Research in *B*-physics at CDF

Jennifer Pursley

Second Year Seminar

March 23, 2004

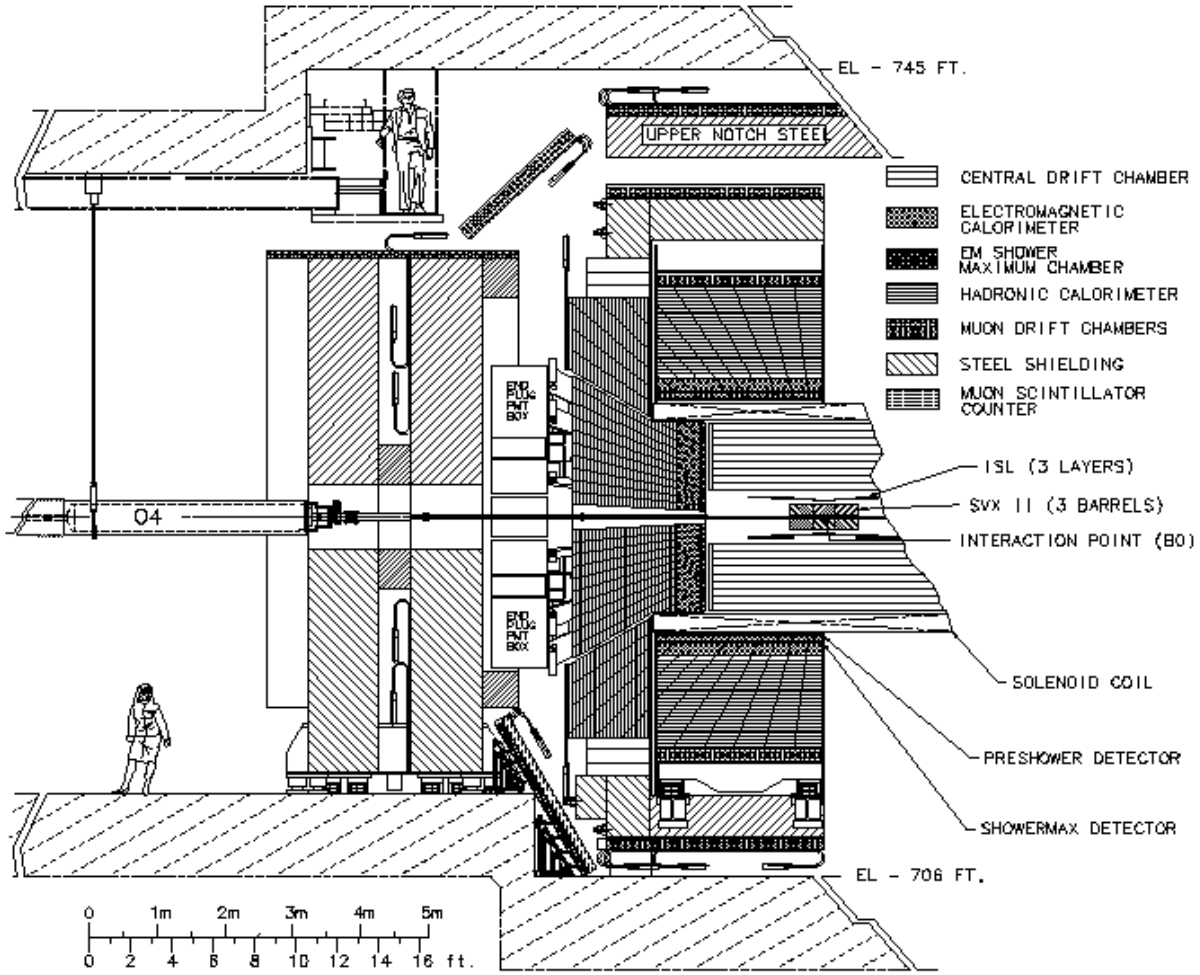
Outline

- Intro: Why *B*-physics
- *B*-physics at CDF
  - The detector
  - The tracking
  - The programs
- Ongoing research in *B*-physics
  - Orbitally excited states (L=1) of B^{*0}
- Future research

Why study the bottom quark?

