Improving the Magnet
A Half-Baked Idea

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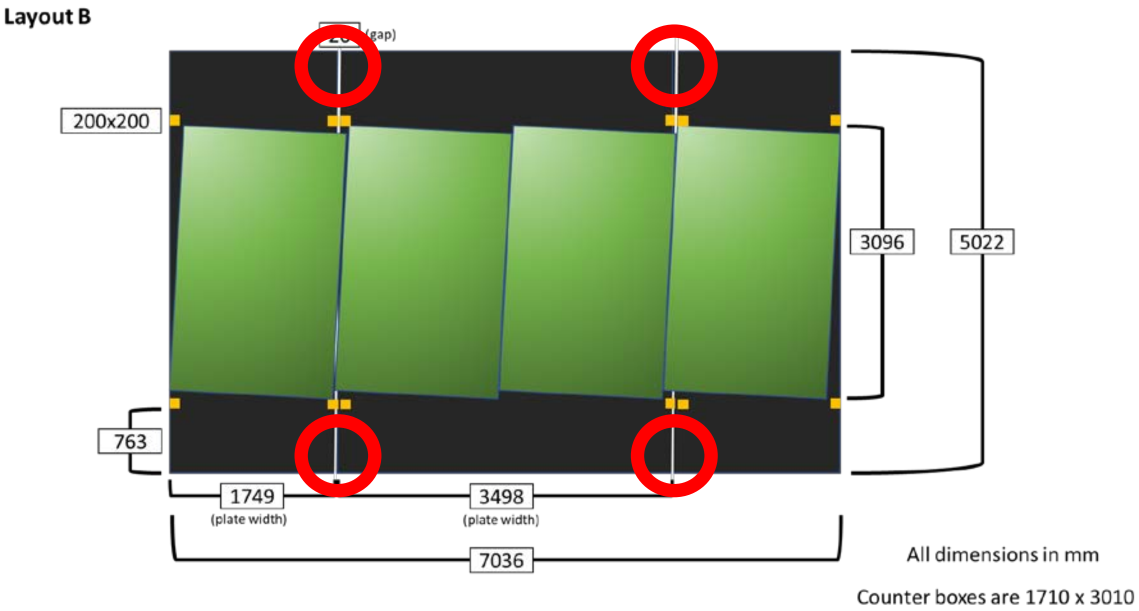
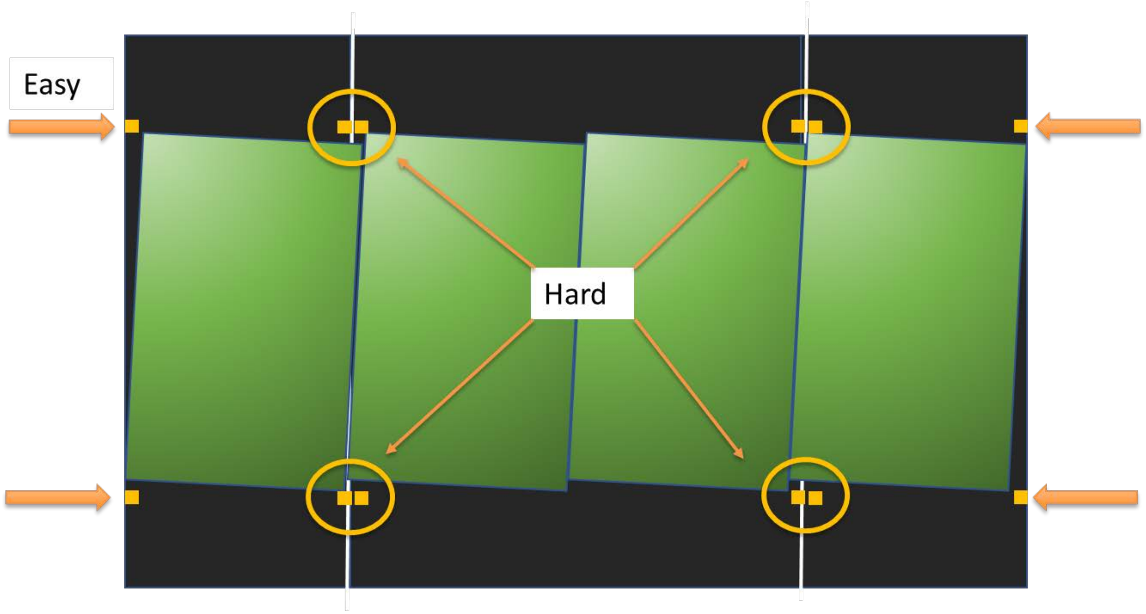
Features of Our Magnet

