KSU Simulation Work, etc.

- Simulation tools
- Scintillator oil test setups
  - Simple setup to look at attenuation lengths, gain some experience.
  - Have secured 110 gal. of NuTeV oil, small sample of Gd-loaded oil.
  - Two students + technician+Noel Stanton involved.
- Wolf Creek
  - Have resumed contact after WC re-fueling operation (completed 12/9/03).
  - Attempting to negotiated "Excelon-type" type agreement.
  - Awaiting response from WCNOC.

Simulation work--general

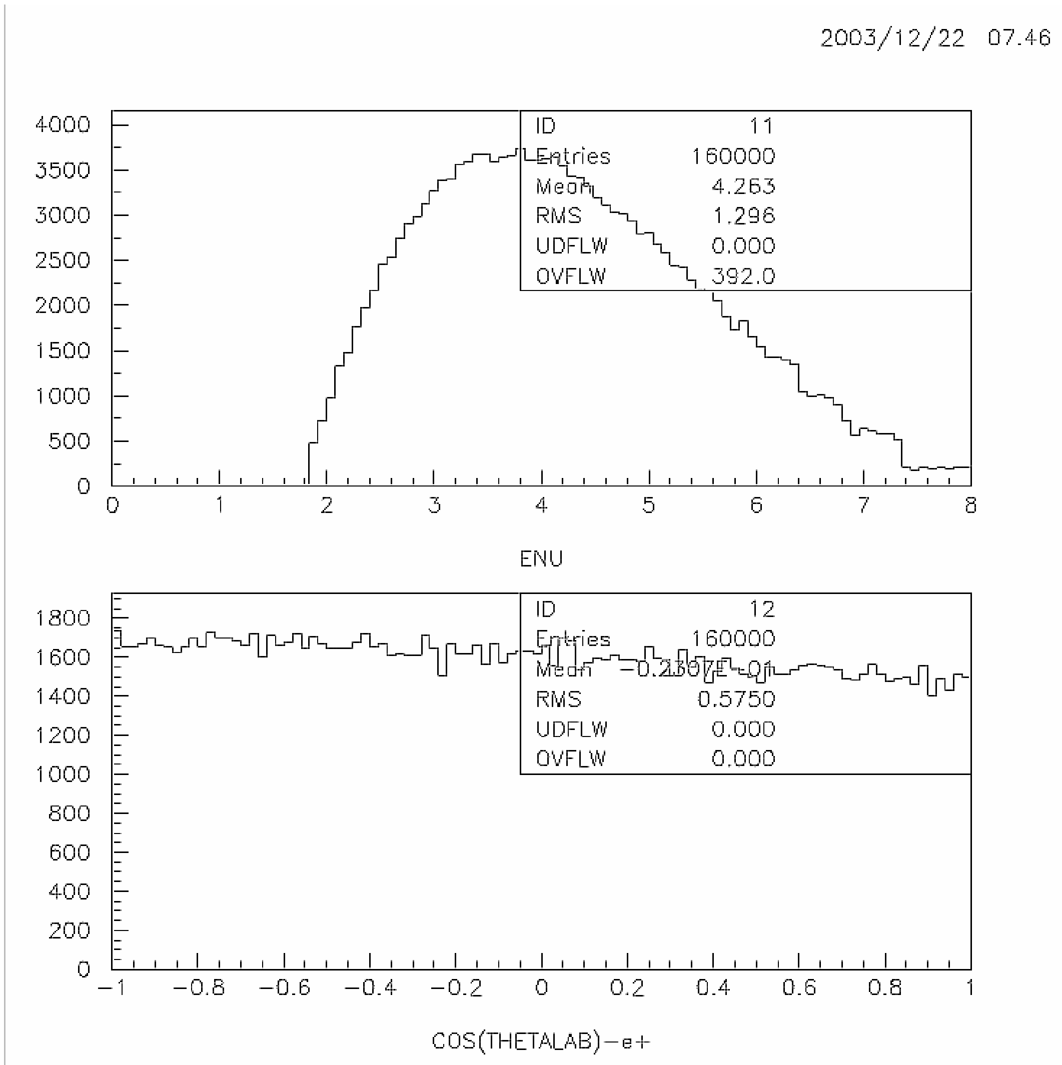
- Some progress in gathering tools (or gathering promises to gather tools):
  - Byron→ time dependent flux.
  - Josh→ PMT simulation from SNO.
  - Jon→ Neutron propagation.
- KSU work:
  - Simple Geant4 geometry.
  - Simple neutrino event generator set up.
  - Simple fast simulation.
- Need:
  - A better way to work together.
  - = a “managed” Fermilab host computer.

