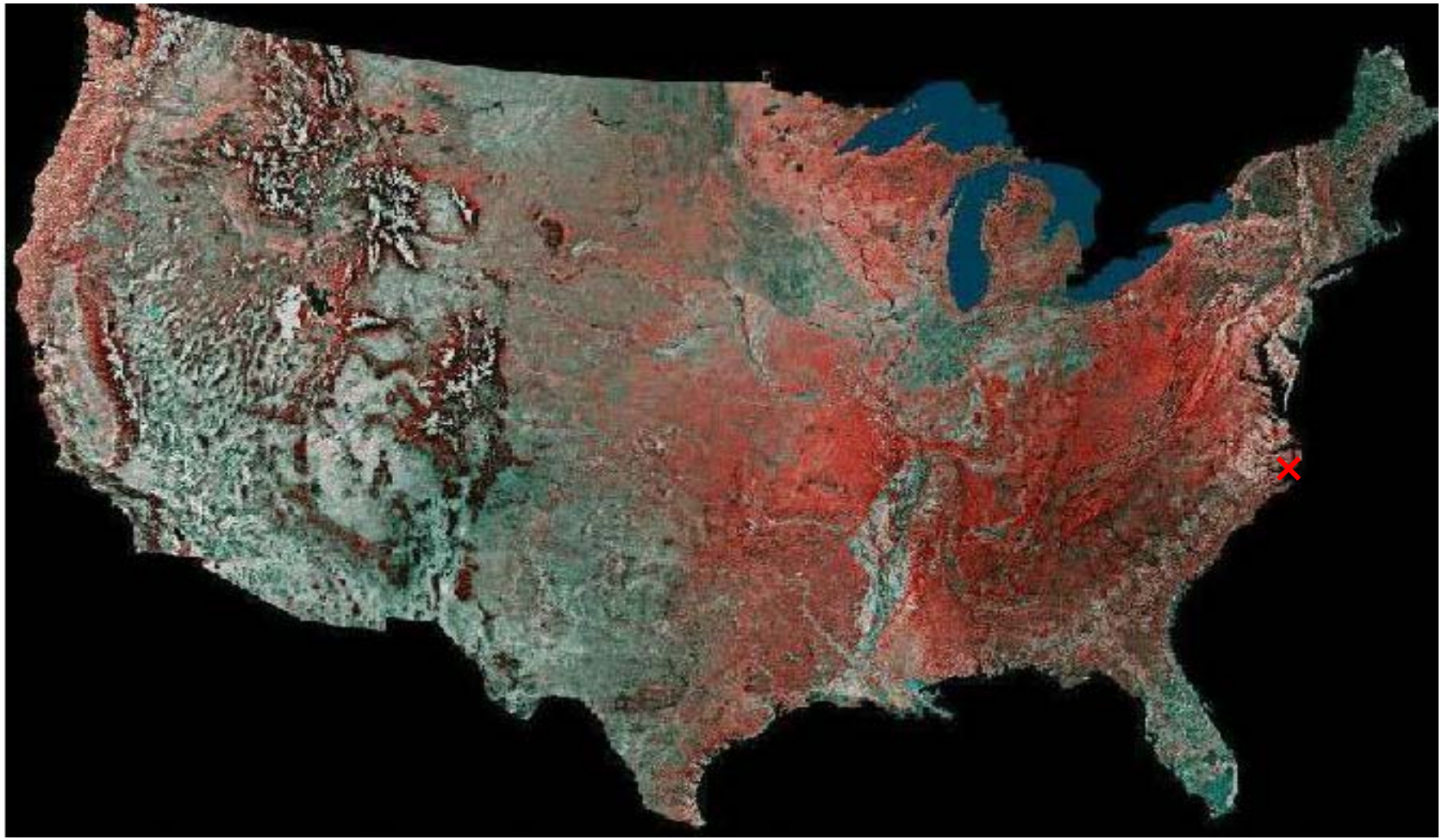
Reliability at the JLab Nuclear Physics Accelerator

Steve Suhring

Accelerator Reliability Workshop
ESRF, Grenoble, France
February 4, 2002

JLab is a World Leader in Nuclear Physics Research

JLab uses electrons to study the quark structure of the nucleus



JLab's annual budget is ~$75M

JLab employs ~500 people and is located in Newport News, Virginia, USA

Continuous Electron Beam Accelerator Facility

J’aime Powerpoint

Ich liebe Powerpoint

Amo Powerpoint

Watashi wa Powerpoint o aisuru!