- Our magnet has two issues
  - It is very sensitive to the exact size of four 20 mm air gaps
    - These are necessary to install the steel plates
  - Installing the central eight coil bus bars is difficult

- It also does one thing way too well.
  - The field at the ND-LAr face is a maximum of 13 Gauss, 20x the Earth's field
  - ND-LAr has not provided a spec, but a half-pixel deflection requirement is a few hundred Gauss. That's comparable to the expected fringe from ND-GAr.

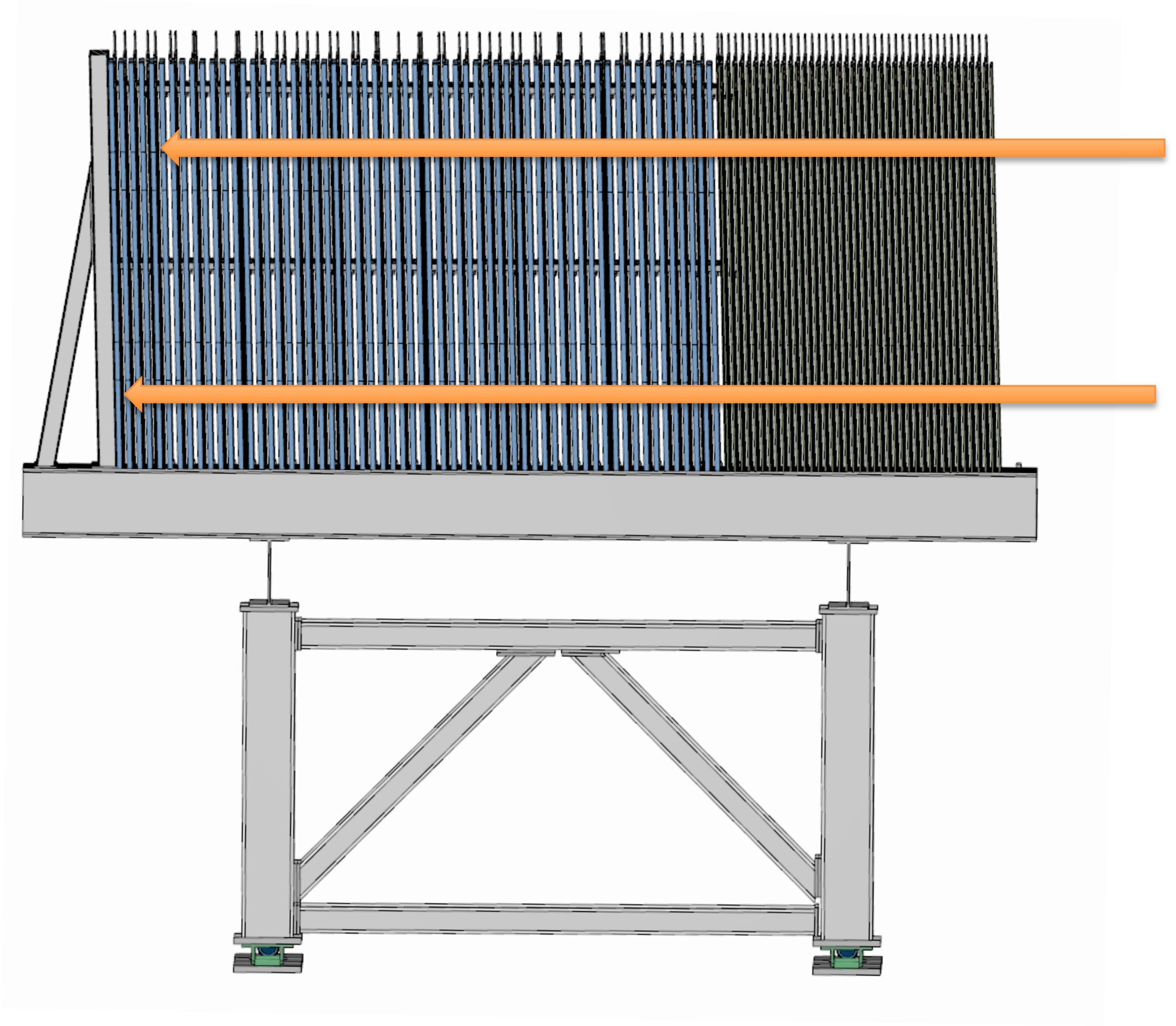
