Experimental perspective and needs: SBN/MicroBooNE

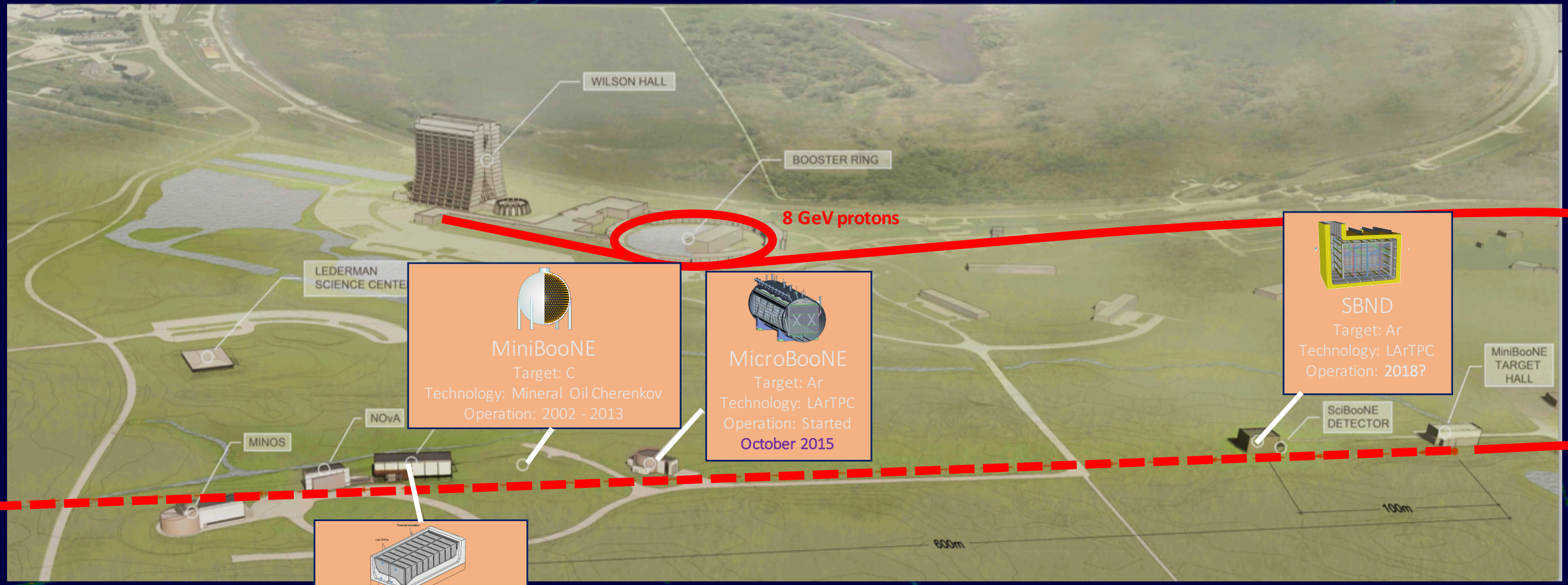
Anne Schukraft, Fermilab

NuTune2016, U Liverpool, July 11, 2016

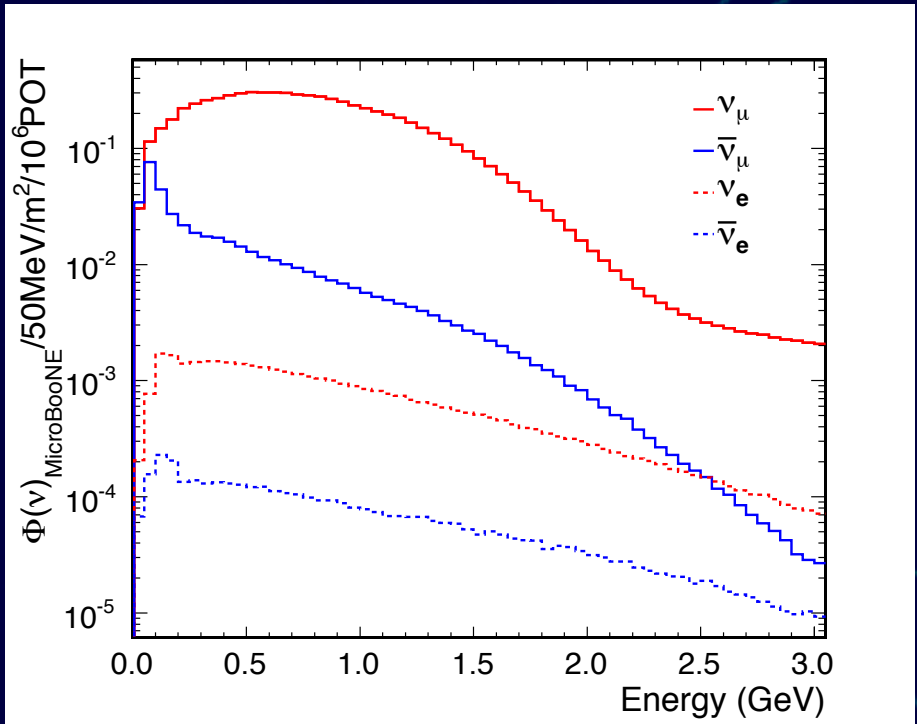
Fermilab

Fermilab's short baseline neutrino program

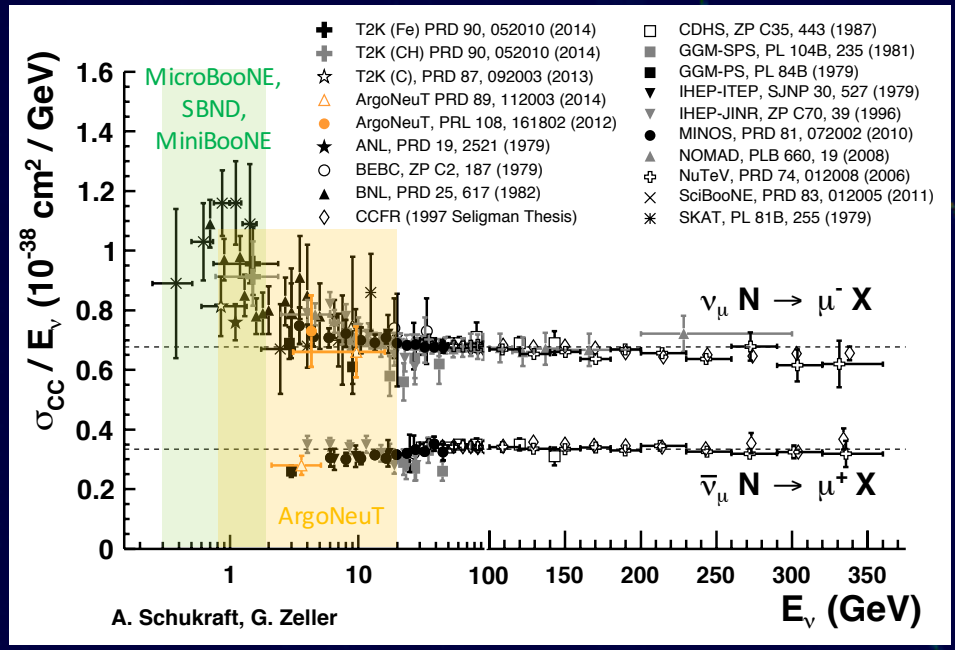
Four neutrino experiments in the same beam

