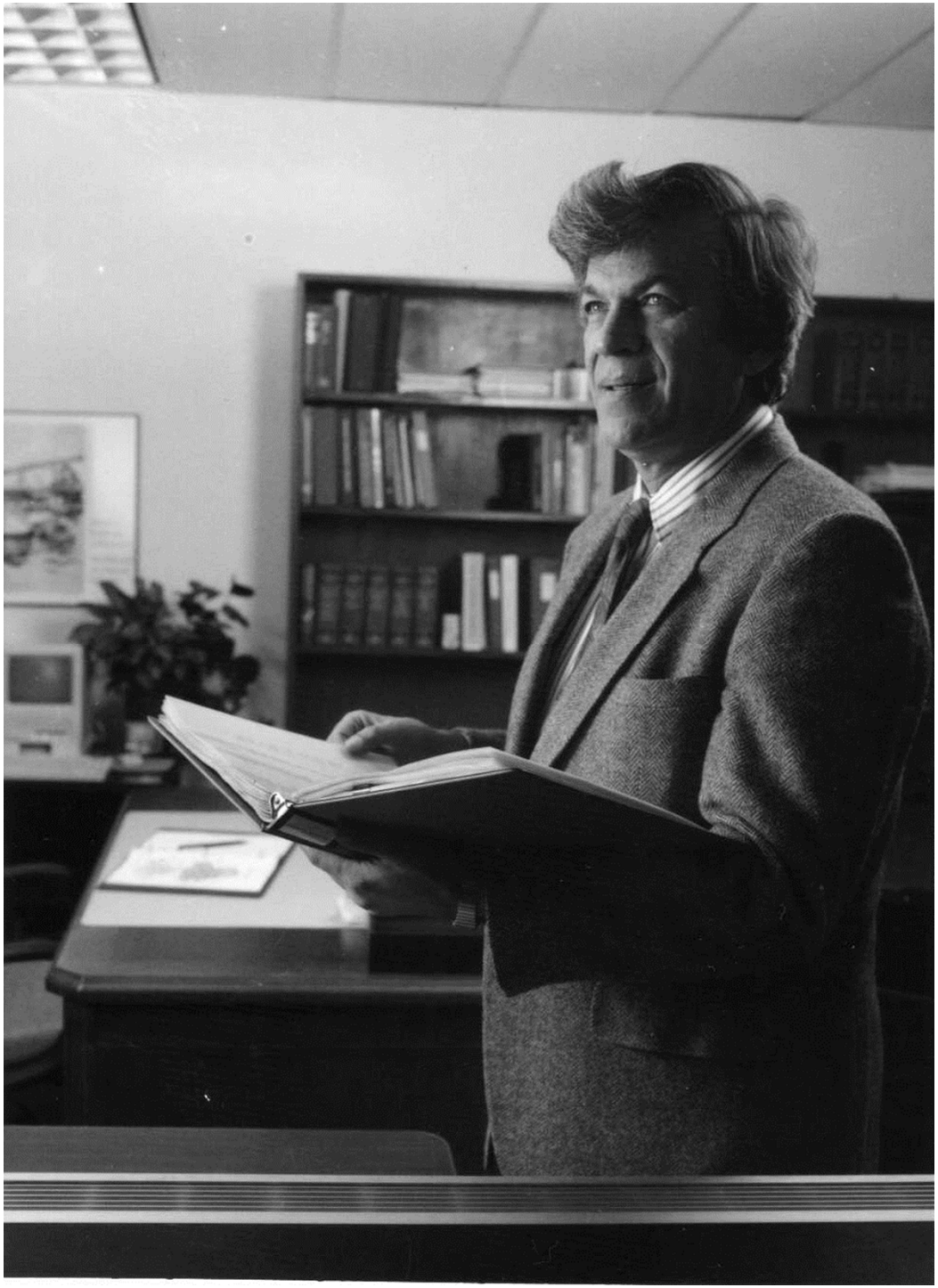


Ronald C. Davidson

1941 – 2016

Erik P. Gilson

Princeton Plasma Physics Laboratory

HIF2016

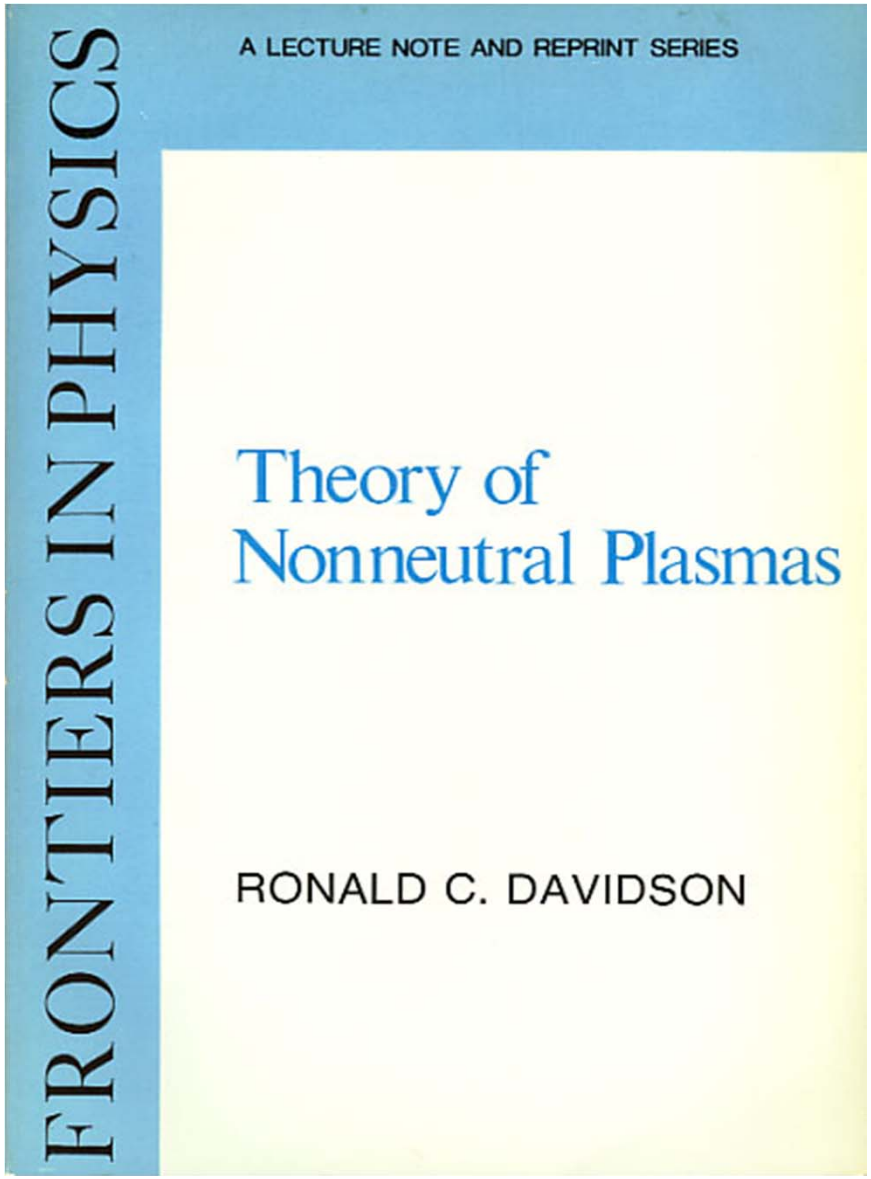
21st International Symposium on Heavy Ion Fusion

