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'Bad' Operating Experience in ISAC-II

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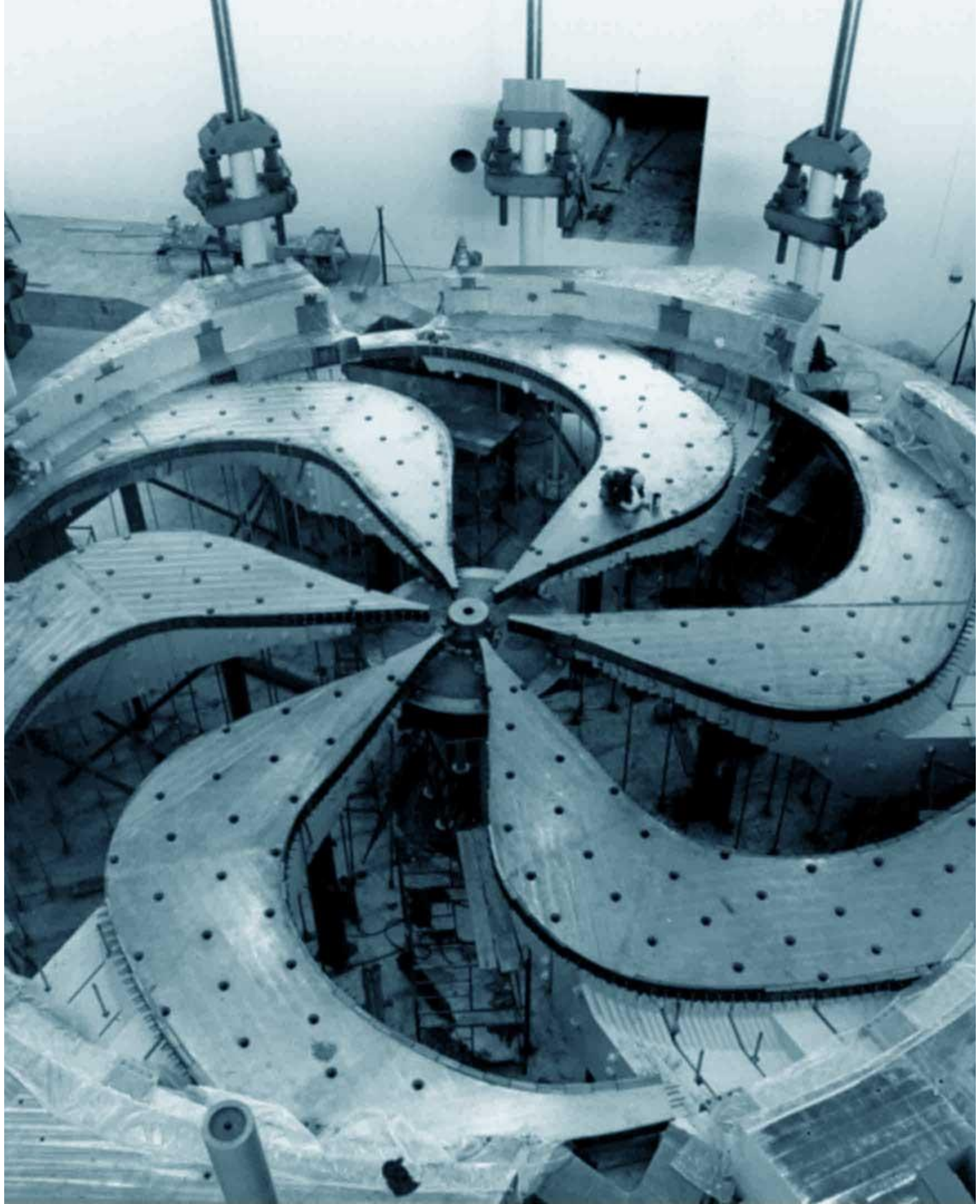
WG-4, TTC meeting, Aomori-city

Oct. 11 – 14, 2022



QST

TESLA TECHNOLOGY TTC COLLABORATION

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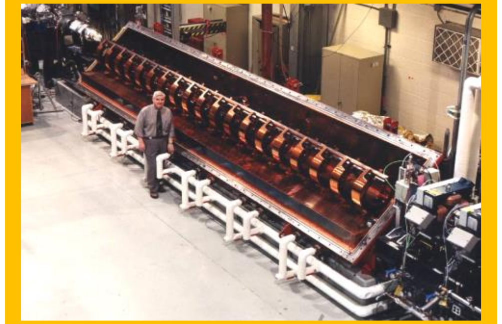
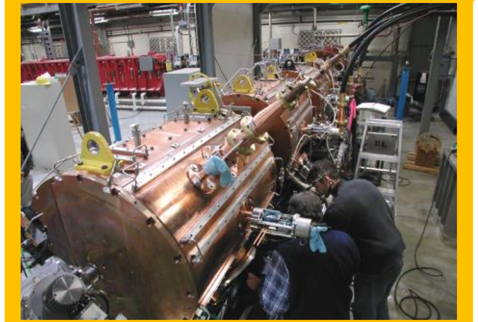
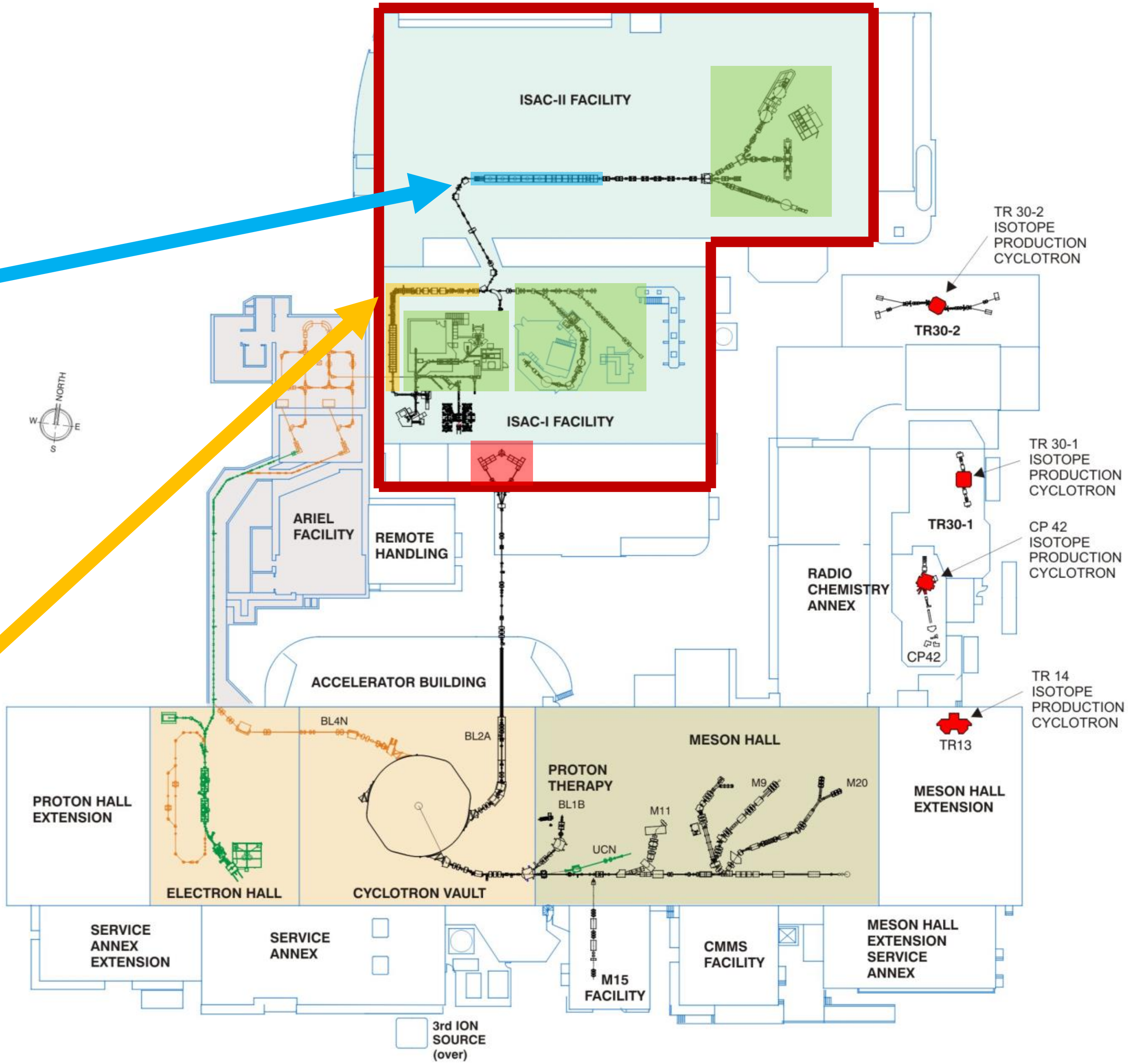
Isotope Separator & ACcelerator (ISAC)

