Things We Don’t Know

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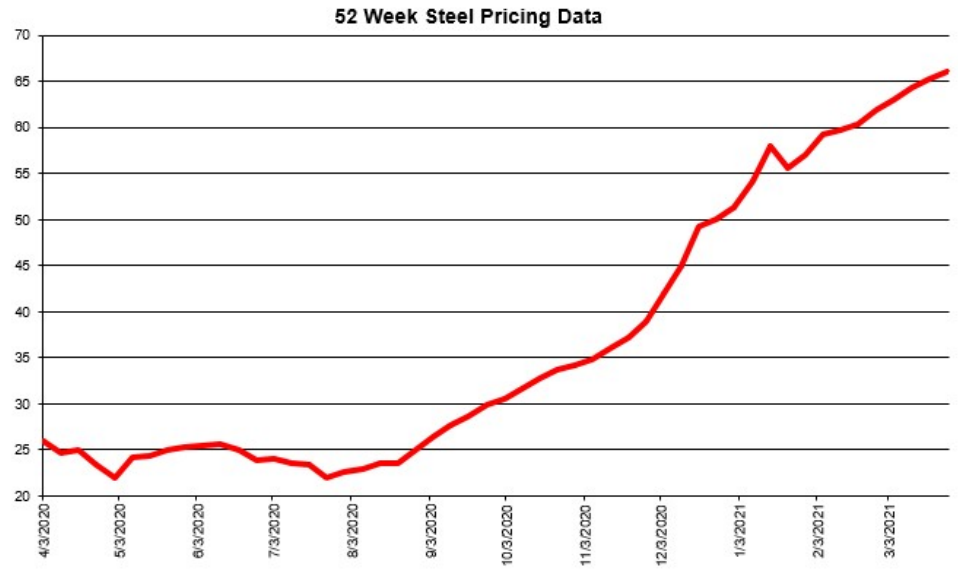
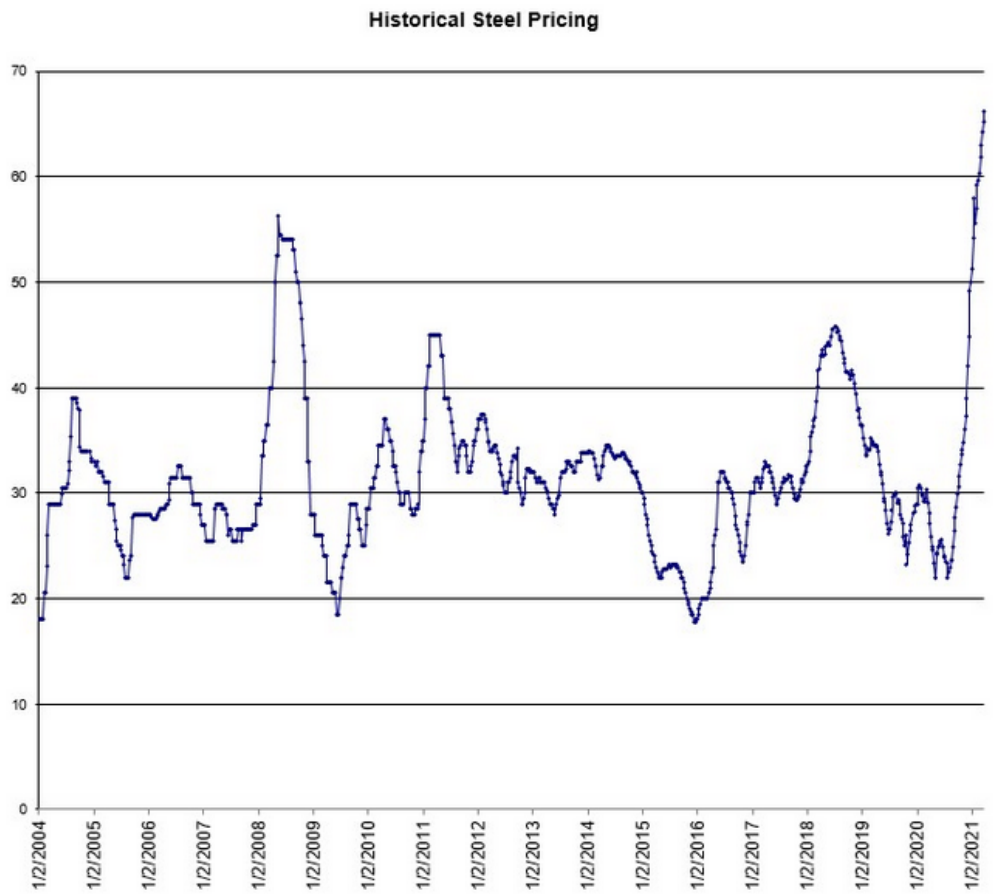
Start with the Summary