Geant simulation

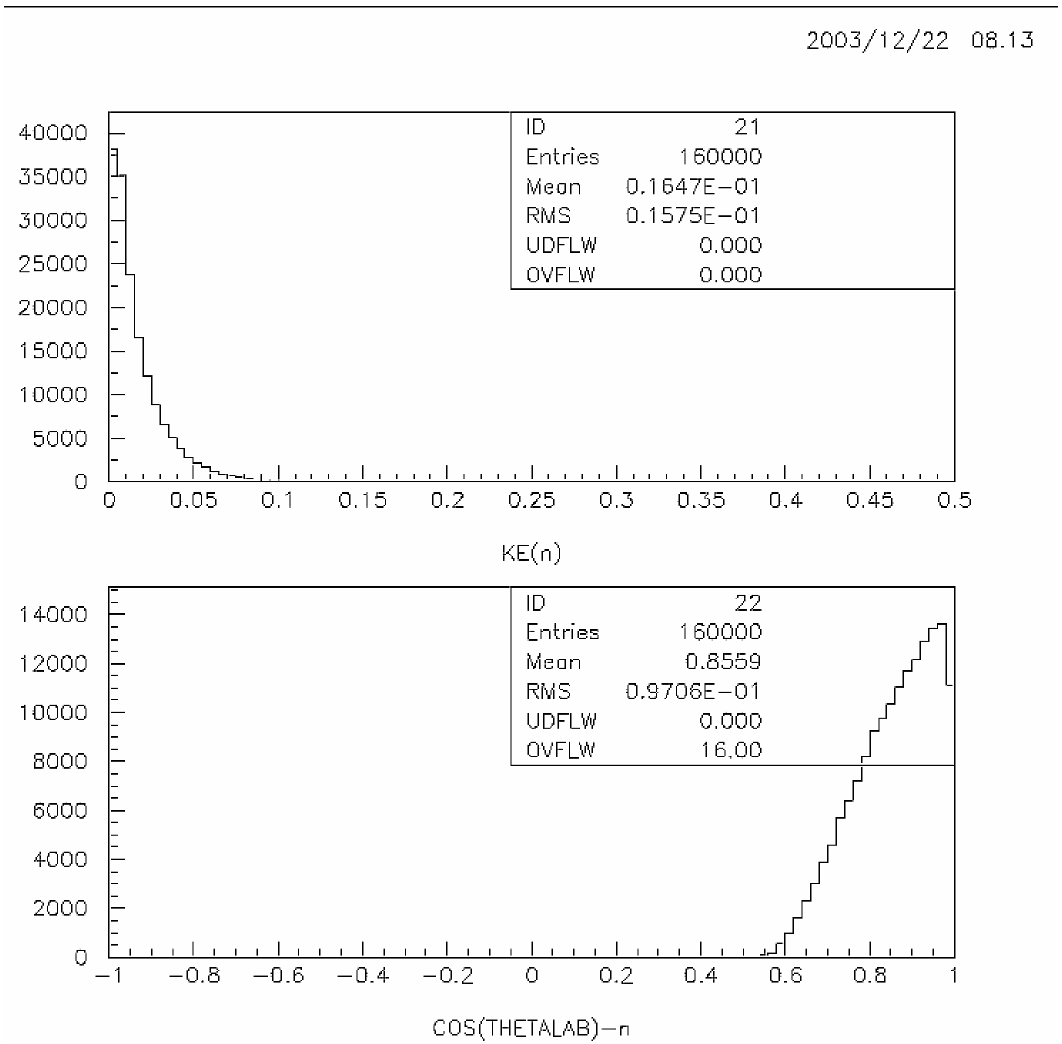
- Implemented simple geometry (Yu Fu)…
- Works for single particles, e.g. sums electron/positron path lengths
- But lost post-doc who did work!
- Plan: marry geometry with event generator over break (with E. von Toerne).

Event Generator

- Beacom/Vogel cross section with
  - $(\Delta/M)^1$ corrections; $\Delta=M_n-M_p$;
  - Final state neutron kinematics.
  - "Inner" radiative corrections
- Features:
  - Slight negative asymmetry in $\cos\theta_L(e^+)$.
  - KE(e+) → E(n)-Δ-m_e-KE(n).
  - $\theta_{L,max}$(n)~55 deg.
  - KE_{max}(n)~100 KeV.
  - Very close to $(\Delta/M)^0$ result except near threshold.
- Flux from Gratta,Vogel RMP.



2003/12/22 07.46
ID 11
Entries 160000
Mean 4.263
RMS 1.296
UDFLW 0.000
OVFLW 392.0
0 500 1000 1500 2000 2500 3000 3500 4000
0 1 2 3 4 5 6 7 8
ENU
ID 12
Entries 160000
Mean −0.2307E−01
RMS 0.5750
UDFLW 0.000
OVFLW 0.000
0 200 400 600 800 1000 1200 1400 1600 1800
−1 −0.8 −0.6 −0.4 −0.2 0 0.2 0.4 0.6 0.8 1
COS(THETALAB)−e+


2003/12/22 08.13
ID 21
Entries 160000
Mean 0.1647E−01
RMS 0.1575E−01
UDFLW 0.000
OVFLW 0.000
KE(n)
ID 22
Entries 160000
Mean 0.8559
RMS 0.9706E−01
UDFLW 0.000
OVFLW 16.00
COS(THETALAB)−n

