Calibration Kick-off

Sowjanya, Kendall

DUNE Physics week
November 15 - 17, 2017
Fermilab

DUNE FD/SP Calibrations

Stringent physics requirements

- CDR: Uncertainty of 2% on energy scale is already important to physics goals; calibration must be <2%

- 1% Lepton energy bias is already important to physics goals; calibration must be <1%

- ….and calibrations are not the only source of uncertainty!

Tough path ahead:

- Need to define calibration driven physics requirements (currently no detailed ties exist) and understand impact on LBL; Need Sim/reco tools

- Need a calibration strategy for TDR timeline (clarify assumptions; present arguments/studies to meet precision goals)

The Calibration Challenge

We will never get tired of saying this :)

TPC response model
- Argon ionization energy
- Electron drift velocity
- t_0 offsets
- Electron lifetime
- Recombination parameters
- Electric field
- Longitudinal and transverse electron diffusion
- Wire positions/geometry
- Wire field response
- Channel gain
- Overall electronics analog transfer function
- Electronic crosstalk
- Electronics noise, including correlated noise
- ADC linearity (differential and integral).

Correlations!!!

Photon detector response model:
- <similar list here>

(See Backup for more)

High level quantities
- Position reconstruction biases
- Direction reconstruction biases
- Energy scale
- Energy resolution
- Particle ID efficiencies
- Noise removal efficiencies
- …
- …

Particle response
- Charged hadron propagation
- Neutron response
- …

- Is this list complete?
- Position/time dependance?
- Needed precision?
- How to constrain? How much can you relay on external measurements?

DUNE SP/DP Calibration Task Force

- Formed at the last Collaboration meeting
- Mailing list: “DUNE-CALIBRATION-TF” — subscribe if you haven’t already
- Indico meeting list: https://indico.fnal.gov/category/703/
- Weekly meetings, alternating times
  - Thursdays, 2 pm Central
  - Tuesdays, 8 am Central
- A lot of productive discussions on a range of calibration topics, if you are a calibration enthusiast, we want you there!

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Tough path ahead:

Task Force Goals — long term

- Need to define calibration driven physics requirements (currently no detailed ties exist) and understand impact on LBL; Need Sim/reco tools — ***kick off discussion Thursday***

- Need a calibration strategy for TDR timeline (clarify assumptions; present arguments/studies to meet precision goals) — ***kick off discussion Thursday***

Calibration Feedthroughs

- For the last couple of months, the TF was focused on defining Calibration Feed Through requirements for DUNE SP
  - Laser
  - Radioactive sources
  - Photon System
  - Field Response Calibration …

See our Indico page for detailed talks on all these topics

- While we will continue to perform FT driven studies, the initial (intense) phase is coming to a wrap-up (phew!)
  - Our focus now is towards defining a calibration strategy and launching studies as needed

Lessons learned

- Focus topic for TF for the next few weeks: Launch a series of “lessons learned” talks from other experiments (plus possible studies and information to be gathered from on-going and future experiments)
  - MicroBooNE, 35-ton
  - ProtoDUNE SP/DP
  - T2K, ICARUS, LArIAT…
- Given that DUNE is a unique challenge (size, location and precision-wise), direct extrapolation from external data is questionable for all calibration needs, nevertheless there will be wealth of information to be learnt especially ProtoDUNE (minus the space charge)
  - E.g. what possible studies can be planned in ProtoDUNE that can feed into DUNE?
  - Closely collaborate with ProtoDUNE DRA group to pipeline information — will start discussions at the physics week

Food for thought

(by no means a complete list)

- *Calibration with Cosmics*
  - Alignment (local vs global), Stability monitoring, diagnosing failures (e.g. HV), electron lifetime, recombination, diffusion etc.
  - Rate of cosmics is very low, need to understand what is achievable.
  - The laser context (as an independent calibration probe)?
  - Reach with cosmics vs laser?
- *Radioactive source calibration*
  - Calibration needs for position and energy resolution?
  - How to disentangle various effects in visible energy spectrum?

