American Physical Society Special Sessions on Cold Fusion

1–2 May 1989

Baltimore, Maryland

Abstracts of talks submitted to the Special Session on Cold Fusion. For further information on a particular talk, please contact the author(s) directly. Videotapes of a selected number of the talks are available for purchase from The American Physical Society.

SPECIAL SESSION ON COLD FUSION

Monday evening, 1 May 1989 at 7:30 P.M.; Exhibit Hall E,
Baltimore Convention Center; E. F. Redish, presiding

Introduction. E. F. REDISH, *University of Maryland*

Comments. J. A. KRUMHANSL, *APS President*

INVITED TALKS:

1 **Cold Nuclear Fusion: Recent Results and Open Questions.** S. E. Jones, Brigham Young University. (Same Paper as J1 3.)

2 **Cold Fusion: Can It Be True? A Theoretical Point of View.** J. Rafelski, University of Arizona, Tucson.

3 **Theoretical Issues and Problems Raised by Cold Fusion Experiments.** S. E. Koonin, University of California, Santa Barbara.

4 **Calorimetry, Neutron Flux, Gamma Flux, and Tritium Yield from Electrochemically Charged Palladium in D$_2$O.** Nathan Lewis, Charles Barnes, Steven Koonin, California Institute of Technology.

CONTRIBUTED TALKS:

5 **Boson Screening of Deuterium in Metals.** K. B. Whaley, University of California, Berkeley.

6 **An Investigation of Cold Fusion Using a Sensitive Neutron Detector.** W. K. Brooks, D. G. Marchlenski, J. D. Kalen, M. S. Islam, M. Kaitchuck, R. McCreery, R. N. Boyd, P. Holbrooke, H. Dyke, The Ohio State University.

7 **Search for Neutron Production in a Palladium-Heavy Water Electrolytic Cell.** R. Hirosky, E. Buchanan, J. Jorne, A. C. Melissinos, J. Toke, University of Rochester.

8 **A Search for Cold Fusion Neutrons at ORELA.** D. P. Hutchinson, R. K. Richards, C. A. Bennett, C. C. Havener, C. H. Ma, F. G. Perey, R. R. Spencer, J. K. Dickens, B. D. Rooney, Oak Ridge National Laboratory; J. Bullock IV, G. L. Powell, Y-12 Development.

9 **Analysis of "Excess Power in Cold Fusion."** W. E. Meyerhof, Stanford University; D. L. Huestis, D. C. Lorents, SRI International.

9A **Generation of D-D Fusion-Reaction Bursts in Metal Deuterides.** H. Furth, S. Bernabei, S. Cowley, R. Kulsrud, Princeton Plasma Physics Laboratory, Princeton University.

10 **Gammas from Cold Fusion.** D. Bailey, University of Toronto.

11 **Sources of Neutrons and Tritium from D-Li-6 Mixtures.** Lawrence Cranberg, TDN, Inc.

12 **Searches for Cold Fusion.** E. B. Norman, B. Sur, K. T. Lesko, K. R. Czerwinski, H. L. Hall, R. A. Henderson, D. C. Hoffman, Lawrence Berkeley Laboratory.

13 **Search for Cold Fusion in Electrolytic Cells.** D. R. McCracken, J. Paquette, R. E. Johnson, N. A. Briden, W. G. Cross, A. Arneja, D. C. Tennant, M. A. Lone, W. J. L. Buyers, Chalk River Nuclear Laboratories.

14 **Search for DD-Fusion Neutrons.** D. Seeliger, K. Weisener, A. Meister, D. Ohms, D. Rahner, R. Schwierz, P. Wustner, Technical University, Dresden.

15 **Fusion Rates for Hydrogen Isotopic Molecules of Relevance for Cold Fusion.** K. Szalewicz, J. D. Morgan III, University of Delaware; H. J. Monkhorst, University of Florida.

16 **Upper Limits to Fusion Rates of Isotopic Hydrogen Molecules at High Electron Density Interstitial Pd Sites.** L. Wilets, M. Alberg, J. J. Rehr, J. Mustre de Leon, University of Washington.

17 **"Solid-State" Effects Cannot Enhance the Cold Fusion Rate Enough.** A. J. Leggett, G. Baym, University of Illinois.

18 **Electrochemically Induced Excess Heat in a "Cold Fusion" Cell with a Zr$_2$Pd Electrode.** Joseph Cantrell (Dept. of Chemistry), William E. Wells (Dept. of Physics), Miami University.

19 **Search for Fusion Products Using X-Ray Detection.** M. R. Deakin, J. D. Fox, K. W. Kemper, E. G. Myers, W. N. Shelton, J. G. Skofronick, Florida State University.

20 **Search for Neutrons and Gamma-Rays from "Cold Fusion" in Deuterided Metals.** M. Gai, S. L. Rugari, R. H. France, B. J. Lund, Z. Zhao, Yale University; A. J. Davenport, H. S. Isaacs,

K. G. Lynn, Brookhaven National Laboratory.

SPECIAL SESSION II ON COLD FUSION

Tuesday evening, 2 May 1989 at 7:30 P.M.; Room 317, Baltimore Convention Center; David Micha, presiding

CONTRIBUTED TALKS:

21 **A Survey of Cold Fusion.** Douglas R. O. Morrison, CERN.

Experimental

22 **Dynamic Response of Thermal Neutron Measurements in Electrochemically Produced Cold Fusion Subject to Pulsed Current.** J. R. Granada, J. Converti, R. E. Mayer, G. Guido, P. C. Florido, N. E. Patiño, L. Sobehart, S. Gomez, A. Larreteguy, Centro Atomico Bariloche and Instituto Balseiro, Argentina.

23 **Examination of Nuclear Measurement Conditions in Cold Fusion Experiments.** D. Abriola, E. Achterberg, M. Davidson, M. Debray, M. C. Etchegoyen, N. Fazzini, J. Fernández Niello, A. M. J. Ferrero, A. Filevich, M. C. Galia, R. Garavaglia, G. García Bermúdez, R. T. Gettar, S. Gil, H. Grahmann, H. Huck, A. Jech, A. J. Kreiner, A. O. Macchiavelli, J. G. Magallanes, E. Maqueda, G. Marti, A. J. Pacheco, M. L. Pérez, C. Pomar, M. Ramírez, M. Scasserra, CNEA, Argentina.

24 **γ-Ray Spectra in the Fleischmann, Pons, Hawkins Experiment.** R. D. Petrasso, X. Chen, K. Wenzel, R. R. Parker, C. K. Li, C. Fiore, Plasma Fusion Center, Massachusetts Institute of Technology.