- Heaviest quark to hadronize
  - Top quark too heavy - decays immediately
  - Best means of testing heavy quark theories
- Measure weak mixing angles
  - CKM mixing matrix
  - Unitarity triangle
- Measure other Standard Model parameters
  - CP violation
  - Suppressed decays

Review: The CDF



Tracking

- Three trigger levels
  - L1 and L2 are hardware triggers
  - L3 is a software trigger
  - At each step, $\sim$ 95% of the signals are rejected
- "Outside in" tracking
  - Too many hits in Si detector to distinguish tracks
  - Relatively easy to find tracks in COT (see following slide) and muon chambers
- Fully reconstructed vs. Partially reconstructed decays
  - Fully reconstructed $\rightarrow$ NO missing energy (neutrinos, photons, or other)

COT and Si tracks

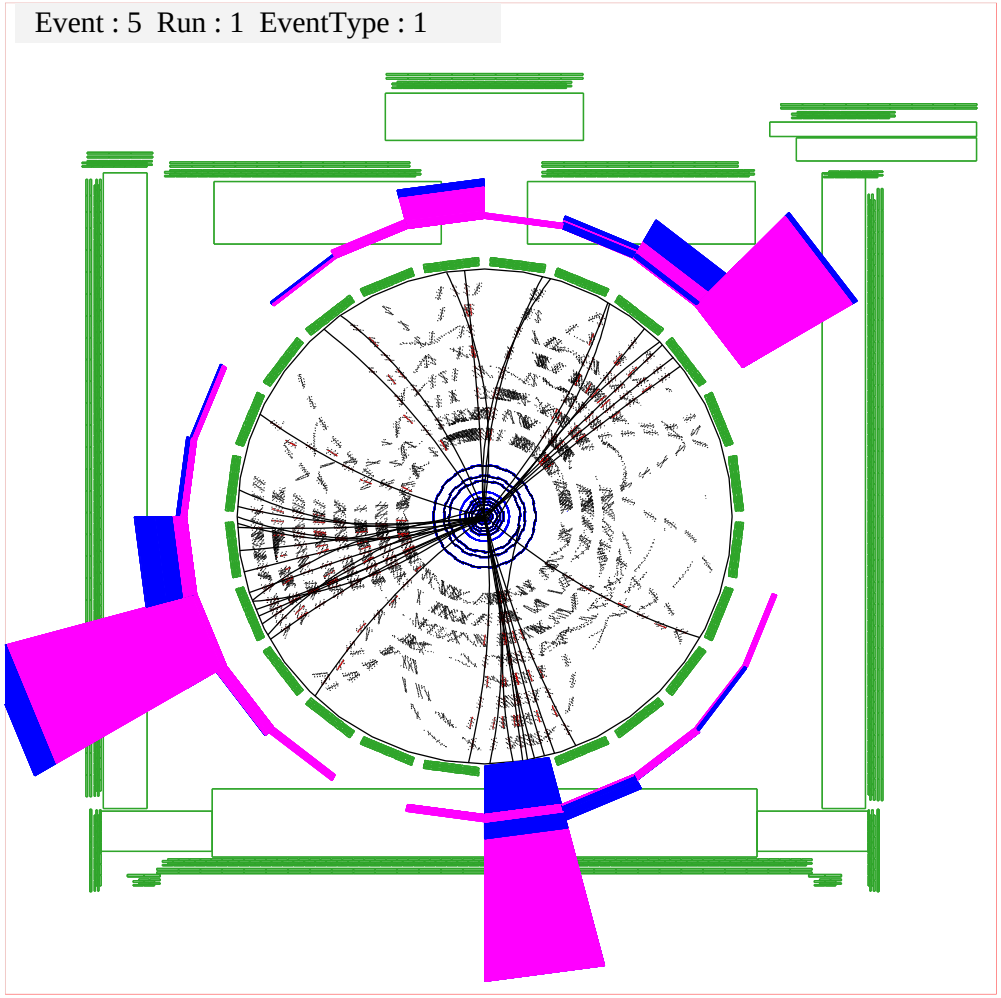


Figure 1: Pink $\rightarrow$ energy deposited in EM calorimeter, blue $\rightarrow$ Hadronic.

