The TAO of the τ with CLEO II

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· 1 of 6 !c

The TAO of the τ with CLEO-II

In a perfect world, this talk would be a complete review of present results and projections for:

1. Particle properties in the tauonic sector
   (a) Measurements of the τ mass (1777.8 ± 0.7 ± 1.7 MeV - CLEO92)
   (b) Limits on the τ neutrino mass (CLEO/ARGUS: < 31 MeV)
   (c) Measurements of the τ lifetime (CLEO94): (2.91 ± 0.03 ± 0.07) × 10^{-13} sec.
   (1 vs. 1/IP: (2.94 ± 0.07 ± 0.12) 10^{-13} 3 vs. 3 vtx: (2.91 ± 0.04 ± 0.07) (2.85 ± 0.13 ± 0.10)
2. Leptonic Decays
   (a) precision tests of Standard Model - $e\mu$ universality $\left\{\frac{\tau \to e\nu\bar{\nu}}{\tau \to \mu\nu\bar{\nu}}\right)$
   (b) tests of Lorentz structure: $V - A$ and weak current parameters:
      i. Michel parameter ρ from dN/dx
      ii. Low energy parameter η
      iii. Polarization parameter ξ'
      iv. Decay asymmetry parameters ξ and δ

CLEO94: use $\tau^- \to \pi^- \nu_\tau$ vs. $\tau^+ \to \pi^+ \bar{\nu}_\tau$

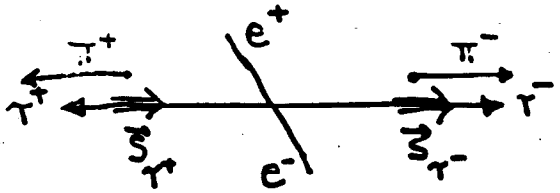
$\Rightarrow \xi_\pi = h_\nu$: Find $h_\nu = -0.99 \pm 0.06 \pm 0.10$

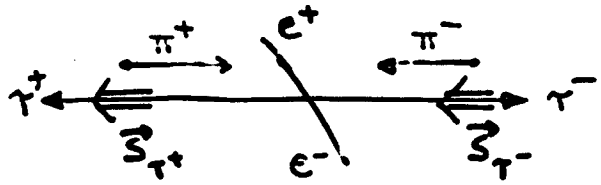
(ν helicity) (V-A expects 1.0)

Jun Masui

π-V-π Energy-energy correlations

$\boxed{\text{V-A}}$





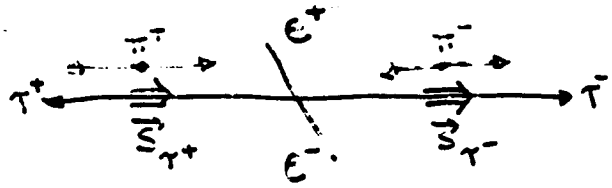
$\pi^\pm$ has preferred direction: $\frac{d\Gamma}{d\Omega_{\pi^-}} \propto 1 + \hat{p}_{\pi^-} \cdot \vec{S}_{\tau^-}$

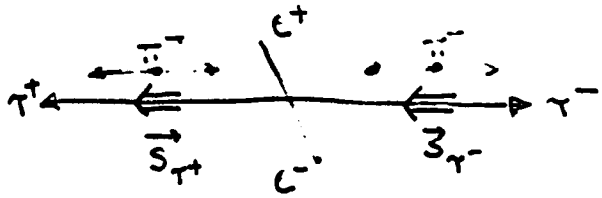
$\frac{d\Gamma}{d\Omega_{\pi^+}} \propto 1 - \hat{p}_{\pi^+} \cdot \vec{S}_{\tau^+}$

High-Low and Low-High combinations are suppressed.

Similiar argument, same result for V+A

$\boxed{\text{V, or A}}$





$\pi^\pm$ is isotropic: $\frac{d\Gamma}{d\Omega_{\pi^\pm}} \propto 1$.

All four combinations allowed: H-H, L-L, H-L, L-H

Tau data	1322 events $\mathcal{L} = 1.1\ fb^{-1}$		
Tau MC	577	π-π	88%
	58	π-μ	10%
	16	π-ρ	2%
Mumug MC	2 pass, 99700 start.		$\epsilon = 2\times10^{-5}$ $\sigma = 0.91$ nb
	$\epsilon\sigma\mathcal{L} = 20$ evnts.		
$\gamma\gamma \to \pi^+\pi^-$ MC	9 pass, $\mathcal{L}^{MC} = 23\ fb^{-1}$		
	$9 \times \frac{1.1}{23} = 0.4$ evnts.		
$\gamma\gamma \to \mu^+\mu^-$ MC	0 pass, $\mathcal{L}^{MC} = 170\ pb^{-1}$		

Bottom line

π-π	~ 85%
π-μ	~ 10%
π-ρ	few %
non-tau	few %

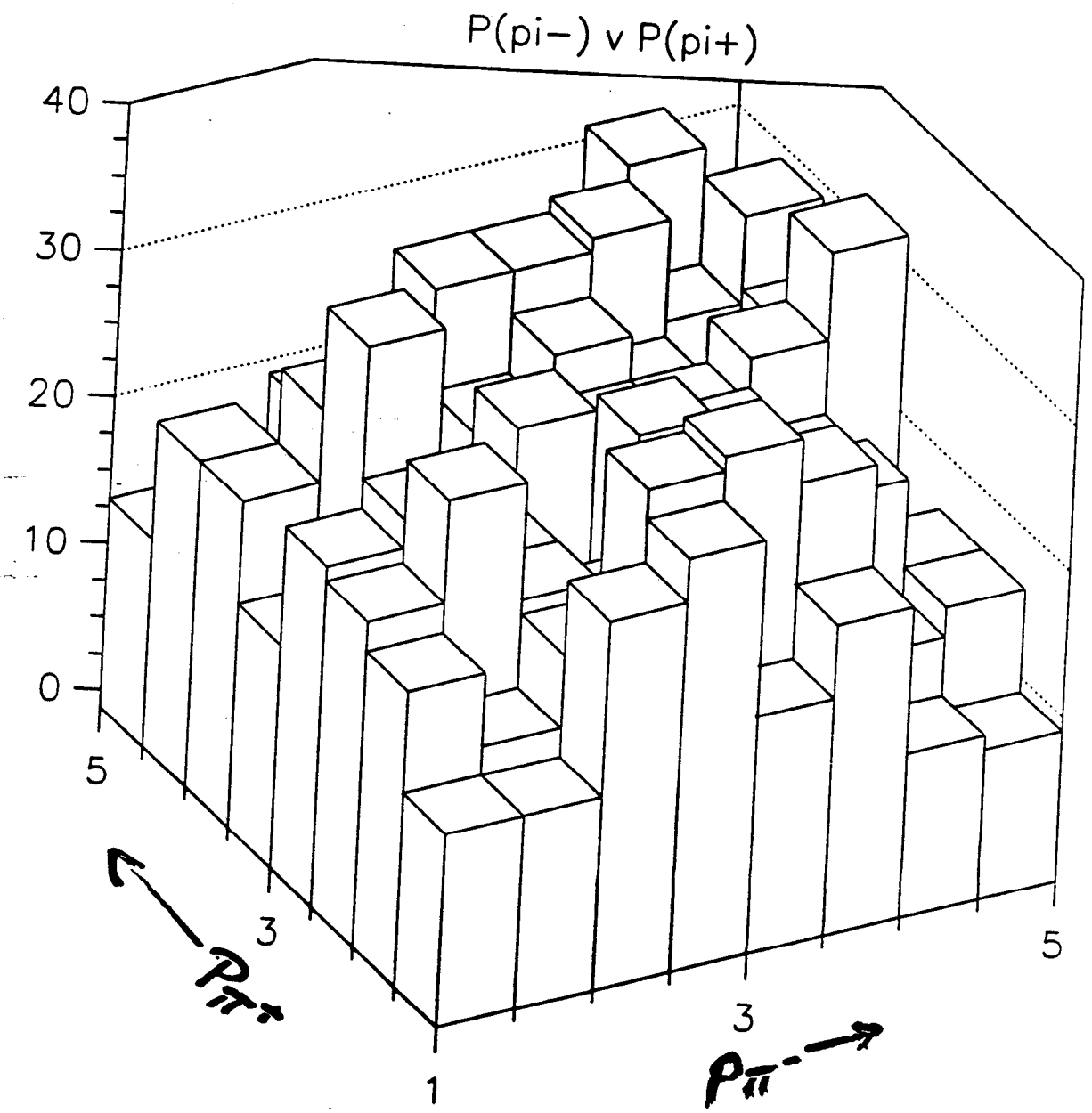
$|\sigma \cdot p| \equiv 1$ for χ_τ // Measure $(g_A g_V)^2 = \xi^2$

$\tau \to 3\pi$ gives sign of helicity

File: /amd/Ins276/cdat/mtm/masui/data.hbook

ID	IDB	Symb	Date/Time	Area	Mean	R.M.S.
5	0		930201/1800	1322.	3.012	1.095
					3.051	1.096

ϑ 30°, φ 30°



The ν_τ

- the ν_τ has yet to be directly observed!

