WG 2 – Semileptonic & Rare Decays

Summary

modes

1) FCNC decays

(a) $B \to K^* \mu\mu$

(b) $B \to X_s \mu\mu$

(c) $B_s \to \mu\mu$

2) Radiative Decays

$B \to K^* \gamma$, $B_s \to \phi \gamma$, $B_s \to K^* \gamma$

$\Lambda_b \to \Lambda \gamma$

3) Semi leptonic Decays

$\Lambda_b \to \Lambda_c \ell \nu$

Why is $b \to s\, \ell^+ \ell^-$ interesting?

loop level process (like $b \to s\gamma$)

more operators contribute

Burdman Hiller Hewett

C_7 ($b \to s\gamma$) + C_9, C_{10}

complementary to $b \to s\gamma$

additional constraints on new physics

$\mu\mu$ final state:

kinematic distributions

ex: FB asymmetry

$B \to K^* \mu\mu$

Burdman Hiller

- A_{FB} : model indendent ⇝ graph

* sensitive to NP ⇝ graph

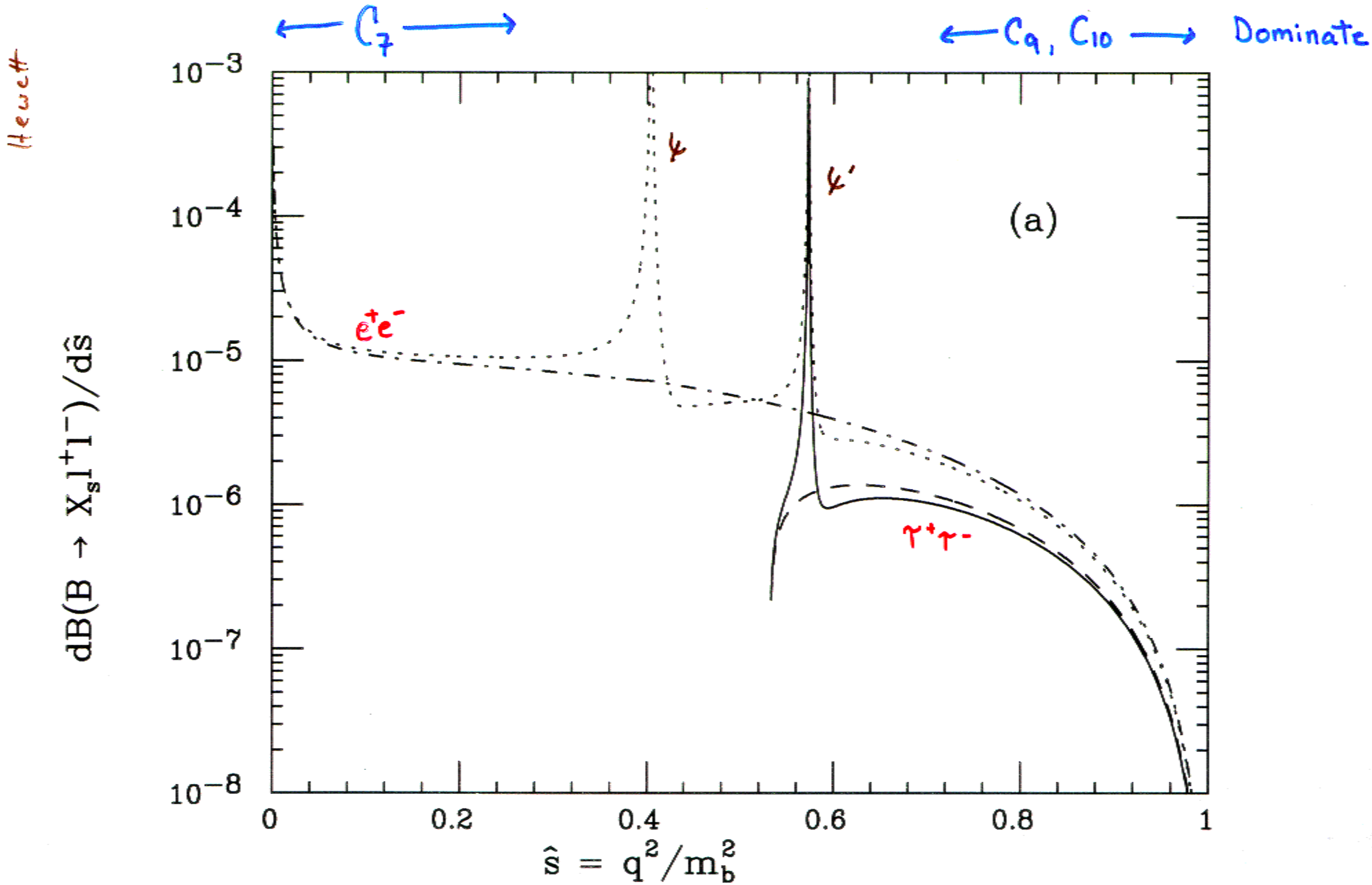
* CP asymmetry in A_{FB} small in SM ⇝ graph

extract the form factors from

Grinstein

$\frac{d\Gamma}{dq^2}$, $\cos\Theta_{K^*}$, ...

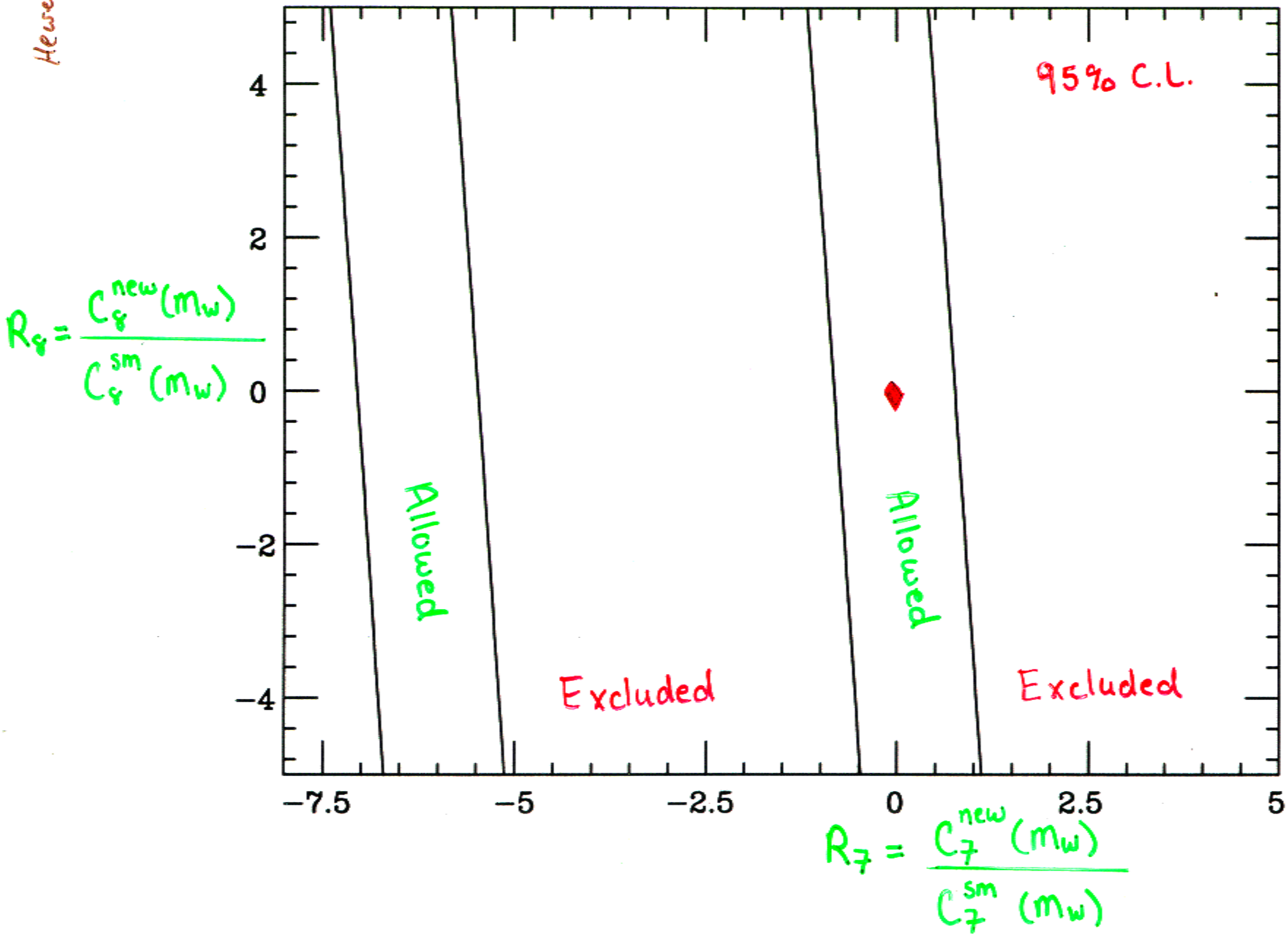
⇝ V_{ub} from $B \to q\, \ell\nu$



short distance + ψ/ψ' resonance contributions

Model Independent Constraints from $b \to s\gamma$ - new CLEO data

Hewett



$b \to sg$ constraint

$|R_8| < 8.9$

from

$\mathcal{B}(b \to sg) < 0.068$

[CLEO]

