Design Options

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SLAC

Preview

- These are the results of some non-Geant (purely analytic) studies having to do with geometry

- The point is to set the scale, not the exact number
  - John Wheeler once told me “never start a calculation before you know the answer:
    - Yes, *that* John Wheeler
  - Is this a fraction of a precent? Tens of percent?

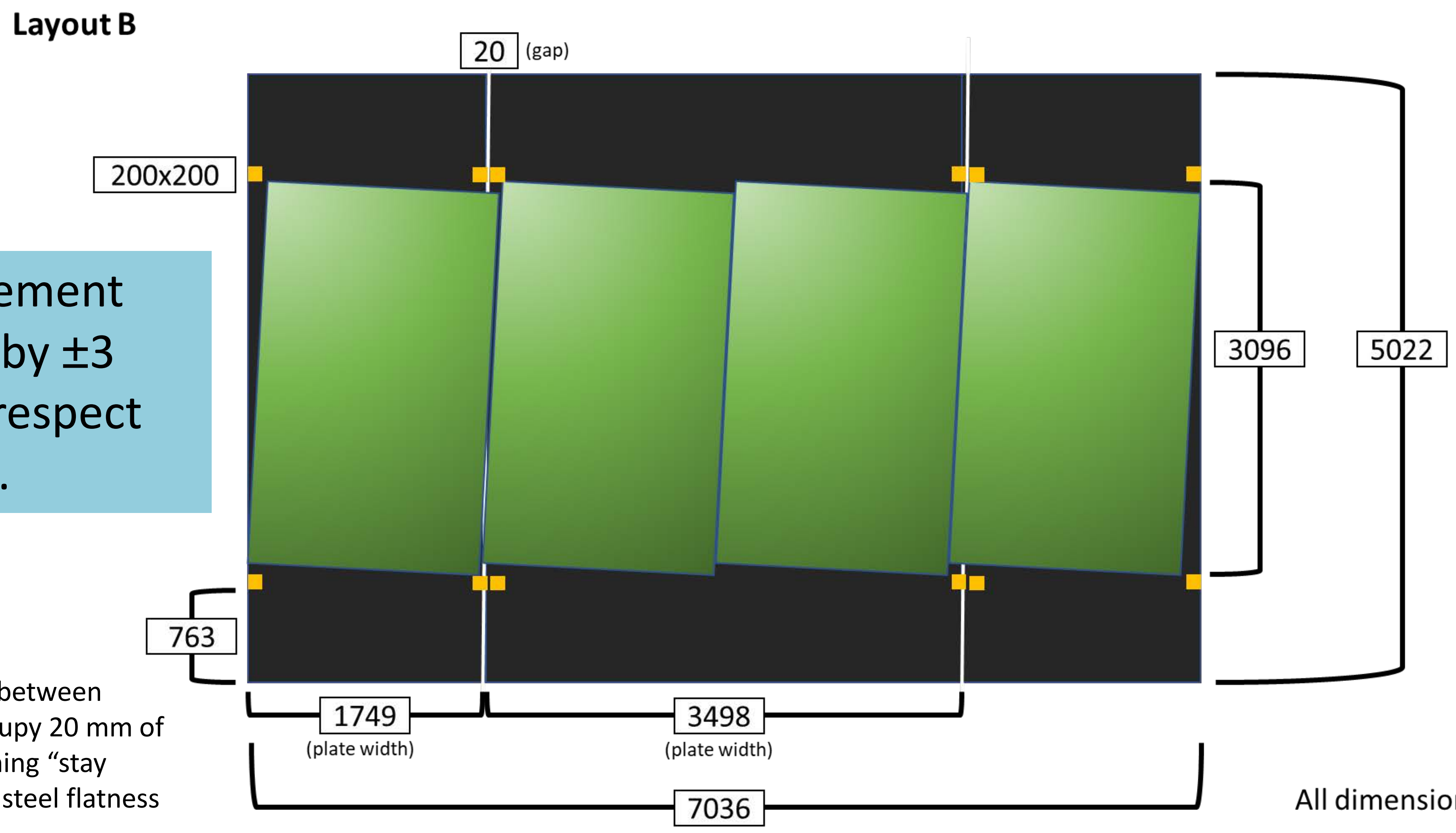
- Preview of the answer: our decisions won’t be driven by a large effect with a given design change – we are talking modest changes with pros and cons

