# skdetsim for sk-1 LE mode

17/12/2007

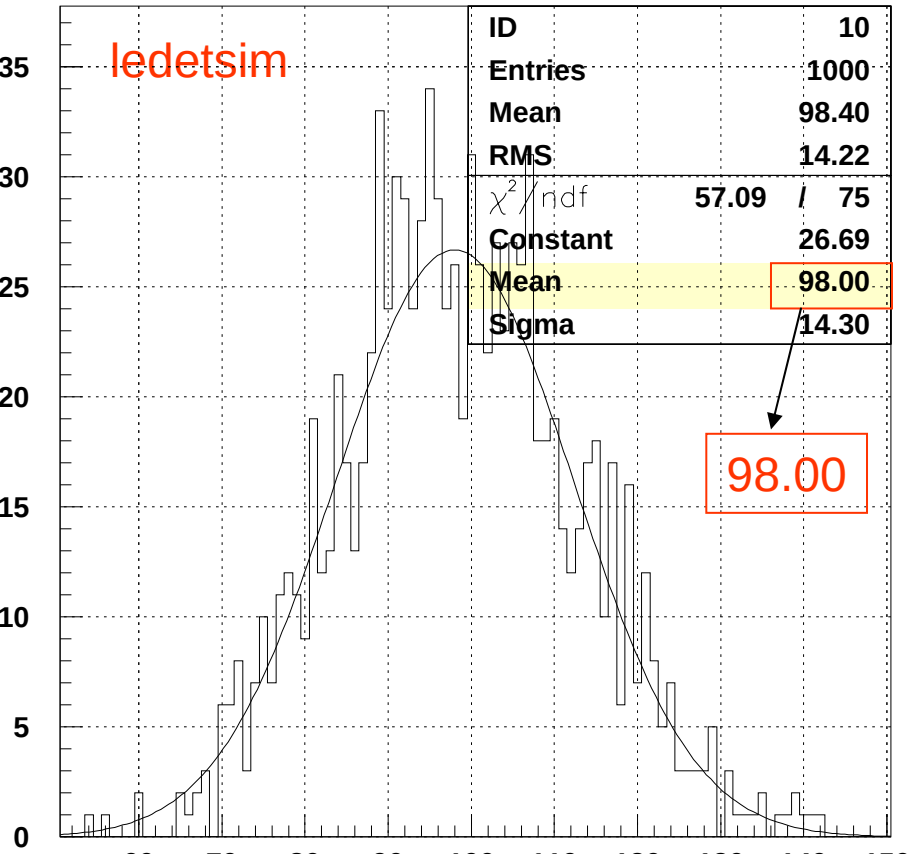
Report to skdetsim working group

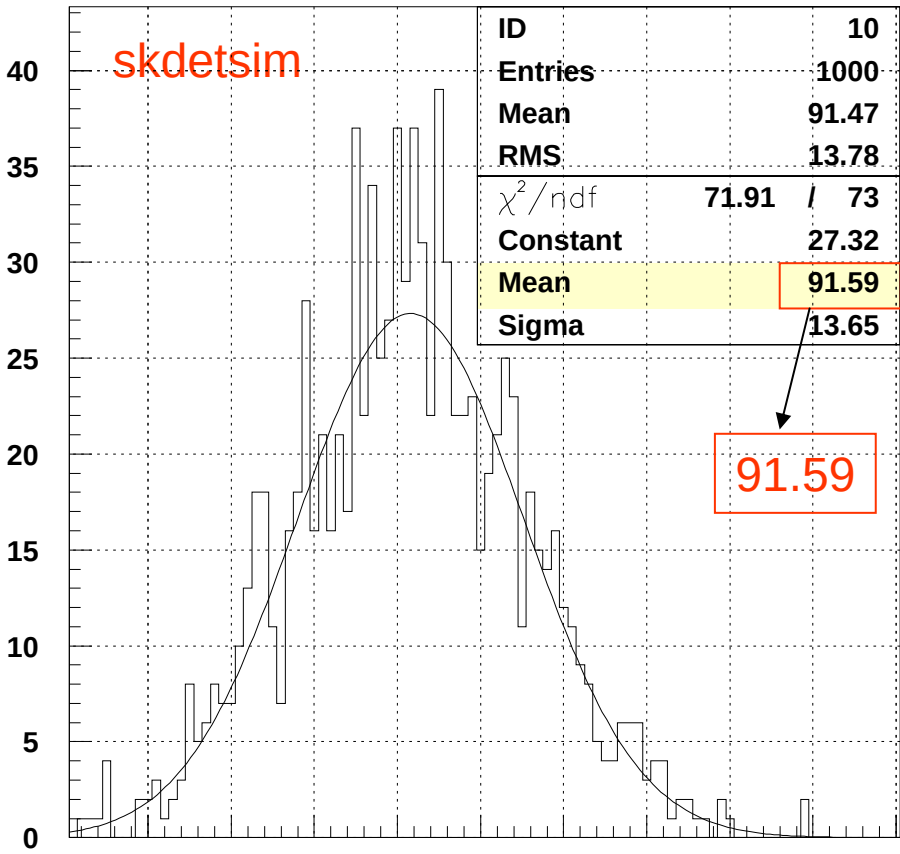
Y.Koshio

# ledetsim vs skdetsim sk-1 LE mode

- Iida-san found several % differences of energy scale between them, even though the input kinematics is same.