Food for thought

(by no means a complete list)

- *Does DUNE need a Cosmic Ray Tagger?*
  - gives reconstruction efficiency with CRT, independent from TPC
  - More useful for Dirt or cosmic muons?
  - What is the most optimal location for the CRT?
- *T0-tagging*
  - PDS to TPC Calibration? (Is low cosmic rate an issue to do this on a short time scale?)
  - Is light from Ar-39 an issue? probably not but need simulations to show this.
  - Can CRT help here?
- *What can be done with dirt muons?*

Food for thought

(by no means a complete list)

- *How does fluid flow impact Space charge contributions from Cosmics & other Ionization sources (e.g. Ar-39 and Ar-42)?*
  - SP vs DP?
  - More complications for DP given the gas phase?
- *Drift field deformations from CPA/FC deformations? FC resistor failures?*
  - SP vs DP?
  - Can various effects add up to produce a worst case scenario?
  - E.g. Can steady state fluid flow + FC resistor failure impact space charge significantly?
  - Need to simulate worse case possible scenarios

Food for thought

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  failur
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Achieving a list of studies to be done (or questions to be answered) for a given topic in itself is a significant To-Do item.

We encourage you to contribute to such a list. (Just shoot an email to Sowjanya/Kendall)

Also Discussions planned

- Agenda: https://indico.fnal.gov/event/15181/other-view?view=standard
- Thursday, 9 to 11 am: *Calibration Joint session with FD Sim/Reco*
- Thursday, 11 am to 1 pm: *TDR organization/plans and Discussion*
- Thursday, 2 to 4:30 pm: *Calibration Joint session with LBL* (regular Task Force meeting slot)
- Friday, 1 to 3 pm: *Calibration Close-out talks & workshop summary/discussion*
- All other times: working group time — we want to get some work done along with important discussions!

This session

- Calibration with Cosmics kick-off (lead: Tom)
  - Focus: Alignment studies (Cosmics vs Laser?)
- Calibration for low energy events kick-off (lead: Juergen)
  - Focus: Energy and position resolution studies
- Working group time planned for both topics
- For other topics, we will form working groups as needed

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If you are new to DUNE or to DUNE Calibrations and not sure where to get started or how to contribute, please contact **Sowjanya (and Kendall)** and we will direct you to the relevant WG or contact point.

Your help is very much welcome!

Working group & Discussion space

- Working groups and informal discussions will happen in Atrium (let's hijack a table and label it "Calibration")

