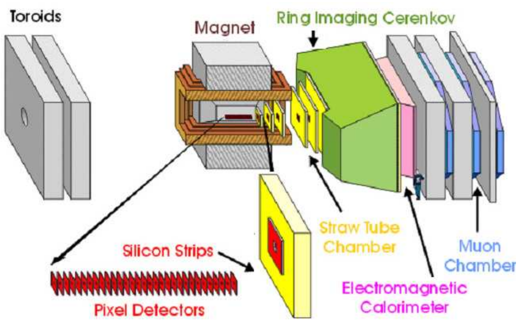


B. Cox
University of Virginia
October 18, 2003

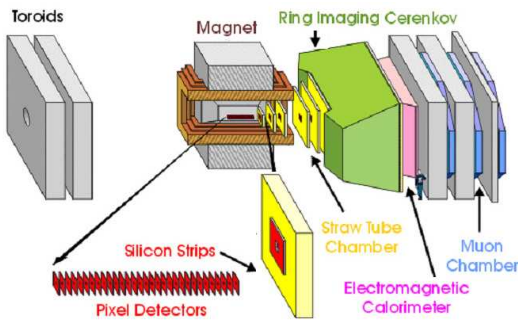
The Physics Reach of BTeV

BTeV was recently described by unanimous decision of the P5 committee as

"potentially the best quark flavor physics experiment into the next decade"

The P5 recommendation:

"P5 supports the construction of BTeV as an important project in the world-wide flavor physics area. Subject to constraints within the HEP budget, we strongly recommend an earlier BTeV construction profile and enhanced C0 optics"



The BTeV Collaboration (32 universities)

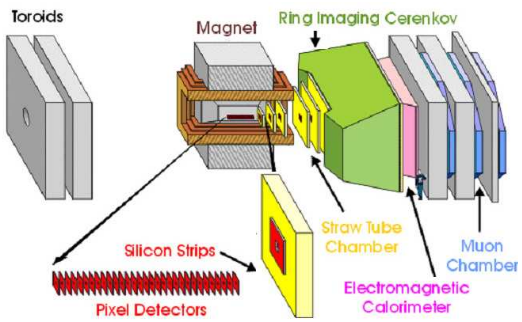
FNAL Fixed Target

Cleo

Hera/Hera-B

Other

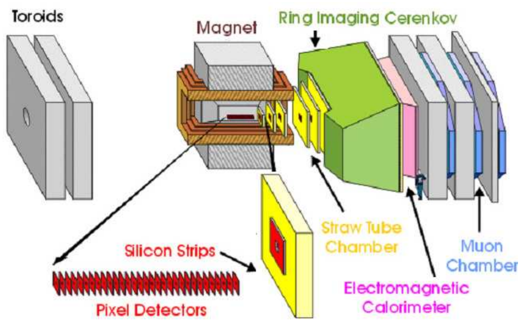
Belarussian State
UC Davis
Univ. Of Colorado
Fermilab
Univ. Of Florida
Univ. of Houston
Illinois Inst. of Tech.
Univ. of Illinois
Univ. of Insurbia in Como
INFN - Frascati
INFN - Milano
INFN - Pavia
INFN - Torino
IHEP - Protvino
Univ. of Iowa
Univ. of Minnesota
Nanjing Univ.
Northwestern Univ.
Ohio State Univ.
Univ. of Pennsylvania
Univ. of Puerto Rico
Univ. of Sci. and Tech of China
Shandong Univ.
Southern Methodist Univ.
Suny Albany
Syracuse Univ.
Univ. of Tennessee
Vanderbilt Univ.
Univ. of Virginia
Wayne State Univ.
Univ. of Wisconsin
York Univ.



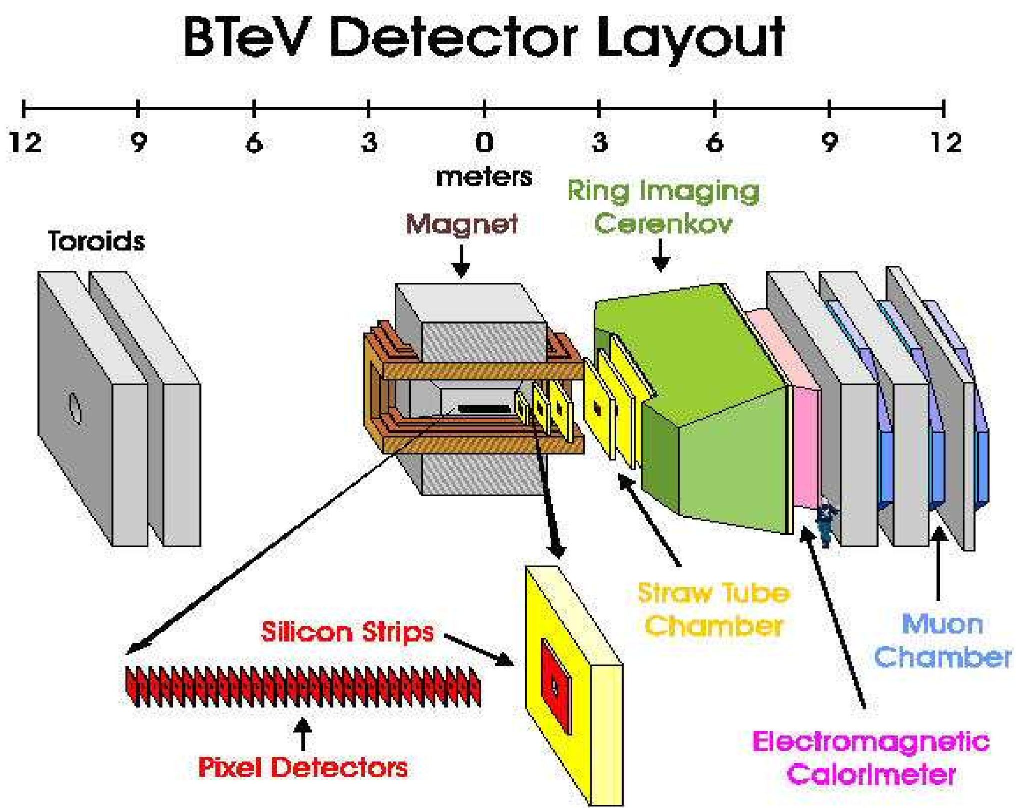
Objectives of BTeV

Comprehensive study of b and c quark production, mixing, decays

- ***new physics in measurements of CP phases in b and c quark decays***
- ***new physics in detection of rare b and c decays***
- ***precision measurement of CKM matrix elements***
- ***b and c quark production***
- ***structure of b baryonic states***
- $B_{s\ decays}$

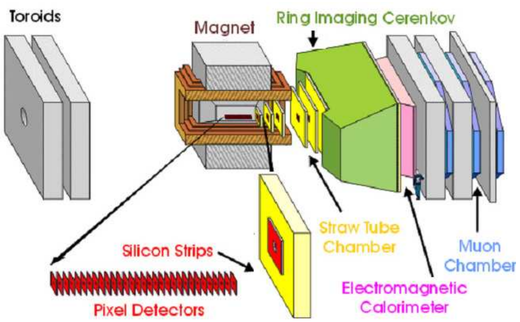


The Single Arm BTeV Spectrometer

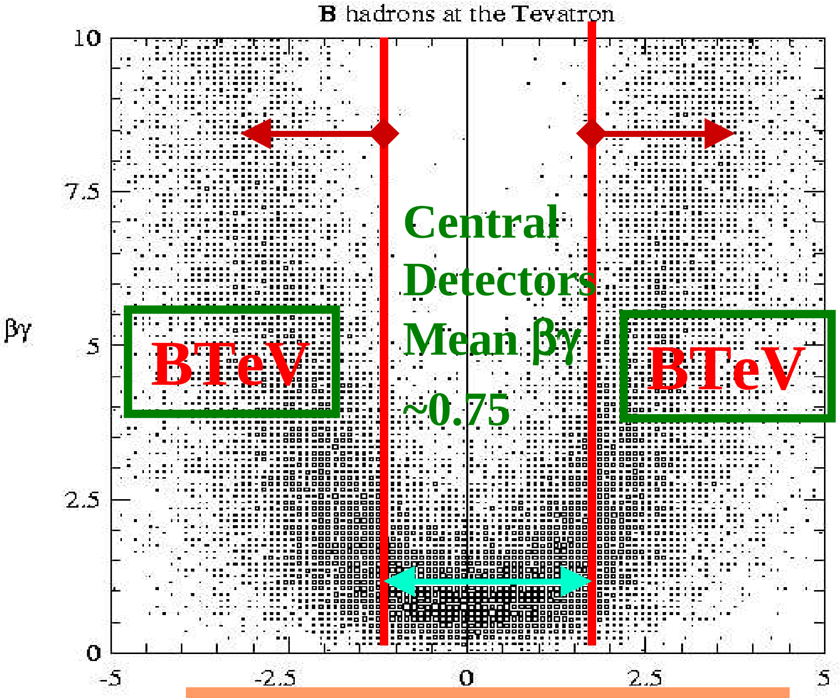


Factor of two from enhanced C0 optics. Recommended by P5 for initial operation.

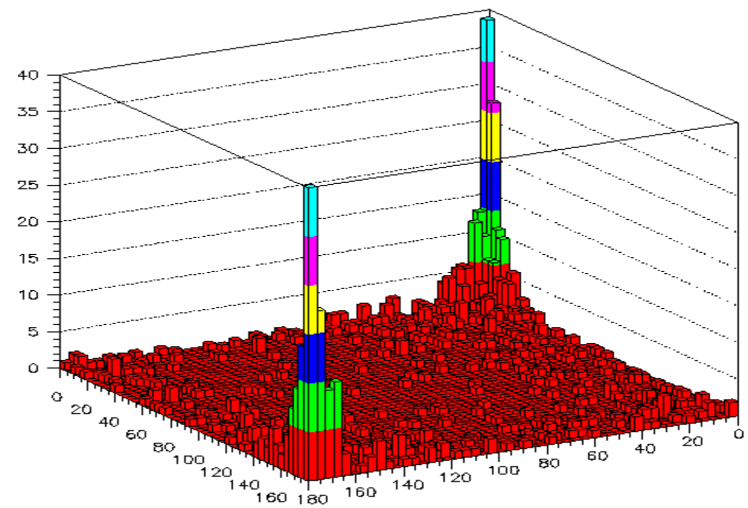
Natural upgrade for additional factor of two by additional of second arm, if indicated by physics results



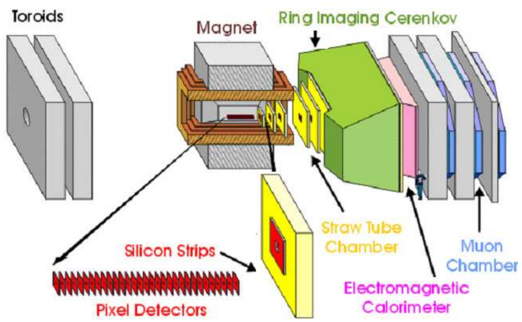
$\bar{b}$ b production peaks along both beam directions



