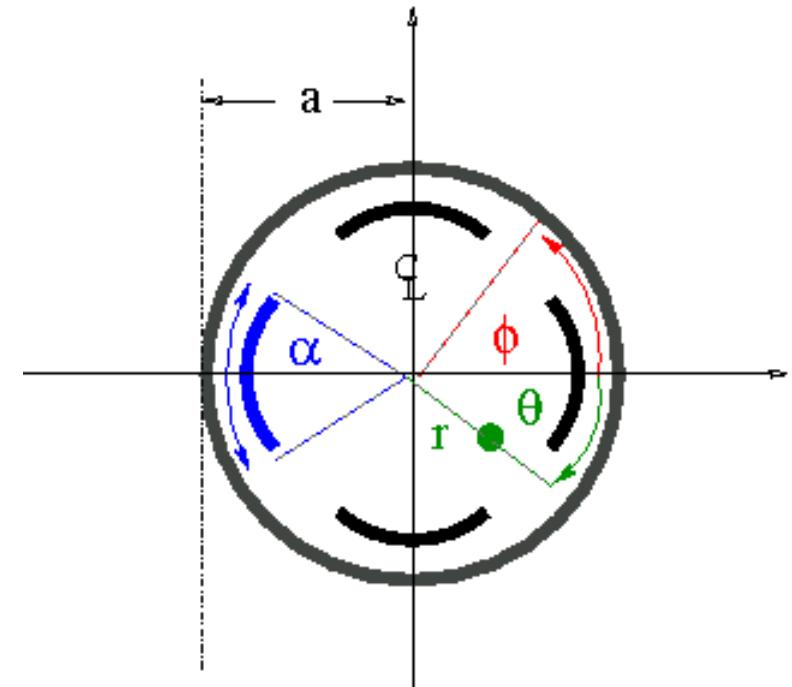
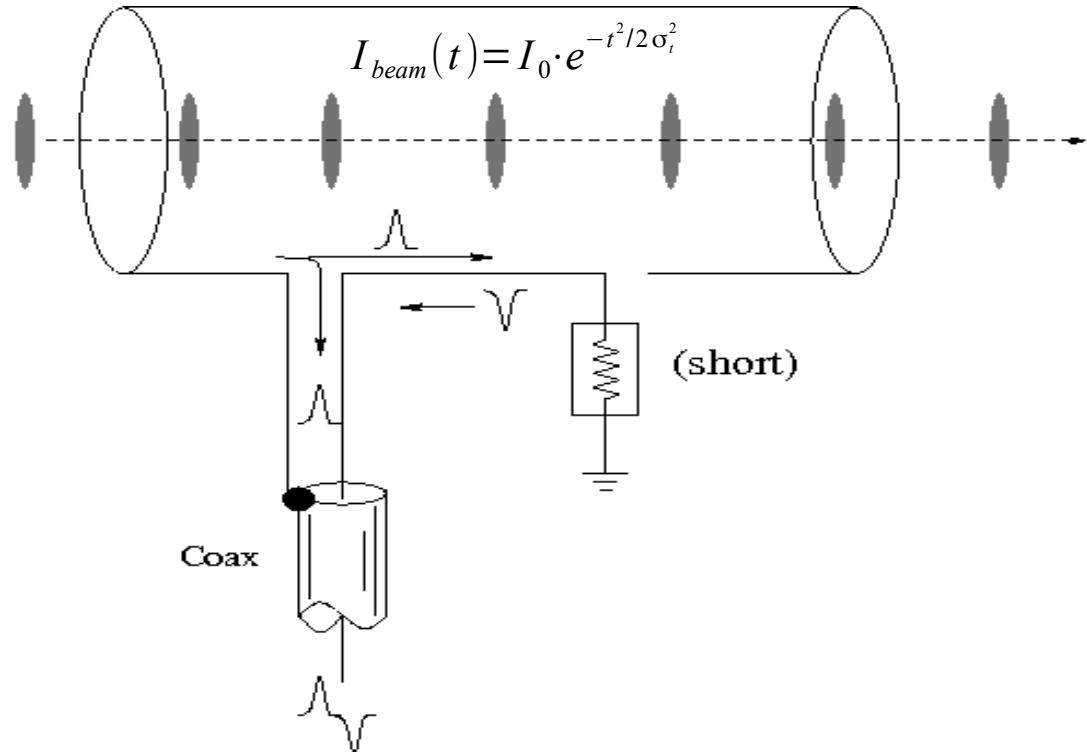


Stripline BPMs



Voltage

$$U_1(t) = \frac{1}{2} \frac{\alpha}{2\pi} \cdot R_1 \left(I_{beam}(t) - I_{beam}\left(t - \frac{2l}{c}\right) \right)$$

$$U_1(t) = \frac{Z_{strip}}{2} \frac{\alpha}{2\pi} \cdot \left(e^{-t^2/2\sigma_t^2} - e^{-(t-2l/c)^2/2\sigma_t^2} \right) \cdot I_0$$

Current

$$j_3(\varphi) = \frac{I_{beam}}{2\pi a} \cdot \left(\frac{a^2 - r^2}{a^2 + r^2 - 2ar \cdot \cos(\varphi - \theta)} \right)$$

$$I_3 = \int_{-\alpha/2}^{+\alpha/2} a \cdot j_3(\varphi) d\varphi$$

$$Z_t(\omega) = \frac{Z_{strip} \cdot \alpha}{4\pi} \cdot e^{-\omega^2 \sigma_t^2/2} \cdot \sin(\omega l/c) \cdot e^{i(\pi/2 - \omega l/c)}$$

Transfer Impedance

Propagation of Errors

(A review!)

