JLab Update

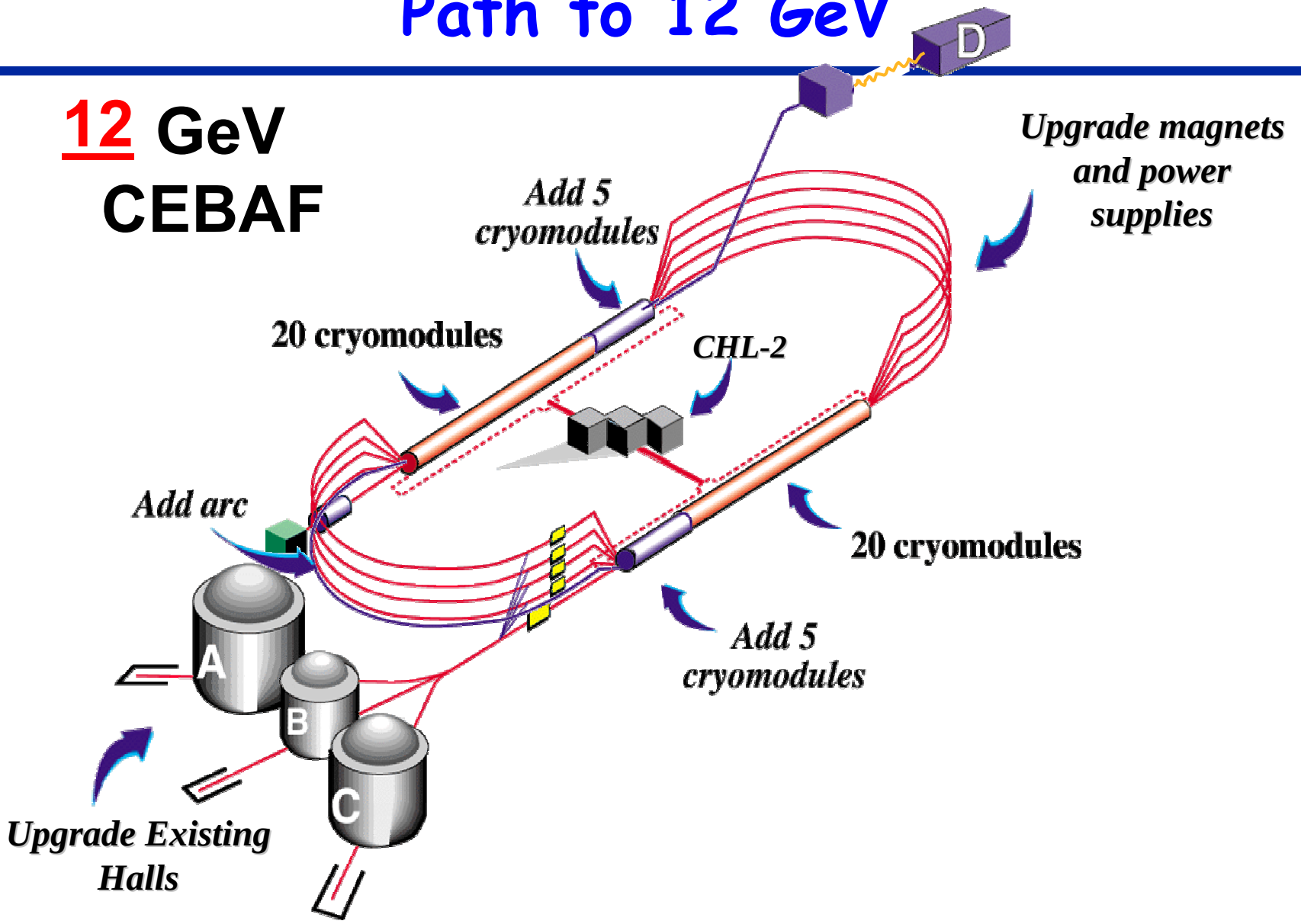
Rick Nelson

12 GeV

- DOE Road to Upgrade is Critical Design Path
- CD-0 Formal Project Definition Phase (2004)
- CD-1 Approve PED Project Engineering/Design (2006)
- CD-2 Approve Performance Baseline (2007)
- CD-3 Approve Construction Start (expected 2008)
- CD-4 Approve Start of Operations (expected 2015)

Path to 12 GeV

12 GeV CEBAF



Major RF Changes

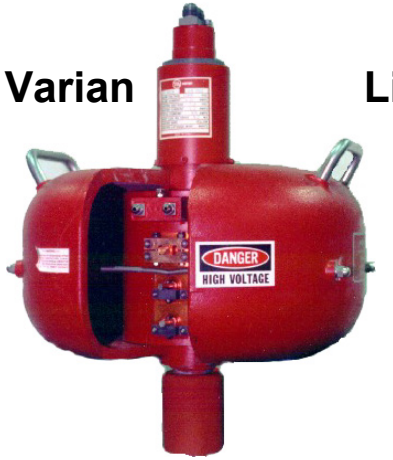
- Upgrade existing systems
- Add new higher power RF systems

- Upgrade existing systems for higher power
- Existing cryomodules are being refurbished
  - C50 (50 MV/m) result
  - Increase RF capabilities from 5 to 6.5 kW
    - Take advantage of better cryomodule performance
    - Retain original klystrons
    - Upgrade to existing HVPS
- Add new RF zones
  - Ten C100 cryomodules (100 MV/m)
  - Ten new RF systems
    - Includes new designs for high power and low level elements

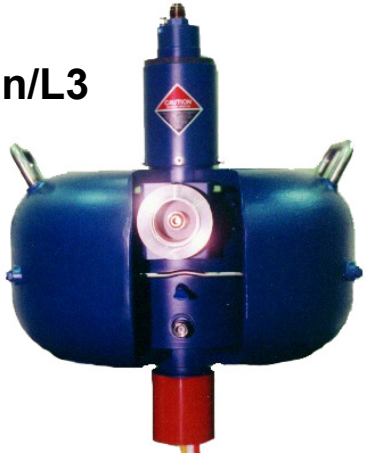
VKL7811W Klystron History

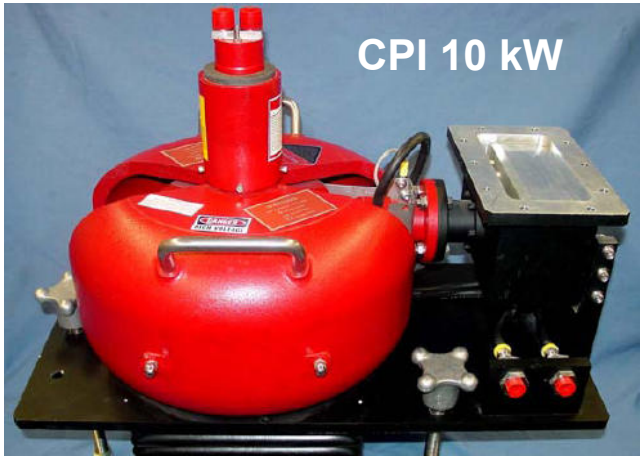
- Originally: ~2 kW and air-cooled collector
- Modified for CEBAF: 5kW, water-cooled collector, modulating anode added
- JLab FEL: voltage increase, for 8 kW
- Voltage increase and cooling additions to tube for 10 kW (Stanford FEL & others @ 1.3 GHz)
- This upgrade: only increase voltage & cooling

