Stereo Studies

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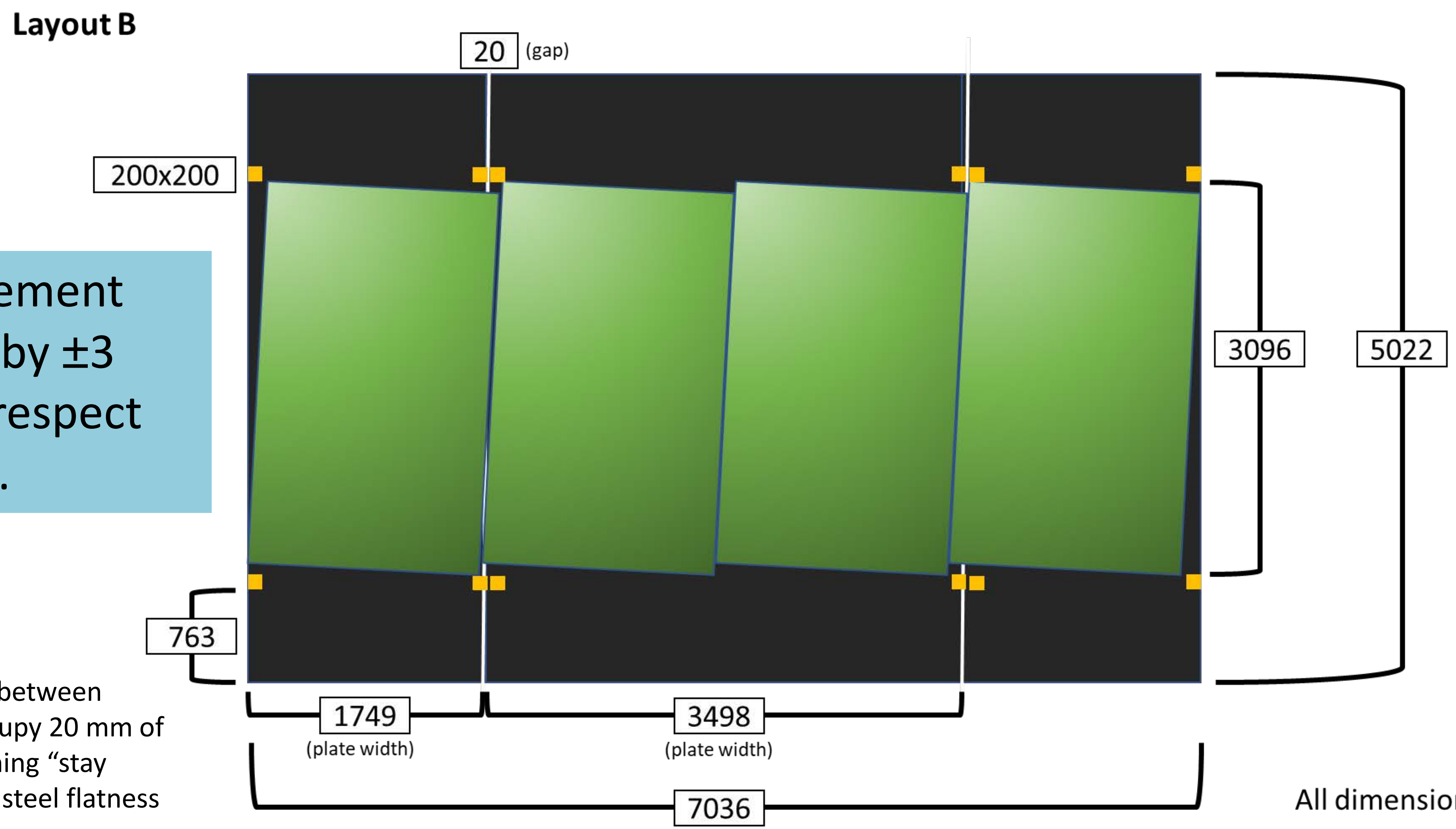
SLAC

