

Characterizing Pressure and Transmission Measurement Discrepancies in the LCLS-II SXR Gas Attenuator and GMD/XGMD

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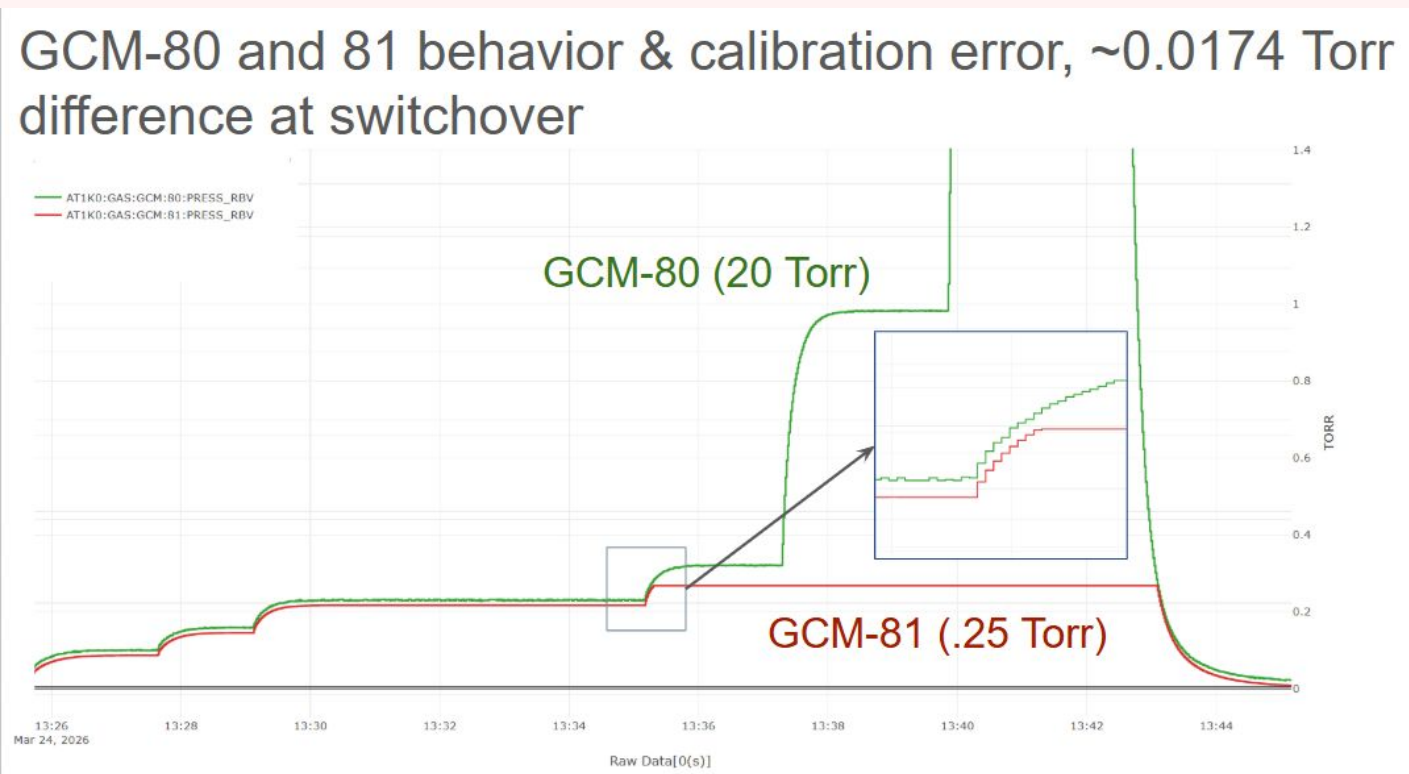
INTRODUCTION

The SXR Gas Attenuator (GATT) is an instrument that uses Argon (Ar) or Nitrogen (N₂) gas to adjust the attenuation of the SXR Free-Electron Laser (FEL) beam.

