Multi-Beam Strategy for Low Energy Neutrino-Nucleus Cross-Sections

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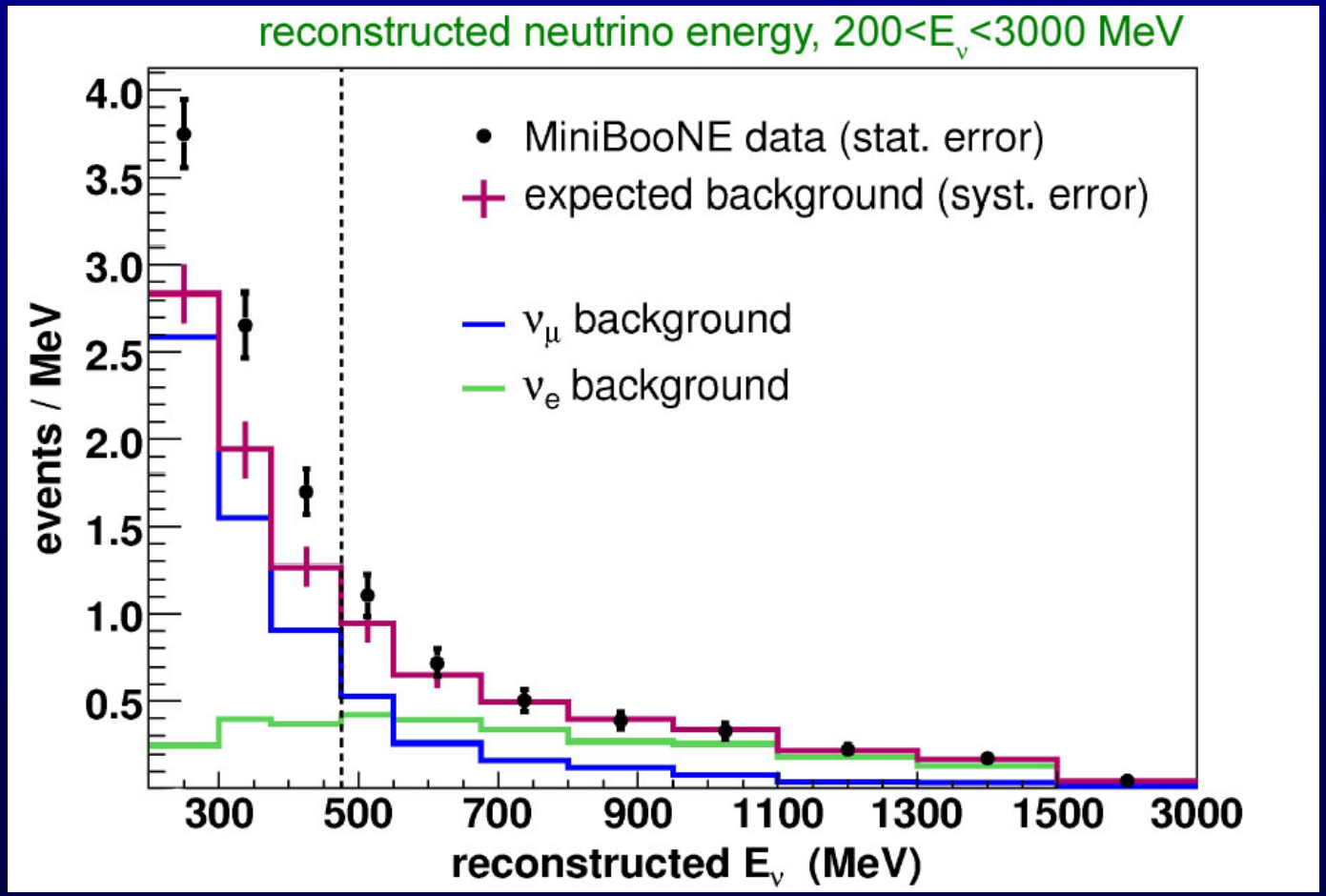
Last year at Pheno …
MiniBooNE Low Energy Excess



