Canada RFD CM series challenges – procurements and schedule

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Discovery, accelerated

Project Strategy

- The project strategy calls for procurement of parts for a single cryomodule, TCM0, followed by procurement of parts for the production series TCM1-4
- Project slippages due to Covid and other forces vs. boundary conditions on project funds are having an impact on this strategy
  - Shifting timelines for
    - TCM0 cavities from AUP
    - Released drawings, deliverables and parts lists from CERN
  - Fixed timeline for spending the funds
- The present strategy has been to procure series components as soon as drawings are released and strategically assign some scope to CERN in order to spend $$ within fixed timeline

Funding constraints

- Due to the nature of the funding agreement ALL funds for the project must be spent and all parts received (to trigger payment) before April 2025

- ✓ Over 5M$ has been committed over the last year - TRIUMF has presently spent or committed 97% of the funds – (now 98%)

- Present risks

  - Over 50% of funds are encumbered including 19% from CERN that need delivery to TRIUMF before April 2025

  - Some drawing packages and procured parts lists are still not released

Spent	Encumbered	CERN scope	Remaining
$4,328,342	**$3,531,564**	**$1,873,701**	**$266,393**
43.3%	35.3%	18.7%	2.7%
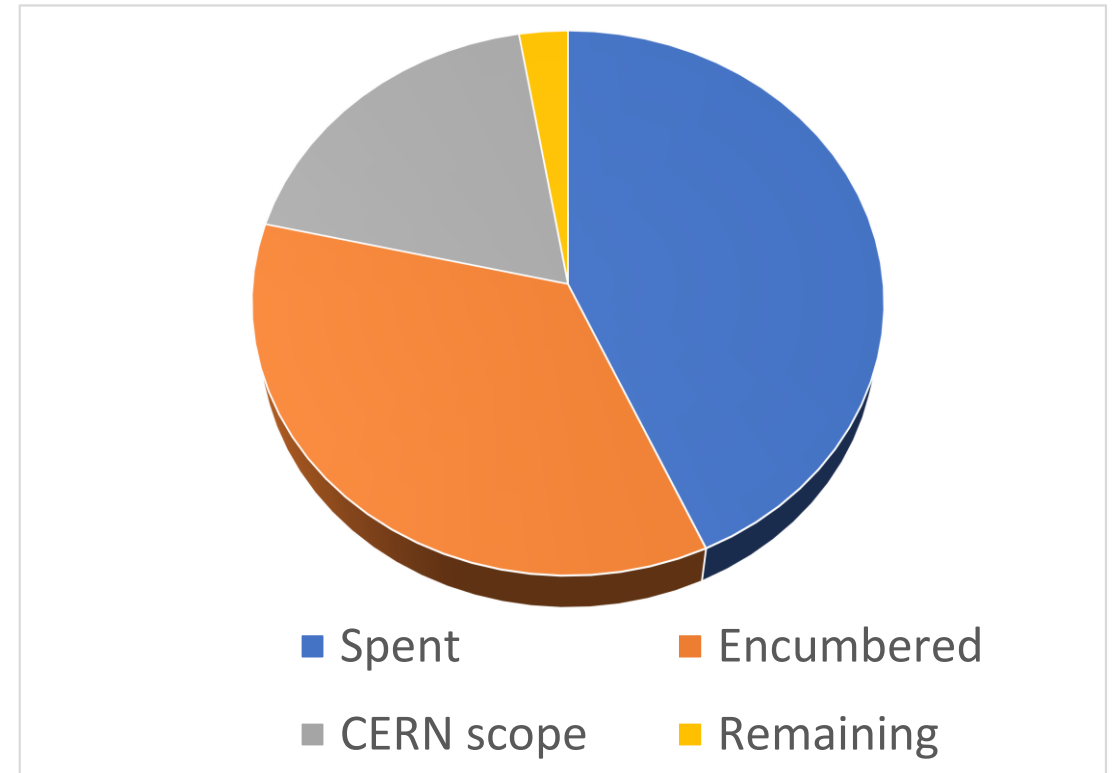
Schedule Discussion

Cryomodule Assembly Boundary Conditions

- CM string assembly requires cavities from AUP, FPCs and beamline assemblies from CERN – first articles are required to assemble TCM0 and TCM1

- The critical path runs through delivery of the prototype cavity (rigid) and CM design (coupled to parts fabrication schedule)

- TRIUMF also requires delivery of CM parts from CERN for both *in scope* articles and *added scope* articles (at least for first units):
  - Rf test adaptors – Jan 2024 - Dec 2024
  - String assembly components – Mar 2024 - Mar 2025 – partial PIMs received
  - CM assembly – April 2024 - May 2025
  - CM test – May 2024 - Oct. 2025

  * indicates requested dates as of Oct. 2023

AUP Delivery Projection		
Cavity Pair	**Module**	**Delivery**
Prototype	TCM0	Feb 2025
Caviies 1 and 2	TCM1	May 2025
Caviies 3 and 4	TCM2	Jun 2025
Caviies 5 and 6	TCM3	Jul 2024
Caviies 7 and 8	TCM4	Aug 2025
Caviies 9 and 10	TCM5	Sep 2025

The `TRIUMF' Schedule Issue

- The `TRIUMF' schedule shown at the plenary is a reflection of a long list of dependencies, delays and lessons learned

  - AUP/ZANON challenges with jacketing - delays TC0

  - JLAB cavity testing shutdown - delays TC0

  - CERN delays in final design, FPC/rf adaptors production and lessons learned from CM testing – impacts `bravery factor' for TCM0 and CM production times

  - UK lessons learned in the RFD prototype build timing – experience argues against being too aggressive with schedule

- TRIUMF is the last in the queue but the slippages in the schedule to date are a WP4 issue and need understanding in that context

