LA INTERACCIÓN DÉBIL

Seminar FC-UAEM
Guernavaca, January 17, 2000
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Outline:

- Introduction to Particle Physics
- Conservation Laws and Violation
- Charm – SELEX
- CP Violation in Kaons – CKM

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Elementary Particles

$\approx$ 1950 : Known elementary particles:
Electron (1897), Proton (1905), Neutron (1932), Positron (1932), Myon (1937), Pion (1947)

Still missing today:
Tau Neutrino ν_τ, Higgs, Graviton

Periodic Table

Conservation Laws

Classical

Hamiltonian invariant under space translation

$\Longrightarrow$ Conservation of momentum

Hamiltonian invariant under time translation

$\Longrightarrow$ Conservation of energy

Hamiltonian invariant under rotation

$\Longrightarrow$ Conservation of angular momentum

gauge invariant

$\Longrightarrow$ Conservation of electric charge

Quantum Mechanics equivalent description:

(a) Momentum is conserved

(b) Hamiltonian is invariant under space translations

(c) Momentum operator commutes with Hamiltonian

Important in Particle Physics:

- Parity

$$\mathcal{P}\Psi(\vec{r}) \rightarrow \Psi(-\vec{r})$$

  Strong and Electromagnetic Interaction conserve Parity

  Weak Interaction violates Parity (1957)

- Charge Conjugate $\mathcal{C}$
  - exchange sign of electric charge and magn. moment
  - exchange particle with antiparticle
- Time Reversal $\mathcal{T}$

Until 1964: All Interaction are invariant under $\mathcal{CP}$

$$\begin{array}{llll} K_L^0 & \rightarrow \pi^0\pi^0\pi^0 & (21\%) & \mathcal{CP} = +1 \\ & \rightarrow \pi^+\pi^-\pi^0 & (13\%) & \mathcal{CP} = +1 \\ & \rightarrow \pi^+\pi^- & (0.2\%) & \mathcal{CP} = -1 \quad \text{CP Violation!!!} \end{array}$$

Weak Interaction

$\approx$ 1960 weak decay of strange particles

Why "strange"?

- produced abondandly
- long living

Explanation:

- produced in pairs by <u>Strong Interaction</u>
- decay by <u>Weak Interaction</u> supressed
  eigenstates to Strong Interaction and mass **NOT** eigenstates to Weak Interaction

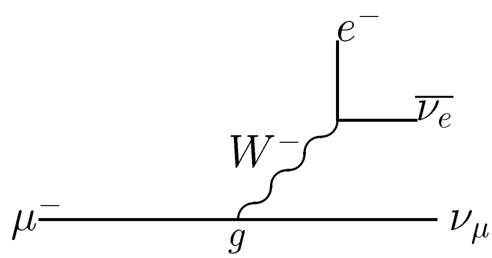
$\longrightarrow$ Cabbibo theory (1963)

2×2 rotation matrix for quarks (not! for leptons)

$$\begin{pmatrix} d' \\ s' \end{pmatrix} = \begin{pmatrix} \cos\theta_c & \sin\theta_c \\ -\sin\theta_c & \cos\theta_c \end{pmatrix} \begin{pmatrix} d \\ s \end{pmatrix}$$

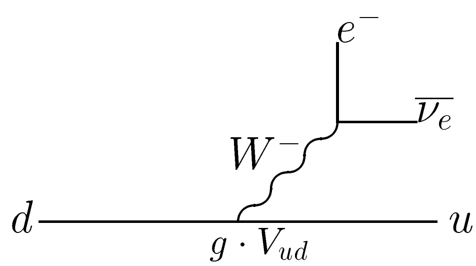
Examples for Weak Decays

$\mu^- \to e^- + \overline{\nu_e} + \nu_\mu$



beta decay: $n \to p + e^- + \overline{\nu_e}$.

On quark level: $d \to u + e^- + \overline{\nu_e}$



Some more History

$\approx$ **1970:** Are there more quarks? (most people: NO!)
If yes, how to change Cabbibo theory?

1972: Kobayashi and Maskawa: If there are 6 quark, we can describe CP Violation (3×3 matrix)

1973: "September Revolution" charm quark discovered (Brookhaven, SLAC)

1976: b quark (Fermilab)

1994: t quark (Fermilab)

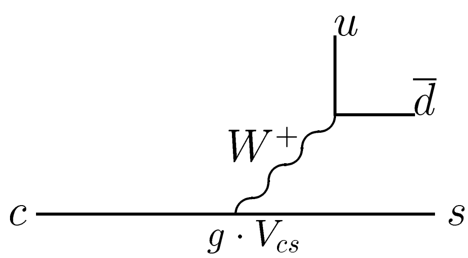
Cabibbo-Kobayashi-Maskawa (CKM) Matrix

$$\begin{pmatrix} d' \\ s' \\ b` \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

$$\begin{pmatrix} 0.9745 - 0.9760 & 0.217 - 0.224 & 0.0018 - 0.0045 \\ 0.217 - 0.224 & 0.9737 - 0.9753 & 0.036 - 0.042 \\ 0.004 - 0.013 & 0.035 - 0.042 & 0.9991 - 0.9994 \end{pmatrix}$$

Decay of charm

Just like strange:



Measure V_{cs}? Yes, but... quarks are never alone!
Need a lot of measurements $\longrightarrow$ SELEX

Decay of beauty

Big experiments starting now
B-Factories:

BaBar (SLAC) (1999)

Belle (KEK) (1999)

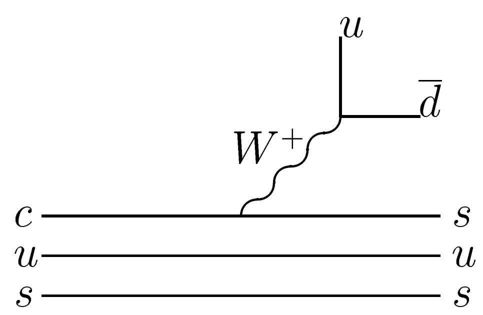
CLEO3 (Cornell) (1999)

HERA-B (Hamburg) (1999)

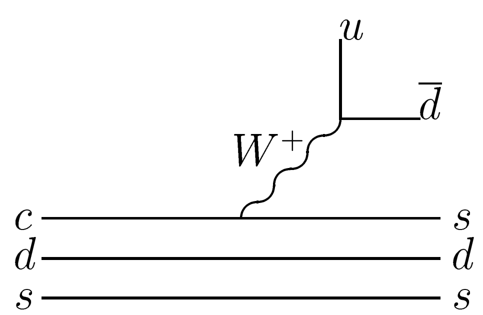
BTeV (Fermilab) (2002?)

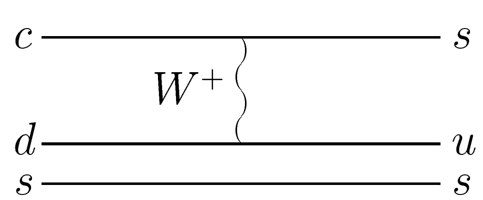
LHC-B (CERN) (2005?)

Ξ_c^+ (csu) decay: $\tau = 350 \cdot 10^{-15}\,\mathrm{sec}$



Ξ_c^0 (csd) decay: $\tau = 64 \cdot 10^{-15}\,\mathrm{sec}$





Experimental Setup

To do a good job on charm, you need:

– High Statistic
(charm cross section small)

– Good Trigger or Software Filter
($\sigma_c \approx 10^{-3}\sigma_{tot}$)

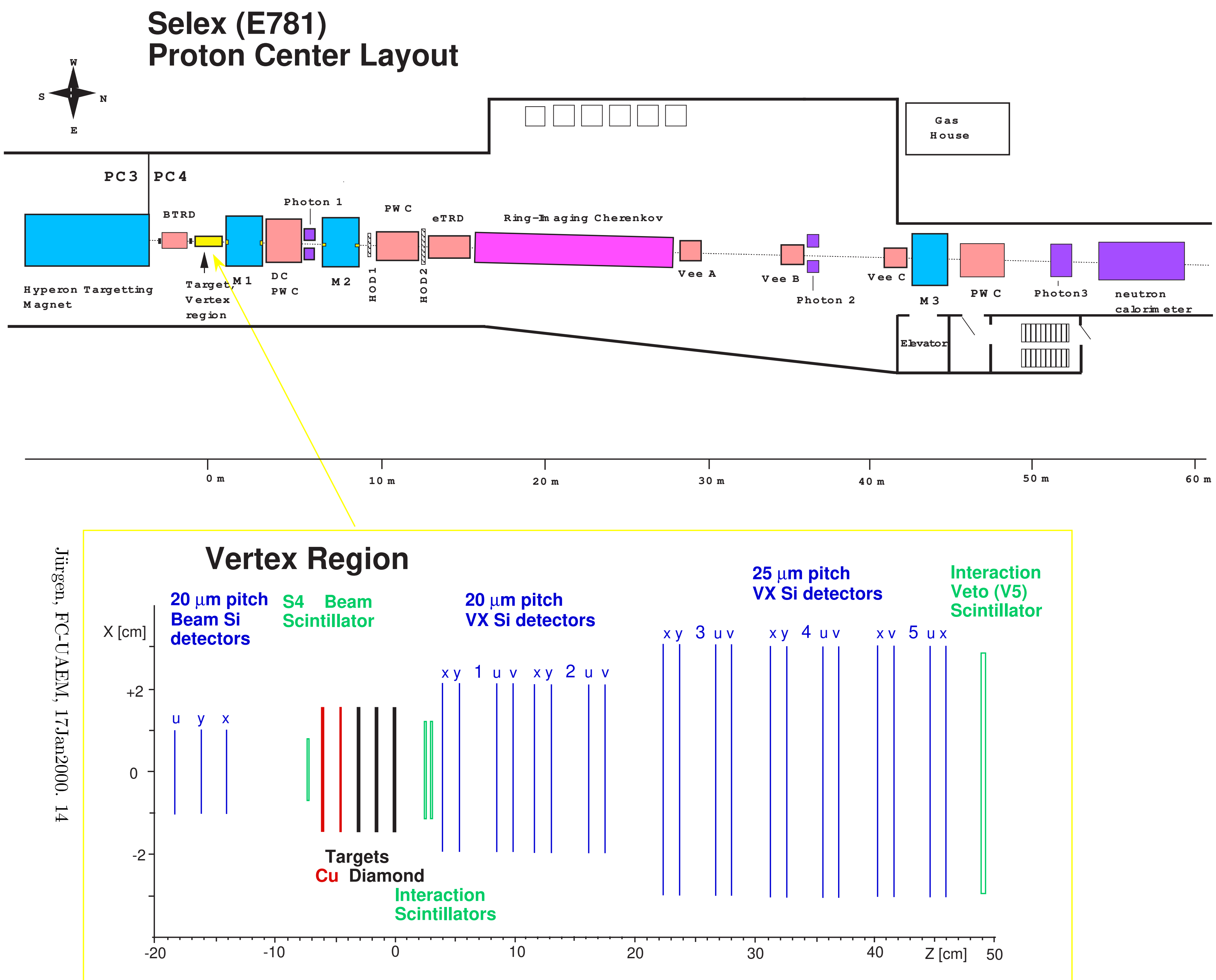
– Extremely good Silicon Detectors
(sec. vertex, lifetime)

– Extremely good Particle Identification
(proton, kaon)

Or even better: All of the above!

