BTeV RICH

Orlokh Dorjkhaidav, on behalf of BTeV RICH group, Syracuse University, LP2003

The BTeV Program

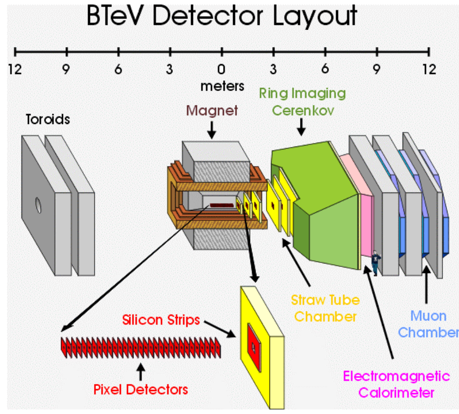
•The BTeV experiment is designed to challenge the Standard Model explanation of CP violation, mixing and rare decays of beauty and charm quark states. The Standard Model has been the baseline particle physics theory for several decades and BTeV aims to find out what lies beyond the Standard Model. In doing so, the BTeV results will also shed light on phenomena associated with the early universe such as why the visible universe is made up of matter and not anti-matter.

• BTeV is a forward spectrometer.

• It is designed to search for physics beyond Standard Model and make precise measurements of SM parameters:

- CP violation in B^o , B_s and D^o mesons
- B_s mixing
- Rare b decays.

A window to new physics



Advantages of the Tevatron as a source of *b* & *c* quarks.

Large samples of b quarks are available:

•B cross section is ~100μb at 2 TeV resulting in ~4x10^{11} b hadrons per 10^7 sec at luminosity of 10^{32} cm^{-2} s^{-1} . In comparison e^+e^- machines at the Y(4S) with a luminosity of L = 10^{34} cm^{-2} s^{-1} produce only **~2x10^8** B's per 10^7 s (2000x fewer per 10^7 s !).

•B_s , B_c & b-baryons are produced at hadron machines but not at e^+e^- machines operating on the Y(4S).

•Lots of charm hadrons also produced.

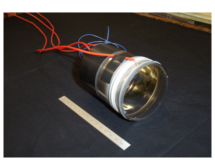
For the luminosity of 2fb^{-1} BTeV will perform "clean measurements" for the CKM matrix phases with the following precision.

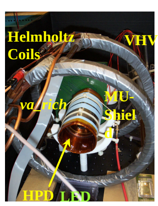
Physics quantity	Decay mode	Error on Angle
sin(2χ)	$B_s \to J/\psi\eta'$, $J/\psi\eta$	0.7°
sin(2β)	$B^o \to J/\psi K_s$	0.7°
	$B^o \to \varphi K_s$	4.5°
sin(2α)	$B^o \to \rho\pi \to \pi^+\pi^-\pi^o$	4°
sin(γ)	$B_s \to D_s K^-$	8°

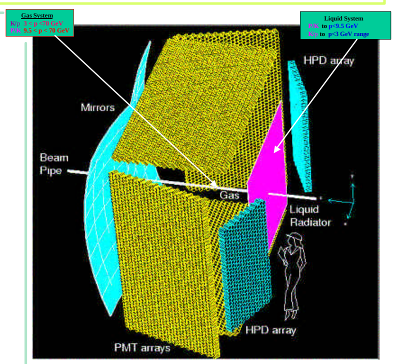
BTeV RICH

The BTeV RICH is a state-of-the-Art detector. It consists of two separate systems. The first one has a 3m long C_4F_{10} gas radiator with the Cherenkov photons detected either on Hybrid PhotoDiodes (HPD) or multianode photomultiplier tubes (MAPMT) after focusing on a low mass mirror. The second system consists of a 1cm thick liquid C_5F_{12} radiator with the Cherenkov photons detected on 3" diameter photo-multiplier tubes; this system is used mainly to separate kaons from protons up to 9 GeV/c. The primary system is capable of separating kaons from pions up to 70 GeV/c, electrons from pions up to 22 GeV/c and muons from pions up to 17 GeV/c.

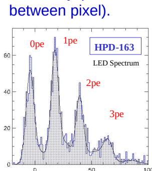
HPD planes, light blue on the right sketch, cover a total area of 13.15 m^2 with an active area of 62%. Since the RICH is in the fringe field of the detector magnet some additional shielding is needed.





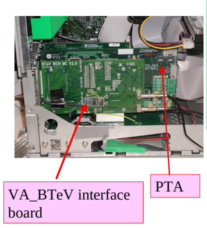


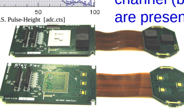
The HPD is designed to have sensitivity to single photoelectrons, a large active area (>80%), fast response time, highly linear response (with gain vs. HV), good uniformity (<10% variation), and low crosstalk (<2% between pixel).

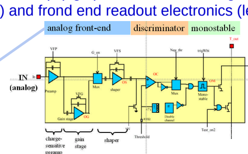


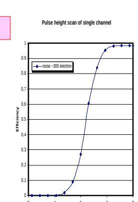
The pulse-height spectrum obtained for a single channel of the BTeV HPD with VA-RICH (analog) readout is presented on the left. One can see the clear separation between photoelectron peaks. In BTeV, the RICH readout will be binary. A new generation of VA chip family adapted to this purpose has been produced (VA-BTEV).

The experimental setup (right), schematic of a single channel (below) and frond end readout electronics (left) are presented.