Astana, Kazakhstan

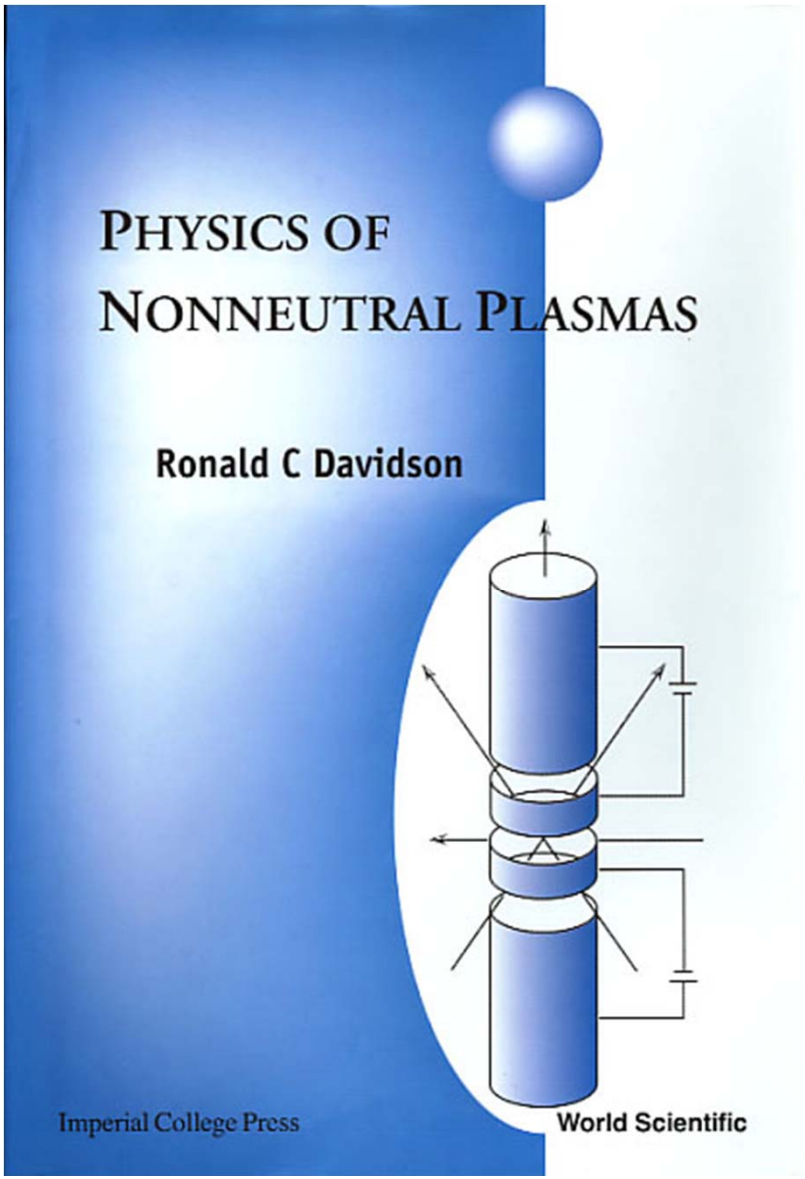
July 18 – 22

Ron was a Pioneer of Nonneutral Plasmas

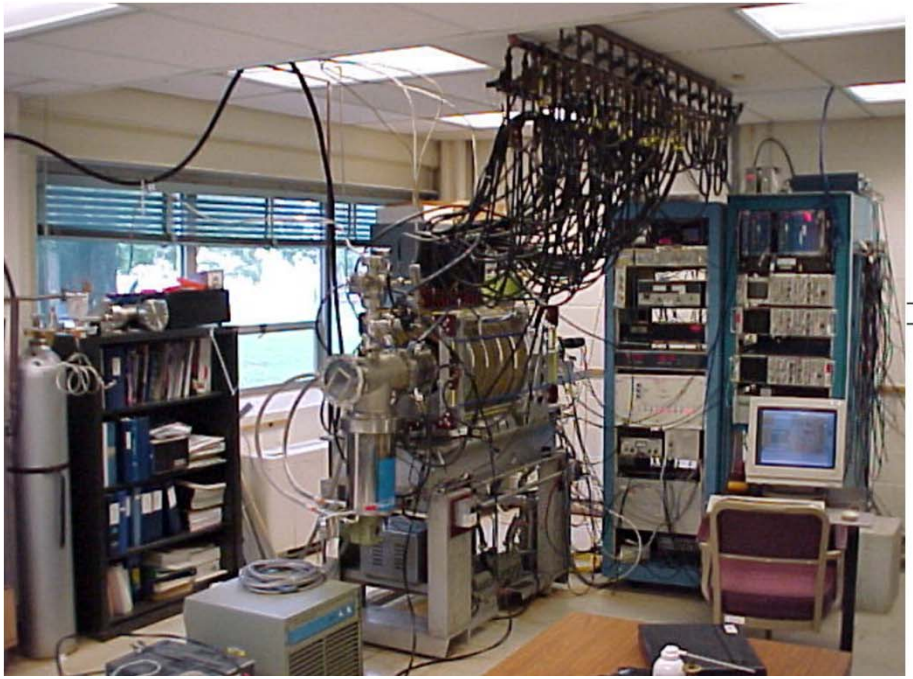
1974

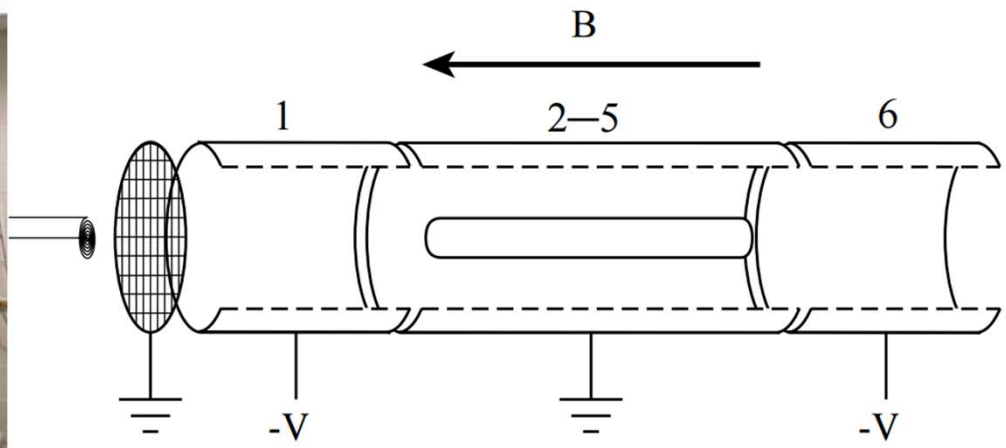


1990



Electron Diffusion Gauge (EDG) Experiment





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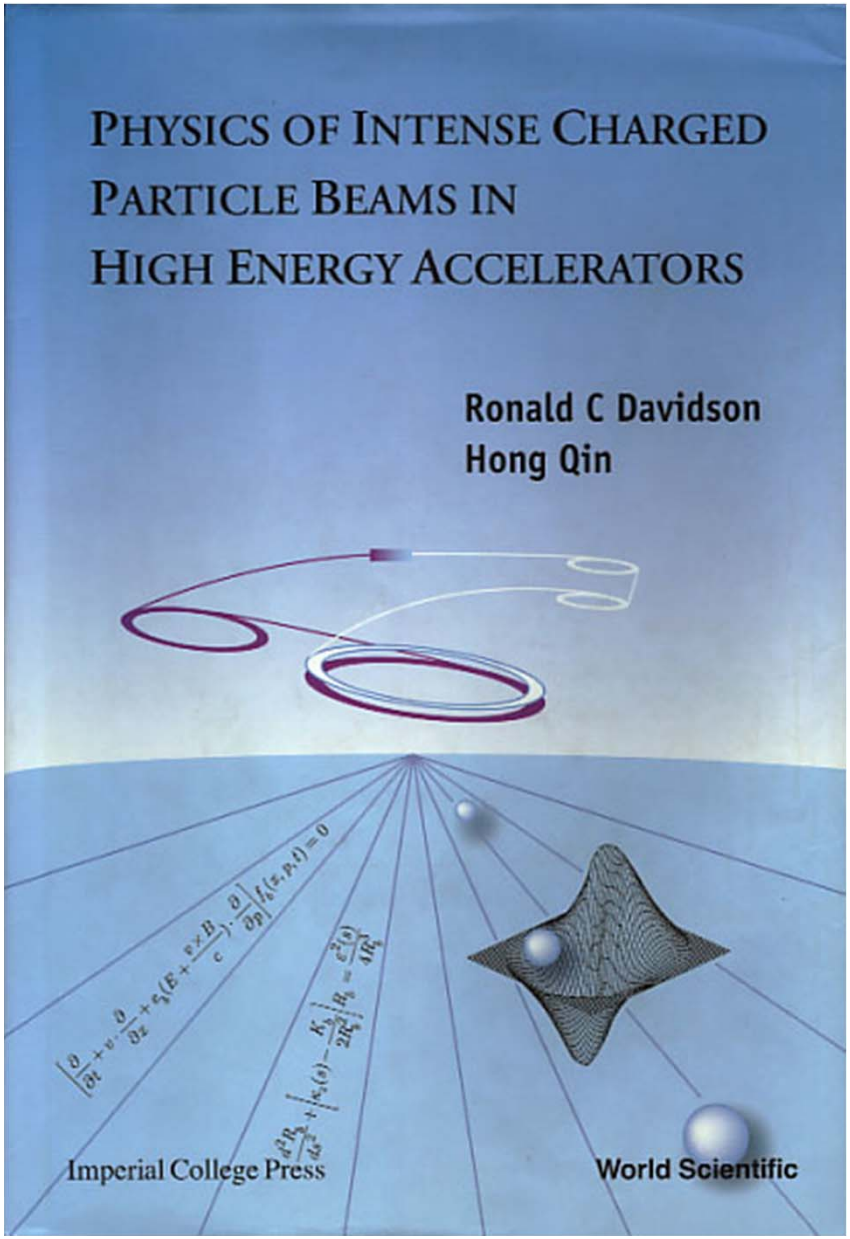
Beams as Nonneutral Plasmas



- "Nonlinear Dynamics of an Intense Nonneutral Ion Beam Propagating Through a Periodic Focusing Field," Q. Qian, Ph.D. Thesis, Princeton University (1995).
- "Nonlinear Dynamics and Collective Processes in Intense Charged Particle Beams," S. Strasburg, Ph.D. Thesis, Princeton University (2001).

