Spare Parts at APS

C.Y. Yao, Glenn Decker, Rod Gerig

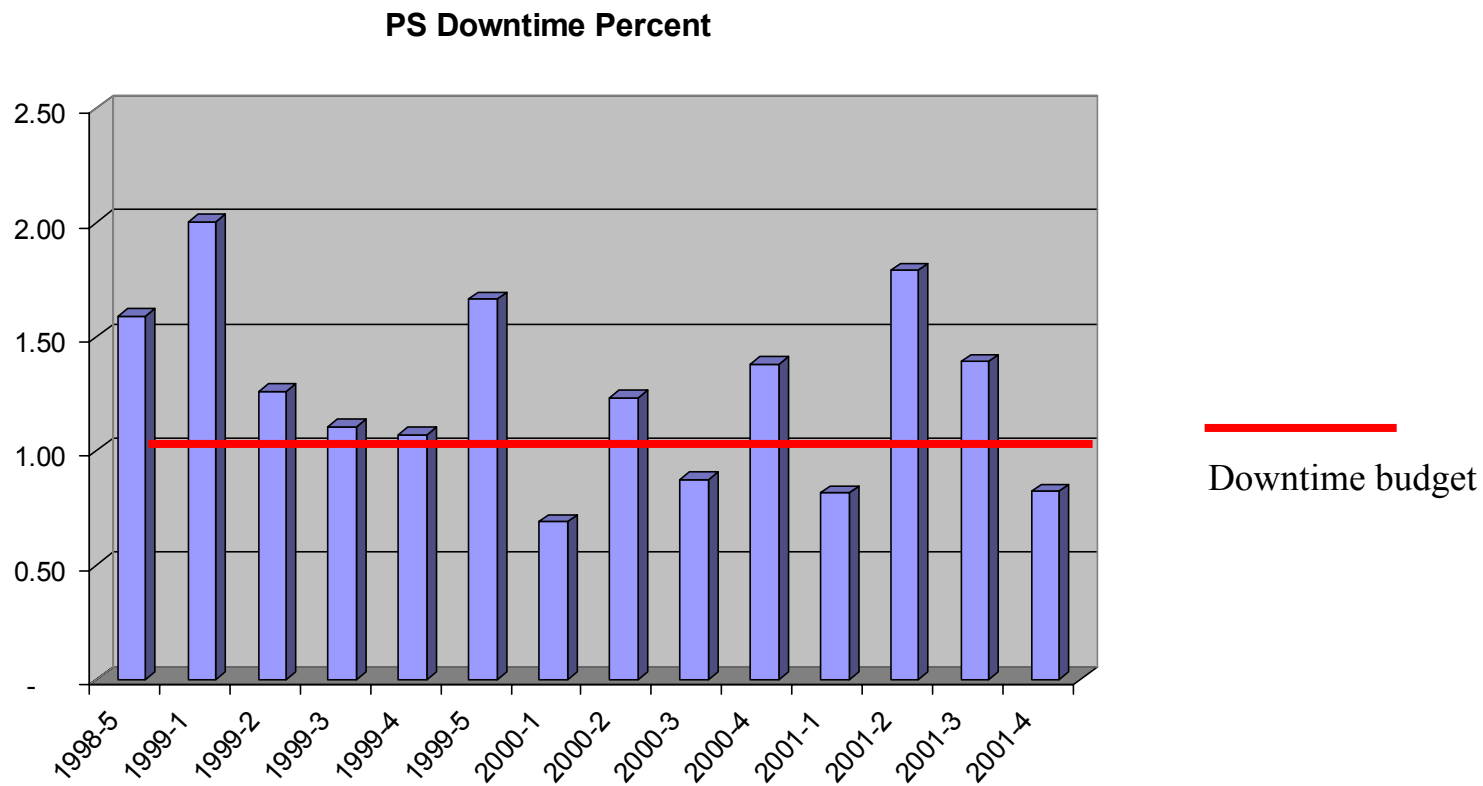
Contents

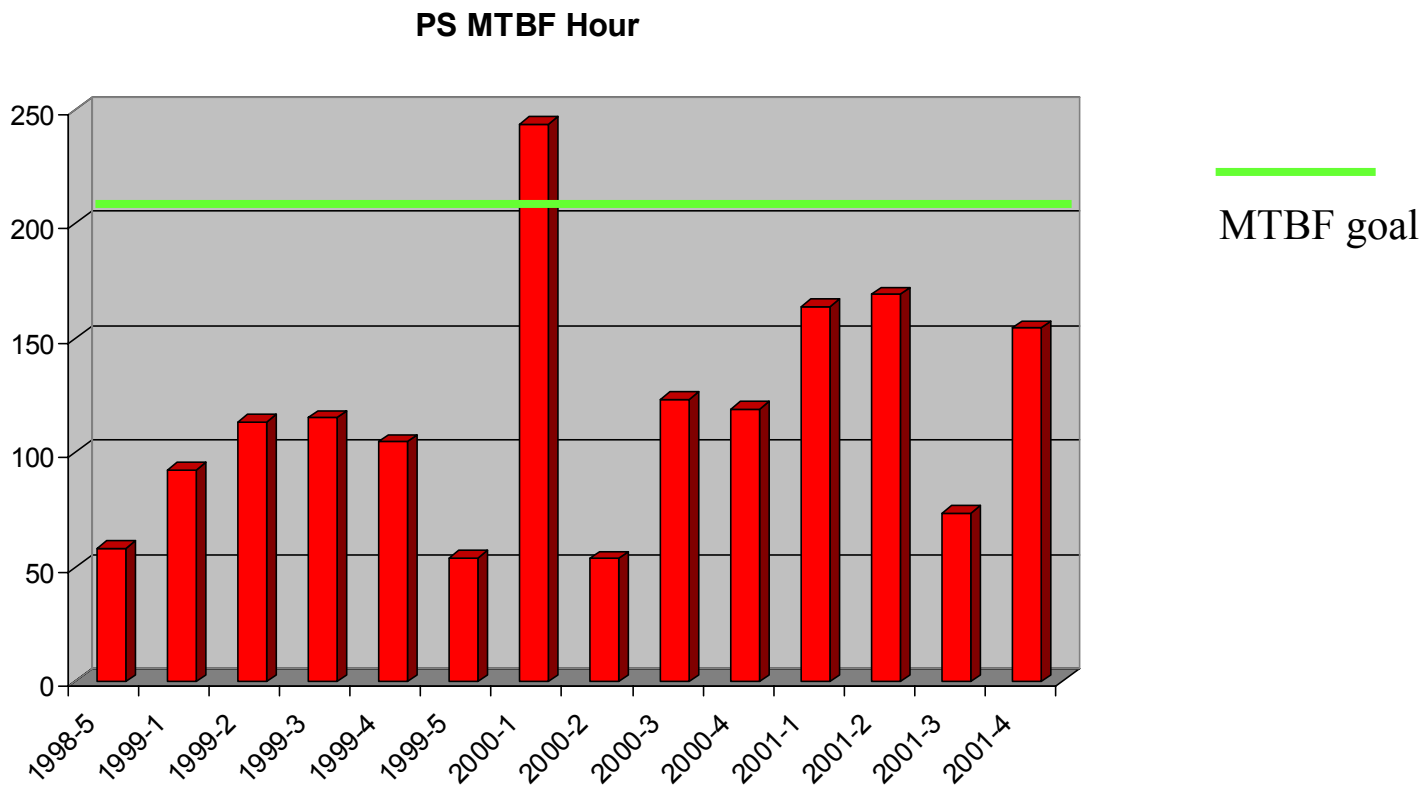
- Introduction
- Magnet Power Supplies
- Storage Ring and Booster RF System
- Linac RF System
- Electron Guns
- References
- Acknowledgments

