



Muon fitter II

neutrino.lbl.gov/~snoman/currat/talks/

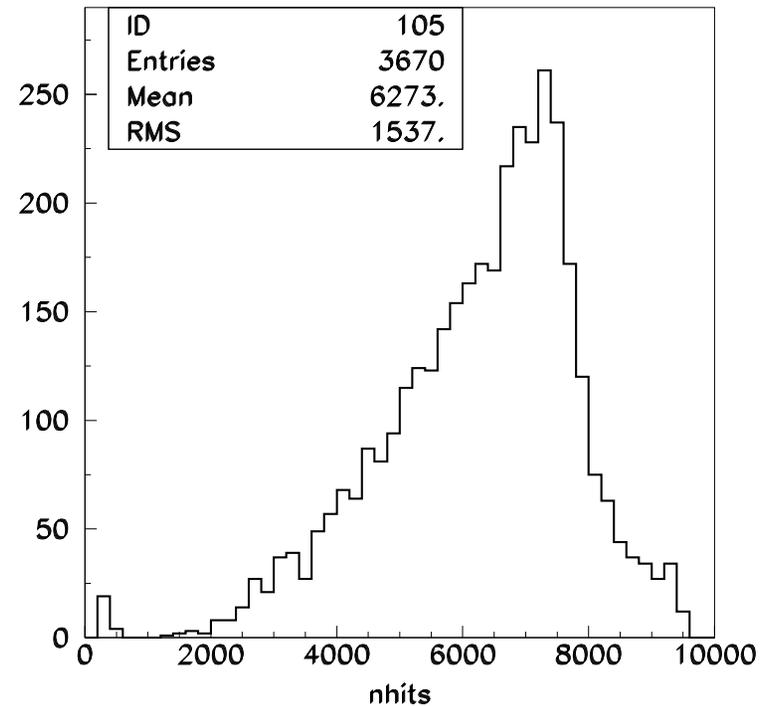
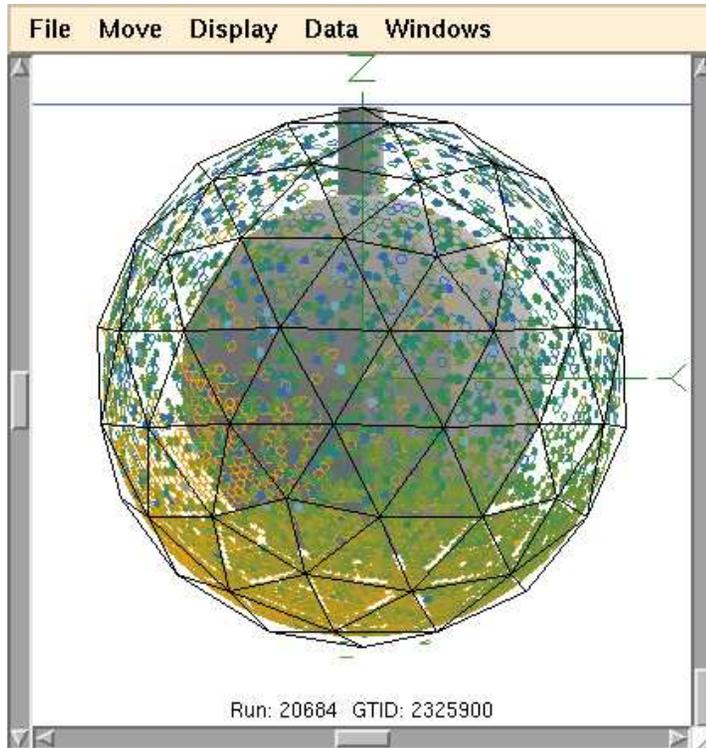
Charles Currat
LBNL

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SNO coll. meeting, LBNL

- ❖ Update on muons generation in Snoman
- ❖ Reviving 2001 through-going muon analysis
- ❖ Perspectives

Muon events

Unlike a neutrino event, a muon event is on average highly busy...



