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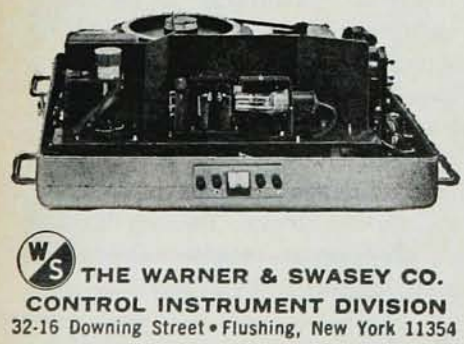

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41 meters long. An iron-free synchrotron, with 70–100-kG field, will inject 500–1000 MeV protons into the ring; 10^{14} particles are expected. In a one-minute interval the field will be increased until the protons reach 25 GeV. The proton beam will then strike a target, and a much smaller number of antiprotons will come off —10^7 antiprotons are expected; antiprotons will be stored in a small additional ring. By repeating the process 1000 times Budker expects to obtain 10^{10} antiprotons. Once that intensity is reached the protons and antiprotons will be accelerated and allowed to meet.

The device is expected to cost $8 million. (Budker notes that 1000 GeV from a conventional accelerator would cost more like $1 billion.) Tunnel construction was scheduled for completion in October before the Siberian ground froze.

Meanwhile the 160-MeV electron-electron-storage rings have been used to study elastic scattering at 43, 135 and 160 MeV. Results agree, within experimental error, with theory.

The 700-MeV electron-positron ring, which recently started running, produces a 2-ampere electron current, and 20 milliampere positron current. Characteristic instabilities of the electron and positron beams have been photographed with the synchrotron light produced by the beam itself. The very intense light lasts for many hours. As electrons disappear, the light drops off in steps; at the last step only one electron remains and one can observe with the naked eye, the light from the single electron. The lifetime of this last electron has been as long as 12 hours. So one can leave the electron at night and still see its light the following morning.

When electrons interact with positrons, one can observe elastic scattering or annihilation with formation of two photons, two muons, two pions or two kaons. Right now pion formation at 380 MeV and kaon formation at 510 MeV are being studied. Next year physicists expect to examine photon and muon formation.

Other laboratories are also doing colliding-beam experiments, including a Stanford-Princeton group, operating electron-electron rings at 500 MeV, and a French group, which is expected to start experiments with a 500-MeV electron-positron ring in a few months.—GBL.

PPA beam extracted

After a year of effort physicists at the Princeton-Pennsylvania accelerator have succeeded in extracting the synchrotron's beam. The method of extraction, which is the same as the one used on the electron accelerator at Frascati, employs betatron oscillation to blow up and spill the beam. Specifically the radial betatron resonance, $\nu_r = 2/3$, is excited so that the radial oscillations of the beam build up and move the protons so far from the equilibrium orbit that they find their way into the field of an extraction magnet that bends them out of the accelerator.