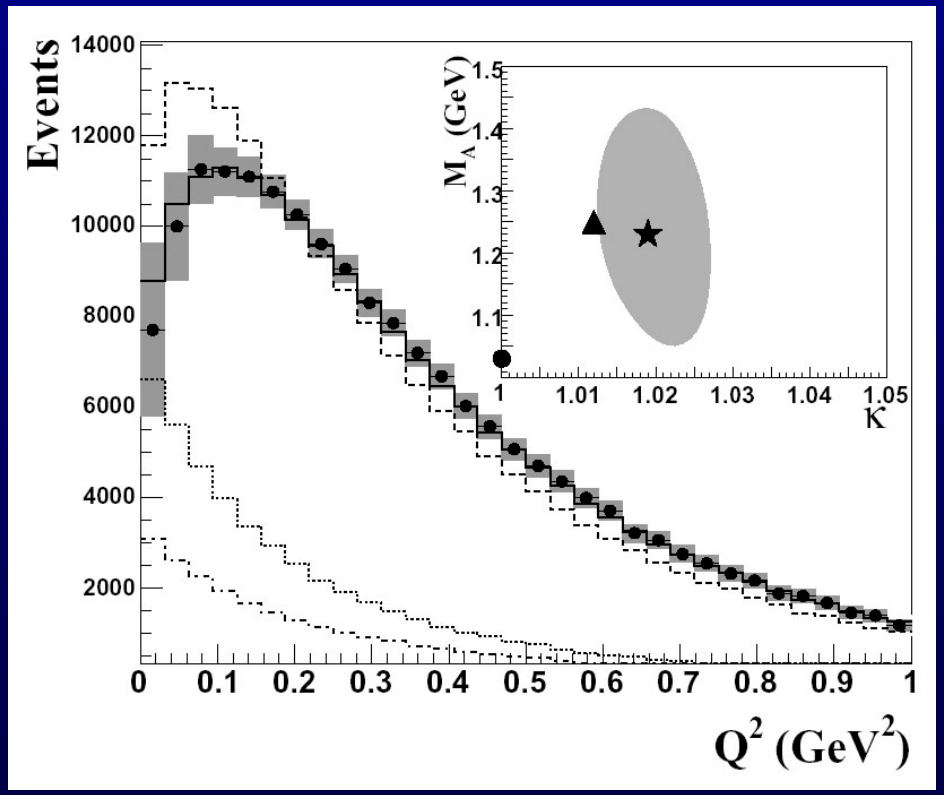
Source: R. Tayloe, Neutrino Oscillation Results from MiniBooNE

Some Ideas to Explain the Low Energy Excess

Sterile Neutrinos (3+2, 3+3 models)	Lorentz Violating Neutrinos
ν_2 decay to ν_1 + unparticle	Shortcuts Through Extra Dimensions
Muon Internal Bremsstrahlung	Nuclear Target Effects in ^{12}C

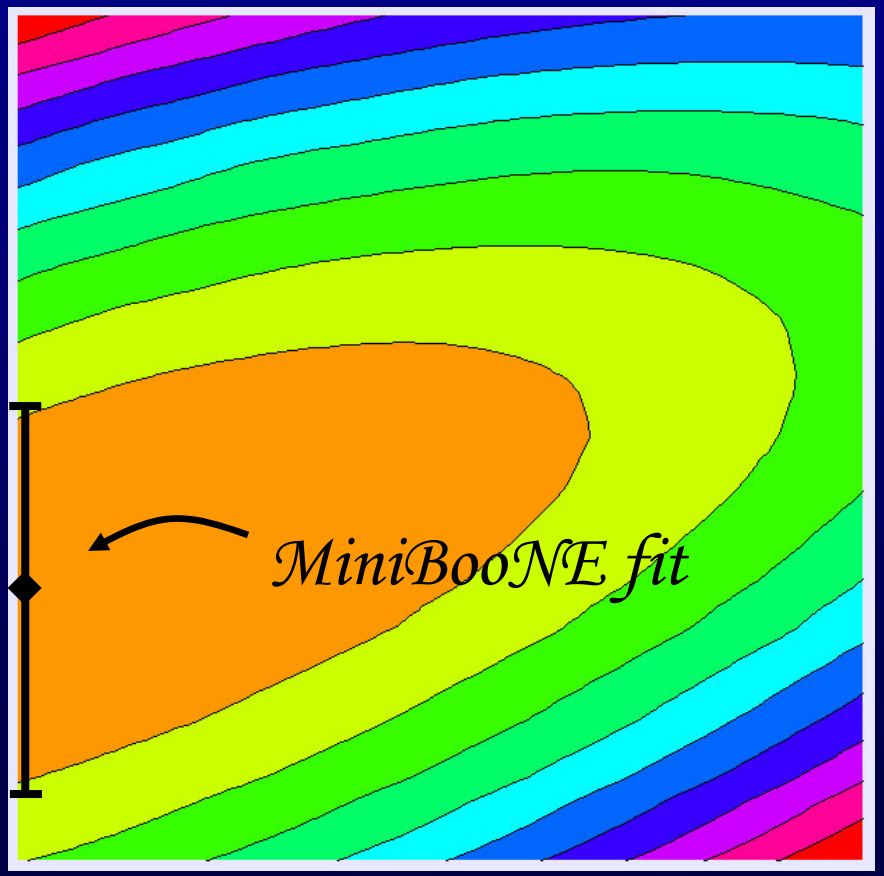
MiniBooNE fits Parameters based on Muon Data …

