BTeV Goals and Aspirations

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Overview

- Physics goals
- Detector description
- Simulation results

BTeV PTDR
http://www-btev.fnal.gov/public_documents/ptdr/ptdr.html

This talk
http://hepc06.phys.cmu.edu/~procario/talks/run2work.ps

Physics Goals

- Complete study of standard model CP violation in the B sector.
  - Expect β to be done.
  - Multiple consistent measurements of the UT phases and sides.
  - Measure γ from $B_s \to D_s^{\pm} K^{\mp}$ or $B^+ \to D^0 K^+$ and $B^+ \to \overline{D^0} K^+$.
  - Measure γ from $B^0 \to \pi^+\pi^-$ and $B_s \to K^+K^-$.
  - Measure α from a Dalitz plot analysis of $B^0 \to \rho\pi$.
  - Measure small CP asymmetry (sb triangle) in $B_s \to \psi\eta$ or $B_s \to \psi\eta'$
  - Make precision measurements of x_s and $\Delta\Gamma$ in B_s mixing.

- Rare decays to test the standard model.

- Spectroscopy, production, semileptonics, etc.

Detector Requirements

- An unbiased trigger that does not rely extensively on leptons.
  - Secondary vertex/impact parameter trigger can be used for any states with at least two charged tracks.
  - A pixel vertex detector has low enough occupancy to make such a trigger possible.

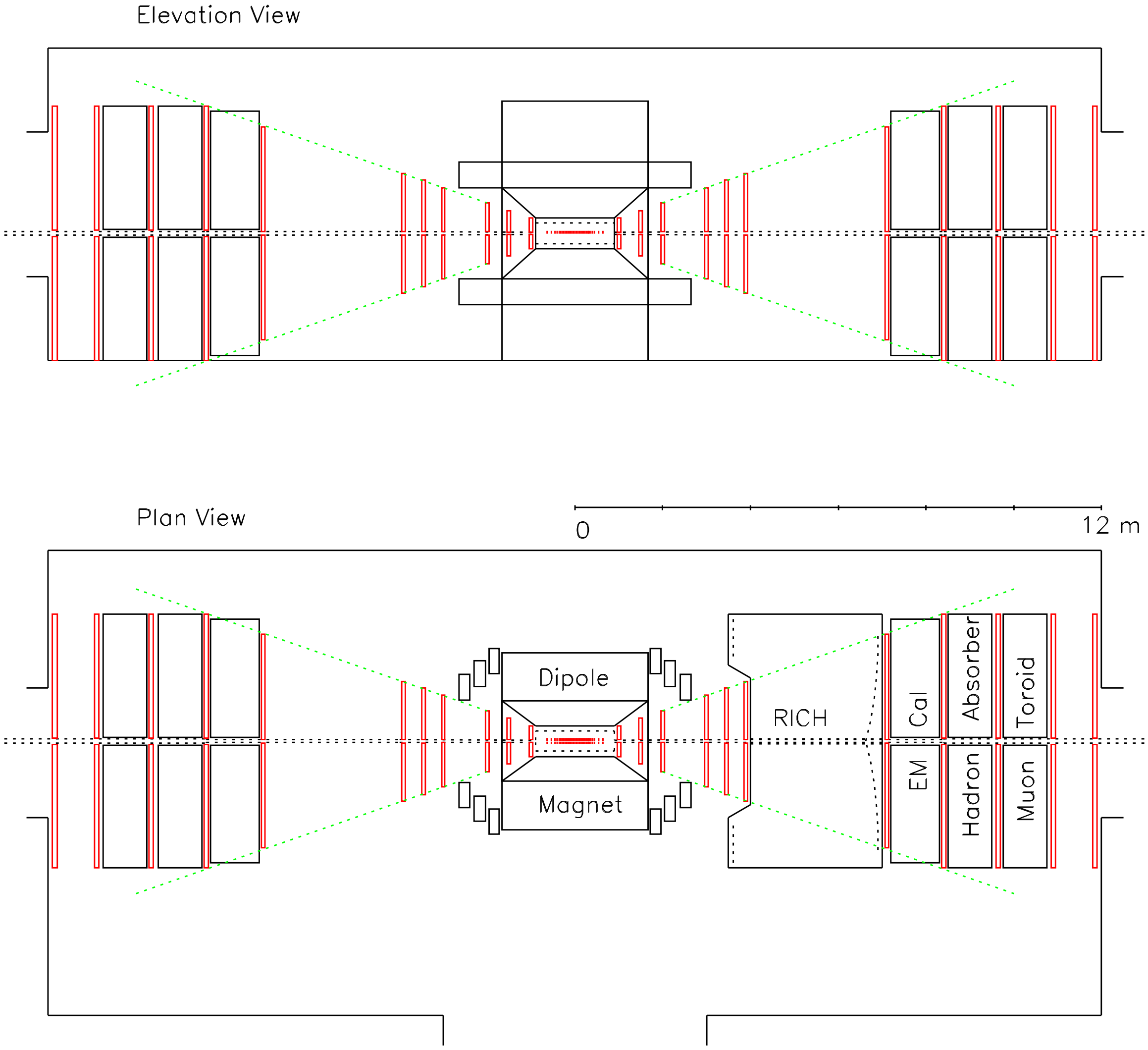
- Excellent time resolution to work with B_s oscillations.
  - A silicon pixel detector with a forward geometry solves this problem.

