



UNIVERSITÀ DEGLI STUDI  
DI TRENTO

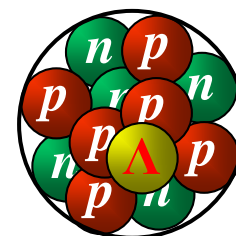
Dipartimento di Fisica



120 ANNI  
1872-2012

# 103° CONGRESSO NAZIONALE della SOCIETÀ ITALIANA DI FISICA

Trento, 11-15 settembre 2017



***L'energia di legame degli ipernuclei  $\Lambda$   
e  
la possibile violazione della simmetria di carica  
nell'interazione forte iperone-nucleone***

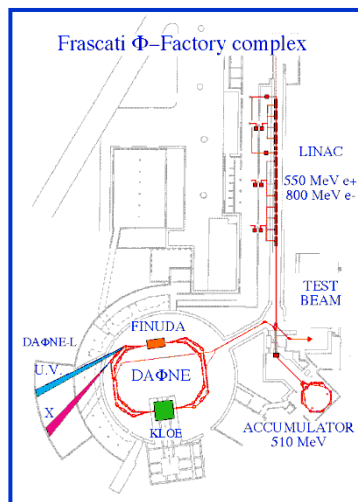
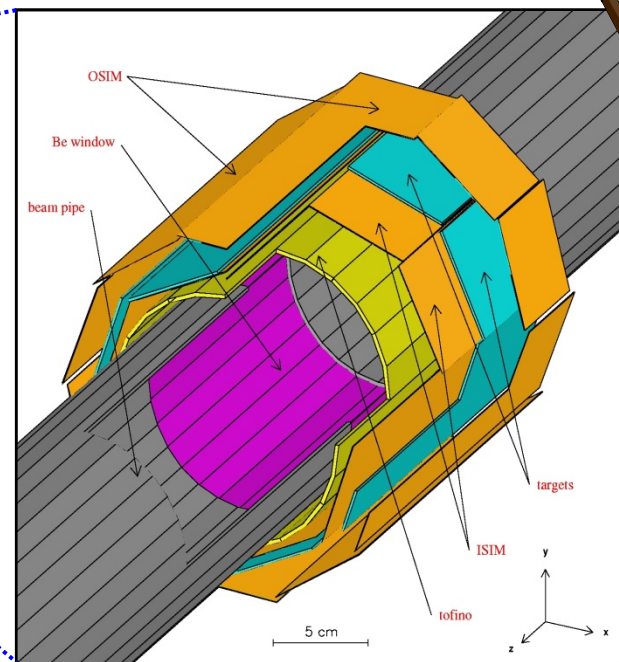
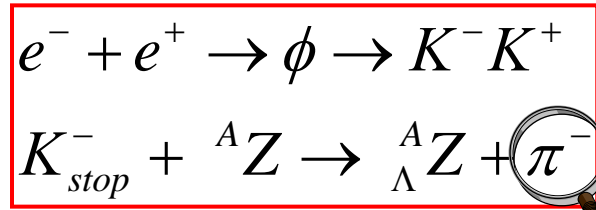
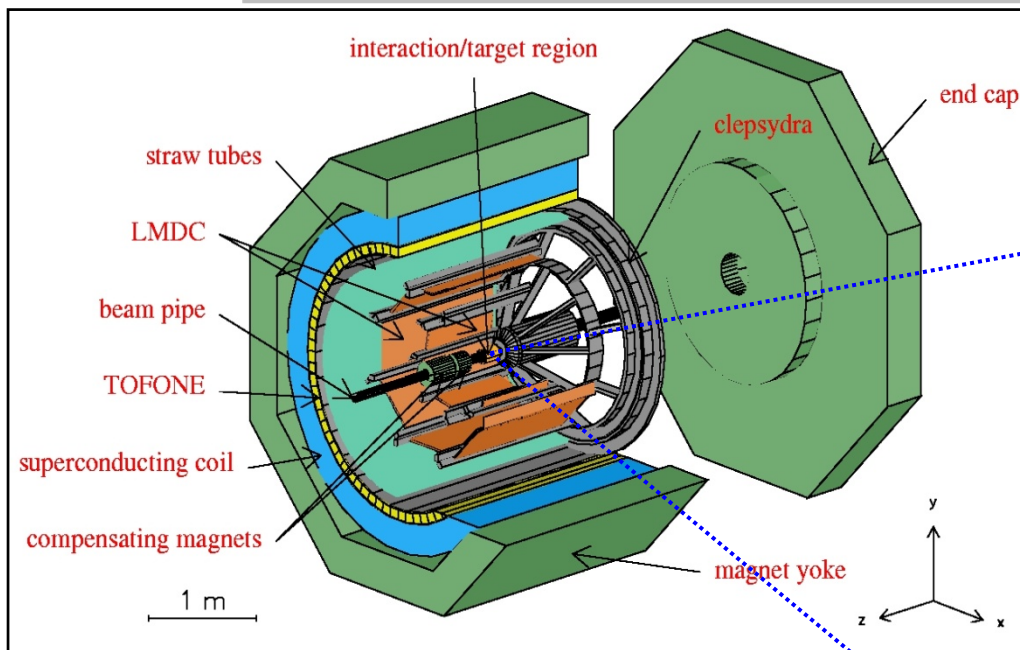
*Alessandro Feliciello*