Accessing Data

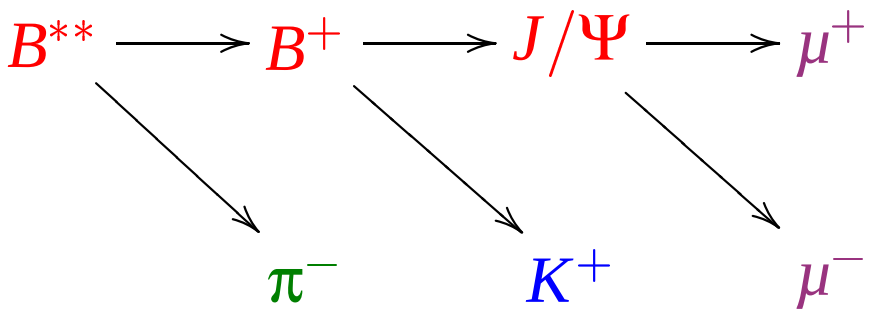
- After passing L3 trigger, data is written to tape.
- Currently CDF has gathered about 220 pb^{-1} of data.
- Data is further sorted by specific event triggers.
  e.g. dimuon trigger, dilepton trigger, high p_T electron trigger
- Data Handling group *tries* to make data access easy...
  Difficult to succeed with CDF software development progressing so rapidly.
- Anyone with a CDF account can access any data written to tape.
- Run large jobs on the CAF (Central Analysis Farm).

Analyzing Data - The Universal Finder

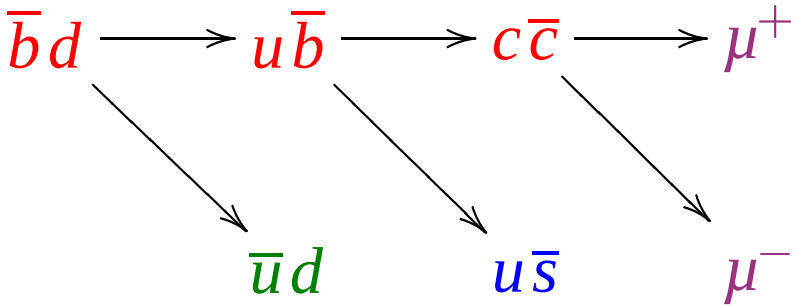
- Primarily written by Petar Maksimović and Mat Martin of JHU.
- Designed to reconstruct particle decays:
  - Highly flexible and generic
  - Designed for use with CDF, but could be coded for a different detector
  - Written in C++, but requires no knowledge of any programming language to use
  - Available to all CDF users
- Other options for reconstructing decays also available.

The Search for B^{**}

- Research project involves looking for doubly excited states of B mesons using fully reconstructed B decays.
- First decay mode analyzed is



- On the quark level, this decay looks like



B^{**}: Theory

Name	**J**	J_q	Mass (GeV/c^2)			Width	Decays
			EHQ[1]	ref.[2]	EGF[3]	MeV/c^2	
B_0^*	0	$\frac{1}{2}$	5.650	5.870	5.738	100	$(B\pi)_{L=0}$
B_1^*	1	$\frac{1}{2}$	5.650	5.875	5.757	100	$(B^*\pi)_{L=0}$
B_1^*	1	$\frac{3}{2}$	5.759	5.700	5.719	20	$(B^*\pi)_{L=2}$
B_2^*	2	$\frac{3}{2}$	5.771	5.715	5.733	24	$(B\pi, B^*\pi)_{L=2}$

[1] E. Eichten, C. Hill, C. Quigg, “Properties of Orbitally Excited Heavy-Light Mesons,” Phys. Rev. Lett. 71, 25 (1993); “Orbitally Excited Heavy-Light Mesons Revisited,” FERMILAB-CONF-94/118-T (1994).