Number of photons arriving at PMTs for 10MeV electron (done by sukop)



# The list of differences

- Check step by step, and the differences is as follows;

A
- When the new tuned parameters are applied after SK-II LE mode, but the branch is not perfect.
  - sgbst.F (-2%), wtrsg.F (+1%), rfbssg.F (-2%)
- Only apdetsim versions are applied into skdetsim.
  - skdonuts.F and sgpmt.F (+3%)
  - pmtqesg.F (+10%)
- The PMT band stainless reflection is set to 5% in ledetsim, but in skdetsim is only absorption. (less than 1%)

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The followings are the bug fixed or merged to atmpd after skdetsim.

B
- de/dx for electron was modified by atmpd.
- When the photon arrived at PMT in top/bottom, the tracking was forced to stop by 0.01% probability.
- The maximum step size becomes small.
- The declaration in sgmies.F has minor bug. (integer vs real)
- When a particle arrive at the missing PMT position, it is forced to stop.

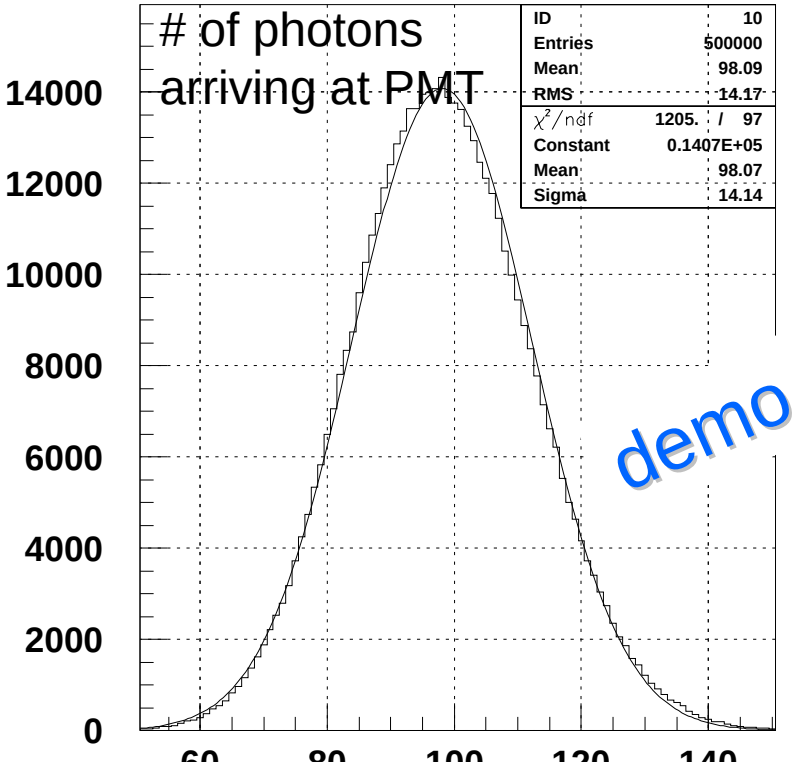
The results of both became exactly same.

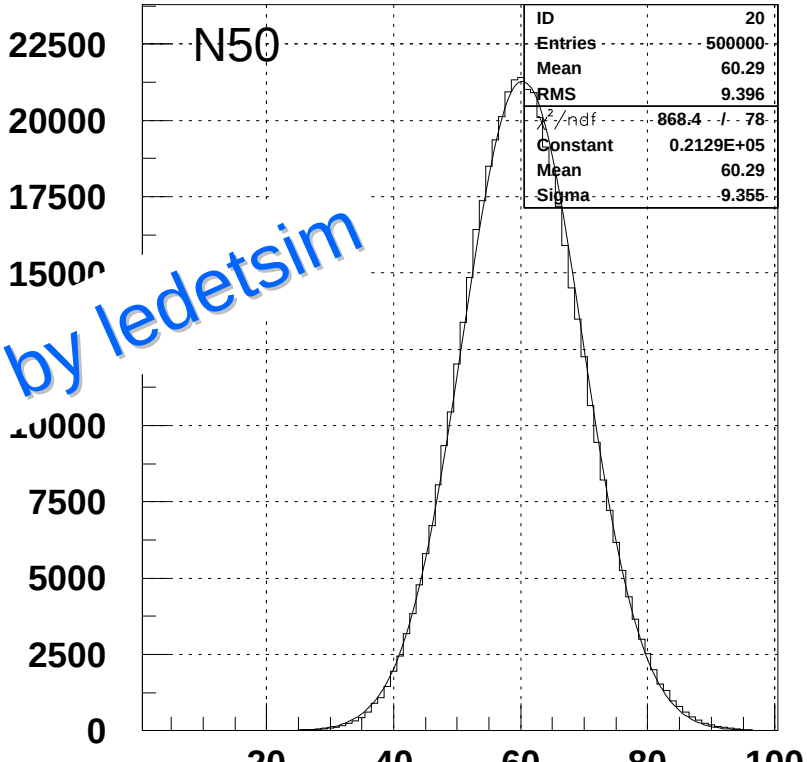
# How to do?

