$^{127}I(\nu_e,e^-)^{127}Xe$ reaction for solar neutrino spectrum clarification

A.N. Fazliakhmetov[1,2], G.A. Koroteev[1], Yu.S. Lutostansky[3], V.N. Tikhonov[3]

[1]Moscow Institute of Physics and Technology (National Research University), Moscow, Russia
[2]Institute for Nuclear Research of the Russian Academy of Sciences, Moscow, Russia
[3]National Research Center «Kurchatov Institute», Moscow, Russia

Motivation

Direct research of the neutrino-nuclear interaction is very hard experimental problem

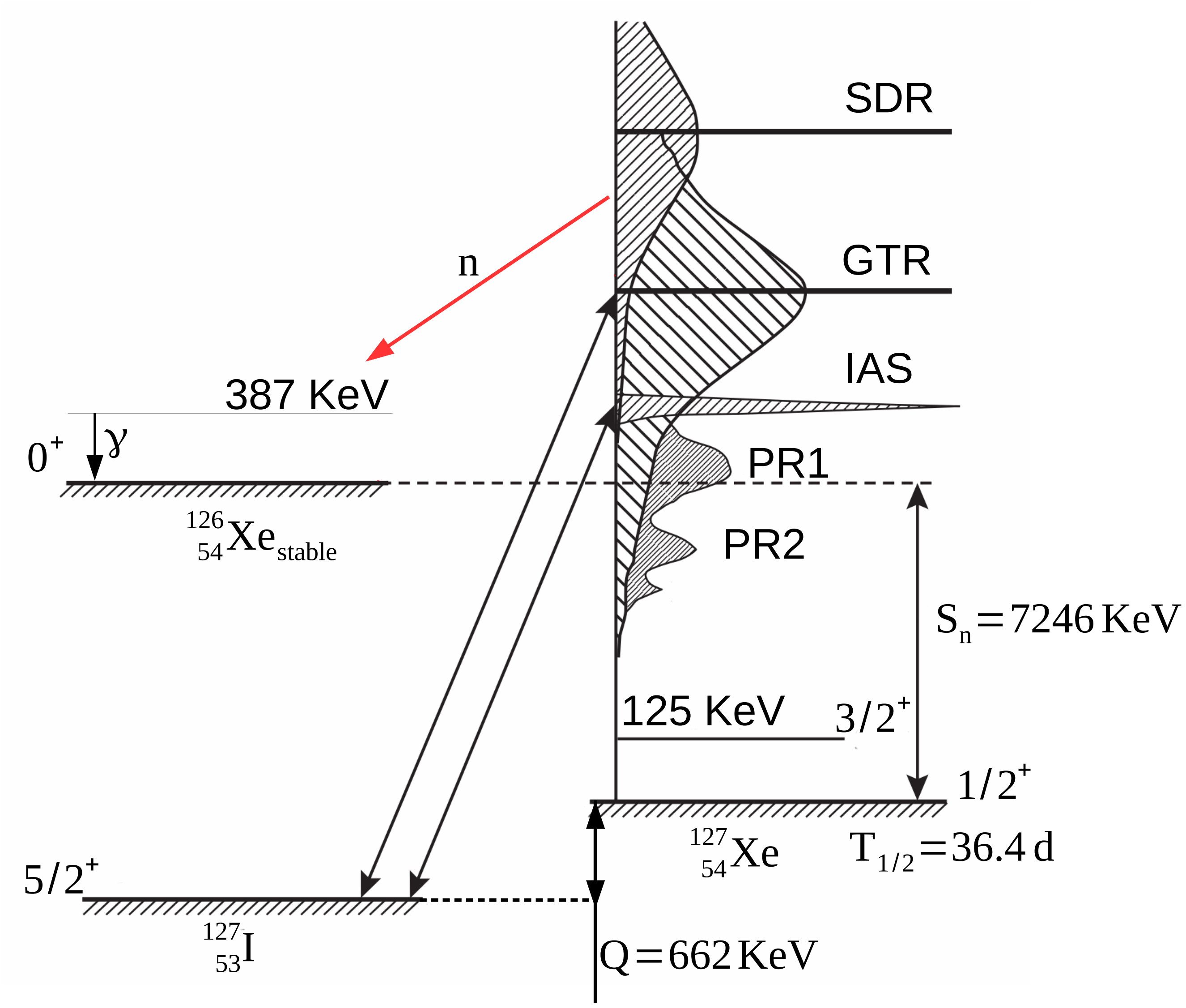
Relatively high energy neutrinos excite states of nucleus including nuclear resonances

Giant GT-resonance and pygmy-resonances determine a significant part neutrino interaction cross-section

The threshold of $^{127}I(\nu_e,e^-)^{127}Xe$ reaction is relatively high which allows focus on the neutrinos with energy >0.787 MeV

How strong the neutron emission effects on the capture rate?

