Looking Back 40 Years—Recollections of the History and Development of the PEP-4 TPC

Not guaranteed to be historically accurate. With apologies to the many people whose contributions I may have neglected to acknowledge.

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Nygren-fest Symposium

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Some Background

- Dave received his PhD from University of Washington in 1967 and then went to Columbia to work with Jack Steinberger.

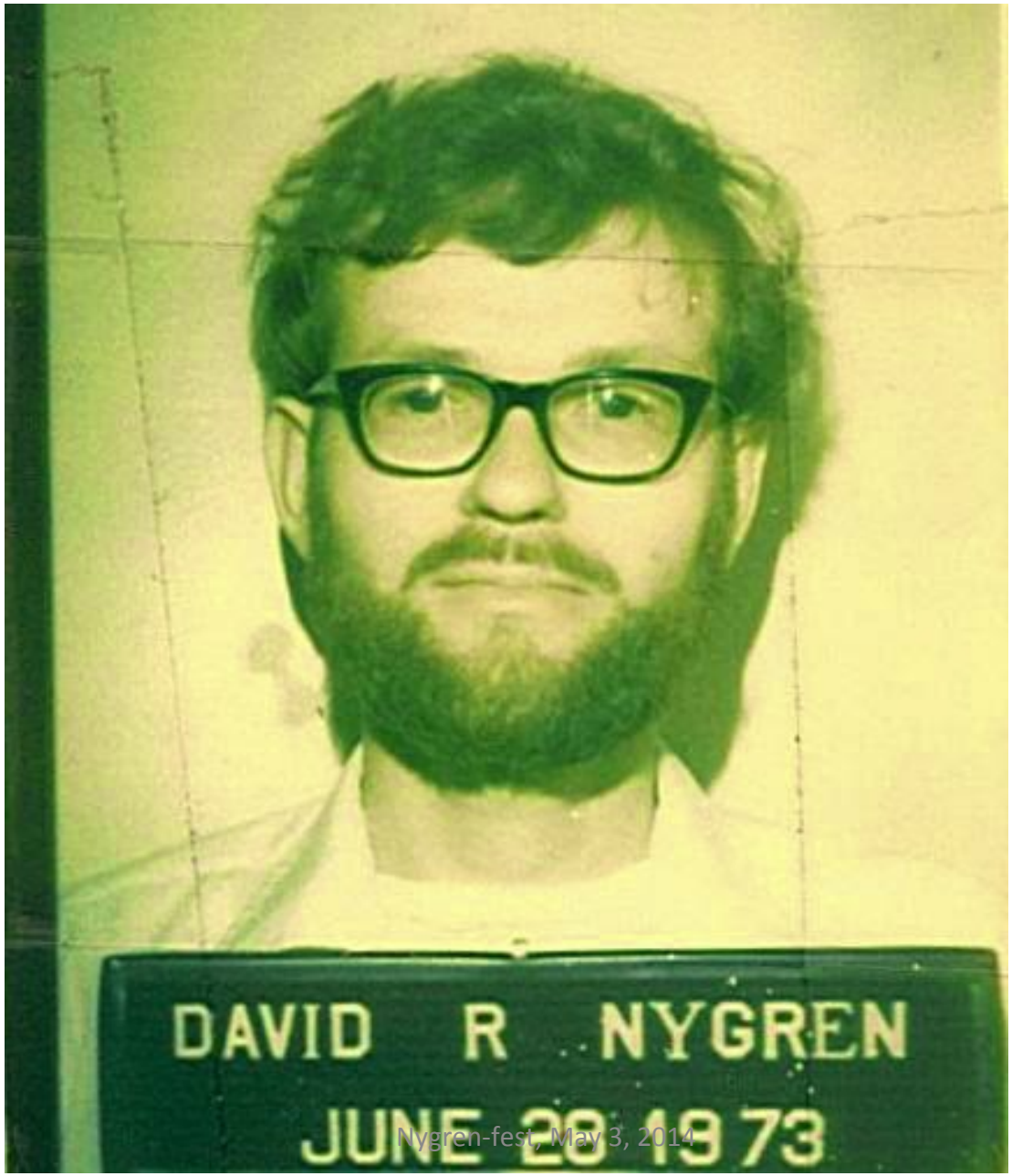
- As a graduate student I met Dave in summer 1967
  - I had a student job at Brookhaven working on Steinberger experiment to measure charge asymmetry in K_{e3} decay (CP violating effect).

- In 1968 an improved version of K_{e3} decay experiment became my thesis experiment.
  - Group working on experiment at Brookhaven AGS—Steinberger (at CERN), Dave, Tom Kirk (Harvard Assistant Prof.), John Peoples (Columbia Assistant Prof.)

The good old days- Brookhaven 1968
--Dave is the photographer--

- June 1973--- Dave arrived at LBL as the first "Division Fellow"
  - Position that allowed Dave freedom to explore novel detection techniques.
  - "The freedom to just sit in front of a drawing board and think."
- With PEP electron-positron collider on the horizon, Dave took up the challenge of how to measure charged particles in entire event over 4-pi with excellent resolution.