Fast Detector Simulation

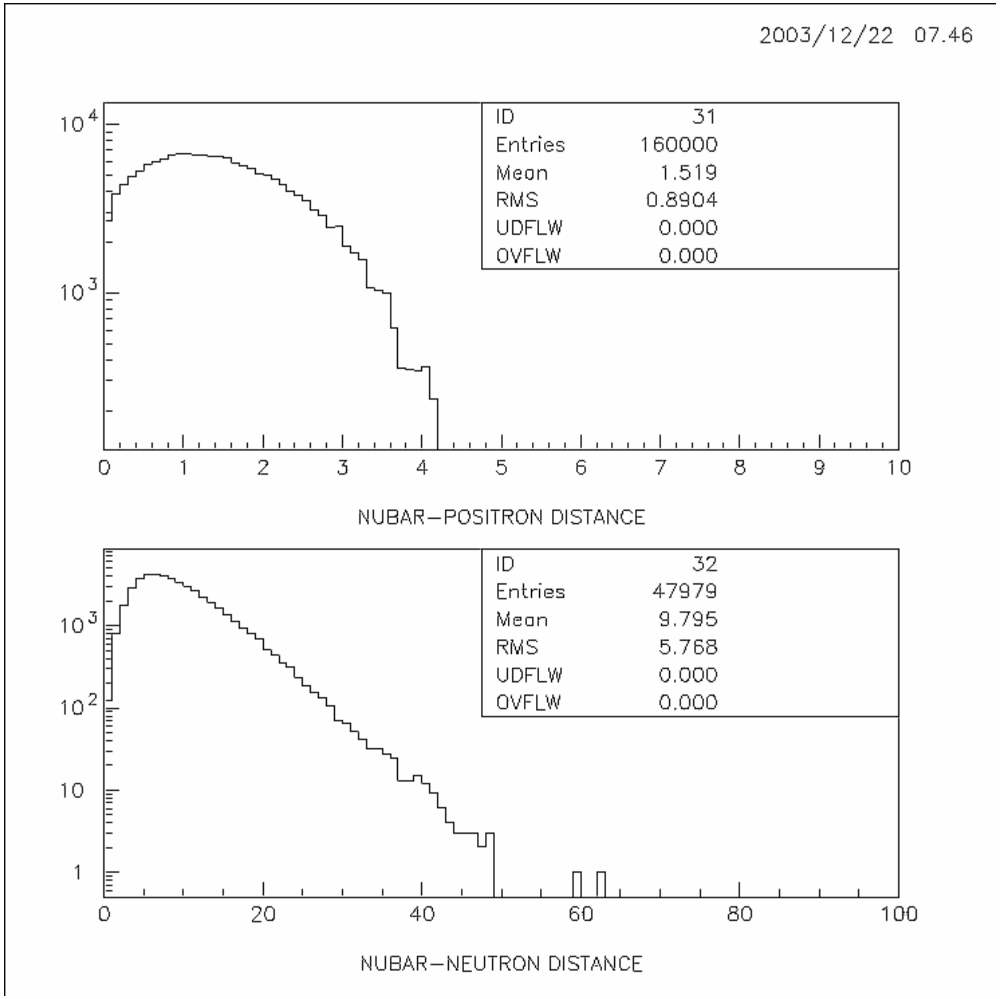
- Allows way to check generator.
- Tool for cross-checking Geant.
- Maybe more useful than Geant for “simple” studies.
- Ingredients:
  - Event generator$\rightarrow$positron, neutron kinematics.
  - Generates gamma ray “secondaries”.
    - Positron dE/dx via Bethe-Seltzer formula.
    - n-capture on H, Gd-155, or Gd-157.
  - Propagates secondaries
    - Gammas to first Compton scatter.
    - Neutrons via diffusion(fast) or stepping via cross section(slower).

