Controls Issues in Advanced LIGO

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Control is Complicated

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Models are critical, but it's also important to have specific measurements that we can take to compare to models

- What is the minimum frequency vector that will give sufficient information?

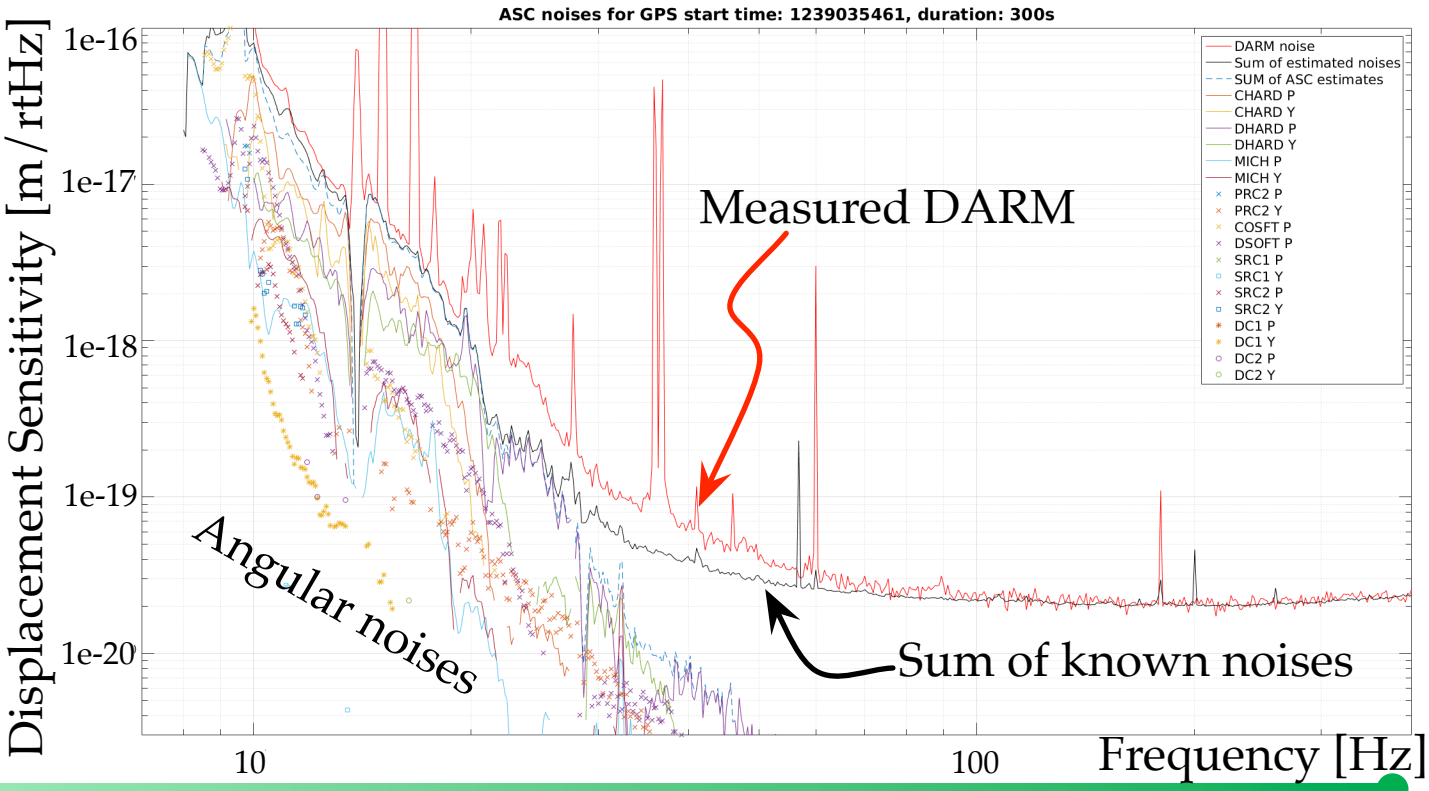
Lowering Control Gains

A major source of noise at low frequencies is control noise

It is difficult to lowpass enough for loops with unity gain at a few Hz

Given some requirement on the residual motion, for what loops can we lower the unity gain frequency?

What would be the effect on 'nearby' loops?



Increasing Control Gains

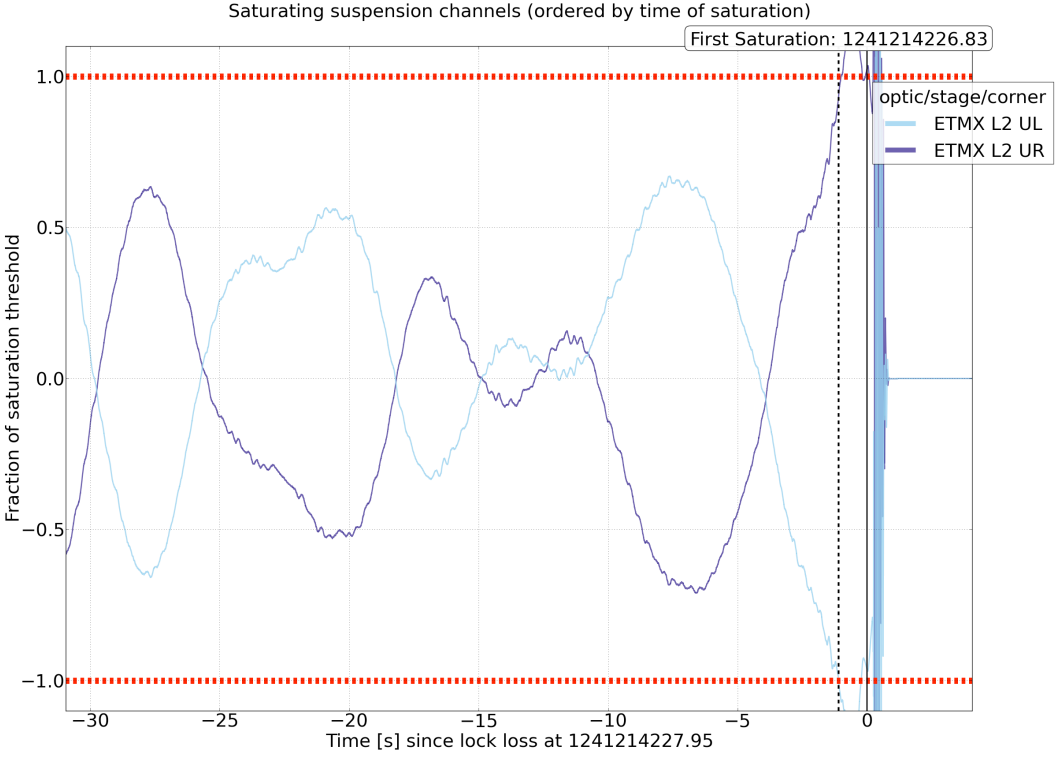
For what loops do we need more gain? If we were suppressing some motion better, are there any lock losses that we could have prevented?

We are doing better holding lock through more earthquakes by changing our seismic isolation control authority

Where is the residual motion high enough that we lose lock?

Do we fall too far from linear range of system?

Where are places that our control authority runs out of range?



