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

microboone

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- *Columbia University*: L. Camilleri, R. Carr, G. Cheng, G. Karagiorgi, C. Mariani, B. Seligman, M. Shaevitz, B. Willis, B. Sippach, C. Chi
- *FermiLab*: B. Baller, D.Bogert, B. Carls, M.Cooke,H. Greenlee, C. James, H. Jostlein, H .Jostlein, M. Kirby, S. Lockwitz, B. Lundberg, S. Pordes, J. Raaf, G. Rameika, B. Rebel, R. Schmitt, D. Schmitz, J-Y. Wu, T.Yang, G. Zeller
- *Kansas State University*: T. Bolton, G. Horton-Smith, D. McKee
- *Los Alamos Lab*: G. Garvey, J. Gonzales, B. Louis, C. Mauger, G. Mills, Z. Pavlovic, R. Van de Water, H. White
- *Massachusetts Institute of Technology*: W. Barletta, L. Bugel, J. Conrad, C. Ignarra, B. Jones, T. Katori, T. Smidt, A. Prakash
- *Michigan State University*: C. Bromberg, D. Edmunds
- *New Mexico State University*: V. Papavassiliou, S. Pate
- *Princeton University*: K. McDonald, C. Lu, Q. He
- *St. Marys*: P. Nienaber
- *Syracuse University*: J. Asaadi, M. Soderberg
- *University of Cincinnati*: R. Grosso, R. Johnson, B. Littlejohn
- *University of Texas at Austin*: S. Kopp, K. Lang, R. Mehdiyev
- *Laboratory for HighEnergy Physics, University of Bern, Switzerland*: A. Ereditato, I. Kreslo, M. Weber, C-R vonRohr, T .Strauss
- *Istituto Nazionale di Fisica Nucleare,Italy*: O. Palomara, F. Cavanna
- *Yale University*: C. Brasco, E. Church, B. T. Fleming, R. Guenette, K. Partyka, J. Spitz, A. Szelc, E. Klein

16 institutions
91 collaborators

Spokespersons: Bonnie Fleming, Sam Zeller

Motivation

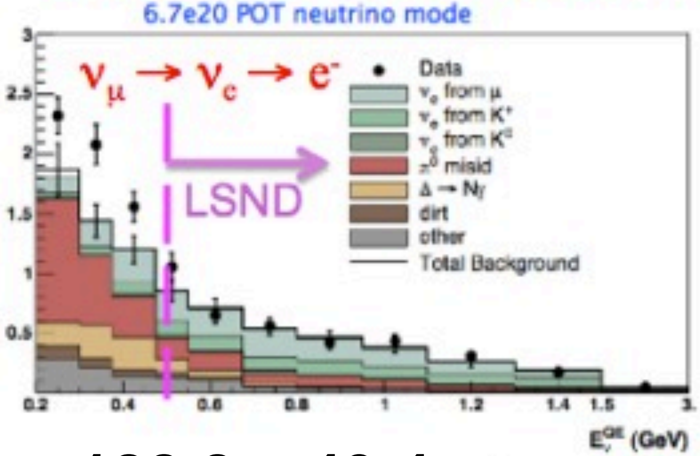
Spring, 2014!

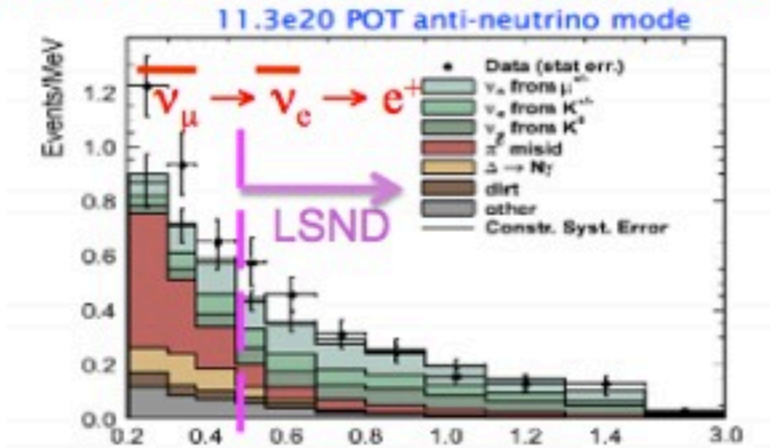
- Physics
  - MiniBooNE low energy excess
  - Cross Sections
  - Supernova neutrinos
- R&D
  - Long drift length (2.5m)
  - DAQ: Cold front-end electronics (up through shaper)
  - DAQ: Continuous readout with offline SN trigger
  - UV Laser
  - Reconstruction/pID: LArSoft
  - LAr fill w.o. evacuation

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

low E mBooNE excess

e/γ identification in MiniBooNE based on Cerenkov Rings



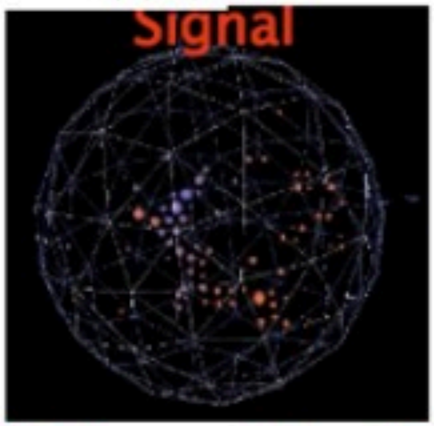


128.8 ± 43.4
0.2<E<0.475 GeV

57.9 ± 21.6
0.2<E<0.475 GeV

$\nu_e X \rightarrow e + \ldots$

Single fuzzy ring



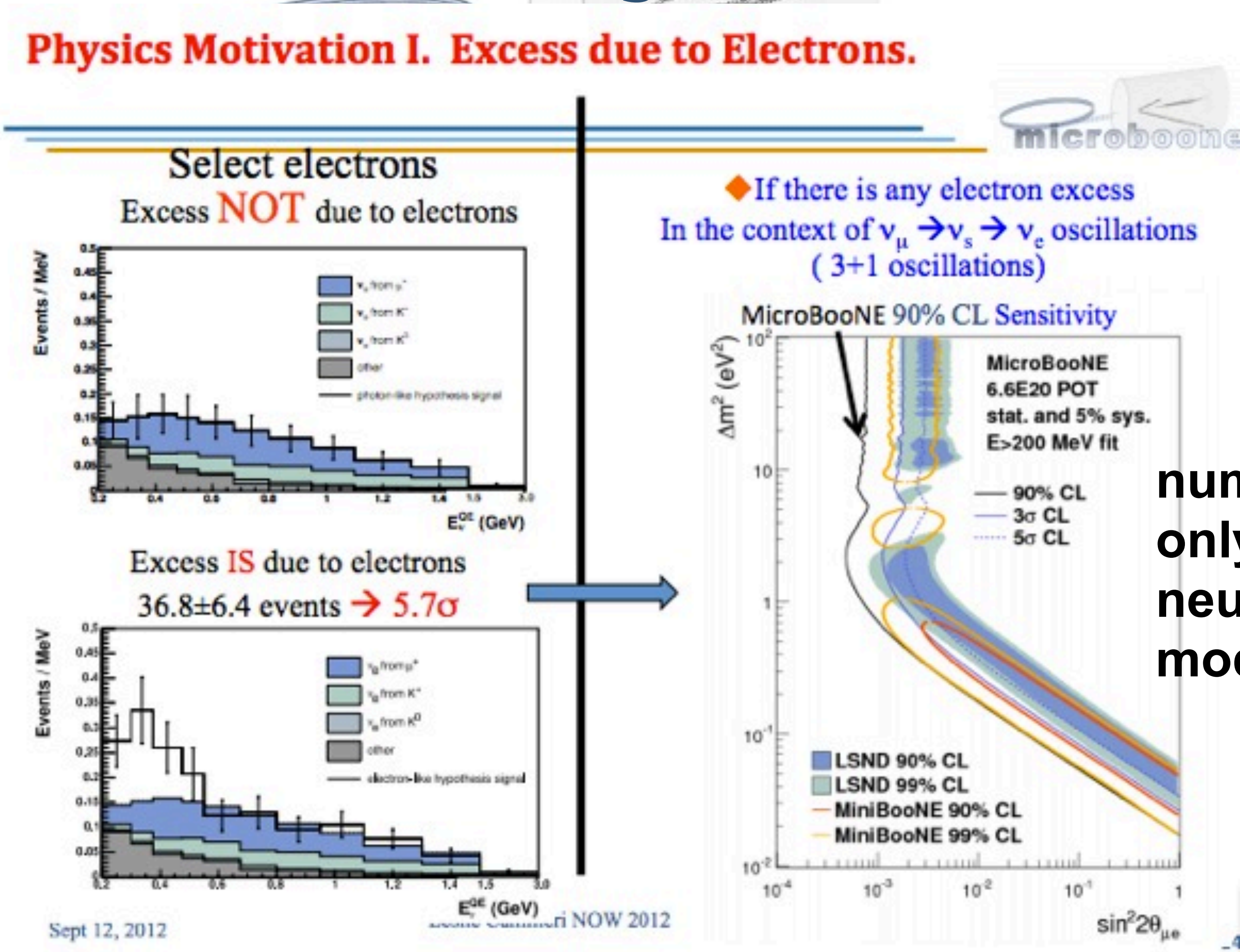
For a converting γ the two rings from e^+ and e^- overlap.