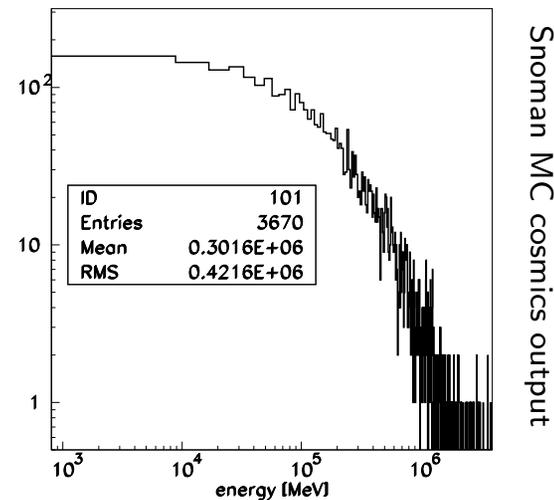
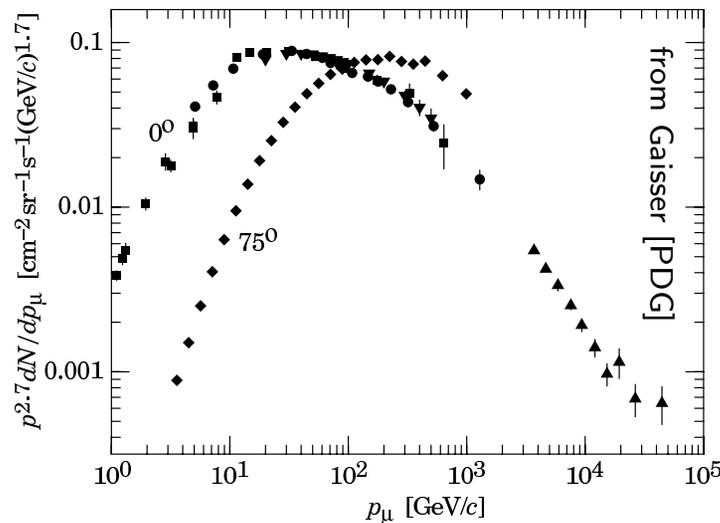
👉 Special care needed: mostly through-going, high energy but unavailable in the detector, the same code must be able to handle them

Muon code

Level of description of muon simulation in Snoman has fairly increased in 2 years:

- ❖ Bremsstrahlung, Moller scattering (knock-on electrons), decay vs muon capture, pair generation, LEPTO for DIS in photo-nuclear interactions, neutron production [J. Formaggio]
- ❖ Code became usable: good number of bugs recently fixed that prevented the generation of any muon without saturating the data structure (“store full” errors) [C.C.]
- ❖ Timing issue in the fitter [T. Tsui]

Now generation of muons over full range of cosmic energy spectrum is possible



👉 Nice achievement to accomodate **TeV-muons** and/**down-to thermal neutrons** in the same code, about 14 orders of magnitude difference...!!

The muon fitter

Presently used “as is”, developed by N. Tagg (2001). 5 independent pars that specify a μ track: time t_f it left PSUP, exit point on PSUP (θ, ϕ) , direction (η, ψ)

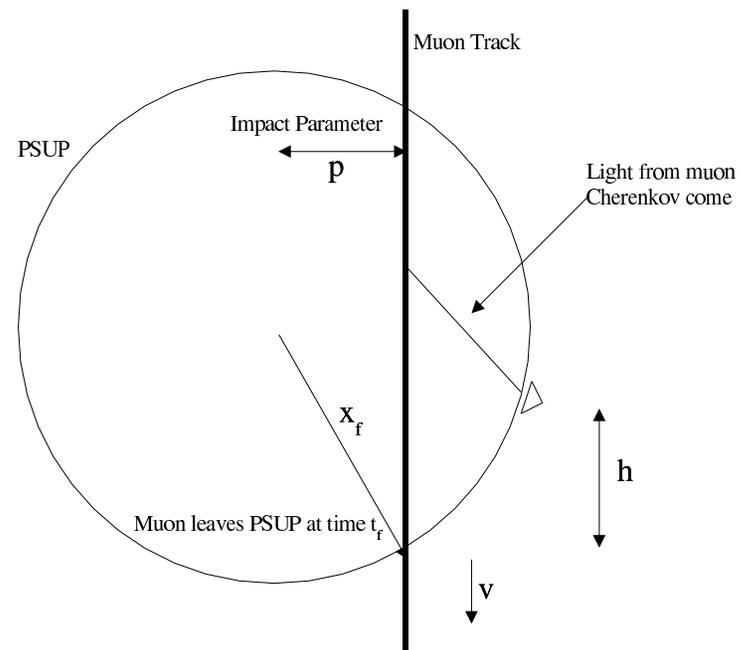
👉 (1) cull down list of “good” tubes to ~ 1000 / (2) educated guess of exit wound / (3) use of PMTs timing to find direction

