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Baryon Number Violation Group Meeting

Experimental Searches for Neutron-Antineutron Transformation inside Nuclei

Offered for discussion

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Existing N-Nbar limits

Vacuum oscillations: $\tau_{n\to\bar{n}} > 0.86\cdot 10^8 \sec\ \text{(at ILL, 1994)}$

Sensitivity for free neutron search (appearance probability)

$$P \propto N_n \left(\frac{t_{obs}}{\tau_{n\to\bar{n}}} \right)^2$$

Will use ILL experiment limit as a unit of sensitivity = 1u

Sensitivity for bound neutron search (in nucleon decay expts)

$$P_{left} \propto N_n \cdot \exp\left(-\frac{t_{obs}}{\tau_{nucl}} \right)$$

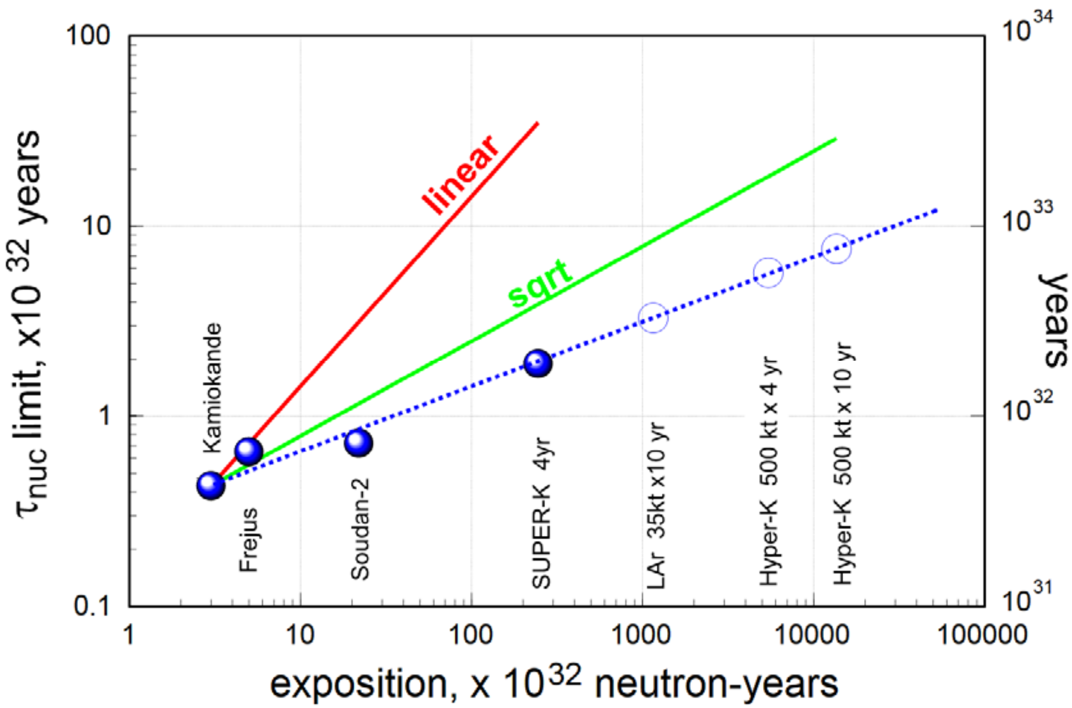
$\tau_{nucl} \gtrsim 2\cdot 10^{32}\, yr\ \text{(SK-2011)}$

$$\tau_{nucl} = R \times \tau^2_{n\to\bar{n}} \quad \text{where } R \text{ "nuclear suppression factor"}$$

