# GENIE, Geant4, Pythia{6,8}: tau and charm hadron decays

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DUNE NearDet Software 2021-03-10

# Background

- For a high enough energy in the flux spectrum, GENIE will produce charm hadrons in final state.
- Additionally for an oscillated flux, tau leptons.
- The default handling would be to hand these over to Geant4 for propagation and decay.
- circa ~May 2012 NOvA was surprised to find that Geant4 didn't generate secondaries for charm...

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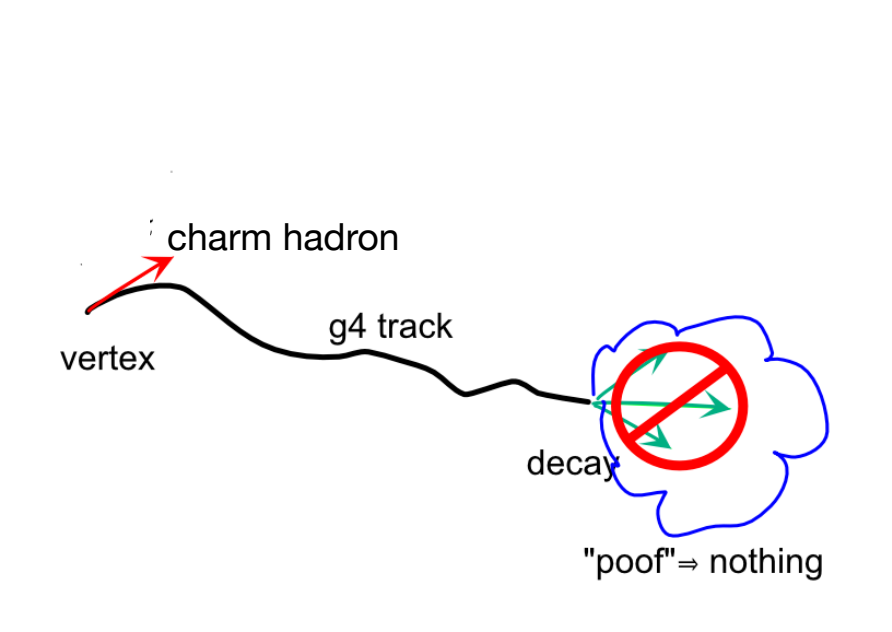

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## Bug #2852

Edit Watch

### No code takes responsibility for decaying charm (and B) mesons

Added by Robert Hatcher over 7 years ago. Updated over 3 years ago.

| | | | |
|---|---|---|---|
| **Status:** | Rejected | **Start date:** | 05/15/2012 |
| **Priority:** | Normal | **Due date:** | |
| **Assignee:** | Robert Hatcher | **% Done:** | 50% |
| **Category:** | - | **Estimated time:** | |
| Duration: | | | |

**Description**

Quote

GENIE currently leaves charmed mesons/baryons (e.g. D, etc) as part of the final state of the interaction (status code = 1) to allow then to decay during propagation. Geant4, for reasons to do with correlated production and spin kinematics important for other experiments, does not come configured out-of-the-box to decay these heavy mesons/baryons. It was suggested by the G4 experts that the code should interface to an existing package such as pythia6 (or pythia8).