- its existence is inferred from the energy spectrum of observed charged leptons or hadrons in decay products of τ

- it is distinct from ν_e, ν_μ:

- ν_e, ν_μ beams are not observed to interact via charged current $\nu_l N \rightarrow \tau^- X$ in Fermilab E531

- $\Gamma(Z^0 \rightarrow \text{unobserved})/\Gamma(Z^0 \rightarrow \nu\nu) = 3.00 \pm 0.05$

3. Semi-hadronic decays

   (a) spectral functions - strange and non-strange (Evidence for $\tau^- \to \rho^- \nu_\tau$, e.g.)
   $3h^- = (9.82 \pm 0.09 \pm 0.34)\%$; $3h^-(\pi^0) = (4.25 \pm 0.09 \pm 0.26)\%$

   (b) tests of QCD - extraction of α_s ($\alpha_s(M_Z) = 0.119 \pm 0.003 \pm$)

   (c) strange resonance dynamics - production mechanism for KKX final states

      i. Understanding K_1 states (connection to HQET)

      ii. KKπ from K^*K or $\rho\pi$; $\rho \to K\bar{K}$? Decker et al.: $\tau \to K^*K$.

   (d) Comparison with predictions of CVC

4. Rare/forbidden decays

   (a) lepton family number violation, neutrino mixing

   (b) Second-class currents, etc., physics beyond the Standard Model! $\tau^- \not\to \eta\pi\nu_\tau$

5. Nostradamus comes to CLEO - looking into the future, brightly

   (a) Detector design of CLEO-III - τ physics into the next millenium

   (b) What are the limiting systematics of doing tau measurements?

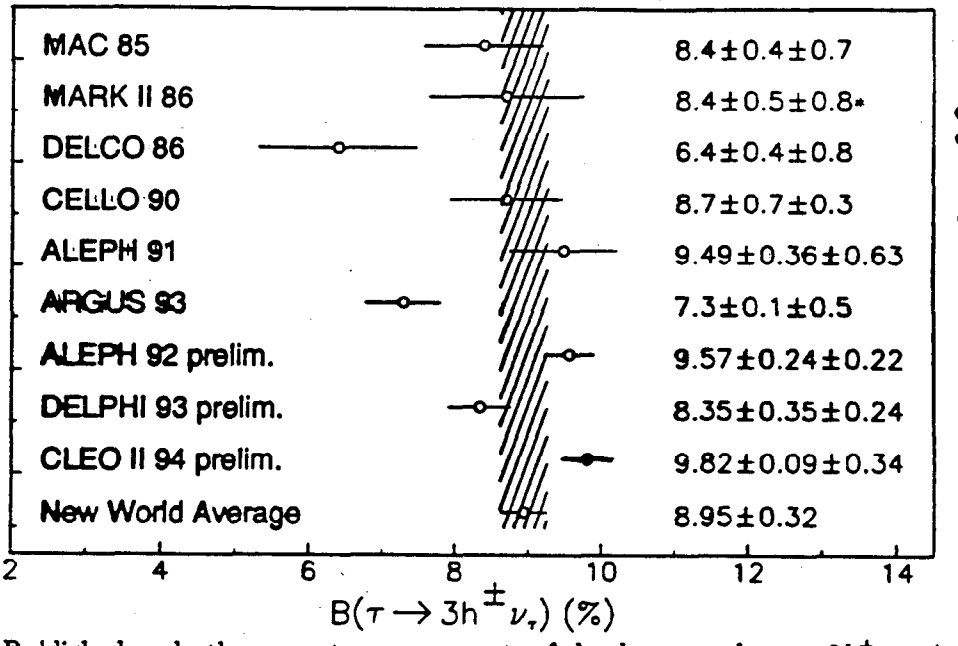


FIG. 7. Published and other recent measurements of the decay mode $\tau \to 3h^{\pm}\nu_{\tau}$. A correction has been applied to the Mark II result [20].

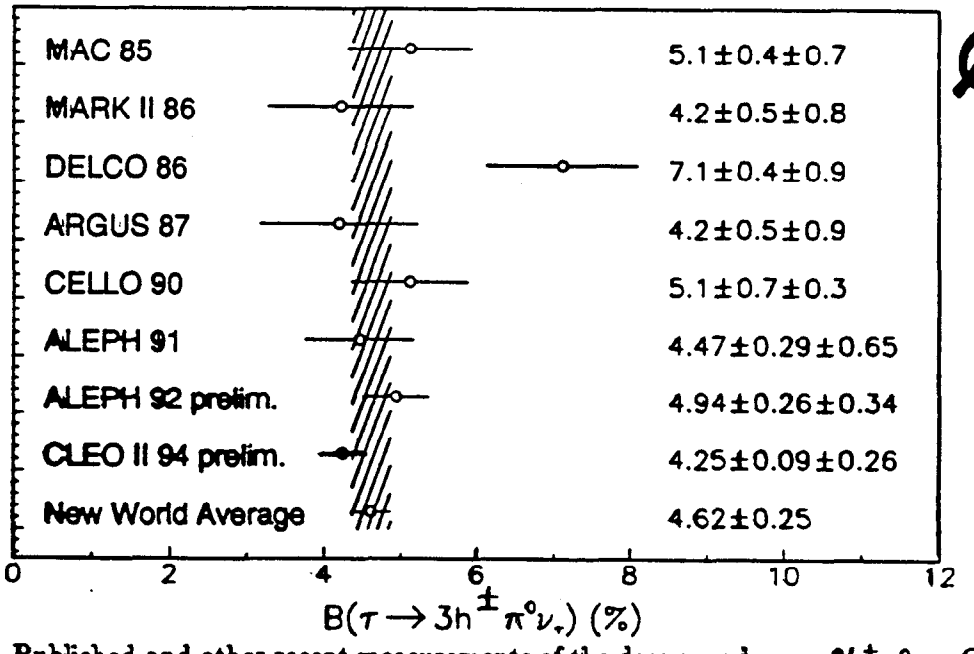


FIG. 8. Published and other recent measurements of the decay mode $\tau \to 3h^{\pm}\pi^{\circ}\nu_{\tau}$. Correction (see text) have been applied to all but the ARGUS and CLEO results.

$\mathcal{B}_3^{CLEO} = 0.1455 \pm 0.0013 \pm 0.0059$

- Another important lepton family number violating decay: $\tau \to \ell\ell\ell$, where the final leptons are either $e^{\pm}$ or $\mu^{\pm}$

- decays like $\tau^- \to \mu^- e^+ e^-$ are FCNC at one vertex; decays like $\tau^- \to \mu^+ e^- e^-$ are FCNC at two vertices!

- SINDRUM 1985: $\mathcal{B}(\mu \to eee) < 2.4 \times 10^{-12}$

- once again, mass-dependent couplings give interesting range for tau decays: $\mathcal{B}(\tau \to \ell\ell\ell) \lesssim 3 \times 10^{-6}$
  - ARGUS 1991: $\mathcal{B}(\tau \to \ell\ell\ell) < (15 - 20) \times 10^{-6}$
  - CLEO II 1993: $\mathcal{B}(\tau \to \ell\ell\ell) < (3 - 8) \times 10^{-6}$
  depending on mode, using 2M $\tau^+\tau^-$ events

Exclusive semi-hadronic decays: $\tau \to \pi X$ and CVC

- $\tau^{\pm} \to \nu_{\tau} h^{\pm} \pi^{0}$ is the largest τ decay mode (most expts can't distinguish $\pi^{\pm}$ from $K^{\pm} \Rightarrow h^{\pm}$)
  $\to$ Normalize $\tau \to \nu_\tau h^\pm n(\pi^0)$, $n \geq 2$ to $n=1$

- proceeds via the weak charged vector current: $W^{\pm} \to \pi^{\pm}\pi^{0}$

- EW unification: vector part of weak charged current is related to neutral EM current via isospin rotation: CVC

  - CVC relates $\Gamma(\tau^{\pm} \to \nu_{\tau}\pi^{\pm}\pi^{0})$ to $\sigma(e^{+}e^{-} \to \pi^{+}\pi^{-})$ radiative corrections have been calculated

- procedure:

  1. extract *isovector* part of $\sigma(e^+e^- \to \pi^+\pi^-)$ up to $s = m_\tau^2$

  2. fit to pion form-factor $F_\pi^{I=1}(q^2)$; compare with $F_\pi^{I=1}(q^2)$ extracted from $\tau \to \nu_\tau W$ *charged* current

- total $\mathcal{B}(\nu_\tau \pi^\pm \pi^0) \propto \int dq^2 F_\pi^{I=1}(q^2)$

- Standard Model predicts: $\mathcal{B}(\pi^\pm\pi^0\nu_\tau)^{\mathrm{SM}} = (24.58 \pm 0.93 \pm 0.50)$ (1st error: $e^+e^- \to \pi^+\pi^-$ data; 2nd: 2% uncertainty in rad-corr)

$\longrightarrow$ CLEO 99: $\mathcal{B}(h^\pm\pi^0) = (25.87 \pm 0.12 \pm 0.42)\%$ •
1-prong implications

- Results after subtracting off $K^* \to K^\pm\pi^0$:
  (World Average) in agreement with CVC (4% precision)

Aside: $\tau^- \to \bar{K}^0 K^+ \nu_\tau = (0.123 \pm 0.023 \pm 0.023)\%$
ALSO agrees w/ CVC-based pred.

