MicroBooNE Status and Plans
or
A LArTPC: Physics and R&D

Eric Church, Yale

NNN2012, 4-Oct-2012

Outline

- MicroBooNE physics motivation
- The MicroBooNE detector
- MicroBooNE research and development
  - in particular, nucleon decay bkd research
  - DAQ

Collaboration

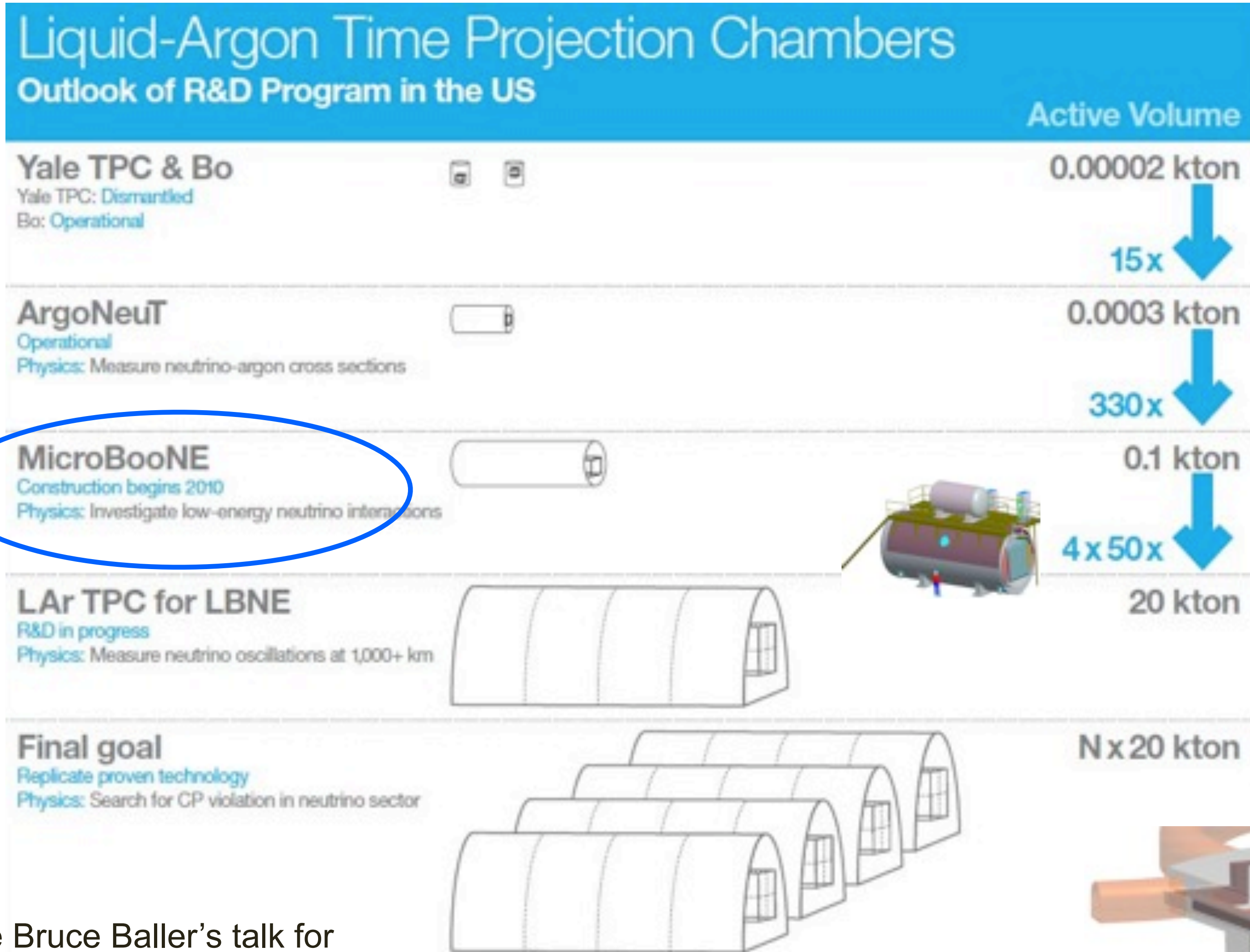
- **Brookhaven Lab:** Hucheng Chen, Jason Farrell, Francesco Lanni, David Lissauer, Don Makowiecki, Joseph Mead, Susan Duffin, George Mahler, Veljko Radeka, Sergio Rescia, Jack Sondericker, Craig Thorn, Bo Yu, Kuo-Chen Wu, Yichen Li
- **Columbia University:** Leslie Camilleri, Rachel Carr, Gary Cheng, Georgia Karagiorgi, Bill Seligman, Mike Shaevitz, Bill Willis, Bill Sippach, Cheng-Yi Chi
- **Fermilab:** Bruce Baller, Dixon Bogert, Ben Carls, Herb Greenlee, Cat James, Hans Jostlein, Mike Kirby, Sarah Lockwitz, Byron Lundberg, Stephen Pordes, Jennifer Raaf, Gina Rameika, Brian Rebel, Rich Schmitt, Dave Schmitz, Jin-Yuan Wu, Tingjun Yang, **Sam Zeller**
- **Kansas State University:** Tim Bolton, David McKee, Glenn Horton-Smith
- **Los Alamos National Lab:** Gerry Garvey, Jackie Gonzales, Bill Louis, Chris Mauger, Geoff Mills, Zarko Pavlovic, Richard Van de Water, Hywel White
- **Massachusetts Technological Institute:** William Barletta, Len Bugel, Janet M. Conrad, Christina Ignarra, Ben Jones, Teppei Katori, Tess Smidt, Arati Prakash
- **Michigan State University:** Carl Bromberg, Dan Edmunds
- **New Mexico State University:** Vassili Papavassiliou, Steve Pate
- **Otterbein College:** Nathaniel Tagg
- **Princeton University:** Kirk McDonald, Changguo Lu, Qing He
- **St. Mary's University:** Paul Nienaber
- **Syracuse University:** Mitch Soderberg, Jonathan Asaadi
- **University of Chicago:** Dave Schmitz
- **University of Cincinnati:** Ryan Grosso, Randy Johnson, Bryce Littlejohn
- **University of Texas at Austin:** Sacha Kopp, Karol Lang, Rashid Mehdiyev
- **Laboratory for High Energy Physics, University of Bern, Switzerland:** Antonio Ereditato, Igor Kreslo, Michele Weber, Christoph Rudolf von Rohr, Thomas Strauss
- **Istituto Nazionale di Physica Nucleare, Italy:** Ornella Palamara, Flavio Cavanna
- **Virginia Tech:** Camillo Mariani, Leonidas Kalousis
- **Yale University**: **Bonnie T. Fleming**, Ornella Palamara, Flavio Cavanna, Eric Church, Roxanne Guenette, Andrzej Szelc, Kinga Partyka, Ellen Klein, Christina Brasco

Motivation

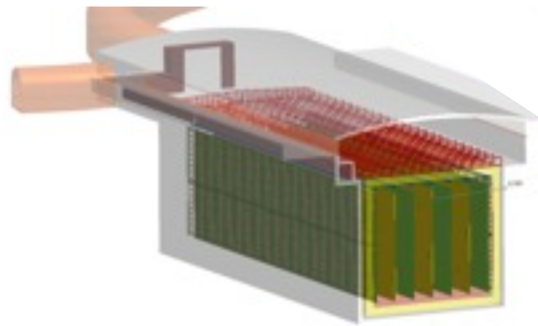
Spring, 2014!

- Physics
  - MiniBooNE low energy excess
  - Cross Sections
  - Burst Supernova neutrinos
- R&D
  - Long drift length (2.5m)
  - DAQ: Cold front-end electronics (up through shaper)
  - DAQ: Continuous readout with offline SN trigger
  - Reconstruction/pID: LArSoft
  - LAr fill w.o. evacuation
  - Surface Running
  - Nucleon Decay Backgrounds
  - UV Laser

