

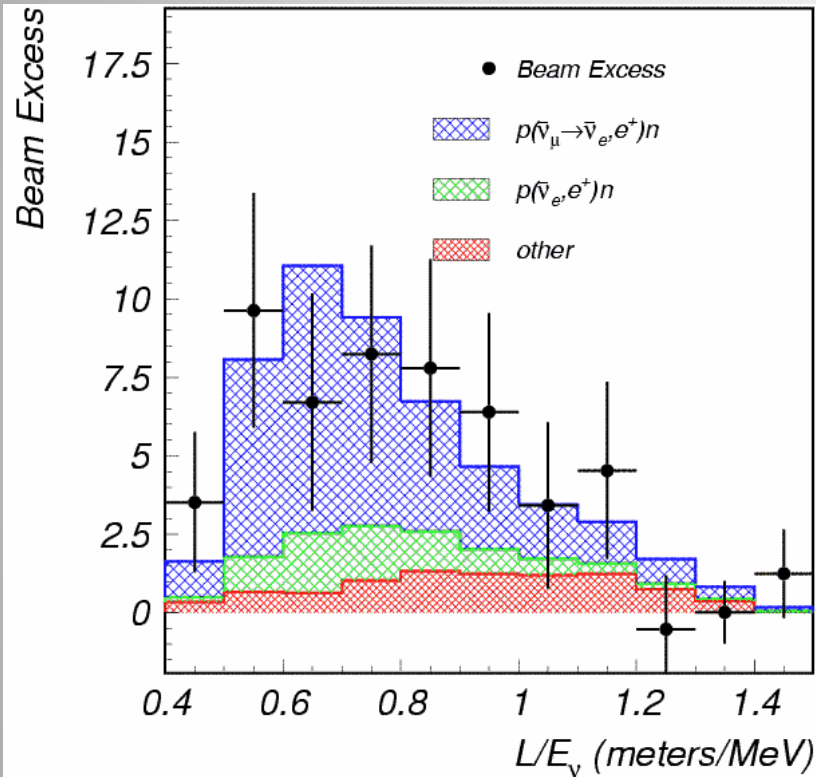
MINIBOONE UPDATE: CROSS SECTIONS & OSCILLATIONS

PAUL NIENABER
SAINT MARY'S UNIVERSITY OF MINNESOTA
FOR THE
MINIBOONE COLLABORATION

JULY 28 2009 -- DPF2009

MiniBooNE's original *raison d'être*

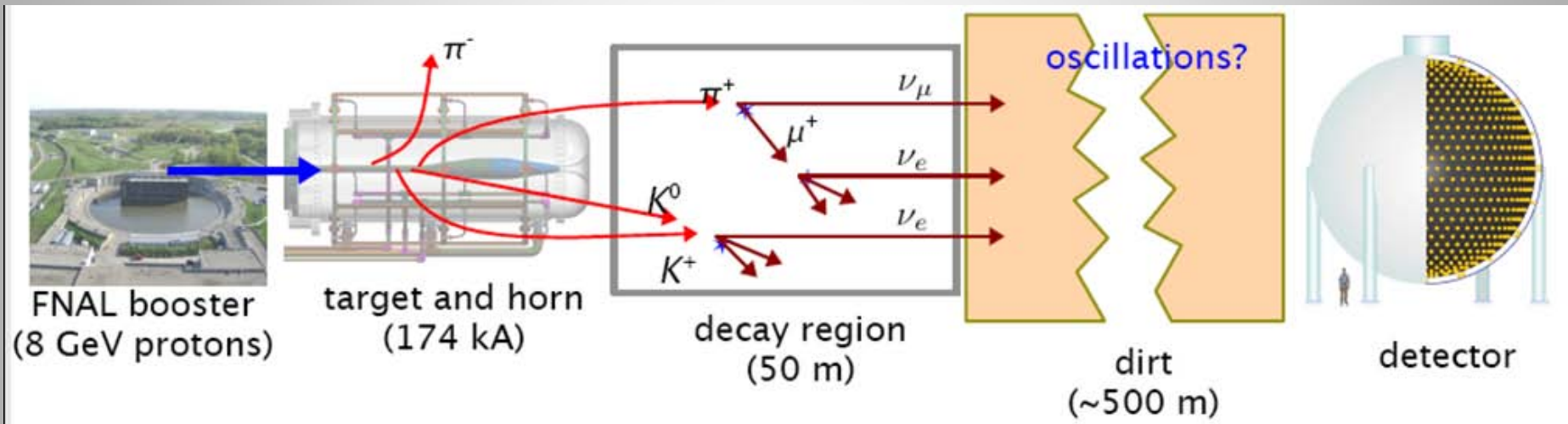
- motivated by LSND observation of electron antineutrino events in a muon antineutrino beam



PRD 64, 112007 (2001)

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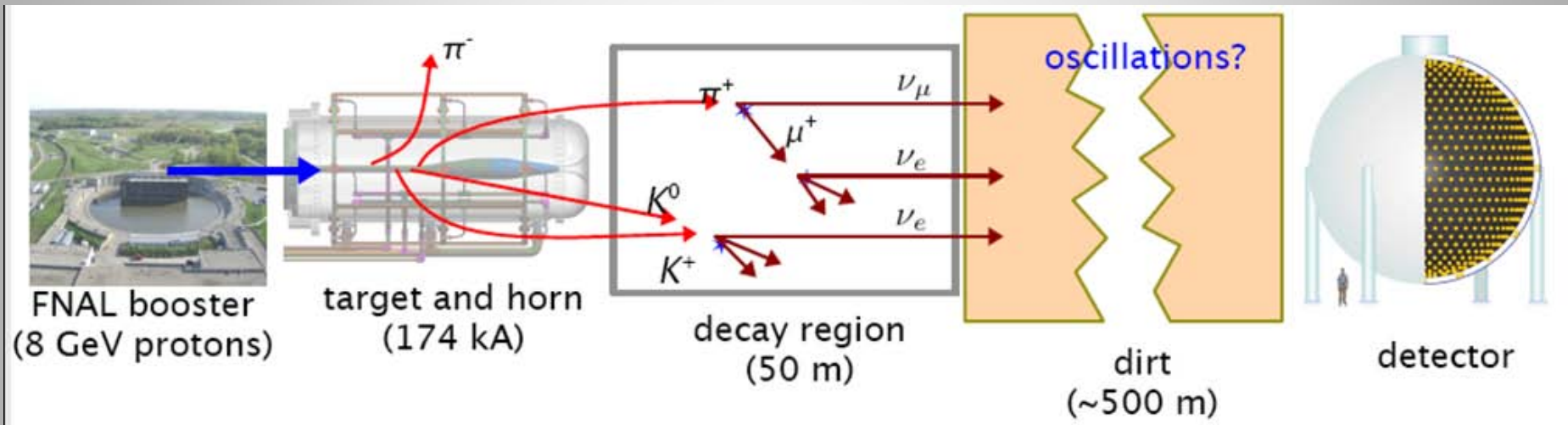
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- MB start: muon neutrino beam
- different L, E; same L/E

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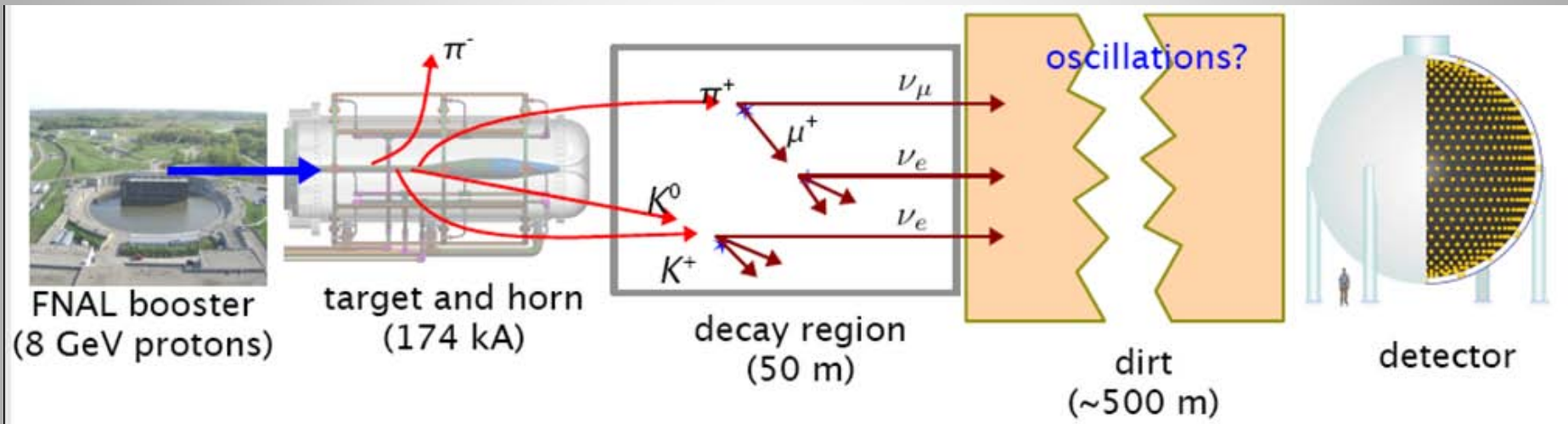


about 2 mg of
protons
delivered
to date!

