



# BTeV Status

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## What is BTeV?

- Tevatron  $p$ - $\bar{p}$  collider experiment, at Fermilab:
  - Forward spectrometer @ C0 interaction region
  - Beauty and charm physics:
    - Precision measurements of SM parameters
    - Exhaustive search for new physics.
- BTeV is a part of broad program to address fundamental questions in flavor physics.
- Details at: <http://www-btev.fnal.gov>.

# A Brief History of BTeV

- June 2000: Stage I approval from lab.
- May 2002: Stage I approval for descoped detector.
- October 2003: “P5 supports the construction of BTeV as an important project in the world-wide quark flavor physics area.”
- Office of Science – “Facilities for the Future of Science, a 20 year Outlook” – BTeV given priority 12 out of 28
- 2004: DOE – 4 stage approval process
  - Completed reviews for first 2 stages with positive recommendations
  - Final schedule and budget profile in the fall.
  - DOE requires very conservative schedule – BTeV is still competitive in decay modes with all charged tracks and dominant in modes with neutrals. (PAC June 2004, P5 July 2004)
- Start Construction 2005 (in President’s FY05 budget)
- Start data taking 2009

## Physics Goals

- CP violation in SM is unique, predictive and testable
- Almost any extension of SM has new sources of CPV
- Measure CP violation in  $B_{(uds)}$ ,  $B_s$  mixing, rare b decay rates, CP violation and rare decays in the charm sector.
- Precise measurement of SM parameters
- Make an exhaustive search for physics beyond SM
  - Look for rare/forbidden decays
  - Test for inconsistencies in the Standard Model: If found, go beyond the SM and elucidate the new physics.

# Why do b and c Physics at Tevatron?

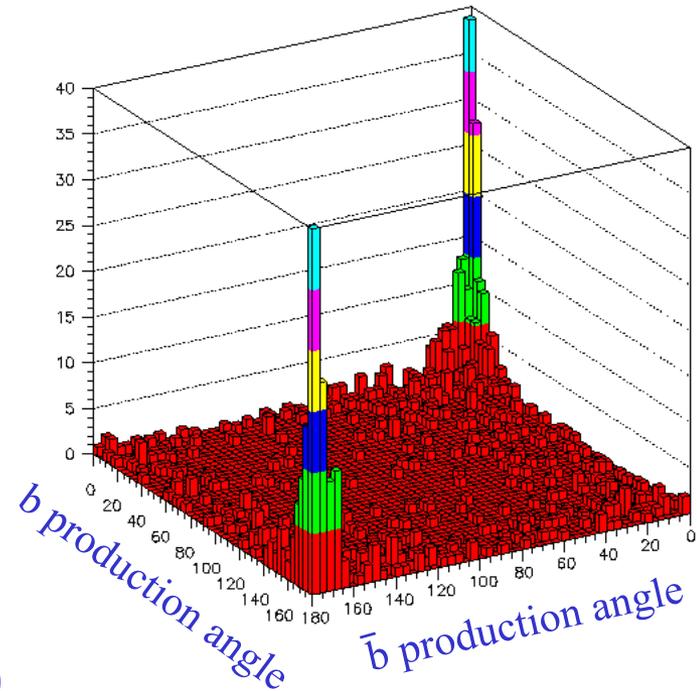
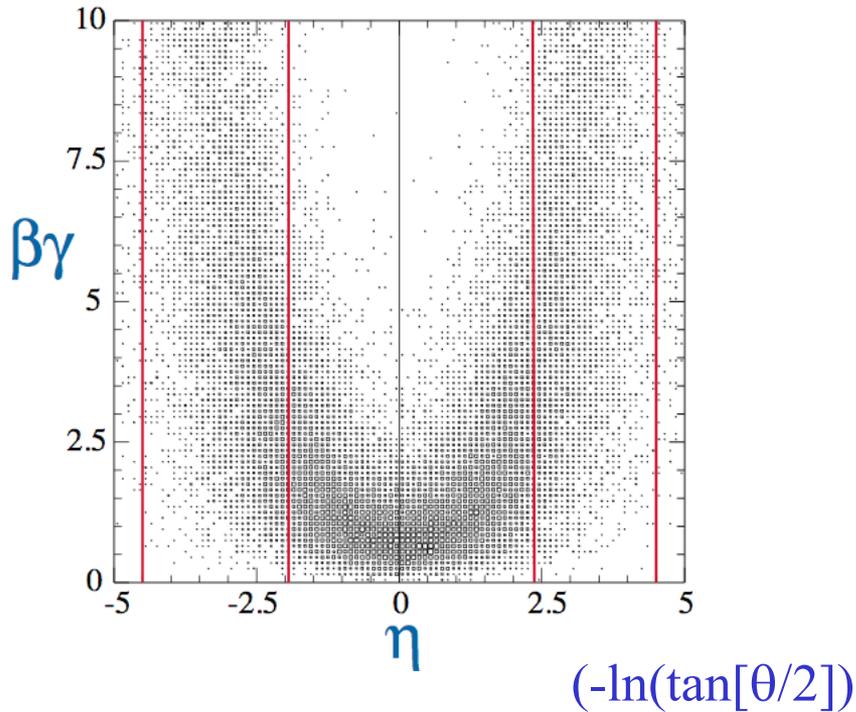
- Large samples of b quarks
  - Get  $\sim 4 \times 10^{11}$  b hadrons per  $10^7$ s at  $L = 2 \times 10^{32} \text{ cm}^{-2}\text{s}^{-1}$
  - $e^+e^- \Upsilon(4S)$  get  $2 \times 10^8$  B hadrons per  $10^7$ s at  $10^{34} \text{ cm}^{-2}\text{s}^{-1}$
- $B_s$ ,  $\Lambda_b$  and other b-flavored hadrons are accessible for study at the Tevatron
- Charm rates are  $\sim 10 \times$  larger than b rates

Nominal Tevatron parameters :

- CMS energy = 2 TeV
- Peak Luminosity  $L = 2 \times 10^{32} \text{ cm}^{-2}\text{s}^{-1}$
- Integrated luminosity  $1.6 \text{ fb}^{-1}/\text{year}$
- Time/crossing = 396 ns
- Interaction region  $\sigma_z = 30 \text{ cm}$  and  $\sigma_{x,y} = 50 \mu\text{m}$
- $b\bar{b}$  cross section =  $100 \mu\text{b}$

