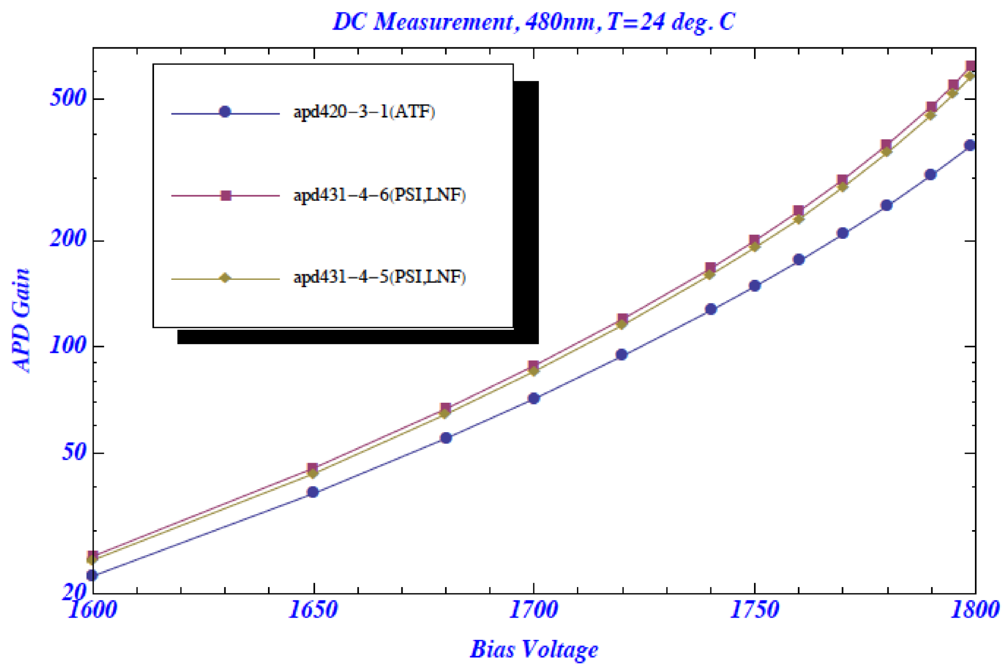
Analysis of DESY testbem data. Scope inputs are:1)front APD,2)back APD,3)4mm**2 APD(trigger)
preamps are Cividec for channels 1 and 2 and Wenteq for 3. All have same gain and BW. For all data the APD bias
voltage was 1795 volts.
SNW-Mar. 1, 2014

First calculate expected signal amplitude for min. ionizing particle in the 8 x8 mm^2 APDs (area enters because this has large capacitance leading to a loss in peak amplitude into a 50 Ω voltage amplifier - by a bit over a factor of 10).



$ehpairs = 90;\ thick = 40;\ G_{APD} = 530.;\ t_{pulse} = 5 * 10^{-9};\ Qe = 1.6 * 10^{-19};\ R = 50.;$

$Q = ehpairs * thick * G_{APD} * Qe;$

$i_{peak} = Q / (t_{pulse} / 2);$

$v_{peak} = i_{peak} * R$

0.0061056

Conclusion : We should expect an input signal with peak amplitude of about 6 mV into the preamp and should take into account a factor of about 10

reduction for the capacitance.
Inspection of the DESY data below shows a peak amplitude of about 600 mV, roughly as expected for the low capacitance 2*2mm^2 detector. The 64 mm^2 detector has an amplitude reduction

by about 1 / 4 but the shape is very different.
This means that, with a 1 nsec risetime signal the preamp noise at the output, in order to have less than 20 picosecond contribution to the time jitter, should be less than 3 mV- ie :

```
G_AMP = 100.; SNR = 50.;
```

```
Noise_Target = v_peak * G_AMP / 4. / SNR
```

```
0.0030528
```

```
(*Quantity["ElectronCharge"]*)
```

Below we find that we are close to that, (8mV), even before the data with least count reduced by a factor of 20.

```
SetDirectory["~bastian/Desktop/desydata/"];
Namelist = FileNames[];
Namelist // Length;
nfiles = %;
```

