Ga anomaly :
Neutrino oscillation to sterile neutrino
Neutrino nuclear responses for ^{71}Ga.

Hiro Ejiri RCNP Osaka Univ.

Ga Anomaly:

0.87 : 2.6 σ missing neutrino signal??

Neutrino response, or
Oscillation to Sterile neutrino ?

H. Ejiri, et al., Phys. Lett. B. 433 257 (1998).

C. Giunti and M. Laveder, PR C 83, 065504 (2011).

D. Frekers, H. Ejiri, H. Akimune, V. Gavrin et al. PL B 706, 134 (2011

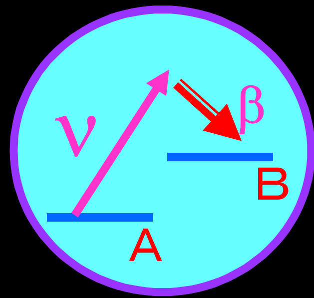
H. Ejiri, World Scientific Conf2018, p141 (2018) Dresden18

H. Ejiri, J. Suhonen, K. Zuber, Phys. Rep. 791, 1 (2019).

* V. Gavrin, Proposal BEST (2019)

1 Neutrino nuclear responses, renormalization (quenching) and charge exchange reactions

(Solar ν, β)   A + ν = B + β



Nucleus 10^{-15}m
Femto (fm) lab.
selectively
ν-excitation
$\sigma \sim 10^{-41\text{-}45}$cm^2

Flux: ν oscillation
Solar model

EXP

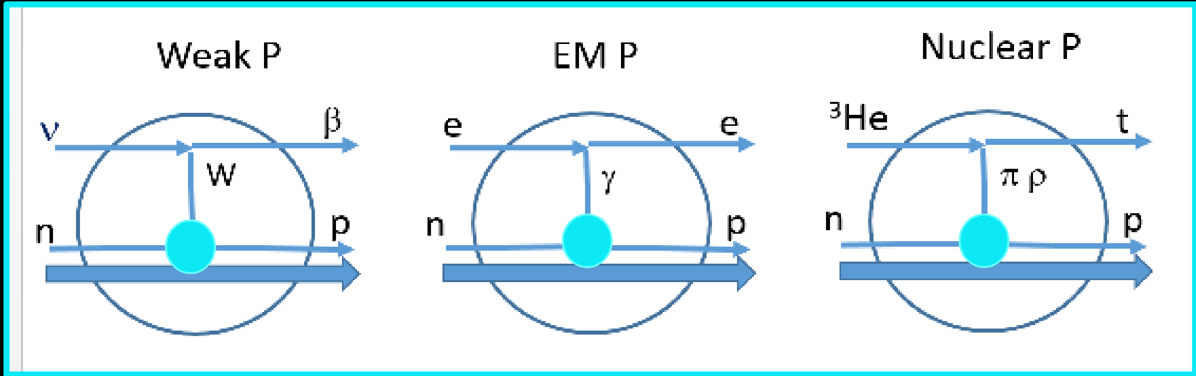
$$T^{\beta} = G^{\beta}\,[M^{\beta}\; I_{\nu}]^2$$

Phase space

MMR Nucl. phys.
B(GT), Nucl. medium

Review   H.Ejiri J.I. Fujita Phys. Rep 38 1978 85
H. Ejiri Phys. Rep. 338 2000 265
H. Ejiri J. Suhonen K. Zuber Phys. Rep. Submitted 2018

