B Experiments: the next generation

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Fermilab
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The future of B physics

The e+e- B factories should continue operating for many years.

Run II experiments CDF/D0 will begin data collection in March 2001.
  – CDF and D0 should collect 2 fb⁻¹ in first two years and will continue running until the LHC begins

The LHC is scheduled to begin operations in 2006.

Precision measurements of CP violation in the B system will just be beginning at this time.
**B physics at hadron machines**

- **Large $bb$ cross section**
  - $10^{11}$ to $10^{12}$ produced per year
- **Large total cross section**
- **Production of $B_s$, $\Lambda_b$, $B_c$**
- **High statistics measurements in $B$ physics will be done at a hadron machines.**

- **Correlated $b$ production in the forward region**
- **Large boost in the forward region gives an advantage for improved decay length resolution.**
CKM parameters

Expected from CDF after 2 fb⁻¹ during Run II: error on \( \sin 2\beta = 0.08 \)

CDF, D0 Belle and Babar will make measurements of the angle \( \beta \), but many other parameters that require high statistics and precision measurements will remain interesting at time the LHC begins.
The 6 CKM triangles

- "ds" - indicates rows or columns used
- There are 4 independent phases, which can be used to construct entire CKM matrix
The 4 CKM Phases

\[ \beta = \text{arg}\left( -\frac{V_{tb} V_{td}^*}{V_{cb} V_{cd}^*} \right) \]

\[ \gamma = \text{arg}\left( -\frac{V_{ub}^* V_{ud}}{V_{cb}^* V_{cd}} \right) \]

\[ \chi = \text{arg}\left( -\frac{V_{cs} V_{cb}^*}{V_{ts}^* V_{tb}} \right) \]

\[ \chi' = \text{arg}\left( -\frac{V_{ud}^* V_{us}}{V_{cd}^* V_{cs}} \right) \]

\[ \alpha = \pi - (\beta + \gamma) \]

\[ \beta \text{ and } \gamma \text{ probably large} \]

\[ \chi \text{ small } \sim 0.03 \]

\[ \chi' \text{ smaller} \]
**CKM measurements**

**Unitarity Triangle**

\[
(V_{ub}^* V_{ub} + V_{cb}^* V_{cd} + V_{tb}^* V_{tb} = 0)
\]

\[
(\rho(1-2/\lambda^2), \iota \eta(1-2/\lambda^2))
\]

\[
\begin{align*}
\alpha & \quad \gamma \\
\beta & \quad \delta \gamma
\end{align*}
\]

**Unitarity Triangle**

\[
(V_{ud}^* V_{ud} + V_{ue}^* V_{us} + V_{ub}^* V_{tb} = 0)
\]

\[
(\rho, \ i \eta)
\]

\[
(1-\rho^2\lambda^2/2+\rho\lambda^2, i\lambda^2\eta)
\]

\[
V = \begin{pmatrix}
1 - \frac{1}{2} \lambda^2 & \lambda & A\lambda^3 \left( \rho - i\eta \left(1 - \frac{1}{2} \lambda^2 \right) \right) \\
-\lambda & 1 - \frac{1}{2} \lambda^2 - i\eta A^2 \lambda^4 & A\lambda^2 \left(1 + i\eta \lambda^2 \right) \\
A\lambda^2 (1 - \rho - i\eta) & -A\lambda^2 & 1
\end{pmatrix}
\]

**Formulation of the CKM Matrix**

Aspen 2001 B experiments
BTeV and LHC-b Experiments

BTeV and LHC-b are “Second Generation” experiments to study CP violation in B (and charm) decays.

BTeV and LHCb are scheduled to begin running in 2006.

Physics Goals: measurements of angles $\alpha$, $\gamma$, rare decays, (charm physics)

Features:
- Forward geometry
- Large b cross section at hadron colliders
- Higher momentum b’s in forward region

Challenges:
- Large data volume
  - Trigger and computing
- Competition from other experiments
There are at least 3 methods to determine the angle $\gamma$ at a dedicated $b$ experiment at a hadron collider.

