Contents

Post-analysis for ELENA B-train data acquisition during both acceleration and deceleration

by Christian Grech (TE-MSC-MM) v2.0 28.09.2018 The script recognizes .mat files recorded using MATLAB 2014/15 in CCM (ELENA_Btrain_acq.m and myCallback.m under /nfs/cs-ccr-nfs6/vol28/u1/elenaop/chgrech/ELENA_qualitative). The mat files consists of B-train signals from C1 and C2 systems (bdot included), the marker times, marker signals and possibly the current from the Sampler. The files are produced separately for each cycle, and this script takes care of skipped cycles in the numbering of files.

```
% The script outputs all performance measurements possible to be measured.
% Make sure that cycle parameters are set accordingly. There are two
% options for cycles measured.
```

Close and clear all previous data

```
clear all;
close all;
```

Constants

```
numberOfCyclesStat = 1999;
                                                    % Number of cycles recorded
numberOfMarkers = 15;
                                                  % Number of cycles recorded
 number_recorded = 0;
skippedData = 2;
                                                        % Iterations skipped due to 'incorrect' data
n =100;
                                                               % Downsampling constant for plotting large number of iterations
oper = 'OP_HMMD1';
spare = 'SP_HMMD1';
marker_times = 'MarkerTime_PBMD1';
curr = 'current';
marker = 'Marker';
iter = [];
```

Define cycle parameters

```
Fs=1000;
                                                                % FESA Sampling freq
I_drift = 5.4e-4;
                                                               % in A/s
signal = 0;
                                                                 % 1 if HMMD1/PBMD1 cycle or 0 is PBMD2 cycle
    if signal == 1
        cyclename = 'PBMD2';    % Antiproton cycle deceleration
        injection = 2727;
                                                           % time in ms
        extraction = 31000;
        fieldCheckAtD1 = 3350;
        fieldCheckAtD2 = 3650;
        fieldCheckAtD1e = 31000;
        fieldCheckAtD2e = 34000;
        dBdI_inj = 3598/275.946;
        dBdI_ex = 493/37.132;
                                                       % in G/A
        Marker_fraction_plot = 10;
        stable_time = 300;
    elseif signal == 0
        cyclename = 'HMMD1';   % GBAR_100KeV_SHORT_CYCLE
        injection = 1029;
        extraction = 1229;
        fieldCheckAtD1 = 1000;
        fieldCheckAtD2 = 1090;
        fieldCheckAtD1e = 1500;
        fieldCheckAtD2e = 1700;
        dBdI_inj = 454.765/34.79;
        dBdI_ex = 493.2/37.752;
        Marker_fraction_plot = 6;
        stable_time = 90;
     elseif signal == -1
        cyclename = 'PMD2';  % Proton test cycle
        injection = 1029;
        extraction = 1229;
        fieldCheckAtD1 = 890;
        fieldCheckAtD2 = 1090;
        fieldCheckAtD1e = 1600;
```

```
        fieldCheckAtD2e = 1800;
        dBdI_inj = 454.765/34.79;
        dBdI_ex = 493.2/37.752;
        Marker_fraction_plot = 6;
        stable_time = 200;
      elseif signal == 2
        cyclename = 'PBMD1';  % Accelerating test cycle
        injection = 1029;
        extraction = 3138;
        fieldCheckAtD1 = 890;
        fieldCheckAtD2 = 1090;
        fieldCheckAtD1e = 3138;
        fieldCheckAtD2e = 5000;
        dBdI_inj = 454.765/34.79;
        dBdI_ex = 493.2/37.752;
        Marker_fraction_plot = 6;
        stable_time = 200;
    end

id = 'MATLAB:colon:nonIntegerIndex';
warning('off',id)
k = 0;
```