Nuclear level scheme for ^{127}Xe



Neutrino Capture Cross-Section

$$\sigma_{total}(E_\nu)=\sigma_{discr}(E_\nu)+\sigma_{res}(E_\nu)$$

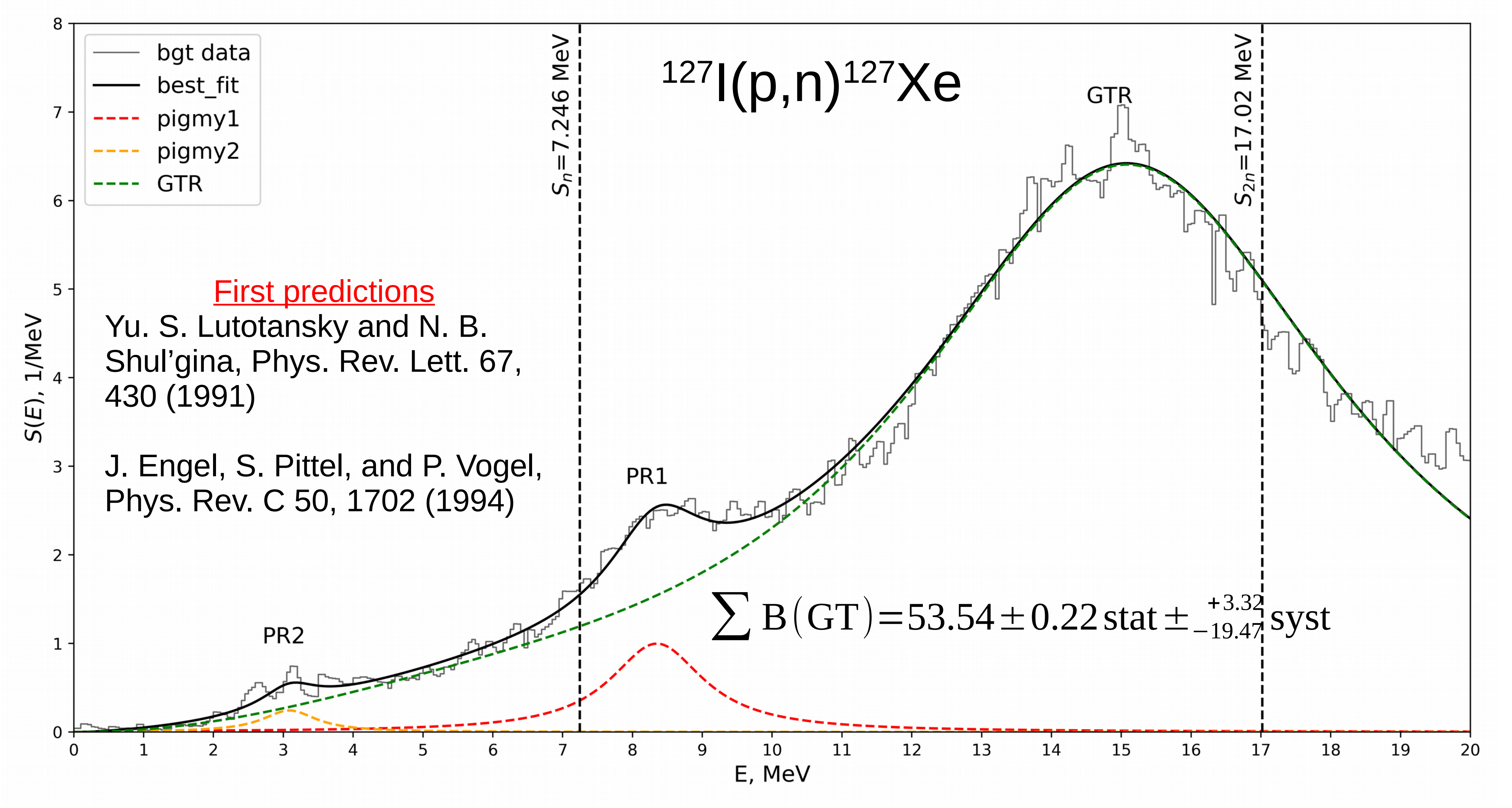
$$\sigma_{discr}(E_\nu)=\frac{1}{\pi}\sum_k G_F^2\cos^2\theta_C\, p_e E_e F(Z,E_e)\left[B(F)_k+\frac{g_A}{g_V}B(GT)_k\right]$$

$$E_e-m_e c^2=E_\nu-Q_{EC}-E>0$$

$$\sigma_{res}(E_\nu)=\frac{1}{\pi}\int G_F^2\cos^2\theta_C\, p_e E_e F(Z,E_e)S(E)dE$$