25 **Measurements of Neutron and Gamma-Ray Emission Rates and Calorimetry in Electrochemical Cells Having Palladium Cathodes.** S. C. Luckhardt, X. Chen, C. Fiore, M. Gaudreau, D. Gwinn, P. Linsay, R. Parker, R. Petrasso, K. Wenzel (Plasma Fusion Center), R. Crooks, V. Cammarata, M. Schloh, D. Albagli, M. Wrighton (Dept. of Chemistry), R. Ballinger, I. Hwang (Dept. of Material Science and Engineering), Massachusetts Institute of Technology.

26 **Tests of "Cold Fusion" in a New Configuration.** F. Skiff, H. M. Milchberg, J. Rogers, Laboratory for Plasma Research, University of Maryland.

Theoretical

27 **Cold Nuclear Fusion of Dense Metallic Hydrogen: Implications for Astrophysics.** C. J. Horowitz, Nuclear Theory Center, Indiana University.

28 **Theory of Cold Fusion.** M. Danos, National Institute of Standards & Technology.

29 **Limits on Cold Fusion in Matter: A Parametric Study.** J. Rafelski, M. Gajda, D. Harley, S. E. Jones, University of Arizona.

30 **Electron Catalyzed Fusion in Metals.** D. A. Browne, R. G. Goodrich, P. N. Kirk, E. F. Zganjar, Louisiana State University.

31 **The Cold Fusion Rate of d-d in PdDx Hydride and the Branching Ratio of He-4 to (p,n) Production Reactions.** Hiroshi Takahashi, Brookhaven National Laboratory.

32 **Criterion for Cold Fusion in the Condensed State.** E. A. Stern, University of Washington, Seattle.

33 **Theoretical Estimates of the Enhancement of Cold Fusion of Deuterium in Deuterated Palladium Systems.** M. W. C. Dharma-wardana, G. C. Aers, National Research Council of Canada, Ottawa.

34 **Chemical Forces Associated with Confinement of Deuterium in Palladium.** B. I. Dunlap, J. W. Mintmire, D. W. Brenner, R. C. Mowrey, H. D. Ladouceur, P. P. Schmidt, C. T. White, W. E. O'Grady, Naval Research Laboratory.

35 **Molecule-Nucleus Resonance Enhancement of Cold Nuclear Fusion.** A. V. Barnes, Heath Pois, Center for Atomic and Molecular Physics at Surfaces and Vanderbilt University.

36 **The Bond Length of the Deuterium Molecule in a Metallic Lattice.** A. B. Hassam, University of Maryland; A. N. Dharamsi, Old Dominion University.

37 **Fluctuations and Cold Fusion.** Ming Li, University of Maryland.

38 **Simple yet Accurate Model Potential for Calculating Cold Fusion Rates.** J. D. Morgan III, Harvard University; H. J. Monkhorst, University of Florida.

39 **Exotic QED and Cold Nuclear Fusion.** Ming Li, University of Maryland.

40 **Search for Radiations from Cold Fusion in Pd-D System.** R. S. Raghavan, L. C. Feldman, M. M. Broer, A. James, D. Murphy, AT&T Bell Laboratories, Murray Hill, NJ.

1 Cold Nuclear Fusion: Recent Results and Open Questions. S. E. JONES, *Brigham Young University.*

We have shown that nuclear fusion between hydrogen isotopes can be induced by binding the nuclei closely together for a sufficiently long time, without the need for hig-temperature plasmas. For example, muon-catalyzed fusion occurs rapidly when negative muons are added to liquid deuterium-tritium mixtures, forming small muon-bound d-t molecules that fuse in picoseconds. Recent experimental results illuminate the rich tapedtry of processes that constitute the muon catalysis cycle, while a number of question remain yet unresolved [1]. We have also accumulated considerable evidence for a new form of cold nuclear fusion which occurs when hydrogen isotopes are loaded into various materials, notable crystalline solids (without muons). Implications of these findings on geophuysics and fusion research will be considered.

Supported by the U.S. Department of Energy, Advanced Energy Products Division

[1] S.E.Jones, J. Rafelski, H.J.Monkhorst, eds. "Muon Catalyzed Fusion 1988", AIP Publication 181, pp.1-469 (1989).

2 Cold Fusion: Can it be True? A Theoretical Point of View. J. RAFELSKI, *University of Arizona, Tucson.*

It is shown that the fusion rates observed by the BYU team of S.E. Jones during electrolytic infusion of hydrogen into Pd and Ti cathodes can readily be explained by combination of standard nuclear physics data and WKB penetration integrals in the metal lattice environment. A specific mechanism for the process invoking formation of Bose macroscopic state (drop) of deuterium ions neutralised by an electron cloud will be described.

State of the attempts to skew the branching ratios of nuclear reactions by 12 orders of magnitude towards processes not involving production of neutrals (neutrons, gammas) will be given. This would be needed to account for production of heat without penetrating radiation in a nuclear process, as suggested by the press release of the University of Utah.

3 Theoretical Issues and Problems Raised by Cold Fusion Experiments.* S. E. KOONIN, *Institute for Theoretical Physics, UCSB.*†

I will discuss several challenges to our current understanding posed by recent cold fusion experiments. In particular I will review calculations of the rates for various hydrogen fusion reactions in molecular and condensed matter systems. I will also discuss the potentially large effect of lattice fluctuations on fusion rates in solids. Finally, I will review the shortcomings of various proposals to "hide" the radiation produced in $d + d$ and $p + d$ fusion.

*Supported by the National Science Foundation, grants PHY86-04197 and PHY88-17296.

†On leave from the California Institue of Technology.

4 Calorimetry, Neutron Flux, Gamma Flux, and Tritium Yield from Electrochemically Charged Palladium in D_2O.

NATHAN LEWIS, CHARLES BARNES, and STEVE KOONIN, *California Institute of Technology.*

We report the results of our work on cold fusion using palladium. We have used extremely sensitive neutron, gamma ray, and photon counters, and can place strict upper limits on the flux of expected nuclear products emitted from charged Pd cathodes. Liquid scintillation counting has been used to measure tritium production, which was found at background levels for extended periods of time. However, a subtle chemical interference that generates chemiluminescence has been shown to yield trituim signals and lead to overestimates of the fusion yield based on tritium production. We have also performed accurate, calibrated calorimetry, and have identified several serious errors that can make the measurements appear to show excess power production. When these common errors are eliminated, a correct energy balance is obtained. We will also discuss the calorimetric experiments performed by the Utah researchers, will explain their calculations to the physics community, and will clearly state the assumptions and corrections implicit in the Utah calculations.