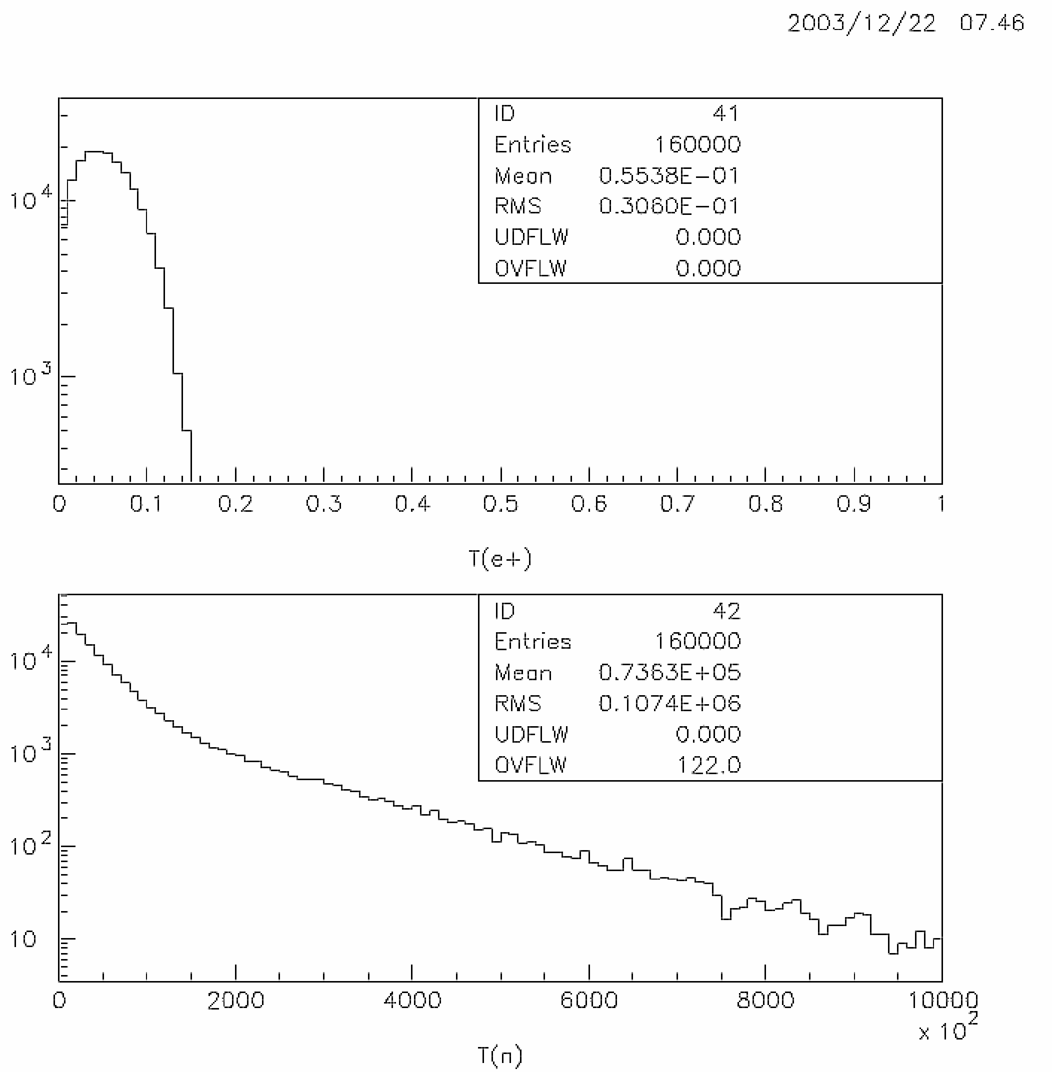
Secondary generation

- Positron dE/dx via Bethe-Seltzer formula (but no MCS).
- e^+e^- annihilation→from rest.
  - Does not include time distribution from prompt and delayed (~3 ns) positronium contributions.
- n-capture on H, Gd-155, or Gd-157.
  - Single isotropic gamma from H.
  - “Minor” Gd isotopes ignored.
  - Capture on C ignored.
  - Gd is complicated!
  - Sweep under rug and approximate by Poisson distribution of phase-space generated photons.

Neutrons

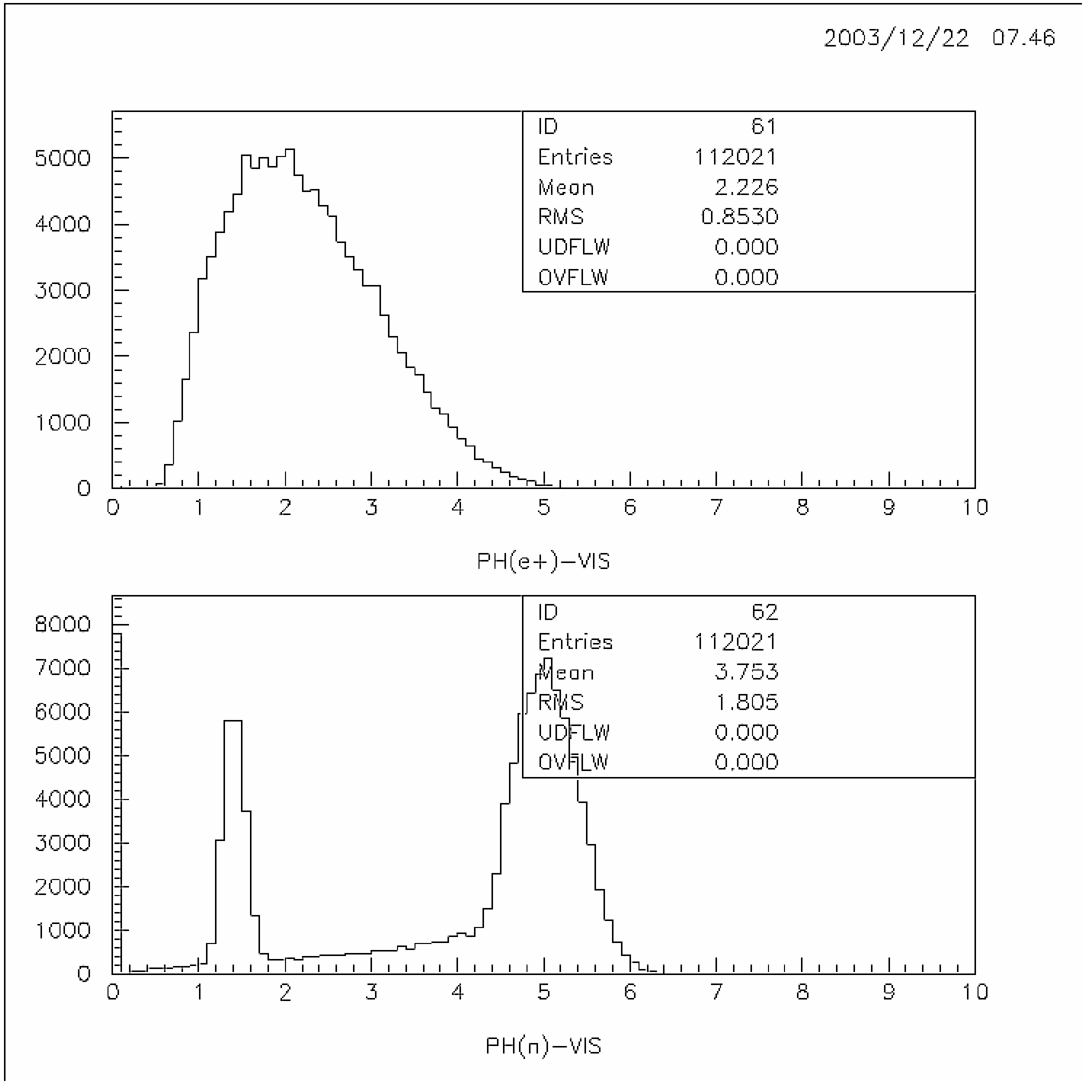
- Fast mode: diffusion with mean free path, mean time taken from Chooz.
  - <r> ~ 6(30) cm in Gd-loaded (unloaded) scintillator.
  - Capture time ~ 30(180) ms in Gd-loaded (unloaded) scintillator.
  - Simple minded at loaded/unloaded boundary: use constants at neutron vertex, then ignore boundary.
    - N propagate too far (not far enough) in transitioning into (out of) Gd-loaded region.
- Some experimentation with stepping mode.
  - Cross sections (ENDF) available from BNL (be mindful of temperature of target!).
  - Geant4 implements these as well.
  - Pretty close to fast mode, discovered bug in fast mode time distribution (should be exponential, not Gaussian).