- What follows is an attempt to rationalize and understand TRIUMF's estimate of what is possible and critical path
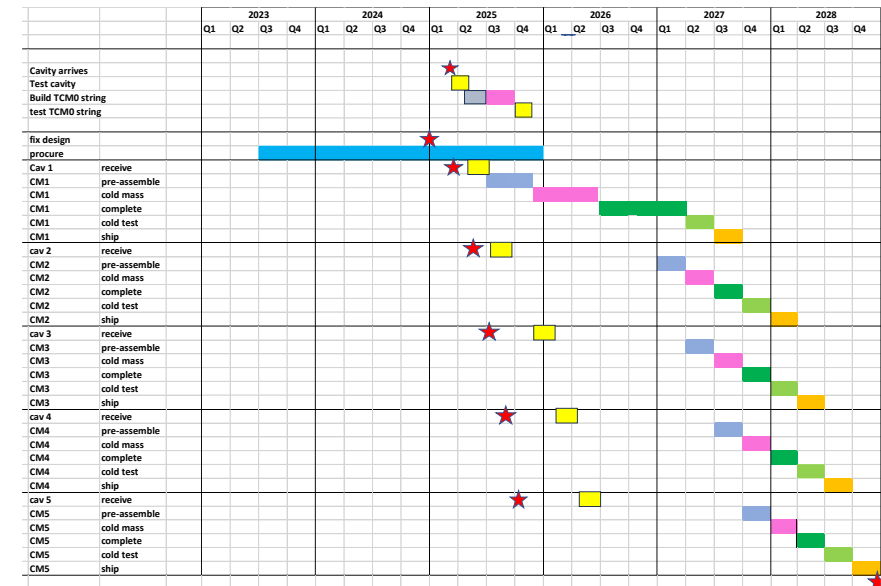
Schedule Methodology

In preparing the estimate of the schedule update considering the TRIUMF 2026 SD we first estimated the present timeline without it

- Finding: Project end date (without SD) anticipated as May 2028

TCM0 strategy and string assembly qualification logic

- The prototype cavity TC0 will be requalified after arrival from Jlab
    - The test coupler will be removed and the FPC installed
- The dummy cavity will be prepared for string installation
- The string will be assembled and leak checked and then vented and disassembled
- TC0 will be retested via cooldown to 2K
- The successful test of TC0 after string assembly is a critical milestone for the project and is required before string assembly of TCM1
- The arrival of TC0 at TRIUMF is on the critical path for all deliverables to CERN – the arrival has been steadily being pushed out over the last year