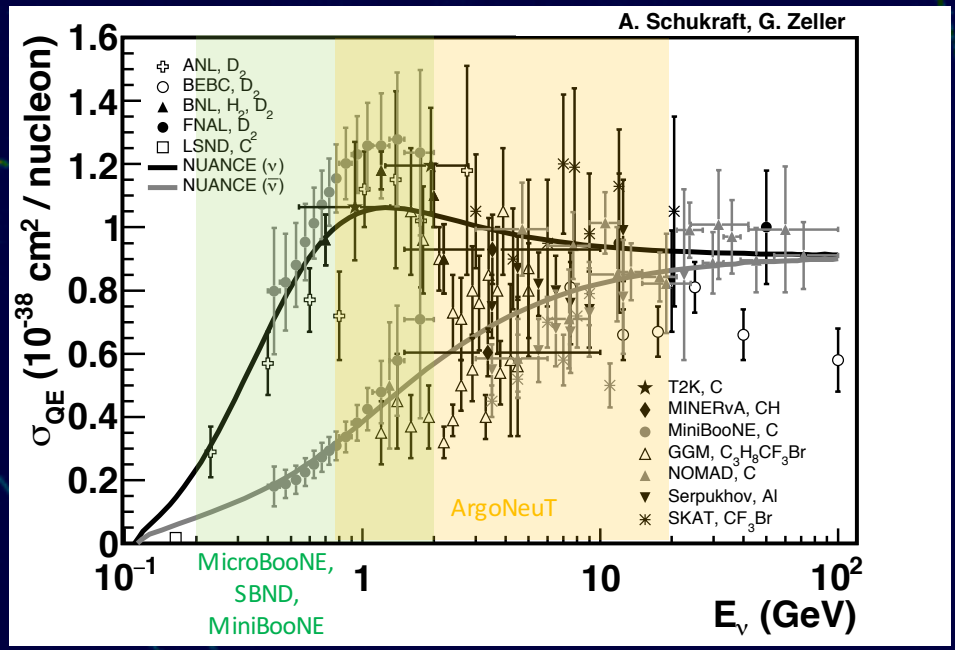


Booster neutrino beam flux

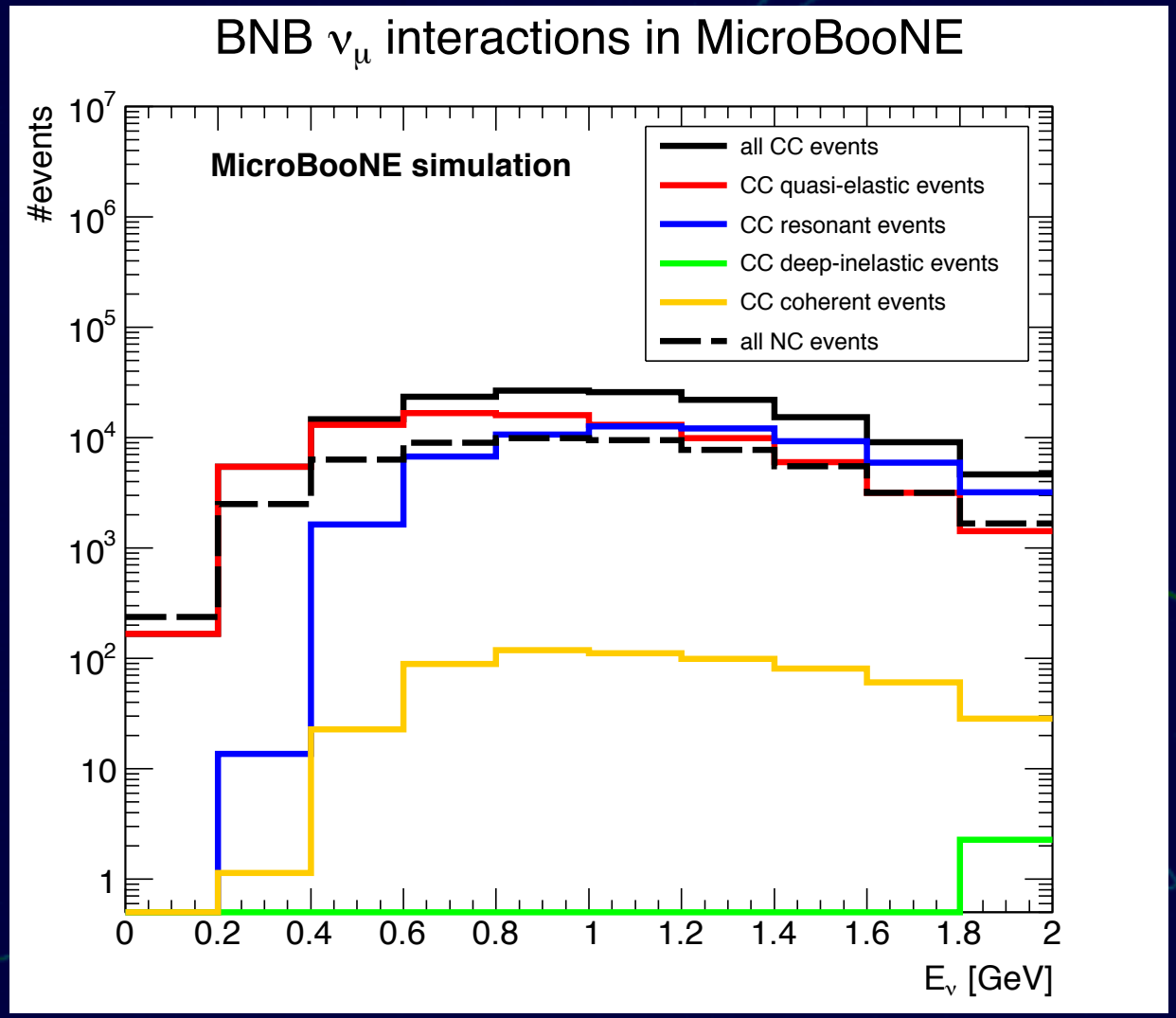


- Up to 5 Hz
- 4.2 x 10^{12} protons per pulse
- Average neutrino energy: ~ 800 MeV
- ~ 94% ν_μ (neutrino mode)
  ~ 6% $\bar{\nu}_\mu$
  ~ 5% $\bar{\nu}_e$
  ~ 1% ν_e





Expected event composition



CC	
QE	55%
RES	43.5%
DIS	1%
COH	0.5%

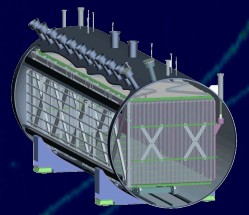
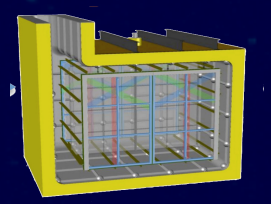
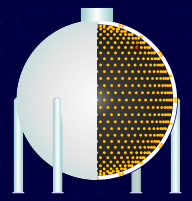
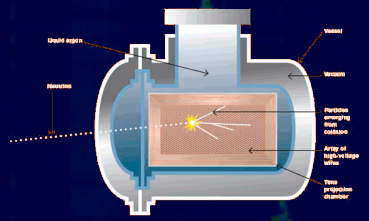
NC	
QE	55.5%
RES	42.5%
DIS	1%
COH	1%

Using hadronic mass W < 2 GeV (RES) and W > 2 GeV (DIS)

> 100 000 ν interactions in MicroBooNE already

Plot is for **1 x 10^{20}** POT.
Now on tape: > 3 x 10^{20} POT.