[2] N. Isgur, “Spin-Orbit Inversion of Excited Heavy Quark Mesons,” JLAB-THY-97-26.

[3] D. Ebert, V. O. Galkin, R. N. Faustov, “Mass spectrum of orbitally and radially excited heavy-light mesons in the relativistic quark model,” hep-ph/9712318, HUB-EP-97/90 (1997), and references therein.

Table replicated from D. Vucinic, ”Observation of Excited B Mesons in p-pbar Collisions at sqrt(s) = 1.8 TeV”, PhD thesis,

1998, Massachusetts Institute of Technology, http://www-cdf.fnal.gov/htbin/cdfnoteSelNum?number=4817

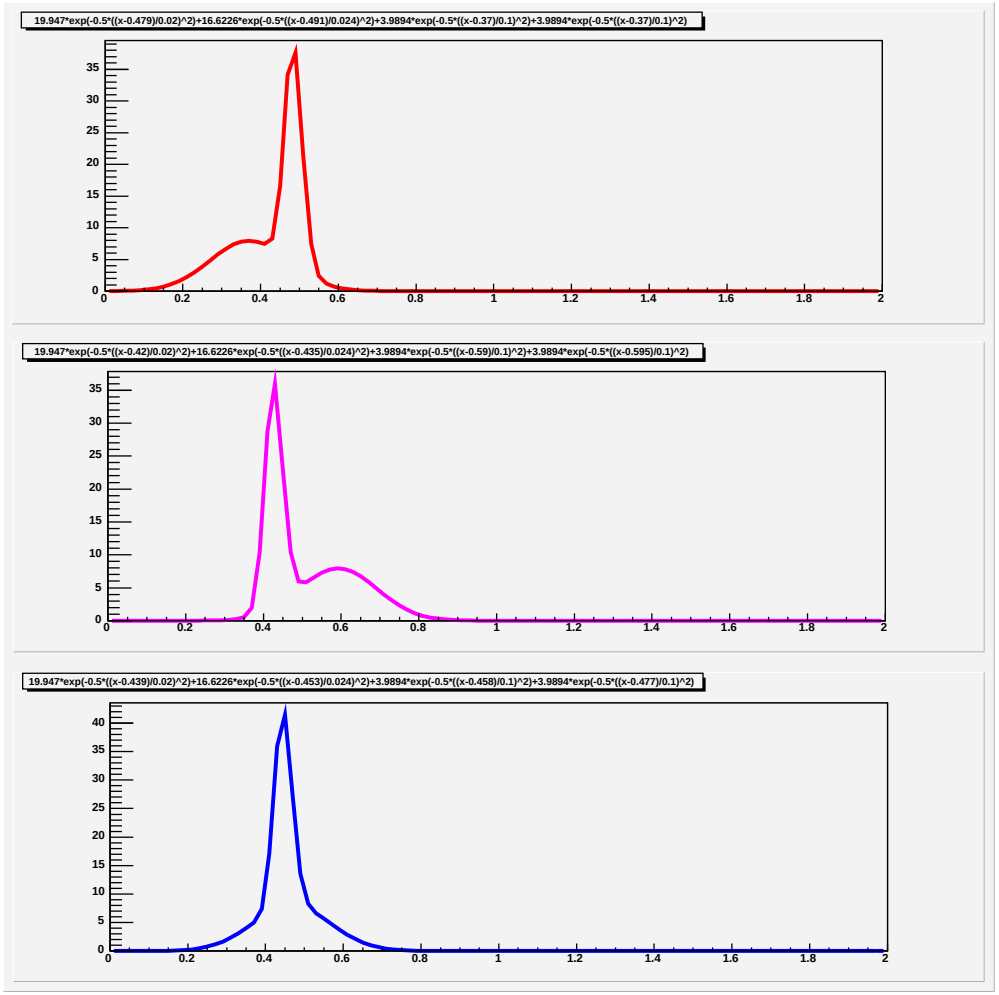


Figure 2: Plot of the three theoretical predictions of B^{**} resonances. Top: EHQ; middle: nonrelativistic; bottom: EGF.