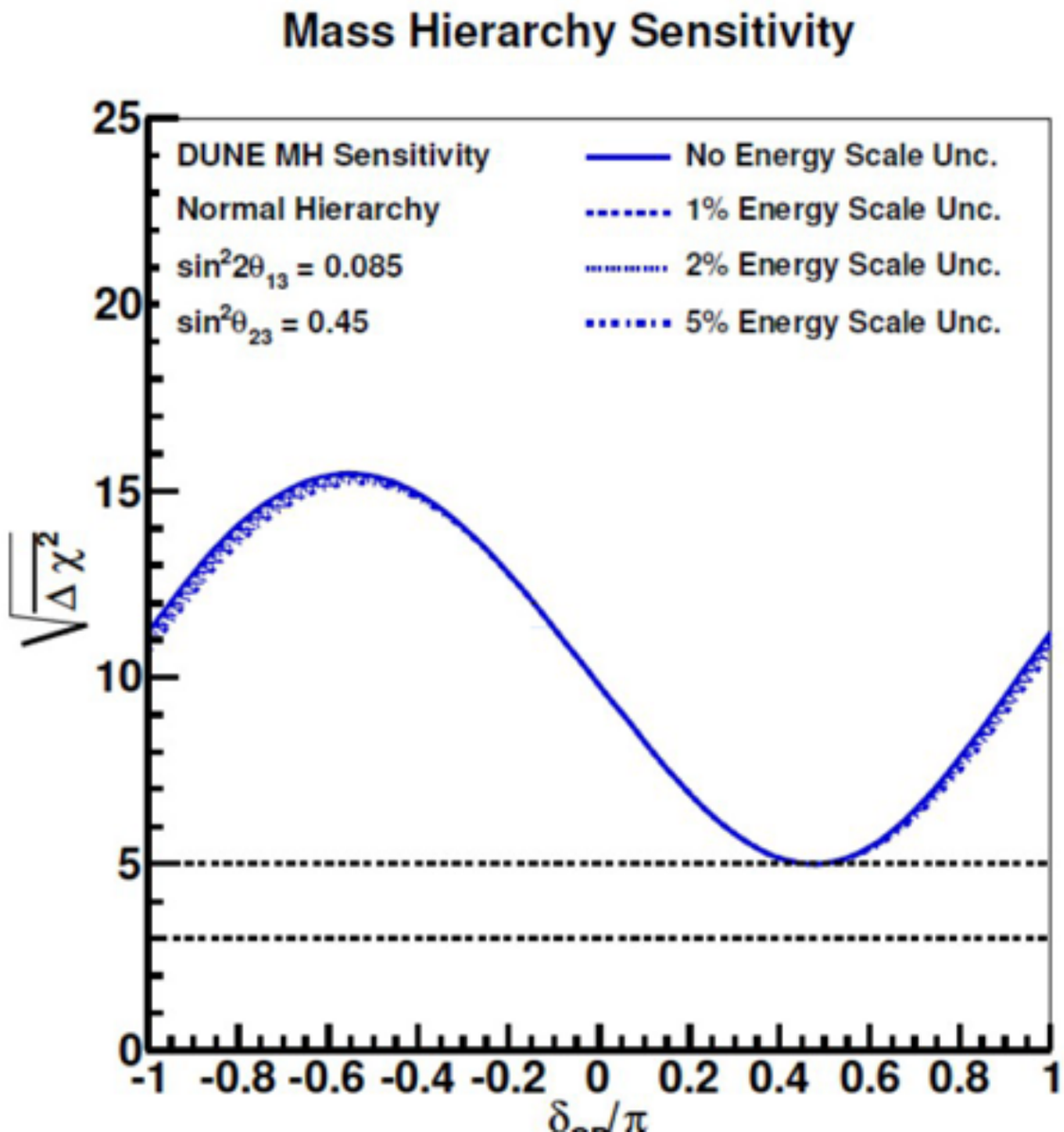
- The small dining room space (next to the wending machines in Atrium) is also available for discussions and interaction.

