Silicon Strip Detectors

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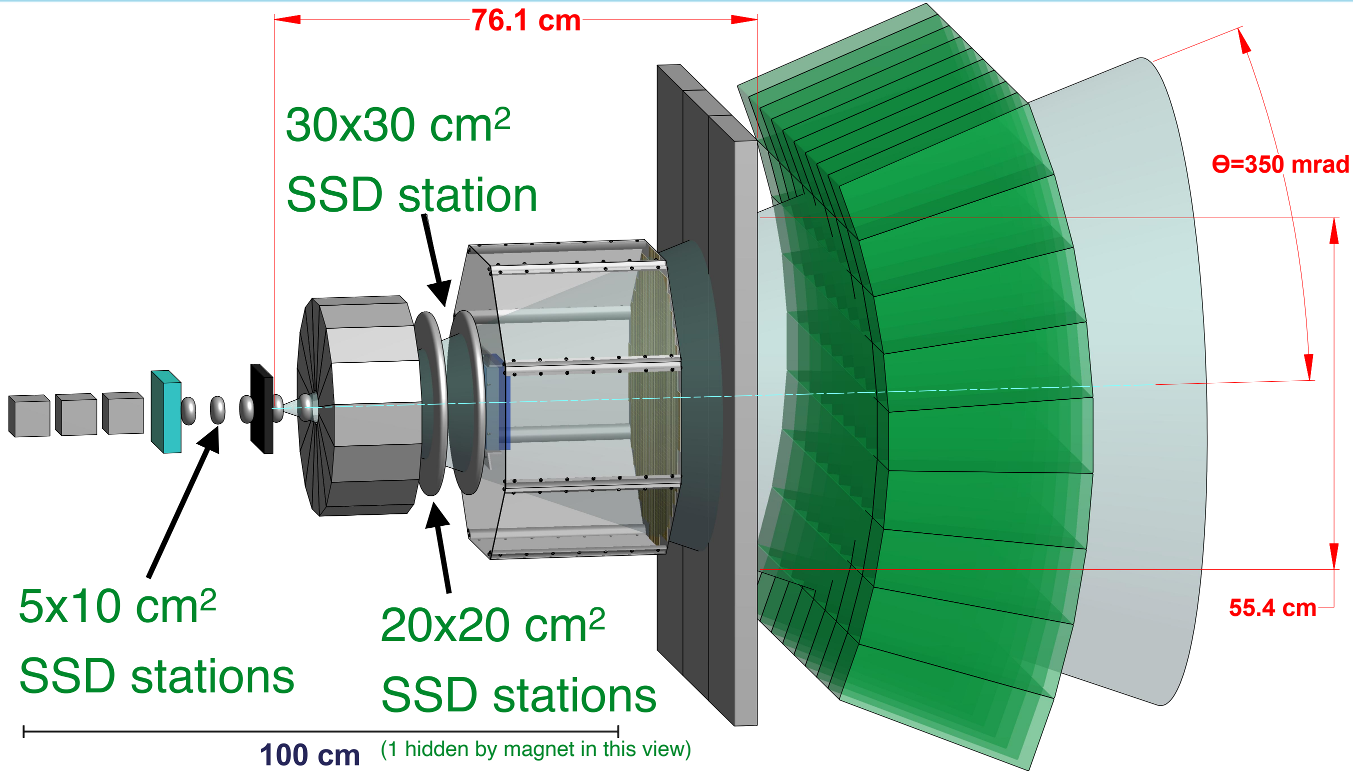
Cost and Schedule Review

