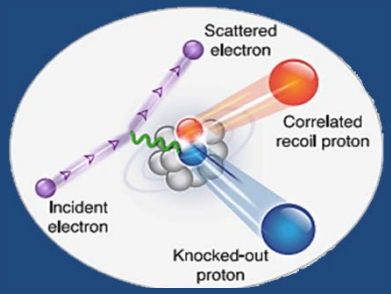
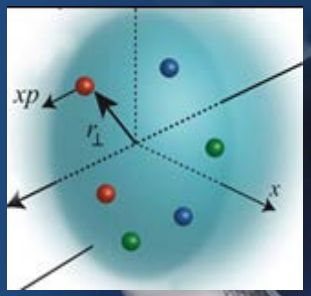
COOL'15
Welcome and Opening Comments

Andrew Hutton

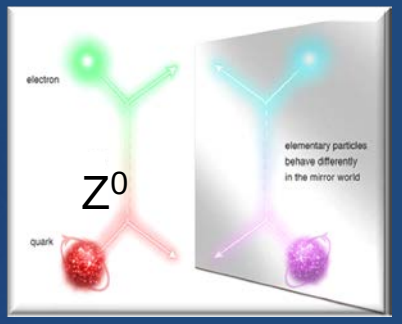
JLab: A Laboratory for Nuclear Science



Nuclear Structure



Structure of Hadrons



Fundamental Forces & Symmetries

Medical Imaging

Nuclear Astrophysics

Cryogenics

Accelerator S&T

Theory & Computation

Liouville's Theorem

- Liouville's theorem states that the phase-space distribution function is constant along the trajectories of the system — that the density of system points in the vicinity of a given system point traveling through phase-space is constant with time

J. Liouville., Journ. De Math. 3, 349 (1838)

- The history of beam cooling research has been to find loopholes in this theorem!

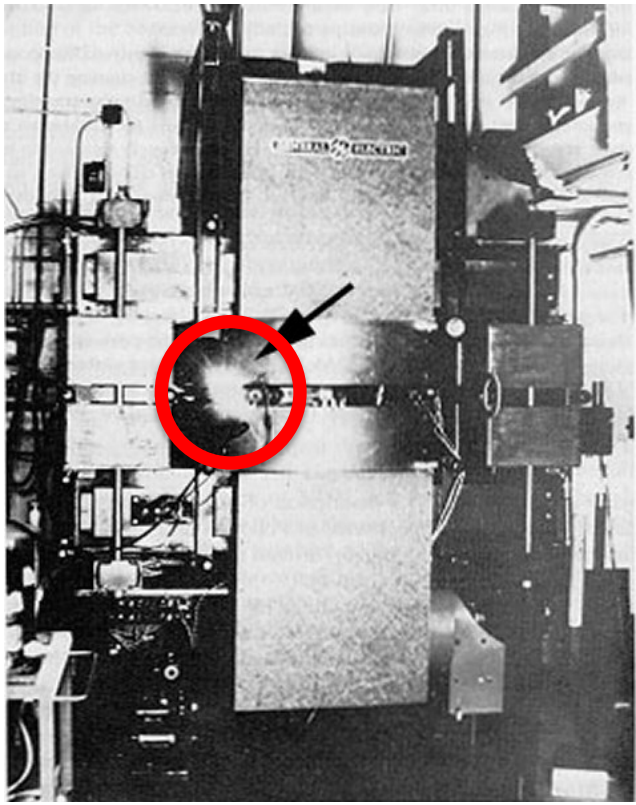
Synchrotron radiation

- Relativistic particles emit a photon in a strong dipole field and lose energy
- The simple physical picture is that the outer region of the electric force field that accompanies a relativistic particle would be required to exceed the speed of light to keep up, so it breaks off as a photon
- Energy is lost in longitudinal and transverse planes
- Energy is replaced in longitudinal plane by RF
- Result is a reduction in longitudinal and transverse emittances
  - ➢ Cooling
- Liouville's theorem is only valid for conservative systems

History of Synchrotron Radiation

- Dmitri Ivanenko and Isaak Pomeranchuk predicted the phenomenon of synchrotron radiation in 1943

Synchrotron radiation was first observed by Frank Elder, Anatole Gurewitsch, Robert Langmuir, and Herb Pollock at the General Electric Synchrotron in May 1947