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

Channel Geometry II

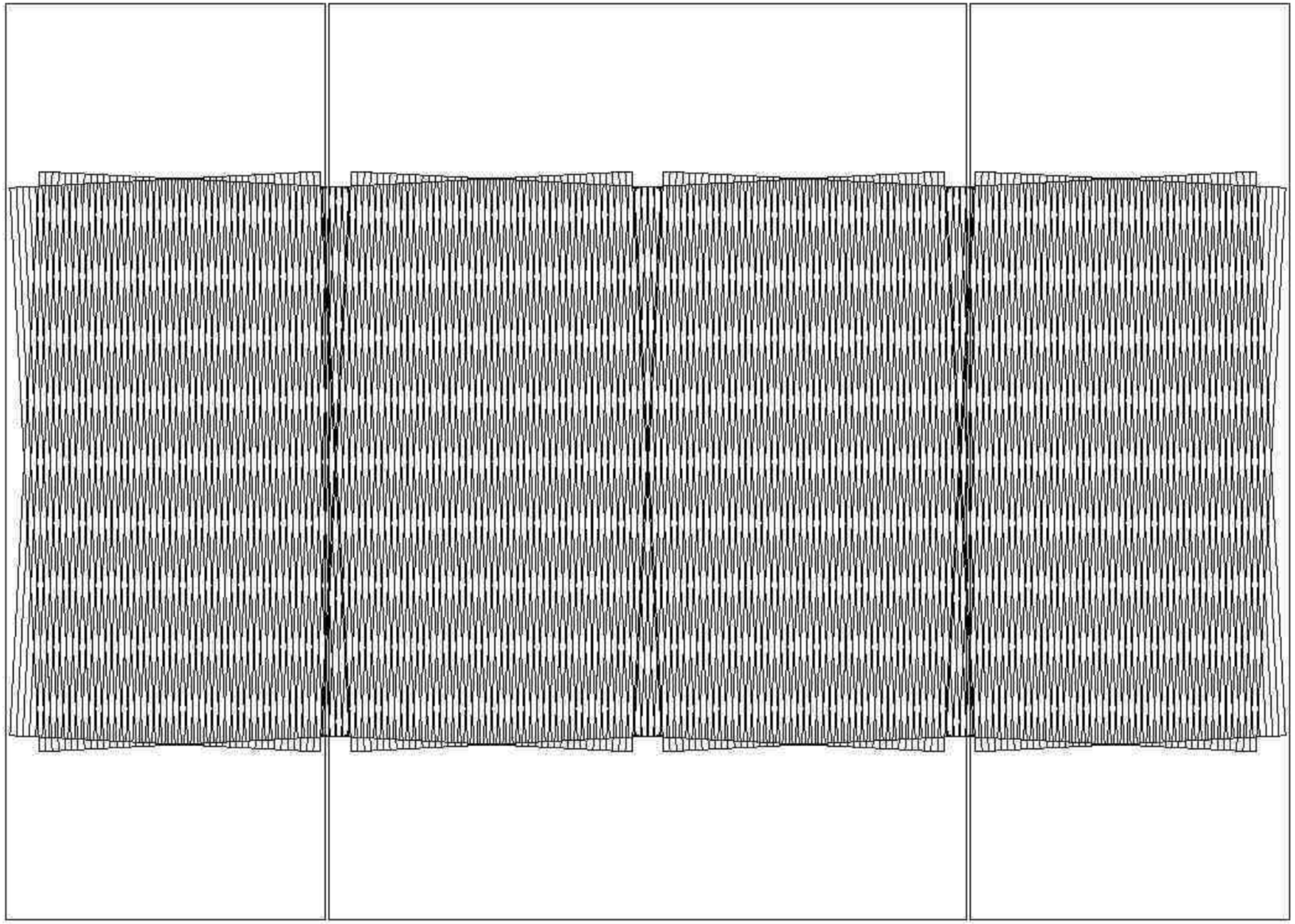
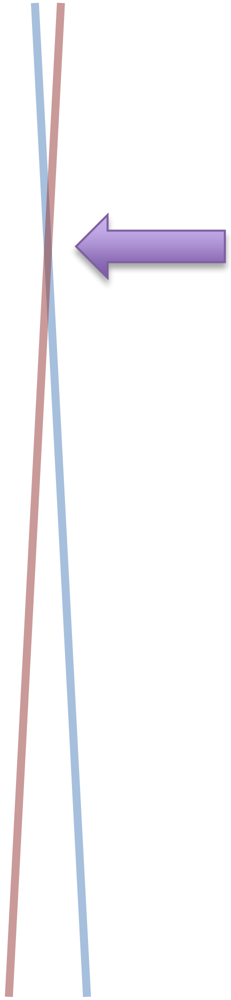


Figure by Palash Roy, Wichita State



Stereo tracking localizes a muon about this well.

