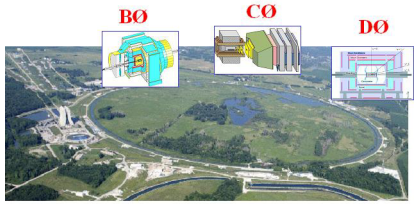
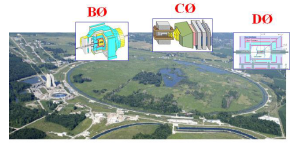


QCD Physics with BTeV

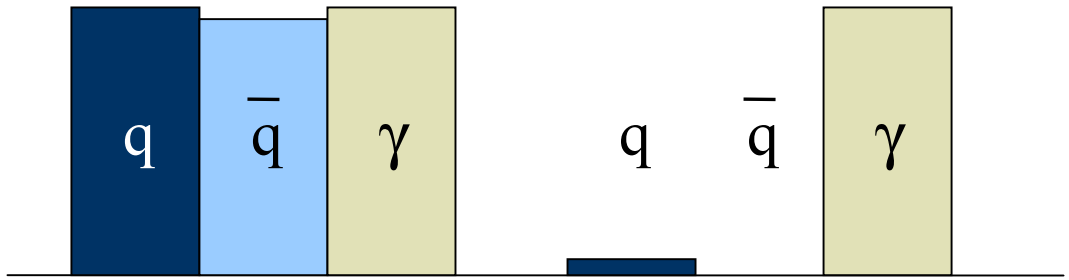
- The main physics motivation for BTeV
  - CP Violation using b & c decays
  - Physics Beyond the Standard Model
- Detector description
- Opportunities for QCD studies at BTeV



CP Violation: A Fertile Frontier

How did we become a matter (dominated) universe?

Andrei Sakharov's conditions (1967):



?

Early Universe

Now

$(n_q - n_{\bar{q}})/n_q \sim (n_q - n_{\bar{q}})/n_\gamma \sim$ $n_B/n_\gamma \sim 10^{-9}$ ← ? — Standard Model

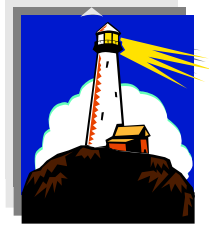
Electroweak Baryogenesis

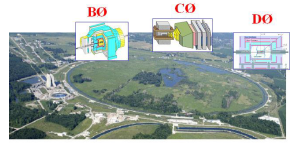
Get $n_B/n_\gamma \sim 10^{-20}$

→ New Physics beyond SM(!)

- Additional sources of CP violation

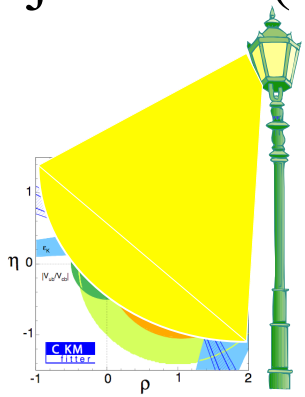
Where to look! ←

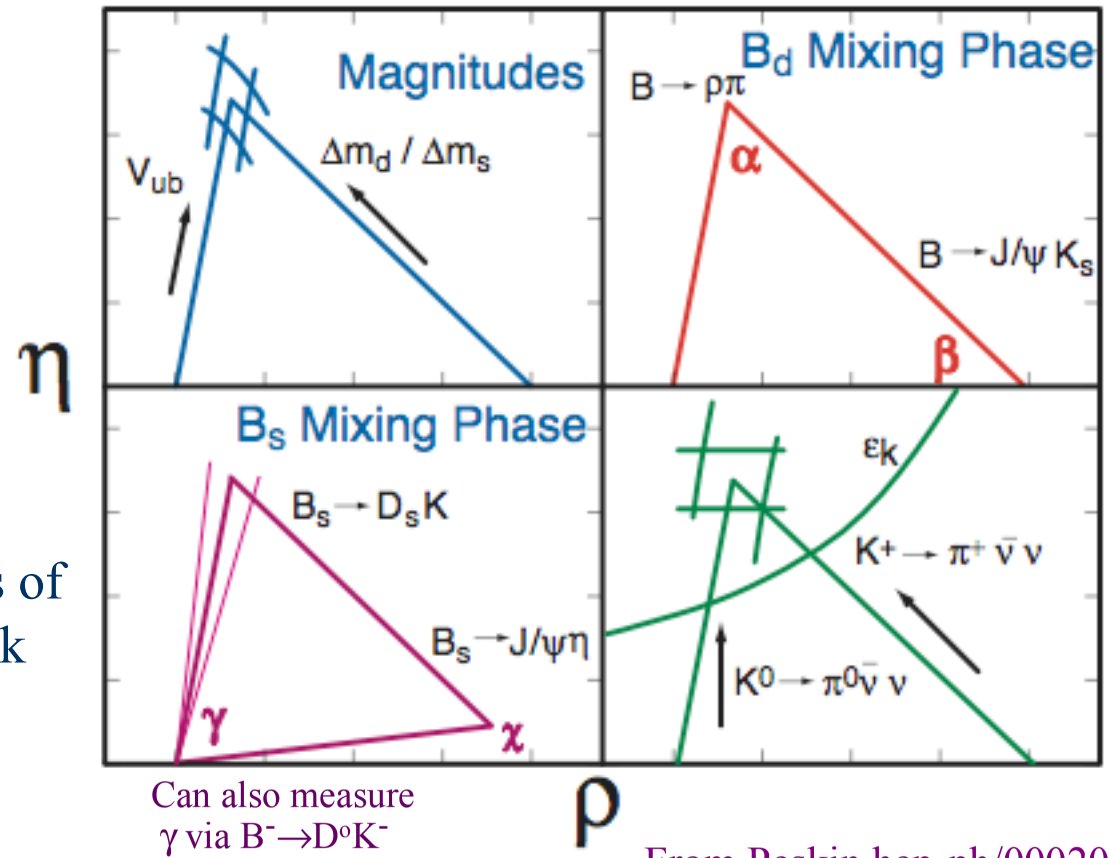




Measurements of the CKM Matrix

Don't just look (measure) under one lamp post!



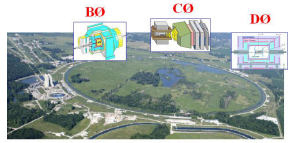


- Compare to the comprehensive tests of EW: repeat for quark flavour physics!