Timeline **without** SD2026 **(First cavity)**

Timeline **without** SD2026 **(Cryomodule design)**
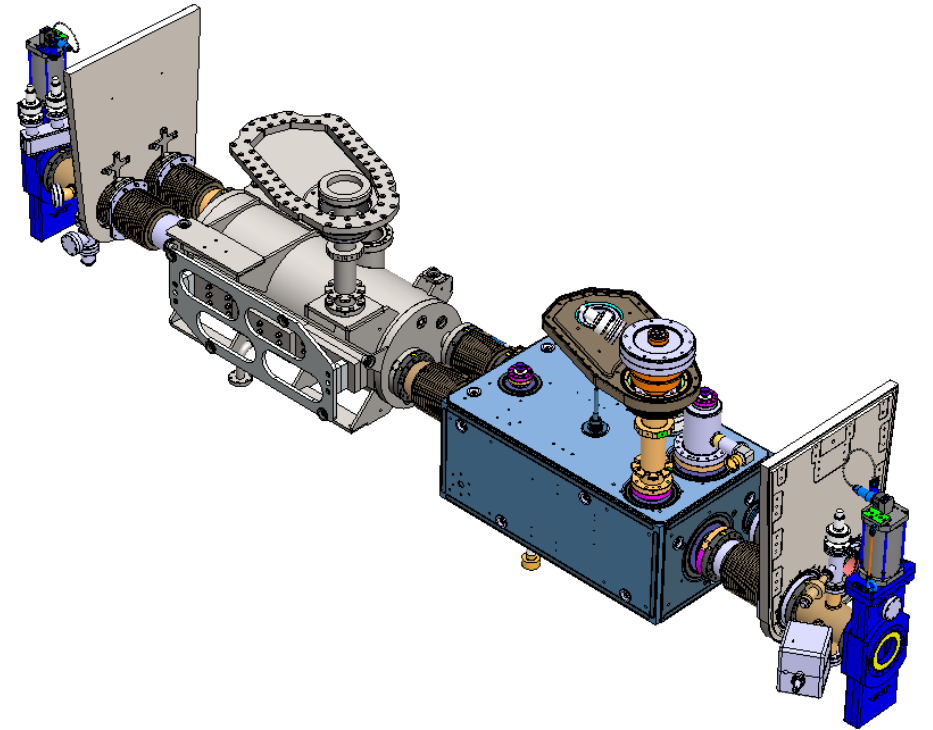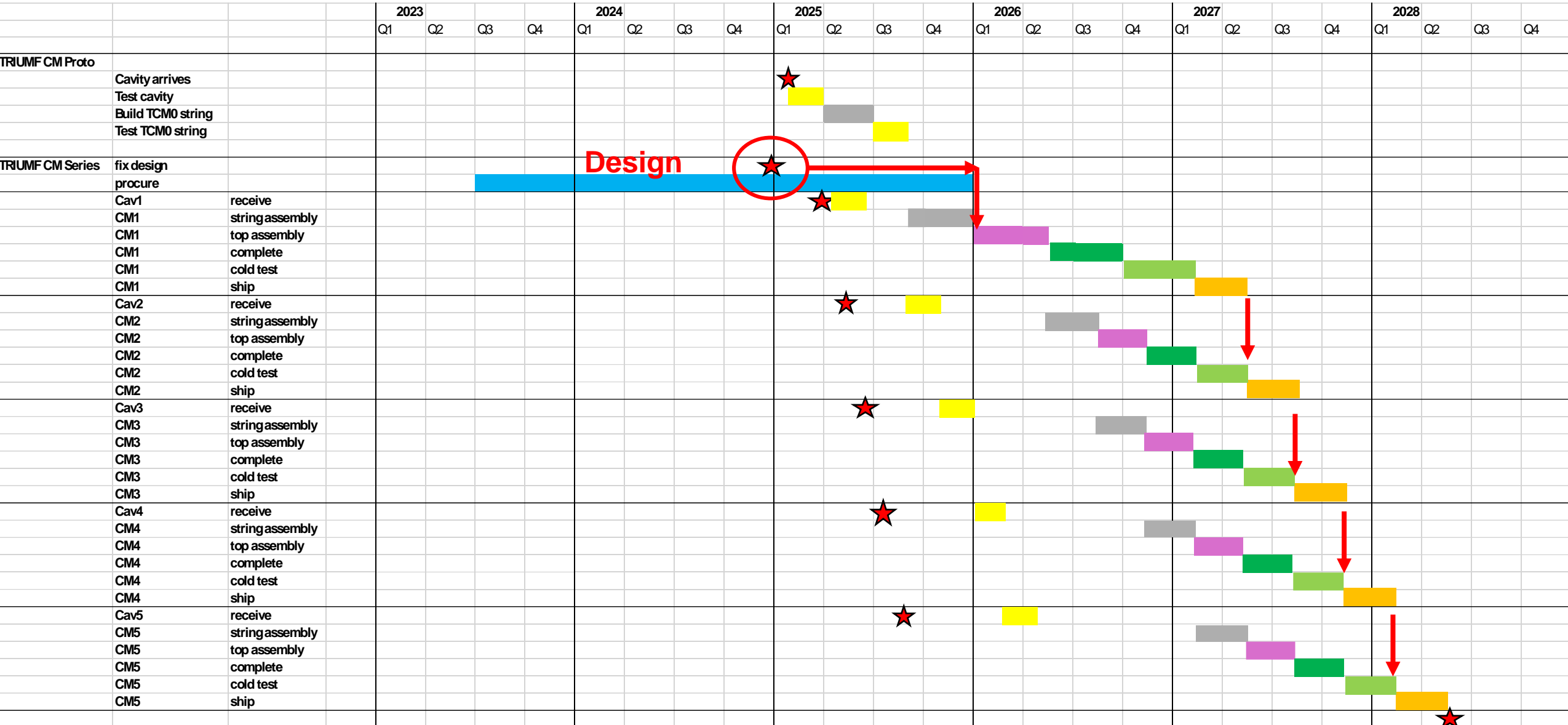
Timeline **without** SD2026 **(Cold tests)**
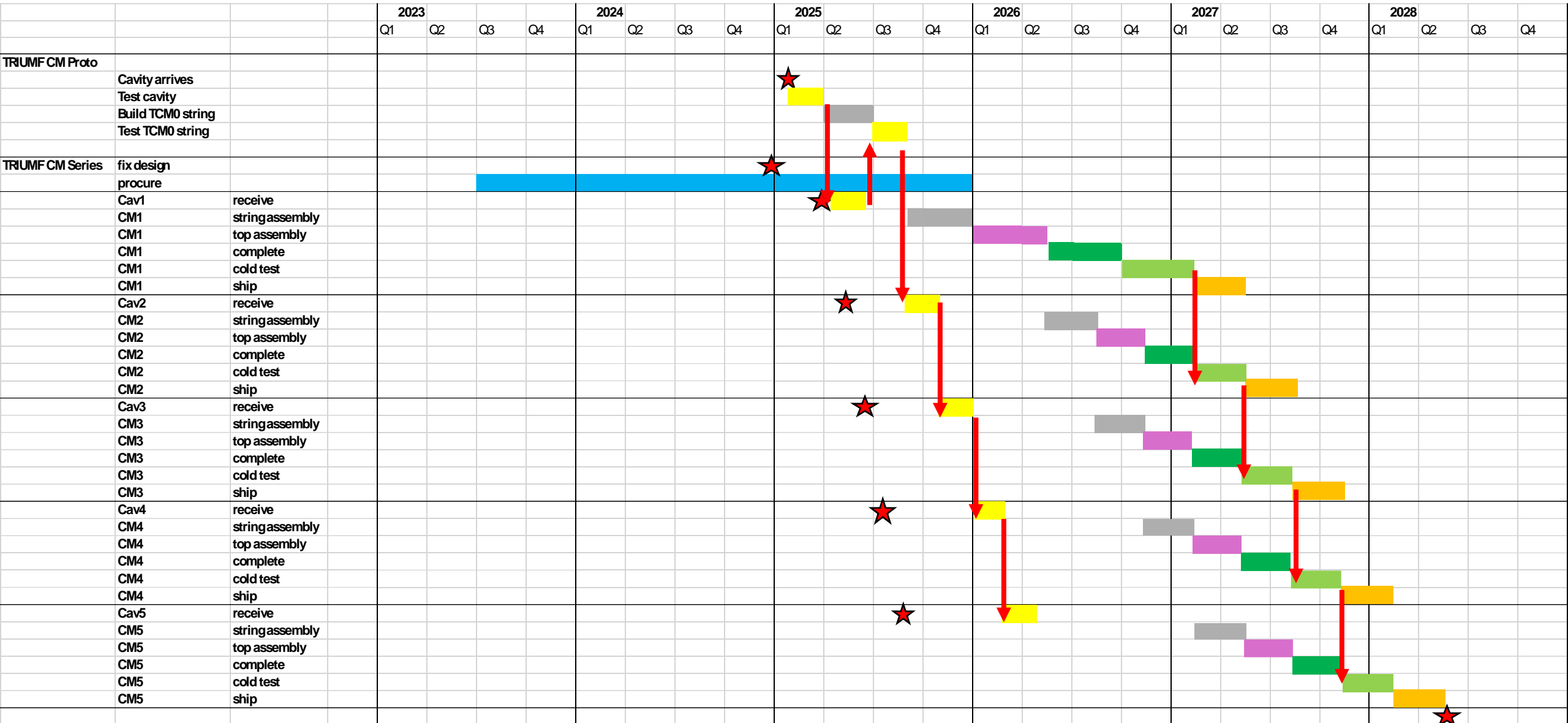
