Mu2e status 2019

S.Miscetti , LNF/INFN

Meeting with CSN1 Referees

Universita' degli Studi di Roma

"La Sapienza"

20-9-2019

Mu2e

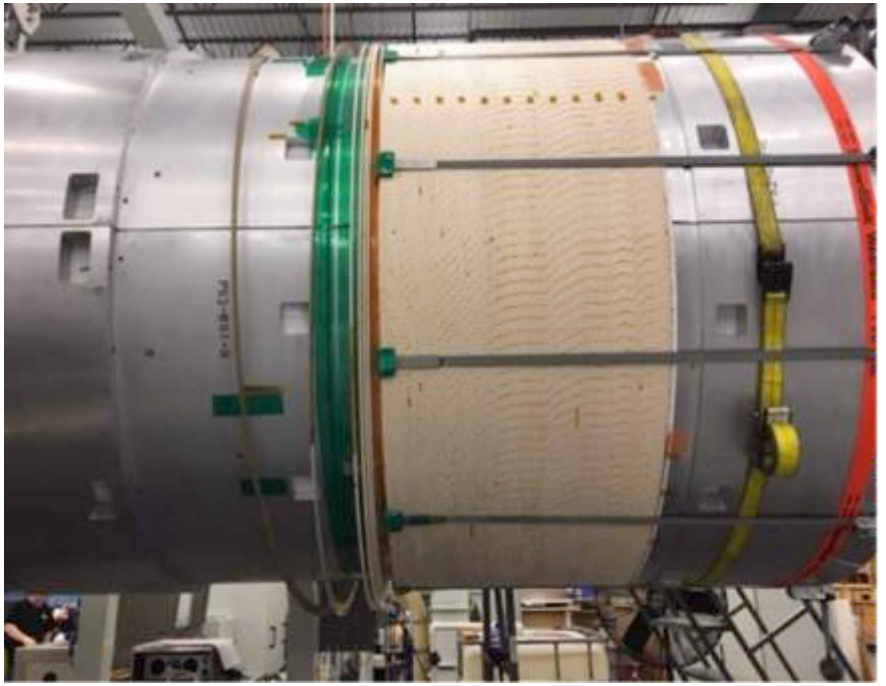
Talk layout and agenda

Status of the experiment

→ Magnet status
→ Tracker & CRV status
→ Contingency problem
→ “Strawmen” Transition to operation schedule
→ “Strawmen” physics running schedule

PS coil winding status (GA, Tupelo, MS)

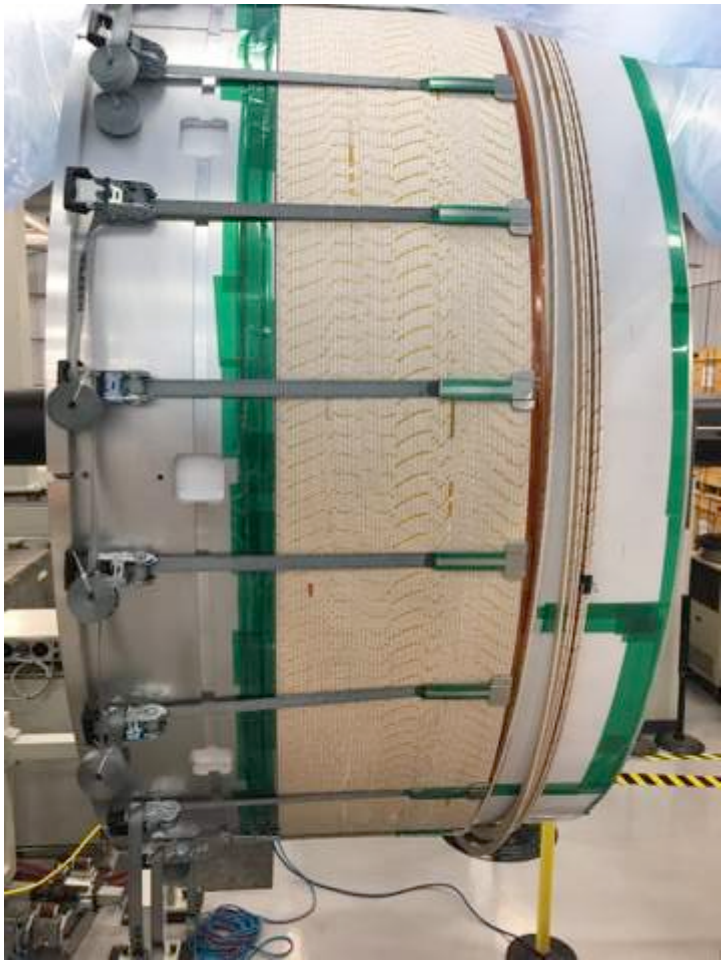
- Winding of PS3 began week of 4/8/19
- Completed winding in June
- Final machining of coil completed
- Final machining of Shell beginning of September
- Coil insertion scheduled for the week of September 23



Great success:
After 1 year of test, mockups and winding tries, the solenoid L2 works weekly with GA for oversight the delivery schedule

Detector Solenoid → DS1/DS2

- DS1 and DS2 - 73 turn/2 layer
  - DS1
    - Two layers wound. Winding radial/ axial compaction looks good.
    - Mandrel removed from winding machine. Waiting for completion of inner/outer layer splice tooling to complete coil wind.
  - DS2
    - First layer coil winding was completed. Turns look visual good.



Detector Solenoid → DS8/DS10

- DS8 (DS10) - 244 turn/1 layer
  - Coil winding completed. Turns look visually good. Decided to store coil off-mandrel pending results of Fermilab test (Ic, RRR, bond strength).
  - Fermilab tests should be completed in 2 weeks.

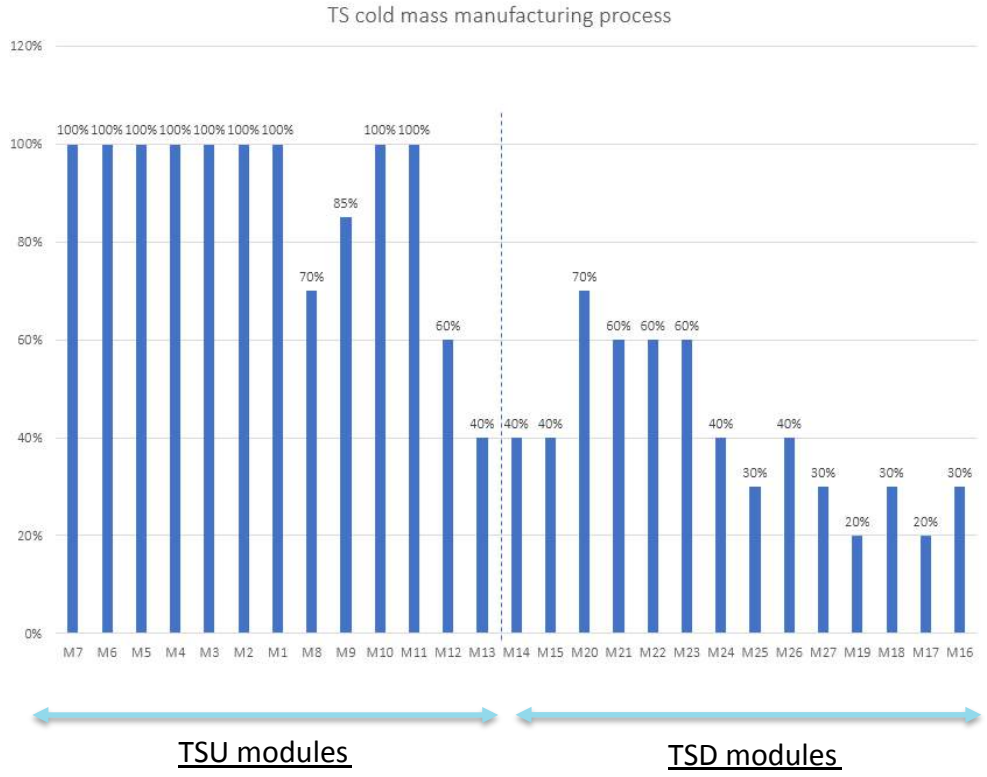
Status of PS/DS construction

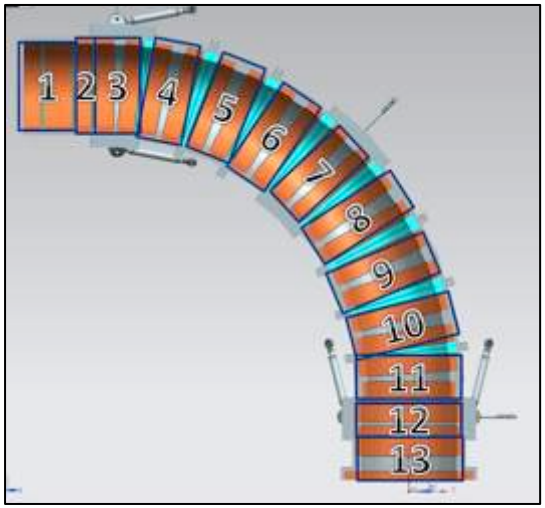
- PS/DS Cryostats being completed @ Joseph Oat (GA Subcontract)