Dave arrives at LBL



Early 1974-Dave came up with the basic ideas for the TPC

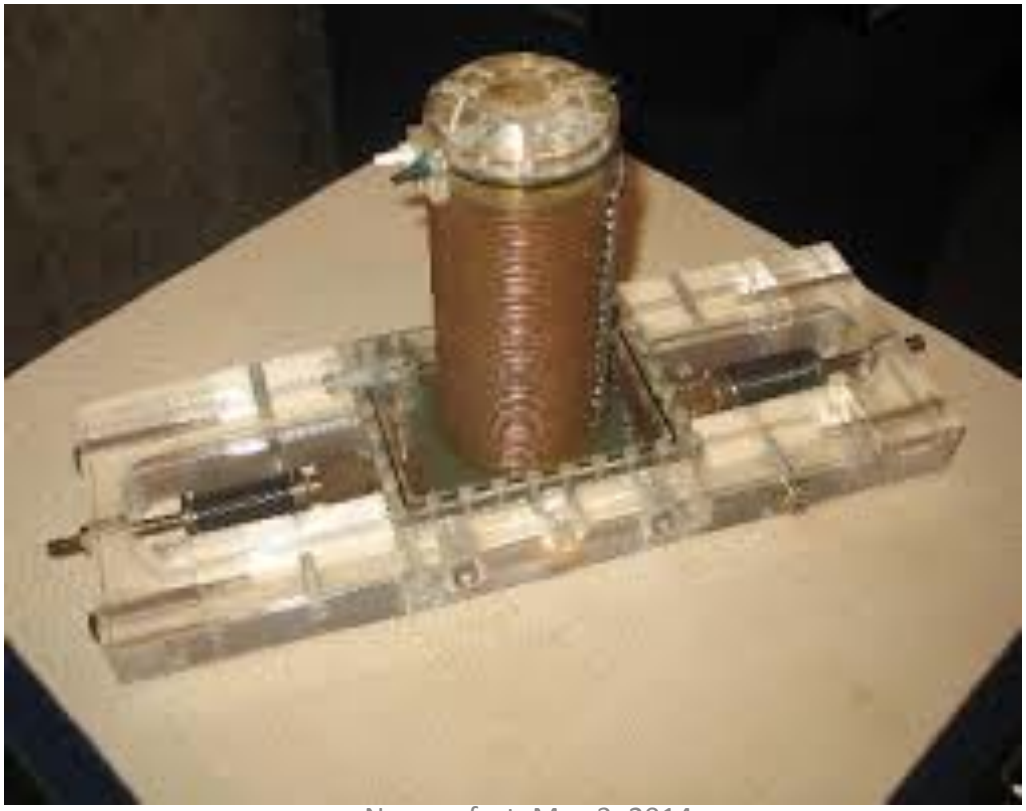
1. With B parallel to E, diffusion can be suppressed, allowing tracking information to be preserved while ionization drifts over long distances.

2. Detect drifting ionization with 2-D endcap sensor array and use arrival time of ionization to get longitudinal position.

- Gives fully 3-D tracking information with no ambiguities due to 2-D projections as with arrays of planar or cylindrical chambers.
- All of the complexity is in the sensor planes at the endcap.

An elegant, simple, irresistible idea!!!

- Early in this period Peter Robrish and Marcel Urban joined with Dave to successfully demonstrate diffusion suppression in the E parallel to B configuration



- And to develop early concept for endcap sensors---tiny platinum balls on wires operating in proportional mode, isolated from each other by a honeycomb structure
  - The ball wires had problems. Large variation in timing of signal due to variation in electron spiral path the ball, and fluctuation in signal amplitude to imperfect surface of the platinum balls.

