Design Alternative Decisions

Name: **Water Closed-Loop Cooling the Coils**

Description: Replace the air-cooled coils with water-cooled coils. The water is closed-loop, i.e. not provided by the energy chain or other external source. Water takes heat from the coils and transports it to the steel, where the heat is then transferred to the air.

Intended benefits: Reduced cost, reduced time to install coils (which in turn increases module accessibility)

Other changes: allows us to use less copper in the coils for the same field. Requires a different power supply, which has its own cost impact.

What would change our mind: A design showing this would work and be a net cost savings.

Name: **Change WLS Fiber Diameter**

Description: Change the WLS fiber diameter from the present 1.2 mm to a different radius. Other common radii are 1.5 mm, 1.4 mm, 1.0 mm and 0.8 mm.

Intended benefits: Reduced cost (smaller), improved performance by increased light (larger)

Other changes: may have implications for groove or hole co-extrusions. Affects all the downstream optics.

What would change our mind: A design showing a smaller diameter would work and be a net cost savings, or alternatively that a larger diameter would provide physics impact (beyond just “more light”) commensurate with the cost increase. This physics impact is probably demonstrated via simulations.

Name: **Include 3D-printed Diffuser/Coupler.**

Description: A 3D-printed diffuser and coupler is installed into the Fiber Guide Bars, which now serve to position the coupler rather than the individual fibers.

Intended benefits: Reduced assembly time, secondarily increased energy resolution.

Other changes: (none)

What would change our mind: A working prototype showing this does in fact reduce assembly time. Improved energy resolution would be a bonus, but would be unlikely to be sufficient on its own.

Name: **Scintillator Fiber Hole**

Description: Replace the present MINOS-like scintillator groove design with a more mu2e-like hole through the scintillator. A variation on this is not to glue the fiber in at all.

Intended benefits: Increased light (in theory – the quality of the optical coupling between scintillator and fiber may not be as good with a hole than a groove)

Other changes: This may change assembly time (in either direction). This may also limit our options on fiber diameter and have an effect on scintillator cost.

What would change our mind: Either of the following without major cost implications

- A working prototype showing this reduces assembly time without decreasing light output.
- A working prototype (or acceptance of mu2e studies) showing that this increases the light output without increasing assembly time

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Name: **Move On-Panel Boards Off-Panel**

Description: Replace the On-Panel Boards with a light fiber cartridge connecting to the counters at one end, and running 2m of clear fiber to a readout box located outside the steel structure.

Intended benefits: Reduced electronics cost, increased accessibility to more components during operations.

Other changes: Might reduce assembly time. One could conceivably move the Data Concentrator functionality into the new unit.

What would change our mind: A design showing this could be constructed and that the net cost is reduced (and we're not simply shifting costs from electronics to mechanical). Such a design needs to show that this solution fits within the available space.

Name: **Move DC functionality to OPBs**

Description: Move the Data Concentrator functionality to the OPBs. This essentially turns the TMS to 400 independent detectors, sending data via ethernet to a commercial switch.

Intended benefits: Substantially reduced electronics cost, especially FPGA programming costs.

Other changes: This replaces much of the FPGA programming with C, C++ or possibly even Python, which has a much wider base, and may allow effort to be shifted to uncosted scientific labor. It moves the power and timing distributions off the DCs, since they no longer exist.

What would change our mind: A design showing this could be constructed and that the estimated net cost is reduced. A technical issue is how to keep 400 detectors in sync to better than 10ns (one-half bucket) over one second. PTP is a possibility, possibly coupled with an on-board OCXO or TCXO.

Name: **Switch to Single-Channel SiPMs**

Description: Replace the 16-Channel SiPM with sixteen single-channel SiPMs. These would be located nearer to the scintillator strips than in the present design.

Intended benefits: Reduced assembly time.

Other changes: Triggers a redesign of the Panel downstream of the scintillator. This may also slightly reduce costs.

What would change our mind: This decision was based on cost. SiPM prices are presently falling, so presumably the cost differential is shrinking as well. If the net cost differential is smaller than the benefit of the simpler design, this decision should be reconsidered.

Name: **Orthogonal Tracking**

Description: Replace the 3 degree stereo by panels that read out in either x or y.

Intended benefits: Improved pattern recognition, especially at high intensities.

Other changes: Reduces steel needed slightly. Requires a design of the y-measuring counters and a possibly a slight redesign of the x-measuring counter. May require increased counter length to meet our area KPP. May alter the channel count and associated costs.

What would change our mind: We would need a plan on where these counters are installed, and where they replace x-view counters and where they are added. This plan would need to show our charge separation still meets requirements. If it reduces the amount of steel, the impact on high momentum thresholds would need to be understood. The physics impact needs to be commensurate with any cost increase.

Because of the substantial physics impact, such a change would require collaboration approval as well as project approval.

Name: **TMS yz-tilt**

Description: Have each steel plate at a slightly different height so that the beam center is always at the counter center.

Intended benefits: Slightly improved acceptance.

Other changes: Requires a change in the infrastructure design.

What would change our mind: Showing that this is effectively a zero cost change.

Name: **Calibration and Monitoring**

Description: Add an LED flasher system and SiPM voltage readback for monitoring.

Intended benefits: Better debugging in commissioning and operations periods

Other changes: Electronics needs to support this.

What would change our mind: The physics impact needs to be commensurate with any cost increase. This might be triggered by a review recommendation.

Name: **Steel Thickness Distribution**

Description: Change the 40 thin layer and 60 thick layer design to some other distribution, possibly involving a third thickness.

Intended benefits: Improved resolution for some muon momenta.

Other changes: Potentially could change channel count

What would change our mind: The physics impact needs to be commensurate with any cost increase.

Because of the substantial physics impact, such a change would require collaboration approval as well as project approval.