Varian



Litton/L3

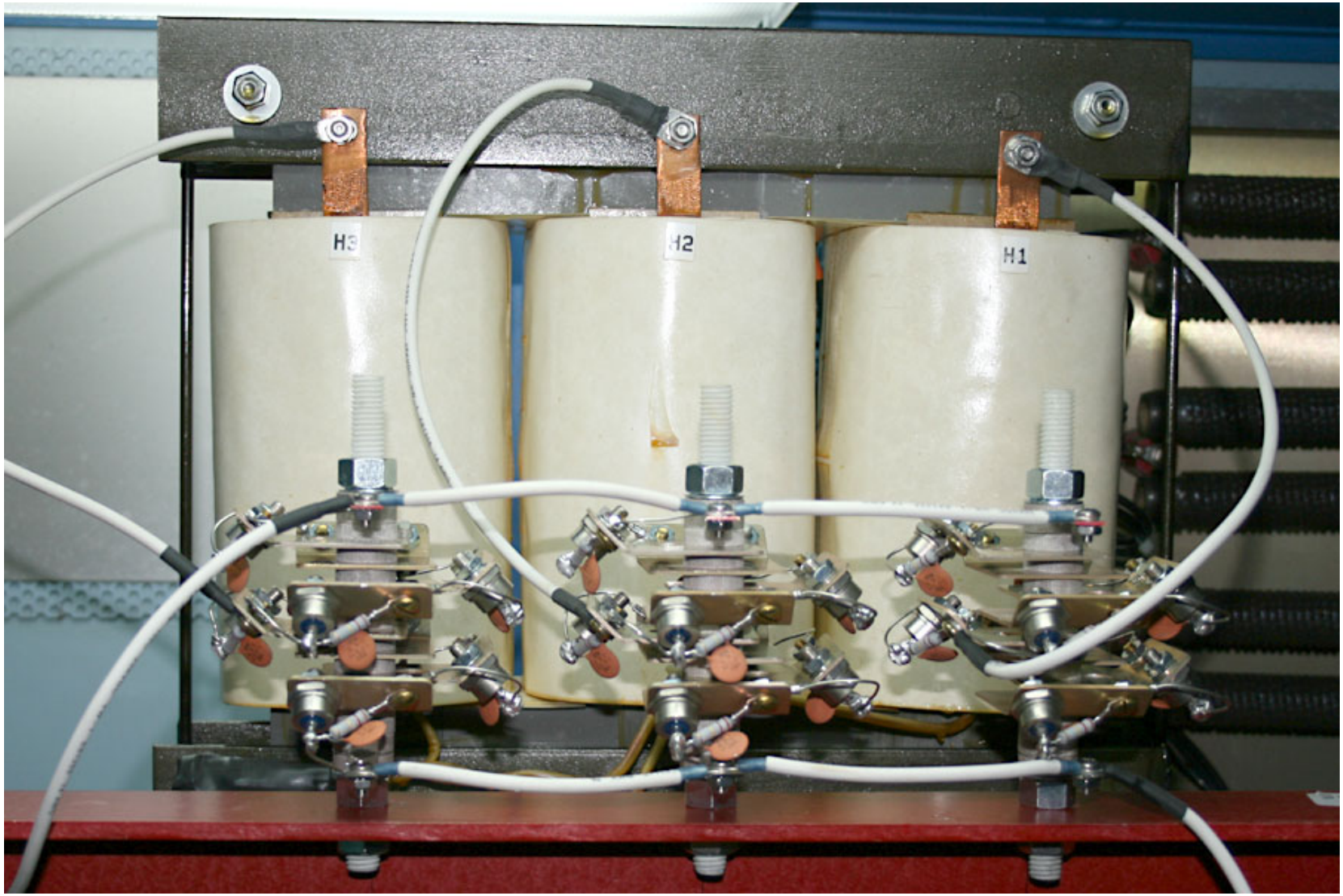




Upgrade Existing Zones

- Increase voltage
  - 11.6 kV to ~12.6 kV
  - A minimal cost upgrade (few k$ per zone)
  - Original power supply is delta-wye, 12-pulse supply (series-connected bridges)
  - Addition of simple boost supply
    - Transformer & 6-pulse rectifier only
  - Components added in return leg (ground)
    - Reduces transformer insulation requirements
  - Filter network unchanged
- Install klystrons recertified for 6.5 kW