All theory + exp't errors included – 'scanning' method

Hiller

Forward-Backward asymmetry

$q^2 = (p_+ + p_-)^2$

$$A_{FB}(q^2) \;=\; \frac{\int_0^1 \frac{d\Gamma}{dq^2 d cos\theta} - \int_{-1}^0 \frac{d\Gamma}{dq^2 d cos\theta}}{+}$$

$$\sim \quad \alpha(q^2) Re(C_{10}^* C_7^{\text{eff}}) + \beta(q^2) Re(C_{10}^* C_9^{\text{eff}})$$

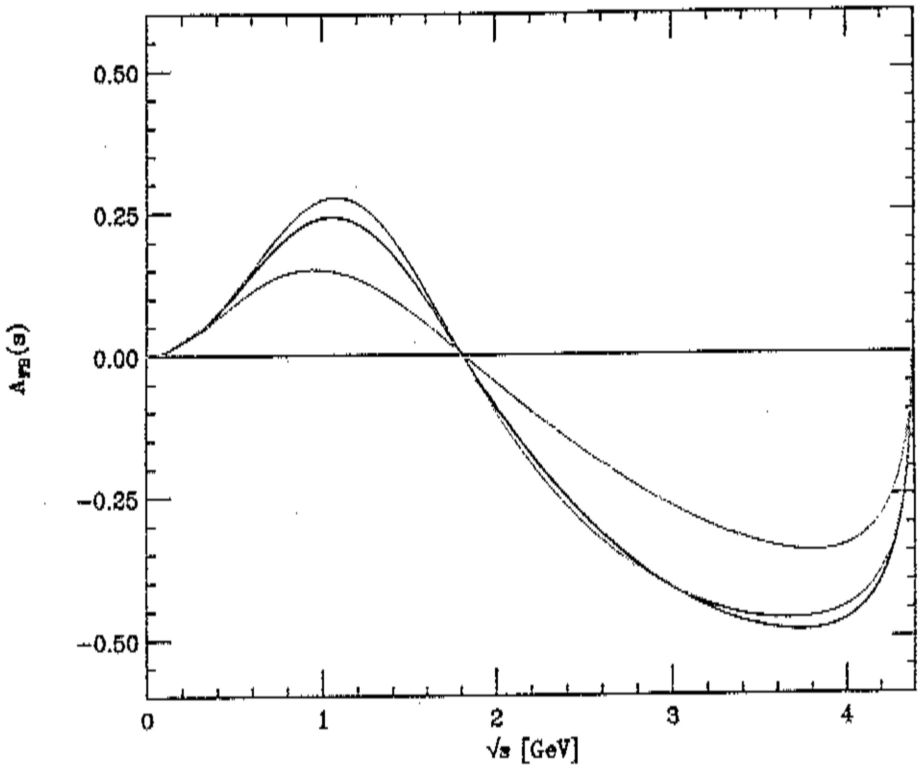
α, β: real functions of FF's
we are lucky: contribution of C'_{10} is suppressed by FF's

low q^2 region: SM: zero around 3GeV^2, whether zero or not tests the sign of C_7^{eff} ($C_7^{\text{eff}}|_{SM} = -0.31$), important test of the SM and models beyond. e.g. in SUGRA only $C_7^{\text{eff}} > 0$ for large $\tan\beta$, Goto et al

in $0.25\text{GeV}^2 \leq q^2 < 8\text{GeV}^2$ for $C_7^{\text{eff}} = +(-)C_7^{\text{eff}}|_{SM}$:
$\Delta\mathcal{B}_{K^*} = 7.7(13.1) \cdot 10^{-7}$ and $\Delta\mathcal{A}'_{FB} = -9.2(-26.5)\%$

position of the zero: very small theoretical uncertainties from FF's
G.Burdman, ABHH'99 ratios involved: T_2/A_1, T_1/V

$*$ The ratio R_V is very stable across models!



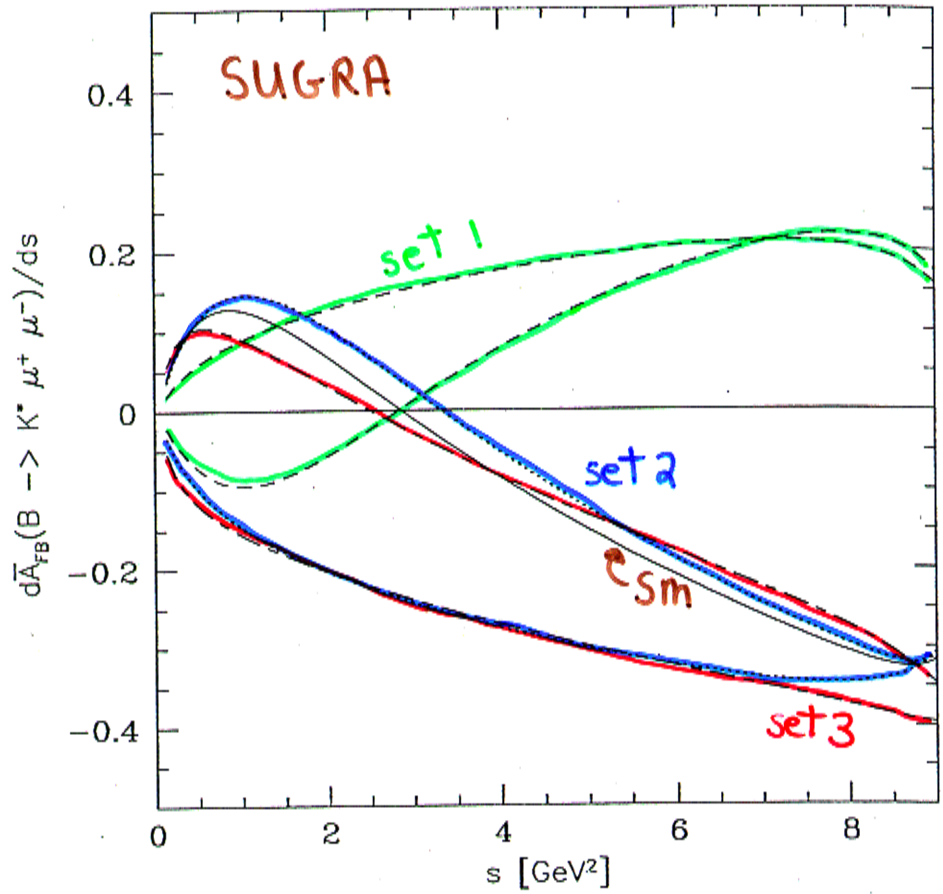
⟶ BSW*: Bauer, Stech and Wirbel, Z. Phys. C29, 637 (1985); Stech, Phys. Lett. B354, 447 (1995).

⟶ LCSR: Ball and Braun, Phys. Rev. D55, 5561 (1997).

⟶ MNS: Melikhov, Nikitin and Simula, Phys. Lett. B410, 210 (1997).

Hewett

Position of Asymmetry changes / vanishes with NP!



Ali, Ball, Handoko, Hiller '99

Clear indication of New Physics!

