DEEP UNDERGROUND
NEUTRINO EXPERIMENT

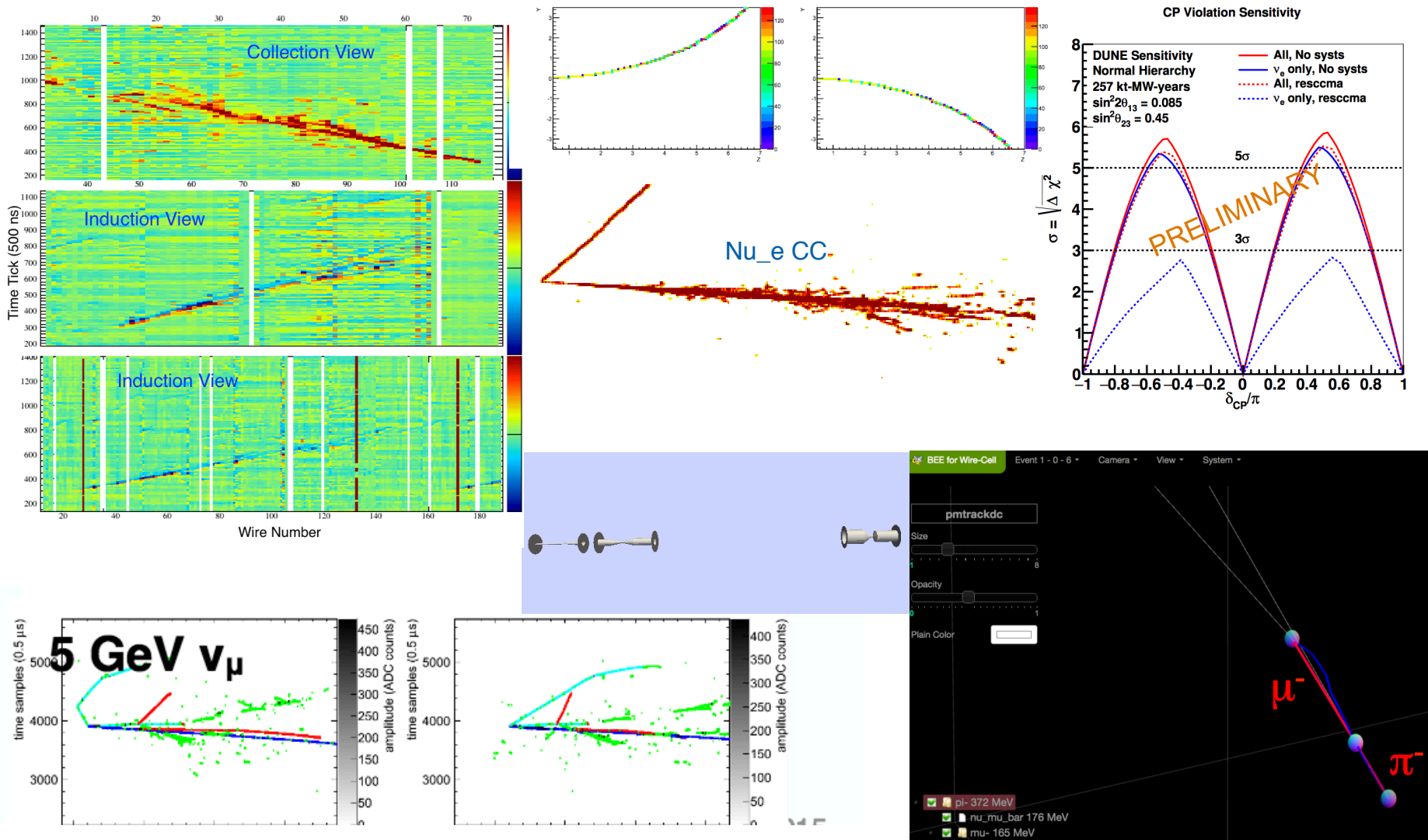# Opportunities in Software And Computing

Laura Fields

Outline

- Ongoing simulation/reconstruction efforts in DUNE
- Opportunities in protoDUNE software & computing
- Development of community tools for DUNE
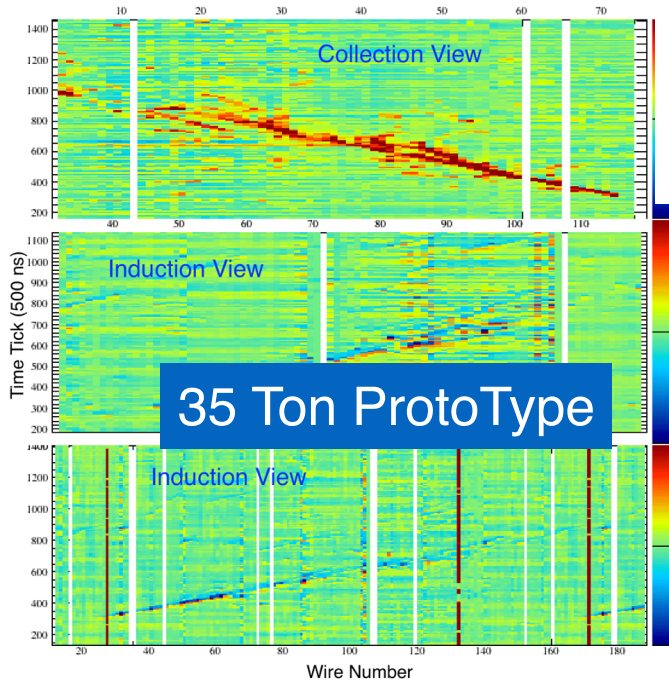
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A Note About Commitment

