The Short Baseline Neutrino Program

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On behalf of the MicroBooNE, ICARUS, and SBND Collaborations

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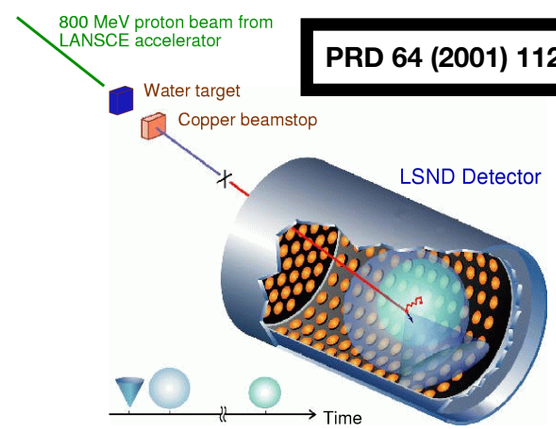
THE UNIVERSITY OF CHICAGO

Sterile Neutrinos

- There are multiple experiments which provide evidence for sterile neutrinos
- The must significant of these come from LSND and its follow-up experiment MiniBooNE

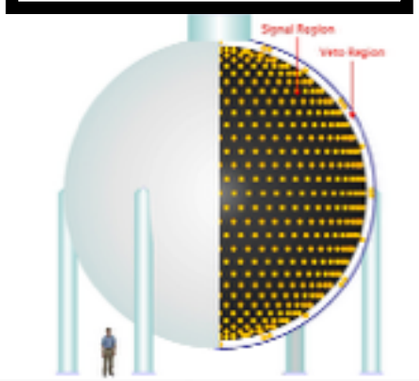
LSND

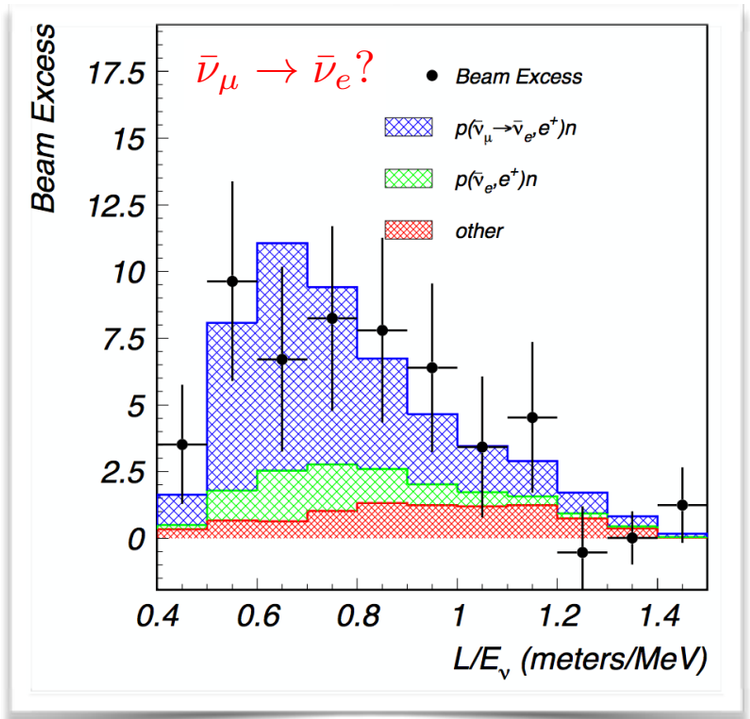
PRD 64 (2001) 112007

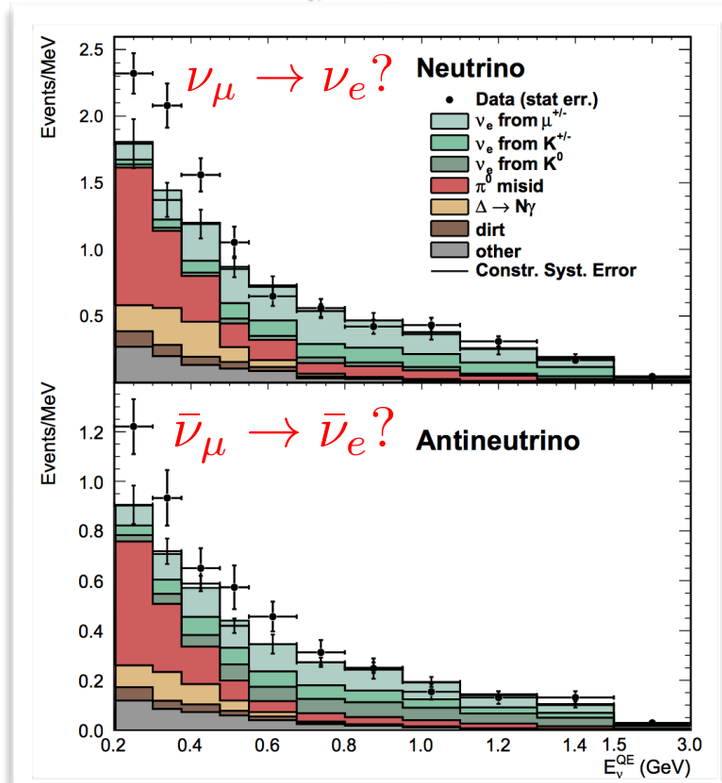


MiniBooNE

PRL 110 (2013) 161801





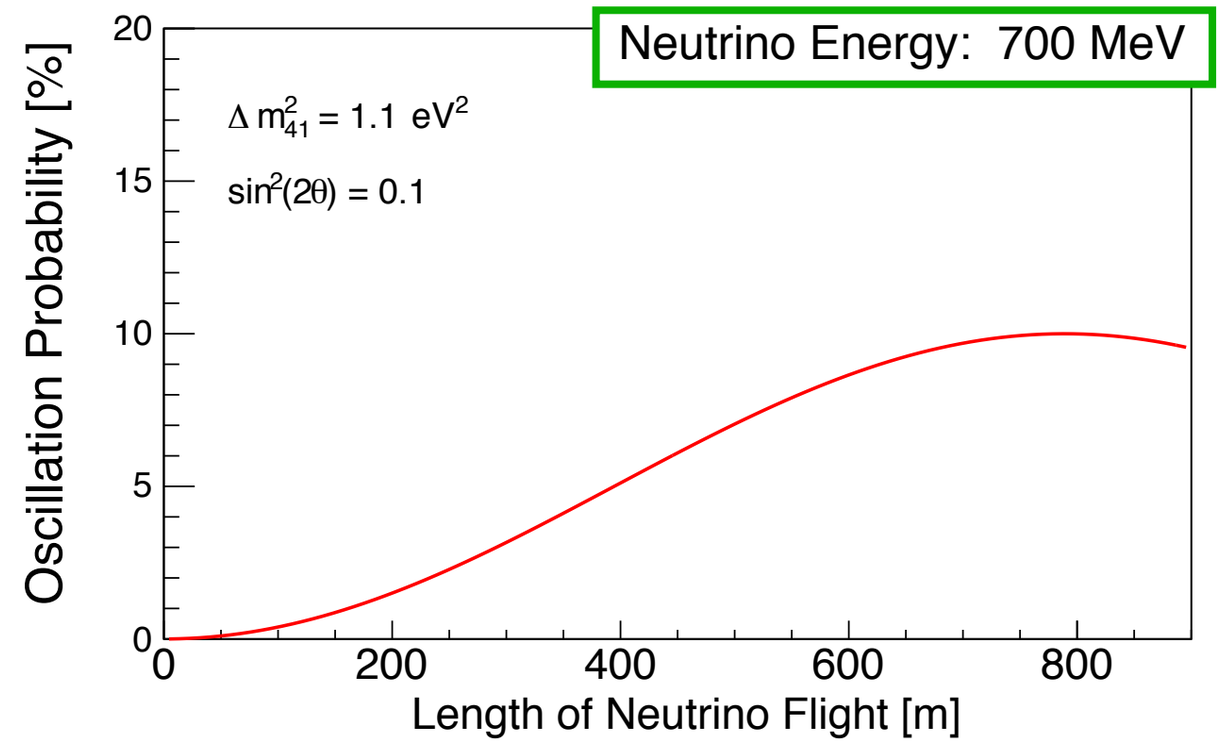


Both results can be interpreted as oscillations involving an eV scale sterile neutrino with an L/E ≈ 1 km/GeV

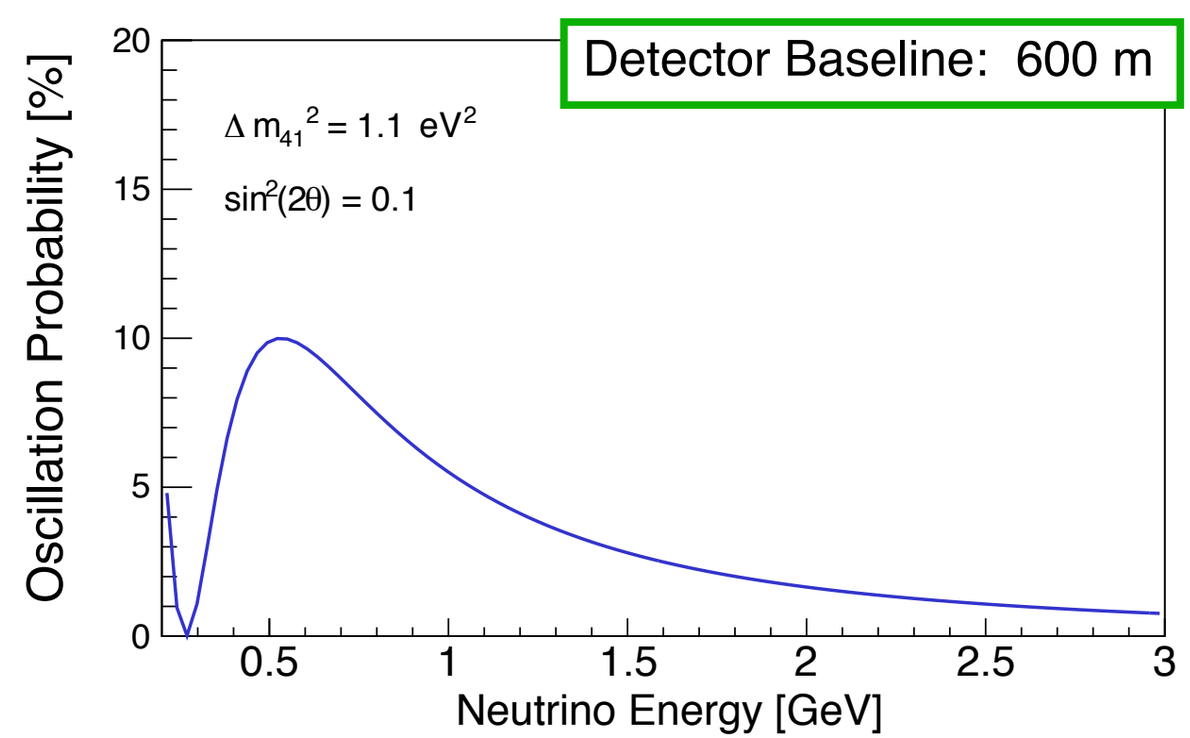
Sterile Neutrino Oscillations

- Due to the large mass splitting we can study these oscillations with a simple two neutrino model

$$P^{3+1}_{\nu_\alpha \to \nu_\beta} = \sin^2 2\theta \sin^2 \frac{\Delta m^2_{41} L}{4E}$$

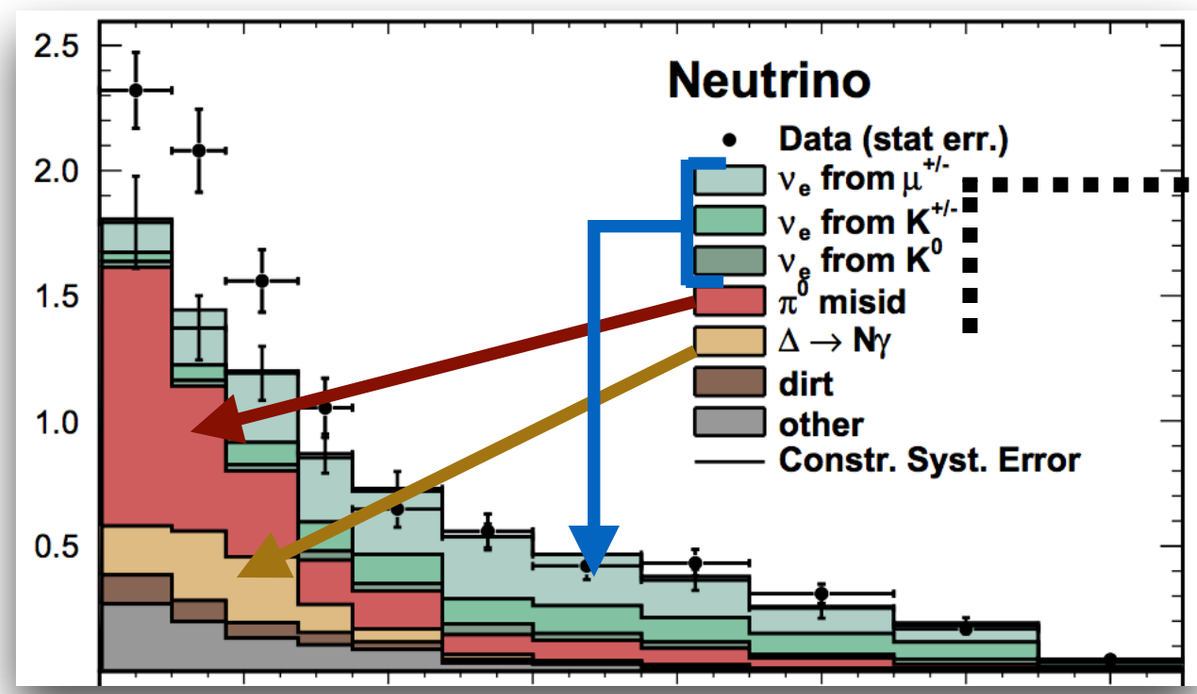


- The hallmark of this would be the transformation of one type of neutrino into another over a baseline



MicroBooNE

- The main physics goal of MicroBooNE is to define the the composition of the Low Energy Excess
- Relying on the LAr TPC capabilities we can see if the excess is described by single photon backgrounds or an excess of electron-neutrinos



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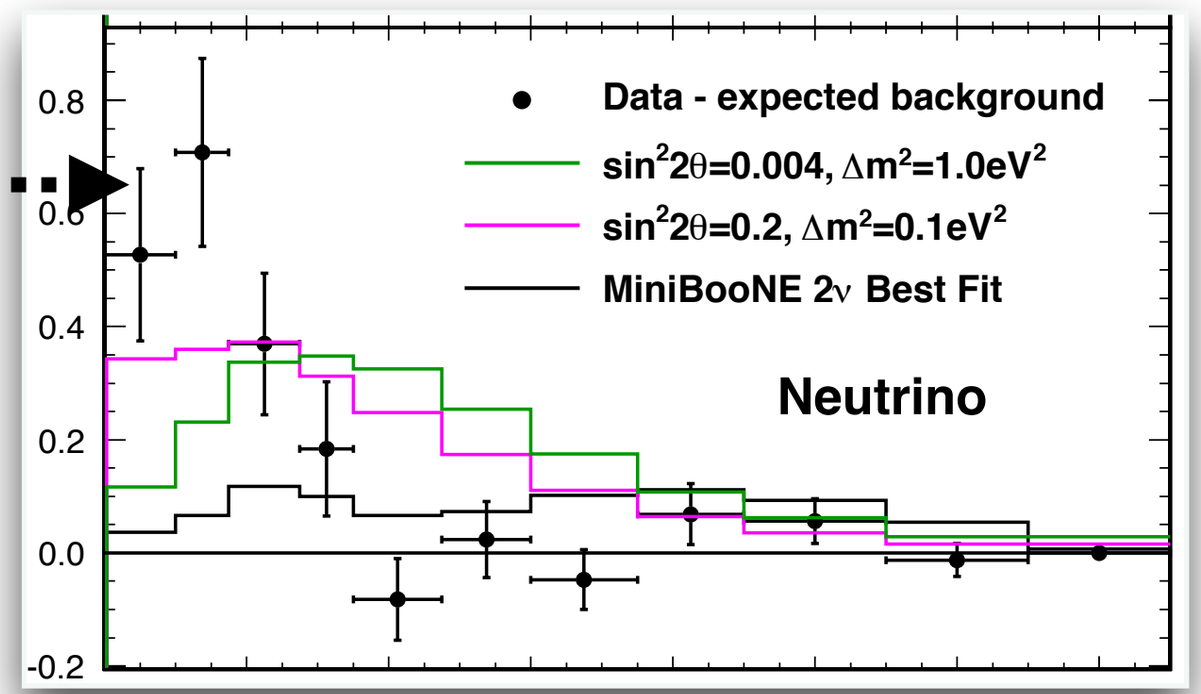
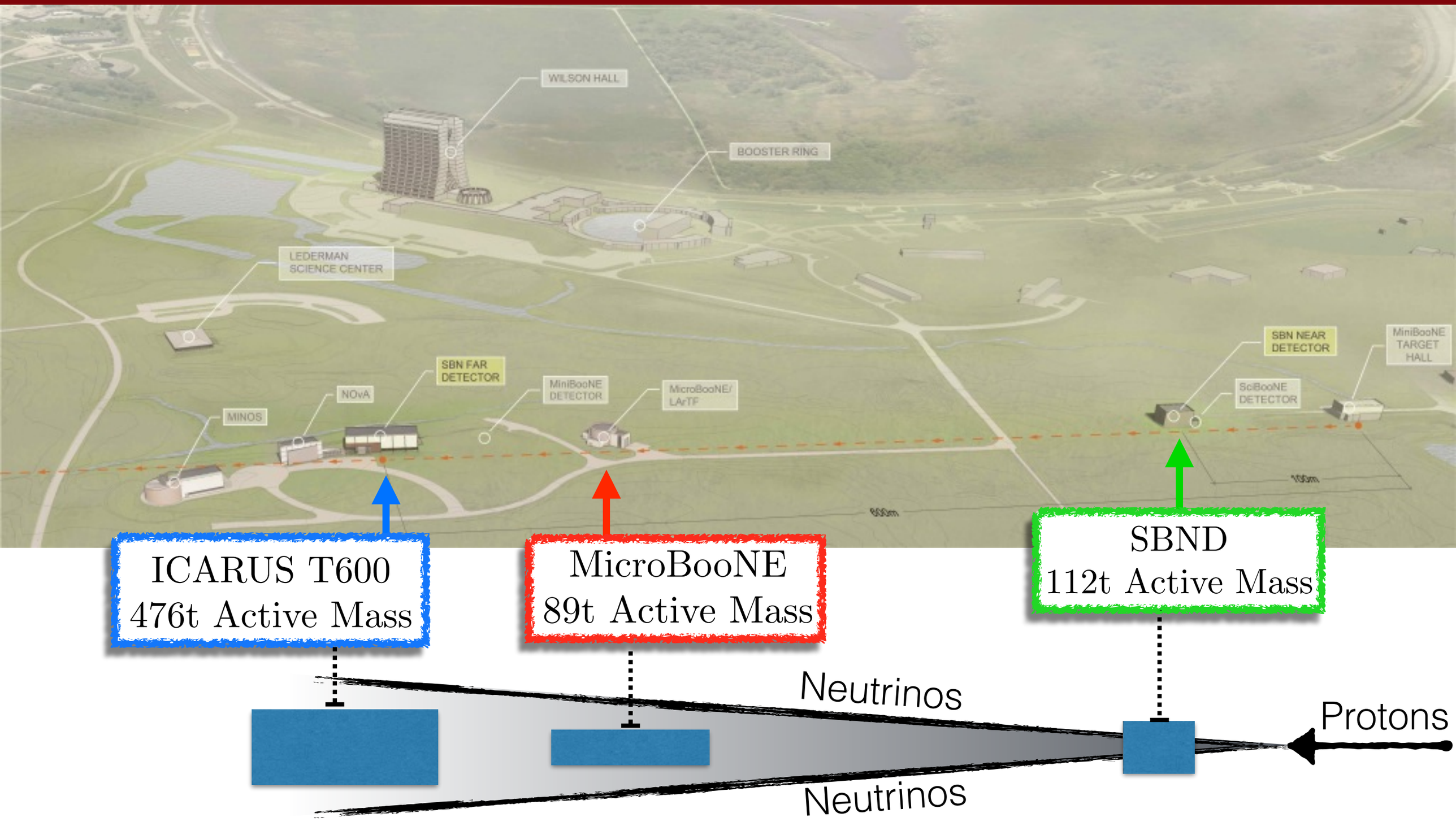