Fermilab View 1

Fermilab View 2



Selex (E781)
Proton Center Layout
W
S
N
E
Gas House
PC3
PC4
BTRD
Photon 1
PWC
eTRD
Ring-Imaging Cherenkov
Hyperon Targetting Magnet
Target, Vertex region
M1
DC PWC
M2
HOD1
HOD2
Vee A
Vee B
Photon 2
Vee C
M3
PWC
Photon3
neutron calorimeter
Elevator
0 m
10 m
20 m
30 m
40 m
50 m
60 m
Vertex Region
20 µm pitch Beam Si detectors
S4 Beam Scintillator
20 µm pitch VX Si detectors
25 µm pitch VX Si detectors
Interaction Veto (V5) Scintillator
X [cm]
+2
0
-2
u y x
x y 1 u v x y 2 u v
x y 3 u v x y 4 u v x v 5 u x
Targets
Cu Diamond
Interaction Scintillators
-20
-10
0
10
20
30
40
Z [cm]
50

The SELEX Collaboration

N. Akchurin[p], V.A. Andreev[k], A.G. Atamantchouk[k], M. Aykac[p], M.Y. Balatz[h], N.F. Bondar[k], A. Bravar[t], P.S. Cooper[e], L.J. Dauwe[q], G.V. Davidenko[h], U. Dersch[i], A.G. Dolgolenko[h], D. Dreossi[t], G.B. Dzyubenko[h], R. Edelstein[c], L. Emediato[s], A.M.F. Endler[d], J. Engelfried[e,m], I. Eschrich[i,1], C.O. Escobar[s,2], A.V. Evdokimov[h], I.S. Filimonov[j,3], F.G. Garcia[s], M. Gaspero[r], S. Gerzon[l], I. Giller[l], V.L. Golovtsov[k], Y.M. Goncharenko[f], E. Gottschalk[c,e], P. Gouffon[s], O.A. Grachov[f,4], E. Gülmez[b], He Kangling[g], M. Iori[r], S.Y. Jun[c], A.D. Kamenskii[h], M. Kaya[p], J. Kilmer[e], V.T. Kim[k], L.M. Kochenda[k], K. Königsmann[i,5], I. Konorov[i,6], A.P. Kozhevnikov[f], A.G. Krivshich[k], H. Krüger[i], M.A. Kubantsev[h], V.P. Kubarovsky[f], A.I. Kulyavtsev[f,c], N.P. Kuropatkin[k], V.F. Kurshetsov[f], A. Kushnirenko[c], S. Kwan[e], J. Lach[e], A. Lamberto[t], L.G. Landsberg[f], I. Larin[h], E.M. Leikin[j], Li Yunshan[g], Li Zhigang[g], M. Luksys[n], T. Lungov[s,7], D. Magarrel[p], V.P. Maleev[k], D. Mao[c,8], Mao Chensheng[g], Mao Zhenlin[g], S. Masciocchi[i,9], P. Mathew[c,10], M. Mattson[c], V. Matveev[h], E. McCliment[p], S.L. McKenna[o], M.A. Moinester[l], V.V. Molchanov[f], A. Morelos[m], V.A. Mukhin[f], K.D. Nelson[p], A.V. Nemitkin[j], P.V. Neoustroev[k], C. Newsom[p], A.P. Nilov[h], S.B. Nurushev[f], A. Ocherashvili[l], G. Oleynik[e,8], Y. Onel[p], E. Ozel[p], S. Ozkorucuklu[p], S. Patrichev[k], A. Penzo[t], S.I. Petrenko[f], P. Pogodin[p], B. Povh[i], M. Procario[c], V.A. Prutskoi[h], E. Ramberg[e], G.F. Rappazzo[t], B.V. Razmyslovich[k], V.I. Rud[j], J. Russ[c], P. Schiavon[t], V.K. Semyatchkin[h], J. Simon[i], A.I. Sitnikov[h], D. Skow[e], V.J. Smith[o], M. Srivastava[s], V. Steiner[l], V. Stepanov[k], L. Stutte[e], M. Svoiski[k], N.K. Terentyev[k,c], G.P. Thomas[a], L.N. Uvarov[k], A.N. Vasiliev[f], D.V. Vavilov[f], V.S. Verebryusov[h], V.A. Victorov[f], V.E. Vishnyakov[h], A.A. Vorobyov[k], K. Vorwalter[i,11], J. You[c], Zhao Wenheng[g], Zheng Shuchen[g], R. Zukanovich-Funchal[s]

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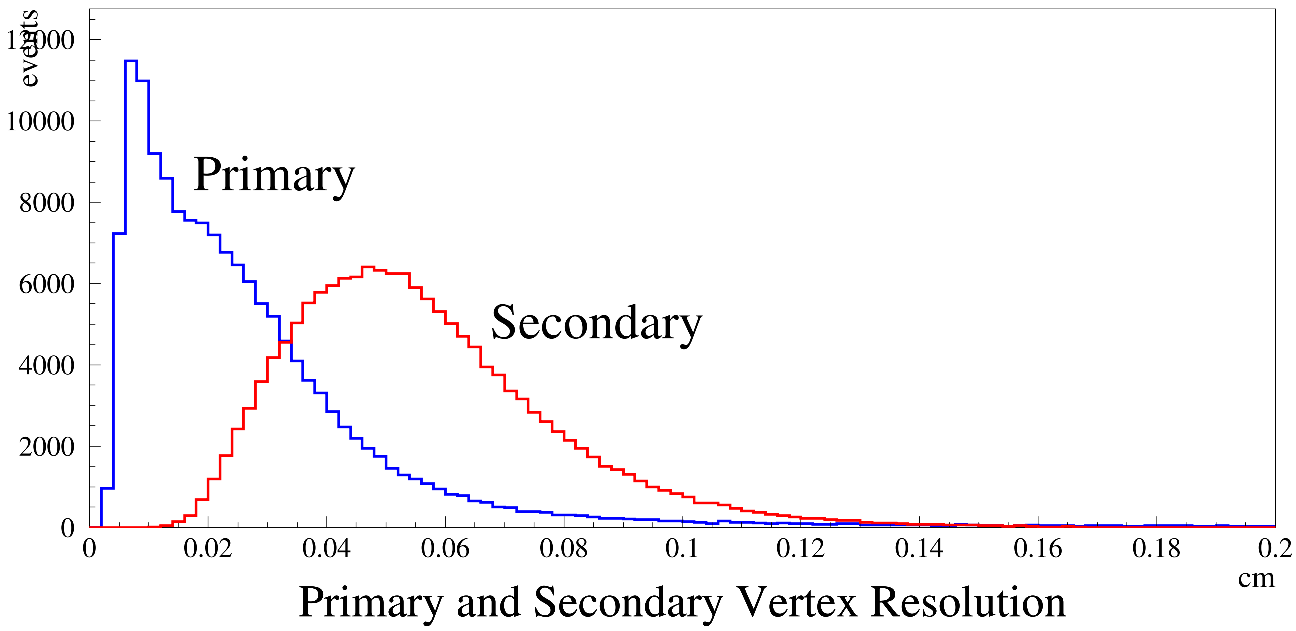
SELEX Apparatus

3 segment forward spectrometer ($x_F > 0.1$)

- 74000 strip silicon system, $4\mu m$ transverse position resolution at 600 GeV
- Beam tagging ($\Sigma^-/\pi^-, p/\pi^+$) with Beam TRD
- 3000 phototube RICH - K/π separation up to 165 GeV
- Secondary e^- with Electron TRD for semileptonic decays
- Precise downstream tracking
  - 18 large silicon planes ($\sigma \sim 8\mu m$)
  - 26 PWC planes ($\sigma \sim 0.6 - 1mm$)
  - 3×24 Vector Drift chambers ($\sigma \sim 100\mu m$)
- 3 lead glass photon detectors



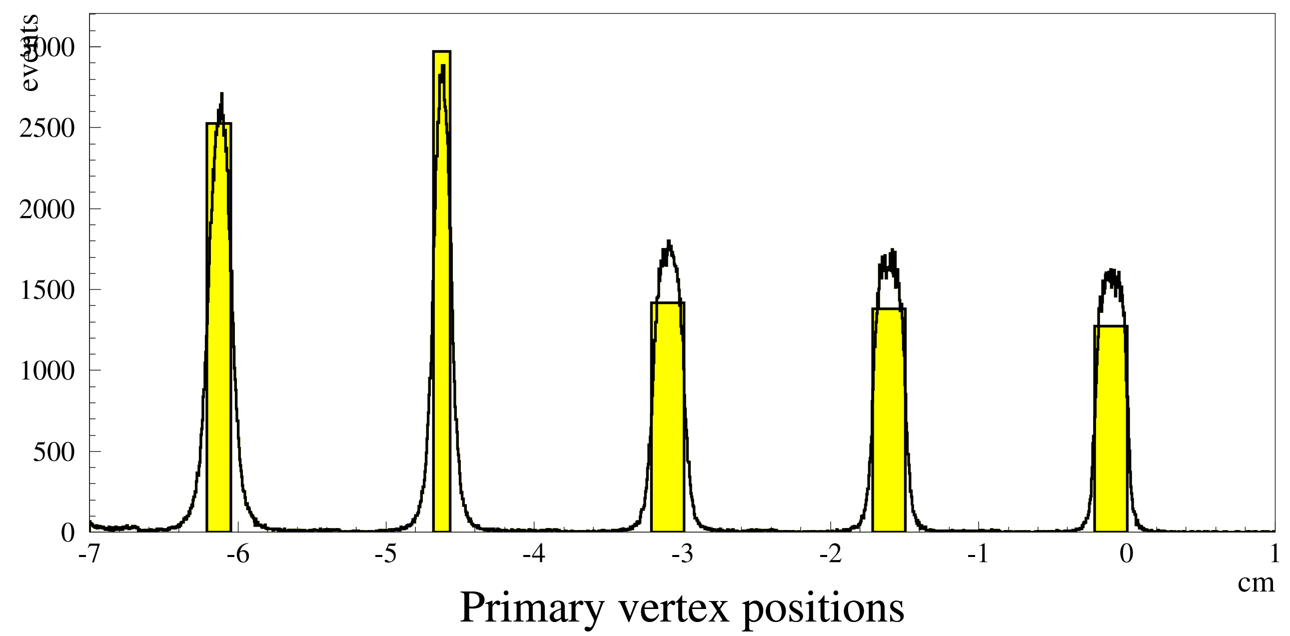
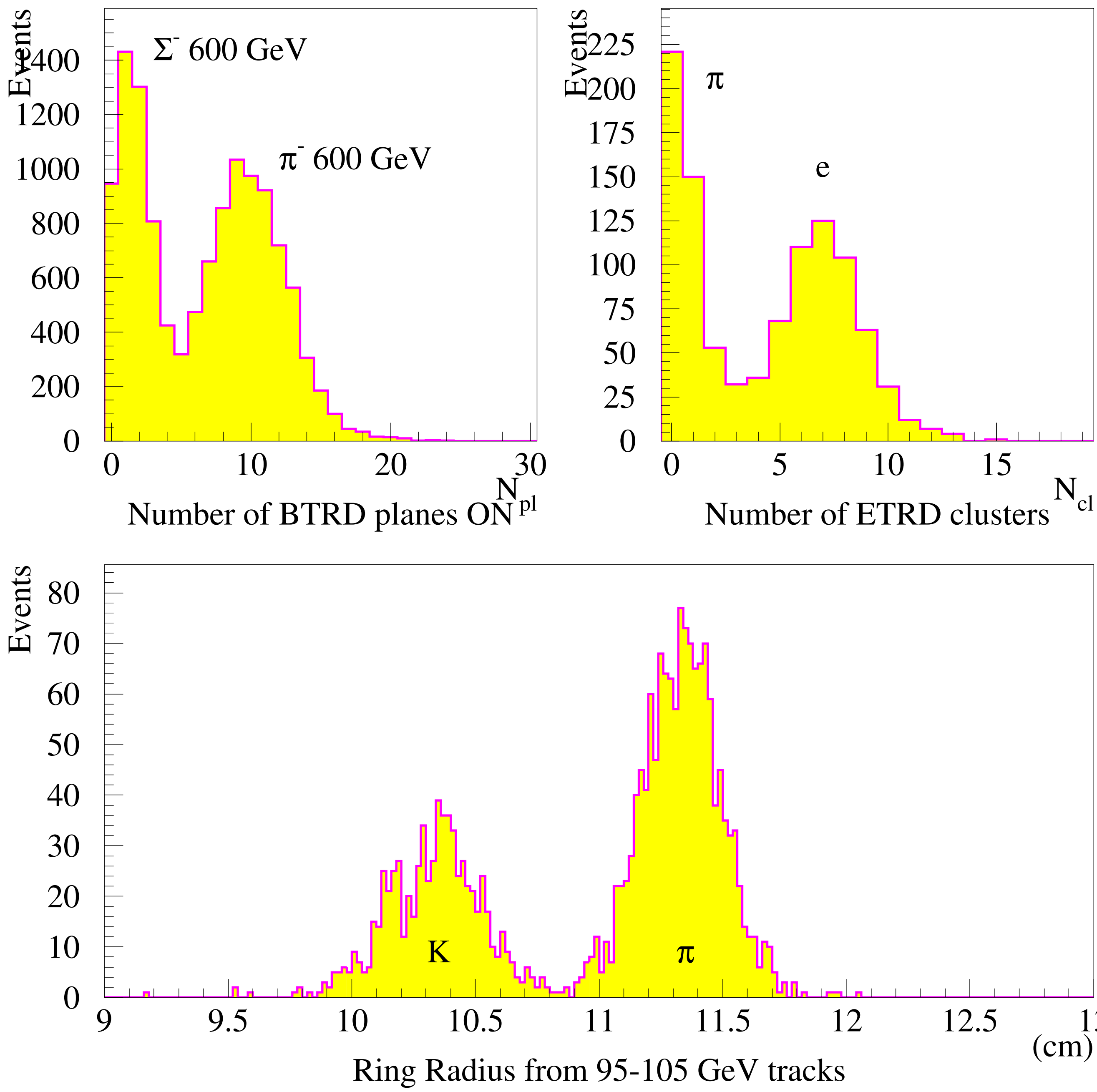


Fig. 3: Vertex resolution

SELEX Particle ID detectors



Online Filter

Filter is **Online Program** which select events that have evidence for a secondary vertex.