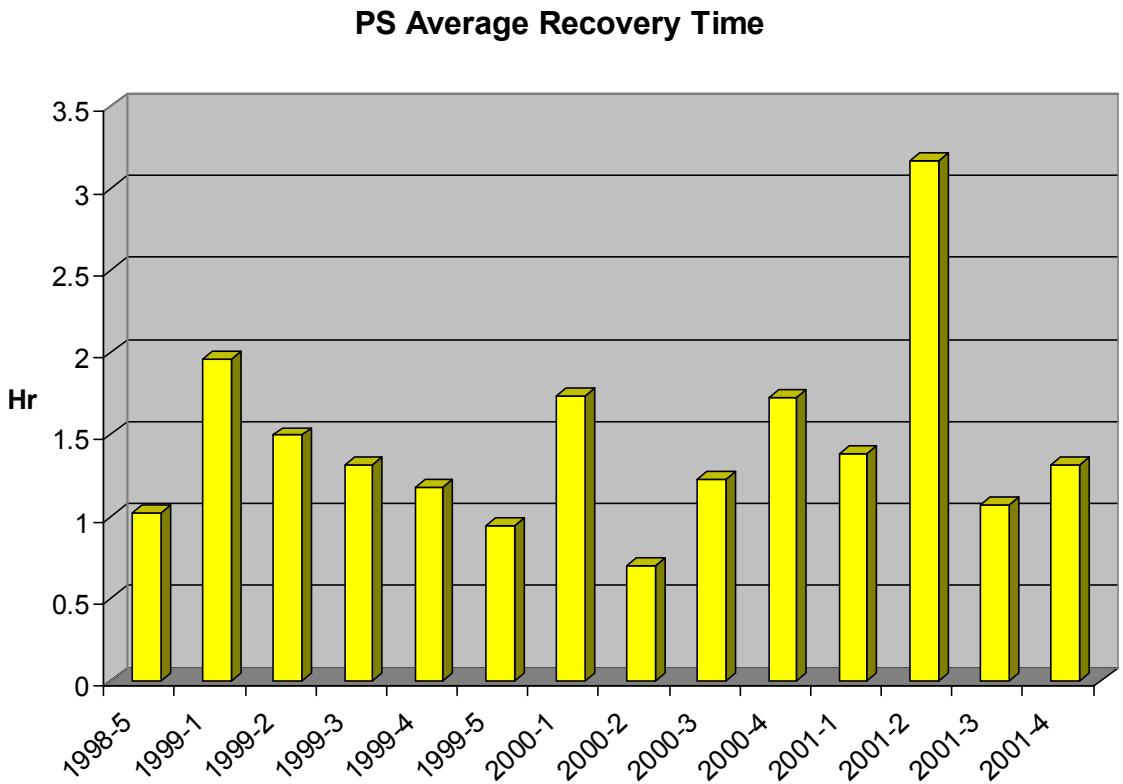
Introduction

- APS availability goal is 95% of scheduled user time and reliability goal is 50 hours of MTBF.
- The actual results from most recent run (Run2001-4) are 96.5% and 24 hours, respectively.
- Judging by the numbers, APS is doing OK for availability, but still has a way to go on reliability.
- Power Supply (PS) and RF systems contribute about 50% of downtime.
- Average recovery time is around 1 hours for PS faults and 0.5 hour for RF faults.

