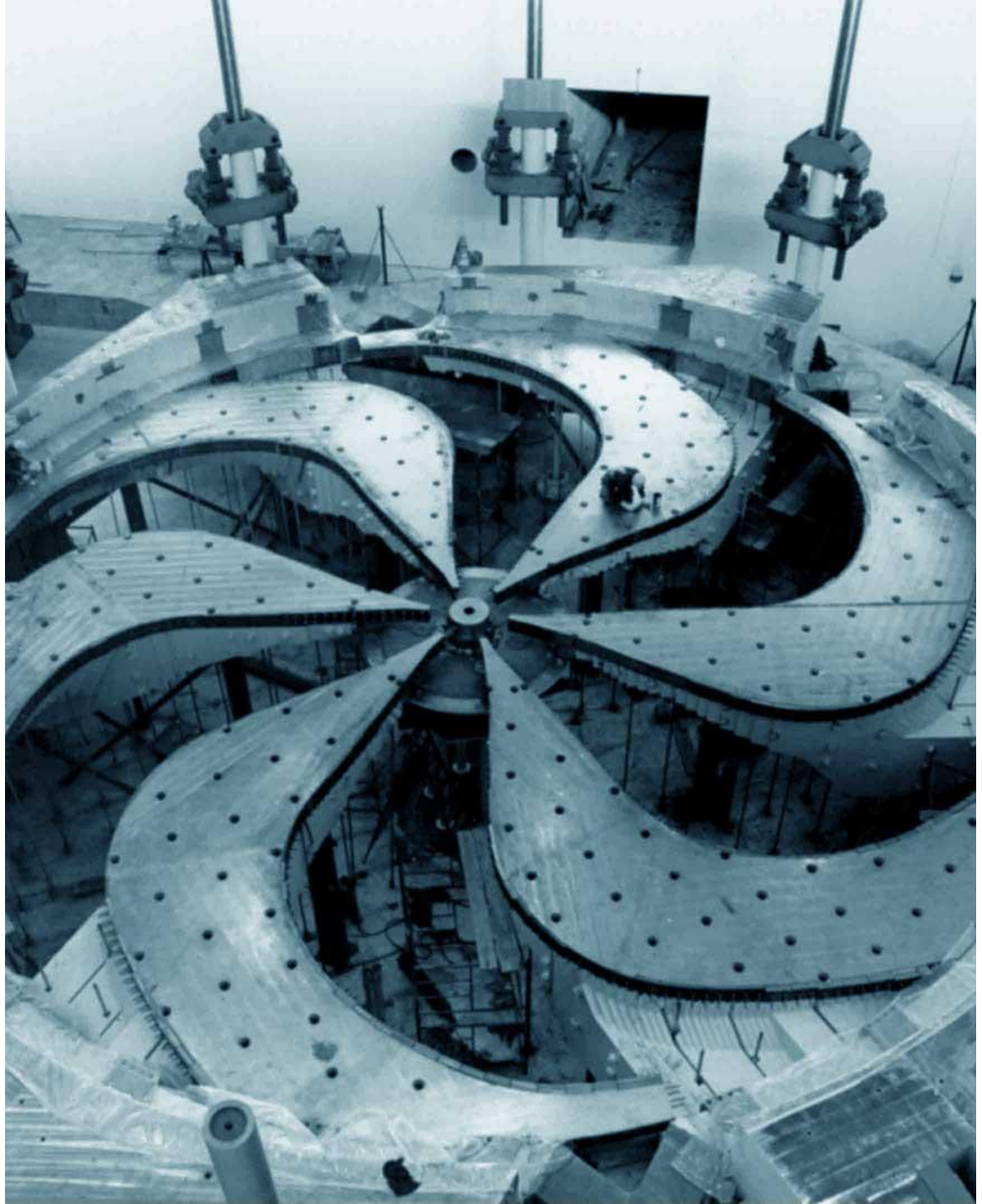
TRIUMF

Commissioning of ISAC-II Style Separated Vacuum QWR Cryomodule

Zhongyuan Yao

WG-2, TTC meeting, Aomori-city
Oct. 11 – 14, 2022



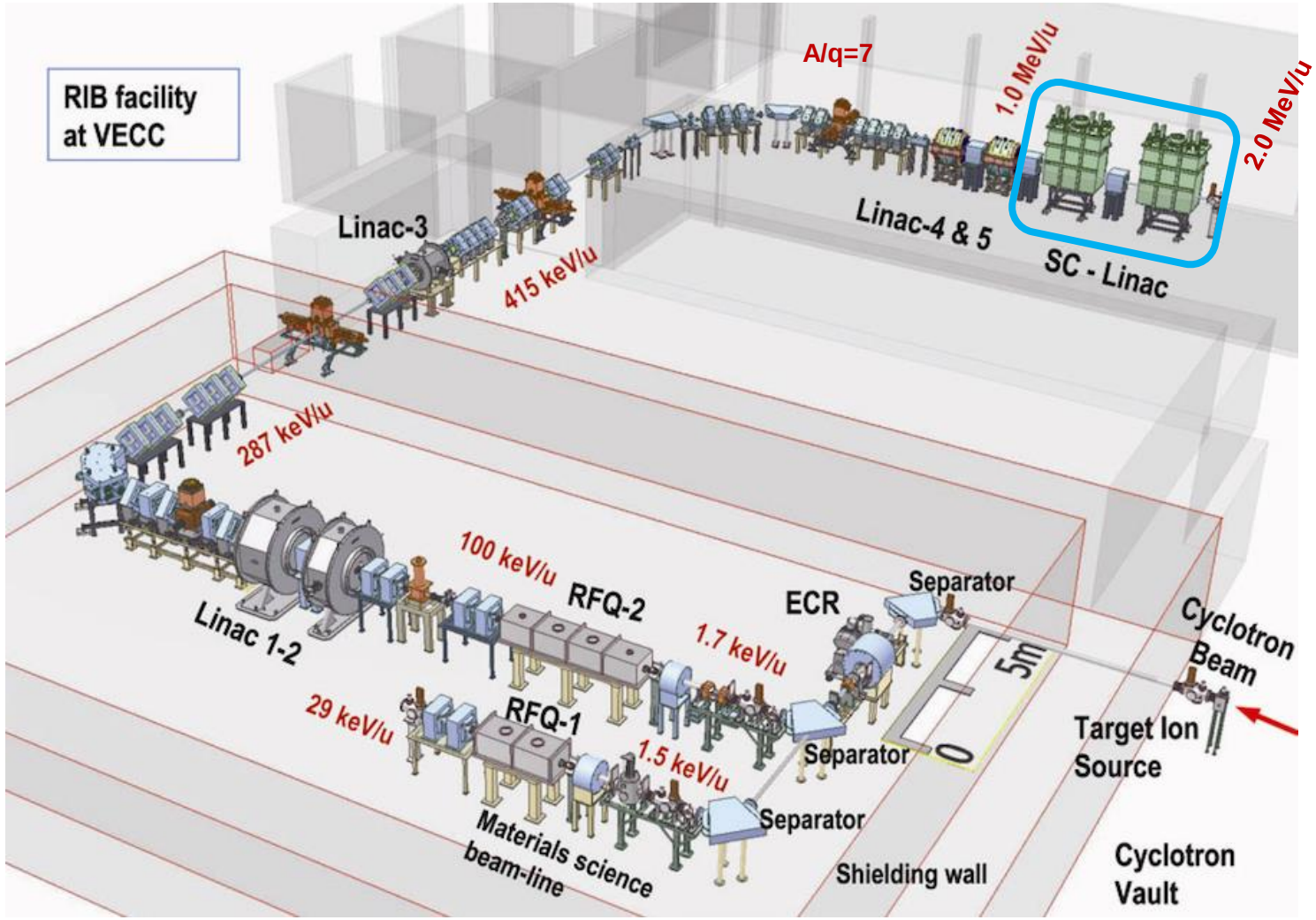
QST

TESLA TECHNOLOGY
TTC
COLLABORATION

Discovery, accelerated

RIB Facility @ VECC, Kolkata

- 2 QWR cryomodules boost RIB energy from 1MeV/u to 2MeV/u with A/q≤7
- TRIUMF SRF team developed, produced and commissioned the prototype CM



