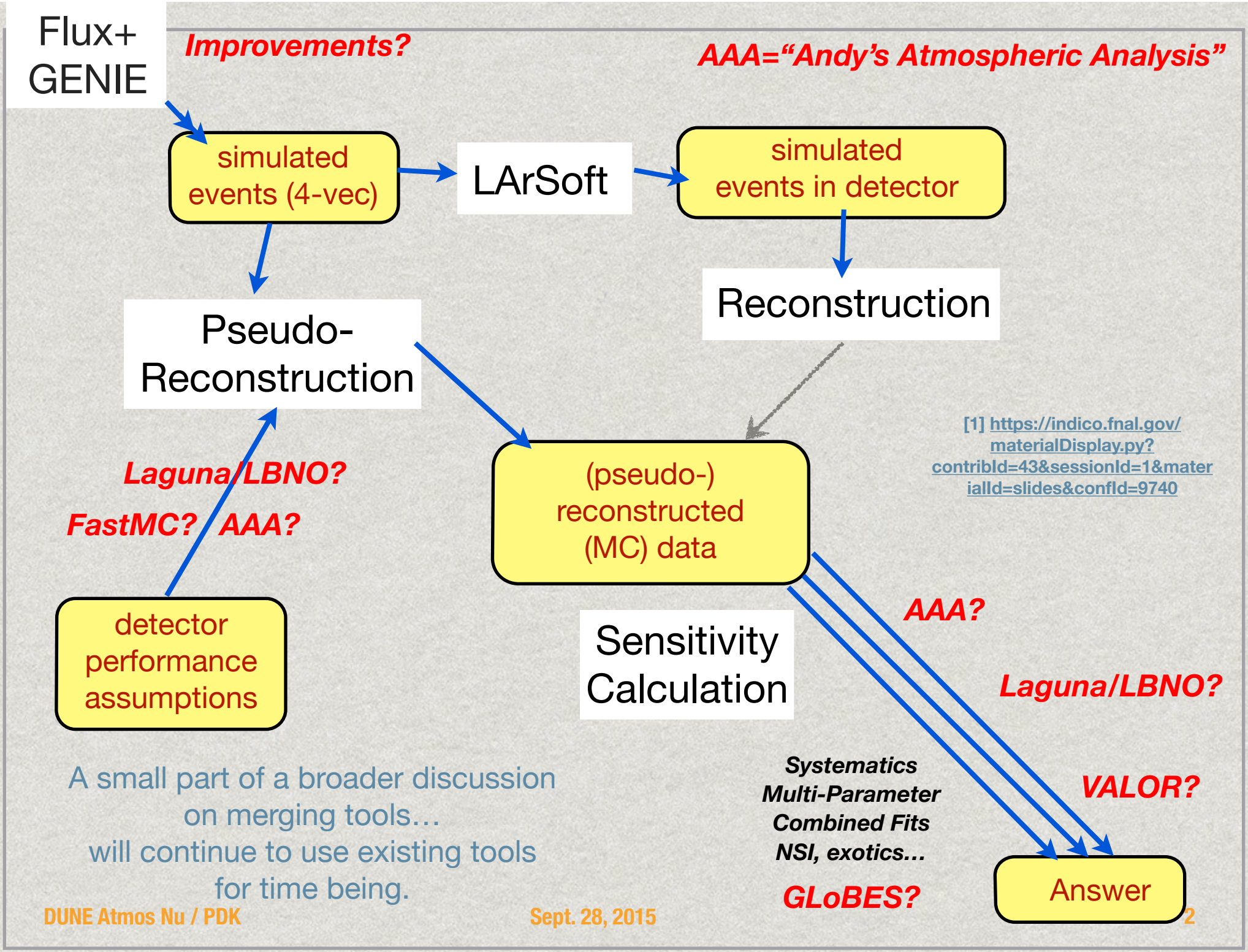
Atmospheric Neutrinos

H. Gallagher, Sept. 28, 2015, DUNE Atmos Nu/PDK Mtg

1) Summarizing recent discussions on tools / short-term plans.

