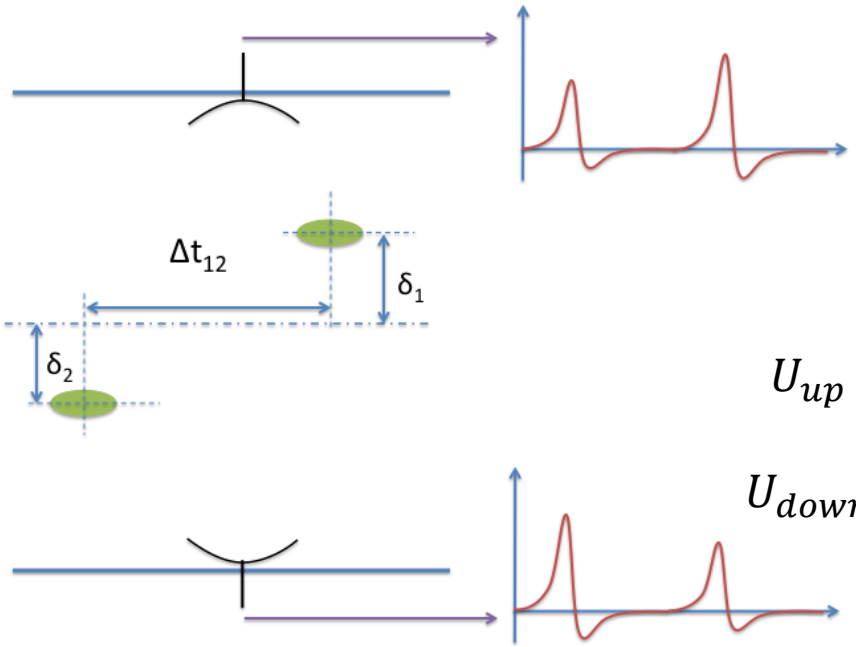
Testing ERL BPM

Igor Pinayev

June 30, 2023

Theory

$$y = k\frac{U_{up} - U_{down}}{U_{up} + U_{down}}$$



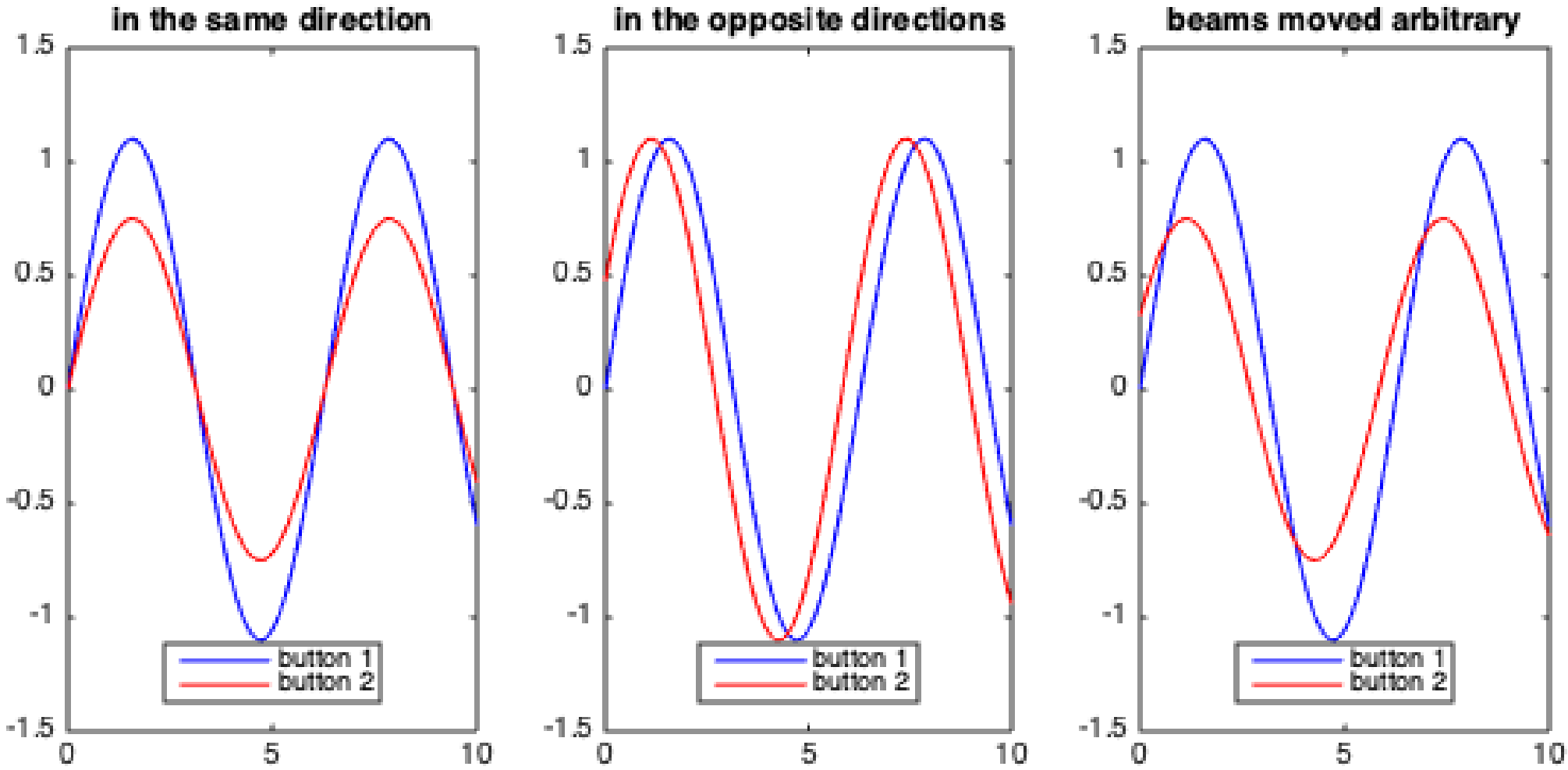
$$U_{up} = U_1(1 + S\delta_1)\sin\omega(t + \Delta t_{12}/2) + U_2(1 + S\delta_2)\sin\omega(t - \Delta t_{12}/2)$$
$$U_{down} = U_1(1 - S\delta_1)\sin\omega(t + \Delta t_{12}/2) + U_2(1 - S\delta_2)\sin\omega(t - \Delta t_{12}/2)$$

$$U_{up} = U_0\cos\frac{\omega\Delta t_{12}}{2}\left(2 + S(\delta_1 + \delta_2)\right)\sin\omega t + U_0\sin\frac{\omega\Delta t_{12}}{2}\left(2 + S(\delta_1 - \delta_2)\right)\cos\omega t$$
$$U_{down} = U_0\cos\frac{\omega\Delta t_{12}}{2}\left(2 - S(\delta_1 + \delta_2)\right)\sin\omega t - U_0\sin\frac{\omega\Delta t_{12}}{2}\left(2 + S(\delta_1 - \delta_2)\right)\cos\omega t$$

Two beams are in the same pipe with different arriving time at pick-up

$$A_{up} \approx A\left(2 + S(\delta_1 + \delta_2)\right)\cos\frac{\omega\Delta t_{12}}{2} \qquad \varphi_{up} \approx \frac{S(\delta_1 - \delta_2)}{2}\tan\frac{\omega\Delta t_{12}}{2}$$
$$A_{down} \approx A\left(2 - S(\delta_1 + \delta_2)\right)\cos\frac{\omega\Delta t_{12}}{2} \qquad \varphi_{down} \approx -\frac{S(\delta_1 - \delta_2)}{2}\tan\frac{\omega\Delta t_{12}}{2}$$