40MV accel. 2≤A/q≤6 RIB to 6.5–16MeV/u







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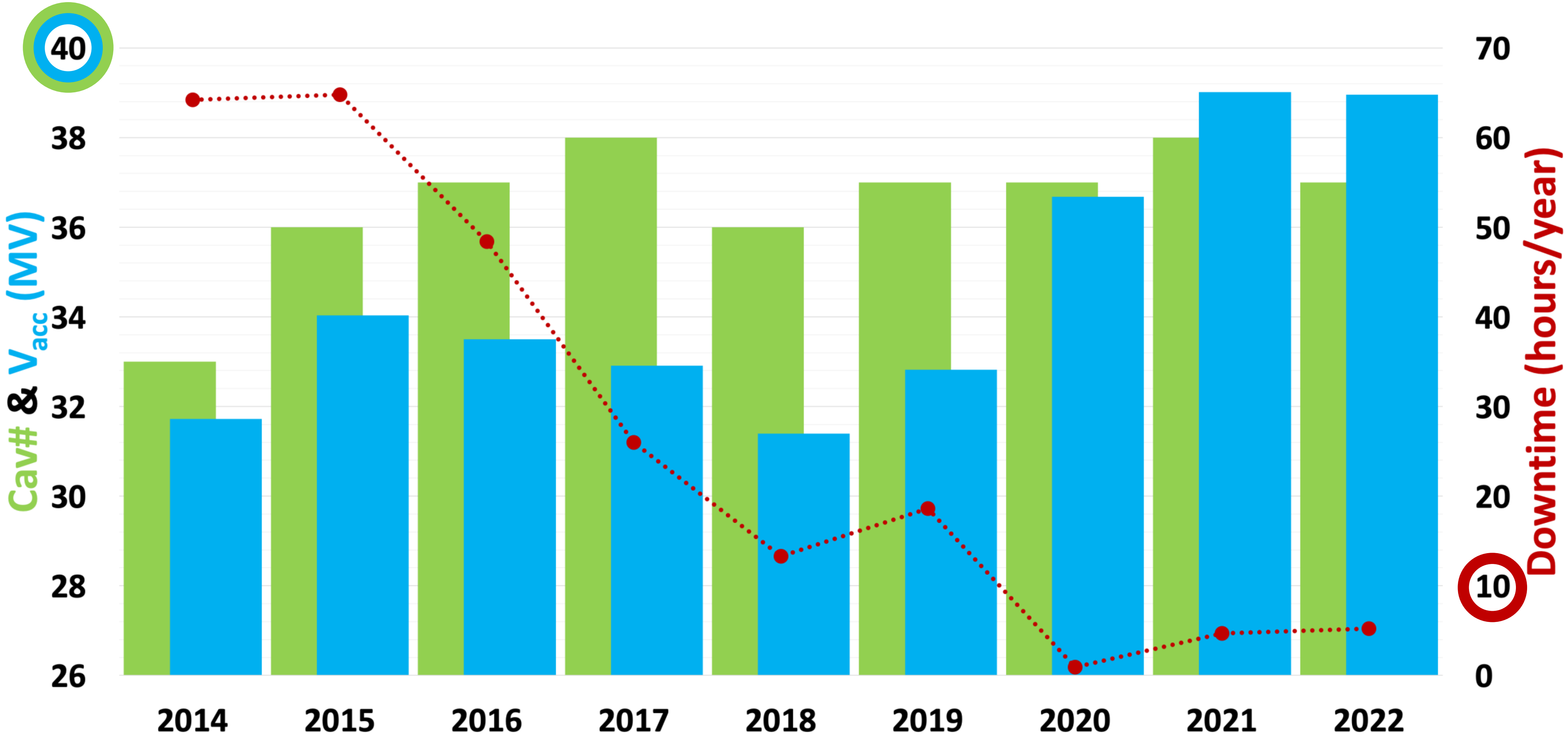
ISAC-II Performance



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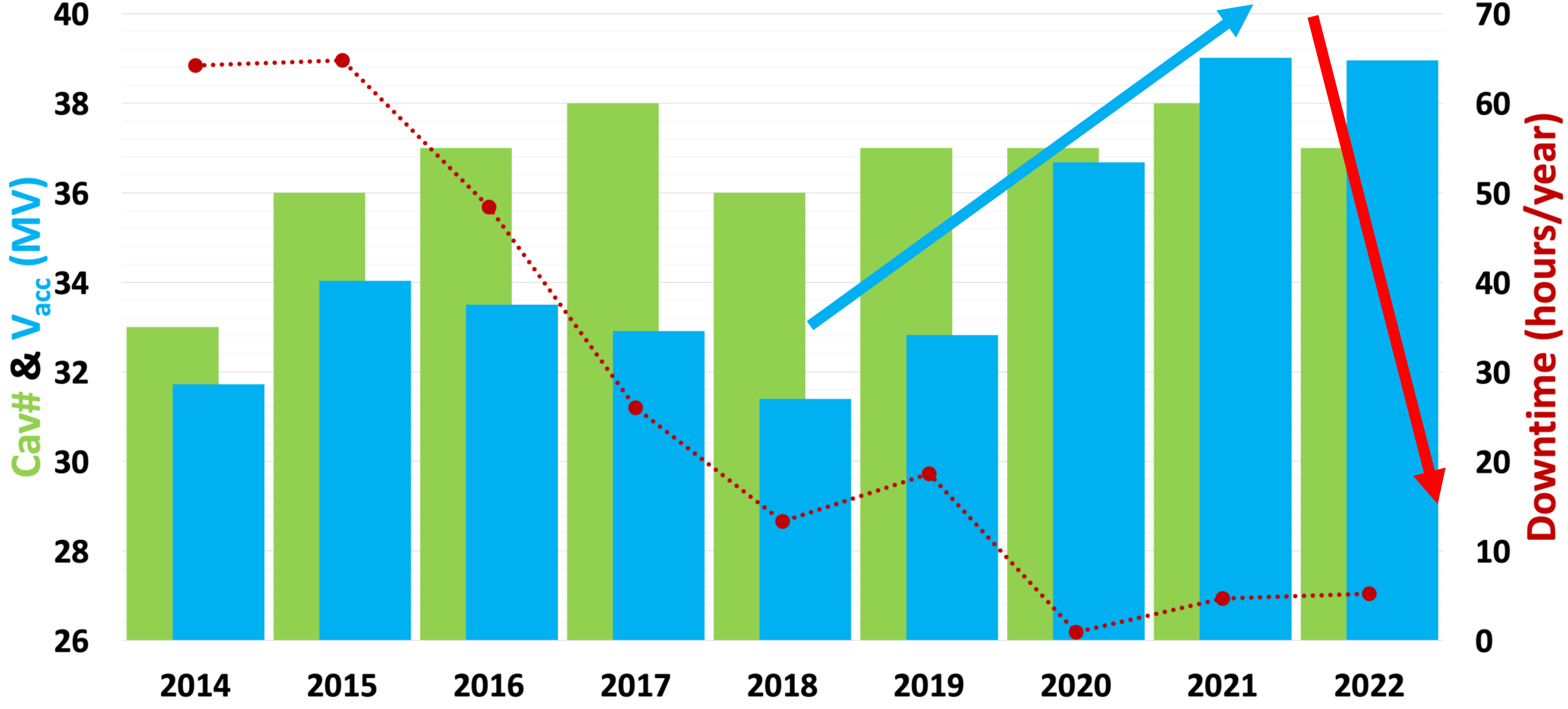
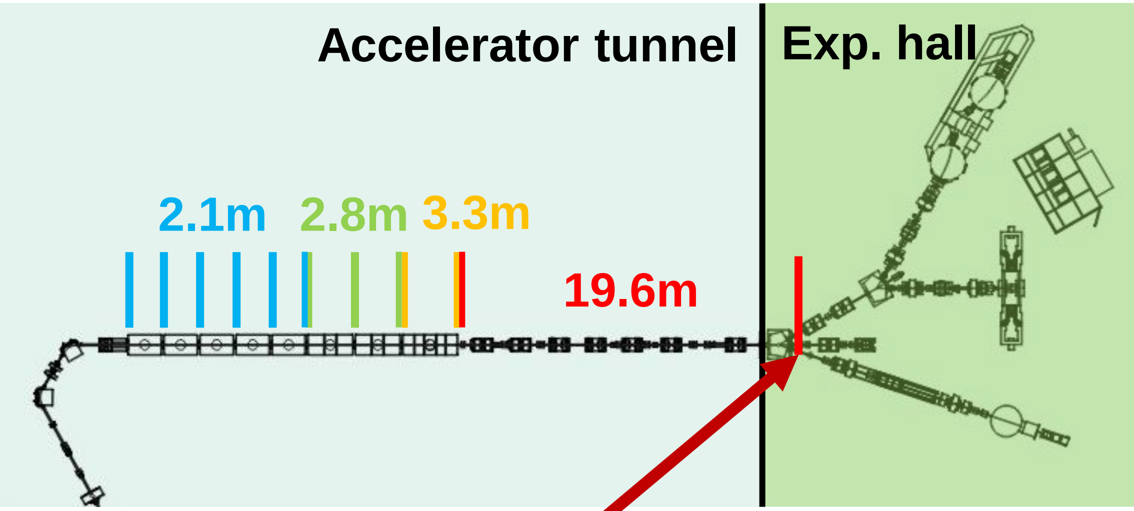
Expectation & Reality