- MB start: muon neutrino beam
- different L, E; same L/E
- **6.9 E+20 POT neutrino mode**
- **5.1 E+20 POT antineutrino mode**

MiniBooNE's original *raison d'être*

- motivated by LSND observation of electron antineutrino events in a muon antineutrino beam



pion production (& hence ν_μ flux) well constrained by HARP data/analysis
Eur. Phys. J. C52, 29 (2007)

- MB start: muon neutrino beam
- different L, E; same L/E
- **6.9 E+20 POT neutrino mode**
- **5.1 E+20 POT antineutrino mode**



Collaborators from

Alabama, Bucknell, Cincinnati, Colorado, Columbia, Embry-Riddle, Fermilab, Florida, Illinois, Indiana, Los Alamos, LSU, MIT, Michigan, Princeton, Saint Mary's, Virginia Tech, Yale

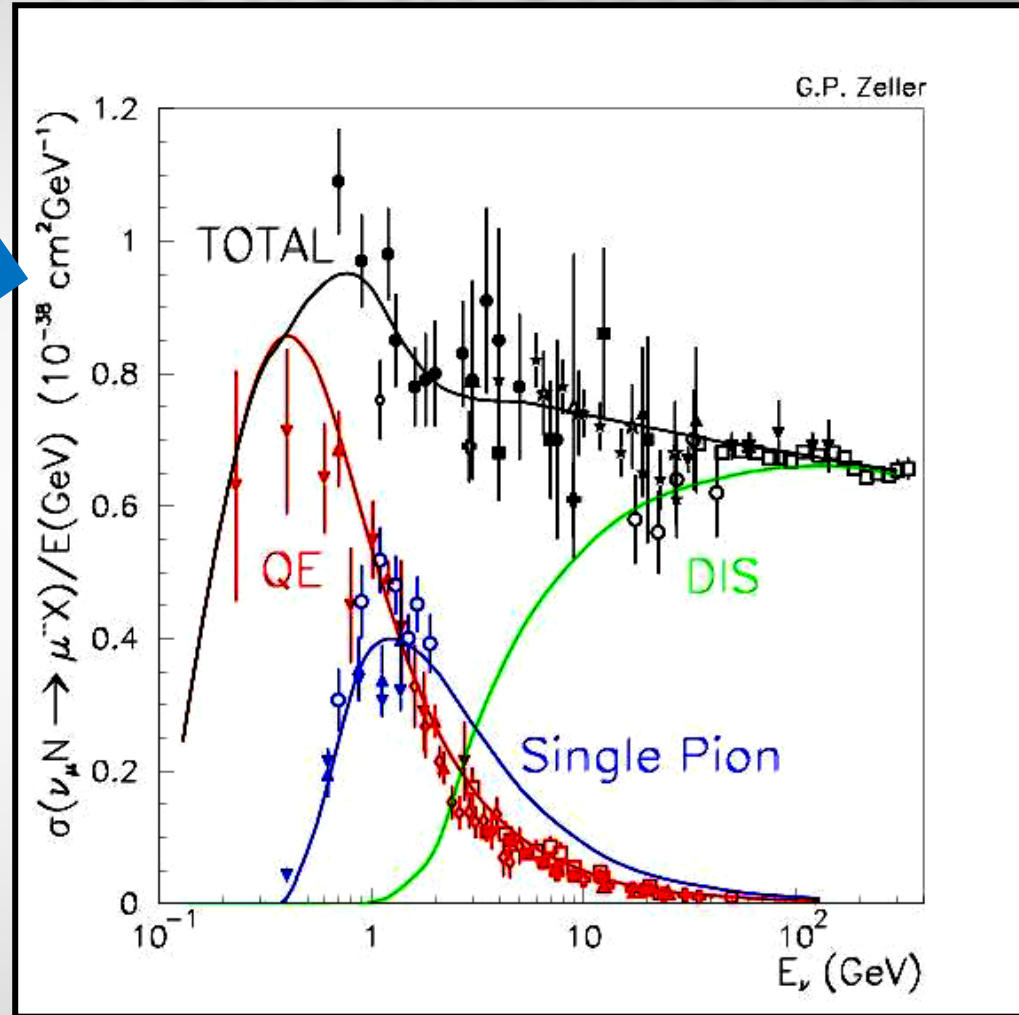
overview

- **cross section measurements**

- **oscillation analyses**

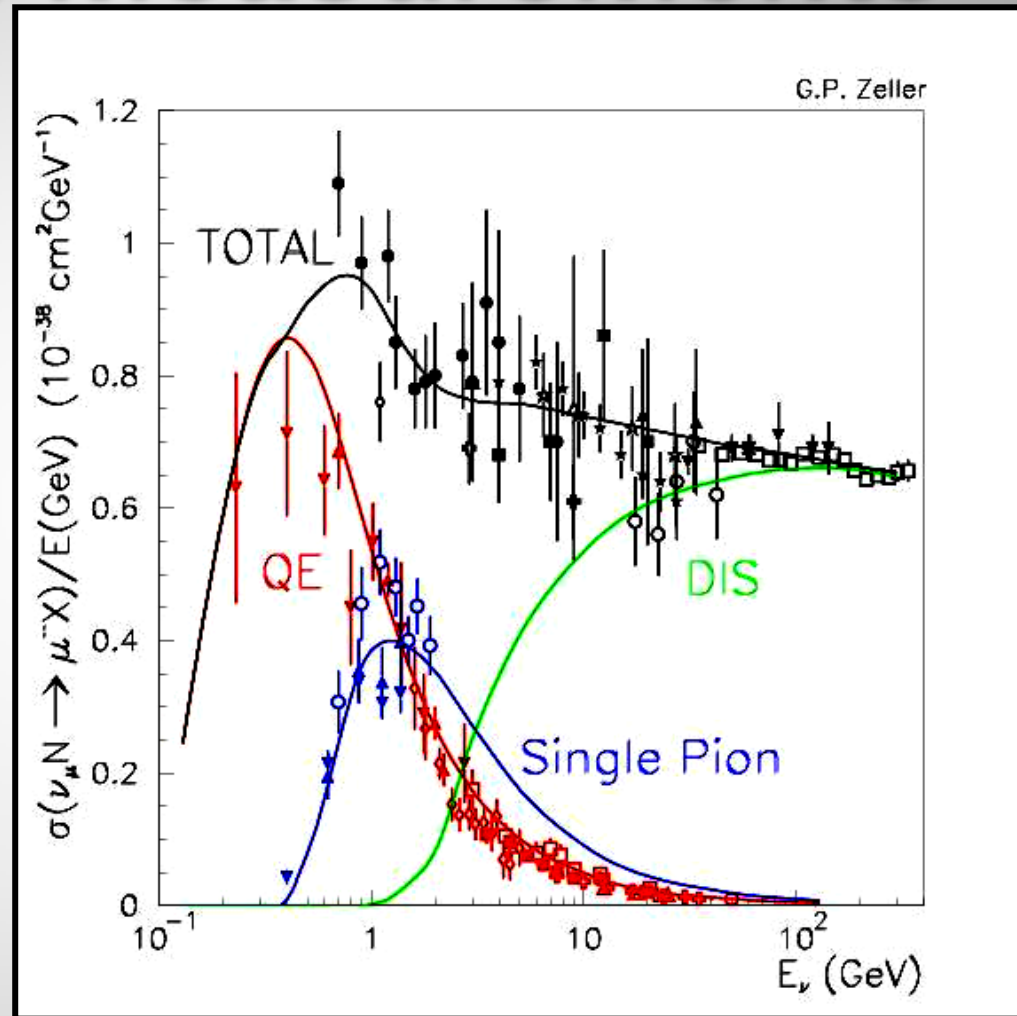
cross section measurements

neutrino CC cross sections
when dinosaurs roamed the Earth
(i.e., pre- MiniBooNE)



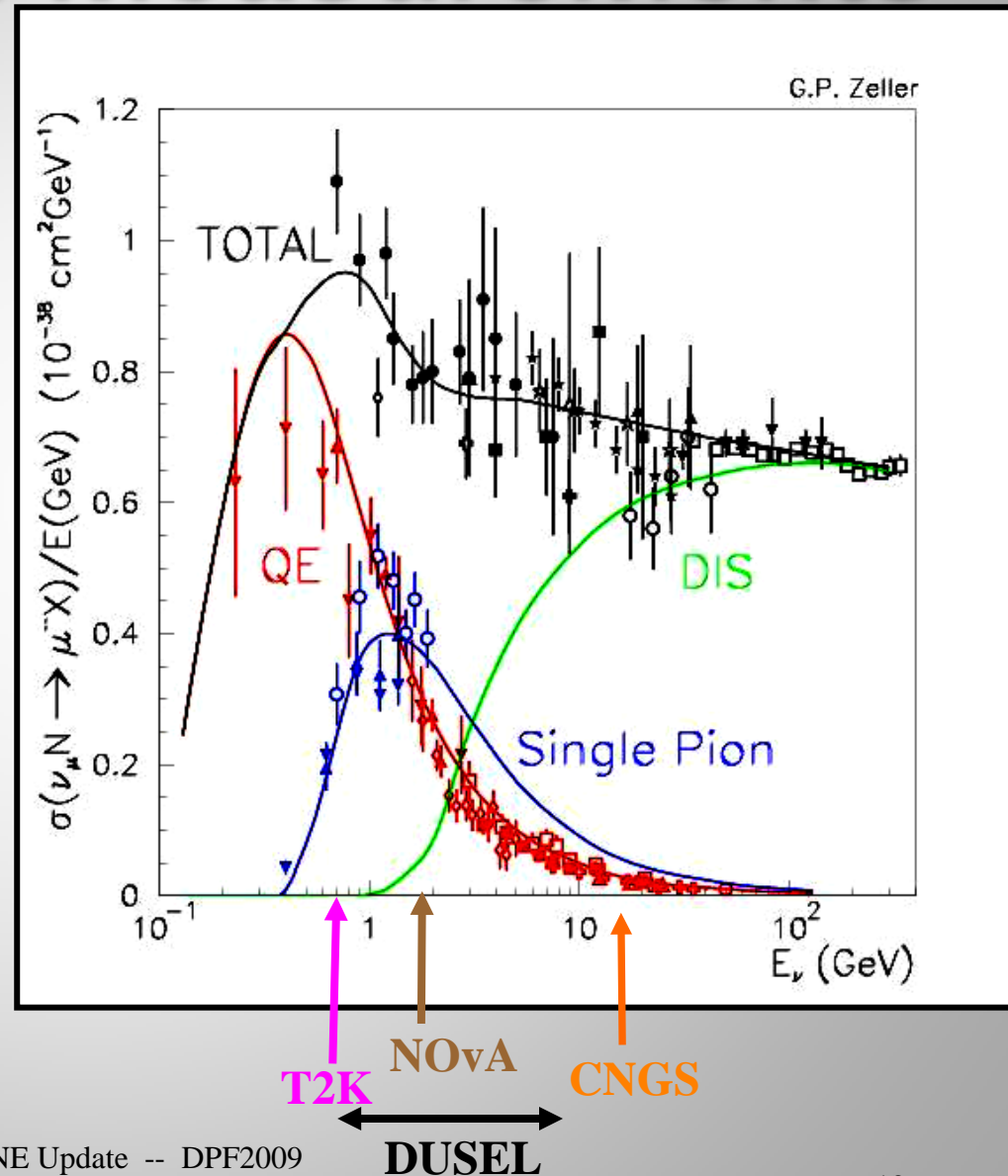
cross section measurements

these numbers are of fundamental interest, but also relevant to future experiments