https://ldas-jobs.ligo-wa.caltech.edu/~lockloss/index.cgi?event=1241214228

Length-Angle Coupling

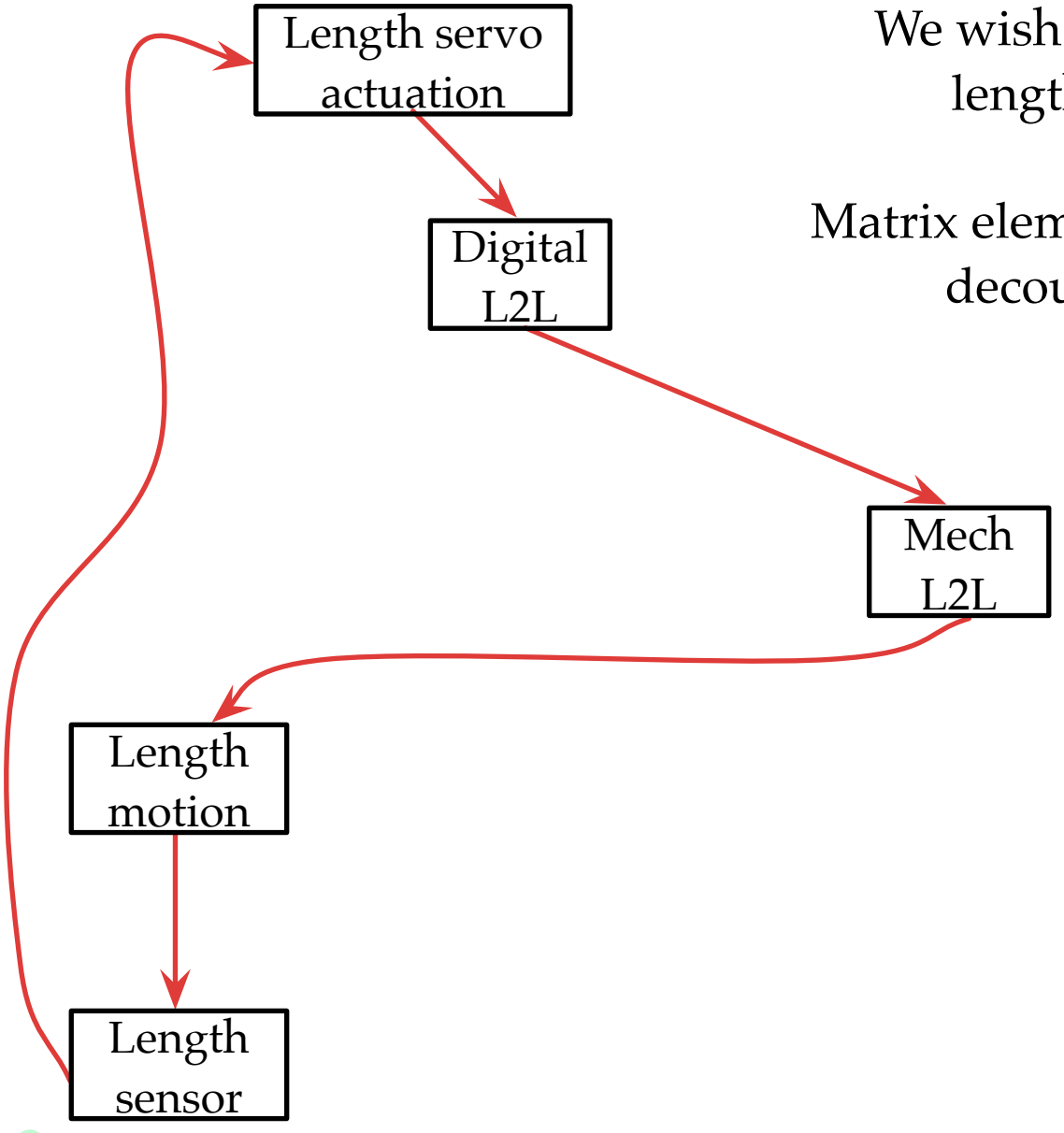
We know that we have a 4.2 Hz and an 8 Hz instability in the DARM loop, but we don't fully understand where

Most of our measurements indicate that everything should be very stable

It is at a frequency likely related to the L1-L2 (UIM-PUM) suspension stage crossover

We can change the length crossover by changing the angular loops

Length-Angle Coupling

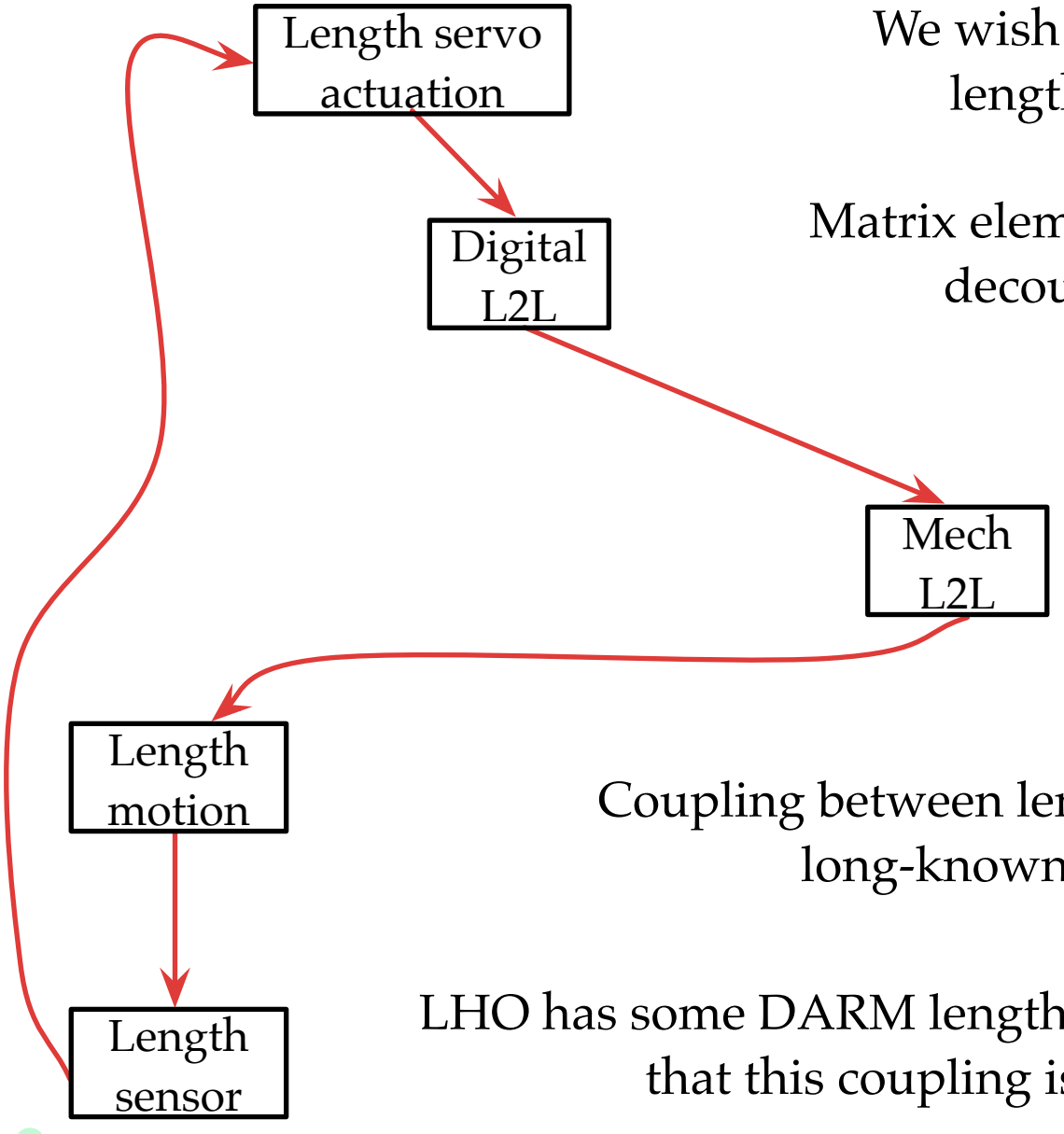


We wish we had just a simple length loop for DARM

Matrix elements in our digital system for decoupling length and angle

Transfer function from actuating on L2 PUM stage to motion at the L3 test mass stage

Length-Angle Coupling



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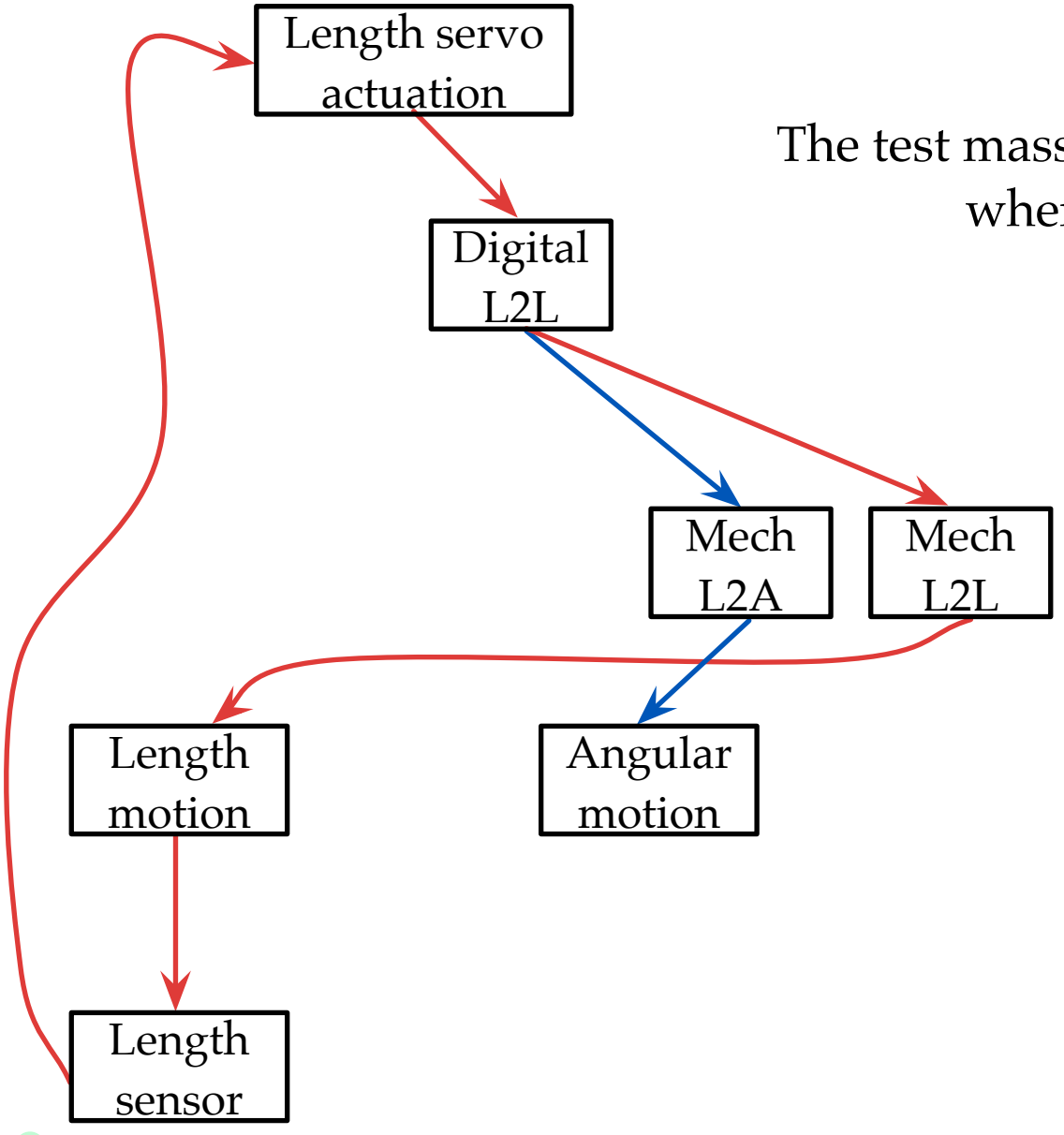
Matrix elements in our digital system for decoupling length and angle