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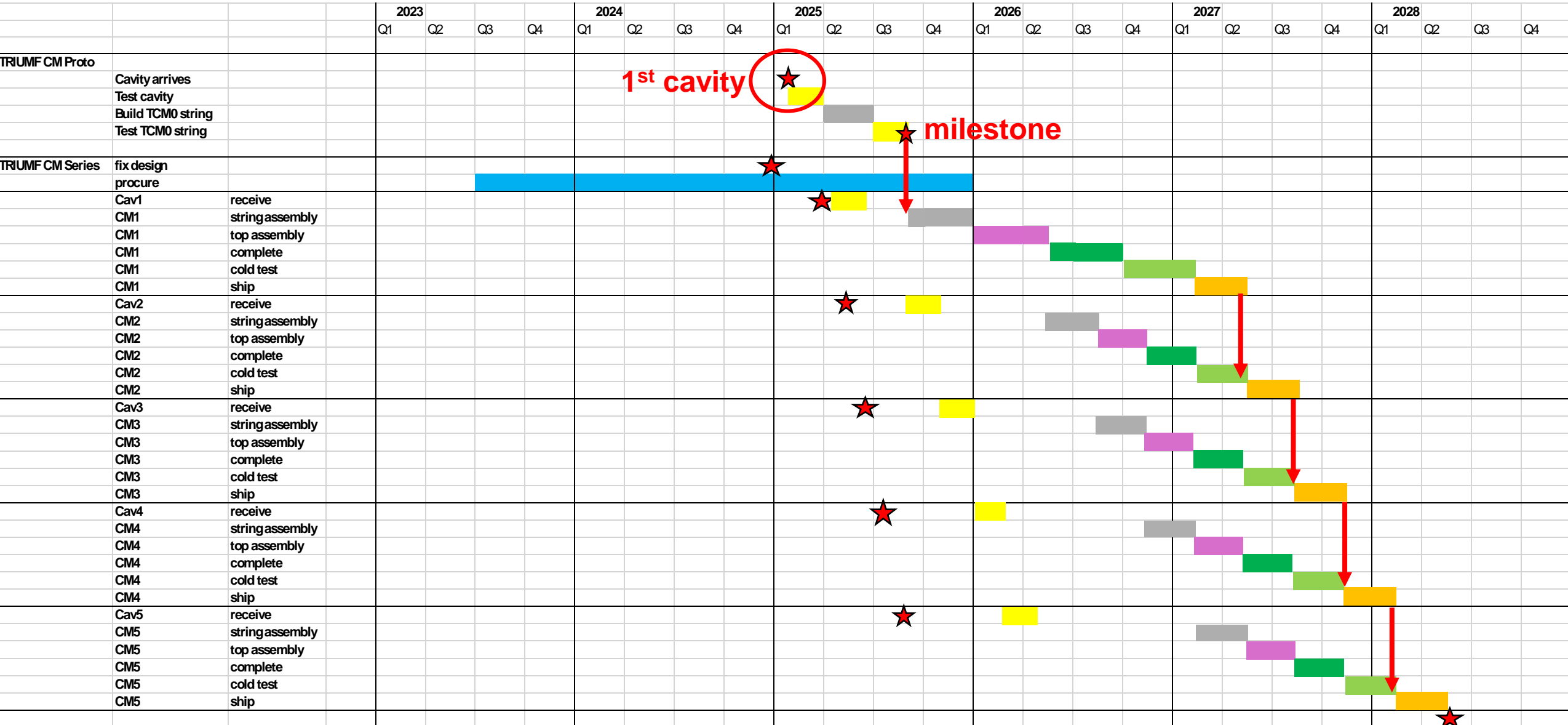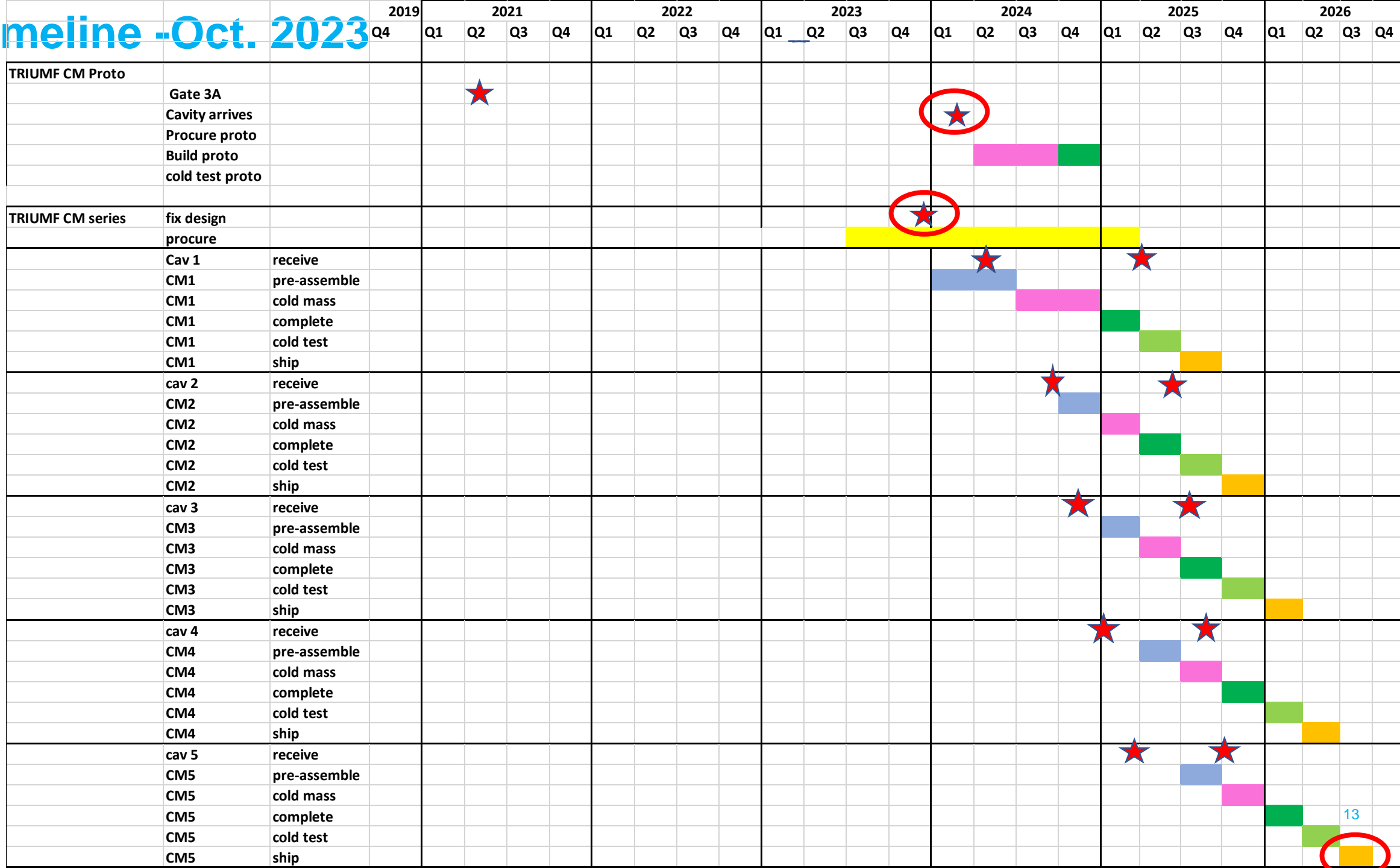- Finding: Project end date (without SD) anticipated as May 2028
- Fact: Estimated end date at Oct. 2023 meeting was Oct. 2026 (19 months earlier)