The US Integrated Plan for LAr



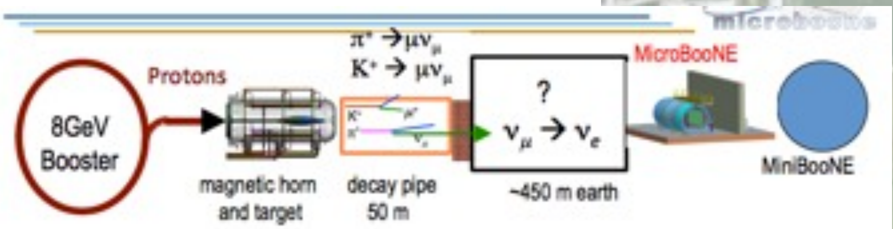
N=2

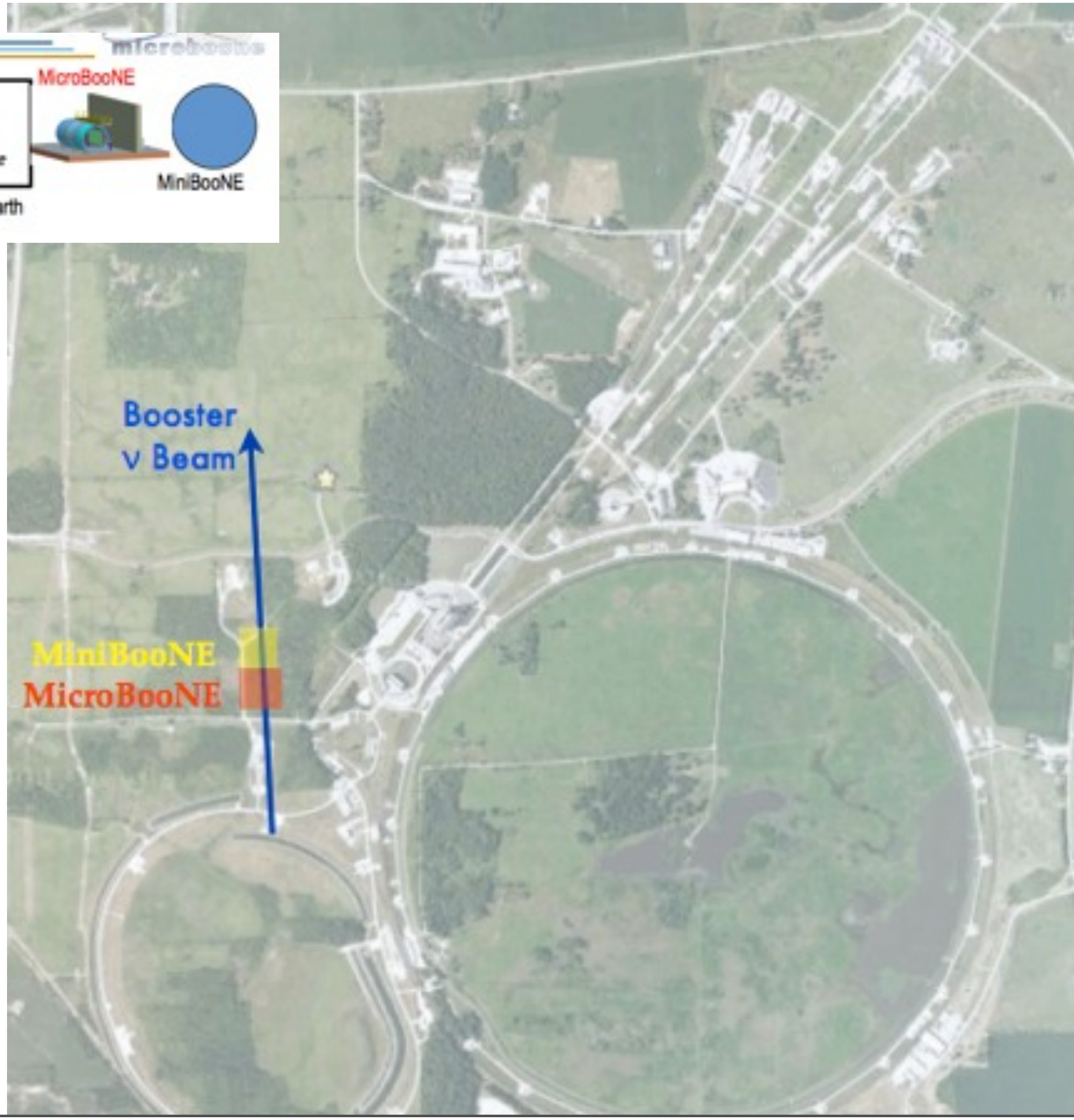


See Bruce Baller's talk for general physics and program of LAr detectors

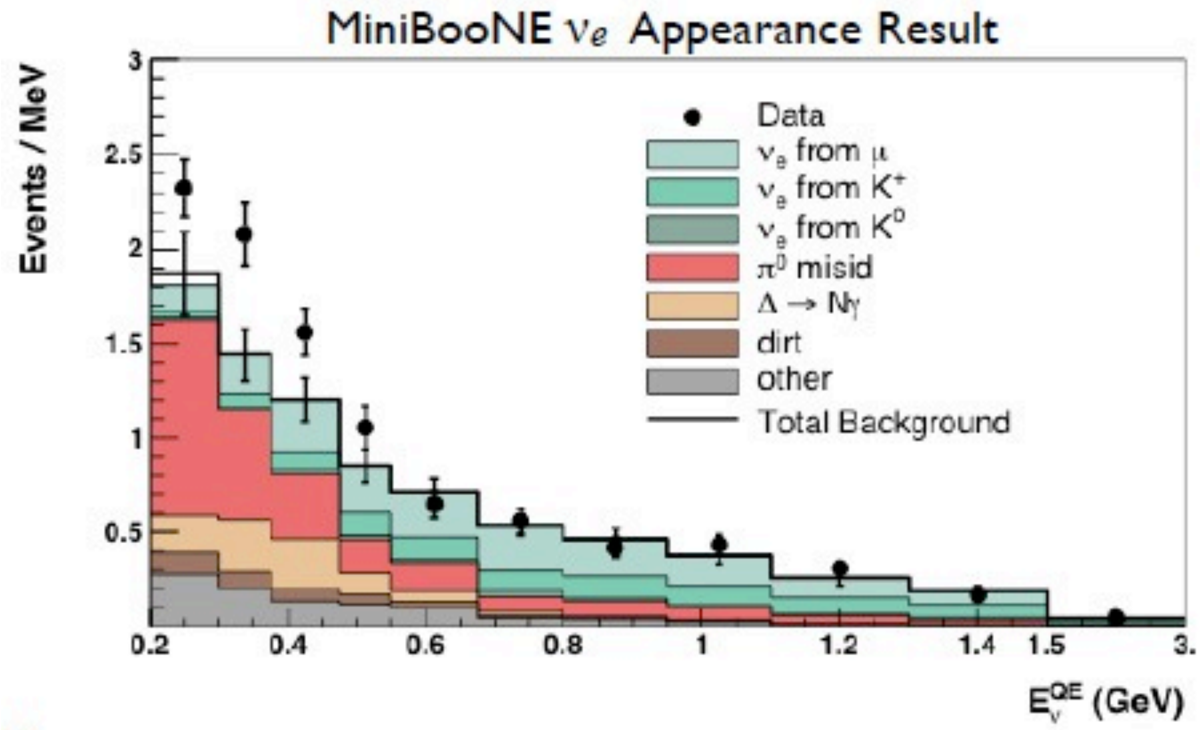
May 4, 2011

MicroBooNE is in the BNB





low Energy MiniBooNE excess

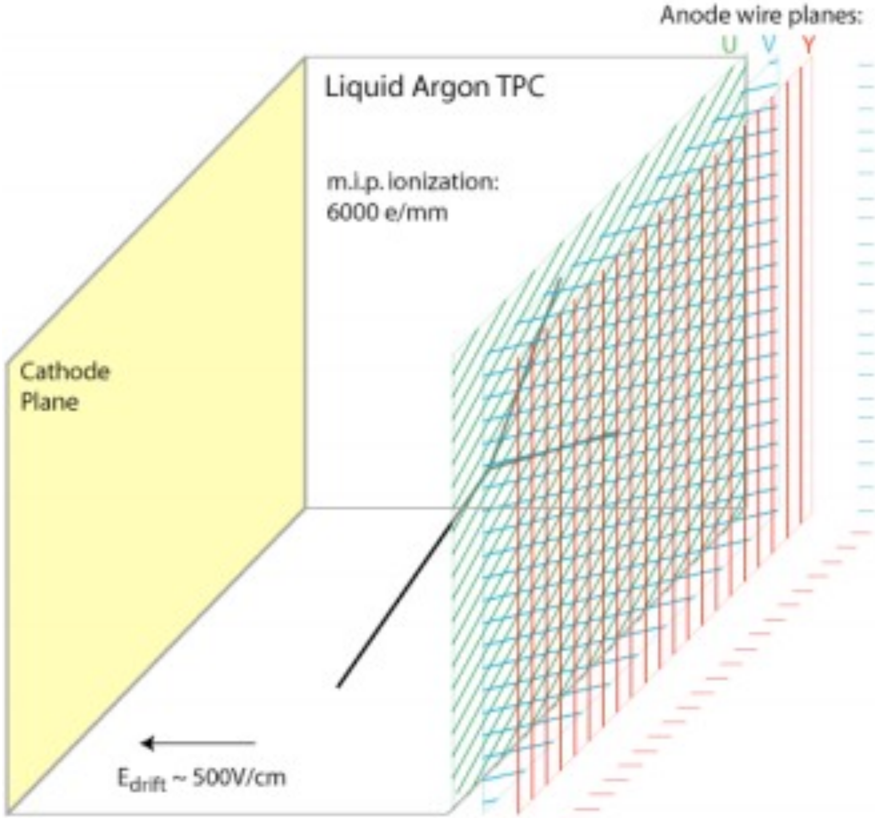


electrons or gammas?

128.8 ± 43.4 events

0.200<E<0.475 GeV

MicroBooNE properties

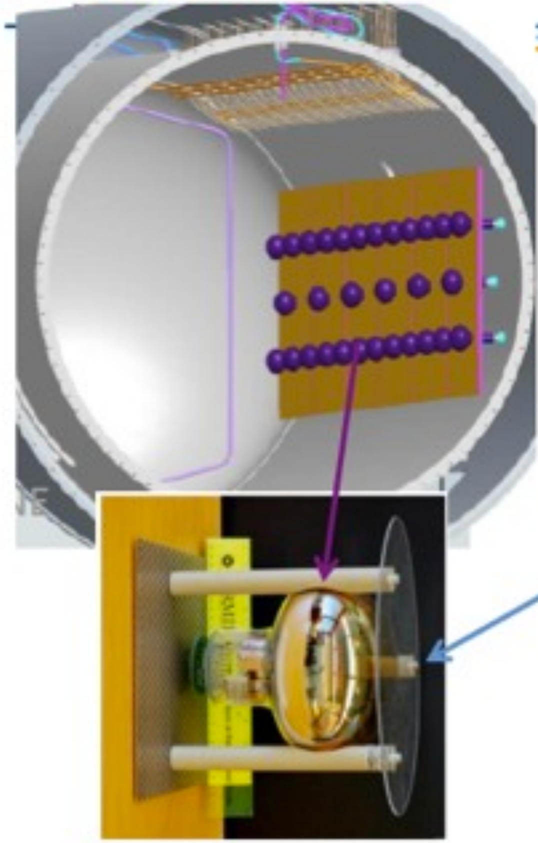


Two induction planes and a collection plane. 3mm wire and plane pitch.

See Bruce Baller's talk for animation!

Image of PMTs in TPC

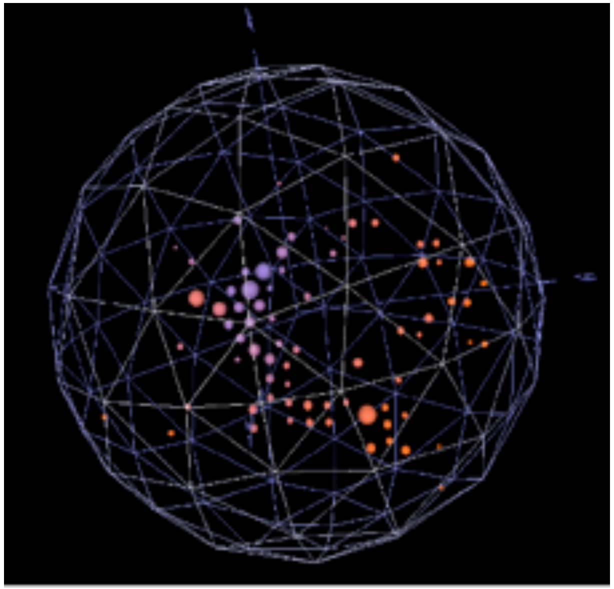
Photodetectors



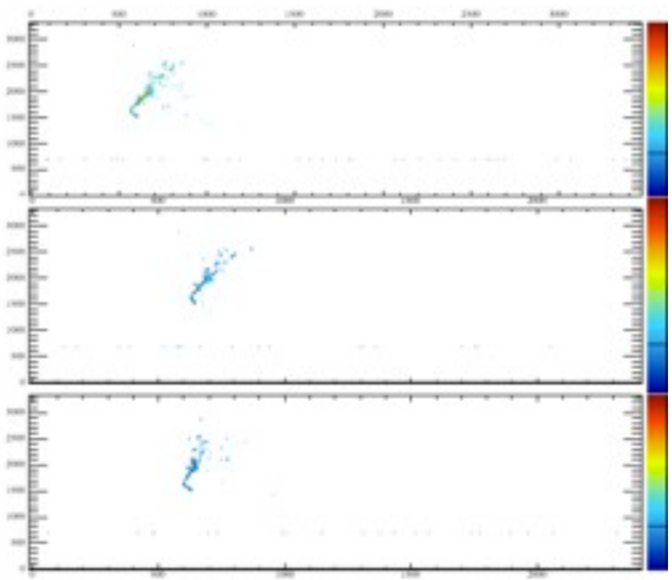
LAr scintillates in the UV at 128nm:
Use it
- To determine time of event
- To trigger on events in time with beam

- 30 Hamamatsu R5912-02 14 stage 8 inch pmt's.
- Located behind collection plane
- Plate coated with Tetraphenyl-butadiene (TPB) to shift UV light to visible in front of each pmt.
- 6ns fast component: expect 6000 photons/MeV
- 4 photo-electrons/MeV **recorded**

signals in the detectors: nueCC



MiniBooNE nue CC candidate DATA

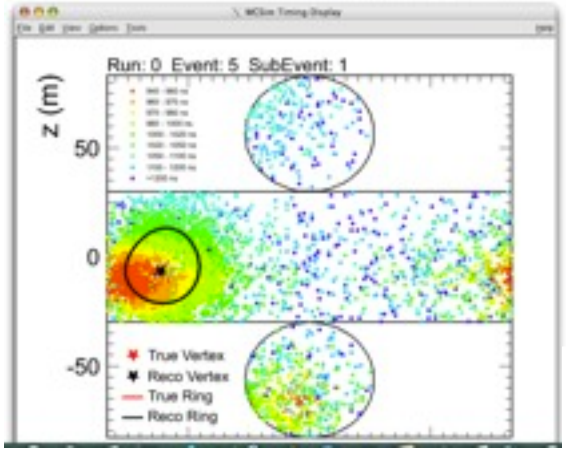


MicroBooNE nue CCQE (0.8 GeV/c neutrino) SIMULATED

signals in the detectors: pi0s

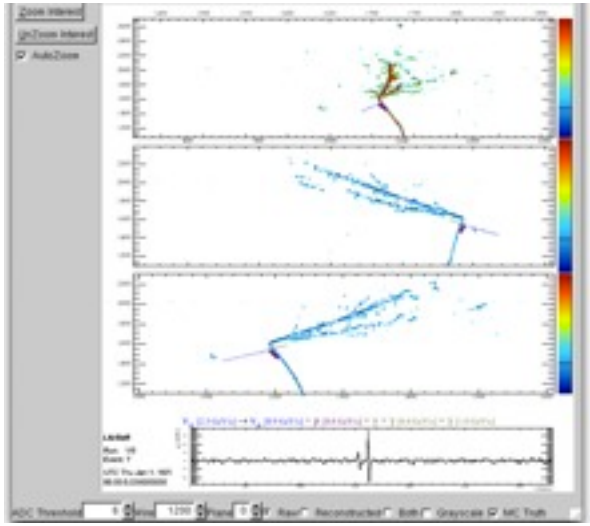
Simulation

NC mis-ID (overlapping rings)