A.K. Vyborov et. al Phys.Atom.Nucl. 82 (2019) 5, 477-482

Strength function

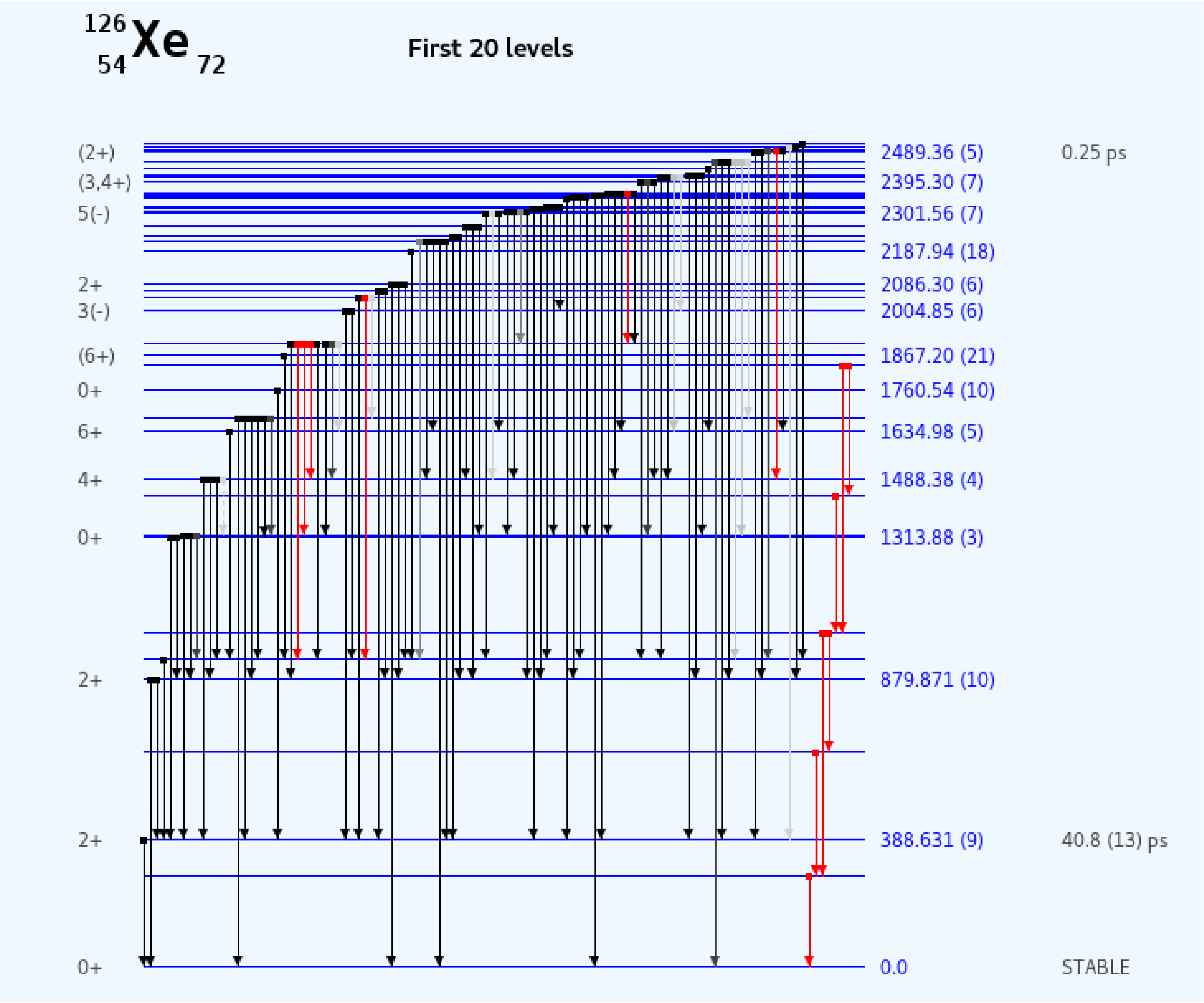


B(GT) spectrum from M. Palarczyk *et al.* PHYSICAL REVIEW C V59 #1 (1999)

What can we get from detection ^{126}Xe?