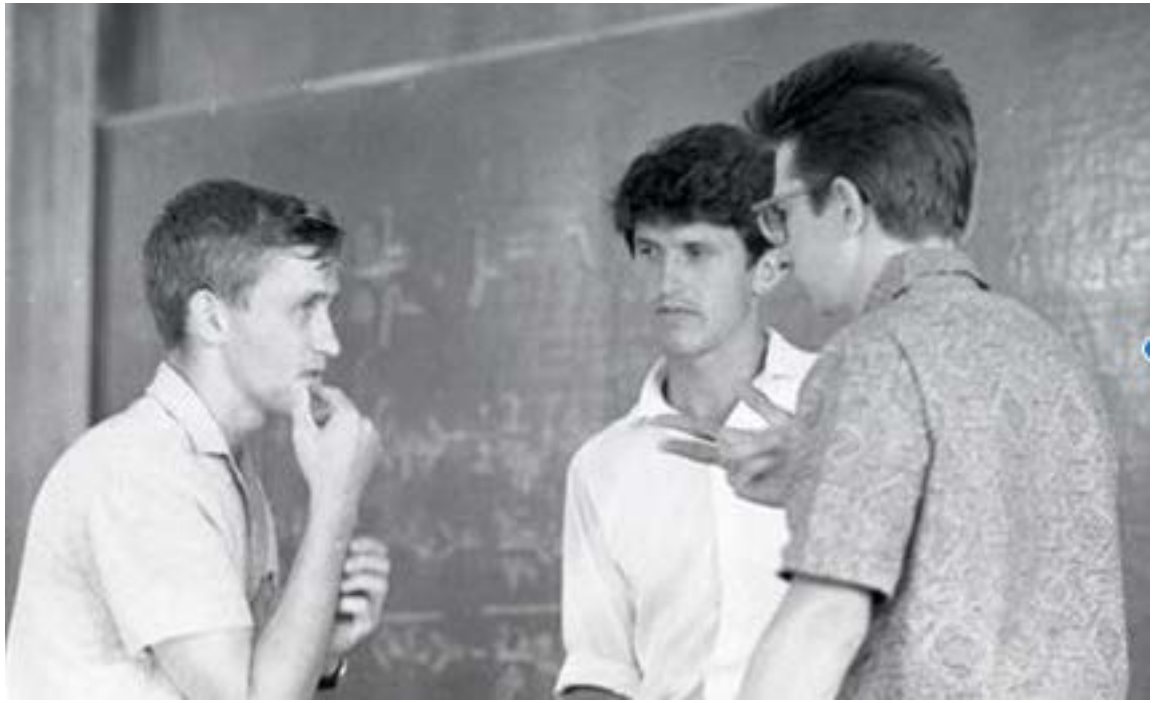


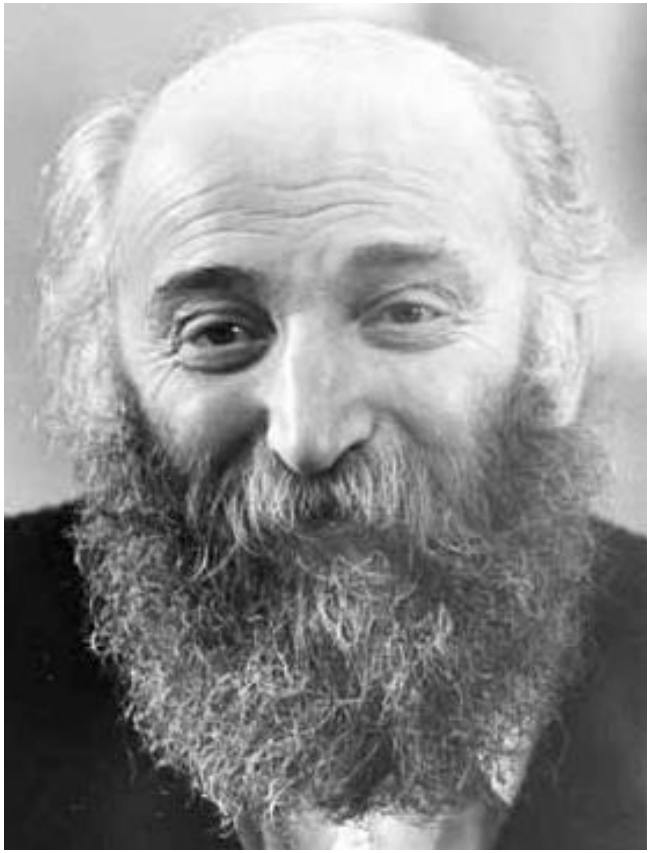
Update

- For over 60 years, synchrotron radiation has been synonymous with electrons
- LHC ushered in the era of synchrotron radiation damping of protons
  - Damping time ≈13 hours at 7 TeV
- Synchrotron radiation damping at the FCC is even faster!
  - Transverse damping time ≈ 1 hour at 100 TeV

