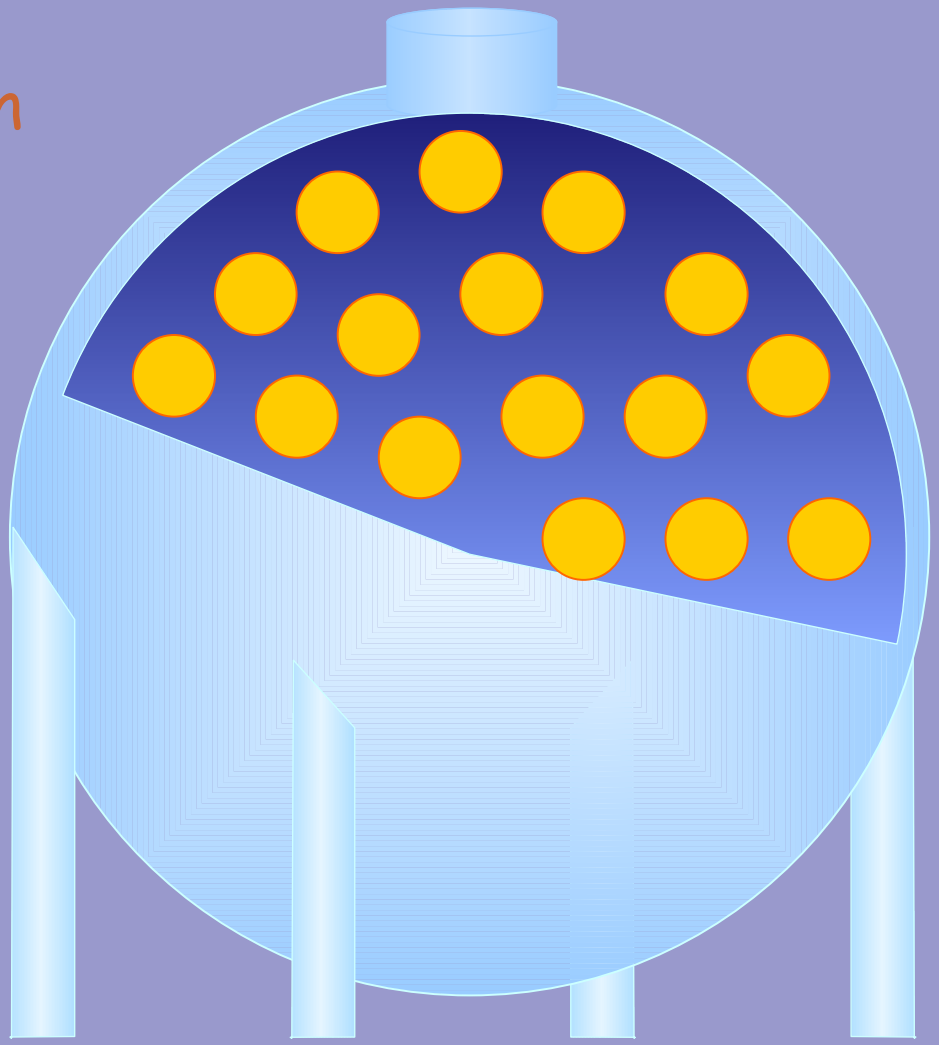
A Search for $\nu_\mu \rightarrow \nu_e$ oscillations with MiniBooNE

MiniBooNE does not yet have a result for the $\nu_\mu \rightarrow \nu_e$ oscillation search. The analysis is in final stages.

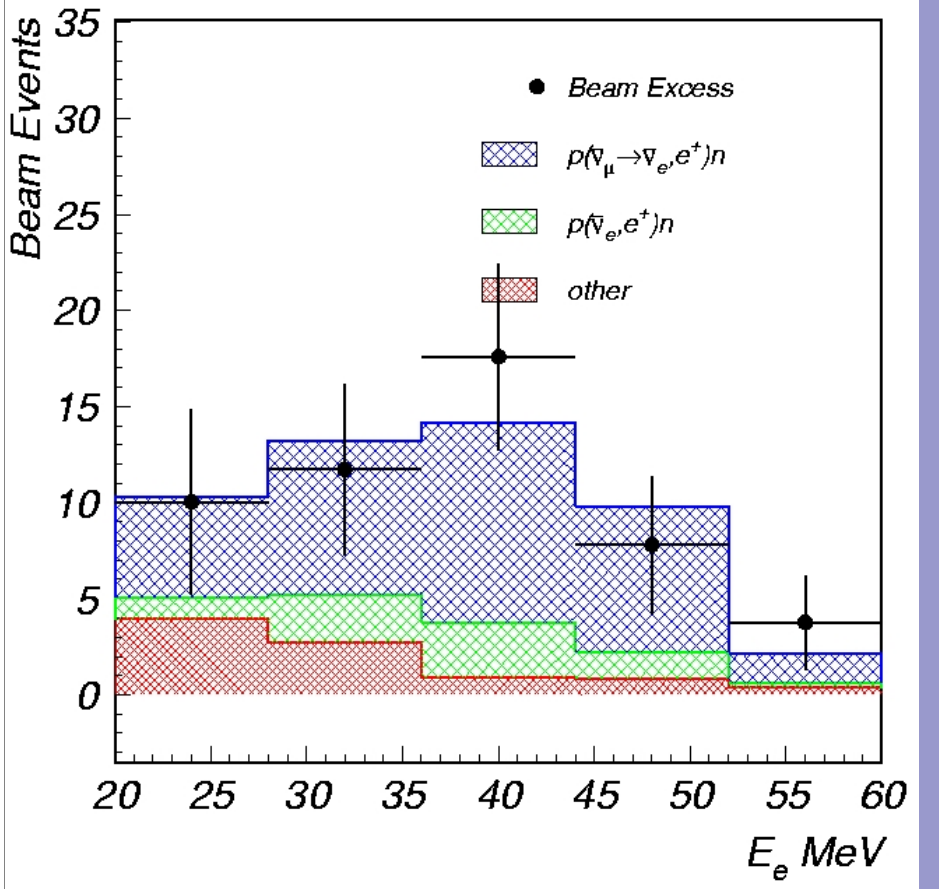
Outline:
- Goal of experiment
- MB detector
- status of the analysis