- Excellent particle ID for tagging and to reject background.

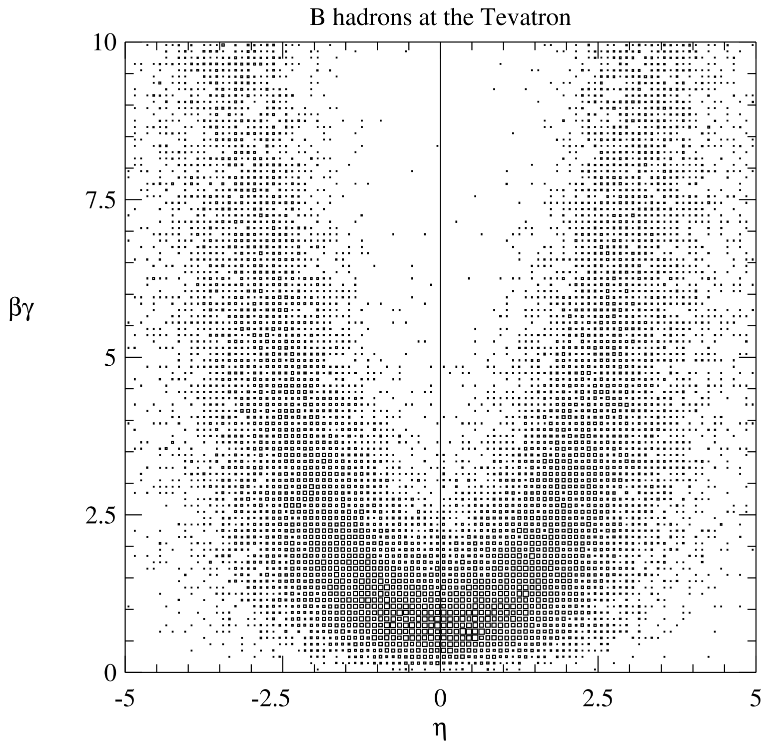
- Electromagnetic calorimeter to allow the use of states with photons, π^0's, and η's.

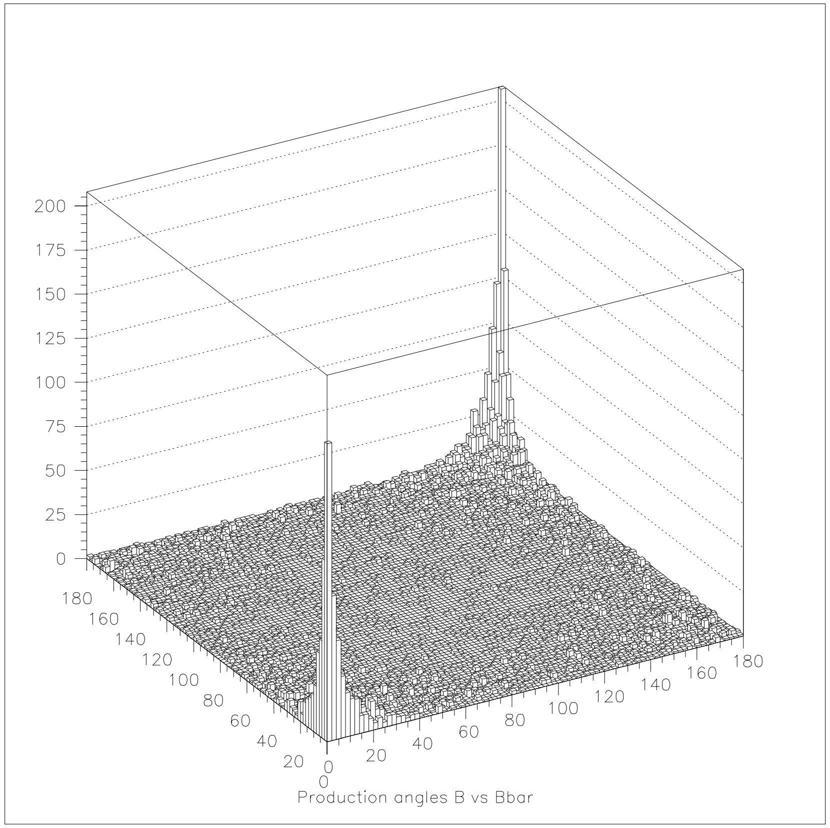
Detector Description

- Dipole magnet - two armed spectrometer
- Pixel vertex detector - level 1 vertex trigger
- Straw chambers
- RICH
- EM calorimeter
- Muon toroids