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

From the MiniBooNE presentation at Neutrino 2012

240.3 ± 62.9 (3.8sigma)
over 0.2<E<1.250 GeV, joint
http://arxiv.org/pdf/1207.4809.pdf

Excess due to e or gamma?

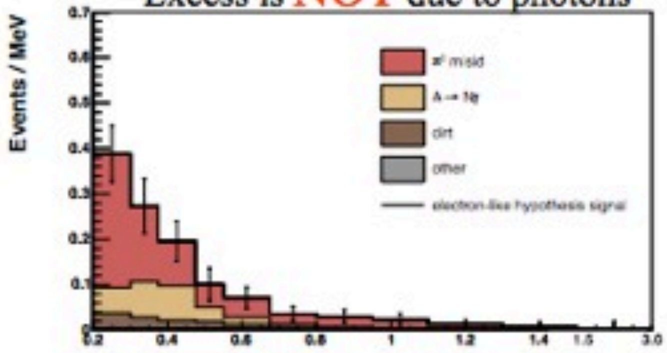


numu only. 2 neutrino model

Physics Motivation. Excess due to: Photons.

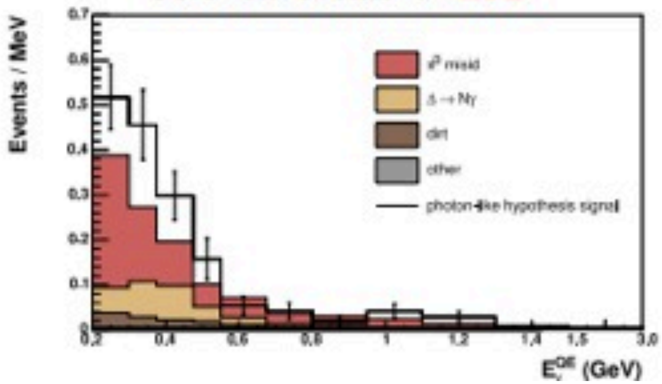
Select photons

Excess is NOT due to photons



Excess IS due to photons

36.8±8.9 events → 4.1σ



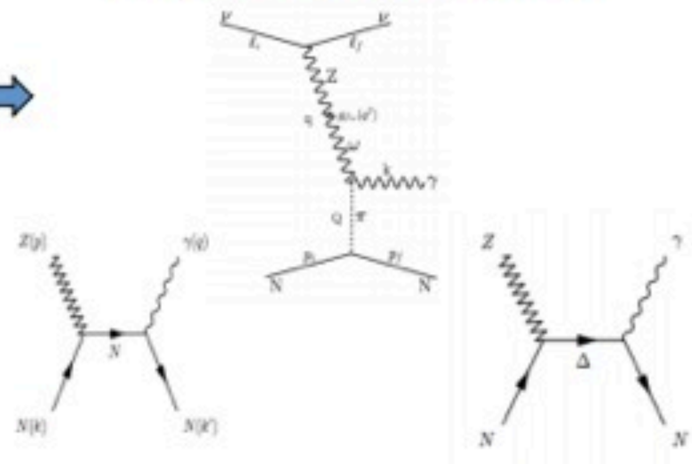
- Background: γ or π^0

OR

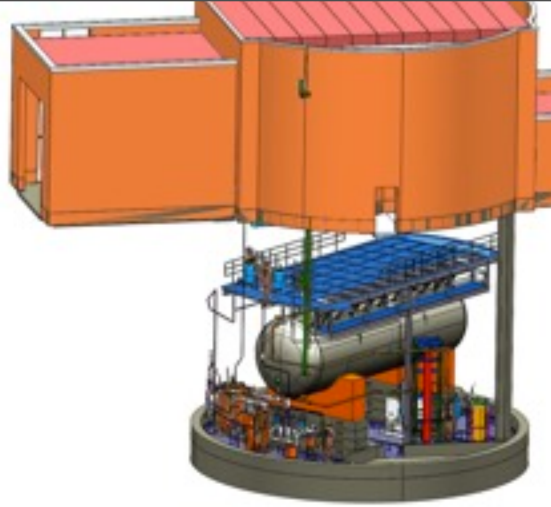
- Radiative ν interaction

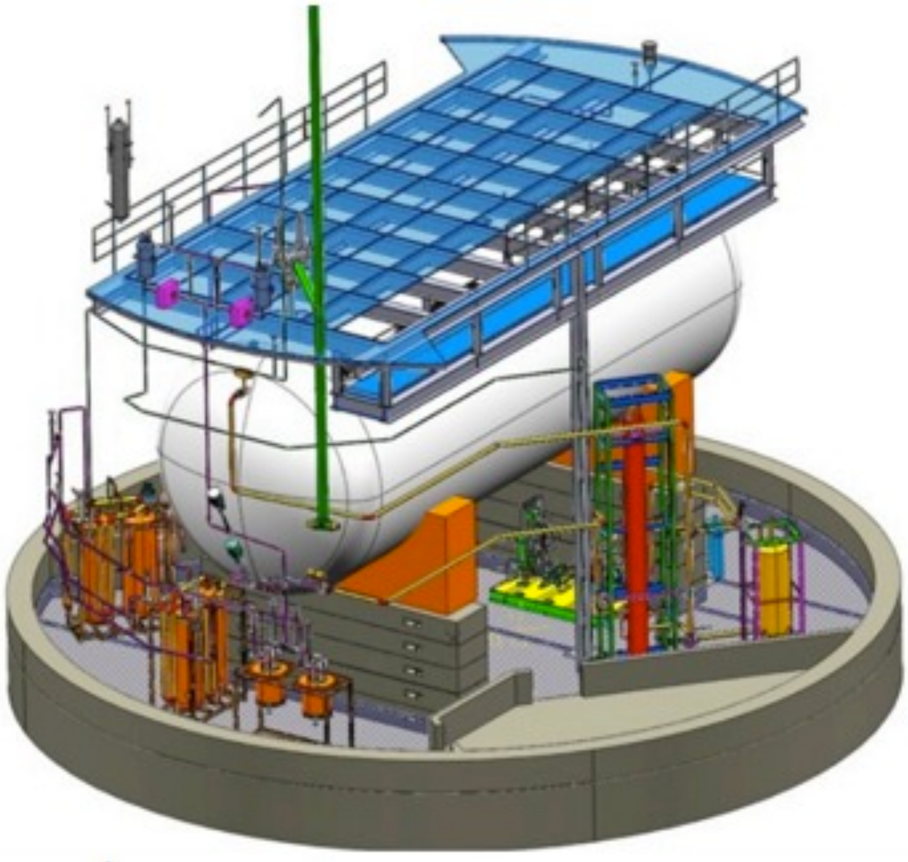
Examples:

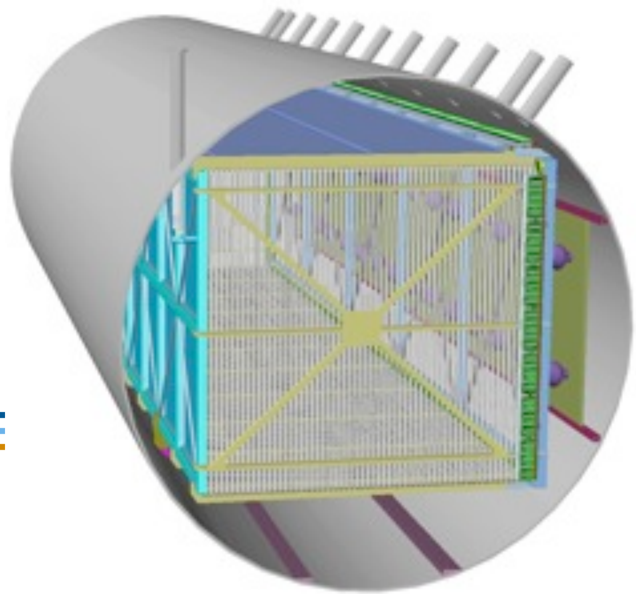
- R. Hill arXiv: 0905.0291
- Jenkins et al arXiv:0906.0984
- Serot et al arXiv: 1011.5913