Timeline -Oct. 2023

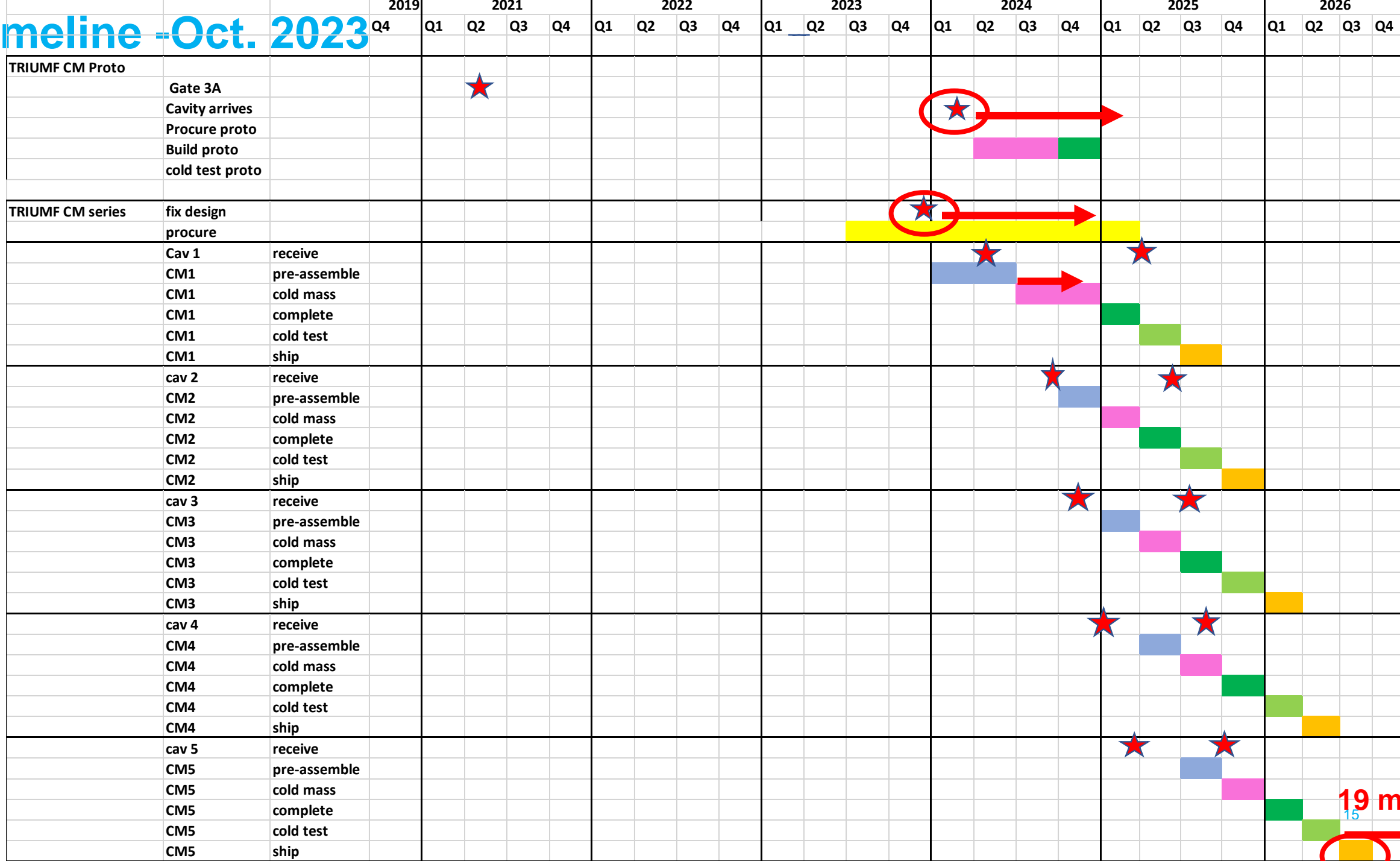|		2019	2021				2022				2023				2024				2025				2026			
		Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
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Rationalization of dates

- In Oct. 2023 collaboration meeting the end date was indicated as Oct. 2026
  - so why now is it May 2028 (+19 months)?
- Consider
  - First cavity delayed by 11 months
  - Cryomodule design delayed by 12 months
  - TCM0 logic was not appropriately considered – recommend to add a characterization milestone – add +4 months
  - First build (TCM1) too aggressive based on UK experience – add +4 months