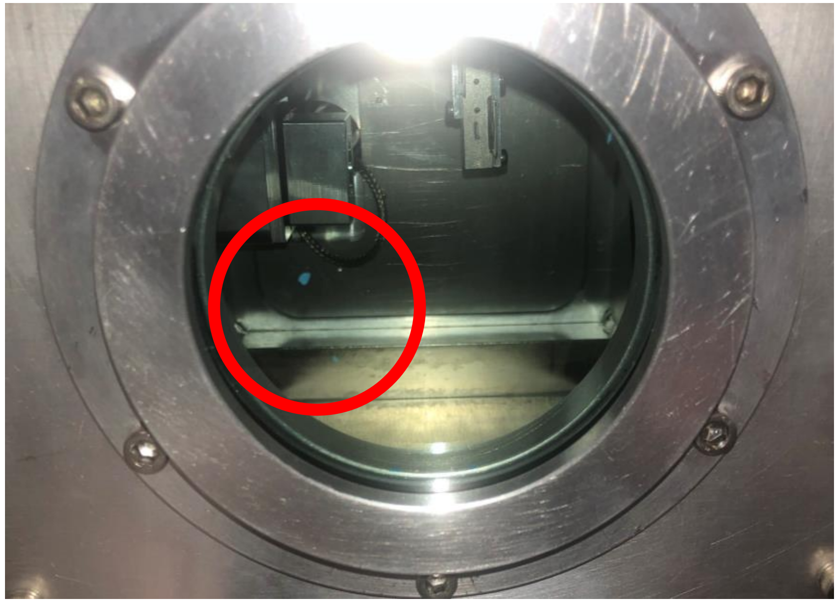
Vacuum Accident



- Beamline vented with **Air** by human error from experimental hall
- 6 isolation valves and 1 fast valve (not armed, 5m from CM) in open state
- **Conventron gauge** (0.6m from CM) saw **200Torr** pressure (data every 5 min)
- Missed ‘2 fingers’ of rubber glove from vent spot

Observation after Accident

- Looking for missed ‘2 fingers’ of glove or damages on beamline
  - Bits of glove in diagnostic box (~5m from venting spot)
  - 3 of 4 stripping foils damaged



