Non-Linear studies: summary and planning

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24th April 2012

Outline

$Q,\ Q',\ Q'',\ Q'''$

· In 2011 several measurements of the variation in tune with momentum were performed.

$$Q\left(\frac{dp}{p}\right) = Q_0 + Q'\left(\frac{dp}{p}\right) + \frac{1}{2!}Q''\left(\frac{dp}{p}\right)^2 + \frac{1}{3!}Q'''\left(\frac{dp}{p}\right)^3 \ldots$$

· All indicated a substantial discrepancy between the Q'' & Q''' obtained in beam based measurements and expected from measured magnetic and alignment errors.

Table: Modelled and measured NL-chromaticities for B1 (10/6/11) and B2 (2/7/11).

	$\mathbf{Q''_x}[10^3]$	$\mathbf{Q''_y}[10^3]$	$\mathbf{Q'''_x}[10^6]$	$\mathbf{Q'''_y}[10^6]$
B1	−1.8 (0.02)	0.88 (0.02)	−2.3 (0.06)	0.81 (0.06)
B1 model	0.060	0.28	−1.0	0.12
B2	−2.1 (0.02)	0.74 (0.01)	−1.9 (0.06)	0.82 (0.09)
B2 model	−0.20	0.21	−0.86	0.12

$Q,\ Q',\ Q'',\ Q'''$

· During the 2011 Non-linear MD tested corrections for the Q'' & Q'''.

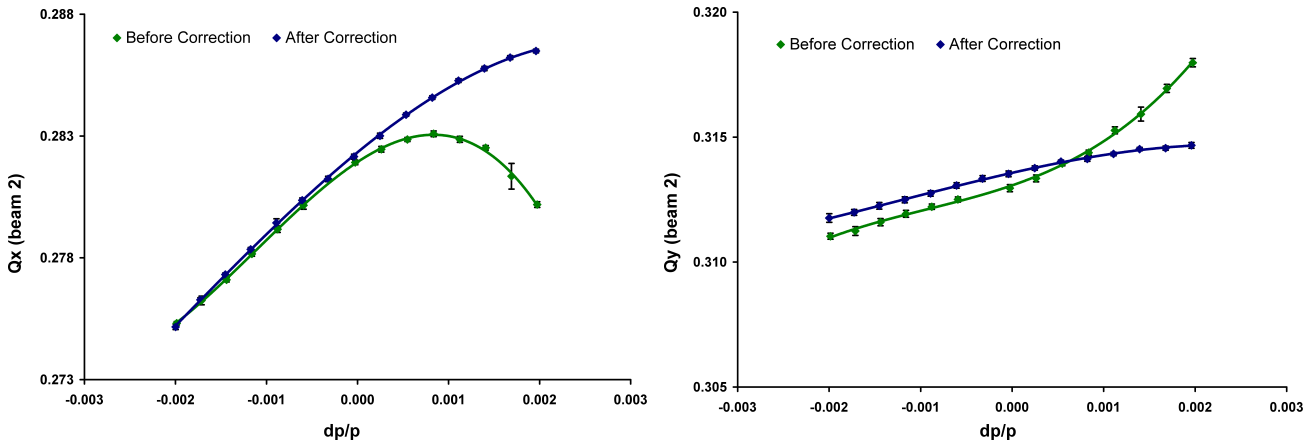

Figure: $Q_{x,y}$ vs dp/p before and after correction with octupolar and decapolar spool pieces (B2)

Table: Measured NL-chroma of B2 before and after correction.

	$\mathbf{Q''_x}[10^3]$	$\mathbf{Q''_y}[10^3]$	$\mathbf{Q'''_x}[10^6]$	$\mathbf{Q'''_y}[10^6]$
Before	$-2.1\ \ (0.02)$	$0.74(0.03)$	$-1.9\ \ (0.06)$	$0.8\ \ (0.09)$
After	$-0.72(0.02)$	$-0.19(0.02)$	$-0.37(0.05)$	$-0.15(0.04)$

$Q,\ Q',\ Q'',\ Q'''$

Two explanations suggested:
$\longrightarrow$ hysteresis of the Octupolar (MCO) spool pieces.
$\longrightarrow$ systematic misalignment of Decapolar (MCD) spool pieces wrt dipoles.