TMS has the single-track localization of a ~100,000 channel detector with only 19,200 channels.

But it still has the pattern recognition of a 19,200 channel detector.

LBNF/DUNE

How Did We Get Here?

We had been thinking about y-direction measurements from the very beginning.

- The very first TMS designs had a vertical magnetic field bend
  - The “MPD” – what became ND-GAr – had a horizontal field
  - Scintillator strips were horizontal, to measure the vertical bend.
- This design was mechanically unstable
  - The steel wouldn’t support its own weight and would end up in a pile on the floor. This is less than ideal.
- We switched to a horizontal bend
  - This is better anyway – you want the bend in the long dimension not the short dimension
- With small angle stereo, you win as sin(ϕ) or ϕ, but only lose as cos(ϕ) or ϕ^2.
  - Why stop at 3^o? The larger than angle, the wider the plates get, and the wider they get, they heavier they get → we’re coming up against PRISM/Hilman limits, steel cost is an issue, interferences are an issue, etc.

Where Does TMS Go Wrong?

- The TMS is at its worst/struggles the most
  - Determining whether a muon exits the top or bottom or stops
    - Left/right is less of a problem because there's less opportunity and better measurements
  - Measuring the charge of low-momentum muons
  - Few hits, so ranges out before magnetic bend can beat the multiple scattering
  - High momentum muons – they exit the back, so we don't have range information, and usually not enough bend.
  - Mostly these are event-by-event; statistically there are more handles

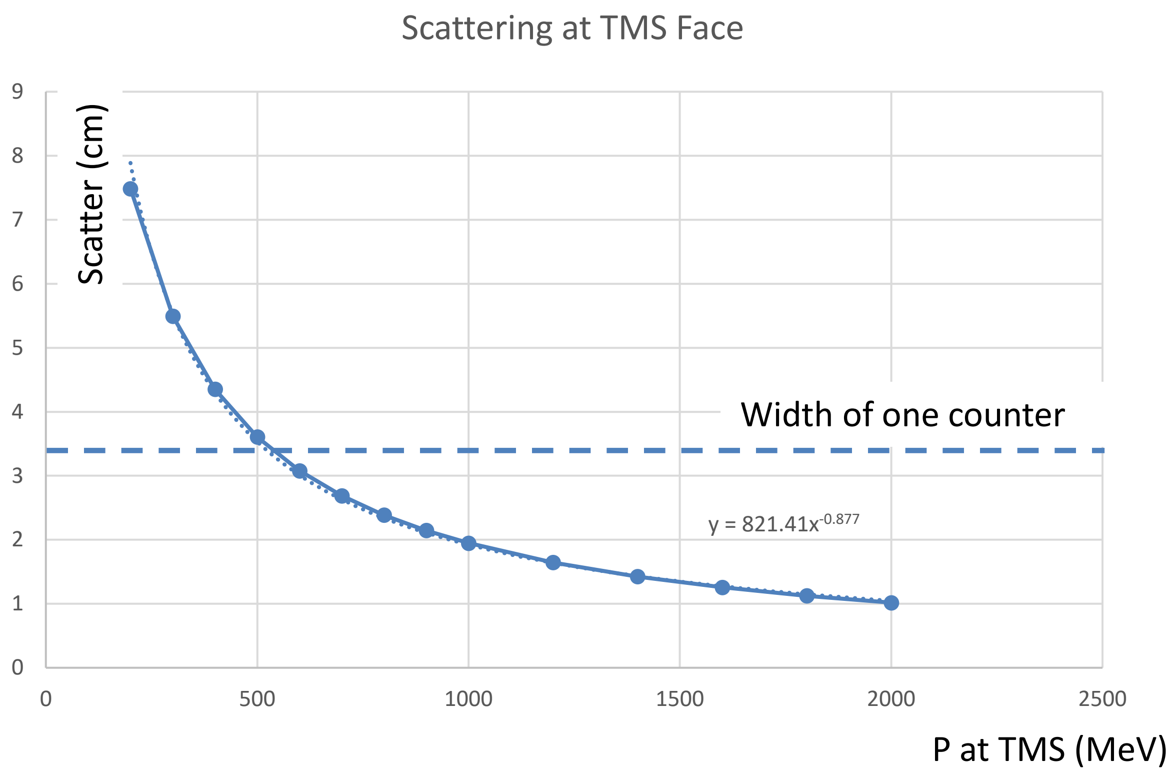
Generally, we say that TMS has traded off better position resolution in the x-direction (the bend view) for worse position resolution in the y-direction (the non-bend view). We usually use the shorthand "pattern recognition" to describe the impact of confusion between nearby muons.