Some History

- In the early days of the TMS one of the complaints was that it didn’t go high enough (then 10 GeV) in momentum.
- This caused us to jam as much steel as we could in the space we had.
- Detector space was at a premium, and stereo allows you to emphasize the bend view

- At this point, the ND-Lar aspect ratio was settled, so the TMS shape was too. A more symmetric shape, perhaps with a toroidal field was already precluded.

Detector Plane + Detector Panel Geometry



Every measurement plane is tilted by ±3 degrees with respect to the vertical.

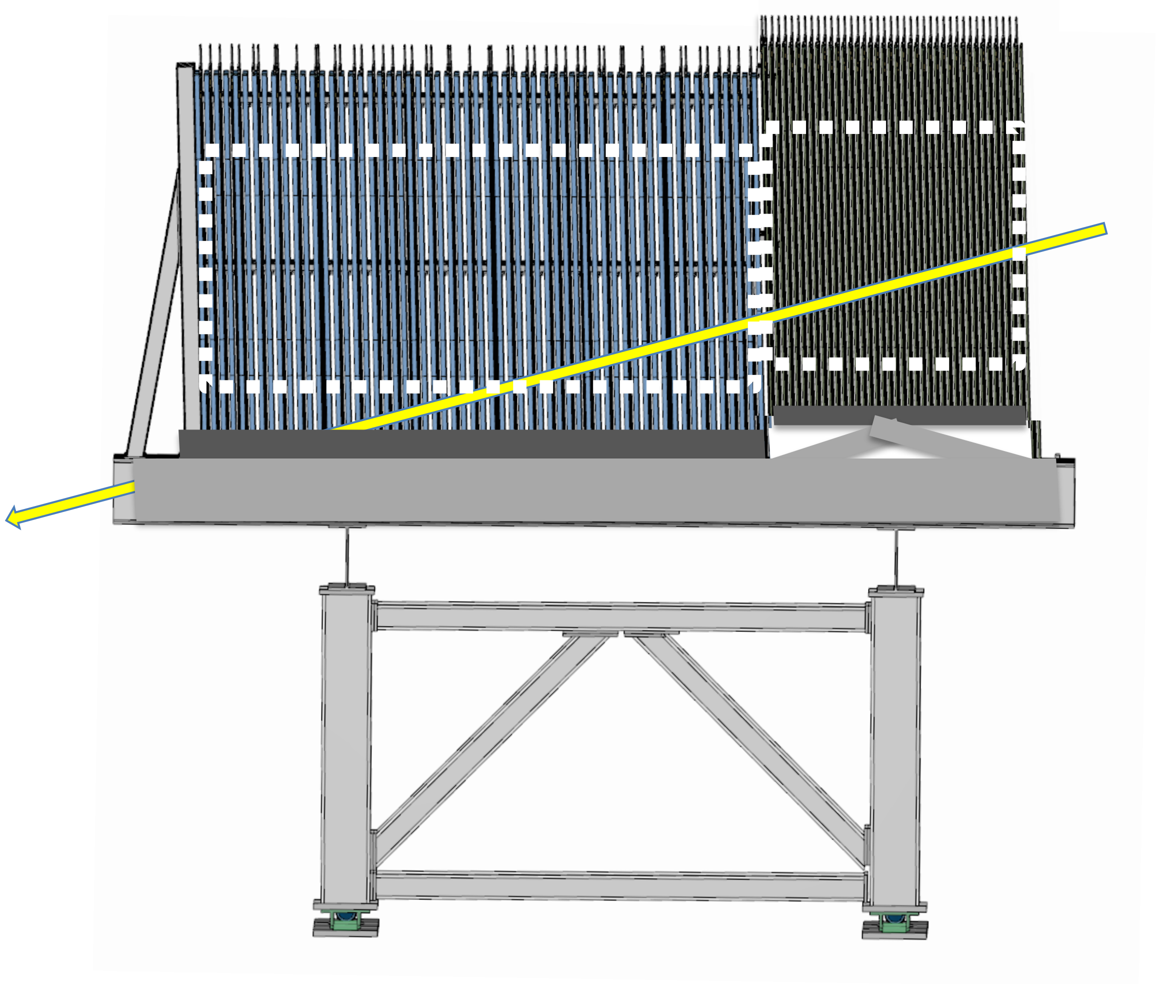
There is a 40 mm gap between plates. The panels occupy 20 mm of this space. The remaining "stay clear" accommodates steel flatness tolerances.

