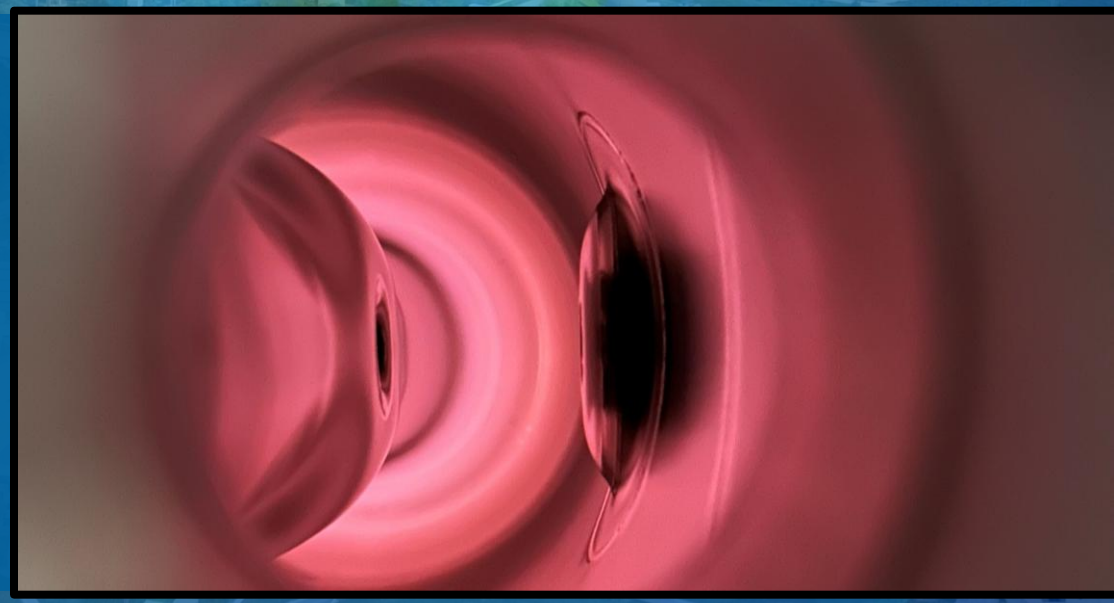
JUNE 2026 – TTC MEETING

IN-SITU PLASMA PROCESSING, PULSE CONDITIONING, HELIUM PULSE PROCESSING, AND THERMAL CYCLING ON LOW-BETA CAVITIES IN ATLAS



MEGAN MCINTYRE
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Mike Kelly
Troy Petersen
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U.S. DEPARTMENT of ENERGY

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Argonne Tandem Linac Accelerator System

OUTLINE

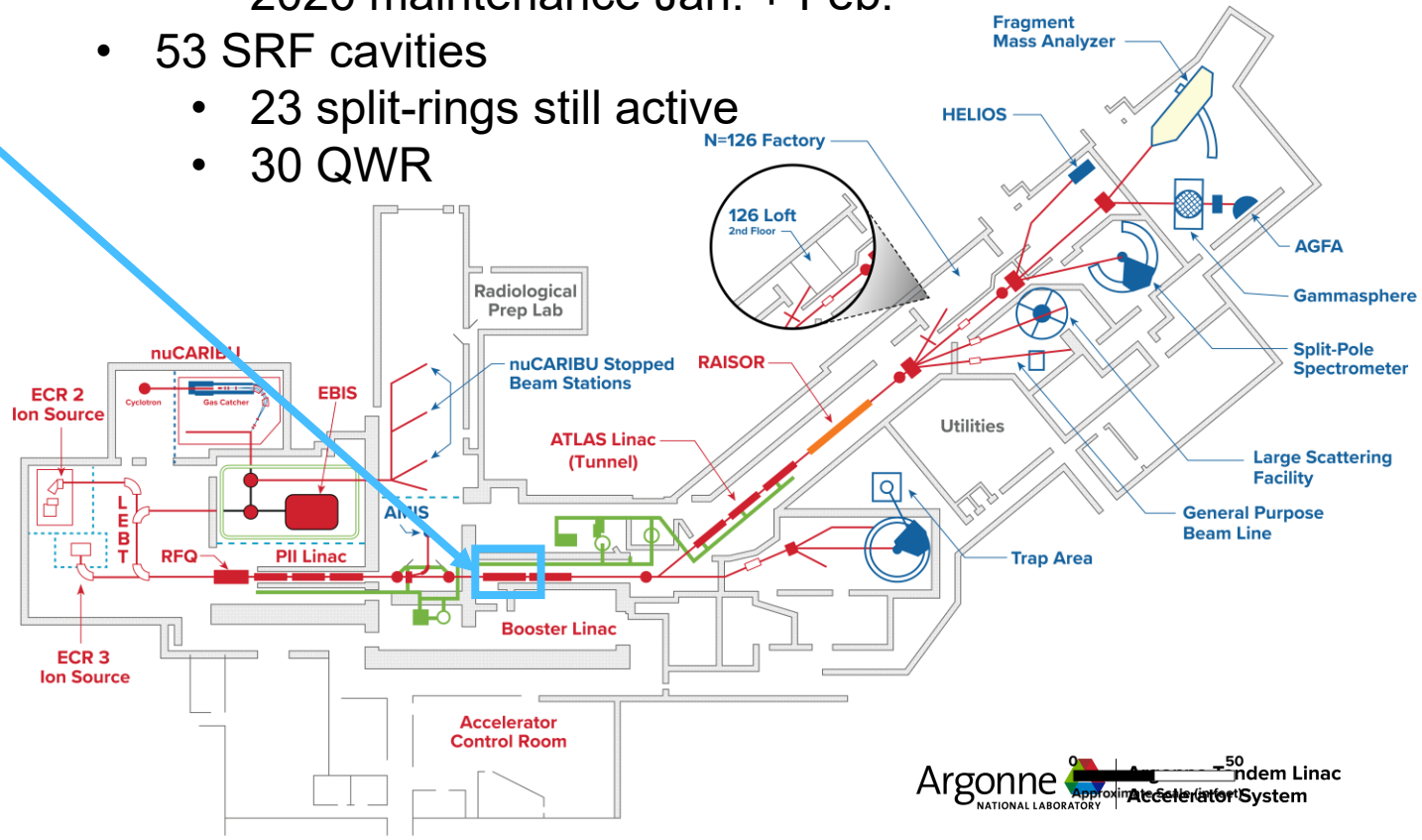
- ATLAS overview / target SRF cavities
- Investigations + setup
  - —Pulse Conditioning (PC)
  - —Helium Pulse Processing (HPP)
  - —Plasma Processing (PP)
    - Thermal cycle
- Goals for investigations before/during/after scheduled winter 2026 maintenance period
- Results and conclusions from investigations
- Next steps/plans and discussion points

ATLAS FACILITY

Cryostats of interest for HPP, PP, and Thermocycle

- **A-tank:**
  - **Seven 72 MHz QWR installed 2014: has not been refurbished since initial install *(12 years operation)***
  - **Regular pulse conditioning**
  - **Possible leak from cold trap(s) causing frozen N2 on end cavities**
  - **Degradation evident in heat load and radiation, not running at previous amplitudes**
  - **2015 and 2016 exit valve struck with beam, degraded R217**
    - **2016 Up to 4 pnA of 12C**
    - **PC and conditioned, little improvement**
- **G-tank:**
  - Seven 109 MHz QWR installed 2002
  - Refurbished, upgraded, and additional cavity re-install 2022

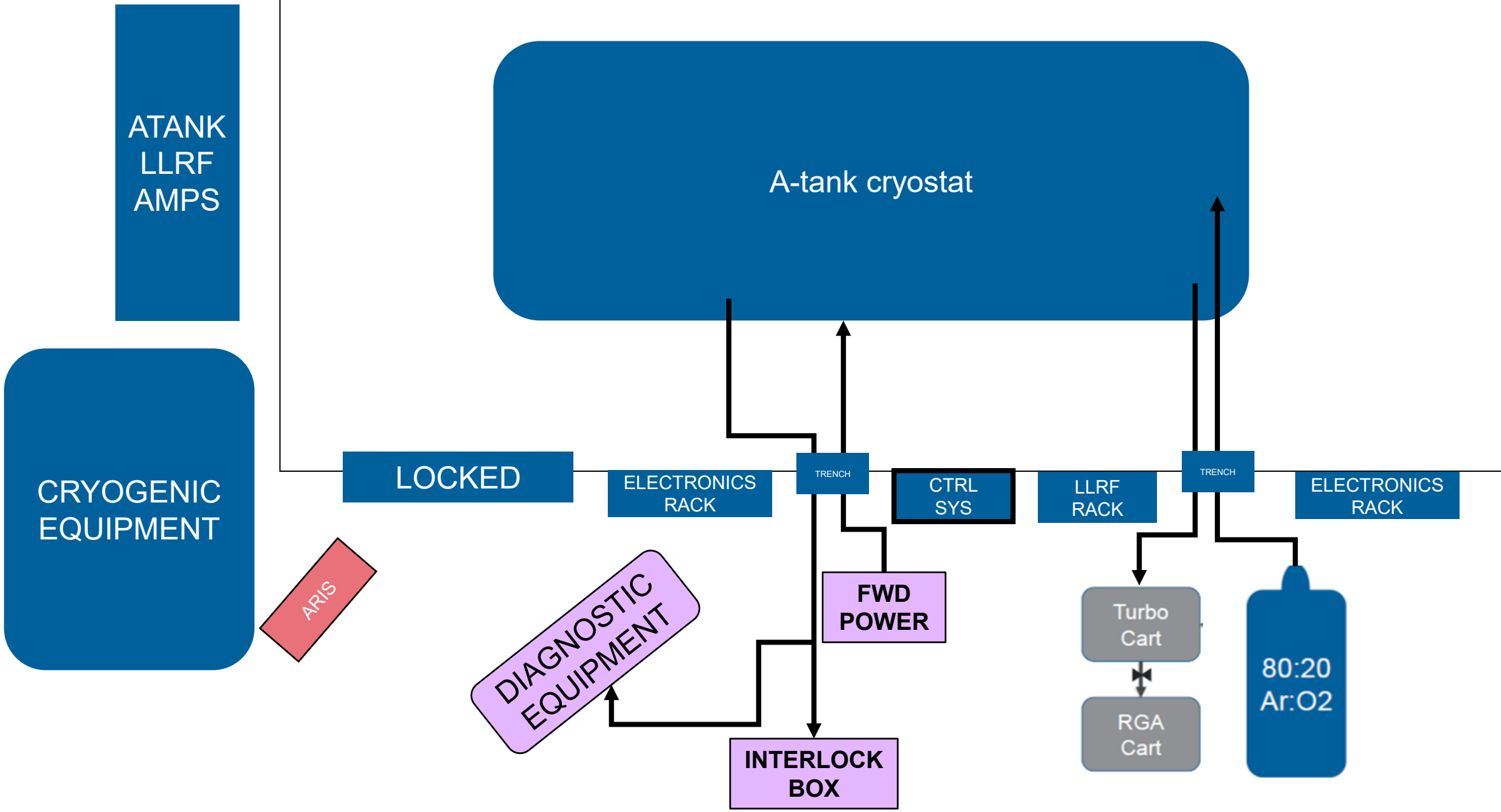
- **ATLAS: Argonne Tandem Linac Accelerator System**
  - 1986 first beam (happy 40th birthday ATLAS 🥳)
  - Over 6000 hrs/yr
  - Beams H up to Ur, radioactive and stable
  - One month winter maintenance in January
    - 2026 maintenance Jan. + Feb.
  - 53 SRF cavities
    - 23 split-rings still active
    - 30 QWR