- These are a set of areas that have open issues and need work
  - I did not include the issue of how much light we need, as Faiza is working on that (and maybe we will hear from her today)

- Expect similar talks every few months
  - I want to make sure the group understands where we are
  - It's also an opportunity for people to say "I can help figure that out!" (if it's under our control)

When Will The Price of Steel Go Down?



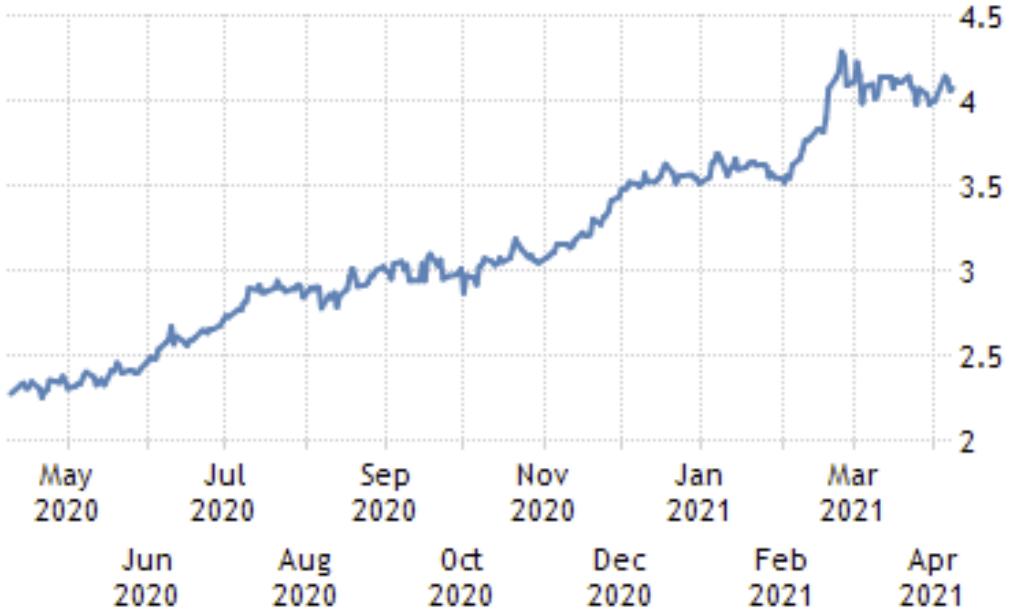


- Prices are at record highs
  - Worse, costs other than raw materials (e.g. cut to shape) are rising proportionally
- This is at least partially Covid-related
  - Supply and demand are both down. Supply is down more.

How Do We Insulate the Magnet Bus Bars?

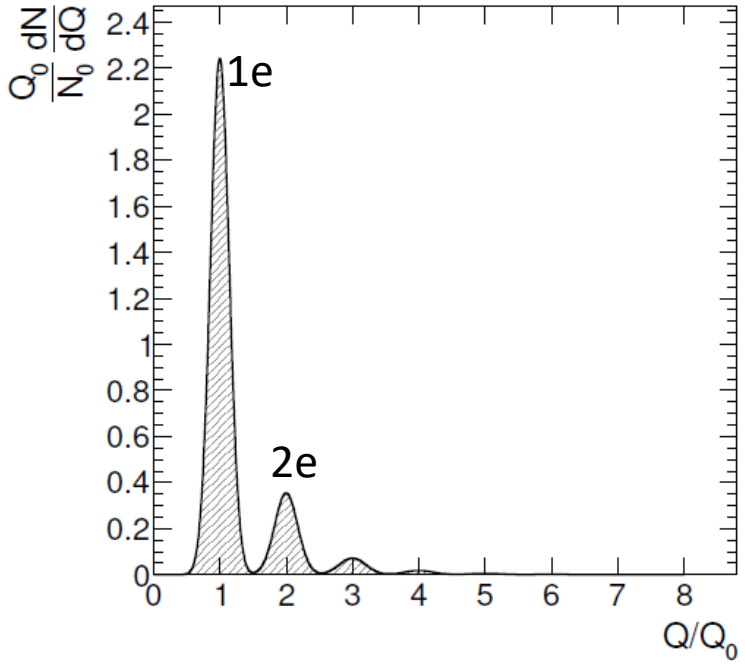
- Luvata quoted $200,000+ to wrap the bus bars
  - "It is a little unclear what will be the final insulation material…"
  - This is probably a sign that they don't want to do this, but will take our money if we insist