Electron Cooling

- Electron cooling was invented by Gersh Budker in 1966 at INP
- It has since become a specialty of BINP under the leadership of Sasha Skrinsky

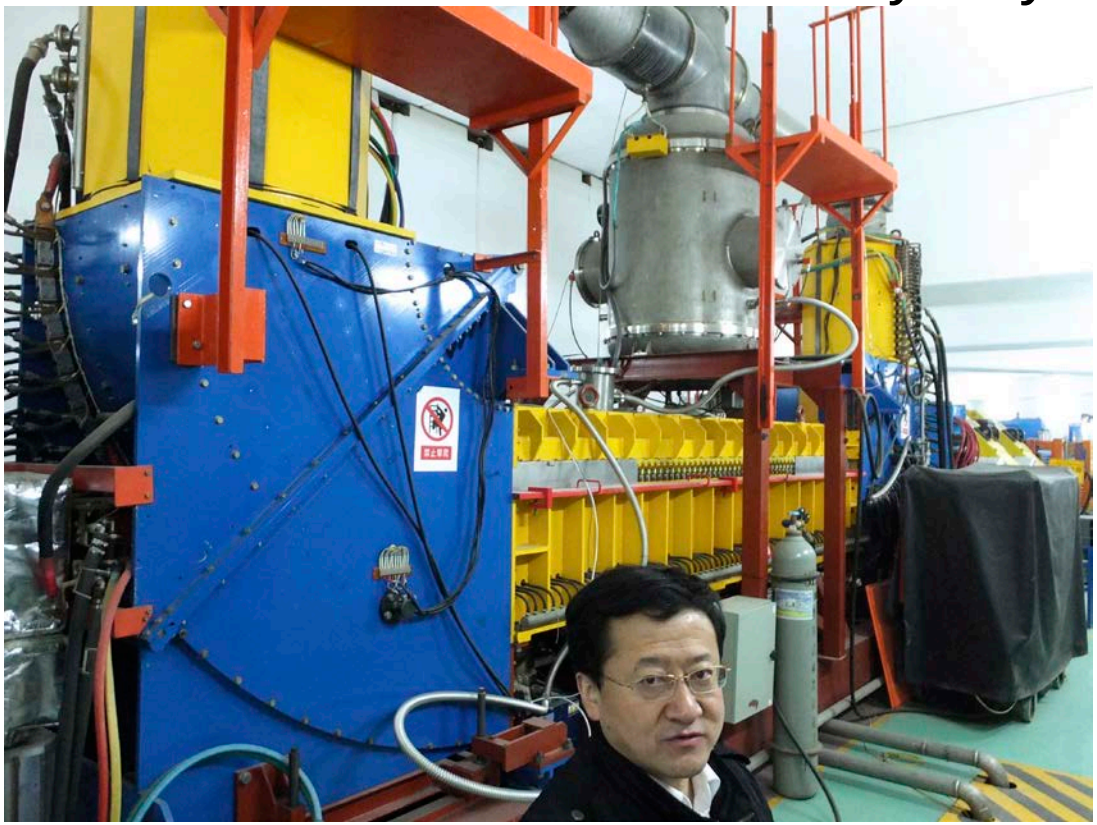




Liouville's theorem is only valid for weakly-interacting particles

Present State of Electron Cooling

- CW electron cooling is now a “commodity”
  - BINP has delivered many fully functional systems



Sergei Nagaitsev built a 4.3 MeV system at FNAL

Future of Electron Cooling

- Higher energies cannot be supported with DC beams
  - There is a lot of activity on bunched beam cooling
- IMP (Lanzhou) and JLab are developing an experiment at IMP
- BNL is building a bunched beam cooling system for RHIC (the LEReC Project)
- JLab is proposing an ERL cooling system for MEIC
- BNL is proposing Coherent Electron Cooling (CEC) for eRHIC

