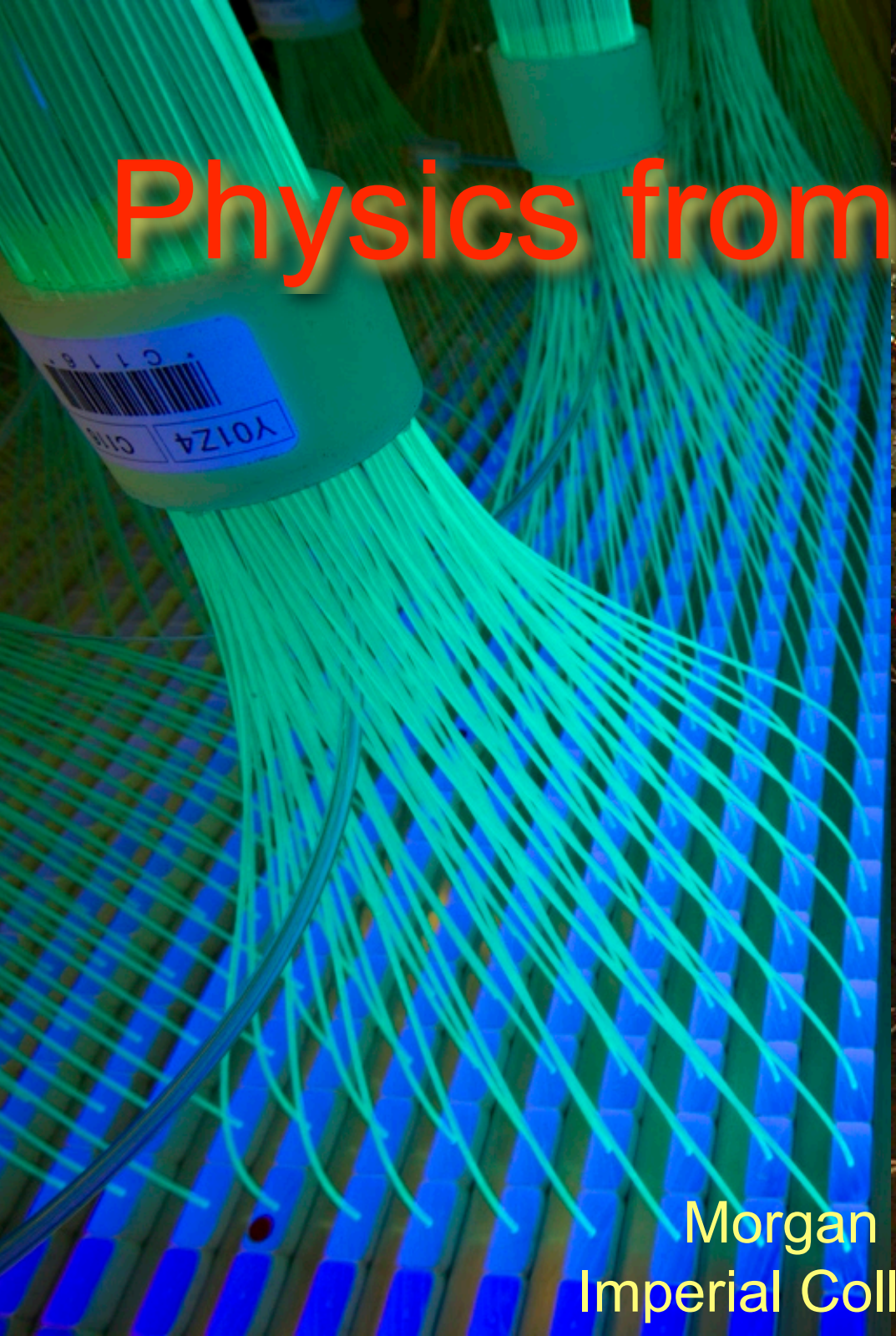
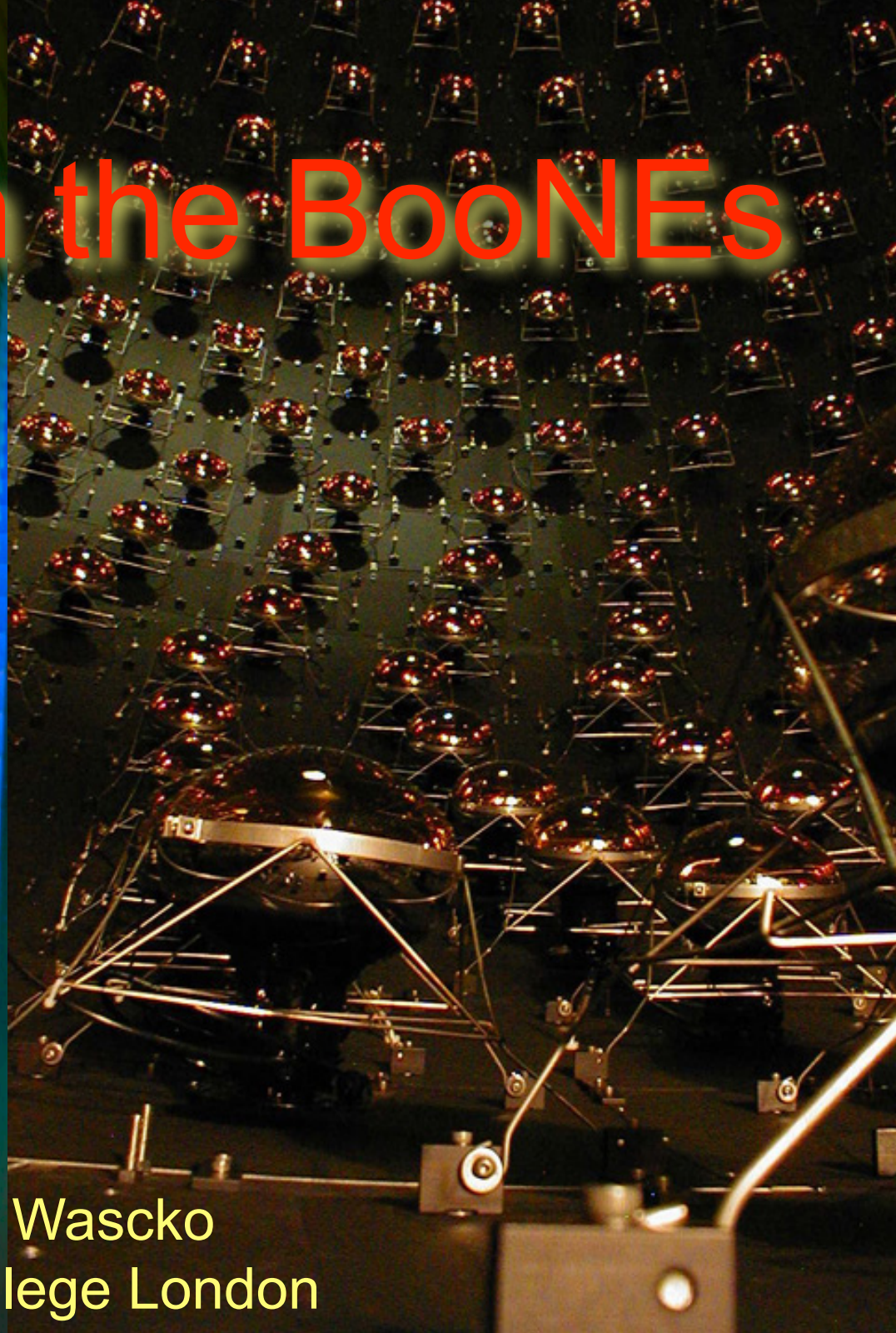
Physics from the BooNEs

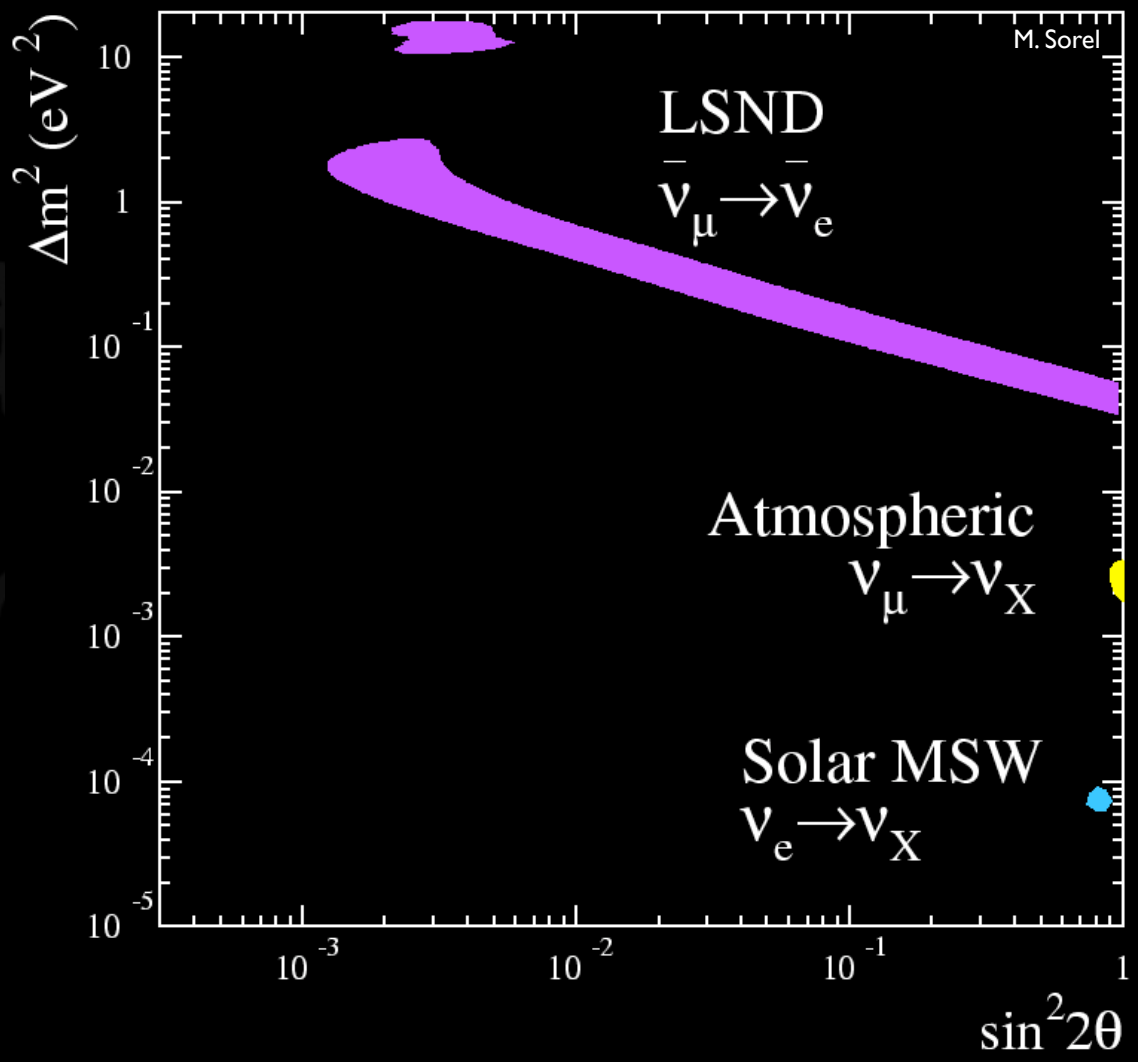




Morgan Wascko
Imperial College London

Goals of the BooNEs

- MiniBooNE: Confirm or rule out LSND
- SciBooNE:
  - Near detector measurements for MiniBooNE
  - Precise cross section measurements
    - Especially useful for T2K



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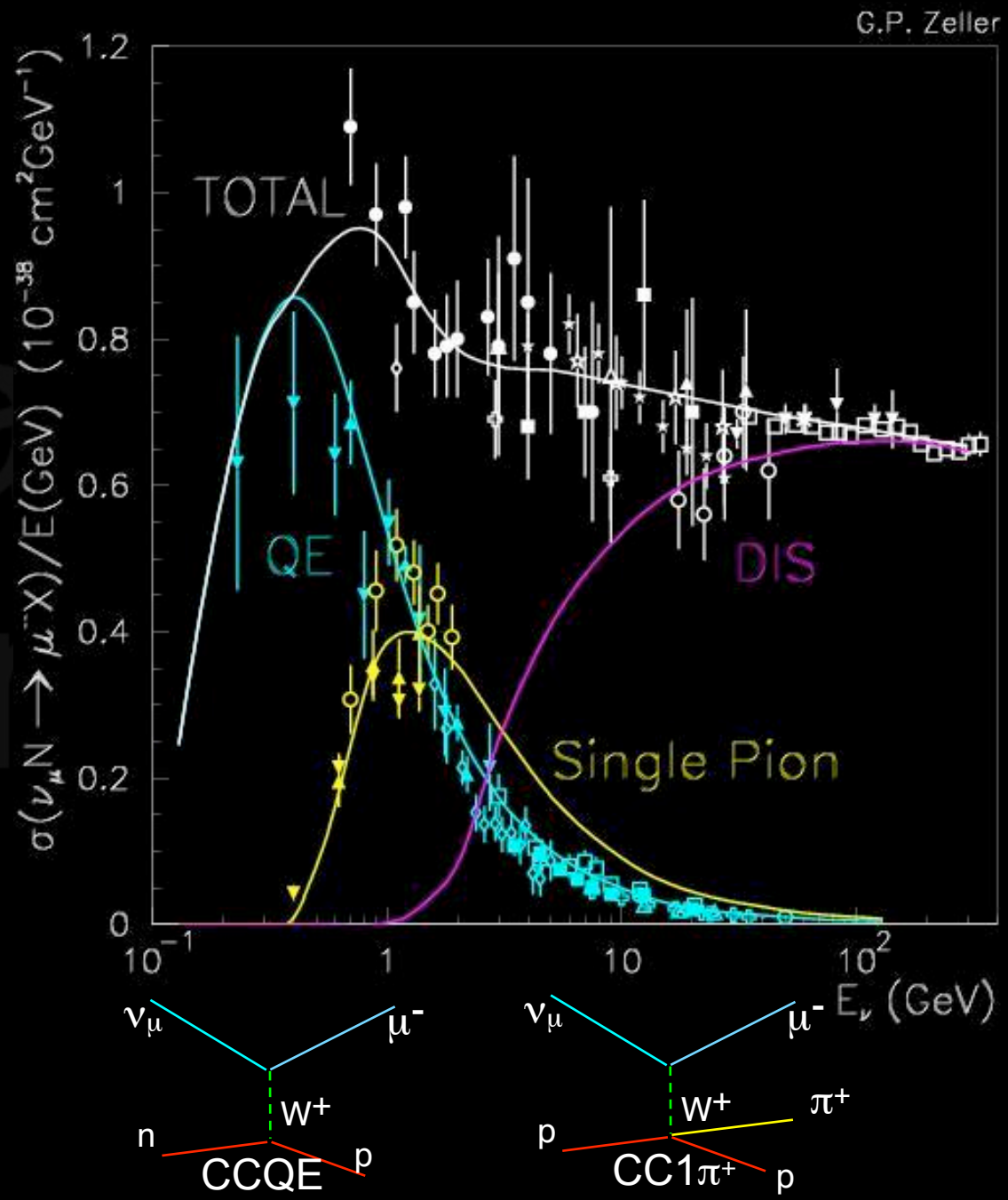

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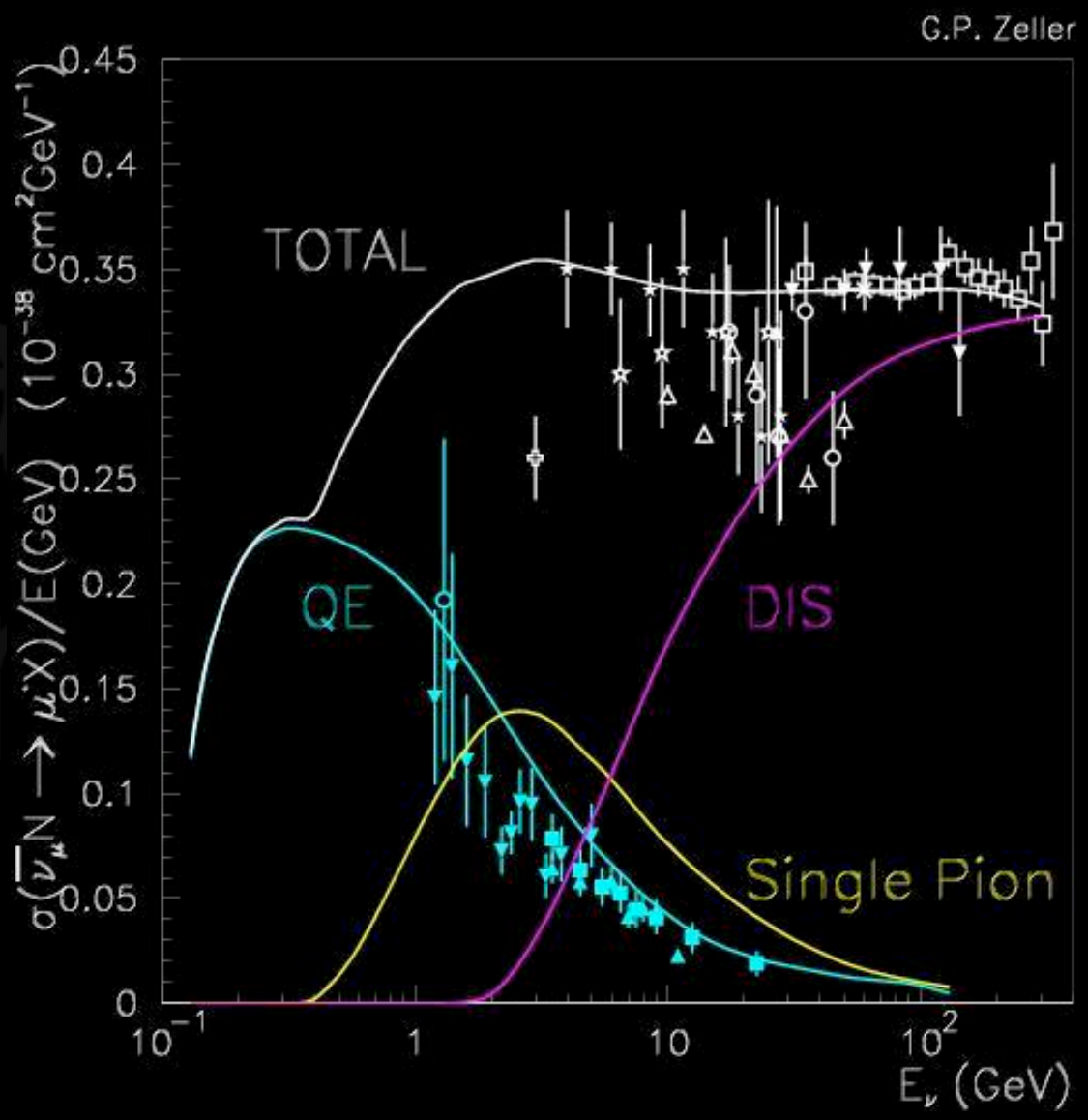