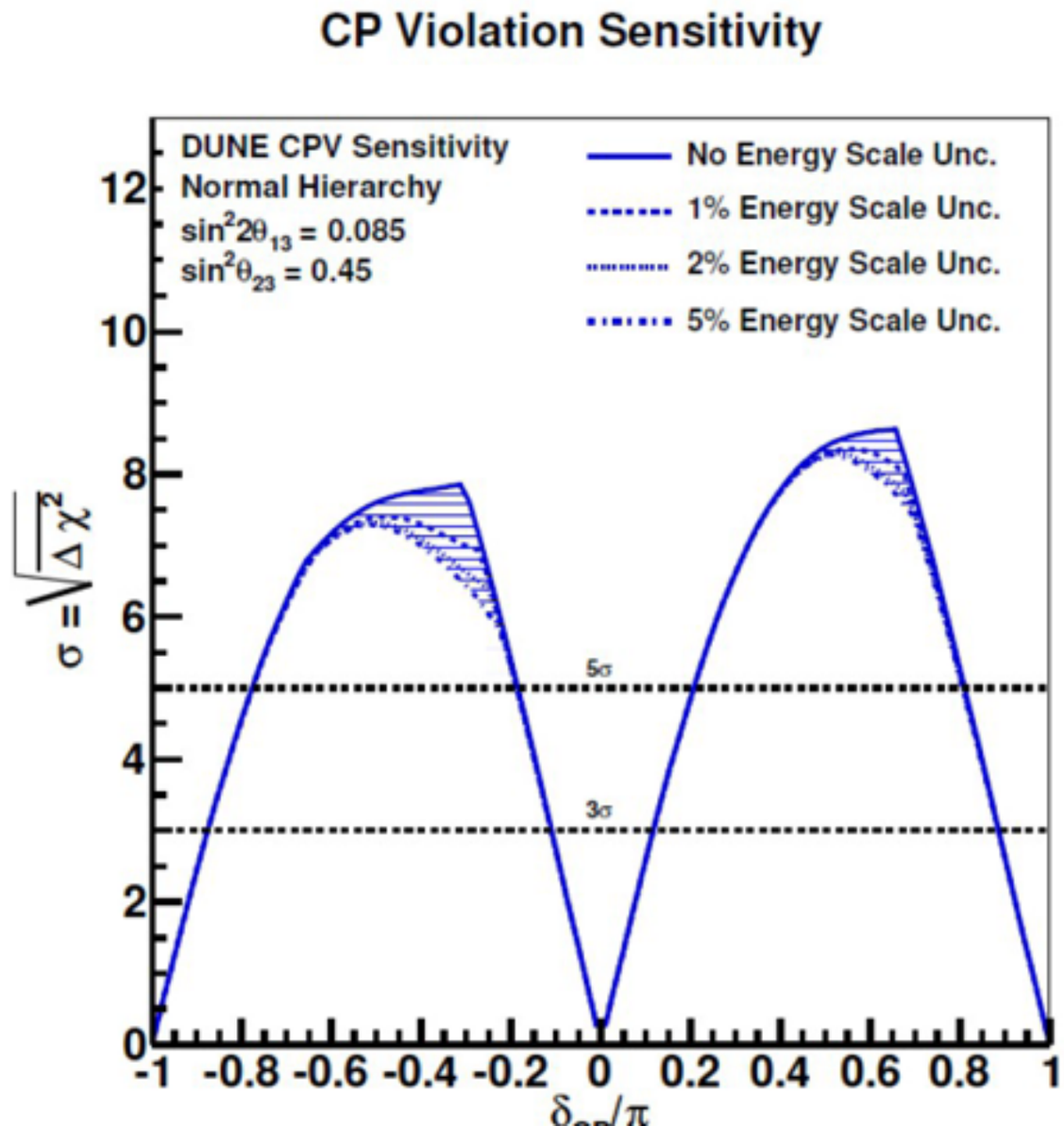
- *Let's get started!*

Backup

Issue: Unprecedented Physics Requirements of DUNE

CDR: Uncertainty of 2% on energy scale is already important to physics goals; calibration must be <2%





