Muon simulation

```
function tout = Mymuonsim(timeres)
n=1000000; %no of muons
c = 3e10; %cm/s speed of muons between scintillators
%v = 2e10; % time for signal to traverse optical fibres. Not c, but assumed
for now.
 %choose time resolution to smear results by.

X=zeros(1,n);
Y=zeros(1,n);
Z=zeros(1,n);
x=zeros(1,n);
y=zeros(1,n);
z=zeros(1,n);
u=zeros(1,n);
v=zeros(1,n);
w=zeros(1,n);
U=zeros(1,n);
V=zeros(1,n);
%starting point, top scintillator.
RR = 25*rand(n,2)-12.5;



%plot(RR(:,1),RR(:,2),'.');

%Need to set radius, so muon is stopped when it hits the next scintillator.
for i=1:n

    %generate random direction
    [x(i),y(i),z(i),u(i),v(i),w(i)]=myspherdist(60.7+13.6,13.6);

    %choose end point.
    X(i) = RR(i,1) + x(i);
    Y(i) = RR(i,2) + y(i);

    U(i) = RR(i,1) + u(i);
    V(i) = RR(i,2) + v(i);

end

%Work out whether end point is outside of base scintillator
%Choose limits between -12.5 and +12.5 on x/y axis.
K=1;

for j=1:n
    if X(j) >= -12.5 && X(j) <= 12.5 && Y(j) >= -12.5 && Y(j) <= 12.5
        K = K+1;
    end
end

A=zeros(1,K);
```

```
B=zeros(1,K);
t_top=zeros(1,K);
t_bot=zeros(1,K);
t_mid=zeros(1,K);
t_flight_tb=zeros(1,K);
t_flight_tm=zeros(1,K);
t_flight_mb=zeros(1,K);
T=zeros(1,K);
T_top_mid=zeros(1,K);
T_mid_bot=zeros(1,K);
Smeared_T_top_mid = zeros(1,K);
Smeared_T_mid_bot = zeros(1,K);
Smeared_T_top_bot = zeros(1,K);

k=1;

for j=1:n

    if X(j) >= -12.5 && X(j) <= 12.5 && Y(j) >= -12.5 && Y(j) <= 12.5

        B(k) = Y(j); %final y-coord on bottom scint
        A(k) = X(j); %final x-coord on bottom scint

        t_top(k) = (12.5 - (X(j)- x(j)))./(2e10);
        t_bot(k) = (12.5 - X(j))./(2e10);
        t_mid(k) = (12.5 - U(j))./(2e10);

        %Calculate distance between initial and final points, then time
        %Need to account for time taken for signals to travel to edge of
scintillator. Choose to go to x = 12.5
        t_flight_tb(k) = (sqrt((x(j)).^2 + (y(j)).^2 + (z(j)).^2))/c;
%Distance between initial and final points, if final still in scint (cm)
        t_flight_tm(k) = (sqrt((u(j)).^2 + (v(j)).^2 + (w(j)).^2))/c;
        t_flight_mb(k) = (sqrt((x(j)-u(j)).^2 + (y(j)-v(j)).^2 + (z(j)-
w(j)).^2))/c;



        T_top_mid(k) = (t_flight_tm(k) + t_top(k) + t_mid(k))*(10.^9);
        T_mid_bot(k) = (t_flight_mb(k) + t_mid(k) + t_bot(k))*(10.^9);
        T(k) = (t_flight_tb(k) + t_bot(k) + t_top(k))*(10.^9);

        Smeared_T_top_mid(k) = normrnd(T_top_mid(k),timeres);
        Smeared_T_mid_bot(k) = normrnd(T_mid_bot(k),timeres);
        Smeared_T_top_bot(k) = normrnd(T(k),timeres);

        k = k+1;
    end
end



 %in ns

%Plot of all final destination
```

```
%plot3(x,y,z,'.')


%plot(A,B,'.')