Quality of B-train signals

```
for i = 1:numberOfCyclesStat
     filename2 = sprintf('%s_%d.mat',oper,i+skippedData);
             % Load files
     filename3 = sprintf('%s_%d.mat',spare,i+skippedData);
     filename6 = sprintf('%s_%d.mat',marker_times,i+skippedData+1);
                 % MarkerTime_
         if signal ==0
                filename4 = sprintf('%s_%d.mat',curr,i+skippedData);
         end

    if exist(strcat(pwd,'\data1\',filename2), 'file' ) == 2
                               % Check if file exists, else skip
             number_recorded = number_recorded+1;
            load(strcat(pwd,'\data1\',filename2));
             load(strcat(pwd,'\data1\',filename3));
             load(strcat(pwd,'\data1\',filename6));
                      if signal ==1
                                load(strcat(pwd,'\data1\',filename4));
                                curr_(:,1) = I_sam(1:10:end);
                      end;

             timeNewBtrainOp = linspace(0, length(OP_signals(:,1))/1000,  length(OP_signals(:,1)));
             newBtrainOp =  double(OP_signals(:,1));
             timeNewBtrainSp = linspace(0, length(SP_signals(:,1))/1000,  length(SP_signals(:,1)));
             newBtrainSp = double(SP_signals(:,1));

% MarkerCTime values
            M1markerC1(i) = Check_signals(1);
            M1markerC2(i) = Check_signals(2);
            M2markerC1(i) = Check_signals(3);
            M2markerC2(i) = Check_signals(4);

 % Bdot signals
            newBdotOp = OP_signals(:,2);
            BdotC1(i) = max(abs(newBdotOp));
            newBdotSp = SP_signals(:,2);
            BdotC2(i) = max(abs(newBdotSp));

 % DeltaC1C1 in Gauss
            DeltaC1C2_inj(i) = newBtrainOp(injection)-newBtrainSp(injection);
            DeltaC1C2_ex(i) = newBtrainOp(extraction)-newBtrainSp(extraction);

 % Drift calculation
             DriftC1(i) = ((newBtrainOp(fieldCheckAtD2)- newBtrainOp(fieldCheckAtD1))/((fieldCheckAtD2/1000)-(fieldCheckAtD1/1000)))-(dBdI_inj*
I_drift);
             DriftC2(i) = ((newBtrainSp(fieldCheckAtD2)- newBtrainSp(fieldCheckAtD1))/((fieldCheckAtD2/1000)-(fieldCheckAtD1/1000)))-(dBdI_inj*
I_drift);
             DriftC1ex(i) = ((newBtrainOp(fieldCheckAtD2e)- newBtrainOp(fieldCheckAtD1e))/((fieldCheckAtD2e/1000)-(fieldCheckAtD1e/1000)))-(dBd
I_ex*I_drift);
             DriftC2ex(i) = ((newBtrainSp(fieldCheckAtD2e)- newBtrainSp(fieldCheckAtD1e))/((fieldCheckAtD2e/1000)-(fieldCheckAtD1e/1000)))-(dBd
I_ex*I_drift);
            DriftC1_new(i) = driftcalc(newBtrainOp, fieldCheckAtD2, fieldCheckAtD1, dBdI_inj, I_drift);
            DriftC2_new(i) = driftcalc(newBtrainSp, fieldCheckAtD2, fieldCheckAtD1, dBdI_inj, I_drift);
            DriftC1ex_new(i) = driftcalc(newBtrainOp, fieldCheckAtD2e, fieldCheckAtD1e, dBdI_ex, I_drift);
            DriftC2ex_new(i) = driftcalc(newBtrainSp, fieldCheckAtD2e, fieldCheckAtD1e, dBdI_ex, I_drift);

 % Stability
            for j = 1:stable_time
                stable_rmsC1(i,j) = (newBtrainOp((fieldCheckAtD1+j))-newBtrainOp(fieldCheckAtD1)-(DriftC1(i)*(j/1000)));
                stable_rmsC2(i,j) = ((newBtrainSp((fieldCheckAtD1+j))-newBtrainSp(fieldCheckAtD1)-(DriftC2(i)*(j/1000))));
                stable_rmsC1ex(i,j) = (newBtrainOp((fieldCheckAtD1e+j))-newBtrainOp(fieldCheckAtD1e)-(DriftC1ex(i)*(j/1000)));
                stable_rmsC2ex(i,j) = ((newBtrainSp((fieldCheckAtD1e+j))-newBtrainSp(fieldCheckAtD1e)-(DriftC2ex(i)*(j/1000))));
            end;

            stab_rmsC1(i) = std(stable_rmsC1(i,:));
            stab_rmsC2(i) = std(stable_rmsC2(i,:));
            stab_rmsC1ex(i) = std(stable_rmsC1ex(i,:));
            stab_rmsC2ex(i) = std(stable_rmsC2ex(i,:));
            pp_rmsC1(i) = max(stable_rmsC1(i,:))-min(stable_rmsC1(i,:));
            pp_rmsC2(i) = max(stable_rmsC2(i,:))-min(stable_rmsC2(i,:));
            pp_rmsC1ex(i) = max(stable_rmsC1ex(i,:))-min(stable_rmsC1ex(i,:));
```

```
            pp_rmsC2ex(i) = max(stable_rmsC2ex(i,:))-min(stable_rmsC2ex(i,:));

 % Repeatability at injection and Extraction
            RepC1inj(i) = newBtrainOp(injection);
            RepC2inj(i) = newBtrainSp(injection);
            RepC1ex(i) = newBtrainOp(extraction);
            RepC2ex(i) = newBtrainSp(extraction);

% FFT calculation
            fft_C1(i) = fftnew(Fs, length(newBtrainOp), newBtrainOp, 200);
            fft_C2(i) = fftnew(Fs, length(newBtrainSp), newBtrainSp, 200);
            fft_C1_full(i,:) = fftsig(Fs, length(newBtrainOp), newBtrainOp, 200);
            fft_C2_full(i,:) = fftsig(Fs, length(newBtrainSp), newBtrainSp, 200);
            fft_C1_Bdot(i) = fftnew(Fs, length(newBdotOp), newBdotOp, 200);
            fft_C2_Bdot(i) = fftnew(Fs, length(newBdotSp),newBdotSp, 200);
            disp(strcat('Data calculation ongoing...',num2str(i/(numberOfCyclesStat)*100,'%6.2f'),'%'))  %update the loading bar
     else
                k=k+1;
                disp(strcat('No file for iteration...',num2str(i-1)))
                iter(k) = i-k+1;
       end
end
         disp(strcat('Number of B-train signals recorded...',num2str(number_recorded)))
         figure; movegui(gcf,'northeast'); plot( timeNewBtrainOp,  newBtrainOp/10, 'k', 'LineWidth', 1.5); hold on;
%          plot(  injection/1000, newBtrainOp(injection)/10, 'r+', extraction/1000,  newBtrainOp(extraction)/10, 'g+');
         plot(M1markerC1(9), newBtrainOp(round(M1markerC1(9)*1000))/10, 'bx', M2markerC1(9), newBtrainOp(round(M2markerC1(9)*1000))/10, 'rx','L
ineWidth', 1.5);  hold on;
         ylabel('$\bar{B}$ [mT]', 'interpreter', 'latex');
         xlabel('Time [s]', 'interpreter', 'latex');
         xlim([0 4]);
         xline(injection/1000, 'k--');
         xline(extraction/1000, 'k--');
         legend('B-train signal', 'Low-field marker', 'High-field marker', 'Location','northwest', 'interpreter', 'latex');

         numberofMarkers_recorded = 0;
         j=0;
         figure; movegui(gcf,'southeast');
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Number of B-train signals recorded...1000
```
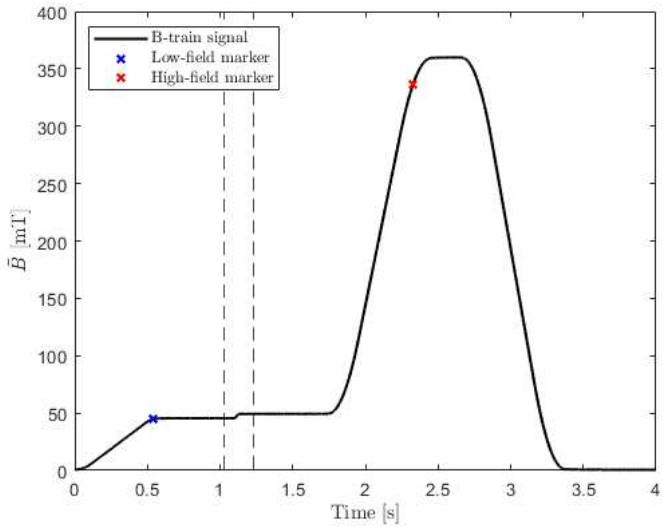
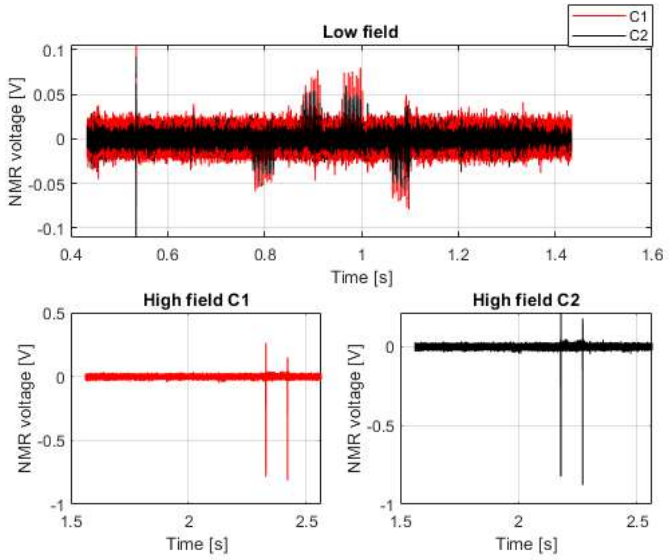