Functional Form

$$z = x + y$$

$$z = x \cdot y$$

$$q = f(x_1, x_2, \dots, x_n)$$

Uncertainty

$$\delta z = \sqrt{\delta x^2 + \delta y^2}$$

$$\frac{\delta z}{z} = \sqrt{\left(\frac{\delta x}{x}\right)^2 + \left(\frac{\delta y}{y}\right)^2}$$

$$\delta q = \sqrt{\left(\frac{\partial q}{\partial x_1} \delta x_1\right)^2 + \dots + \left(\frac{\partial q}{\partial x_n} \delta x_n\right)^2}$$

Resolution Analysis

Difference-over-sum

$$X = \frac{a}{2} \cdot \frac{V_L - V_R}{V_L + V_R}$$

$$\frac{\partial X}{\partial V_L} = \frac{a \cdot V_R}{(V_R + V_L)^2}$$

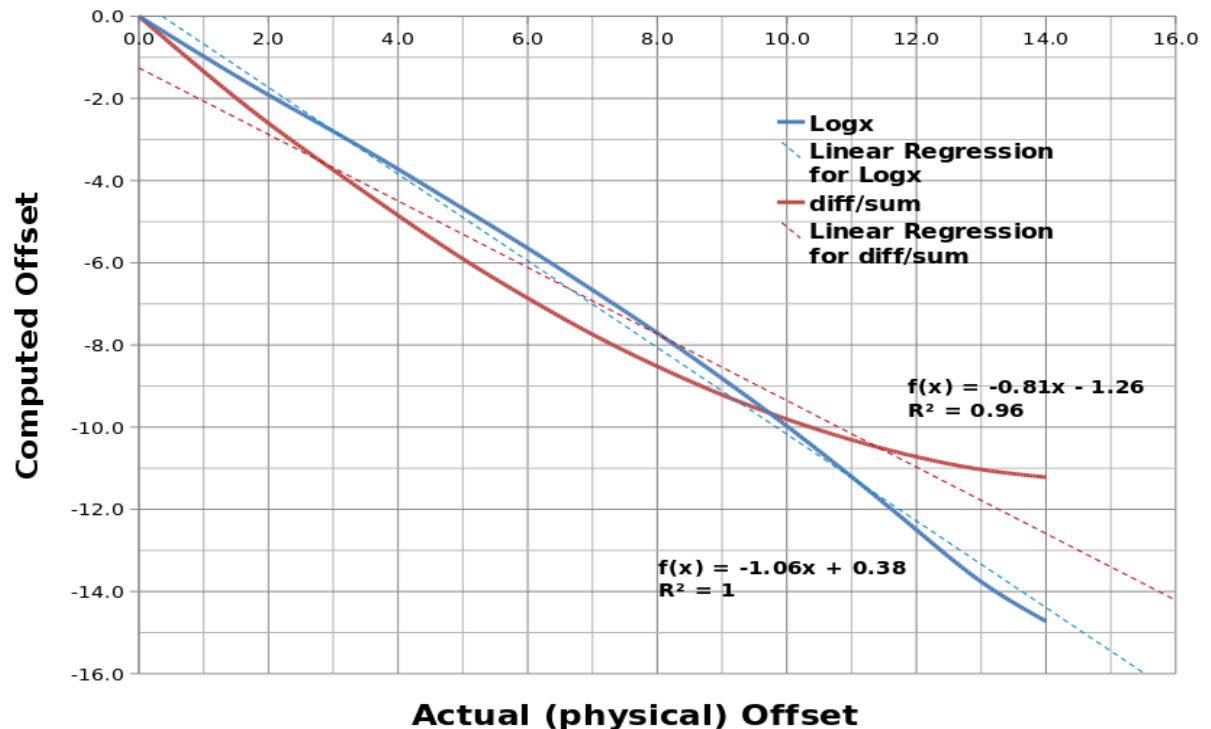
$$\frac{\partial X}{\partial V_R} = \frac{-a \cdot V_L}{(V_R + V_L)^2}$$

$$\sigma_X = \frac{a}{(V_R + V_L)^2} \cdot \sqrt{V_L^2 \delta V_R^2 + V_R^2 \delta V_L^2} \quad (\text{Rule #3})$$

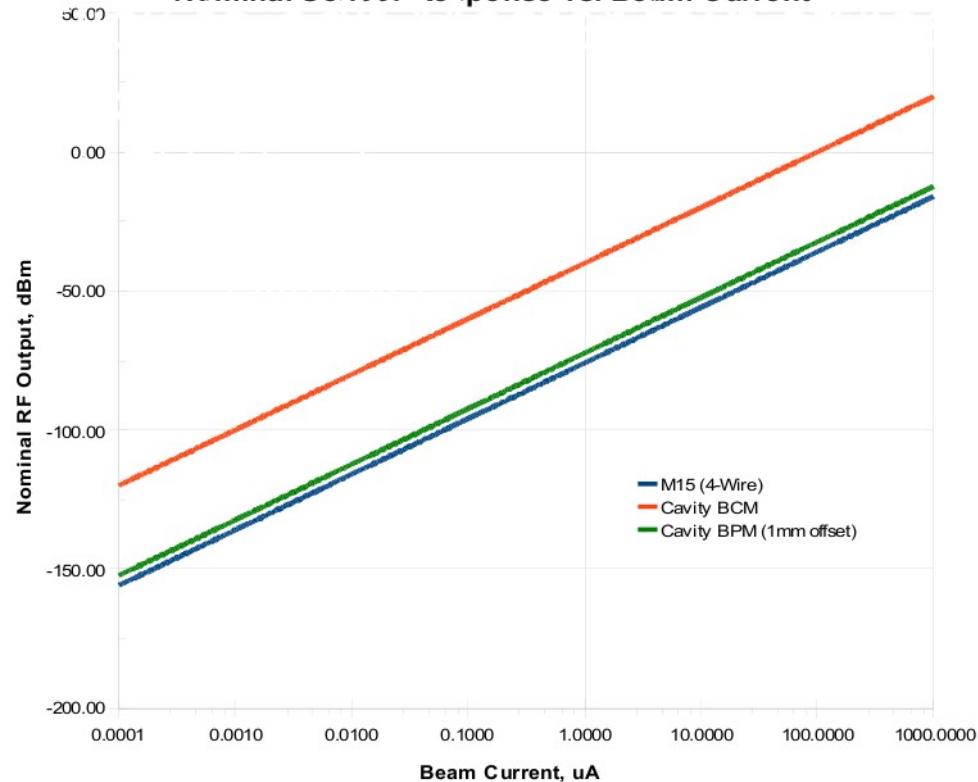
At boresight....

$$\sigma_X = \frac{a}{2} \cdot \frac{\sqrt{2} \sigma_v}{2V} = \frac{a}{2\sqrt{2}} \cdot \frac{1}{\sqrt{SNR}}$$