Hiller

Proposal: testing the phase of $\bar{s}_L \gamma_\mu b_L Z^\mu (C_{10})$ with the FB-CP asymmetry

$$FB_{CP} = \frac{A_{FB} - \bar{A}_{FB}}{A_{FB} + \bar{A}_{FB}} = \tan\theta \frac{Im(\mathcal{C}_9{}^{\text{eff}})}{Re(\mathcal{C}_9{}^{\text{eff}})} [1 + \cdots]$$

$C_{10} = |C_{10}| \exp i\theta$, $\mathcal{C}_9{}^{\text{eff}} = \mathcal{C}_9 + Y$, $Y(q^2)$: charm loop

- $FB_{CP} = 0$ for real C_{10}
- large effects for $\mathcal{O}(1)$ CP violating phases possible
- scales with $Im(\mathcal{C}_9{}^{\text{eff}})$

high q^2 region $14.0\text{GeV}^2 \leq q^2 < (m_B - m_{K^*})^2$

uncertainties: A) FF's: same ratios as for A_{FB} zero, $\lesssim 1\%$
B) SM background from up quark loops could fake C_{10} phases up to 1^0, ($b \to d$: $\theta_{eff} = -24^0$)

$$\tan\theta_{eff} \simeq \frac{Im(\lambda_t^* \lambda_u)}{|\lambda_t|^2} = \eta\lambda^2$$

$|\mathcal{FB}_{CP}(\hat{s})|_{SM}| \leq 0.6\%$ in high q^2 region, integrated $\triangle\mathcal{FB}_{CP}(\hat{s})|_{SM} = -6.2 \cdot 10^{-5}$

$B \to K^* \mu\mu$

- easy @ Tevatron

- CDF, DØ expect ~ 400 events each

Tanaka
Zieminski
⇝ combined $\mathcal{O}(1000)$ events

- CDF study:

Masa
  - cuts don't introduce a bias
  - A_{FB} : no asymmetry in background (run I data)

measure $\frac{d\Gamma}{dq^2}$, A_{FB}, $\cos\theta_{K^*}$

- BTeV :

Smith
study $B \to K \mu\mu$ ~ 1000 events
⇝ $B \to K^* \mu\mu$ ~ 4000 events

to date: B backgrds only

complete background analysis is in progress

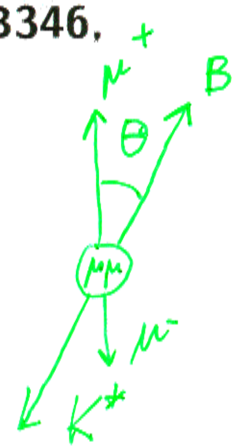
study asymmetry, ff's

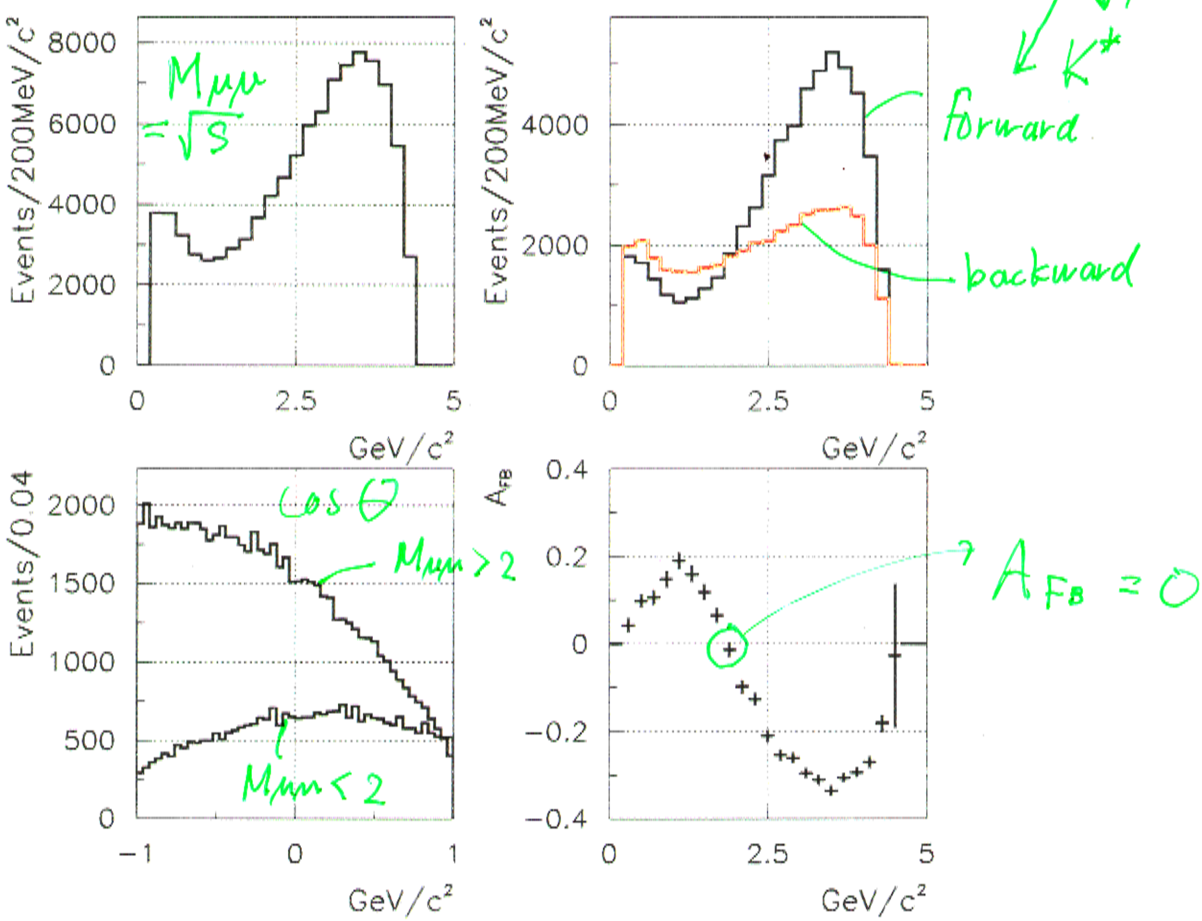
Forward Backward Asymmetry

Tanaka (CDF)

A decay MC based on SM calculation of the Wilson coefficient and form factors, only short distance (PLB346, 149 by C. Greub, et al)

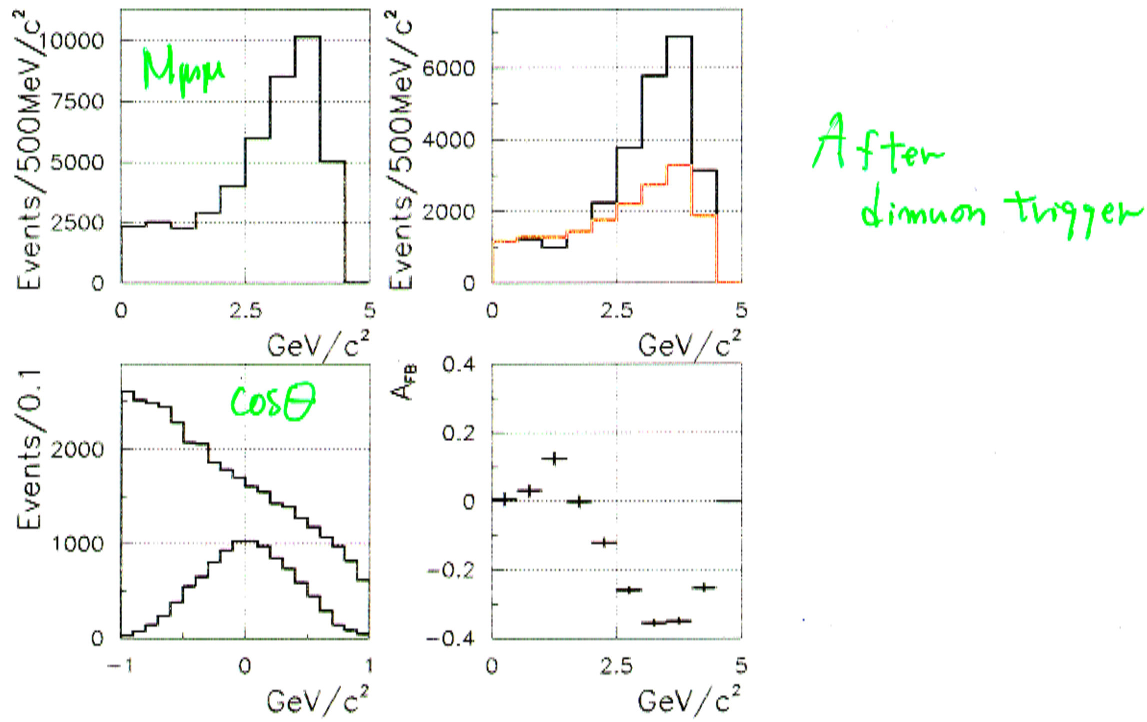
$$A_{FB} = \frac{N(\cos\Theta > 0) - N(\cos\Theta < 0)}{N(\cos\Theta > 0) + N(\cos\Theta < 0)}$$