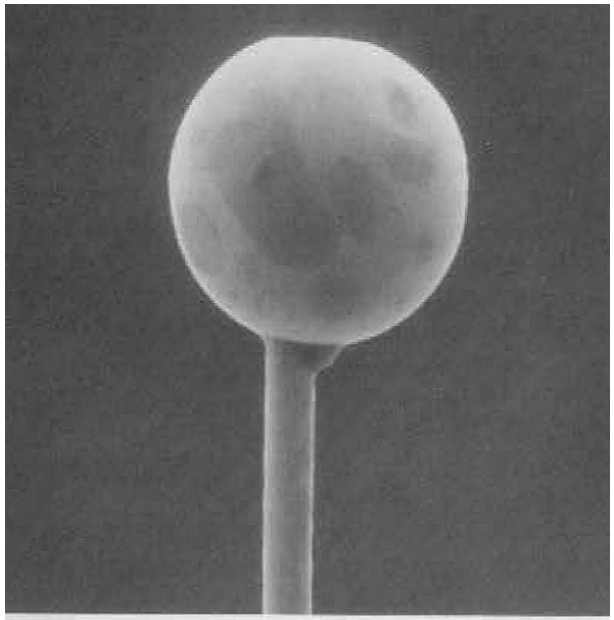
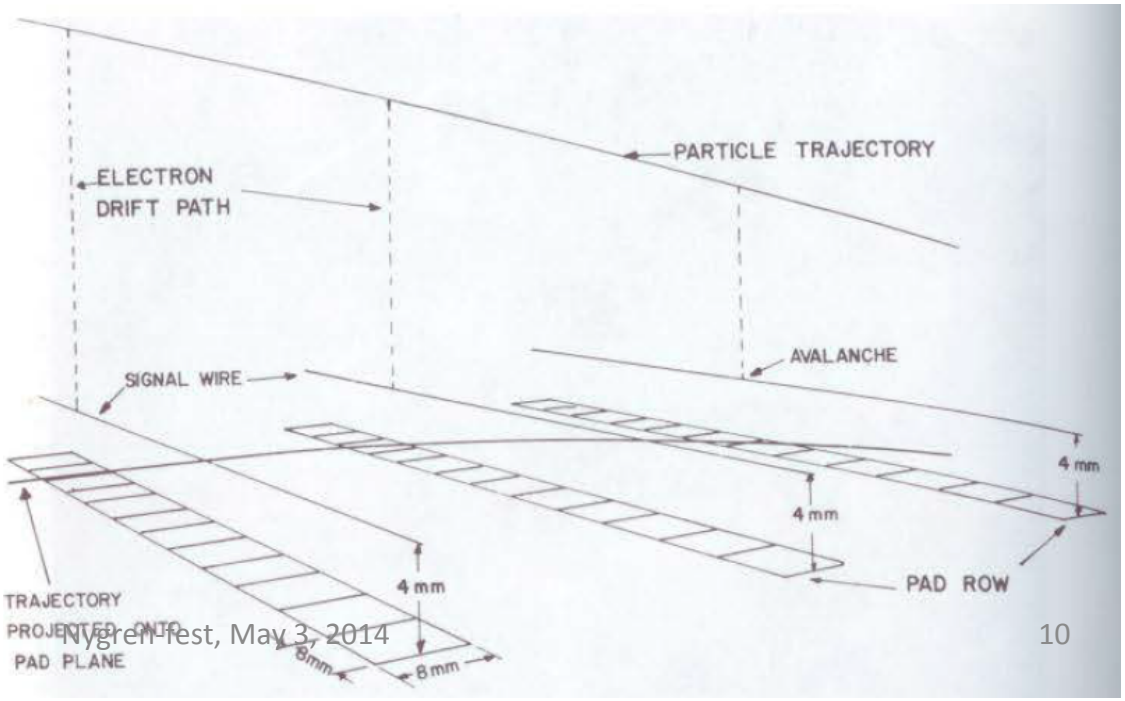


Figure 7.1 Honeycomb and ball-wire detector (1974).

Another challenge--- how to readout the sensors

- Need to store the ionization information from each sensor with high fidelity in many small time bins.
- Solution--- In early 1974 Dave found an article in Scientific American about a new technology —the Charge Couples Device (developed by Fairchild) and recognized that this new technology was the ideal solution to storing time sampled signals from the sensors.

- Later the ball wires were dropped as the endcap sensors and replaced by an array of proportional wires with segmented cathodes to give spatial resolution in the direction along the sense wires.
- CCDs with 455 time buckets, enough to cover the full TPC drift time, would provide the time slicing and event storage.



Towards a proposal to build a big facility based on the TPC

- April 1974--- SLAC and LBL submit proposal to Atomic Energy commission to build PEP (15 GeV e^+e^- collider) on the SLAC site

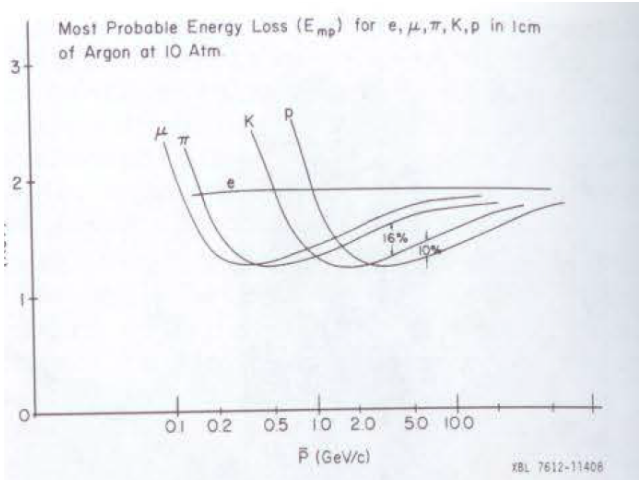
- Summer 1974—PEP Summer Study at LBL--- Goal—to educate community about PEP and consider which experiments should be done.

- Dave talked about his TPC idea. I was at the summer study and, along with many others, was taken by the elegance of it.

- In 1975 I came to LBL as a visitor, supported by a faculty fellowship from Yale, to work with Dave on the TPC. The team was still small with Dave, Peter and Marcel and me full time.

- Through seminars at LBL and discussions with potential colleagues, interest in a TPC-based detector for PEP was growing rapidly in the LBL Physics Division.

- It also became clear that the appeal of a TPC-based detector would be significantly greater if the TPC could identify the charged particles.



- It was recognized that in the PEP energy range, particle ID by multiple sampling of dE/dx was possible.
  - This could be achieved in the TPC. The many endcap proportional wires would allow multiple sampling of each track's ionization and the high pressure gas would reduce the ionization fluctuations of each samples.

- With the possibility of particle identification using the TPC itself, a number of strong LBL physicists began to participate in the effort to design a TPC-based facility for PEP.

