Pursuing $b \xrightarrow{V_{ub}} u \ell\nu$ at $\Upsilon(4S)$

The challenge

- large $b \to c\ell\nu$ rate (100 × $u\ell\nu$)
- limited understanding of decay spectra, form factors

Inclusive techniques

- sensitive mainly where $b \to c\ell\nu$ kinematically forbidden

$$E_e \gtrsim \frac{m_B^2 - m_D^2}{2m_B} \sim 2.3 \text{ GeV}$$

$$s_H \lesssim m_D^2 \quad \text{(hadronic mass)}^2$$

$$q^2 = (p_e + p_\nu)^2 \gtrsim (m_B - m_D)^2 \sim 12 \text{ GeV}^2$$

- quark/hadon duality ?
  - studies in various limits/models ⇒ cautious optimism
  - can't rule out > 5% affects

Exclusive measurements: $B \to \pi\ell\nu$, $\rho\ell\nu$, $\eta\ell\nu$ ...

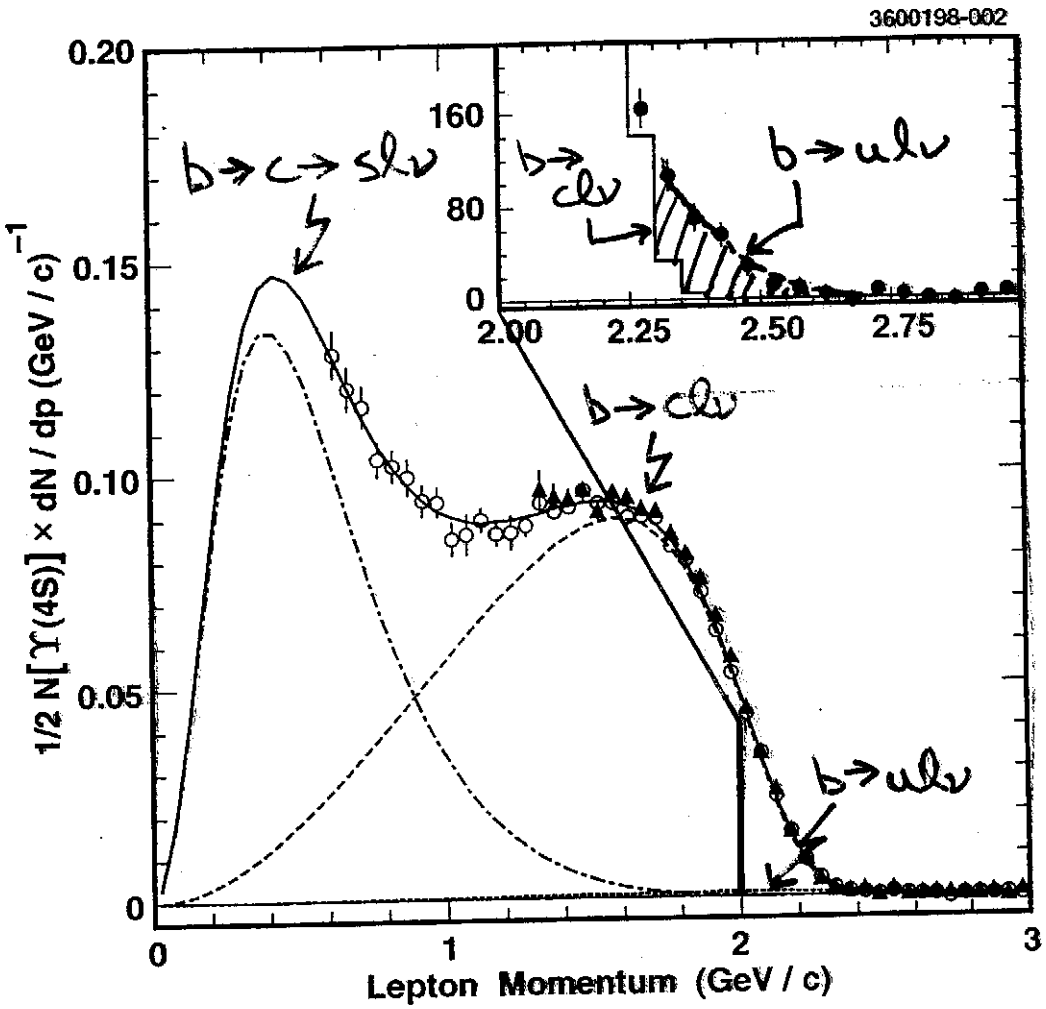
- need hadronic form factors to extract $|V_{ub}|$

Current status: CLEO, LEP → $|V_{ub}| \sim 0.003$, $\sigma \sim 20\%$

... following (crude) estimates: extrapolate CLEO studies → 75 fb^{-1}

Neubert: PRD49, 3392, '94
Bigi et al: Int. J. Mod. Phys. A9 2467, '94
Leibovich et al: hep-ph/9909404

Lepton spectrum studies



direct $|V_{ub}|$ extraction:

