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

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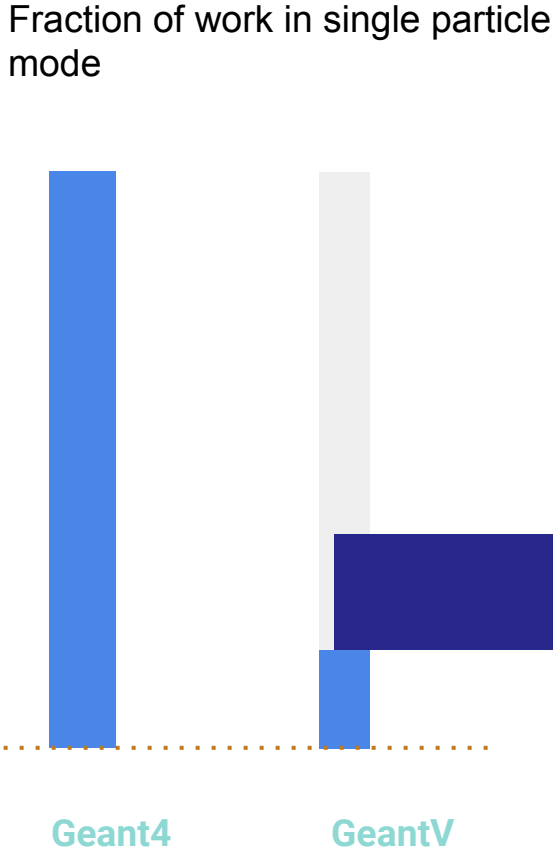
The challenge

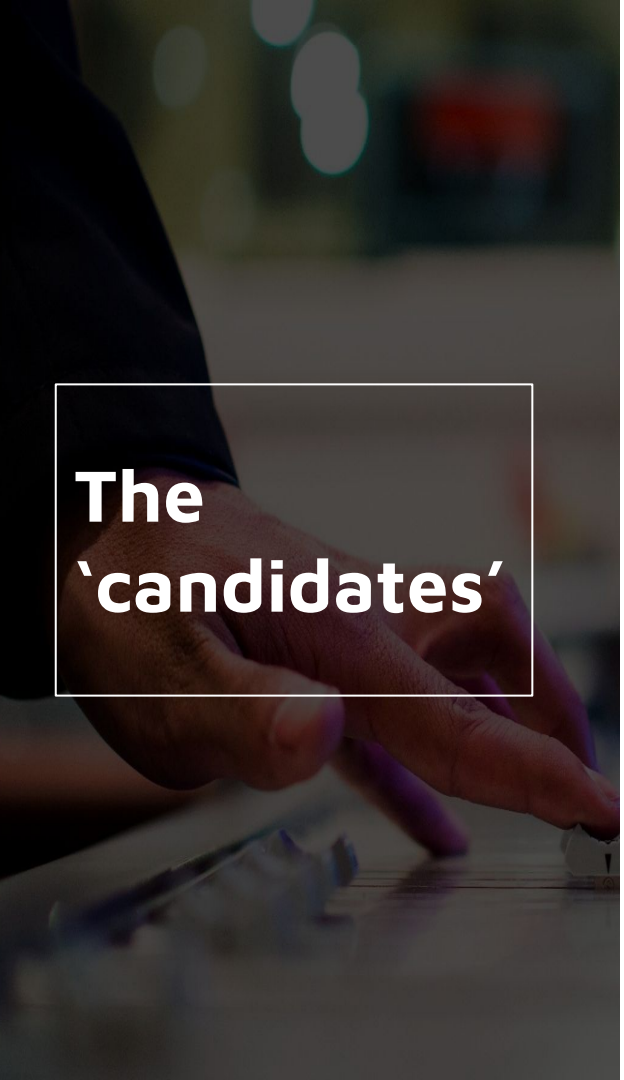
In Geant4 particles are always tracked one at a time.

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)



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

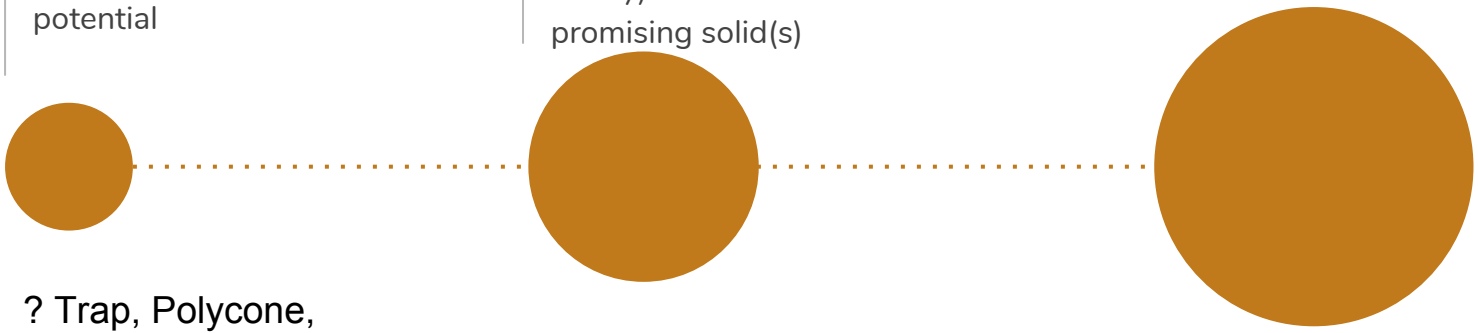
Identify solids with most vectorisation potential

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



? Trap, Polycone, Polygon?