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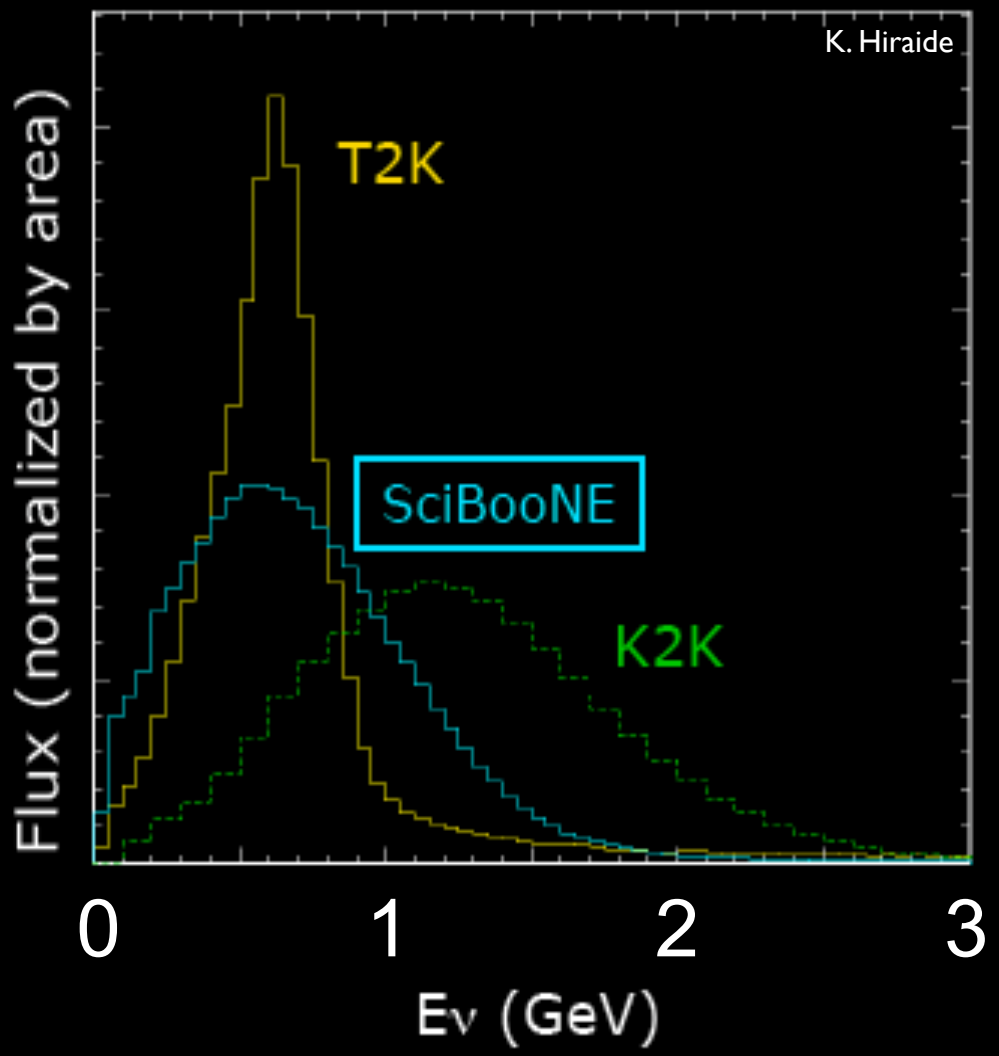


Outline

- Introduction
- MiniBooNE $\nu_\mu \rightarrow \nu_e$ oscillation updates
- MiniBooNE and SciBooNE cross section updates
  - Oscillation signal and backgrounds
- Oscillation outlook

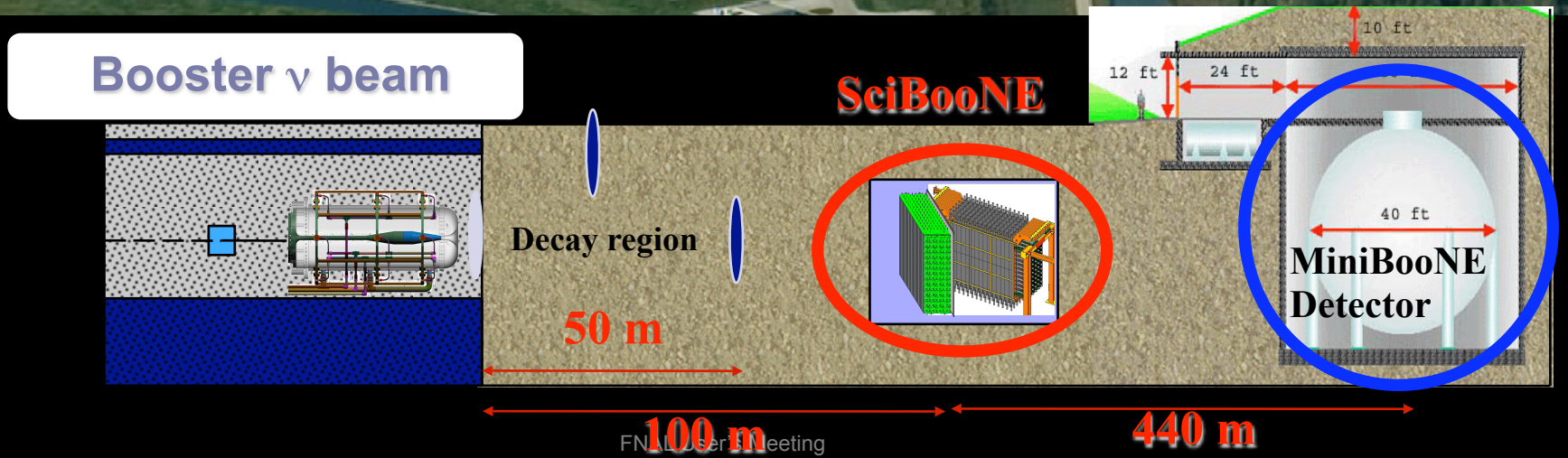
SciBooNE

MiniBooNE

Imperial London

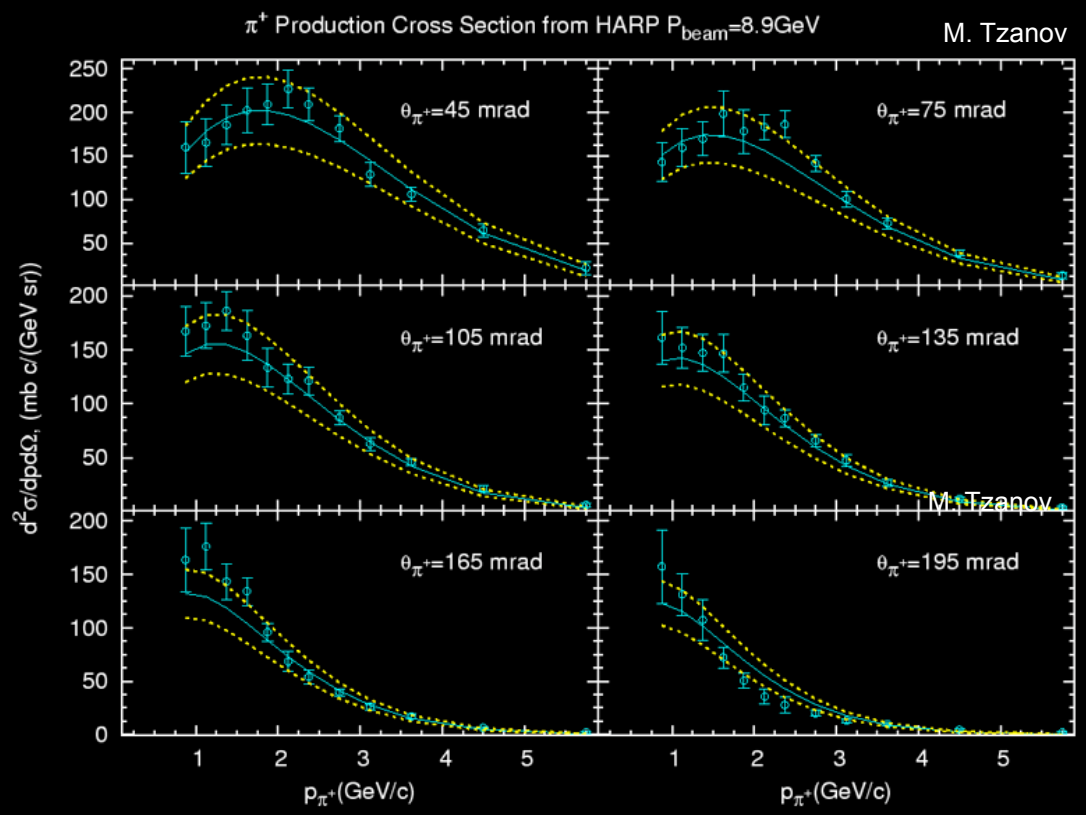
Overview

Fermilab Visual Media Services

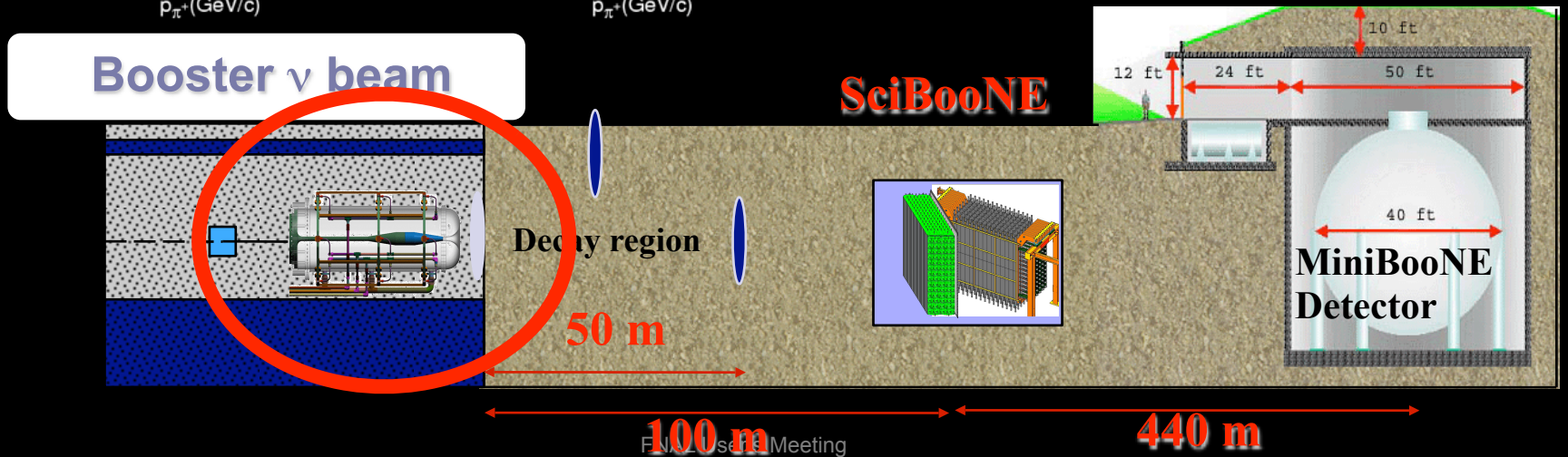

Booster ν beam
SciBooNE
Decay region
50 m
100 m
440 m
10 ft
12 ft
24 ft
40 ft
MiniBooNE
Detector

ν Flux Prediction

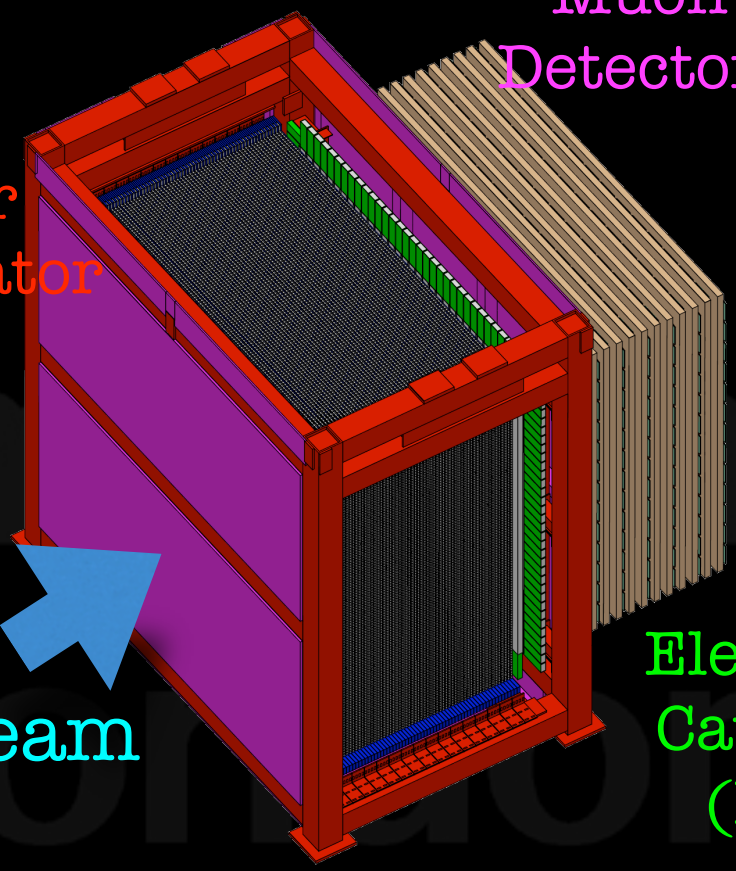
paper in preparation



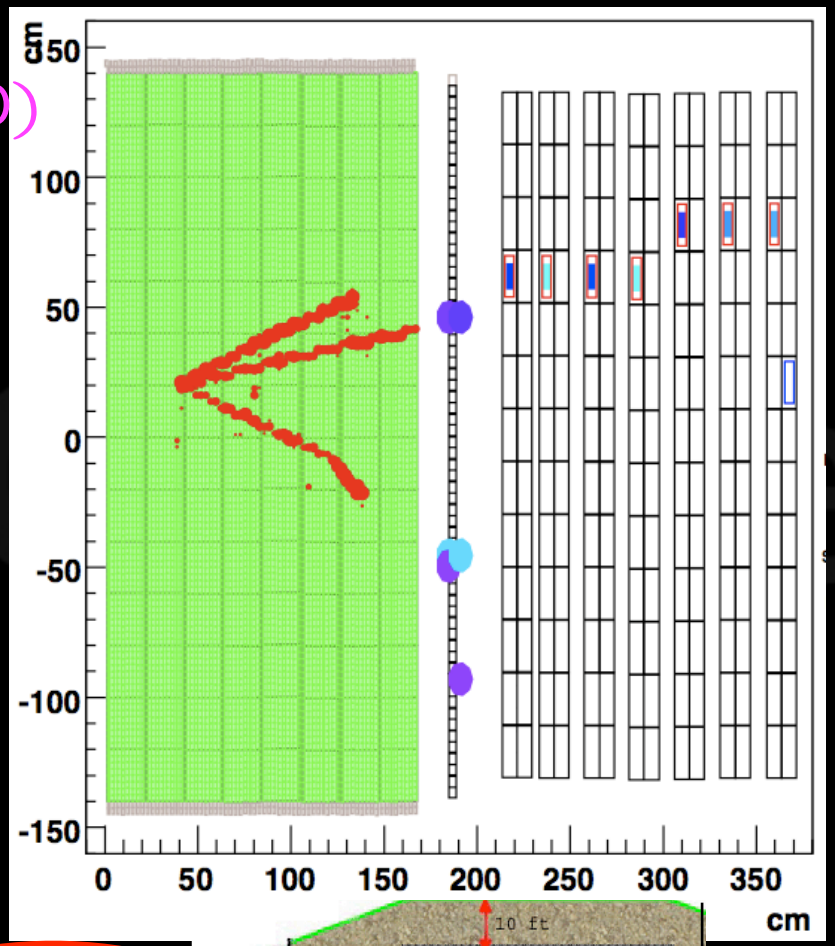
- External meson production data
  - HARP data (CERN)
  - Need thick target data for absolute cross sections
- Parametrisation of cross sections
  - Sanford-Wang for pions
  - Feynman scaling for kaons