Maybe there is something we can do…





The Hard Installation

- You need 7 free meters on the east (LAr) side to do this
- Coils weigh 2½ tons.
- For installation, we want a big stay-clear. For operation, we want a small gap.
- We budgeted 16 working days for this
  - Eight moves, one day to line everything up and one day to insert the bus bars.
  - This requires professional riggers



Reminder: Magnetic Field

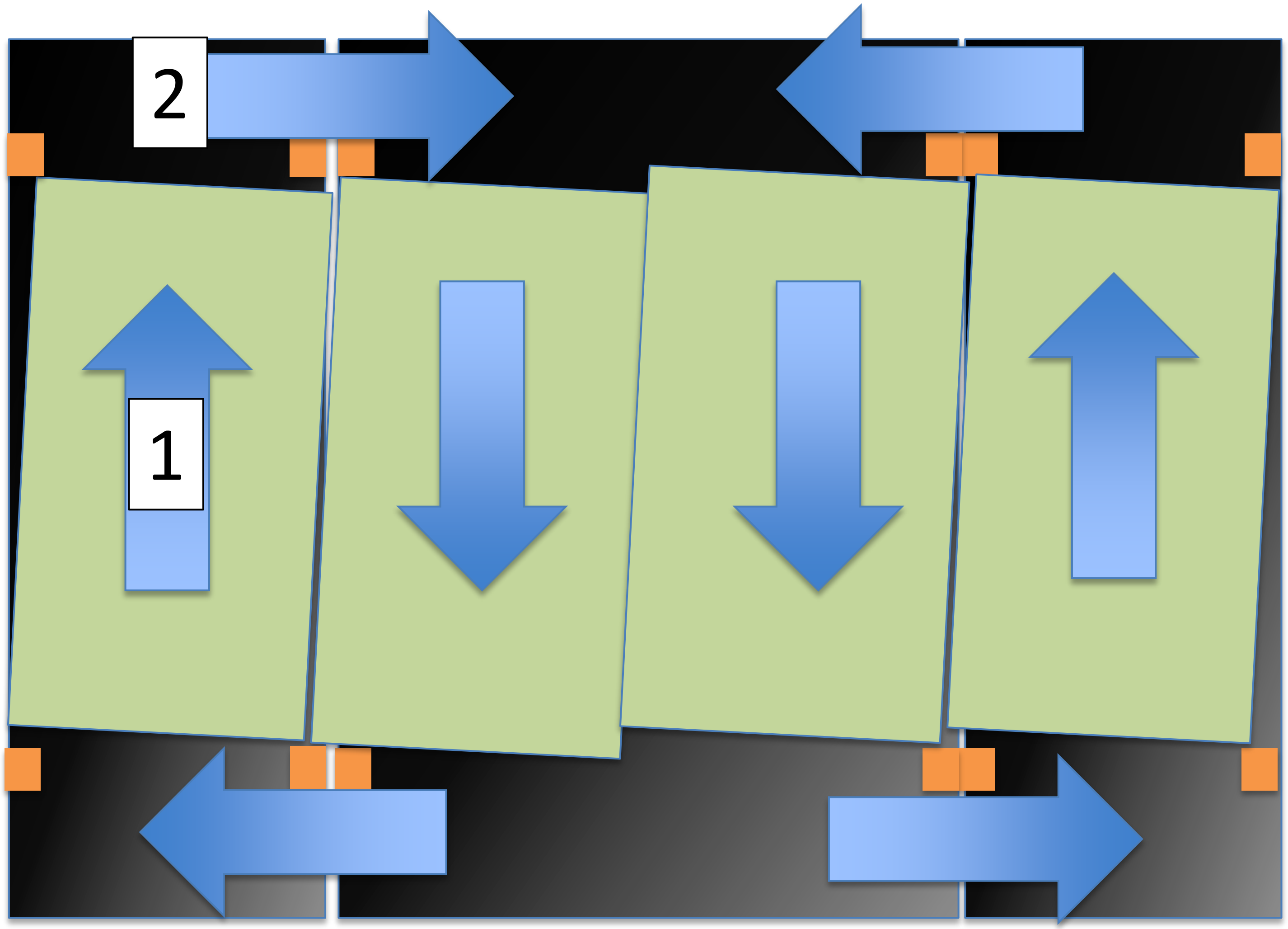
We use AISI 1006 steel (i.e. "Minos steel") μ = 700