- Copper prices are also very high
  - Chinese demand up
  - Supply low because of Covid

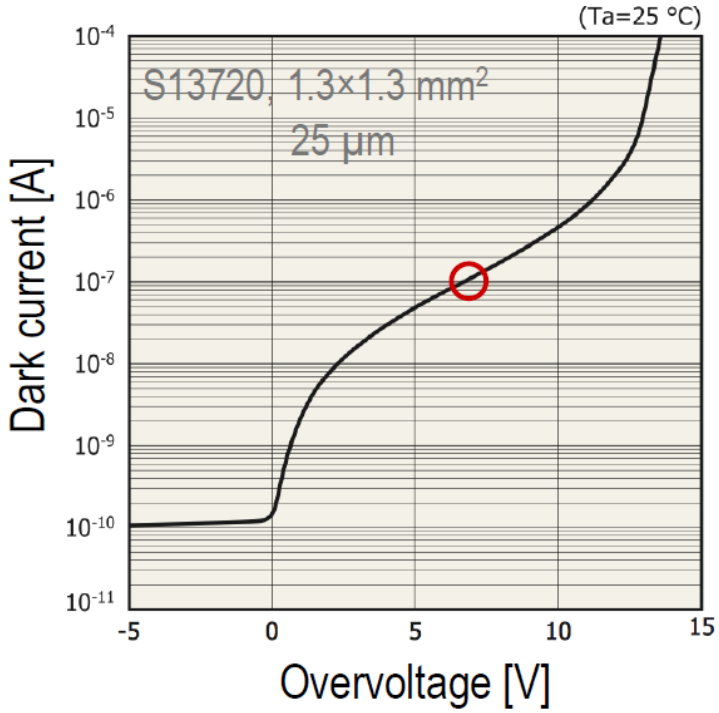


How Noisy are the SiPMs?

- All the SiPMs we are looking at have noise (dark count rate) in the 0.5-1.0 MHz ballpark
  - For a 2 bucket-wide pulse, that's an "occupancy" of 2-3%.
  - "Occupancy" is for at least 1 photoelectron
    - At 2 pe, it's more like 0.4%
- We don't know the noise spectrum for any of the candidate SiPMs.
  - Much less coherent noise
  - Reminder: the front-end chip is more susceptible to coherent noise than others



arXiv:1710.11410



Hamamatsu

Why Does it Matter?

- DAQ rates are driven by noise
  - ~600 hits per RF bucket noise; a 5 GeV muon has 100 signal hits
  - 750 kHz of noise at ~10 bytes/hit → 140 GB/s

- Requiring a total minimum energy (½ mip?) to read out an event
  - The catch: we can't look at the entire detector early in the readout chain
    - A panel can look at 48 channels
    - A data concentrator can look at 5 panels (makes sense to organize them in z)
    - Downstream – after we hand the event to the DAQ - we can look at the whole detector
      - If this is too late, we would need to add an Event Filter computer in between the DCs and the DAQ

Things Are Better Then They Look

- Beam comes in ~530 bunches (588 less abort gap) 10 μs per second
  - ~700 hits @ 10 bytes @ 10 Gb/s → 3 ms
  - I would just read out all 530 buckets (actually, 800 or so), noise and all.

- The issue is really with cosmic rays (more precisely, out-of-spill)
  - It's OK to fall behind a little during the spill
  - How much do we care about a tiny energy bias to cosmic rays?
  - How much do we care about pre-scaling cosmic rays?