%Final points within second scintillator


%Plot histogram, find time resolution. BEFORE SMEARING

nbins = 100;

%h1=figure;
histfit(T,nbins);
title('Histogram showing simulated time difference between signals from top
and bottom scintillators');
xlabel('Time difference/ns');
ylabel('No. of events');
%saveas(h1, 'Time_histogram_top_bot.png');
hold off;

%h2=figure;
histfit(T_top_mid,nbins);
title('Histogram showing simulated time difference between signals from top
and middle scintillators');
xlabel('Time difference/ns');
ylabel('No. of events');
%saveas(h2, 'Time_histogram_top_mid.png');
hold off;
%h3=figure;
histfit(T_mid_bot,nbins);
title('Histogram showing simulated time difference between signals from
bottom and middle scintillators');
xlabel('Time difference/ns');
ylabel('No. of events');
%saveas(h3, 'Time_histogram_mid_bot.png');
hold off;

[mu,sigma,muci,sigmaci] = normfit(T); %Fit T to normal distribution
hold off;
[mutm,sigmatm,mucitm,sigmacitm] = normfit(T_top_mid);
hold off;
[mumb,sigmamb,mucimb,sigmacimb] = normfit(T_mid_bot);
hold off;


%disp('Time resolution');
%disp(2.355*sigma) ;
%disp(2.355*sigmatm);
%disp(2.355*sigmamb) ;

%disp('Number of events')
%disp(k) %Number of muons that went through both scintillators
```

```
%Need to produce standard distributions from all these results, and thus
%introduce smearing.

%AFTER SMEARING
%disp('AFTER SMEARING')

nbins = 100;

h4=figure;
histfit(Smeared_T_top_bot,nbins);
title('Histogram showing simulated time difference between signals from top
and bottom scintillators with smear');
xlabel('Time difference/ns');
ylabel('No. of events');
saveas(h4, 'Time_histogram_top_bot_smear.png');
hold off;
h5=figure;
histfit(Smeared_T_top_mid,nbins);
title('Histogram showing simulated time difference between signals from top
and middle scintillators with smear');
xlabel('Time difference/ns');
ylabel('No. of events');
saveas(h5, 'Time_histogram_top_mid_smear.png');
hold off;
h6=figure;
histfit(Smeared_T_mid_bot,nbins);
title('Histogram showing simulated time difference between signals from
bottom and middle scintillators with smear');
xlabel('Time difference/ns');
ylabel('No. of events');
saveas(h6, 'Time_histogram_mid_bot_smear.png');
hold off;

[mus,sigmas,mucis,sigmacis] = normfit(Smeared_T_top_bot); %Fit T to normal
distribution
hold off;
[mutms,sigmatms,mucitms,sigmacitms] = normfit(Smeared_T_top_mid);
hold off;
[mumbs,sigmambs,mucimbs,sigmacimbs] = normfit(Smeared_T_mid_bot);
hold off;


tout = 2.355*sigma;

%disp('Time resolution')
%disp('top bottom ')
%disp(2.355*sigmas)
%disp('top middle')
%disp(2.355*sigmatms)
%disp('middle bottom')
%disp(2.355*sigmambs)
end
```

Generate Random Direction

```
function [x,y,z,i,j,k]=myspherdist(a,b)

RR=rand(2,1);


%sqrt from cos^2 distribution
theta=acos((RR(1,:))*2 -1);
phi=2*pi*RR(2,:);
ra=sqrt((a./(cos(theta))).^2);
rb=sqrt((b./(cos(theta))).^2);

x=ra.*sin(theta).*cos(phi);
y=ra.*sin(theta).*sin(phi);
z=a;

i=rb.*sin(theta).*cos(phi);
j=rb.*sin(theta).*sin(phi);
k=b;

%-------------------------------------------------
%h=figure;
%plot3(x,y,z,'b.');
%saveas(h,'Spherical_distribution','png');
%title('Uniform spherical distribution');
%xlabel('x');
%ylabel('y');
%zlabel('z');
%-------------------------------------------------
end
```