CC Coherent Pion Production by Neutrinos

Aaron Higuera
Universidad de Guanajuato

New Perspectives 2013, Fermilab USA

Outline

CC Coherent Pion Production by Neutrinos.

MINERvA Experiment.

Isolating Coherent Candidates.

Preliminary Results.

Summary.

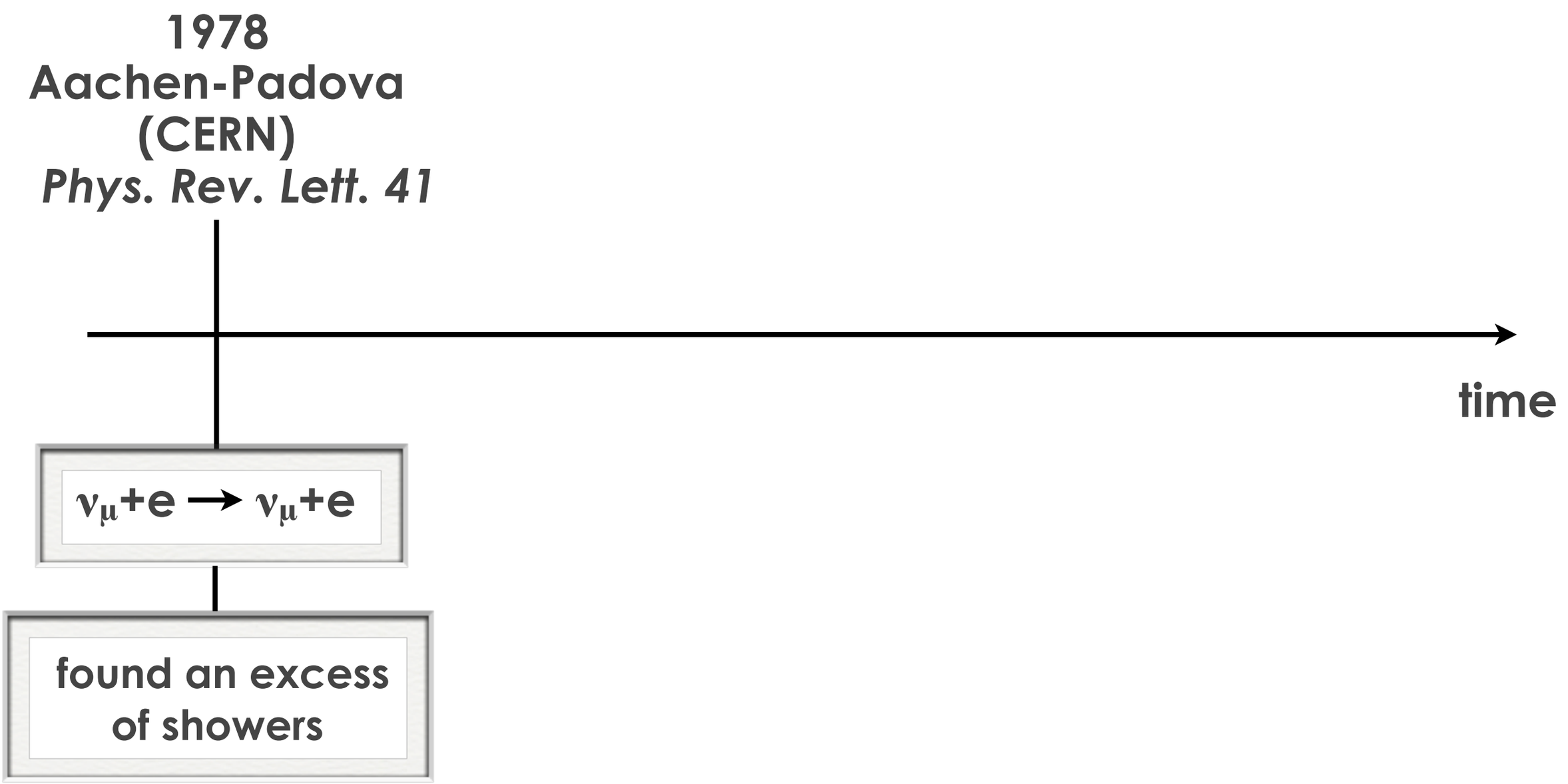
Neutrinos back in 1968

Neutrino beam delivered by the CERN proton synchrotron (PS)

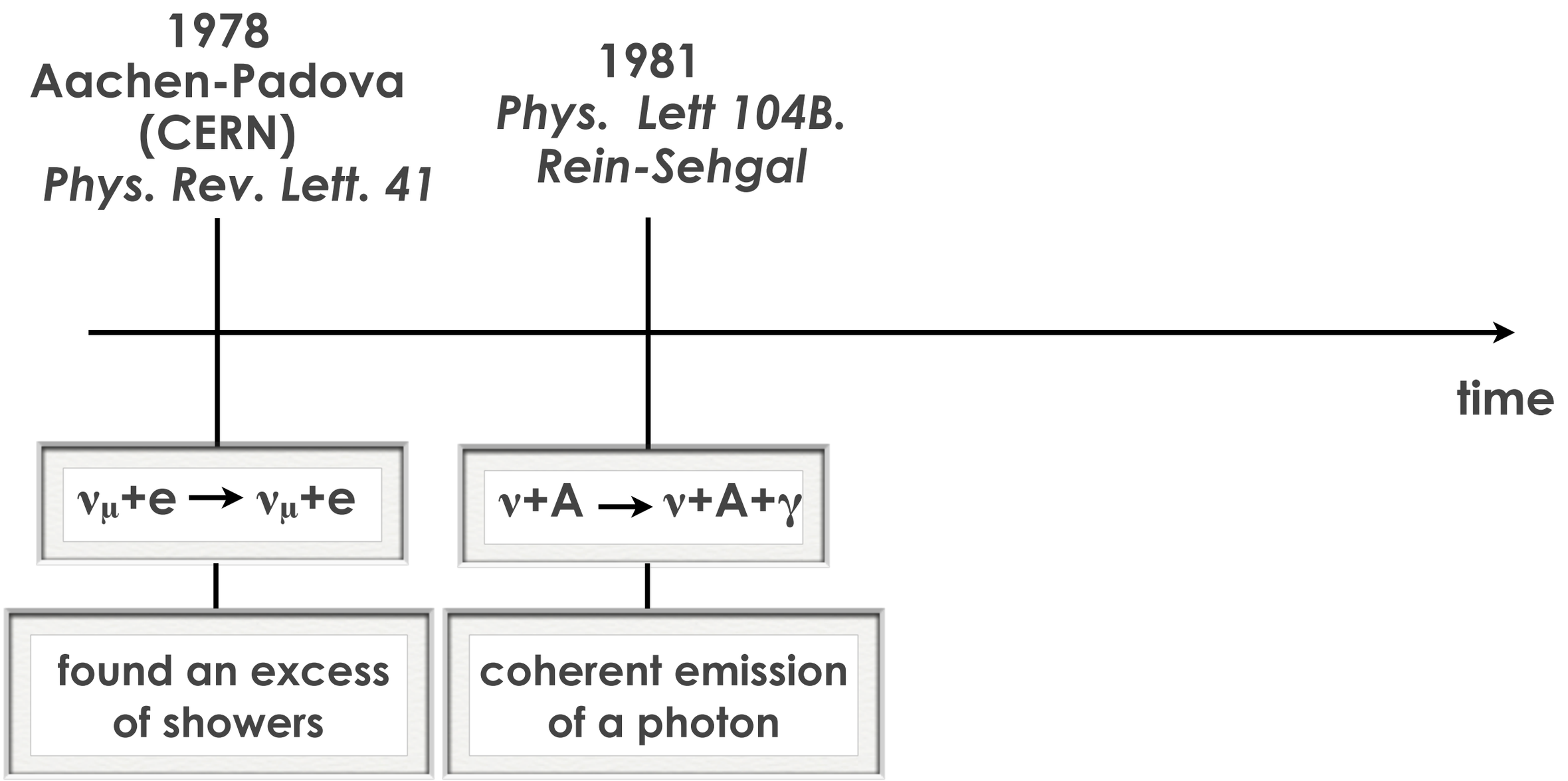
A high intensity 10^{13} protons per pulse.

An inner conductor for the new neutrino "reflector".
CERN Courier Archive

CC Coherent Pion Production by Neutrinos



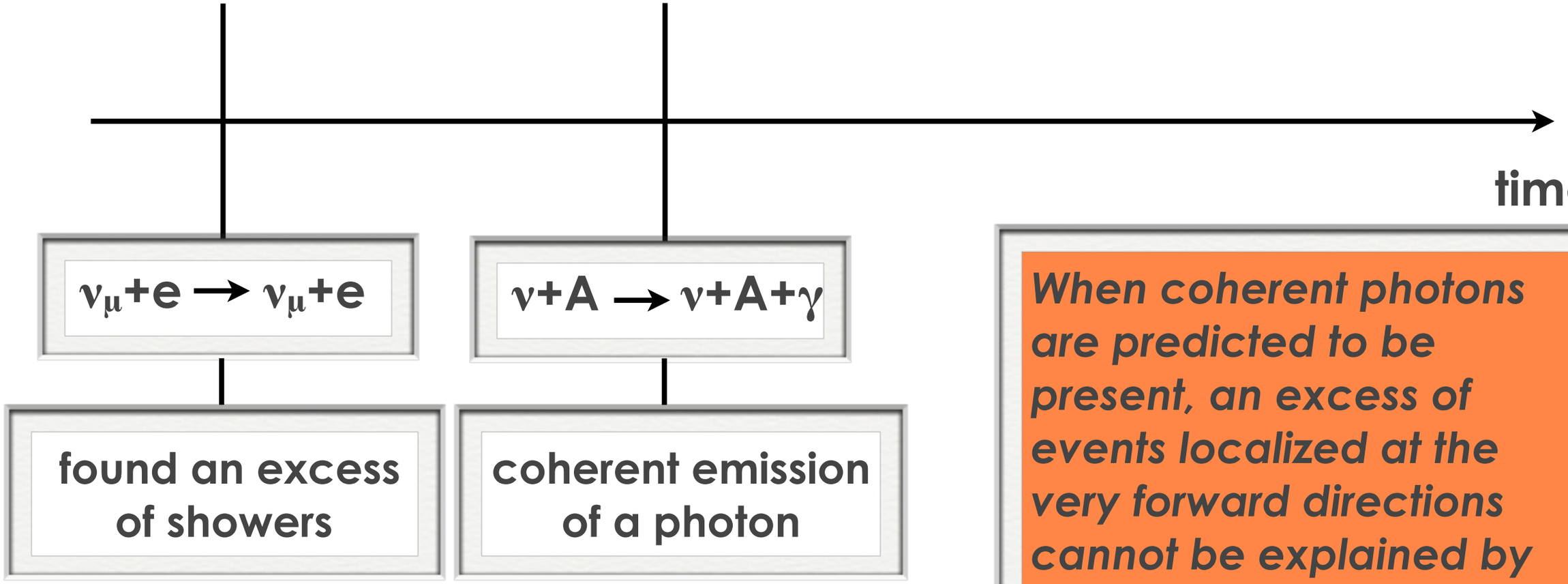
CC Coherent Pion Production by Neutrinos