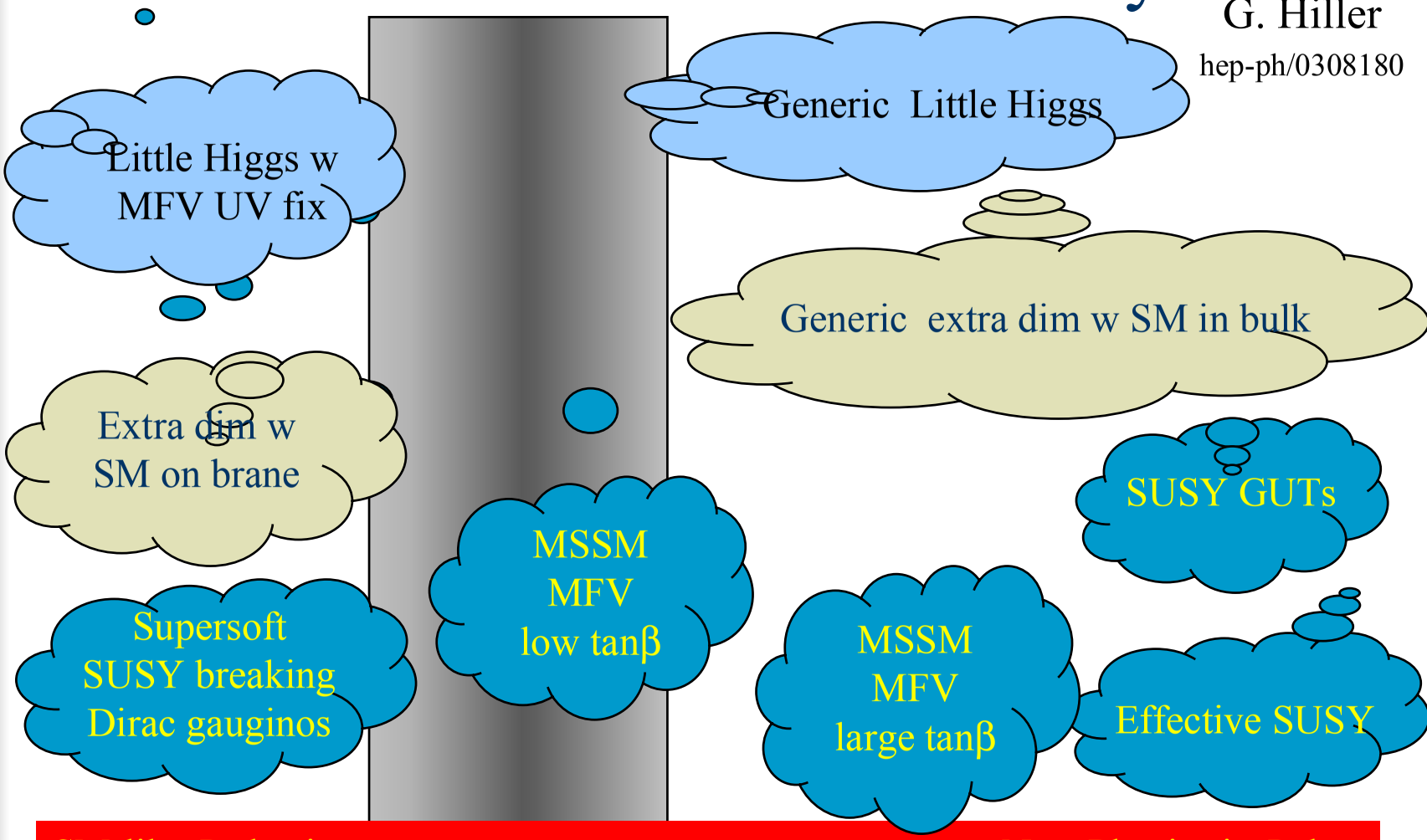
Can also measure γ via $B^- \to D^0 K^-$

From Peskin hep-ph/0002041

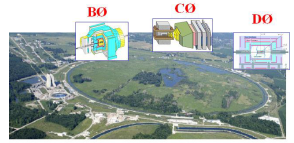
Flavour Violation in Models which address the Hierarchy