Marker signals

```
for i = 1:numberOfMarkers
        filename5 = sprintf('%s_%d.mat',marker,i+skippedData+10);

if exist(strcat(pwd,'\data1\',filename5), 'file' ) == 2
        load(strcat(pwd,'\data1\',filename5));
        M1C1 = markers(:,1)/25;                                 dVM1C1(i) =max(M1C1)-min(M1C1);
        M2C1 = markers(:,2)/5;                                dVM2C1(i) =max(M2C1)-min(M2C1);                % high field markers are downsample
d by 2 in the ELENA B-train acquisition
        M1C2 = markers(:,3)/25;                                 dVM1C2(i) =max(M1C2)-min(M1C2);
        M2C2 = markers(:,4)/5;                                dVM2C2(i) =max(M2C2)-min(M2C2);                % high field markers are downsample
d by 2 in the ELENA B-train acquisition

        samples = 1:length(M1C1);                                                                   % Graph x-axis for marker signals
        samples2 = 1:length(M1C1);
        numberofMarkers_recorded = numberofMarkers_recorded+1;
        fft_M1C1(i) = fftnew(50e3, length(M1C1), M1C1,10000);
        fft_M2C1(i) = fftnew(50e3, length(M2C1), M2C1, 10000);
        fft_M1C2(i) = fftnew(50e3, length(M1C2), M1C2, 10000);
        fft_M2C2(i) = fftnew(50e3, length(M2C2), M2C2, 10000);

        subplot(2,2,[1 2])
                h1=plot(0.4339+(samples/50000), M1C1,'r', 0.4339+(samples/50000), M1C2, 'k'); hold on; grid on;
                title('Low field');
                xlabel('Time [s]');
                ylabel('NMR voltage [V]');
        subplot(2,2,3)
                plot(1.5627+(samples2/50000), M2C1, 'r'); hold on; grid on;
                title('High field C1');
                xlabel('Time [s]');
                ylabel('NMR voltage [V]');
          subplot(2,2,4)
                plot(1.5627+(samples2/50000), M2C2, 'k'); hold on; grid on;
                title('High field C2');
                xlabel('Time [s]');
                ylabel('NMR voltage [V]');
else
```

```
                j=j+1;
                disp(strcat('No file for iteration...',num2str(i-1)))
                iter_marker(j) = i;
end
end;

                lgd = legend(h1,'C1','C2');
                 set(lgd,'position',[0.82, 0.945, 0.06, 0.03]);                                                    % Adjusting
 legend's position
                disp(strcat('Number of Marker signals recorded...',num2str(numberofMarkers_recorded)))
```

```
Number of Marker signals recorded...15
```



Remove zero elements due to skipped files, and calculate statistics

```
if length(iter) > 0
                for j = 1:length(iter);
                            DriftC1(iter(j)) = [];
                            DriftC2(iter(j))= [];
                            DriftC1ex(iter(j)) =[];
                            DriftC2ex(iter(j)) = [];
                            DriftC1_new(iter(j)) = [];
                            DriftC2_new(iter(j))= [];
                            DriftC1ex_new(iter(j)) =[];
                            DriftC2ex_new(iter(j)) = [];
                            DeltaC1C2_inj(iter(j)) = [];
                            DeltaC1C2_ex(iter(j)) = [];
                            M1markerC1(iter(j)) = [];
                            M1markerC2(iter(j)) = [];
                            M2markerC1(iter(j)) = [];
                            M2markerC2(iter(j)) = [];
                            BdotC1(iter(j)) = [];
                            BdotC2(iter(j)) = [];
                            stab_rmsC1(iter(j)) = [];
                            stab_rmsC2(iter(j)) = [];
                            pp_rmsC1(iter(j)) = [];
                            pp_rmsC2(iter(j)) =[];
                            stab_rmsC1ex(iter(j)) =[];
                            stab_rmsC2ex(iter(j)) = [];
                            pp_rmsC1ex(iter(j)) = [];
                            pp_rmsC2ex(iter(j)) = [];
                            RepC1inj(iter(j)) = [];
                            RepC2inj(iter(j)) = [];
                            RepC1ex(iter(j)) = [];
                            RepC2ex(iter(j)) = [];
                            fft_C1(iter(j)) = [];
                            fft_C2(iter(j)) = [];
                            fft_C1_Bdot(iter(j)) = [];
                            fft_C2_Bdot(iter(j)) = [];
                end;
                dVM1C1 = nonzeros(dVM1C1)';
                dVM2C1 = nonzeros(dVM2C1)';
                dVM1C2 = nonzeros(dVM1C2)';
                dVM2C2 = nonzeros(dVM2C2)';
                fft_M1C1 = nonzeros(fft_M1C1)';
                fft_M1C2 = nonzeros(fft_M1C2)';
                fft_M2C1 = nonzeros(fft_M2C1)';
                fft_M2C2 = nonzeros(fft_M2C2)';
end;

                dVM1C1 = dVM1C1(1:2:end);
                dVM2C1 = dVM2C1(1:2:end-1);
                dVM1C2 = dVM1C2(1:2:end);
                dVM2C2 = dVM2C2(2:2:end);
                fft_M1C1 = fft_M1C1(1:2:end);
                fft_M2C1 = fft_M2C1(1:2:end-1);
                fft_M1C2 = fft_M1C2(1:2:end);
```

```
                fft_M2C2 = fft_M2C2(2:2:end);
```