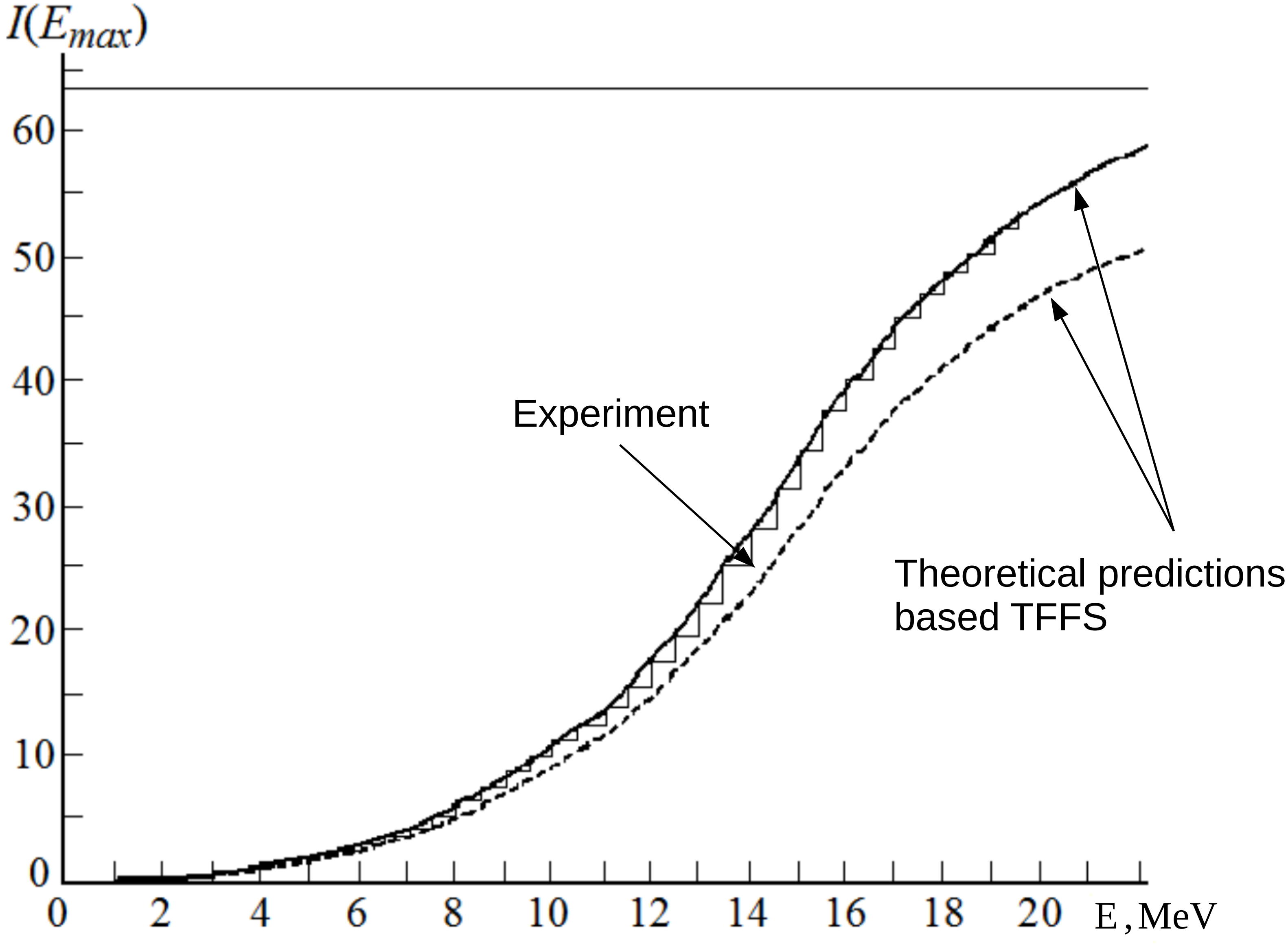
1) quenching clarification
2) clarification of B(GT) distribution

How can we measure ^{126}Xe abundance?
1) mass-spectrometry
2) activation analysis