# Why look in the Forward Region?

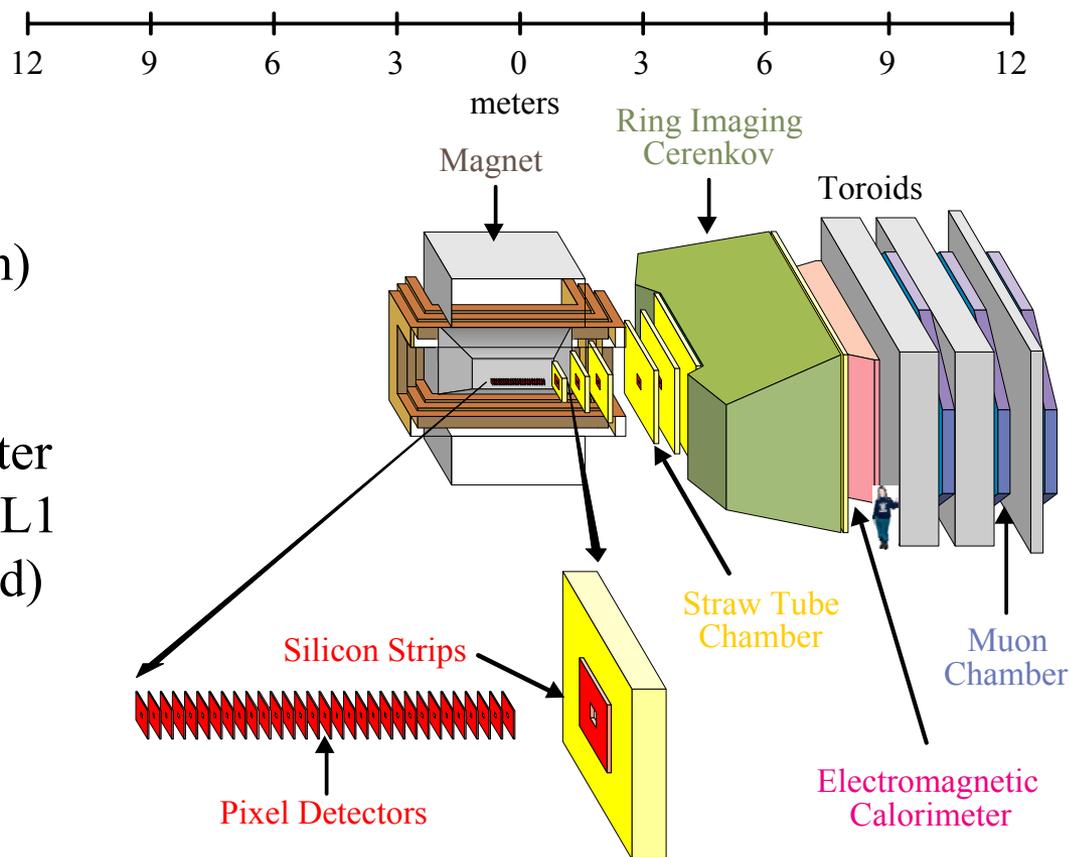
BTeV detects in the forward region ( $|\eta|$  from 1.9 to 4.5)



- Better decay length separation
- Less multiple scattering
- More BB in the Detector
- Better away side tagging

# The BTeV Detector

## BTeV Detector Layout



### Main/Unique Features

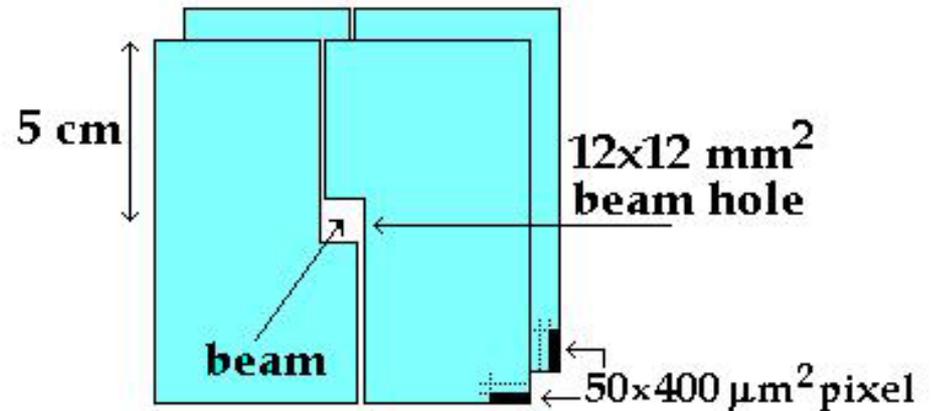
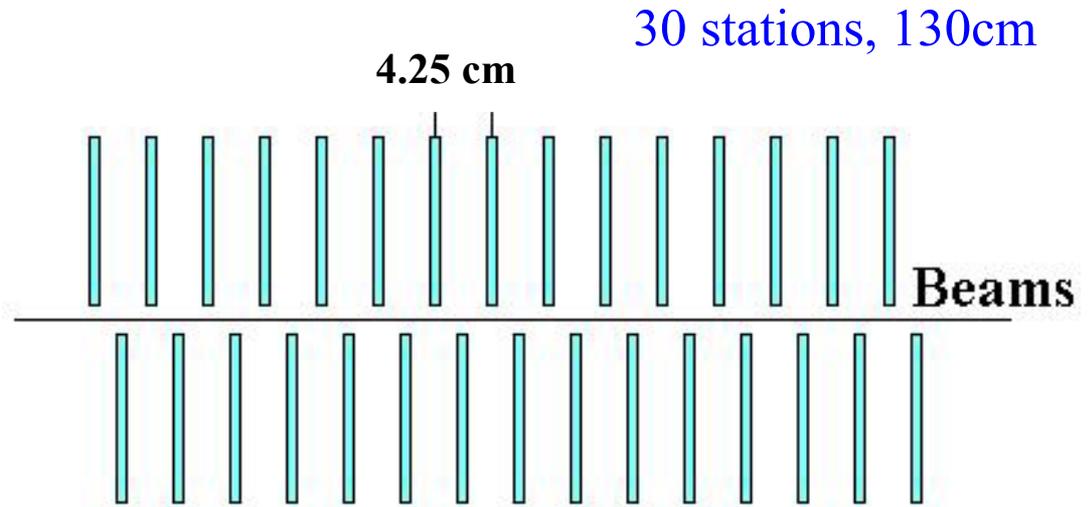
- Vertex pixel ( $50\mu\text{m} \times 400\mu\text{m}$ ) detector in dipole magnet
- RICH for particle ID
- $\text{PbWO}_4$  crystal EM calorimeter
- Vertex separation Trigger at L1 (primary vertex reconstructed)
- Powerful high speed DAQ (output rate at 4KHz)