- $m(\pi^\pm\pi^0)$ spectrum from τ decays agrees well with e^+e^- prediction; good evidence for $\rho'(1370)$

FIGURES

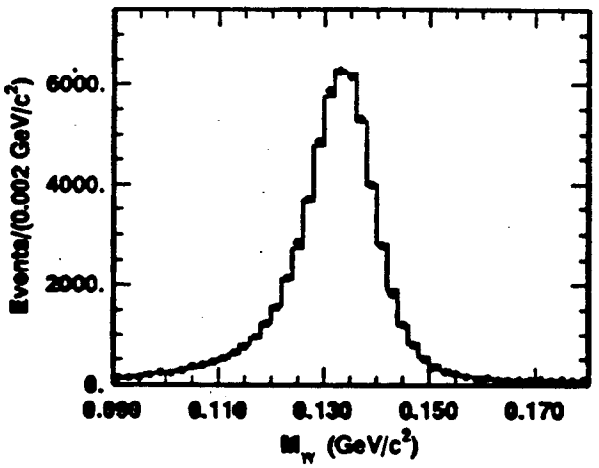
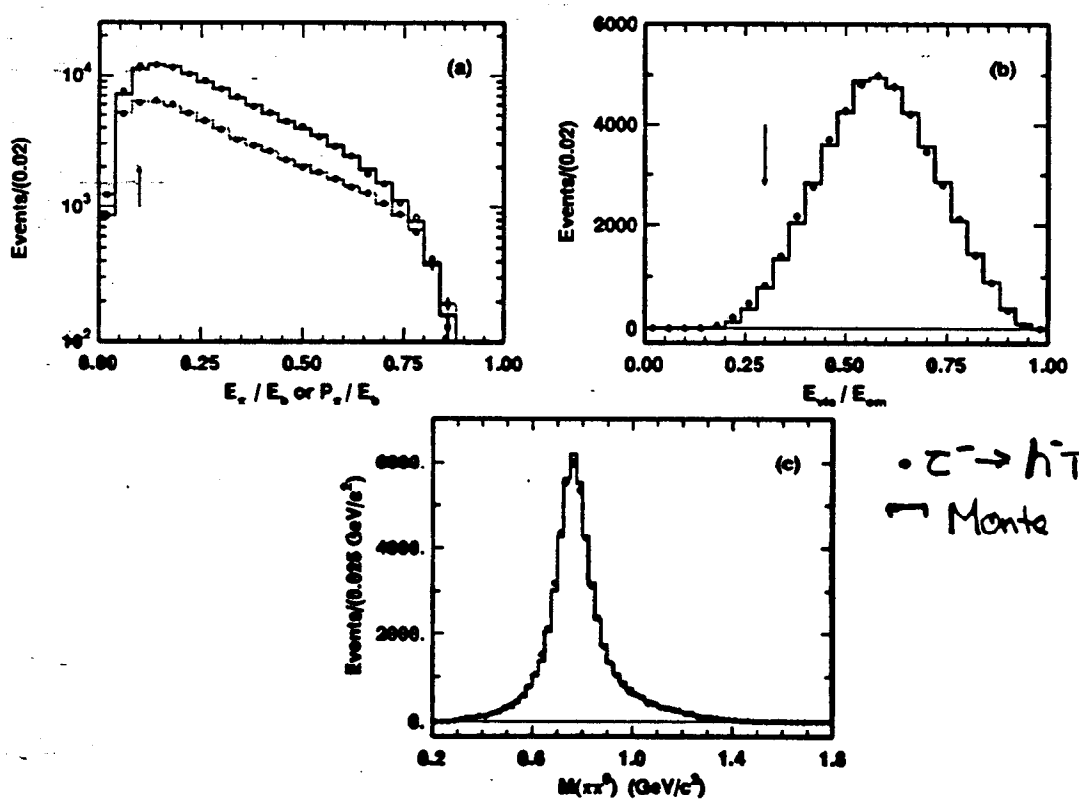


FIG. 1. The $M_{\gamma\gamma}$ distribution for the data (points) and the Monte Carlo (histogram), summed over all tags.



• $\tau^- \to h^- \pi^0 \nu_\tau$; $m_{h^-\pi^0}$ data
— Monte Carlo

FIG. 2. The distributions of a variety of kinematical variables for the data (points) and the Monte Carlo (histogram), summed over all tags. (a) The scaled momentum of the charged particles, p_π/E_b (open circles and solid histogram), and the scaled energy of the π^0, E_{π^0}/E_b (solid circles and dotted histogram), scaled by a factor 3 for clarity); (b) the scaled visible energy, E_{vis}/E_{cm}; (c) the $\pi^\pm\pi^0$ invariant mass. The accepted region is to the right of the vertical lines in (a) and (b).

$\tau \to K^0 X$

1. Precise $\mathcal{B}(\tau^- \to (\pi\pi)^- \nu_\tau)$ and $\mathcal{B}(\tau^- \to (K\pi)^- \nu_\tau)$ can be used as either
   - a test of the Das-Mathur-Okubo (DMO) sum rule, or
   - a check of $\left|\frac{V_{us}}{V_{ud}}\right|$ (expect a final $\approx 3\%$ error).

$$\frac{\mathcal{B}(\tau^- \to (K\pi)^- \nu_\tau)}{\mathcal{B}(\tau^- \to (\pi\pi)^- \nu_\tau)} = \text{(phase space factor)} \left|\frac{V_{us}}{V_{ud}}\right|^2 \boxed{\frac{f_{K^*}^2}{f_\rho^2}}$$

(Assuming single resonance (ρ^- and K^{*-}))

DMO sum rule equates this to $\boxed{\frac{M_{K^*}^2}{M_\rho^2}}$

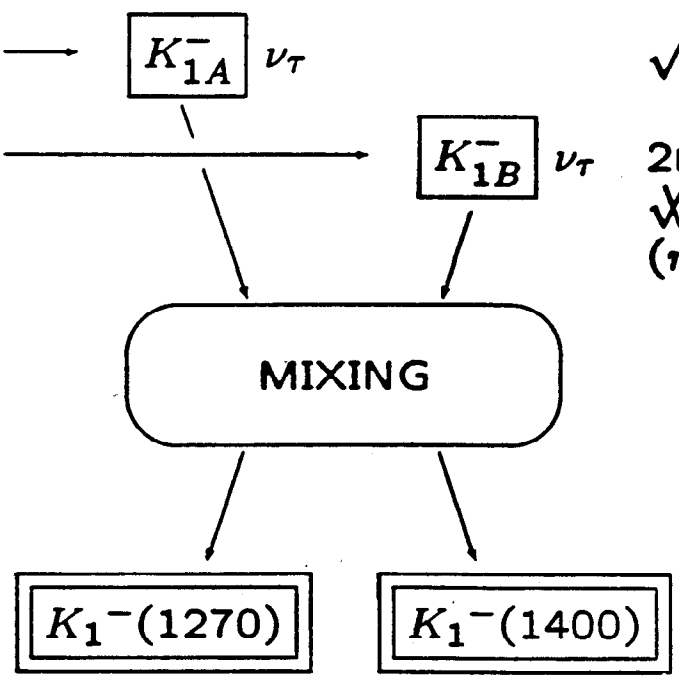
2. Study resonant structure of vector and axial-vector $S = \pm 1$ charged current

3. Use the ratio

$$\frac{\mathcal{B}(\tau^- \to K_1{}^-(1270)\nu_\tau)}{\mathcal{B}(\tau^- \to K_1{}^-(1400)\nu_\tau)}$$

to study the effects of K_1 mixing and $SU_f(3)$ symmetry breaking:

Decay	Allowed?
$(\pi\pi\pi)^-$ **final states:**	
$\tau^- \longrightarrow \boxed{a_1^-}\ \nu_\tau$	✓
$\tau^- \longrightarrow \boxed{b_1^-}\ \nu_\tau$	2nd class current ✗ under isospin symmetry
$(K\pi\pi)^-$ **final states:**	
$\tau^- \longrightarrow \boxed{K_{1A}^-}\ \nu_\tau$	✓
$\tau^- \longrightarrow \boxed{K_{1B}^-}\ \nu_\tau$	2nd class current ✗ under broken $SU_f(3)$ $(m_s > m_{u,d})$