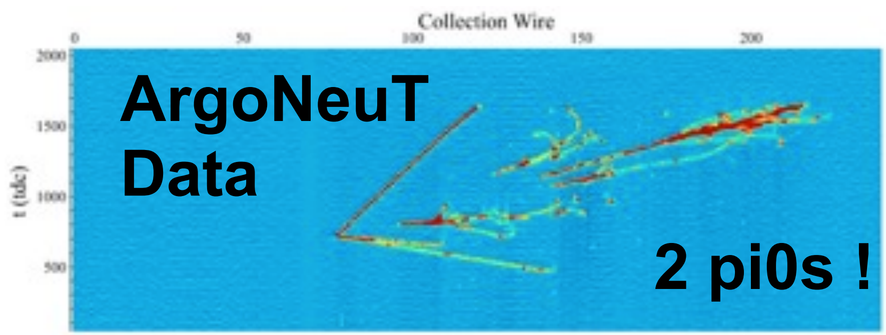


Identical event simulated in WCSim

Simulation



Identical event simulated in MicroBooNE

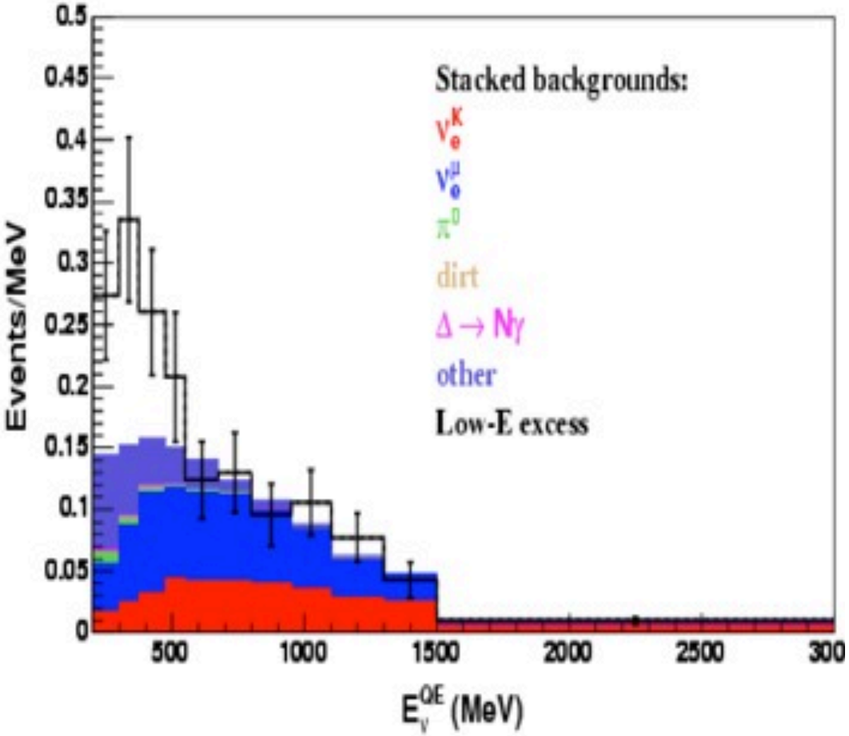


Note the high (x2) ionization early in each gamma

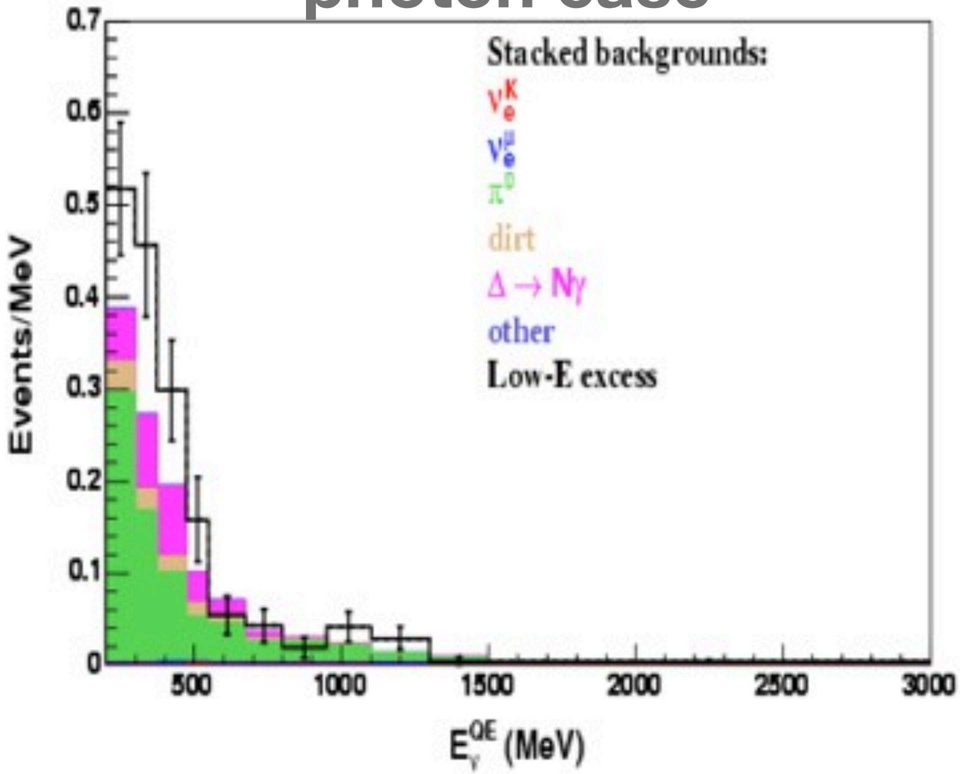
electrons or gammas?

Expected MiniBooNE Excess in MicroBooNE

electron case



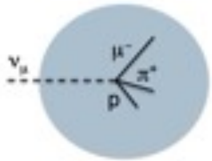
photon case



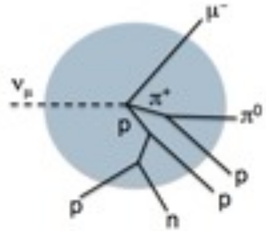
... are 5.7 and 4.1 sigma, respectively

Cross Sections

signature: CC Res example	NuWro	NUANCE	GENIE
$\nu_\mu p \to \mu^- \Delta^{++} \to \mu^- p \pi^+$	27900	20300	46070



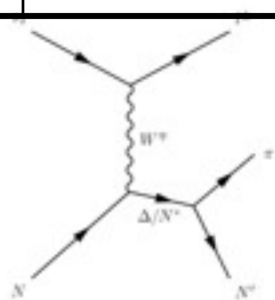
Traditional accounting



FS particle accounting

signature	NuWro	NUANCE	GENIE
$\mu + Np + 1\pi, (N \geq 2)$	700	18900	18500

ArgoNeuT will lead the way here.



cross section parameters in each generator not tuned to be consistent with each other!

Burst Supernovae

$$\nu_e + Ar \rightarrow K^* + e^-$$

F. Cavanna: 20 +/- 10 evts

in a galactic supernova

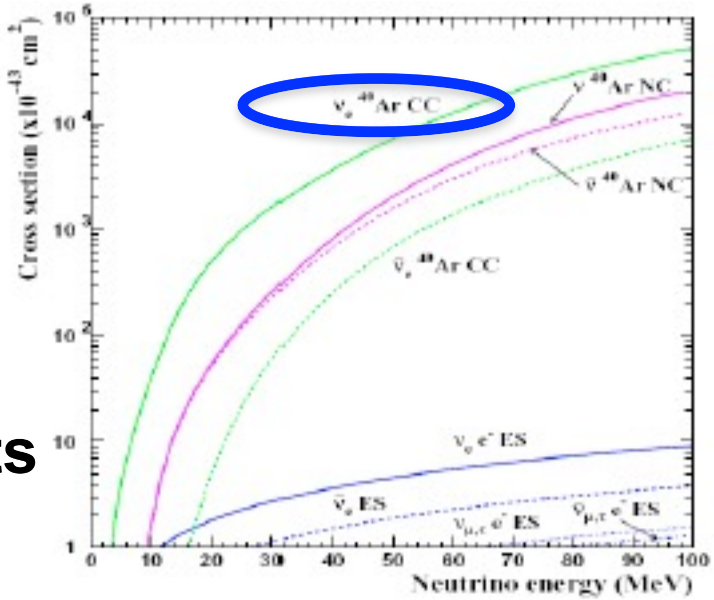
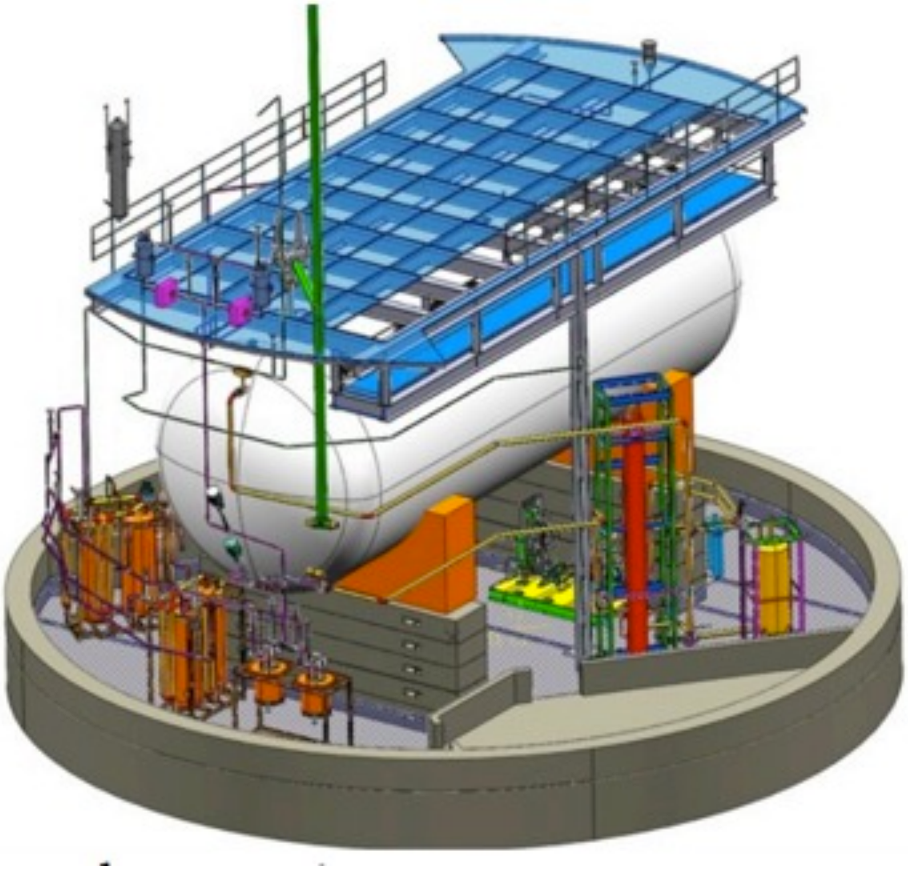
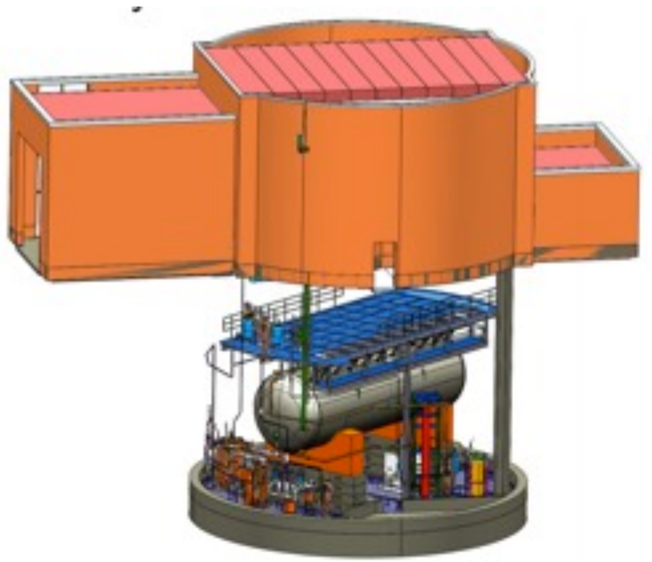


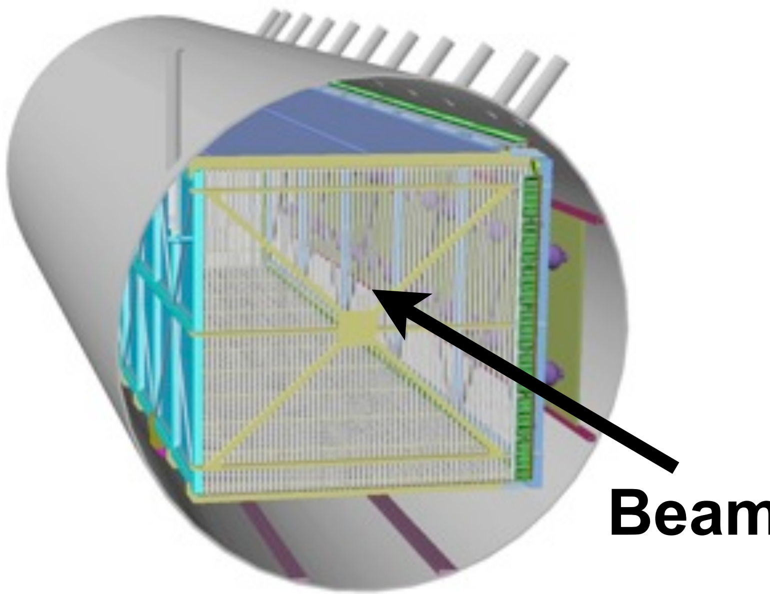
Figure 3: Neutrino cross sections relevant to the supernovae detection with a I
Argon TPC detector.

Kolbe, Langanke, Martinez-Pinedo

The Design







2.5x2.4x10.4 m^3

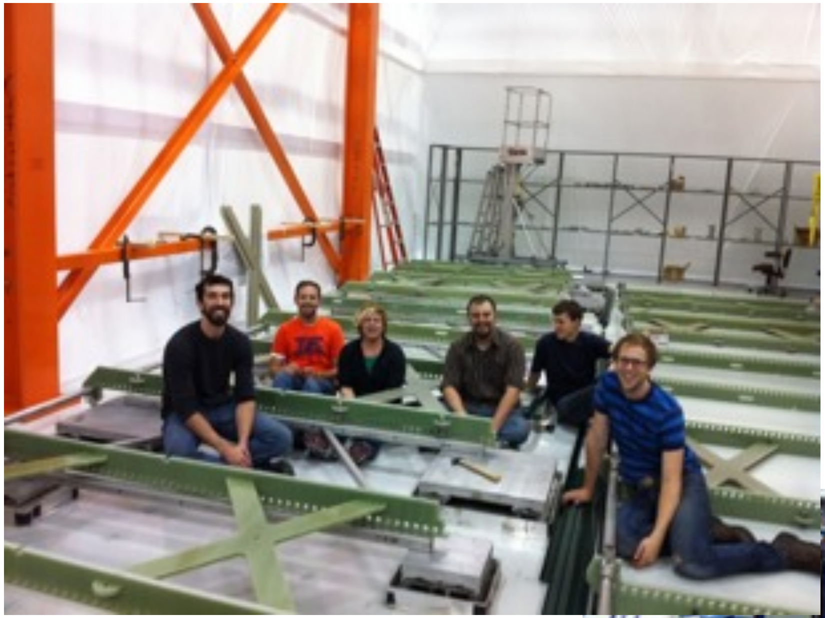
Site Construction

June, 2012

September, 2012

LArTF

Detector Construction



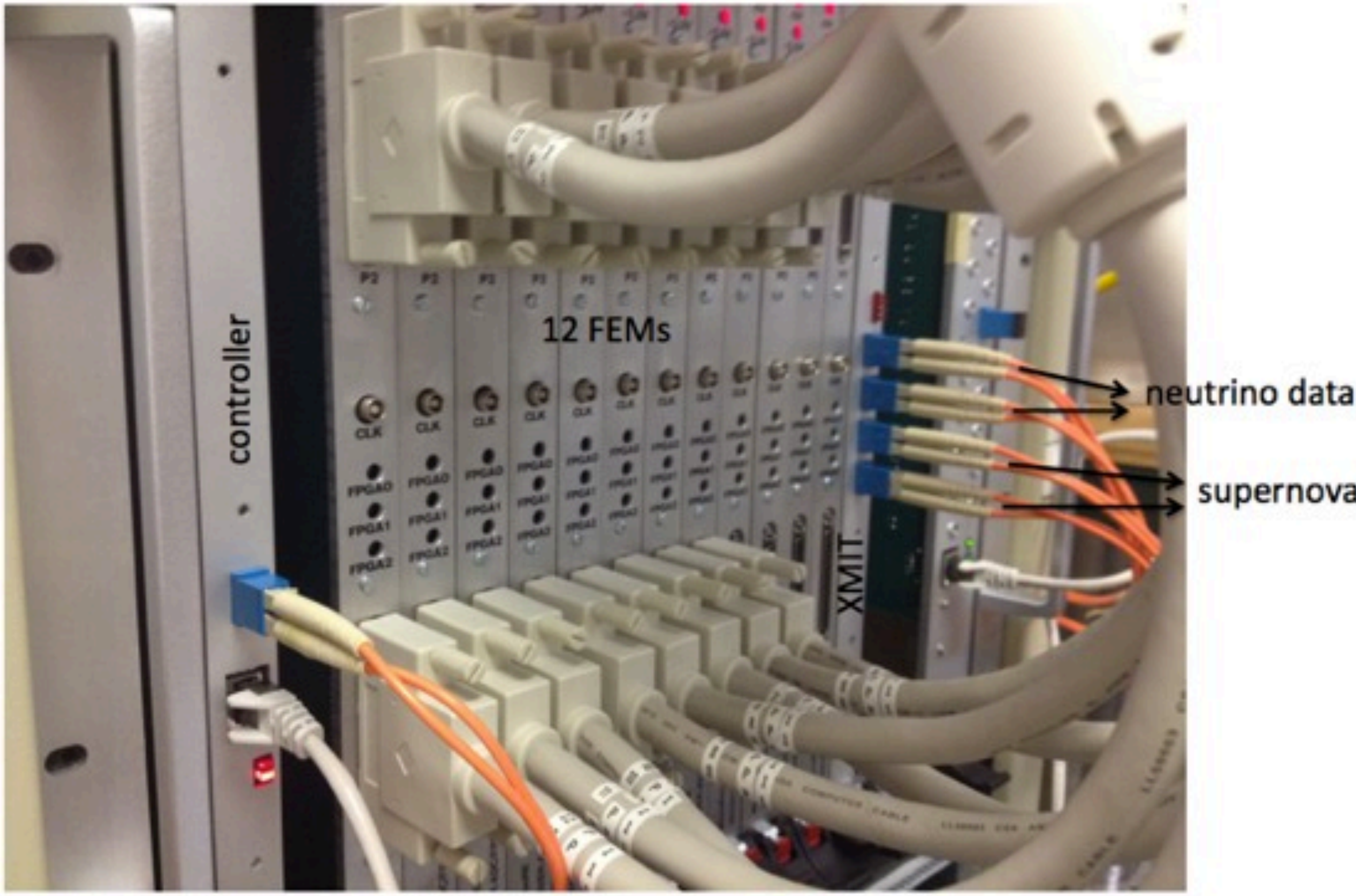
TPC at D0 Assembly Building.