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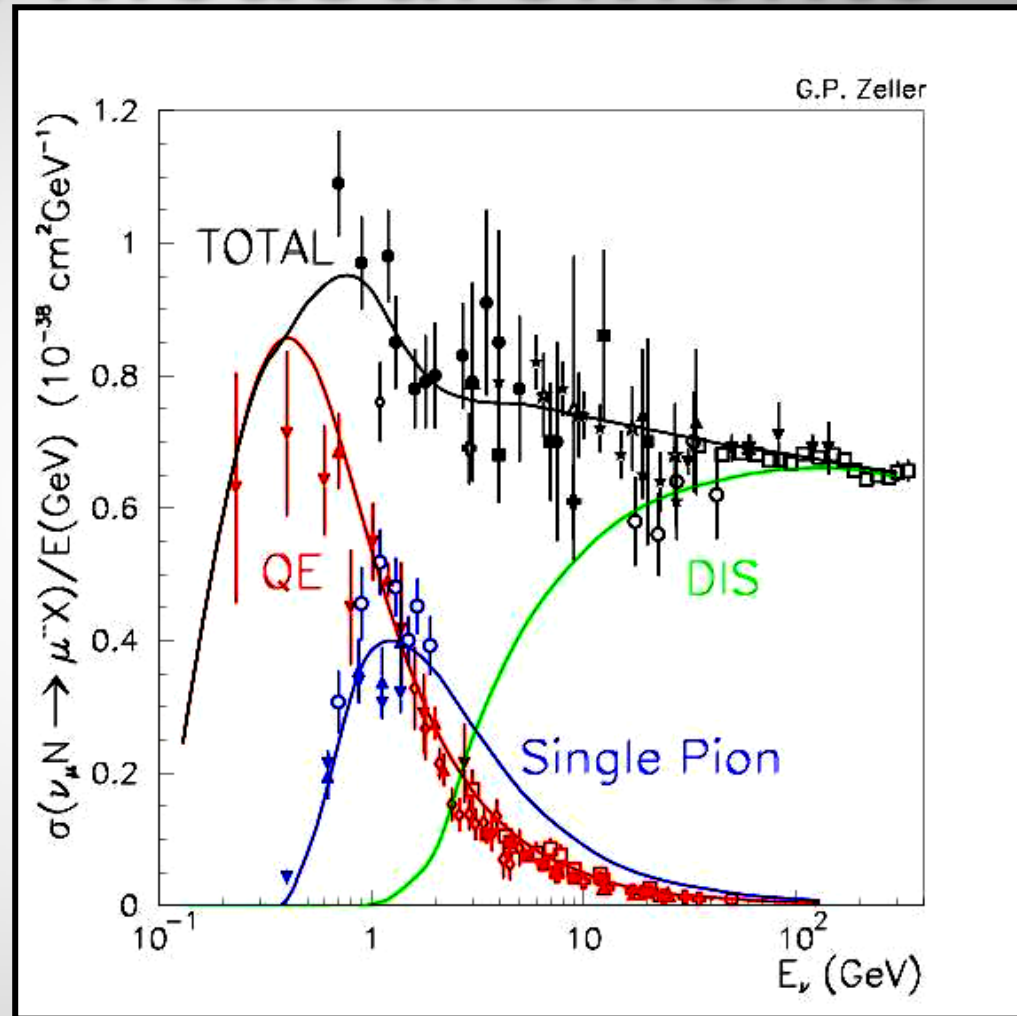


cross section measurements

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focus here on two processes:

CC QE
(signal for oscillation)



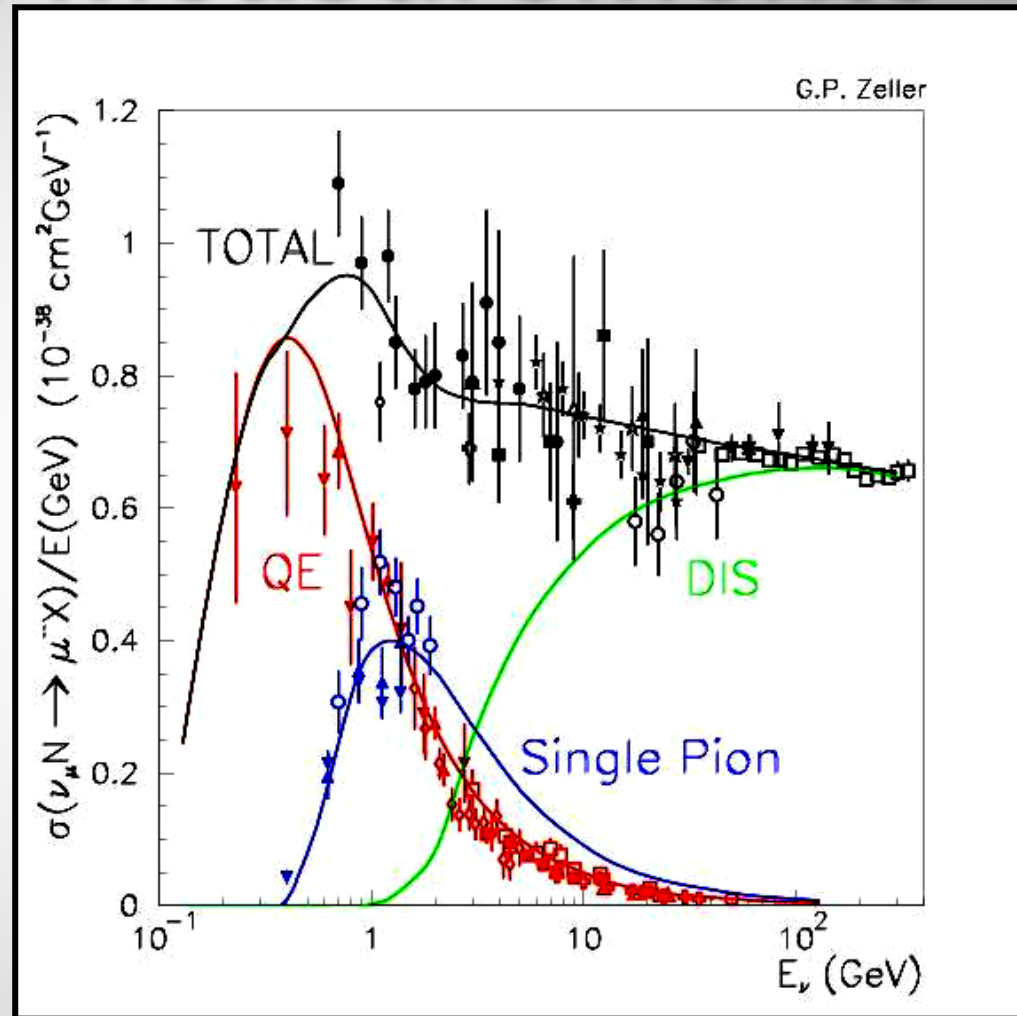
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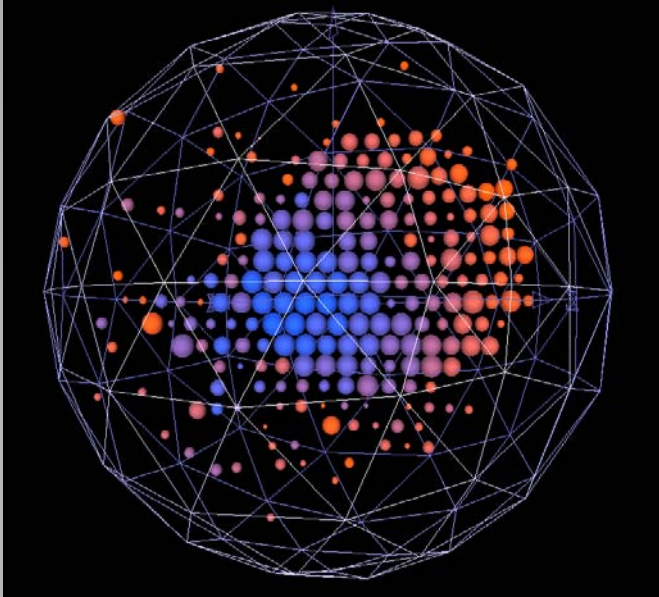
focus here on two processes:

CC QE
(signal for oscillation)

NC π^0
(background)



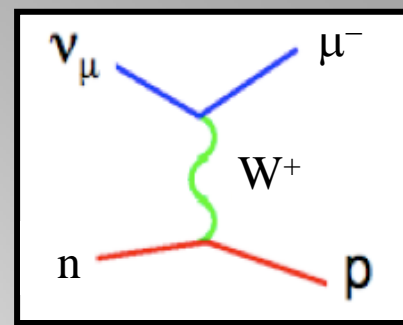
cross sections: CCQE



LARGE SAMPLE!