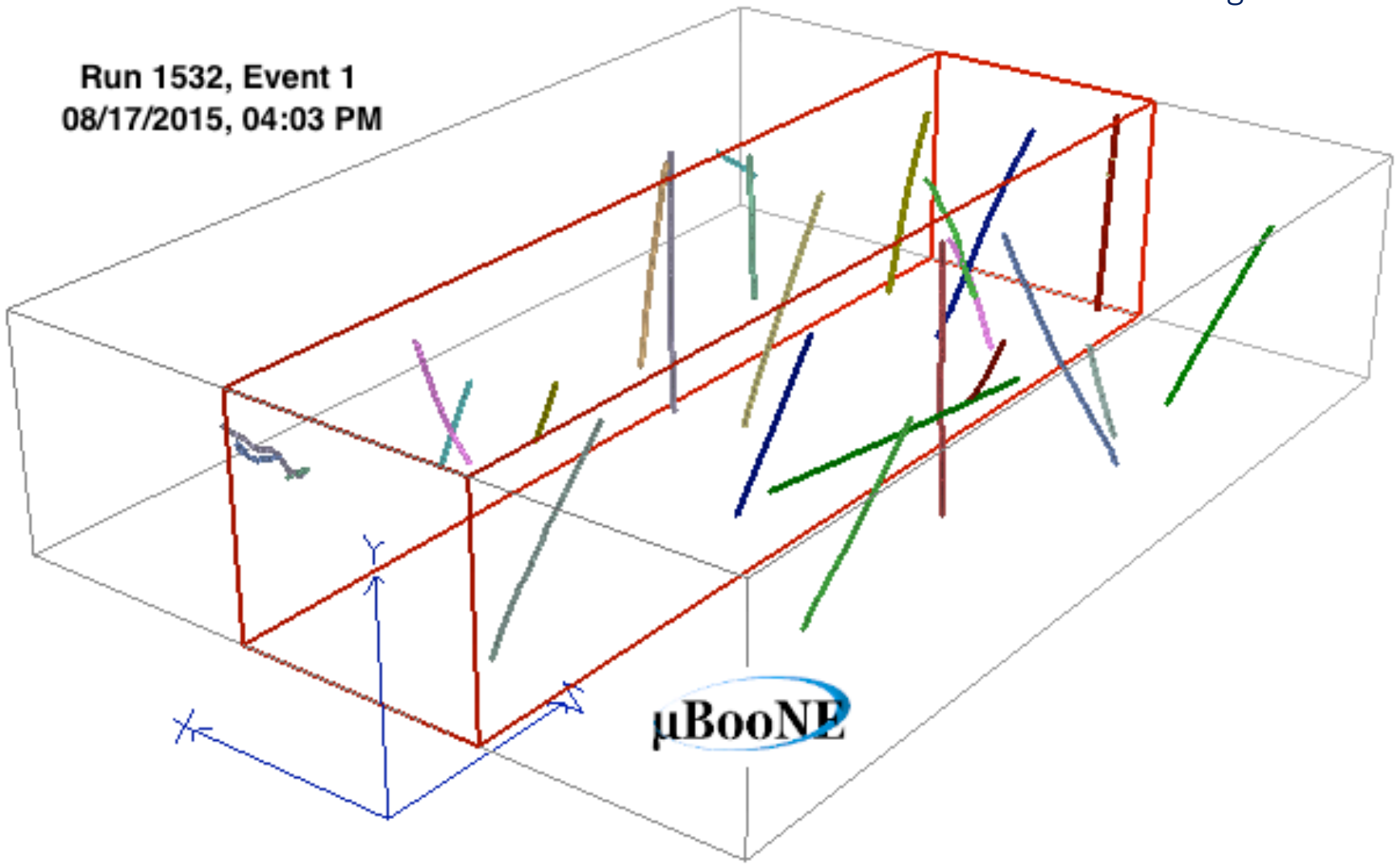
Event rates

ν_μ rates only	MicroBooNE 6.6 x 10^{20} POT (3 years)	SBND 6.6 x 10^{20} POT (3 years)	MiniBooNE ~ 6 x 10^{20} POT	ArgoNeuT 1.2 x 10^{20} POT (5 months)
	EXPECTED		SELECTED	
CC inclusive	*175k*			~3k (ν_μ and $\bar{\nu}_\mu$)
CC 0π	*112k*	*3500k*	146k	~1k (ν_μ and $\bar{\nu}_\mu$)
1μ + 2p	*12k*	*360k*		30 (ν_μ and $\bar{\nu}_\mu$)
NC single π^0	*11k*	*358k*	21k	~150 (ν_μ and $\bar{\nu}_\mu$)
NC elastic	***17k***		95k	
CC coherent π production		*19k*		~15 (ν_μ and $\bar{\nu}_\mu$)
CC ν_e		*37 k*		
		BNB		NuMI

Where is MicroBooNE now?

Challenge for a LArTPC on the surface: cosmics!



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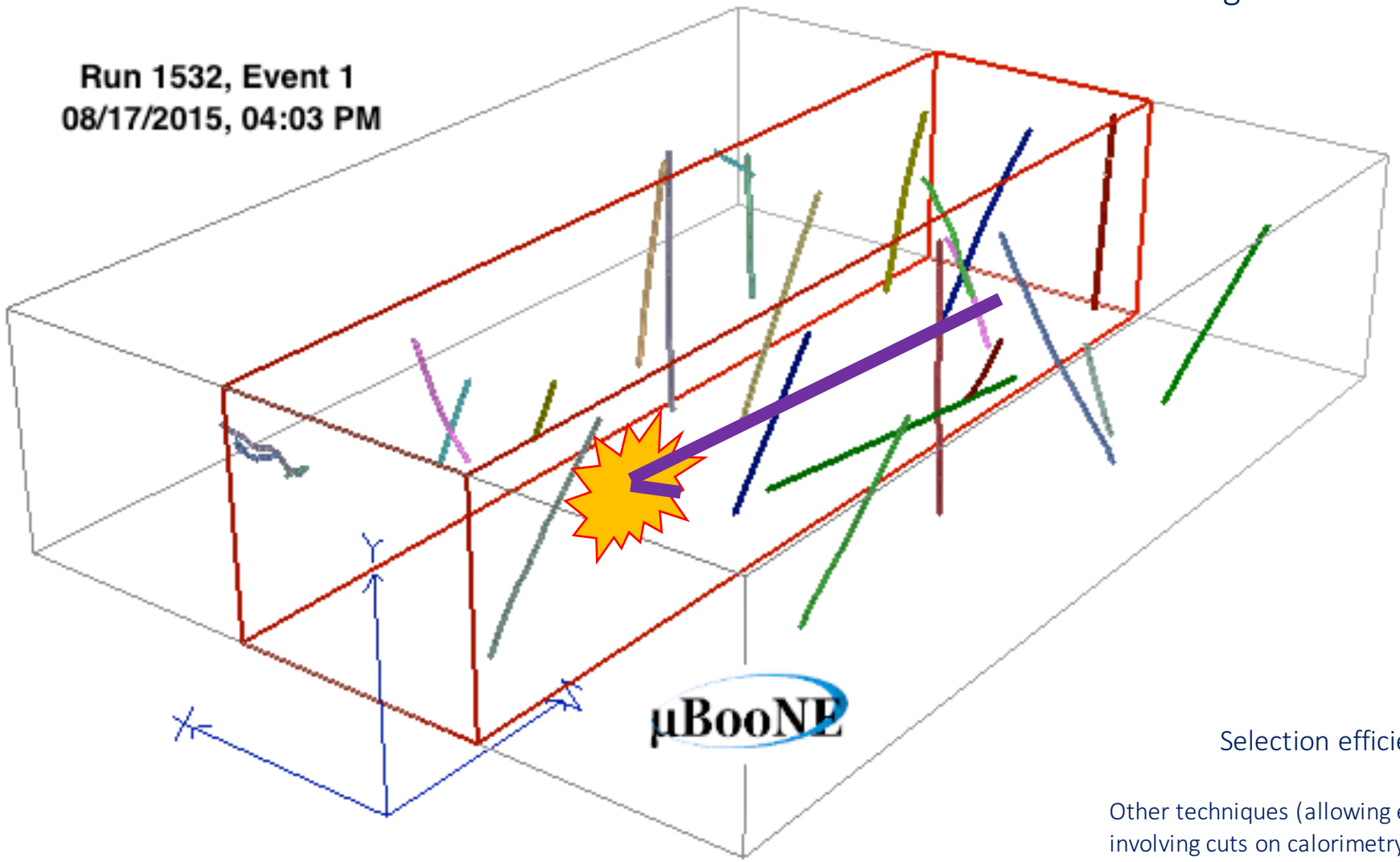


Two different approaches to select ν_μ CC interactions in MicroBooNE (presented at NEUTRINO2016)