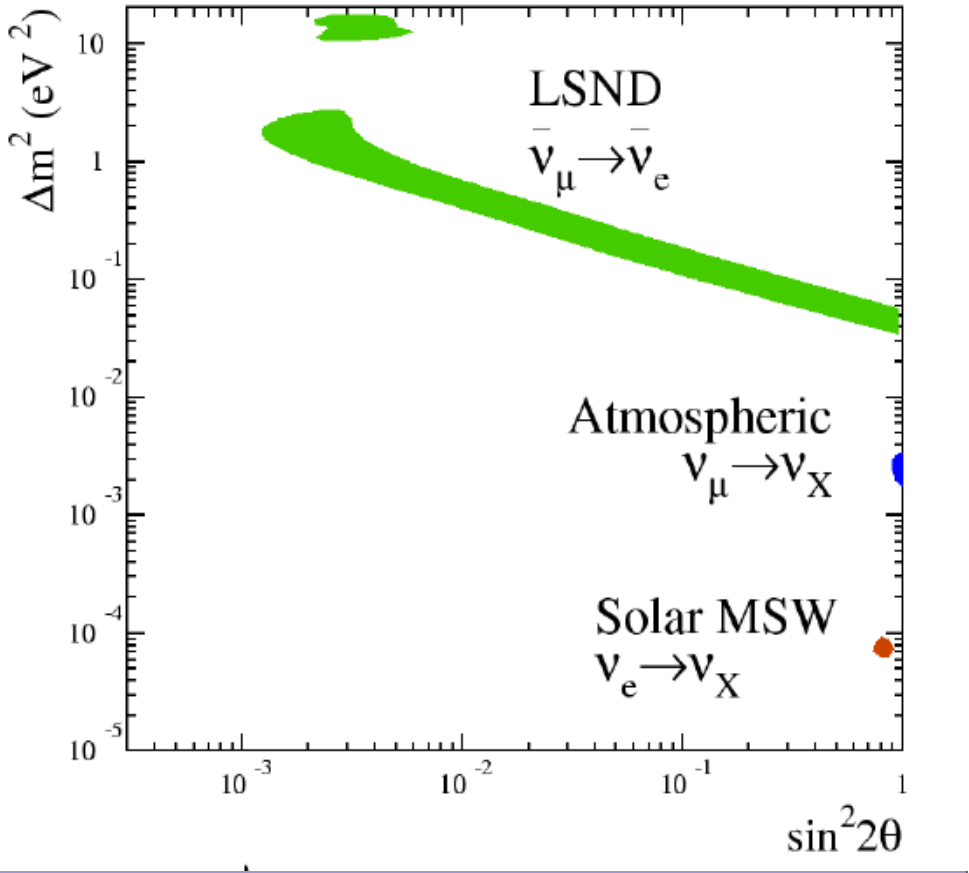
MiniBooNE goal: test the LSND result

- Primary goal of MiniBooNE is a $\nu_\mu \rightarrow \nu_e$ search to test the LSND result.
- LSND reports a (4σ) excess of $\bar{\nu}_e$ events ($87.9 \pm 22.4 \pm 6.0$) in $\bar{\nu}_\mu$ beam

