LS-118
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The Positron Injection Process for the 7-GeV Advanced Photon Source

The following is a list of the main components used for production and acceleration of positrons for the 7-GeV Advanced Photon Source.

1. 200-MeV Electron Linac (2.8 GHz. Rep. Rate 60 Hz)
2. Tungsten Positron Production Target.
3. 450-MeV Positron Linac (2.8 GHz. Rep. Rate 60 Hz).
4. Energy Spread Suppressor (Debuncher)
5. 450-MeV Positron Accumulator Ring (PAR).
6. 450-MeV to 7-GeV Injector Synchrotron (Rep. Rate 2 Hz).

A brief description of the performance of each of these components is presented in the following sections.

1. 200-MeV Electron Linac

The electron linac accelerates electrons to 200 MeV at a 60-Hz rate. Each linac macropulse is 30 nsec. long and contains 50 nanocoulombs of charge. The 200-MeV electrons are focused to a 3-mm diameter spot at the positron production target.

2. Tungsten Positron Production Target

The tungsten positron production target is 7-mm thick. The target yields 0.0083 positrons per incident electron within a solid angle of 0.15 steradian and an energy range of 8 $\pm$ 1.5 MeV. The positrons from the target are focused by a high-field pulsed solenoid for injection into the positron linac system. Each 30-ns positron pulse contains a charge of 0.4-nanocoulomb and has a 95th percentile emittance of 330 x 330 $(\text{mm}\cdot\text{mrad})^2$.

3. 450-MeV Positron Linac

The positron linac system accepts the focused positrons from the target and accelerates about 62% of them to 450 MeV. Each 30-nsec macropulse from the linac contains 0.25 nanocoulombs of charge (1.5×10^9 positron/pulse). With a 1.12 linac dilution factor, the 95th percentile emittance is 6.6 x 6.6 $(\text{mm}\cdot\text{mrad})^2$. This corresponds to an rms emittance of 1.1 x 1.1 $(\text{mm}\cdot\text{mrad})^2$. The 450-MeV positron to 200-MeV electron ratio is 0.005.

4. Energy Spread Suppressor (Debuncher)

The debuncher is made up of four 30° bending magnets and a 10-MV waveguide. The bending magnets first bend and then restore the direction of the positrons from the linac. The bends produce different path lengths for positrons which have energies greater than and less than the average energy. This leads to a lengthening of the 6.8-MHz microbunches in the waveguide where the rf voltage reduces the energy spread. The energy spread after the debuncher is $\pm$ 0.5%.

5. Positron Accumulator Ring (PAR)

The positron accumulator ring is more fully described in LS-109. The 450-MeV positrons from the positron linac are injected into the horizontal phase space of the PAR at a 60 Hz rate. As many as 24 linac 30-nsec macropulses can be accumulated as a single bunch in the PAR during each 0.5-sec cycle of the injector synchrotron. This leaves 0.1 sec for final compression of the PAR bunch length before extraction and injection into one of the 352-MHz rf buckets of the injector synchrotron. With 24 pulses injected at 60 Hz for each 0.5 cycle, the duty factor for the linac becomes 80%.

The PAR circumference is 30.577 m (1/12 of the injector synchrotron). The 30-nsec positron pulses are accumulated in a first harmonic 9.8-MHz rf system operating at 40 kV. A 30-kV 12th harmonic cavity is turned on for the final compression of the accumulated bunch length.

The total number of positrons injected into the PAR can be as large as 3.6 x 10^{10} (24 pulses x 1.5 x 10^9/pulse). The design and operation of the PAR is very similar to that of the PIA[(1)] used for the accumulation of positrons before injection into the DESY synchrotron in Hamburg, West Germany. This ring has been in operations for nine years with an accumulation efficiency of 50-60%. There is no further loss of beam during injection and acceleration of the positrons in DESY.

6. Injector Synchrotron and Filling Time for the Storage Ring.

The injector synchrotron operates at a repetition rate of 2 Hz. Once each cycle, the bunch accumulated in the PAR is transferred to the injector synchrotron for acceleration to 7 GeV. The rf system for the injector synchrotron has the same frequency, 352.96 MHz, as that of the storage ring. At 7 GeV, the bunch is extracted and injected into a desired rf bucket of the storage ring.

Operating at 2 Hz, with 24 linac-pulses-per-cycle and assuming a PAR efficiency of 60%, the 7-GeV positron production rate is 4.3. x 10^{10}/sec. The time required for an initial storage ring fill of 2.2 x 10^{12} positrons (100 mA) can therefore be as short as 0.85 min.

Reference

1. A. Frebel and G. Hemmie, “PIA, the Positron Intensity Accumulator for the PETRA Injection,” IEEE Transactions on Nuclear Science, Vol. NS-26, No. 3 (June 1979).