Vertex reconstruction in scintillator

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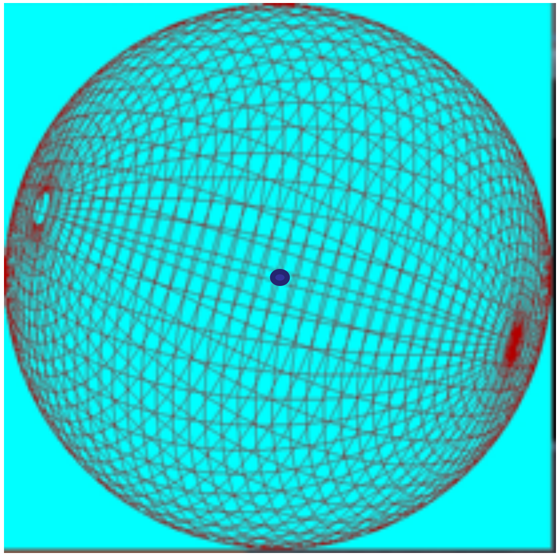
Outline

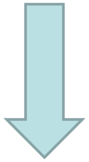
- Introduction of project
- Monte Carlo Simulation
- Vertex reconstruction

Introduction

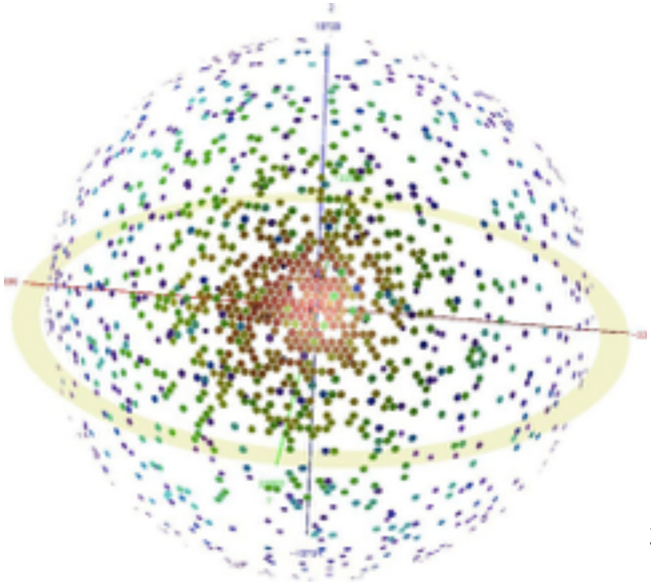
Solar neutrino detector

- Sphere r = 5 m
- Liquid scintillator
- PMTs





reconstruction algorithm for the position of the event vertex from the information extracted from the position and arrival time pattern



Monte Carlo simulation

Photon class

- Each photon is defined with a position of emission, a direction of propagation and a time of emission.

Event class

- Assuming they are point-like, an event is defined by its energy and its true position.
- Attributes of this class are the collection of photons and the collection of hits. Each hit consists of 3 spatial coordinates and the time of arrival.

Monte Carlo simulation

Physics class - Generation

- Takes event as an input, the first method is used to generate the photons.
- The number of photons is defined by the energy of the event and the light yield of the scintillator (600 photons per MeV).
- They are generated isotropically from the given position of the event.
- To simulate the characteristic of the light emission we generate at a time following an exponential decay (time constant 3 ns). Due to the deadline we set this emission time at 0 for all photons simplifying the problem drastically.

Monte Carlo simulation

Physics class - Propagation

- Takes also an event as an input.
- For each generated photon in the photon collection we compute the position of the hit on a sphere of 5m diameter.
- We make the reasonable assumptions that we have perfect transparency, infinite granularity, 100% photodetection probability and no light scattering.