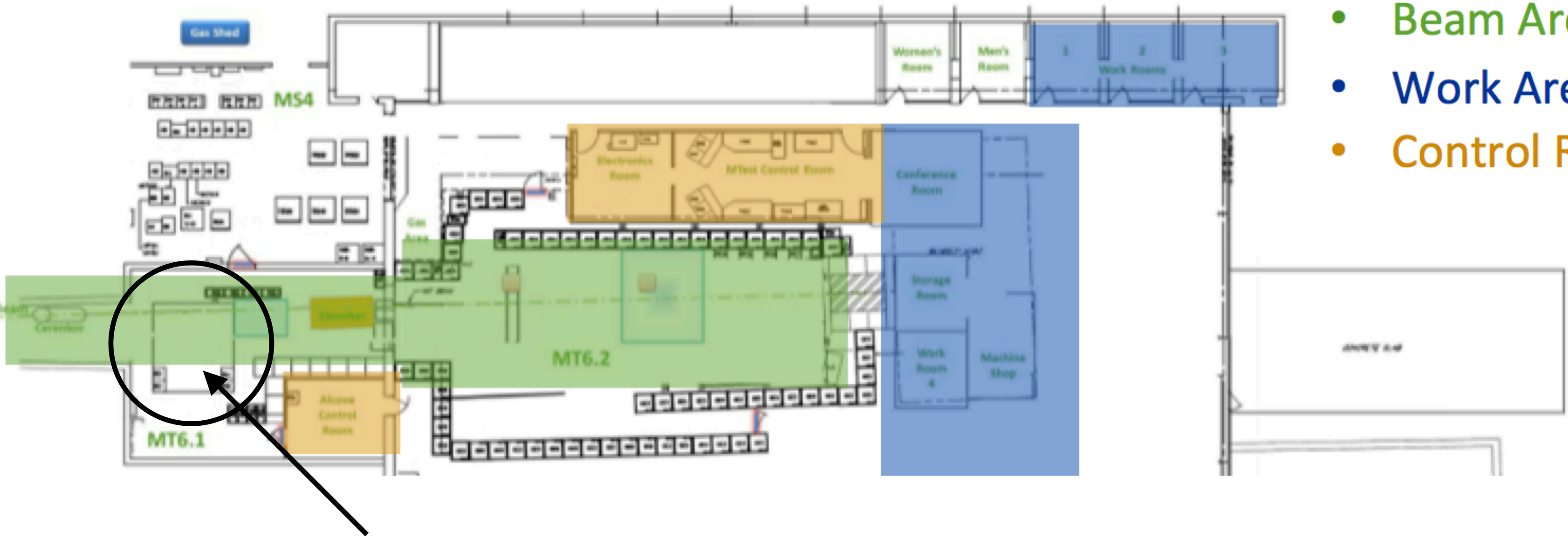
January 22, 2021

Sizes and Locations of Silicon Strip Detectors



- 2 (x,y) single-sensor 5x10^2 cm stations upstream of target, 2 (x,y) 5x10^2 cm stations between target and magnet, 2 (x,y) 20x20 cm^2 stations and 1 (x,y) 30x30 cm^2 station downstream of target.
- Want high resolution tracking detectors in single-sensor stations because these will be used for the small-angle scattering measurements.
- We are requesting additional funding for 10 single-sensor planes for particle tracking upstream of magnet. We need these to be able to move out of MT6.1a.

Current Location - MT6.1a

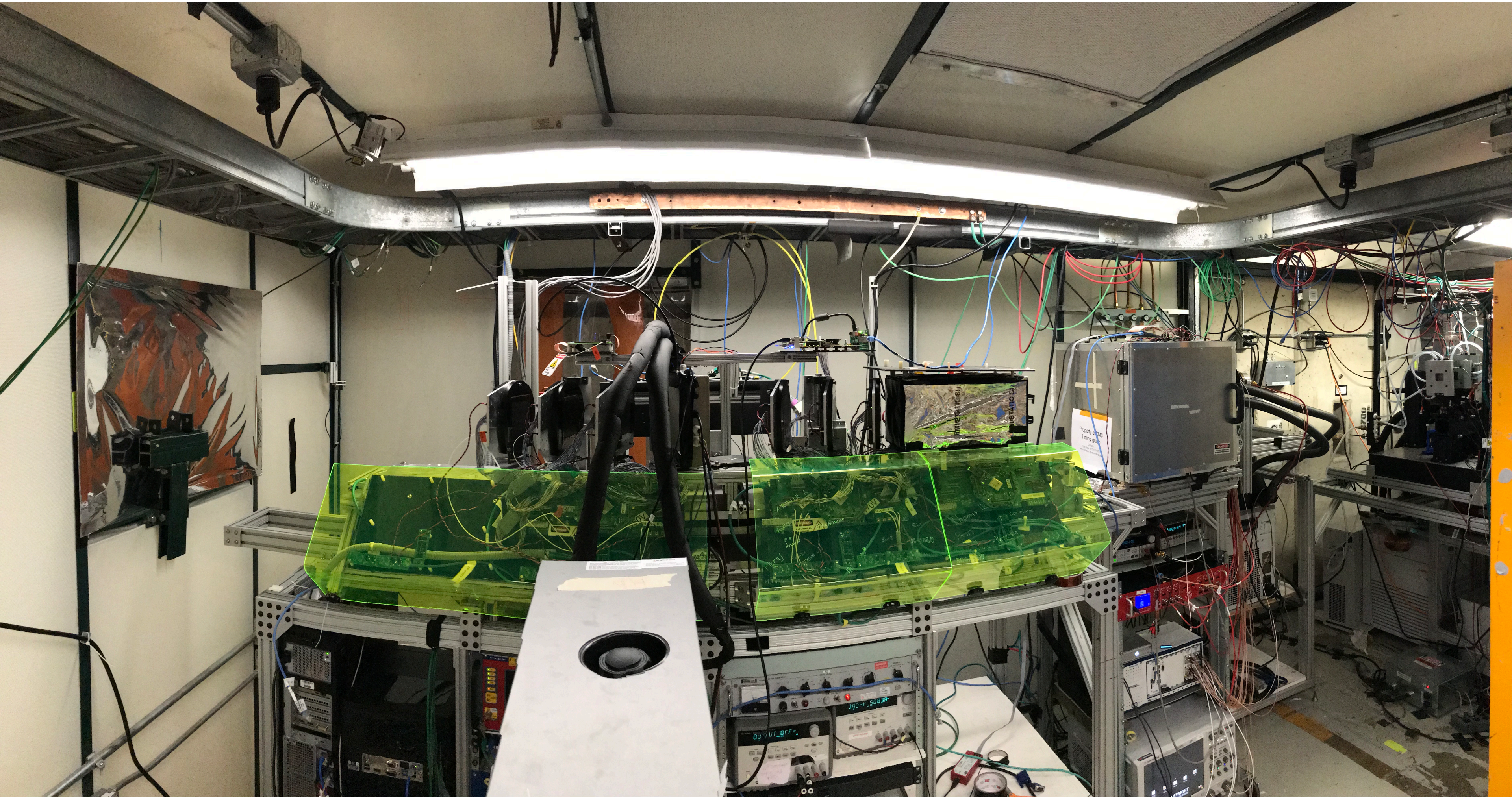


- Beam Areas
- Work Areas
- Control Rooms

We are here now. This is a very popular space for test-beam experiments, in high demand.

Using this space requires installation, commissioning and tear-down for each Phase of the experiment. Many reasons why one would want to avoid this.

Current Location - MT6.1a



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Moving to our own space

Currently unoccupied, we could move here. The move could happen before (preferred) or after Phase 1. If before, require new “small” SSDs for tracking upstream of the magnet.

Offers greater flexibility with our schedule, and leaves the experiment in a stable setup.

