Fermilab Fixed Target Charm Program

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Tau-Charm Factory Workshop
SLAC
Stanford, California
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Charm Particle Yield from Fixed Target Experiments

1. Experiments with 10,000 Reconstructed, 10^6 Produced
   (a) **E691**-1985 photoproduction, > 10K events
   (b) **NA-32**-1986 hadroproduction – 3-4K range
   (c) **E687**-1988, photoproduction, 10K events
   (d) **E653**-1988, hadroproduction, 10K events
   (e) **E769**-1988 hadroproduction – 6-7K range
   (f) **WA-89**-1993, Hyperon Beam – 6-7K range
   (g) **WA-92**-1993, hadroproduction – 10K range
   (h) **E771**-1992 π^- beam, limits on $D^0 \to \mu\mu$
   (i) **E789**-1992 p beam – two-arm spectrometer ???
2. Experiments with 100K Reconstructed and 10^7 Produced
   (a) **E687**-1991, photoproduction
   (b) **E791**, hadrons — (200K evts?)
3. Guess at the e^+-e^- competition by end of 1995
   (a) **CLEO II** – $5\times10^6 B\bar{B}$ events
   (b) **LEP** – 3×10^6 Z's and $6\times10^5 D\bar{D}$ events
4. Experiments with 1,000,000 Reconstructed, 10^8 Produced
   (a) **E831** 1996-1997? photoproduction
   (b) **E781** Charm Baryons??? hadron beam
   (c) **CLEO III** ???
   (d) **B Factory** ???
   (e) **τ-Charm Factory**

Will run in next fixed target run

Charm Baryons from E781

(Jim Russ)

Σ^- beam, new spectrometer

Goals

A. Weak Decay Physics

i) Precision lifetimes, Λ_c^+, $\Xi_c^{+,0}$, Ω_c^0

$\sim 3\%$

ii) Baryon semileptonic decays

B. Spectroscopy

i) Comprehensive description of J^P structure + hyperfine splittings

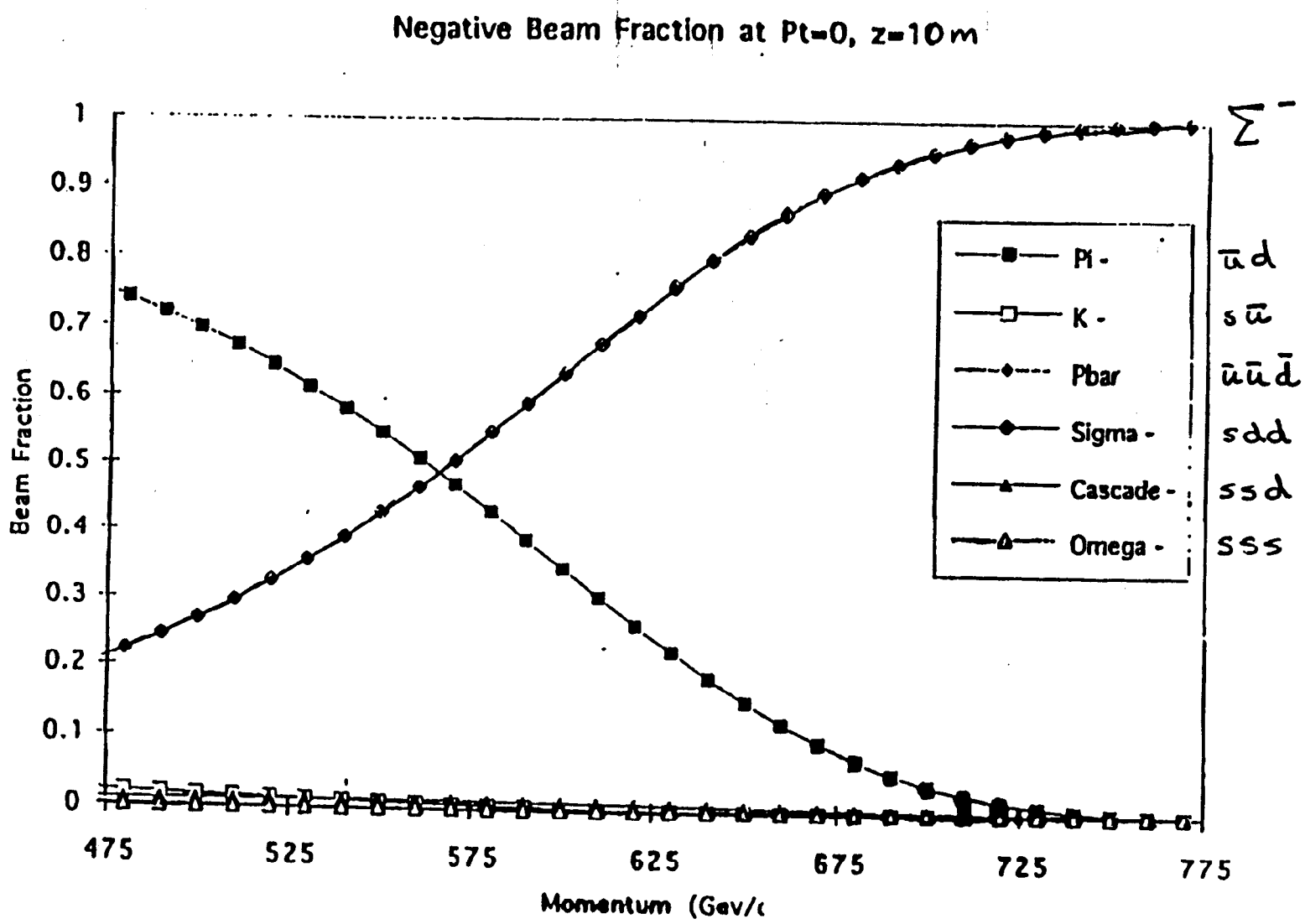
C. Production Mechanisms

i.) Leading particle effects

ii) x_F dependence

iii) Elucidate role of diquarks

iv) ccq baryons


Negative Beam Fraction at Pt=0, z=10m
Beam Fraction
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
475
525
575
625
675
725
775
Momentum (Gev/c
Pi -
K -
Pbar
Sigma -
Cascade -
Omega -
Σ^-
$\bar{u}d$
$s\bar{u}$
$\bar{u}\bar{u}\bar{d}$
sdd
ssd
sss

E-781 : High Momentum Hyperon Experiment

Goals: Charm Baryon Production $0.1 < x < 1.0$
Primakoff Studies of Hybrid Mesons (qqg)
Hadronic Structure Studies (EMFF, Polarizabili

New Feature: On-line Charm Trigger

Beam : ≤ 650 GeV Σ^-, $p_\perp = 0$ production

Id : Beam TRD

Downstream Spectrometer: e^- TRD
RICH
γ- cal
n - cal
(μ?)

Beam Momentum Definition $\Delta p/p \sim 1\%$

Scattered Particle: $\Delta\theta \sim 30\,\mu$rad @ 100 GeV/c ; 130 μrad @ 15 Ge
$\frac{\Delta p}{p} \sim 0.05\%$ @ 500 GeV/c ; .2% at 15 GeV

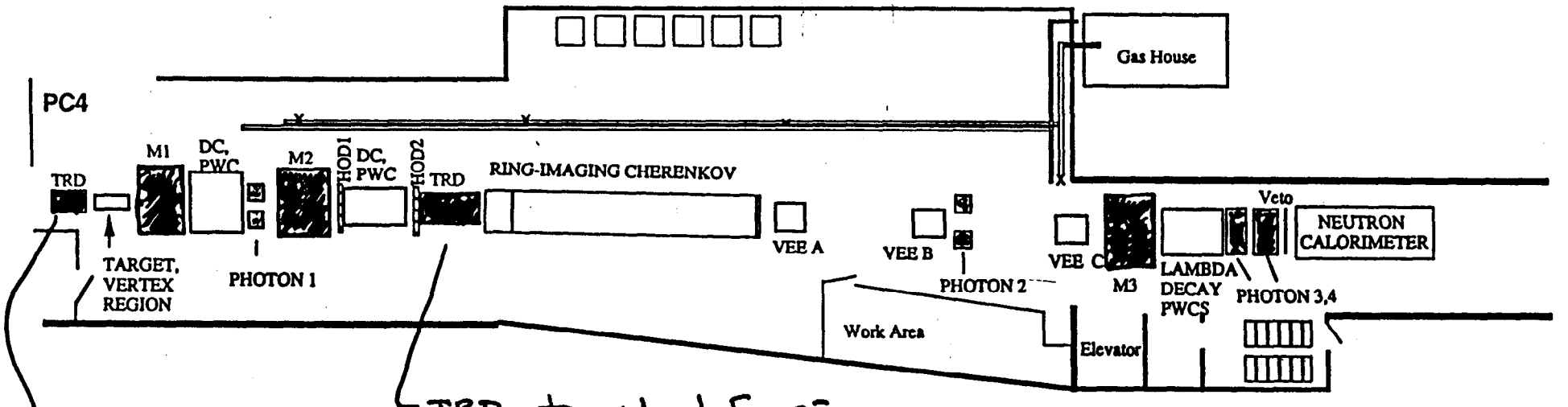
3 Stage Magnetic Spectrometer

Stage 1 Soft pions from D^*, D_s^*, Λ^*
Second Charm

Stage 2 Trigger Charm
EMFF , Hybrid Tracking

Stage 3 Very High Energy Λ decays
Forward Physics

J. Lach , J. Russ
July 3, 1994
H-460R5



TRD to identify e⁻

TRD to identify beam

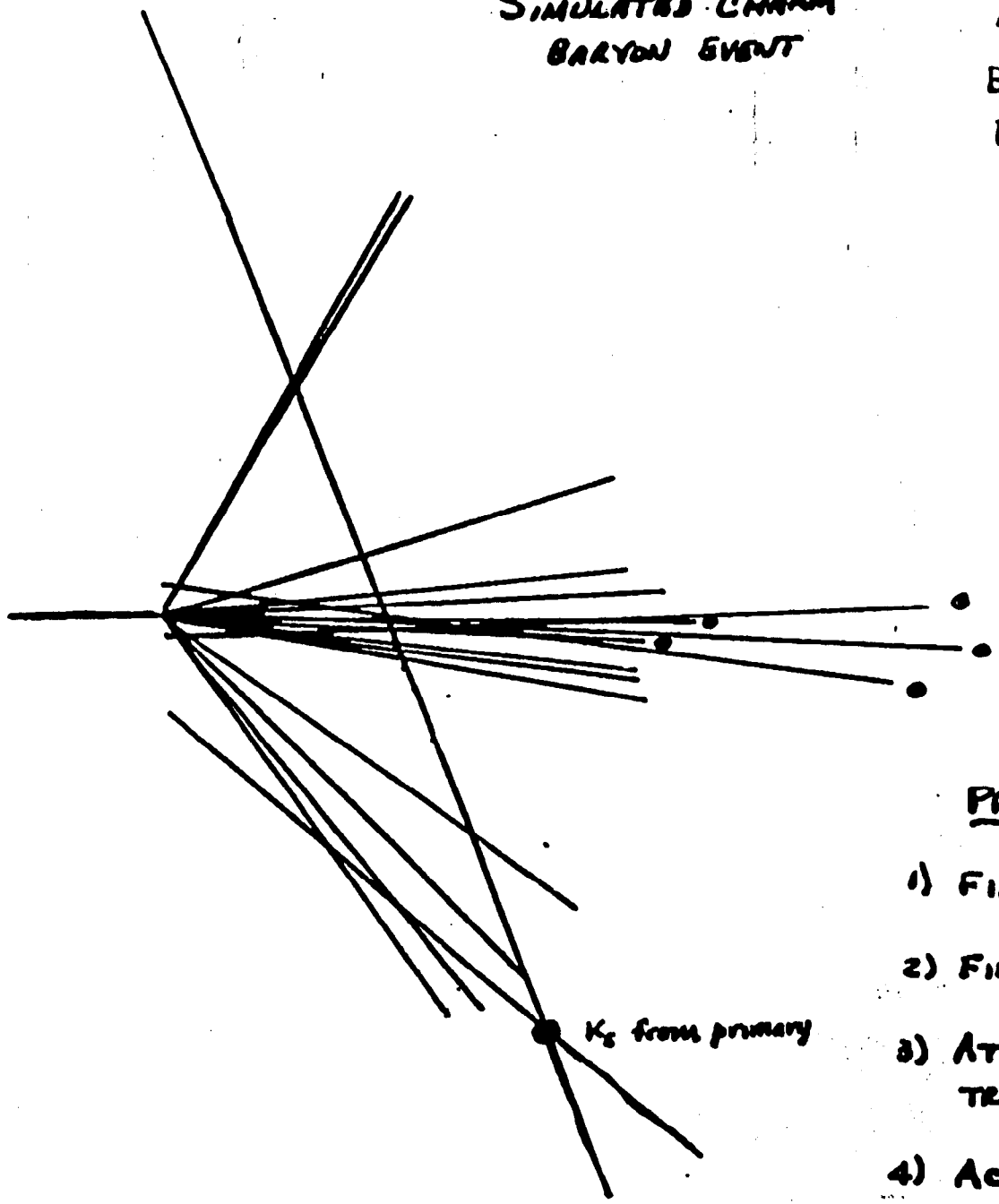
4 PHOTON Calorimeters

Vertex Region : 20 planes arranged in 4 views (SSD has 25 μm pitch)

Target is 5 foils of 1.5 mm thickness

E781 TRIGGER SCHEME

SIMULATED CHARM BARYON EVENT



LEGEND

Beam —

Primary —

K_s^0 decay —

$\Xi_c^+ \to \Lambda^0 K^- \pi^+ \pi^+$ —

• TRACK SEEN AFTER M2

PROCEDURE

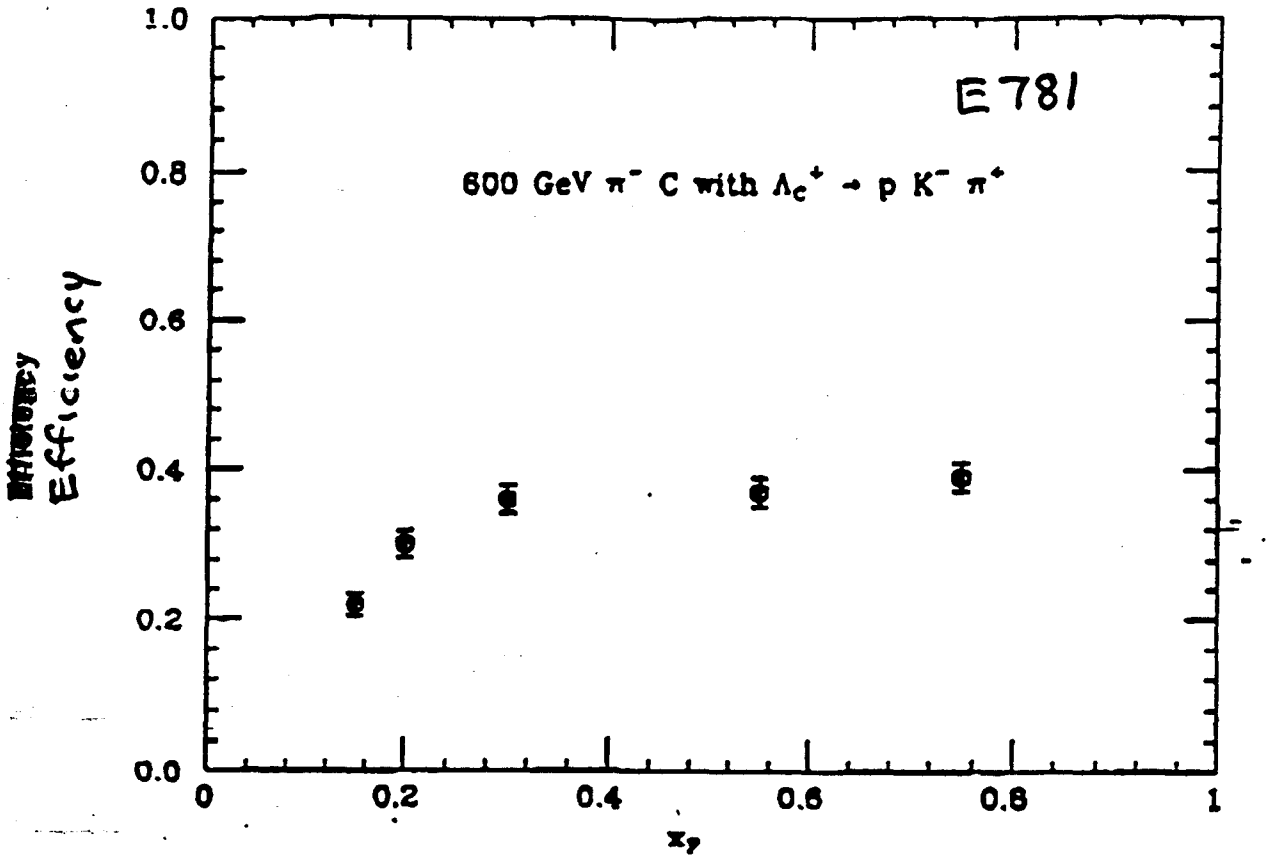
1) FIND BEAM TRACK

2) FIND TRACKS AFTER M2

3) ATTACH SILICON VERTEX HITS TO TRACKS FROM STEP 2

4) ACCEPT EVENT IF ≥1 TRACK MISS BEAM TRACK BY >30μm.