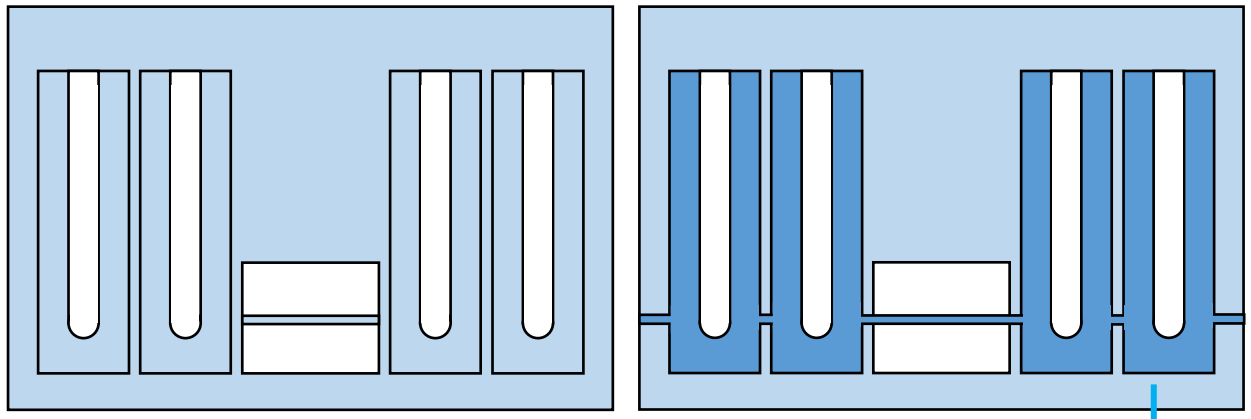
ISAC-II Style QWR Cryomodule

- Top loading CM
- Operate @ 4K
- 4 QWRs – V_{acc} 1MV each
  - 113.61MHz, optimized β 5.5%
  - 120μm BCP, HPR, 120ºC bake
- 7T superconducting solenoid
- Variable inductive RF coupler
- Lever tuner with warm servo motor
- Steering effect corrected with offset
- Warm μ-metal shield
- 80K thermal shield

Separated Vacuum Design

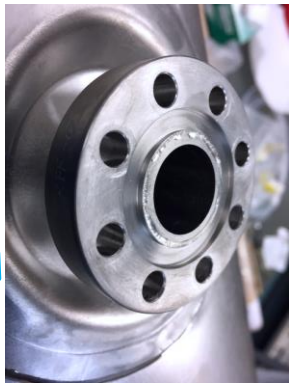
ISAC-II style CM

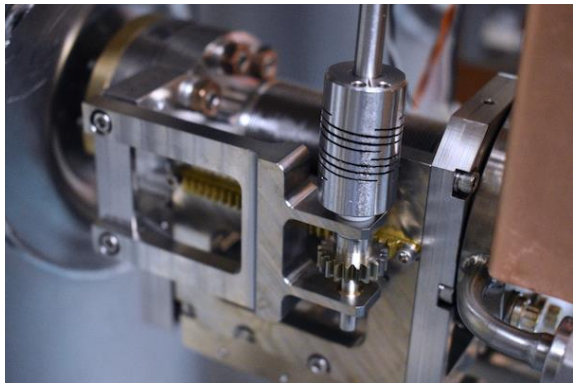
Separated vacuum CM

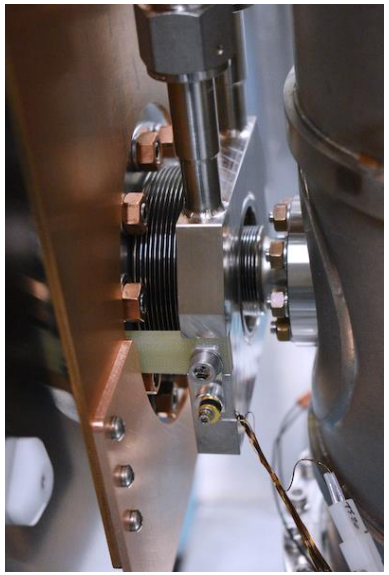


- Better cavity cleanness => better cavity performance
- Less material/environment REQs for isolation space
- Allows on-line cryomodule service

