

# Stanford

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## Martin Breidenbach

Professor of Particle Physics and Astrophysics, Emeritus

### Bio

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#### BIO

I have worked for more than 45 years in experimental particle physics, often in developing new kinds of electronics and instruments critical to the detectors that enable the physics experiments of interest. In 1965 through 1971, I was involved in the electron scattering program at SLAC. The deep inelastic experiments that discovered the scaling and point like structure in the nucleon, later interpreted as quarks, was my Ph.D. thesis. I then spent a year at CERN, mostly doing an experiment on minimum bias behavior of proton-proton scattering at the newly operating Intersecting Storage Rings. Despite intentions to stay longer at CERN, I was persuaded by Professor Richter to return to SLAC and join his SPEAR storage ring group. In the 1974 “November Revolution”, we discovered the  $\chi$  and  $\chi'$  particles, soon interpreted as bound states of charm-anti-charm quarks, which caused essentially complete acceptance of the quark model as real. Another critical discovery at SPEAR was the  $\chi$  lepton, leading to the third family of the Standard Model.

Subsequently Professor Charles Baltay and I were co-spokesmen of the SLD, a comprehensive large detector for the SLAC Linear Collider (SLC), where we did Z physics, particularly polarization asymmetries possible because of the SLC polarized electron beam which led to a (correct) prediction of the Higgs mass, and precision b physics with a 300 MPixel CCD vertex detector.

I am now involved in the design of a detector for the International Linear Collider which may be built in Japan, which has led to substantial involvement in Si detector sensors and associated readout ASIC's. I believe we have developed the first wafer scale sensors with on sensor traces leading to a relative small area “readout system on a chip” that delivers processed digital signals to a DAQ.

I also work on a search for neutrinoless double beta decay ( $0\nu 2\beta$ ) in  $^{136}\text{Xe}$ . The  $0\nu 2\beta$  experiment utilizes a liquid xenon TPC requiring ultra-low background materials, techniques, and locations, which was an education into rather different experimental techniques from collider detectors.

I am working on a new concept for an  $e^+e^-$  linear collider called C<sup>3</sup> for the Cool Copper Collider. The Cool Copper Collider (C3) is an advanced concept for a high energy  $e^+e^-$  linear collider. It is based on a new SLAC technology that dramatically improves efficiency and breakdown rate. C3 uses distributed power to each cavity from a common RF manifold and operates at cryogenic temperatures (LN2, ~80K). This makes it robust at high gradient: 120~MeV/m.

C3 is a promising option for a next-generation  $e^+e^-$  collider. It has the potential to reach energies of up to 1 TeV, which would allow it to study the properties of particles that are difficult to access with current experiments. C3 is also relatively affordable, which makes it a more viable option than some of the other proposed linear colliders.

Finally, these recent experiences have led to exploratory collaborative efforts in neuroscience, where we believe our SLAC expertise in sensors and electronics could be rather synergistic with Stanford efforts in tACs and in neural recording probes.

## ACADEMIC APPOINTMENTS

- Professor Emeritus, Particle Physics and Astrophysics

## HONORS AND AWARDS

- Panofsky Prize, American Physical Society (2000)
- Fellow, American Physical Society (1985)

## PROFESSIONAL EDUCATION

- Ph.D., MIT, Physics (1970)
- B.S., MIT, Physics (1965)