CC Coherent Pion Production by Neutrinos

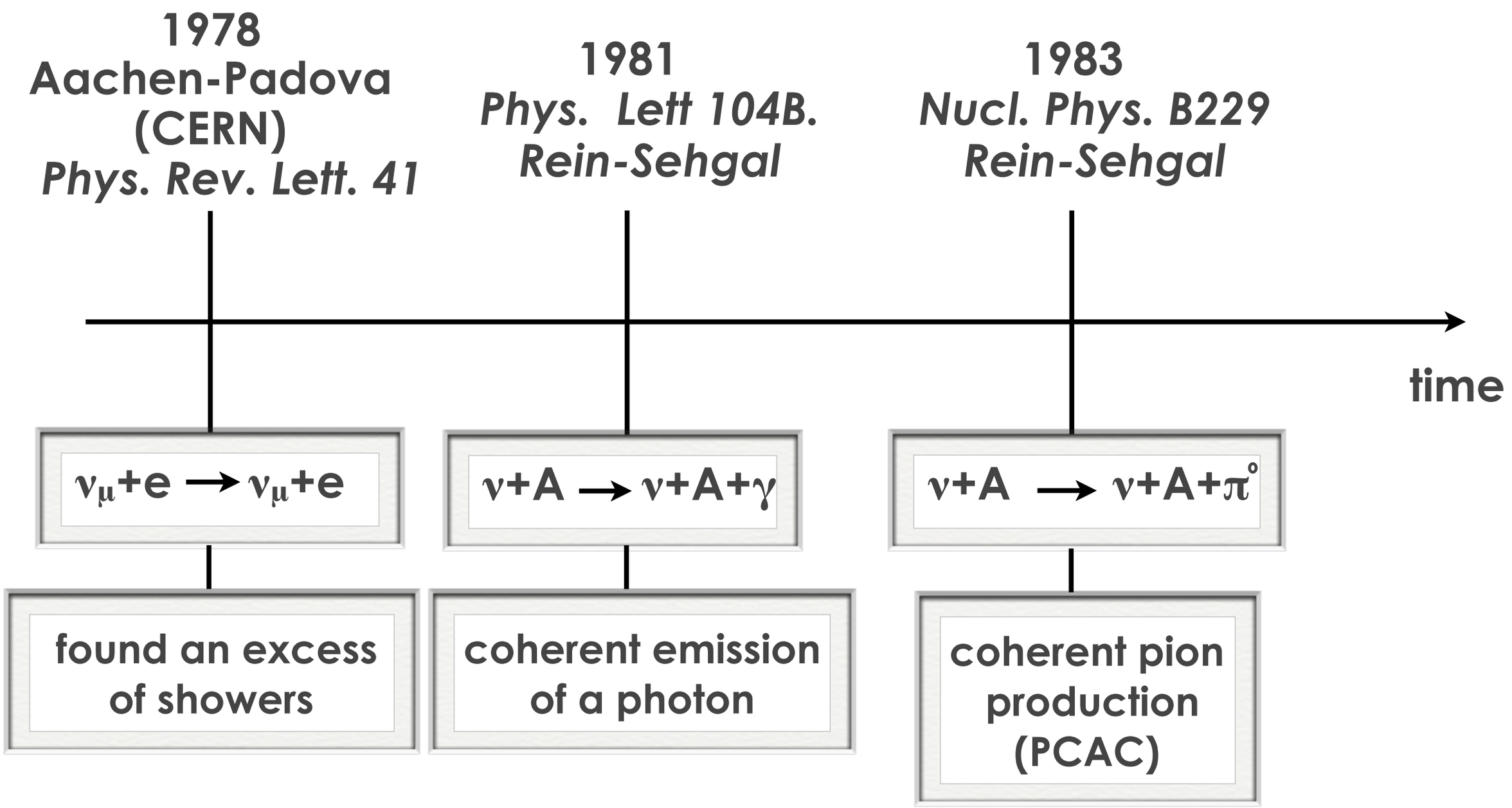
1978
Aachen-Padova
(CERN)
Phys. Rev. Lett. 41

1981
Phys. Lett 104B.
Rein-Sehgal



When coherent photons are predicted to be present, an excess of events localized at the very forward directions cannot be explained by the coherent-photon mechanism alone

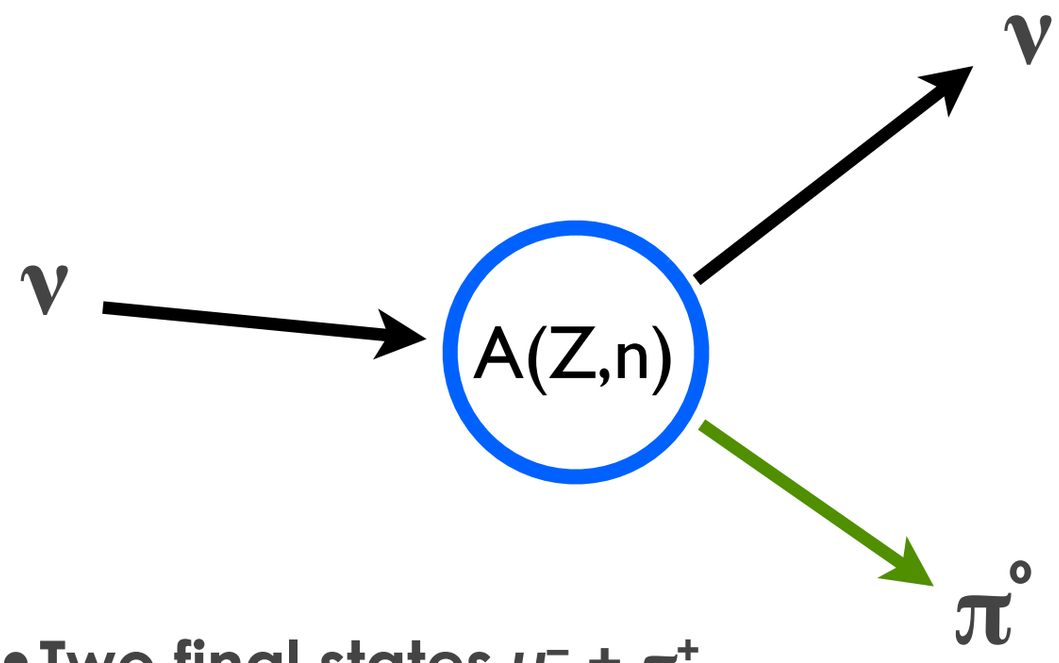
CC Coherent Pion Production by Neutrinos



CC Coherent Pion Production by Neutrinos

$\nu + A \longrightarrow \nu + A + \pi^{\circ}$

Alder's theorem (Phys. Rev. 135, B963) and Partially Conserved Axial Current (PCAC)



$$\left(\frac{d\sigma}{dx\,dy\,dt}\right)_{Q^2=0} = \frac{G_F^2 ME}{2\pi^2} f_\pi^2 (1-y) \frac{d\sigma(\pi^0 + A \to \pi^0 + A)}{dt}$$

$$\left(1 + \frac{Q^2}{M_A^2}\right)^2_{Q^2 \neq 0}$$

- Two final states $\mu^- + \pi^+$
- Small Q^2
- Nucleus remains in its ground state
- Small $t = (q - p_\pi)^2$

relates the weak interaction process $\nu_l + \alpha \to l + \beta$ in the forward direction ($Q^2 = 0$) to the hadronic interaction process $\pi + \alpha \to \beta$

CC Coherent Pion Production by Neutrinos

1983 (NC)
Nucl. Phys. B229
Rein-Sehgal

1984 (NC)
Phys. Rev. Lett 52
GARGAMELLE

1986
Z. Phys. C 31
BEBC-WA59 CC π^-

time

1985 (NC)
Phys. Lett 157B
CHARM

1986
Z. Phys. C 31
SKAT (CC)
π^- π^+ π^0

$\nu + A \rightarrow \nu + A + \pi^0$

coherent pion production (PCAC)

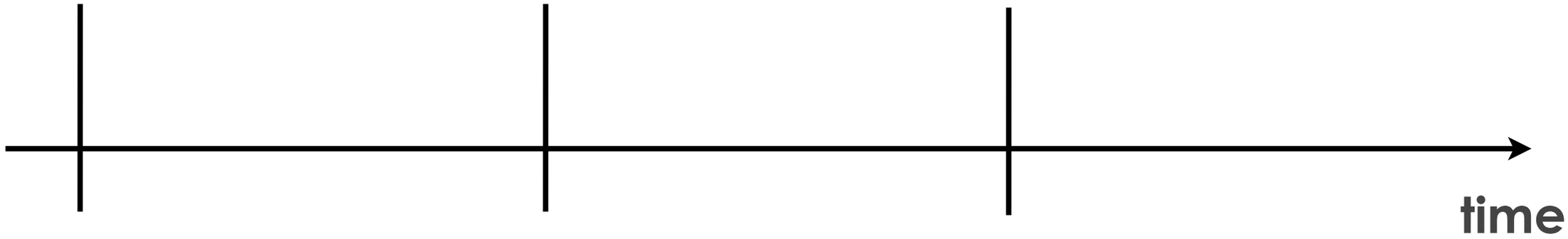
Aachen-Padova
coherent π^0
Phys. Lett. 125B, 1983

CC Coherent Pion Production by Neutrinos

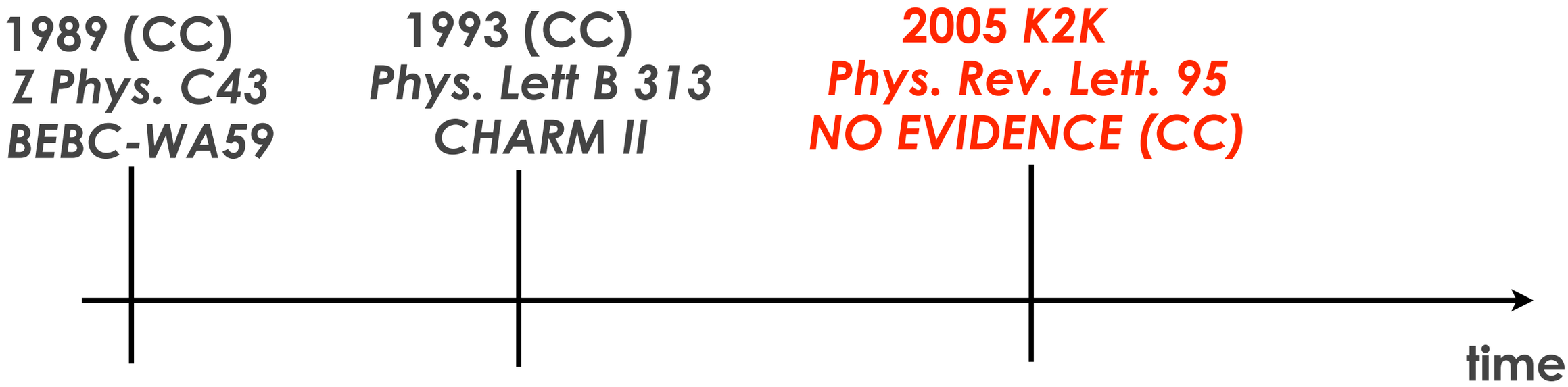
1986 (NC)
Phys. Rev. Lett 57
Fermilab 15ft

1989 (CC)
Z Phys. C43
BEBC-WA59

1993 (CC)
Phys. Lett B 313
CHARM II



CC Coherent Pion Production by Neutrinos



CC Coherent Pion Production by Neutrinos

1993 (CC)
Phys. Lett B 313
CHARM II

2005 K2K
Phys. Rev. Lett. 95
NO EVIDENCE (CC)

time

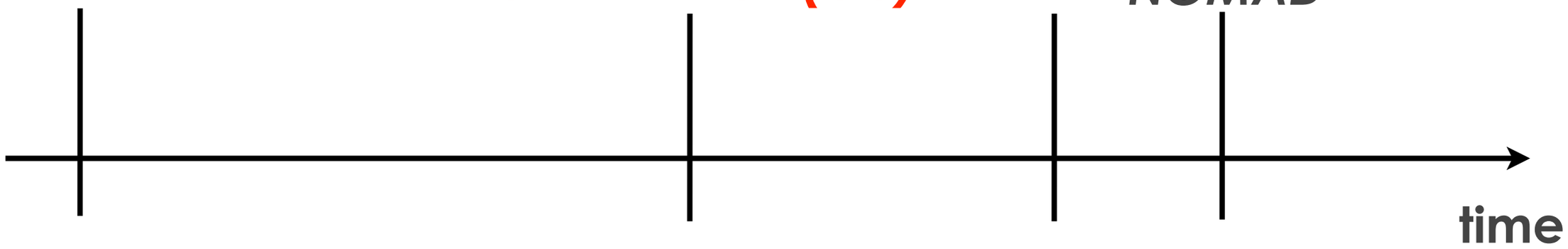
2008 SciBooNE
Phys. Rev. D78.
NO EVIDENCE (CC)

