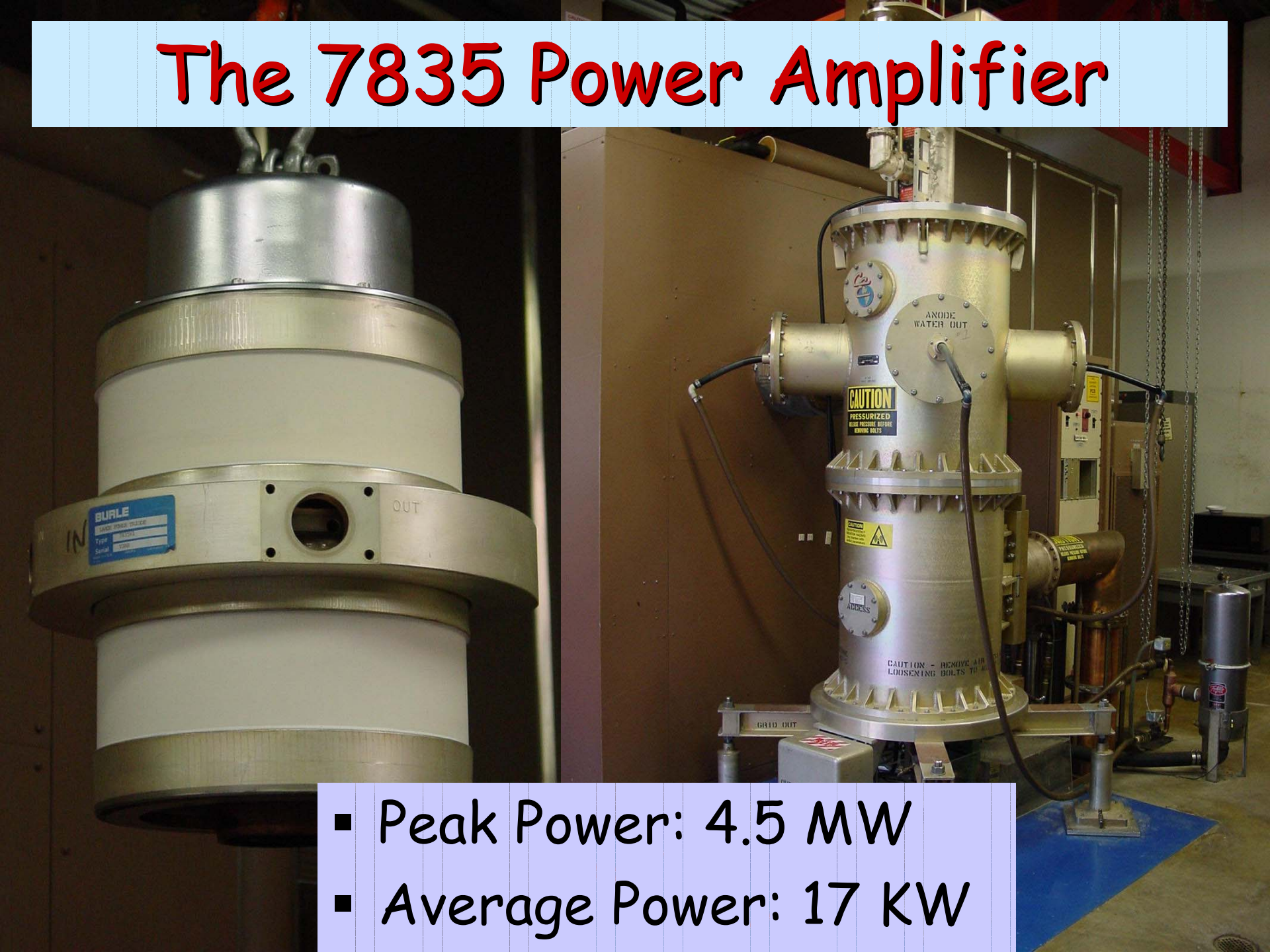
# The 7835 Power Amplifiers in the Fermilab Linac