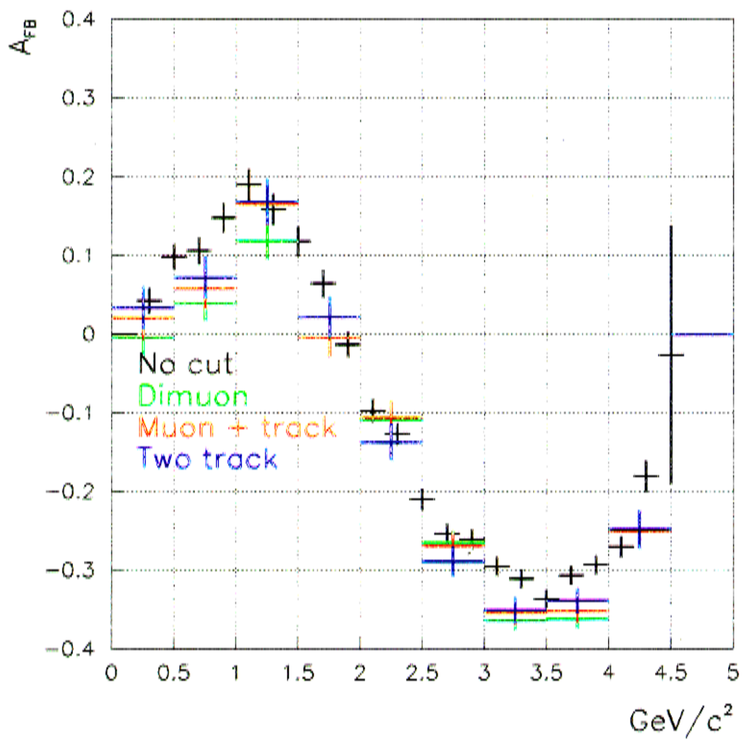




Selection Bias to $A_{FB}(M_{\mu\mu})$

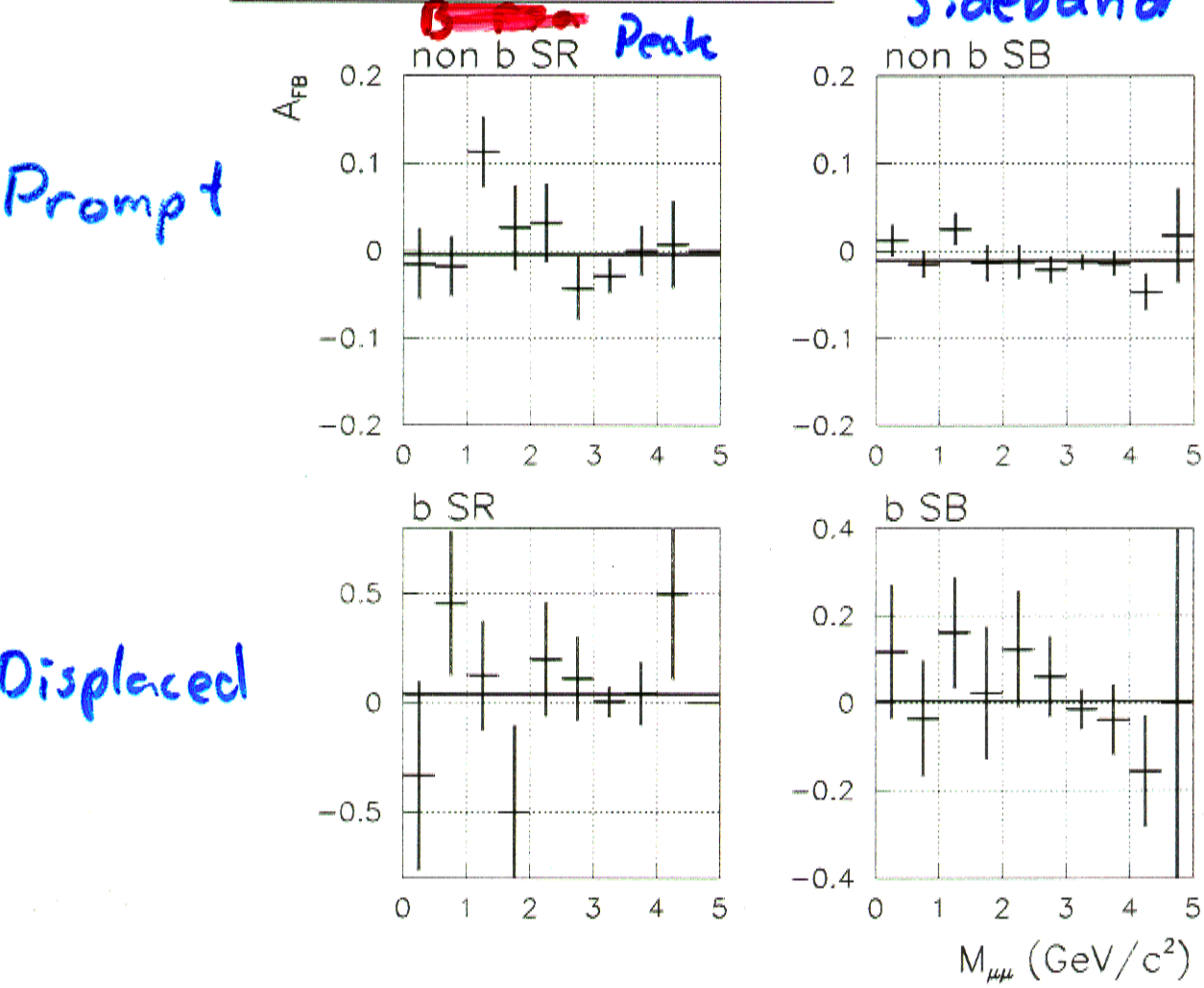
Apply the Run II trigger requirement and the same offline requirement as the Run I analysis





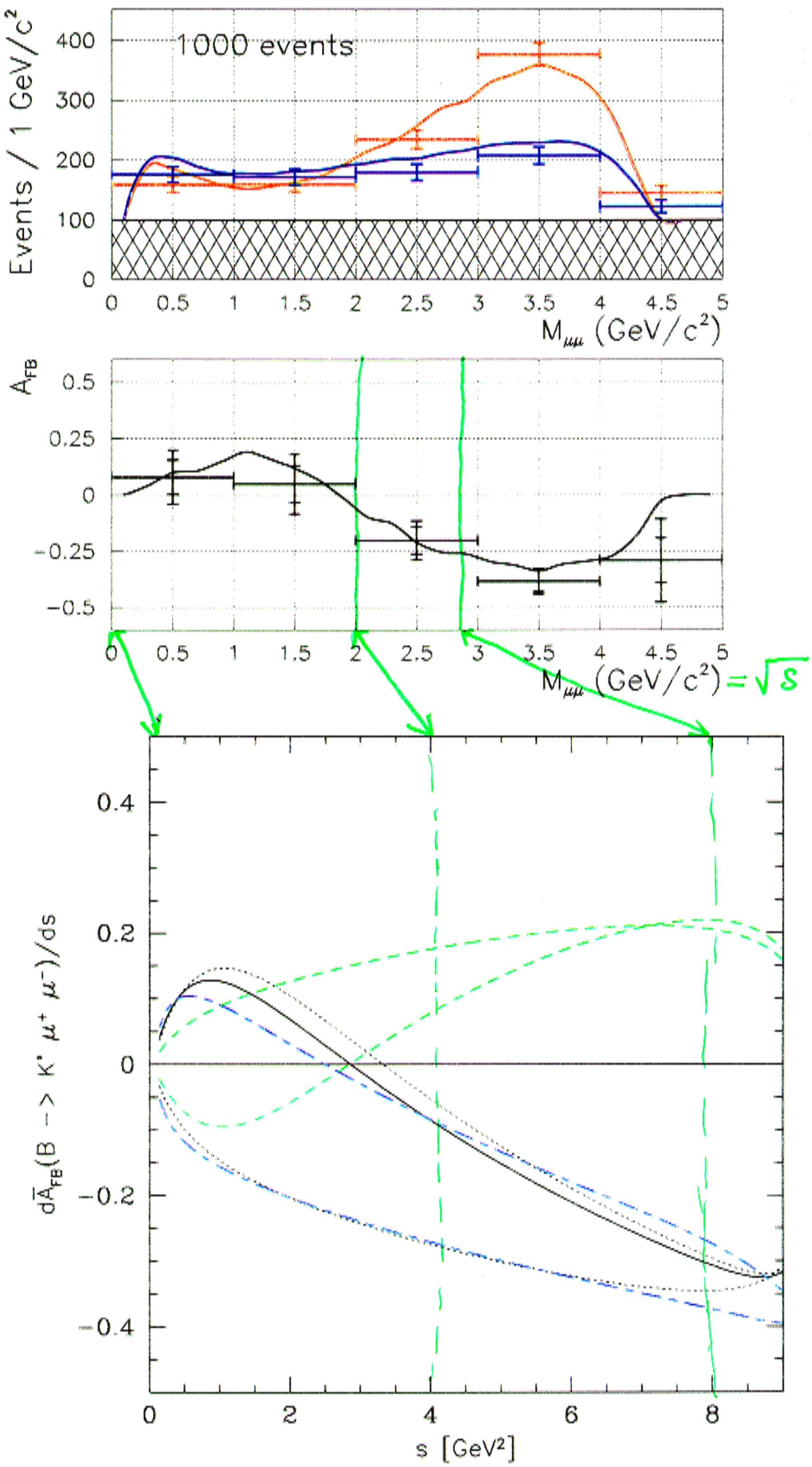
A_{FB} looks stable under various kinematical cuts.