G. Hiller
hep-ph/0308180

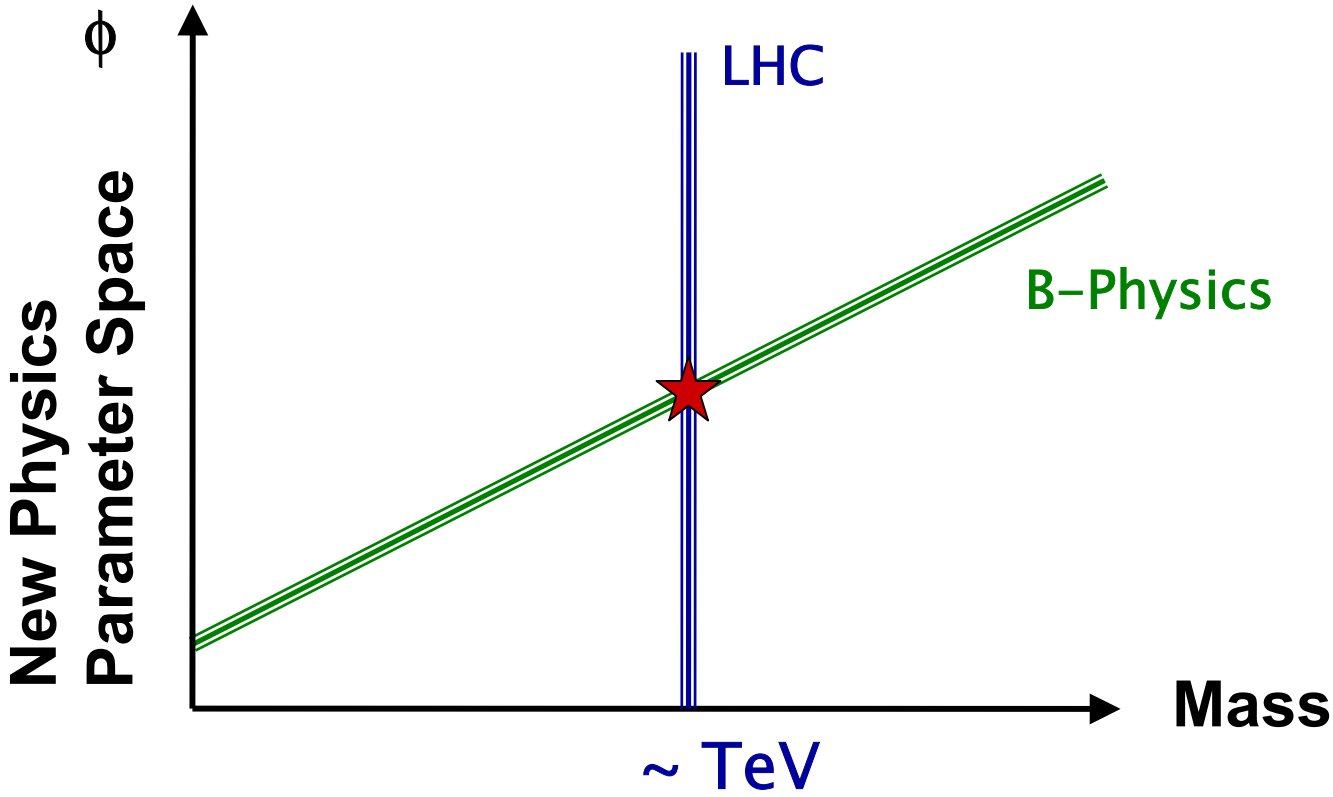


SM-like *B* physics | New Physics in *B* data

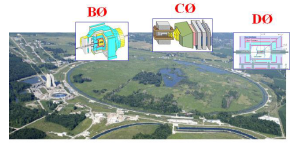


Physics Beyond the SM: LHC?

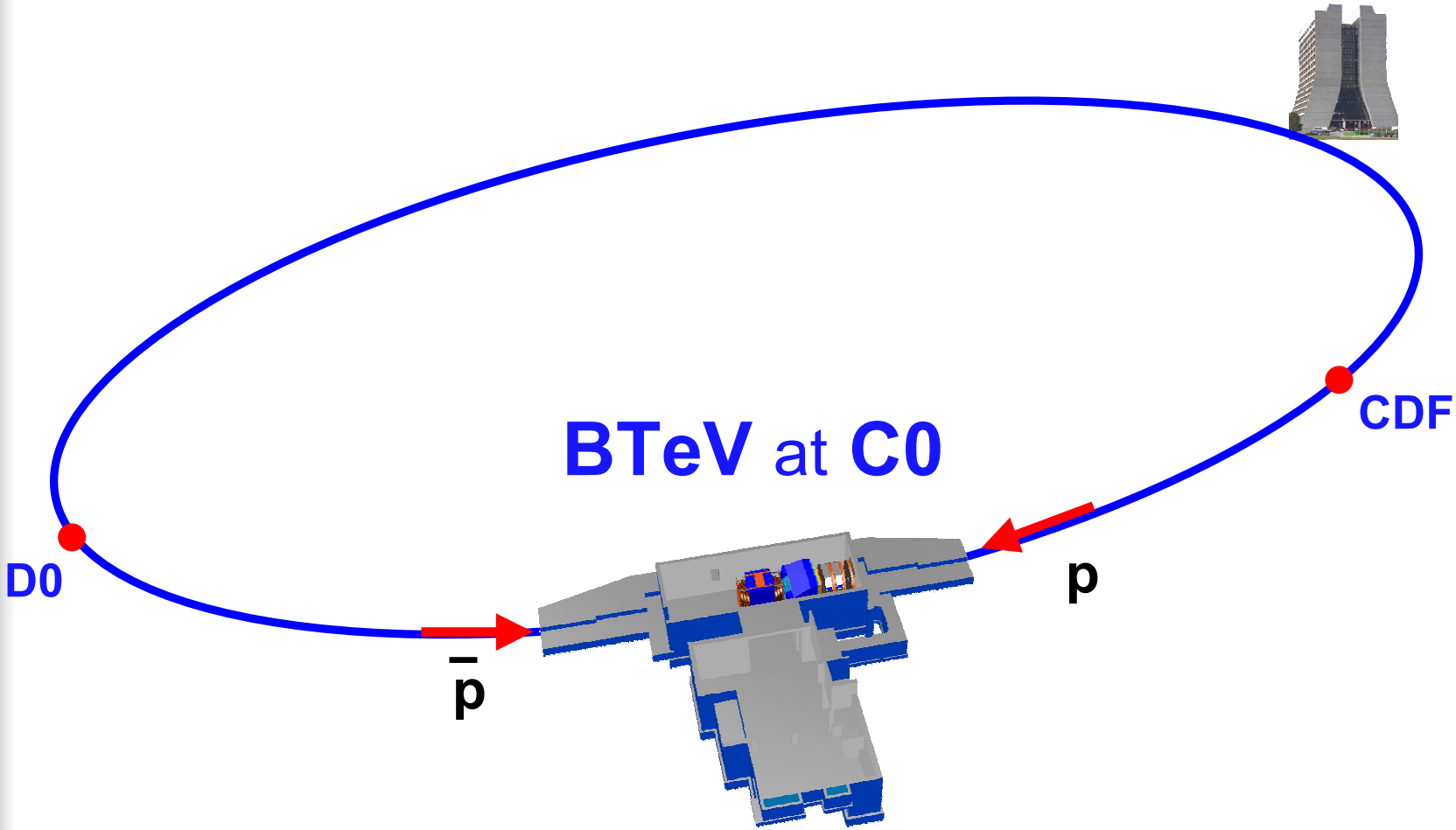
Pictorial Example from Hewett (WIN03):

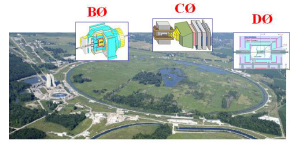


Complementary knowledge from LHC and B Decays!



BTeV at the Fermilab Tevatron





BTeV Collaboration

Origins: Fnal FT CLEO Hera/HeraB

Belarussian State: D .Drobychev, A. Lobko, A. Lopatrik, R. Zouversky

UC Davis: P. Yager

Univ. of Colorado: J. Cumalat, P. Rankin, K. Stenson

Fermilab: J.Appel, E.Barsotti, C.N.Brown, J.Butler, H.Cheung, D.Christian, S. Cihangir, M.Fishler, I.Gaines, P.Garbincius, L.Garren, E Gottschalk, A.Hahn, G.Jackson, P.A.Kasper, P.H.Kasper, R.Kutschke, S.Kwan, P. Lebrun, P.McBride, J.Slaughter, M.Votava, M.Wang, J.Yarba

Univ. of Florida: P. Avery

University of Houston: A.Daniel, K.Lau, M.Ispiryan, B.W.Mayes, V.Rodriguez, S.Subramania, G.Xu

Illinois Institute of Technology: R.A.Burnstein, D.Kaplan, L.M.Lederman, H.A.Rubin, C.White

