AP0 Target Hall spare status and manpower requirements for Run II

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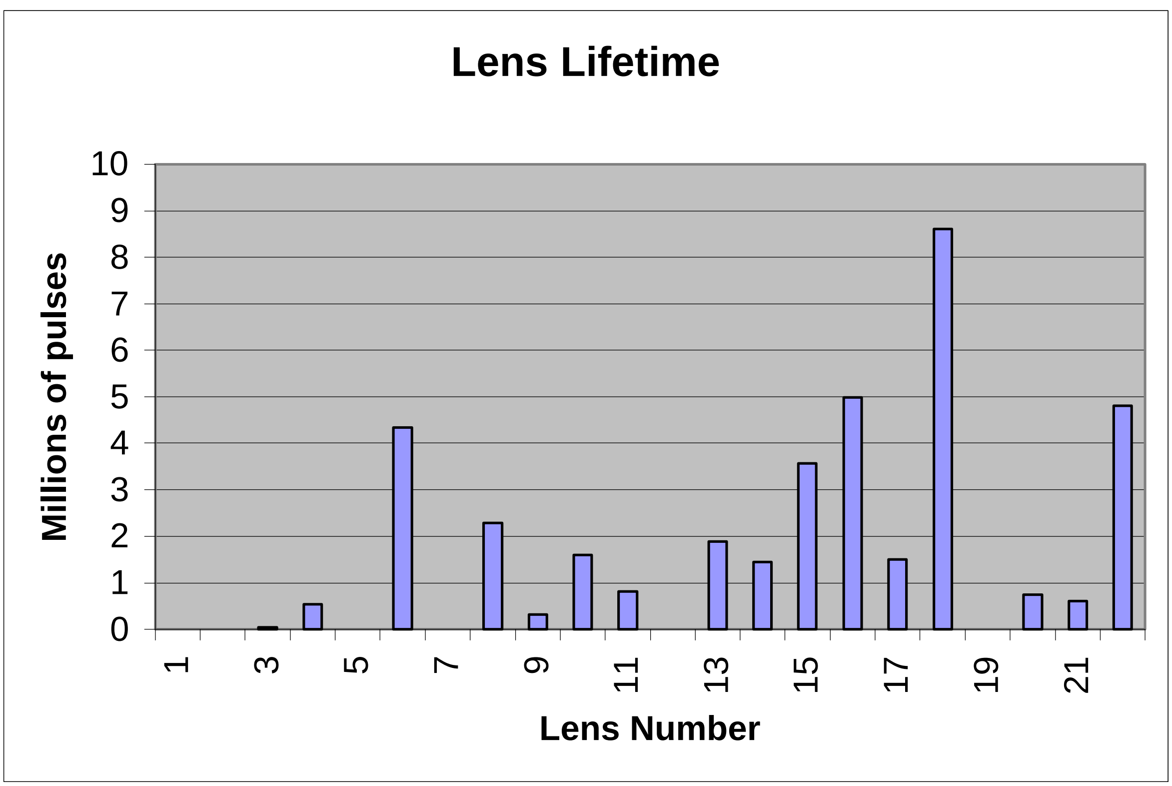
4/8/99

Run II is expected to begin in approximately one year. The present schedule also includes a short period of E835 operation during the Fixed Target run later this year. More than a year ago Steve O'Day summarized the spare situation (attached as an appendix) and estimated the number of devices needed and associated manpower requirements for Run II. This document reviews the estimates made by Steve and reports the progress since the estimates were made.

Support for the AP0 target hall currently consists of two full time mechanical engineers, two target station physicists and four technicians working under the guidance of an Operations Specialist. The technicians divide their time between Pbar related tasks and NuMI prototype development. Over the past year their time has been evenly divided between Pbar and NuMI tasks. Most recently NuMI involvement has dropped to less than 25% until their prototype horn is ready for fabrication sometime in the summer or fall.

What follows is a summary of the major components required for antiproton production and their spare status:

Lithium Collection Lens ($45,000): Steve O'Day estimated that with a typical run schedule and historic proportion of downtime, the collection lens will be required to pulse 11.8 million pulses per year in Run II. The estimate takes into account the reduction in stacking cycle time from 2.4 seconds in Run I to 1.5 seconds in Run II. These estimates are based on a nominal gradient of 740 Tesla/meter, increasing the gradient results in a shorter lens life. Figure 1 provides a history of lens lifetime combining both pulses on the test stand and service pulses.



