Some Thoughts on MC Convergence

- first, would like to define what I mean
- two kinds of convergence …

  - "convergence" = experiments all working towards using same MC generator (common basis for comparison)

  - "convergence" = experimentalists & theorists working together to converge on best theoretical description of σ_ν

- the two are obviously related, will focus on the latter

Current Situation

- **experimental side**: use event generators that are based on outdated calcs & range of FSI models that are exp-specific

- **theory side**: a lot of new calcs & theoretical developments

• the two really haven't converged very effectively
(though with concentrated effort, have been making some strides in this direction; but we're still nowhere close to being there yet)

• how do we come together? and how do we move forward?

• my opinion <u>from an experimentalist's perspective</u>
(and based on our experience on MiniBooNE)

How did We Get in this Situation?

- event generators provide everything we need
- initial interactions (ν_μ, $\overline{\nu_\mu}$, ν_e, $\overline{\nu_e}$) + kinems + nucl effects
  - for ex., NUANCE simulates 99 different ν processes (QE, NC EL, 1π, multi-π, coh π, ρ, η, KΛ, KΣ, DIS, e^-)
- full description of final state (what exp sees is only what exits nucleus)
  - final state interaction model (hadron re-scattering)
- meet our practical needs (can generate large MC samples in finite time)

  - can see why have remained married to such generators
    - they provide a complete calculation
    - do a lot of us, hard to abandon
    - non-trivial effort to replace/validate (requires manpower)

What We Need for Experiments

in order to converge, first need to know what we need

for experimental simulations …

- ideal if are provided **actual code**
  - models are now more complex
  - coding from papers prone to error
  - experiments don't always have this manpower
  - code must run in finite amount of time
- clearly define **region of validity**
  - need to know where model performs reliably
  - some understanding of uncertainties
- need to know **how to patch in** new calculation
  - want models that match up smoothly
  - need to be able to describe broad kinematic range

need to work closely together

- this is what need from theorists

- what experiments can provide are σ_ν measurements

Two Different Modes Exps Operate In

(1) ν oscillation experiments (specific use)

- σ_ν results produced for internal use by experiment
- interested in specific σ_ν processes needed to predict signal rates and backgrounds
- absolute flux not so important (N/F)

(2) ν cross section experiments (general purpose)

- σ_ν results produced for general use by people outside the experiment (theorists to test & improve their calcs, or other experiments to use)
- in this case, interested in physics interpretation of data & overall utility
- carefully define what you are measuring (correcting out FS effects?)
- places new demands on flux determination (absolute σ's)

- these two do not always want/need the same thing
- MiniBooNE has moved from mode (1) to (2)

Reality of a ν Oscillation Experiment

(σ's for specific use)

- MiniBooNE is first and foremost a ν oscillation experiment
  (this was our primary focus and first job had to get done)
- had to do what you have to do; tuned up existing models
  (timely and effective)
- produced two results for ν_e appearance analysis:

  1 - **M_A, κ fit results** (PRL 100, 032301 (2008))
  driven by need to simulate QE kinem on nuclear target
  RFG works with M_A, κ adjustments (?!)

  2 - **π^0 mom tuning & NC coh π^0 fraction** (PLB 664, 41 (2008))
  driven by need to predict NC π^0 bkgs as fcn p_π, θ_π

- crucial for MB osc analysis (perhaps not so useful to theorists, outlined technique!)