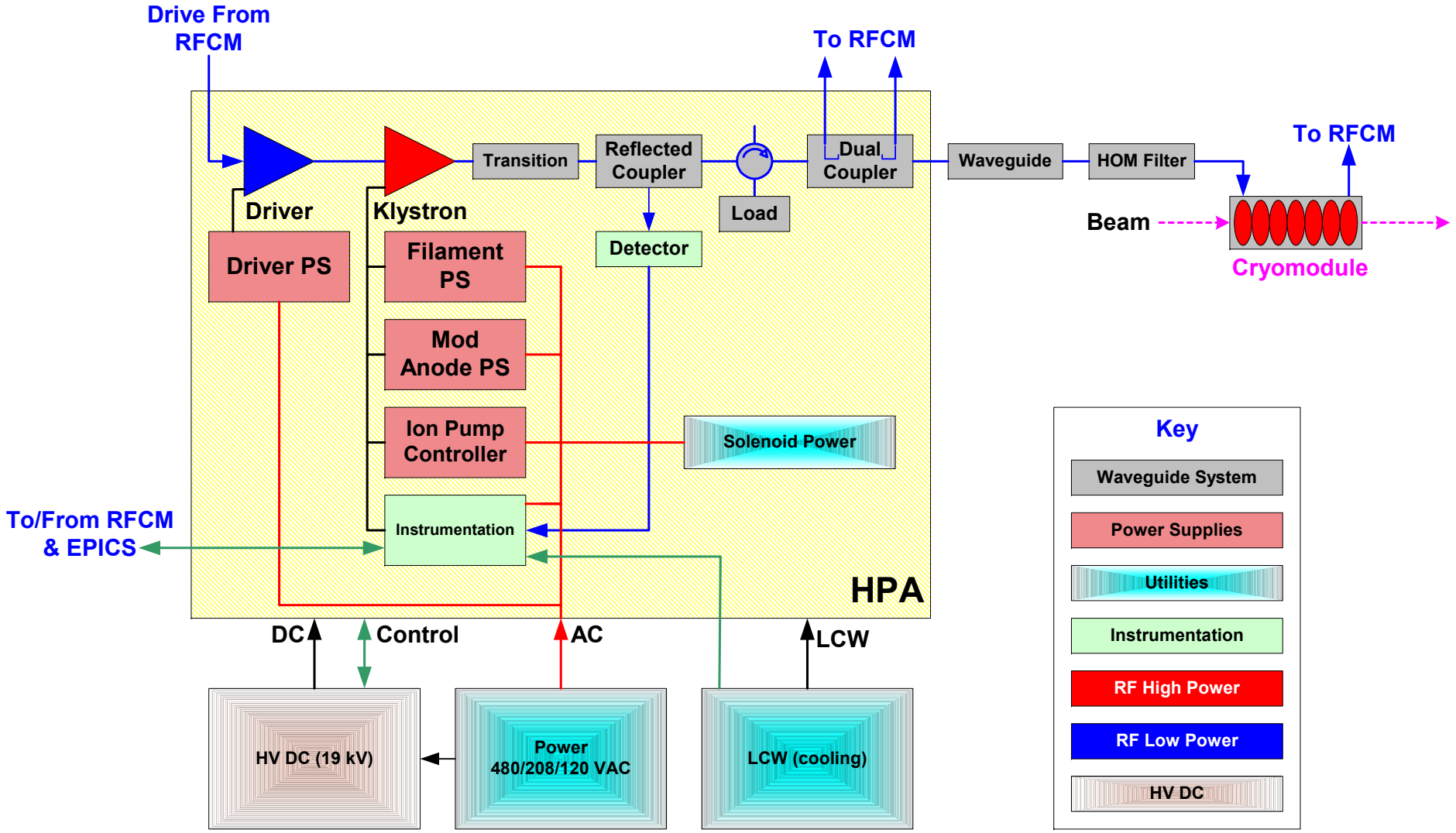
Boost Supply



New RF Zones

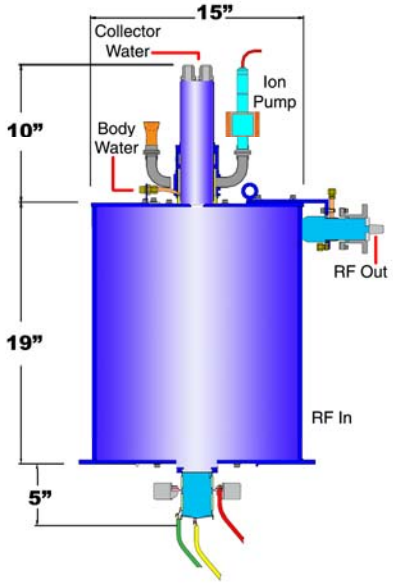
- Use the same general topology as before
  - 1 klystron feeding one cavity
  - 8 klystrons per zone
- 12 GeV HP RF project organized as three systems
  - Klystron
  - DC Power
  - Waveguide
- Main requirement change is for 13 kW device
  - IOT possible
  - Cost is a key factor
  - Budgetary pricing suggest IOT will cost more
  - IOT driver cost significant

New Zones

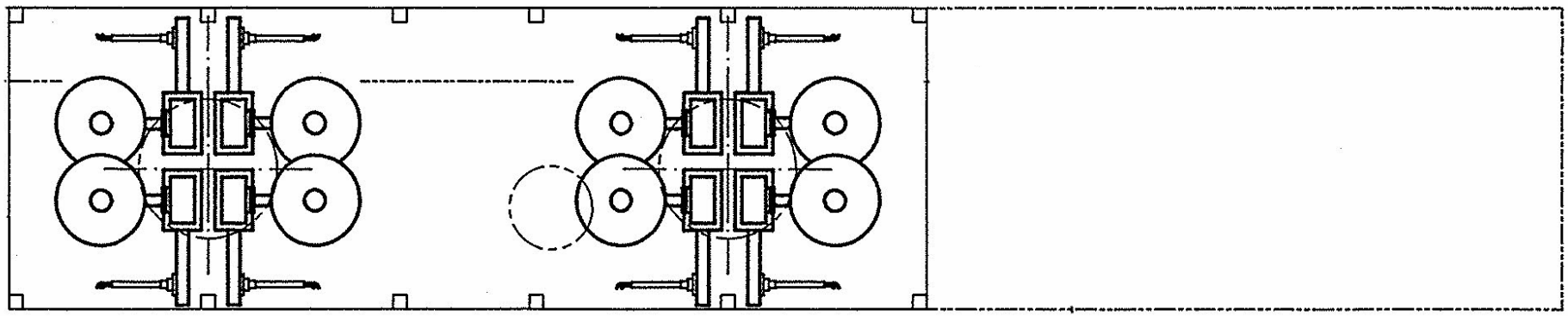

Drive From RFCM
To RFCM
Transition
Reflected Coupler
Dual Coupler
Waveguide
HOM Filter
To RFCM
Load
Driver
Klystron
Beam
Driver PS
Filament PS
Detector
Cryomodule
Mod Anode PS
Ion Pump Controller
Solenoid Power
To/From RFCM & EPICS
Instrumentation
HPA
DC
Control
AC
LCW
HV DC (19 kV)
Power 480/208/120 VAC
LCW (cooling)
Key
Waveguide System
Power Supplies
Utilities
Instrumentation
RF High Power
RF Low Power
HV DC