CERs for CC

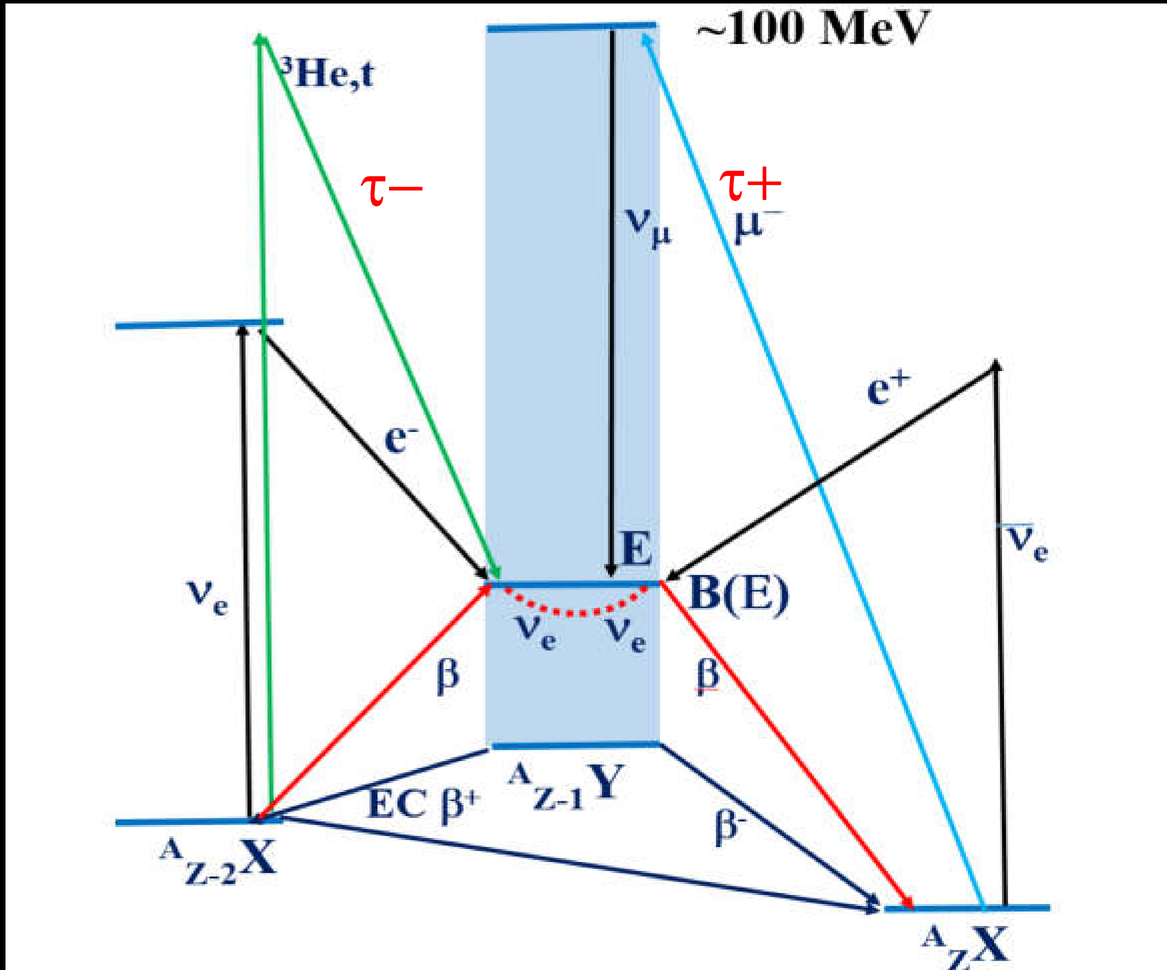


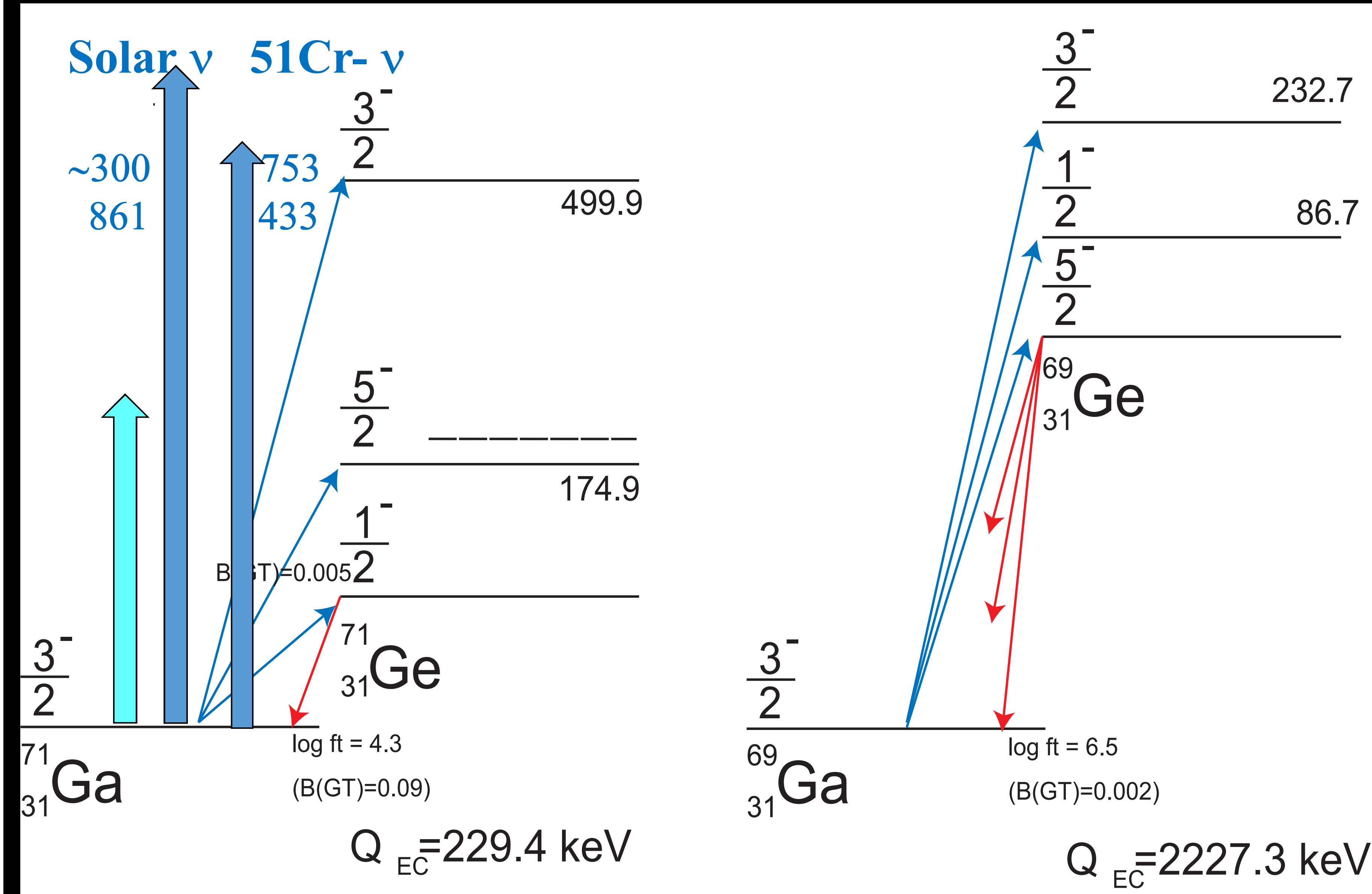
Neutrinos

^{51}Cr EC
753, 433 keV

^{37}Ar EC
814 KeV

Lowest 3 states





Solar ν
51Cr- ν
~300
861
753
433
3/2 -
499.9
5/2 -
174.9
1/2 -
B T)=0.005
71 31 Ge
3/2 -
71 31 Ga
log ft = 4.3
(B(GT)=0.09)
Q EC=229.4 keV
3/2 -
232.7
1/2 -
86.7
5/2 -
69 31 Ge
3/2 -
69 31 Ga
log ft = 6.5
(B(GT)=0.002)
Q EC=2227.3 keV

Low E solar and ^{51}Cr ν_e question

^{51}Cr-ν N(ν- Ga detectors)/N(evaluated from ^{71}Ga B(GT))

	SAGE ^{51}Cr	SAGE ^{37}Ar	GALLEX Cr1	GALLEX Cr2
Activity, kCi	516.6±6.0	409±2	1714^{+30}_{-43}	**1868^{+89}_{-57}**
p, atoms ^{71}Ge/day	14.0±1.5±0.8	$11.0^{+1.0}_{-0.9}$±0.6	11.9±1.1±0.7	**10.7±1.2±0.7**
Mass of Ga (t)	13.1 (metal)	13.1 (metal)	30.4 ($GaCl_3$:HCl)	**30.4 ($GaCl_3$:HCl)**
R=$p_{meas}/p_{theor.}$	**0.95±0.12**	**0.79±0.10**	**0.953±0.11**	**0.812±0.11**

R=0.87±0.05 (*) , suggests 1. detectors efficiency, 2. B(GT) or 3. a new ν oscillation and the CPT violation in short distance ν_e disappearance and oscillation to sterile ν [gav10] [giu10].

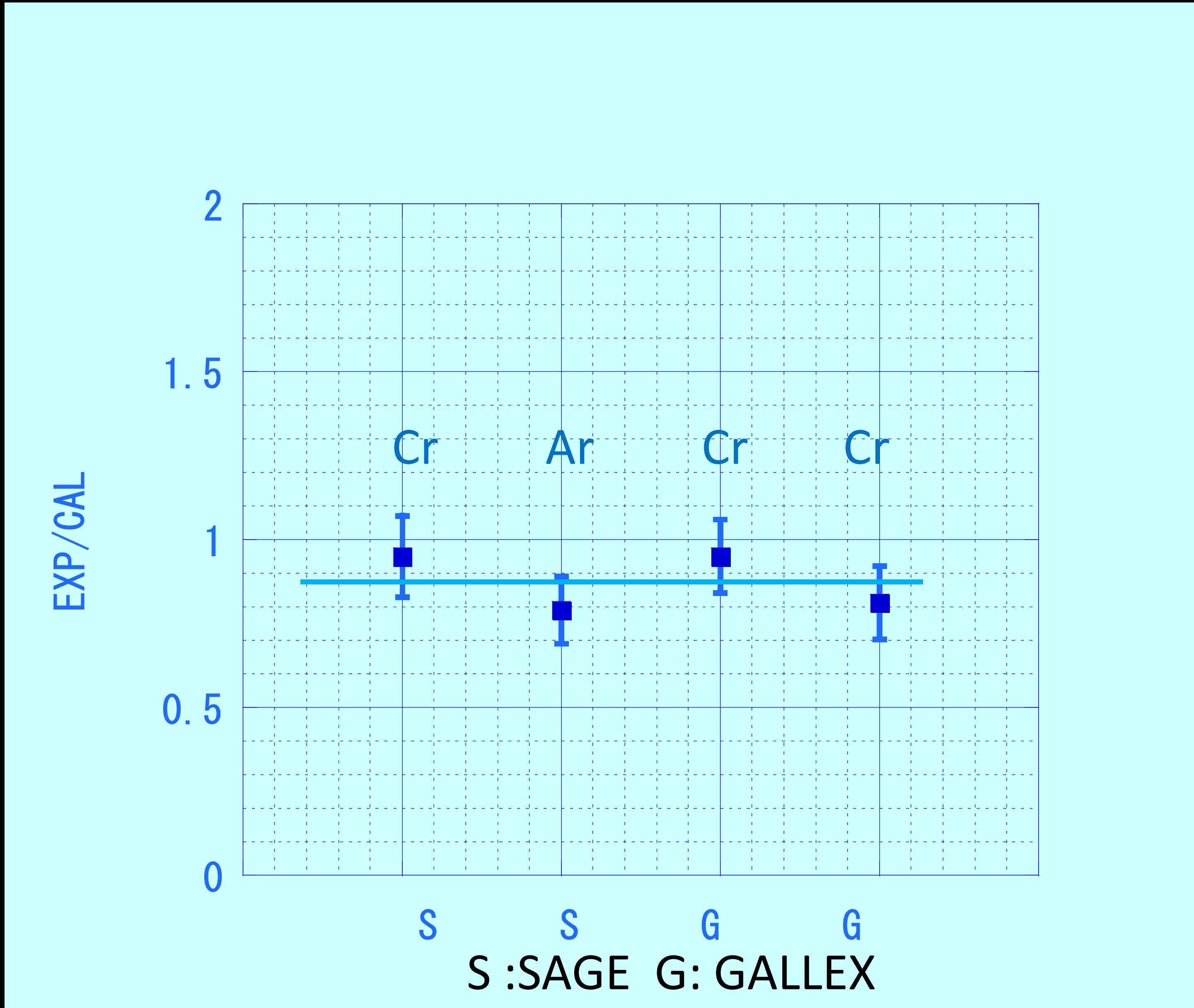
a . [kae10] F. Kaether et al., Phys. Letters B 685 47-54 2010

b. [abd99]. J. N. Abdurashitov et al., Phys. Rev. C59, 2246 (1999)

c. [abd06]. J. N. Abdurashitov et al., Phys. Rev. C73, 045805 1-12 (2006)

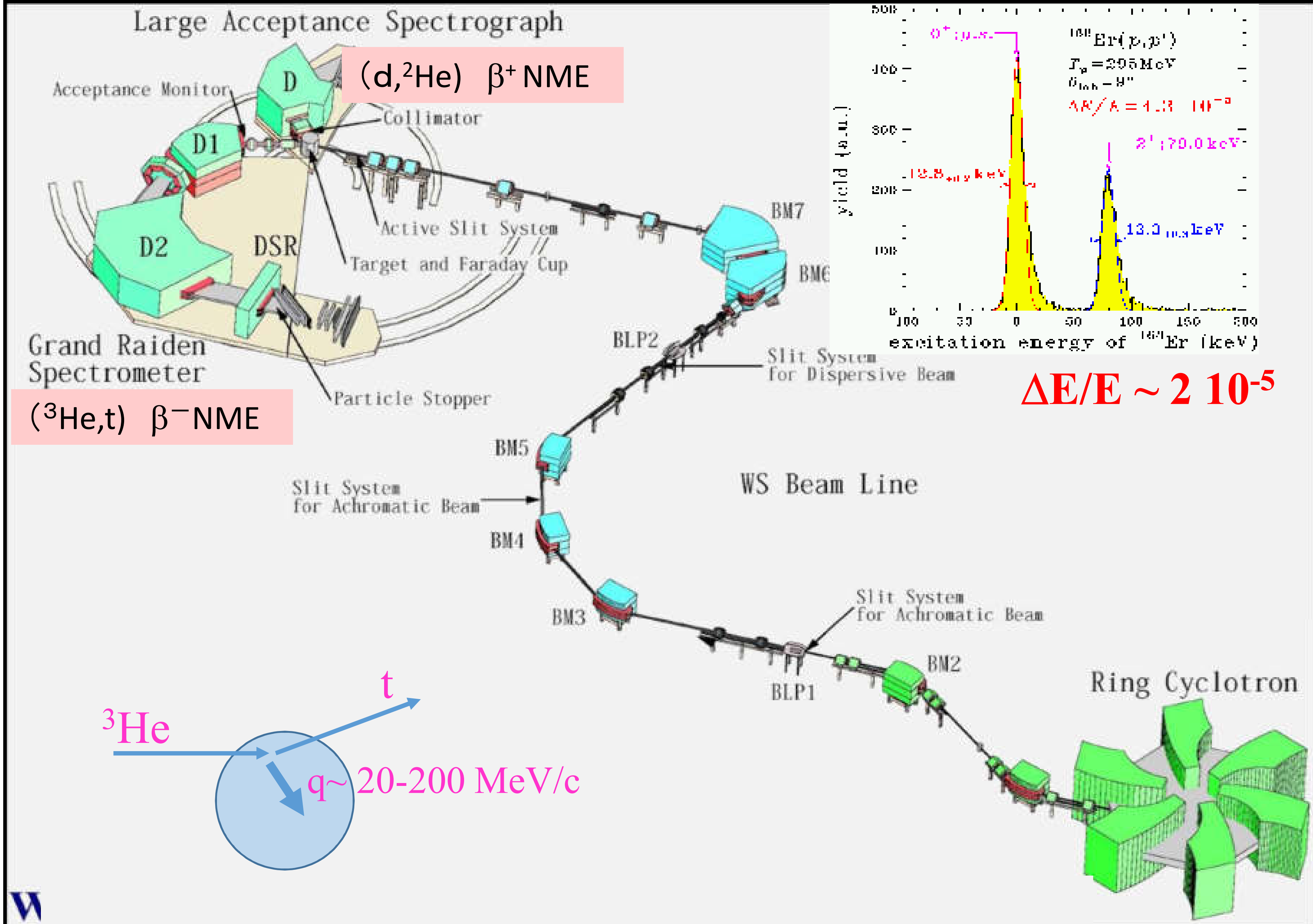
d. [abd09]. J. N. Abdurashitov et al., Phys. Rev. C80, 015807 1-16 (2009)