- Time dependent flavor tagged analysis of $B_s \rightarrow D_s K^-$
- Measure rate difference between $B^- \rightarrow D^0 K^-$ and $B^+ \rightarrow D^0 K^+$
- Branching ratios of the decays $K^0 \pi^\pm$ and $K^{\pm} \pi^\mp$ (as outlined by Gronau-Rosner).

Ambiguities are different in each method; with the use of several methods they can be resolved.

BTeV and LHCb should be able to measure the angle $\alpha$ using the decay $B^0 \rightarrow \rho^+ \pi^-$

These experiments will study a large number of rare decays of the $B$

High statistics sample of charm decays opens up a variety of topics in charm physics.
### B physics program

<table>
<thead>
<tr>
<th>Physics Quantity</th>
<th>Decay Mode</th>
<th>Vertex Trigger</th>
<th>K/π sep</th>
<th>γ det</th>
<th>Decay time σ</th>
</tr>
</thead>
<tbody>
<tr>
<td>sin(2α)</td>
<td>$B^o \rightarrow \rho \pi \rightarrow \pi^+ \pi^- \pi^0$</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>sin(2α)</td>
<td>$B^o \rightarrow \pi^+ \pi^- &amp; B_s \rightarrow K^+ K^-$</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>cos(2α)</td>
<td>$B^o \rightarrow \rho \pi \rightarrow \pi^+ \pi^- \pi^0$</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>sign(sin(2α))</td>
<td>$B^o \rightarrow \rho \pi &amp; B^o \rightarrow \pi^+ \pi^-$</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>sin(γ)</td>
<td>$B_s \rightarrow D_s K^-$</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>sin(γ)</td>
<td>$B^o \rightarrow D^o K^-$</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>sin(γ)</td>
<td>$B \rightarrow K \pi$</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>sin(2χ)</td>
<td>$B_s \rightarrow J/\psi \eta', J/\psi \eta$</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>sin(2β)</td>
<td>$B^o \rightarrow J/\psi K_s$</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cos(2β)</td>
<td>$B^o \rightarrow J/\psi K^* &amp; B_s \rightarrow J/\psi \phi$</td>
<td>✓</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$x_s$</td>
<td>$B_s \rightarrow D_s \pi$</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>ΔΓ for $B_s$</td>
<td>$B_s \rightarrow J/\psi \eta', K^+ K^-, D_s \pi^-$</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
### The Tevatron as a b and c source for BTeV

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Luminosity</strong></td>
<td>$2 \times 10^{32} \text{ cm}^{-2} \text{ sec}^{-1}$</td>
</tr>
<tr>
<td><strong>bb cross section</strong></td>
<td>$100 \mu b$</td>
</tr>
<tr>
<td><strong># of b’s per $10^7$ sec</strong></td>
<td>$4 \times 10^{11}$</td>
</tr>
<tr>
<td><strong>$\sigma(bb)/\sigma(\text{total})$</strong></td>
<td>~0.15%</td>
</tr>
<tr>
<td><strong>cc cross section</strong></td>
<td>$&gt;500 \mu b$</td>
</tr>
<tr>
<td><strong>Bunch spacing</strong></td>
<td>$132 \text{ ns}$</td>
</tr>
<tr>
<td><strong>Luminous region length</strong></td>
<td>$\sigma_z=30 \text{ cm}$</td>
</tr>
<tr>
<td><strong>Luminous region width</strong></td>
<td>$\sigma_x, \sigma_y \approx 50 \mu m$</td>
</tr>
<tr>
<td><strong>Interactions/crossing</strong></td>
<td>$&lt;2.0&gt;$</td>
</tr>
</tbody>
</table>
## The LHC and B production