Beginning with lens 13, a more robust septum geometry has been used that includes parabolic endcaps. Prior to lens 18, several lenses had problems with water cooling lines developing leaks due to radiation damage. Beginning with lens 18, improvements were made to the cooling lines that appear to have ended the systematic problem with external leaks. Lens 18-27 can be considered “modern” lenses that have incorporated all of the successful mechanical design changes.

Steve estimated that the present lenses have a lifetime of 6-8 million pulses at the nominal 740 Tesla/meter, but increasing the gradient to 800-850 T/m will reduce the lifetime by 50%. Lens 18 survived more than 8 million pulses and lens 22 has accumulated 4.8 million pulses without failure. The other modern lenses have not fared as well, lens 19 was broken during the filling process and lenses 20 and 21 had septum failures before reaching 1 million pulses. It is believed that these two failures were due to prior septum breaches and lithium hydroxide entering the LCW system, but is not known for certain.

An estimate of 5 years of scheduled Run II operation, which includes the short E835 run, results in an estimate of 59 million pulses required of the lenses. Steve O'Day used a “conservative” estimate of 6 million pulses per lens to estimate a total of 10 lenses required for the duration of the run. Based on the history of the modern lenses, that estimate is reasonable for lenses that manage to avoid infant mortality. As many as 15 may be required if no further improvements are made and historical trends continue.

Lens 22 has accumulated 4.8 million pulses without failure, but may be approaching the end of its operational life. Two spare lenses have been built and test pulsed, an additional spare lens is being prepared for testing. Two more lenses are partially completed and should be finished in the spring of 2000. Steve expected that 4 spare lenses would have been finished late last fall, so clearly we are behind his anticipated schedule. This is largely due to the target station technicians being required to support NuMI projects with no increase in manpower.

There are two proposed changes to the lens design that would hopefully improve the lens lifetime or allow an increase in the nominal gradient while preserving the present lifetime. The first is to lower the pre-load pressure of the lithium during the filling process. The pre-load is required because of the magnetic pinch that occurs during the lens pulse that could lead to poor contact between the lithium and the septum surface. Adequate pre-load ensures good contact throughout the current pulse. Unfortunately the pre-load contributes substantially to the hoop stress that is believed to be the primary cause of septum failure. The hoop stress reaches a maximum when the lens temperature peaks shortly after the current pulse. Most of the heat comes from power dissipated during the current pulse. Reducing the pre-load on the lens will reduce the hoop stress, too much of a reduction would cause poor lithium to septum contact during the magnetic pinch. The pre-load pressures used previously, 2,400 psi and greater, was based on a conservative calculation that would ensure good contact during the magnetic pinch. It is believed that pre-load as low as 500 psi could be used without loss of septum contact (although a modified turn-on circuit or reference may be required). Reducing the pre-load from 2,200 psi to 500 psi should reduce the hoop stress by about 20%. This would result in extended lens life, or similar lifetime at a 10% higher gradient (gradient scales with current, heat dissipated with the square of the current).

The second proposed change is to reduce the diameter of the lithium conductor from a radius of 1.0 cm to 0.8 cm. The ideal conductor diameter is a compromise between beam acceptance and lens gradient. Simulations suggest that a smaller diameter lens can be run at higher gradients with similar stresses at the cost of a decrease in acceptance. It appears that the original lens size was based on the design beam spot size on target of σ=0.38 mm. Through studies and tuning the minimum spot size has been reduced to σ=0.14 mm. A smaller spot size increases pbar yield by reducing the size of the cone of secondaries emanating from the target. Initial calculations, based in part on an imperfect understanding of the AP-2 lattice, suggest that by reducing the lens diameter to 0.8 cm, there will be only be a few percent loss in pbar yield at the same lens gradient. By significantly reducing stresses on the lens, extended lifetime and/or increased nominal gradient would be possible. Calculations need to be done in detail to quantify how much reduction in stress to expect.