- Algorithm:
  - Start from downstream tracking to find high-momentum $(p > 20GeV)$ tracks in PWC chambers
  - extrapolate tracks back to vertex silicon within the roads predicted by downstream tracking
  - Reject events if tracks form just a primary vertex

- Charm efficiency about 50%, Rejection 8

- 4 times more charm per tape. 8 times faster to process.

Reconstruction of Λ_c^+

- Λ_c^+ consists of (udc) quarks
- Mass $m_0 = 2.285\,\text{GeV}$ (remember: proton $0.938\,\text{Ge V}$)
- Lifetime: $\tau = 2.1 \cdot 10^{-13}\,\text{sec}$
- Decays to $\Lambda_c \to pK^-\pi^+$ in $4.4\,\%$ of the time.
- Only in 1 out of 1000 collisions a charm quark gets produced.

Special Theory of Relativity:

$$\begin{aligned}
E &= m \cdot c^2 \\
m &= m_0 \cdot \gamma \\
\gamma &= \frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} = \frac{E \cdot c^2}{m_0} \\
p &= m \cdot v \approx m_0 \cdot \gamma \cdot c \\
\text{Time dilation:} \quad t &= t_0 \cdot \gamma \\
\text{Mean flight path:} \quad L &= c \cdot \tau \cdot \gamma
\end{aligned}$$

$\Longrightarrow$ A Λ_c^+ with momentum $200\,\text{GeV}$ flies on avarage $5.4\,\text{mm}$
$\Longrightarrow$ Do a Fixed Target Experiment
But even there we cannot observe a Λ_c directly

What do we do?

- Measure type, direction, momentum, and charge of all decay products
- Apply momentum and energy conservation to ”interesting” decay vertex and calculate energy and momentum of hypothetical mother particle
- Transform into rest system of mother particle to obtain rest mass
- Do this for a lot of events, fill histogram with results

Measuring direction and decay vertex

- Use silicon microstip detectors

Measuring momentum and charge

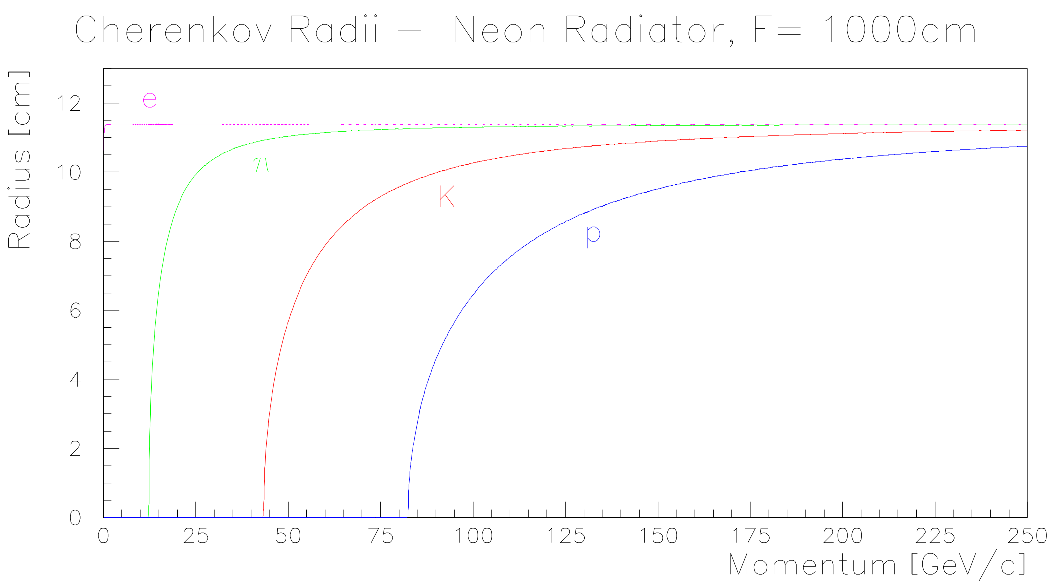
- Deflection in magnetic field, measure track angles before and after with wire chambers

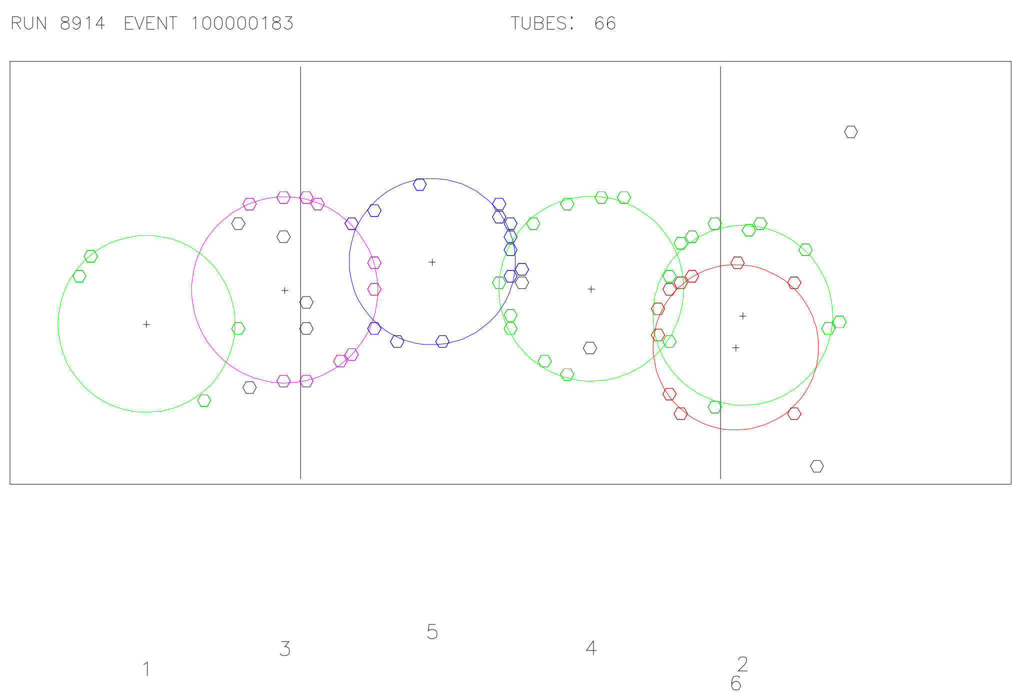
Measuring type (is it a proton?)

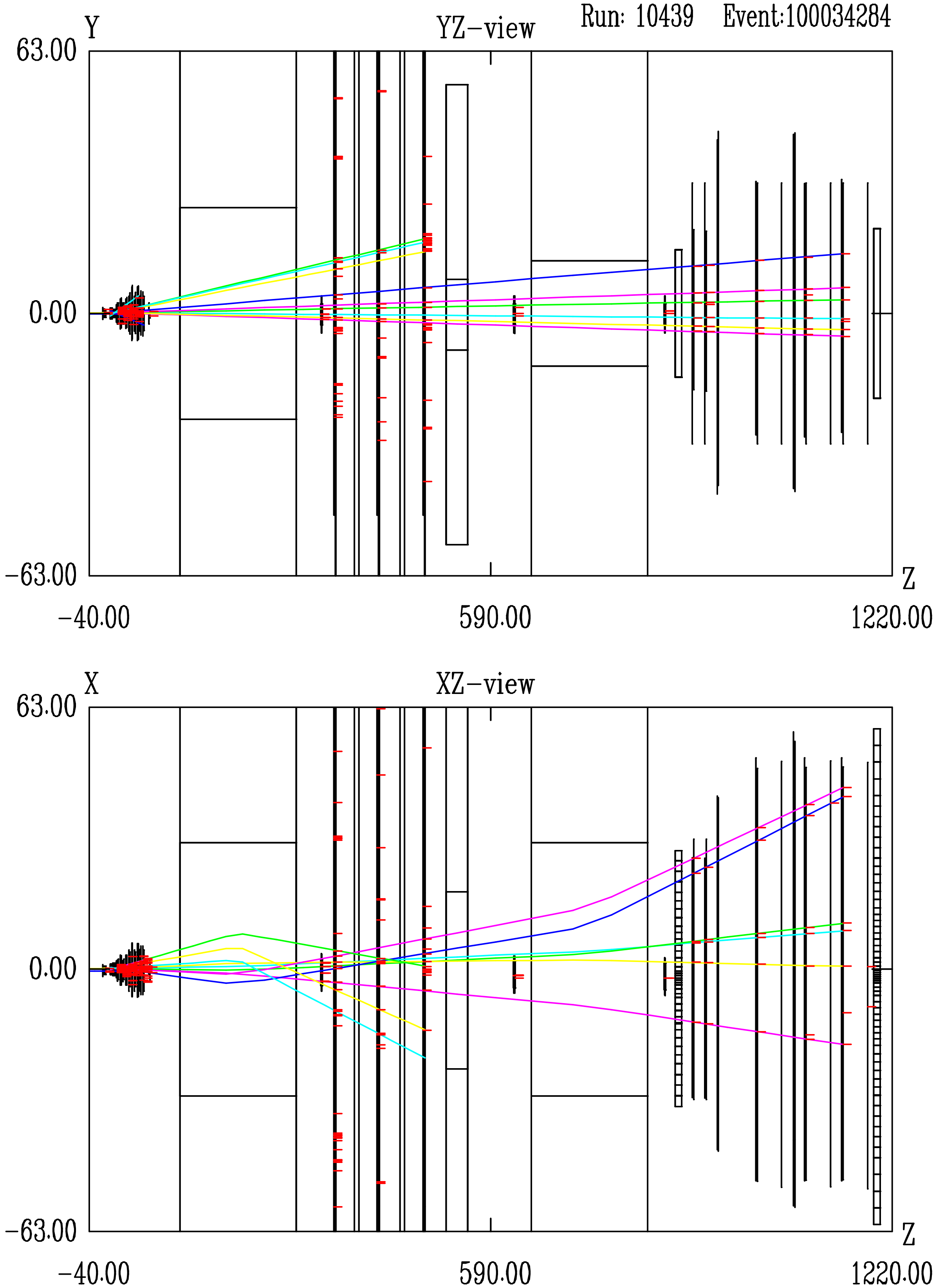
- Measure total energy in calorimeter, calculate mass
- Measure velocity with Cherenkov effect

Ring Imaging Cherenkov Counter (RICH)

$$\cos\Theta_C = \frac{1}{\frac{v}{c}\cdot n}$$
$$R = L\cdot\tan\Theta_C$$






Y
YZ−view
Run: 10439
Event:100034284
63.00
0.00
−63.00
−40.00
590.00
1220.00
Z
X
XZ−view
63.00
0.00
−63.00
−40.00
590.00
1220.00
Z