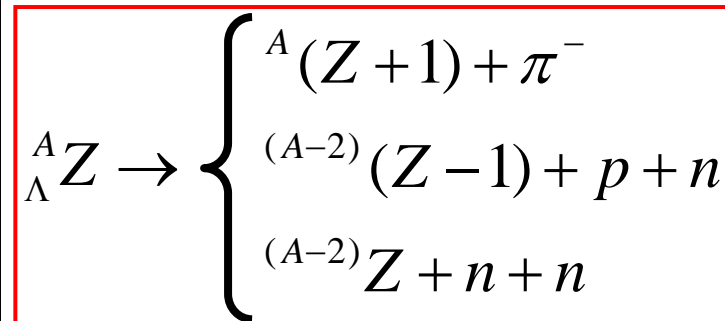
Istituto Nazionale di Fisica Nucleare  
SEZIONE DI TORINO

# Outline

- ❖ The **FINUDA** experiment @ **LNf**
- ❖ **Physics results** about hypernucleus **binding energy**
- ❖ **Impact** on the possible **C**harge **S**ymmetry **B**reaking effect in hyperon-nucleon **strong interaction**
  - 👉 **p-shell** hypernuclei
  - 👉 **s-shell** hypernuclei (preliminary)



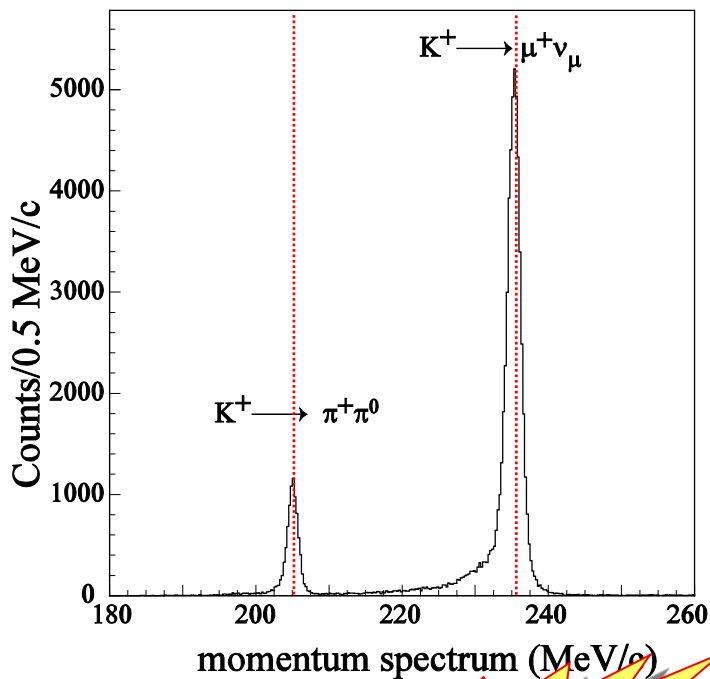
energy	510 MeV
luminosity	$5 \cdot 10^{32} \text{ cm}^{-2} \text{ s}^{-1}$
$\sigma_x$ (rms)	2.11 mm
$\sigma_y$ (rms)	0.021 mm
$\sigma_z$ (rms)	35 mm
bunch length	30 mm
crossing angle	12.5 mrad
frequency (max)	368.25 MHz
bunch/ring	up to 120
part./bunch	$8.9 \cdot 10^{10}$
current/ring	5.2 A (max)