The Paul Trap Simulator Experiment

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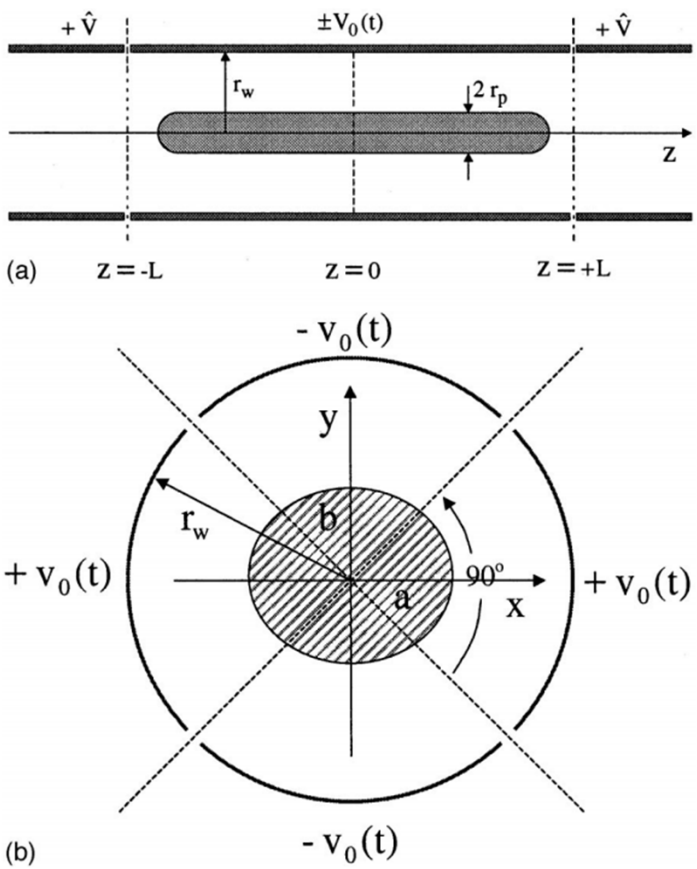


$$t \rightarrow s,$$

$$(\dot{x},\dot{y}) \rightarrow (x',y'),$$

$$\frac{q}{m}\phi_s(x,y,t) \rightarrow \psi(x,y,s),$$

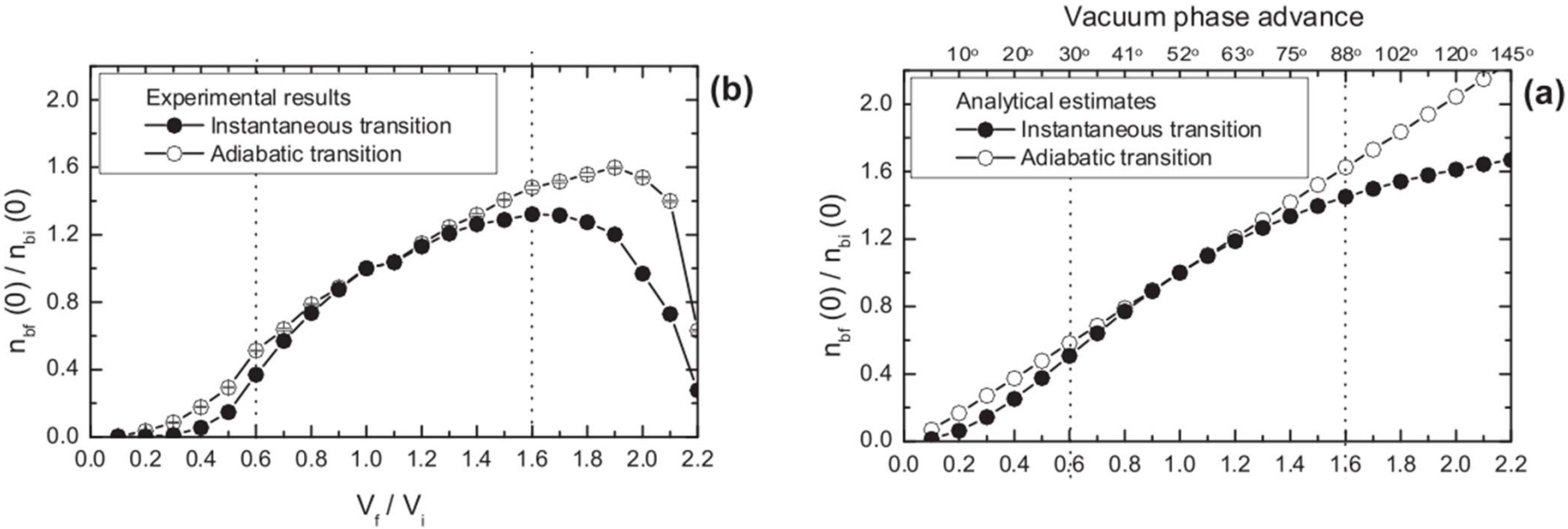
$$\kappa_q(t)[\text{Eq. (9)}] \rightarrow \kappa_q(s)[\text{Eq. (2)}]$$

$$\frac{1}{m}H_\perp(x,y,\dot{x},\dot{y},t) \rightarrow \hat{H}_\perp(x,y,x',y',s),$$

$$\kappa_q(t) \equiv \frac{8qV_0(t)}{m\pi r_w^2}.$$

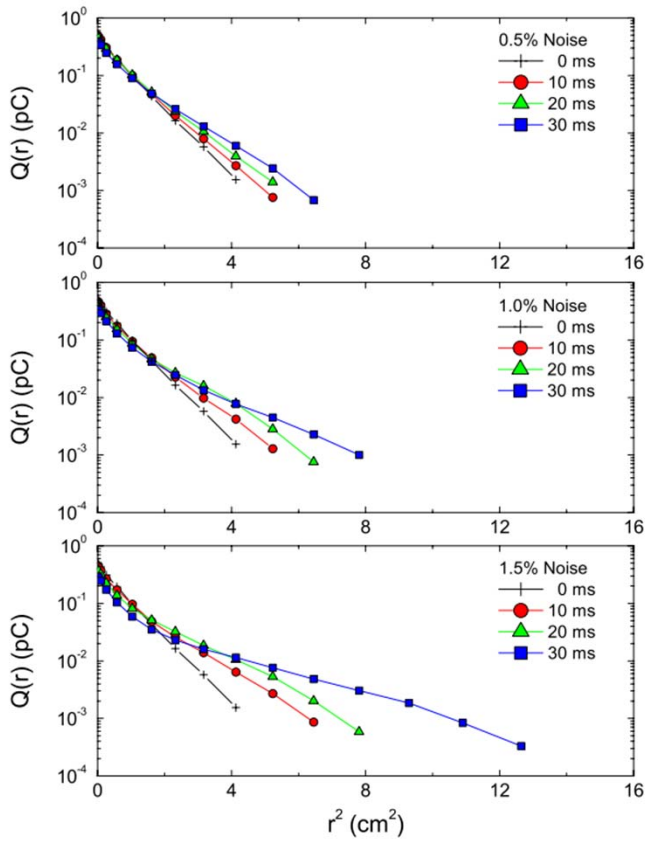
$$\kappa_q(s) = \frac{q_b B_q'(s)}{\gamma_b m_b \beta_b c^2}.$$

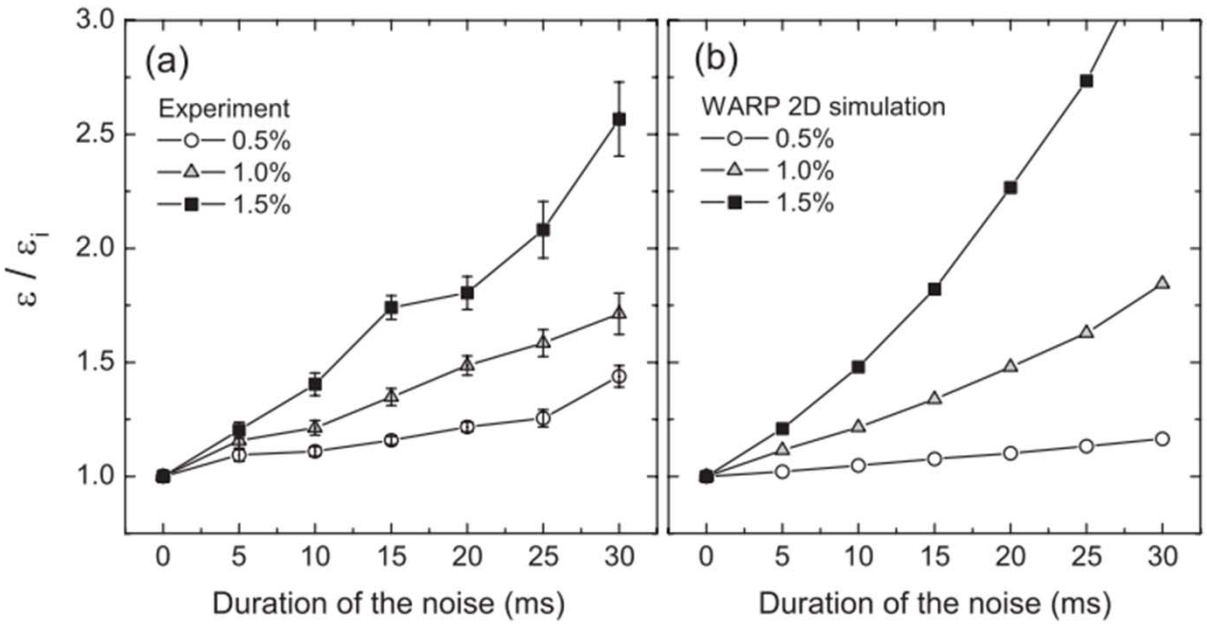
Adiabatic and Instantaneous Lattice Change were Compared



"Experiments on Transverse Compression of a Long Charge Bunch in a Linear Paul Trap", M. Chung, E.P. Gilson, M. Dorf, R. C. Davidson, P.C. Efthimion and R. Majeski, Physical Review Special Topics Accelerators and Beams **10**, 064202 (2007).