- I'll discuss opportunities with a **range of commitments**
- Most collaborators are only able to devote a **small fraction** of their research time to DUNE
  - Some of these **small contributions have had a big impact**
    - Valuable contributions to S&C projects have been made by undergraduate students working for only a few months
- But there is a **major need** for collaborators who can devote **large fractions of time** to DUNE software/computing, and commit for long periods
  - Ability to be **resident at Fermilab or CERN** for a period is very useful
  - Such commitments are likely to lead to **a huge impact** to the experiment
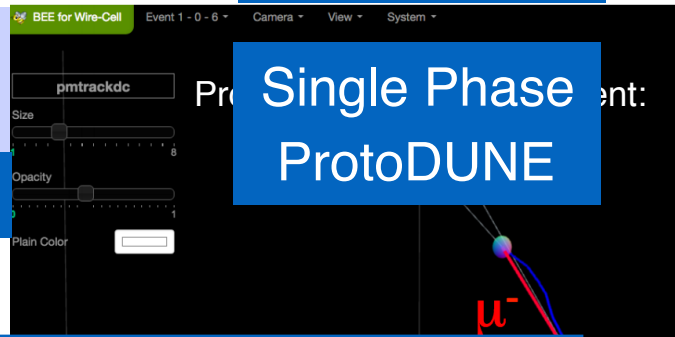
🔶 **Fermilab**

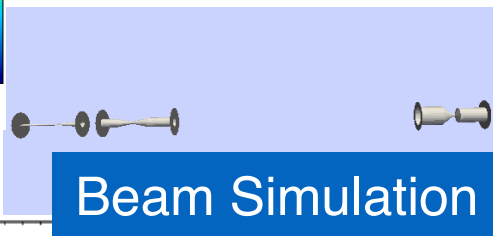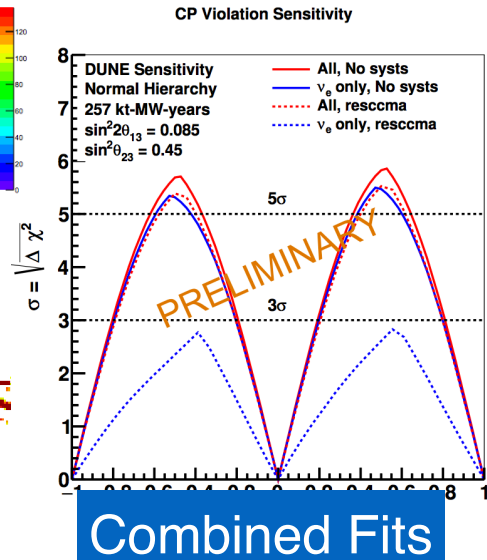# Ongoing Simulation/Reconstruction Efforts

Ongoing Simulation/Reconstruction Efforts

35 Ton Single Phase ProtoType @ FNAL

Collection View

Induction View

Induction View

35 Ton ProtoType

Near Detector

Nu_e CC

Far Detector

Dual Phase ProtoDUNE

Beam Simulation

Single Phase ProtoDUNE

CP Violation Sensitivity

DUNE Sensitivity
Normal Hierarchy
257 kt-MW-years
$\sin^2 2\theta_{13} = 0.085$
$\sin^2 \theta_{23} = 0.45$

All, No systs
ν_e only, No systs
All, resccma
ν_e only, resccma

5σ

3σ

$\sigma = \sqrt{\Delta \chi^2}$

PRELIMINARY

Combined Fits

BEE for Wire-Cell   Event 1 - 0 - 6   Camera   View   System

pmtrackdc

Size

Opacity

Plain Color

μ^-

π^-

There is a lot going on!
# Many projects groups can take responsibility for.