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Luminosity</strong></td>
<td>$2 \times 10^{32} \text{ cm}^{-2} \text{ sec}^{-1}$</td>
</tr>
<tr>
<td><strong>$bb$ cross section</strong></td>
<td>$500 \mu b$</td>
</tr>
<tr>
<td><strong># of $b$’s per $10^7$ sec</strong></td>
<td>$2 \times 10^{12}$</td>
</tr>
<tr>
<td><strong>$\sigma(bb)/\sigma(\text{total})$</strong></td>
<td>$\sim 0.6%$</td>
</tr>
<tr>
<td><strong>Bunch spacing</strong></td>
<td>$25 \text{ ns}$</td>
</tr>
<tr>
<td><strong>Luminous region length</strong></td>
<td>$\sigma_z = 5 \text{ cm}$</td>
</tr>
<tr>
<td><strong>Luminous region width</strong></td>
<td>$\sigma_x, \sigma_y \approx 100 \mu m$</td>
</tr>
<tr>
<td><strong>Interactions/crossing</strong></td>
<td>$&lt; 1$</td>
</tr>
</tbody>
</table>
**BTeV and LHC-b Design**

There is a strong correlation in the production of BB pairs in the forward direction.

Production angle of the B vs Bbar at the TeVatron

**BTeV will cover the range**

1.9 < |\(\eta\)| < 4.5

**LHC-b covers the range**

2.1 < |\(\eta\)| < 5.3

B yield vs \(\eta\)

Aspen 2001 B experiments
The LHCb detector

The detector will be installed in the IR8 collision hall that was used by Delphi

Aspen 2001 B experiments
C0 Hall at Fermilab

A new collision hall has been constructed at the Tevatron half way between CDF and D0.

Design of a collision region at C0 is underway. Some new magnets must be constructed to complete the interaction region.
**B Detector design Goals**

*(trigger and vertex detector)*

- **Trigger efficiently on purely hadronic modes**
  - BTeV plans to have a vertex trigger that detects detached tracks at the first level
  - LHC-b also has a vertex trigger, but after Level-0

- **excellent decay time resolution**
  - Both detectors have time resolution of about 40-45 fs. (B\(_s\) studies)
LHCb tracking subsystems

Vertex Detector
17 stations
≈ 200 μm Si single-side
• R and φ measuring planes
• 220 k channels, analog R/O, S/N =15

Magnet: Warm dipole 4 Tm
magnet construction has been approved

Tracker:

Inner: (40x60 cm²) triple GEM ,
Silicon strips 3 stations

Outer: straw-tube drift chambers

\[ \sigma_{p/p} = 0.3 \% \quad [5, 200] \text{ GeV/c} \]
\[ \sigma(M_{B \rightarrow \pi \pi}) = 15 \text{ MeV/c}^2 \]
\[ \sigma(M_{D \rightarrow KK\pi}) = 4 \text{ MeV/c}^2 \]
BTeV Vertex Detector
Side View
BTeV Pixel detector – Close up of 3 stations

• Detectors in vacuum
• 50µm x 400µm pixels
• Two pixel planes per station (supported on a single substrate)
• Half planes retract when Tevatron beams are not stable.

30 stations in total extending over about a meter along the beam
BTeV Pixel detector development

The sensors & the readout are “bump bonded” to one another.

FPIX1 bonded to an ATLAS detector.
Mechanical Support and cooling for the Pixel detectors

Mechanical support and cooling for two planes will be provided by a “fuzzy carbon” structure in the current design.
**Pixels in the test beam**

This track density in the test beam is much **HIGHER** than what is expected in BTeV.
**Pixel Test Beam**

- The **Solid curve** is a piece wise linear fit to the results of a detailed simulation.
- The **green** points are test beam results from FPIX0 with an 8 bit pulse height and the **red** points are with a 2-bit pulse height
SM3 Magnet

Iron originally from the Nevis Cyclotron

\[ \int B \times dl = 5.2 \, T \cdot m \]

1.6 Tesla at center

Steel Length = 3.2 m

Total Length = 5.3 m
BTeV Forward Tracking System

14 tracking stations
7 in each arm

Straw Tracker
4 mm diameter
3 views per station
3 layers per view

Silicon Tracker
single sided
100 µm pitch strips
200 µm thick
12 stations
3 views/station
LHC-B Trigger

Level-0: reduction of rate to \( \sim 1 \text{ MHz} \)
rejactong minimum bias events by
high \( p_T \) muon, electron or hadron.