MT6.2d

MT6.2d

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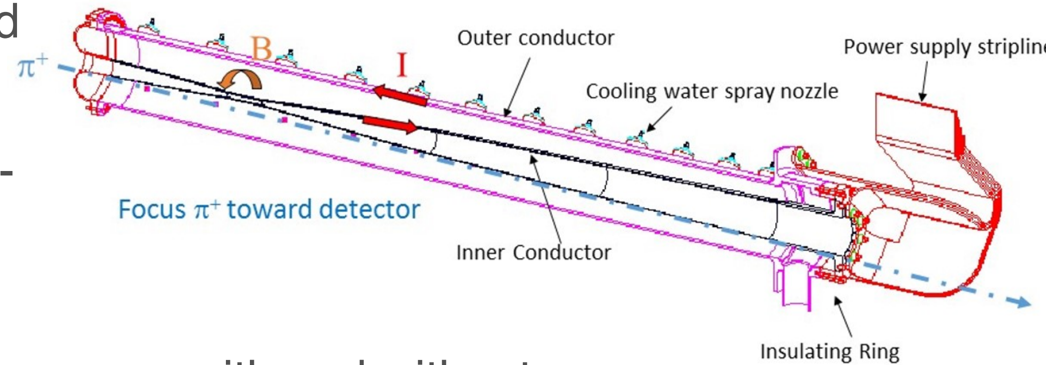
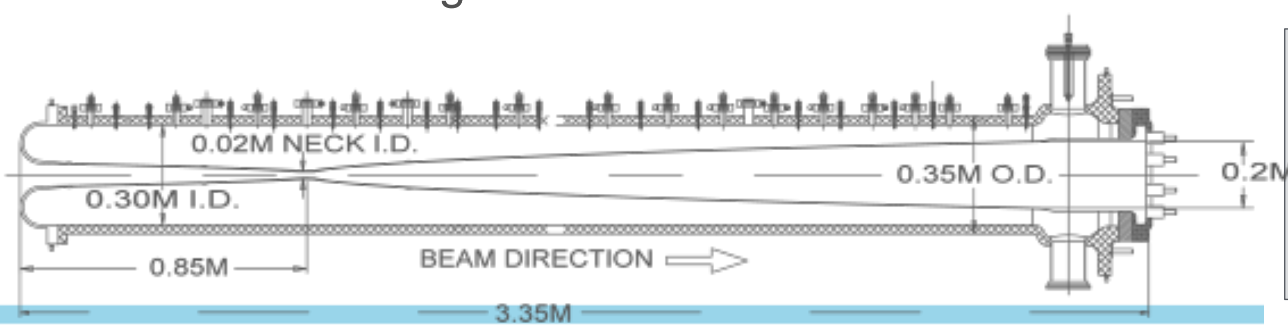
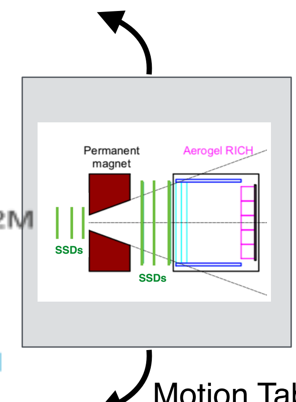
EMPHATIC Phase 4 - Beyond Target HP Uncertainties

- Put EMPHATIC on a motion table downstream of spare NuMI horn and target.
- Minimal goal is to measure charged-particle spectrum downstream of target+horn.



- Power supply also available; aim to measure with and without current.
- Establishes program to address questions re: HP in horns and modeling of horn geometry and magnetic field.
- With %-level flux uncertainties, we could begin to probe new physics with ν-A and ν-e scattering measurements.





Motion Table

EMPHATIC Phase 4 - Beyond Target HP Uncertainties

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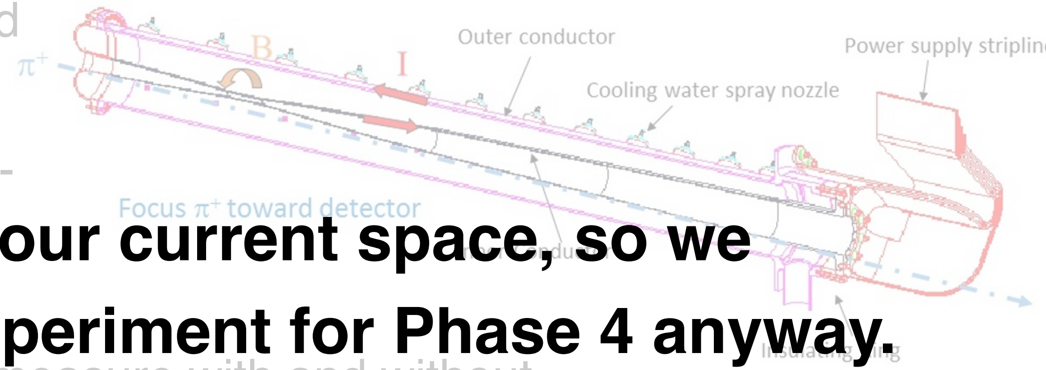
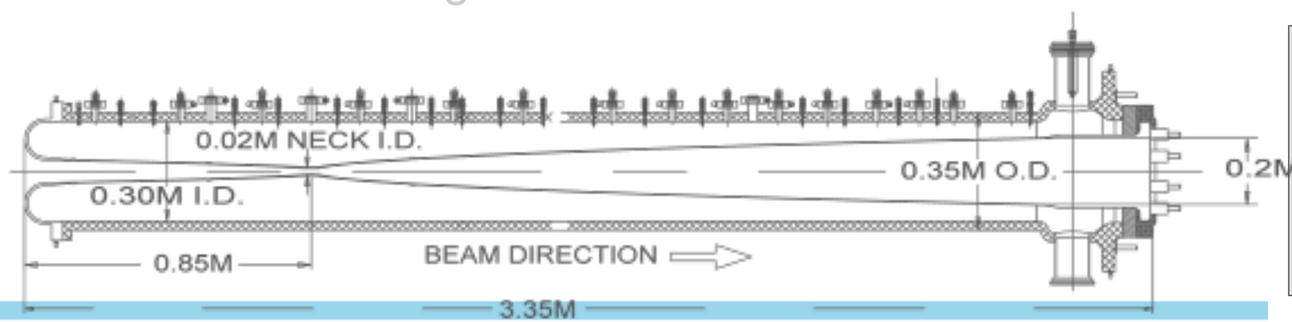