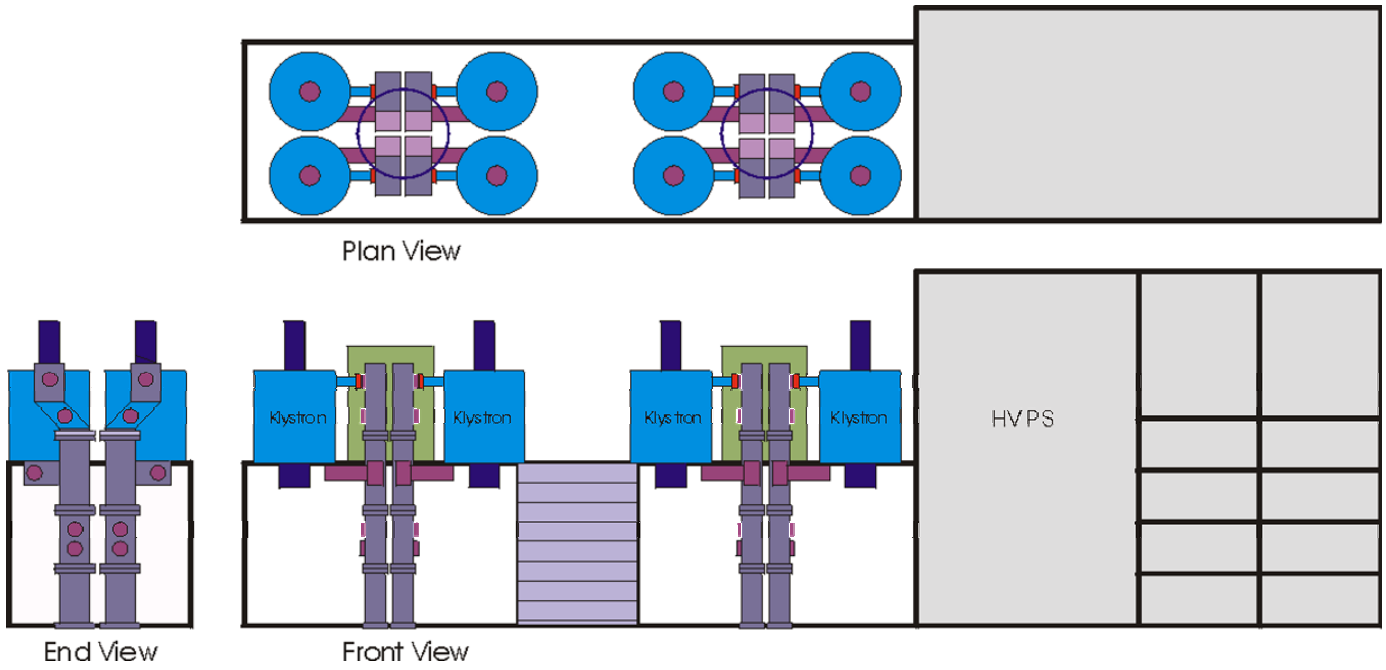
10 Pounds… 5 Pound Bag

- It must fit existing available space
  - CEBAF was originally conceived as a 4 pass / 25 zone machine for 4 GeV
  - Built as 5 pass / 20 zone to save money
  - Linac buildings and tunnel were built for 25 RF zones
  - Upgrade will fill the empty slots
- New RF (10 zones) must fit same footprint
  - Larger klystrons

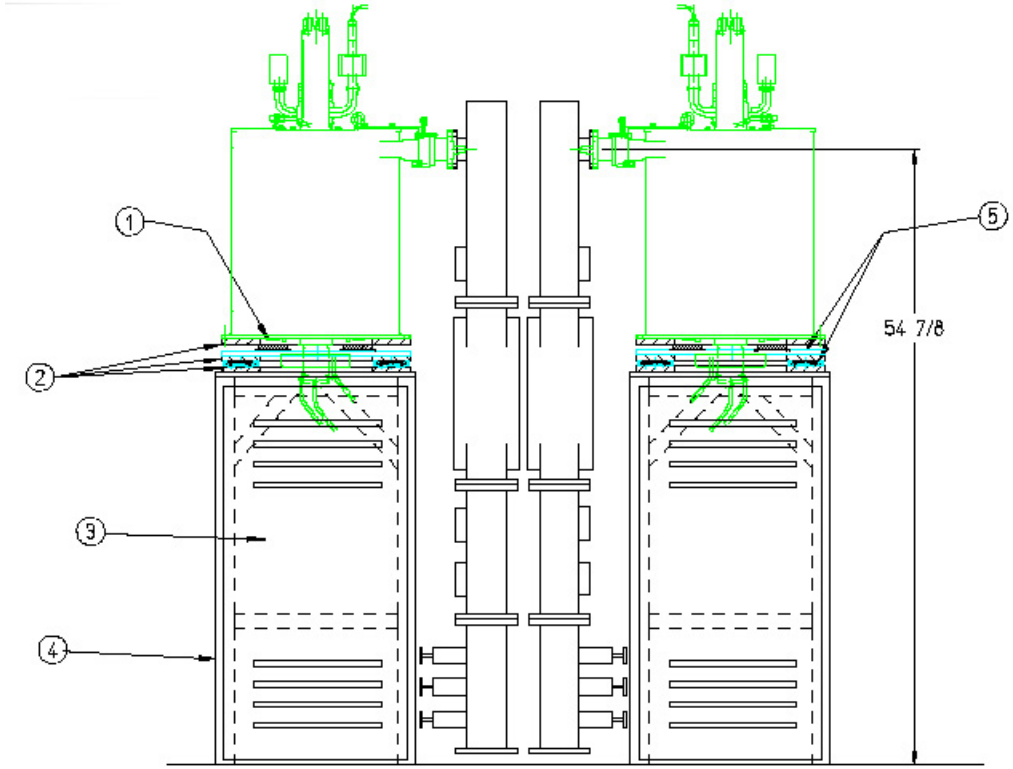


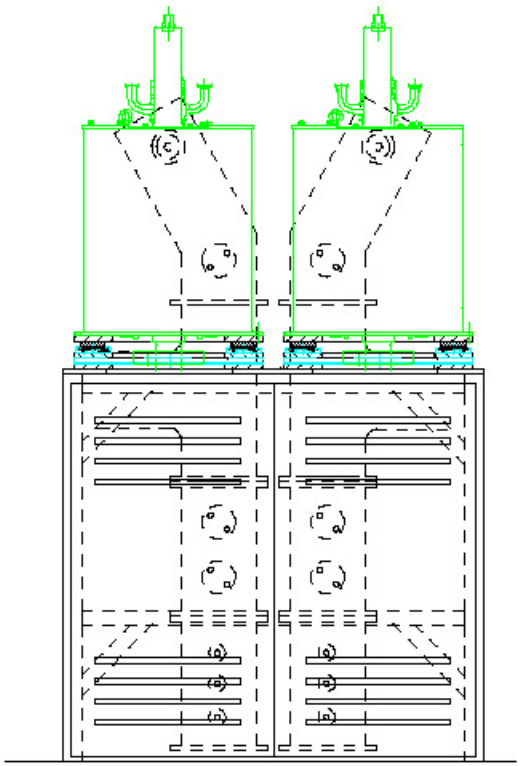
Layout




Plan View
Klystron
Klystron
Klystron
Klystron
HVPS
End View
Front View

Layout





High Power RF

- Basic requirements are
  - 13 kW CW
  - 1497 MHz
  - Klystron or IOT
    - Efficiency, cost, historical reliability
      - Driver cost could be significant
      - Previous lifetime experience is limited at other than UHF)
    - A klystron design approach started with an SBIR
      - Expected to speed procurement process
      - Developed tube worked but was killed during test
      - Only 1 vendor of 4 was willing to build the design
- No money for early procurement as with CEBAF
  - Soliciting vendor interest in either
    - Responses are due by next week
    - For easier cost comparison, IOT must include driver amp