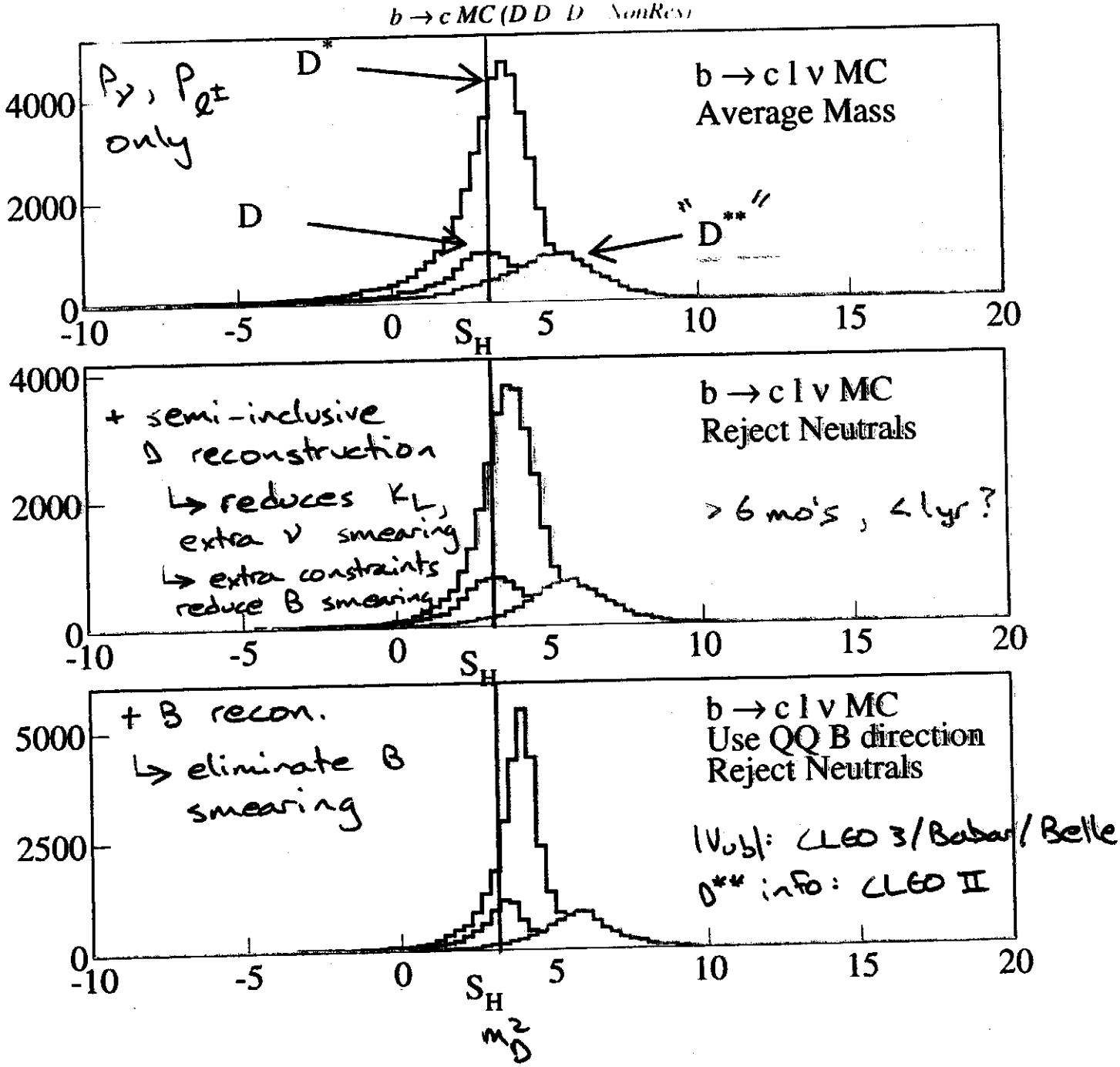
- "Fermi motion" of b quark → theory $\pi \sim$ 20-30%
  can be rolled into (unknown) structure fcn., universal for b→ massless partons

⇒ $\left|\frac{V_{ub}}{V_{ts}V_{tb}^*}\right|^2$ by combo' of { E_ℓ endpoint spectrum : $B\to X_u\ell\nu$; γ spectrum : $B\to X_s\gamma$

expect { 20K ℓ's ; 2300 γ's } reconstructed, $b\to s\gamma$ rate ∧ systematics 12%

⇒ $|V_{ub}|$ to ~6% (exp) + 5-10% (th) + DUALITY

$D \to c l \nu$ smearing in S_H



Other inclusive + exclusive techniques

rely on info from entire $e^+e^- \to \Upsilon(4S) \to B\bar{B}$ event

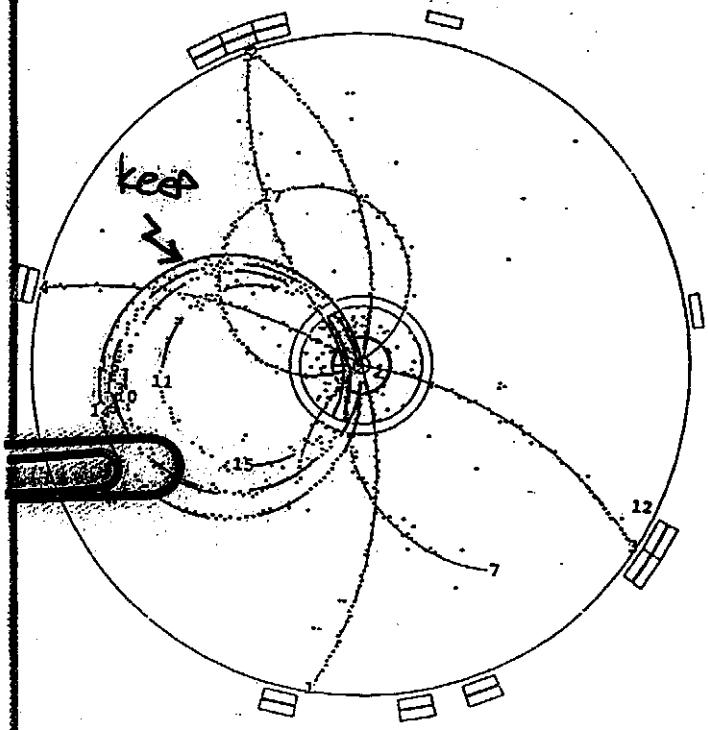
- exclusive: $(E_{miss}, \vec{p}_{miss}) \to p_\nu$
  - extra kinematic constraints of full B recon (E, $\vec{p}$ conservation) → needed $b \to c\ell\nu$ suppression

- inclusive: p_ν (from p_{miss}) + $p_{\ell^\pm}$
  - calculate $-q^2$, estimate S_H

