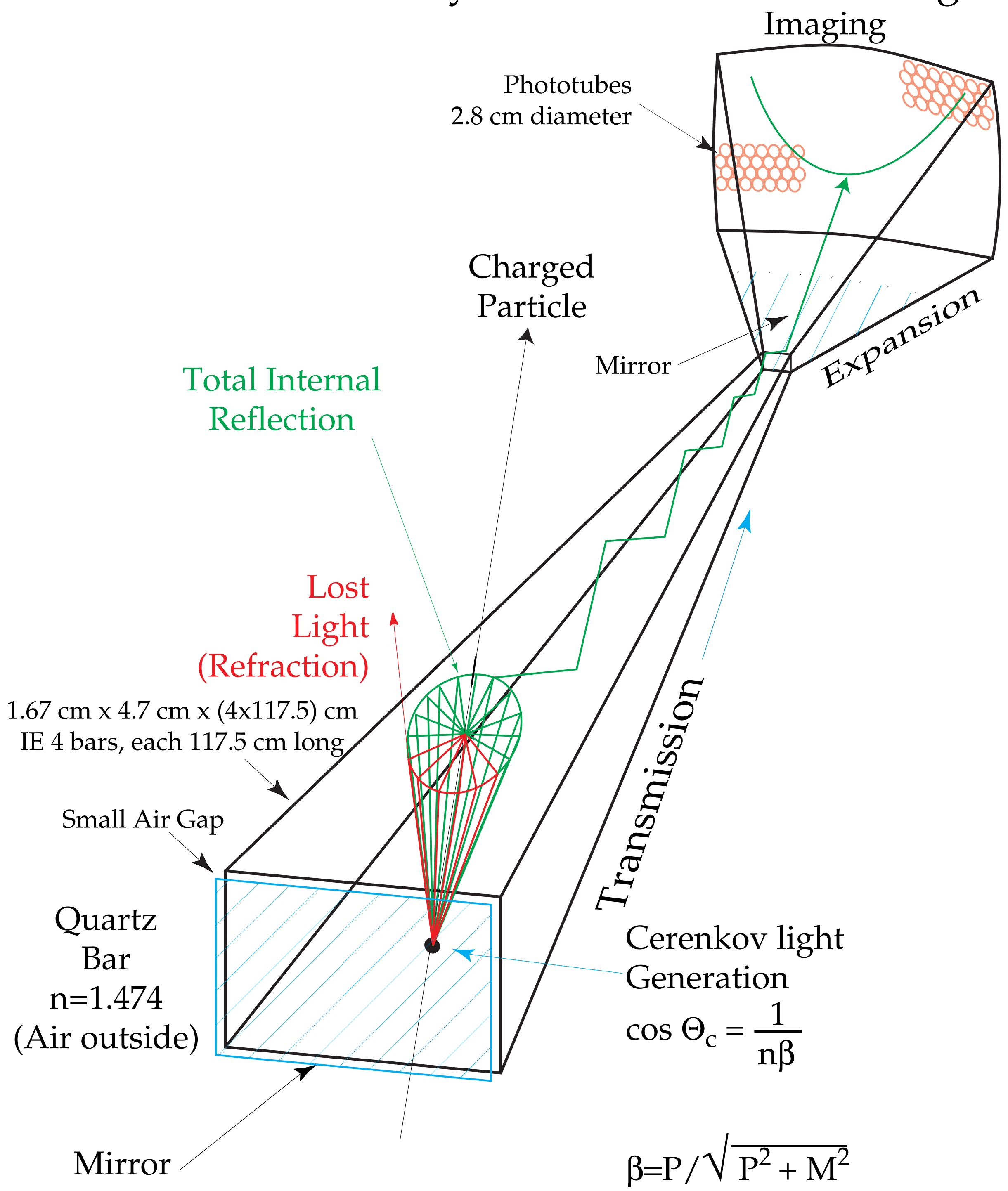
Test of a Large Scale Prototype of the DIRC Ring Imaging Cherenkov Counter for Babar

Roy Aleksan, David Aston, Christophe Beigbeder, Maurice Benayoun, Mehdi Benkebil, Pierre Besson, Zhang Bo, Teresa Bolognese, Gerard Bonneaud, Philippe Bourgeois, Dominique Breton, Helen Briand, **David Brown**, Luigi del Buono, Jacques Chauveau, Richard Cizeron, Pascal David, Bill Dunwoodie, Andre Gaidot, Jean-Francois Genat, Louis Gosset, David Hale, Gautier Hamel de Monchenault, Odile Hamon, Chris Hearty, Didier Imbault, Patrick Jarry, John Kadyk, Hideaki Kawahara, Henning Krueger, Philippe Leruste, Alain de Lesquen, Georges London, Mike Long, Jacqueline Lory, Al Lu, Anne-Marie Lutz, Gerry Lynch, Rusty Malchow, Don McShurley, Brian Meadows, David Muller, Jean-Louis Narjoux, Jean-Marie Noppe, Gerard Oxoby, Stephane Plaszczynski, Bill Pope, Moishe Pripstein, Joseph Rasson, Blair Ratcliff, Robert Reif, Christophe Renard, Xavier Sarazin, Marie-Helene Schune, Jochen Schwiening, Sumit Sen, Steve Shapiro, Mike Sokoloff, Hermann Staengle, Paul Stiles, Walter Toki, Kai Truong, Marie-Luisa Turluer, Jaroslav Va'vra, Christian de la Vaissiere, George Vasileiadis, Georges Vasseur, Marc Verderi, Dave Warner, Tom Weber, Bill Wenzel, Bob Wilson, Guy Wormser, Steve Yellin, Marco Zito

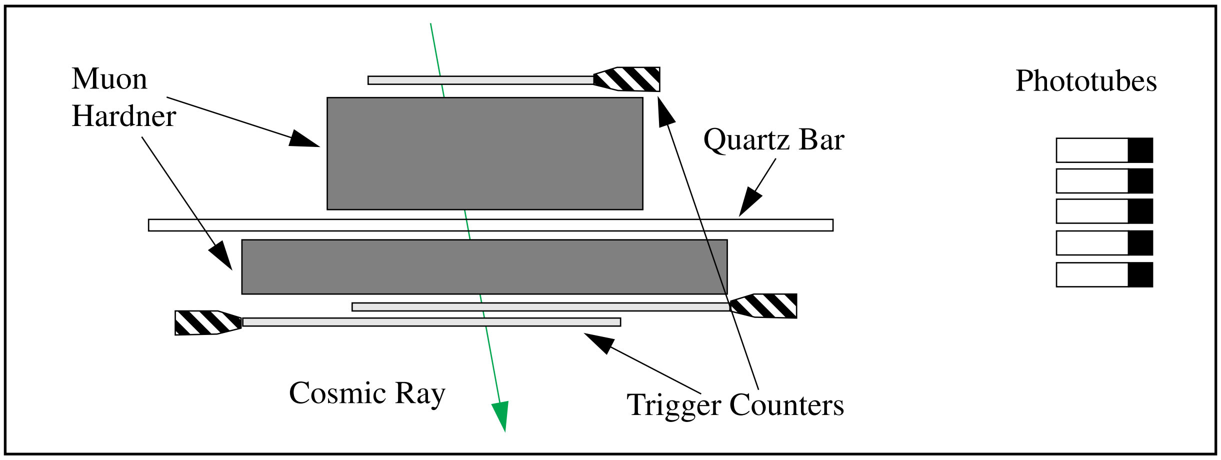
- The DIRC Principle
- The DIRC in BaBar
- The DIRC Full Scale Prototype
  - Prototype and Testbeam Description
  - Test Results
    - Basic System Performance
    - Photon Yield, Resolution and Attenuation
  - Future Tests
- Current Engineering Status of the DIRC in Babar
- Conclusions

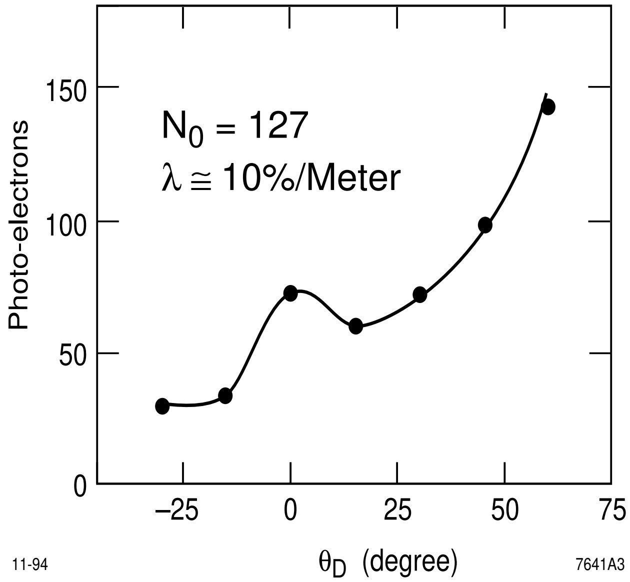
Detection of Internally Reflected Cerenkov Light

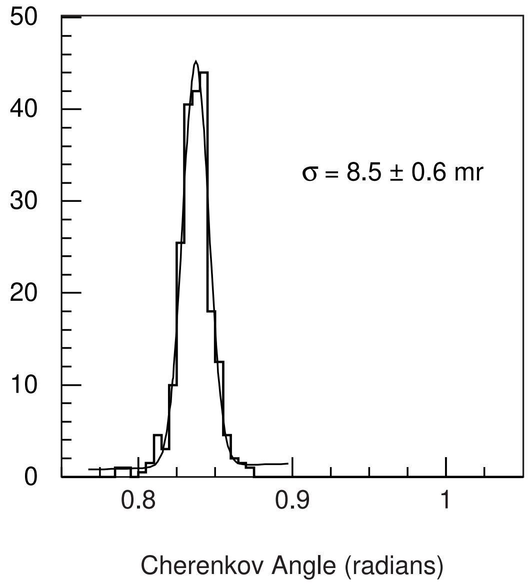


The First Prototype

A DIRC prototype was constructed in 1993 to test the operation principle. This prototype had an air standoff region and a very limited number of photons. The results from a cosmic ray test of that device were presented at the 1994 IEEE Nuclear Science Symposium (SLAC-PUB 6731).