Averages over N cycles

Bdot average

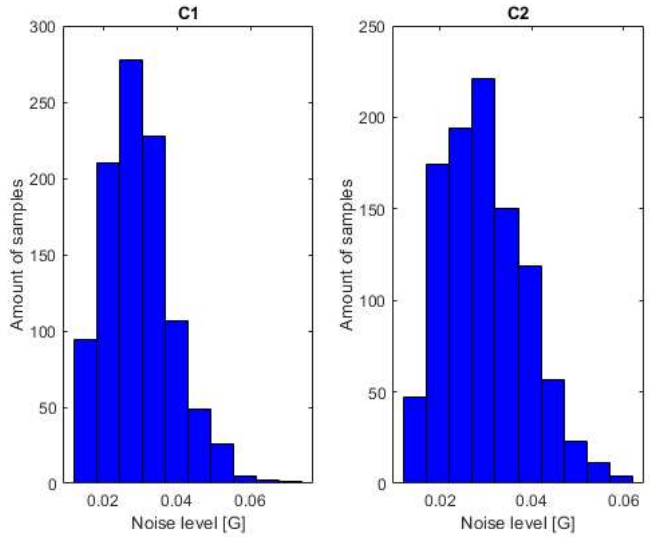
```
                 BdotC1_average = mean(BdotC1);
                 BdotC2_average = mean(BdotC2);

% Difference between measured chains
                DeltaC1C2_average = mean(DeltaC1C2_inj);
                DeltaC1C2e_average = mean(DeltaC1C2_ex);

% Drift
                DriftC1_average = mean(DriftC1);
                DriftC2_average = mean(DriftC2);
                DriftC1e_average = mean(DriftC1ex);
                DriftC2e_average = mean(DriftC2ex);

                DriftC1new_average = mean(DriftC1_new);
                DriftC2new_average = mean(DriftC2_new);
                DriftC1enew_average = mean(DriftC1ex_new);
                DriftC2enew_average = mean(DriftC2ex_new);

% Noise level
                StabC1_average = mean(stab_rmsC1);
                StabC2_average = mean(stab_rmsC2);
                ppC1_average = mean(pp_rmsC1);
                ppC2_average = mean(pp_rmsC2);
                StabC1ex_average = mean(stab_rmsC1ex);
                StabC2ex_average = mean(stab_rmsC2ex);
                ppC1ex_average = mean(pp_rmsC1ex);
                ppC2ex_average = mean(pp_rmsC2ex);

% Marker signal amplitudes
                dVM1C1_average = mean(dVM1C1);
                dVM2C1_average = mean(dVM2C1);
                dVM1C2_average = mean(dVM1C2);
                dVM2C2_average = mean(dVM2C2);
                 dVM1C1_std = std(dVM1C1);
                dVM2C1_std = std(dVM2C1);
                dVM1C2_std =std(dVM1C2);
                dVM2C2_std = std(dVM2C2);
% Markers repeatability in sec
                 M1markerC1_rep = std(M1markerC1);
                 M1markerC2_rep = std(M1markerC2);
                 M2markerC1_rep = std(M2markerC1);
                 M2markerC2_rep = std(M2markerC2);

% Standard deviation time at injection and extraction time
                C1inj_stdev = std(RepC1inj);
                C2inj_stdev = std(RepC2inj);
                C1ex_stdev = std(RepC1ex);
                C2ex_stdev = std(RepC2ex);

% Mean field level at injection and extraction time
                C1_mean =mean(RepC1inj);
                C2_mean = mean(RepC2inj);
                C1ex_mean = mean(RepC1ex);
                C2ex_mean = mean(RepC2ex);

 %FFT
                FFT_C1_mean = mean(fft_C1);
                FFT_C2_mean = mean(fft_C2);
                FFT_C1_Bdot_mean = mean(fft_C1_Bdot);
                FFT_C2_Bdot_mean = mean(fft_C2_Bdot);
                fft_M1C1_mean =mean(fft_M1C1)';
                fft_M1C2_mean =mean(fft_M1C2)';
                fft_M2C1_mean =mean(fft_M2C1)';
                fft_M2C2_mean =mean(fft_M2C2)';
                FFT_C1_std = std(fft_C1);
                FFT_C2_std = std(fft_C2);
                FFT_C1_Bdot_std = std(fft_C1_Bdot);
                FFT_C2_Bdot_std = std(fft_C2_Bdot);
                fft_M1C1_std =std(fft_M1C1)';
                fft_M1C2_std =std(fft_M1C2)';
                fft_M2C1_std =std(fft_M2C1)';
                fft_M2C2_std =std(fft_M2C2)';
```