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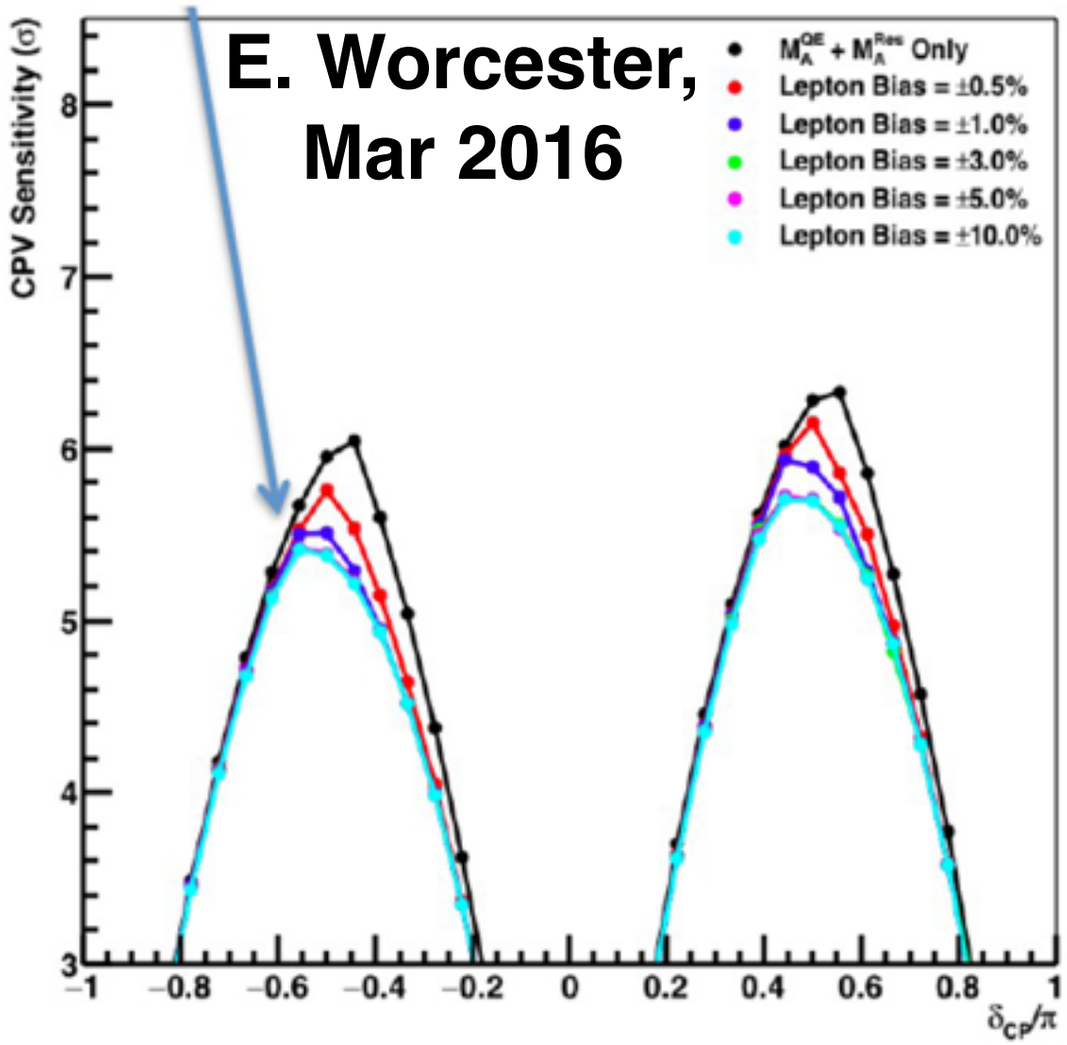
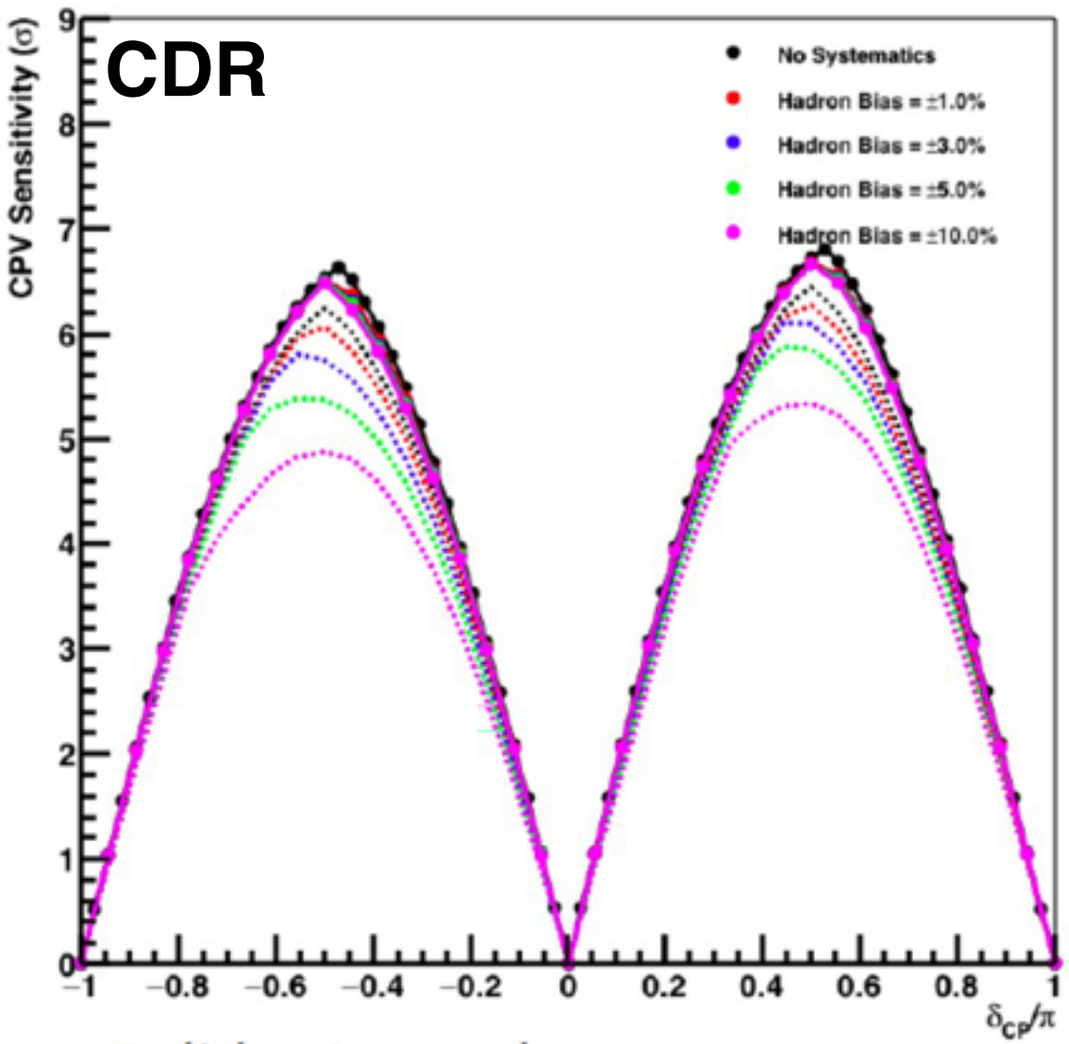