e. [gav10]. V.N. Gavrin et al., arXiv:1006.2103vl

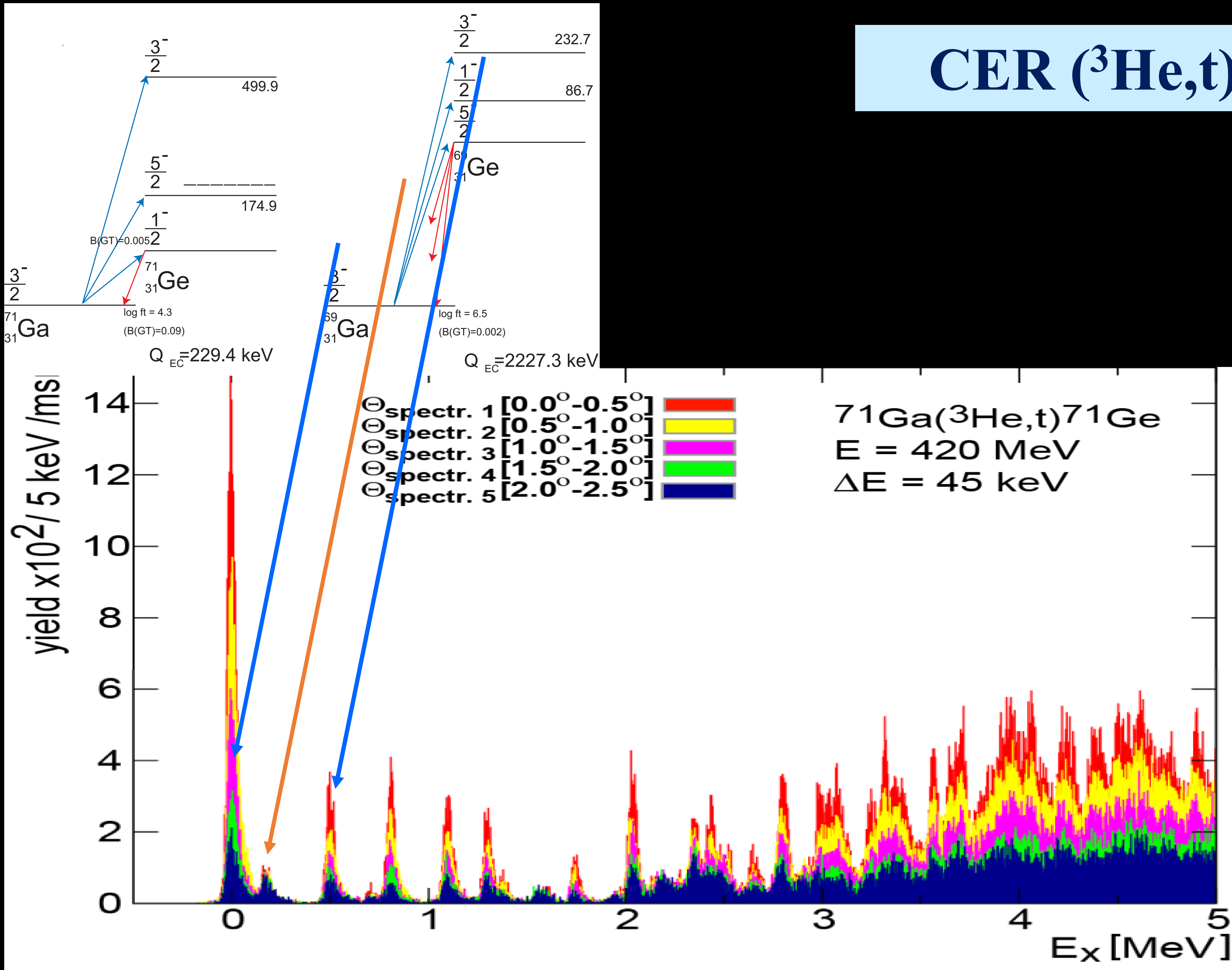


EXP/CAL
2
1.5
1
0.5
0
Cr
Ar
Cr
Cr
S
S
G
G
S :SAGE G: GALLEX

High E resolution (³He,t) CERs at RCNP Osaka



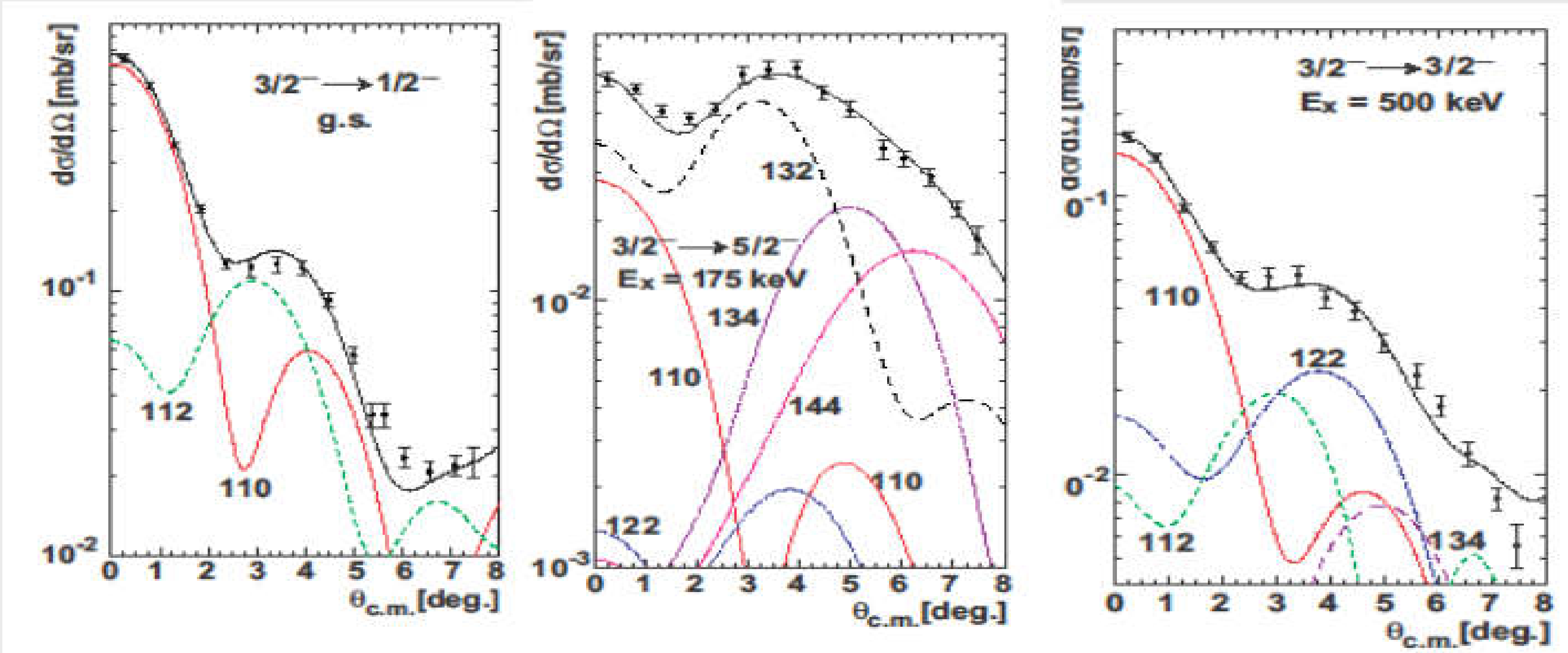
CER (^{3}He,t)



3/2⁻
499.9
5/2⁻
174.9
1/2⁻
B(GT)=0.005
3/2⁻
71 31 Ge
71 31 Ga
log ft = 4.3
(B(GT)=0.09)
Q EC=229.4 keV
3/2⁻
232.7
1/2⁻
86.7
5/2⁻
69 31 Ge
3/2⁻
69 31 Ga
log ft = 6.5
(B(GT)=0.002)
Q EC=2227.3 keV
yield x10²/ 5 keV /msr
Θspectr. 1 [0.0°-0.5°]
Θspectr. 2 [0.5°-1.0°]
Θspectr. 3 [1.0°-1.5°]
Θspectr. 4 [1.5°-2.0°]
Θspectr. 5 [2.0°-2.5°]
71Ga(3He,t)71Ge
E = 420 MeV
ΔE = 45 keV
Ex [MeV]

Non-GT in CER $\sigma(q\sim0) = \Sigma\sigma(J_p, J_T, J_R) = \sigma(110) + \sigma(112) + \ldots$

$^{71}Ga \rightarrow {}^{71}Ge$ Ground state 1/2 known B(GT)



Ga	0	GT ratio	92%	B(GT) =8.52	$R(^{51}Cr)$=1.00
1 st	175		40%	0.34	0.027
2^{nd}	500		87%	1.76	0.045

Excited state contribution=7.2 ±2% (Bahcall 5%, Ejiri 8%)

Using the measured response, missing = 0.85 (uncertainty 2%)

Not due to the nuclear response, but something, sterile or ?

arXiv 1006 21-3 v3

Gallium experiments with artificial neutrino sources as a tool for investigation of transition to sterile states

V. N. Gavrin,* V. V. Gorbachev,* E. P. Veretenkin,* and B. T. Cleveland†

20 July 2010

We propose to place a very intense source of ^{51}Cr at the center of a 50–tonne target of gallium metal that is divided into two concentric spherical zones and to measure the neutrino capture rate in each zone. This experiment can set limits on transitions from active to sterile neutrinos with $\Delta m^2 \approx 1$ eV^2 with a sensitivity to disappearance of electron neutrinos of a few percent.