2) Atmos Nu-specific Far Detector items:

- Resolutions / Detector Performance Assumptions
- Veto Shield
- Uptime
- Detector Monitoring



[1] https://indico.fnal.gov/materialDisplay.py?contribId=43&sessionId=1&materialId=slides&confId=9740

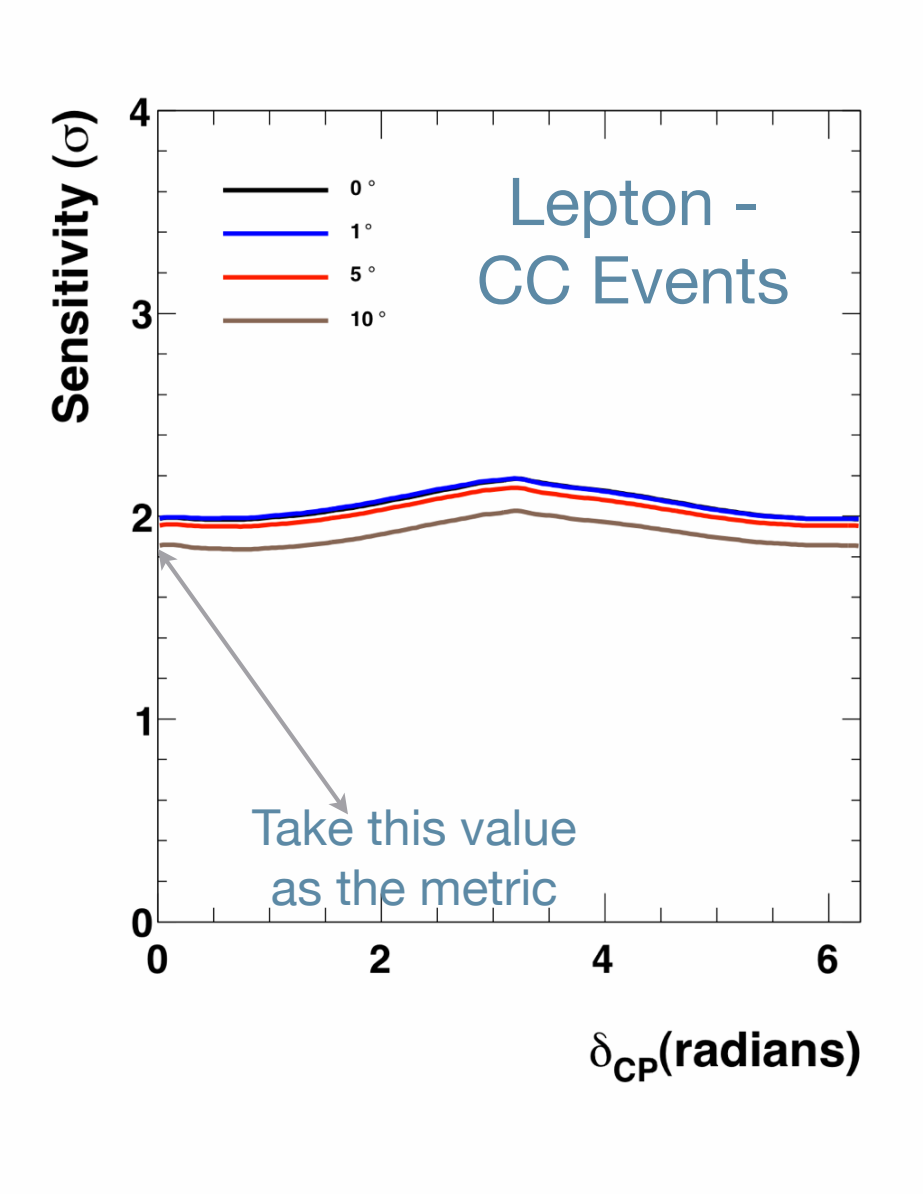
A small part of a broader discussion
on merging tools…
will continue to use existing tools
for time being.

