

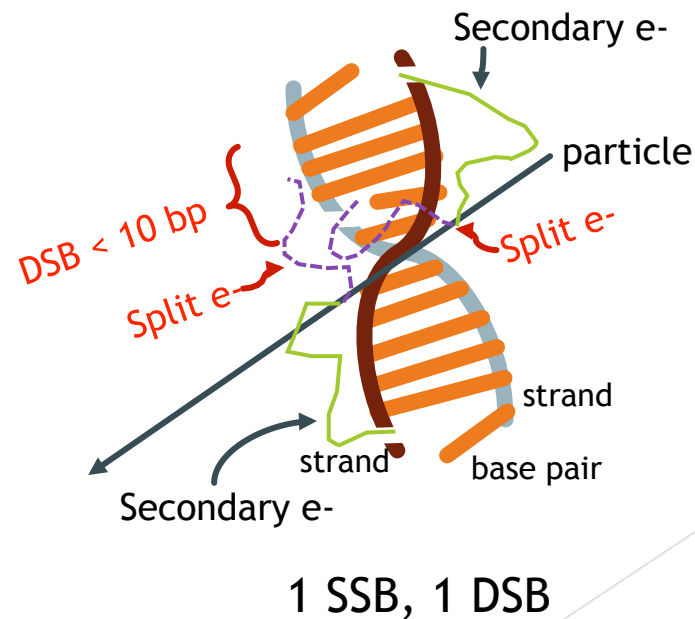
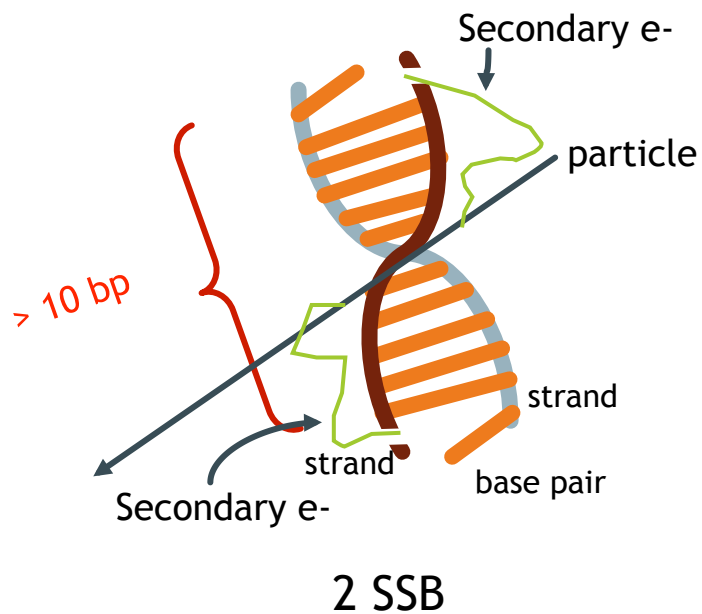


# New extended example medical/dna/splitting

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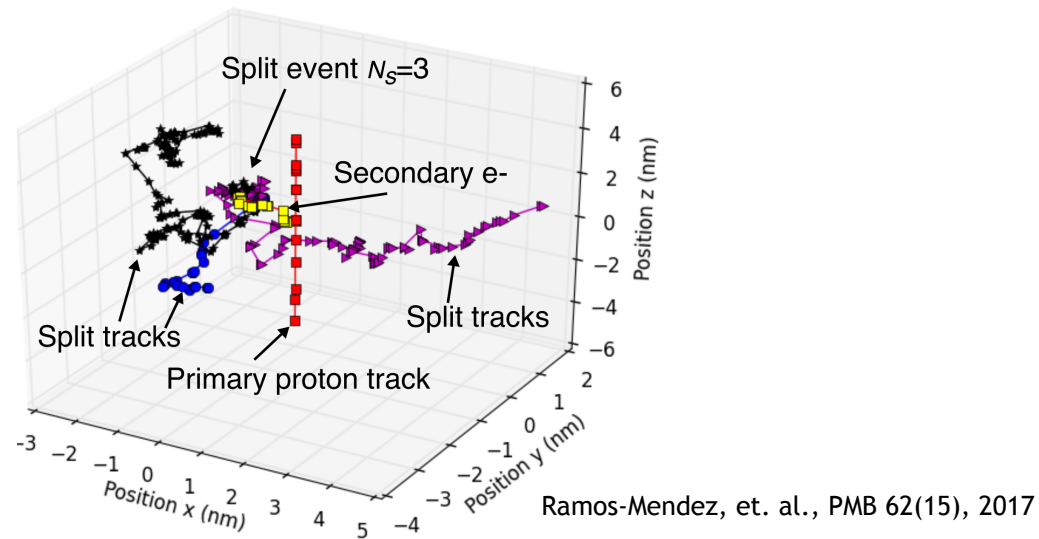
# Background