Elliott McCrory

21-Feb-2005

# The 7835 Power Amplifier




- Peak Power: 4.5 MW
- Average Power: 17 KW

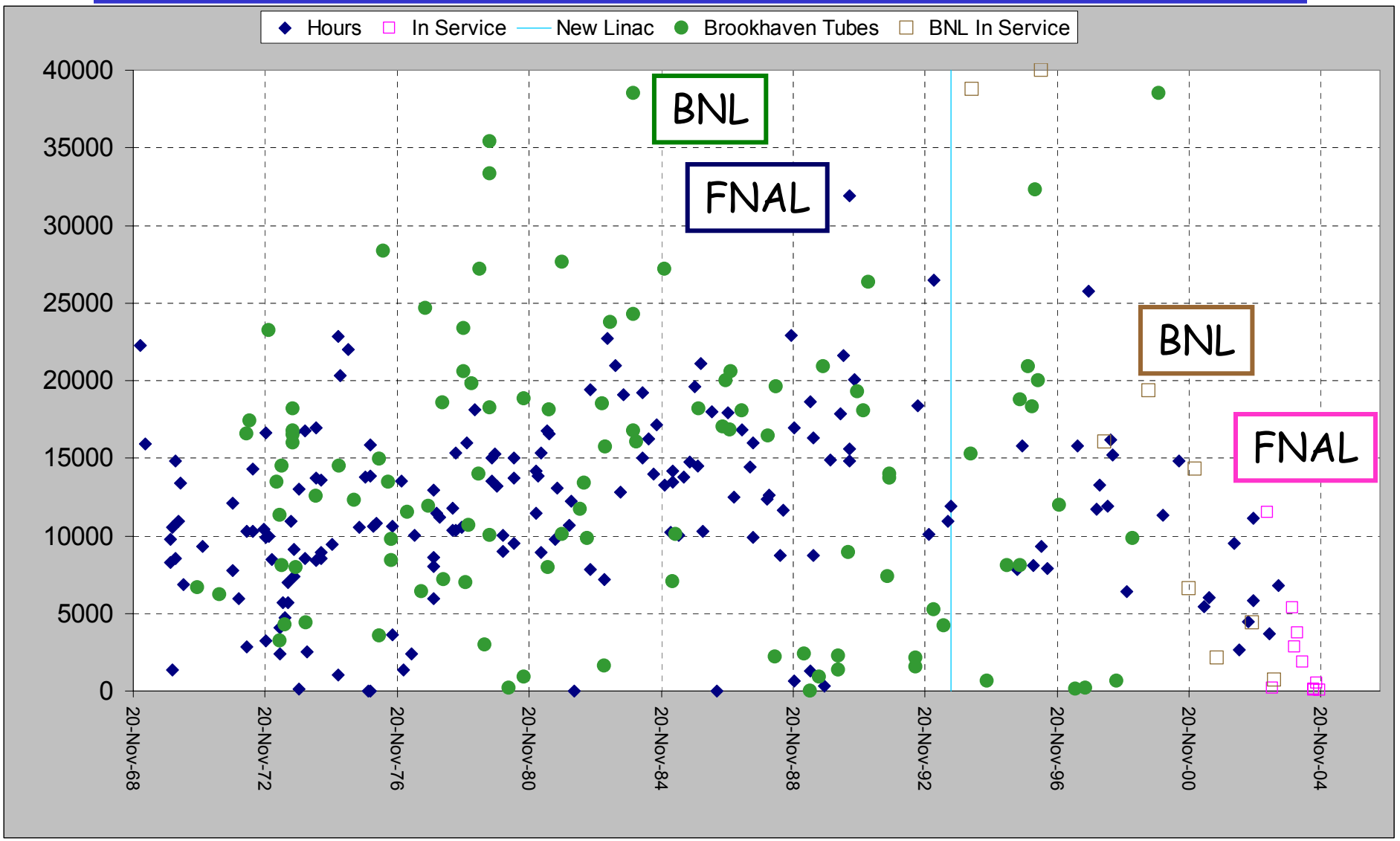
# Recent History of the 7835

- Linac Upgrade in 1993
  - Went from 9 sockets to 5
  - Increase peak power & stability demands
    - *Booster loves 400 MeV beam*
    - *Hypersensitive to variations in beam quality*
- Spare inventory ≈0, 2001 to 2003
  - Borrowed
    - *Two tubes from BNL, one from ANL*
- Poor lifetime
  - 7 tubes average ~6000 hours lifetime
  - A couple died at 3000 hours!
  - All reached "Emission Limit"
    - *Which is the normal End Of Life*