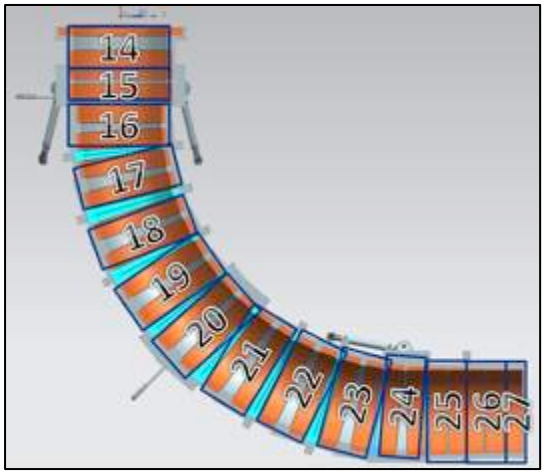
Status of TS cold mass at a glance

All coils completed

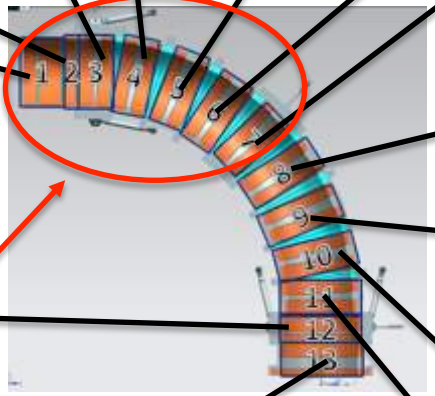
More than 40% of modules assembled







TSU

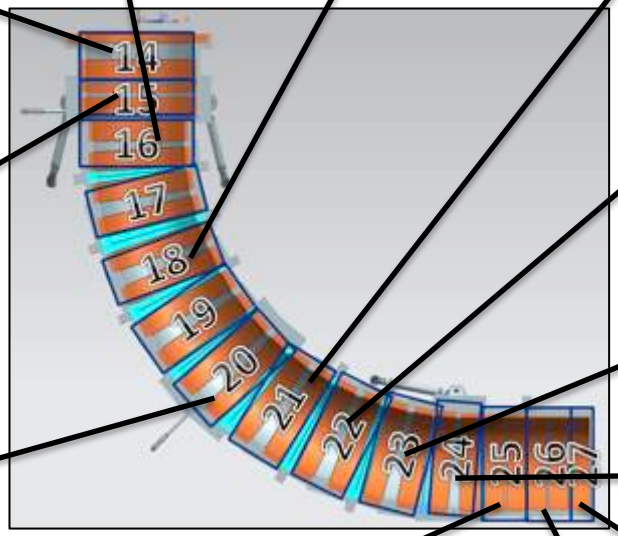


First half of TSU delivered to FNAL.
Progress on second half moving forward at a good pace.