Monte Carlo simulation

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Monte Carlo simulation

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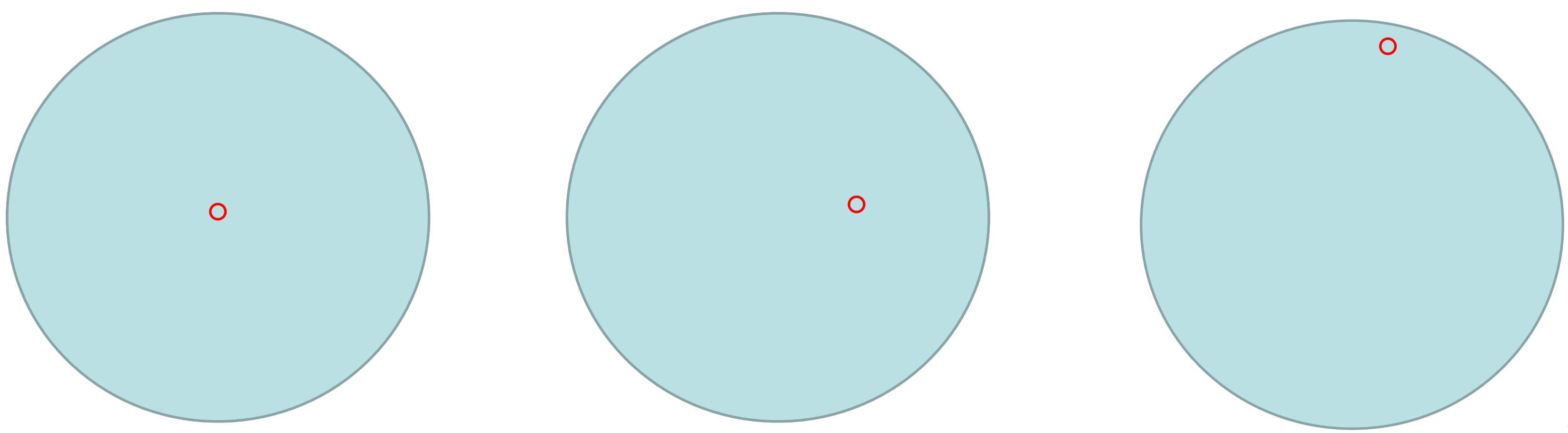
- The registered hit position and time of arrival are then registered and passed to our vertex reconstruction program.

Generated events

For all the photons collected:

- Cartesian coordinates
- Spherical coordinates
- Arrival time on the sphere surface

Three situations

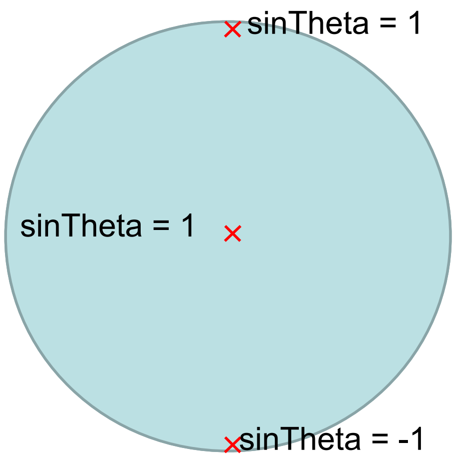


a) P(0,0,0) b) P(1,0,3) c) P(0,4.75,0)