CC Coherent Pion Production by Neutrinos

1993 (CC)
Phys. Lett B 313
CHARM II

2005 K2K
Phys. Rev. Lett. 95
NO EVIDENCE (CC)

2009 (NC)
Phys. Lett B 682
NOMAD



2008 SciBooNE
Phys. Rev. D78.
NO EVIDENCE (CC)

CC Coherent Pion Production by Neutrinos

1986 (NC)
Phys. Rev. Lett 57
Fermilab 15ft

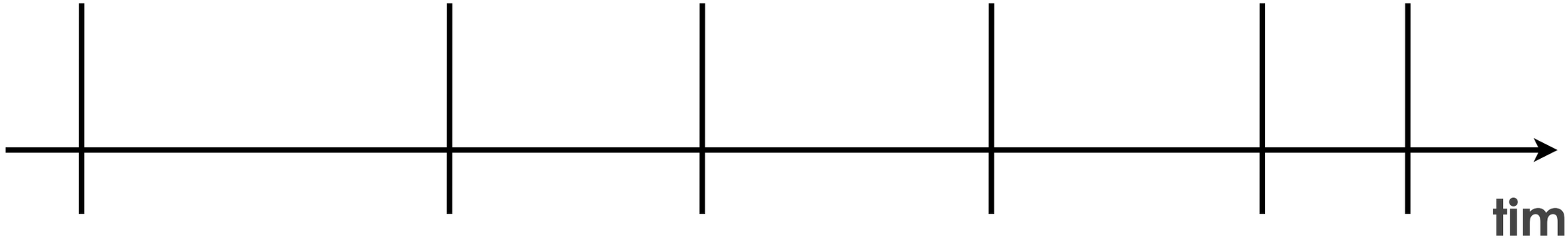
1989 (CC)
Z Phys. C43
BEBC-WA59

1993 (CC)
Phys. Lett B 313
CHARM II

2005 K2K
Phys. Rev. Lett. 95
NO EVIDENCE (CC)

2008 SciBooNE
Phys. Rev. D78.
NO EVIDENCE (CC)

2009 (NC)
Phys. Lett B 682
NOMAD



coherent π production at CERN

no coherent π production at Booster (Fermilab)

no coherent π production at Japan

CC Coherent Pion Production by Neutrinos

1986 (NC)
Phys. Rev. Lett 57
Fermilab 15ft

1989 (CC)
Z Phys. C43
BEBC-WA59

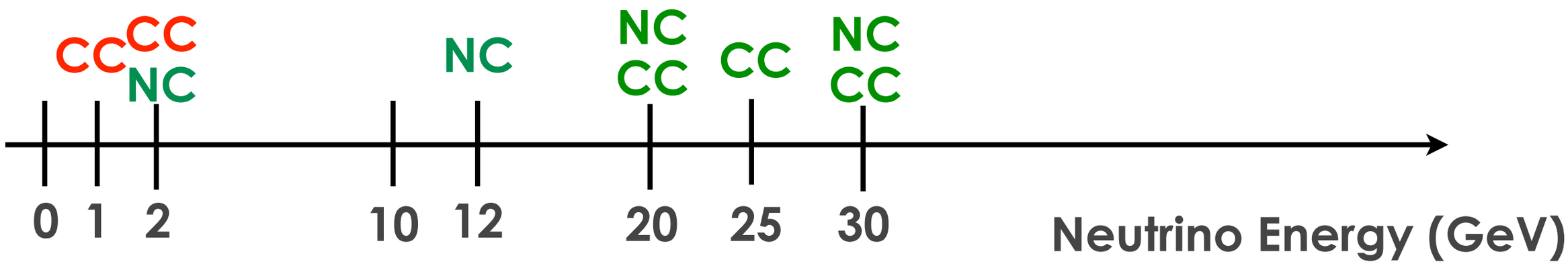
1993 (CC)
Phys. Lett B 313
CHARM II

2005 K2K
Phys. Rev. Lett. 95
NO EVIDENCE (CC)

2008 SciBooNE
Phys. Rev. D78.
NO EVIDENCE (CC)

2009 (NC)
Phys. Lett B 682
NOMAD

time



CC Coherent Pion Production by Neutrinos

1986 (NC)
Phys. Rev. Lett 57
Fermilab 15ft

1989 (CC)
Z Phys. C43
BEBC-WA59

1993 (CC)
Phys. Lett B 313
CHARM II

2005 K2K
Phys. Rev. Lett. 95
NO EVIDENCE (CC)

2008 SciBooNE
Phys. Rev. D78.
NO EVIDENCE (CC)

2009 (NC)
Phys. Lett B 682
NOMAD

time

MINERvA

CC CC NC NC CC NC CC NC CC

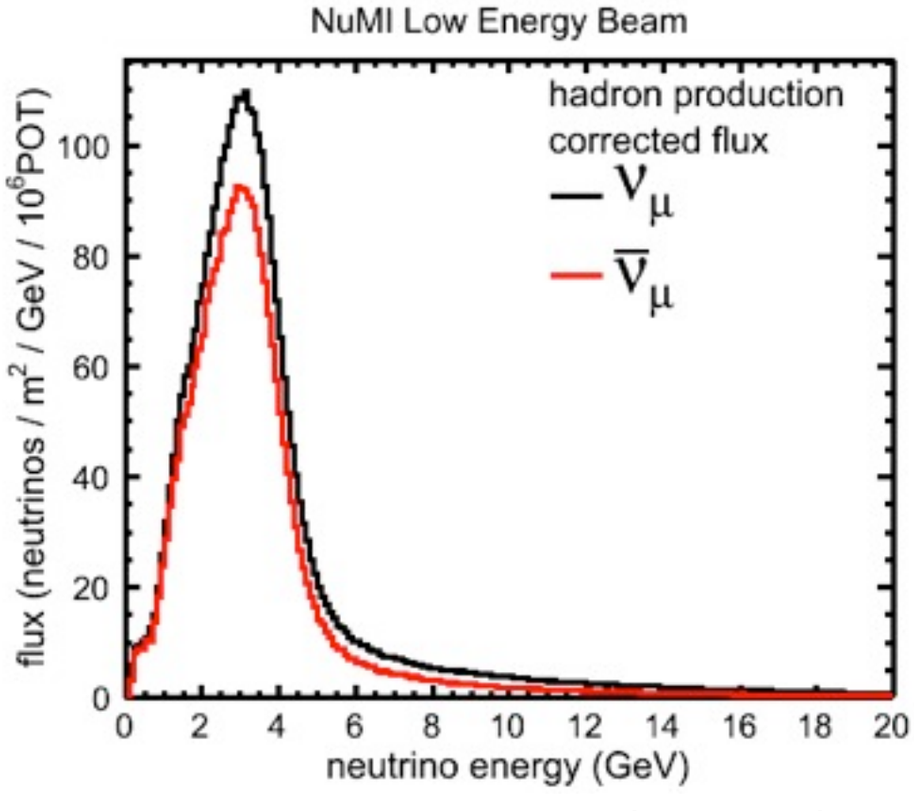
0 1 2 3.5 10 12 20 25 30

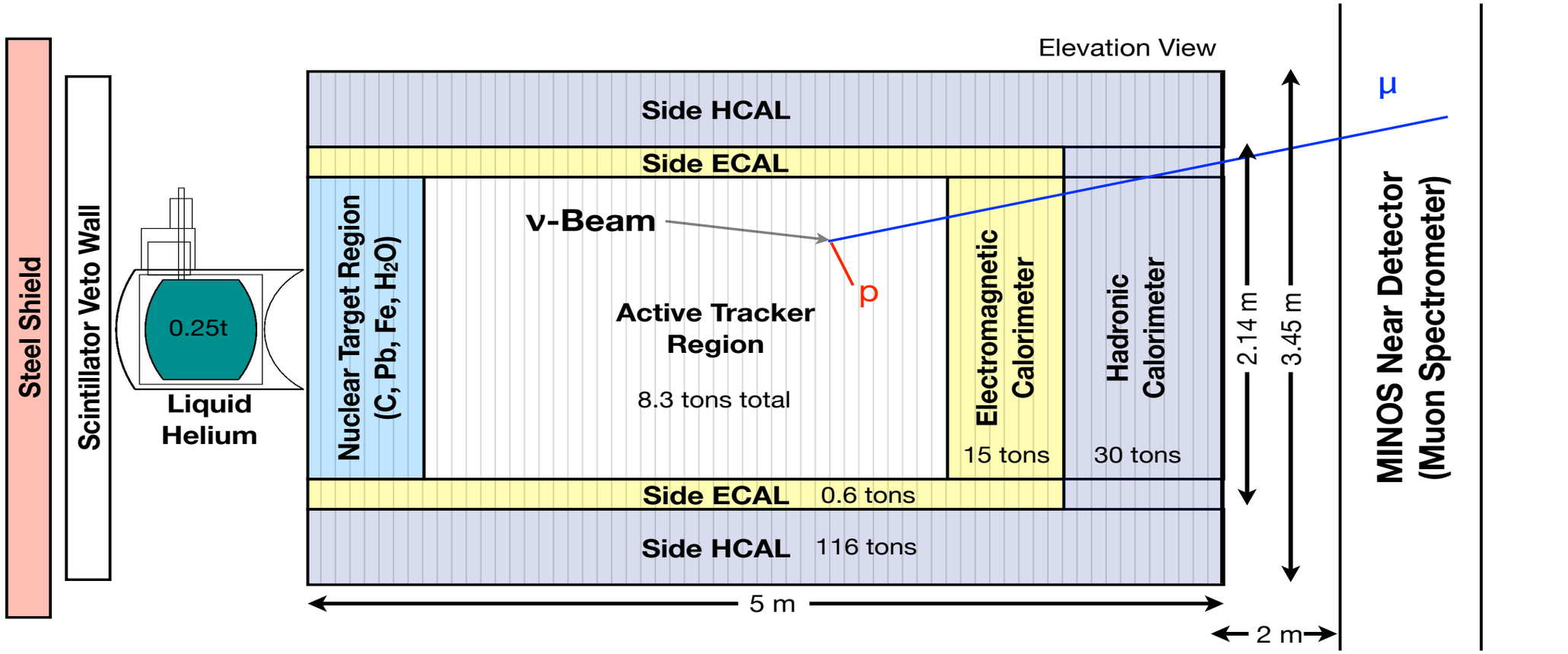
Neutrino Energy (GeV)

MINERvA Experiment

MINERvA is a neutrino scattering experiment in the NuMI beamline at Fermilab.

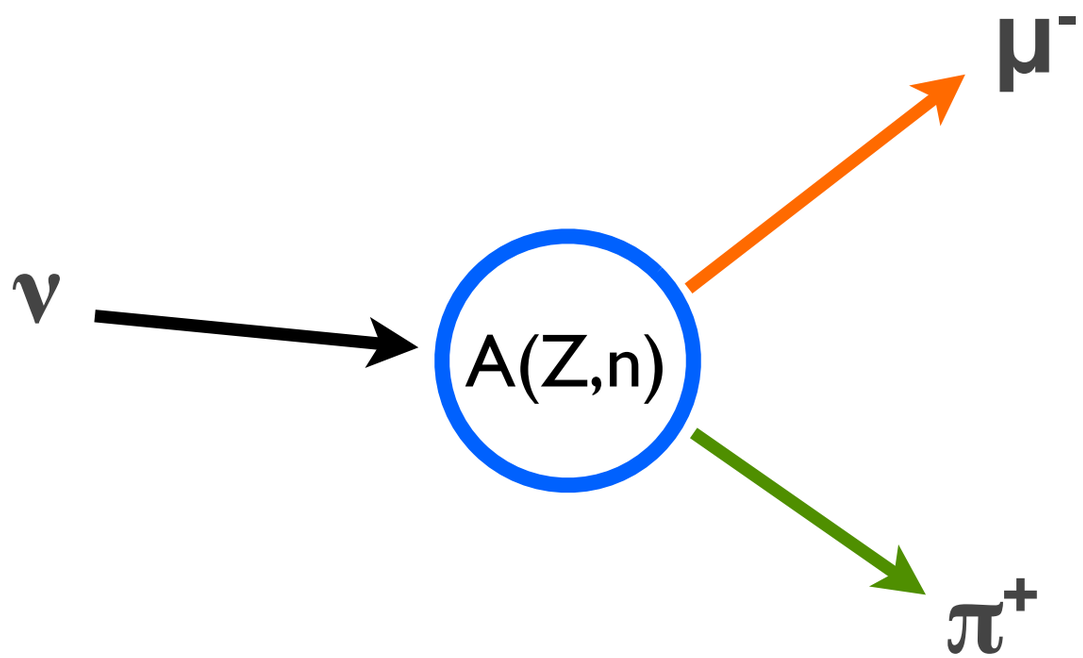
Designed to measure neutrino cross sections, final states, nuclear effects and A-dependence on a variety of targets in the few-GeV region.