- The interaction-by-interaction transport used by Monte Carlo track structure (MCTS) requires much higher computational effort than condensed-history MC.
- Variance reduction technique has been used in condensed-history MC for many years.
- Particle splitting is the gold standard in condensed-history MC where averaged quantities (dose, fluence, etc) are of interest, but implemented 'as is' could produce unexpected results.



# Background

- ▶ To overcome the biasing, an identification number (flag) is assigned to each split particle, which is inherited by all progeny and used to separate the new tracks.
- ▶ In *splitting* example, uniform particle split is performed at ionizations events of secondary  $e^-$ .

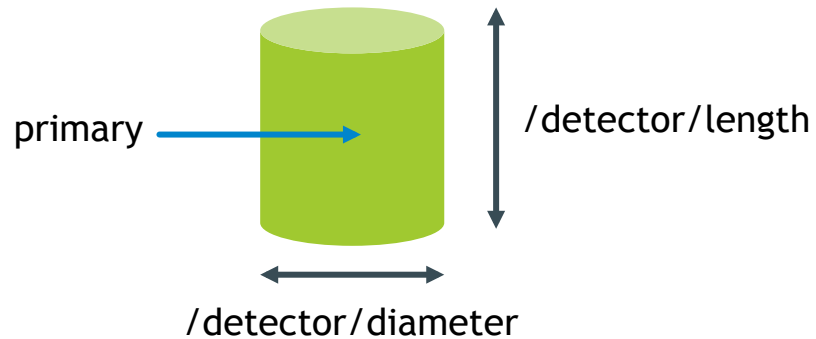


A secondary  $e^-$  (yellow) of a 0.5-MeV primary proton moving vertically upwards (red) was split into  $N_s = 3$  split electrons with flag equal to 3 - blue, 4 - black, 5 - magenta). The statistical weight of the new electrons is set to  $w=1/3$