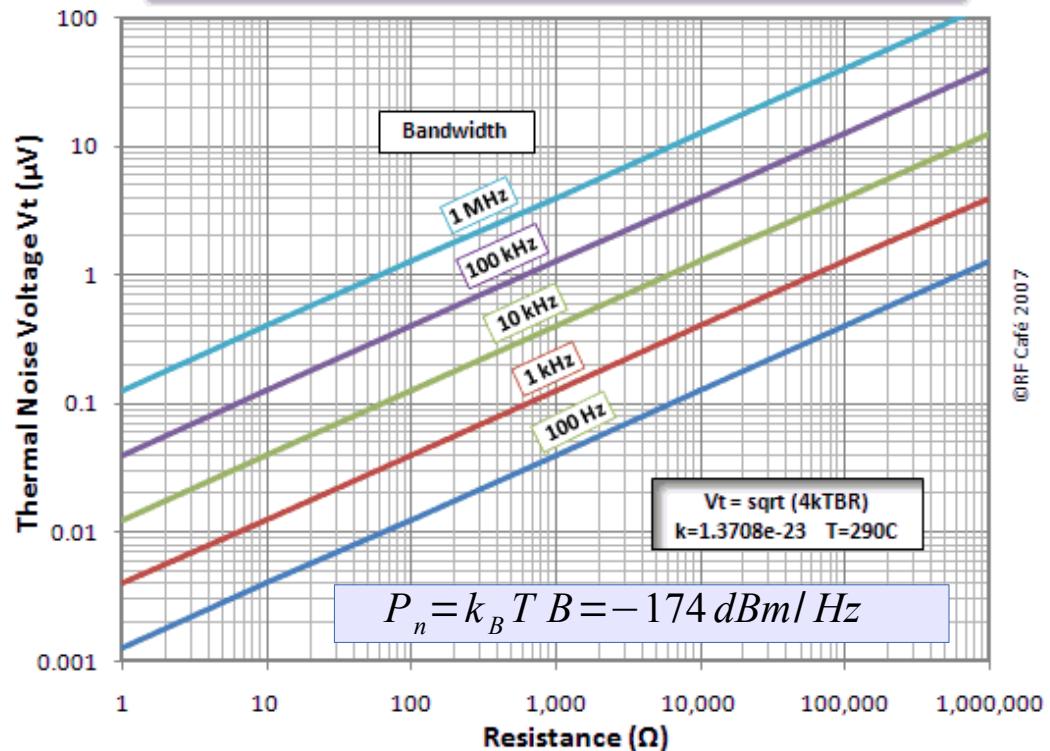
$$SNR = \frac{P_s}{P_n} = \frac{V_s^2}{V_n^2}$$