· Model and measurements agree closely on the shift in Q'' & Q''' due to the correction.
$\longrightarrow$ Limits systematic misalignment of MCD to ≤ 0.3mm H
$\longrightarrow$ 0.1mm gives best agreement with the $\Delta Q''$ during correction.

The modelled Q'', incorporating the 0.1mm MCD misalignment and an estimate of the hysteresis in the MCO, agrees well in the vertical plane, and accounts for the vast majority of the horizontal discrepancy.

Next step: analyze the Q' during the NL-chroma correction to see if it is consistent with the misalignment

$Q,\ Q',\ Q'',\ Q'''$

Tune discrepancy:

FiDEL have deduced a discrepancy in the bare tunes at injection:
$\longrightarrow$ (+0.035,-0.07) from (0.28,0.31) respectively.
$\longrightarrow$ Is this expected from the model?

	B2 seed 1 Full model	B2 seed 2 Full model
Q_x	0.3147	0.2959
Q_y	0.2939	0.2683
Q'_x	2.0000	1.9999
Q'_y	1.9999	2.0000
$\Delta Q_{x\ nom}$	0.0348	0.0160
$\Delta Q_{y\ nom}$	-0.0160	-0.04169

Obtained bare tune estimates for seeds 1 & 2 from ptc model including all measured errors and misalignments.

Large difference between seeds would suggest discrepancy is coming from MQs.
$\longrightarrow$ Should perform analysis over all seeds.

A similar study at 4TeV may be of interest.

Q, Q', Q'', Q''' - Future work

Studies to perform:

- Analysis of Q' for NL-chroma correction.
  $\longrightarrow$ *before next non-linear MD*
- Tune estimates in the full ptc model. Study of all 60 seeds at injection.
  $\longrightarrow$ *this week.*
- Tune estimates in the full ptc model at 4TeV.
  $\longrightarrow$ *(if and when time permits).*

If opportunity arises:

- Measurement of the natural chromaticity?
- Variation of Q and Q' with MCO, MCD settings.

Feed down studies in the IR's

Non-linear magnetic errors in low$-\beta^*$ sections may have significant detrimental effects on beam lifetime and dynamic aperture.

On encountering high order multipoles, an off axis beam will experience a shift in tune or coupling due to the feed down.

Table: Feed down to normal gradient (ΔQ) / Coupling (ΔC).

	$\mathbf{b}_3$	$\mathbf{a}_3$	$\mathbf{b}_4$	$\mathbf{a}_4$	$\mathbf{b}_5$	$\mathbf{a}_5$	$\mathbf{b}_6$
H bump	ΔQ	ΔC	ΔQ	ΔC	ΔQ	ΔC	ΔQ
V bump	ΔC	ΔQ	ΔQ	ΔC	ΔC	ΔQ	ΔQ

We have measured parasitically the Tune and Coupling under a variety of circumstances where the IP crossing angles have been varied.

(*Aperture MDs, spectrometer polarity switch, crossing angle collapse...*)

Measurements performed.

2011:

- IP1 → aperture measurement H&V
- IP5 → aperture measurement H&V
- IP2 → aperture measurement H&V
  → aperture measurement (switched Xing polarity) V
  → Xing polarity switch V

2012:

- crossing angle collapse in all IPs, (IP8 with both HV and V)

Some Results...