- The category ‘A’ must be returned to the original ledetsim.
- After modify the category ‘A’, the difference becomes about 1% level.
- In the category ‘B’, need to check more precisely.
  - The check items are ‘num. of photons arriving at the surface of PMTs’ and ‘N50’.
  - Note that the energy scale systematic error in SK-1 lowe analysis is ±0.5%.

# More detailed check for categ. B

- The MC statistics were poor, so you could not see the effect less than 1%.
- 500,000 events are generated. (10MeV e)



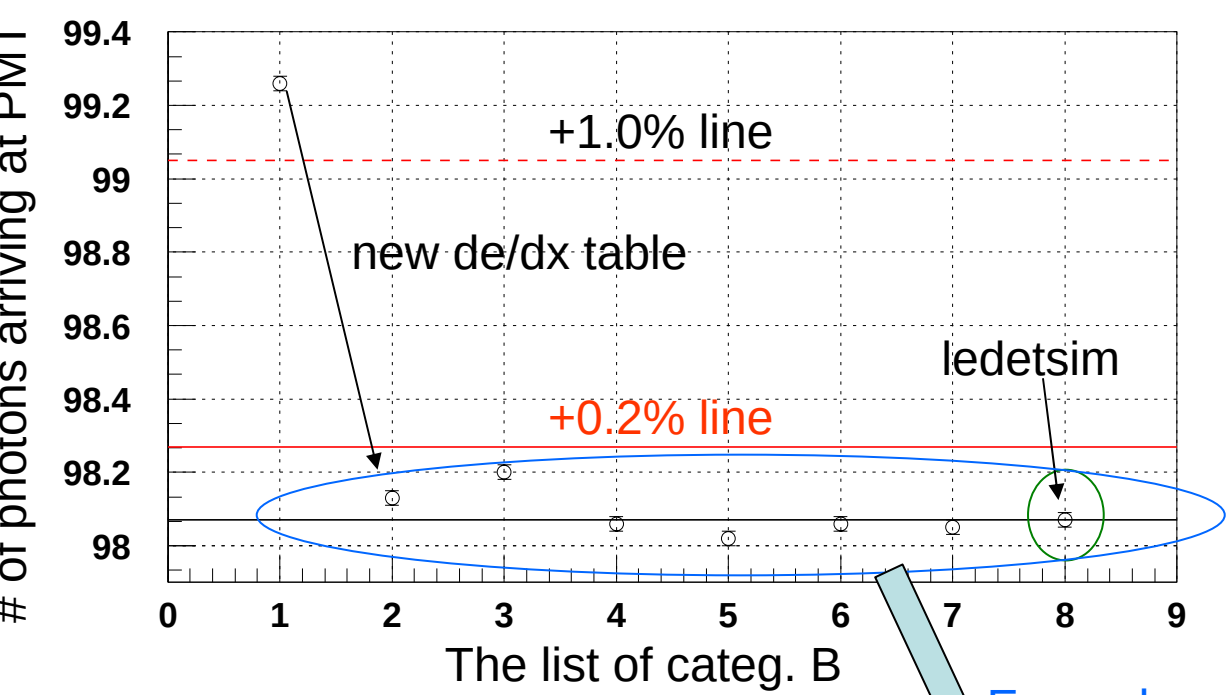




demo. by ledetsim

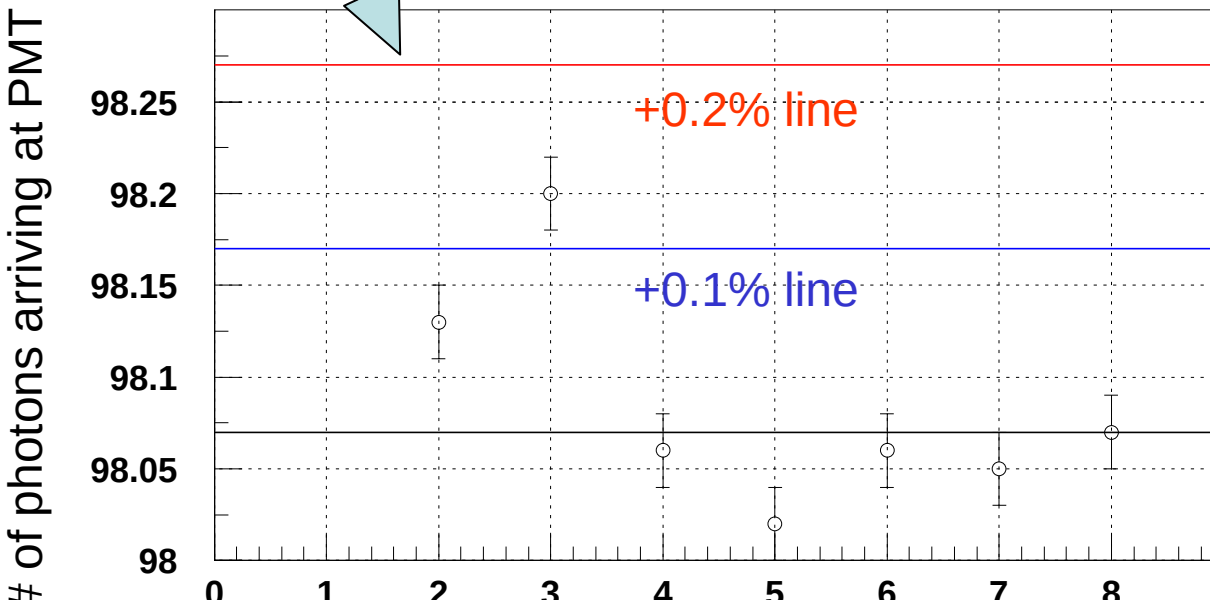