Efficiency: 3 H2 tracks; 1 with AMISS > 30 μm



SIMULATION FOR
COMBINED HARDWARE AND SOFTWARE TRIGGER
EFFICIENCY

EVENT SIMULATION : 600 GeV π^- CARBON INTERACTION
(FRITIOF PROGRAM)

ADD $\Lambda_c^+ \to p K^- \pi^+$ EVENT AT x_F POINT;
RESCALE BACKGROUND PE TO CONSERVE
$\Sigma P_{E_i} = 600$ GeV.

TRACK ALL CHARGED PARTICLES;
DEMAND THAT HARDWARE TRIGGER
CONDITION IS SATISFIED.

WHAT IS THE PHYSICS YIELD FROM E-781 ?

CONSIDER THE "CLASSIC" DECAY $\Lambda_c^+ \to p K^- \pi^+$

PRESENT WORLD DATA SETS DOMINATED BY

CLEO	~ 6000 $\Lambda_c^+ \to p K^- \pi^+$	NO VTX INFO. $S/B \lesssim 1/5$
E687	~ 1500 $\Lambda_c^+ \to p K^- \pi^+$	LIFETIME MEASUREMENT $S/B \sim 1/3$

USING MEASURED HADRONIC CROSS SECTIONS AND SIMULATION-BASED RECONSTRUCTION EFFICIENCIES, E781 EXPECTS

INCLUDES:
PRIMARY VTX
SECONDARY VTX
NO AMBIGUOUS TRACKS

$\boxed{100{,}000 \quad \Lambda_c^+ \to p K^- \pi^+}$

LIFETIME MEASUREMENT $S/B \sim 1/1.5$

REMEMBER, ALL OTHER MODES WILL BE SEEN WITH COMPARABLE GAIN IN STATISTICS.

- GOOD SEMILEPTONIC DATA
- RARE DECAY CHANNELS $\Lambda_c^+ \to p + \gamma$ FOR
- POLARIZATION STUDIES

FOR C-S BARYONS, PRESENT SAMPLES ARE "A FEW HUNDRED" FROM WA 89 MEASUREMENTS IN A HYPERON BEAM, E781 EXPECTS

$> 50{,}000$	$\Xi_c^+ \to \Lambda K^- \pi^+ \pi^+$
$> 50{,}000$	$\Xi_c^0 \to \Lambda K^- \pi^+$
$> 5{,}000$	$\Omega_c^0 \to \Xi^- K^- \pi^+ \pi^+$

ALONG WITH SEMI-LEPTONIC DATA AND MANY OTHER MODES

Fermilab E687 Collaboration

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E687 → E831

A High Statistics Study of States Containing Heavy Quarks Using the Wideband Photon Beam and the E687 Multiparticle Spectrometer

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Physics of a High Statistics Charm Experiment

1. $D^0 - \overline{D^0}$ Mixing and Doubly-Suppressed Cabibbo Decays

   300K $D^0 \to K^- \pi^+$

   (a) Classic Mechanism using the well-known box diagram predicts mixing at the 10^{-6} level, but long distance effects may be important and estimates are as large as 5×10^{-4}.

   ~60K from $D^{*+} \to \pi^+ D^0$

   (b) Conclusively identify several DCSD channels, D^+ is clearest with signature not confused with mixing. Sample channels are $D^+ \to K^+K^+K^-$, $D^+ \to K^+\pi^+\pi^-$, $D^+ \to K^+\rho^0$, and $D^+ \to K^+\omega$.

2. Absolute Branching Fractions

   (a) CLEO value 2% Statistical and 4.4% Systematic

   (b) Measurement of BR($K^-\pi^+$) to 2% or better

   (c) Measurement of BR($K^-\pi^+\pi^+$) to 3% or better

3. Semileptonic Decays

   $D^0 \to K^- \mu^+ \nu$ 20K from D^{*+}

   $K^- e^+ \nu$ ~10K

   $D^0 \to \pi^- \mu^+ \nu$ ~2K

   (a) Measurement of $|V_{cs}|$ to 1%

   (b) Measurement of $|V_{cd}|$ to 2%

   (c) Measurement of $|V_{cd}|/|V_{cs}|$ to 1.5%

   (d) Measurement of vector and axial vector form factors might be used to predict the Beauty form factors

Fixed Target D^o Absolute Branching Ratios

1. Basic idea
   (a) Fully reconstruct a recoil charm particle ($\overline{D}^{(r)}$)
   (b) Find $\tilde{\pi}$ from $D^{*+} \rightarrow \tilde{\pi}^+ D^o$ Decays
   - Correlate $\tilde{\pi}$ charge and P_t with $\overline{D}^{(r)}$
   - The $\overline{D}^{(r)}$ serves to "tag" the $\tilde{\pi}$

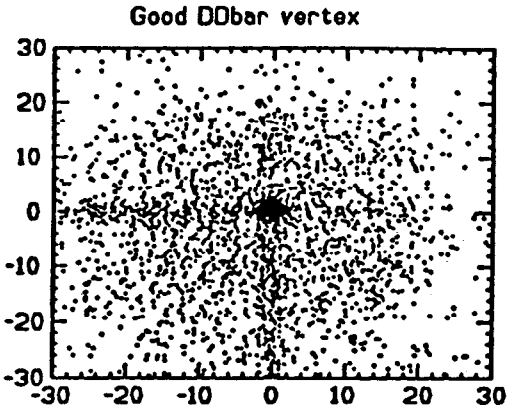
   (c) Reconstruct specific πD^o final state against $\overline{D}^{(r)}$

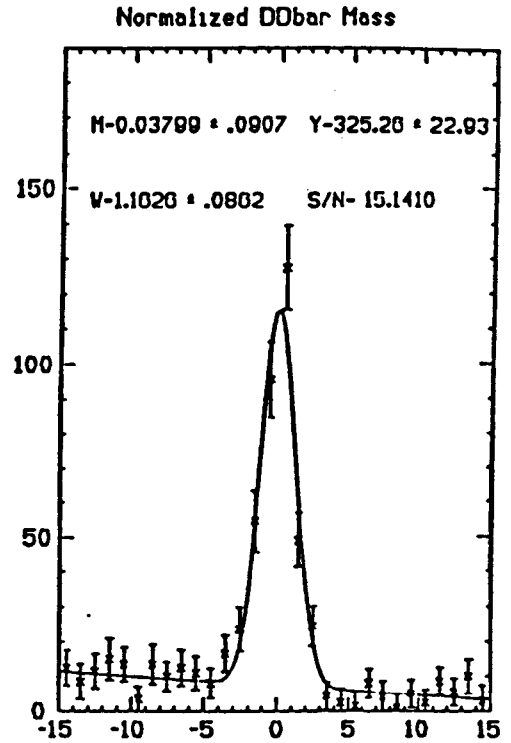
$$BR(K\pi) = \frac{1}{\epsilon} \frac{(K\pi)\tilde{\pi}^+}{(\quad)\tilde{\pi}^+}$$

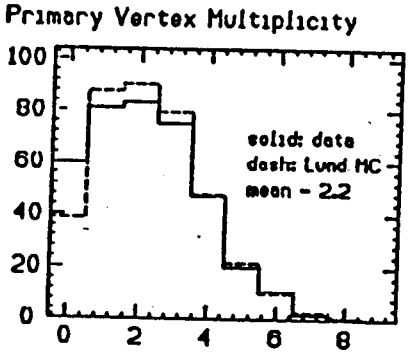
- Statistics limited –both D and $\overline{D}^{(r)}$ reconstructed!
- Combine several channels to improve statistics.

Expect $\pm 2.5\% \rightarrow 4\%$ fractional errors

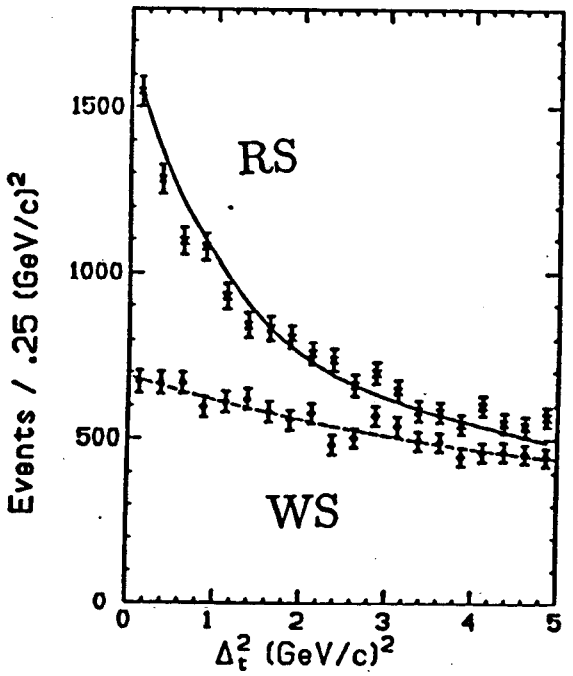
IN E831

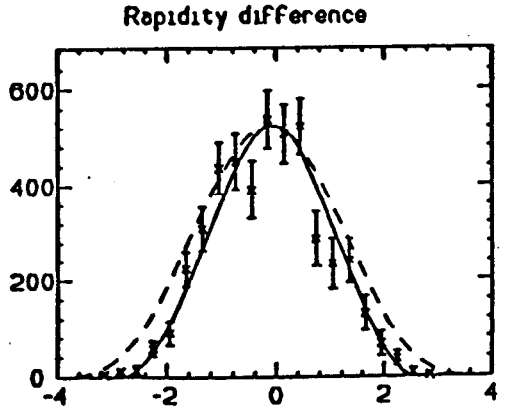






Pt Balance $\Delta_t^2 = \left(\vec{D}_t + (m_*/m_\pi)\vec{\pi}_t\right)^2$





$$\gamma g \rightarrow D^{*-} D \rightarrow (\tilde{\pi}^- \underline{D}) \;\; D$$

$D^+ \to \overline{K}^{*0}\mu\nu$ Form Factors

1. As $M_\ell \to 0$:

$$H_\pm = \alpha\ A_1\ (t) \mp \beta\ V(t)$$

$$H_o = \delta\ A_1\ (t) - \epsilon\ A_2(t)$$

$$\alpha(t, M_{K\pi}, K)\ ,\ \beta(t, M_{K\pi}, K)\ ,\ \delta(t, M_{K\pi}, K)\ ,\ \epsilon(t, M_{K\pi}, K)$$

α, β, δ, and ϵ are functions of t, $M_{K\pi}$, and K

2. Following E691:

$$R_V = \frac{V(0)}{A_1(0)}\ \ ,\ \ R_2 = \frac{A_2(0)}{A_1(0)}$$

$$F(t) = \frac{F(0)}{1 - t/M_p^2}$$

- $M_V = 2.1\ M_{A_1} = 2.5\ M_{A_2} = 2.5$

3. Polarization:

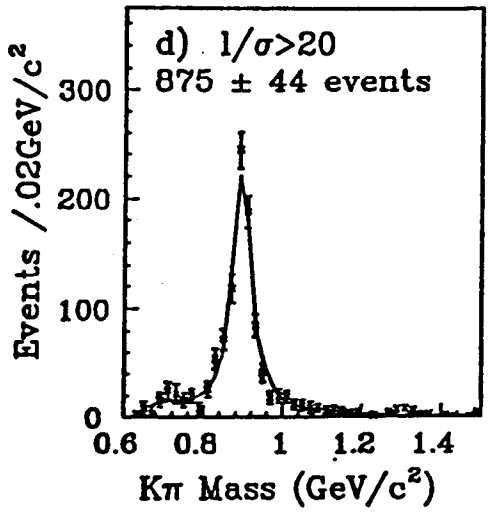
$$\frac{dN}{d\Omega} \propto 1 + \left(\frac{2\Gamma_\ell}{\Gamma_t} - 1\right)\ cos^2\ \theta_v$$

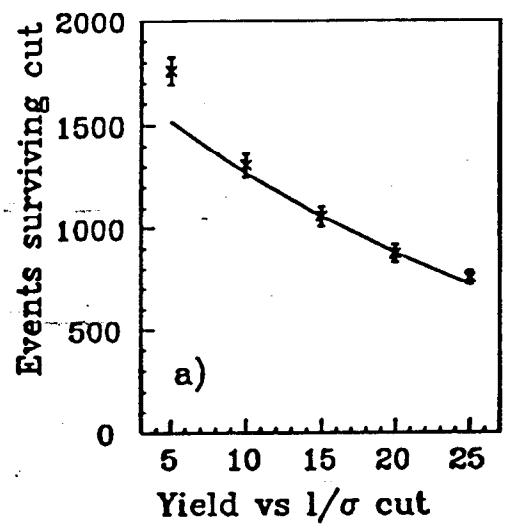
$$\frac{\Gamma_\ell}{\Gamma_t} = \frac{\int dt\ G(t)\ |H_o(t)|^2}{\int dt\ G(t)\ \ (|H_+(t)|^2 + |H_-(t)|^2)}$$