Elevation View
Plan View
0
12 m
Dipole
Magnet
RICH
Cal
EM
Absorber
Hadron
Toroid
Muon

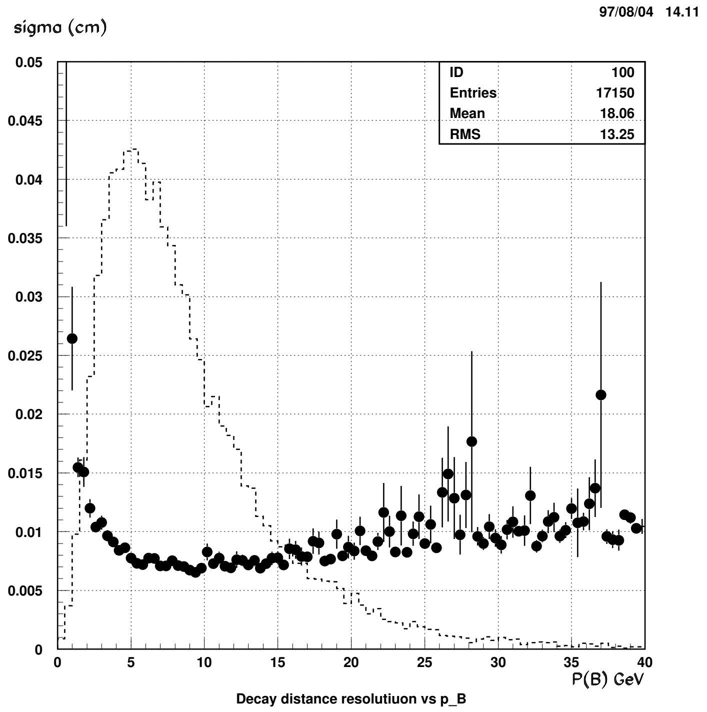
Advantages of Forward Geometry



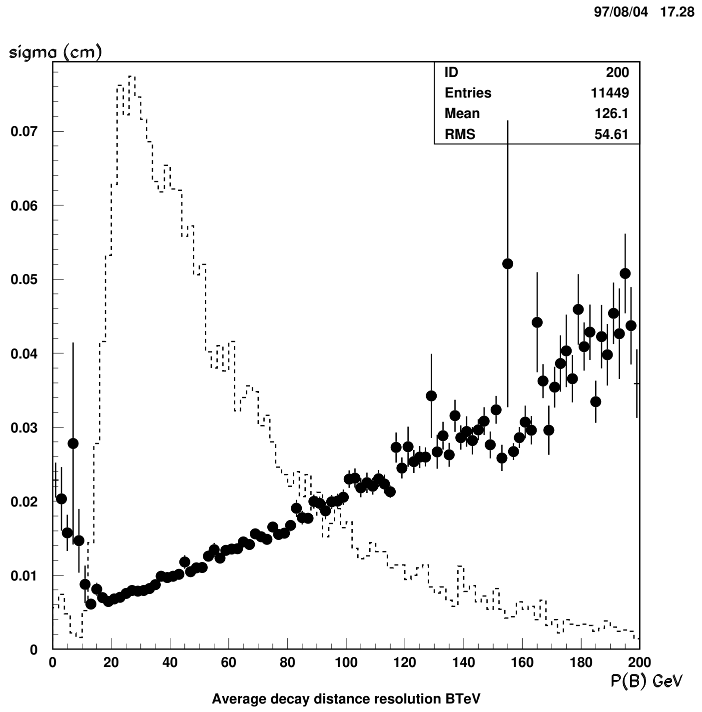


Vertex Resolution

Central Detector



Forward Detector

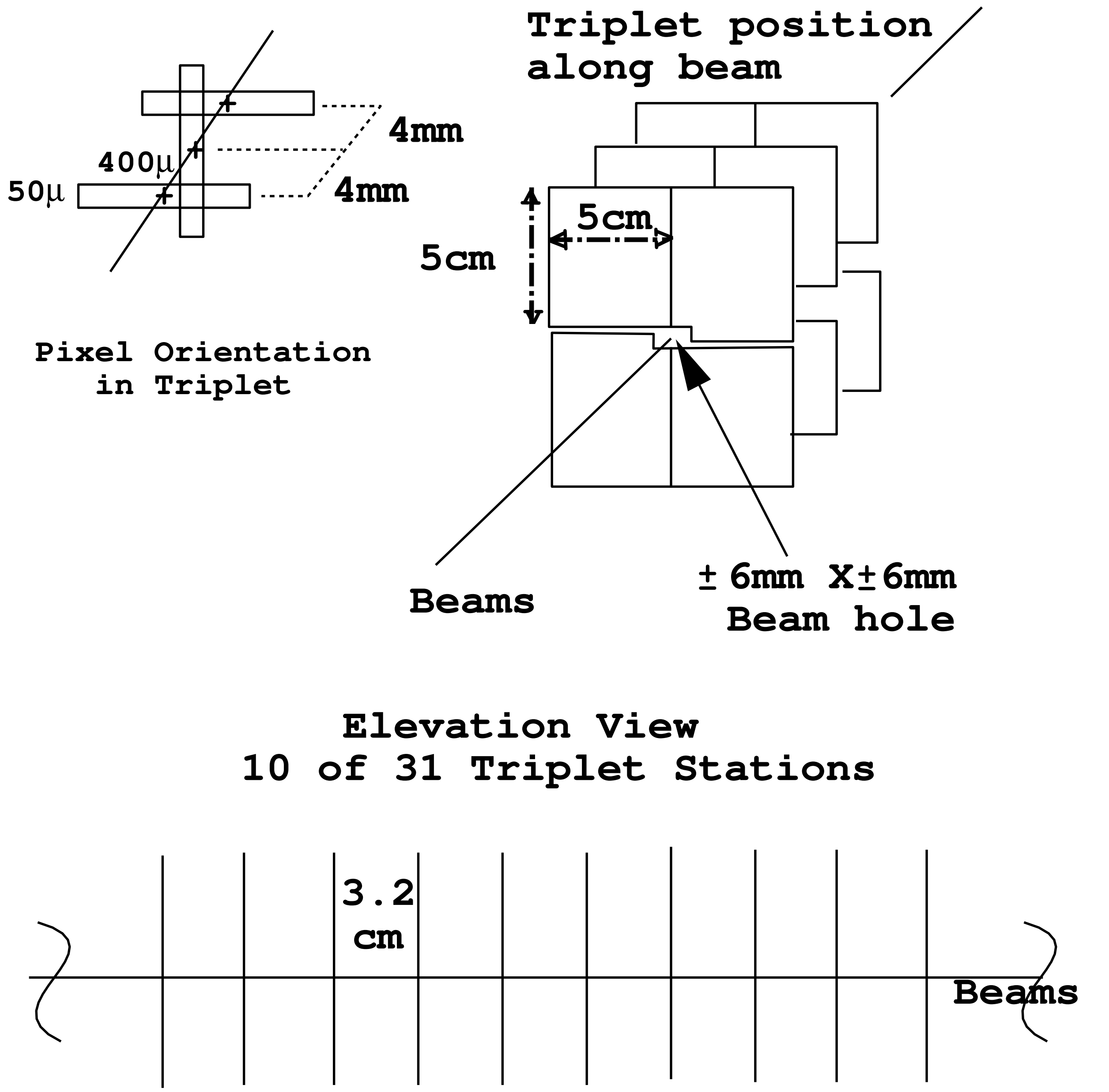


Running Conditions

- $\mathcal{L} = 2 \times 10^{32}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$
- Crossing time of 132 ns
- Mean number of interactions per crossing 2.0.
- Interaction region $\sigma_z = 30$ cm, $\sigma_x \sim \sigma_y = 50$ microns.