Nominal Sensor Response vs. Beam Current



Thermal Noise as a Function of Resistance and Bandwidth



Typical SL output power = -102 dBm - 100nA

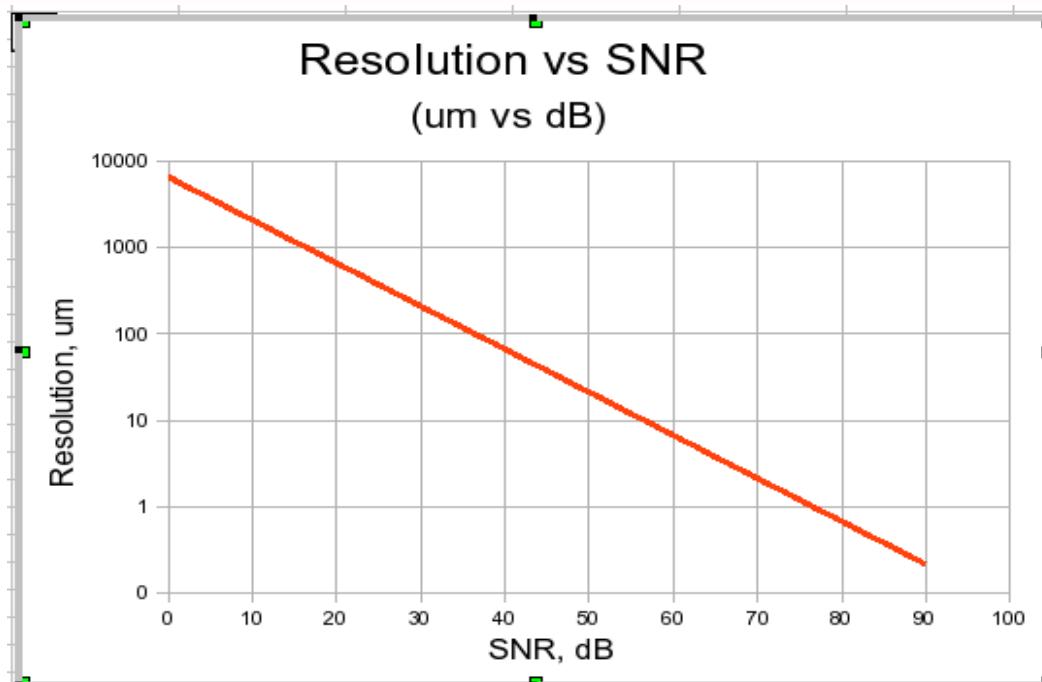
Expected noise power = -160 dBm - 10 Hz

$SNR = 58 \text{ dB } (B = 10 \text{ Hz})$

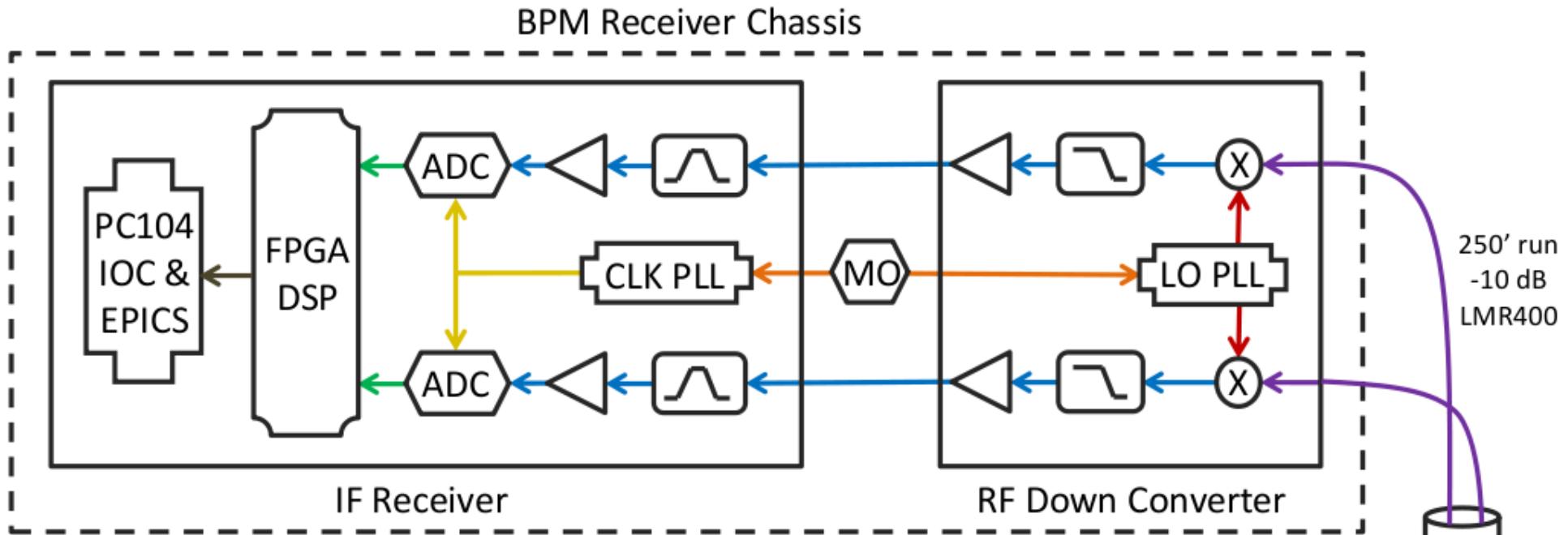
$\sigma = 10 \text{ um}, I = 100 \text{ nA}, B = 10 \text{ Hz}$

Note: Resolution is NOT accuracy!!

Resolution vs SNR (um vs dB)



Stripline BPM Electronics

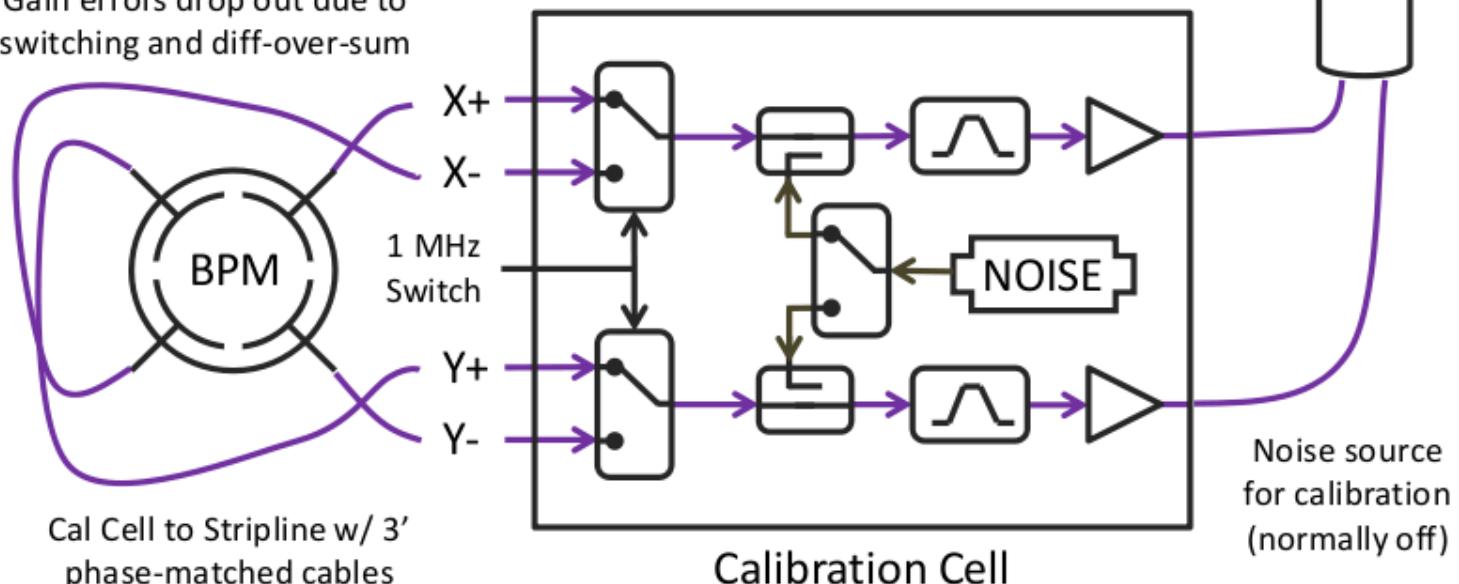


60 MHz, 16-bit ADCs
sample I&Q data

FPGA filters and provides
channel waveforms to EPICS

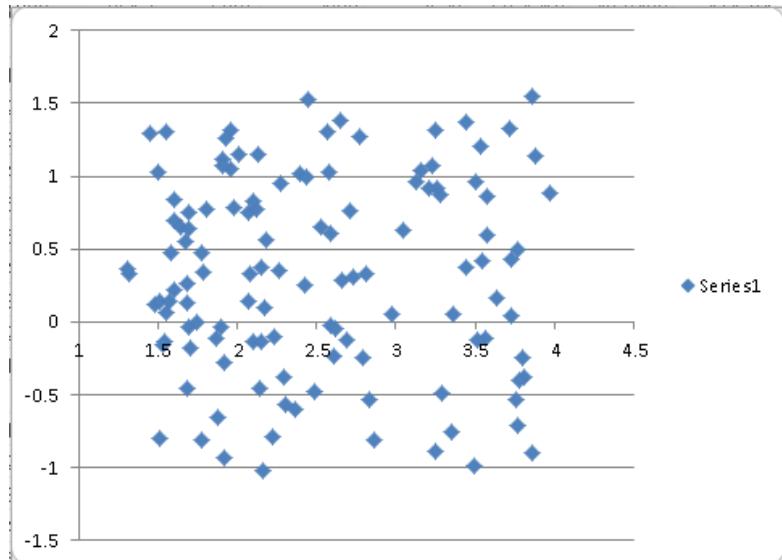
Legend	
1497 MHz	—
1452 MHz	—
45 MHz	—
60 Msps	—
I&Q Data	—
10 MHz	—