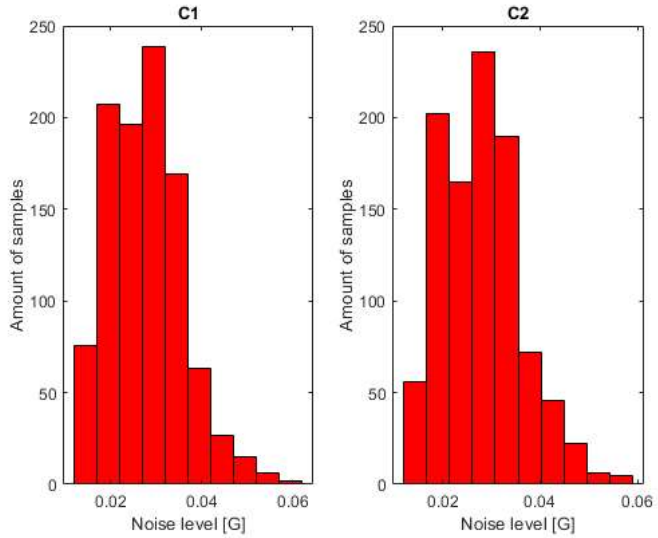
Plots

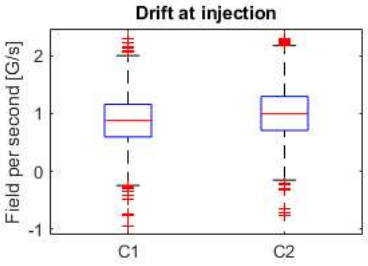
```
figure; movegui(gcf,'northwest');
    nbins = 10;
    title('Noise distribution at injection')
    subplot(1,2,1)
           histogram(stab_rmsC1, nbins, 'FaceColor','b','FaceAlpha',1);
           title('C1')
           xlabel('Noise level [G]');
           ylabel('Amount of samples')
    subplot(1,2,2);
           histogram(stab_rmsC2, nbins, 'FaceColor','b','FaceAlpha',1);
            title('C2')
           xlabel('Noise level [G]');
           ylabel('Amount of samples')
```

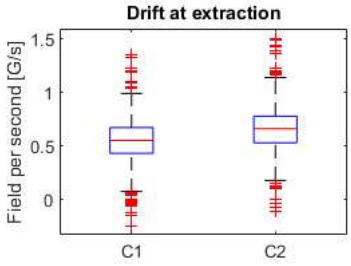
```
figure; movegui(gcf,'southwest');
   nbins = 10;
   title('Noise distribution at extraction')
   subplot(1,2,1)
          histogram(stab_rmsC1ex, nbins, 'FaceColor','r','FaceAlpha',1);
          title('C1')
          xlabel('Noise level [G]');
          ylabel('Amount of samples')
   subplot(1,2,2);
          histogram(stab_rmsC2ex, nbins, 'FaceColor','r','FaceAlpha',1);
           title('C2')
          xlabel('Noise level [G]');
          ylabel('Amount of samples')

    % Quality signals
   figure;  set(gcf, 'Position', [400, 150, 1100, 750])
      subplot(3,3,8)
             boxplot([DeltaC1C2_inj; DeltaC1C2_ex]','Labels',{'Injection','Extraction'});  ylabel('Field [G]'); title('C1 - C2');
       subplot(3,3,1)
             boxplot([DriftC1; DriftC2]','Labels',{'C1', 'C2'});  ylabel('Field per second [G/s]'); title('Drift at injection');
        subplot(3,3,2)
             boxplot([DriftC1ex; DriftC2ex]','Labels',{'C1', 'C2'});  ylabel('Field per second [G/s]'); title('Drift at extraction');
       subplot(3,3,3)
             boxplot([stab_rmsC1; stab_rmsC2]','Labels',{'C1', 'C2'});  ylabel('Stability [G]'); title('RMS Stability at injection');
       subplot(3,3,4)
             boxplot([stab_rmsC1ex; stab_rmsC2ex]','Labels',{'C1', 'C2'});  ylabel('Stability [G]'); title('RMS Stability at extraction');
       subplot(3,3,5)
             boxplot([pp_rmsC1; pp_rmsC2]','Labels',{'C1', 'C2'});  ylabel('Stability [G]'); title('p-p Stability at injection');
       subplot(3,3,6)
             boxplot([pp_rmsC1ex; pp_rmsC2ex]','Labels',{'C1', 'C2'});  ylabel('Stability [G]'); title('p-p Stability at extraction');

  % Other signals
  figure;  set(gcf, 'Position', [600, 0, 800, 550])
       subplot(2,2,1)
             boxplot([dVM1C1; dVM1C2]','Labels',{'C1','C2'});  ylabel('Voltage [V]'); title('Low-field marker amplitude');
       subplot(2,2,2)
             boxplot([dVM2C1; dVM2C2]','Labels',{'C1','C2'}); ylabel('Voltage [V]'); title('High-field marker amplitude');
      subplot(2,2,3.5)
             boxplot([BdotC1; BdotC1]','Labels',{'C1','C2'});  ylabel('Bdot [G/s]'); title('Maximum Bdot value');

   % FFTs
   figure;  set(gcf, 'Position', [600, 600, 800, 550])
            subplot(2,2,1)
             boxplot([fft_C1; fft_C2]','Labels',{'C1','C2'});  ylabel('\Psi(f)'); title('\Psi(f) of B-train');
       subplot(2,2,2)
             boxplot([fft_M1C1; fft_M1C2]','Labels',{'C1','C2'});  ylabel('\Psi(f)'); title('\Psi(f) of Marker 1');
       subplot(2,2,3)
             boxplot([fft_M2C1; fft_M2C2]','Labels',{'C1','C2'});  ylabel('\Psi(f)'); title('\Psi(f) of Marker 2');
      subplot(2,2,4)
             boxplot([fft_C1_Bdot; fft_C2_Bdot]','Labels',{'C1','C2'});  ylabel('\Psi(f)'); title('\Psi(f) of Bdot');


  % Statistical measurements
  figure;  set(gcf, 'Position', [700, 150, 800, 550])
            subplot(2,2,1)
             boxplot([M1markerC1; M1markerC2]','Labels',{'C1','C2'});  ylabel('Time [s]'); title('Low-field marker time');
       subplot(2,2,2)
             boxplot([M2markerC1; M2markerC2]','Labels',{'C1','C2'});  ylabel('Time [s]'); title('High-field marker time');
       subplot(2,2,3)
             boxplot([RepC1inj; RepC2inj]','Labels',{'C1','C2'});  ylabel('Field [G]'); title('Field reproducibility at injection');
      subplot(2,2,4)
             boxplot([RepC1ex; RepC1ex]','Labels',{'C1','C2'});  ylabel('Field [G]'); title('Field reproducibility at extraction');

disp('Data plotting done')  %update the loading bar
```