Background Asymmetry



We found no significant asymmetries in the background events.

A_{FB} with 1000 events (Next generation)



$B \to X_s \mu\mu$

experiment: difficult

theory: clean without $m_{\mu\mu}$ cut

(a) with $m_{\mu\mu} > m_{\psi'}$

Bauer OPE breaks down → graph

but $B \to X_\mu \ell\nu$ shape → graph

is similar → V_{ub}

Zieminski • DØ study:

physics background 100 : 1

need vertex, isolation, impact parameter cuts

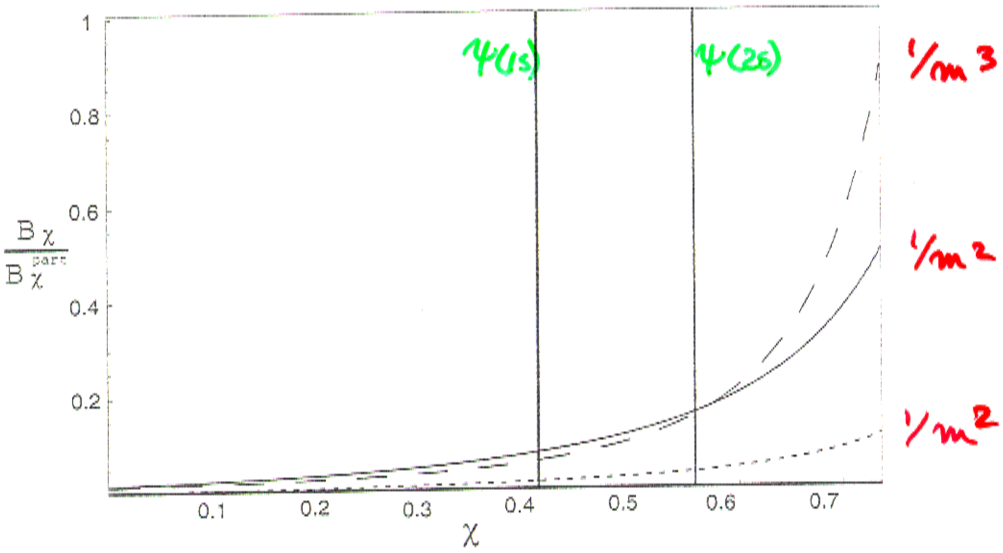
~ 1000 events

Bauer

The partially integrated rate

The rate with a lower cut on q^2

$$B_x = \int_x^1 \frac{dB}{d\hat{s}}\, d\hat{s}\,, \qquad x = \frac{s_0}{m_b^2}$$



The size of the nonperturbative contributions

for $x = \frac{14.3\,GeV^2}{m_b^2} = 0.59$

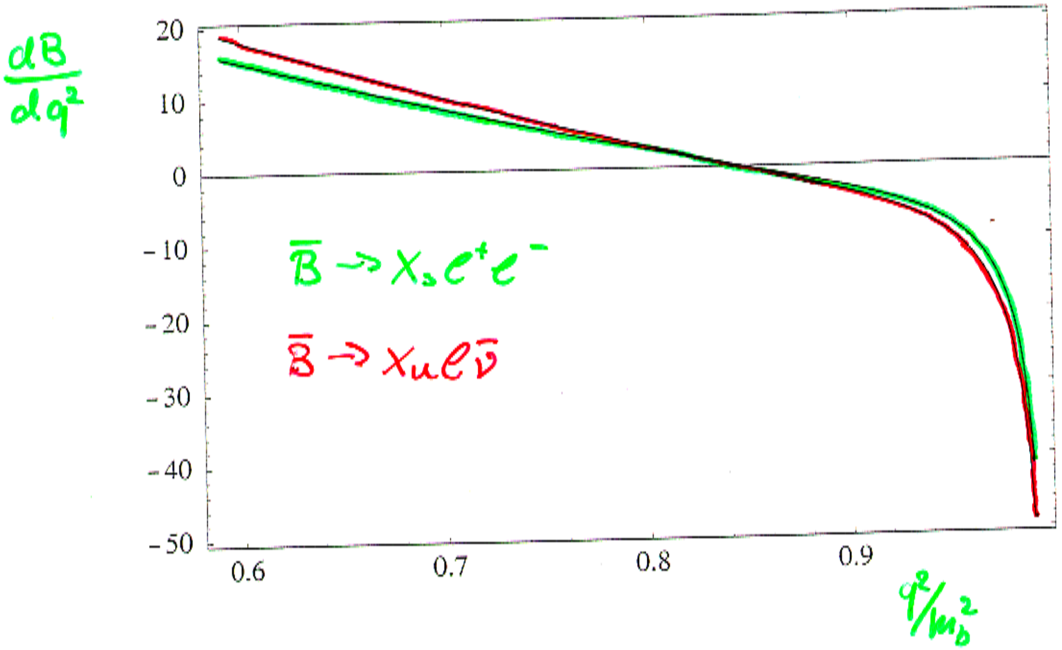
$$B_{0.59} = 3.8 + 1.9\left(\frac{\lambda_1}{m_b^2} + \frac{\tau_1 + 3\tau_2}{m_b^3}\right) - 134.7\left(\frac{\lambda_2}{m_b^2} + \frac{\tau_3 + 3\tau_4}{m_b^3}\right)$$

$$+ 614.9\,\frac{\rho_1}{m_b^3} + 134.7\,\frac{\rho_2}{m_b^3} + 560.2\,\frac{f_1}{m_b^3}$$

Bauer

- $\tilde{C}_9 \sim -C_{10} \gg C_7$

$\Rightarrow$ the $\bar{B} \to X_s e^+ e^-$ spectrum is very close to the $(V-A)\times(V-A)$ spectrum of $\bar{B} \to X_u \ell \bar{\nu}$



- $$\frac{\mathcal{B}(\bar{B} \to X_u \ell \bar{\nu})|_{q^2 > q_0^2}}{\mathcal{B}(\bar{B} \to X_s e^+ e^-)|_{q^2 > q_0^2}} = \frac{|V_{ub}|^2}{|V_{ts} V_{tb}|^2} \frac{8\pi^2}{\alpha^2} \frac{1}{|\tilde{C}_9|^2 + |C_{10}|^2 + 12\,\mathrm{Re}(C_7 \tilde{C}_9)\, B(q_0^2)}$$

$$B(q_0^2) = \frac{2}{3(1+Q_0^2)} - \frac{4\bar{\Lambda}}{3 M_B} \frac{Q_0^2}{(1+Q_0^2)^2}$$

- Expected to hold at ~15% level

Expected number of events for $b \to X_s \mu^+ \mu^-$

- Assumed luminosity 2 fb^{-1}
- Normalized to $\sigma(B^o) = 3\mu b$ for $p_T(B) > 6$ GeV, y(B)< 1
- Assumed BR$(b \to X_s \mu^+ \mu^-) = 2 \times 10^{-6}$
- Muons with $p_T(\mu) > 1.5(3.0)$ GeV and $\eta(\mu) < 1.6$
- Dimuon mass range (3.9 - 4.4) GeV
- Expected number of events is 30 % larger for (3.8 $< M(\mu\mu) <$ 4.4) GeV

		$p_T^{\mu} > 1.5$ GeV	$p_T^{\mu} > 3$ GeV
	$p_T^{\mu\mu} > 2$ GeV	$p_T^{\mu\mu} > 5$GeV	$p_T^{\mu\mu} > 5$GeV
Trigg. effic. (%)	32%	55%	60 %
Recorded	2300	1750	1000
Vtx cut	900	850	500
Isolation cut	720	650	400
$b\bar{b}$ Bkgd	3,300,000	400,000	100,000

before VTX, isolation cuts

(b) $B \rightarrow X_s \mu\mu$ inclusive

theoretically clean

CLEO-like pseudo-inclusive measurement

X_s : $K + n\ \pi$'s

Smith

BTeV : study is part of proposal work

CDF : will study

$B_s \rightarrow \mu\mu$

best channel for observation

current exp. limit:

~ x 700 above SM prediction

Zielinski • DØ study

sensitive to NP Logan
Hewett

Expected number of events for $B^0 \to \mu^+\mu^-$

- Assumed luminosity 2 fb^{-1}
- Normalized to $\sigma(B^o) = 3\mu b$ for $p_T(B) > 6$ GeV, y(B)< 1
- Assumed BR($B^0 \to \mu^+\mu^-$) = 2 $\times 10^{-10}$
- Muons with $p_T(\mu) > 1.5(3.0)$ GeV and $\eta(\mu) < 1.6$

	$p_T^{\mu\mu} > 2$ GeV	$p_T^{\mu\mu} > 5$GeV ($p_T^{\mu} > 1.5$GeV)	$p_T^{\mu\mu} > 5$GeV ($p_T^{\mu} > 3$GeV)
Trigg. effic. (%)	32%	55%	60%
Recorded	2	1.5	1
Vtx cut	0.8	0.7	0.4

(3 - 4)x more for $B_s \to \mu^+\mu^-$

Radiative Decays

$B \to K^* \gamma$ competition from e^+e^-

- $B_s \to \phi \gamma$
  $B_s \to K^* \gamma$ } $\frac{V_{td}}{V_{ts}}$

$\Lambda_b \to \Lambda \gamma$

Hewett Hiller

polarization ⇝ measure left-right structure

CP asymmetry ⇝ small in SM

- CDF :

Tanaka

trigger on converted electrons

B mass resolution 15 - 20 MeV

but only 10 % of all γ's

expect ~ 200 events (completely recon.) $B \to K^* \gamma$

(~ 100 events $B_s \to \phi \gamma$)

- BTeV :

plan to study

use calorimetry (GEANT)

Hewett

Radiative Baryon Decays - $\Lambda_b \to \Lambda + \gamma$ - Mannel Recksiegel

$$H_{eff} = \frac{4G_F}{\sqrt{2}} V_{tb} V_{ts}^* \, C_7(\mu)\, \mathcal{O}_7(\mu)$$

$$\mathcal{O}_7(\mu) = \frac{e}{32\pi^2} m_b \bar{s} \sigma_{\mu\nu} (g_V - g_A \gamma_5) b F^{\mu\nu}$$

$$g_V^{sm} = 1 + m_s/m_b \,, \qquad g_A^{sm} = -1 + m_s/m_b$$

$$\Gamma(\Lambda_b \to \Lambda + \gamma) = \Gamma_0 (1 + \alpha\, p \cdot S_\Lambda)$$

$$\Gamma_0 \sim (C_7 g_V)^2 + (C_7 g_A)^2$$

$$\alpha \sim \frac{2 g_V g_A}{g_V^2 + g_A^2}$$

$\Rightarrow$ Polarization of Λ sensitive to new physics!

Probes helicity structure of H_{eff}

- $B(\Lambda_b \to \Lambda + \gamma) \sim (1 - 4.5) \times 10^{-5}$
- Small long distance corrections

Tanaka

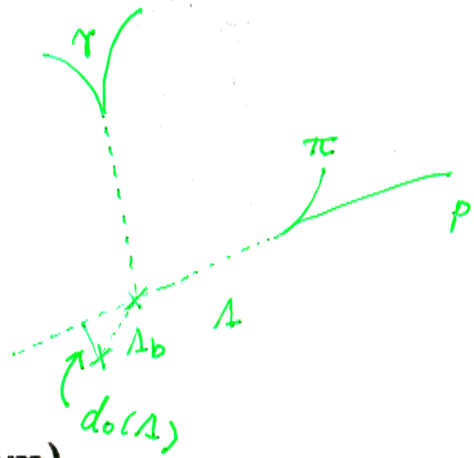
- CDF : $\Lambda_b \to \Lambda \gamma$

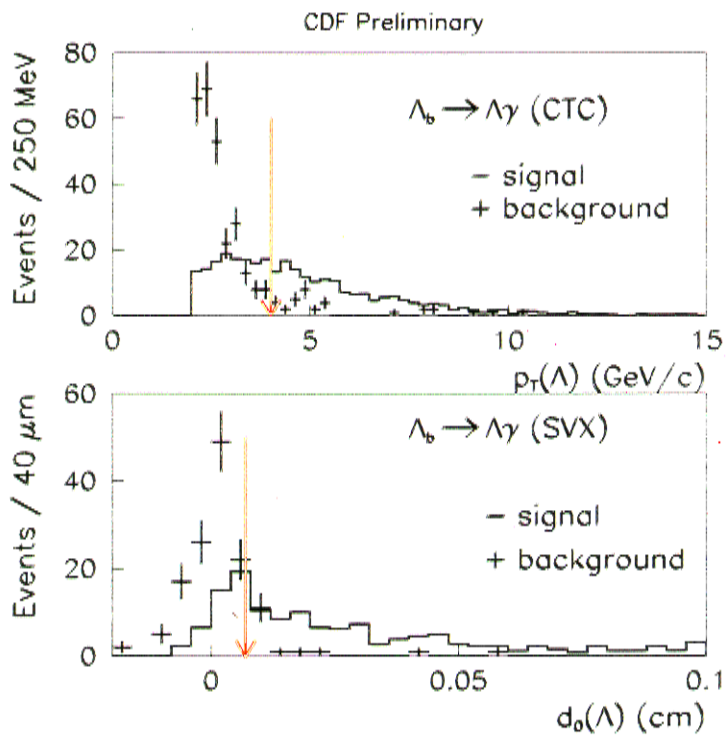
  Λ : long decay length

  need to find a better trigger

Λ_b

- Λ has long lifetime (ct = 8 cm)
  → Λ_b decay vertex is unknown
  - 85% : decay outside of the SVX
    → no 2ndary vertex information
  - 15% : decay in the SVX
    → Λ impact parameter ($\sigma \sim 40\ \mu$m)





Semi leptonic Decays

$\Lambda_b \to \Lambda_c \, l \nu$

Grinstein
Luke

test HQET, measure $\bar{\Lambda}$

only one form factor
(including $\frac{1}{m_b}$ corrections)

- need to reconstruct p_ν to study q^2 dependence
- goal: measure ff's

- CDF:

Kirk

good trigger: lepton
+ displaced track

~ 16 000 events (e+μ)