BTeV HAS ACCESS TO ALL SPECIES OF B'S



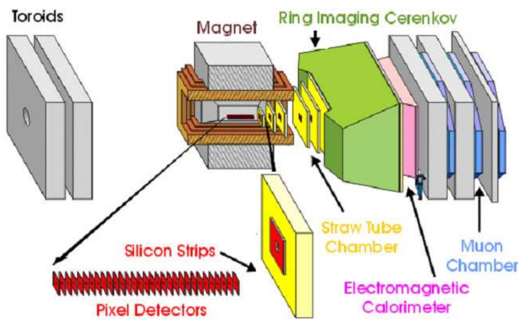
Acceptance 1.3 > |η| >3.5



B Physics at Hadron Colliders

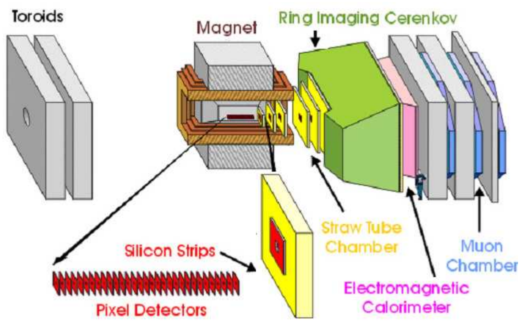
- ***The Opportunity***
  - The Tevatron, at 10^{32}, produces 10^{11} b-pairs/year
  - It is a "High Luminosity B Factory" due to the broadband vertex trigger, giving access to B_d, B_u, B_s, b-baryon, and B_c states.
  - Because you are colliding gluons, it is intrinsically asymmetric so time evolution studies are possible (and integrated asymmetries are nonzero)

- ***The Challenge***
  - The b events are accompanied by a very high rate of background events
  - The b's are produced over a very large range of momentum and angles
  - Even in the b events of interest, there is a complicated underlying event so one does not have the stringent constraints that one has in an e^+e^- machine



Anticipated Properties of the Tevatron

Luminosity	**2×10^{32}**
b cross-section	**$>100\ \mu b$**
# of b-pairs per 10^7 sec	**2×10^{11}**
b fraction.	**2×10^{-3}**
c cross-section	**$>500\ \mu b$**
Bunch Spacing	**396 ns**
Luminous region length	**$\sigma_z = 30$ cm, $\sigma_x \sim \sigma_y \sim 50\ \mu m$**
Luminous region width	
Interactions/crossing	**<2.0>**

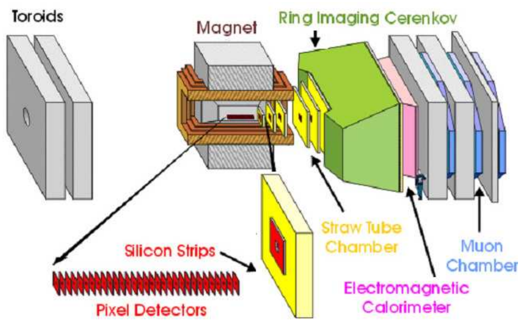


Operation at 396 ns Bunch Crossing

- BTeV was designed for L = 2×10^{32} $cm^{-2}s^{-1}$ at 132 ns or ⟨2⟩ int/crossing
- Now expect L ~ 2.0×10^{32} $cm^{-2}s^{-1}$ at 396 ns, i.e. ⟨6⟩ int/crossing

  or L ~ 1.3×10^{32} $cm^{-2}s^{-1}$ at 396 ns, i.e. ⟨4⟩ int/crossing
- Verified performance by repeating many of the simulations at ⟨4⟩ and ⟨6⟩ int/crossing (without re-optimizing the code)

  Average impact across store is ~10%
- Key potential problems areas - trigger, EMCAL and RICH all hold up well based on simulations
- Ongoing work to understand fully the impact of a change to 396 ns bunch spacing.



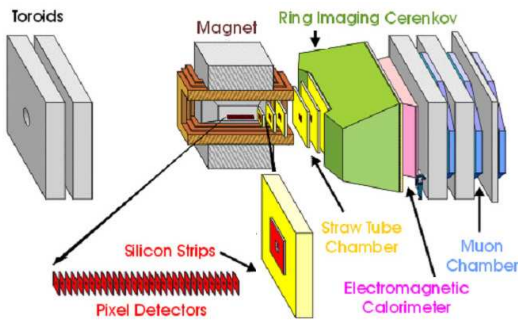
Trigger Performance

- ***For a requirement of at least 2 tracks detached by more than 6σ, only 1% of the beam crossings have interactions that satisfy the BTeV trigger.***

- ***The BTeV trigger has the following efficiencies for these states:***

State	efficiency(%)	state	efficiency(%)
$B \rightarrow \pi^+\pi^-$	63	$B^o \rightarrow K^+\pi^-$	63
$B_s \rightarrow D_sK$	74	$B^o \rightarrow J/\psi\ K_s$	50
$B^- \rightarrow D^oK^-$	70	$B_s \rightarrow J/\psi K^*$	68
$B^- \rightarrow K_s\pi^-$	27	$B^o \rightarrow K^*\gamma$	40

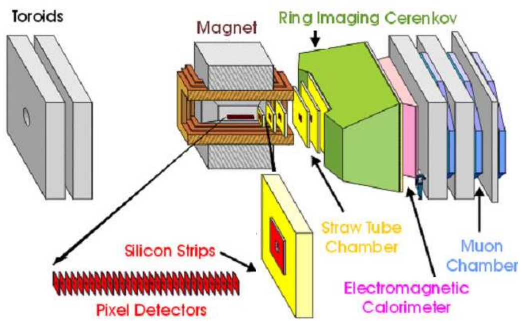
At < 2 > interactions per crossing



Flavor Tagging in BTeV

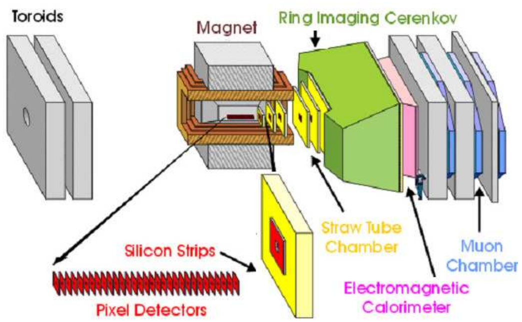
- $\varepsilon \equiv$ efficiency
- $D \equiv$ Dilution or $(N_{right}-N_{wrong})/(N_{right}+N_{wrong})$
- Effective tagging efficiency $\equiv \varepsilon D^2$
- Extensive study for BTeV uses
  - Opposite sign $K^{\pm}$
  - Jet Charge
  - Same side $\pi^{\pm}$ (for B^o) or $K^{\pm}$ for (B_s)
  - Leptons
- **Conclusion: $\varepsilon D^2 (B^o) = 0.10$ $\varepsilon D^2 (B_s) = 0.13$,**

(difference due to same side tagging)



Yield Calculation
$B^o \rightarrow \pi^+ \pi^-$

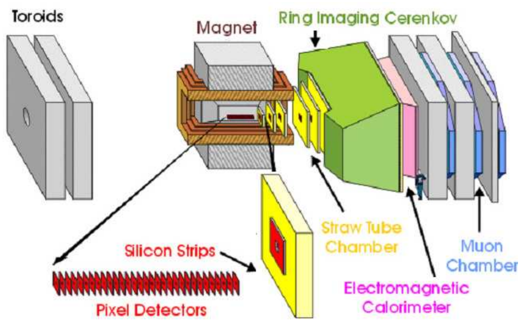
Cross-section	**100 μb**
Luminosity (<2> interactions/crossing)	**2×10^{32}**
# of B^o/Year (10^7 s)	**1.5×10^{11}**
$B(B^o \rightarrow \pi^+\pi^-)$	**0.45×10^{-5}**
Reconstruction efficiency – one arm	**0.04**
Particle I.D. efficiency	**0.82**
Triggering efficiency (after all other cuts) L1+L2	**0.55**
# ($\pi^+\pi^-$)	**12.200**
εD^2 for flavor tags ($K^\pm$, $l^\pm$, same + opposite side jet tags)	**0.1**
# of tagged $\pi^+\pi^-$	**1,220**
Signal/Background	**3**
Error in $\pi^+\pi^-$ asymmetry (including bkgrd)	**±0.033**



CKM Matrix Wolfenstein Parametrization

V_{cr}	d	s	b
u	$1-\frac{1}{2}\lambda^2$	λ	$A\lambda^3\left(\rho-i\eta\left[1-\frac{1}{2}\lambda^2\right]\right)$
c	$-\lambda$	$1-\frac{1}{2}\lambda^2-i\eta A^2\lambda^4$	$A\lambda^2\left(1+i\eta\lambda^2\right)$
t	$A\lambda^3(1-\rho-i\eta)$	$-A\lambda^2$	1

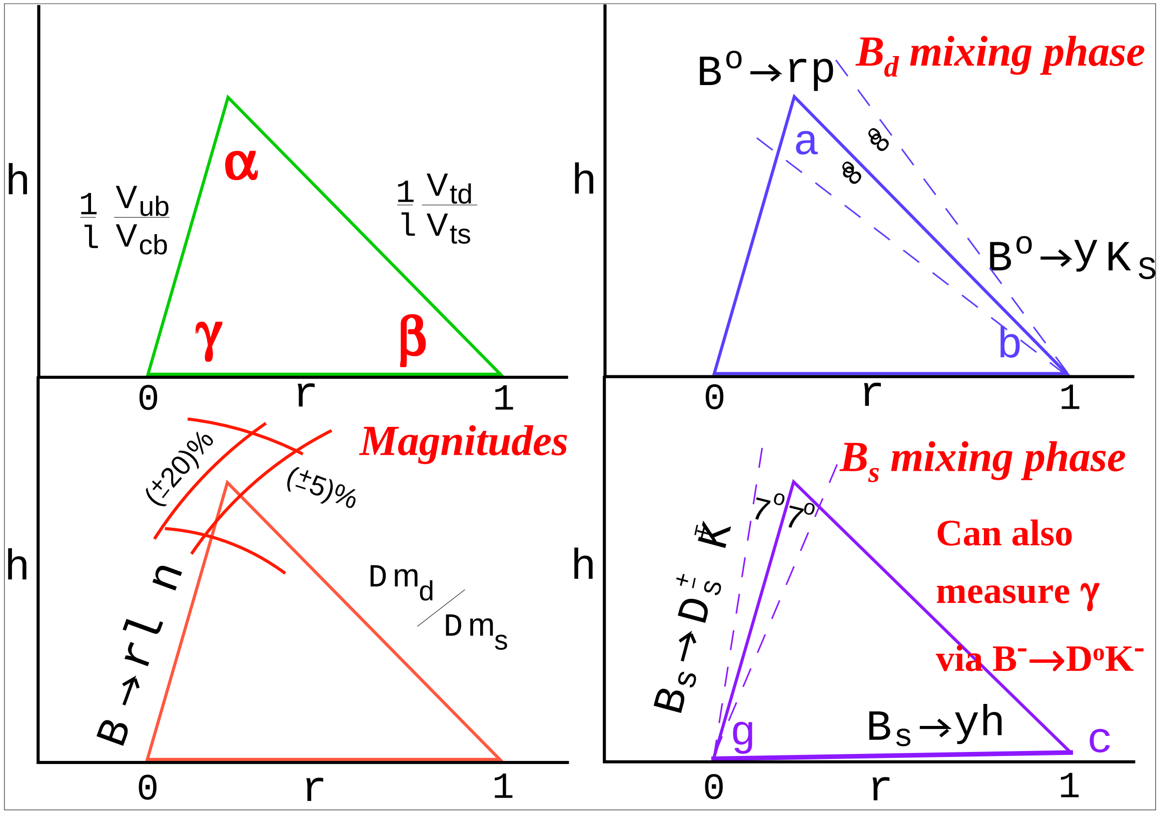
- **Good to λ^3 in real part & λ^5 in imaginary part**
- **We know λ=0.22, A~0.8; constraints on ρ & η**