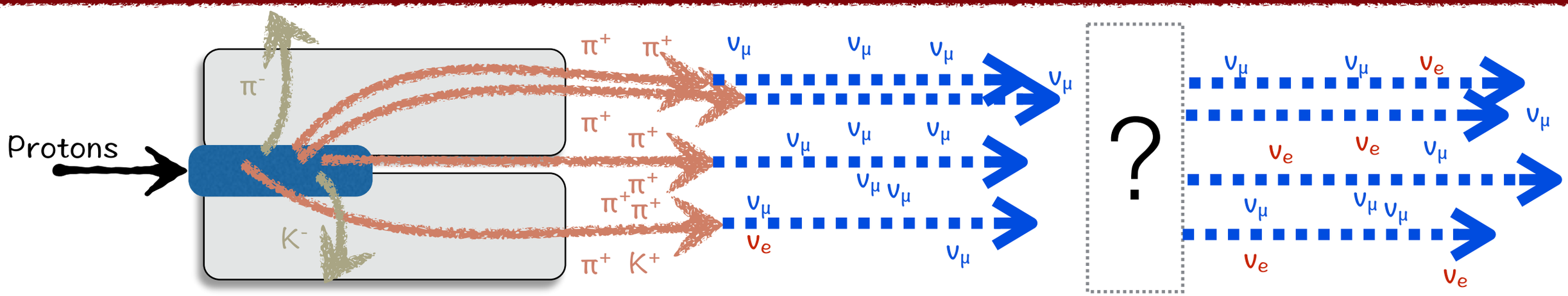
PRL 110 (2013) 161801

Short Baseline Neutrino Program

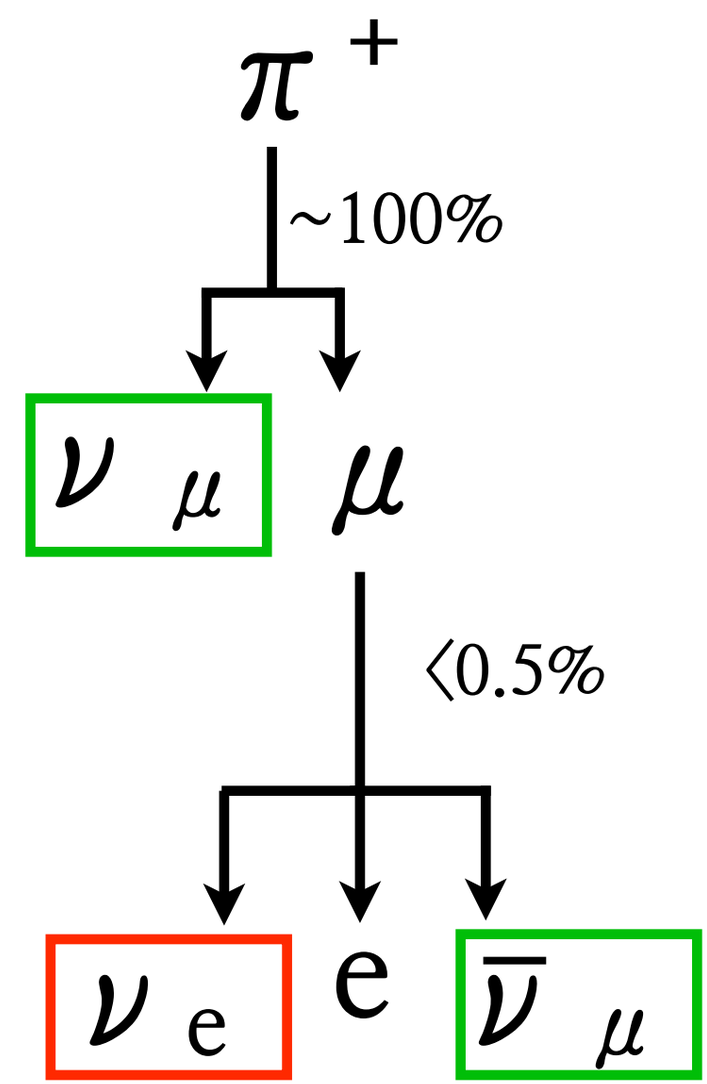


Reduced systematics!

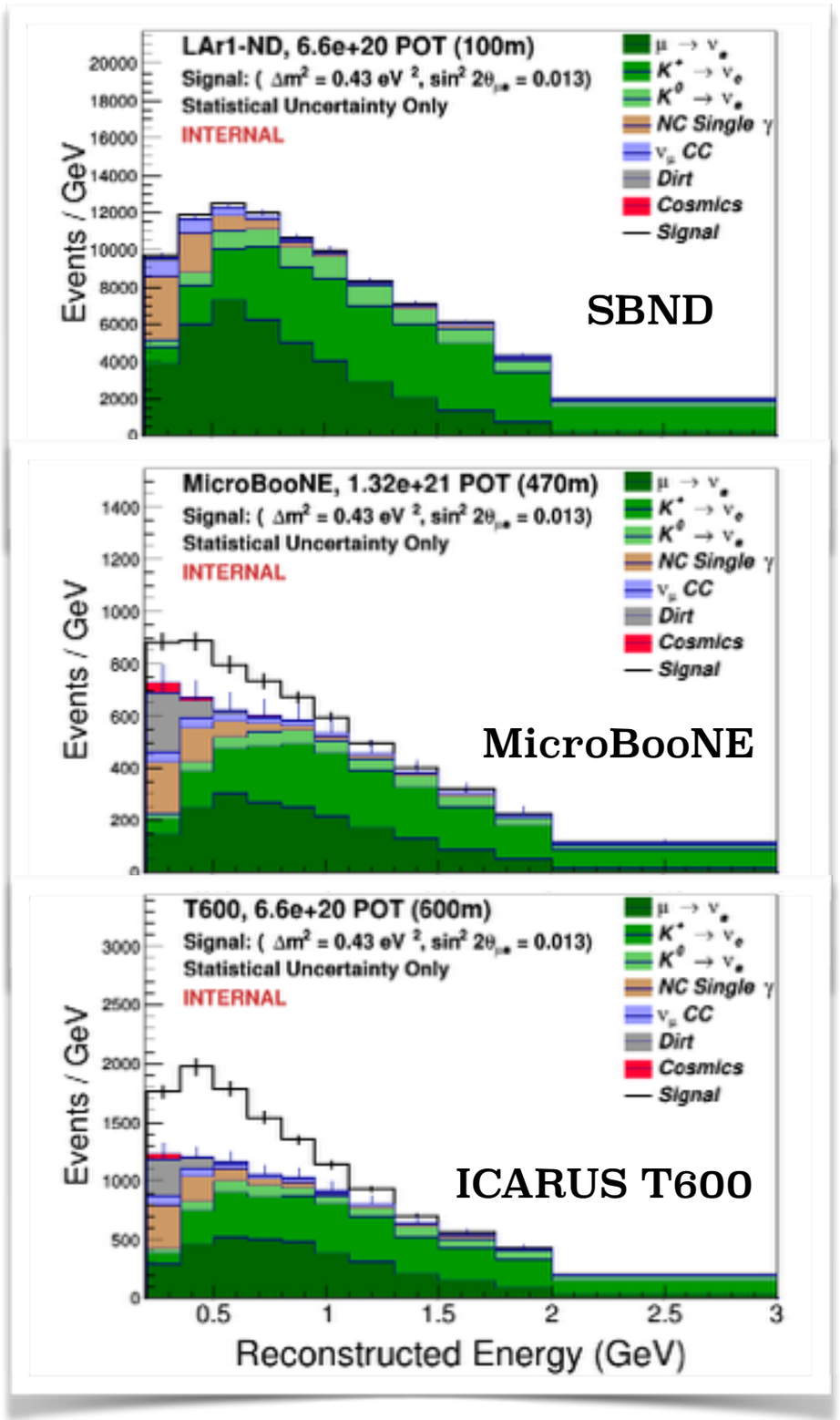
Booster Neutrino Beam



- Booster Neutrino Beam has been stably run for a decade
- Mesons from 8 GeV proton-beryllium collisions are focused forward by a magnetic horn
- This results is a beam of mostly muon neutrinos, where we can search for flavor disappearance and appearance



Electron Neutrino Appearance



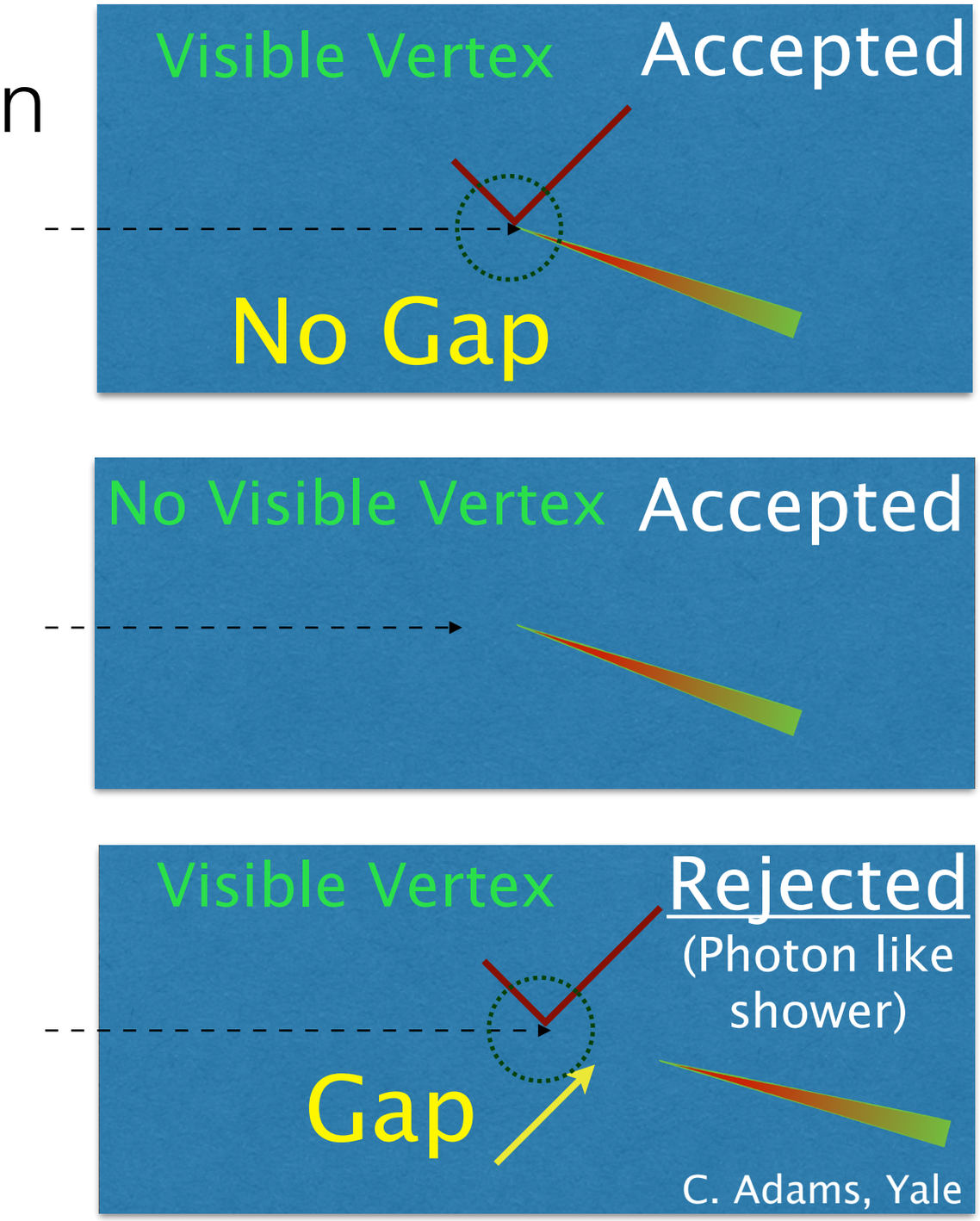
- Electron neutrino CC interactions
  - $\pi \rightarrow \mu \rightarrow \nu_e$
  - $K^+ \rightarrow \nu_e$
  - $K^0 \rightarrow \nu_e$

  Intrinsic beam ν_e
  - Sample appearance signal

- Photon-induced backgrounds
  - NC misIDs
  - ν_μ CC misIDs
  - "Dirt" Backgrounds: beam-related but out-of-detector interactions
  - Cosmogenic photon sources

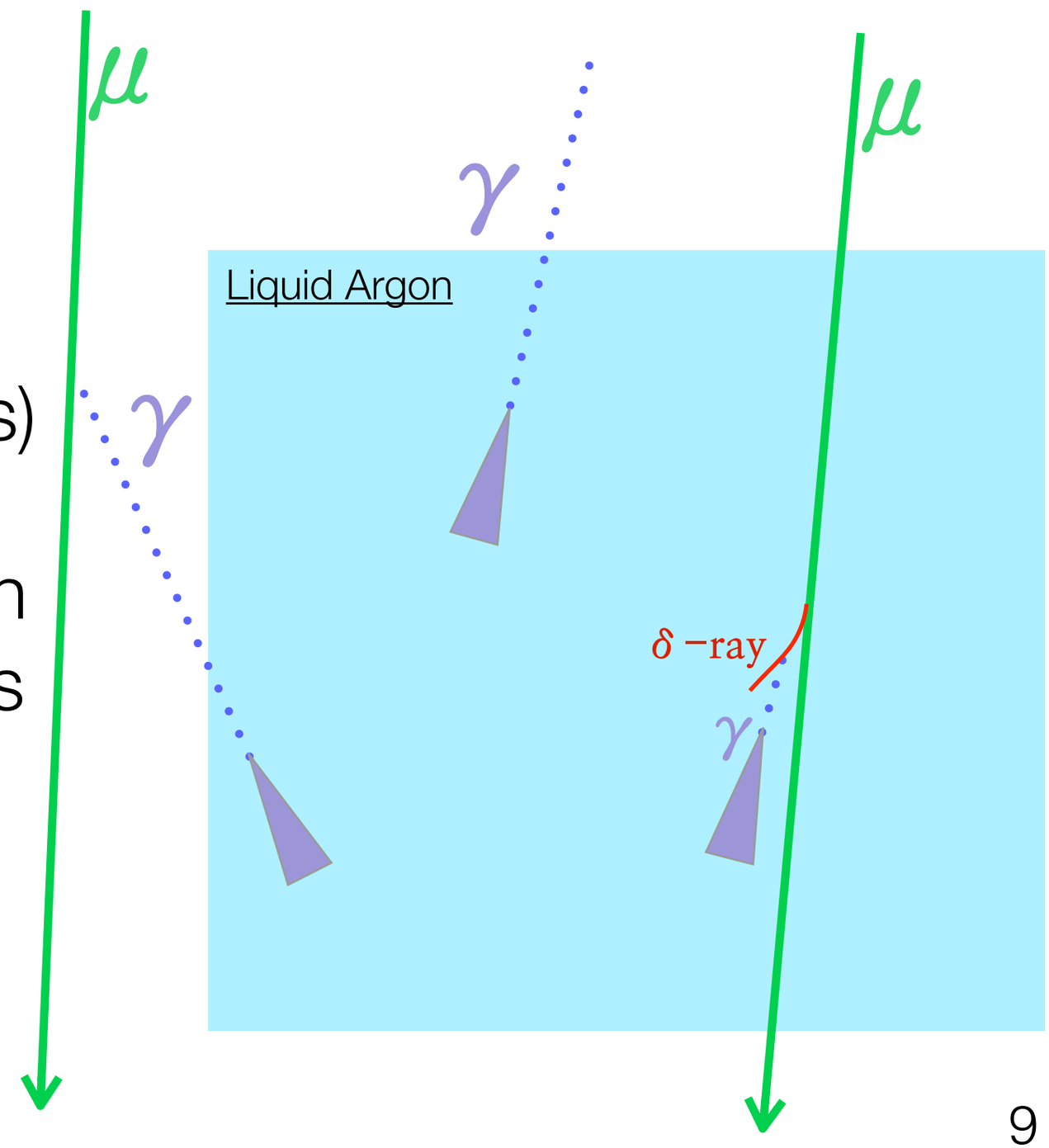
Electron Appearance: Event Selection

- Events are selected based upon their topology
- We require that an event have no *gap* between the shower and an *energetic vertex*
- Vertices must have >50MeV to be detected and the shower must be >3cm away to be rejected