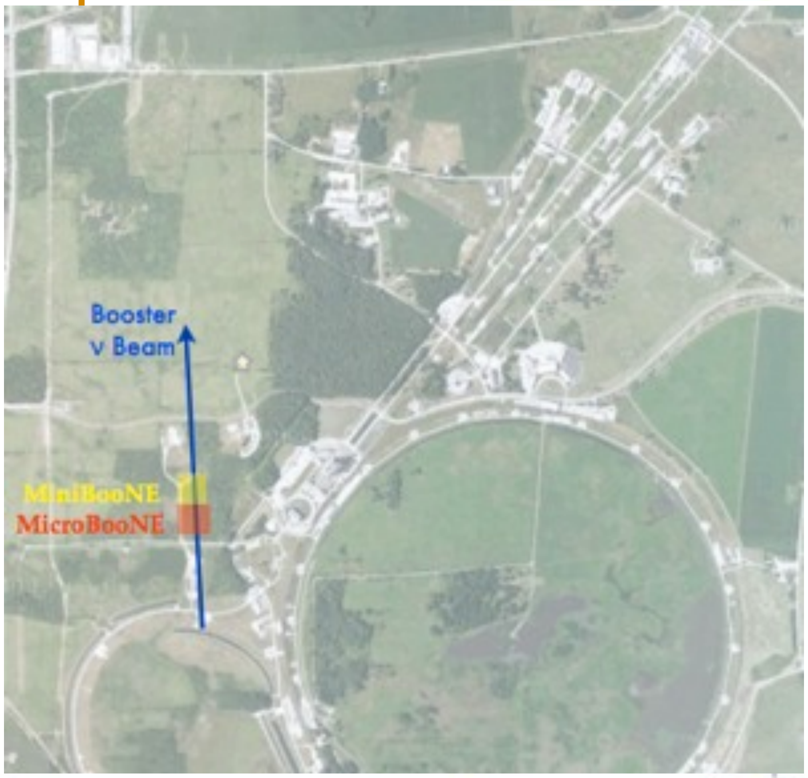
Site Construction



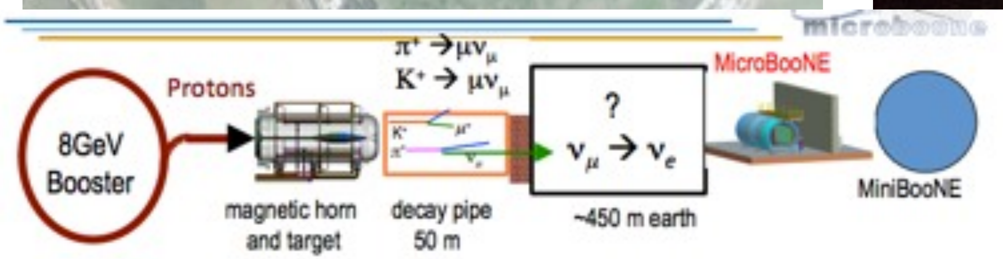





June, 2012


Booster
ν Beam
MiniBooNE
MicroBooNE


September, 2012


8GeV Booster
Protons
magnetic horn and target
$\pi^+ \rightarrow \mu\nu_\mu$
$K^+ \rightarrow \mu\nu_\mu$
decay pipe 50 m
?
$\nu_\mu \rightarrow \nu_e$
~450 m earth
MicroBooNE
MiniBooNE

Detector Construction

Field cage tubes at Lab F.

TPC at D0 Assembly Building.

MicroBooNE properties

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

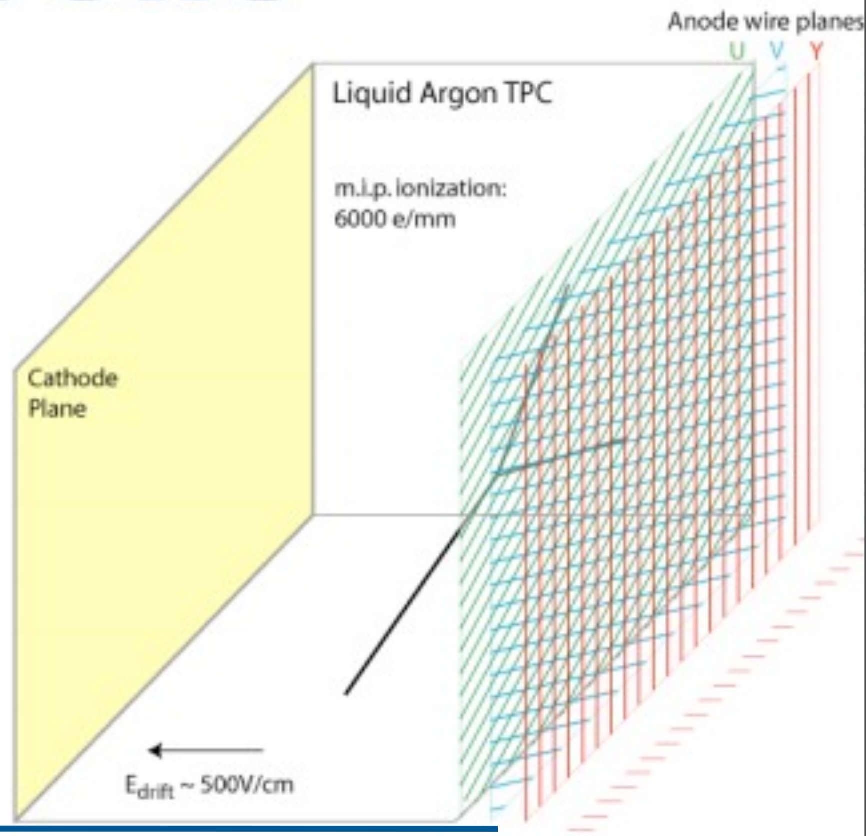
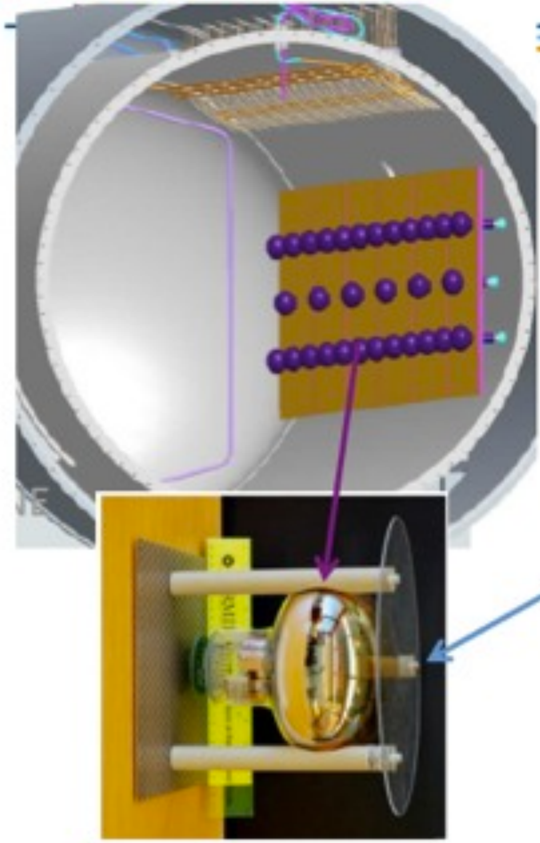


Image of PMTs in TPC

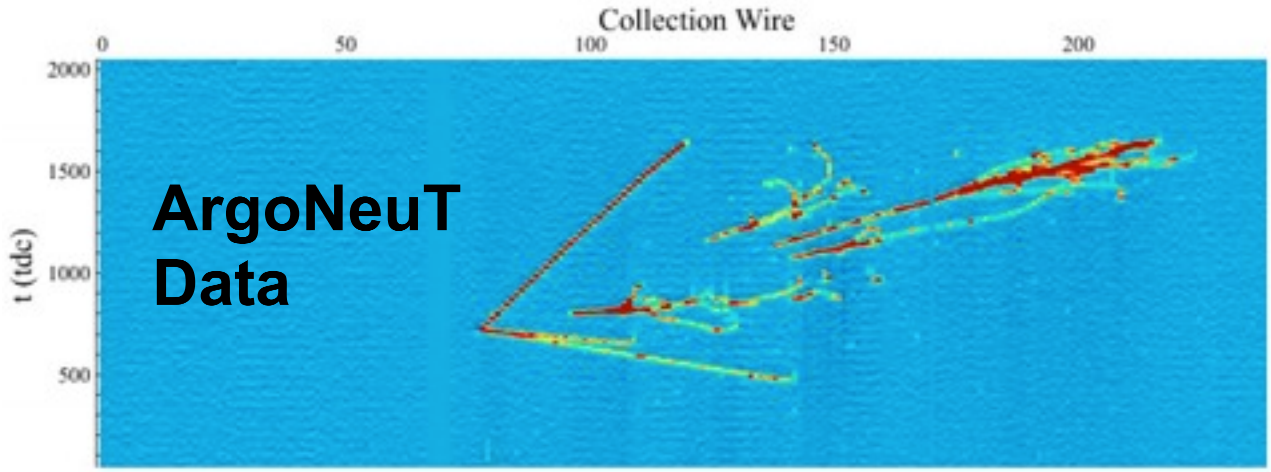
Photodetectors



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**



ArgoNeuT Data

2 pi0s !