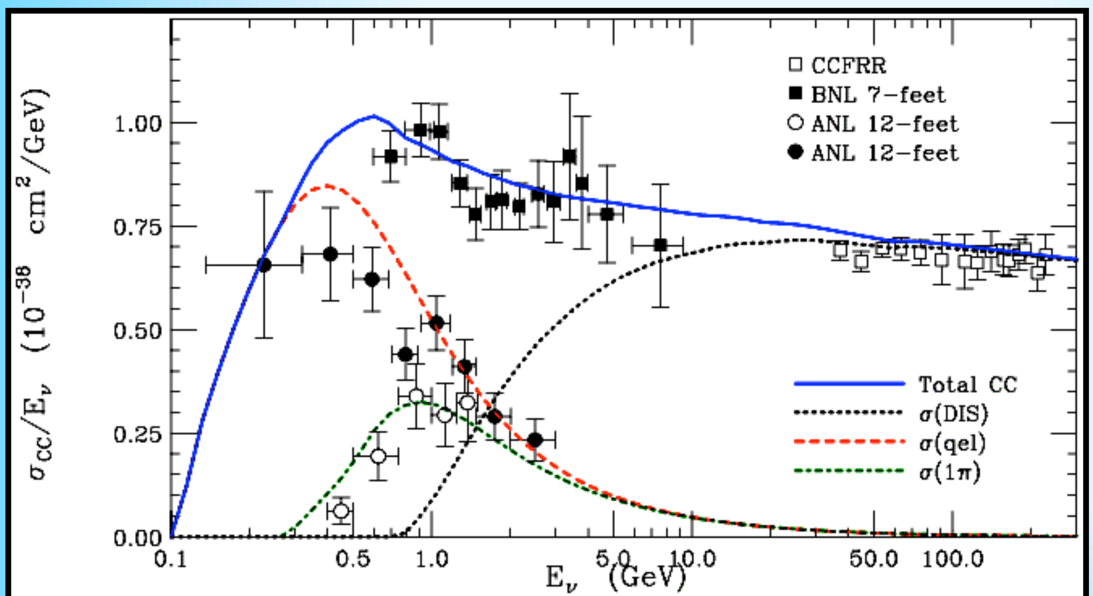
Cross Section Measurements

(σ's for general use)

- have realized that maybe part of the problem is that theorists have not had new ν data to work with
- MiniBooNE approach has been to make our data available
  - moving from specific use to general use
  - not only σ ratios but absolute cross sections
  - concerted effort to break circular argument used by many past experiments: do NOT use same data to extract flux & then turn around to measure σ!
- hope is that, in return, theorists can give us improved models with full kinematic coverage (make data available & then this is clear)
- overall philosophy: report what we measure (minimize corrections)
- thought hard about reducing model dependence of results

Reducing Model Dependence

- realized that it's not enough to compare M_A values (model dependent) or to just simply populate "Lipari plot"



- what experiments reported in the past with limited statistics
- should not just repeat the past
- we need to do better to make progress

- how determine E_ν? often, to form E_ν one has to assume a model
- have the results been corrected for final state/nuclear effects?

MiniBooNE Approach

- reduce dependence of event selection on physics model
  - heavy use of muon decay tag in selecting events - doesn't rely on physics model
- report differential or double-differential cross sections
  - move away from $\sigma(E_\nu)$ although we do provide for historical comparison
- report "observed" cross sections (report what we measure)
  - do not correct out FSI effects like π absorption & charge exchange which are large and depend on a model (to allow theorists to plug in their own model to test and not have to undo what the experiment has done)
- thanks to theorists for feedback!

	# events	purity	MiniBooNE σ results
CC π^+/QE ratio (S. Linden, J. Nowak)	193,000 QE 46,000 CC π^+	83% (72%) 92% (87%)	observed ratio in E_ν (& FSI-corr) Q^2 studies in CC π^+ sample
ν_μ CCQE (T. Katori)	146,000	76%	$d^2\sigma/dT_\mu d\theta_\mu$ $d\sigma/dQ^2$, $\sigma(E_\nu)$
ν_μ NC EL (D. Perevalov)	94,000	65% (80% w/ Irreducibles)	$d\sigma/dQ^2$
ν_μ CC π^+ (M. Wilking)	48,000	90%	$d\sigma/dT_\mu$, $d\sigma/d\theta_\mu$, $d^2\sigma/dT_\mu d\theta_\mu$ $d\sigma/dT_\pi$, $d\sigma/d\theta_\pi$, $d^2\sigma/dT_\pi d\theta_\pi$ $d\sigma/dQ^2$, $\sigma(E_\nu)$
ν_μ NC π^0 $\overline{\nu}_\mu$ NC π^0 (C. Anderson)	21,000 2,000	73% 58% ($\overline{\nu}$-only)	$d\sigma/dp_\pi$ $d\sigma/d\theta_\pi$ total observed NC $1\pi^0$ σ
ν_μ CC π^0 (B. Nelson)	9,000	62%	kinematic comparisons
$\overline{\nu}_\mu$ CCQE (J. Grange)	27,000	54% ($\overline{\nu}$-only)	M_A, κ

Conclusions

- **as experimentalists:**
  - need to make our data available in a way that is useful (need to make every attempt to reduce model dependence of results)
  - rethink what we report (need to move beyond comparing M_A, $\sigma(E_\nu)$)
  - define what we need (as specifically as possible down to code level; nice if all experiments have the same structure so theorists have to code only once)
- **as theorists:**
  - ideal if can provide experiments with actual code
  - define region of validity of model (where is it safe to use?)
  - guidance on how to put everything together (initial ν interaction + nuclear re-interactions; how to describe full kinematic range?)