Cosmic Induced Backgrounds

- Being surface detectors we need to deal cosmogenic backgrounds
- Each detector will see many muons per drift window (~1ms)
- If we can tag the cosmic muon we can use simple correlations to highly suppress this background



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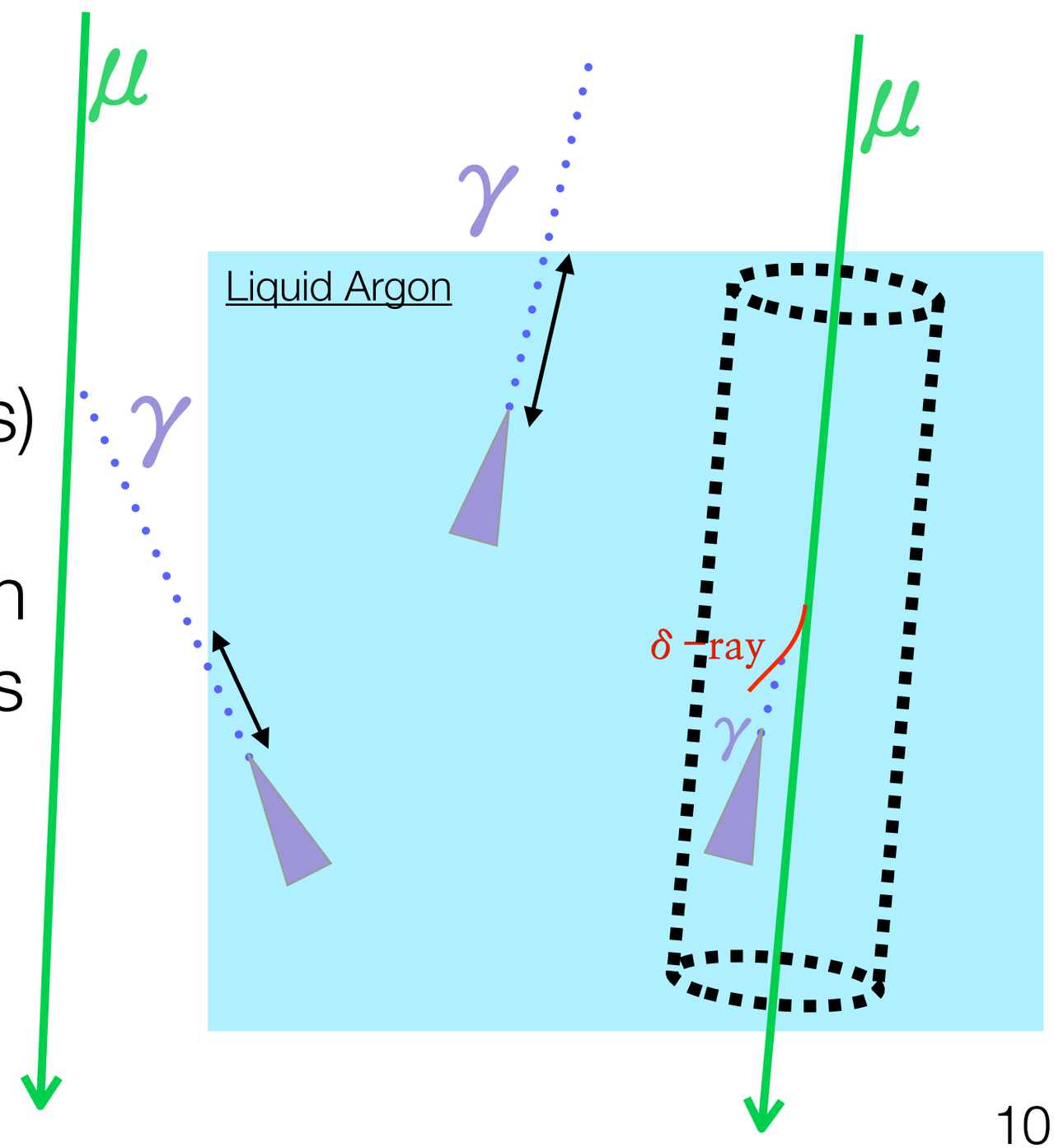
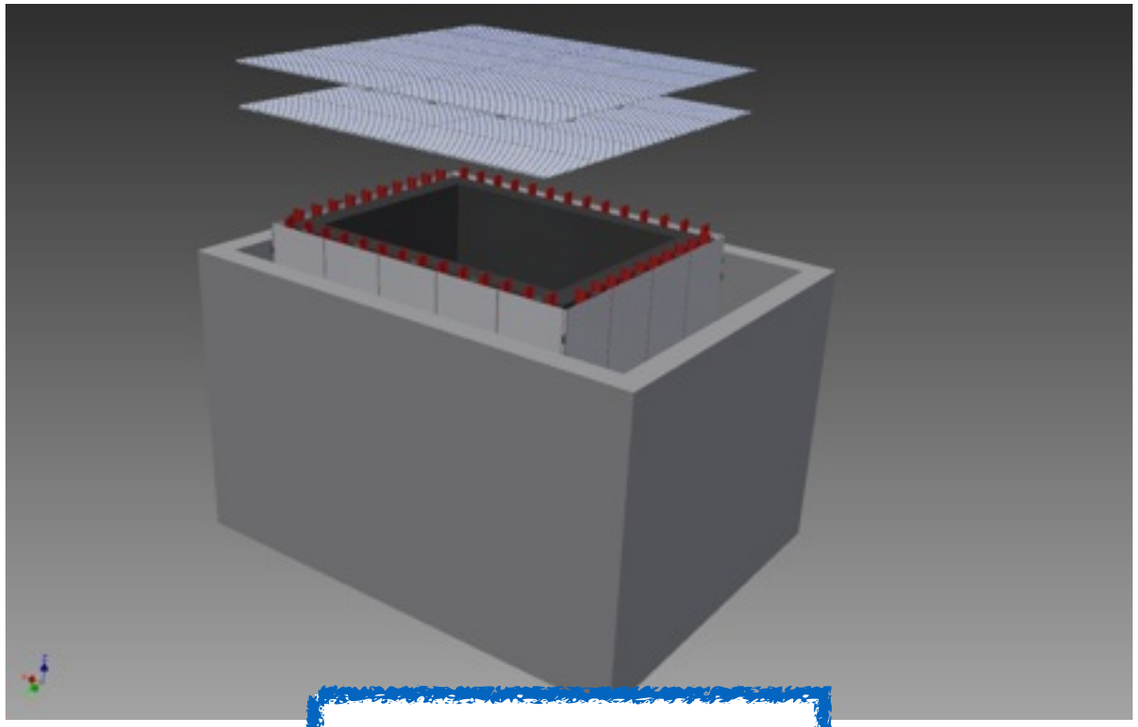
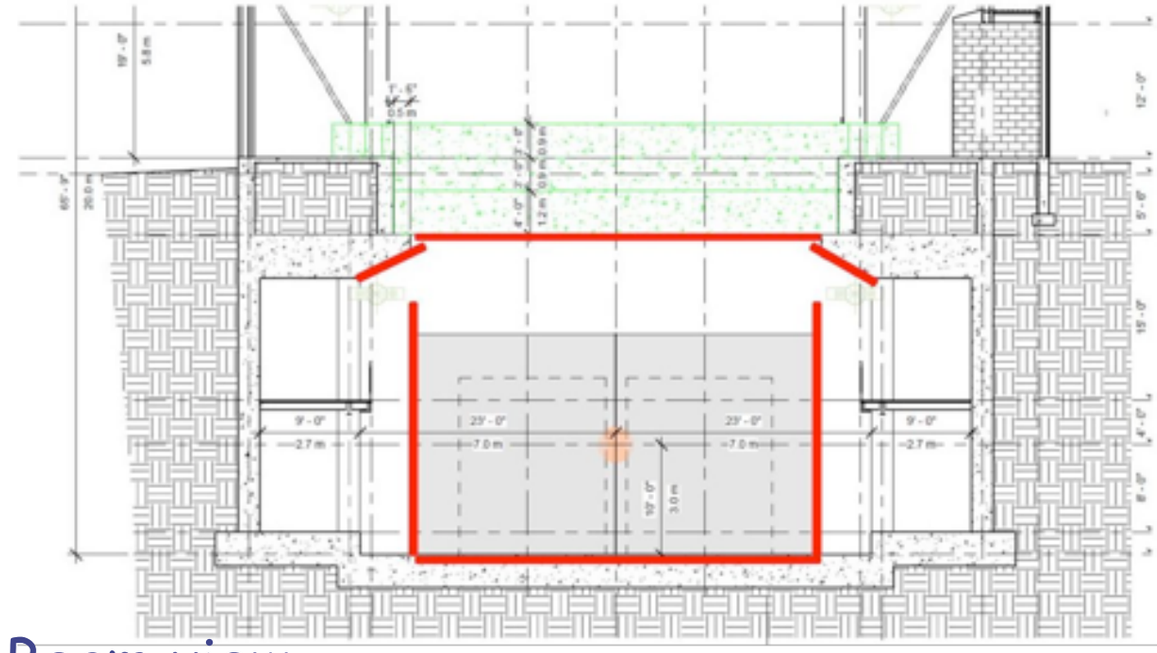