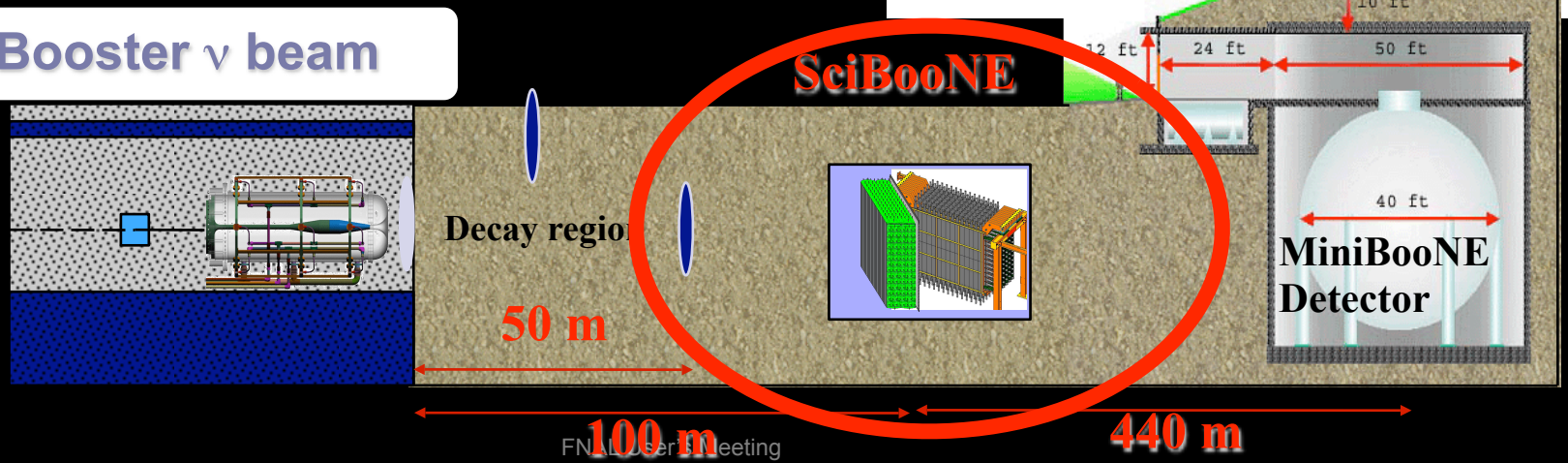


SciBooNE

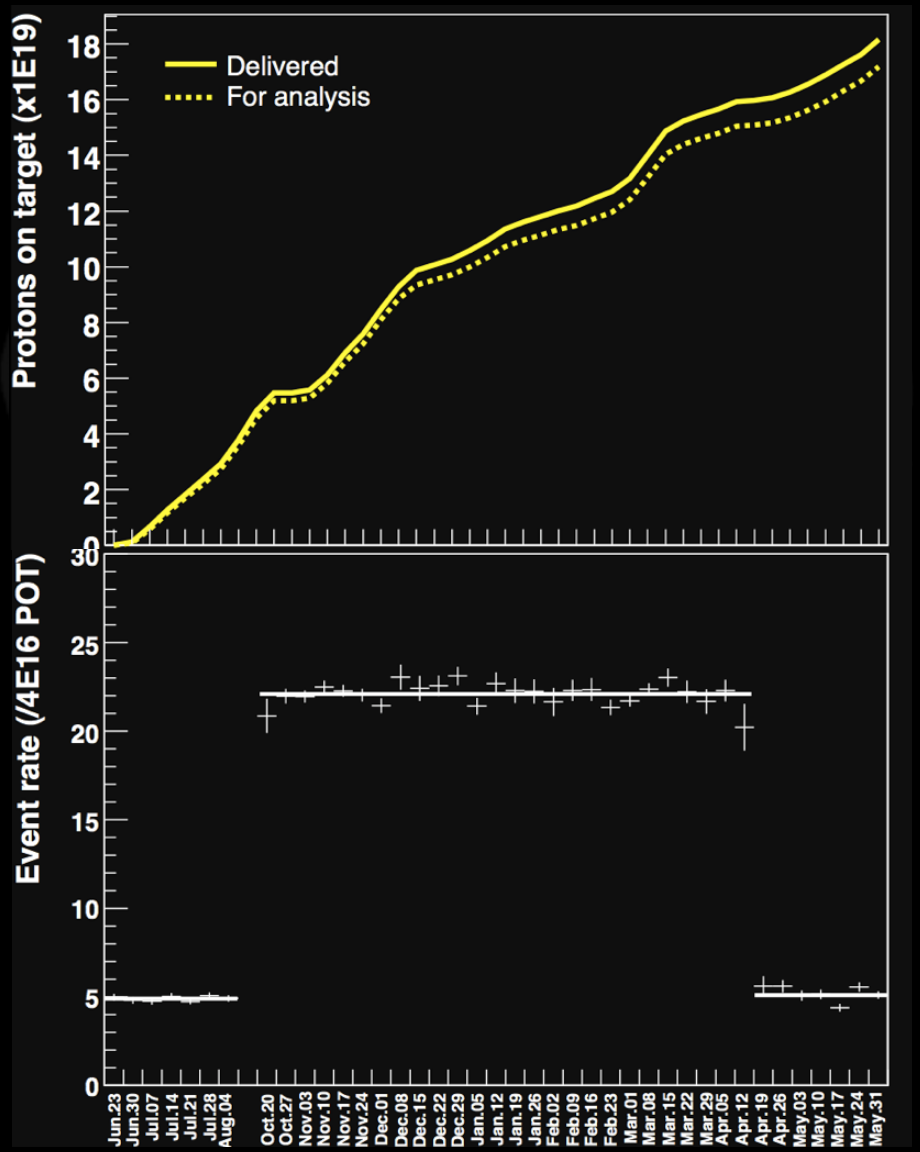


SciBooNE data





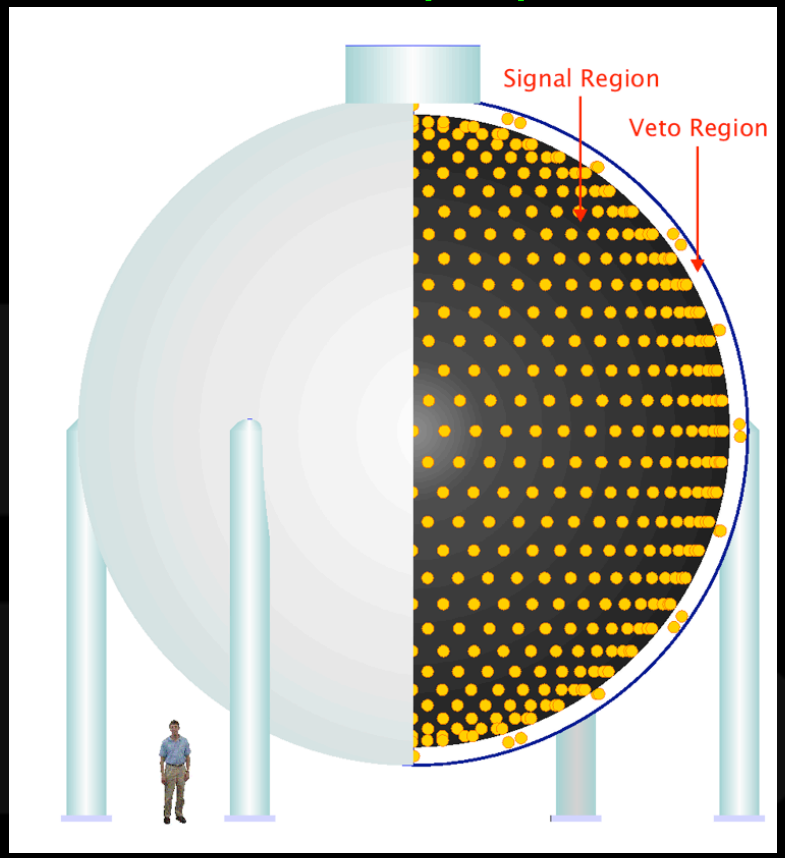
SciBooNE Progress

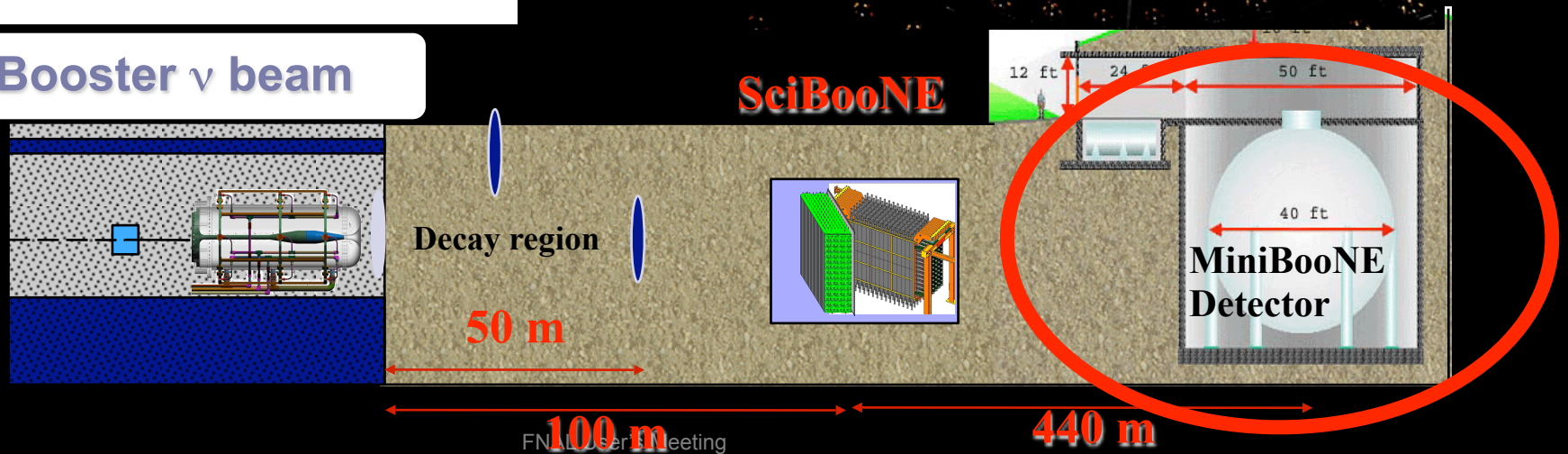


Goal: 2E20 POT

MiniBooNE

NIM article in preparation





MiniBooNE Oscillation Updates

Progress since the release of first results last year

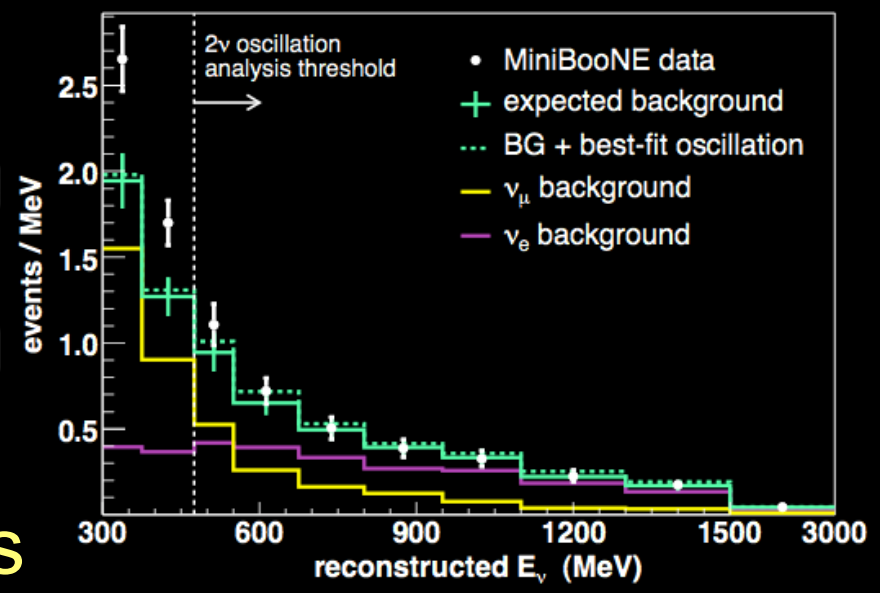
- Low energy excess studies
- Combining two ν_e data sets
- Global fits using multiple experiments
- NuMI neutrinos in MiniBooNE

<u>MiniBooNE Posters:</u>
M. Fisher on Supernova searches (7)
G. Karagiorgi on νe appearance (10)

Low Energy Updates

Nearing end of comprehensive review of ν_e appearance backgrounds & uncertainties
→ Not Quite Ready for Release Yet

- Photonuclear effects
- Hadronic errors
- Better handling of beam π^+ errors
- Improved measurements of π^0s
- Incorporation of coherent π^0 fraction
- Better handling of Δ radiative decays
- Better modeling and cuts to remove dirt BGs

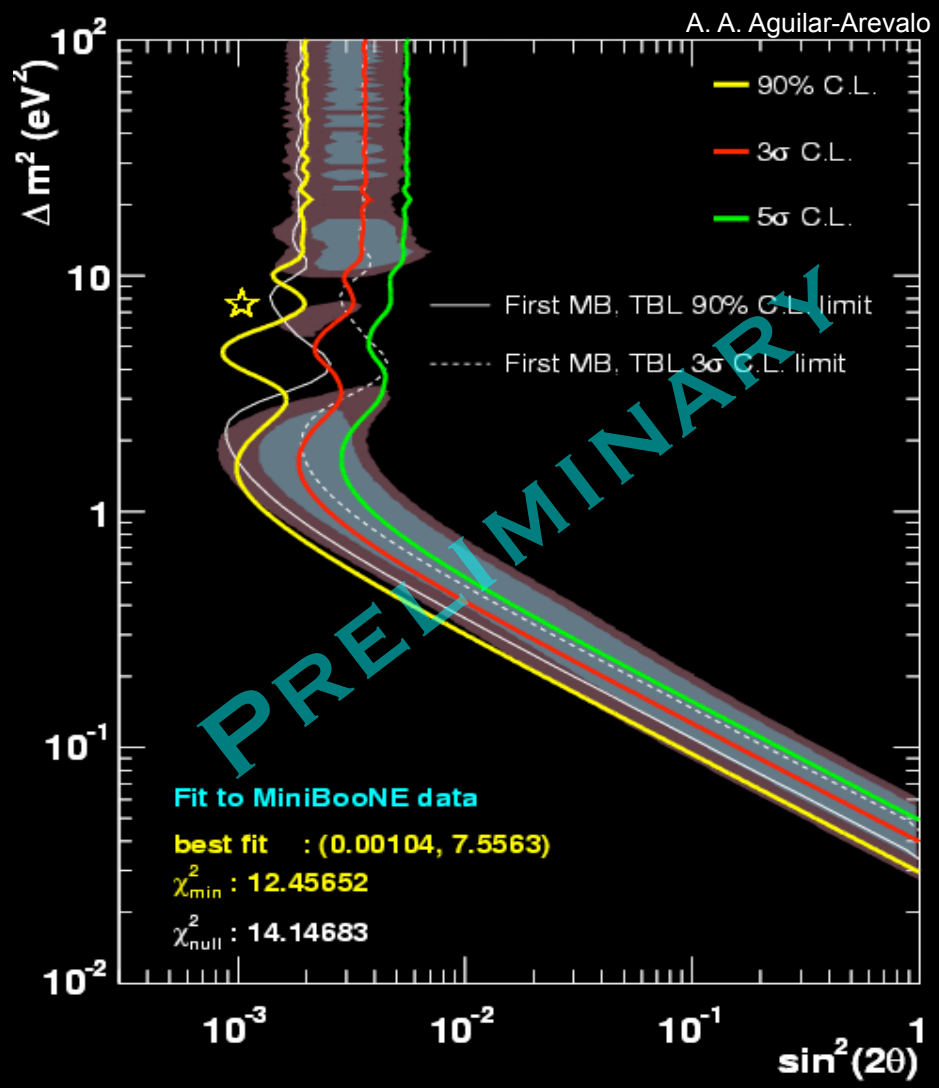


Phys. Rev. Lett. 98, 231801 (2007)

Two ν_e data sets

- MiniBooNE pursued two independent analyses
  - Track based likelihood (TBL)
  - Boosted Decision Trees (BDT)
- Combining both data sets increases coverage in $\Delta m^2 < 1 eV^2$

paper at draft stage

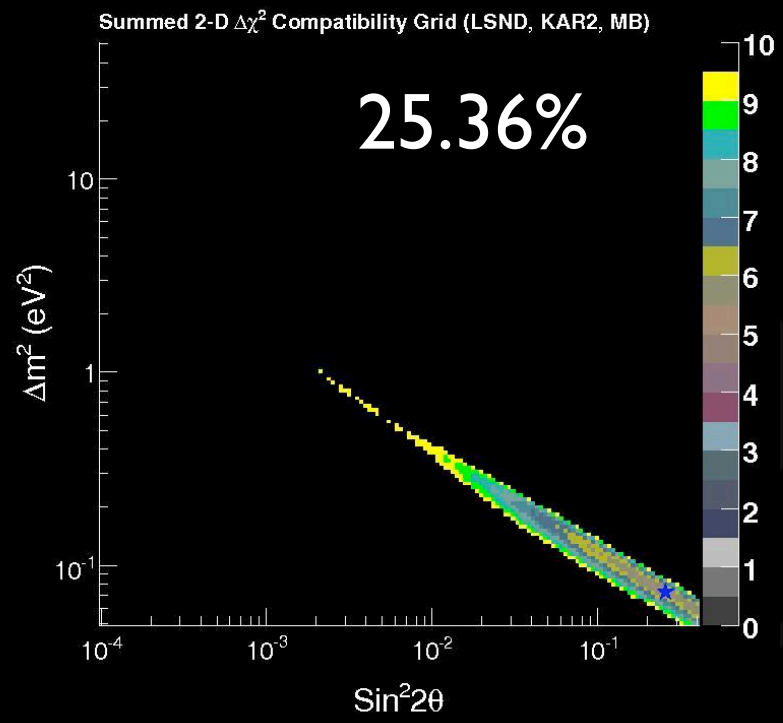


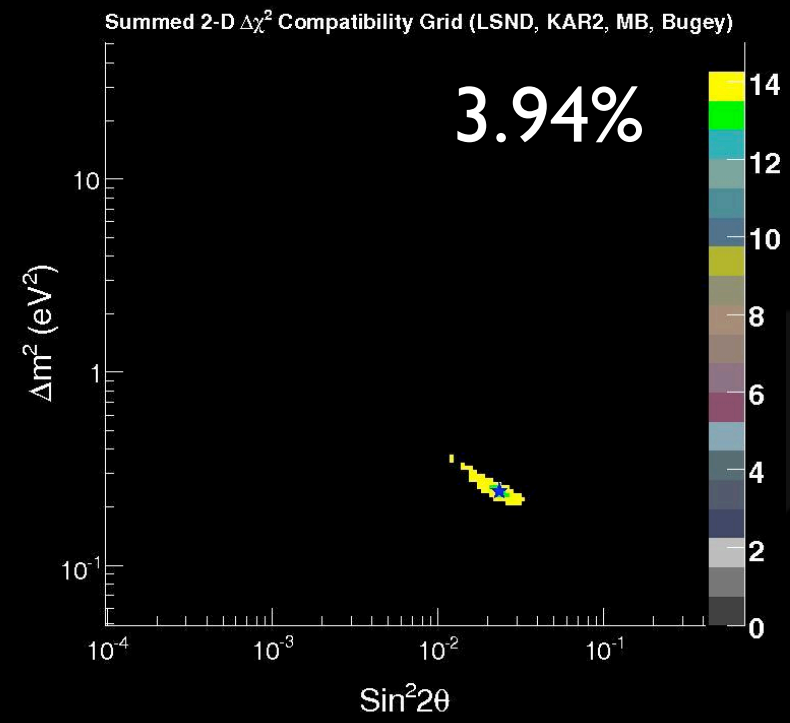
10%-30% improvement in 90% C.L. limit below ~1eV^2.