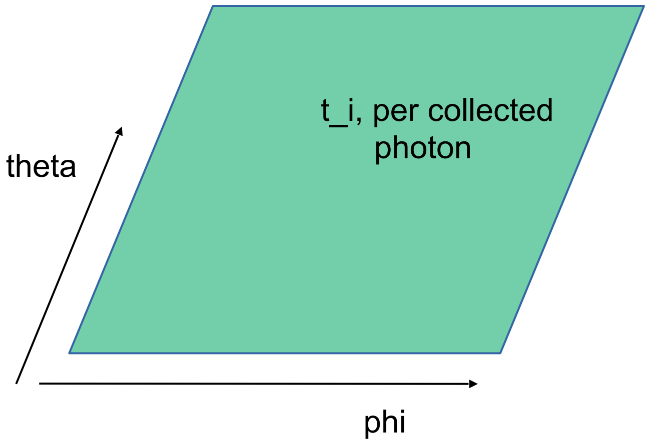
Hit maps and arrival time

Hit maps

- phi:sinTheta

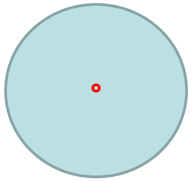


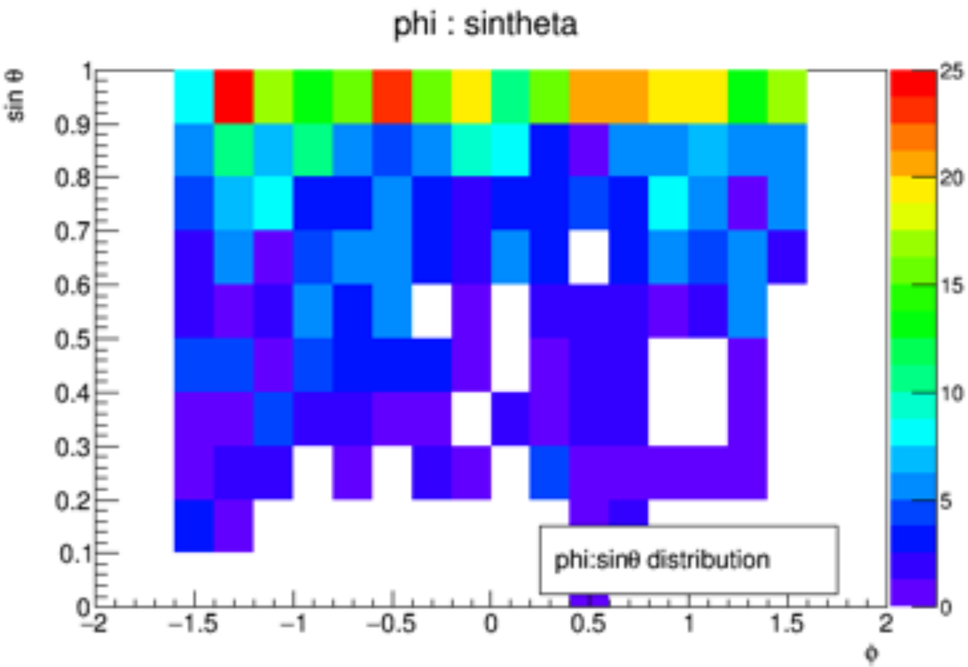
photons arrival time in the (phi,theta) plane

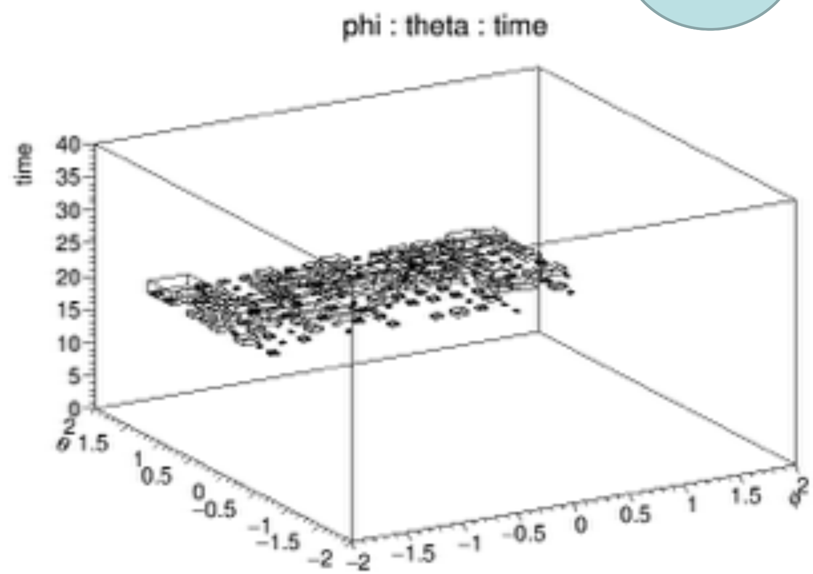


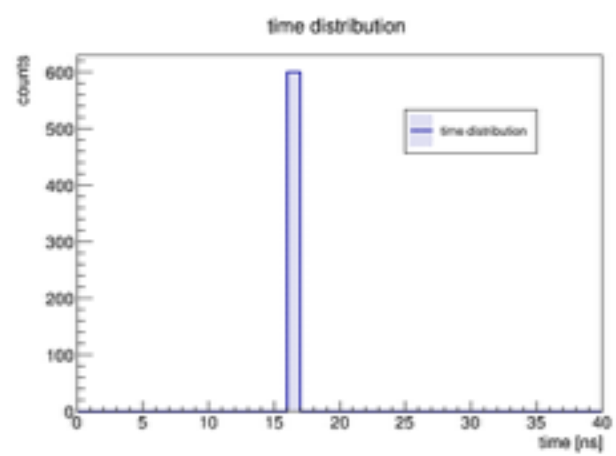
Generated events

a) P(0,0,0)