# Ongoing Simulation/Reconstruction Efforts
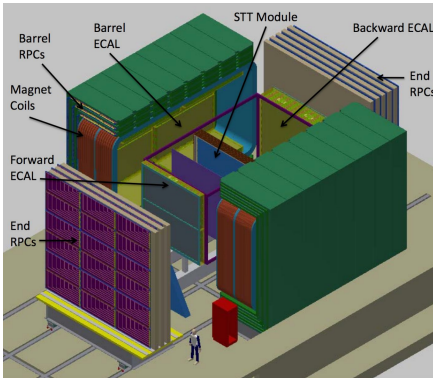
- **Near Detector** Simulation and reconstruction is an area of **critical need** for the collaboration

- **Near Detector task force** is currently analyzing relative merit of three detector options
  - Fine Grained tracker
  - High Pressure Gas TPC
  - Liquid Argon TPC

- Near detector software and computing current **coordinated by task force**

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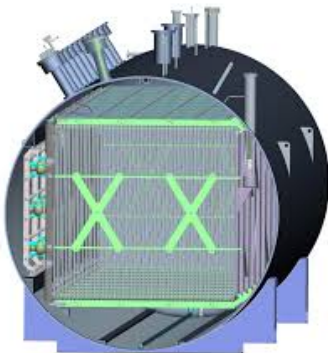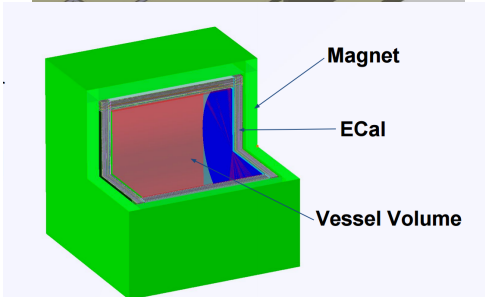
Ongoing Simulation/Reconstruction Efforts
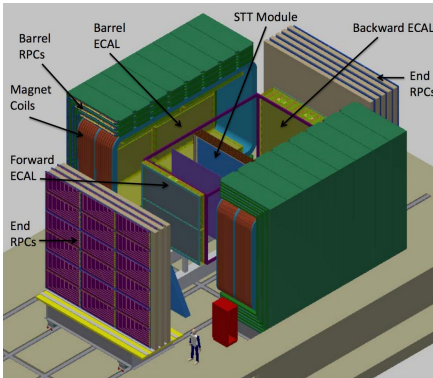
- **Fine grained tracker** Needs:
  - Development of real (not "fast") reconstruction algorithms
  - Detector electronics simulation
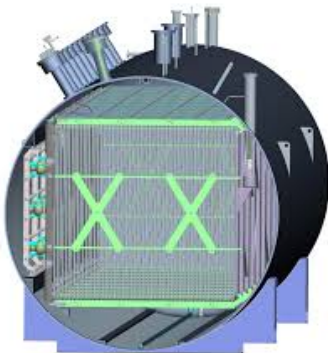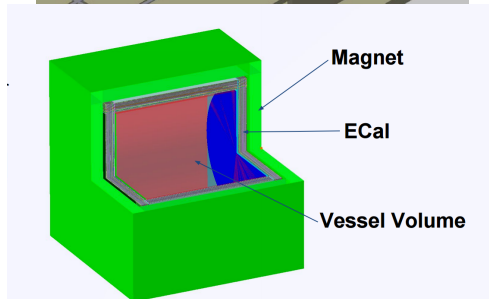 - Validation of background subtraction
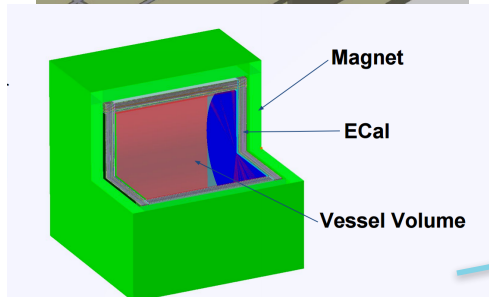
- **High Pressure Gas TPC** Needs:
  - Development of real (not "fast") reconstruction algorithms
  - Detector electronics simulation
  - Adaptation of T2K ND280 reco libraries
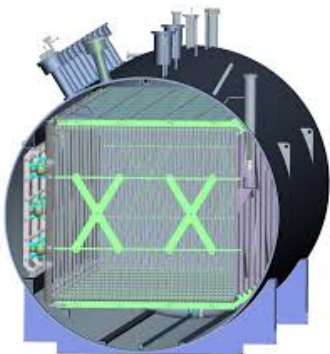
- **Liquid Argon TPC** Needs:
  - Reco of LAr events in magnetic field (how are resolutions, PID, etc different)?

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Ongoing Simulation/Reconstruction Efforts
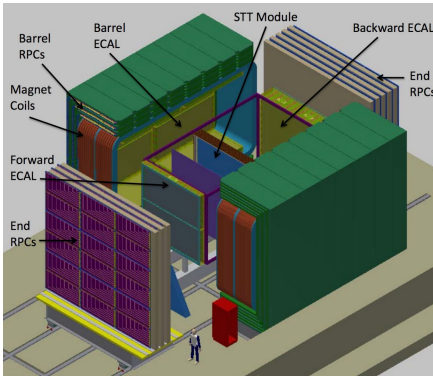
- **Opportunities exist to get involved** in simulation of any of the three detector options **on all levels**:
  - Simulation
  - Reconstruction
  - Event Selection
  - Simulated analyses:
    - Neutrino-electron scattering
    - "Low-nu"
    - How well can the three detector options perform these high-priority measurements aimed at flux constraint?

