New Result on $K^+ \to \pi^+ \nu \overline{\nu}$ from BNL E787

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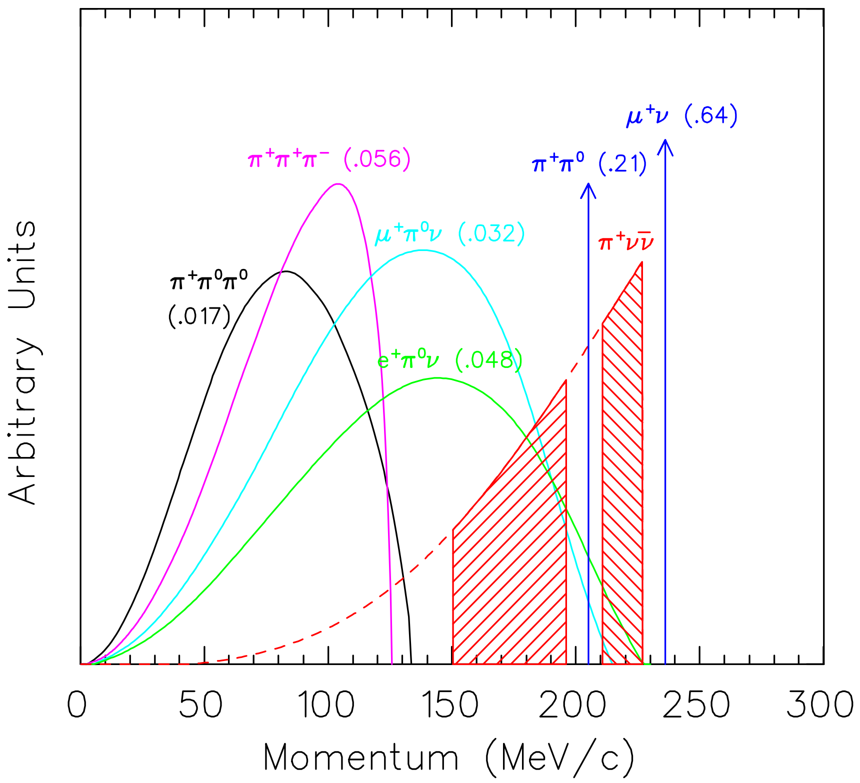
E787 strategy



- Work in kaon rest frame $\Rightarrow$ stopped kaon beam (BeO degrader, scintillating fiber stopping target)
- Search in the high-momentum region ($p_\pi > 211$ MeV/c)
- Stop the decay pion in scintillator
  - Redundant measurements of track kinematics: energy and range
  - π/μ separation
    - Observe $\pi^+ \to \mu^+ \to e^+$ decay sequence $\Rightarrow$ high-speed digitizers (2ns samples, ~ 7 μs depth)
    - dE/dx separation in scintillator
- π momentum measurement $\Rightarrow$ low-mass tracking
  - Chamber resolution: $\Delta P/P \sim 0.9\%$ at 205 MeV/c
  - $\sim 1.2\%$ overall resolution

- Photon veto
  - 4π coverage, typically $15X_0$
  - Time windows typically 2-3 ns; energy thresholds $\sim$ 0.2 - 3 MeV
  - CsI, Pb-scint, Pb glass, "Shashlik"
- Beam instrumentation
  - K/π separation
    - Cerenkov counter, lucite radiator
    - Scintillator hodoscopes (dE/dx)
  - Fine spatial segmentation, tracking, good timing
    - Scintillating fiber (5mm square fiber) kaon stopping target
    - MWPC's (1.27 mm wire spacing)
- Rate capability
  - ~ 5 MHz of incoming K^+
  - 500 MHz digitizers in barrel, endcap, target, beam hodoscopes
- Minimize inactive material (undetected energy loss)

Main "online" improvements since 1995 run

- 1996
  - Lower K^+ momentum (790 MeV/c $\rightarrow$ 730 MeV/c) $\Rightarrow$ higher K stopping fraction, lower accidental loss (but, requires more protons to maintain K flux)
  - Higher acceptance in trigger
- 1997
  - Further lowered K^+ momentum (710 MeV/c, 670 MeV/c)
  - Lower deadtime (28%/MHz of stopped kaons $\rightarrow$ 17%/MHz)
    - x2 more trigger rejection
  - Higher acceptance ($\mu^+ \rightarrow e^+$) from increased TD depth