- p_ν with 3-D vertex
- Q^2 dependence

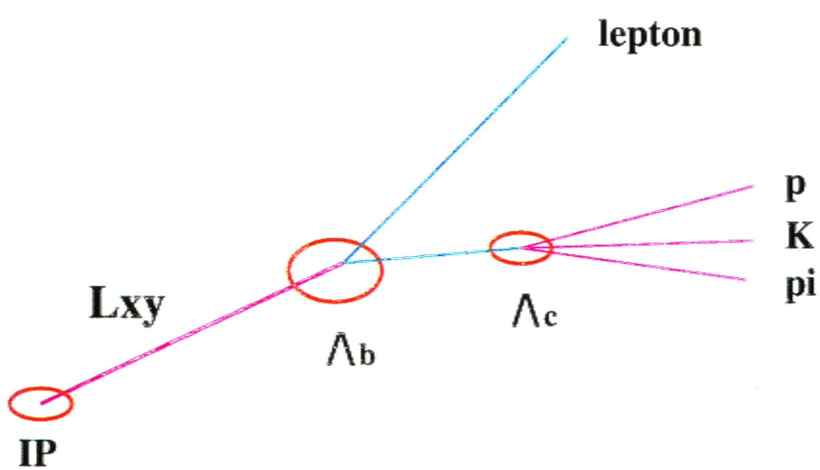
but ~30% contamination
from excited Λ_c

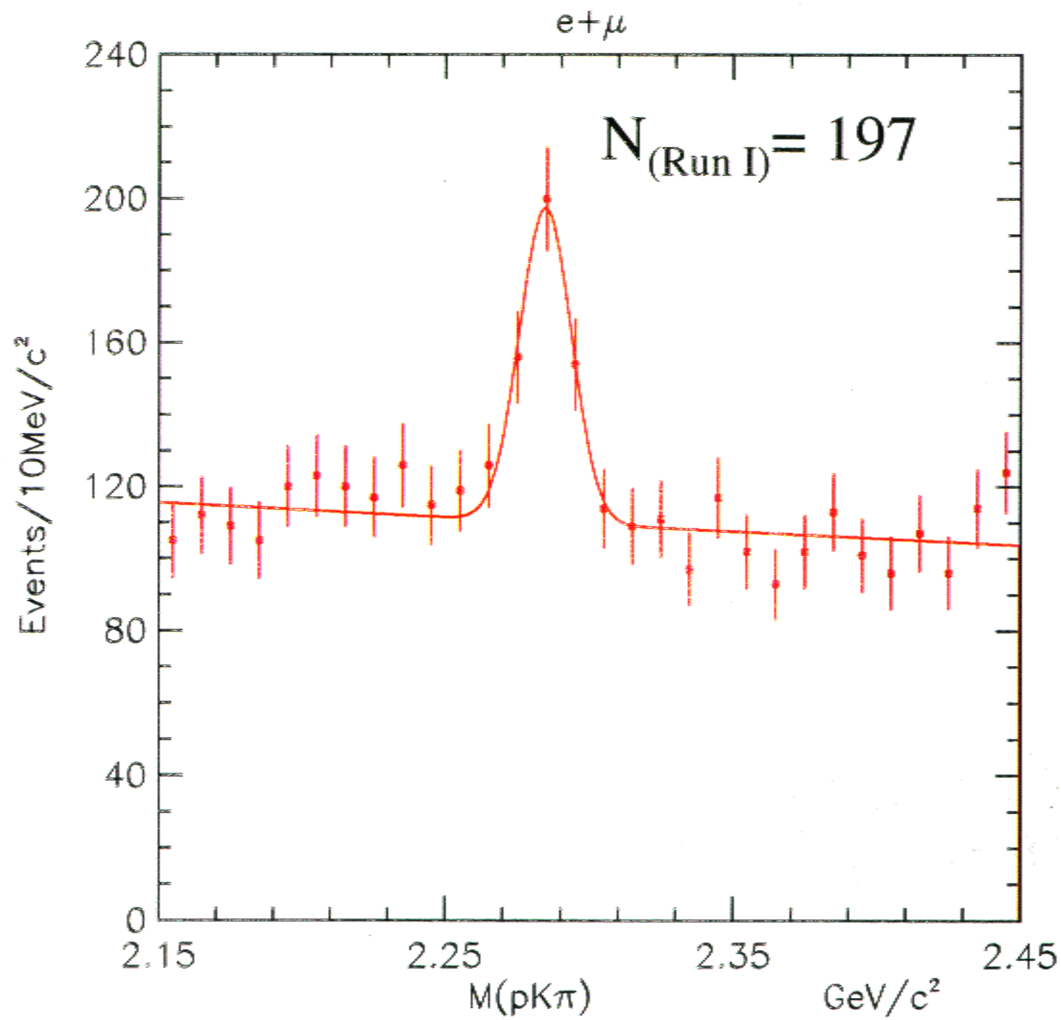
need to study how to exclude
additional tracks

Mike Kirk
B-Workshop
Working Group 2
02/25/00

Run I Yield: $\Lambda_b \to \Lambda_c\, l\, \nu$

- Single Lepton trigger
- $P_T > 8$ GeV/c
- Measured lifetime and production fractions





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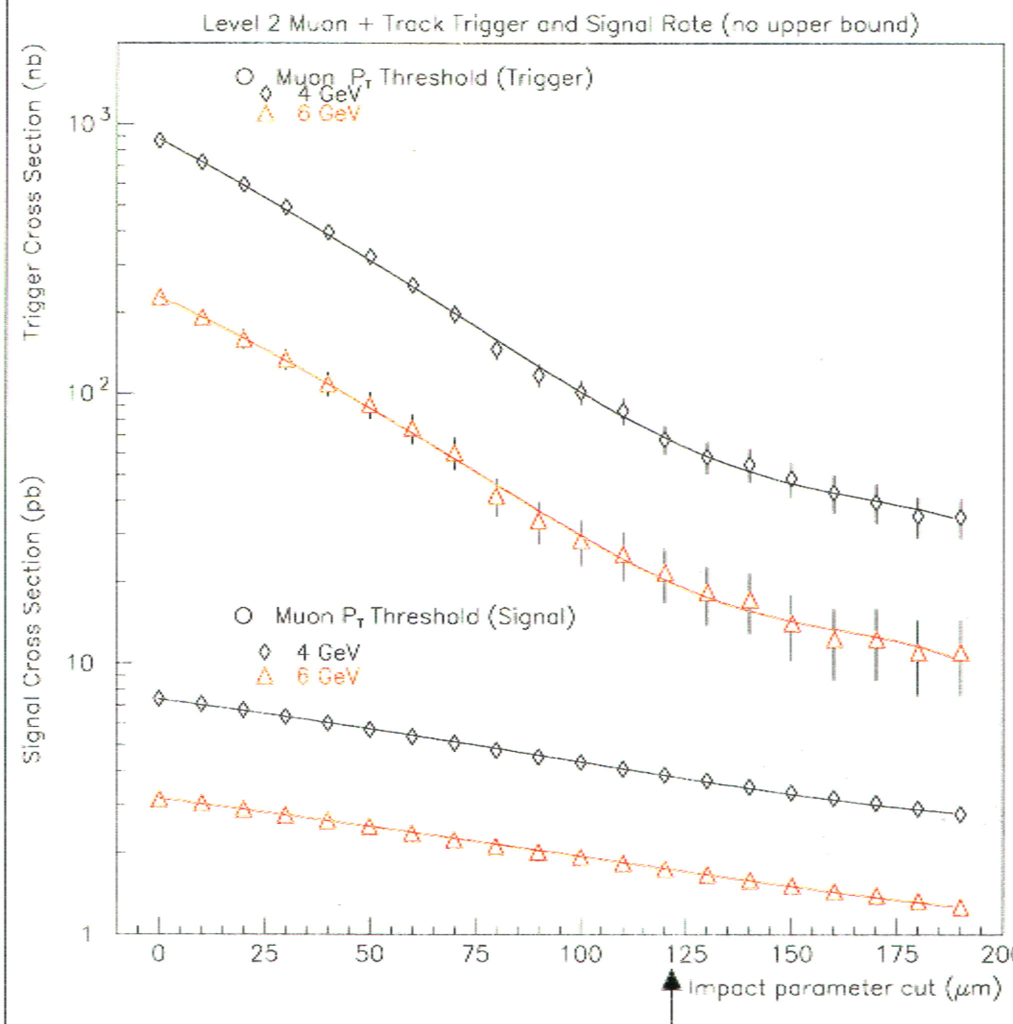
Level 2: Impact Parameter Study

- Level 2 Trigger:
  - Displaced track trigger via Silicon Vertex Tracker.
- Study highest impact parameter cut.
- $|d_0| > 120\ \mu m$.
- $P_T^{Track} > 2$ GeV/c, $|\eta| < 1$.
  - Same as 2 track trigger.