TSD

Module 16
- Rough machining completed

Module 18
- Rough machining completed



Module 24
- Rough machining completed
- Welding completed

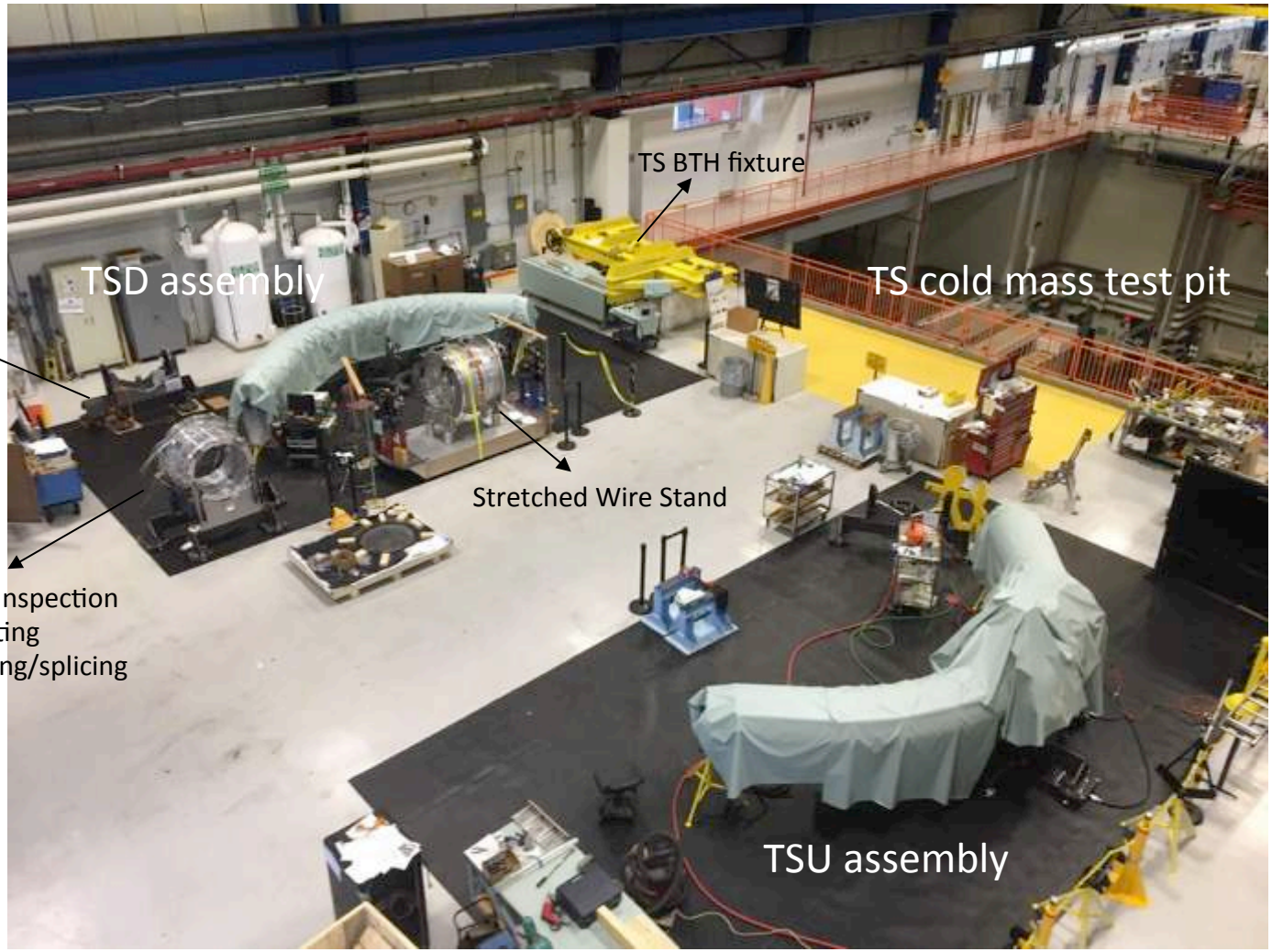
Module 25
- Rough machining completed

Module 27
- Rough machining ongoing

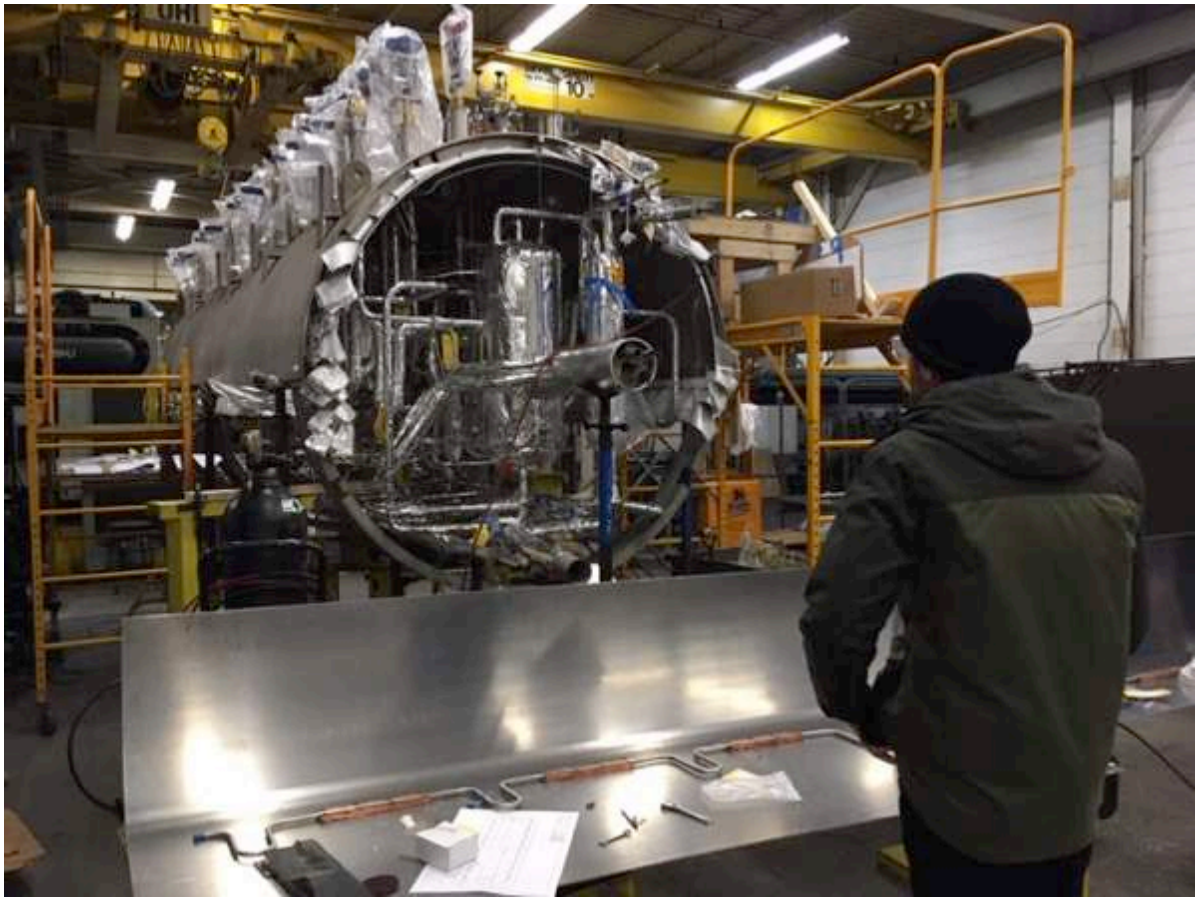
Module 26
- Rough machining completed
- Welding completed

Work is ongoing on 12 out of 14 TSD modules

Transport Solenoid in HAB



Progress on Cryo distribution Box



- All +100 spools welded in place, cold shocked and leak checked.
- LN2 thermal shield (foreground) is being assembled for installation

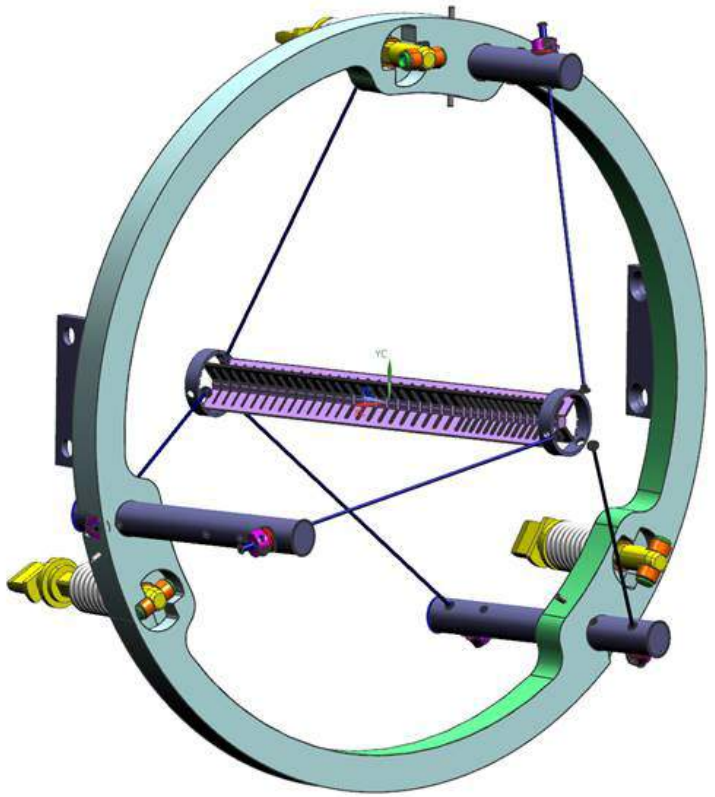
Accelerator: Production Target

Target Station

Problem of cooling for Production Target required modifying the baseline design

(reminder: this is not a radiatively cooled target)

- Target design selected “Hayman2”



- Proceeding to modify design of of target mounting
  - Spoke attachment not yet worked out
- Target design requires minor tweaks to mitigate stresses in support rings
- **Muon yield for “Hayman2” is approximately 0.00145 m/POT (~25% below TDR yield).**

- Peak temperature during baseline design (8 kW) operation is ~ 1100 ^{o}C

Mu2e Tracker Design

Detector requirements:

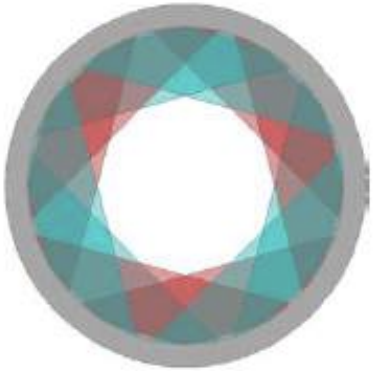
1. Small amount of X_0
2. σ_p < 180 keV @ 105 MeV
3. Good rate capability:
   - 20 kHz/cm^2 in live window
   - Beam flash of 3 MHz/cm^2
4. dE/dx capability to distinguish e^-/p
5. Operate in B = 1 T, 10^{-4} Torr vacuum
6. Maximize/minimize acceptance for CE/DIO

Low mass straw drift tubes design:

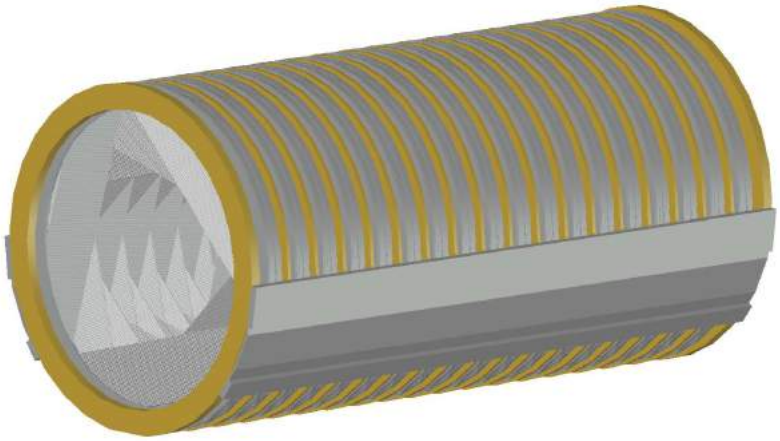
- 5 mm diameter, 33 – 117 cm length
- 15 μm Mylar wall, 25 μm Au-plated W wire
- 80:20 Ar:CO_2 @ 1 atm
- Dual-ended readout

Tracker Plane

Tracker Station:
2 rotated planes



Tracker:18 stations (>20k tubes)



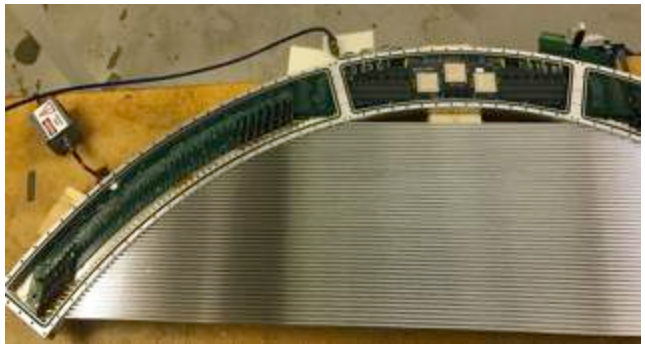
Mu2e Tracker status

- Straw Procurement completed (30k straws). Straw production well progressed. Complete fixtures in May 2020

- **Panels**
  - Design Complete
  - Production assembly fixtures being fabricated
  - **UMN Panel Factory & QC Station set up**

  → Now working on the 12th pre-production panel.

