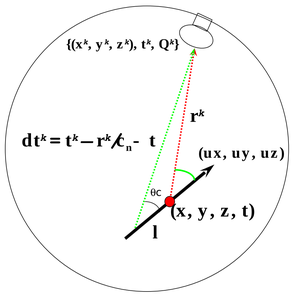
MiniBooNE Event Reconstruction and Particle Identification

Point- like light source model



- ***Cerenkov light - directional***

$$\mu_i^{cer} = \epsilon_i \phi_{cer} \exp\left(\frac{-r_i}{\lambda_{cer}}\right) \frac{f(\cos\eta)}{r_i^2} F(\cos\theta)$$

- ***Scintillation light - isotopic***

$$\mu_i^{sci} = \epsilon_i \phi_{sci} \exp\left(\frac{-r_i}{\lambda_{sci}}\right) \frac{f(\cos\eta)}{r_i^2}$$

- ***Predicted charge***

$$\mu_i = \mu_i^{cer} + \mu_i^{sci}$$

Input

An event consists of a set of charge, time, and spatial information for each PMT.

$\{(x^k, y^k, z^k), t^k, Q^k\}$; k = 1, 2, …, N PMT hit
$\{(x^l, y^l, z^l)\}$; l = 1, 2, …, N PMT nohit

↓

Reconstruction

↓

Output

Many primary and reconstructed variables:

- coordinate, time
- (direction)
- energy
- (track length)
- event topology

Charge Likelihood

The probability of measuring a charge q for a predicted charge μ

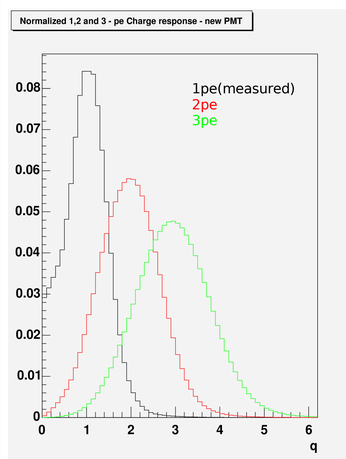
Three methods to extract the charge likelihood

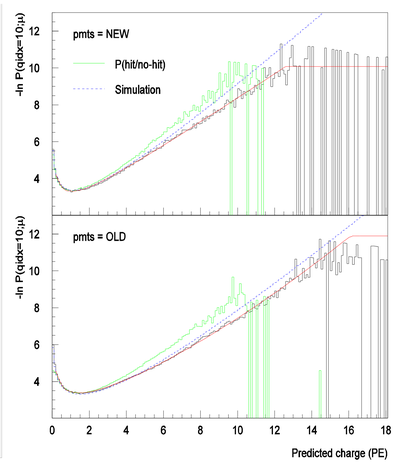
A.Fill 2-D histogram H(q,μ), normalize q distribution for each bin.

B. From hit/no-hit probability minimization procedure, get H(q, μ), then same as A.

C. Get 1-PE charge response from laser data.
Start from 1-PE charge response curve, generate P(q;n), assume Poisson distribution, calculate P(q;μ).

$$P(q;\mu) = \sum_{n=0}^{\infty} P(q;n) P(n;\mu) \qquad P(n;\mu) = \frac{\mu^n e^{-\mu}}{n!}$$



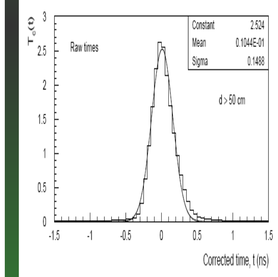


Time Likelihood

The probability of measuring a corrected time t_{corr} for a predicted charge μ and energy E of an event

1.Corrected time $t_{corr}^i = t_i - t_0 - \frac{r_i}{c_n}$

2. Cerenkov light $t_{corr}^{(i)}$ distribution



Gaussian
(t_0^{cer}, σ^{cer})

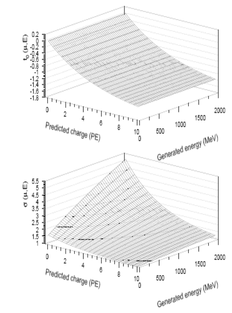
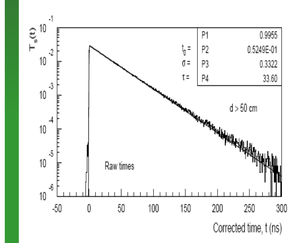


Fig. 13. Cherenkov timing parameters, $t_0(\mu_c, E)$ and $\sigma(\mu_c, E)$ – new PMTs.