Effect of transverse displacement of beams

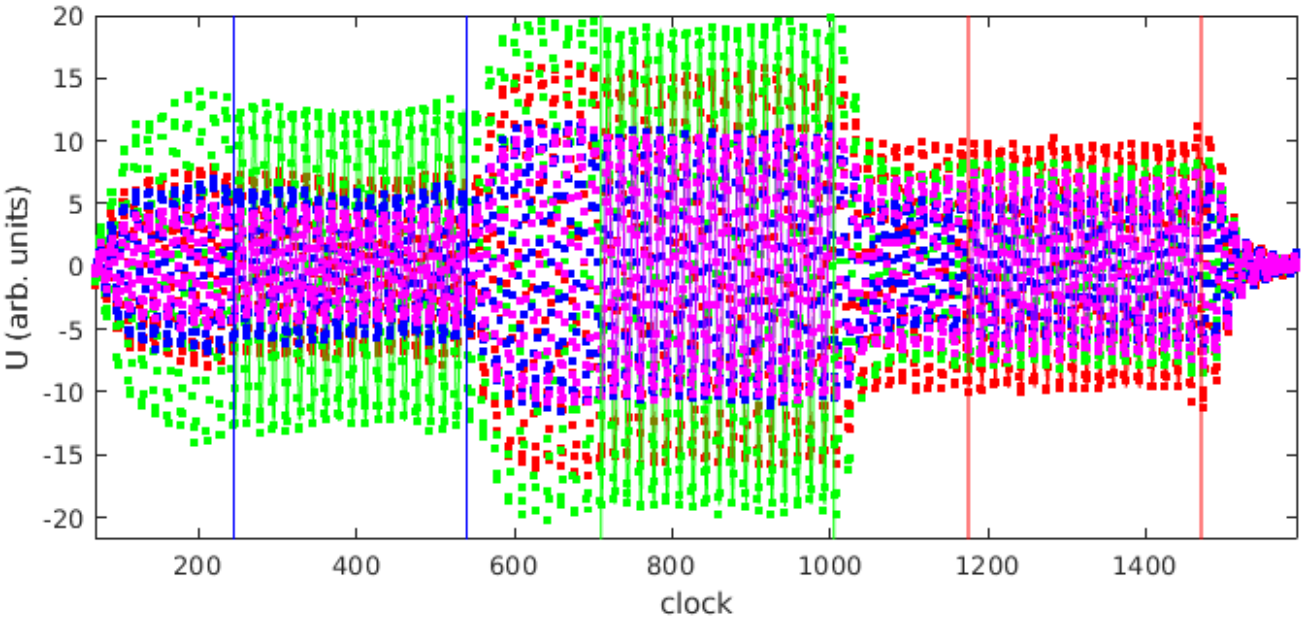


Experiment Set-up

Process Hadron BPMs Data BPM_LDRD_June-14-2023_08-52-59.mat gc1-amp.bb2-y

Nsample	Gap	Bleft	Bright	Gleft	Gright	Yleft	Yright
3	25	220	515	685	980	1150	1445

phOffs	modXo	modYo	ampXo	ampYo	kckXo	kckYo
0	0.7000	3	3.5000	5.1000	1.5000	3.8000



	phA-C	phB-D	phY-B	0
mod	0.0831	-0.2981	2.5546	2.5549
amp	-0.1882	-0.0396	-0.4150	-0.4324
kck	-0.2440	-0.2270	-2.5673	-2.5549

	AmpA	PhA	AmpB	PhB	AmpC	PhC	AmpD	PhD
mod B	9.2264	-0.3526	13.5097	-0.6198	9.6960	-0.4457	6.0025	-0.3129
mod G	5.1863	1.0098	7.9451	-0.0926	5.1367	0.5420	4.9435	1.5411
mod Y	10.5423	2.1907	8.4031	1.9449	8.7078	2.1176	9.7412	2.2341
amp B	7.0134	-0.2938	12.4597	-0.3083	5.7035	-0.1021	4.2479	-0.2598
amp G	15.3965	-0.5274	19.0443	-0.4552	10.4430	-0.3089	10.1587	-0.5193
amp Y	9.6644	-0.7141	7.7817	-0.7057	5.5906	-0.5293	6.9230	-0.6750
kck B	7.3207	-3.0216	9.8024	-2.8138	7.3193	-2.7654	4.5288	-2.5822
kck G	4.3426	1.8911	5.9938	2.9343	3.9198	2.5589	4.0366	1.8152
kck Y	8.5215	0.7061	6.0798	0.9071	6.5031	0.9379	7.5410	1.1295