  → Production is starting
- **Plane**
  - Plane assembly tooling fixture design nearly complete
- **Electronics**
  - Incorporation of rad hard FPGA in progress



Panel w/Front-End Electronics

Panel: Straw Installatior

Three panels installed in plane

Mu2e Tracker → help from INFN ?

Due to the MU2E contingency problem (see later) and to the Current tracker status, the request from EB is to use as much "unpaid"-"less-paid" labour as possible.

→ Required possible INFN help with techs for construction

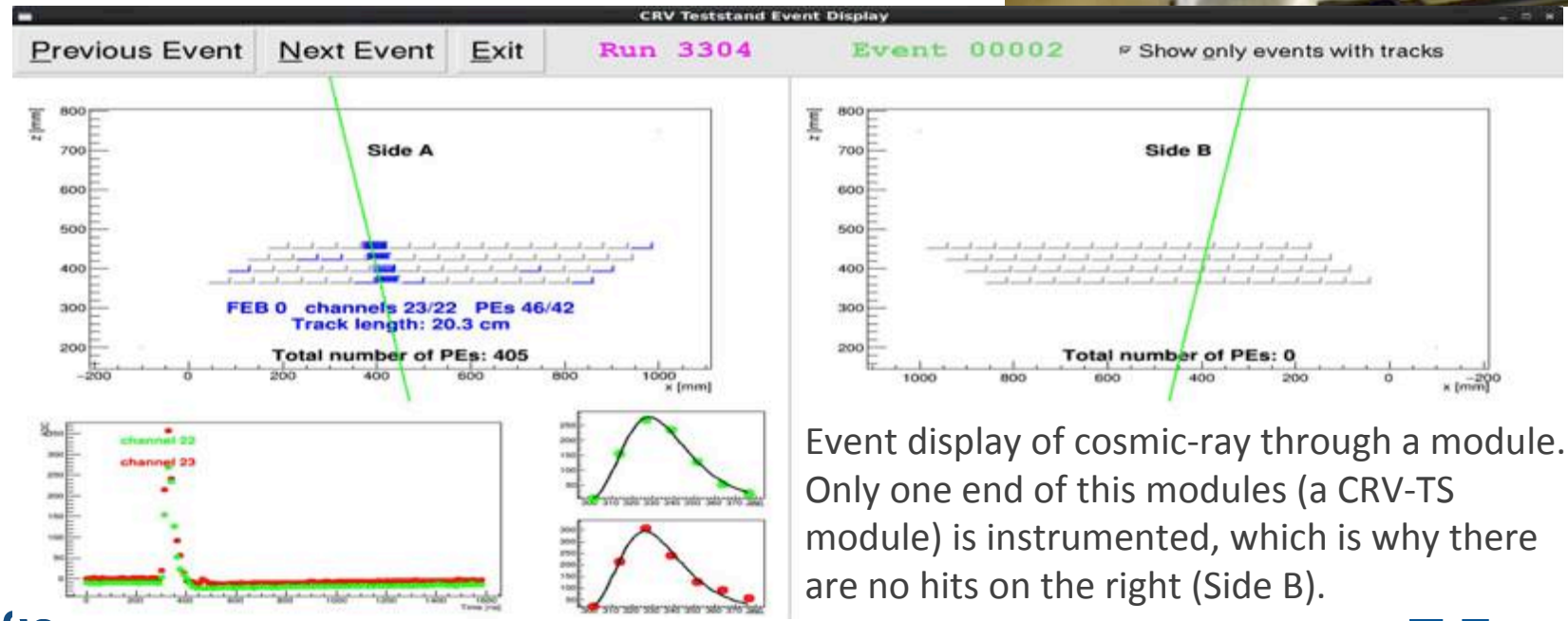
→ Possibility to contribute with QC control on the second assembly station for Panels at FNAL

→ G. Tassielli will be in contact with the Tracker L2 to organize a first visit during October

CRV Module Fabrication (July 2019)

- **Scint/fibers OK, SiPM production OK (1/3)**
- **5 pilot production modules produced.**
- Physical measurements meet requirements.
- Testing of the completed modules delayed due to lack of FEB electronics.
  - Electronics now in hand.
- First shipping crates arrived at factory.

First module being vacuum bagged.



Event display of cosmic-ray through a module. Only one end of this modules (a CRV-TS module) is instrumented, which is why there are no hits on the right (Side B).

CRV Module Fabrication

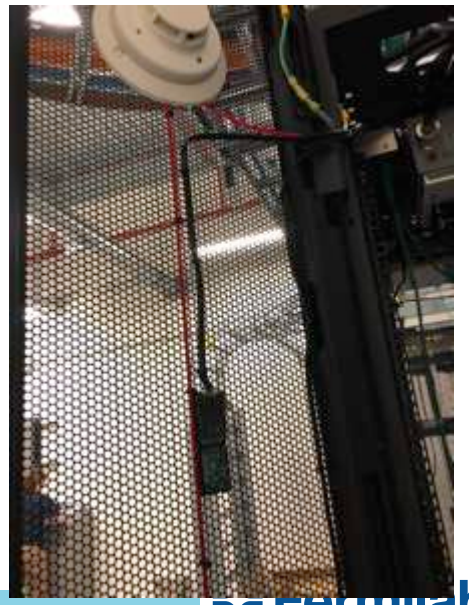
- Di-counter production on track: fabricated and tested 55%.
- Module production:
  - The 5 pilot production modules have been fabricated and tested.
  - 4 modules were shipped to Fermilab and received on 8/27/2019. They are in Wideband. (One has been kept at UVA for further tests.)

Module crates loading in Virginia

Module crates in Wideband

TDAQ

- All 14 rack protection/monitoring units for DAQ control room assembled, tested and installed.
- Placing orders for production FPGA hardware and timing distribution
  - Received the all the Timing Card boards. Orders for FPGAs and optical components placed, none received so far.
- At multi-subsystem test stand: using OTSDAQ
- with artdaq to provide a maturing web based online DAQ system
  - STM, CRV, Tracker, Calorimeter, and Trigger experts have been notably active this month at the test stand interfacing with online DAQ instances.



Project cost (7/2019) w/o Contingency/Risks

Currency in: $K	Current Period							Cumulative to Date								
Work Package.WBS (2)	Budget	Earned	Actuals	SV ($)	SV (%)	CV ($)	CV (%)	Budget	Earned	Actuals	SV ($)	SV (%)	CV ($)	CV (%)	SPI	CPI
475.01 Project Management	214	214	160	0	0%	54	25%	21,472	21,472	22,083	0	0%	(611)	-3%	1.00	0.97
475.02 Accelerator	294	419	364	125	42%	55	13%	33,263	32,176	34,211	(1,086)	-3%	(2,034)	-6%	0.97	0.94
475.03 Conventional Construction	0	0	(0)	0	0%	0	-	19,751	19,751	18,589	0	0%	1,162	6%	1.00	1.06
475.04 Solenoids	1,513	2,624	2,620	1,111	73%	5	0%	77,018	76,125	87,012	(894)	-1%	(10,887)	-14%	0.99	0.87
475.05 Muon Beamline	71	71	55	(0)	-1%	16	22%	9,026	8,742	8,611	(284)	-3%	131	2%	0.97	1.02
475.06 Tracker	100	367	168	266	265%	199	54%	9,561	7,958	10,304	(1,604)	-17%	(2,346)	-29%	0.83	0.77
475.07 Calorimeter	25	69	80	43	173%	(12)	-17%	4,489	3,680	4,069	(809)	-18%	(389)	-11%	0.82	0.90
475.08 Cosmic Ray Veto	70	90	3	20	29%	87	97%	7,469	7,046	7,293	(423)	-6%	(246)	-3%	0.94	0.97
475.09 Trigger & DAQ	22	59	78	37	173%	(19)	-32%	4,653	4,776	5,143	123	3%	(367)	-8%		
Total	**2,310**	**3,913**	**3,528**	**1,603**	**69%**	**385**	**10%**	**186,703**	**181,726**	**197,314**	**(4,977)**	**-3%**	**(15,588)**	**-9%**	**0.97**	**0.92**