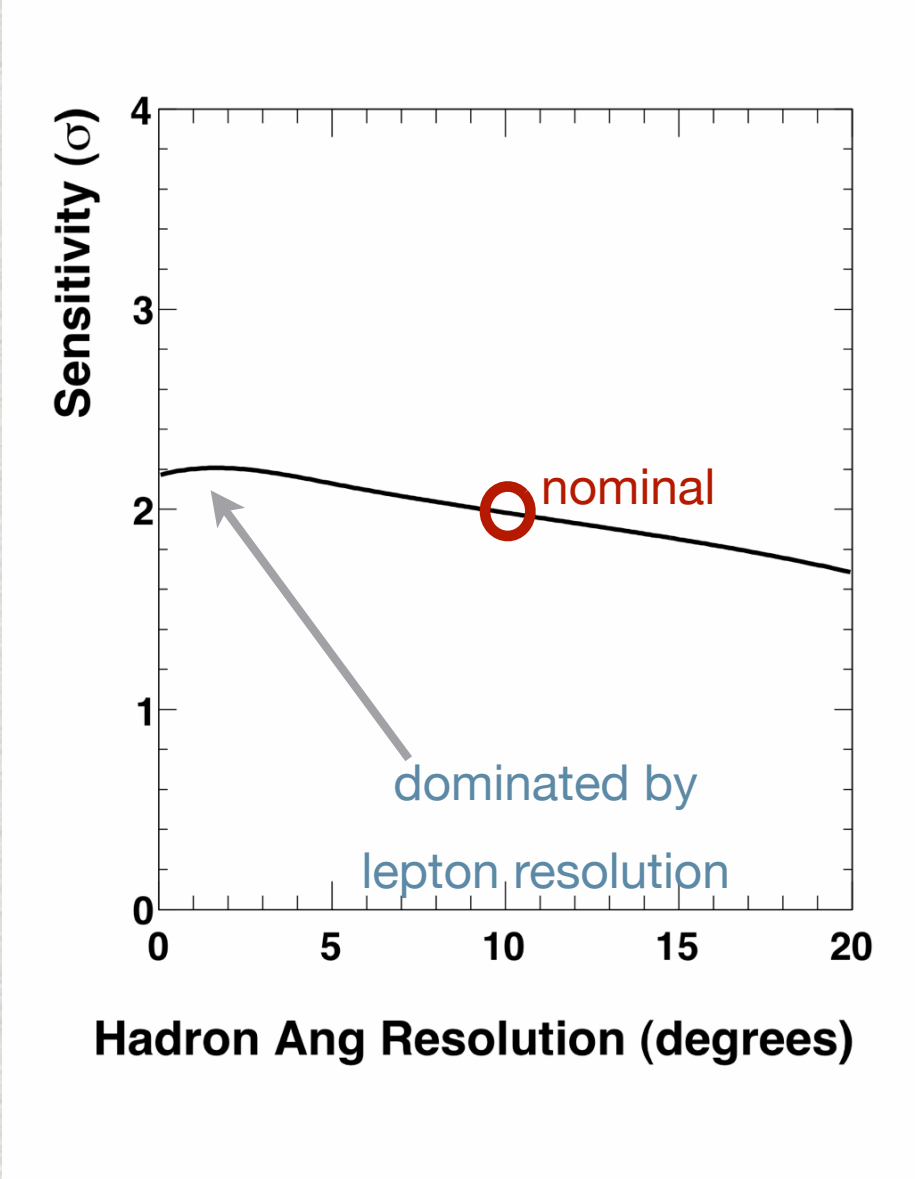
LBNE studies looked at how the MH determination sensitivity was affected by changes in the detector performance assumptions.

Lepton angular resolution	*nominal is 2°*
Hadron angular resolution	*nominal is 10^0*
Hadron energy resolution	*nominal is 30%/sqrt(E)*
FC electron resolutions	*nominal is 1% ⊕ 1%/sqrt(E)*
FC muon resolutions	*nominal is 3%*
PC muon resolutions	*nominal is 15%*
Background rejections	*nominal is* $\gamma = 95\%$
	$\pi^0 = 95\%$
	$\pi^{\pm} = 99\%$