Bound neutron N-Nbar search experiments

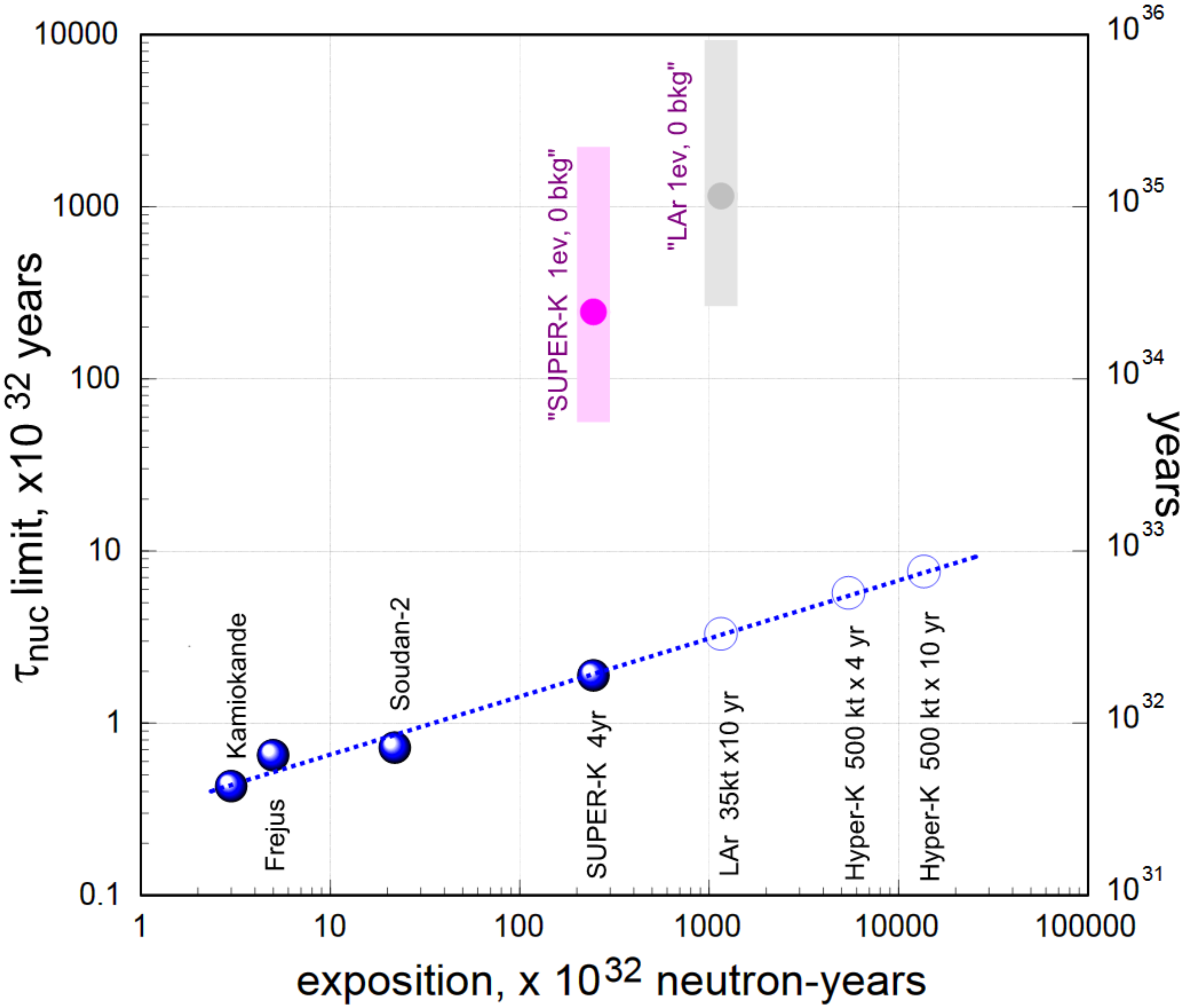
Experiment	Year	A	n·year (10^{32})	Det. eff.	Candid.	Bkgr.	τ_{nucl}, yr (90% CL)
Kamiokande	1986	O	3.0	33%	0	0.9/yr	$>0.43\times10^{32}$
Frejus	1990	Fe	5.0	30%	0	4	$>0.65\times10^{32}$
Soudan-2	2002	Fe	21.9	18%	5	4.5	$>0.72\times10^{32}$
SNO *	2010	D	0.54	41%	2	4.75	$>0.301\times10^{32}$
Super-K	2011	O	245	12.1%	24	24.1	$>1.89\times10^{32}$