Univ. of Illinois: M.Haney, D.Kim, M.Selen, V. Simaitis, J.Wiss

INFN - Frascati: M. Bertani, L. Benussi, S. Bianco, M. Caponero, F. Fabbri, F. Felli, M. Giardoni, A. La Monaca, E. Pace, M. Pallotta, A. Paolozzi

INFN - Milano: G.Alimonti, M.Dinardo, L.Edera, S.Erba, D.Lunesu, S.Magni, D.Menasce, L.Moroni, D.Pedrini, S.Sala, L.Uplegger

INFN - Pavia: G. Boca, G. Cosssali, G. Liguori, F.Manfredi, M.Manghisoni, M.Marengo, L.Ratti, V. Re, M.Santini, V.Speziali, P.Torre, G.Traversi

IHEP Protvino, Russia: A.Derevschikov, Y.Goncharenko, V.Khodyrev, V.Kravtsov, A.Meschanin, V.Mochalov, D.Morozov, L.Nogach, P.Semenov, K.Shestermanov, L. Soloviev, A.Uzunian, A.N.Vasiliev

Univ. of Insubria in Como: P. Ratcliffe, M. Rovere

University of Iowa: C. Newsom, & R. Braunger

University of Minnesota: J. Hietala, Y.Kubota, B.Lang, R.Poling, A.Smith

Nanjing Univ. (China): T.Y.Chen, D.Gao, S.Du, M.Qi, B.P.Zhang, Z.Xi Zhang, J W.Zhao

New Mexico State Univ.: V.Papavassiliou

Northwestern University: J.Rosen

Ohio State University: K. Honscheid, & H. Kagan

Univ. of Pennsylvania: W. Selove

Univ. of Puerto Rico: A.Lopez, H.Mendez, J.E.Ramirez W. Xiong

Univ. of Science & Tech. of China: G. Datao, L. Hao, Ge Jin, T. Yang, & X. Q. Yu

Shandong Univ. (China): C. F. Feng, Yu Fu, Mao He, J. Y. Li, L. Xue, N. Zhang, & X. Y. Zhang

Southern Methodist Univ: T. Coan, M. Hosack

Syracuse University: M.Artuso, S.Blusk, J Butt, C.Boulahouache, O.Dorjkhaidav, J.Haynes, N.Menaa, R.Mountain, M.Muramatsu, R.Nandakumar, L.Redjimi, R. Sia, T.Skwarnicki, S.Stone, J.C.Wang, K. Zhang

Univ. of Tennessee: T. Handler, R. Mitchell

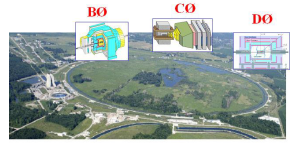
Vanderbilt University: W. Johns, P. Sheldon, E. Vaandering, M. Webster

Univ. of Virginia: M. Arenton, S. Conetti, B. Cox, A. Ledovskoy, H. Powell, M. Ronquest, D. Smith, B. Stephens, Z. Zhe

Wayne State University: G. Bonvicini, D. Cinabro, A. Shreiner

University of Wisconsin: M. Sheaff

York University: S. Menary

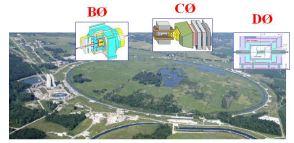


Why do b and c Physics at Tevatron?

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

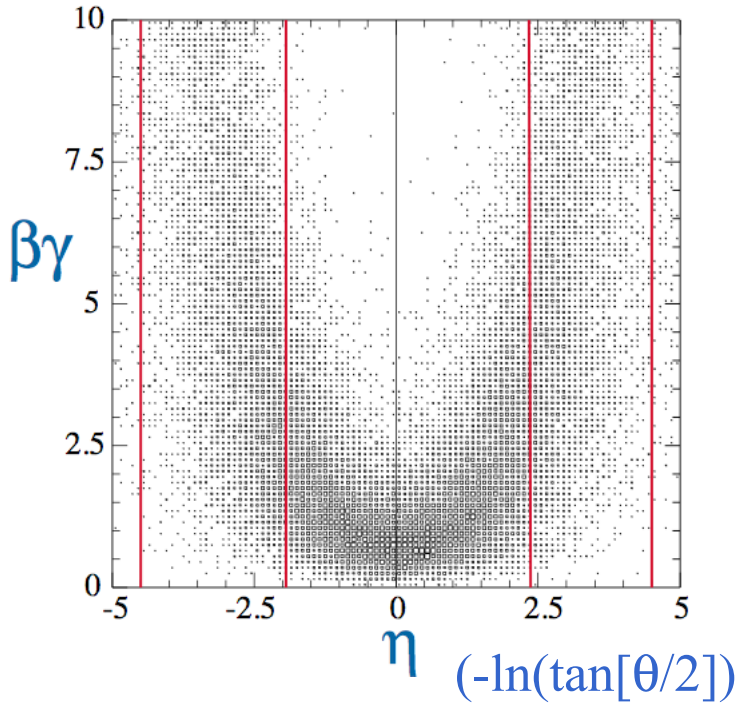
Some assumed parameters for the Tevatron for simulations:

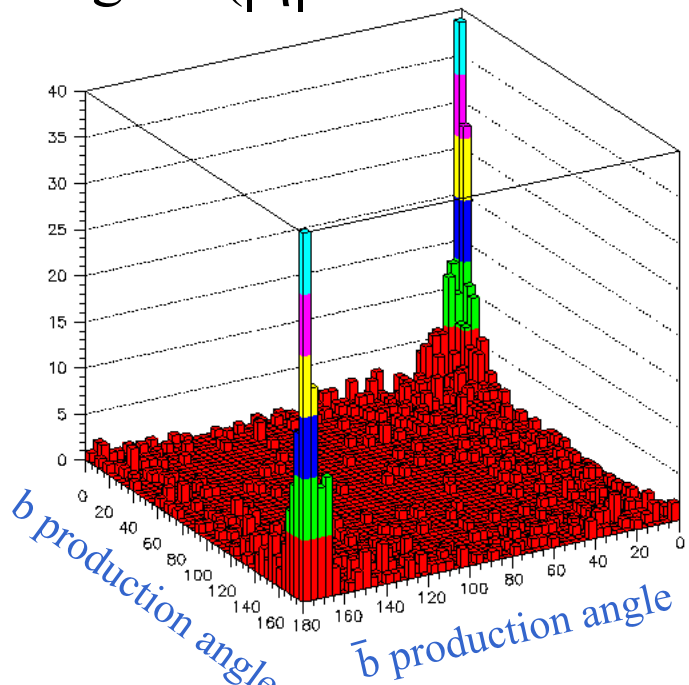
- CMS energy = 2 TeV and L = 2×10^{32} $cm^{-2}s^{-1}$
- Time/crossing = 396 ns
- Interaction region σ_z= 30cm and $\sigma_{x,y}$= 50μm
- $b\bar{b}$ cross section = 100 μb



Why look in the Forward Region?