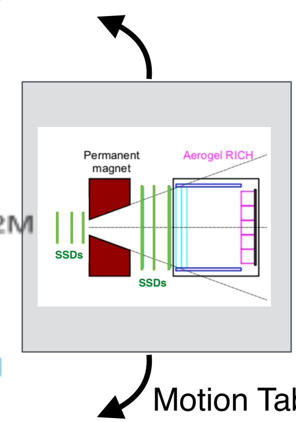
This also does not fit in our current space, so we will need to move the experiment for Phase 4 anyway.

- Power supply also available; aim to measure with and without current.
- Establishes program to address questions re: [illegible] horns and modeling of horn geometry and magnetic field.

Laura is working with AD engineers and FTBF personnel about setting this up in MCenter in 2023/24.

- With %-level flux uncertainties, we could begin to probe new physics with ν-A and ν-e scattering measurements.



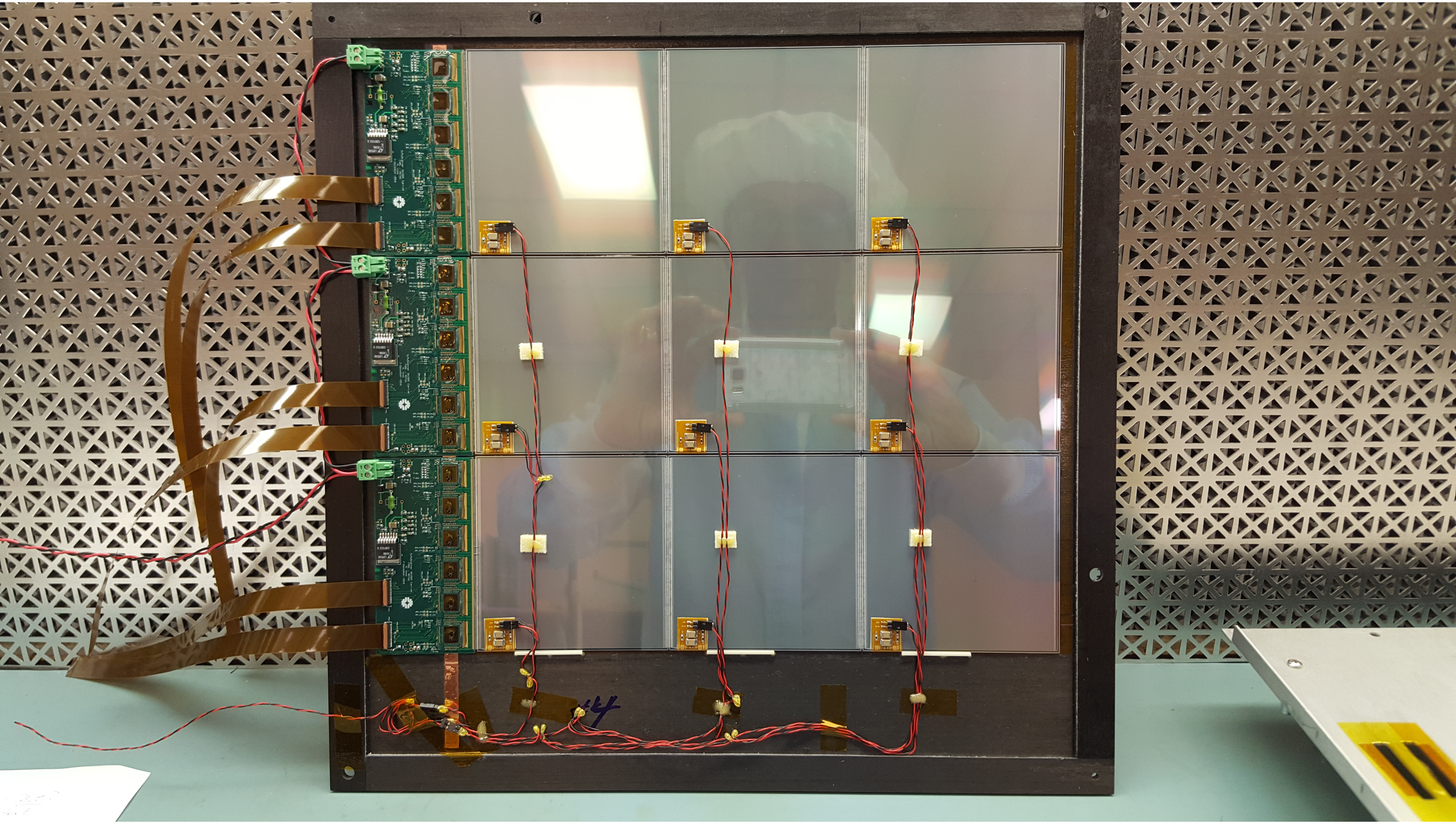


Motion Table