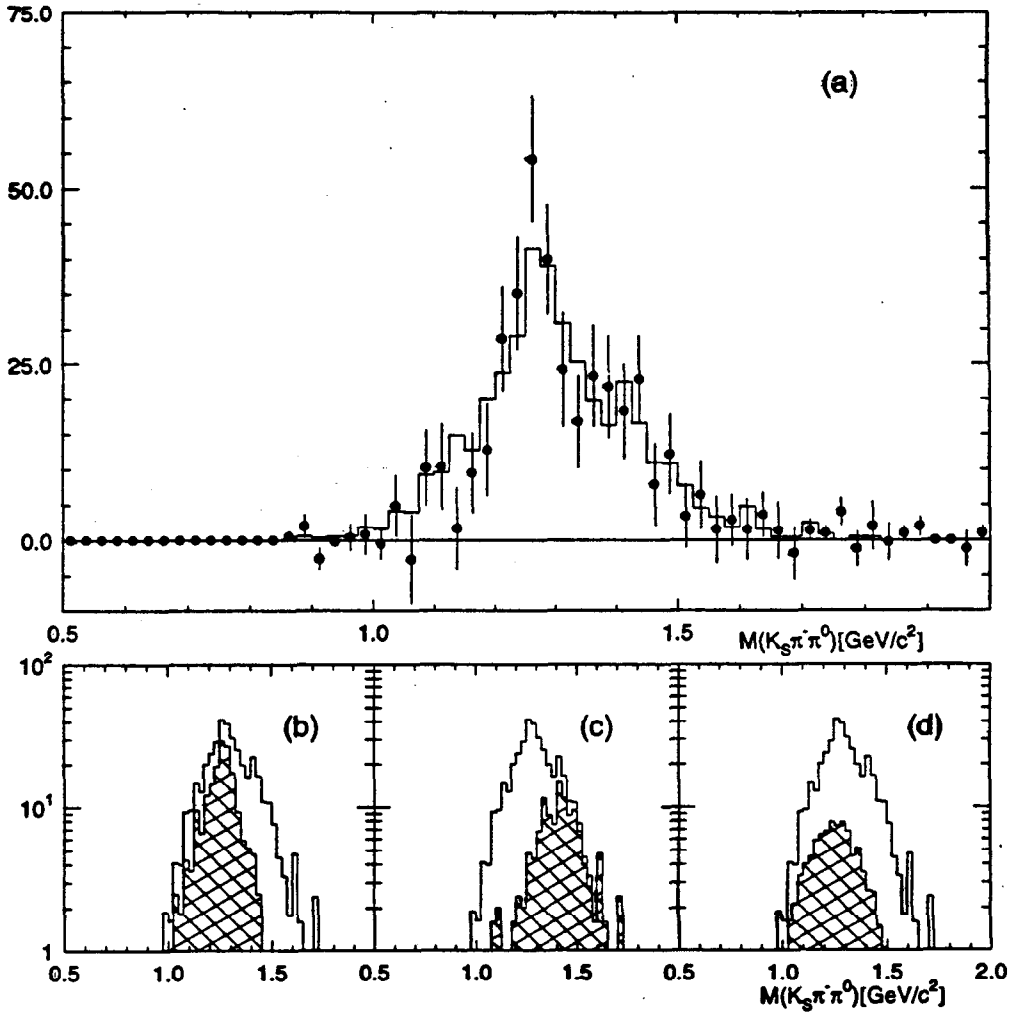


FIG. 6. (a) The $M(K_S^0\pi^-\pi^0)$ distribution for data (points) after sideband and background subtraction. The solid histogram is the result of a fit to the Monte Carlo predicted distributions for $K_1(1270)$ and $K_1(1400)$, and a fixed contribution from $K_S^0K^-\pi^0$ (according to the result in [8]). Their contributions are shown as hatched histograms in (b) ($K_1(1270)$), (c) ($K_1(1400)$) and (d) ($K_S^0K^-\pi^0$).

ν_τ Mass

- neutrinos are light!
- $m_{\nu_e} < 7.3$ eV$/c^2$
- $m_{\nu_\mu} < 0.27$ MeV$/c^2$ (90% CL)
- Standard Model assumes massless neutrinos
- most extensions include neutrino mass; "see-saw model": *e.g.*, $m_{\nu_\tau}/m_{\nu_e} = m_\tau^2/m_e^2$.
- neutrino mass is very important in astrophysics!
  - $m_{\nu_\tau} \sim 10eV$ closes the universe

RECENT MEASUREMENTS

- Statistical error $\approx$ 10% for $(K\pi)^-$ mode, > 25% for $(K\pi\pi)^-$ mode.
  - Statistically limited.

Mode	Expt	$\mathcal{B}$(%)('94 Prelim.)
K^{*-}	ARGUS	$0.97 \pm 0.15 \pm 0.12$
$K^0 h^-$	ALEPH	$1.28 \pm 0.16 \pm 0.12$
$\overline{K}^0\pi^-$	ALEPH	$0.88 \pm 0.14 \pm 0.09$
K^0K^-	ALEPH	$0.29 \pm 0.12 \pm 0.03$
$\overline{K}^0\pi^-\pi^0$	ALEPH	$0.33 \pm 0.14 \pm 0.07$
$K^0K^-\pi^0$	ALEPH	$0.05 \pm 0.05 \pm 0.01$

- TPC/2γ sees more $K_1{}^-(1400)$ through $K^-\pi^+\pi^-$ channel:

τ decay mode	$\mathcal{B}$(%)('93 Prelim.)
$K_1{}^-(1400)$	$0.74^{+0.40}_{-0.33}$
$K_1{}^-(1270)$	$0.43^{+0.40}_{-0.34}$

ANALYSIS

- K_S^0 detected by looking at secondary vertex.
- No particle ID on h^- or X^+ ($= e^+\nu_e, \mu^+\nu_\mu, \pi^+, K^+, \rho^+$). Assign π^- mass when calculating invariant mass.
- All π^0's (signal or tag side) explicitly reconstructed.

FIND:

(1) $\tau^- \to \bar{K}^0 h^- \nu_\tau$: $(0.977 \pm 0.023 \pm 0.108)\%$ (K^* dom.)

(2) $\tau^- \to \bar{K}^0 h^- \pi^0 \nu_\tau$ = $(0.519 \pm 0.035 \pm 0.062)\%$ (lots of K^*)

(1a) $\tau^- \to \bar{K}^0 K^- \nu_\tau$: $(0.123 \pm 0.023 \pm 0.023)\%$ ✓CVC

(1b) $\tau^- \to \bar{K}^0 K^- \pi^0 \nu_\tau$: $(0.129 \pm 0.050 \pm 0.032)\%$

– $m_{K\bar{K}\pi}$ consistent w/ K^*K

(3) $\tau^- \to K^0 \bar{K}^0 \pi^- \nu_\tau$ = $(0.083 \pm 0.017 \pm 0.017)\%$ should equal $\bar{K}^0 K^- \pi^0$ if <u>all</u> K^*K

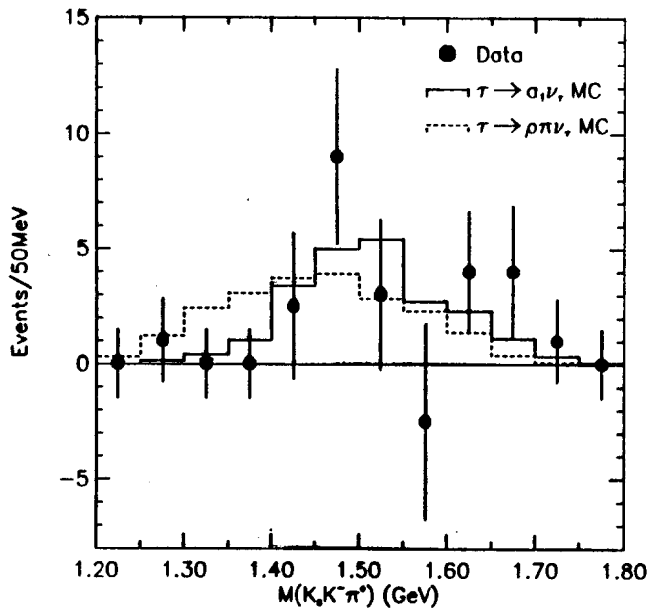


FIG. 8. The $K_sK^-\pi^0$ invariant mass distribution for $\tau^- \to K^0K^-\pi^0\nu_\tau$ candidates. The data points are obtained by taking 50 MeV "slices" in invariant mass and fitting the background subtracted σ_K distribution for those events. The solid histogram shows the invariant mass spectrum from a full Monte Carlo simulation of $\tau^- \to a_1\nu_\tau$, $a_1 \to K^0K$ decays. The dashed histogram shows the mass distribution for a simulation of $\tau^- \to \rho\pi\nu_\tau$, $\rho \to K^0K^-$ decays.

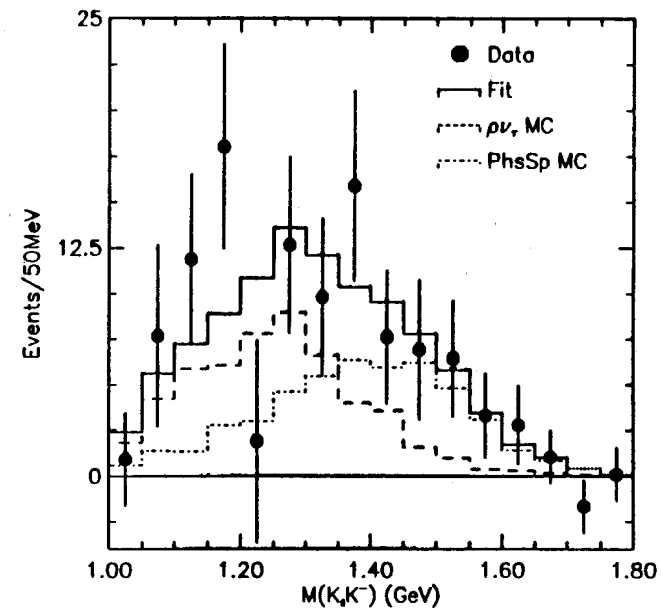


FIG. 5. The K_sK^- invariant mass of $\tau^- \to K^0K^-\nu_\tau$ events. The filled circles, with error bars, are for the data. The solid histogram is the result of a fit to the sum of $\tau^- \to \rho^-\nu_\tau$, $\rho \to K_sK^-$ (dashed) and $\tau^- \to K^0K^-\nu_\tau$ phase space (dot-dashed) Monte Carlo models.