# Problems with Manufacturer

- Burle Industries, Lancaster, PA
- Retirement of key experts
  - Anode bakeout temperature example
- Bad filament material
  - Short lifetime
- Bad "getter" materials
- Aging owners
  - Seeking to sell out and retire

# Tube Life: FNAL & BNL



# 3 Labs; Slightly Different Linacs

| Item | FNAL | LANL | BNL |
|---|---|---|---|
| Beam Duration | 30 μsec | 1000 μsec | 500 μsec |
| Repetition Rate | 15 Hz | 120 Hz | 7.5 Hz |
| →Beam Duty Factor | 0.06% | 12% | 0.4% |
| Peak Power | 4.5 MW | 2.9 MW | 3 - 4.5 MW |
| Peak/Ave Current | 40 mA / 0.024 mA | 15 / 1.8 mA | 0 - 35 / 0.14 mA* |
| Sockets | 5 | 4 | 9* |
| Hours/year | 8000 | 7000 | 4000 |
| Tube Lifetime | 11,000 Hours | 22,000 Hours | 15,000 Hours |

* BNL operations: Two modes →
  - Isotope production
    - *35 mA, 116 MeV beam,*
    - *Drift through tanks 6, 7, 8 and 9*
  - Polarized Protons
    - *200 MeV, No beam loading*

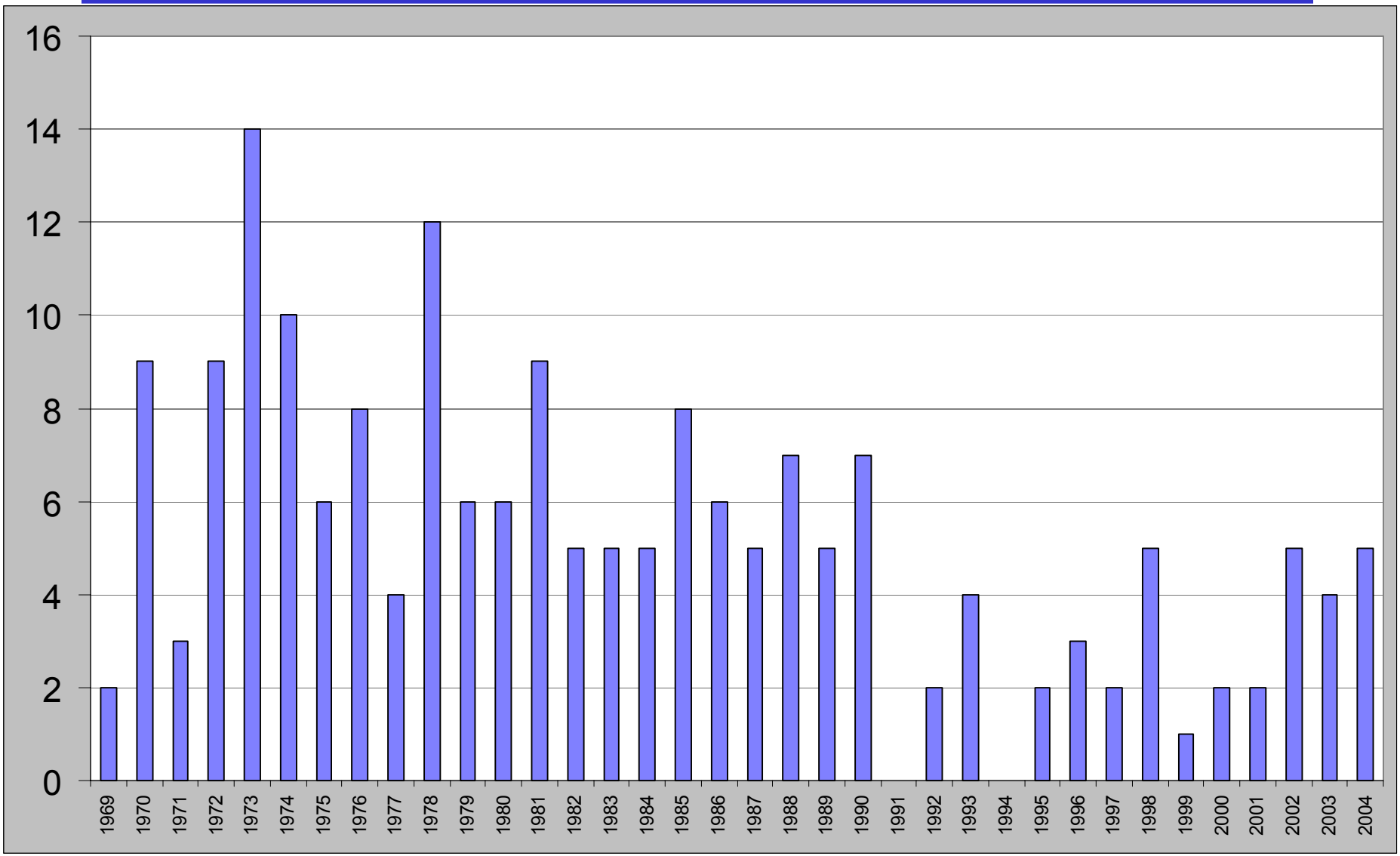
- LANL
  - Rarely see emission limit
  - Often: Ceramic failures
  - Currently: all tubes > 20000 hrs