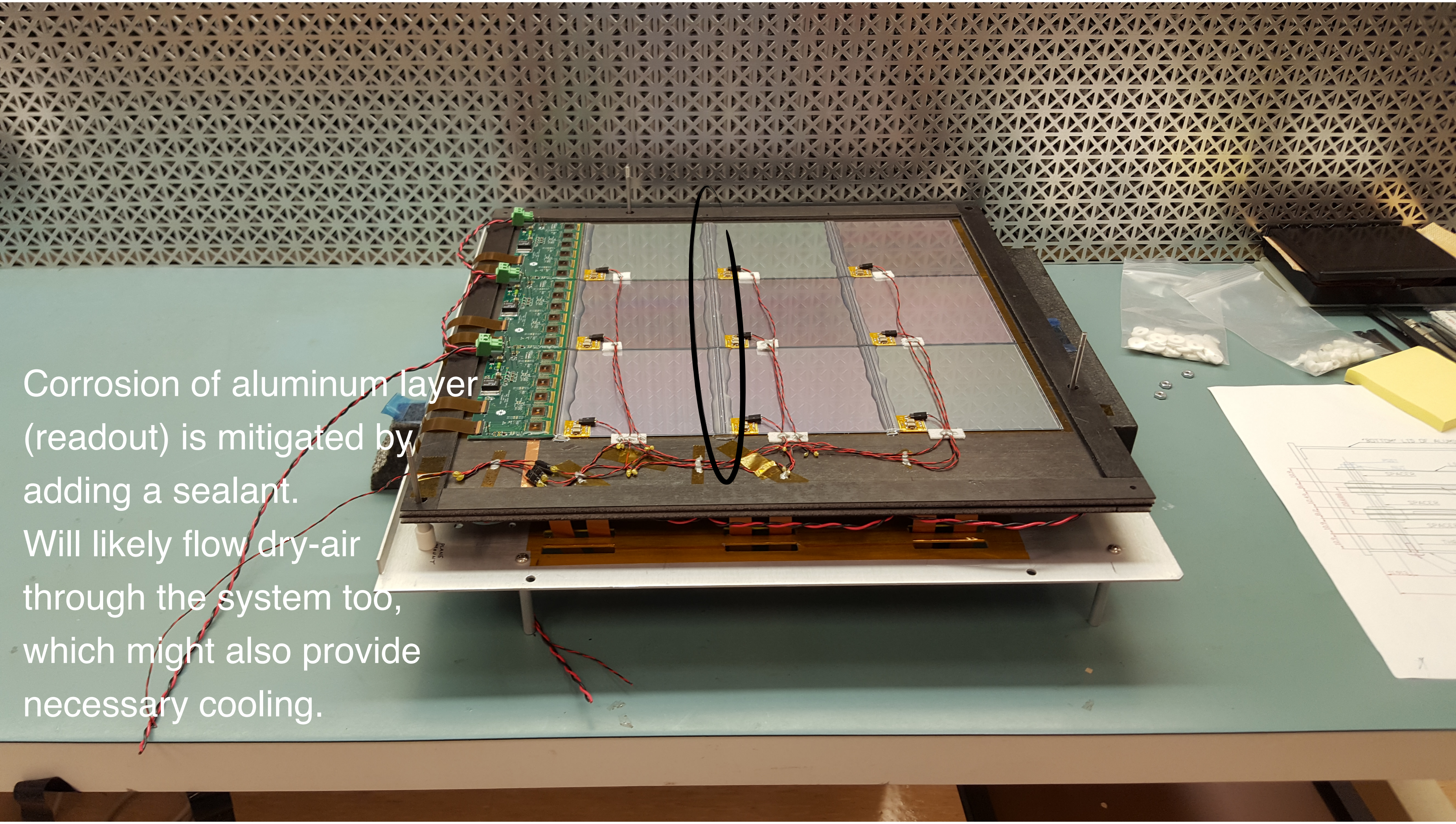
Silicon Strip Sensor Options

- Two types of silicon sensors are available for our use at Fermilab:
  - "D0" sensors:
    - 5 x 10 cm^2, 60 um pitch, 300 um thickness
    - bonds on one side only, highly non-trivial to tile
    - 5 readout chips/sensor (Alivata GP8 chips)
  - "CMS" sensors:
    - 10 x 10 cm^2, 122 um pitch, 500 um thickness
    - bonds on both ends, trivial to tile
    - 6 readout chips/sensor (Alivata GP8 chips)
    - **highly susceptible to corrosion effects, known mitigation procedure**
- Many more sensors are available than we need.

