$B \to J/\psi\ K^0_S$ and $B_s \to J/\psi\ \phi$

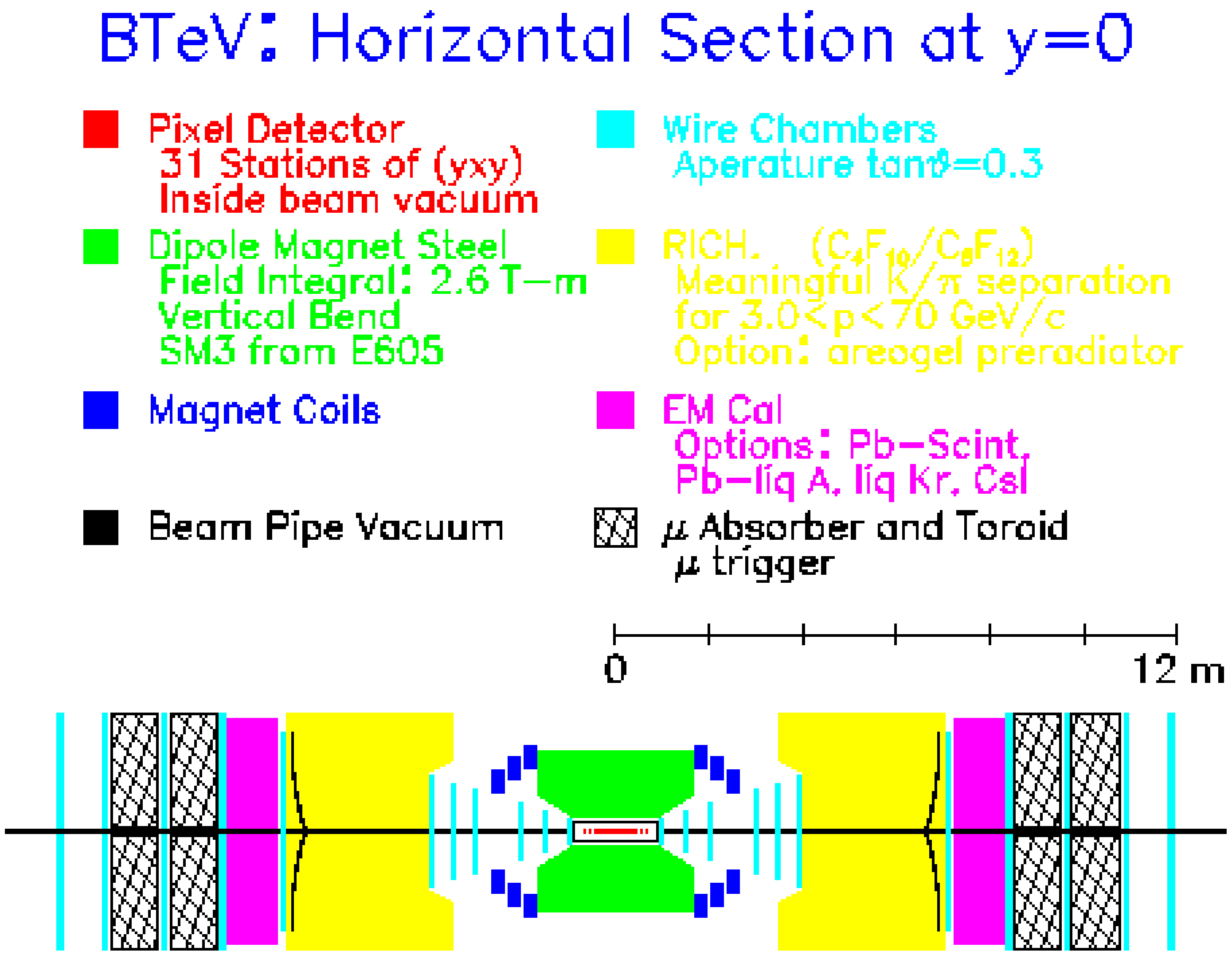
Robert K. Kutschke
Fermi National Accelerator Laboratory

Workshop on B Physics at Run II
and Beyond

Fermilab
February 24, 2000

- The Evolving Baseline Detector
- Decay Chains
- Outline of Method
- Recap of $B \to J/\psi\ K^0_S$ (PTDR, 1999)
- Fast and Dirty Look at $B_s \to J/\psi\ \phi$

http://home.fnal.gov/~kutschke/BTeV/talks/000224_wg1.ps



BTeV: Horizontal Section at y=0
Pixel Detector
31 Stations of (yxy)
Inside beam vacuum
Wire Chambers
Aperature tanϑ=0.3
Dipole Magnet Steel
Field Integral: 2.6 T−m
Vertical Bend
SM3 from E605
RICH. (C_4F_{10}/C_5F_{12})
Meaningful K/π separation
for 3.0<p<70 GeV/c
Option: areogel preradiator
Magnet Coils
EM Cal
Options: Pb−Scint,
Pb−liq A, liq Kr, CsI
Beam Pipe Vacuum
μ Absorber and Toroid
μ trigger
0
12 m