- Early LBL participants included
  - Phillipe Eberhard who along with Mike Green led the effort to design and later build the superconducting magnet.
  - Lynn Stevenson, Moishe Pripstein, Orin Dahl from the former Alvarez Group.
  - Bill Wenzel who played a major role in the design of the electromagnetic calorimeter.
  - Mark Strovink who, I believe, suggested the use of cathode pads on the endcaps.
- Bob Birge, head of the Physics Division at the time, as was tremendously supportive of the TPC effort.

- Other physicists who joined later and played major roles-
  - Ron Madaras and Owen Chamberlain who lead the 200 kV TPC drift field effort,
  - Mike Ronan who lead the trigger system,
  - Lina Galtieri who led the data analysis effort
  - Roy Kerth who was responsible for the complex assembly of PEP-4 at SLAC.
  - Pier Oddone was deeply involved in the design of the experimental areas for PEP and later became the PEP-4 spokesperson during the physics phase.
- And our talented 1st crop of graduate students—Marjorie Shapiro, Nick Hadley and John Huth.

Proof of principle TPC prototype

- A prototype TPC was constructed to measure the special resolution and de/dx resolution using the argon-methane gas, and endcap configuration envisioned for a PEP TPC. But with a short drift distance.
- This prototype was successfully operated at the Bevatron and provided important results—the TPC's 2-D spatial resolution in the plane of the endcap and dE/dx resolution were demonstrated to be as predicted.

Figure 7.14 Prototype (1978). Before construction on the TPC could begin—or the device could even successfully compete for funds and authorization from PEP—its supporters had to build and operate a small-scale prototype that would demonstrate its capacity to perform precision measurements. Source: LBL CBB 787 9080.

- With a clear interest at LBL in proposing a TPC-based facility for PEP, there was a need to bring together a larger, multi-institution collaboration. The power of the TPC idea, the respect for Dave and the capabilities of LBL attracted a number of strong University groups.

- By mid-1976 Yale (Mike Zeller et al), Johns Hopkins (Aihud Pevsner et al), and UCLA (Harold Ticho et al) had joined the collaboration.

- The call for proposals for PEP experiments was issued in early June 1976 with proposal due at the end of December 1976.

- With only 6 months until the proposal was due, the collaboration organized itself and elected Dave as the Spokesman.

- A collaboration Council chaired by Dave was set up to organize the development of a proposal, assign tasks, roles and responsibilities and consider additional collaborators.
  - UC Riverside (Ben Shen et al) would join during this period.

- After many months of intensive work under the pressure of a deadline, the PEP-4 proposal was submitted just before the December 31, 1976 deadline.

- We believed our proposal was strong and that the TPC-based facility was what PEP needed.
  - But we believed that we were underdogs because the SLAC/LBL Mark II was sure to be approved and there was another SLAC proposal that we expected would have the home-field advantage and so be approved.

- The PEP Experimental Program Committee (EPC) met in February 1977 to advise Pief Panofsky and Andy Sessler, the SLAC and LBL Directors as to which proposals should be approved and funded for the first round of PEP experiments.

- Dave gave our presentation to the EPC.

- According to an article in the LBL News Magazine,
  - "Dave Nygren, prime mover of the LBL time projection chamber project and now its spokesman before the committee, was wearing a coat and tie for the occasion."
  - "Obviously well prepared, he seemed at ease detailing the $6,087,000 proposal."
  - EPC had concerns about construction in 2 ½ years.

- In April 1977 we learned that the PEP-4 proposal had been approved by Pief and Andy.
  - The elegance and power of Dave's TPC concept had proven too good to ignore.
  - I was surprised and I'm sure that was true of many others.
- Very soon after learning of the approval, Dave had a party at his Berkeley home to celebrate.
- I clearly remember one telling moment from that party. Dave and I look up and into each other's eyes. My heart sank. The words that went through my mind were "Oh shit, now we have to do it." And I believe that Dave felt the same way.