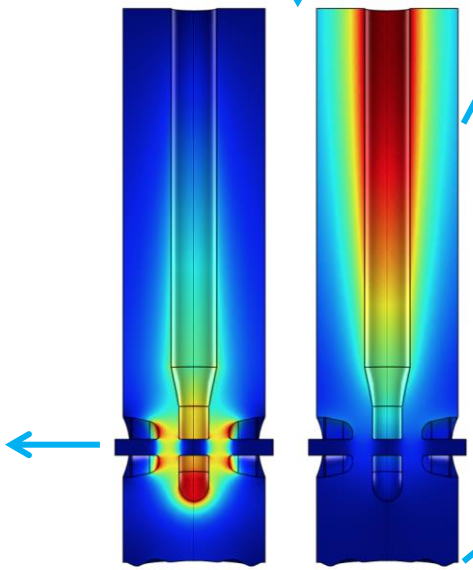
RF port & variable inductive coupler

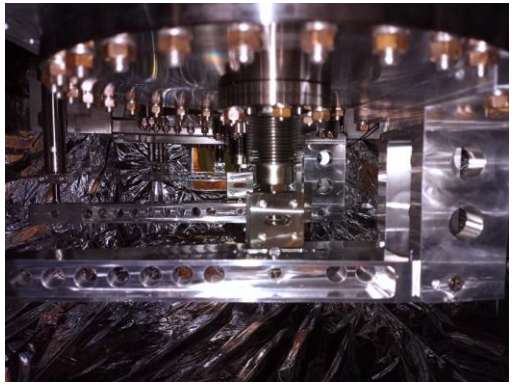






‘Diamond’ seal





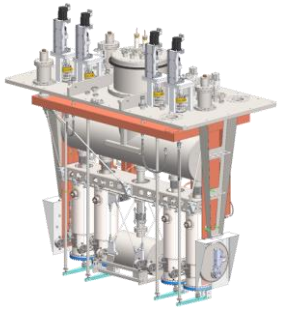
Beam port & warm/cold transition

Cavity RF design

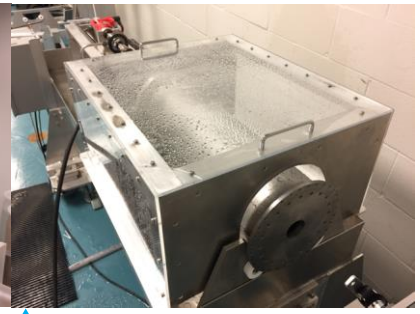
Frequency tuner & bottom assembly

Milestones

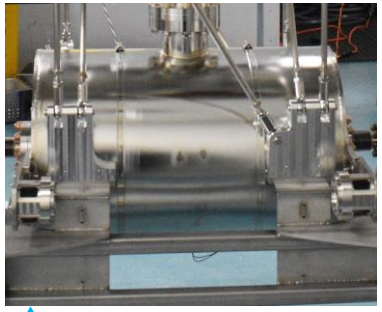
Design



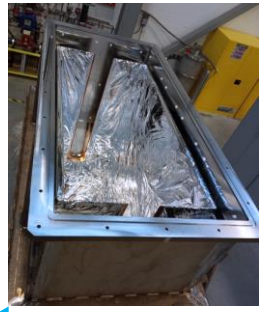
Cavity treatments



Solenoid



Tank assembly

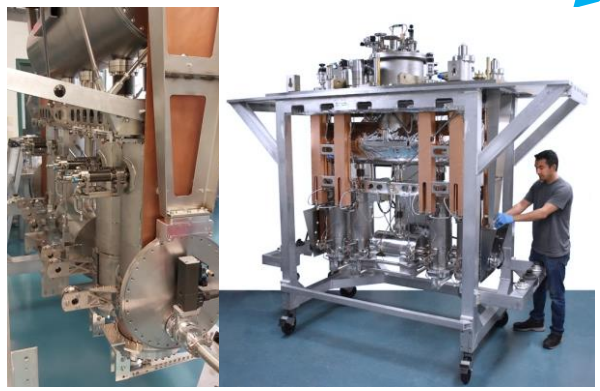


CM assembly

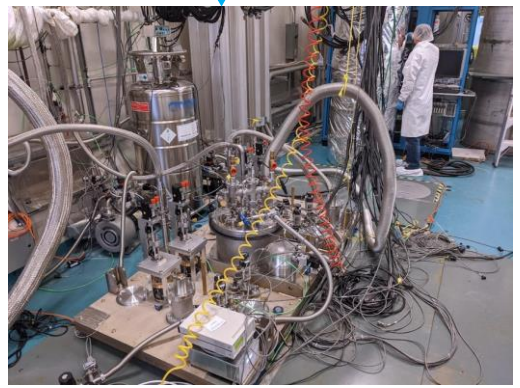
2018 | 2019 | 2020 | 2021 | 2022

Cavity fabrication

Cryostat test



Clean & dirty assembling

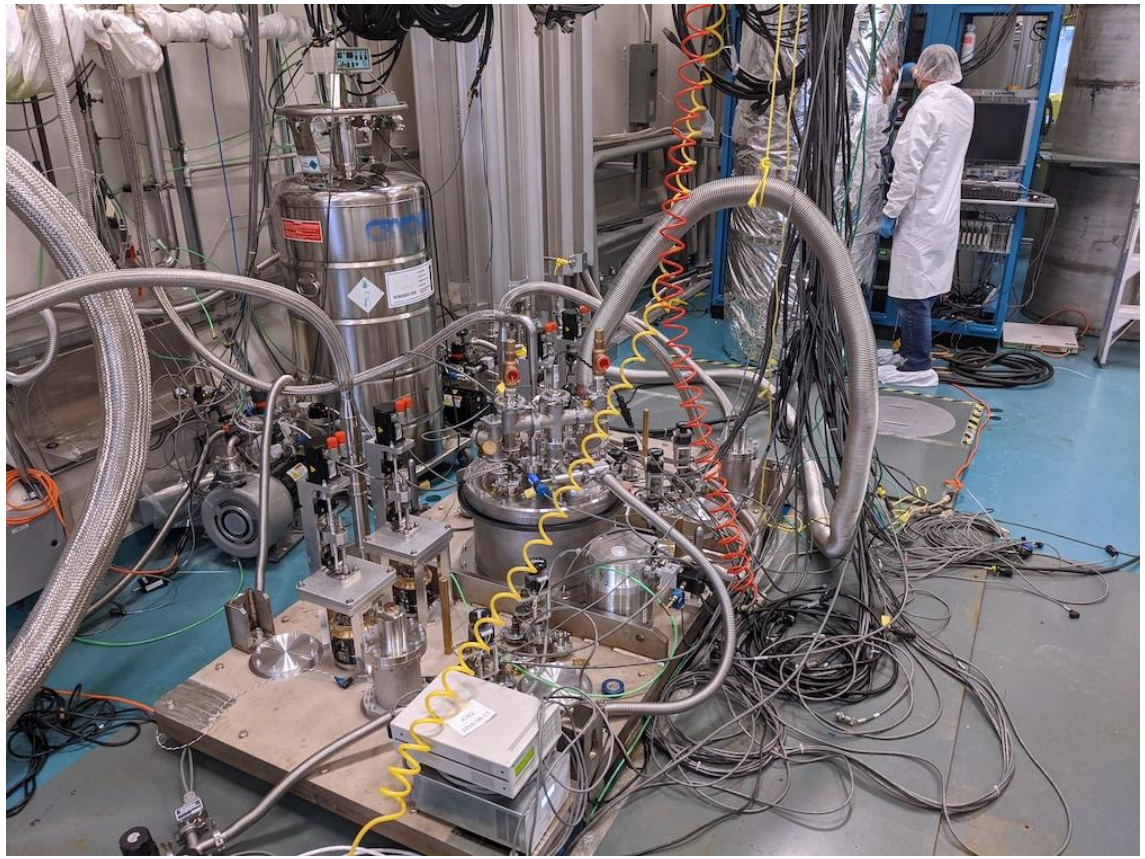


Commissioning

Discovery, accelerated

Scope of Commissioning

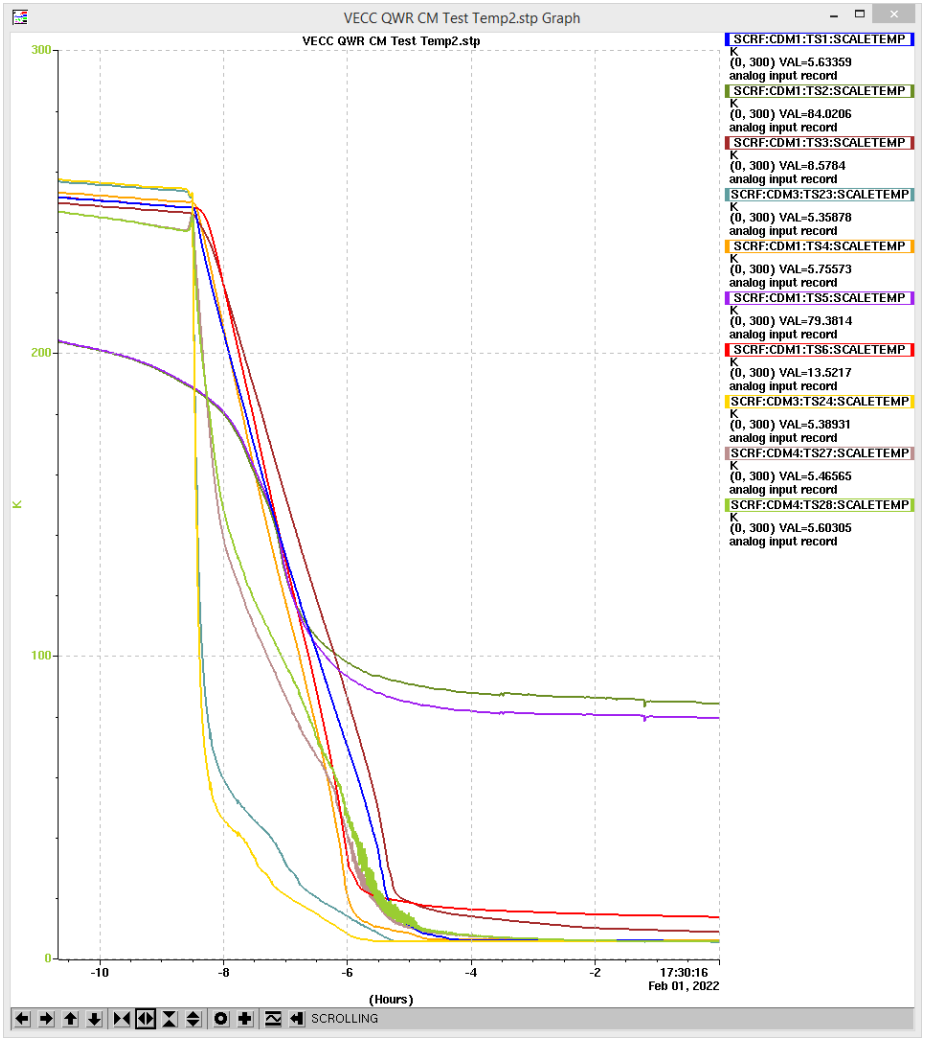
- Vacuum✓, Diagnostics✓, Alignment✓
- Cryogenic
  - LN2 and LHe cooldown✓
  - Static and dynamic heat loads✓
- RF
  - Cavity frequency and tuning range✓
  - Cavity performance✓
  - Performance degradation/recovery✓
  - Operating regime✓
- Solenoid✓
- Beam commissioning not included