# The list of categ. B

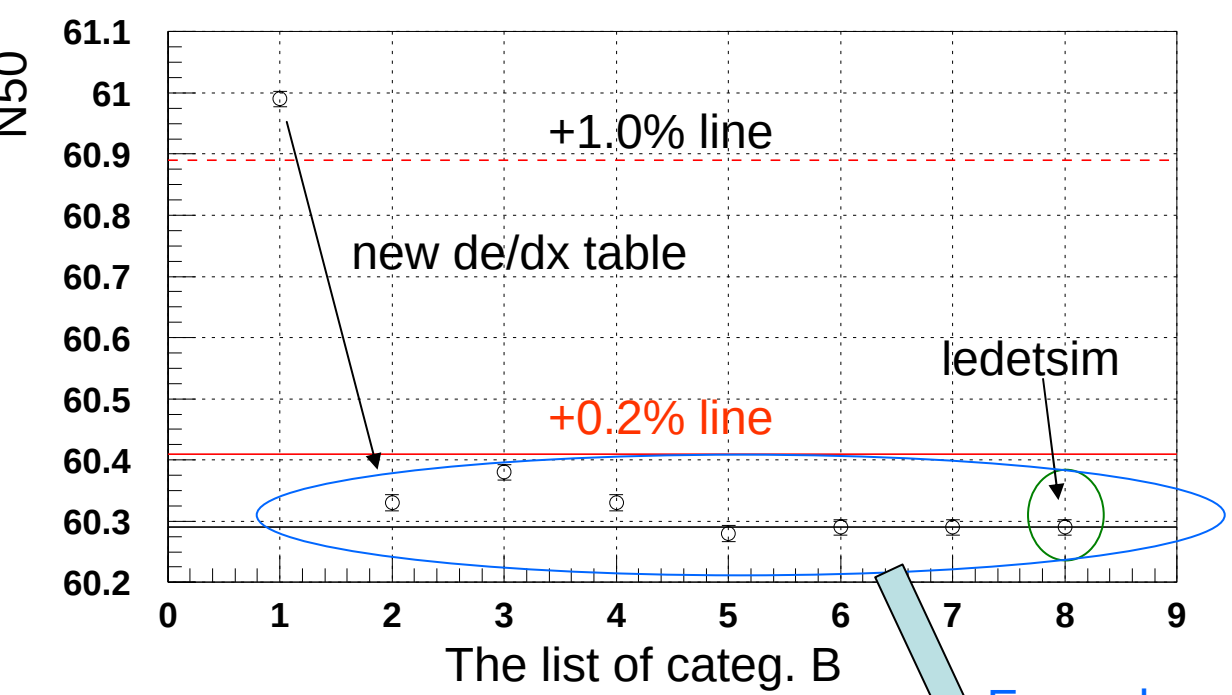
## (modify to skdetsim from ledetsim)

1. Just after categ. A
2. de/dx for electron was modified by atmpd.
3. When the photon arrived at PMT in top/bottom, the tracking was forced to stop by 0.01% probability.
4. The maximum step size becomes small.
5. The declaration in sgmies.F has minor bug. (integer vs real)
6. When a particle arrive at the missing PMT position, it is forced to stop.
7. When a photon arrive at the Tybek, its tracking forced to stop. (should not be, but very few photons arrive.)
8. The original ledetsim.