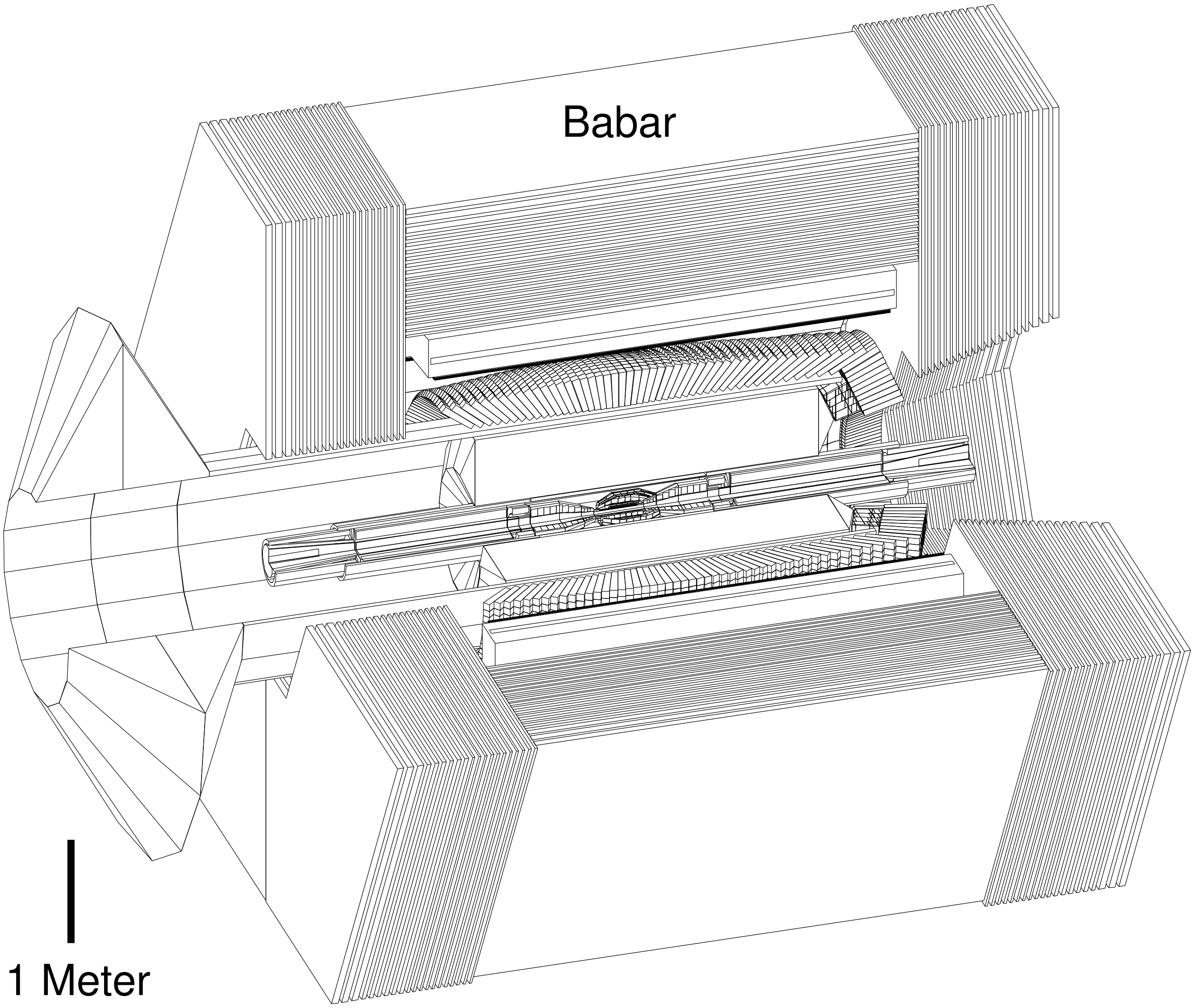






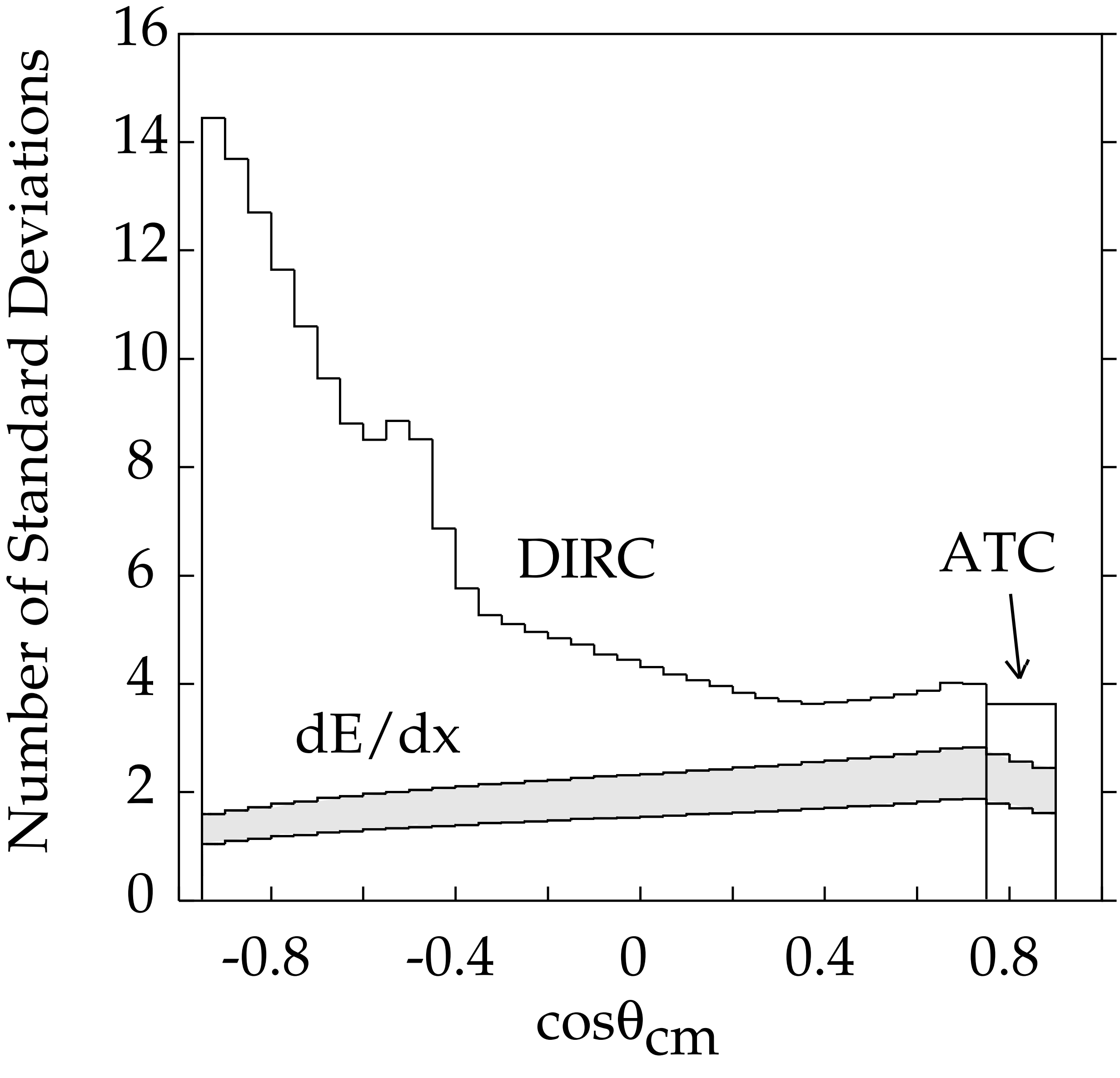
The DIRC in Babar

Babar is the name of the collaboration building a large detector for the PEP-II asymmetric B factory. The role of the DIRC will be to identify the particles in the barrel region of the detector. Particle ID plays a crucial role in the primary mission goal of extracting a signal for CP violation signal in neutral B decays.



The DIRC in Babar (2)

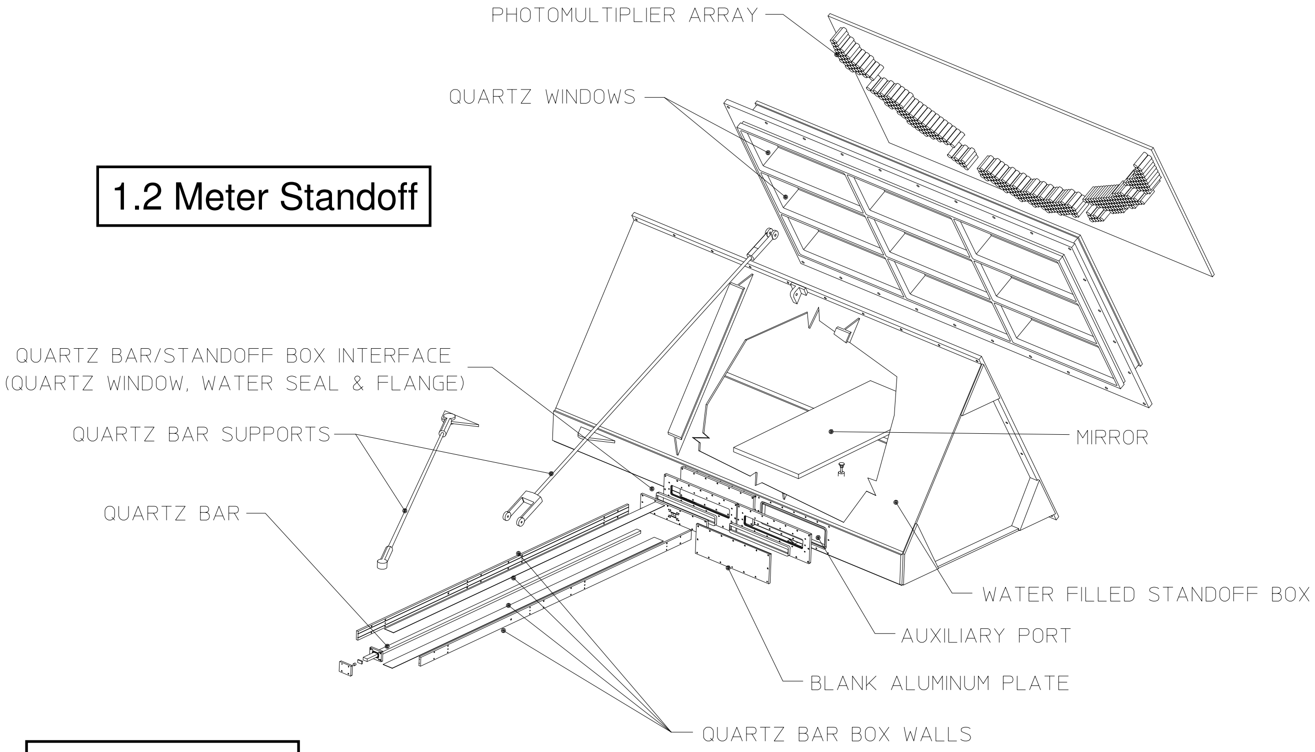
For example, $B^0 \rightarrow \pi^+\pi^-$ must be distinguished from $B^0 \rightarrow K^+\pi^-$ in order to measure the CKM mixing matrix angle α.