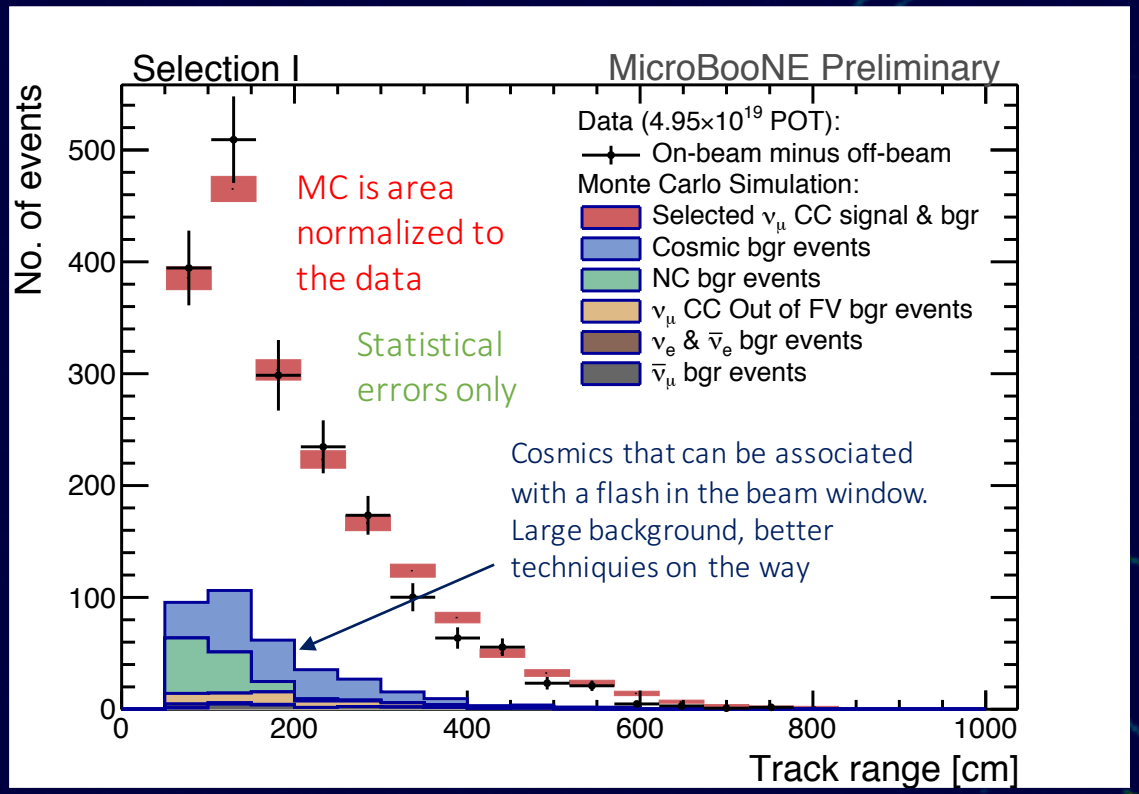
One approach:

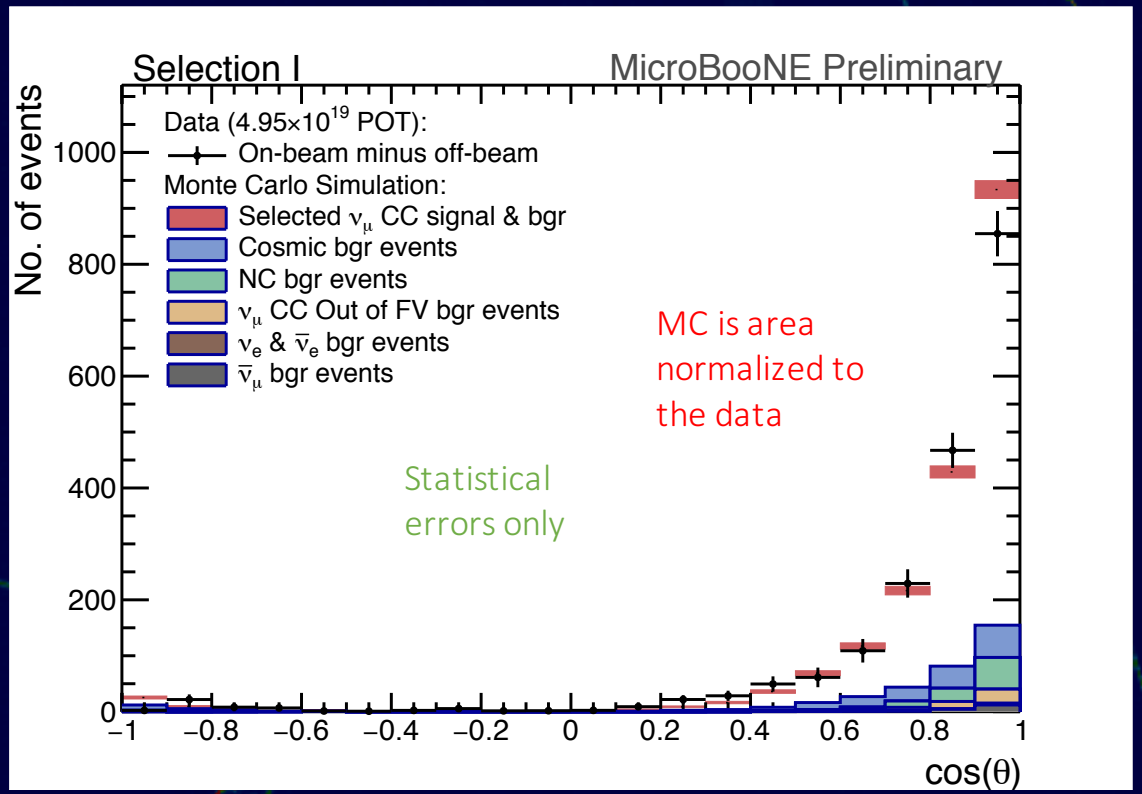
- Select the most forward-going interaction that is fully contained
- Can be single track or higher multiplicity
- Muon candidate track must be longer 75 cm
- Must be able to be associated to a flash during the beam window

Selection efficiency: ~ 12% (mostly due to containment)

Other techniques (allowing exiting tracks in case of multiplicity >= 2, and involving cuts on calorimetry currently achieve ~ 30% selection efficiency)

The first distributions of ν_μ CC events in MicroBooNE





- Using only 4.95 x 10^{19} POT
  > 3 x 10^{20} POT on tape already
- Already ~ 2000 events in 4.95 x 10^{19} POT, despite very low selection efficiency

Presented at NEUTRINO2016
http://www-microboone.fnal.gov/publications/publicnotes/

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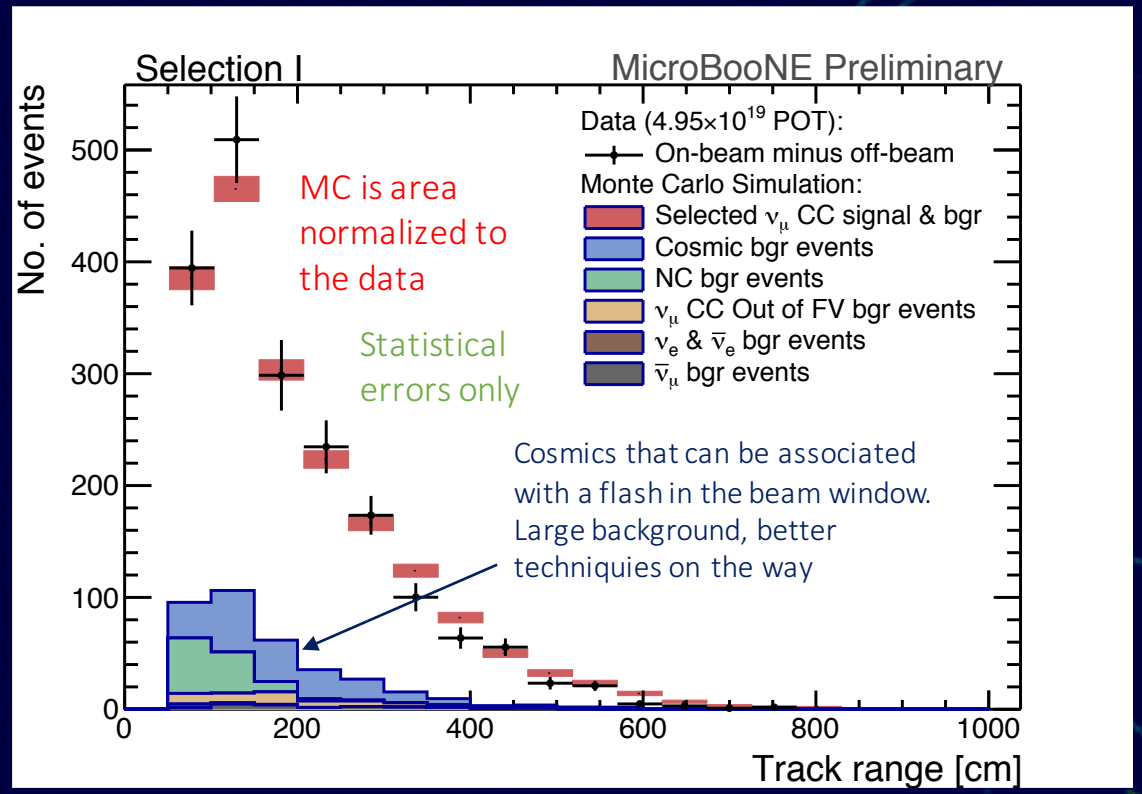