## Summary of Required Measurements for CKM Tests

Physics Quantity	Decay Mode	Vertex Trigger	K/ $\pi$ sep	$\gamma$ det	Decay time $\sigma$
$\sin(2\alpha)$	$B^0 \rightarrow \rho\pi \rightarrow \pi^+\pi^-\pi^0$	✓	✓	✓	
$\sin(2\alpha)$	$B^0 \rightarrow \pi^+\pi^-$ & $B_s \rightarrow K^+K^-$	✓	✓		✓
$\cos(2\alpha)$	$B^0 \rightarrow \rho\pi \rightarrow \pi^+\pi^-\pi^0$	✓	✓	✓	
$\text{sign}(\sin(2\alpha))$	$B^0 \rightarrow \rho\pi$ & $B^0 \rightarrow \pi^+\pi^-$	✓	✓	✓	
$\sin(\gamma)$	$B_s \rightarrow D_s K^-$	✓	✓		✓
$\sin(\gamma)$	$B^0 \rightarrow D^0 K^-$	✓	✓		
$\sin(\gamma)$	$B \rightarrow K \pi$	✓	✓	✓	
$\sin(2\chi)$	$B_s \rightarrow J/\psi\eta', J/\psi\eta$		✓	✓	✓
$\sin(2\beta)$	$B^0 \rightarrow J/\psi K_s$				
$\cos(2\beta)$	$B^0 \rightarrow J/\psi K^*$ & $B_s \rightarrow J/\psi\phi$		✓		
$x_s$	$B_s \rightarrow D_s\pi^-$	✓	✓		✓
$\Delta\Gamma$ for $B_s$	$B_s \rightarrow J/\psi\eta', K^+K^-, D_s\pi^-$	✓	✓	✓	✓

# Pixel Vertex Detector

- Low occupancy
- Excellent signal/noise
- Fast readout
- Excellent resolution (5-10  $\mu\text{m}$  in 1999 FNAL test beam run)
- radiation hard sensors and readout chips (demonstrated in exposures at IUCF)
- Used in lowest level trigger

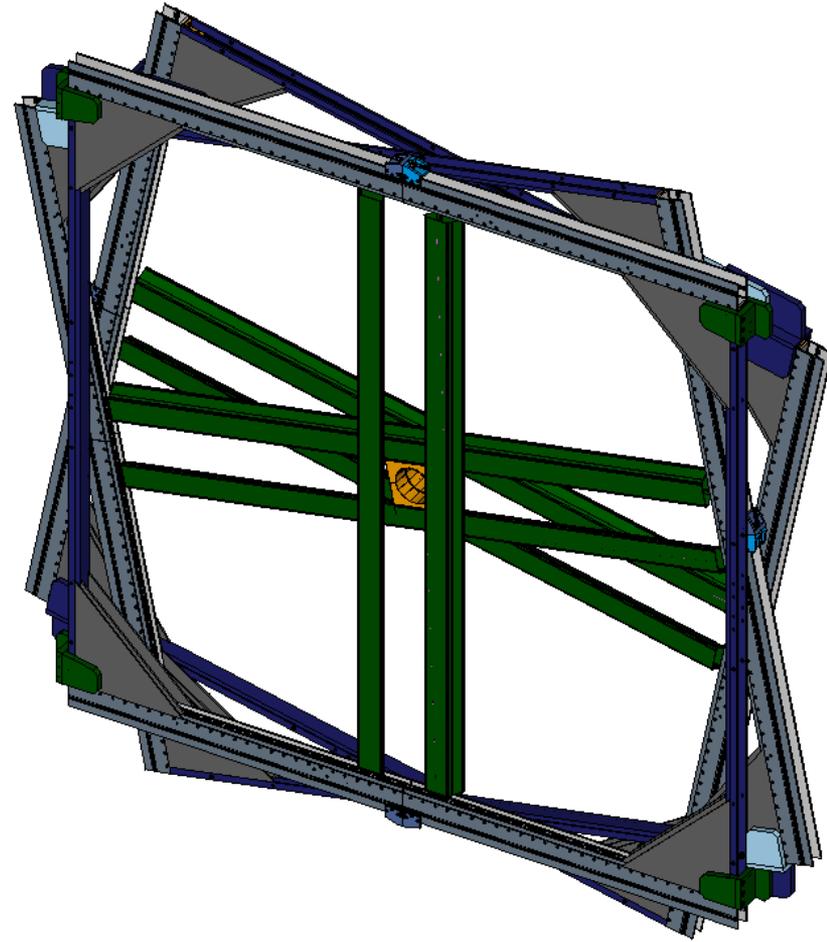
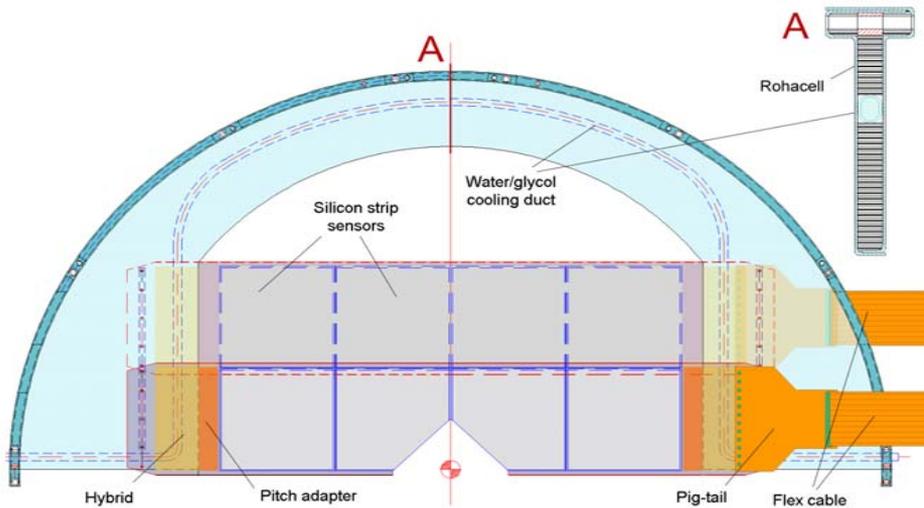