95-97 dataset

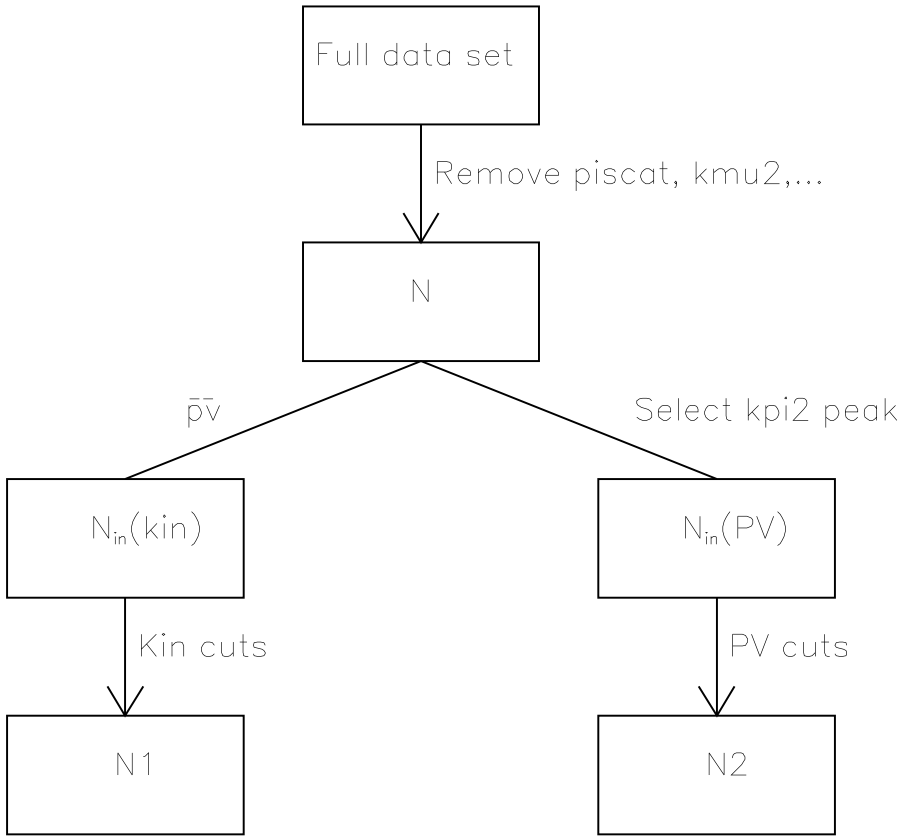
	1995	1996	1997	Total
KB(live) (10^{12})	~ 1.53	~ 1.16	~ 0.59	~ 3.28
No. exabyte tapes	~ 4800	~ 4900	~ 1400	~ 11100
No. evts to tape				$\sim 3.1 \times 10^8$

Offline analysis overview

- Blind analysis
  - Signal region is hidden (by inverting cuts) while cuts are developed and background levels estimated
  - In addition, blind analysis for background estimation.
    - Eliminate low statistics bias.
    - A fraction ($\sim 1/3$) of the data is used to set the cuts; actual cut performance is measured on the remaining data.
- "Bifurcated" analysis
  - A priori identification of background sources
  - Same dataset for background studies and signal search
  - Two independent cuts with high rejection for each background
  - Measurement of background levels in the signal region at the 10^{-3}–10^{-2} event level
- Correlation studies
- Prediction of background levels around signal region (followed by confirmation)
- Background likelihood analysis (using predetermined likelihood functions) in the signal region for assessing candidate events.