5 Boson Screening of Deuterium in Metals

K.B. Whaley, University of California, Berkeley

We analyze the role which bose nuclear statistics of deuterium can have in enhancing local density fluctuations and coulomb screening deuterium in metals. Results of boson tight binding calculations for D in Pd are used to assess the feasibility of rate enhancements for D-D nuclear fusion, due to boson screening and lattice fluctuations. The possible relevance of a bose condensate, and implications for experimental observation of cold nuclear fusion of deuterium in metals are discussed.

6 An Investigation of Cold Fusion using a Sensitive Neutron Detector. W.K. BROOKS, D.G. MARCHLENSKI, J.D. KALEN, M.S. ISLAM, M. KAITCHUCK, R. MCCREERY*, R.N. BOYD, P. HOLBROOKE, H. DYKE, The Ohio State Univ -- A careful measurement of neutron production from a Pd electrode in an electrolytic cell has been performed. The neutron detection system consisted of a BC 501 liquid scintillator contained in a 4.0 cm thick, 18.5 cm dia. pyrex cylinder, surrounded by a plastic anticoincidence shield and lead housing. Pulse shape discrimination was used to identify neutron signals. This system yielded low backgrounds with approximately 1% counting efficiency. Initial results indicate no neutron production over a period of about 40 hours of counting. Estimates will be presented of how this may be compared to previous data. Further plans for more detailed studies of cold fusion will be described, including chemical analyses of the palladium electrode.

*Department of Chemistry

7 Search for Neutron Production in a Palladium-Heavy Water Electrolytic Cell* R. HIROSKY, E. BUCHANAN, J. JORNE, A.C. MELISSINOS, and J. TOKE, University of Rochester** We have searched for neutrons produced in an electrolytic cell filled with heavy water (D_2O) and having a Palladium cathode. We set a limit of 1 count/sec from 0.7 cm^3 of Pd, operated continuously for five days at a current of 2A. This limit is $4X10^4$ lower than the rate claimed by Pons and Fleischmann[1] for a similar cell.

* Submitted by A. C. Melissinos

** Supported by the DOE and the NSF.

[1] M. Fleischmann and S. Pons, paper submitted to Journal of Electroanalytical Chem., March 20, 1989.

8 A Search for Cold Fusion Neutrons at ORELA. D.P. HUTCHINSON, R.K. RICHARDS, C.A. BENNETT, C.C. HAVENER, C.H. MA, F.G. PEREY, R.R. SPENCER, J.K. DICKENS, B.D. ROONEY, ORNL,* J. BULLOCK IV, and G.L. POWELL, Y-12 Development--A number of experiments were begun on 29 March 1989 to look for neutron emission from a palladium cathode in an electrolytic cell using a deutrated electrolyte. Several different electrode configurations were tried. The fast neutron detector utilized a pair of NE213 scintillator/photomultiplier pairs in a shielded enclosure. Data will be presented on the efficiency and background level of the detector system. At present no neutron counts above the background level have been detected.

*Operated by Martin Marietta Energy Systems, Inc. for the U.S. Department of Energy under contract No. DE-AC05-84OR21400.

9 Analysis of "Excess Power in Cold Fusion". W. E. MEYERHOF, Stanford University,* D. L. HUESTIS and D. C. LORENTS, SRI International. The apparent excess energy release of 4 MJ in heavy-water electrolysis with Pd electrodes[1] is impossible to explain with known chemical or physical processes. Solution of the heat equation for cylindrical calorimeters with the geometries of Ref. 1 or 2 show that in steady-state calorimetry temperature gradients exist even with weak stirring. Hence, fictious excess power can be found, depending on the placement of the thermometer. This is particularly severe in Pd+D electrochemical reactions because the dissipative part of the 0.8 to 2 V overvoltage[1] releases heat at the surface of the Pd electrode. The observed differences between ordinary and heavy water[2] can also be explained because for Pd+H the overvoltage is much smaller than for Pd+D.

1. M. Fleischmann and S. Pons, J. Electroanaly. Chem. 261, 301 (1989).
2. A. Belzner, U. Bischler, C. Crouch-Baker, T. Gur, G. Lucier, M. Schreiber, R. A. Huggins, to be published.

*Supported in part by NSF grant PHY 86-14650.

9A **Generation of D-D Fusion-Reaction Bursts in Metal Deuterides.** H. Furth, S. Bernabei, S. Cowley, and R. Kulsrud. *Princeton Plasma Physics Laboratory, Princeton University.** The emission of D-D fusion neutrons from "cold" objects could be due to bombardment by bursts of energetic deuterons. One key test of this interpretation is the consistency of the observed neutron-count statistics with the predicted Poisson distribution for intense, short neutron bursts. We find that the data shown in Fig. 2 of Ref. 1 are fitted perfectly by this mathematical model. The smaller count rates of Ref. 2 do not lend themselves to as sharp a statistical test—though perhaps serving to exclude "large-burst" theories such as cosmic μ-meson catalysis. A possible means for the acceleration of deuterons is mechanical fracture–as in the reported generation of neutrons during impact of high-velocity projectiles on lithium deuteride crystals.[3] Repeating the experiments of Refs. 1–3 with mixtures of hydrides and deuterides could provide a measure of the relative importance of quantum-mechanical tunneling versus simple cold-target bombardment.

*Work supported by U.S.D.o.E. Contract No. DE-AC02-76CHO3073.

[1] A. DeNinno, *et al.*, submitted to Europhysics Letters.

[2] S. E. Jones, *et al.*, Nature, **338**, April 27 (1989).

[3] V. A. Klyuev, *et al.*, Sov. Tech. Phys. Lett. **12**, 551 (1986).

10 Gammas from Cold Fusion. D. Bailey* University of Toronto: **. – The absence of both neutrons and gamma

rays can be used to constrain possible cold fusion processes in deuterium-metal systems. In particular, milliwatt cold fusion processes in palladium producing fast protons, tritium, ^3He or ^4He nuclei would also usually produce easily observable numbers of Coulomb excitation palladium gamma rays. Typical expected yields are $\sim 10^4 - 10^6$ gammas per joule of fusion energy in lines at 0.374, 0.434, 0.512 and 0.556 MeV. Reported[1] 2.2 MeV np capture gamma rays are consistent with the ubiquitous radon daughter ^{214}Bi 2.204 MeV background line.

* BITNET address: DBAILEY@UTORPHYS

** Supported in part by NSERC (Canada).

[1] M.Fleischmann, S. Pons, and M. Hawkins, J. Electroanal. Chem. 261 (1989) 301, and *errata*.

11 Sources of Neutrons and Tritium from D-Li-6 Mixtures. Lawrence Cranberg, TDN, Inc. --The work of Fleischmann, Pons, and Hawkins (1) claims detection of room temperature fusion of deuterons based in part on detection of neutrons and of tritium in electrochemical experiments with vessels containing mixtures of compounds of deuterium and lithium-6. Alternative, well-known nuclear reactions induced by ambient gamma-rays and neutrons in the experimental materials are suggested, together with suitable control experiments to measure those effects. It is significant to note that a negative result on (1) or on the work of Jones et al. (2), with experimental cells replaced by a blank or hydrogen-filled cell is not a check on the proposed background sources.