- There is a relationship between the field and the geometry of regions 1 & 2:

$$B_1 = \frac{h_2}{w_1} B_2$$

$$(\nabla \cdot B = 0)$$

- Saturating the iron in Region 2 gives a magnetic field of 1.0-1.1 T in Region 1 (where we measure muons)
  - Region 2 is about as big as we can make it in both cost and weight



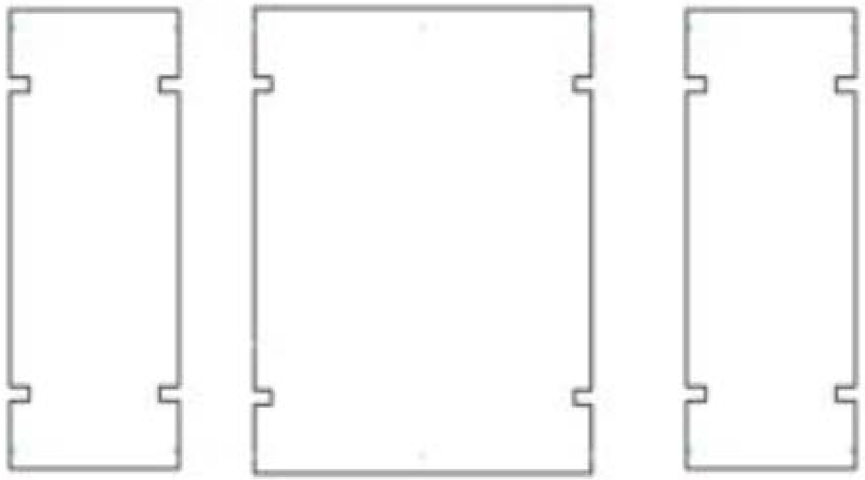
The Idea

- You need ~200 tons of steel below the coils to return the flux.
- We do this with 60 cm of our steel plates
  - There is no reason this has to be extensions of the plates
- We could make the bottom a slab* of steel
  - The plates will be correspondingly shorter
  - The weight is the same as before
  - Magnetic reluctance down ~40%; power potentially lower
  - The field lines outside of the panel area take a “detour” in z.
  - It’s a lot easier to install.
  - This messes up some of the cancellations in the original design. It likely means more field in the liquid argon. How much? I don’t know –100 Gauss?

*A “slab” is probably not a slab. It’s probably a set of bars running in x. They need to be light enough to lift and place. It would be convenient if these had slots for the steel plates to rest in.

