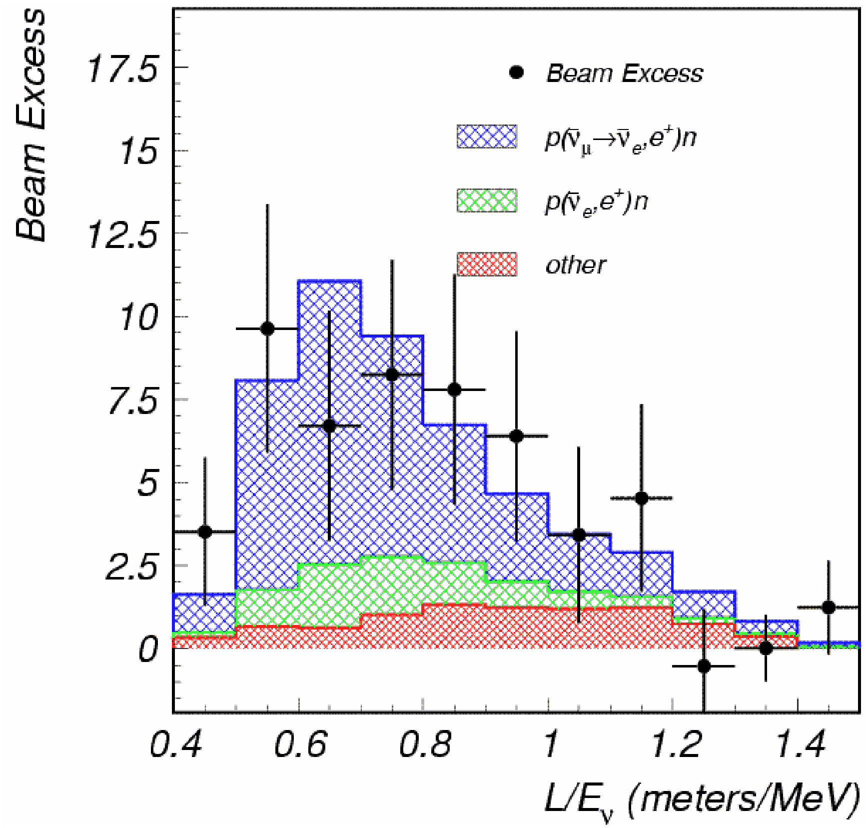
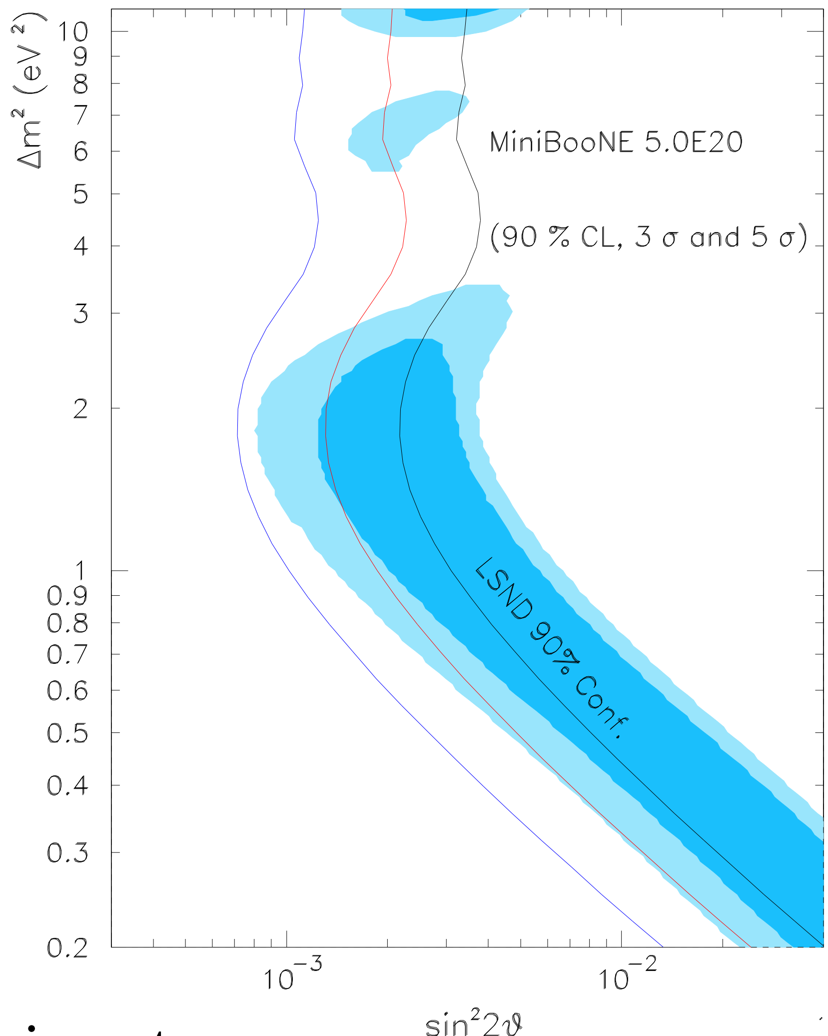
Progress on a Neutrino Oscillation Search at MiniBooNE

B. T. Fleming for the
MiniBooNE Collaboration

Yale University

The LSND experiment observed $\bar{\nu}_e$ appearance in a $\bar{\nu}_\mu$ beam

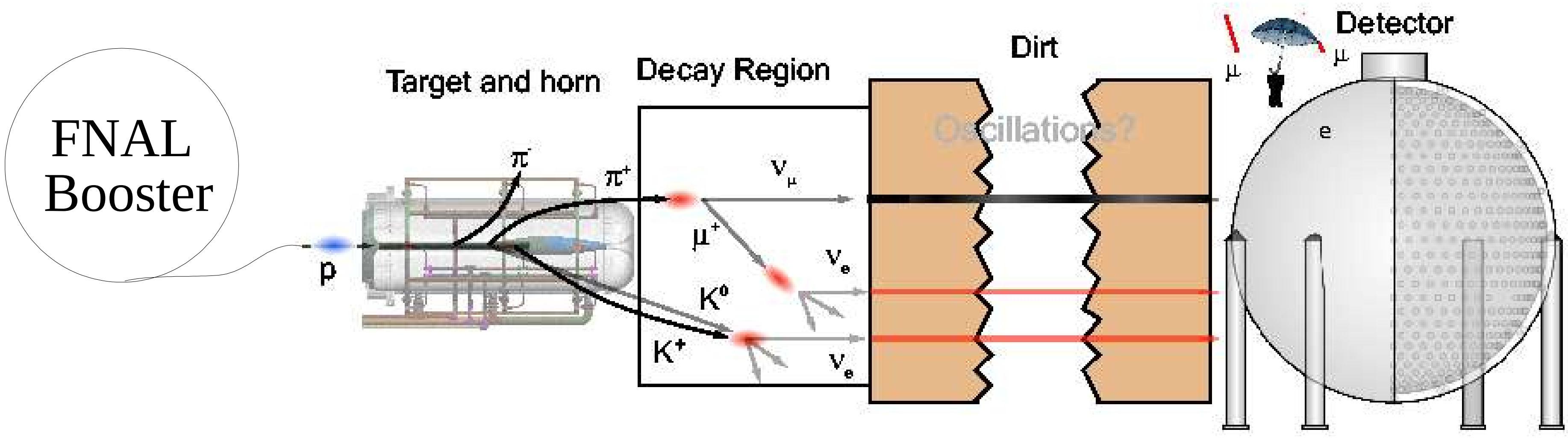




MiniBooNE experiment:
designed to confirm or rule out the LSND result

ν_e appearance in a ν_μ beam →

L=540 m (~x20 LSND)
E = 800 MeV (~x20 LSND)



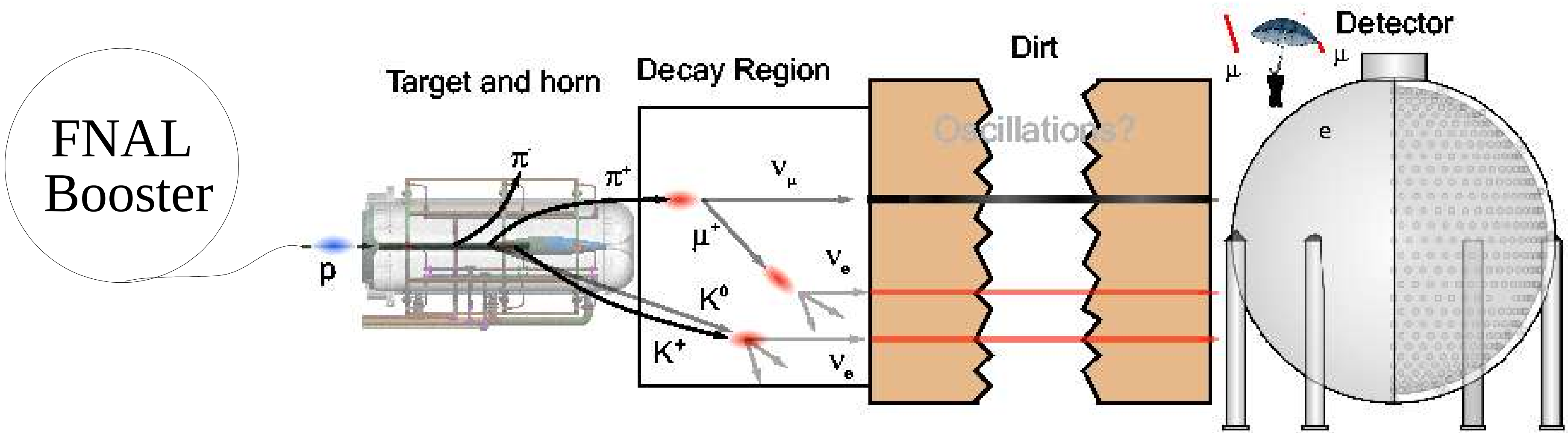
8 GeV protons from Fermilab Booster incident on target inside horn
π's and k's decay to neutrinos and decay products in 50 m decay channel

~800 MeV ν_μ beam which travels ~540 m to detector
ν_e appearance in ν_μ beam?

Running since 2002 with 5.7 x 10^{20} POT for neutrino mode

Oscillation analysis: In progress ...