Background estimation

Take $K^+ \to \pi^+ \pi^0$ as an example:



$R_{PV} = N2/N_{in}(PV)$

$N_{bg} = N1/(R_{PV} - 1)$

Offline analysis of 1995-7 dataset

Themes:

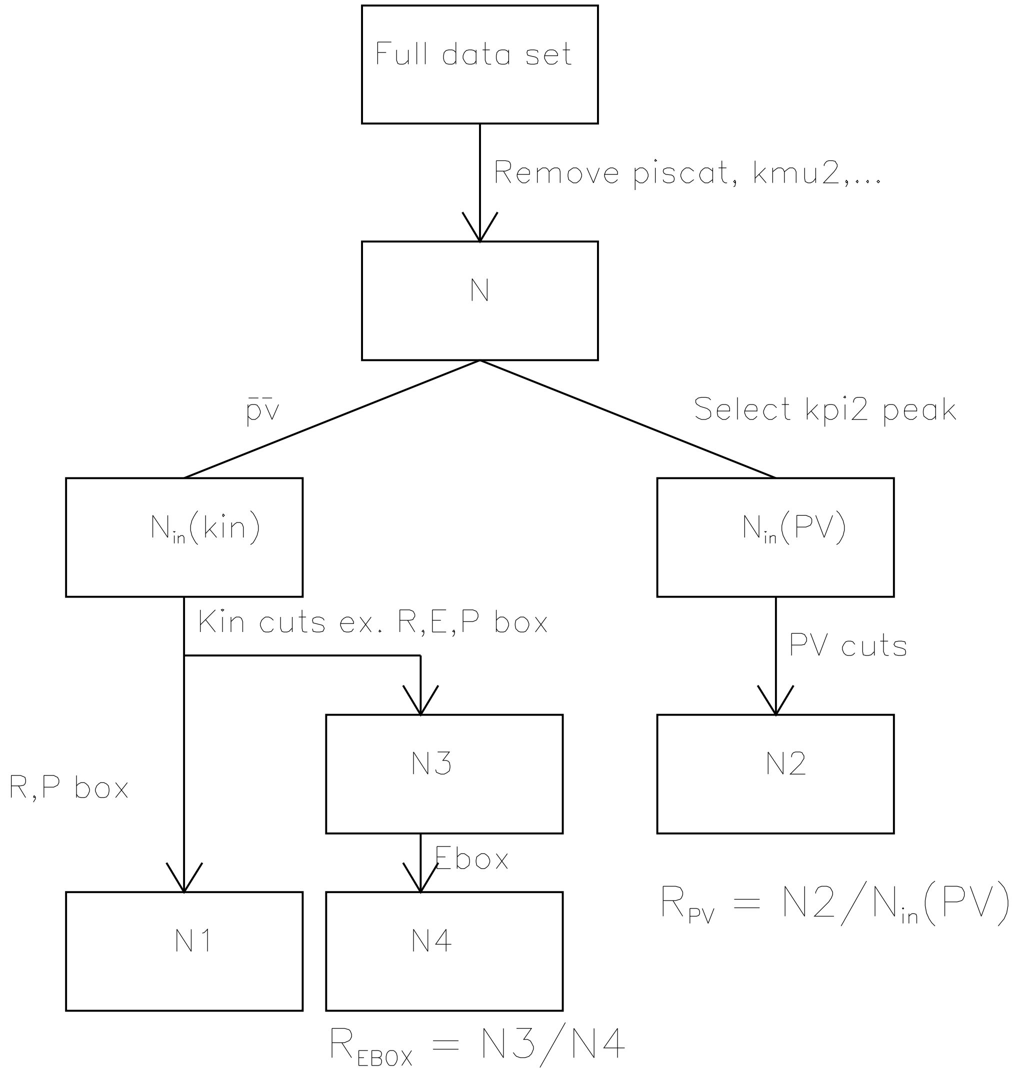
- Increase rejection by about a factor of 3 to maintain same bkg level as 1995 analysis for the 95-7 dataset.
- Maintain (or possibly even increase) acceptance at the same time
- Devise methods to increase bkg samples (beyond the obvious increase from increased exposure)
- Further test our understanding of the backgrounds

Analysis chronology

- Cuts and analysis improvements were developed on 1/3 of the 1995 dataset, then tested on 2/3 of 1995 data.
- Calibrations were retuned where necessary on 1/3 1996-7 data. A few cuts were tweaked, based on high statistics. Background measurements from 1/3 96-7 were basically consistent with expectations from 1995. $\Rightarrow$ completely unbiased measurement of bkg levels in 96-7 data up to this point.
- Bkg survivors from 1/3 96-97 examined. Some new cuts devised to gain rejection.
- Final 96-97 bkg level estimated from measurements on 2/3 96-97 data.

