neutron-antineutron oscillations in a LAr TPC

Ed Kearns

Boston University
& Fermilab

LAr R&D Meeting
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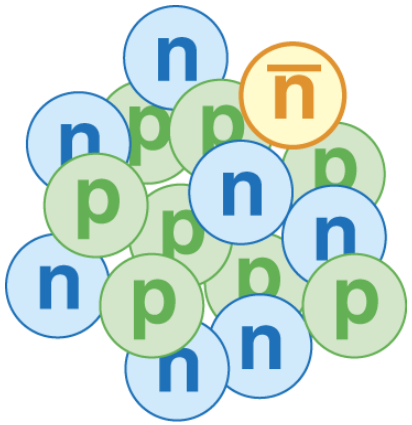
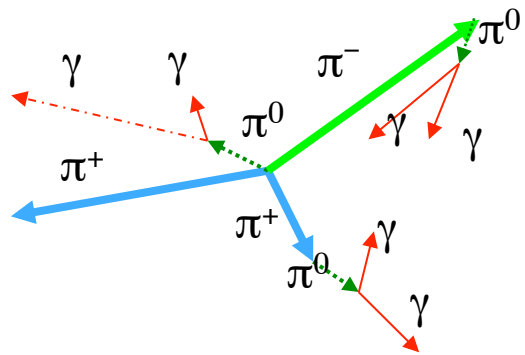
Signature





$\bar{n}+p$		$\bar{n}+n$	
$\pi^+\pi^0$	1%	$\pi^+\pi^-$	2%
$\pi^+2\pi^0$	8%	$2\pi^0$	1.5%
$\pi^+3\pi^0$	10%	$\pi^+\pi^-\pi^0$	6.5%
$2\pi^+\pi^-\pi^0$	22%	$\pi^+\pi^-2\pi^0$	11%
$2\pi^+\pi^-2\pi^0$	36%	$\pi^+\pi^-3\pi^0$	28%
$2\pi^+\pi^-2\omega$	16%	$2\pi^+2\pi^-$	7%
$3\pi^+2\pi^-\pi^0$	7%	$2\pi^+2\pi^-\pi^0$	24%
		$\pi^+\pi^-\omega$	10%
		$2\pi^+2\pi^-2\pi^0$	10%

- Created antineutron annihilates with nearby nucleon
- About 2x nucleon mass is released as pions
  net momentum near zero (< p_{fermi})
- Final states may be predicted from annihilation data
- Pion propagation in nucleus must be modeled
- Atmospheric neutrino background rejection:
  no CC muons or electrons
  no energetic recoil protons or neutrons