Solid = 4 sample
Dashed = ν_e only

https://indico.fnal.gov/contributionDisplay.py?contribId=4&confId=11718

Response Parameter Correlations

Igor's Matrix

	Source value ->	Mechanical accuracy	LAr purity (e lifetime)	Preamp gain	Coordinate	LAr temperature	dE/dx MIP	dQ/dx MIP	Momentum by MCS	Drift velocity	Drift field	Recombination, MIP	LAr density	Space charge	dE/dx Laser	dQ/dx Laser	Laser power	Laser track deviation
Affected value																		
Mechanical accuracy		0.01																
LAr purity (e lifetime)			0.10															
Preamp gain				0.02														
Coordinate		1.00			0.03					1.00								
LAr temperature						0.01												
dE/dx MIP							0.01						1.00					
dQ/dx MIP			0.20	1.00	1.00		1.00	0.04				1.00						
Momentum by MCS									0.00									
Drift velocity						2.98				0.03	0.50							
Drift field		1.00									0.01							
Recombination, MIP											0.16	0.00						
LAr density						1.00							0.01					
Space charge								1.00						0.01				

Measured relative error

Error correllation (color coded)

Derived relative error

Error correllation (color coded)

Error correllation (color coded)

But also: Noise model, FE response (beyond gain), induction wire resp.