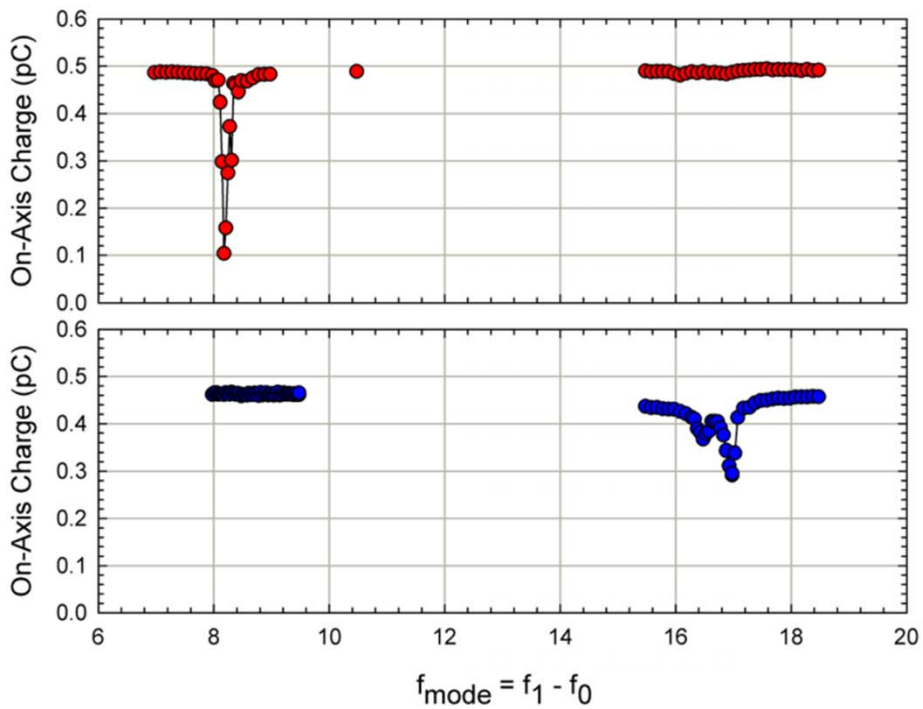
Noise Drives Emittance Growth and Halo Particles

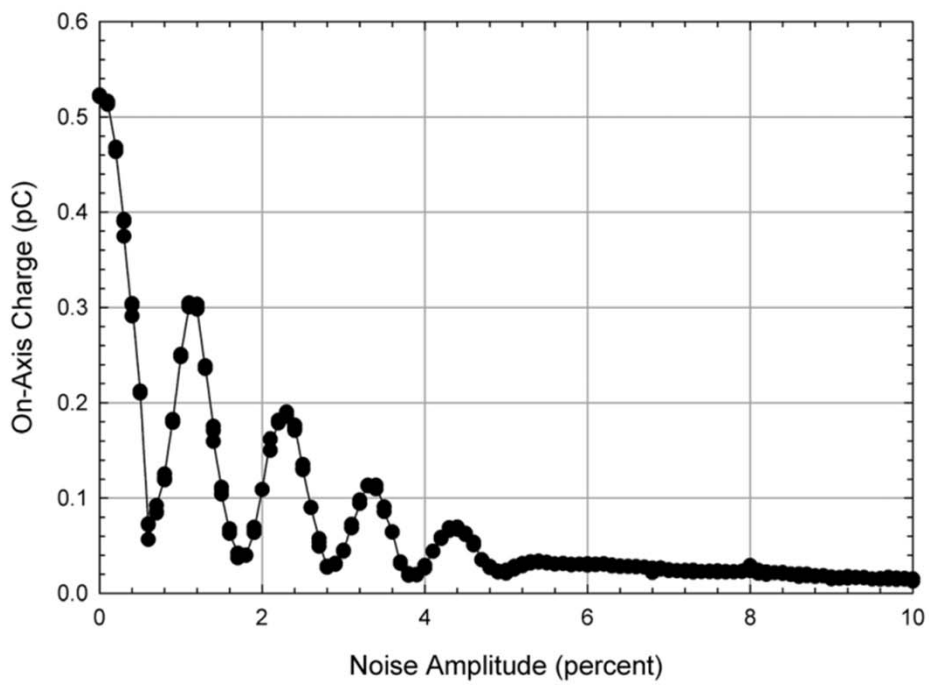




"Use of a Linear Paul Trap to Study Random Noise-Induced Beam Degradation in High-Intensity Accelerators", M. Chung, E. P. Gilson, R. C. Davidson, P. C. Efthimion, and R. Majeski, Physical Review Letters **102**, 145003 (2009).

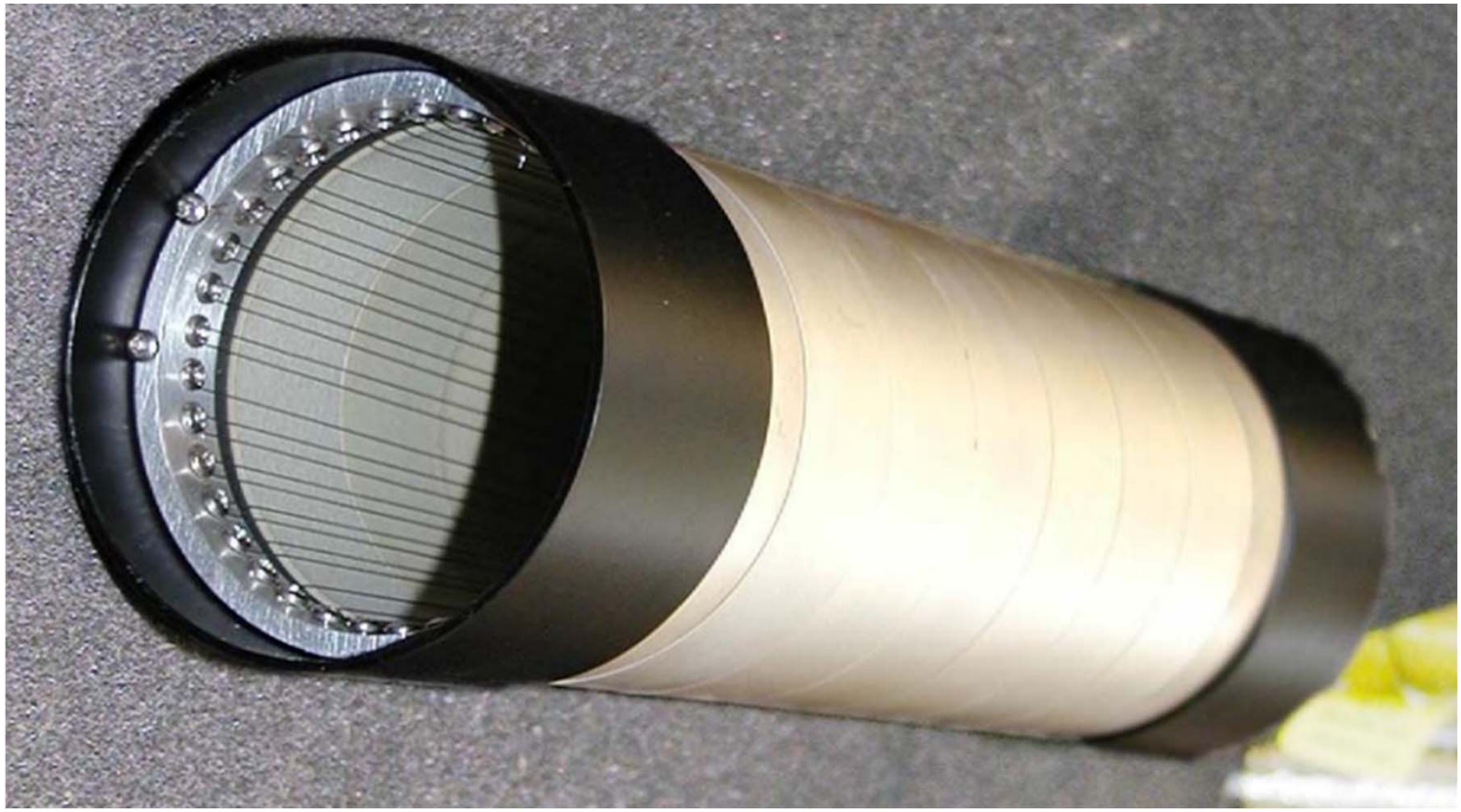
Dipole and Quadrupole Modes Driven to Nonlinear Regime