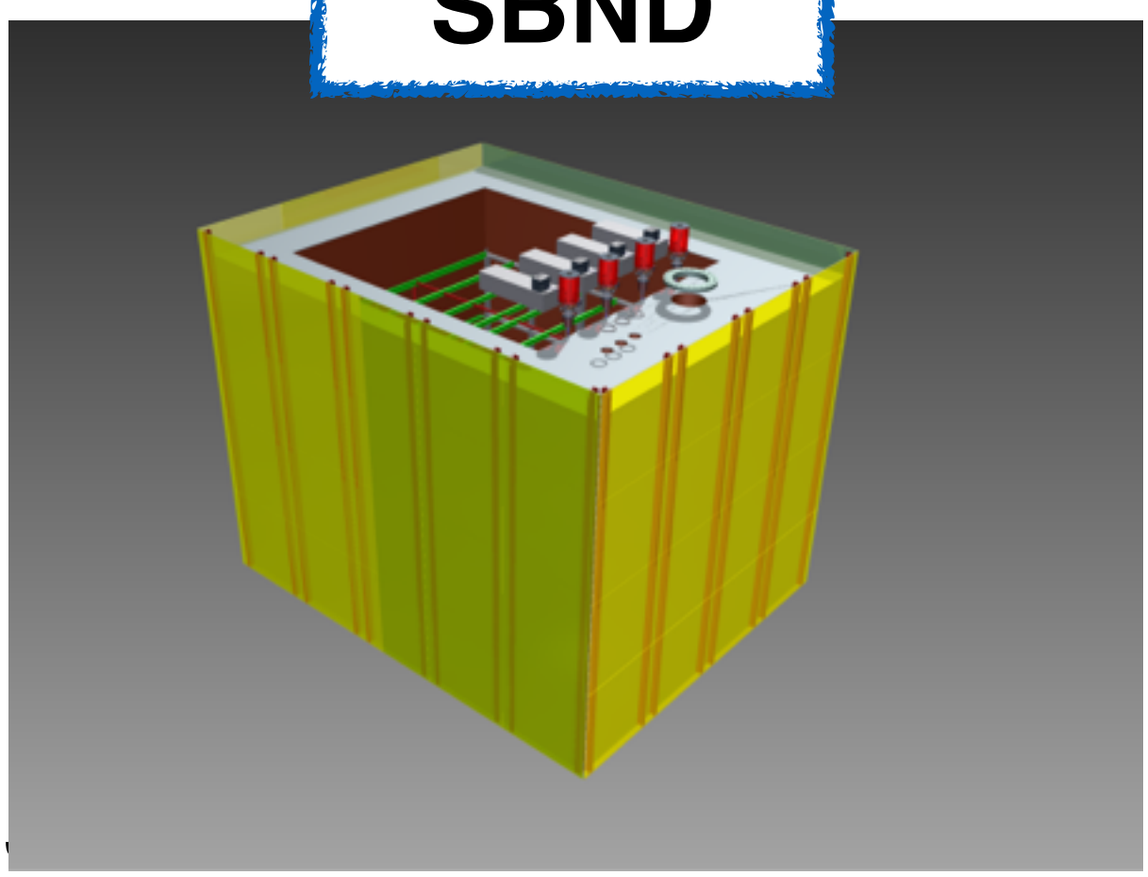
Cosmics Tagger Systems



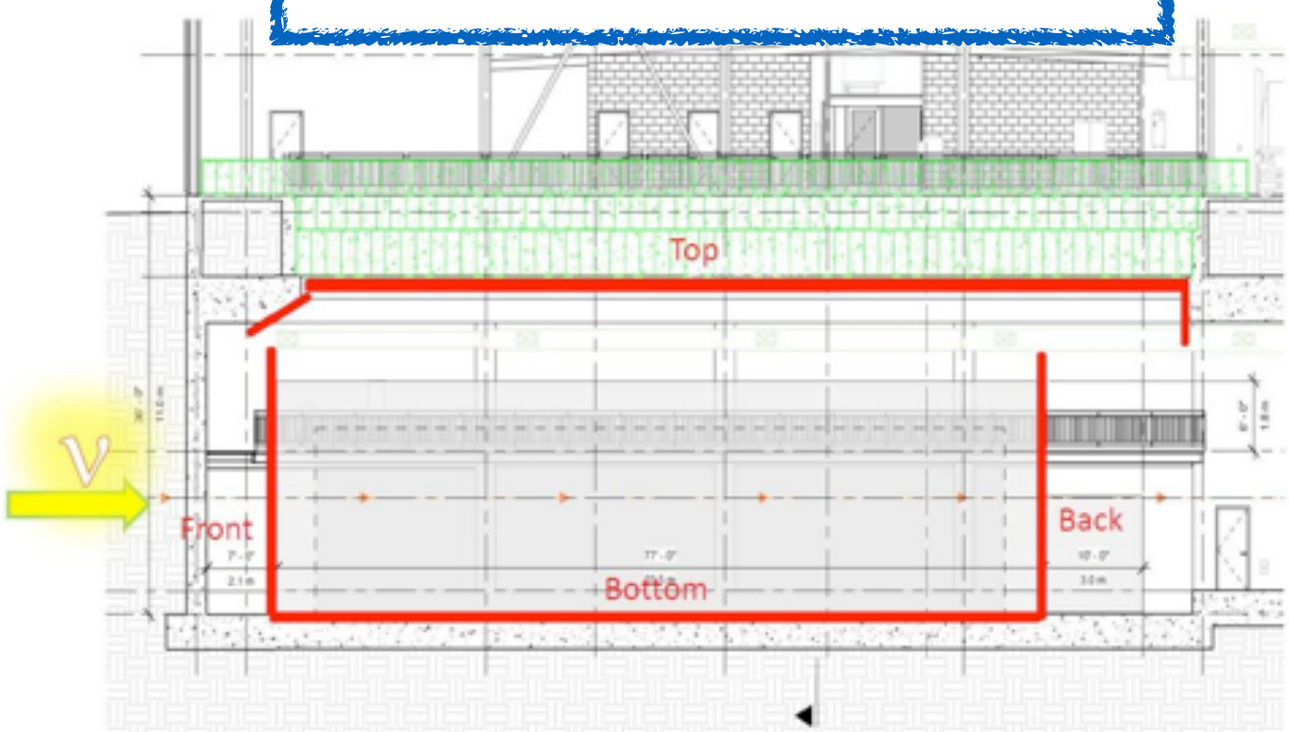


Beam view

SBND



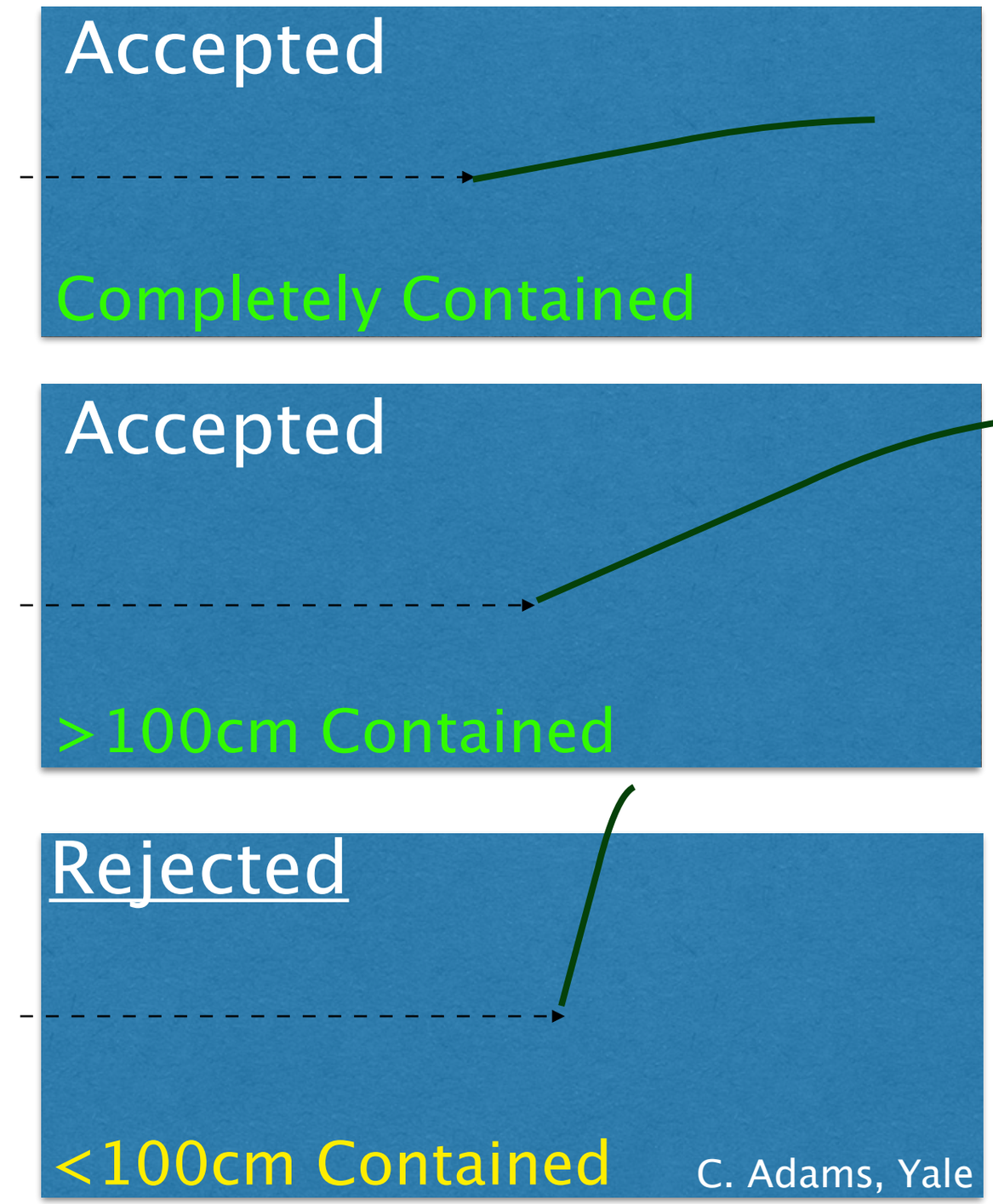
ICARUS T600



Side view

Muon Disappearance: Event Selection

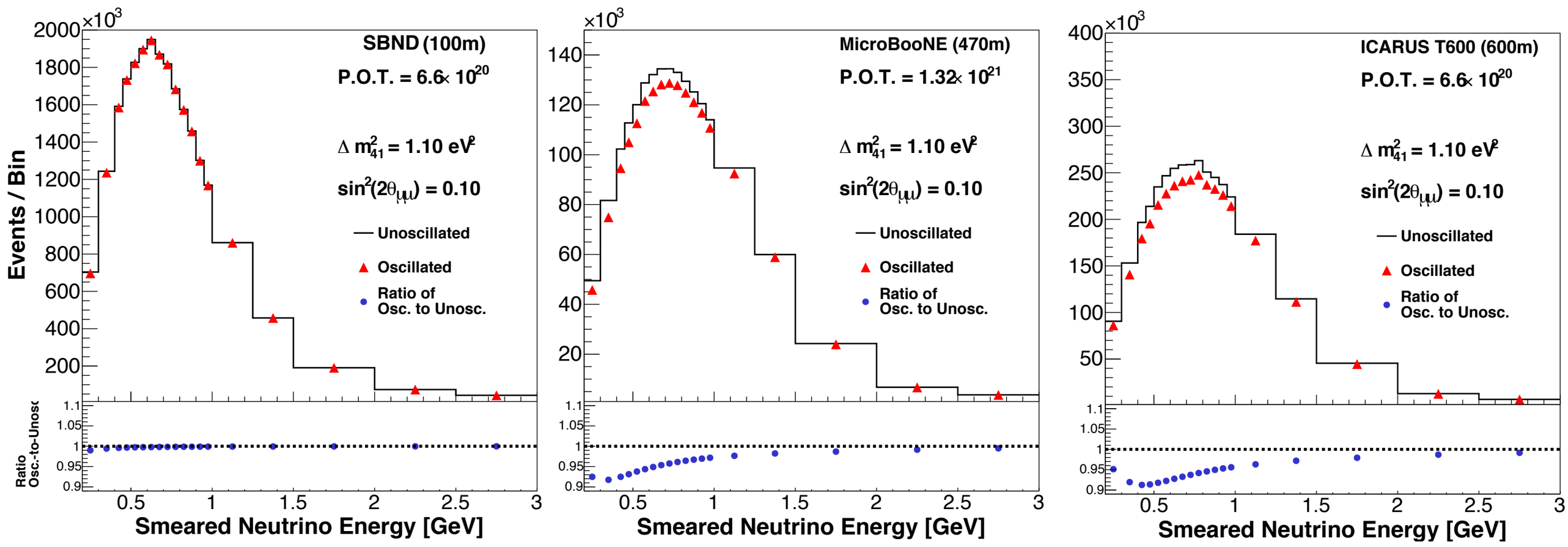
- A fairly background free analysis
- Fully contained muon energy is well measured from the range
- For exiting tracks must rely multiple coulomb scattering to estimate its energy
- This requires at least 1m track length to correctly assess



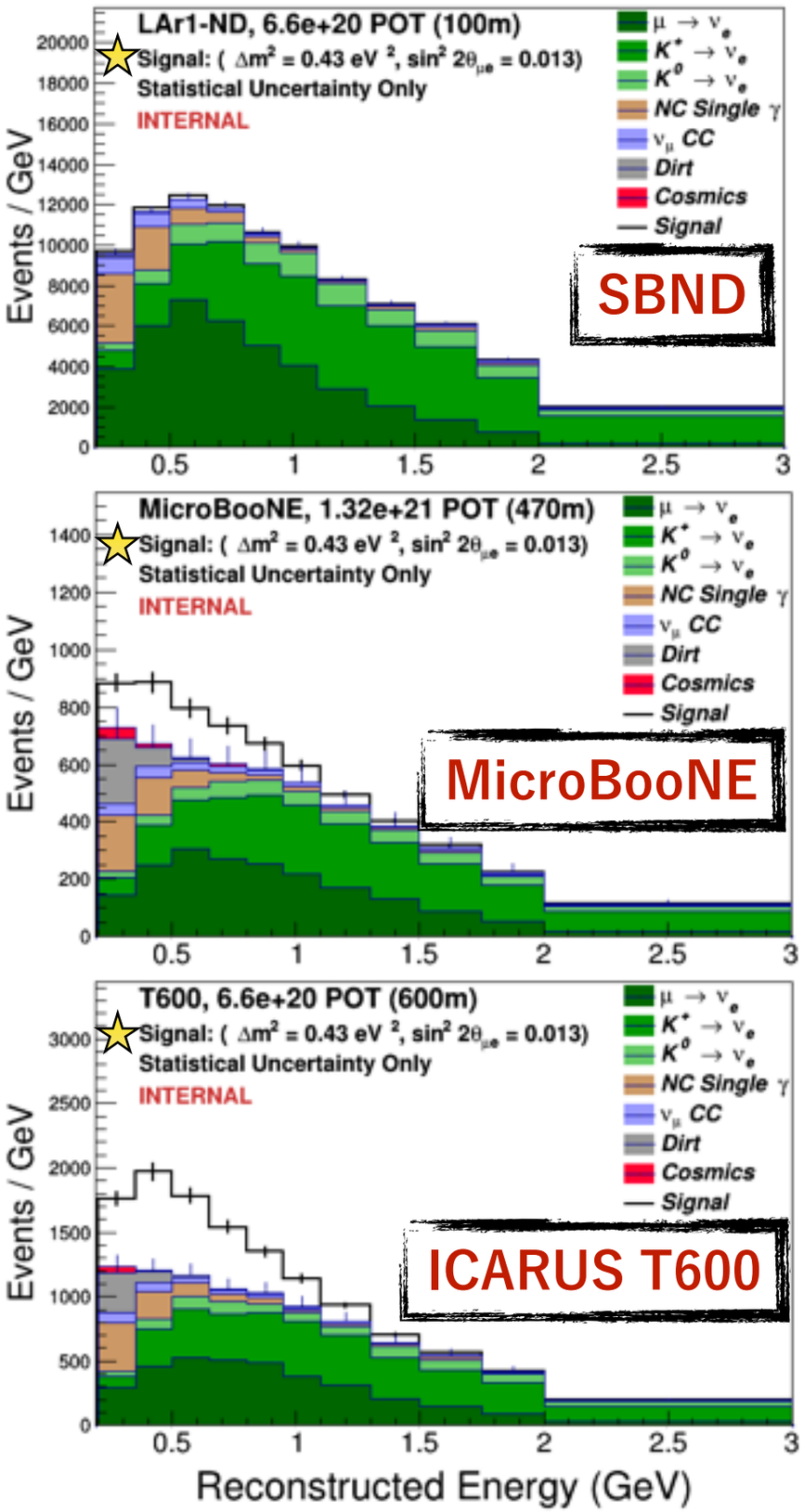
Disappearance Signature

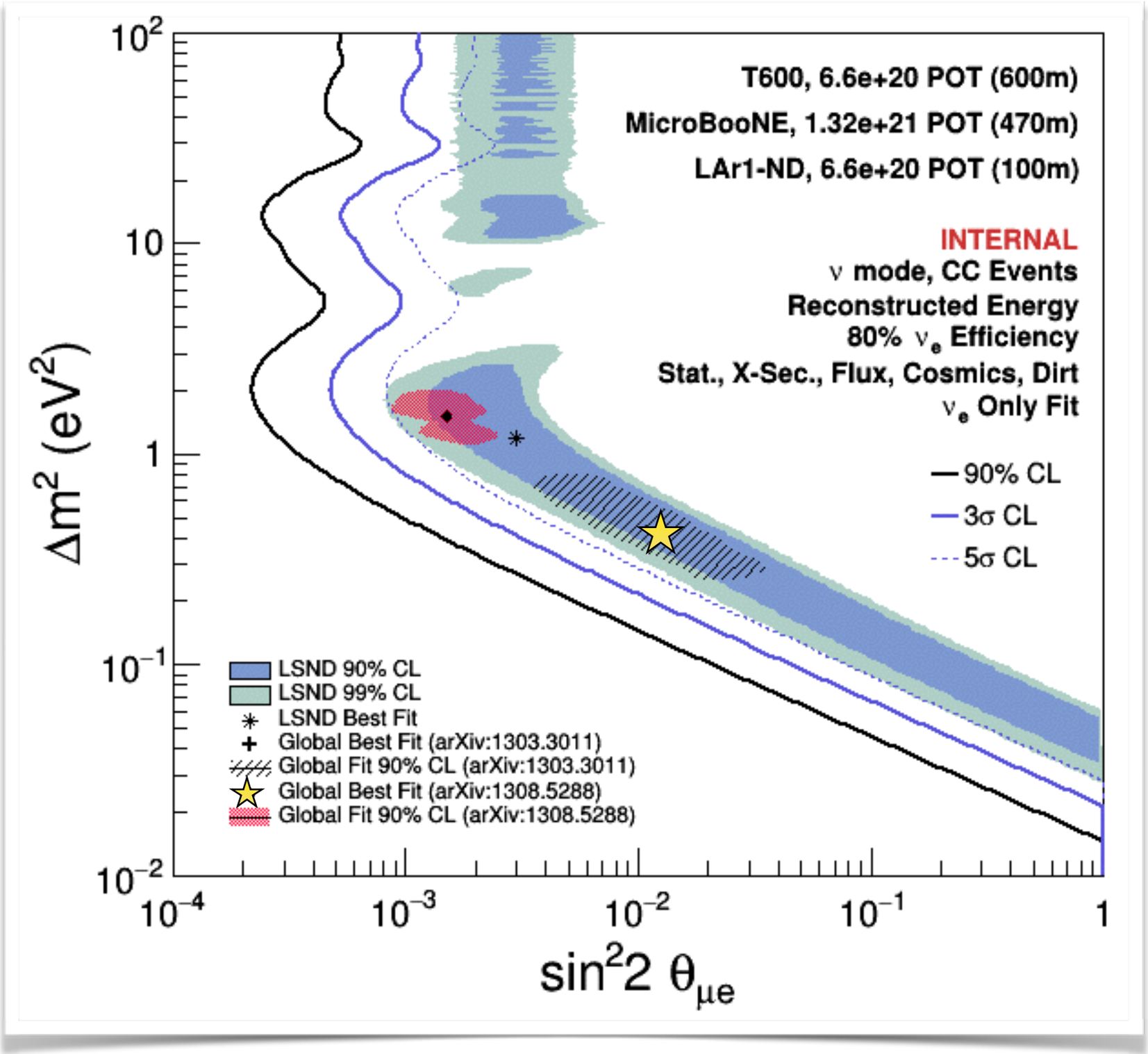
To simulate the effect of oscillations we take the initial muon energy distribution and modulate it based upon the oscillation parameters we are studying

$$P^{3+1}_{\nu_\mu \to \nu_\mu} = 1 - \sin^2 2\theta_{\mu\mu} \sin^2 \left(\frac{\Delta m^2_{41} L}{4E_\nu} \right)$$

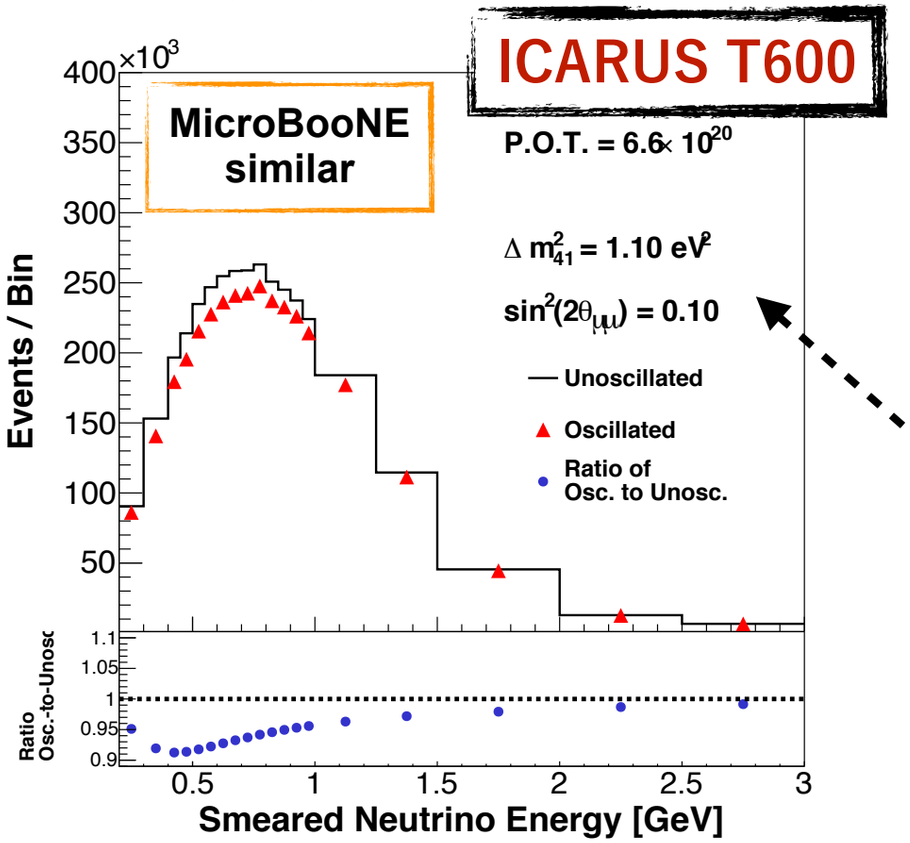


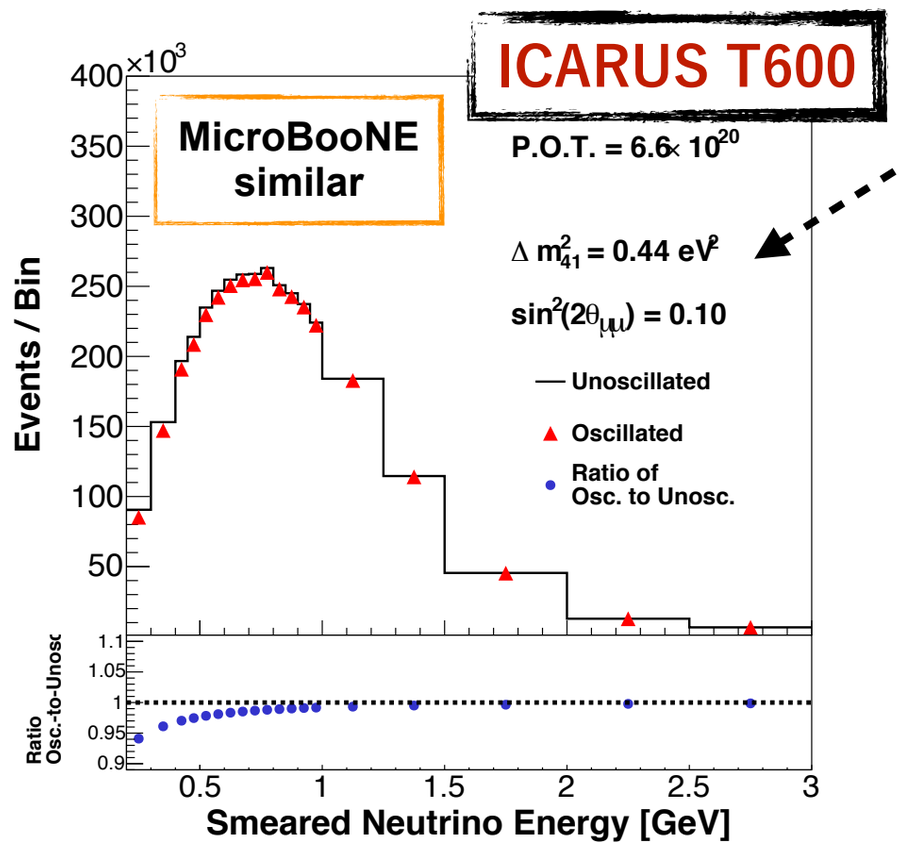
Sensitivity: Electron Neutrino Appearance