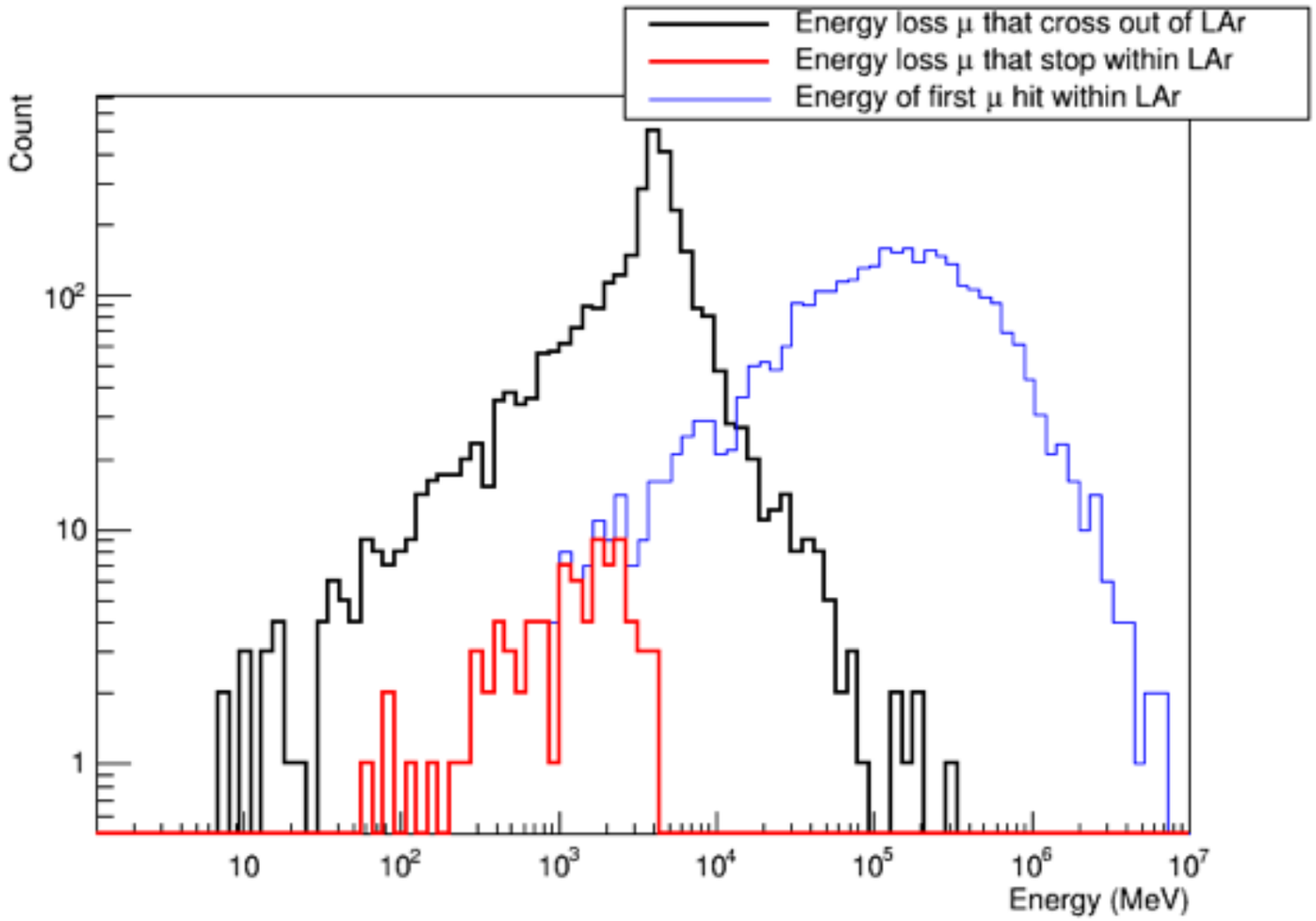
Cosmics and other sources of muons

- *Overall cosmic rate:* 4000 per day per 10 kt module
  - https://indico.fnal.gov/getFile.py/access?contribId=3&resId=0&materialId=slides&confId=14909 (Vitaly)
  - Stopping muons: 30/d/10kt, APA-CPA crossing tracks 200-500/d/10kt
    - Limited angular coverage: No muons at zenith angles >75 degrees
    - Roughly, each collection plane wire is hit only every 2-3 days **at best** (assuming 100% efficiency and no geometry considerations)
- *Beam induced rock muons:* 1 - 3/d/10kt
- *Atmospheric neutrinos:* ICARUS saw 0.33 v per day (476 ton active volume), implies 7/d/10kt for DUNE. Similar rate from atm nu - rock interactions.
  - typically lower energy, multiple Coulomb scattering effects dominate

Cosmics

https://indico.fnal.gov/conferenceDisplay.py?confId=14909

V. Kudryavtsev



- Stopping: 30 per day
- APA-CPA module crossing tracks: 200-500 per day
- No muons at zenith angles >75 degrees

Back of the envelope calculations showing collection wires are hit only 2-3 per day

- Assume 200 crossing tracks/d/10kt,
- Assume 1000 wires hit per cosmic.
- CDR: 384,000 wires/10kt cryostat => 380k/ 1000/200=2
- Roughly implies 2 days to hit all wires.

Back of the envelope calculations of extrapolation of atmospheric neutron rate from ICARUS to DUNE

Atmospheric neutrino rate, scale up from ICARUS:

ICARUS saw 1 neutrino per 3 days => 0.33333 nu per day
ICARUS has 476 tons of active volume
DUNE active volume for a 10kt detector is 10 kt
which results in about 7 muons per day per 10 kt volume