TABLES

TABLE I. The detection efficiencies, ϵ, and upper limits for the branching fractions at 90% CL, $\mathcal{B}$, together with the most restrictive limits from previous experiments [1,4].

Decay channel	ϵ (%)	$\mathcal{B}$ (in units of 10^{-6}) Previous	This analysis
$\tau^- \to e^-e^+e^-$	20.4	13	3.3
$\tau^- \to \mu^-e^+e^-$	19.6	14	3.4
$\tau^- \to \mu^+e^-e^-$	19.9	14	3.4
$\tau^- \to e^-\mu^+\mu^-$	18.8	19	3.6
$\tau^- \to e^+\mu^-\mu^-$	19.4	16	3.5
$\tau^- \to \mu^-\mu^+\mu^-$	15.9	17	4.3
$\tau^- \to e^-\pi^+\pi^-$	15.5	27	4.4
$\tau^- \to e^-\pi^-K^+$	14.6	58	4.6
$\tau^- \to e^-\pi^+K^-$	14.9	29	7.7
$\tau^- \to e^+\pi^-\pi^-$	15.5	17	4.4
$\tau^- \to e^+\pi^-K^-$	15.1	20	4.5
$\tau^- \to \mu^-\pi^+\pi^-$	9.1	36	7.4
$\tau^- \to \mu^-\pi^-K^+$	7.4	77	15
$\tau^- \to \mu^-\pi^+K^-$	7.8	77	8.7
$\tau^- \to \mu^+\pi^-\pi^-$	9.8	39	6.9
$\tau^- \to \mu^+\pi^-K^-$	7.7	40	20
$\tau^- \to e^-\rho^0$	16.2	19	4.2
$\tau^- \to e^-K^{*0}$	10.7	38	6.3
$\tau^- \to e^-\bar{K}^{*0}$	10.5	—	11
$\tau^- \to \mu^-\rho^0$	11.9	29	5.7
$\tau^- \to \mu^-K^{*0}$	7.2	45	9.4
$\tau^- \to \mu^-\bar{K}^{*0}$	7.8	—	8.7

CLEO94: Searches for neutrinoless τ-decay $\Leftrightarrow$ Beyond S.M. physics

Also: $\tau^- \to \mu\gamma \leq 4.2 \times 10^{-6}$

cf: $\mu^- \to e\gamma < 5 \times 10^{-11}$

Supersymmetric models, e.g. give $\left(\frac{m_\tau}{m_\mu}\right)^5$ enhancement of τ modes

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$\tau^- \to e^+ \pi^- K^-$	15.1	20	4.5
$\tau^- \to \mu^- \pi^+ \pi^-$	9.1	36	7.4
$\tau^- \to \mu^- \pi^- K^+$	7.4	77	15
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From CLEO-II and a half to CLEO-III

BaBar/CLEO-III detector design driven by **B-physics**, not tau-physics.

Must have:

- Particle ID: 4σ separation π/K at 2.8 GeV/c for $B \rightarrow \pi\pi / B \rightarrow K\pi$ ($D \rightarrow \pi\ell\nu / D \rightarrow K\ell\nu$)
  - CLEO-II, present: 1.8σ in Rel. Rise

- Lepton ID down to 400 MeV/c for electrons, 800 MeV/c for muons

- 3-dim vertex resolution $\leq 50\mu$ (improve S:N for charm, measure D^* widths?)

- Momentum resolution: $(\frac{dp}{p})^2 \leq (0.0015\ p)^2 + (0.005)^2$
  - Important to know momentum resolution for measurement of m_{ν_τ}.

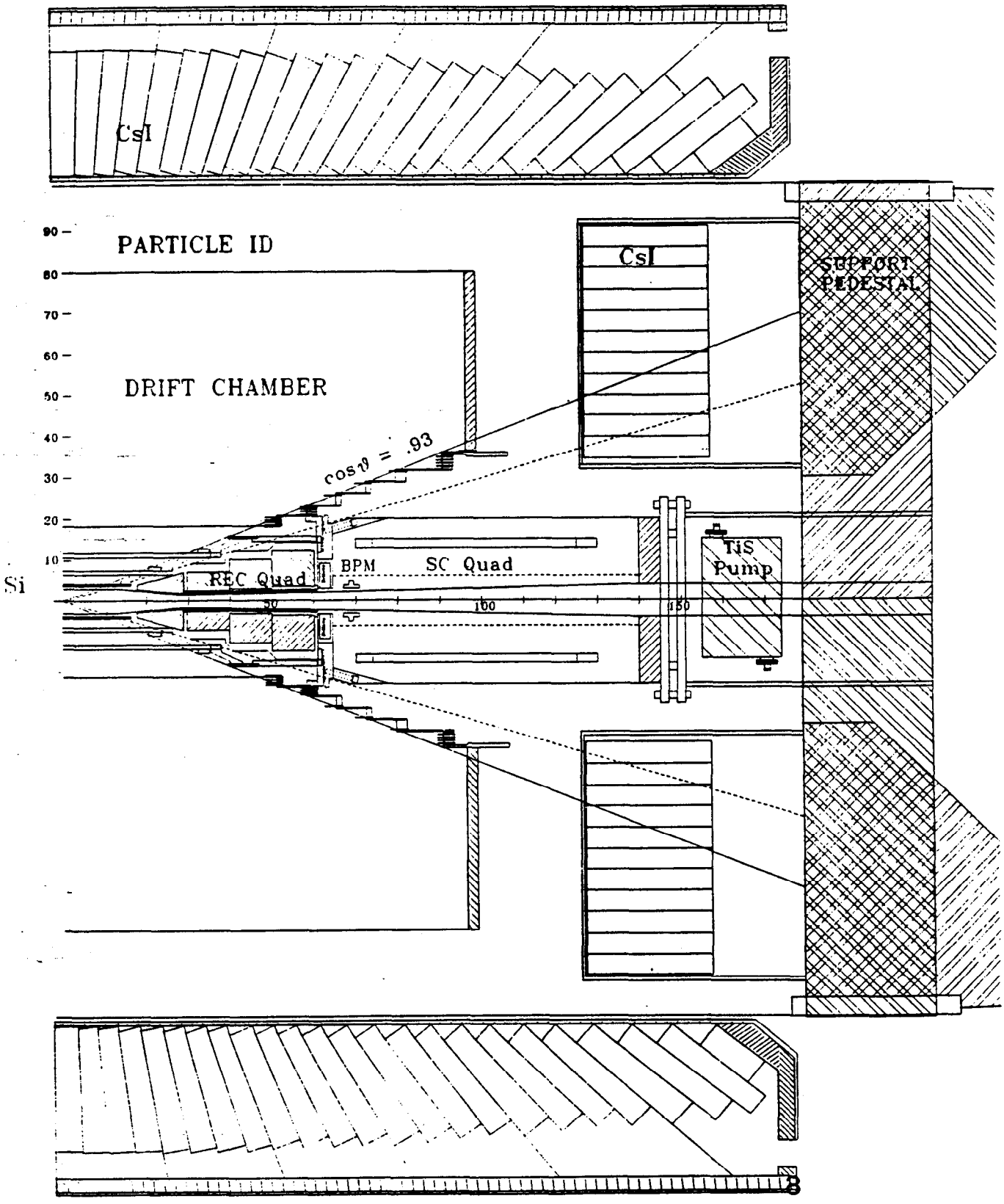
- Photon resolution and segmentation at least as good as CLEO-II ($D^{*+} \rightarrow D^{+}\pi^{0}$, charm decays w/ neutrals)

- Ability to handle high rates $> 10^2$ at L2 with small dead times

- Silicon vertexing ($\sim 50\mu$ in two-track vertex in $r - \phi$)