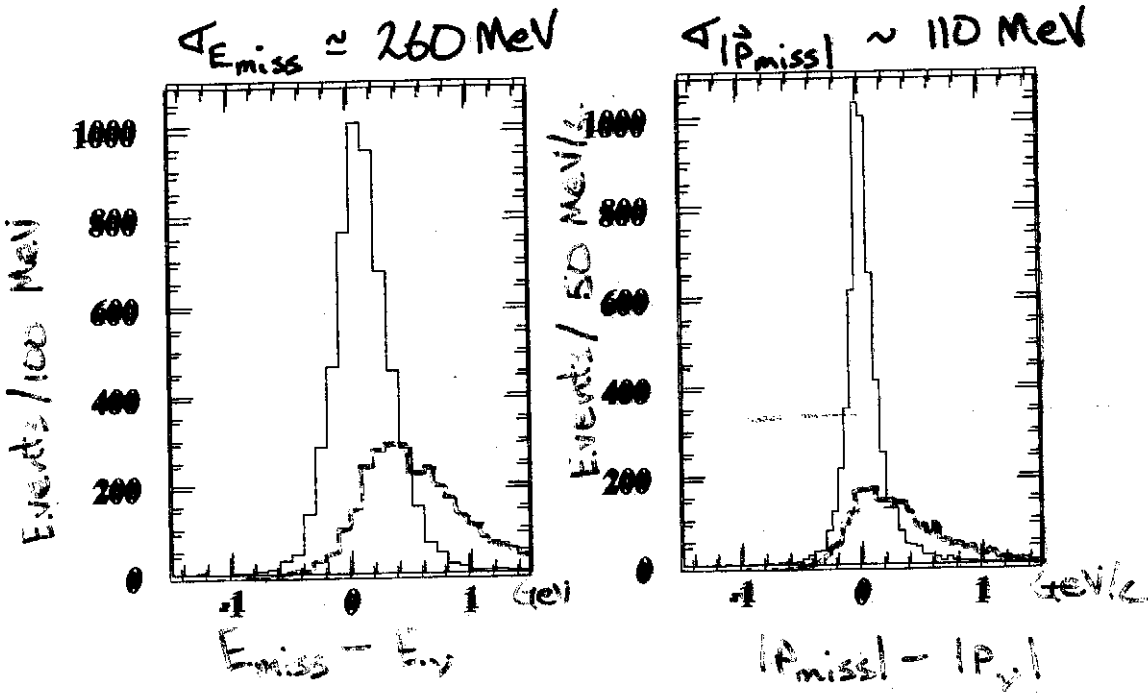
  + reconstruct one D (from other B)
    - improve S_H est., reduce $b \to c\ell\nu$ smearing

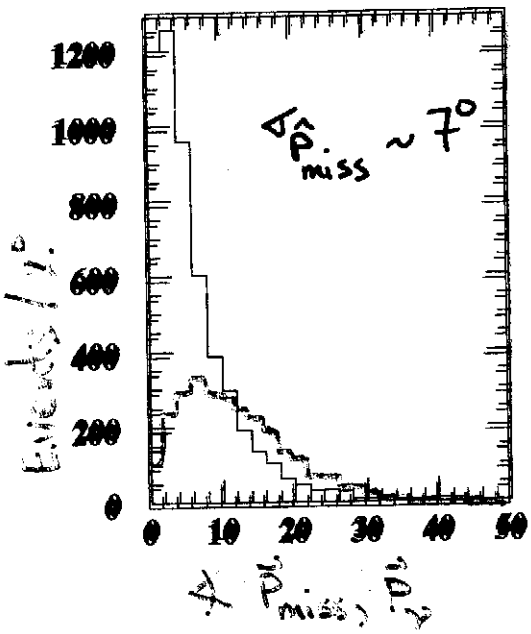
  + reconstruct other B
    - calculate S_H, further reduce smearing

Event cleanliness is key.



- Want only real B daughter tracks, showers for E_{miss}, $\vec{p}_{miss}$
- Main background source: $b \to c\ell\nu$
  - ↳ undetected neutrals ($c \to s\ell\nu$)





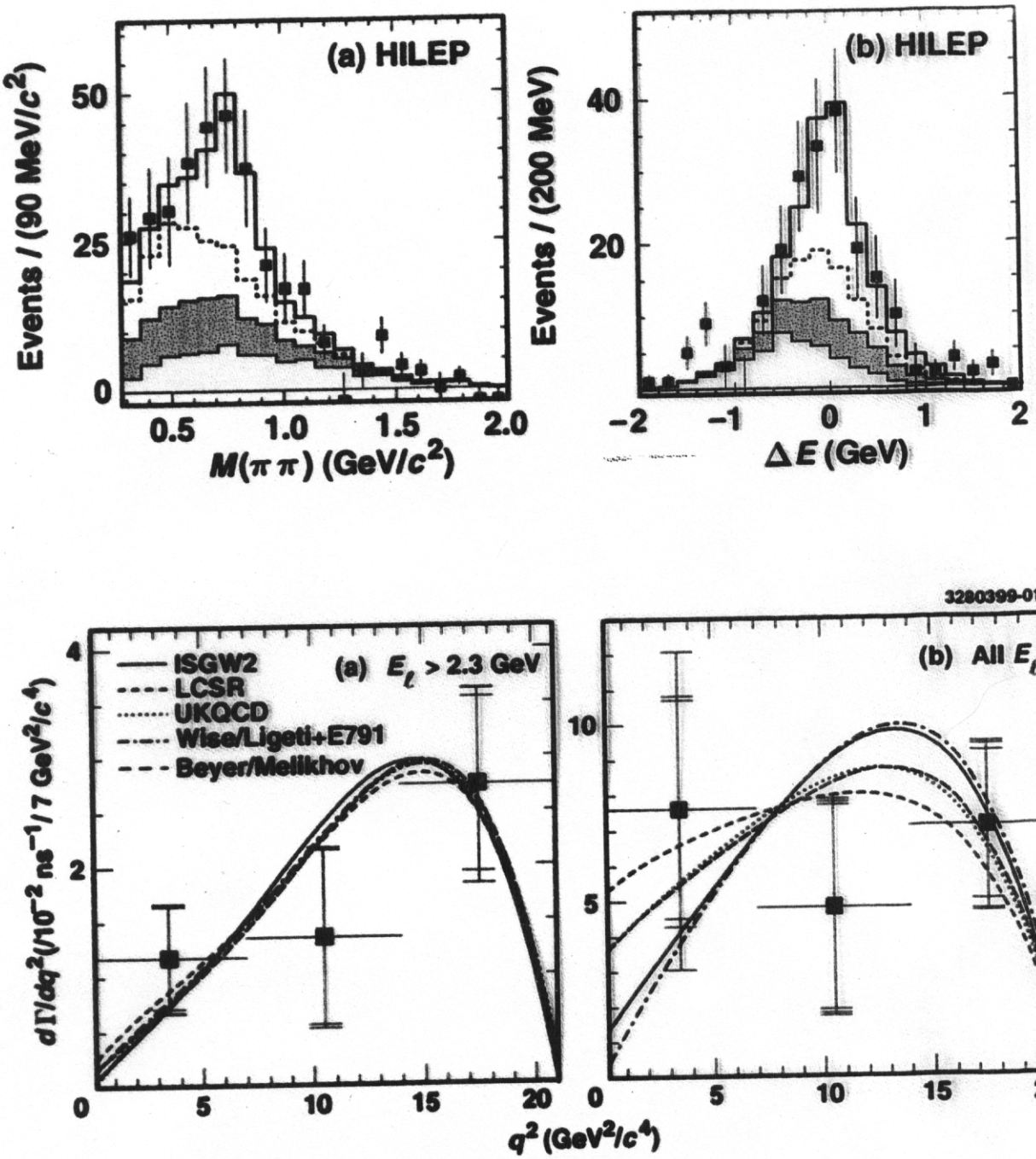
$B \to \pi \ell \nu$ M.C.