Summary of Results

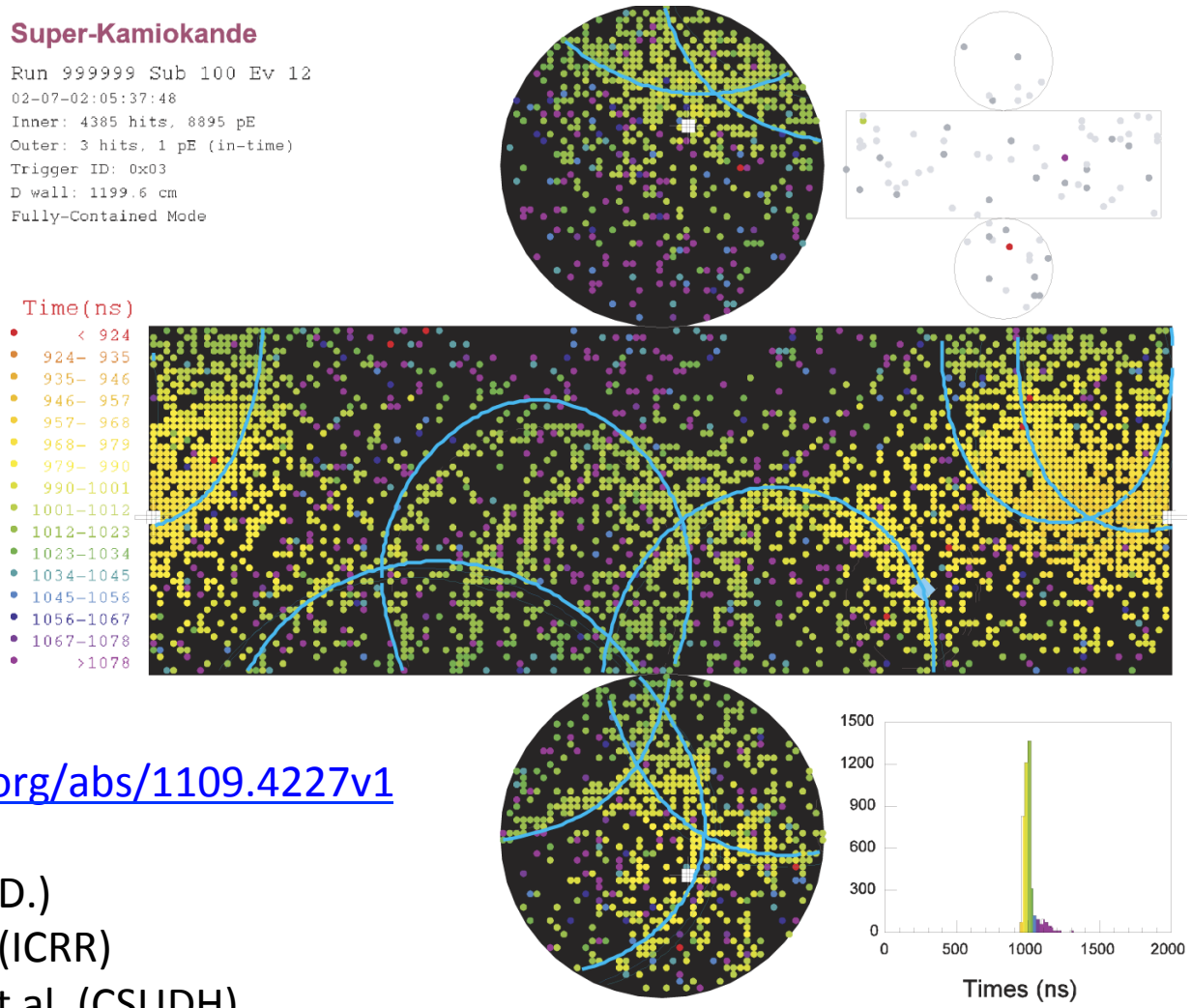
Cf. $\tau > 0.86 \times 10^8$ s [ILL/Grenoble]

Experiment	nucleus	N(10^{32}) [n years]	Effic.	Bkgd.	Cand.	R (10^{23}) [s^{-1}]	$T_{nucl.}$(10^{32}) [yr]
IMB	^{16}O	3.2	50%	-	3	1.0	0.24 $t > 0.9 \times 10^8$ s
Kamiokande	^{16}O	3.0	33%	0.9	0	1.0	0.43 $t > 1.2 \times 10^8$ s
Frejus	^{56}Fe	5.0	30%	2.5	0	1.4	0.65 $t > 1.2 \times 10^8$ s
Soudan 2	^{56}Fe	21.9	18%	4.5	5	1.4	0.72 $t > 1.3 \times 10^8$ s
Super-K	^{16}O	245.5	12%	24.1	24	1.0	**1.89** $t > 2.4 \times 10^8$ s
SNO	$^{2}H/^{16}O$	2.7	52%	9.7	4	0.85	1.52 $t > 2.4 \times 10^8$ s