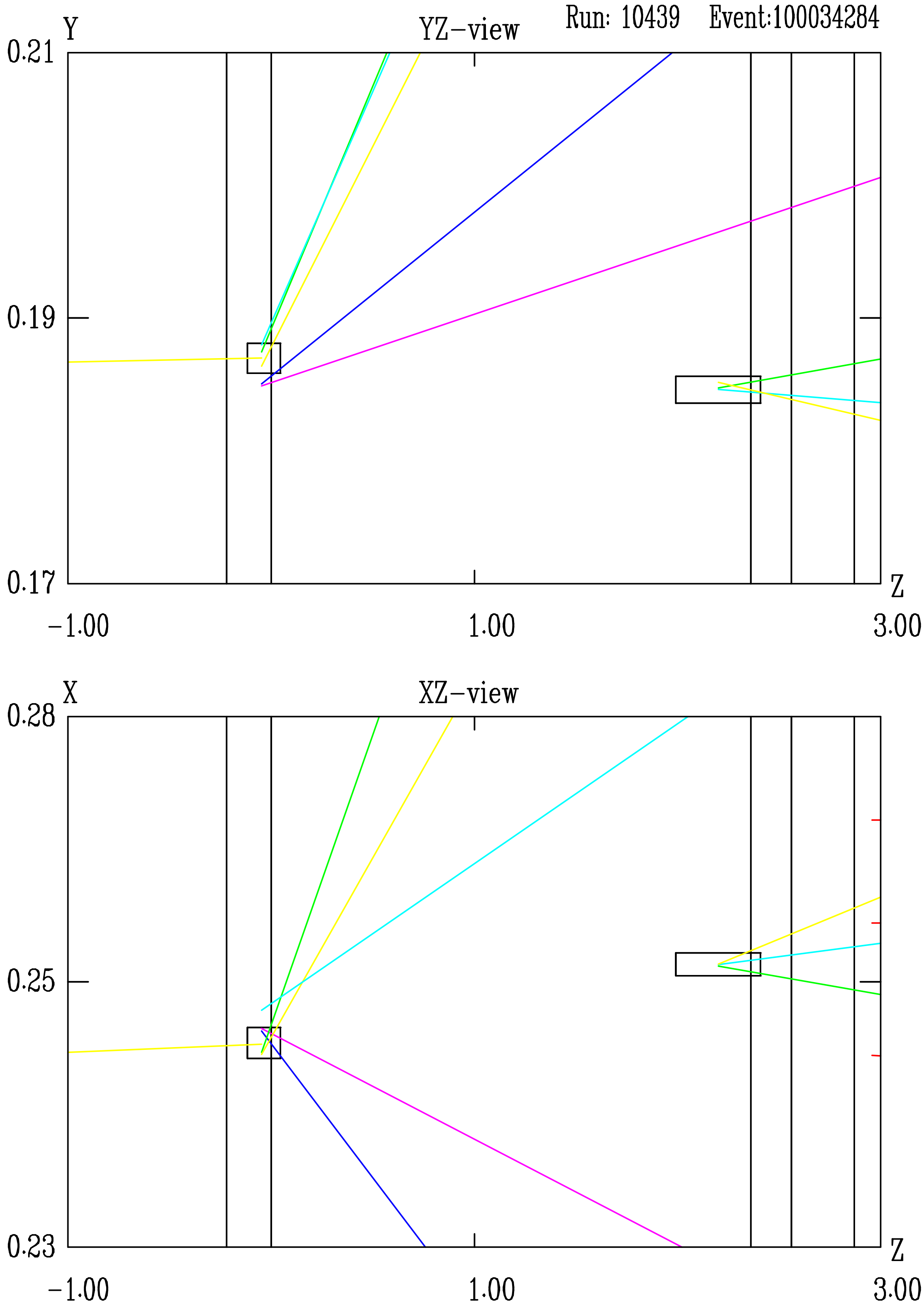
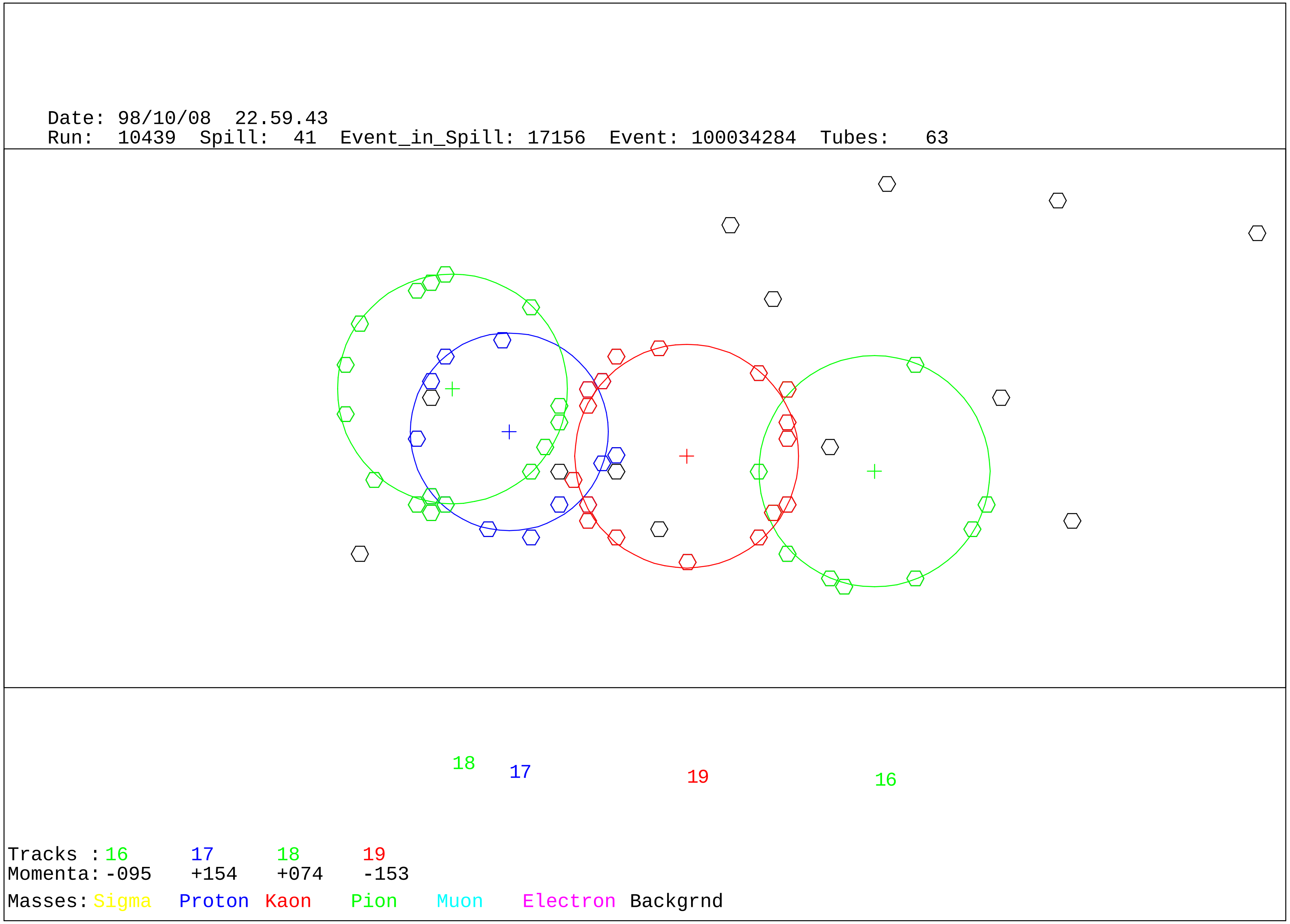


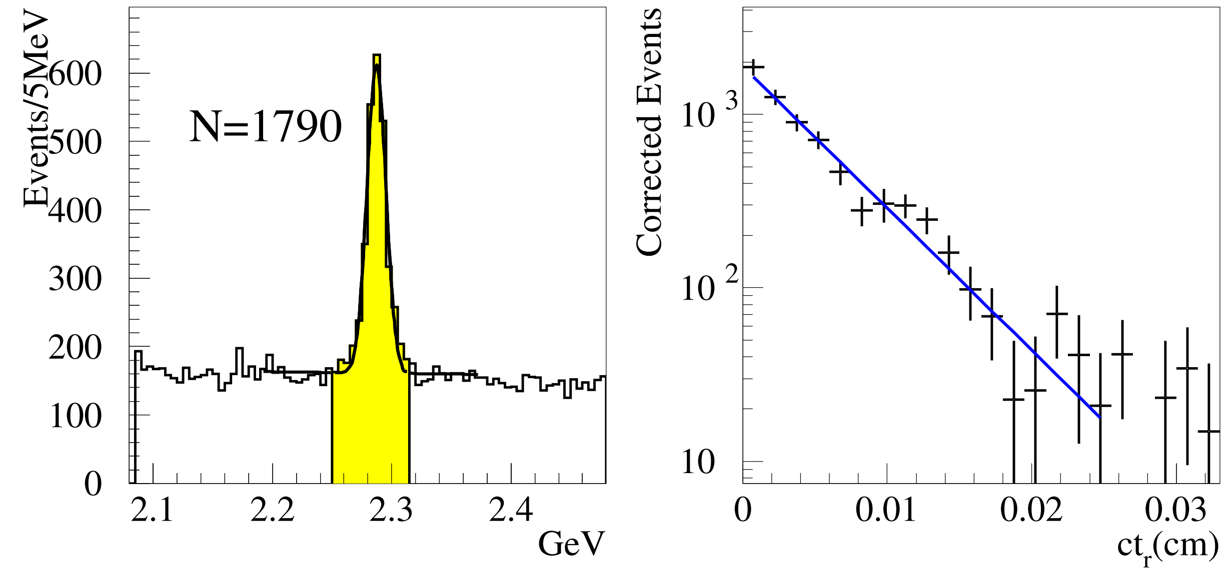
Fig. 8: $\Lambda_c^+ \to pK^-\pi^+$ event – vertex view

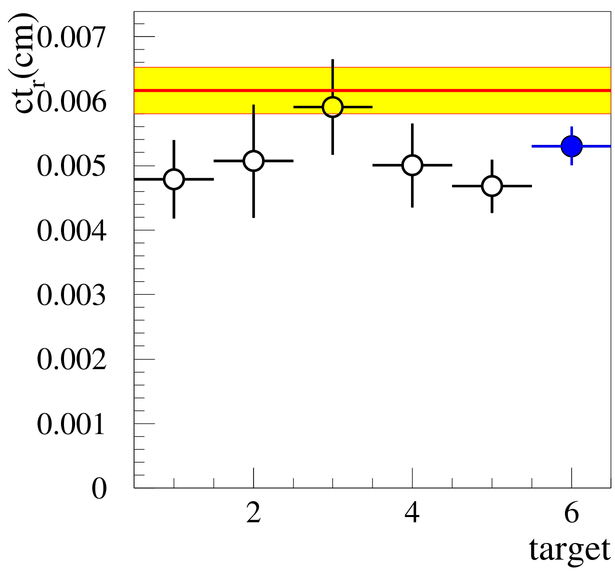


Date: 98/10/08 22.59.43
Run: 10439 Spill: 41 Event_in_Spill: 17156 Event: 100034284 Tubes: 63
18
17
19
16
Tracks : 16 17 18 19
Momenta: -095 +154 +074 -153
Masses: Sigma Proton Kaon Pion Muon Electron Backgrnd