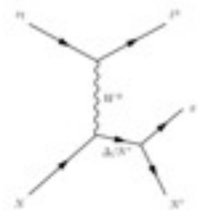
Note the high (x2) ionization early in each gamma

Cross Sections

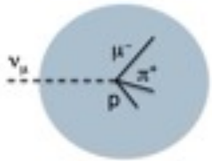
Traditional accounting

signature	NuWro (Eric/Josh)	NUANCE**(Sam/Josh)	GENIE* (Jennette & others
CCQE	74919	74040	7776
NC elastic	28582	24280	2955
CC res p2ppi+	27865	20300	(all CCRes) 4607
CC res n2ppi0	7976	7610	
CC res n2npi+	7871	7420	
NC res p2ppi0	5825	3620	(all NCRes) 17484
NC res p2npi+	3446	2230	
NC res n2npi0	4478	4540	
NC res n2ppi-	3288	2990	
CC DIS	4933	1600	16919
NC DIS	2886	570	5592
NC COH	752	1160	378
CC COH	489	1790	502
Total of Above	173313	151000	194266
Grand Total	173313	155000	[illegible]

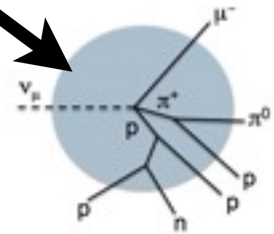
Very Preliminary



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



From here to here



signature	NuWro (Eric/Josh)	NUANCE** (R&C/Sam/JS)	GENIE** (Jennette & others)
1mu0p0pi	3970	7	2110
1mu1p0pi	68832	20210	59533
1muge2p0pi	8396	59044	37230
1mu0p1pi	9410	1220	6909
1mu1p1pi	26658	5324	22228
1muge2p1pi	700	18878	18548
1mu0pge2pi	1574	420	775
1mu1pge2pi	5842	2075	2543
NC	49537	(incl "others") 49200	24000
Total	173313	155000	194000

ArgoNeuT will lead the way here.

FS particle accounting

Supernovae

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

F. Cavana: 20 +/- 10 evts

in a galactic supernova

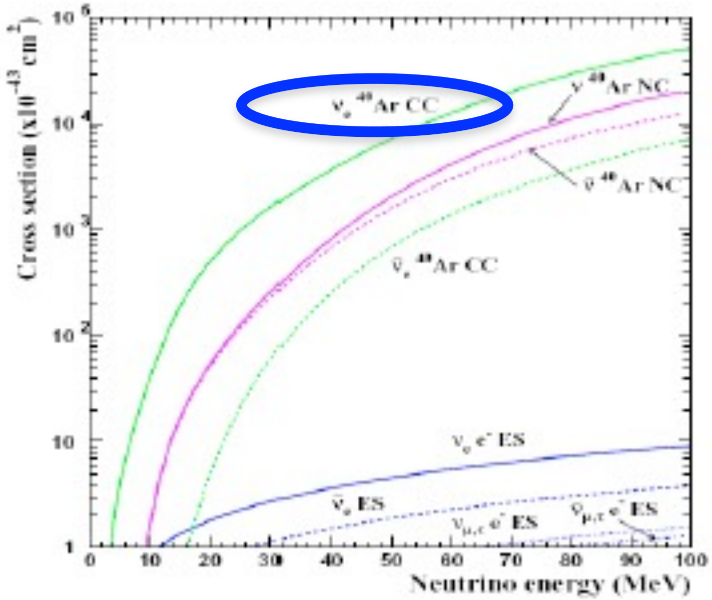


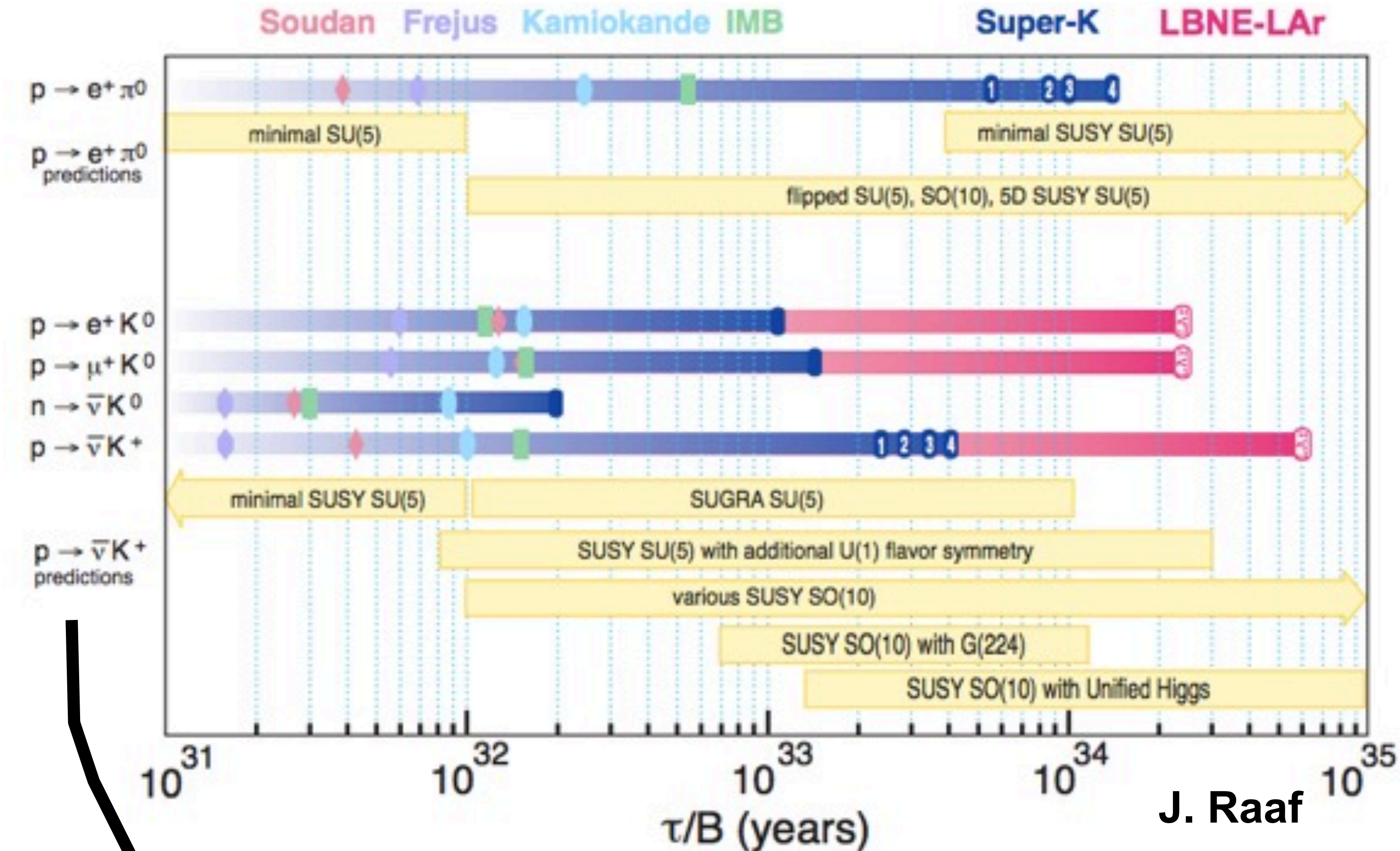
Figure 3: Neutrino cross sections relevant to the supernovae detection with a l Argon TPC detector.

Kolbe, Langanke, Martinez-Pinedo

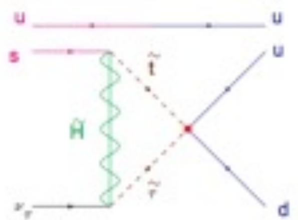
R&D

- 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)