Pauli-blocking Parameter κ



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

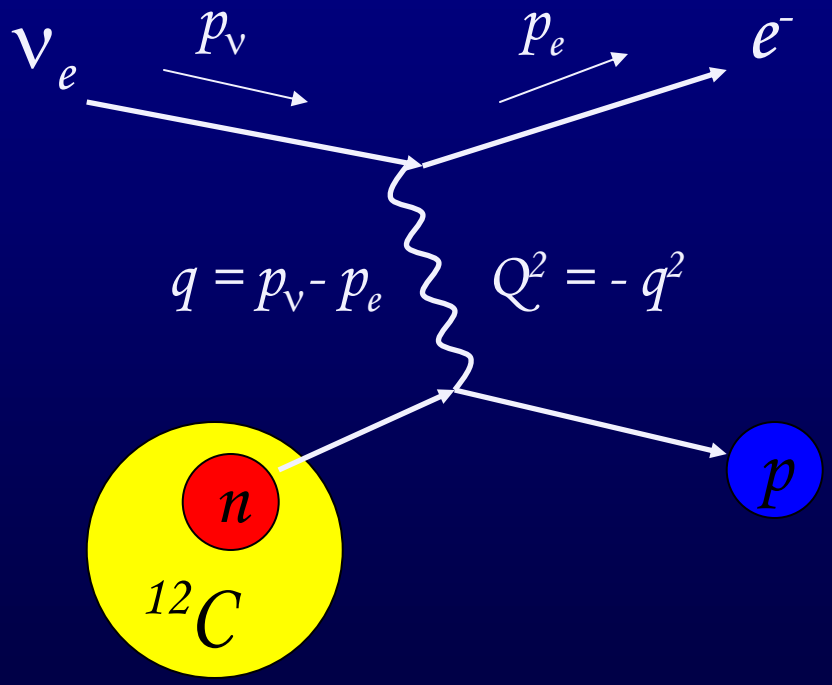
… but neglects Coherent Scattering!



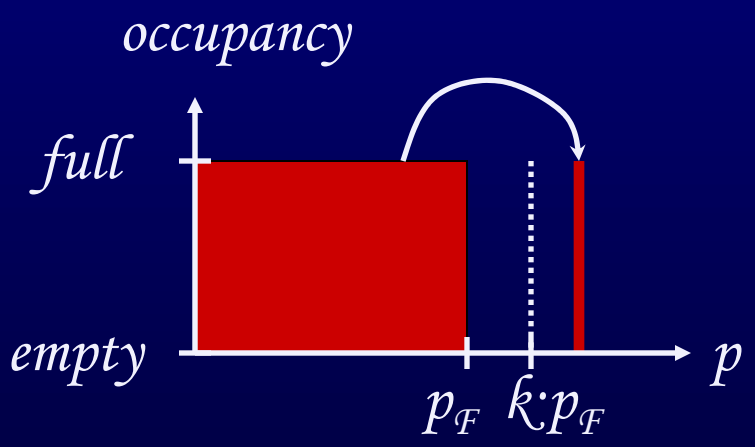
Parameter degeneracy!

MiniBooNE analysis neglects coherent scattering!

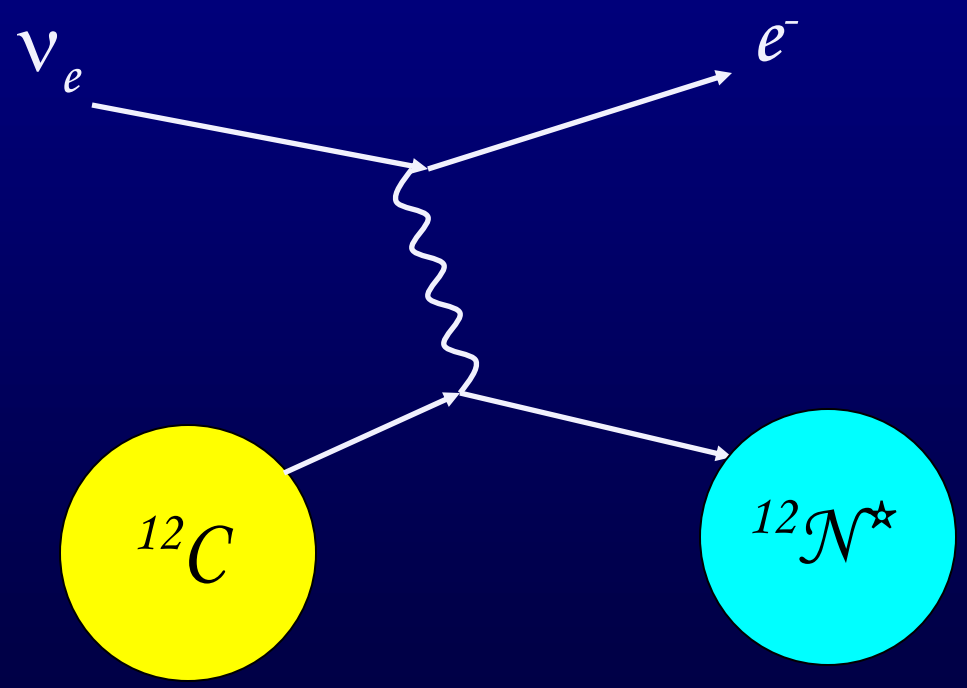
Charged-Current Quasi-Elastic Process "CCQE"