Pixel Vertex Detector

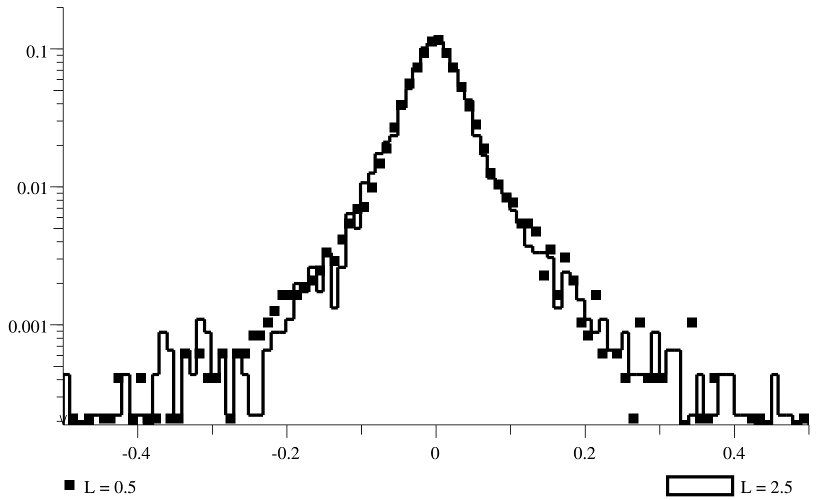
The BTeV Baseline Pixel Detector



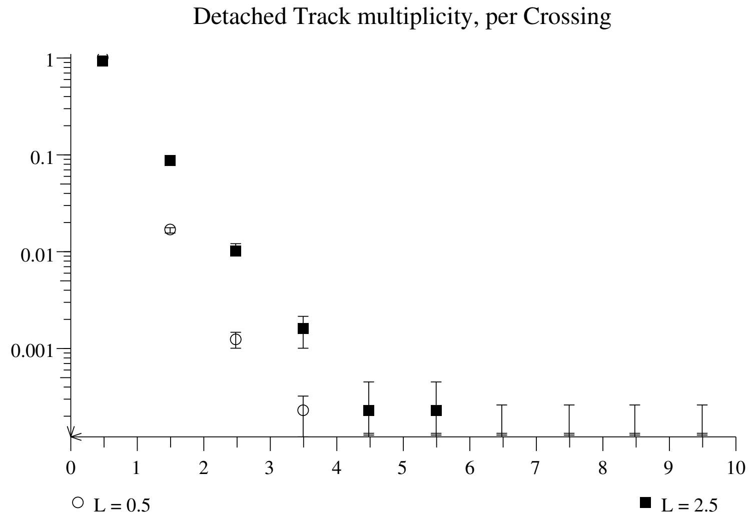
Vertex Trigger

- Level 1 finds tracks in the pixel detector only.
  - Requires low occupancy: For 50 μm by 400 μm pixels we get an occupancy of 0.6×10^{-4}.
  - Use massive parallelism:
    - Find mini-vectors with 32 DSP per station $\times$ 31 pixel stations.
    - Make mini-vectors into tracks with 2048 CPU
    - vertex processing is done by 256 CPU
- A primary vertex is found.
- Trigger requires n tracks with $p_t > p_t(min)$ and more than $m\sigma$ separation from the primary vertex.
- Level 2 trigger refines this calculation and information from forward tracking detector.
- Level 3 completely reconstructs all surviving events.

Level 1 Trigger Simulation Results



Z resolution of primary vertex



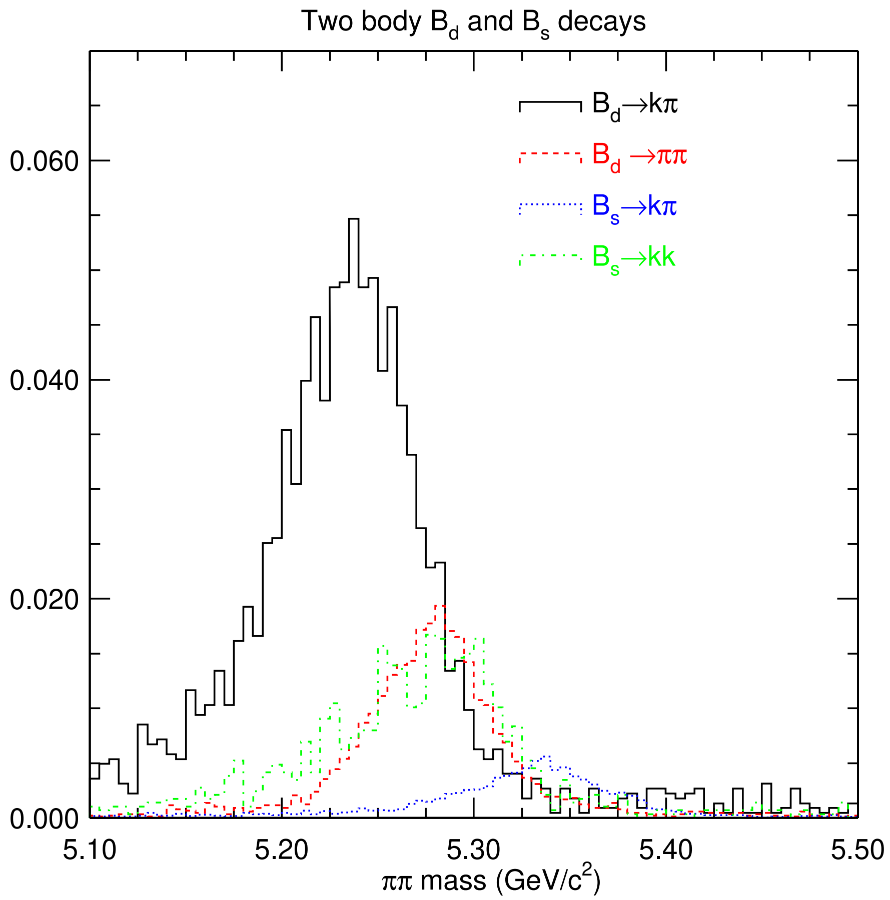
Number of detached ($> 3\sigma$) tracks in uds events

Efficiency for events that would pass a full reconstruction

Final State	Efficiency
$B^0 \to \pi^+\pi^-$	55%
$B_s \to D_s K$	70%
$B^- \to D^0 K^-$	60%
$B^- \to K_s \pi^-$	40%
$B^0 \to K^+\pi^-$	54%
$B^0 \to \psi K_s$	50%
$B_s \to \psi K^*$	69%
$B^0 \to K^*\gamma$	40%

While triggering on 1% of crossings by requiring 2 tracks 4σ separation.

Need for Particle ID



- There is no kinematic separation of $B^0 \to \pi^+\pi^-$ from $B_s \to K^+K^-$.