Changes to the Baseline Detector since PTDR

- Pixel planes now doublets, not triplets.
  - Motivation: much less material.
    conversions; pair production;
    cost; complexity; ...
  - Trigger algorithm now demonstrated with doublets. See Erik Gottshalk's talk in WG1.
- Forward tracking system has Si strips at small radii, straws at larger radii.
  - Motivation: occupancy.
- $PbWO_4$ is the plan for the EMCal.
  - Motivation: rad hard.

Decay Modes Considered

$$
\begin{array}{l}
B \rightarrow J/\psi\ K^0_S \\
\qquad\qquad\quad \hookrightarrow \pi^+\pi^- \\
\qquad\quad \hookrightarrow \mu^+\mu^- \\
\qquad\quad \hookrightarrow e^+e^-
\end{array}
$$

- 2 prong primary.
- 2 prong long lived secondary.
- Vertex trigger and muon trigger.

$$
\begin{array}{l}
B_s \rightarrow J/\psi\ \phi \\
\qquad\qquad\quad \hookrightarrow K^+K^- \\
\qquad\quad \hookrightarrow \mu^+\mu^- \\
\qquad\quad \hookrightarrow e^+e^-
\end{array}
$$

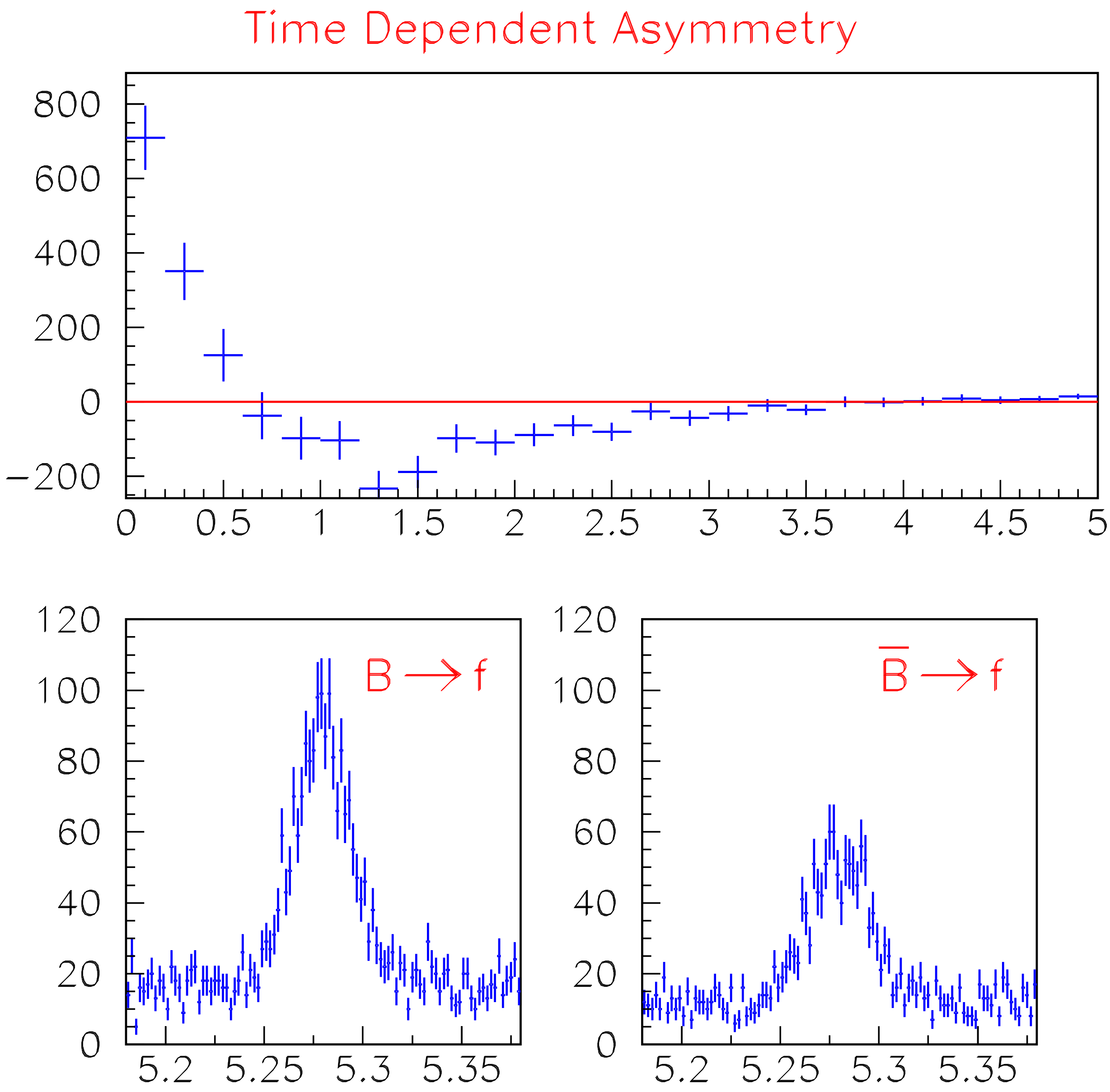
- 4 prong primary: better time resolution.
- Topologically identical to $B_s \rightarrow J/\psi\ \bar{K}^{*0}$.