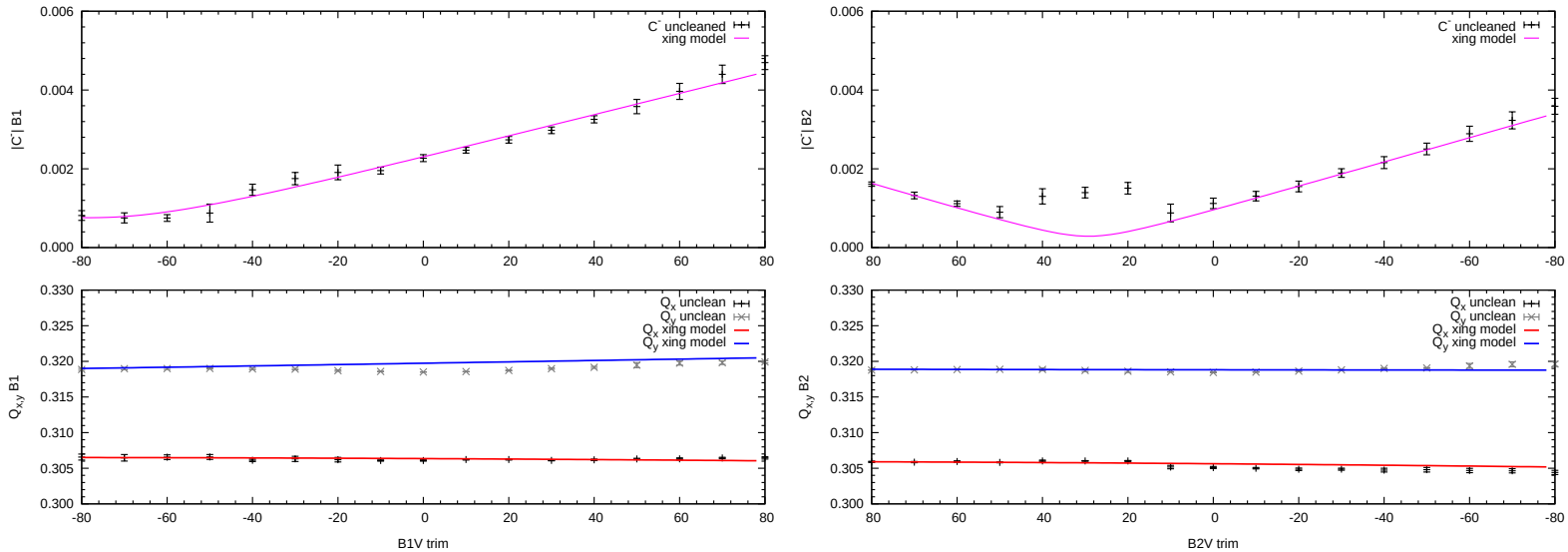

Figure: IP2 Xing polarity flip, model vs measurements.

- Match Tune and Coupling in model to the start of the scan.
- Apply knobs in the model as in MD.

Some Results...

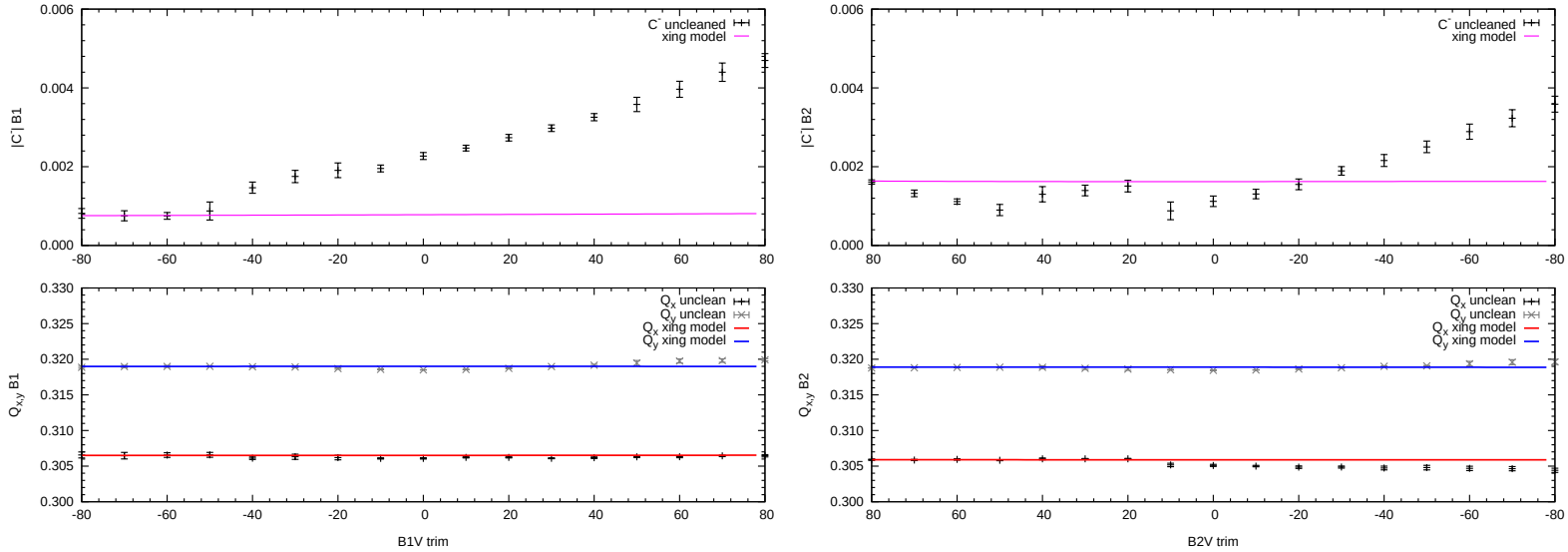

Figure: IP2 Xing polarity flip, model with MCX vs measurements.