Level-1: reduction of rate to \( \sim 40 \text{ KHz} \)
rejactong minimum bias events by vertex detector
and tracking stations (separately).

Readout to data acquisition buffer

Level-2: reduction of rate to \( \sim 5 \text{ KHz} \)
mainly rejacting minimum bias events by combining
several different detectors.

Level-3: reduction of rate to \( \sim 200 \text{ Hz} \) (16 MB/sec on tape)
rejacting uninteresting \( B \) events by
partial and full reconstruction of \( B \) final states.
The LHCb trigger is robust and flexible must operate at 40 Mhz

Level 0
1 MHz
high pt muon, photons, hadrons
pile up veto

Level 1
40 kHz
identify secondary vertices

Aspen 2001
B experiments
The Level 1 algorithm has three phases:

- Track “segment finding”
- Segment matching and track fitting
- Vertex finding
Pattern recognition in the BTeV L1 trigger

For more information see the trigger “movie” at
www-btev.fnal.gov/public_documents/animations/Animated_Trigger/

Aspen 2001 B experiments


**Trigger efficiencies**

![Graph showing trigger efficiencies for $B^0 \rightarrow D^{*+} \rho^-$, $D^{*+} \rightarrow \pi^+ D^0$, $D^0 \rightarrow K^- \pi^+$ for various detachment requirements.]

The trigger response for min-bias crossings.

Aspen 2001 B experiments
## BTeV Level-1 Vertex Trigger efficiencies

<table>
<thead>
<tr>
<th>Physics Process (2 interactions/crossing)</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Bias</td>
<td>1%</td>
</tr>
<tr>
<td>$B^0 \to D^{*+} \rho^-$</td>
<td>64%</td>
</tr>
<tr>
<td>$B^0 \to \rho^0 \pi^0$</td>
<td>56%</td>
</tr>
<tr>
<td>$B^0 \to J/\psi K^0_s$</td>
<td>50%</td>
</tr>
<tr>
<td>$B_s \to J/\psi K^{*0}$</td>
<td>68%</td>
</tr>
<tr>
<td>$B^- \to D^0 K^-$</td>
<td>70%</td>
</tr>
<tr>
<td>$B^- \to K^0_s \pi^-$</td>
<td>27%</td>
</tr>
<tr>
<td>$B_s \to D_s^{+} K^-$</td>
<td>74%</td>
</tr>
<tr>
<td>$B^0 \to 2$-body modes</td>
<td>63%</td>
</tr>
<tr>
<td>($\pi^+ \pi^-, K^+ \pi^-, K^+ K^-$)</td>
<td></td>
</tr>
</tbody>
</table>

Aspen 2001  
B experiments
The BTeV Trigger is a three-level scheme designed to be efficient for events with reconstructable b hadrons.

**Level one:** impact parameter in combination with lepton triggers

**Level two:** combine with tracking systems

**Level three:** full reconstruction!
**More B Detector Goals**

*(ECAL + Particle ID)*

- **Both detectors will have ECAL which detect electrons, γ (and π⁰’s) with good resolution**
  - Increases the physics capabilities
    - can study states such as K*γ, ρπ
  - Triggers for high pt electrons and photons

- **Both detectors will have excellent particle identification based on a Ring Imaging Cerenkov (RICH) detector.**
  - Many states that will be of interest can only be observed with sufficiently low backgrounds if this capability exists.
    - (π⁺π⁻, B_s → D_s K)
  - The RICH enables kaon tagging.
LHCb calorimeters

Pre-shower sandwich Pb - scintillator

ECAL -- Shashlik type, 25 \( X_0 \)

HCAL Fe + scintillating tiles, 5.6l

Readout by wave-length shifting fibers and PMTs

\[ \frac{\sigma(E)}{E} = \frac{10\%}{\sqrt{E}} \oplus 1.5\% \]

\[ \frac{\sigma(E)}{E} = \frac{80\%}{\sqrt{E}} \oplus 5\% \]
**BTeV Electromagnetic Calorimeter**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transverse block size</td>
<td>26.0 mm x 26.0 mm</td>
</tr>
<tr>
<td>Block length</td>
<td>22 cm</td>
</tr>
<tr>
<td>Radiation Length</td>
<td>25</td>
</tr>
<tr>
<td>Inner Dimension</td>
<td>R=10 cm</td>
</tr>
<tr>
<td>Outer radius</td>
<td>R=160 cm</td>
</tr>
<tr>
<td>Total # blocks/arm</td>
<td>11850</td>
</tr>
</tbody>
</table>

