New Technology for Accurate LENR Measurements and Materials

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Outline

- Introduction to CEES at Texas Tech
- Improved Calorimeters
- New Pulsed Evaporative Calorimetry
- New Mass Spectrometer System for Nuclear Science
- Concluding Thoughts and Opportunities

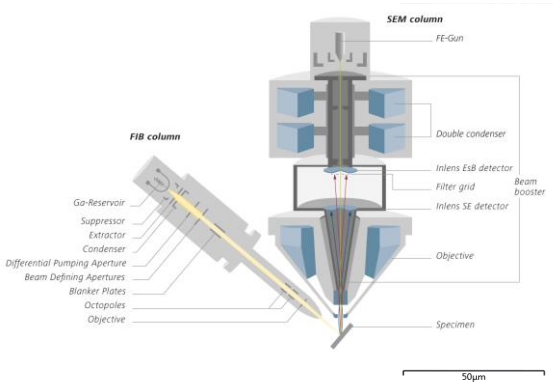
CEES at Texas Tech University

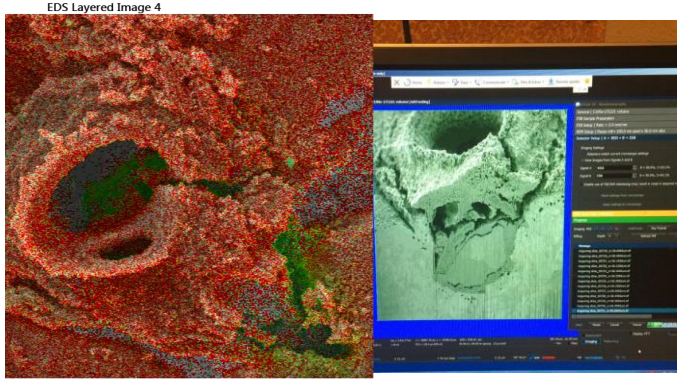
Four Ph.D. scientists, five M.S. engineers, five technicians, one admin. We center our efforts on greatly improved metrology and advanced material science for use in LENR, and in the development of alternative nuclear tech.

Many interesting LENR observations still remain unexplained, with a huge potential value to society if they someday prove viable in energy science. This justifies a substantial development in new technology. This new technical capability has facilitated alternative nuclear technology development at universities.

CEES capabilities include advanced metallurgy and welding, 3D printing, machining, SEM / TEM imaging, FIB nano-milling, CVD, wide-area mapping of electrodes, change detection, AI-based emergent feature detection in materials / statistical analysis, and physical and chemical characterization technologies (XRD, XRF, EDS, EBSD, etc.)

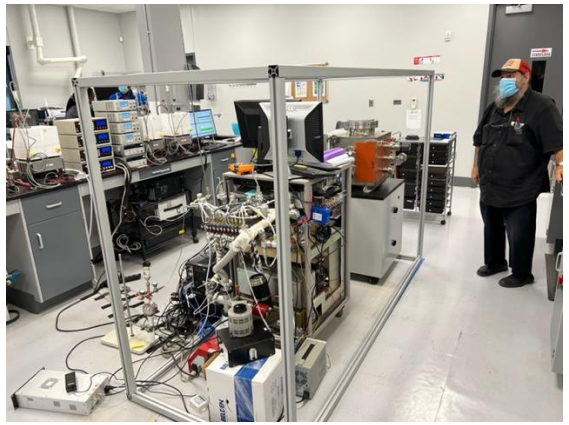
Includes a Zeiss 540 Cross-Beam Imaging / FIB System:
20 nm imaging / elemental analysis / structure res,
50 nm FIB cut-away resolution across entire cathode.
Advanced Hitachi TEM capabilities, and collaborations (MURR) for reactor and cyclotron irradiations.