	X (mm)	Y (mm)
Blue S2	-0.9918	5.0196
Blue mod	-1.1641	4.1947
Blue mod*	-1.6973	5.1294
Blue amp	-1.5738	4.0910
Blue amp*	-1.2608	5.1918
B kck	-1.4982	3.0812
Blue kck*	-1.7134	3.5656
Blue S1	-1.3769	0.5940
Yellow S2	0.9400	-4.9796
Yellow mod	1.0821	-4.3791
Yellow mod*	0.4770	-2.4193
Yellow amp	1.4938	-4.0081
Yellow amp*	1.4304	-4.0122
Yellow kck	1.0782	-5.8061
Yellow kck*	0.6272	-3.8678
Yellow S1	1.0484	-5.0200

RHIC at injection γ=10.52

Three Libera Electron Single Pass receivers tunes to 9.34 MHz (-6.5, -1.1, 6.5 meters from center)

Blue filled bunches 1-56
Yellow filled bunches 29-84

Transient region excluded from analysis

Phase shifts for individual channels are found from region with single beam present

Offsets are added (same for both rings)

Measured orbit shift

X_{blue} = 0 mm X_{yellow} = 0 mm

	X (mm)	Y (mm)
Blue S2	-0.0017	5.0052
Blue mod	-0.3088	4.1991
Blue mod*	-0.3855	5.1430
Blue amp	-0.6949	4.2016
Blue amp*	-0.7915	4.9874
B kck	-0.5660	3.0270
Blue kck*	-0.4298	3.5998
Blue S1	-0.3706	0.5940
Yellow S2	-0.0276	-4.9838
Yellow mod	0.0579	-4.4039
Yellow mod*	-0.0807	-2.6008
Yellow amp	0.5935	-3.9363
Yellow amp*	0.7421	-3.9677
Yellow kck	0.0327	-5.7625
Yellow kck*	-0.0813	-3.9535
Yellow S1	0.0202	-5.0103

X_{blue} = 0 mm X_{yellow} = 1 mm

	X (mm)	Y (mm)
Blue S2	-0.0156	4.9871
Blue mod	-0.2364	4.1074
Blue mod*	-0.4377	5.1233
Blue amp	-0.6622	4.2001
Blue amp*	-0.7774	5.3091
B kck	-0.5492	3.0915
Blue kck*	-0.6712	-13.8502
Blue S1	-0.3923	0.5940
Yellow S2	0.9375	-4.9823
Yellow mod	1.0901	-4.3041
Yellow mod*	0.7371	-2.4321
Yellow amp	1.5634	-3.9525
Yellow amp*	1.7324	-4.1928
Yellow kck	1.0140	-5.7781
Yellow kck*	0.8290	13.6374
Yellow S1	1.0531	-5.0138

X_{blue} = -1 mm X_{yellow} = 1 mm

	X (mm)	Y (mm)
Blue S2	-0.9918	5.0196
Blue mod	-1.1641	4.1947
Blue mod*	-1.6973	5.1294
Blue amp	-1.5738	4.0910
Blue amp*	-1.2608	5.1918
B kck	-1.4982	3.0812
Blue kck*	-1.7134	3.5656
Blue S1	-1.3769	0.5940
Yellow S2	0.9400	-4.9796
Yellow mod	1.0821	-4.3791
Yellow mod*	0.4770	-2.4193
Yellow amp	1.4938	-4.0081
Yellow amp*	1.4304	-4.0122
Yellow kck	1.0782	-5.8061
Yellow kck*	0.6272	-3.8678
Yellow S1	1.0484	-5.0200

Anomalous readings shown with arrows are due to the 2π uncertainty in phase

What next

- Find phase advance per ADC clock established (looks the same for all BPMs)
- Find phase offsets in the channels are found from the acquired signal
- Find phase shift between two beams is from the acquired signal
- Adjust calculations for phase
- Perform statistical analysis of the acquired data (errors in phase, positions)
- Repeat the measurements with changing cogging phase (phase shift between two beams) when updated script is ready