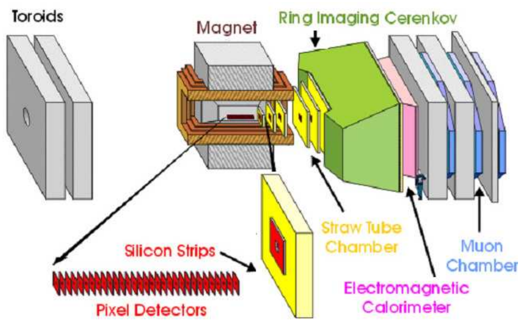


Determination of the of the bd Triangle

- Using different measurements to define apex of triangle

- Also have ε_K (~~CP~~ in K_L system)



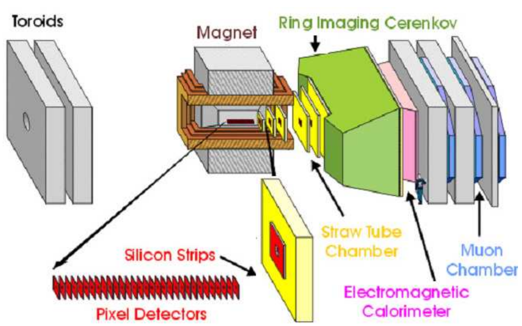


The CKM Phases (Angles)

$$\beta = \arg\left(-\frac{V_{tb} V_{td}^*}{V_{cb} V_{cd}^*} \right) \qquad \gamma = \arg\left(-\frac{V_{ub}^* V_{ud}}{V_{cb}^* V_{cd}} \right)$$

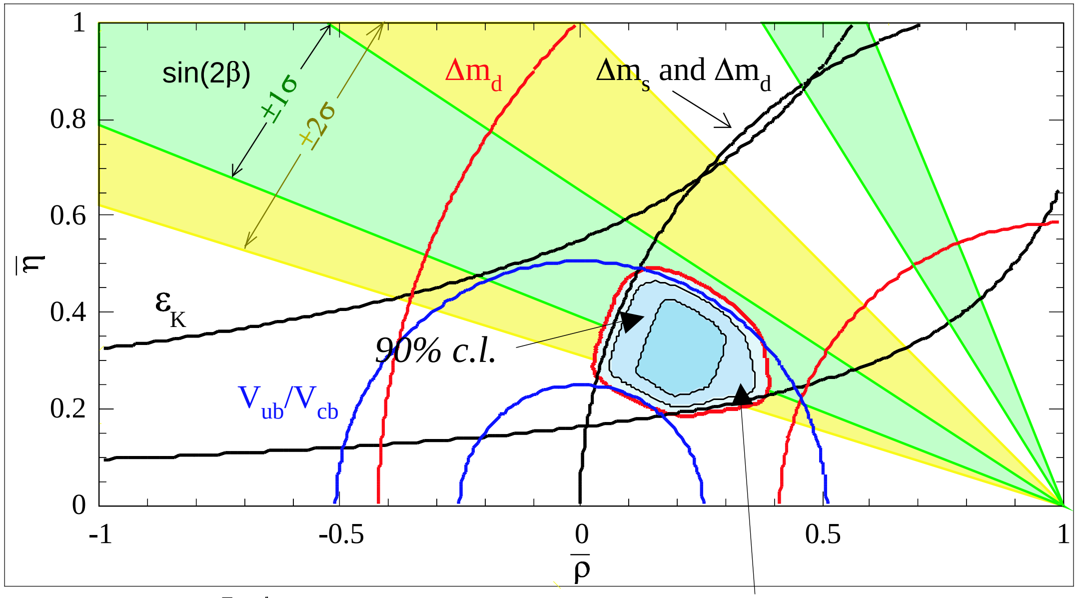
$$\chi = \arg\left(-\frac{V_{cs}^* V_{cb}}{V_{ts}^* V_{tb}} \right) \qquad \chi' = \arg\left(-\frac{V_{ud}^* V_{us}}{V_{cd}^* V_{cs}} \right)$$

$\alpha = \pi - (\beta + \gamma)$, β & γ probably large, χ small ~0.03 χ' smaller

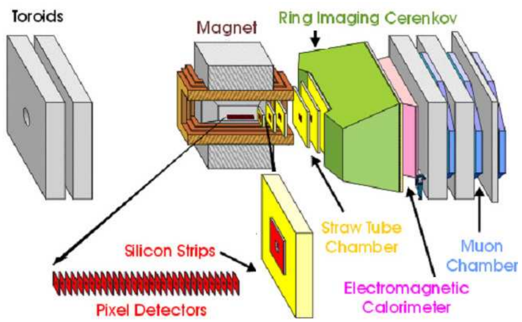


Current Status of Knowledge of ρ, η

- Constraints on ρ & η from Hocker et al.
- Theory parameters are allowed to have equal probability within a restricted but arbitrary range

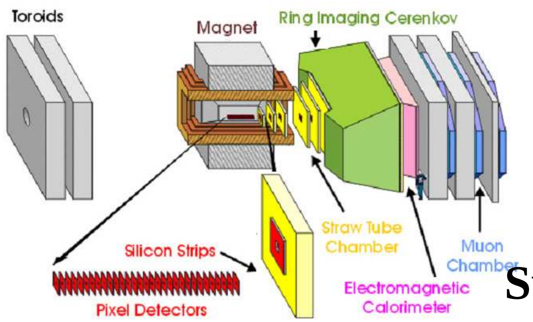


- ***Large model dependence for V_{ub}/V_{cb}, ε_K and Δm_d,***
- ***Smaller but significant model dependence for Δm_s.***
- ***Virtually no model dependence for sin(2β)***



Primary Modes for Determining CKM Angles (at the moment)

- $B^0 \rightarrow J/\Psi K_s$ — $\sin(2\beta)$
- $B^0 \rightarrow \rho\pi \rightarrow \pi^+\pi^-\pi^0$ — $\sin(2\alpha)$
- $B_s \rightarrow D^\pm K^\mp$ — $\sin(\gamma)$
- $B^- \rightarrow D^0_s K^-$ (and c.c.) — $\sin(\gamma)$
- $B_s \rightarrow J/\Psi \eta'$ — $\sin(2\chi)$



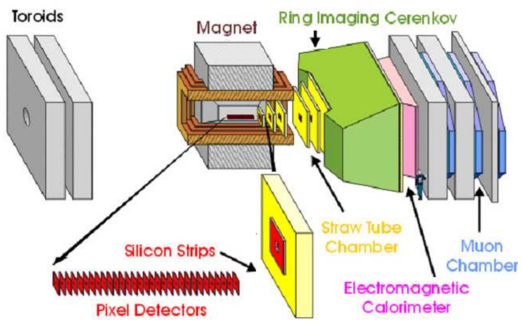
BTeV Capabilities

High rate capability **Excellent particle ID**

Broad band trigger **High speed/ capacity DA**

Superb vertex resolution **Excellent photon „^{0} resolution**

Physics Quantity	Decay Mode	Vertex Trigger	K/π sep	γ det	Decay time σ
sin(2α)	$B^o \to \rho\pi \to \pi^+\pi^-\pi^o$	¥	¥	¥	
sin(2α)	$B^o \to \pi^+\pi^-$ & $B_s \to K^+K^-$	¥	¥		¥
cos(2α)	$B^o \to \rho\pi \to \pi^+\pi^-\pi^o$	¥	¥	¥	
sign(sin(2α))	$B^o \to \rho\pi$ & $B^o \to \pi^+\pi^-$	¥	¥	¥	
sin(γ)	$B_s \to D_s\ K^-$	¥	¥		¥
sin(γ)	$B^o \to D^o\ K^-$	¥	¥		
sin(γ)	$B \to K\pi$	¥	¥	¥	
sin(2χ)	$B_s \to J/\psi\eta'$, $J/\psi\eta$		¥	¥	¥
sin(2β)	$B^o \to J/\psi K_s$				
cos(2β)	$B^o \to J/\psi K^*$ & $B_s \to J/\psi\phi$		¥		
x_s	$B_s \to D_s\pi^-$	¥	¥		¥
ΔΓ for B_s	$B_s \to J/\psi\eta'$, K^+K^-, $D_s\pi^-$	¥	¥	¥	¥

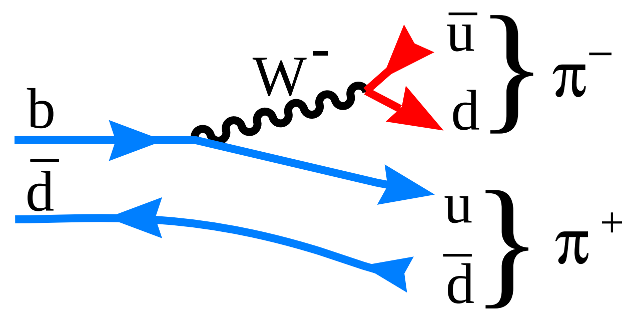


Measuring α
Using $B^{o}\rightarrow\pi^{+}\pi^{-}$

- **Using $B^{o}\rightarrow\pi^{+}\pi^{-}$ has the problem of a large Penguin term (CLEO+BABAR+BELLE):**

  $B(B^{o}\rightarrow\pi^{+}\pi^{-}) = (4.5 \pm 0.9)\times10^{-6}$

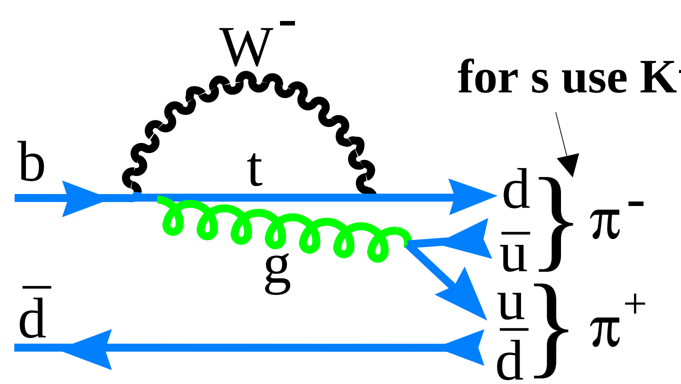
  $B(B^{o}\rightarrow K^{\pm}\pi^{m}) = (17.3\pm1.5)\times10^{-6}$

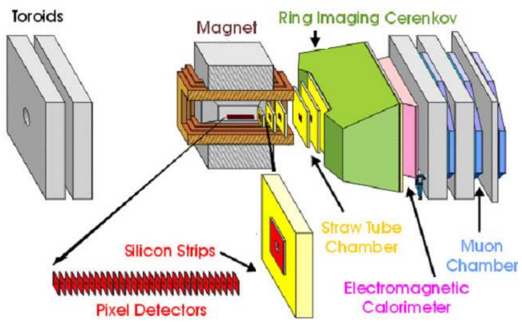


- **The effect of the Penguin must be measured in order to determine α. Can be done using Isospin, but requires a rate measurements of**

  $\pi^{-}\pi^{0}$ and $\pi^{o}\pi^{o}$ (Gronau & London).

  However, this is complicated.