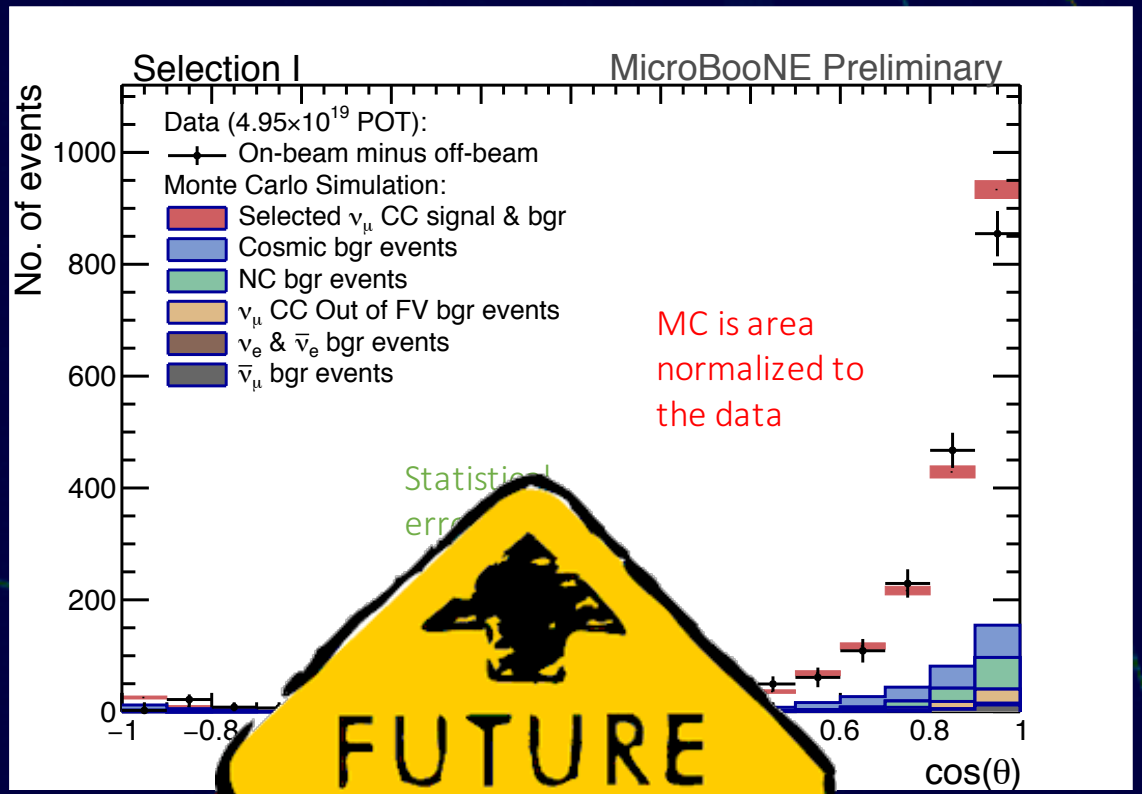

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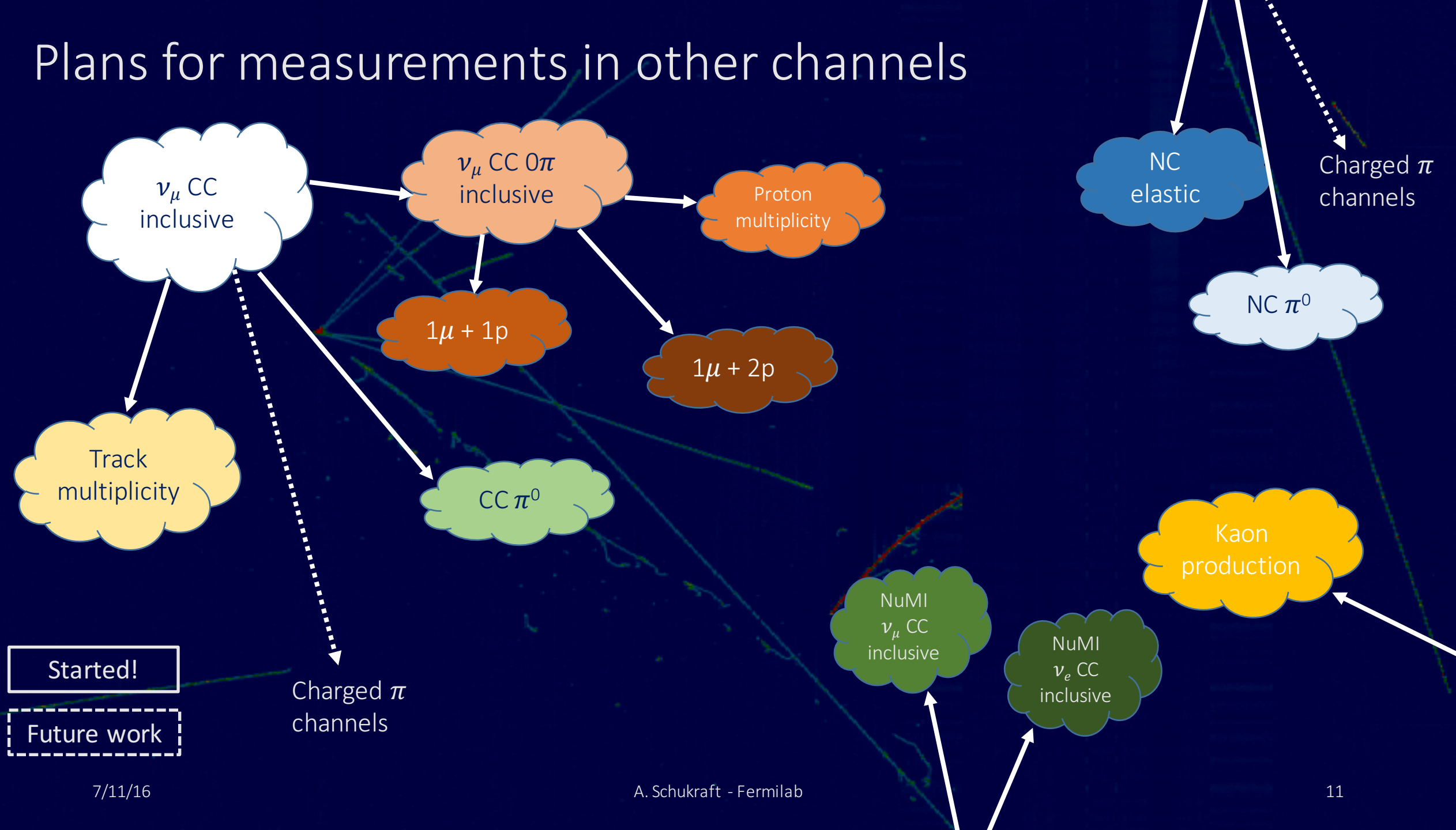
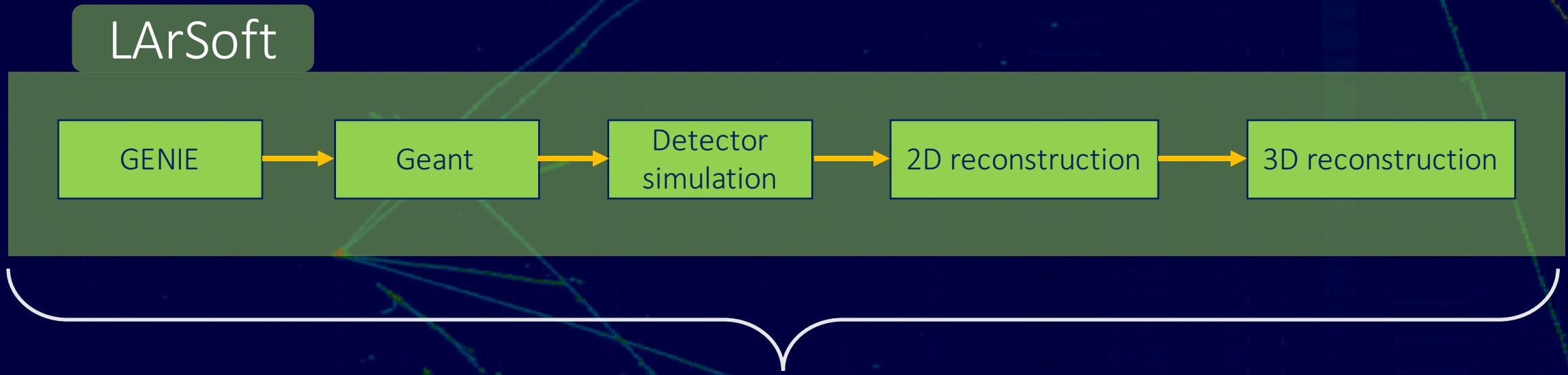
Putting pieces together for a first ν_μ CC inclusive cross section measurement