Switch horn polarity to run anti-neutrinos
first anti-neutrino data -- January 2006



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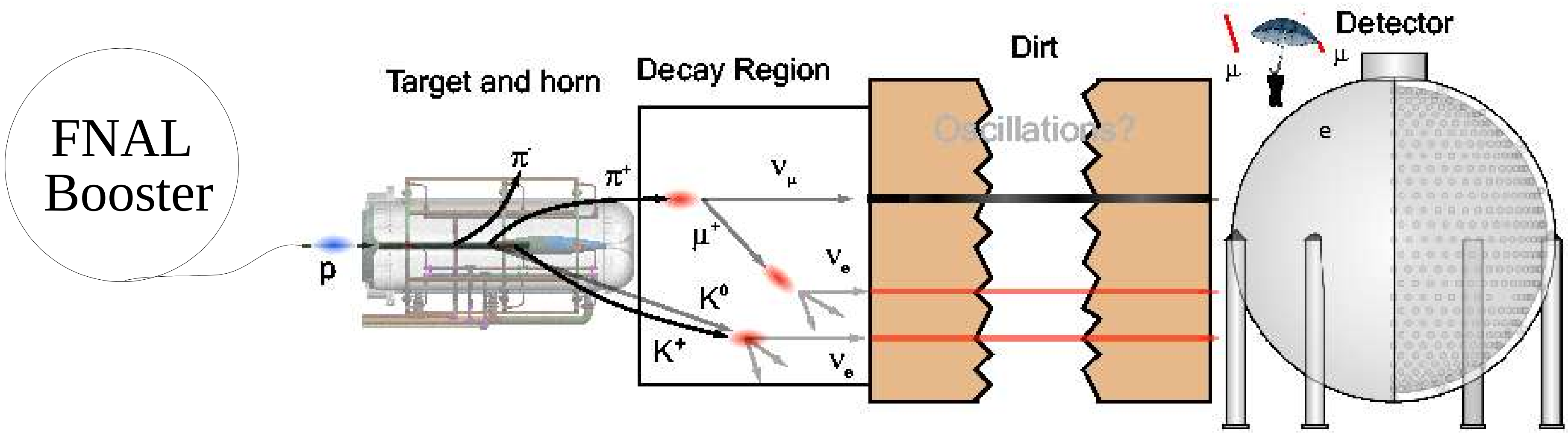

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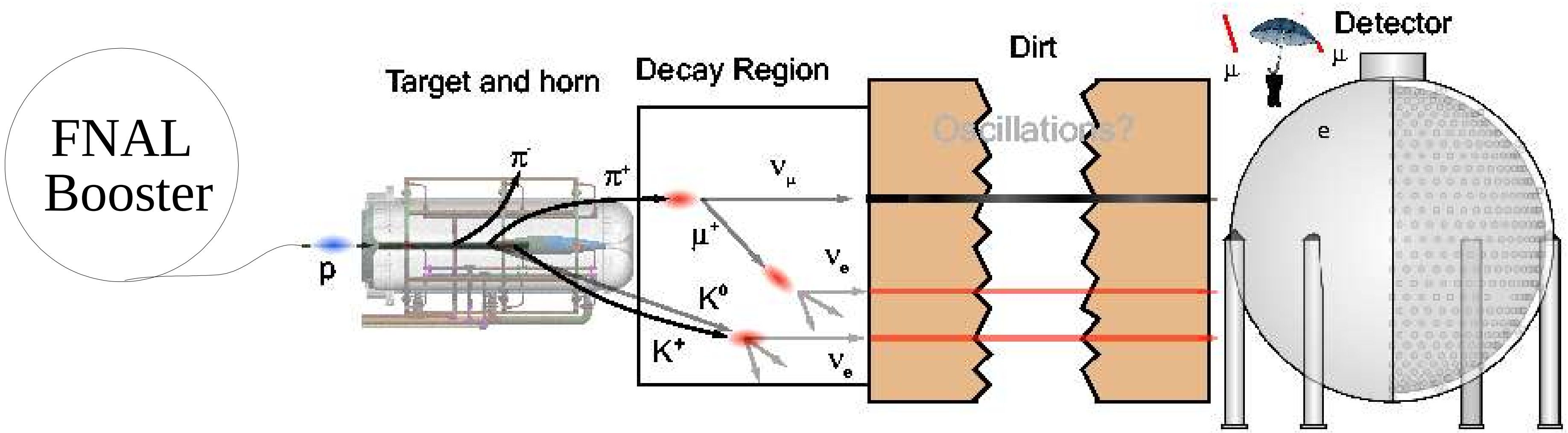

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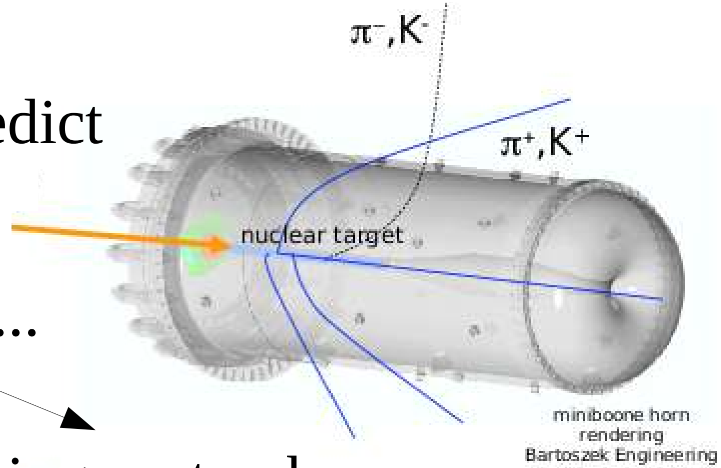
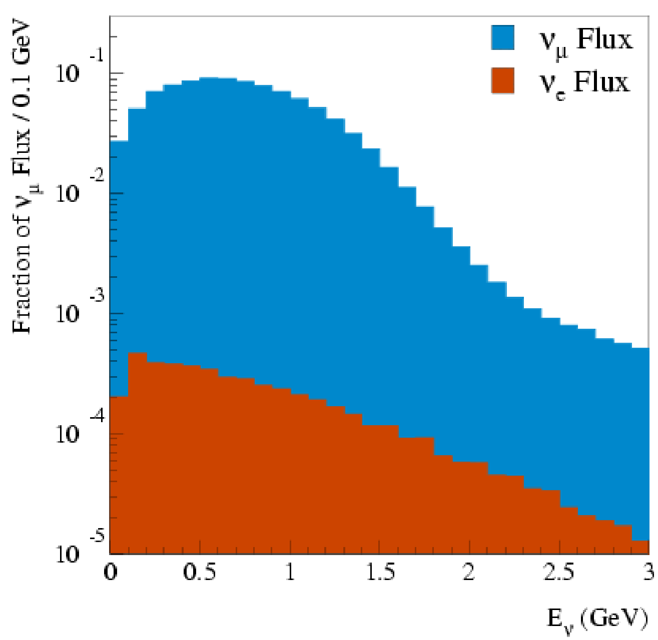
To predict flux, we study....



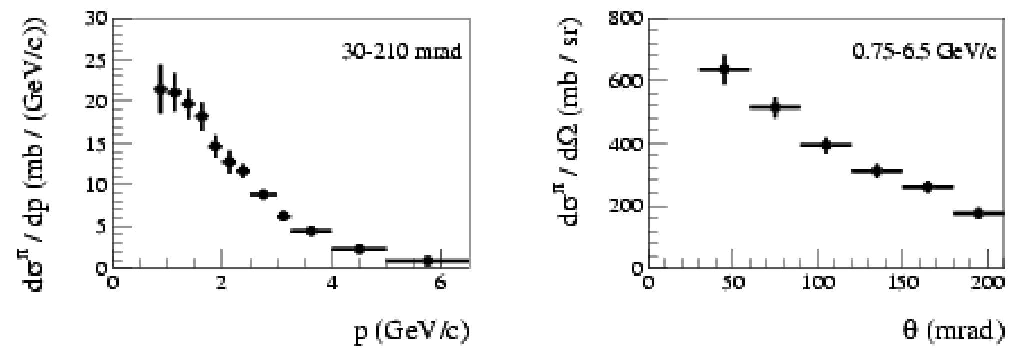
- incoming proton beam
- magnetic focussing horn
- meson production off our target
  - production cross sections
  - re-interactions in lengthy target

MiniBooNE flux

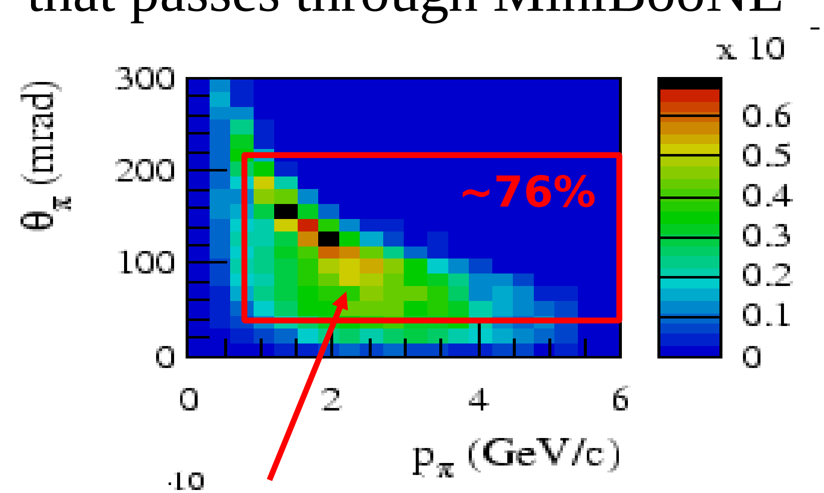


data from HARP:

p(8.9 GeV/c) + Be $\rightarrow \pi^+$+X



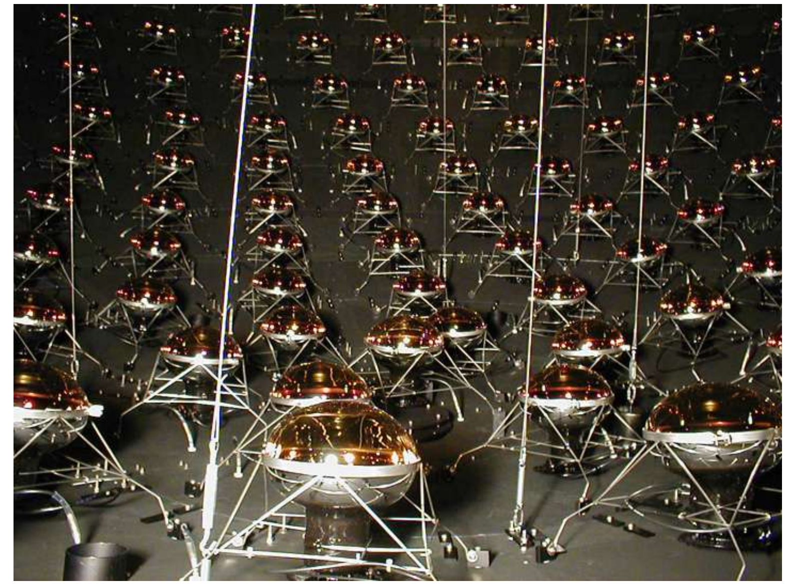
Momentum and angular distribution of pions decaying to a neutrino that passes through MiniBooNE



HARP kinematics cover ~76% of this region

Thesis work of D. Schmitz

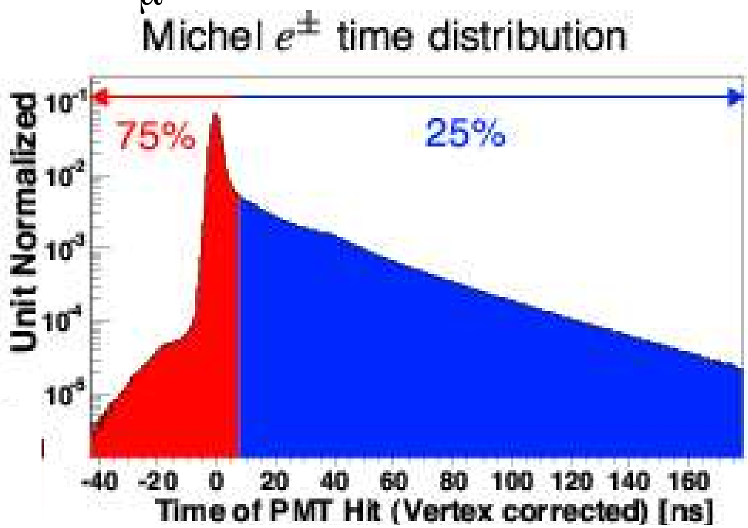
What do we measure
at the detector?