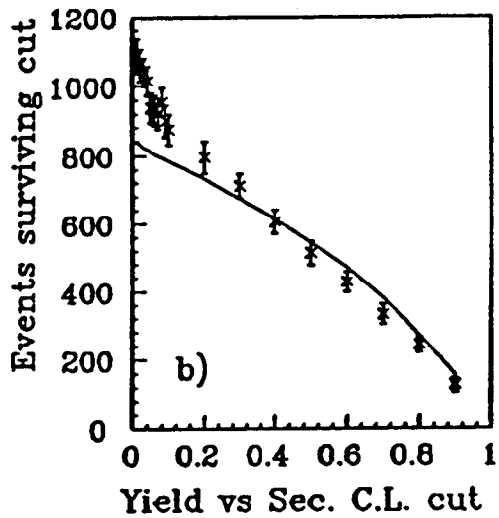
- $G(t)$ depends on M_ℓ

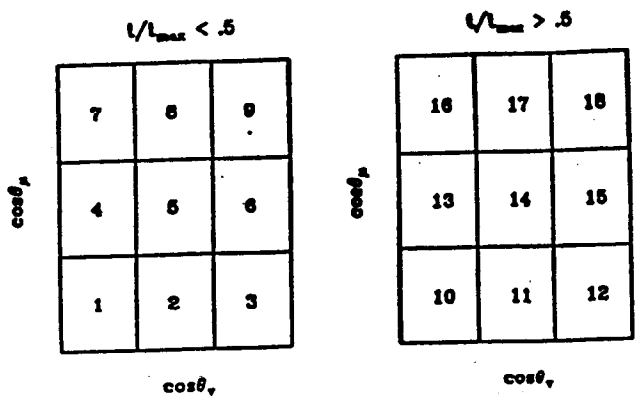
E687

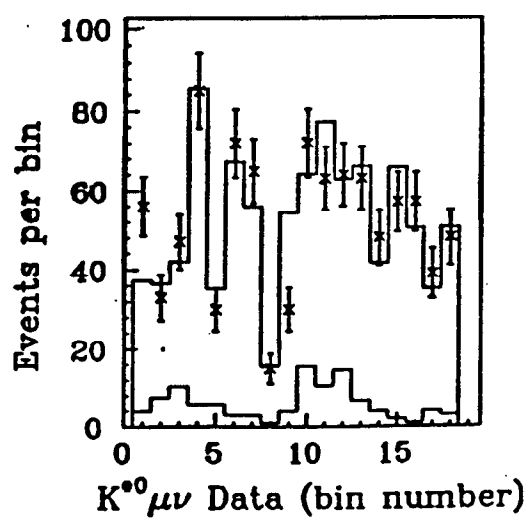
$D^+ \to \overline{K}^{*0} \mu^+ \nu$



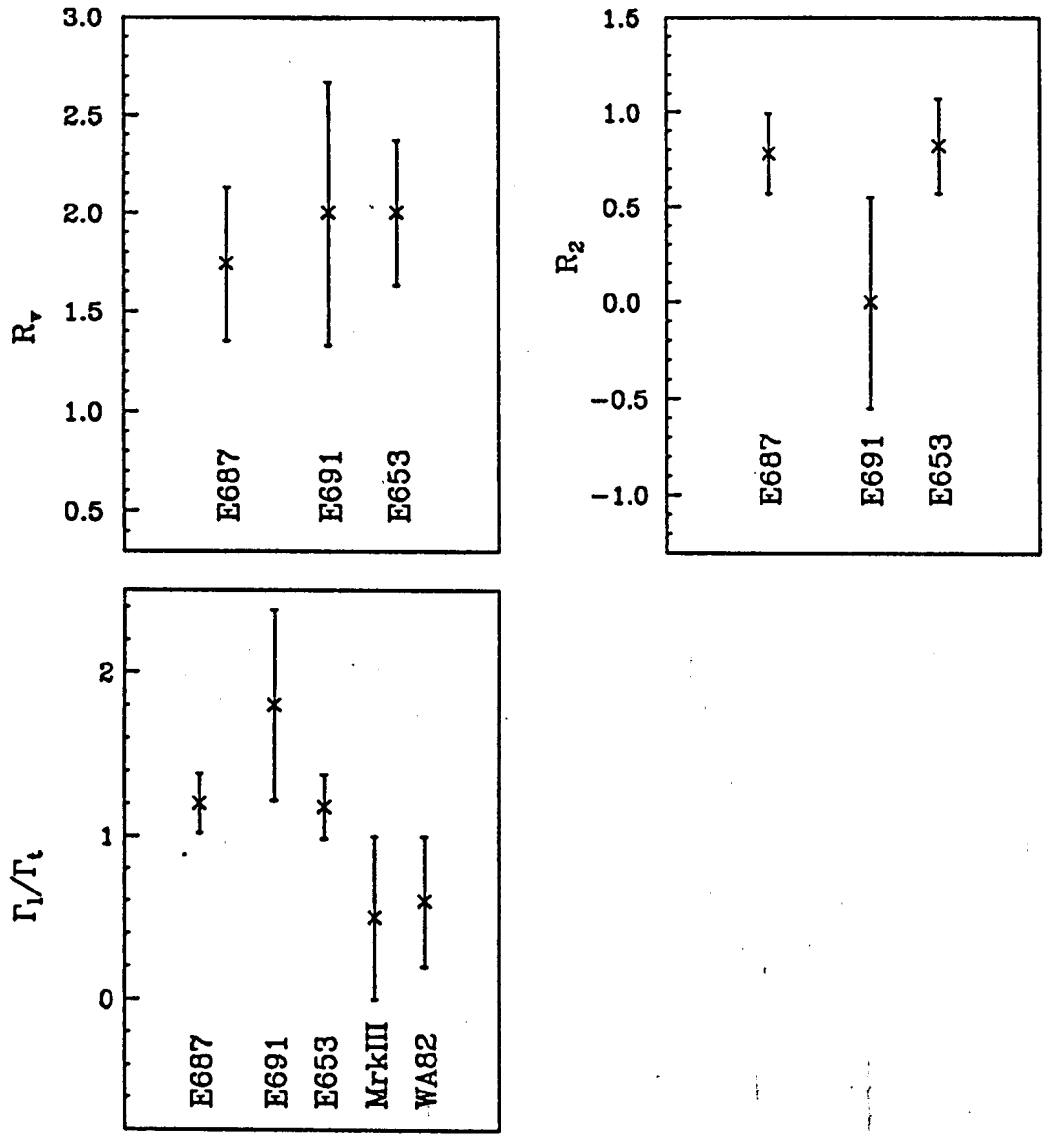








Experiment comparisons



Comparing Experiment to Theory

A Fixed-target Average

Exp	R_2	R_v	Γ_l/Γ_t
E687/E691/E653	$.74 \pm .14$	$1.86 \pm .20$	$1.21 \pm .10$

- The confidence level that the three experiments agree on R_2 and R_v is 60%.

- Compute confidence level (CL) of agreement between this and theory

Authors	CL(%)	R_2	R_v	Γ_l/Γ_t
BSW[1]	1	1.31	1.44	.91
KS[1]	1	1.0	1.0	1.16
AW/GS[1]	99	.75	1.88	1.20
BBD[2]	7	$1.2 \pm .2$	$2.2 \pm .2$	$.86 \pm .11$
ELC[3]	47	$.01 \pm .7$	$1.63 \pm .27$	$1.84 \pm .63$
BES[3]	95	$.70 \pm .16 \,^{+.20}_{-.15}$	$1.99 \pm .22 \,^{+.31}_{-.35}$	$1.21 \pm .12 \,^{+.15}_{-.13}$

[1] Quark models, [2]QCD sum rules, [3]Lattice

$D_s^+ \to \phi\mu\nu$ Form Factors

<u>All Exp</u>:

1. Reconstruct the decay as for the D^+ case
2. no WS

Exp	mode	sample	fit to	Method
E653	μ	19	θ_v,θ_μ,t	MC wht
E687	μ	90 ± 12	θ_v,θ_μ,t,χ	MC wht bins

- Statistically dominated

	R_v	R_2	Γ_ℓ/Γ_t
E653	$2.3\ ^{+1.1}_{-0.9} \pm 0.4$	$2.1\ ^{+0.6}_{-0.5} \pm 0.2$	$.54 \pm .21 \pm .10$
E687	$1.8 \pm 0.9 \pm 0.2$	$1.1 \pm 0.8 \pm 0.1$	$1.0 \pm .5 \pm .1$
E653 (D^+)	$2.00\ ^{+.34}_{-.32} \pm .16$	$.82\ ^{+.22}_{-.23} \pm .11$	$1.18 \pm .18 \pm .08$
E687 (D^+)	$1.74 \pm 0.27 \pm 0.28$	$0.78 \pm 0.18 \pm 0.10$	$1.20 \pm .13 \pm .13$

- E687 consistent with $D_s^+ \approx D^+$
- E653 R_2 may disagree

E831 Extrapolations

	Now (K^*)	$K^*\mu\nu$ 20 000	$\phi\mu\nu$ 2250	$\rho\mu\nu$ 500
$\sigma(R_v)$	$\pm.20$	.05	.15	.32
$\sigma(R_2)$	$\pm.14$	.04	.11	.23
$\sigma(\Gamma_\ell/\Gamma_t)$	$\pm.10$	.02	.06	.13
$\sigma(M_v)$	($\pm.10$)	.16	.50	1.0
$\sigma(M_a)$		.38	1.2	2.5

- Theoretical uncertainty $\approx 5\%$
- Background Systematics ≈ 10 %
    - But > statistics leads to > understanding.

- Full expression for the rate

$$\frac{d\Gamma}{dE_K} = \frac{G_F^2}{4\pi^3}|V_{cs}|^2\left|f_+(q^2)\right|^2 P_K\left(\frac{W_0 - E_K}{F_0}\right)^2$$

$$\left[\frac{1}{3}m_D P_K^2 + \frac{1}{3}m_l^2\frac{P_K^2}{F_0}\right.$$

$$+\frac{m_l^2}{8m_D}(m_D^2 + m_K^2 + 2m_D E_K)$$

$$+\frac{1}{4}m_l^2\frac{m_D^2 - m_K^2}{m_D}Re\left(\frac{f_-(q^2)}{f_+(q^2)}\right)$$

$$\left.+\frac{1}{4}m_l^2 F_0\left|\frac{f_-(q^2)}{f_+(q^2)}\right|^2\right],$$

$$W_0 = \frac{m_D^2 + m_K^2 - m_l^2}{2m_D},$$

$$F_0 = W_0 - E_K + \frac{m_l^2}{m_D}$$

- Must measure both muon and electron modes to get f_- behavior

- Other experiments M_{pole} compared to E687

Exp.	Mode	m_{pole}
E691	$K^- e^+ \nu_e$	$2.1^{+0.4}_{-0.2} \pm 0.2$
CLEO(91)	$K^- e^+ \nu_e$	$2.1^{+0.4+0.3}_{-0.2-0.2}$
MKIII	$K^- e^+ \nu_e$	$1.8^{+0.5+0.3}_{-0.2-0.2}$
CLEO(93)	$K^- l^+ \nu_l$	$2.0 \pm 0.12 \pm 0.18$
E687	$K^- \mu^+ \nu_\mu$	$1.98^{+0.13+0.04}_{-0.10-0.10}$ *

$$\overline{m}_{pole} = 1.99^{+.11}_{-.09}$$

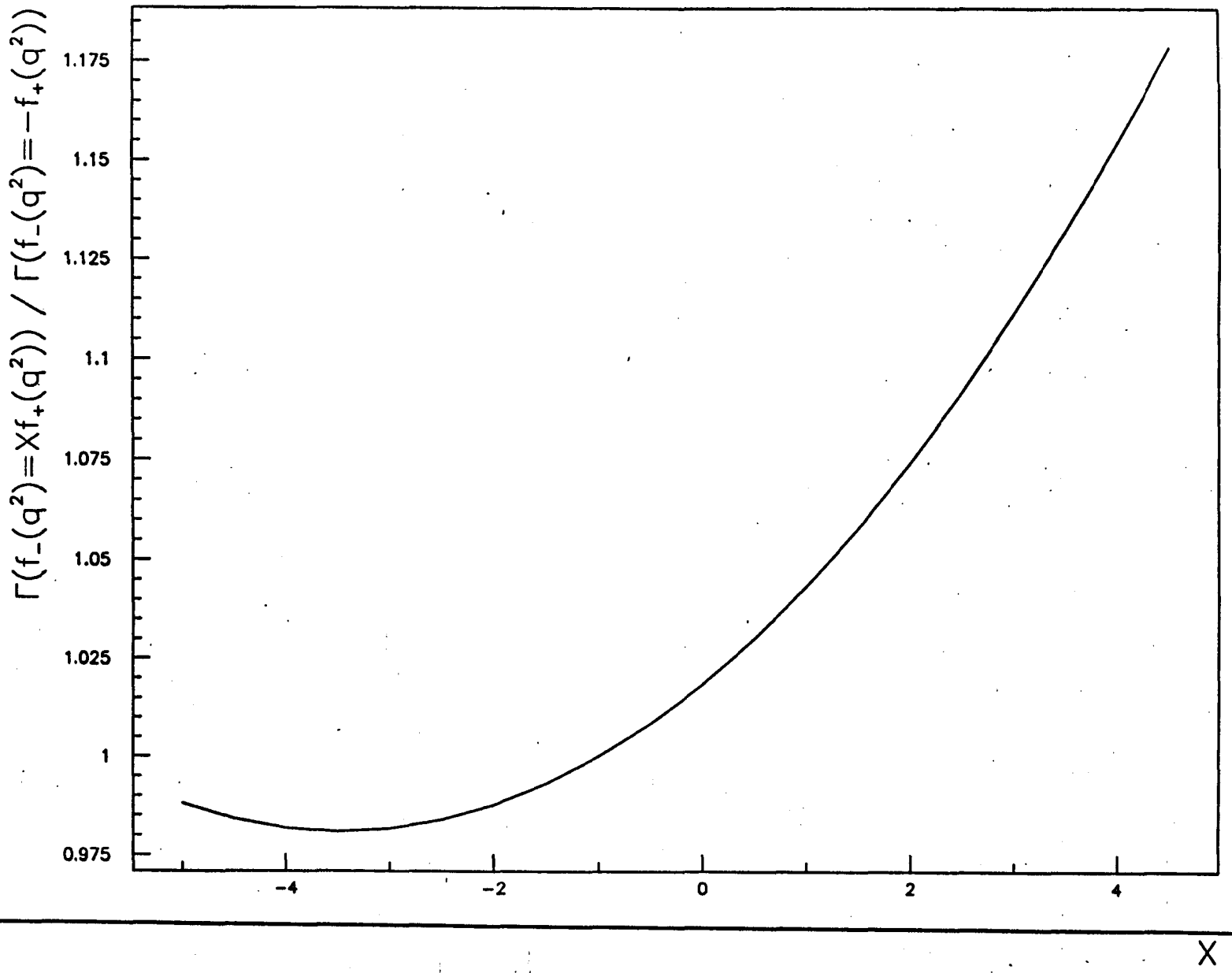
* Preliminary

- Also fit to tagged sample as systematic
  - no variation from data with no tag

- Other experiments relative to $D^0 \to K^-\pi^+$ compared to E687

Exp.	Mode	BR(rel. to $K\pi$
E691	$K^-e^+\nu_e$	$0.90 \pm 0.07 \pm 0.11$
CLEO(91)	$K^-e^+\nu_e$	$0.91 \pm 0.06 \pm 0.06$
CLEO(91)	$K^-\mu^+\nu_\mu$	$0.79 \pm 0.08 \pm 0.09$
E687(93)	$K^-\mu^+\nu_\mu$	$0.82 \pm 0.13 \pm 0.13$
CLEO(93)	$K^-l^+\nu_l$	$0.978 \pm 0.027 \pm 0.044$
E687(94)	$K^-\mu^+\nu_\mu$	$0.860 \pm 0.028^{+0.042}_{-0.039}$ *

* Preliminary


$\Gamma(f_-(q^2)=Xf_+(q^2)) / \Gamma(f_-(q^2)=-f_+(q^2))$
1.175
1.15
1.125
1.1
1.075
1.05
1.025
1
0.975
-4
-2
0
2
4
X

- Other experiments $f_+(0)$ compared to E687

Exp.	Mode	$\mid f_+(0) \mid$
E691	$K^- e^+ \nu_e$	$0.79 \pm 0.05 \pm 0.06$
CLEO(91)	$K^- e^+ \nu_e$	$0.81 \pm 0.03 \pm 0.06$
MKIII	$K^- e^+ \nu_e$	$\mid V_{cs} \mid (0.72 \pm 0.05 \pm 0.04)$
CLEO(93)	$K^- l^+ \nu_l$	$0.77 \pm 0.01 \pm 0.04$
E687	$K^- \mu^+ \nu_\mu$	$0.730^{+0.020+0.029}_{-0.021-0.033}$ * †

* use $|V_{cs}| = .9743$

† preliminary

$D^o \to K^-\ell^+\nu$ form factor

- Find $\Gamma(K\mu\nu)$ using abs. BR, τ
- assume V_{cs}
- assume simple pole
- integrate to find: $|f_+(0)|$

Exp.	Mode	m_{pole}	$\mid f_+(0) \mid$
E691	$K^-e^+\nu_e$	$2.1^{+0.4}_{-0.2} \pm 0.2$	$0.79 \pm 0.05 \pm 0.06$
CLEO(91)	$K^-e^+\nu_e$	$2.1^{+0.4+0.3}_{-0.2-0.2}$	$0.81 \pm 0.03 \pm 0.06$
CLEO(93)	$K^-l^+\nu_l$	$2.00 \pm 0.12 \pm 0.18$	$0.77 \pm 0.01 \pm 0.04$
MKIH	$K^-e^+\nu_e$	$1.8^{+0.5+0.3}_{-0.2-0.2}$	$\mid V_{cs} \mid (0.72 \pm 0.05 \pm 0.04)$
E687	$K^-\mu^+\nu_\mu$	$1.98^{+\cancel{0.26}+?}_{-\cancel{0.16}-?}$ $^{+.137\ .04}_{-.10\ -.60}$	~~$0.70 \pm 0.04 \pm ?$~~ $0.73^{+.02}_{-.02}{}^{+.029}_{-.033}$

E687 #'s are **PRELIMINARY**

q^2 Dependence: $\boxed{\text{All consistent with } D_s^* = 2.1\text{GeV pole}}$

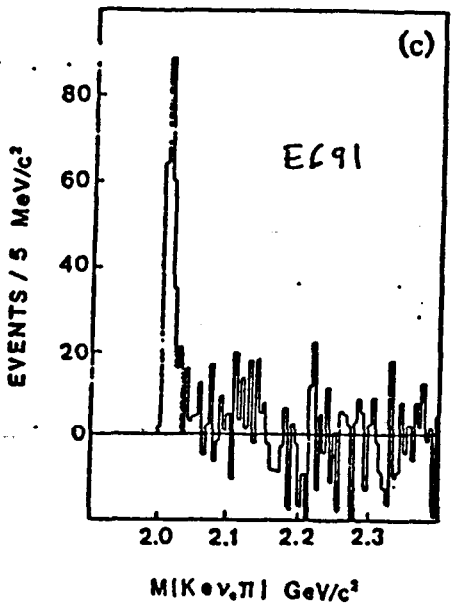
- CLEO II: $f_+(q^2) = f_+(0)e^{\alpha q^2}$