4 channels of LRS 1 GHz scope with 5 GHz sampling. Ch1= front, Ch2=back 64mm**2 APD.
Ch3= 4 mm**2 APD, triggers scope at 40 mV.

```
filename = Namelist[[1]]
scopedata = Import[filename, "csv"];
```

```
LeCroy-RTW-2014-03-01-001.csv
```

```
Dimensions[scopedata]
```

```
{8000, 255}
```

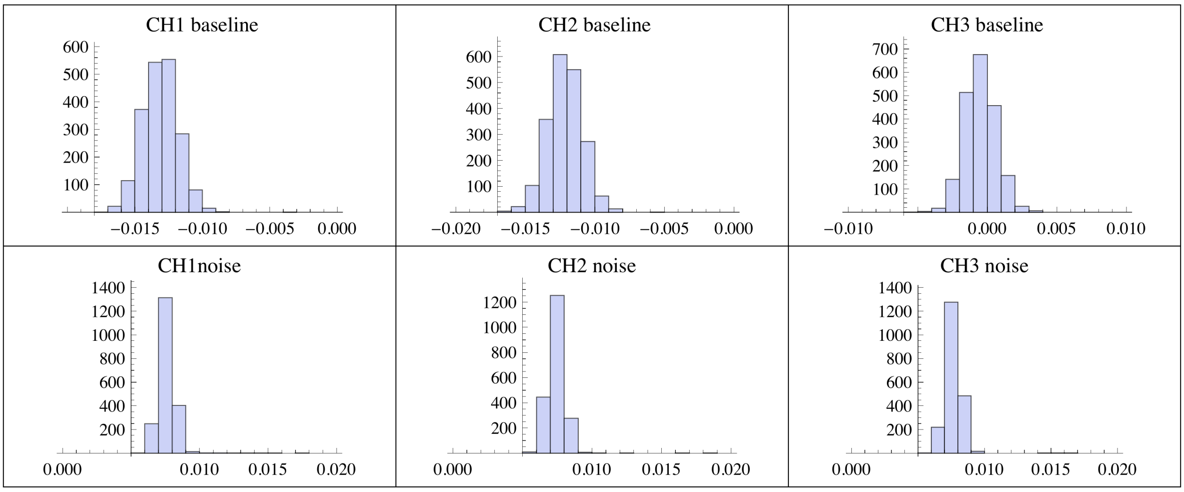
```
t0 = scopedata[[1, 2]];
dt = scopedata[[1, 3]] * 10^9
time = Range[0, 251] * dt;
```

```
0.2
```

```
v1 = Table[Take[scopedata[[4 * (i - 1) + 1]], {4, 255}], {i, 2000}];
v2 = Table[Take[scopedata[[4 * (i - 1) + 2]], {4, 255}], {i, 2000}];
v3 = Table[Take[scopedata[[4 * (i - 1) + 3]], {4, 255}], {i, 2000}];
```

“iorder” specifies level of filtering. ie iorder=5 reduces 5 GHz to 1 GHz average of 5 pts. Expect noise reduction from sampling to be 1/sqrt(5).