(similar for other $b \to u \ell \nu$ modes)

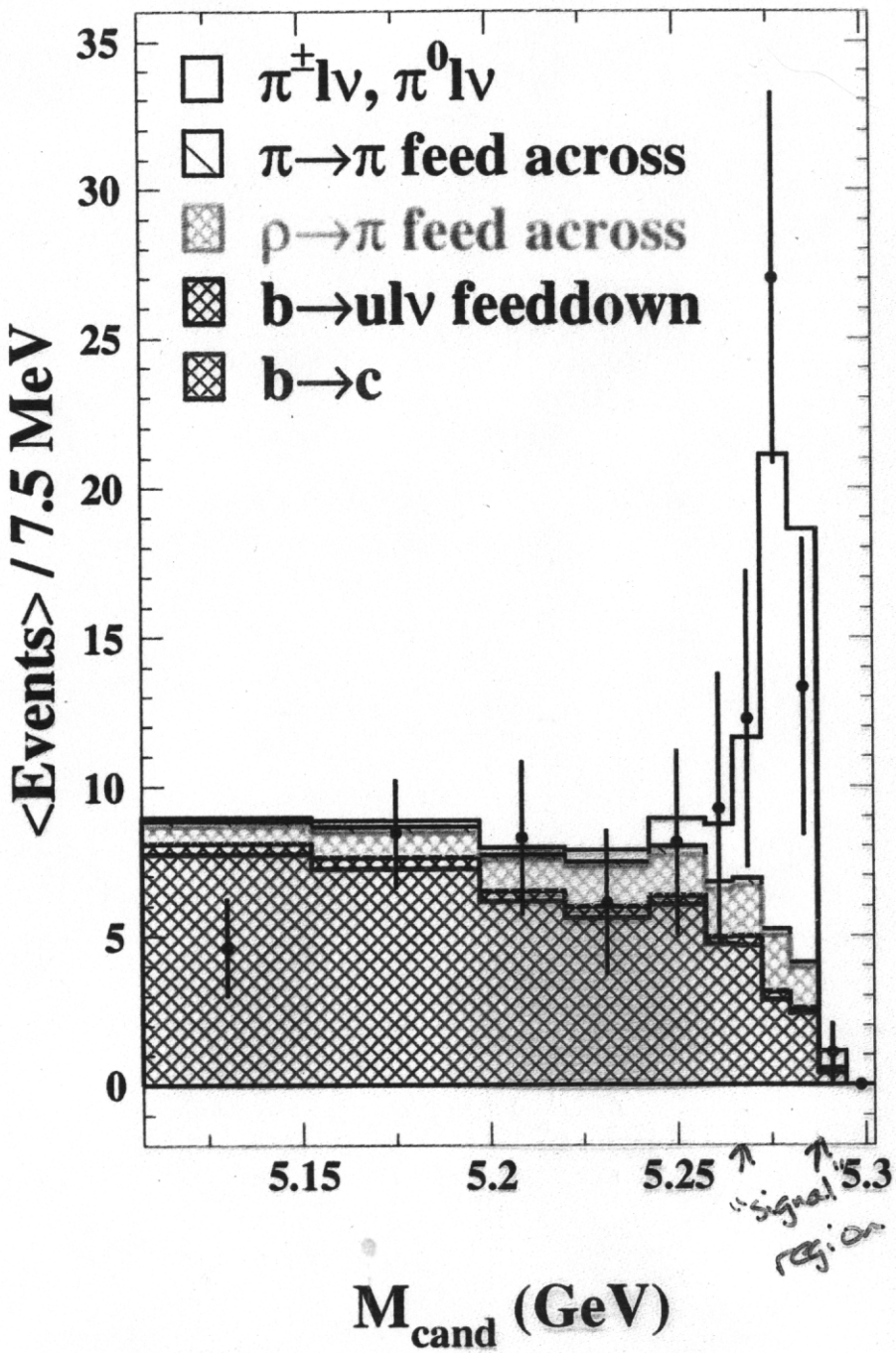
K_L, ν_{extra} present