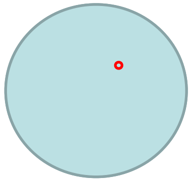


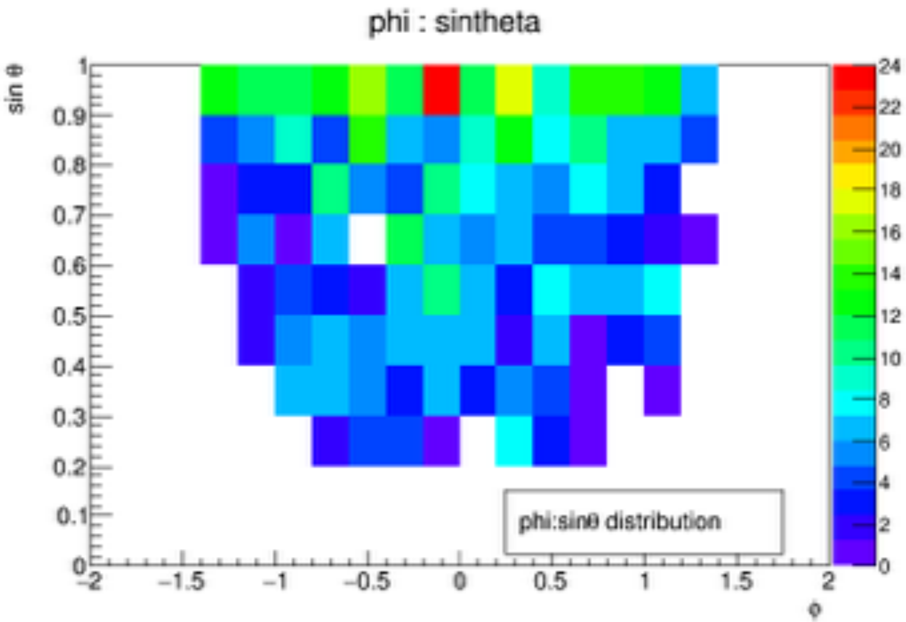


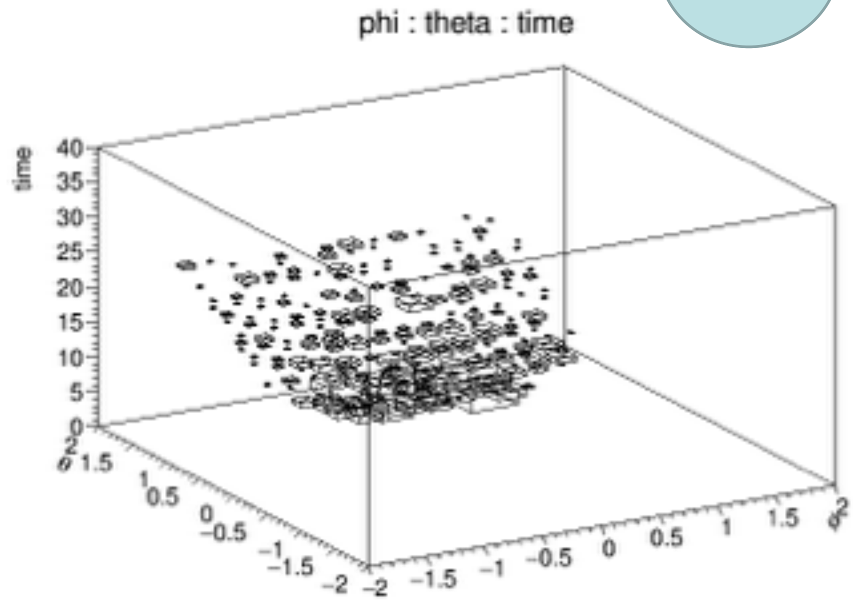


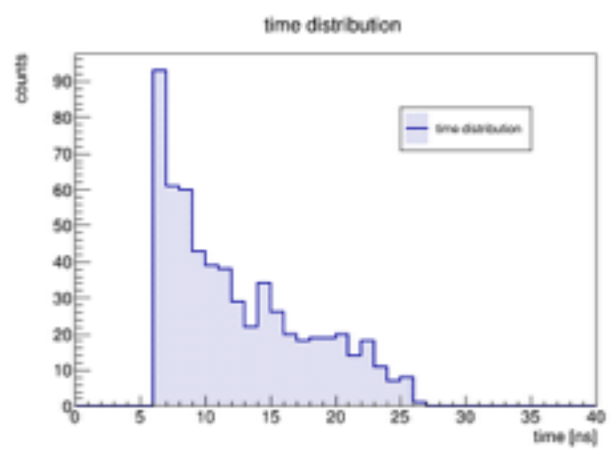
Generated events

b) P(1,0,3)