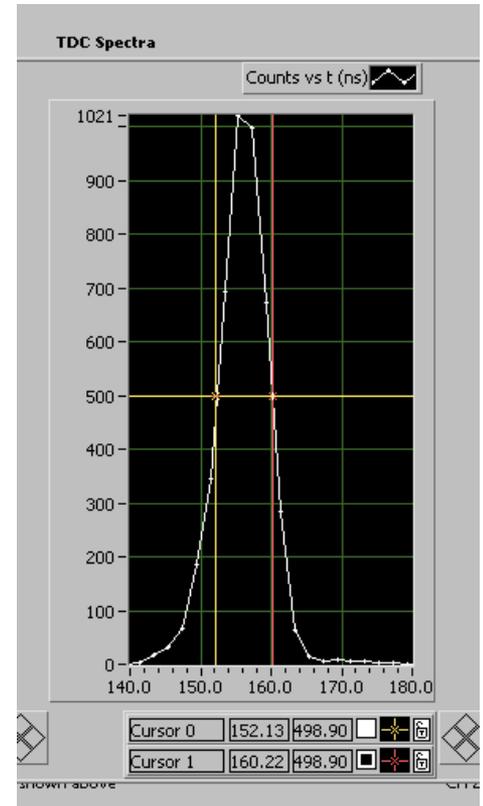
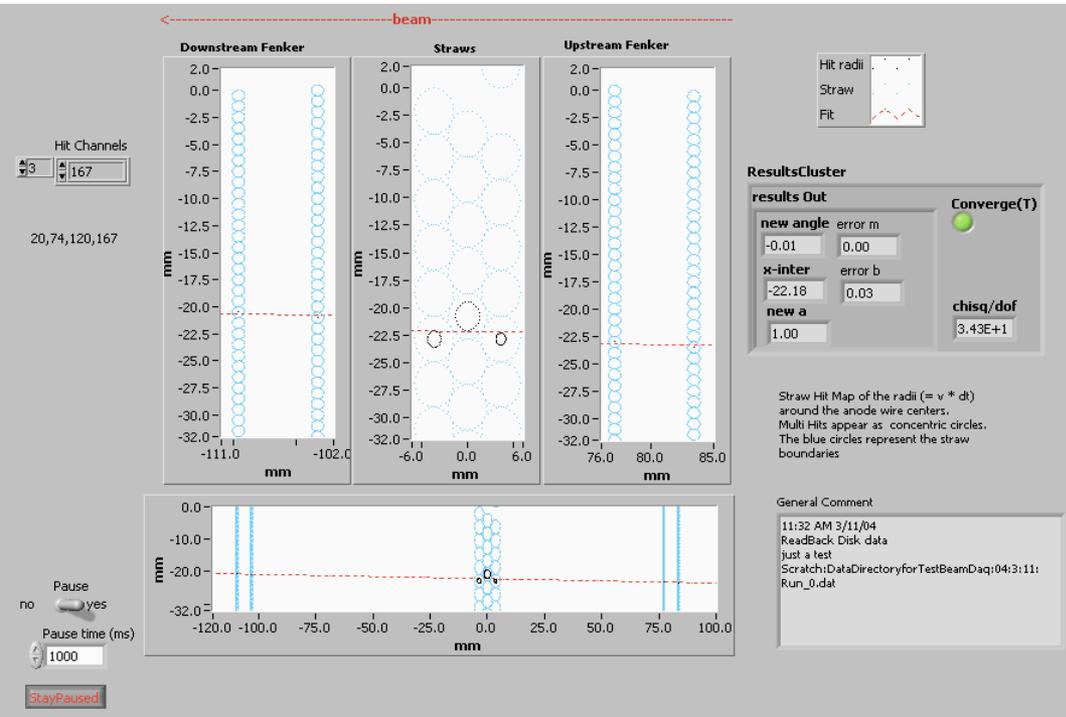
# Forward Tracking

## 7 Stations – Silicon strips and straws

3 views

Momentum resolution  $< 1\%$



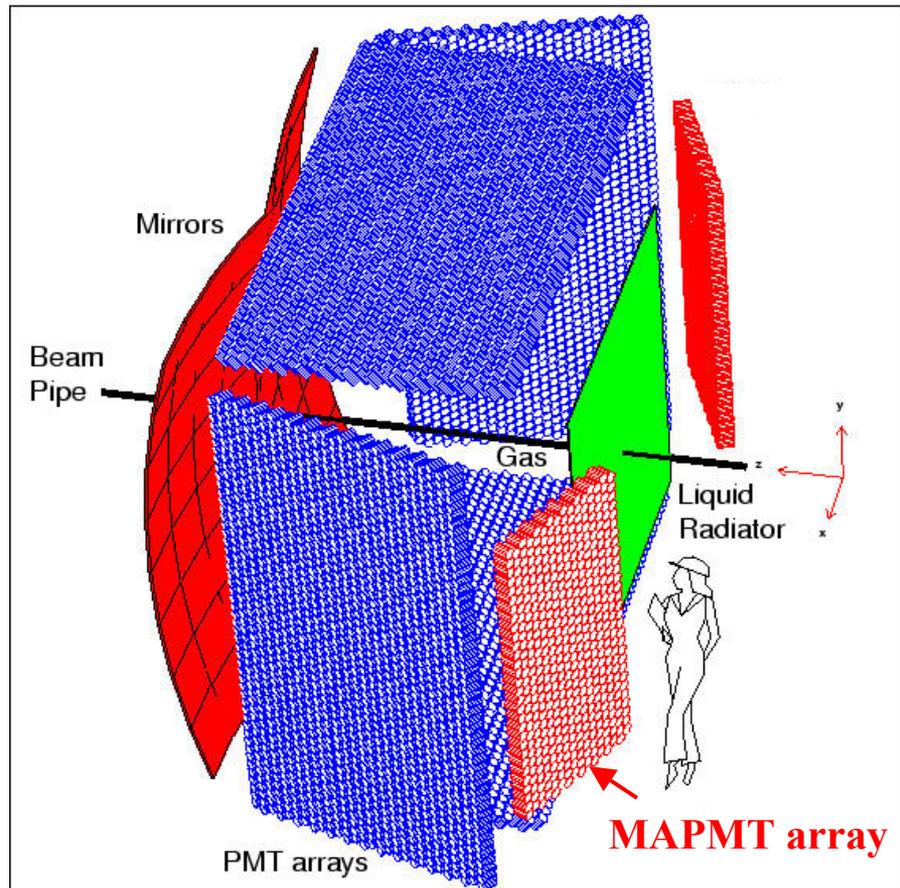


TDC Spectrum  
 FWHM = 8.1 ns  $\Rightarrow$  486  $\mu$ .  
 RMS = 206  $\mu$ .  
 MWPC position resolution = 144  $\mu$ .  
 Quadrature Subtraction gives  
Straw Resolution = 148  $\mu$ .

This meets the needs for BTeV  
 Forward Tracking

# Ring Imaging Cerenkov Counter

- Gas radiator ( $C_4F_8O$ ) detected on planes of Multi-Anode PMTs
- Liquid radiator ( $C_5F_{12}$ ) detected on array of side mounted PMTs