From LBL News Magazine- 1977

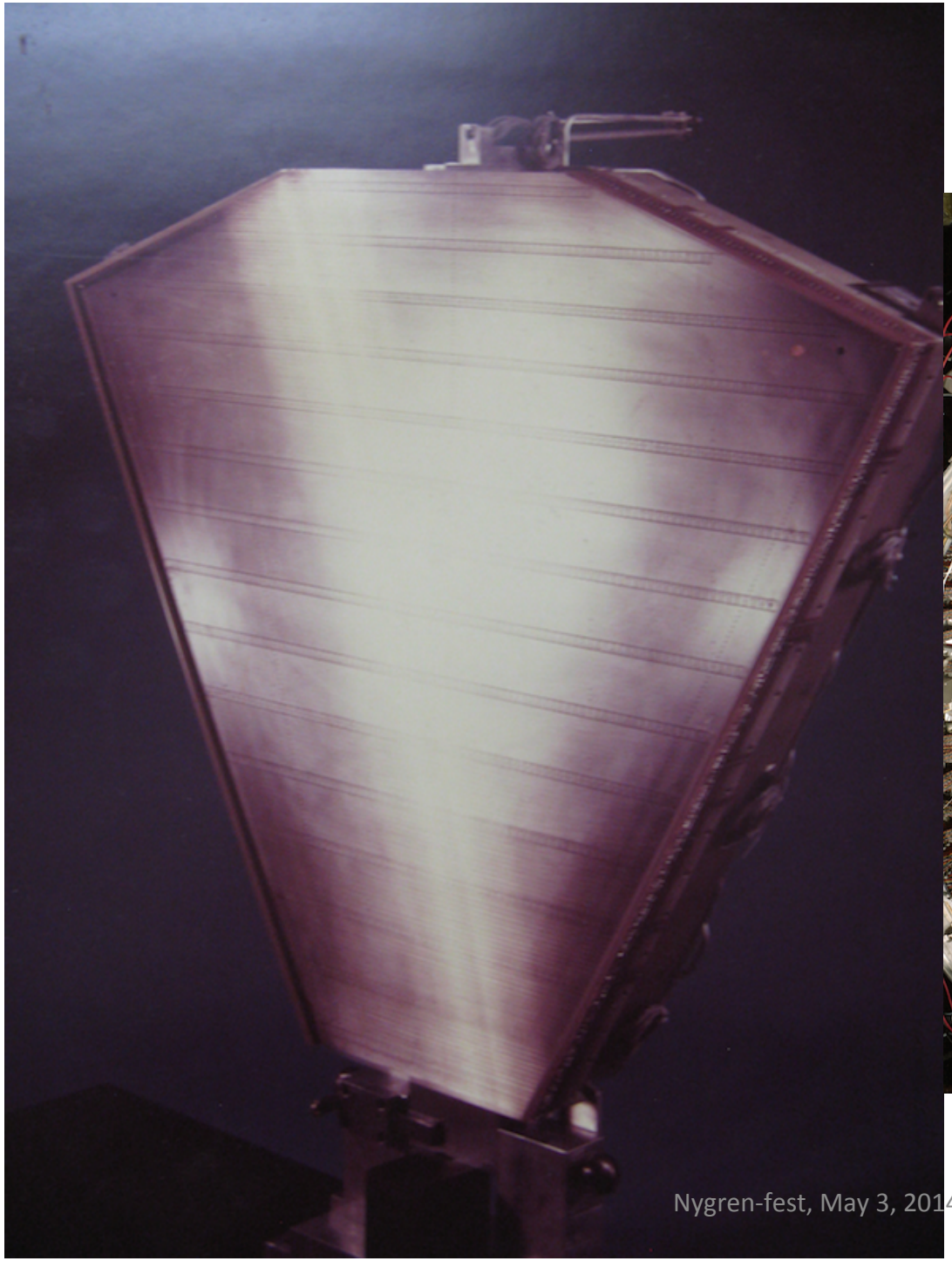
Nygren: A mixture of elation and dread

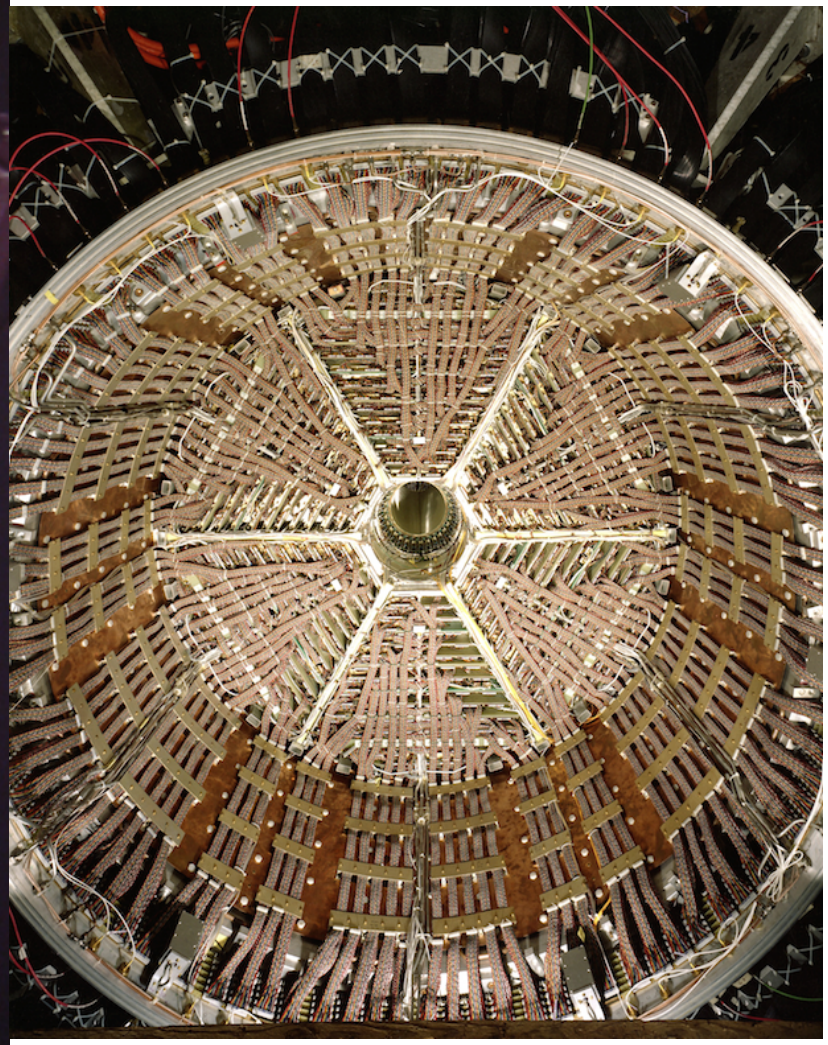
Construction of the PEP-4/TPC facility

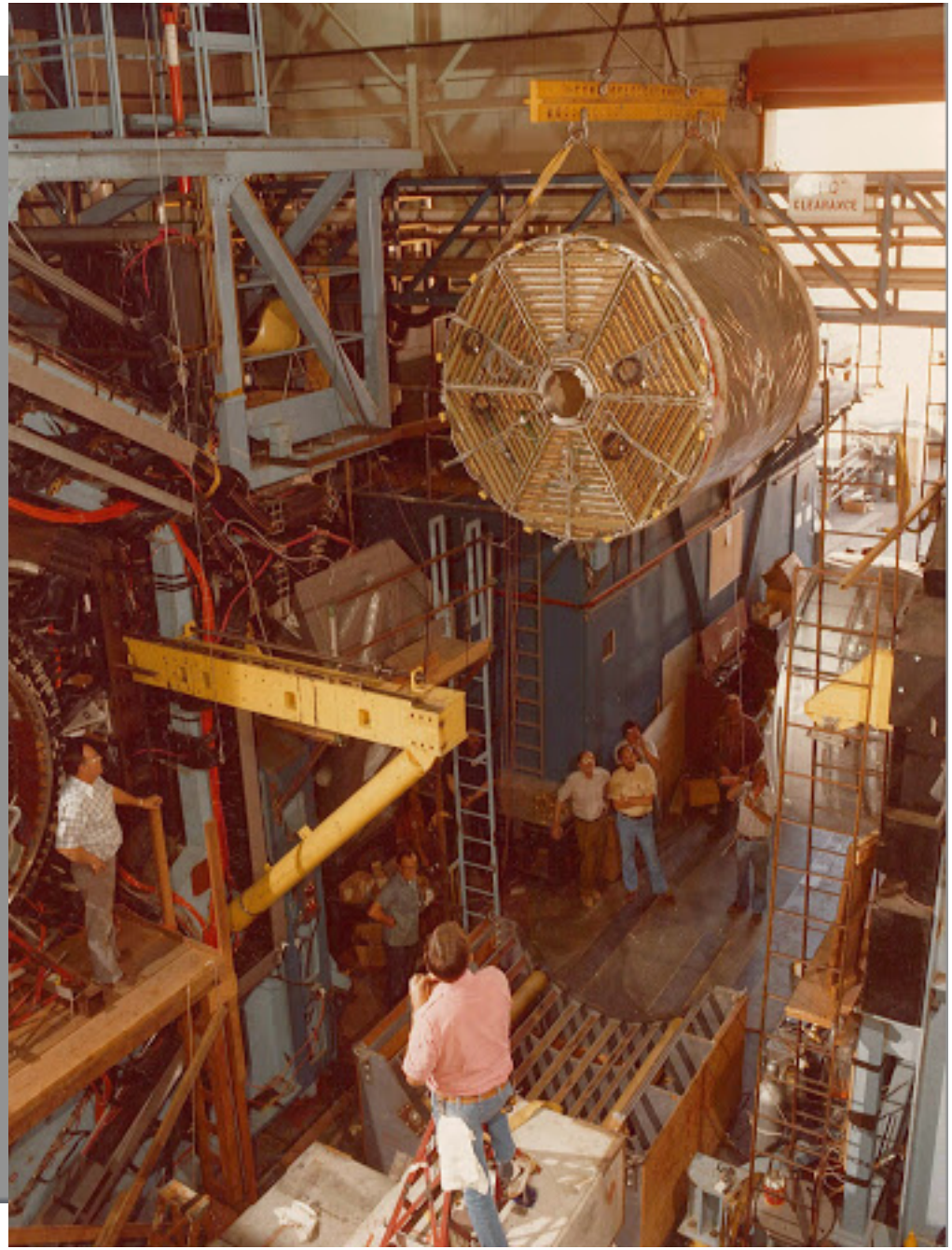
- "Doing it" represented a very challenging, often painful 6-year period.
- We later described it as being like going from a Wright Brother's-scale airplane to a 747 in one step.
- There were many technical challenges in the design and construction of perhaps the most complex particle physics detector up to that time.