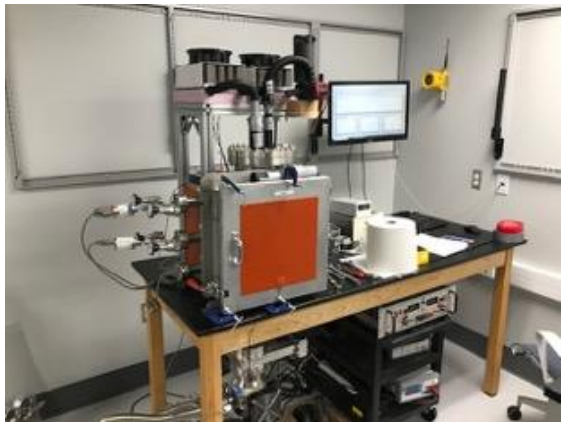


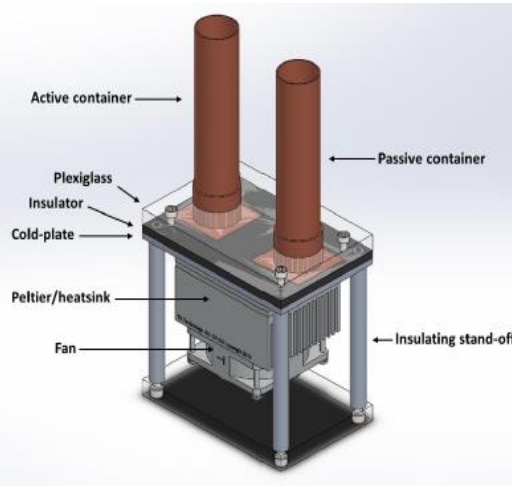


Improved Calorimeters at CEES

- All calorimeters feature concurrent analysis of ^{4}He, ^{3}He with 0.5 pMole accuracy, and tritium analysis to better than fMole accuracy
  - Immediate vapor phase analysis (discussed later in detail)
  - Advanced solid-state extraction technologies
- New vacuum calorimeters support both electrochemical and gas-loaded LENR measurements
  - Calorimetric sensitivity of 0.5 mW
  - Reproducibility to within 0.1% to 10W, better than 2% to 20W
  - 'Gold Standard' verification of open-air calorimetry
  - Different, and much smaller systematic errors than in open-air
- New inexpensive open-air calorimeters for LENR
  - Calorimetric sensitivity of 0.5 mW
  - Reproducibility to within 0.5% to 10W