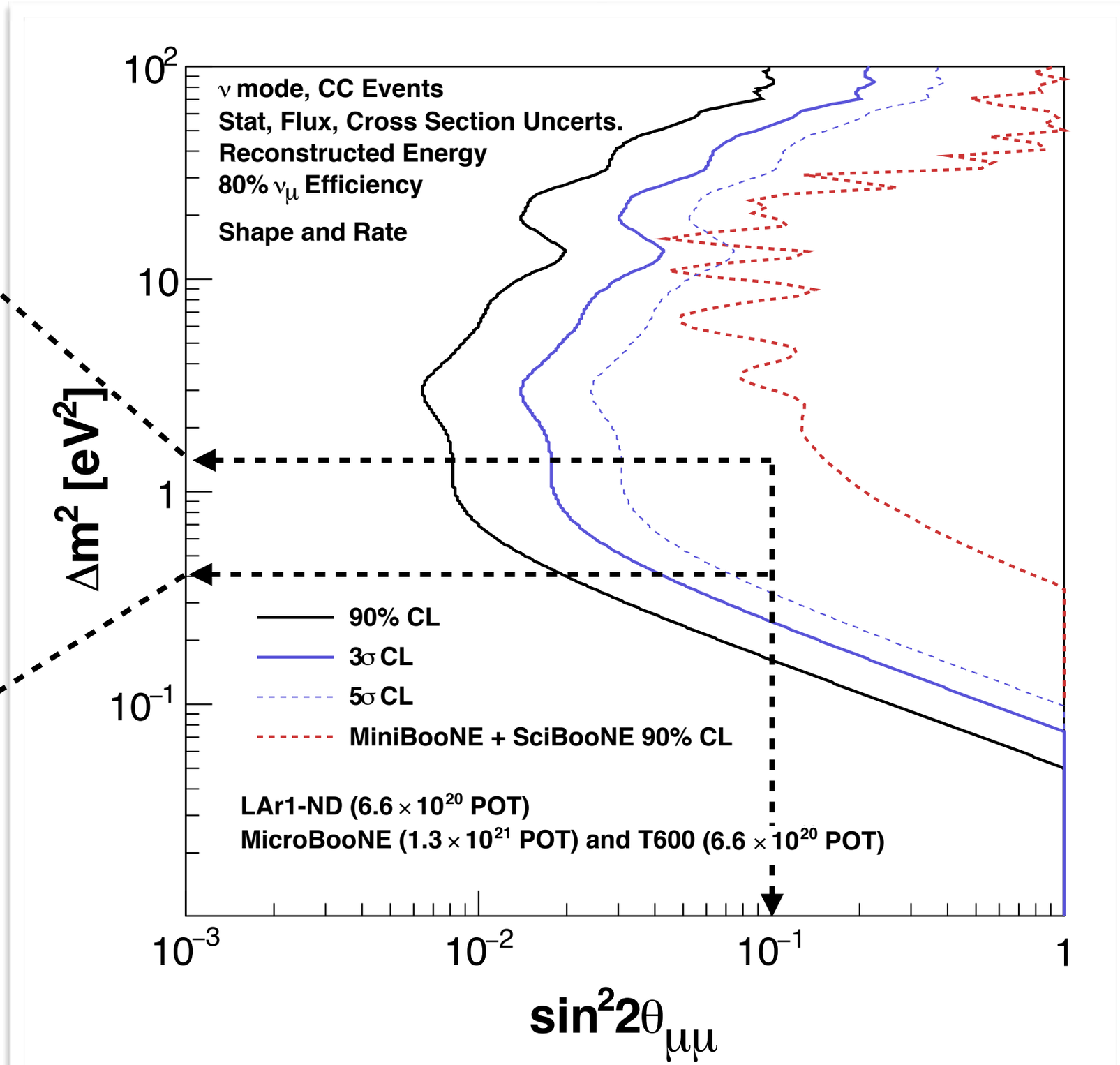




Sensitivity: Muon Neutrino Disappearance

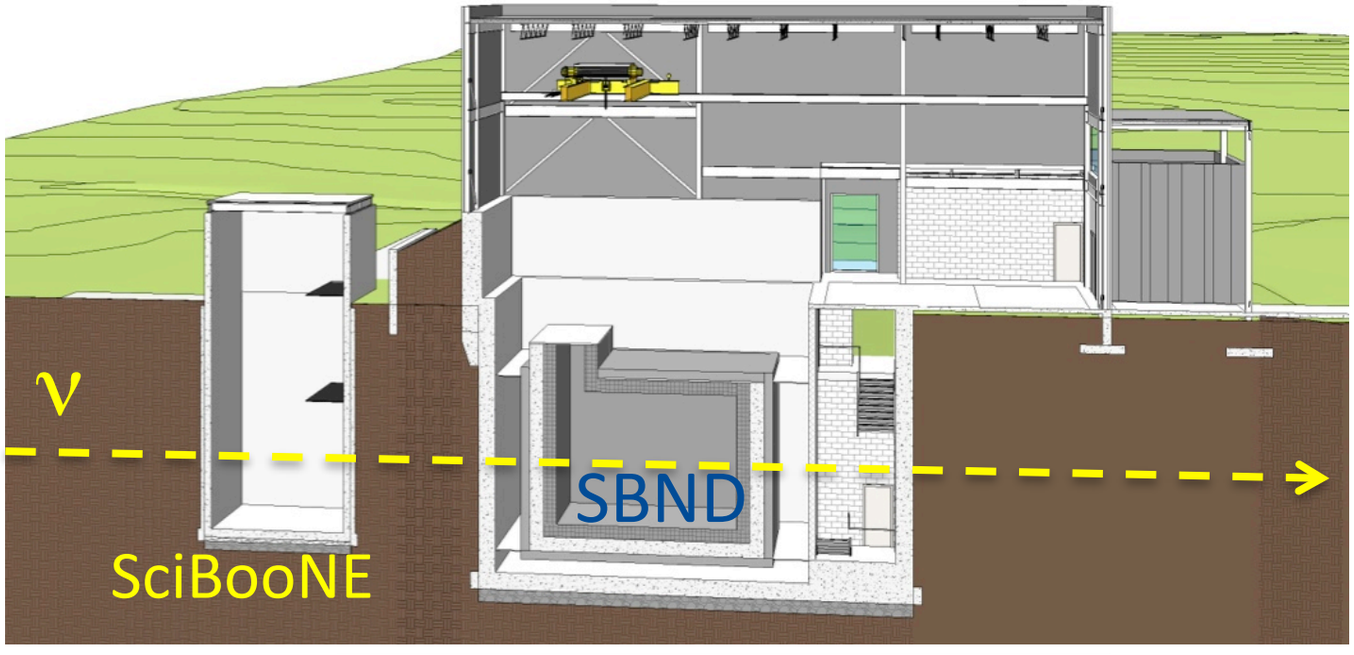




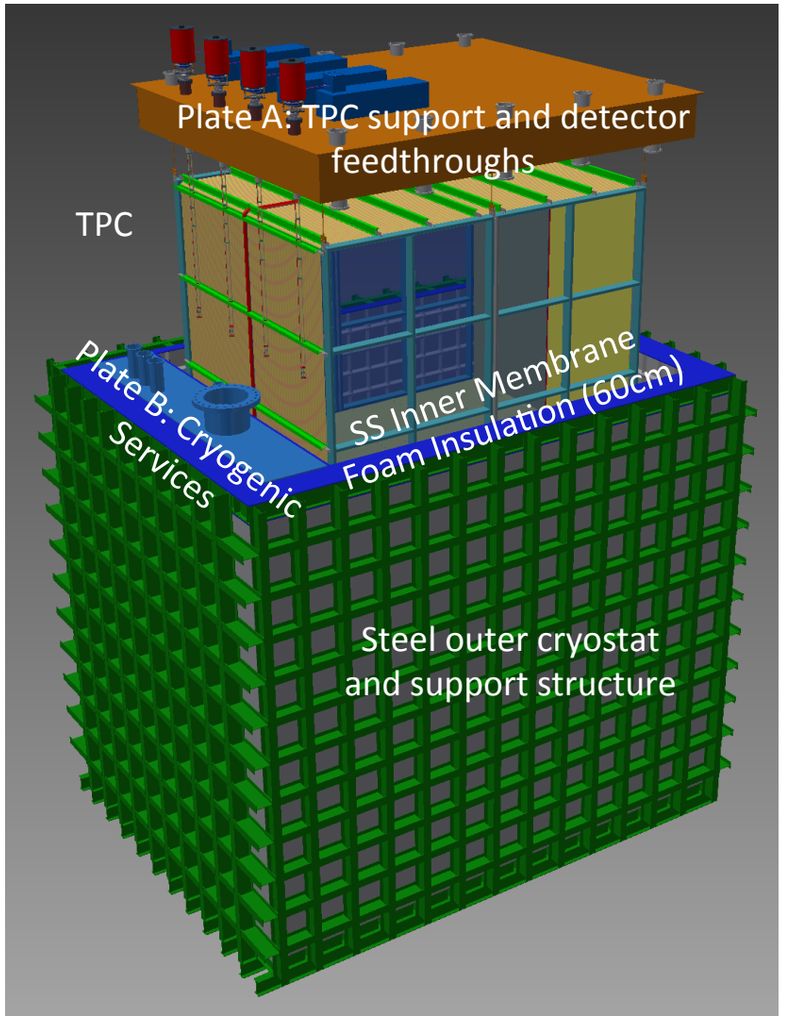


Building the Program: SBND

- The near detector building is finalizing its design with construction scheduled to begin this August

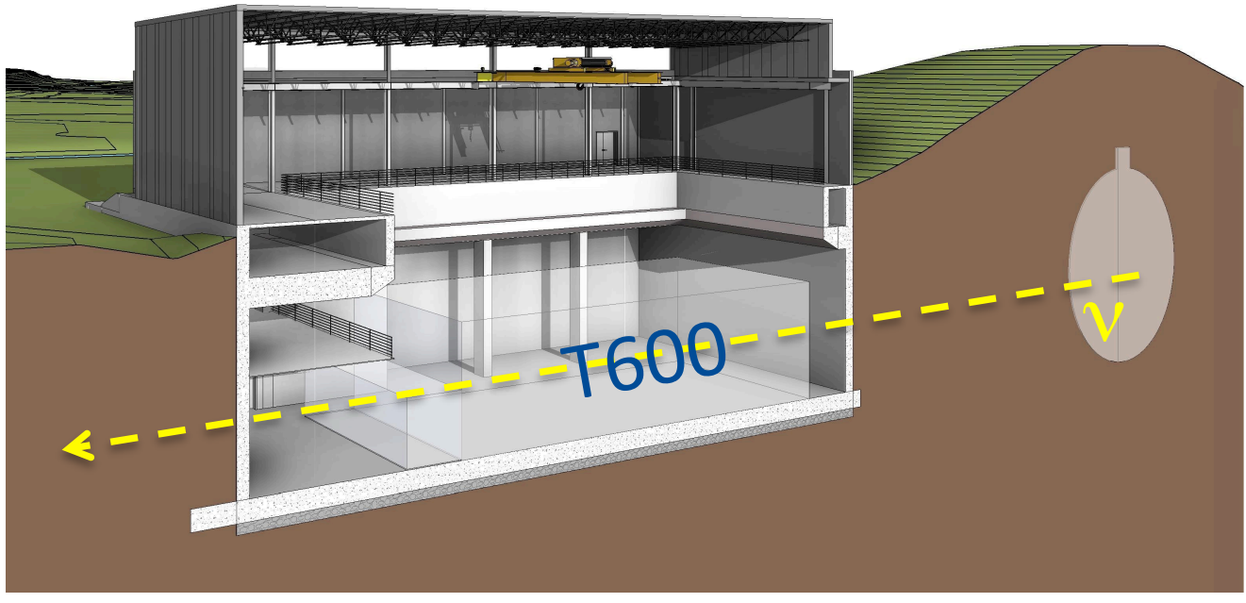


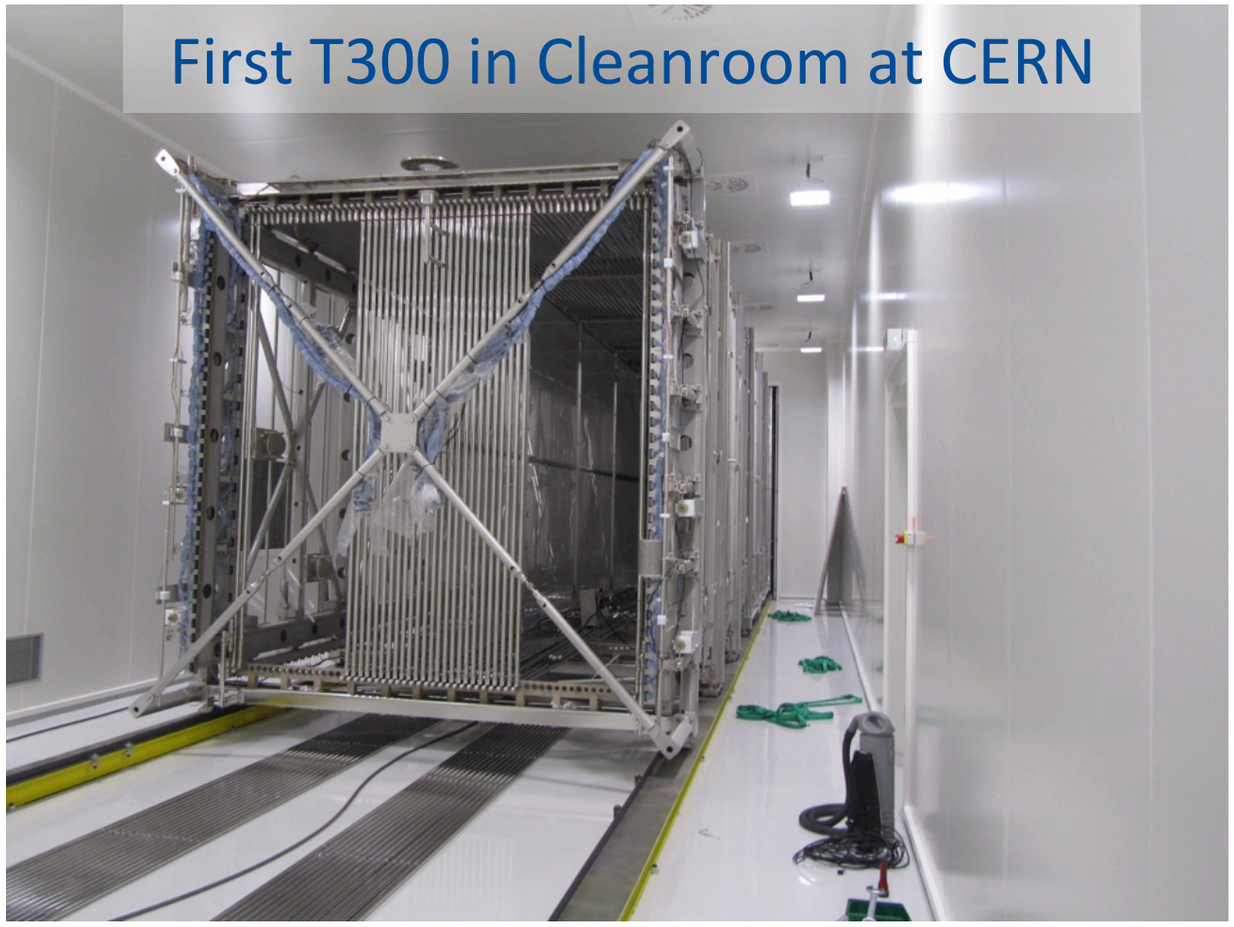
- The designs for the cryostat and TPC are maturing quickly with close collaboration between Fermilab, CERN, and many institutions!



Building the Program: ICARUS T600

- The building which will house the far detector has been finalized!
- The first of the two T300 modules will finish refurbishment by the end of 2015
- The second module will be completed by the end of 2016





Ground Breaking(s)

- The ground breaking for the SBN detector buildings will take place in a few weeks
- This starts an exciting period for all three collaborations whose activities range from design, to construction, to commissioning
- MicroBooNE will provide us the first look at what we might be seeing at short baselines

Finding Any Number of Sterile Neutrinos Would be Ground Breaking!