* Preliminary



- From Kamiokande to Super-K atmospheric ν background is present in data.
- Large D_2O, Fe, H_2O detectors are dominated by backgrounds; <u>LAr detectors are yet undersood!</u>
- Observed improvement is weaker than SQRT due to irreducible background and uncertainties in efficiency and background.
- Still possible to improve a limit but impossible to claim a discovery.

What if detectors would be backgroundless ?



24 candidate events in Super-K might contain several genuine n-nbar events.
Backgroundless detectors needed to explore nnbar > 10^{33} years.
Can atmospheric neutrinos and nnbar signals be separated in LAr detectors?

Conversion of Bound Limit to free Oscillation Limit

Experiment	Year	A	τ_{nucl}, yr (90% CL)	R(old), s^{-1}	R(new), s^{-1}	τ(old), s	τ(new), s
Kamiokande	1986	O	$>0.43\times10^{32}$	10×10^{22}	5×10^{22}	$>1.2\times10^{8}$	$>1.65\times10^{8}$
Frejus	1990	Fe	$>0.65\times10^{32}$	14×10^{22}	?	$>1.2\times10^{8}$	?
Soudan-2	2002	Fe	$>0.72\times10^{32}$	14×10^{22}	?	$>1.3\times10^{8}$	?
SNO * (0.002 × SK)	2010	D	$>0.301\times10^{32}$	2.48×10^{22}	2.94×10^{22}	$>1.96\times10^{8}$	$>1.8\times10^{8}$
Super-K	2011	O	$>1.89\times10^{32}$	10×10^{22}	5×10^{22}	$>2.44\times10^{8}$	$>3.45\times10^{8}$

Dover, Gal et. al, old

V. Kopeliovich 2011, Deuterium

Friedman and Gal 2008, Oxygen

$$\Rightarrow \tau_{n\bar{n}}(\text{from bound}) > 3.5\times10^{8}s \quad \text{or} \quad \alpha < 2\times10^{-24}eV$$

Vacuum N-Nbar transformation from bound neutrons:

Best result so far from Super-K in Oxygen-16

$$\tau_{^{16}O} > 1.89 \times 10^{32} yr \quad (90\% \text{ CL}) \quad \leftarrow \begin{cases} \text{24 observed candidates;} \\ \text{24.1 exp. background} \end{cases}$$

$$\tau_{nucl} = R \times \tau^2_{n\bar{n} \text{ free}}$$

if $R_{^{16}O} = 5 \cdot 10^{22} s^{-1}$ from Friedman and Gal (2008)

$$\Rightarrow \tau(\text{from bound}) > 3.5 \times 10^8 s \quad \text{or} \quad \alpha < 2 \times 10^{-24} eV$$