Transfer function from actuating on L2 PUM stage to motion at the L3 test mass stage

Coupling between length and angle is a long-known problem

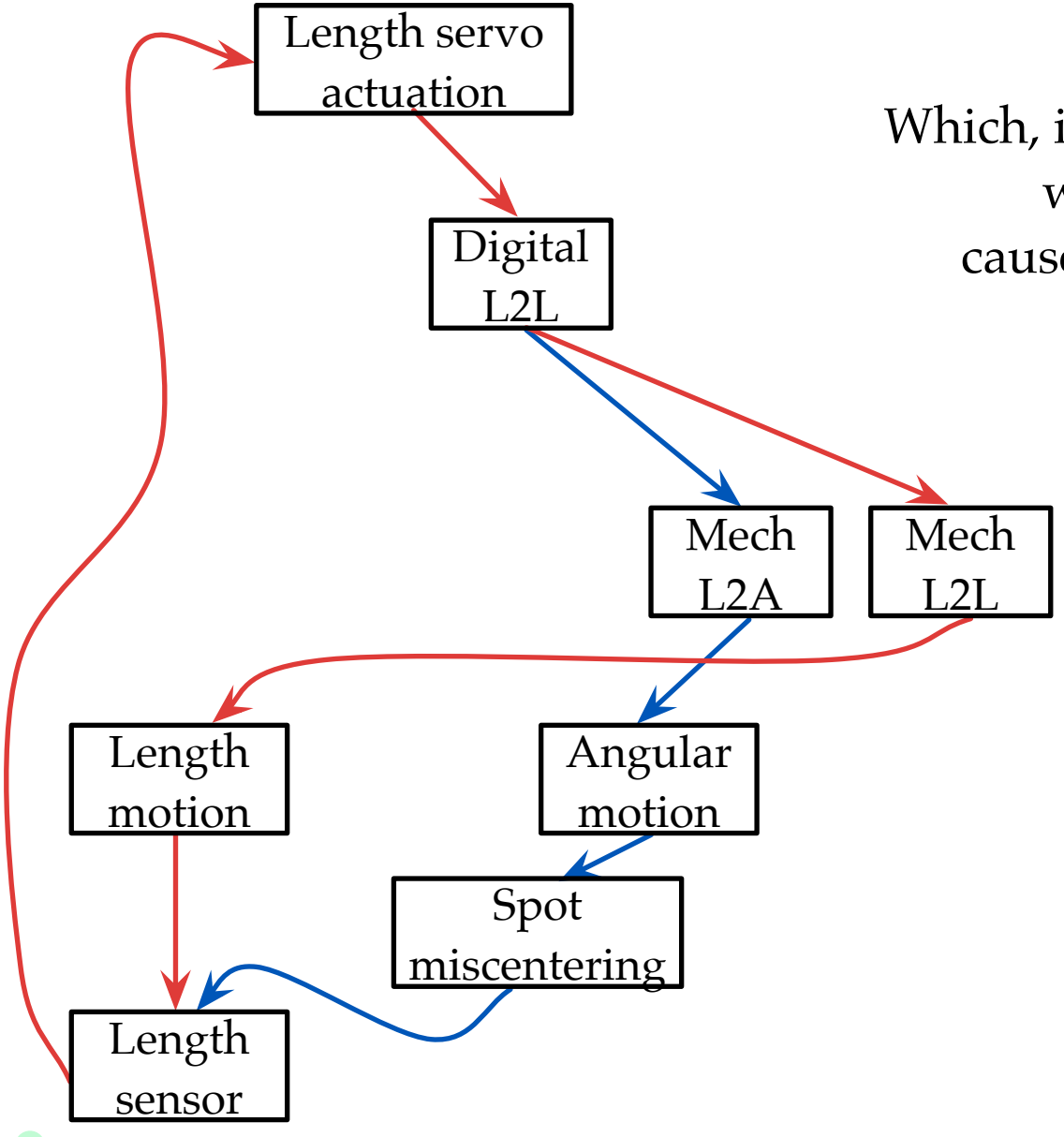
LHO has some DARM length instabilities, and we think that this coupling is likely involved

Length-Angle Coupling

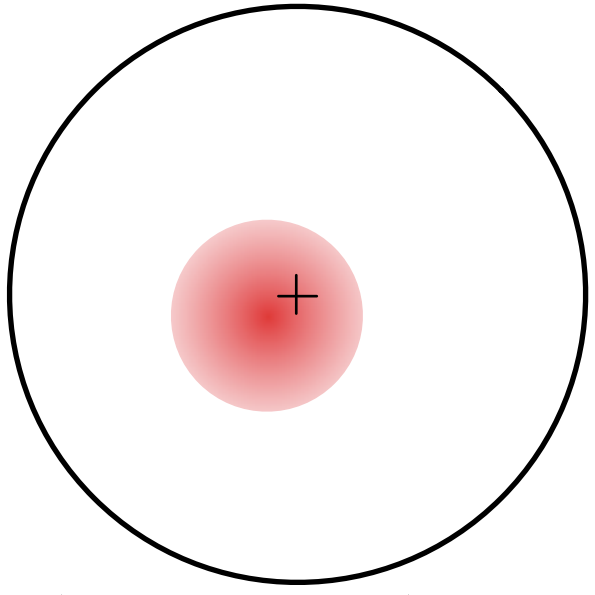


The test mass stage will move also in angle, when we actuate in length

Length-Angle Coupling



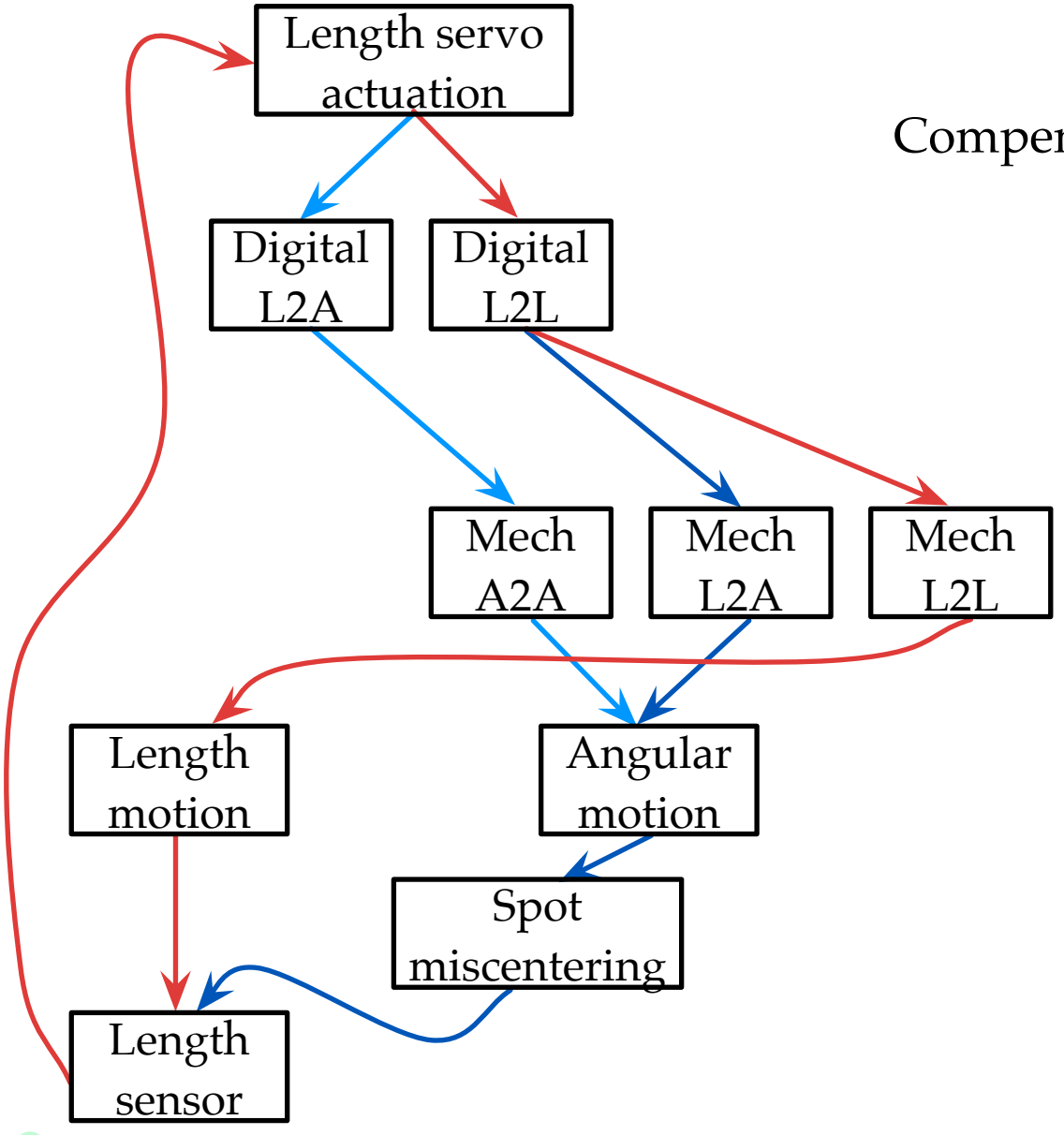
Which, if our spots are not co-located with the rotation node, causes cavity length to change