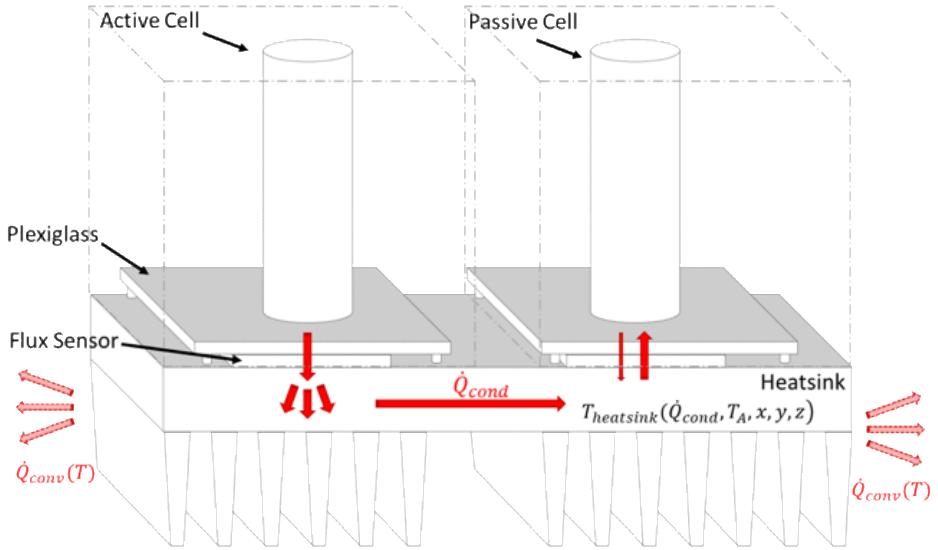


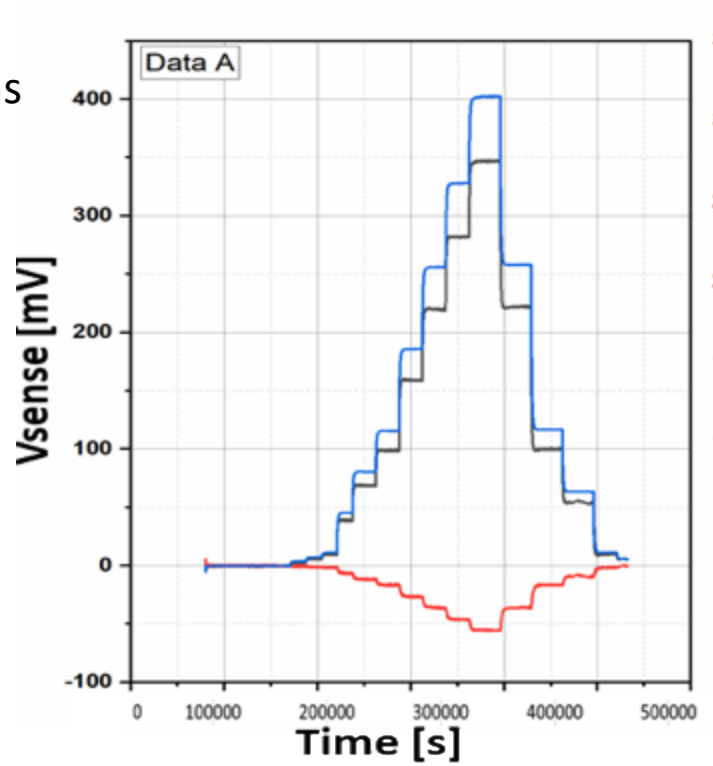
"A solid-state, open-system, differential calorimeter" by Shelby Lacouture, Trevor Dardik, Dennis Van der Vliet, Jephtah Akene, Samuel Adeosun, and Robert V. Duncan, Review of Scientific Instruments **91**(9), 095102 (2020). doi: 10.1063/5.0013591

Open-air calorimeters, cooled baseplate performance data

LENR measurements are often conducted on differential open-air calorimeters, but these conventional devices give false excess heat indications
Gradients in the baseplate heat sink create the appearance of excess heat

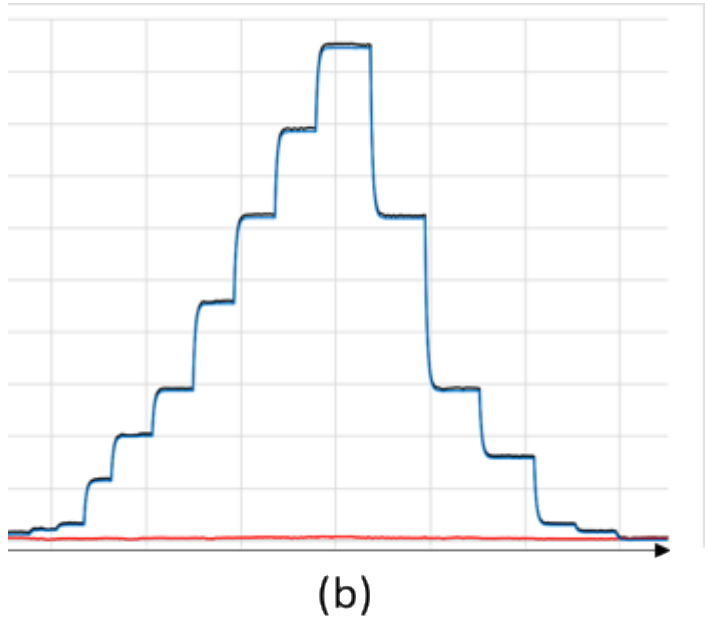
- Out-of-balance between the active and dummy calorimeter tubes result in sensitivity to environmental variations (temperature, air flow, etc.)