Fermi Gas Model:

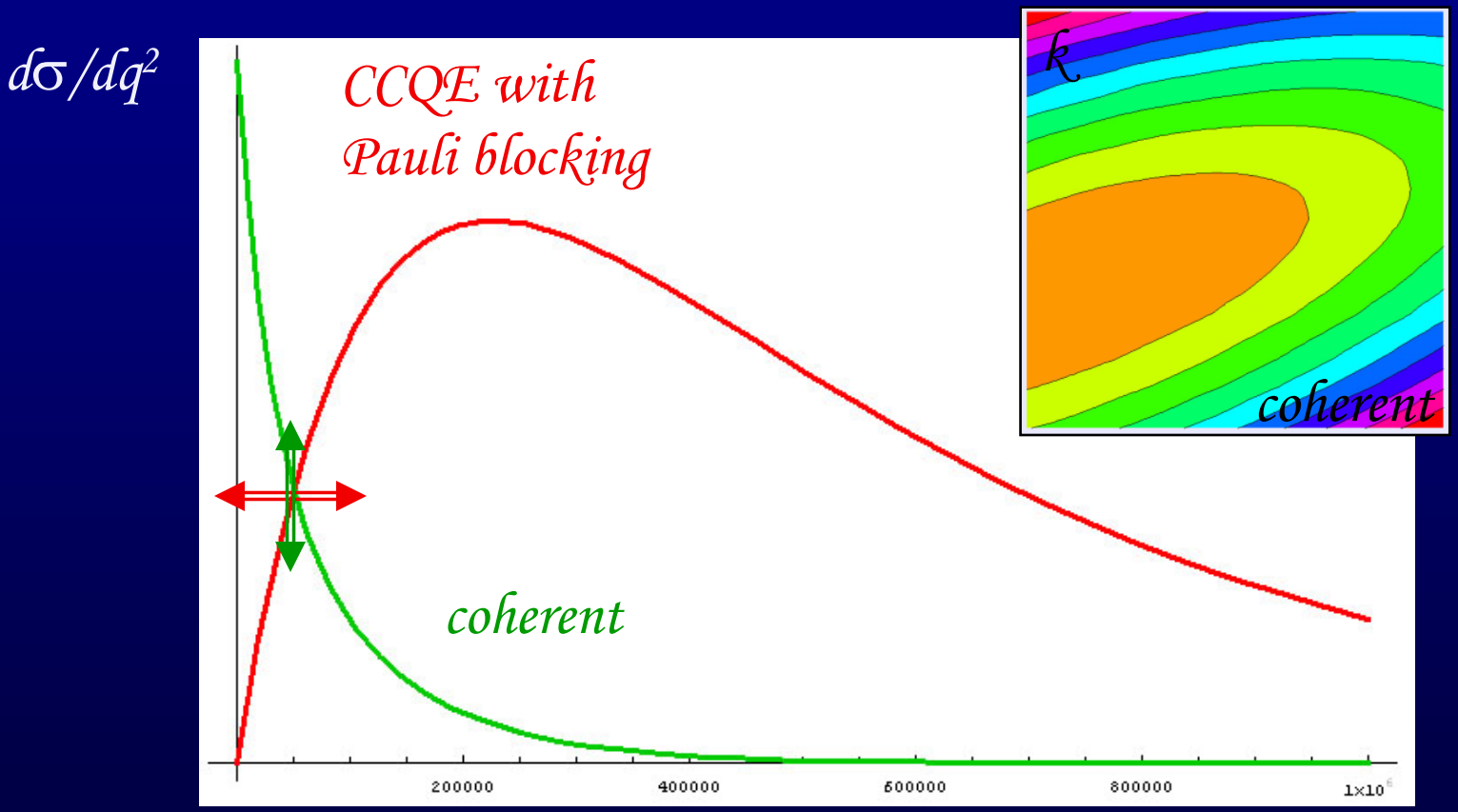


Coherent Scattering



- *Important at lower energies!*
- *Use inclusive cross-section (to ground and excited states)*