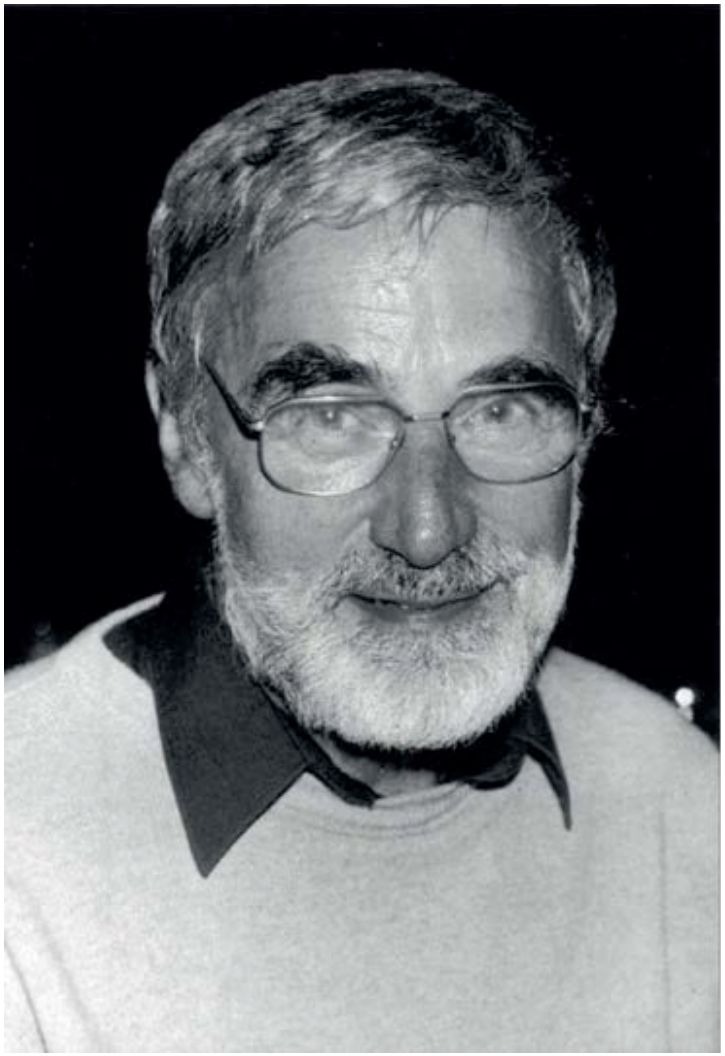
Stochastic Cooling

- Invented in the 70s at CERN by Simon van der Meer
- The seminal paper is by Dieter Möhl, Guido Petrucci, Lars Thorndahl, and Simon van der Meer

Liouville's theorem doesn't hold if an external device detects particle positions and moves the particles onto better orbits

Dieter Möhl Medals and Award

- Dieter Möhl was an extremely inventive physicist and a much-loved human being
- Two medals and an award will be awarded on Thursday in honor of Dieter Möhl



Future of Stochastic Cooling

- Stochastic cooling works best for high-energy hadrons
  - Radiation cooling works best for electrons
    - e.g. CEPC
  - Electron cooling works well for low-energy hadrons
    - Hopefully, it will soon be confirm that it also works for higher energy hadrons
    - e.g. eRHIC, MEIC
  - Stochastic cooling will be the primary cooling technique for the FCC

Ionization Cooling

- Invented at (B)INP, Novosibirsk
  - Seminal papers by Gersh Budker (1970), Sasha Skrinsky (1971)
  - Taken up in the early 90s for muon cooling
  - Now being developed for a Muon Collider/Neutrino factory
- Mike Zisman (1944-2015)
  - Played a major role in developing the muon programs in the US
  - He will be missed by his many friends

Liouville's theorem is only valid for conservative systems

Future of Ionization Cooling

- Ionization cooling is currently envisioned for muon cooling
- Neutrino Factories and Muon Colliders are currently low priority in the HEP community (at least in the US)
- However:
  - MICE will continue
  - Theoretical studies will continue, albeit at a slower pace
    - Helical cooling channels look really promising . . . .

COOL'15

- I would like to thank the Program Committee for developing a first-rate scientific program:
- Co-Chairs Yaroslav Derbenev and Yuhong Zhang (JLAB)
- Ilan Ben-Zvi (BNL), Juergen Dietrich (TU Dortmund),
  Anders Källberg (Stockholm University),
  Dan Kaplan (Illinois Inst. of Technology),
  Takeshi Katayama (Nihon University), Igor Meshkov (JINR),
  Sergei Nagaitsev (FNAL), Hiromi Okamoto (Hiroshima University),
  Vasily Parkhomchuk (BINP), Dieter Prasuhn (FZJ),
  Markus Steck (GSI), Grigory Trubnikov (JINR),
  Gerard Tranquille (CERN), Masanori Wakasugi (RIKEN),
  Andreas Wolf (MPIK), Xiaodong Yang (IMP),
  Katsuya Yonehara (FNAL)

COOL'15

Workshop on Beam Cooling and Related Topics

Sept. 28 - Oct. 2, 2015

Jefferson Lab

Newport News, Virginia USA

JSA Jefferson Lab

The workshop will highlight the state of the art in electron cooling, stochastic cooling, muon cooling, laser cooling, and storage of particles in antiproton and heavy ion traps. Presentations of new developments and techniques, as well as the status of existing and future facilities are invited.