126
54
Xe
72
First 20 levels
(2+)
(3,4+)
5(-)
2+
3(-)
(6+)
0+
6+
4+
0+
2+
2+
0+
2489.36 (5)
2395.30 (7)
2301.56 (7)
2187.94 (18)
2086.30 (6)
2004.85 (6)
1867.20 (21)
1760.54 (10)
1634.98 (5)
1488.38 (4)
1313.88 (3)
879.871 (10)
388.631 (9)
0.0
0.25 ps
40.8 (13) ps
STABLE

Quenching



$I(E_{max})$
60
50
40
30
20
10
0
0
2
4
6
8
10
12
14
16
18
20
E , MeV
Experiment
Theoretical predictions
based TFFS

^{127}I as the solar neutrino detector

First proposal: W. C. Haxton, Phys. Rev. Lett. 60, 768 (1988)
Homestake iodine detector: *K. Lande et al./Nuclear Physics B 77 (1999) 13-19*

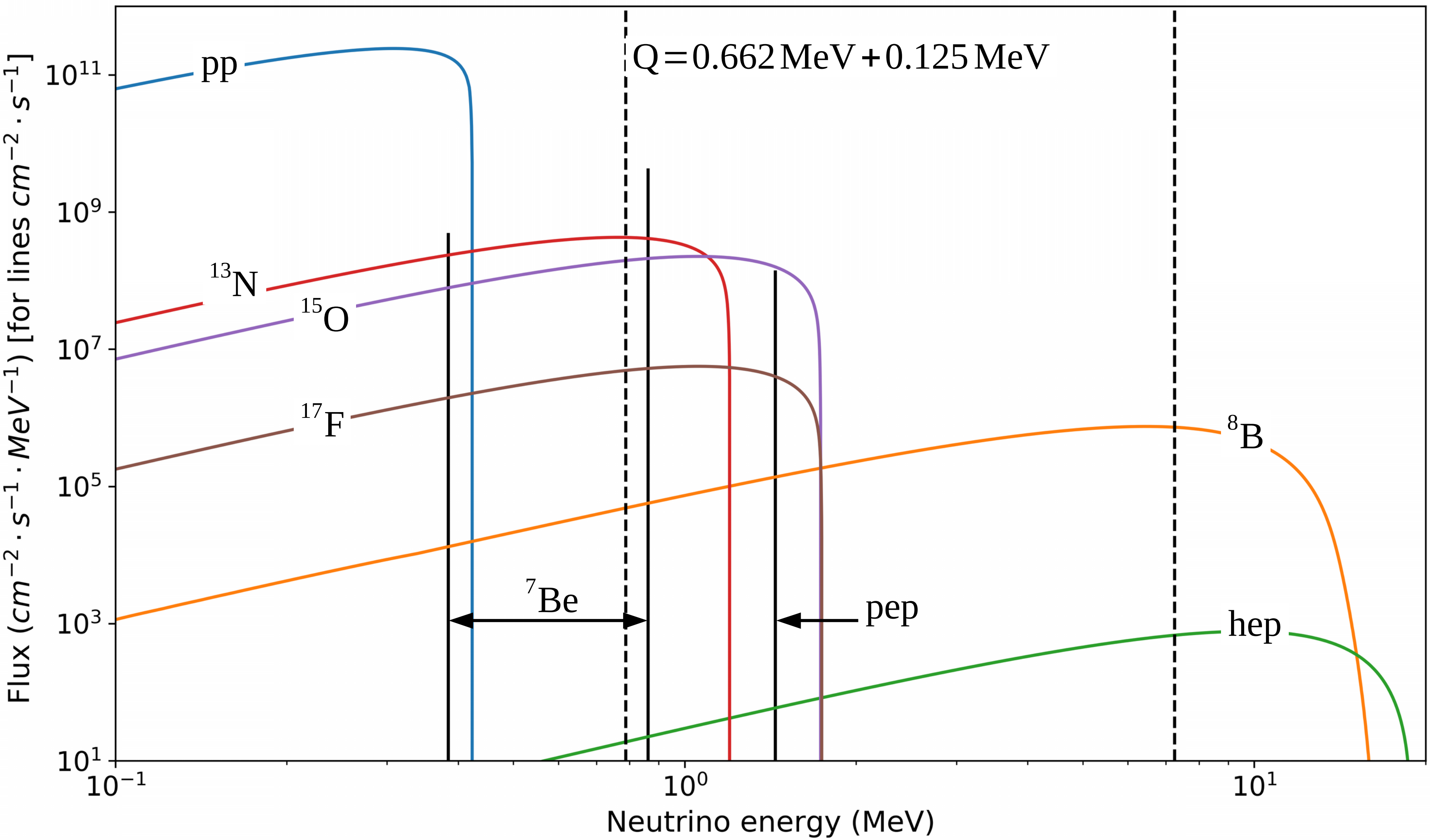
- 100 tonnes of ^{127}I
- Similar to radiochemical approach used at Homestake with ^{37}Cl