# Description of the example

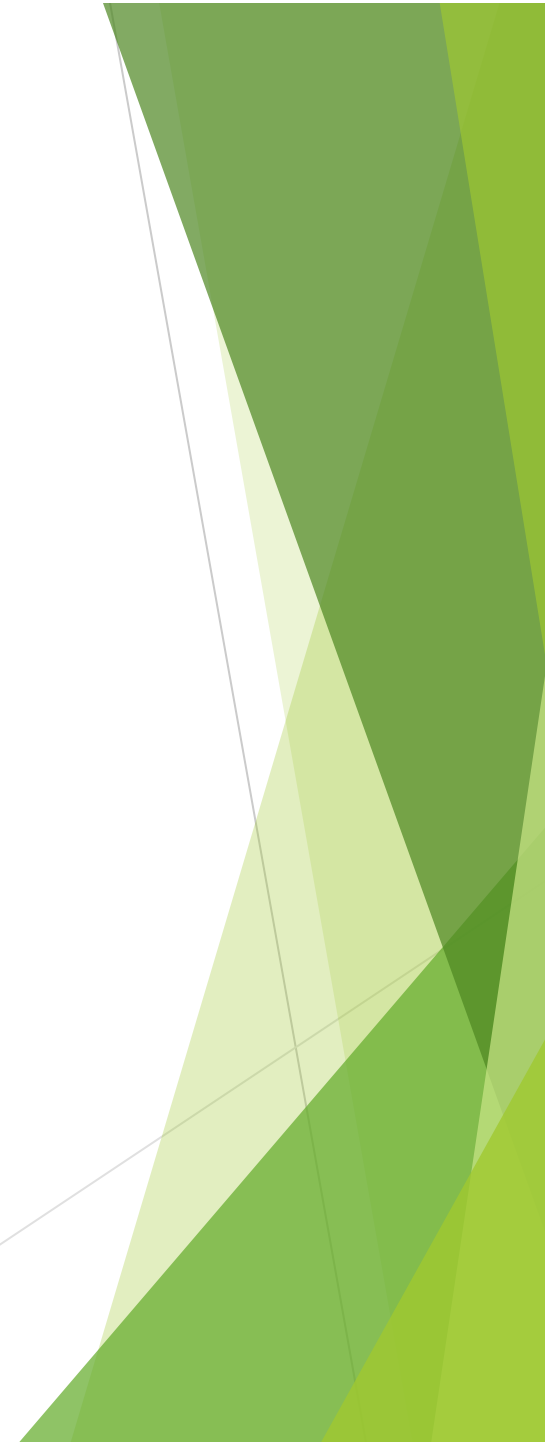
- ▶ VRT is used in calculations of ionization cluster size distributions.
- ▶ Ionized electrons generated by the first generation of secondary electrons are split, i.e. new clone electrons are generated, labeled and propagated.
- ▶ The label is used to classify those new particles as if they were produced by independent histories to avoid overlapping of tracks at final analysis.
- ▶ The splitting is performed only if the ionization event occurred in the cylinder.

Split is controled by: `/vrt/numberOfSplit`



# Splitting: information of interest.

- ▶ First, at UserTrackingInformation (G4VUserTrackInformation) the flag is defined as an integer value.
- ▶ Second, at TrackingAction (G4UserTrackingAction)
  - ▶ ...PreUserTrackingAction(...)
    - ▶ // The flag is assigned to all the particles
  - ▶ ...PostUserTrackingAction(...)
    - ▶ // The flag is passed to all secondary particles
- ▶ Third, the flag is updated at SplittingProcess (G4WrapperProcess)
- ▶ SplittingProcess wraps e-\_G4Ionisation process.