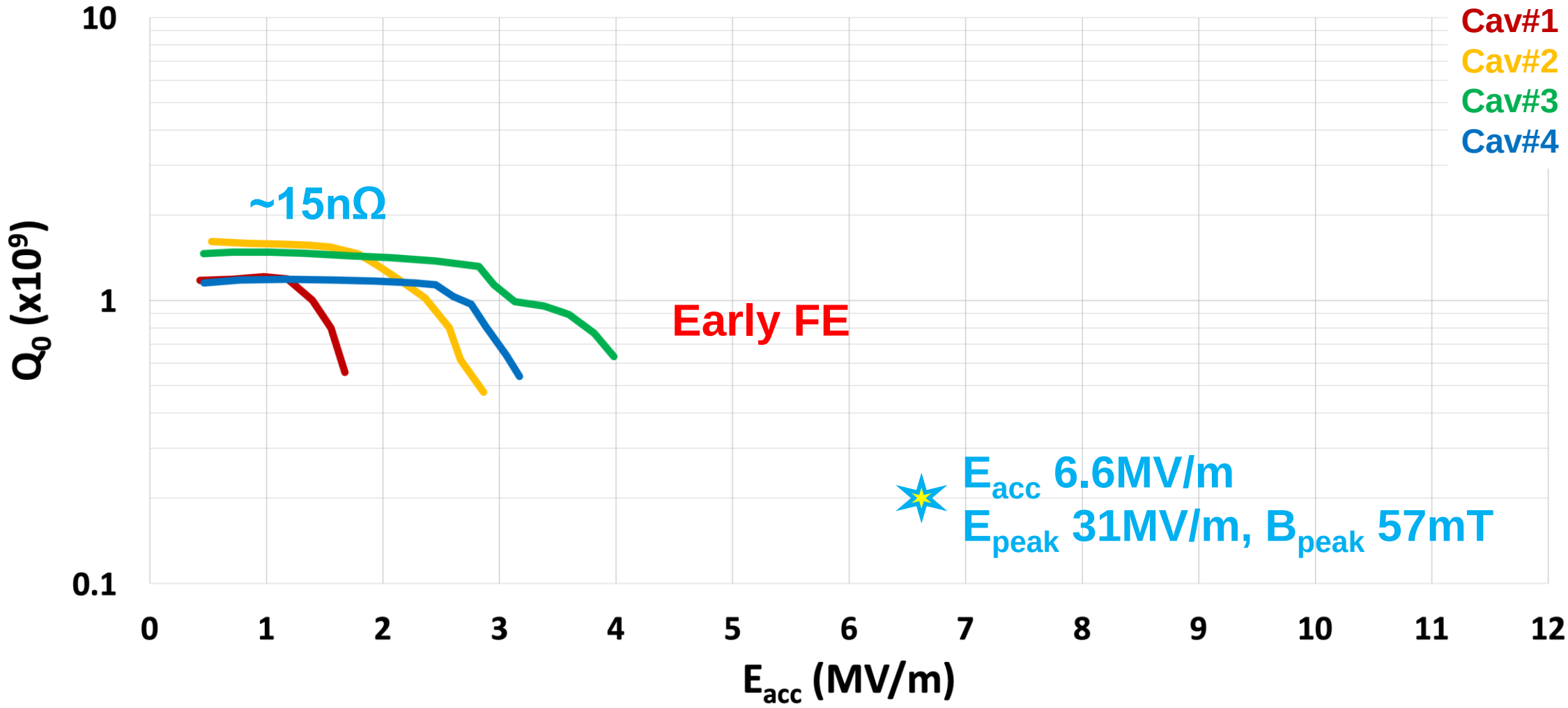
ISAC-II Test Bunker

Cooldown

- 80K shield cooling 24 hours prior to LHe
- Cavity >250K prior to LHe
- LHe cooldown
  - Cavity in 200-50K range 20-70 minutes
  - Cavity cooled to 4K ~3.5 hours
  - Cold mass in liquid ~7 hours



