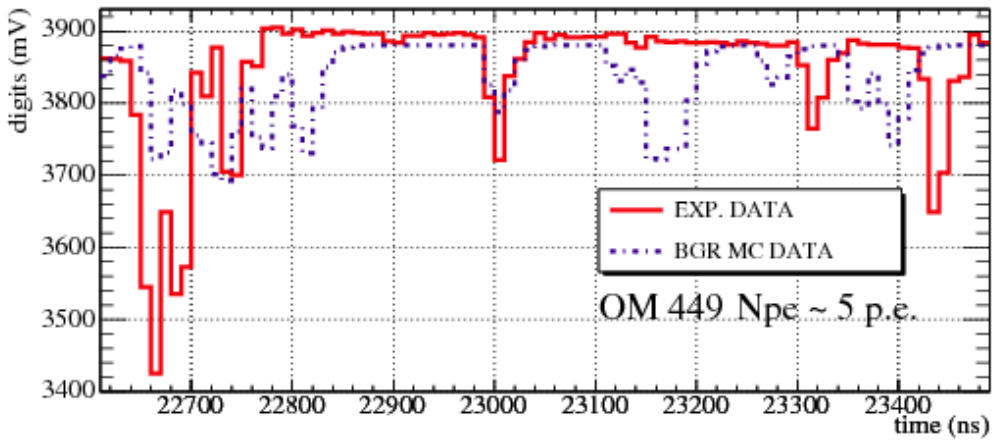


- 13% of systematic uncertainties calculated from variation of primary composition and physics interaction models
- Correcting factor 0.5, implies ~ 7% of systematic uncertainties

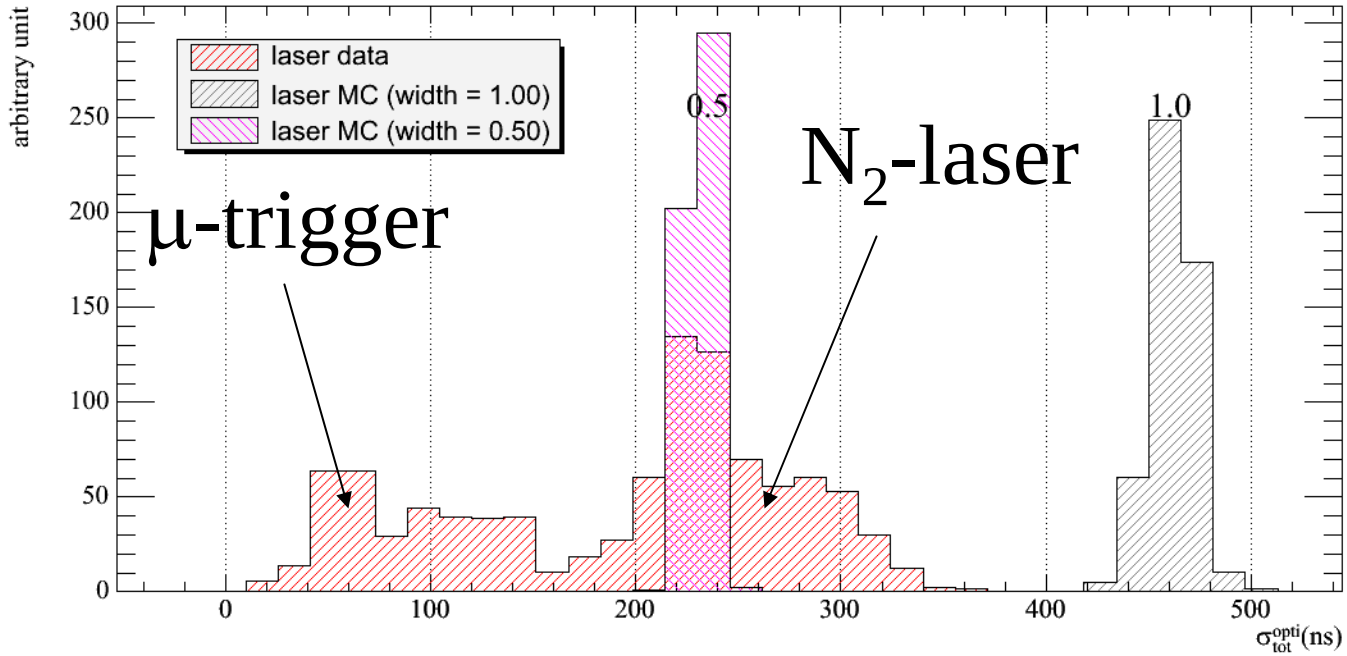
Waveform Investigation

- Waveform analysis confirms that simulated WF's show a width-broadening by a factor of 2 compared to data WF's





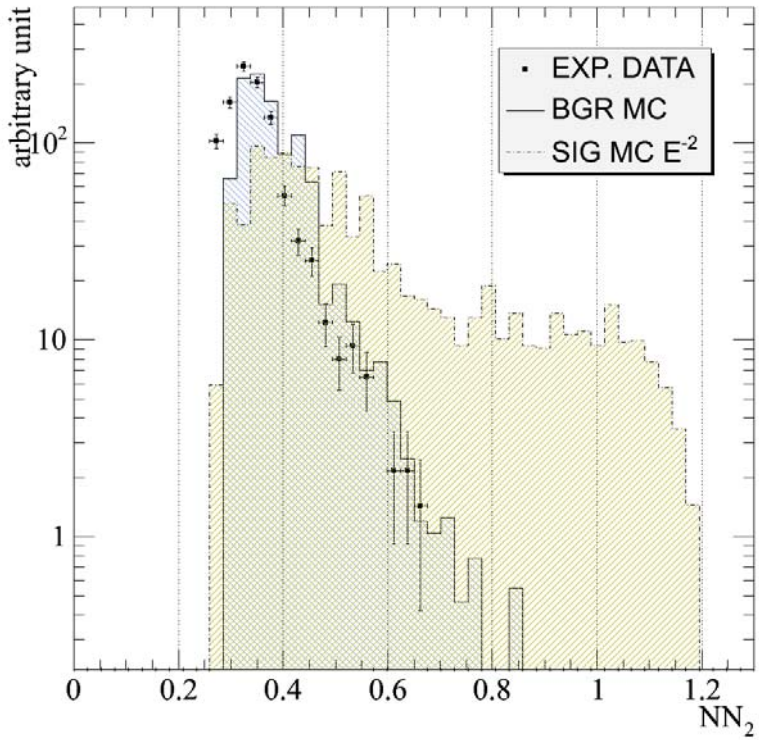
N_2-laser Calibration



- N_2-laser data used to calibrate the width correction applied to simulated WF's