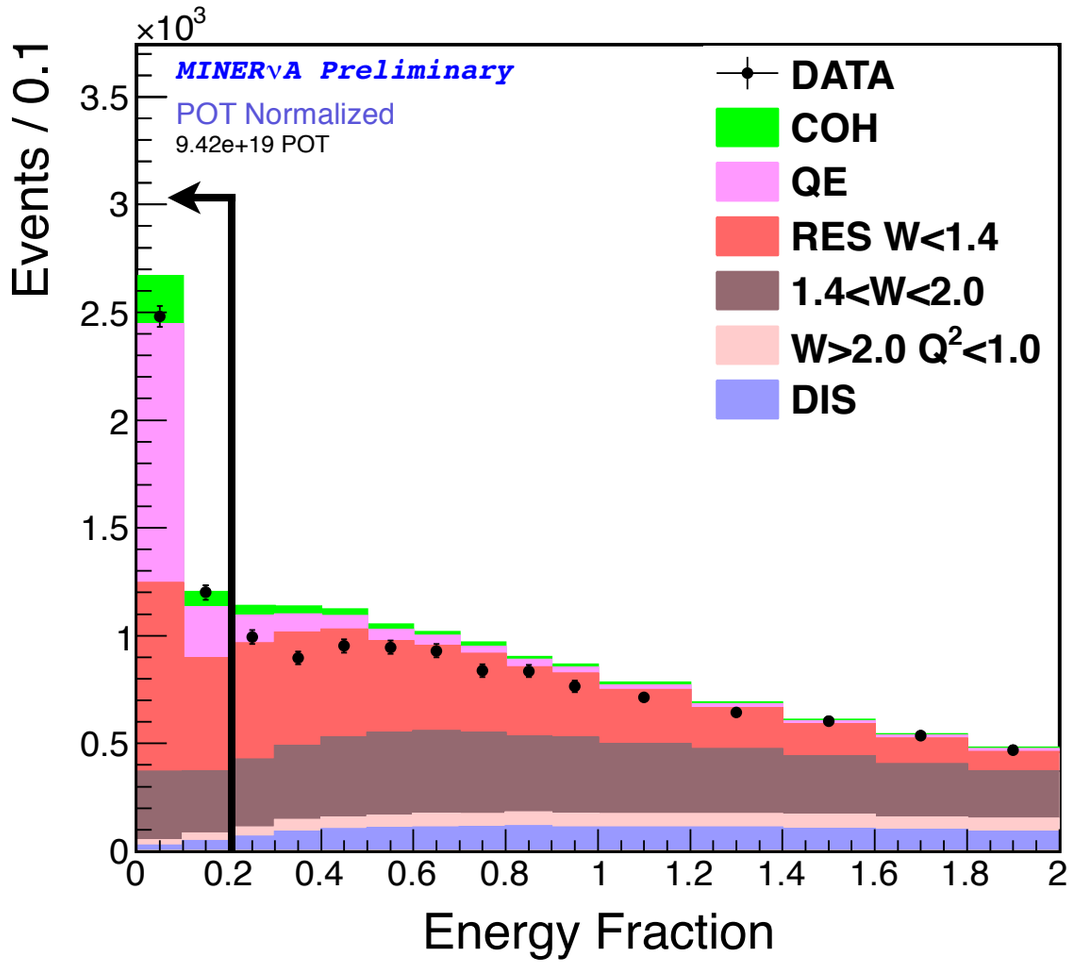
Isolating Coherent Candidates

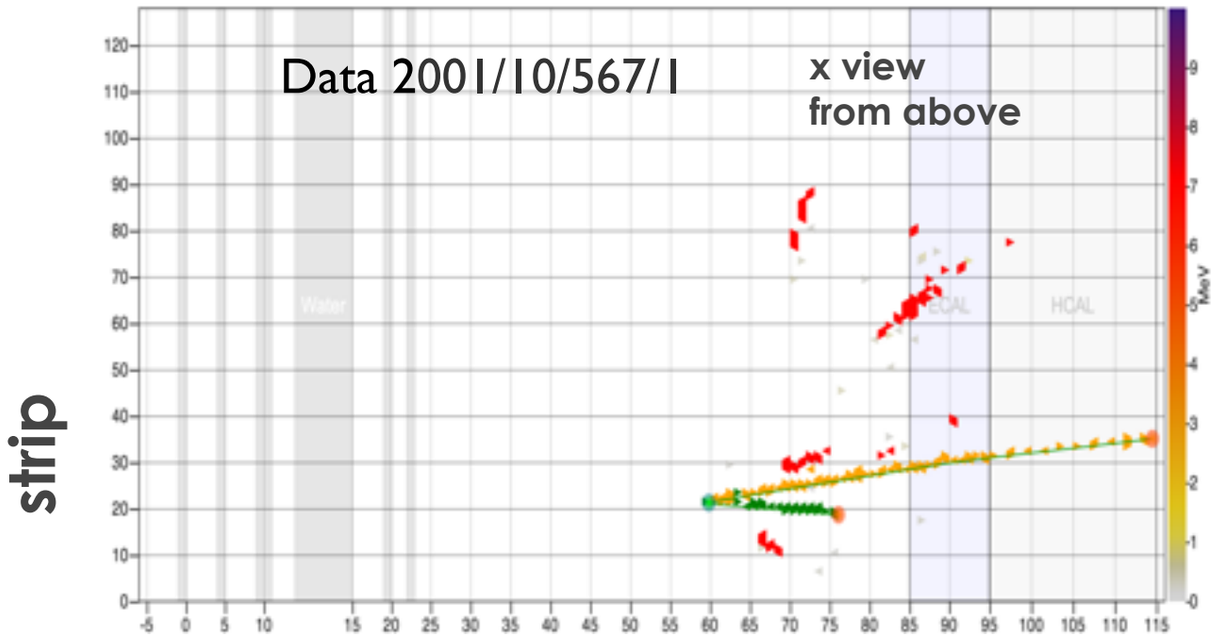
$\nu + A \longrightarrow \mu^- + A + \pi^+$



- Two final states μ^- + π^+
- Small Q^2
- Nucleus remains in its ground state
- Small $t = (q - p_\pi)^2$

Isolating Coherent Candidates





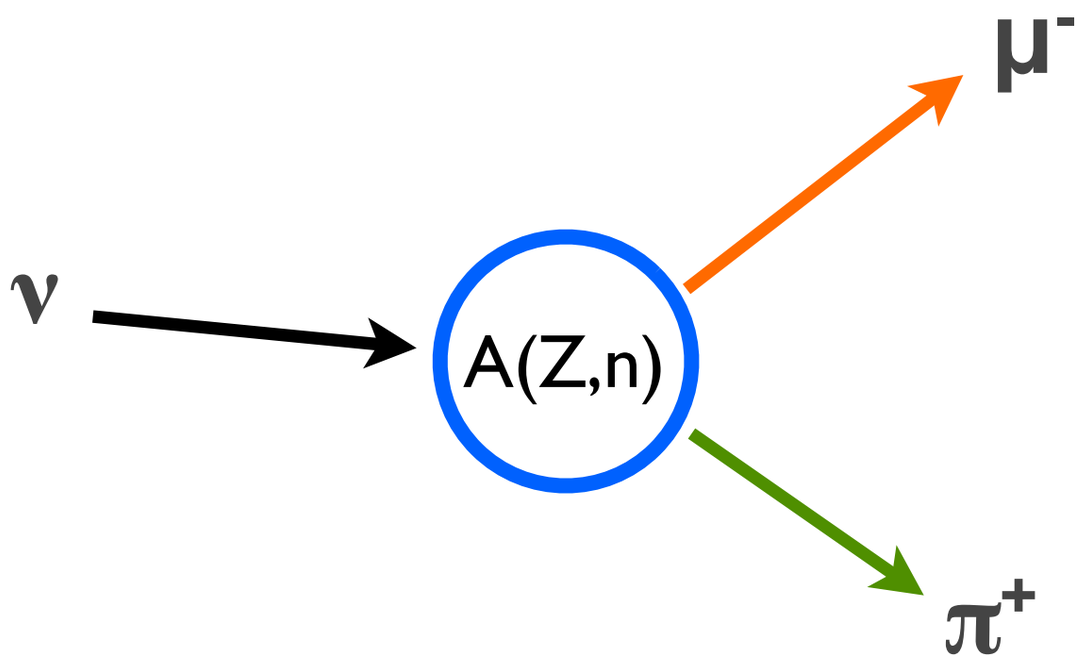
- [x] Two final states $\mu^- + \pi^+$
- [ ] Small Q^2
- [ ] Nucleus remains in its ground state
- [ ] Small $t = (q - p_\pi)^2$

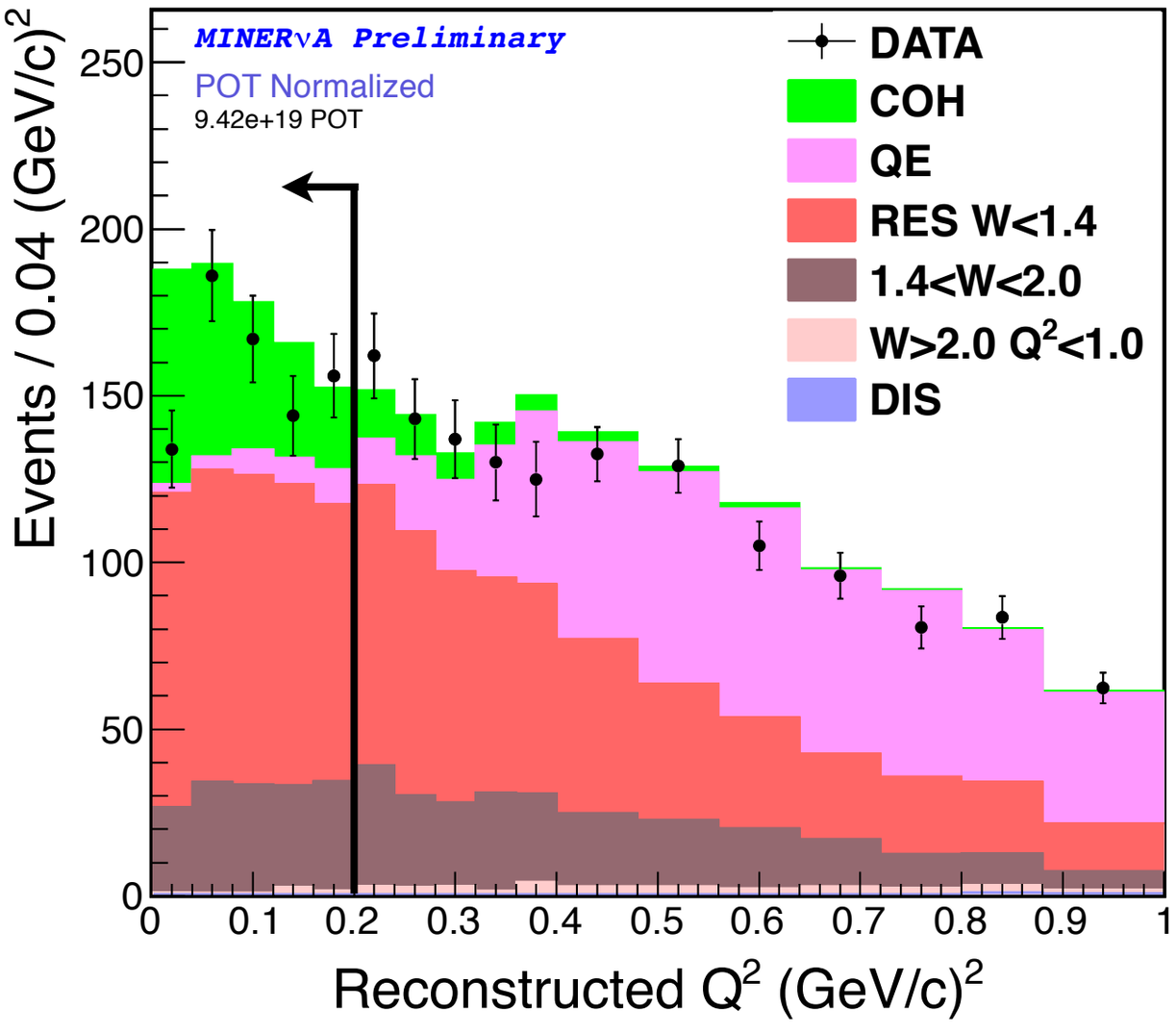
fraction= $\frac{\text{Extra Energy}}{\text{Hadron Prong}}$