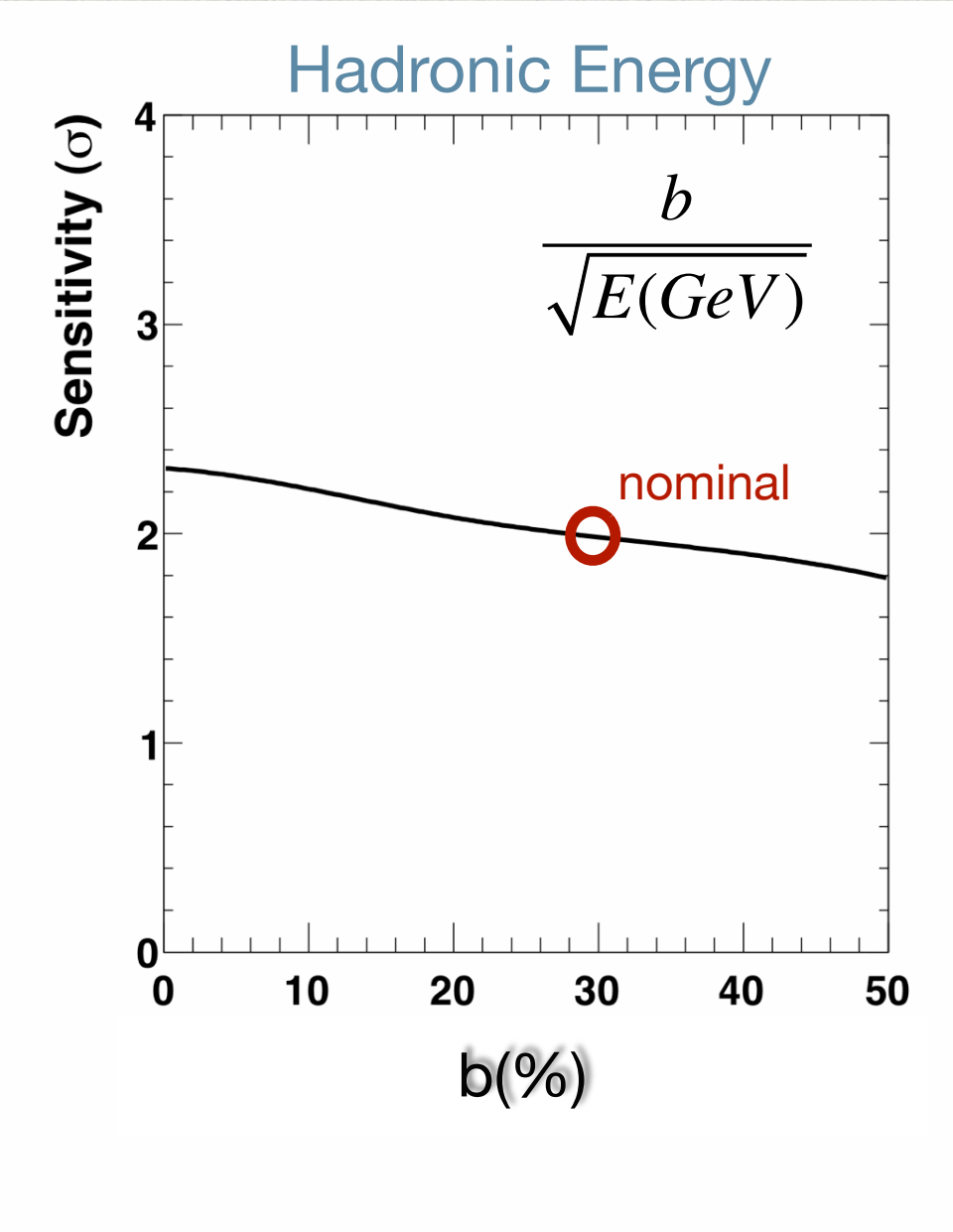
with/without nu/nubar separation

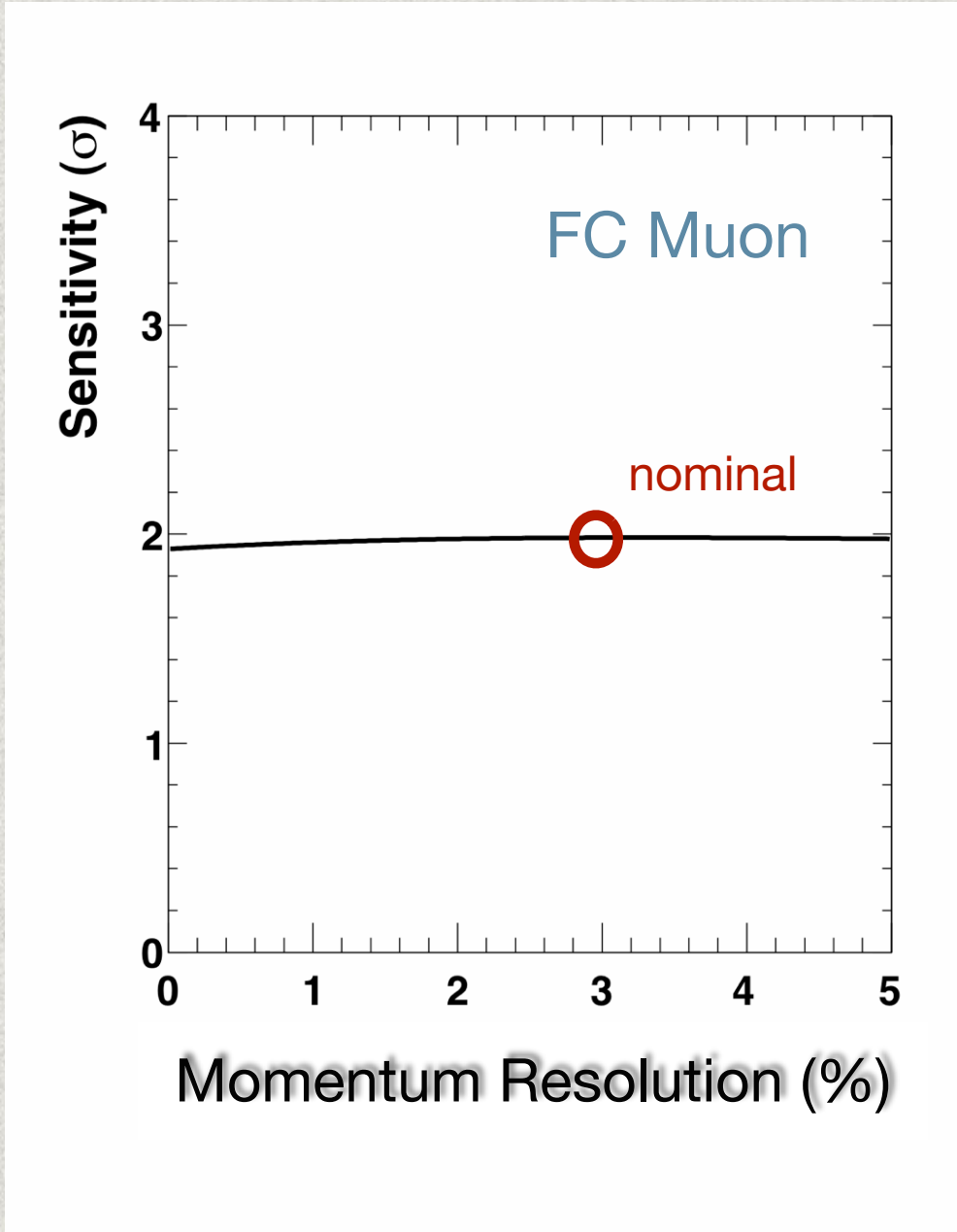
Angular Resolutions





Resolutions





What Limits Resolution?

Detector Performance	Nominal	Case 1: Great resolutions	Case 2: Perfect	Case 3: Perfect detector[1]
Detector Resolutions	Nominal	Perfect	reco=neutrino	perfect (lepton/hadron)
Nu/Nubar Separation	None	None	perfect	perfect
MH Sensitivity (σ) δ_{CP}=0	1.983	3.366	6.739	6.511

[1]: Consistent with literature, e.g. Petcov and Schwetz hep-ph/0511277.

Detector Performance Characteristics

Charge separation relies on our ability to image and ID:

- Protons (assumption was 100% for KE>50 MeV).
- Decays of contained muons (separated in drift direction).

MH Sensitivity currently limited by hadronic measurements:

- Hadronic shower energy determination in particular

Detector Performance Assumptions

Atmospheric analyses incorporate events over a range of energy, angle - and inoculation to systematics comes from distinctive features in the oscillograms.

Uncertainty in our acceptance as a function of energy, zenith angle could be an important systematic.

Backgrounds

Previous experiments have taken care of cosmogenic backgrounds using a variety of approaches:

- depth
- shielding
- fiducial volume cuts
- energy cuts
- analysis-level background corrections

For the purposes of PDK/atmos nu analyses, what combination of the above gives DUNE the best sensitivity?

Uptime / Monitoring

We would obviously like the detector to be live as much as possible. There should be a broader discussion of setting an aggressive but achievable uptime target.

Atmospheric neutrino analyses can be affected by detector problems on a small spatial and temporal scale. e.g. loss of readout from one set of wires, creating a 'hole' through which muons can enter the fiducial volume, stopping muons would then look like downward going contained muon neutrino CC events.

Summary

There is a lot of room for new people to take on important studies immediately, relying mainly on existing tools.