- ❖ high charge \sim accurate time, cut on low-charge tubes on an evt/evt basis $q_i \geq 1.2 \times \langle q \rangle_{evt}$
- ❖ initial pars: guess for exit vertex by charge-weighted cluster, time given by last (uncut) tube to fire
- ❖ search for direction and exit position on a grid \Rightarrow minimization for t_f

- ❖ for best χ^2 scenario, full minimization $(\theta, \phi, \eta, \psi, t_f)$, throw out tube with worst χ^2 contribution, iterate

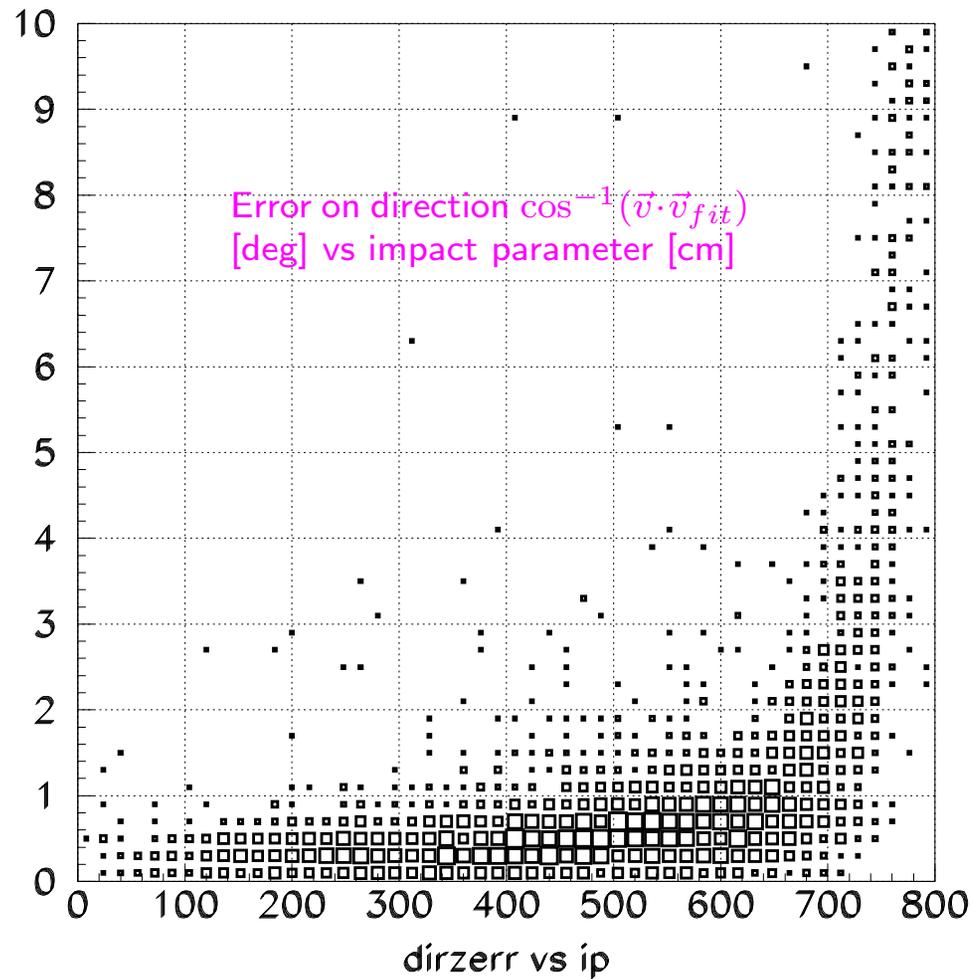
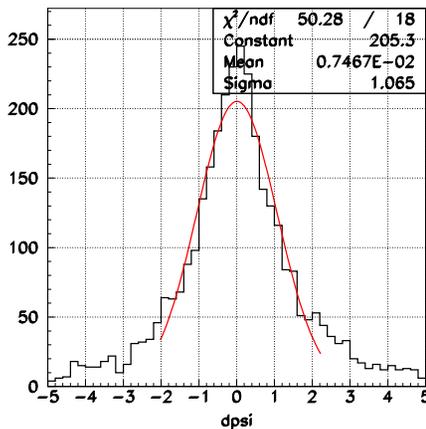
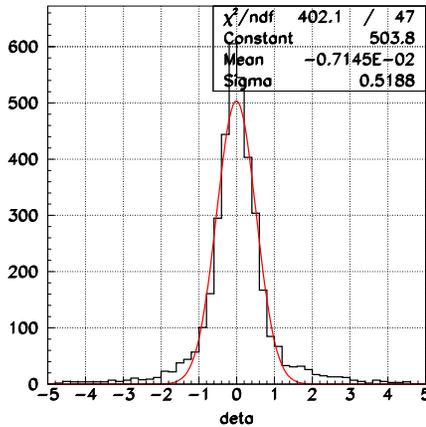
$$\chi^2 = \sum_i \frac{(t_i - t_i^{fit})^2}{(\sigma_t^{PMT})^2}$$