Increasing bkg statistics with extra bifurcations

Again, taking $K^+ \to \pi^+\pi^0$ as an example:



$$N_{bg} = N1/(R_{EBOX})/(R_{PV}-1)$$

Analysis improvements

$K_{\pi 2}$

- Tracking improvements in range stack and target $\Rightarrow$ better range resolution (core) and smaller tail

$K_{\mu 2}$

- Tracking improvements in drift chamber and better tracking quality cuts $\Rightarrow$ smaller momentum tail
- Range stack dE/dx likelihood analysis $\Rightarrow$ effective against muons downshifting in energy and range
- Improved algorithm for finding the electron from $\mu^+ \rightarrow e^+$ decay $\Rightarrow$ 17% gain in acceptance
- Better optimization of TD likelihood functions
- Better understanding of different sources ot TD bkg in $K^+ \rightarrow \mu^+ \nu_\mu$peak compared to $K^+ \rightarrow \mu^+ \nu_\mu \gamma$and $K^+ \rightarrow \pi^0 \mu^+ \nu_\mu \Rightarrow$ much higher statistics for estimating TD rejection

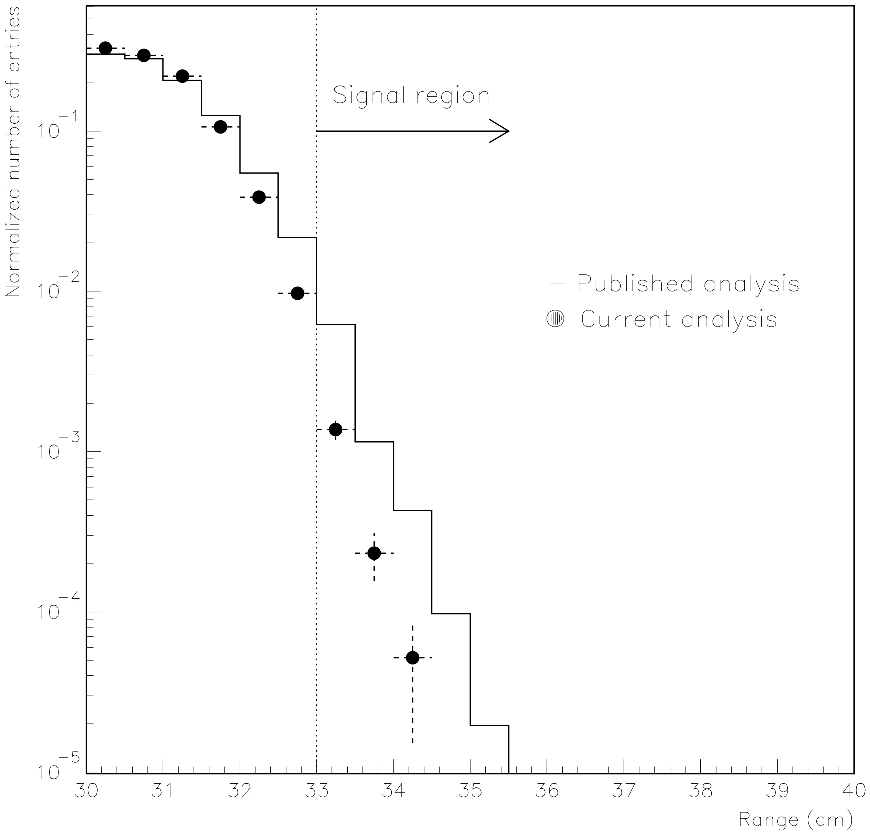
Beam bkg

- New cuts against K decay-in-flight.
- Improved cuts in target CCD and K Cerenkov against second track.
- Separation into kaon-entering and pion-entering samples.