NN2 Improved Results

NEW



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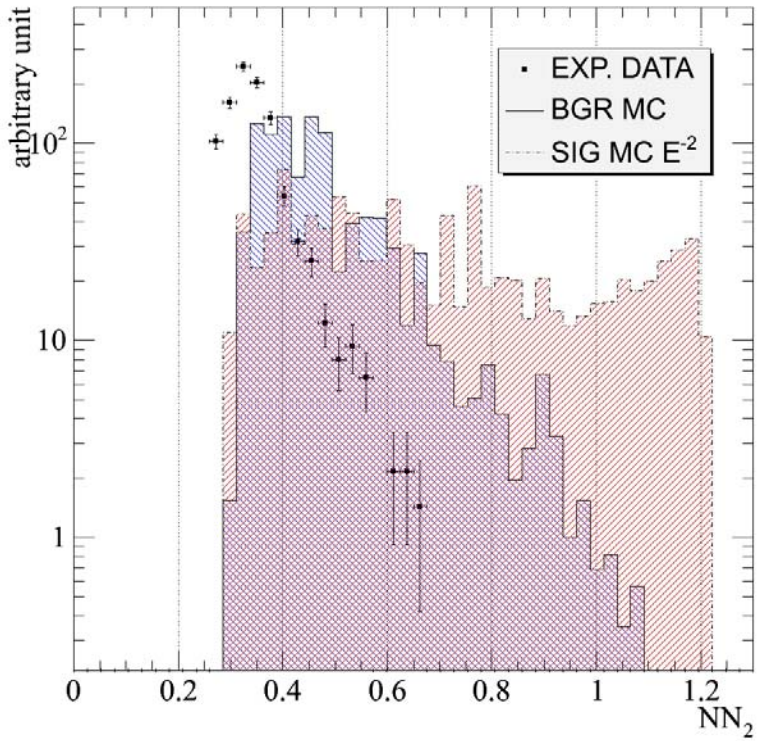
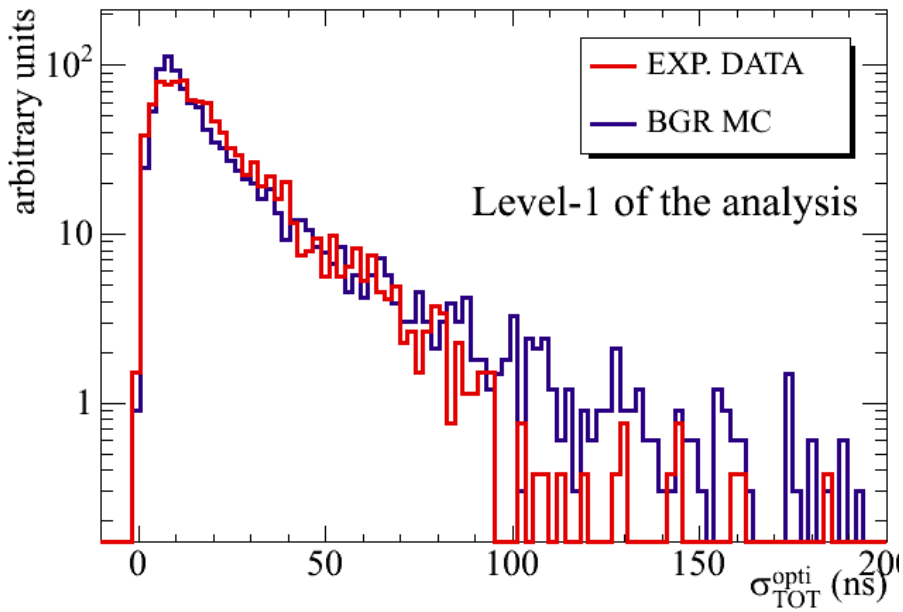
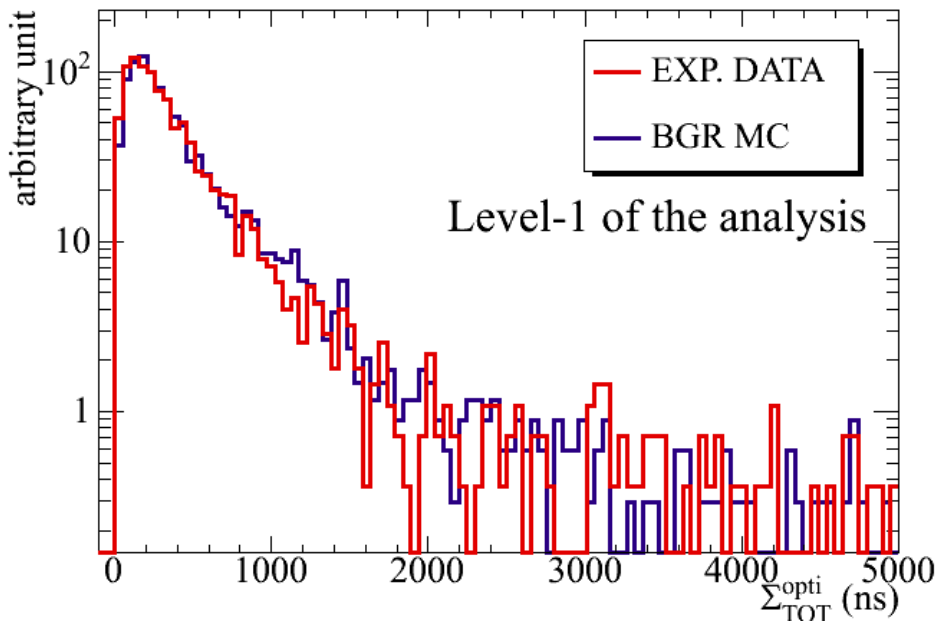