The Full Scale Prototype

A full scale prototype was constructed to refine the performance estimates and to study system engineering. The prototype has a single half-length bar connected to a water filled standoff box.

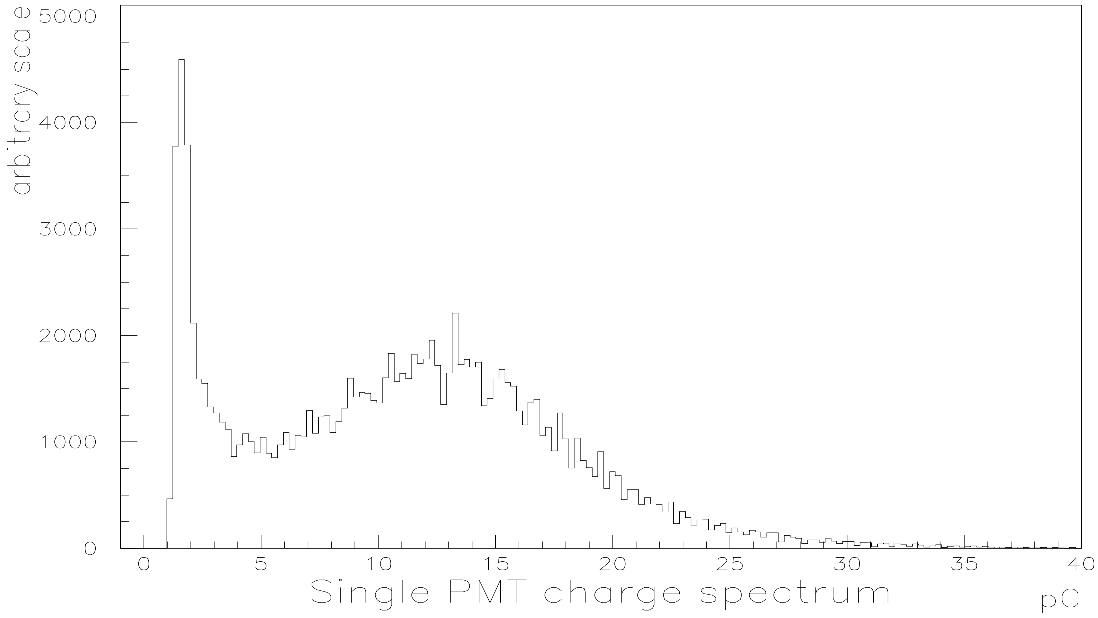
1.2 Meter Standoff



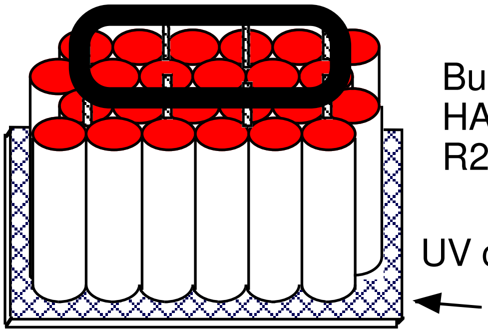
2.4 Meter bar

The Phototubes

Hamamatsu R268 phototubes were chosen because of their small size, their high quantum efficiency, and their ability to detect single photons. These were run above the manufacturers specified voltage limit without any problems.



Phototubes were bundled into groups of 24 to facilitate the electronics connections and moving the tubes.



Bundle of 24
HAMAMATSU
R268 phototubes

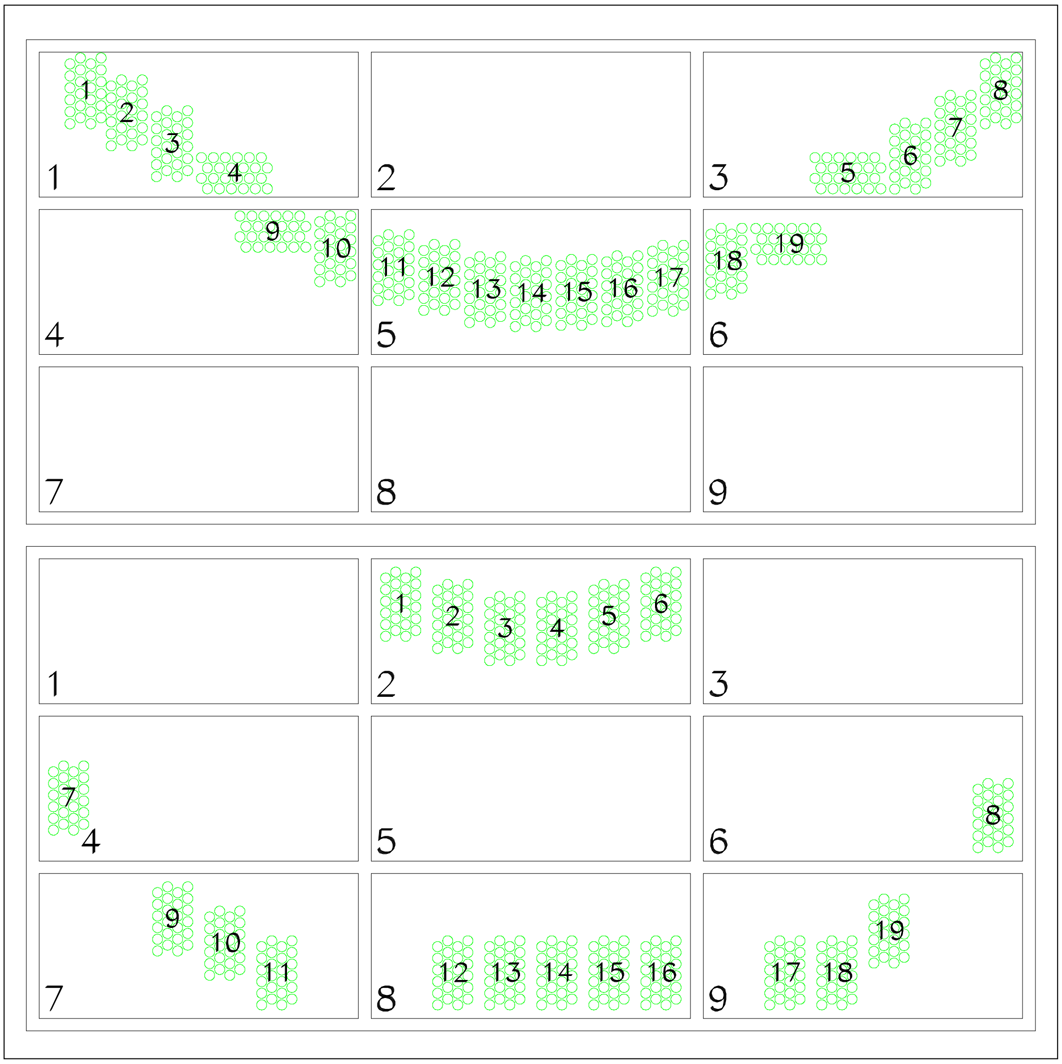
UV clear RTV mat

Diameter = 2.8 (2.5 active) cm
Length = 11.2 cm
<Eq> = 0.29
<Risetime> = 8 nSec
RMS(T) = 1.7nSec

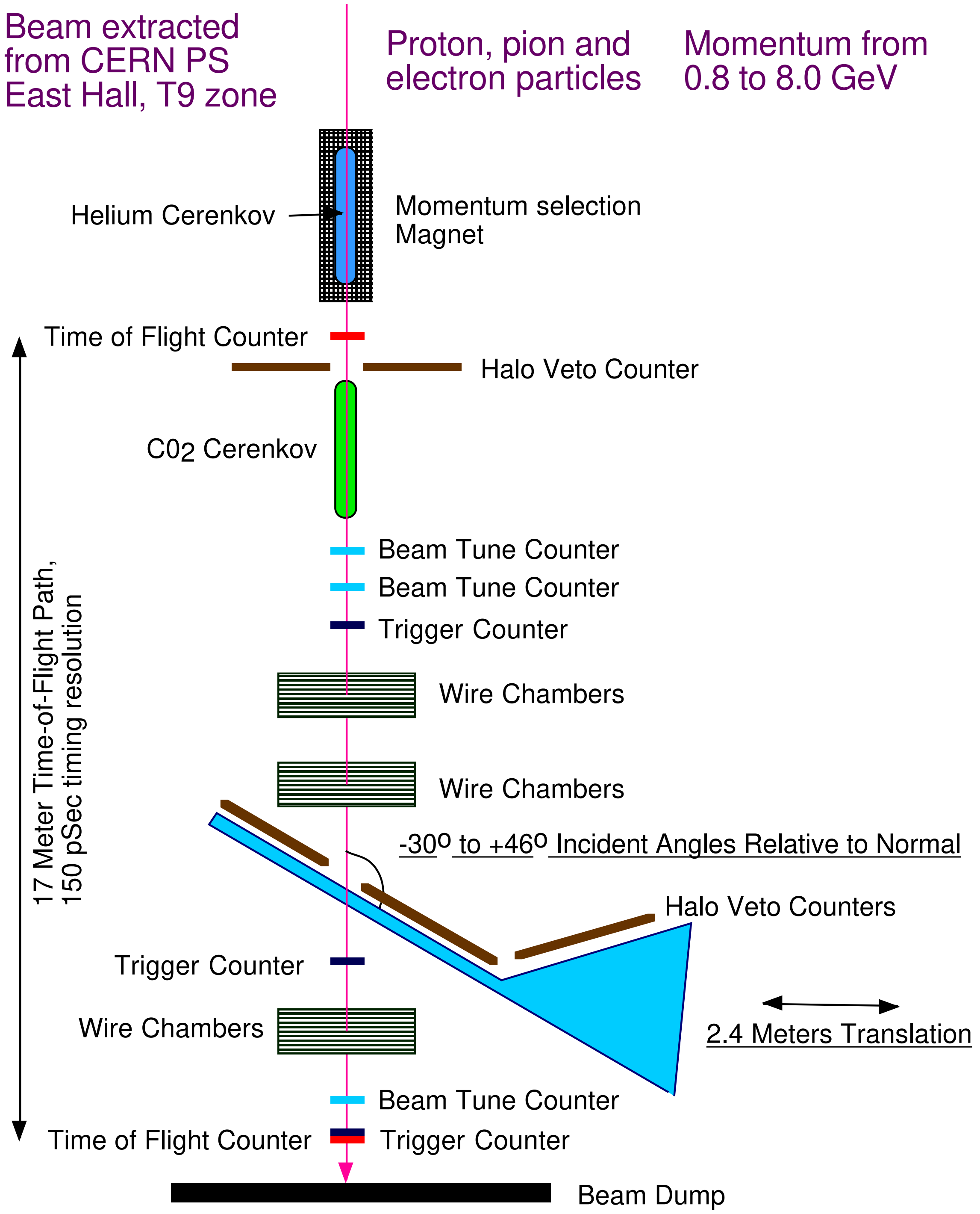
The Image Plane Instrumentation

Only 500 phototubes were available for the tests. These were moved to cover different rings corresponding to different particle incident angles.