Isolating Coherent Candidates

$\nu + A \longrightarrow \mu^- + A + \pi^+$

$$Q^2 = 2E_\nu(E_\mu - P_\mu cos\theta_\mu) - m_\mu^2$$

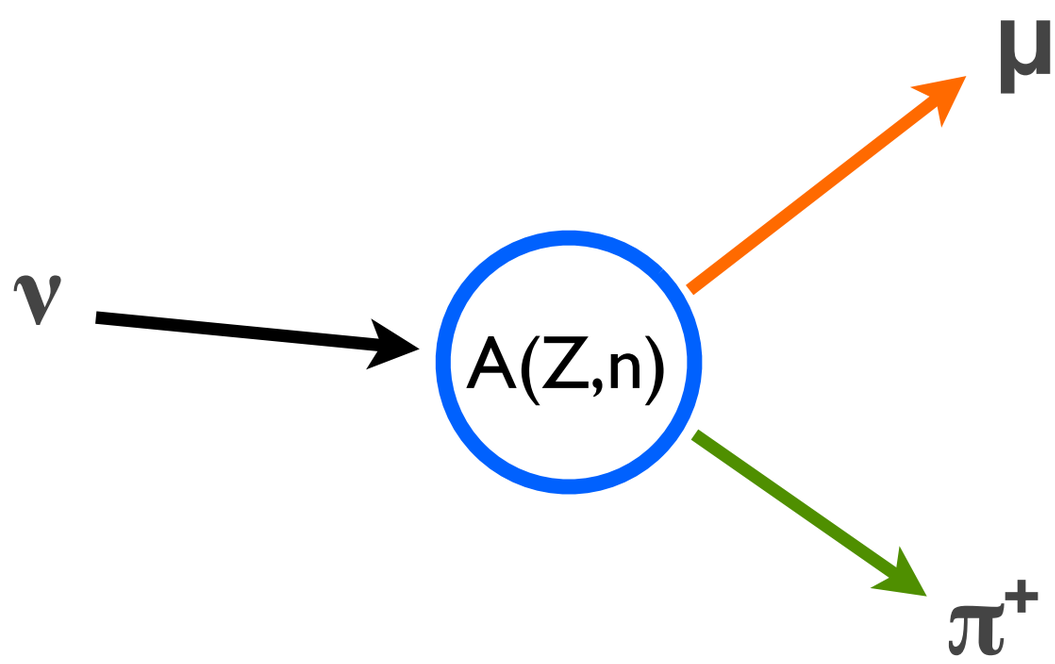


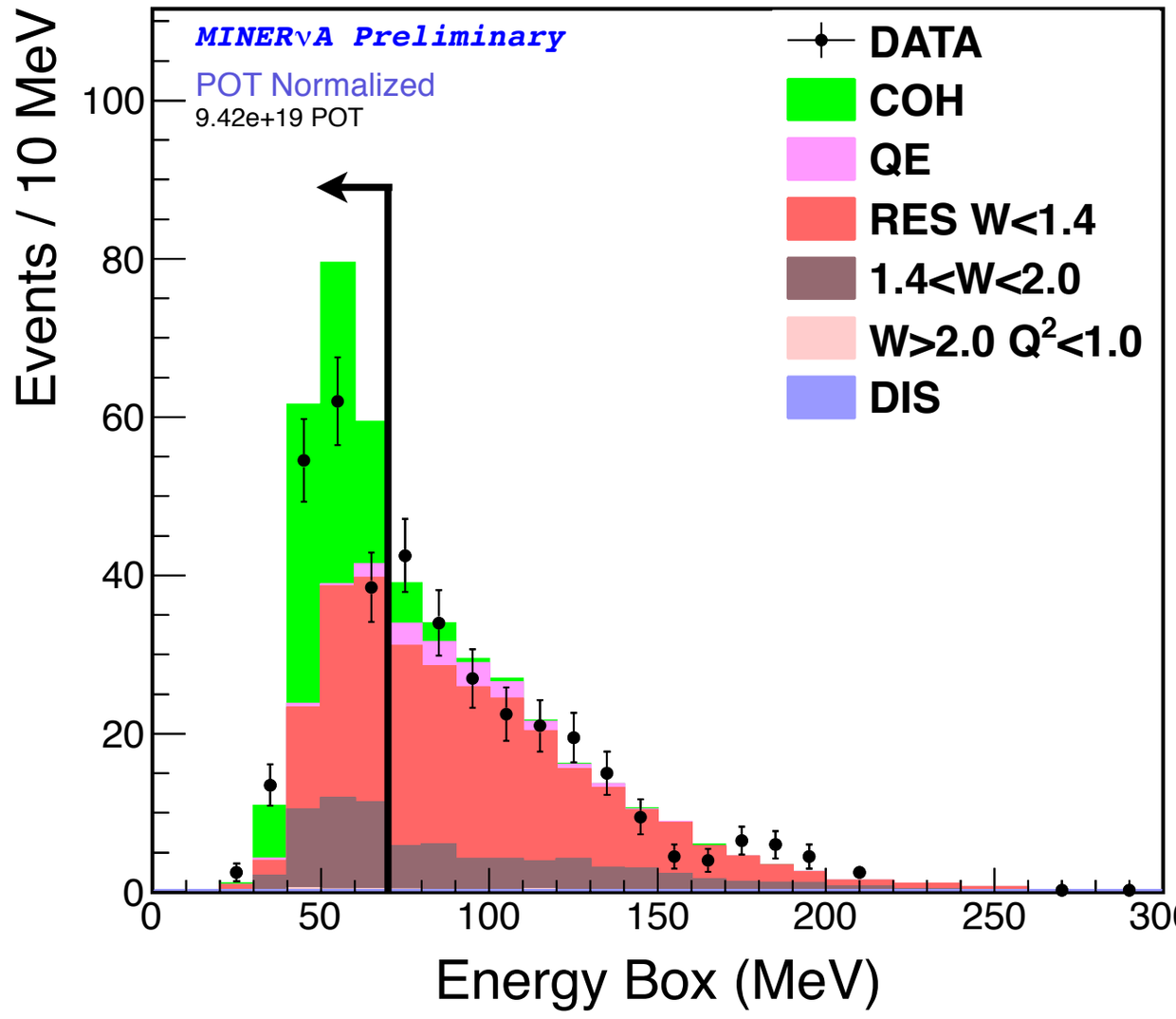


- ☑ Two final states $\mu^- + \pi^+$
- ☑ Small Q^2
- ☐ Nucleus remains in its ground state
- ☐ Small $t = (q - p_\pi)^2$

Isolating Coherent Candidates

$\nu + A \longrightarrow \mu^- + A + \pi^+$



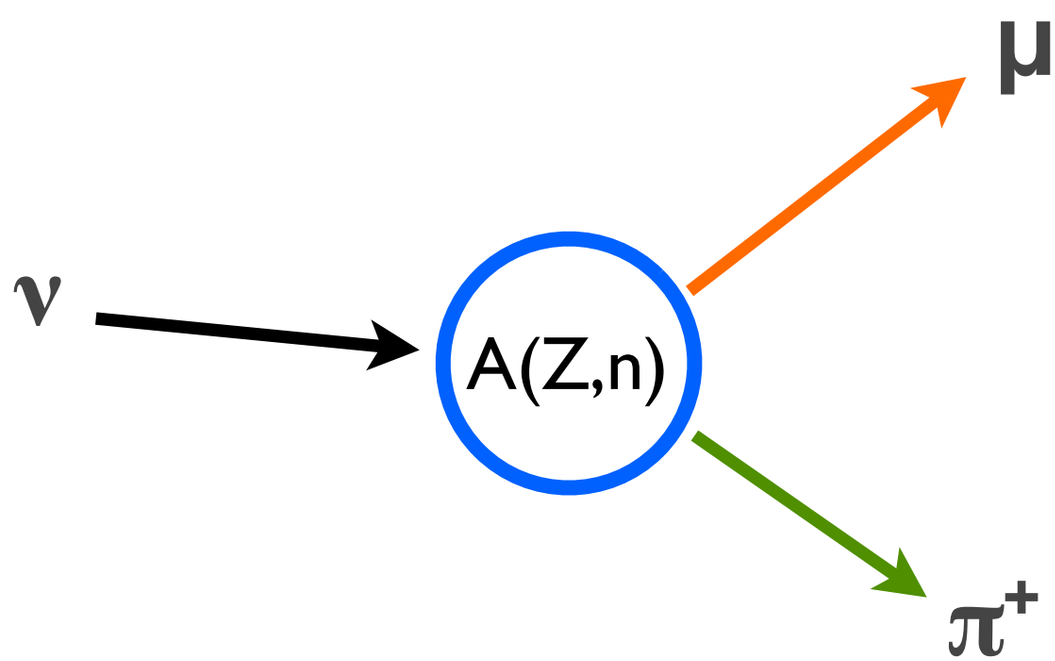


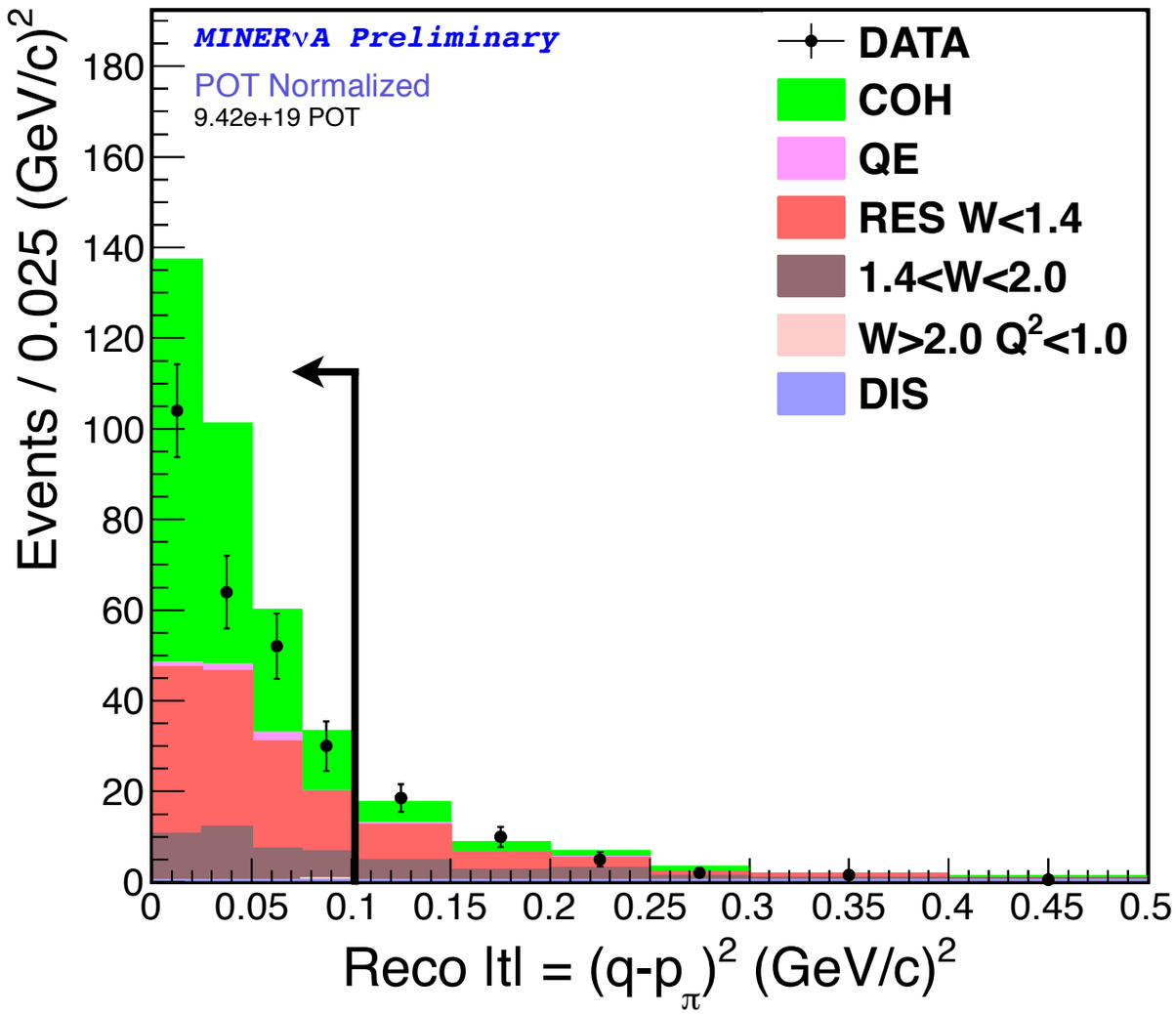
- ☑ Two final states μ^- + π^+
- ☑ Small Q^2
- ☑ Nucleus remains in its ground state
- ☐ Small $t = (q - p_\pi)^2$

Energy within ± 5 planes from the muon vertex and 200 mm in transverse direction.