The Code:

```
#  This is a full-blown tcl file for a realistic Bˆ** search.
#  It should be executed with
#     % bin/Linux2-KCC_4_0/Sin2BetaModuleTest
#                              <this_file> <main_tcl_file>
#  where <main_tcl_file> contains everything else:
#     input, output, filters, "begin" and "exit".

talk TrackSelectorModule
   trackCutManager
      cut ptCutL = Pt > 0.5
      cut etaCut = AbsEta < 2.0
      cut cotCut = HasCOTHits 20 16 0 0 0 0
      cut svxCut = HasSIHits   3  0 0 0
      cut errCut = PhysicalError
      cut pi_std = etaCut&&HasHelixFit&&cotCut&&svxCut&&ptCutL&&errCut
      cut K_std  = etaCut&&HasHelixFit&&cotCut&&svxCut&&ptCutL&&errCut
      cut mu_std = etaCut&&HasHelixFit&&cotCut&&svxCut&&ptCutL&&errCut
   exit
```

```
        inputTracks set defTracks
        trackRefit
             refitTracks     set true
             dropL00         set true
             dropISL         set false
             # refit method
             refitMethod     set KAL
             # rescale COT covariance matrix
             rescaleCOTCov   set true
             curvCOTFactor   set 5.33
             d0COTFactor     set 3.01
             phi0COTFactor   set 3.7
             lambdaCOTFactor set 0.580
             z0COTFactor     set 0.653
            show
        exit
exit
```

```
talk TrackAssocModule
  K_Std_Assoc
    doSvt  set t
    doDedx set t
    doTof  set t
  exit
  mu_Std_Assoc
    doMuons set true
    doSvt   set t
    doDedx  set t
    doTof   set t
  exit
  pi_Std_Assoc
    doSvt  set t
    doDedx set t
    doTof  set t
  exit
  verbose set f
exit
```

```
talk UFindModule
   FinderManager
     #--- Setup some finders and a BeamlineVertexGuru
      new TrackAssocCandFinder Mu1     13
      new TrackAssocCandFinder Mu2     13
      new TrackAssocCandFinder Pi      211
      new UnstableCandFinder   Psi     443
      new TrackAssocCandFinder K       321
      new UnstableCandFinder   Bu      521
      new UnstableCandFinder   Bdstar  10511

      decay Psi to Mu1 Mu2
      decay Bu to Psi K
      decay Bdstar to Bu Pi

      new BeamlineVertexGuru   OO  0
      OO
         BeamWrapper
            Verbose set 1
            BeamlineType set SVX
            FixtoProdVersion set 491
         exit
      exit
```

```
      #--- Now set cuts for each particle
:
:
  Bu
      #verboseLevel set 5
      selection_actions
         new UpdateKinematics uk
         new PtCut            pt > 6.0
         new MassCut          mass window 5.155 5.4
         #new TTTCut_lopt      ttt
         new VertexFit        vf
#             vf
#                 constrain Psi -mass
#                 constrain Bu  -mass
#             exit
         new FitProbCut           prob > 0.001
         #new MassCut             massF window 5.1 5.5
         new FitD0Cut             d0  calculate_only -signed -ntuplable
         new FitPointingAngleCut  pa  calculate_only -ntuplable
         new FitCtCut             ct calculate_only -ntuplable
         new FitLxyCut            lxy > 0.01
      exit
```

```
          Bu
             add CandKinemNt kinRAW -version RAW
             add CandKinemNt kinFT2 -version 2 -prefix F2
             add DecayVertexFitNt dec
          exit

     exit
⋮

#--- Now tell the Universal Finder to figure everything else out!
          prepare_search

       exit

   exit

exit
```

And that’s it! (Well, practically.)