# The absolute energy scale

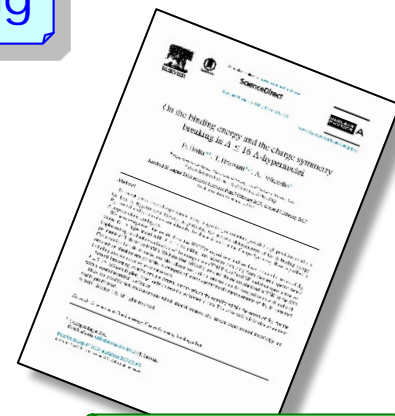
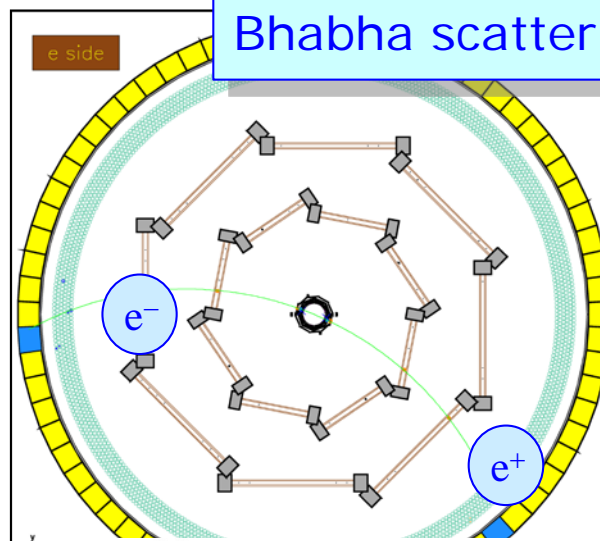