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Ongoing Simulation/Reconstruction Efforts
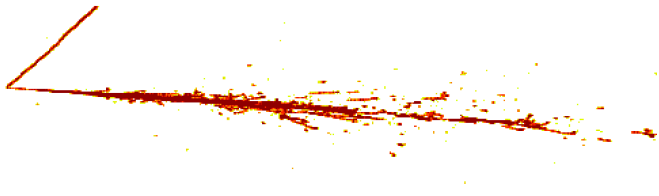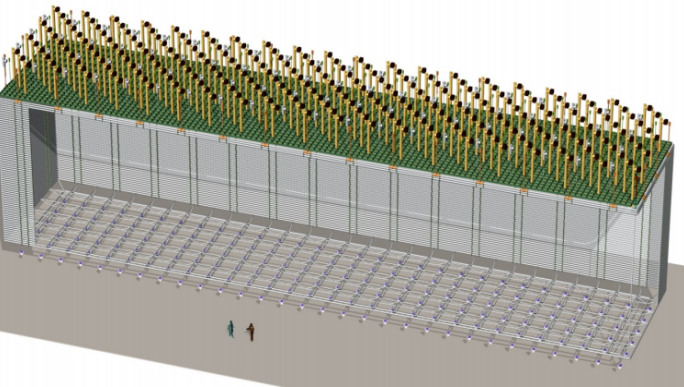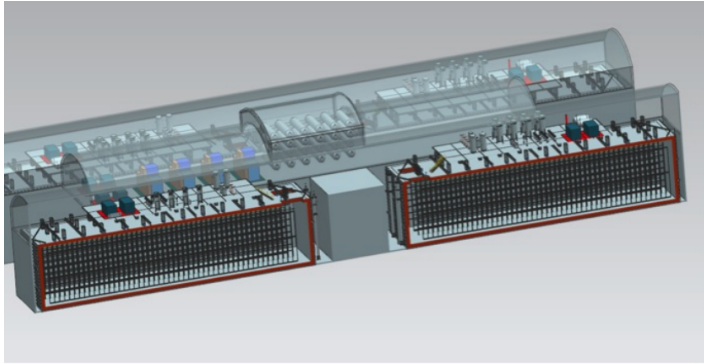
- Far detector effort currently focused on the goals of the **far detector optimization task force**, which was charged with:

  - Developing **full sim/reco chain**

  - Producing **optimization studies** (e.g. wire pitch, photon detector configuration, etc)

  - Developing simulation/ reconstruction of **SNB and Proton Decay** physics

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Ongoing Simulation/Reconstruction Efforts
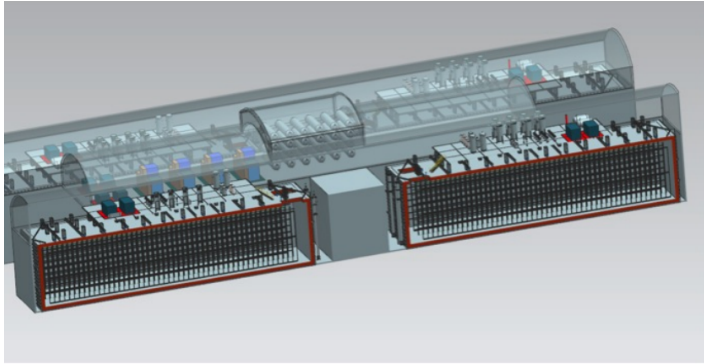
- Far detector needs:
  - Neutrino **event selection**
  - Neutrino **event classification** and energy measurement
  - **Systematic uncertainty** evaluation
  - **Wire angle**, spacing, orientation