- Turning on the IP normal sextupole correctors in the model.

Some Results...

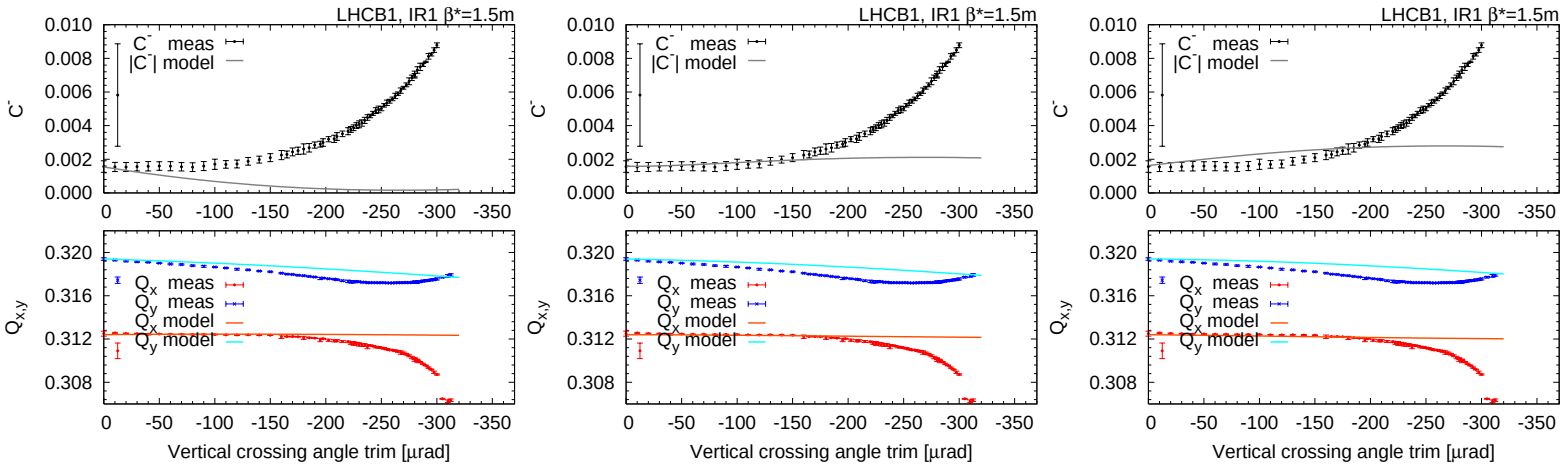

Figure: IP1 aperture measurement (Lumiscan knobs).

· Large discrepancy in IP1 $\longrightarrow$ skew octupole or closed orbit?

· Lack of a reliable coupling phase measurement makes comparison to model, and correction, difficult.

Future work.

Analysis:

- Analysis of 2012 data so far for crossing angle collapse (first look at IP8!).
  - → *Examine measured data this week.*
  - → *if reasonable quality then will compare to model.*
- IP1,5 model
  - → examine issue of closed orbit generating feed-down in the arcs.
  - → *May*
- Correction for skew octupole in IP1.

New measurements *(if opportunity arises)*:

- Measurement of coupling phase during scan!
  - → AC dipole, or Tobias' coupling tool.
- IP2 measurement with correctors active.
- Correction in IP1...

Search for resonance driving terms.

During 2012 commissioning had 2 occasions where high amp kicks were performed.

· 22/3/12 @ 4TeV, 0.6m.
→ Accidental kick on Q_x, $\approx 5\%$.
→ Beam 2 horizontal only. 1 kick only.

· 30/3/12 @ 4TeV, 0.6m.
→ High kicks, $\approx 45\%$
→ Both beams, HV. Multiple kicks.

An initial (extremely crude) analysis was done to see if it was worthwhile pursuing this data further.