Analysis of neutrino experiments has given convincing evidence of transitions between flavors, i.e., neutrino oscillations. These neutrino transitions are well described in the framework of three neutrino generations with masses m_1, m_2, and m_3 whose mass-squared differences are $\Delta m^2_{12} \approx 8 \times 10^{-5}$ eV^2 ("solar") and $\Delta m^2_{23} \approx 2 \times 10^{-3}$ eV^2 ("atmospheric"). Almost all neutrino experiments can be explained by assuming that there are only these three neutrino generations.

The existence of three dominant neutrino generations has been further proven by experiments at LEP on the decay of the Z_0 boson. The LEP experiment, however, does not rule out the possibility that there may be additional sub-dominant neutrino species and there are some indications that the number of neutrino generations may be more than three. First and foremost is the accelerator experiment LSND whose results can be explained if there are neutrino transitions with $\Delta m^2 \approx 1$ eV^2. Such a large value cannot be obtained with

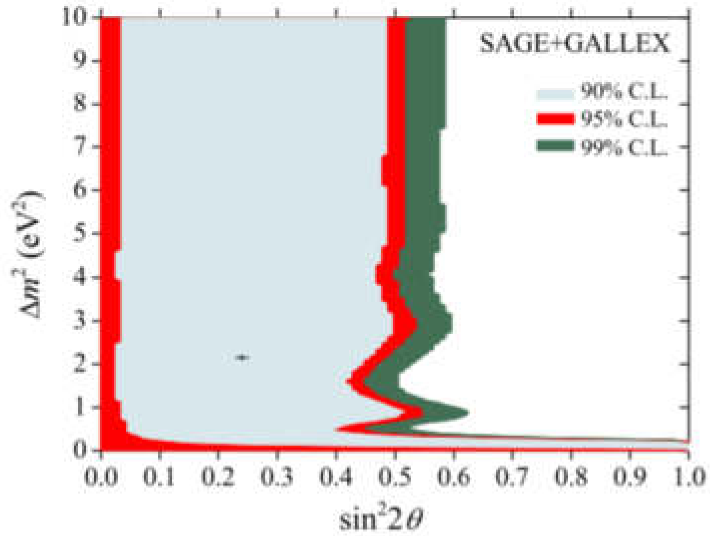
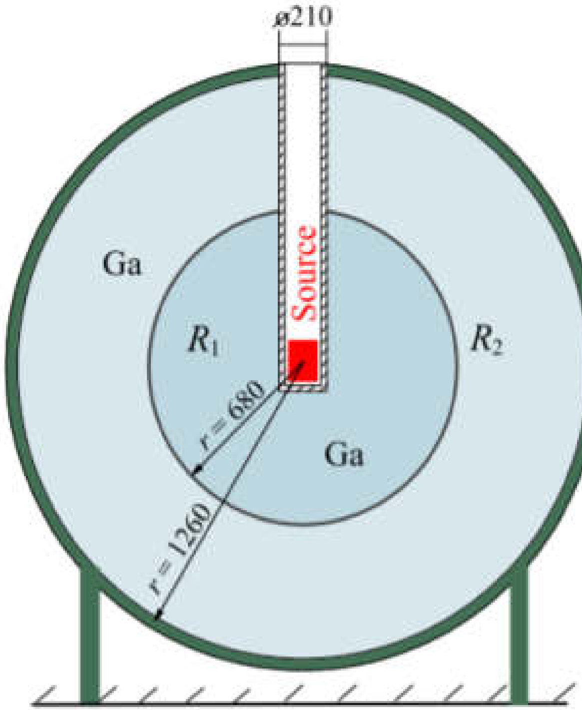


FIG. 1. Region of allowed mixing parameters inferred from gallium source experiments assuming oscillations to a sterile neutrino. Plus sign at $\Delta m^2 = 2.15$ eV^2 and $\sin^2 2\theta = 0.24$ indicates the best-fit point.



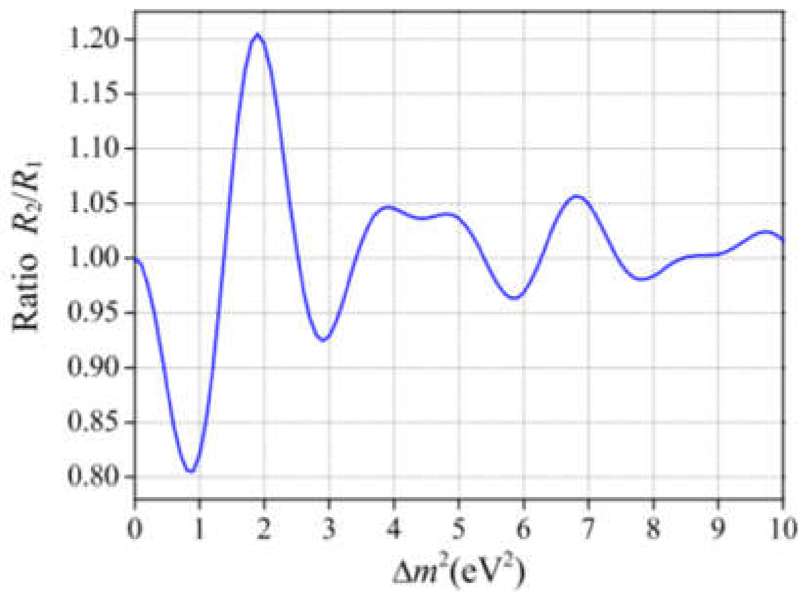


FIG. 3. Ratio of rates in the outer and inner zones versus Δm^2 for the case of $\sin^2 2\theta = 0.3$.

Gavrin (···Ejiri····)