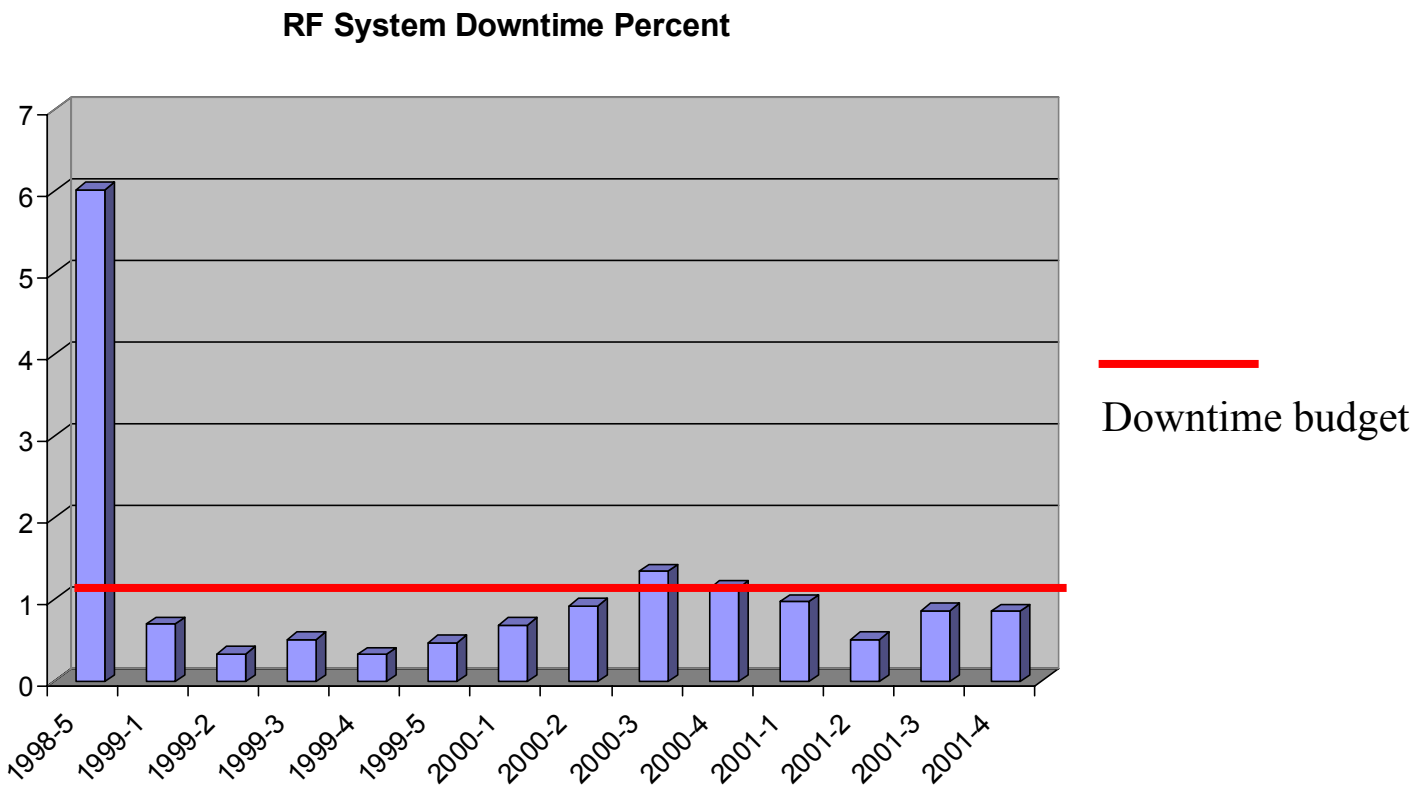
PS System Statistics

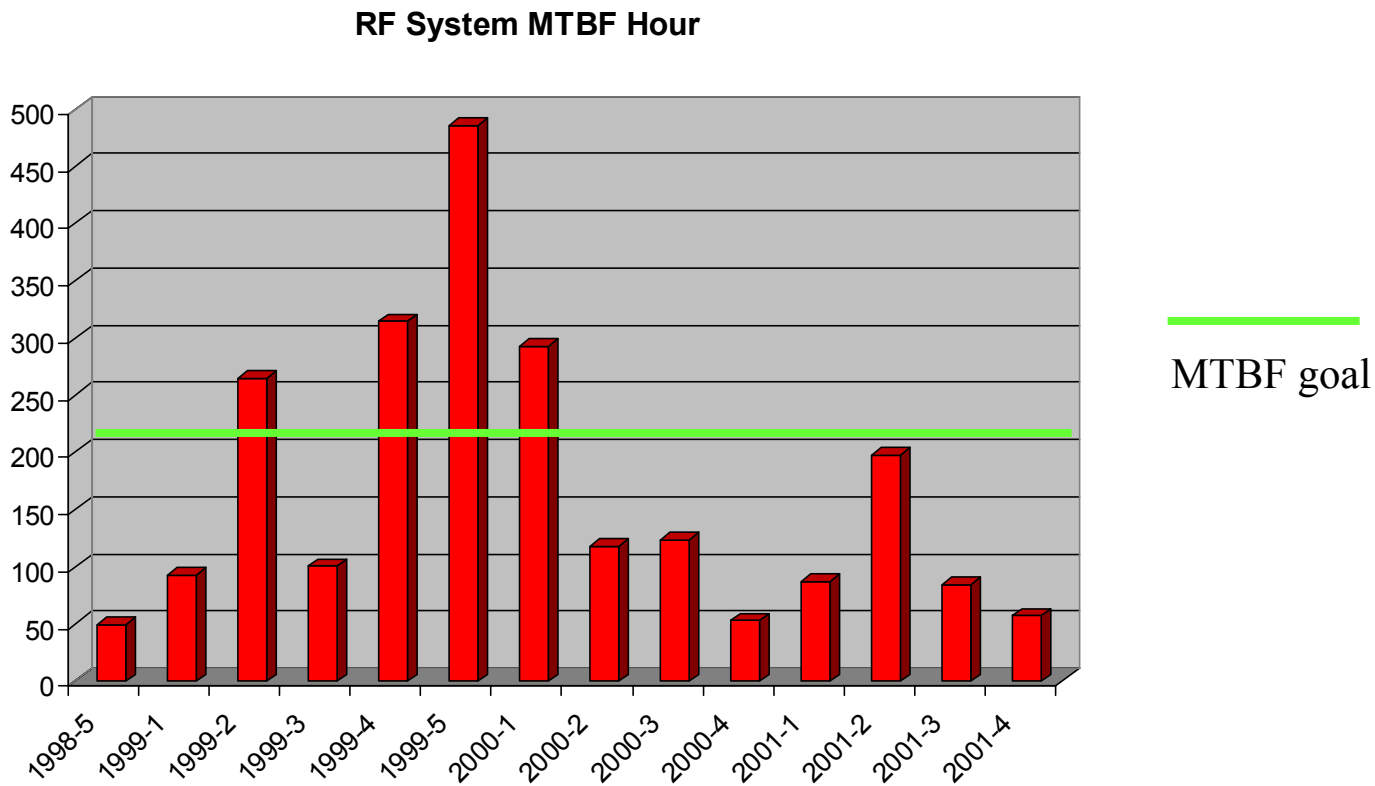



PS MTBF Hour
250
200
150
100
50
0
1998-5
1999-1
1999-2
1999-3
1999-4
1999-5
2000-1
2000-2
2000-3
2000-4
2001-1
2001-2
2001-3
2001-4
MTBF goal

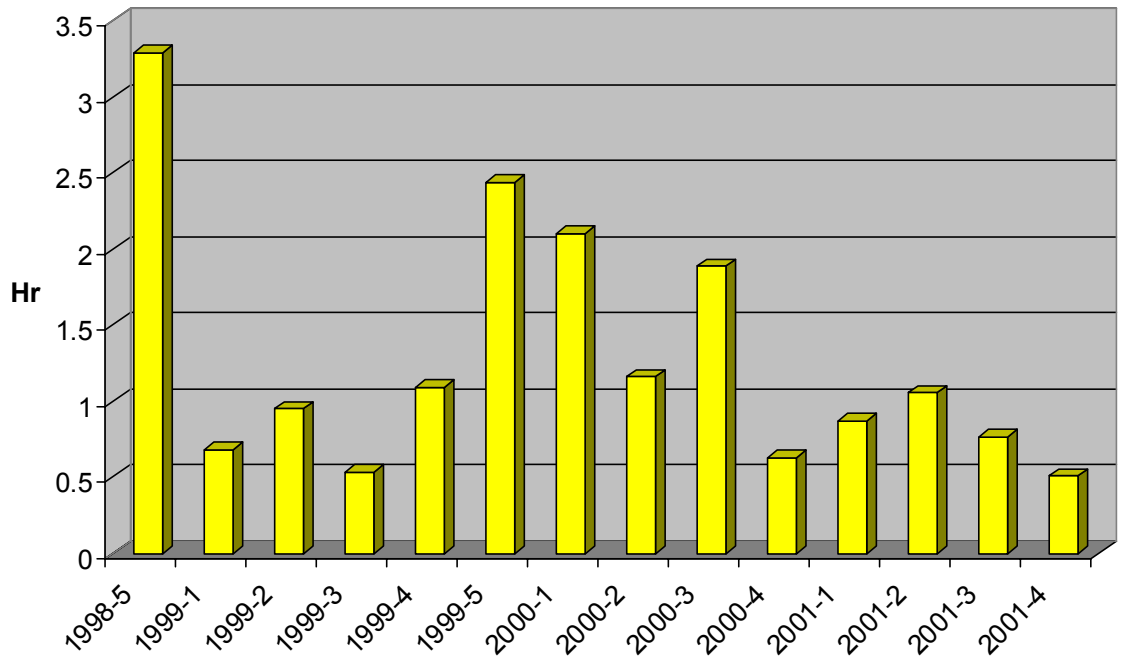

PS Average Recovery Time
Hr
3.5
3
2.5
2
1.5
1
0.5
0
1998-5
1999-1
1999-2
1999-3
1999-4
1999-5
2000-1
2000-2
2000-3
2000-4
2001-1
2001-2
2001-3
2001-4

RF System Statistics




RF System MTBF Hour
500
450
400
350
300
250
200
150
100
50
0
1998-5
1999-1
1999-2
1999-3
1999-4
1999-5
2000-1
2000-2
2000-3
2000-4
2001-1
2001-2
2001-3
2001-4
MTBF goal

RF System Average Recovery Time



Reliability Improvement

- Overall machine reliability is directly related to the number of components and the reliability of individual components.
- There are continued efforts directed at improving and upgrading the power supplies and RF systems.
- Substantial improvement of component reliability is difficult and expensive because of:
  - *The large number of units in service*
  - *Technical difficulties*
  - *The cost of developing new components*

Spare Strategy

- Availability can be improved by adequate spares, “hot” spares, accurate diagnosis, more efficient repair practices, and avoiding errors.
- A good spare program may not have as much impact on the fault rate.
- APS spare part efforts focus mainly on the DC power supplies and RF systems.

Spare Strategy

- Factors affecting the decision on spare strategy are:
  - Failure rate of equipment
  - The impact of a particular failure on user beam
  - Downtime of replacement
  - Cost and implementation of spares
  - Total number of interchangeable units in service

Repair Guideline

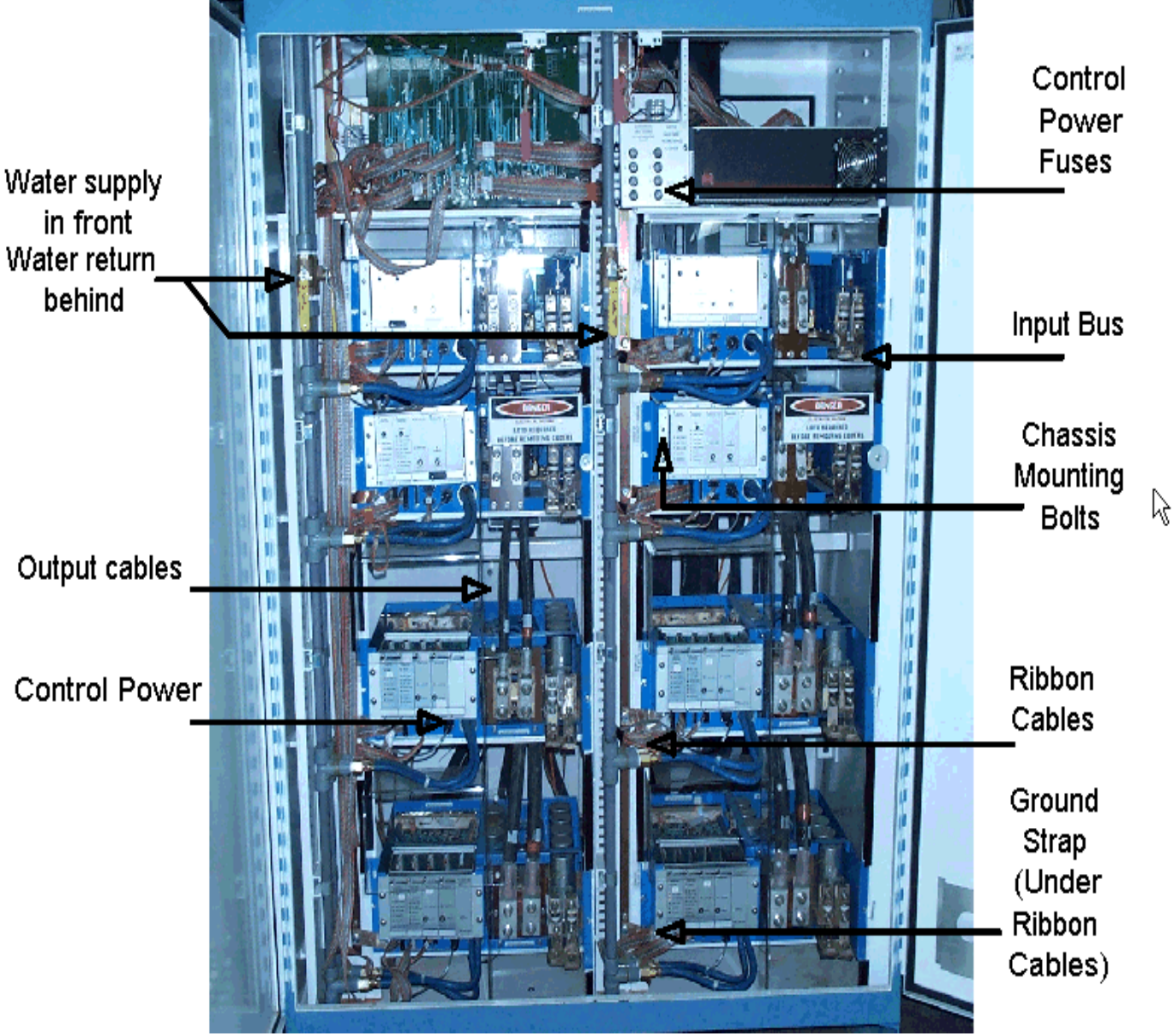
- General guideline: correct any known fault if the beam is lost.
- If the beam is not lost, and if the user studies are not affected (orbit, beam lifetime, and refilling are affected significantly), repair is scheduled at a time with advance notice to the users.
- Repairs are generally performed by personnel from the responsible system groups.
- Off-hour repair is performed by Operations crew only if clear instructions or procedures are provided.