LHO: (18mm, -18mm)

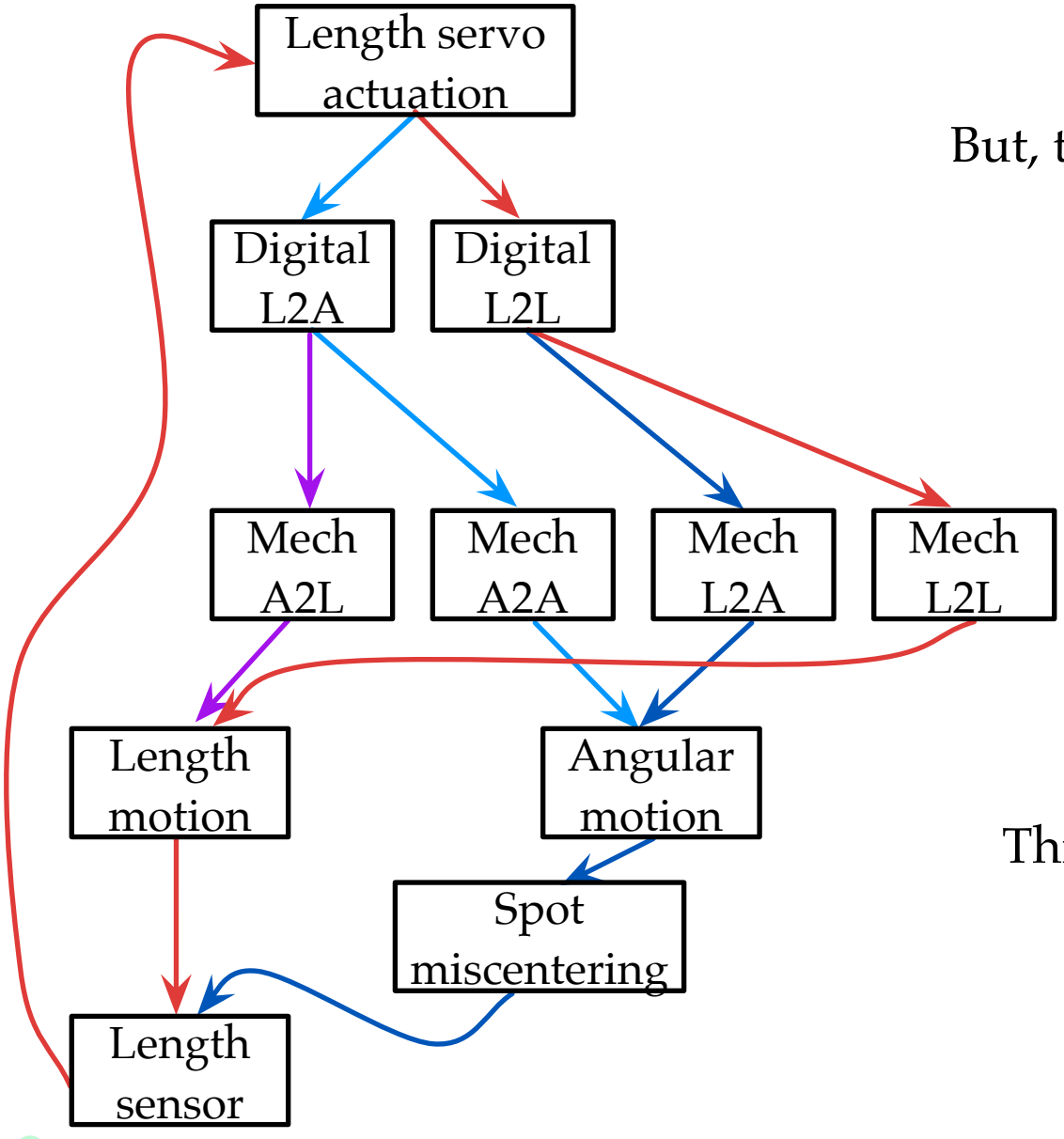
LLO: (17mm, -12mm)