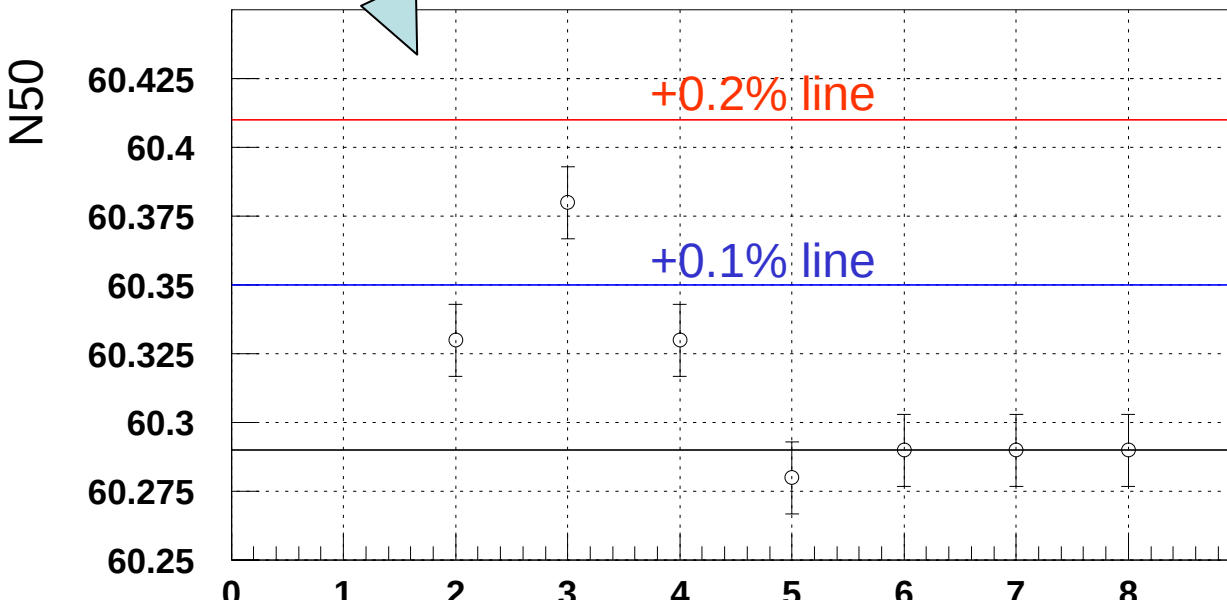

99.4
99.2
99
98.8
98.6
98.4
98.2
98
# of photons arriving at PMT
+1.0% line
new de/dx table
ledetsim
+0.2% line
0
1
2
3
4
5
6
7
8
9
The list of categ. B

Expand


98.25
98.2
98.15
98.1
98.05
98
# of photons arriving at PMT
+0.2% line
+0.1% line
0
1
2
3
4
5
6
7
8


N50
61.1
61
60.9
60.8
60.7
60.6
60.5
60.4
60.3
60.2
+1.0% line
new de/dx table
ledetsim
+0.2% line
0
1
2
3
4
5
6
7
8
9
The list of categ. B

Expand


N50
60.425
60.4
60.375
60.35
60.325
60.3
60.275
60.25
+0.2% line
+0.1% line
0
1
2
3
4
5
6
7
8

# How to do?

- The category ‘A’ must be returned to the original ledetsim.
- After modify the category ‘A’, the difference becomes about 1% level.
- In the category ‘B’, need to check more precisely.
  - The check items are ‘num. of photons arriving at the surface of PMTs’ and ‘N50’.
  - Note that the energy scale systematic error in SK-1 lowe analysis is ±0.5%.
- Return only original de/dx for category ‘B’

# Summary

- For the official version of skdetsim for sk-1 LE mode, the category ‘A’ and de/dx is returned to the original ledetsim code.
- The version number will be 4.72. (the current version is 3.72. The new tag name will be ‘skdetsim-v4p72’.)