1. M. Fleischmann, B. Pons, M. Hawkins, J. Electroanalytical Chemistry, 261, 301 (1989).
2. S. E. Jones, E. P. Palmer, J. B. Czirr, D. L. Decker, G. L. Jensen, J. M. Thorne, S. F. Taylor, and J. Rafelski, Preprint of article submitted to Nature.

12 Searches for Cold Fusion * E. B. Norman, B. Sur, K. T. Lesko, K.R. Czerwinski, H. L. Hall, R. A. Henderson, and D. C. Hoffman, Lawrence Berkeley Laboratory -- Following the reported observations of nuclear fusion reactions of deuterium nuclei loaded into metallic crystalline lattices[1,2], we have searched for neutrons and gamma rays that should be produced by such processes. Two separate D_2O cells containing the electrodes and electrolytes described in Refs. 1 and 2 have been operated over a period of three weeks. Fast neutrons have been searched for using liquid scintillators and dosimetry film. Prompt gamma rays have been searched for using NaI detectors; induced radioactivity in the electrodes was searched for using Ge detectors. Background measurements have been conducted with the cells turned off. Measurements of the mass of a palladium electrode before and after electrolysis showed that the number of deuterium atoms loaded was 0.5 per Pd atom. No excess of neutrons or gamma rays above background has been observed. Upper limits on the possible rates of fusion reactions occurring in these cells will be presented.

*Supported by the U.S. Dept. of Energy under Contract No. DE-AC03-76SF00098.

1. M. Fleischmann and S. Pons, preprint
2. S. E. Jones et. al., preprint

13 **Search for Cold Fusion in Electrolytic Cells,** D. R. McCRACKEN, J. PAQUETTE, R. E. JOHNSON, N. A. BRIDEN, W. G. CROSS, A. ARNEJA, D. C. TENNANT, M. A. LONE, AND W. J. L. BUYERS, *Chalk River Nuclear Laboratories.* A variety of electrolytic cells have been studied having palladium cathodes in the form of wires, tubes, rods or foil and having anodes of platinum wire or foil, or of nickel tube. Some of these cells have a cylindrical configuration similar to the cell in which cold fusion is claimed by Fleischmann and Pons to have occurred. The electrolyte was 0.1 molar LiOD in virgin D_2O. An AECL wet proofed catalyst above the cell was used to recombine the evolved D_2 and O_2. Current densities up to 140 mA/cm^2 have been applied. Arrays of 3 to 5 ^{3}He detectors were mounted beside each cell in a central 20 cm cavity of a large 130 cm × 120 cm × 90 cm wax neutron shield. This gives a very low, constant background of 30±2 counts/hour summed over all five detectors or 18±2 counts/hour for three detectors. After running the cells for times of three to four days no excess neutrons were observed above background. The cells were run mainly in continuous mode but a search for transient neutrons was also done after switching on the current. No measurable excess heat was observed in the water from the cooling jacket. In a cell without a recombiner the enrichment in tritium in the electrolyte was not inconsistent with the range of D/T separation factors that occur at palladium electrodes.

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Search for DD-Fusion Neutrons, D. Seeliger, K. Wiesener, A. Meister, D. Ohms, D. Rahner, R. Schwierz, P. Wustner, Technical University, Dresden. Using a large volume liquid scintillation detector and other neutron and gamma-ray detectors, we measured the radiation arriving from the electrolysis of heavy water with a palladium cathode. Using an efficient proton recoil neutron spectrometer (NE-213 scintillator coupled to an XP-2040 phototube) equipped with electronic depression of gamma rays and cosmic ray muon background, evidence was found for a weak fast neutron production. In the proton recoil energy range between 2 MeV and 3 MeV at an average background rate of about 85 counts per hour, the order of 20 ±5 counts per hour coming from the 60 x 47 x 3 mm^3 palladium sheet was observed. This results in a neutron producing reaction rate of approximately 0.1 s^{-1} in the whole volume of the electrode.

15 Fusion Rates for Hydrogen Isotopic Molecules of Relevance for Cold Fusion* K. SZALEWICZ, J.D. MORGAN III; U. Delaware; H.J. MONKHORST; U. Florida. — In response to the recent announcements of evidence for room-temperature fusion in the electrolysis of D_2O, we have analyzed how the fusion rate depends on several factors, including the reduced mass of the fusing nuclei and the degree of vibrational excitation. Calculations have been performed within the adiabatic approximation employing an accurate Born-Oppenheimer potential energy curve and including the adiabatic and relativistic corrections. We have also used the WKB approximation which displays the essence of these factors. Our results predict fusion rates for the ground vibrational states up to 14 orders of magnitude larger than previously estimated and exhibit a strong dependence of the Coulomb barrier penetration factor on the reduced mass of the pair of nucleons. We have found that fusion out of vibrationally excited states is enhanced by several orders of magnitude, which may be of particular significance in light of the experimental evidence for the importance of non-equilibrium conditions. To assist in the investigation of whether a 'heavy' electron arising from complicated collective solid-state effects could play a role in the enhanced fusion rates seen in the experiments, we study how the Coulomb barrier penetration factor depends on the mass of a hypothetical particle (or quasi-particle) of charge -1. We examine the issue of whether the excess heat observed in one of the experiments could arise from the aneutronic fusion reaction $p+d \rightarrow ^3He+\gamma$. We find that under the conditions implied by the measurements of the neutron flux from the reaction $d+d \rightarrow ^3He+n$, it is unlikely that the excess heat observed by one of the groups could arise from $p+d$ fusion.

*Supported by the NSF and by the Division of Advanced Energy Projects, DOE.

16 **Upper Limits to Fusion Rates of Isotopic Hydrogen Molecules at High Electron Density Interstitial Pd Sites.*** L. WILETS, M. ALBERG, J.J. REHR and J. MUSTRE de LEON, **Univ. of Washington.**—We have studied upper bounds for p-d and d-d fusion rates in a degenerate electron gas as a function of screening electron density ($\propto r_s^{-3}$) and confinement potential in a Pd lattice. At tetrahedral (T) and octahedral (O) sites of saturated PdD we estimate r_s to be between 2.0 and 2.8 a_0, which gives an upper limit of $10^{-57}/s$ for p-d and $10^{-67}/s$ for d-d. A rate $10^{-20}/s$ would require an r_s of 0.27 a_0 for p-d.