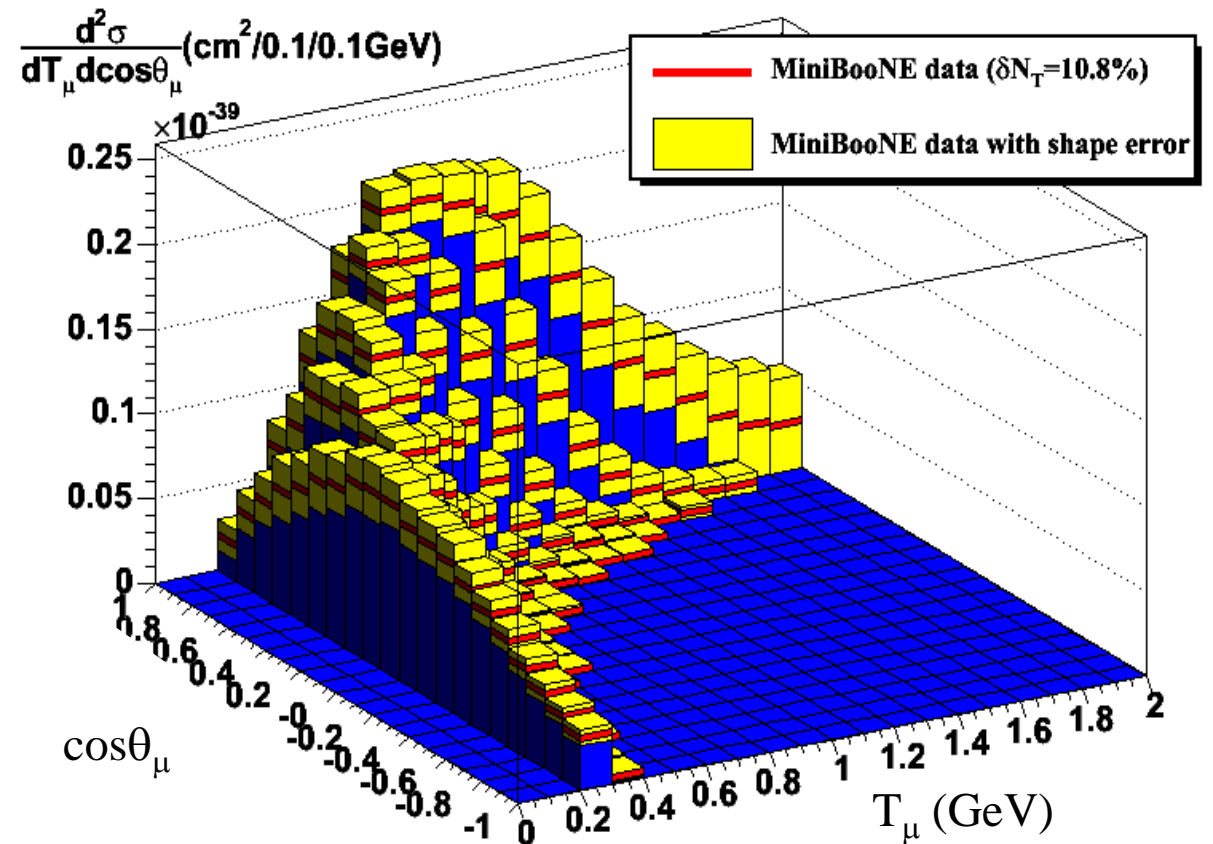
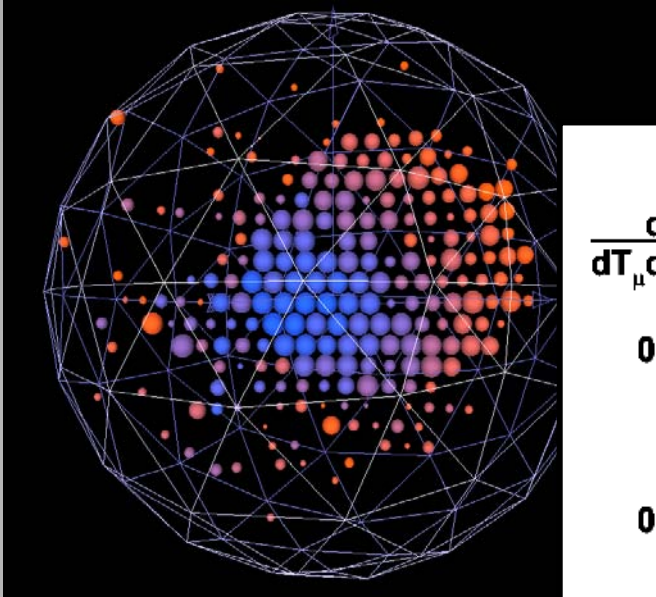
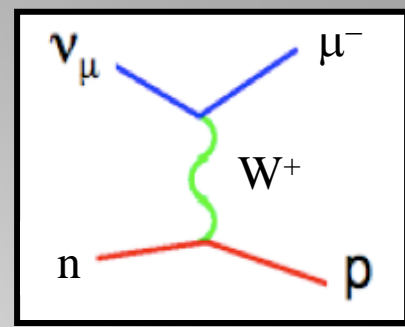
146,070 ν_μ QE events
(76% purity, 27% ϵ)
[analyzed, after cuts]

provide most complete
information on ν_μ QE
scattering to date
(full μ kinematics: E_μ and θ_μ)



cross sections: CCQE

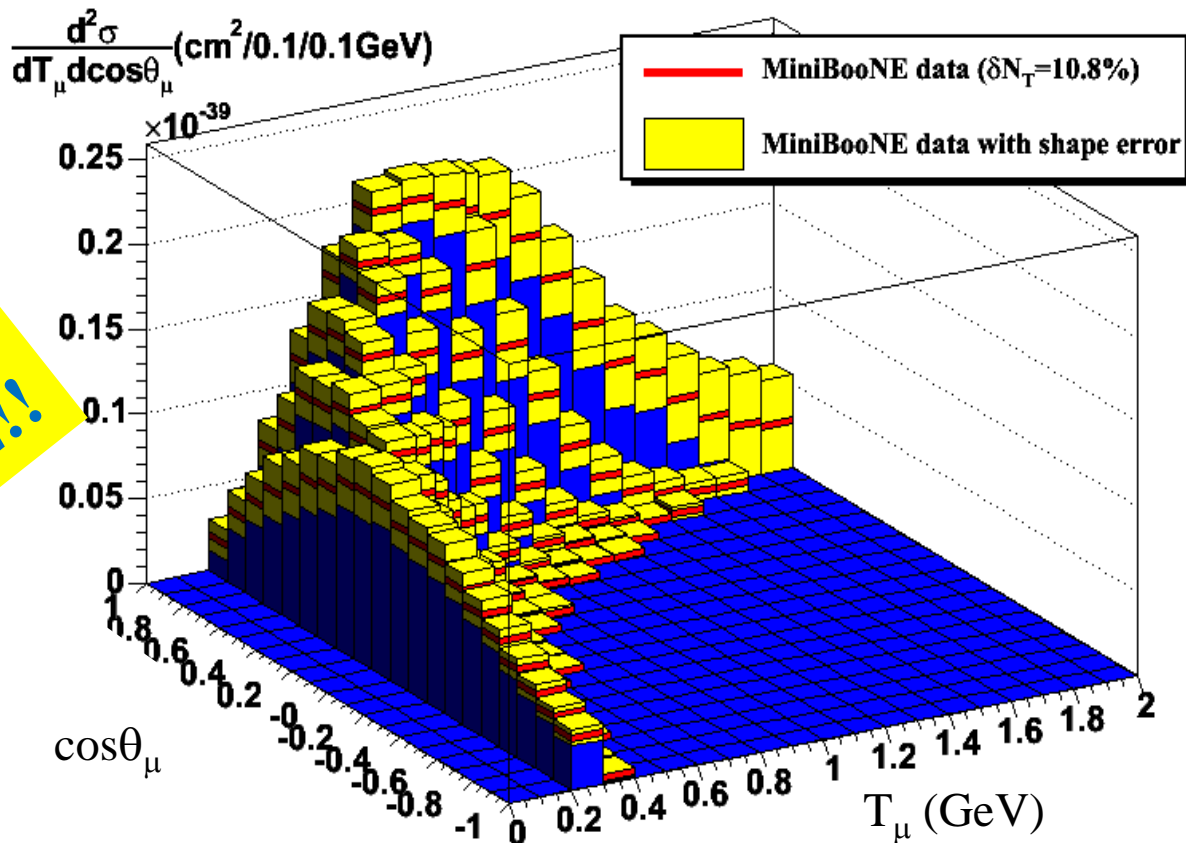
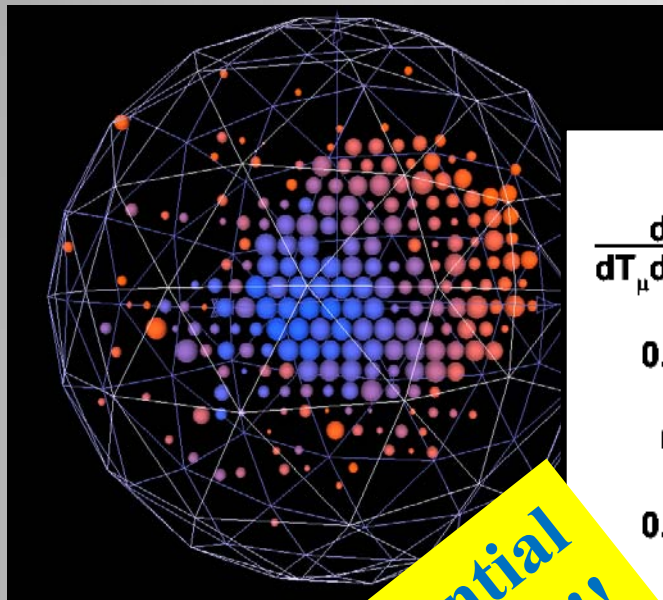
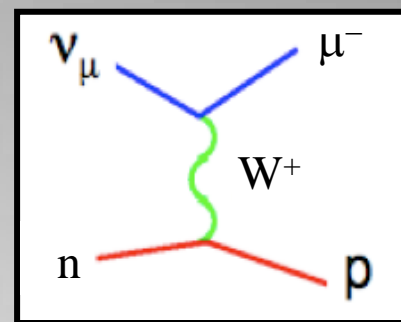
(T. Katori)