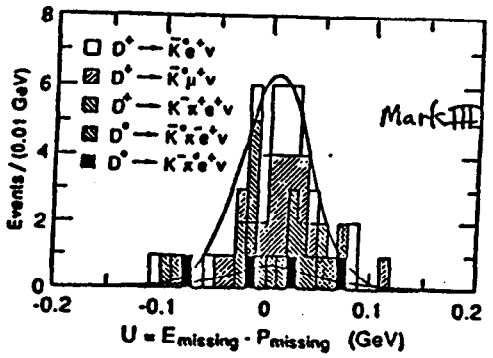
  $\alpha = .29 \pm .04 \pm .06$

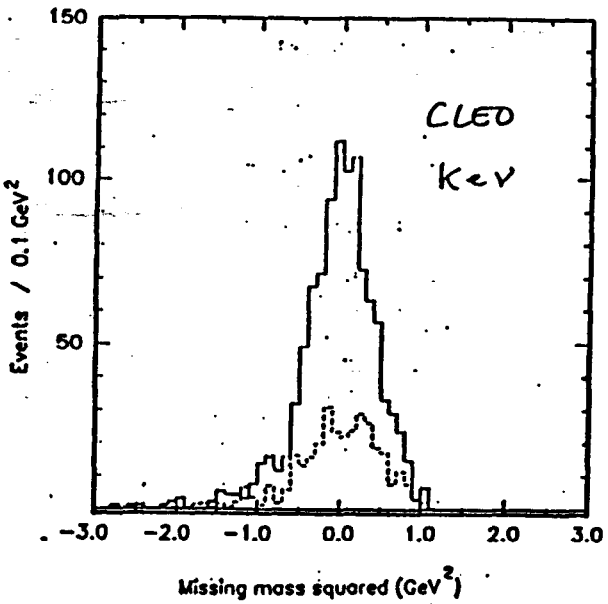
$f_+(0)$: $\boxed{\text{Agrees with predictions } (\approx .7)}$

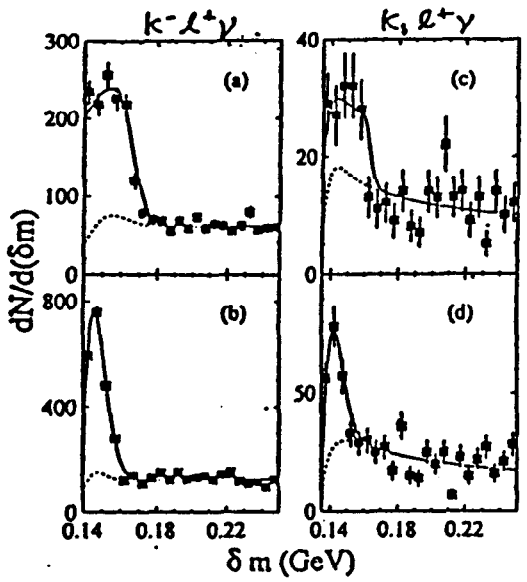
$$\frac{(D^o \to K^-\mu^+\nu)}{(D^o \to K^-\pi^+)} = 0.86 \pm 0.028 \; {}^{+.042}_{-.039}$$

Kℓν Signals

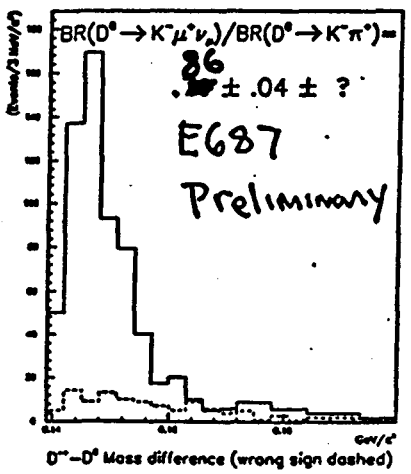




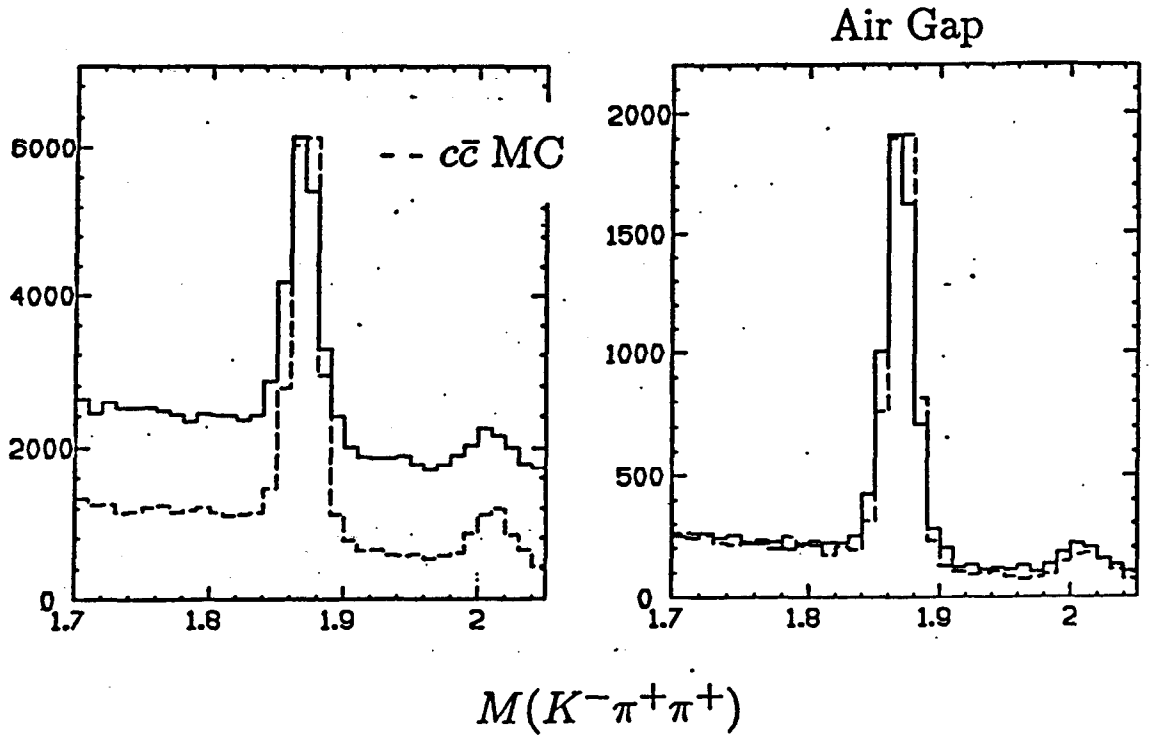




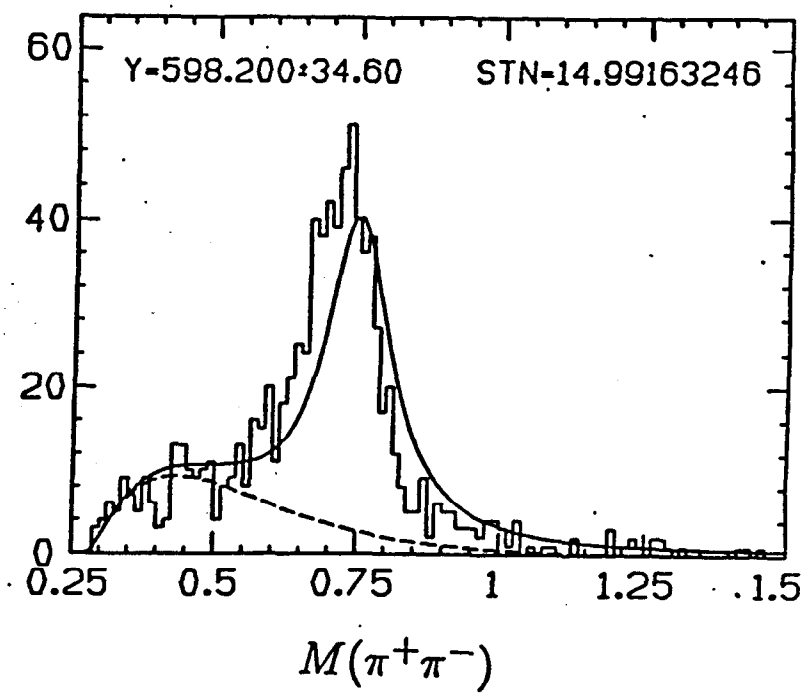
CLEO



Today's signal → Tomorrows' background



$D^+ \to K^*\mu^+\nu$ mimics $D^+ \to \rho\mu^+\nu$ (Loose $\check{C}$)



4. Leptonic Decays – f_D pseudoscalar decay constant
   (a) Involves observing $D^+ \to \mu\nu_\mu$, $D^{+*} \to D^+\pi^0$
   (b) Also search for $D_s^+ \to \tau^+\nu_\tau$
5. D_s^+ Decays
   (a) 20,000 $D_s^+ \to K^+K^-\pi^+$
   (b) Study excited states
6. Λ_c^+ Decays
   (a) 20,000 $pK^-\pi^+$
   (b) Absolute Branching Ratio (20% or better)
   (c) Search for new modes (containing neutrons) using the Λ^{+*} tags
7. D^{**} States
   (a) Look at carefully with very clean Double D samples
8. Charmed Baryon Spectroscopy and Lifetimes
   (a) Demonstrated ability to form states with Λ^0, $\Sigma^\pm$, Ξ^-, and Ω^-
   (b) New ability to use Ξ^0 as a daughter decay particle
   (c) Search for Doubly-charmed baryons
9. Hadronic Decays of the D^0 and D^+
   (a) Improved Dalitz Plot Analysis
   (b) Ability to use K_L^0 with new hadron calorimeter

10. Study charm production dynamics and make a detailed comparison with models
    (a) Double charm events will be particularly useful (10K events)
11. Rare Decays
    (a) Set limits for D^0 decays to $\mu^+\mu^-$ and e^+e^-
    (b) Set limits for $D^0 \to \rho\gamma$ and $D^0 \to K^*\gamma$
12. Forbidden Decays
    (a) μ^+e^-
13. CP Violation Sensitivity
    (a) Difference in rates between D^0 and $\overline{D^0}$ decays using the D^* as a tag
    (b) Polarization tests using $D^+ \to \overline{K^{0*}}K^{+*}$

E831 should lower E687 by factors of 10 - 80

Table 1: 90% CL Upper Limits ($\times 10^5$) on FCNC, LFNV, and LNV Charm Decay Modes.

Type	Mode	E653	E687	E771	E789	E791	PDG	(expt.)
FCNC	$D^0 \to e^+e^-$						13	MK3
	$D^0 \to \mu^+\mu^-$		2.7	1.2	3.1		1.1	E615
	$D^0 \to \rho^0 e^+e^-$						45	CLEO
	$D^0 \to \rho^0 \mu^+\mu^-$	24					81	CLEO
	$D^0 \to \pi^0 \mu^+\mu^-$	17						
	$D^0 \to \overline{K}^0 e^+e^-$						170	MK3
	$D^0 \to \overline{K}^0 \mu^+\mu^-$	25						
	$D^+ \to \pi^+ e^+e^-$						250	MK2
	$D^+ \to \pi^+ \mu^+\mu^-$	22	9.7			4.6	290	CLEO
	$D^+ \to K^+ e^+e^-$						480	MK2
	$D^+ \to K^+ \mu^+\mu^-$	33	8.5				920	MK2
	$D^+ \to \rho^+ \mu^+\mu^-$	58						
	$D_s^+ \to K^+ \mu^+\mu^-$	60						
	$\Lambda_c^+ \to p \mu^+\mu^-$	33						
LFNV	$D^0 \to \mu^\pm e^\mp$						10	ARGUS
	$D^+ \to \pi^+ \mu^+ e^-$						330	MK2
	$D^+ \to \pi^+ e^+ \mu^-$						330	MK2
	$D^+ \to \pi^+ \mu^\pm e^\mp$						380	CLEO
	$D^+ \to K^+ \mu^+ e^-$						340	MK2
	$D^+ \to K^+ e^+ \mu^-$						340	MK2
LNV	$D^+ \to \pi^- e^+ e^+$						480	MK2
	$D^+ \to \pi^- \mu^+ e^+$						370	MK2
	$D^+ \to \pi^- \mu^+ \mu^+$	20	17				680	MK2
	$D^+ \to K^- e^+ e^+$						910	MK2
	$D^+ \to K^- \mu^+ e^+$						400	MK2
	$D^+ \to K^- \mu^+ \mu^+$	33	20				430	MK2
	$D^+ \to \rho^- \mu^+ \mu^+$	60						
	$D_s^+ \to K^- \mu^+ \mu^+$	60						
	$\Lambda_c^+ \to \Sigma^- \mu^+ \mu^+$	72						

Working on a number for each entry

Using sidebands in the dimuon invariant mass spectrum to estimate the background in the D^0 mass region, they find -4.1 ± 4.8 candidate events, and set a limit of $BR(D^0 \to \mu^+\mu^-) < 3.1 \times 10^{-5}$ (90% CL). They believe it is possible that their limit will drop below 1.0×10^{-5} when they include all of their data.

1.2.3 E771 ($D^0 \to \mu^+\mu^-$ Search)

Fermilab E771 also has a preliminary limit on $BR(D^0 \to \mu^+\mu^-)$, from data collected during the 1990–91 fixed-target run with the 800-GeV primary proton beam (interacting in

CP Asymmetry: $(\Gamma_D - \Gamma_{\bar{D}})/(\Gamma_D + \Gamma_{\bar{D}})$

	E687 Measurement	E831 Extrapolation
$D^0 \to K^+K^-$	0.024 ± 0.084	$A_{CP} \pm 0.03$
$D^+ \to K^-K^+\pi^+$	-0.031 ± 0.068	$A_{CP} \pm 0.02$
$D^+ \to K^{*0}K^+$	$-.12 \pm 0.13$	$A_{CP} \pm 0.04$
$D^+ \to \phi\pi^+$	0.066 ± 0.086	$A_{CP} \pm 0.04$

Assumes no improvement in Signal to noise from E687

Plan to Increase our Charm Yield a Factor of 10

- Increase DAQ and Efficiency by a factor of two

1. Previous livetime was 60%
2. Improve Trigger – Change Hadron Calorimeter to Scintillator
3. Detector Upgrades
   (a) Faster and thinner Microstrip
   (b) Segmented Target

- Increase Beam Flux a factor of five

- Assume that we have a year run - same amount of beam as there was in 1990 and 1991 Running periods