Confinement by the Pd atoms considerably enhances these rates. With a T-site hard cell radius of 0.65 a_0 we obtain upper bounds of $10^{-30}/s$ and $10^{-34}/s$ respectively; rates at O-sites are lower. However, a more realistic confinement potential at the T-sites is softer and gives only $10^{-49}/s$; moreover, occupation of T-sites is chemically (and perhaps structurally) unfavorable, given a D_2 confinement energy of about 30 eV. We conclude that fusion in Pd is most favorable at the T-site, but even there at rates significantly less than quoted experimental values of $10^{-19} - 10^{-23}/s$.

* Supported in part by the DOE and the NSF.

17 **"Solid-State" Effects Cannot Enhance the Cold Fusion Rate Enough.** A. J. LEGGETT and G. BAYM, *Department of Physics, University of Illinois at Urbana-Champaign, 1110 W. Green St., Urbana, Illinois 61801.* To achieve the rate of neutron production, $\sim 10^{-23}$/sec/deuteron pair, by cold fusion of deuterium in solid Pd or Ti, requires the solid-state environment to produce either an unusual enhancement of the fusion reaction rate, or a large suppression of the Coulomb barrier between deuterons—the latter presumably arising from some kind of sophisticated many-body screening effect. We point out that a very severe exact quantum-mechanical constraint is imposed on *all* such enhanced screening mechanisms in solids in equilibrium by observable behavior of a ^{4}He atom in the metal in question. Unless the latter is quite anomalous, or the deuteron pair correlation function is of order 10^{12} at atomic separations, no enhancement of the Coulomb barrier penetration anywhere near the magnitude required to explain the fusion rates inferred from the experiments is possible in a solid in at zero temperature; in thermal equilibrium at room temperature such an enhancement would require at a minimum very exotic long range influences on the tunneling process.

18 Electrochemically Induced Excess Heat in a "Cold Fusion" cell with a Zr_2Pd Electrode Joseph Cantrell, Dept of Chemistry and William E. Wells, Dept. of Physics, Miami university, Oxford, Ohio—A "Cold Fusion" cell patterned after that of Fleischmann and Pons[1] was constructed using Zr_2Pd foils instead of Pd rods. The total volume of the electrode was 0.014 cm^3. At a room temperature of 289 K, the electrodes drew 90 mA with 4.8 V applied, and presented a 6 K change in temperature. When a 10 ohm resister, drawing 219 mA in the heavy water bath, was used to produce heating instead of the electrodes, the temperature rise over the 289 K background was 3 K. No neutron measurements have been made as yet. The temperature dependence of the process is positive. The process continued for more than 100 hours, before decaying. DOE Mound Labs-EG&G examined the cell electrode, electrolyte solution, and a copious precipitate in the bottom of the test tube, with SEM-microprobe, XRD, Auger, and Atomic Absorption. These results will be presented.

1. Fleischmann and Pons J. Electroanal. Chem., 261 301-308 (1989)

19 Search for Fusion Products Using X-Ray Detection. M. R. DEAKIN, J. D. FOX, K. W. KEMPER, E. G. MYERS, W. N. SHELTON, and J. G. SKOFRONICK, Florida State University.* -- The fusion of deuterons should produce energetic protons in about half the reactions in an electrolysis cell with Pt anode and Pd cathode. Our cell is specially constructed with a thin window so that K x-rays of Pd, excited by charged fusion products (mostly protons) can be detected. The background of the x-ray detector, 3 counts per hour in the vicinity of the Pd K x-rays, corresponds to fewer than 50 fusions per second or a fusion energy release rate of less than 10^{-10} watts in the Pd cathode. The cell has been operated for two weeks as of 4/29/89.

*Supported by the National Science Foundation and the State of Florida.

20 **Search for Neutrons and Gamma-Rays from "Cold Fusion" in Deuterided Metals.*** M. GAI, S. L. RUGARI, R. H. FRANCE, B. J. LUND, and Z. ZHAO, *A. W. Wright Nuclear Structure Laboratory, Yale University, New Haven, Connecticut 06511;* A. J. DAVENPORT and H. S. ISAACS, *Dept. of Applied Science, Brookhaven National Laboratory, Upton, NY 11973;* and K. G. LYNN, *Dept. of Physics and Applied Science, Brookhaven National Laboratory, Upton, New York 11973.* A search for neutrons and gamma-rays emitted in "cold fusion" in electrolytically deuterided metals was carried out with a very low background and a sensitive neutron detection system, composed of an array of six liquid-scintillator neutron counters, with efficiency of ~1%. Pulse shape, pulse height and time of flight were measured for scattered neutrons. Gamma-rays were detected in two large (12.5 cm) NaI(Tl) detectors, with efficiency of 0.1% at 5.5 MeV. The detection system was shielded from background radiation and two large area cosmic-ray veto counters were utilized. Up to four electrochemical cells, similar to the ones used by Fleischmann and Pons and Jones *et al.*, ran concurrently, with Pd or cold worked Ti rods as cathodes. The Pd electrodes were cold worked or annealed in vacuum or argon, one electrode was predeuterided and various surface treatments were carried out. The metals were electrochemically charged with deuterium in heavy water (97.5% or 99.8% D_2O) electrolytes containing LiOD or a variety of salts. Ti alloy powder deuterided at high temperature and pressure was also used for comparison. During electrochemical charging, no statistically significant deviation from the background was observed in either gamma-ray or neutron detectors, after some of the cells were on for almost three weeks. Using our neutron detector system we estimate (e.g., for a 7 hour run at the end of two weeks of cell electrolysis) the rate of "cold fusion" of $d+d$ in our Pd and Ti samples to be smaller than the order of 10^{-25} fusions/atom pair/sec (3σ limit), and the gamma ray data yield a rate of "cold fusion" of $p+d$ smaller than the order of 10^{-22} fusions/atom pair/sec (3σ limit). The $p+d$ reaction was recently estimated to be eight orders of magnitude larger than the $d+d$ rate. The estimated neutron flux in our experiment is at least a factor of 100 smaller than that reported by Jones *et al.* and some million times smaller than that reported by Fleischmann and Pons. Cosmic rays have been observed to produce neutrons with energies expected for fusion events. An attempt to initiate "cold fusion" with 5 MeV alpha particles produced no measurable effect.

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21 **A Survey of Cold Fusion.** DOUGLAS R. O. MORRISON*, *CERN, Geneva, Switzerland.* The history of fusion of hydrogen to helium from 1926 until today is reviewed. World results are tabulated and summarized. Problems with the 1989 original papers from Utah and BYU are described. Consequences from the structure of palladium hydrides are drawn. Possible explanations are considered. Conclusions on cold fusion are made and placed in historical perspective.

*Member APS.