Parameter Degeneracy

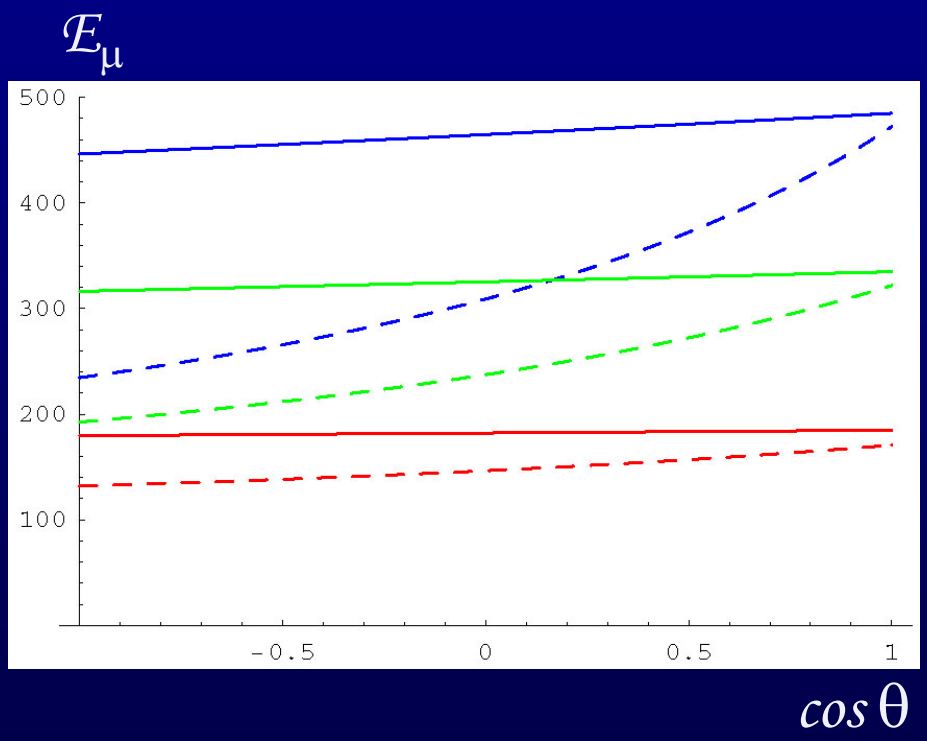


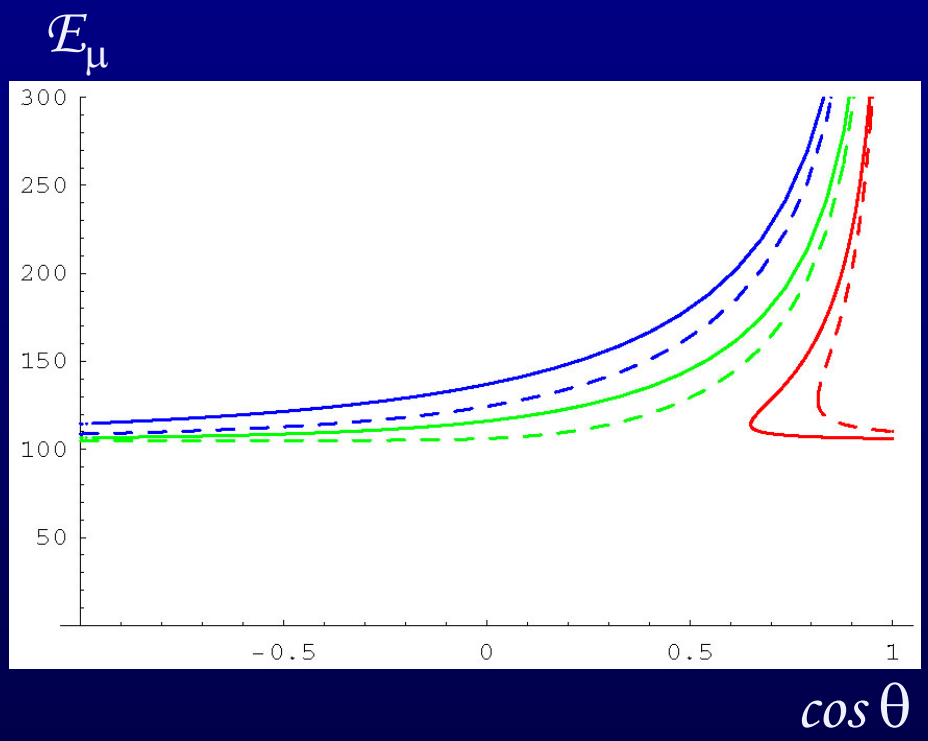
How to Resolve the Parameter Degeneracy

- Measure the recoiled target
  - K2K did this with discouraging results
  - And it gets harder at lower energies!
- Use a monochromatic neutrino beam
  - Only available from charged pion decay, yielding too low energies

Kinematics

coherent —— vs. incoherent (CCQE) - - -





E_ν = 200 MeV, 350 MeV, 500 MeV

Q^2 = (105 MeV)^2, (140 MeV)^2, (176 MeV)^2

Multi-Beam Strategy

event rate *flux*

$$R^A(p,\theta) = \frac{d\sigma_{QE}}{dq^2} f^A(E_\nu | p,\theta,QE) + \frac{d\sigma_{coh}}{dq^2} f^A(E_\nu | p,\theta,coh)$$

