CERN's first Nobel prize

Stockholm's recognition of the importance of the discovery of the intermediate vector bosons W *and* Z *is nicely tempered by an appreciation of the technical ingenuity which underlies it.*

Carlo Rubbia, Italian-born discoverer of the W and Z particles that carry the weak nuclear force, and Simon van der Meer, the Dutch accelerator designer without whom, says Rubbia, "we couldn't have done it", share the 1984 Nobel Prize for Physics. But neither is sitting back. They are, instead, separately at work on the proton–antiproton collider at the European Organization for Nuclear Research (CERN) near Geneva that won them the prize.

Rubbia is at present working flat out to exploit the collider to its utmost. There are two objectives. While the approximate masses and decay properties of the W and Z particles are now known, there is much detail yet to discover — such as the particles' lifetimes. Clearly, CERN would be well-advised to wring as much as possible from the machine before Stanford's Single Pass Collider (planned to produce a million Zs a year, compared with CERN's present few dozen) comes on line towards the end of 1987. But Rubbia and his colleagues have also been stimulated by hints from his "UA1" detector on the collider that all is not quite as expected at energies beyond the W and Z particles.

"Our chance is now" he says. Rubbia is pleased at finding the Ws and Zs, but clearly feels like an explorer who arrives at the South Pole and finds footprints in the snow — here, the footprints of Abdus Salam, Steven Weinberg and Sheldon Glashow whose "electroweak" unification predicted the presence and exact properties of the particles. "For me these anomalies — and I must be frank with you, we're not sure they're there — represent hope", he said last week. "We may be on the threshold of a whole new territory."

Rubbia has been the driving force behind the collider. "The road was very long", he said. "You have to be a hell of a persistent person. You have to be very stubborn." With two American colleagues, he first presented the idea, in 1976, to Robert Wilson, then director of Fermilab near Chicago, who rejected it. Rubbia, ebullient and outspoken, feels the reasons were partly personal. "I didn't get on with Wilson. He'd had enough of me." Fermilab went ahead instead with its Tevatron project, an upgrade to 1,000 GeV beams. (This was a lengthy project, involving the development of superconducting magnets, and it will not provide competition for the CERN collider before 1986–87 — when it will collide protons and antiprotons at 2,000 GeV total energy.)

The Rubbia project went ahead instead at CERN, assisted by the better vacuum in the CERN super proton synchrotron, through which the colliding proton and antiproton beams now circulate. In the poorer Fermilab vacuum, the beams would have been rapidly damped, and a new beam-tube would have been necessary. CERN also had van der Meer ("our best accelerator man"), whose essential contribution to the collider has been "stochastic cooling", a technique which allows an accumulation of antiprotons to collide with protons in the collider.

Stochastic cooling is much more than a technical *tour de force* but, on the face of things, is a violation of Liouville's theorem of statistical mechanics describing the motion of collections of particles. Only once before has a Nobel prize been awarded to an accelerator physicist — Ernest O. Lawrence, for his design of the cyclotron. The comparison of van der Meer with Lawrence is a measure of the stature of the Dutchman's achievement.

The problem van der Meer has solved is this. Antiprotons are formed in high-energy collisions of a proton beam with a target, and collected into a rough beam. But the particles so produced have a wide spread of velocities, and so could not be accelerated coherently in a synchrotron machine. The velocity spread has to be reduced or, in the jargon, the beam has to be "cooled". An earlier (1960s) Soviet solution (due to the late Gersh Budker of Novosibirsk) was to inject a "cool" (mono-energetic) beam of electrons to run alongside the protons: the electrons would "heat up" and the protons "cool" until the beams reached the same "temperature" (this thermodynamic analogy is exact). Then further cooling would be done with a new injection of electrons until the proton beam was sufficiently cool that it could be accelerated up to the 270 GeV planned in the collider (the super proton synchrotron). This idea worked, but proved too complicated to use in practice.

van der Meer's approach is different. Liouville's theorem has it that the crowd of points representing a collection of particles in phase space (embodying both momentum and position) will keep a constant density, whatever the external forces acting on it. According to Liouville, a beam is like toothpaste in a tube: if you squeeze it somewhere in phase-space, it must come out somewhere else. But "cooling" aims to increase phase-space density, by putting all the particles in a physic bunch in real space, each with the same momentum. How does van der Meer's cooling method get around this difficulty?

"I began thinking that if you can control a single particle perfectly in an accelerator, then why can't you control several?" he says. He developed the idea that an uncooled beam of particles is represented in phase space by points (one for each particle) with plenty of space between them, and that in principle these points can be squeezed closer to each other without changing the phase-space density around each point.

In practice, the technique is to control the fluctuations of the beam. Antiprotons are accumulated in a storage ring called the Antiproton Accumulator. Sensors detect deviations at one point on the ring, ultrafast electronics calculate the necessary corrections and correcting signals are relayed to some point later in the trajectory. The process is possible — with both beam and signal travelling near the speed of light — because a chord of a circle is shorter than the circumference which it intercepts. This whole correction process takes a few tens of nanoseconds, and is repeated for each circuit of the beam. Roughly 24 hours are needed to accumulate and cool enough antiprotons for a collider run, but van der Meer is working on a new accumulator (ACOL) that will reduce this by a factor of ten.

ACOL will take its first beam only in May 1987. Meanwhile, Rubbia and his 130-strong UA1 collaboration* will try to get as much time and energy as possible to explore the "new territory".

Robert Walgate

***The UA1 group includes teams from West Germany (Aachen and Kiel), Austria (Vienna), CERN, the United States (Harvard, Riverside and Wisconsin), Finland (Helsinki), Italy (Padua and Rome), France (Annecy, Collège de France and Saclay), the Netherlands (Amsterdam) and the United Kingdom (Birmingham, Queen Mary College London and the Rutherford-Appleton Laboratory).**

Erratum

In the penultimate paragraph of Stephen Budiansky's article "Jumping the smoking gun" (*Nature* 4 October, p.407), the statement that "none of the bacteria residing in the gut of farm animals is resistant" should have read "not all of the bacteria . . .".