Initial Performance

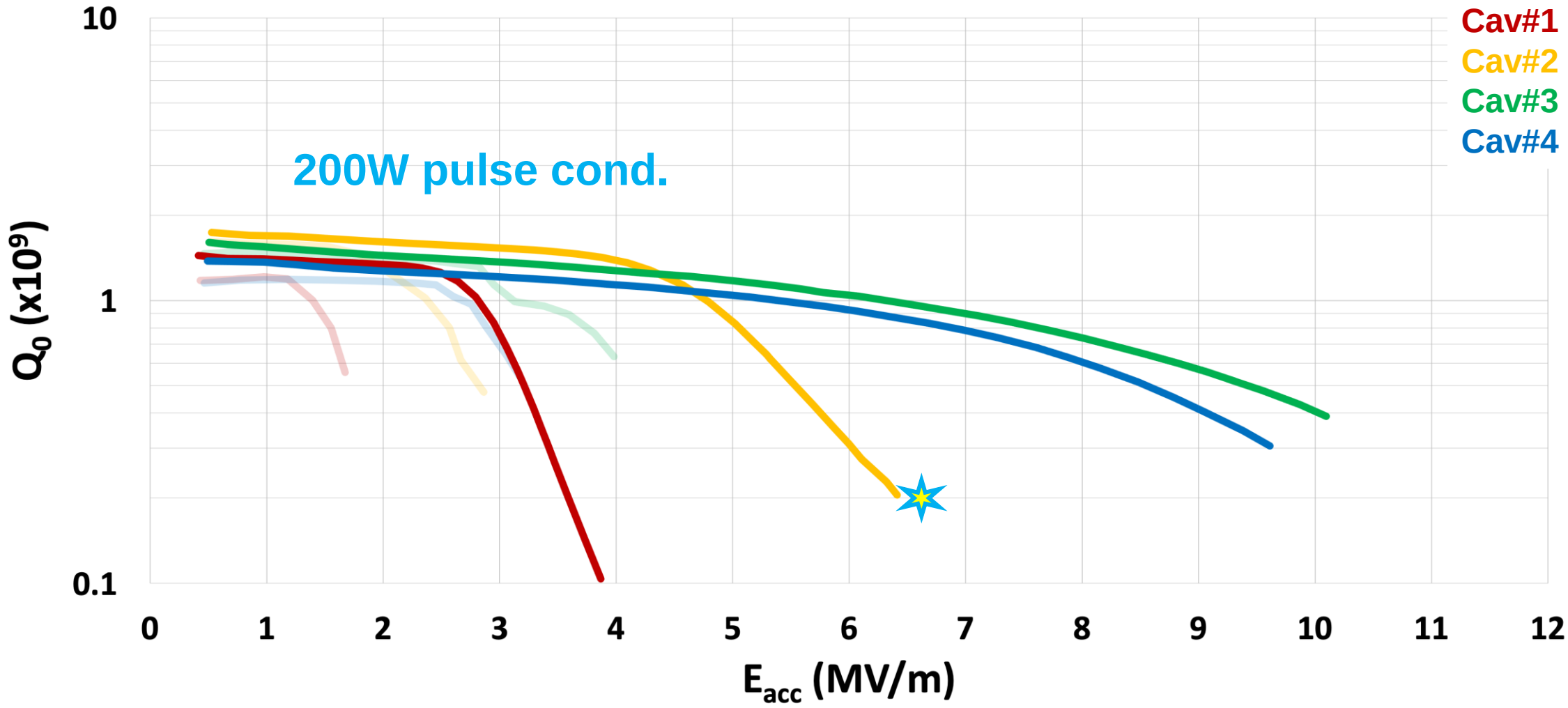


Discovery, accelerated

‘Big’ Leak @ Gate Valve

- Pump from upstream gate valve (Cav#1)
- Found leak at the downstream gate valve (Cav#4)
  - Misaligned aluminum ‘Diamond’ gasket
    - w/ support ring for metal KF seal
  - Required pump and vent a few times to find the leak spot
  - Fixed by replacing gasket

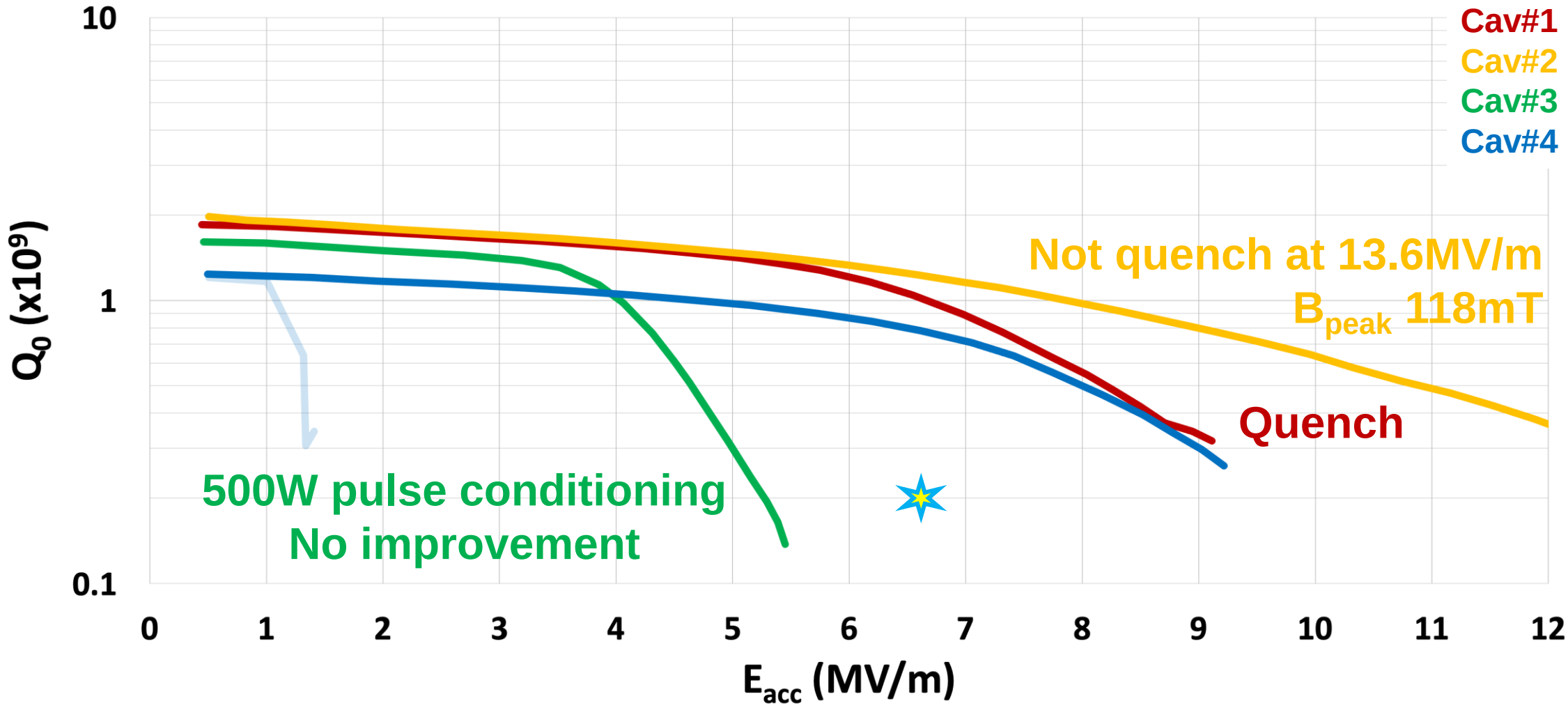
High Power Pulse Conditioning



Cavity Recovery

- Helium conditioning planned, but could not proceed
  - CM needs warmup due to power outage at Xmas
- HPR Cav#1 and Cav#2
  - Vent cavity string in cleanroom
  - Remove Cav#1 and Cav#2 for HPR
  - Reassemble after HPR

HPR Cav#1 & Cav#2



Discovery, accelerated

Clean Venting

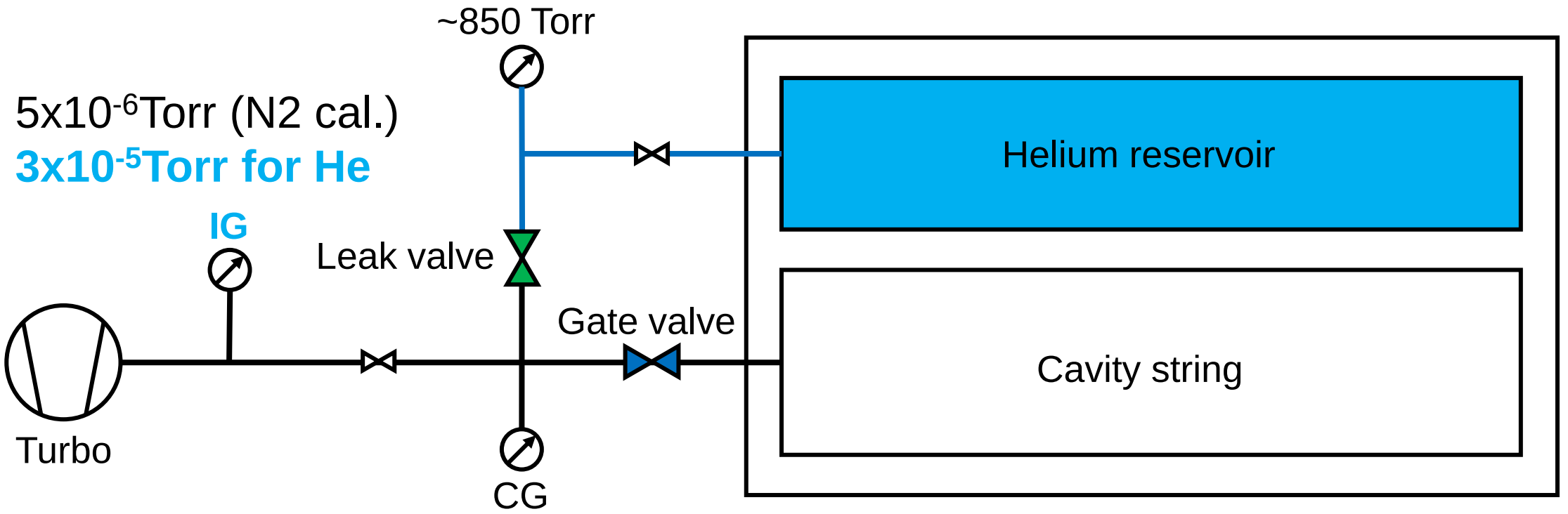
- Vent cavity string with TRIUMF procedure
  - Controlled by pressure rate on clean side
  - Specified <1Torr/s
  - Manual adjusted needle valve
  - Backfill with filtered (0.01μm) bottled N_2 gas (NI4.8)
  - Vent from vacuum to atmosphere pressure took **~1hour**
- Compare to ISAC-II CM
  - Vent in **2~3hours** online for maintenance
  - Volume comparison
    - SCB CM **3400L** vs VECC cavity string **70L**
  - Not observed pollution