2003/12/22 07.46
ID 31
Entries 160000
Mean 1.519
RMS 0.8904
UDFLW 0.000
OVFLW 0.000
NUBAR–POSITRON DISTANCE
ID 32
Entries 47979
Mean 9.795
RMS 5.768
UDFLW 0.000
OVFLW 0.000
NUBAR–NEUTRON DISTANCE

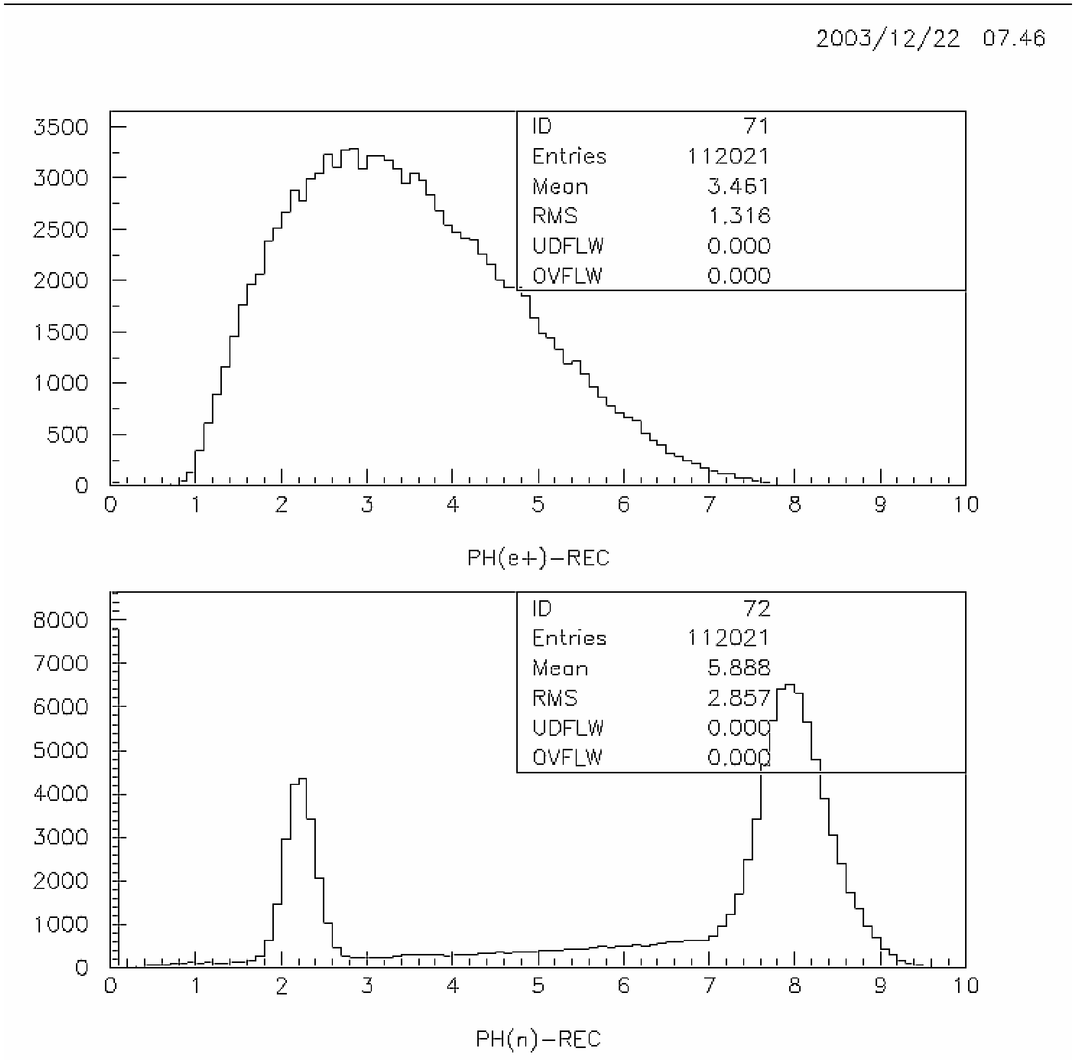

2003/12/22 07.46
ID 41
Entries 160000
Mean 0.5538E−01
RMS 0.3060E−01
UDFLW 0.000
OVFLW 0.000
T(e+)
ID 42
Entries 160000
Mean 0.7363E+05
RMS 0.1074E+06
UDFLW 0.000
OVFLW 122.0
x 10^2
T(n)

PMT simulation

- Include attenuation using Chooz parameters (4m in Gd, 10 m in unloaded).
- 5300 photons/MeV (from Chooz).
- 20% PMT coverage with 8in. tubes.
- 20% QE→ Typical #photo-electrons ~ 3-5/tube.
- Time, PH, npe, attenuation length saved for each “hit”.
- Mimic reconstruction by including photo-statistics and spread in attenuation correction (no real reconstruction).



2003/12/22 07.46
ID 61
Entries 112021
Mean 2.226
RMS 0.8530
UDFLW 0.000
OVFLW 0.000
0
1000
2000
3000
4000
5000
0 1 2 3 4 5 6 7 8 9 10
PH(e+)-VIS
ID 62
Entries 112021
Mean 3.753
RMS 1.805
UDFLW 0.000
OVFLW 0.000
0
1000
2000
3000
4000
5000
6000
7000
8000
0 1 2 3 4 5 6 7 8 9 10
PH(n)-VIS



2003/12/22 07.46
ID 71
Entries 112021
Mean 3.461
RMS 1.316