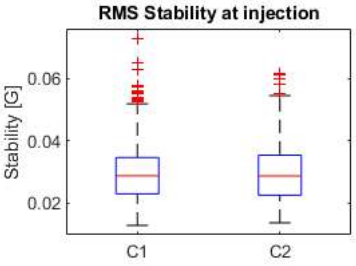
```
Data plotting done
```

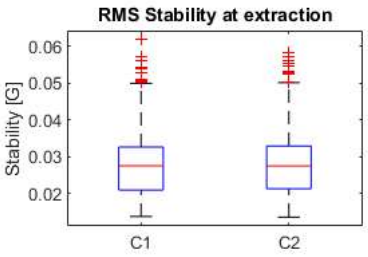

C1
C2
Amount of samples
Noise level [G]
0
50
100
150
200
250
300
0.02
0.04
0.06

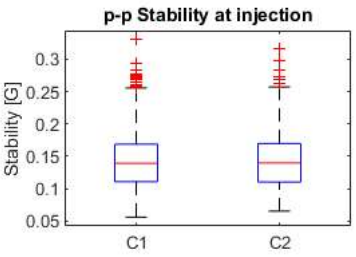

C1
C2
Amount of samples
Noise level [G]
0
50
100
150
200
250
0.02
0.04
0.06

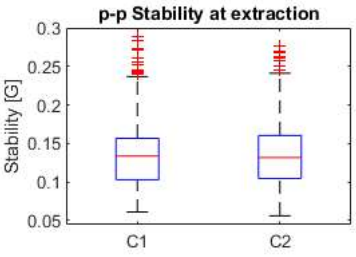

Drift at injection
Field per second [G/s]
2
1
0
-1
C1
C2

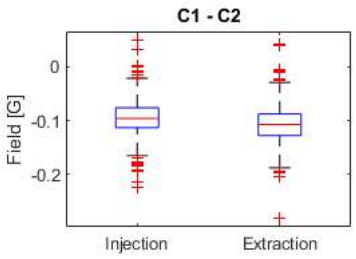

Drift at extraction
Field per second [G/s]
1.5
1
0.5
0
C1
C2

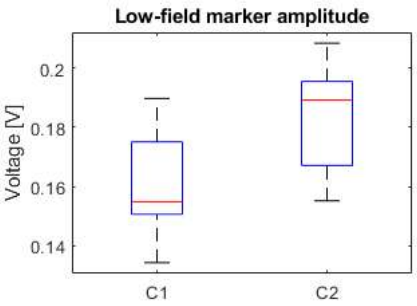

RMS Stability at injection
Stability [G]
0.06
0.04
0.02
C1
C2

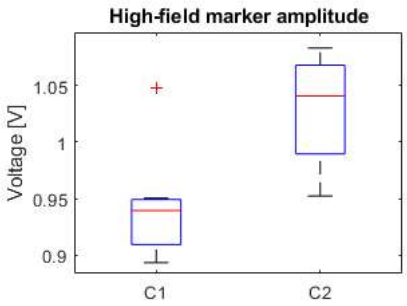

RMS Stability at extraction
Stability [G]
0.06
0.05
0.04
0.03
0.02
C1
C2

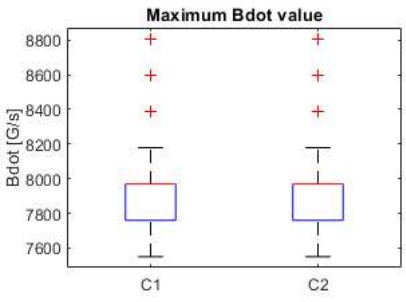

p-p Stability at injection
Stability [G]
0.3
0.25
0.2
0.15
0.1
0.05
C1
C2

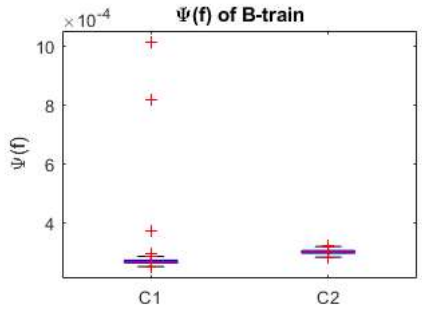

p-p Stability at extraction
Stability [G]
0.3
0.25
0.2
0.15
0.1
0.05
C1
C2

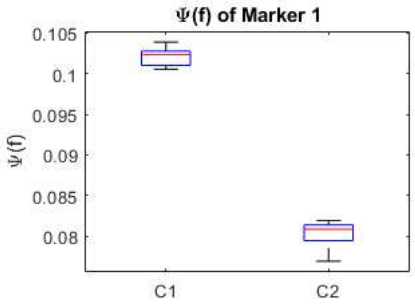

C1 - C2
Field [G]
0
-0.1
-0.2
Injection
Extraction

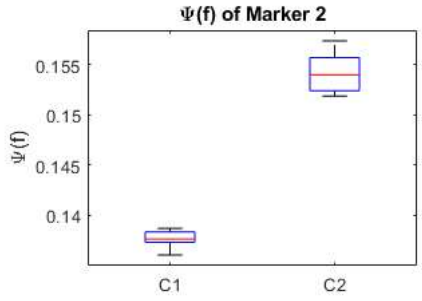

Low-field marker amplitude
Voltage [V]
0.2
0.18
0.16
0.14
C1
C2

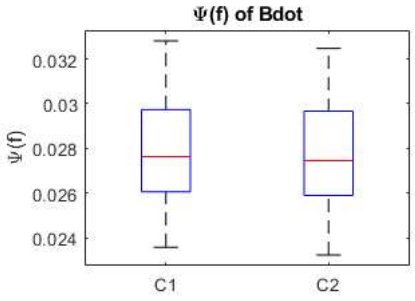

High-field marker amplitude
Voltage [V]
1.05
1
0.95
0.9
C1
C2

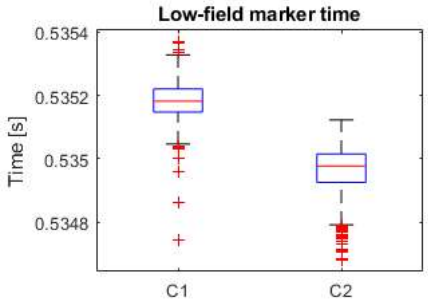

Maximum Bdot value
Bdot [G/s]
8800
8600
8400
8200
8000
7800
7600
C1
C2

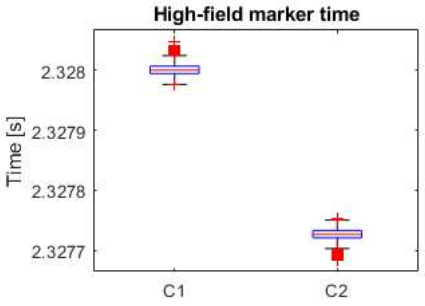


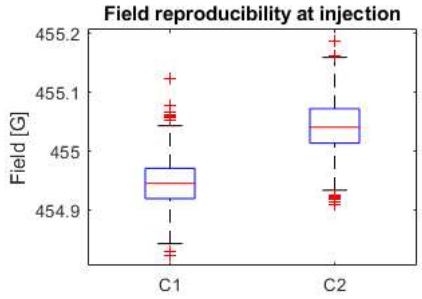


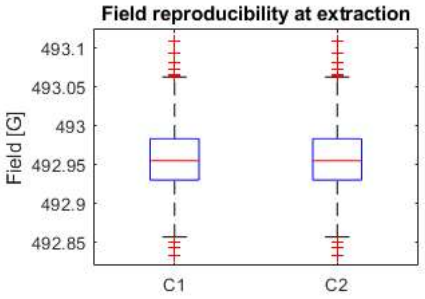












Output indicators

```
disp('---------------------Per-cycle magnetic measurement indicators---------------------');
disp(strcat('B @ injection:..........', num2str(C1_mean), ' G'));
disp(strcat('B @ extraction:..........', num2str( C1ex_mean), ' G'));
disp('--------------------------------Systematic errors-----------------------------------------------');
disp(strcat('Measured chain difference @ injection:.........   ', num2str(DeltaC1C2_average), ' G'));
disp(strcat('Measured chain difference @ extraction:.........   ', num2str(DeltaC1C2e_average), ' G'));
disp('--------------------------------Drift-----------------------------------------------');
disp(strcat('Measured drift C1 @ injection:..........', num2str(DriftC1_average), ' G/s'));
disp(strcat('Measured drift C2 @ injection:..........', num2str( DriftC2_average), ' G/s'));
 disp(strcat('Measured drift C1 @ extraction:..........', num2str(DriftC1e_average), ' G/s'));
disp(strcat('Measured drift C2 @ extraction:..........', num2str( DriftC2e_average), ' G/s'));
 disp('--------------------------------Drift NEW-----------------------------------------------');
disp(strcat('Measured drift C1 @ injection:..........', num2str(DriftC1new_average), ' G/s'));
disp(strcat('Measured drift C2 @ injection:..........', num2str( DriftC2new_average), ' G/s'));
 disp(strcat('Measured drift C1 @ extraction:..........', num2str(DriftC1enew_average), ' G/s'));
disp(strcat('Measured drift C2 @ extraction:..........', num2str( DriftC2enew_average), ' G/s'));
disp('-----------------------------Noise levels-----------------------------------------------');