INVESTIGATIONS

PULSE CONDITIONING	HELIUM PULSE PROCESSING	PLASMA PROCESSING	THERMAL CYCLE
COLD (4K)	COLD (4K)	WARM	COOL DOWN
• Standard procedure used by operators • Use already installed equipment • Post shutdown commonly executed • Long or short pulse • Consistently improves performance if breakdowns are seen	• Used in early operation (1979 split rings) • **Equipment:** normal RF circuit, gas filter, gas cylinder, and clean inlet line • **Vacuum in cryostat normally E-9 Torr range, during HPP E-5 Torr range** • Improves FE onset, no Q change seen	• **Ar/O2 Gas** • **10 WATTS PFWD, 50 – 100 mTorr** • Improves FE onset, no Q change seen (for us) • **Equipment:** Gas mix, turbo cart w/ RGA, diagnostics (SA, NA, scope, etc.), fast acting valve, amplifier, SG, ***coupler protection***	• Can improve Q of cavities if particles frozen to surface • Can be implemented within scheduled maintenance • **Goal: Desorb N2 frozen to end cavities**

Could be combined with other processes for optimization



ATANK
LLRF
AMPS

A-tank cryostat

CRYOGENIC
EQUIPMENT

LOCKED

ELECTRONICS
RACK

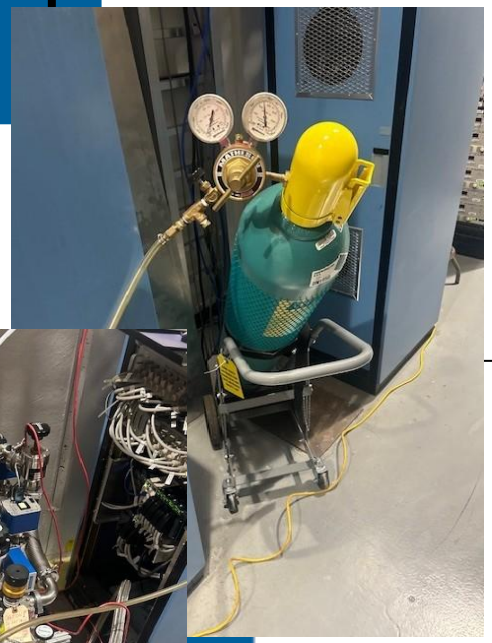
TRENCH

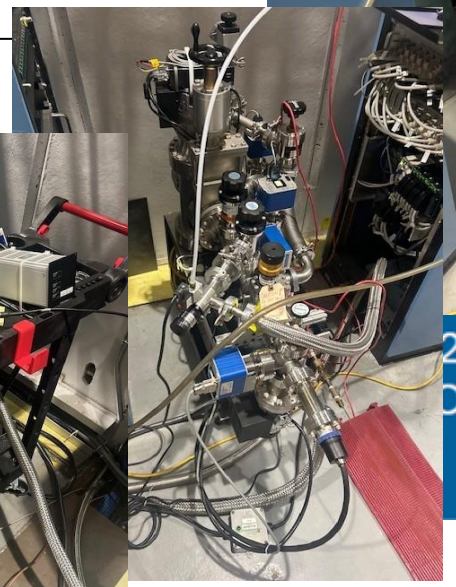
CTRL
SYS

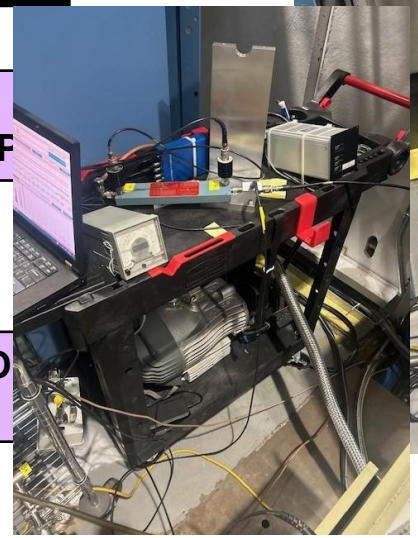
ARIS

DIAGNOSTIC
EQUIPMENT

INTERLO
BOX







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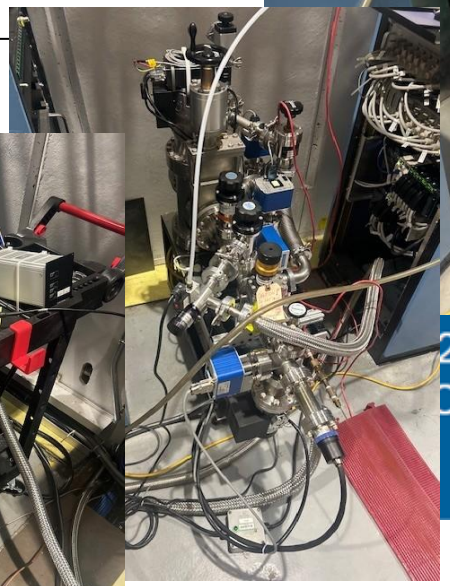