I recommend filling the next lens (#26) with a 500 psi pre-load and extensively test pulsing the lens. If it survives nominal gradient for an extended period, testing at higher gradient should confirm whether or not the pre-load change will reduce the stresses that lead to a septum failure. If careful calculations confirm that a smaller septum diameter will further reduce stresses, a lens of that design should be expedited. It is important to identify if either or both of these proposed changes live up to expectations before too many spares are completed. A balance must be made between adequate spares to ensure stable operation and incorporating improvements in time for them to be used for a significant part of Run II. As previously mentioned, there are presently two spare lenses completed with a third ready for power testing. Two more lenses are partially complete, and should be finished early next year. I believe these five spare lenses should be adequate to begin Run II. Over the next 12-18 months we will attempt to identify if either of the proposed design modifications work well enough to be incorporated into an operational lens. If so, the next series of lenses will be modified in time to be used over a large portion of Run II.

Lithium Proton Lens ($45,000): The proton lens is intended for use in conjunction with target sweeping. Presently there is one complete proton lens and parts to make a spare. The proton lens has a very small septum radius, 0.3 cm, and should have considerably lower mechanical stresses than the collection lens. Steve O'Day recommended two spares be built, the second would not be undertaken until the original lens fails. The proton lens is not required for beam sweeping and about a 10% improvement in pbar yield is estimated when it is used. Not having a spare proton lens available is not nearly as serious as a collection lens or pulsed magnet. Since target sweeping isn't anticipated for more than a year, building of the spare proton lens remains a somewhat low priority.

Lithium Lens Transformers ($50,000): Every lens, both collection and proton, requires a transformer. In addition a modified transformer has been built to support testing of the prototype NuMI horn and the liquid lithium lens development will require a transformer. Transformers have been installed on lenses 23-25 and transformers have already been constructed for lenses 26 and 27. Parts for two more transformers are being ordered. Eventually at least an additional 5, and possibly as many as 10 transformers will be required over the course of Run II for collection lenses. Also transformers for two more proton lenses will be needed. At the moment the transformer construction is somewhat ahead of the other lens components. An acceptable pace should be the building of another six over the next two years, followed by a reassessment of the requirements. It is also possible that the transformers from lenses #20 and 21 could be salvaged and reused.

Sweeping System: The sweeping system is scheduled for completion in approximately one year, coinciding with the beginning of Run II. In order to achieve this aggressive goal, a substantial amount of engineering (both mechanical and electrical) effort is required. Two electrical engineers are working exclusively on this project and nearly a full-time effort is required from a mechanical engineer. Technicians will need to build four sweeping magnets, complete a double module for the downstream magnet and work on instrumentation and other systems relating to the project. It is difficult to estimate the technician time required as the only previous experience with the sweeping magnets came from building a prototype.

Pulsed Magnet ($65,000): The modern pulsed magnet design has proven very reliable in service. The last magnet survived 28 million pulses before radiation damaged torlon insulators resulted in a ground fault. The magnet currently in the vault has accumulated only 5 million pulses and has torlon that is 50% more radiation resistant. Two spares have been built, one of them is yet to be tested. Unless the present pulsed magnet fails prematurely, the two spares should be adequate through Run II.

Target Assembly ($24,000): Each target assembly contains 5 targets, it's not clear how much integrated beam intensity the Nickel targets can handle. The present target assembly has been use for several years. A several millimeter area of discoloration and swelling on the titanium container was observed during a visual inspection in 1996. Periodically making a small adjustment to the vertical position of the target could reduce any deterioration to a particular portion of the target. Steve said that one spare was made and he requested two more, this continues to be the situation. A second spare should be relatively high priority with work on another spare following in a year or two.

Target SEM ($35,000): Although the SEM is not required for pbar production, it is an extremely valuable diagnostic. Without a way to measure the size of the proton beam on the target, it is very difficult to minimize spot size. The present design is very vulnerable to mis-steered beam since the wires are close to the beam even when the SEM is fully retracted. Only beam intensities of a few E11 are considered safe, increased intensity can melt the wires. There is presently no spare target SEM. A significant design improvement to consider would be one that allows the SEM wires to be moved far enough from the beam so that they would not be accidentally destroyed. I recommend that the construction of a spare target SEM of the same design as the one presently in use be a high priority. While the spare is being constructed, design changes could be considered for the next generation, and eventually another target SEM constructed.