- Improved Neural Network results after applying width correction.
- Independent variables improved as well such as SUM_tot , Mean_tot, σ^{opti}_{TOT}

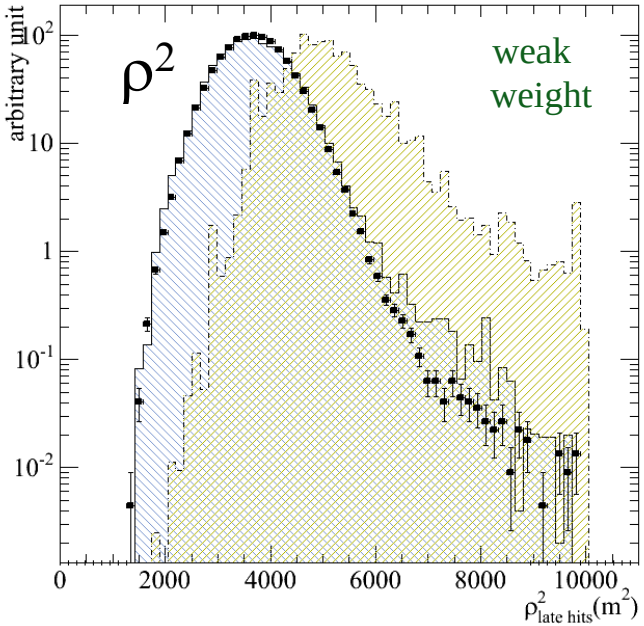
Amasim (aluminum-fix) versus (aluminum-opt5)

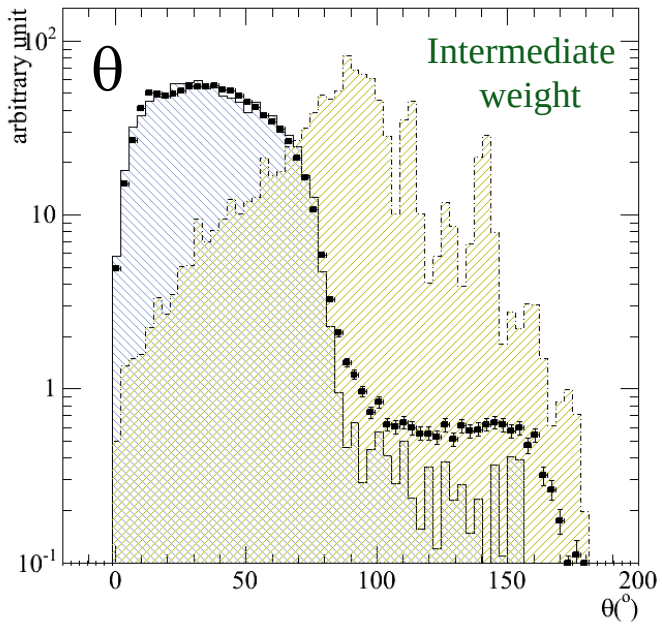
- Amasim version used for this analysis:
  - 2.90.10 (aluminum-fix) 23/3-06 [(aluminum-fix) detail not in proposal] + UHE specific updates (see Sec.4), which fixed many bugs.
- MC WF's were extensively investigated using 2003 Point-Source analysis (published at: (A.Silvestri et al. astro-ph/0701319 and Mod. Phys. Lett. A Vol. 22, No. 24, 1769-1778 (2007))
  - No evidence for significant WF corruption in MC as reported by Johan.
  - No evidence for significant impact on NHITS, LE, or TOT distributions
- Also, TOT based distributions at TRIGGER LEVEL (low energy) do agree
  - The plots below for σ^{opti}_{TOT} and Σ^{opti}_{TOT} suggest that MC WF are fine for low energy events.
  - No evidence that Amasim (aluminum-fix/upgraded) distorts distributions of analysis variables.