(draft in preparation)

cross sections: CCQE

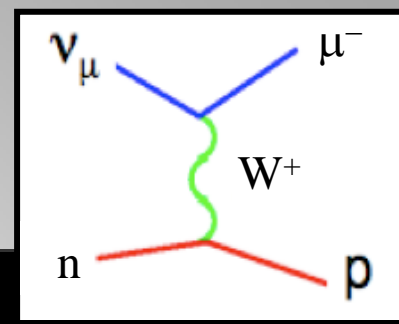
(T. Katori)



first double differential cross section for ν QE!!

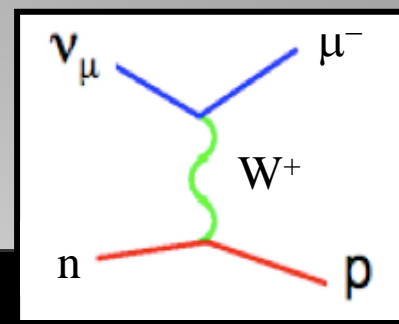
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cross sections: CCQE

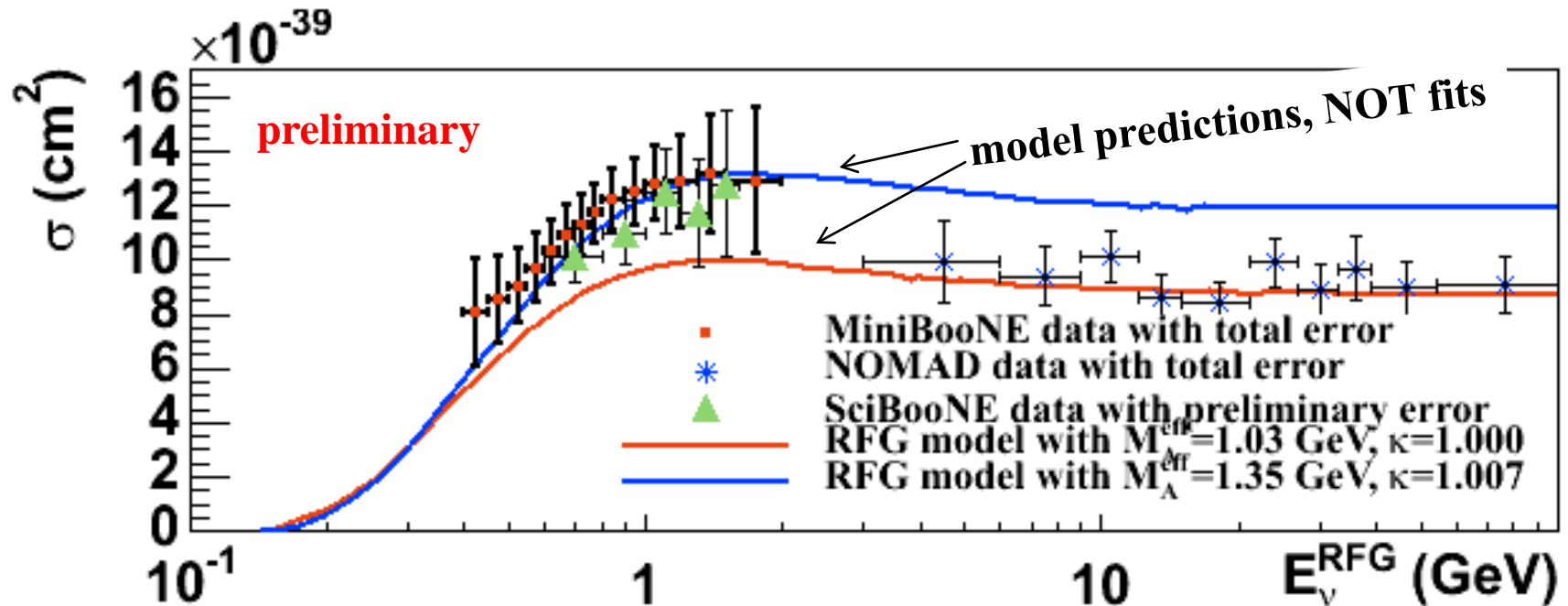


- Q^2 shape fit results: $M_A = 1.35 \pm 0.17$ GeV
- Higher value of M_A also consistent with σ_{total} vs. E_ν
- Consistent w/ K2K, MINOS, but not w/ $M_A^{D2} = 1.03$ GeV

cross sections: CCQE

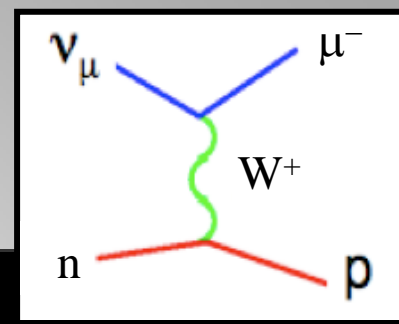


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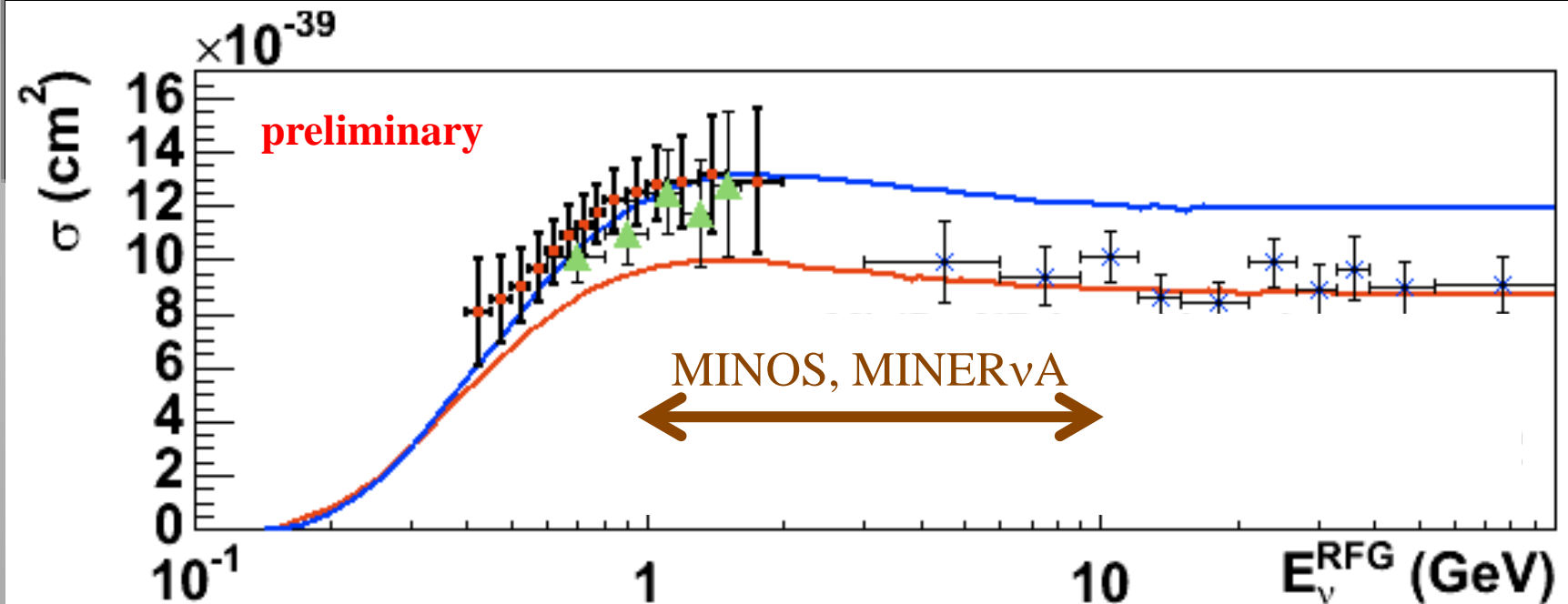


RFG = relativistic Fermi gas (*v. Smith & Moniz, NP B43, 605 [1972]*)