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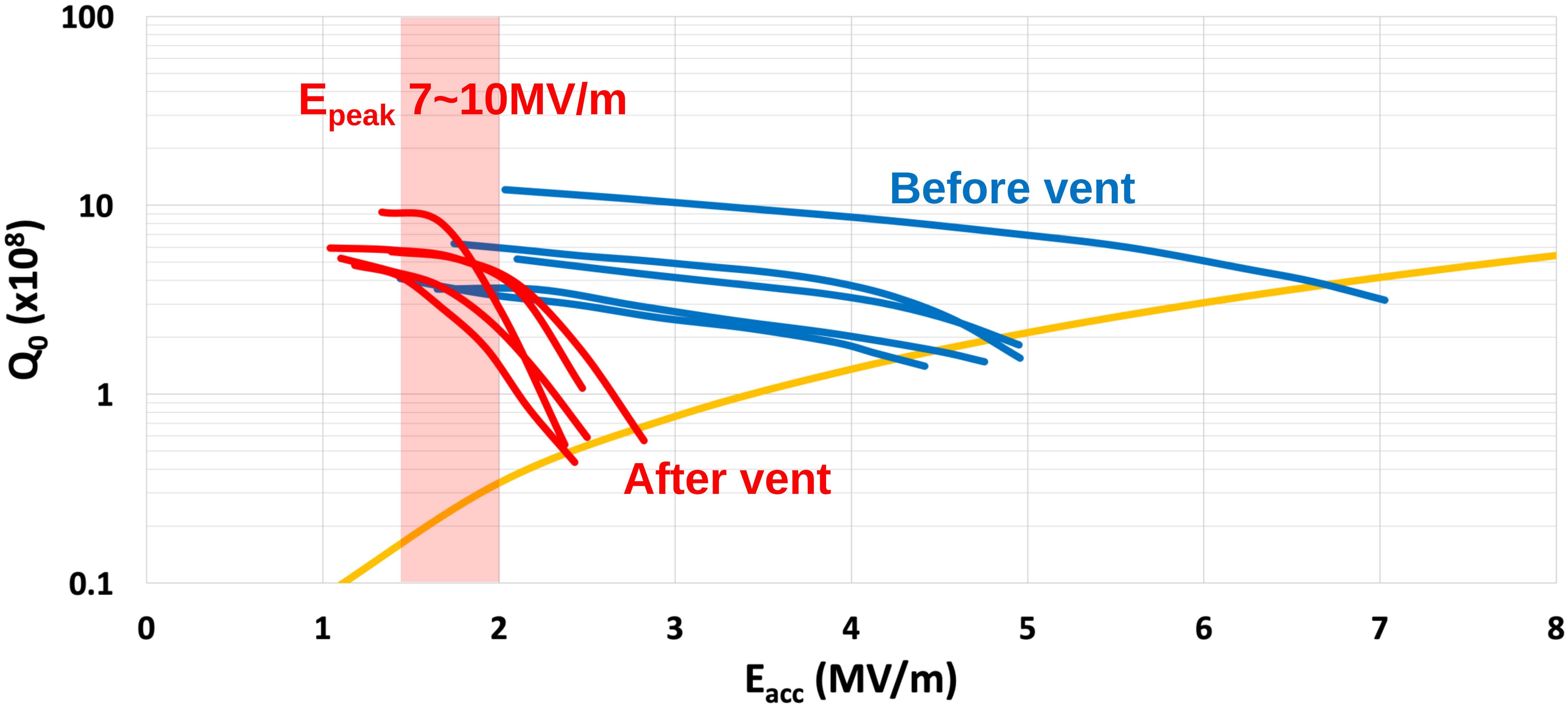
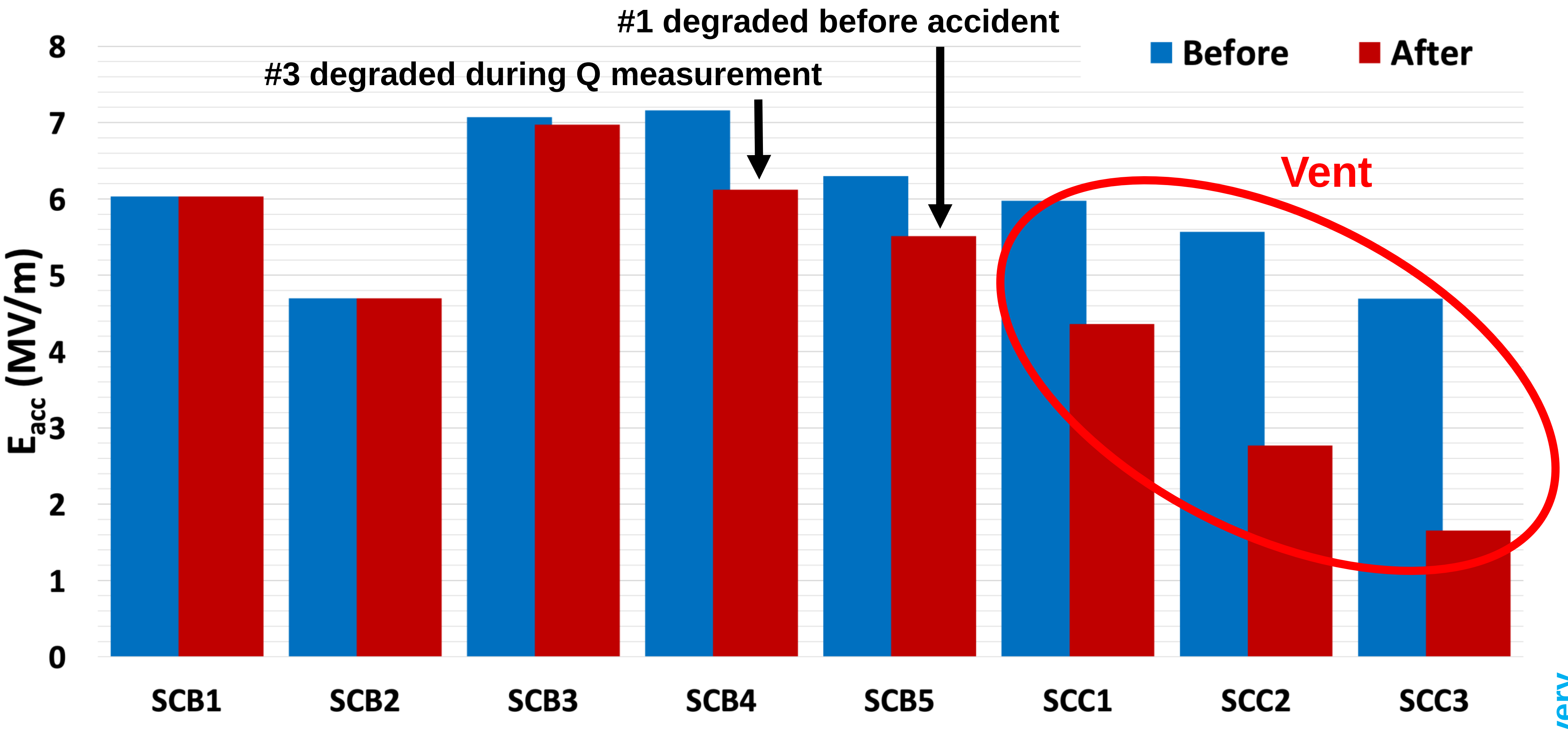
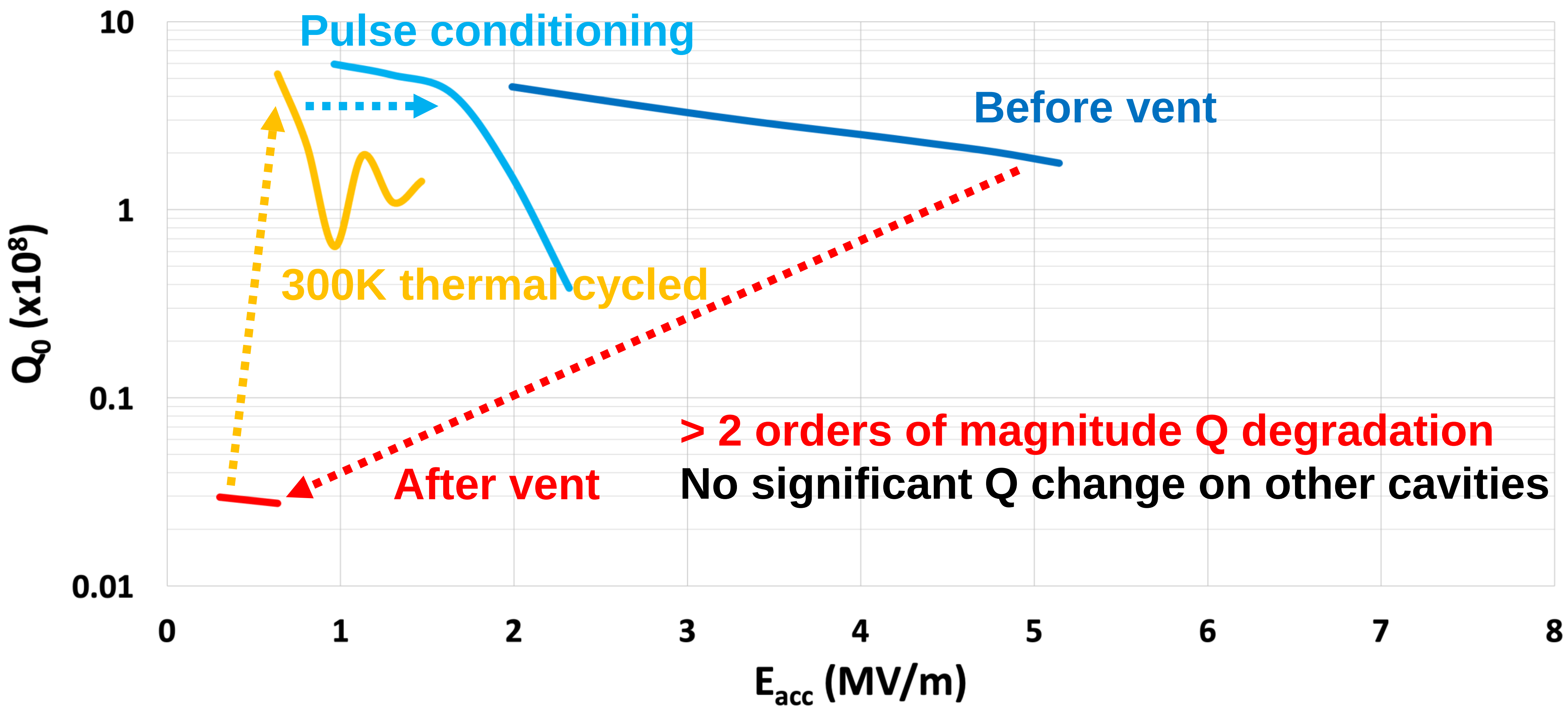
SCC3 Cavities