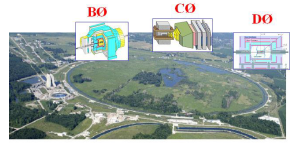
BTeV detects in the forward region (|η| from 1.9 to 4.5)





- Better decay length separation
- Less multiple scattering

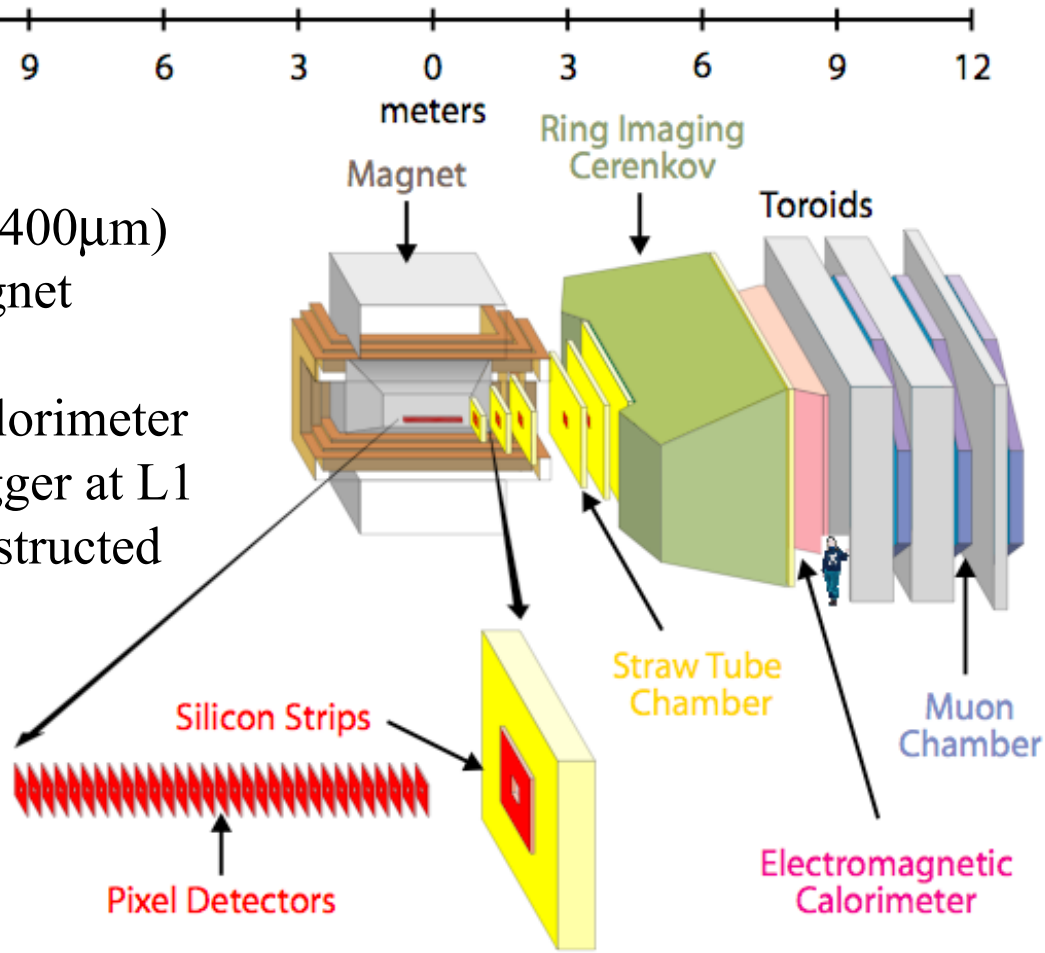
- More $B\bar{B}$ in the Detector
- Better away side tagging

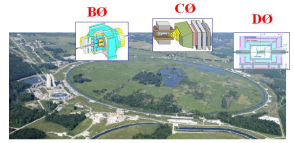


The BTeV Detector

Main/Unique Features

- Vertex pixel (50μm × 400μm) detector in dipole magnet
- RICH for particle ID
- $PbWO_4$ crystal EM calorimeter
- Vertex separation Trigger at L1 (primary vertex reconstructed event-by-event)
- Powerful high speed DAQ (output up to 4KHz)