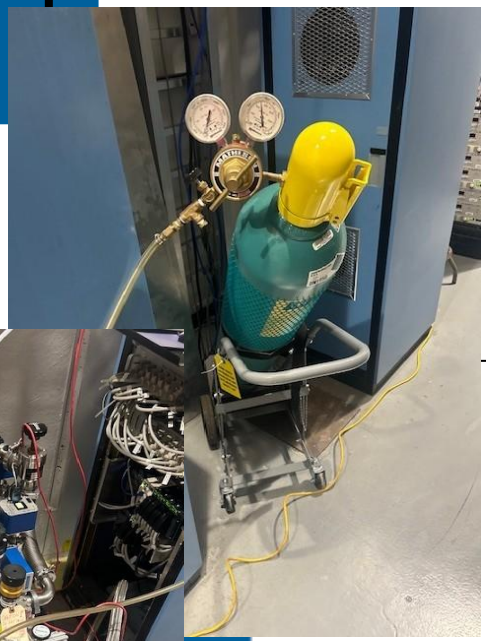

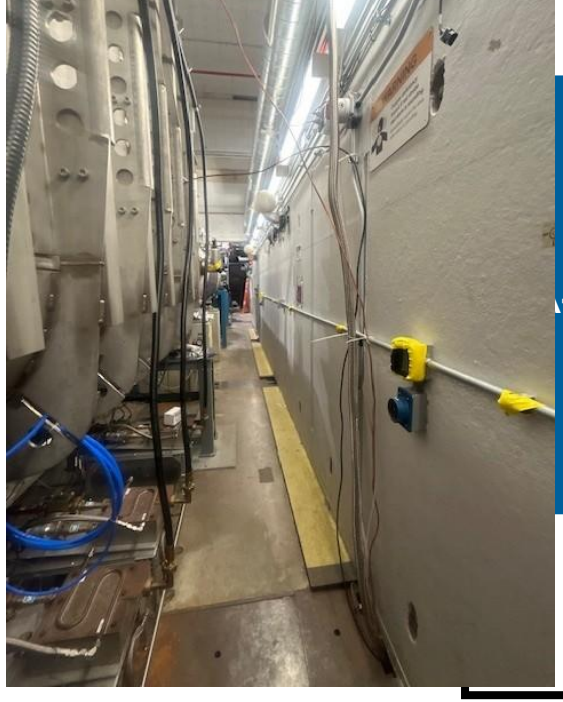

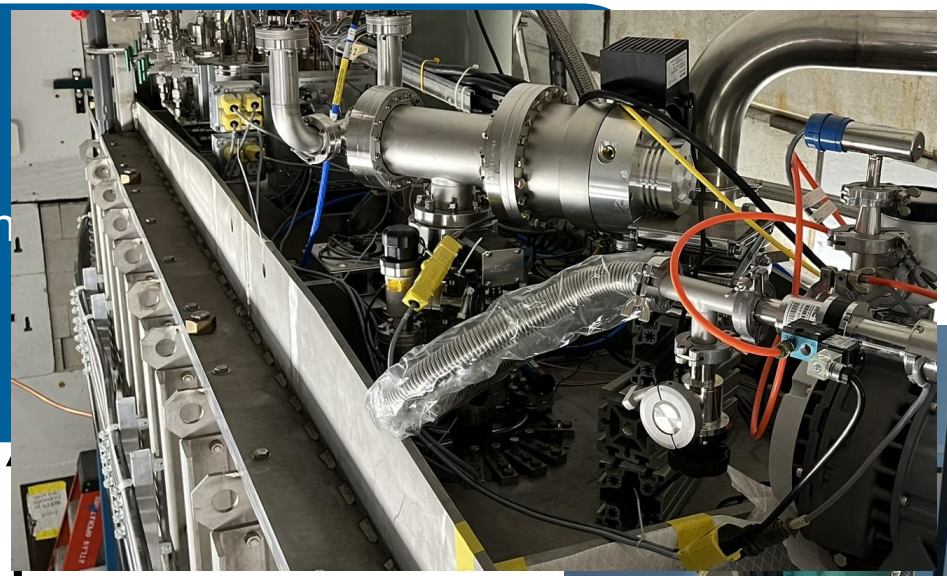

CRYOGENIC EQUIPMENT

ARIS

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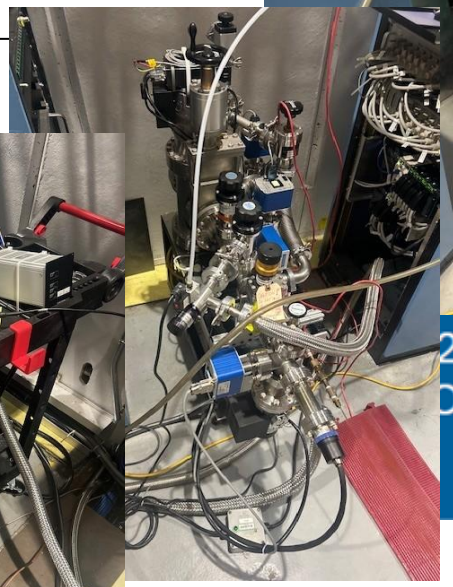
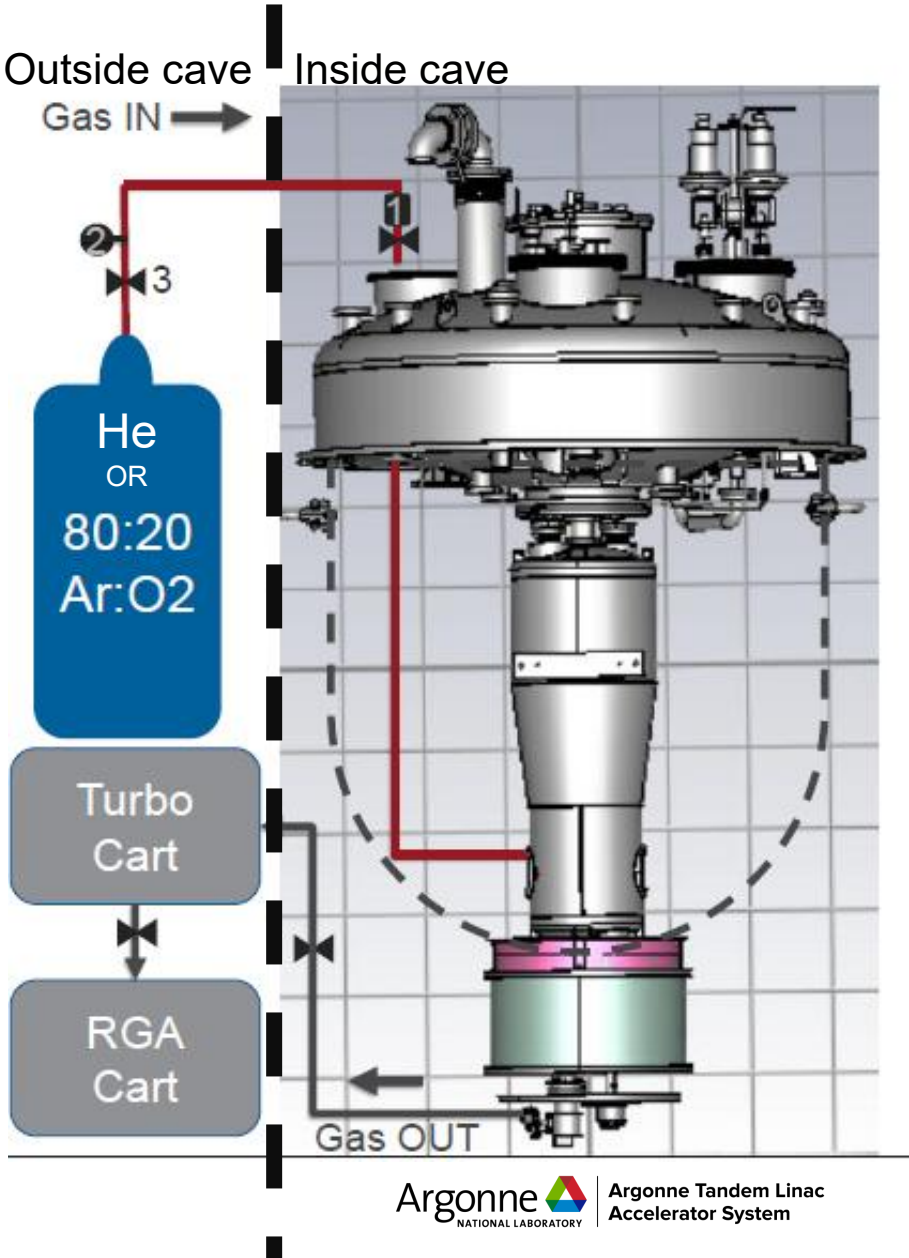
CTRL SYS



PROOF OF CONCEPT, PC, PP, HPP INVESTIGATIONS AND RESULTS

PROOF OF CONCEPT: TEST CRYOSTAT WITH A-TANK CAVITY DESIGN

- *72 MHz QWR bench top tests successful → pseudo in-situ w/ TC3*
  - Same cavity and coupler design as A-tank (moveable coupler by 3 in (7.62 cm))
  - Fundamental eigenmode plasma ignition
  - Clean room assembly: ultrasonic rinse, HPR, N2
  - PC, HPP, and PP with before and after cold tests
- Gas inlet: 1/8” cu line cleaned with HPR and N2
  - 0.01 micron filter on inlet
  - PP: Pre-mixed 80:20 Ar:O2 gas cylinder
  - HP: Pure He gas cylinder
- Had to use higher power amplifier for HPP vs PP
- Simulated valve incident: 50 Torr pure Ar gas into cavity space
  - Cold test after then comparison of PC, HPP, PP
- ➢ Parameters for PP:
  - 50-100 mTorr, ~10 watts, 72 hours total processing time
- ➢ Parameters for HPP:
  - ~5E-5 Torr vacuum, differential pumping
  - Not using RGA during He conditioning only plasma



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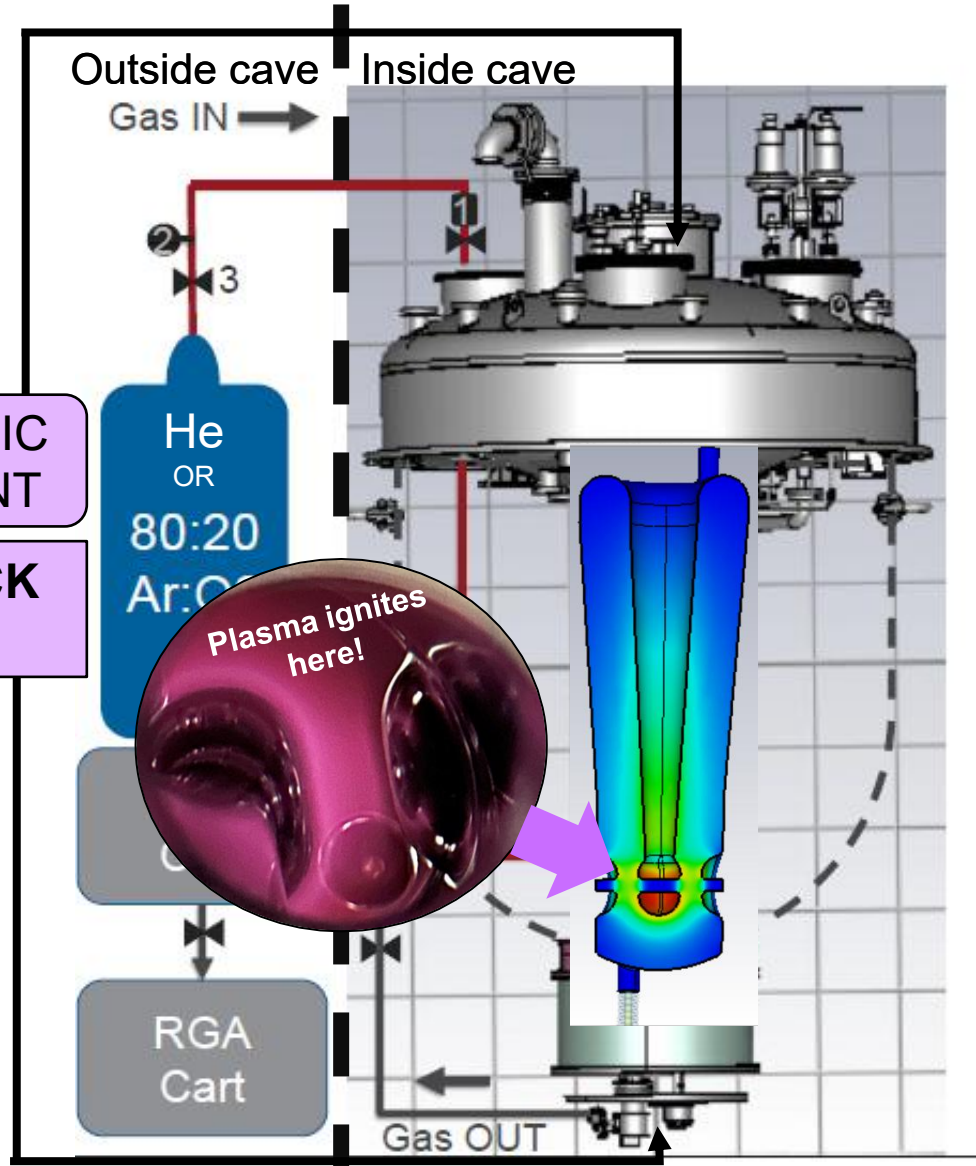
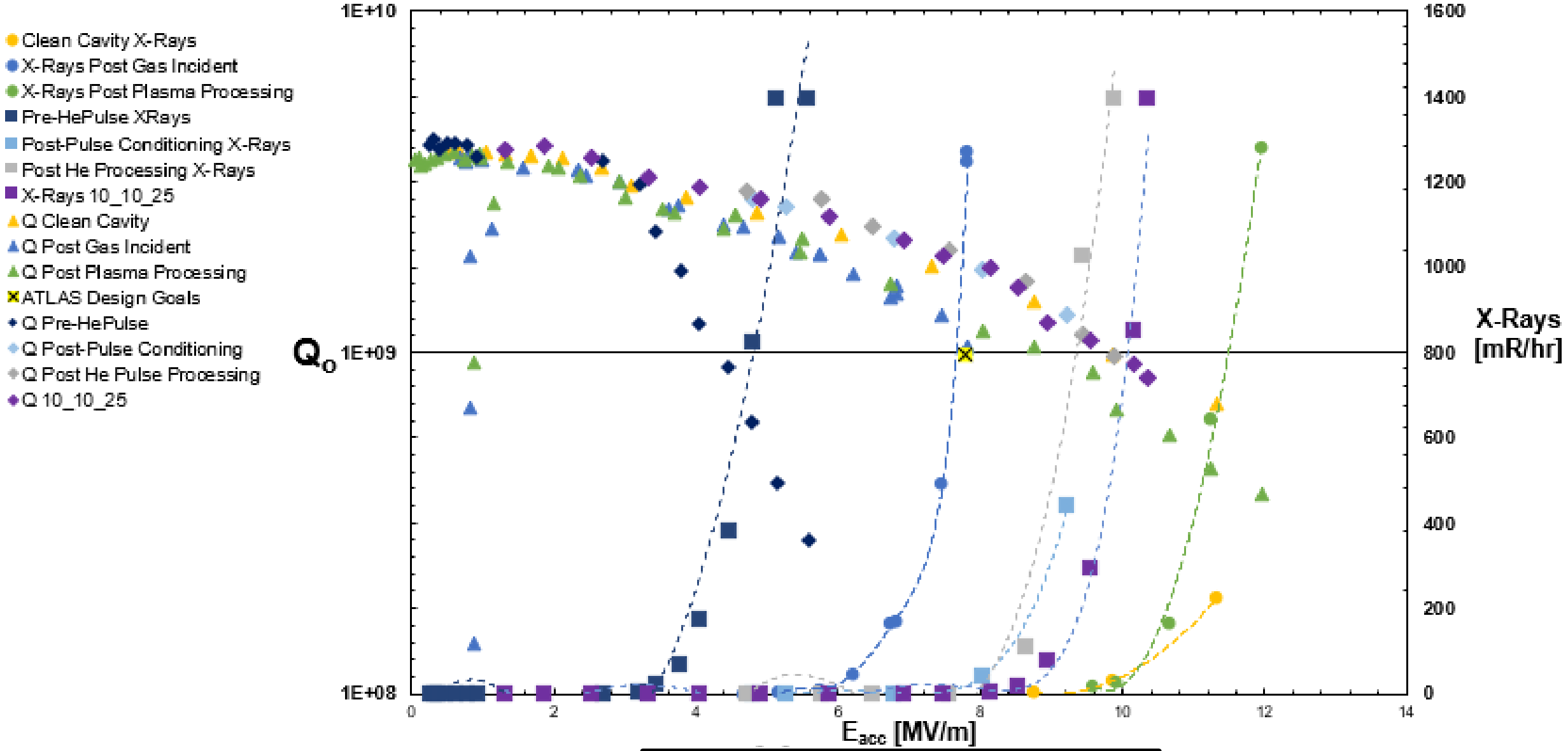
DIAGNOSTIC EQUIPMENT