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

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

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

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

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

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

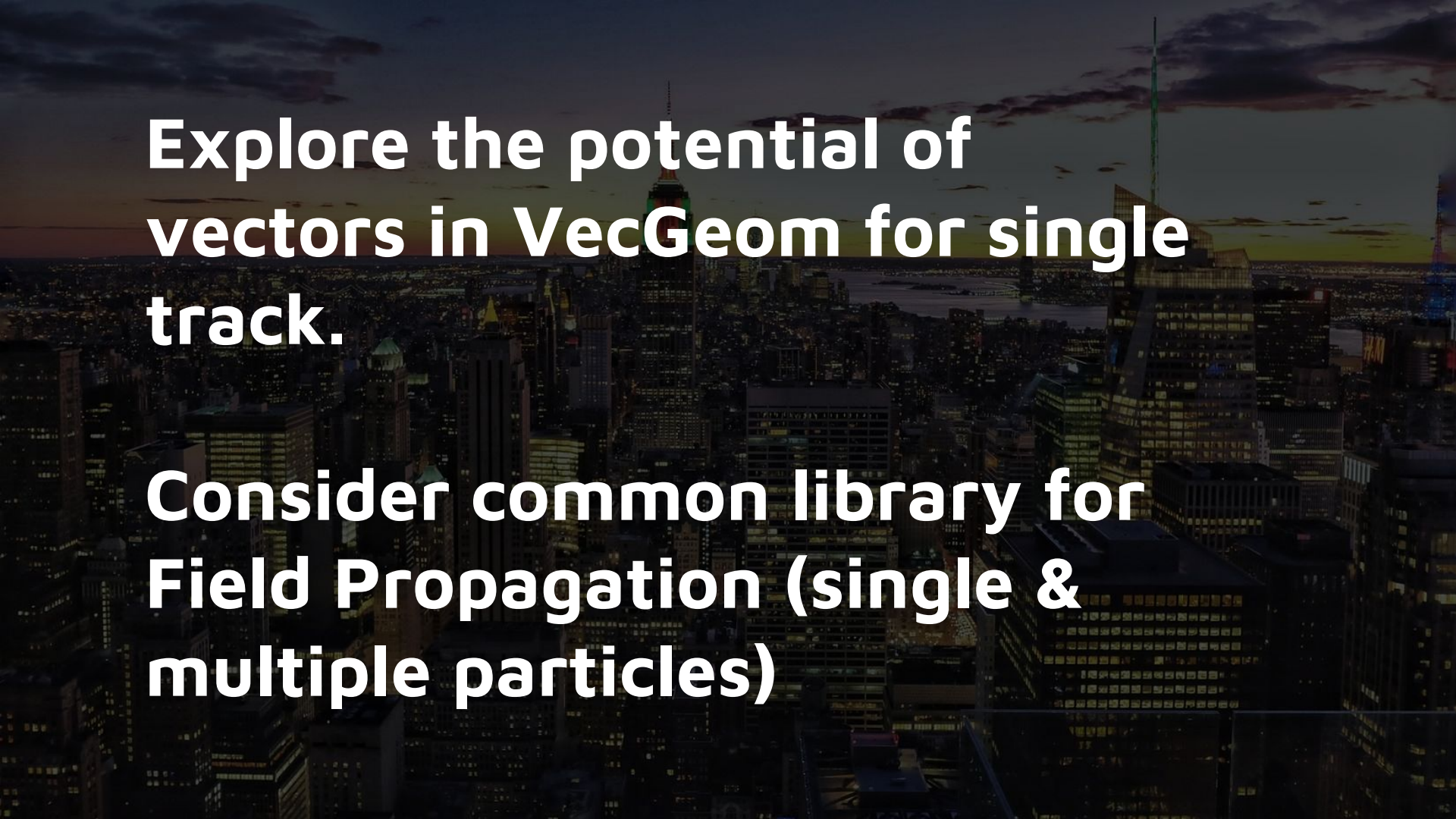
$b_4 = a_{40} f_0 + a_{41} f_1 + a_{42} f_2 + a_{43} f_3$

….

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

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

where ‘b_i’ & ‘v_i’ vectors of 6-8 values
a_{ij} are constants of the method
f is ‘force’ = q (E + q x v)


Explore the potential of vectors in VecGeom for single track.
Consider common library for Field Propagation (single & multiple particles)