Notes: just reusing published adopted values for R, not a topic for today

Super-Kamiokande Result

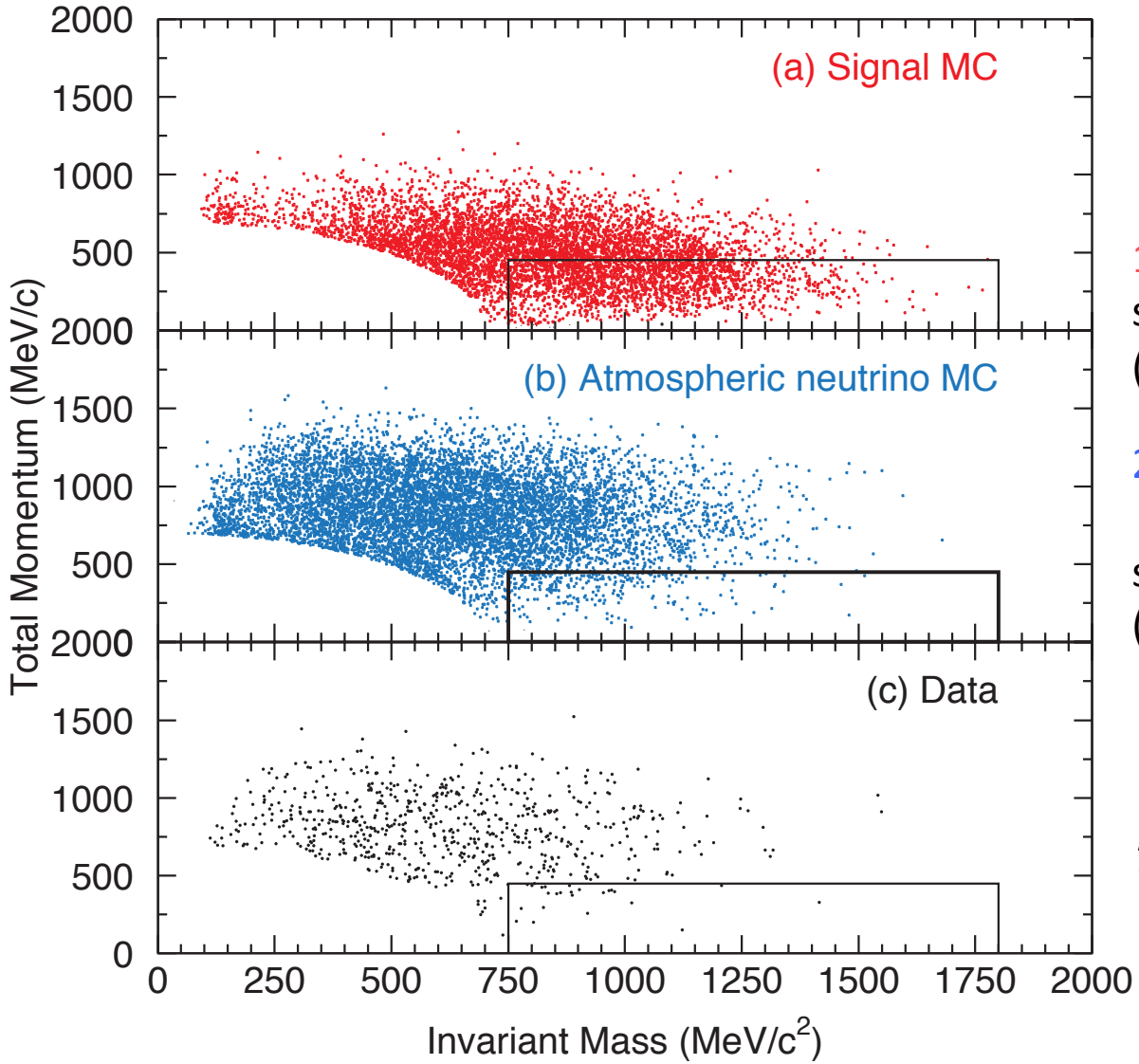
The Search for $n - \bar{n}$ Oscillation in Super-Kamiokande I



http://arxiv.org/abs/1109.4227v1

J.S. Jang (Ph.D.)
Jun Kameda (ICRR)
K. Ganezer et al. (CSUDH)

Super-Kamiokande Result



Selection Criteria:
$N_{ring} \geq 2$
E_{vis} between 700-1300 MeV

12 % detection efficiency
sys. uncertainty 23%
(mostly intranuclear scattering)

24.1 background events
ν osc. effects are included
sys. uncertainty 24%
(mostly flux, cross sections)