Magnet Power Supplies

- Large number: A total of 400 quads, 280 sextuples, 19 skew quads, 636 correctors, 30 trim supplies, and a dipole supply.
- Directly impact user beam.
- Due to the factor that all multipole magnets are driven by individual supplies, it is not practical to have a switching network to perform online swapping.
- Due to safety consideration and enclosed cabinet design, replacement and repair of a supply requires substantial downtime.
- Extra time is needed for magnet standardization.

SR Multipole Supplies

- About 10 spare converters for each category of quad, sextuple, and corrector
- Written procedure and training available on convertor swapping
- Convertor swapping training is part of operator qualification program
- An Oracle application is used to keep track of converters and faults
- Power supplies technicians perform the task during work hours, while the operations crew handles off-hour repairs
- Typical swapping time is 0.5 hour, not including magnet standardization
- Two test stands with spare magnet loads allow testing of 16 converters


Control
Power
Fuses
Water supply
in front
Water return
behind
Input Bus
Chassis
Mounting
Bolts
Output cables
Control Power
Ribbon
Cables
Ground
Strap
(Under
Ribbon
Cables)

Dipole and Pulsed Magnet Supplies

- Only spare parts are available for the dipole and pulsed supplies
- Requires call-in and *in situ* diagnosis and repair
- Longer repair time

Injector Power Supplies

- In non-top-up injection mode, injector supply repairs are performed between SR refills. Sometimes the storage ring refill has to be delayed due to injector unavailability.
- Spare units are available for DC supplies.
- Replacement is performed by PS technician.
- Only spare parts are available for injector dipole supplies and pulsed supplies, requiring *in situ* repair and longer repair time.

Storage Ring and Booster RF Systems

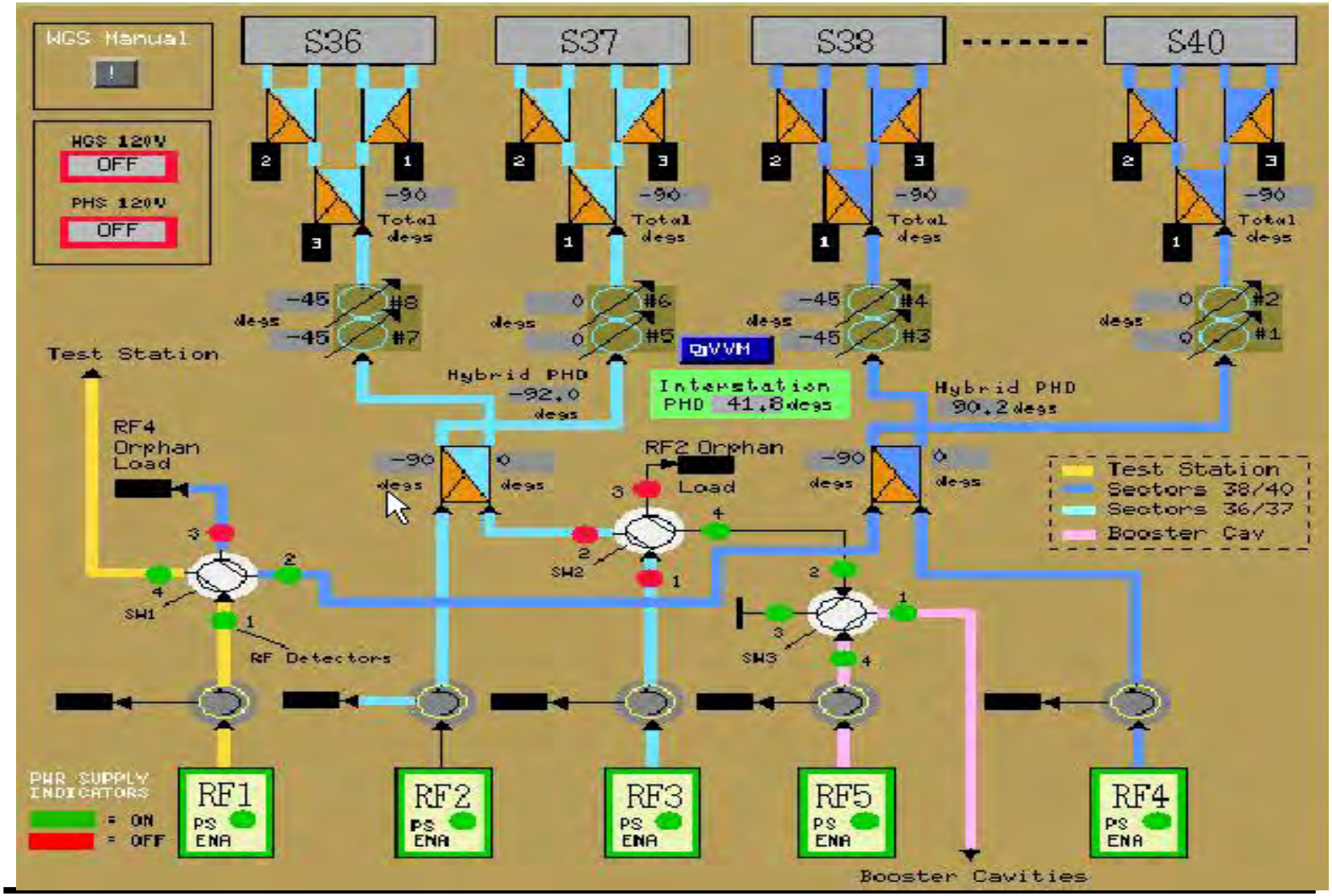
- Directly impact user beam.
- Relatively higher failure rate due to its complexity and high power, high voltage nature.
- The complexity of the RF system also leads to longer troubleshooting and repair times.
- Waveguide switching network is implemented to reduce downtime.
- The switching network also simplifies future transition to 300mA high current operation.

Waveguide Switching Network

- Total of five RF stations, one is used for the booster, two stations for the storage ring, and two as hot spares.
- One of the RF station can also be spare for the booster RF.
- One RF station can be switched to drive an RF test stand for klystron or cavity conditioning.
- The systems are interconnected by a network of 352-MHz waveguides.
- Motor driven mechanical waveguide switches are used for the switching.
- Motor-driven phase shifters are used for phase compensation.
- A PLC-based control system is used for switching system control, monitoring, and interlock.

Waveguide Switching Network

- In standby mode, the high voltage supply (85 kV, 5A) and klystron heater are kept on to reduce turnaround time.
- Written procedure and training available to Operations and RF personnel.
- The training is part of operator qualification program.
- Typical switching time is about 30 min.
- A total of 20 RF station switches were performed in 2001 alone, most of these were for system maintenance. The stations are rotated so any problem is detected and repaired.