Plans for measurements in other channels



Simulation and reconstruction in LArSoft



Used by MicroBooNE, ArgoNeuT, SBND, DUNE… (and other non-neutrino LAr experiments).

- Setting of GENIE run parameters through LArSoft config files
- Using official GENIE versions
- No private GENIE tuning or modifications

} Is this feasible? What is the experience from other experiments?

- Turn-around time for new LArSoft releases linking to new GENIE version: ~ 1 week
- Possibility to translate standalone GENIE output to LArSoft for further steps in the chain exists

Simulating non-default GENIE models through LArSoft

Setup the GENIE version to be used:

UPS products:
(/grid/fermiapp/producs/larsoft/)

- **genie**
- **genie_phyopt**
- **genie_xsec** (pointing to xsec splines and xml files)

GXMLPATH path: where GENIE looks for XML files

Can be set within LArSoft fcl (= job config) files to overwrite pre-defined search path

```
physics.producers.generator.GXMLPATH
physics.producers.generator.Environment
```

Example 1: MEC
Change the event generator list in the fcl file

From prodgenie_bnb_nu_uboone_MEC.fcl:

```
#include "prodgenie_common_uboone.fcl"

process_name: GenieGen

outputs.out1.fileName: "prodgenie_bnb_nu_uboone_%tc_gen.root"

physics.producers.generator: @local::microboone_genie_simple
physics.producers.generator.GlobalTimeOffset: 3125.
physics.producers.generator.RandomTimeOffset: 1600.
physics.producers.generator.TopVolume: "volCryostat"
physics.producers.generator.BeamName: "booster"

physics.producers.generator.EventGeneratorList: "DefaultPlusCCMEC"
```

From $GXMLPATH/EventGeneratorListAssembler.xml:

```
<param_set name="DefaultPlusCCMEC">
  <param type="int" name="NGenerators">  14                          </param>
  <param type="alg" name="Generator-0">  genie::EventGenerator/QEL-CC      </param>
  <param type="alg" name="Generator-1">  genie::EventGenerator/QEL-NC      </param>
  <param type="alg" name="Generator-2">  genie::EventGenerator/RES-CC      </param>
  <param type="alg" name="Generator-3">  genie::EventGenerator/RES-NC      </param>
  <param type="alg" name="Generator-4">  genie::EventGenerator/DIS-CC      </param>
  <param type="alg" name="Generator-5">  genie::EventGenerator/DIS-NC      </param>
  <param type="alg" name="Generator-6">  genie::EventGenerator/COH-CC      </param>
  <param type="alg" name="Generator-7">  genie::EventGenerator/COH-NC      </param>
  <param type="alg" name="Generator-8">  genie::EventGenerator/DIS-CC-CHARM </param>
  <param type="alg" name="Generator-9">  genie::EventGenerator/QEL-CC-CHARM </param>
  <param type="alg" name="Generator-10"> genie::EventGenerator/NUE-EL      </param>
  <param type="alg" name="Generator-11"> genie::EventGenerator/IMD         </param>
  <param type="alg" name="Generator-12"> genie::EventGenerator/IMD-ANH     </param>
  <param type="alg" name="Generator-13"> genie::EventGenerator/MEC-CC      </param>
</param_set>
```

Example 2: ESF+TEM
Point to a different UserPhysicsOptions.xml file

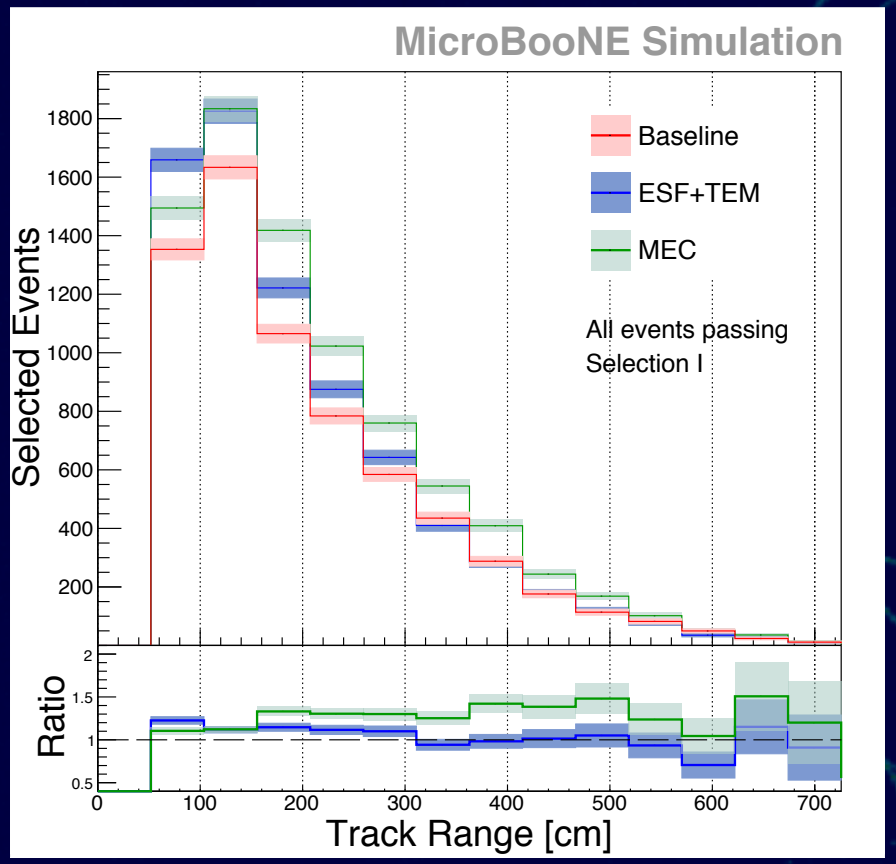
- Setup of UPS product:
  Default+ESF+TEM splines: genie_xsec v2_10_6a -q effspec:tem
- Point to modified UserPhysicsOptions.xml by setting GXMLPATH in the fcl file