- Improving the accuracy of the GATT can allow users to obtain the desired attenuation for LCLS experiments quicker and in a more reliable way

PROBLEM STATEMENT

- There are **significant differences** between transmissions calculated by the GATT and the measured transmission with FEL beam using the upstream GMD and downstream XGMD
- Especially prominent at lower pressures, < ~3 x 10⁻² torr
- The GATT uses two pressure gauges depending on the operating range (0–0.25 and 0–20 Torr)
- There are **inconsistencies** in readings between the two gauges—GCM-80 (20 Torr) & GCM-81 (.25 Torr)



- Based on data sheet & trends, need for zero adjustment suspected

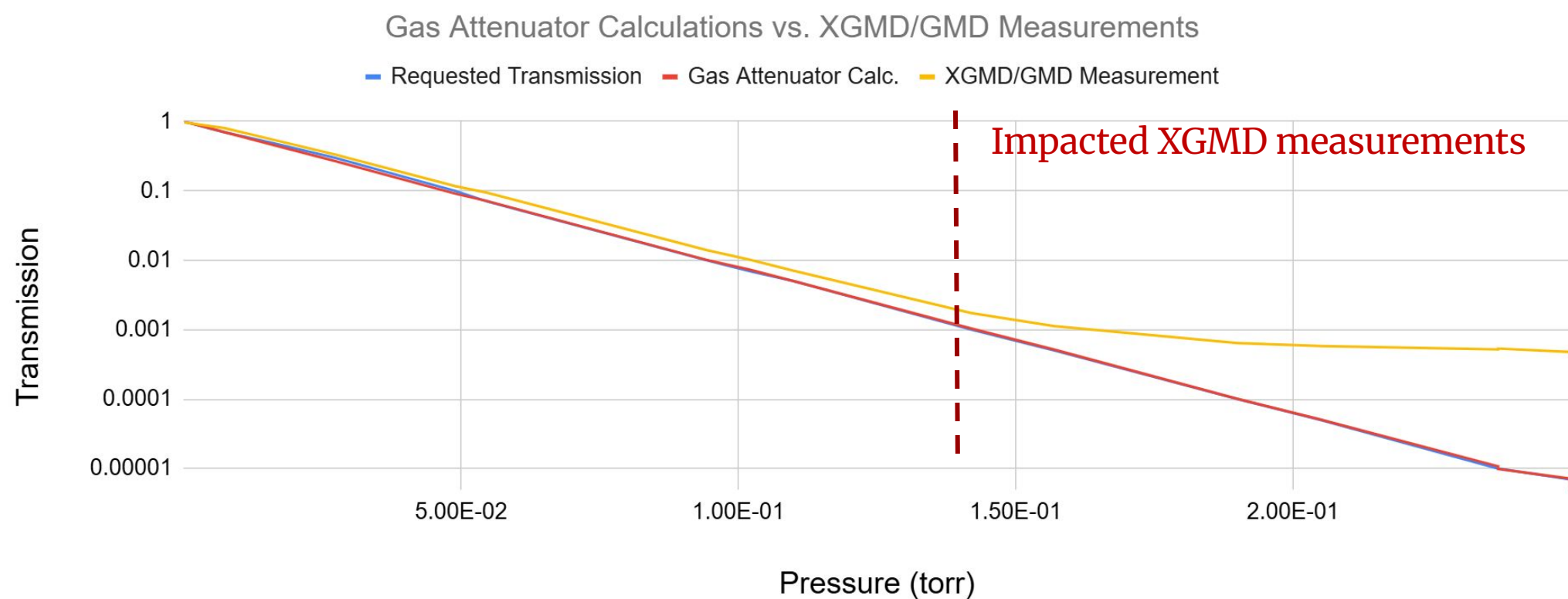
Accuracy - % of Reading* 0.25% for 1 to 1000 Torr, 0.50% for < 1 Torr (626C only)
Resolution 0.001% of Full Scale

OBJECTIVES

- Calculation Validation:** Verify GATT transmission calculations w/ the Beer-Lambert Law
- Evaluate Pressure Gauge Discrepancies:** Determine whether a zero adjustment resolves discrepancies or if a third gauge is required
- Explore other potential causes of error:** discrepancies in eV readings, temperature, inherent uncertainty with mass attenuation coefficients