Cavity Performance



Special One – SCC3#8



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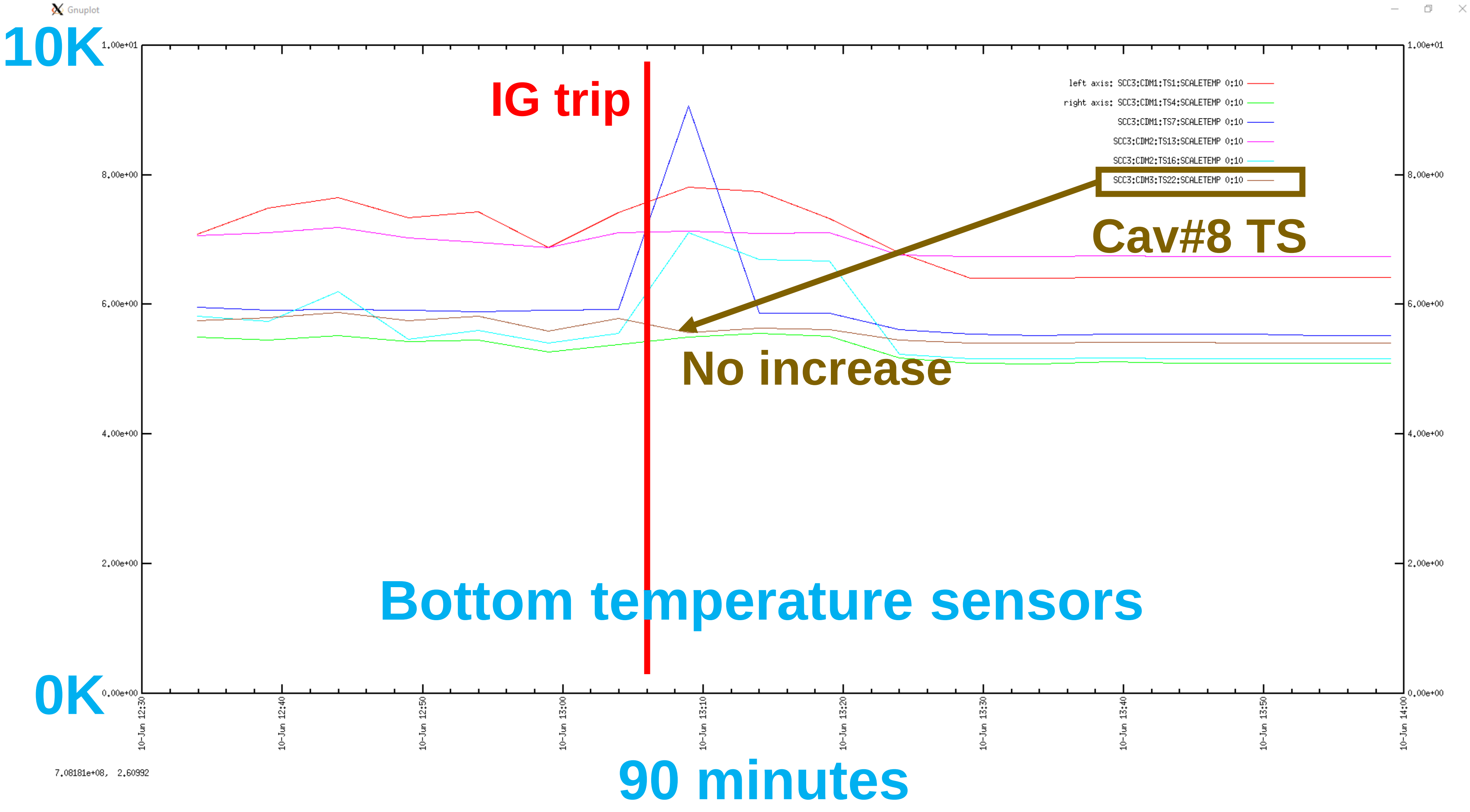
What Happened on SCC3#8?

- Trapped flux from operating solenoid?
  - Solenoid operating @ 5.3 T
  - Magnetic field @ Cav#8 **?**
  - Hypothesis
    - Bad vacuum significant increased heat load to cavity
    - Cavity quenched (including helium jacket/magnetic shield)
    - Trap flux after cooldown
    - Look for evidence of cavity quench in archive
      - 3 temperature sensors each cavity
      - Inner conductor – in LHe
      - Cavity top and bottom flanges – in vacuum

Cavity Quenched?



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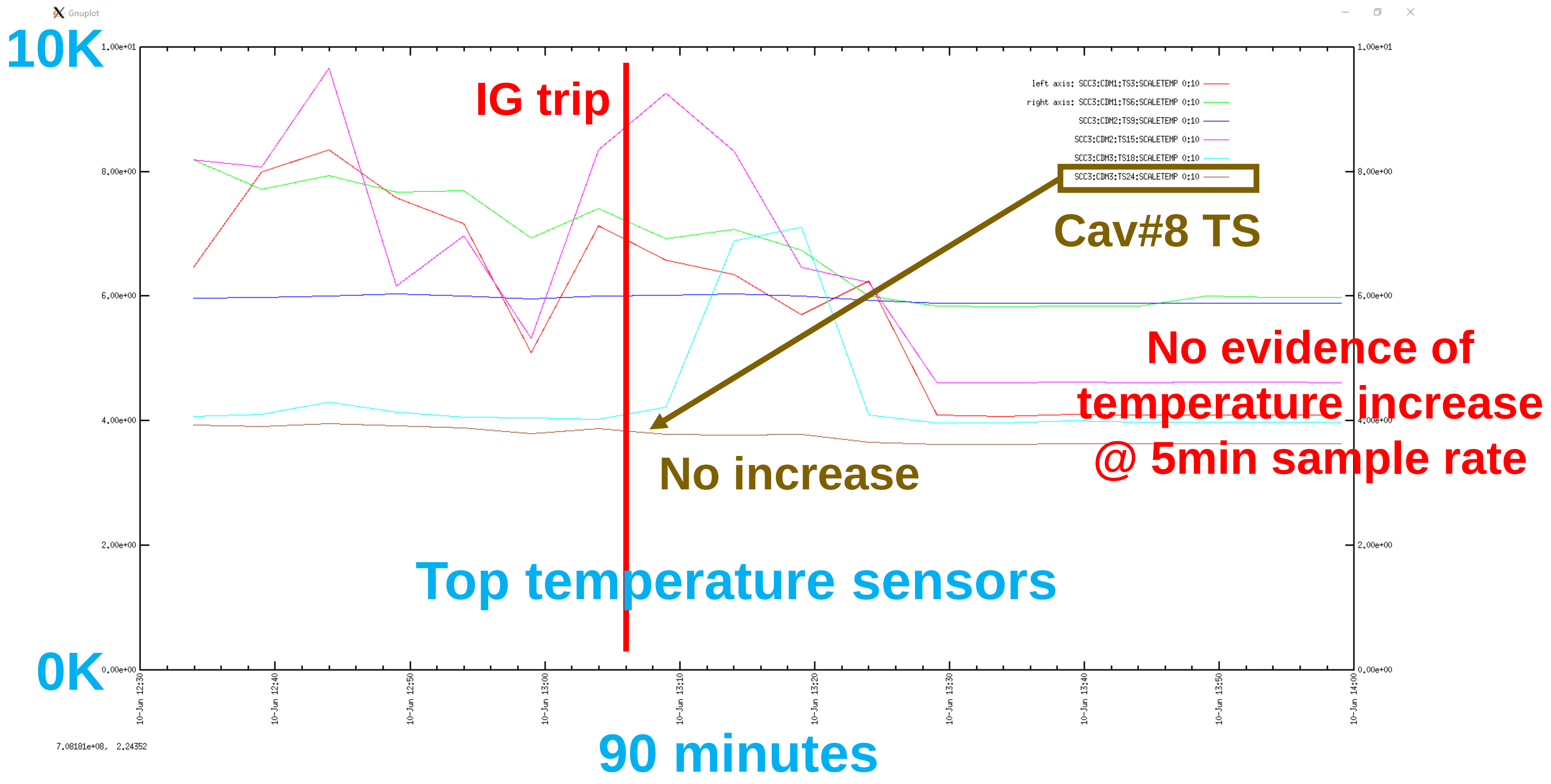
Cavity Quenched?