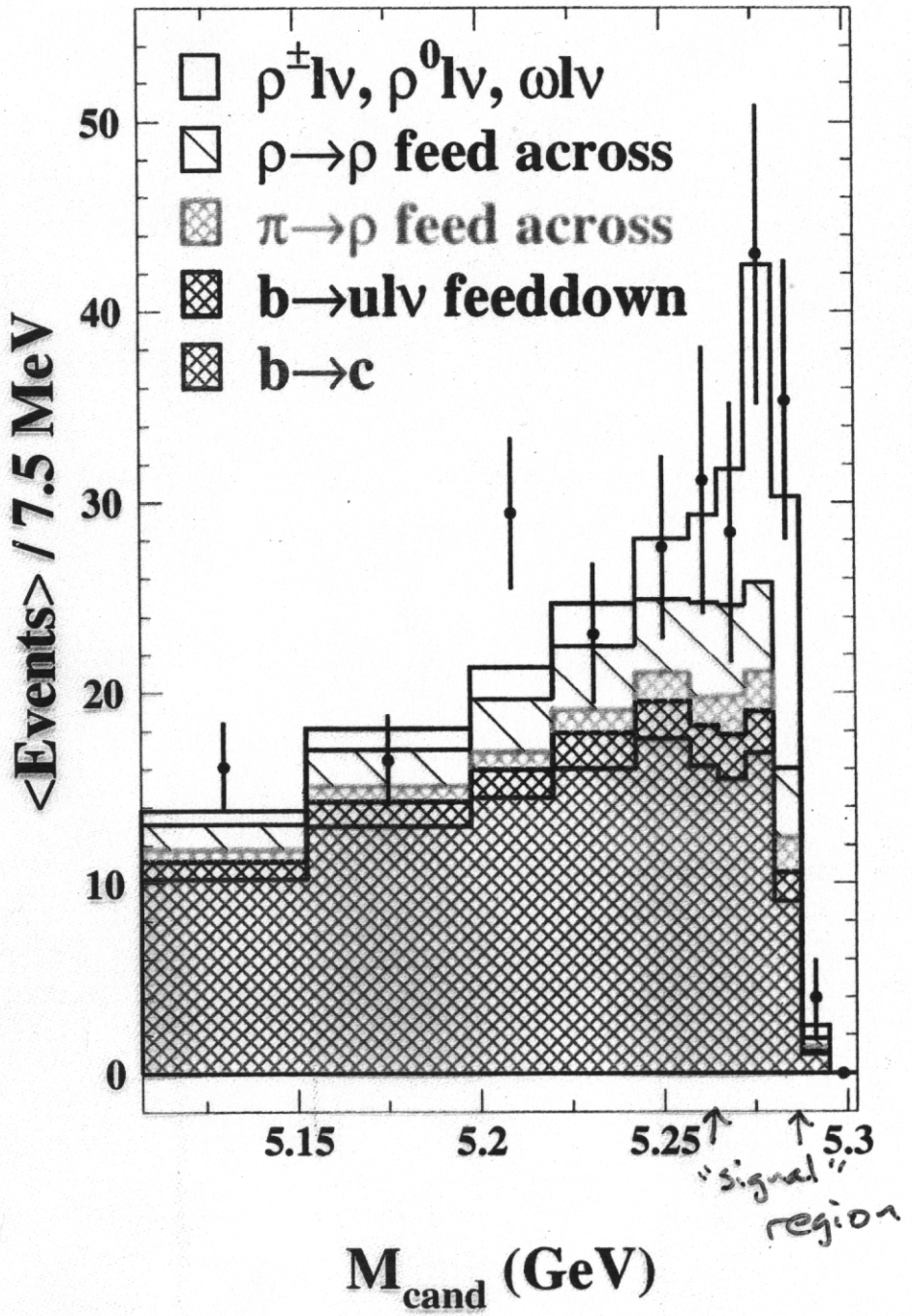
q^2 resolution ~ 1 GeV^2

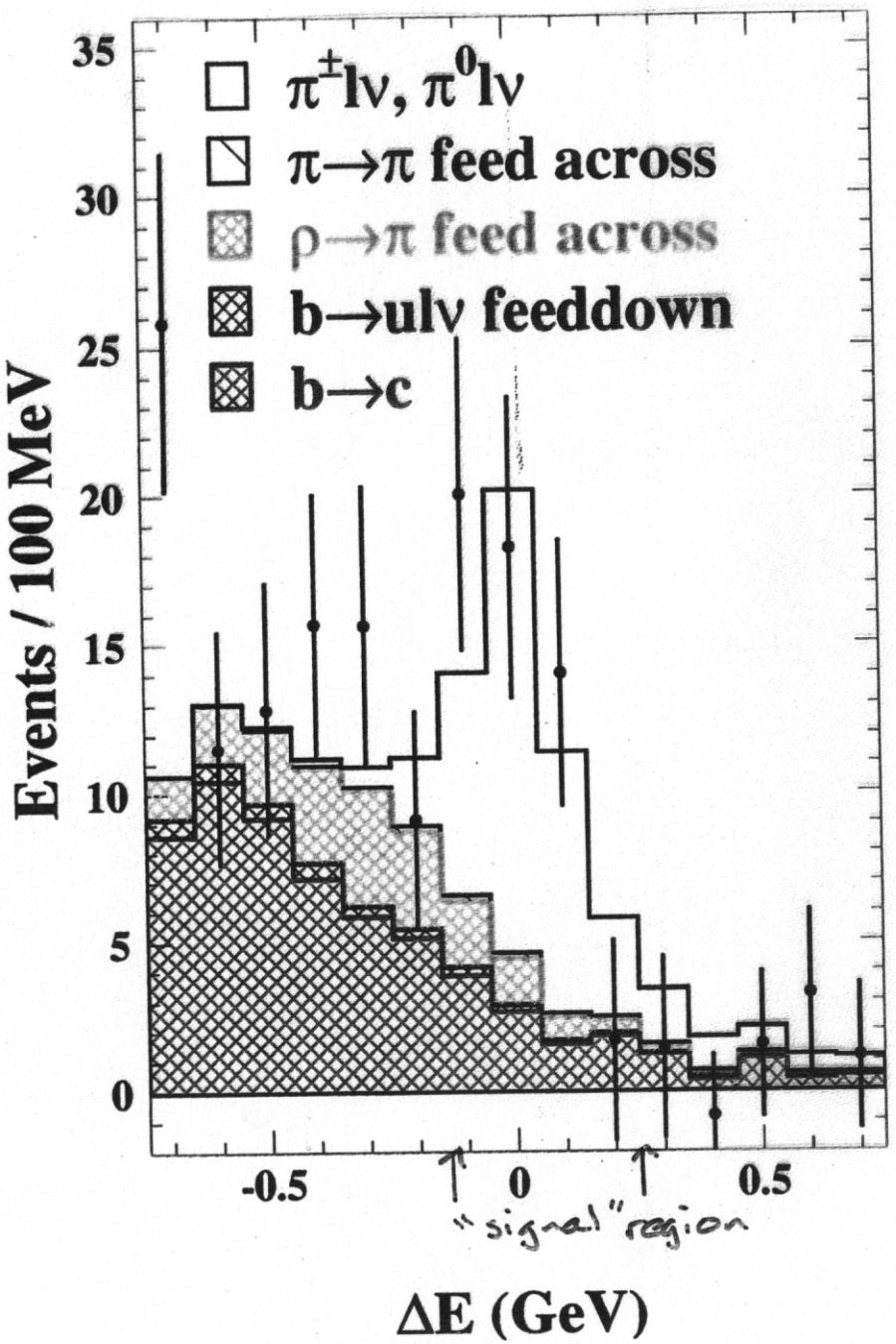
q^2 tails - expect sizeable