Measuring α

Using $B^o \to \rho\pi \to \pi^+\pi^-\pi^o$

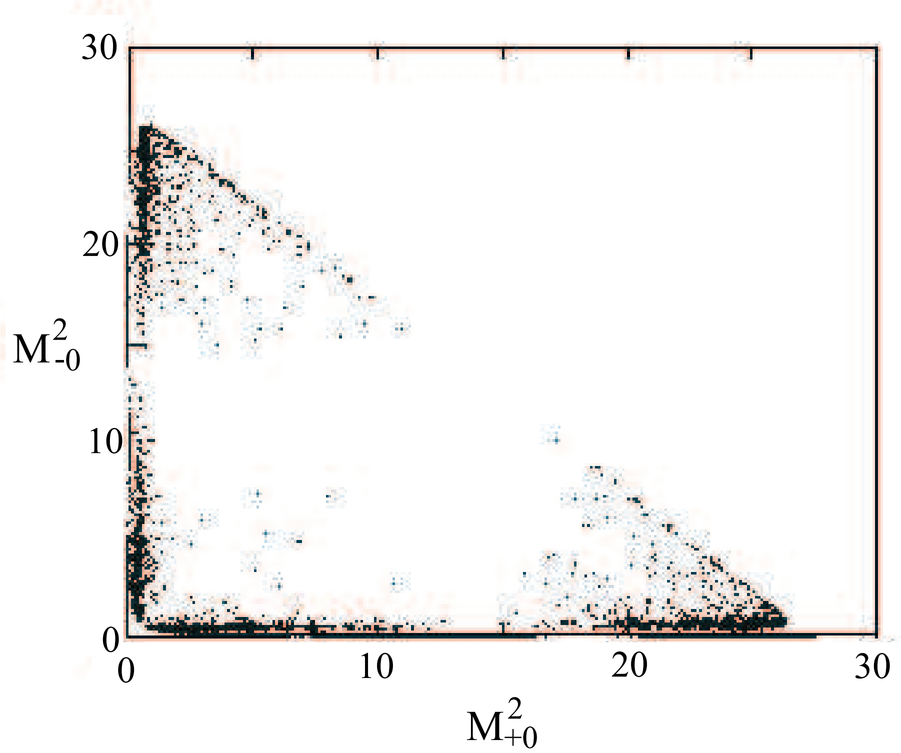
- **A Dalitz Plot analysis gives both sin(2α) and cos(2α) (Snyder & Quinn)**
- **Measured branching ratios are:**

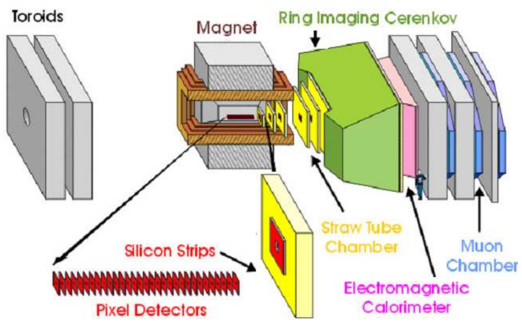
$B(B^- \to \rho^o\pi^-) = \sim 10^{-5}$

$B(B^o \to \rho^-\pi^+ + \rho^+\pi^-) = \sim 3\times10^{-5}$

$B(B^o \to \rho^o\pi^o) < 0.5\times10^{-5}$

- **BTeV simulations indicate that 1000-tagged events are sufficient to determine α with an error $\delta\alpha \sim 4^o$.**



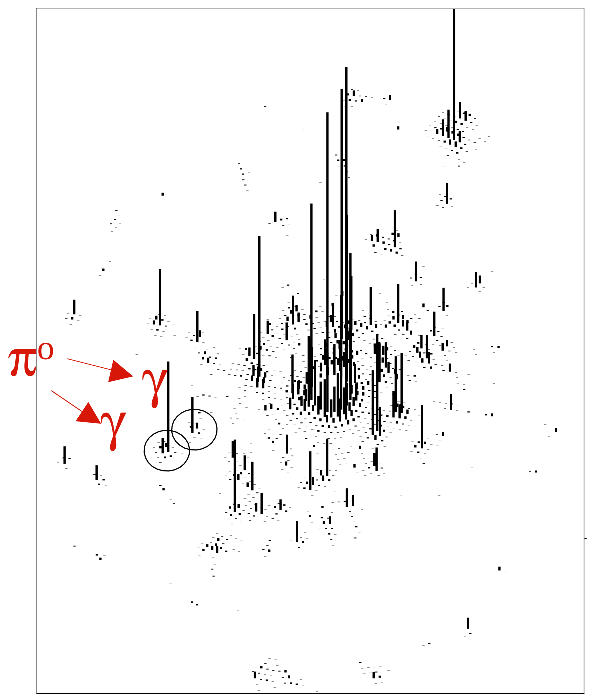


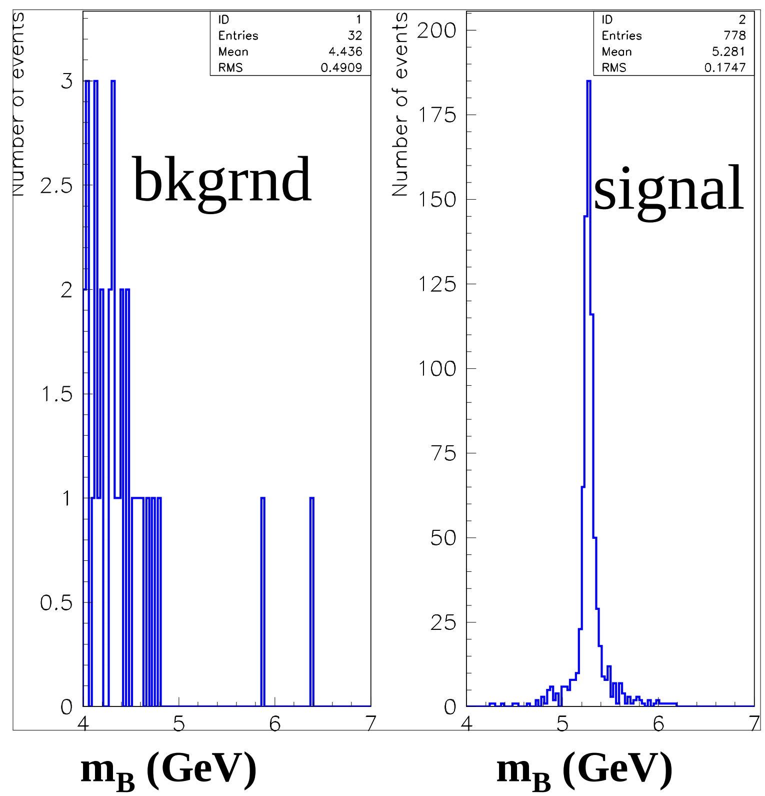
Detecting $B^o \to \rho\pi$

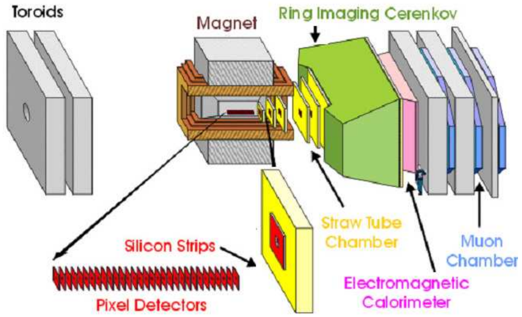
Based 9.9x10^6 background events

$B^o \to \rho^+\pi^-$ S/B = 4.1

$B^o \to \rho^o\pi^o$ S/B = 0.3





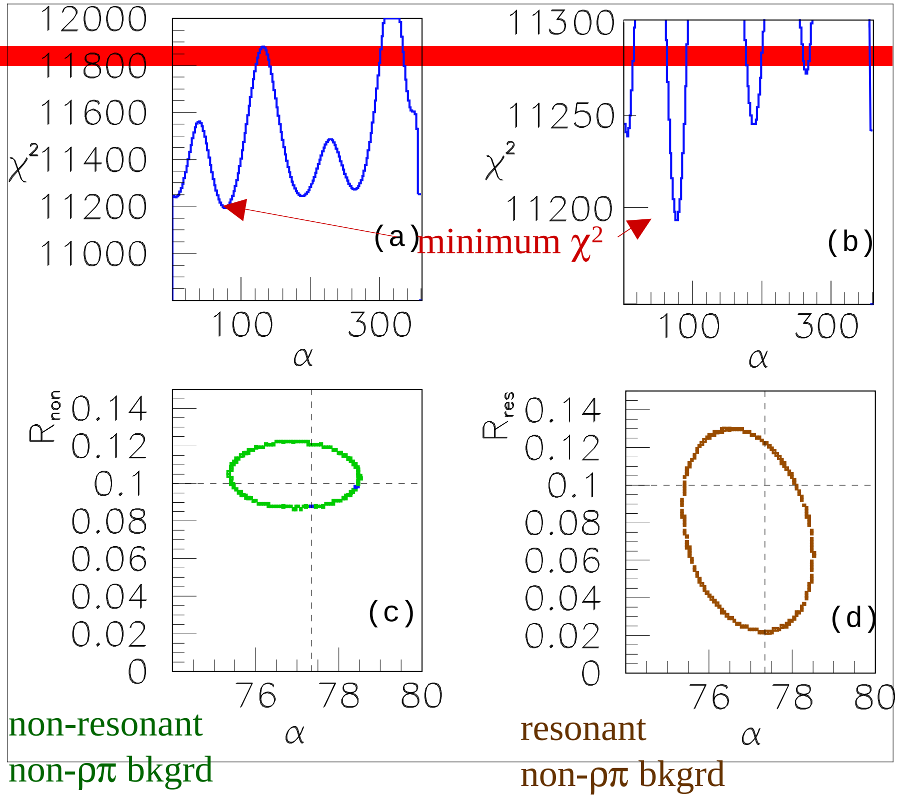


Estimated Accuracy on α

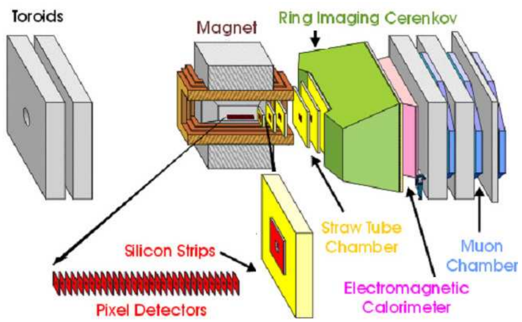
- **Simulation of $B^o \rightarrow \rho\pi$, (for 1.4×10^7 s)**

  Resonant (R_{res}) + Non-Resonant (R_{non})

α (gen)	R_{res}	R_{non}	α (recon)	δα
77.3°	0.2	0.2	77.2°	1.6°
77.3°	0.4	0	77.1°	1.8°
93.0°	0.2	0.2	93.3°	1.9°
93.0°	0.4	0	93.3°	2.1°
111.0°	0.2	0.2	111.7°	3.9°
111.0°	0.4	0.2	110.4°	4.3°