SELEX

Very preliminary Λ_c lifetime using D^0 to measure efficiency



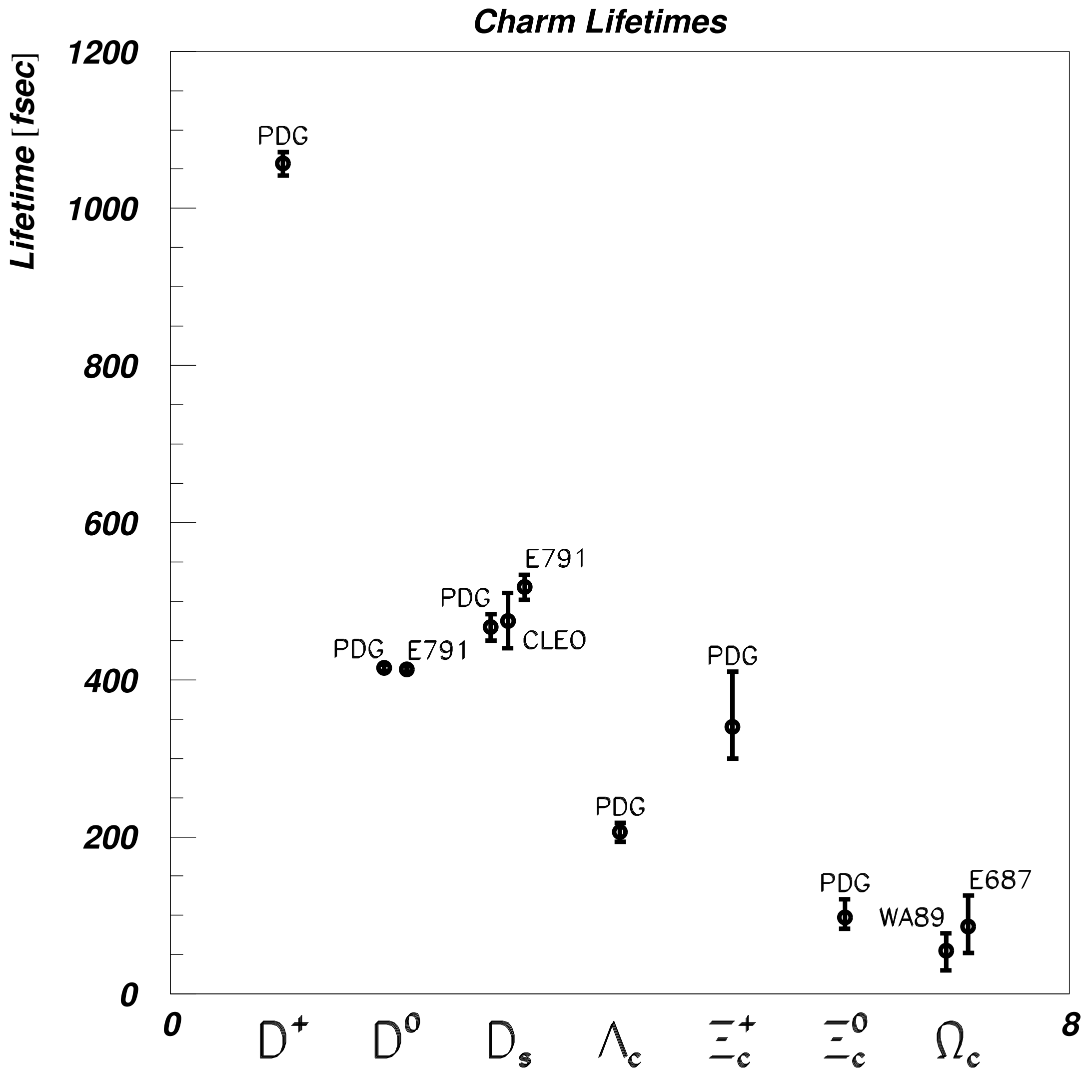


T=206 ± 12 (fs) PDG

T=177 ± 10 (fs) E781

Statistical error only

Charm Lifetimes



Most PDG98 values are dominated by E687

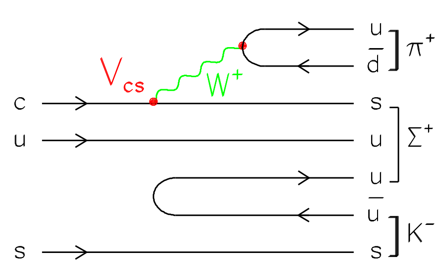
PDG, Eur. Phys. J. C 3 (1998) 1
E791 Collaboration, accepted in PRL, hep-ex/9903012
CLEO Collaboration, Proceedings Moriond 1998
E791 Collaboration, Phys. Lett. B 445 (1999) 449
WA89 Collaboration, Phys. Lett. B 358 (1995) 151
E687 Collaboration, Phys. Lett. B 357 (1995) 678

Introduction

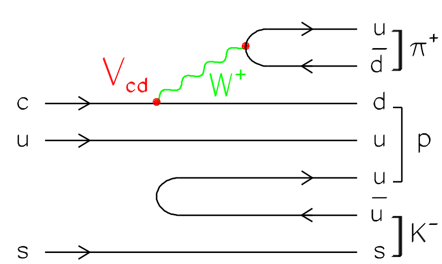
- Charmed Baryon Studies at SELEX(E781)
  - Precision measurement of mass and lifetime
  - Search for new decay modes
  - Study of Cabibbo-suppressed(CS) modes

- Cabibbo-favored vs. Cabibbo-suppressed Mode

$$\Gamma \propto G_F^2 \sum_{q=d,s} \left| V_{uq} V_{cq} \right|^2 \mathcal{F}$$

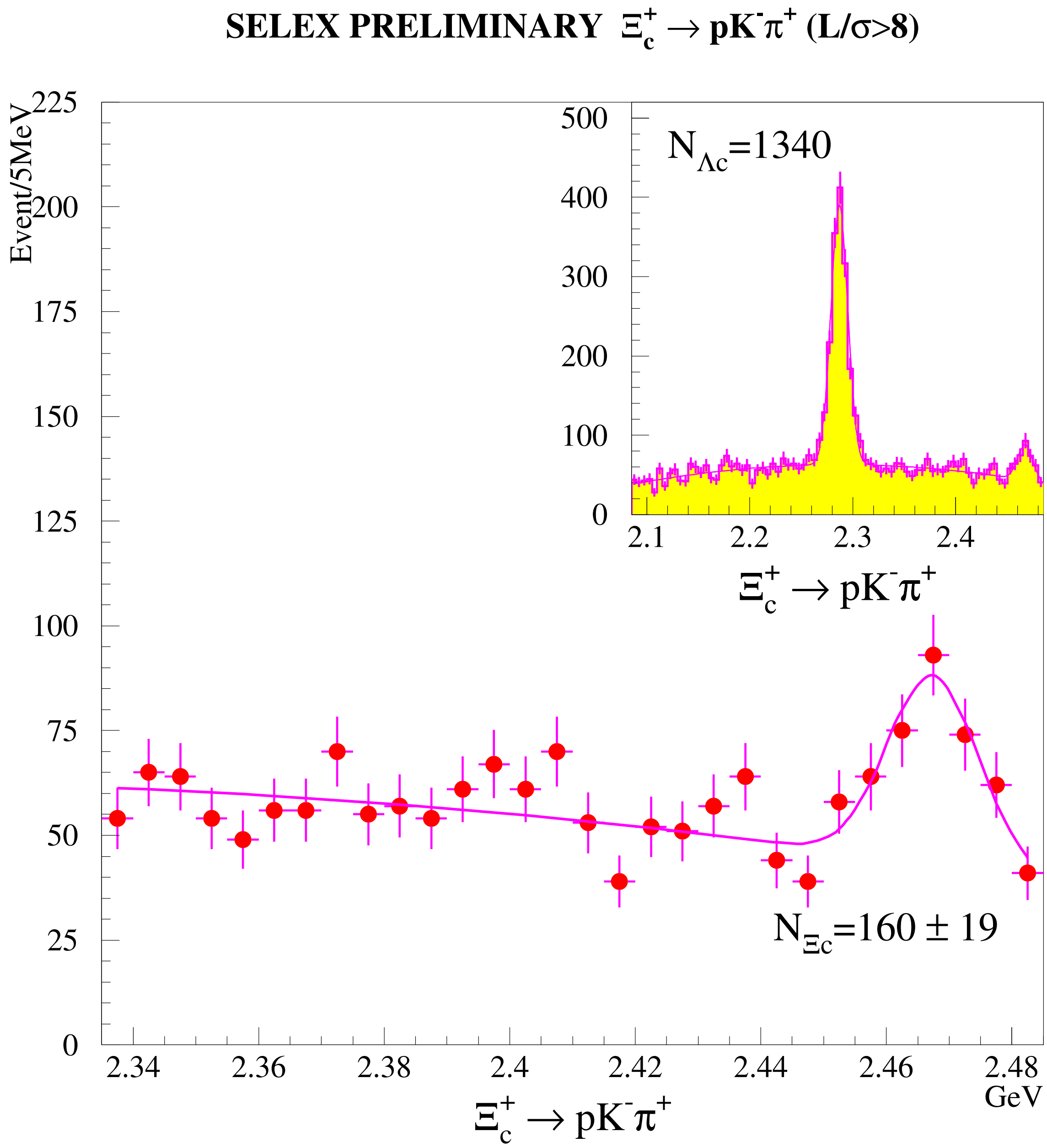


$\Xi_c^+ \longrightarrow \Sigma^+ K^- \pi^+$



$\Xi_c^+ \longrightarrow p K^- \pi^+$

$$\frac{\Gamma_{CS}}{\Gamma_{CF}} \approx \mathcal{O}(\left|\frac{V_{cd}}{V_{cs}}\right|^2 = tan^2\theta_c \approx 0.053)$$



SELEX PRELIMINARY $\Xi_c^+ \rightarrow pK^-\pi^+$ (L/σ>8)
Event/5MeV
$N_{\Lambda c}$=1340
$\Xi_c^+ \rightarrow pK^-\pi^+$
$N_{\Xi c}$=160 ± 19
GeV
$\Xi_c^+ \rightarrow pK^-\pi^+$

First Observation of Cabibbo-suppressed decay $\Xi_c^+ \to pK^-\pi^+$

Final Numbers:

Observed 150 ± 22 Events

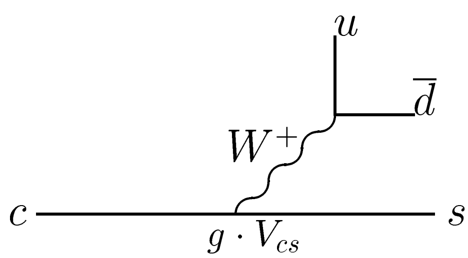
$$\frac{B(\Xi_c^+ \to pK^-\pi^+)}{B(\Xi_c^+ \to \Sigma^+K^-\pi^+)} = 0.22 \pm 0.06 \pm 0.01$$

$$\frac{B(\Xi_c^+ \to pK^-\pi^+)}{B(\Xi_c^+ \to \Xi^-\pi^+\pi^+)} = 0.20 \pm 0.04 \pm 0.01$$

SELEX Collaboration, accepted in PRL, hep-ex/9907062

Decay of charm

Just like strange:



Measure V_{cs}? Yes, but... quarks are never alone!
Need a lot of measurements $\longrightarrow$ SELEX

Decay of beauty

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HERA-B (Hamburg) (1999)

BTeV (Fermilab) (2002?)

LHC-B (CERN) (2005?)

Work in San Luis Potosí on SELEX

Mostly analysis work:

Search for exotic state decaying into $\Lambda\bar{p}\pi^+\pi^+$

Measuring charm lifetimes

Polarisation of Λ_c^+

Cabibbo-Kobayashi-Maskawa (CKM) Matrix

$$\begin{pmatrix} d' \\ s' \\ b` \end{pmatrix} = \begin{pmatrix} V_{ud} & V_{us} & V_{ub} \\ V_{cd} & V_{cs} & V_{cb} \\ V_{td} & V_{ts} & V_{tb} \end{pmatrix} \begin{pmatrix} d \\ s \\ b \end{pmatrix}$$

Theory (Standard Model): Matrix is unitary and hermitian.

$$|V| = \begin{pmatrix} 0.9745-0.9760 & 0.217-0.224 & 0.0018-0.0045 \\ 0.217-0.224 & 0.9737-0.9753 & 0.036-0.042 \\ 0.004-0.013 & 0.035-0.042 & 0.9991-0.9994 \end{pmatrix}$$

Wolfenstein parameterization:

$$V = \begin{pmatrix} 1-\frac{\lambda^2}{2} & \lambda & A\lambda^3(\rho - i\eta) \\ -\lambda & 1-\frac{\lambda^2}{2} & A\lambda^2 \\ A\lambda^3(1-\rho-i\eta) & -A\lambda^2 & 1 \end{pmatrix}$$

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$$\begin{aligned} \bar\rho &= \frac{\rho}{A\lambda^3} \\ \bar\eta &= \frac{\eta}{A\lambda^3} \end{aligned}$$