R&D

- DAQ
  - Cold Electronics
  - Continuous read-out in addition to triggered stream
    - enables SN detection and nucleon decay bgd study
- Also new: long drift length (2.5m)
  - UV laser (See Thomas Strauss's talk and poster)

DAQ test stand

At Nevis...
At D0 next week.

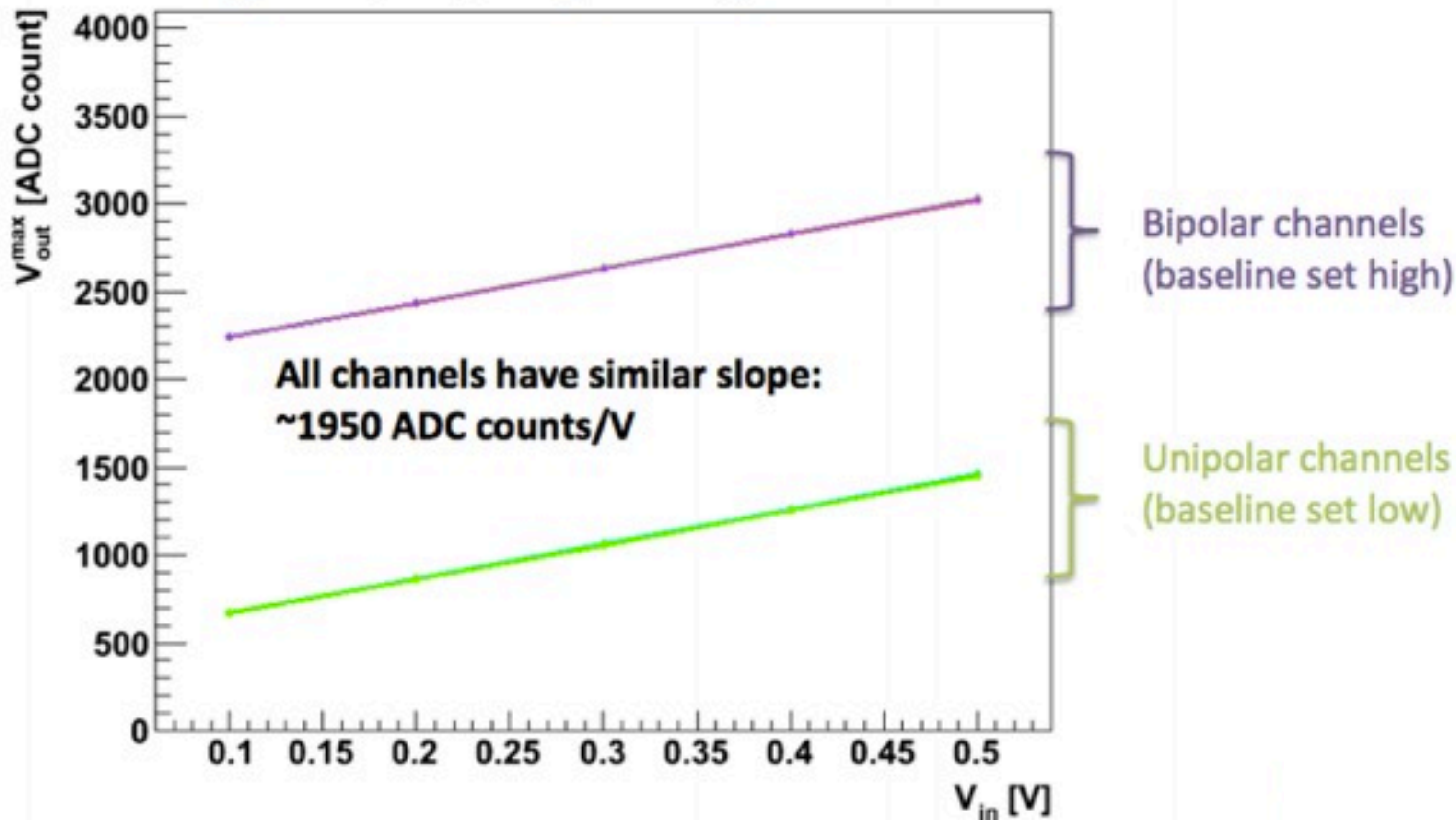


Nevis DAQ test stand results

Linearity/gain measurements

Example: FEM 9, all 64 channels overlayed

Measured amplitude (ADC) vs input voltage:



What and How to explore Nucleon decay background at MicroBooNE?

Concentrate on Golden Mode decay bgd. Good fit for tracking capabilities of LAr:

- $p \rightarrow K^+ + \overline{\nu}_t$ >4.0 x 10^{34} yrs after 340 ktonne-yrs

With simulation studies of Charge Exchange K+.

- Have started study with Truth Info.
- With a development of a TPC based trigger.

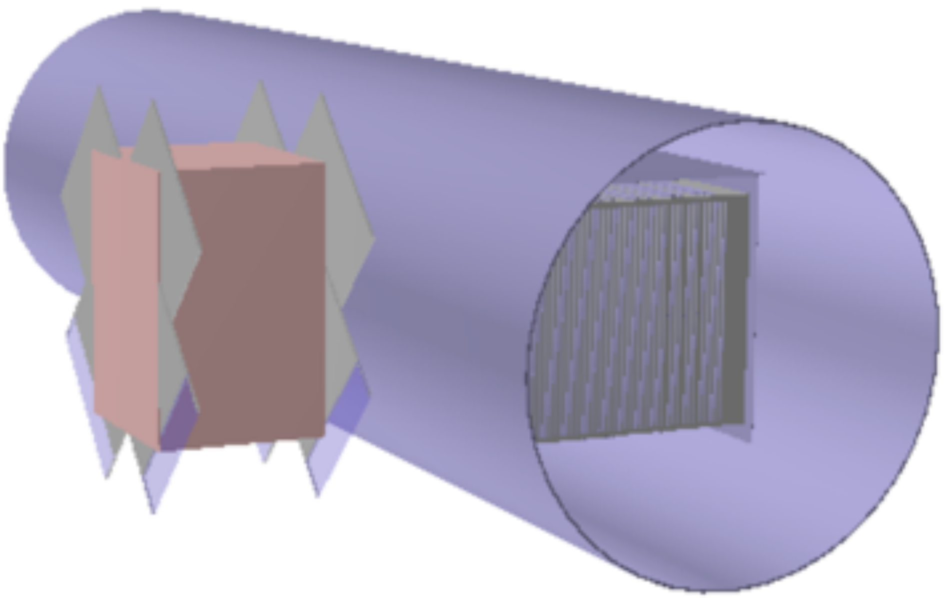
With the inclusion of:

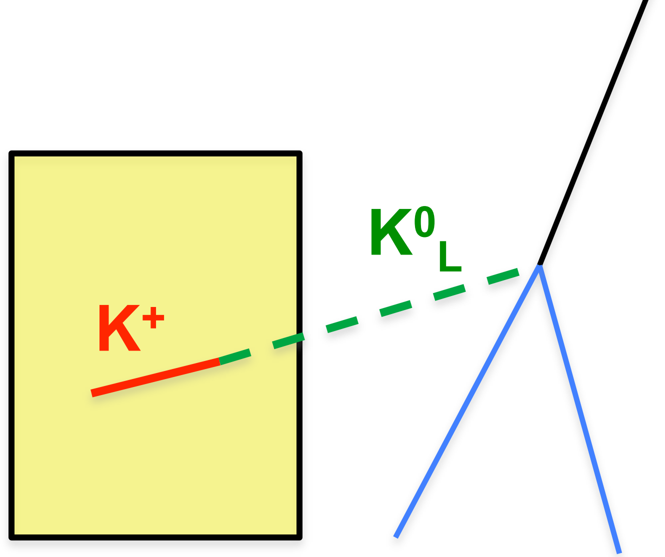
- a granite block to simulate LBNE "walls",
- and scintillation counters between it and the cryostat to tag particles entering the TPC.
- use the untriggered data

(Under conditions that would NOT harm the MicroBooNE program)

Preliminary simulations

- Working on studies of granite block and scintillators in LArSoft.
- Charge exchange K+ looks like a K^+ from p decay.
- Particle ID to distinguish Kaons from protons, etc, are mature and will be refined in ArgoNeuT studies with LArSoft!





Rate of kaon production

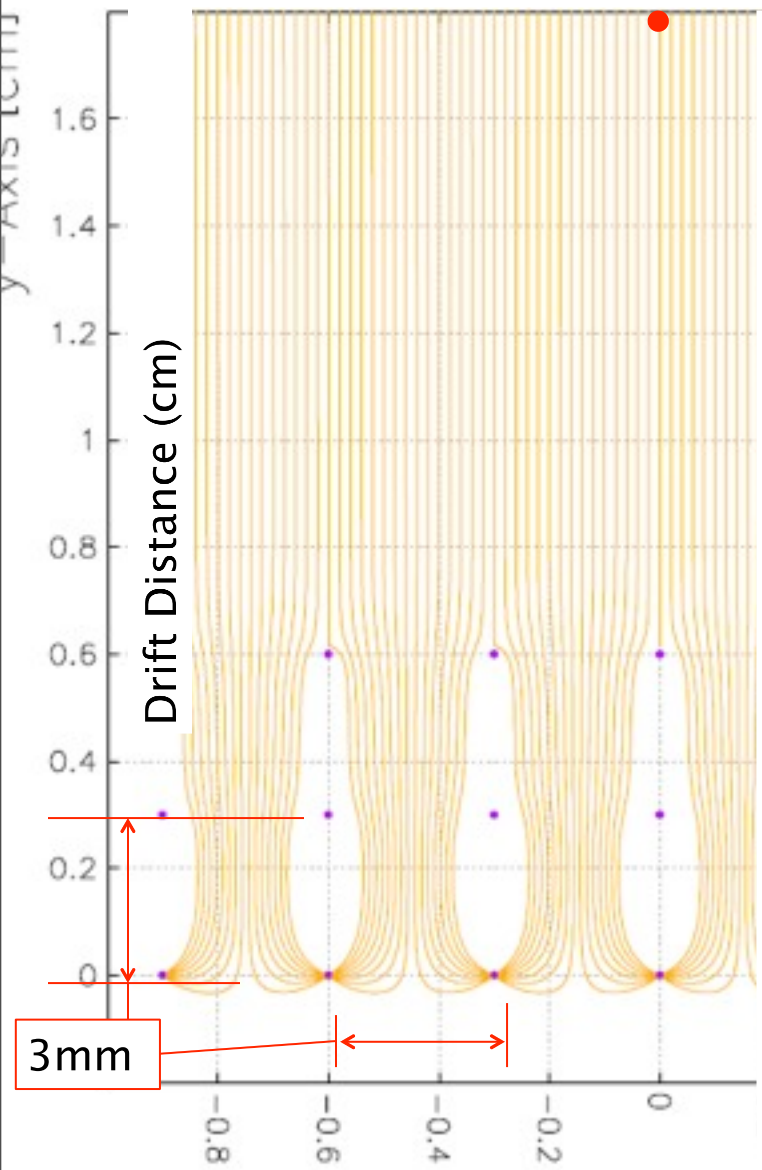
- 1440 K^0_L in a 30 day exposure exit block towards TPC.
- For a charge exchange cross section of 9.6mb, ~ 860 will charge exchange.