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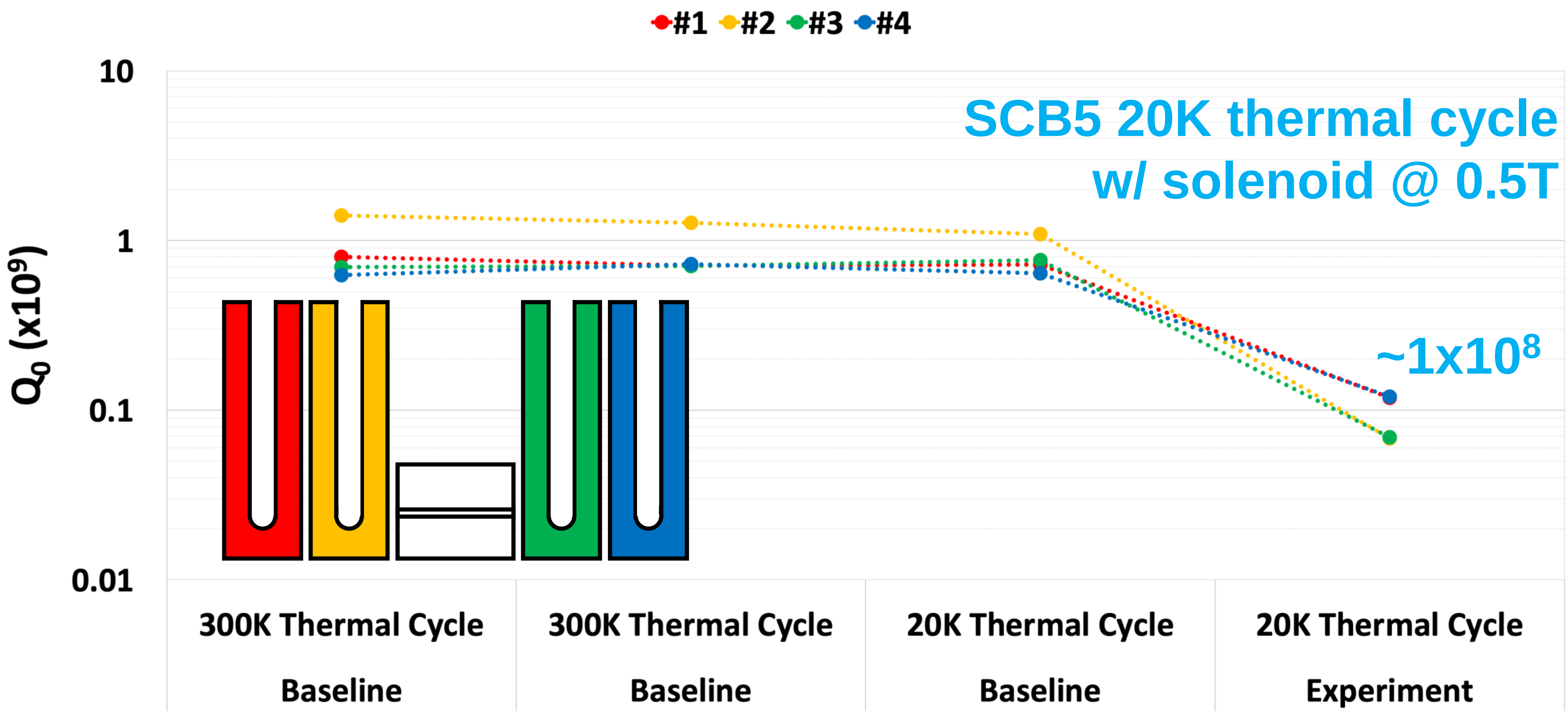
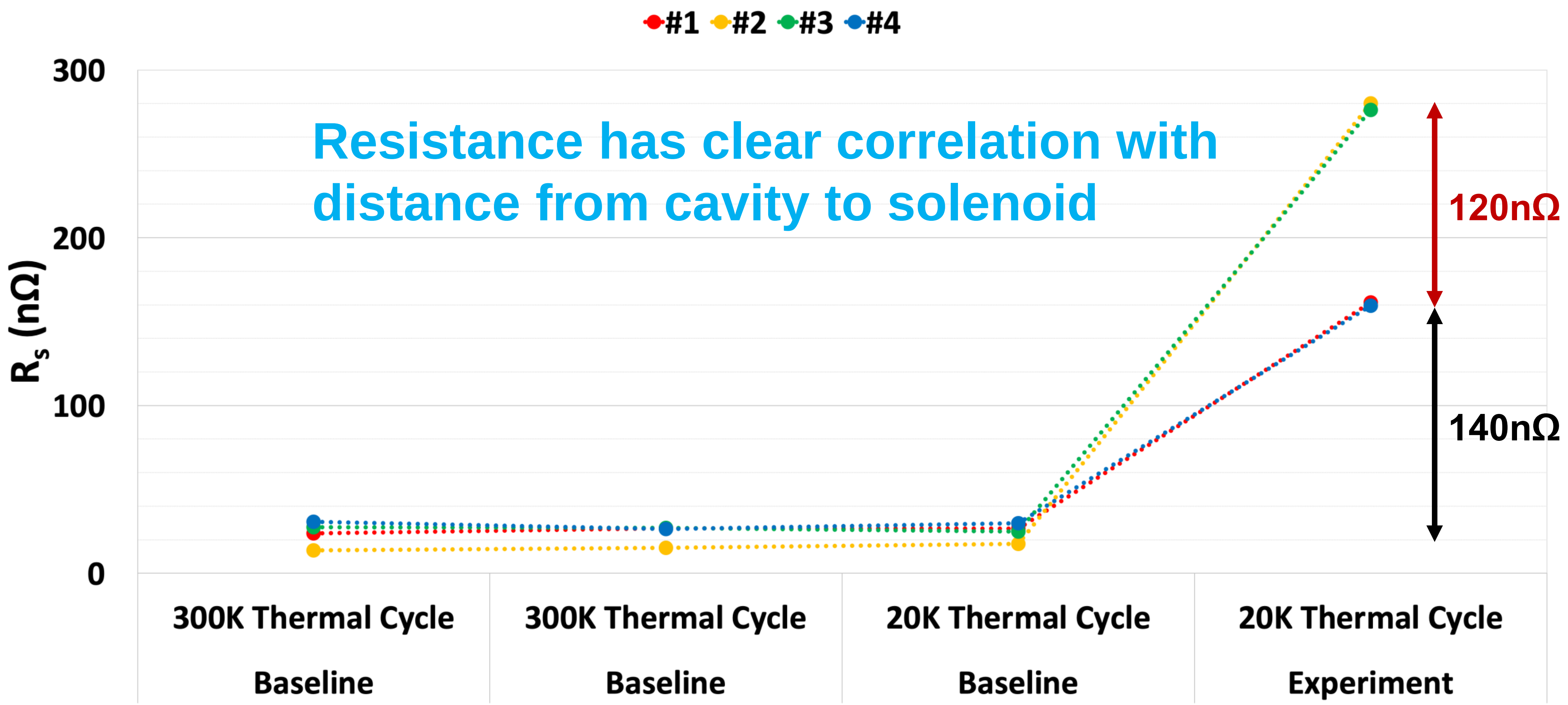
Magnetic Pollution

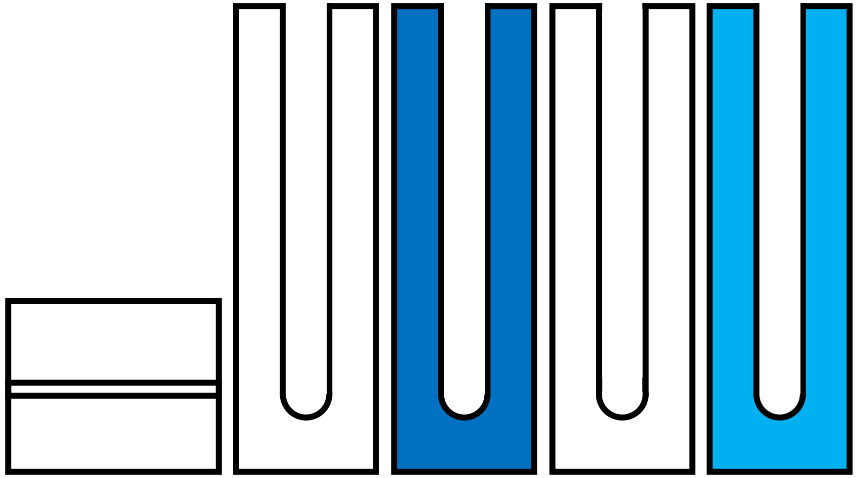


Magnetic Pollution



Require Higher Magnetic Field

- Compare to SCB5#1/4
  - Full cavity transition in magnetic field
  - $1x10^8$ @ 0.5T → **$1x10^7$** @ 5T
- But SCC3#8
  - 615mm further away from solenoid
  - Should not have higher local magnetic field
  - Should not have lower Q_0
  - **But Q_0 ~$3x10^6$**