Best Experiment

Cr 50 enriched .97% 4005 gr

Reactor irradiation July 7 3.8.M Ci

Source sent to BNO

Baksan Neutrino Observatory

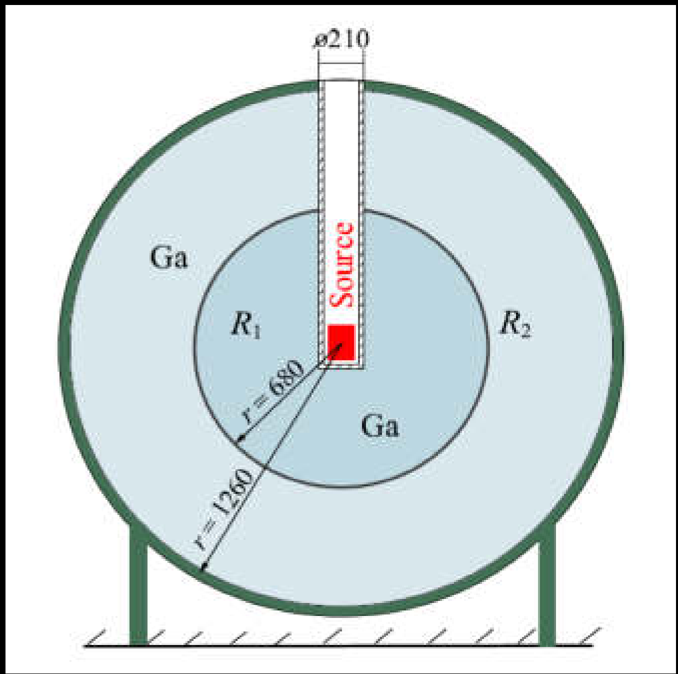
July 12

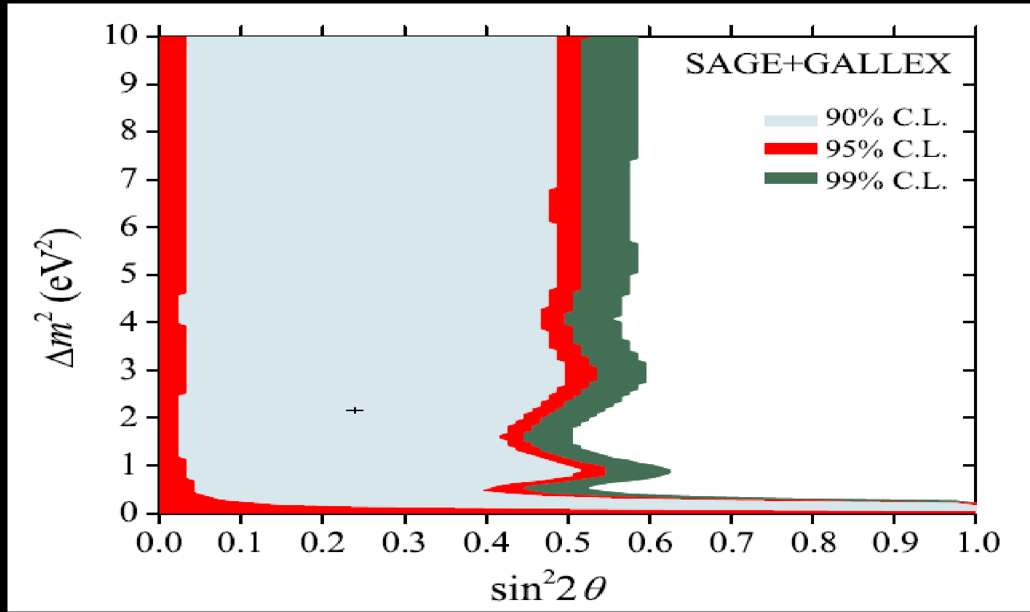

Thanks for your attention　Greenary Nimph 翠の精

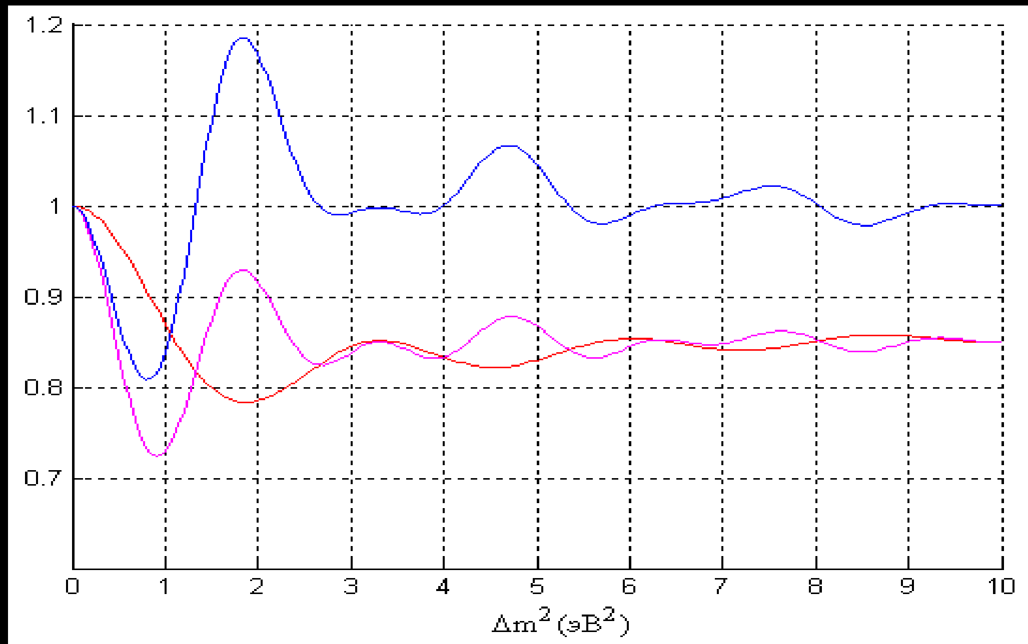
Short range oscillation

V. Gavrin et al. 3 MC Cr51

50t Ga with 40% of Ga71







$Sin^2\ \pi l/L$ L=1.8m at 1eV

$Sin^2 2\theta=0.3$

Inner and outer rates

Reactor anti- ν CPT Sterile

MiniBOONE

No with muon neutrinos,
Excess with anti-muon neutrinos
as LNSD anti-muon yes

arXiev 1007.1150 2010 Sep

Not by 3 ν, but 4; sterile ν

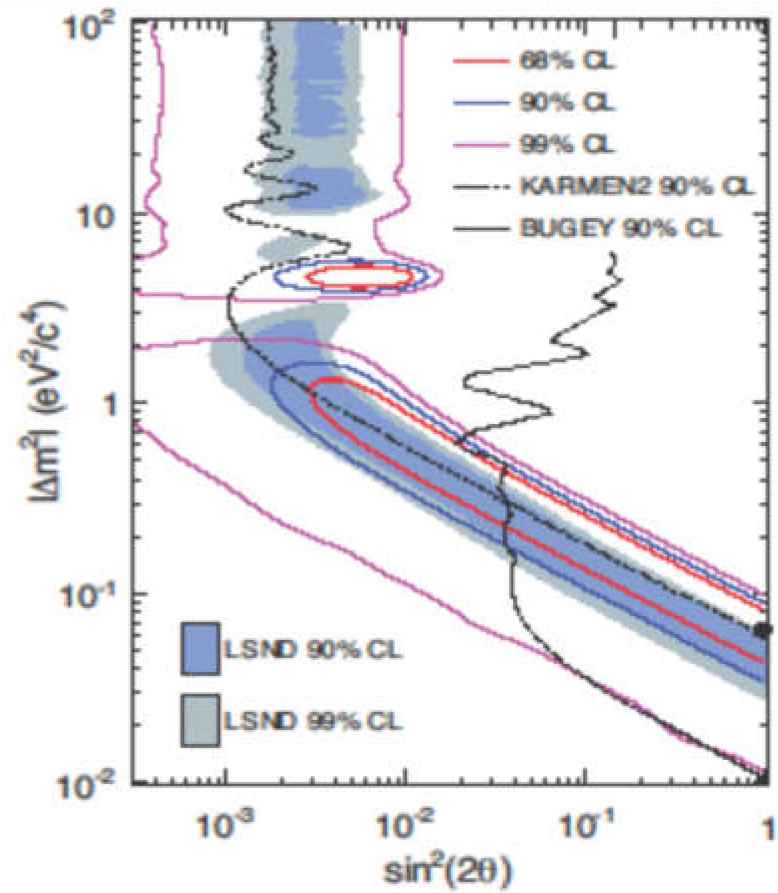
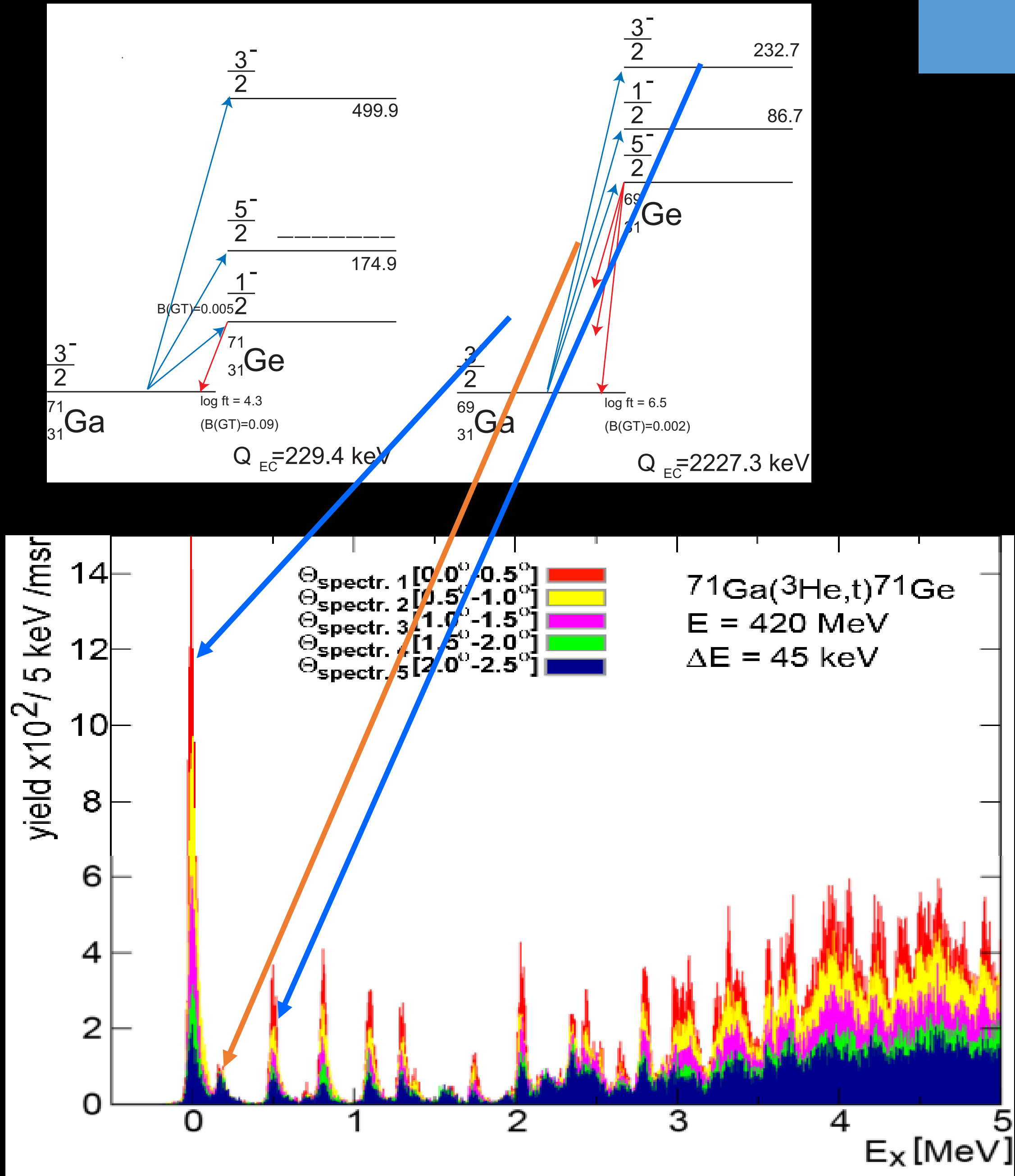
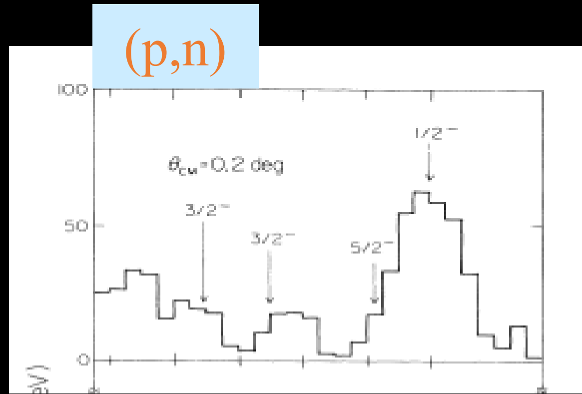
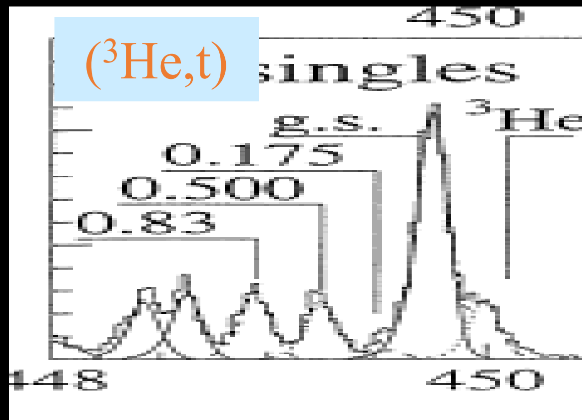