Gain errors drop out due to
switching and diff-over-sum

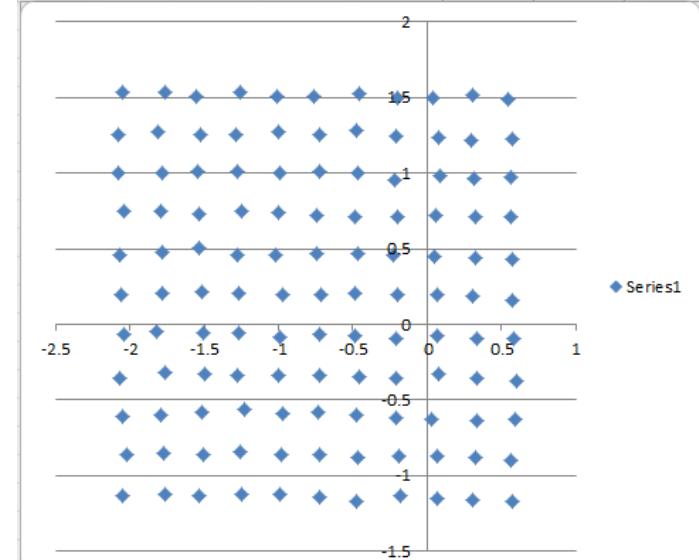


BPM Test Stand Stripline Electronics Testing

~30nA @ 10 Hz

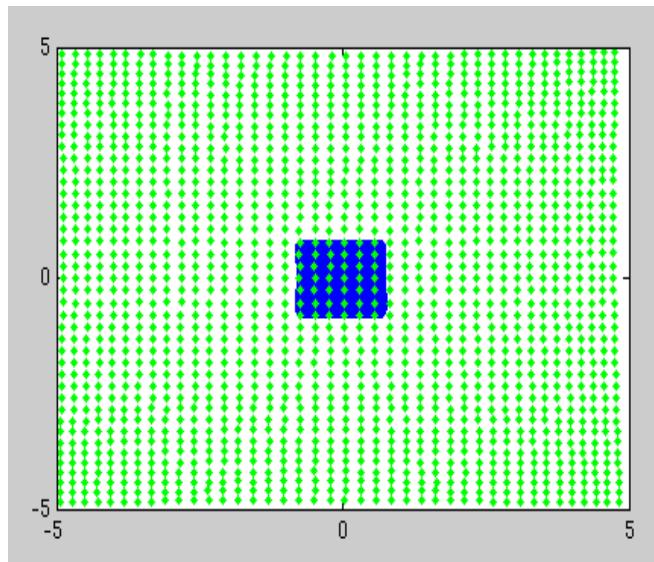


~30 nA @ 1 Hz

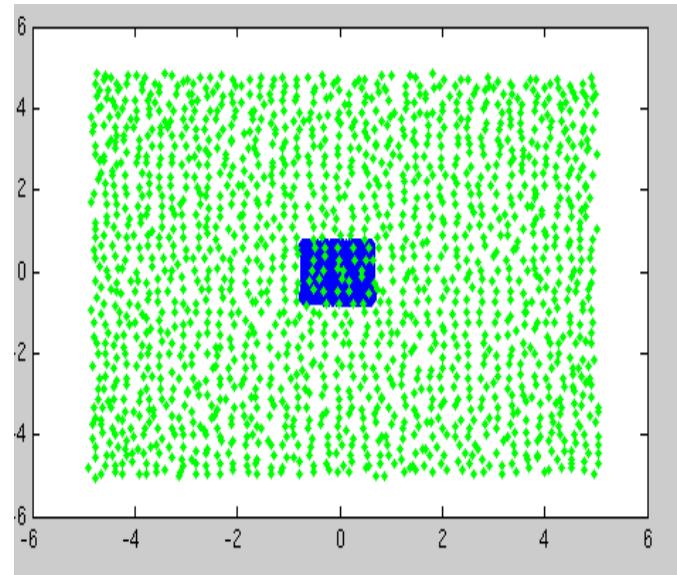


- Improving the signal-to-noise improves performance
- Filtering down to 1 Hz instead of 10 Hz gives an improvement factor of about 3 (excessive noise is due to algorithm)
- This square root of bandwidth improvement holds true as long as the noise is Gaussian
- Scan: 250 um/step, yielding 10s of um resolution (per calc)