Nucleon decay background

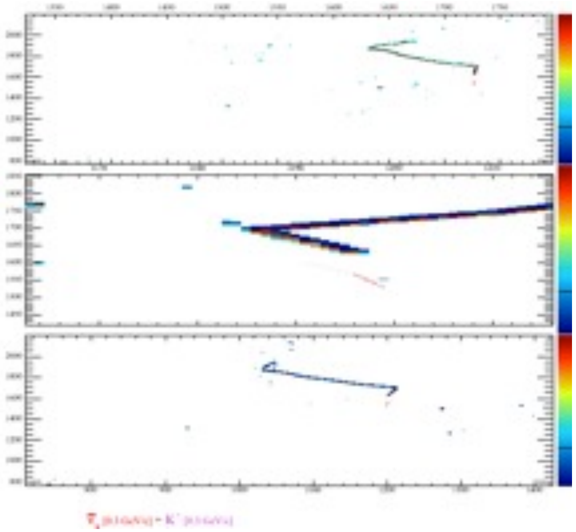


J. Raaf

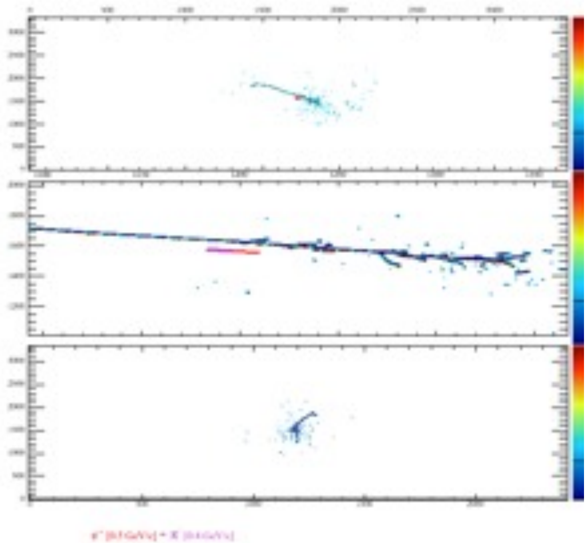


nucleon decay in LBNE-like detector

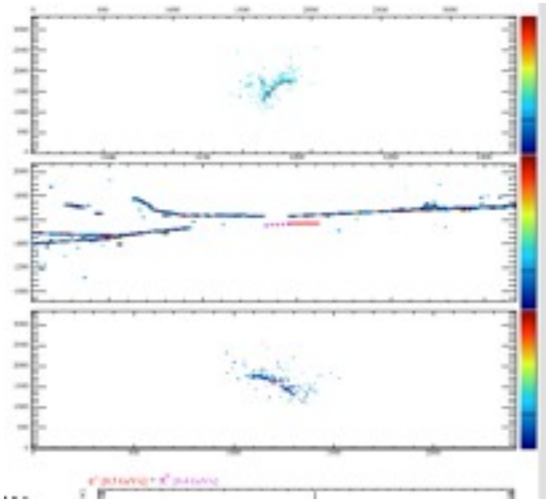
A LAr detector that hopes to compete with HyperK must demonstrate great efficiency at detecting many modes: including evts w FSI-absorbed pions, via the de-excitation gammas. e.g. Along with demonstrating heightened bgd rejection.



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.

What and How to explore this at uBooNE?

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 Chg Exchg K+.

- Have started study with Truth Info. Extend to Reconstructed variables.

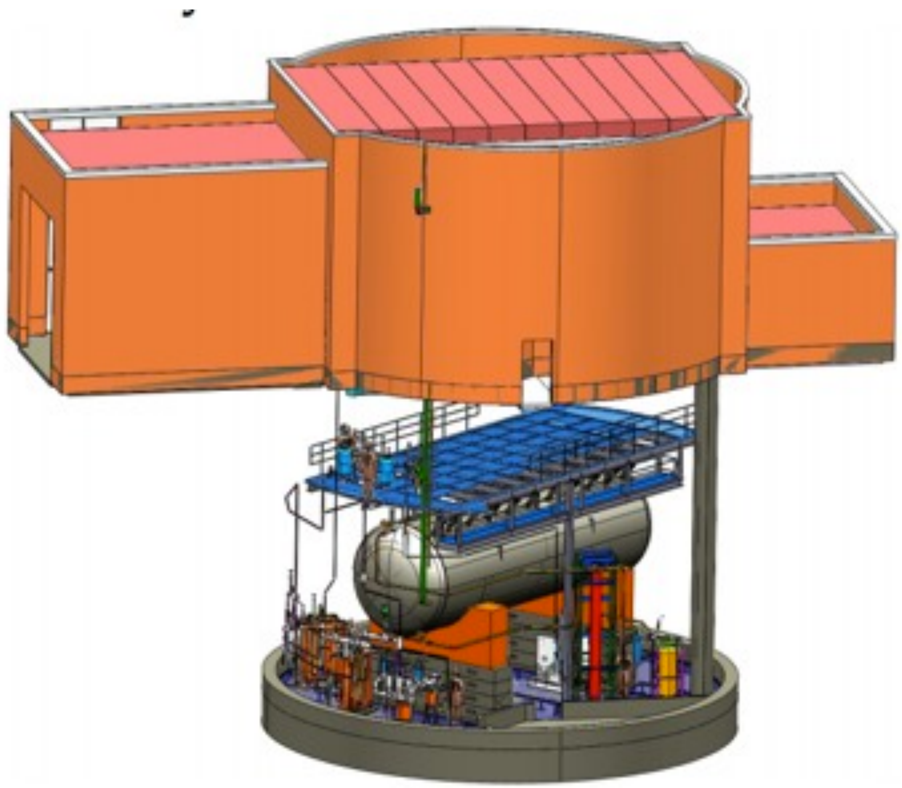
With a development of a TPC based trigger.

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.

(Under conditions that would NOT harm the MicroBooNE program)

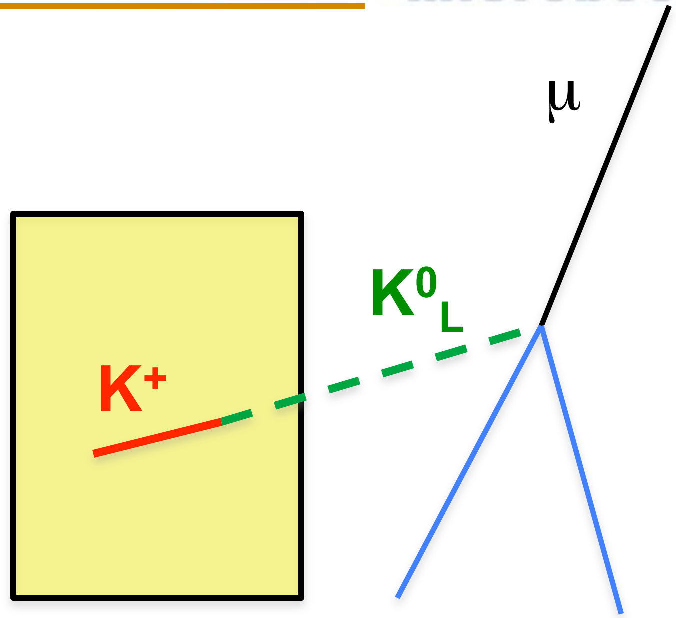
Simulation Studies



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 ?

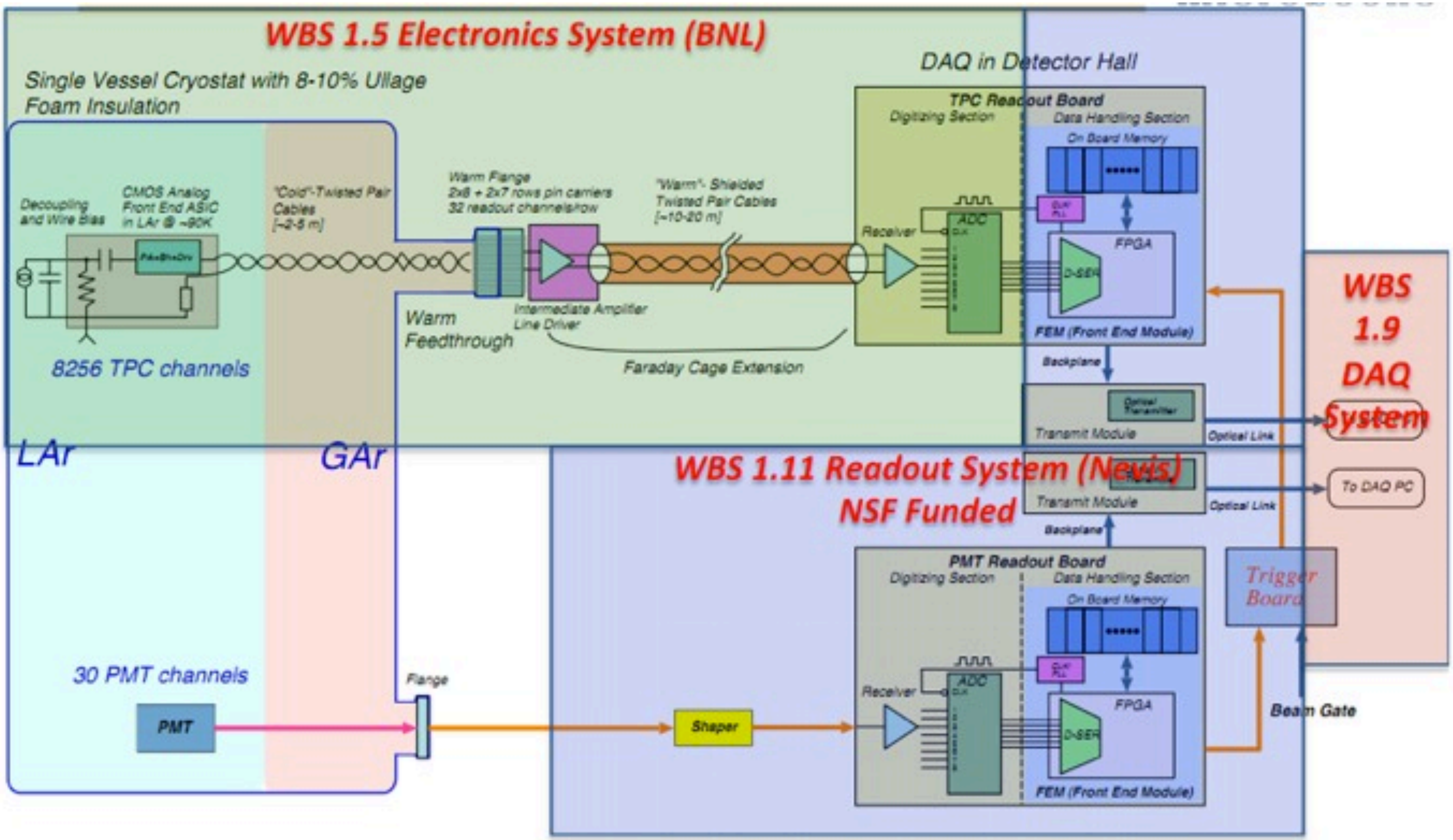
How do we produce them and detect them?