ANALYSIS

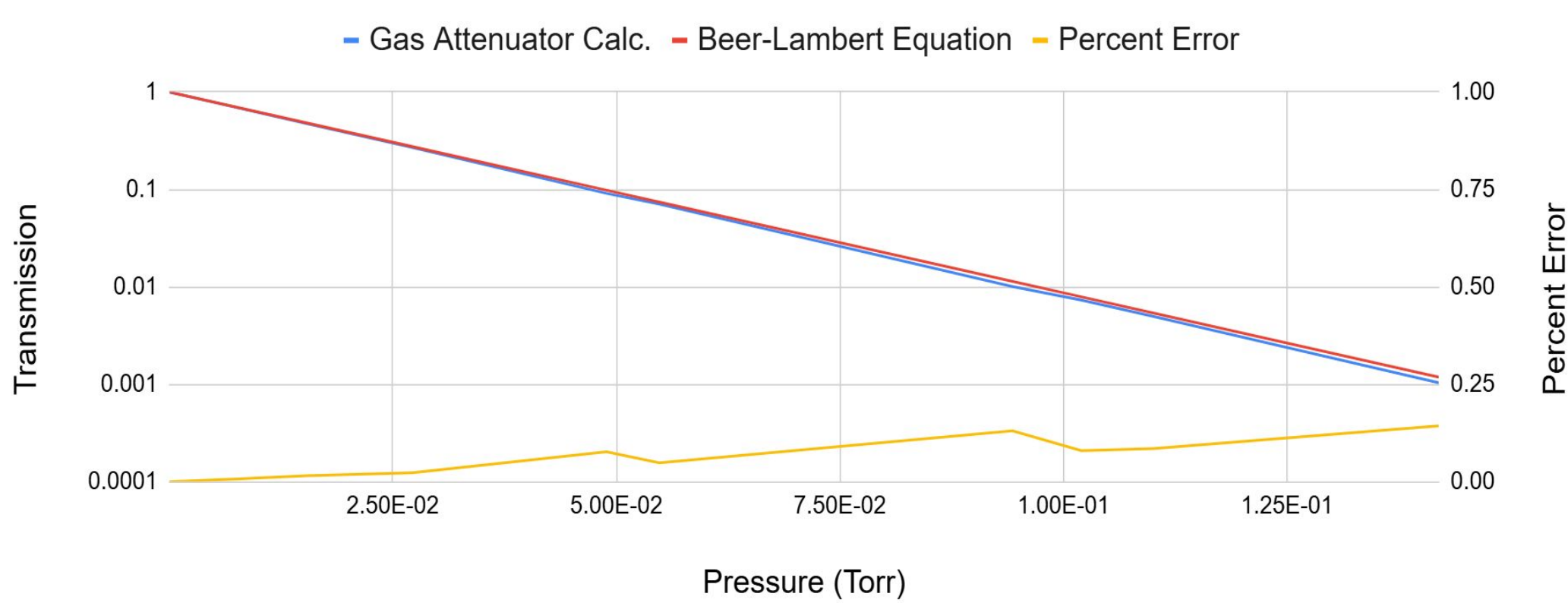
Data Collection



- XGMD/GMD measurements used as a baseline reference for expected transmission values & GATT performance
- Removed data points at transmissions < 10⁻³ due to dark current impacting the accuracy of the XGMD