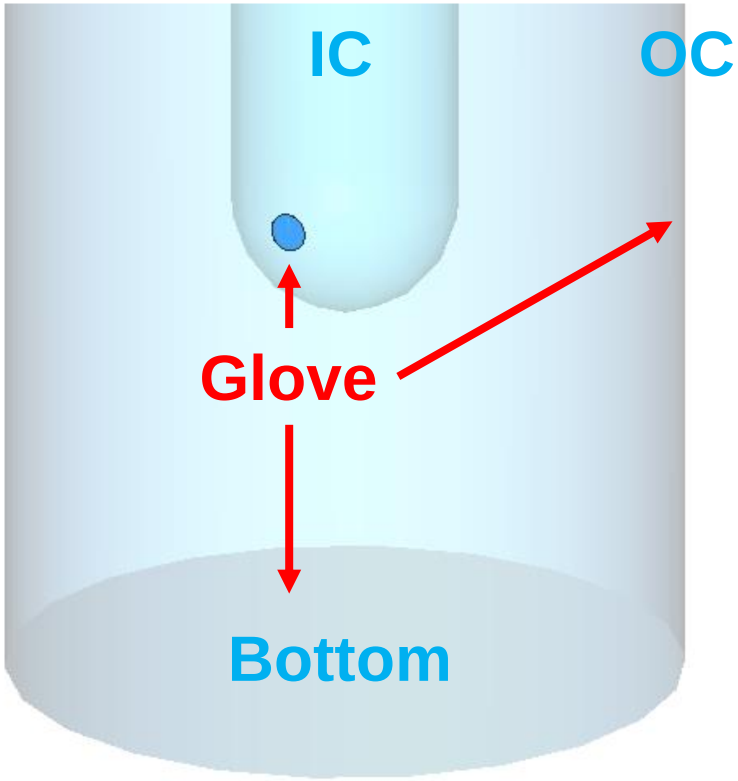


What Happened on SCC3#8?

- Bits of glove blown into SRF cavity?
  - Dielectric RF loss
  - Estimation
    - Material, nitrile butadiene rubber (NBR)
    - Thickness 0.1mm (from glove spec.)
    - Dielectric constant ~5 @ 100MHz
    - Loss tangent ~0.2 @ 100MHz
    - Very rough parameters at unknown temperature
  - Drop material to a simplified simulation model

Dielectric Loss?

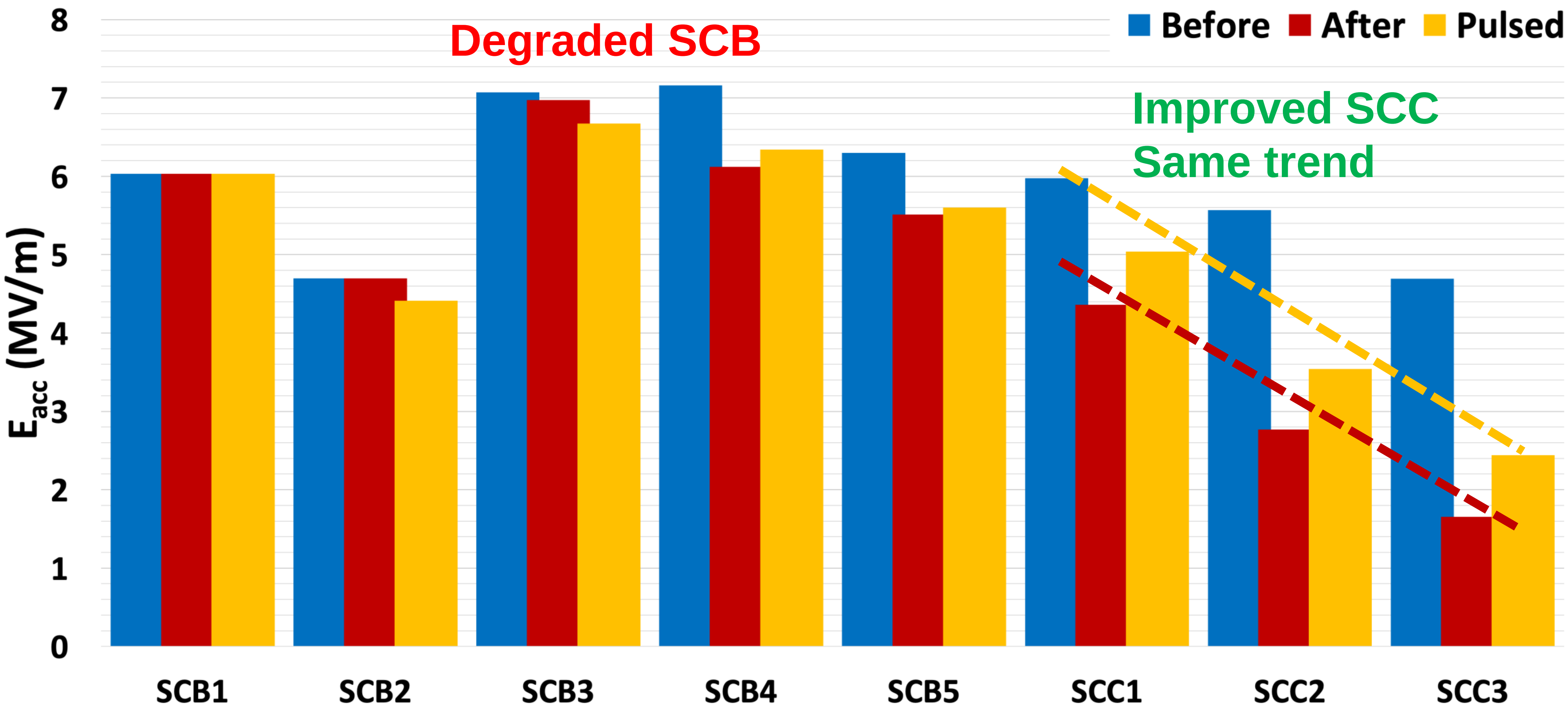
- Simulation with CST
  - Stick to IC (high e-field region)
    - **10mm** diameter bit, **$Q_0 \sim 2x10^6$**
  - Stick to OC (high e-field region)
    - 40mm diameter bit, $Q_0 \sim 2x10^6$
  - Drop on the bottom plate
    - Require unrealistic big piece
- **Yes or No?**
  - Maybe realistic size if on IC
  - To find bits of glove in cavity or CM
  - How 300K thermal cycle restored Q_0?