Global oscillation fits

Colours represent $\Delta\chi^2$

H. Ray





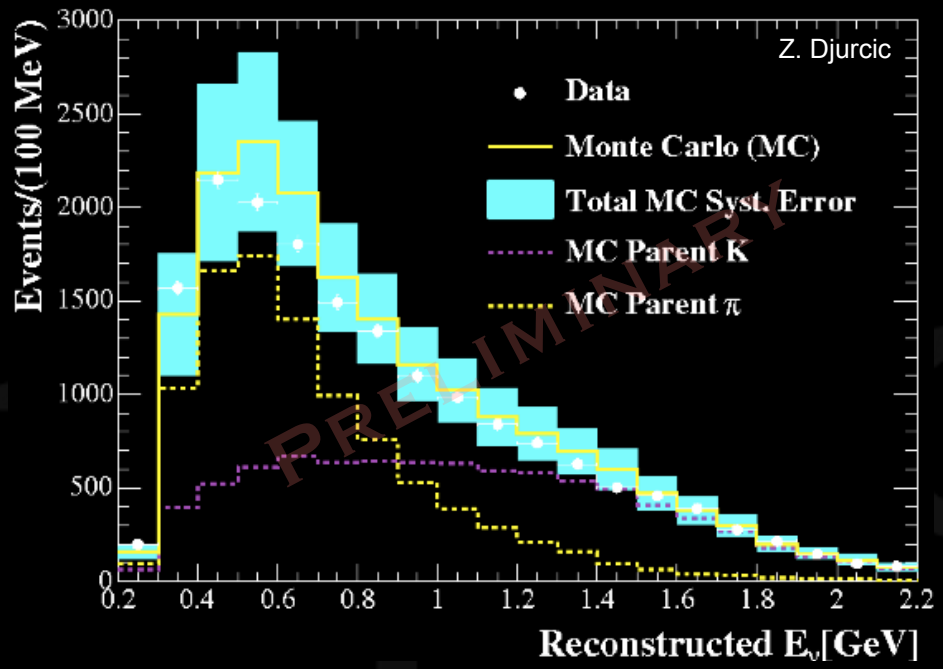
- Compatibility
  - How likely is it that all experiments arise from the same underlying 2 ν oscillation hypothesis?

arXiv:0805.1764;
accepted by PRD

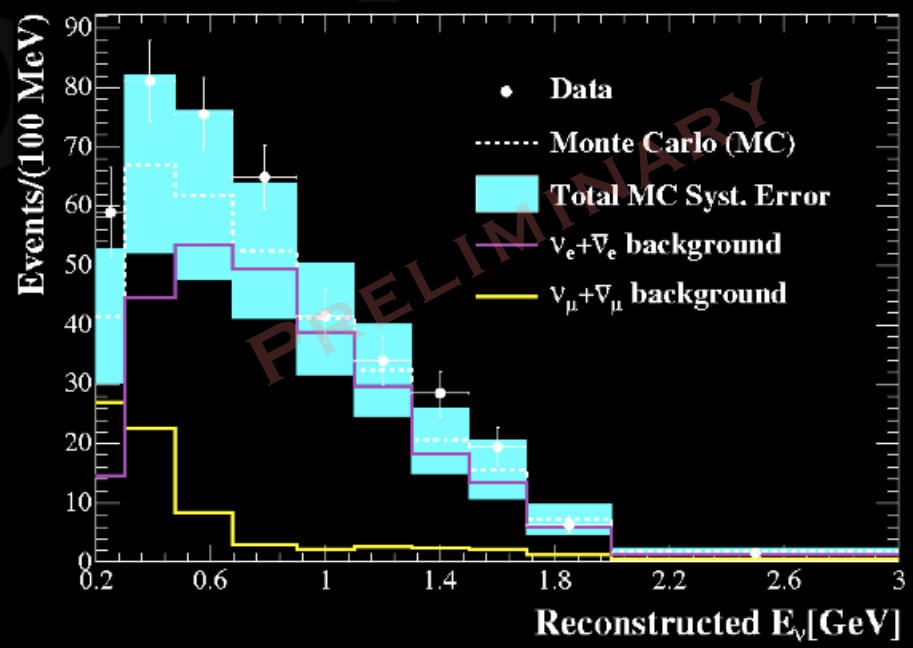
See Heather Ray's Wine&Cheese June 13

NuMI νs in MiniBooNE

ν_μ CCQE sample



ν_e CCQE sample



paper at draft stage

Good agreement between data and Monte Carlo: tuning MC using on-axis data works well!

Very different backgrounds compared to MB

Ongoing effort to reduce ν_e CCQE sample systematics

See Wine & Cheese slides by Z. Djurcic and Z. Pavlovich

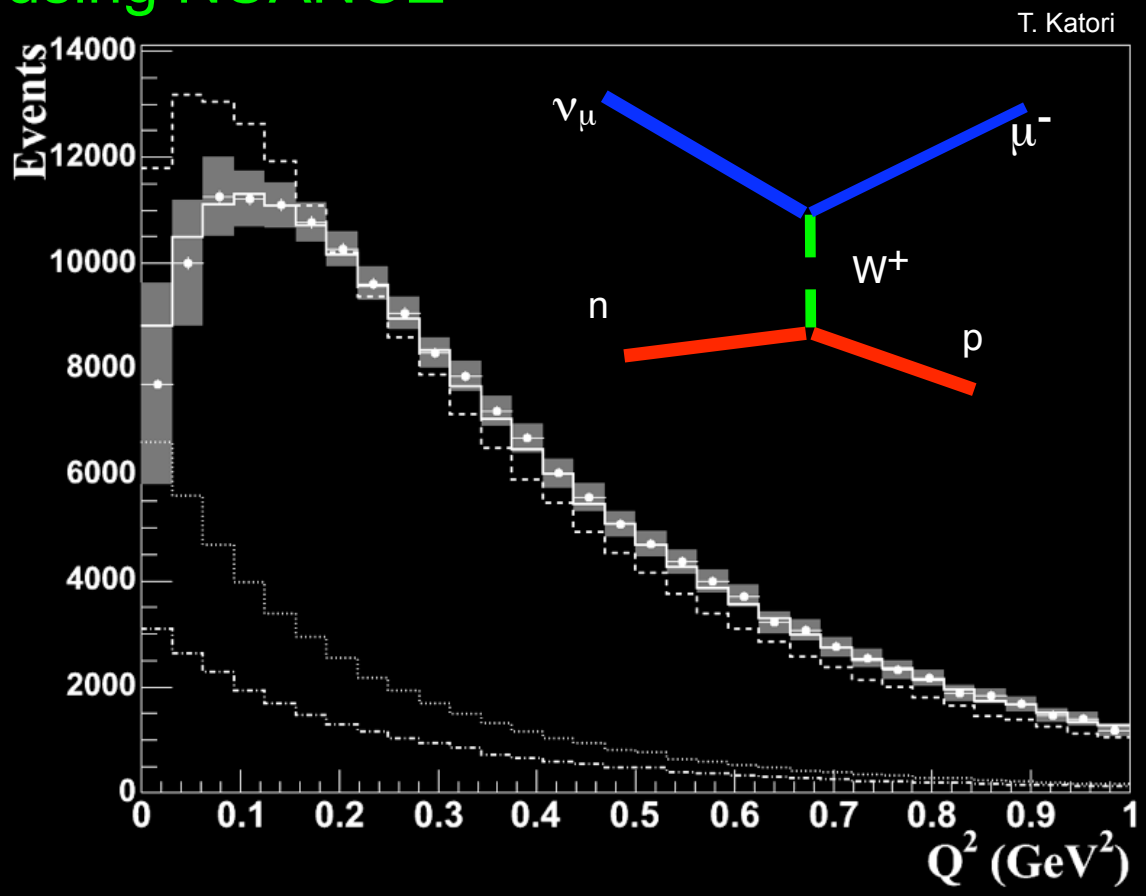
Neutrino cross sections & upcoming oscillation searches

- CCQE
- CC1π^+
- ν_μ disappearance
- NCπ^0 measurements
- ν_e backgrounds from K^+ decay constraints
- $\bar{\nu}$ cross sections
- $\bar{\nu}_e$ appearance

MiniBooNE CCQE

charged current quasi-elastic

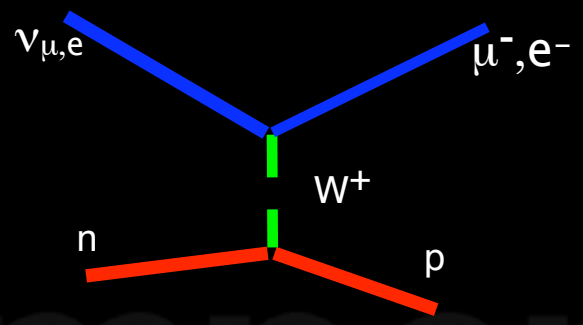
using NUANCE



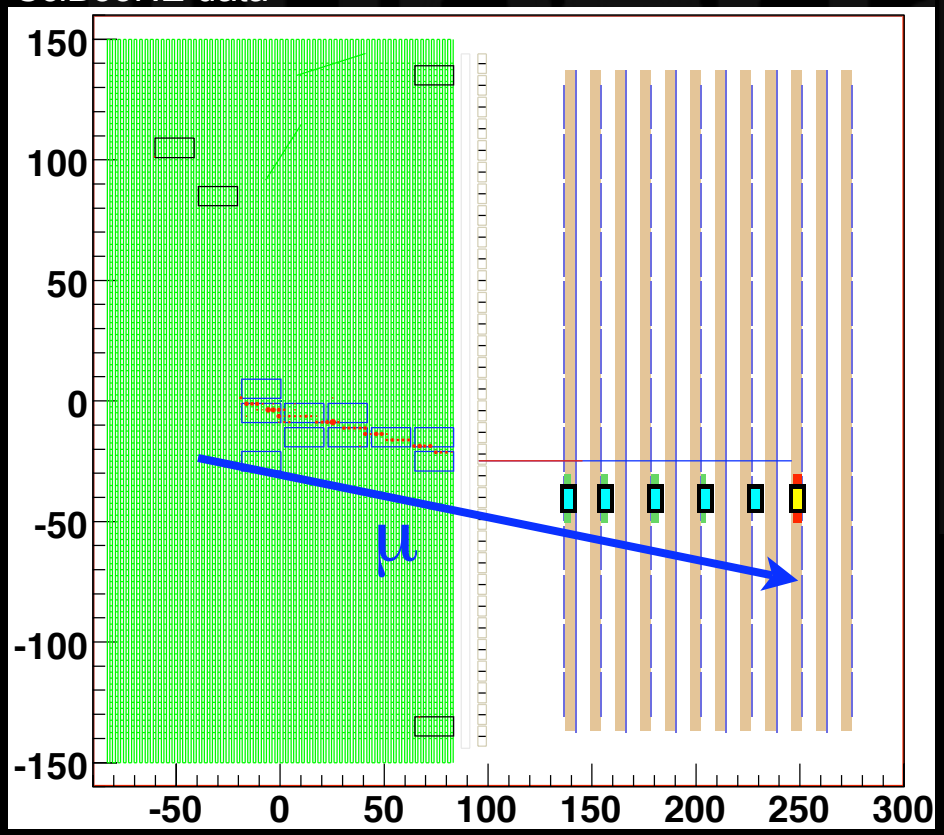
arXiv:0706.0926 [hep-ex], Phys. Rev. Lett. 100, 032301 (2008)

- simple cuts yield 74% pure CCQE sample
- Fit nuclear model parameters to get data-MC agreement
- Extracted value of axial mass parameter
  - M_A = 1.23±0.20 GeV^2
  - higher than bubble chambers
  - consistent with K2K

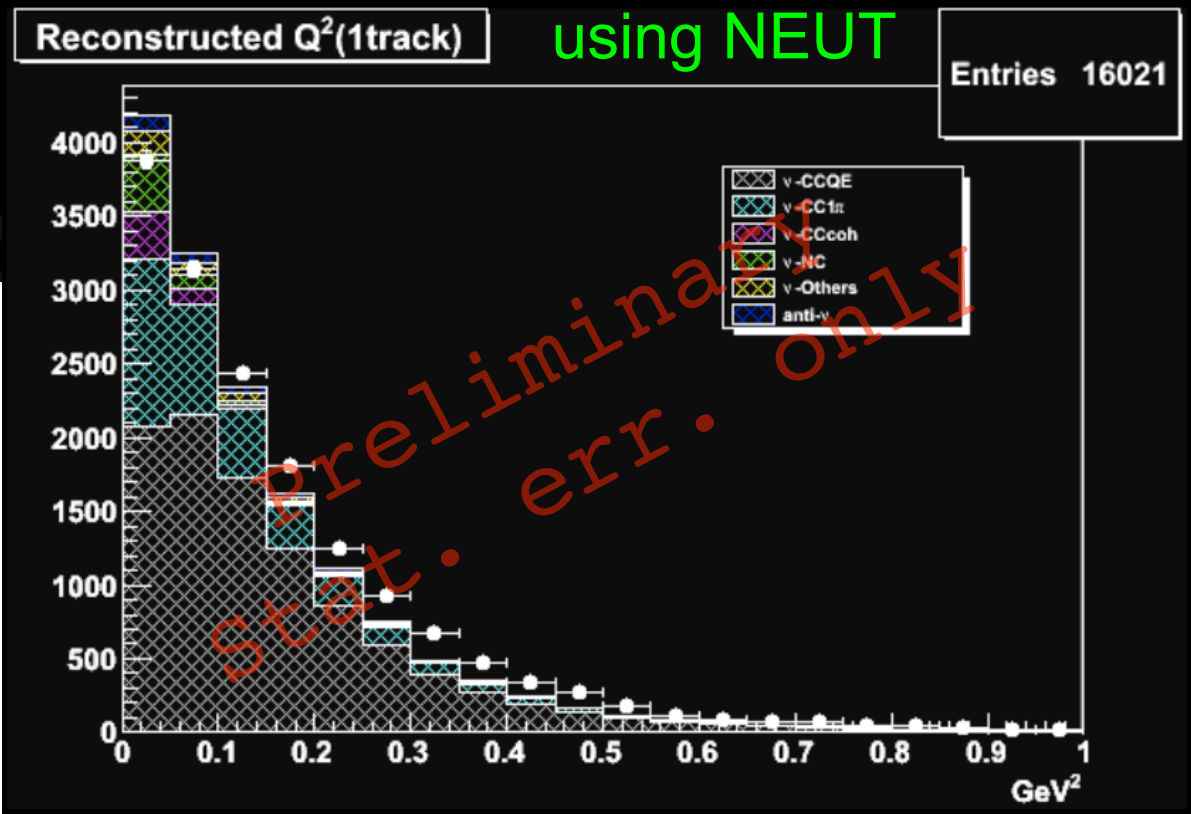
SciBooNE CCQE



SciBooNE data

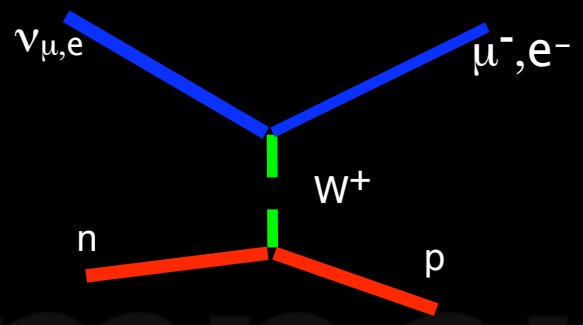


J. Alcaraz-Aunion

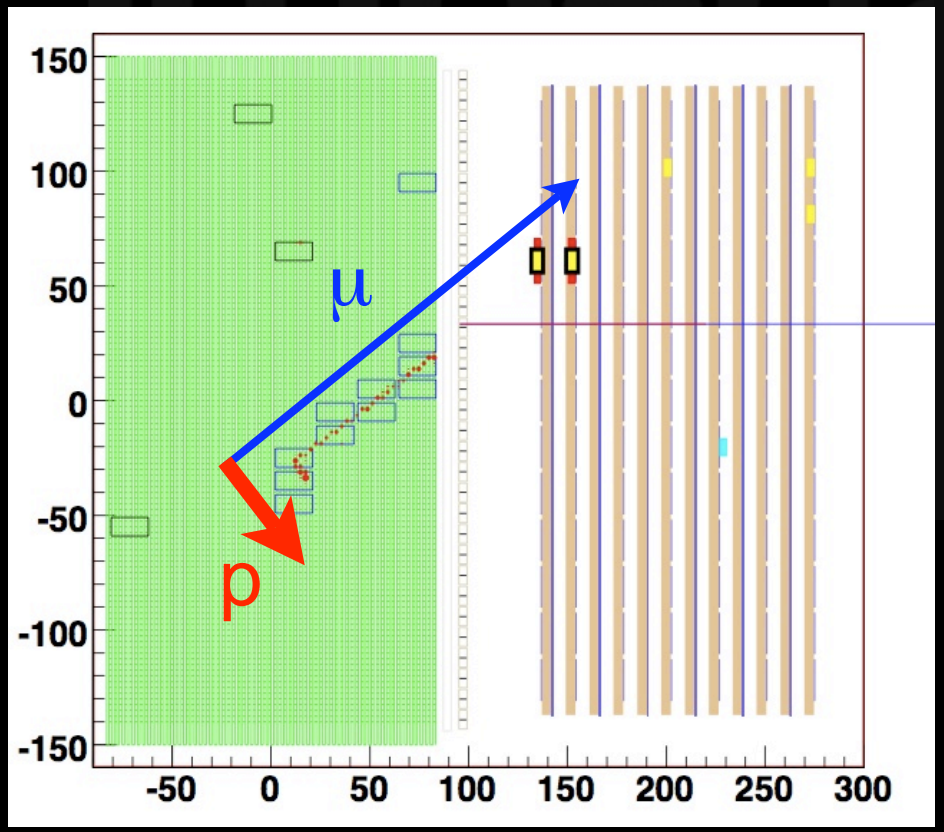


1 track events 67% pure CCQE

SciBooNE CCQE



SciBooNE data



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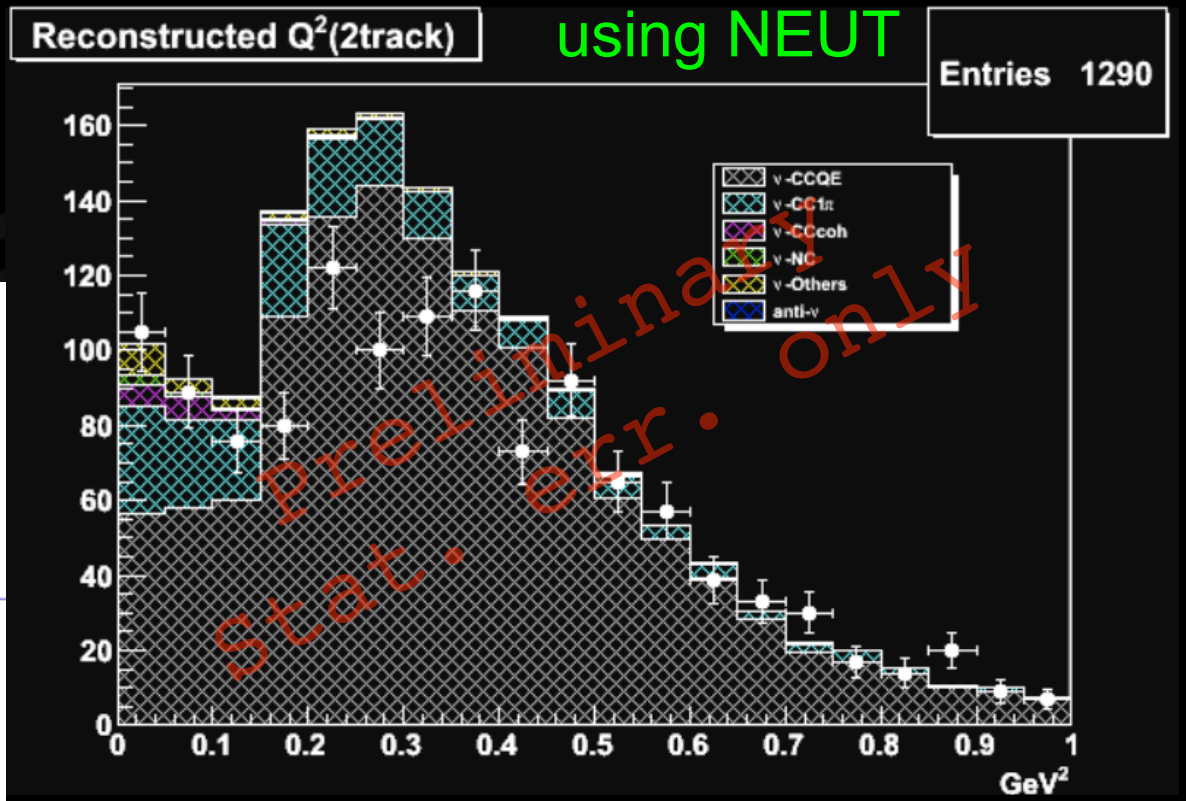