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

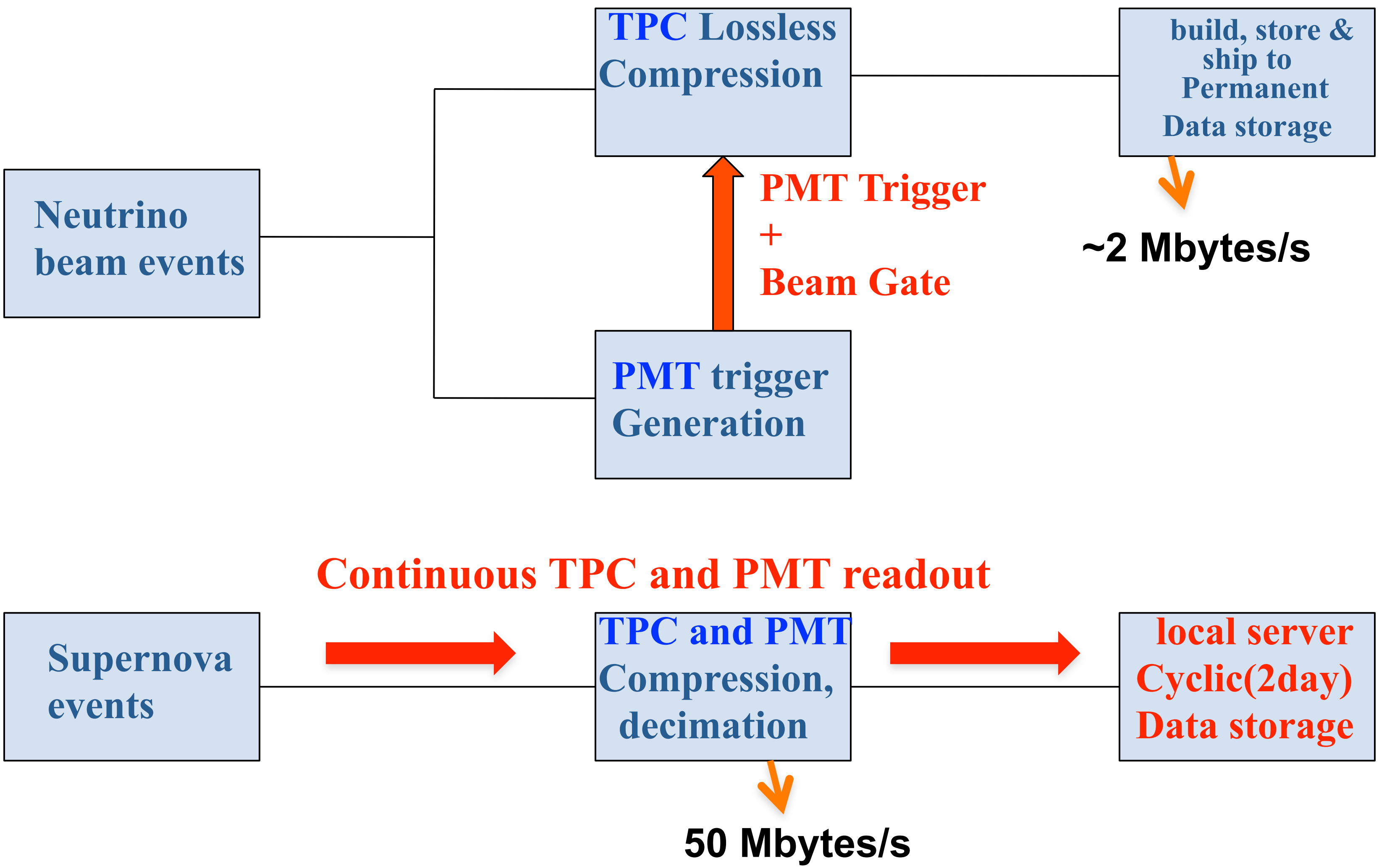
A lot of cosmic muons but few K's.→ **Need a trigger:**

Unaccompanied energy deposition in center of detector

Electronics+Readout+DAQ



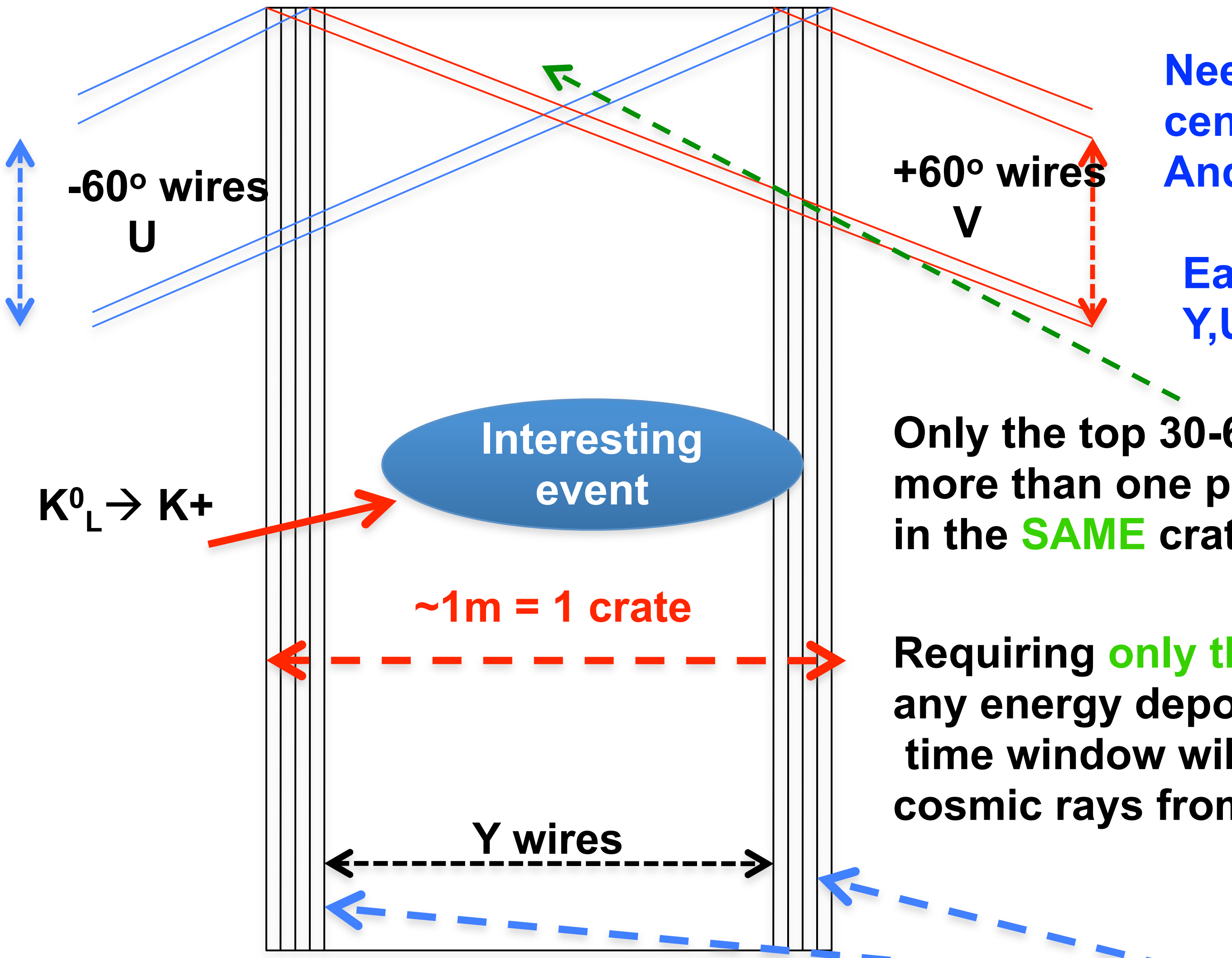
Digitizing Boards: Current MicroBooNE design