Length-Angle Coupling



Compensate such that the angular motion is zero-ish

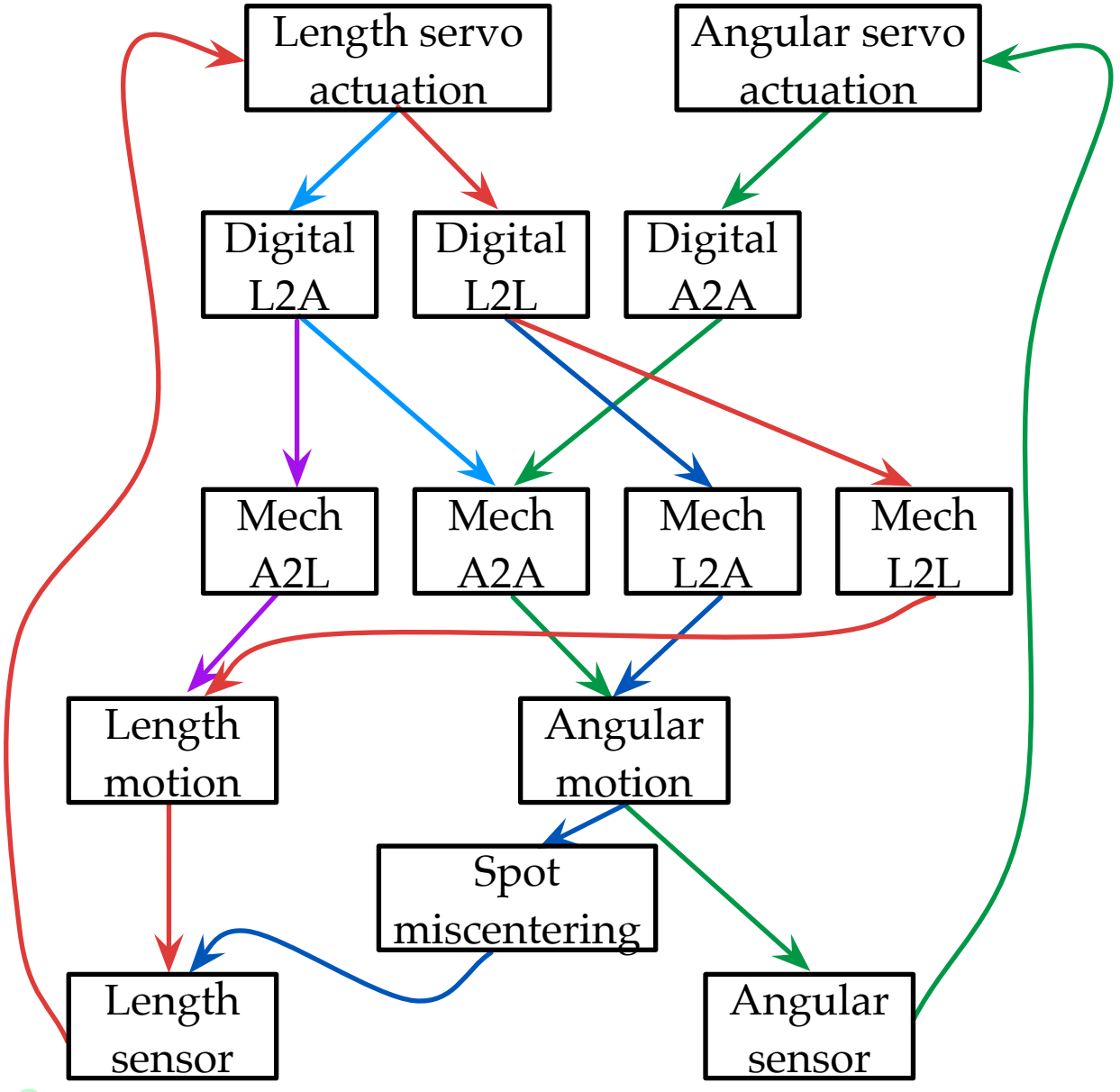
Length-Angle Coupling



But, there is mechanical angular to length coupling

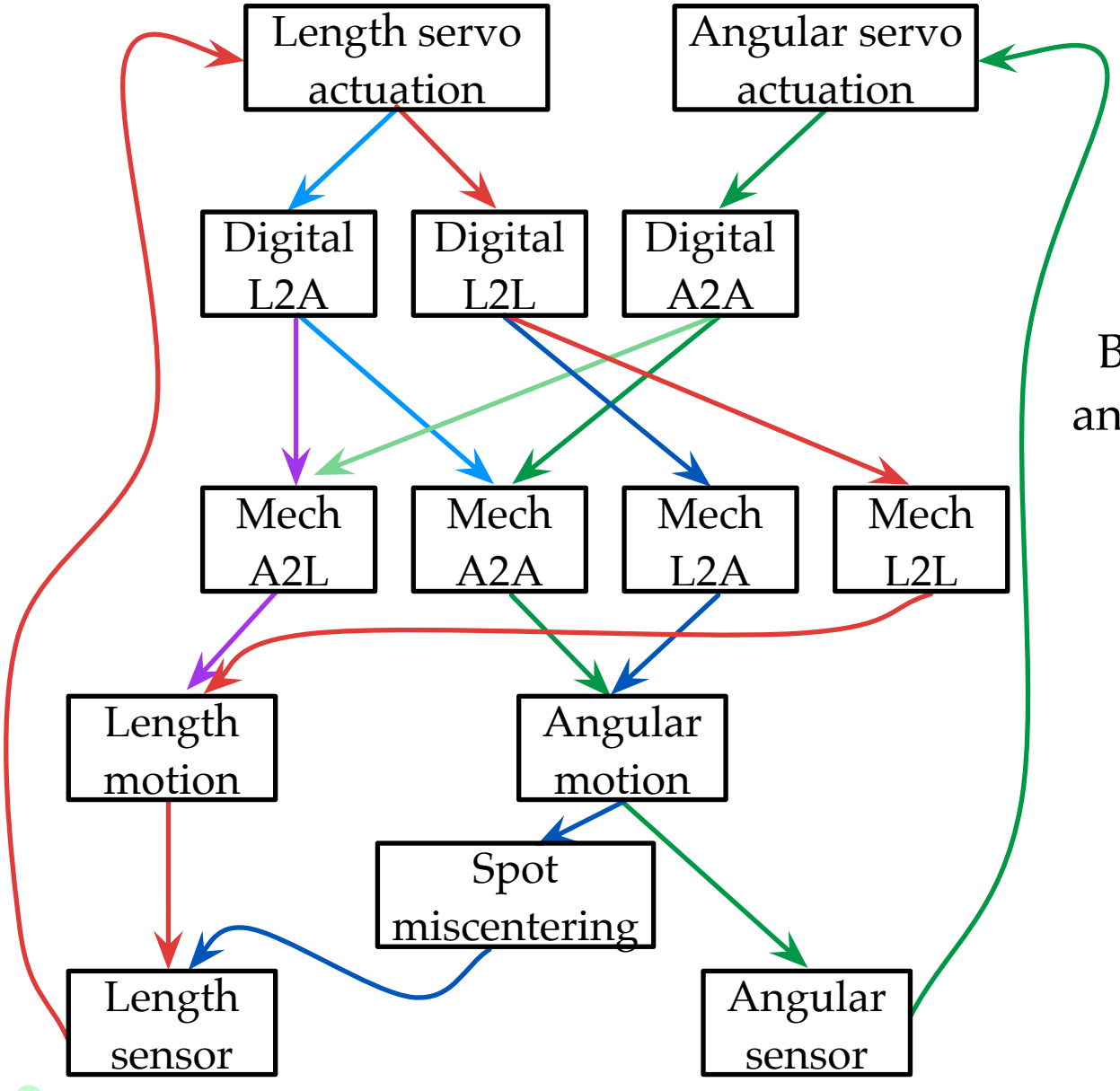
This is the L-to-A-to-L problem, without any angular loop

Length-Angle Coupling



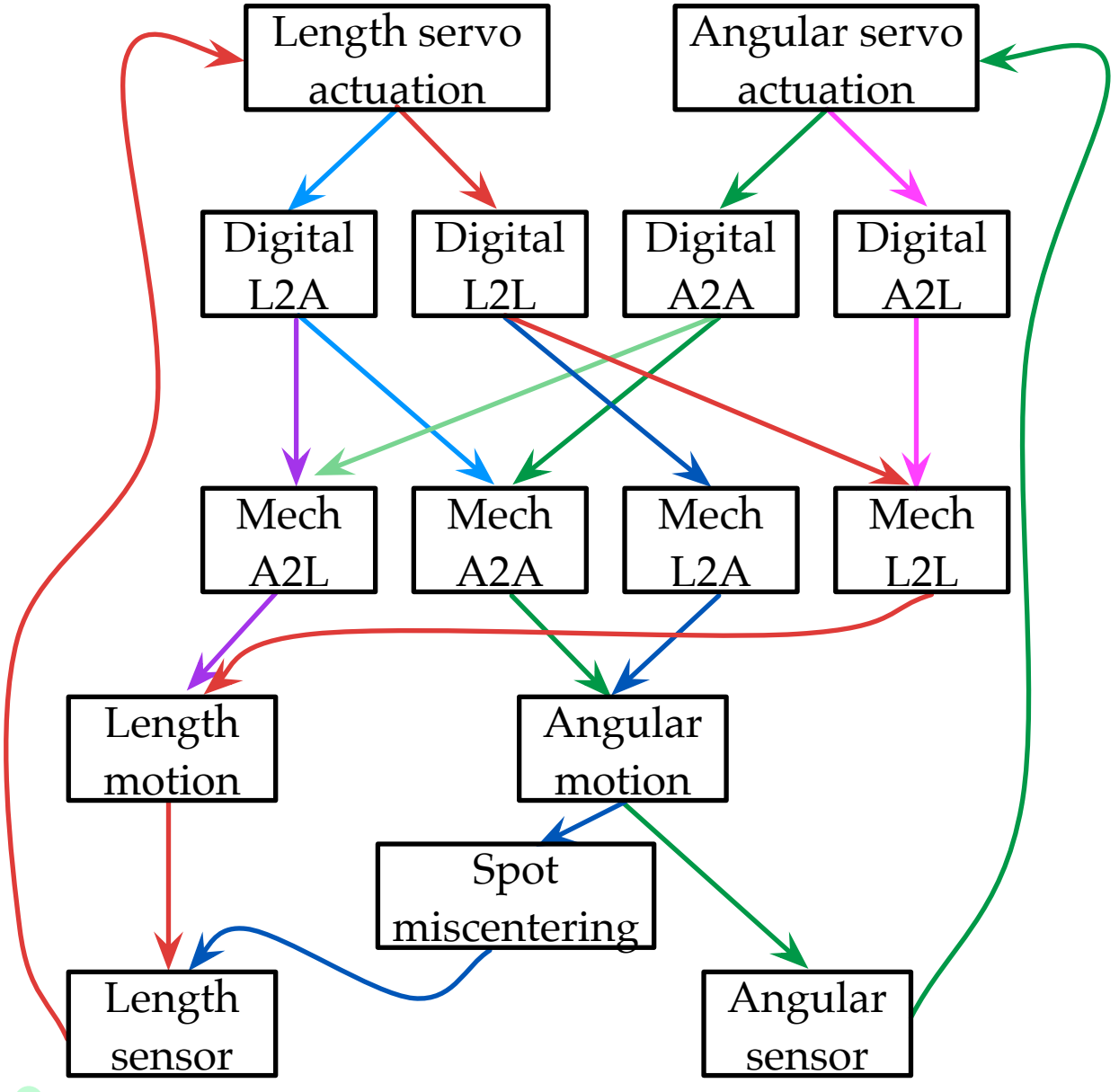
Angular loops will have same spot miscentering coupling to length