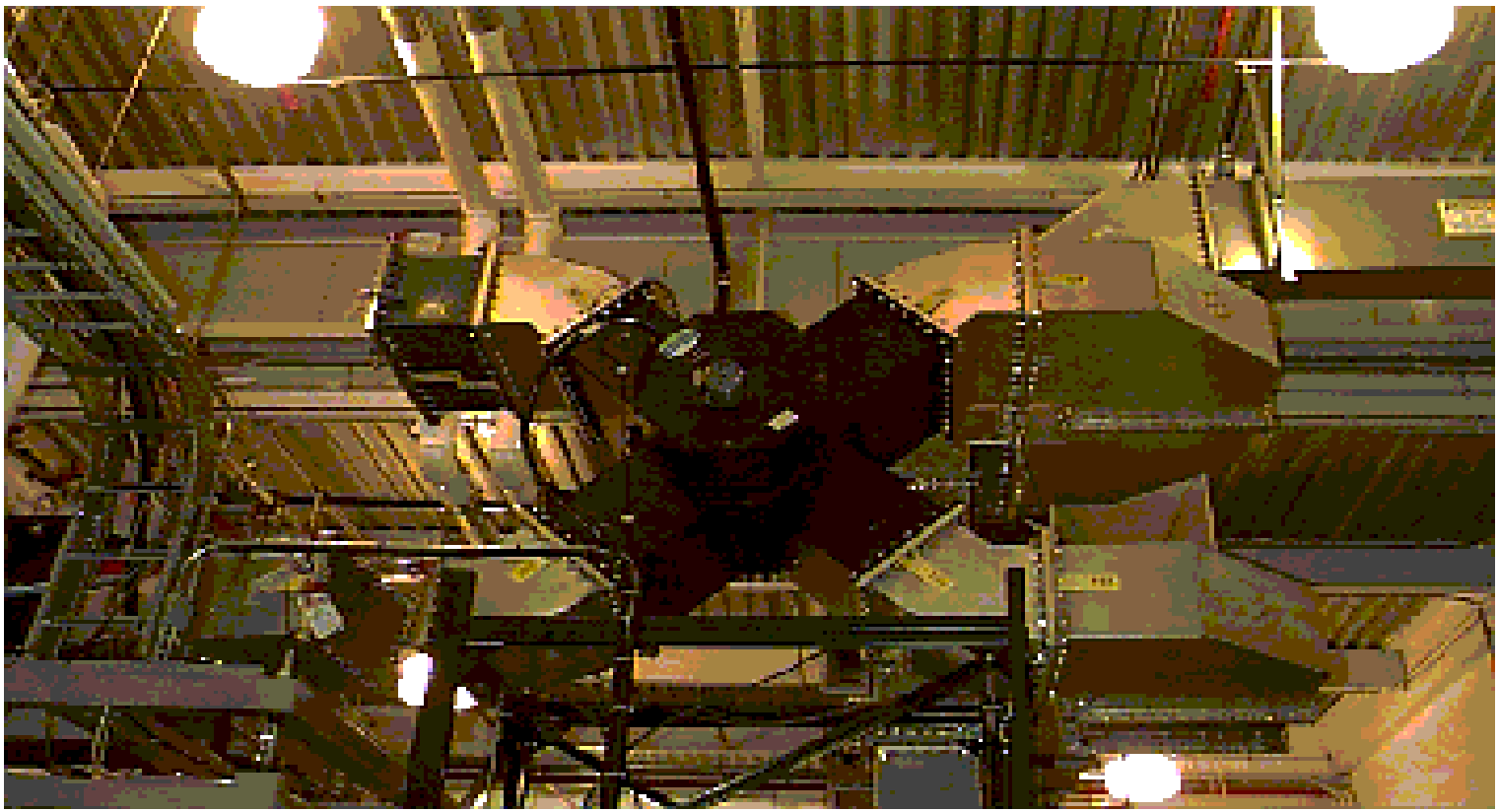

WGS Manual
HGS 120V
OFF
PHS 120V
OFF
S36
S37
S38
S40
-90
Total
degs
-45
#8
#7
0
#6
#5
#4
#3
#2
#1
Test Station
Hybrid PHD
-92.0
degs
VVM
Interstation
PHD 41.8degs
Hybrid PHD
90.2degs
RF4
Orphan
Load
RF2 Orphan
Load
SW1
SW2
SW3
RF Detectors
Test Station
Sectors 38/40
Sectors 36/37
Booster Cav
PWR SUPPLY
INDICATORS
= ON
= OFF
RF1
RF2
RF3
RF5
RF4
PS
ENA
Booster Cavities

RF Mode Selection Table

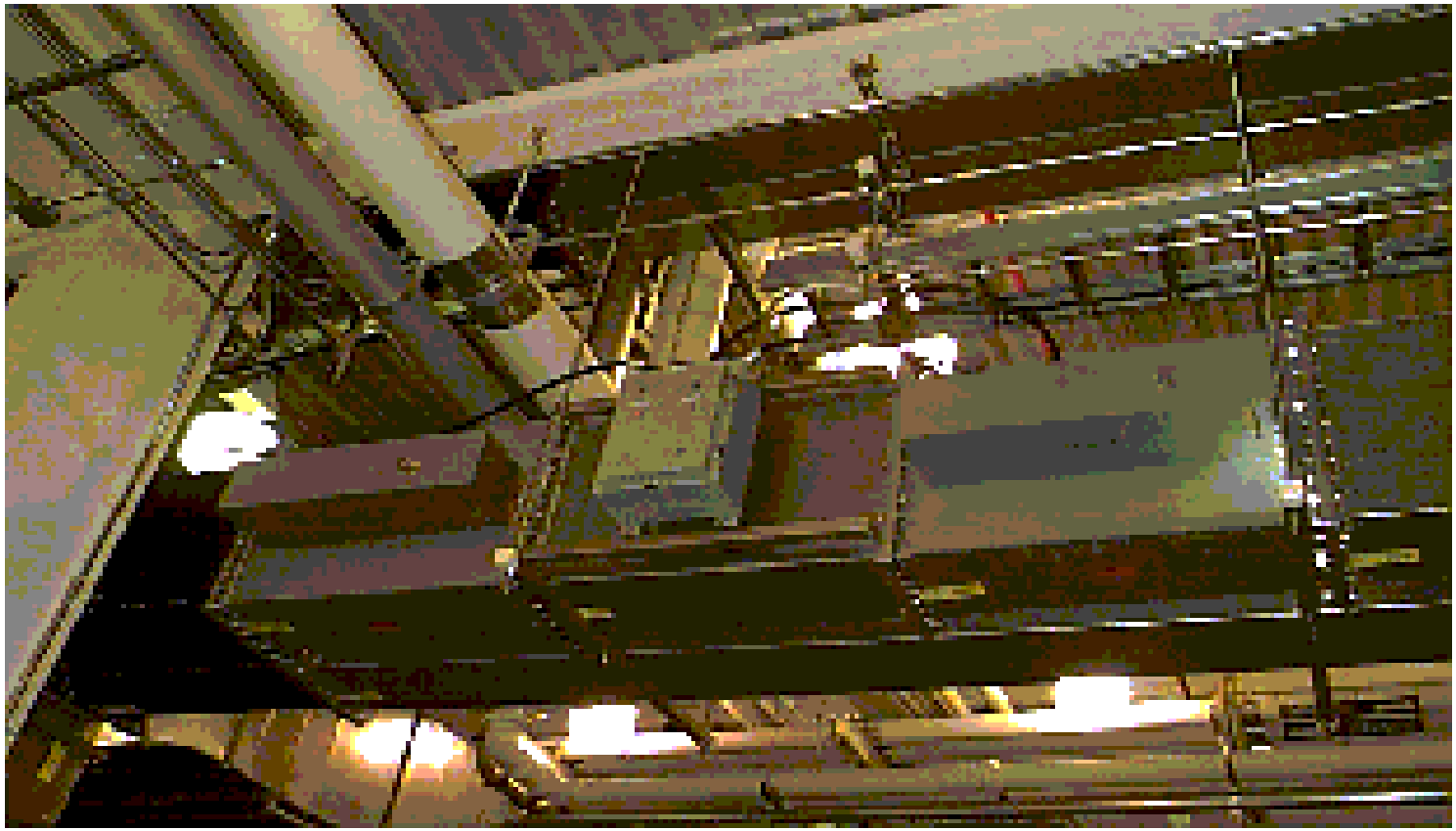
Mode	Storage Ring Supplies	Booster Supply	Test Stand	Supply Down	Is this Mode available?
1	RF1,RF2,RF3,RF4	RF5			NO
2	RF2,RF3,RF4	RF5	RF1	RF1	NO
3	RF1,RF3,RF4	RF5		RF2	NO
4	RF1,RF2,RF4	RF5		RF3	NO
5	RF1,RF2,RF4	RF5		RF4	NO
6	RF1,RF2,RF4	RF3		RF5	NO
7	RF2,RF4	RF3	RF1	RF5,RF1	NO
8	RF1,RF2	RF3		RF4,RF5	NO
9	RF1,RF2	RF5		RF3,RF4	YES
10	RF3,RF4	RF5	RF1	RF2,RF1	YES
11	RF2,RF4	RF5	RF1	RF3,RF1	YES
12	RF1,RF3	RF5		RF2,RF4	YES

nassiri@aps.anl.gov (Alireza Nassiri)