## Publications

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### PUBLICATIONS

- **Search for Majorana neutrinos with the first two years of EXO-200 data** *NATURE*  
Albert, J. B., Auty, D. J., Barbeau, P. S., Beauchamp, E., Beck, D., Belov, V., Benitez-Medina, C., Bonatt, J., Breidenbach, M., Brunner, T., Burenkov, A., Cao, G. F., Chambers, et al  
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- **Fine grained silicon-tungsten calorimetry for a linear collider detector** *IEEE TRANSACTIONS ON NUCLEAR SCIENCE*  
Strom, D., Frey, R., Breidenbach, M., Freytag, D., Graf, N., Haller, G., Milgrome, O., Radeka, V.  
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- **High-precision measurement of the left-right Z boson cross-section asymmetry** *PHYSICAL REVIEW LETTERS*  
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- **Accelerators and detectors** *REVIEWS OF MODERN PHYSICS*  
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- **Design and performance of the SLD vertex detector: a 307 Mpixel tracking system** *NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH SECTION A-ACCELERATORS SPECTROMETERS DETECTORS AND ASSOCIATED EQUIPMENT*  
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- **AN INVERTED-GEOMETRY, HIGH-VOLTAGE POLARIZED ELECTRON-GUN WITH UHV LOAD LOCK** *NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH SECTION A-ACCELERATORS SPECTROMETERS DETECTORS AND ASSOCIATED EQUIPMENT*  
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1994; 350 (1-2): 1-7
- **FAST TRACK-FINDING TRIGGER PROCESSOR FOR SLAC-LBL MARK-II DETECTOR** *IEEE TRANSACTIONS ON NUCLEAR SCIENCE*  
BRAFMANN, H., Breidenbach, M., HETTEL, R., Himel, T., HORELICK, D.  
1978; 25 (1): 692-697
- **EVIDENCE FOR ANOMALOUS LEPTON PRODUCTION IN E+ -E- ANNIHILATION** *PHYSICAL REVIEW LETTERS*  
PERL, M. L., Abrams, G. S., Boyarski, A. M., Breidenbach, M., Briggs, D. D., Bulos, F., CHINOWSKY, W., DAKIN, J. T., FELDMAN, G. J., Friedberg, C. E., Fryberger, D., Goldhaber, G., HANSON, et al  
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- **EVIDENCE FOR JET STRUCTURE IN HADRON PRODUCTION BY E+E- ANNIHILATION** *PHYSICAL REVIEW LETTERS*  
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- **DISCOVERY OF A NARROW RESONANCE IN E+E- ANNIHILATION** *PHYSICAL REVIEW LETTERS*  
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- **DISCOVERY OF A SECOND NARROW RESONANCE IN E+E- ANNIHILATION** *PHYSICAL REVIEW LETTERS*  
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- **ELASTIC ELECTRON-PROTON SCATTERING AT LARGE 4-MOMENTUM TRANSFER** *PHYSICAL REVIEW D*  
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- **A “Cool” route to the Higgs boson and beyond. The Cool Copper Collider** *JINST - Journal of Instrumentation*  
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- **Richard Edward Taylor** *PHYSICS TODAY*  
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- **First search for Lorentz and CPT violation in double beta decay with EXO-200** *PHYSICAL REVIEW D*  
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- **Search for 2 nu beta beta decay of Xe-136 to the 0(1)(+) excited state of Ba-136 with the EXO-200 liquid xenon detector** *PHYSICAL REVIEW C*  
Albert, J. B., Auty, D. J., Barbeau, P. S., Beck, D., Belov, V., Breidenbach, M., Brunner, T., Burenkov, A., Cao, G. F., Chambers, C., Chaves, J., Cleveland, B., Coon, et al  
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- **Measurements of the ion fraction and mobility of alpha- and beta-decay products in liquid xenon using the EXO-200 detector** *PHYSICAL REVIEW C*  
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2015; 92 (4)
- **Investigation of radioactivity-induced backgrounds in EXO-200** *PHYSICAL REVIEW C*  
Albert, J. B., Auty, D. J., Barbeau, P. S., Beck, D., Belov, V., Benitez-Medina, C., Breidenbach, M., Brunner, T., Burenkov, A., Cao, G. F., Chambers, C., Cleveland, B., Coon, et al  
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- **An RF-only ion-funnel for extraction from high-pressure gases** *INTERNATIONAL JOURNAL OF MASS SPECTROMETRY*  
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- **Search for Majoron-emitting modes of double-beta decay of Xe-136 with EXO-200** *PHYSICAL REVIEW D*  