Multi-Beam Strategy

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$$R^B(p,\theta) = \frac{d\sigma_{QE}}{dq^2} f^B(E_\nu|p,\theta,QE) + \frac{d\sigma_{coh}}{dq^2} f^B(E_\nu|p,\theta,coh)$$

Multi-Beam Strategy

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Can solve for cross-sections if fluxes are linearly independent:

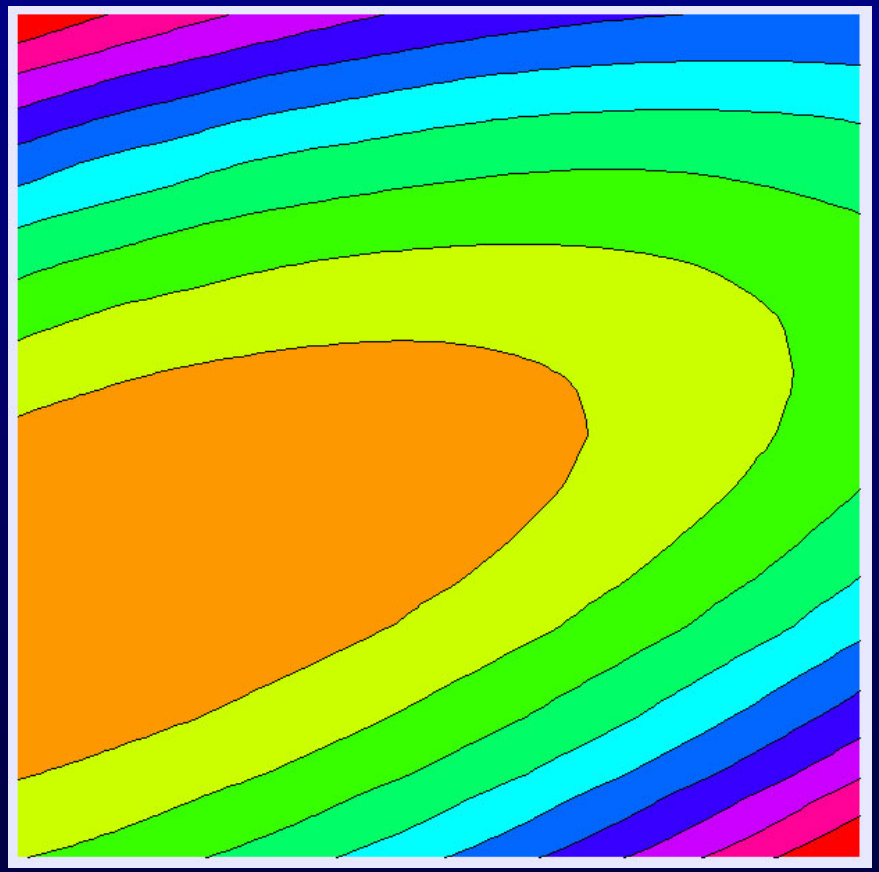
$$f^A(E_\nu|p,\theta,QE) f^B(E_\nu|p,\theta,coh) - f^A(E_\nu|p,\theta,coh) f^B(E_\nu|p,\theta,QE) \neq 0$$

→ *Need two neutrino beams with different neutrino spectra!*

Multi-Beam Strategy

- The "LSND beam" perfectly complements the "MiniBooNE beam" for low energies
- Integrate in (p, θ) space to get better statistics