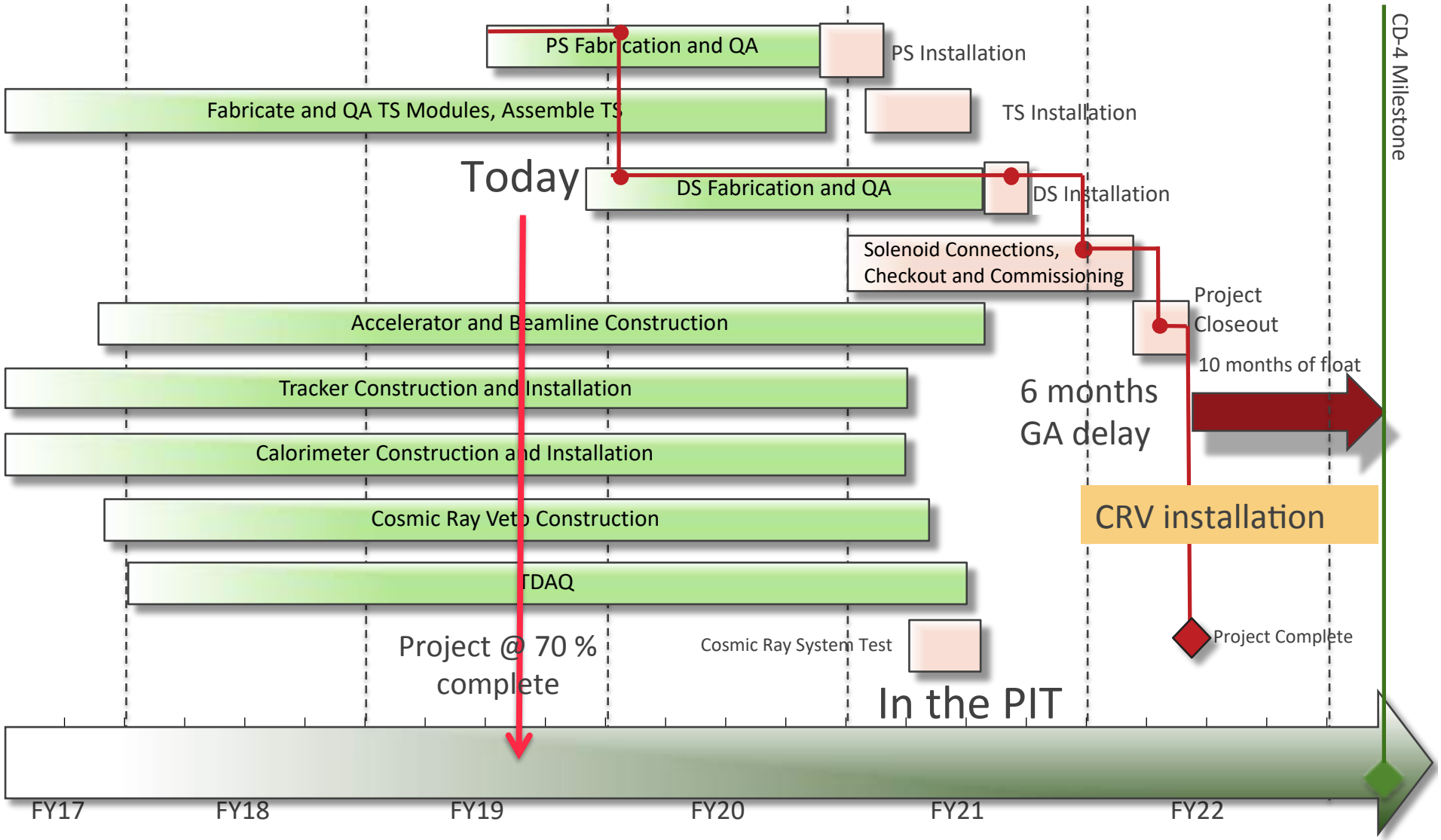
	At Complete					
Work Package.WBS (2)	BAC	EAC	VAC	% Plan	% Comp.	% Spent
475.01 Project Management	26,085	27,095	(1,010)	82%	82%	82%
475.02 Accelerator	43,453	45,648	(2,195)	77%	74%	75%
475.03 Conventional Construction	20,951	19,789	1,162	94%	94%	94%
475.04 Solenoids	101,259	113,399	(12,140)	76%	75%	77%
475.05 Muon Beamline	20,760	20,749	11	43%	42%	41%
475.06 Tracker	12,893	15,552	(2,659)	74%	62%	66%
475.07 Calorimeter	5,367	5,946	(579)	84%	69%	68%
475.08 Cosmic Ray Veto	9,496	9,830	(335)	79%	74%	74%
475.09 Trigger & DAQ	5,978	6,350	(373)			
Total	**246,240**	**264,359**	**(18,119)**	**76%**	**74%**	**75%**

- SPI up by 1%. CPI unchanged
- Positive schedule variances for Solenoids and Tracker result from catching up on late work.
- Persistent cost variances for solenoids and Tracker.
- Calorimeter schedule variance primarily due to crystal deliveries from St. Gobain and infrastructure delays.