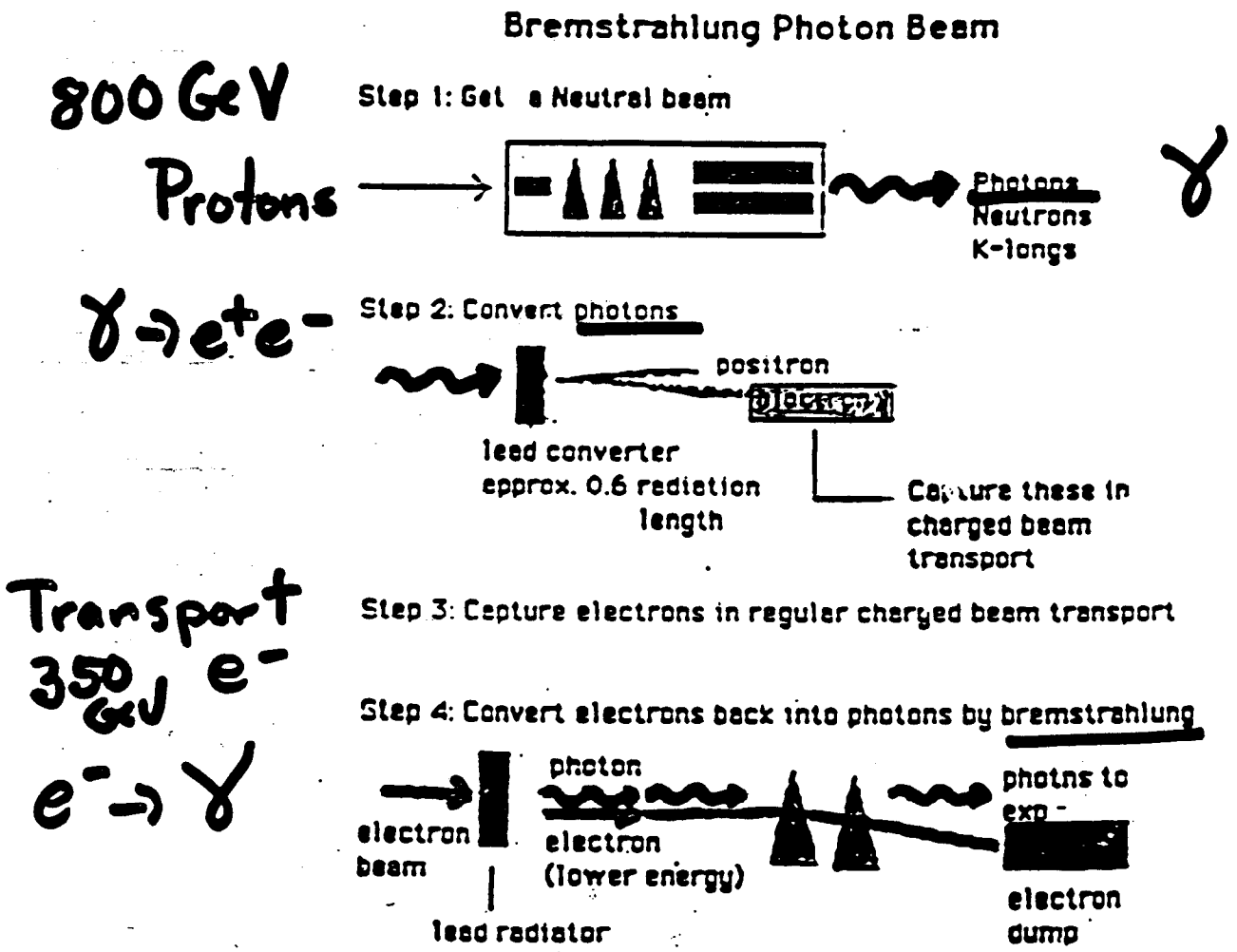
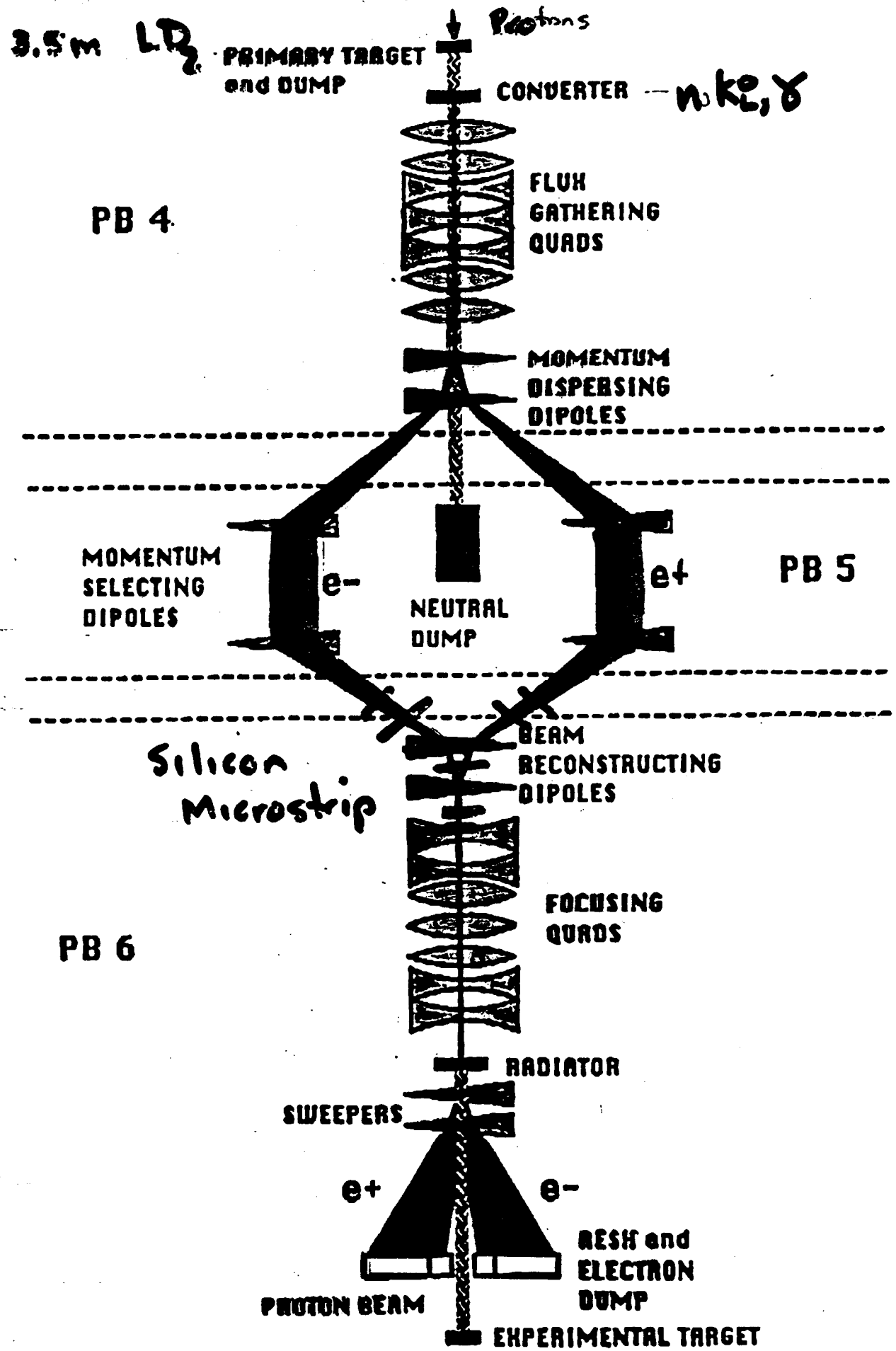
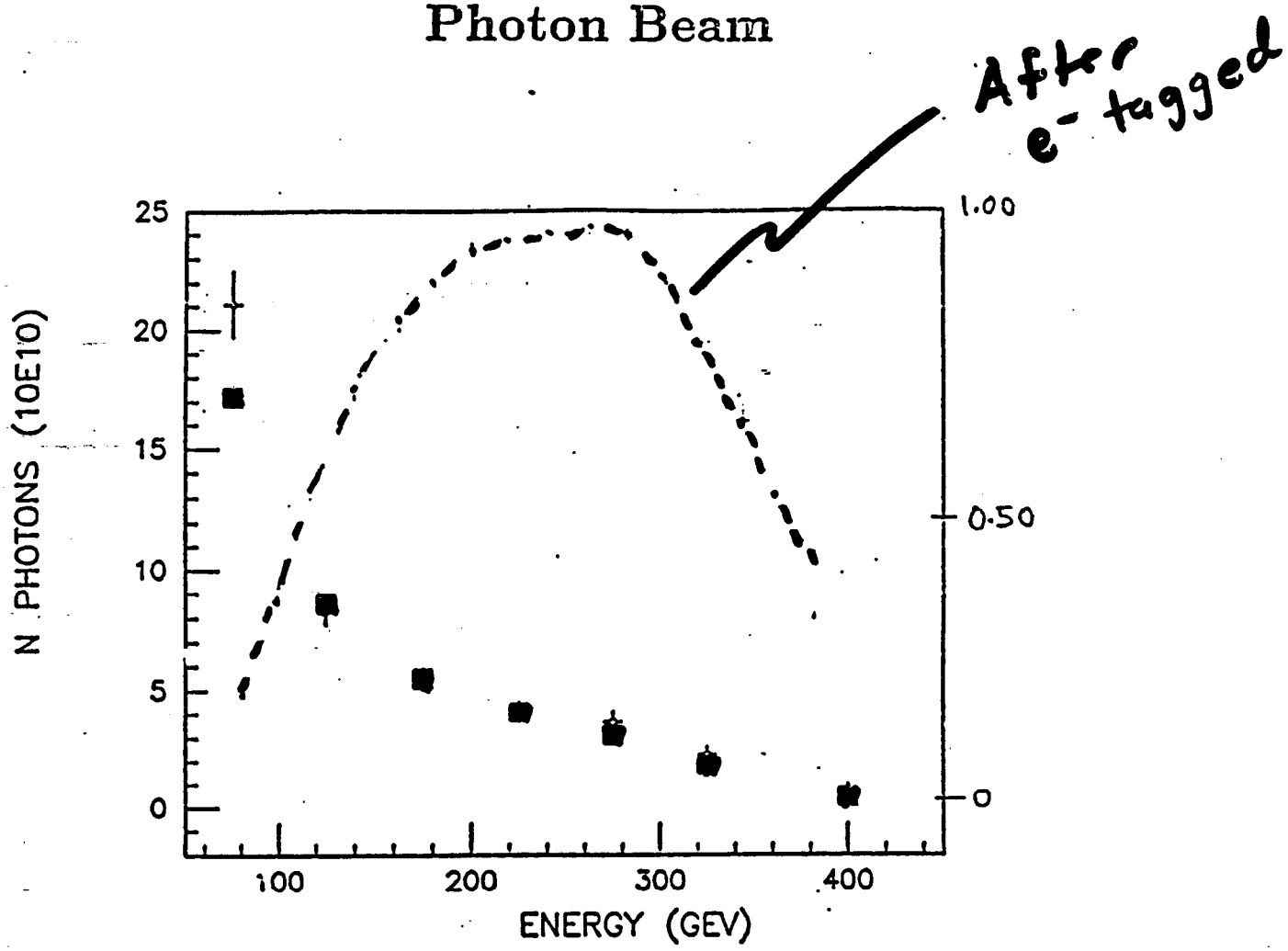


Figure 3: Steps required to produce a bremsstrahlung photon beam


3.5m LD2
PRIMARY TARGET and DUMP
Protons
CONVERTER
n, K°L, γ
PB 4
FLUX GATHERING QUADS
MOMENTUM DISPERSING DIPOLES
MOMENTUM SELECTING DIPOLES
e-
NEUTRAL DUMP
e+
PB 5
Silicon Microstrip
BEAM RECONSTRUCTING DIPOLES
FOCUSING QUADS
PB 6
RADIATOR
SWEEPERS
e+
e-
RESH and ELECTRON DUMP
PHOTON BEAM
EXPERIMENTAL TARGET

Photon Beam



- 350 GeV electron beam with ± 13% momentum spread.
- 30% radiator.

Mean Energy 221 GeV

Method for Obtaining Higher Flux

- Also Use Positron Beam $\times 1.5$
- Change the Secondary Energy
- Reduce Material in Beamline
- Use More Intense Primary Proton Beam 6 $\times 10^{12}$

1. Only need 4.5 $\times 10^{12}$ scaling from last run

- Coherent Bremstrahlung Beam

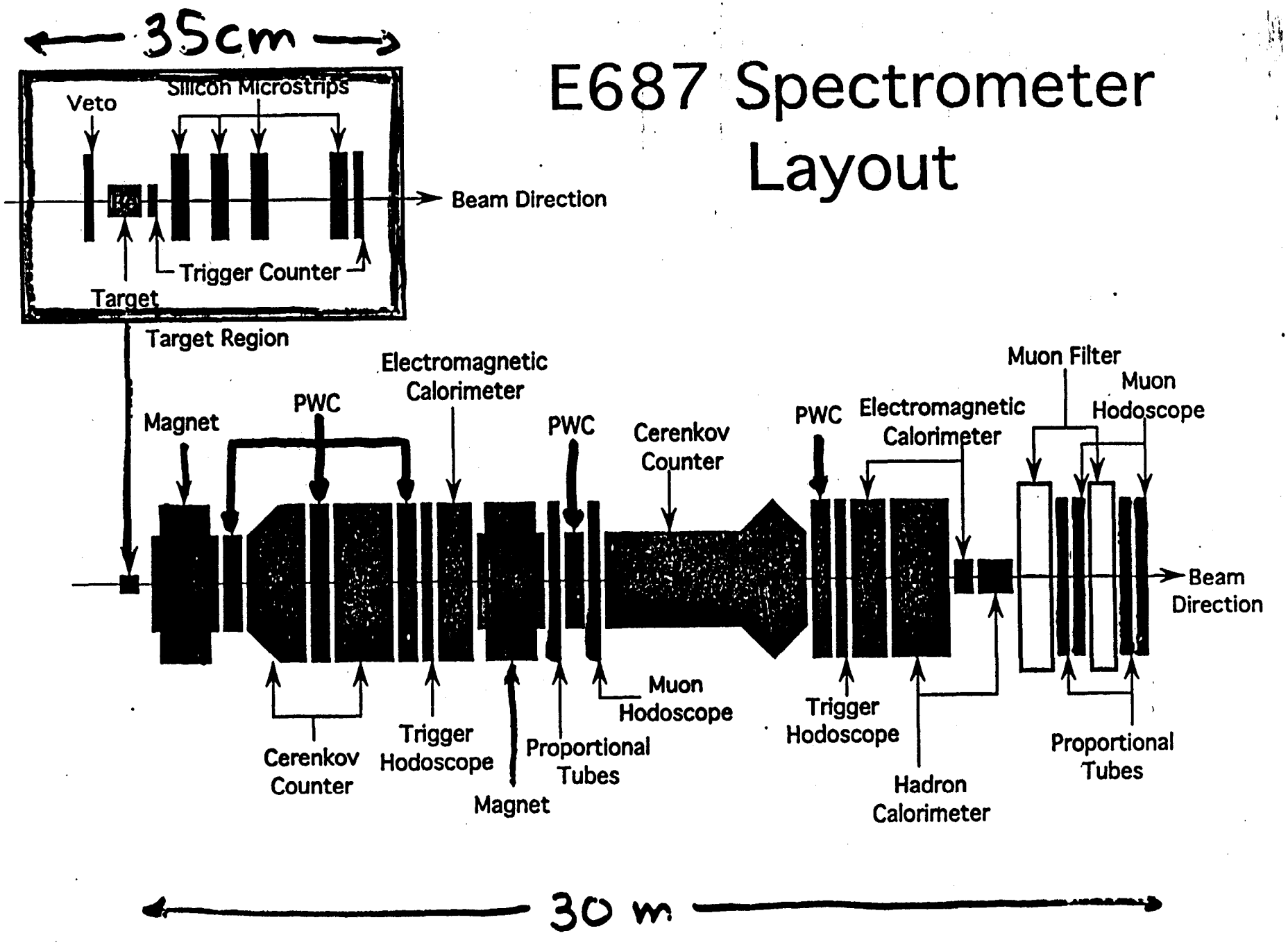
1. Consulted Experts From Europe (Uggerhoj)
2. Calculations underway (Bologna and Artru)

Planned Changes	350 GeV	250 GeV
* Add Positrons	1.5	1.5
[Proton Energy to 900 GeV	1.88	1.68]
* Secondary Energy (includes σ_c)	1.0	(2.65) 2.0
Reduce Material in Beamline	1.1	1.1
More Intensity	1.5	1.5
Total	2.5	5.0

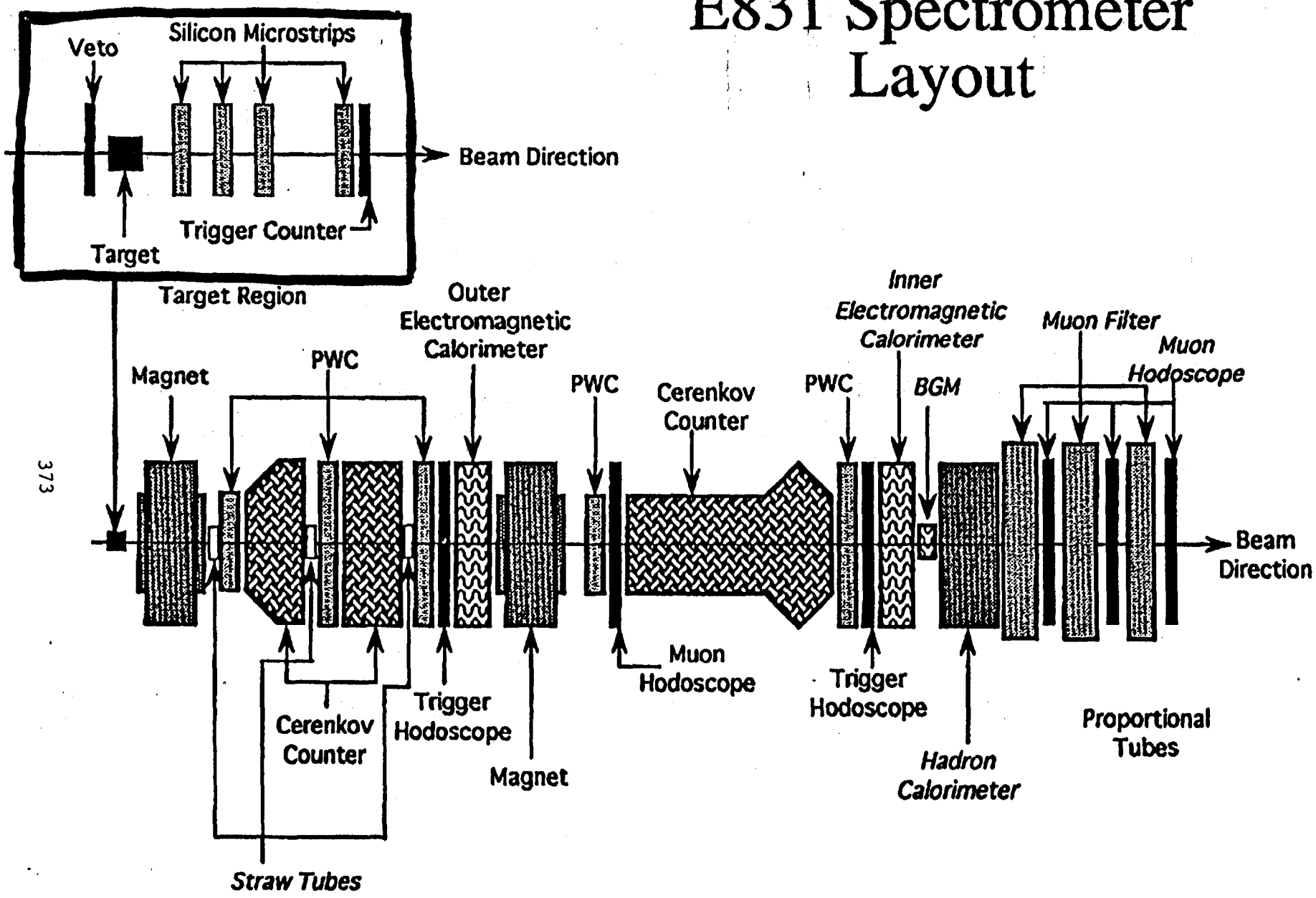
[8.4]