800 tons of ultra pure mineral oil
combination of
Cerenkov and Scintillation light

eg: ring imaging
ν_e versus ν_μ

IDs neutral currents

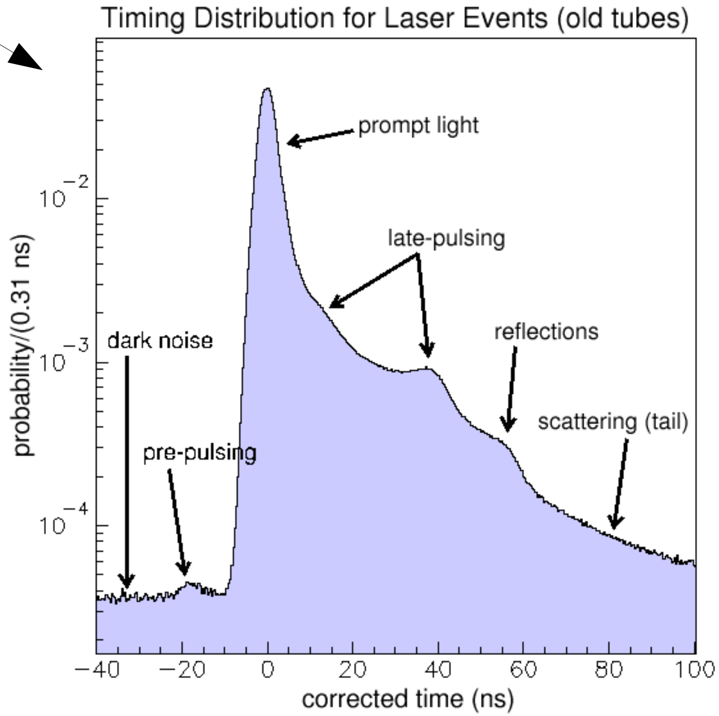


need a well understood
Optical Model
and well understood
PMTs

external and in situ
measurements

Optical Model

- Cerenkov light propagation for particles with $v/c_{medium} > 1$
- Scintillation light from charged particles
- Fluorescence from absorbed and re-emitted Cerenkov light
- Reflection from tank walls, PMTs, etc.
- Scattering in mineral oil
- PMT collection effects



External measurements collected
and made for many properties

corrections to external measurements
- relative amplitudes
- external conditions
- short to long tracks

Combine with MiniBooNE data:
laser data, Michel data, NC elastic data

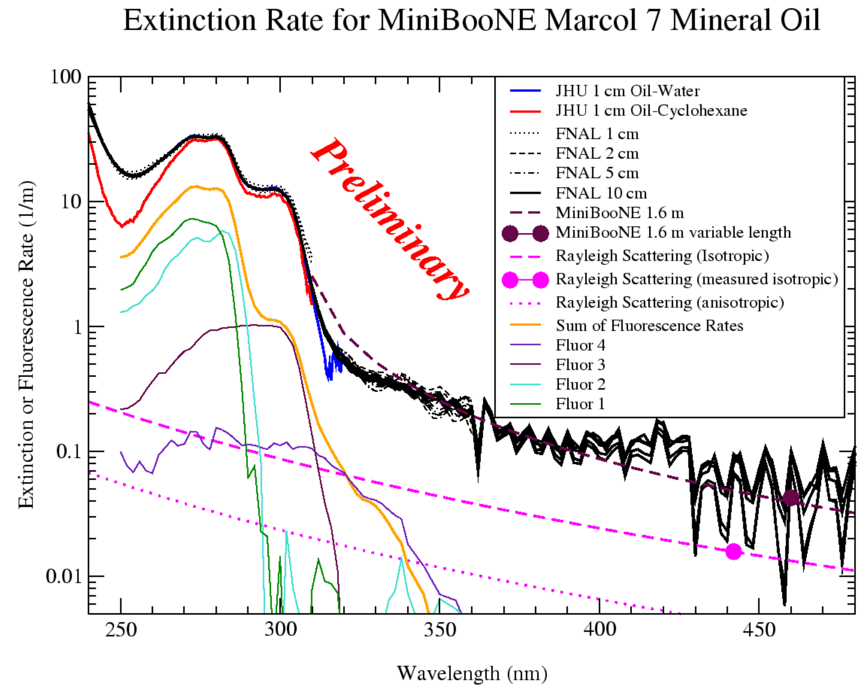
External measurements & laser calibration

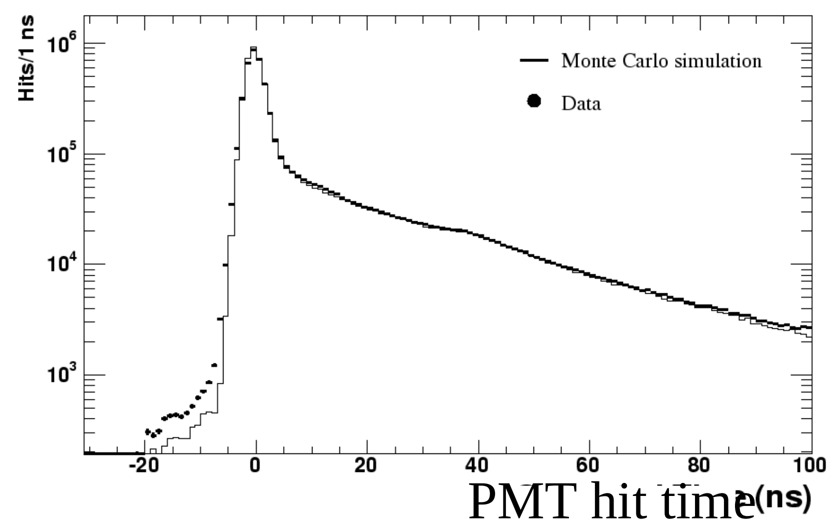
First calibration with Michels

calibration of scintillation light with NC events

Final calibration with Michels

validation with cosmic muons and ν_μ CCQE



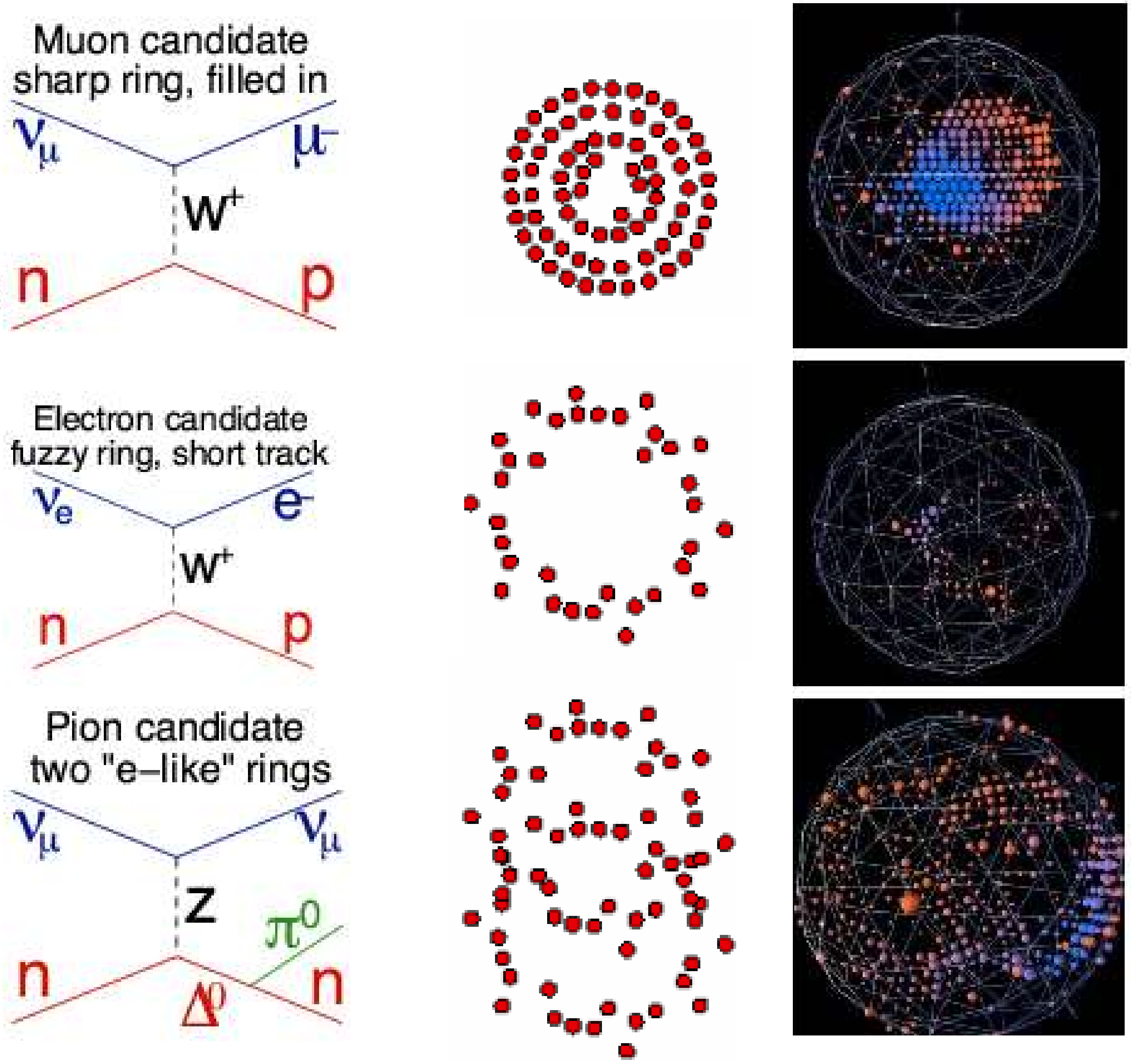


Reconstruction

Identify
electrons
vs
particles
through
hit
topology

↓

particularly
π°
background...