disp(strcat('Measured noise level C1 @ injection:..........   ', num2str(StabC1_average), ' G'));
disp(strcat('Measured noise level C2 @ injection:..........   ', num2str(StabC2_average), ' G'));
 disp(strcat('Measured noise level C1 @ extraction:..........   ', num2str(StabC1ex_average), ' G'));
disp(strcat('Measured noise level C2 @ extraction:..........   ', num2str(StabC2ex_average), ' G'));
 disp(strcat('Peak-Peak noise level C1 @ injection:..........   ', num2str(ppC1_average), ' G'));
disp(strcat('Peak-Peak noise level C2 @ injection:..........   ', num2str(ppC2_average), ' G'));
```

```
 disp(strcat('Peak-Peak noise level C1 @ extraction:.........   ', num2str(ppC1ex_average), ' G'));
 disp(strcat('Peak-Peak noise level C2 @ extraction:.........   ', num2str(ppC2ex_average), ' G'));
   disp('---------------------------------Bdot signal-----------------------------------------------');
 disp(strcat('Peak Bdot level C1 :.........   ', num2str(BdotC1_average), ' G/s'));
disp(strcat('Peak Bdot level C2 :.........   ', num2str(BdotC2_average), ' G/s'));
 disp('--------------------------------Marker Signals-------------------------------------------');
 disp(strcat('Time harmonic B C1 :.........   ', num2str(FFT_C1_mean), ' ', '+/-', num2str(FFT_C1_std), ' '));
 disp(strcat('Time harmonic B C2 :.........   ', num2str(FFT_C2_mean), ' ', '+/-', num2str(FFT_C2_std), ' '));
 disp(strcat('Time harmonic Bdot C1 :.........   ', num2str(FFT_C1_Bdot_mean), ' ', '+/-', num2str(FFT_C1_Bdot_std), ' '));
 disp(strcat('Time harmonic Bdot C2 :.........   ', num2str(FFT_C2_Bdot_mean), ' ', '+/-', num2str(FFT_C1_Bdot_std), ' '));
  disp(strcat('M1 Voltage C1 :.........   ', num2str(dVM1C1_average), ' V', '+/-', num2str(dVM1C1_std), 'V'));
 disp(strcat('M2 Voltage C1 :.........   ', num2str(dVM2C1_average), ' V', '+/-', num2str(dVM2C1_std), 'V'));
 disp(strcat('M1 Voltage C2 :.........   ', num2str(dVM1C2_average), ' V', '+/-', num2str(dVM1C2_std), 'V'));
 disp(strcat('M2 Voltage C2 :.........   ', num2str(dVM2C2_average), ' V', '+/-', num2str(dVM2C2_std), 'V'));
 disp(strcat('Time harmonic M1 C1 :.........   ', num2str(fft_M1C1_mean), ' ', '+/-', num2str(fft_M1C1_std), ' '));
 disp(strcat('Time harmonic M2 C1 :.........   ', num2str(fft_M2C1_mean), ' ', '+/-', num2str(fft_M2C1_std), ' '));
 disp(strcat('Time harmonic M1 C2 :.........   ', num2str(fft_M1C2_mean), ' ', '+/-', num2str(fft_M1C2_std), ' '));
 disp(strcat('Time harmonic M2 C2 :.........   ', num2str(fft_M2C2_mean), ' ', '+/-', num2str(fft_M2C2_std), ' '));
 disp('----------------------Statistical magnetic measurement indicators------------------');
 disp(strcat('Measured field rep C1 @ injection:.........', num2str(C1inj_stdev),  '  G'));
 disp(strcat('Measured field rep C2 @ injection:.........', num2str(C2inj_stdev),  '  G'));
 disp(strcat('Measured field rep C1 @ extraction:.........', num2str(C1ex_stdev),  '  G'));
 disp(strcat('Measured field rep C2 @ extraction:.........', num2str(C2ex_stdev),  '  G'));
 disp(strcat('Marker jitter C1 @ 450 G, 3400 G:.........', num2str(M1markerC1_rep*1e6), ' us,.........   ', num2str(M2markerC1_rep*1e6), ' us
'));
 disp(strcat('Marker jitter C2 @ 450 G, 3400 G:.........', num2str(M1markerC2_rep*1e6), ' us,.........   ', num2str(M2markerC2_rep*1e6), ' us
