CorsikaGen Timing Fix

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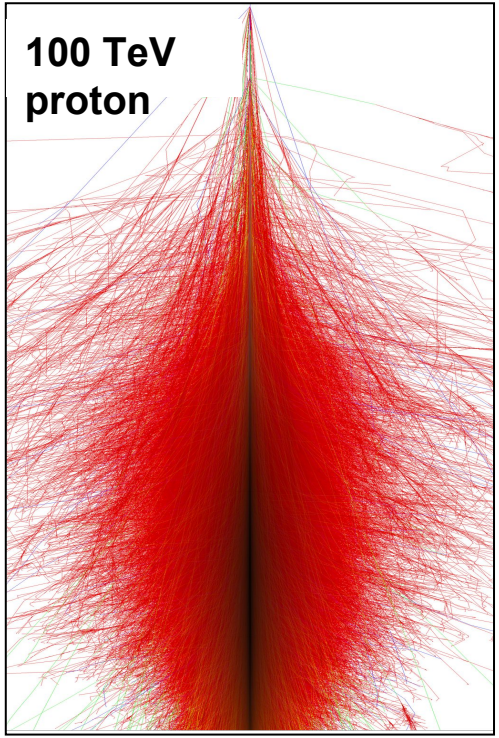
LArSoft Coordination Meeting

5/9/2017

CORSIKAGen

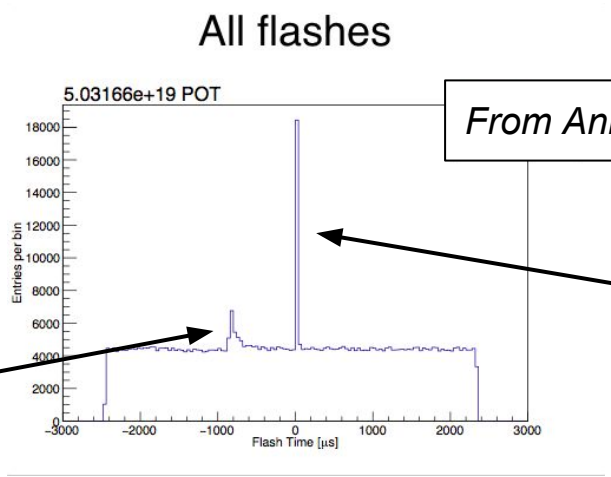
- CORSIKA is "a program for detailed simulation of extensive air showers initiated by high energy cosmic ray particles. Protons, light nuclei up to iron, photons, and many other particles may be treated as primaries."
- **CORSIKAGen** is a LArSoft EDProducer module that produces cosmic events
  - Does not run CORSIKA, but uses libraries of pre-generated EAS's
  - Lives in larsim
- Allows for **tunable** cosmic ray fluxes
  - Mixing of CORSIKA EAS fluxes (CMC model is H+He+N+Mg+Fe)
  - Tuneable flux normalizations
  - Model selections (e.g. hadronization with FLUKA or GHEISHA)
- Gives different predictions than CRY
  - Default tune predicts more muons (mostly due to altitude)
  - FLUKA model predicts 4-5x more protons/neutrons



The Problem

- Anne Schukraft and Marco Del Tutto have pointed out an additional excess of flashes in the timing distribution of flashes in MicroBooNE's intime CORSIKA samples
- Not new, has been there since we started generating CORSIKA samples

MicroBooNE's "in time" CORSIKA samples are generated by only accepting events with light in the beam gate.



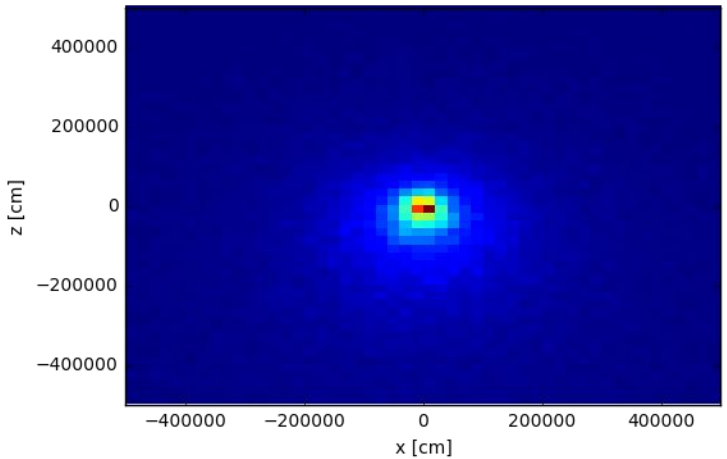
From Anne S.