with $\sigma_t^{PMT} = 1.6$ ns and $t_i^{fit} = t_f + \frac{1}{c}d(x_i^{PMT}, \theta_C)$ assuming direct Cherenkov light. Late tubes thrown out, $|t - t^{fit}| < 10$ ns



Fitted **direction** after full minimization (FTM core)

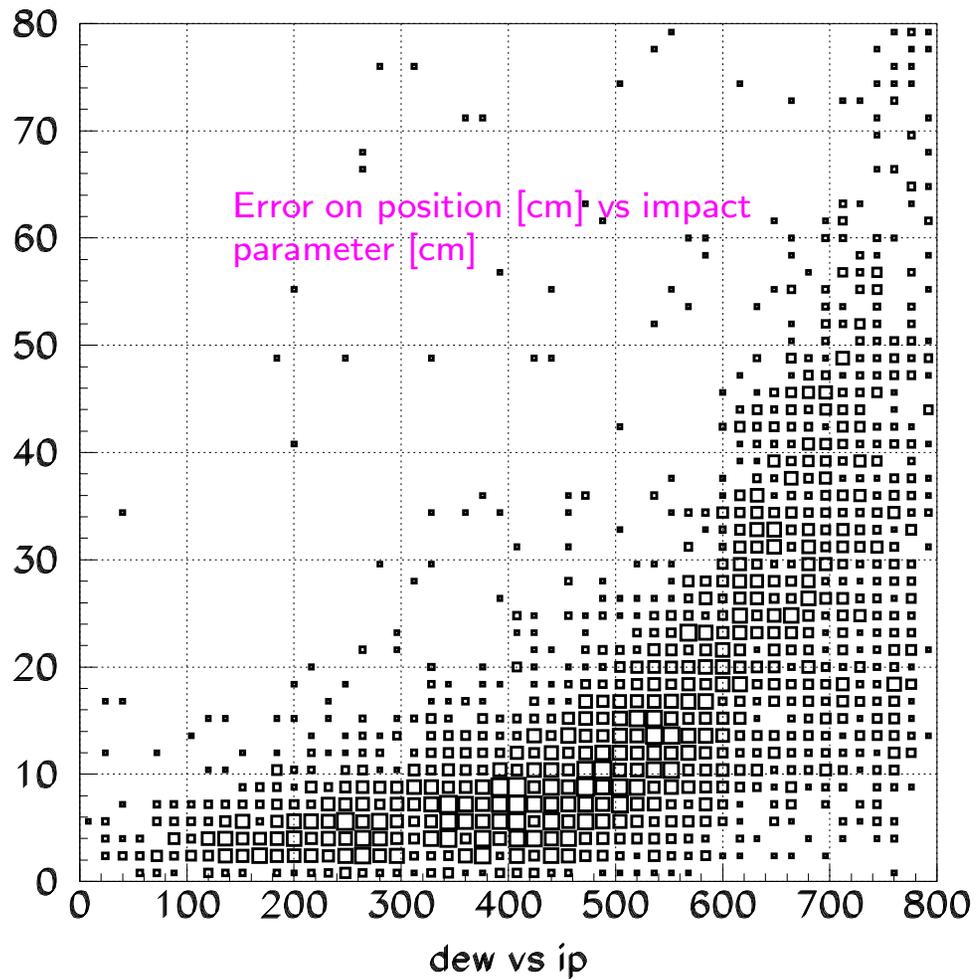
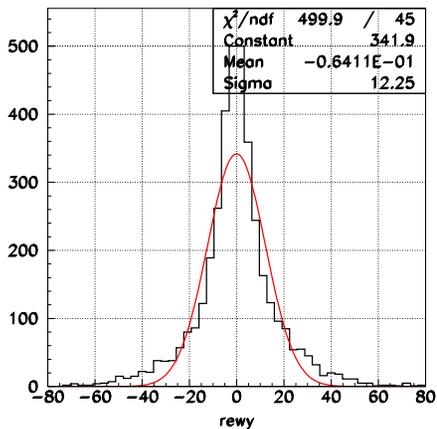
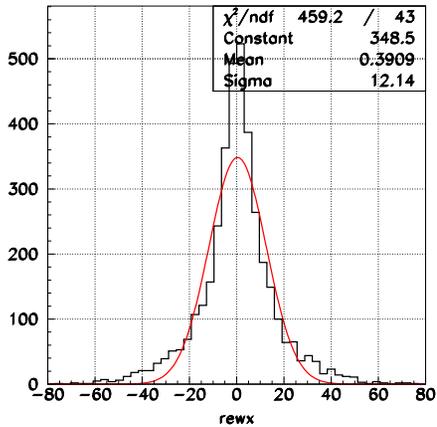
$$(\eta - \eta_{fit}, \psi - \psi_{fit})$$