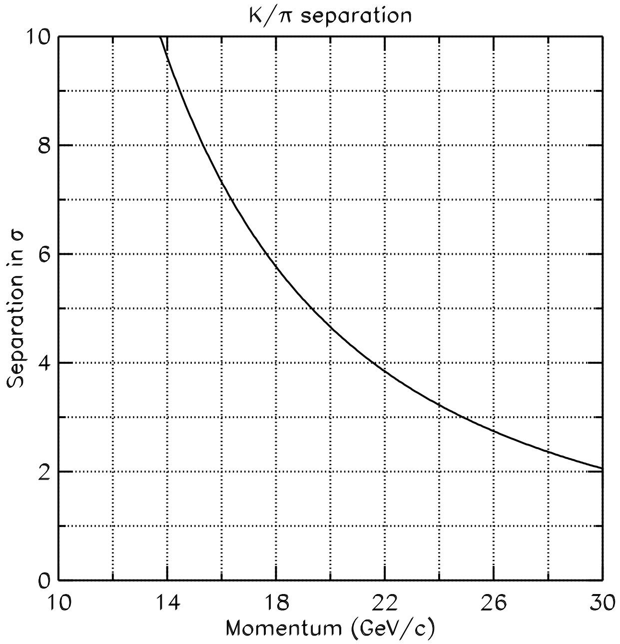
- Recent CLEO $B^0 \to h^+h^-$ measurements imply that these two modes have equal $\sigma \cdot B$.

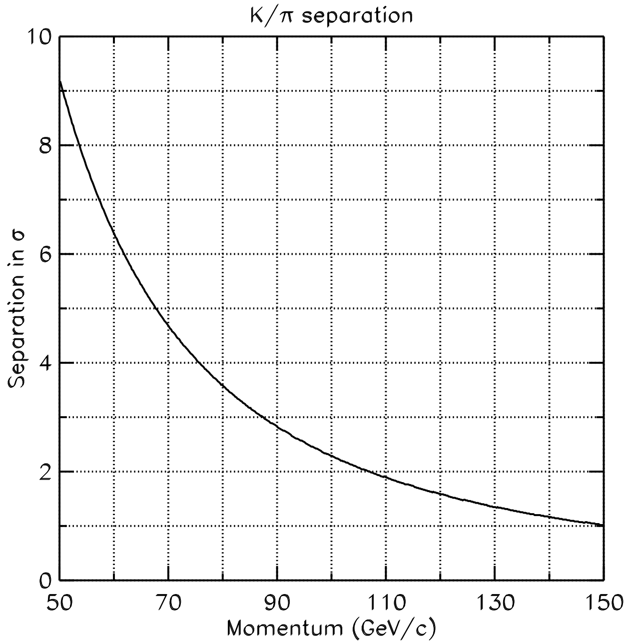
RICH Design

- Require particle ID over range 3 GeV/c $< p <$ 70 GeV/c.
  - Tagging dominates the lower momentum range.
  - The lower limit is given by momentum needed to escape the magnet.
  - High momentum is dictated by $B^0 \to \pi\pi$, $B^0 \to K\pi$, etc
- C_4F_{10} has kaon threshold at 9 GeV/c and provides $> 4\sigma$ K/π separation at 70 GeV/c.
- Aerogel 5 cm thick has a K threshold of 2.0 GeV.
- Both radiators provide visible light so multi-anode phototubes can be used.

RICH Performance

Aerogel C_4F_{10}





Calorimeter Design

Wide range of γ energies need to be reconstructed.

Needs to be radiation hard.

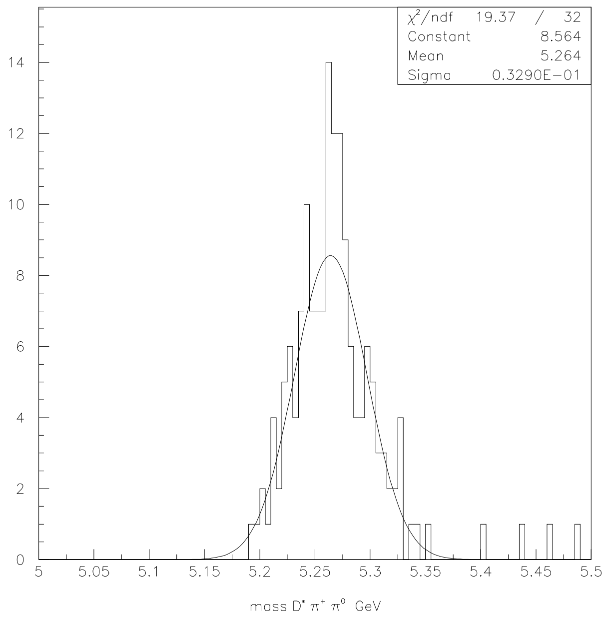
Must be fast enough to associate pulse height with beam crossing.