$K^+$  two body decays:  
benchmark for spectrometer  
energy calibration

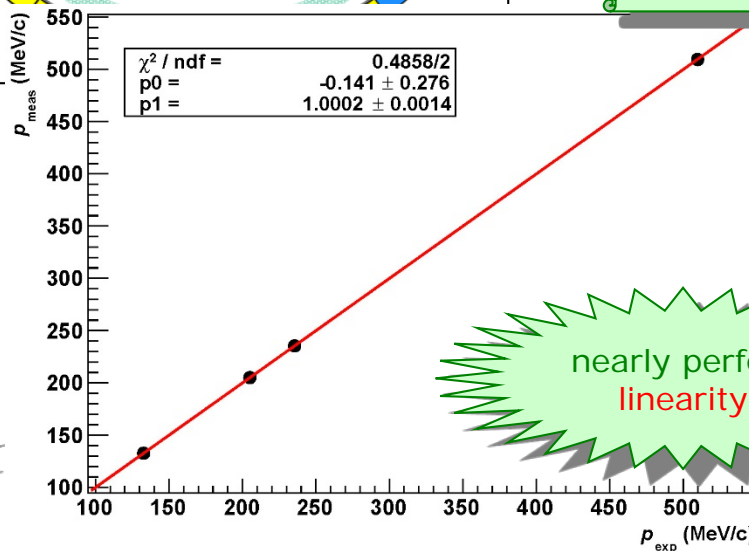


**copiously available**  
( $\sim 10^3 \times$  YN rate)

## Bhabha scattering



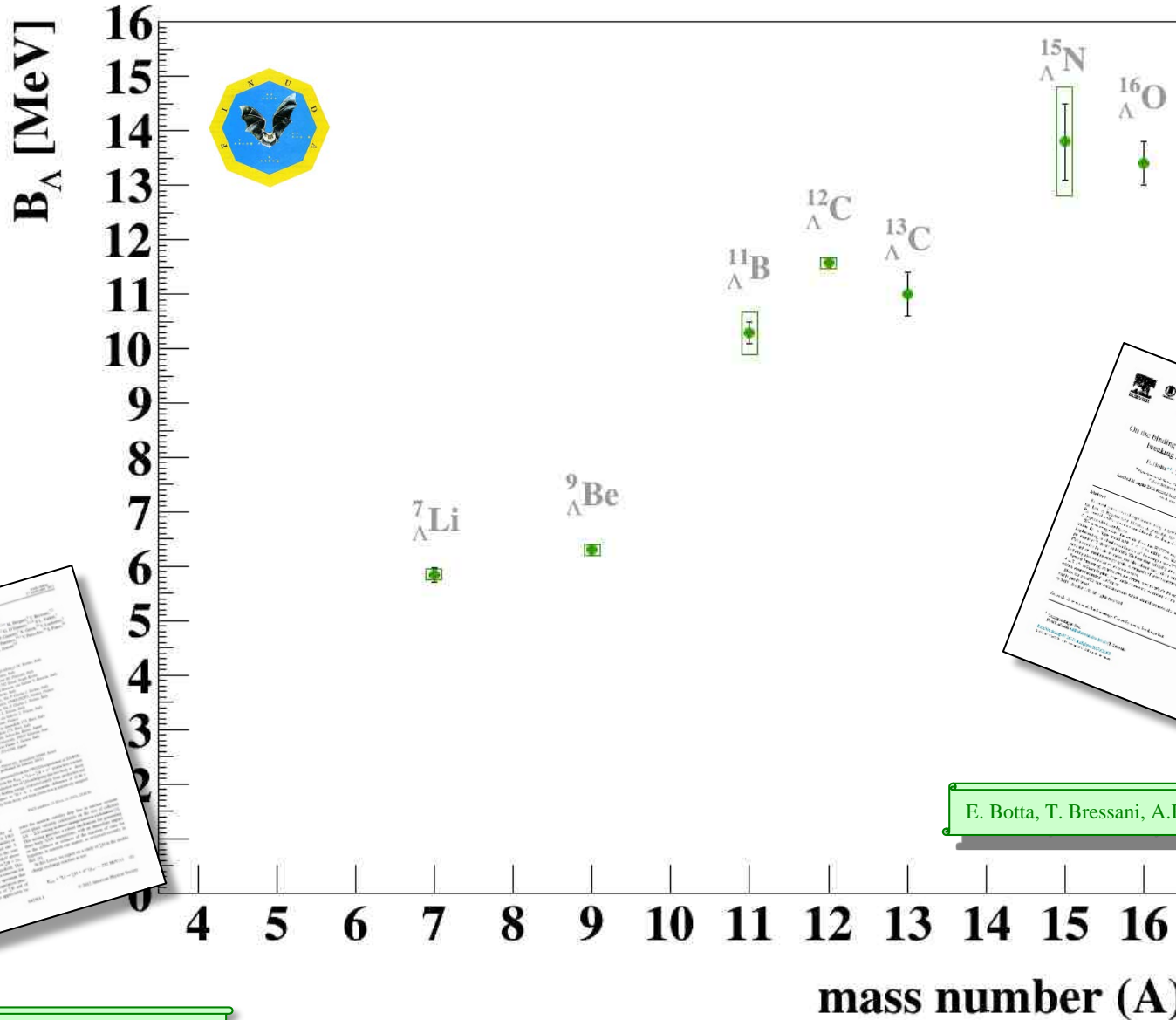
E. Botta, T. Bressani, A.F.,  
NPA 960 (2017) 165