Length-Angle Coupling



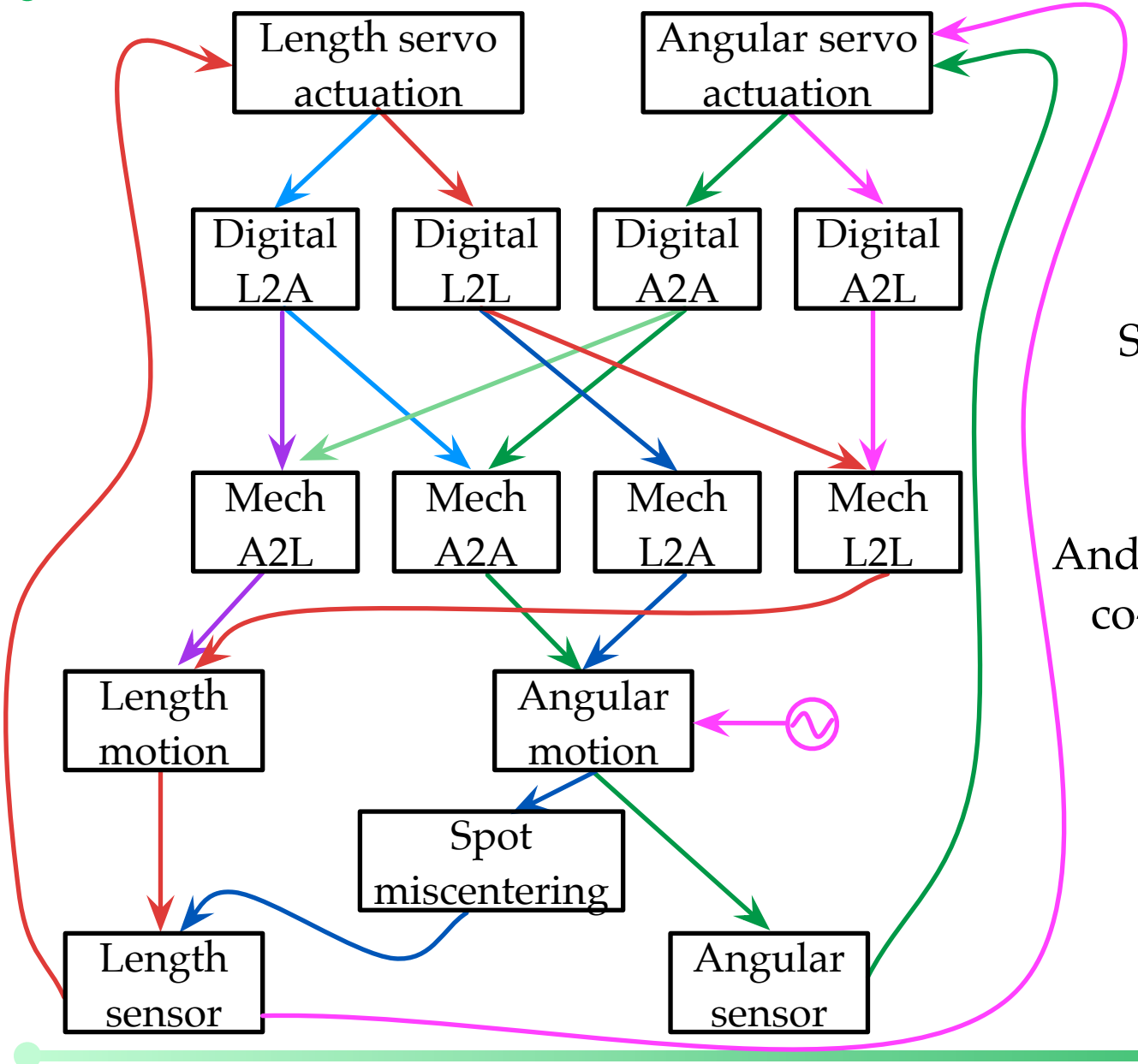
But also, the mechanical angular to length coupling

Length-Angle Coupling



So, we'll compensate with some A2L

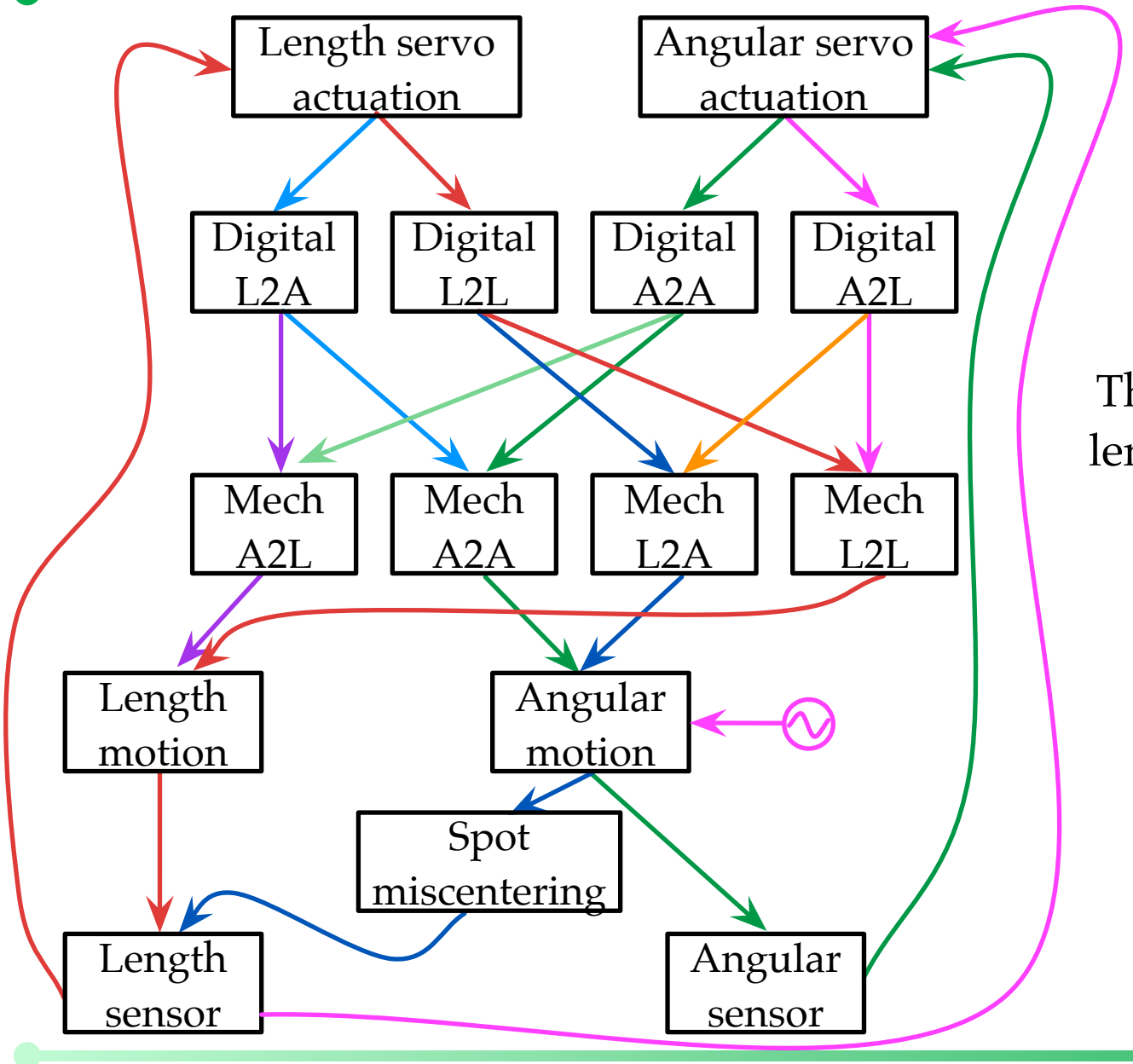
Length-Angle Coupling



So, we'll compensate with some A2L

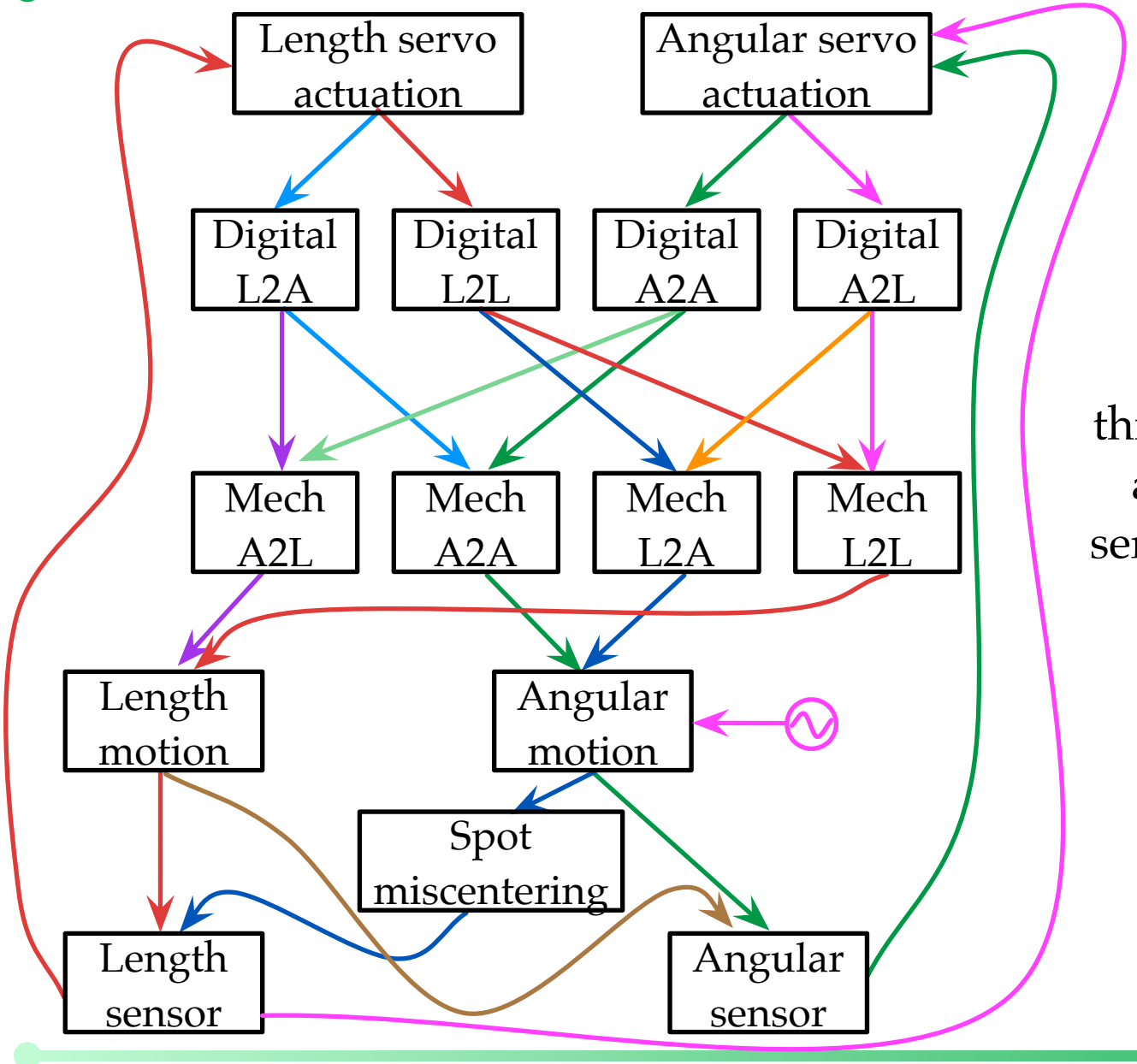
And keep the actuation node co-located with the beam