Resolution

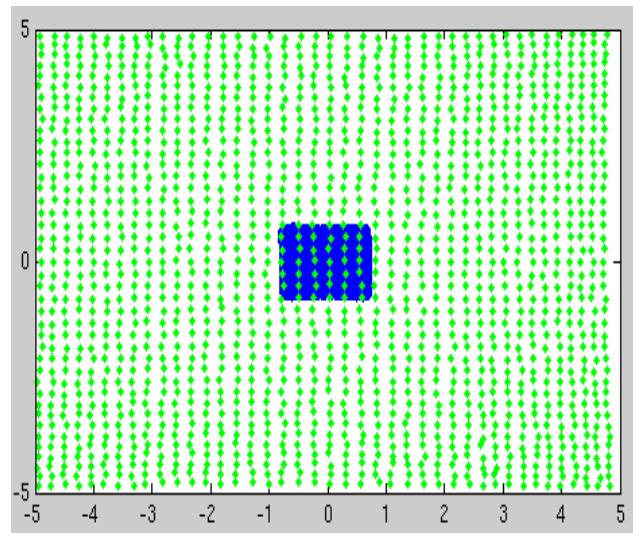


$I \sim 800\text{nA}$; $B = 10 \text{ Hz}$

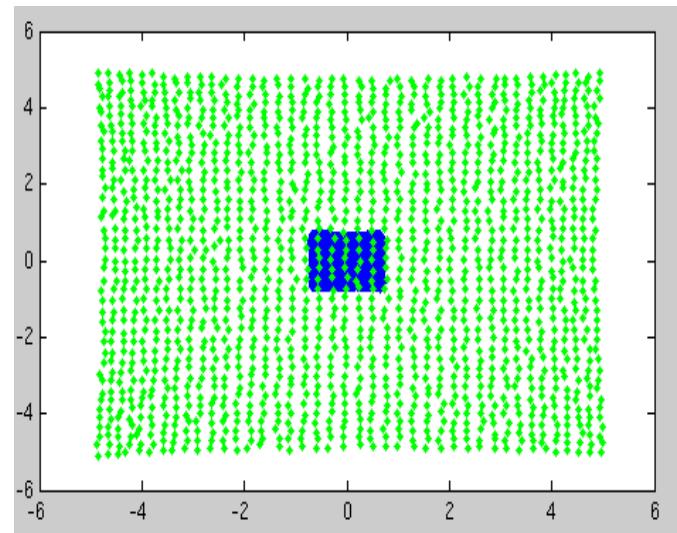


Step = 250 μm

$I \sim 100\text{nA}$; $B = 100 \text{ Hz}$



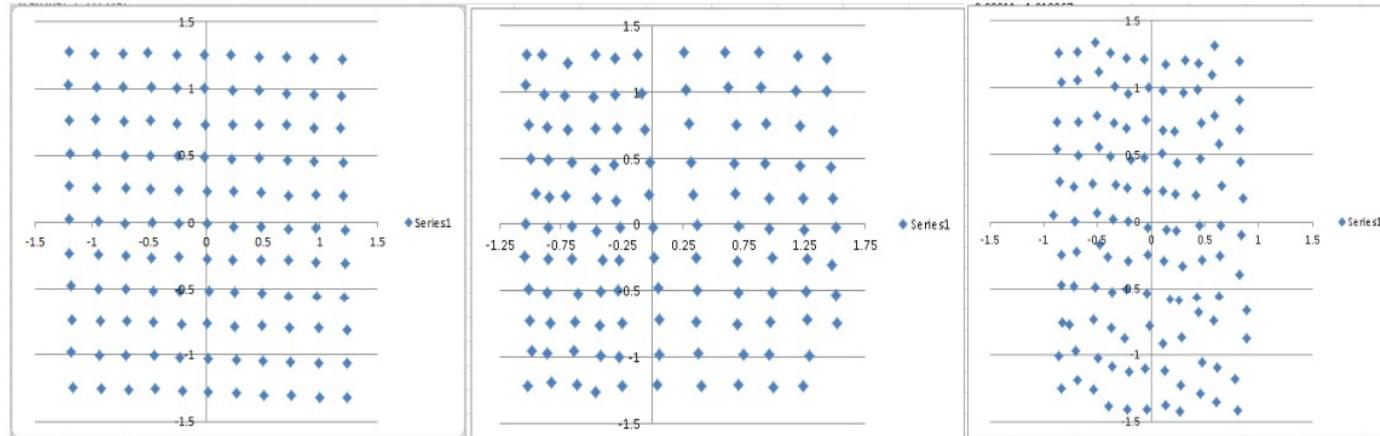
$I \sim 100\text{nA}$; $B = 10 \text{ Hz}$



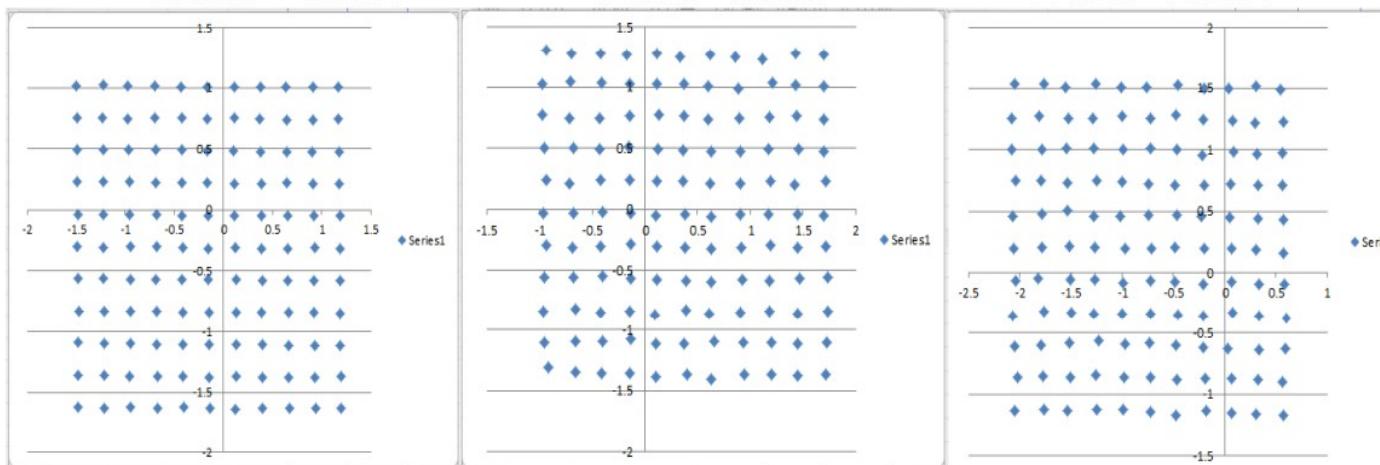
$I \sim 70\text{nA}$; $B = 10 \text{ Hz}$

Resolution (cont.)

SEE Electronics with M15 (Pulsed, -59dBm @ source = 800nA, -75dBm)
-65dBm = 400 nA -71dBm = 200nA -77dBm = 100nA