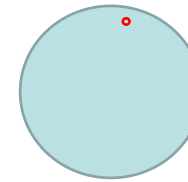


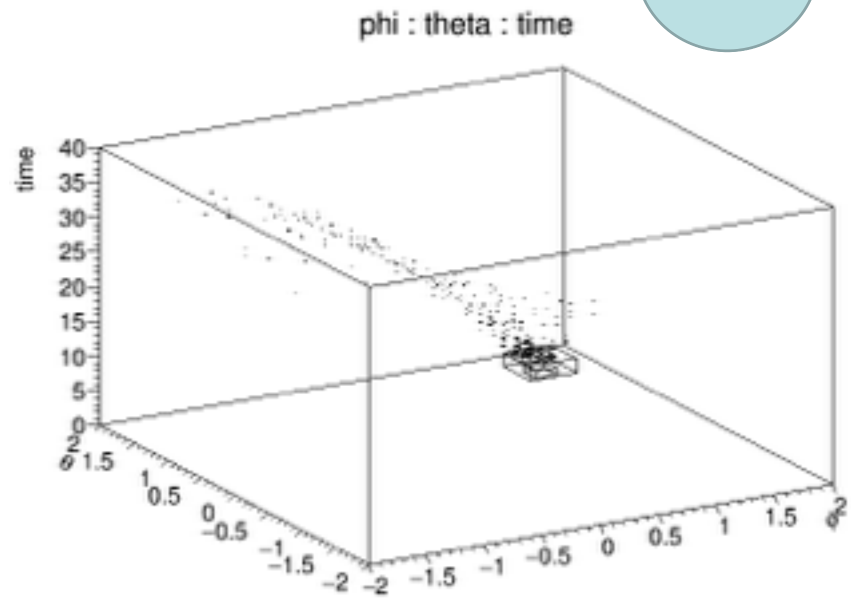


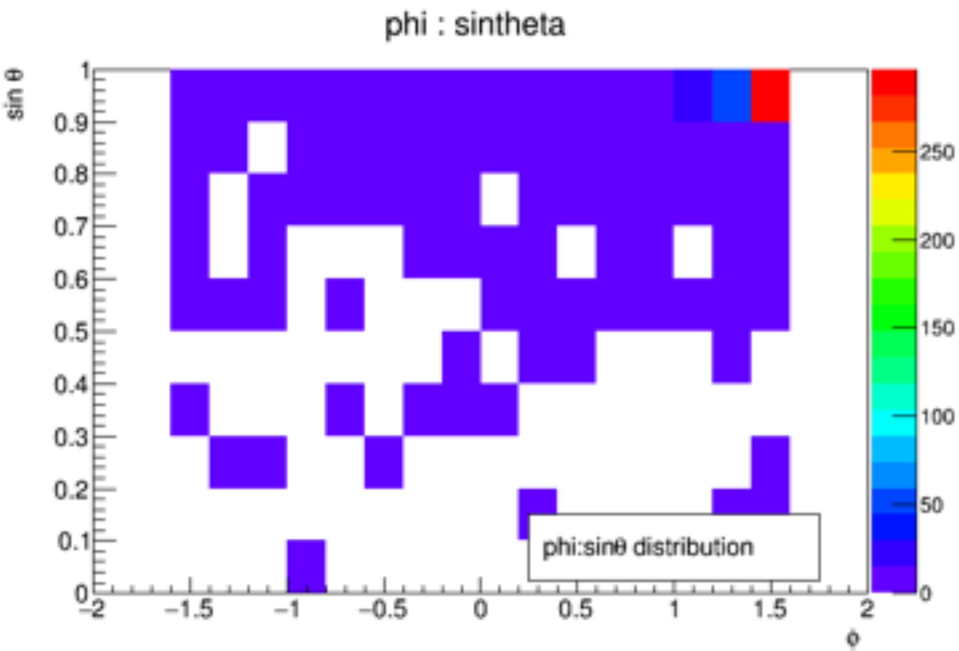


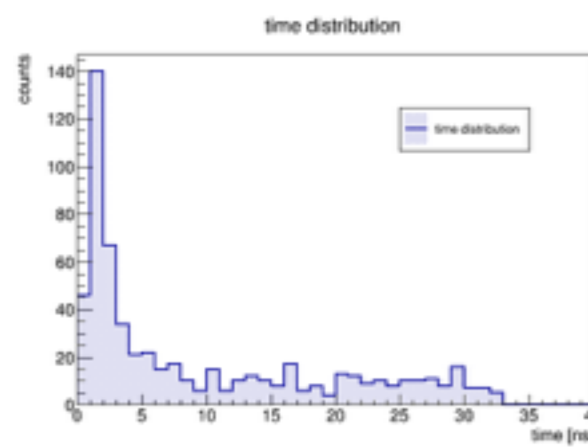
Generated events

c) P(0,4.75,0)