Verifying Gas Attenuator Calculations

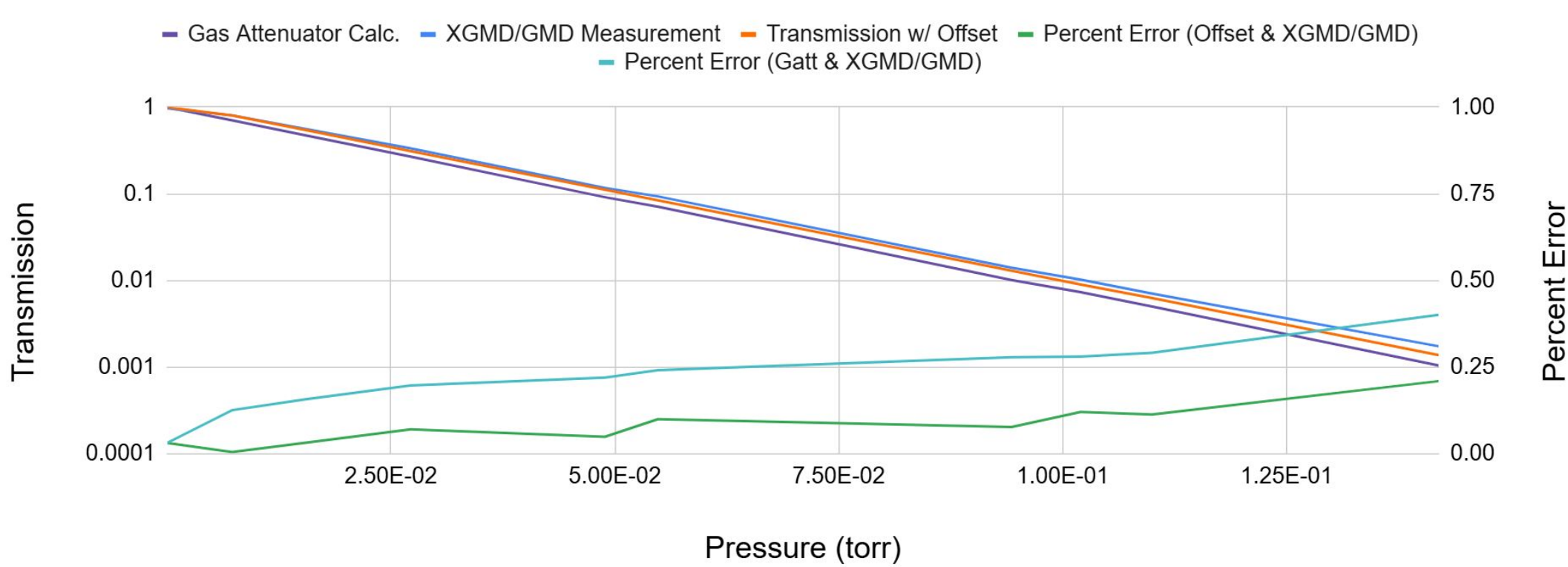
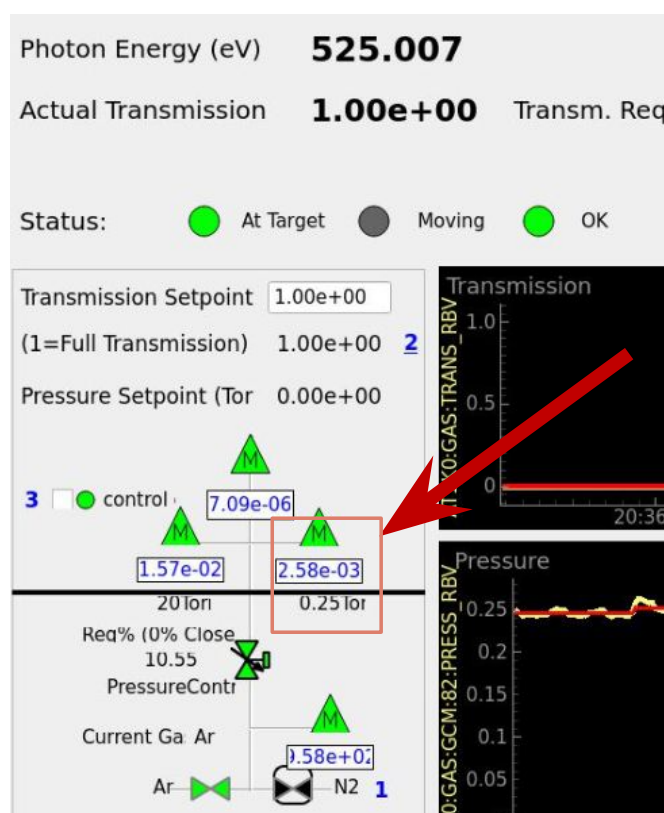
- Comparing GATT calculations with what would be calculated using the Beer-Lambert Law