Isolating Coherent Candidates

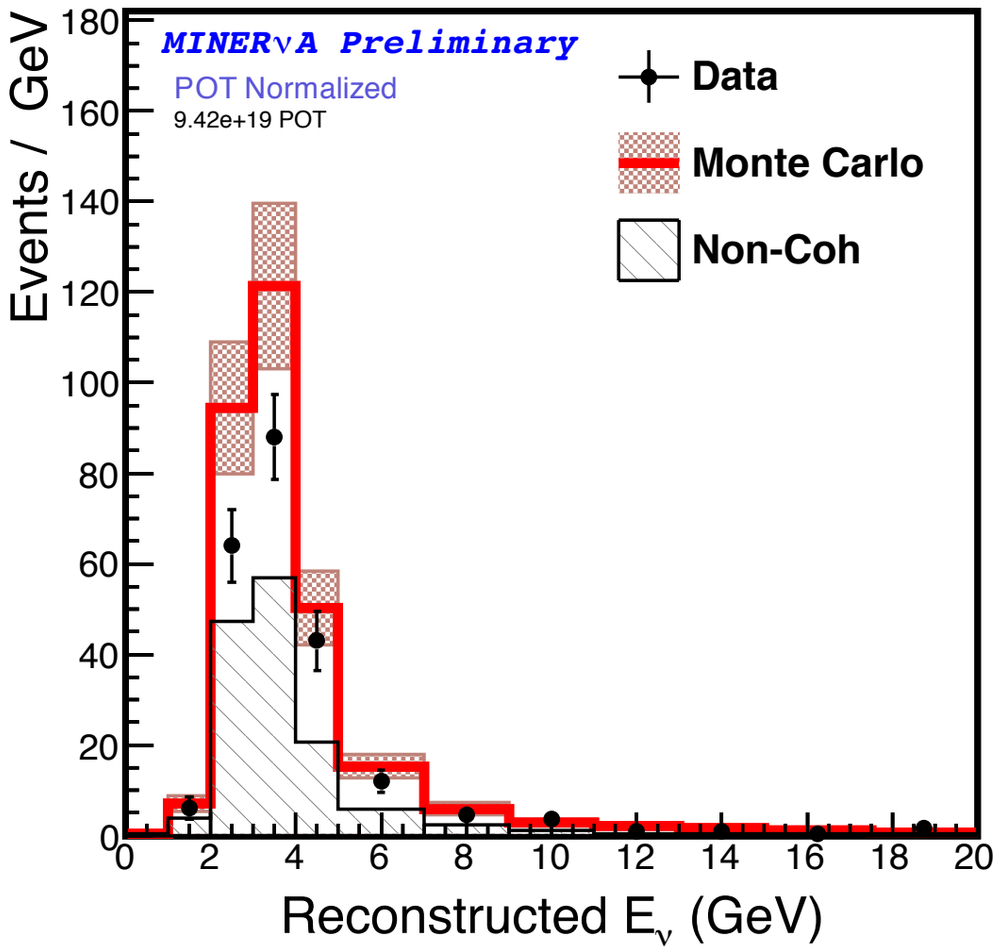
$\nu + A \longrightarrow \mu^- + A + \pi^+$

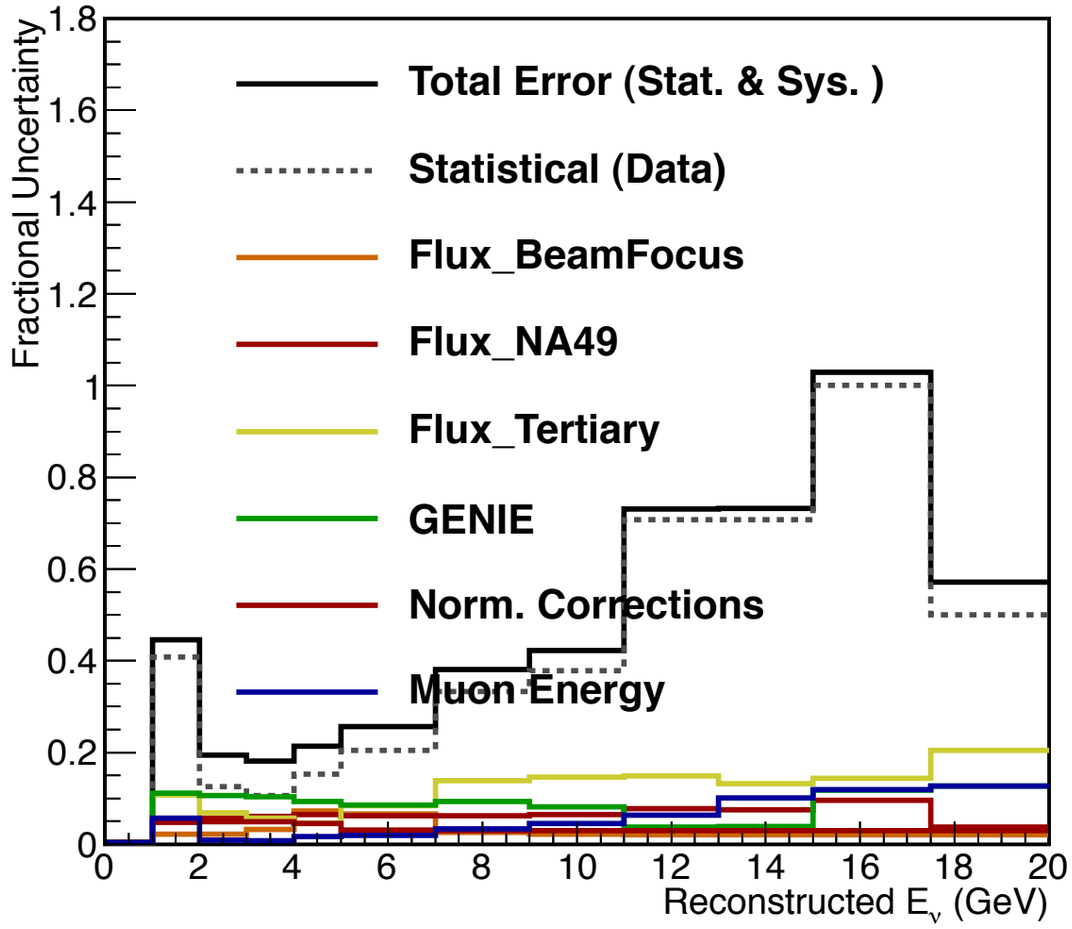




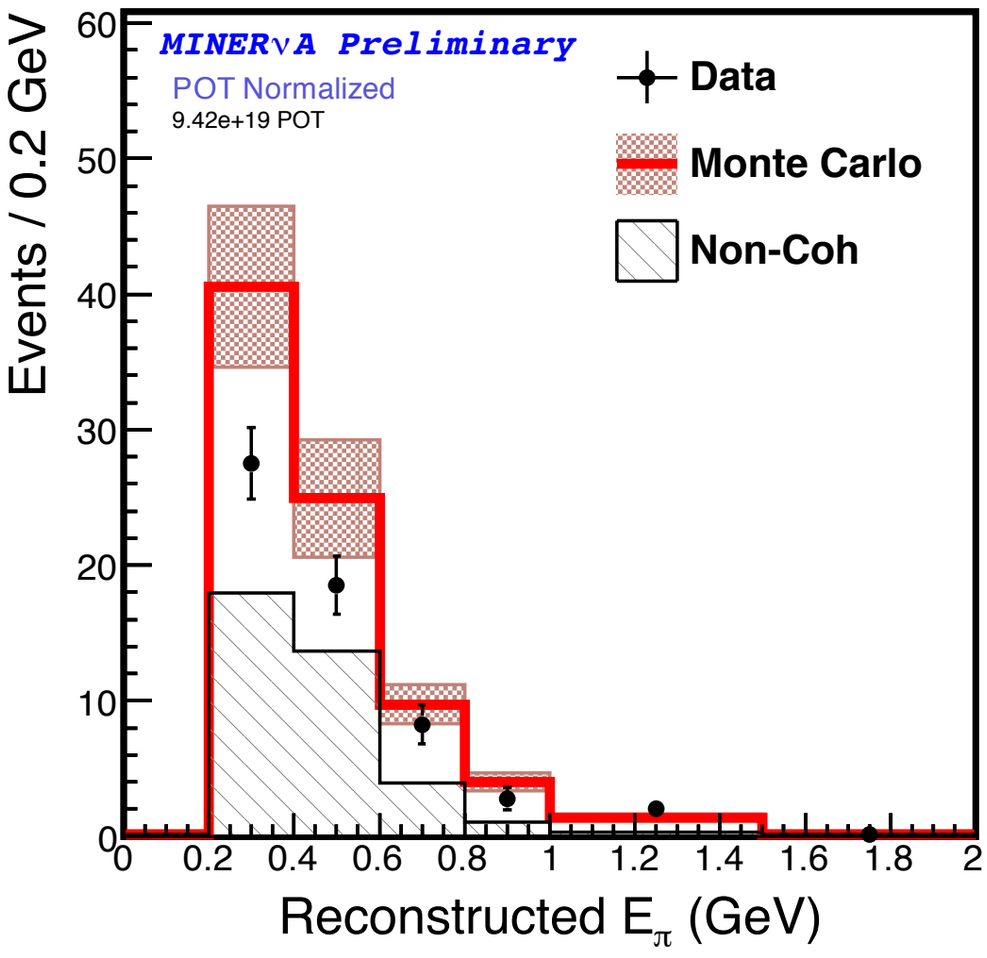
- ☑ Two final states $\mu^- + \pi^+$
- ☑ Small Q^2
- ☑ Nucleus remains in its ground state
- ☑ Small $t = (q-p_\pi)^2$