DC Power

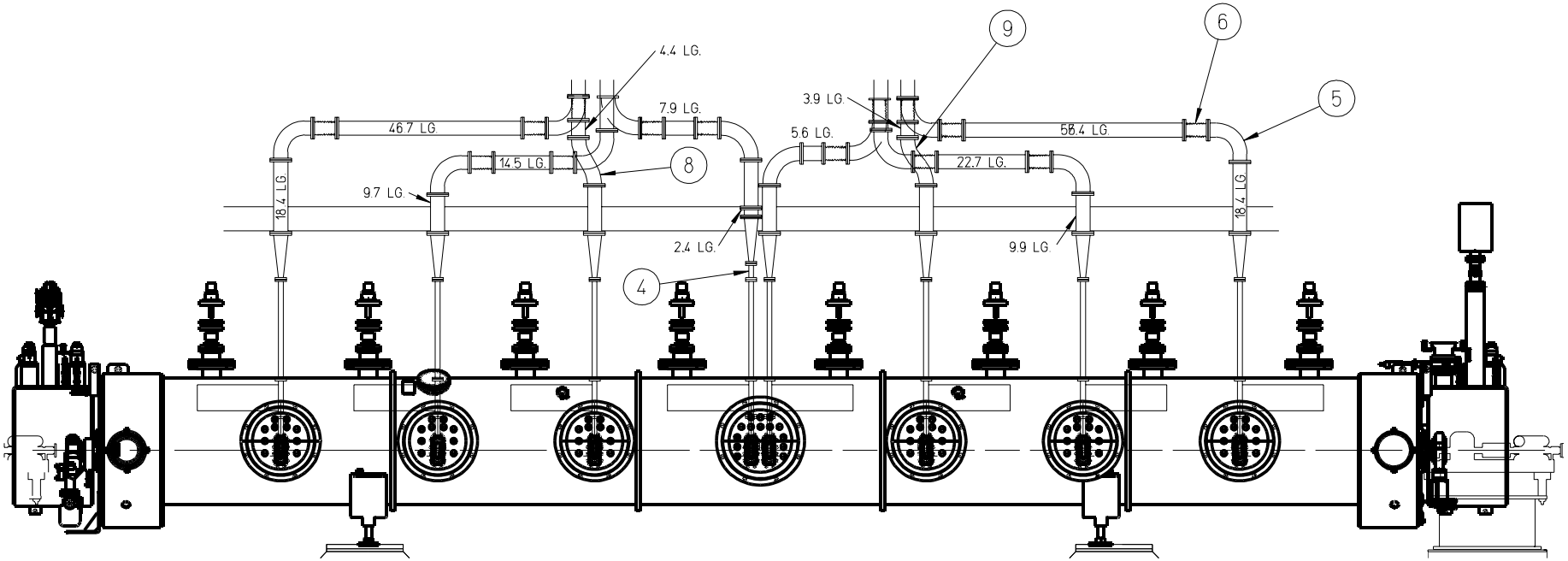
- HV PS could be switcher or conventional (transformer/rectifier)
- Again, size may be a factor
- HPA / transmitter
  - Unlike before, not fully enclosed
  - Klystron rack (pedestal with 2 klystrons each)
- Contains aux supplies (filament – mod anode – ion pump)
- Instrumentation & interlocks
  - Must monitors & control all klystron signals
    - Filament V/I, mod anode V/I, ion pump V/I, cathode I, body I, reflected power, interlocks…
    - Data logging & fault capture
- Final design has been slowed until klystron details are known
  - Accurate mechanical drawings not possible
  - Klystron not yet available

HPA

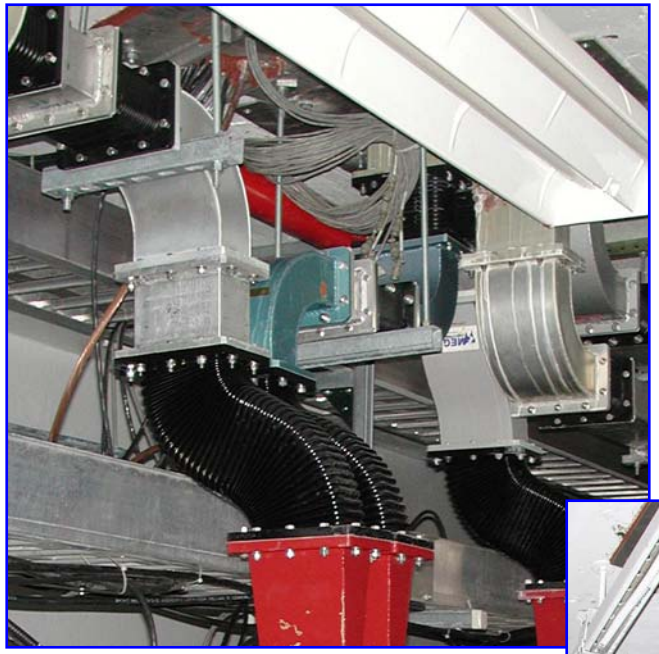
- CEBAF original approach was to purchase from industry
- Original costing for 12 GeV was based on design & build
- Recent reevaluation of this approach suggest no change
  - This depends on vendor pricing
  - Latest vendor estimates are high
- Final design has been slowed until klystron details are known
  - Klystron not yet available
  - Procurement process has begun
  - Expect award this year
  - Design & build to
  - Purchased system
  - HPA Controller - Altera FPGA + PC-104 to EPICS
    - 128 ADC
    - 32 DAC
    - 48 relay out
    - 48 digital in

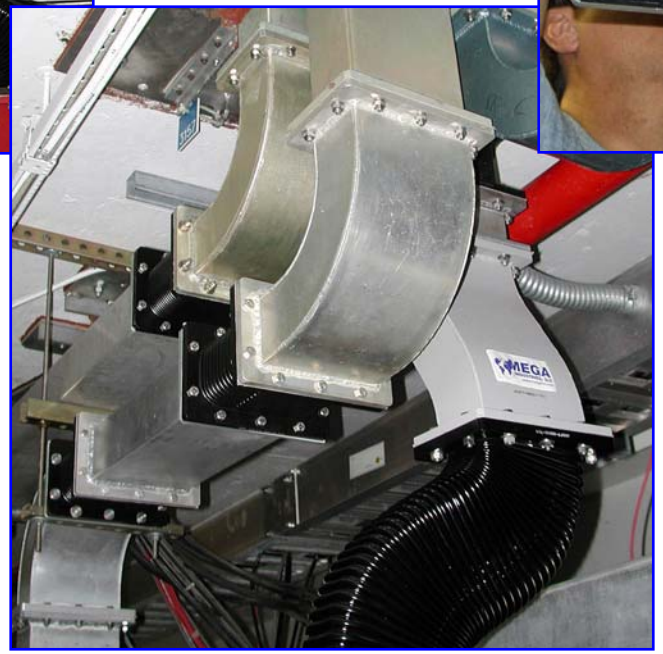
Waveguide Systems

- WR650 waveguide exits down to CM in tunnel
- Original layout kept path lengths 1/2λ multiples (no circulator)
- Layout is different with waveguide on one side only
- Two installed cryomodules use this layout
- Routing not as convenient as before, but possible