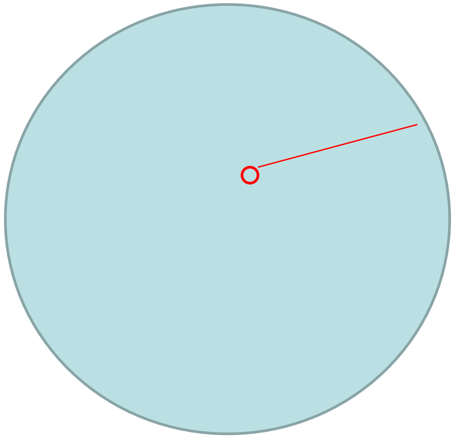




Vertex reconstruction

Algorithm principle

- When particles like e+,e- or γ deposit energy in liquid scintillator , definite the residual time:



$$t_{i,res} = t_i - tof - t_0$$

where:

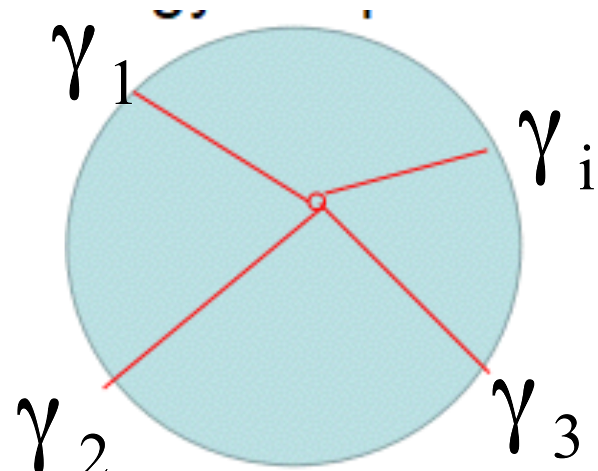
t_i :first hit time of each PMT

t_{tof}: the time of flight for scintillator photon

t_0 : real time of an event, but in this project, is should be 0.

Vertex reconstruction

Algorithm principle



- For a certain scanned point $\overrightarrow{R_0}$, caculate $\mathrm{t}_{\mathrm{i,res}}$

$$\mathrm{t}_{\mathrm{i},res} = t_i - \frac{n * L\left(\overrightarrow{R_0} - \overrightarrow{R_i}\right)}{c}$$

where n: refractive index of liquid scintillator;

c: light speed in vaccum;

$\overrightarrow{R_\mathrm{i}}$:hit location in the detector, the total number is 600.

and definite the parameter :

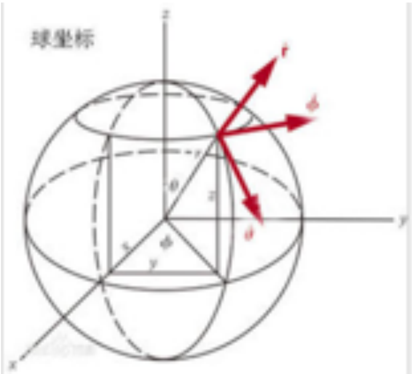
$$F(\overrightarrow{R_0})_{\min} = \sum_{i=600} t_{i,res} * t_{i,res} \Longrightarrow \overrightarrow{R_0}$$

$\overrightarrow{R_0}$ is the event vertex reconstructed by us.