Thank You From

The ICARUS-WA104 Collaboration

M. Antonello[16], B. Baibussinov[31], V. Bellini[5], P. Benetti[32], S. Bertolucci[6], H. Bilokon[15], F. Boffelli[32], M. Bonesini[17], J. Bremer[6], E. Calligarich[32], S. Centro[31], A.G. Cocco[19], A. Dermenev[20], A. Falcone[32], C. Farnese[31], A. Fava[31], A. Ferrari[6], D. Gibin[31], S. Gninenko[20], N. Golubev[20], A. Guglielmi[31], A. Ivashkin[20], M. Kirsanov[20], J. Kisiel[38], U. Kose[6], F. Mammoliti[5], G. Mannocchi[15], A. Menegolli[32], G. Meng[31], D. Mladenov[6], C. Montanari[32], M. Nessi[6], M. Nicoletto[31], F. Noto[6], P. Picchi[15], F. Pietropaolo[31], P.Płoński[42], R. Potenza[5], A. Rappoldi[32], G. L. Raselli[32], M. Rossella[32], C. Rubbia[*,6,11,16], P. Sala[18], A. Scaramelli[18], J. Sobczyk[44], M. Spanu[32], D. Stefan[18], R. Sulej[43], C.M. Sutera[5], M. Torti[32], F. Tortorici[5], F. Varanini[31], S. Ventura[31], C. Vignoli[16], T. Wachala[12], and A. Zani[32]

The LAr1-ND Collaboration

C. Adams[45], C. Andreopoulos[23], A. Ankowski[41], J. Asaadi[40], L. Bagby[10], B. Baller[10], N. Barros[33], M. Bass[30], S. Bertolucci[6], M. Bishai[3], A. Bitadze[25], J. Bremer[6], L. Bugel[26], L. Camilleri[9], F. Cavanna[a,10], H. Chen[3], C. Chi[9], E. Church[10], D. Cianci[7], G. Collin[26], J.M. Conrad[26], G. De Geronimo[3], R. Dharmapalan[1], Z. Djurcic[1], A. Ereditato[2], J. Esquivel[40], J. Evans[25], B.T. Fleming[45], W.M. Foreman[7], J. Freestone[25], T. Gamble[37], G. Garvey[24], V. Genty[9], D. Göldi[2], H. Greenlee[10], R. Guenette[30], A. Hackenburg[45], R. Hänni[2], J. Ho[7], J. Howell[10], C. James[10], C.M. Jen[41], B.J.P. Jones[26], L.M. Kalousis[41], G. Karagiorgi[25], W. Ketchum[24], J. Klein[33], J. Klinger[37], U. Kose[6], I. Kreslo[2], V.A. Kudryavtsev[37], D. Lissauer[3], P. Livesly[22], W.C. Louis[24], M. Lu□thi[2], C. Mariani[41], K. Mavrokoridis[23], N. McCauley[23], N. McConkey[37], I. Mercer[22], T. Miao[10], G.B. Mills[24], D. Mladenov[6], D. Montanari[10], J. Moon[26], Z. Moss[26], S. Mufson[14], M. Nessi[6], B. Norris[10], F. Noto[6], J. Nowak[22], S. Pal[37], O. Palamara[*,b,10], J. Pater[25], Z. Pavlovic[10], J. Perkin[37], G. Pulliam[40], X. Qian[3], L. Qiuguang[24], V. Radeka[3], R. Rameika[10], P.N. Ratoff[22], M. Richardson[37], C. Rudolf von Rohr[2], D.W. Schmitz[*,7], M.H. Shaevitz[9], B. Sippach[9], M. Soderberg[40], S. Söldner-Rembold[25], J. Spitz[26], N. Spooner[37], T. Strauss[2], A.M. Szelc[25,45], C.E. Taylor[24], K. Terao[9], M. Thiesse[37], L. Thompson[37], M. Thomson[4], C. Thorn[3], M. Toups[26], C. Touramanis[23], R.G. Van De Water[24], M. Weber[2], D. Whittington[14], T. Wongjirad[26], B. Yu[3], G.P. Zeller[10], and J. Zennamo[7]

The MicroBooNE Collaboration

R. Acciarri[10], C. Adams[45], R. An[13], A. Ankowski[41], J. Asaadi[40], L. Bagby[10], B. Baller[10], G. Barr[30], M. Bass[30], M. Bishai[3], A. Blake[4], T. Bolton[21], C. Bromberg[27], L. Bugel[26], L. Camilleri[9], D. Caratelli[9], B. Carls[10], F. Cavanna[a,10], H. Chen[3], E. Church[10], G.H. Collin[26], J.M. Conrad[26], M. Convery[39], S. Dytmam[34], B. Eberly[39], A. Ereditato[2], J. Esquivel[40], B.T. Fleming*[45], W.M. Foreman[7], V. Genty[9], D. Göldi[2], S. Gollapinni[21], M. Graham[39], E. Gramellini[45], H. Greenlee[10], R. Grosso[8], R. Guenette[30], A. Hackenburg[45], O. Hen[26], J. Hewes[25], J. Ho[7], G. Horton-Smith[21], C. James[10], C.M. Jen[41], R.A. Johnson[8], B.J.P. Jones[26], J. Joshi[3], H. Jostlein[10], D. Kaleko[9], L. Kalousis[41], G. Karagiorgi[25], W. Ketchum[24], B. Kirby[3], M. Kirby[10], T. Kobilarcik[10], I. Kreslo[2], Y. Li[3], B. Littlejohn[13], D. Lissauer[3], S. Lockwitz[10], W.C. Louis[24], M. Lu□thi[2], B. Lundberg[10], A. Marchionni[10], C. Mariani[41], J. Marshall[4], K. McDonald[35], V. Meddage[21], T. Miceli[28], G.B. Mills[24], J. Moon[26], M. Mooney[3], M.H. Moulai[26], R. Murrells[25], D. Naples[34], P. Nienaber[36], O. Palamara[b,10], V. Paolone[34], V. Papavassiliou[28], S. Pate[28], Z. Pavlovic[10], S. Pordes[10], G. Pulliam[40], X. Qian[3], J.L. Raaf[10], V. Radeka[3], R. Rameika[10], B. Rebel[10], L. Rochester[39], C. Rudolf von Rohr[2], B. Russell[45], D.W. Schmitz[7], A. Schukraft[10], W. Seligman[9], M. Shaevitz[9], M. Soderberg[40], J. Spitz[26], J. St. John[8], T. Strauss[2], A.M. Szelc[25,45], N. Tagg[29], K. Terao[9], M. Thomson[4], C. Thorn[3], M. Toups[26], Y. Tsai[39], T. Usher[39], R. Van de Water[24], M. Weber[2], S. Wolbers[10], T. Wongjirad[26], K. Woodruff[28], M. Xu[13], T. Yang[10], B. Yu[3], G.P. Zeller*[10], J. Zennamo[7], and C. Zhang[3]

Additional Fermilab Contributors

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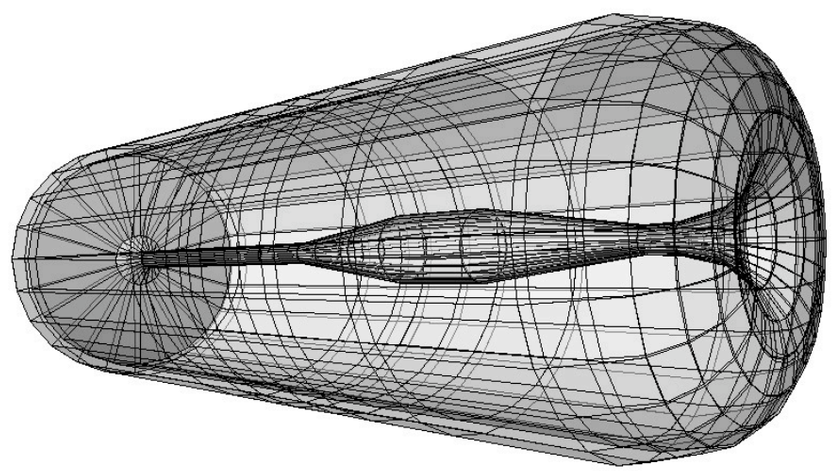
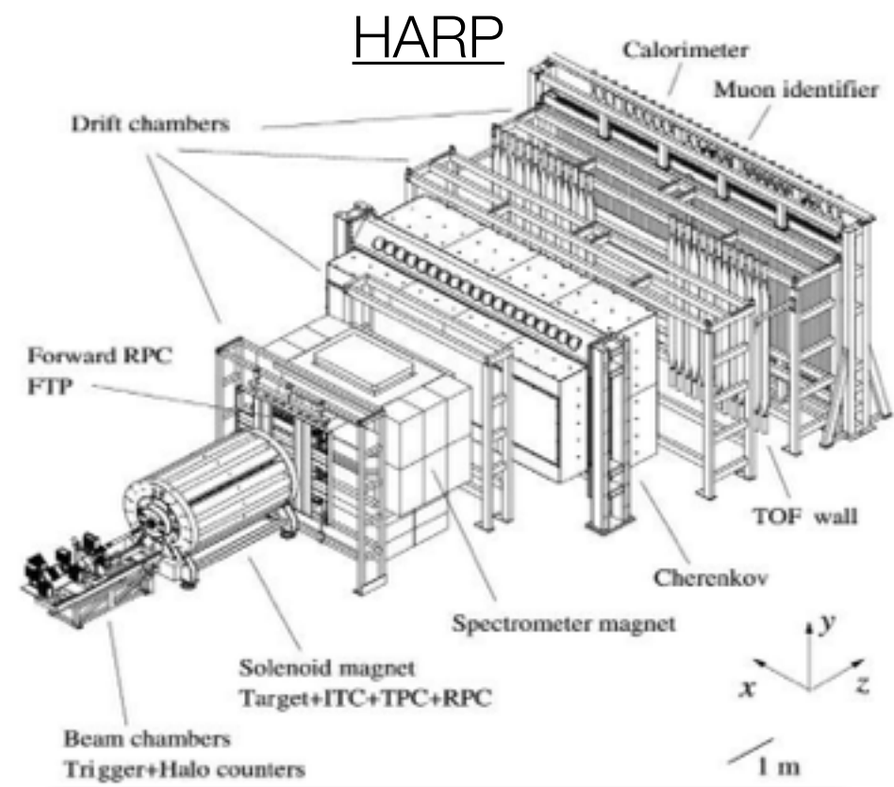
Backups

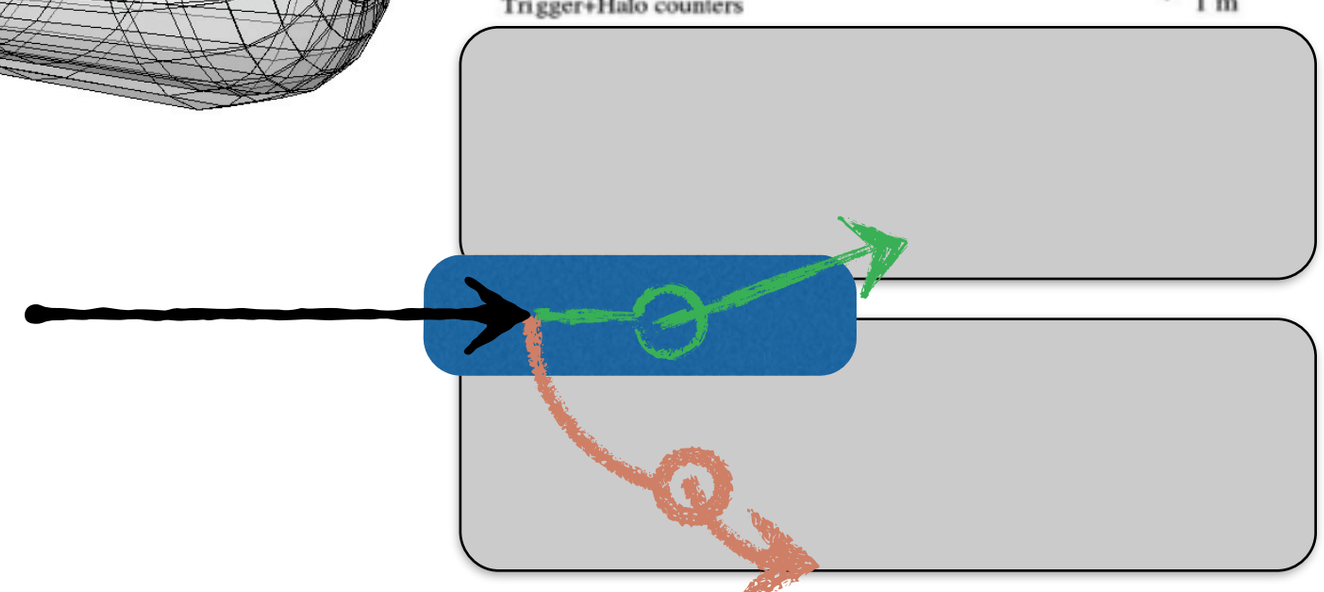
Systematics

Systematic Uncertainties: Neutrino Flux

- Hadron Production
  - Charged Pions
  - Kaons
- Beam Focusing
  - Current
  - Skin Effects
- Secondary Interactions
  - Within the target and horn