22 **Dynamic Response of Thermal Neutron Measurements in Electrochemically Produced Cold Fusion Subject to Pulsed Current.** J. R. GRANADA, J. CONVERTI, R. E. MAYER, G. GUIDO, P. C. FLORIDO, N. E. PATIÑO, L. SOBEHART, S. GOMEZ, AND A. LARRETEGUY, *Centro Atomico Bariloche and Instituto Balseiro, Comision Nacional de Energia Atomica and Universidad Nacional de Cuyo, 8400 S.C. de Bariloche, Rio Negro, Argentina.* The present work shows the results of measurements performed on electrolytic cells using a high efficiency (22%) neutron detection system in combination with a procedure involving a non-stationary current through the cell's circuit. Cold fusion was produced in electrolytic cells containing LiH dissolved in heavy water with a Palladium cathode. The dynamic response to low frequency current pulses was measured. Characteristic patterns showing one or two bumps were obtained in a repeatable fashion. These patterns are strongly dependent on the previous charging history of the cathode. The technique employed seems to be very convenient as a research tool for a systematic study of the different variables governing the phenomenon.

23 **Examination of Nuclear Measurement Conditions in Cold Fusion Experiments.** D. ABRIOLA, E. ACHTERBERG, M. DAVIDSON,** M. DEBRAY, M. C. ETCHEGOYEN,[†] N. FAZZINI, J. FERNÁNDEZ NIELLO,[†] A. M. J. FERRERO, A. FILEVICH, M. C. GALIA, R.

GARAVAGLIA, G. GARCÍA BERMÚDEZ,[+] R. T. GETTAR,[*] S. GIL, H. GRAHMANN, H. HUCK, A. JECH, A. J. KREINER,[+] A. O. MACCHIAVELLI, J. F. MAGALLANES,[*] E. MAQUEDA,[+] G. MARTÍ, A. J. PACHECO,[+] M. L. PÉREZ, C. POMAR, M. RAMÍREZ, and M. SCASSERRA, *Departamento de Física, Comisión Nacional de Energía Atómica, 1429 Buenos Aires, Argentina.* The possible production of nuclear fusion through electrochemical processes was studied by the simultaneous detection of γ-rays and neutrons. The importance of high energy resolution for γ-ray measurements is discussed. Both types of measurements yield consistent results for the upper limits of the neutron production rates in this experiment.

[*] Departamento Química Analítica, Comisión Nacional de Energía Atómica.

[**] Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires.

[+] Fellows of the CONICET, Argentina.

24
γ-Ray Spectra in the Fleischmann, Pons, Hawkins Experiment,[*] R.D. PETRASSO, X. CHEN, K. WENZEL, R. R. PARKER, C. K. LI, and C. FIORE, Plasma Fusion Center, Massachusetts Institute of Technology, Cambridge, MA. -- Fleischmann, Pons, and Hawkins (FPH)[1] recently announced that significant fusion heating was occurring in their cold fusion experiments. As compelling evidence of fusion processes, they reported the detection of 2.2 MeV γ rays that result from neutron-capture-on-hydrogen. We have carefully analyzed their published γ-ray spectra. We have also performed detailed terrestrial γ background measurements and neutron-capture-on-hydrogen experiments. From our analyses we conclude that the FPH γ line is specious on the basis of three quantitative considerations: (1) It has a line width a factor of 2 smaller than the detector instrumental resolution at 2.2 MeV; (2) There is no evidence of a Compton edge at 1.99 MeV (i.e., 2.22 MeV - 0.23 MeV), and this edge should be distinctly prominent; and (3) FPH's estimate of the neutron source rate is a factor of 40 too large. Additionally, from terrestrial γ background considerations, we conjecture that FPH's purported γ line actually resides at 2.5 MeV rather than 2.2 MeV. Based solely on the three quantitative arguments, we conclude that the γ signal reported by FPH cannot be the 2.2 MeV neutron-capture-on--hydrogen γ ray. Supported in part by U. S. Department of Energy Contract No. DE-AC02-78ET51013. [*] MIT Report PFC/JA-89-24.

[1] J. Electroanal. Chem. 261 (1989) 301-308; and errata.

25 Measurements of Neutron and Gamma Ray Emission Rates and Calorimetry in Electrochemical Cells Having Palladium Cathodes. S.C. LUCKHARDT, X. CHEN, C. FIORE, M. GAUDREAU, D. GWINN, P. LINSAY, R. PARKER, R. PETRASSO, K. WENZEL, Plasma Fusion Center, R. CROOKS, V. CAMMARATA, M. SCHLOH, D. ALBAGLI, M. WRIGHTON, Department of Chemistry, R. BALLINGER, I. HWANG, Department of Material Science and Engineering. MIT--Results of experiments intended to reproduce the excess heat and neutron emission from electrochemical cells reported in Ref. 1 are presented. Radiation emission and power balance measurements were carried out on a set of electrochemical cells consisting of Pd cathodes, Pt anodes, D_2O or H_2O solvent with LiOD or LiOH electrolyte. The current density at the Pd cathode was 32 mA/cm^2 to 250 mA/cm^2 at applied voltages of 3.0V to 15.0V. Moderated BF_3 neutron detectors were absolutely calibrated; for a source strength of 160neutrons/sec count rates would be twice the background level. X-ray pulse height spectroscopy with NaI(Tl) detectors monitored the neutron capture process $p(n,\gamma)d$. Power balance during electrolysis was monitored by means of a constant temperature calorimeter in both D_2O and H_2O electrolytic cells with accuracy of $\pm$15mW.

1. M.Fleischmann, S.Pons, and M.Hawkins, Journal of Electroanalytical Chemistry, 261, 301 (1989).

26 **Tests of "Cold Fusion" in a New Configuration.** F. SKIFF, H. M. MILCHBERG, and J. ROGERS, *Laboratory for Plasma Research, University of Maryland, College Park, MD 20742.* Loading palladium metal with hydrogen isotopes is accomplished in a plasma environment as opposed to an electrolyte in order to permit sensitive tests of potential nuclear events. A palladium electrode is immersed into a plasma of deuterium and ion absorption is enhanced by drawing ion current. The plasma environment permits rapid loading of the metal, sensitive tests of gas composition, as well as searching for neutrons without moderation by water. Preliminary results will be discussed.

27 Cold Nuclear Fusion in Dense Metallic Hydrogen: Implications for Astrophysics. C.J. HOROWITZ, Nuclear Theory Center, Indiana U.[*]— The rate of nuclear fusion from tunnelling of zero point motion in very dense metallic hydrogen is calculated assuming a simple crystal of nuclei interacting via screened coulomb potentials. At a density of five g/cm^3 the fusion rate is 10^{-50} per H-D pair per second. Thus fusion may not contribute to the heating of Jupiter unless a more efficient mechanism is found. However increasing the density to 300 to 2600 g/cm^3 increases the rate to 10^{-21} to 10^{-12} sec^{-1}. It is speculated that a cold condensed object with a small amount of deuterium could be reheated via p + D cold fusion and start conventional thermonuclear fusion.