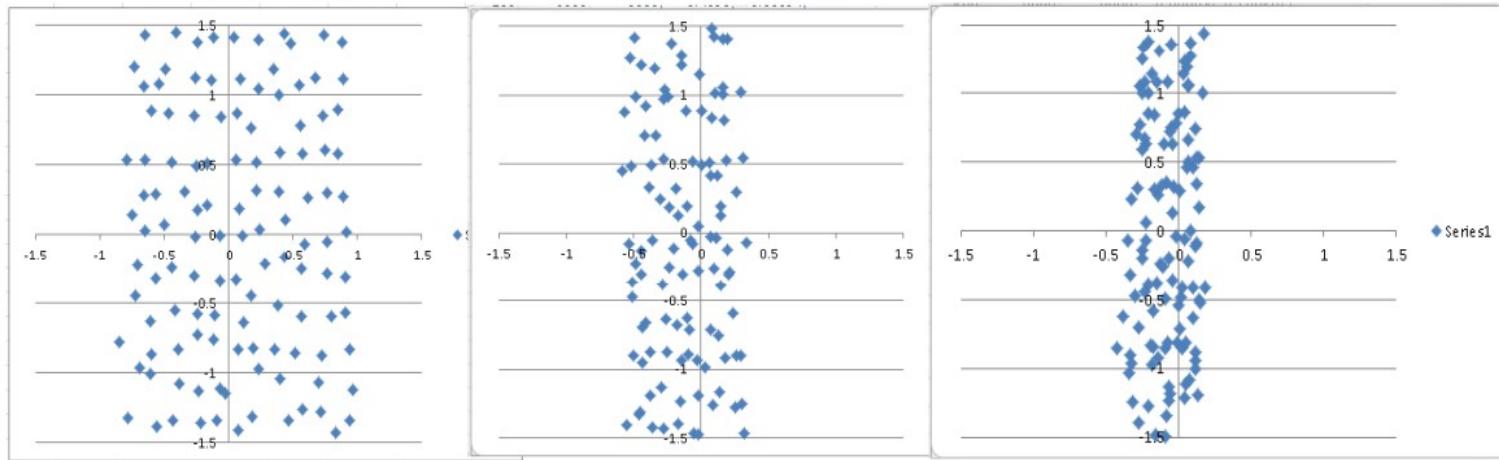


12 GeV Electronics with Stripline (10Hz)
-65dBm = 400 nA -71dBm = 200nA -77dBm = 100nA

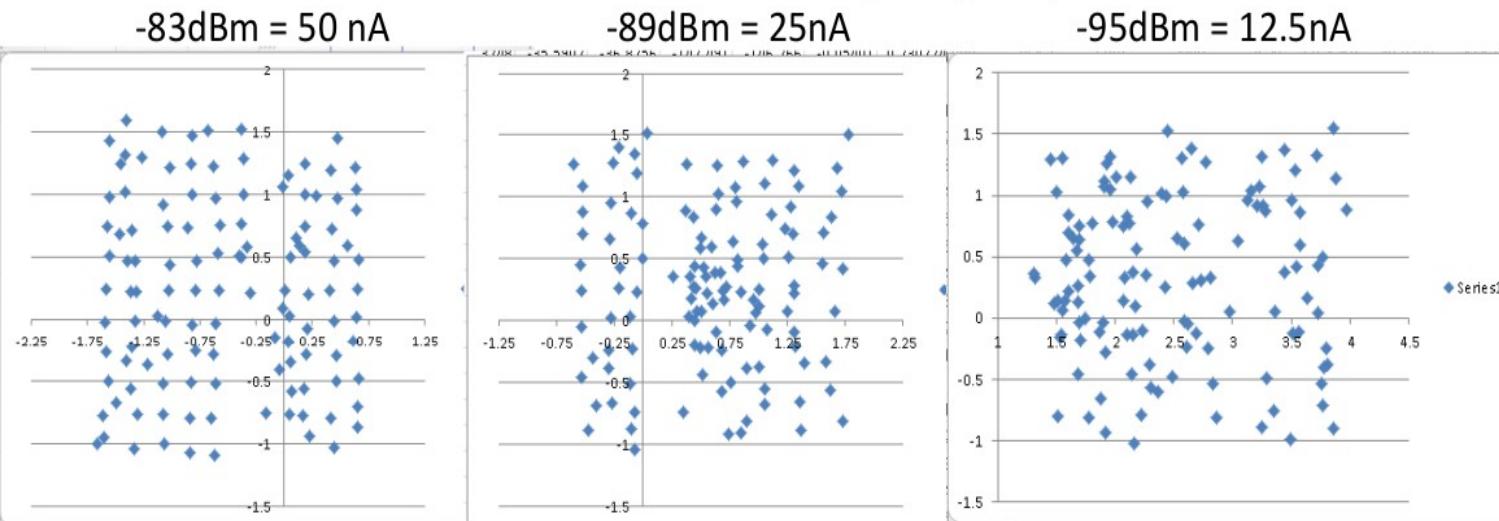


Resolution (cont.)

SEE Electronics with M15 (Pulsed, -59dBm @ source = 800nA, -75dBm)
-83dBm = 50 nA -89dBm = 25nA -95dBm = 12.5nA