Example of 30x30 cm^2 Planes Built for Muon Tomography Project



Example of 30x30 cm² Planes Built for Muon Tomography Project

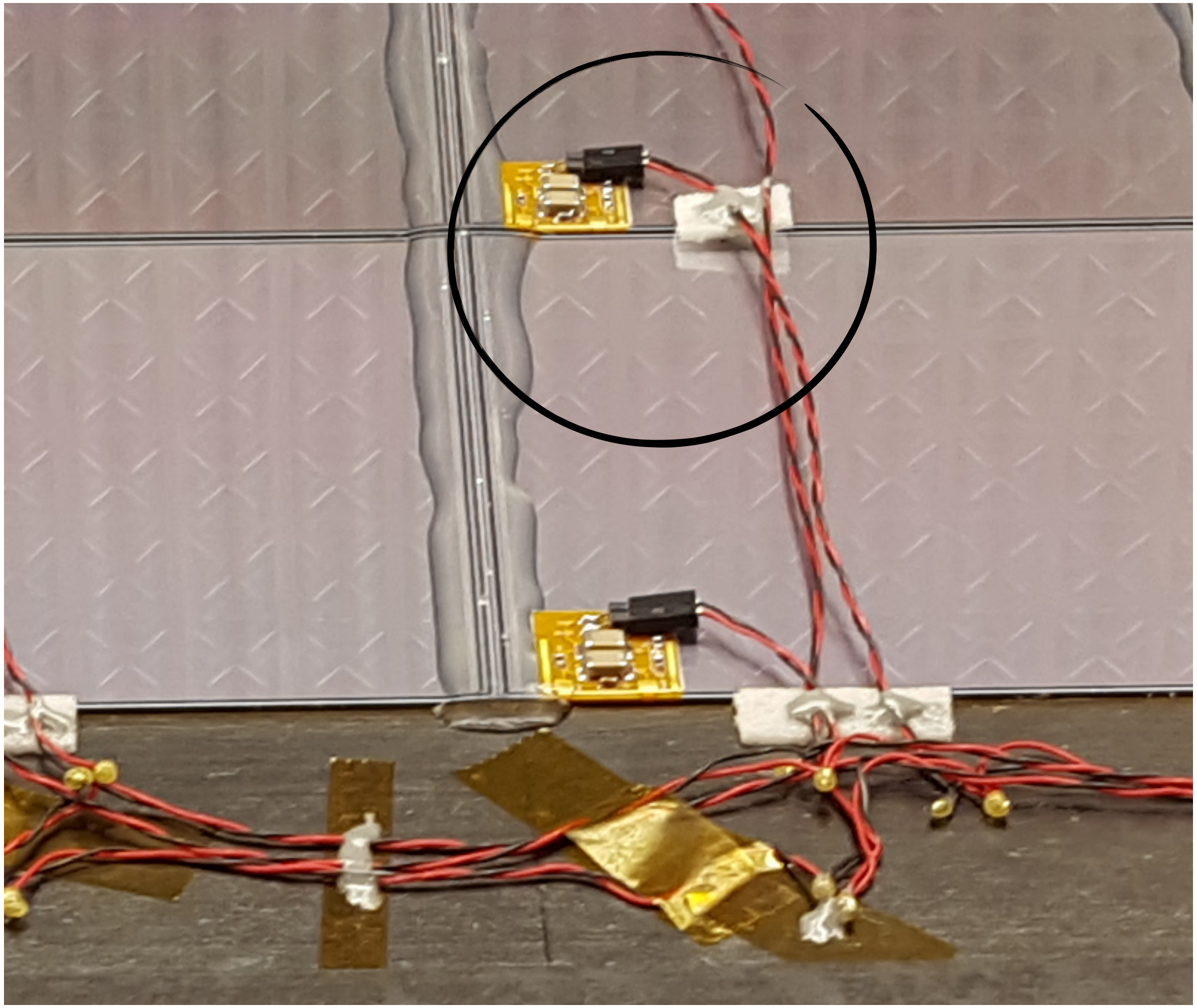


Corrosion of aluminum layer (readout) is mitigated by adding a sealant.
Will likely flow dry-air through the system too, which might also provide necessary cooling.

Example of 30x30 cm² Planes Built for Muon Tomography Project

This project was looking at energetic muons and so didn't need to worry about energy loss or scattering.

Would replace these materials with lower profile and lower mass components.

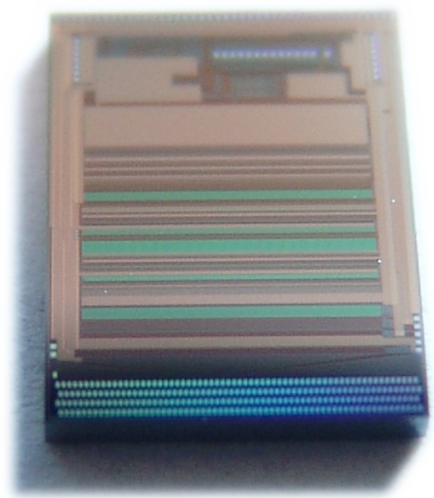


SSD Readout Chips

- Plan to use IDEAS VATA GP7.1 (or GP8) chips:
  - 128 channels, designed for counting and imagine applications
  - Off-the-shelf solution, test kits available. Quote: 200 chips = ~$165.4k
  - Experience by RD50 Collaboration using this system

Product Features

Detectors	Si, hybrid photon detector (HPD)
Application	Counting, Imaging
Number of inputs	128
Input charge range	±30 fC
Shaping time	500ns (VA), 50ns (TA)
Nominal capacitive load	10 pF
Equivalent Noise Charge (ENC)	70e + 12e/pF
Trigger threshold	Programmable by 5-bit DAC
Trigger outputs	Digital address of triggering channel
Outputs	Multi-hit, multi-plexed amplitude, differential current, serial analogue, sparse readout
Test and calibration	Internal calibration circuit

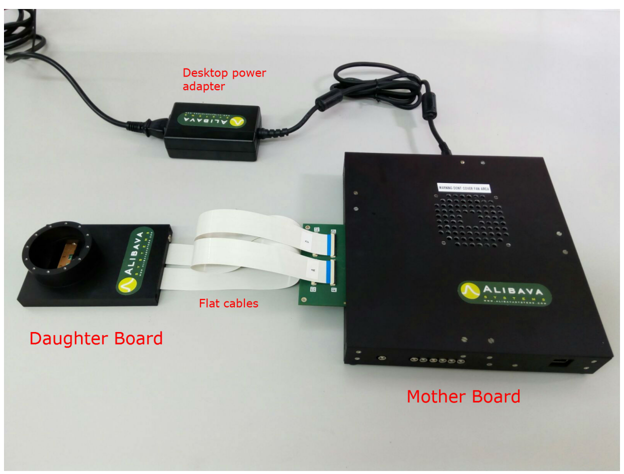


SSD Front-End Electronics

- AliVATA system from Alibava (company) is another OTS commercial solution.
- Quotes: EUR$60.6k (for 6 boards), EUR$90k (for 10 boards) (lead time for all is 4-6 months)
- Each board is guaranteed to read out 4 streams of 8 chips.
- We will require a minimum of 6 boards to read out all SSDs:
  - Two boards for the single-sensor stations upstream of the magnet
  - Three boards for the 20x20 cm^2 stations downstream of the magnet, reading out an effective 122 um pitch (five boards if we read out every strip on D0 sensors)
  - One board for the 30x30 cm^2 station (with some strips ganged together in the outer regions)