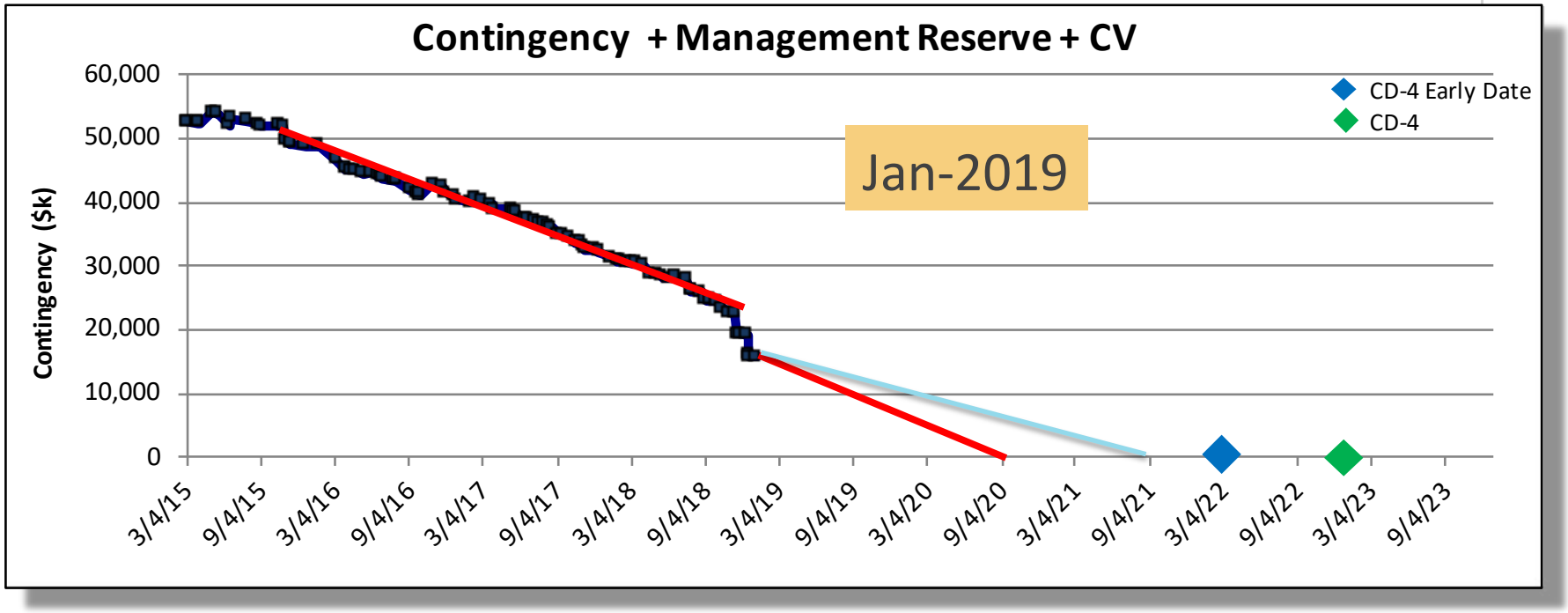
Cost Increase from CD-2 of ~ 18 M$

Project is 75% complete

Mu2e Schedule revised – July 2019

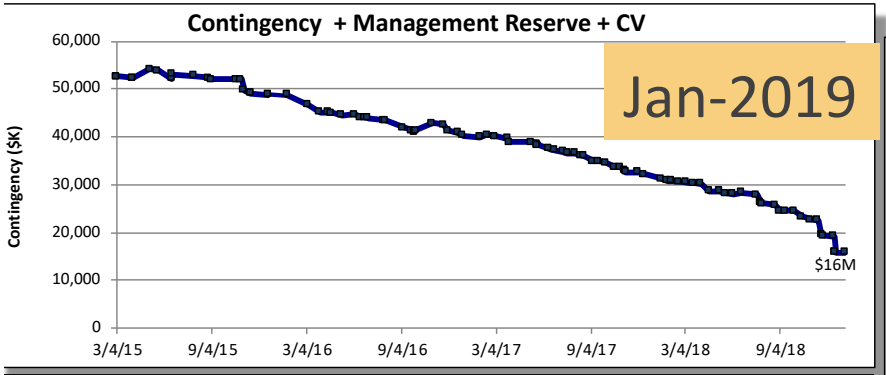


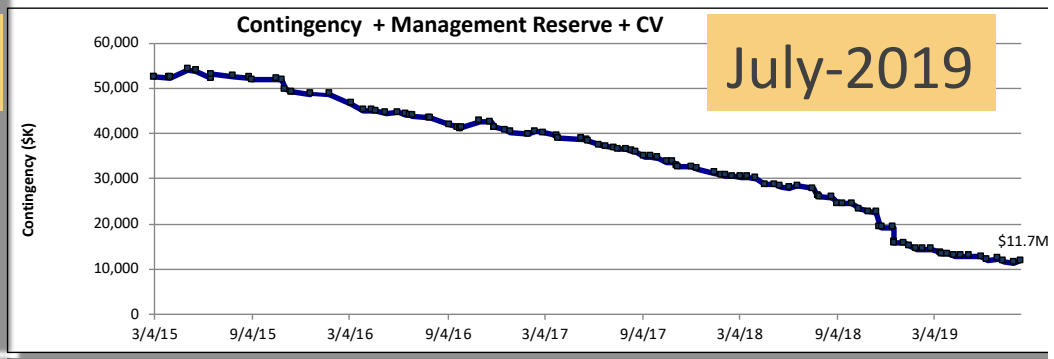
Contingency situation

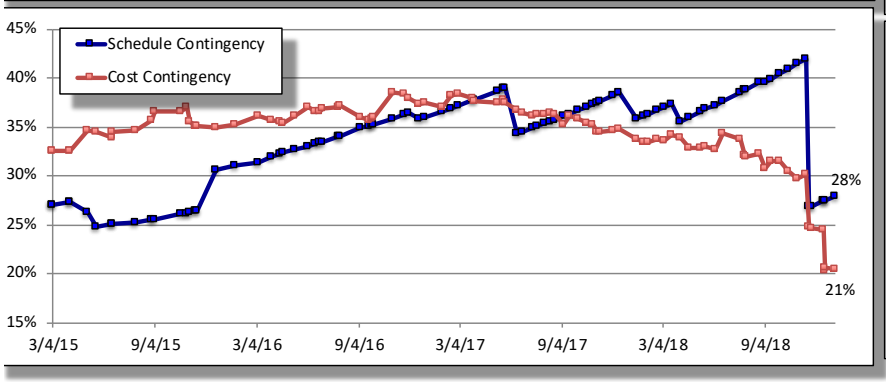


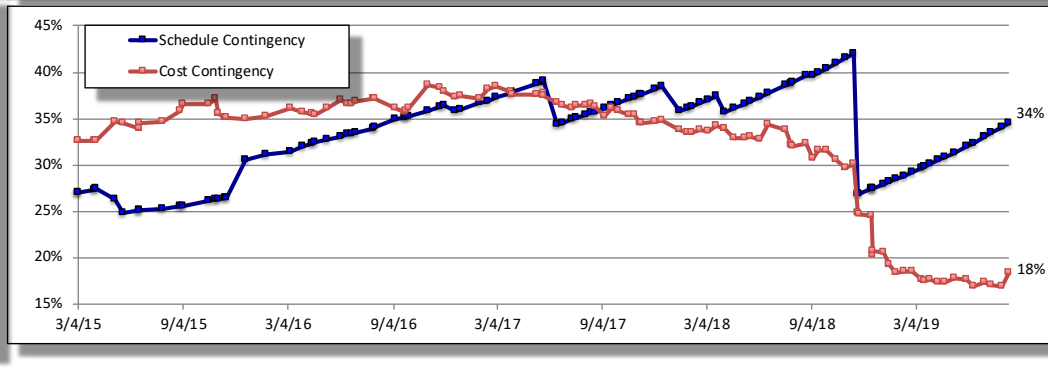
- Eye fit of contingency drop done in Jan 2019
- Largest contingency (6-7 M$/2 months) drop due to:
  → 6 months delay of GA schedule, 3 M$ of payment,
  → 3 M$ of TS cryostat .. trend/slope is really dangerous

Last months: Contingency Improvement





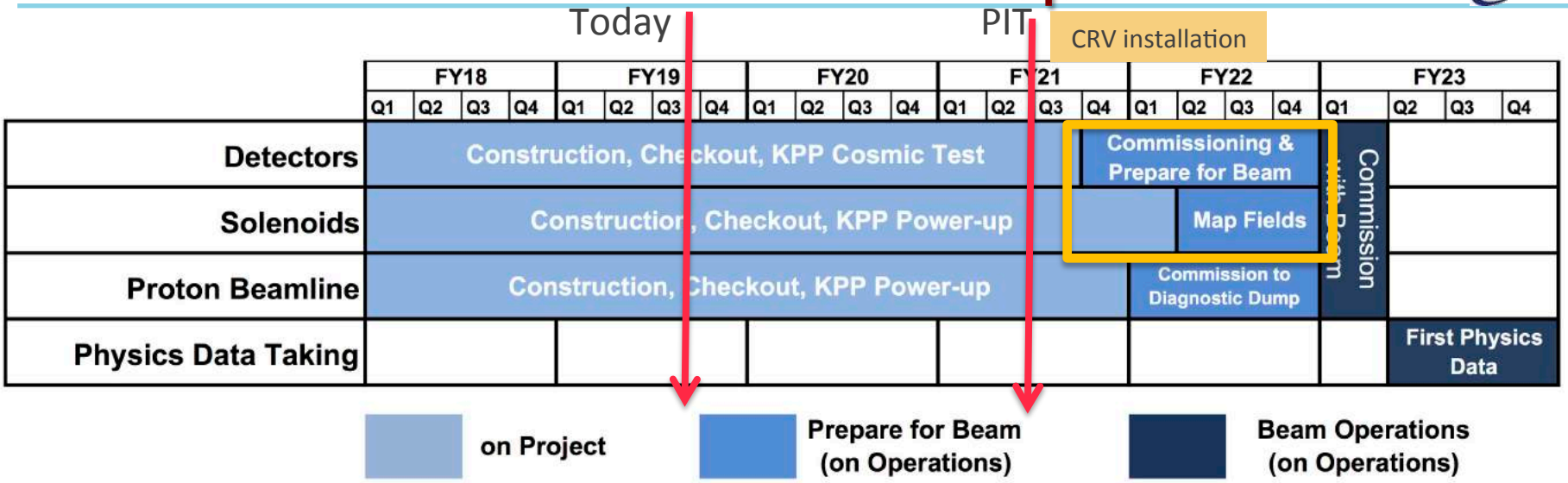




- Contingency Drop-Slope changed in the last seven months
- Still worrisome if GA needs more money for further magnet work