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- **Improved measurement of the 2 nu beta beta half-life of Xe-136 with the EXO-200 detector** *PHYSICAL REVIEW C*  
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- **Xenon purity analysis for EXO-200 via mass spectrometry** *NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH SECTION A-ACCELERATORS SPECTROMETERS DETECTORS AND ASSOCIATED EQUIPMENT*  
Dobi, A., Hall, C., Slutsky, S., Yen, Y., Aharmin, B., Auger, M., Barbeau, P. S., Benitez-Medina, C., Breidenbach, M., Cleveland, B., Conley, R., Cook, J., COOK, et al  
2012; 675: 40-46
- **The EXO-200 detector, part I: detector design and construction** *JOURNAL OF INSTRUMENTATION*  
Auger, M., Auty, D. J., Barbeau, P. S., Bartoszek, L., Baussan, E., Beauchamp, E., Benitez-Medina, C., Breidenbach, M., Chauhan, D., Cleveland, B., Conley, R., Cook, J., COOK, et al  
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- **THGEM-based detectors for sampling elements in DHCAL: laboratory and beam evaluation** *JOURNAL OF INSTRUMENTATION*  
Arazi, L., Natal da Luz, H., Freytag, D., Pitt, M., Azevedo, C. D., Rubin, A., Cortesi, M., Covita, D. S., Oliveira, C. A., Oliveri, E., Herbst, R., Park, S., Yu, et al  
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- **A xenon gas purity monitor for EXO** *NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH SECTION A-ACCELERATORS SPECTROMETERS DETECTORS AND ASSOCIATED EQUIPMENT*  
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- **A simple radionuclide-driven single-ion source** *REVIEW OF SCIENTIFIC INSTRUMENTS*  
Diez, M. M., Twelker, K., Fairbank, W., Gratta, G., Barbeau, P. S., Barry, K., DeVoe, R., Dolinski, M. J., Green, M., LePort, F., Mueller, A. R., Neilson, R., O'Sullivan, et al  
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- **Characterization of large area APDs for the EXO-200 detector** *NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH SECTION A-ACCELERATORS SPECTROMETERS DETECTORS AND ASSOCIATED EQUIPMENT*  
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- **Systematic study of trace radioactive impurities in candidate construction materials for EXO-200** *NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH SECTION A-ACCELERATORS SPECTROMETERS DETECTORS AND ASSOCIATED EQUIPMENT*  
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- **Observation of single collisionally cooled trapped ions in a buffer gas** *PHYSICAL REVIEW A*  
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2007; 76 (2)
- **A liquid xenon ionization chamber in an all-fluoropolymer vessel** *NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH SECTION A-ACCELERATORS SPECTROMETERS DETECTORS AND ASSOCIATED EQUIPMENT*  
LePort, F., Pocar, A., Bartoszek, L., DeVoe, R., Fierlinger, P., Flatt, B., Gratta, G., Green, M., Koffas, T., Diez, M. M., Neilson, R., O'Sullivan, K., Waldman, et al  
2007; 578 (2): 409-420
- **A linear RFQ ion trap for the enriched xenon observatory** *NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH SECTION A-ACCELERATORS SPECTROMETERS DETECTORS AND ASSOCIATED EQUIPMENT*  
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- **Mobility of thorium ions in liquid xenon** *NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH SECTION A-ACCELERATORS SPECTROMETERS DETECTORS AND ASSOCIATED EQUIPMENT*  
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- **Measurement of the branching ratios of the Z(0) into heavy quarks** *PHYSICAL REVIEW D*  
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- **Direct measurements of A(b) and A(c) using vertex and kaon charge tags at the SLAC detector** *PHYSICAL REVIEW LETTERS*  
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- **Correlated fluctuations between luminescence and ionization in liquid xenon** *PHYSICAL REVIEW B*  
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- **Improved direct measurement of the parity-violation parameter A(b) using a mass tag and momentum-weighted track charge** *PHYSICAL REVIEW LETTERS*  
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- **Measurement of the  $b$ -quark fragmentation function in  $Z(0)$  decays** *PHYSICAL REVIEW D*  
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