351-MHz waveguide switch



RF Phase Shifter



Control System for RF Switch

RF Test Stand

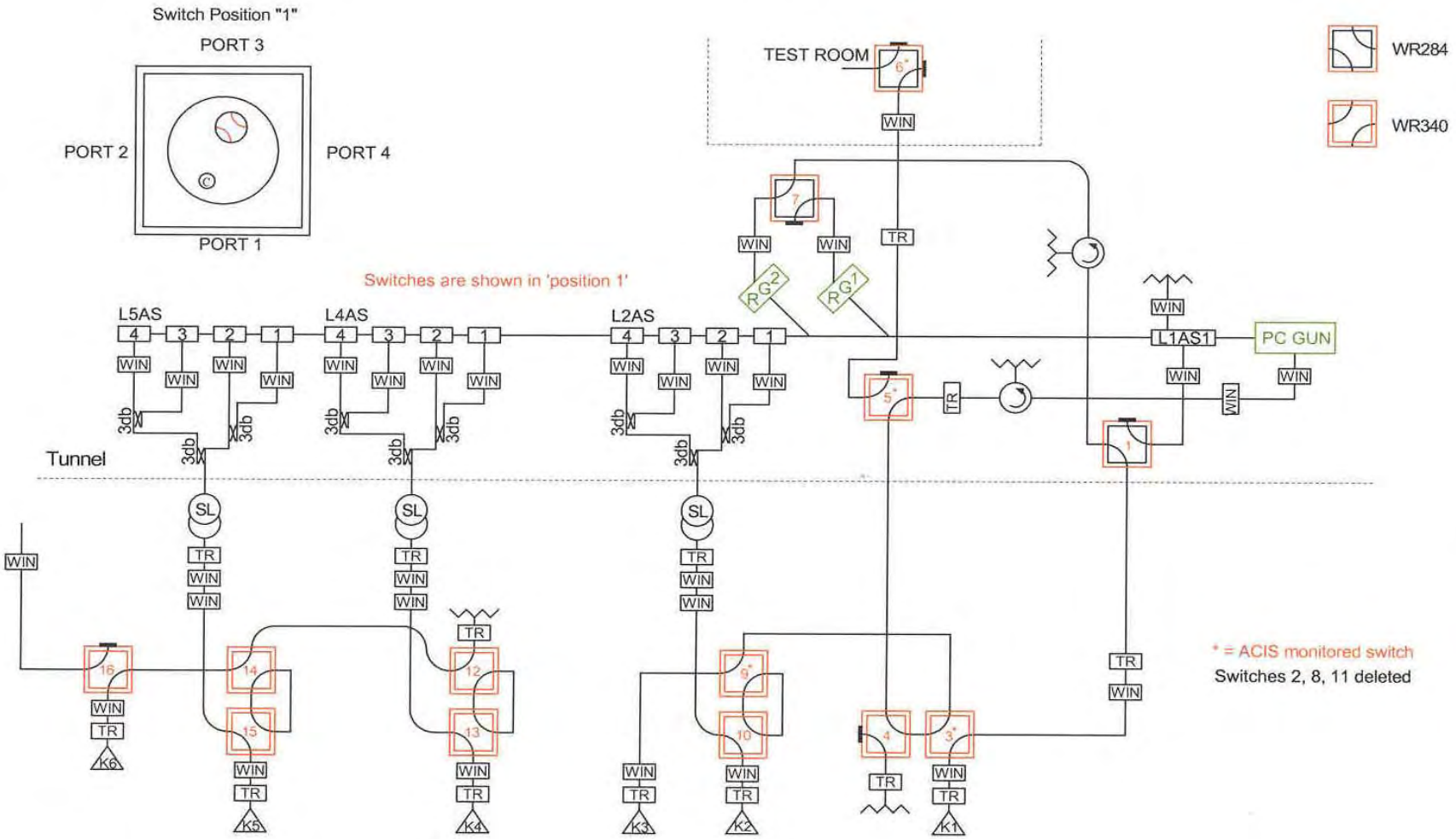
PAR RF System

- The particle accumulator ring has two RF systems: a 9.7-MHz fundamental system and a 117-MHz harmonic system.
- Both systems have two driving amplifiers.
- Switching from one to the other can be done through control screens and only takes a few minutes.

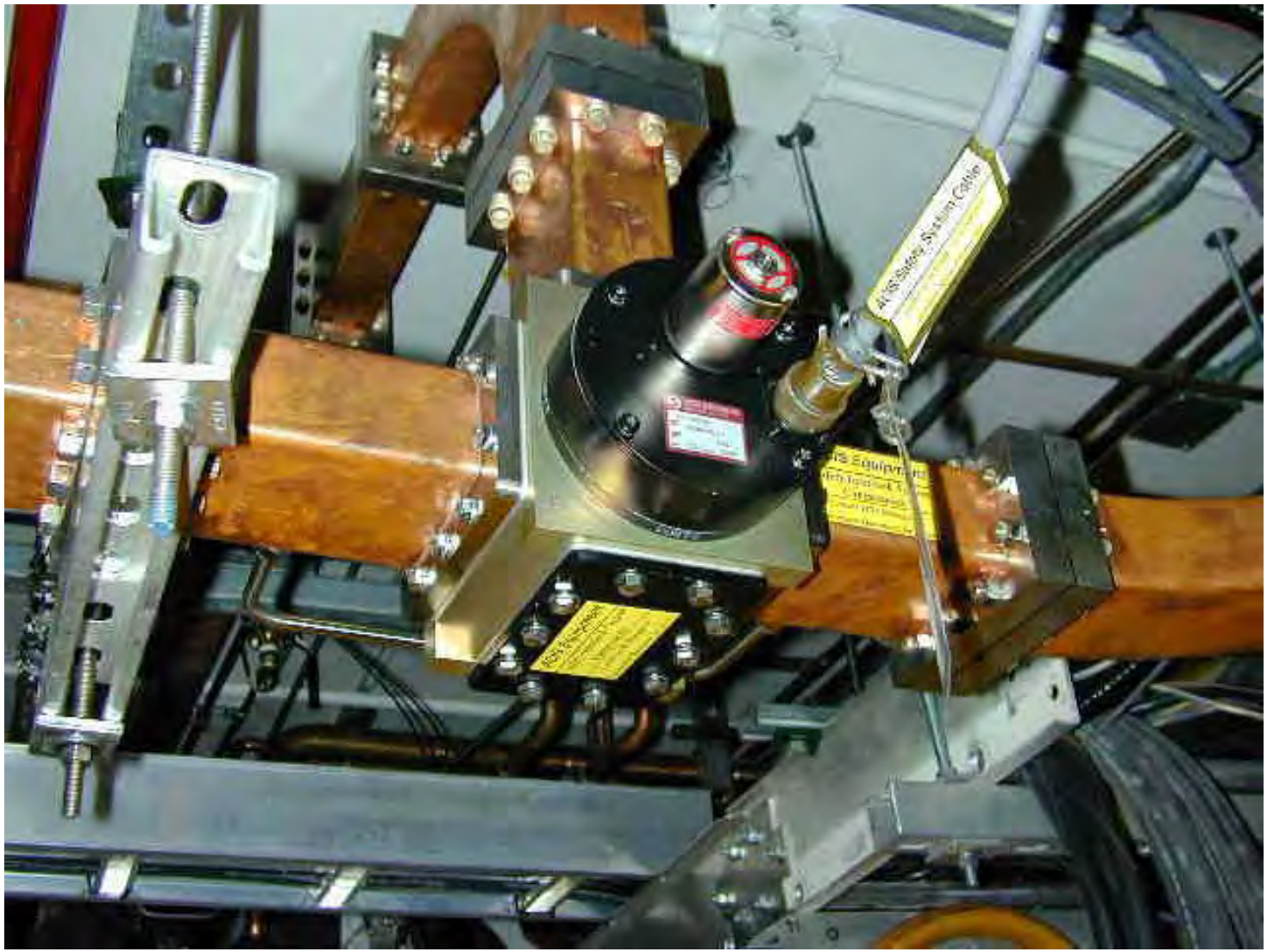
Linac RF System

- The APS linac was originally designed to produce a 450-MeV positron beam or a 650-MeV electron beam with five RF stations.
- Currently we run 325 MeV for storage ring injection and 217 MeV for LEUTL studies with four klystrons.
- The demand on the injector beam increased greatly because of the top-up operation of APS storage ring and parasitic LEUTL studies.
- A spare linac RF station (L6) was built in 1999 and is currently used to power a test stand.
- Design and development of an S-band waveguide switching network is underway.
- When the switching network is completed, the current L3 klystron will be spare for L1 and L2, and the L6 will be spare for L4 and L5.