# Supplement

- Comparison of solaris and Linux
- de/dx study by Itow-san in 2001

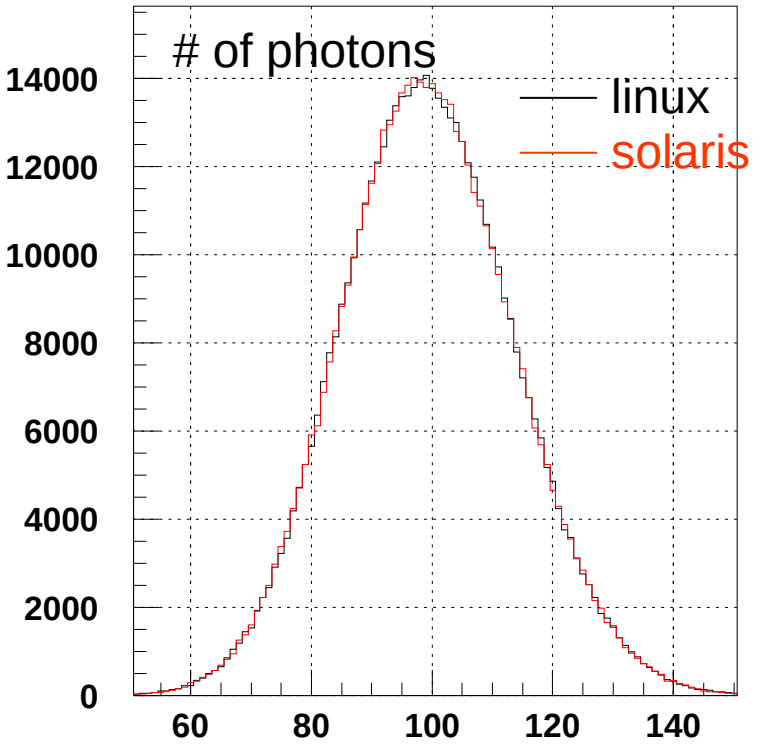
# The differences between solaris and Linux

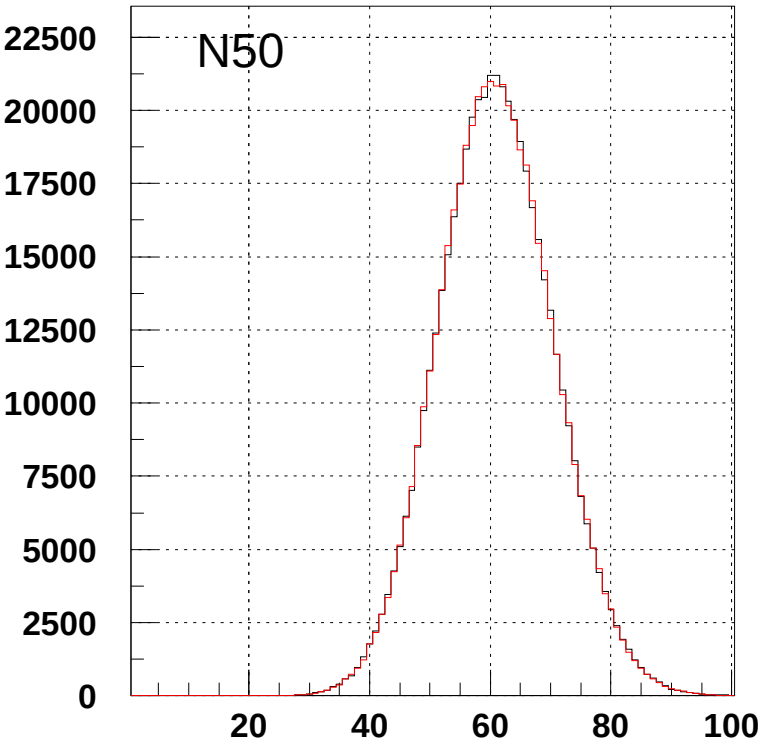
- Results in categ. A

| | # of photons | N50 |
|---|---|---|
| – Linux | 99.26(0.02) | 60.99(0.013) |
| – Solaris | 99.24(0.02) | 60.99(0.013) |

Very good agreement

- Speed (10MeV electron, 500,000events)
  - Linux 0.083 sec/event
  - Solaris 0.156 sec/event



# Improved density correction in GEANT dE/dx routines

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For SK collaboration meeting @Hawaii, 15,OCT,2001

# dE/dx formula

Bethe-Broch Formula

$$\frac{1}{\rho}\left(\frac{dE}{dx}\right) = D\frac{ZZ_{inc}^2}{A\beta^2}\left[\ln\left(\frac{T_{max}}{I}\right) - \beta^2 - \frac{\delta}{2} - \frac{C_e}{Z}\right] \quad \rightarrow \text{ p,μ, etc}$$

Berger-Seltzer Formula

$$\frac{dE}{dx} = \frac{2\pi r_0^2 mn}{\beta^2}\left[\ln\frac{2(\tau+2)}{(I/m)^2} + F^{\pm}(\tau,\Delta) - \delta\right] \quad \rightarrow \text{ } e^+,e^-$$

| | |
|---|---|
| $\tau$ | $\gamma - 1$ |
| $\tau_c$ | $\frac{DCUTE}{m}$ |
| DCUTE | energy cut for $e^\pm$ |
| $\tau_{max}$ | maximum possible energy transfer in e⁻ mass: $\tau$ for $e^+$, $\tau/2$ for $e^-$ |
| $\Delta$ | $\min(\tau_c, \tau_{max})$ |
| $n$ | electron density of the medium |
| $I$ | average mean ionisation energy |
| $\delta$ | density effect correction. |