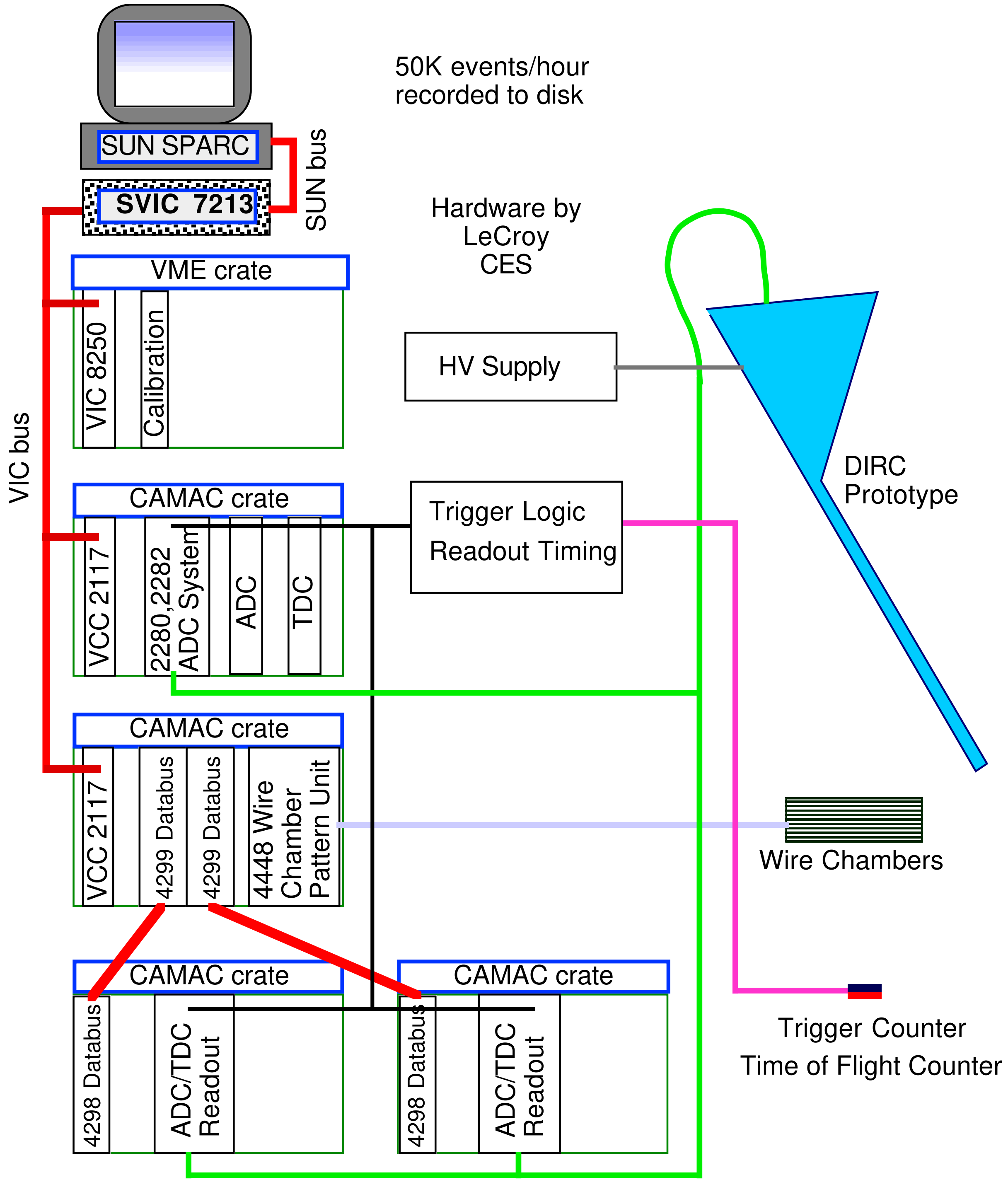
DIRC Prototype II - Bundle Layouts



CERN Test Beam Setup

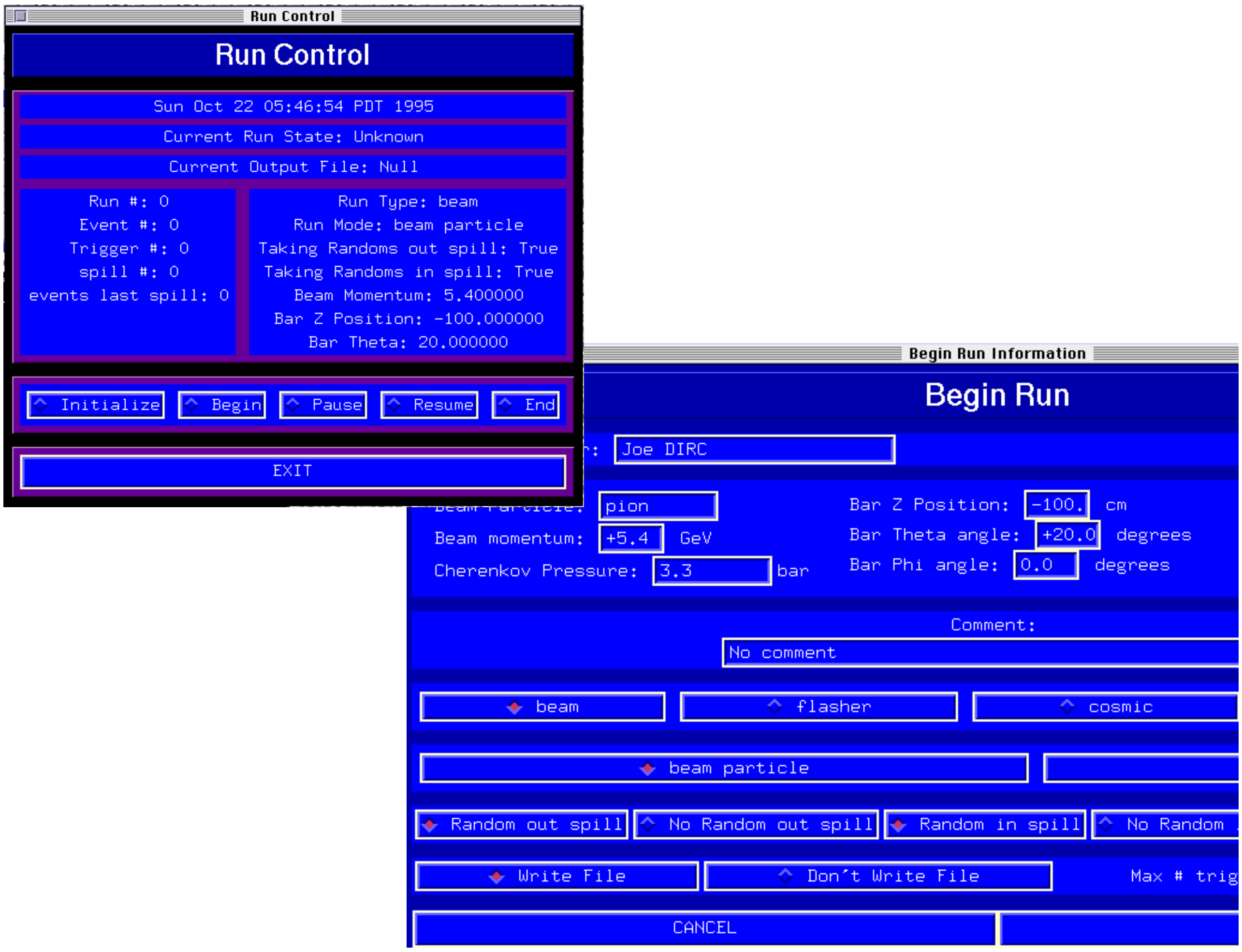


CERN Test DAQ Hardware



CERN Test DAQ Software

- Custom DAQ written in C and Tcl/Tk
- GUI
- Run status incorporated in the control panel



The Data Sample

A brief cosmic ray run was conducted at LBNL in May 1995 to commission the detector.

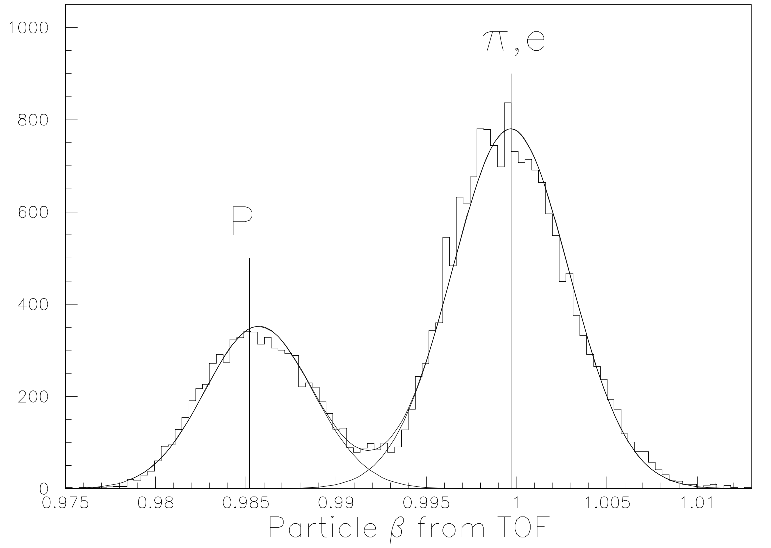
- The assembly procedure was developed
- The electronics and the software were debugged
- Rings were observed
- The observed photon yield was close to expected

Three running periods at CERN in June and August allowed us to accumulate over 5 million events, including;