* Actual Measurements

E687 Spectrometer Layout



E831 Spectrometer Layout



E831 Changes from E687

1. SSD
   (a) Faster
   (b) Thinner
2. MWPC
   (a) Lower gain - get more efficiency
   (b) Deaden Central Region
   (c) Add straw tubes in central region to keep good efficiency
3. New fast Hadron Calorimeter
   (a) Tower Geometry
   (b) Scintillating tiles
4. Segmented Target
   (a) Allows for 50% of D^0's to decay outside of target
5. Upgraded and expanded muon system
   (a) Expect at least a factor of 20 increase in decays containing muons
   (b) Inner muon signals should have 4× better pion misidentification
   (c) Outer muon detector to be made faster and will further increase our muon yields

6. Improved Electromagnetic Calorimetry
   (a) Change from Scintillating fiber to Lead Glass
   (b) Outer Electromagnetic calorimeter to have better pattern recognition
7. New Data Acquisition System
8. Improved trigger
   (a) Transverse Energy Trigger
   (b) Zero degree blind counter
9. Improved Monte Carlo
   (a) Allows for many more particles
   (b) Ready to go from E687 Experience

Modifications to the E687 Apparatus

- *Segmented Target*

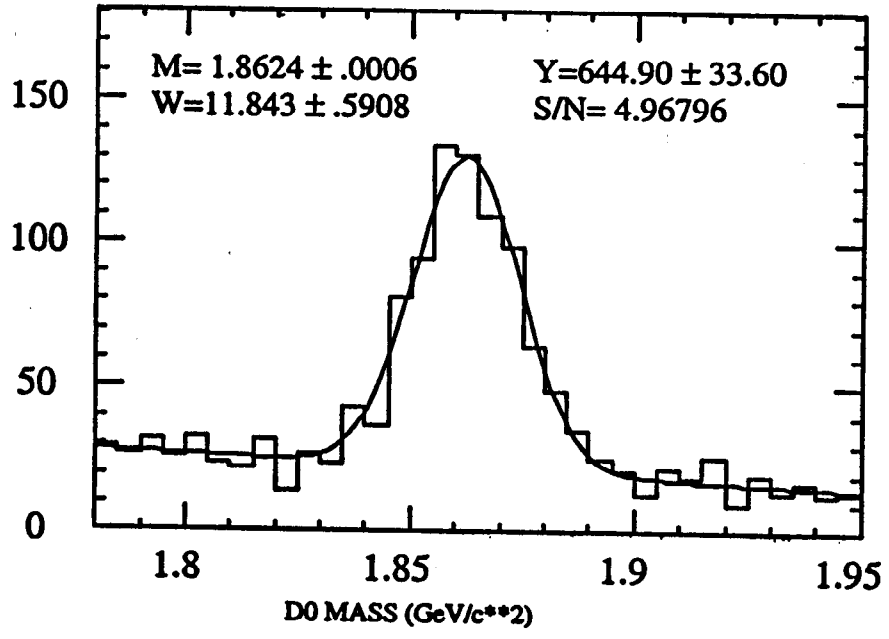
1. Segmented Target allows for better Signal to Noise
2. Denser Target allows for 50% of D^0 outside target
3. Diamond Target Could Be Instrumented (Colorado)

- *Microstrip Detector* (Milan Group)

1. Replace Preamps to shorten gate to 50ns
   (a) Already submitted production of new monolithic preamps
   (b) New preamps have 20% reduced noise from old
2. New frames, fanouts, and supports being readied
   (a) Dissipate additional heat from new preamps
   (b) G-10 to Alumina frames improves rigidity and reduces bowing
3. Wafer thickness will be reduced
   (a) Tests will be made on 250 micron and 140 micron thick pieces obtained from Micron Semiconductor.
   (b) Decision on the thickness to be made in June 1994

K π Background study: in and outside E687 target

OUT OF TARGET



IN TARGET

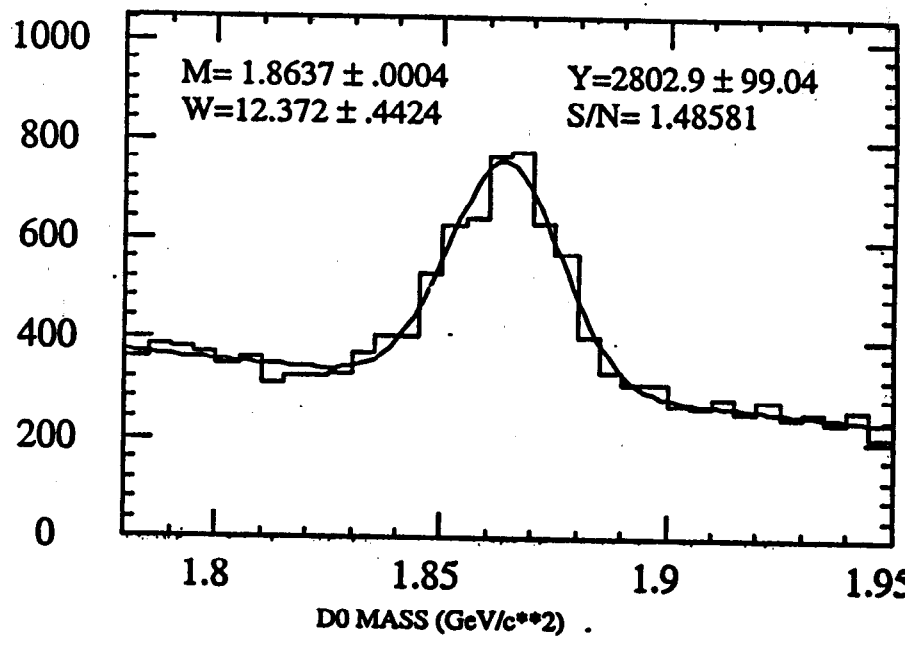
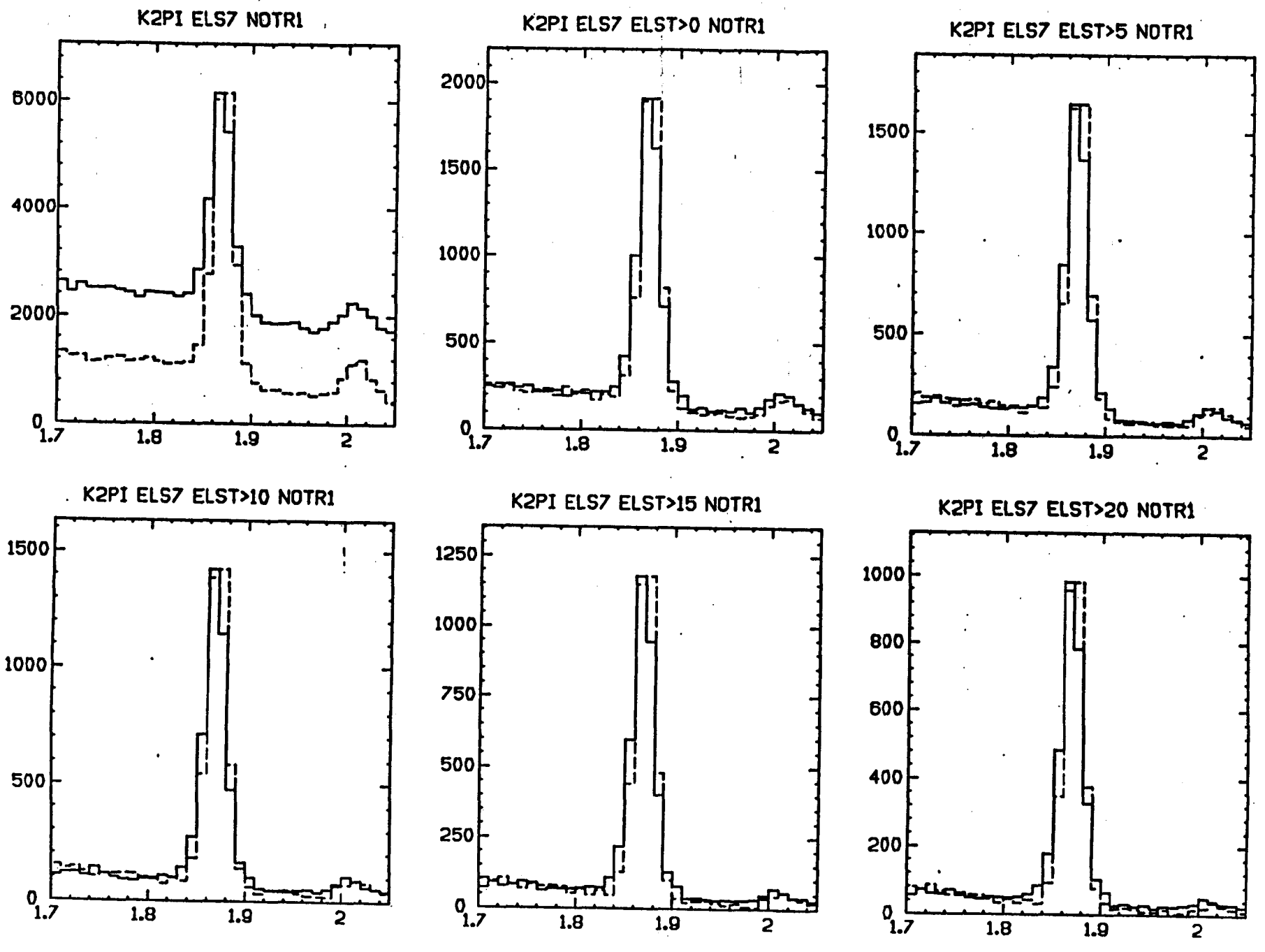
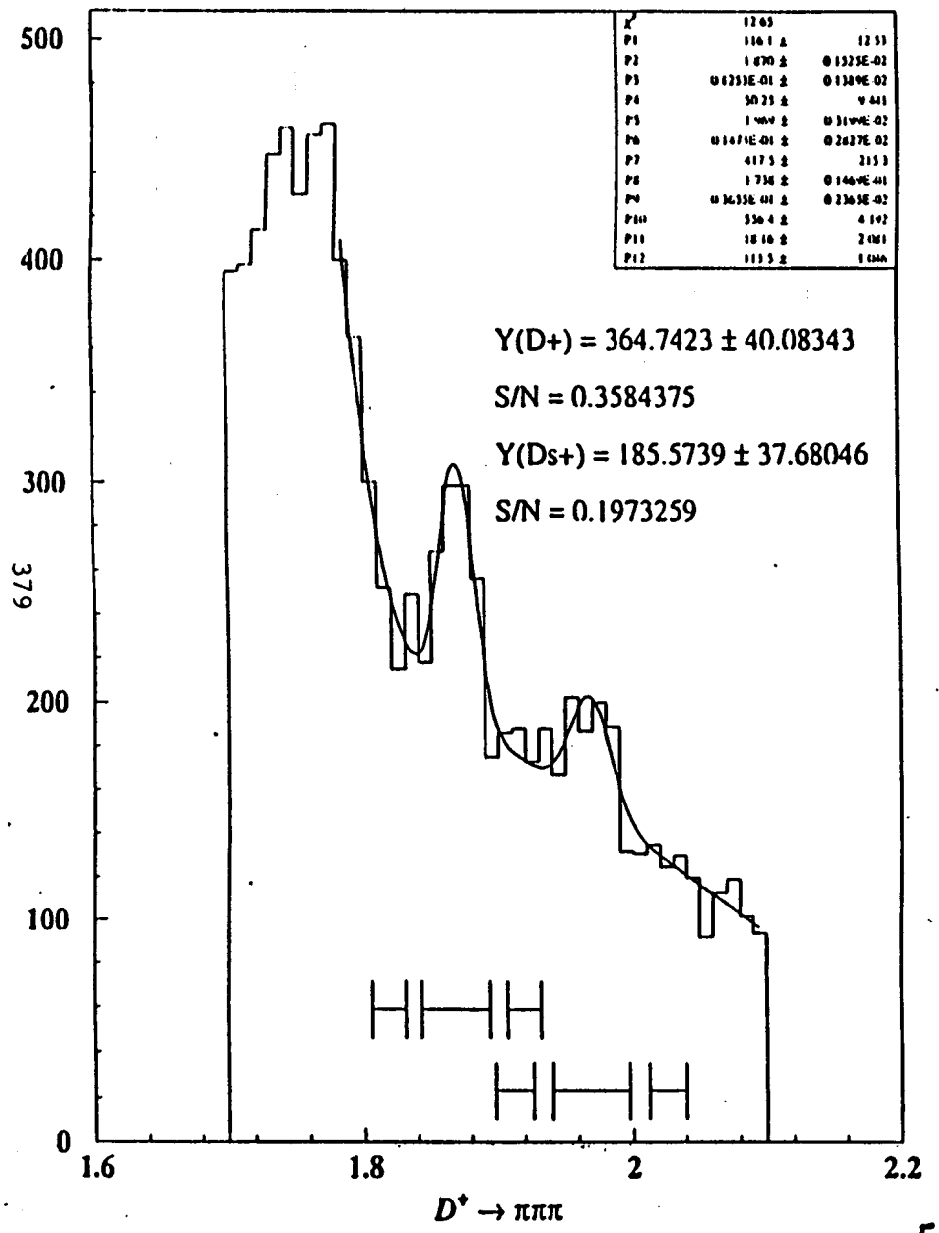