I love Powerpoint

CEBAF Specifications

Polarized electrons to ~80%

Current from 140uA to 10pA

Design Energy: 4GeV

Operating Energy: at 5.7GeV

Energy Spread ~10^{-5}

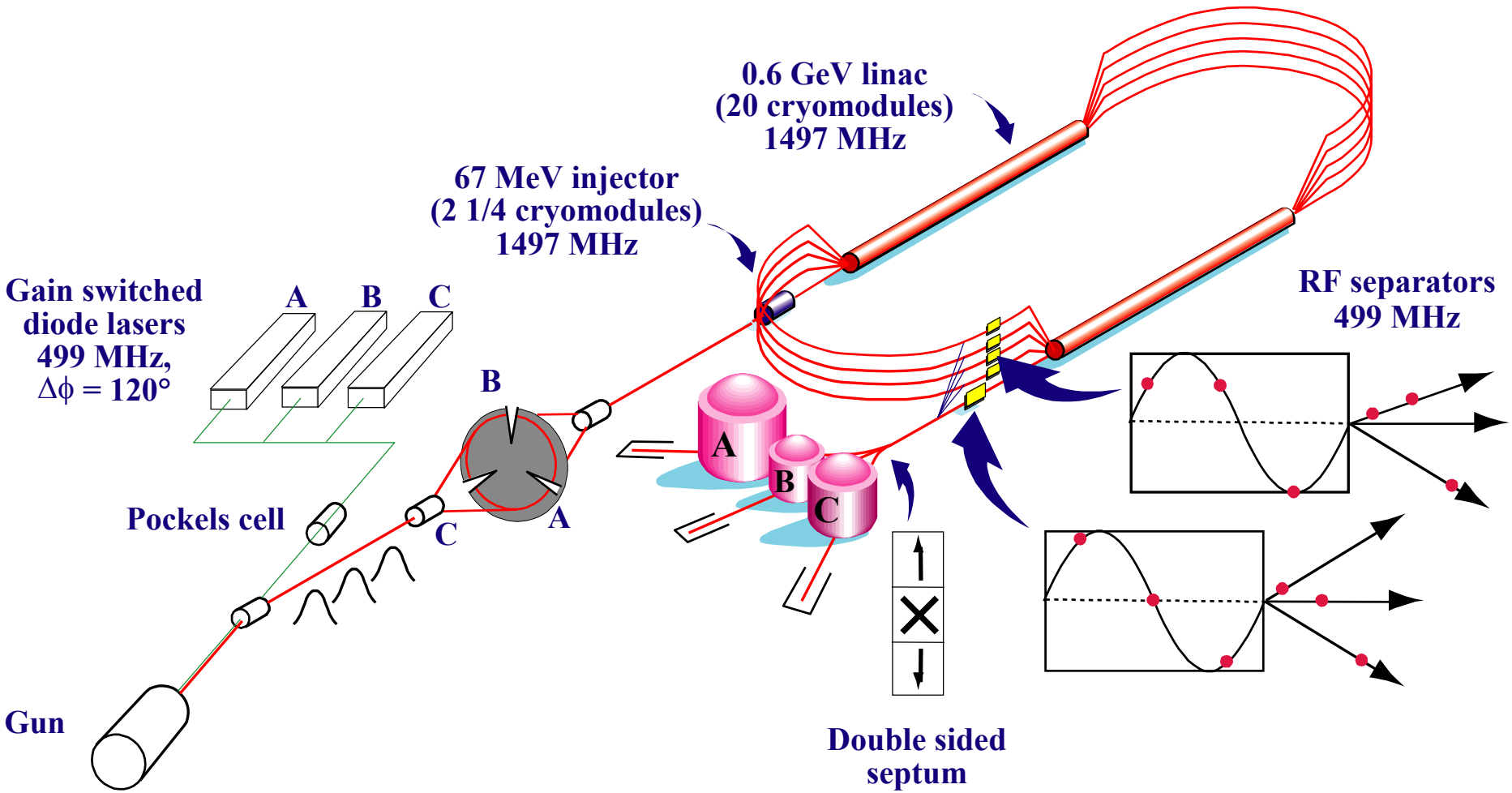
Simultaneous beam delivery to three experimental areas.

8,000 hours of beam for Physics in 2001.