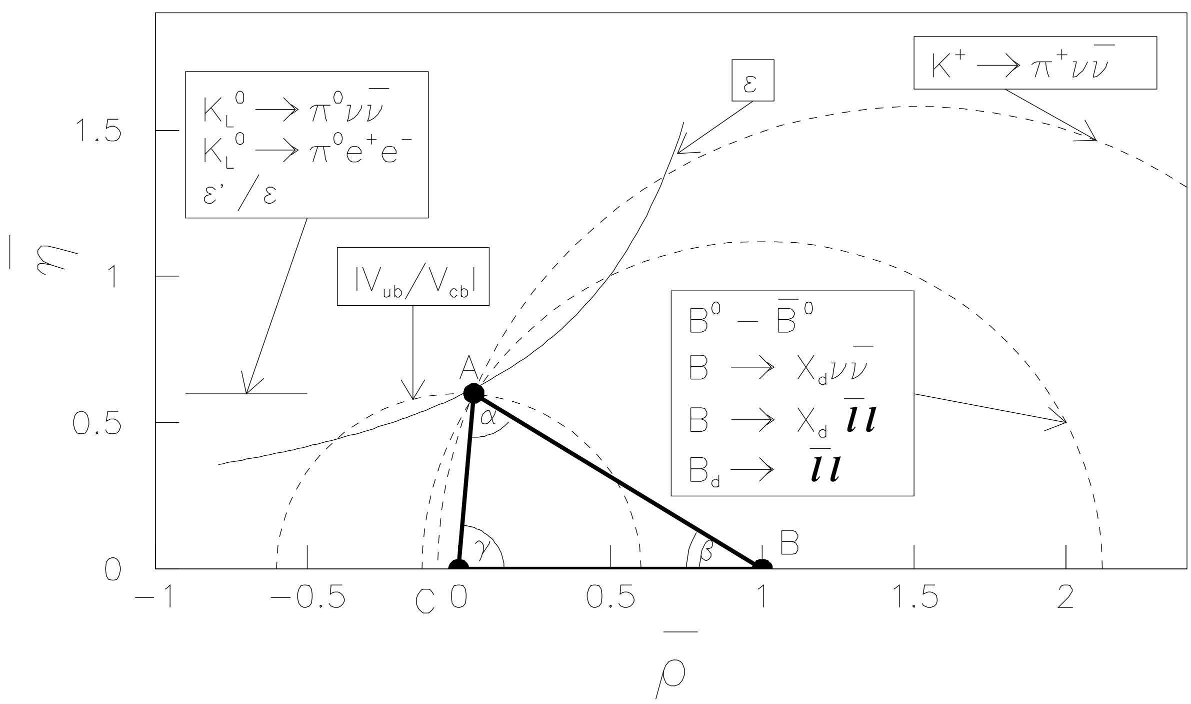


Figure 1: The ideal Unitarity Triangle. For illustrative reasons the value of $\bar\eta$ has been chosen to be higher than the fitted central value

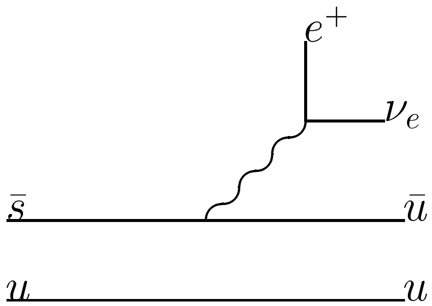
Quantitative Access to CKM parameters

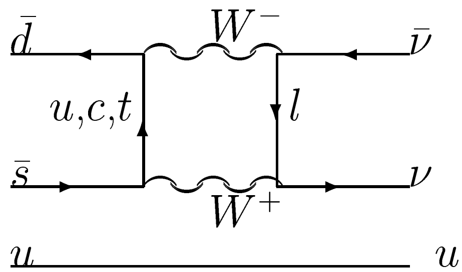
- Goal is to test the Standard Model hypothesis that a single phase in the CKM matrix is the sole source of CP violation.
- This means *over-constraining* the prediction, and testing for consistency. Paraphrasing Wolfenstein: "…I invented the parameters ρ and η, and I don't care what the values are so why should you?? The substance here is to *over-constrain* the model and test for consistency…"[2]
- To falsify the Standard Model hypothesis the only foreseeable results with controlled errors are:
  - B physics: $B_d^0 \to \Psi K_s$, and perhaps x_x/x_d mixing.
  - K physics: $K^+ \to \pi^+ \nu \bar{\nu}$ and $K^0 \to \pi^0 \nu \bar{\nu}$.

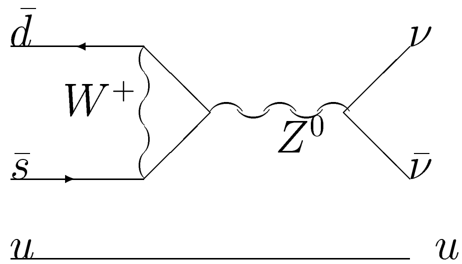
[2]Wolfenstein at Kaon'99

$K^+ \to \pi^+ \nu\bar{\nu}$ Theory

Calculated[3] by weak isospin rotation from $K^+ \to \pi^0 e^+ \nu$







$$\frac{B(K^+ \to \pi^+ \nu\bar{\nu})}{B(K^+ \to \pi^0 e^+ \nu)} = \frac{3\alpha^2}{8\pi^2 \sin^4\theta_W} |V_{cs}^* V_{cd} D(X_c) + V_{ts}^* V_{td} D(X_t)|^2 \frac{1}{|V_{us}|^2}$$

$$D(X) = \frac{1}{8}\{1 + \frac{3}{(1-X)^2} - \frac{(4-X)^2}{(1-X)^2}\} X ln(X) + \frac{X}{4} - \frac{3X}{4(1-X)}$$

$$X_j = \{\frac{m_j}{m_W}\}^2; \quad j = c, t.$$

$$\begin{aligned} Br[K^+ \to \pi^+ \nu\bar{\nu}] &= [0.44 \pm 0.15] \times 10^{-10}[(1.4 - \bar{\rho})^2 + \bar{\eta}^2] \\ &= (0.9 \pm 0.3) \times 10^{-10} \end{aligned}$$

[3] T. Inami and C.S. Lim, Progress of Theoretical Physics **65** (1981) 297-314

Total theoretical uncertainty of 8 % estimated by Buras, et al.[4]

Dominated by uncertainty in charmed quark mass.

Structure of K^+ is put in with measured $K^+ \to \pi^0 e^+ \nu$ branching ratio.

All other corrections are small and calculated (NLO QCD, isopsin, long distance contributions).

$\Longrightarrow$ We can measure V_{td} to 10 % if we can measure $Br[K^+ \to \pi^+ \nu \bar{\nu}]$ to 10 % (100 Events).

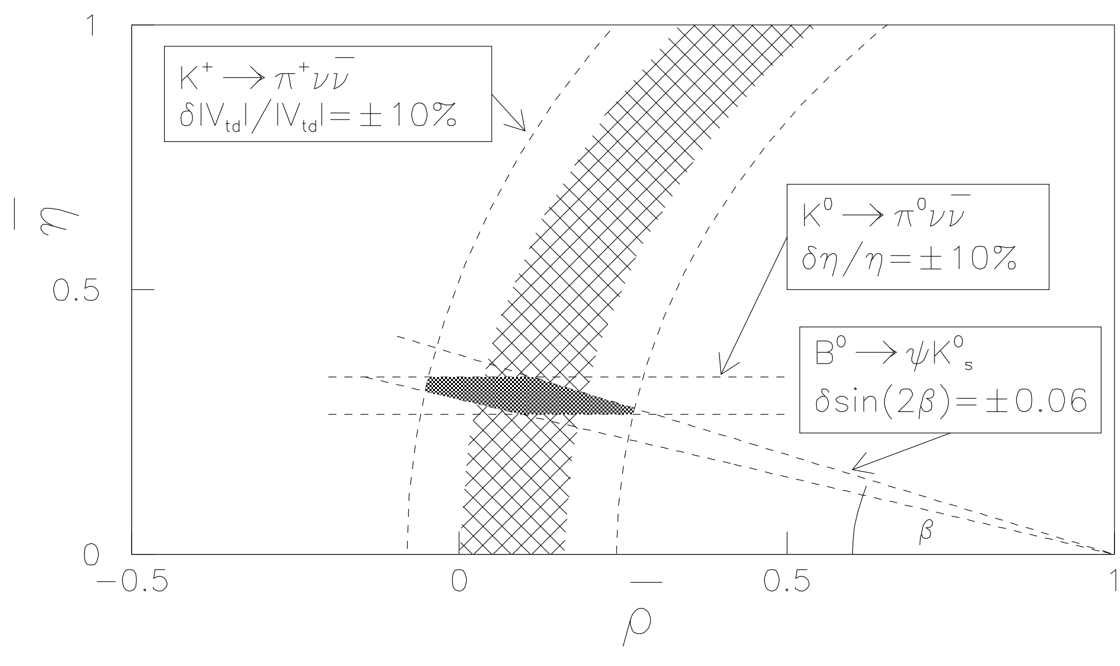


Figure 2: A possible outcome from measurements of $K^+ \to \pi^+ \nu \bar{\nu}$, $K_L \to \pi^0 \nu \bar{\nu}$ and $B^0 \to \psi K^0_s$. The hashed annulus indicates the statistical precision of a 100 event measurement, and the total band indicates the combined statistical and theoretical errors.

[4]A.J. Buras, hep-ph/971217

A short estimate for an inflight decay experiment

- $BR = 10^{-10}$
- 100 Events
- Acceptance 1 %

$\Longrightarrow 10^{14}$ live K^+

- Duty cycle of machine 30 % (Fermilab MI)
- Lifetime of machine and experiment 50 %
- 2 years of running time

$\Longrightarrow$ 30 MHz of K^+

In addition: Only a few background events
$\Longrightarrow$ Suppress background to 10^{-12}

Charged Kaons at the Main Injector

A Proposal for a Precision Measurement of the Decay $K^+ \to \pi^+\nu\bar{\nu}$ and Other Rare K^+ Processes at Fermilab Using the Main Injector

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[6]Resident at Fermilab, on leave from Tel Aviv University.

Experimental Method

BIGGEST PROBLEM IS BACKGROUND

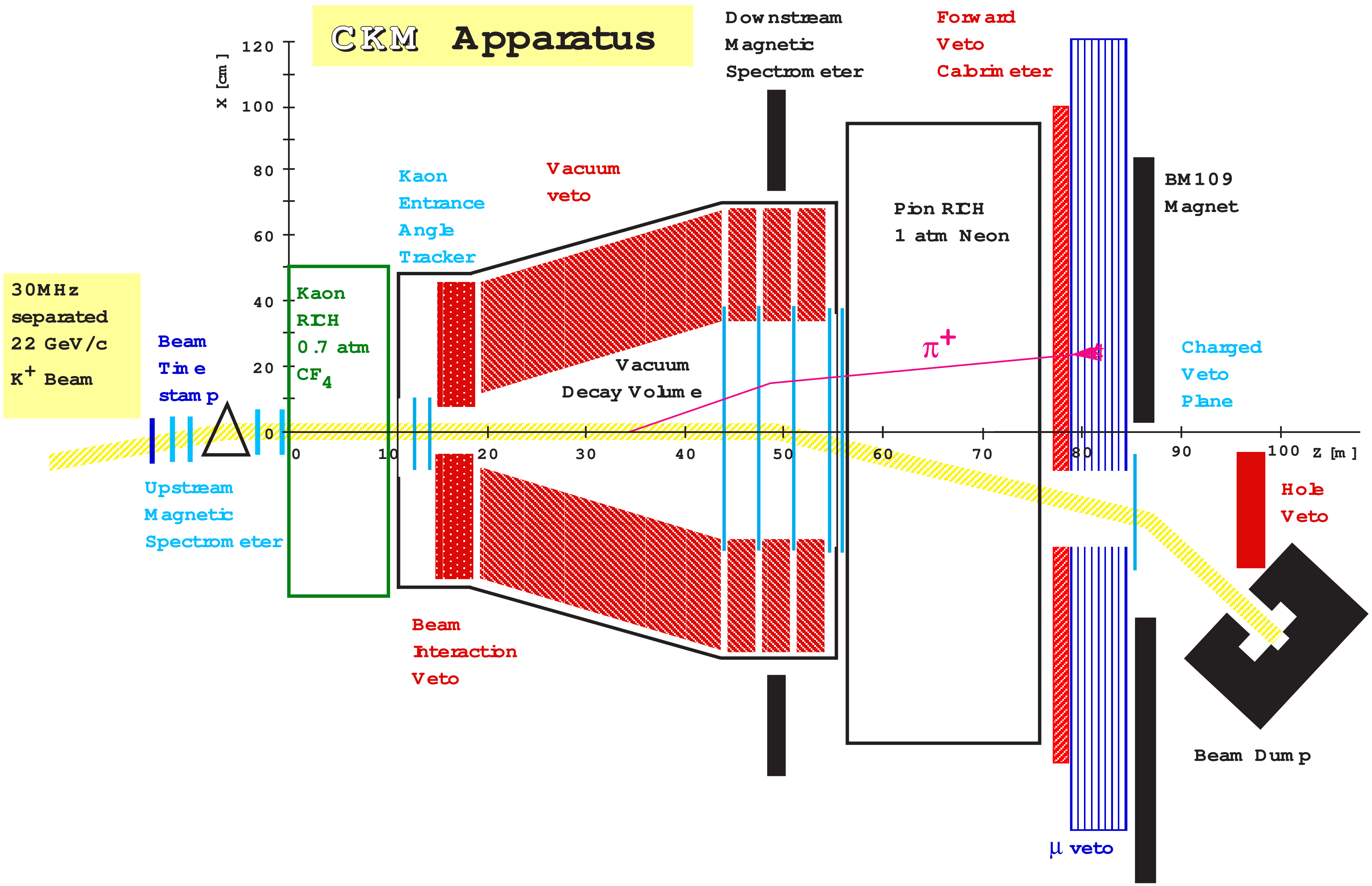
- Only measurable: K^+, π^+
- Biggest backgrounds: $K^+ \to \mu^+\nu$ (64 %) and $K^+ \to \pi^+\pi^0$ (21 %)