Vertex reconstruction

Algorithm details

- create the cartesian coordinates

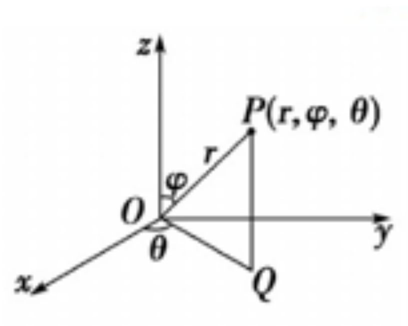


$$\theta \in (0, \pi) \quad \varphi \in (0, 2\pi) \quad r \in (0, 5)$$

$$x = r \sin\theta \cos\varphi$$
$$y = r \sin\theta \sin\varphi$$
$$z = r \cos\theta$$

- set the step for the loop of θ, φ, r, and get $\overrightarrow{R_0}$

$$\theta: \ \pi / 200$$
$$\varphi: \ \pi / 200$$
$$r: \ 5/200$$



Vertex reconstruction

Algorithm Results

reconstruction vertex

true vertex

difference

For only one event:

```
x=-1.55113e-15   y=4.2434e-16    z=-5
x=-1.5576e-15    y=3.99924e-16   z=-5
x=-1.56369e-15   y=3.75409e-16   z=-5
x=-1.56939e-15   y=3.50801e-16   z=-5
x=-1.57471e-15   y=3.26107e-16   z=-5
x=-1.57964e-15   y=3.01332e-16   z=-5
x=-1.58418e-15   y=2.76483e-16   z=-5
x=-1.58832e-15   y=2.51566e-16   z=-5
x=-1.59208e-15   y=2.26586e-16   z=-5
x=-1.59544e-15   y=2.01551e-16   z=-5
x=-1.59841e-15   y=1.76466e-16   z=-5
x=-1.60099e-15   y=1.51338e-16   z=-5
x=-1.60317e-15   y=1.26172e-16   z=-5
x=-1.60495e-15   y=1.00975e-16   z=-5
x=-1.60634e-15   y=7.5753e-17    z=-5
x=-1.60733e-15   y=5.05124e-17   z=-5
x=-1.60792e-15   y=2.52593e-17   z=-5
x=-1.60812e-15   y=-1.03442e-30  z=-5
X=0
Y=0
Z=0
root [1]
```

$\boxed{(0,0,0)}$ → $\boxed{(0,0,0)}$ → 0m

```
x=-1.56939e-15   y=3.50801e-16   z=-5
x=-1.57471e-15   y=3.26107e-16   z=-5
x=-1.57964e-15   y=3.01332e-16   z=-5
x=-1.58418e-15   y=2.76483e-16   z=-5
x=-1.58832e-15   y=2.51566e-16   z=-5
x=-1.59208e-15   y=2.26586e-16   z=-5
x=-1.59544e-15   y=2.01551e-16   z=-5
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x=-1.60634e-15   y=7.5753e-17    z=-5
x=-1.60733e-15   y=5.05124e-17   z=-5
x=-1.60792e-15   y=2.52593e-17   z=-5
x=-1.60812e-15   y=-1.03442e-30  z=-5
X=1.02034
Y=6.56333e-16
Z=2.98017
root [1]
```

$\boxed{(1.02, 6.5E-16, 2.98)}$ → $\boxed{(1,0,3)}$ → 0.0284m

```
x=-1.54427e-15   y=4.48652e-16   z=-5
x=-1.55113e-15   y=4.2434e-16    z=-5
x=-1.5576e-15    y=3.99924e-16   z=-5
x=-1.56369e-15   y=3.75409e-16   z=-5
x=-1.56939e-15   y=3.50801e-16   z=-5
x=-1.57471e-15   y=3.26107e-16   z=-5
x=-1.57964e-15   y=3.01332e-16   z=-5
x=-1.58418e-15   y=2.76483e-16   z=-5
x=-1.58832e-15   y=2.51566e-16   z=-5
x=-1.59208e-15   y=2.26586e-16   z=-5
x=-1.59544e-15   y=2.01551e-16   z=-5
x=-1.59841e-15   y=1.76466e-16   z=-5
x=-1.60099e-15   y=1.51338e-16   z=-5
x=-1.60317e-15   y=1.26172e-16   z=-5
x=-1.60495e-15   y=1.00975e-16   z=-5
x=-1.60634e-15   y=7.5753e-17    z=-5
x=-1.60733e-15   y=5.05124e-17   z=-5
x=-1.60792e-15   y=2.52593e-17   z=-5
x=-1.60812e-15   y=-1.03442e-30  z=-5
X=-7.63858e-16
Z=-7.63858e-16
root [1]
```

$\boxed{(-7.64E-16, 4.75, -7.64E-16)}$ → $\boxed{(0, 4.75, 0)}$ → 1.08×10^{-15}