

# Speeding up single-particle tracking in Geant and GeantV using vectorisation

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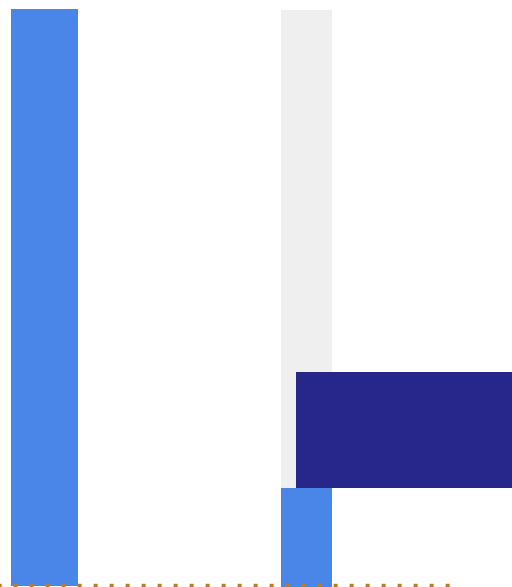
# The challenge

In Geant4 particles are always tracked one at a time.

In GeantV non-trivial fraction,  $O(10\%)$  is currently tracked in single particle mode

- volumes with small flux or volume
- 'straggler' tracks to end event(s)

Fraction of work in single particle mode



Geant4

GeantV

A laptop screen displaying a data dashboard. The dashboard features a line graph at the top with a blue line and a pie chart below it. The text "Components with vectorisation potential" is overlaid in large white font. The laptop keyboard is visible at the bottom.

# Components with vectorisation potential



**The  
'candidates'**

**VecGeom** is an existing common component. Two parts suit vectors:

- Solids with several similar faces
- Intersection of bounding boxes
- Intersection of same solids\*

Runge Kutta **integration** of charged particle trajectories

- integrates 6-8 variables at once

Others?



# Geometry - Solids

Solids with vector code for one 'track': LIST HERE

## Step 1

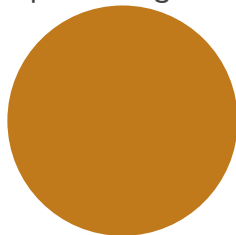
Identify solids with most vectorisation potential



? Trap, Polycone, Polygon?

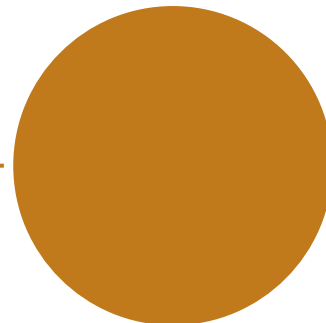
## Step 2

Implementation of key methods (intersection, safety) of 1-2 most promising solid(s)



## Step 3

Benchmark and extend to additional candidates types of solids





## Vectors in 'scalar' Navigation

VecGeom Navigator vectorizes over bounding boxes of candidate volumes

- first results reported in a previous Geant4 meeting
- Good speedups (2-3) in volumes with many daughters, no speedup in case of 0-1 daughters!

Trial integration for navigation in G4 is under study.



# Runge Kutta integration

Intertwines

- Vector operations over 6 (x,p) or 8 (x, p, E, t) variables
- calls to field evaluation and force calculation

Using templated 'calls' to inline field methods, all the code can be put into one compilation unit

- Prototype in G4 by Josh Xie (GSoC '14), reused in GeantV

Plan to investigate vectorisation potential for scalar tracks - potential GSoC project in 2018

$$f_1 = f(y_0 + c_1 f_0 s)$$

$$b_2 = a_{20} f_0 + a_{21} f_1$$

$$f_2 = f(y_0 + c_2 f_0 s)$$

$$b_3 = a_{30} f_0 + a_{31} f_1 + a_{32} f_2$$

$$f_3 = f(y_0 + c_3 f_0 s)$$

$$b_4 = a_{40} f_0 + a_{41} f_1 + a_{42} f_2 + a_{43} f_3$$

$$\dots$$

$$y_{\text{end}} = y_0 + s * \square d_i f_i$$

$$y_{\text{error}} = \square (d_i - d_i^*) f_i$$

where 'b<sub>i</sub>' & 'v<sub>i</sub>' vectors of 6-8 values  
 a<sub>ij</sub> are constants of the method  
 f is 'force' = q ( E + q x v )

An aerial view of a city skyline at dusk, with numerous skyscrapers and buildings illuminated by city lights. The sky is dark with some clouds, and the overall scene is dimly lit, emphasizing the lights from the buildings. The text is overlaid on the upper left portion of the image.

**Explore the potential of  
vectors in VecGeom for single  
track.**

**Consider common library for  
Field Propagation (single &  
multiple particles)**