1000 $B^o \rightarrow \rho\pi$ signal + backgrounds with input α=77.3°



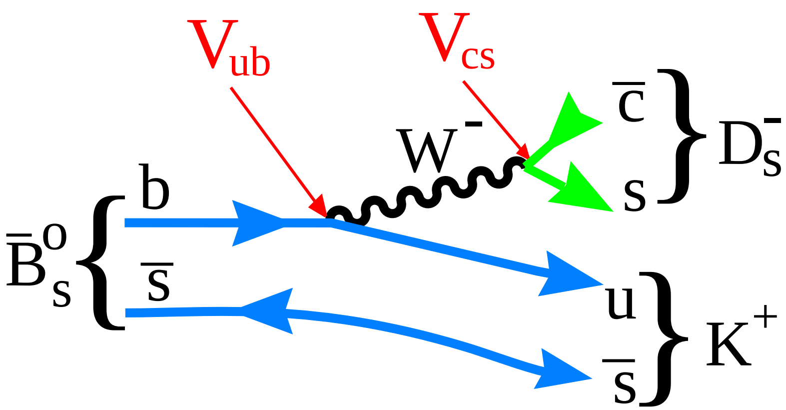
Measuring γ

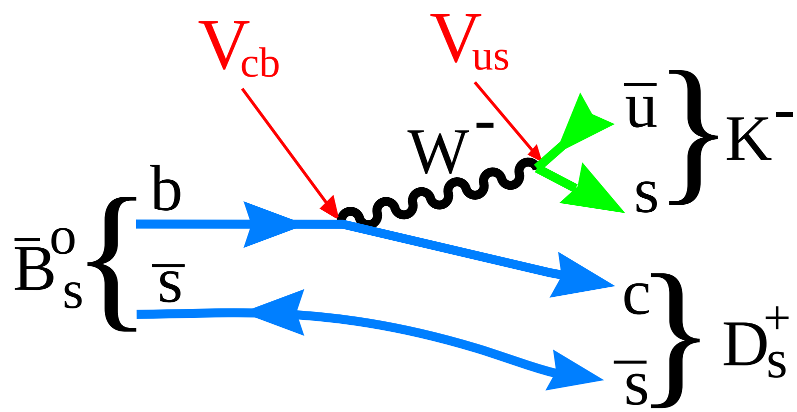
using $B_s \to D_s K^{m}$

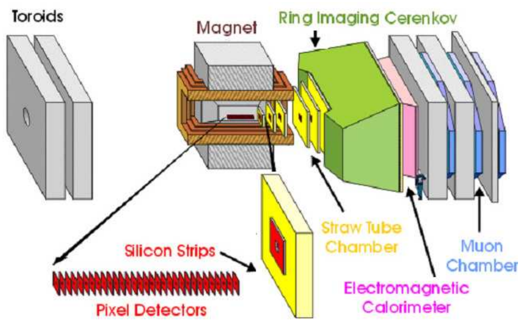
Model Independent

Time dependent flavor tagged analysis of $B_s \to D_s K^{\pm}$

Diagrams for the two decay modes, BR ~ 10^{-4} for each







Measuring γ using

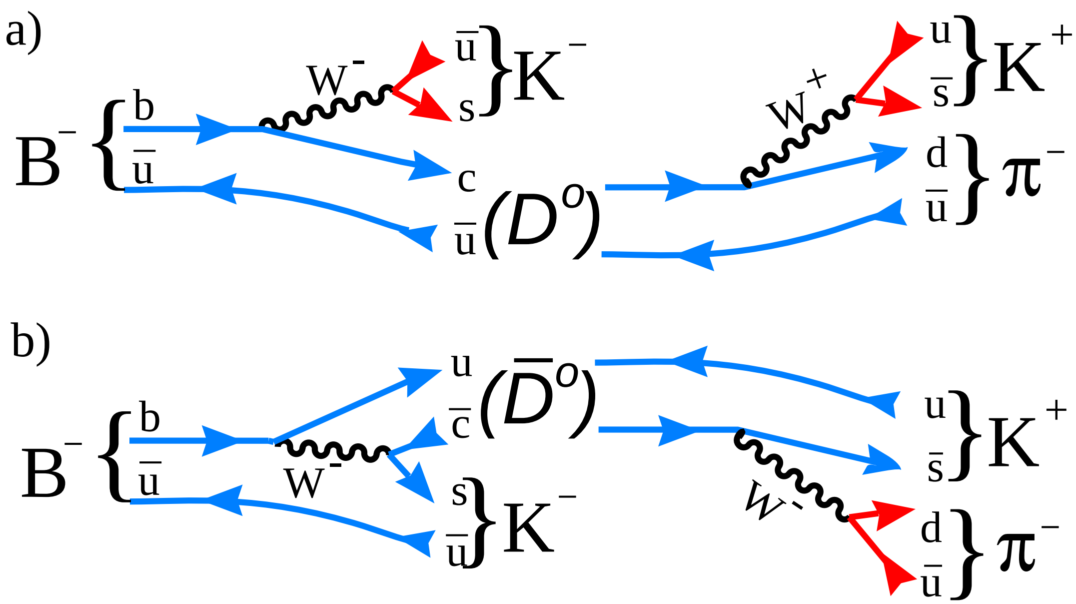
$B^- \to D^0 K^- \to [K^+\pi^-]K^-$

$B^- \to D^0 K^- \to [K^+\overline{\pi}]K^-$

Decay processes

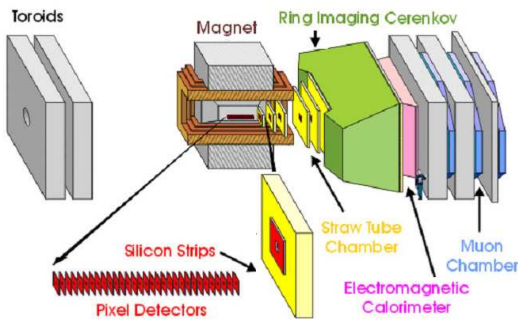
Model independent

Rate difference between $B^- \to D^o K^-$ & $B^+ \to D^o K^+$



B ~ 1x10^{-7}

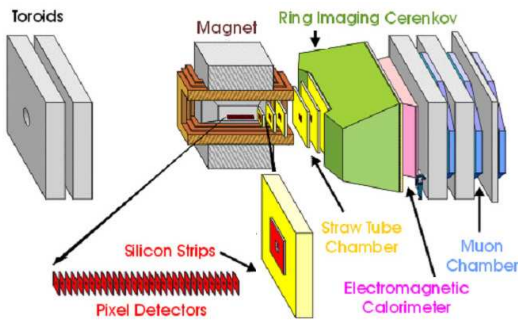
B ~ 0.7x10^{-7}



Other ways of Measuring γ

Model Dependent

- There are two more ways of determining γ
  - Rate measurements in $K^o\pi^\pm$ and $K^\pm\pi^\mp$ (Fleisher-Mannel) or rates in $K^o\pi^\pm$ & asymmetry in $K^\pm\pi^o$ (Neubert-Rosner, Beneke et al) . Has theoretical uncertainties.
  - Use U spin symmetry d$\Leftrightarrow$s: measure time dependent asymmetries in both $B^o\to\pi^+\pi^-$ & $B_s\to K^+K^-$ (Fleischer).
  - Ambiguities here as well but they are different in each method, and using several methods can resolve them.

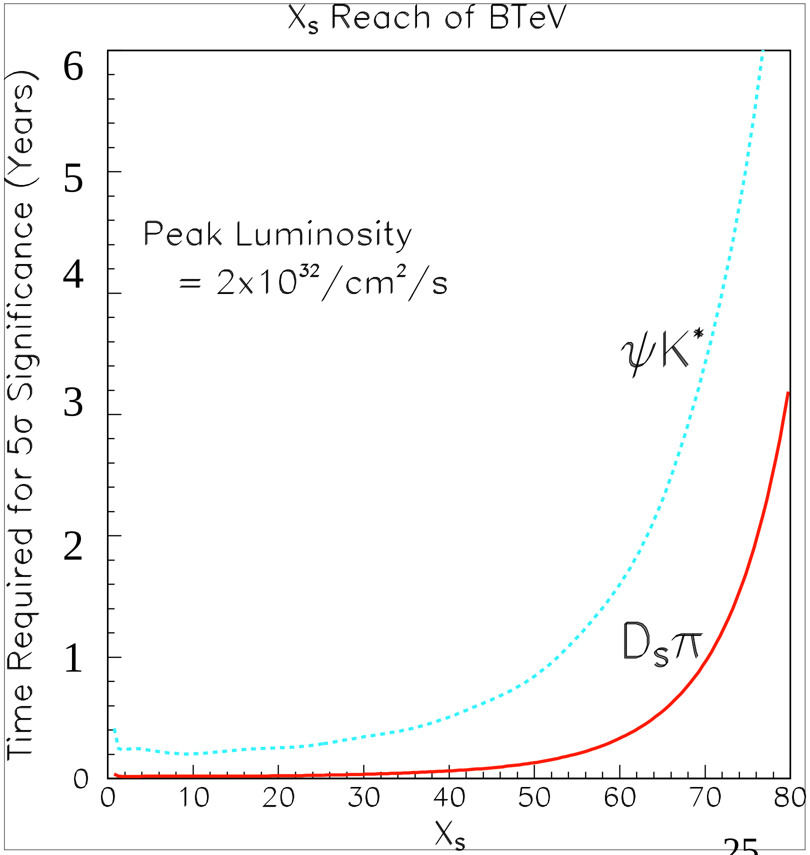


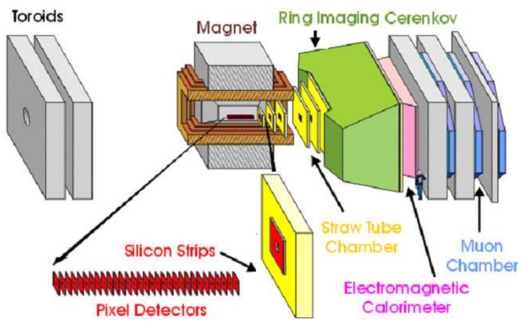
x_s Reach

- BTeV reaches sensitivity to x_s of **80** in **3.2 years**

Using

$B_s \to D_s \pi^-$





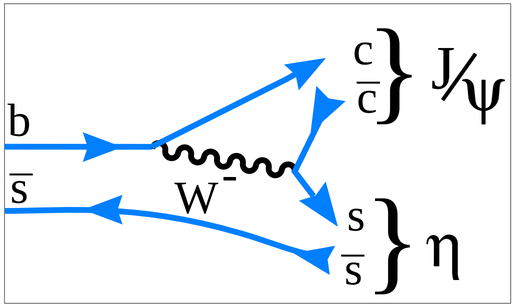
Measuring χ

- **BTeV can use CP eigenstates in B_s decay to measure χ, for example**

– **$B_s \to J/\psi\eta^{(\prime)}$, $\eta\to\gamma\gamma$, $\eta'\to\rho\gamma$**

– **Can also use $J/\psi\phi$, but need**

– **a complicated angular analysis**

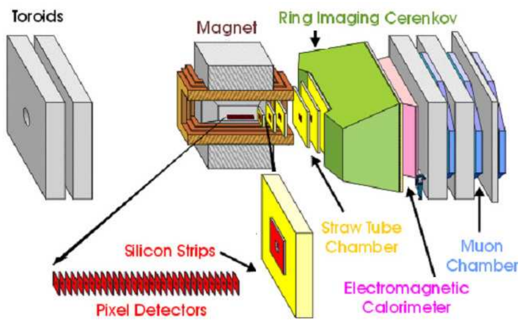


Note: Silva & Wolfenstein (hep-ph/9610208), (Aleksan, Kayser & London), propose a test of the SM, that can reveal new physics; it relies on measuring the angle χ.