Preliminary Data Results

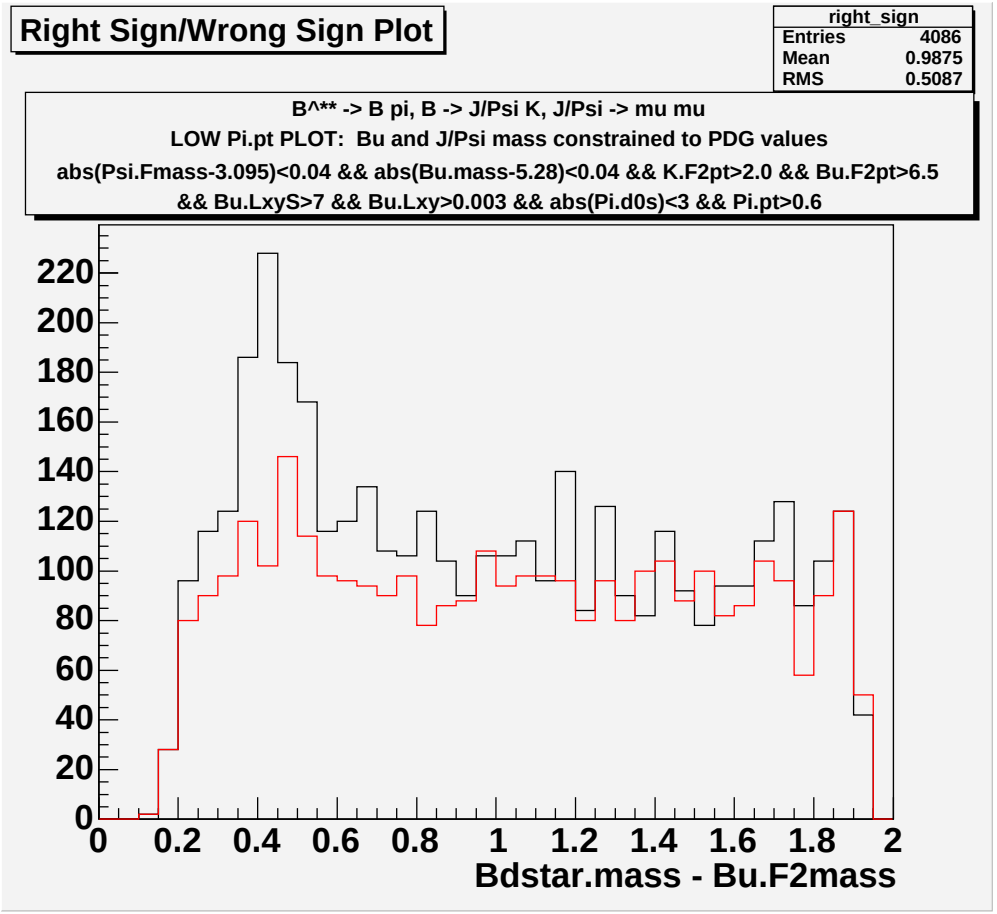


Figure 3: B and J/Ψ masses both constrained; uses lower $p_T(\pi^-) > 0.6$ cut but includes all other cuts.