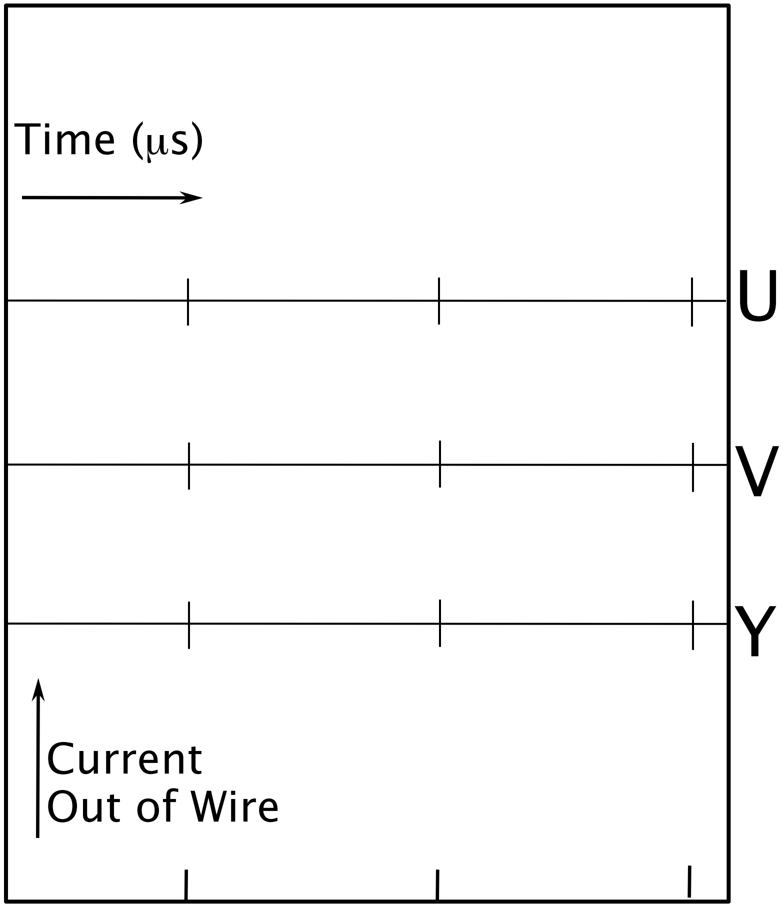
Conclusion

It is an exciting time for MicroBooNE. Stay tuned!

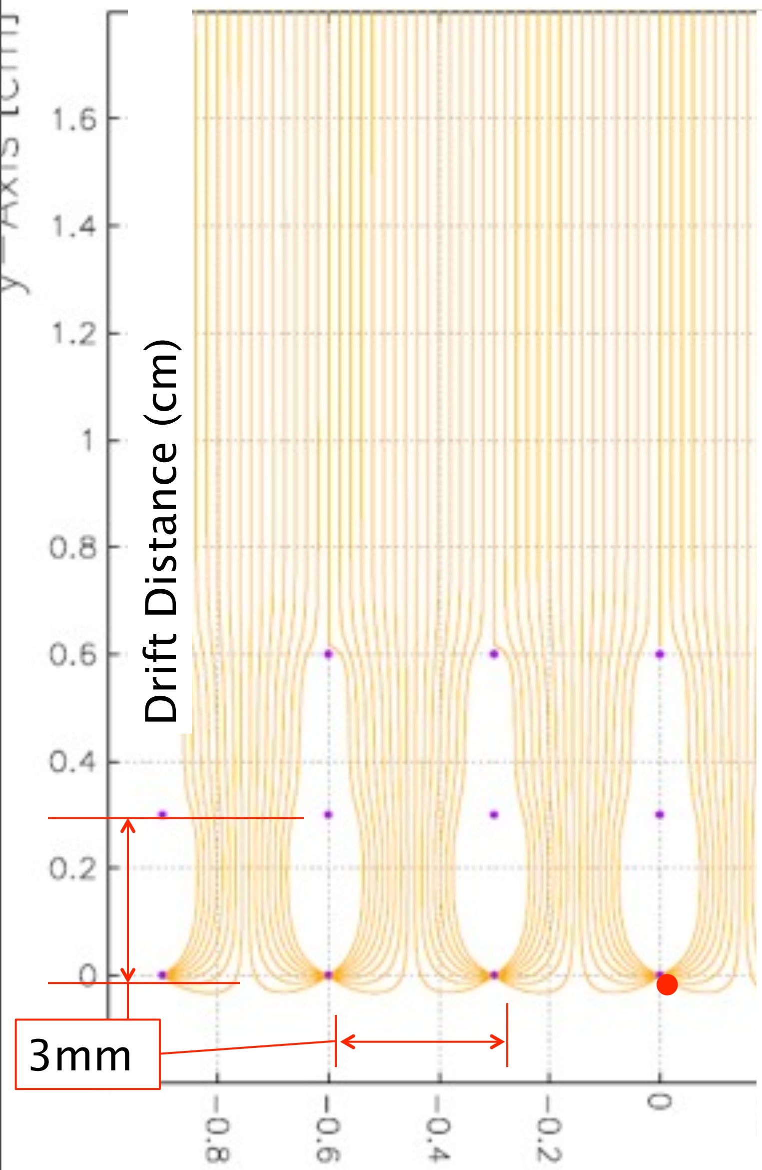
Back-up Slides

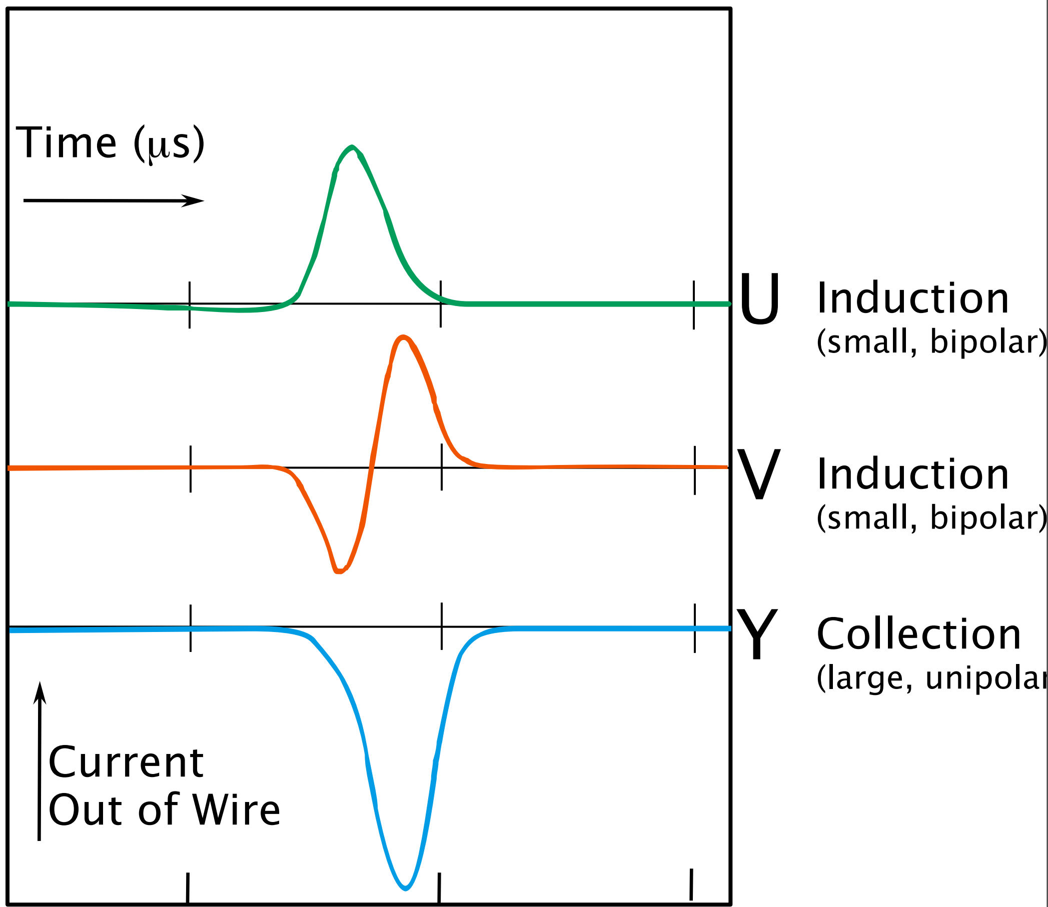
Charge Signal Formation



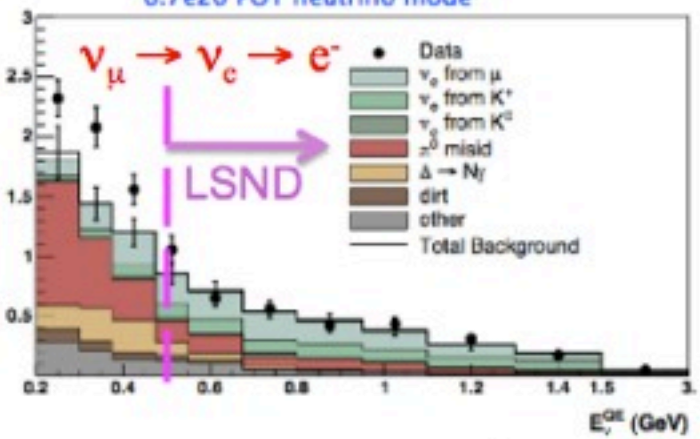


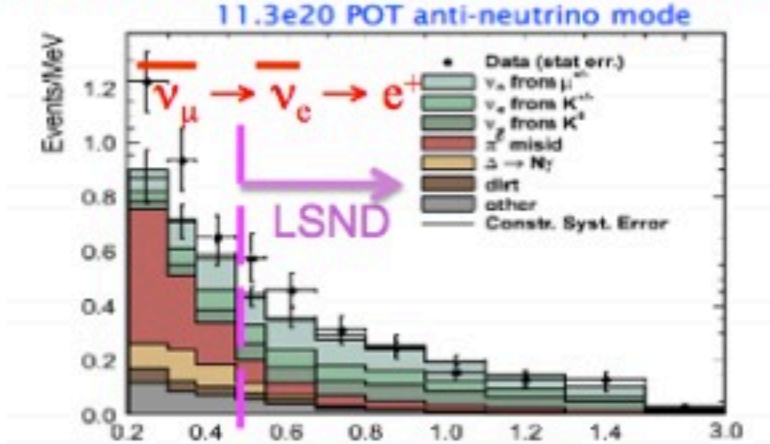
Charge Signal Formation





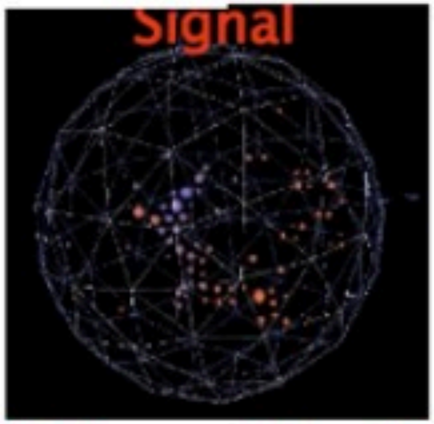
e/γ identification in MiniBooNE based on Cerenkov Rings





$\nu_e X \rightarrow e + \ldots$

Single fuzzy ring

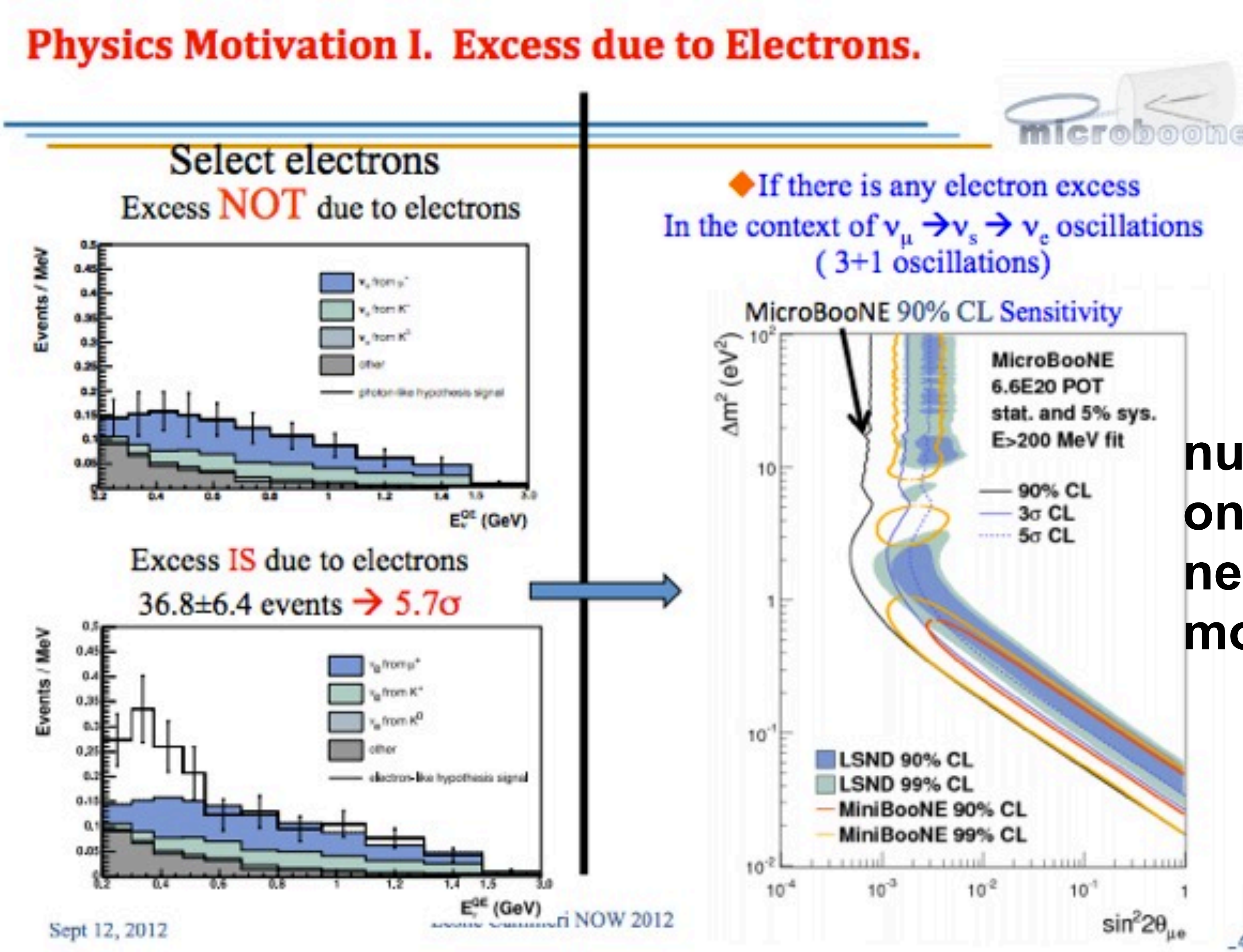


For a converting γ
the two rings from e^+ and e^- overlap.