Fig 10: Cutting downstream of the target



$l/\sigma>10$ and $p/\sigma<3$, $z_{sec}>-.8$



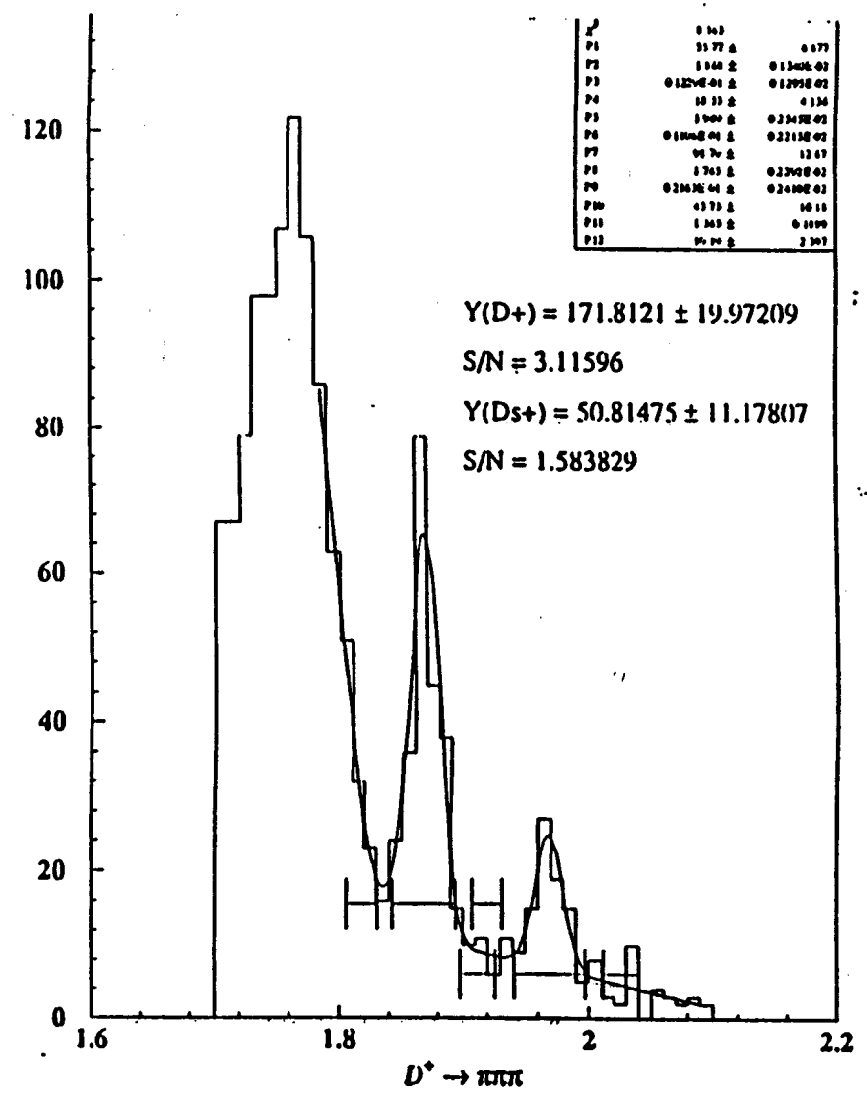


FIG 1

Figure 2: Present target

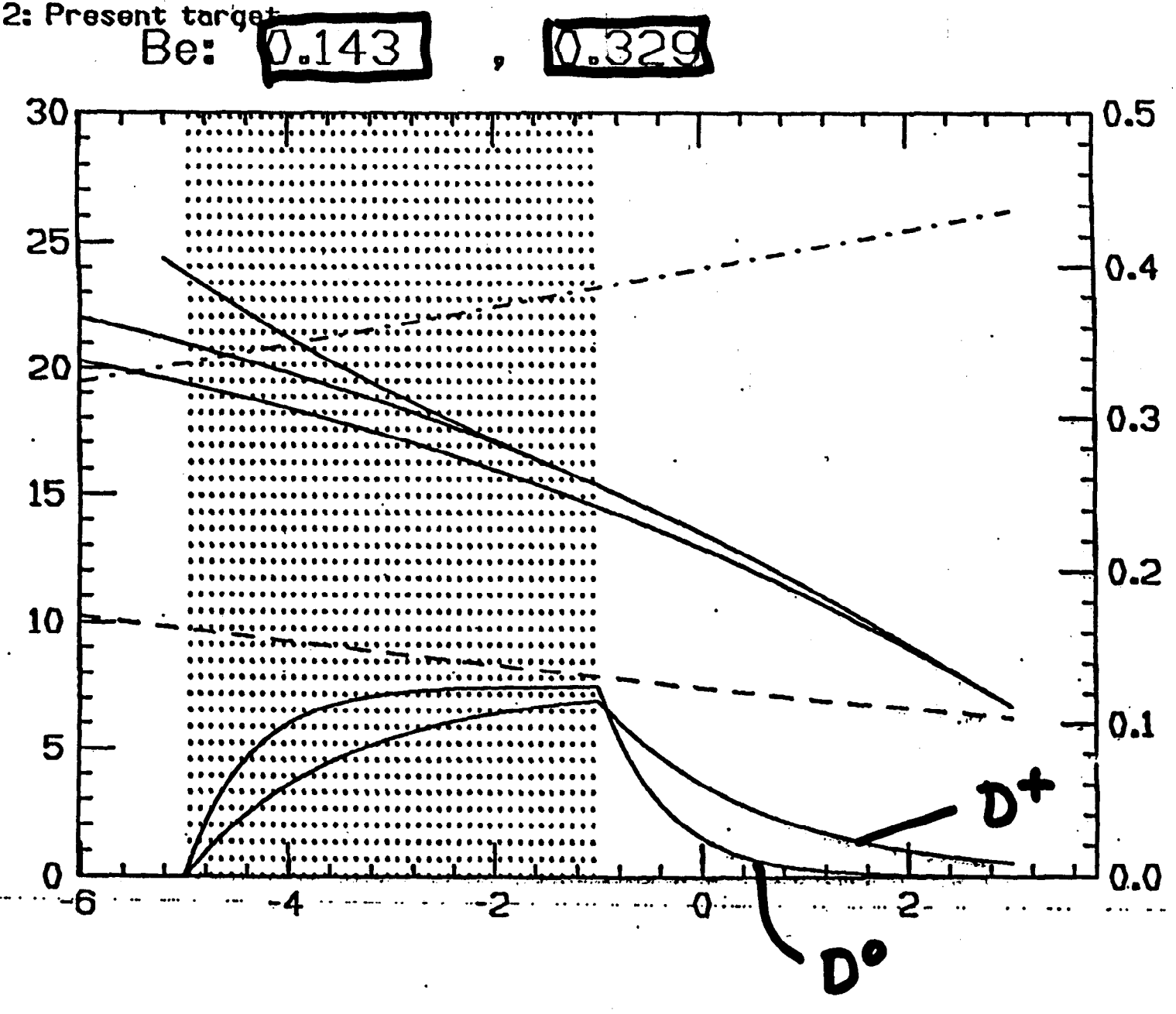
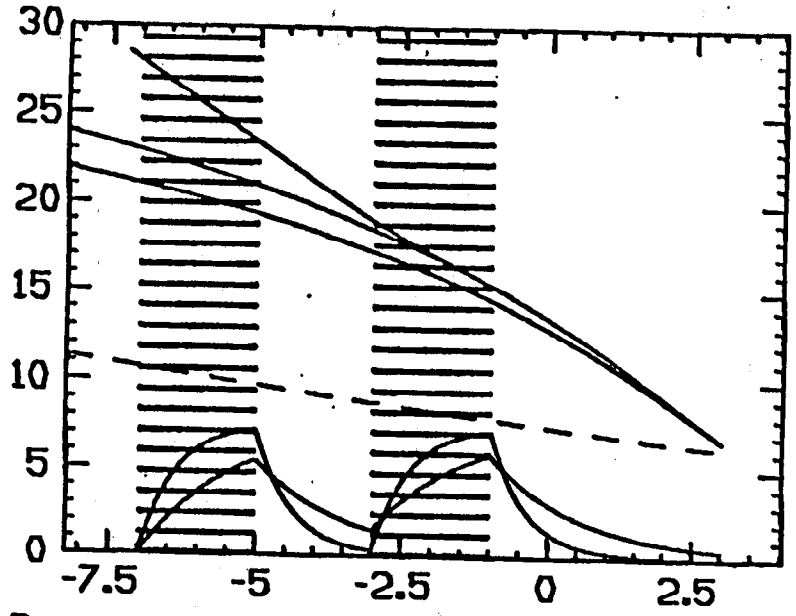
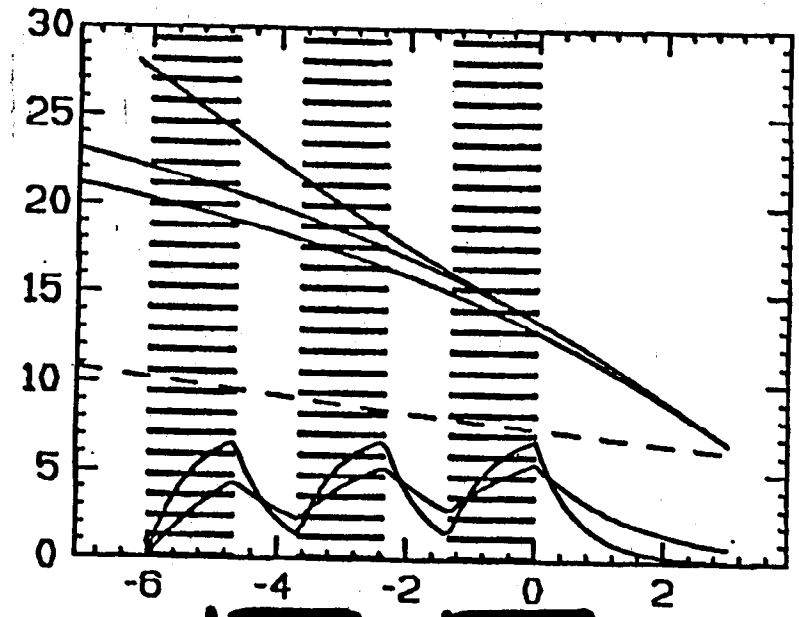