Gas

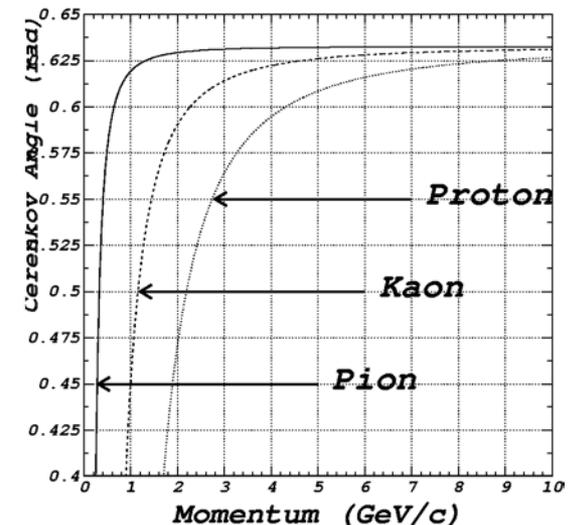
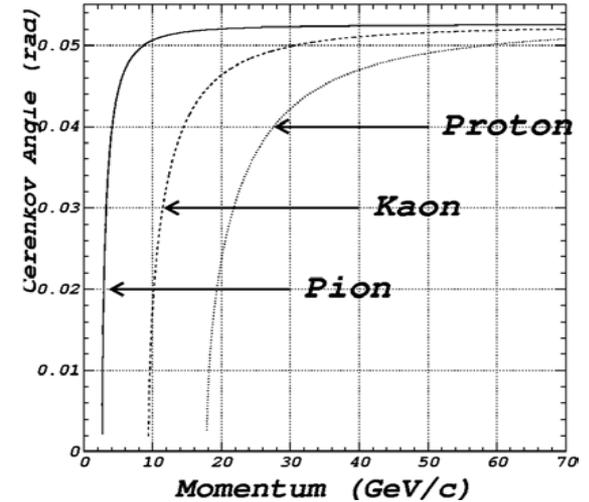


$n=1.00138$

Liquid



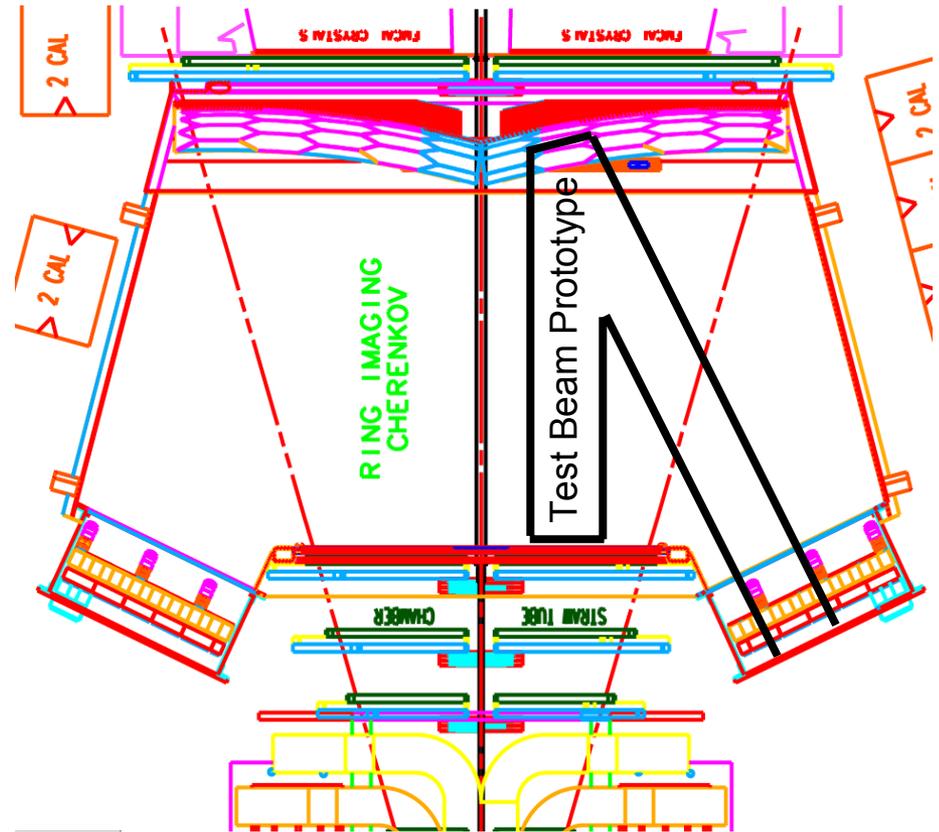
$N=1.29$



# Rich Detector – beam test (I)

## Design

- Small section of full RICH
- Sizes as current design of full RICH



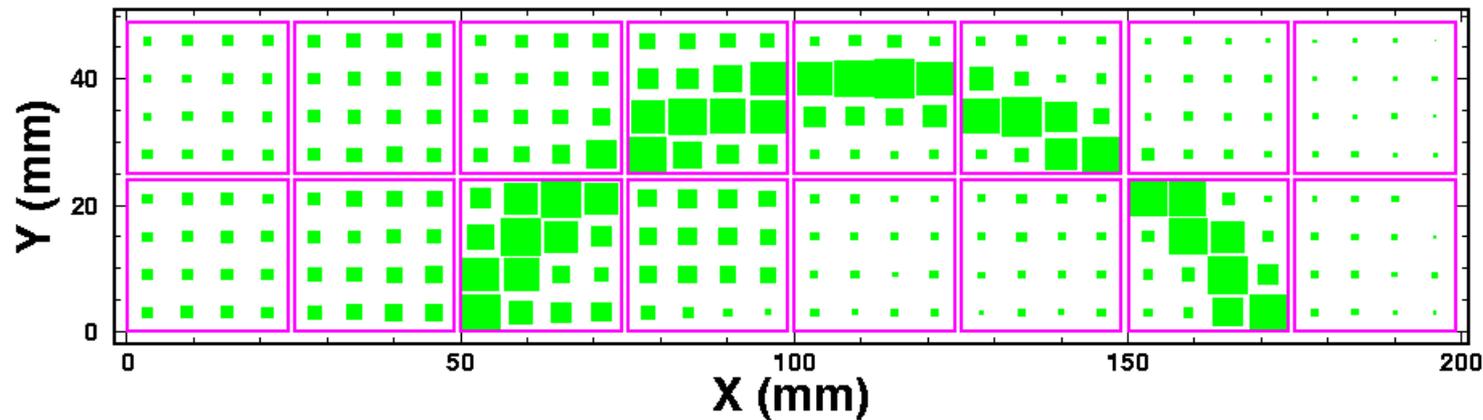
## Goal

- Full system test of real RICH design (as much as possible)
  - Systems test: photon detectors, real readout electronics, mechanical design
  - Plus reasonable HV, BV, LV, mirror, cooling, gas, shielding (mag+em), alignment, etc...