The critical check is

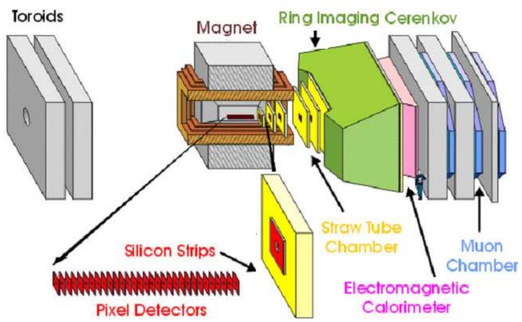
$$\sin\chi = \lambda^2\left(\frac{\sin\beta\sin\gamma}{\sin(\beta+\gamma)}\right)$$

Very sensitive since λ =0.2205±0.0018; Since χ ~ 0.03, lots of data needed

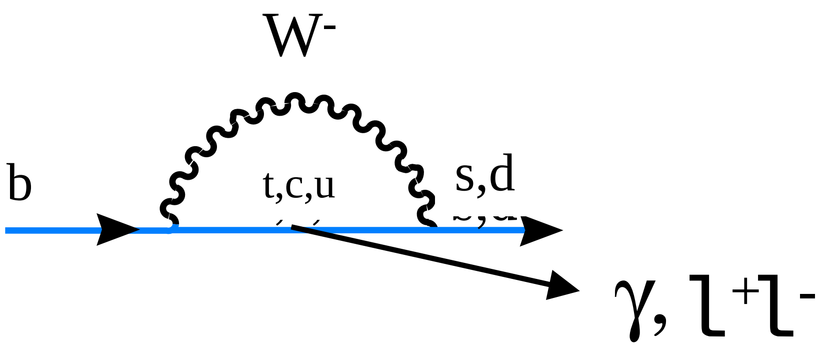


Current Constraints on New Physics

- All our current measurements are a combination of SM *and* New Physics-any proposed Models must satisfy current constraints
- SM tree level diagrams are probably large; consider them a background to New Physics.
- Loop diagrams & CP violation are the best places to see New Physics.
- The most important constraints are
  - neutron electric dipole moment $<6.3 \times 10^{-26}$ *e* cm
  - $B(b \to s\gamma) = (2.88 \pm 0.39) \times 10^{-4}$
  - CP violation in K_L decay, $\varepsilon_K = (2.271 \pm 0.017) \times 10^{-3}$
  - B^o mixing parameter $\Delta m_d = (0.487 \pm 0.014)\ ps^{-1}$

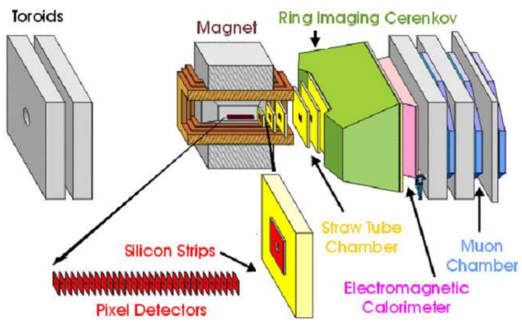


New Physics in Rare b Decays



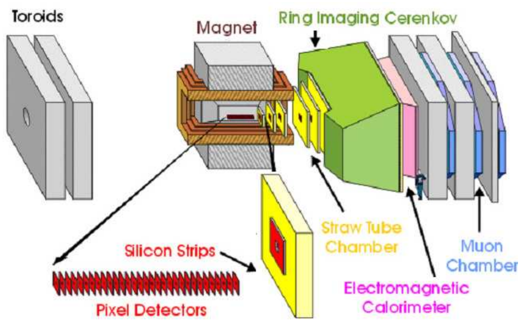
- **New fermion like objects in addition to t, c or u**
- **Exclusive Rare Decays such as $B \to \rho\gamma$ Dalitz plot & polarization**
- **Inclusive Rare Decays such as inclusive $b \to s\gamma$, $b \to d\gamma$, $b \to s l^+ l^-$**

¥ **$B \to K^* l^+ l^-$ Da;itz plot & polarization**



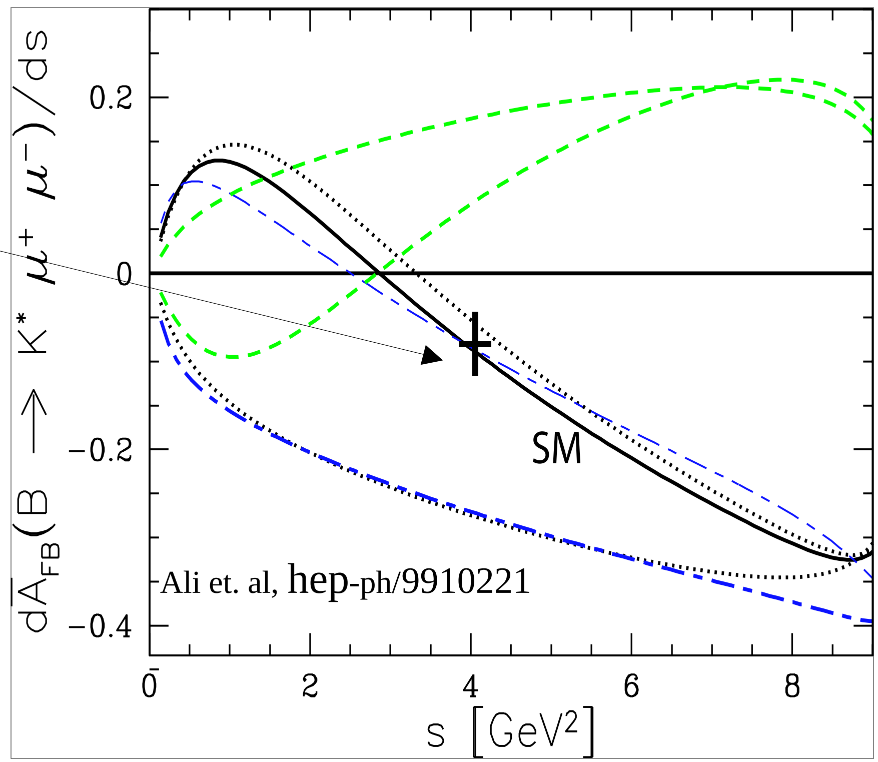
New Physics in $B \to K l^+ l^-$ and $B \to K^* l^+ l^-$

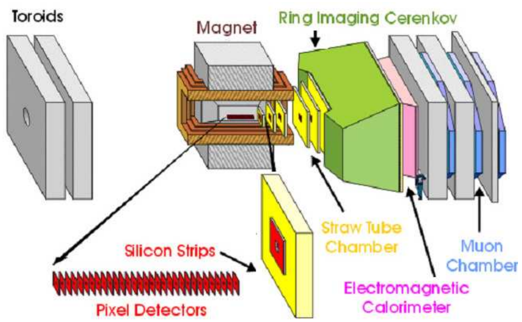
- Example of non-specific models of specific decays,
  - effects on dilepton invariant mass & Dalitz plot for $B \to K l^+ l^-$ & $B \to K^* l^+ l^-$ decays.
  - "***Especially the decay into K* yields a wealth of new information on the form of the new interactions since the Dalitz plot is sensitive to subtle interference effects***" **(Greub, Ioannissian & Wyler hep-ph/9408382)**



SUSY Test in
$B \rightarrow K^* \ell^+ \ell^-$ polarization

TYPICAL BTEV ERROR BAR 10^7s

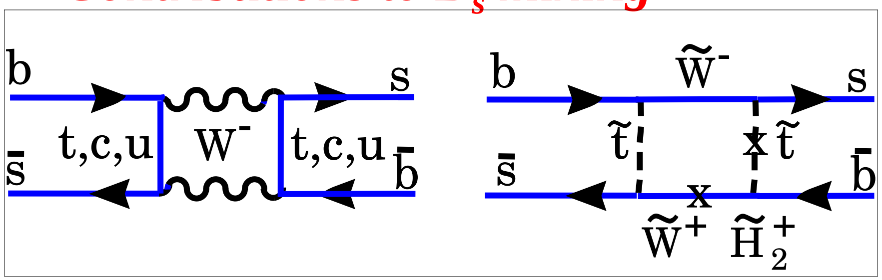




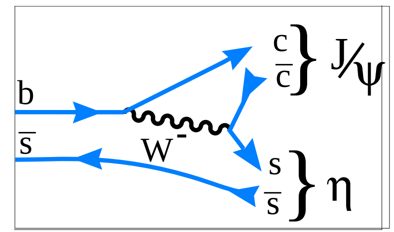
MSSM Measurements from Hinchcliff & Kersting

(hep-ph/0003090)

- ***Contributions to B_s mixing***

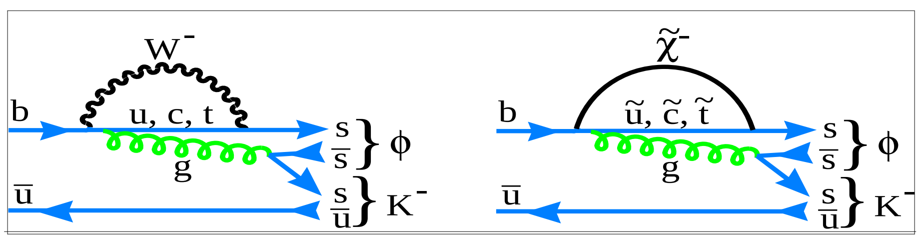


$B_s \rightarrow J/\psi\eta$

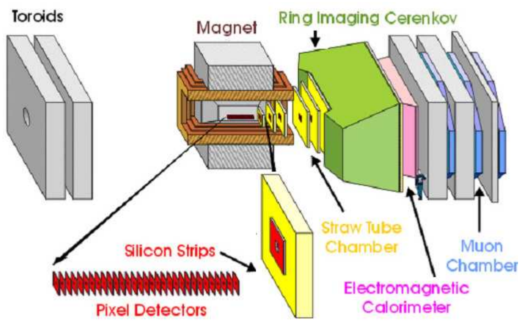


CP asymmetry ≈ $0.1\sin\phi_\mu\cos\phi_A\sin(\Delta m_s t)$, ~10 x SM

- ***Contributions to direct CP violating decay***



asymmetry=$(M_W/m_{squark})^2\sin(\phi_\mu)$, ~0 in SM



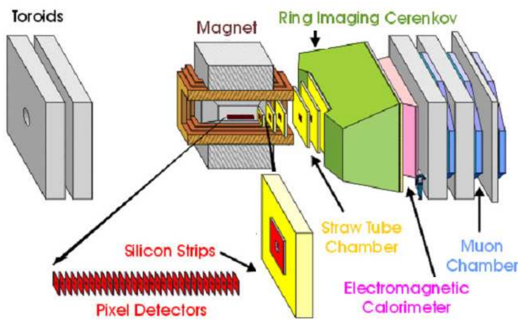
Other Tests for New Physics

- New Physics in B^o mixing, θ_D , B^o decay, θ_A, D^o mixing, $\phi_{K\pi}$
- Example: In Supersymmetry there are 80 constants & 43 phases, while in MSSM: 2 phases (Nir, hep-ph/9911321)

Process	Quantity	SM	New Physics
$B^o \to J/\psi K_s$	CP asym	$\sin(2\beta)$	$\sin 2(\beta+\theta_D)$
$B^o \to \phi K_s$	CP asym	$\sin(2\beta)$	$\sin 2(\beta+\theta_D+\theta_A)$
$D^o \to K^- \pi^+$	CP asym	0	$\sim\sin(\phi_{K\pi})$

Difference $\Rightarrow$ NP

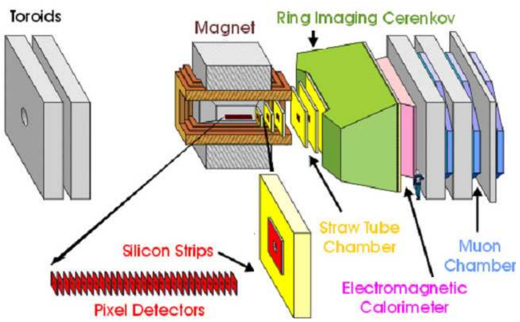
NP



SUSY Predictions (Nir)