- Hermiticity: Important for rejection of $q\bar{q} \rightarrow \pi^{0}$'s

CLEO-III


CsI
PARTICLE ID
CsI
SUPPORT PEDESTAL
DRIFT CHAMBER
cosθ = .93
BPM
SC Quad
REC Quad
TiS Pump
Si
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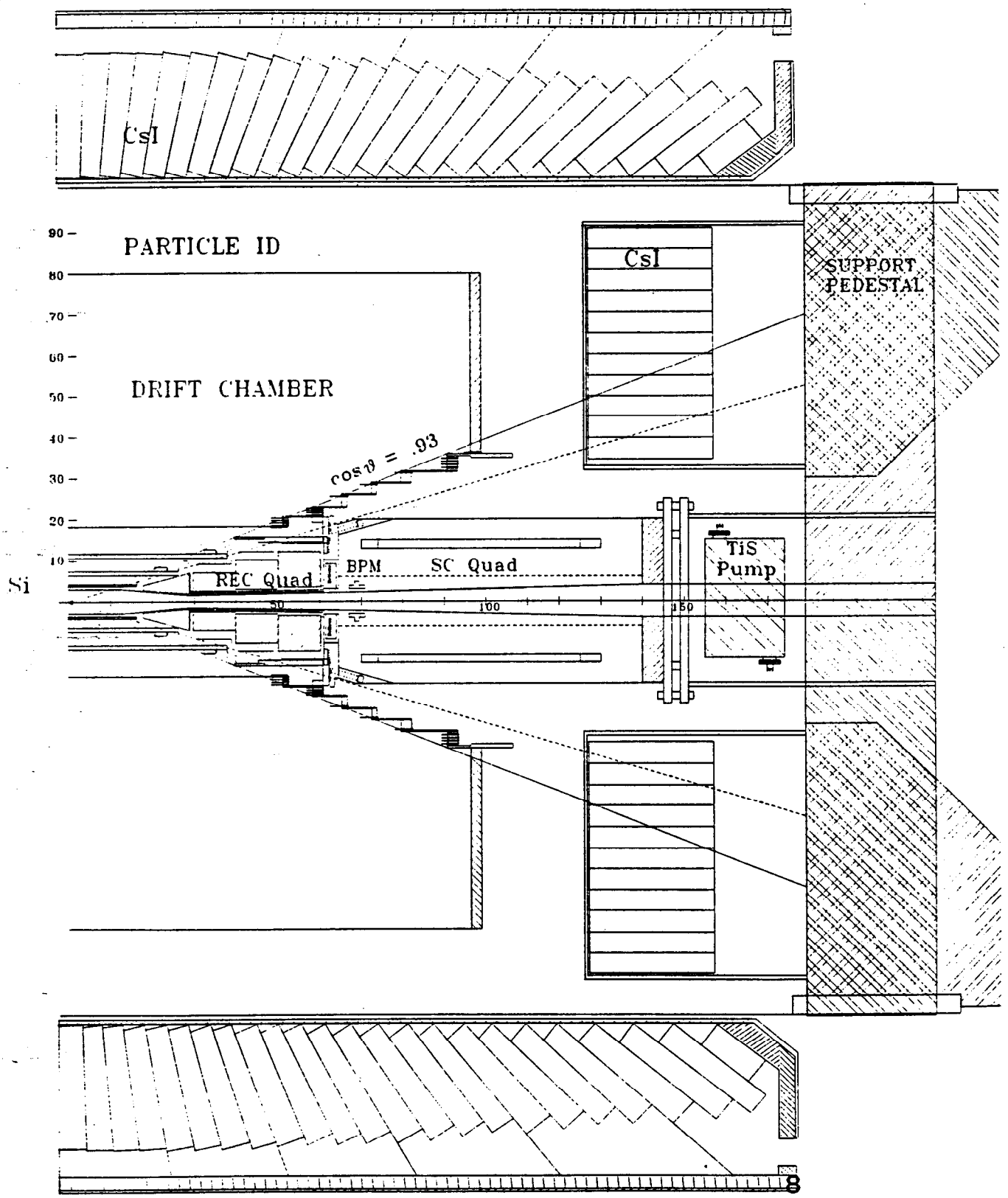
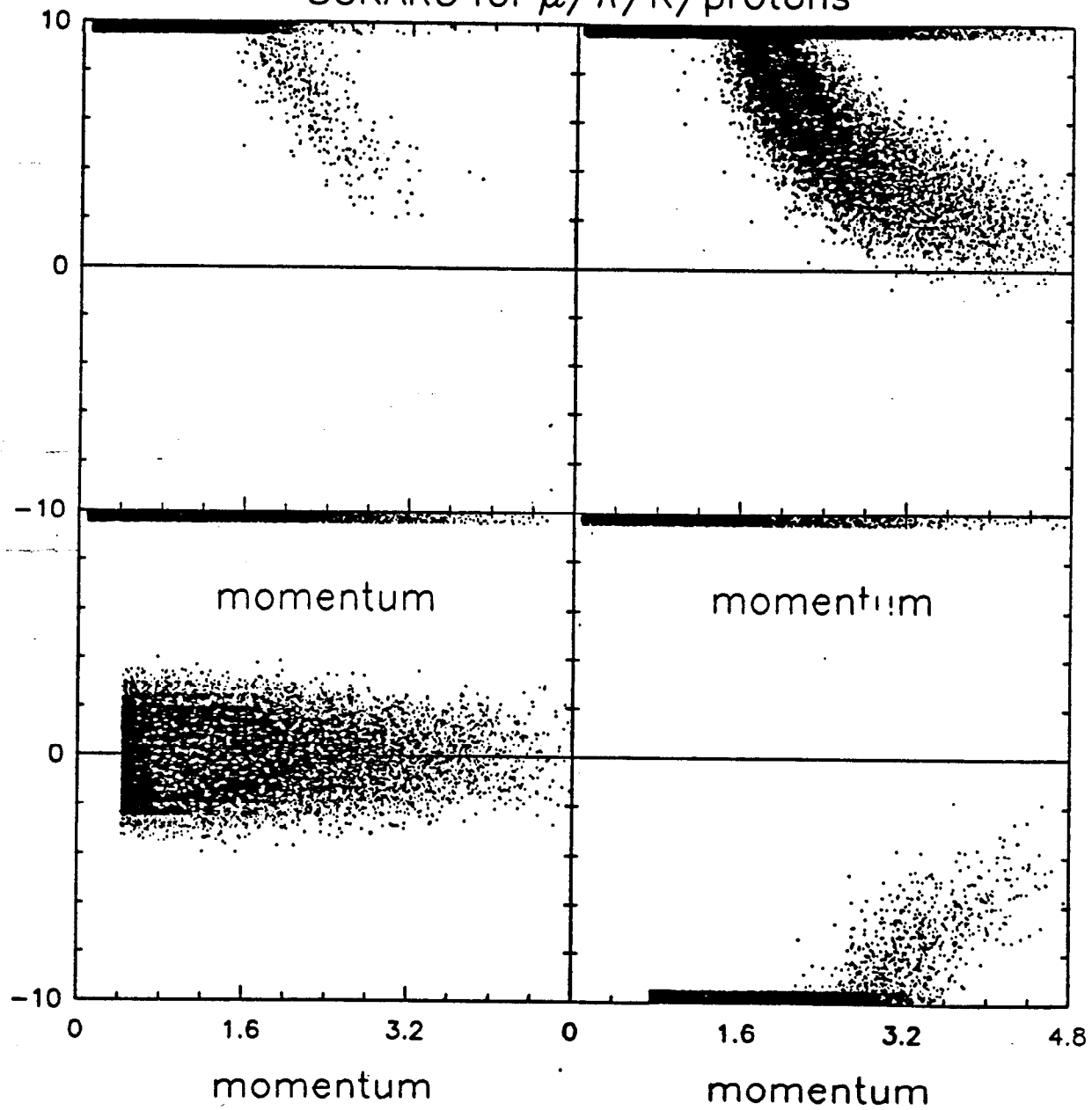

CsI
PARTICLE ID
DRIFT CHAMBER
CsI
SUPPORT PEDESTAL
cos ϑ = .93
Si
REC Quad
BPM
SC Quad
TiS Pump
90
80
70
60
50
40
30
20
10
50
100
150

File: pid.def_qq_hist_18916

ID	IDB	Symb	Date/Time	Area	Mean	R.M.S.
13024	0	1	940728/0812	7854.	0.8322	0.5601
					9.609	0.7306
13025	0	1	940728/0812	6.4396E+05	0.6773	0.5339
					9.616	0.7973
13026	0	1	940728/0812	9.5550E+04	1.077	0.6968
					2.585	4.395