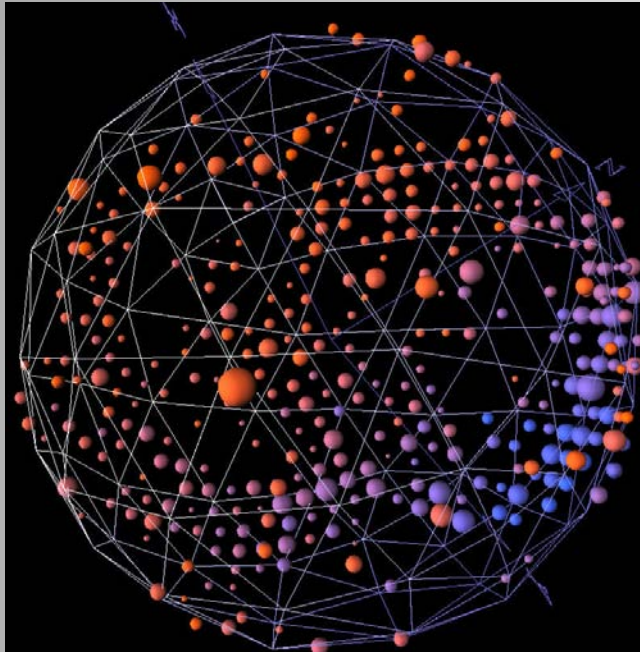
cross sections: CCQE



- MiniBooNE and recent SciBooNE in good agreement
- Both *higher* than recent NOMAD σ_{QE} ?! (all three on ^{12}C)
 \Rightarrow look to MINOS and MINERvA for more data



cross sections: NC π^0



$\pi^0 \rightarrow \gamma\gamma$

LARGE SAMPLE!

neutrino: 21,542 NC π^0 events
(73% purity, 36% ϵ)

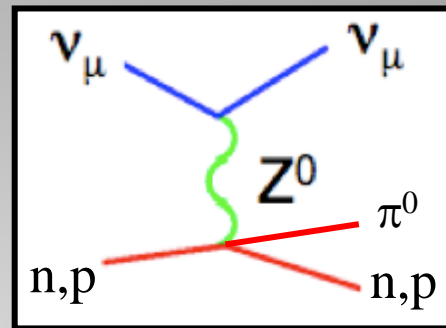
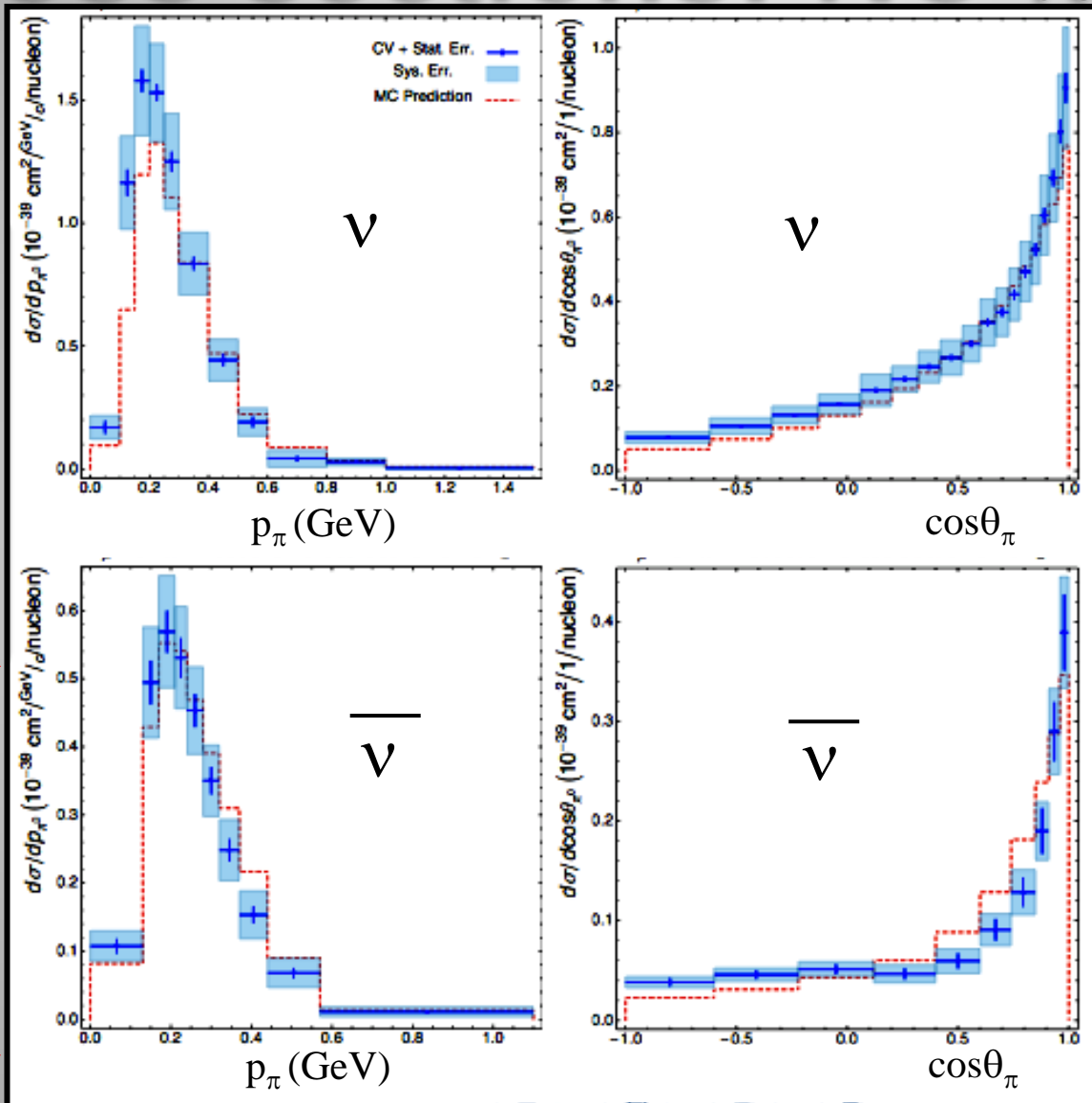
antineutrino: 2,305 NC π^0 events
(58% purity, 36% ϵ)



cross sections: NC π^0

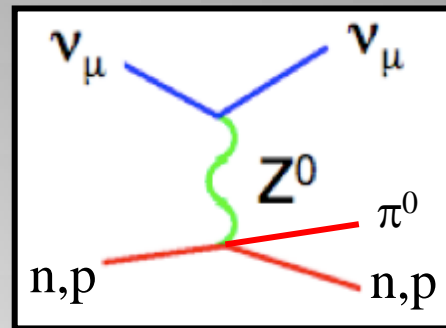
(draft in preparation)

(C. Anderson)

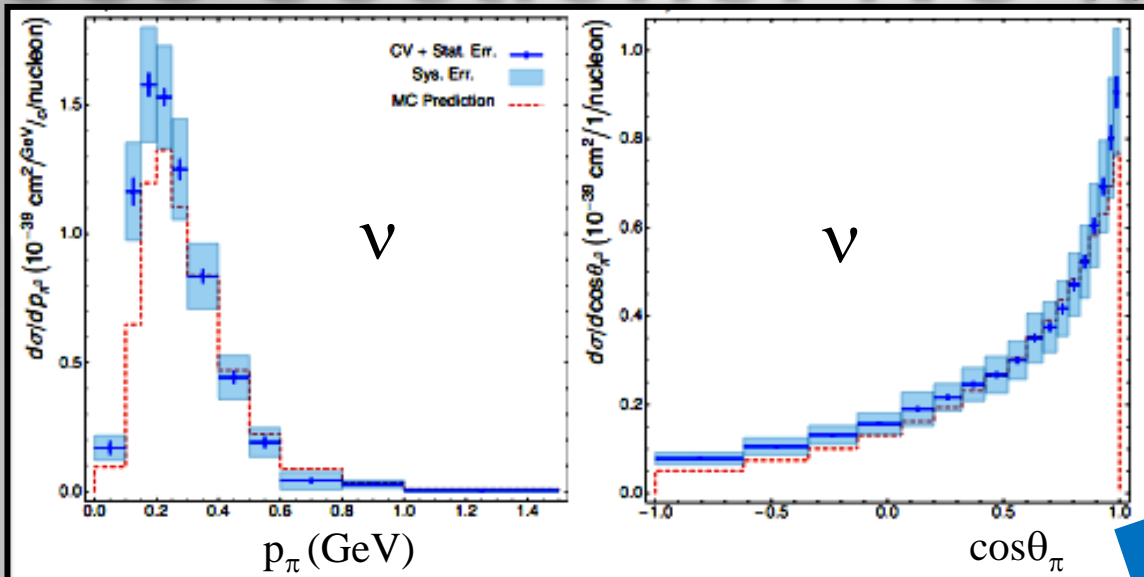


[flux averaged]

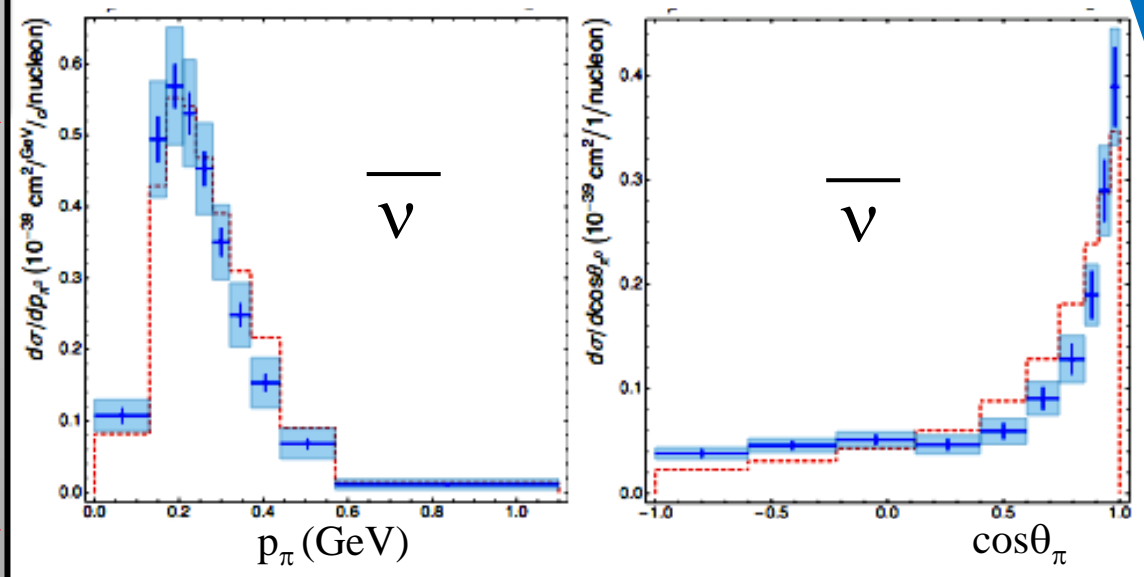
cross sections: NC π^0



(draft in preparation)



(C. Anderson)



**first measurement
of absolute NC π^0
differential
cross section**

[flux averaged]

cross sections: summary

MORE!!!