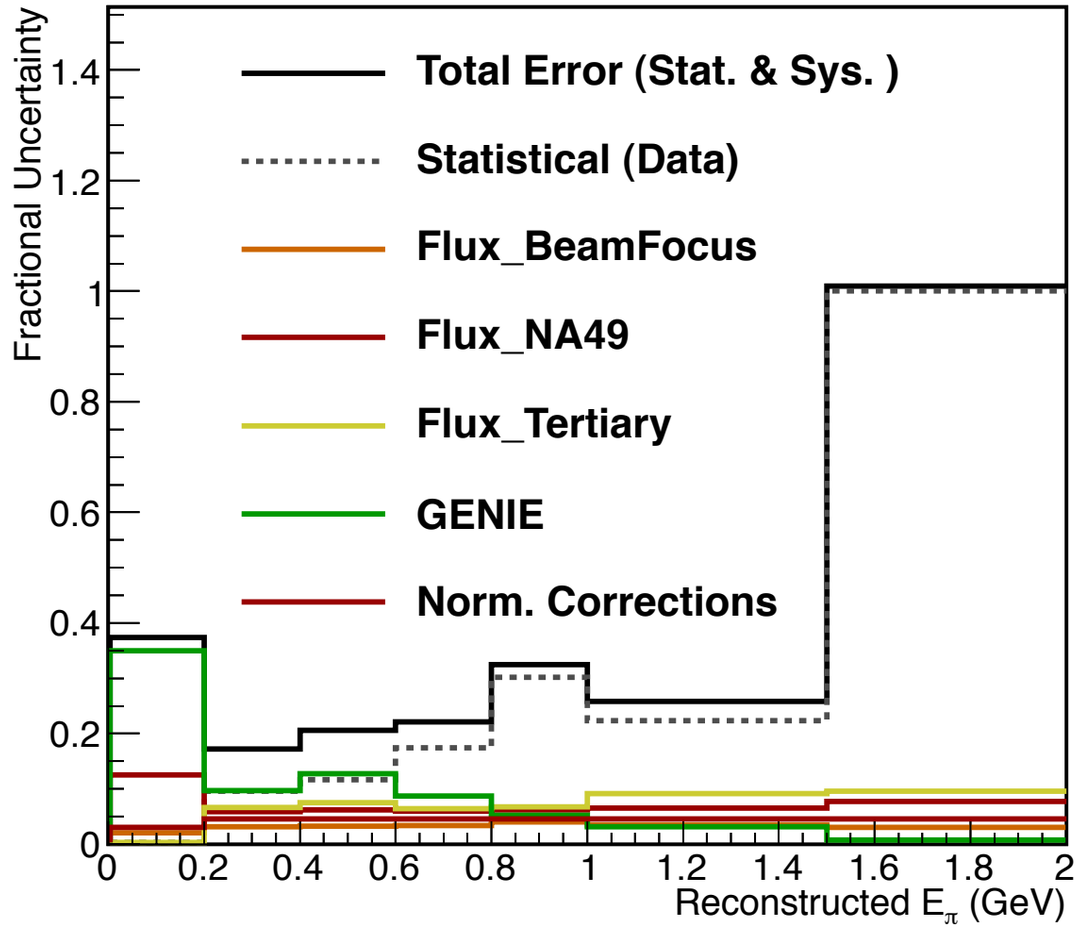
Coherent Candidates



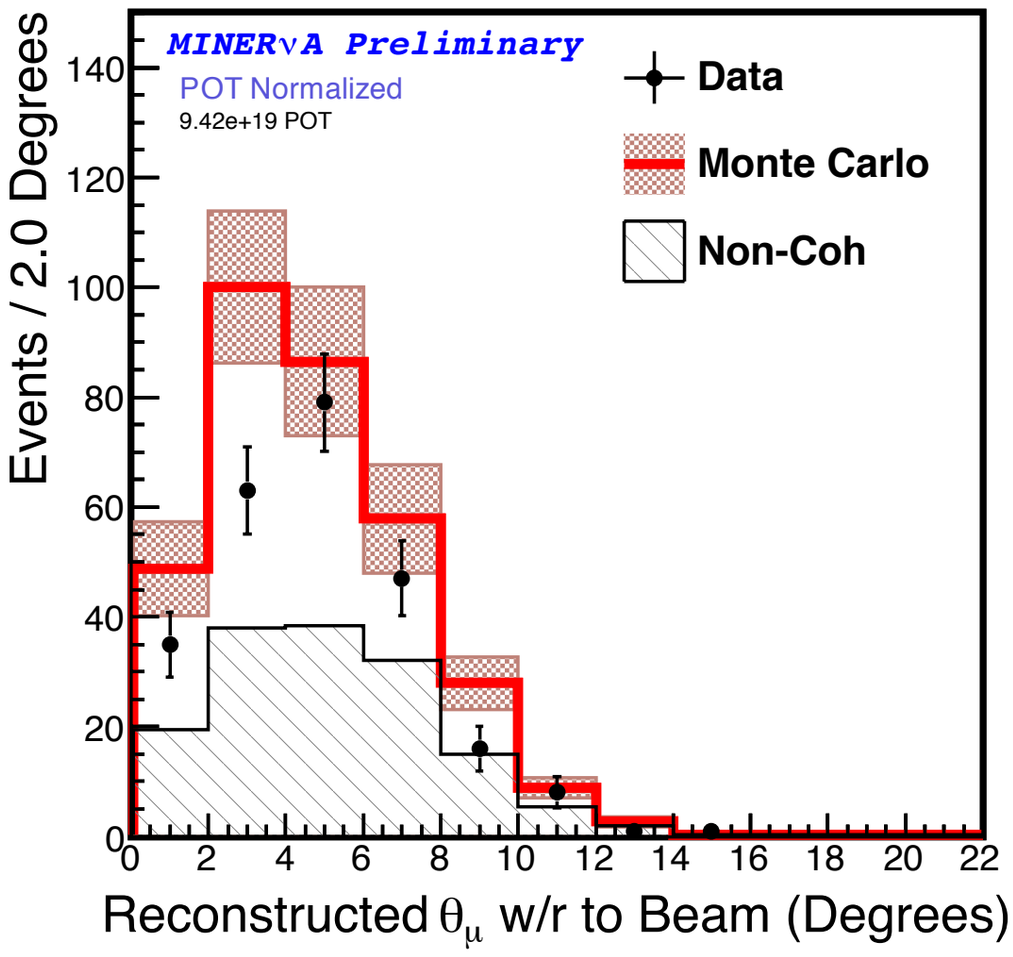


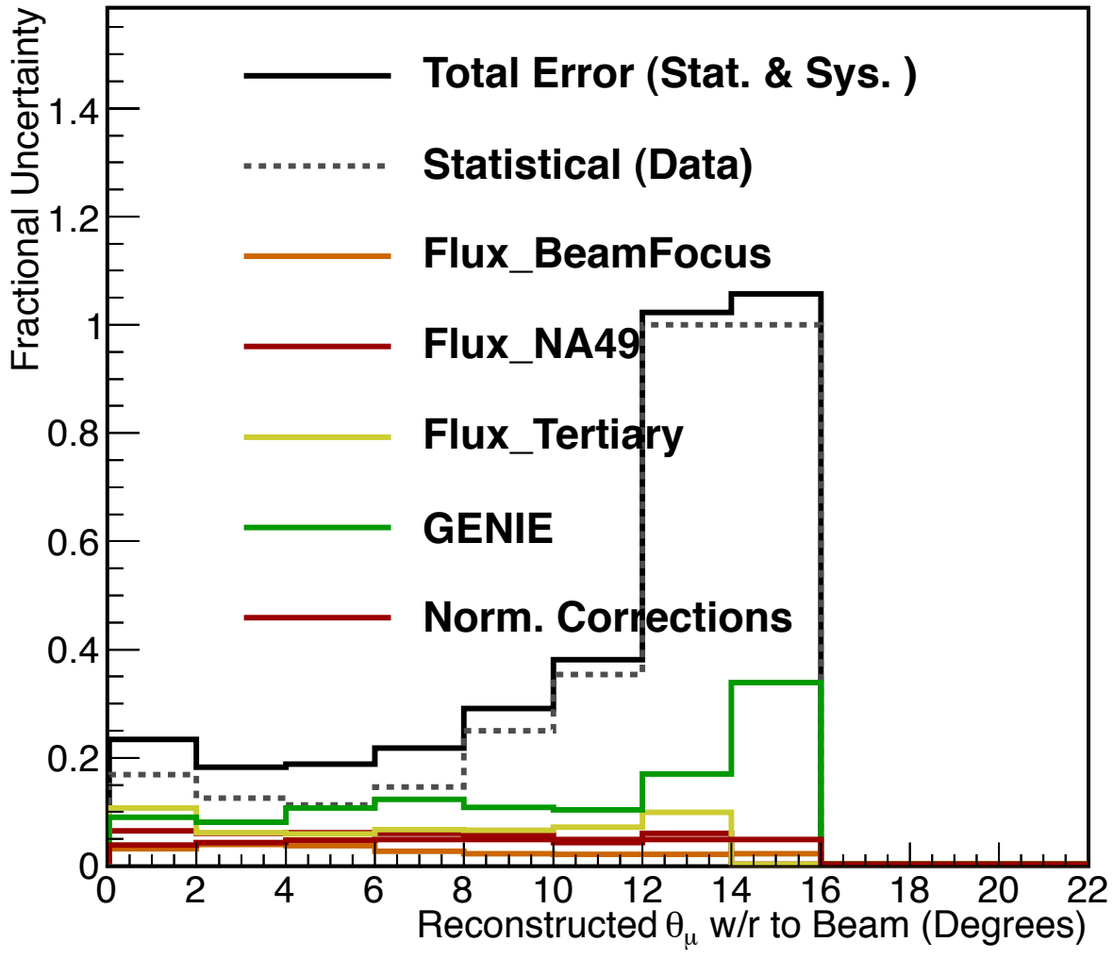
Coherent Candidates



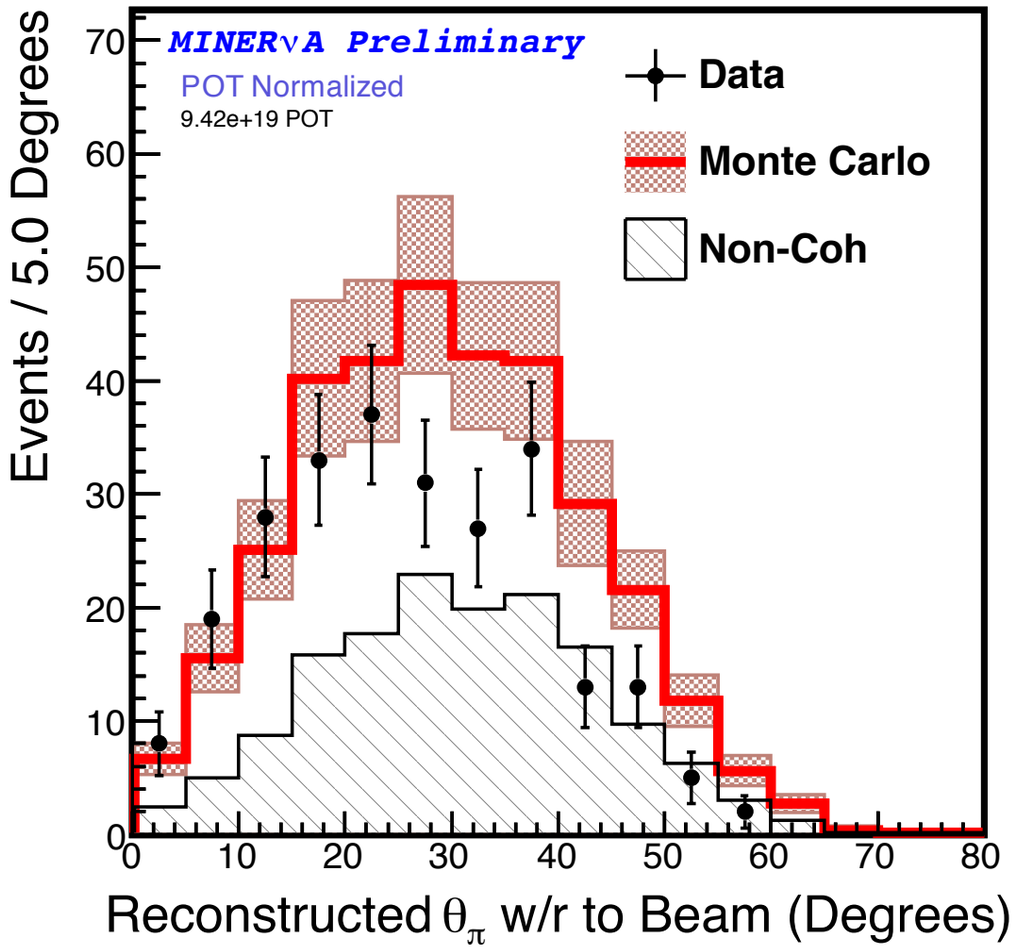


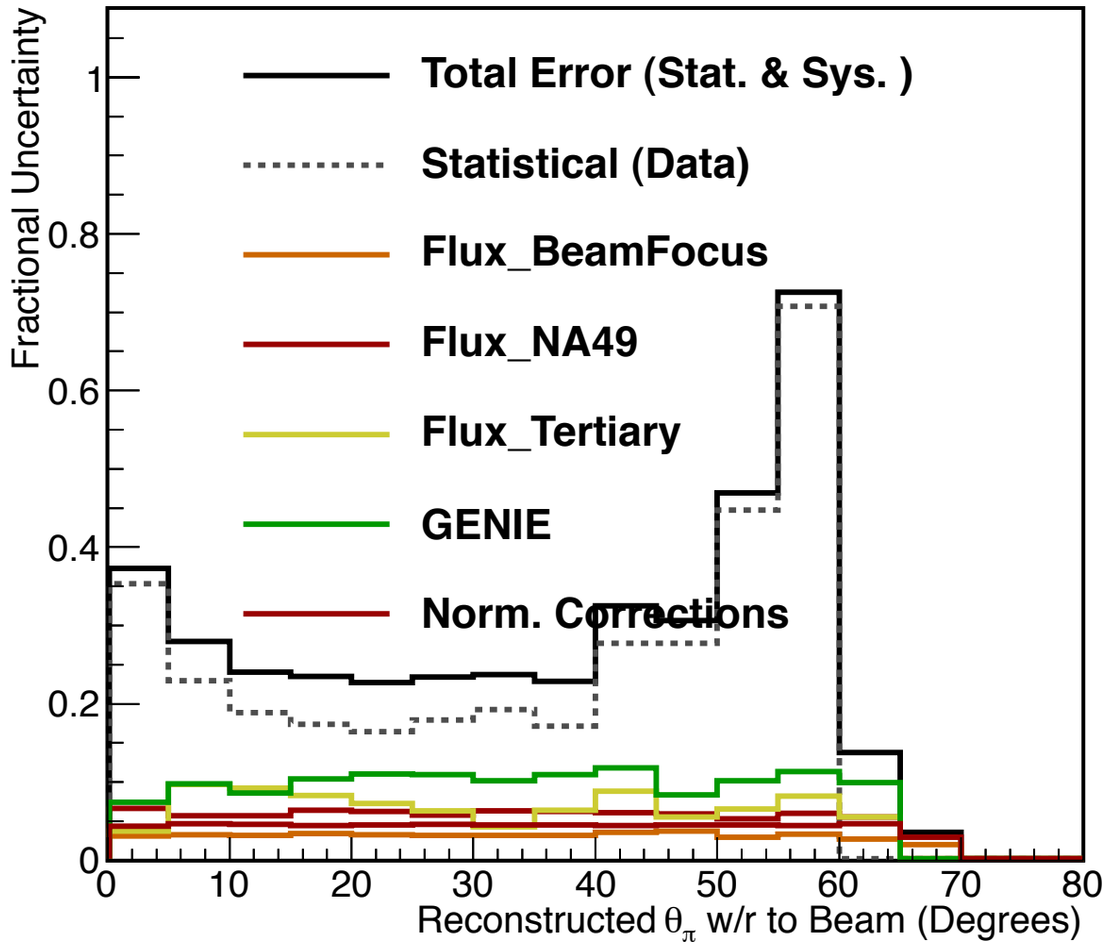
Coherent Candidates



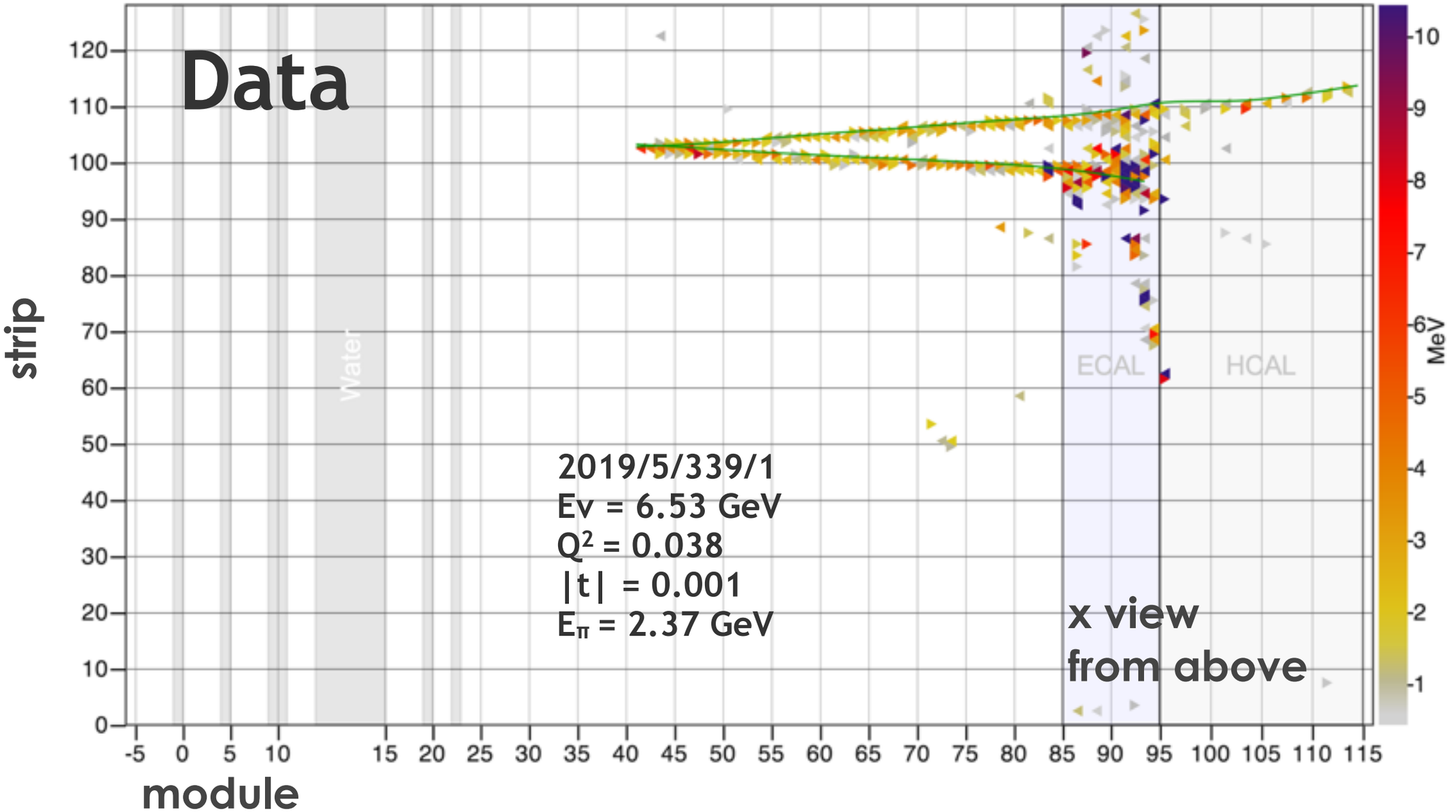


Coherent Candidates





Coherent Candidates



Summary

Rein-Sehgal model agrees with the high energy existing data.

Is there CC coherent pion production at low energies (few GeVs)?

There are new models that predict a small cross section for coherent scattering specially at low energies (Paschos-Schalla, Berge-Sehgal, etc).

MINERvA has analyzed 1/3 of its neutrino data on disk in order to isolate coherent pion production candidates.

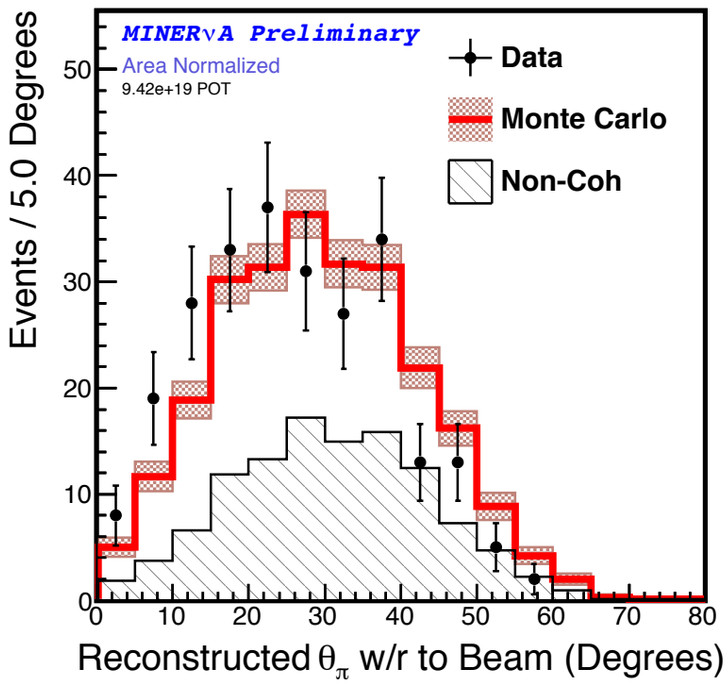
MINERvA will compare its results with the new models.

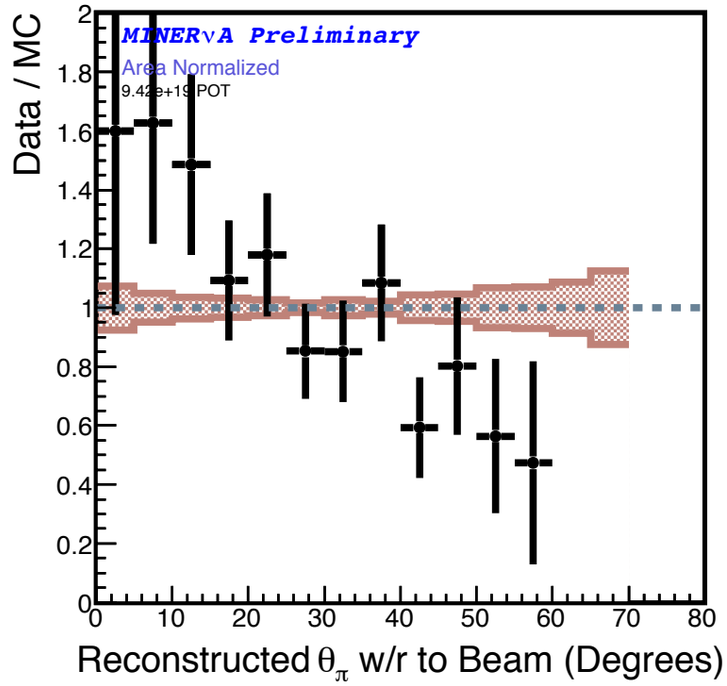
Stay tuned for results soon!!!

Thanks for Listening!

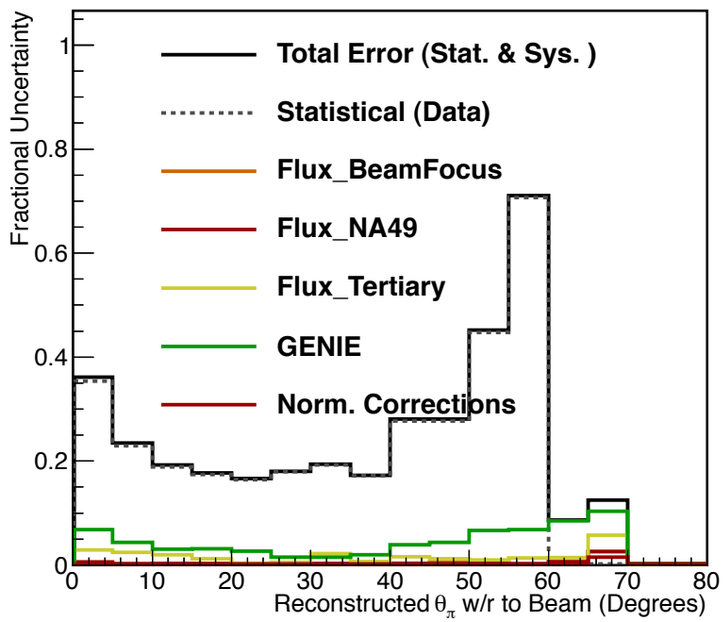
Back-up Slides

Coherent Candidates

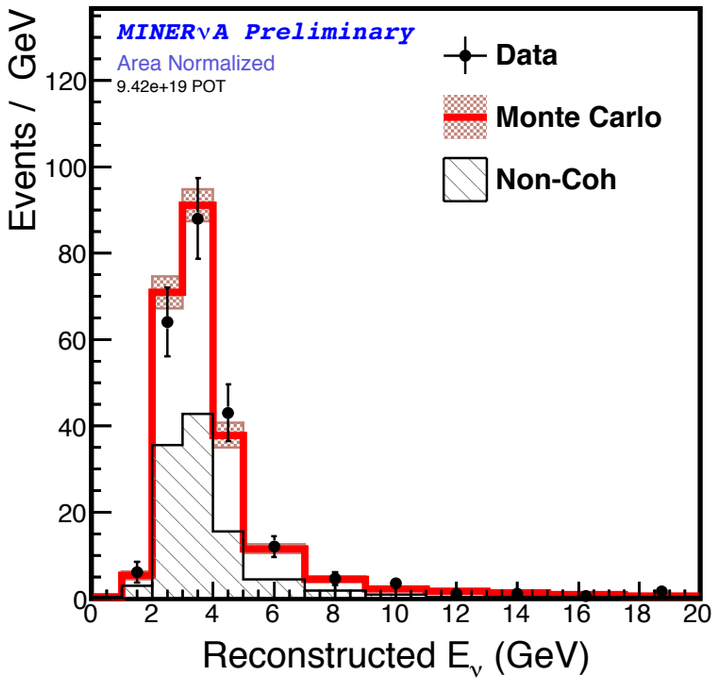