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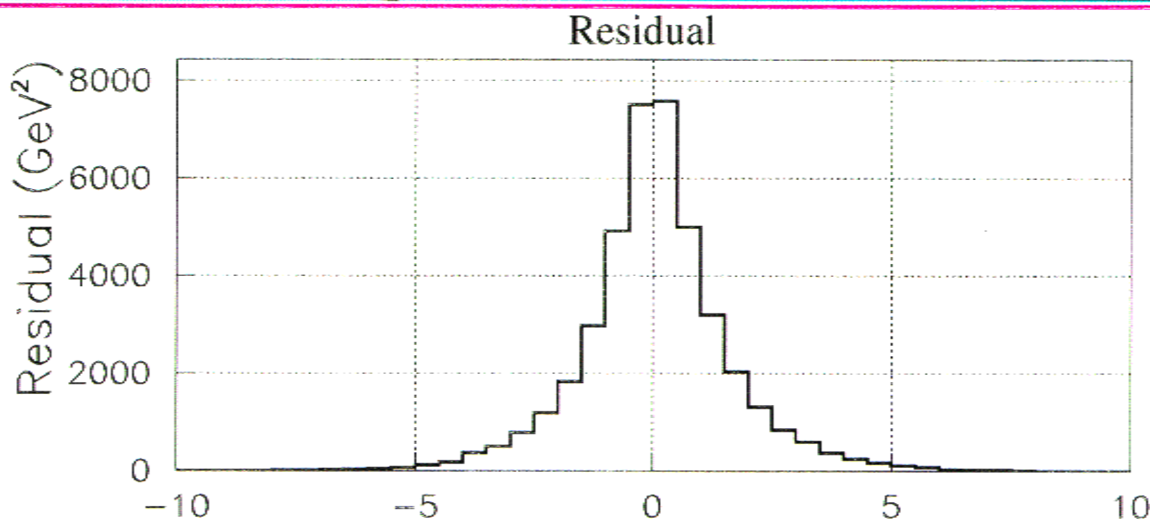
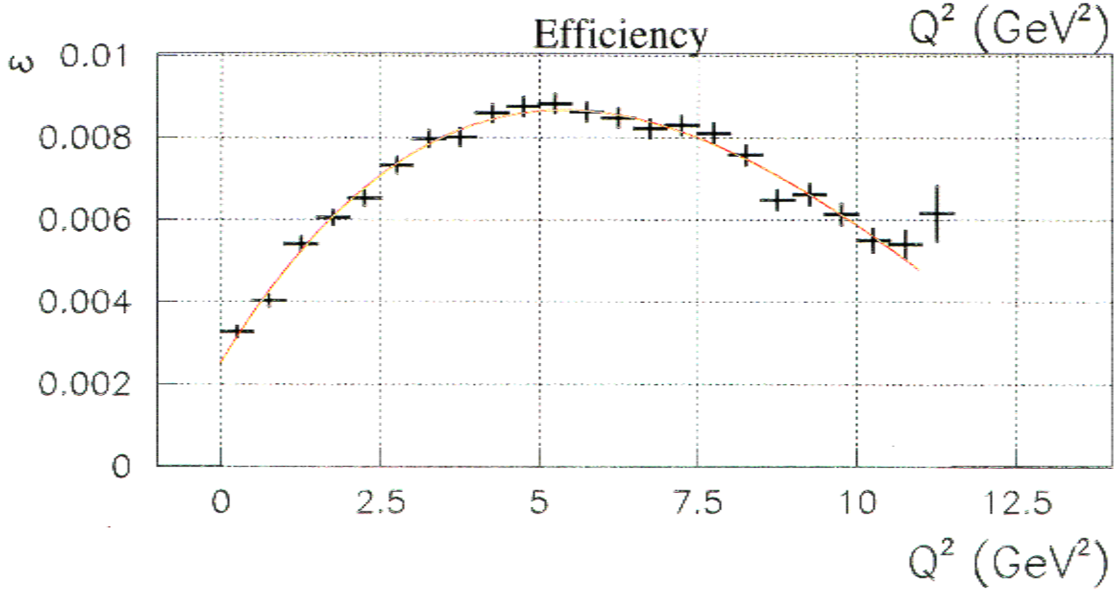
Q^2 Resolution





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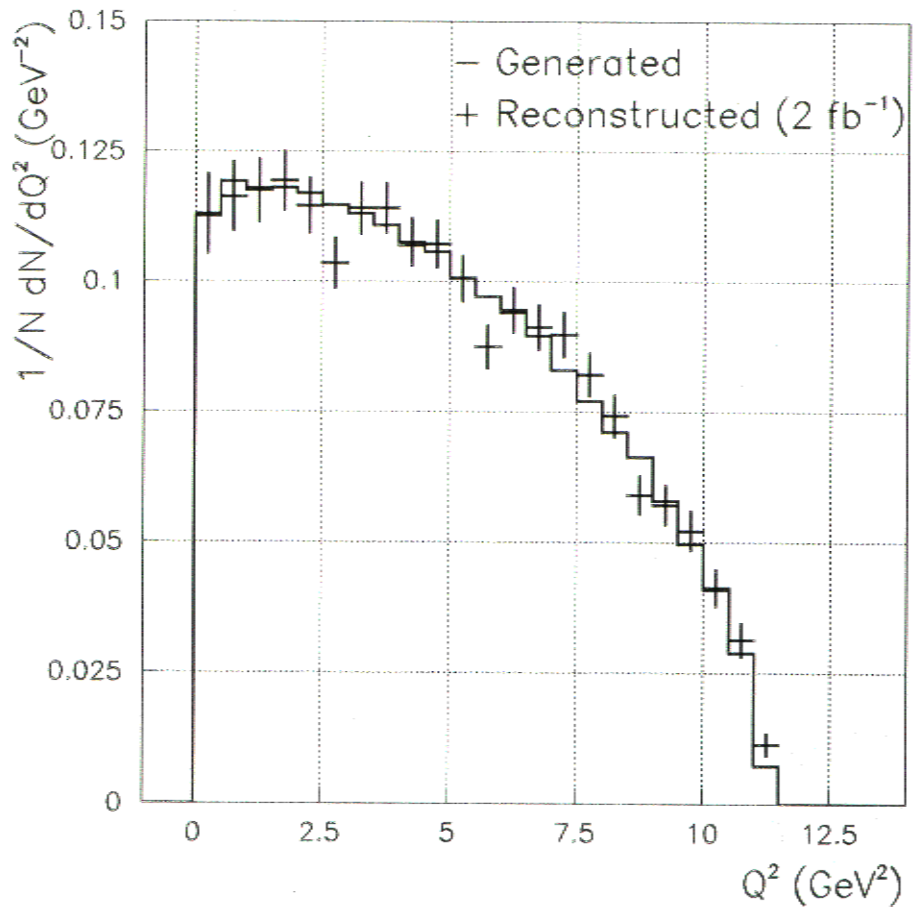
MC Experiment

- Check reconstruction of Q^2.
- 2 independent samples:
  - Generator level Q2 distribution.
  - Reconstructed Q2 distribution normalized to expected Run II yield.



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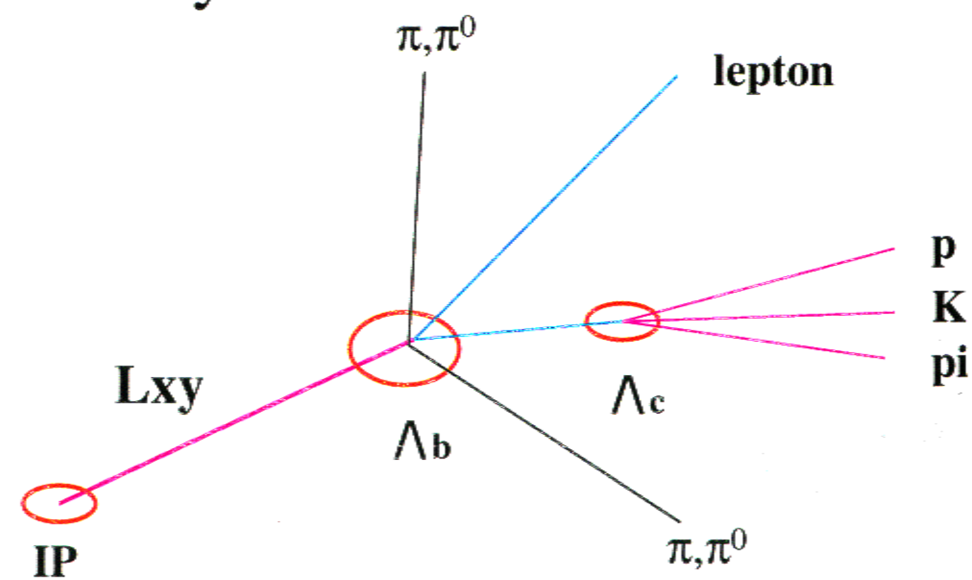
Conclusions

- Lepton + displaced track trigger decreases trigger rate by factor of 2 and increase physics rate by factor of 2 relative to Lepton only trigger.
- Need to study higher order decay contamination:
  - $\Lambda_b \to \Lambda_c^{**} l \nu$,
    - $\Lambda_c^{**} \to \Lambda_c \pi\pi$, $\Lambda_c \to pK\pi$
  - $\Lambda_b \to (\Sigma_c \pi)_{I=0} l \nu$,
    - $\Sigma_c \to \Lambda_c \pi$, $\Lambda_c \to pK\pi$



- BTeV

Smith MC code (✓)

study $B \to D^* \ell \nu$

$B \to D^* \mu X$: expect ~ 6 million events

use 3-D vertex

reconstruct pv

plan for proposal:

study Q^2 resolution, ff's, ...

The WG2 report

- Theory Introduction
  - SM
  - Lattice QCD — AXK
  - NP — Hewett
- Rare Decays
  - $b \to s \mu\mu$ — Bauer
    - $m_{\mu\mu} > m_{\psi'}$
    - inclusive
  - $B \to K, K^* \ell^+\ell^-$ — Burdman, Hiller
    - asymmetry
    - CP̸
  - $b \to s \gamma$ — Hewett
  - $B \to \mu\mu$ — Logan
- SL Decays — Luke
  - $\Lambda_b \to \Lambda_c \ell \nu$
- sub sections from each experiment