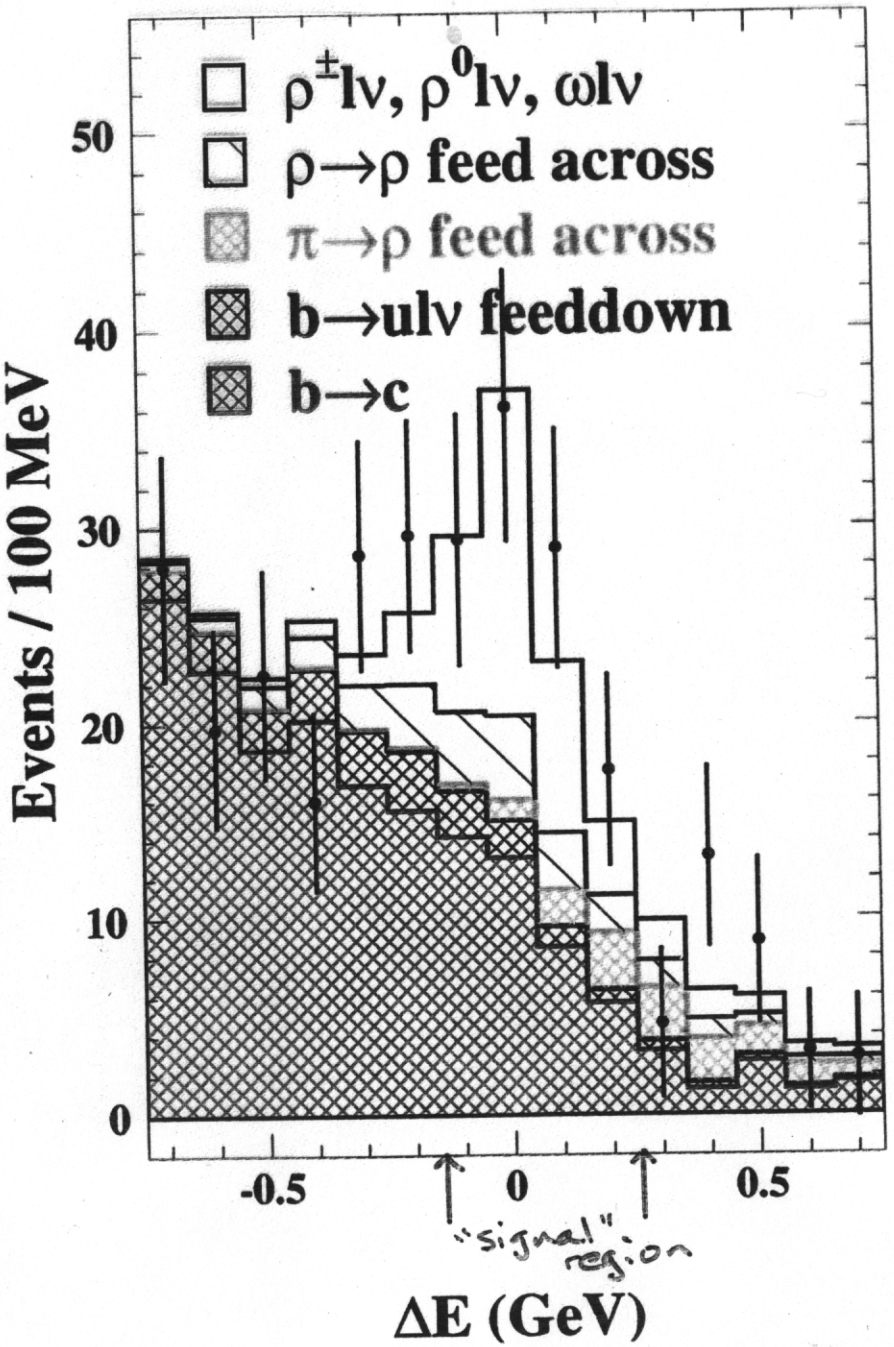


- Clear ρ signal
- 1st q^2 measurement ($E_e > 2.3$ GeV)
  - can't discriminate "models" yet