👉 Error on direction seems to usually be less than 1° up to the AV (good!)

Fitted **exit wound** position after full minimization (FTM core)

$$(x - x_{fit}, y - y_{fit})$$



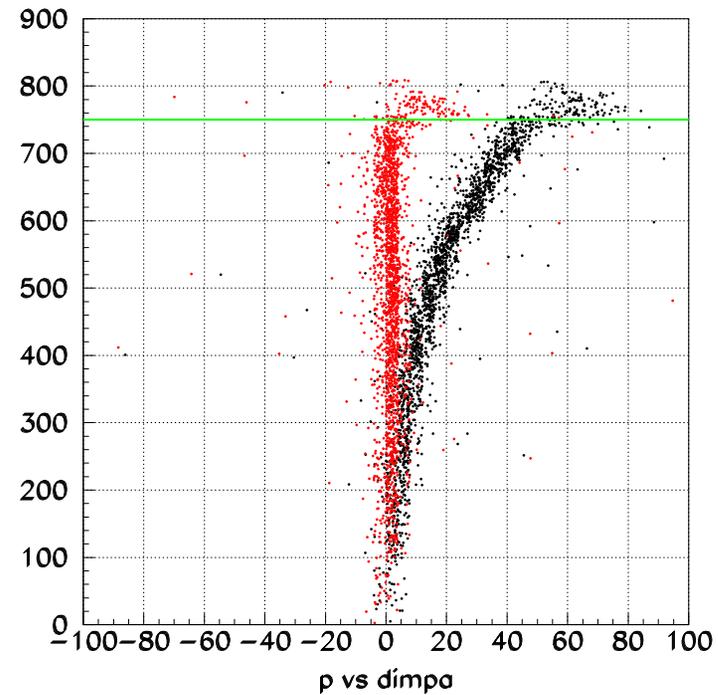
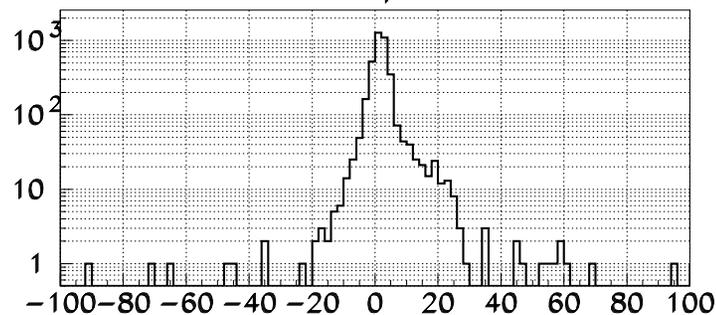
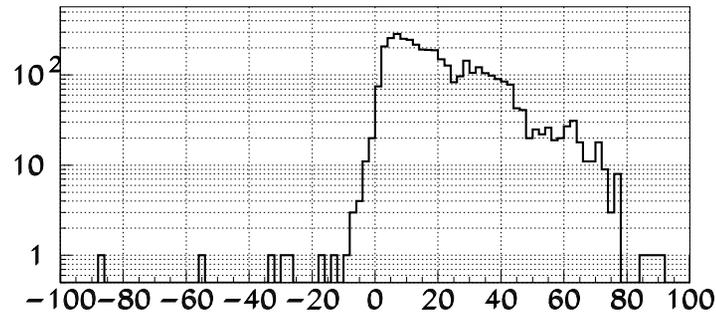
👉 Error on exit wound position, $\sigma_{ew} \simeq 12$ cm

Impact parameter

For clipping tracks, hits mostly on one side of the track \Rightarrow fitter tends to reconstruct at an early time.