Striplines and Modules (stripline $10,000, universal module $58,000, module refit $12,000): There is a spare for each stripline type, but the liquid lithium lens will require a stripline. One collection lens stripline will need to be built, otherwise striplines only need to be built if there is a failure. Parts are available to build a collection lens module. The existing collection lens module has an eccentric used for horizontal movement that is stuck. This does not allow independent horizontal position and rotational movement of the lens. The next collection lens module should be used to replace the existing one, and another spare will be required. In addition, a universal module should be built that would be adaptable to other applications.

Heip Le's technician group has 180 man-weeks per year of time available, what follows is the anticipated requirements for work on existing systems only (no NuMI, MiniBoone, etc.). The total time category is the estimated time of completion for one device including technician and vendor/shop time.

Job	Technician Time		Total Time
Finish work on 3 collection lenses	2 techs x 3 lenses x 20 weeks =	120 man-weeks	20 weeks
6 (at least) new collection lenses	2 techs x 6 lenses x 29 weeks =	348 man-weeks	49 weeks
2 proton lenses	2 techs x 2 lenses x 29 weeks =	116 man-weeks	49 weeks
8 lens transformers	1 tech x 8 transformers x 9 weeks =	72 man-weeks	29 weeks
2 targets	1 tech x 2 targets x 6 weeks =	12 man-weeks	22 weeks
2 target SEM's	2 techs x 2 SEM's x 14 weeks =	56 man-weeks	34 weeks
2 universal modules	2 techs x 2 modules x 4 weeks =	16 man-weeks	10 weeks
4 sweeping magnets	? techs x 4 magnets x ? weeks =	? man-weeks	? weeks

These jobs total 740 man-weeks (plus sweeping magnet fabrication), more than four years of full-time commitment. In addition, Heip's group is expected to do the following tasks in support of Run II:

Installation of sweeping magnets, including any required module modification.
Expansion of AP0 test area to provide space for NuMI horn and liquid lithium lens test
Target station maintenance
Operational support (component replacement, etc.)

Priorities for the major target station tasks are listed below

1999

Priority	Description
1	Fill lens #26 with 500 psi preload, build and test extensively.
1	Pending confirming calculations, make design changes for 8mm lens.
1	Engineer new target SEM that fully retracts from beam path.
1	Build spare target SEM ($35,000).
1	Stripline for liquid lithium lens ($10,000).
1	Operational support (summer/fall).
2	Build spare target assembly ($24,000).
2	Procure parts for 2 universal modules ($116,000)
2	Prepare test area for liquid lithium lens/NuMI horn testing.
2	Complete and test lens #25
2	Build sweeping magnets as parts become available (summer/fall) ($?).
3	Complete and test lens #27
3	Build spare proton lens ($45,000).
3	Build 3 transformers ($150,000).

2000

Priority	Description
1	Finish low priority 1999 tasks that have not been completed.
1	Build and test an 8mm collection lens ($45,000).
1	Build 3 collection lenses of new design ($135,000).
1	Install sweeping system.
1	Operational support.
2	Build 3 transformers ($150,000).
2	Build new design target SEM ($35,000+).
2	Build universal modules.
2	Assist in liquid lithium lens test.
3	Build another spare target ($24,000).

2001 and beyond

Priority	Description
1	Finish low priority 2000 tasks that have not been completed.
1	Build additional lenses and components as needed.
1	Operational support.

The technicians already have assembled two prototype NuMI targets and have been committed to assist during the testing period. A prototype NuMI focussing horn is being produced and the technicians are expected to be involved in the testing at AP0. It is clear that Heip Le and his technicians are already over-committed for target station work in support of Run II. Any additional work for NuMI with his present staffing will only serve to further compromise Target Station operations over the course of the run. A minimum of two additional technicians is required to support the construction and testing of the prototype NuMI horn.

It is also worth mentioning that the target station technicians have limited operational experience, expect the first few lens replacements to require extra time. I recommend that Heip's technicians be allowed to devote their time to tasks specifically in support of pbar E835 and Run II operation. Numi and Mini-Boone jobs should be assigned to other individuals working under Heip Le's guidance.