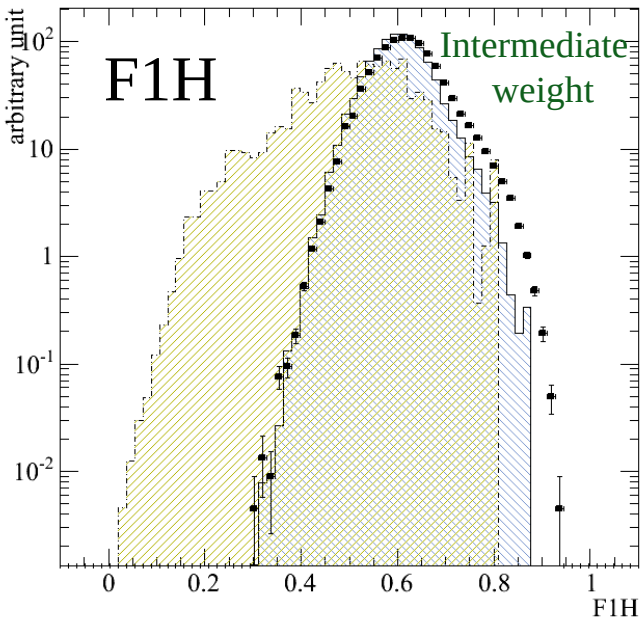


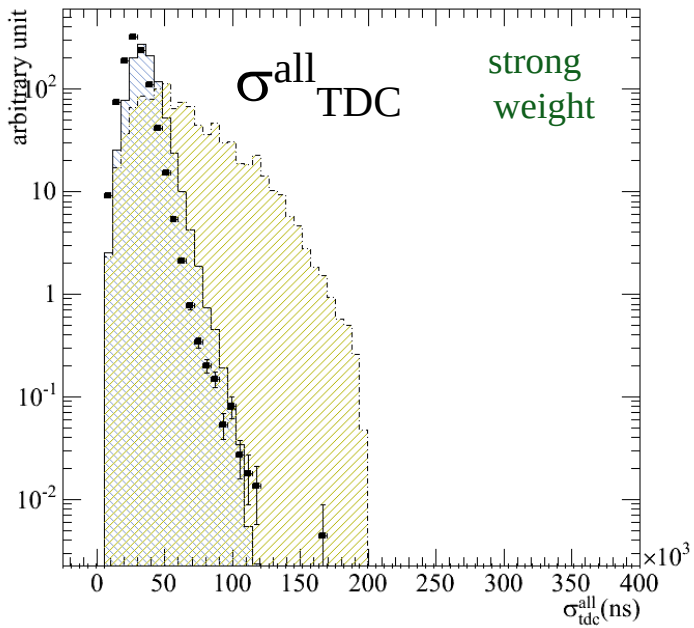


Only plots for variables used in NN1

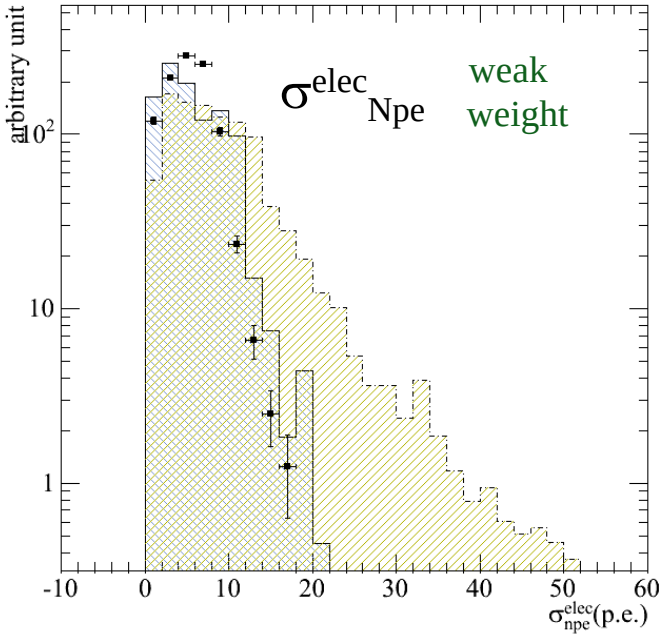


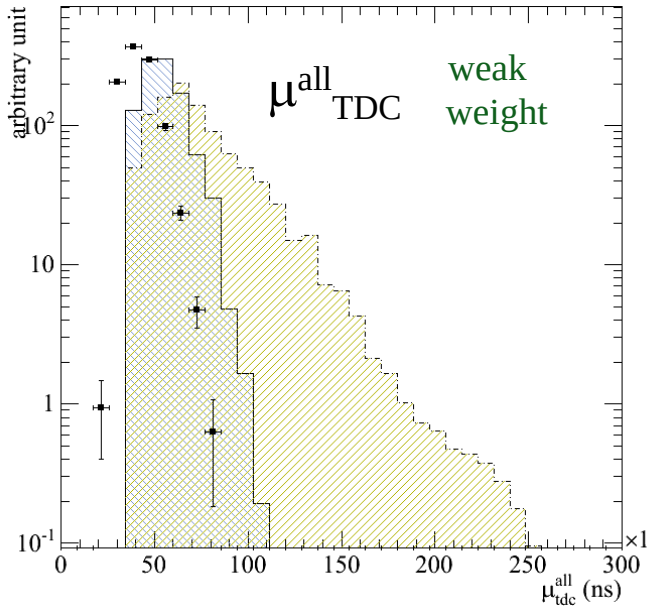


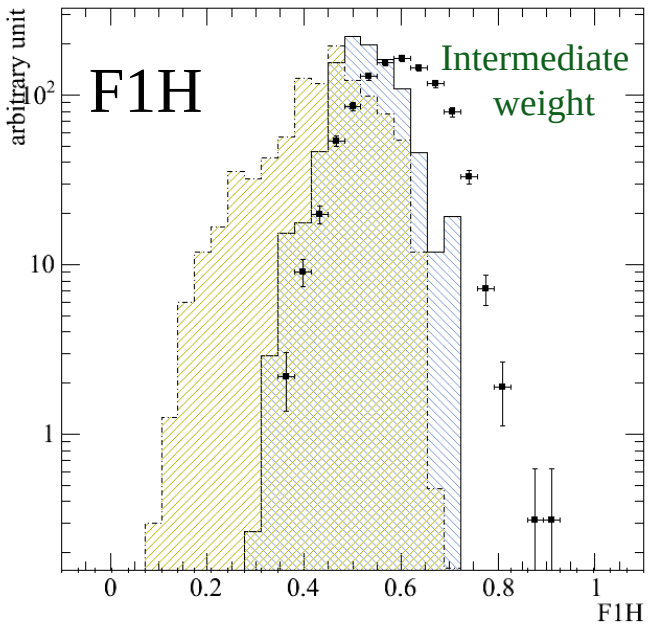


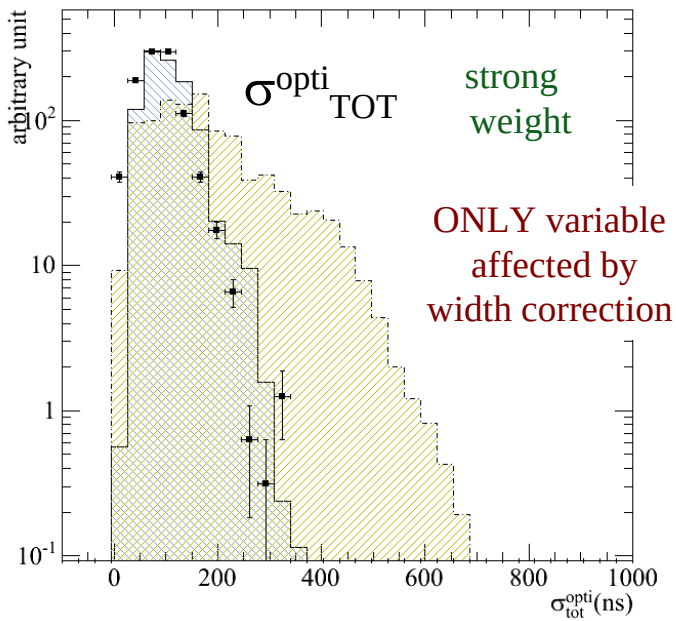


Only plots for variables used in NN2









Comment on distributions of NN2 variables

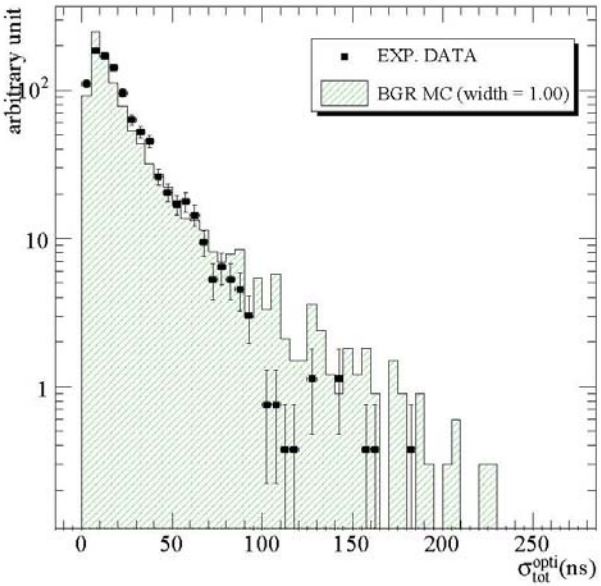
- After NN1: BGR has low statistics and high energy [$E_{prim.} \sim 10^{16}$ eV].
  - slight discrepancy BGR/data can be expected.
- The only perceptible discrepancy is observed on variables (F1H and μ^{all}_{TDC}).