INTERLOCK BOX



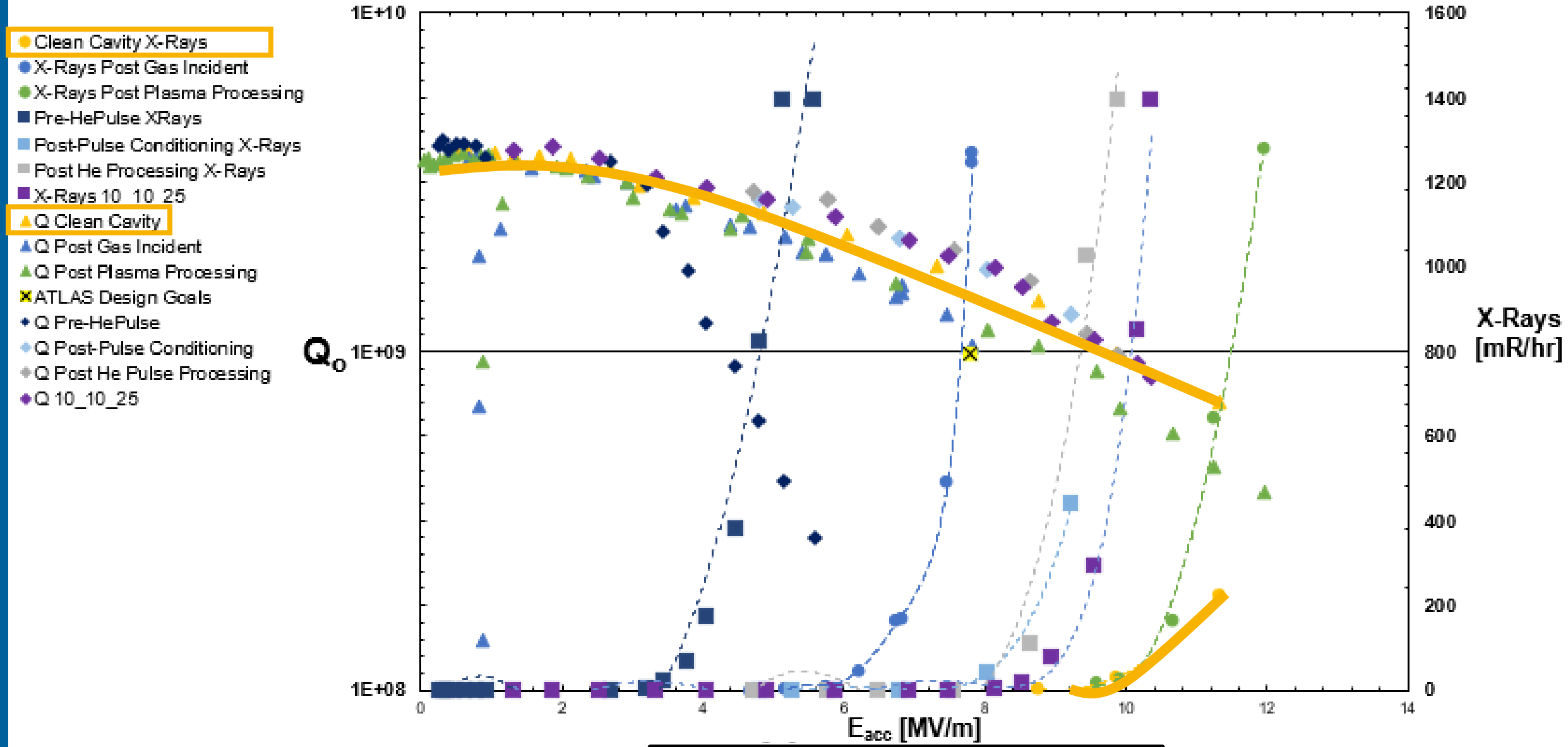
Interlock box to prevent coupler ignition