Venting procedure and controller need update

Benefit of single vacuum CM

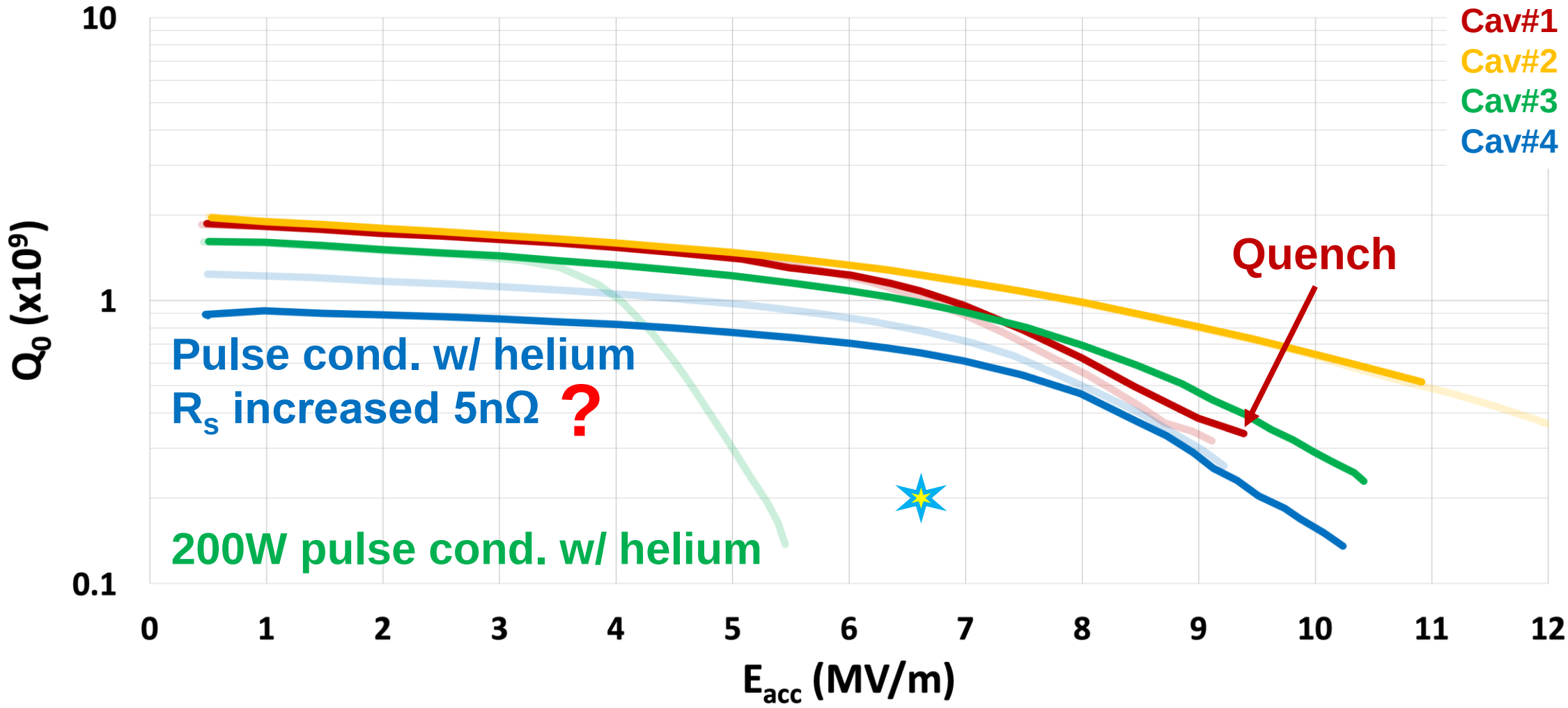
Discovery, accelerated

Helium Conditioning



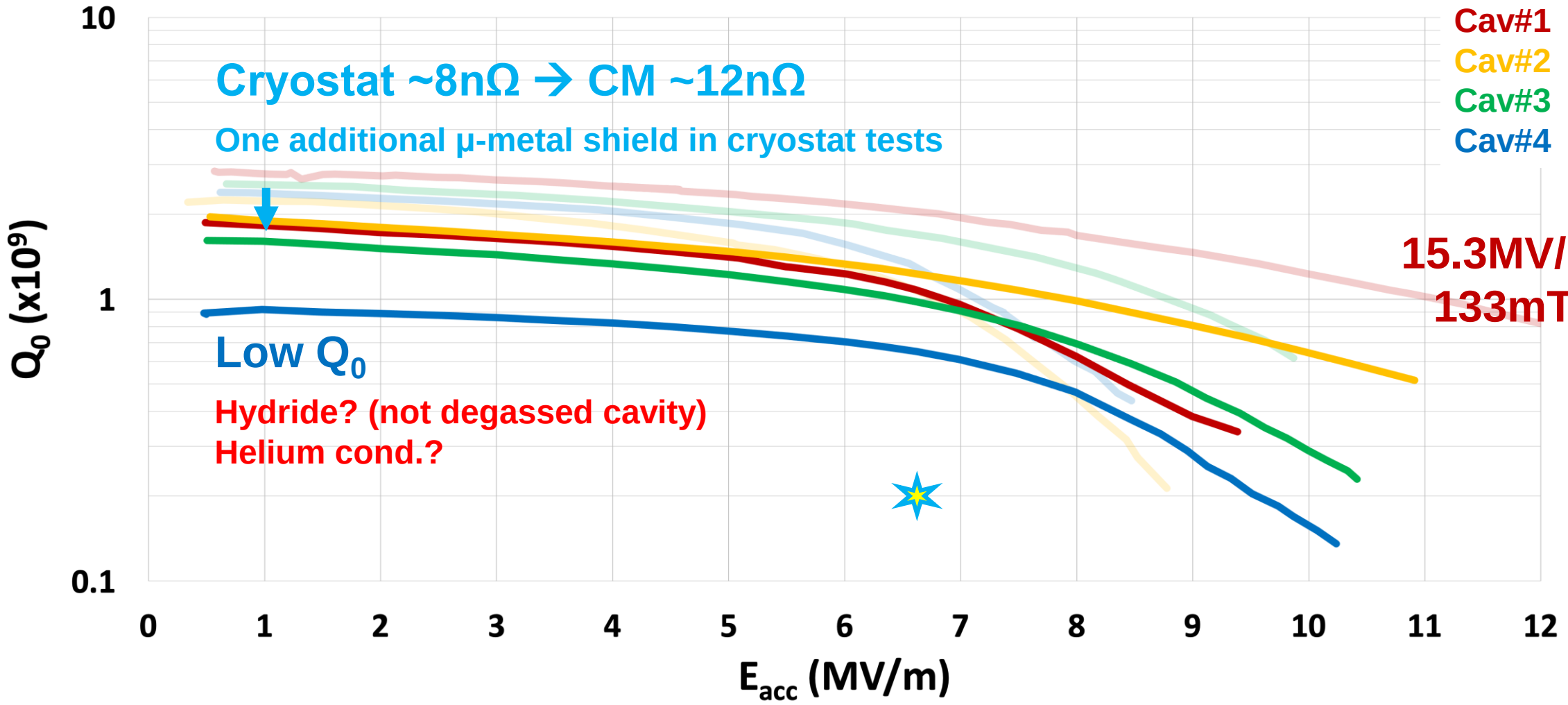
- After helium conditioning, helium gas was pumped out w/o cavity string thermal cycle
- RF measurements at RF space <1x10^{-7}Torr