3. Scintillation light $t_{corr}^{(i)}$ distribution



Exponential*Gaussian
(t_0^{sci}, σ^{sci}, τ^{sci})

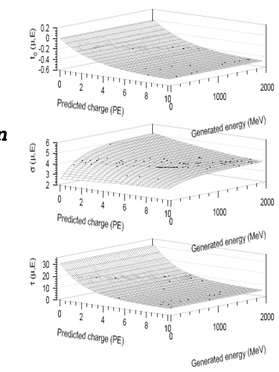
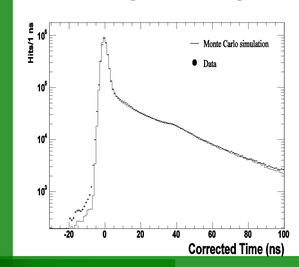


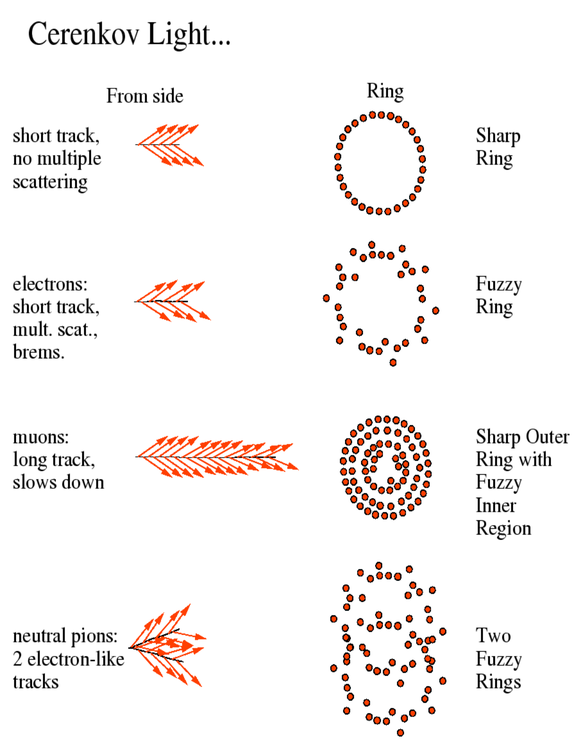
Fig. 14. Scintillation timing parameters, $t_0(E, \mu_s)$, $\sigma(E, \mu_s)$ and $\tau(E, \mu_s)$.

4. Putting them together

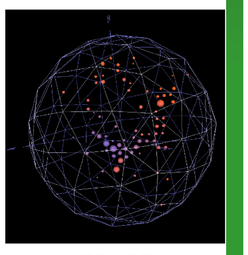


$$T(t_{corr}^{(i)}, E) = \frac{\mu_c}{\mu_c + \mu_s} T_{cer}(t_{corr}^{(i)}, \mu_c, E) + \frac{\mu_c}{\mu_c + \mu_s} T_{sci}(t_{corr}^{(i)}, \mu_s, E)$$

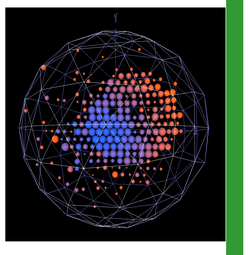
Event topologies



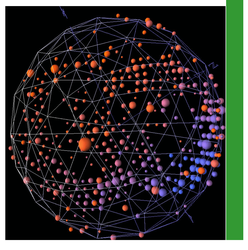
electron



muon



neutral pion



Particle Identification

ParticleID variables that we get after fitting the event under different hypotheses fitting:

- ***Variables in cosθ, t_{corr} and ring sharpness bins***
  - number of hits per PMT, measured/predicted charge, time/charge likelihood
- ***Reconstructed physical observables***
  - such as π^0 mass, energy, track length and Cerenkov/scintillation light flux, production angle
- ***Reconstructed geometry quantities***
  - Position, direction of the event
- ***Difference of likelihood between different hypotheses fitting***
  - electron/muon/π^0 fitting

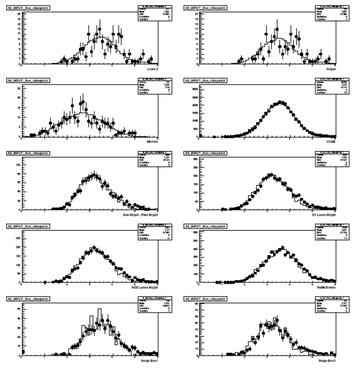
ParticleID variables selection:
reliability and efficiency

1. Variable distribution Data/MC agree

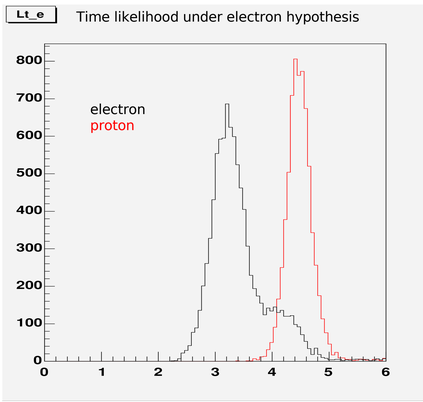
Check with open box, cosmic ray calibration and NuMI data/MC

2. The correlation between variables Data/MC agree

These two requirements ensure output Data/MC agree and so the reliability of ParticleID



3. The variable/combination powerful in separation



3 different algorithms are used for ParticleID

- ***Simple cuts***
- ***Artificial Network***
- ***Boosted decision trees***

Boosting is preferred in MiniBooNE to get better sensitivity but Simple Cuts method and ANN can provide cross check.