ALIBAVA SYSTEMS
The AliVATA system

First AliVATA for Microdosimeters



ALIBAVA SYSTEMS
The AliVATA system

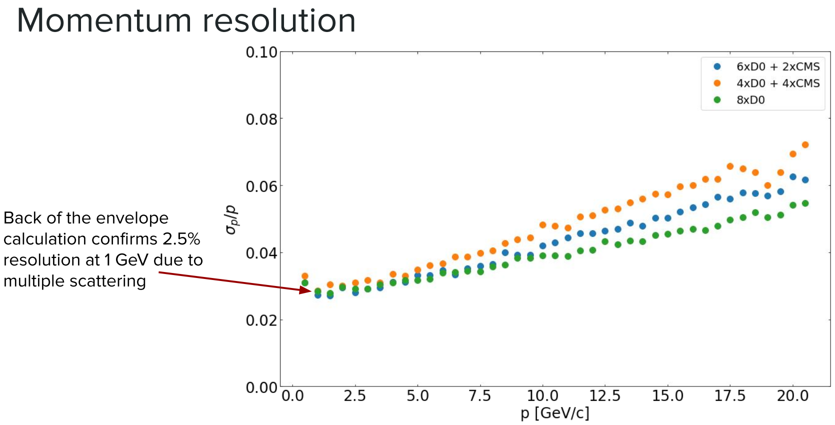
Summary

✔ ALIVATA readout system for spectroscopy

- ➔ Several detector types (Silicon strips, pads or pixels, SiPM, etc.)
- ➔ Self-trigger
- ➔ Time stamping
- ➔ Really scalable (with the IDEAS GP7 chip, up to 8192 channels per motherboard)

Single-sensor and 20x20 cm² planes

- The 10 single-sensor planes will use the D0 sensors. The finer pitch provides better resolution for the low-angle scattering measurements, and each plane requires only 5 chips.
- The 20x20 cm2 planes will have an array of:
  - CMS sensors:
    - 2x2 grid of 122 um pitch sensors
    - 12 chips/plane or 24 chips/plane if we're worried about pileup (we're not)
    - will probably require gas system for corrosion mitigation
  - or D0 sensors:
    - 4x2 grid of 60 um pitch sensors
    - 40 chips/plane; can gang adjacent strips together for an effective 120 um pitch, reducing number of chips by factor of 2. Simulation studies indicate a small decrease in the momentum resolution.
    - no corrosion concerns



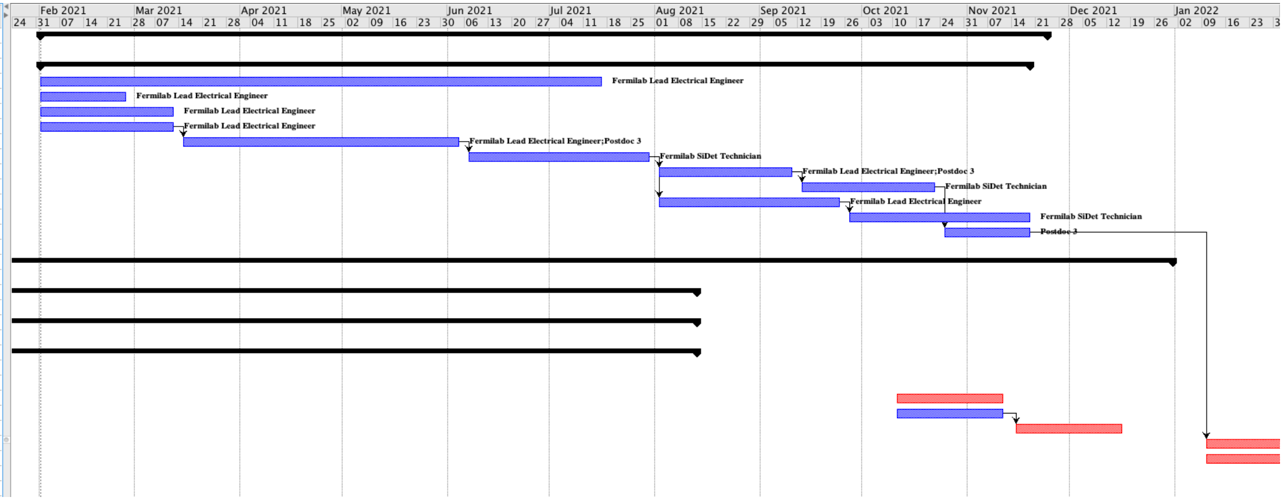
  - Our strong preference is use the D0 sensors for the 20x20 cm² stations (less risk).
  - In either case, temperature of chips will need to be maintained… will investigate if flowing dry air will suffice, which we need anyway for the CMS sensors.

CMS Sensors for 30x30 cm^2 planes

- To use D0 sensors for these larger detectors:
  - Need to come up with a solution to tile D0 sensors.
    - This will introduce a lot of extra labor, and significantly increase the noise in the system (eg, will need jumpers).
    - Also will introduce more dead space between sensors and increase material budget.
  - Each plane would require 30 chips for readout.
- **Fermilab experts feel that CMS sensors are best option for the larger 30x30 cm^2 planes.**
  - Corrosion issues are a risk, but probably acceptable.
    - If sensors degrade, we can swap them out. Spare planes will be needed.
    - Tests are underway to test longevity of wire bonds over time after epoxy layer is applied.
  - Each plane requires only 18 chips for readout, more affordable.