24 hours per day operation. On-Call Support by ~60 people

JLab has a strong SRF group and has developed a 1kW IR FEL that is being upgraded to 10kW IR and 1kW UV

Continuous Electron Beam Accelerator Facility



CEBAF Major Components

- Tunnel ~ 1.4 km long, 10 m underground, 7 m under water
- Electrical Distribution – 40 MW
- Low Conductivity Water ~ 400,000 liters at 1MΩ
- Beamlines 7 km at 10^{-6} torr – 10^{-13} torr
- 2 Polarized Photocathode Electron Guns
- 42 Cryomodules with eight 5 cell Superconducting Niobium Cavities each
- 2 Kelvin Helium Refrigeration Plant
  - 80,000 liquid liters at ~ 210 g/sec

CEBAF Cryomodule / LINAC

CEBAF Major Components (cont.)

- 338 5kW klystrons each with independent controls
- ~ 2100 Magnets and Power Supplies
- EPICS. Experimental Physics and Industrial Control System
- CAMAC and VME with ~ 65,000 I/O Control Points 250,00 EPICS Records 140 IOC's, and 80 UNIX Machines

CEBAF Arc Transport Magnets

CEBAF Operation in FY01

- Unlike a storage ring, the operating conditions of CEBAF are changed frequently based on User needs
- In FY01 there were:
  - **8** linac energy changes
  - **17** pass changes in Hall A
  - **5** pass changes in Hall B
  - **5** pass changes in Hall C
- In all, the accelerator state was changed 31 times – roughly once per operating week.
- This does not include special set-ups for polarization, current, and energy measurements.

Breakdown of Operations in FY01

Type of Operation	Days scheduled	Actual Days
All Accelerator Operations	290	291
Total Operation for Physics	**236**	**235**
One Hall Operation	**0**	**2**
Two Hall Operation	**40**	**45**
Three Hall Operation	**196**	**188**
Beam for Accelerator Development	16	10
Beam Tuning Activities (Restore)	14	15
Maintenance	26	32
Major Shutdowns & Holidays	75	74

Redundancy at CEBAF

- Cryogenic Compressors (Warm and 2K)
- Low Conductivity Water Pumps
- Water Filters
- Power Feeds
- Cooling Towers and Pumps
- Emergency Power for Communication
- Uninterruptable Power Supplies for Controls
- RF Power (until the Physicists take it)