All dimensions in mm

Counter boxes are 1710 x 3010

The Problem With Stereo

- The good news with stereo is it measures x better than y
- The bad news with stereo is that it measures y worse than x
- Did the particle exit or was it stopped?
  - Top and bottom are worse than sides (they're bigger)
  - Bottom is worse than top (beam point down)



LBNF/DUNE

So How Often Does This Happen?

- I started with the 100K TMS muon sample Chris Marshall gave me at the start of TMS
  - Required them to exit the west face of ND-Lar, enter the east face of TMS, and have sane energies
  - See how often they exist assuming average energy loss and no side-to-side multiple scattering (on average the same number scatter up as scatter down)

- 3.5% of muons exit before stopping
  - This is predominately at high momentum – at and below oscillation max it's 1.7%
  - That sets the scale for the size of error we might make

How Much Error Does This Introduce?

- There is an upper bound – the size of the effect
  - If we assume nothing ever exited, we would underestimate the energy of 3.5% of our muons by some non-zero amount. (But its small, as this is a steeply falling function of p)
- We have more information
  - We have the y-slope from ND-Lar
  - We have (at least statistical) information on slowing tracks from the Bragg peak
  - We have the location of Michel electrons
  - We have the energy spectrum (problem is worse at high p)
- I believe we are looking at ~20% of the magnitude of the effect or better
  - Double it to determine what might exit, and take 10% of that.
  - That's 0.7% overall, and 0.4% at oscillation max – comparable to confusion because two muons end up in the same strip (see previous talk)

One Comment

- If you are worried about a 0.4% error in acceptance, get involved in the strip extrusion process: this corresponds to about 140 microns in the scintillator active width.