Correction for the systematic outward pull is part of the fitter.

Abcissa is $p - p_{fit}$ [cm]



\Rightarrow Recommended to cut $p_{corr} < 750$ cm

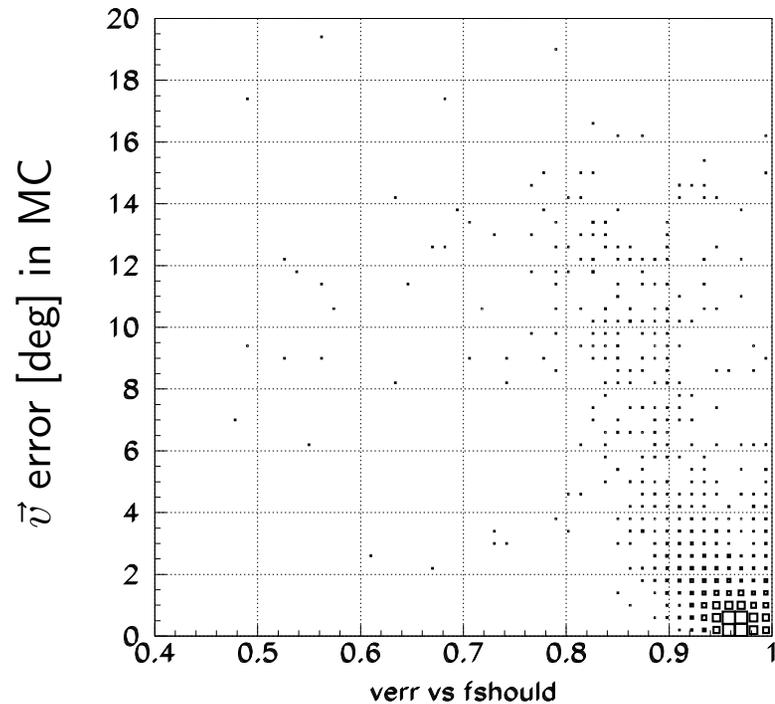
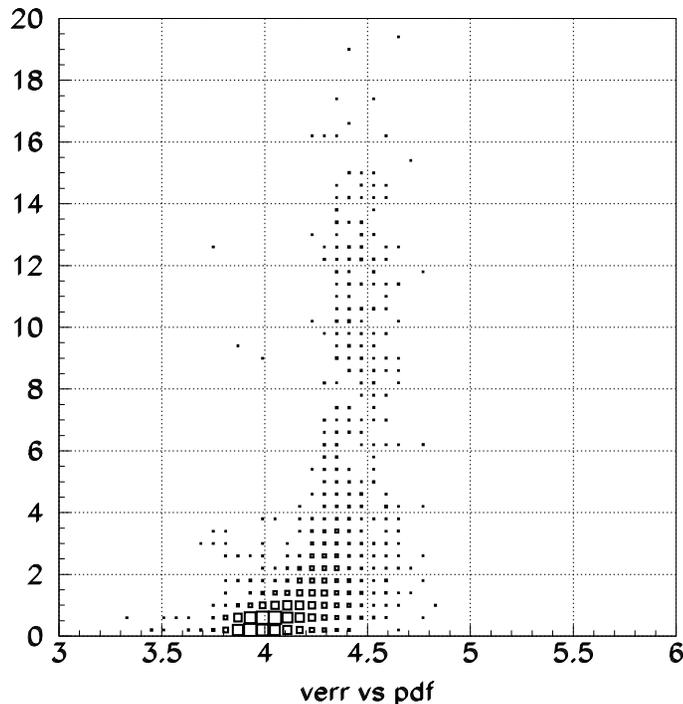