# Rich Detector – beam test (II)

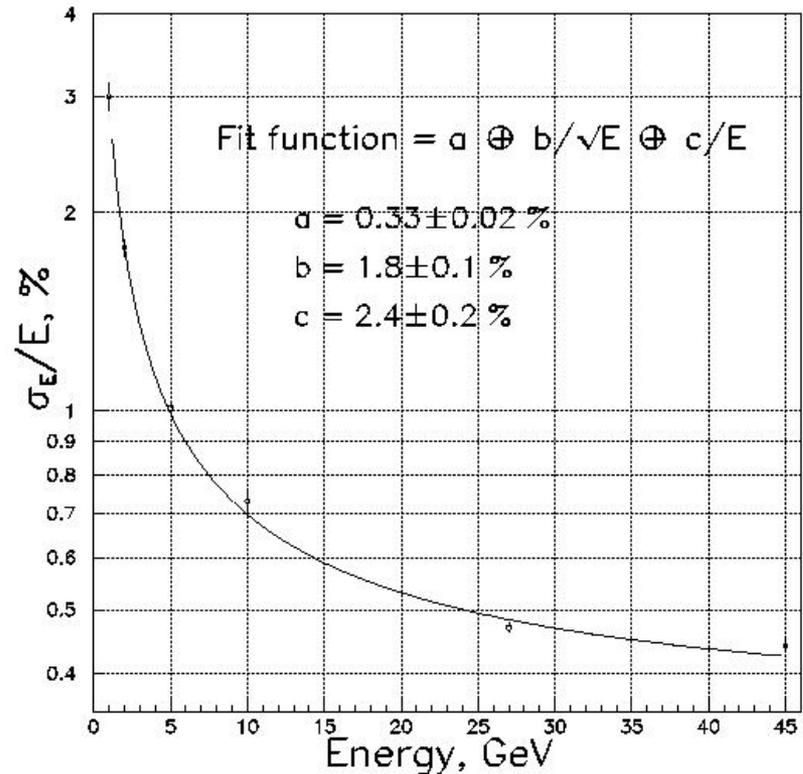
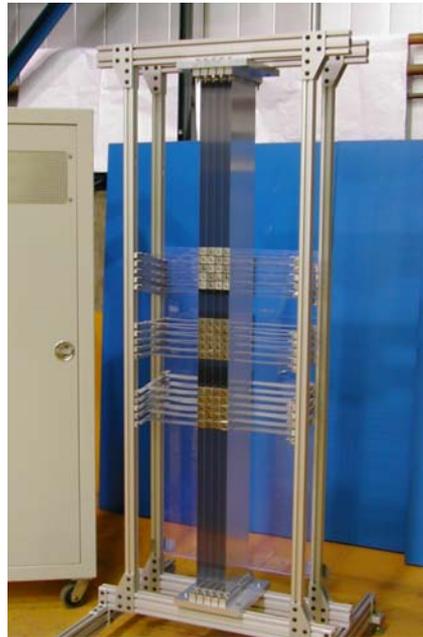
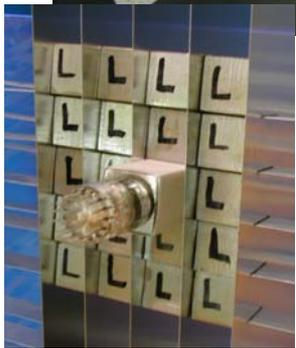
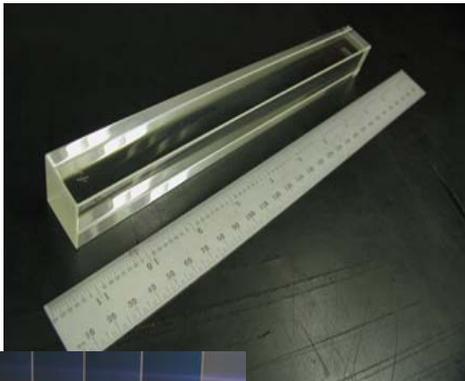


First Rings in air



# Lead Tungstate EM Calorimeter

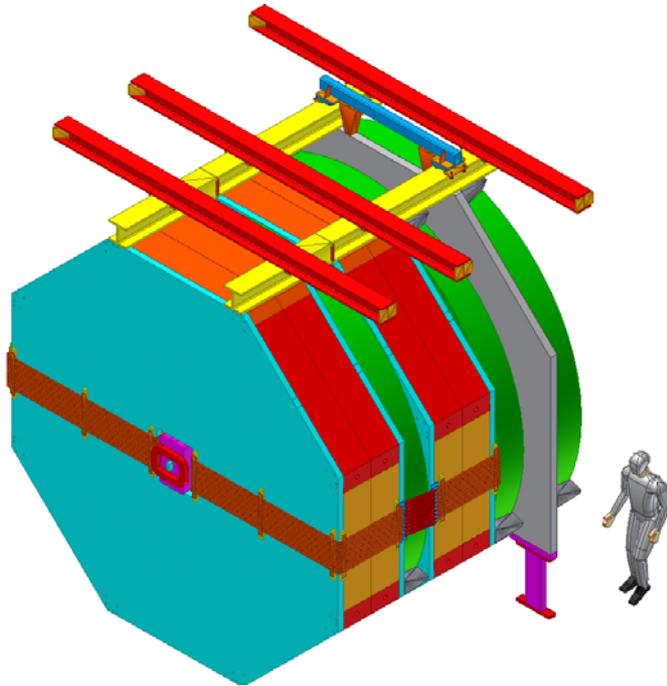
- PWO  $28 \times 28 \text{mm}^2 \times 22 \text{cm}$  tapered crystals
- Excellent energy and spatial resolution
- Fast, compact, radiation hard



## Beam tests (Protvino):

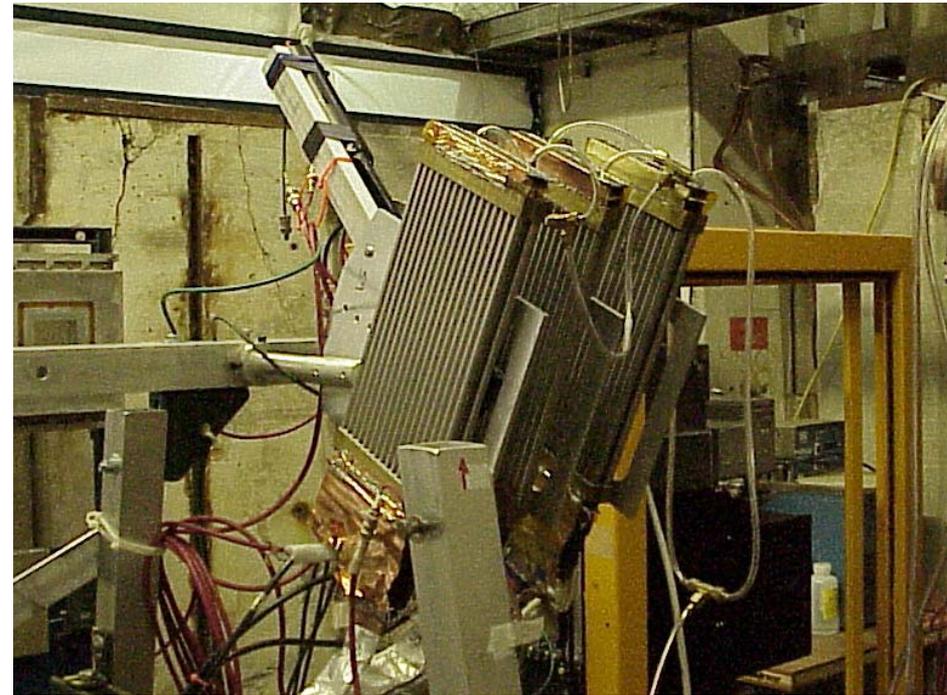
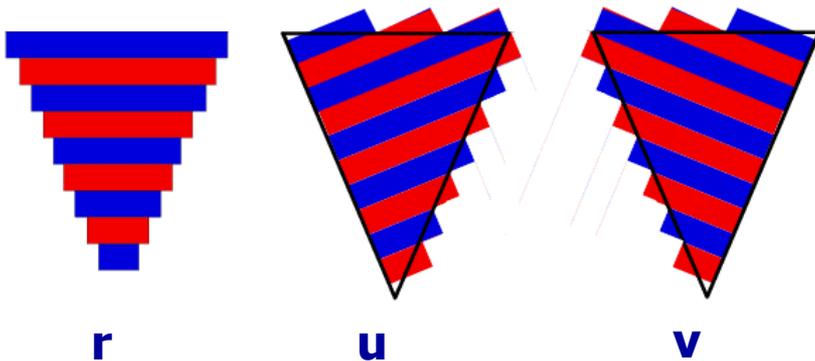
- established energy and position resolu.
- Studied radiation damage and recovery
- Calibration methods.
- Crystals from 4 vendors