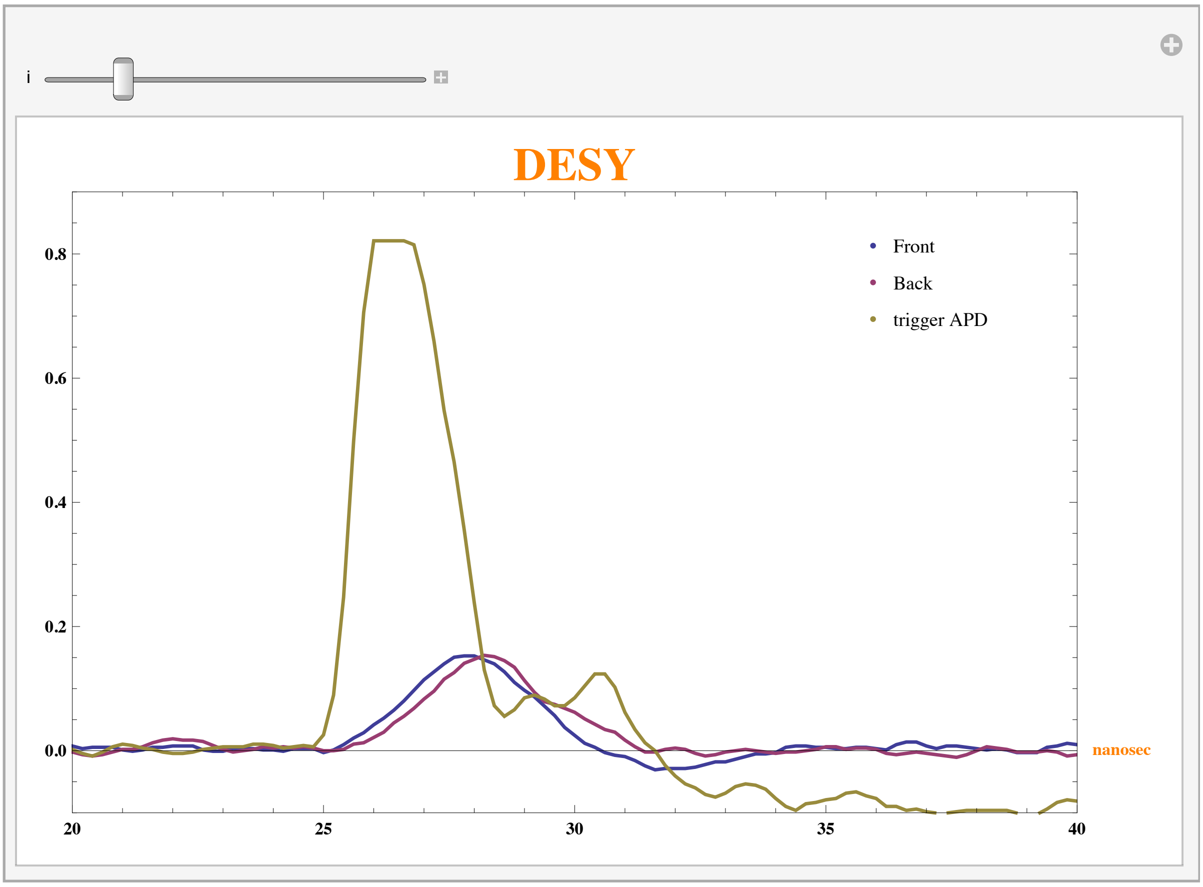
```
iorder = 3;
i = 34;

inbase1 = Table[Mean[Take[v1[[i]], 120]], {i, 2000}];
innoise1 = Table[RootMeanSquare[Take[v1[[i]], 120] - inbase1[[i]]], {i, 2000}];
inbase2 = Table[Mean[Take[v2[[i]], 120]], {i, 2000}];
innoise2 = Table[RootMeanSquare[Take[v2[[i]], 120] - inbase2[[i]]], {i, 2000}];
inbase3 = Table[Mean[Take[v3[[i]], 120]], {i, 2000}];
innoise3 = Table[RootMeanSquare[Take[v3[[i]], 120] - inbase3[[i]]], {i, 2000}];

GraphicsGrid[{{Histogram[inbase1, {-.02, 0., .001}, PlotLabel → "CH1 baseline"],
    Histogram[inbase2, {-.02, 0., .001}, PlotLabel → "CH2 baseline"],
    Histogram[inbase3, {-.01, 0.01, .001}, PlotLabel → "CH3 baseline"]},
   {Histogram[innoise1, {0., 0.02, .001}, PlotLabel → "CH1noise"],
    Histogram[innoise2, {0., .02, .001}, PlotLabel → "CH2 noise"],
    Histogram[innoise3, {0., 0.02, .001}, PlotLabel → "CH3 noise"]}},
 Frame → All, ImageSize → Full]
```




```
Print[Style[{" noise1= ", Mean[innoise1], " noise2= ",
    Mean[innoise2], " noise3= ", Mean[innoise3], " volts"}, Large, Red]]
```