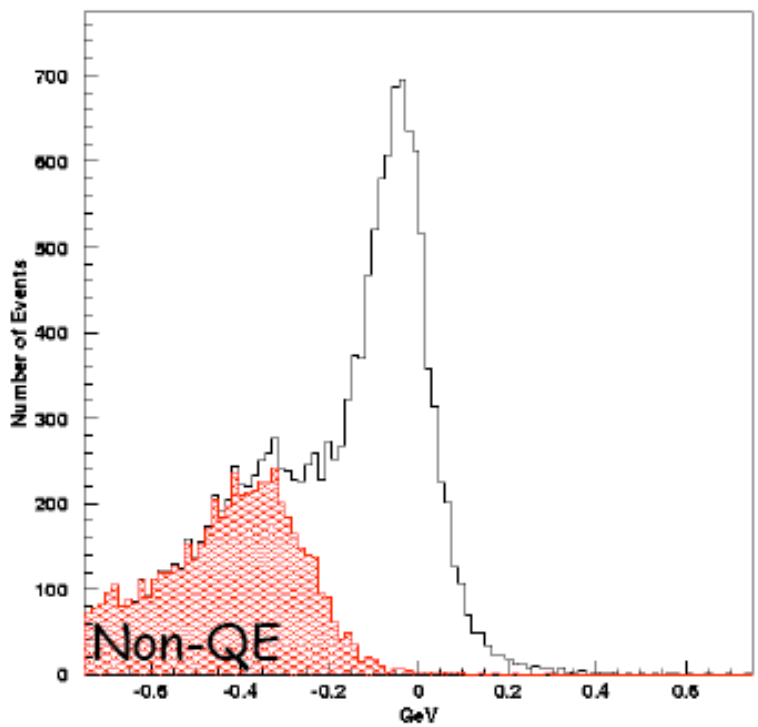
2 track events 81% pure CCQE

Results for NuInt09

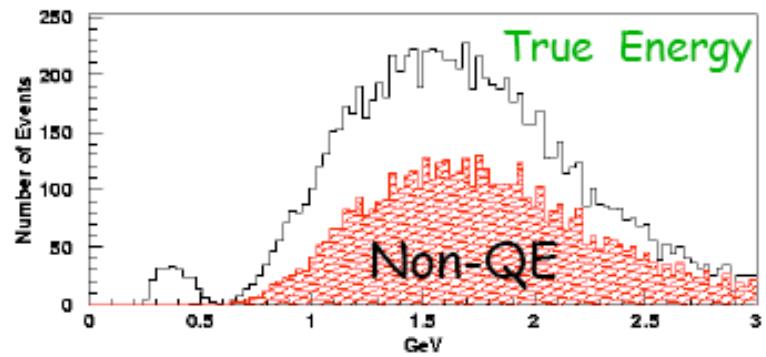
Single π backgrounds

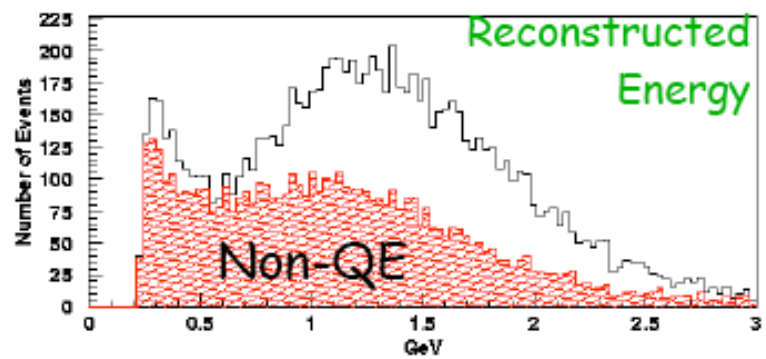
Non-QE interactions and E_ν Reconstruction

Example: K2K Flux MC



True - Reconstructed Energy



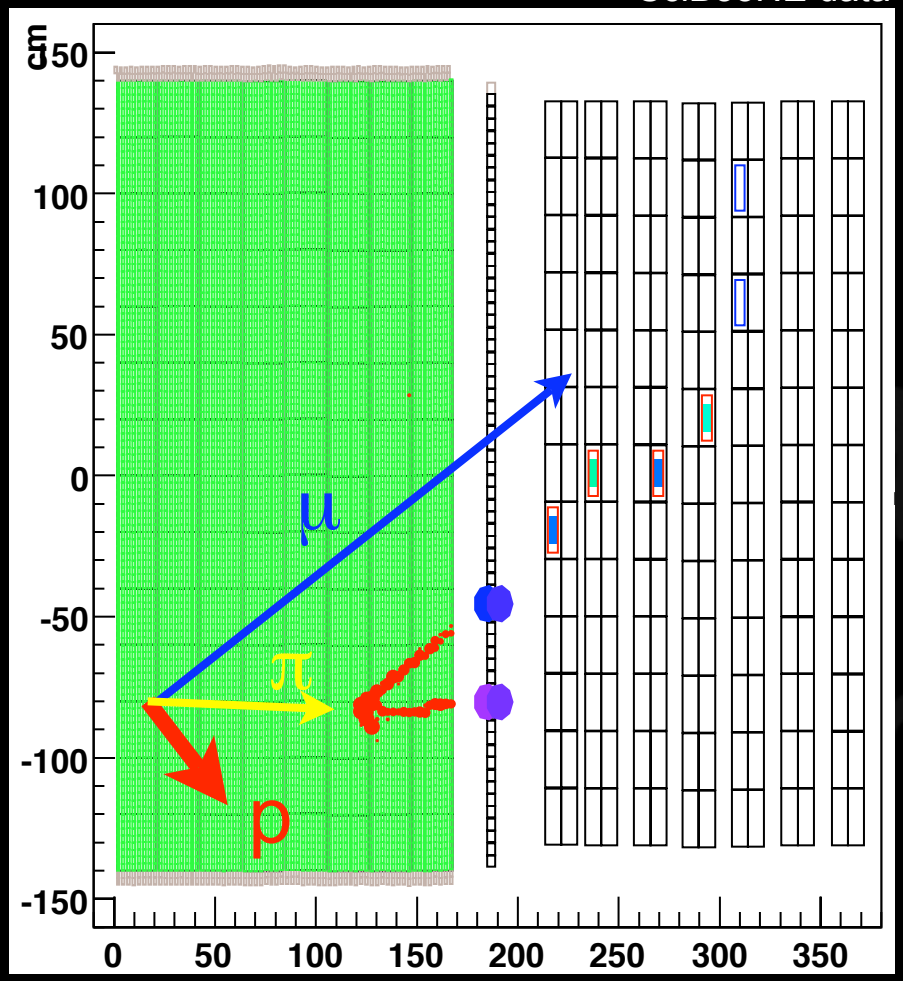


Non-QE reconstructs at low-energy in the oscillation dip!