# Muon Detector



3 stations of steel proportional tubes

2 toroids – independent momentum measurement

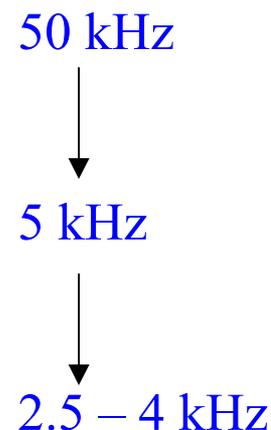


Prototype Planks in test beam

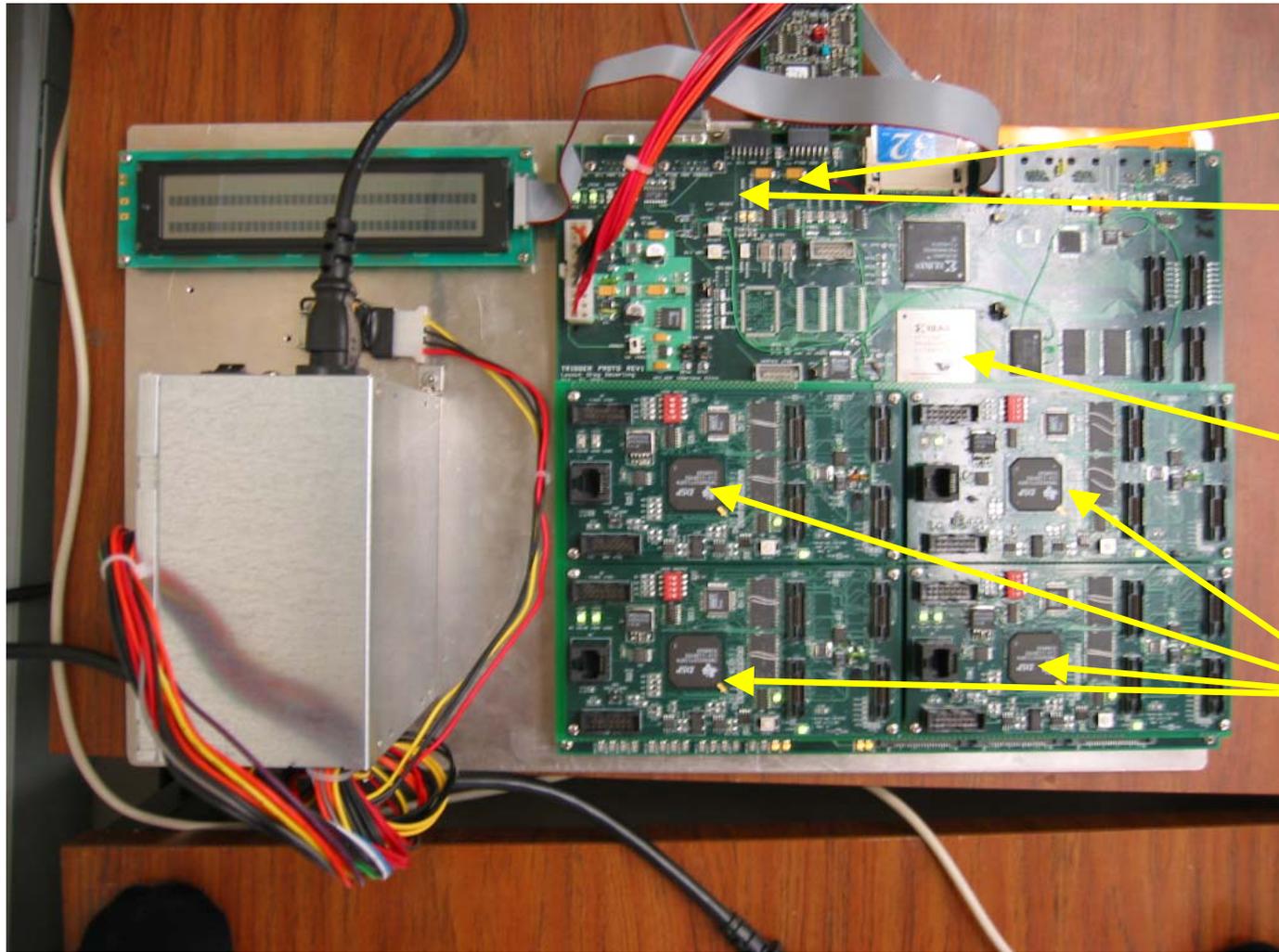
# BTeV Trigger

- Reconstructs primary vertex and looks for detached decays every crossing
- Made possible by vertex detector (3D space points with excellent resolution and low occupancy)
- Pipelined and parallel processing with 1 TB of buffer
- 3 Stage Trigger
  - L1: FPGAs and DSPs
  - L2/L3: Linux PCs

- Level 1: accepts >50% B events that pass analysis cuts, rejects 98% light quark background.
- Level 2: accepts 90% of B events from Level 1, rejects 90% background from Level 1
- Level 3: rejects another factor of 2 in background, does full offline reconstruction



# Trigger R&D : Farm pre-prototype



PTSM interface

GL1 interface

High speed  
Data I/O  
controller  
(Buffer  
Manager)

4 DSPs

# Summary of CKM Physics Reach $2 \text{ fb}^{-1}$

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

# Comparisons to Belle/BaBar

- No  $B_s$ ,  $B_c$  and  $\Lambda_b$  at B-factories
- Number of flavor tagged  $B^0 \rightarrow \pi^+ \pi^-$  ( $BR=0.45 \times 10^{-5}$ )