Linac Waveguide Switching System



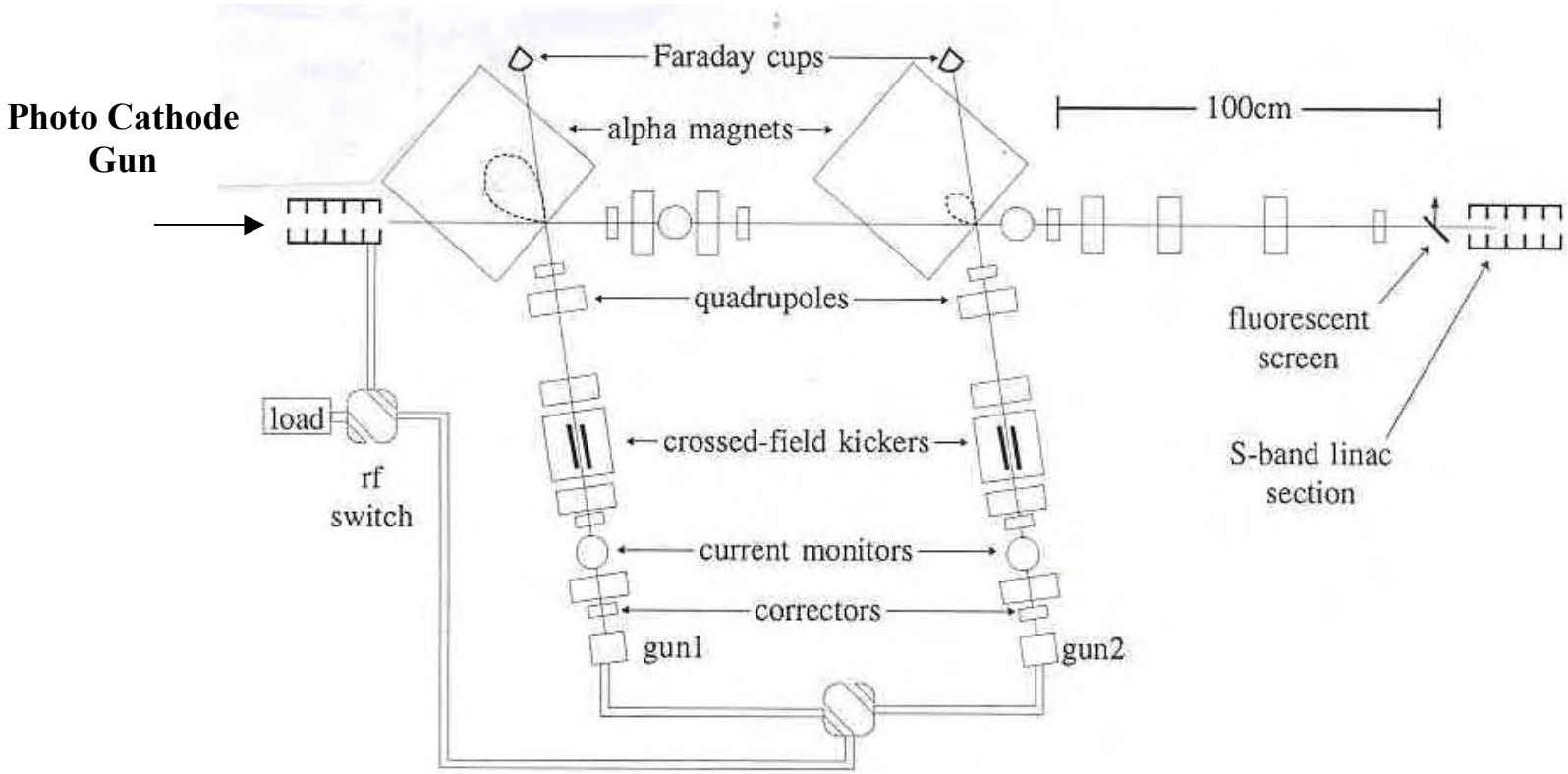
An S-band waveguide switch



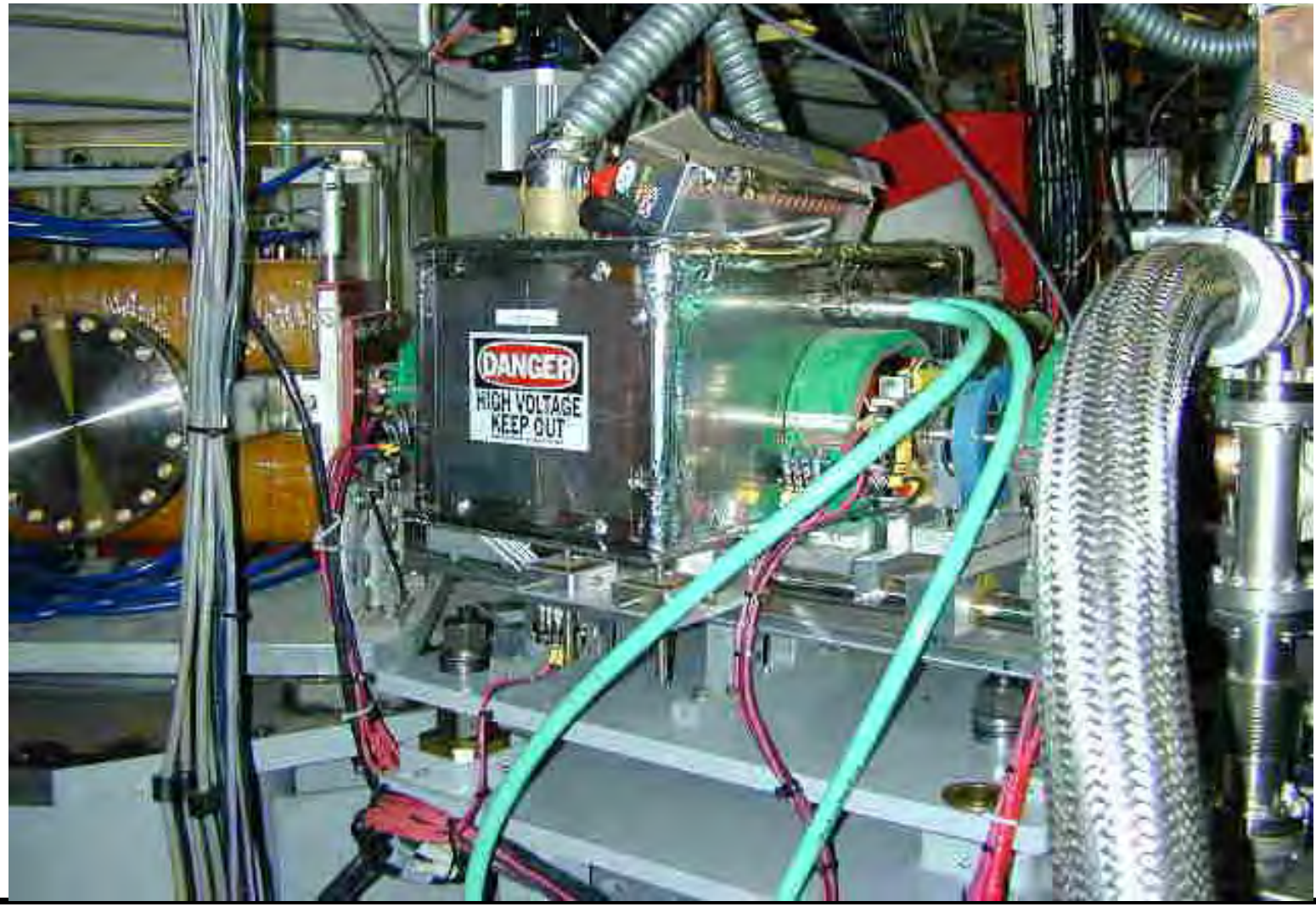
Electron Guns

- The APS injector has two RF guns and a photocathode gun.
- The RF guns have a pulse width of ~8nS. One is used for storage ring injection and the other as a hot spare.
- The PC gun, with a pulse width of only a few pS, which is mainly for SASE FEL studies, can also be used for SR injection in non-top-up mode.
- Both written instructions and automatic Procedure Execution Managers (PEM) are available to assist the operators to perform the gun switching.
- Switching time between the RF guns is about 15 min.
- Switching time between an RF gun and the PC gun is about 15 min excluding the setup time for the laser source.