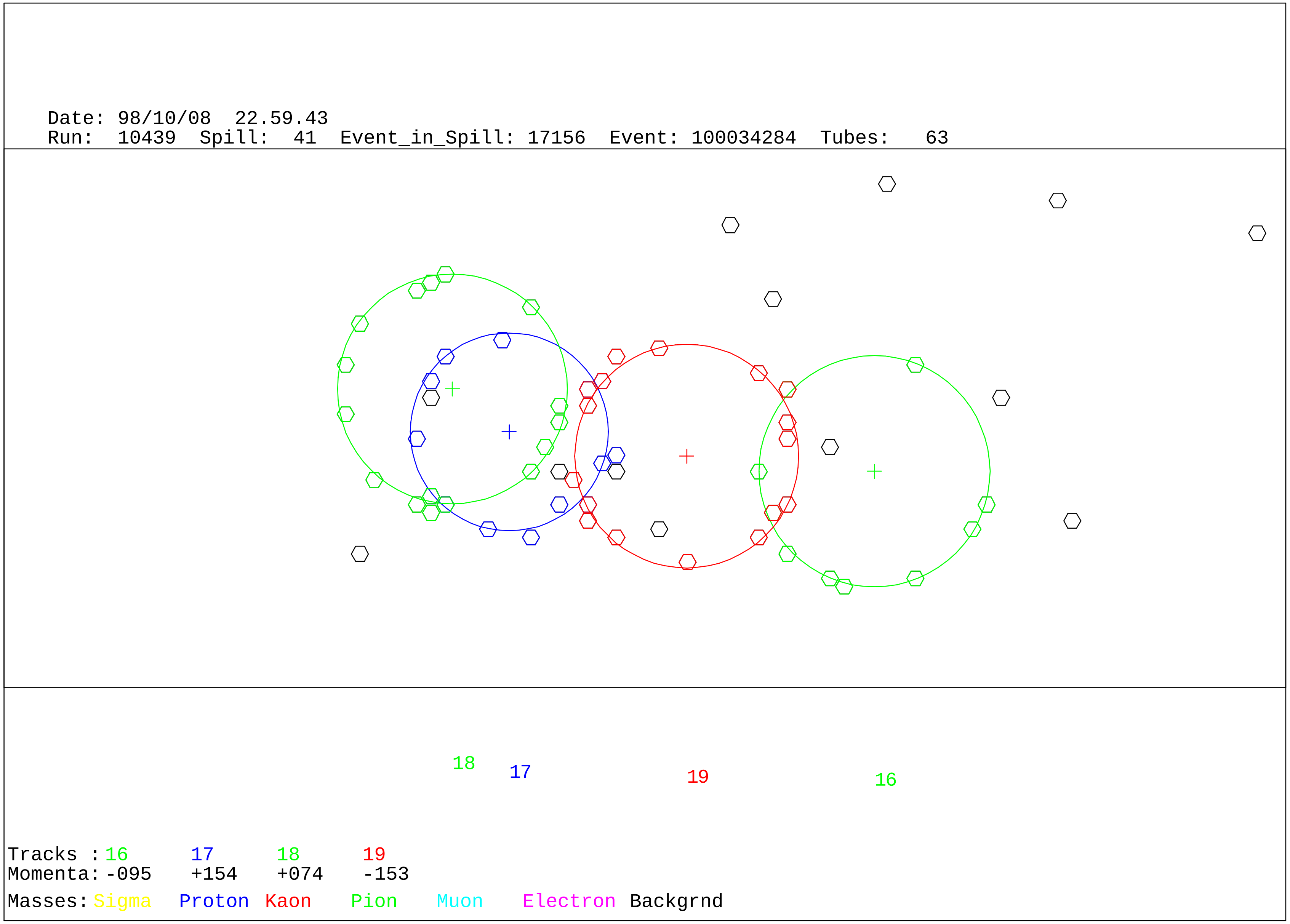
Calculate "Missing Mass"

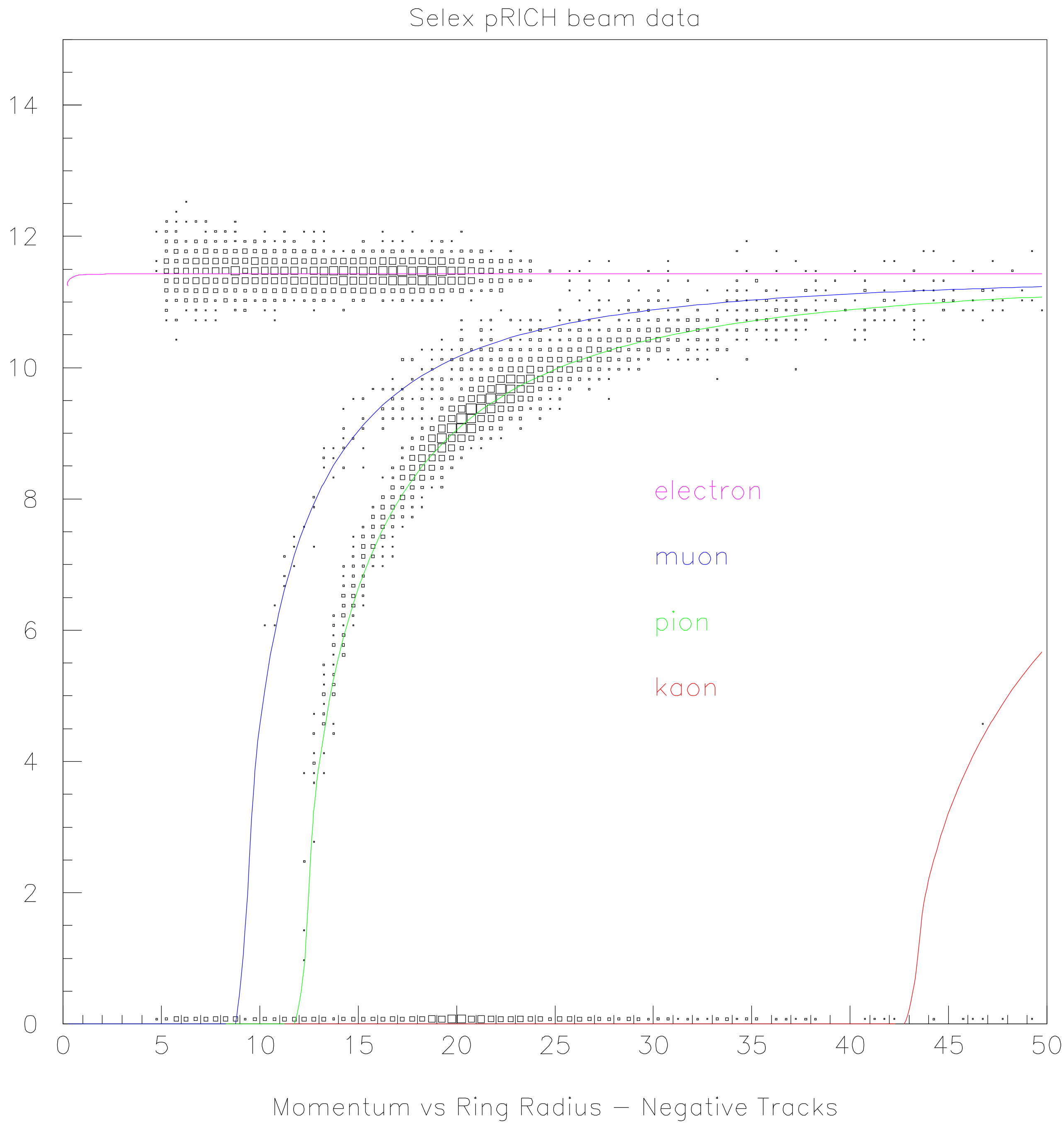
$$M_{miss}^2 = M_K^2(1 - p_\pi/p_K) + m_\pi^2(1 - p_K/p_\pi) - p_\pi p_K \theta^2$$

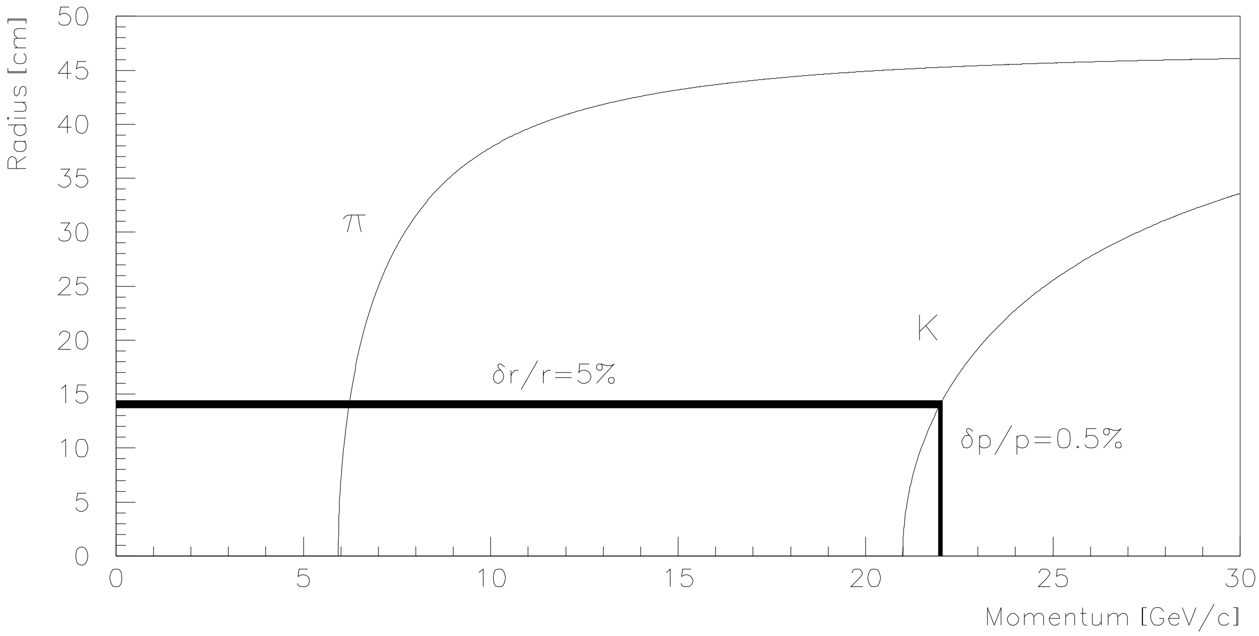
For 2-body decays, M_{miss} is fixed value. For signal, M_{miss} has distribution.