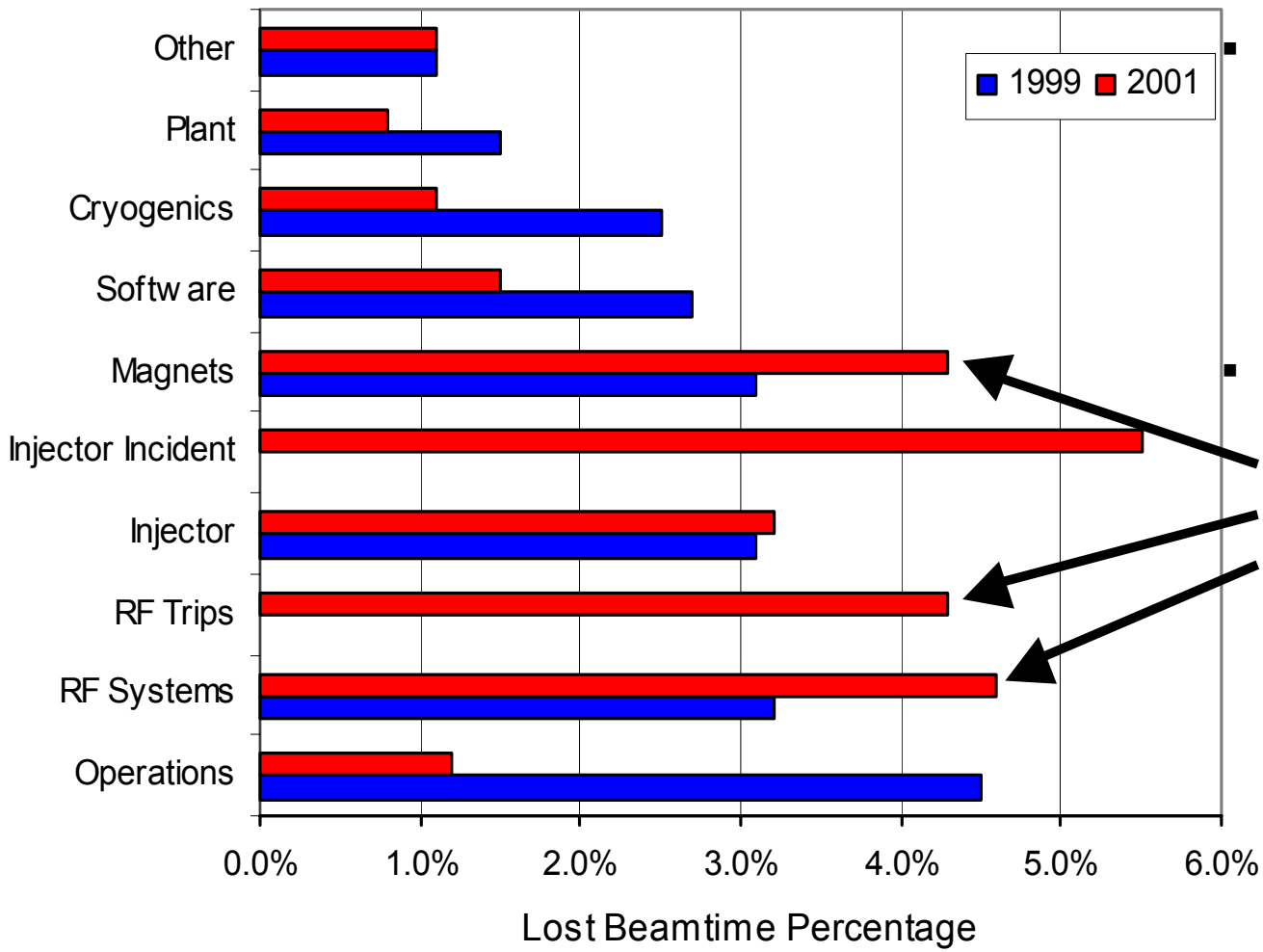
Reliability at CEBAF

- All lost time events are tracked by system and component
- Database is analyzed for trends
- Component and system upgrades based on lost time
- Spares inventory managed on availability of parts and mean time between failure

Preventive Maintenance at CEBAF

- Regular replacement of water and air filters
- Regular replacement of belts, hoses, and lubricants
- IR detection of electrical connections: 3 year cycle
- Cleaning of HV cables and components every 6 months
- Vibration / frequency analysis of rotating equipment every 3 months