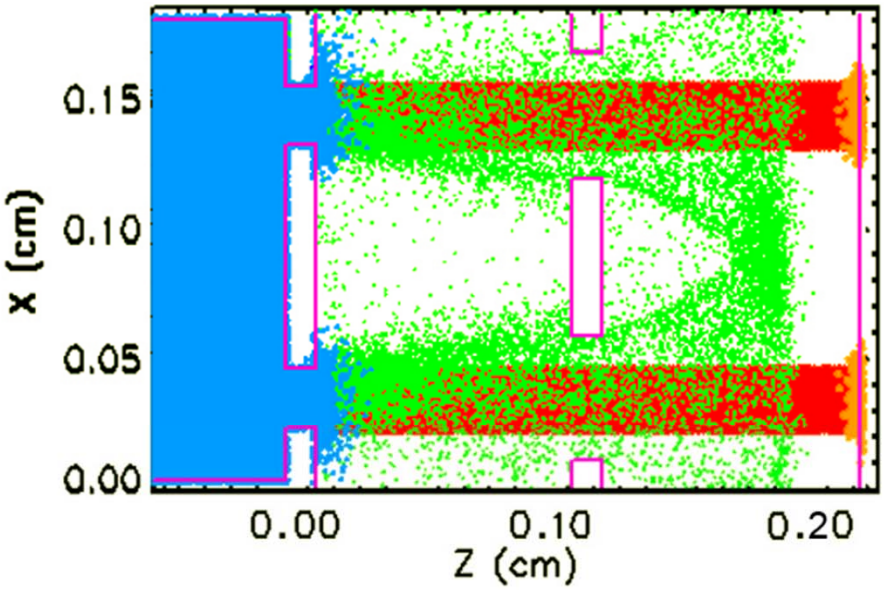
"Excitation of Transverse Dipole and Quadrupole Modes in a Pure Ion Plasma in a Linear Paul Trap to Study Collective Processes in Intense Beams", E. P. Gilson, R. C. Davidson, P. C. Efthimion, R. Majeski, E. A. Startsev, H. Wang, S. Koppell, M. Talley, Physics of Plasmas **20**, 055706 (2013).

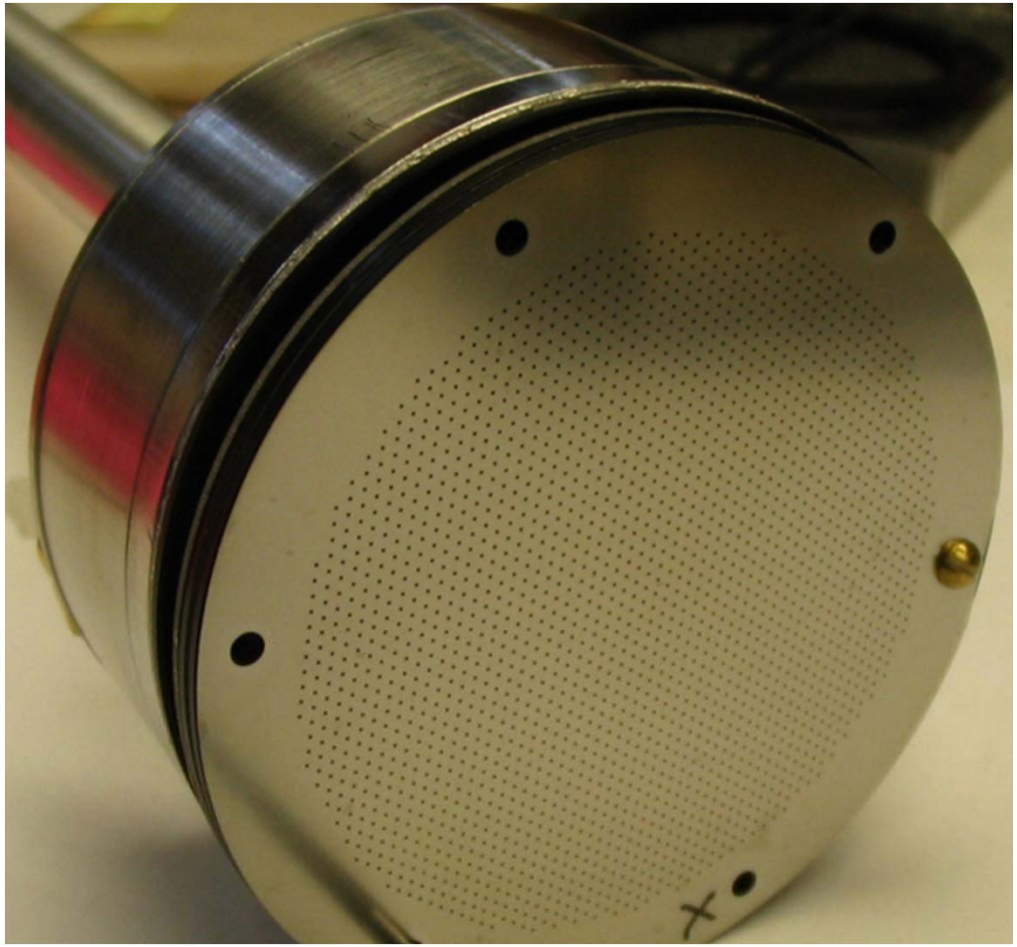
Heavy Ion Fusion Science Virtual National Laboratory



“Development of a One-Meter Plasma Source for Heavy Ion Beam Charge Neutralization”, P. C. Efthimion, E. P. Gilson, R. C. Davidson, S. S. Yu and B. G. Logan, Nuclear Instruments and Methods in Physics Research A **544**, 378 (2005).

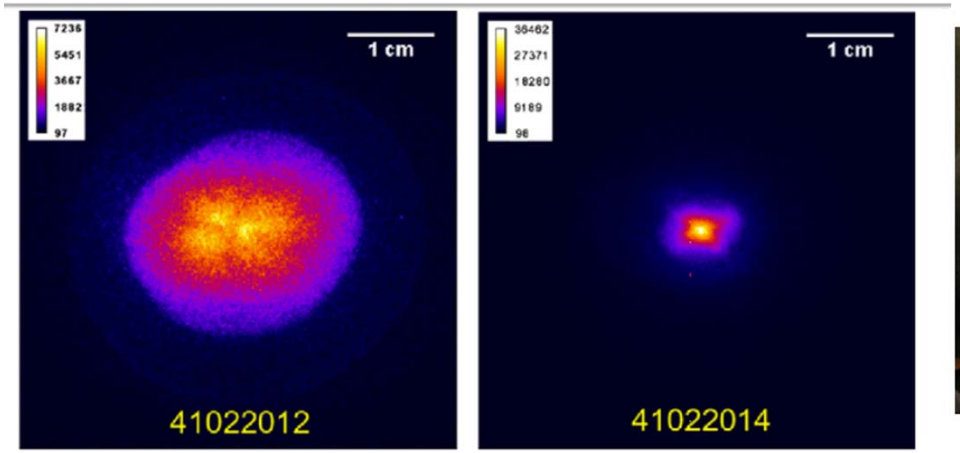
Fast Faraday Cup





"Fast Faraday Cup to Measure Neutralized Drift Compression in Intense Ion Charge Bunches", A. B. Sefkow, R. C. Davidson, P. C. Efthimion, E. P. Gilson, S. S. Yu, P. K. Roy, F. M. Bieniosek, J. E. Coleman, S. Eylon, W. G. Greenway, E. Henestroza, J. W. Kwan, D. L. Vanecek, W. L. Waldron, and D. R. Welch, Phys. Rev. ST Accel. and Beams **9**, 052801 (2006).