Analysis Plan

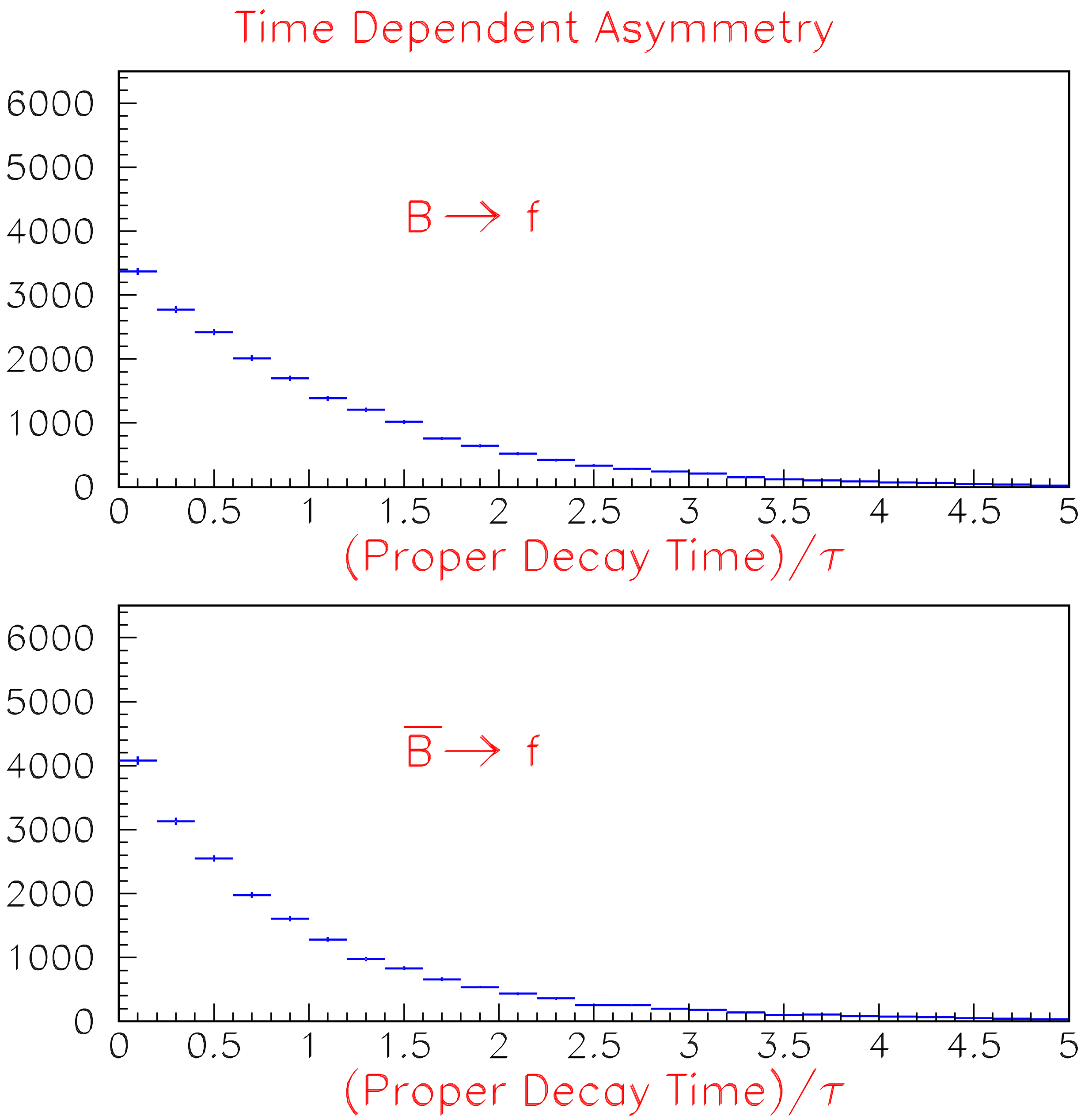
- Simulations with MCFast
  - Signal Channels
    - Efficiency (including trigger).
    - Mass resolution (σ_m).
    - Proper decay time resolution. (σ_t).
  - High stats simulation of BG
    - S/B; feedback to analysis cuts.
    - $B \to \Psi X$.
    - Generic B.
  - Tagging ϵD^2 from a separate study.
  - Details of cuts can be found in Preliminary TDR on BTeV web site.
- Standalone Calculations
  - Ensemble of Mini Monte Carlo runs.
  - "Analytic" *á la* McDonald. Princeton-HEP 92-04.