UDFLW 0.000
OVFLW 0.000
PH(e+)-REC
ID 72
Entries 112021
Mean 5.888
RMS 2.857
UDFLW 0.000
OVFLW 0.000
PH(n)-REC

Some code details

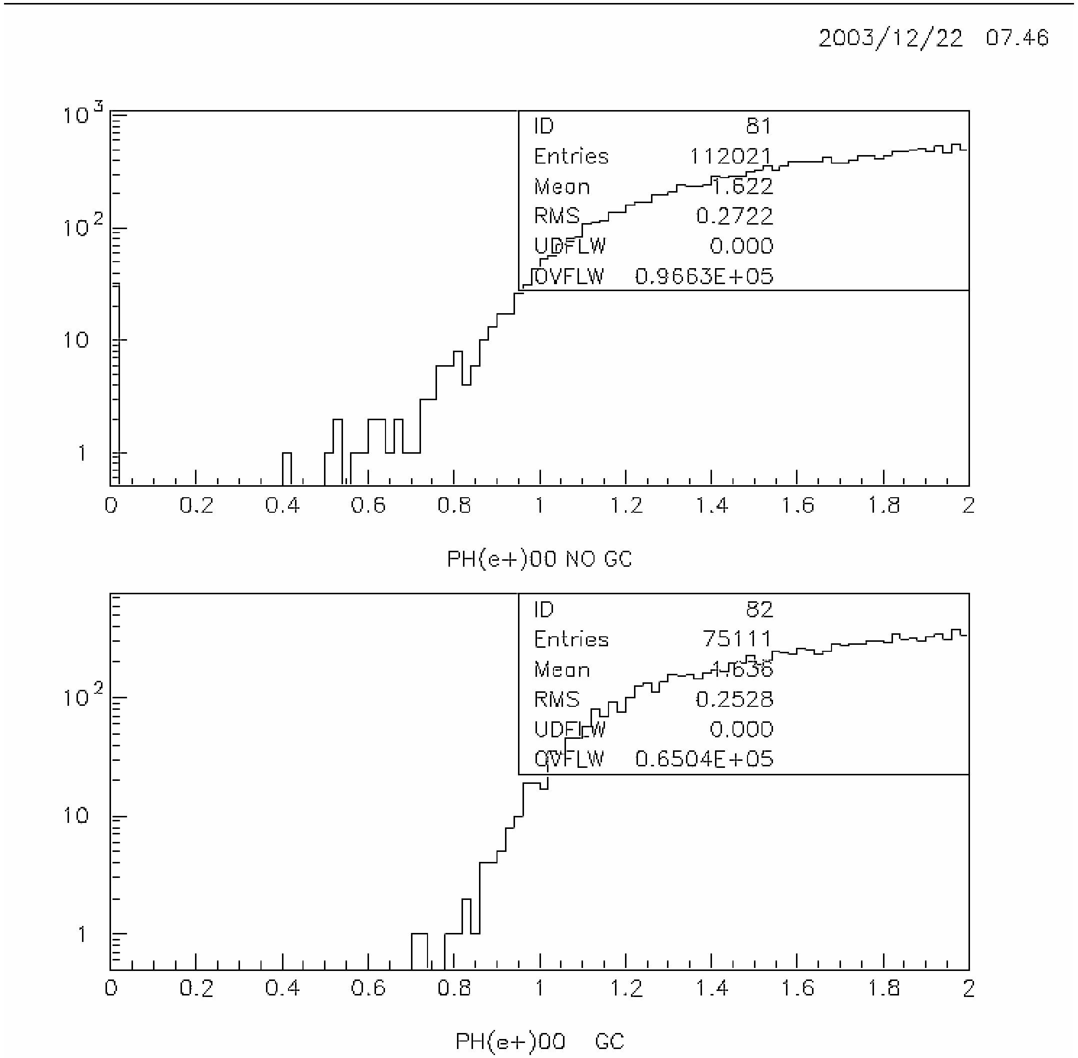
- In “easy” C++ to use parts in Geant4.
- Calls some Fortran when needed.
- “Constants” class ReactorConstant.hh pretty handy compilation of parameters.
- Interfaces to PAW because I think more people know it.
- Easy to run several “models” at once for comparison.

```
//
ReactorDetector DetectorA;
ReactorNtuple ModelA(1,"model A",dirName);
DetectorA.SetParam_FastNeutronOption(0);
DetectorA.SetParam_R0(200);
DetectorA.SetParam_R1(200);
DetectorA.SetParam_R2(275);
//
ReactorDetector DetectorB;
DetectorB.SetParam_FastNeutronOption(0);
DetectorB.SetParam_R0(175);
DetectorB.SetParam_R1(200);
DetectorB.SetParam_R2(275);
ReactorNtuple ModelB(2,"model B",dirName);
//
// event loop
//
for (int events = 0;events<nevents;events++){
  //
  // create neutrino event
  //
  ReactorEvent Event(rmaxgen);
  //
  // create fast detector simulation
  //
  DetectorA.LightsOut(Event);
  ModelA.Fill(Event,DetectorA);
  //
  DetectorB.LightsOut(Event);
  ModelB.Fill(Event,DetectorB);
}
```