Flux, $cm^{-1}s^{-1}$	B16-GS98* high metallicity	B16-AGSS09met* low metallicity	BS05OP**
Φ(pp), 10^{10}	5.98	6.03	5.99
Φ(pep), 10^{8}	1.44	1.46	1.42
Φ(hep), 10^{3}	7.98	8.25	7.93
Φ(^{7}Be), 10^{9}	4.93	4.50	4.84
Φ(^{8}B), 10^{6}	5.46	4.50	5.69
Φ(^{13}N), 10^{8}	2.78	2.04	3.07
Φ(^{15}O), 10^{8}	2.05	1.44	2.33
Φ(^{17}F), 10^{6}	5.29	3.26	5.84

* N. Vinyoles et al. Astrophysical Journal, V835, #2 (2017)

** J. N. Bahcall et al. Astrophysical Journal Letters, V621, #1 (2005)

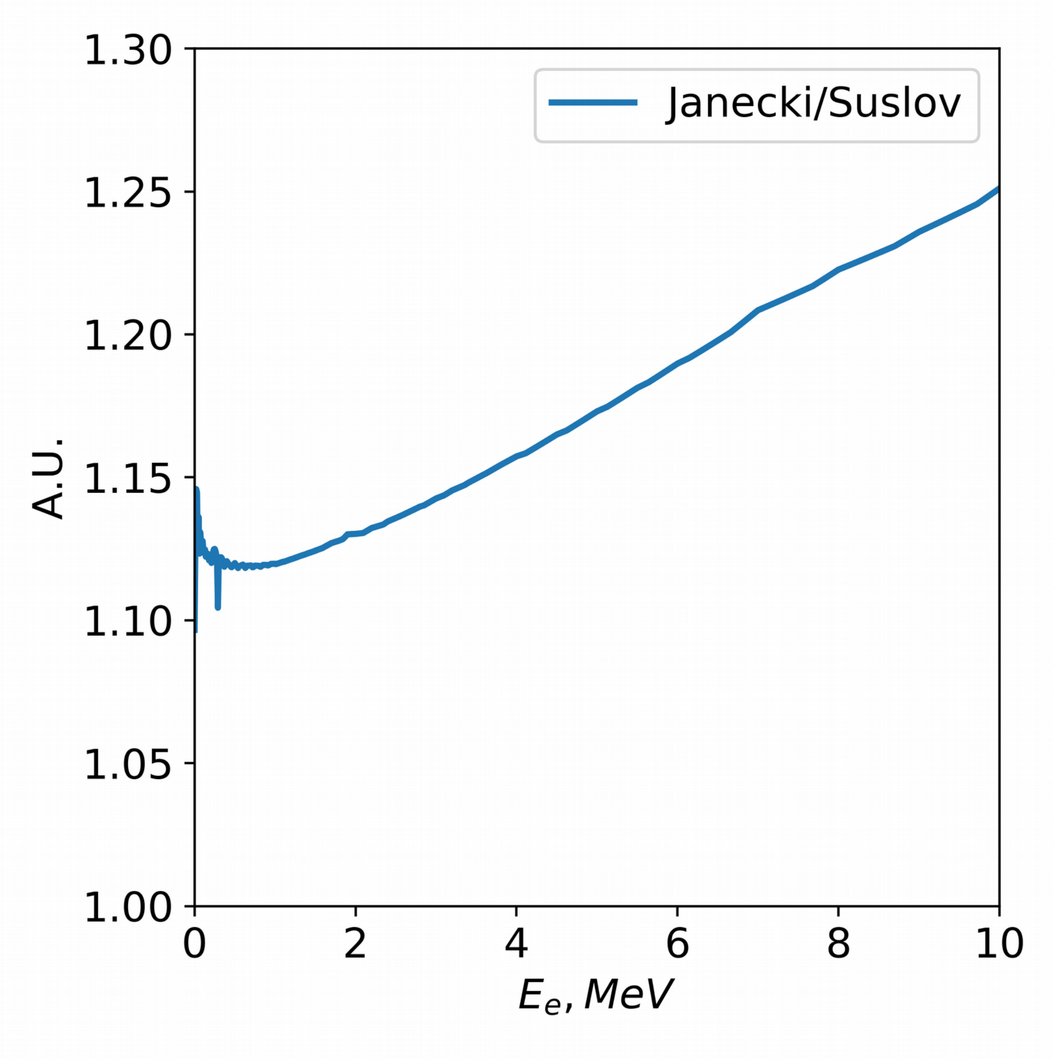
Region of interest for $^{127}I(\nu_e,e^-)^{127}Xe$ and solar neutrino spectrum