{ noise1= , 0.00808383, noise2= , 0.00768651, noise3= , 0.00765881, volts}

```
Manipulate[ListPlot[{Transpose[{MovingAverage[time, iorder],
      MovingAverage[(v1[[i]] - inbase1[[i]]), iorder]}],
    Transpose[{MovingAverage[time, iorder],
      MovingAverage[(v2[[i]] - inbase2[[i]]), iorder]}],
    Transpose[{MovingAverage[time, iorder],
      MovingAverage[-(v3[[i]] - inbase3[[i]]), iorder]}]},
  PlotStyle → Directive[AbsoluteThickness[1.8]],
  LabelStyle → Directive[Orange, Bold],
  PlotLabel → Style[DESY, Large],
  AxesLabel → {nanosec, V}, PlotStyle → {Red, Blue, Green},
  PlotLegends → Placed[{"Front", "Back", "trigger APD"}, {0.85, 0.85}],
  PlotRange → {{20., 40.}, {-.1, .9}}, Joined → True,
  ImageSize → Large, Frame → True, FrameStyle → Black],
 {i, 1, 200, 1}, SaveDefinitions → True]
```

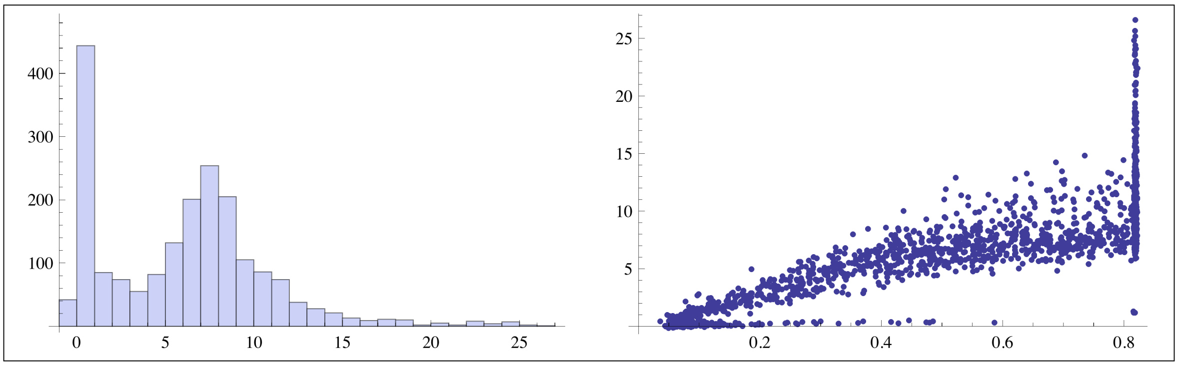


Now look at peak amplitude on all 3 APDs expecting to see a Landau distribution.

```
peak1 = Table[Max[Take[v1[[i]] - inbase1[[i]], {125, 150}]], {i, 2000}];
peak2 = Table[Max[Take[v2[[i]] - inbase2[[i]], {125, 150}]], {i, 2000}];
peak3 = Table[Max[Take[-(v3[[i]] - inbase3[[i]]), {125, 150}]], {i, 2000}];

area3 = Table[Sum[-(v3[[i, j]] - inbase3[[i]]), {j, 125, 160}], {i, 2000}];
```

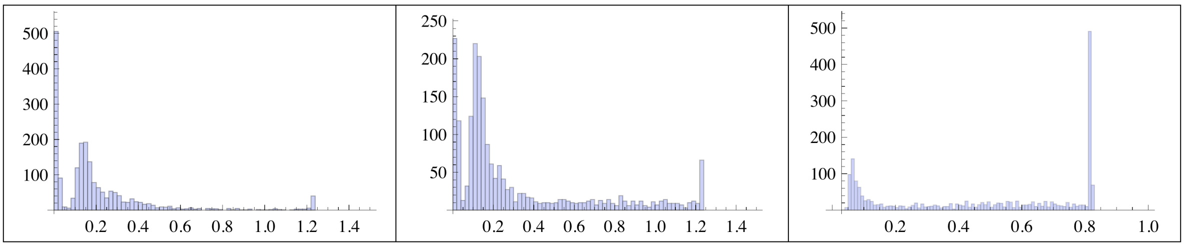
```
GraphicsRow[{Histogram[area3],
  ListPlot[Transpose[{peak3, area3}]]}, Frame → True,
 PlotLabel → "Ch3 area used to extend dynamic range beyond peak saturation",
 ImageSize → Full]
```

