Abstract for an Invited Paper
for the DAMOP16 Meeting of
the American Physical Society

**Entangled states of spin and clock oscillators**
EUGENE POLZIK, Niels Bohr Institute, University of Copenhagen

Measurements of one quadrature of an oscillator with precision beyond its vacuum state uncertainty have occupied a central place in quantum physics for decades. We have recently reported the first experimental implementation of such measurement with a magnetic oscillator [1]. However, a much more intriguing goal is to trace an oscillator trajectory with the precision beyond the vacuum state uncertainty in both position and momentum, a feat naively assumed not possible due to the Heisenberg uncertainty principle. We have demonstrated that such measurement is possible if the oscillator is entangled with a quantum reference oscillator with an effective negative mass [2,3]. The key element is the cancellation of the back action of the measurement on the composite system of two oscillators. Applications include measurements of e.m. fields, acceleration, force and time [4] with practically unlimited accuracy. In a more general sense, this approach leads to trajectories without quantum uncertainties and to achieving new fundamental bounds on the measurement precision.