- Beer-Lambert predictions closely match the GATT calculations, with errors ranges from ~0.01% to 14%

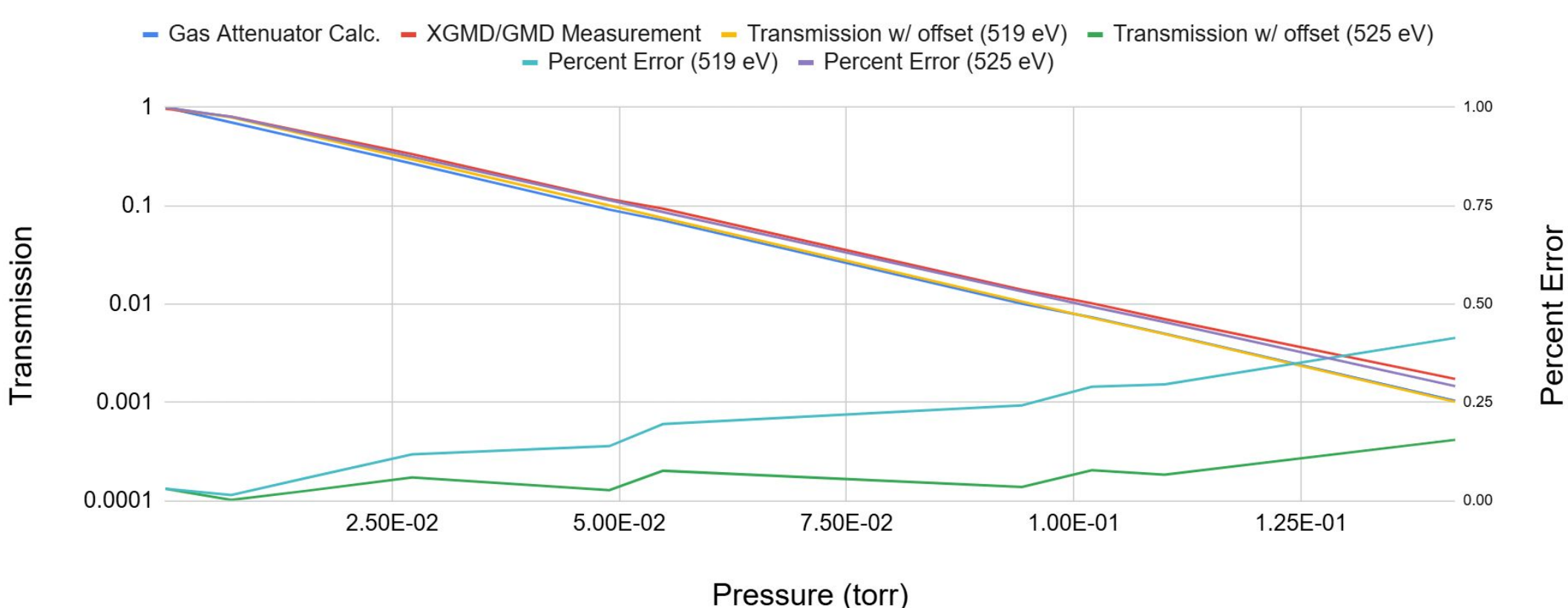
Simulating a Gauge Zero Adjustment

- Applied a -2.58E-03 torr offset to all pressure readings
- Based off GCM-81 pressure readings at full transmission
- Used 525 eV in calculations



- Before offset:** Percent Error range from ~ 3% to 40%
- After offset:** Percent Error range from ~0.4% to 21%

Difference in eV readings: XGMD read 519 eV while GATT read 525 eV



BACKGROUND

Attenuation - measure of how much the incident X-ray beam is weakened by the material it is passing through
Transmission - fraction of the initial X-ray beam that passes completely through a material without being absorbed or scattered