FIG. 3: MiniBooNE 68%, 90%, and 99% C.L. allowed regions for events with $E_\nu^{QE} > 475$ MeV within a two neutrino $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$ oscillation model. Also shown are limits from KARMEN [15] and Bugey [25]. The Bugey curve is a 1-sided limit for $\sin^2 2\theta$ corresponding to $\Delta\chi^2 = 1.64$, while the KARMEN curve is a "unified approach" 2D contour. The shaded areas show the 90% and 99% C.L. LSND allowed regions. The black dot shows the best fit point.





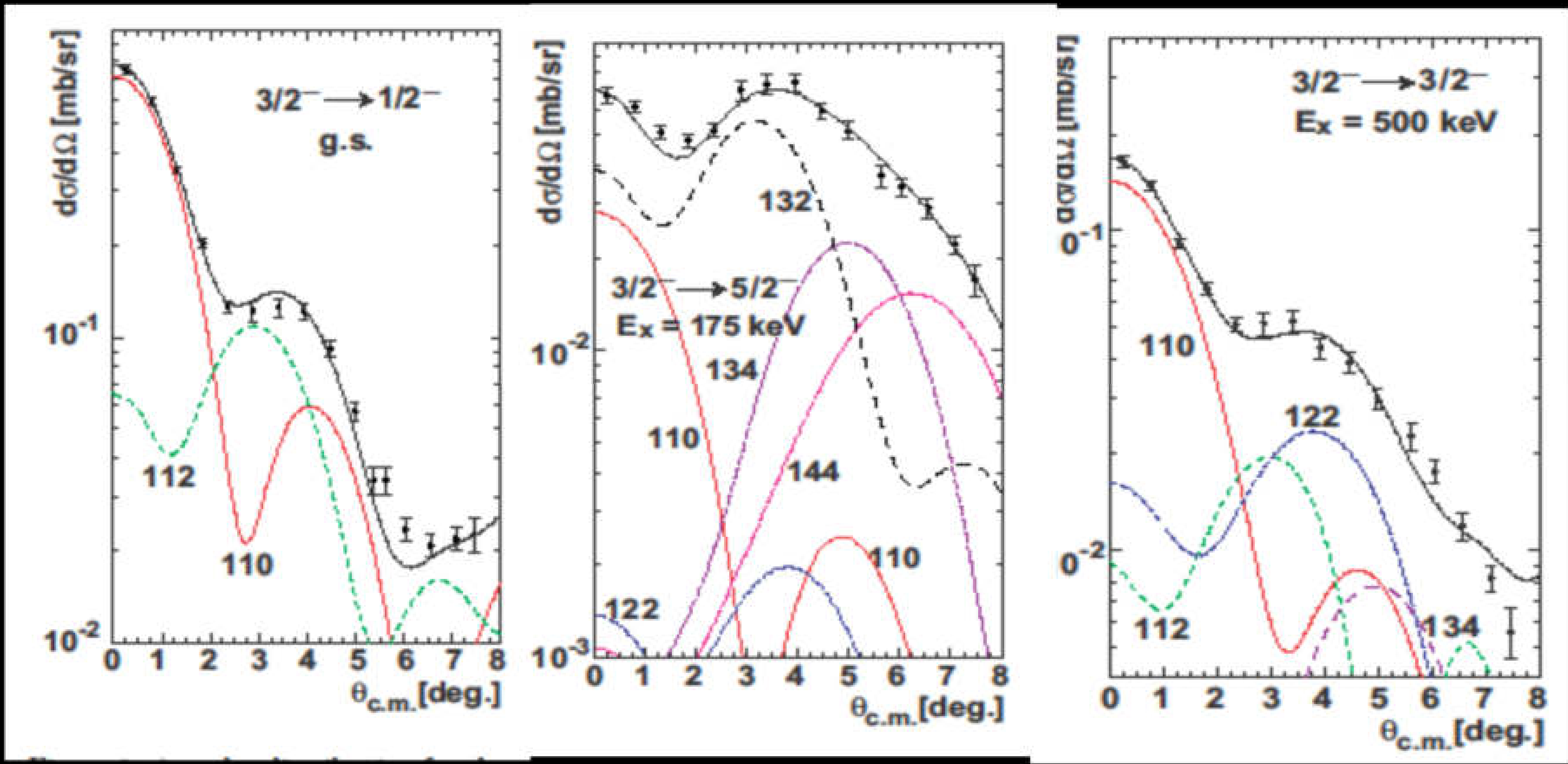


RCNP 2005

RCNP 1995

Non-GT in CER $\sigma(q\sim0) = \Sigma\sigma(J_p, J_T, J_R) = \sigma(110) + \sigma(112) + \ldots$

$^{71}Ga \rightarrow {}^{71}Ge$ Ground state 1/2 known B(GT)



1. 3/2 → 1/2 is mainly (J_p, J_T, J_R)=(110), which is lkely to be GT
2. 3/2 → 5/2 is not (110), which is unlikely GT
3. 3/2 → 3/2 is partially (110), which is partially GT.

Summary

$$d\sigma_{110}/d\omega = k\,B(110) = (2J_i+1)^{-1}\,[M(\sigma) + \delta\,M(Y_2 \times \sigma)_1]^2$$

State MeV	dσ/dω mb q=0	dσ/dω mb (110)	B(GT)	Ratio of ^{51}Cr
1/2 0	0.79	0.72	0.083 0.0865*	1.0
5/2 0.175	0.071	< 0.03	0.002±0.002 [a])	0.015 ±0.015
3/2 0.500	0.18	0.15	0.017±0.003 [b])	0.04±0.007

* Beta decay rate consistent

1. Contribution of the 2 excited states : ~ 0.055±0.03 (preliminary).

B(GT) = B(GT gr) + 0.66 B(GT 175) + 0.22B(GT 500)

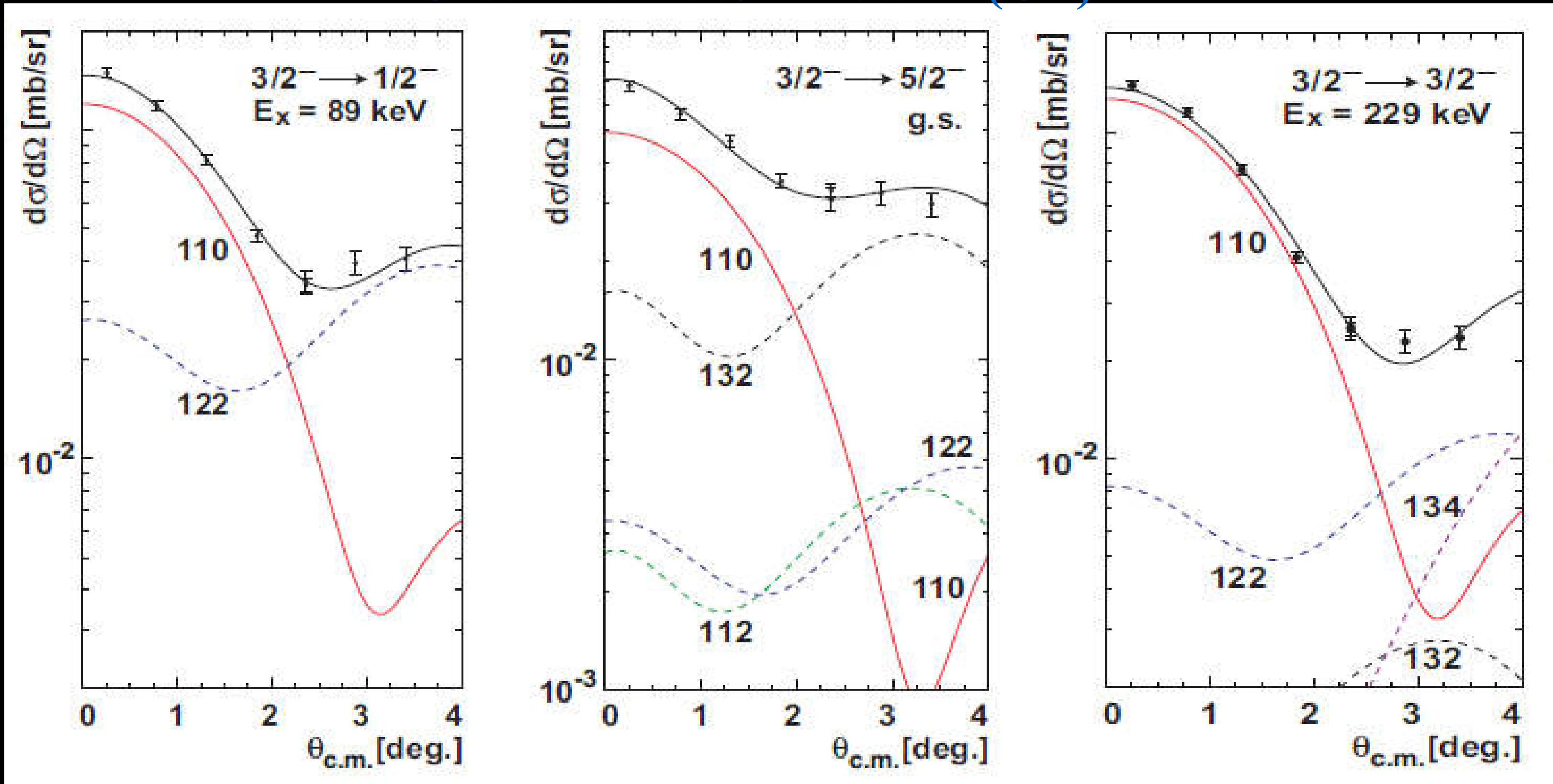
2. B(GT) is consistent with those in this mass region
   a) 3/2-5/2 p-f forbidden B(GT) = 0.002± 0.002 very small
   b) 3/2 – 3/ p-p allowed 0.015±0.005 non-zero