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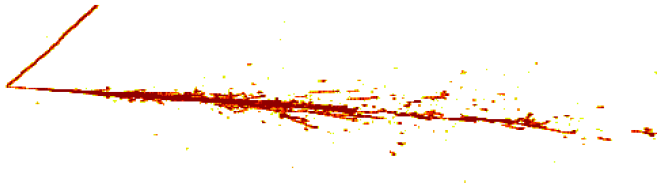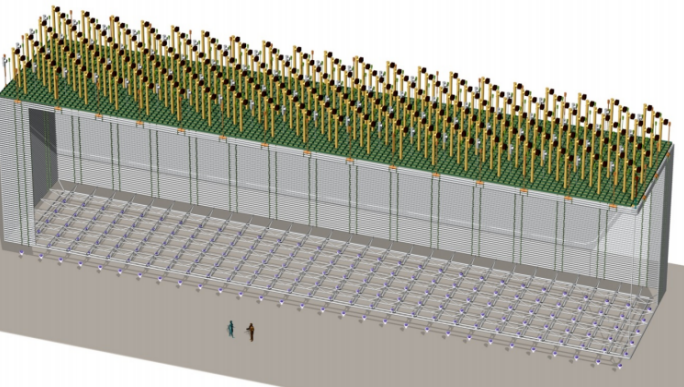
Ongoing Simulation/Reconstruction Efforts
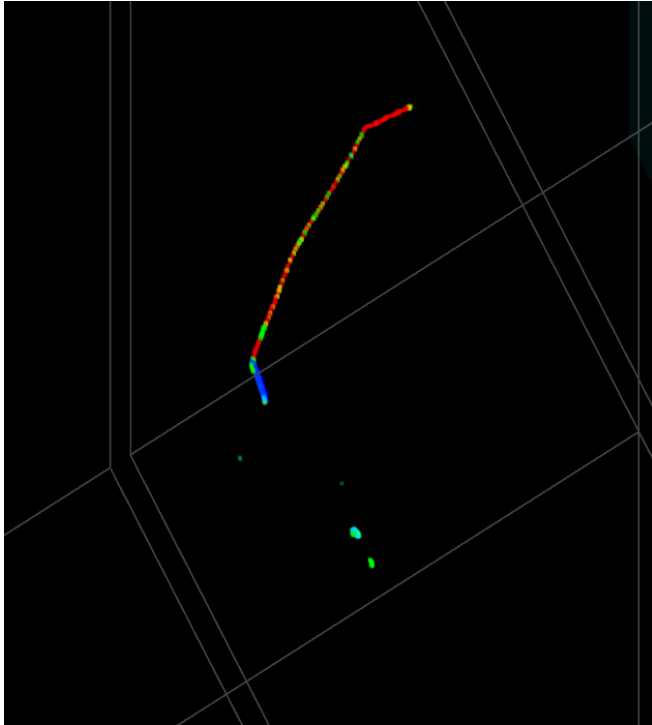
Bee Event Display

p -> K nubar in Far Detector

http://www.phy.bnl.gov/wire-cell/

- Another far detector need: development of reconstruction using **Wire-Cell reconstruction package**

Wire-Cell Imaging:
- 2D images at fixed time slice are reconstructed
- 2D images are then stitched together to form 3D object
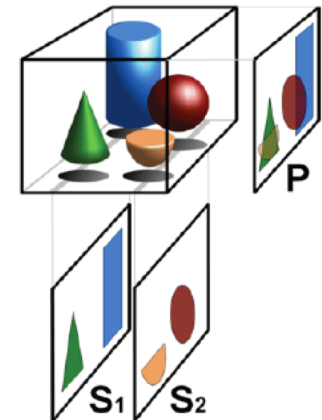
X. Qian

- One area of potential involvement: development of direct 3D pattern recognition.

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Ongoing Simulation/Reconstruction Efforts

- **35 Ton ProtoType** Needs
  - On a **short timescale** — data is already taken
  - **Noise** filtering
  - **Disambiguation** with just two planes
- **Célio Moura from UFABC** is contributing to this effort

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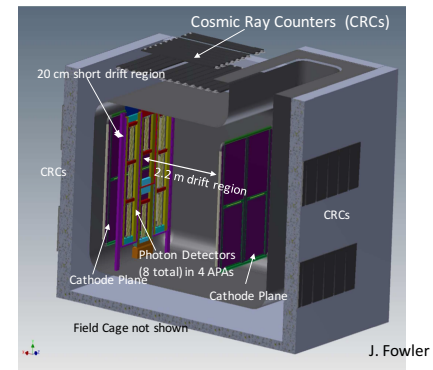
Ongoing Simulation/Reconstruction Efforts

- ## Beam Simulation effort:

  - Currently focused on beam **optimization task force** charge of identifying and comparing various beam options

  - Have identified **several idealized designs** that produce substantially better flux

  - Over the next months/years, work will shift to developing **detailed simulation of conceptual and preliminary designs**

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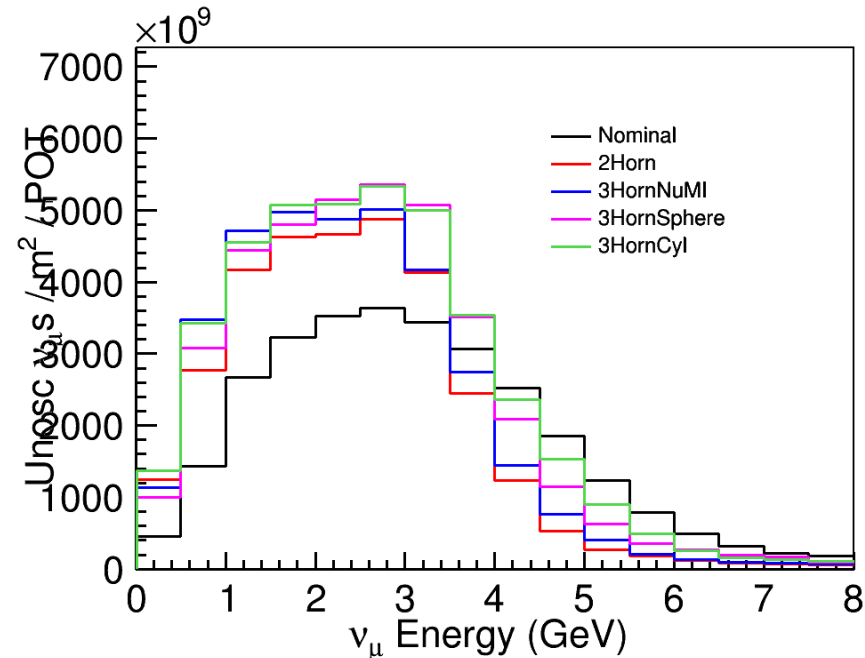
Ongoing Simulation/Reconstruction Efforts