(we can of course mix the two)

Electronics Naming Convention

Original	Today
Not needed.	Quad-counter motherboards. Takes SiPM signals and places them on an HDMI connector.
“On Panel Boards” – only board on the panel. Took SiPM output and digitizes it and sends on ribbon cables to the Data Concentrators.	Digitizes the SiPM signal, zero-suppresses it, and sends it on DisplayPort cables to the Data Concentrator. mu2e calls the equivalent a “front-end board”
“Data Concentrators” – Builds the partial event, zero-suppresses it, and sends it on to the DAQ.	Builds the partial event and sends it on to the DAQ. Also supplies power and timing to the OPB-equivalent.

We could use better names than OPB and DC now.

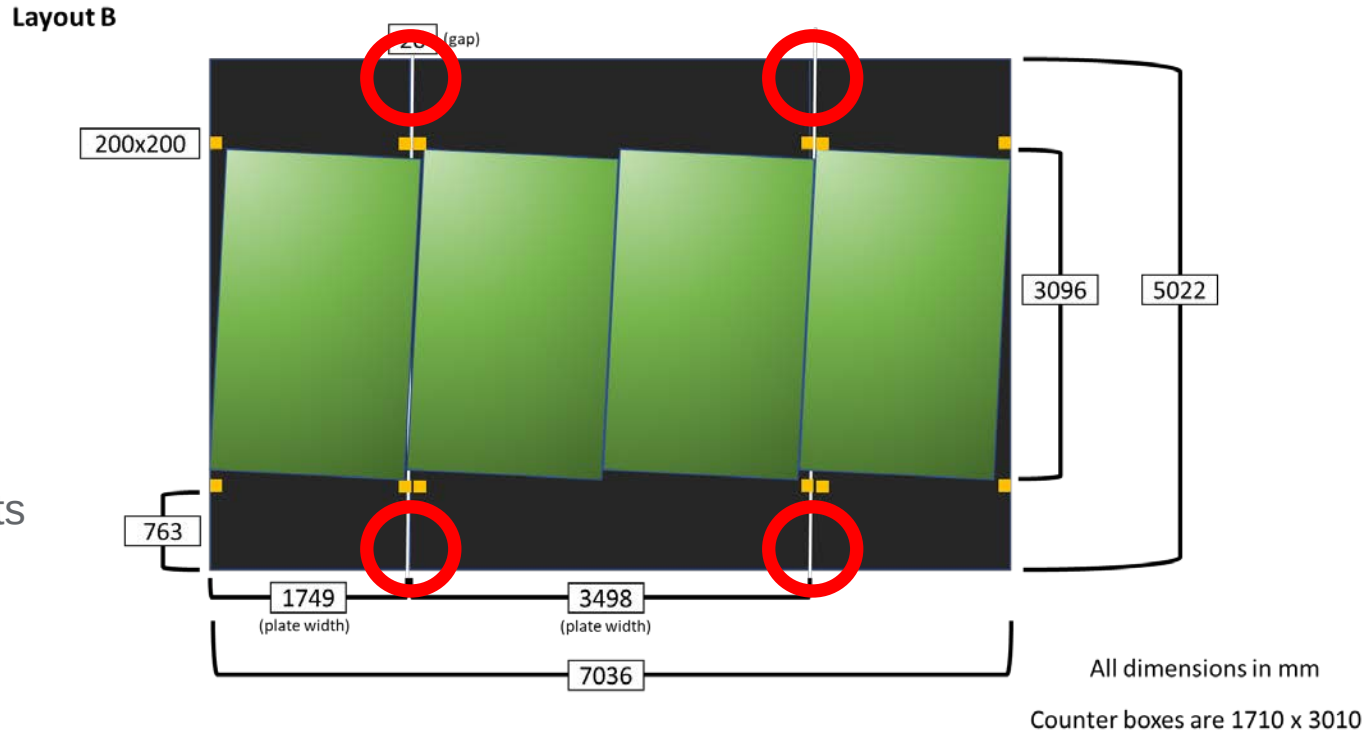
Open Question: how do we get the Main Injector RF timing into the system?

How Many Magnet Power Supplies Do We Need?

- The issue: the gaps between panels plays an important role in the magnetic circuit.
  - Flux path lengths are between 6200 and 17,000 mm.
  - There is 40mm of air gap
  - For μ=700, 60-80% of the reluctance comes from the gaps.
  - Tolerances in the gap width imply different currents needed to supply a uniform field. → need multiple supplies

- How many power supplies?
  - Unless the effect is small, probably one per coil (6)

- How do we measure the field to tune it? It's in the iron.