Ch3 area used to extend dynamic range beyond peak saturation



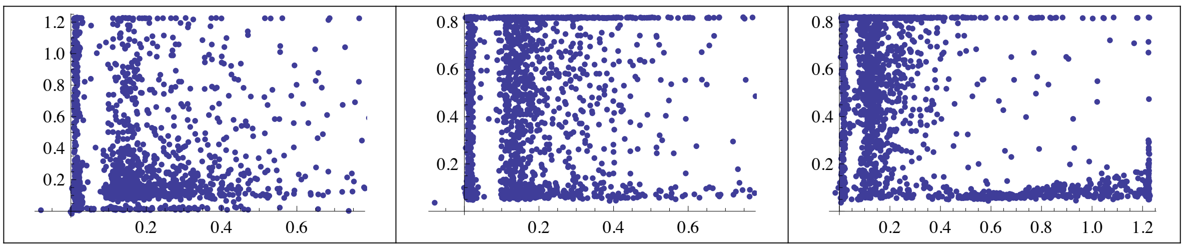
```
GraphicsRow[{Histogram[peak1, {0, 1.5, .02}],
  Histogram[peak2, {0, 1.5, .02}], Histogram[peak3, {0, 1., .01}]}, Frame → All,
 PlotLabel → "Raw Pulseheight Distributions (Ch 1,2,3 )", ImageSize → Full]
```

Raw Pulseheight Distributions (Ch 1,2,3)



```
GraphicsRow[
 {ListPlot[Transpose[{peak1, peak2}]], ListPlot[Transpose[{peak1, peak3}]],
  ListPlot[Transpose[{peak2, peak3}]]}, Frame → All,
 PlotLabel → "Raw Correltions (1 vs.2, 1 vs. 3, 2 vs.3 )", ImageSize → Full]
```

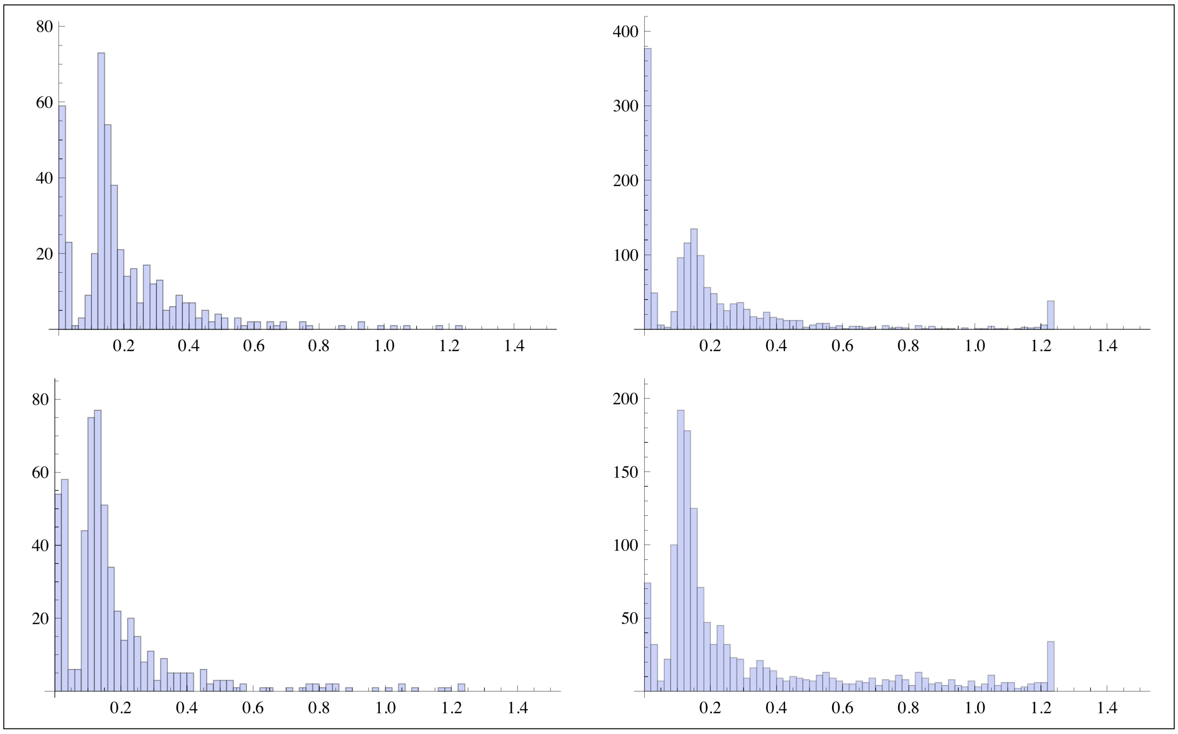
Raw Correltions (1 vs.2, 1 vs. 3, 2 vs.3)