How it Works

Instead of this…



Do this…

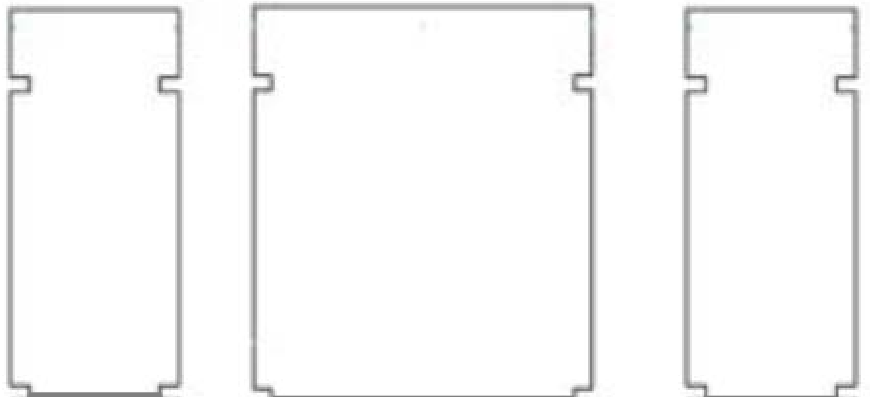
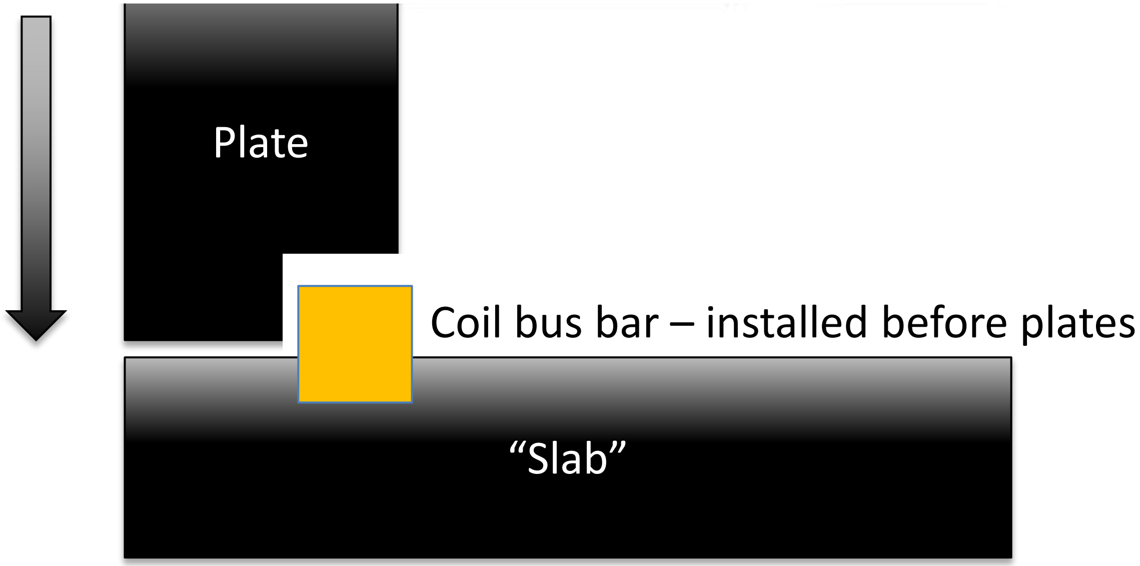


Plate installs down onto coils.

The field lines return through the slab: no gap!