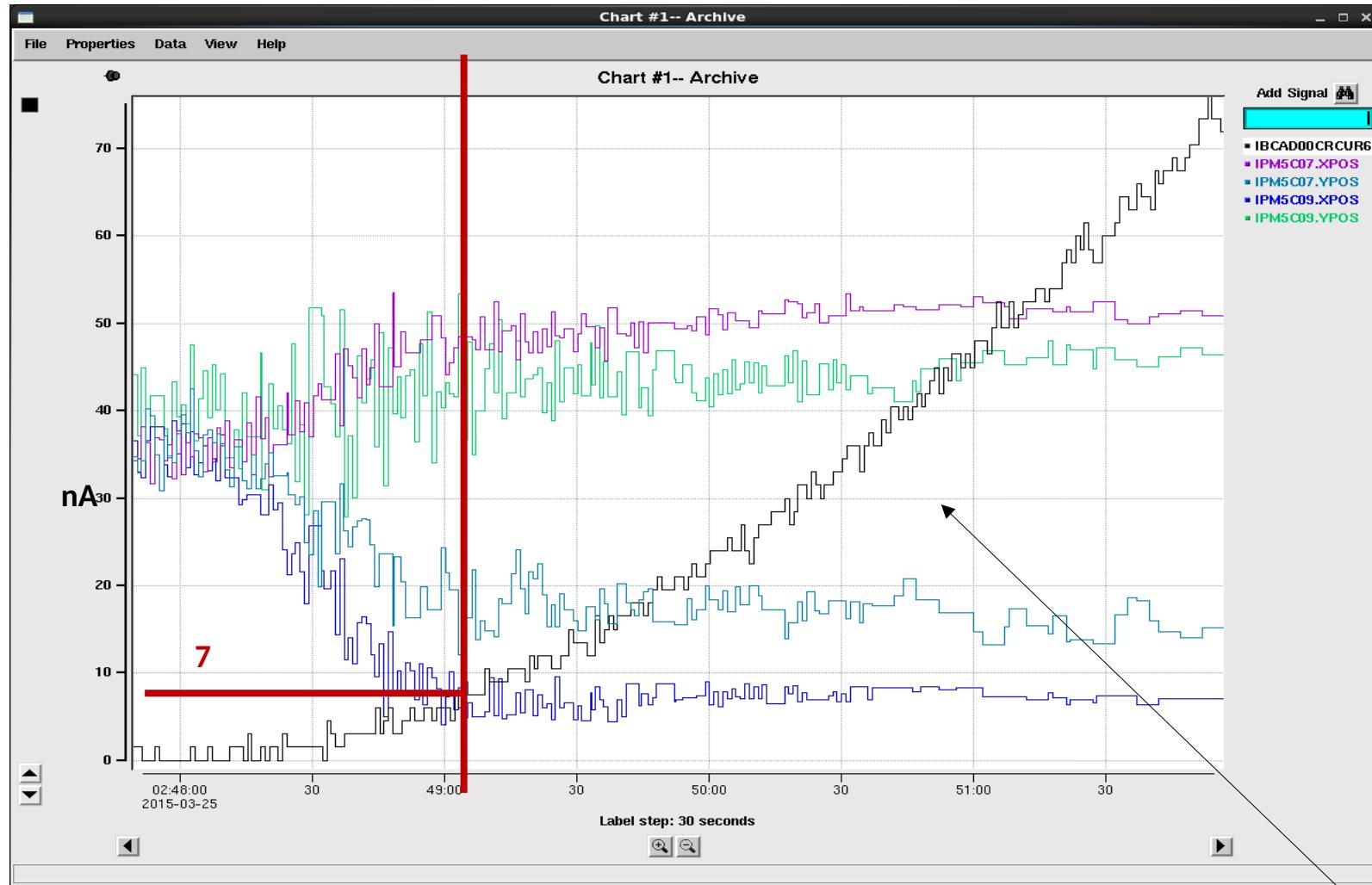


12 GeV Electronics with Stripline (10Hz)



Premature signal breakup mainly due to algorithm inefficiencies.....

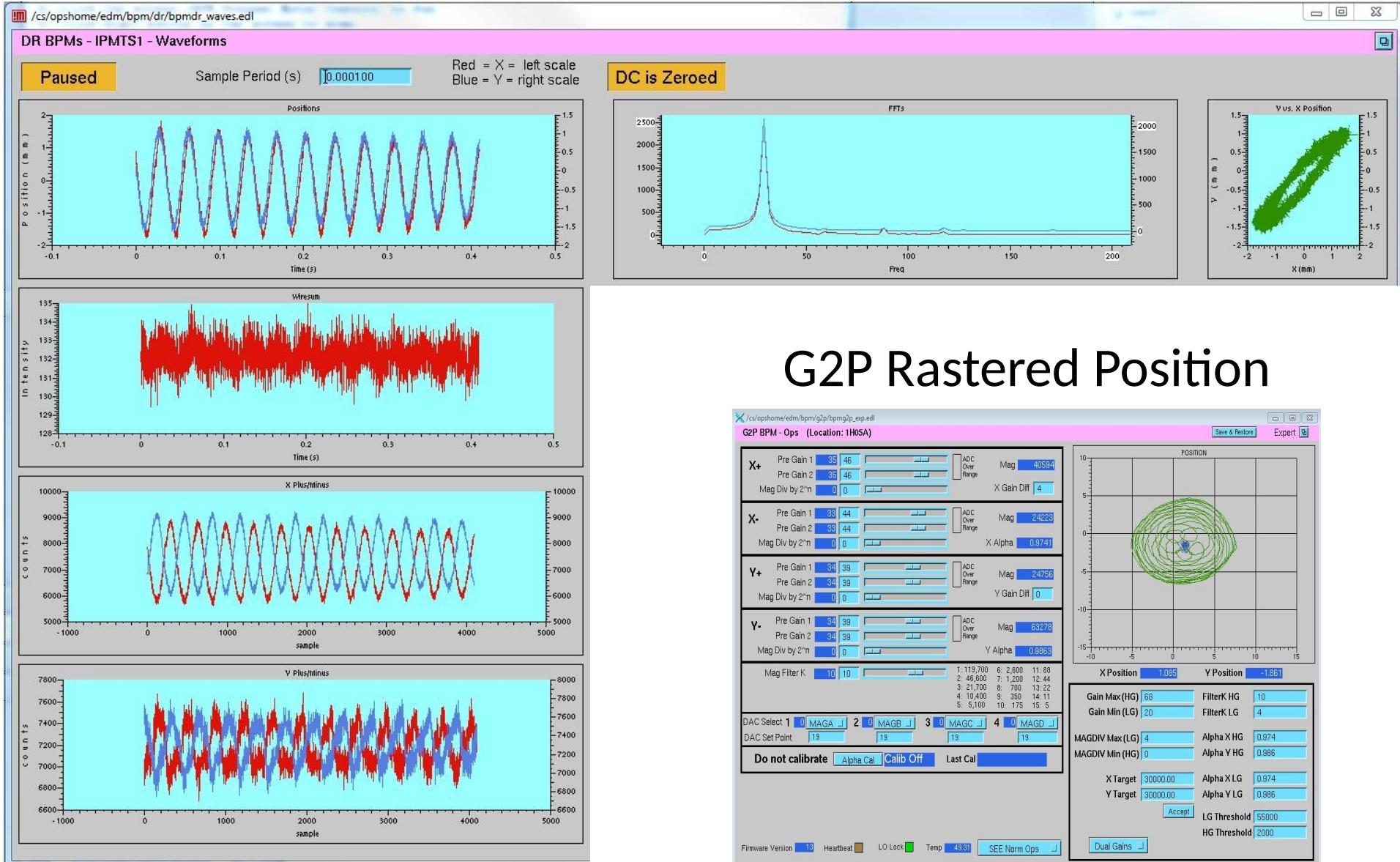
Stripline BPM Testing



- Hall D current in black ramping from 0 to 75 nA
- The 5C07 and 5C09 BPM positions settle at ~7nA and accuracy improves as the signal-to-noise goes up (bandwidth of ~1Hz)

Stripline BPM Software

Screen Shot of ~30Hz Oscillation (Time & Frequency Plots)



Resolution vs SNR

Stripline and Cavity BPM