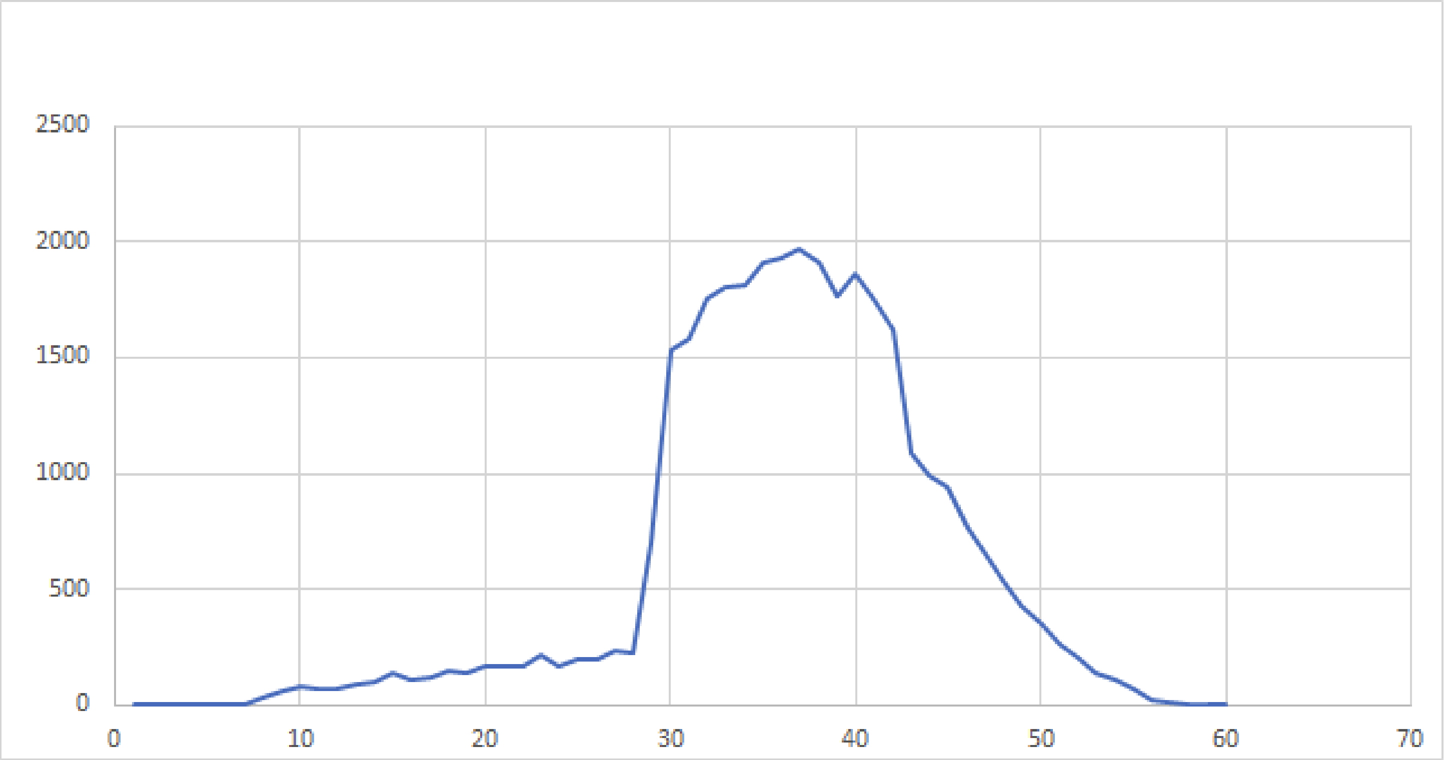
  That will take work.

Charge Identification

- I have often said that trading x-information for y-information messes up your charge identification. Is that true?

- Well, sort of.

- Start with the same sample and look at where muons stop if the parent neutrino is within 20% of oscillation max.



Charge Identification II

- We start getting good charge ID (several percent misidentification) above about 8 hits

- With 30 hits we expect 20σ separation, assuming errors are Gaussian
  - They aren't – at that level they are driven by large angle scatters and catastrophic energy loss
  - We should see sub-percent errors at oscillation max, even with fewer counters in the bend view

- What about the second oscillation max?
  - These muons barely make it into the TMS (if they do at all). I don't trust this level of study.
  - But the point is well-taken: the problems with charge identification will present themselves for muons in the few hundred MeV range.