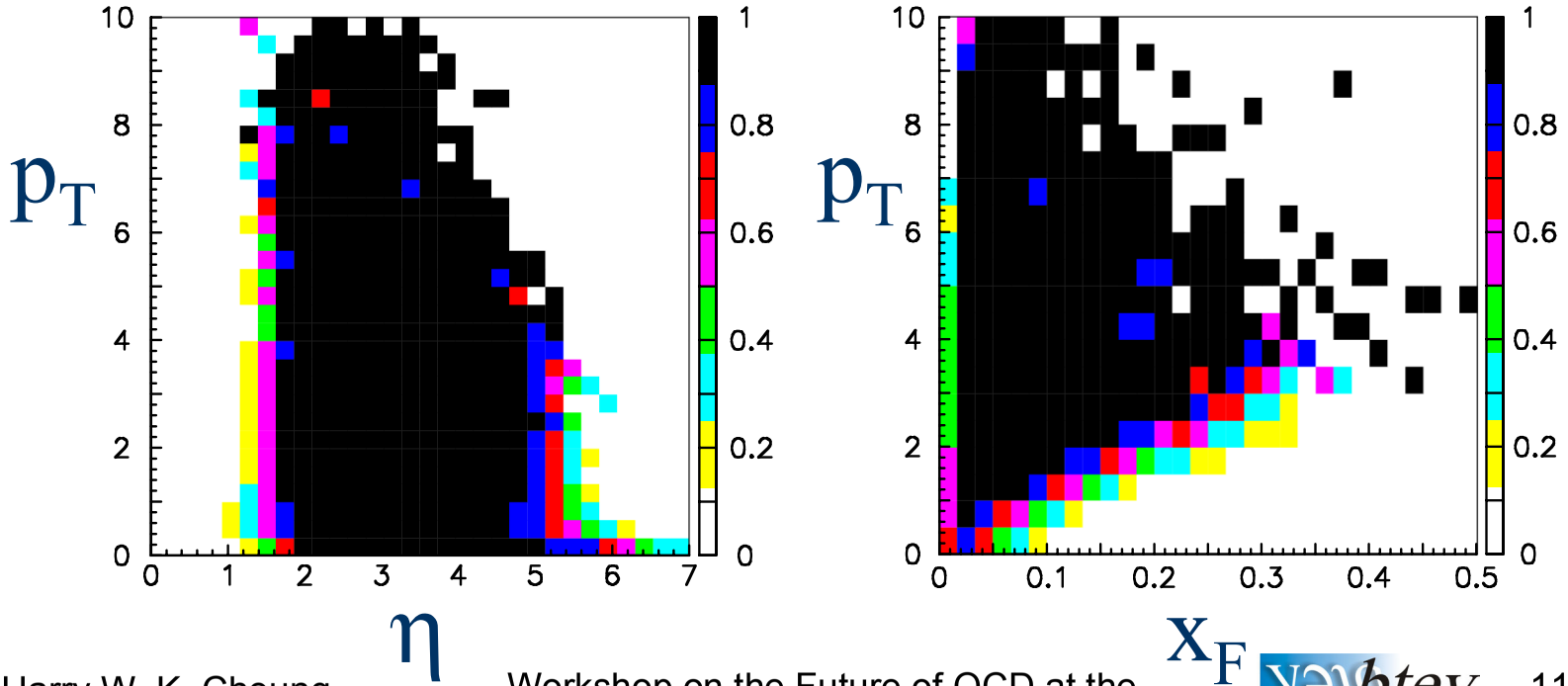


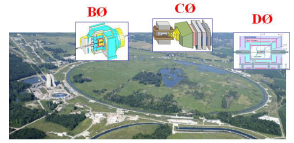


Implications for QCD Physics

- Important BTeV detector features:
  - Excellent tracking 10 - 300 mrad ($\eta \sim 1.9 - 5.3$) for single tracks
    - ◊ Good (flat) acceptance down to small angles and small p_T

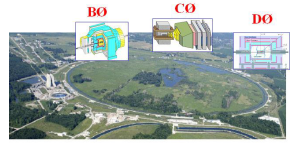
Acceptances for single tracks (lack of statistics at high p_T):





Implications for QCD Physics

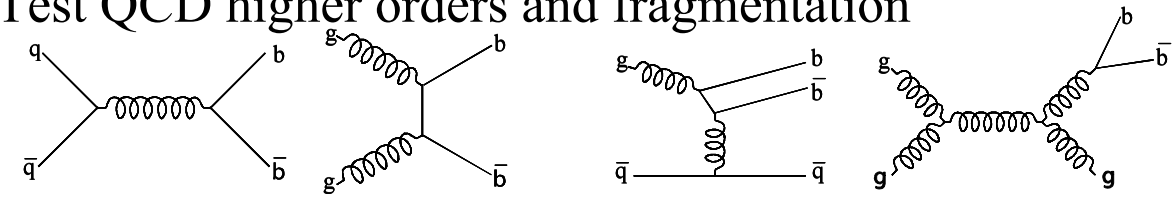
- Important BTeV detector features:
  - Excellent tracking 10 - 300 mrad ($\eta \sim 1.9 - 5.3$)
    - ◊ Good acceptance down to small angles
    - ◊ Good acceptance for low p_T tracks
  - EM $PbWO_4$ crystal calorimeter ($25\lambda_0$ and $1\lambda_I$)
    - ◊ Excellent (multiple) photon detection and resolution
  - No Hadronic calorimeter, no 4π coverage
    - ◊ No jet studies? (jets with poor energy resolution)
    - ◊ No missing E_T measurement, No rapidity-gap detection
  - Trigger on displaced tracks/vertices or muons only
    - ◊ Excellent heavy quark production and decay studies
    - ◊ No trigger for e.g. direct photon studies, diffractive, jets



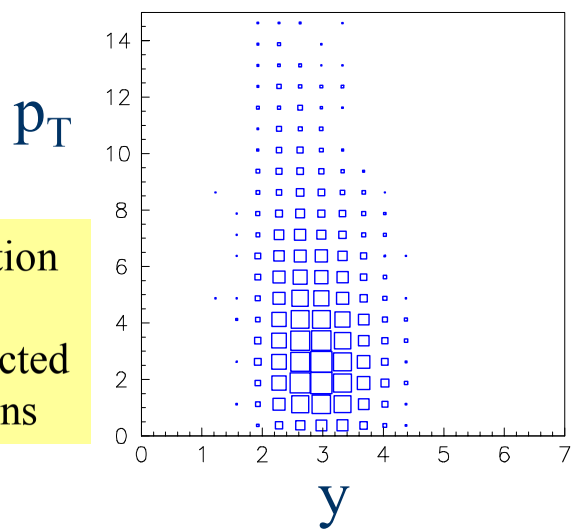
QCD Physics at BTeV

Heavy quark production in the forward region:

- Study region of (p_T,y) complementary to CDF, D0 central detectors
- Test QCD higher orders and fragmentation

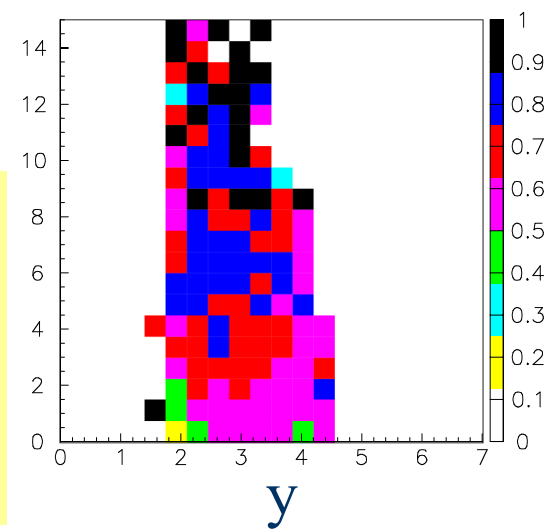


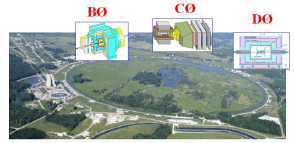
Distribution of reconstructed B mesons



Trigger efficiency for B mesons ≈flat

(plot is statistics limited)