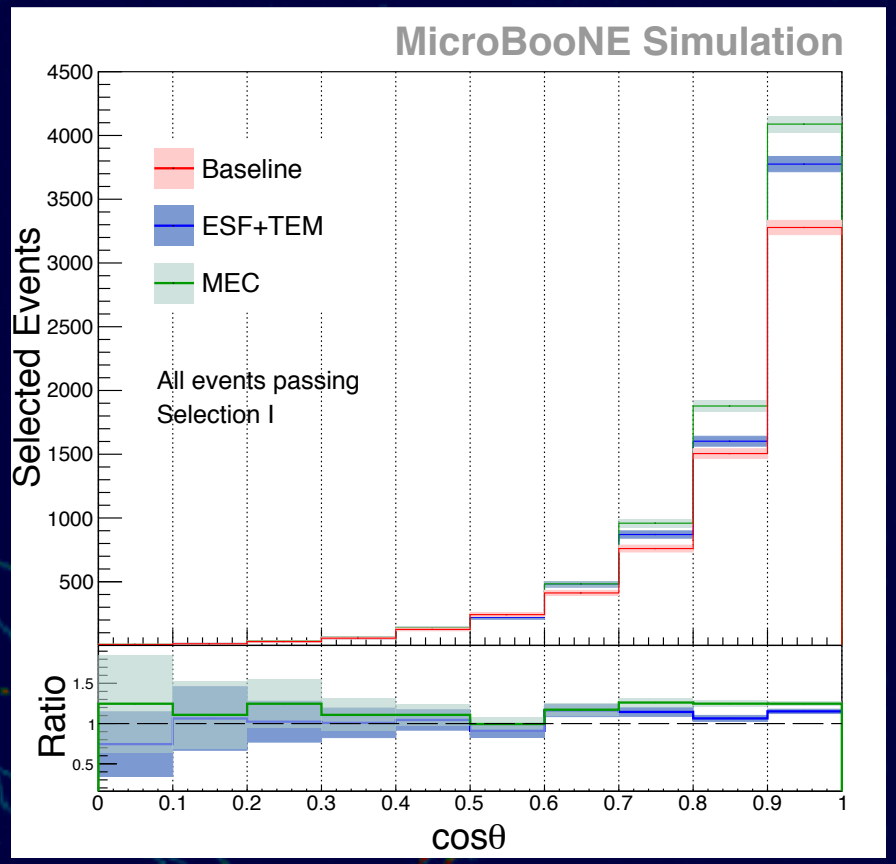
From $GXMLPATH/UserPhysicsOptions.xml:

```
<param type="alg"  name="NuclearModel"> genie::EffectiveSF/Default </param>

<param type="bool" name="UseElFFTransverseEnhancement">  true  </param>
<param type="alg" name="TransverseEnhancement">
                    genie::TransverseEnhancementFFModel/Default </param>
```

Different nuclear models in MicroBooNE





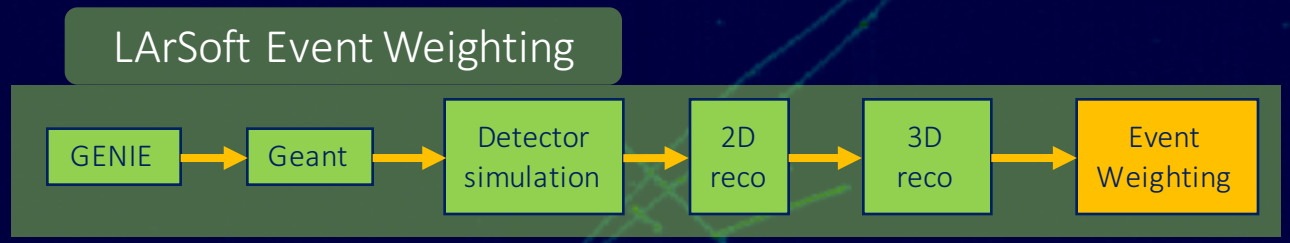
CC inclusive selected events

- X-axis: reconstructed observables
- Backgrounds NOT yet subtracted
- Bands are statistical errors on the MC

Proof of principle:
We are able to simulate different models implemented in GENIE and propagate through our software chain to analysis level

No comparisons with data, yet.
Some effects are large in normalization. Will move forward to more sensitive channels.

GENIE re-weighting in LArSoft



Multisim I

Parameter A = X
Parameter B = Y
Parameter C = Z
…

Multisim II

Parameter A = X'
Parameter B = Y'
Parameter C = Z'
…

Multisim III

Parameter A = X
Parameter B = Y
Parameter C = Z
…

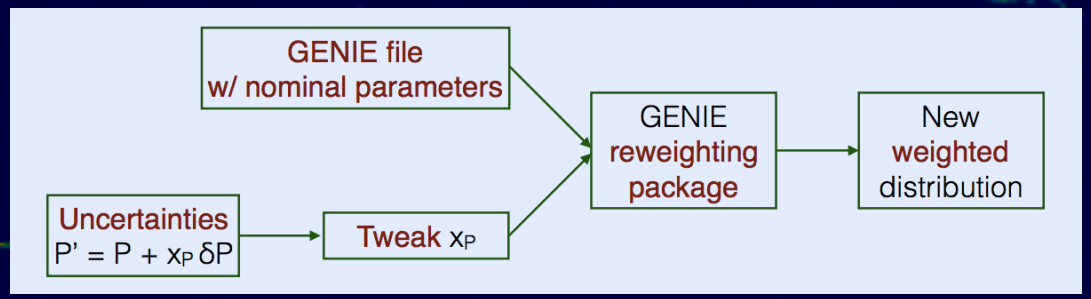
Multisim IV

Parameter A = X'''
Parameter B = Y'''
Parameter C = Z'''
…

…

Used to evaluate
- Beam uncertainties
- Cross section uncertainties → GENIE re-weighting package

Creates multisims with different parameter sets
Appends event weights for each multisim to an event

