Discussion on "Detector" Systematics

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based on discussion with Tiago Alves (Imperial College London) et al.

The starting point

Recent studies have provided detailed parameterisations of flux systematics, a lot of work is ongoing on neutrino interactions, but for "detector" systematics there has been ~no update w.r.t. TDR (or even CDR…)

Some talks that addressed this:

Chris Marshall "Energy uncertainties in LBL analysis"
on 23/11/2023 at Calibration WG meeting

Tiago Alves "Detector systematics"
on 01/11/2024 at joint LBL + ND Sim/Reco meeting

FD in the "TDR" Analysis (from Chris' talk)

- Energy is purely calorimetric, there is no attempt to do particle ID (besides the lepton), correct for recombination, etc.

- There are no uncertainties in the reconstruction or event selection

- "Detector" uncertainties are implemented with a 19-parameter model based on other experiments

FD in the "TDR" Analysis: can we do better?

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A lot of work is already ongoing to improve the reconstruction
incomplete list :
- muon momentum (Henrique, Anselmo)
- electron shower energy (Ginevra)
- neutrino energy (Henrique, Pierre, Marcelo)
- neutrino direction for atmospherics (Pierre)
- …

Some discussion and new activity is probably needed

cfr joint LBL + ND Sim/Reco meetings "aimed at developing ND analyses and systematic uncertainties towards the ND TDR and for future LBL sensitivity updates"

"Detector" uncertainties in TDR analysis

- Energy scale : $E'_{rec} = E_{rec} \times (p_0 + p_1 \sqrt{E_{rec}} + \frac{p_2}{\sqrt{E_{rec}}})$

  - some dependence on <u>energy</u>
 - 3 parameters per particle type, varied at fit time

  > Parameter values are educated guesses from other experiments, calorimetric (NOvA, MINERVA) or LArTPCs (LArIAT, MicroBooNE, ArgoNeuT)

Particle type	Allowed variation		
	p_0	p_1	p_2
all (except muons)	2%	1%	2%
μ (range)	2%	2%	2%
μ (curvature)	1%	1%	1%
p, $\pi^\pm$	5%	5%	5%
e, γ, π^0	2.5%	2.5%	2.5%
n	20%	30%	30%

- Energy resolution: uncertainties on the width of the measured energy
  - 4 parameters (for µ, charged had., E.M., n)

- Direction: nothing
  - not used in LBL analysis, but will be relevant for atmospherics!

Workflow (Tiago for ND)

(See details in [Tiago's talk](#))
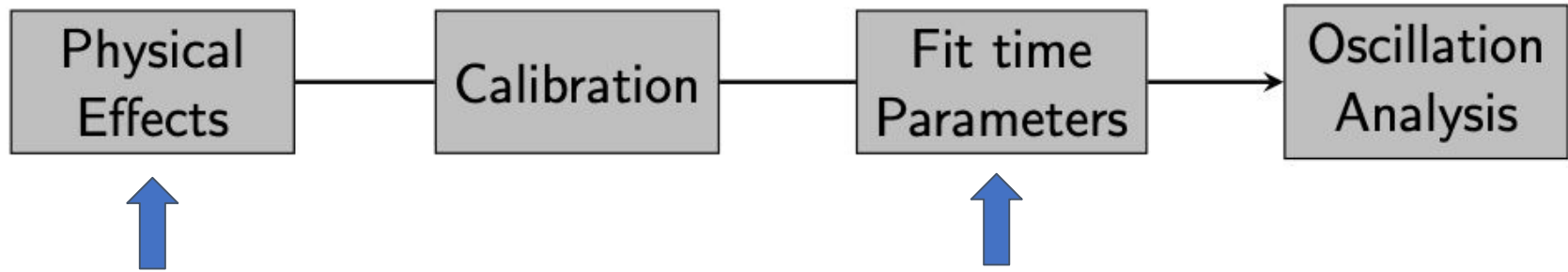
- the Sim/Reco group should play a role mainly for "Physical Effects""
- but also for "fit time parameters"
  - to decide which effects to include individually or a grouped way
  - and to make sure the necessary variables are available at fit time

Questions for discussion in the FD Sim/Reco group

- Which physical effects should be considered?

  Tiago's list for ND

  - some <u>detector effects</u> are already discussed, more (containment, E non-uniformity, gaps, space charge..) or less (channel efficiencies, field response, short track dE/dx..) extensively
  - should also add effects from <u>selection</u> and <u>reconstruction</u>

- How to study them?
  - apply effects to existing reco files? run dedicated simulations? use interpolations (e.g. SnowStorm)? …

- What is the size of the associated uncertainties?

  example @ND:
  Tiago is studying the dependence on position of TMS momentum reco for non-contained muons

  - to be (re)discussed with Calibration WG for <u>detector effects</u>
  - and also with ProtoDUNE DRA for <u>selection</u> and <u>reconstruction</u>

- Which physical variables do they depend on?
  - parametrize uncertainties also as a function of position? direction? …

- Are the necessary variables stored in the CAF files for use at osc. fit time?

Conclusions

- Should we reconsider the systematics related to <u>detector and reconstruction</u> at the FD, to update the TDR parameterisations in view of future oscillation analyses?

- Discussion is needed within the FD Sim/Reco group on "how" and "who"

- Joint effort with other WGs
    - size of uncertainties → Calibration, ProtoDUNE
    - study of effects → ND Sim/Reco
    - impact on oscillation analysis → LBL/AMA
    - implementation in fit framework → Mach3

    - Regular joint meetings are already organised
    - Should we join them, or think of something similar for the FD?