Conventional Calorimeter
False excess heat indication

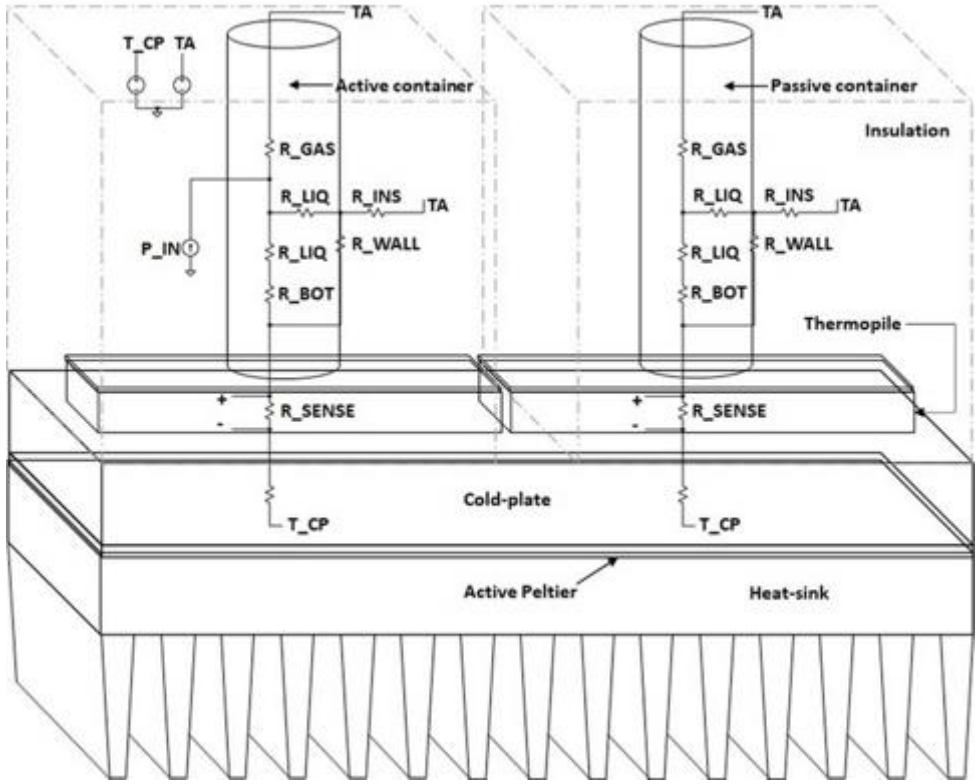
V_p: Active, Passive, Active - Passive



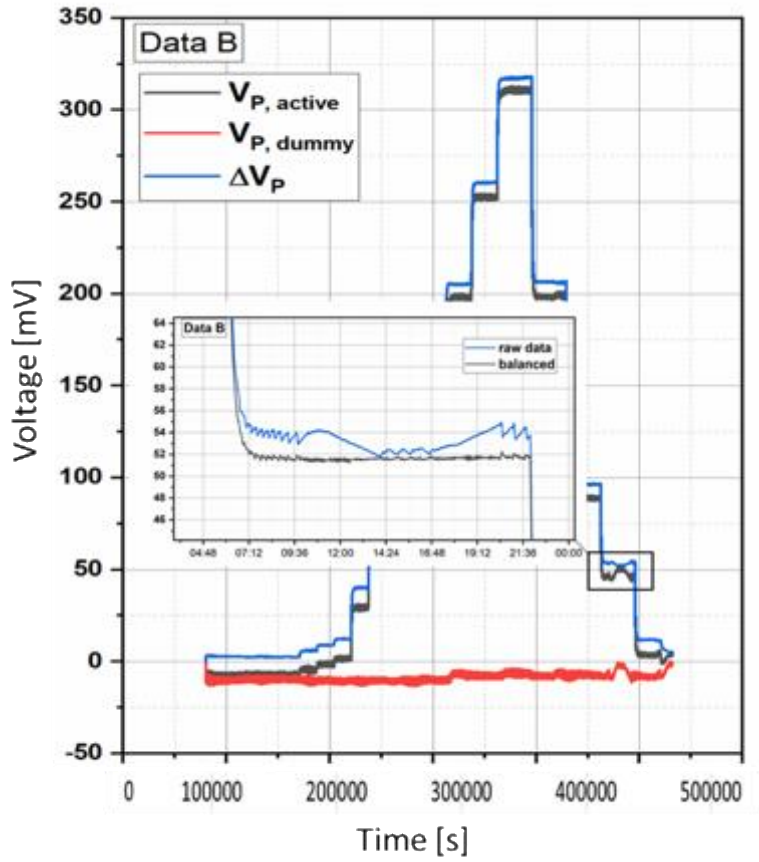
(b)