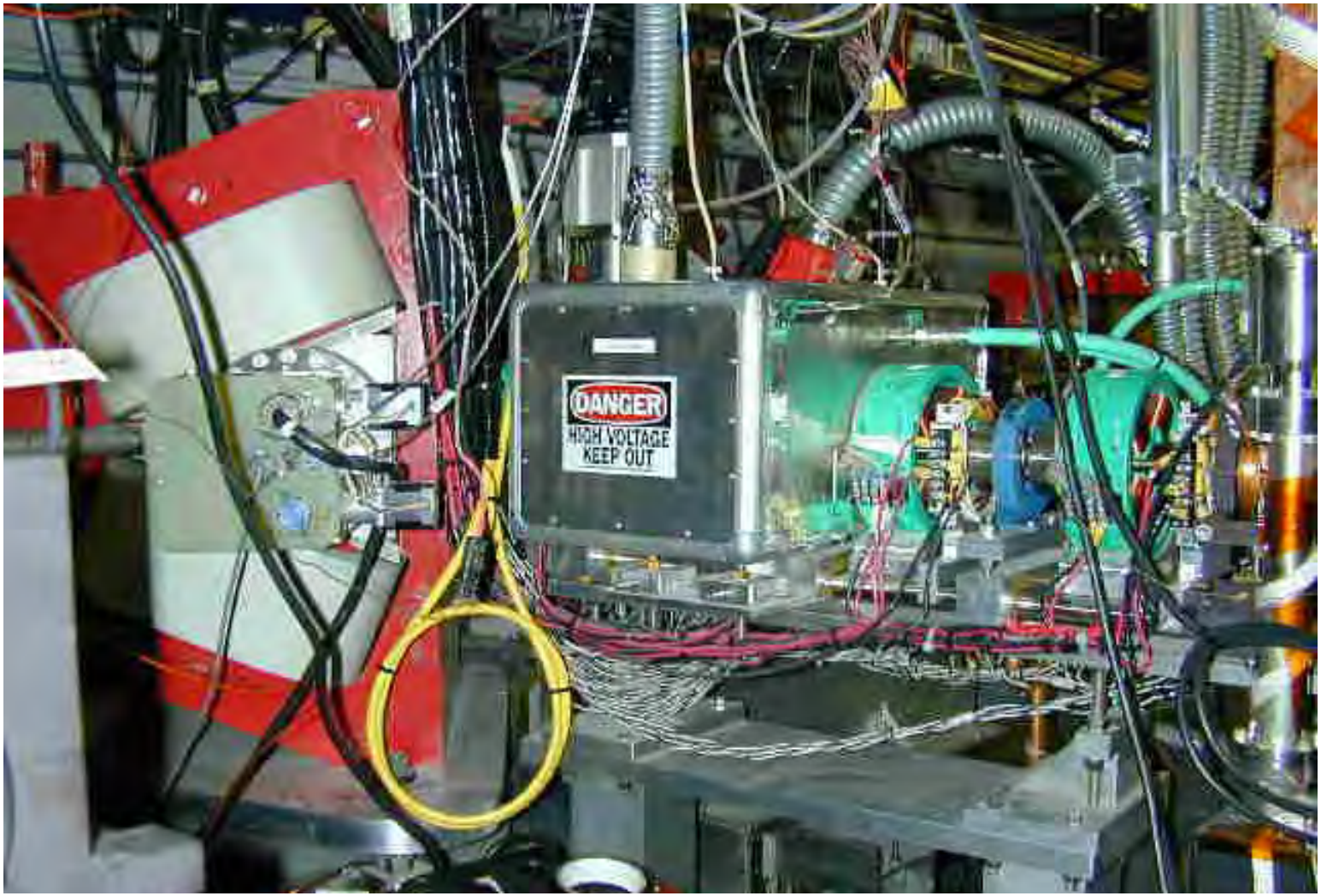
APS Injector Layout



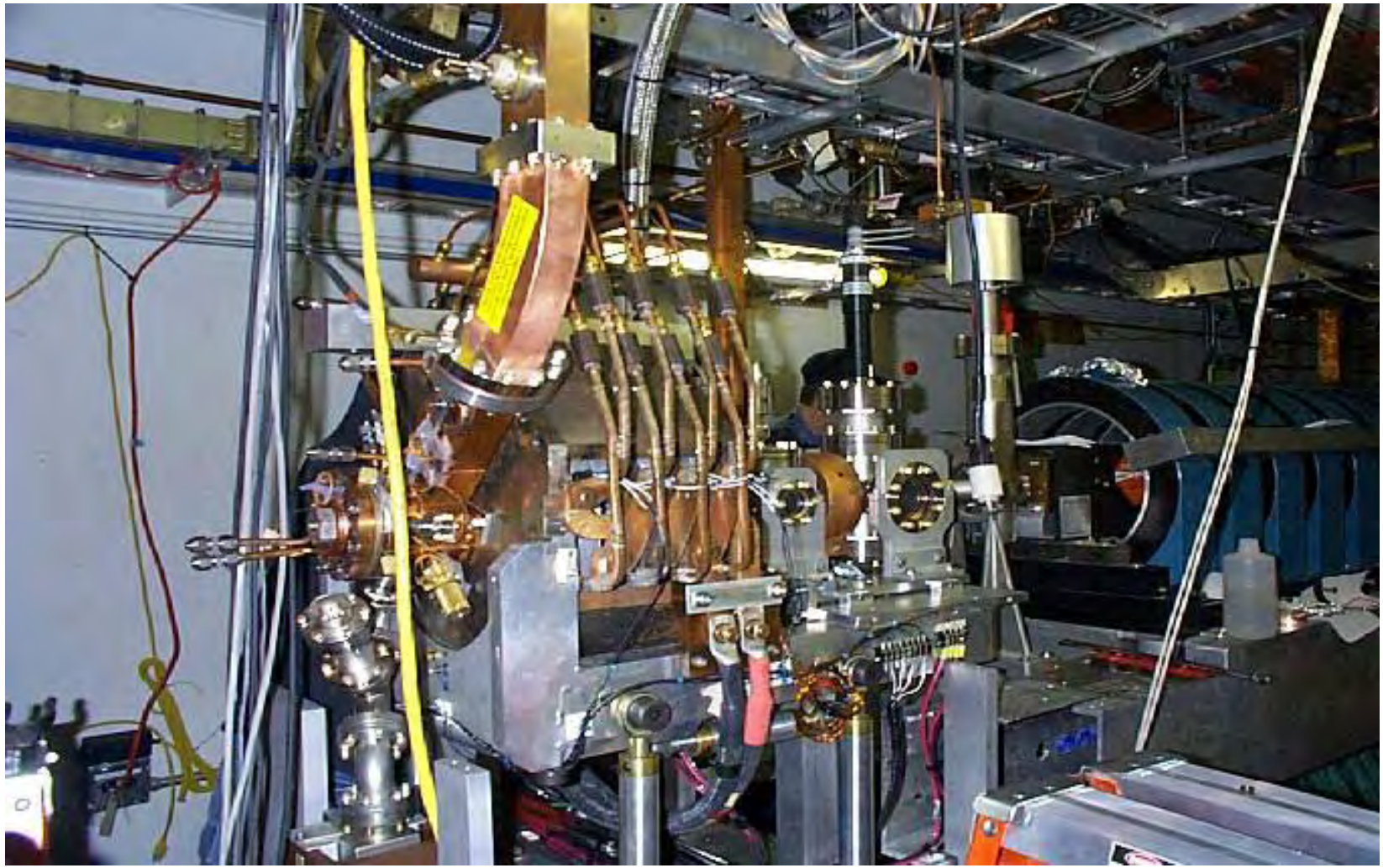
RF Gun and its Kicker Magnet



Second RF Gun, Alpha Magnet, and Kicker Magnet



Photocathode Gun



References

- R.Soliday et al., Automated Operation of APS Linac using the Procedure Execution Manager, Proceedings of Linac2000
- J. Lewellen et al., A Hot-Spare Injector for the APS Linac, Proceedings of PAC99
- John Carwardine, Internal presentation

Acknowledgements

John Carwardine, Art Grelick, Stan Pasky, Doug Horan

APS Power Supply Group, RF Group, and Operations Group