Two examples:

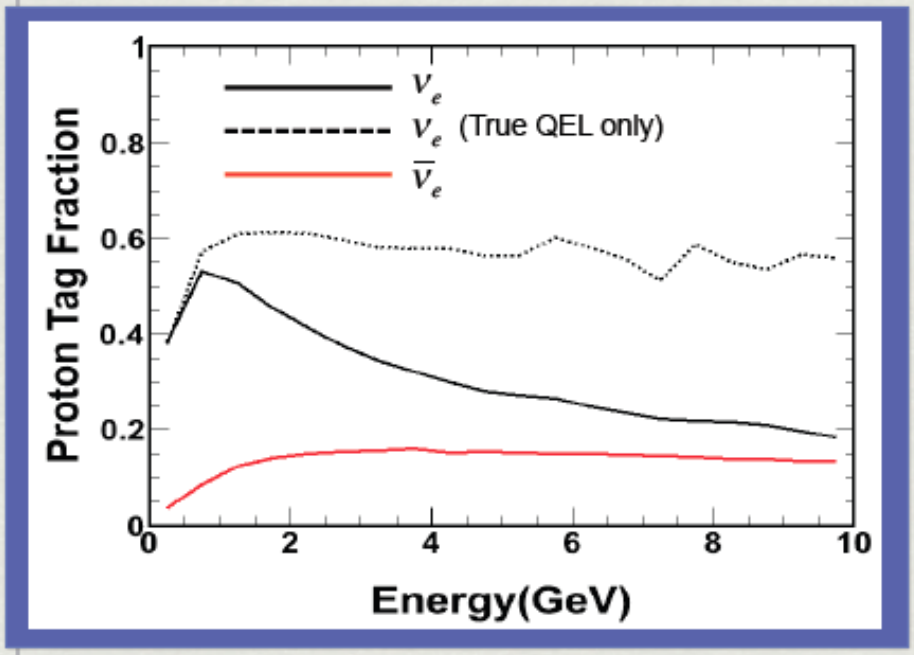
What are our specifications on (energy, angle) acceptance +efficiency uncertainty?

What is the rate (+ energy distribution, zenith angle distribution, topology) of cosmogenic backgrounds, as a function of fiducial volume cut, with and without a veto shield?

BACKUP

Algorithm now includes proton and decay-electron tagging.

- Proton tagging: Assume 100% if K.E.>50 MeV.
- Electron tagging: Assume 75% for μ- and 100% for μ+.



Proton Tagging

	ν	anti-ν
e-like, p-tag	30.2%	5.5%
e-like, no p-tag	42.7%	21.6%

	ν	anti-ν
μ-like, p-tag	26.9%	5.2%
μ-like, no p-tag	49.1%	18.8%

Electron Tagging

	ν	anti-ν
μ-like, e-tag	18.9%	24.0%
μ-like, no e-tag	57.1%	0.0%

A. Blake, doc-6144

Can also consider statistical separation based on y-distribution differences between neutrinos and anti-neutrinos, a la SuperK.

DPA	Nominal	Better Angular Resolutions	Better Energy Resolutions	Improved FCE	Improved FCMU	Improved PCMU	Improved Hadrons
Nu/Nubar separation	None	None	None	None	None	None	None
Muon Energy	15% exiting 3% contained	15% exiting 3%contained	7.5% exiting 1.5% containd	15% exiting 1.5% containd	15% exiting 1.5% containd	7.5%exiting 3% contained	15% exiting 3% contained
EM shower energy	1%⊕1%/ sqrt(E)	1%⊕1%/ sqrt(E)	.5%⊕.5%/ sqrt(E)	.5%⊕/.5%/ sqrt(E)	1%⊕1%/ sqrt(E)	1%⊕1%/ sqrt(E)	1%⊕1%/ sqrt(E)
Hadronic resolution	30%/sqrt(E)	30%/sqrt(E)	15%/sqrt(E)	30%/sqrt(E)	30%/sqrt(E)	30%/sqrt(E)	15%/sqrt(E)
Lep angular resolution	2°	1°	2°	2°	1°	1°	2°
Had angular resolution	10°	5°	10°	10°	10°	10°	5°
MH Sensitivity (σ) δ_{CP}=0	**1.983**	**1.987**	**2.314**	**2**	**1.981**	**2.107**	**2.382**