➔ Discussion with GA in progress at very high level (FNAL/DOE)

Strawman Mu2e-schedule for operations



- Accelerator shutdown for LBNF/DUNE currently scheduled for FY2026-FY2027
- Mu2e is planning to start commissioning with beam fall 2022
- First Physics Data running @ beginning of CY 2023

“Contingency problem” → Staging

- Initial email and kick-off meeting straddled election for new EB… spokespersons decided to keep both old+new EB members engaged
  - Oksuzian, Murat, Miscetti (chair), Hitlin, Ginther, Echenard, Dhongia, Byrum, Brown, Bernstein + Whitmore, Ray, Goodenough, Brown, Dukes
  - Additional expert input from: Werkema, Lamm, Kasper, Gaponenko
  - Incorporates expertise from all the major sub-systems of the experiment including the solenoids and accelerator beam line

- We asked EB for any ideas to help mitigate the project contingency… but particularly sought their input for ways to reduce the project cost
  - Consider scenarios in which our first physics run uses a less-capable experiment… Which systems can be reduced or (partially) delayed and still allow us to achieve significant physics goals?
  - Subject to some important ”ground rules”

"Contingency problem" → Staging

Our ultimate goal remains unchanged – explore μ→e conversion with a sensitivity ~10^4 better than SINDRUM-II

- Consider "staging" scenarios that have a straight-forward path to recovering full capabilities
- Ensure first physics run confidently enables a world's best sensitivity
  - Current World's Best: $R_{\mu e}$(Au) < 7 x 10^{-13} @90% CL (SINDRUM-II)
  - We have competition: COMET-I expects x100 improvement by ~2023
- Ensure we remain a discovery experiment… keep background small
- Brainstorm a wide variety of possibilities… don't worry about implications for cost, schedule, partnerships, etc
  - These things will be assessed in a second pass by the Project in consultation with other relevant Stakeholders

“Strawmen” Physics Running schedule

- Run at reduced beam intensity for an extended period
  - Take advantage of reduced rates and occupancies to realize savings
  - Still allows us to reach compelling sensitivity within first year of running (nb. at full intensity: match SINDRUM-II in ~100 minutes, x100 better in ~7d)
  - Use LBNF/PIP-II Shutdown to recover full capability

FY	Weeks of Physics Beam	Beamline Uptime	Fraction of time spent on Special Runs	Physics Run Time (s)	POT at nominal intensity	SUM(POT) at nominal intensity	assumed intensity relative to nominal	POT weighted by intensity	SUM(POT) weighted by intensity	Notes
2023	26	0.80	0.30	8.81E+06	5.03E+19	5.03E+19	0.5	2.52E+19	2.52E+19	Assumes an additional 14w of beam for commissioning
2024	34	0.85	0.30	1.22E+07	6.97E+19	1.20E+20	0.5	3.49E+19	6.00E+19	
2025	40	0.90	0.30	1.52E+07	8.69E+19	2.07E+20	0.8	6.95E+19	1.30E+20	
2026	LBNF / PIP-II Shutdown									
2027										
2028	40	0.90	0.30	1.52E+07	8.69E+19	2.94E+20	1.0	8.69E+19	2.16E+20	
2029	40	0.90	0.30	1.52E+07	8.69E+19	3.81E+20	1.0	8.69E+19	3.03E+20	
2030	40	0.90	0.30	1.52E+07	8.69E+19	4.67E+20	1.0	8.69E+19	3.90E+20	

nb. nominal total POT from the TDR: 3.6e20

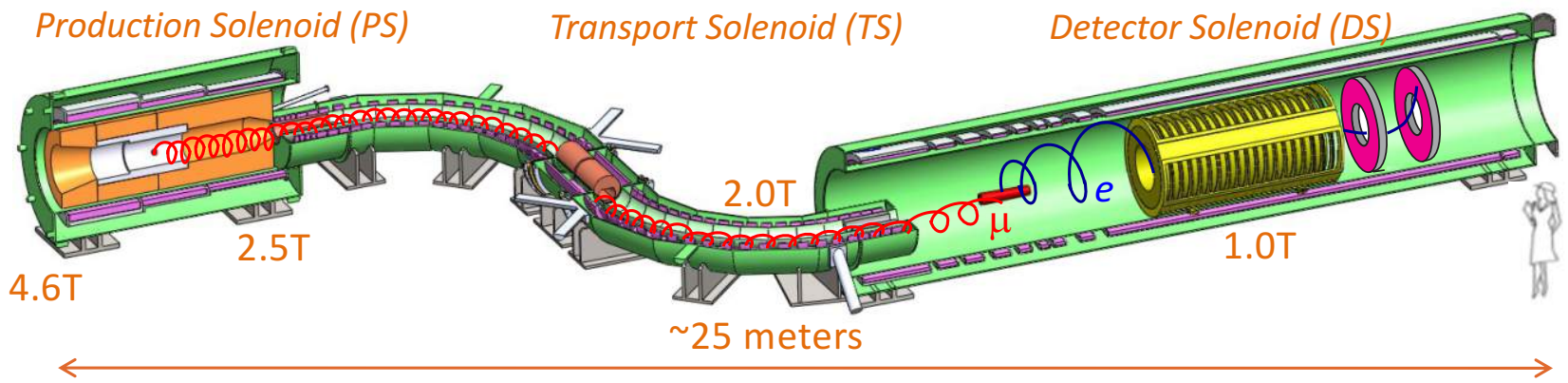
- Remove borated shielding, recover after shutdown
- Reduce hatch shielding from 2 to 1 m thick
- minor cuts/savings on the detector

→ 2 M$ Saving
→ + payback From the lab

ADDITIONAL MATERIAL

Challenges in Mu2e: 1 summary slide

A System of superconducting solenoids and an intense muon beam



Goal: O(10000) increase sensitivity w.r.t. sindrum-II, Ru = 8×10^{-17}
Method: Use $3.6E^{20}$ POT on production target to funnel (via solenoids) up to O(E18) muon stop on Aluminum target with a pulsed beam

Mu2e is challenging everywhere .. but in order of difficulty:

→ Solenoids .. High fields, with high gradients, large volumes

→ Production Target .. it is really hot and radioactive

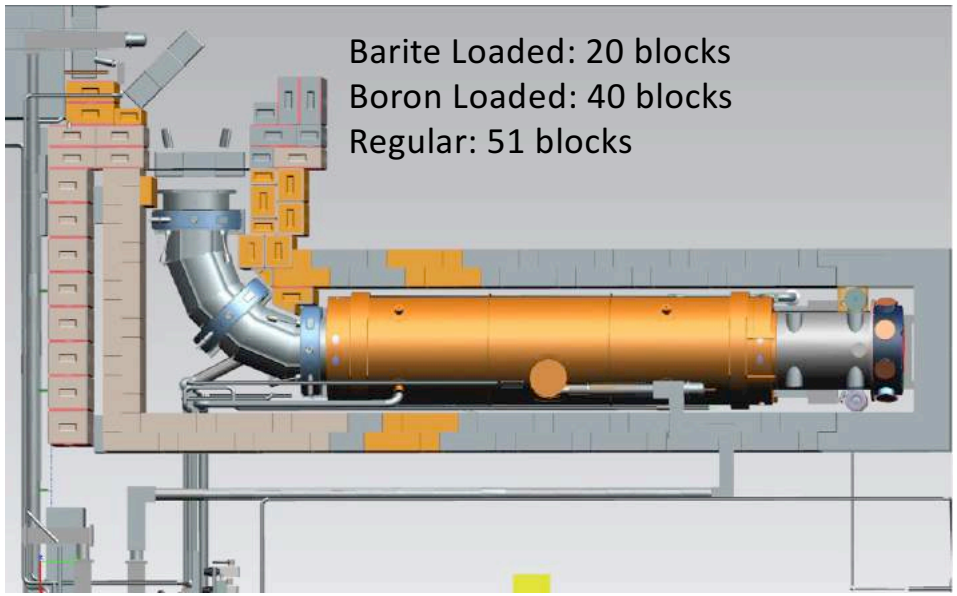
Detectors in DS: space-like approach. Work in 10^{-4} Torr vacuum, no access/repair in 1 year