CEES Calorimeter
No excess heat indication

Open-air calorimeters, balanced performance data



Calorimeters were modeled using COMSOL, and a lumped-element model (shown here). Mis-matches in the resistances and thermopile calibrations between the Active and Passive cells may be balanced in post-processing to greatly reduce environmental error

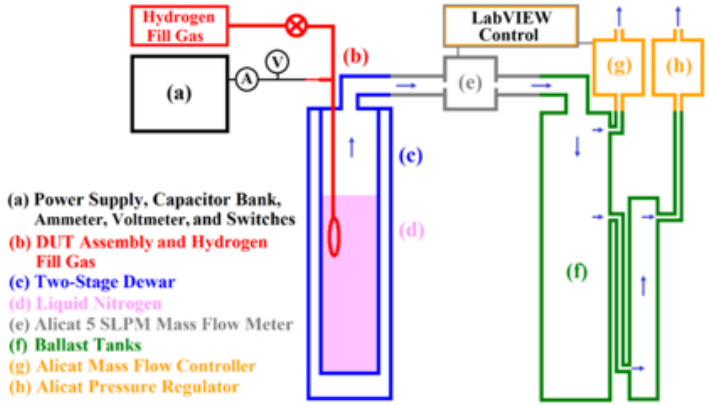


'Symmetry factor' was applied in data analysis to match sensitivities and to greatly reduce environmental bias

Pulsed Evaporative Calorimetry at CEES

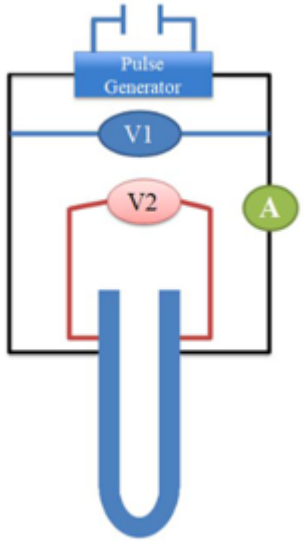
- Small changes in atmospheric pressure create large changes in the evaporation rate (see paper below for quantification discussion)
  - LN_2 pressure must be maintained to one part in 10,000 continuously
  - Range: 1 to 50 J heat pulses, from 10μs to 1 ms duration
  - As-built calorimeter is 96% efficient and very repeatable, with a calorimetric sensitivity of ~ 25 μW
  - Dewar was carefully designed to eliminate super-heating
  - N_2 mass flow resolution of 0.05 std. ml / s

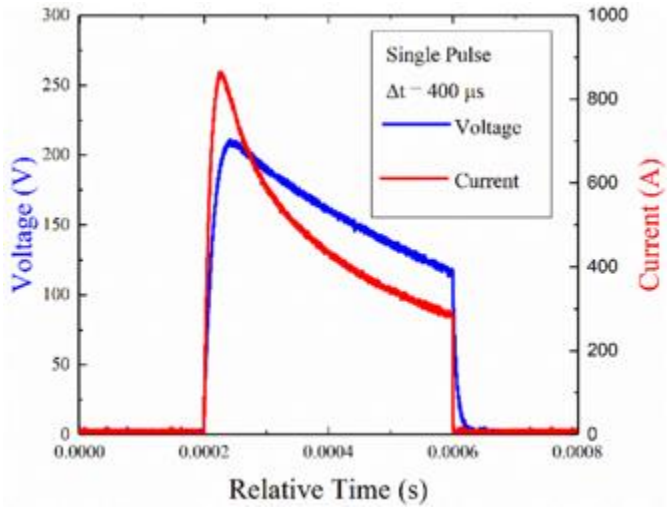
- Part of the applied heat pulse results in boil-off, some is converted to work as it raises the LN_2 column above
  - Heat pulse must be applied at a constant, calibrated depth
  - This work results in long-duration flows that are not associated with the pulse, resulting errors in energy balance