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

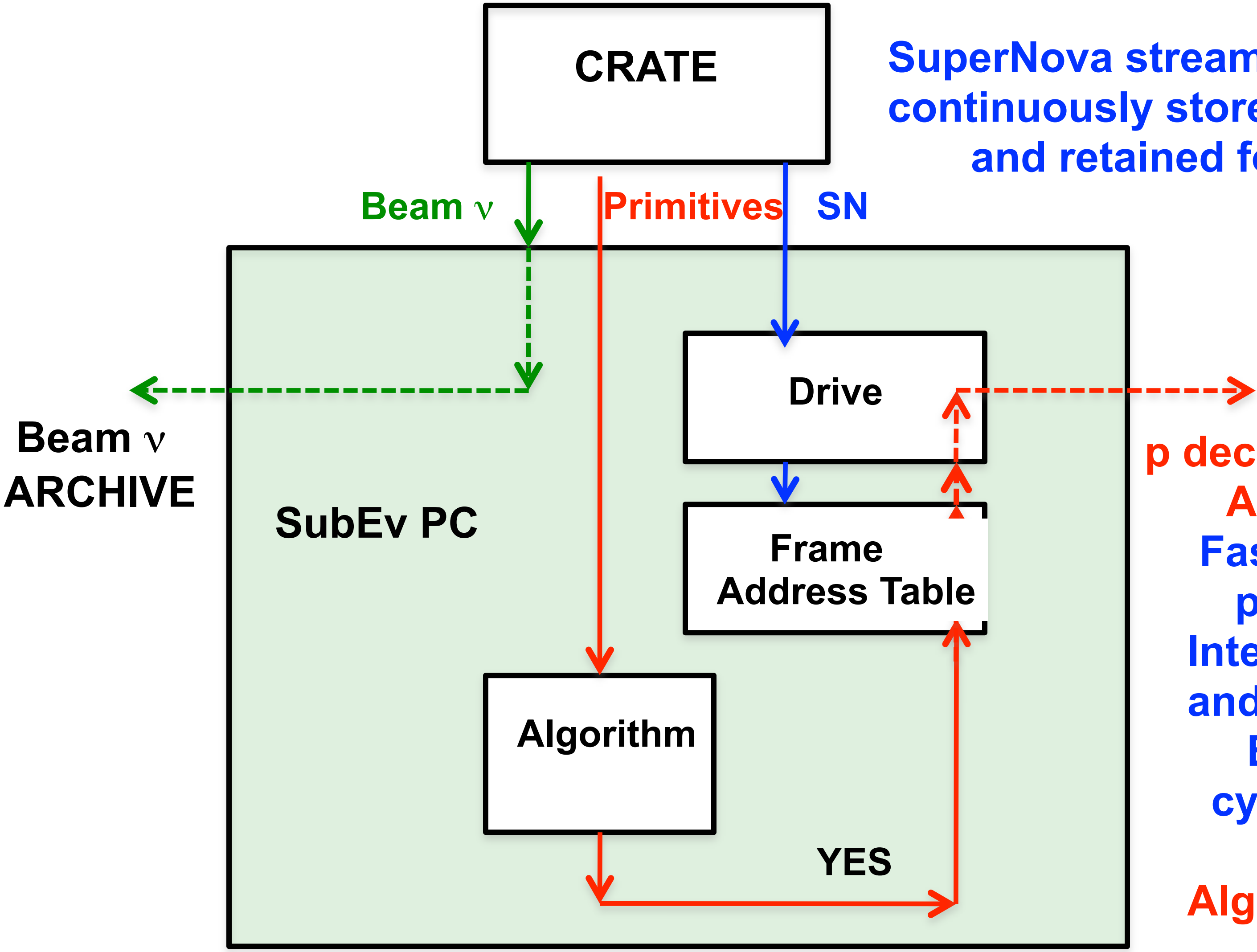
Each of 9 crates, reads Y,U and V wires over 1m

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?

Background Studies Using a Granite Block

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?

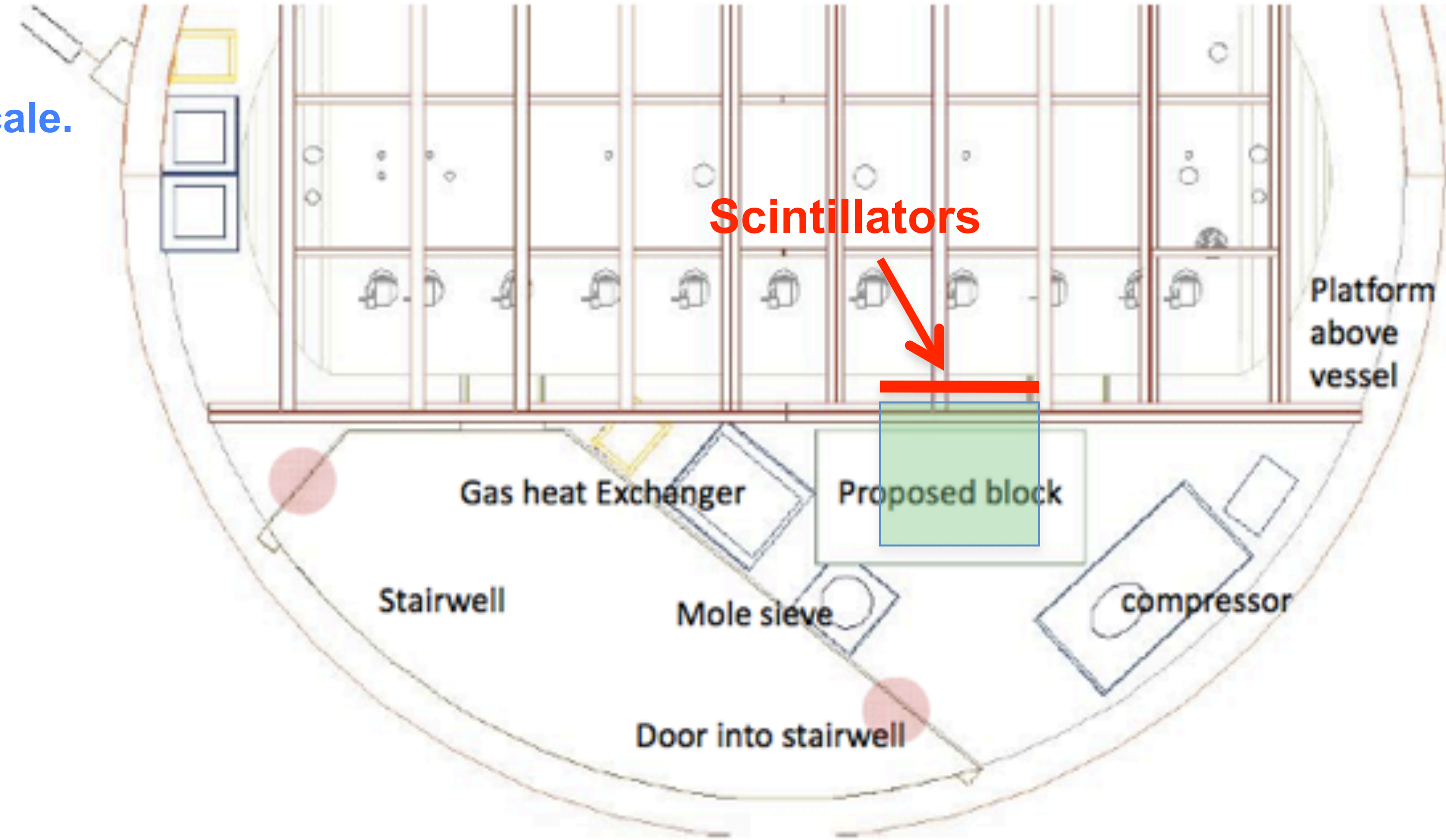
1.5m-2m.