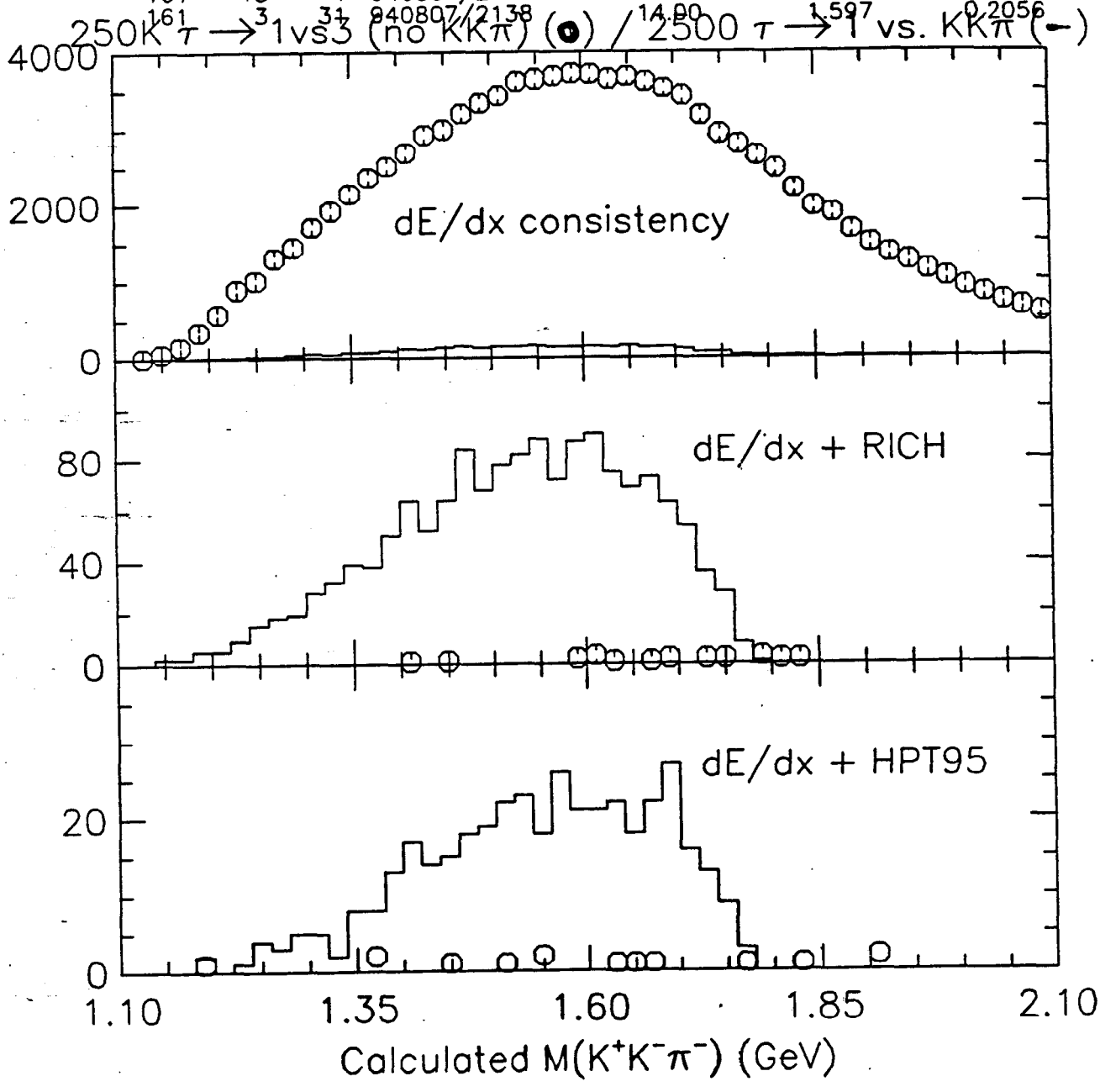
SGKARC for $\mu/\pi/K/$protons



5/fb equivalent

File: t1v3_pid_nokkpi_3prong_250K.hist

ID	IDB	Symb	Date/Time	Area	Mean	R.M.S.
161	1	31	940807/2133	1.0690E+05	1.638	0.2301
161	11	1	940807/2139	3154.	1.559	0.1608
161	12	1	940807/2140	1498.	1.528	0.1291
161	2	31	940807/2136	22.00	1.689	0.1143
161	13	1	940807/2140	395.0	1.548	0.1245
161	3	31	940807/2138	14.00	1.597	0.2056



Determination of Systematic Errors

"I have seen the future of τ physics and it is *precision* physics" - D. Marsh, 1975

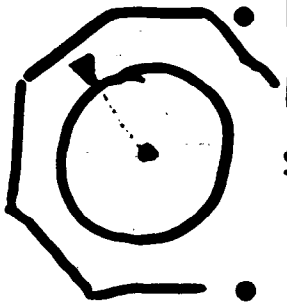
At CLEO, ϵ_{MC} vs. ϵ_{data} increasingly THE dominant error

Need to measure ϵ as function of:

- Momentum (h^+, π^0)
- Particle type $(\pi^+, k^+, p^+, e^+, \mu^+)$
- Dip angle wrt beam axis (h^+, π^0)
- Event parameters: thrust and mulitplicity (h^+, π^0)

1. Absolute charged particle reconstruction efficiency

(a) Track-<u>finding</u> efficiency (topological BR's, e.g.)



- MinIPeak in calorimeter tags charged particle, count how often one is observed
  → with 2 independent tracking systems (Si/DR or UD/DR)
- High-energy showers in CC from B-decay 90% from e^{+-}. count how often one is track matched.

- Multiplicity correlations - data vs. MC

  – Use ratio of evts with net charge ± 1 relative to net charge $= 0$ in data vs. MC $N_+ \approx N_0(1-\varepsilon)$

  – N_ℓ *vs* 2/N_ℓ *vs* 3

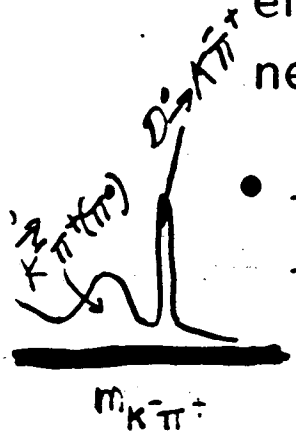
  – $\gamma\gamma \to h^+h^-$; count $N_{h^+}/N_{h^+h^-}$.

  For τ decay, quoted systematic error varies from 0.4% ($\tau \to \rho^-\nu_\tau$) to 1.25% ($\tau \to$5-prong)

- Have observed ε loss due to evt. multiplicity/confusion

(b) Product of track-finding and track-fitting efficiency (for finding the yield underneath $\eta \to \pi^+\pi^-\pi^0$ peak, e.g.)

- Depends on modeling hit resolution function, e.g.



- $D^{*+} \to D^0\pi^+; D^0 \to K^-\pi^0(\pi^+)/D^0 \to K^-\pi^0\pi^+$ using "satellite peak" (both $\varepsilon_{\pi^0}, \varepsilon_{\pi^\pm}$)

  Q: How often are evts. in $K^-\pi^+(\pi^0)$ peak fully reconstructed w/ π^0?

- $\pi^0 \to e^+e^-\gamma$; use shower due to e, trace back helical path to origin and produce a π^0 peak. How often is track found within some window?

Quoted systematic error varies from 2% ($p > p_{curl}$, barrel) to 5% ($p < p_{curl}$)

Note that efficiency outside of barrel region well-reproduced in MC (isotropy of charged tracks from B's - will this be done at τcF with D^0 or D^+ decays at threshold

Note: Potentially BIG τcF advantage:

Multiplicity low, particles well i.d.'d $\Rightarrow$ calibrate efficiencies VERY well using MC techniques as f(particle type, co.s.)

e.g. $\psi \to K^+K^-\pi^+(\pi^-)$

MINUIT-χ^2 Fit to Plot 191&1

pizero gge Dist. of. Proj. onto xmtot axis

File: pi0eeg.hist

30-JUN-93 18:17

Plot Area Total/Fit 12590. / 12590.

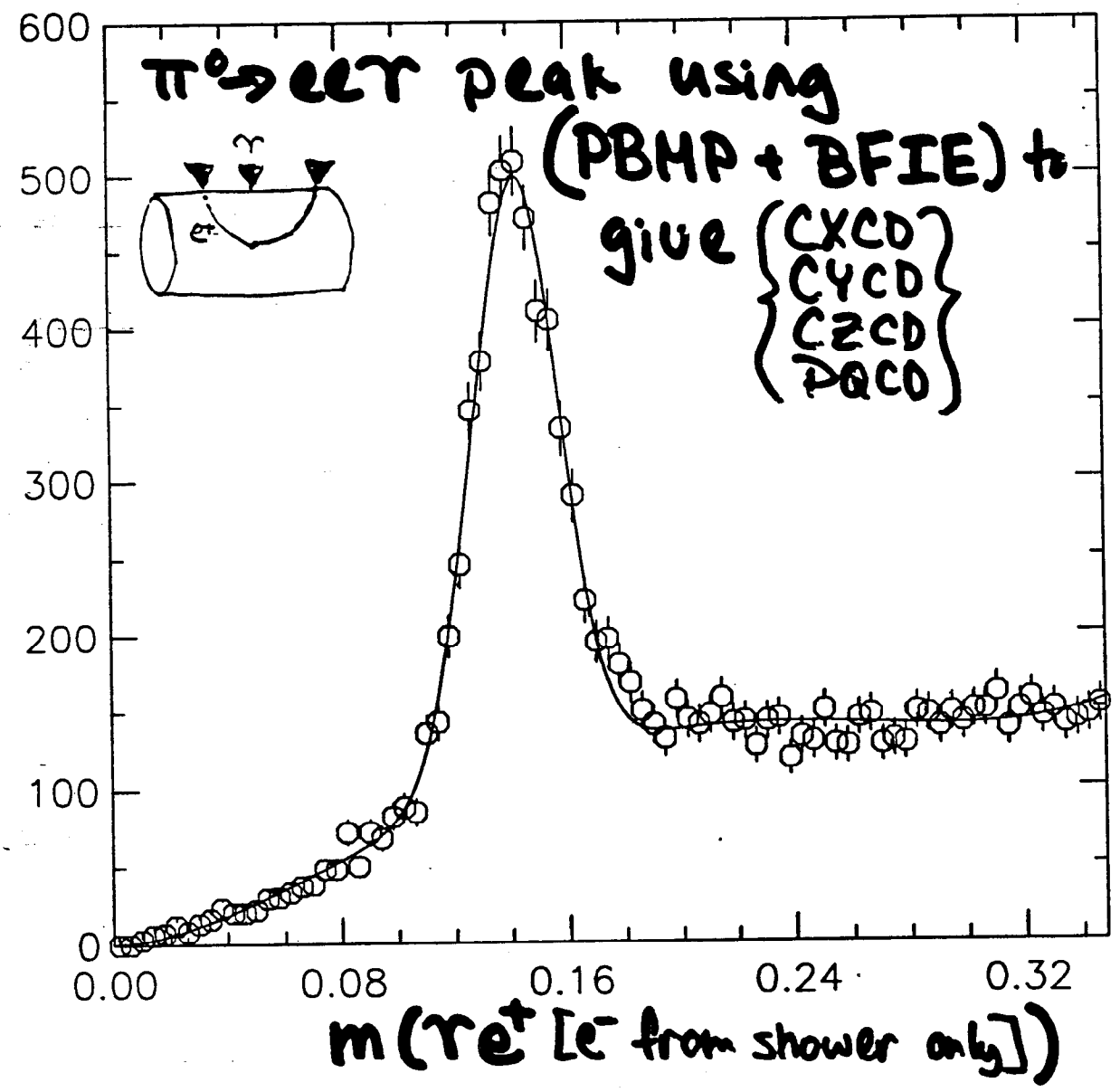
Fit Status 3

Func Area Total/Fit 12515. / 12515.