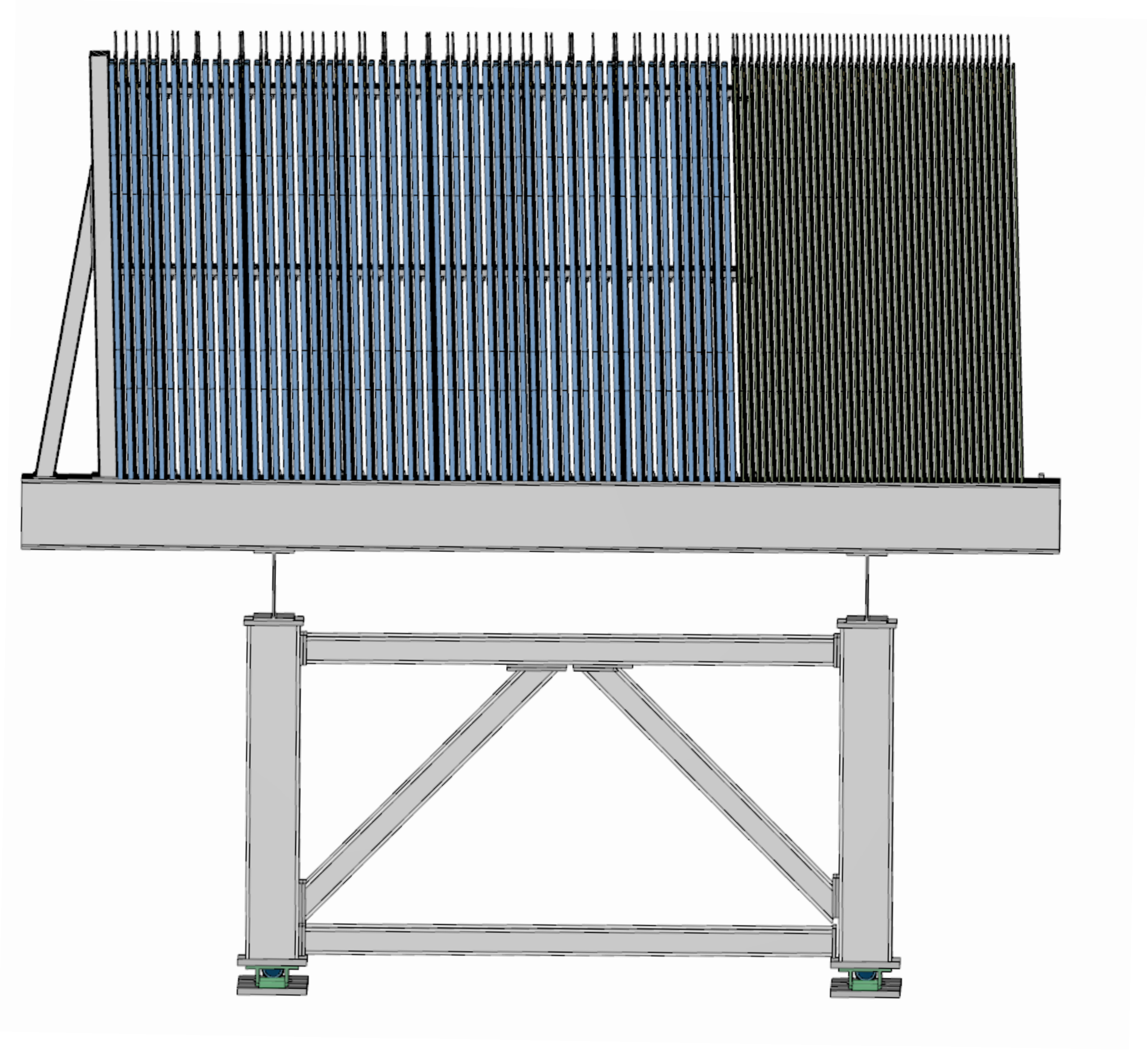


A Mechanical Issue

- The thin front plates have 15mm of steel for 40 mm of gaps (now I am talking about the z-gaps): 60 cm → 16 cm

- The thick rear plates have 40 mm of steel for 40 mm of gaps. 60 cm → 30 cm

- The back will be 14 cm higher than the front, and the whole structure will need to move up.
  - This keeps the mass constant but the center of gravity goes up. That increases the moment of inertia and thus the restoring torque needed for stability against perturbations.