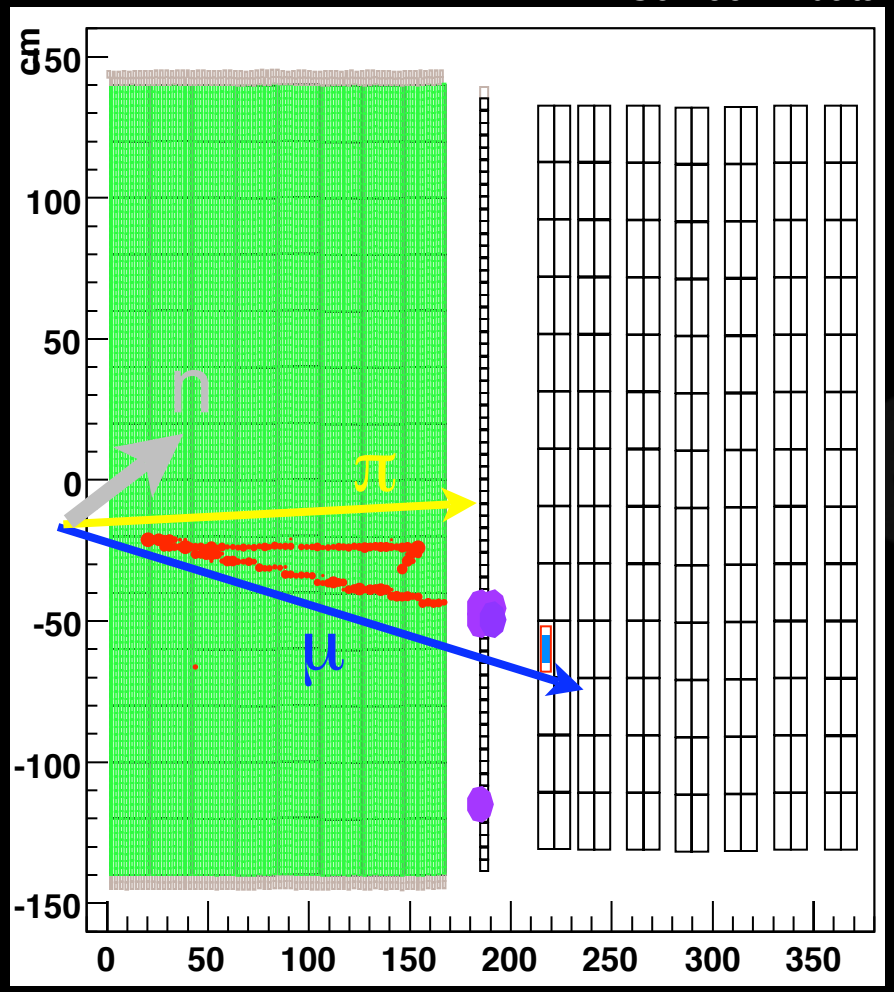
C. Walter (Duke), NuInt07

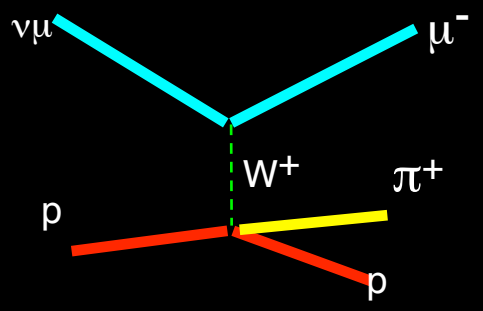
SB CC1π^+ events

SciBooNE data



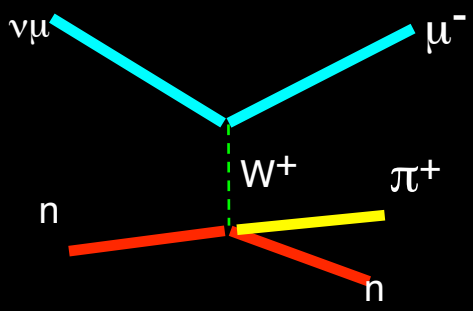
SciBooNE data





$\nu_\mu p \rightarrow \mu^- \Delta^{++}$

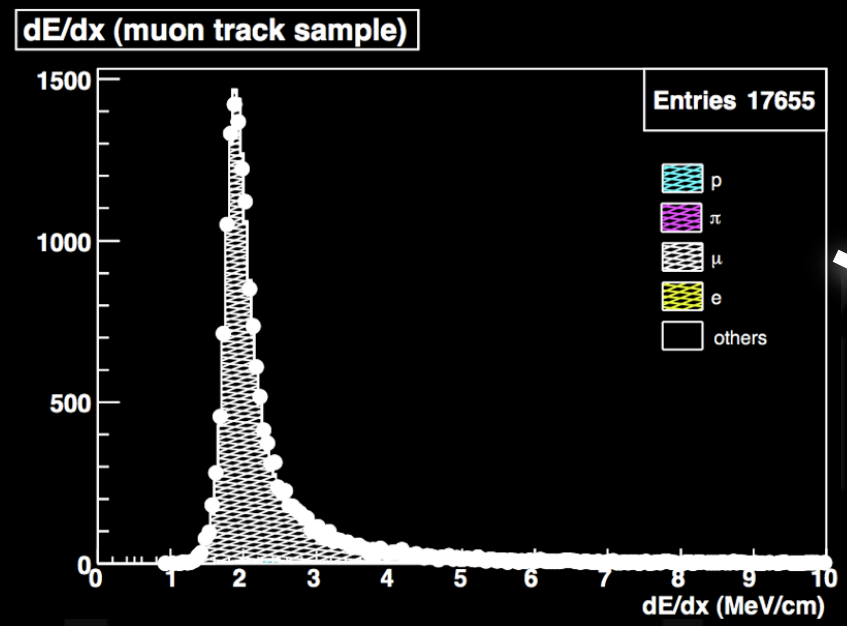
$\searrow p\pi^+$

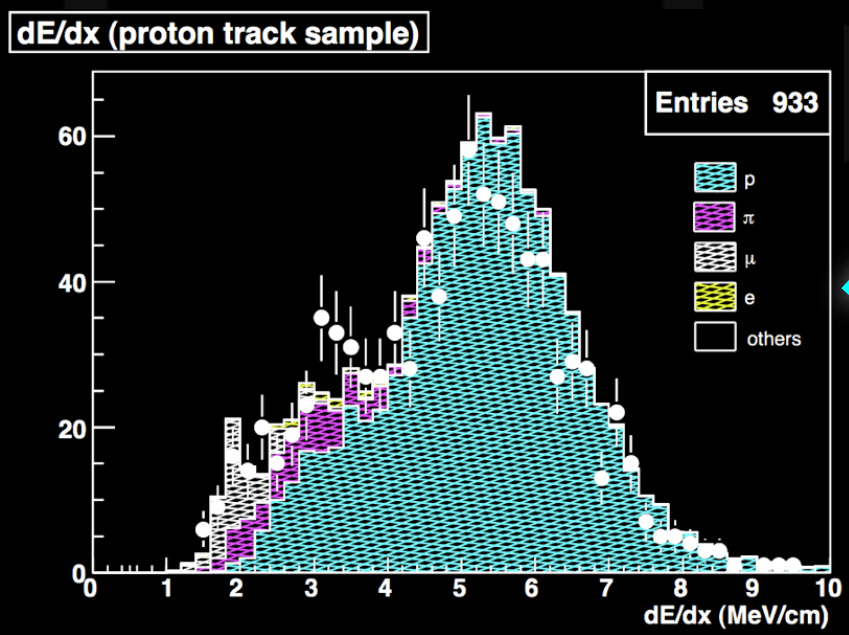


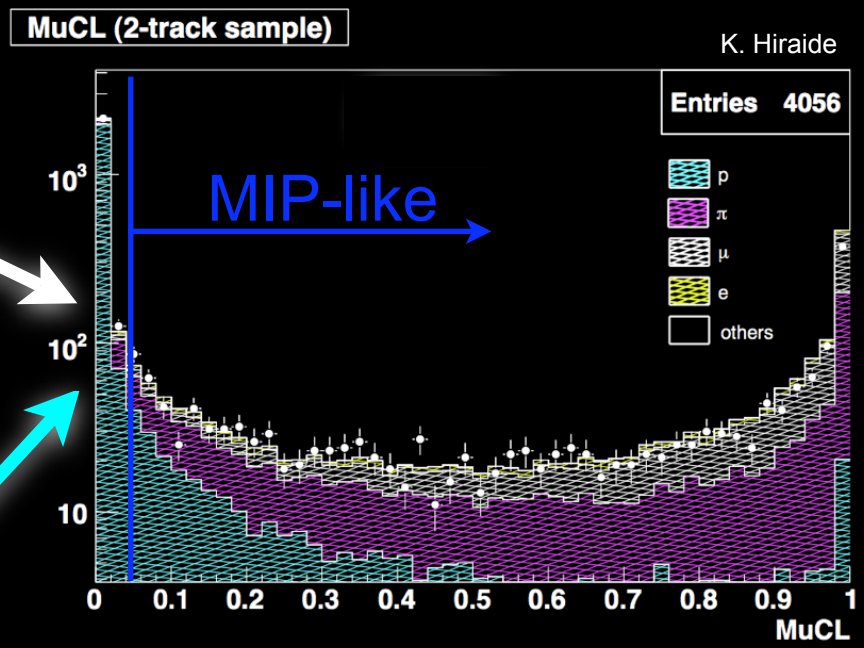
$\nu_\mu n \rightarrow \mu^- \Delta^+$

$\searrow n\pi^+$

SciBooNE CC1π^+ PID



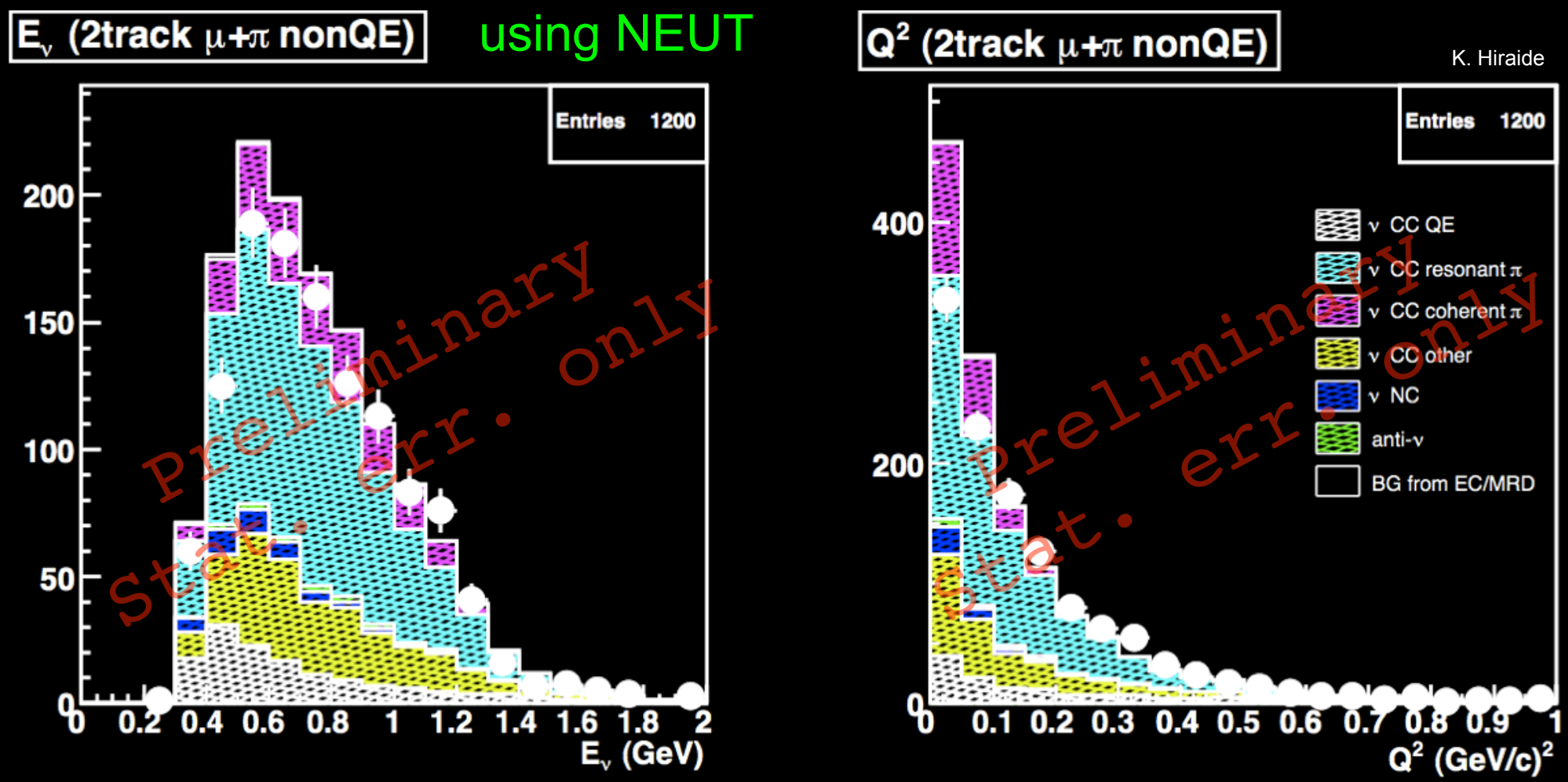




84% π+ efficiency
~13% p contamination

Also cut on direction - require non-QE kinematics

SciBooNE CC1p+



Important measurements of major background for ν_μ disappearance (both T2K and MiniBooNE)

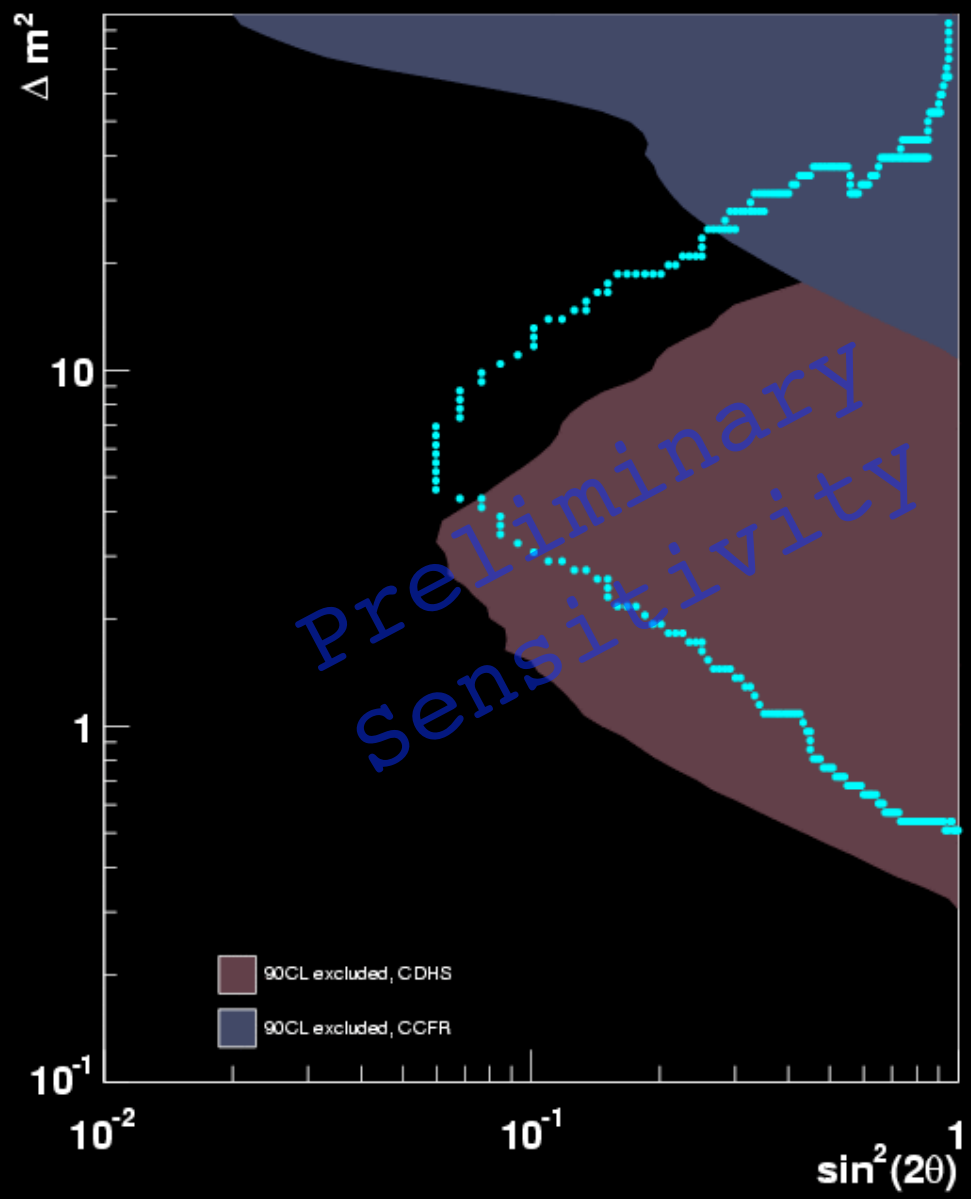
Results for ICHEP08

ν_μ disappearance

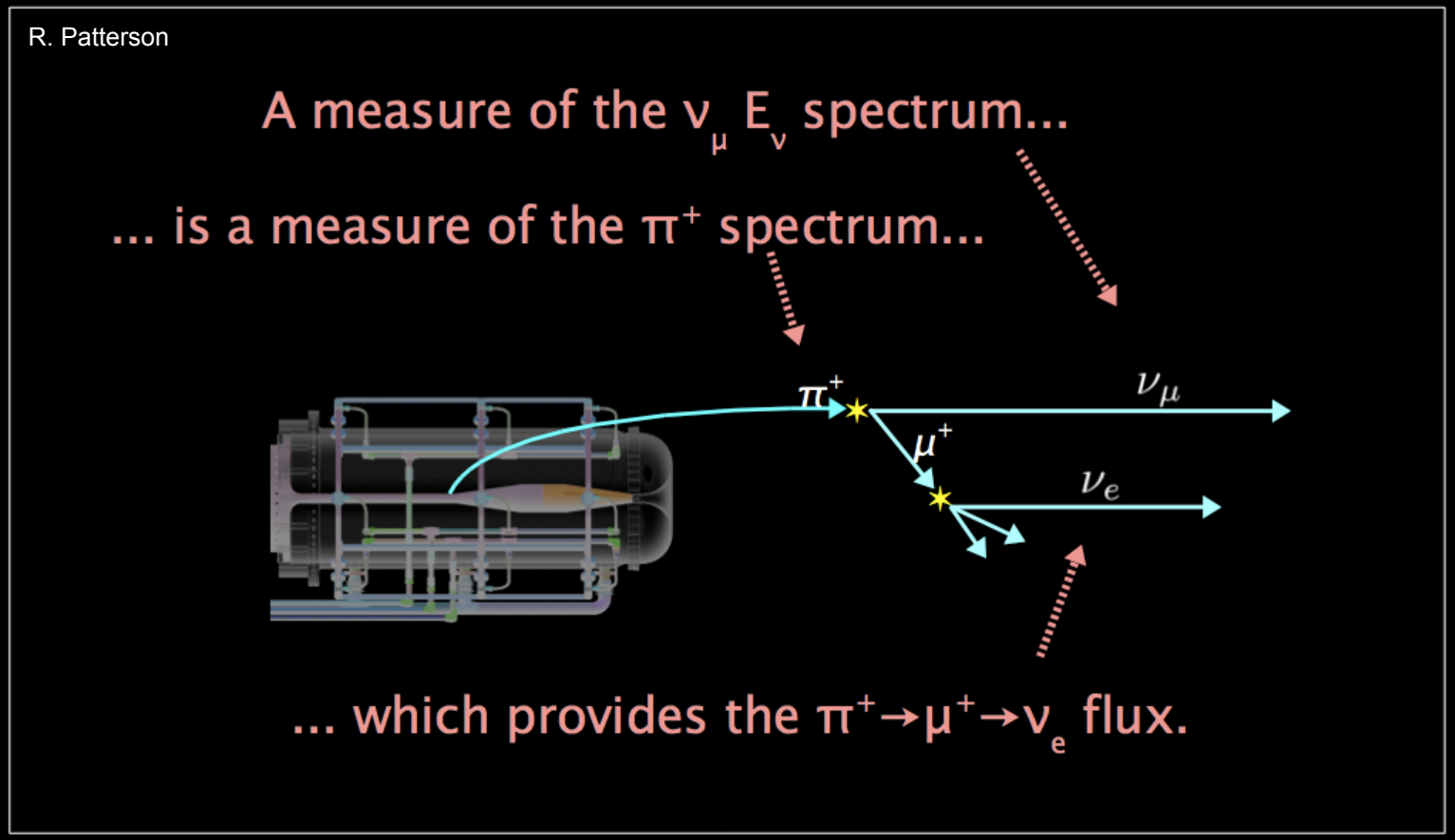
- With one detector, compare Eν data to MC and look for shape distortions
- MiniBooNE alone has significant reach in sensitivity

Results coming soon!

K. Mahn



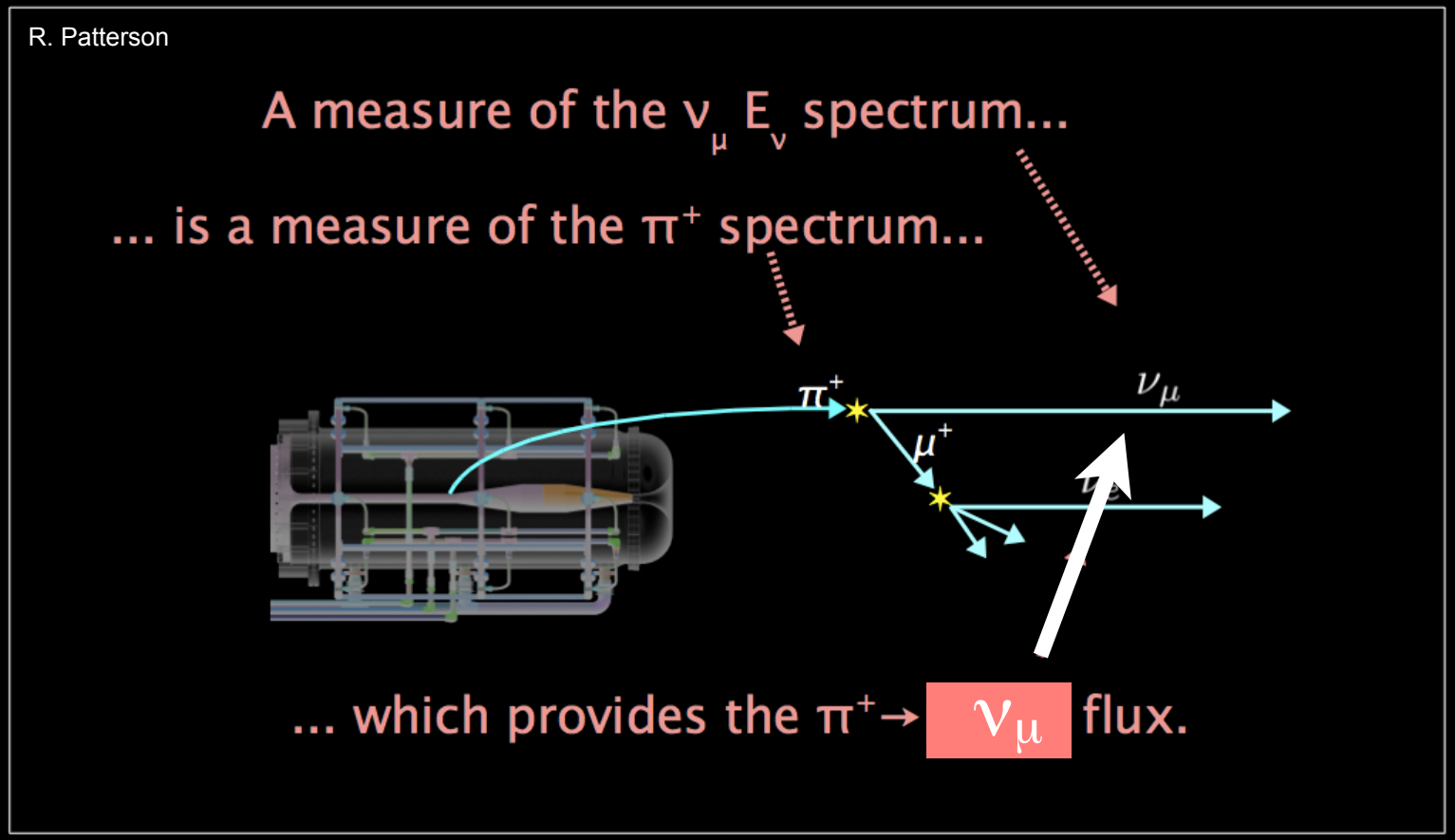
Joint ν_μ disappearance



SciBooNE provides constraint on π^+ parents of ν_μ events in MiniBooNE *with same nuclear target*

results later this year

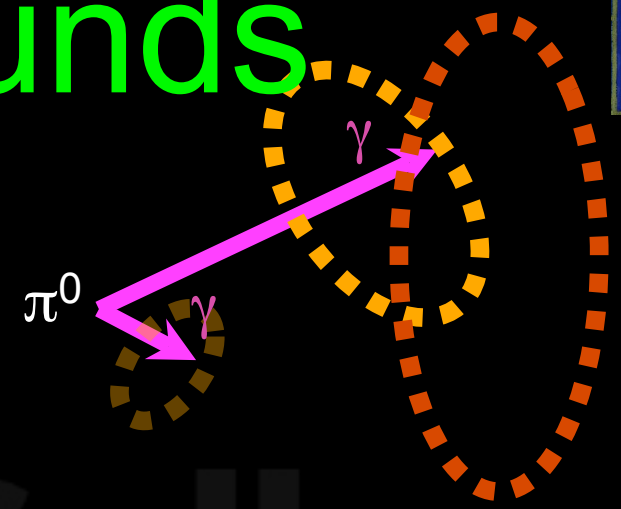
Joint ν_μ disappearance



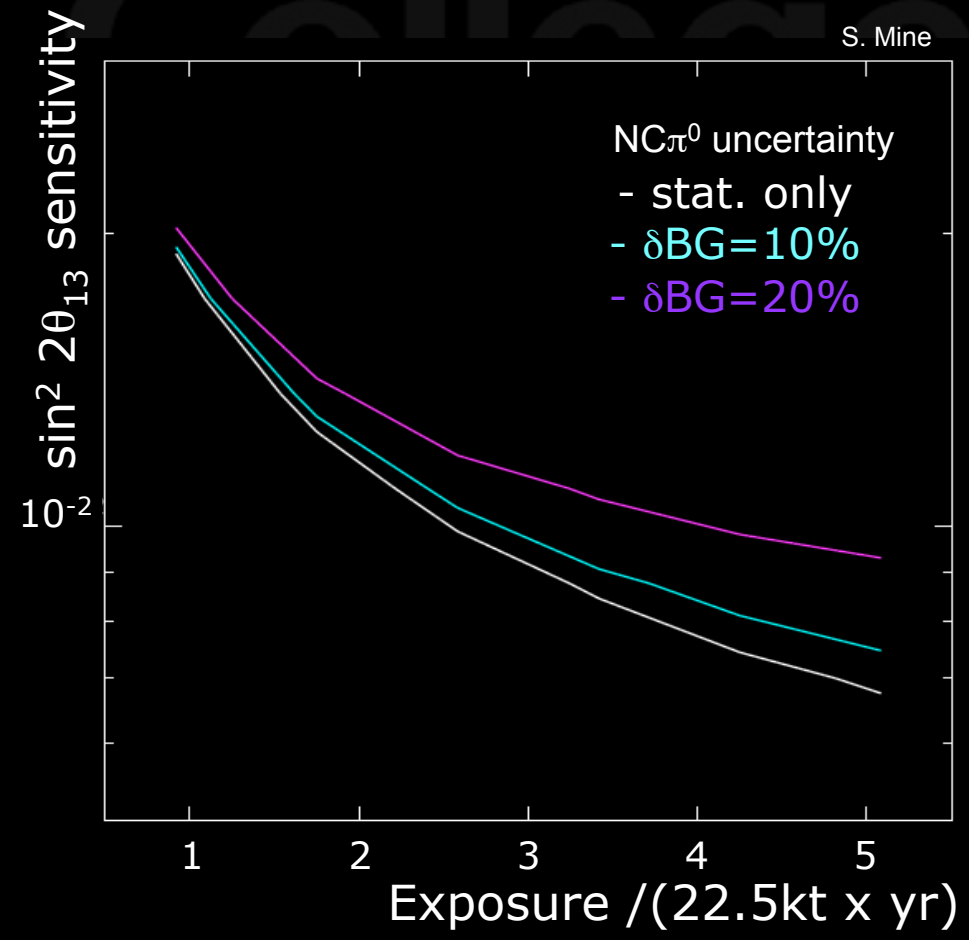
SciBooNE provides constraint on π^+ parents of ν_μ events in MiniBooNE *with same nuclear target*