Preliminary MC Results

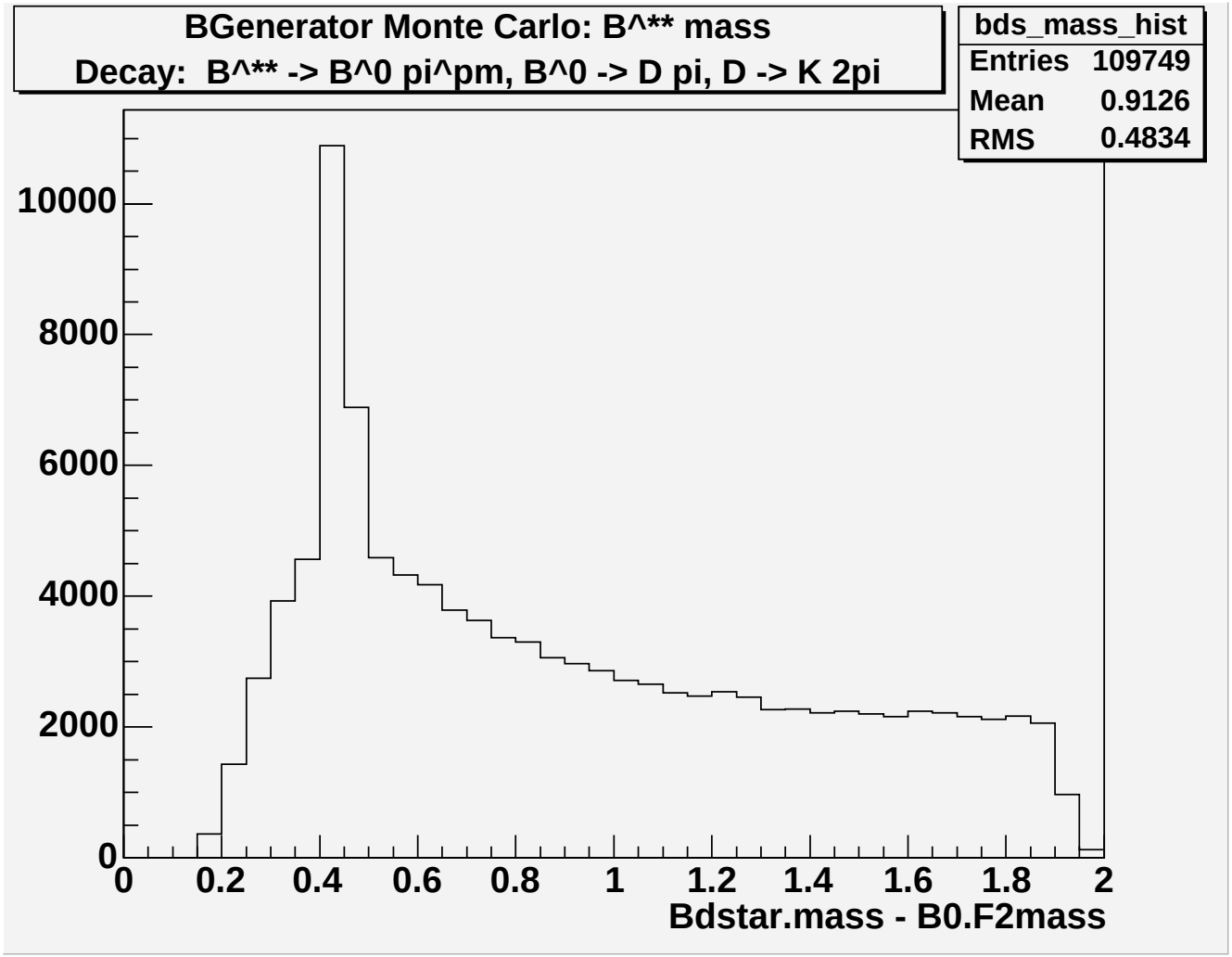
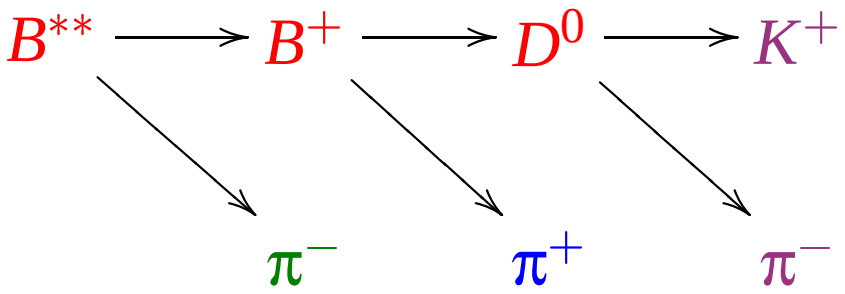


Figure 4: Bgen MC with baseline analysis cuts.

Future Research

- Continue analysis of B^{**} :
  - Generate realistic Monte Carlo samples
  - Perform efficiency studies
  - Run on real data with optimized cuts
  - Explore other decay modes, such as



  - Extend search to include $B^{**\pm}$

Conclusions

- *B*-physics is a ‘hot topic’ in particle physics research right now.
- *B*-physics can be successful at CDF.
- Currently we see indications of a B^{**} mass peak

  - a bit more work is needed to make those results conclusive.
- Goal: be ready for B^{**} publication by this August.