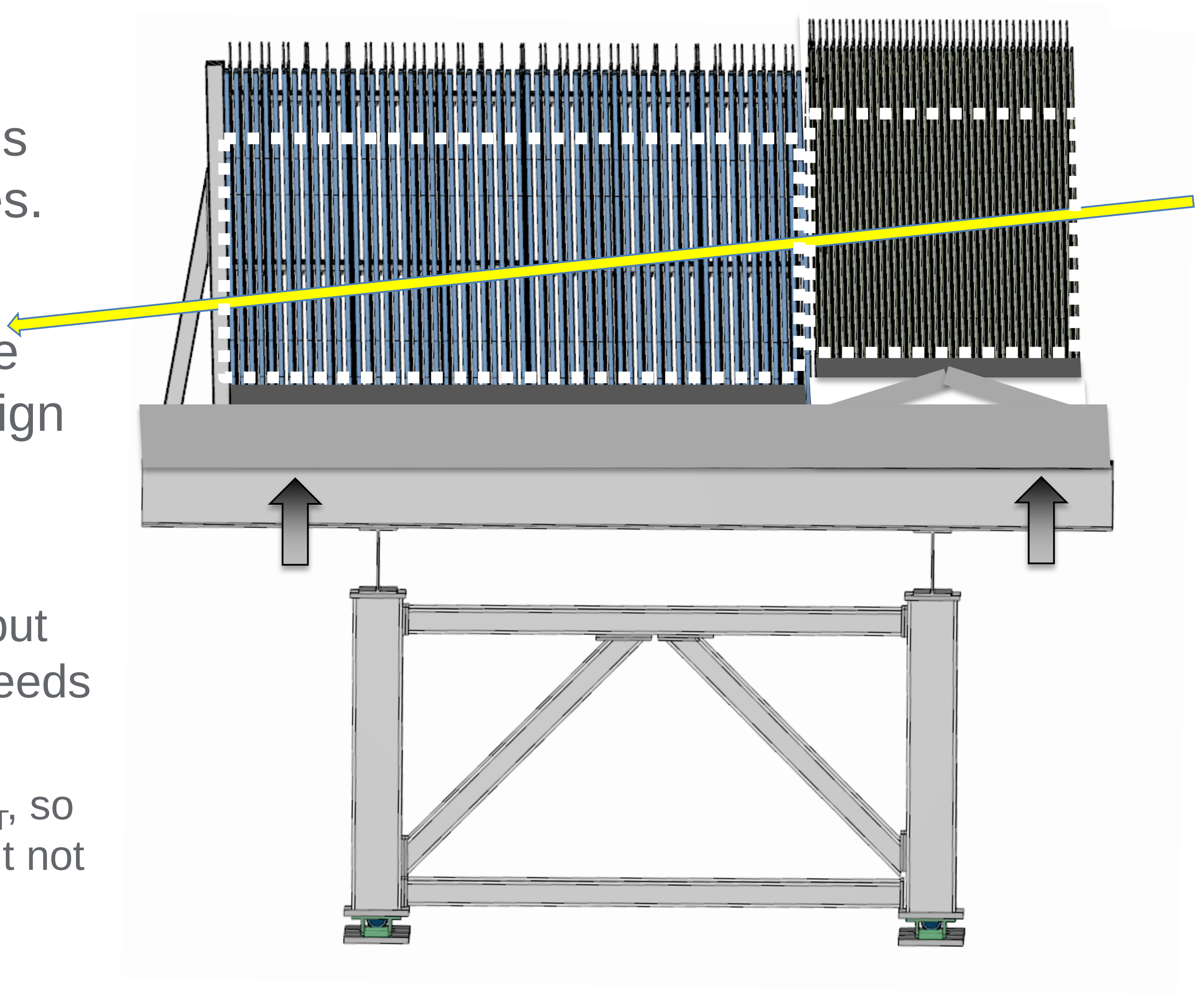
Moiré pattern is due to my incompetence with Acrobat 3D rotations

LBNF/DUNE

A Silver Lining?

- The present height is set so the beam is centered on the middle of the thin plates.

- Since this plan requires we recenter the two halves separately, we can better align them with respect to the beam.
  - Coil bus bars are still horizontal (!)
  - This must improve overall acceptance, but we gain some muons and lose others. It needs a study.
    - It has no effect at low p_T, improves high p_T, so negative effects must be at mid p_T. We might not want to do this.



What About the Top Gaps?

- A 200 ton steel canopy is hard to support, and even harder to install if you only have a 60 ton crane
- The top is more complex than the bottom and may not be worth it from an installation time perspective
  - It would improve the magnetic circuit (lower reluctance) and keep almost all the field lines out of air and in the iron
  - It probably makes the dipole more asymmetric and will require better balancing of the current. The field may be less uniform than in the baseline
- Idea: you could make a notch big enough to install from the top, and fill it with steel bars after the coil has been installed. You probably want a top piece to better guide the field.
- We need to think carefully about how loads are supported, and not just static loads: PRISM, magnet crowbars, etc.

Not to scale

Summary

- If we give up on the idea of crazy low fields in the liquid argon and settle for merely low fields, we can make the installation a lot easier.

- This is roughly price-neutral on the steel, with moderate savings (six figures) on installation and power supplies

- We have the opportunity to improve the acceptance as we do this
  - This may not be exactly what we want
  - This may negatively impact the dipole uniformity

- This is all, of course, purely conceptual. The baseline remains unchanged.