→ Tracker, extremely light (15 um thick straw), low leak rate,

→ Calorimeter, state of the art CsI + SiPM detector, high redundancy and MTTF

DS: surrounded by 300 m^2 of cosmic veto scintillator counters with a lot of neutrons

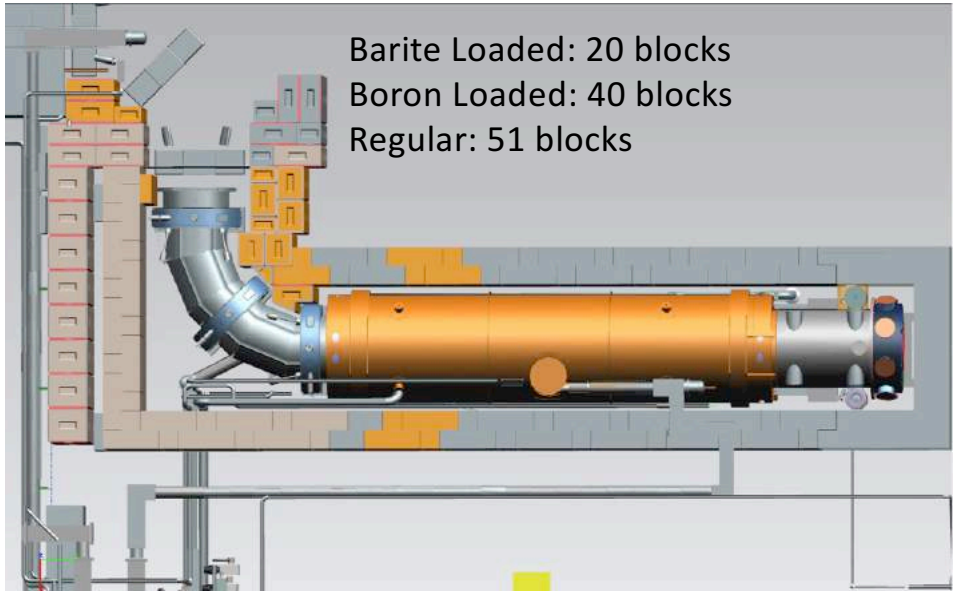
Mu2e – External Shielding



- Main role is to reduce rates in cosmic-ray veto (CRV) system from neutron-induced interactions
  - Neutron sources: production target, middle collimator, stopping target, muon beam stop
- Baseline configuration optimized over several years of detailed simulation work and measurements

- Significant cost savings available by eliminating specialty concretes

Mu2e – External Shielding



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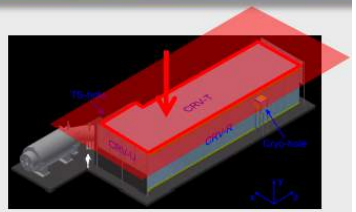
Impact of Reduced External Shielding on CRV Deadtime

Dead-time: regular concrete

- As part of "de-scope" option, we consider a shielding design with regular concrete only
- Upstream region is covered by borated poly
- The dead-time and rates are higher in the upstream region and around the stopping target
- The dead-time is within the requirement
- The rates are above the required 1 MHz value



Y. Oksuzian
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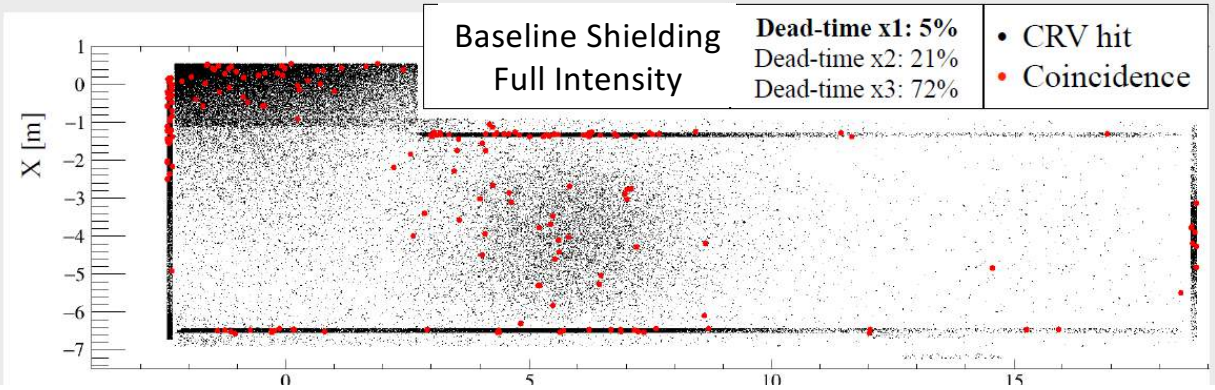
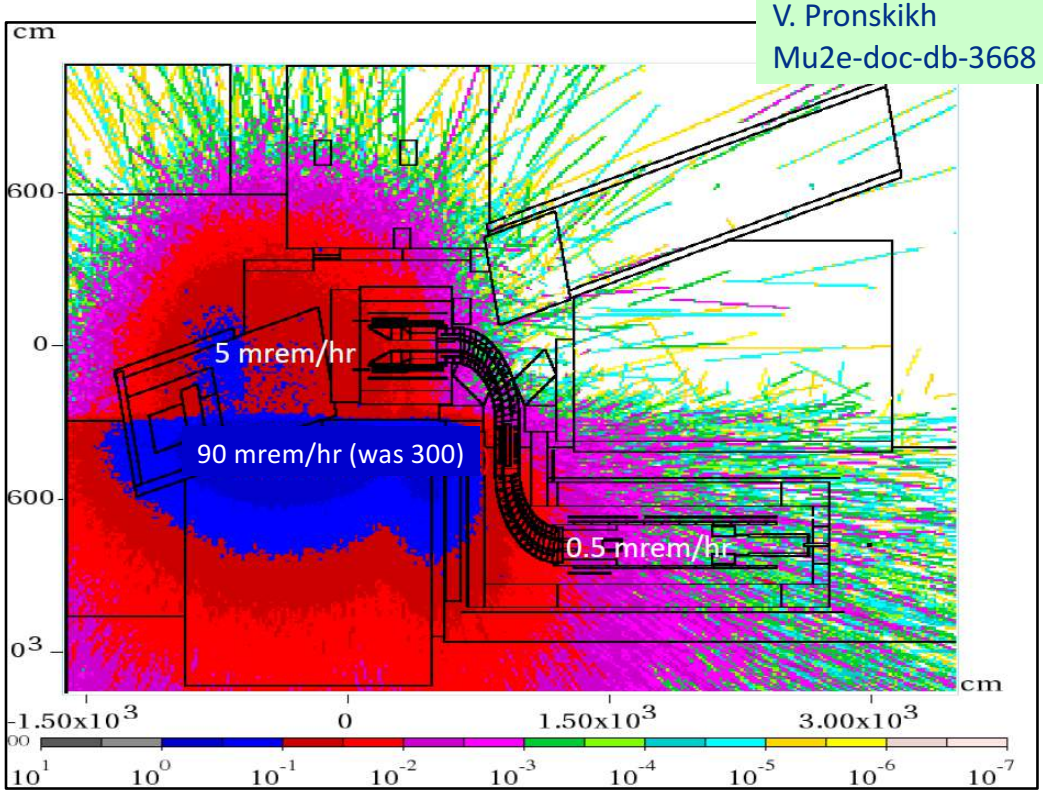


- At reduced intensity can keep dead-time <10% with external shielding package that eliminates specialty concrete
  - nb. still requires the borated poly sheets

For All Regular Concrete Shielding	Full Average Intensity	50% Average Intensity
Dead-time at x1 occupancy	5%	2%
Dead-time at x3 occupancy	72%	11%

Residual radiation levels with reduced hatch shielding

V. Pronskikh
Mu2e-doc-db-3668



At Full Intensity, but using only 3' of hatch shielding instead of the 6' currently in Project baseline

- At reduced intensity, can likely reduce hatch shielding and still meet radiation safety requirements
  - Will be confirmed with updated simulations
- Reducing hatch shielding by x2 would increase the CR-induced background by ~10% (cf. CDR)