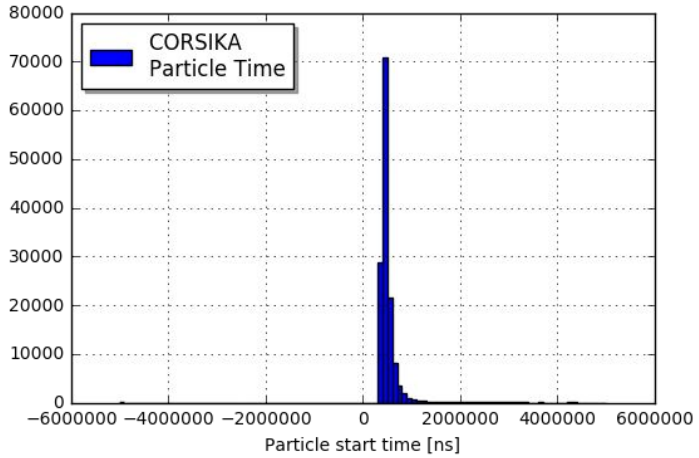
Neutrinos

???

Shower Space & Time Distribution

- CORSIKA resets the clock for each EAS. T=0 is when the primary first interacts in the atmosphere.
- This is how the resulting shower particles come out of CORSIKA:
  - EAS's all start at t=0, x=0, z=0. Clock resets for each EAS.



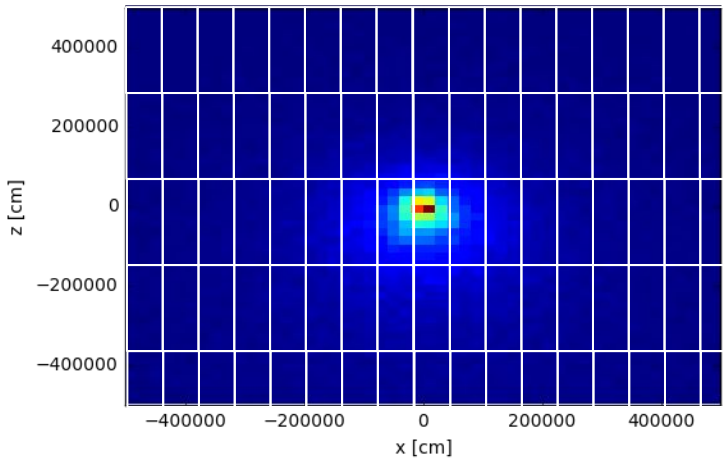


Shower Space & Time Distribution

- We have to **distribute** these EAS's in space & time ourselves, based on the measured fluxes of primary particles $I_N(E) \approx 1.8 \times 10^4 \, (E/1\ \mathrm{GeV})^{-\alpha} \, \frac{\text{nucleons}}{\mathrm{m}^2\ \mathrm{s}\ \mathrm{sr}\ \mathrm{GeV}}$
- But this would be very limiting computationally if we had to simulate protons striking the atmosphere across the whole horizon…

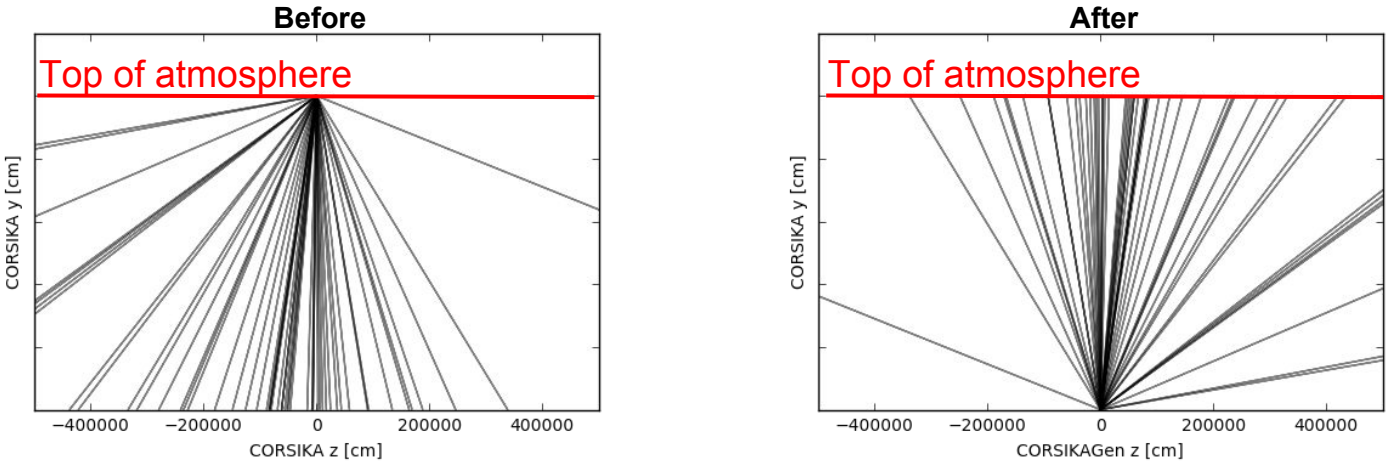
Group	K	γ
p	1.72×10^4	2.71
α	9.20×10^3	2.71
CNO	6.20×10^3	2.71
Mg	9.20×10^3	2.71
Fe	6.20×10^3	2.71