Availability Comparison by System FY99-FY01

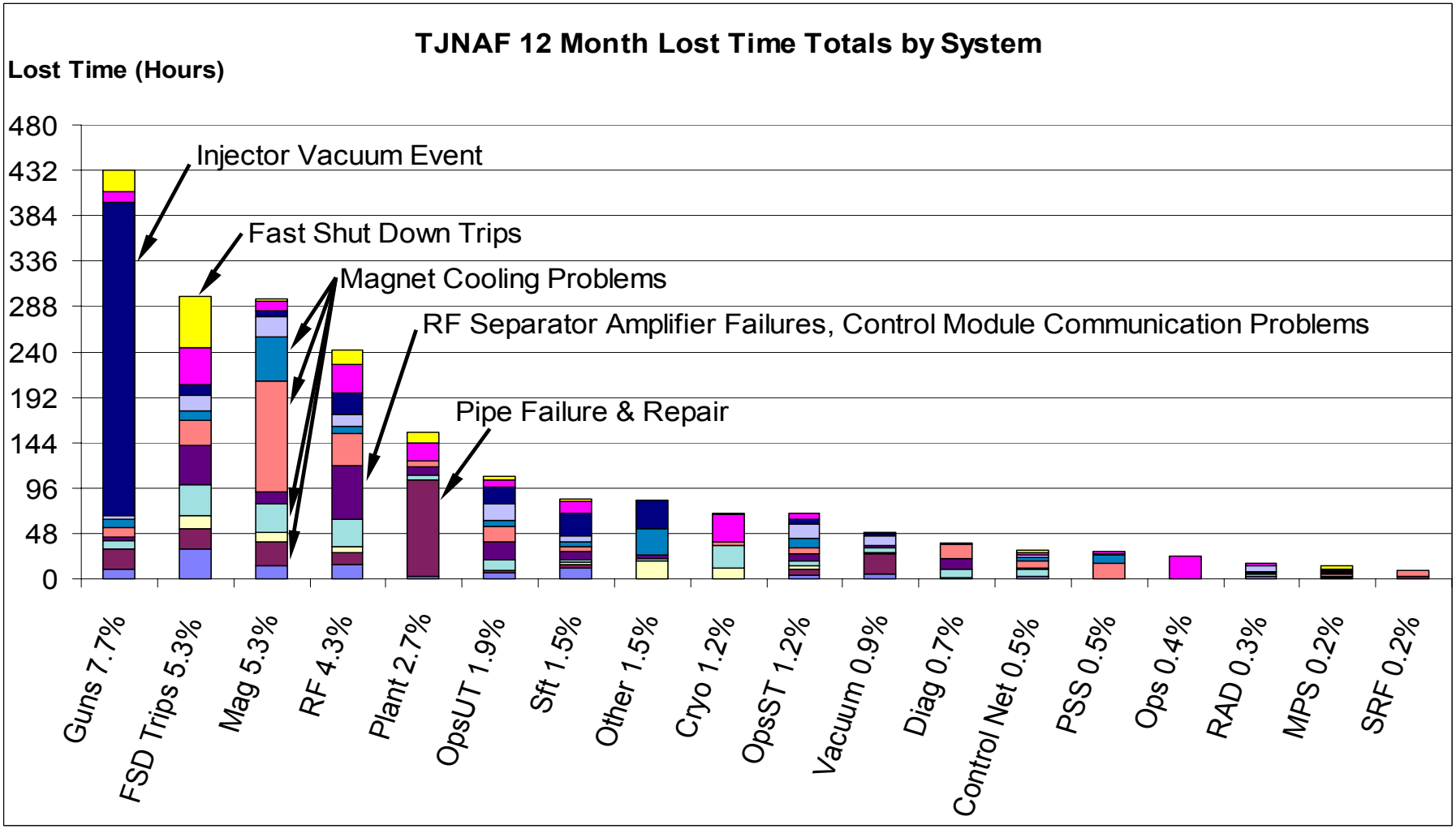


Issues:

- Operation at higher energy of 5.6/5.7 GeV (conscious decision by Physics Division staff to increase the science productivity in the three halls)
- System Reliability

Beam Energy Related

12 Month Roll Up 12/00-11/01



Major Sources of Lost Time in 2001

- Injector Vacuum Event
- Fast Shut Down Interruptions
- Magnet Cooling Problems
- RF Communication Problems
- Underground Pipe Failures

Injector Vacuum Event

- **Problem: Vacuum vent and equipment damage**
- Took place during a major shutdown
- Vacuum valve modified to be motorized–
  - Valve didn't fully seal
- Vacuum interlocks had been disabled
- RF power in a partial vacuum caused significant heating and failure of ceramic feedthrough
- Spare feedthrough unavailable
- Long fabrication time and high cost of replacement part very costly to JLab

Fast Shutdown Trips: 2nd in Lost Time

- **Problem: Fast Shut Down Trips: Machine Protection that turns off the beam due to RF window arcing or other interrupts**
  - Higher Energy = More FSD Trips
  - Now: ~ 45 sec to reestablish beam. Operator function
  - **FSD Auto Recovery from RF Trips: 4.5 sec recovery. Automated Machine function**
  - Beam off only as long as fault condition exists
  - Hardware and Software code to discriminate on severity of fault and time between events

Magnet Overheating: 3rd Largest Problem

Problem: Magnet coils become blocked by Copper Oxides prevent circulation of low conductivity cooling water

- Magnet coil temperature monitoring
- Build up and certify spare magnets ready to go
- Magnet flushing system (citric acid etch small bore copper coils)
- Low Conductivity Water full flow filters (1 micron)
- LCW de-Ox system upgrade (to reduce copper oxidation)

4th Largest Source of Lost Time: RF System

- **Problem: Aging equipment**
- Electrical connections oxidizing
- Communication faults ensue
- HV breakdown of dirty cables
- Availability of Spares becoming an issue
- RF control board redesign underway
  - Improvements to calibration and stability

Underground Pipe Replacement

- Fibercast pipe failures (4+ events in the past 3 years)

  Repaired in place

  Replacement under consideration, but costly

- Iron pipe corrosion (2 events in the past 3 months)

  Abandoned 110m of failed pipe

  Temporary Cooling Tower rented 12/21/01

  New permanent cooling tower due by 3/25/02

- Recent failures account for ~112 hours of lost time

- All piping is being evaluated by team of Plant and Engineering Group engineers.

Summary

- CEBAF is a complex machine
- CEBAF relies on system experts and technicians to identify problems
- Detailed analysis of system failures is necessary to raise machine availability from 70% to ~80%
- Maintaining machine availability over the long term will require significant resource commitment or a reduction of the machine performance requirements

The Reliability Challenge