  - F1H agreement is better/same as previous UHE (Lisa's) analysis.
    - See http://www.ps.uci.edu/~gerhardt/uhe01/frac1.html
  - μ^{all}_{TDC} has a weak weighting in the NN2 training.
- Modest disagreement in distributions not enough to significantly impact NN2 distribution (see Fig.13). Good agreement between data and BG MC is seen for NN2.

Does width correction impact the trigger?

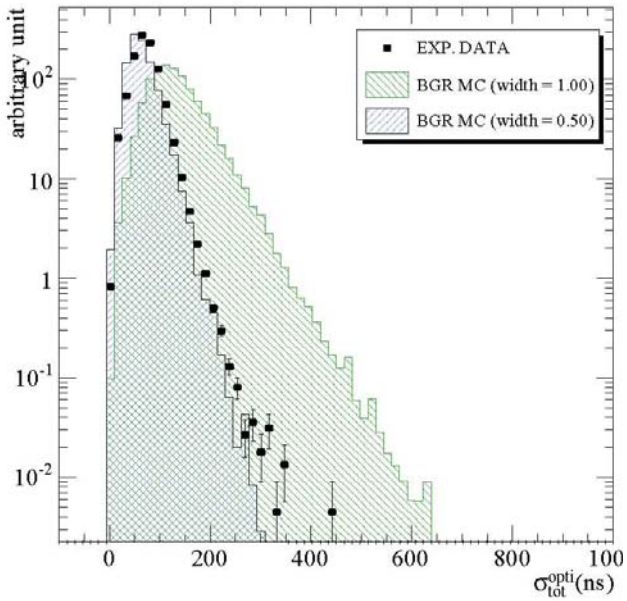
- No.
- The width correction has been applied after Amasim
- No hits removed. so trigger conditions are unaffected.

Is signal properly simulated?