	$L(\text{cm}^{-2}\text{s}^{-1})$	$\sigma$	$\#B^0/10^7\text{s}$	$\epsilon_{\text{rec}}$	$\epsilon D^2$	$\#\text{tagged}$
$e^+e^-$	$10^{34}$	1.1nb	$1.1 \times 10^8$	0.45	0.26	56
BTeV	$2 \times 10^{32}$	100 $\mu\text{b}$	$1.5 \times 10^{11}$	0.021	0.1	1426

- Number of  $B^- \rightarrow D^0 K^-$  (Full product  $BR=1.7 \times 10^{-7}$ )

	$L(\text{cm}^{-2}\text{s}^{-1})$	$\sigma$	$\#B^0/10^7\text{s}$	$\epsilon_{\text{rec}}$	$\#$
$e^+e^-$	$10^{34}$	1.1nb	$1.1 \times 10^8$	0.4	5
BTeV	$2 \times 10^{32}$	100 $\mu\text{b}$	$1.5 \times 10^{11}$	0.007	176

## New Physics (1)

- Decays that occur in the SM only through loops are particularly sensitive to “new physics”
- The leptonic decay  $b \rightarrow s \ell^+ \ell^-$  is sensitive to the actual form of the new interactions as one can measure  $M(\ell^+ \ell^-)$  and Dalitz plot as well as total rate

Reaction	B( $10^{-6}$ )	Yield/year	S/B
$B \rightarrow K^* \mu^+ \mu^-$	1.5	2530	11
$B \rightarrow K \mu^+ \mu^-$	0.4	1470	3.2

## New Physics (2)

- SM predicts  $A_{\text{CP}}(B^0 \rightarrow \psi K_S) = A_{\text{CP}}(B^0 \rightarrow \phi K_S)$
- $B^- \rightarrow \phi K^-$  penguin only,  $A_{\text{CP}} \sim 0$  in SM but interference between penguin and super-penguin amplitudes could give rise to large asymmetry

- Using b and c decays mediated by loop diagrams BTeV is sensitive to mass scales of up to few TeV.
- The New Physics effects in these loops may be the only way to distinguish among models.

Mode	BTeV ( $10^7$ s)			B-Factory ( $500 \text{ fb}^{-1}$ )		
	Yield	Tagged	S/B	Yield	Tagged	S/B
$B_s \rightarrow J/\Psi \eta^{(\prime)}$	12650	1645	>15	-	-	-
$B^- \rightarrow \phi K^-$	11000	n/a	>10	1000	n/a	4
$B^0 \rightarrow \phi K_s$	2000	200	5.2	350	90	4
$B^0 \rightarrow K^* \mu^+ \mu^-$	2530	n/a	11	~50	~50	3
$B_s \rightarrow \mu^+ \mu^-$	6	0.7	>15	-	-	-
$B^0 \rightarrow \mu^+ \mu^-$	1	0.1	>10	0	-	-
$D^{*+} \rightarrow D^0 \pi^+, D^0 \rightarrow K \pi^+$	$\sim 10^8$	$\sim 10^8$	large	$8 \times 10^5$	$8 \times 10^5$	large

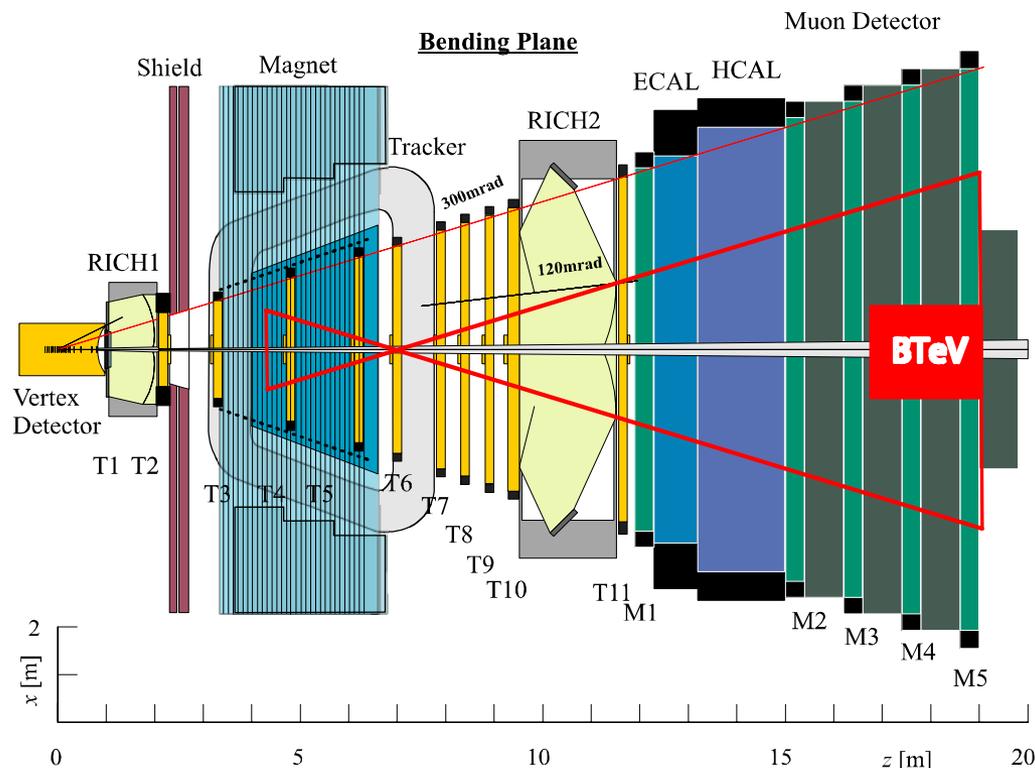
# Comparison to LHCb

## LHCb advantages:

- $\sigma_{bb}(\text{LHCb}) = 5 \times \sigma_{bb}(\text{BTeV})$   
 $\sigma_{\text{tot}}(\text{LHCb}) = 1.6 \times \sigma_{\text{tot}}(\text{BTeV})$
- $\langle \text{Interactions/Crossing} \rangle$   
 $\sim 3 \times$  lower than BTeV

## BTeV advantages:

- Detached vertex trigger at lowest level
- Higher rate DAQ
- Better resolution EMCAL



BTeV and LHCb have comparable sensitivities in charged modes, BTeV is superior in modes with  $\gamma$ 's and  $\pi^0$ 's

# Summary and Conclusions

- BTeV will make critical contributions to our knowledge of CP violation as attention turns from initial observations to the work of finding out if the Standard Model explanation is correct and complete.
- BTeV is not just doing SM physics. It is sensitive enough to reveal new phenomena
- Level 1 trigger based only on presence of detached vertices – BTeV can investigate any new ideas that might arise.
- **Positive recommendations from DOE reviews**
- Tevatron has recently made significant improvements in luminosity and overall performance.