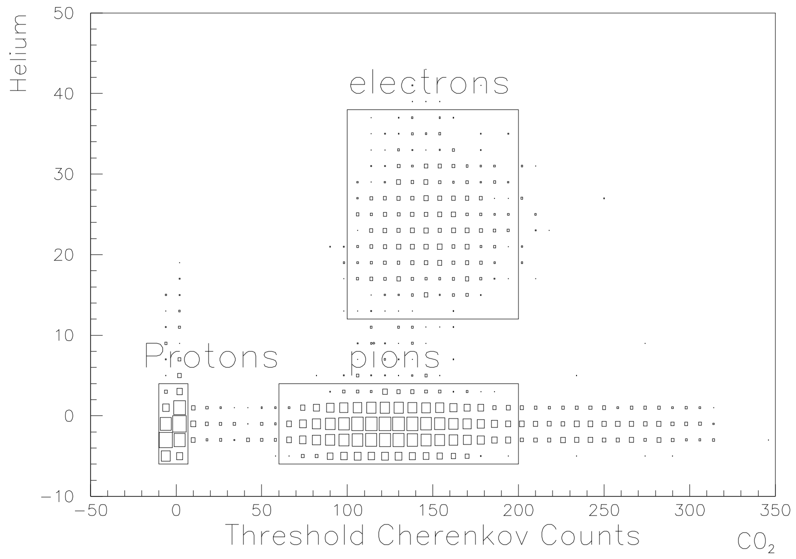
- Scans along the length of the bar at -20^{o}, 0^{o},$+20^{o}$ and $+46^{o}$ incident angles.
- Momentum scans from 0.8 GeV to 8.0 GeV
- Special optimization runs
  - Mirror inclination angle scans
  - HV scans
  - Background studies

Support System Performance

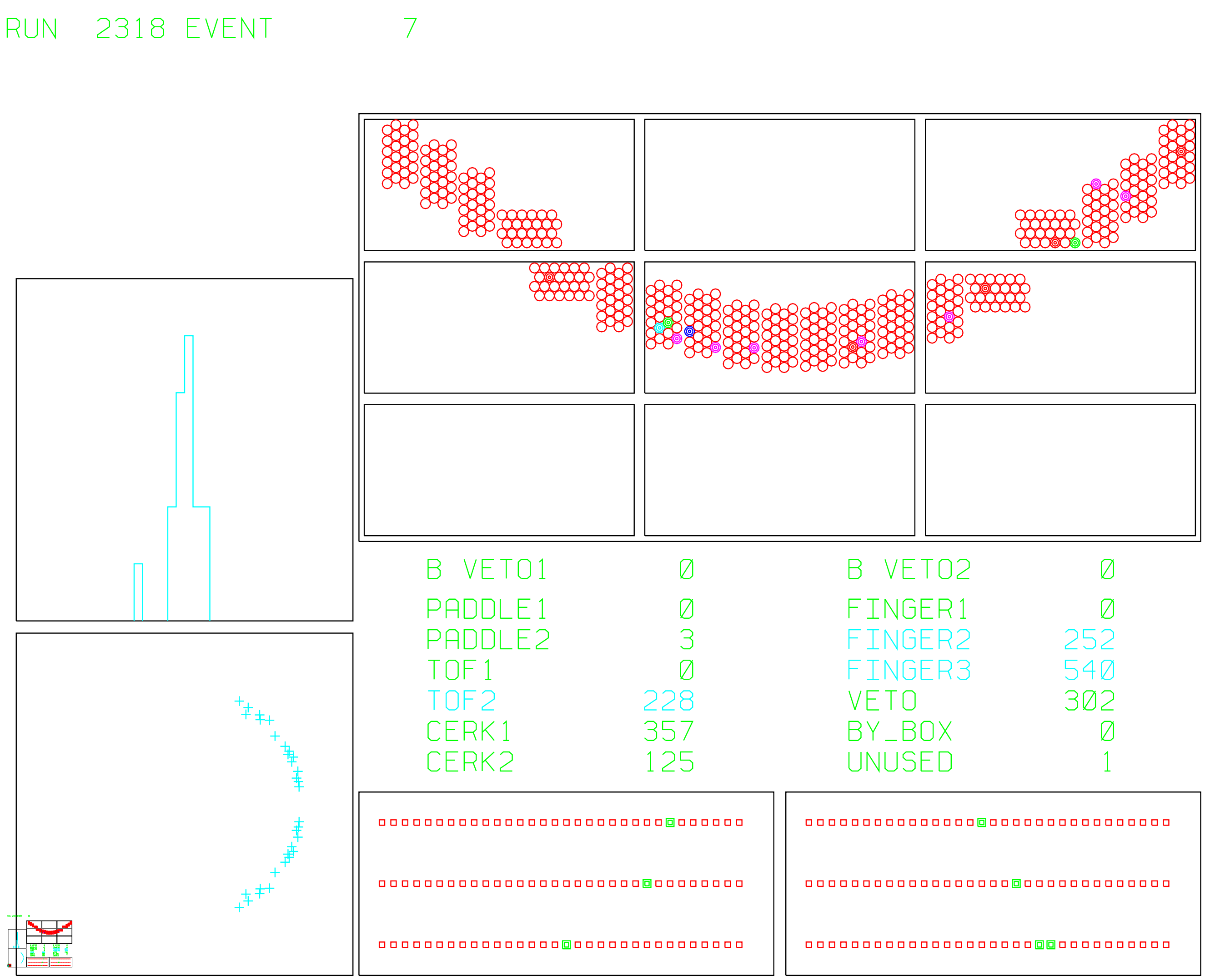
The prototype tests relied on external systems for particle identification, tracking, and background reduction. These systems performed well.



5.4 GeV
Momentum

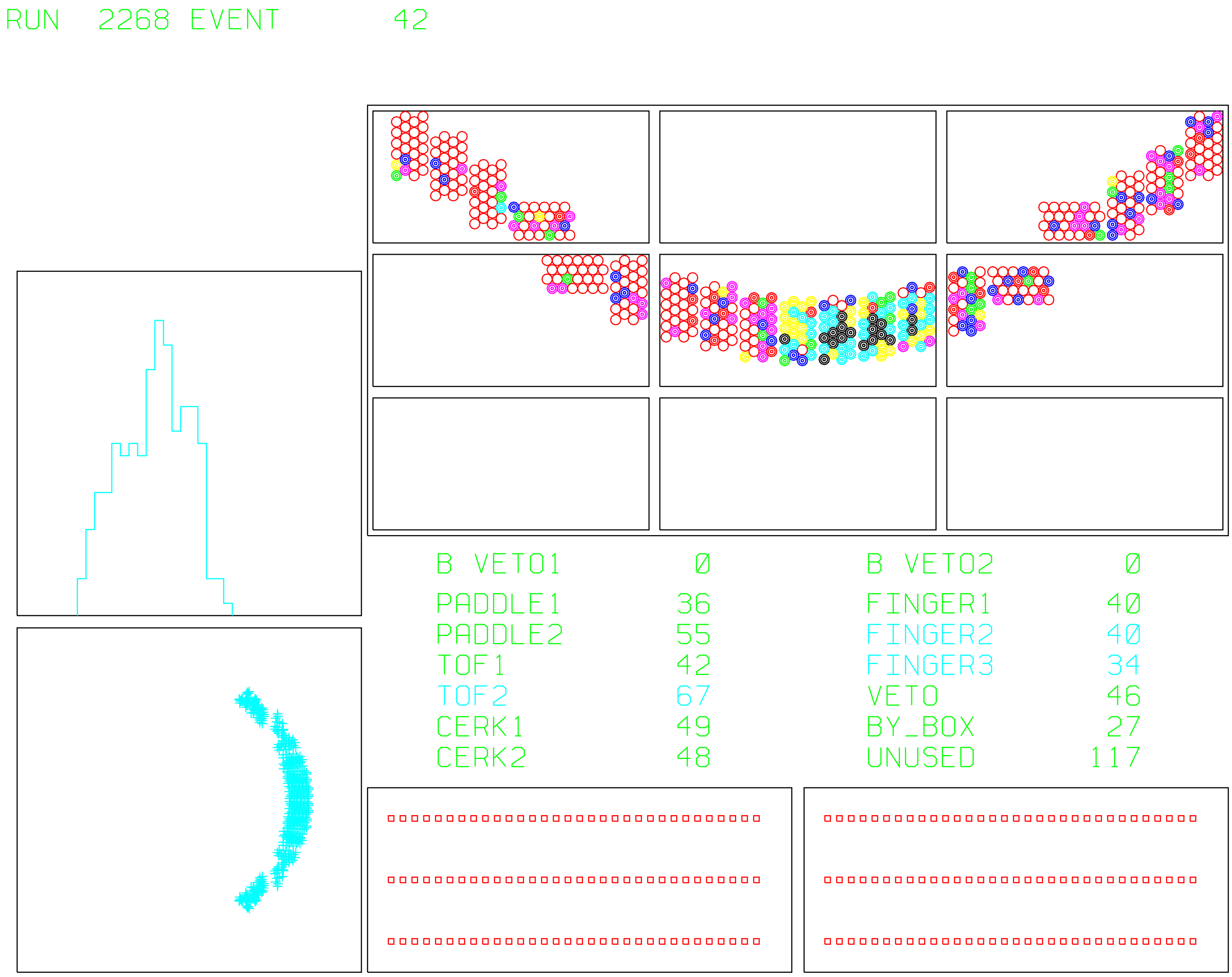


A 'Typical' DIRC Prototype Event



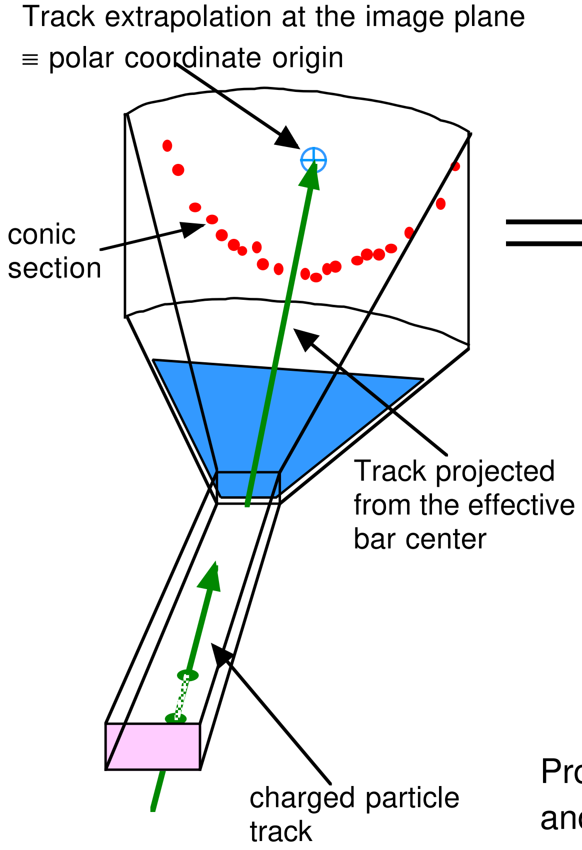
A Background Event

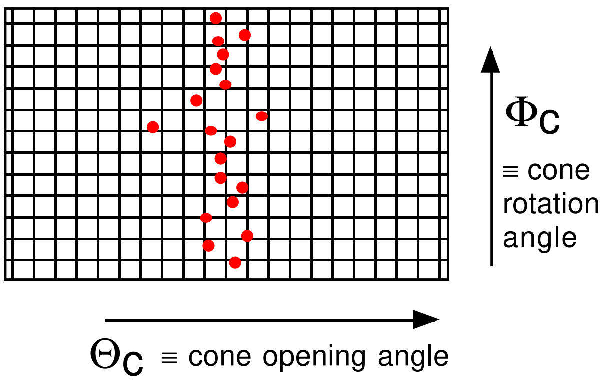
We observed backgrounds coming from beam halo. These were mostly eliminated by cuts on veto counters, and requiring the number of hits in the DIRC to be reasonable.