Efficiency as a function of radius for the process $B^0 \rightarrow D^{*+} \rho^-$

**Energies in the PbWO$_4$ calorimeter (E > 10MeV) from a $B^0 \rightarrow \rho^0 \pi^0$ event. (photons from the $\pi^0$ are circled)**

Aspen 2001 B experiments
BTeV ECAL resolution and efficiency

Radial distribution of generated and detected photons from $B^0 \rightarrow K^* \gamma$

Expected energy resolution:
$\sigma_E/E = 1.6% / \sqrt{E} \oplus 0.55%$

Expected position resolution:
$\sigma_x = 3500 \mu m / \sqrt{E} \oplus 200 \mu m$

The $\gamma\gamma$ invariant mass for 10 GeV $\pi^0$’s incident on the calorimeter.
BTeV Charged Particle Identification System

RICH xz view

$C_4F_{10}$ and Aerogel $n=1.03$

$3 \text{ GeV/c} < P < \sim 70 \text{ GeV/c}$

PP0380 HPD

Typical $B^0 \rightarrow \pi^+ \pi^-$ event
LHCb RICH Detectors

LHC-B

2 RICH detectors
Covers momentum range
from 1 – 150 GeV

Aspen 2001 B experiments
The Power of Particle Identification

$B^0 \rightarrow \pi^+\pi^- (BTeV)$
Tagging  
(BTeV preliminary studies)

<table>
<thead>
<tr>
<th>Tag Type</th>
<th>$\epsilon$</th>
<th>$D = (1-2w)$</th>
<th>$\epsilon D^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muon</td>
<td>4.5%</td>
<td>0.66</td>
<td>2.0%</td>
</tr>
<tr>
<td>Electron</td>
<td>2.3%</td>
<td>0.68</td>
<td>1.0%</td>
</tr>
<tr>
<td>Kaon</td>
<td>18%</td>
<td>0.52</td>
<td>4.9%</td>
</tr>
<tr>
<td>Vertex Charge</td>
<td>32%</td>
<td>0.36</td>
<td>4.1%</td>
</tr>
<tr>
<td>Same Side Kaon</td>
<td>40%</td>
<td>0.26</td>
<td>2.6%</td>
</tr>
<tr>
<td>Same Side Pion</td>
<td>88%</td>
<td>0.16</td>
<td>2.2%</td>
</tr>
<tr>
<td>Total $B_s$</td>
<td></td>
<td></td>
<td>14.6%</td>
</tr>
<tr>
<td>Total $B_d$</td>
<td></td>
<td></td>
<td>14.2%</td>
</tr>
<tr>
<td>Total $B_s$ with overlaps</td>
<td>65%</td>
<td>0.37</td>
<td>8.9%</td>
</tr>
</tbody>
</table>

BTeV has assumed $\epsilon D^2 = 10\%$ for physics studies

LHCb: $\epsilon = 0.4$; $w = 0.3$; $\epsilon D^2 = 6\%$ (lepton and kaon only)
**Sin2α from**

\[ B^0 \rightarrow \rho \pi \rightarrow \pi^+ \pi^- \pi^0 \]

- A Dalitz Plot analysis of \( B^0 \rightarrow \rho \pi \) gives **both** \( \sin(2\alpha) \) and \( \cos(2\alpha) \) (Snyder & Quinn)
  - \( BR \) for \( B^0 \rightarrow \rho^+ \pi^- = 2.8 \times 10^5 \)
  - **not many events produced at e+e- B factories**
  - **a tagged time-dependent analysis is required**