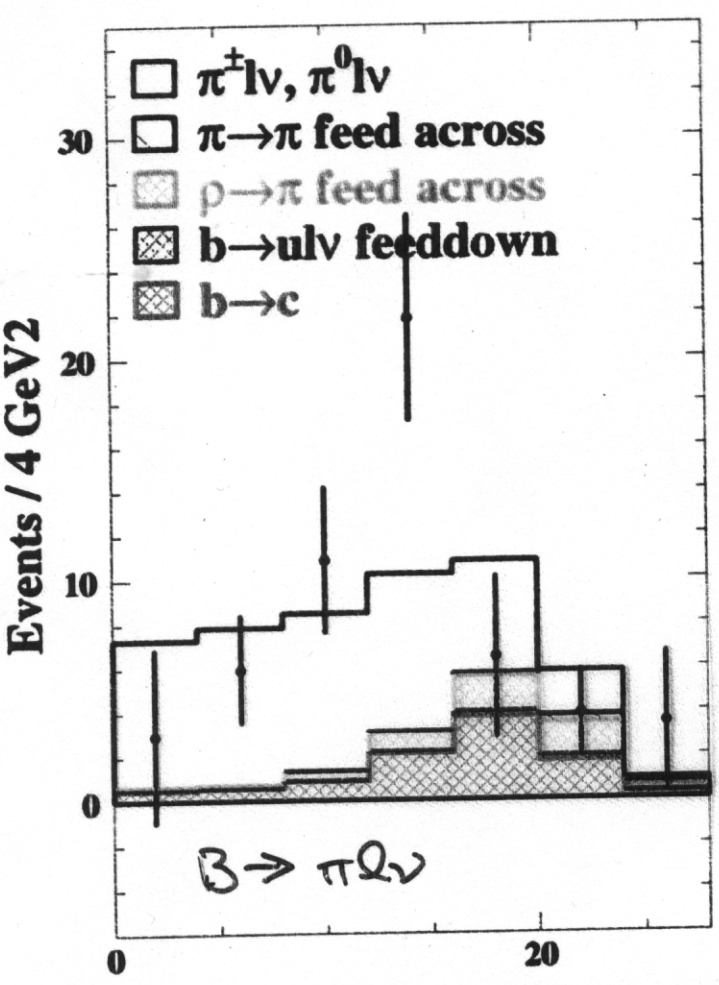

$\pi^{\pm}l\nu$, $\pi^0 l\nu$
$\pi\to\pi$ feed across
$\rho\to\pi$ feed across
$b\to u l\nu$ feeddown
$b\to c$
<Events> / 7.5 MeV
0
5
10
15
20
25
30
35
5.15
5.2
5.25
5.3
"signal" region
M_{cand} (GeV)

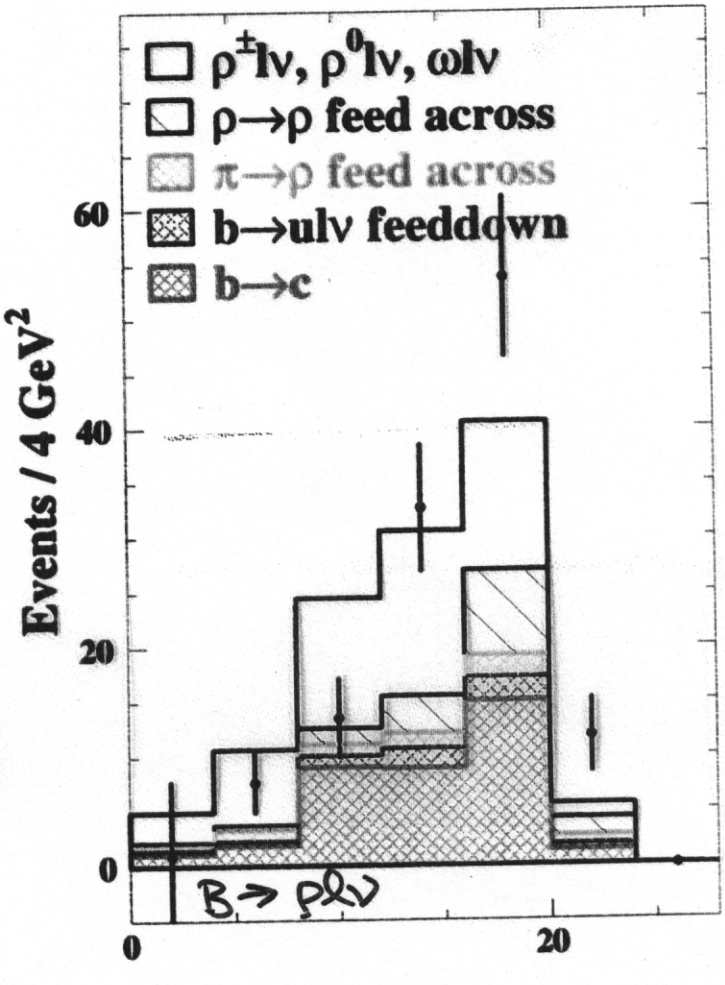

$\rho^{\pm}l\nu$, $\rho^0 l\nu$, $\omega l\nu$
$\rho\to\rho$ feed across
$\pi\to\rho$ feed across
$b\to u l\nu$ feeddown
$b\to c$
<Events> / 7.5 MeV
0
10
20
30
40
50
5.15
5.2
5.25
5.3
"signal" region
M_{cand} (GeV)


$\pi^{\pm}l\nu$, $\pi^0 l\nu$
$\pi \to \pi$ feed across
$\rho \to \pi$ feed across
$b \to ul\nu$ feeddown
$b \to c$
Events / 100 MeV
35
30
25
20
15
10
5
0
-0.5
0
0.5
"signal" region
ΔE (GeV)


$\rho^{\pm}l\nu$, $\rho^0 l\nu$, $\omega l\nu$
$\rho \to \rho$ feed across
$\pi \to \rho$ feed across
$b \to ul\nu$ feeddown
$b \to c$
Events / 100 MeV
50
40
30
20
10
0
-0.5
0
0.5
"signal" region
ΔE (GeV)

as of 1996:





Exclusive prospect's: branching fractions 4% stat ~8% sys

$|V_{ub}|$ from light cone sum rules: $0 - 15\ \mathrm{GeV}^2$

$\sigma_{theory} > 10\%$ (duality)

*** unquenched lattice calc's at high q^2 (low p_π)

$\sigma_{lattice} < 10\%$, 300-400 $\pi l\nu$ evt's $\Rightarrow \frac{8\% \oplus 8\%}{2}$

$\sigma_{exp} \sim 6\%$

Heavy Quark Symmetry: $B \to \rho l\nu$ vs $D \to \rho l\nu$ / $D \to K^* l\nu$

$\mathcal{O}(15\%)$ uncertainties

Inclusive approaches using s_H, q^2

$s_H < m_D^2$: in principle, affected by Fermi motion structure fcn.
- uncertainties appear controllable at 10-15% level (eg. Bigi et al)