Analysis Technique

The hits are transformed into `Cerenkov Angle Space' using the track extrapolation and momentum.

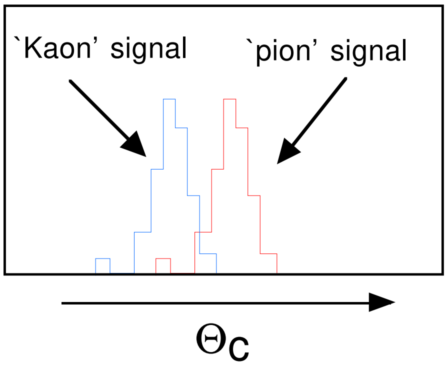




$$\Theta_C = \mathrm{Cos}^{-1}(1/n\beta)$$

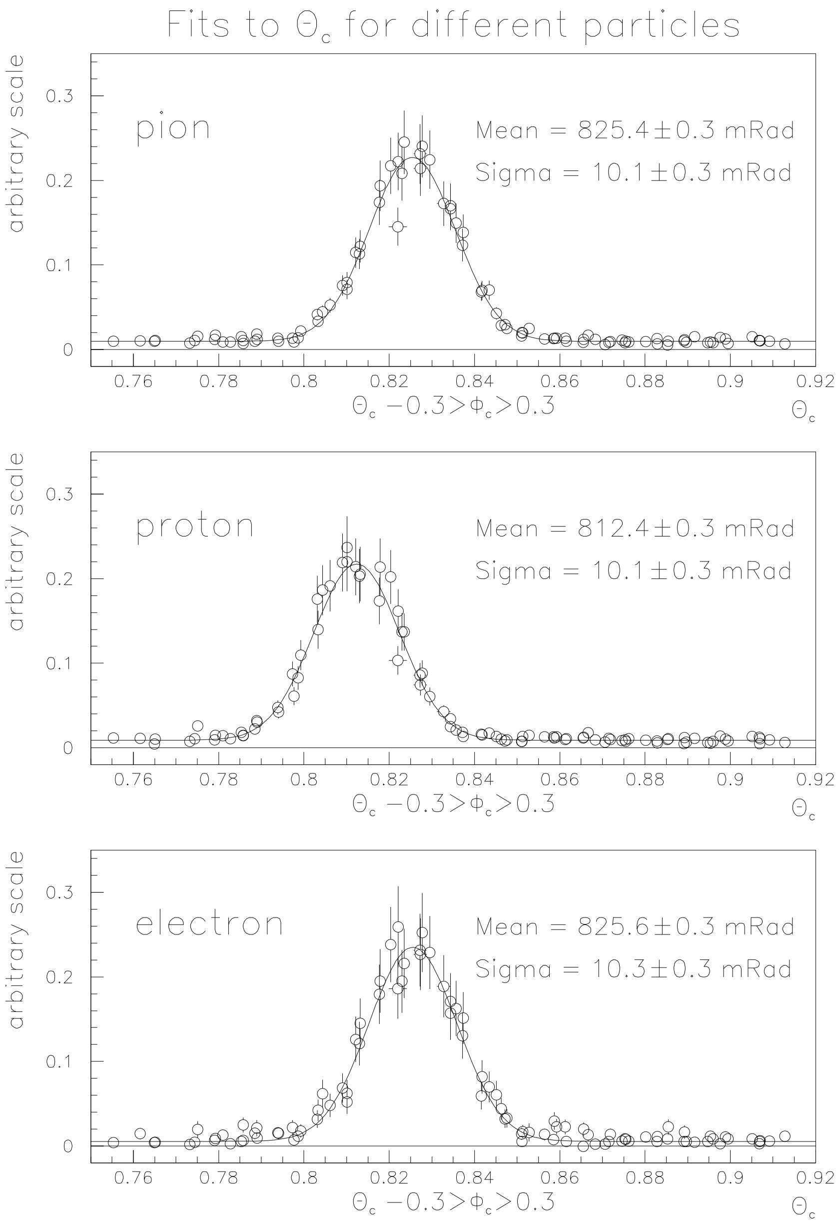
Project onto Θ_C axis and histogram

This technique will also be used for pattern recognition in the real device.



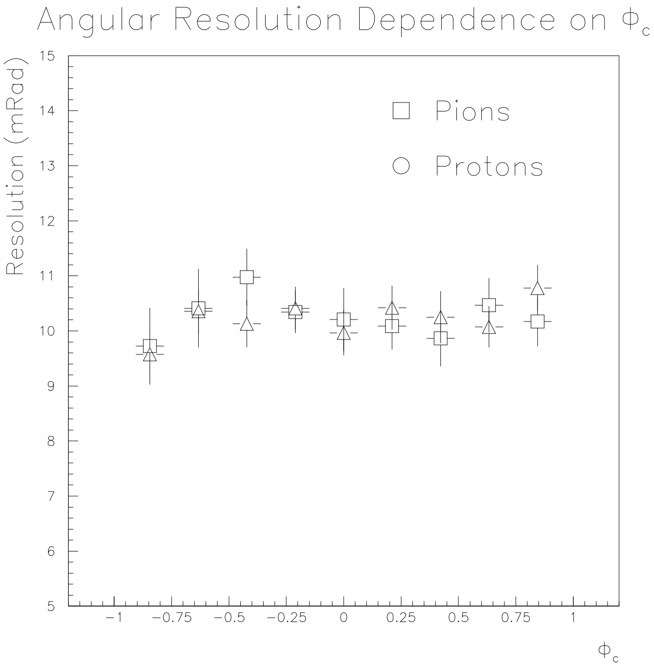
Single Photon Angular Resolution

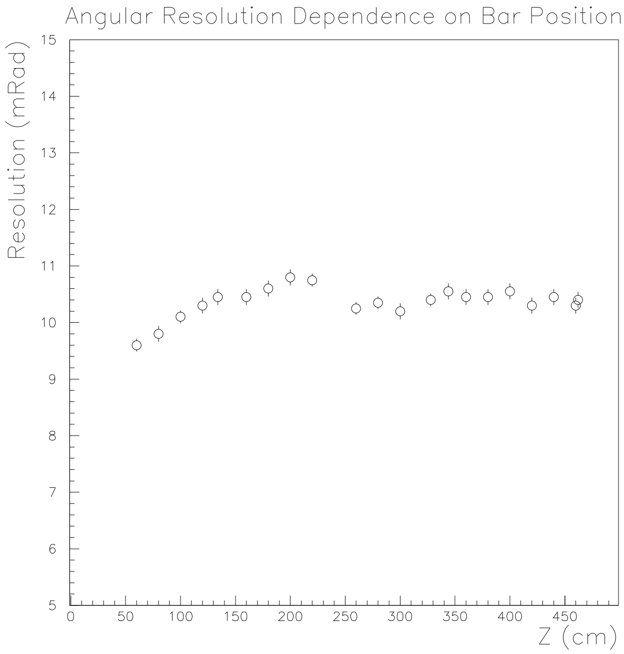
The single photon angular resolution was measured to agree with expectations.



Single Photon Angular Resolution (2)

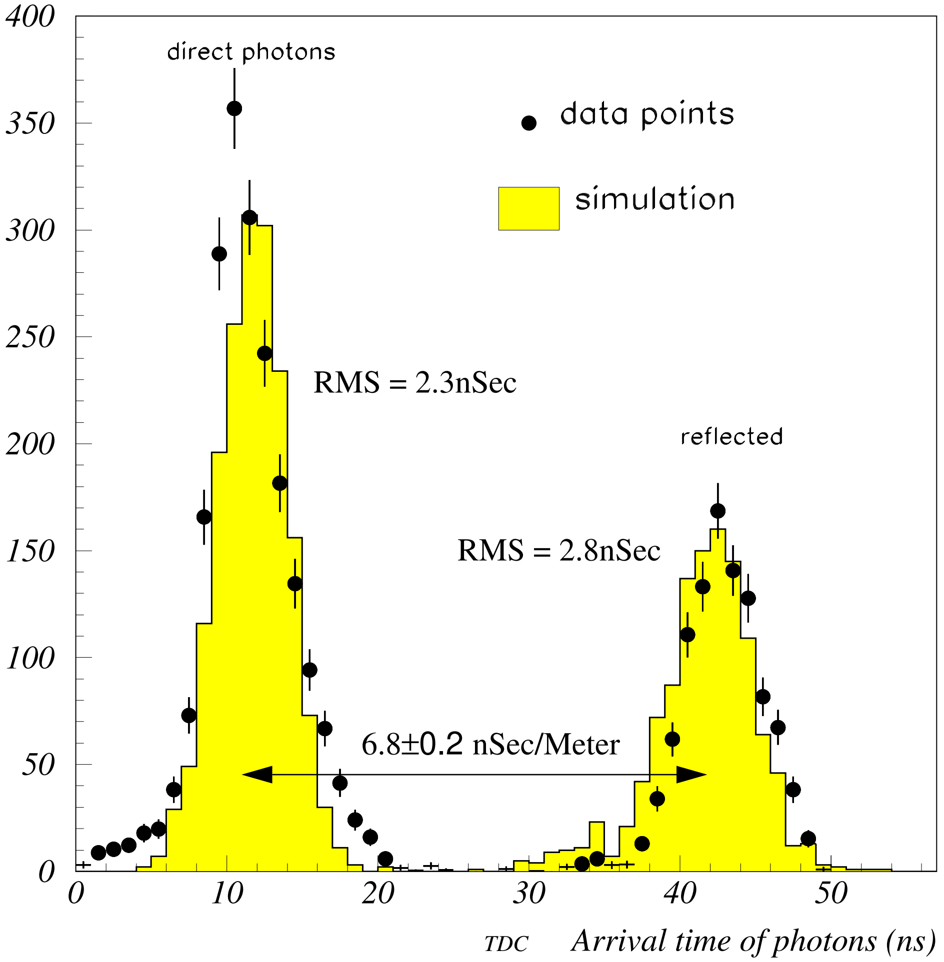
The resolution dependence on position along the bar or with Φ_c was roughly constant, as expected.