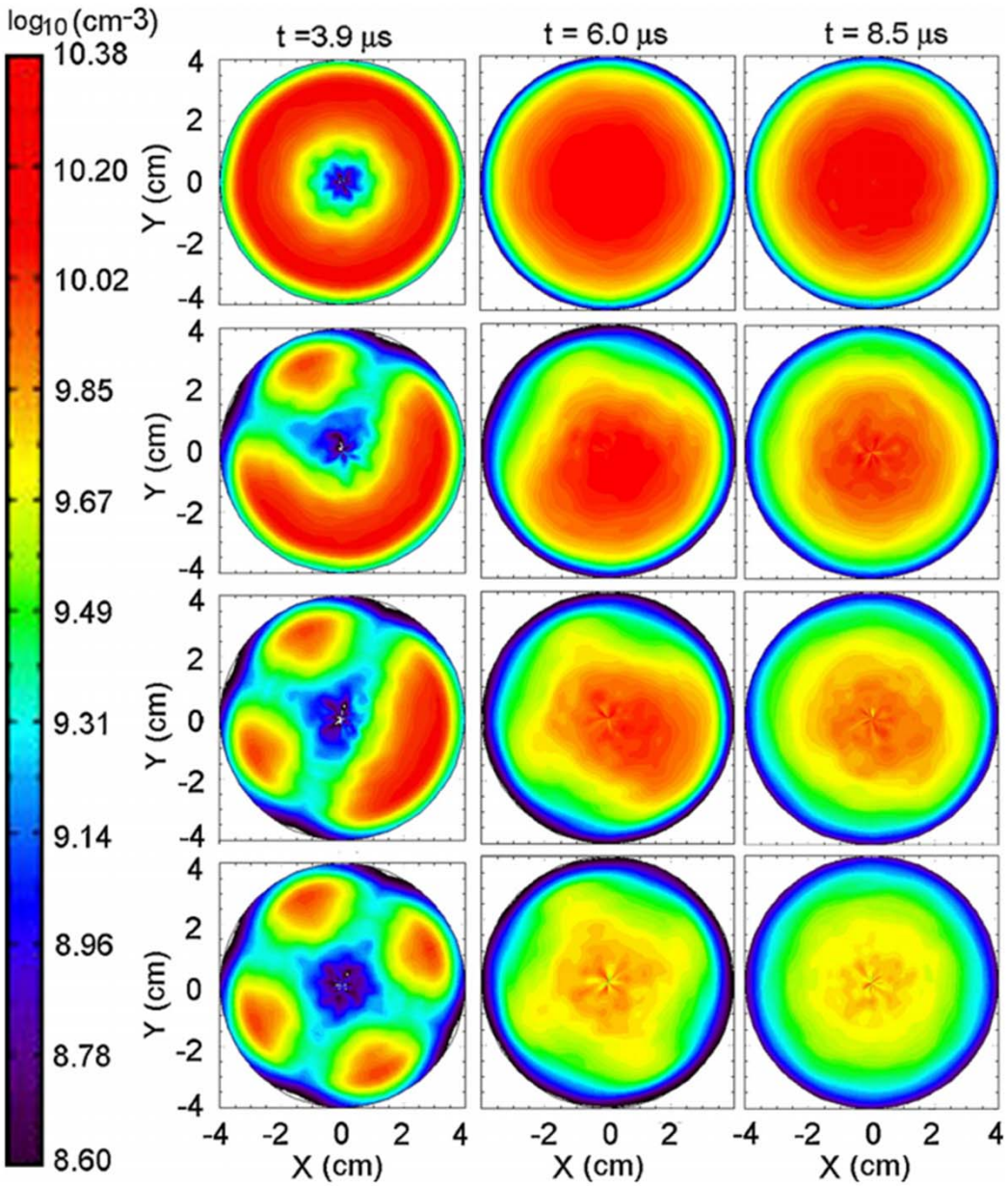
Neutralization by Bulk Plasma



Before Neutralization After Neutralization

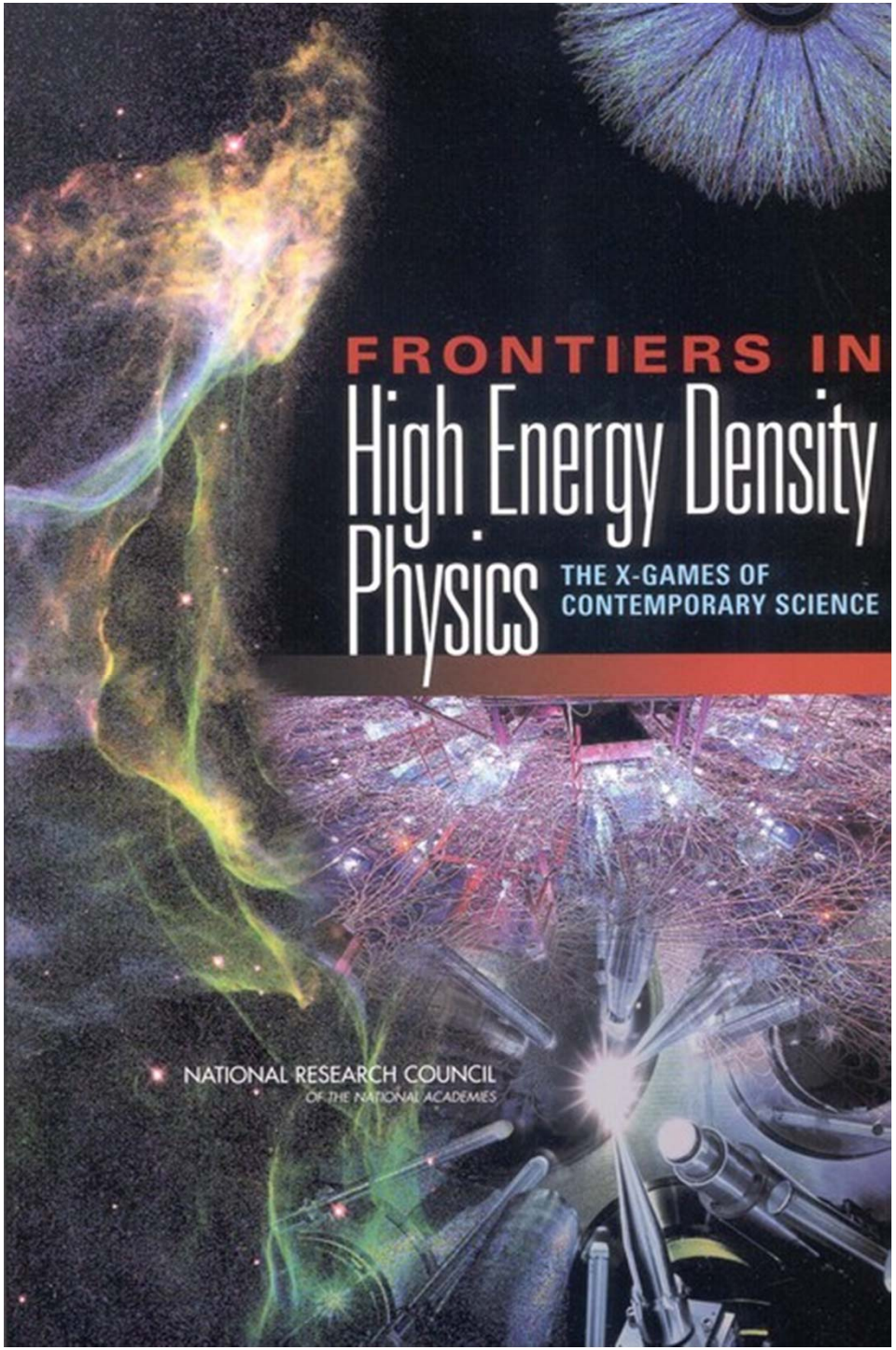
"Ferroelectric Plasma Source for Heavy Ion Beam Charge Neutralization", P. C. Efthimion, E. P. Gilson, R.C. Davidson, L. Grisham, B.G. Logan, P. A. Seidl, W. Waldron and S. S. Yu, Nuclear Instruments and Methods in Physics Research A **577**, 203 (2007).

Simulations of Plasma Source



"Advanced Plasma Flow Simulations of Cathodic-Arc and Ferroelectric Plasma Sources for Neutralized Drift Compression Experiments", A. B. Sefkow, R. C. Davidson, and E. P. Gilson, Physical Review Special Topics Accelerators and Beams **11**, 070101 (2008).


Particle Accelerator Conference, Knoxville, TN, 2005
Photo by Adam Sefkow
Ron Davidson
Erik Gilson
Igor Kaganovich
Ed Startsev



"… a consensus is emerging… that many opportunities exist for significant advances…"