Comment On Beam Monitoring

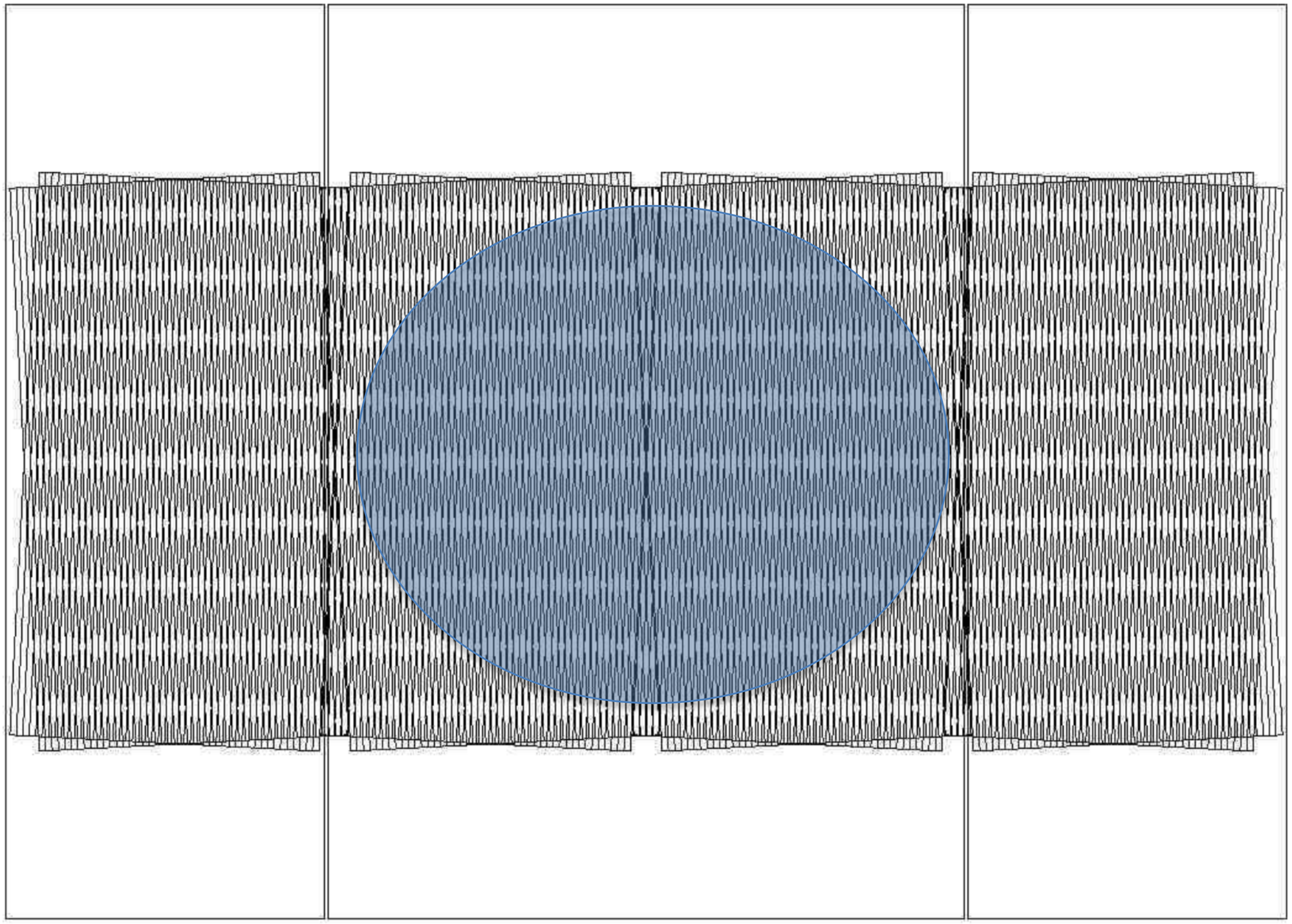


Figure by Palash Roy, Wichita State

- Clarence Wret showed that in most cases beam issues manifest earlier as a energy change than a position change.,
  - Even a horn tilt – the reason is that this effectively moves TMS off-axis

- The best position resolution is when the muon beam spot is fully contained on the face
  In the limit of a uniform beam spot much larger than TMS, there is of course no sensitivity.

Beam Monitoring

- TMS gets millions of muons per day

- That allows us to determine the beam spot average to within 3 mm in minutes
  - A time short compared to deciding who, if anyone, should be called
  - Assuming the beam spot as described last slide – the more uniform the beam is, the less good monitoring is (and the less important the details of the detector)

- What’s special bout 3 mm?
  - That’s about the PRISM accuracy in x-positioning
  - That’s coincidentally about the expected motion in y (1000 tons moves the building)

Summary

- It doesn't make a huge difference whether we have orthogonal vs. stereo counters
  - Worried about sub-percent acceptance effects? Orthogonal is better
  - Worried about charge ID for few hundred MeV muons?* Stereo is better
  - Neither is hugely better

- I don't believe a Geant-level study will change anyone's mind: It's more about what you want to measure than performance near the edges.

- Beam monitoring limitations on position are driven more by how accurately we know where TMS is than its internal construction.

* My preference, as DIF muons are our only window into the charge of ND-Lar hadrons. But your interests may differ.