	Oct. 2023	**Oct. 2024**	**Oct. 2024 ****	**Oct. 2024 ******
TC0 arrival	March 2024	Feb. 2025 (+11)		
CM design frozen	Dec. 2023	Dec. 2024 (+12)		
Project complete	Oct. 2026	Sept. 2027 (+11)	Jan 2028 (+4)	May 2028 (+4)

** consider to add a TCM0 qualification milestone
**** consider to increase time of TCM1 (first full build – based on UK experience)

Timeline -Oct. 2023

			2019 Q4	2021 Q1	Q2	Q3	Q4	2022 Q1	Q2	Q3	Q4	2023 Q1	Q2	Q3	Q4	2024 Q1	Q2	Q3	Q4	2025 Q1	Q2	Q3	Q4	2026 Q1	Q2	Q3	Q4
TRIUMF CM Proto																											
	Gate 3A				★																						
	Cavity arrives													★	→												
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19 months

15

And ….. Impact of TRIUMF SD2026

- TRIUMF management has decided (just) to implement a long shutdown in 2026 to focus effort on the completion of the ARIEL project
- Technicians on HiLumi will be assigned tasks with ARIEL during 2026 that will slow effort on CM assembly
- Qualification of arriving AUP cavities will not be impacted – cavity testing facilities will be supported
- The actual impact on HiLumi will only be known once the ARIEL tasks are fully assigned – the goal will be to add sufficient effort to determine that all parts are in hand for the series starting in 2027
- We estimate that this will push out project completion by ~6 months

Timeline **without** SD2026

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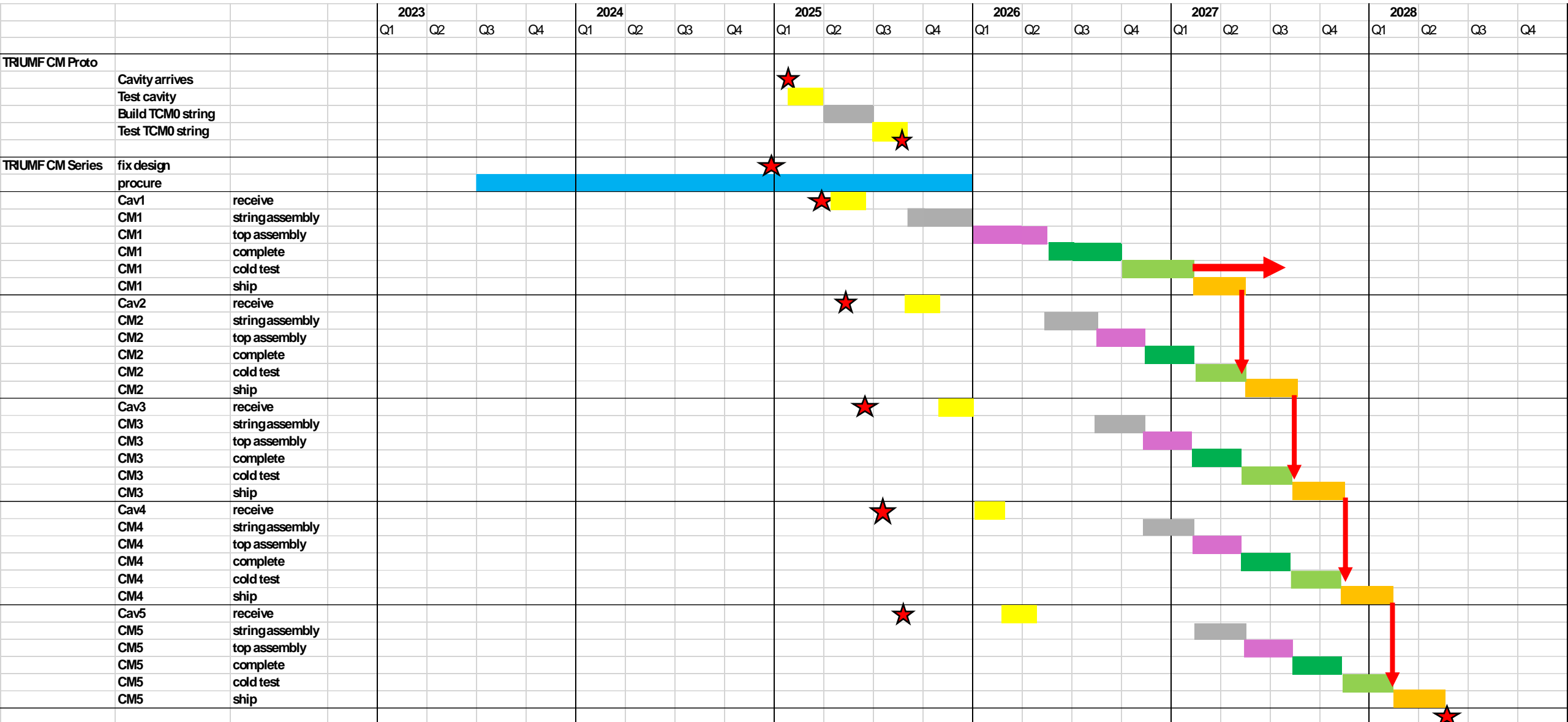
Timeline with SD2026
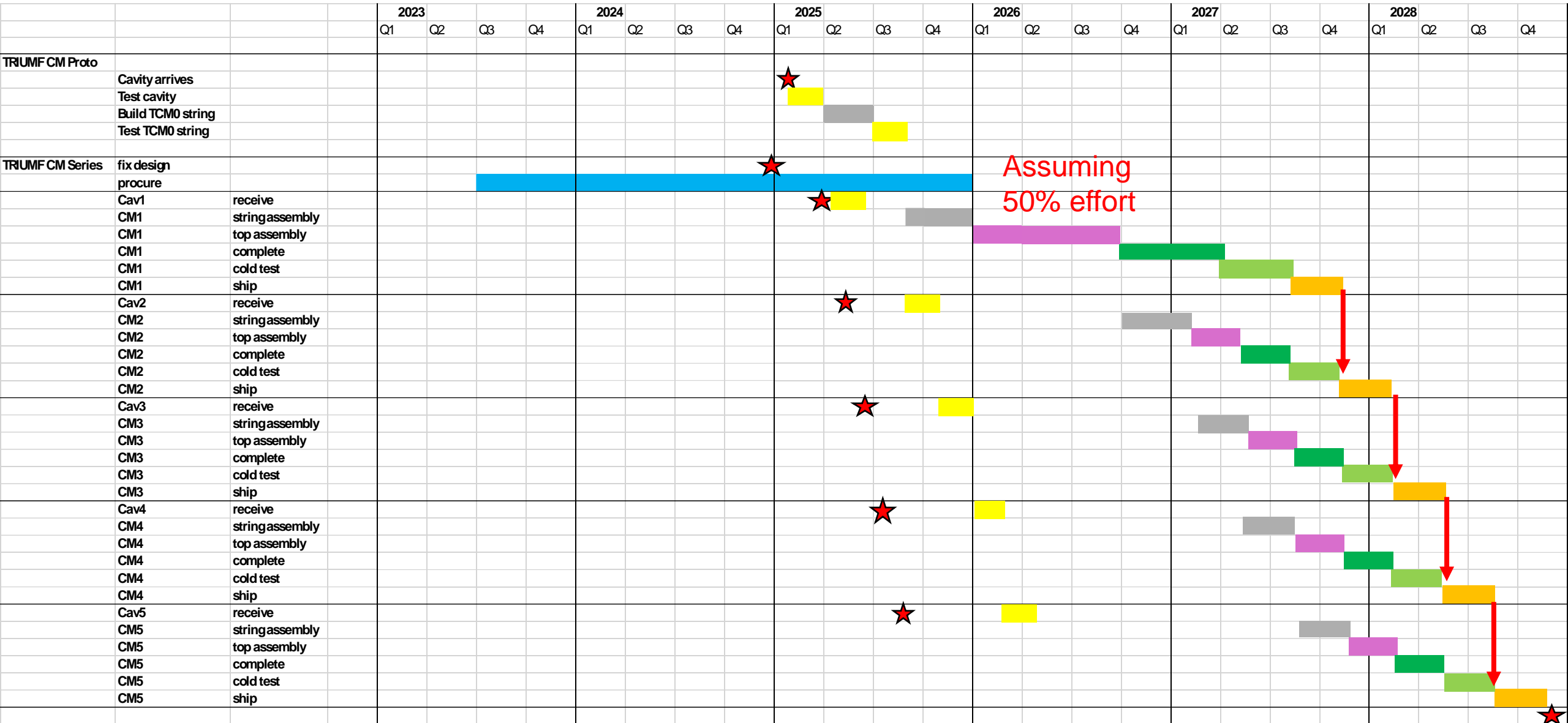
What can be done?