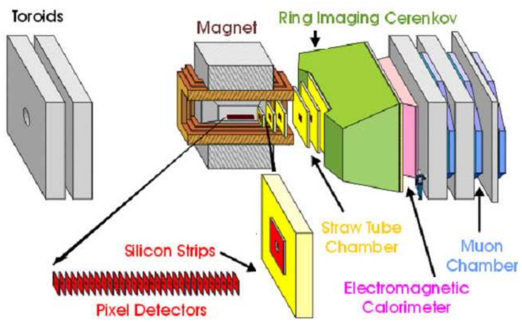
Model	neutron dipole/10^{-25}	θ_D	θ_A	$asy_{D\to K\pi}$
SM	$\leq 10^{-6}$	0	0	0
Approx. Universality	$\geq 10^{-2}$	O(0.2)	O(1)	0
Alignment	$\geq 10^{-3}$	O(0.2)	O(1)	O(1)
Heavy squarks	$\sim 10^{-1}$	O(1)	O(1)	O(10^{-2})
~~Approx. CP~~	~~$\sim 10^{-1}$~~	~~$-\beta$~~	~~0~~	~~O(10^{-3})~~

- Specific pattern in each model $\Rightarrow$ ways of distinguishing among models

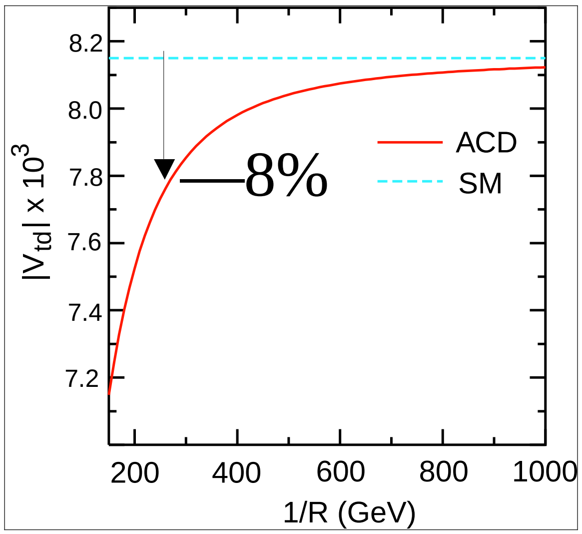


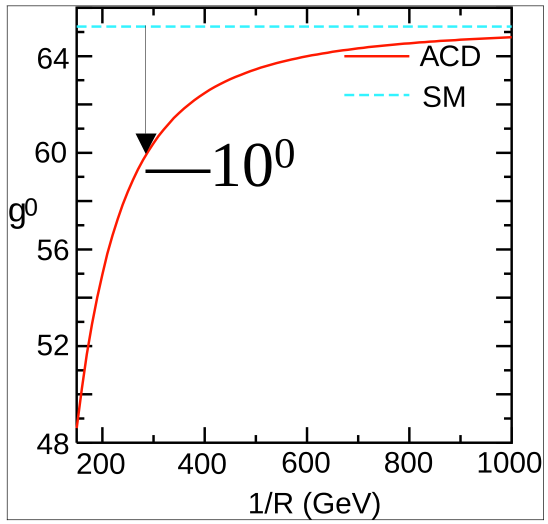
One Extra Dimension

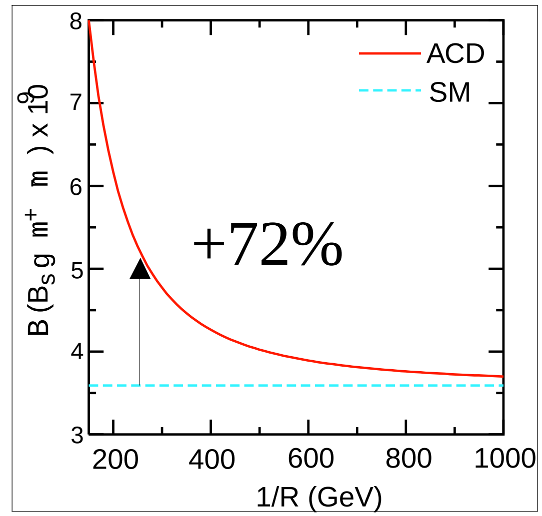
- Extra spatial dimension is compactified at a scale 1/R > 250 GeV
- Contributions from Kaluza-Klein modes- Buras, Sprnger & Weiler (hep-ph/0212143) using model of Appelquist, Cheng and Dobrescu (ACD)
- No effect on $|V_{ub}/V_{cb}|$, $\Delta M_d/\Delta M_s$, $\sin(2\beta)$
- However, has effects on V_{td}, γ, $BR(B_s \to \mu^+\mu^-)$

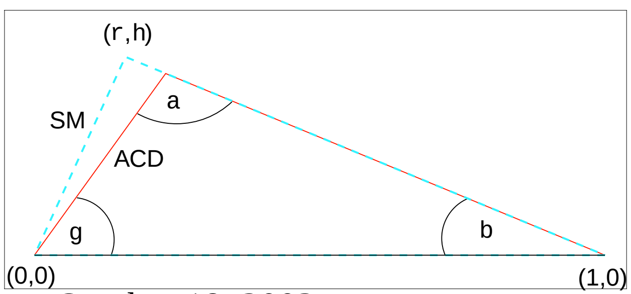


One Extra Dimension Effects

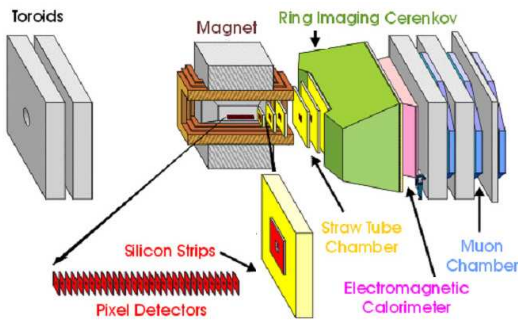






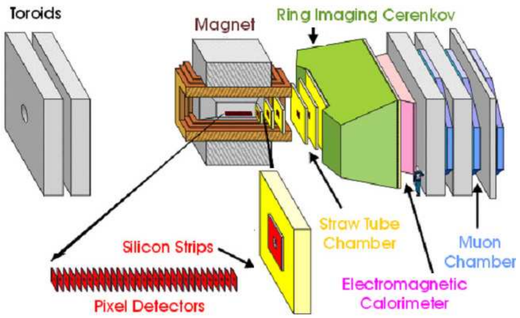


- Precision measurements needed for large 1/R



Other Extra Dimensions Speculations

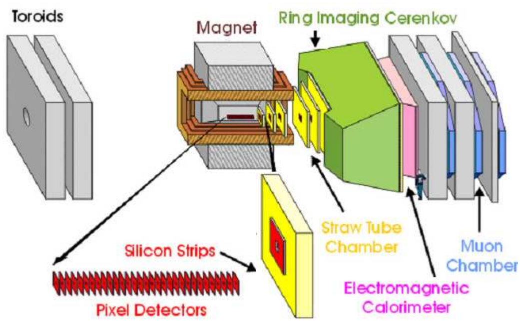
- **Chakraverty, Huitu & Kundu, "Effects of Universal Extra Dimensions on B^o Mixing (hep-ph/0212047)**
- **Kubo & Terao, "Suppressing FCNC and CP-Violating Phases with Extra Dimensions" (hep-ph/0211180)**
- **Huber, "Flavor Physics and Warped Extra Dimensions" (hep-ph/0211056)**
- **Barenboim, Botella, & Vives, "Constraining models with vector-like fermions from FCNC in K and B physics" {CPV in J/ψK_s & $\mathcal{B}(b \to s \ell^+ \ell^-)$} (hep-ph/0105306)**
- **Aranda & Lorenzo Diaz-Cruz, "Flavor Symmetries in Extra Dimensions" (hep-ph/0207059)**
- **Chang, Keung & Mohapatra, "Models for Geometric CP Violation with Extra Dimensions" (hep-ph/0105177)**
- **Agashe, Deshpande & Wu, "Universal Extra Dimensions & $b \to s\gamma$"(hep-ph/0105084)**
- **Branco, Gouvea & Rebelo, "Split Fermions in Extra Dimensions & CPV" (hep-ph/0012289)**
- **Papavassiliou & Santamaria, "Extra Dimensions at the one loop level: $Z \to bb$ and B-B mixing" (hep-ph/0008151)**



Relevance of B Physics for New Physics Searches

- BTeV is sensitive using b and c decays in loop diagrams to mass scales ~few TeV depending on couplings (model dependent). The **New Physics** effects in these loops may be the <u>only</u> way to distinguish among models.

- Masiero & Vives: ***"the relevance of SUSY searches in rare processes is not confined to the usually quoted possibility that indirect searches can arrive 'first' in signaling the presence of SUSY. Even after the possible direct observation of SUSY particles, the importance of FCNC & CPV in testing SUSY remains of utmost relevance. They are & will be complementary to the Tevatron & LHC establishing low energy supersymmetry as the response to the electroweak breaking puzzle"*** (hep-ph/0104027)

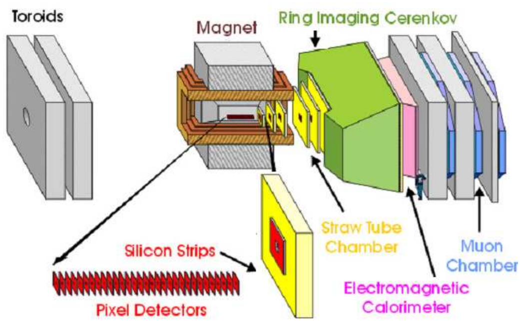


BTeV Physics Reach in 10^7 s

MODEL DEPENDENT

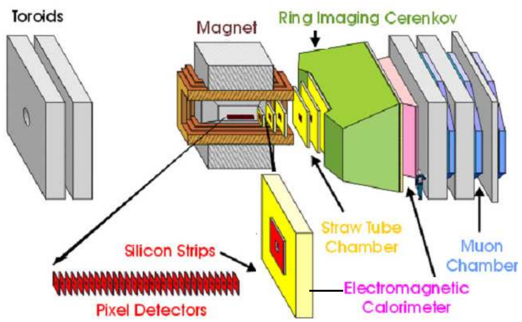
MODEL INDENPENDENT

Reaction	BR ($\times 10^{-6}$)	# of Events	S/B	Parameter	Error or (Value)
$B^o \to \pi^+\pi^-$ $B^0 \to K^+K^-$	4.5 17	14,600 18,900	3 6.6	Asymmetry Asymmetry	0.030 0.020
$B_s \to D_s K^-$	300	7500	7	$\gamma - 2\chi$	8^o
$B^o \to J/\psi K_S$ $J/\psi \to l^+ l^-$ $B^o \to J/\psi K^0$, $K^0 \to \pi l \nu$	445 7	168,000 250	10 2.3	$\sin(2\beta)$ $\cos(2\beta)$	0.017 ~0.5
$B_s \to D_s \pi^-$	3000	59,000	3	x_s	(75)
$B^- \to D^o (K^+\pi^-) K^-$ $B^- \to D^o (K^+K^-) K^-$	0.17 1.1	170 1,000	1 >10	γ	13^o
$B^- \to K_S \pi^-$ $B^o \to K^+\pi^-$	12.1 18.8	4,600 62,100	1 20	γ	$< 4^o$ + theory errors
$B^o \to \rho^+\pi^-$ $B^o \to \rho^o\pi^o$	28 5	5,400 780	4.1 0.3	α	$\sim 4^o$
$B_s \to J/\psi \eta$, $B_s \to J/\psi \eta'$	330 670	2,800 9,800	15 30	$\sin(2\chi)$	0.024