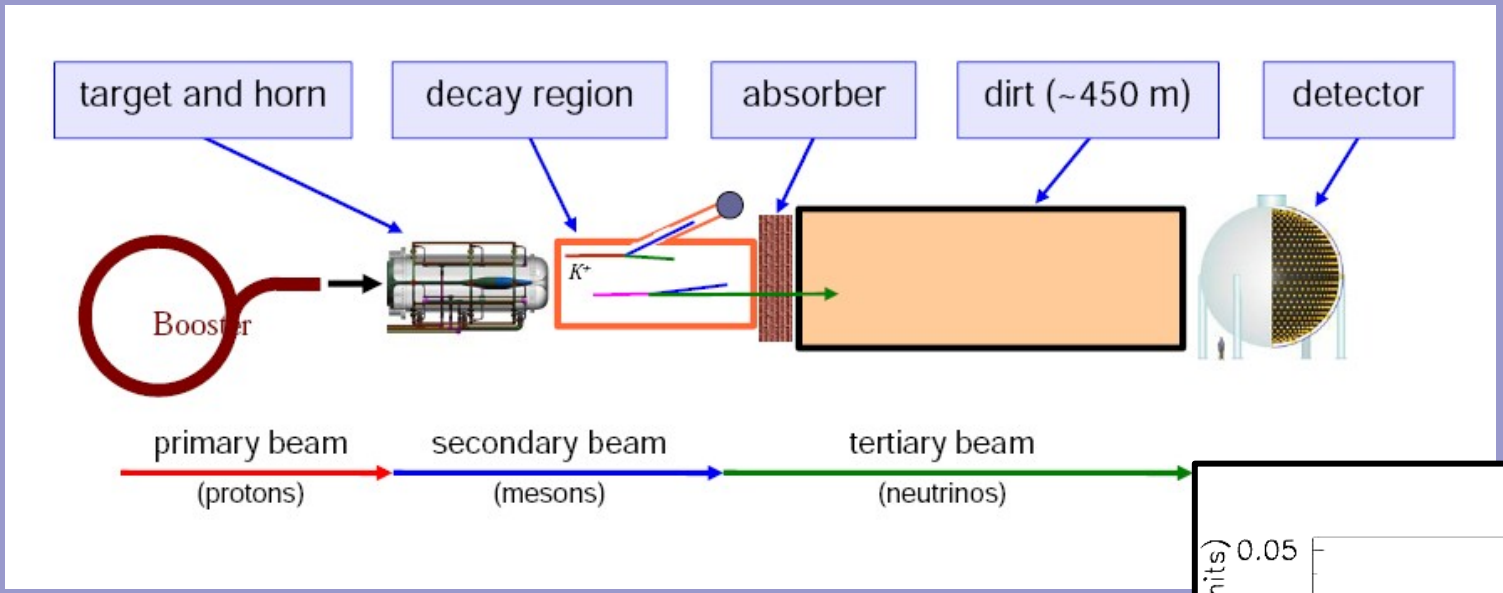
LSND $\bar{\nu}_e$ events vs energy



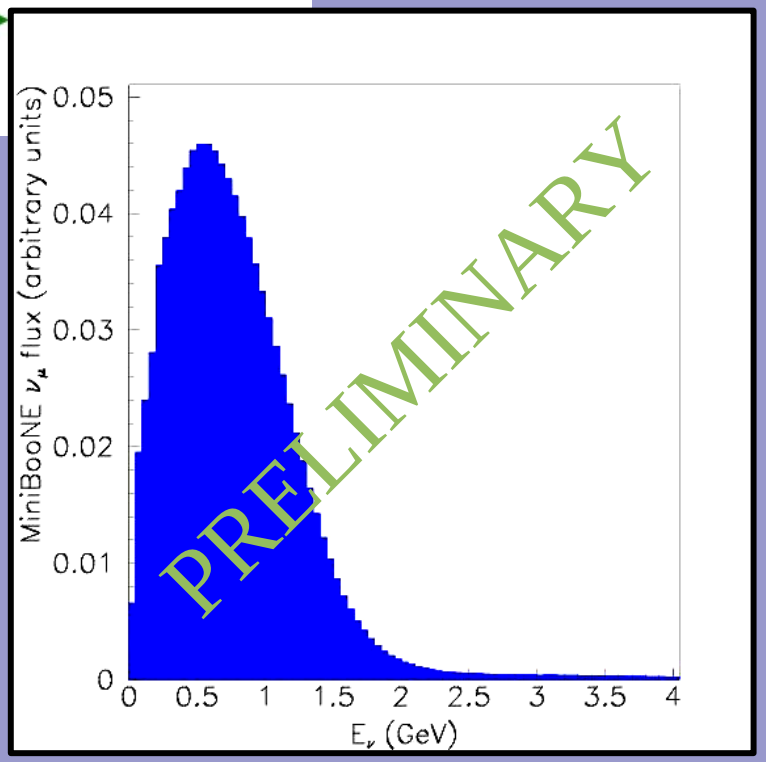
LSND oscillation parameters



MiniBooNE ν_μ beam



MB ν flux

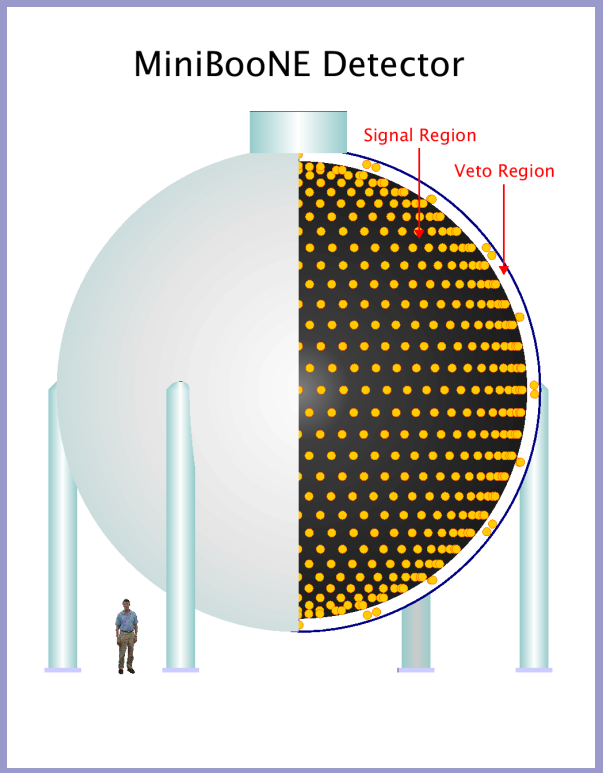


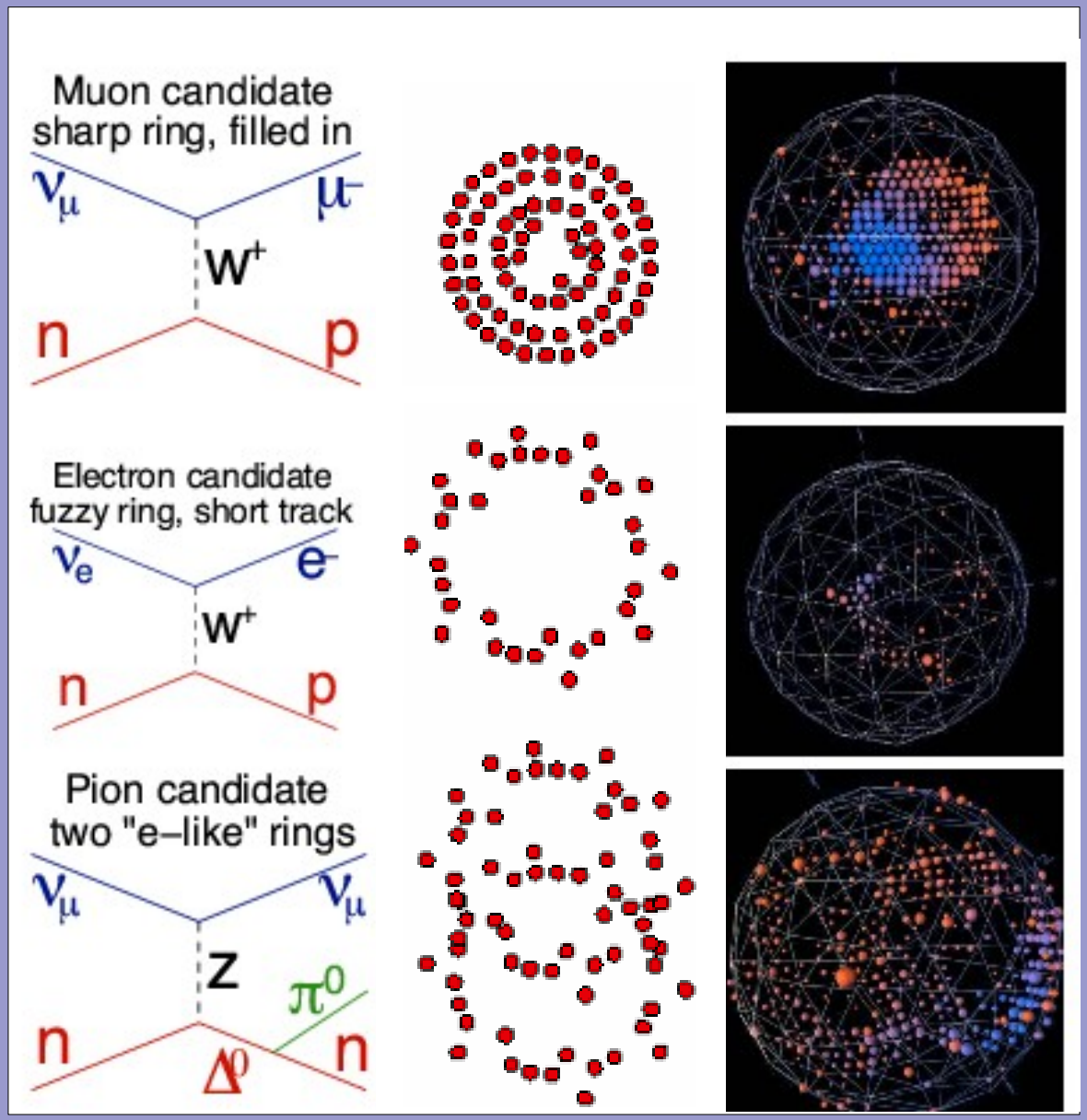
- "horn-focussed" beam using
  8 GeV protons on Be ($p\,Be \rightarrow \pi^+ \rightarrow \mu^+ \nu_\mu$)
- $\langle E_\nu \rangle \sim 0.7$ GeV
- detector located at L=550m for same L/E as LSND

$$P(\nu_\mu \rightarrow \nu_e) = \sin^2 2\theta \, \sin^2(1.27 \Delta m^2 L/E)$$

MiniBooNE Detector

- 800 tons mineral oil (CH_2), viewed by 1280 8" PMTs (10% coverage)