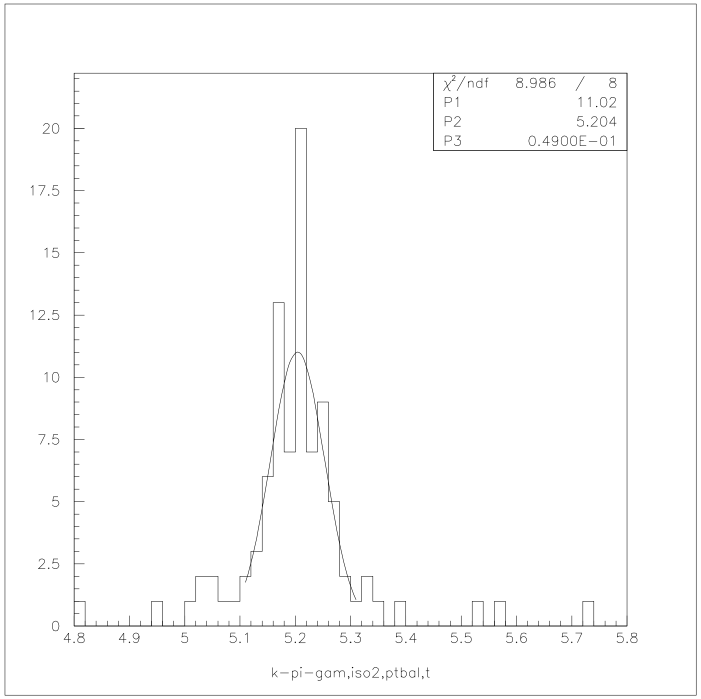
Choice is $PbWO_4$ crystals which CMS is using.

- Our radiation environment is less challenging than CMS.
- We can read out slower than CMS.
- We can use phototubes for readout to achieve better resolution

$$\sigma_E = \frac{1.6\%}{\sqrt{E}} \oplus 0.55\%$$

Mass Resolution Examples





$D^{*+}\rho^-$ $\sigma_m = 33$ MeV/c^2

$\rho\pi$ $\sigma_m = 49$ MeV/c^2

Measuring γ

Analyze the time dependent asymmetry of $B_s \to D_s K$. It requires

- excellent time resolution due to the rapid oscillation of the B_s;
- good K/π separation since $B_s \to D_s \pi$ is larger;
- tagging of the B_s flavor;
- the vertex trigger.

Example result: If $\gamma = 45^\circ$, $x_s = 20$, and $\left|\frac{\langle f|\overline{B}\rangle}{\langle f|B\rangle}\right| = 0.5$ then we get $\delta\gamma = 11^\circ$

Look for a time independent CP asymmetry in $B^- \to D^0 K^-$ and $B^- \to \overline{D^0} K^-$. Where the D^0 and $\overline{D^0}$ go into the same final state. It requires

- two different D^0 final states ($K\pi$ and KK);
- a non-zero strong phase;
- excellent particle ID since the a doubly Cabbibo suppressed decays used'
- a vertex trigger.

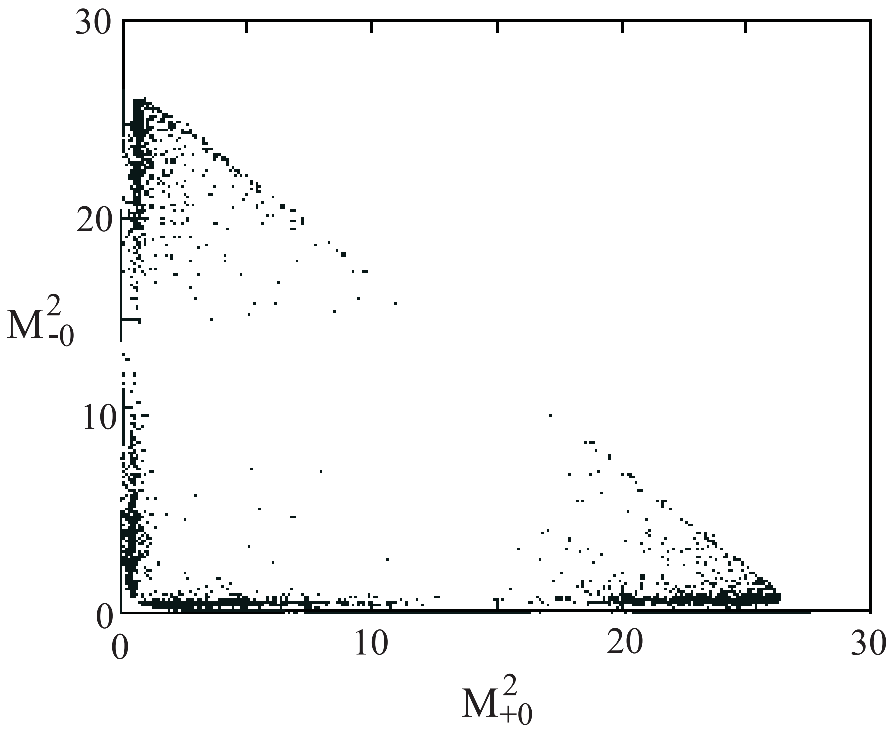
One year of running gives 320 events in the $K\pi$ mode and 1600 in the KK modes.