[*] Supported by the DOE.

28 Theory of Cold Fusion, M. Danos, NIST. --The lowest order Feynman graph leading to dd fusion in the vicinity of a lattice nucleus, M, is given by the tree graph Fig. 1. We assume that the deuteron d_1 is trapped (trapping wave function $\psi_0(t)$) and the deuteron d_2 flies by with relative velocity $v^2 = (2T/m)$ ($\hbar = c = 1$). All momenta $t_i \lesssim 50$ meV are thermal. Hence the initial state is given by a density matrix. In the final state $E_f + \epsilon_f = Q \approx 24$ MeV. The electromagnetic vertices F(q) and f(q), even though off-the-mass-shell, are given in order of magnitude by the form factors known from electron scattering, and $\psi(p)$ is the momentum space wave function of the d-d component of the ^{4}He ground state, which can be estimated from nuclear structure data. The order of magnitude of the resulting rates corresponds to the observed rate of 10^{-10} sec^{-1}. (The reaction mechanism is easiest understood by considering the time-reversed reaction.) The suppression of the emission of protons or neutrons arises from the replacement of f(q) by the break-up from factor $\tilde{f}(q,q_1)$, Fig. 2, and by the replacement of the 2-body by the 3-body density of states. Similarly, the photon emission is suppressed by the replacement of the fusion vertex $\psi(p)$ by $\tilde{\psi}(p,k)$, Fig. 3. The details will be presented.

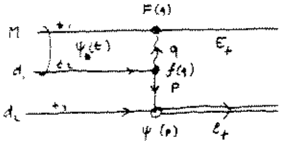

Fig. 1

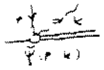

Fig. 2 Fig. 3

29 Limits on Cold Fusion in Matter: a Parametric Study.[*] J. RAFELSKI, M. GAJDA, D. HARLEY and S.E. JONES[**], University of Arizona —The rate of nuclear fusion of d-d hydrogen isotopes is studied as a function of several parameters, and is found to be critically sensitive in a regime of the parameter space that could be of physical relevance and also account for the fusion rate recently measured by Jones *et al.* The fusion rate in the $(dde)^+$ ion-like structure is computed as a function of the maximum allowed hydrogen separation and as a function of an effective electronic mass and charge, leading to a fusion rate of the needed magnitude. These numerical exercises highlight the extraordinary sensitivity of the fusion rate to the physical parameters and the environment characterizing the system in which the $(dde)^+$ complex is embedded. It is further shown that the effect each of these parameters has on the fusion rate is cumulative and that a neutron rate of 10^{-23} s^{-1} per atom is obtained with a plausible combination of these parameters. The fusion rate resulting from a low energy, less than 100 eV d-d scattering description is also computed and is shown to be too small.

[*] Work supported by DOE/AEP

[**] Brigham Young University

30 Electron Catalyzed Fusion in Metals*. D. A. BROWNE, R. G. GOODRICH, P. N. KIRK and E. F. ZGANJAR, L.S.U. — We present a simple model for the induction of nuclear fusion in metals through the formation of neutral and charged deuterium complexes similar to the mechanism of muon catalyzed fusion. The role of various materials properties of Pd and other metals in enhancing the fusion rate will also be discussed. We are currently taking measurements on a sample of Pd and a heavy fermion material and will present the results of our experiment in light of the model.

*Supported by LSU Center for Energy Studies

31 **The Cold Fusion Rate of *d*-*d* in PdDx Hydride and the Branching Ratio of the He-4 to (*p*,*n*) Production Reactions.** HIROSHI TAKAHASHI, *Brookhaven National Laboratory.* Many electrons from the *d* and *s* conduction bands of PdDx hydride pile up near deuterons. This accumulation results to large screening of potential between deuterons and enhances the cold fusion rate. The number of the piled up electron is approximately proportional to the inverse of the density of the conduction electron level at the Fermi level; the linear response theory underestimates the number of electrons by about a factor of 4 less than the nonlinear response theory. The branching ratio of the production process of He-4 to (*p* and *n*) is extremely small in the collision experiment, and the transition from the *s* wave channel in cold fusion to the ground He-4 0+ state by emitting gamma-ray is prohibitive. The He-4 production process of emitting the surrounding electrons becomes appreciable, and to get an extremely large branching ratio requires the coherent direct excitation of optical phonons of PdDx hydride or coherent excitation through the surrounding conduction electrons by a strong electron lattice coupling. This work is supported by DOE Advanced Energy Project Division.

32 **Criterion for Cold Fusion in the Condensed State** E.A. STERN* *Physics Dept. FM-15, University of Washington, Seattle, WA 98195* -- To increase the rate of tunneling through the coulomb barrier between two nuclei of isotopic hydrogen in the condensed state, the surrounding electrons must provide a more efficient shielding than occurs in the molecule. Koonin and Nauenberg(1) expressed this increased shielding requirement in terms of at least a five-fold increase in the electron mass to be consistent with claims of experiments. From Thomas-Fermi screening theory this requirement translates to at least a $5^3 = 125$-fold increase in the electron density from its value in the molecule. This required density is several orders of magnitude greater than occurs in metallic hydrides in either the interstitial sites or any defect sites where hydrogen can reside. Cold fusion cannot occur in the condensed state under conditions employed in the reported experiments.

*Research supported by DOE grant DE-FG06-84ER45163.

(1) S.E. Koonin and M. Nauenberg, Santa Barbara Institute for Theoretical Physics preprint NSF-ITP-89-48. April 1989.

33 **Theoretical Estimates of the Enhancement of Cold Fusion of Deuterium in Deuterated Palladium Systems.** M. W. C. DHARMAWARDANA AND G. C. AERS, *Division of Physics, National Research Council of Canada, Ottawa, Canada K1A 0R6.* [Bitnet: Chandre at NRCVMO1, FAX: (613) 957-8734]. We have estimated the enhancement of the nuclear fusion rate of Pd-D type systems and the D_2^+-muonium molecule in comparison with the fusion rate in a D_2-molecule at room temperature. The theoretical model uses standard ideas on screening and nuclear reaction rate. If very conservative estimates are made the enhancements for a pair of D^+-nuclei in Pd, PdD and in the D_2^+-μ molecule are found to be 10^{14}, 10^{21}, and 10^{64}. We also discuss the dependence of the enhancement on temperature, localization of D^+ in Pd etc. These results are quite encouraging for the possibilities of cold fusion of deuterium in palladium.