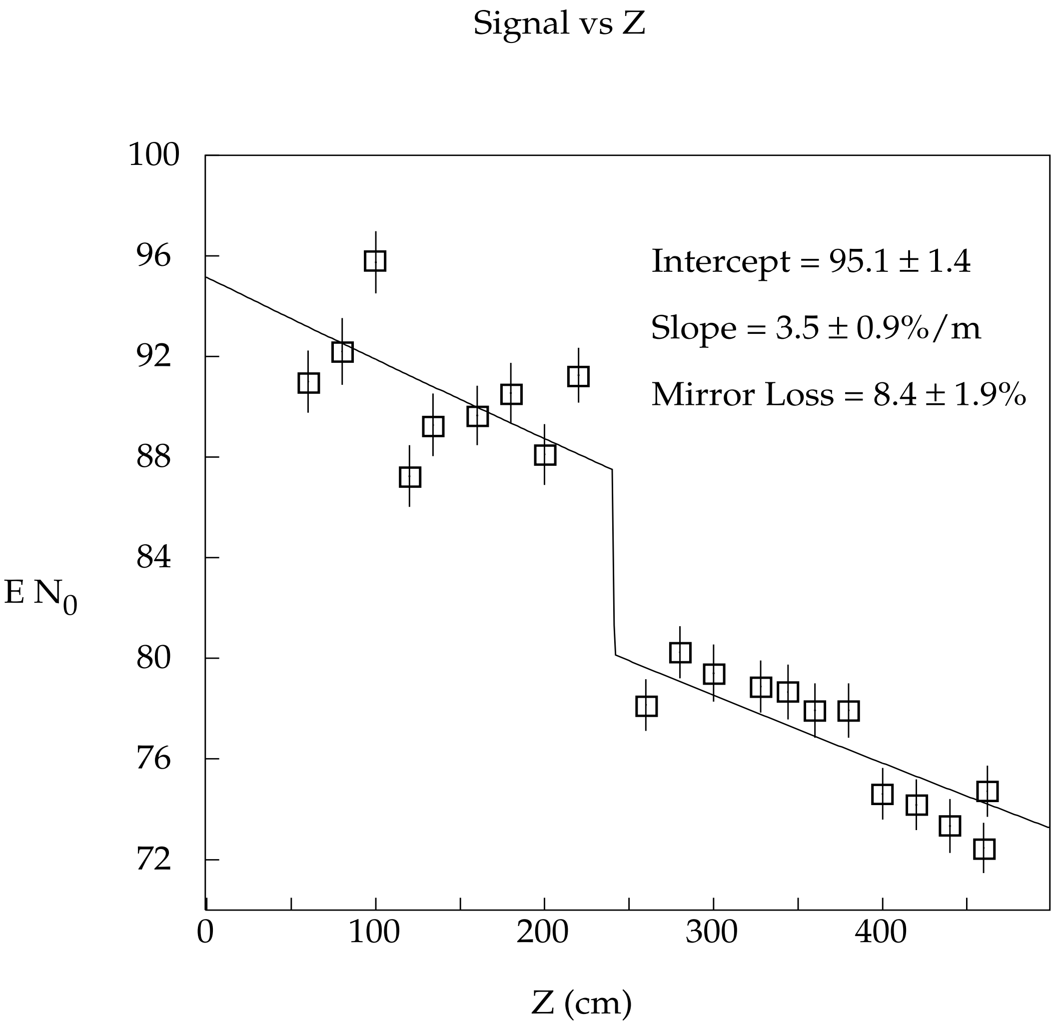
Timing Resolution

Some phototube bundles were equipped with combined TDC/ADC readout electronics. At 0^{o} incidence, we expect two separate arrival time peaks, one from direct, the other from reflected photons. These runs permit us to determine the timing resolution. Timing will be used to reduce backgrounds and help pattern recognition in the real detector.



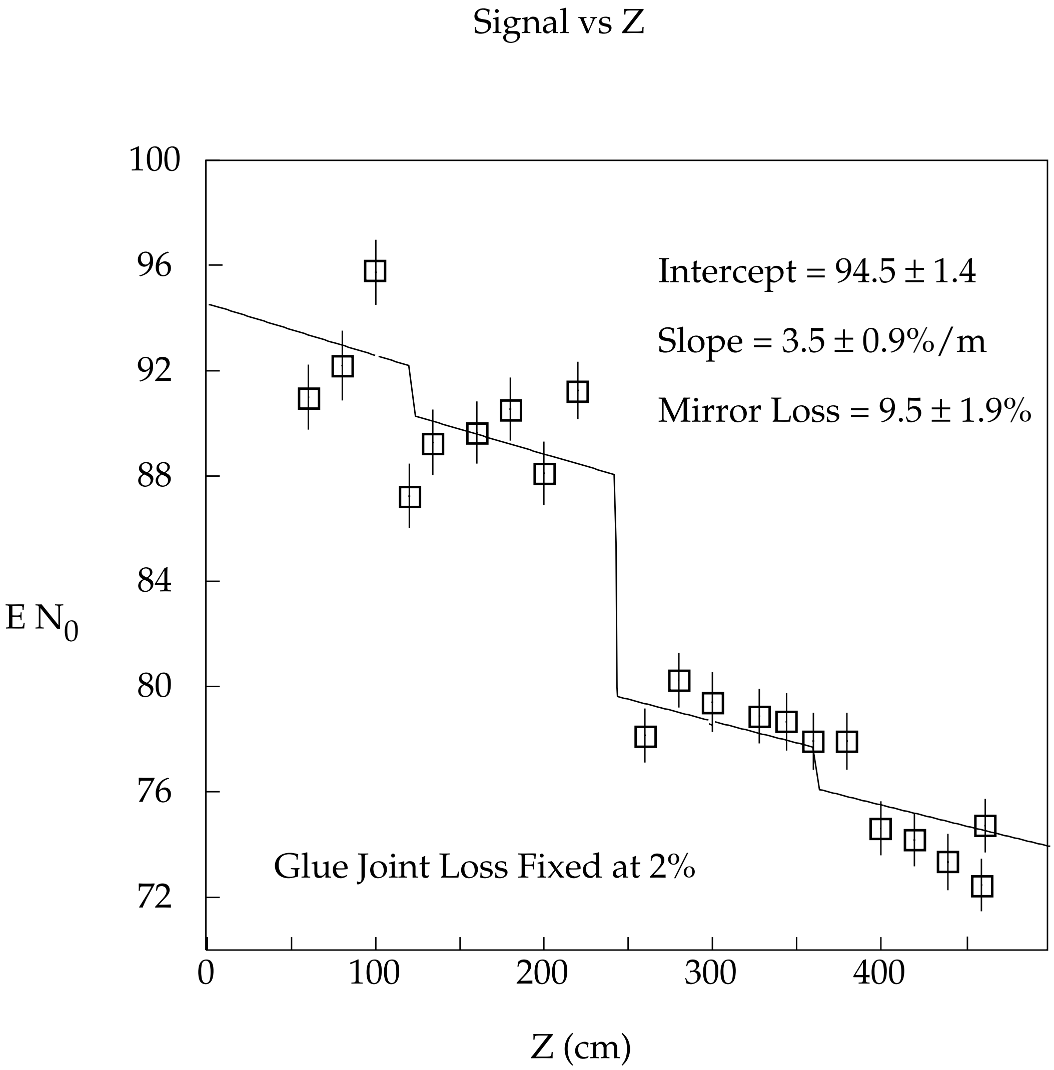
Photon Detection Efficiency

The photon yield was measured with data from the length scan at 20^{o}. We observed an N_0 of 95 and an overall attenuation of 3.5% per meter. The overall photon yield exceeds the value used to estimate the performance of the Babar DIRC in the Babar Technical Design Report.



Photon Detection Efficiency (2)

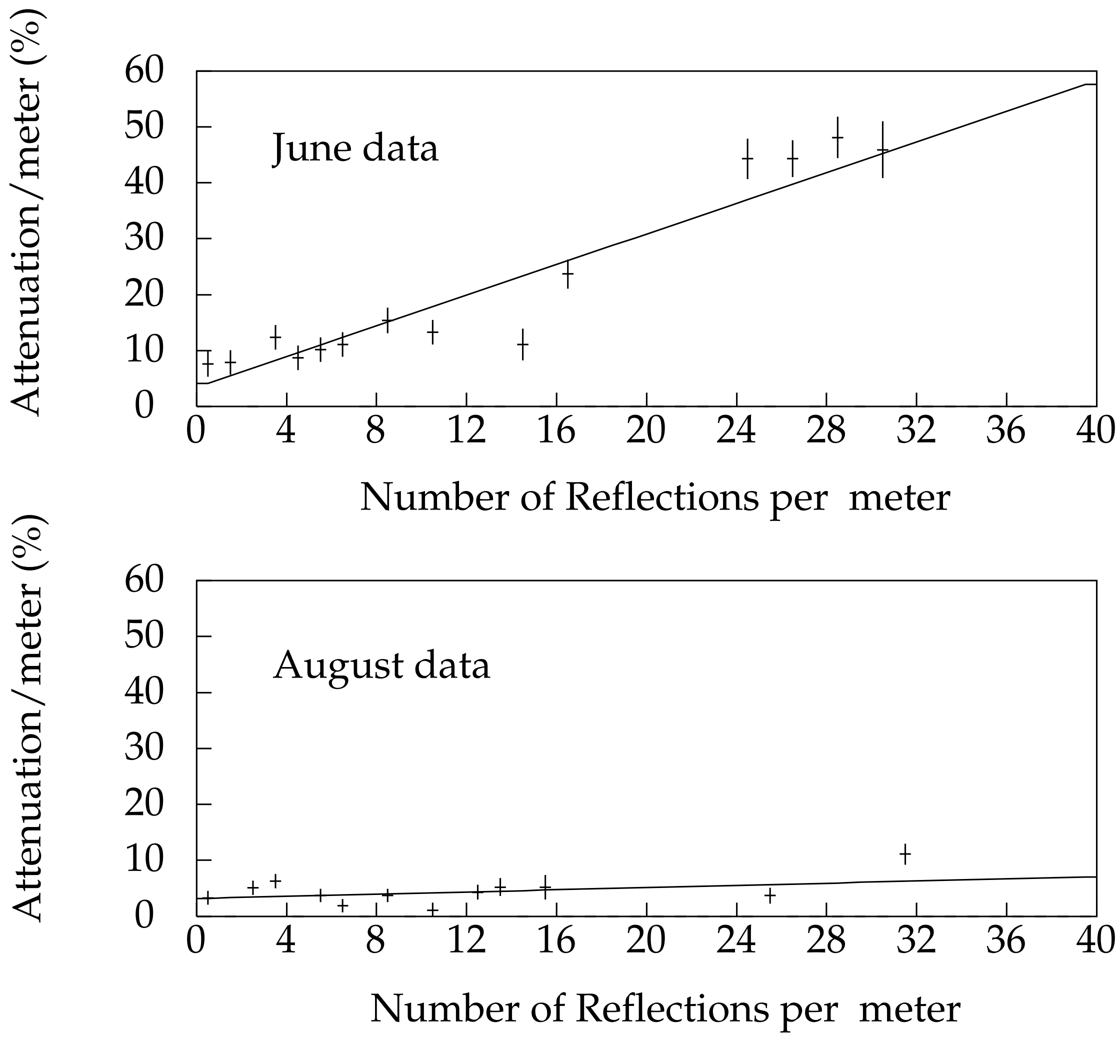
A fit including the estimated 2% loss at the glue joint was also performed.