- Reduce all material to minimum
- Make redundant measurements

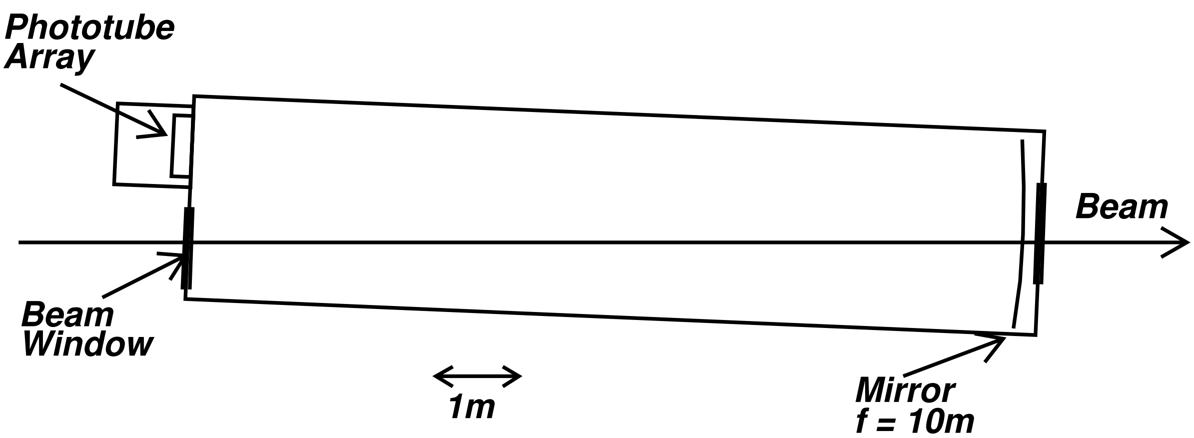

CKM Apparatus
30MHz
separated
22 GeV/c
K+ Beam
Beam
Time
stamp
Upstream
Magnetic
Spectrometer
Kaon
RICH
0.7 atm
CF4
Kaon
Entrance
Angle
Tracker
Vacuum
veto
Beam
Interaction
Veto
Vacuum
Decay Volume
Downstream
Magnetic
Spectrometer
Pion RICH
1 atm Neon
π+
Forward
Veto
Calorimeter
μ veto
BM109
Magnet
Charged
Veto
Plane
Hole
Veto
Beam Dump
x [cm]
z [m]


Date: 98/10/08 22.59.43
Run: 10439 Spill: 41 Event_in_Spill: 17156 Event: 100034284 Tubes: 63
18
17
19
16
Tracks : 16 17 18 19
Momenta: -095 +154 +074 -153
Masses: Sigma Proton Kaon Pion Muon Electron Backgrnd

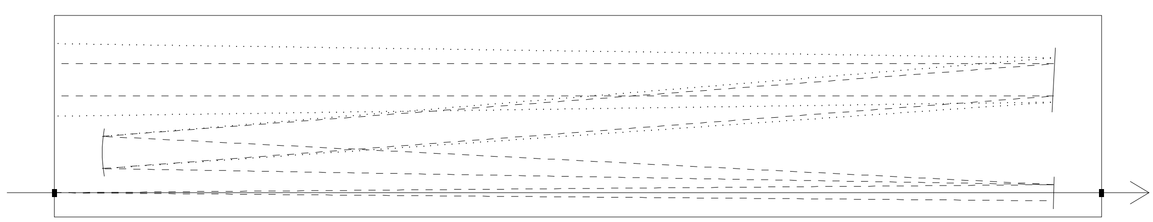

Selex pRICH beam data
14
12
10
8
6
4
2
0
0
5
10
15
20
25
30
35
40
45
50
electron
muon
pion
kaon
Momentum vs Ring Radius – Negative Tracks



Pion RICH: Like SELEX RICH, but with 20 m Vessel



Kaon RICH: 10 m Vessel, folded light path



The Final Signal Plot

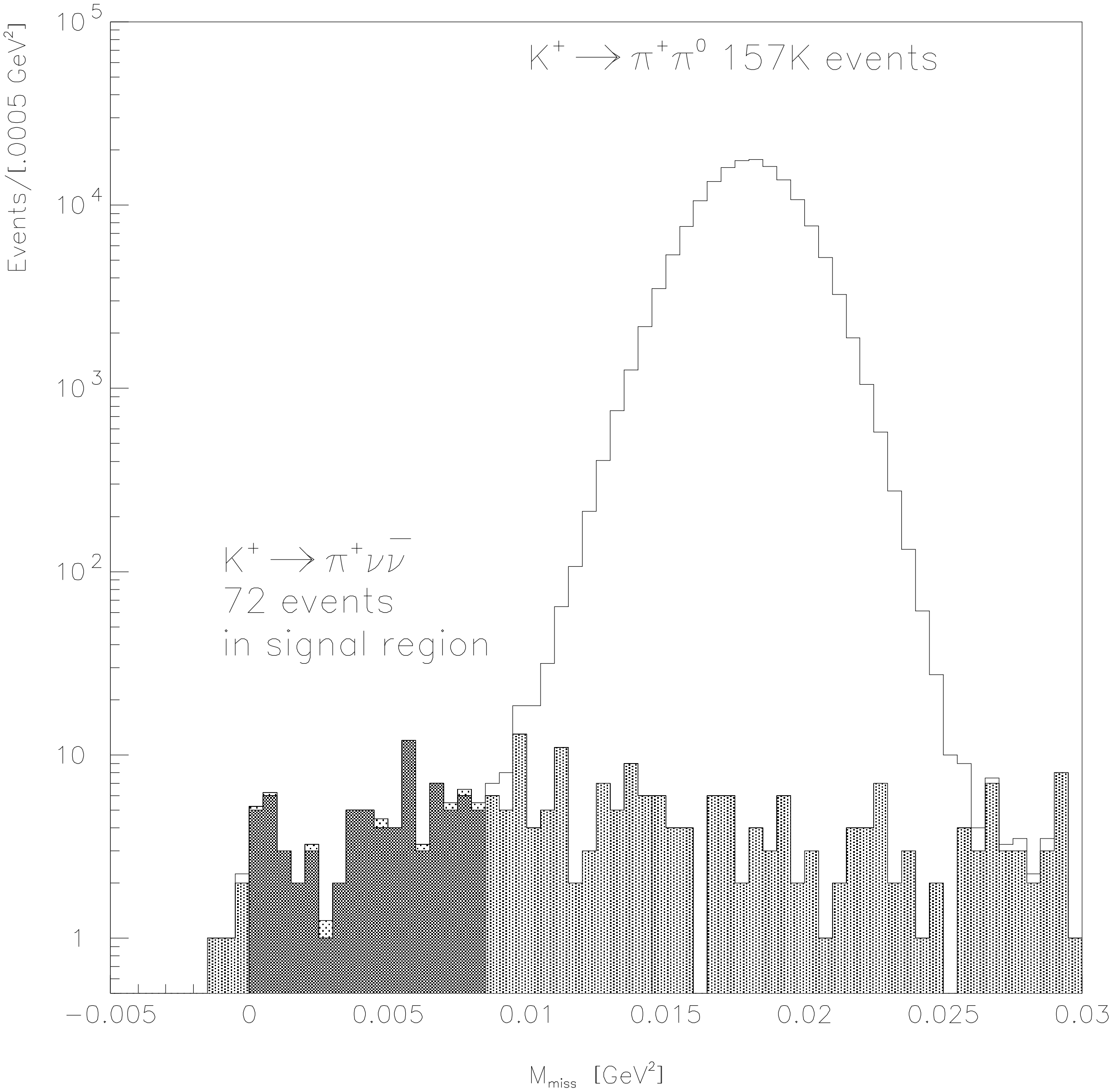


Figure 3: Missing mass squared ($M^2_{\rm combined}$) for $K^+ \rightarrow \pi^+\pi^0$ events passing all cuts superimposed on the signal (light shading). The sensitivity shown in this plot corresponds to the experimental sensitivity of 72 $K^+ \rightarrow \pi^+\nu\bar{\nu}$ events in our mass window (single event sensitivity of 1.4×10^{-12}) which are indicated with the dark shading.

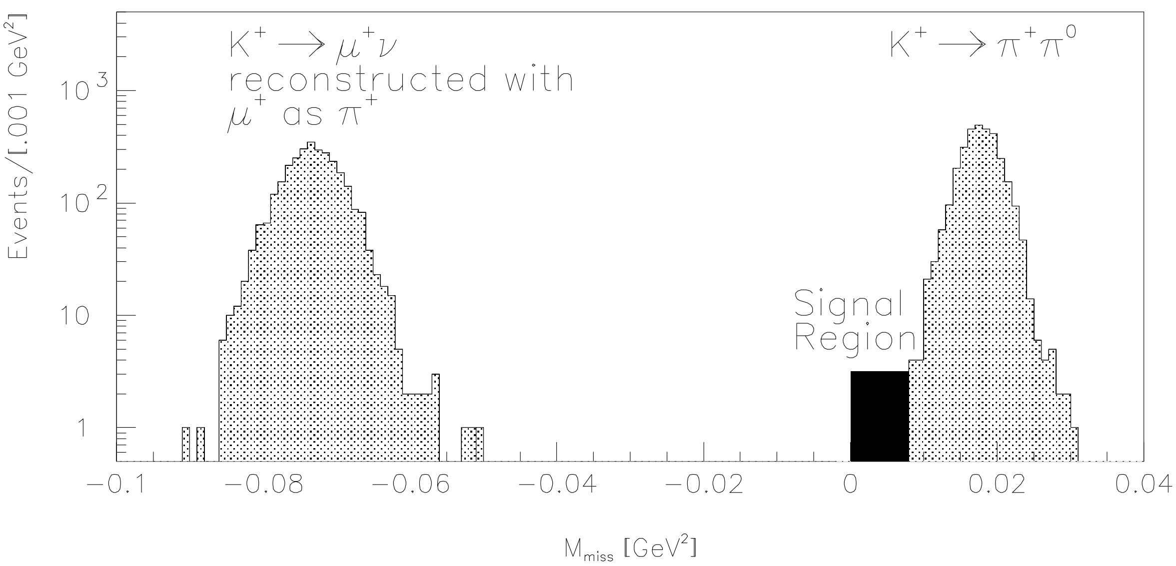


Figure 4: Missing mass of $K^{\pm} \rightarrow \mu^{\pm}\nu_{\mu}$ decays where the muon is reconstructed under the pion mass hypothesis.

Other possible measurements

10^{-12} in single event sensitivity is a long way.
There are a lot of interesting modes to be picked up.
This list is NOT finished, and is open to more suggestions.

These are just a few examples we where thinking of:

- $K^+ \to \mu^+ \nu_\mu \gamma$ Form Factor: Test of Chiral Perturbation Theory
- $K^+ \to \pi^+ e^+ e^-$, $K^+ \to \pi^+ \mu^+ \mu^-$, Form Factor and Branching Ratio: Test of Chiral Perturbation Theory
- $K^\pm \to \pi^\pm \pi^+ \pi^-$, $K^\pm \to \pi^\pm \pi^0 \pi^0$, $K^\pm \to \pi^\pm \pi^0 \gamma$, $K^\pm \to \pi^\pm \gamma\gamma$: Test of Chiral Perturbation Theory, Search for Direct CP Violation in $K^\pm$ decays.
- $K^+ \to \pi^0 e^+ \nu$, $K^+ \to \pi^0 \mu^+ \nu$ Branching Ratio: Measurement of V_{us}

Work in San Luis Potosí

- Design work on Kaon and Pion RICH
- Monte Carlo studies
- Construction of flat, thin mirror for Kaon RICH
- Tests and Classifications of Photomultipliers
- (Maybe:) Supervision of spherical mirror production (in Mexico?)

Schedule

April 1996: Expression of Interest (EOI)

April 1998: Proposal submitted

October 1998: Approved as an Fermilab R&D project

October 1999: R&D project financed

April 2001: Submission of Technical Proposal

2003-2005: Running

2005-2007: Data analysis and publications.

Conclusion

- High Energy Physics is a very active field
- Experimentally and Theorectically
- Weak Interaction very interesting

- IF-UASLP is collaborating in SELEX
- IF-UASLP is collaborating in CKM
- IF-UASLP has a theoretician

More Information:

`http://www.fnal.gov`

`http://www.ifisica.uaslp.mx`

`http://www.ifisica.uaslp.mx/~jurgen`

`http://fn781a.fnal.gov`

`http://www.fnal.gov/projects/ckm/Welcome.html`