E.D.M. 2.542E-08

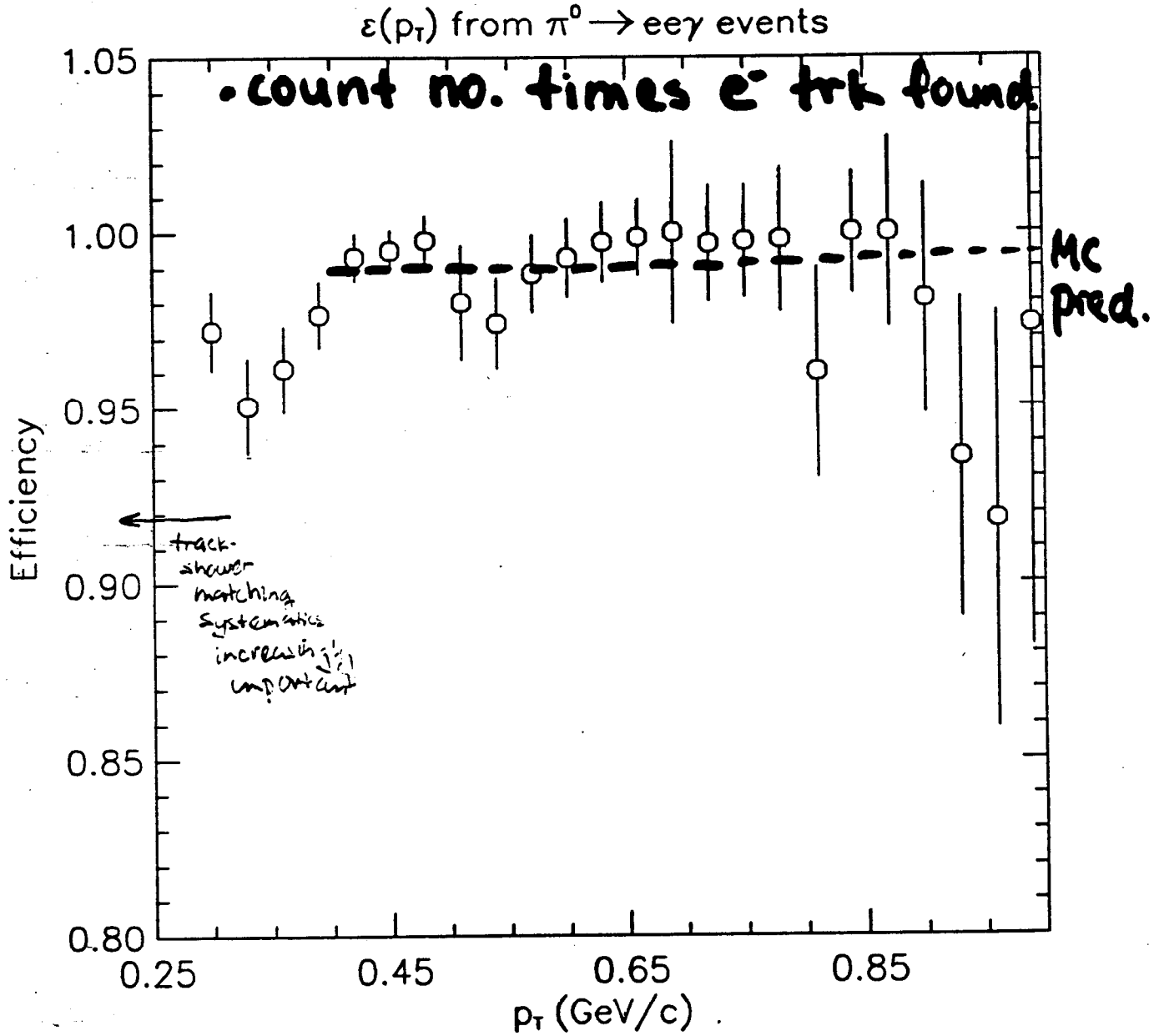
χ^2= 76.6 for 87 - 8 d.o.f., C.L.= 55.6%

Errors		Parabolic	Minos	
Function 1: Gaussian Distribution (FWHM)				
AREA	3709.3	±103.5	−0.0000E+00	+0.0000E+00
MEAN	0.14187	±3.7182E−04	−0.0000E+00	+0.0000E+00
FWHM	3.57964E−02	±9.4573E−04	−0.0000E+00	+0.0000E+00
Function 2: Chebyshev Polynomial of Order 4				
NORM	93.455	±1.390	−0.0000E+00	+0.0000E+00
CHEB01	79.047	±1.884	−0.0000E+00	+0.0000E+00
CHEB02	−25.193	±2.012	−0.0000E+00	+0.0000E+00
CHEB03	−1.1371	±1.860	−0.0000E+00	+0.0000E+00
CHEB04	9.6265	±1.657	−0.0000E+00	+0.0000E+00



File: Generated internally

ID	IDB	Symb	Date/Time	Area	Mean	R.M.S.
3	0	31	930717/1203	28.82	0.6782	0.2543



⇒ agreement in track-fitting at (0.3 ± 0.5)% level between data/MC for $e^{\pm}$

2. Absolute γ finding efficiency

- Use $D^{*0} \rightarrow D^0\pi^0; \pi^0 \rightarrow \gamma(\gamma)$ relative to case of fully reconstructed π^0

- Use flatness of dN/dE_γ from $\pi^0 \rightarrow \gamma\gamma$ to extrapolate efficiency in region 30 MeV to 2 GeV. (shape of ε_γ curve)

- Use flatness of $dN/dcos\theta$ spectrum to extrapolate endcap (noise??) ε.

Quoted error of 2% per photon, includes uncertainty on photon line shape (shower containment uncertainties, e.g.)

3. Absolute π^0 finding efficiency

- $D^{*+} \rightarrow D^0\pi^+; D^0 \rightarrow K^-\pi^+(\pi^0)/D^0 \rightarrow K^-\pi^0\pi^+$ using "satellite peak"

- mass recoiling against $\pi^+\pi^-\pi^+\pi^-$ in $\Upsilon \rightarrow \pi^+\pi^-\pi^+\pi^-\pi^0$ events vs. number of times π^0 fully reconstructed.

- $\eta \rightarrow \pi^0\pi^0\pi^0/\eta \rightarrow \gamma\gamma$, efficiency-corrected

BR compared with PDG value

Quoted error of 5% per π^0

4. Ratio of $\frac{\pi^+}{\pi^0}$ efficiencies:

- Assume equality of cross-sections of Ξ's: $\Xi^- \to \Lambda\pi^-/\Xi^0 \to \Lambda\pi^0$

- R(Ispin ratio) in $D^{*\prime}$ decay:

$$R = \frac{\Gamma(D^{*+} \to D^0\pi^+)}{\Gamma(D^{*+} \to D^+\pi^0)} = 2.17 \pm 0.08$$

- $\Upsilon(2S) \to \Upsilon(1S)\pi^+\pi^-$: $\Upsilon(2S) \to \Upsilon(1S)\pi^0\pi^0 = 2.0$

- $\eta \to \pi^+\pi^-\pi^0/\eta \to \pi^0\pi^0\pi^0$, cf. PDG

- Inclusive spectra

Quoted error of 6% on ratio (8% for V_{cb} analysis)

The World According to Dave - 10 GeV vs. τcF

Physics	τcF	10 GeV/Systematic
Tau mass	\$\$\$	\$
leptonic decays	\$\$	\$\$/fakes,QED
lifetime		\$\$
Lorenz structure	\$\$	\$\$
spin structure	\$\$	\$\$
hadronic decays	\$\$	\$ ($q\bar{q}$, $\gamma\gamma$)
inclusive/exclusive BR's	\$\$	\$ ($q\bar{q}$, $\gamma\gamma$)
spectral functions/α_s	\$\$	\$ ($q\bar{q}$, $\gamma\gamma$)
spectral functions/K_1's	\$\$	\$ ($q\bar{q}$, $\gamma\gamma$)
Rare decays/L-viol.	\$\$	\$\$
ν_τ mass	\$\$	\$\$

Conclusions

- τ physics very active at CLEO - World-class precision for almost all measurements

  BUT: progress requires high statistics, good control of systematics

- The era of very high data rates means that control of systematics will become increasingly important, and will require knowing, at the 0.1% level, systematics from:

  1. Absolute tracking efficiencies

  2. Knowledge of fake rates for leptons, e.g.

  3. Knowledge of backgrounds

Monte Carlo tuning will become a full-time preoccupation!