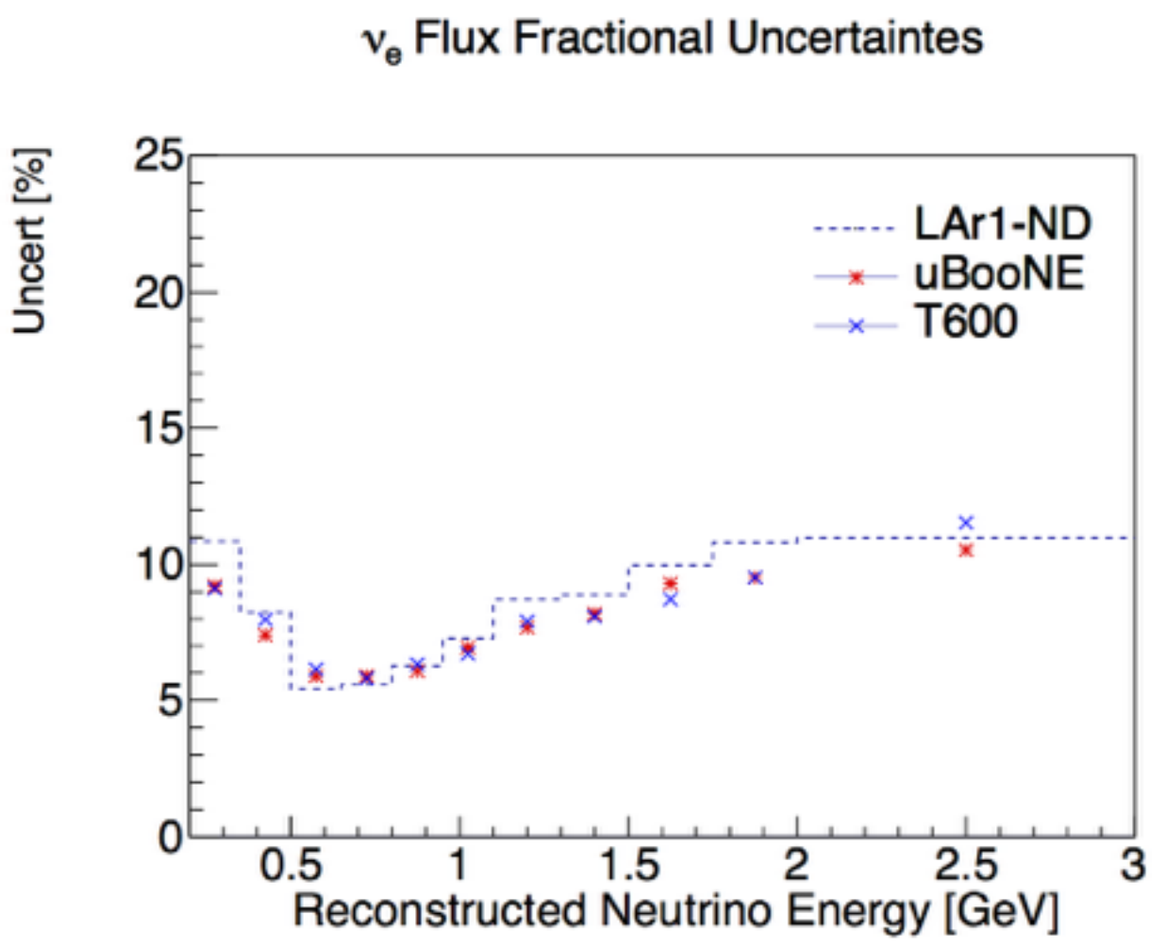


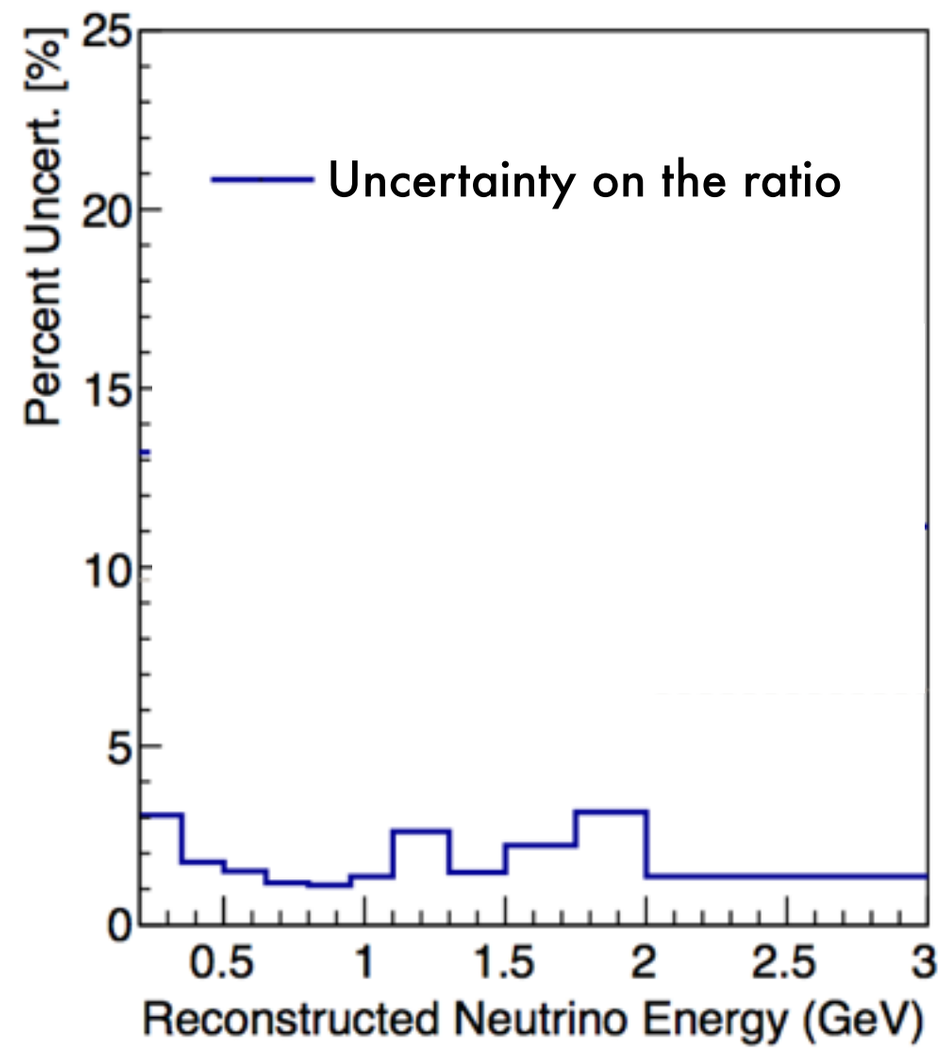




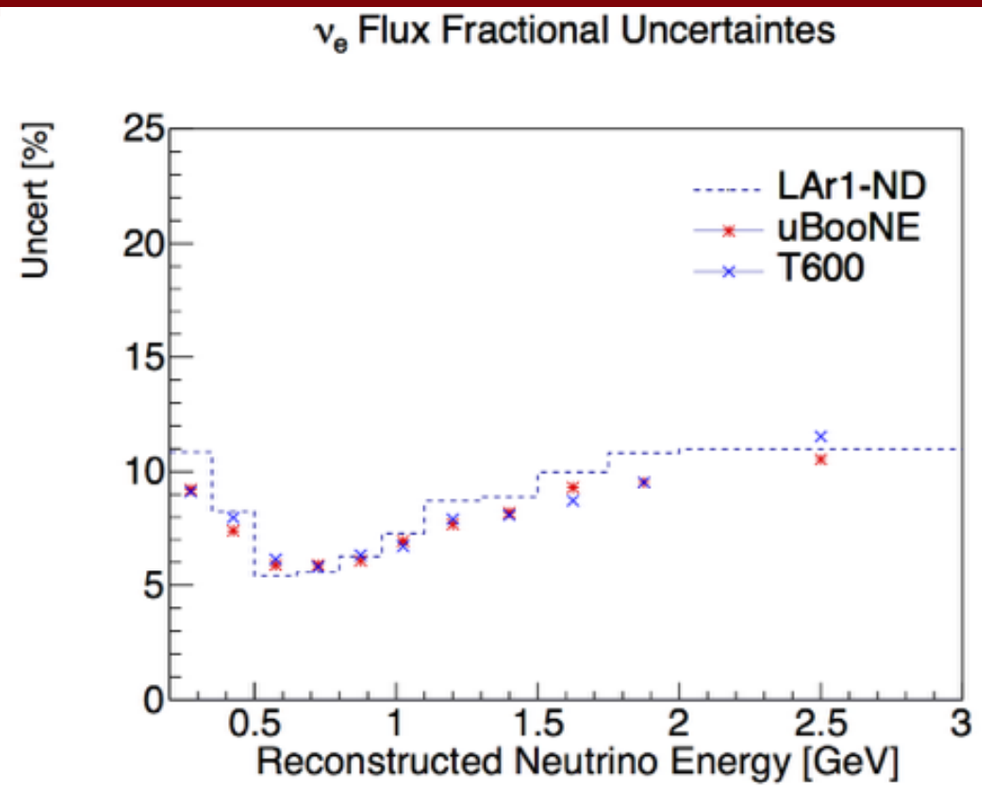
Systematics

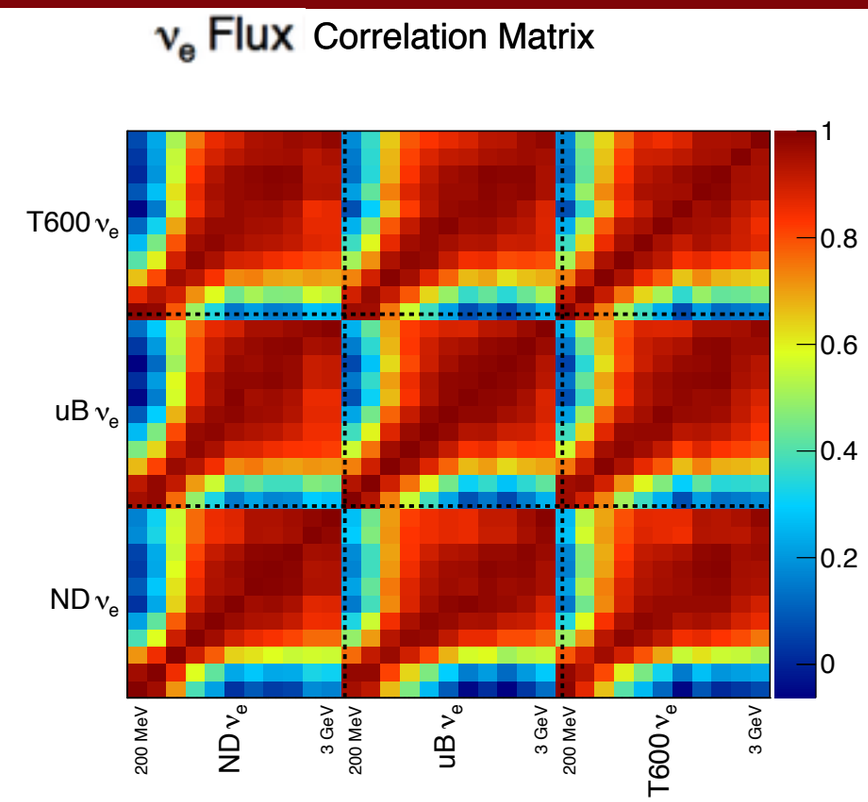
Systematic Uncertainties: Neutrino Flux

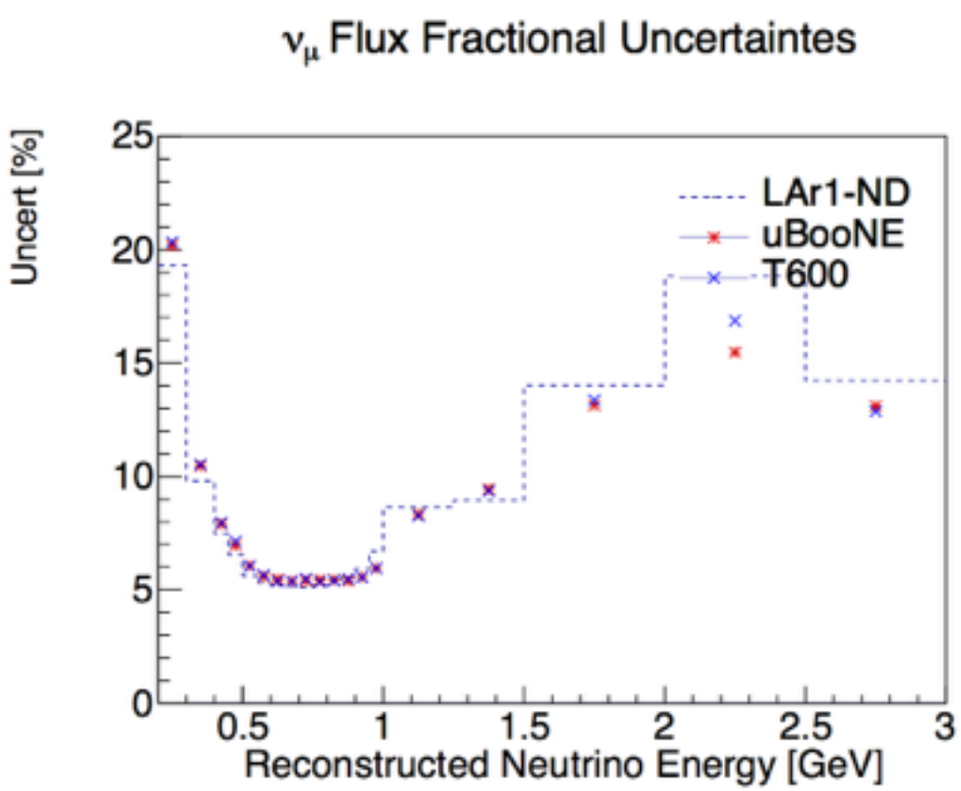


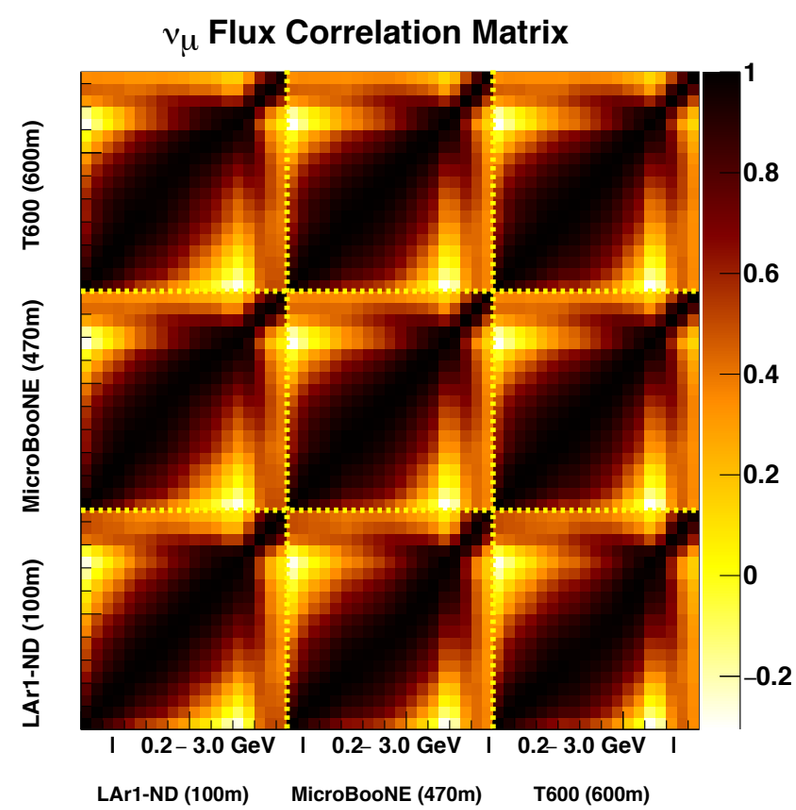


Systematics





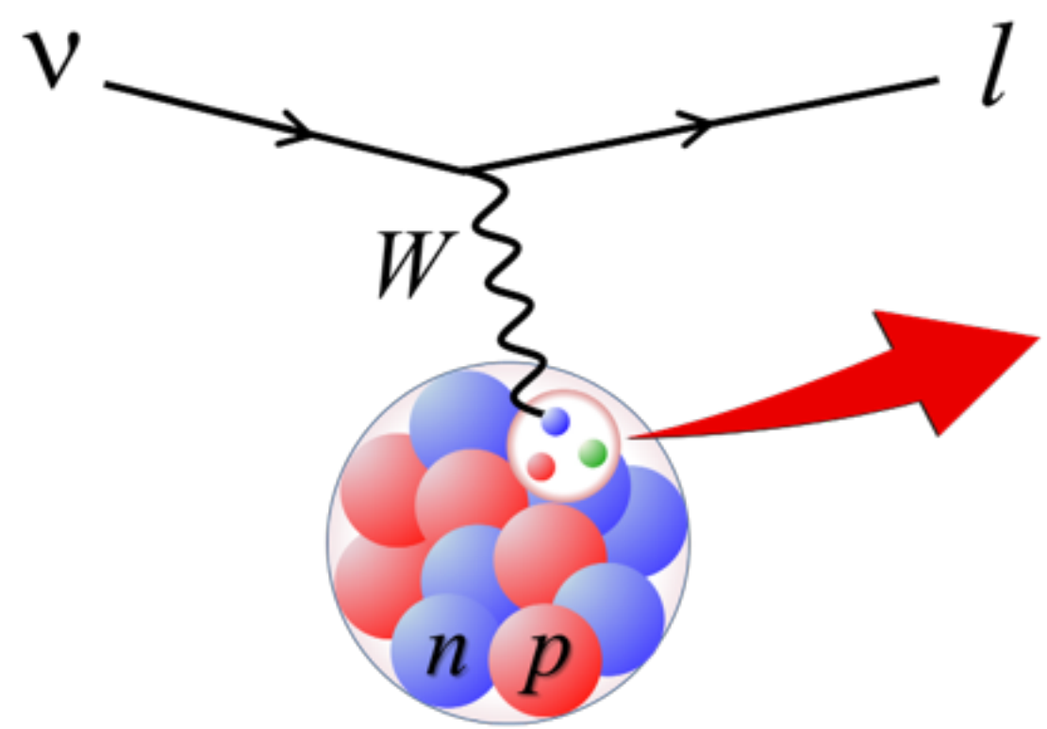




Systematics

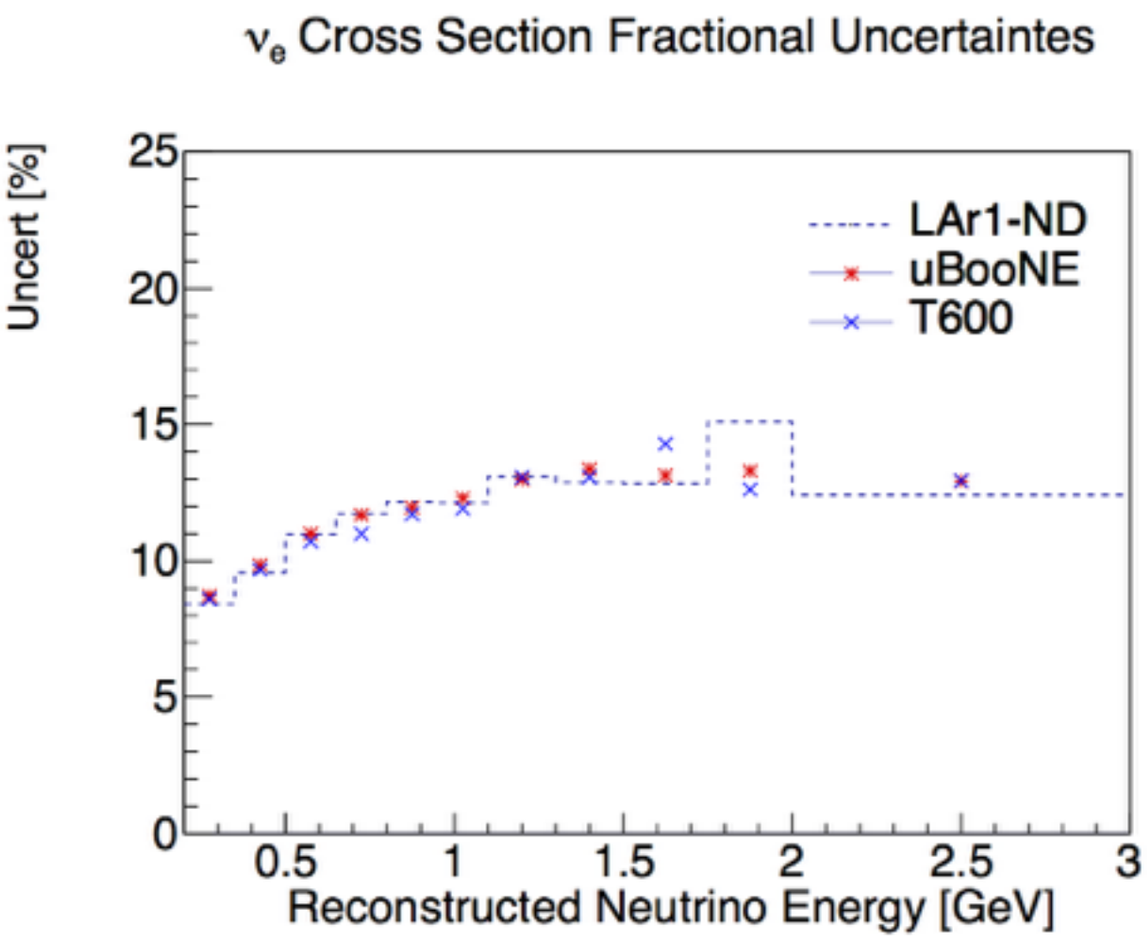
Systematic Uncertainties: ν -Argon Cross Sections

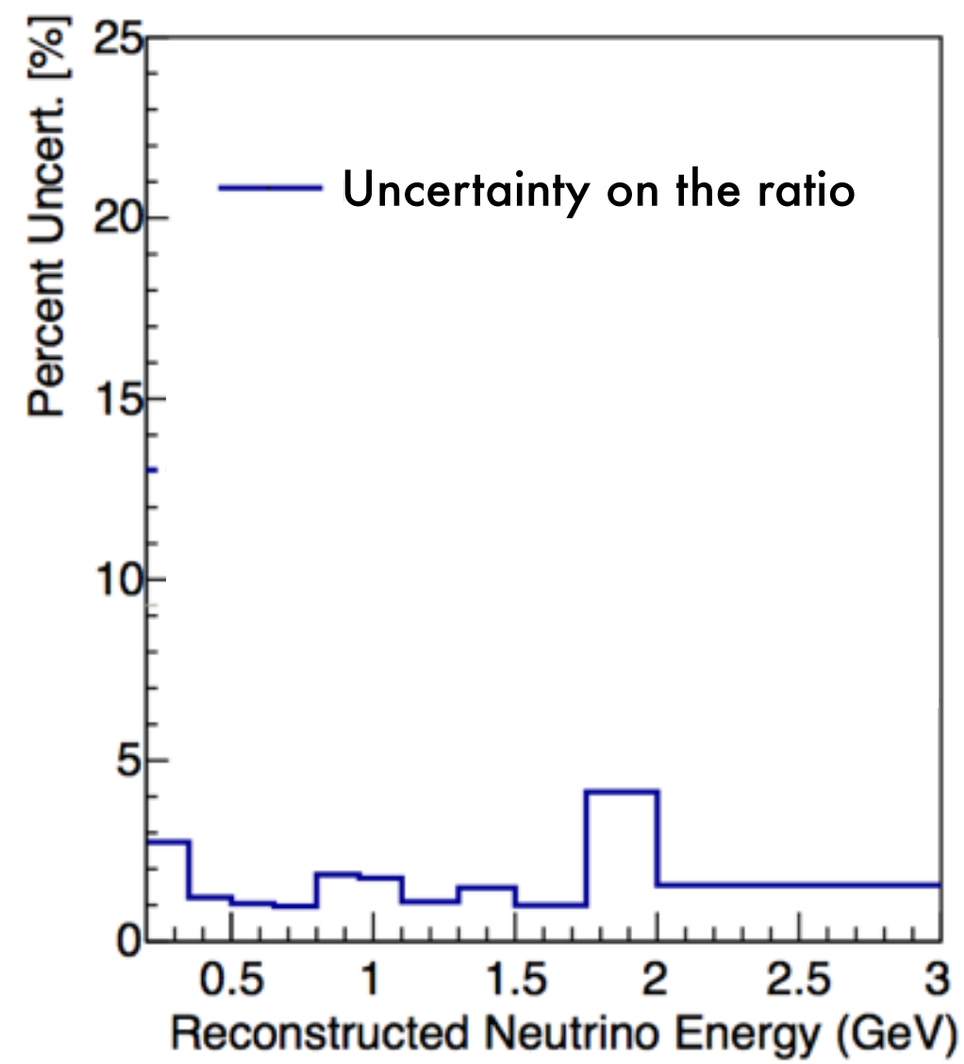
The three detectors use the same target nucleus but differences in the flux, detector acceptances, and other effects can lead to a different composition of event types which can lead to systematic differences between the detectors