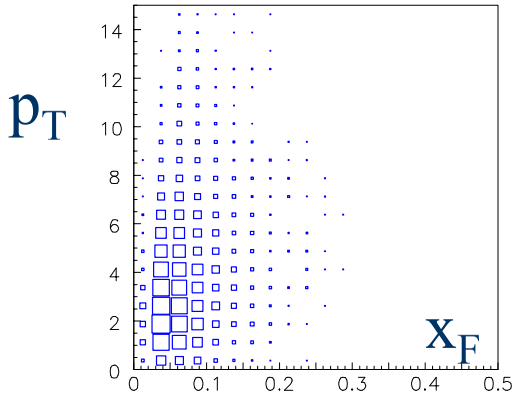


QCD Physics at BTeV

Heavy quark production in the forward region:

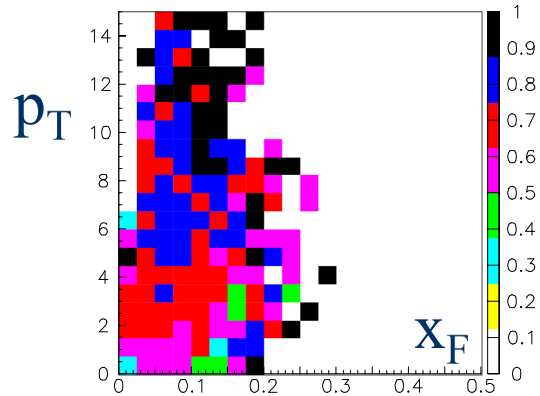
- Probe PDF's at low and high x_{Bj}

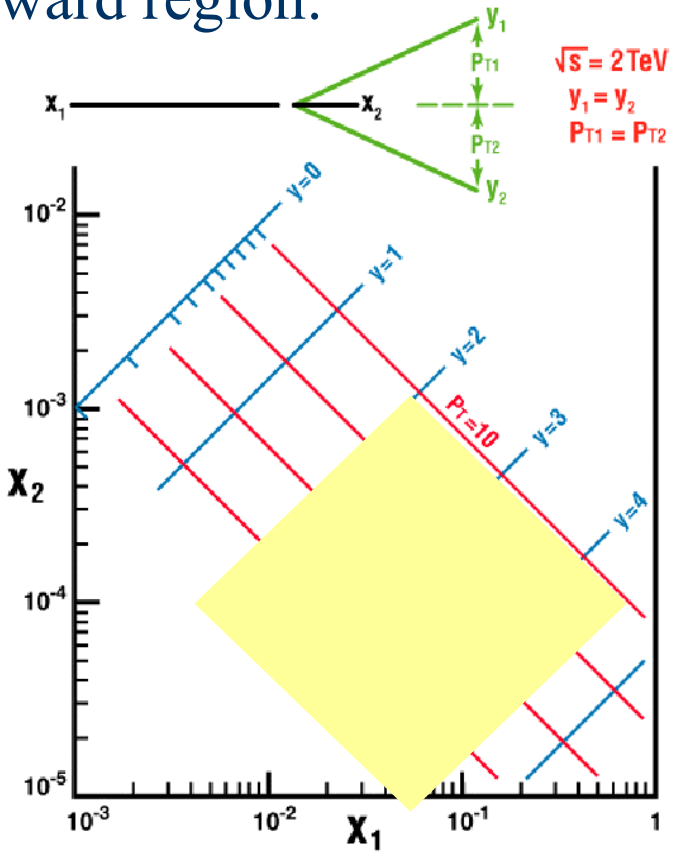
Distribution of reconstructed B mesons



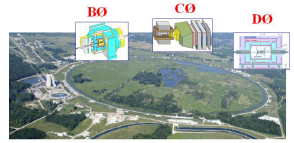
Trigger efficiency for B mesons ≈flat

(plot is statistics limited)





From M.Albrow, "GTEV", DESY, Mar. 2004



QCD Physics at BTeV

Heavy quark production - $b\bar{b}$ correlations ($\Delta\phi$, Δy, Δp_T,…)

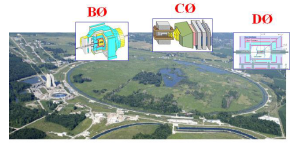
- Sensitive to higher order QCD contributions & low x in PDF(?)
- Less model dependence in QCD predictions(?)

Our studies concentrated on rare decays and tagging, but…

- Estimate ~10^7 fully reconstructed B mesons (in 2 fb^{-1})
- ~10^6 fully recon. B + opposite tagged $\bar{B}$ (not a jet)
- ~10^3 fully recon. BB + $B\bar{B}$ (c.f. 10^5-10^6 di-b-jets CDF/D0)
- ~10^4-10^5 fully reconstructed $D\bar{D}$ (depends on trigger)

Could also look at bb or $\bar{b}\bar{b}$ events (besides from B mixing)

- E.g. due to gluon splitting in fragmentation
- SUSY $\tilde{g} \rightarrow b\tilde{b}$ (~c.f. done at Run I and Run II?)



QCD Physics at BTeV

Drell-Yan processes as probes of PDF (not direct photon)

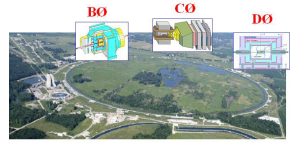
- Possible to trigger, but backgrounds unknown at low dilepton mass

Production and polarization of J/ψ and Υ in the forward region

- Useful in discriminating NRQCD vs CEM, colour-singlet vs octet?
- Can reconstruct excited states of $c\bar{c}$ and $b\bar{b}$ (different J^P) using γ's

Spectroscopy (excellent charged particle+γ det. and part. ID)

- B_c spectroscopy and decays, ~10^4 fully reconstructed (~10^3 Run II)
- Spectroscopy of other b and c hadrons (many excited states)
- Light quark spectroscopy via B and D meson decays



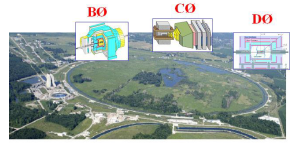
QCD Physics at BTeV

Search/measure more exotic quark states

- Must be able to trigger on these states (lifetime or muons in decay)
- qqQ and qQQ and even QQQ baryons
- pentaquarks, tetraquarks and hybrids with b and c quarks

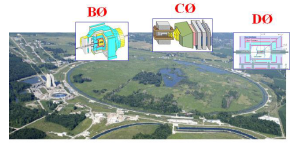
More QCD Physics at BTeV?