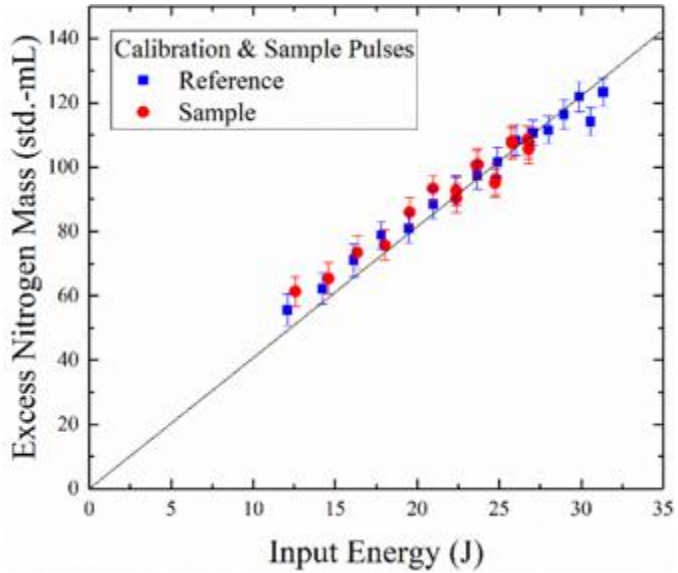


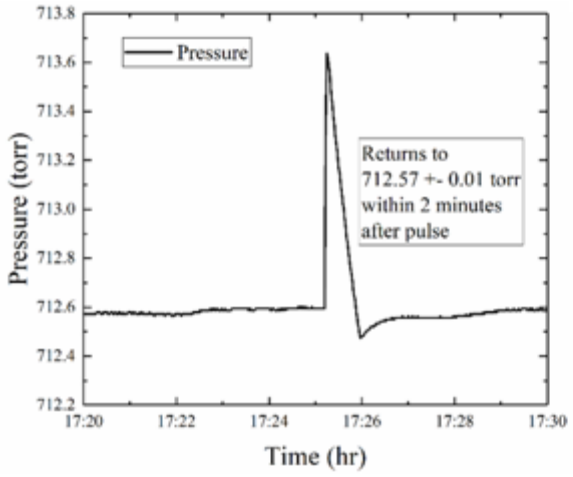
Gillespie, A. K., Lin, C., Thorn, R. P., Jr., Higgins, H., Baca, R., Durso, A. A., Jones, D., Ogu, R., Marquis, J., & Duncan, R. V. (2020): "A new fast response cryogenic evaporative calorimeter" *Review of Scientific Instruments*, *91*(8), 085103. https://doi.org/10.1063/5.0013713 ('Editor's Pick' publication)