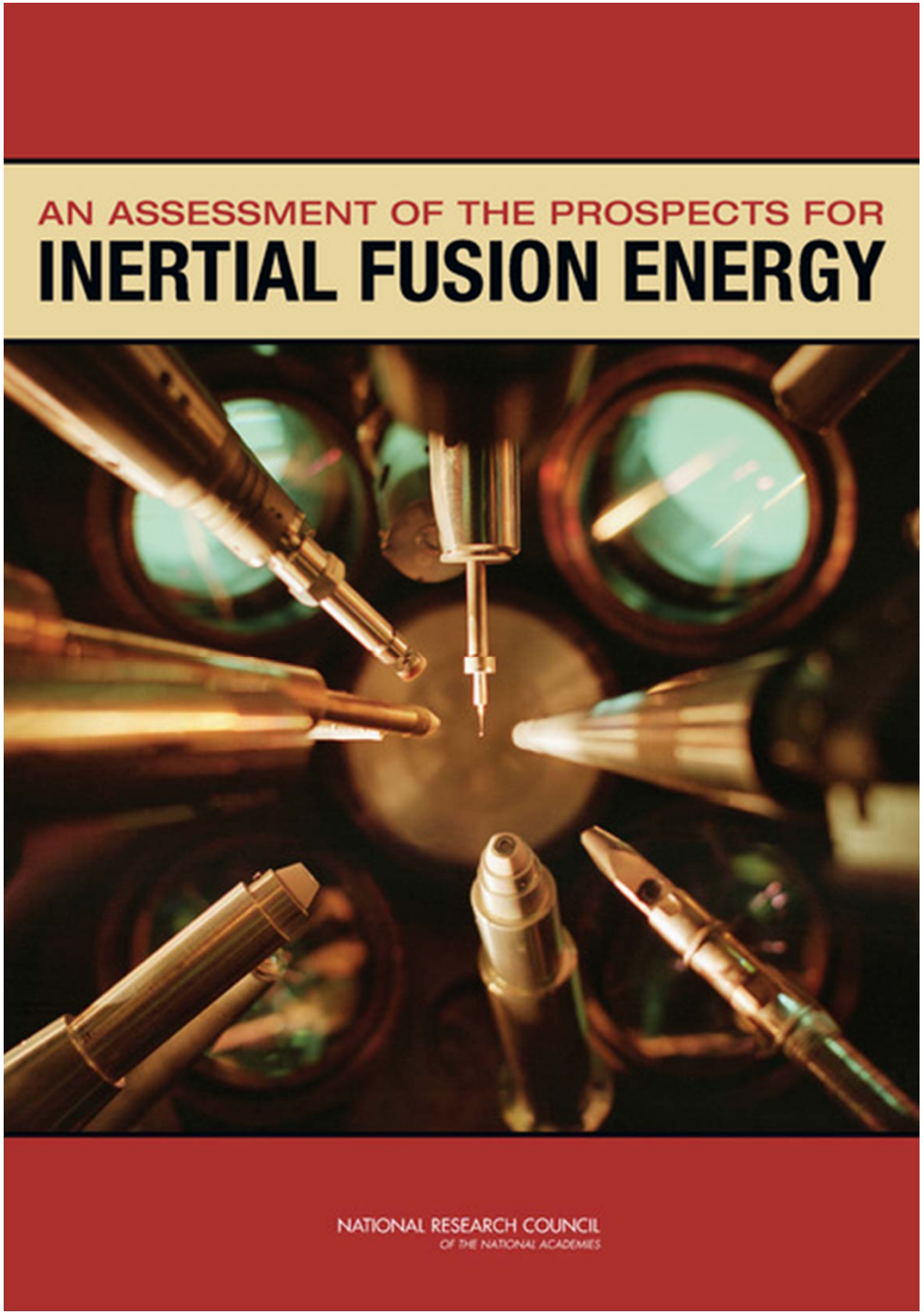
"… understanding… will also lead to new applications and will benefit other areas of science."

"… benefit national programs… through the development of new ideas and the training of a new generation of scientists and engineers."

"… convinced that research opportunities in this crosscutting area of physics are of the highest intellectual caliber and are fully deserving of consideration of support by the leading funding agencies…"

"… broad federal support base for research in high energy density physics, including plasma science… would greatly strengthen the ability of the nation's universities to have a significant impact on this exciting field of physics."

"… rapidly developing area of research abroad…"



"… does not believe that the fact that NIF did not achieve ignition by the end of… September 30, 2012 lessens the long-term technical prospects for inertial fusion energy."

"The scientific and technological progress in inertial confinement fusion has been substantial… "

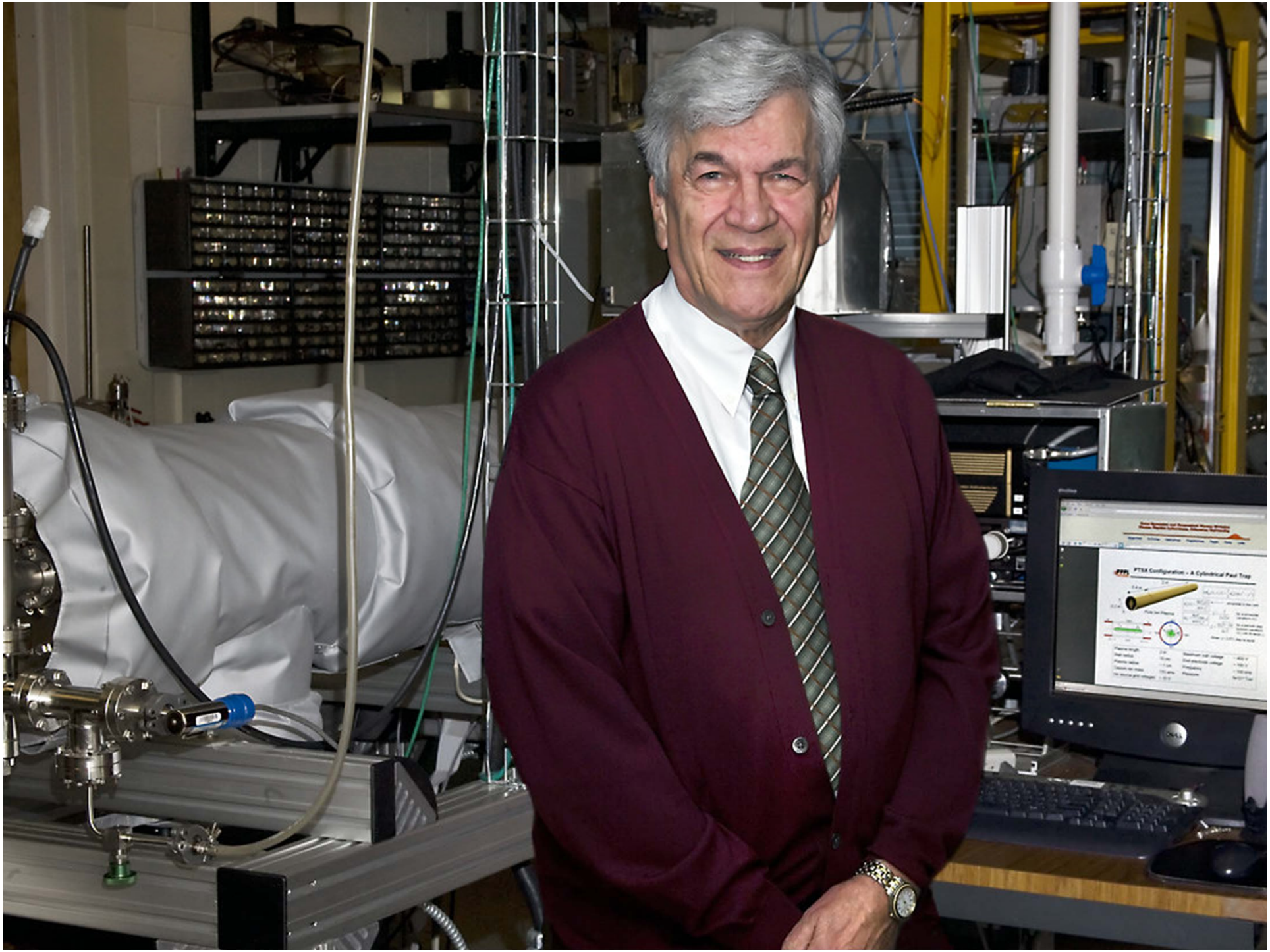
"It would be premature to choose a particular driver approach… "

"The potential benefits of inertial confinement fusion energy… provide a compelling rationale for establishing inertial fusion energy R&D as part of the long-term U.S. energy R&D portfolio."