Cannot distinguish an electron from a single γ to e+e-.

From the MiniBooNE presentation at Neutrino 2012

Excess due to e or gamma?

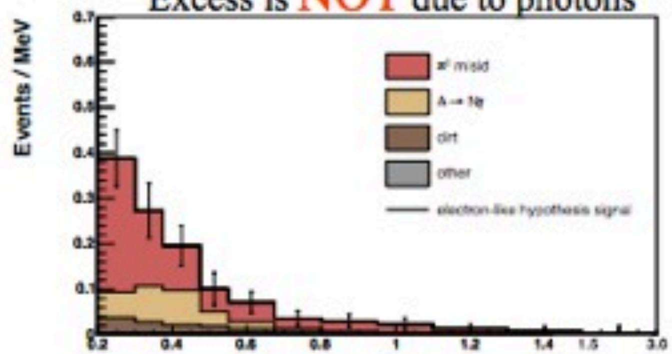


numu only. 2 neutrino model

Physics Motivation. Excess due to: Photons.

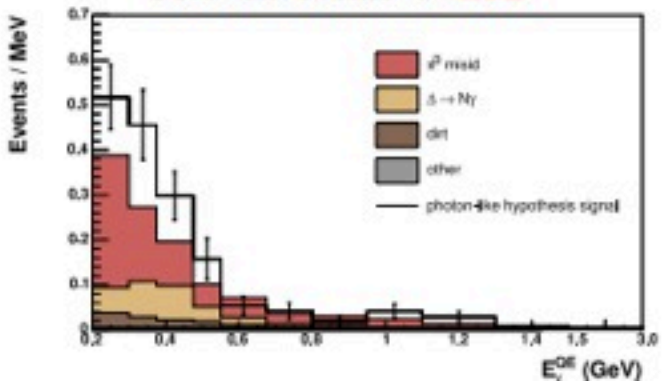
Select photons

Excess is NOT due to photons



Excess IS due to photons

36.8±8.9 events → 4.1σ



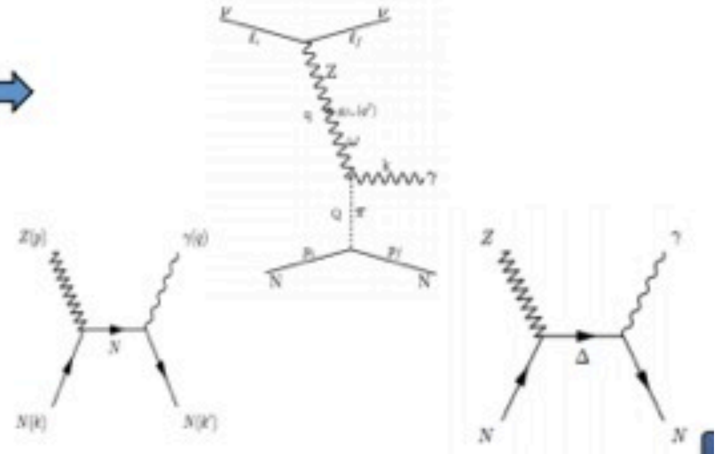
- Background: γ or π^0

OR

- Radiative ν interaction

Examples:

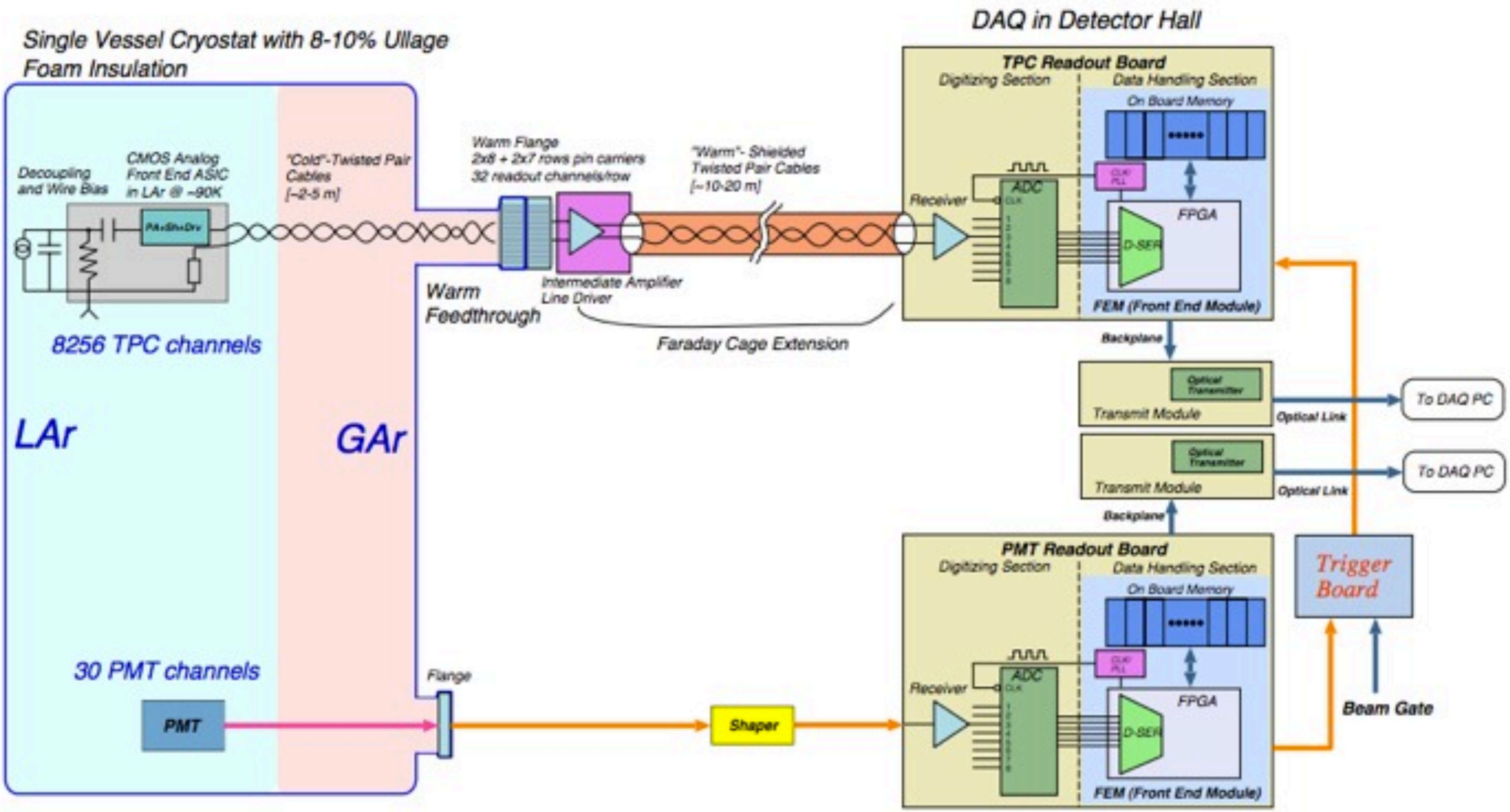
- R. Hill arXiv: 0905.0291
- Jenkins et al arXiv:0906.0984
- Serot et al arXiv: 1011.5913



Specs

Cryostat Volume	150 Tons
TPC Volume (l x w x h)	89 Tons (10.4m x 2.5m x 2.3m)
# Electronic Channels	8256
Electronics Style (Temp.)	CMOS (87 K)
Wire Pitch (Plane Separation)	3 mm (3mm)
Max. Drift Length (Time)	2.5m (1.5ms)
Wire Properties	0.15mm diameter SS, Cu/Au plated
Light Collection	~30 8" Hamamatsu PMTs

MicroBooNE DAQ



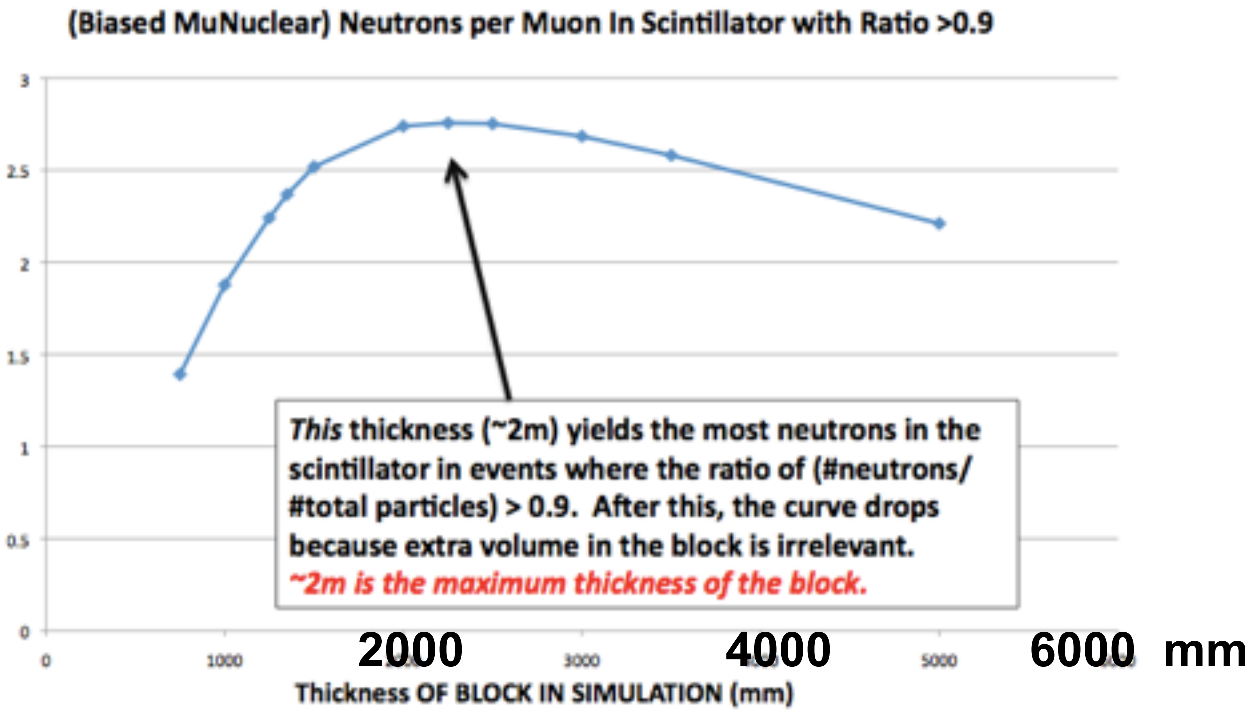
Further hardware work:

- Develop readout scheme for Trigger primitives.
- Develop "TPC Top" veto software.
- Determine installation/removal procedure for granite block. (Key is that block is far away and downstream during beam-on time.)
- Develop modification of Double Chooz scintillator readout for MicroBooNE.
- Test Scintillator modules and readout.
- Cabling and HV for Scintillators.

How thick should the block be?

- Maximum number of neutrons observed in scintillators in "deep" (R > 0.9) showers occurs for 2m thick granite block

"Deep" Showers – Maximum Thickness



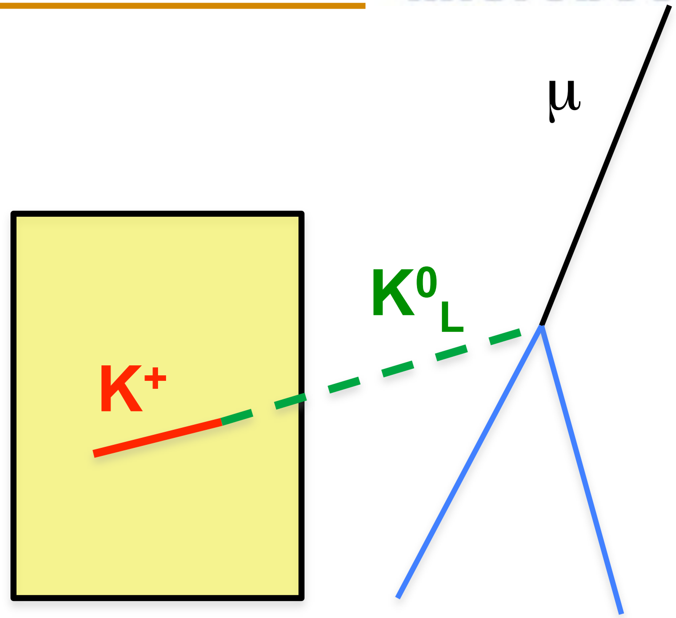
Neutron detection in scintillators

- Overlapping 3 modules: 6 cm of scintillator
- Using first layer as a charged particle veto: 5 cm for neutron detection
- Probability of neutron interacting: 15% → 5% between 400 and 1000 MeV/c

A Measurement of Background to p→K decay mode

Cosmic ray:

- μ interacting in the rock around the detector.
- Producing a K^0_L
- Enters the detector (No track) and
  charge exchanges $K^0_L p \rightarrow K^+ n$
- Looks like a K^+ from p decay.



Study:

- How many cannot be rejected on the basis of accompanying particles ?