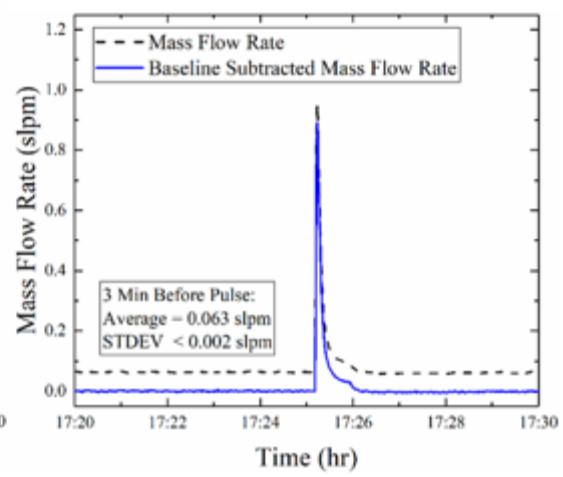
Evaporative Calorimetry – Performance

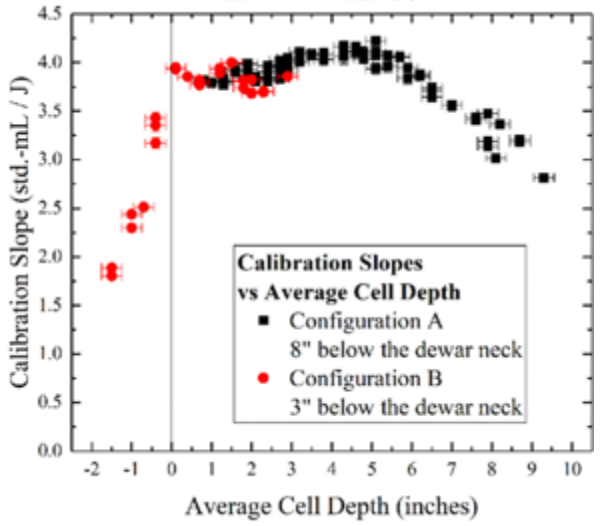










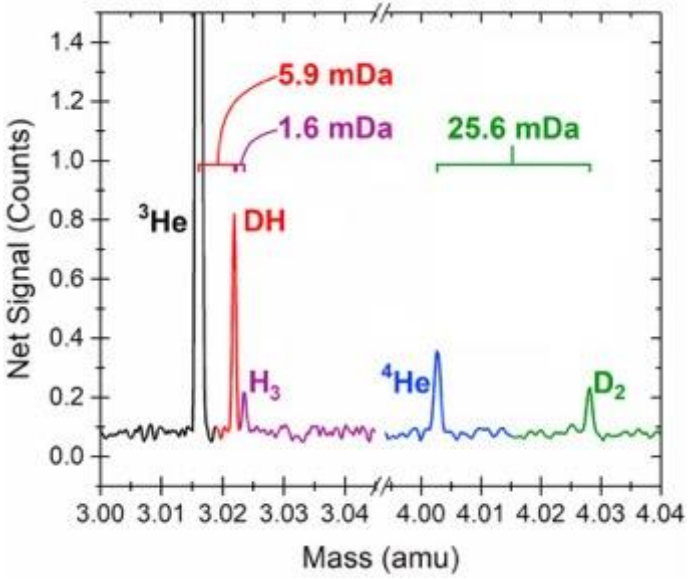


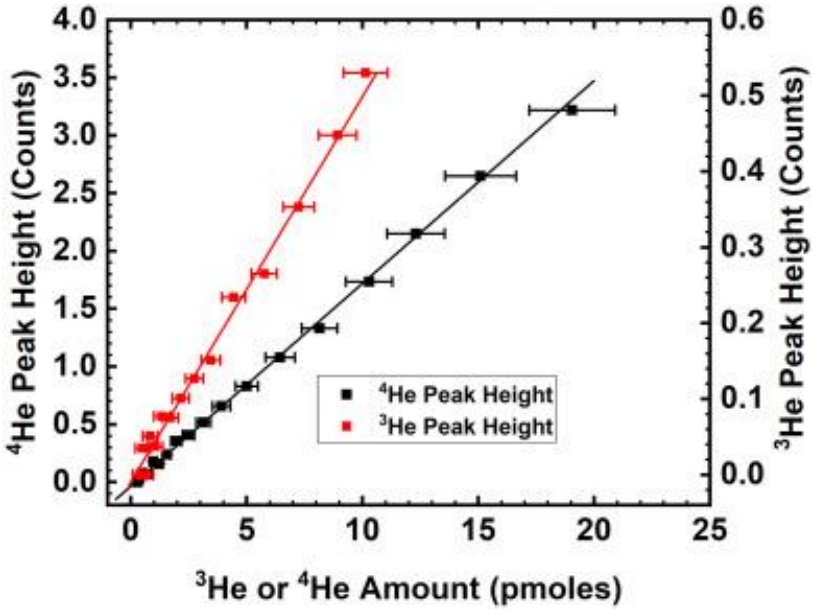
New Mass Spectrometer System for Nuclear Science

- Custom FT-ICR Mass Spectrometer for quantitative measurements of dilute ^{3}He, ^{4}He, and Air Invasion (^{40}Ar, ^{20}Ne) in balance hydrogen
  - Quantitative measurements from 0.5 pM, with excellent linearity
    - Corresponds to a sensitivity of one joule of excess heat, if one ^{4}He atom is produced for each d+d fusion event that releases 23.8 MeV of energy
    - Mass resolution: better than 1 mDa (Da = 1 AMU) at mass-3, and excellent stability
  - Tritium may be detected as T^{+}, HT^{+}, DT^{+}, H_2T^{+}, etc., but scintillation is better
    - Perkin Elmer's Quantulus achieves ~ 1 fM sensitivity to T, with excellent linearity
    - We have this capability within CEES, and advanced tritium extraction techniques
  - Five custom FT-ICR MS are calibrated, some weekly now for many years, and up to ten more may be brought into future service as needed
  - Useful for LENR, climate change research, and for new novel fission / fusion hybrid reactor designs that we are pursuing now