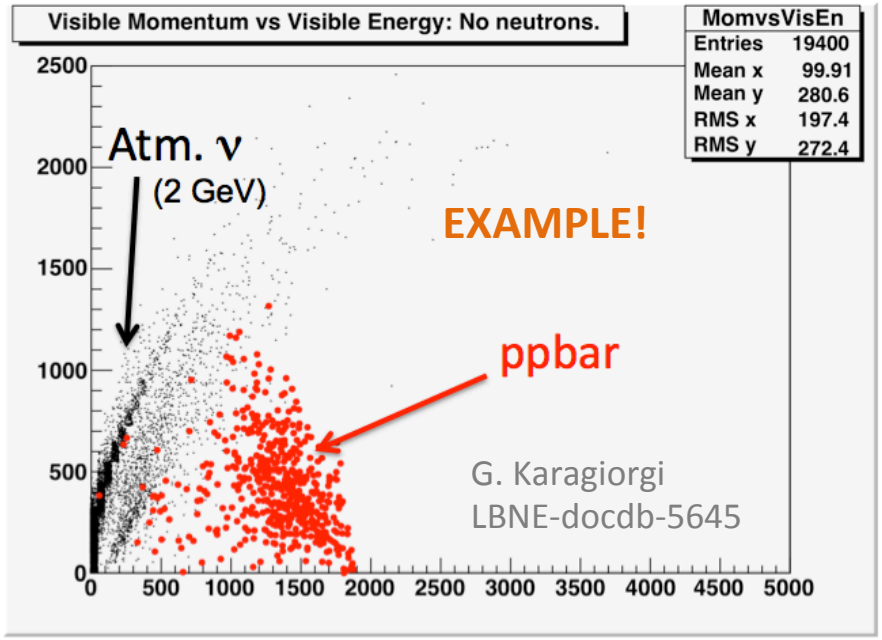
24 candidates

$$T_{bound} > 1.89 \times 10^{32} \text{ years}$$

$$\tau_{free} = \sqrt{\frac{T_{bound}}{1 \times 10^{23} \text{ s}^{-1}}} = 2.4 \times 10^{8} \text{ s}$$

Liquid Argon TPC

Potentially powerful detector for high efficiency with good background rejection!



Good discrimination at least at truth level.

Reject: CC muon
CC electron
recoil proton
energetic neutron?

Measure: invariant mass
net momentum

To estimate sensitivity for a large LAr TPC (e.g. LBNE 34 kton 10 years)
we need: (1) signal efficiency
(2) background rate
For some set of selection criteria.

First Steps

To estimate sensitivity for a large LAr TPC (e.g. LBNE 34 kton 10 years) we need:

(1) signal efficiency
(2) background rate

Background Rate is hardest:

- should have full spectrum of atmospheric neutrinos
- should model nuclear effects with state of the art
- vector level OK to start!
  - need minimum proton momentum
  - efficiency for e/gamma confusion
  - efficiency for CC muon ID (nearly 100%?)
- GENIE vectors generated for LBNE should do
- hard work seems to be done already!

Signal Efficiency is easier if done crudely:

- antiproton annihilation in LAr via GEANT4 is a good start
- full generator with nuclear potential and Fermi momentum
  - and nuclear scattering would be an upgrade

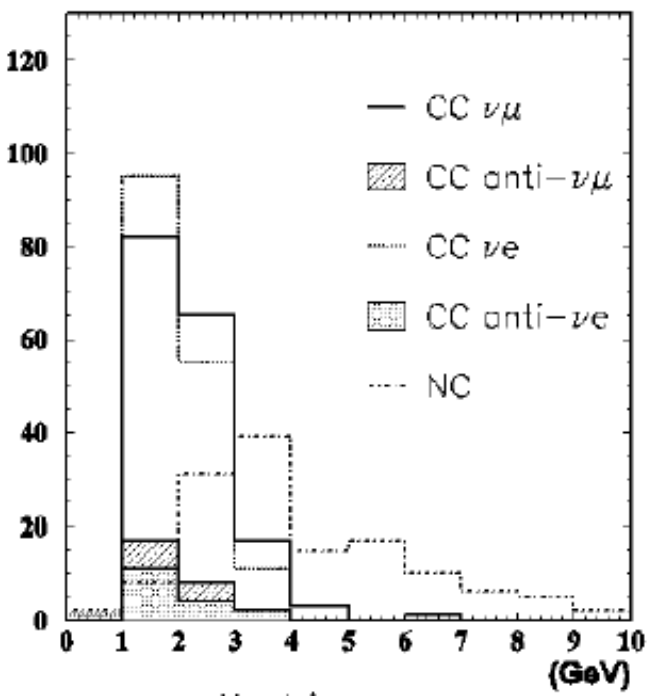
Experiment	nucleus	N(10^{32}) [n years]	Effic.	Bkgd.	Cand.	$T_{nucl.}$(10^{32}) [yr]
Super-K I	^{16}O	245	12%	24	24	2
SK 1-4 new	^{16}O	700	?	?	?	Goal is 3x to 5x improvement
Hyper-K (10 yr)	^{16}O	1500	?	?	?	20-50
LBNE (34 kt x 10 yr)	^{40}Ar	165	50%	3	3	100 $t > 10^9$ s

Purely speculative numbers for LAr, targets not results.
Target of < 1 events/100 kty background
While maintaining 50% efficiency

Can we do it?!

Backup

Atmospheric Neutrino Background (SK)



Neutrino Energy

DIS :	58%
1-meson resonance :	37%
CC/NC ES :	5%

Interaction Type:

CC 1π : 27.2% (6.5 evt)

NC 1π : 4.1% (1.0 evt)

CC mπ : 32.5% (7.8 evt)

NC mπ : 25.4% (6.1 evt)

Most CC atm. nu BG comes from
nu (not nubar) due to higher momentum transfer