34 *Chemical Forces Associated with Confinement of Deuterium in Palladium.* B. I. DUNLAP, J. W. MINTMIRE, D. W. BRENNER, R. C. MOWREY, H. D. LADOUCEUR, P. P. SCHMIDT, C. T. WHITE, and W. E. O'GRADY Naval Research Laboratory—First-principles and embedded-atom methods were used to study the effective interaction between two deuterons in a palladium lattice. At scales ranging from 0.1 to 1.0 Å no effects are found to suggest that the effective interaction between two deuterons in palladium is significantly reduced from what is expected for gas phase D_2. Our results show clearly that molecular D_2 in palladium should dissociate to distances of the order of 1.0 Å or greater even in PdH_2 lattices.

35 **Molecule-Nucleus Resonance Enhancement of Cold Nuclear Fusion.** A. V. BARNES and HEATH POIS, *Center for Atomic and Molecular Physics at Surfaces and Department of Physics and Astronomy, Vanderbilt University, Nashville, TN 37235.* Resonance between molecular and nuclear states is considered as a possible means of enhancing fusion rates. Calculations of fusion reaction rates based on a two state description of the resonating system are presented. In particular we show the deuterium-deuterium gas phase fusion rates with resonance are orders of magnitude larger than rates without resonance.

36 **The Bond Length of the Deuterium Molecule in a Metallic Lattice.** A. B. HASSAM,* *Department of Physics and Astronomy, University of Maryland, College Park,* and A. N. DHARAMSI,* *Department of Electrical and Computer Engineering, Old Dominion University, Norfolk.* The bond length of the D_2 molecule in vacuum is .7 A. The lattice constant of palladium is 4 A. If the D_2 molecule forms inside a primitive lattice cell, what is the bond length? We suggest that the bond length of the D_2 molecule is reduced by lattice effects as follows: Because of the nature of the metallic bond, a preponderance of electronic charge is expected at the center of the lattice cell from the Fermi sea. The D^+ nuclei in a D_2 molecule forming at the center of the cell, therefore, are subject to an extra attractive force from this preponderance, leading to a reduction in bond length. We present a numerical solution of the ground state wavefunction of the D_2^+ molecular ion in the presence of an externally imposed negative charge concentration. For a total charge on the order of one electronic charge and scale size of the concentration of order 1 A, we show that up to a 50% reduction in the bond length of D_2^+ is effected. Results of the numerical solution for various charge distributions are presented. Similar results for the D_2 molecule, obtained by a model calculation, are also discussed.

*APS member.

37 **Fluctuations and Cold Fusion.*** MING LI, *University of Maryland, College Park.* We examine more closely the recent suggestion of Koonin that fusion rate can be enhanced by fluctuations. We look at several possible mechanisms for the fluctuations. The relevance to the heat generation in the core of Jupiter is also discussed. To gain some insight into these fluctuations, we propose to exactly soluble models: the one-dimensional model of an open quantum system for a harmonic oscillator and the two-dimensional lattice gas model. The fusion rate reported by Jones *et al.* requires fluctuations of such magnitude which are unlikely to be present in the palladium lattice.

*Supported by the U.S. Department of Energy.

38 Simple yet Accurate Model Potential for Calculating Cold Fusion Rates. J.D. MORGAN III, Harvard University,* and H. J. MONKHORST, U. of Florida.** Following the fundamental analysis of Jackson[1] and more recent work by van Siclen and Jones[2], we have developed a very simple model potential which allows us to calculate with remarkable accuracy the Coulomb barrier penetration factor which appears in the fusion rate. Our approach is very useful in showing how the Coulomb barrier penetration factor depends on various physical parameters, and in allowing one to make a simple yet accurate estimate of fusion rates. We will show how one can use our result to relate

the measured d-d fusion rate to the rates of other fusion reactions involving hydrogen isotopes.

[*] Permanent address: Dept. of Physics, U. of Delaware. Supported by NSF grant PHY-8608155.

[**] Supported by the Division of Advanced Energy Projects of the Dept. of Energy.

[1] J.D. Jackson, Phys. Rev. 106, 330 (1957).

[2] C. DeW. van Siclen and S.E. Jones, J. Phys. G 12, 213 (1986).

39 **Exotic QED and Cold Nuclear Fusion.*** MING LI, *University of Maryland, College Park.* If one could see any signal of cold fusion at all using the best state of the art neutron detector, the corresponding fusion rate would still be many orders of magnitude larger than what would be expected on the basis of conventional wisdom. Should unmistakable evidence for cold nuclear fusion be detected in the future, we suggest that non-linear and non-perturbative aspects of QED may provide an explanation for the discrepancy in the fusion rate. Specifically, we explore one such possibility that is motivated by the GSI experiments of anomalous e^+e^- peaks.

*Supported by the U.S. Department of Energy.

40 **Search for Radiations from Cold Fusion in Pd-D System** R. S. Raghavan, L. C. Feldman, M. M. Broer, A. James and D. Murphy, AT&T Bell Laboratories, Murray Hill, NJ, -- We report on a search for neutrons from dd fusion in Pd rods loaded electrolytically with deuterium. Three Pd rods were used: 1) 0.125dia. x9cm long, drawn and cold worked; 2) 0.125dia. x9 cm long, drawn and annealed; 3) 0.41dia. x8cm long, cast and annealed. The rods were held in two different electrolytic cells (D_2O (99.5% D)+0.1M LiOD, current density 64 mA/cm^2) placed before a 12.5dia. x12.5cm NaI(Tl) detector with 5cm of polyethylene (PE) moderator interposed. A pair of plastic scintillator plates above and below the NaI(Tl) vetoed cosmic muons. The entire set-up was housed inside 10cm thick PE surrounded on the outside with Pb and borax. Fusion neutrons are moderated, creating inside the PE housing a slow neutron gas that can be detected by two signal modes of γ-ray producing reactions: (1) n-capture by protons in the PE (2.224 MeV γ); (2) ^{23}Na and ^{127}I n-capture γ-rays in the range 3-7 MeV. The latter is a more sensitive signal since it is produced inside the NaI(Tl) and the background is mostly due to cosmic rays, much less than that below 2.62 MeV (due to natural radioactivity). From the overall n detection efficiency (measured with an Am-Be source at the cell position) and the cosmic ray background limit, we deduce that a neutron production rate of $\sim$ 1 n/sec in the cells can be measured with high confidence. After measuring for approximately three weeks we observe <0.08 n/sec/g Pd, (0.4 cm dia. rod) compared to $\sim 2.7 \times 10^3$ n/sec/g Pd, claimed in recent work* for a closely similar Pd rod.

*M. Fleischmann and B. S. Pons, J. Electroanal. Chem. 261(1989)301.