Goodness of fit 1/2

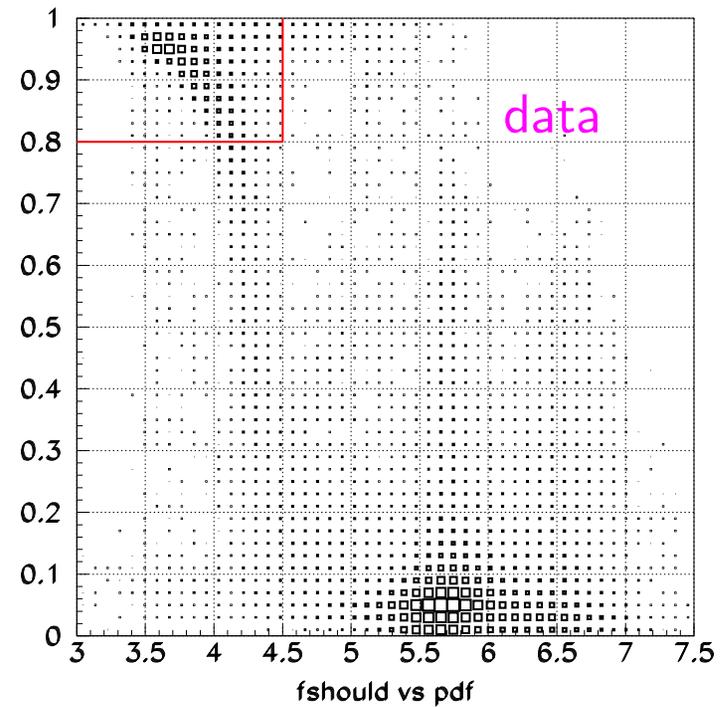
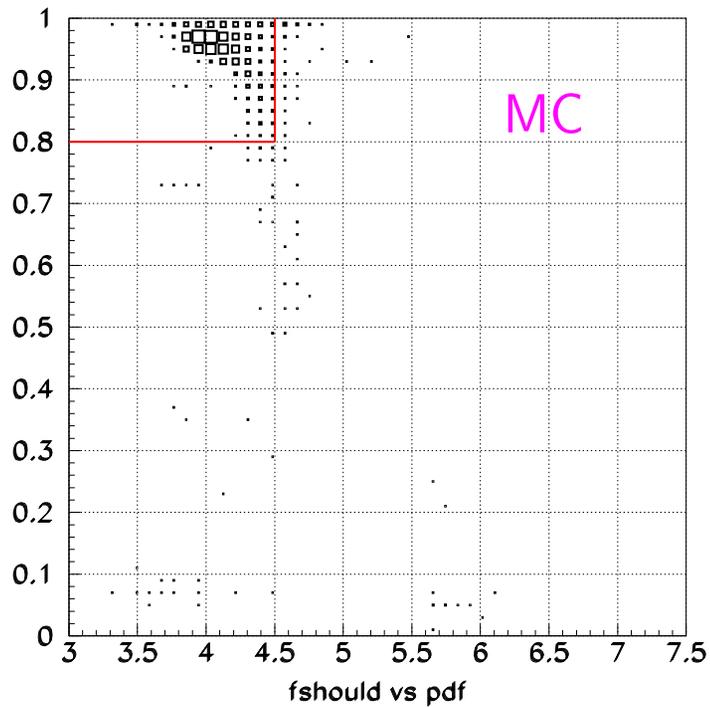


Two criteria used for evaluation [N. Tagg]:

- ❖ $0 < F_{should} < 1$, topology based. Check if live PMT pattern compatible with direct light from fitted muon track
- ❖ *PDF* parameter, probability that PMTs time residuals (sum over *all* tubes) is typical of a muon's



Biparametric view for MC and raw data (salt set I here, cf next slide)



👉 Recommendation is (red boxes):

- ◆ $F_{should} > 0.8$
- ◆ $-\log(pdf)/ndf < 4.5$



Data selection

First pass analysis to assess the fitter performance and cuts validity with salt data

Reminder: original analysis (N. Tagg) used 149 days of D2O data, runs 10000–12168 (Nov'99–Jun'00)

Largest problem in μ analysis is rejection of **instrumental backgrounds**

- ❖ flashers
- ❖ electronic pickup
- ❖ neck light
- ❖ high-voltage breakdown
- ❖ re-triggers
- ❖ tubes off, dead regions ↪ anisotropies
- ❖ orphan events

↪ detector operation working in 'neutrino' mode as opposed to 'supernova' mode.