BTeV Physics Reach
Rare Decays in 10^7 s

Reaction	BR (10^{-6})	Signal	S/B	Physics
$B^o \rightarrow K^{*o}\mu^+\mu^-$	1.5	2530	11	polarization & rate
$B^- \rightarrow K^-\mu^+\mu^-$	0.4	1470	3.2	rate
$b \rightarrow s\mu^+\mu^-$	5.7	4140	0.13	rate: Wilson coefficients



BTeV Charm Physics Reach

- ***D^0-D^0 Mixing: Box diagram:*** $\Delta m_D^{SD}/\Gamma < 1\times10^{-4}$

  LD Dispersive: $\Delta m_D^{LD}/\Gamma \sim 2\times10^{-4}$

  LD HQET: $\Delta m_D^{LD}/\Gamma \sim (1 \text{ to } 2)\times10^{-5}$

  SM Contribution: $\Delta m_D^{SM}/\Gamma < 1\times10^{-4}$

  Current experimental limit $\Delta m_D/\Gamma < 0.1$ ***Lots of Discovery room!***

- ***CP Violation: Possibly observe SM CP violation in charm!***

  SM: $A_{CP} \approx 2.8\times10^{-3}$ ***for*** $D^+ \rightarrow K^{*0}K^+$

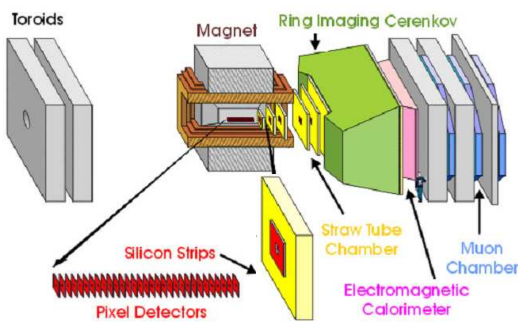
  $A_{CP} \approx -8.1\times10^{-3}$ ***for*** $D_s^+ \rightarrow K^{*+}\eta'$

  Expect $\sigma(A_{CP}) = 1\times10^{-3}$ ***for*** 10^6 ***background-free events***

  Excellent D* tag (efficiency $\approx 25\%$***)***

  Geant simulation gives # reconstructed $D^0 \rightarrow K\pi > 10^8$

BTeV can do charm physics!



Comparisons of BTeV With "Current" e^+e^- B factories

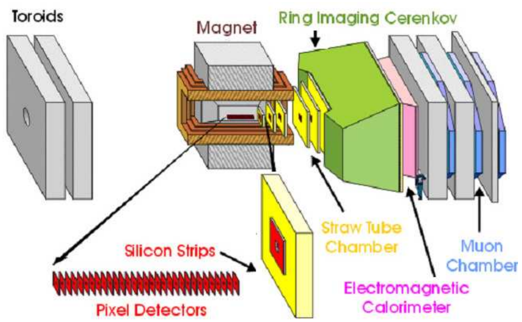
- *Number of flavor tagged $B^o \rightarrow \pi^+ \pi^-$ ($\mathcal{B}=0.45\times10^{-5}$)*

	$\mathcal{L}$ ($cm^{-2}s^{-1}$)	σ	$\#B^o/10^7 s$	ε	εD^2	#tagged
e^+e^-	10^{34}	1.1 nb	1.1×10^8	0.45	0.26	56
BTeV	2×10^{32}	100μb	1.5×10^{11}	0.021	0.1	1426

- *Number of $B^- \rightarrow D^o K^-$ (Full product $\mathcal{B}=1.7\times10^{-7}$)*

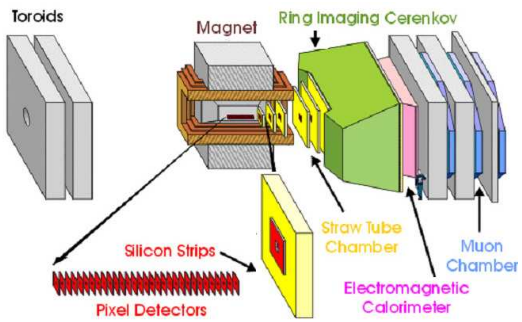
	$\mathcal{L}$ ($cm^{-2}s^{-1}$)	σ	$\#B^o/10^7 s$	ε	#
e^+e^-	10^{34}	1.1 nb	1.1×10^8	0.4	5
BTeV	2×10^{32}	100μb	1.5×10^{11}	0.007	176

- ***B_s, B_c and Λ_b not done at $\Upsilon(4S)$ e^+e^- machines***



Other Comparisons of BTeV with Current B-factories

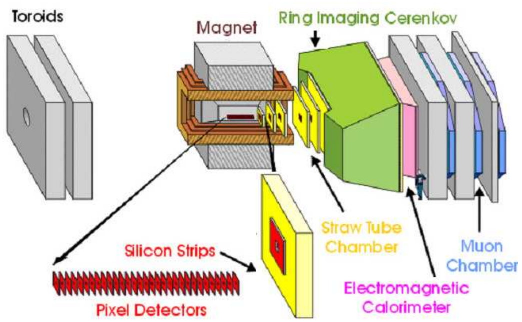
Mode	BTeV (10^7s)			B-fact (500 fb^{-1})		
	Yield	Tagged	S/B	Yield	Tagged	S/B
$B_s \to J/\psi\eta^{(\prime)}$	12650	1645	>15	-	-	
$B^- \to \phi K^-$	11000	11000	>10	700	700	4
$B^o \to \phi K_s$	2000	200	5.2	250	75	4
$B^o \to K^* \mu^+ \mu^-$	2530	2530	11	~50	~50	3
$B_s \to \mu^+ \mu^-$	6	0.7	>15	0		
$B^o \to \mu^+ \mu^-$	1	0.1	>10	0		
$D^{*+} \to \pi^+ D^o$, $D^o \to K\pi^+$	~10^8	~10^8	large	8x10^5	8x10^5	large



BTeV vs. Super BABAR

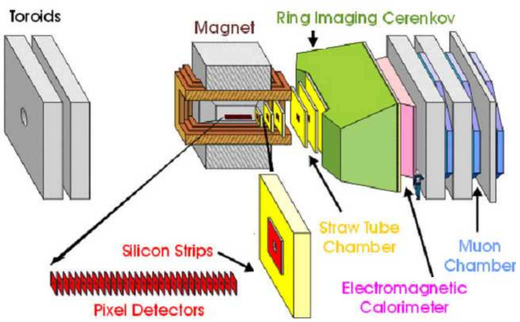
- **L=10^{36} is the goal of Super BABAR (>100 times original design).**
- **This would compete with BTeV in B^o & B^- physics, but not in B_s**
- **Still could not do B_s, B_c, and Λ_b**
- **Problems**
  - **Machine:** M2 review at Snowmass (S. Henderson) said:

    "Every parameter is pushed to the limit-many accelerator physics & technology issues"
  - **Detector:** Essentially all the BABAR subsystems would need to be replaced to withstand the particle densities & radiation load; need to run while machine fills continuously.



BTeV vs. Super KEK

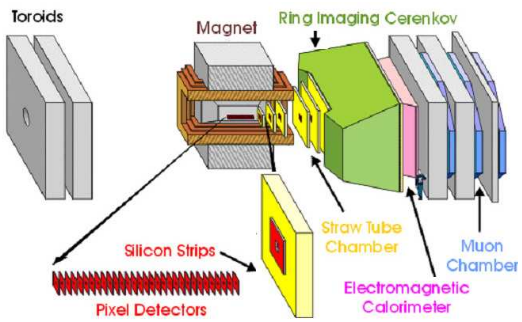
- KEK-B plans for L=10^{35} in 2007 (10 x original design).
- **However #'s in previous tables are still not competitive with BTeV**
  - E2 report at Snowmass: Problems for the detector due to **higher occupancies, trigger rates, synchrotron radiation, increased pressure in the interaction region & larger backgrounds at injection.**
  - Problem areas include: silicon vertex detector, **CsI(Tl) EM calorimeter because it is slow, and Muon RPC's that already have dead-time losses**



BTeV vs. LHCb

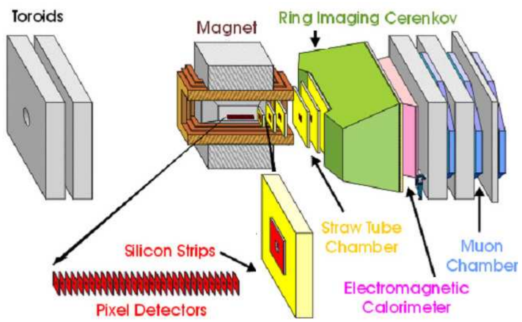
Relative to LHCb
disadvantages
advantages

- **LHCb has much higher B cross section (~ factor of 5)**
- **LHCb has three times lower interaction per crossing.**
- **BTeV has lower total cross section (factor of 1.6 lower)**
- **BTeV has vertex detector in magnetic field which allows rejection of high multiple scattering (low p) tracks in the trigger**
- **BTeV is designed around a pixel vertex detector which has much less occupancy, and allows for a detached vertex trigger in the first trigger level.**
  - **Important for accumulation of large samples of rare hadronic decays and charm physics.**
  - **Allows BTeV to run with multiple interactions per crossing, L in excess of 2x10^{32} cm^{-2} s^{-1}**
- **BTeV will have a much better EM calorimeter**
- **BTeV is planning to read out 5x as many b's/second**



Comparison of BTeV with LHCb (from LHCb TDR)

Mode	BR (B)	BTeV Yield	BTeV S/B	LHCb Yield	LHCb S/B
$B_s \rightarrow J/\psi\, \eta^{(')}$	1.0×10^{-4}	12650	>15	-	-
$B^o \rightarrow \rho^+ \pi^-$	2.8×10^{-5}	5400	4.1	2140	0.8
$B^o \rightarrow \rho^o \pi^o$	0.5×10^{-5}	776	0.3	880	not known

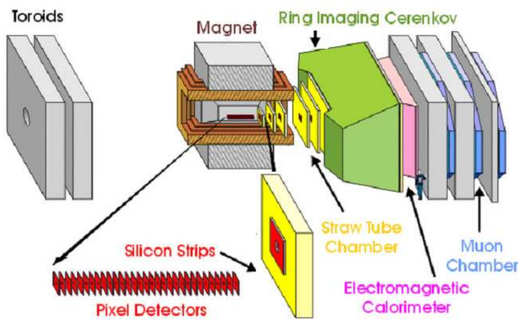


Summary

As the patron saint of Virginia Thomas Jefferson would say,

"We hold these truths to be self evident….."

- ***The BTeV experiment offers a very sensitive way study CP violation and search for new physics in broad spectrum of B and C decays in the coming time period.***
- ***Comparisons with the most ambitious e^+e^- opportunities, even if they can be built, are still favorable to BTeV.***
- ***BTeV when compared with LHCb has significant advantages when the better calorimetry and the broader spectrum of charm and beauty physics made possible by the vertex trigger is taken into account.***
- ***Now that the P5 report has been issued, we hope to proceed expeditiously with the necessary R&D and construction to meet the Fermilab schedule of first beam for BTeV in early 2009.***



Caveat: Ambiguities

- **A measurement of $\sin(2\beta)$ using ψK_s still results in a 4 fold ambiguity- β, $\pi/2-\beta$, $\pi+\beta$, $3\pi/2-\beta$**

- **Only reason $\eta>0$, is $B_k>0$ from theory, and related theoretical interpretation of ε'**