Schedule and Milestones

		Name	Duration	Start	Finish
1		⊞Large-aperture Magnet	213 days	2/1/21 8:00 AM	11/24/21 5:00 PM
11		⊟Silicon Strip Detectors	210 days	2/1/21 8:00 AM	11/19/21 5:00 PM
12		Procure chips	120 days	2/1/21 8:00 AM	7/16/21 5:00 PM
13		Procure sensors	20 days	2/1/21 8:00 AM	2/26/21 5:00 PM
14		Procure Readout Test System	30 days	2/1/21 8:00 AM	3/12/21 5:00 PM
15		Preliminary Design	30 days	2/1/21 8:00 AM	3/12/21 5:00 PM
16		Adopt and Test DAQ	60 days	3/15/21 8:00 AM	6/4/21 5:00 PM
17		Prototype Production	40 days	6/7/21 8:00 AM	7/30/21 5:00 PM
18		Test and Final Design	30 days	8/2/21 8:00 AM	9/10/21 5:00 PM
19		Assemble 8 Single Sensor Planes	30 days	9/13/21 8:00 AM	10/22/21 5:00 PM
20		Procure Remaining Readout Systems	40 days	8/2/21 8:00 AM	9/24/21 5:00 PM
21		Assemble Remaining Planes	40 days	9/27/21 8:00 AM	11/19/21 5:00 PM
22		Commissioning	20 days	10/25/21 8:00 AM	11/19/21 5:00 PM
24		⊞Hybrid RICH	255 days	1/11/21 8:00 AM	12/31/21 5:00 PM
90		⊞RPCs	293 days?	7/1/20 8:00 AM	8/13/21 5:00 PM
130		⊞Lead Glass Calorimeter	160 days?	1/4/21 8:00 AM	8/13/21 5:00 PM
147		⊞Aerogel Detectors	380 days?	3/1/20 8:00 AM	8/13/21 5:00 PM
162		Installation – Phase 1	24 days	10/11/21 8:00 AM	11/11/21 5:00 PM
163		Commission – Phase 1	24 days	10/11/21 7:00 AM	11/11/21 5:00 PM
164		Data Collection – Phase 1	24 days	11/15/21 8:00 AM	12/16/21 5:00 PM
165		Installation – Phase 2	36 days	1/10/22 8:00 AM	2/28/22 5:00 PM
166		Commision – Phase 2	36 days	1/10/22 8:00 AM	2/28/22 5:00 PM
167		Data Collection – Phase 2	89 days?	3/1/22 8:00 AM	7/1/22 5:00 PM



- A preliminary design will begin as soon as funding becomes available. Procurement of sensors, chips, and front-end electronics will begin at the same time. All procurements should take about 5 months to complete; this includes the time for the procurement process at Fermilab.
- In the meantime, a small prototype will be designed (March). This will be followed by the adoption of the AliVATA software and testing (June) of the DAQ.
- The prototype will be produced by end of July.
- Tests and iteration toward the final design until early September.
- Assembly of single-sensor planes will begin as soon as the final design is ready. The goal is to have these detectors ready for Phase 1 (mid-October).
- Larger tiled planes assembled by mid-November.
- Mechanical and electrical designs are tightly coupled, but SiDet/PPD engineers have experience with these types of systems.

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Costs

- Labor: 4 months FTE Fermilab engineering and technicians: $100k (fully burdened).
- M&S:
  - 200 IDEAS VATAGP7.2 (or VATAGP8) ROICs + test card + ROIC development kit: $175k
  - 6 AliVATA motherboards + cables: $75k (U. Houston is considering purchasing these using non-DOE funds)
  - materials for support planes, housing, cables, etc.: $25k
- Total: $375k
- Total + 20% contingency on M&S and 40% on Labor: $470k

Risks - Impact and Mitigation

- **High: Engineering and technician labor is underestimated**
  - **Impact: Will cause cost increase and schedule delay**
  - **Mitigation:**
    - **40% contingency, use as much scientific labor (postdocs and students) as possible.**
    - **if delivery schedule for single-sensor detectors is delayed, use FTBF SSDs in MT6.1a for Phase 1 (original plan), and move experiment to MT6.2d later**
- Moderate: CMS sensors degrade at higher rate than anticipated
  - Impact: Interruption of data collection, additional cost to replace sensors
  - Mitigation: Spare planes (maintained in controlled, low-humidity environment) will be available to swap out.
- Low: CMS sensors unusable
  - Impact: Higher costs associated with adapting 30x30 planes to use D0 sensors, both labor and electronics.
  - Mitigation: Tests are underway. Worst-case scenario is to use 20x20 planes and run with reduced acceptance.
- Low: Delay in procurement of chips and/or AliVATA boards
  - Impact: Schedule delay
  - Mitigation: Schedule has built-in float

Summary

- Additional single-sensor planes will give EMPHATIC much needed flexibility in the schedule for data collection, a stable operating environment, and the ability to move to MCenter (or elsewhere) for Phase 4.
- Fermilab has a wealth of experience and expertise in designing, assembling and commissioning silicon strip detectors.
- Cost is driven by M&S: readout chips and front-end electronics.
- AliVATA front-end electronics is an affordable off-the-shelf solution that will save many months of engineering and testing.
- 4 months FTE engineering and technician labor needed to properly put all of the components needed. Testing will be done with scientific labor.
- There is a high risk that the schedule will slip… **funding is needed ASAP to get started on the design and prototyping.**