CMC variables from: Simulation of atmospheric cascades and deep-underground muons, Forti et al, 1990



- Instead, **divide** the x/z surface into a grid (size is related to cryostat dimensions + buffer box)
- Particles that arrive in each **box** are given a new position that is the modulus of the x/z position with respect to these box dimensions, effectively wrapping the geometry
  - We don't have to simulate EAS's at different points all along the atmosphere
- Each of those boxes gets a random number for the EAS start time
  - This is where the bump came from...

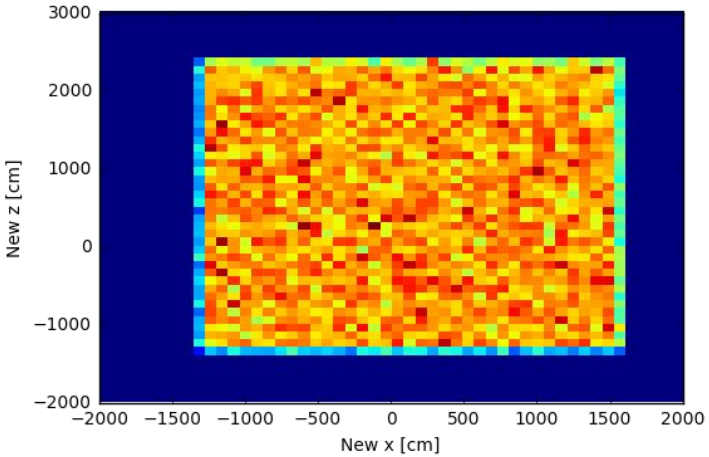
Shower Space & Time Distribution

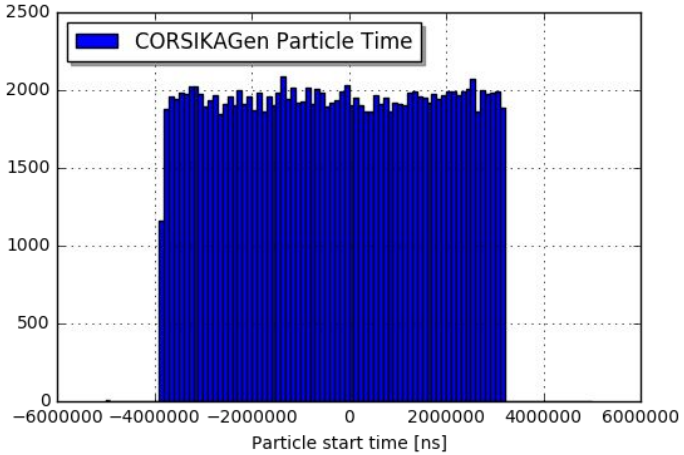


- Point source (what CORSIKA generates) effectively gets distributed across the sky
  - Preserves local shower spatial and temporal correlations