- Understand the dependencies
- Stop the bleeding
  - Deliver TC0 in Feb 2025 in order to make real progress before 2026
    - Goal is to qualify string assembly and parts inventory before end of long shutdown
  - Try to freeze the design as of Dec. 2024 – procurement impacts schedule
  - Deliver all parts on time
- Add risk – for discussion but not recommended
  - Decouple TCM0 build from TCM1 (saves ~2 months)
  - Assume a (more) success-based schedule (saves ~4 months)
    - There is experienced gained that would indicate that the schedule is already somewhat success based – with little contingency – ie no expectation in schedule that CM fails test or cavity fails requalification
  - Send last (spare) module without cold test (saves 3 months)

Other discussion points

Preparation for cavity testing

- TRIUMF will requalify the AUP cavities upon delivery from JLab

- TRIUMF worked with AUP to draft cavity requalification test criteria

- **Important that this gets signed off soon**
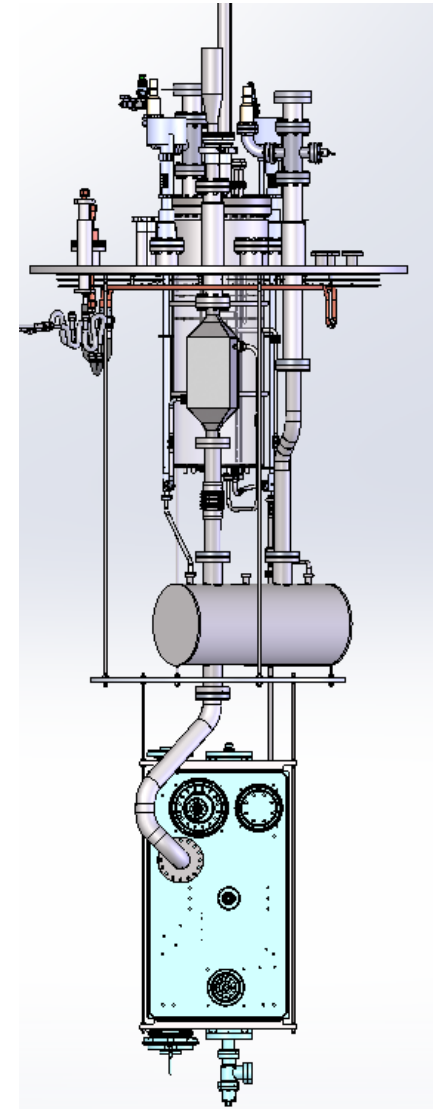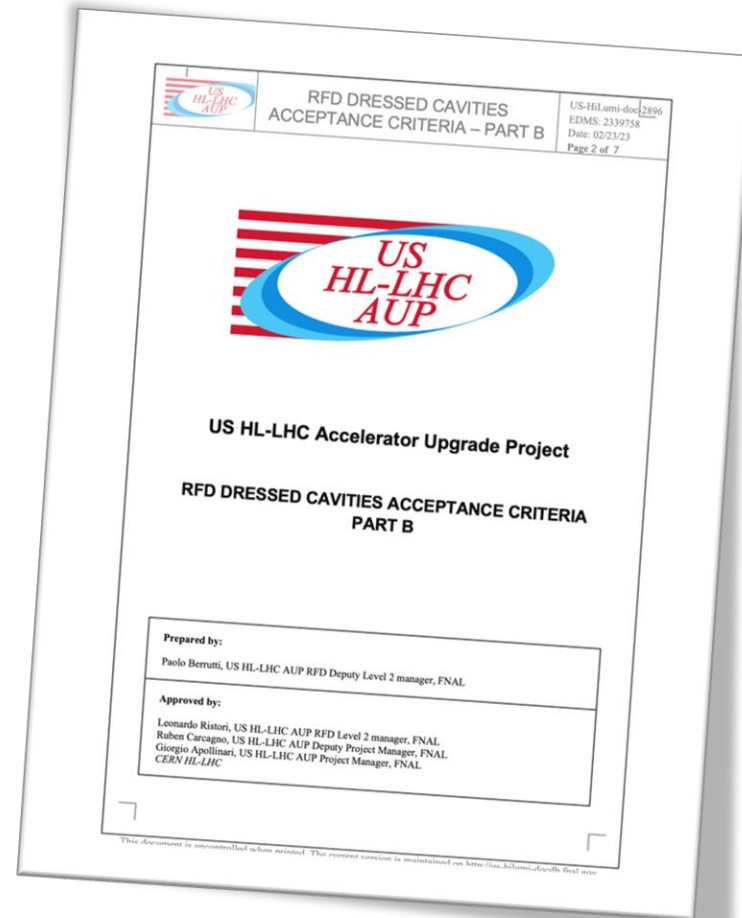
Procurement cooperation