'));
 disp('----------------------------------------END-----------------------------------------------');
```

```
 ---------------------Per-cycle magnetic measurement indicators---------------------
 B @ injection:.........454.9457 G
 B @ extraction:.........492.9574 G
 ---------------------------------Systematic errors-----------------------------------------------
 Measured chain difference @ injection:.........-0.09507 G
 Measured chain difference @ extraction:.........-0.10723 G
 ---------------------------------Drift-----------------------------------------------------
 Measured drift C1 @ injection:.........0.8718 G/s
 Measured drift C2 @ injection:.........0.9999 G/s
 Measured drift C1 @ extraction:.........0.54858 G/s
 Measured drift C2 @ extraction:.........0.65819 G/s
 ---------------------------------Drift NEW-------------------------------------------------
 Measured drift C1 @ injection:.........0.00089072 G/s
 Measured drift C2 @ injection:.........0.0010013 G/s
 Measured drift C1 @ extraction:.........0.00055572 G/s
 Measured drift C2 @ extraction:.........0.00066226 G/s
 -------------------------------Noise levels----------------------------------------------
 Measured noise level C1 @ injection:.........0.029556 G
 Measured noise level C2 @ injection:.........0.029677 G
 Measured noise level C1 @ extraction:.........0.027707 G
 Measured noise level C2 @ extraction:.........0.027889 G
 Peak-Peak noise level C1 @ injection:.........0.1426 G
 Peak-Peak noise level C2 @ injection:.........0.14296 G
 Peak-Peak noise level C1 @ extraction:.........0.13441 G
 Peak-Peak noise level C2 @ extraction:.........0.13488 G
 ---------------------------------Bdot signal-----------------------------------------------
 Peak Bdot level C1 :.........7948.208 G/s
 Peak Bdot level C2 :.........7947.1606 G/s
 ---------------------------------Marker Signals--------------------------------------------
 Time harmonic B C1 :.........0.00027025+/-3.0024e-05
 Time harmonic B C2 :.........0.00030149+/-6.6725e-06
 Time harmonic Bdot C1 :.........0.027868+/-0.0020958
 Time harmonic Bdot C2 :.........0.027782+/-0.0020958
 M1 Voltage C1 :.........0.16063 V+/-0.017929V
 M2 Voltage C1 :.........0.94339 V+/-0.050715V
 M1 Voltage C2 :.........0.18334 V+/-0.018222V
 M2 Voltage C2 :.........1.0276 V+/-0.049095V
 Time harmonic M1 C1 :.........0.10209+/-0.0011468
 Time harmonic M2 C1 :.........0.1377+/-0.00088054
 Time harmonic M1 C2 :.........0.080268+/-0.0016327
 Time harmonic M2 C2 :.........0.1542+/-0.0020548
 ----------------------Statistical magnetic measurement indicators------------------
 Measured field rep C1 @ injection:.........0.039686  G
 Measured field rep C2 @ injection:.........0.043457  G
 Measured field rep C1 @ extraction:.........0.040156  G
 Measured field rep C2 @ extraction:.........0.041897  G
 Marker jitter C1 @ 450 G, 3400 G:.........58.508 us,.........9.8149 us
 Marker jitter C2 @ 450 G, 3400 G:.........70.5241 us,.........10.2094 us
 ----------------------------------------END-----------------------------------------------
```

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