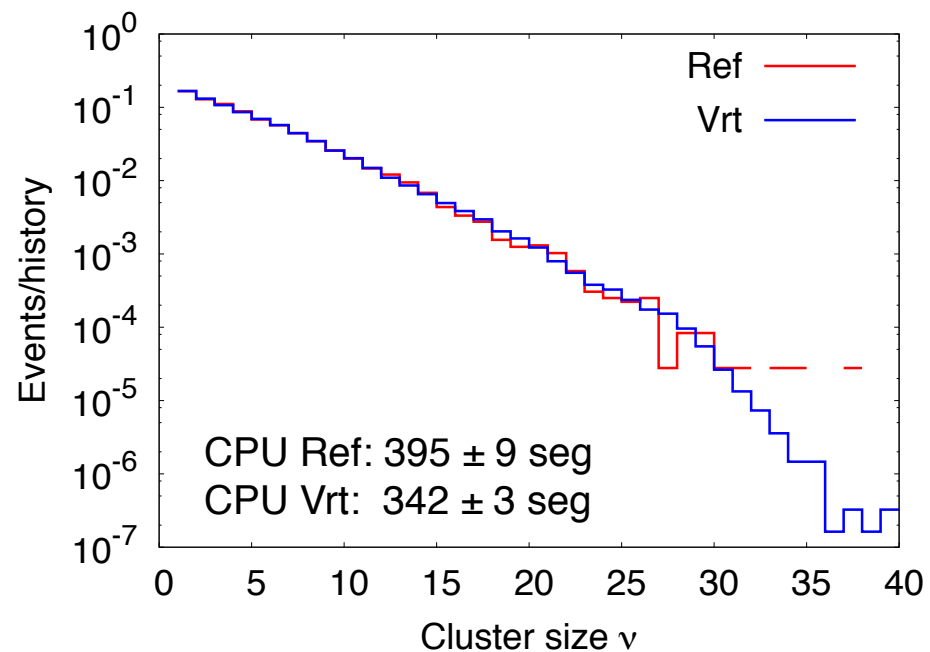
# Scoring

- ▶ `EventAction::BeginOfEventAction(...)`
  - ▶ A vector of length equal to the number of split is created.
- ▶ `EventAction::EndOfEventAction(...)`
  - ▶ The vector is dumped to a histogram, then it is cleared.
- ▶ `SteppingAction::UserSteppingAction(...)`
  - ▶ How to get the flag:

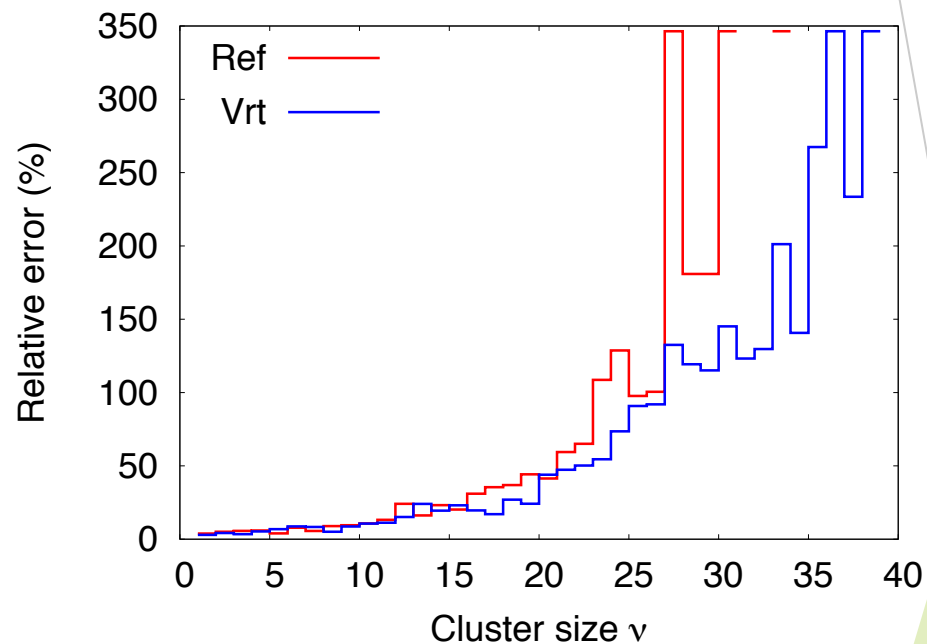
```
UserTrackingInformation* trackInformation =  
    (UserTrackInformation*)(step->GetTrack()->GetUserInformation());  
G4int idx = trackInformation->GetSplitTrackID();  
fpEventAction->Addlonization(idx, 1);
```



# Output: 4 MeV/u alphas.



Ionization cluster size distribution.  
A split number of 256 (arbitrary)  
was used for VRT.



Relative error (bin error divided by  
bin content).

# Remarks

- ▶ The success of particle splitting relies on performing the splitting strategically:
  - ▶ at particular physics event, at specific region, above/below energy thresholds, etcetera.
- ▶ Be careful of over-splitting: few primaries and many split particles.
- ▶ At `EventAction::EndOfEventAction()`, the vector with ionization frequency per event are dumped to a histogram. Then, when using root format the statistical errors associated will be underestimated.
- ▶ It is recommended to separate the simulation into batches and merged them to correctly estimate the statistical uncertainty.



Thanks!