3. Small contribution of 5/2 is supported by the data of ^{69}Ga 3/2-5/2.

Deviation 10% is likely due to the Ga-detectors or new oscillations

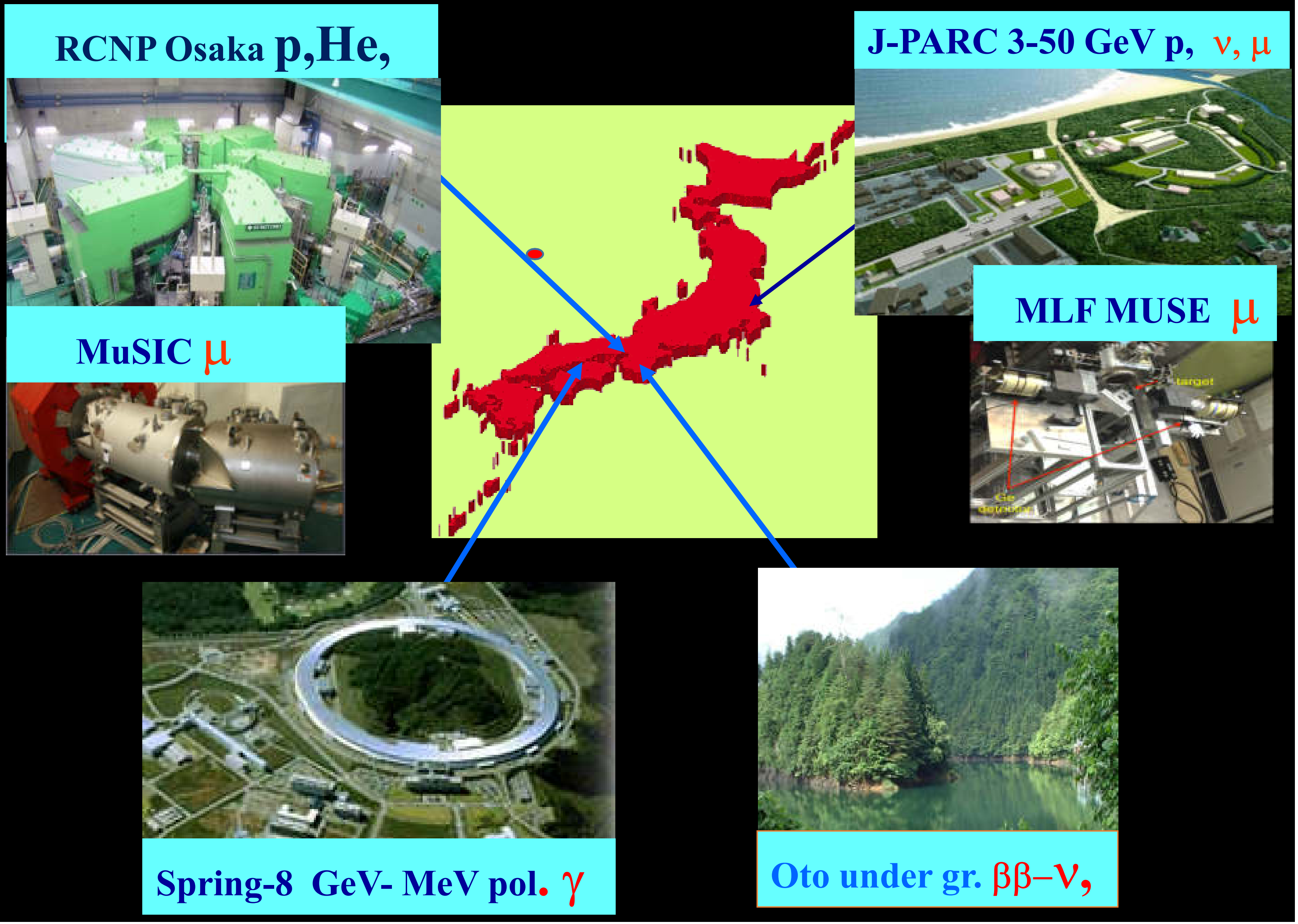
$^{69}Ga \rightarrow ^{69}Ge$

Ground state 5/2 known B(GT)



1. 3/2 → **1/2 is mainly σ(J_p, J_T, J_R)=σ(110), which is likely to be GT**
2. **3/2 → 5/2 is 60% σ(110). B(110) ~ 0.005, M(110) ~ 0.015, M(σ) = 0.086**
3. **3/2 → 3/2 is mainly σ(110), which is mainly GT.** **β–decay B(GT) = 0.0015**

RI production by RCNP/Osaka

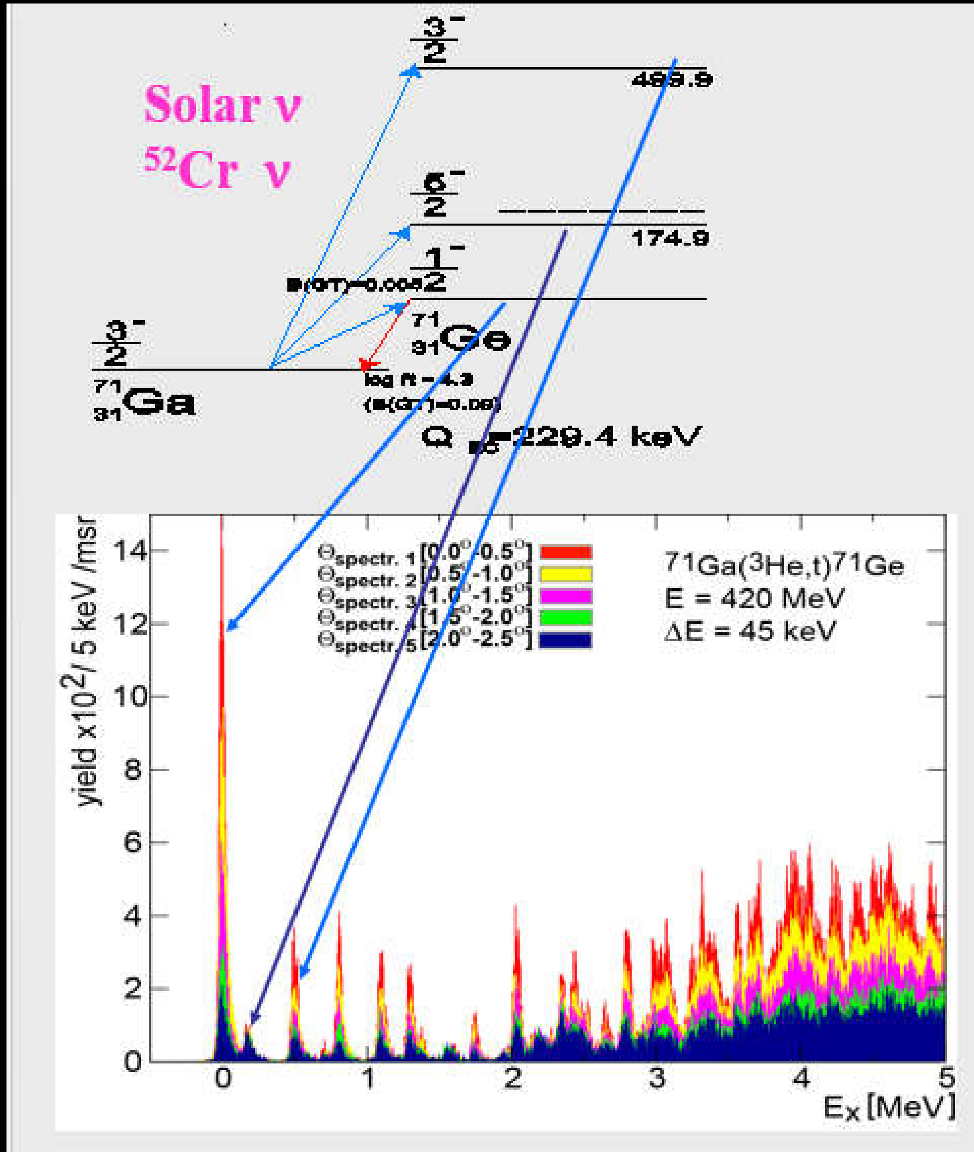


^{71}Ga neutrino response for ^{51}Cr and sterile ν ?