Search for resonance driving terms.

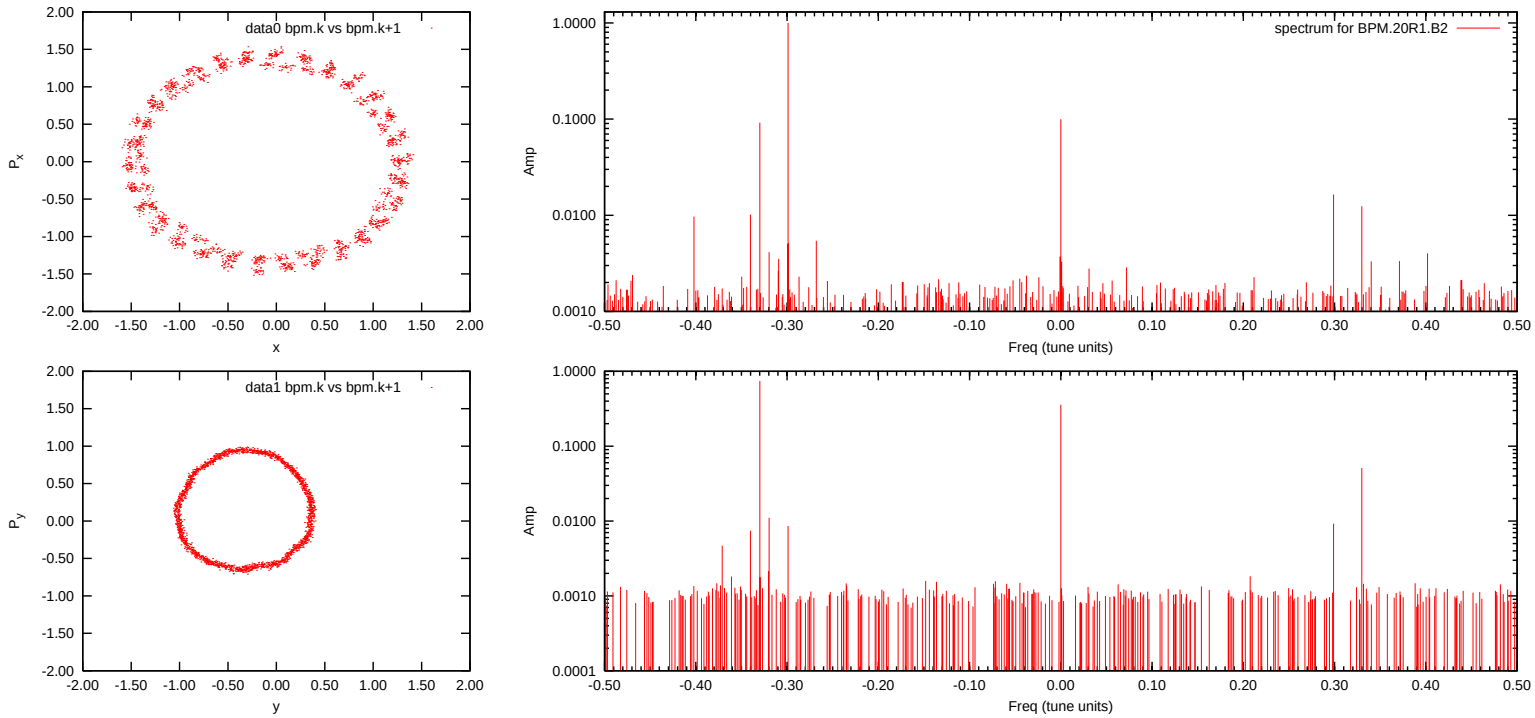

Figure: Spectrum for high kicks on 30/3/12.

Search for resonance driving terms.