Conclusion: Tube lifetime goes as Peak Power, Only!

# How Many Tubes …

- Do we burn up?
  - Assuming:
    - *Historical lifetimes (11,000 hrs)*
      - *→3.2 ± 1.1 per year*
        - » *Error bar = 3*(Statistical RMS/√N)*
    - *2001-2004 lifetimes (6000 hrs/tube)*
      - *→5.7 ± 3.4 per year*
    - *Worst case (3000 hrs/tube)*
      - *→11.0 ± 13.1 per year*
- Have we received? …

# New & Rebuilt Tubes Received/Year



# AD Response

- 7835 Task Force
  - R. Andrews, chair
    - *EM, J. Spalding, Joe Morgan, P. Czarapatta, R. Pasquinelli, B. Baller, V. Lodestro (BNL)*
  - Charge …
- Discussions; questions for Burle; visit to PA.
  - Observations …

# 7835 Task Force: Charge (Phase 1)

- Make plan to improve availability of 7835's
- Get/keep an inventory of spare tubes to support 2 years of operation
- Work with Burle to increase delivery rate to 2 tubes/month
  - Develop relationship with them to encourage on-going supply of tubes at increased rate
- Identify anything that could improve tube performance

# Observations from Burle Visit

- Burle recently has made big capital investments
  - Much improvement in daily work at Burle:
    - *cleanliness*
    - *discipline in following procedures and specifications.*
  - Notable improvement in equipment being used & updating of technology being used
    - *At each phase of the tube assembly process,*
- Documenting all of the steps of production
  - Implement quality control measures
  - Have a repeatable process
- Notable efforts to cross train individuals in each step of the process
- Burle has made significant and serious strides in dealing with many of the problems of the past.

# Actions:

- Purchase twelve (12) new tubes
  - $1.87M
  - Above and beyond our recent nine/year order of new and rebuilt tubes
  - Expect 2 tubes/month, starting in July
    - *In addition to 1 tube/6 weeks regular flux*
- Filaments:
  - Will install and commission "line conditioner" to smooth 480 VAC input
  - Will install shunt to verify the current readback

# Not Considered

- Rebuilding 7835s at Fermilab
  - Tried at BNL over 20 year period
    - *But was not an all-out effort*
    - *Nevertheless, no success achieved*
- Someone else rebuilding 7835s
- Replacing 201 MHz components
  - Two 2.5 MW tubes per Linac tank?
    - *Technically possible*
    - *Installation can be staged*
    - *$1M - $2M per station*
  - New Low-Energy Linac?
    - *Cannot be staged*
    - *O($50M)*
    - *Anticipation of 8 GeV Linac: Kills this idea!*
  - To be considered in Phase 2 of Task Force