Length-Angle Coupling



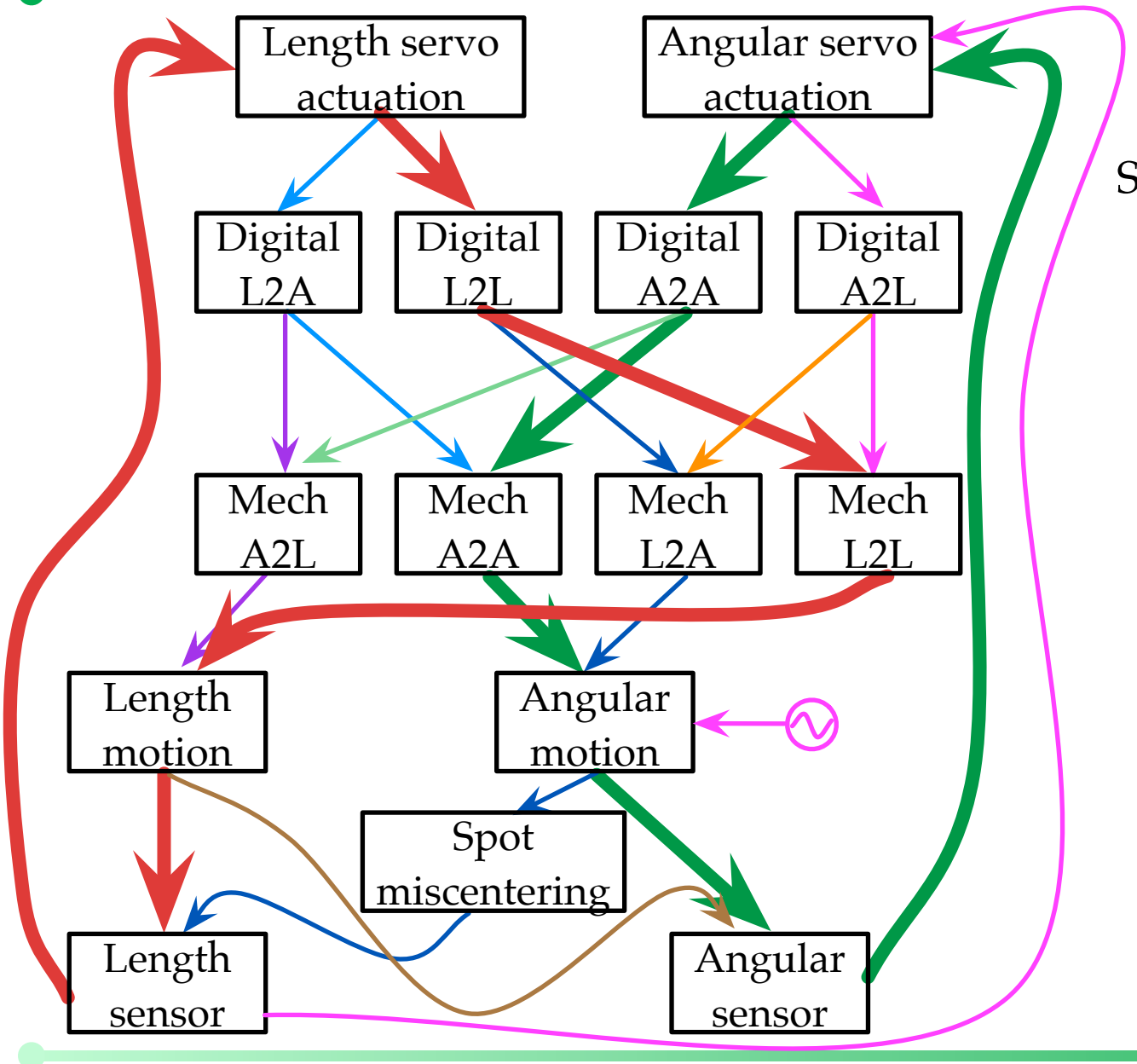
The length actuation has length to angle couplings

Length-Angle Coupling



Further complicating things is possibility of the angular sensors being sensitive to length motion

Length-Angle Coupling



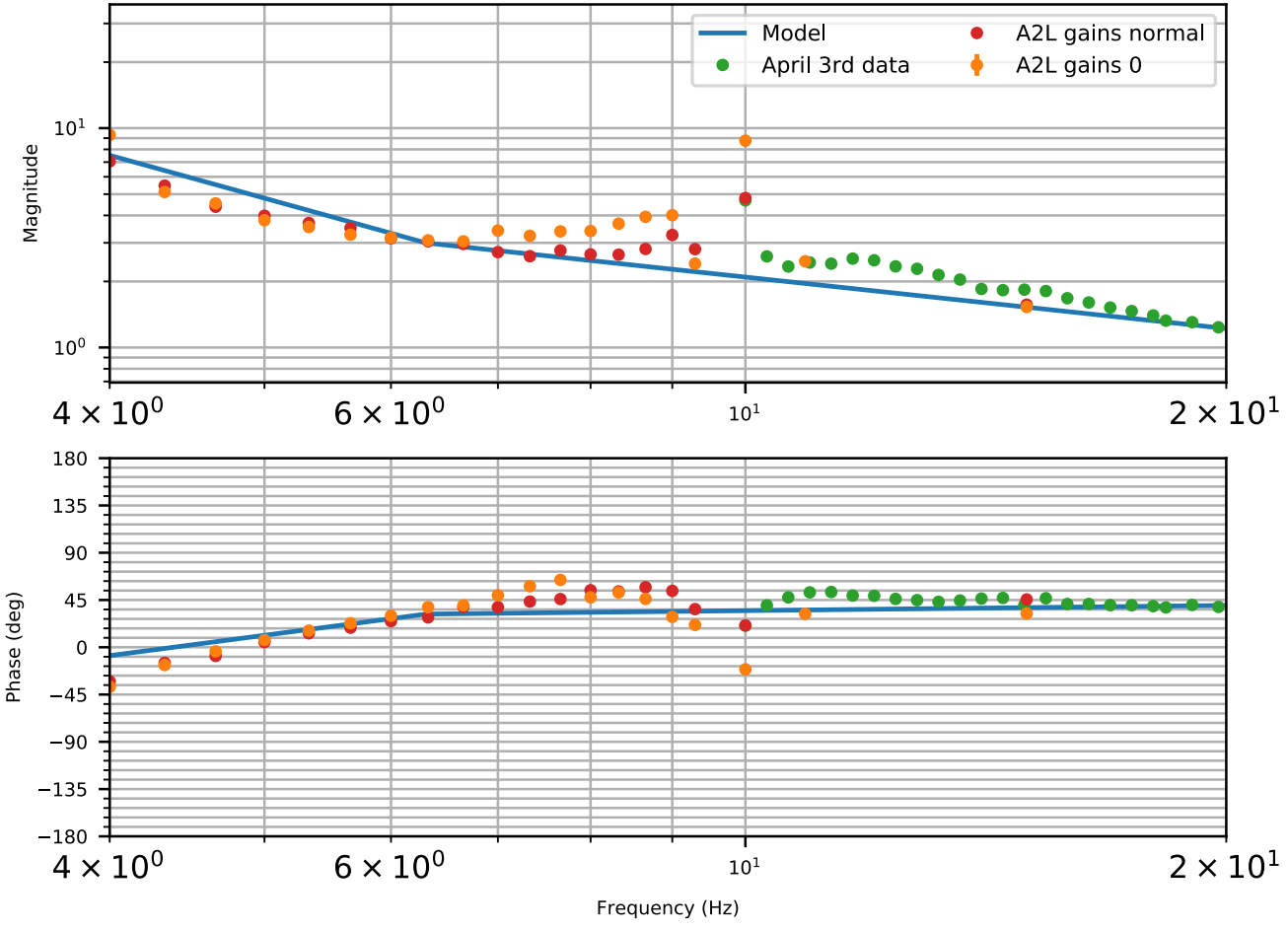
So, we don't really have 2 simple loops

Length-Angle Coupling

How do our length actuators change as we remove A2L decoupling (spot position on mirror same)?