72 MHz QWR: Before/After Plasma Processing, He Pulse Processing, and Pulse Conditioning Cold Tests at 4K



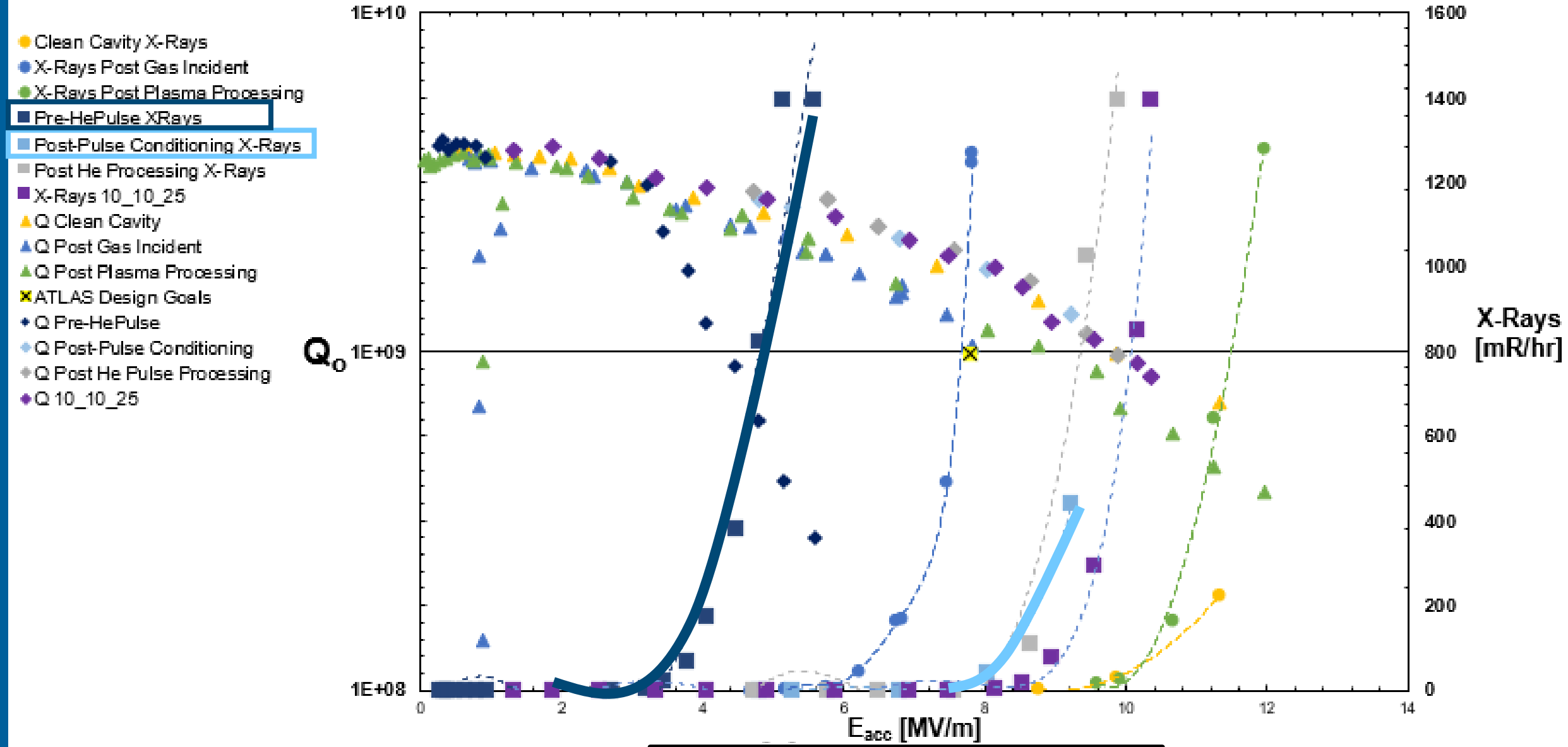
All Results

72 MHz QWR: Before/After Plasma Processing, He Pulse Processing, and Pulse Conditioning
Cold Tests at 4K



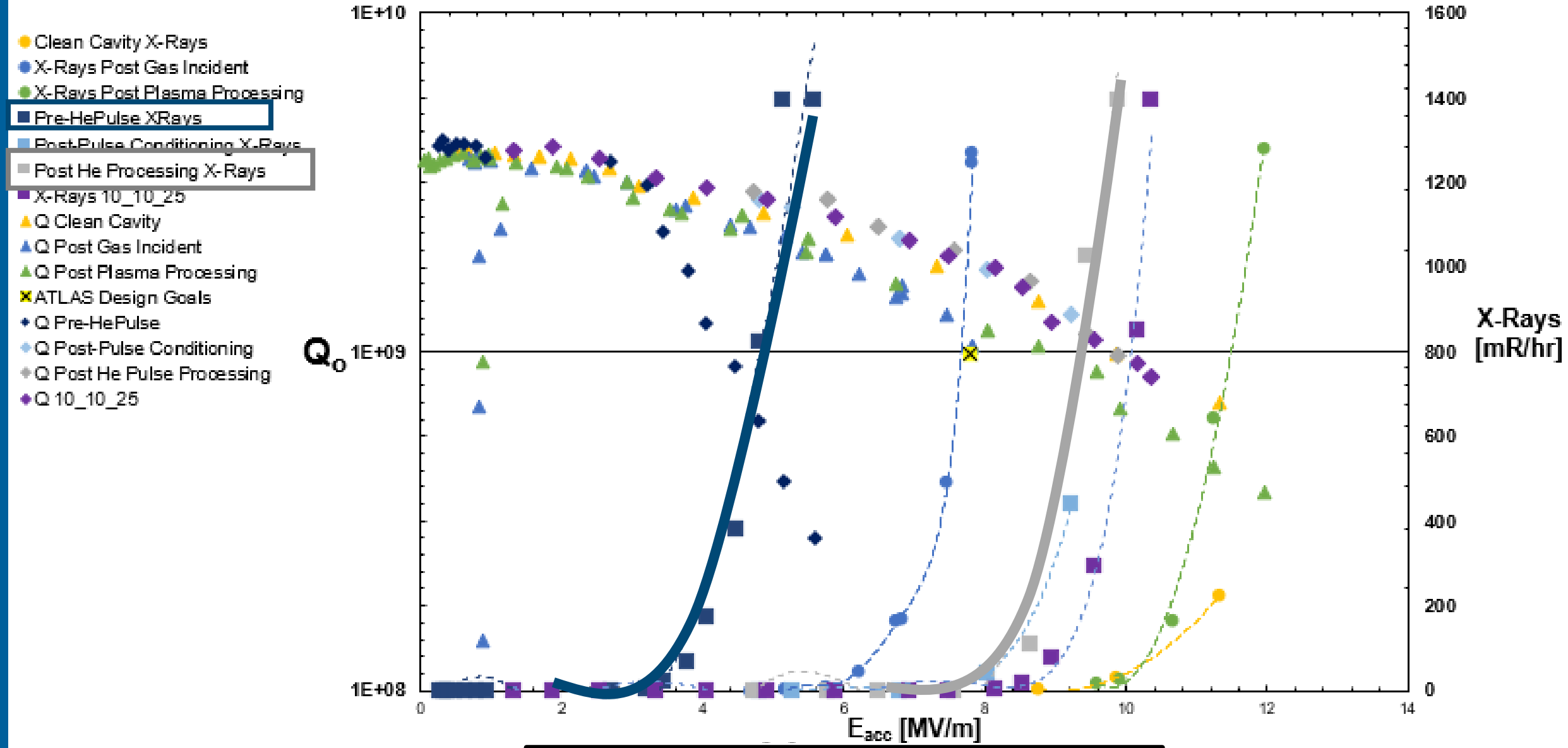
Clean Cavity

72 MHz QWR: Before/After Plasma Processing, He Pulse Processing, and Pulse Conditioning
Cold Tests at 4K



Pulse Conditioning

72 MHz QWR: Before/After Plasma Processing, He Pulse Processing, and Pulse Conditioning
Cold Tests at 4K



Helium Pulse Processing

72 MHz QWR: Before/After Plasma Processing, He Pulse Processing, and Pulse Conditioning
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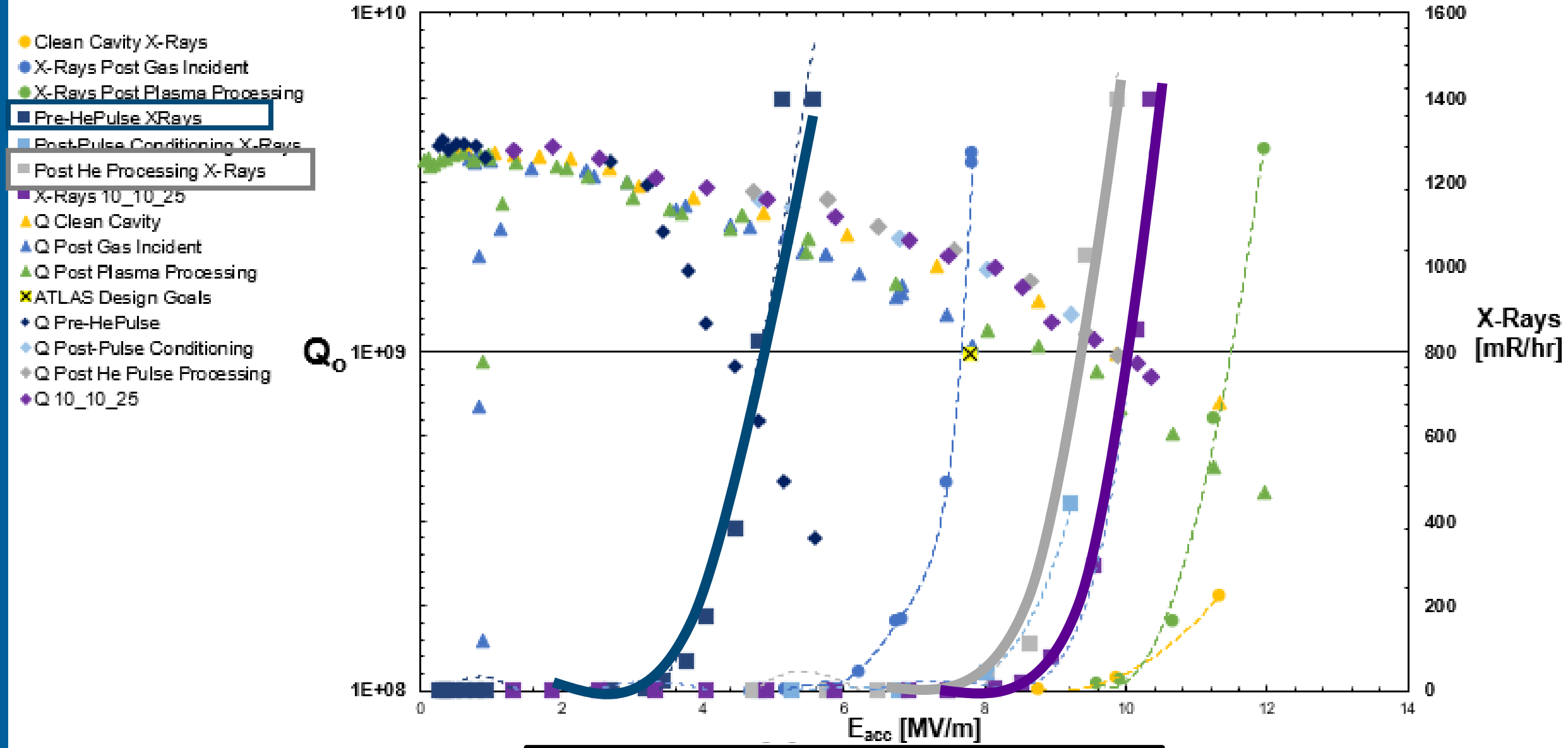