- veto to tag entering/exiting particles
- Particle ID, energy, position, angle via Cerenkov and scintillation light





Oscillation analysis

observed rate of ν_e events in detector =

$P(\nu_\mu \rightarrow \nu_e)$

$\times$ flux (ν_μ)

$\times$ cross-section (ν_e)

$\times$ detector and reconstruction efficiency

$+$ backgrounds

- A large sample of ν_μ-interaction events allow for measurements of many of these quantities (e.g. cross section, π^0 background)

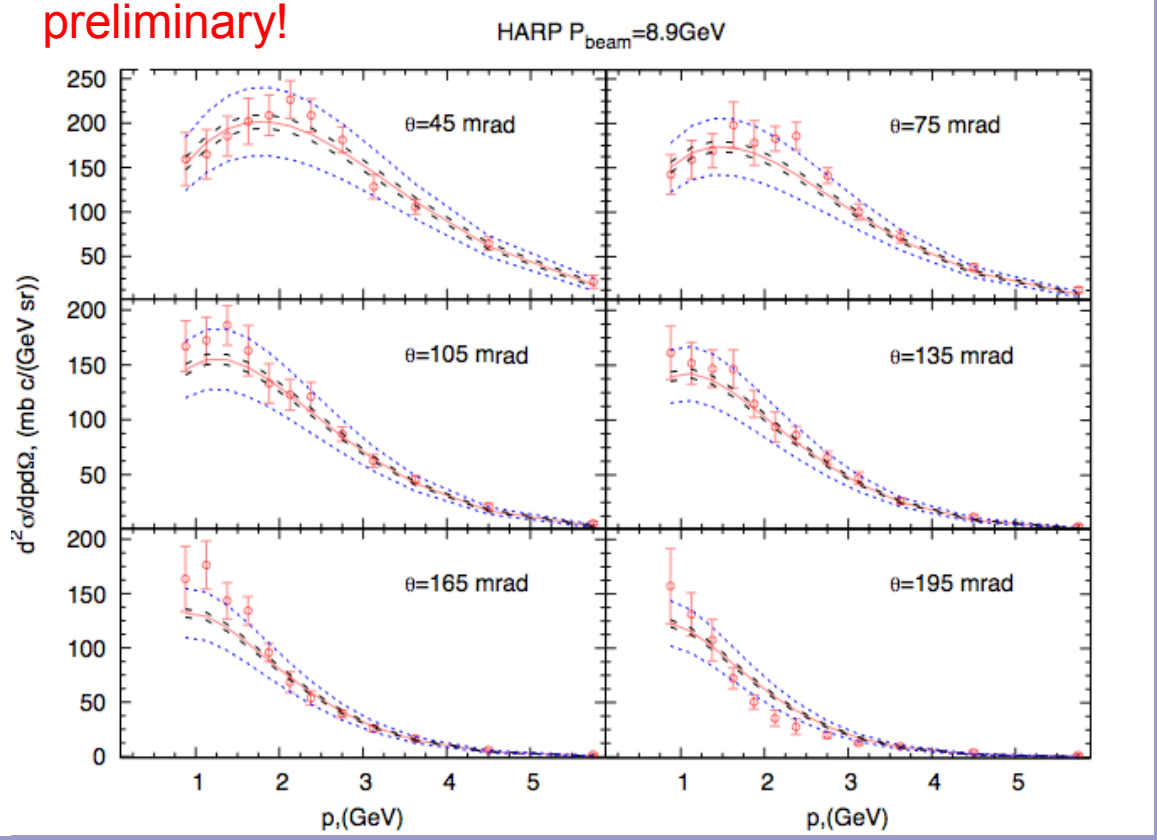
- Many systematic errors on the measured ν_e rate are reduced by measuring the ν_μ events.