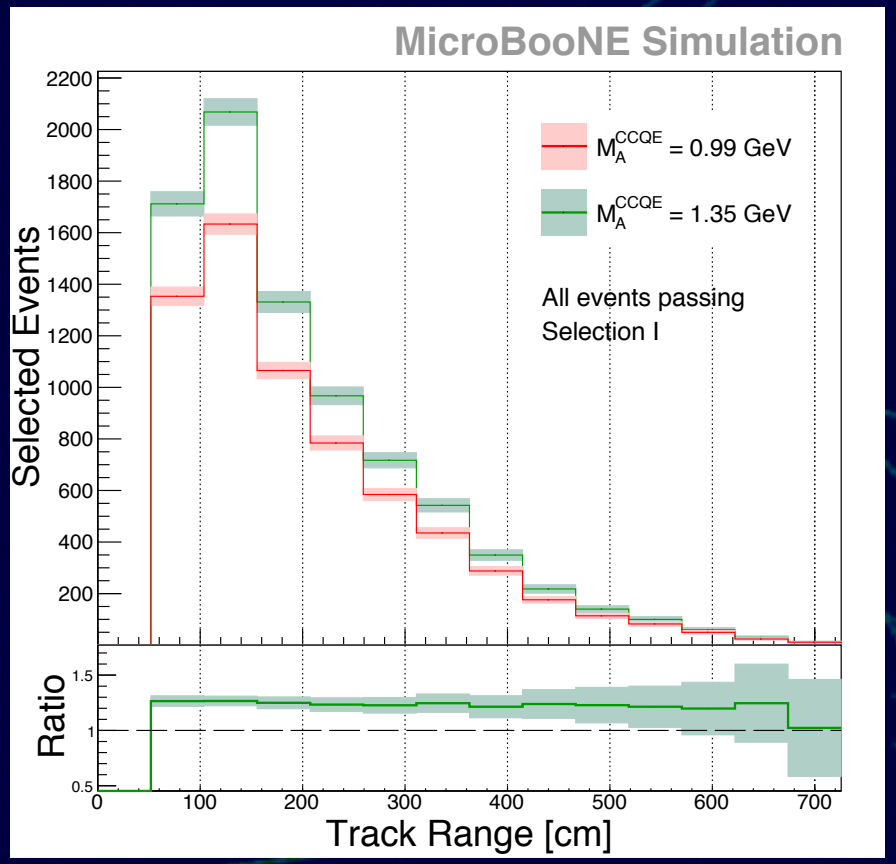


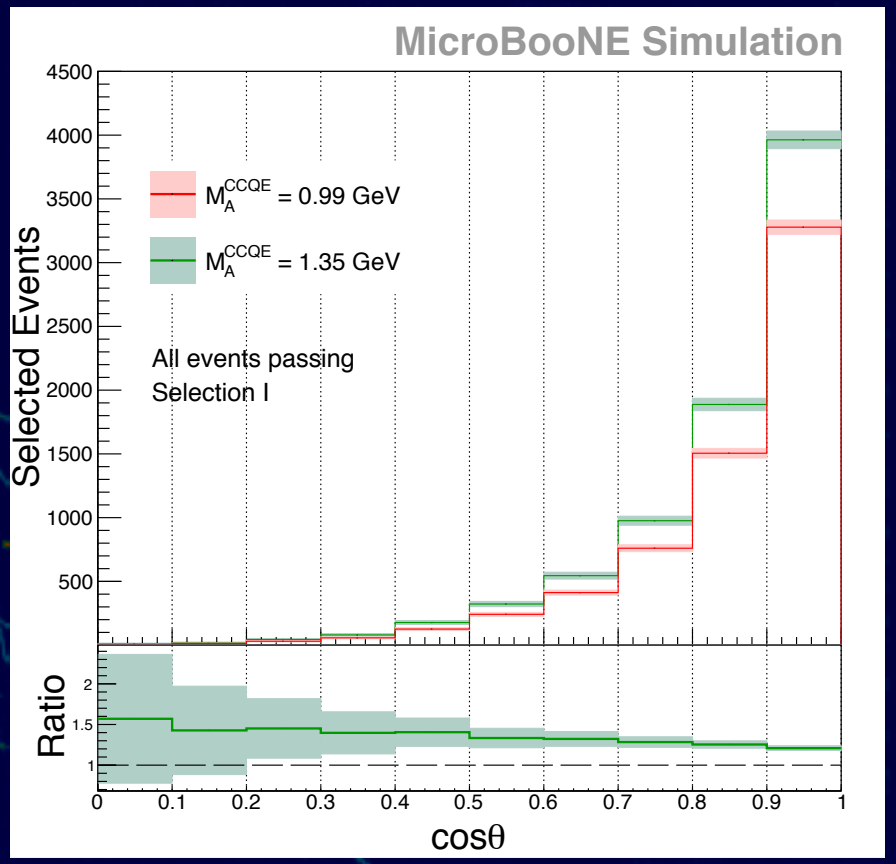
From fcl file:

```
genie_few: {
          type: Genie
          random_seed: 1
          parameter_list:          ["QEMA", "CCRes", "NCRes"]
          parameter_sigma:         [0.1     , 0.1      , 0.1      ]
          mode: multisim
          number_of_multisims: 15
        }
```

(using pre-defined definitions from GENIE re-weighting package for sigma)

Example: re-weighting with M_A^{CCQE} = 1.35 GeV





CC inclusive selected events

- X-axis: reconstructed observables
- Backgrounds NOT yet subtracted
- Bands are statistical errors on the MC

We are also using the re-weighting package to evaluate systematic uncertainties on expected background rates and selection efficiencies.

Experiences from MiniBooNE/NUANCE

Process for developing NUANCE fell into three general categories:

(1) Improvements made by the experiment

- Creation of external packages tied to NUANCE
- Examples: wrappers to allow easier calculation of systematic errors tied to experiment code (*multisims*), add-ons to calculate normalization factors specific to the experiment (*nuance-rates*), etc.

(2) Improvements made by the experiment with generator owner consultation and assistance

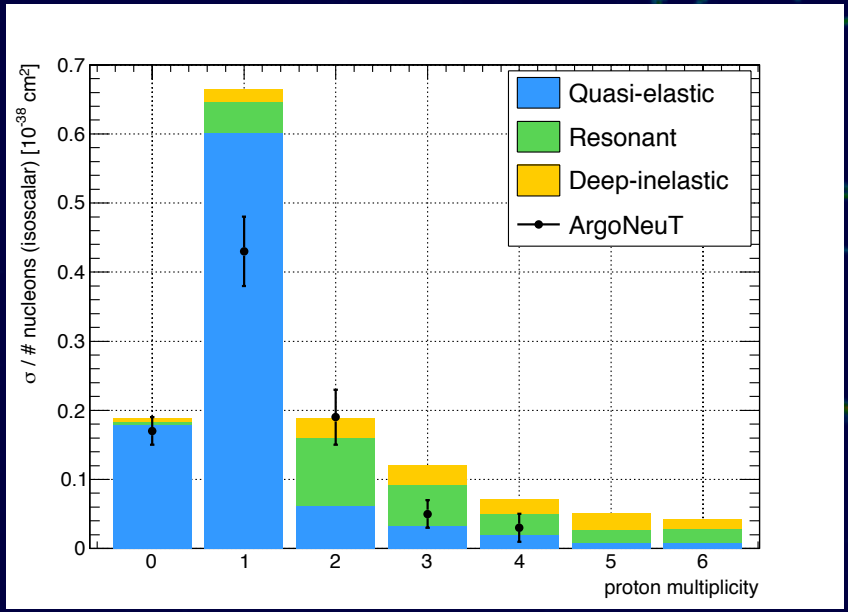
- Modifications impacting a single neutrino interaction process or routine
- Examples: addition of de-excitation photons, non-dipole vector form factors for QE, Pauli blocking rescaling for QE, W-invariant resonance decays, etc.

(3) Improvements made by the generator owner in response to a request or finding from the experiment

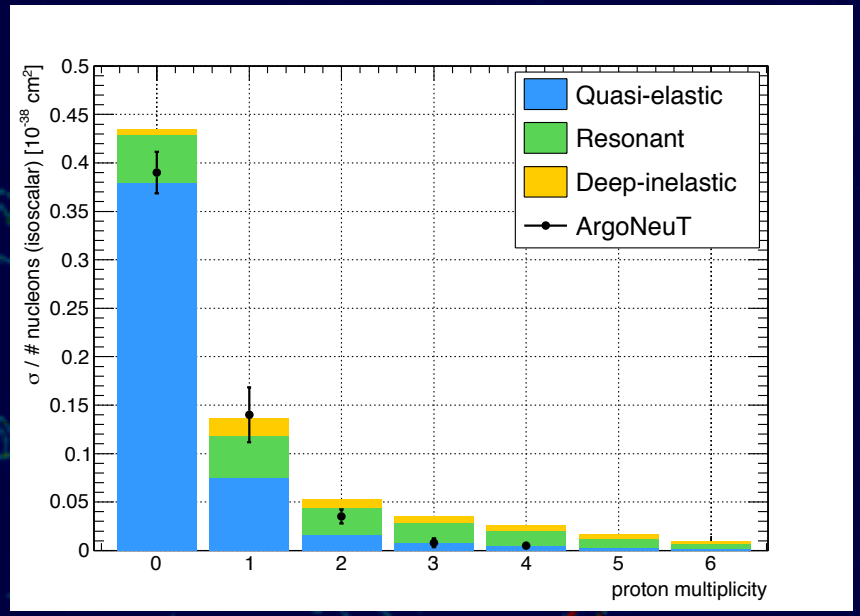
- Modifications requiring re-tuning and impacting multiple routines/interfaces
- Examples: upgrades to final state interaction model, DIS hadronization model

What is the process for tuning GENIE to describe the ArgoNeuT measurement? How are other constraints dealt with at the same time?

ν_μ



$\bar{\nu}_\mu$



ArgoNeuT, presented at NuInt2016

- Proton multiplicity measurements are one of the first things on our list
- Known from ArgoNeuT that data has fewer tracks than predicted by GENIE
- How do we tune GENIE models to describe the ArgoNeuT measurement?
- When tuning GENIE to argon, how do we transfer/scale to other nuclei?

Other MicroBooNE GENIE interests

Single kaon production

Why?
Background for proton decay searches

Proton decay golden mode

$p \rightarrow K^+ \nu$

Background

ν_{atms} $Ar \rightarrow K^+ X$

"Associated production", "ΔS = 0":
pairs of strange particles in final state
$\nu_\mu n \rightarrow \mu^- K^+ \Lambda$
$\nu_\mu n \rightarrow \mu^- K^+ K^- p$
$\nu_\mu n \rightarrow \nu_\mu K^+ \Sigma^-$

Threshold: 1.2 GeV

In GENIE default list
Xsec tuned to data

"Single kaon production", "ΔS = 1":
Cabibbo-suppressed, single kaon final state
$\nu_\mu N \rightarrow \mu^- K^+ N$

Threshold: 0.8 GeV

In GENIE
NOT in GENIE default list
If added, violates total xsec tune

Summary

- MicroBooNE is getting ready to join the cross section market

- Any advise from other experiments and GENIE experts is welcome at this point!

A big thank you to my collaborators
Marco del Tutto, **Elena Gramellini,** Sam Zeller, Corey Adams, and Erica Snider
for providing material and input to this presentation.