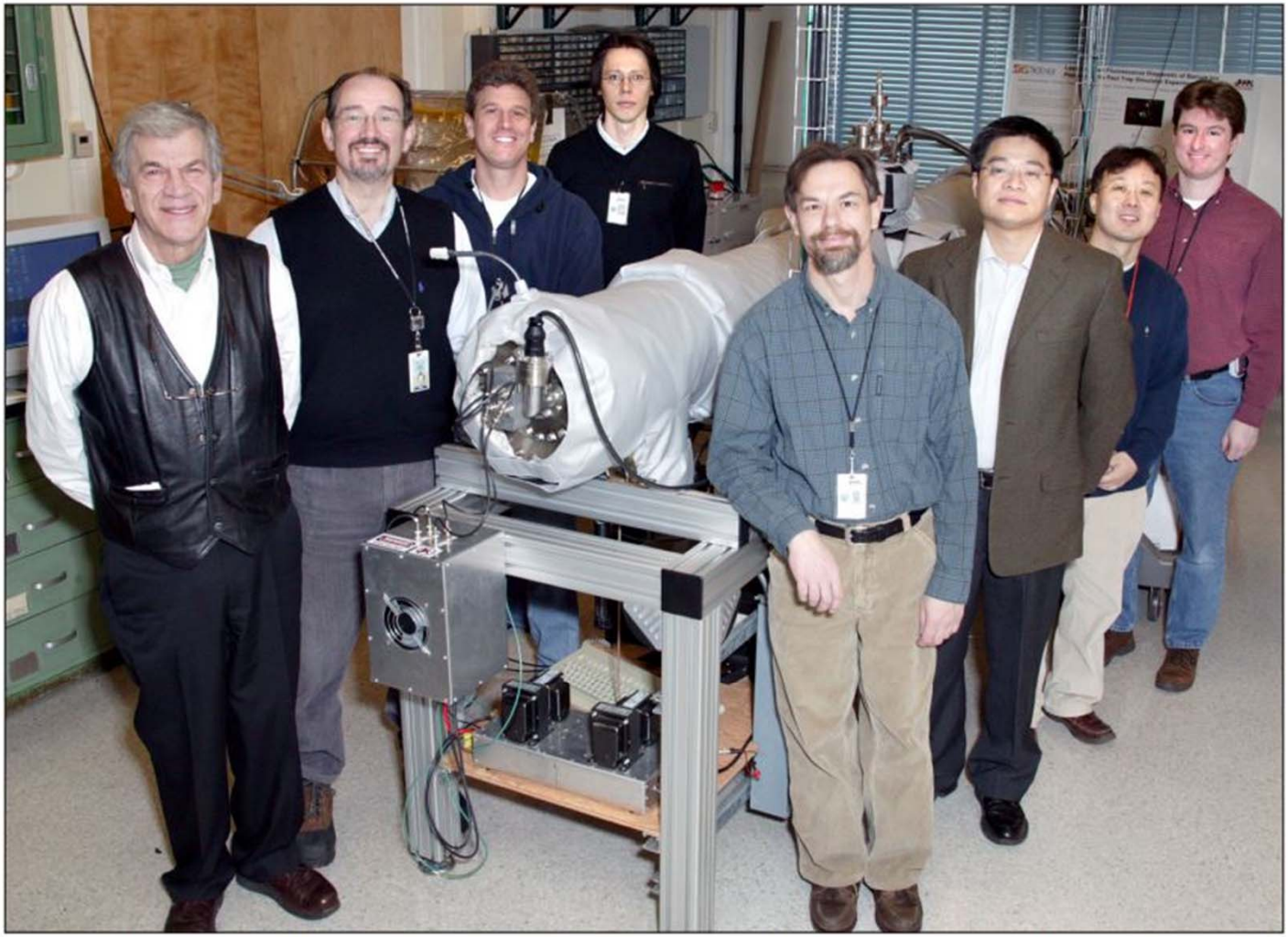
"… there is no nationally coordinated research and development program in the United States aimed at the development of inertial fusion energy that incorporates the spectrum of driver approaches… "

"… the question of 'the best driver approach' remains open. "


TFTR VACUUM VESSEL MOCKUP

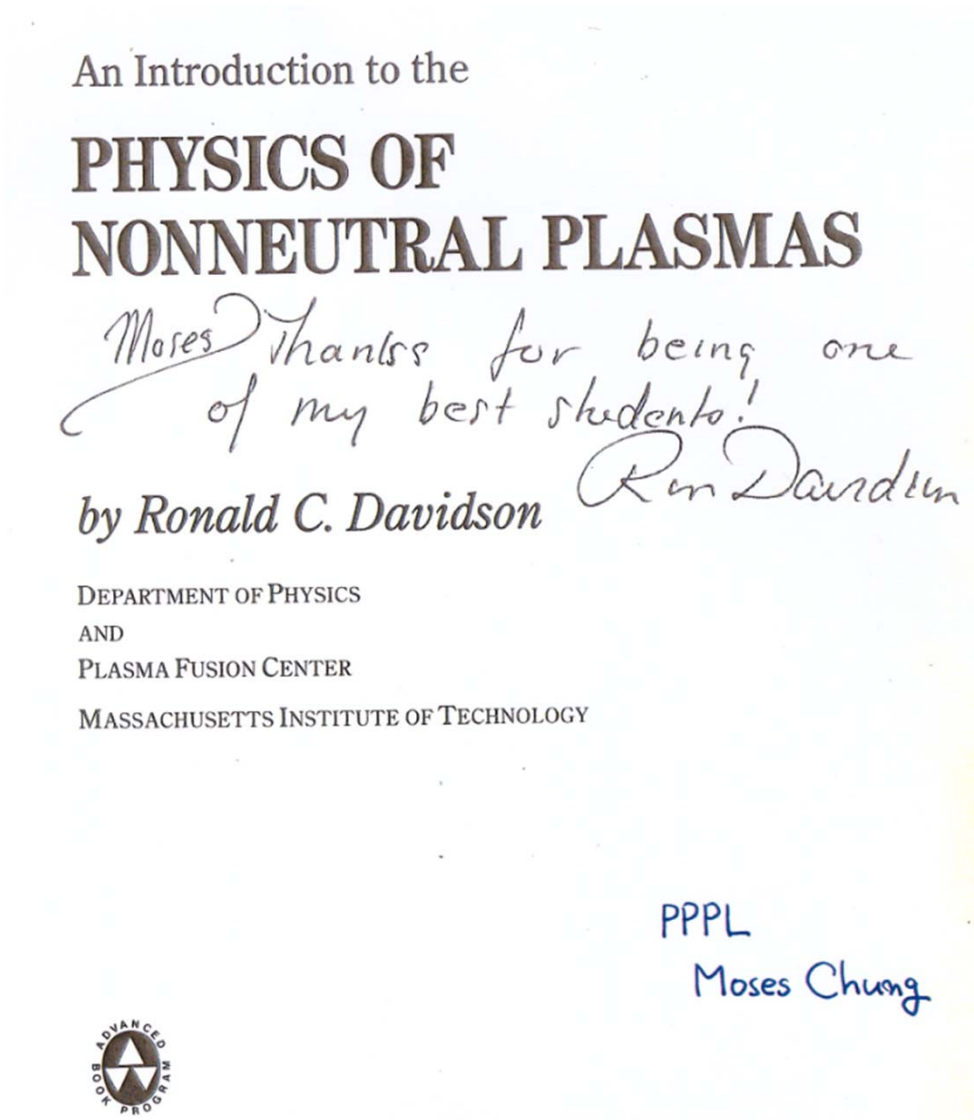

PTSA Configuration – A Cylindrical Paul Trap

Prof. Ronald C. Davidson



From left at the Paul Trap Simulator Experiment are Ron Davidson, Phil Efthimion, Andy Carpe, Ed Startsev, Dick Majeski, Hong Qin, Moses Chung, and Erik Gilson.

Ron was the best professor !



An Introduction to the

PHYSICS OF NONNEUTRAL PLASMAS

Moses Thanks for being one of my best students!
Ron Davidson

by Ronald C. Davidson

DEPARTMENT OF PHYSICS
AND
PLASMA FUSION CENTER
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

PPPL
Moses Chung

Last paper with Ron

RCD: 4/11/16

Envelope Hamiltonian for Charged Particle ~~Beam~~ Dynamics in General Linear Coupled Systems

Moses Chung,[1] Hong Qin,[2,3] and Ronald C. Davidson[2]

[1]*Department of Physics, Ulsan National Institute of Science and Technology, Ulsan 689-798, Korea*

[2]*Plasma Physics Laboratory, Princeton University, Princeton, New Jersey 08543*

[3]*Department of Modern Physics, University of Science and Technology of China, Hefei, Anhui 230026, China*

(Dated: April 9, 2016)

Abstract

We report the discovery of an envelope Hamiltonian describing the charged particle ~~beam~~ dynamics in general linear coupled lattices.

Moses - Revised Letter is in excellent shape. One very important change. You have developed the Hamiltonian for the envelope function $W(s)$ associated with the single-particle orbit $x(s) = A\,W(s)\cos\left[\int_0^s ds'/W^2(s')\right]$ where $A = \text{const.}$ is the single-particle CS invariant, proportional to the orbit area in (x, x') phase space. That is, $W(s)$ is proportional to the amplitude of excursion of the single-particle orbit $x(s)$, for any particle making up the beam. The connection to the outermost envelope of beam particles in the x-direction (denoted by a) only occurs for values of $A\,W_{max}$ proportional to ϵ_x. So you really have developed a Hamiltonian for the single-particle motion, not for the outermost beam envelope (unless I really misunderstood your main points)

Ron Davidson

1

PHYSICS OF PLASMAS **23**, 000000 (2016)

Envelope Hamiltonian for charged-particle dynamics in general linear coupled systems

Moses Chung,[1,a)] Hong Qin,[2,3] and Ronald C. Davidson[2,b)]

[1]*Department of Physics, Ulsan National Institute of Science and Technology, Ulsan 689-798, South Korea*

[2]*Plasma Physics Laboratory, Princeton University, Princeton, New Jersey 08543, USA*

[3]*Department of Modern Physics, University of Science and Technology of China, Hefei, Anhui 230026, China*

(Received 13 April 2016; accepted 28 June 2016; published online xx xx xxxx)

We report the discovery of an envelope Hamiltonian describing the charged-particle dynamics in general linear coupled lattices. *Published by AIP Publishing.* [http://dx.doi.org/10.1063/1.4959112]

a)mchung@unist.ac.kr

b)Deceased.

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supported by the U.S. Department of Energy Grant No. DE-AC02-09CH11466.

Ronald Davidson passed away unexpectedly during the peer review of this paper. He will be missed.