neutrino flux

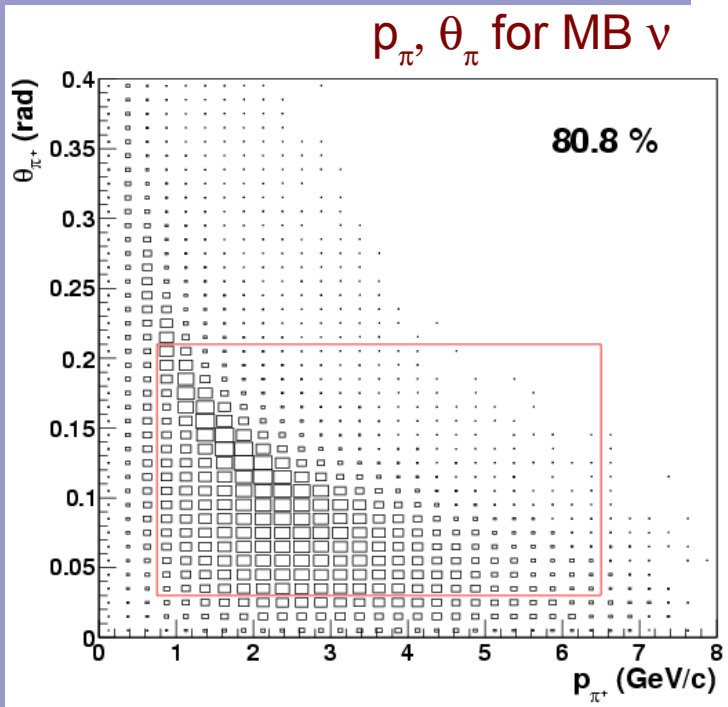
- predominantly from pion decay ($\pi^+ \rightarrow \mu\ \nu_\mu$)
- determined from pBe data from BNL E910 @6,12 GeV, HARP @ 8.9 GeV
- with a "Sanford-Wang" parameterization

fits to HARP data

preliminary!



p_π, θ_π for MB ν



red box: production data coverage

red points : data, red lines: SW fit, blue lines: 1σ errors

- similar procedure is used for Kaons (@10-24 GeV)

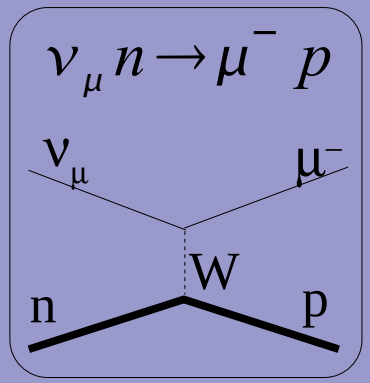
cross section

- measured via the large ν_μ CCQE* data sample in MB

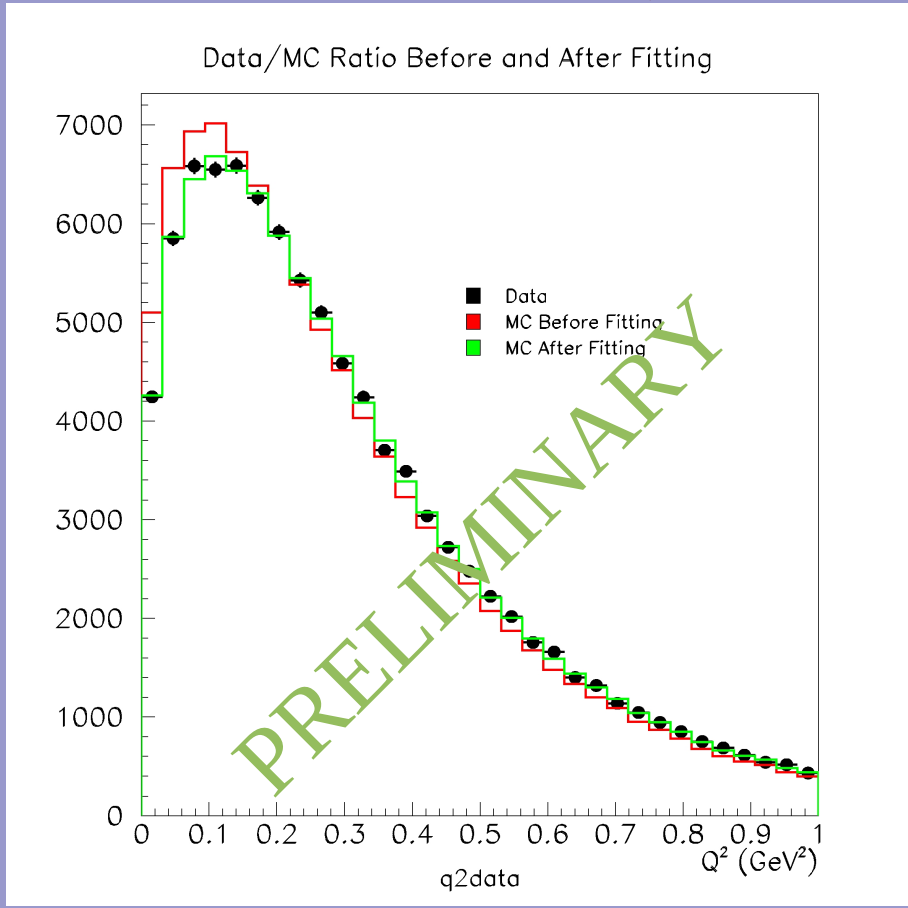
- data used to tune a fermi gas model (within NUANCE evevent generator)
  - binding energy, fermi momentum from e-scattering data on carbon
  - effective axial-mass (M_A) and Pauli-blocking parameter determined from MB data

- cross section applies to ν_e CCQE

* ν_μ charged-current quasielastic process ("CCQE")