Now create an nTuple with the 3 peak values for each event.

```
peakntup = Transpose[{peak1, peak2, peak3, area3}];
GraphicsGrid[{{Histogram[
     Select[peakntup, (#[[3]] > .8 && #[[2]] > 0.05) &][[All, 1]], {0, 1.5, .02}],
    Histogram[Select[peakntup, (#[[3]] > .050 && #[[3]] < .8) &][[All, 1]],
     {0, 1.5, .02}]},
   {Histogram[Select[peakntup, (#[[3]] > .8 && #[[3]] < 1) &][[All, 2]],
     {0, 1.5, .02}],
    Histogram[Select[peakntup, (#[[3]] > .050 && #[[1]] > 0.05) &][[All, 2]],
     {0, 1.5, .02}]}}, Frame → True,
 PlotLabel → "Ch1 with ch3 peak cut and complement, then same for ch2",
 ImageSize → Full]
```

Ch1 with ch3 peak cut and complement, then same for ch2

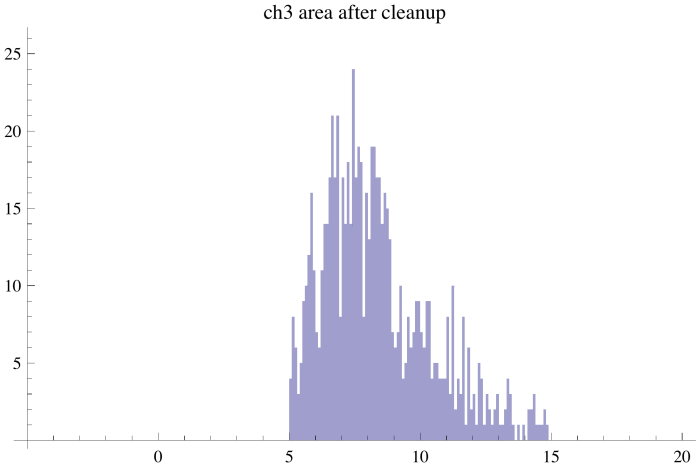



```
peakcut =
  Select[peakntup, (#[[1]] > .050 && #[[2]] > .050 && #[[4]] > 5 && #[[4]] < 15) &];
Dimensions[peakcut]
```

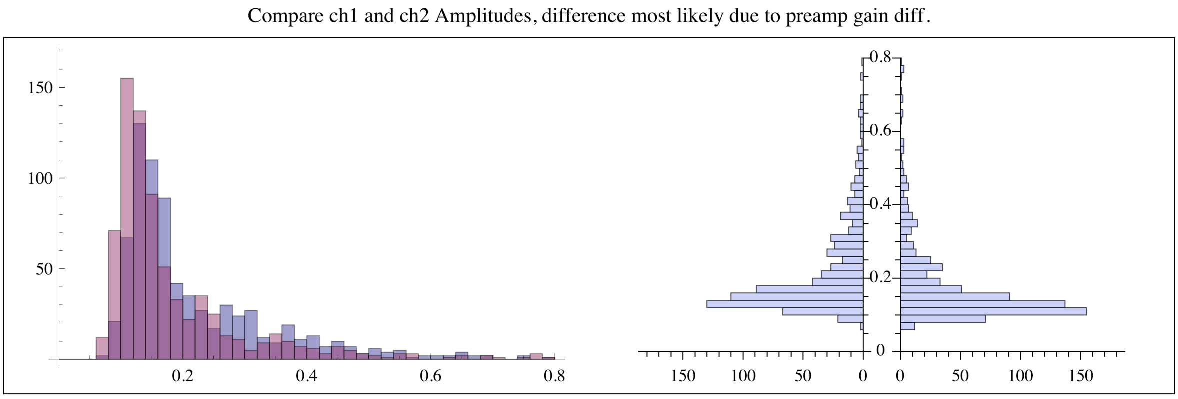
```
{762, 4}
```

```
{p1, p2, p3, a3} = Transpose[peakcut];
```