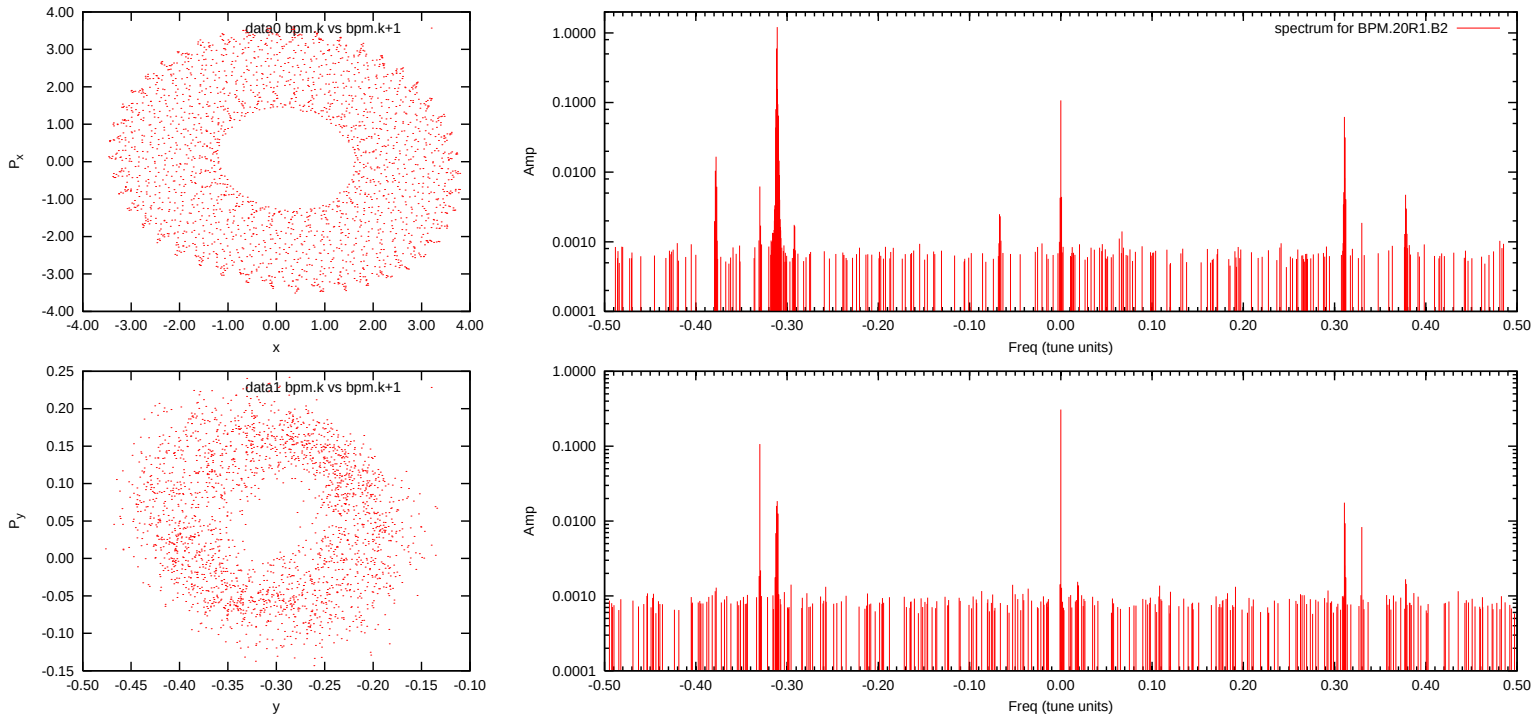

Figure: Spectrum for on-Q_x kick, 22/3/12.

Search for resonance driving terms.

Clear suggestions from the 2012 commissioning high kick data of sextupole lines and hints of octupole from 22/3 kick on the horizontal tune.

Definitely worth pursuing this further:
$\longrightarrow$ Proper analysis with DriveGod/GetLLM.
$\longrightarrow$ Comparison to simulation.
$\longrightarrow$ Update to GetLLM for octupolar terms.

$+$ data outstanding from the 2011 non-linear MD?
$+$ (fingers crossed) a further non-linear MD this summer.

Progressing with this should be a priority in the next month.

One further caveat: comparison of aperture kicker and AC dipole results??

Other.

SOLEIL:

· See large discrepancy between their LOCO and our turn-by-turn FFT optics measurements.
· Eventually aim to examine influence of SOLEIL insertion devices on the non-linear optics.
· *To discuss with Laurent before we can progress further.*

Global correction:

· Upgrade to enable weighting the β^*.
$\longrightarrow$ *as time permits.*

Coupling during recent aperture MD:

· substantial variation in coupling as landau octupoles were powered and unpowered during aperture measurement on 21/4/12.
· may be worth investigating further, comparison to model.
$\longrightarrow$ *as time permits.*