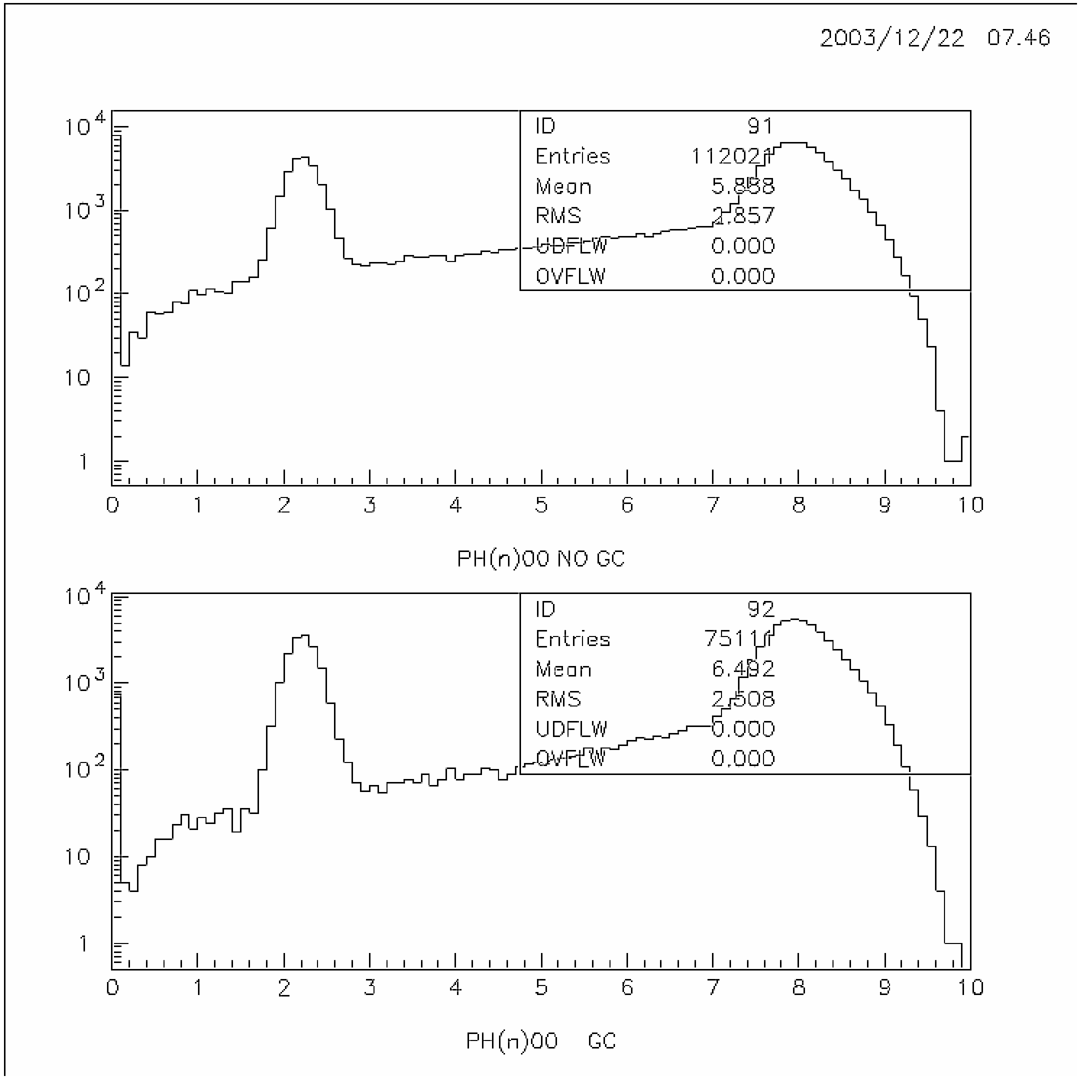
Detector models in ReactorFsim.