The Fix

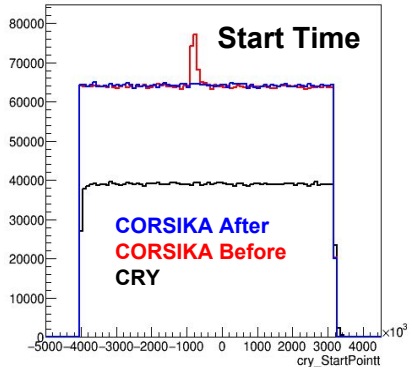
- The shower time was randomly generated using the **same** random number three times:
  - New shower time = {random shower time} + {box # in x}*{random shower time} + {box # in z}*{random shower time}
- This introduced unrealistic temporal-spatial correlations
  - E.g. the box numbers could align & cancel in such a way that: New shower time = {random shower time}
- Really want three **independent** random numbers:
  - New shower time = {random shower time} + {box # in x}*{random x time} + {box # in z}*{random z time}

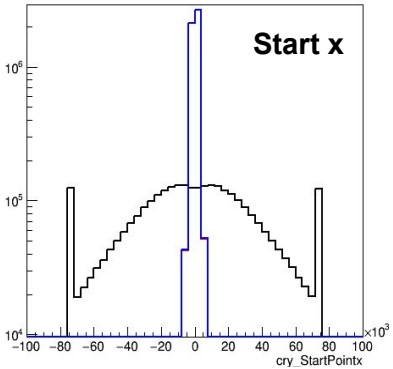


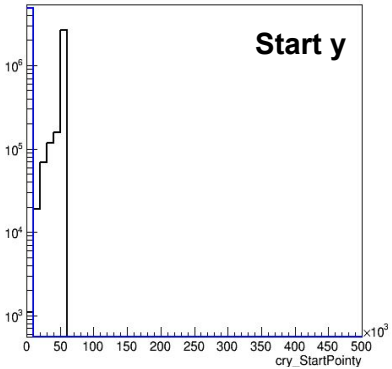


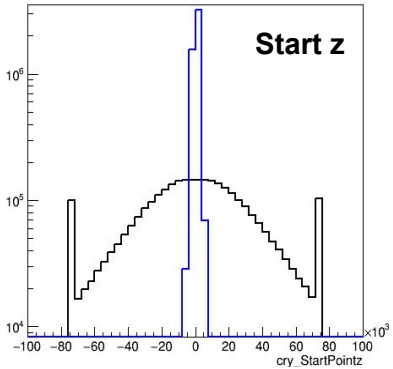
Things look good ✔

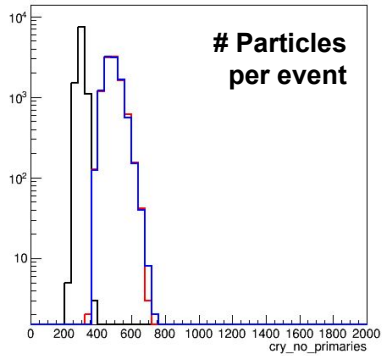
(i.e. only the timing changed)

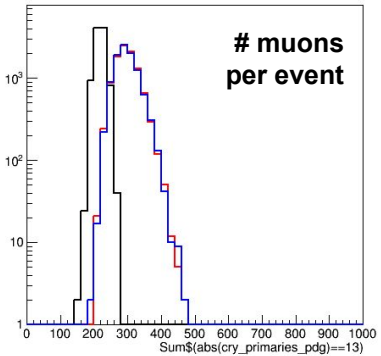


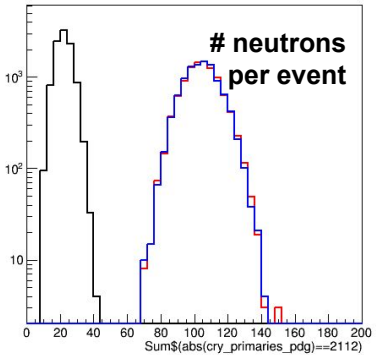


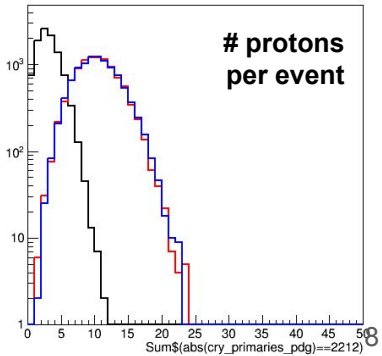












Summary

- Flash timing bump in intime CORSIKA distributions was tracked down to randomness bug in CORSIKAGen
- Fixed & pushed to mibass_CorsikaGenTimingFix
- Tested
  - Compared distributions before and after fix; only timing affected
  - Tested both in time and normal cosmics samples
  - Passing rate on in time samples should be affected by a negligible amount