MB ν_μ CCQE data



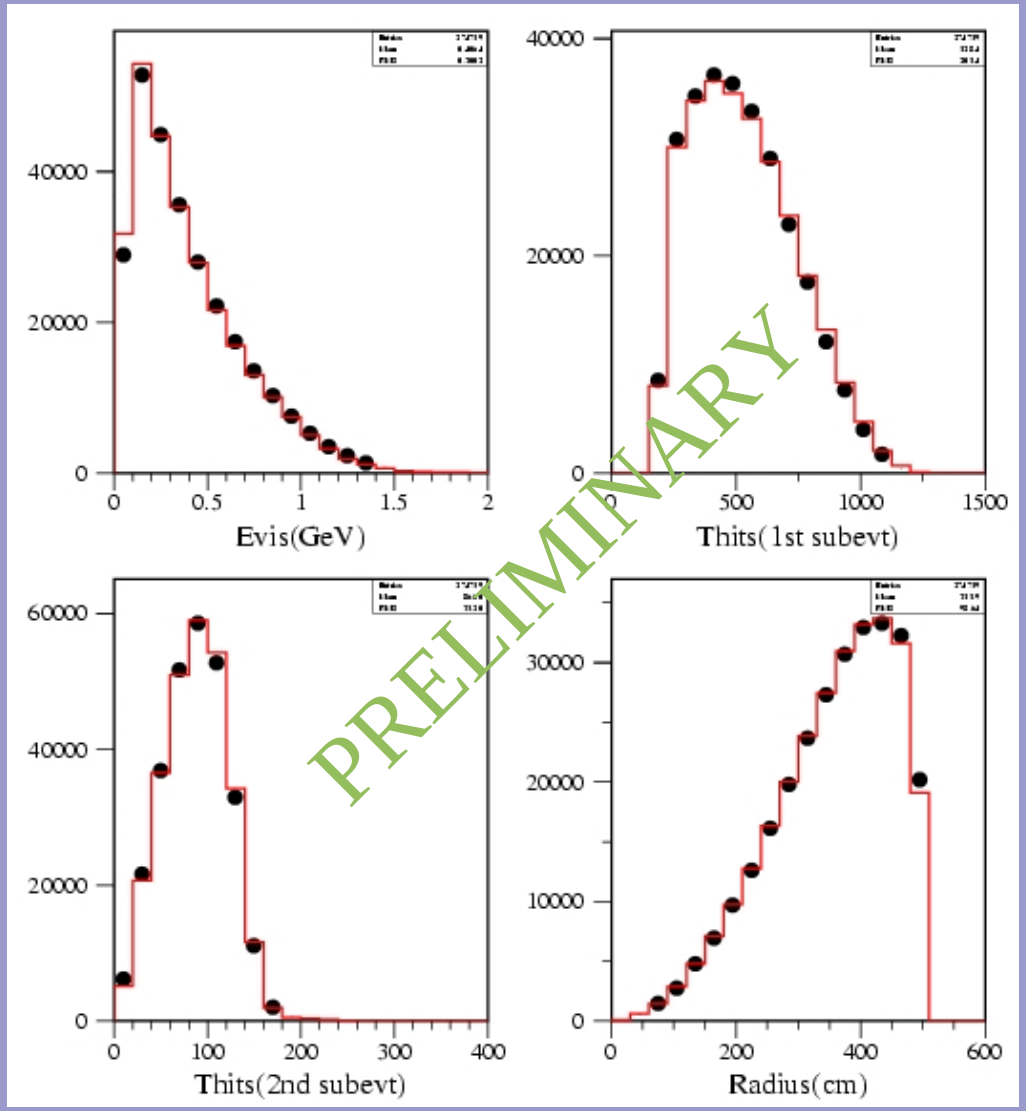
detector simulation

- uses GEANT tuned to external and internal measurements

- required <u>extensive</u> investigation of light propagation in detector

- data/MC agreement is good as can be seen in this inclusive charged-current (CC) sample (tagged by muon decay).

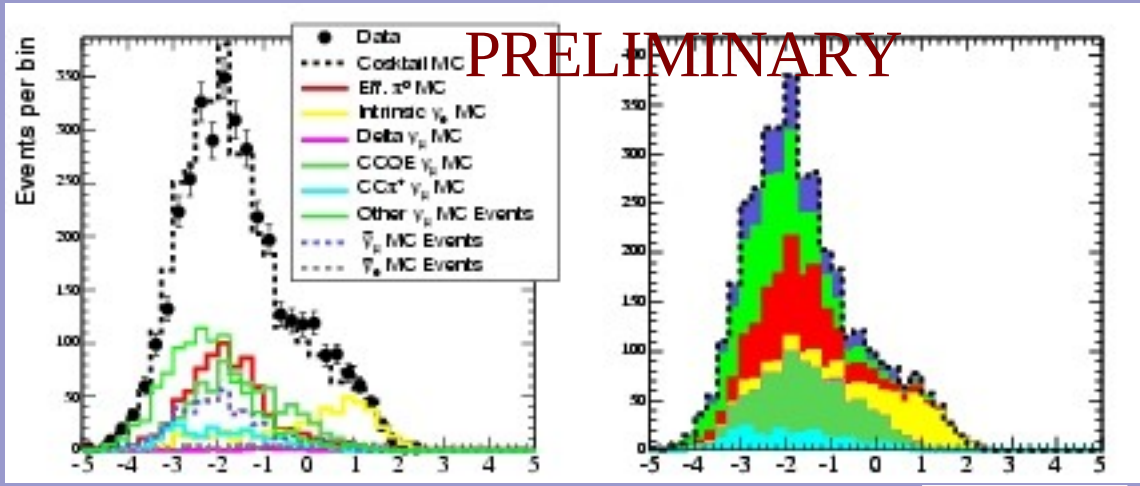
MB inclusive CC data



reconstruction algorithms

- using a 2 different methods:
  - 1) boosted decision trees, see NIM A543 (2005) 577 & NIM A555 (2005) 370.
  - 2) likelihood-based analysis