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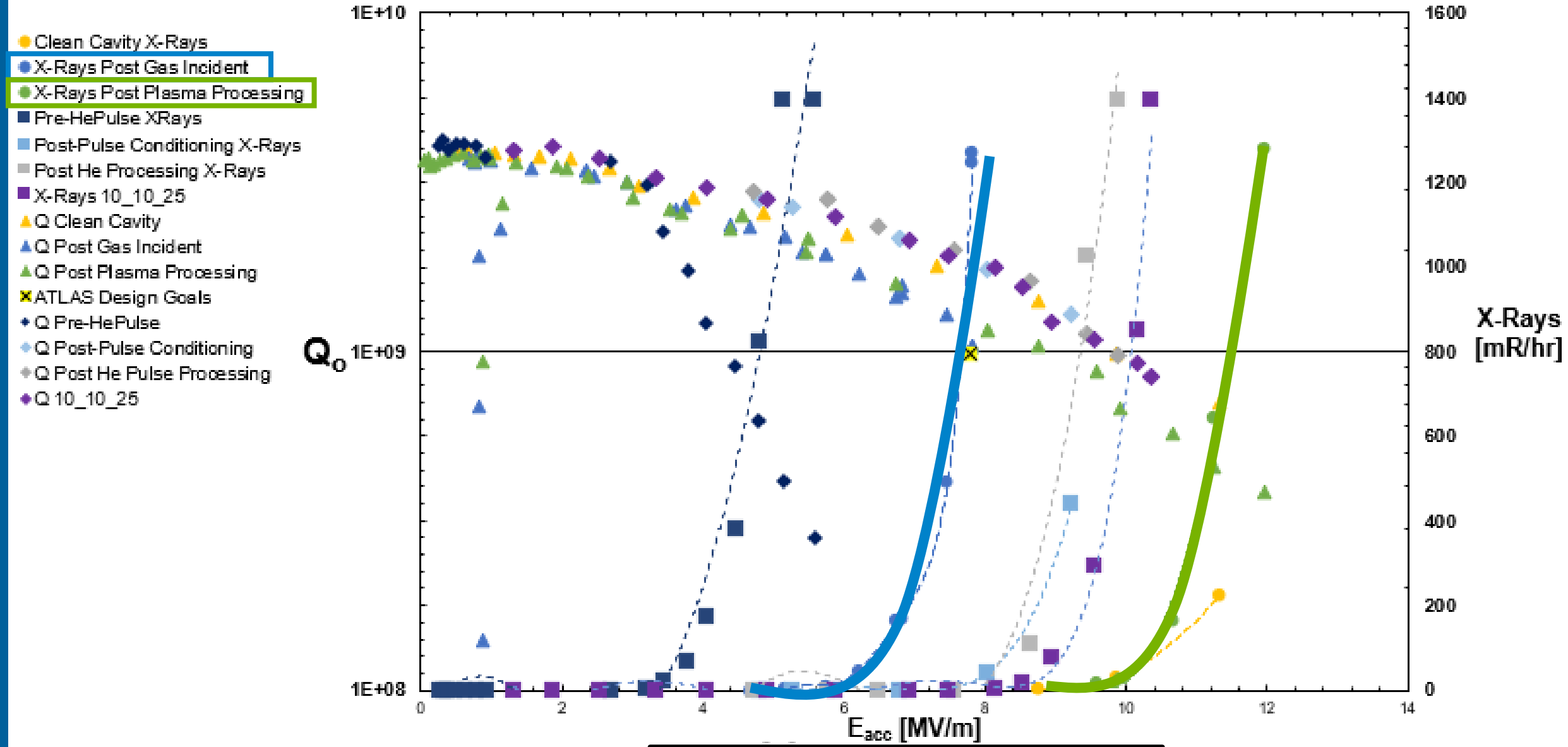
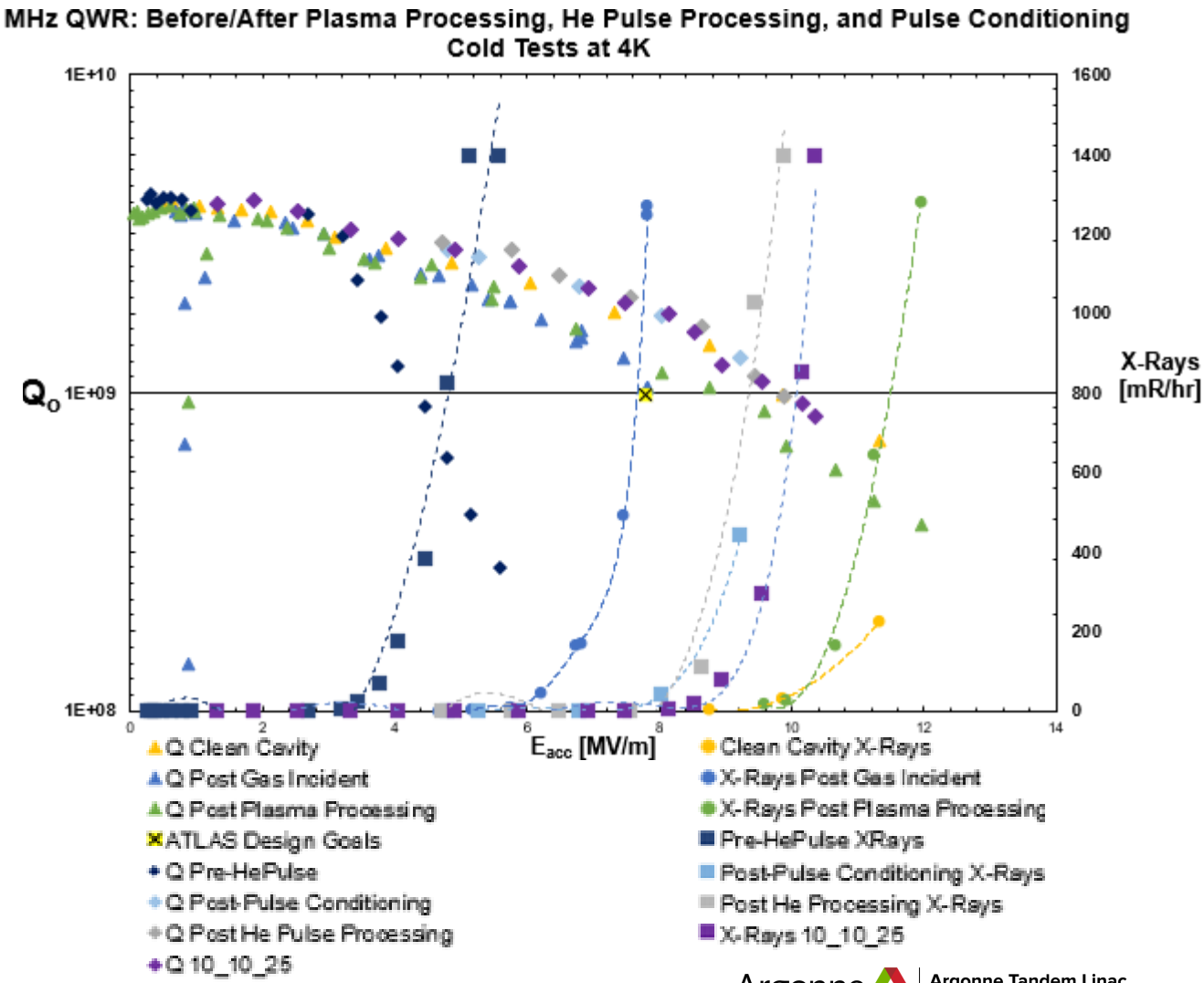


Plasma Processing

PROOF OF CONCEPT WORK CONCLUSIONS

TC3 tests before A-Tank and/or G-tank work

- PC works okay, HPP much better
- HPP with higher power amplifier (100's of Watts vs 1000's) increases improvement
- Plasma works great, though with AR:O2, very long processing time
  - Proven later from IJC Lab work (SRF25, C. Chenney)
  - Setup very possible with existing equipment, only need dedicated RGA and gas mixture
- If HPP has He gas increase too quickly, dragging in room air, could recover
  - Same for plasma gas mixture



IN-SITU TESTS WITH A-TANK CRYOSTAT: 72 MHZ QWR CAVITIES

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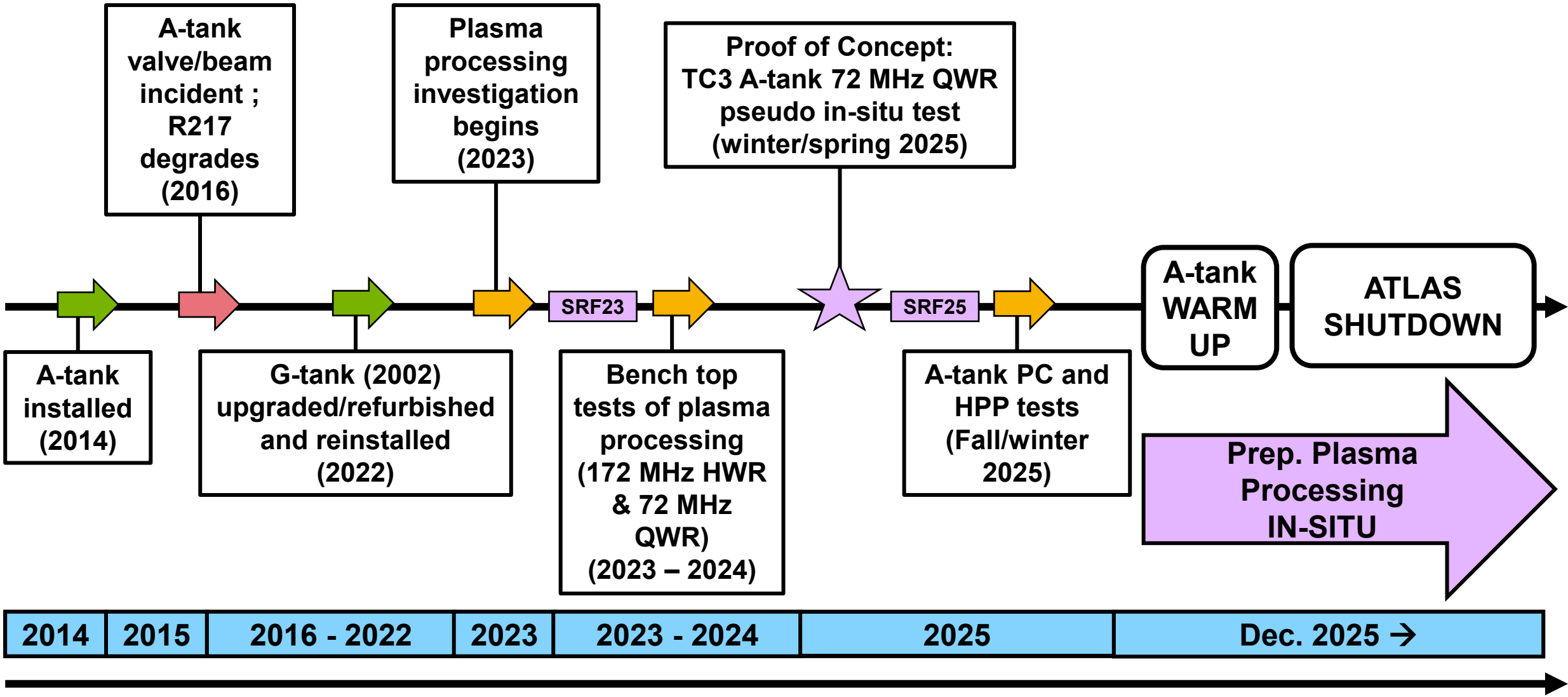
Argonne Tandem Linac Accelerator System