MiniBooNE

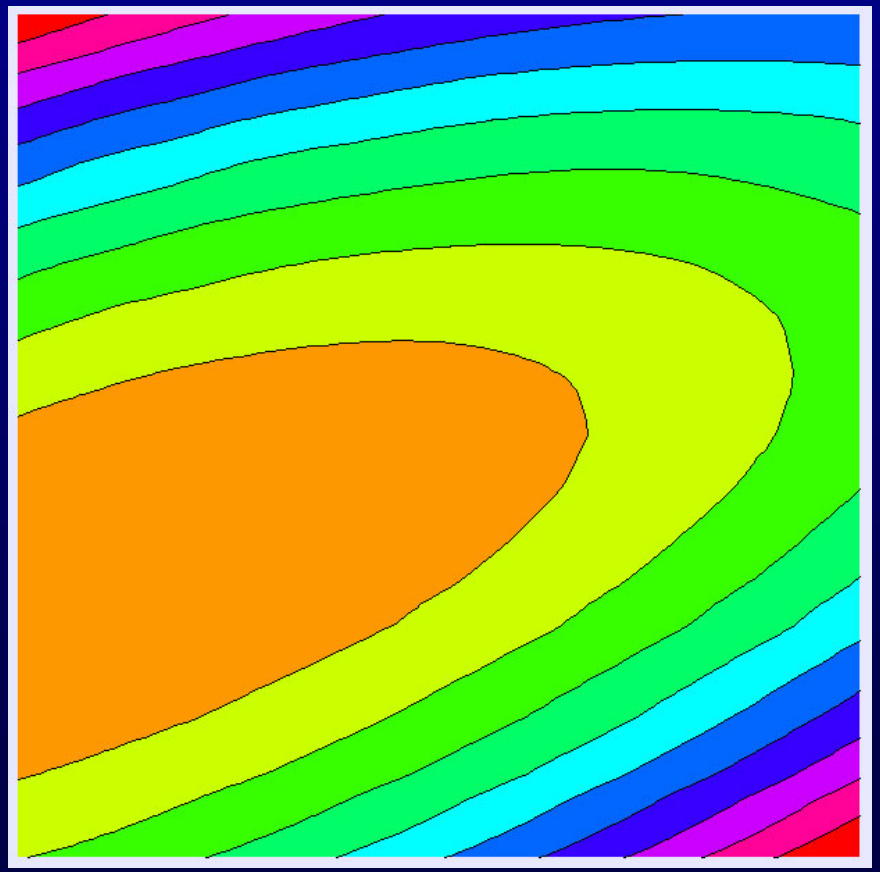


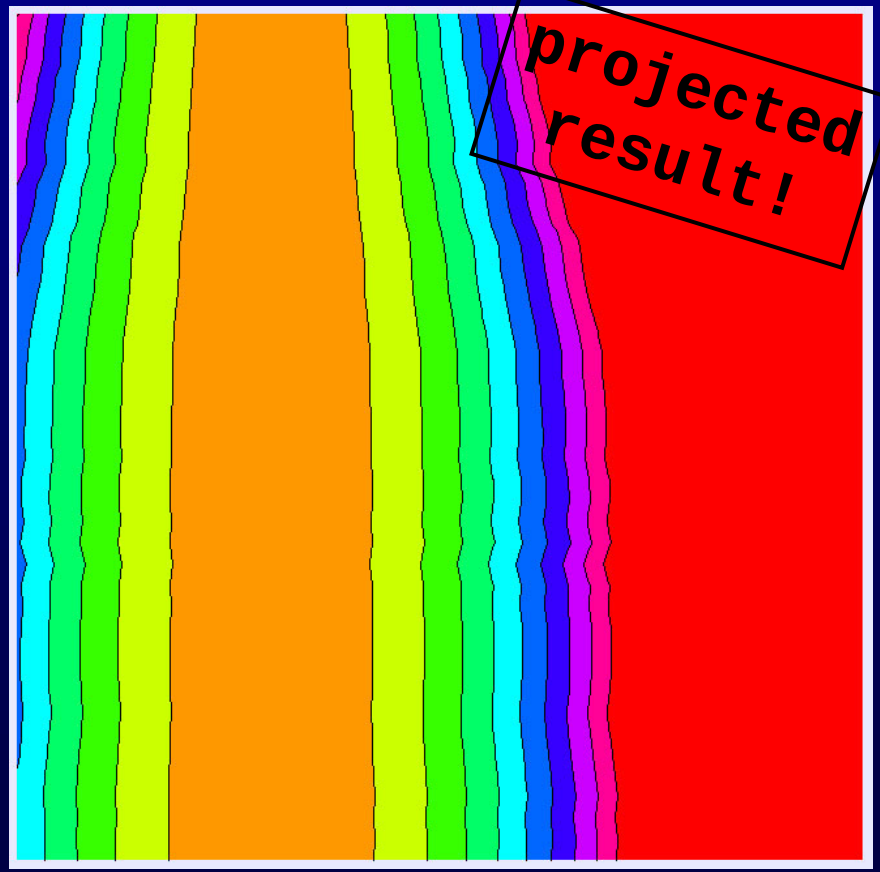
Pauli-blocking Parameter κ

Coherent scattering contribution

MiniBooNE

LSND

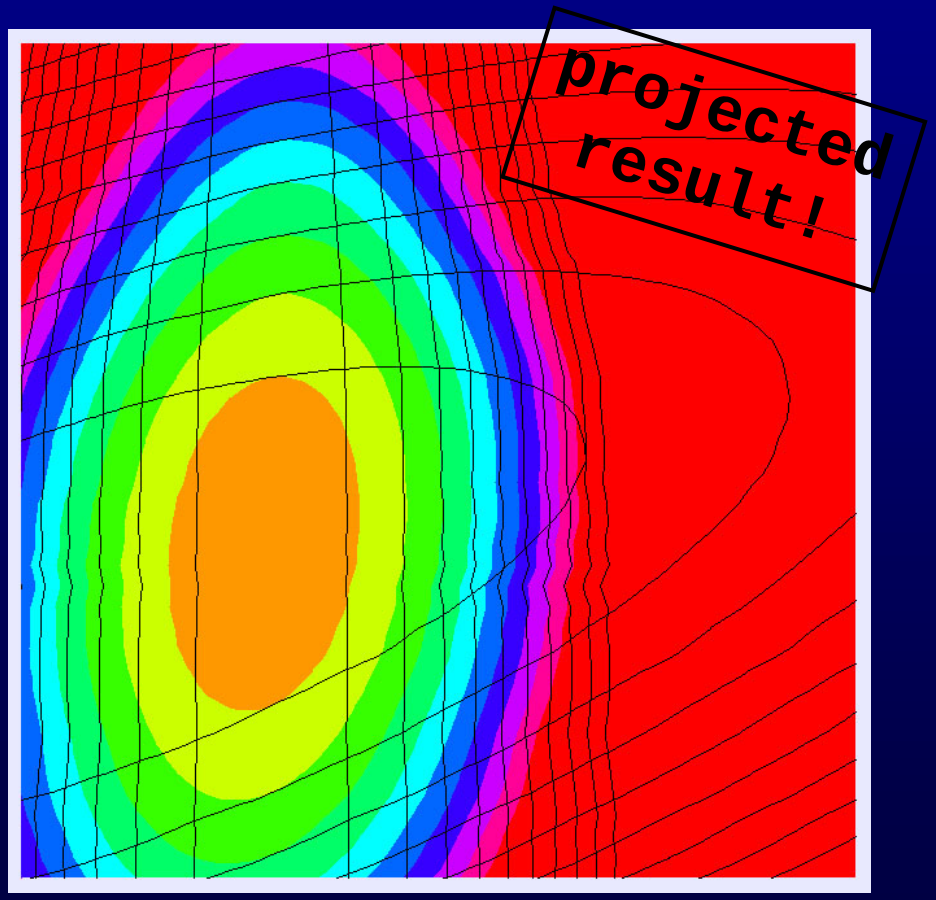




Pauli-blocking Parameter k

Coherent scattering contribution

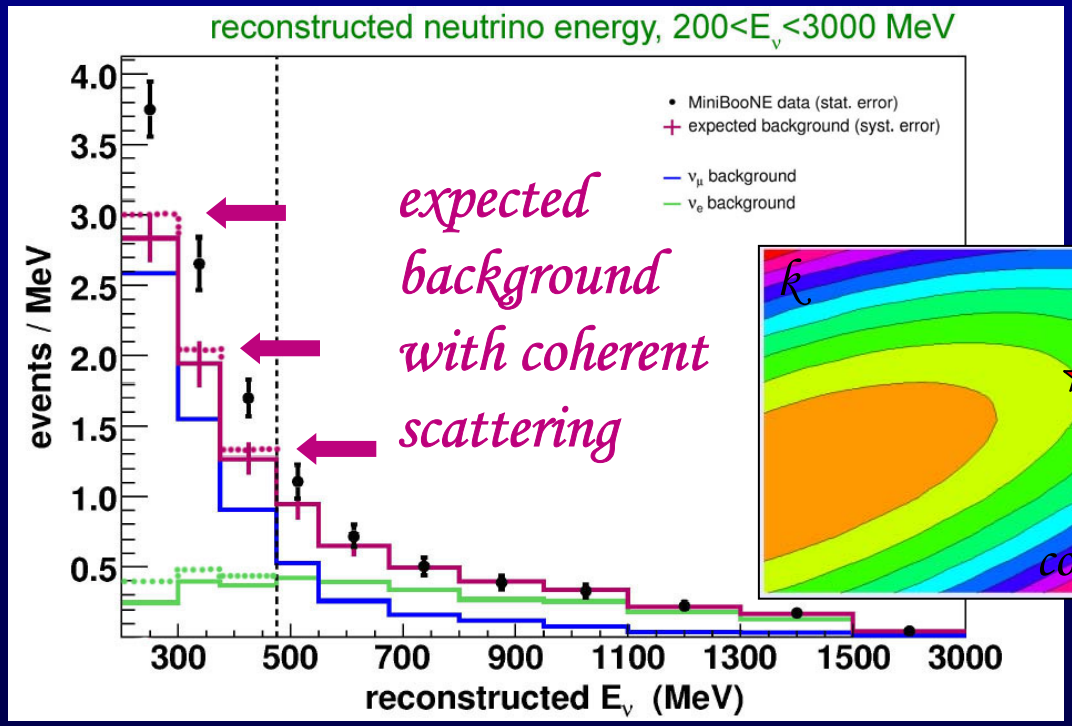
Combined results



Coherent contribution

Degeneracy resolved!

Low E excess revisited



- Even with extreme parameters for coherent scattering, the discrepancy remains
- Is this a real signal, after all?

.... *includes coherent process*

Conclusions

- *Multi-Beam Strategy can resolve the parameter degeneracy*
- *Even extreme parameters don't explain the discrepancy (new physics?)*
- *Coherent contribution is significant, needs to be taken into account in future experiments!*