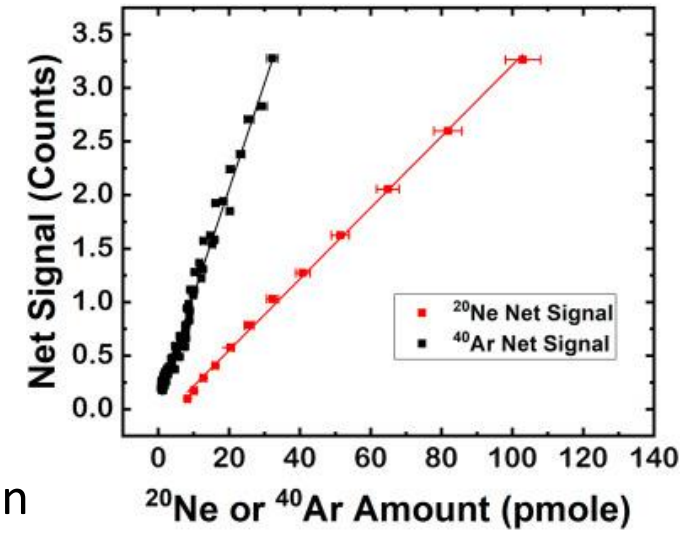
"A Low-Cost, Quantitative Light-Isotope Measurement System for Climate and Energy Applications", Robert P. Thorn, Jr., Andrew K. Gillespie, Cuikun Lin, Heather Higgins, Shelby Lacouture, Robert Baca, Baudilio Tejerina, Andy Durso, Django Ian Jones, Ruth Ogu, Brett Neurohr, Trevor Dardik, and Robert V. Duncan, International Journal of Mass Spectrometry 464, 116574 (June, 2021). Available here: https://doi.org/10.1016/j.ijms.2021.116574

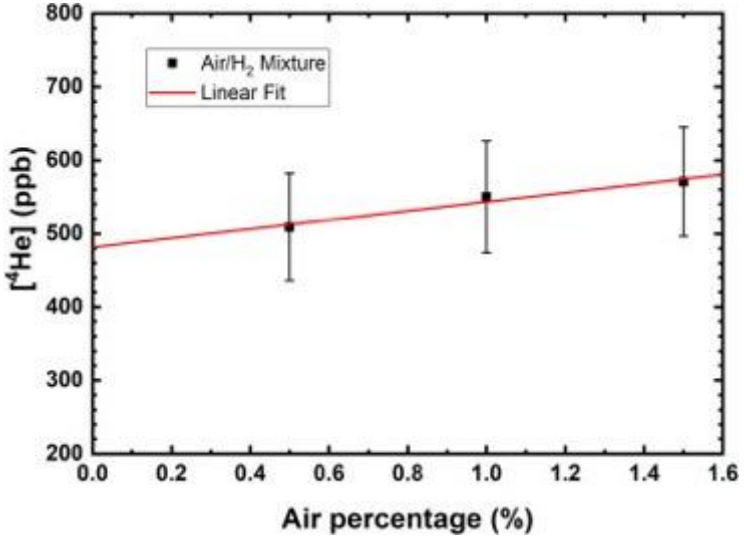
FT-ICR Mass Spec – Performance Results





We conduct real-time air invasion checks on all gas aliquots, and all equipment and LENR cells are surrounded either by vacuum, or by N_2 with < 0.005 ppm ^{4}He. We attempt to correlate excess heat with T, ^{3}He, and ^{4}He production. Continuous ^{1}n, X-ray, gamma monitoring of all experimen





Concluding Thoughts and Opportunities

- CEES collaborates in a respectful manner with experimental groups with a viable candidate LENR / alternative nuclear result, with emphasis on replication and conclusive experimental science
  - All of our collaborator's prior art and intellectual property are respected
  - If CEES is unable to replicate results, then CEES works only with our collaborators to explain the lack of replication in detail, holding results as confidential in the collaboration, until all parties agree to publish
- CEES continues to explore interesting new materials and advanced material production and characterization for LENR, alternative fission, fusion, and hybrid nuclear designs. CEES seeks additional funding to expand these activities in the future