TIMELINE: EXPERIMENTS AND A-TANK IN-SITU

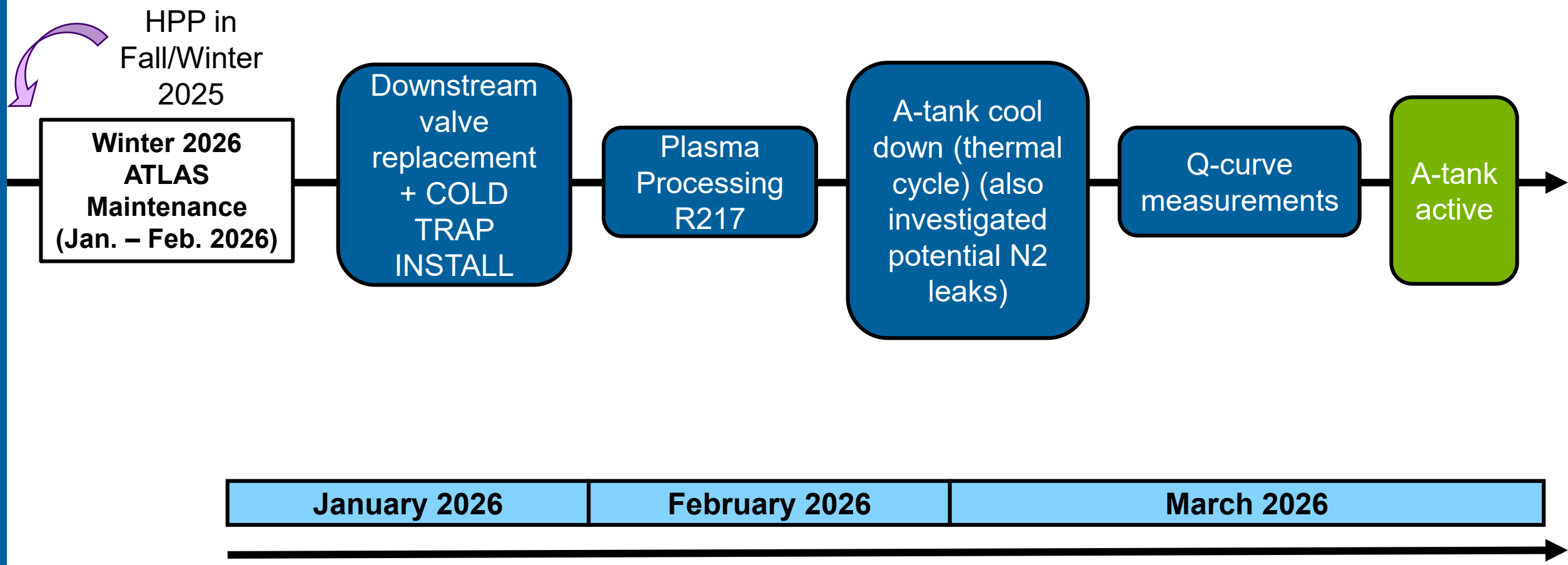


MAINTENANCE WORK ON A-TANK BEFORE PLASMA PROCESSING

Thermal cycle adjustment(s) and pulse conditioning

1. ~~Pulse conditioning~~ generally done after long shut down periods (days, weeks, or month down time)
   - Done before shutdown and after (but waited until post R217 plasma Q-curve)
2. ~~Helium Pulse Process~~
3. Thermal cycle goal: desorb possible frozen nitrogen on A-tank end cavities, improve Q
   - Investigate N2 leak when warming
4. Exit valve replacement on A-tank used portable clean room and HEPA filter(s)
   - Cold trap transported clean and installed under portable clean room
5. *THEN* we can plasma process…

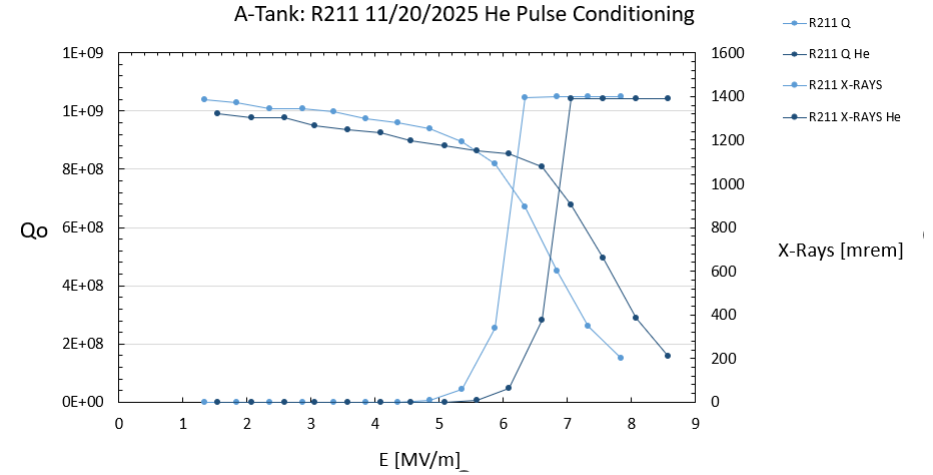
TIMELINE: EXPERIMENTS AND A-TANK IN-SITU

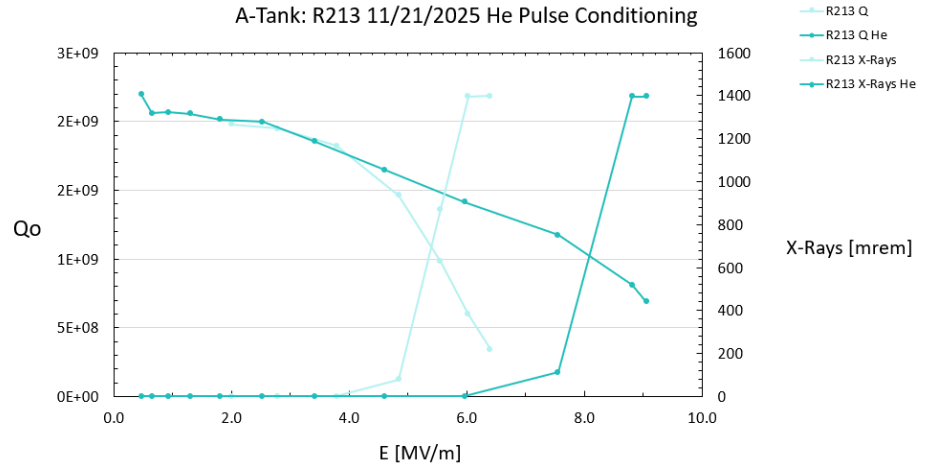


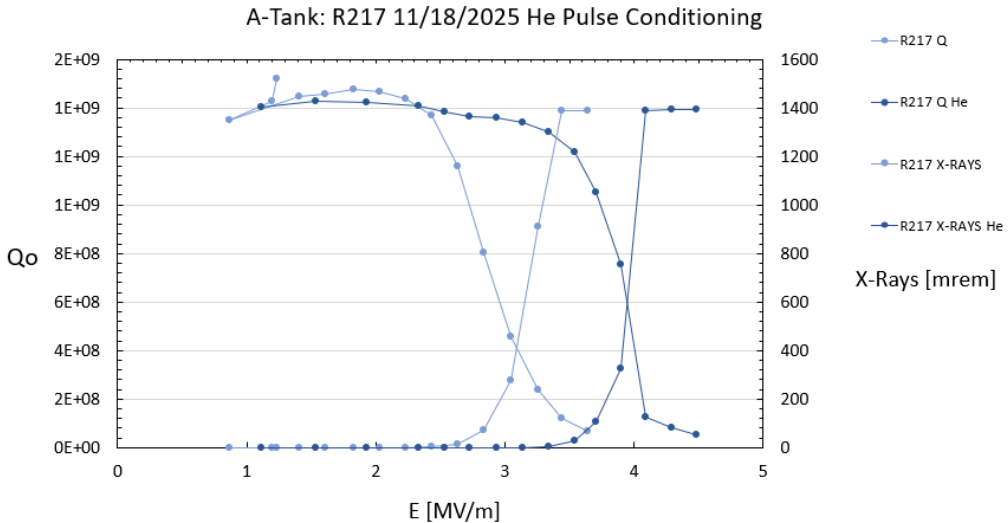
A-TANK HPP RESULTS

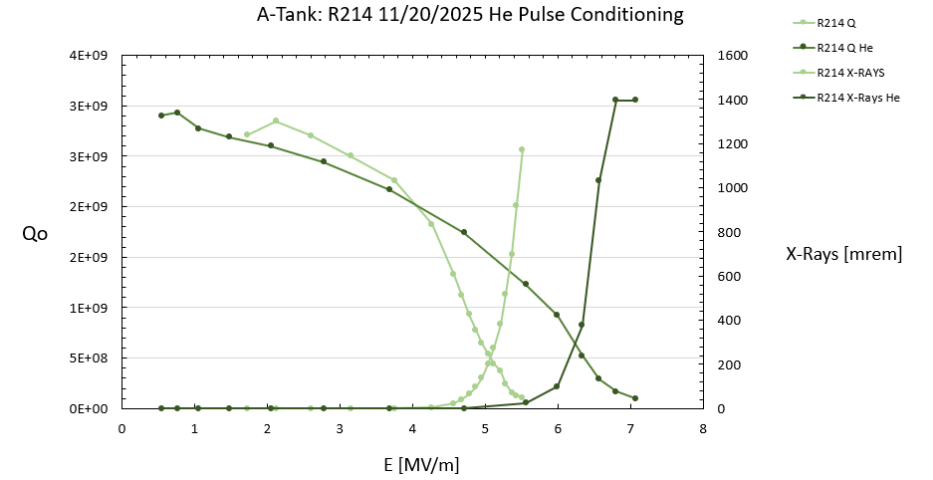
Specific resonator results from cryostat

- Pushed Q curve knee out for all cavities
- FE onset pushed out
- Total cryogenic capacity taken lowered by 10-15 watts
- Currently running at higher amplitudes with overall less radiation
- Overall energy gain from tank is ~10% more MeV