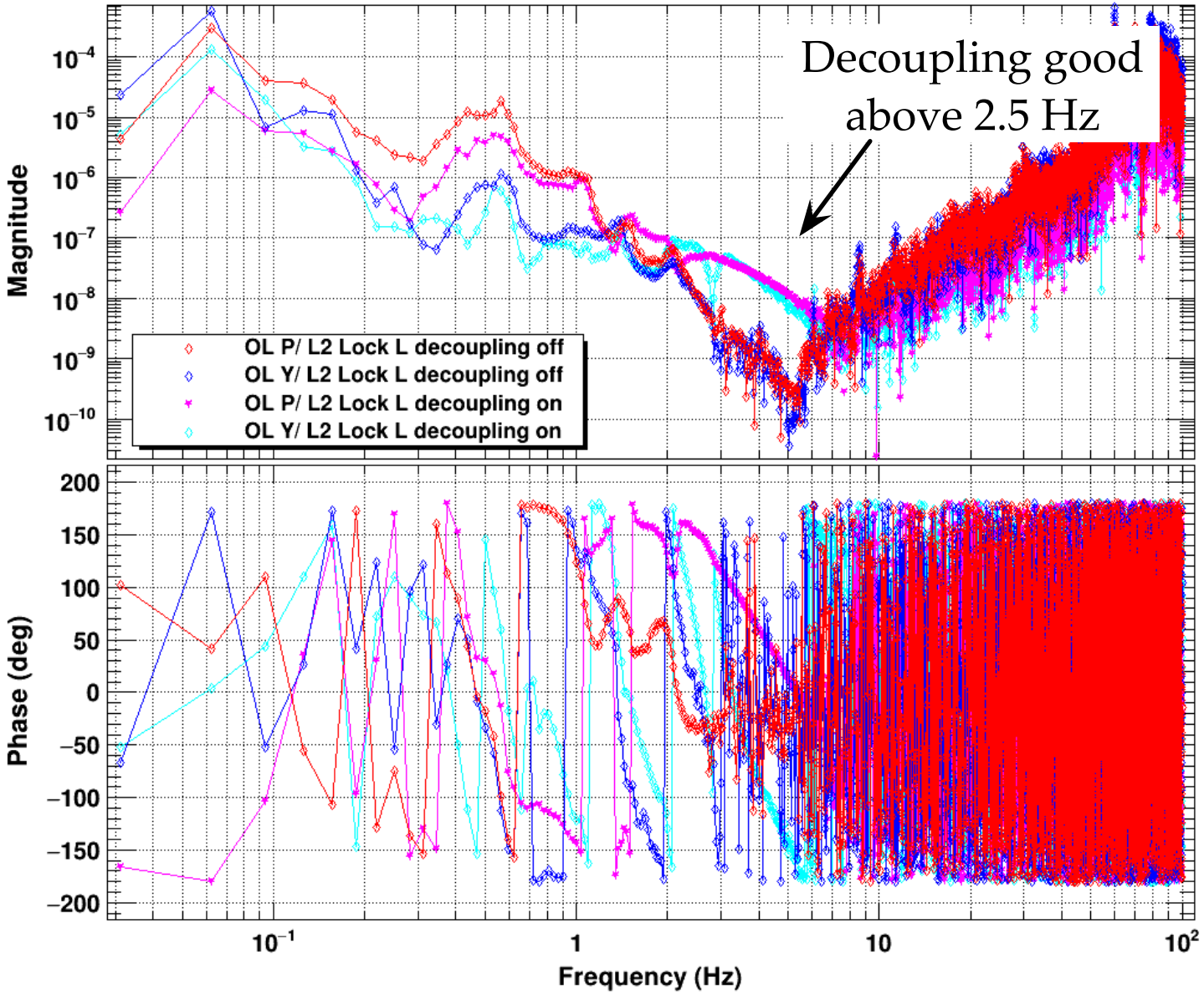
Why are we not matching the model? Our spots are too far off center?

2019-04-25 H1 L2/L3 crossover (L2LOCK IN1/IN2)



Length-Angle Coupling

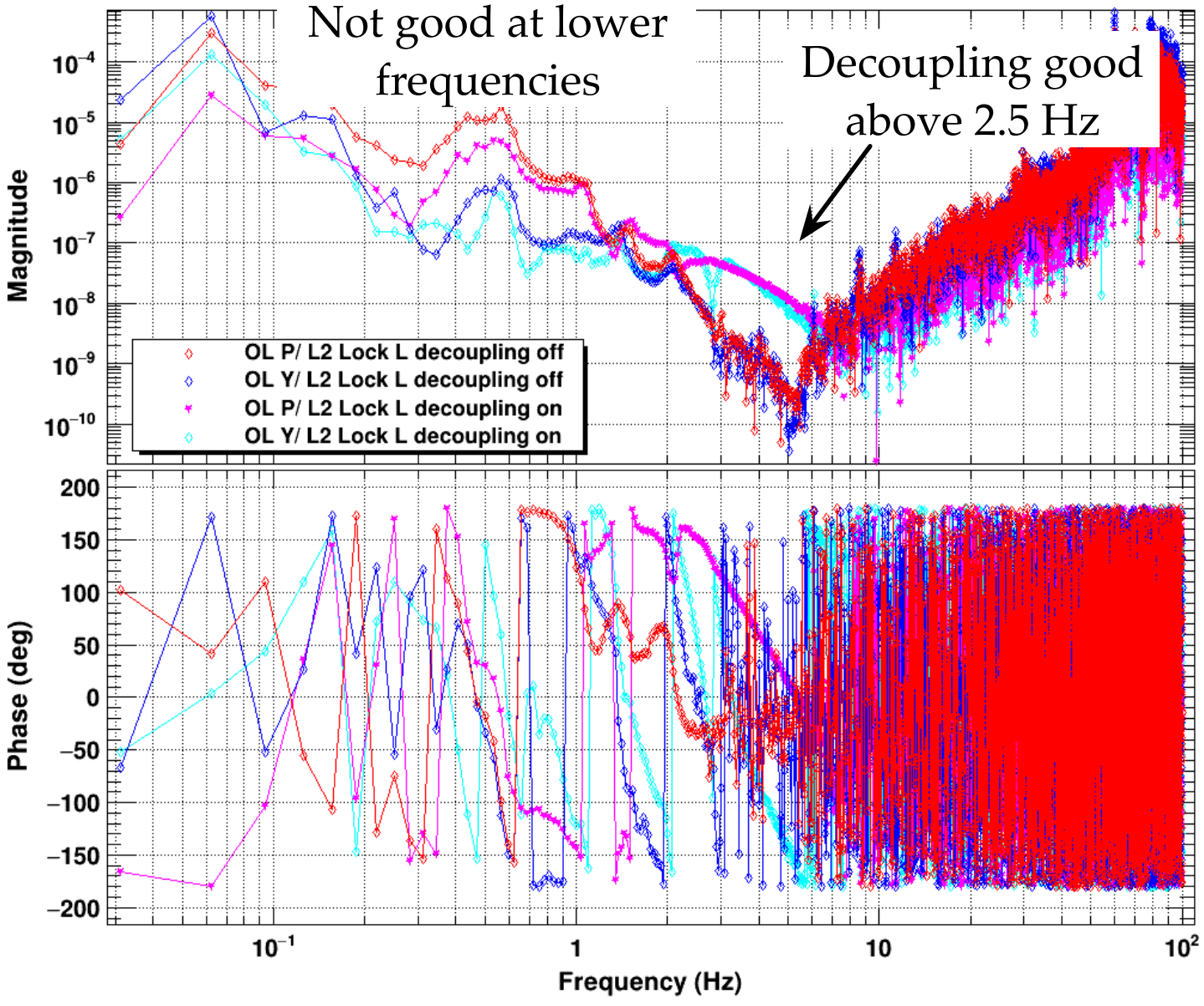
Drive length, see effect in angle



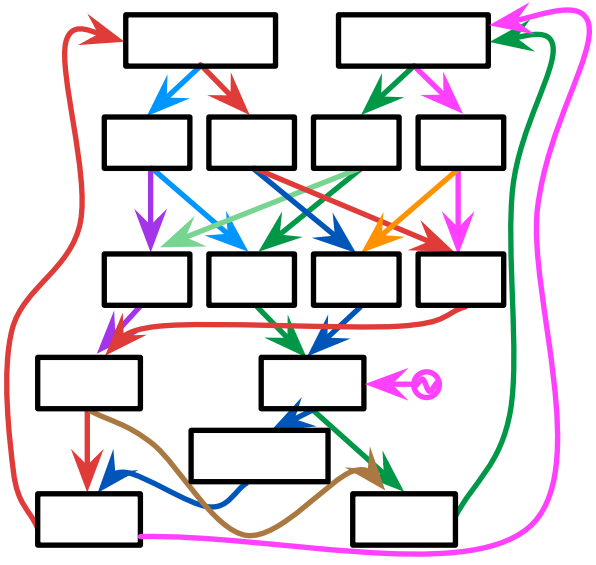
Length-Angle Coupling

Drive length, see effect in angle

What are the consequences of having poor decoupling below 1 Hz?



Questions for Controls Group



Loops that aren't causing problems don't get attention

Is there any low-hanging fruit for improving sensitivity or robustness?

We value robustness for interferometer livetime

For what systems should we operate closer to the edge of stability?

Models are critical

What complexities can we ignore? Which ones must be included?

What are the specific measurements we should take?