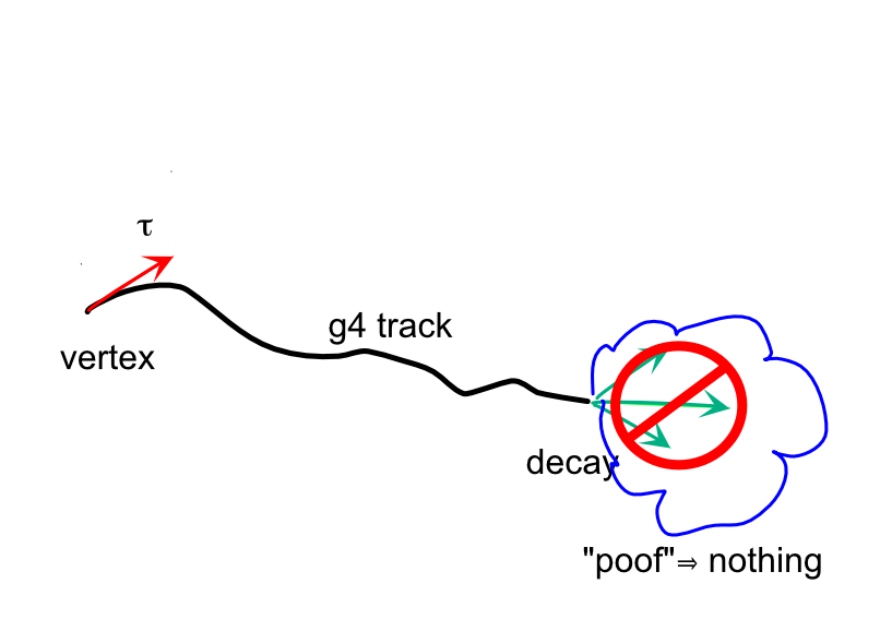
```
G4Decay::DoIt  : decay table not defined  for lambda_c+

*** G4Exception : No Decay Table
     issued by : G4Decay::DecayIt
Decay table is not defined
*** This is just a warning message.
```

Sometimes the particle is a D0, D+, D−, etc

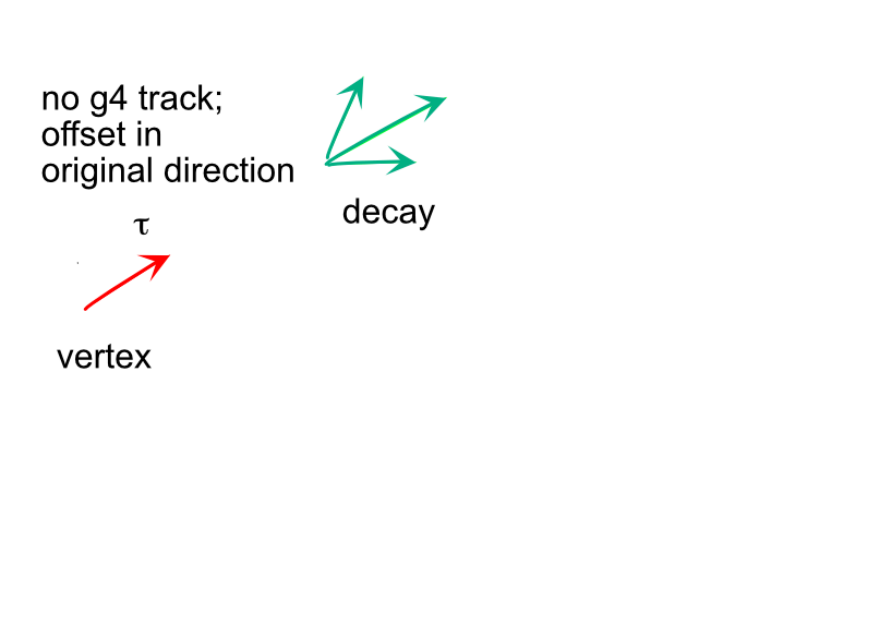
# Past

- circa ~May 2012 NOvA was surprised to find that Geant4 didn't generate secondaries for charm...
- ~October 2012, discovered same for tau
  - yes, we were young and naïve



# Cheap Solution

- Let GENIE decay the particle, using already integrated `pythia6`, before hand-off to Geant4.
- This can be controlled by a GENIE XML configuration file
  - packaged as `genie_phyopt` UPS product
  - either `dkcharmtau` or `dkcharm` qualifier



# Limits to this Solution

- This was sufficient for NOvA -- offset was small, in general, due to low momenta of tau or charm; and energy was once again conserved.
- NOvA's spatial resolution wasn't sufficient to see such offset.