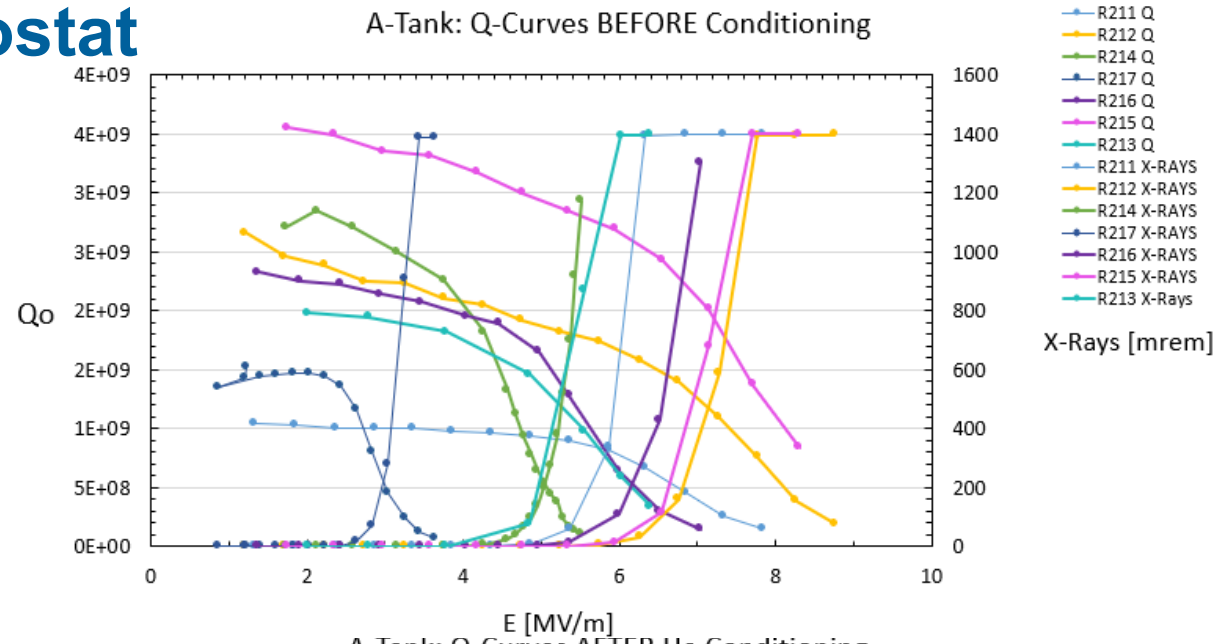


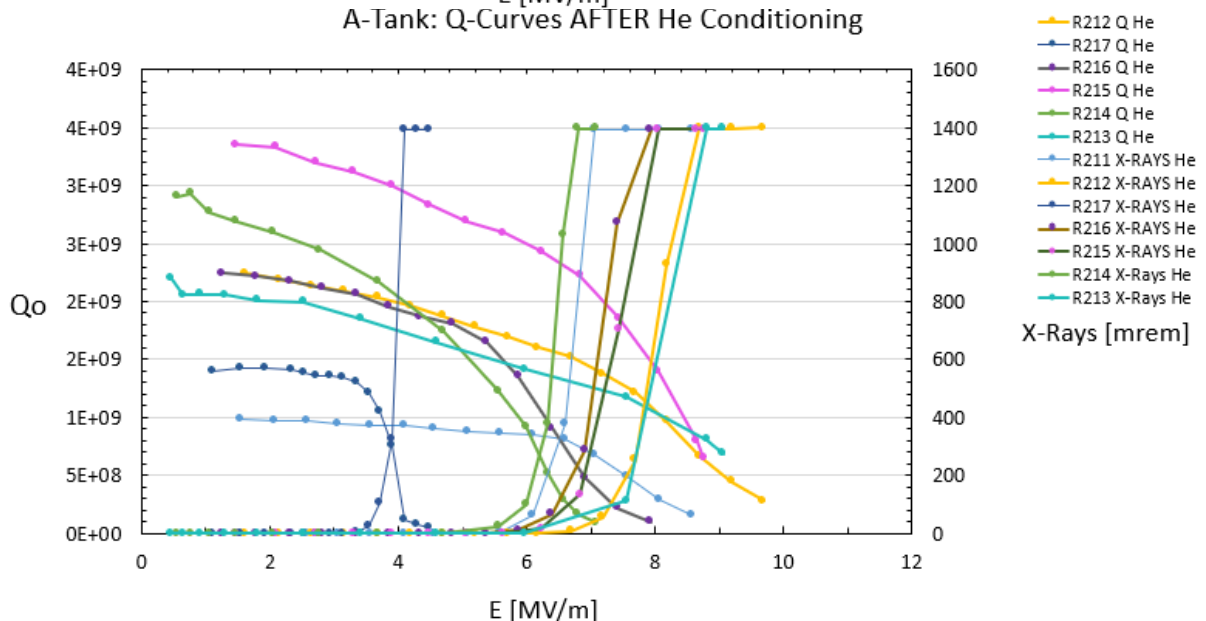


HPP RESULTS PROMISING, EASY TO IMPLEMENT

Executable in 1-2 days for whole cryostat

- Key results for the specific resonators show great improvement, other resonators still improved but less so
- R217 was barely on at 2.7 V, now consistently running 3.45 – 4.0 V
- Implemented on G-tank cryostat June 2026:
  - Gas was introduced to cavity space causing contamination
  - Followed same procedure but adjusted for higher amplitude conditioning and similar vacuum space
  - Operators could easily implement during overnight shifts
- Thermal cycle was able to improve end cavities Q slightly
- Slightly degraded FE on R211 after thermal cycle, He does enter in from the beam left side
  - Could HPP from downstream and work backwards





PLASMA PROCESSING AND THERMAL CYCLE

Executable in 1-2 days for whole cryostat

- Key results for the specific resonators show great improvement, other resonators still improved but less so
- R217 was barely on at 2.7 V, now consistently running 3.45 – 4.0 V
  - Plasma processing pushed FE out even further
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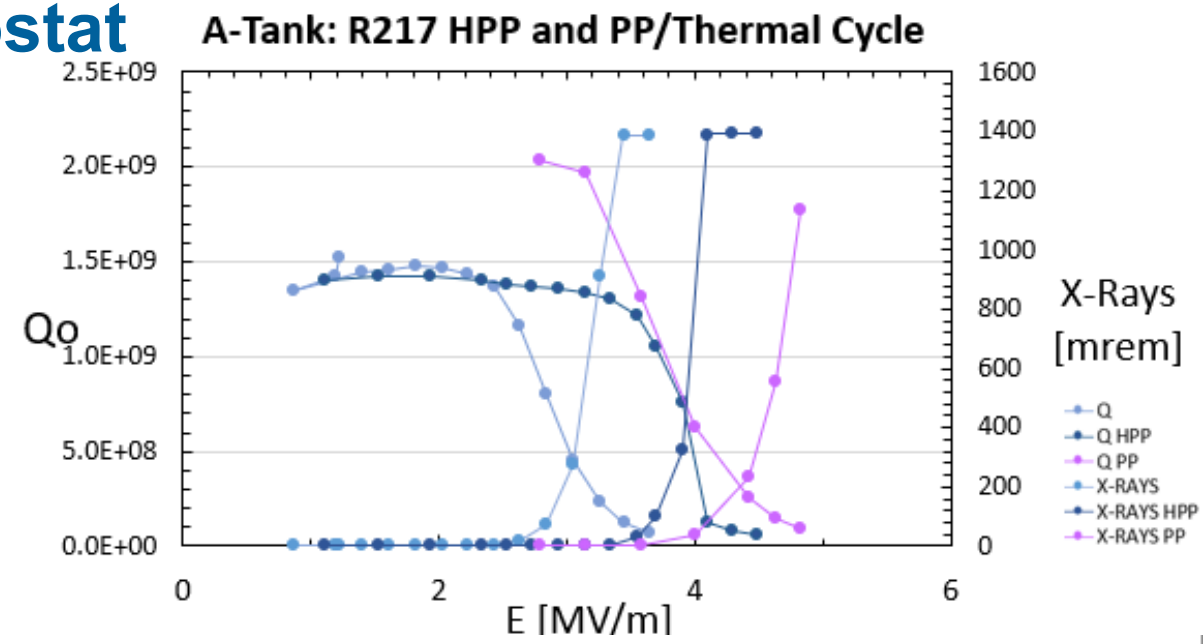

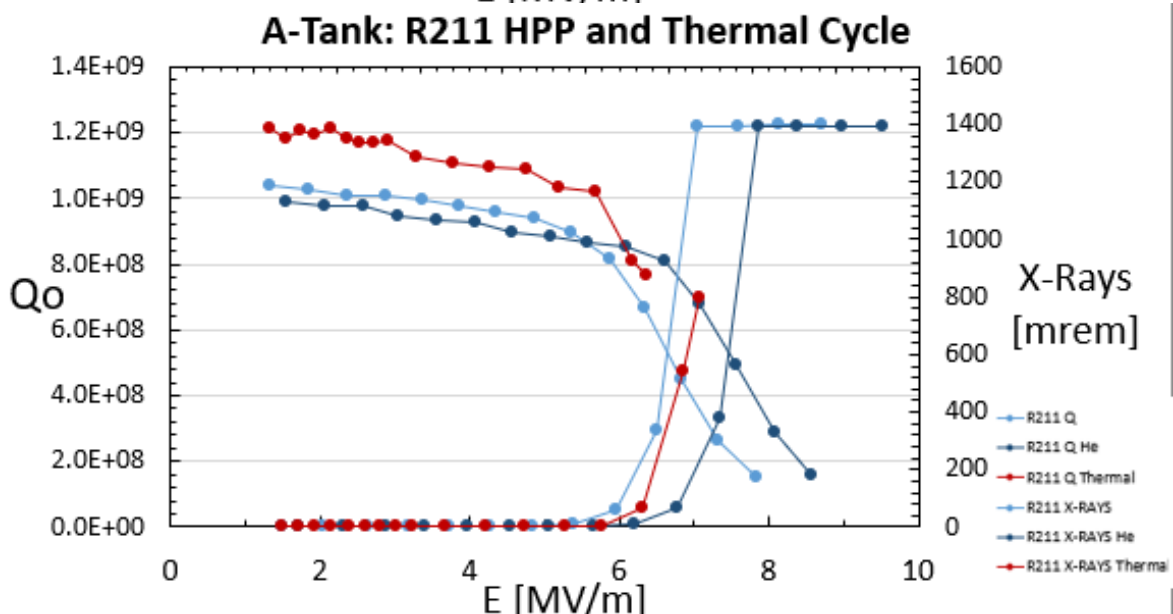

CONCLUSIONS, NEXT STEPS, DISCUSSION…

- **Helium pulse processing:** easy to implement and *operators can perform during downtime (during some development days we did this)*
- **Pulse conditioning** eventually stops helping degradation, pro: general task *operators do*
- For higher power amplifiers, circulators on resonators need to be built to withstand the high-power pulse conditioning
- **Plasma has excellent results in fundamental mode; *if you have equipment around you can implement this at a low cost***
  - Recipe comparison; advantages disadvantages
  - Ways to implement this without any modifications to already installed cryostats vs resonators being upgraded and what could be added to could help later processing
  - HOM's seem like good idea but have shown cavities *degrading* for some cases; needs more study
  - What combination of PC, HPP, and Plasma could be most beneficial
    - Degradation after time passes ?
- **Currently HPP on G-tank 109 MHz QWRs after gas cell incident**
  - **Showing improvement in radiation, heat load, and stability**
- Depending on situation, could need different technique…


THANK YOU ☺


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