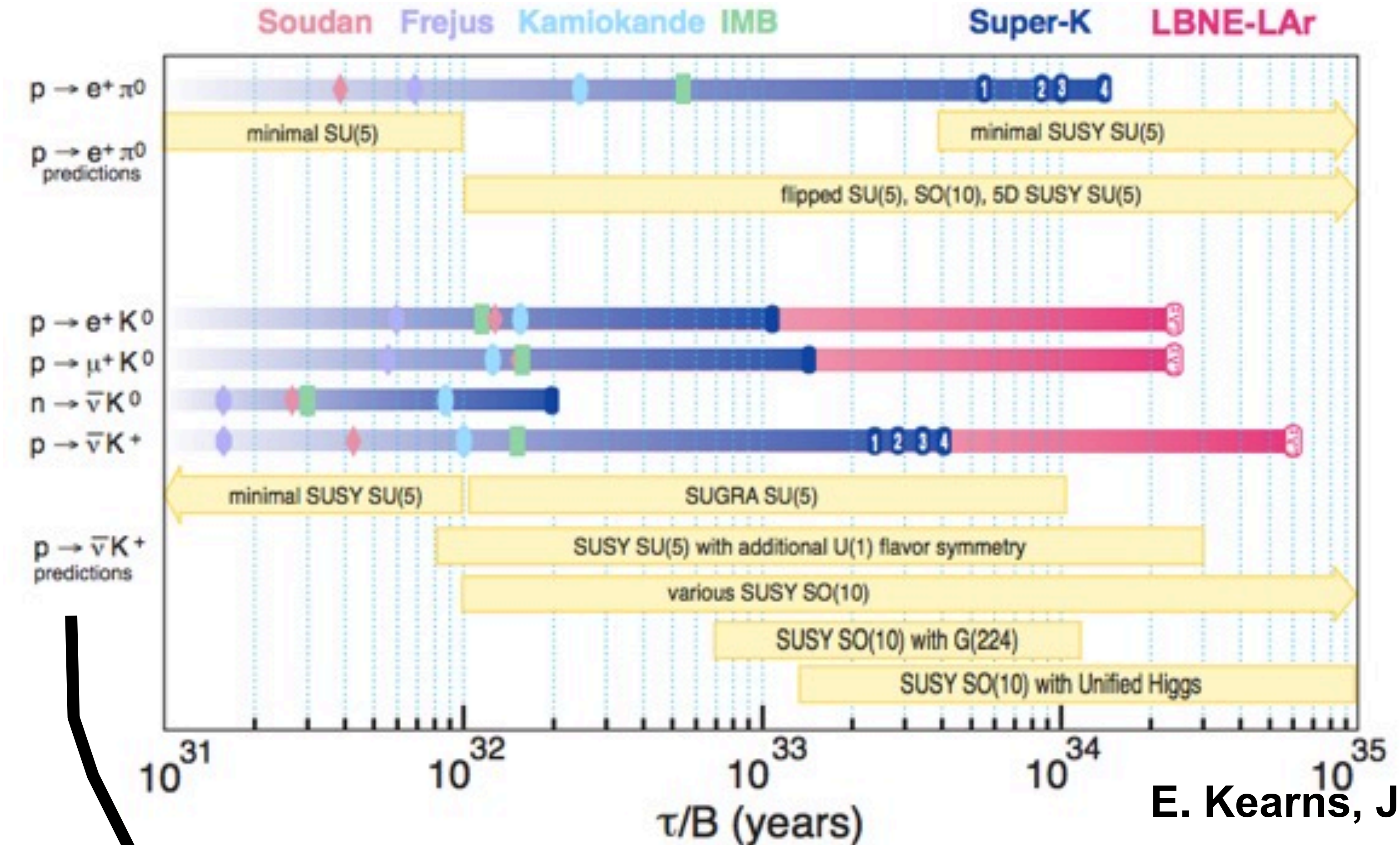
How do we produce them and detect them?

- From above: Produced in MicroBooNE Overburden (~3m).
- From the side: Add instrumented granite block.

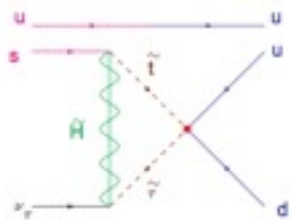
A lot of cosmic muons but few K's.→ **Need a trigger:**

Unaccompanied energy deposition in center of detector

Nucleon decay background

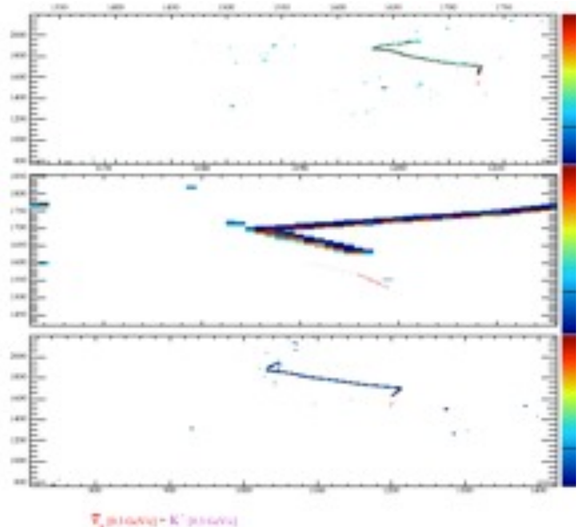


E. Kearns, J. Raaf

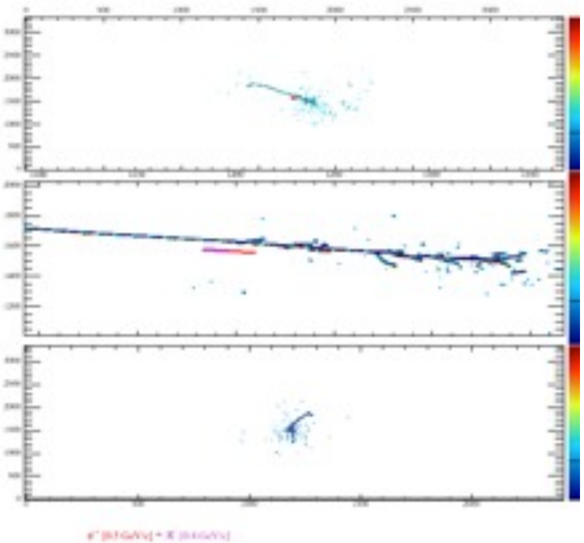


nucleon decay in LBNE-like detector

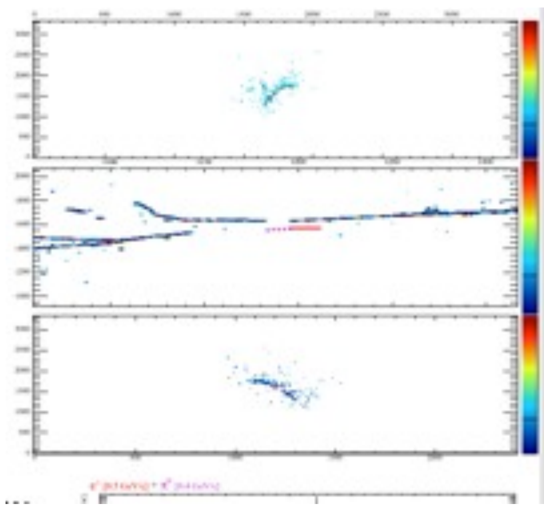
A LAr detector that hopes to compete with HyperK must demonstrate great efficiency at detecting many modes: including evts w FSI-absorbed pions, via the de-excitation gammas. e.g. Along with demonstrating heightened bgd rejection.



p->K^+nubar



n->e^+pi^-



p->e^+pi^0

(None of these events are plagued with FSI complications.)

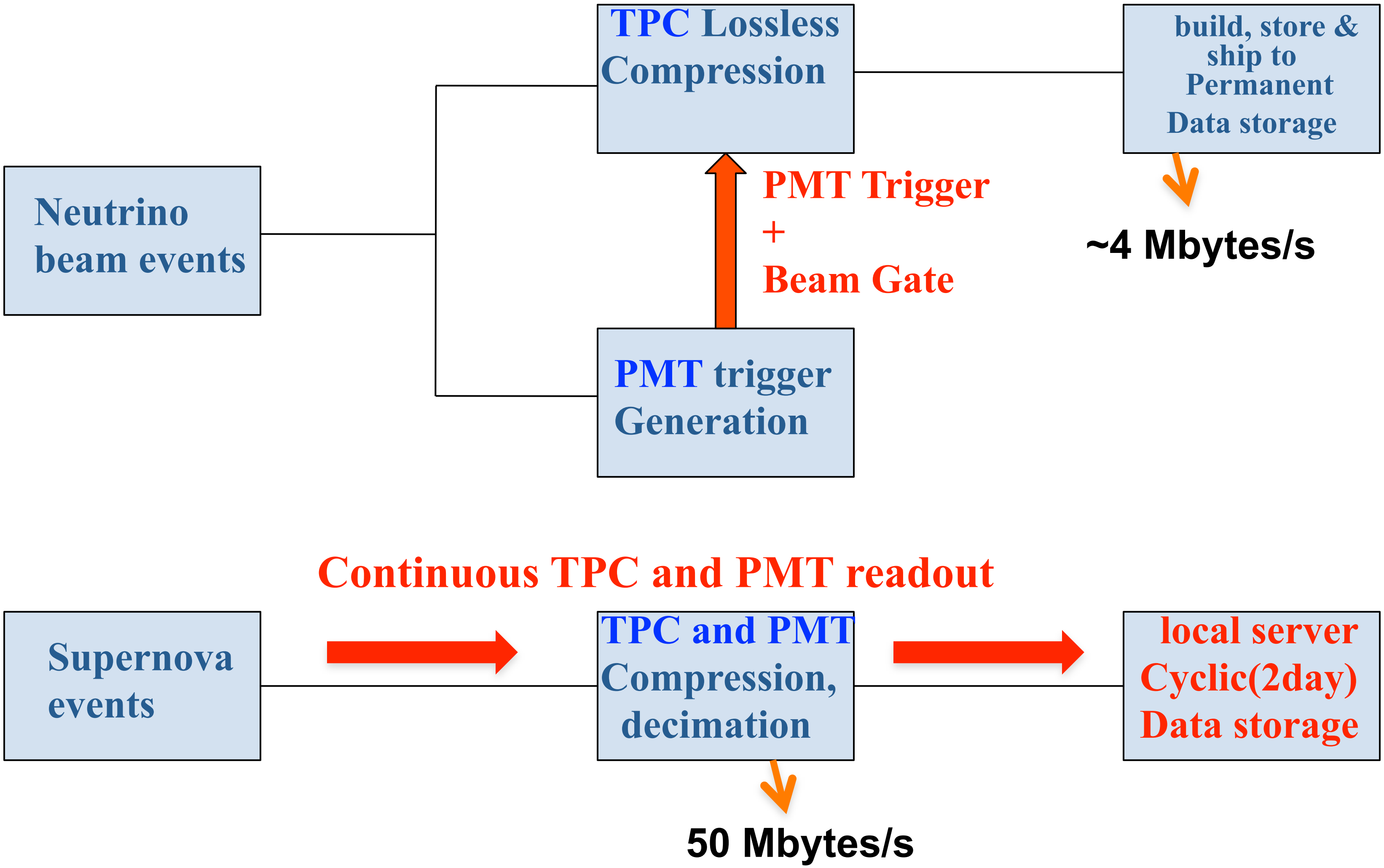
Simulation

- K+ bgd at LAr40 at 800 feet
  - 800' is not what we're doing at Lead, it would seem
  - At 4850 K+ identification still needs doing

- Nevertheless, K0->K+ bgd estimated at 800 feet from Sheffield and Yale groups separately predict a rate that is small compared to irreducible atmospheric neutrino rate w.o. an onerous fiducial volume cut: enabling a measurement of 90% c.l. partial lifetime shown 2 slides ago.

- This bgd detection should be confirmed in data.

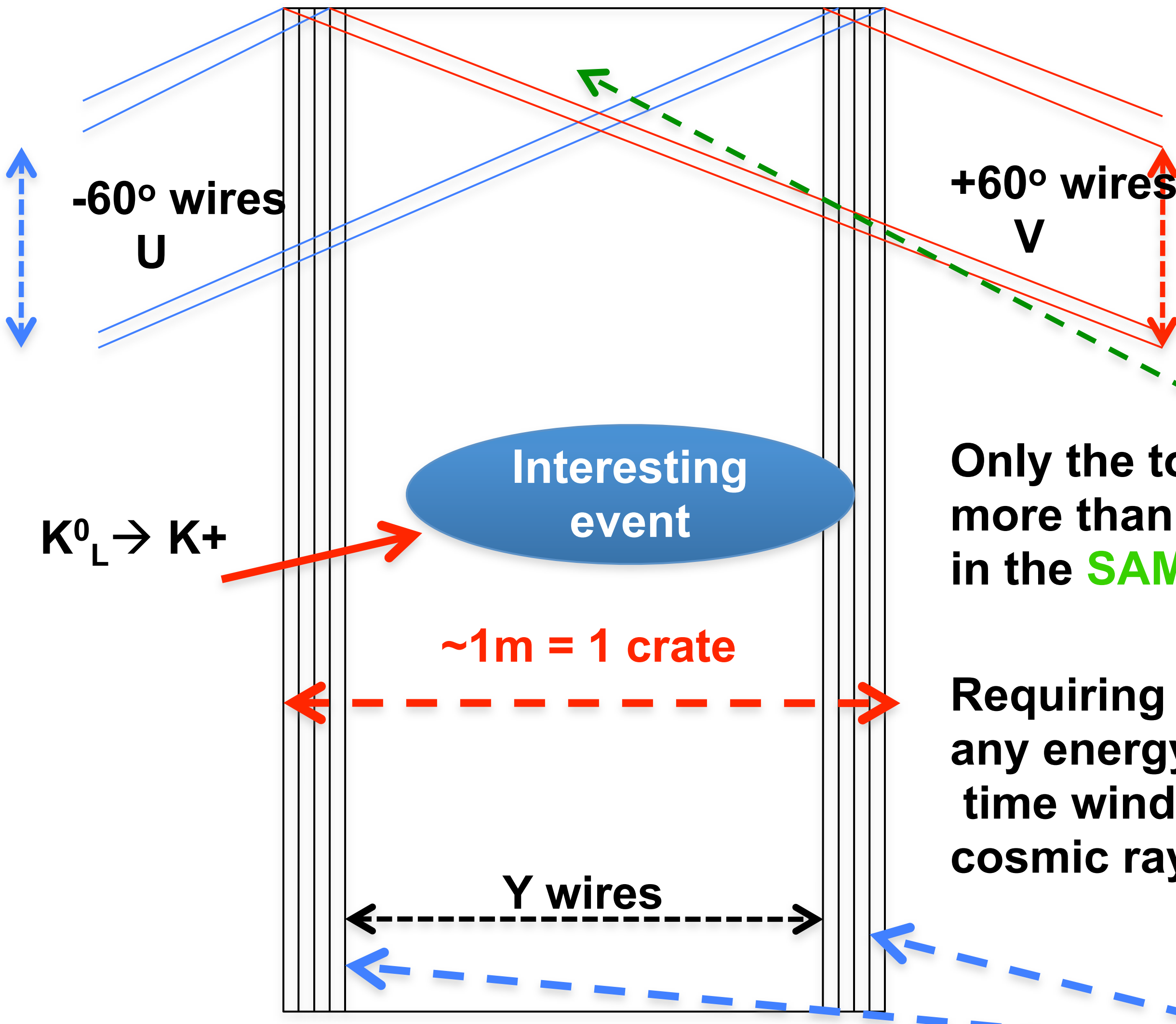
Digitizing Boards: Current MicroBooNE design