- ## Beam Simulation Effort:

  - We know the LBNF/DUNE beam will be **more intense** than any existing neutrino beam

  - To meet our physics goals, it must also be the **best understood**

  - We need people to

    - Develop **detailed Geant4 geometries**

    - **Validate** geometry and physics models

    - Develop of **muon and hadron monitor** simulations
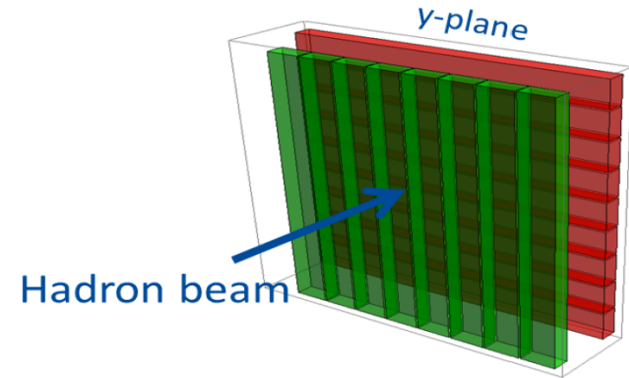
K. Yonehara, H. Dinkel

🧩 **Fermilab**
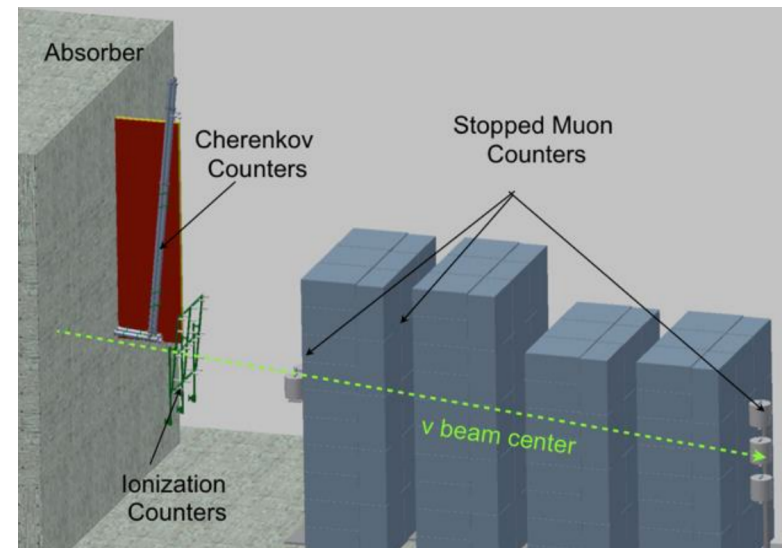
Ongoing Simulation/Reconstruction Efforts

- **General Software/Computing Needs:**
  - Each group needs a software release manager and quality control testing
  - Batch system interfaces -- we have ways to submit jobs to Fermigrid and OSG. Need to expand resource pool to include CERN resources

Fermilab Grid Computing Center
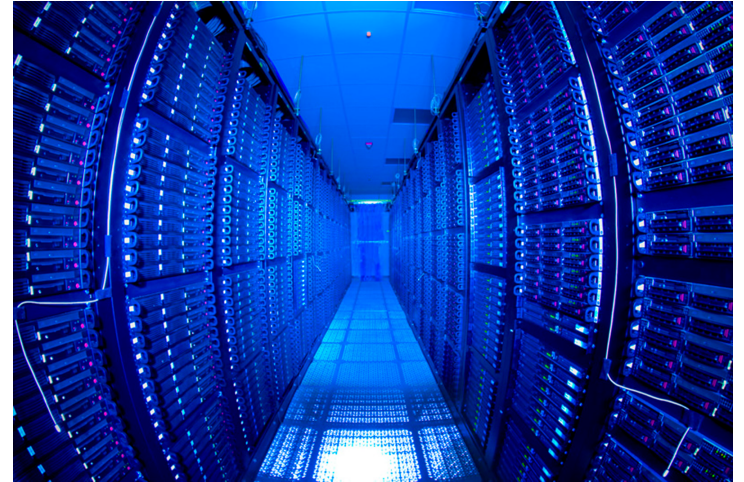
Reider Hahn

CERN Data Centre

http://home.cern/about/computing

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Ongoing Simulation/Reconstruction Efforts

- **General Software/Computing Needs:**

  - Help with **data management infrastructure**

    - For general long term use but specifically for ProtoDUNE in near future

  - Have model for **distributing data** from detector **to external sites**

    - Hosting such a site at **your institution** (even a small one) would help **build distributed data model**

    - Bonus: **local access** to data for analysis!