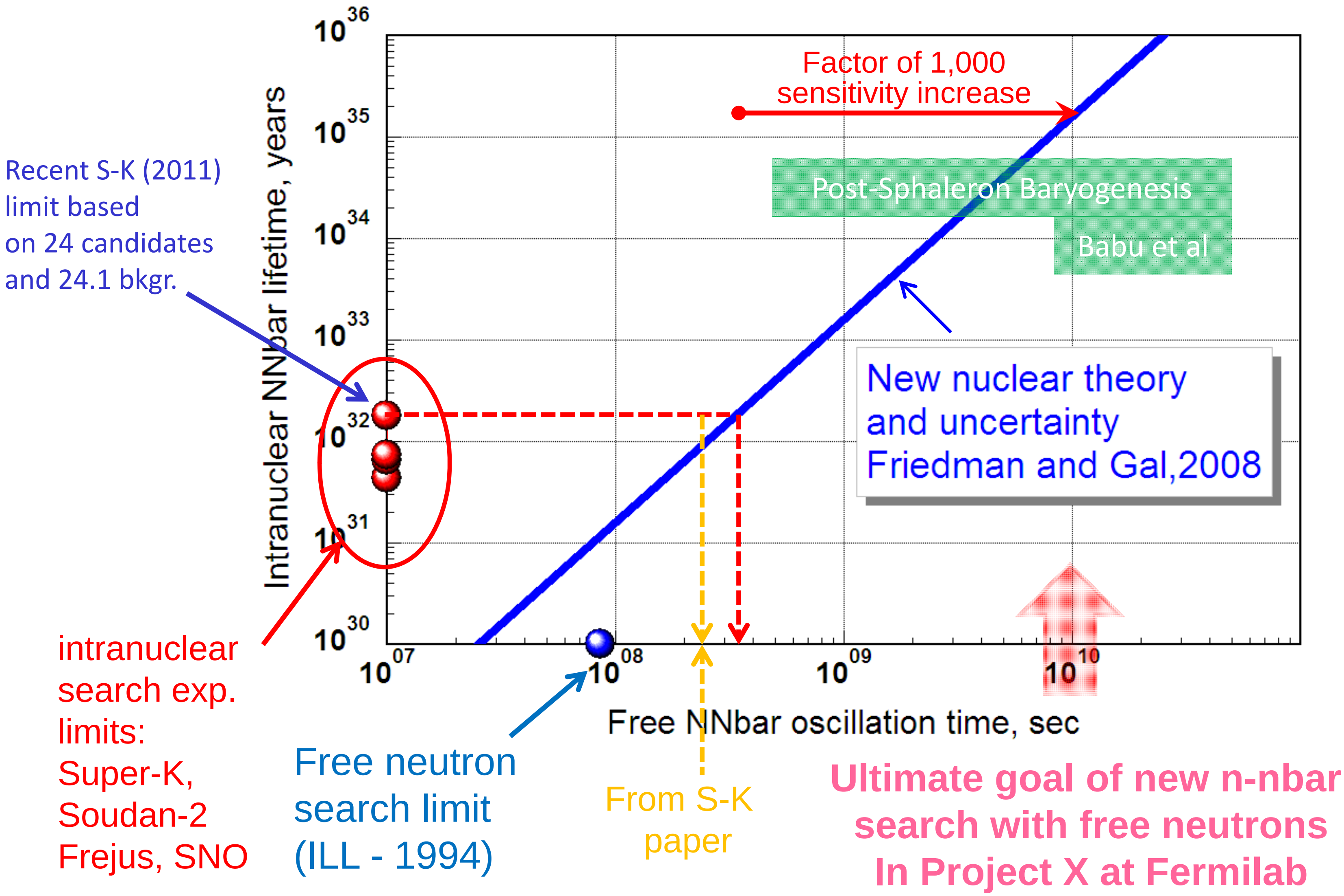
$\times 16$ times higher than sensitivity of ILL expt.