Custom Pieces to Connect Up





Issues

- Klystron not purchased, not designed
  - Final mechanical design difficult
  - Final operating voltages not known which affects many systems
    - Estimated values are being used
    - Based on SBIR outcome, some existing subsystems may work with modifications
- Possible change in acquisition plan from
  - Design & build, to purchased system
  - But, in-house design is ongoing
  - Ultimately choice will depend on vendor pricing

RF Power Systems
Improving Efficiency: Options

Reducing Operating Costs

- US labs are struggling with reduced budgets and rising costs
- Dealing with the shortfalls includes:
  - Reductions in operating time
  - Layoffs & early retirement
  - Deferred/reduced procurements (klystrons…)
  - *Also look at reduce energy consumption*
    - *Primarily large power users like CHL (cryogenics) and RF*

Reducing the RF Power Bill

- Turn off unused/unneeded RF zones
- Adjust supply voltage based on needs
  - Added autotransformer with tap switch for easier adjustment
- Adjust anode to reduce power consumption
  - Software solutions automatically optimized mode anode based on RF needs
    - Good results, but operational difficulties
      - Recovering from trips may leave insufficient headroom to quickly restore beam
      - Not always running economized
  - Another possible solution is higher efficiency RF power sources
  - One possible bonus: more power with same DC voltage

Efficiency Exercise

- History
  - Present klystron is ~ 33% efficient
  - Energy costs are rising
- Goal
  - Explore possibility of replacing existing devices with a higher efficiency device
  - Pay for a new device with a combination of money
    - Already rebuilding and purchasing new klystrons
    - Reinvest the money saved on power in a better device
      - Ultimately, replace all 340 klystrons with a new device over several years

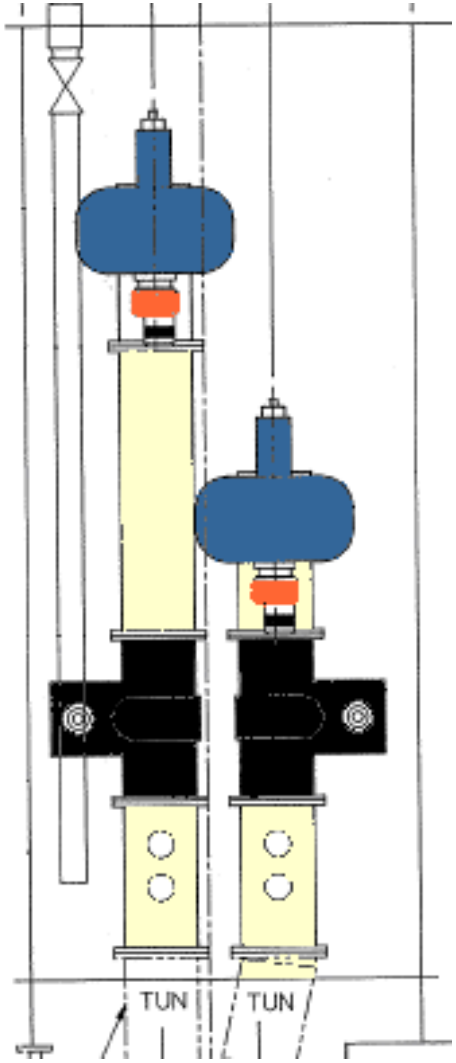
Ground Rules

- Present RF system consumes about 5MW
  - Klystrons provide 33% efficiency (at best)
  - A new design could reach >50%
  - Energy saving would ramp from 270kW to 1.6MW after 6 years
    - Assuming RF runs 80% of calendar year, savings could be $516k/year (FY06$)
    - 10-year savings of $7M (2006$, 15% real increase 2007 and 7%/year real increase out years)
- Cost of our present klystron roughly $25k
  - 10-year breakeven would require tube cost of ~$34k (estimate for 13 kW solenoid tube estimate is higher)
  - Energy savings must offset higher costs of new device
- Problem: a new tube will likely not fit into our existing system without modification (~$50k/zone)… or maybe not at all
  - Replacing full system not in budget

More Ground Rules

- Most tubes would be replaced through attrition
  - Tubes are cheaper to rebuild than buy, but can't rebuild indefinitely
  - New devices will cost more; up front cost / savings later
  - Anticipate $300k in repairs / $500k replacements annually of existing klystron
- Other significant restrictions
  - New device *must be made to fit* into existing hardware
    - Avoid significant changes to present systems
    - Minimize modification costs
    - Must use existing HV PS (presently adjustable)
    - Ideally should get us more power with same HV input (6.5 kW)