Description	Date
4x-HOM adapters and 2x field antenna	TBD
5x Bi-phase and lower cryo-lines for RFD	(1x) Mid-Summer 2024 Remainder Q1 2025
Full set of vacuum equipment for beam Lines and ancillaries	(1x) Q3 2024 Remainder Q1 2025
FSI interferometer unit (sweeping lasers + electronics)	TBD
Full set of Tuner bellows and cavity support (blades) bellows	TBD
Additional AdHoc Equipment for TCM0 and series Cryomodules	TBD

CERN/TRIUMF agreement on parts exchange

- excellent cooperation to help deal with NA material issues and

Bi-phase lines

- Production well advanced at CERN with first article for TCM1 delivered – excellent cooperation

SS316 material

- CERN sends TRIUMF material to overcome lack of certified material in NA

Hardware/Instrumentation

- TRIUMF needs updated list of procured parts ASAP including fastener summary BOM

Invoicing

- WP4 may need to coax the first invoices from CERN-> TRIUMF to get money flowing

First PIMs received from CERN

- Components for first string assembly
- Tested in clean room for particulate
- Results seem acceptable – good to compare with UK experience
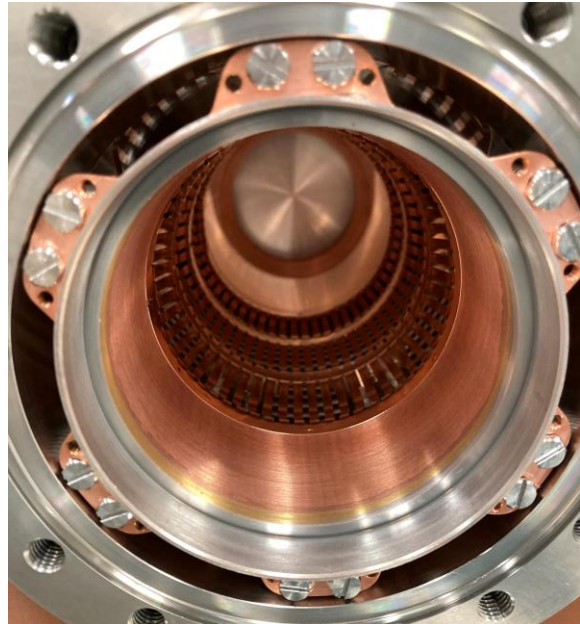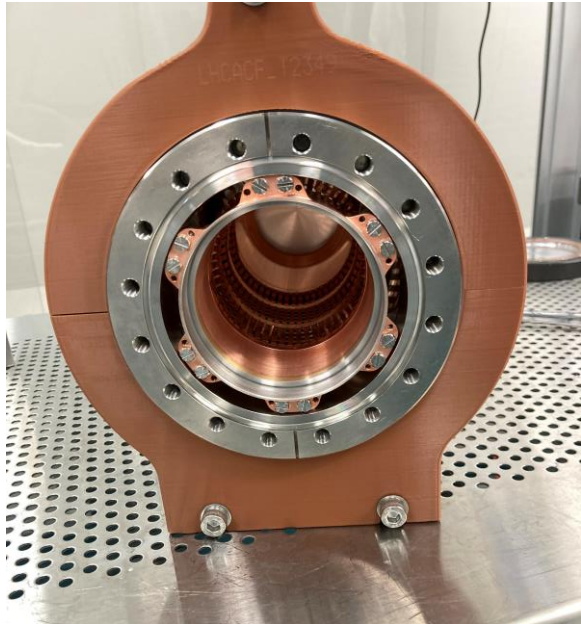
RESULTS

SMALL BELLOW

- Flanges had a particle count of 57 for 0.3 micron.

- The assembly had a particle count of 1257 for 0.3 micron in the beginning.

- The particle count decreased to <250 with continuous cleaning by filtered Nitrogen.

LARGE BELLOW

- Flanges had a particle count of 39 for 0.3 micron.

- The assembly had a particle count of 2282 for 0.3 micron in the beginning.

- The particle count decreased to <100 with continuous cleaning by filtered Nitrogen.

Summary

- First cavity delivery and cryomodule design are both on the critical path for RFD completion
    - Interdependencies of delivery times and RFD project end need to be added to schedule
    - TRIUMF SD2026 estimated to have an impact of ~ 6 months
- 2024 strategy addresses finite time window for spending available funds
    - Requires timely delivery from vendors (and CERN) of agreed deliverables in order to make payments
    - ~1.6MCHF in CERN scope
    - ✓ First out of scope fabricated parts received from CERN