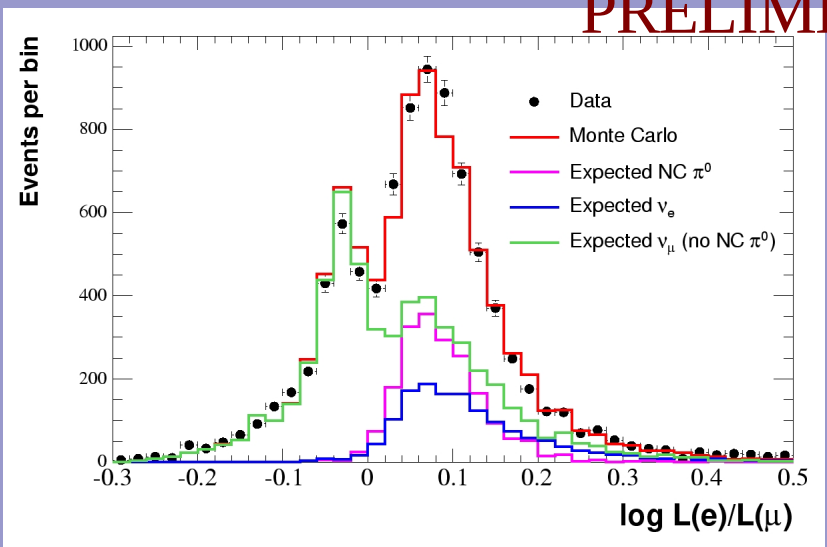
boosting PID output for NuMI data

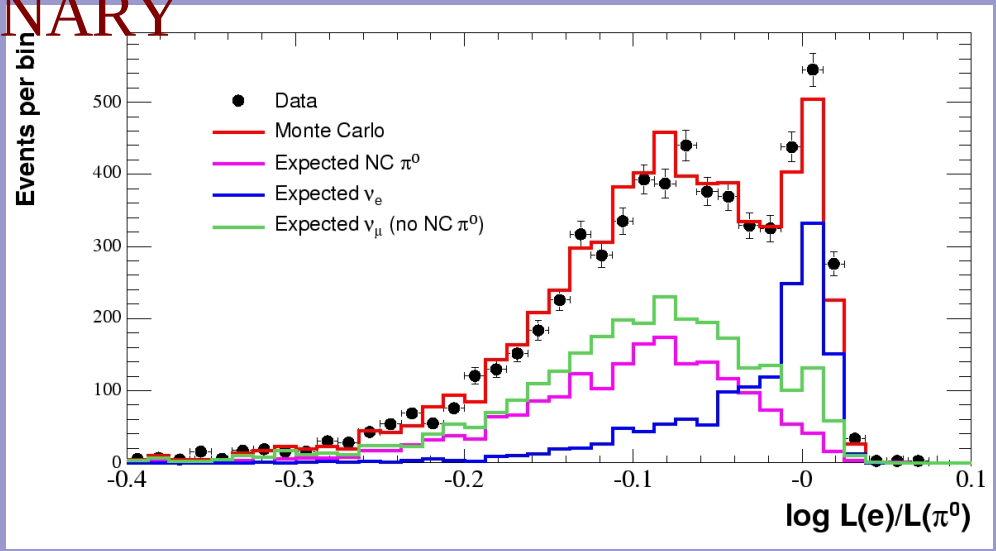


boost_PID

- NuMI data/MC shown here for each method

likelihood PID output for NuMI data





backgrounds

- intrinsic-ν_e backgrounds (from ν_e produced at ν source)
  - $\mu \rightarrow \nu_e$: (indirectly) measured in ν_μ CCQE events
  - $\pi \rightarrow \nu_e$: " " " "
  - $K \rightarrow \nu_e$: measured in high-energy ν_μ CCQE (from Kaons), extrapolate to low-E

- non-ν_e backgrounds
  - Beam Off: measured, negligible
  - CC Inclusive: simulated, tied to data
  - NC π^0: measured (see next page)
  - NC $\Delta \rightarrow N\gamma$: small, yet non-negligible, tied to data, handled in MC
  - NC Coherent γ: calculated, negligible
  - NC Radiative γ: calculated, negligible
  - ν interactions outside tank ("dirt" events), simulated, checked in data
  - beam-unrelated events, determined from random triggers, neglibible