*** $q^2 > (m_B - m_D)^2$: not affected by S.F. (Bauer et al; hep-ph/0002161)
- uncertainties < 10%

s_H prospects

← ½% of $\Upsilon(4S)$ events

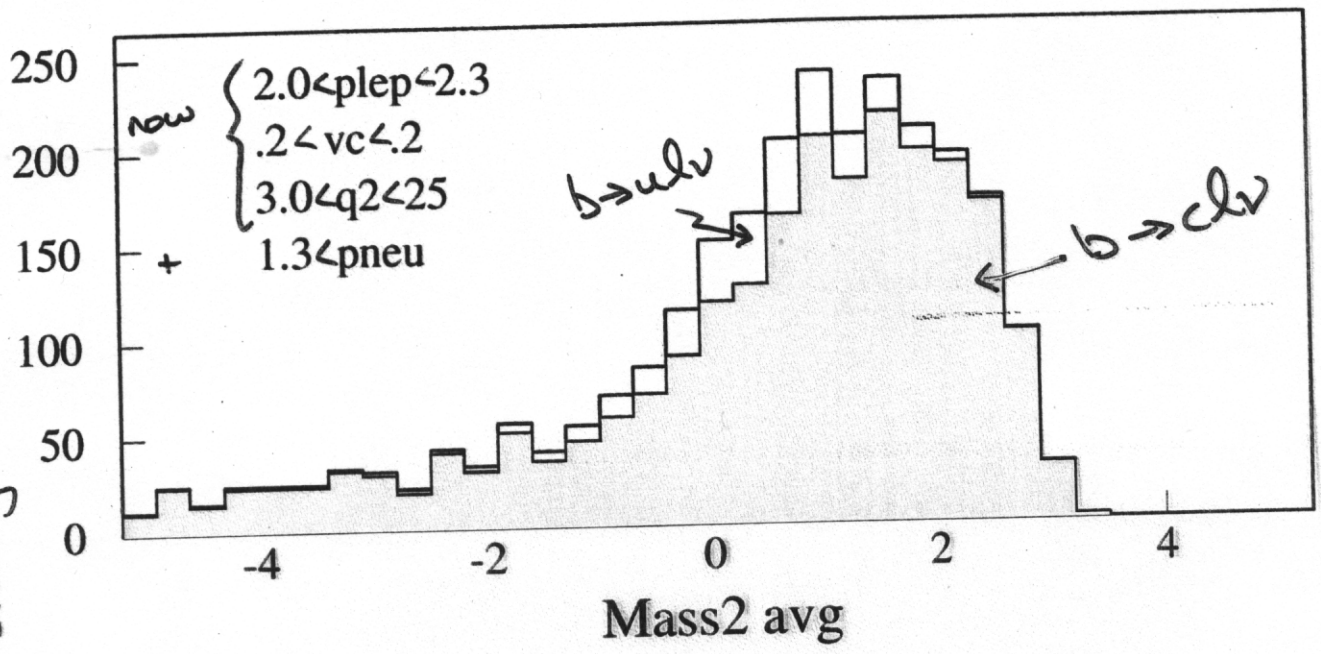
- fully reconstruct other B, calc. s_H
  - 400-600 $b \to u l \nu$ after s_H cuts } 5% on $|V_{ub}|$
  - 1:1 signal : bkg

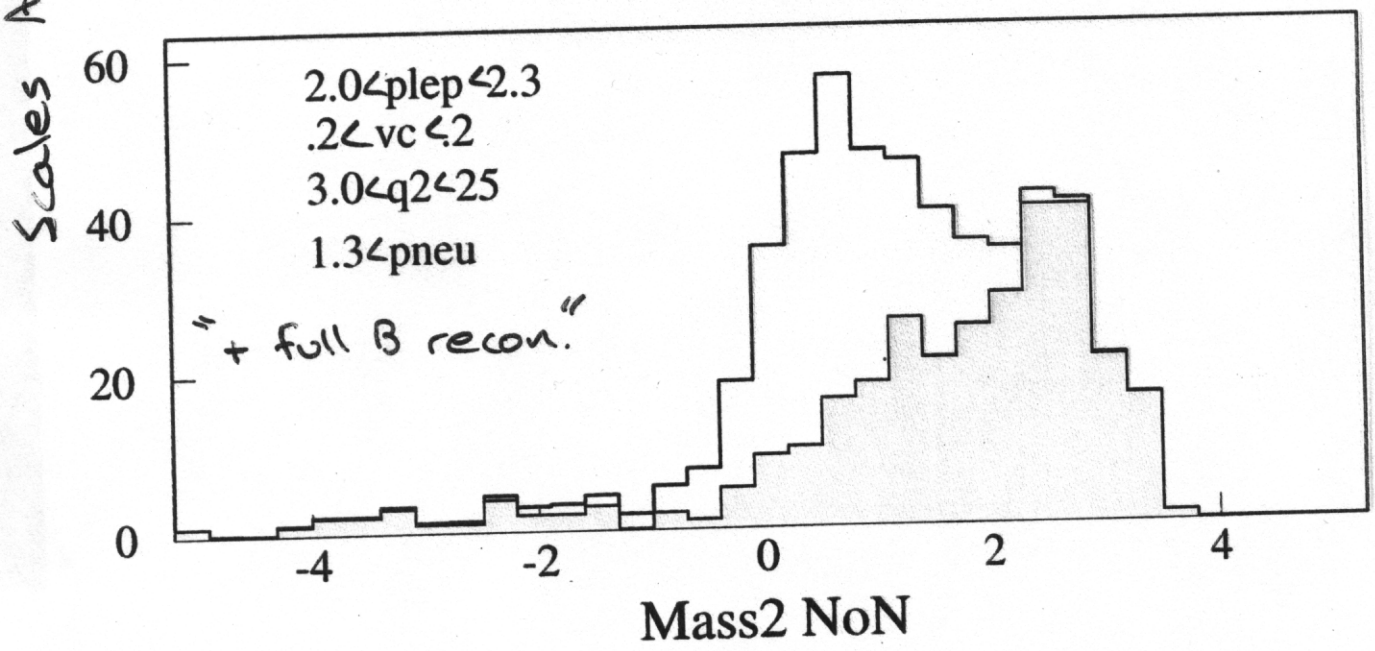
- estimate s_H w/ P_ν, $P_{l^\pm}$, $|\vec{P}_B|$ + D from "other B"
  - ~ 6K (?) evt's } < 5% on $|V_{ub}|$ (stat)
  - 1:3 signal : bkg (?)
  - systematics similar to exclusive : 8% (?)

q^2 prospects

- calc. q^2 from P_ν, $P_{l^\pm}$ + D recon. to reduce B smearing
  - ~ 1200 (?) evt's } < 5% on $|V_{ub}|$
  - 1:2 signal : bkg (?)
  - systematics : ditto

S_H studies below endpoint region





S_H

Summary

- a variety of techniques to extract $|V_{ub}|$ w/ uncertainties 10 - 15% or less at $\Upsilon(4S)$

- complementary systematics:
  we'll want them all to verify we really know $|V_{ub}|$ at 10% level!