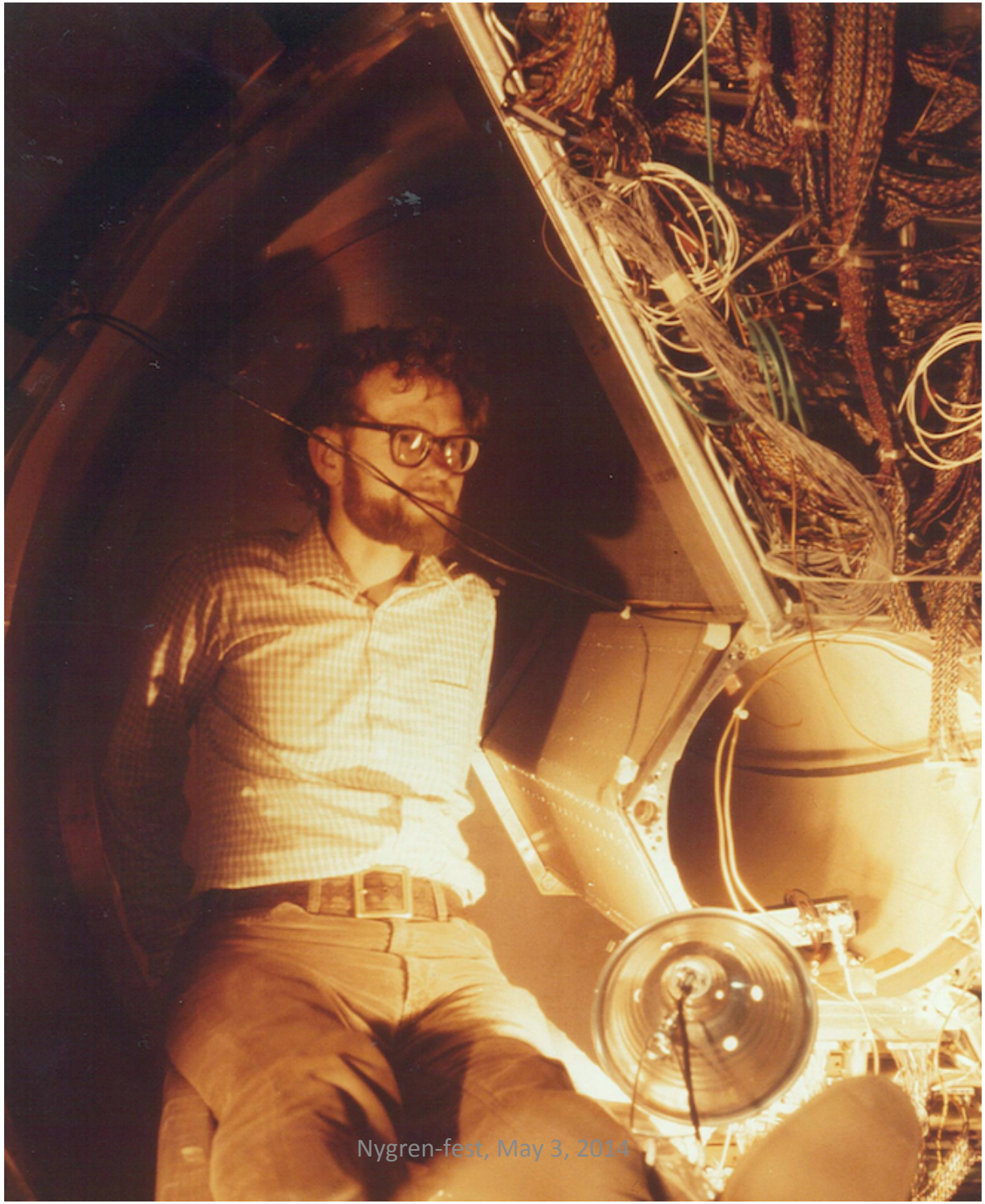
Challenges included—

- The production of the high precision TPC endcap sectors. They were hand-crafted by Ray Fuzesy.
- Implementing a gated grid for the TPC to prevent buildup of positive ions in the TPC sensitive volume.
- The design and fabrication of the 200kV HV system to provide the TPC's drift E field.
- The design and fabrication of the thin high-field superconducting solenoid.
- The 25,000 channel CCD-based readout electronics.
- Etc., etc. etc.