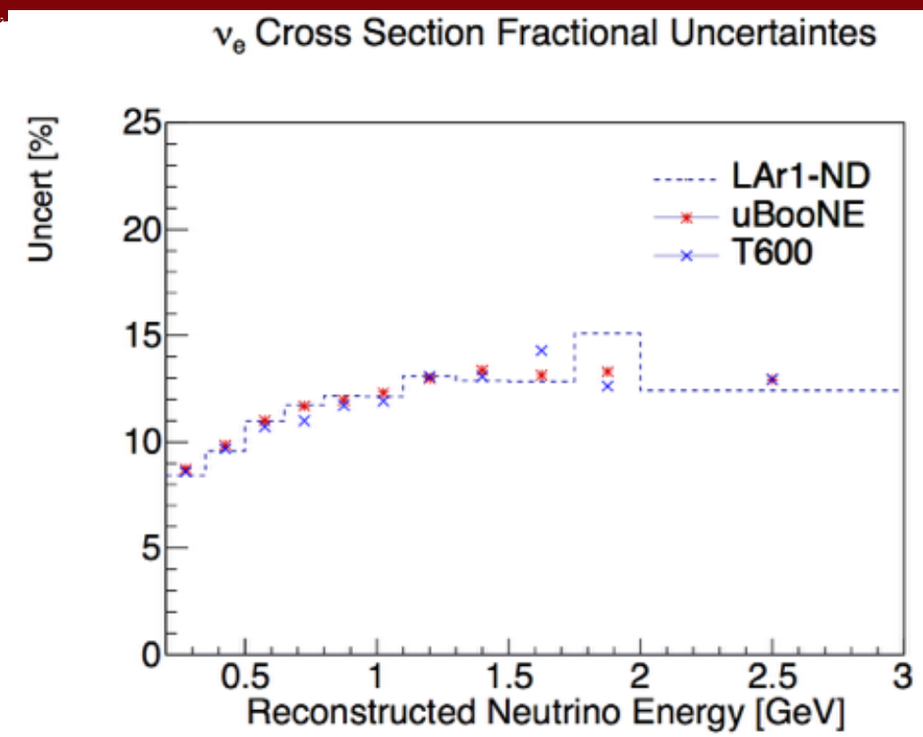
Systematics

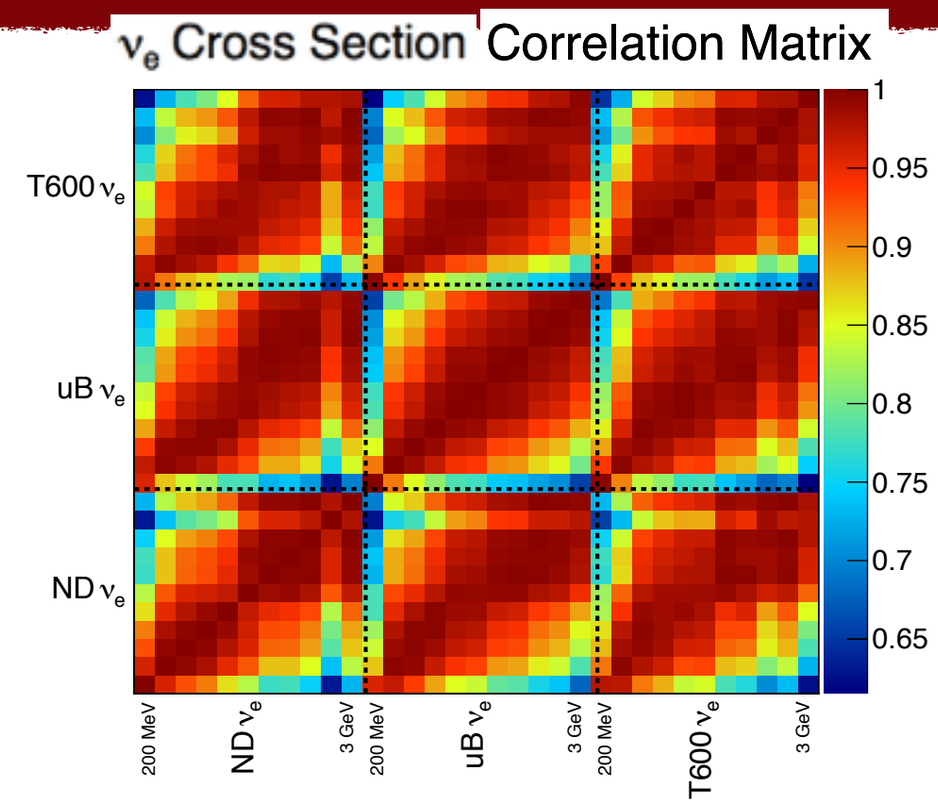
Systematic Uncertainties: ν -Argon Cross Sections

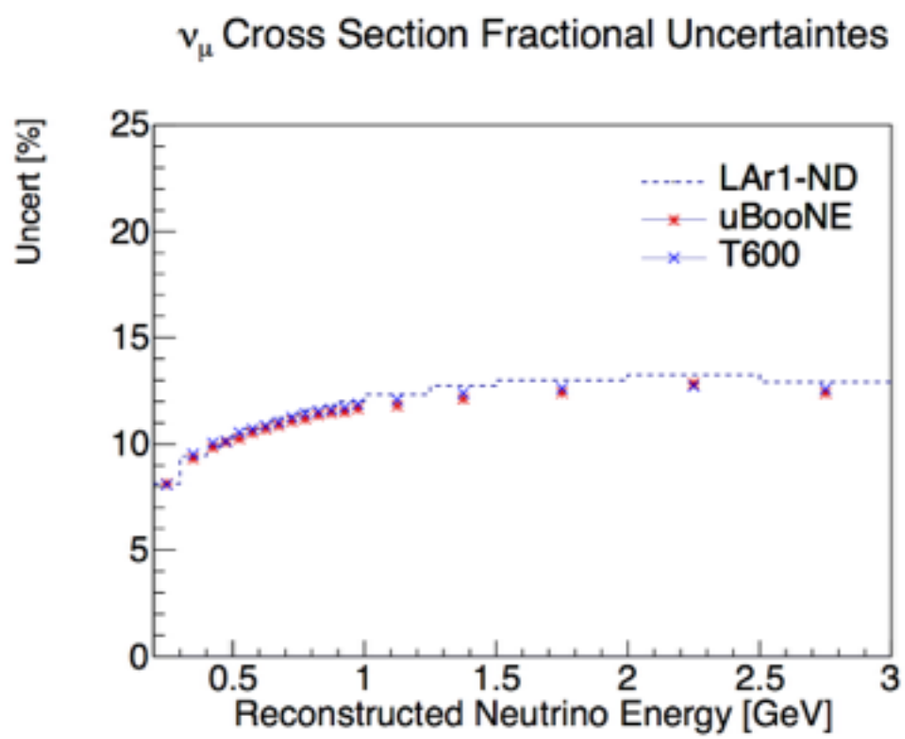


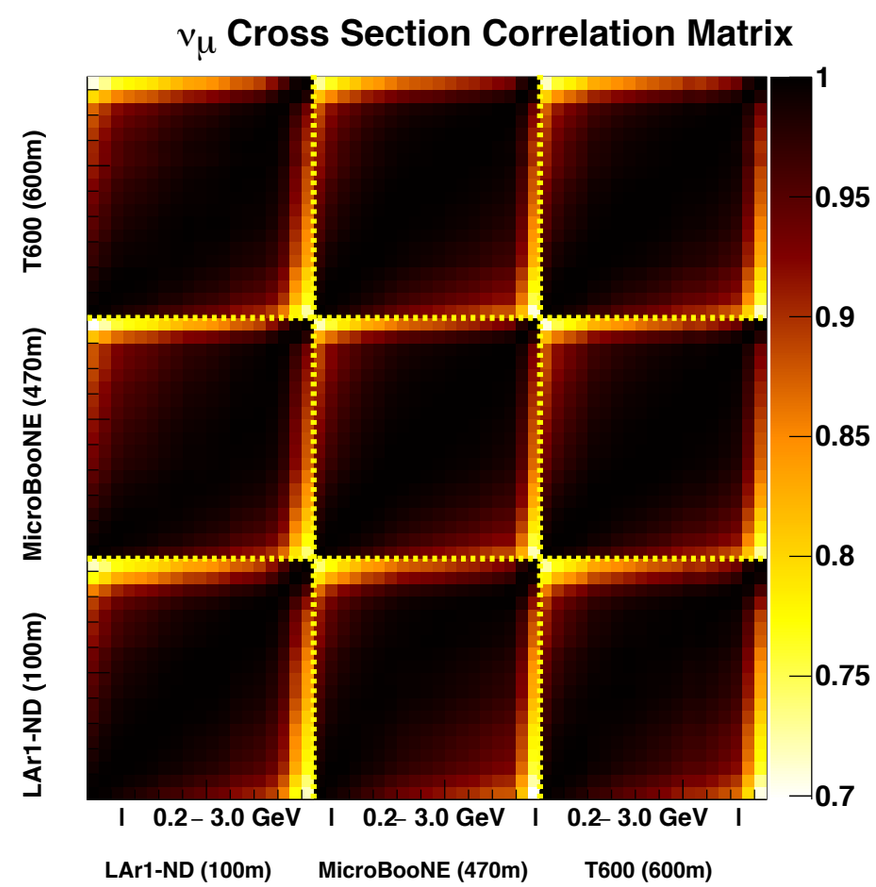


Systematics



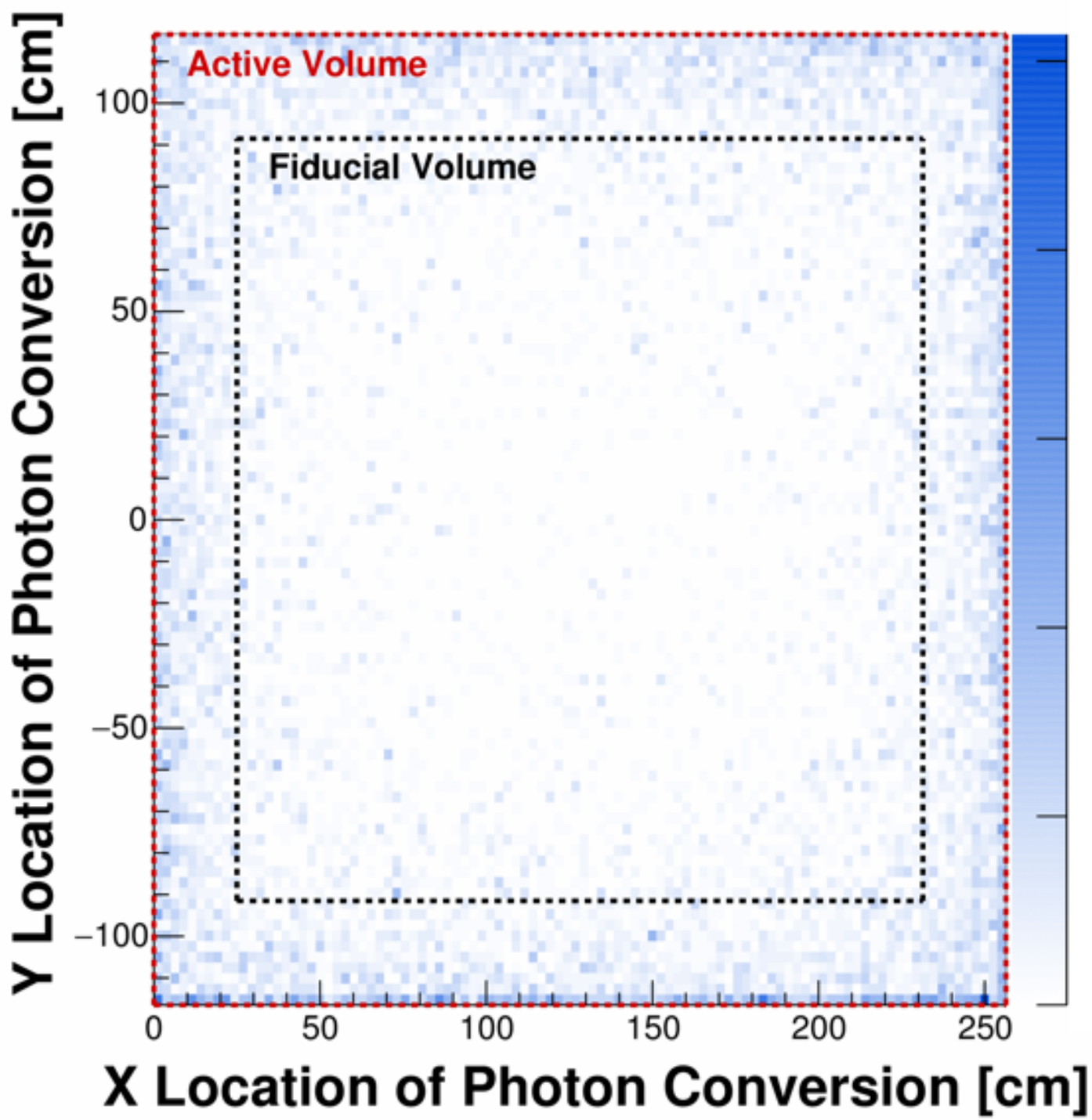






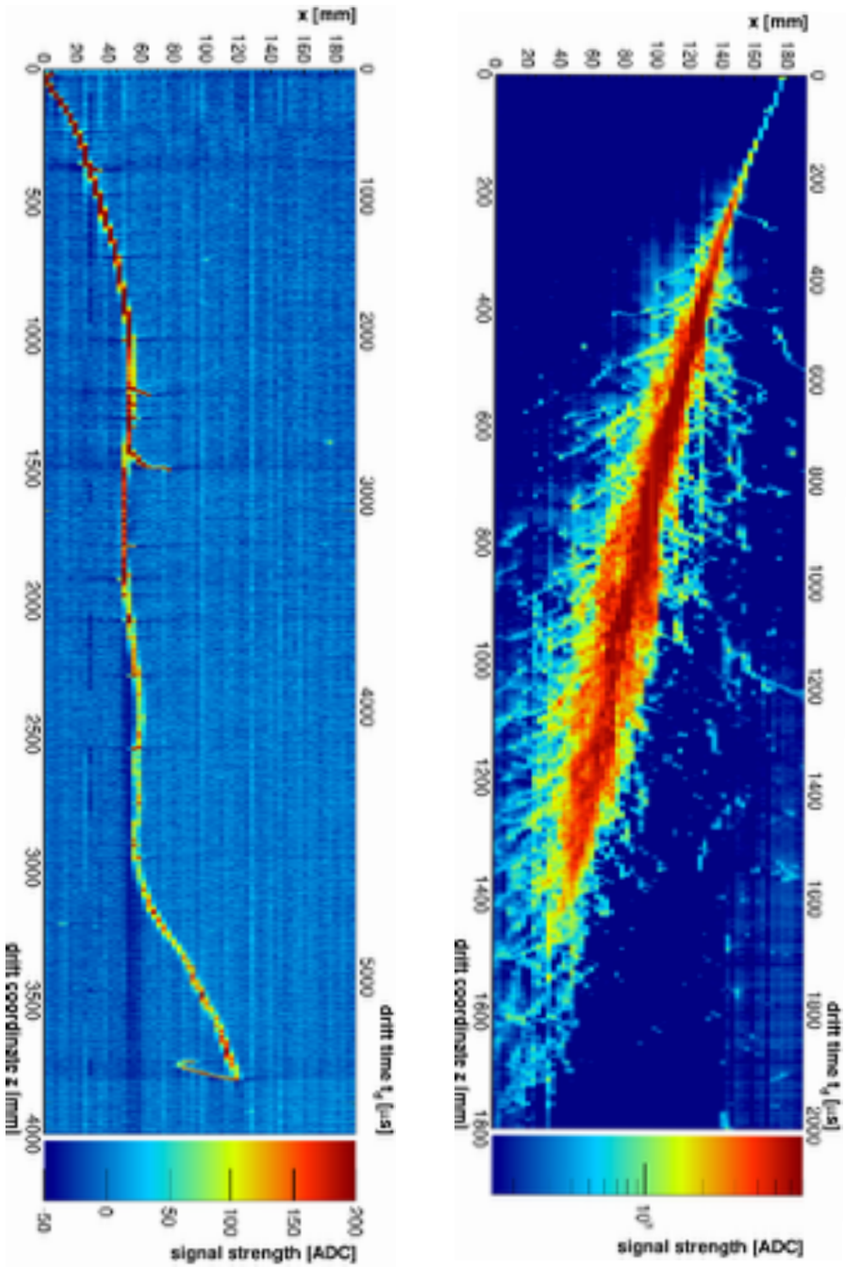
Systematics

Systematic Uncertainties: "Dirt" Background



Systematics

Systematic Uncertainties: Cosmic Ray Background

- One positive aspect of cosmic induced background is that we can measure it directly with arbitrarily high precision
- Using off beam random triggers we will be able to build a large sample of cosmic events
    - The systematic uncertainty on this background becomes the statistical uncertainty of those measurements

ArgonTube Cosmic Ray Events