Idea: the field is a function of the current and the reluctance. Use the relationship between reluctance and inductance to compute the RL time constant, and use the power supplies one coil at a time to determine that.

Anyone taught freshman physics lately?

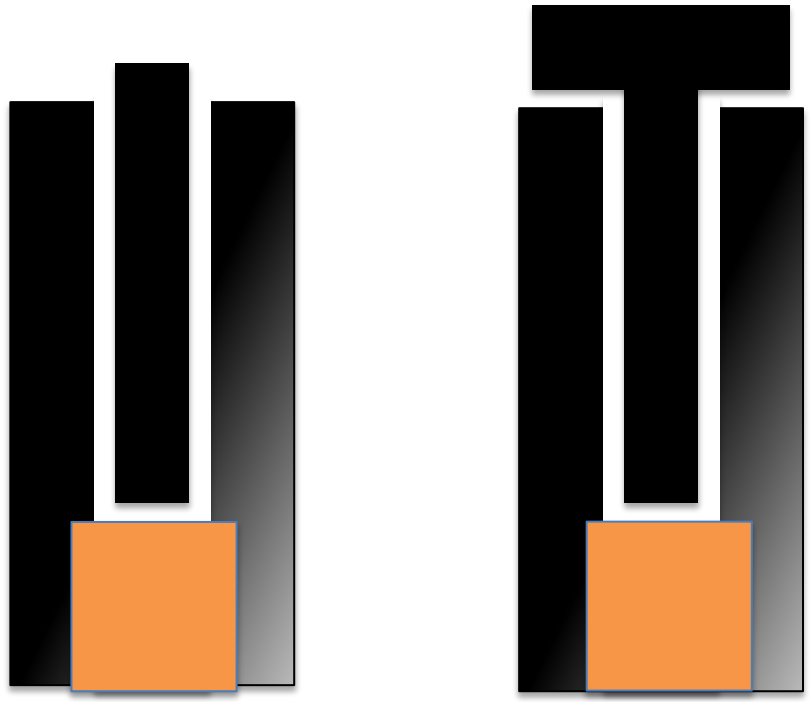
Filling the Gap

- Placing a strip of steel in the upper and lower slots will reduce the reluctance. A top piece will reduce it further (and would make it easier to install).

- This will reduce the current we need (good) but increase the relative variation (not so good).

- Our system is not so simple (the fields are coupled), so we've asked for more Ansys to better understand this.

  - Lower priority than running with the current configuration to establish a baseline, and running with a model where the coil gaps are large enough to install the coils.



Quadcounters? Octo-counters?

- An N-counter has N scintillator strips in a unit, sharing SiPM-end mechanics and electrical connectors
- Advantages of small N
  - Higher yield/less waste in QC
  - More efficient to schedule many small tasks
- Advantages of large N
  - Fewer assembly steps
  - Fewer electrical connectors

A single strip compared to an HDMI connector (approximately to scale)

- We don't think we can fit an HDMI connector on a 2-counter
  - A 3-counter is questionable
- HDMI has enough pins for 1-12 channels
  - USB-C has enough pins for at most 5 (smaller, but unkeyed)
- We are designing/prototyping assuming quad-counters

An Intriguing Possibility

Octo-counter footprint

AFE5807 footprint

- Our front-end chip has 8 channels – if we could mount it next to the SiPMs, all our data would be digital.

- Issues:
  - The footprint for the support circuitry needs to be considered
  - The AFE5807 may not be available in 2024-2025, much less in this exact packaging
  - SiPM signals need moderately long runs (true to a degree in any case, but now we have digital traffic nearby)
  - Designing such a long and skinny PCB with so many functions takes real engineering

- I think it's safe to say we don't really know how to do this today.

The Box

- The box containing the counters has not been designed
  - You can’t do everything first, and other things were higher priority

- This box has many functions
  - Holds the components together
  - Provides support during panel transport and installation
    - Lift points
    - The panels need to be rotated at least once during construction
  - Protects the fragile quad- (or N-) counters
  - Provides an extra layer of light tightening
  - Provides the electronics and power connections

Impossible? Of course not. We’ve done this before. But there is significant work here that hasn’t been done yet.

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