Snyder & Quinn have shown that 1000-2000 tagged events are sufficient

**This measurement will most likely be done at a hadron collider!**


**Measuring alpha with $\rho\pi$ in BTeV**

<table>
<thead>
<tr>
<th>Quantity</th>
<th>$\rho^\pm\pi^\mp$</th>
<th>$\rho^0\pi^0$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Branching ratio</strong></td>
<td>2.8x10^{-5}</td>
<td>0.5x10^{-5}</td>
</tr>
<tr>
<td><strong>Efficiency</strong></td>
<td>0.0044</td>
<td>0.0036</td>
</tr>
<tr>
<td><strong>L1 Trigger eff</strong></td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td><strong>L2 Trigger eff</strong></td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td><strong>S/B</strong></td>
<td>4.1</td>
<td>0.3</td>
</tr>
<tr>
<td><strong>Signal/year</strong></td>
<td>9400</td>
<td>1350</td>
</tr>
<tr>
<td><strong>$\epsilon D^2$</strong></td>
<td>0.10</td>
<td>0.10</td>
</tr>
<tr>
<td><strong>Flavor tagged yield</strong></td>
<td>940</td>
<td>135</td>
</tr>
</tbody>
</table>

*From full Geant simulations 10M $bb$ pairs generated for background studies.*
### LHCb physics reach

<table>
<thead>
<tr>
<th>Value</th>
<th>Channels+c.c.</th>
<th># events</th>
<th>( \sigma ) (1 year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha )</td>
<td>( B_d \rightarrow \pi \pi )</td>
<td>5k</td>
<td>( 2^\circ -5^\circ )</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>( @ \Delta_{P/T} = 30^\circ, )</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(</td>
</tr>
<tr>
<td></td>
<td>( B_d^0 \rightarrow \rho , \pi )</td>
<td>1k</td>
<td>( 5^\circ )</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>( @ \alpha=50^\circ )</td>
</tr>
<tr>
<td>( 2\beta+\gamma )</td>
<td>( B_d \rightarrow D^*(\text{incl.})\pi )</td>
<td>260k</td>
<td>( 12^\circ )</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>( @2\beta+\gamma=0 )</td>
</tr>
<tr>
<td>( \beta )</td>
<td>( B_d \rightarrow J/\Psi K_s )</td>
<td>100k</td>
<td>( &lt;0.6^\circ )</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>( (\sin 2\beta&lt;0.021) )</td>
</tr>
<tr>
<td>( \gamma-2\delta\gamma )</td>
<td>( B_s \rightarrow D_s K )</td>
<td>2400</td>
<td>( 8^\circ (\Delta m_s=15\text{ps}^{-1}) ) -</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>( 12^\circ (45\text{ps}^{-1}) )</td>
</tr>
<tr>
<td>( \gamma )</td>
<td>( B_d \rightarrow D K^* )</td>
<td>400</td>
<td>( 10^\circ )</td>
</tr>
<tr>
<td>( \delta\gamma )</td>
<td>( B_s \rightarrow J/\Psi \phi )</td>
<td>50k</td>
<td>( 0.6^\circ )</td>
</tr>
<tr>
<td>( \chi_s )</td>
<td>( B_s \rightarrow D_s \pi )</td>
<td>35k</td>
<td>up to ( 75 ) (5( \sigma ))</td>
</tr>
<tr>
<td>Rare decays</td>
<td>( B_s \rightarrow \mu \mu )</td>
<td>11</td>
<td>( s/b=3.5 )</td>
</tr>
<tr>
<td></td>
<td>( B_d \rightarrow K^0 \mu \mu )</td>
<td>4500</td>
<td>( s/b=16 )</td>
</tr>
<tr>
<td></td>
<td>( B_d \rightarrow K^* \gamma )</td>
<td>26k</td>
<td>( s/b=1 )</td>
</tr>
</tbody>
</table>
# BTeV Physics Reach (CKM) in $10^7$ s