Example result: For a selected values of γ and strong phases we get $\delta\gamma = 13^\circ$

Other techniques have larger theoretical uncertainties.

Measuring α

Snyder and Quinn have shown that a fit to the $B^0 \to \pi^+\pi^-\pi^0$ Dalitz plot can be used to find α



1000-2000 events are needed.

Experimental considerations

- Has a π^0 in the final state so it requires a calorimeter.
- Triggered by a vertex trigger.
- Requires good K/π separation since $K^*\pi$ is probably larger.
- Needs to be tagged.

First estimate of number of tagged decays is 3000 per year.

Background rejection cuts were based on $B \to K^*\gamma$ study and are not yet optimized.

B_s Oscillations

B_s oscillations can be used to get one side of the UT.

If x_s is large then it may not be measured by the time BTeV runs.

$B_s \to D_s\pi$, $D_s \to \phi\pi$ and $D_s \to K^*K$

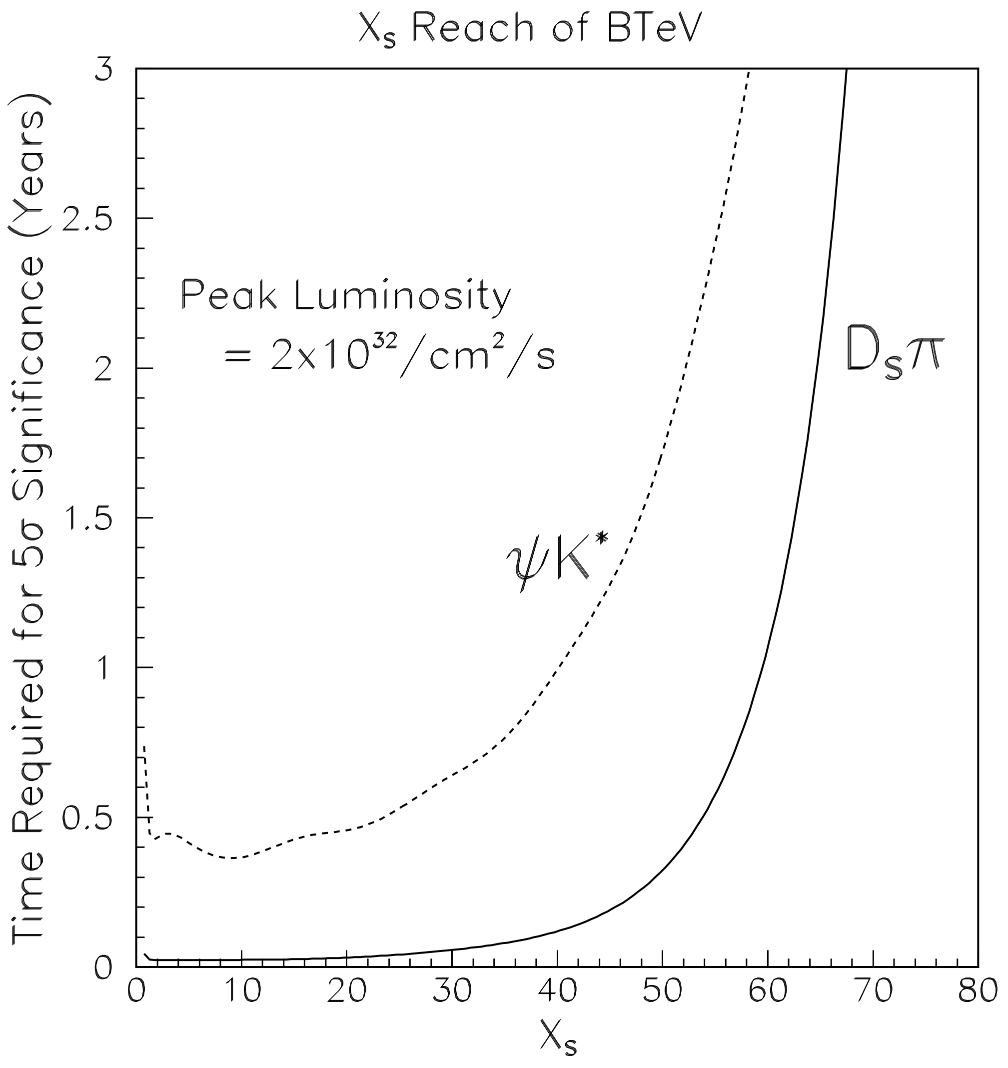
- excellent time resolution
- tagging
- vertex trigger
- good particle ID, lots of K's

$B_s \to \psi K^*$

- excellent time resolution
- tagging

- good particle ID, Cabbibo suppressed decay

Simulation results



Conclusions

In order to complete the study of CP violation in the B sector we need

- a hadron collider to produce enough B's,
- an experiment that can trigger on a wide variety of B decays,
- excellent tracking, particle ID and photon detection.

The BTeV collaboration has begun the job of building such an experiment.