CEX

- Benefitted from improved target tracking
- Discriminant function analysis in target and beam hodoscopes

$K^+ \to \pi^+\pi^0$ range tail. New vs old

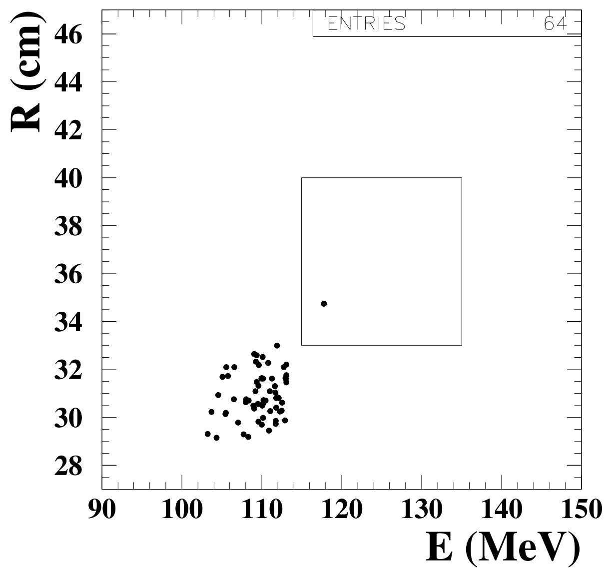


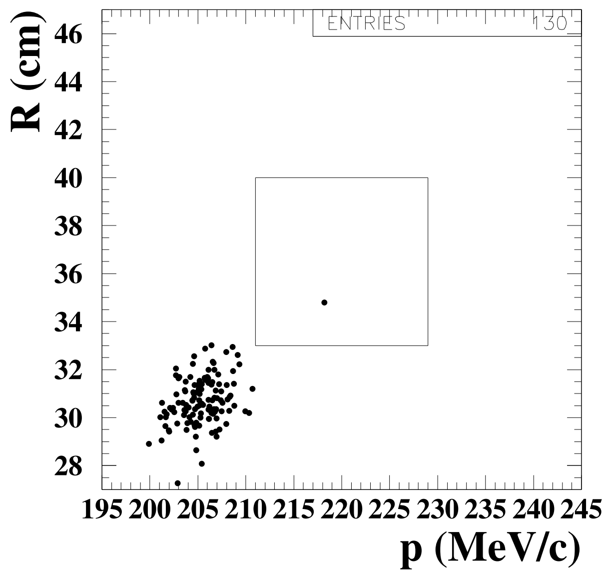
Bkg estimates 95-97

	1995	1996-7	Total
$K^+ \to \pi^+\pi^0$	0.015	0.006	0.021
$K^+ \to \mu^+\nu_\mu$	0.008	0.020	0.028
1-beam	0.0026	0.0015	0.004
2-beam	0.0021	0.0047	0.007
CEX	0.0045	0.0051	0.010
Total			0.07

Statistical and systematic uncertainties on the bkg estimate are still being evaluated.

$K^+ \to \pi^+ \nu \overline{\nu}$ search 95-97





Note: Box position on $K^+ \to \pi^+ \pi^0$ side is shown as a rough guide. Actual cut position depends on the characteristics of each event.

The acceptance calculation is not finalized. The 95-97 sensitivity is between 2 and 3 times that of 95 alone.

Prospects

1998 data on tape: expected sensitivity is twice the combined 95-7 dataset (or about 5 times 95 alone).

BNL E949:

- Aiming to reach sensitivity of $(0.8 - 1.5) \times 10^{-11}$.
- Modest upgrades to existing E787 detector
  - Barrel Veto Liner adds about 2.5X_0.
  - New photon detector along the beam line.
  - Finer segmentation of beam hodoscopes.
  - New preamps for drift chamber.
  - New trigger counters for better efficiency.
  - Trigger/DAQ
    - Pipelined level 0 trigger
    - Reduced data size
    - Reduced online photon veto loss from meantiming
- Longer running per year
  - > 25 weeks per year expected during the RHIC era
- Increased sensitivity/hour

Upgrade	Improvement factor over published 95 result
Lower momentum	1.38
Higher duty factor	1.56
Efficiency improvements already obtained	1.54
Additional efficiency improvements	2.1
Phase space below $K^+ \to \pi^+\pi^0$	(2)
Optimization of offline analysis for higher rate	(2)
Total	14