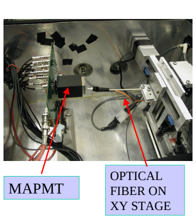


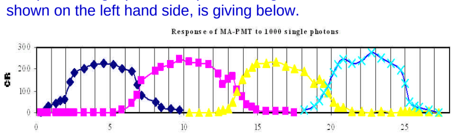
VA_BTeV has fast peaking time of ~100 ns, appropriate for the bunch spacing of the Tevatron. Since each chip has 64 channels a HPD hybrid requires three chips. As can be seen in the picture of the front end electronics, the analog part is well isolated from the digital board via a flex cable. In this configuration one achieves a noise of ~ 500 electrons as can be seen on the pulse height scan to the right.

Main features of HPD.
•163 channels (pixel size ~5.5 mm^2).
• 20 kV accelerating potential → 5000 e$^-$ signal in silicon.
• Electronics are external to tube.

As an alternative to the HPD we are studying the MAPMT R8900 from Hamamatsu, whose dynode structure is transversely segmented creating many independent channels within a single PMT enclosure. The device has 85% active area in a 25.7 mm by 25.7 mm tube.

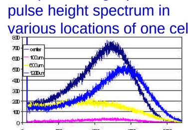
The plot of single photon response along the face of the MAPMT, done using the experimental setup shown on the left hand side, is giving below.





The test setup for Multianode PMT (MAPMT)

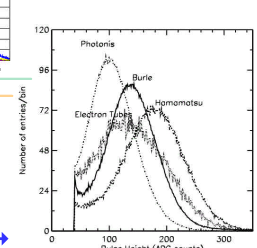
The plot of single photon pulse height spectrum in various locations of one cell.



Main features of MAPMT.
•16 channels
• Moderate voltage required. (HV ~ 1000V)
• Can be close packed.
• low sensitivity to external magnetic field.

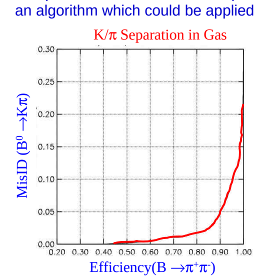
Cherenkov photons generated in the 1 cm thick liquid radiator pass through the quartz window and travel at large angle toward PMT arrays. The PMTs are tilted to match the average angle of incidence of photons and cover the most illuminated portions of the two RICH side walls, as well as top and bottom walls. With this system we expect to get ~12-13 photo-electrons per track, resulting in a per-track resolution of 1.88 mrad.

The single photoelectron (SPE) pulse height spectra for the PMTs are presented on the right. All tubes show a reasonably well defined peak to valley ratio, resulting in good SPE resolution.



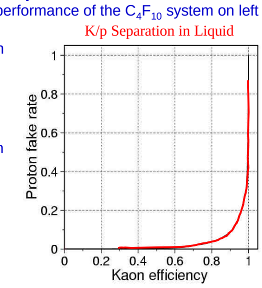
Particle Identification

The performance of the RICH is presented in these plots where we have analysed Monte Carlo simulated data with an algorithm which could be applied to real data. As an illustration of the performance of the C_4F_{10} system on left we show a simulation of $B_d \to K\pi$ background rejection as a function of $B_d \to \pi^+\pi^-$ efficiency in the gas.

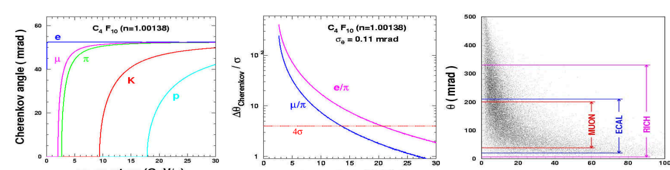


Flavor tagging is enhanced by using the liquid radiator. On the right the cross-efficiency for the identification of a proton as a kaon is plotted as a function of kaon efficiency in the liquid radiator for momenta below 9 GeV/c.

The Gas radiator will also play a significant role in lepton identification as electrons below 22 GeV/c and muons below 15 GeV/c are separated by more than 4σ from pions.

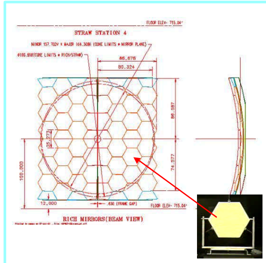


Since the RICH acceptance is much larger than calorimeter and muon systems a large gain in efficiency can be achieved (as can be seen in the following plots along with Cherenkov angle distribution vs. momentum in the gas system).



Critical roles of particle ID:

- To reduce combinatoric background *e.g.* distinguish $B^0 \to \pi^+\pi^-$ from the more copious $B^0 \to K\pi$, as well as $B_s \to K^+K^-$.
- Flavor tagging.
- Lepton identification.



A charged particle will travel through the three meter long gas radiator after passing through the liquid radiator, thus emitting Cherenkov photons in a cone. These photons are focused by the spherical mirrors onto the detection plane creating rings. The mirrors are tilted, allowing the array of HPDs to be out of the spectrometer acceptance and to be shielded by magnet.

The size of the mirror is about 4 m by 4 m in the transverse direction and consists of lightweight, hexagonal individual mirrors. The mirrors, whose prototype is on the stand in the picture above, will have superb optical quality, low radiation length and excellent uniformity of mean radius between different mirror tiles.

Mirror specs:

- Low radiation length (1-2 %).
- A spot size less than 2.5 mm per tile.
- Variance in radii of individual tiles less than 3 cm.
- A surface smoothness within 2.8 nm.
- Reflectivity more than 90 %.