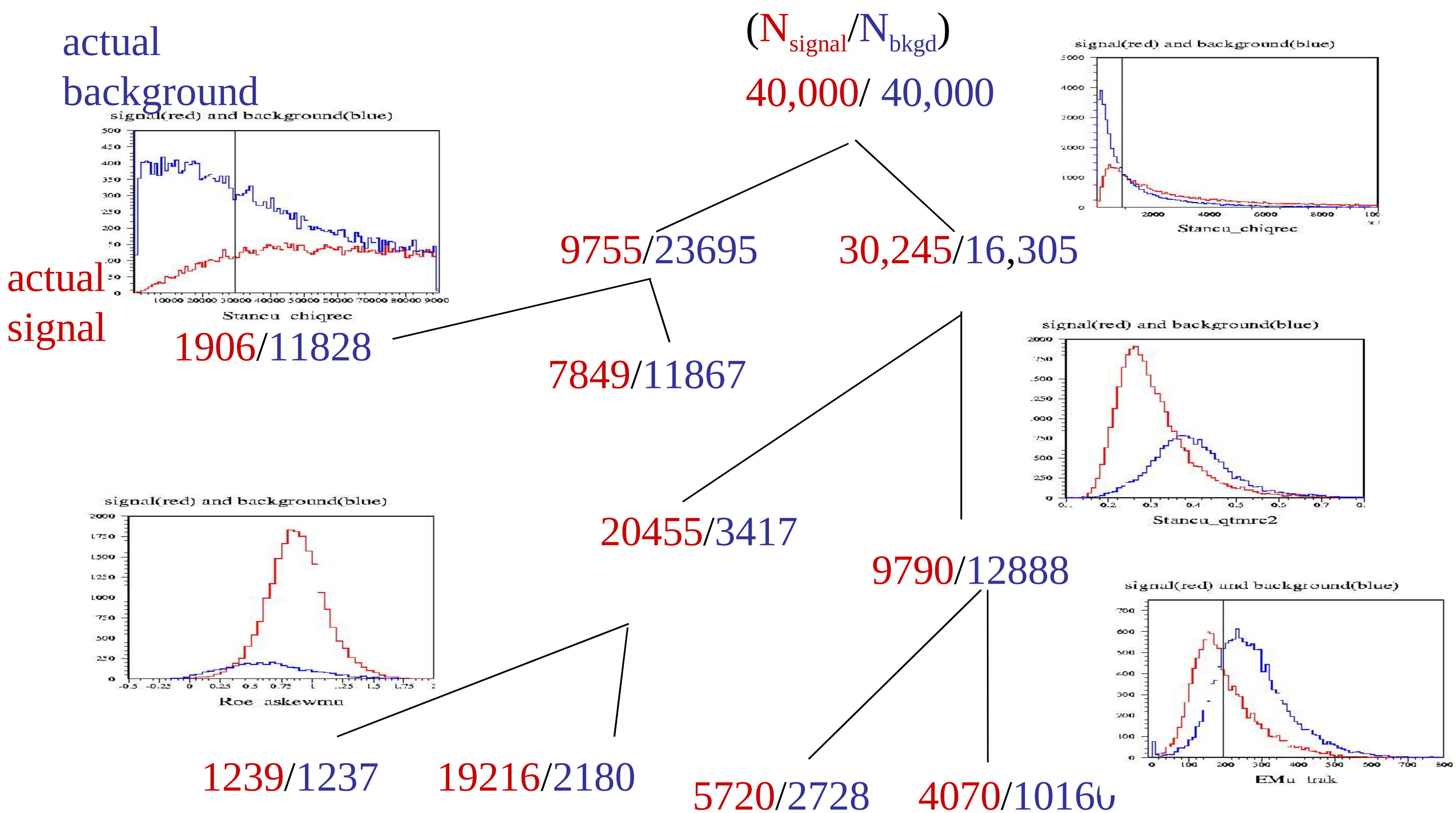
Event Clasification

Two, complementary, parallel approaches:

- Likelihood based analysis: simple to understand but less sensitive
- Boosted decision trees: highly sensitive but harder to understand

Compare backgrounds via both methods:
-Different balance between intrinsic ν_es and misIDed ν_μs
-Cross checks

Boosting uses Decision Trees
(sequential series of cuts)



Continue decision tree until each "leaf"
is either very pure or statistically small.

Combine output of many trees → Boosting

Boosted Decions Trees

A set of deceision trees is created using Monte Carlo

For each tree, the data event is assigned
+1 if it is identified as signal,
-1 if it is identified as background.

The total for all trees is then combined.

Subsequent boosting weights events that misID

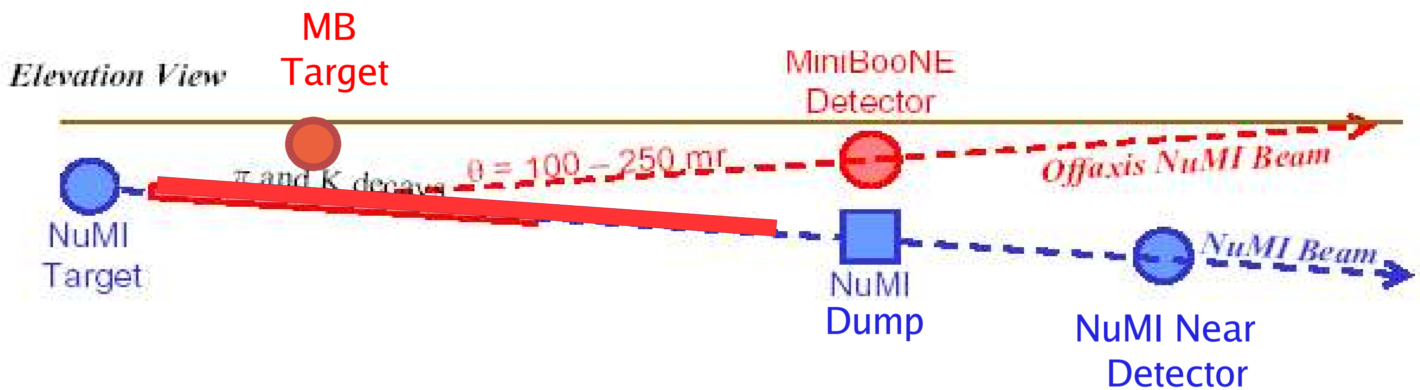
The resulting “score” for the event
can be thought of as a probability that it is signal.
(PID score)

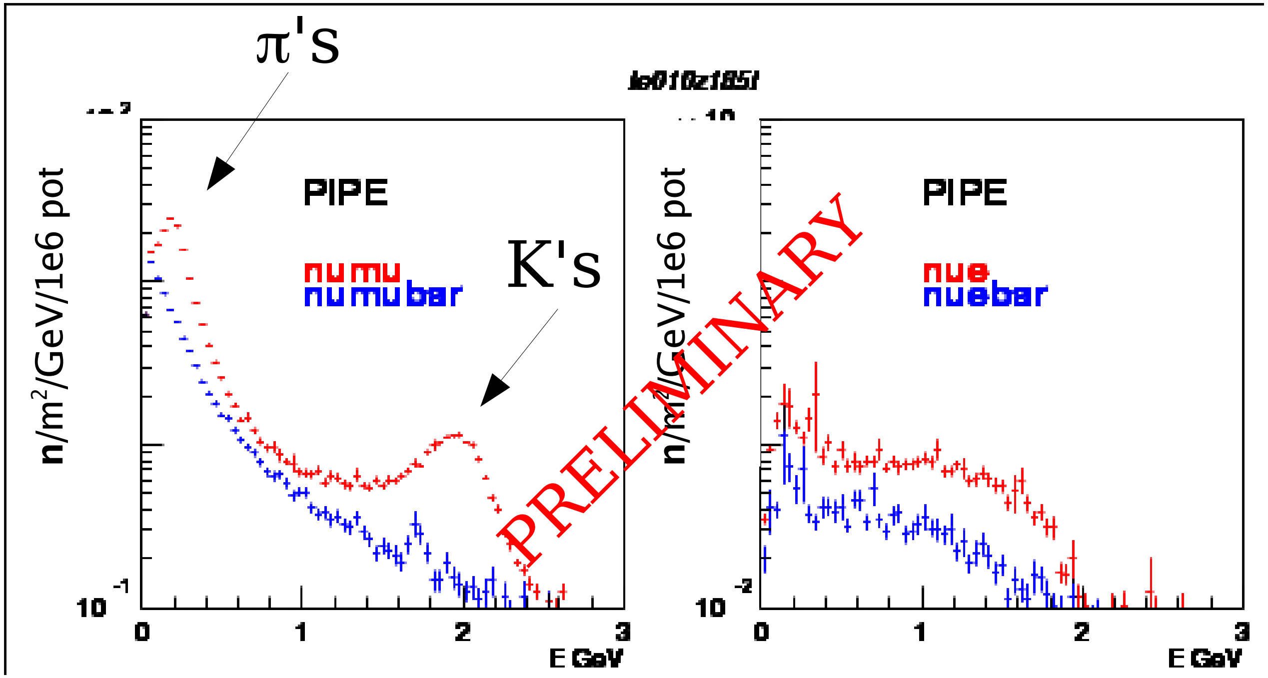
The analysis cuts on the score.

Use NuMI beam as
a cross check for analysis
→ Event Classification

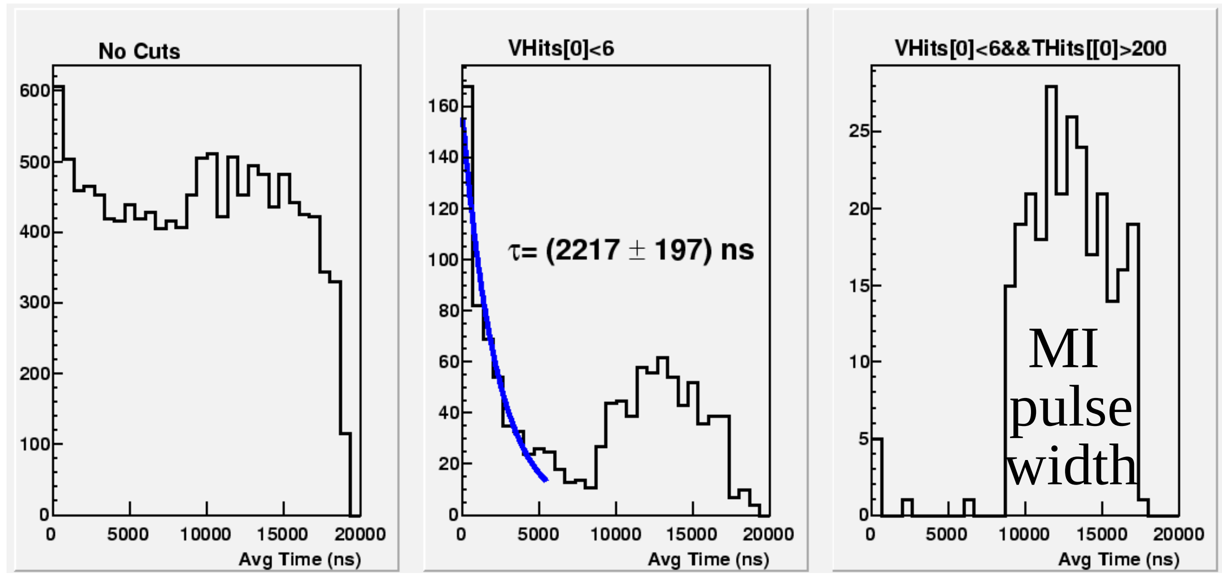
MiniBooNE sees TWO neutrino beams

(World's 1st off axis ν detector!)