Example: Effect of gamma catcher

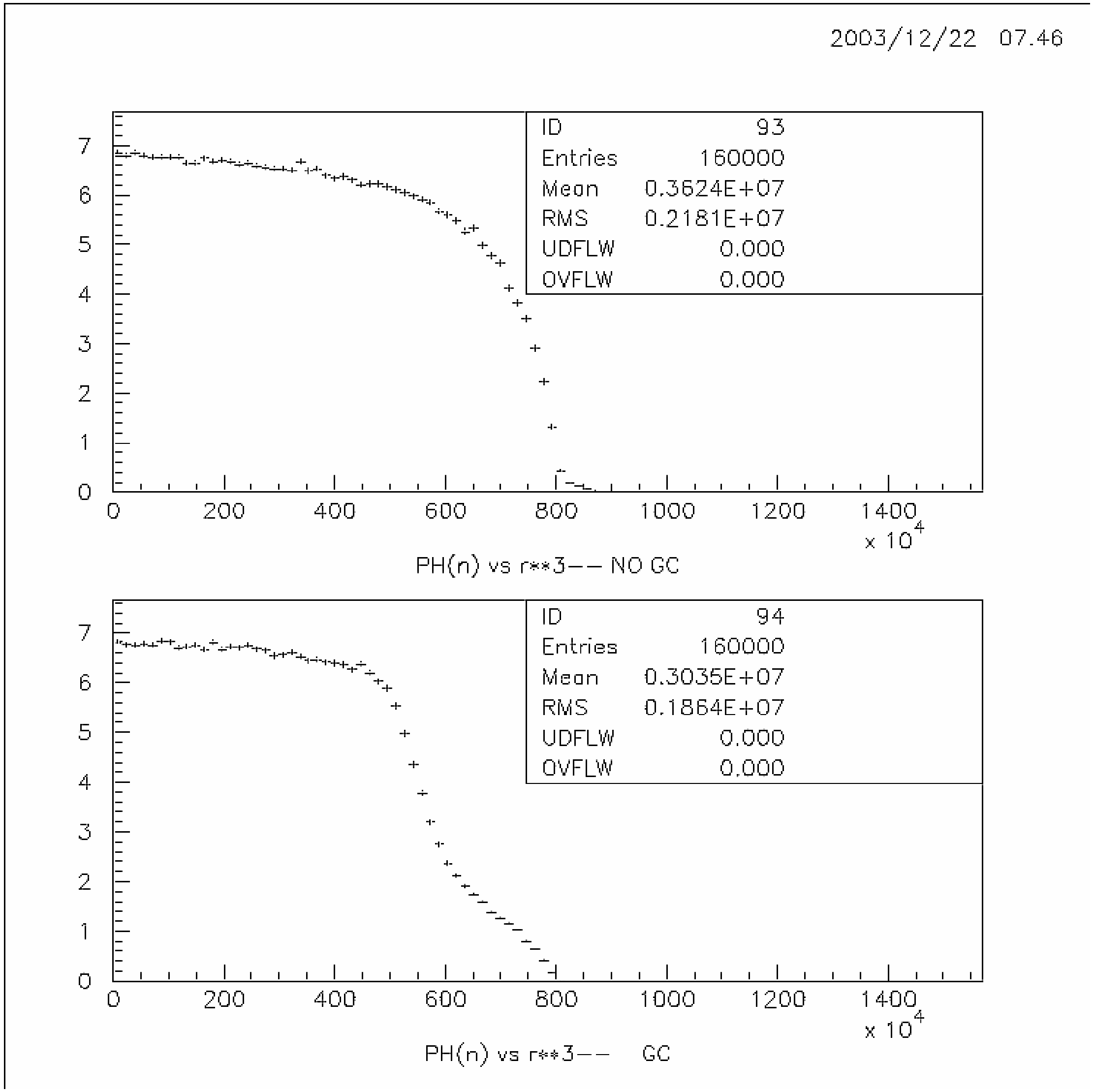
- “Model A”:
  - R0=200 cm = outer radius of Gd-loaded region.
  - R2=275 cm = outer radius of inactive oil region.
- “Model B”:
  - R0=175 cm = outer radius of Gd-loaded region.
  - R1=200 cm = outer radius of active unloaded scintillator region.
  - R2=275 cm = outer radius of inactive oil region.



No gamma catcher→ need positron energy cut?



No gamma catcher→ higher acceptance correction for neutron.



Gamma catcher sharpens fiducial.