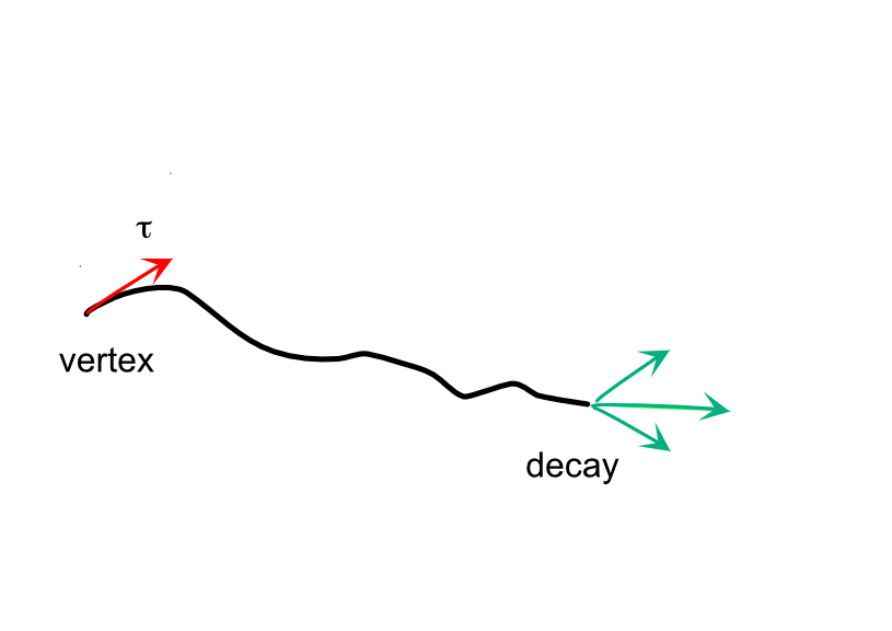
- Then LArSoft came along and the solution was similarly available to them.
  - eventually used by DUNE (upon Robert's insistence).
  - apparently not implemented by microBooNE
    - perhaps not an issue if never tau or charm production
  - ?? other LArSoft experiments ??

# Present

- At some point, Geant4 implemented a rudimentary tau decay (but still not charm hadrons)
  - not sophisticated (phase space only?)
- And ... apparently ... broken in some cases
  - occasionally generate absurd momenta
- Noticed when running without `genie_phyopt` UPS product setup.
- At about the same time other parties also took notice of this "gap" issue for tau/charm

# Future: Better Solution

- Much better would be let Geant4 do it's job, but use Geant4's ability to plug in alternatives to do the decays of charm and tau.
- Ideally this would be semi-automatic or easy to generalize and configure with little coding on the LArSoft side.



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- Make use of the G4 extensible physics list factory to supplement regular standard physics lists.

  - `FTFP_BERT` ⇒ `FTFP_BERT+PY8DK`

# Better Solution Status

- Julia Yarba implemented a proof-of-principle interface to `Pythia8` in a stand-alone Geant4 app
- Robert Hatcher integrated it into the factory system so that physics process can be added by configuring the PhysicsList name.
- Issues:
  - GENIE sets tau polarization (for RES + DIS, but not QES) in its event record
  - polarization info is transferred to `MCTruth` in LArSoft record and from `MCTruth` to `G4PrimaryParticle` (`nug4 ConvertMCToG4`) [not yet validated per se]
  - tests in stand-alone app imply that Pythia8 isn't picking up polarization properly from Geant4; or not configured correctly
    - recently found some extra documentation that might help here.

# Better Solution Status

- Issues continued:
  - Needs clean up and packaging as UPS product
    - depend on Geant4 + Pythia8 version
  - How to get library containing g4 interface _loaded_ at run time ... perhaps as a "service" or a "tool"?
    - nothing needs be done on user side other than load the library to make it available; no explicit compile/link time references
    - might need to allow for some configurability, e.g. have `Pythia8` decayer to _not_ decay tau (see next item)
  - Possibility to do the same kind of interface for the `tauola` package. `Pythia8` documentation implies that the decay models are slightly different in some cases.
  - https://indico.cern.ch/event/300387/contributions/686167/attachments/565826/779490/ilten140915.pdf
  -

# DUNE NearDet Software Group

- Issues continued:
  - Needs integration with edep-sim, not just LArSoft
    - again depend on Geant4 + Pythia8 version
    - as external library needs to be explicitly linked in (optionally?)
    - again controlled by choice of extensible physics list name
    - edep-sim needs some tweaks itself
  - Current versions that play nice together (others?):
    - ROOT v6_22_06a
    - Geant4 v4_10_6_p01c
    - Pythia8 v8_3_02c (p383b)