Use the SN data stream to select and study K background events

A TPC Trigger

From Above: Count and recognize unaccompanied K^+



Need a trigger selecting central energy deposition And No entering tracks

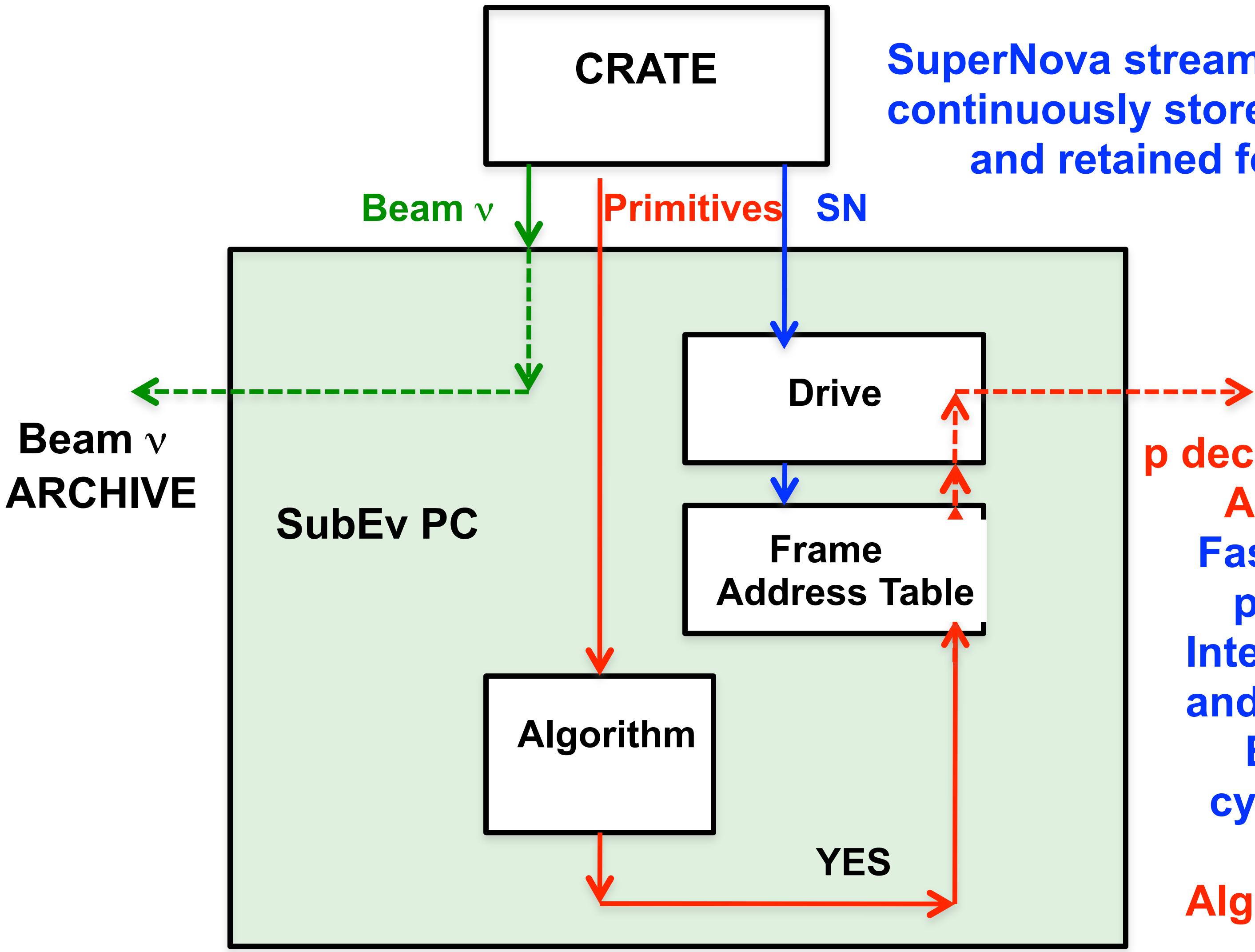
Each of 9 crates, reads Y,U and V wires over 1m

Only the top 30-60 cm are covered by more than one plane of wires, read out in the SAME crate.

Requiring only the Y PLANE to have any energy deposition within a drift time window will veto entering cosmic rays from above.

CR entering from sides: veto on energy deposition in L or R wires

Selection logic



SuperNova stream: All TPC, PMT Data continuously stored in circular buffer and retained for ~1-2 days.

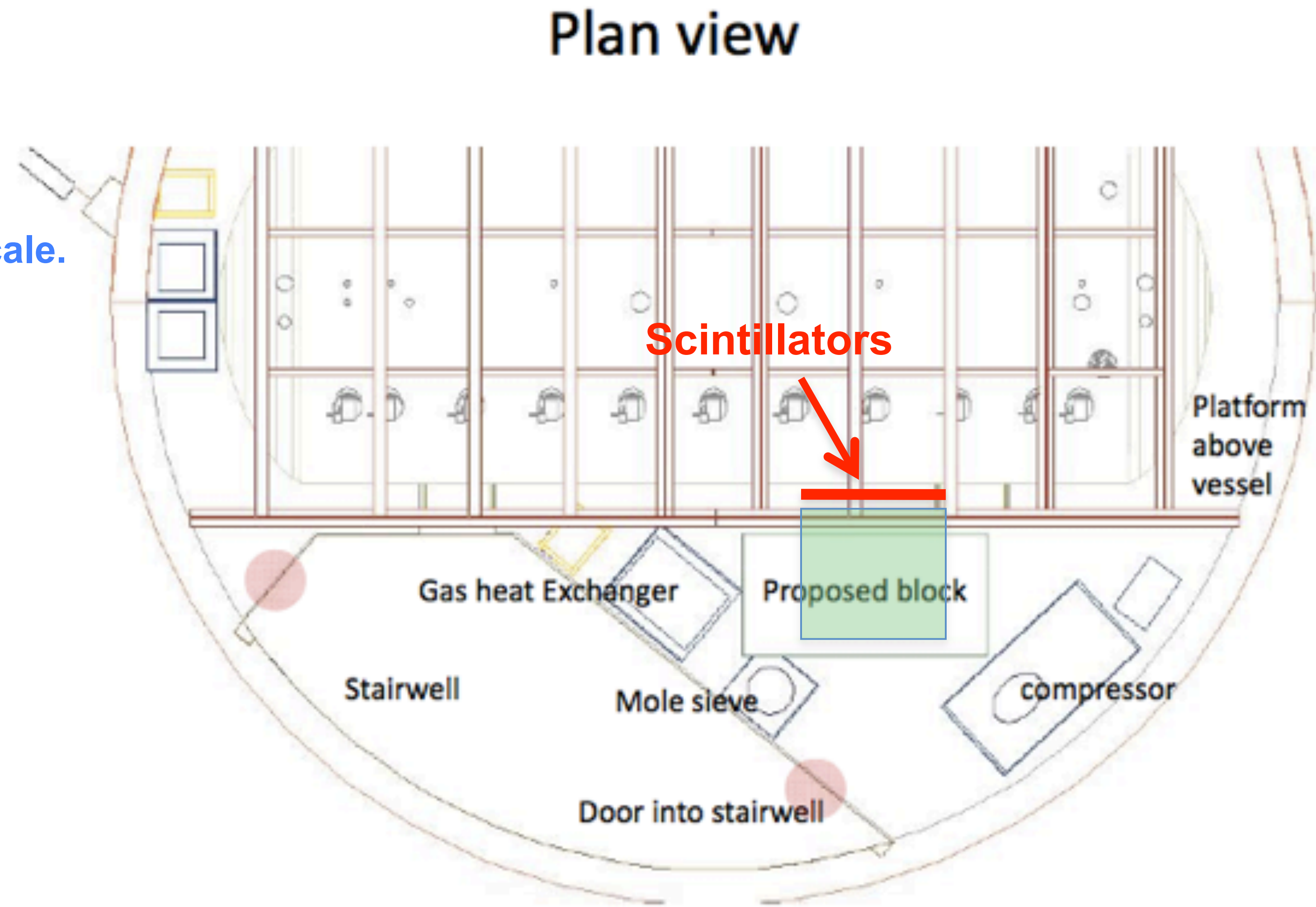
p decay background ARCHIVE

Fast algorithm using primitives selects Interesting candidates and intercepts them Before they are cycled out of buffer

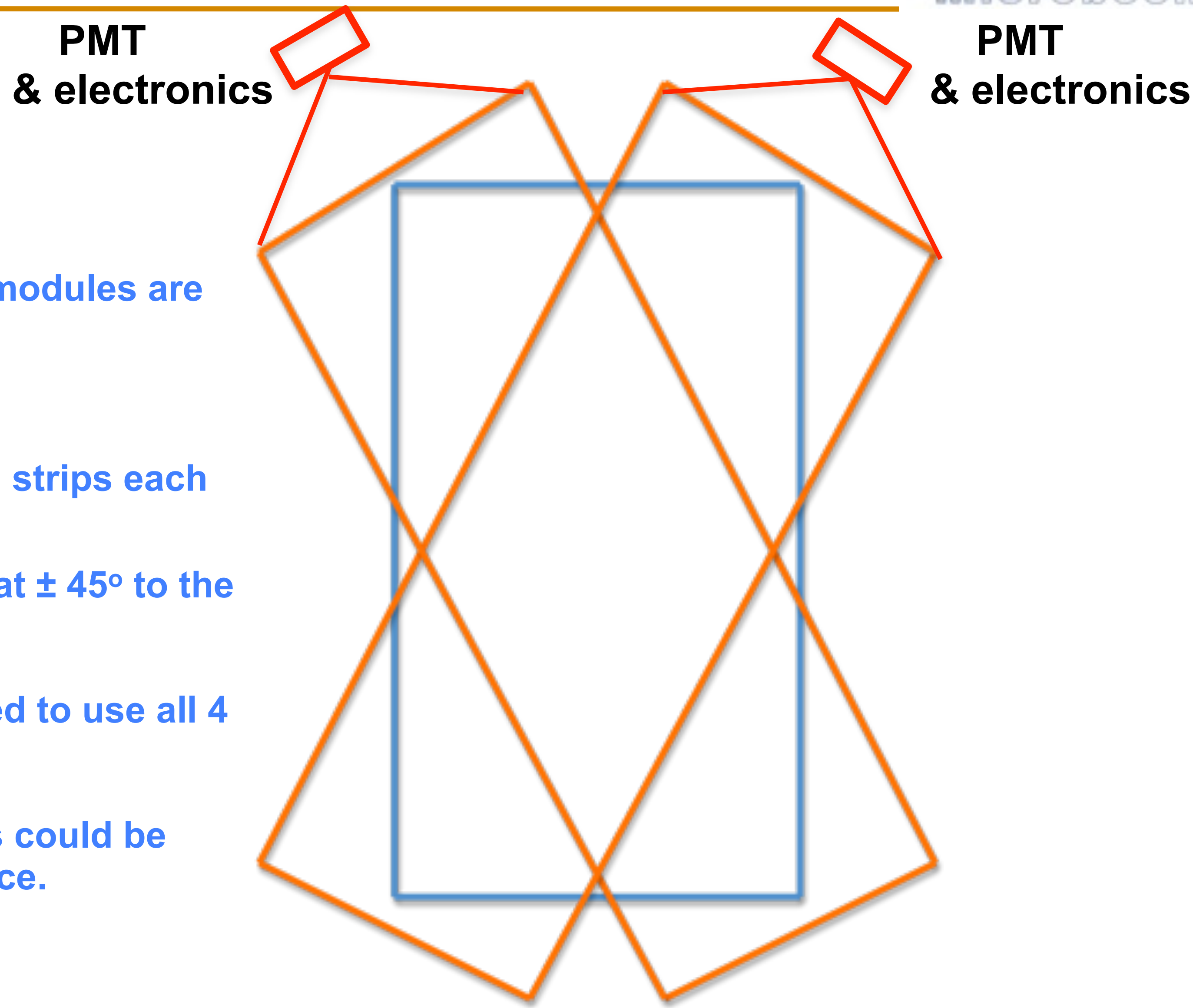
Algorithm execution time?

Sideways Cosmic ray studies: Granite block

Block NOT to scale.



Possible scintillator modules



Four Double Chooz modules are available to us.

Each module=
2 layers of 32 strips each

Two are shown each at ± 45º to the vertical.

They could be doubled to use all 4 modules.

Or the 1 or 2 modules could be installed on the far face.

Sideways Cosmic rays

Simulate LBNE rock with a Granite block

- **How often does an interacting cosmic muon give a K^0_L exiting sideways from block and entering the TPC?**
- **How often is it accompanied by charged particles?**
- **If by no charged particles but only by neutrons? Can we recognize it as background by detecting the neutrons in the scintillators?**
- **How often does the K^0_L charge exchange?**
- **How thick should the block be for optimal studies?**

1.5m-2m.

Start with simulation and then measure to substantiate it