- Besides concerns of uncertainties in extracting CP-violating/CKM measurements in B decays, not much focus on possible QCD physics so far
- Not trying to sell QCD physics at BTeV, but this is an excellent opportunity to see what could be measured at BTeV and get collaborators who might want to do this type of physics

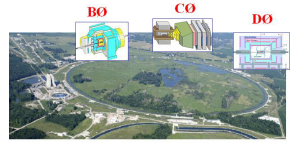


Summary

- BTeV is a Tevatron experiment to study CP violation, rare and forbidden b & c decays in the forward region
- Goal for BTeV is to discover New Physics, or help interpret New Physics found elsewhere, using b & c decays; &
- Measure Standard Model "fundamental parameters"
- Although QCD physics has not been a focus for BTeV there will be many interesting areas of study due to detection in the forward region, excellent charged particle and photon detection & particle ID, and excellent efficiency for b & c hadron reconstruction
- This is an excellent opportunity to see if BTeV can be used to do the type of QCD physics you are interested in.

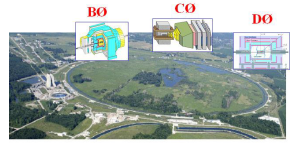


Proceed to Backup Slides



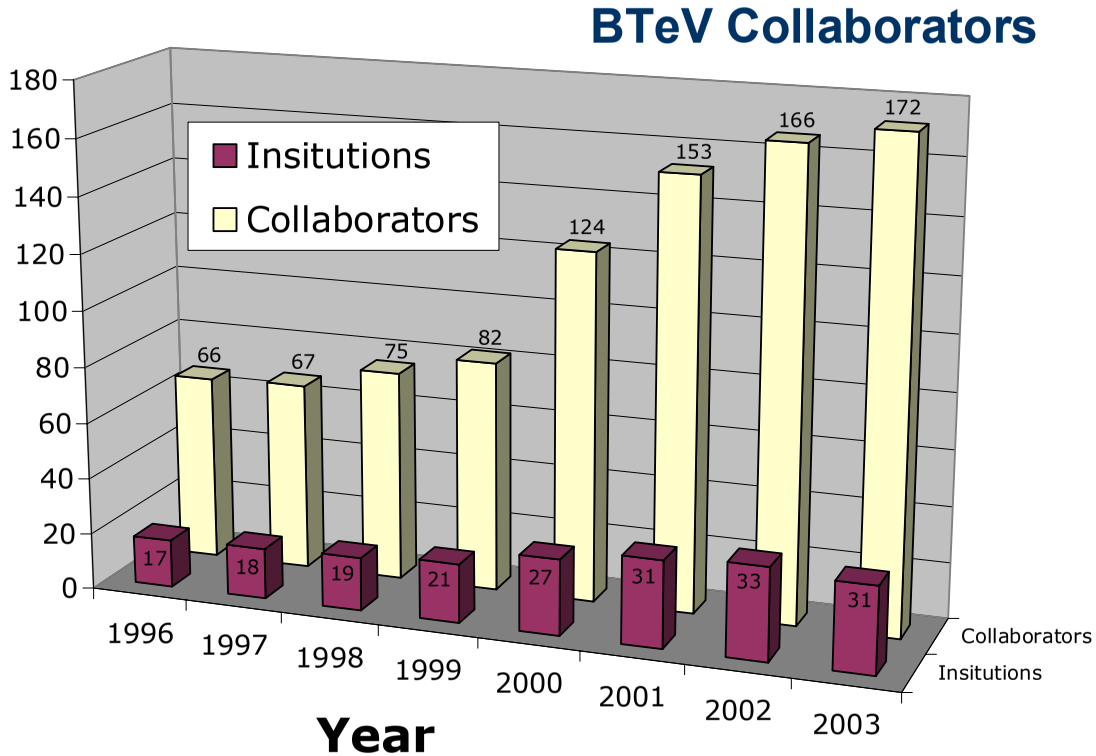
Brief History and Status of BTeV

- May 1997 - EOI, 161 pages
- Dec. 1997 - Addendum, 62 pages - address PAC concerns
  ⇒ BTeV becomes a R&D project
- May 1999 - Preliminary TDR, 373 pages (full BTeV)
- May 2000 - Proposal, 429 pages, submitted to Fermilab
  June 2000 ⇒ PAC unanimously recommends Stage 1 approval
  ⇒ Approval from Director (2-arm)
- Mar. 2002 - Proposal update, 126 pages (request from Lab, 1-arm)
  ⇒ PAC unanimously recommends approval of descoped BTeV
  ⇒ Approval from Director (1-arm)
- Oct. 2002 - Fermilab conducts cost review of BTeV (Temple)
- Mar. 2003 - Review of BTeV by P5
  ⇒ Oct. 2003 - P5 supports building BTeV and recommends earliest construction
  ⇒ Nov. 2003 – BTeV makes the Near-term Priorities list of the DOE "Facilities for the Future of Science – A 20 Year Outlook" announced by Spencer Abraham
  ⇒ Feb. 2004 – BTeV received DOE CD-0 (Mission need for BTeV)
- Mar. 2004 - Temple review of BTeV cost range and schedule range
- Apr. 2004 - DOE Lehman CD-1 review



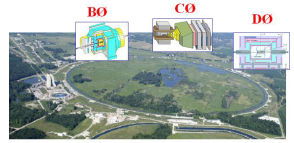
Continual and Growing interest in BTeV

- Despite long review and approval process and problems for universities getting funding (e.g. for R&D):



Most of these are senior members - expect to grow to 300 for construction, running and physics.

- There is very strong interest in the physics and technology of BTeV



Schedule

- If we get DOE approval and funding:

Calendar Year		2004	2005
Tevatron Collider		CDF & Dzero	CDF & Dzero / BTeV
Neutrino Program	B	MiniBooNE	MiniBooNE / OPEN
	MI	MINOS	MINOS
Meson 120	MT	Test Beam	Test Beam
	MC	E907/MIPP	E907/MIPP / OPEN

Calendar Year		2006	2007	2008	2009
Tevatron Collider		BTeV / CDF & D0	BTeV / CDF & D0	BTeV / CDF & D0	BTeV / CDF & D0 / BTeV / Open
Neutrino Program	B	OPEN	OPEN	OPEN	OPEN / OPEN
	MI	MINOS	MINOS	MINOS	MINOS / OPEN / OPEN
Meson 120	MT	TestBeam	TestBeam	TestBeam	TestBeam / TB
	MC	OPEN	OPEN	E906#	E906# / E906#
	ME	OPEN	OPEN	OPEN	E921* / E921*

We are very excited about BTeV and eager to get going
Construction funding anticipated for FY05-FY09

We welcome new collaborators!