Start with simulation and then measure to substantiate it

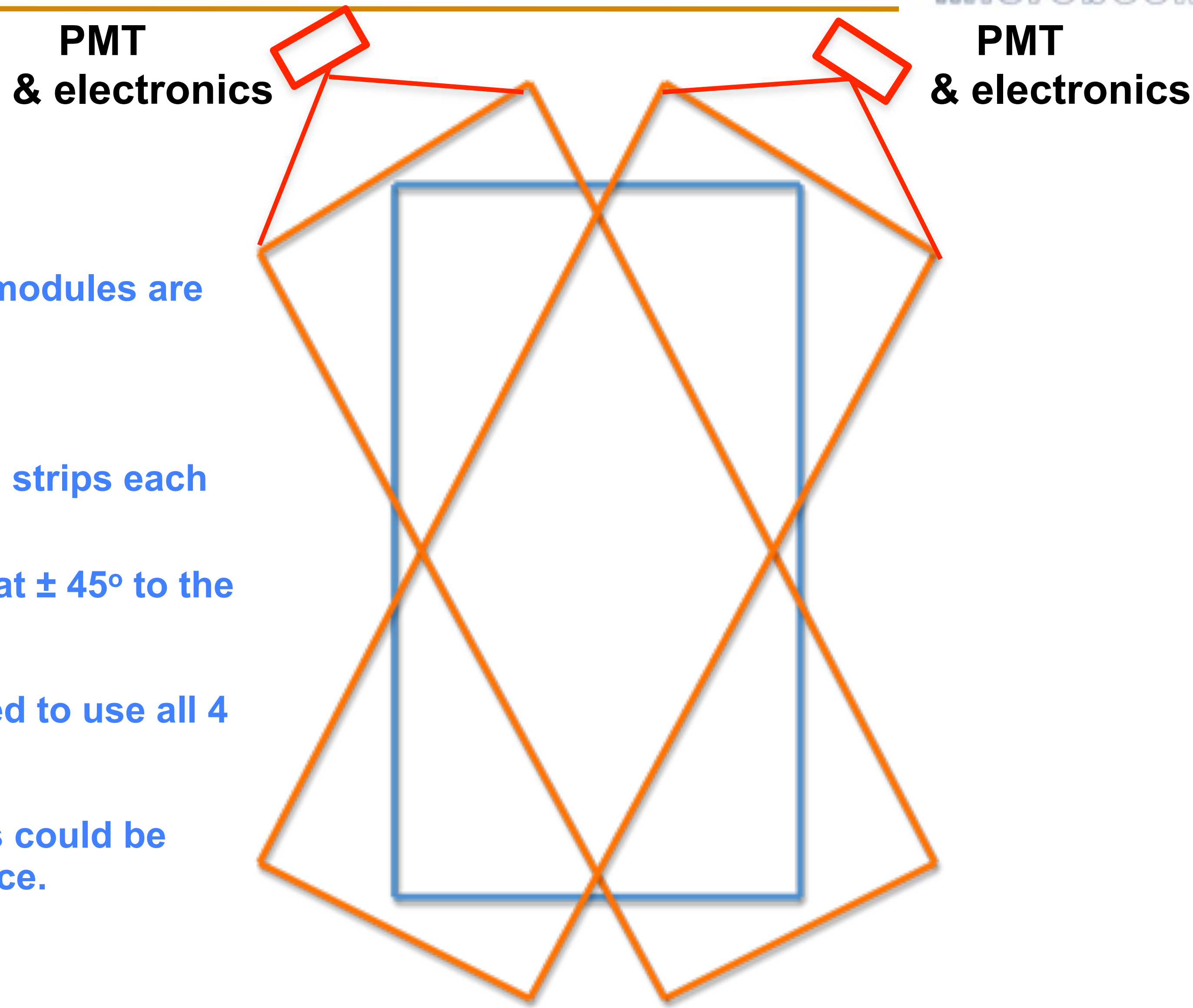
Sideways Cosmic ray studies: Granite block

Plan view

Block NOT to scale.



Possible scintillator modules



Four Double Chooz modules are available to us.

Each module= 2 layers of 32 strips each

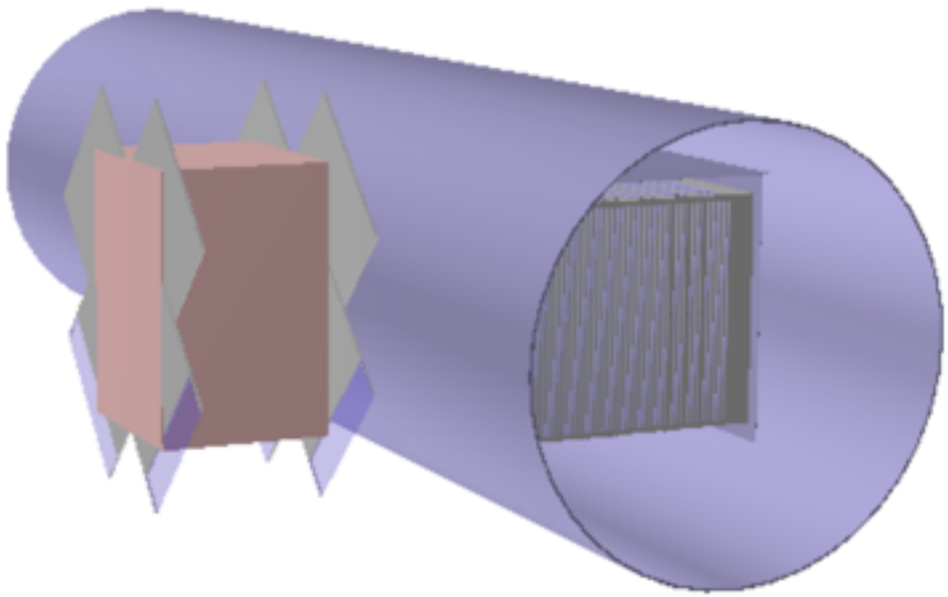
Two are shown each at ± 45º to the vertical.

They could be doubled to use all 4 modules.

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

Preliminary simulations

- Nevis working on studies of block and scintillators in LArSoft.
- Energy deposition in scintillators almost done.
- 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.

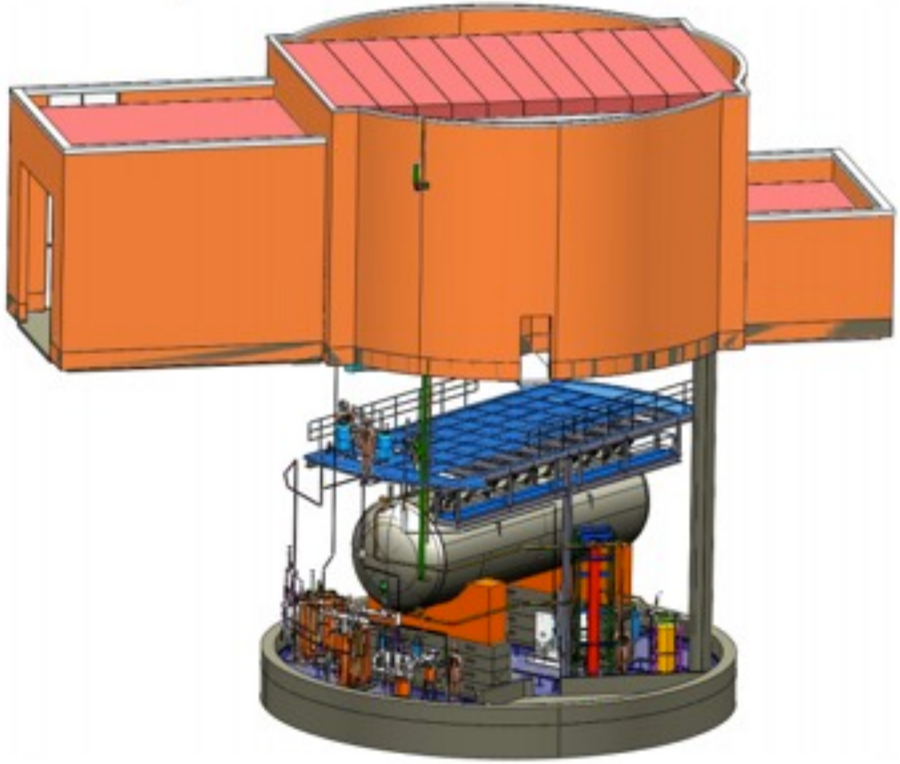
Neutron detection in scintillators

- 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

Conclusion

Stay tuned for exciting times imminently ahead for MicroBooNE.

Backup Slides



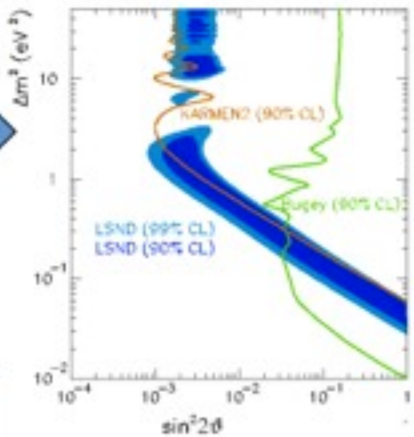
LSND

Interesting effect!

LSND observed a (~3.8σ) excess of $\overline{\nu}_e$ events in a pure $\overline{\nu}_\mu$ beam

L/E → High $\Delta m^2 \sim 1$ eV^2

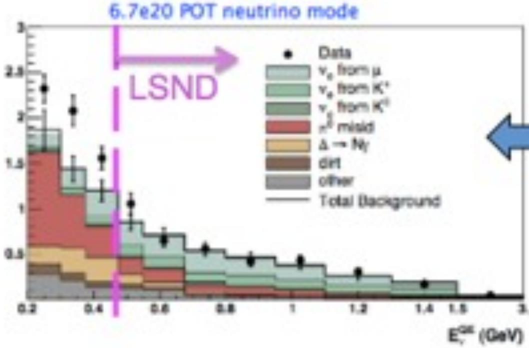
Can only be accomodated by a new STERILE neutrino



MiniBooNE

MiniBooNE Booster Neutrino Beam at Fermilab

6.7e20 POT neutrino mode



Interesting effect

But a different one!

Excess but mostly at **Lower** energy than expected from LSND:

MicroBooNE

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

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

"Deep" Showers – Maximum Thickness