results later this year

ν_e backgrounds

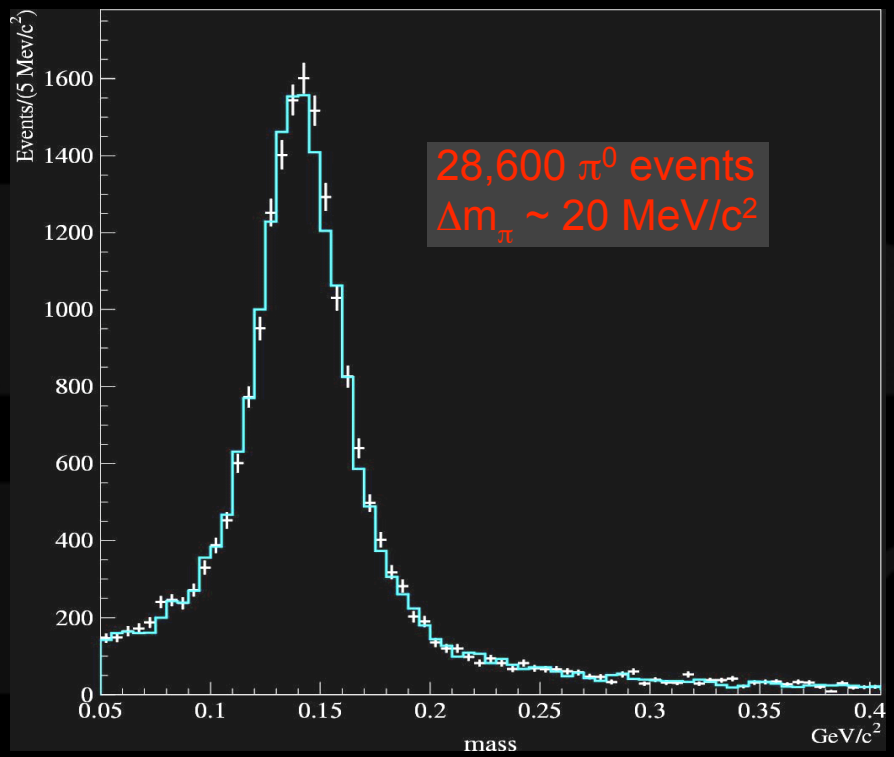


- $\nu_\mu \rightarrow \nu_e$ backgrounds from intrinsic ν_es and misidentified ν_μ events
- Mis-ids come mainly from NC1π^0 events
- Major background for T2K and MiniBooNE
  - Increases θ_{13} sensitivity
  - 4 years vs. 2.5 years



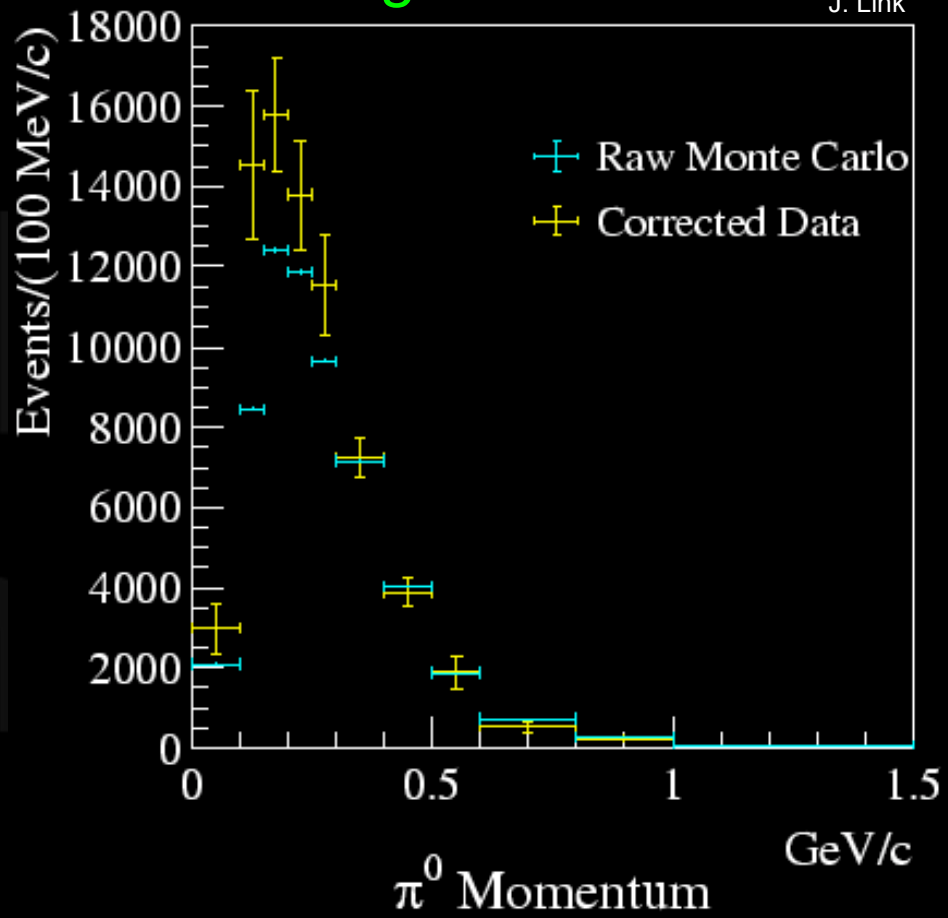
MiniBooNE NCπ^0

largest ν_μ NC π^0 sample ever collected!



using NUANCE

J. Link



π^0 rate measured to a few percent

Critical input to oscillation result → without it, π^0 background errors would be ~25%

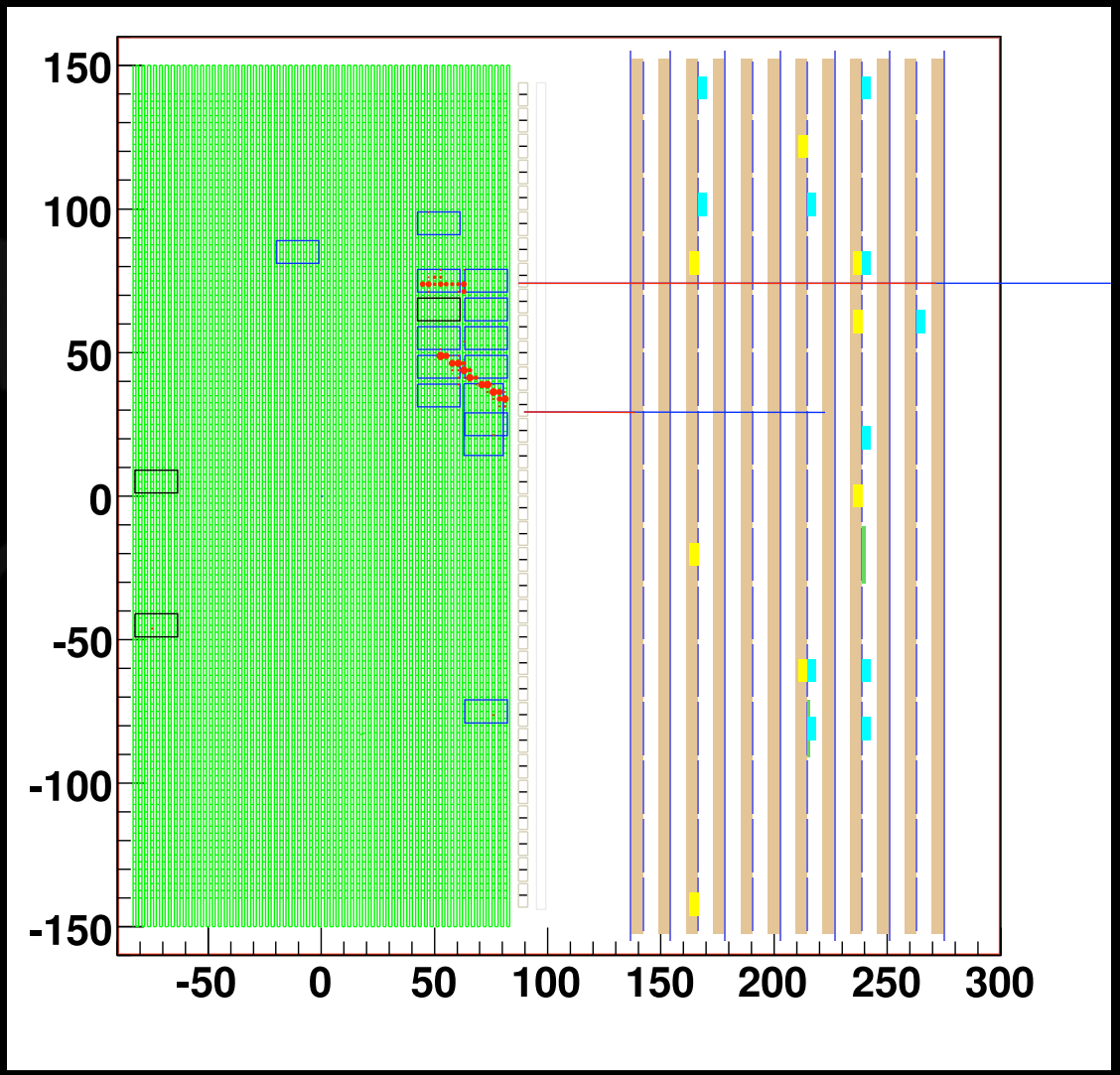
arXiv: 0803.3423
Phys. Lett. B. 664/1-2 pp 41-46 (2008)

SciBooNE NCπ^0

- SciBar's tracking and PID clearly identify γs from π^0 decay
- EC increases acceptance for high momentum π^0s
- Important for ν_e BGs

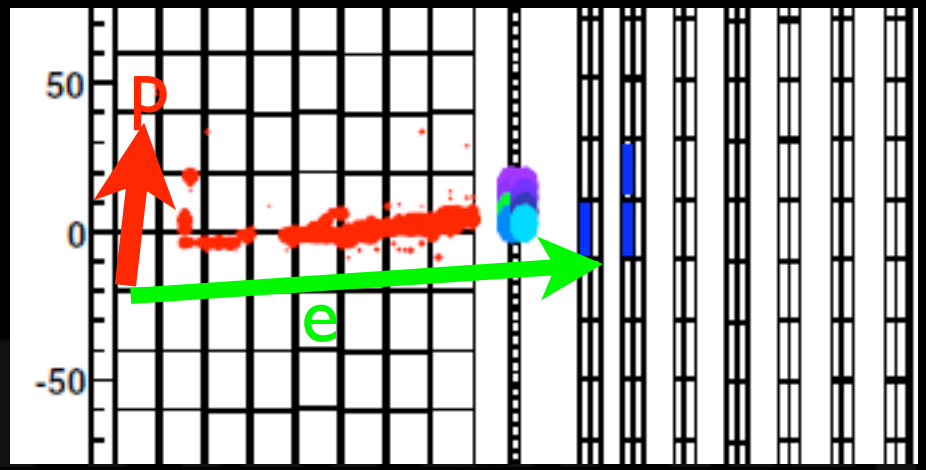
Results for NuInt09

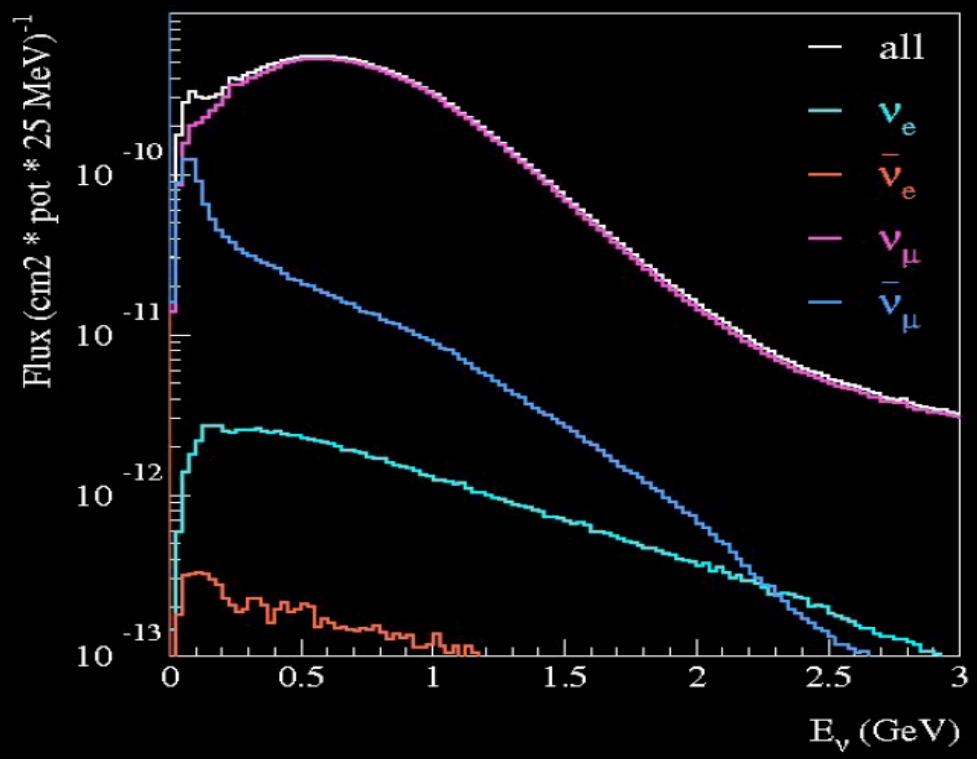
SciBooNE data



ν_e from K^+ decays

SciBooNE data



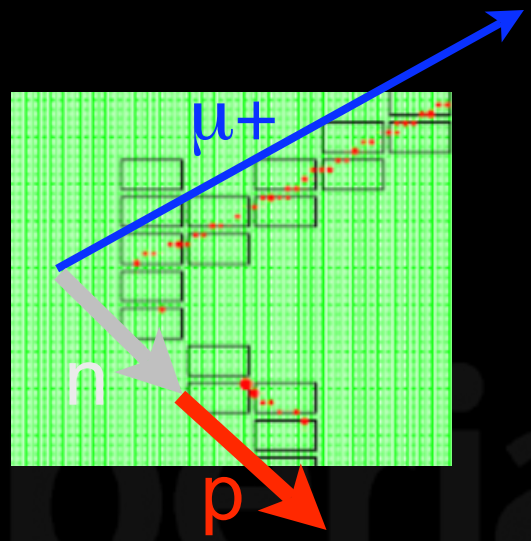


- SciBar/EC events have good acceptance for high energy νe events
  - mainly from K+ decay
- Expect to measure rate with ~17% uncertainty in SciBooNE
- Improve MiniBooNE constraint (~40%)