Helium Conditioning Cav#3 & Cav#4



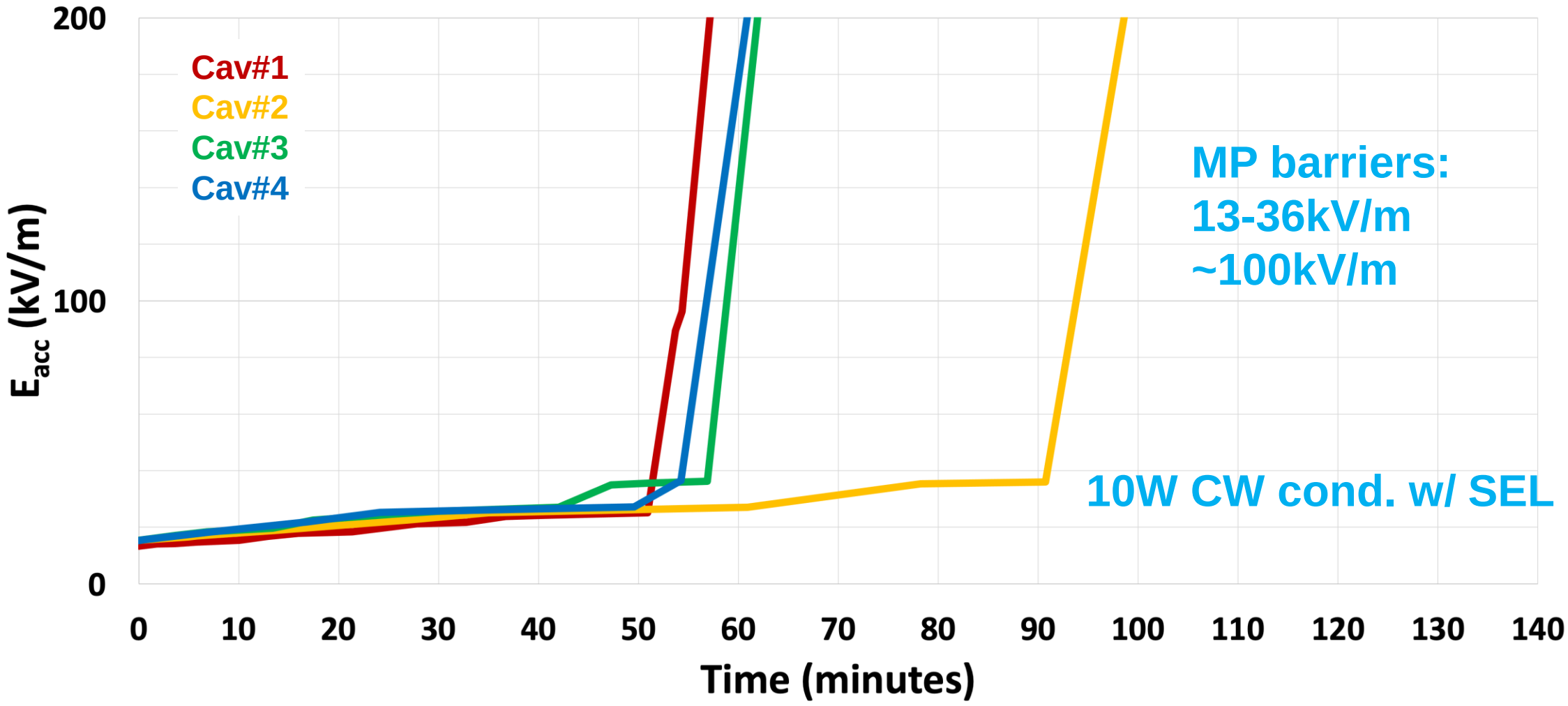
Discovery, accelerated

Compare to Cryostat Tests

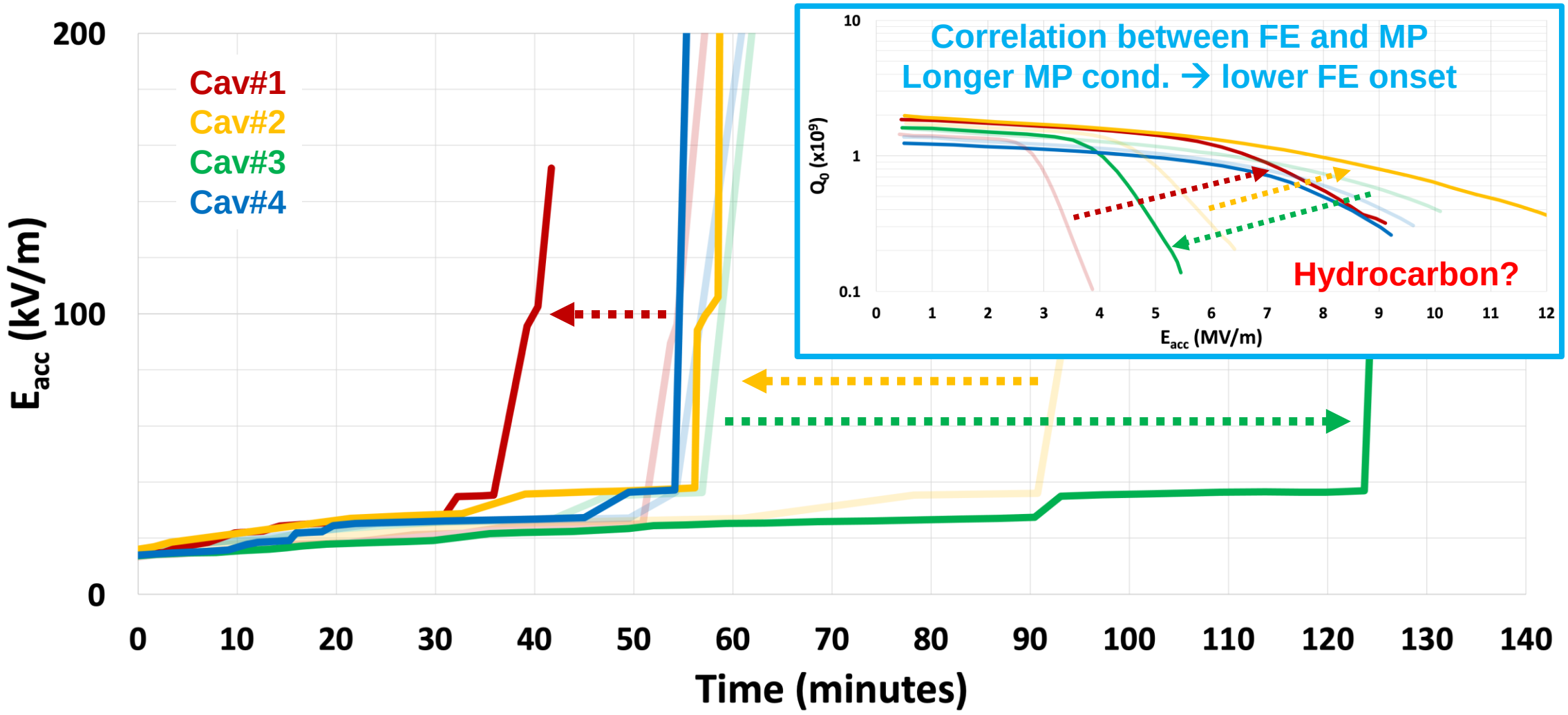


Discovery, accelerated

Multipacting (1)



Multipacting (2)



Discovery, accelerated

Cryogenics

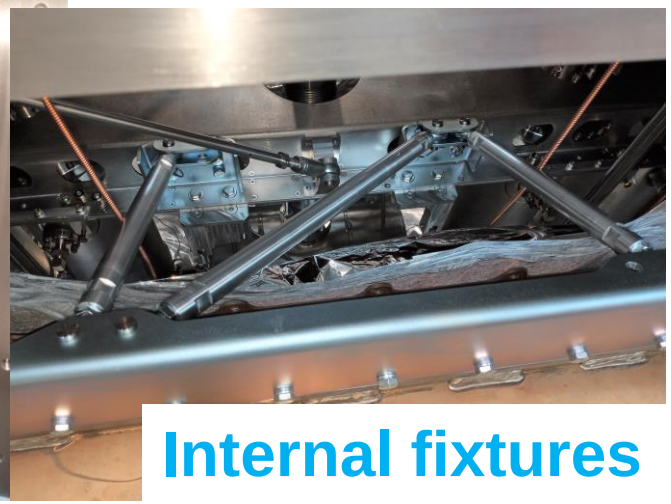
- LN2 consumption
  - 5.1 L/hour measured by gas flow meter
- LHe heat loads
  - Falling level method
  - Static load 9.3W
    - ISAC-II SCB CM ~13W
  - Dynamics loads measured w/ 1 cavity
  - 1.3W at 6.6MV/m and critical coupling (1.5W by RF)
  - 1.6W in operating regime (200W P_{FWD} in full reflection)
    - <1W additional LHe load from RF coupler loop

Others Results

- Cavity frequency on target at 4K with ~15kHz tuning range