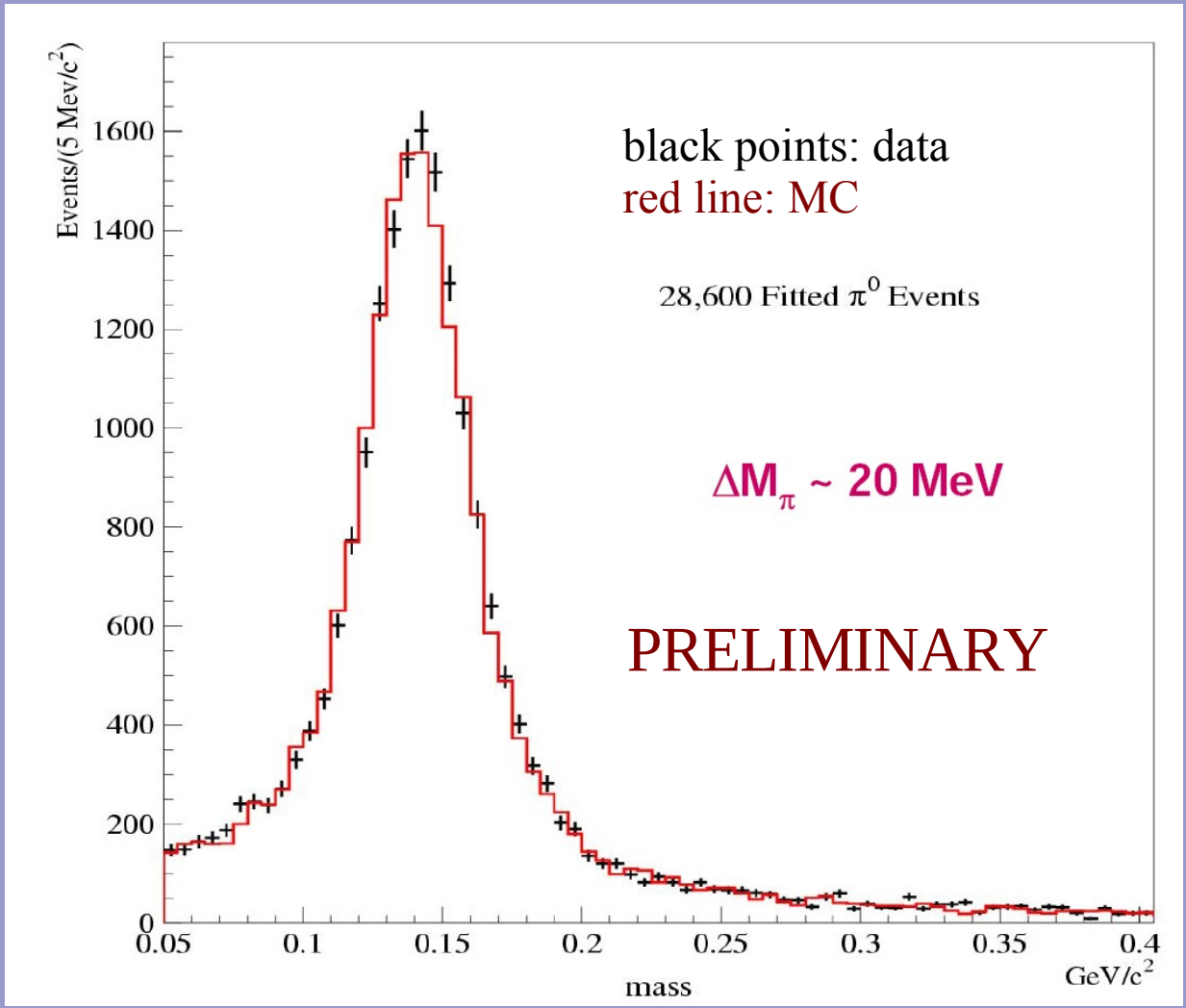
NC π^0 production

- Rate of NC π^0 production is measured as function of π^0 momentum

- Used to estimate NC π^0 background in oscillation sample

- π^0 reconstructed mass distribution is described well in MC simulation

reconstructed π^0 mass



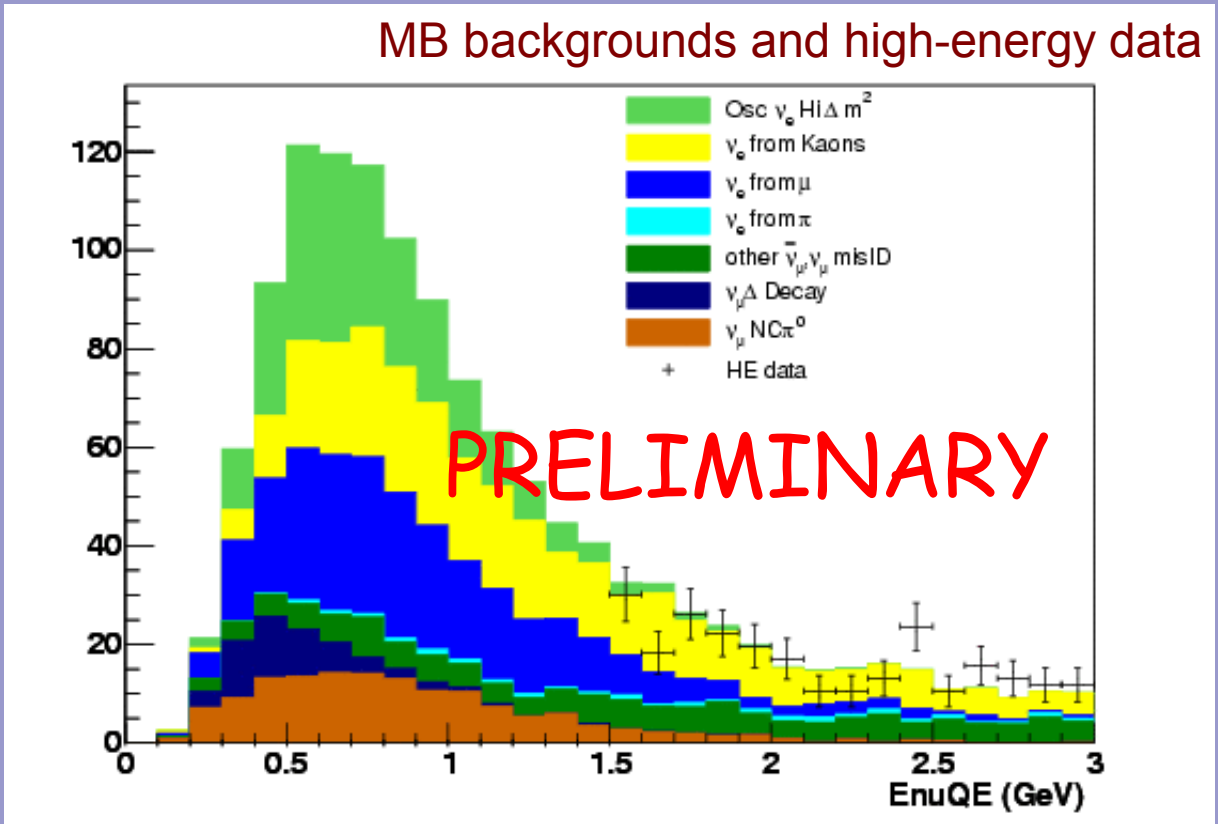
Status

- We are performing a "blind" analysis to avoid experimenter bias (signal region is kept in a "closed-box")

- Plot shows possible (LSND) signal with measured/calculated backgrounds
  - high-energy data overlaid
  - low-energy data (signal) in "closed-box" region

- Currently in final stages of analysis

- When finished, we will "open the box" on the low-E oscillation sample



- And will report result for $\nu_\mu \rightarrow \nu_e$ oscillations