-- ν_μ **CC π^+ /CCQE**: arXiv:0904.3959 [hep-ex]
[S Linden, J Nowak]

-- ν_μ **CC π^+** : $d\sigma/dT_\mu$, $d\sigma/d\theta_\mu$, $d^2\sigma/dT_\mu d\theta_\mu$,
 $d\sigma/dT_\pi$, $d\sigma/d\theta_\pi$, $d^2\sigma/dT_\pi d\theta_\pi$, $d\sigma/dQ^2$,
 $\sigma(E_\nu)$ [M Wilking]

-- ν_μ **NC elastic**: $d\sigma/dQ^2$ [D Perevalov]

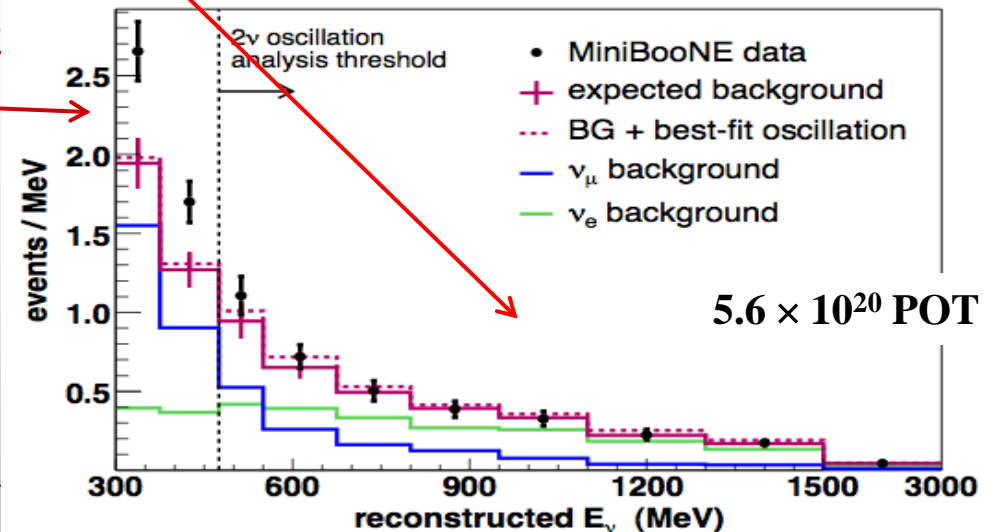
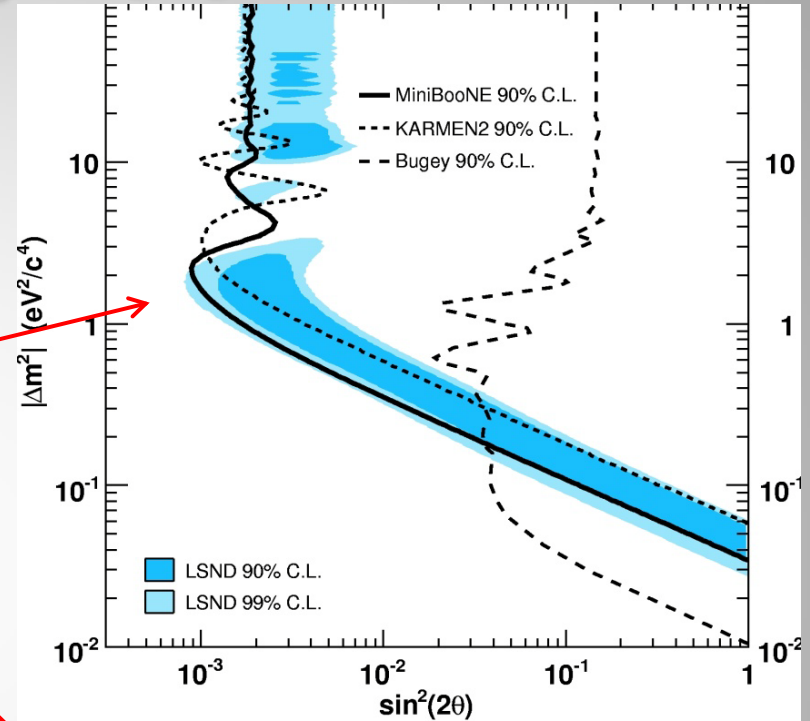
oscillations I: ν_e appearance

2007 result:

In analysis region
 $475 < E_\nu < 3000$ MeV,
no evidence for oscillation
(interpretation of LSND as simple
two-neutrino oscillation excluded at
98% CL)

Unexpected excess of events at
low energy < 475 MeV

PRL 98, 231801 (2007)



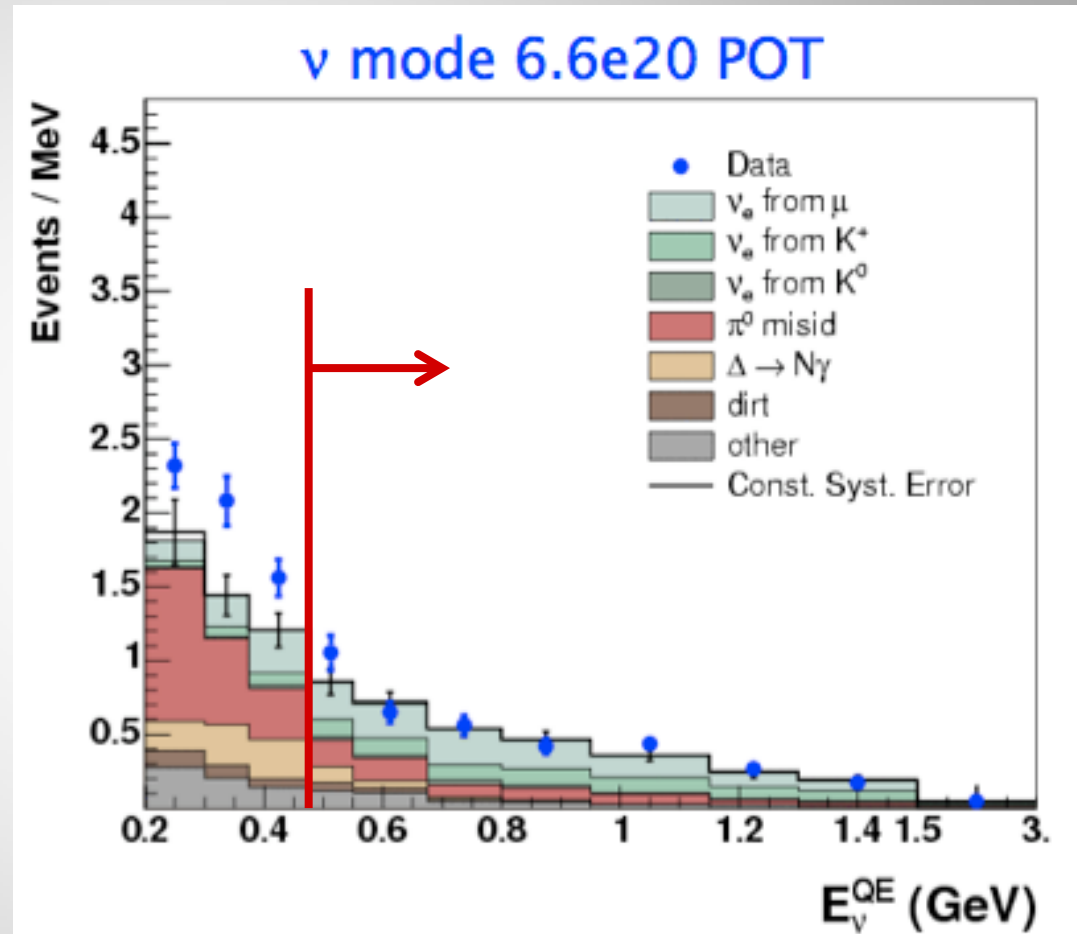
oscillations I: ν_e appearance

2009 update:

improved statistics, better modelling of some background processes, and enhanced cuts on external interactions