Fermilab Grid Computing Center

Reider Hahn

CERN Data Centre

http://home.cern/about/computing

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ProtoDune Software/Computing Opportunities

- ProtoDUNE DAQ/Online Activities
  - RCE, SSP, and Penn Board (trigger) **firmware**
  - Online disk buffer farm
  - DUNE-specific **artDAQ components**
    - Board Reader modules
    - Fragment generators
    - Aggregators
    - Event building
    - Online monitoring of data
    - Compression
  - Online **event display**
  - **Run control**
  - **Conditions database**
  - **Data cataloging tools** -- good run list, web pages, and data curation

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ProtoDune Software/Computing Opportunities

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This is an area where Latin American Institutions have a proven track record at Fermlab — CBPF students wrote MINERvA's online monitoring system

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ProtoDune Software/Computing Opportunities

- **ProtoDUNE: Single-Phase** Opportunities for Involvement:
  - **Signal processing**, noise filtering, and deconvolution
  - **Hit finding** and disambiguation (TPC and photon-detector)
  - Track and shower **reconstruction**
  - **Photon-detector**/TPC association algorithms
  - MC interface and tuning; running **MC samples** and cataloging.
  - **Event selection**
  - **Cosmic-ray** rejection
  - **Analysis design and systematic uncertainty** estimation
    - pion/kaon cross sections
    - electron and photon selection and energy measurement
    - proton ID
    - muon range and multiple scattering measurement
    - space charge constraints
    - detector alignment

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ProtoDune Software/Computing Opportunities

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ProtoDune Software/Computing Opportunities

- **ProtoDUNE: Dual-Phase** Opportunities fo_____t:
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  - _____nstraints
  - de_____gnment

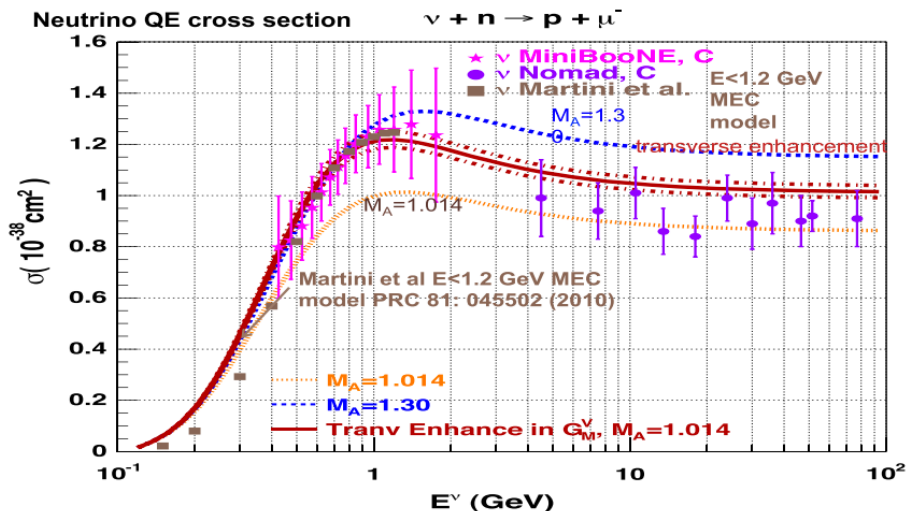*Same needs as single phase*

Residency at CERN may be required for some, but we also expect to have a significant center of mass @ Fermilab.

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Development of Community Tools for DUNE

- There is intense development underway of many **HEP and Neutrino software tools** that will be used by DUNE

Bodek, Christy, Coopersmith EPJ C (2014) 74:3091

- **An Example: The GENIE Event Generator**

  - Ongoing development of many, **many models**

  - Ongoing work to develop **validation and tuning infrastructure** that will incorporate data as it comes in over the next decade and determine tunes used for DUNE

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Development of Community Tools for DUNE

- There is intense development underway of many **HEP and Neutrino software tools** that will be used by DUNE

  - **Another Example: Geant4**
    - Active **development of models** and physics list
    - Work towards **systematic uncertainty** framework underway
    - Re-engineering for **new computing architectures**