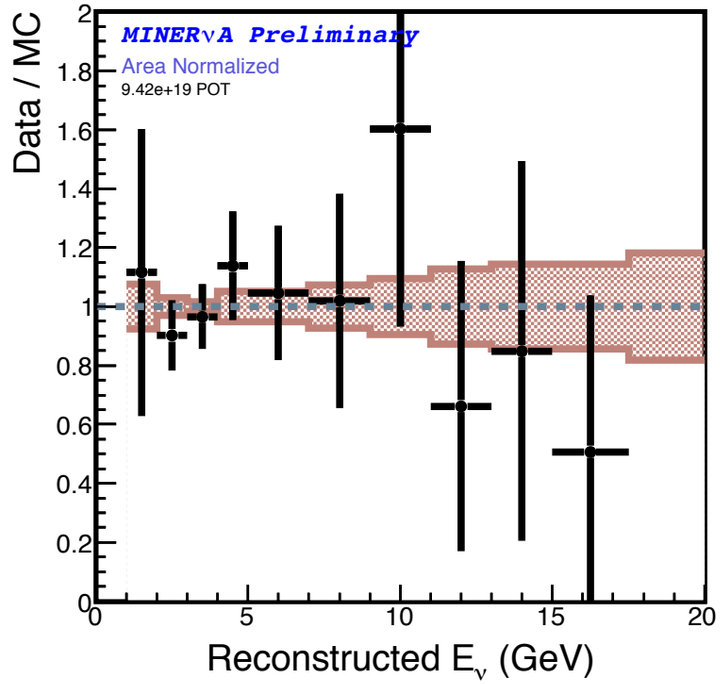


Shape comparison

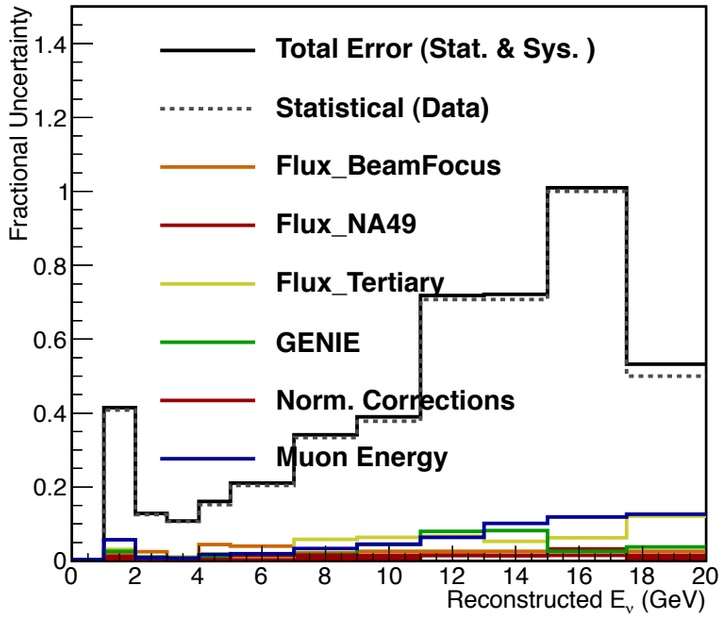


Coherent Candidates





Shape comparison



New Models

There is an updated version of the original Rein-Sehgal model and its extension to charged current reactions made by Berger and Sehgal, where instead of using models for pion nucleus scattering as used in the uses actual data (pion elastic scattering on C) Phys. Rev. D79, 053003 (2009).

Another model especially suited for charged current coherent scattering has been developed by Gounaris, Kartavtsev and Paschos and extended by Paschos and Schalla. As in the previous model πA scattering data are used. This model incorporates the pion-nucleus cross section into the neutrino scattering and uses the lepton mass exactly Phys. Rev D74, 054007 (2006) and Phys. Rev D80, 033305 (2009).

A very different approach describes coherent pion production at very lows energies as the excitation of the Resonance and includes modifications through nuclear medium effects demanding that the nucleus remain in its ground state.