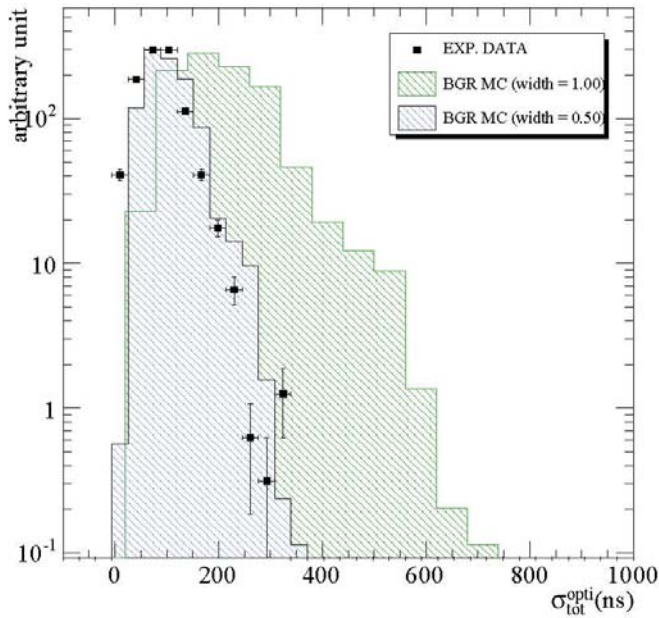
Level-1



Level-2

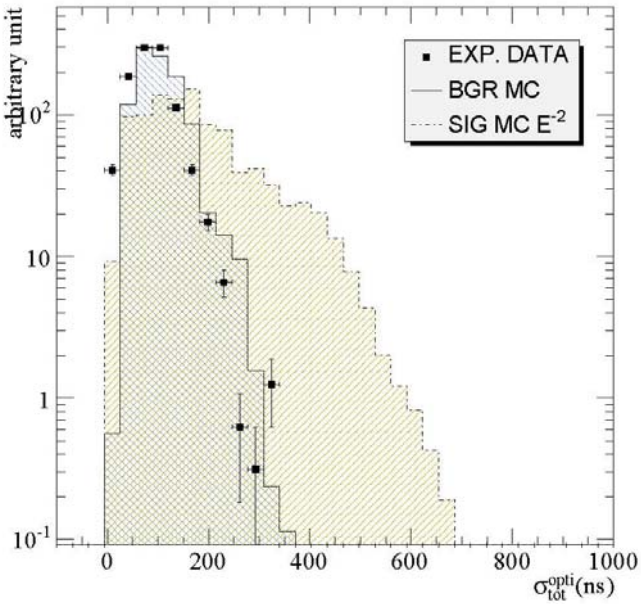


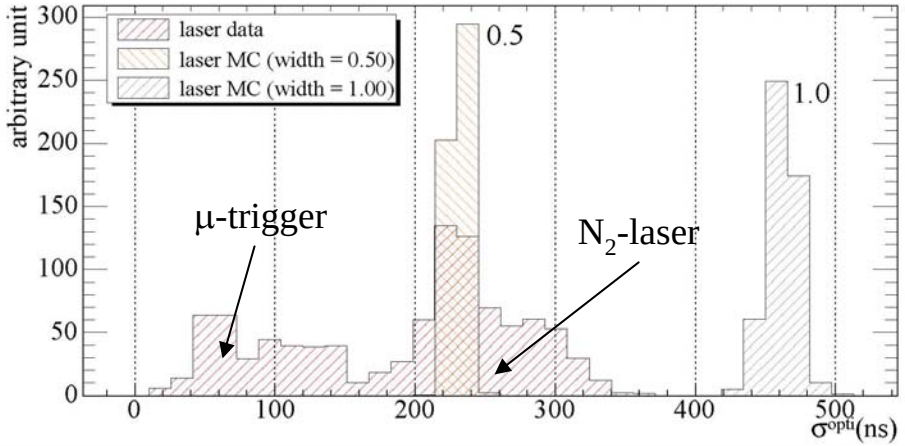
Level-3

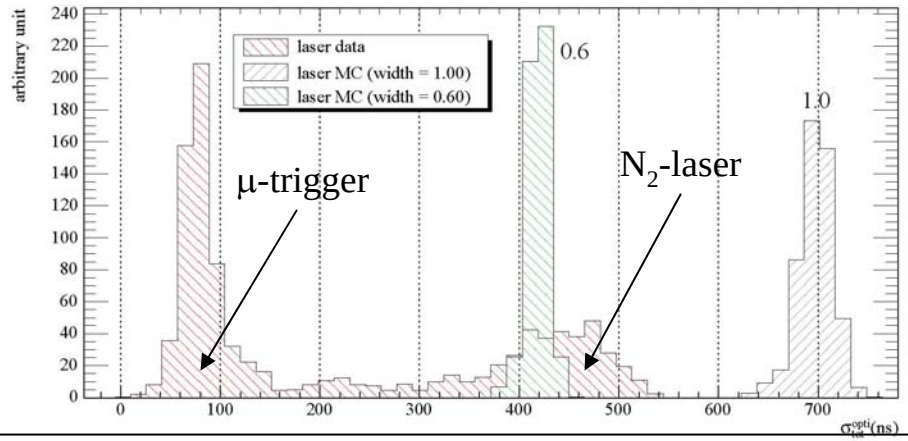


- BGR MC shows that width correction is not necessary at initial level (level-1).
- However, the constant factor of 0.5 width correction is needed to achieve agreement between data and BGR MC.
- Agreement is tested for σ^{opti}_{TOT} (~ 20 ns, 50 ns, 75 ns) for BGR at (level-1, level-2, level-3), respectively.