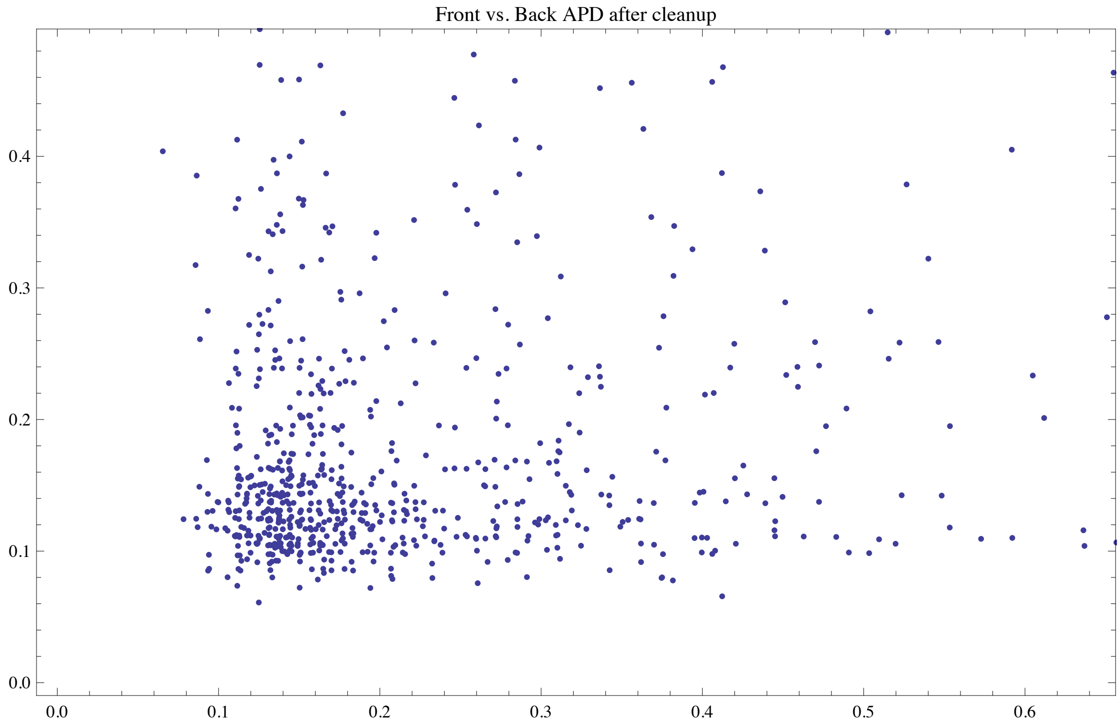
```
Histogram[{(*area3,*)a3}, {-5, 20, .1}, PlotLabel → "ch3 area after cleanup"]
```




```
GraphicsRow[{Histogram[{p1, p2}, {0, 0.8, .02}, AxesOrigin → {0, 0}],
  PairedHistogram[p1, p2, {0, 0.8, .02}, AxesOrigin → {0, 0}]},
 Frame → True, PlotLabel → "Compare ch1 and ch2 Amplitudes, difference
    most likely due to preamp gain diff.", ImageSize → Full]
```



```
ListPlot[Transpose[{p1, p2}], ImageSize → Large,
 PlotLabel → "Front vs. Back APD after cleanup", Frame → True]
```



End of Notebook so far