Operating with Degraded Cavities

- Run 3 months with reduced gradient
  - Total voltage 39MV → **29MV**
  - ‘Benefit’ – broader RF bandwidth
- Last 3 cavities have enhanced multipacting barriers
  - MP conditioning applied
  - 1 cavity still has low level barrier after conditioning, but can jump over
- Planned high power pulse conditioning for SCC cavities when beam schedule allows

Pulse Conditioning



Longer Term Pollution

- Not found immediate degradations on SCB cavities
- But observed degradations after 3 months operation
  - Enhanced FE – SCB2#2/**3**/4, SCB4#**3**, SCB5#**3**
  - Q degradation – SCB3#**1**/4, SCB4#**1**, SCB5#**1**
    - 25%~50% Q drop
    - May accompany with enhanced FE
- **Question #1 – Are #1 & #3 magic numbers?**
- **Question #2 – Are SCB CMs polluted as well?**
- **No Answer Yet**

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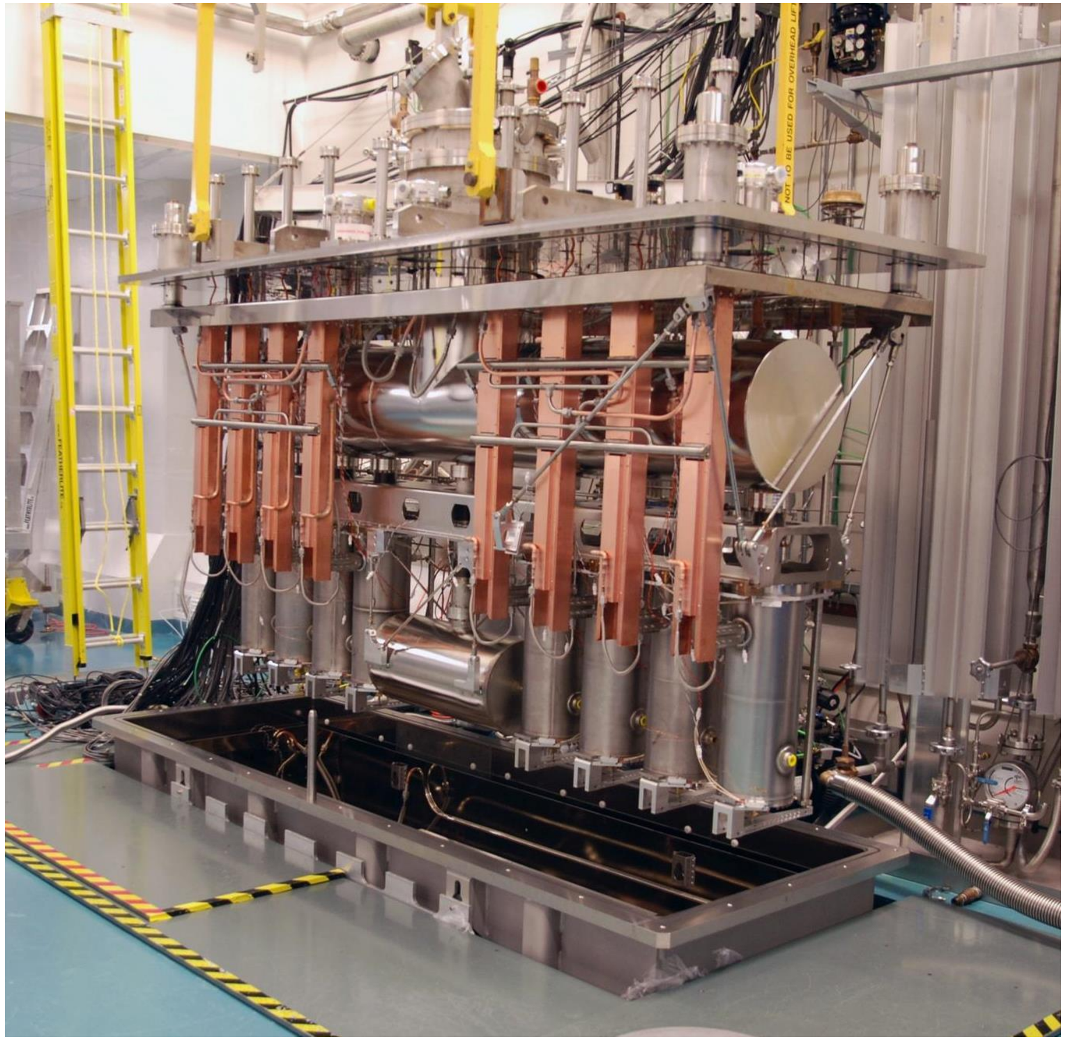
Recovery Plan

- Pulse conditioning could not fully restore cavity performance
  - 29MV → 31MV
- Remove contaminated CMs from tunnel to cleanroom
- HPR all SCC cavities
- SCB cavities not clear
  - To assess performance after 300K thermal cycle
- 1 CM per year in winter shutdown
  - At least 3 years to recover



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Lesson Learned

- Human error
  - Direct cause, but not root cause
- Protection
  - Fast valve was open but not armed
  - Never had chance to ‘test’ since installation
  - Planned to do annual validation/calibration
- Procedure
  - Certain number of isolation valves shall be closed without beam delivery

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Final Remarks

- Hope this is and will be the only available data of linac pollution for SRF community

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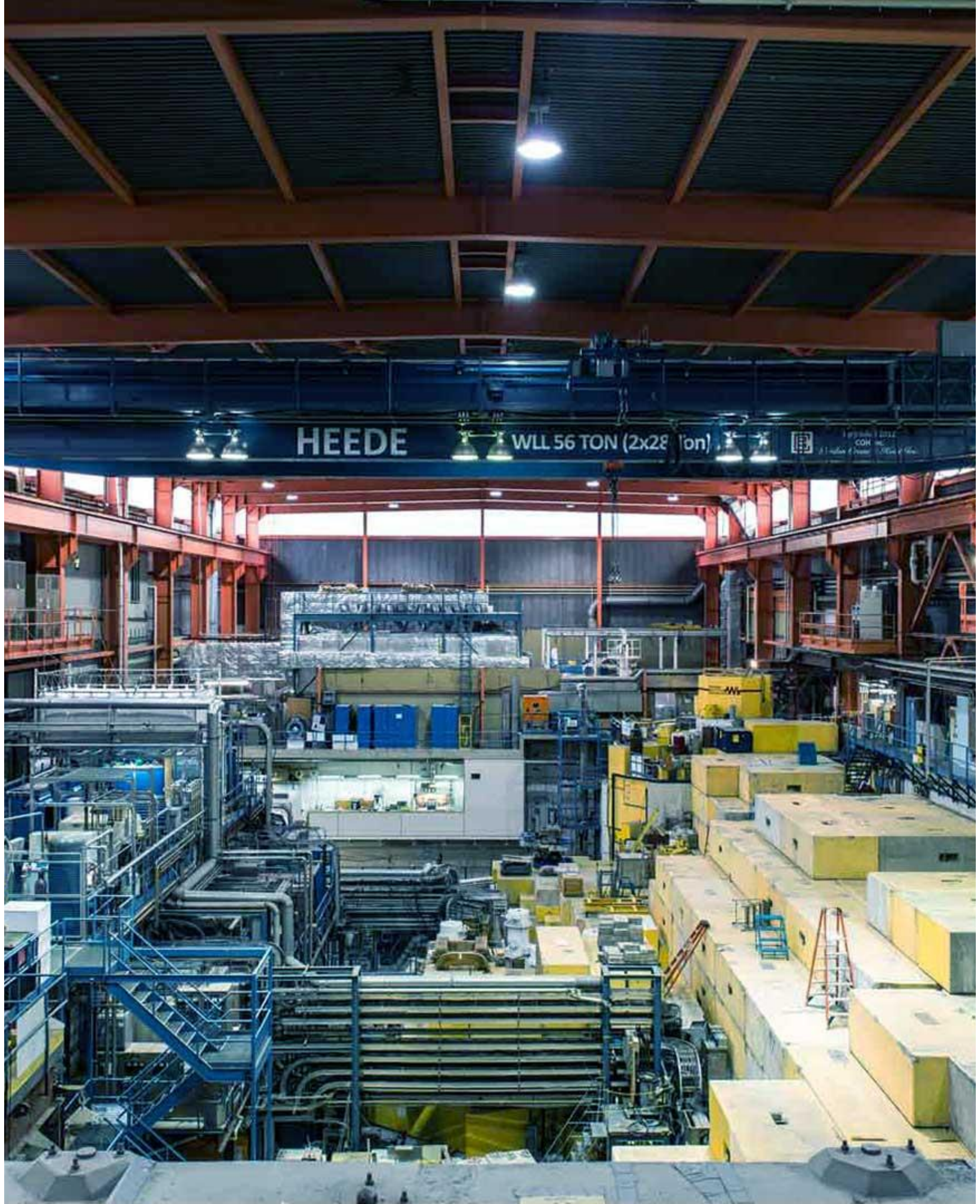
Thank you
Merci

Question?

www.triumf.ca

Follow us **@TRIUMFLab**



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Oct. 13, 2022

How could it be in a separated vacuum CM?