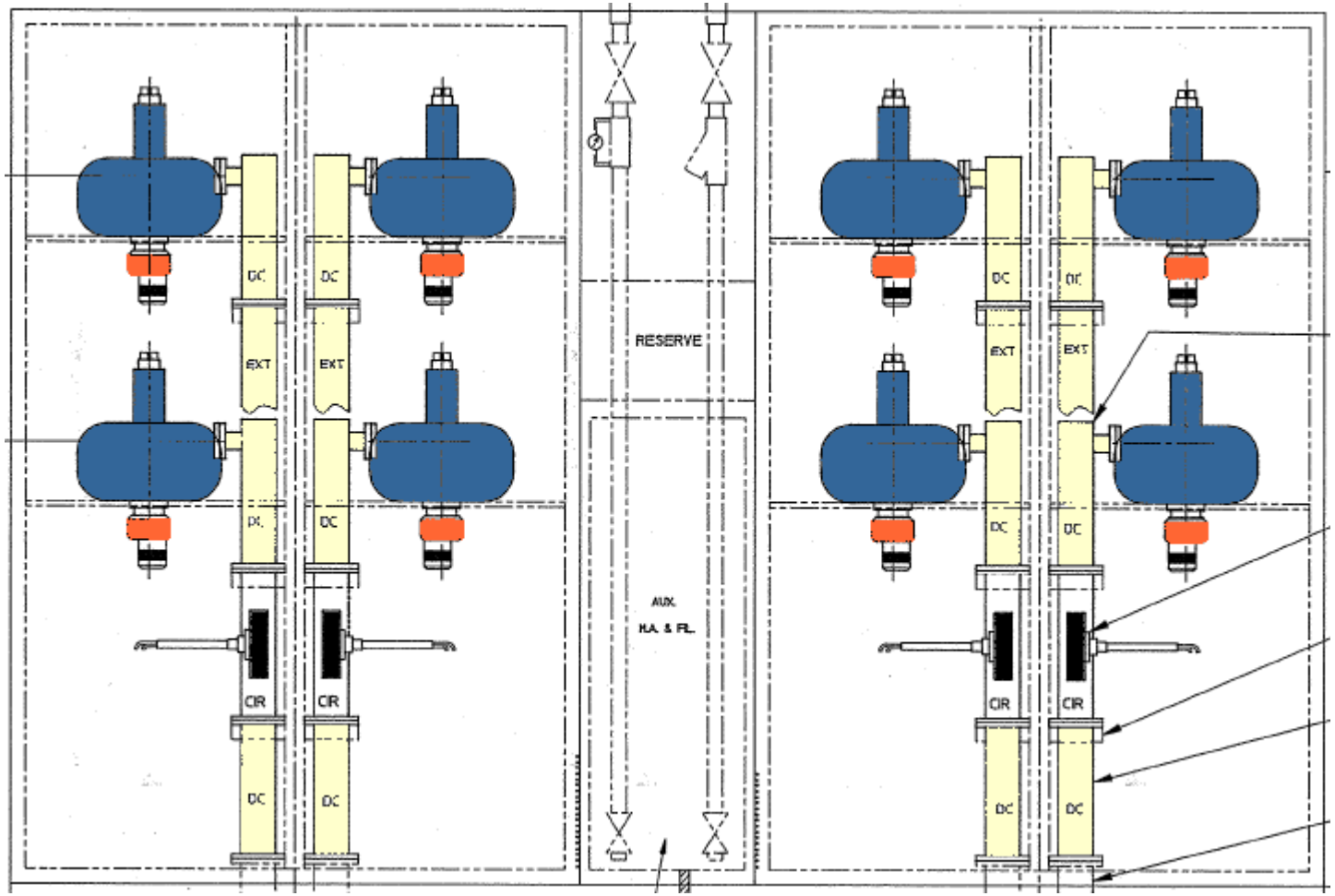
Layout


TUN
TUN


DANGER
HIGH VOLTAGE
3
1


DANGER
HIGH VOLTAGE
WARNING
1

Layout


DC
EXT
DC
EXT
RESERVE
AUX.
H.A. & FL.
CIR
CIR
DC
DC
DC
EXT
EXT
DC
DC
CIR
CIR
DC
DC

New Device: Klystron or IOT

- Vendor responses suggests
  - Solenoid focus (PM not practical)
    - Add solenoid PS $$
    - Significantly larger
      - Won't easily fit existing space $$$$
  - IOT
    - Smaller size could work depending on magnet structure
    - 6.5 kW might be available at existing HV
    - Add solenoid PS $$
    - Low gain = upgrade driver amp
      - From 2W to > 65W $$$
    - No IOTs built yet for 1.497 GHz

No Obvious Winner

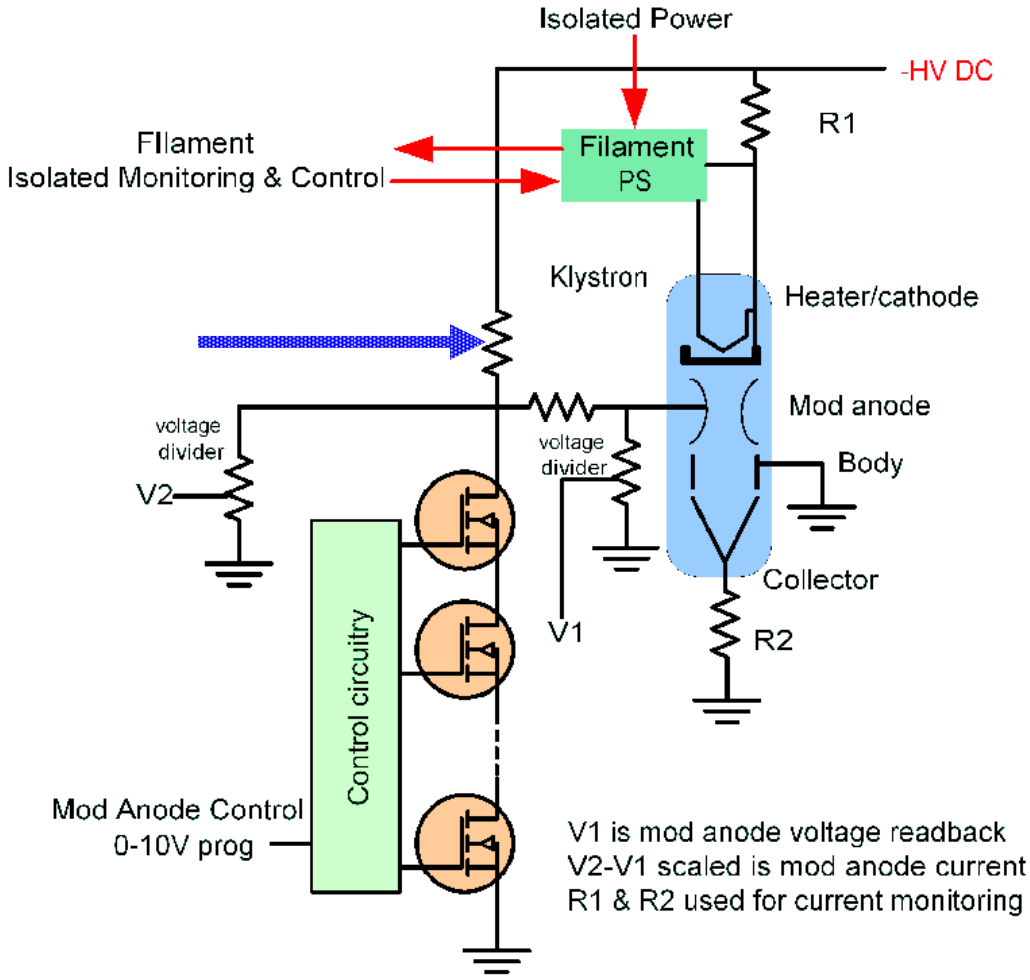
- Based on vendor info and constraints it seems unlikely an upgrade can be made
  - A new device will likely be too large to adapt to existing hardware
  - Expected costs don't fit available budget
- At this point, no further action is expected and no changes are planned – unless other funding is found
  - DOE mandate with special funding?

Mod Anode Update

Mod Anode Control

- Mod anode is primarily used for two functions
  - Energy reduction at low power
    - "Economize mode" under software control
    - Iterative process to reduce power consumption but retain sufficient headroom for stable operation
- Tube protection
  - Used to reduce mod anode leakage current across HV ceramic
  - With software monitoring prevents catastrophic failure
  - Allows tubes to be used longer
  - Richard Walker will discuss this in more detail in his talk tomorrow