$$F^+(\tau,\Delta) = \ln(\tau\Delta)^+ - \frac{\Delta^2}{\tau}\left[\tau + 2\Delta - \frac{3\Delta^2 y}{2} - \left(\Delta - \frac{\Delta^2}{3}\right)y^2 - \left(\frac{\Delta^2}{2} - \tau\frac{\Delta^2}{3} + \frac{\Delta^4}{4}\right)y^3\right]$$

$$F^-(\tau,\Delta) = -1 - \beta^2 + \ln[(\tau-\Delta)\Delta] + \frac{\tau}{\tau-\Delta} + \frac{\left[\frac{\Delta^2}{2} + (2\tau+1)\ln\left(1-\frac{\Delta}{\tau}\right)\right]}{\gamma^2},$$

where $y = 1/(\gamma+1)$.

# Density correction

$$\delta = \begin{cases} 0 & \text{if } X < X_0 \\ 4.606X + C + a(X_1 - X)^m & \text{if } X_0 \le X < X_1 \\ 4.606X + C & \text{if } X \ge X_1 \end{cases}$$

$X = \log_{10}(\gamma\beta) = \ln(\gamma^2\beta^2)/4.606$

$N_{el} = \dfrac{\rho Z N_{Av}}{A}$ electrons $cm^{-3}$

$a = \dfrac{4.606(X_a - X_0)}{(X_1 - X_0)^m}$

$\nu_p = \sqrt{\dfrac{N_{el}e^2}{\pi m}}$ $s^{-1}$ plasma frequency

$C = -2\ln\left(\dfrac{I}{h\nu_p}\right) - 1$

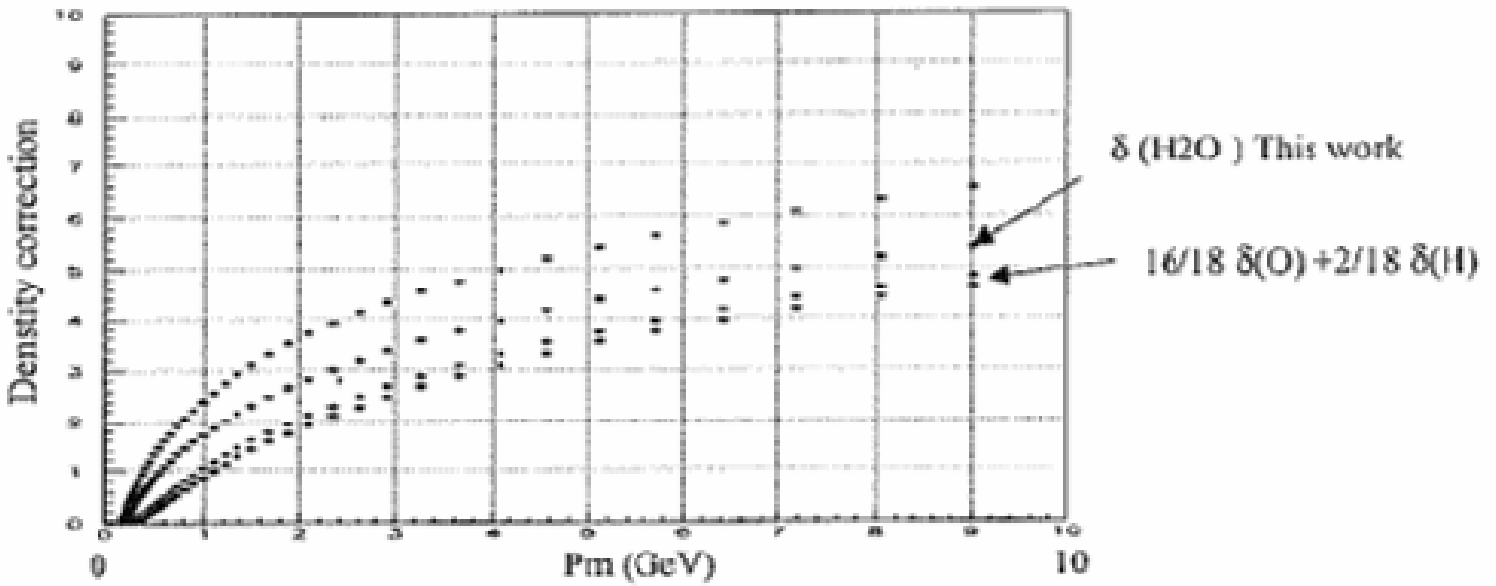