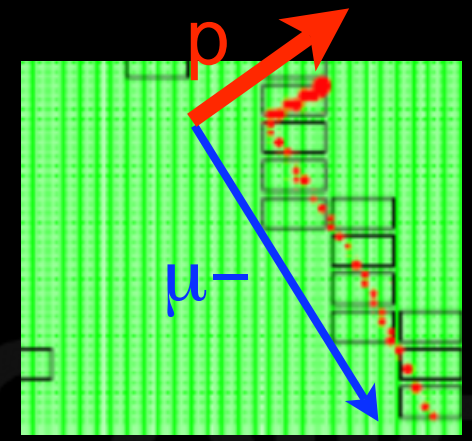
Results later this year

SB $\bar{\nu}$ cross sections

Right Sign

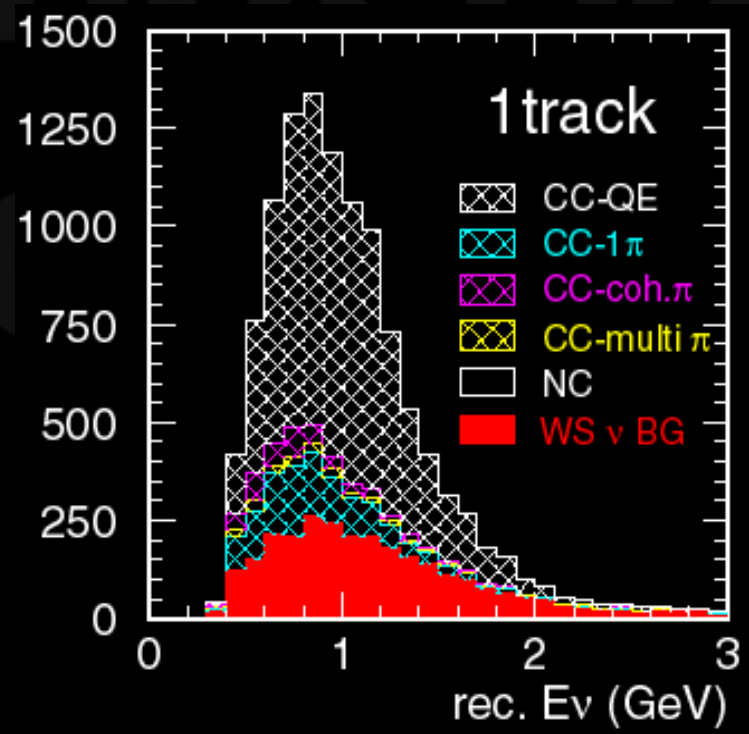


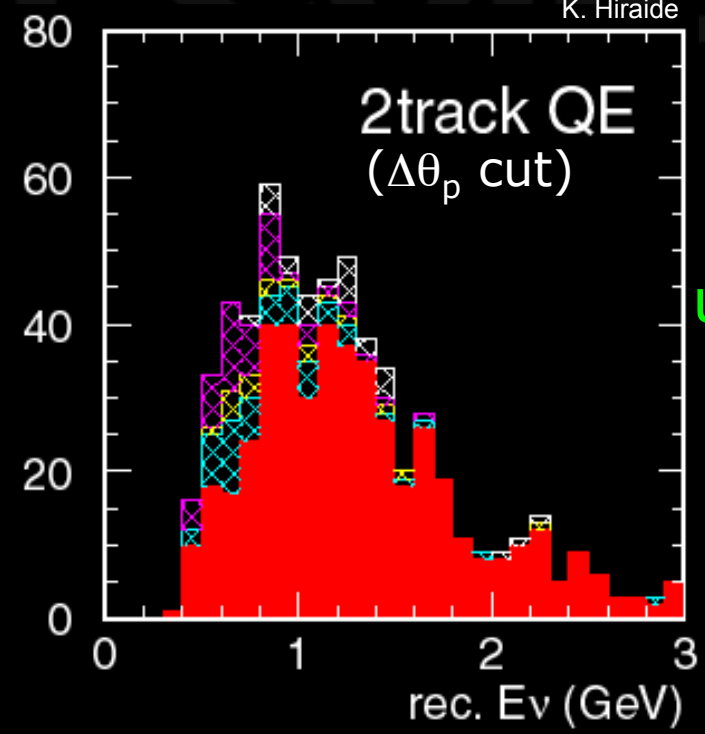
SciBooNE data



Wrong Sign

K. Hiraide



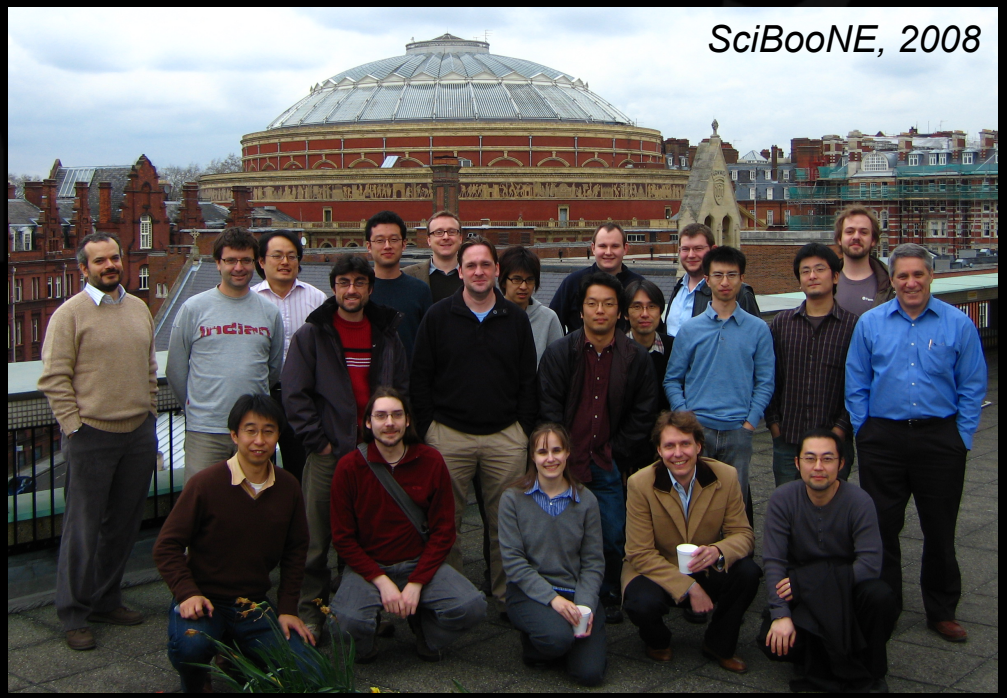


MC only

using NEUT

Conclusion

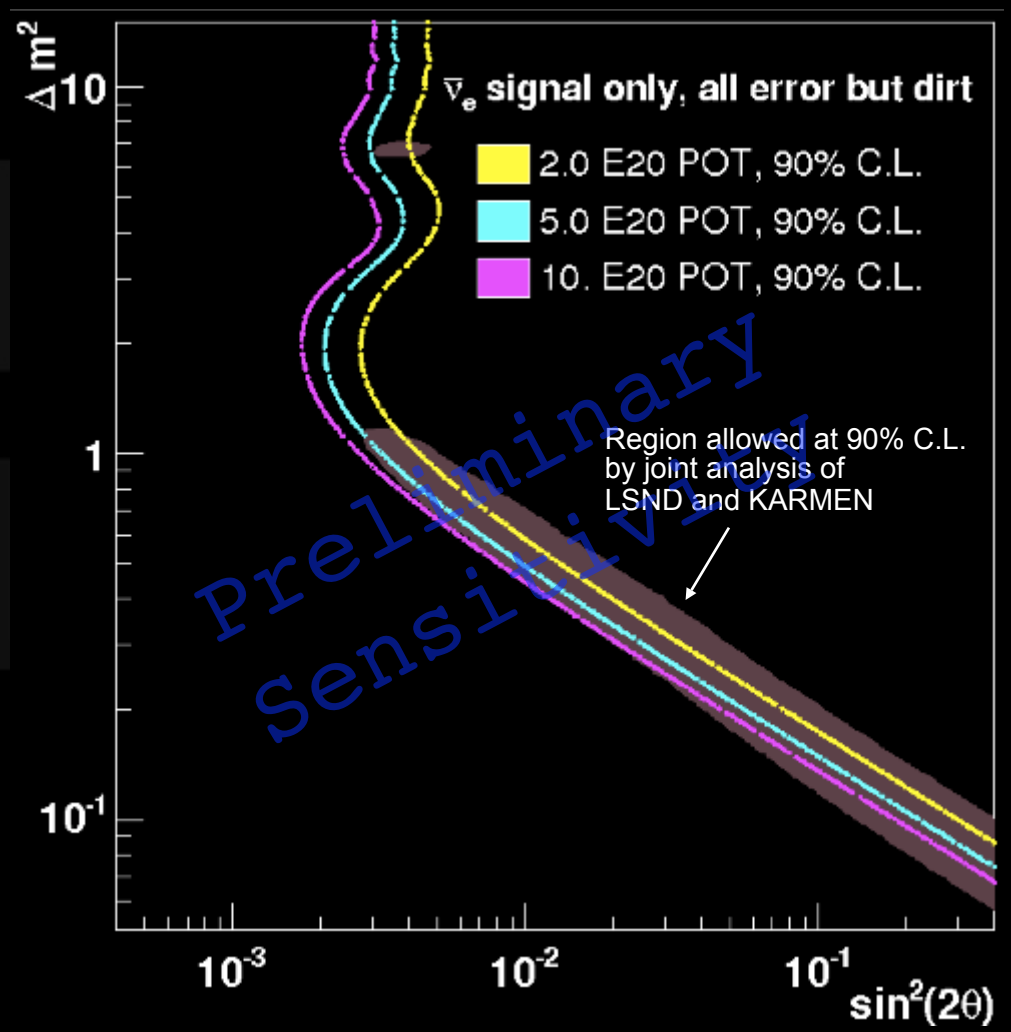
- MiniBooNE's result clarifies the way forward in neutrino physics
  - *But we still need to see the $\bar{\nu}_e$ result!*
- SciBooNE will provide important new constraints for improved MiniBooNE analyses
- SciBooNE and MiniBooNE measurements play an important role for the next generation of experiments



Many new results coming this year!

backup slides

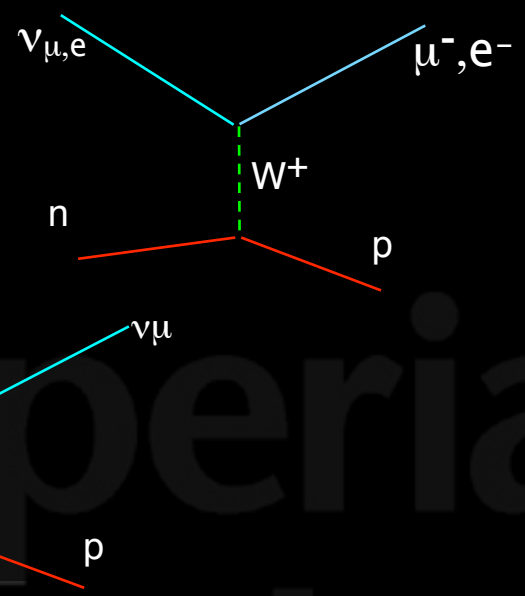
$\bar{\nu}_e$ appearance



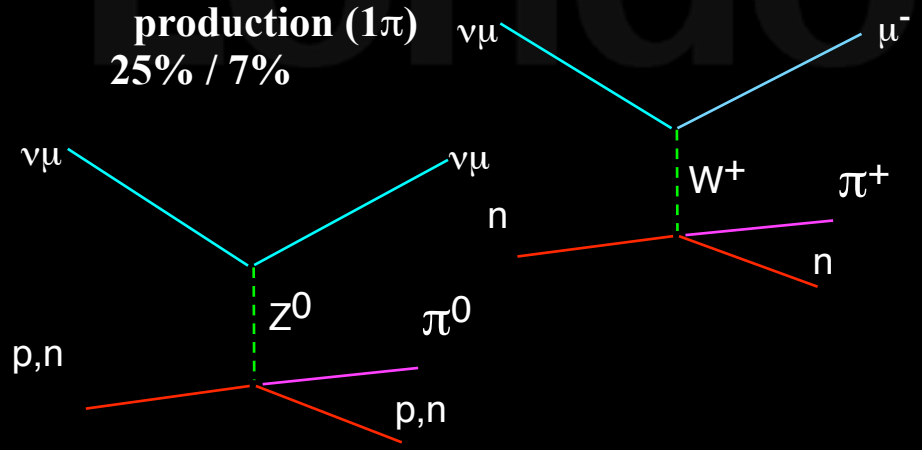
- Goal is to search for $\bar{\nu}_e$ appearance with sensitivity similar to ν_e appearance search

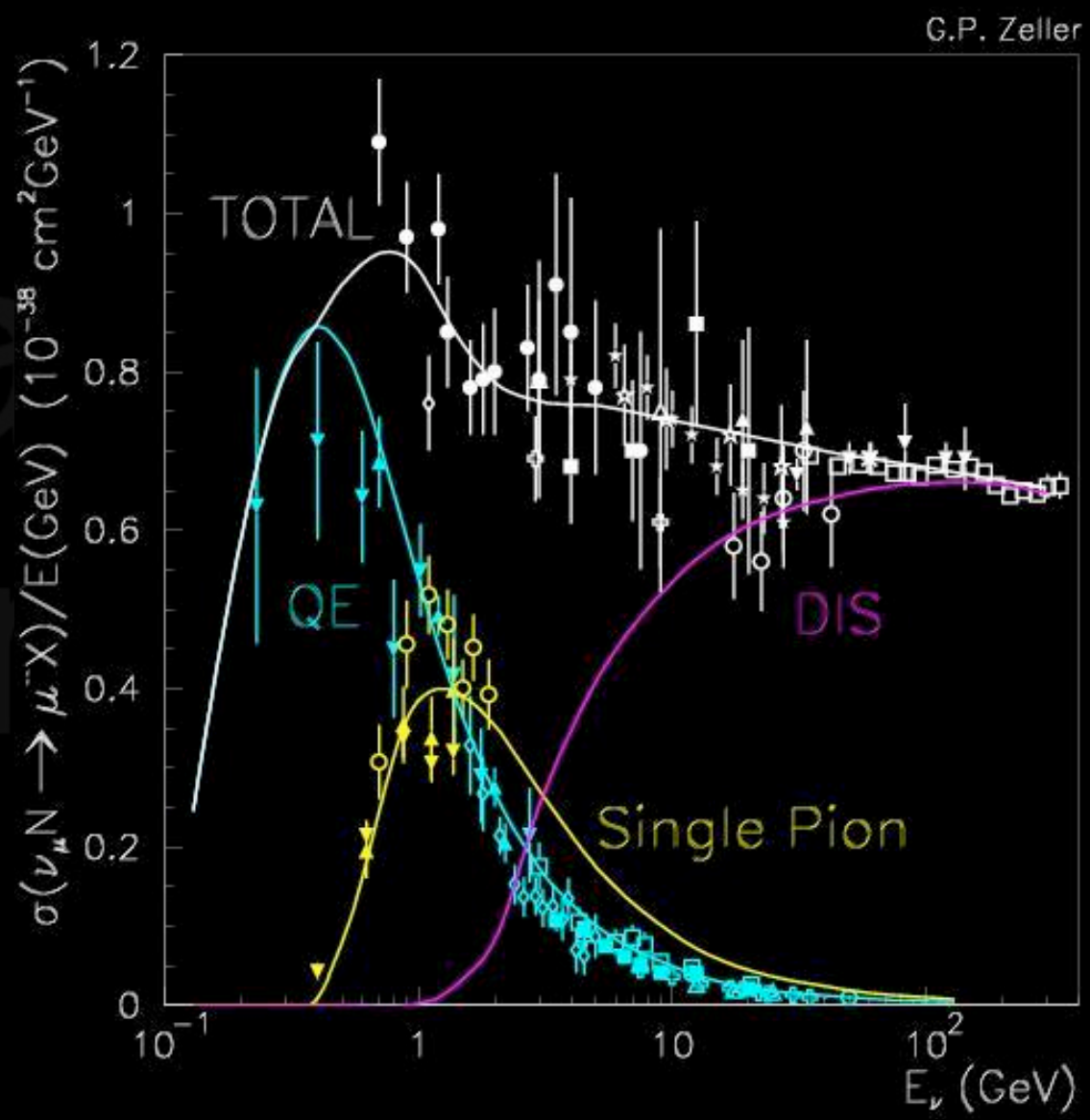
Cross Sections

CC / NC quasi-elastic scattering (QE) 42% / 16%

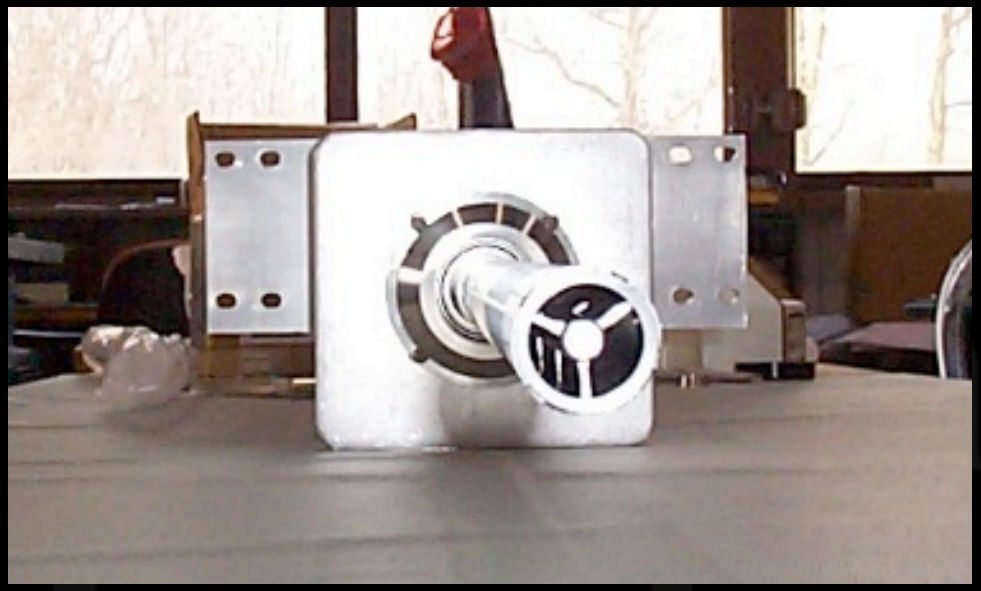


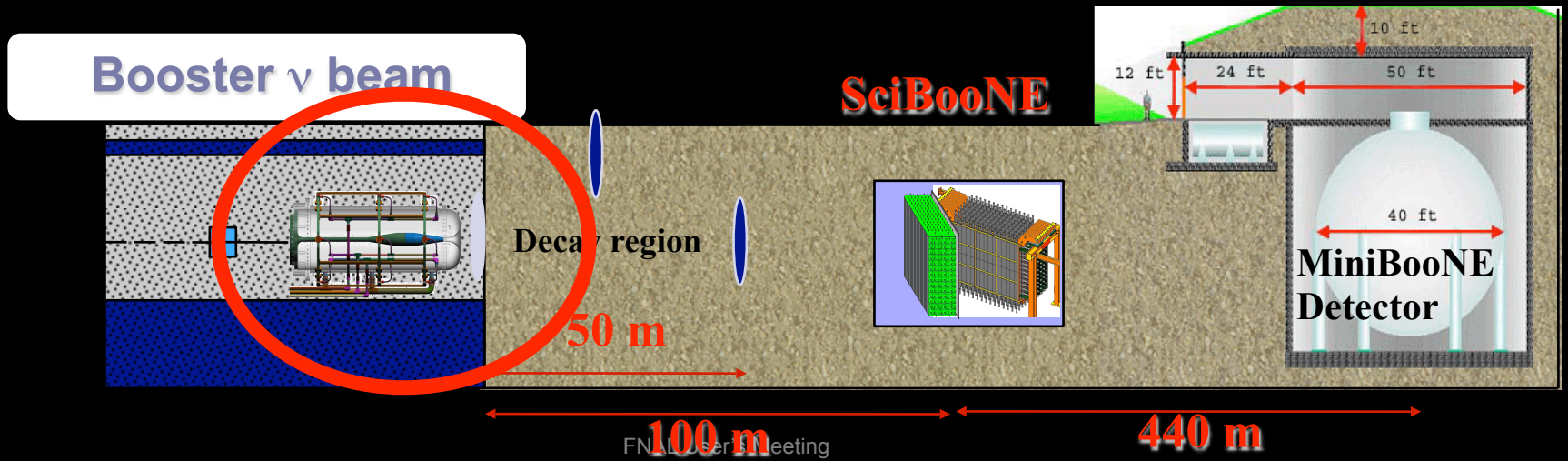
CC / NC resonance production (1π) 25% / 7%





Target & Horn



Main components of Booster Neutrino Beam (BNB)

(96M and 178M+ pulses)