Quantifying the Problem I

- How often do I have two nearby muons in ND-LAr and can't tell which one goes with which TMS track?
  - Defined as closer than 1σ apart at the front face = before TMS multiple scattering makes it worse.

Step 1: Calculate the scatter through the non-fiducial liquid argon, the window and the flight between the window and the TMS face.

$$\theta_0 \approx \frac{13.6\ \text{MeV}}{\beta c p}\sqrt{x/X_0}$$



Quantifying the Problem II

- Take pairs of muons (from a sample Chris Marshall gave me two years ago)
  - With fiducial and sanity cuts 105,394 muons (and pairs)
- Extrapolate them to the TMS face and declare them separable if:
  - They are in different counters AND
  - They are more than 1σ apart

(Assuring no error in ND-LAr)

- Do this for three configurations
  - "Good" – the TMS as designed, with better x resolution than y resolution
  - "Better" – the TMS with 3.5 cm orthogonal (x and y) strips
  - "Best" – assume an infinite number of arbitrarily small pixels
- Count the non-separable pairs

Important caveat: we ignore timing as a means of separation. Including timing will make the absolute numbers better, but for this, we are interested in relative numbers.

Quibbles

- Couldn't you have
  - Picked a different definition? Why not 2σ? Or 3σ?
  - Picked a completely different comparison metric?
  - Considered the ND-LAr timing which you just mentiioned and/or global fits?
  - Used a more `detailed physics model – maybe even\ Geant?
  - Used a more detailed detector model – maybe even Geant?

- The answer is of course "yes".
- The point is not to come up with an analysis-quality number: it's to get a feeling for where we stand, and where the potential gains are.
  - Is this a 10% issue? A 1% issue? Less?
  - The relative effects of the various geometries are probably more meaningful than individual numbers.

Results

	Perfect (Best)	Orthogonal (Better)	Baseline (Good)
Potentially confused pairs	16	44	330
Accuracy	99.98%	99.96%	99.7%

Reminder: 105,394 muons

- Important question – are these the same muons?
  - The inclusive sample has an average momentum (at TMS face) of 1.71 GeV.
  - “Good” (potentiall confused) is 1.71 GeV, “Better” is 1.66 GeV and “Best” is 1.61 MeV.
  - So maybe: as fewer events fail, they may show more commonalities, like low p.
    - But the effect is not large (if it is even real).

Summary

- The TMS baseline loses at most **few muons per thousand** to confusion with nearby muons in the y-direction
  - Probably closer to one per thousand when timing separation is included.
  - This is comparable to or less than other sources of loss, like TiO_2 coating, KlauS deadtime, etc.

- This is largely (85%) recoverable by having a front layer of orthogonal counters
  - The space for these counters doesn't exactly exist.

- Orthogonal counters throughout the stack would mess up charge identification, and recover relatively few muons that the front layer wouldn't pick up.

- The "Chris Marshall Counters" – counters between ND-Lar and TMS – would be a good place to consider orthogonal counters.