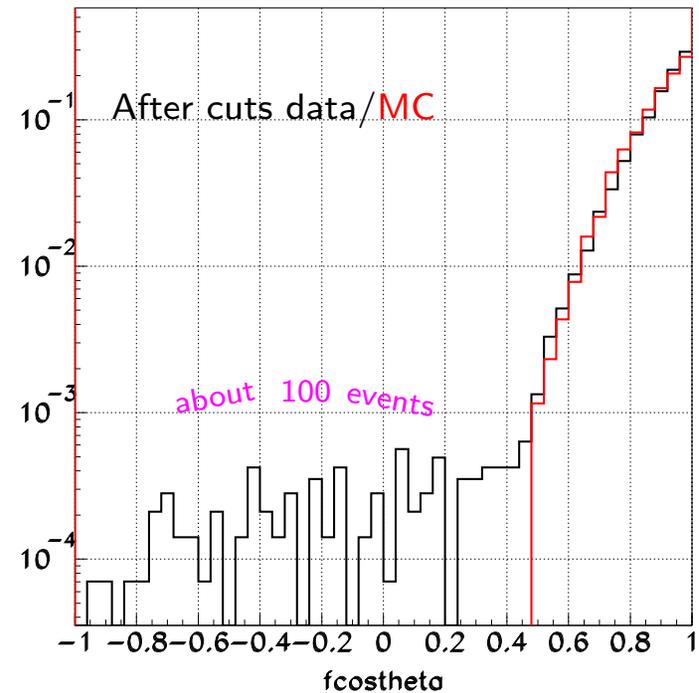
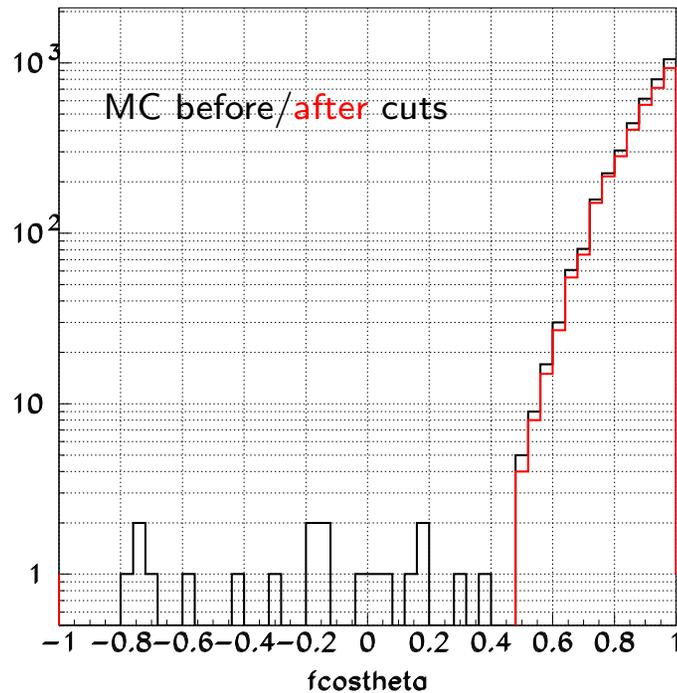
Cuts used in the 2001 analysis:

- ❖ $150 < N_{hit} < 10000$, basic energy cut
- ❖ retrigger cut (DAMN)
- ❖ junk cut (DAMN)
- ❖ Q/NHIT (DAMN)
- ❖ neck tube cut (DAMN)
- ❖ t_{RMS}

↪ reduction of raw data by 10^4

☞ Results shown here use **salt phase set I data**, 254 days, runs 20684–26997
Total data amounts $300+254+151=705$ days ↪ factor **4.7 times** more statistics than original analysis

Looking at the zenith angle distribution in data vs MC and assessing the cuts



👉 The cuts perform efficiently in MC for cosmics. Studies on up-going muons in progress.



- ❖ There's an active muon group again (workshop at UBC last month)
- ❖ The muon MC and the fitter are stable and operational!
- ❖ Original through-going muon analysis still holds

- ❖ More confidence needed in the cuts ↪ understanding “sacrifice”, “contamination”, goodness-of-fit
- ❖ Re-examine event selection ↪ instrumental backgrounds
- ❖ Look at up-going muons ↪ neutrino-induced muons and propagation in MC, NUANCE

- ❖ Generate more cosmics (1 year stats)