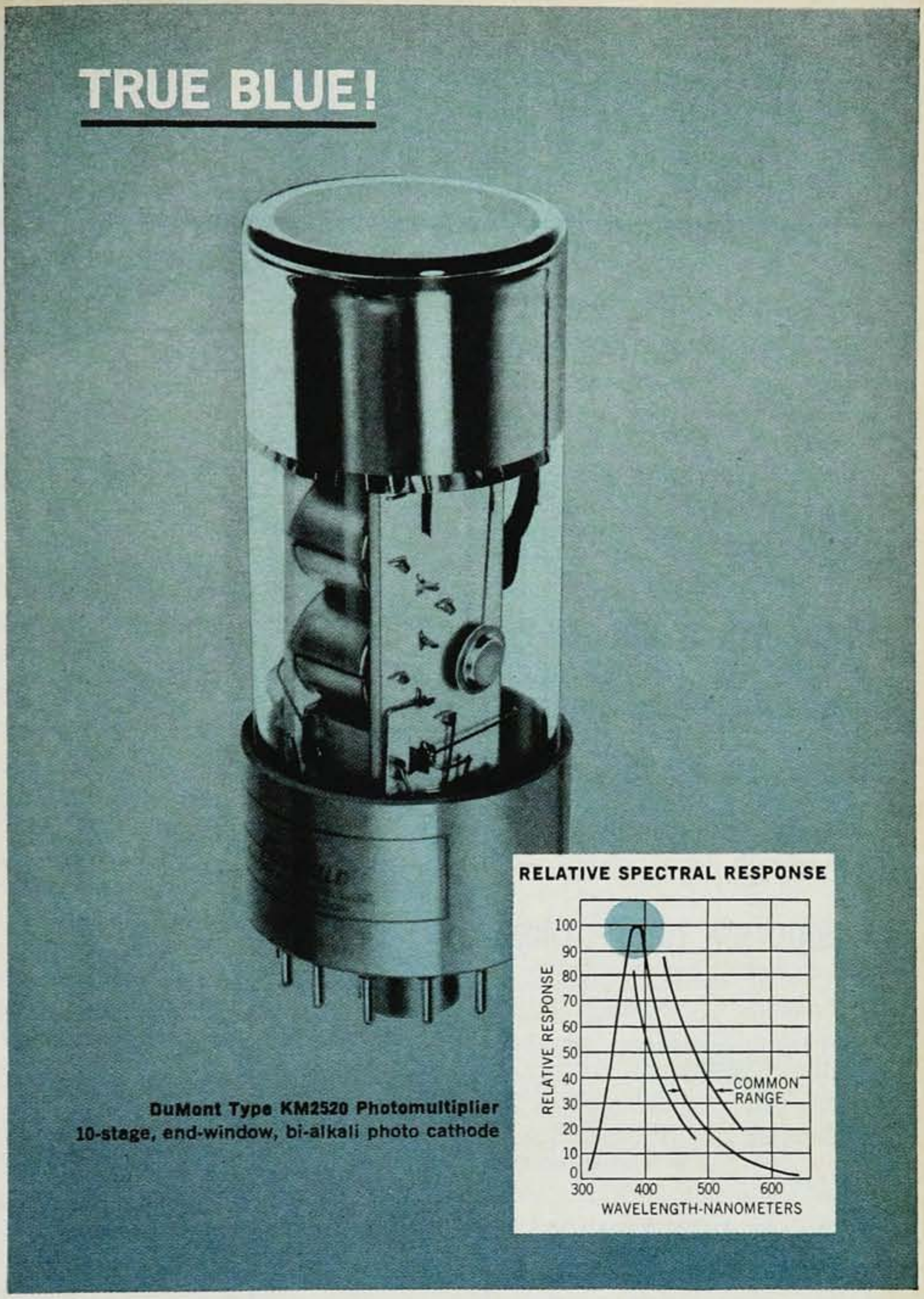
Exciting the oscillation requires special magnets. First the synchrotron's magnetic field index n must be raised from the measured value of 0.60 to 0.67 to tune the machine to the 2/3 resonance. [$n = -(R/B_z)(dB_z/dr)$; R is the radius of curvature of the normal trajectory taken in the center of the beam, B_z is the field along this trajectory, and dB_z/dr is the radial derivative of B_z.] In addition, since the resonance is nonlinear, an azimuthal second harmonic in the radial gradient of n must be provided. Extensive digital calculations determined the quadrupole and hexapole field components needed and thereby showed that the existing pole-face windings on the synchrotron magnet could not be used (this had been done at Frascati) because they could not carry enough current.

Therefore four excitation magnets were constructed and placed symmetrically in four short straight sections around the machine. These are current-sheet magnets, 30 cm long, with an aperture of 6 × 18 cm. Their left and right sides are separately powered by modulators capable of delivering 200 amperes at up to 75 volts. The quadrupole component (approximately 85 gauss/cm), which tunes the betatron oscillations to resonance, is given by the sum of the currents in the two halves of the magnet. The nonlinear or hexapole field required to drive the oscillations is provided by a difference in the currents of the two halves of the magnet. For the desired growth rate, the hexapole field must be about 10 gauss/cm^2 softening to a uniform gradient of about 25 gauss/cm at the edges. The polarity of the hexapole component alternates from one magnet to the next to produce the necessary azimuthal second harmonic in the radial gradient of n. There is also an in-phase hexapole component, which does not alternate, so that it does not drive oscillations but does cancel the inherent radial position variation in n of the synchrotron magnet and thereby allows the quadrupole component required for resonance to be independent, in the first order, of the radial position of the beam in the synchrotron.

When the hexapole fields are turned on and the quadrupole fields are adjusted to approach resonance slowly, the beam spills smoothly and blows up radially in an exponential manner. After the beam has blown up radially by about 5 cm, it enters the aperture of the extraction magnet and is bent clear of the machine. The extraction magnet, a current-septum magnet with a 14-kG peak field, is 135 cm long and has an aperture 1 cm high by 2.5 cm in the radial direction. The current septum is about 0.5 cm thick so that extraction efficiency is limited to 81%. The designers expected that to minimize interference with the multiturn injection into the synchrotron, the extraction magnet, which weighs 200 kg, would have to be "plunged," that is, moved in and out of position, at a rate of 19 Hz with a peak-to-peak amplitude of 5 cm. This turned out to be unnecessary; the magnet could be placed far enough away not to interfere.

By radioactivation measurements the external beam is found to be 75% of the internal beam. A beam spot about 30 meters from the machine is about $2\frac{1}{2}$ cm in diameter, a width that is largely caused by air scattering. A vacuum pipe to conduct the beam should make the spot a good deal smaller.

J. Kirchgessner, J. W. Benoit, and F. C. Shoemaker are responsible for the work.——DET □



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