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close all;
clear all;

%% create initial parameters
nparts = 10000;
emit_g = 2e-6; % m.rad

nx = 11;
ny = 15;
nz = 1001;

mc2 = 0.511; % MeV/c^2
E = 10; % MeV

c = 299792458;

betax = 10;
betay = 5;
alphax = 1.5;
alphay = -2;

sigz = 0.015; %m
sigpz = 0.01;

freq = 3e9; %Hz
gamma = E/mc2;
beta = sqrt(gamma^2 - 1)/gamma;
vz0 = beta*c;

lambda = vz0/freq;
L = 10*lambda;

%% create particle distribution
Xn = sqrt(emit_g)*randn(1, nparts);
Xpn = sqrt(emit_g)*randn(1, nparts);
Yn = sqrt(emit_g)*randn(1, nparts);
Ypn = sqrt(emit_g)*randn(1, nparts);

z0 = sigz/2*(2*rand(1, nparts) - 1);
dp0 = sigpz*randn(1, nparts);

x0 = sqrt(betax)*Xn;
xp0 = (-alphax*Xn + Xpn)/sqrt(betax);

y0 = sqrt(betay)*Yn;
yp0 = (-alphay*Yn + Ypn)/sqrt(betay);

figure();
subplot(2,2,1);
plot(Xn, Xpn, '.b');
axis equal;
subplot(2,2,2);

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plot(x0, xp0, '.r');
subplot(2,2,3);
plot(Yn, Ypn, '.b');
axis equal;
subplot(2,2,4);
plot(y0, yp0, '.r');

%% create field map
E_field = zeros(ny, nx, nz);

xg = linspace(-3e-1, 3e-1, nx);
yg = linspace(-3e-1, 3e-1, ny);
zg = linspace(0, L, nz);

for i = 1 : nz
    E_field(:, :, i) = 10*sin(zg(i)*2*pi/lambda);
end

%% integrate our trajectories through our field map
dt = (zg(2) - zg(1))/vz0/2;

p0 = sqrt(E^2 - (mc2)^2);

pin = p0*(1 + dp0);
ptemp = pin;
ztemp = z0;
t = 0;

x = x0;
xp = xp0;

y = y0;
yp = yp0;

while(min(ztemp) < L)
    vz1 = ptemp*c./sqrt(ptemp.^2 + mc2^2);

    p = ptemp + vz1*dt.*interp3(xg, yg, zg, E_field, x, y, ztemp,
'linear', 0)*imag(exp(1i*2*pi*freq*t));

    t = t + dt;

    vz2 = p*c./sqrt(p.^2 + mc2^2);

    xptemp = xp.*ptemp./p;
    yptemp = yp.*ptemp./p;

    dz = (vz1 + vz2)/2*dt;

    x = x + (xp + xptemp)/2.*dz;
    y = y + (yp + yptemp)/2.*dz;
    z = ztemp + (vz1 + vz2)/2*dt;
end

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    xp = xptemp;  
    yp = yptemp;  
  
    ztemp = z;  
    ptemp = p;  
end  
  
figure();  
subplot(2,2,1);  
plot(x0, xp0, '.b', x, xp, '.r');  
subplot(2,2,2);  
plot(y0, yp0, '.b', y, yp, '.r');  
subplot(2,2,3);  
plot(z0, pin, '.b', z-L-sigz/2, p, '.r');
```