- Variable RF coupler Q_{ext} range $2x10^4$ ~ $>2x10^9$
- df/dp ~ -1Hz/mbar, LFD ~ -2Hz/$(MV/m)^2$
- Phase locked in operating regime for >30min w/o active frequency tuning
- Solenoid ramp up to 7T
  - No affect on cavity performance in normal operation
  - Degaussing is required to avoid cavity Q degradation in case of accidental cavity thermal cycle above T_c
  - Degraded cavity still meets operating specification

After Commissioning

Shipping frame



Internal fixtures

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Thank you
Merci

Question?

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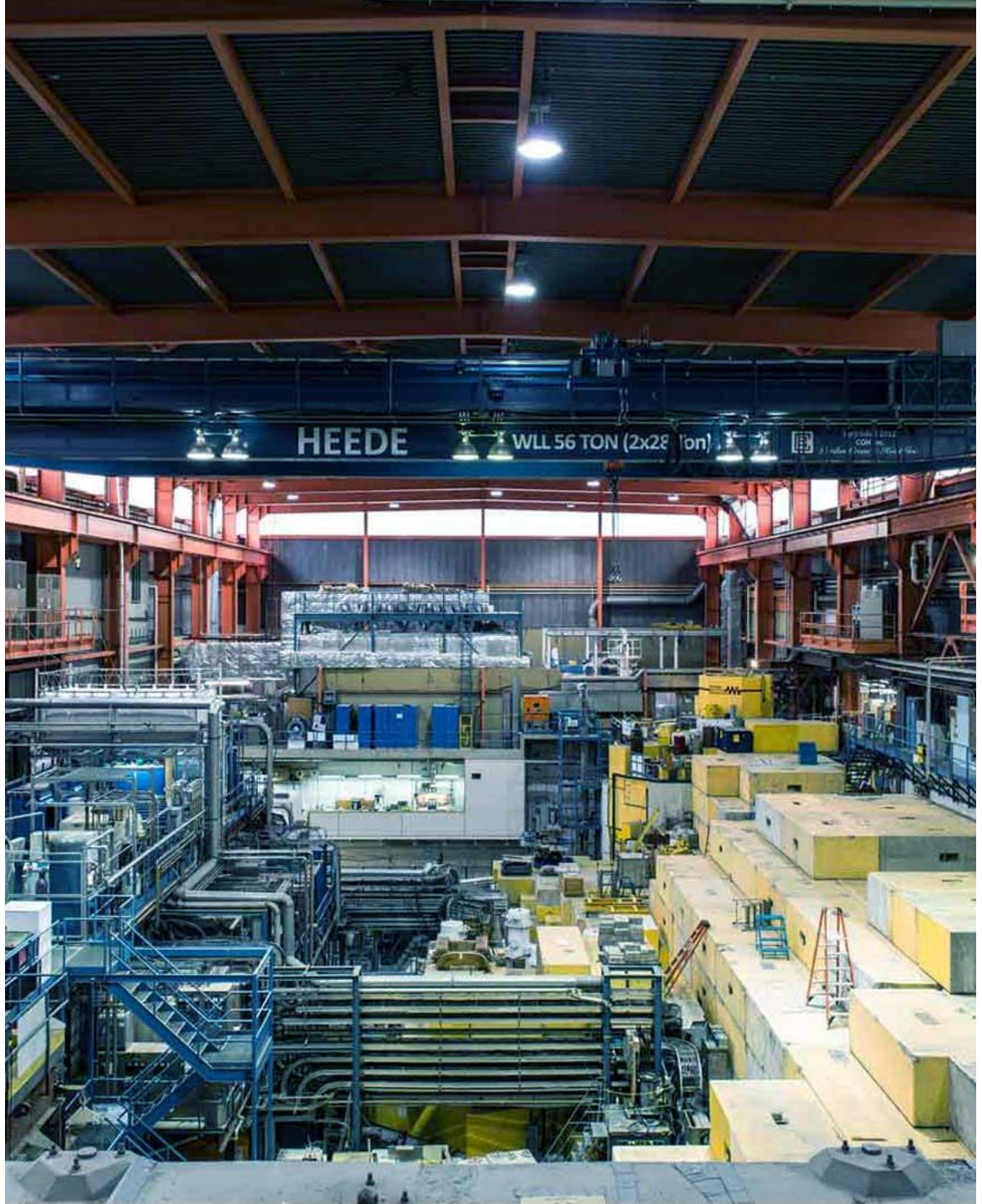

Discovery, accelerated

Oct. 11, 2022