Signal N2-laser Calibration

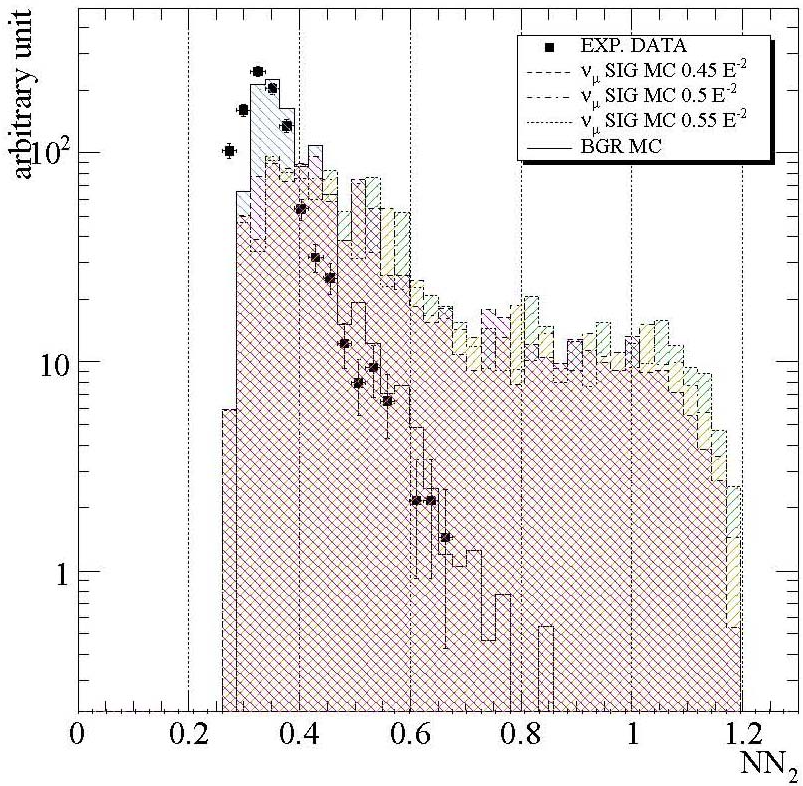


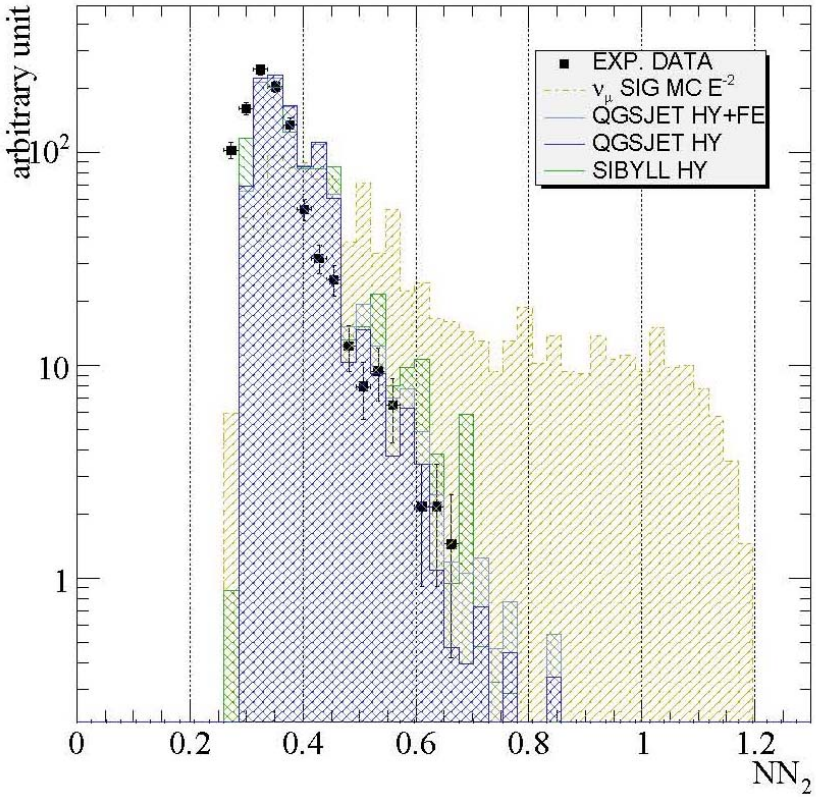




- The σ^{opti}_{TOT} for SIG extends above ~ 400 ns.
- N2-laser studies show that SIG is tested for 0.5 factor (~ 250 ns) and for a factor 0.6 at $\sigma^{opti}_{TOT} > 400$ ns.
- This indicates that a value of 0.5 for SIG may be conservative

Systematic Uncertainty Study



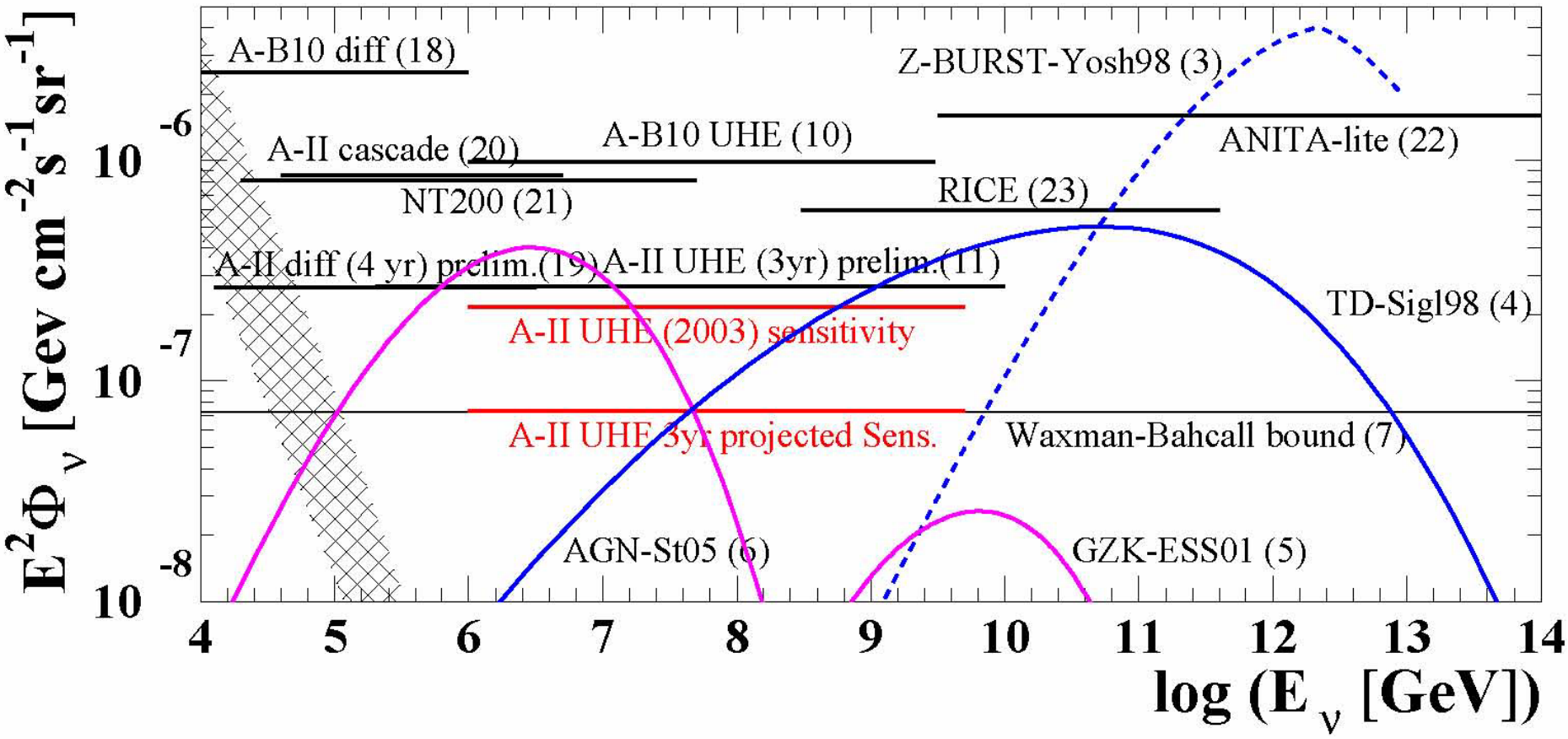


- SIG: N2-laser calibration and variation in width correction ~ 10%
- BGR: Physics input and variation in width correction ~ 150%