Mod Anode Control



Simplified Klystron Power & Metering

Resistor Load Banks

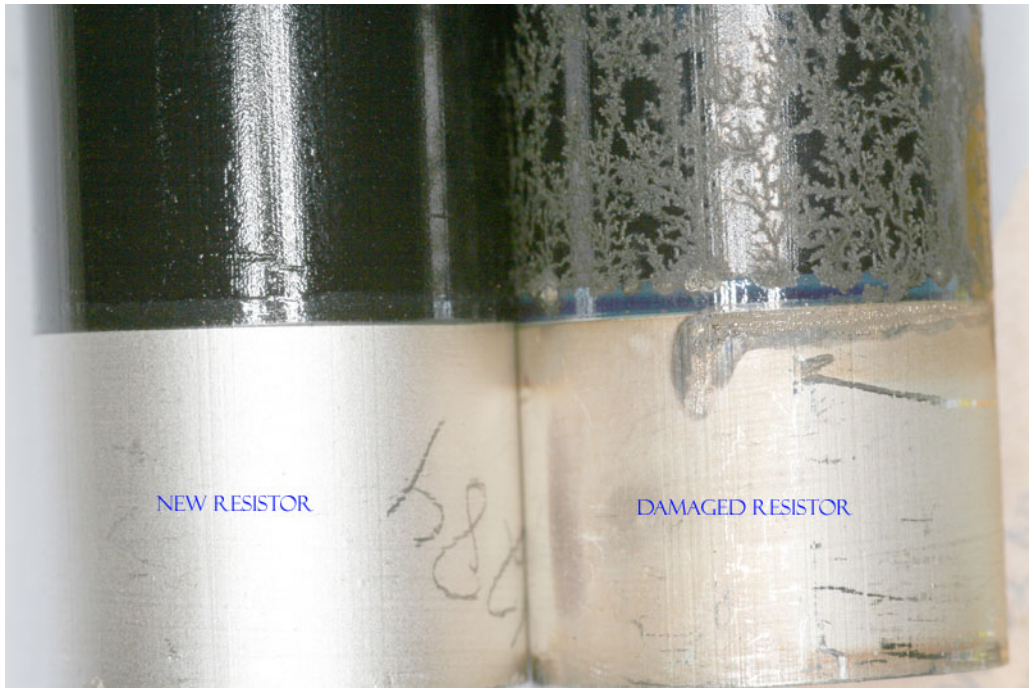
- 11.6 kV / 168W
- 8 x 100k, 50 watt w-w
- Glastic type channel

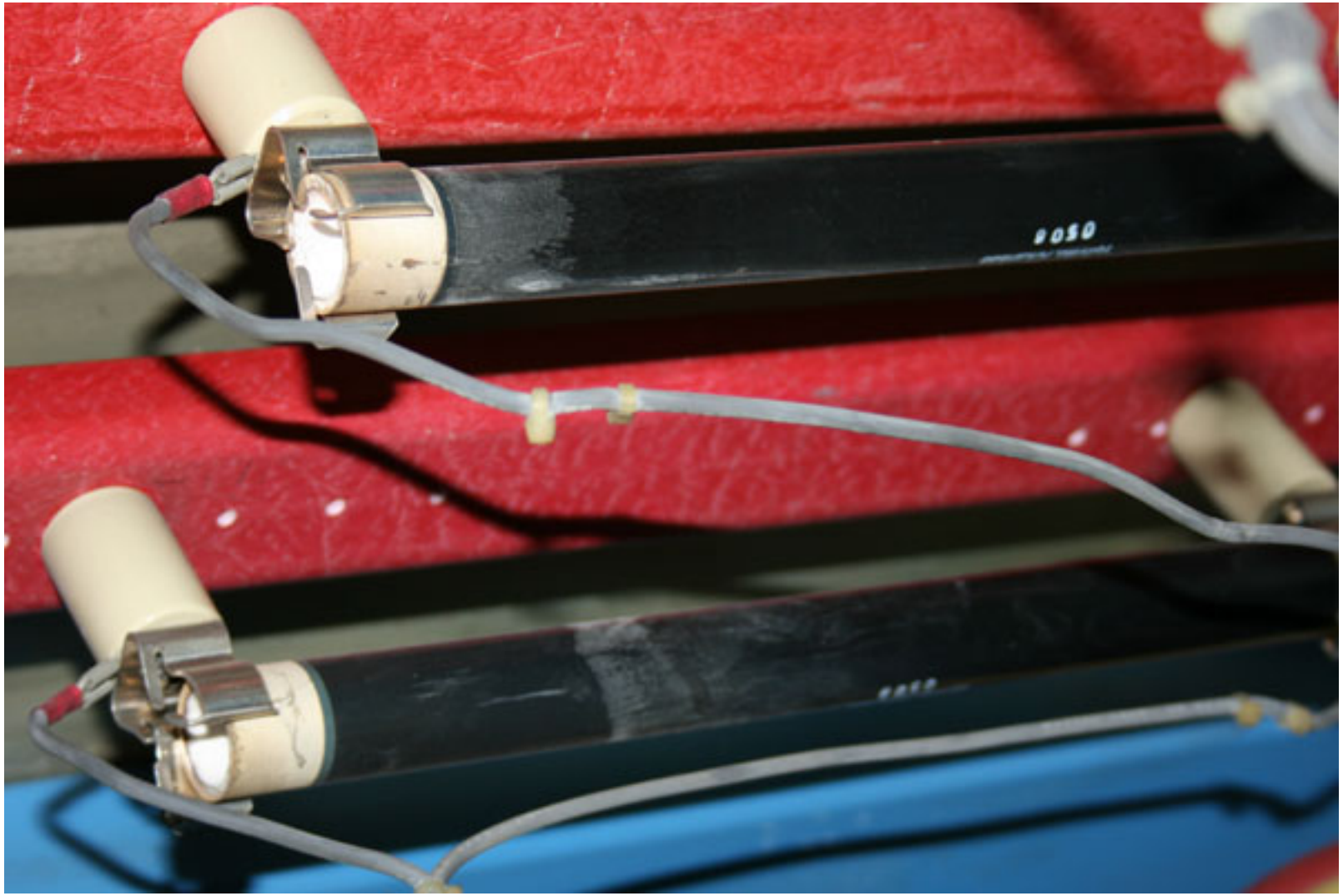
Resistors Are Easy

- 1.6 MegΩ , 11.6 kV (84 watts max @ KMAV=0)
- 1st choice would have been Kanthal/Globar/CESIWID
  - Resistance value at or beyond available
  - Poor performance for high ohm values
    - Heat caused resistors to eventually open
  - Power Film Systems/Altronic Research, Yellville Arakansas
    - PFS12-804CPL
    - 300 watt, air-cooled @ 40 °C ambient
    - 12"x1" thin-film on ceramic core with glass
    - Values to 20 MegΩ, 10 kV/in

Performance to Date

- Old wire-wounds had run over a decade
- Some new resistors have degraded in < 2 years
- Physical (visible) changes were noticed
- Resistance changed





Resistor Degradation

- 1.6 Meg has increased to 2.4 Meg and continues rising
- Vendor suggest corona damage
  - Eliminated power & temperature as an issue
  - Rated at 10 kV/in
- Other suggestions from vendor include
  - Coating problems
    - Uneven thickness, inadequate overlap, glaze too thin
    - Multiple production runs seem to exhibit similar symptoms
  - Modified units are presently being tested
    - Increase glaze thickness
    - Double metallize (sandwich) the connections
    - Add silicone over-coating (Dow Sylgard®)
    - Results aren't in yet, but resistor not essential in most cases