Capture rate (SNU) for solar models

Model	^{7}Be	^{17}F	^{8}B	^{13}N	pep	^{15}O	hep	pp	Total
BS05OP with neutron separation	2.92	0.01	25.71	0.17	0.83	0.55	0.11	0	30.3
BS05OP without neutron separation	2.92	0.01	30.92	0.17	0.83	0.55	0.19	0	35.6
B16-GS98 (high metallicity) with neutron separation	2.92	0.01	24.67	0.15	0.83	0.48	0.11	0	29.18
B16-AGSS09met (low metallicity) with neutron separation	2.92	0.01	20.33	0.11	0.83	0.34	0.11	0	24.66

Fermi function choice



Behrens and J. Janecke, ¨ *Elementary Particles, Nuclei and Atoms, Landolt-Bornstein Group I: Nuclear Physics and ¨ Technology, Vol. 4 (Springer, Berlin, 1969)*

Y. P Suslov, *Bulletin of the Academy of Sciences of USSR: Physics Series 31, 687 (1967)* and *32, 213 (1968) (in Russian)*

Conclusion

- High-lying resonant GT states make a substantial contribution to neutrino capture cross-section.
- Events beyond the neutron emission threshold could significantly (~17%) increase the total capture rate.
- One can distinguish low and high metallicity solar models.
- Needs to measure B(GT) distribution for 127Xe more precisely ((3He,t) charge-exchange reactions?)

Thank you for your attention!