$4.606\,X_a = -C$

Existing data is fitted by Sternheimer et al.
Phys Rev 824 (6288) 1981

$$\frac{16}{18}\,(dE/dx)_O + \frac{2}{18}(dE/dx)_H \neq (dE/dx)_{H2O}$$

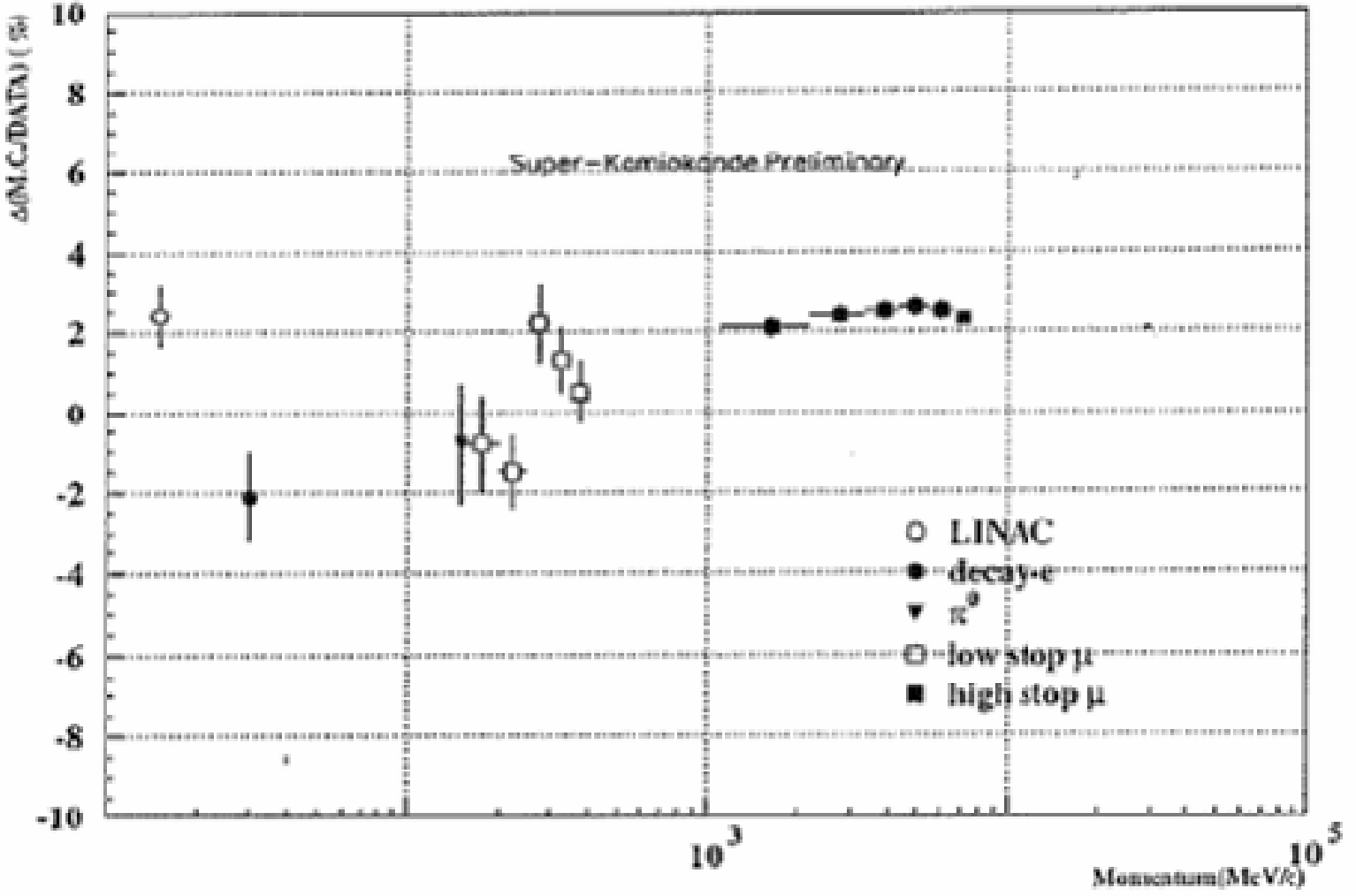
# Parameters

| | Sternheimer | GEANT | |
|---|---|---|---|
| | liquid water | H | O |
| Ionization potential (eV) | 75.0 | 18.8 | 97.7 |
| C | 3.502 | 2.345 | 4.255 |
| X0 | 0.240 | 0.2 | 0.3871 |
| X1 | 2.5 | 2.0 | 2.0 |
| a | 0.2065 | 0.5091 | 0.9238 |
| m | 3.007 | 3. | 3. |



# Energy scale calibration

(1144days)



# Summary

- Correct treatment of density effect for dE/dx in liquid water is installed in APDETSIM based on Sternheimer's work.
- dE/dx decreases by 3% for μ (>300MeV/c), 1% for e (a few- a few ten's MeV).
- New dE/dx for e-,e+ is identical to EGS code.
- Numbers of photoelectrons increase by 2% for μ, by 0.5% for e in GeV region.
- New momentum calculation tables (ASMO70) are ready ( including effect from other modifications)