analysis threshold extended down to 200 MeV

over 475 MeV:
no change



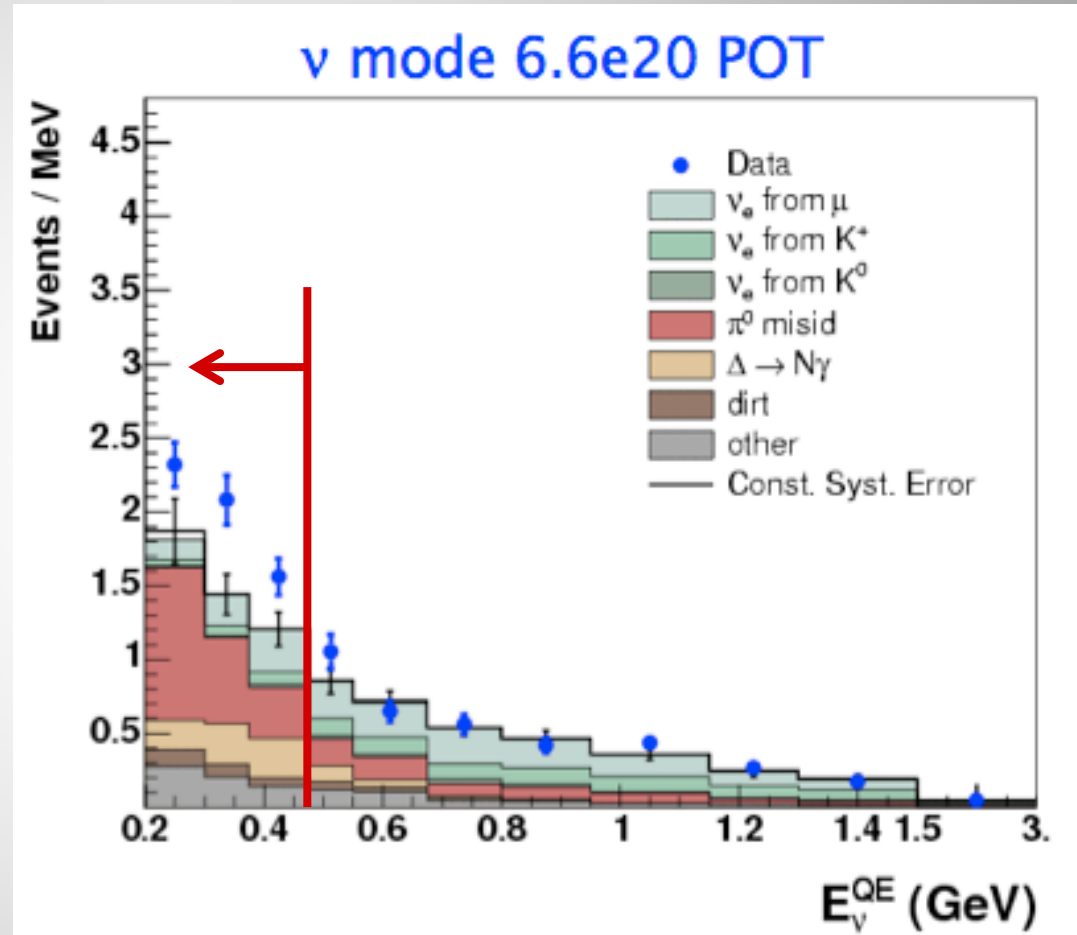
oscillations I: ν_e appearance

2009 update:

improved statistics, better modelling of some background processes, and enhanced cuts on external interactions

analysis threshold extended down to 200 MeV

under 475 MeV:
excess persists



PRL 102, 101802 (2009)

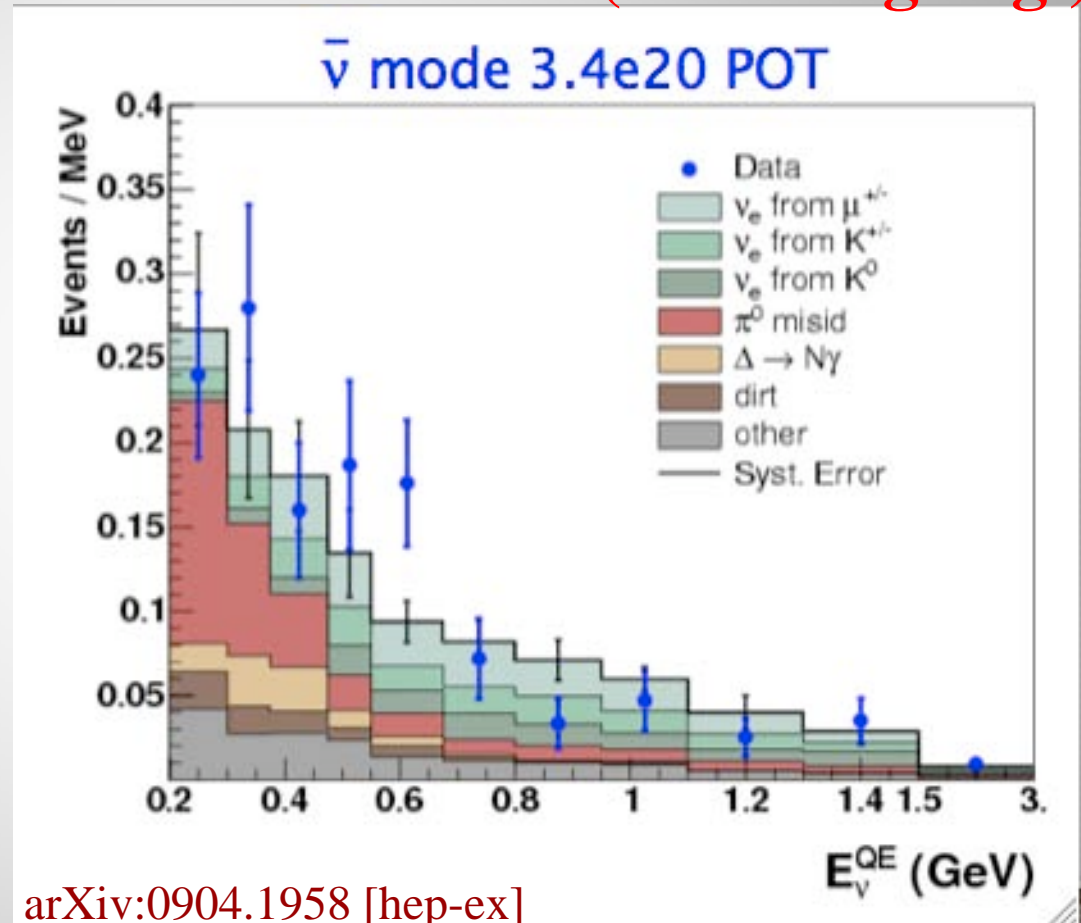
oscillations II: $\bar{\nu}_e$ appearance

(G. Karagiorgi)

-- statistics are low
(does not include
spring 2009 runs)

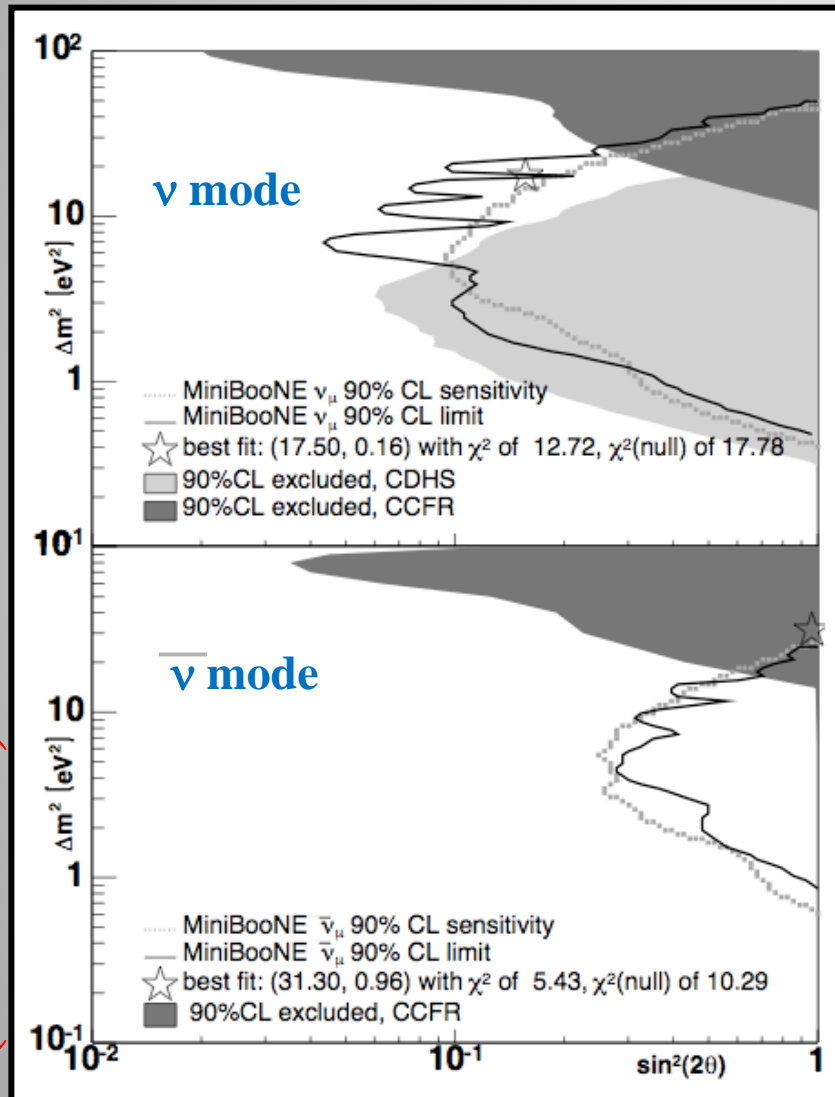
-- no definitive
statement on
LSND yet

-- no low energy
excess?!



arXiv:0904.1958 [hep-ex]
submitted to PRL

oscillations III: disappearance



at 90%CL, no neutrino or antineutrino disappearance observed

neutrino results agree with earlier experiments (CDHS + CCFR)

antineutrino results map out new excluded region in parameter space

(K. Mahn)

conclusions

- **cross section results:**
 - unprecedentedly large samples allow measurements to be unpacked as differential rather than total
 - flux understanding (HARP, &c.) allows absolute rather than ratio measurements
 - some interesting unanswered questions (M_A , &c.)
- **oscillations:**
 - provenance of low energy excess remains an open question
 - antineutrino results await more statistics

coming attractions...

- **combined antineutrino/neutrino appearance analysis**
- **combined MiniBooNE/SciBooNE disappearance analysis**
- **three more years antineutrino running**

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- **three more years antineutrino running**
- **MicroBooNE: liquid argon TPC in BNB line, upstream of MiniBooNE** *see B Fleming Friday morning plenary!*
- **upgrade to BooNE: second detector**