Almaz Fazliakhmetov
fazliakhmetov@phystech.edu

$^{127}I(\nu_e,e^-)^{127}Xe$ cross section measurement at LAMPF*

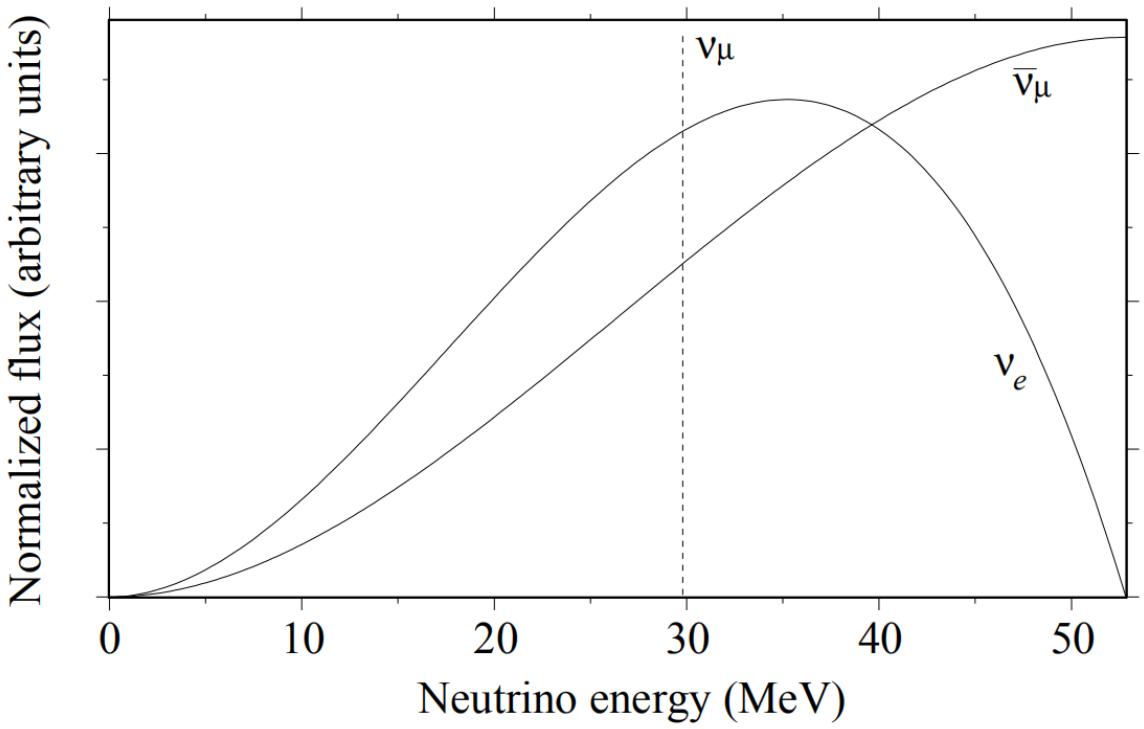
Los Alamos Meson Physics Facility

1540 kg of ^{127}I

Flux at the middle of the tank $5\times10^7\ \nu_e/(cm^2 s)$

Radiochemical approach to extract ^{127}Xe

Exposure time varied from 11 d to 57 d

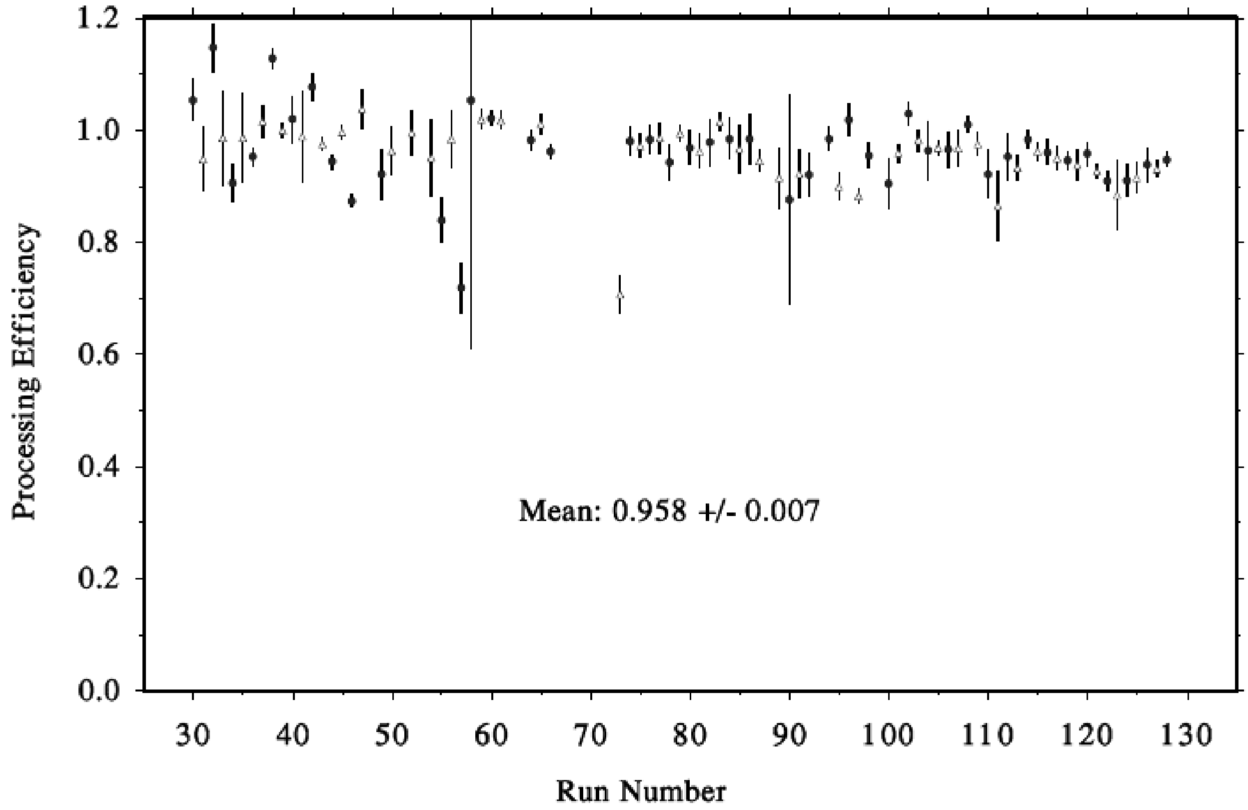


Measured cross-section: [2.84±0.91(stat)±0.25 (syst)]×10^{-40} cm^2

Production rate ^{127}Xe atoms/d: ≈40-60, depends on the run

Expected number of ^{126}Xe atoms: **≈625** for exposure time 30 d

*Distel, et al., Phys. Rev. C 68, 054613, 2003.



Measurement of the solar electron neutrino flux with the Homestake chlorine detector - Cleveland, B.T. et al. Astrophys.J. 496 (1998) 505-526