Beer-Lambert Law - describes attenuation

$$\text{Transmission} = \frac{\text{exit}}{\text{incident}} = \frac{I}{I_0} = e^{-\rho \cdot t \cdot (\mu/\rho)}$$

Note: Changes in pressure has an exponential effect on transmission

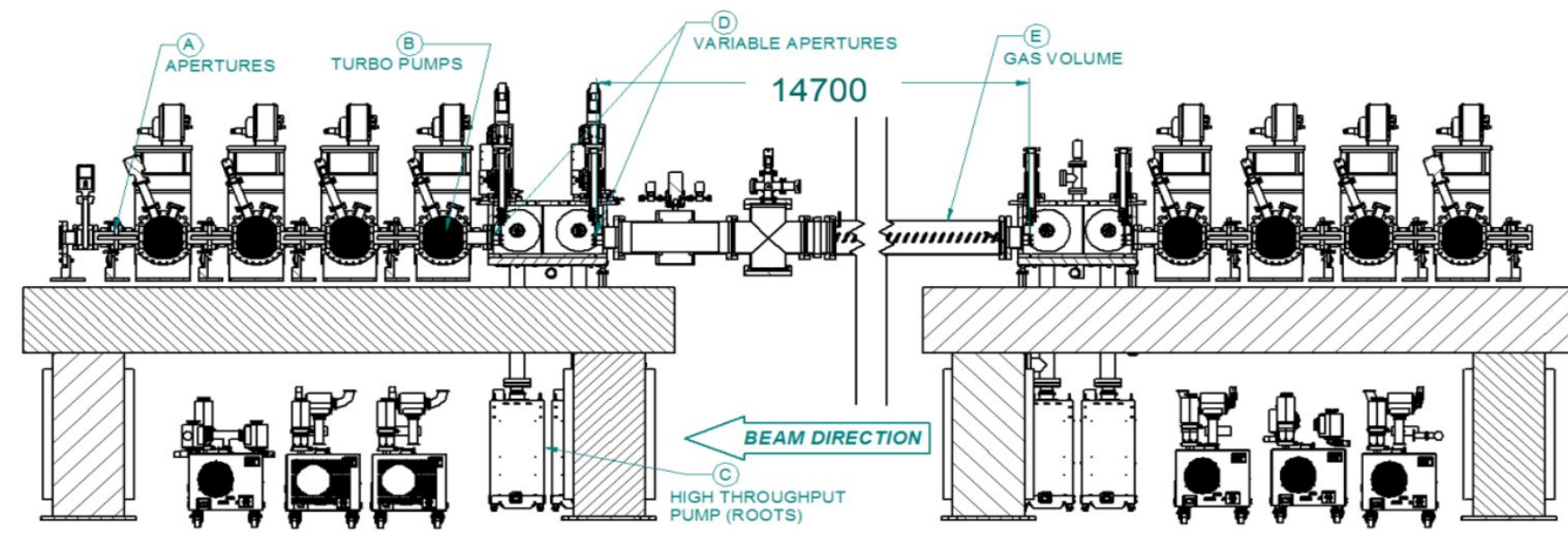


Diagram of the gas attenuator

FINDINGS & CONCLUSIONS

- Findings support applying a zero adjustment to GCM-80 & 81
 - Pressure offset reduced percent error with XGMD/GMD from ~3–40% to ~0.4%–21%
- Differences observed between GATT calculations and Beer-Lambert predictions
 - Further analysis needed to determine whether these difference are intentional and beneficial
- The GATT and the GMDs use a slightly different photon energy value [eV], contributing to additional transmission discrepancies

NEXT STEPS

- Develop a calibration method for the pressure gauge offsets
- Determine combined uncertainty to determine the achievable accuracy of GATT transmission calculations
- Repeat measurements to quantify XGMD/GMD measurement uncertainty
- Expand testing to GCM-80 and additional photon energy ranges

ACKNOWLEDGEMENTS

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REFERENCES

- [1] SLAC National Accelerator Laboratory, XTES Gas Attenuator, LCLSII-3.5-ES-0239-R0, 2015