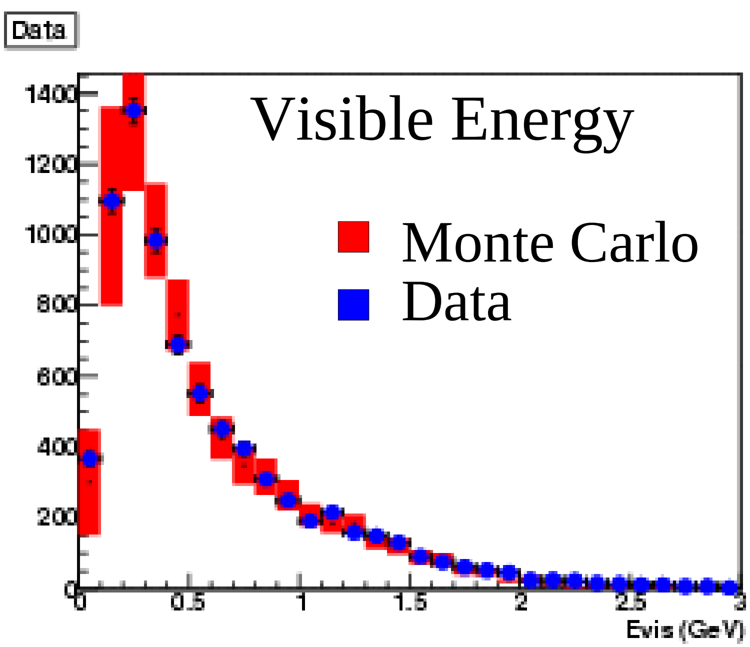


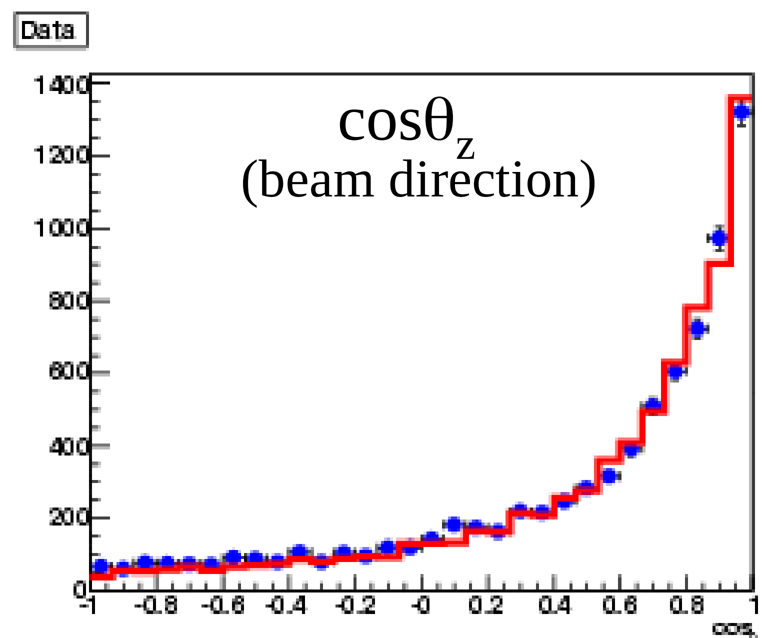


Thesis project: Alexis A. Aguilar-Arévalo simple cuts resolve events from NuMI beam spill →

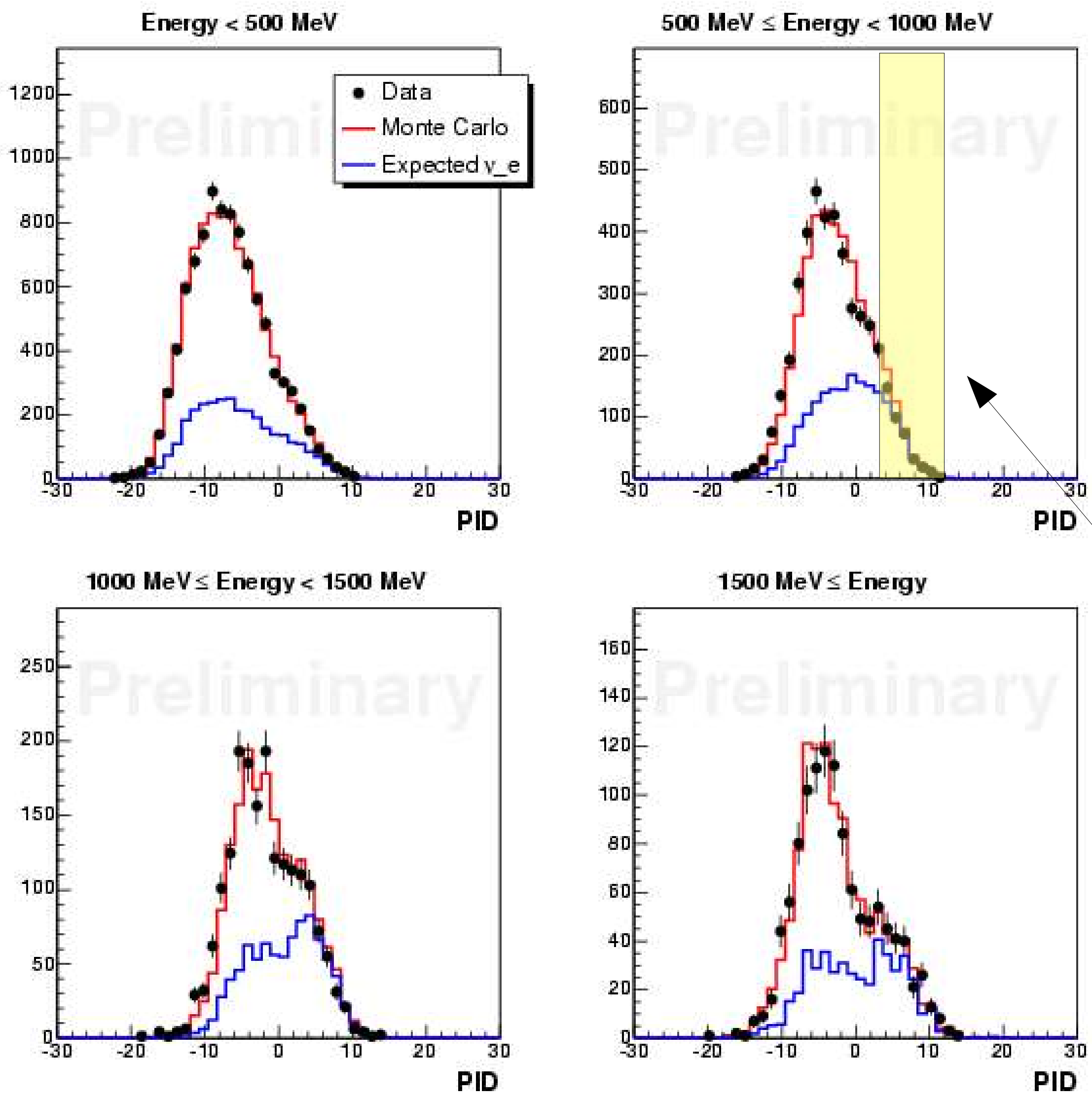


Many events with a similar makeup as MiniBooNE events (~60k) → good data/MC agreement





NuMI Event Classification: Boosted Decision Trees

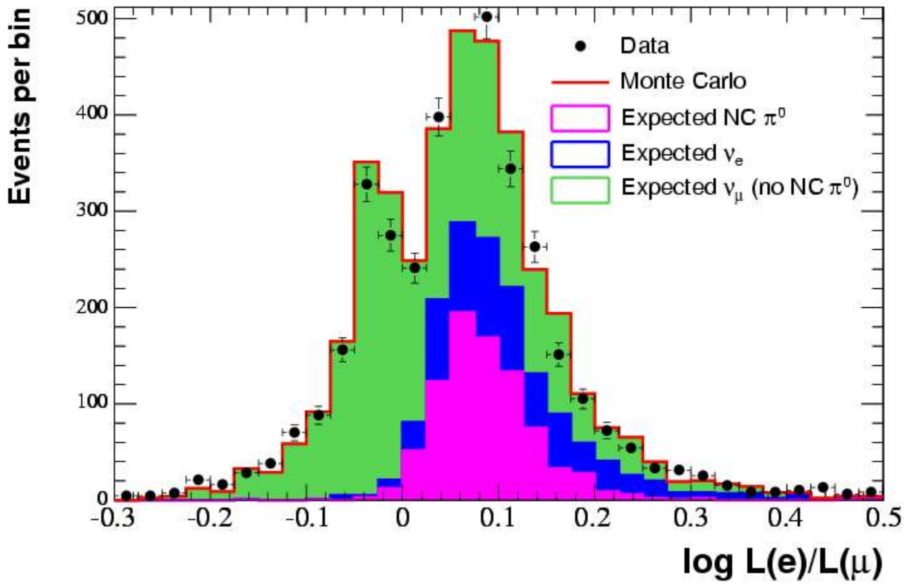


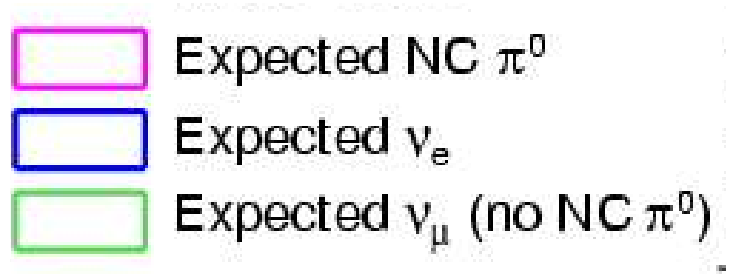
1) good data/MC agreement over range of energies