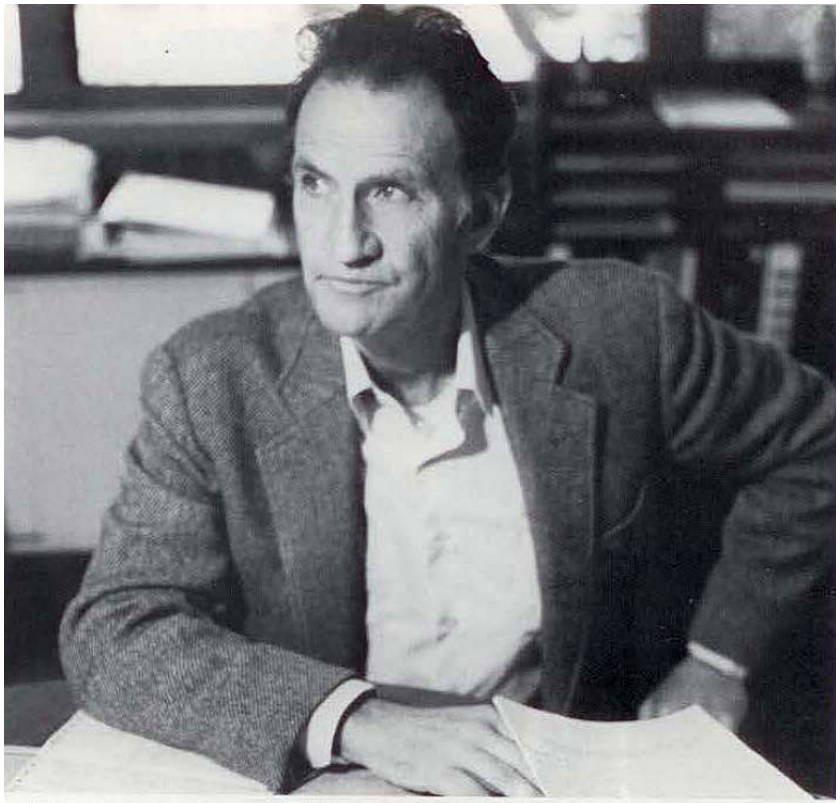




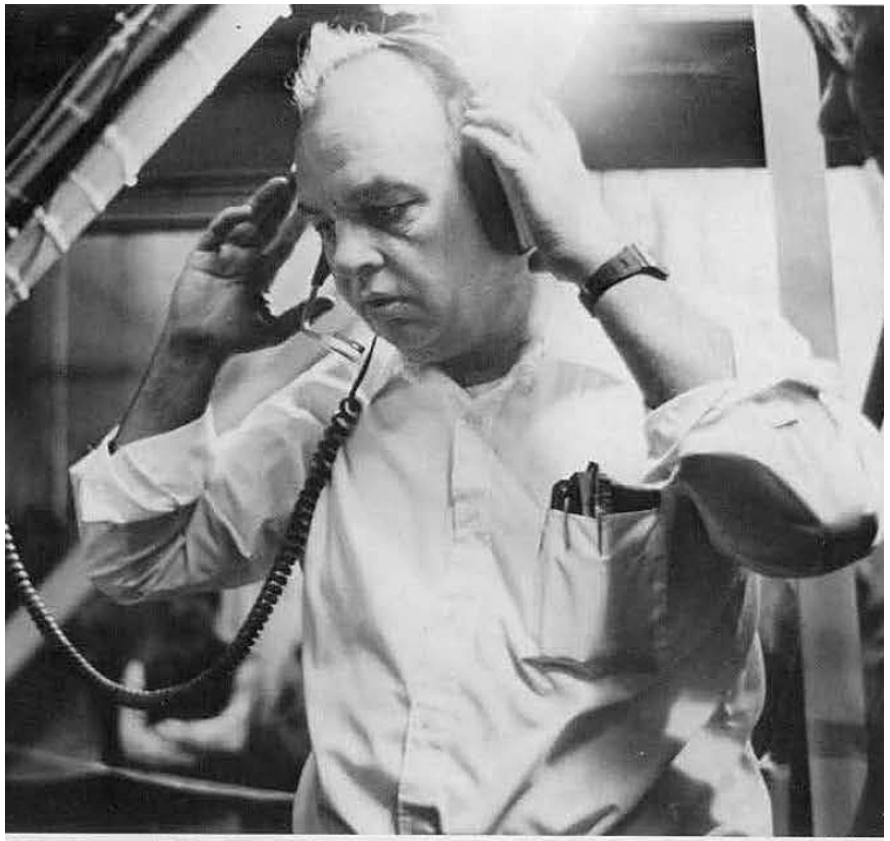


"Marjorie Shapiro was one of the first graduate students to cast her lot with the TPC: now we have about twenty of them. Marjorie's done a bit of everything on the project. Way back at

"Ray Fuzesy's talented hands put together the first Coke-bottle sized model of the TPC, and he then went on to play a leading role in the research and development of the project. Ray was chiefly responsible for the TPC sectors: he designed



Mirk: "A tremendous amount of blood, sweat, and tears has gone into this project"



- There were cultural challenges. Changing how the LBL Physics Division was organized to support a large project and the way physicists and engineers needed to work together on a project of this scale.
- There were management challenges, many due to our inexperience.
  - Dave and I had to learn to manage this big complex project on the job, the hard way, making mistakes along the way.
- Fortunately, Andy Sessler and Pief Panofsky stood by us and provided moral support, good advice and especially patience.

- And there were major setbacks.
- The low point coming in August 1980 when the superconducting magnet coil suffered a short during final testing due to a tiny sliver of iron lodged between the bore tube and coil.
- The project was far over budget and behind schedule. Rebuilding the coil would add a large additional schedule delay. Something had to be done.

- Soon after, Dave Shirley who succeeded Andy Sessler, took strong action by bringing in an experienced team of engineering managers (Ken Mirk and Lee Wagner) to take over the project management.

- And the EPC advised Pief and Andy that PEP-4 should initially use a normal magnet to begin doing physics until a well-tested superconducting coil was available.

Things improved rapidly after that

- In July 1981 the TPC saw its first cosmic rays.
- In early 1982, with a conventional coil, PEP-4 began taking data.
- In May 1983 the rebuilt thin superconducting coil had a successful cooldown.
- There were still technical problems; e.g.
  - tracking distortions caused by the gated grid misalignment
  - insufficient rigidity to the support structure for the superconducting coil.

- Finally all challenges were met and, although several years late and way over the initial cost estimate, the PEP-4 facility was completed.
- PEP-4 was a success scientifically with large numbers of refereed papers, and over 40 PhDs awarded based on data from PEP-4.
- In 1985, Dave was recognized for his seminal contribution of the TPC concept with the DOE's Earnest Lawrence Award.

- The scientific community has benefited greatly from the TPC and many other of Dave's contributions.
- I certainly have and want to thank and congratulate him.
- And to say-- happy birthday Dave.