Methods to Extract A_{CP}

- Time Integrated
  - Least statistical power.
- Time Dependent
  - Simultaneous unbinned maximum likelihood fits to the two tagged distributions.
    - Best statistical power.
    - Systematics could be a problem.



- Each data point in upper curve comes from fitting two mass plots and subtracting.
- Binning reduces statistical power.
  (Not important for B_d. Important for B_s.)



- Do simulateous unbinned maximum likelihood fit to the two tagged samples.
- Requires a priori knowledge of all shapes.

Methods to Extract A_{CP}

- Time Integrated
  - Sensitivity vanishes for large x.
    OK for B_d. Death for B_s.

$$\delta(\sin(2\beta)) = \frac{1+x^2}{x}\sqrt{\frac{1}{\epsilon D^2 N}}\sqrt{\frac{S+B}{S}}$$

- Time Dependent - simultaneous max-like fits.
  - Sensitivity survives at large x.

$$\delta(\sin(2\beta)) = e^{\frac{x^2\Gamma^2\sigma_t^2}{2}}\sqrt{\frac{1+4x^2}{2x^2}}\sqrt{\frac{1}{\epsilon D^2 N}}\sqrt{\frac{S+B}{S}}$$

Recap of $B_d \to J/\psi K^0_S$ from PTDR

Quantity	Value	Yield B_d or $\bar{B}_d$ (Events/year)
Luminosity:	2×10^{32} cm^{-2} s^{-1}	
One Year:	10^7 s	
$\sigma_{b\bar{b}}$:	100 μb	
$\mathcal{B}(\bar{b} \to B_d)$	0.4	1.6×10^{11}
$\mathcal{B}(B_d \to J/\psi K^0_S)$:	5.0×10^{-4}	8×10^7
$\mathcal{B}(\psi \to \mu^+\mu^-) \times \mathcal{B}(K^0_s \to \pi^+\pi^-)$:	0.04	3.2×10^6
ϵ(Reconstruction)	0.04	128,000.
ϵ(Trigger)	0.85	109,000
Tagging: ϵD^2	0.10	
S/B	10:1	
σ(Proper Decay time)	50 fs??	
x_d	0.73	
$\delta(\sin(2\beta))$:		
Time Integrated:	± 0.021	
Time Dependent:	± 0.017	

Numbers in red used in sensitivity calculation.

Fast and Dirty Look at $B_s \to J/\psi\ \phi$

Quantity	Value	Yield (Events/year)
Luminosity:	2×10^{32} cm^{-2}s^{-1}	
One Year:	10^7 s	
$\sigma_{b\bar{b}}$:	100 μb	
$\mathcal{B}(\bar{b} \to B_s)$	0.13	5.2×10^{10}
$\mathcal{B}(B_s \to \psi\phi)$:	$1. \times 10^{-3}$	5.2×10^7
$\mathcal{B}(\psi \to \mu^+\mu^-)$:	0.061	
$\mathcal{B}(\phi \to K^+K^-)$:	0.500	1.6×10^6
ϵ(Geometric)†	0.18	
ϵ(Analysis cuts)†	0.17	48,000.
ϵ(Trigger)†	0.85	41,000.
Tagging: ϵD^2	0.10	
S/B	20:1	
σ(Proper Decay time)	38 fs	
x_s	20-40??	
δ:		
Time Integrated:	$0.31(x_s = 20)$ to $0.62(x_s = 40)$	
Time Dependent:	$0.025(x_s = 20)$ to $0.035(x_s = 40)$	

$\dagger$ Efficiencies assumed equal to those for $B_s \to J/\psi\ \bar{K}^{*0}$.

- Numbers in red used in sensitivity calculation.

Still to Do

- Redo efficiencies with latest detector model.
  (Doing $\psi\varphi$ properly, not as $\psi\bar{K}^{*0}$.)
- Use agreed on values for cross-section etc.
- No plans to verify with Mini-MC ensemble.

Summary

- Results for one year of running:
  - For $B \to J/\psi\ K^0_S$:
    - $\delta(\sin(2\beta)) = \pm 0.017$.
  - For $B_s \to J/\psi\ \phi$:
    - $\delta(\sin(2?)) = \pm 0.025$, $x_s = 20$.
    - $\delta(\sin(2?)) = \pm 0.035$, $x_s = 40$.