<table>
<thead>
<tr>
<th>Reaction</th>
<th># of Events</th>
<th>S/B</th>
<th>Parameter</th>
<th>Error or (Value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B^0 \to \pi^+ \pi$</td>
<td>24,000</td>
<td>3</td>
<td>Asymmetry</td>
<td>0.024</td>
</tr>
<tr>
<td>$B_s \to D_s K^-$</td>
<td>13,100</td>
<td>7</td>
<td>$\gamma$</td>
<td>$7^\circ$</td>
</tr>
<tr>
<td>$B^0 \to J/\psi K_S$, $J/\psi \to \mu^+ \mu^-$</td>
<td>80,500</td>
<td>10</td>
<td>$\sin(2\beta)$</td>
<td>0.025</td>
</tr>
<tr>
<td>$B_s \to D_s \pi^-$</td>
<td>103,000</td>
<td>3</td>
<td>$x_s$</td>
<td>(75)</td>
</tr>
<tr>
<td>$B^- \to D^o (K^+ \pi^-) K^-$</td>
<td>300</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$B^- \to D^o (K^+ K^-) K^-$</td>
<td>1,800</td>
<td>10</td>
<td>$\gamma$</td>
<td>$10^\circ$</td>
</tr>
<tr>
<td>$B^- \to K_S \pi$</td>
<td>8,000</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$B^0 \to K^+ \pi^-$</td>
<td>108,000</td>
<td>20</td>
<td>$\gamma$</td>
<td>$&lt;5^\circ$</td>
</tr>
<tr>
<td>$B^0 \to \rho^+ \pi$</td>
<td>9,400</td>
<td>4.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$B^0 \to \rho^0 \pi^0$</td>
<td>1,350</td>
<td>0.3</td>
<td>$\alpha$</td>
<td>$\sim 10^\circ$</td>
</tr>
<tr>
<td>$B_s \to J/\psi \eta$, $J/\psi \to \mu^+ \mu^-$</td>
<td>1,920</td>
<td>15</td>
<td>$\sin 2\chi$</td>
<td>0.033</td>
</tr>
<tr>
<td>$B_s \to J/\psi \eta^*$</td>
<td>7,280</td>
<td>30</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Aspen 2001

B experiments
# Comparisons with LHC-B from simulation studies

## BTeV / LHCB comparison for $B^0 \rightarrow \rho \pi$

<table>
<thead>
<tr>
<th>Mode</th>
<th>Branching Ratio</th>
<th>BTeV</th>
<th>LHCb</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B^0 \rightarrow \rho^\pm \pi^\mp$</td>
<td>$2.8 \times 10^{-5}$</td>
<td>9400</td>
<td>4.1</td>
</tr>
<tr>
<td>$B^0 \rightarrow \rho^0 \pi^0$</td>
<td>$0.5 \times 10^{-5}$</td>
<td>1350</td>
<td>0.3</td>
</tr>
</tbody>
</table>

## BTeV / LHCB comparison for $B_s \rightarrow D_s^+ K^-$

<table>
<thead>
<tr>
<th>Mode</th>
<th>Branching Ratio</th>
<th>BTeV</th>
<th>LHCb</th>
</tr>
</thead>
<tbody>
<tr>
<td>$B_s \rightarrow D_s^+ K^-$</td>
<td>$3 \times 10^{-4}$</td>
<td>13,100</td>
<td>7</td>
</tr>
</tbody>
</table>
**LHCb milestones and schedule**

- Feb 1996  Letter of Intent
- Sept 1998  Approval of Technical Proposal
- **2000-2002** Technical Design Reports for Detector Subsystems
  - TDRs for the magnet, RICH and calorimeter have been approved
- **2000-2004** Construction
- **Fall 2005** 1\(^{st}\) beam in LHC
BTeV Status and Schedule

BTeV was approved by the Fermilab PAC in the Summer of 2000

Schedule:
2003  Wire target operations possible
2004-2005  Installation of machine IR components
2005  Detector installation/ commissioning 2005
2006  First data 2006
Conclusions

• **BTeV was recently approved and will be a major part of the Fermilab program after 2005.**
  – The next step is to complete the technical design of the detector.
  – BTeV will require a new IR at the TeVatron

• **LHCb will be installed and ready to run when LHC run begins in 2006.**

• **We expect this rich program in B physics and CP violation at hadron colliders will continue for many years.**