Photon Detection Efficiency (3)

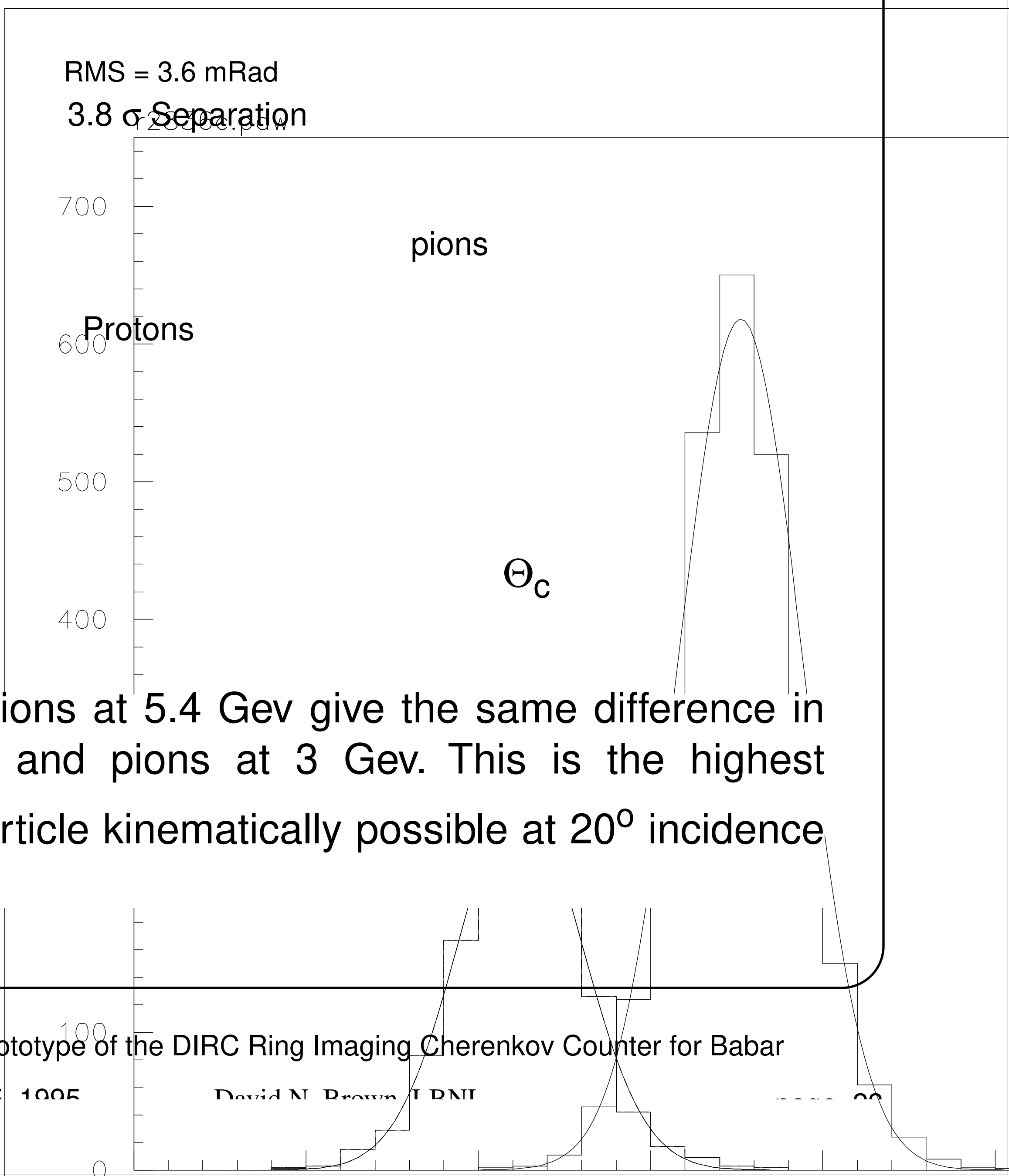
Runs in June indicated a strong dependence of the attenuation on Φ_c. Cleaning the sides of the bar eliminated this effect in August.

Attenuation per meter vs Number of Reflections at Side of Bar



Particle Identification

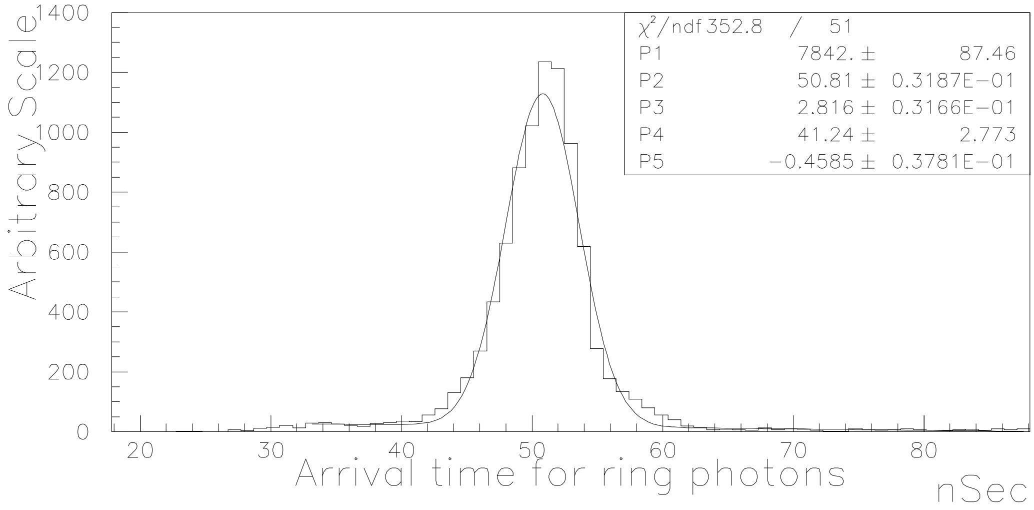
By fitting each event to a Cherenkov ring plus background, an average Θ_c is obtained. Comparing the distribution of this value for identified Protons and pions gives the particle separation power of the prototype.

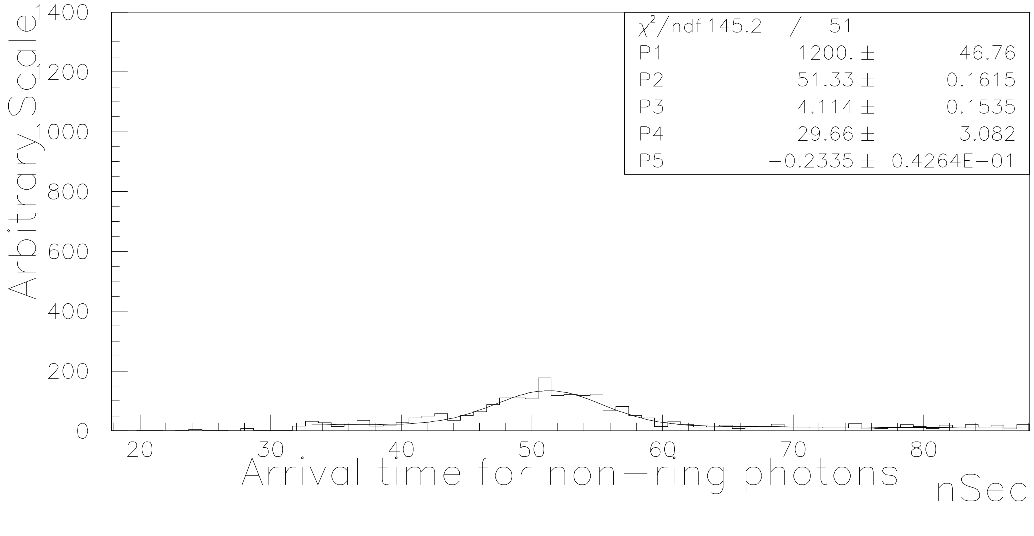


Protons and pions at 5.4 Gev give the same difference in Θ_c as Kaons and pions at 3 Gev. This is the highest momentum particle kinematically possible at 20^o incidence at Babar.

Background Composition

Most of the background observed with the prototype comes from beam halo. Some light outside the cerenkov ring appears to originate from the trigger particle, and arrives at the image plane in time with the cerenkov photons. The source of this ’background’ is still being studied.





Future Tests

Further tests are planned for the near future.

- Testing 2 quartz bars mounted side-by-side.
- Rotating the prototype in the azimuthal direction.
- Mounting phototubes directly in the water (this should increase the transmission efficiency by ~10%).

Conclusions

- A Large Scale Prototype of the Babar DIRC has been Successfully Tested in a CERN Particle Beam.
- The Ancillary Test Systems Performed Well.
- A Large Amount of Data was Accumulated Under Various Running Conditions. The Major Test Results are;
  - Angular Resolution of 10.1 ± 0.3 mRadians.
  - Time Resolution of 2.2 ± 0.1 nSeconds.
  - No Dependence of Resolution on Position Along the Bar or Around the Ring.
  - $N_0 = 95.1 \pm 1.4$
  - Attenuation = $3.5 \pm 0.9\%$
  - Average Photon Efficiency Above Expectations.
- Further Tests are In Progress.
- Engineering of the Babar DIRC is Well Underway.