Systematic Uncertainty Study

- SIG: N2-laser calibration and variation in width correction ~ 10%, small compared to 39% for other effects.
  - We already included 39% of SIG systematic uncertainties which largely incorporates any possible systematic effects from the width correction.
  - SIG shows a very flat distribution which minimally gets impacted by width correction variation
  - Variations on width corrections for signal scale linearly with variations on signal sensitivity.
- BGR: Physics input and variation in width correction ~ 150%
  - Estimated by computing the number of expected events above the cut on NN2> 0.78 by varying three physics models and three factors (0.45, 0.5, 0.55).
- Sensitivity 2.18 x 10^{-7} GeV cm^{-2} $s^{-1}sr^{-1}$, an increase of ~ 23% w.r.t. the sensitivity without systematic uncertainties 1.77 x 10^{-7} GeV cm^{-2} $s^{-1}sr^{-1}$

Results

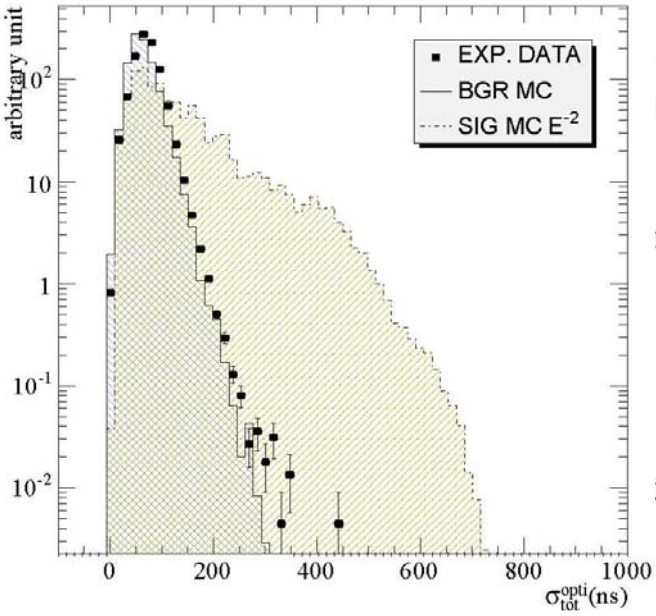


$E^{-2}\Phi_\nu < 2.18 \times 10^{-7}$ GeV cm^{-2} s^{-1}sr^{-1}

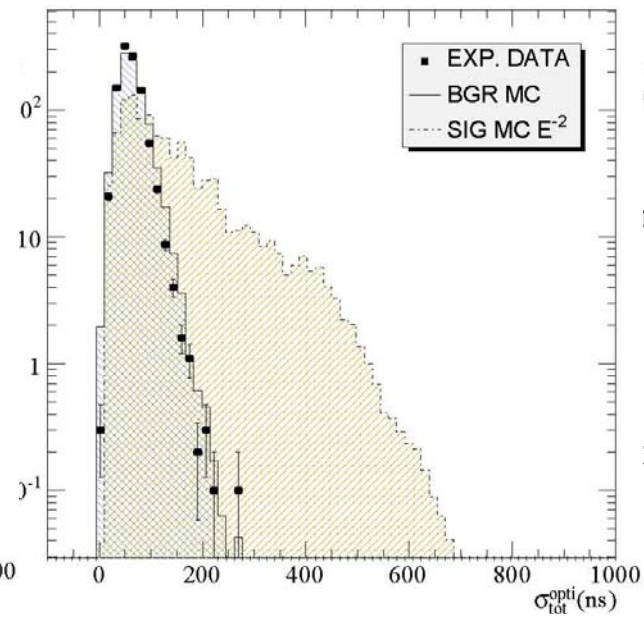
for 10^{15} eV < E_ν < $10^{18.7}$ eV at 90% C.L.

Three Year TWR Data: 2003 – 2004 - 2005

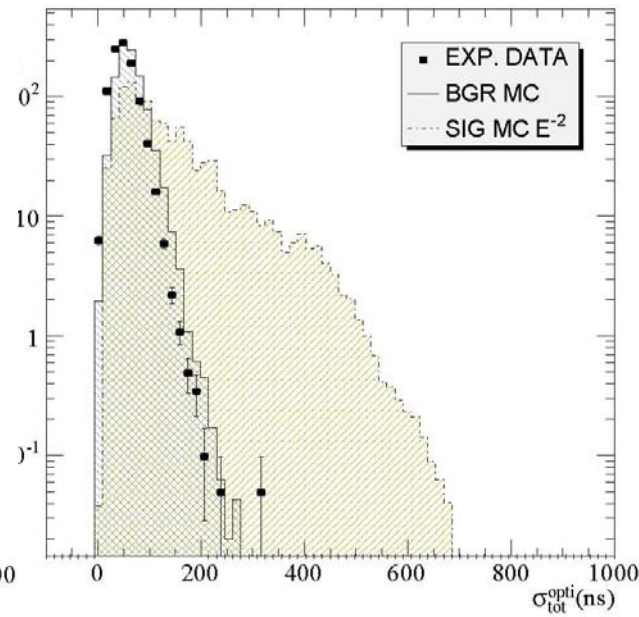
2003



2004



2005



- Same detector stability is observed in data collected in 2004 and in 2005, which suggests comparable results as in data 2003.