ITEP Data : 7.5 GeV/c p Cu

G4 10.1.**ref08** vs 10.1.**ref00**
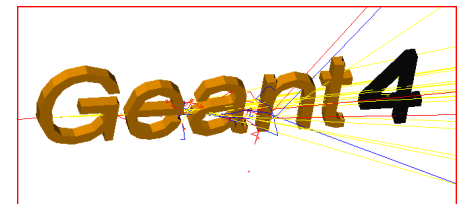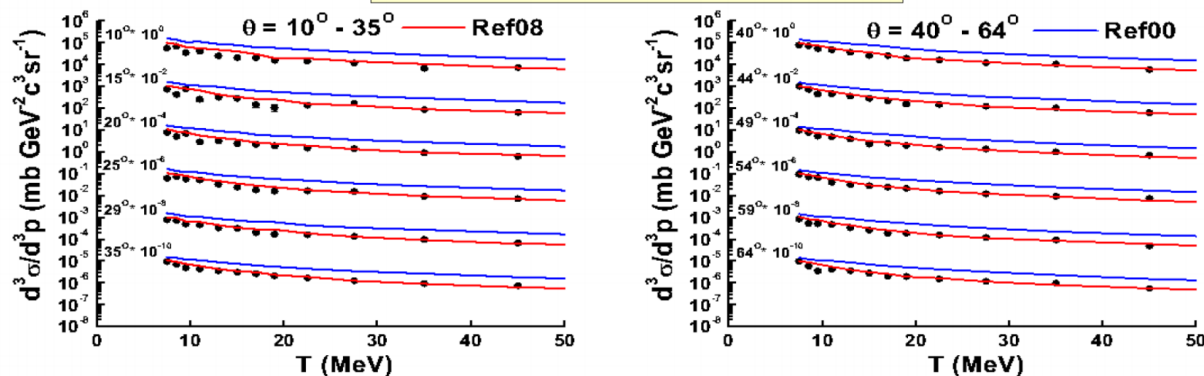
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Development of Community Tools for DUNE
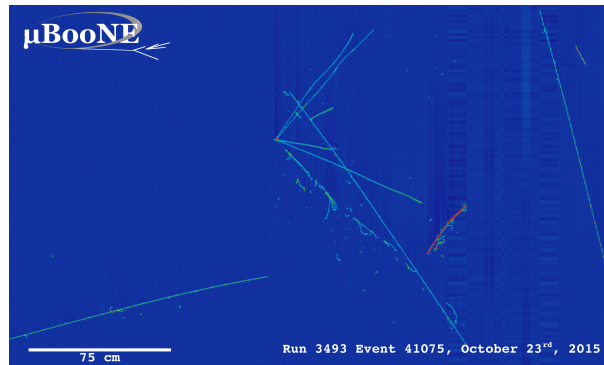
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    - **Another Example: Geant4**
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This is another area of demonstrated success by Latin American groups:

- Rodrigo Castro group @ UBA: working on an alternative integration method to improve speed of Geant4.

- Sergio Novaes group @ UNESP: working on GeantV project to re-engineer for new hardware architectures.

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Development of Community Tools for DUNE

- There is intense development underway of many **HEP and Neutrino software tools** that will be used by DUNE

  - **Another Example: LarSoft**
    - Also engaged in re-engineering for new computer architectures (e.g. enabling multithreading/vector units)
    - Efforts underway to pull forward algorithms tested and used by MicroBooNE for DUNE
    - Many infrastructure expansions that will eventually aid DUNE (e.g. event display improvements)

µBooNE

75 cm   Run 3493 Event 41075, October 23rd, 2015

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Development of Community Tools for DUNE

- There is intense development underway of many **HEP and Neutrino software tools** that will be used by DUNE

  - **Another Example: LarSoft**
    - LArSoft development is a great way to simultaneously contribute to DUNE and other experiments
      - An example: **A. Higuera (former Guanajuato grad student** now at the University of Houston) has developed standardized track/shower efficiency calculations for DUNE that were immediately adopted by MicroBooNE
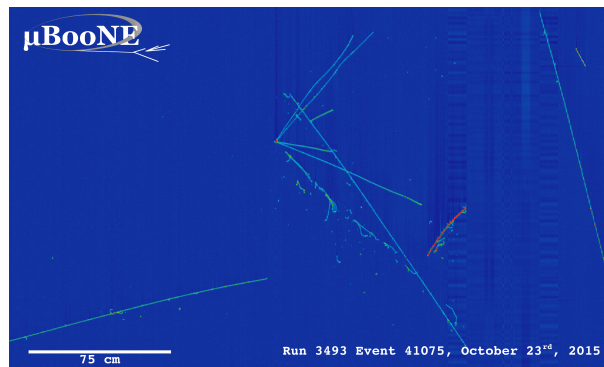
Conclusion

- DUNE is going to be awesome!

- That awesomeness requires an **immense amount of software and computing work** over the next decade

- There are **lots of places your group can make an impact**

- Two areas with a **lot of opportunities**:
  - **ProtoDUNE** Software/Computing
  - **Near Detector** Simulation

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Conclusion

- **Where to find more infomation**
  - **Spokes people** (Mark Thomson and André Rubbia) and/or **S&C coordinators** (Tom Junk and Amir Farbin) should be your first contacts
  - Working groups / conveners can be found on the **DUNE at Work** page
    - **https://web.fnal.gov/collaboration/DUNE/SitePages/Home.aspx**
  - Software and computing mailing lists: https://web.fnal.gov/project/LBNF/SitePages/LBNF%20and%20DUNE%20Mailing%20Lists.aspx
    - General questions go to **dune-communication@fnal.gov**
  - Those interested in developing community tools can join the Simulations for Neutrinos Fermilab mailing list
    - **simulations_for_neutrinos@listserv.fnal.gov**

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Thanks for Listening!

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