Ga SAGE Gallex EXPs
for ^{51}Cr ^{37}Ar neutrinos
Exp. average / Theory
=0.87 ±0.05

1. GT response ?
2. Detector calibration ?
3. Sterile ν oscillation ?

Ga res. theory by Bahcall
Ga res. exp. (^{3}He,t) RCNP

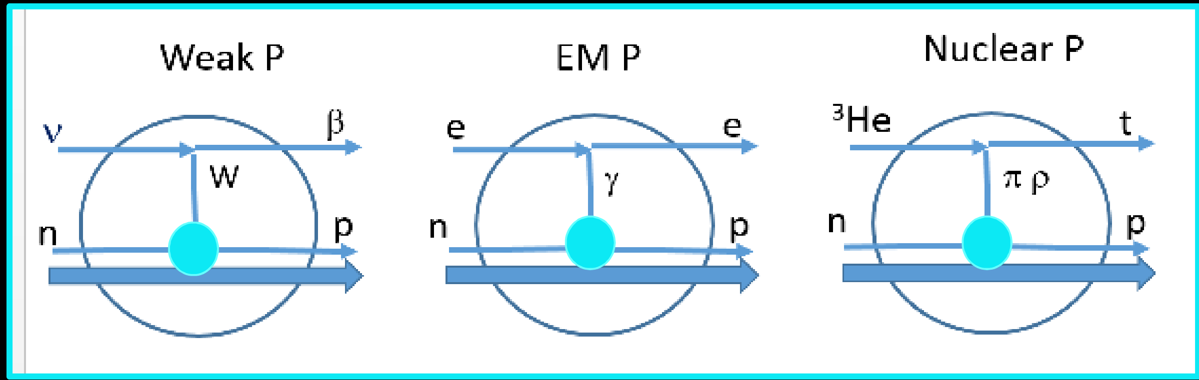


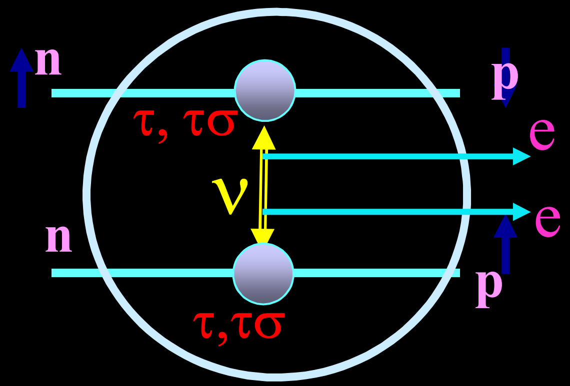
1998 H. Ejiri PL B 433 257
2011 Frekers Ejiri Gavrin et al. PL B 706 134 (2011)

CERs for CC

$M = g^2_A M_{DA} - g^2_F M_D$

Sensitive to NN, NΔ/π nuclear medium effects

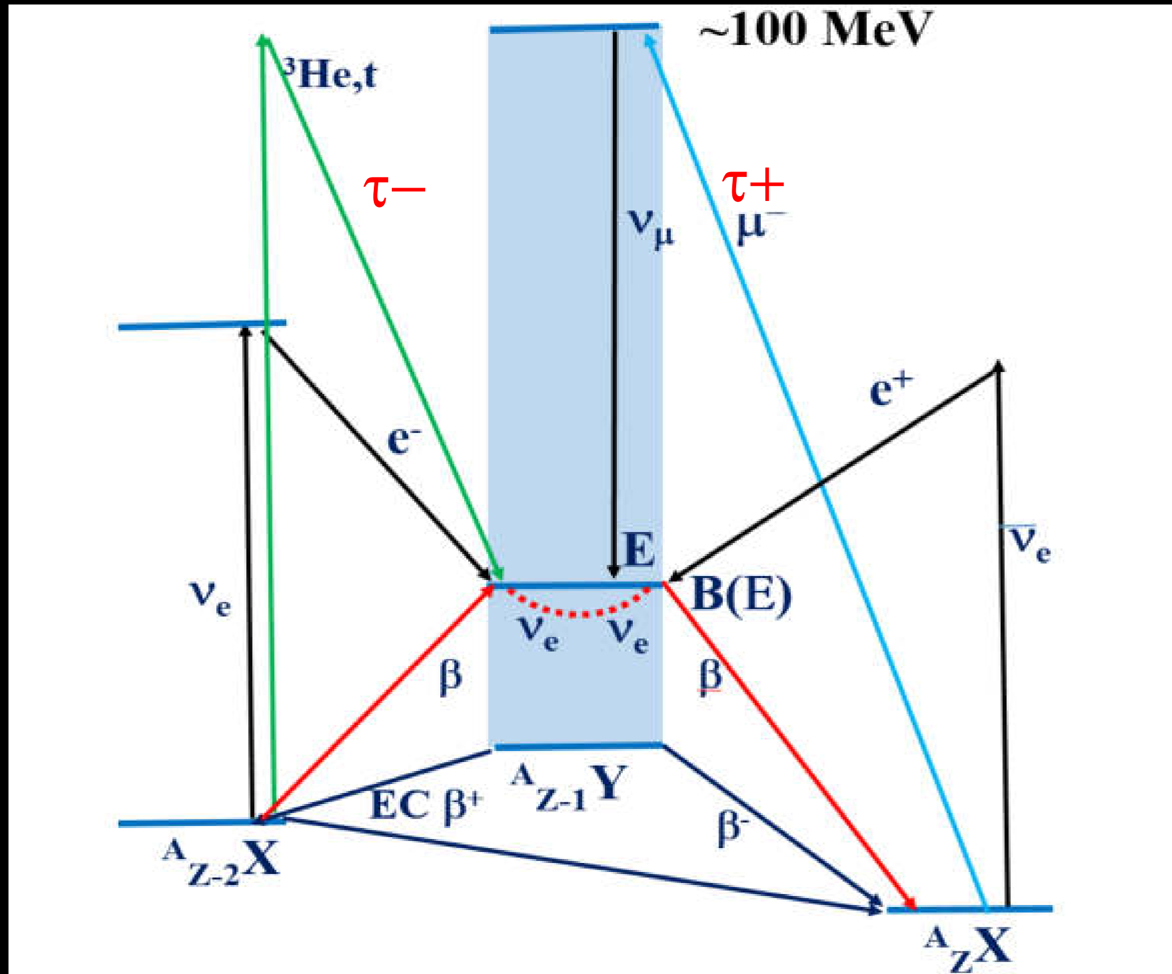




M(EXP) =g_AM

M(EXP) = g_FM

to help calculations



L-forbidden CER

- $|i\rangle = a\,|p3/2\ 2^+\rangle + b\,|p3/2\rangle$
- $|f\rangle = a'|p1/2\ 2^+\rangle + b'|f5/2\rangle$

$$T(CER) = \tau\sigma + \delta\tau(\sigma\times Y_2)_1$$

$\delta \sim 0.1$

^{69}Ga

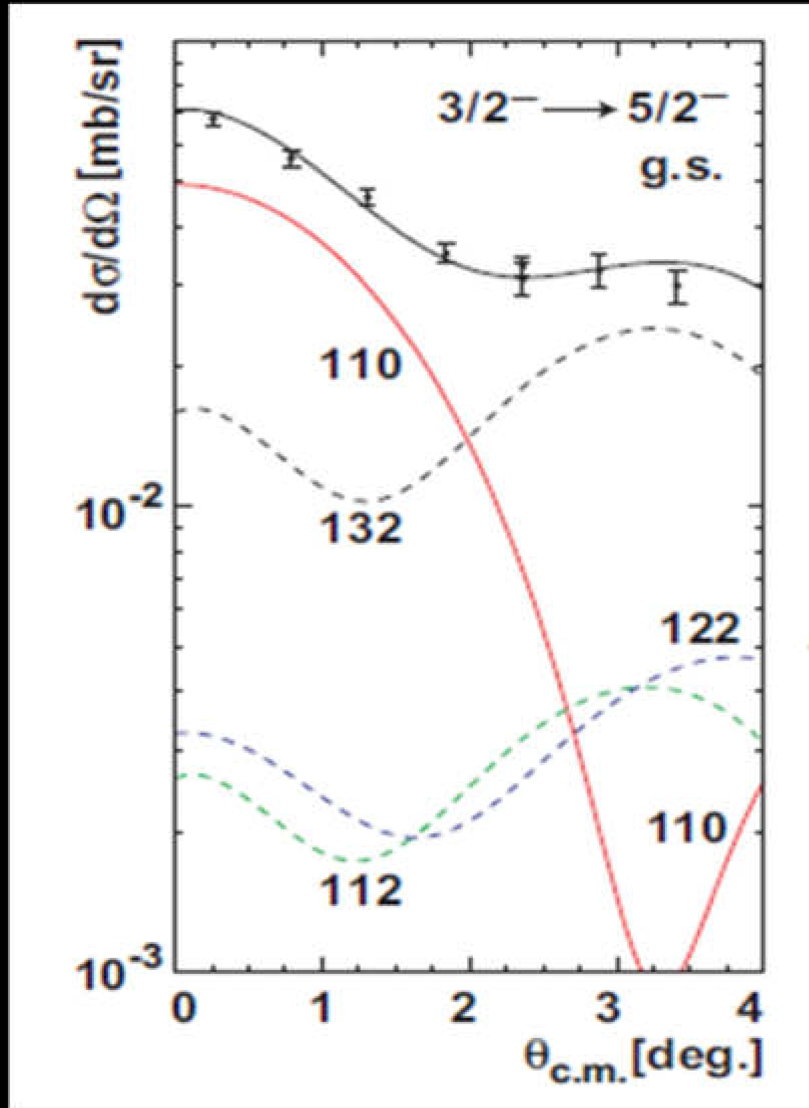
$M(110) = M(\tau\sigma) + 0.1M(\sigma\times Y_2)$

$0.015 = 0.085 + 0.065$

CER **β-decay** **deduced**

^{71}G

$M(110) = 0.01,\ M(\tau\sigma) < 0.1$



^{69}Gr(^{3}He,t)