Figure 3 : Alternative Target Configurations

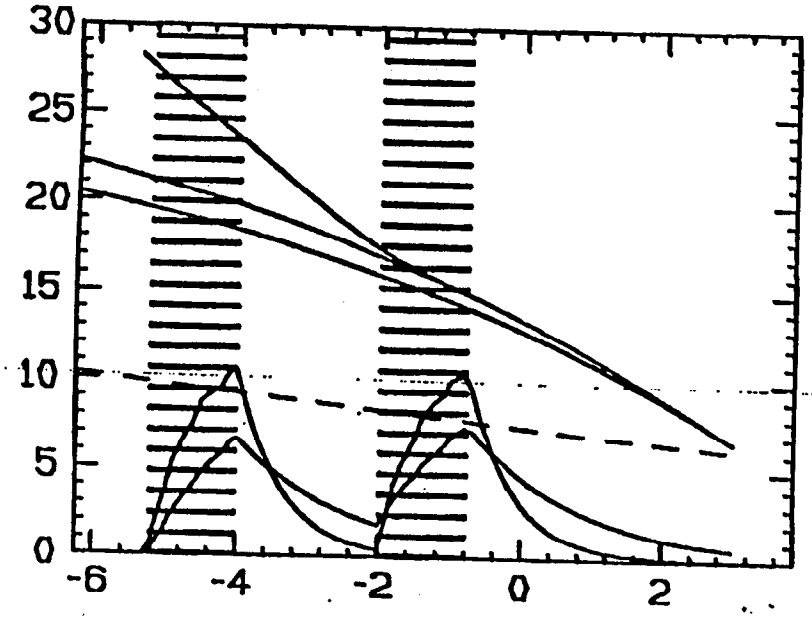
Be: 0.269 , 0.473



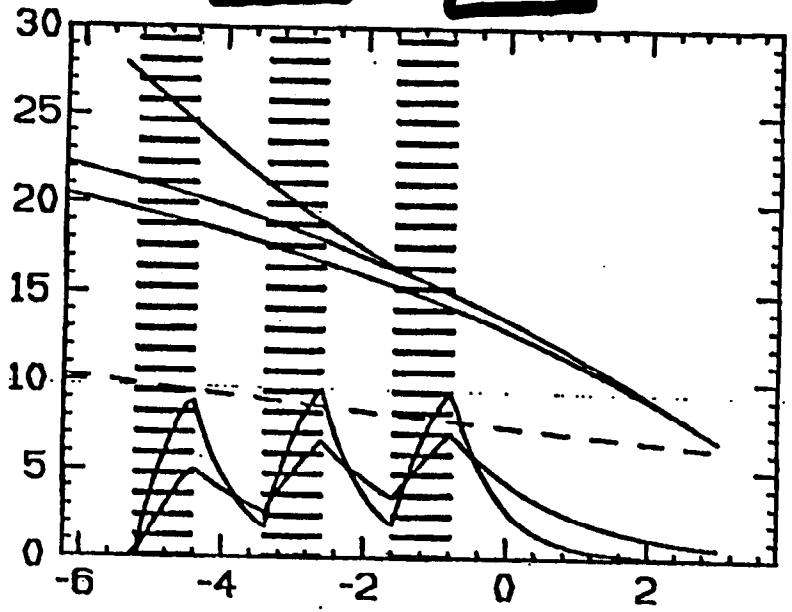
BE: 0.3737027 , 0.5103226



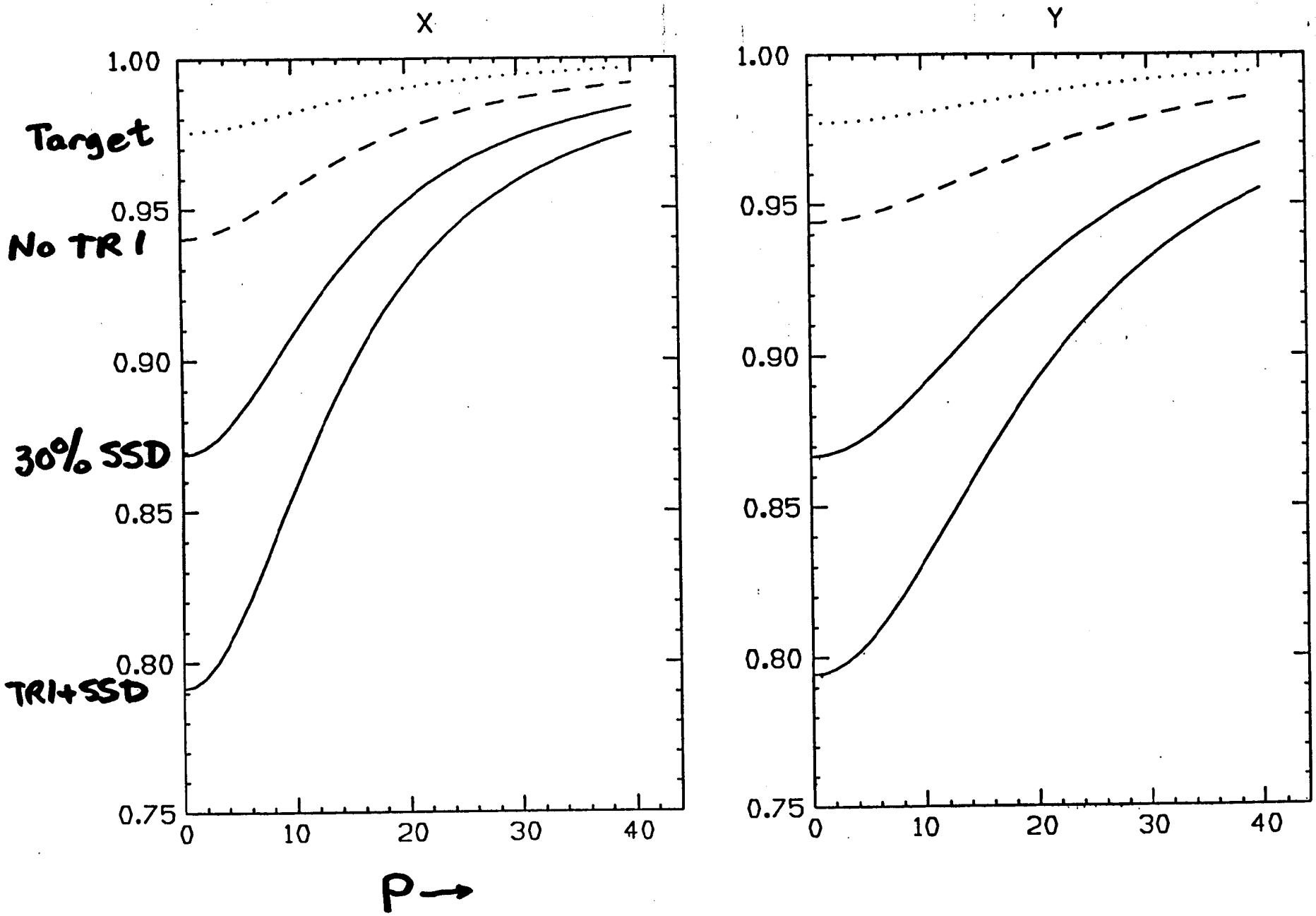
Diamond: 0.403 , 0.606



Diamond: 0.493 , 0.630



Vertex Resolution vs Momentum

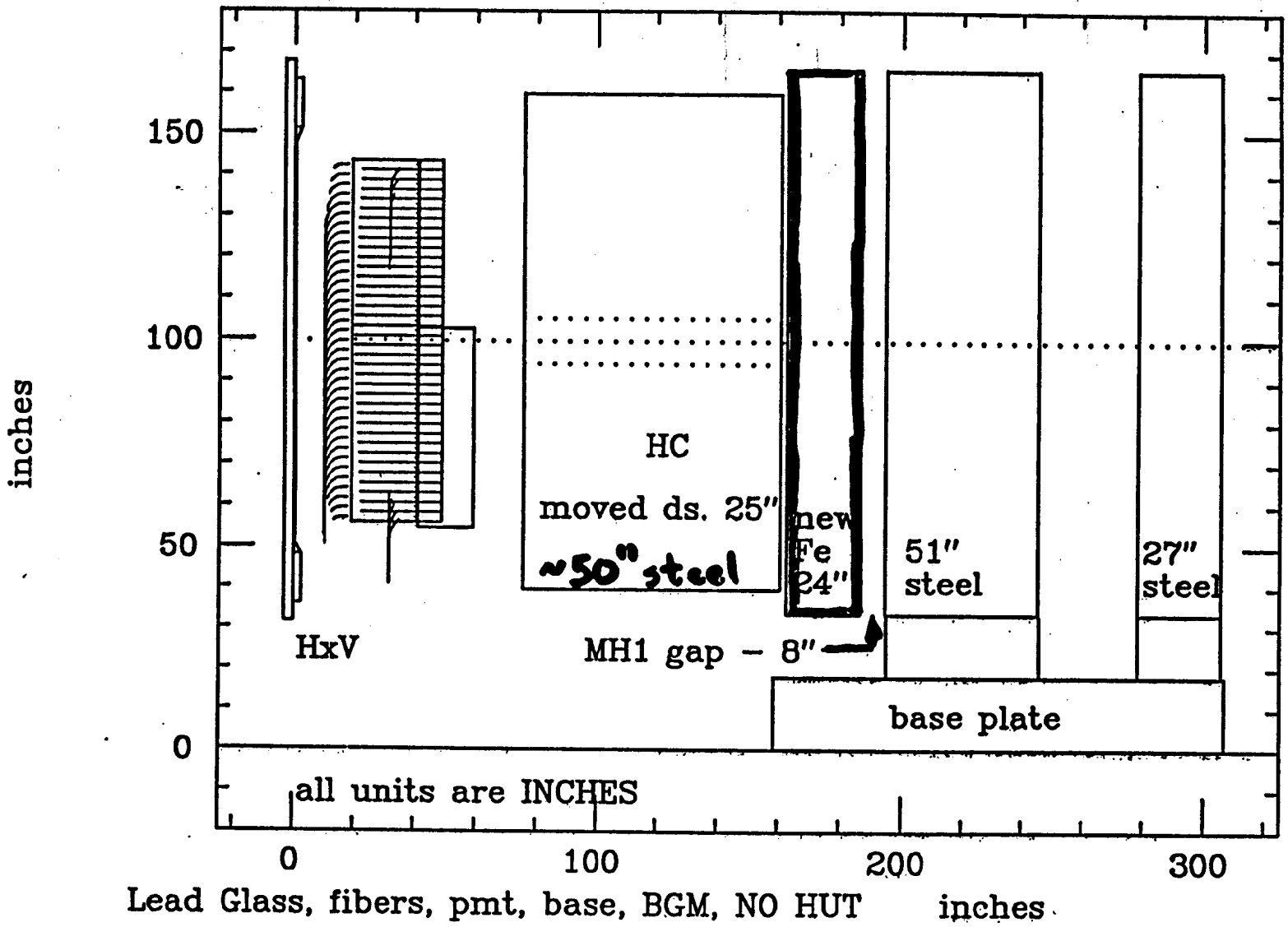


Inner Muon Upgrade Progress

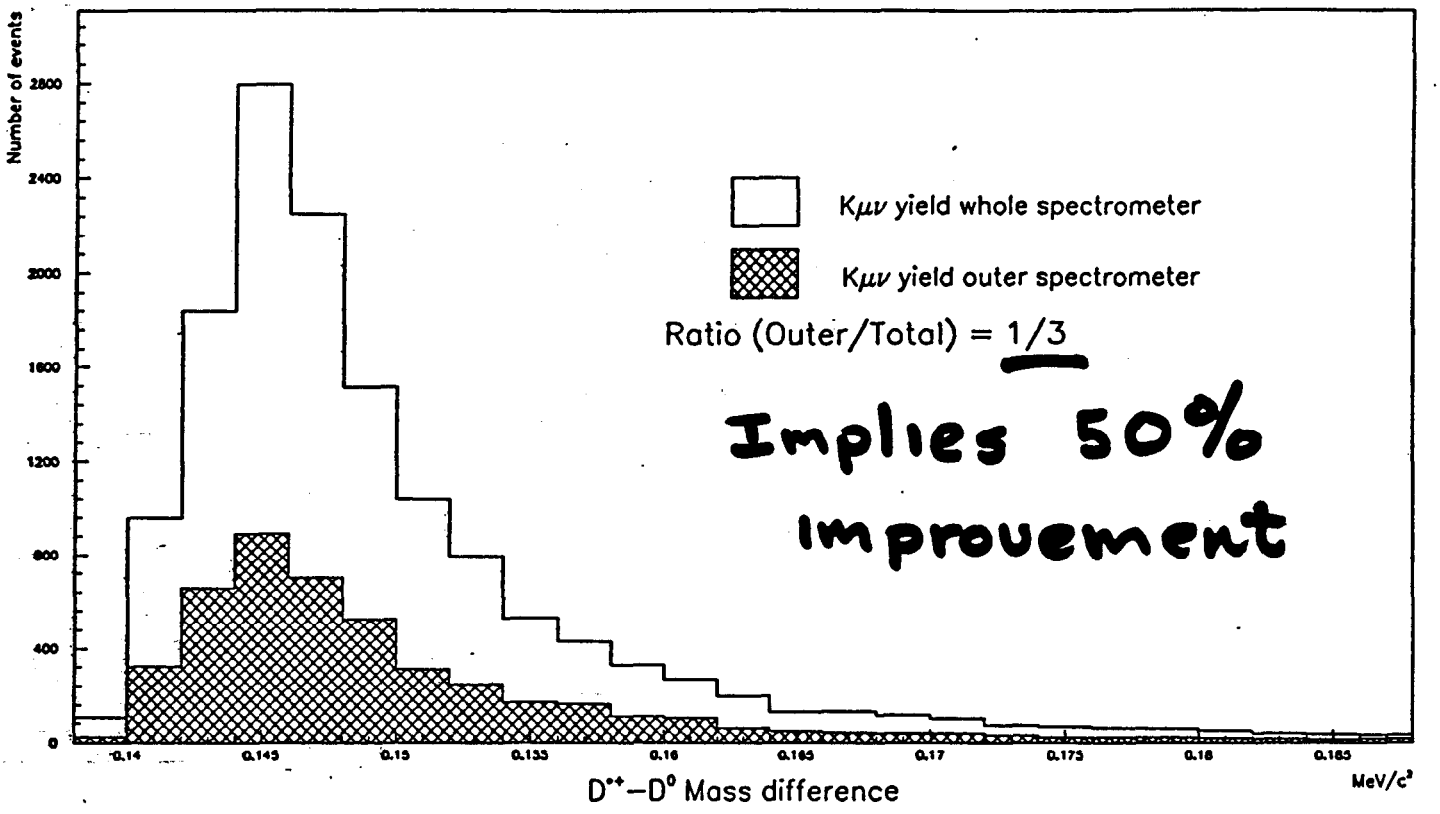
Overview

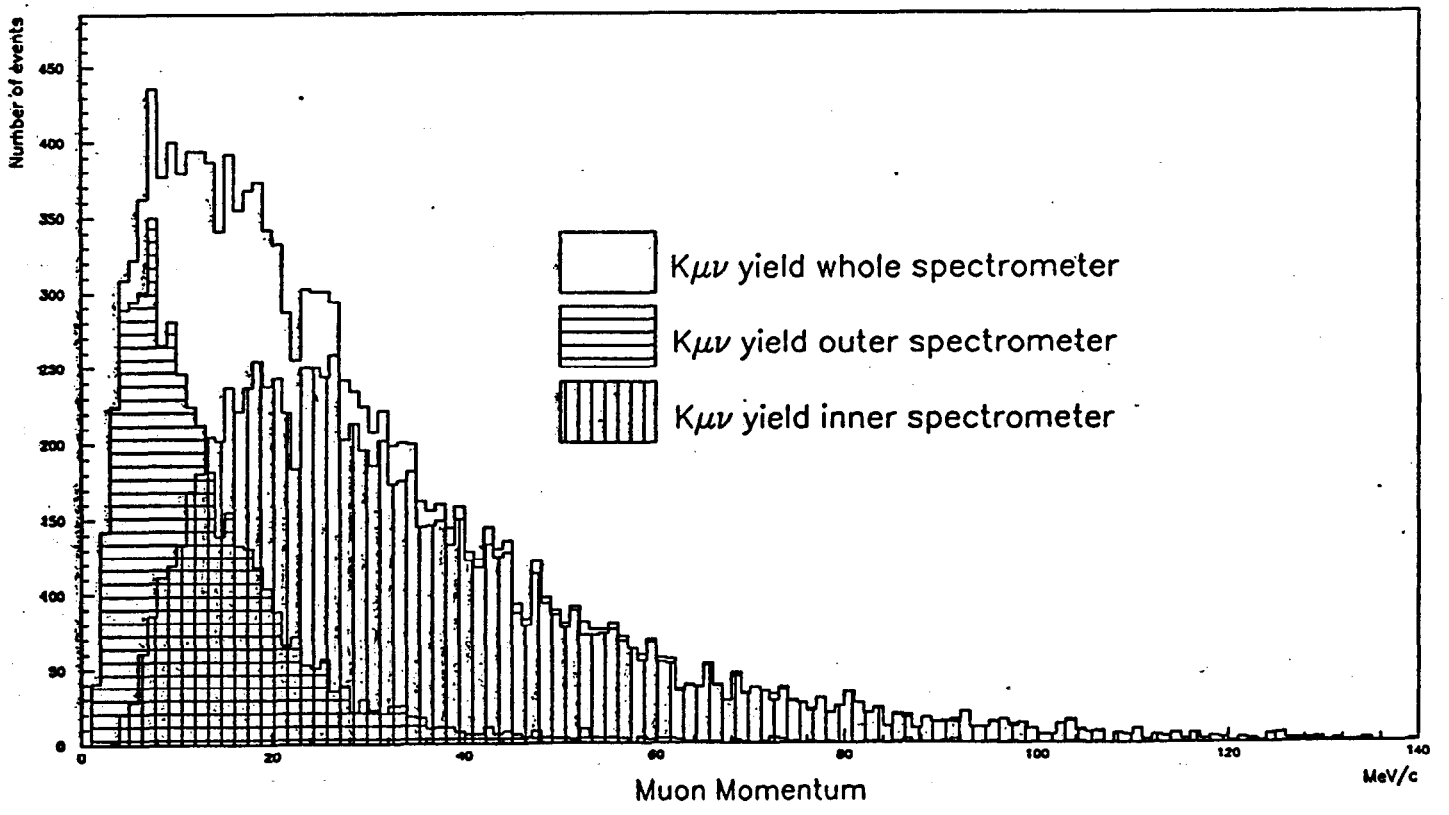
1. Augment p-tubes with scintillator arrays
   - Goal 1 RF bucket timing
2. Two XY stations (MH1 & MH2)
   (a) Fine pitch upstream array (MH1)
   - Reduced MCS for tracking
   (b) Coarse grain downstream array (MH2)
   - Better hadron shielding
3. Spans 2 m × 3 m (X × Y)
   - Two 150 cm spans (X) & Two 100 cm spans (Y)
   - 1 PMT per slab
4. Pitches
   (a) 5 cm width MH1
   - 210 counters
   (b) 10 - 16 cm width MH2
   - 64 - 102 counters

E-831 Downstream Components

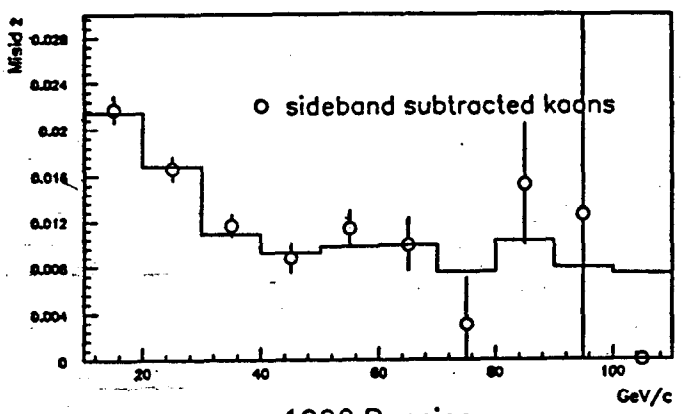


Lead Glass, fibers, pmt, base, BGM, NO HUT

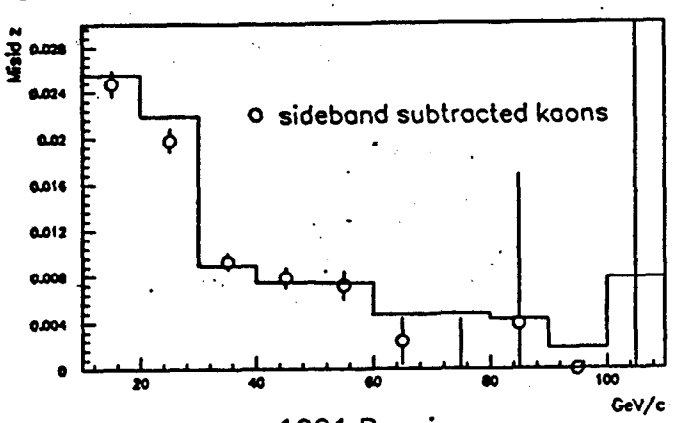

Number of events
Kμν yield whole spectrometer
Kμν yield outer spectrometer
Ratio (Outer/Total) = 1/3
Implies 50% improvement
D*+−D0 Mass difference
MeV/c²


Number of events
Kμν yield whole spectrometer
Kμν yield outer spectrometer
Kμν yield inner spectrometer
Muon Momentum
MeV/c

Muon Misidentification from $\phi \rightarrow K^+K^-$ kaons



1990 Running



1991 Running

- Noise
- Punchthru from hadronic showers
- Kaon unflight decay
- Accidentals (beamline muon)
- Nearby real muon
- Bigger problem than for pions
- Use protons from Λ^0 to test MC without decays

- **We need two more feet of iron!**
- Will extra shield degrade track matching?

	$P \times \sigma$	
E687 system	20 mr-GeV	Exists
IE + HC	8.4 mr-GeV	
IE +HC + 60 cm Fe	10.8 mr-GeV	Planned

- About 30 % worse matching
- Still twice as good as E687! in each view!

2. Miscellaneous studies
   (a) Optical simulations
   (b) δ-ray abatement
   (c) Overlap
   (d) Cable choice

Conclusions

1. E831 will get to 10^6 or better reconstructed charm
   a) Anticipate cleaner signals in E831 than in E687
   b) States containing electrons + muons should see about $\sim \times 20$ improvement
   c) Should do much better on states containing π^0's.
   d) May be able to track several of the D^+ + D_s^+ parent particles

2. E781 will produce a large sample of Charm Baryons
   a) 100K $\Lambda_c^+ \to pK^-\pi^+$
   b) 50K $\Xi_c^+ \to \Xi^-\pi^+\pi^+$

3. Very important to have different types of systematics limiting experiments as statistical errors decrease - FT, e^+e^-, B-factory, τ-Charm

4. Next step in my opinion is a very high statistics expt. at BNL or FNAL using large production σ.

Comparision list of tau/charm measurements						
topic	parameter to be measured	best measurement to date	tc factory	B factory	Fix target	LEP
D0 abs BR						
Double Tag	kpi					
soft pi+	kpi	CLEO			2 %	
D+ abs BR						
Double tag	kpipi					
soft pi0	kpipi	CLEO			3%	
Ds abs BR	phipi				~5%	
Double Tag		BES				
D* abs BR						
gam,pi+, pi0		CLEO				
Charm lifetimes						
	D0,D+,Ds	fix target			<1%	
D semilept						
	K e nu,pi e nu					
	K* e nu,rho e	nu				
Ds semilept						
phi e nu		CLEO				
Ds leptonic						
double tag	mu nu, tau nu	BES				
mu + gamma	mu nu	CLEO				
D+ leptonic						
direct	mu nu tau nu	??				
mu + pi0	mu nu	??				
D mixing						
like sign mu		?				
D*->pi+D		CLEO				
decay len. D*->pi+D		fix target				
double tag						
CP violation						
direct	Ds->K*K	fix target			±0.04	
indirect	time integ.					
RARE charm	gamma+K*					
TAU						
mass		BES				
nu mass	3pi,5pi, kkpi	ARGUS CLEO				
leptonic BR	enunu, mununu	CLEO				
3/5 prg BR						
other BR						
michel param	rho	LEP?				
lifetime		LEP				
rare decays						

} See attached sheets

~ $\phi e \nu / \phi \pi \sim 2.59$

$D^{*+} \to \pi^0 D^+$, $D^+ \to \mu\nu$

~ 3×10^{-4}

No τ's in Fixed Target