ILL limit (1994) for free neutrons: $\tau_{n\bar{n}} > 0.86 \times 10^8 s$

$$\tau_{bound} = R \times \tau^2_{free}$$

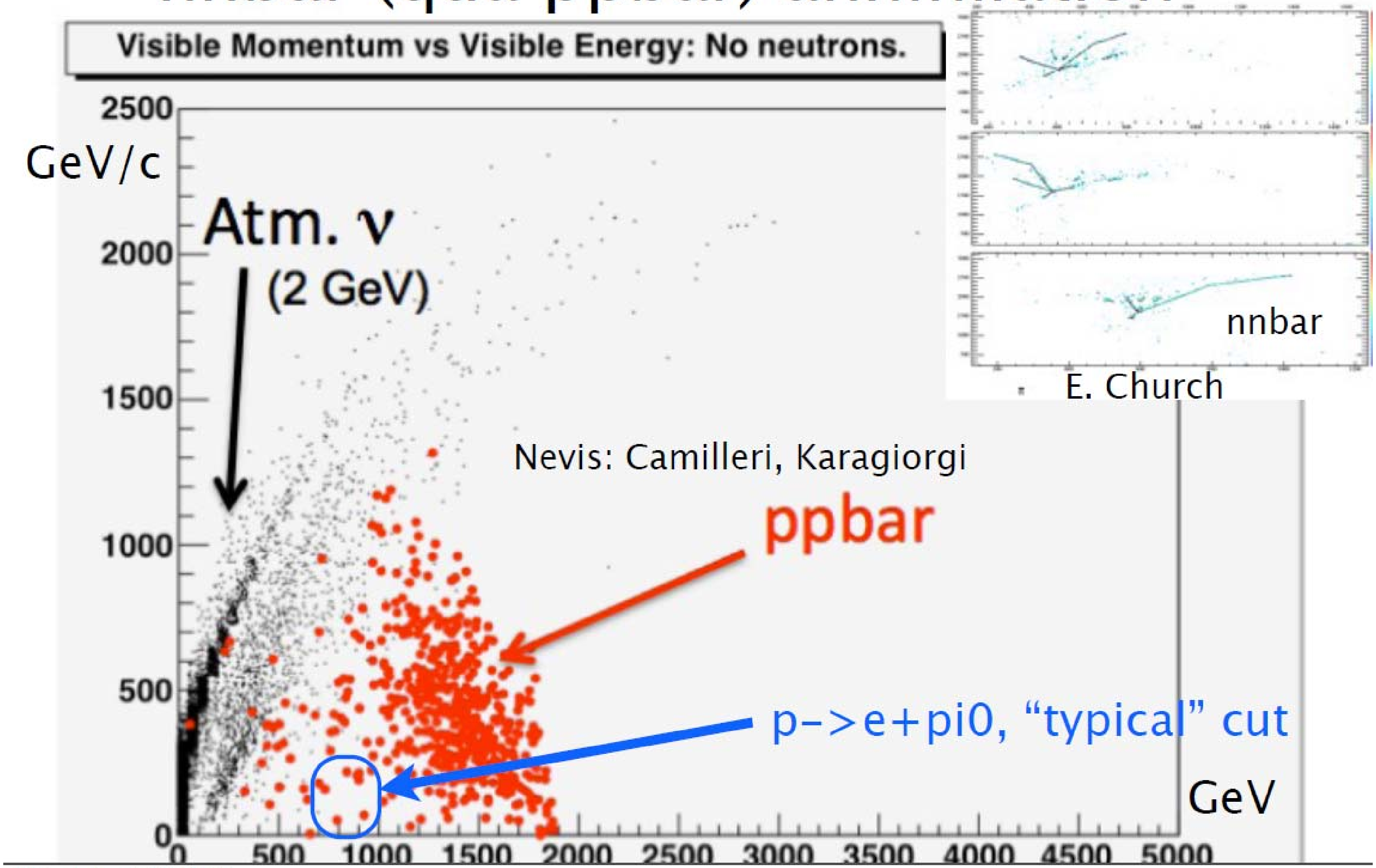
Free Neutron and Bound Neutrons NNbar Search Limits Comparison

Large improvement with free-neutron experiments is possible



NNbar in LAr (Eric Church/Yale for LBNE)

momentum-energy balance in nnbar (qua ppbar) annihilation



Issues for PDK and N-Nbar detection in LAr
(for future large LBNE detector)

1. Atmospheric neutrino CC and NC background modeling.
2. Models of intranuclear cascade for final state products inside Argon.
3. Efficiency of event identification.
4. Nuclear suppression factor for N-Nbar in Ar.
5. Modes of de-excitation of residual nuclei after disappearance of neutron or proton (e.g. for $n \rightarrow 3\nu$).