2) Use regions of greatest resolving power to study

e's vs background

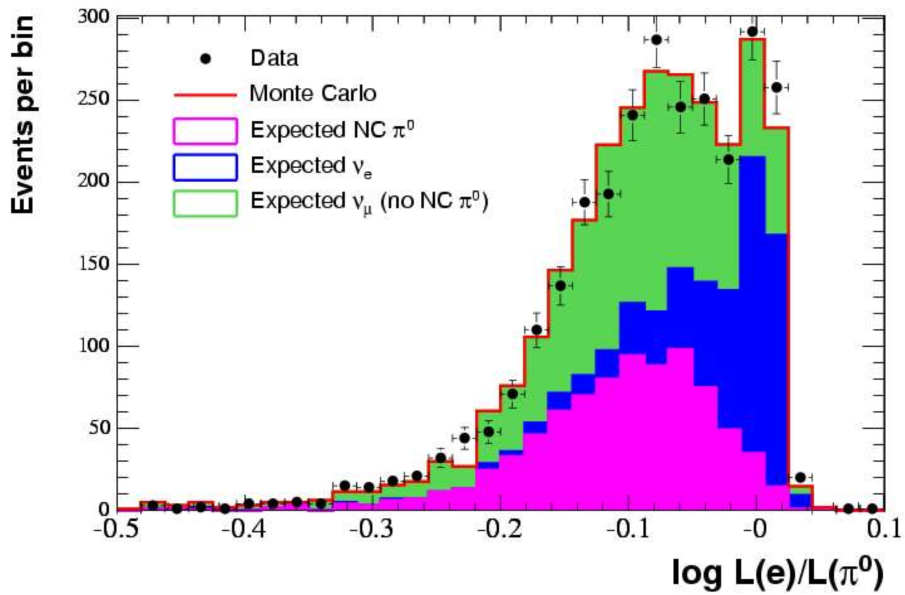
NuMI Event Classification: Likelihood analysis





relatively normalized data/MC

good agreement

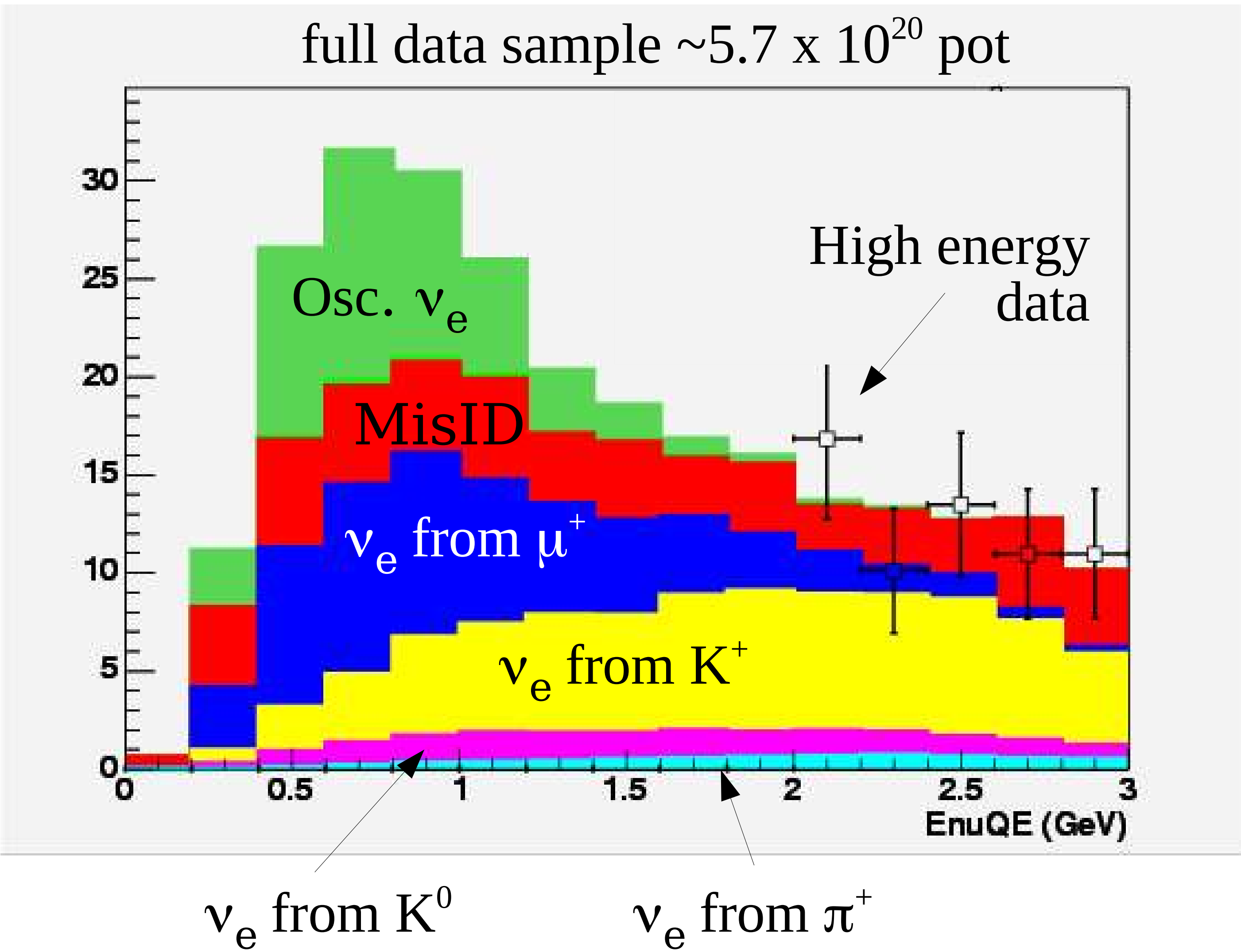


Cut on
log L(e)/L(μ)>0.02

resolving power in
log L(e)/L(π°)

Putting it all together:

Look for ν_es appearing above backgrounds at MiniBooNE



relatively normalzied

Oscillation ν_es

- $\Delta m^2 = 1$ eV^2
- $\sin^2 2\theta = 0.004$

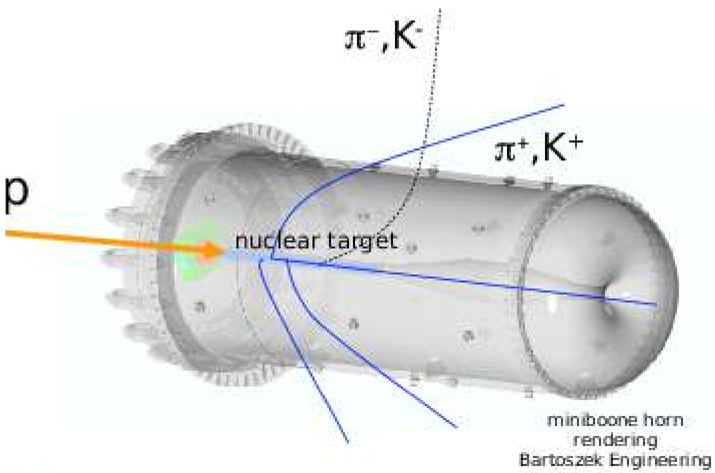
Fit for excess over backgrounds:

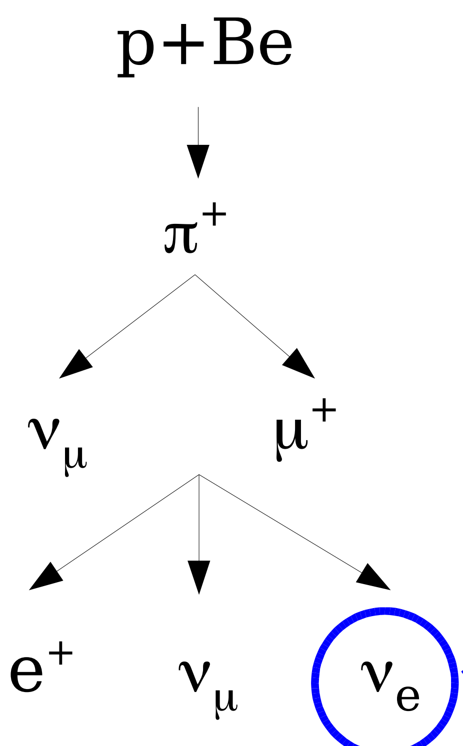
Intrinsic nues

- ν_e from μ^+
- ν_e from K^+
- ν_e from K^0
- ν_e from π^+

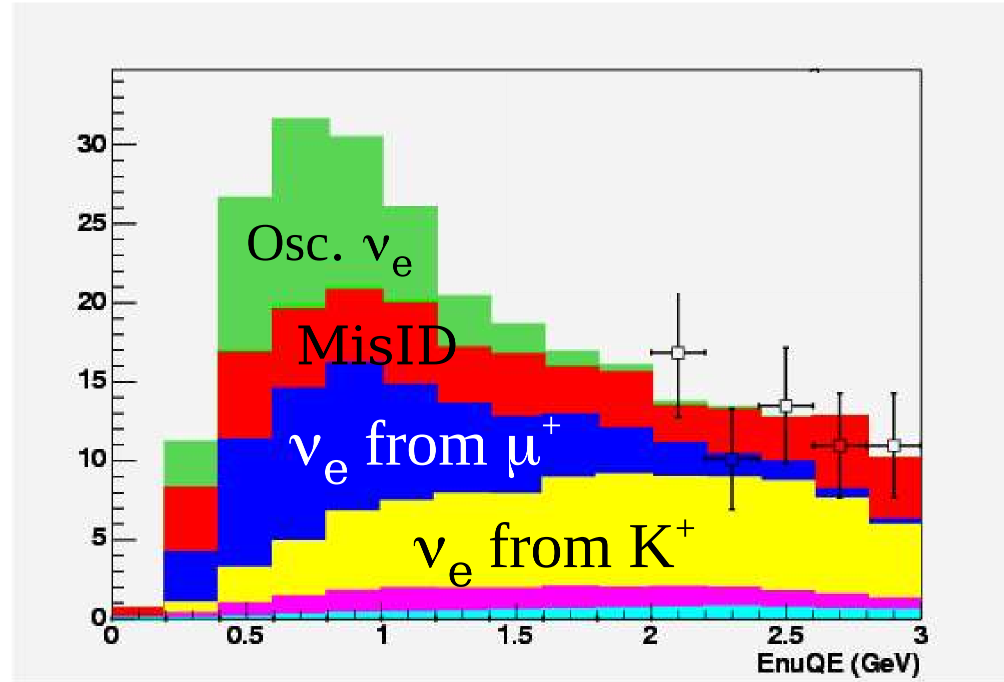
Mis-ID ν_μs

Backgrounds:





Intrinsic ν_e from μ^+decays

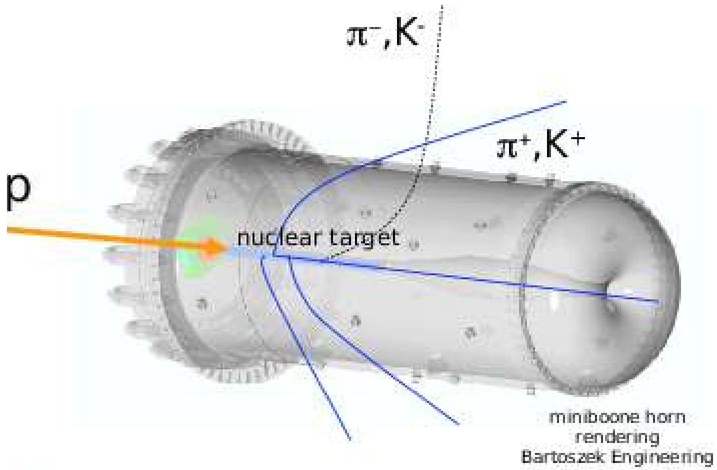


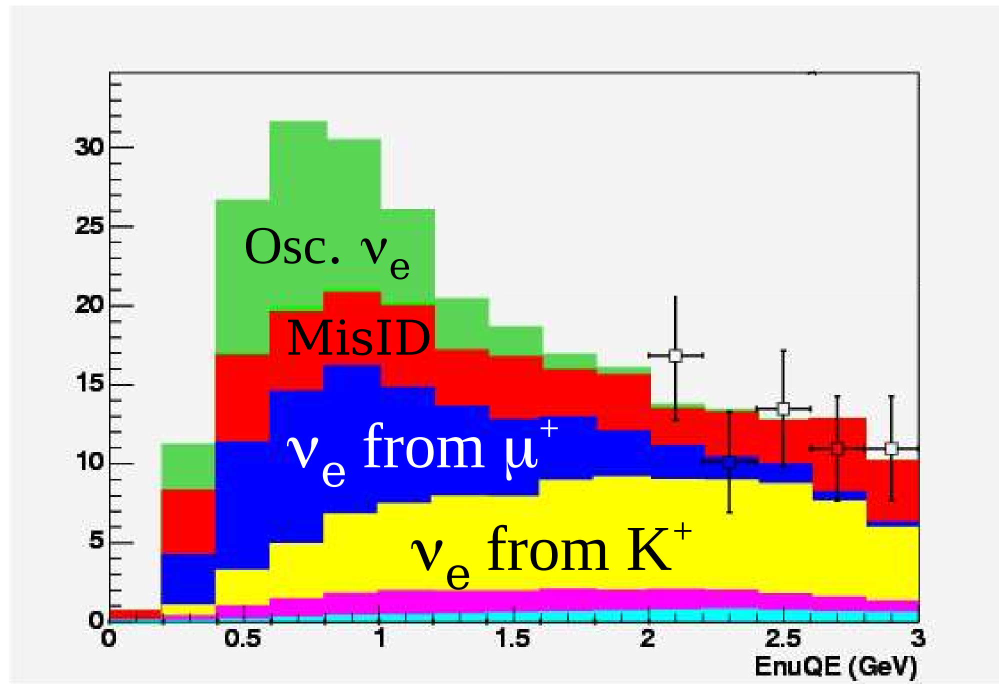
Use ν_μ CCQE sample in detector to measure these

very well constrained to...

→ a few percent

Intrinsic ν_e from K^+ decays





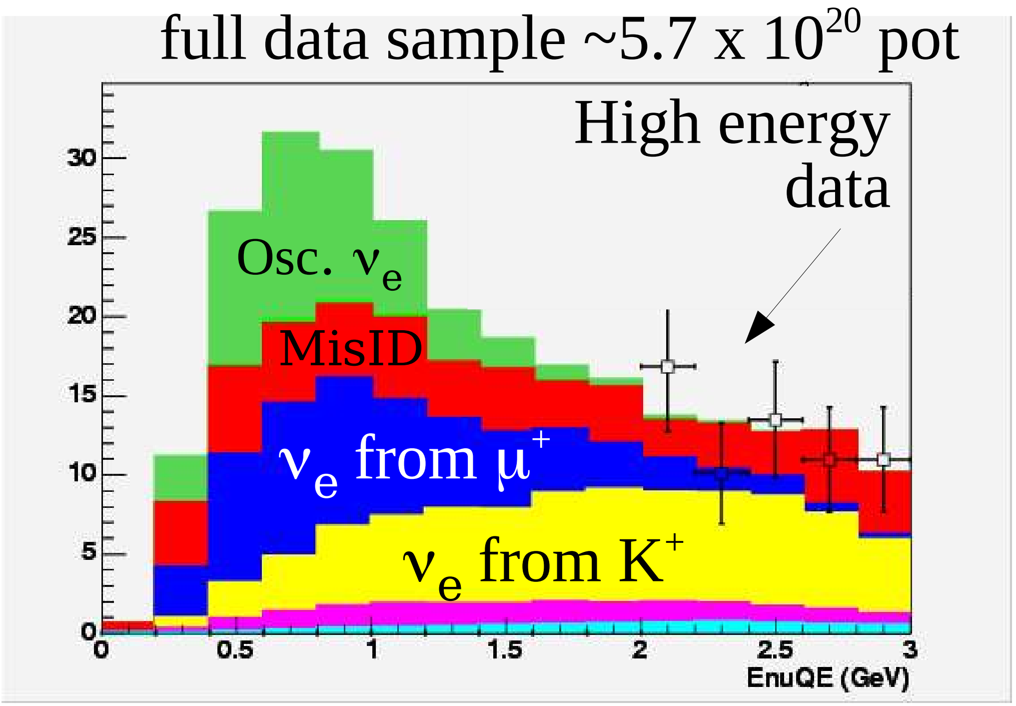
p+Be

↓

K^+

e^+ π° ν_e

- kaon production data to determine shape
- ν_μ and ν_e data at high energy to normalize



MisID ν_μ:

~83% $\pi°$

- (~1% of total $\pi°$s are MisIDs)

~7% $\Delta\gamma$ decays

- Use $\pi°$s to estimate Δ production

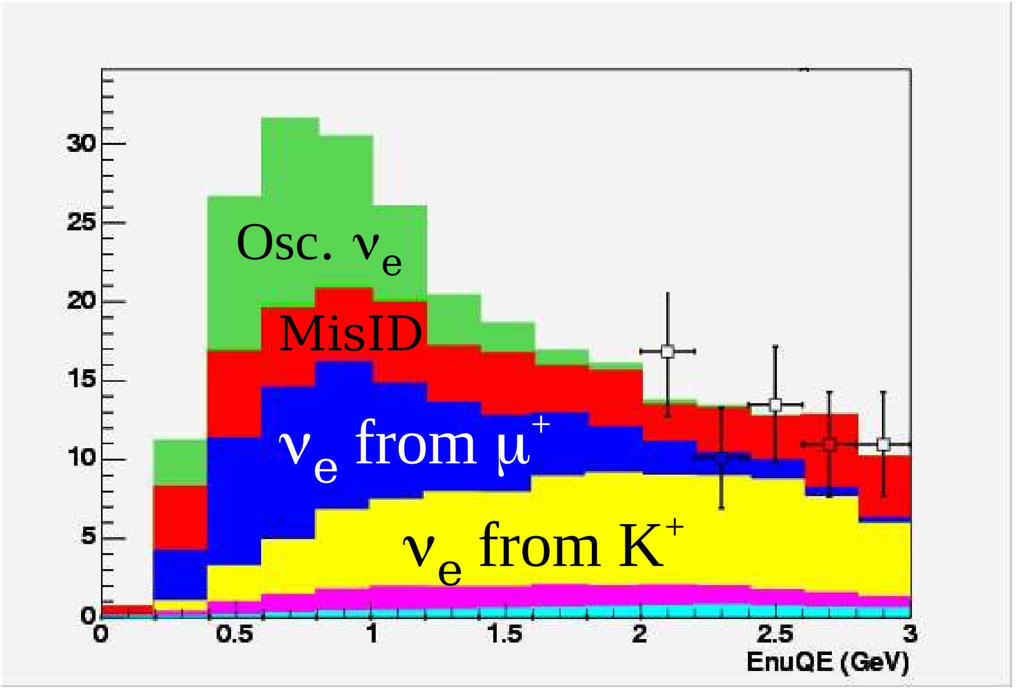
~10% other

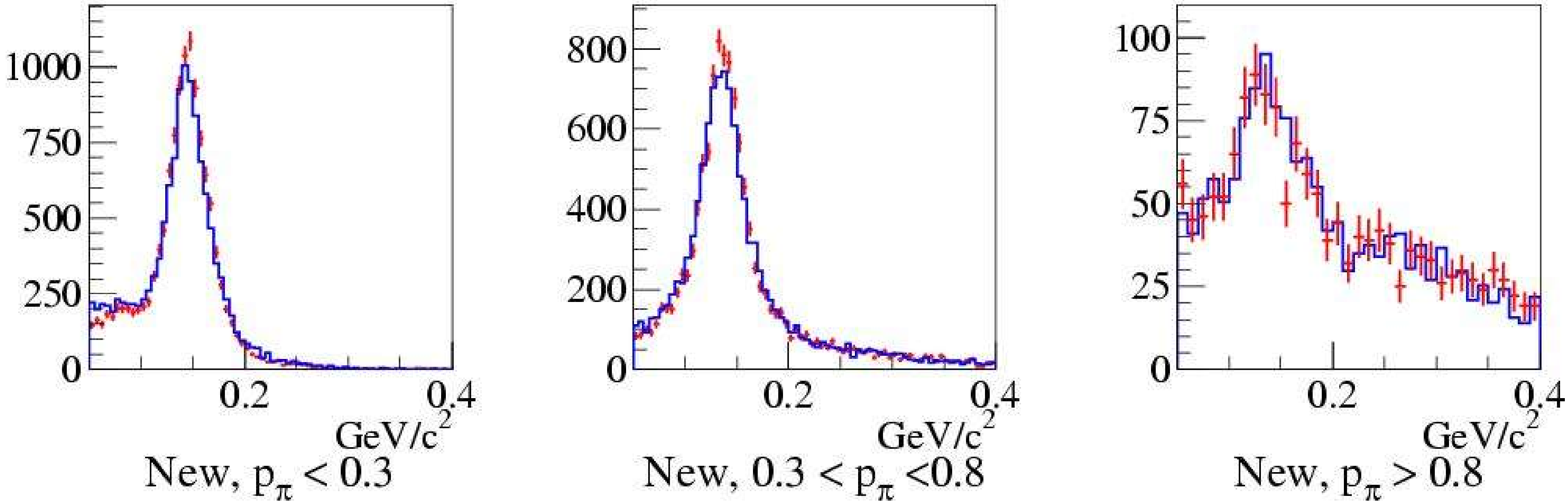
- ν_μ CCQE's for normalization
- Monte Carlo for shape

Reconstructing π°s:

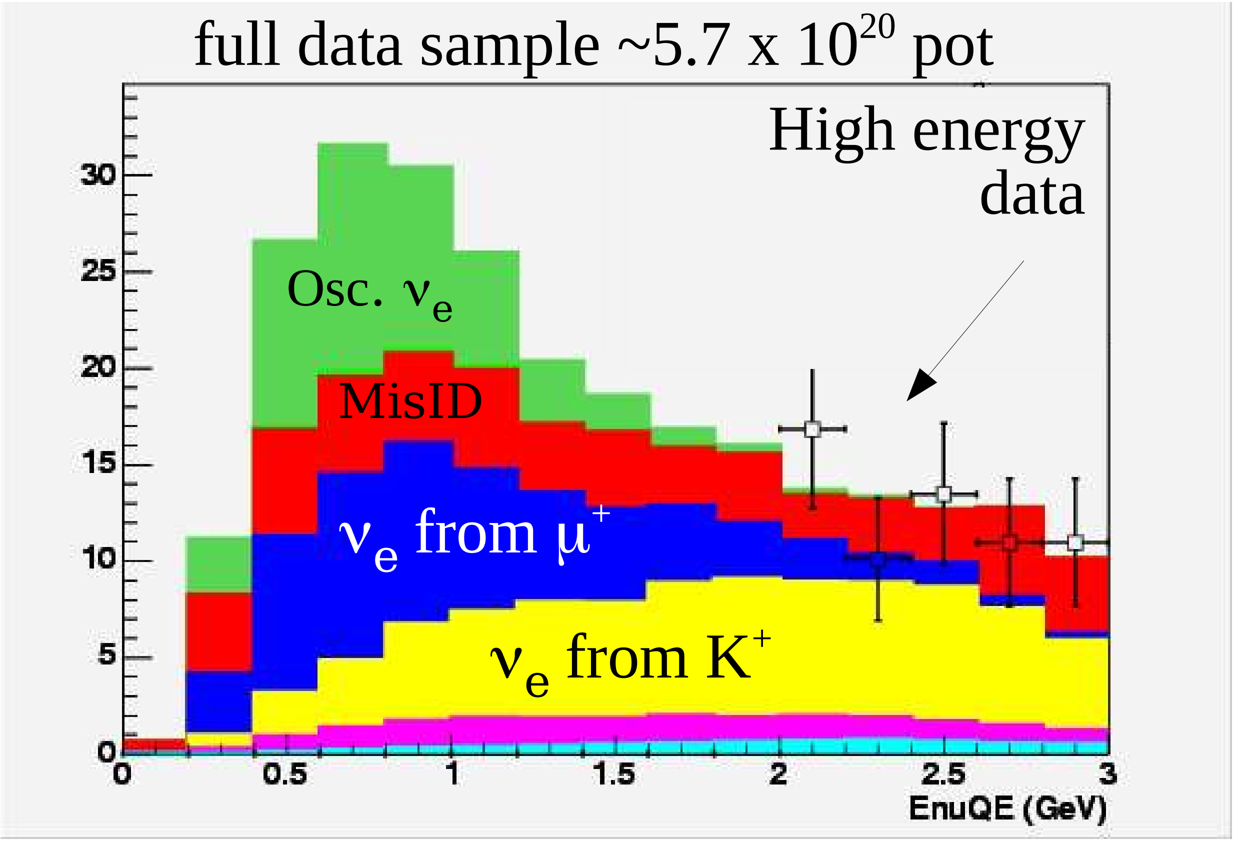
clear π° mass peak with good data/MC agreeement

Reconstruction: crucial over entire oscillation region



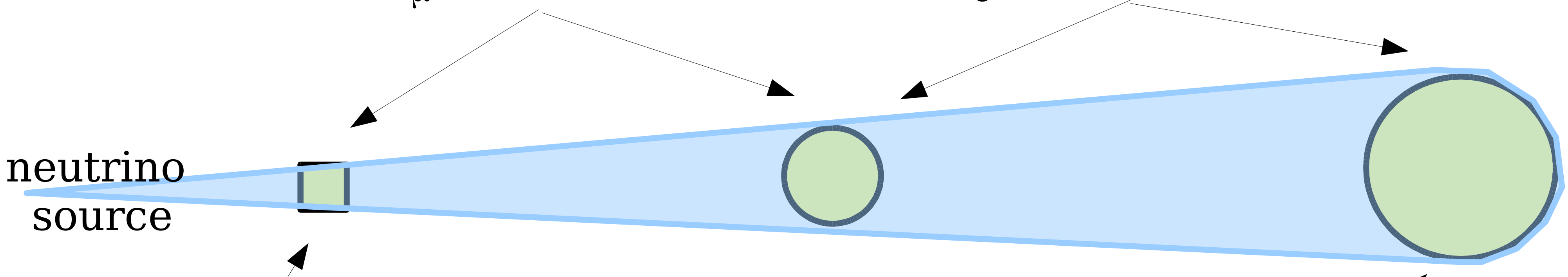


Thesis work of Ryan Patterson



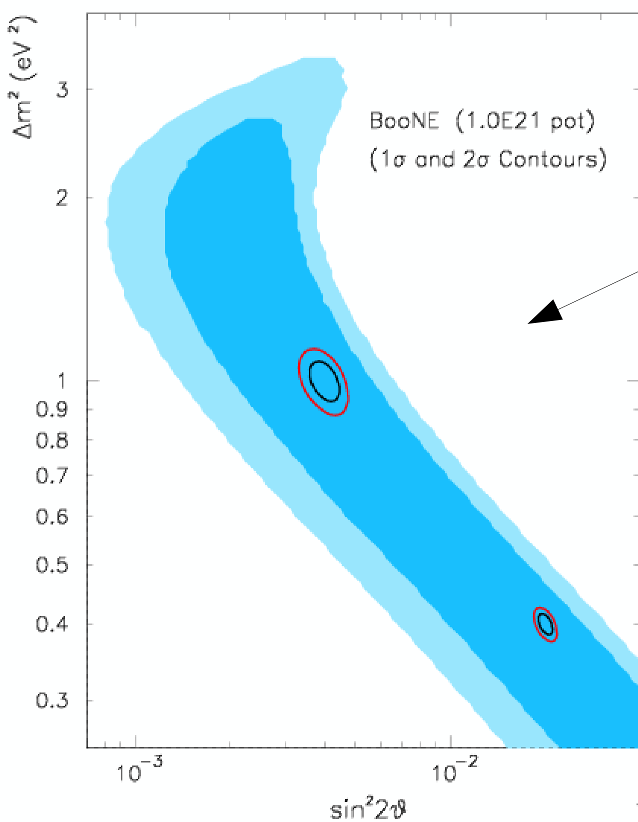
High Energy Data
Verify above oscillation region
(unblind region)

Beyond MiniBooNE:
Precision ν_μ disappearance and ν_e appearance



Present:
SciBooNE:
measure xsecs
at a near location
on BNB
start in late 2006

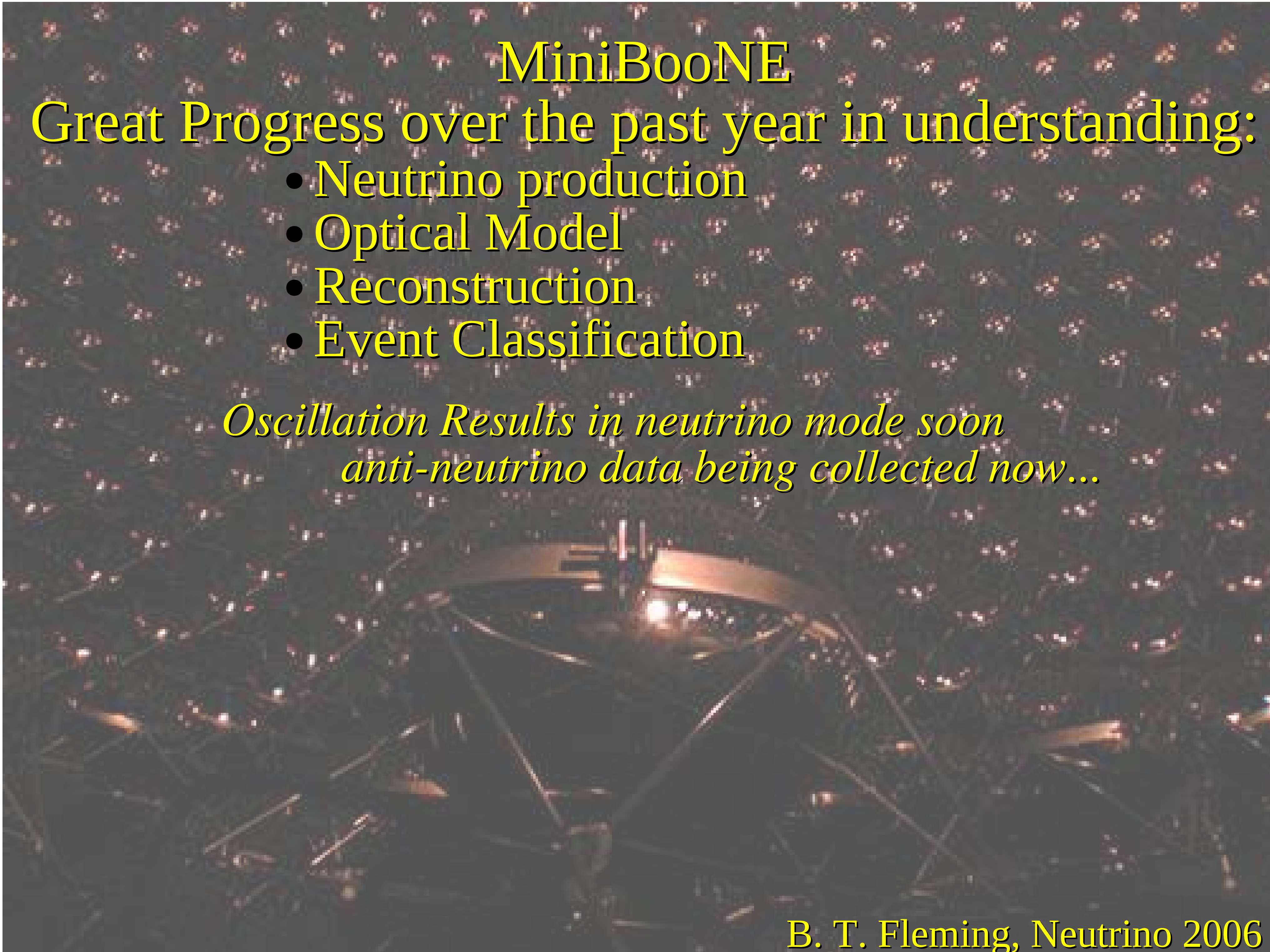
Future:
near detector for
near/far
comparison



BooNE:
location to be guided by
MiniBooNE results:
- ~2km for low Δm^2
- ~0.2km for high Δm^2

Considering technologies
- MiniBooNE Clone
- Liquid Argon TPC

Follow-ons at SNS and possibly JPARC as well....



MiniBooNE

Great Progress over the past year in understanding:

- Neutrino production
- Optical Model
- Reconstruction
- Event Classification

Oscillation Results in neutrino mode soon
anti-neutrino data being collected now…