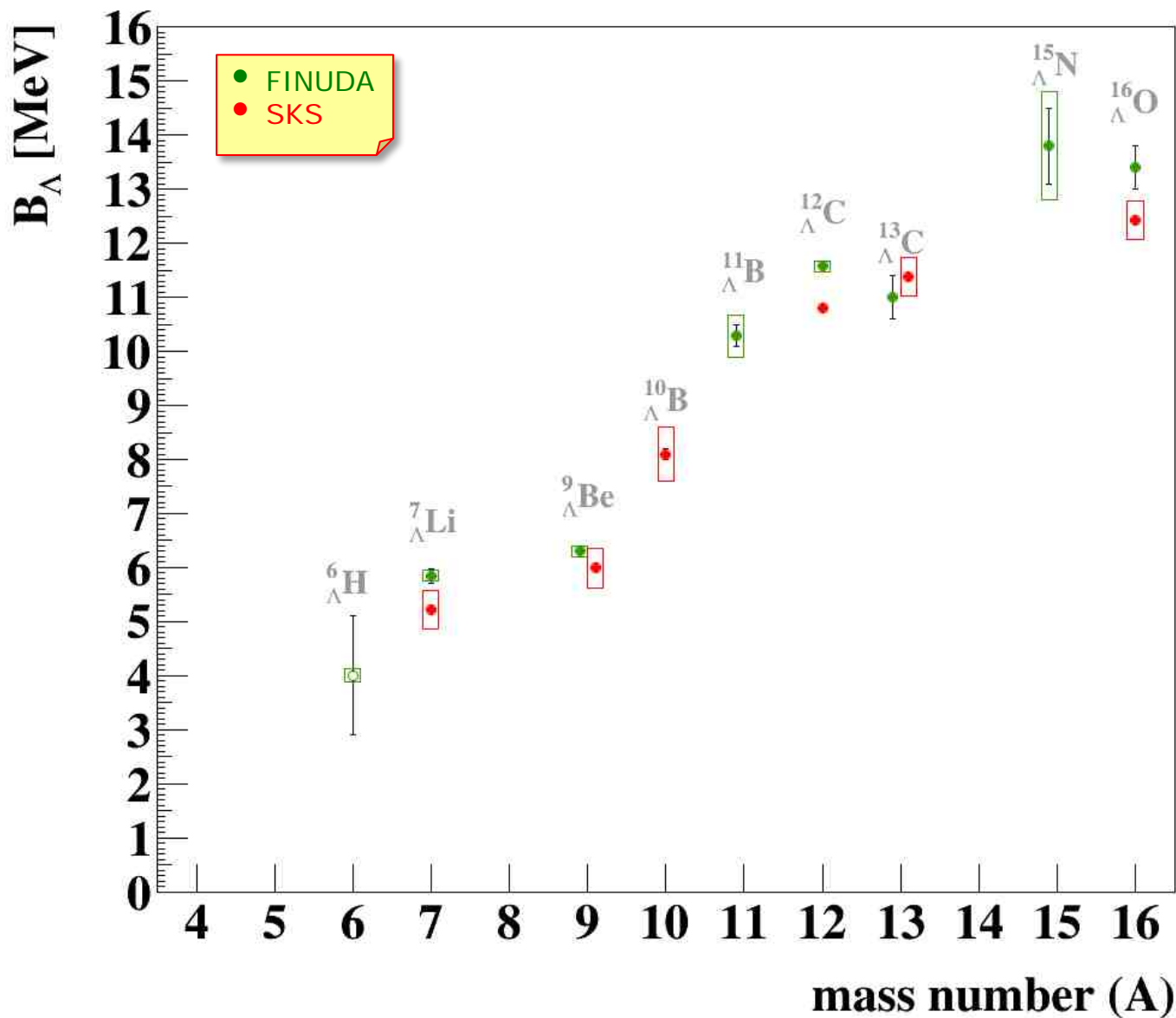
Reaction	$P_{\text{exp}}$ (MeV/c)	$P_{\text{meas}}$ (MeV/c)	$P_{\text{meas}} - P_{\text{exp}}$ (MeV/c)
${}^4\text{H} \rightarrow \pi^- + {}^4\text{He}$	$132.9 \pm 0.1$ [16]	$132.738 \pm 0.038$	$-0.16 \pm 0.11$
$K^+ \rightarrow \pi^+ + \pi^0$	$205.138$ [23]	$205.10 \pm 0.01$	$-0.038 \pm 0.010$
$K^+ \rightarrow \mu^+ + \nu_\mu$	$235.535$ [23]	$235.410 \pm 0.002$	$-0.125 \pm 0.002$
$\phi \rightarrow e^+ e^-$	$509.730$ [23]	$509.5 \pm 5.0$	$-0.23 \pm 5.00$



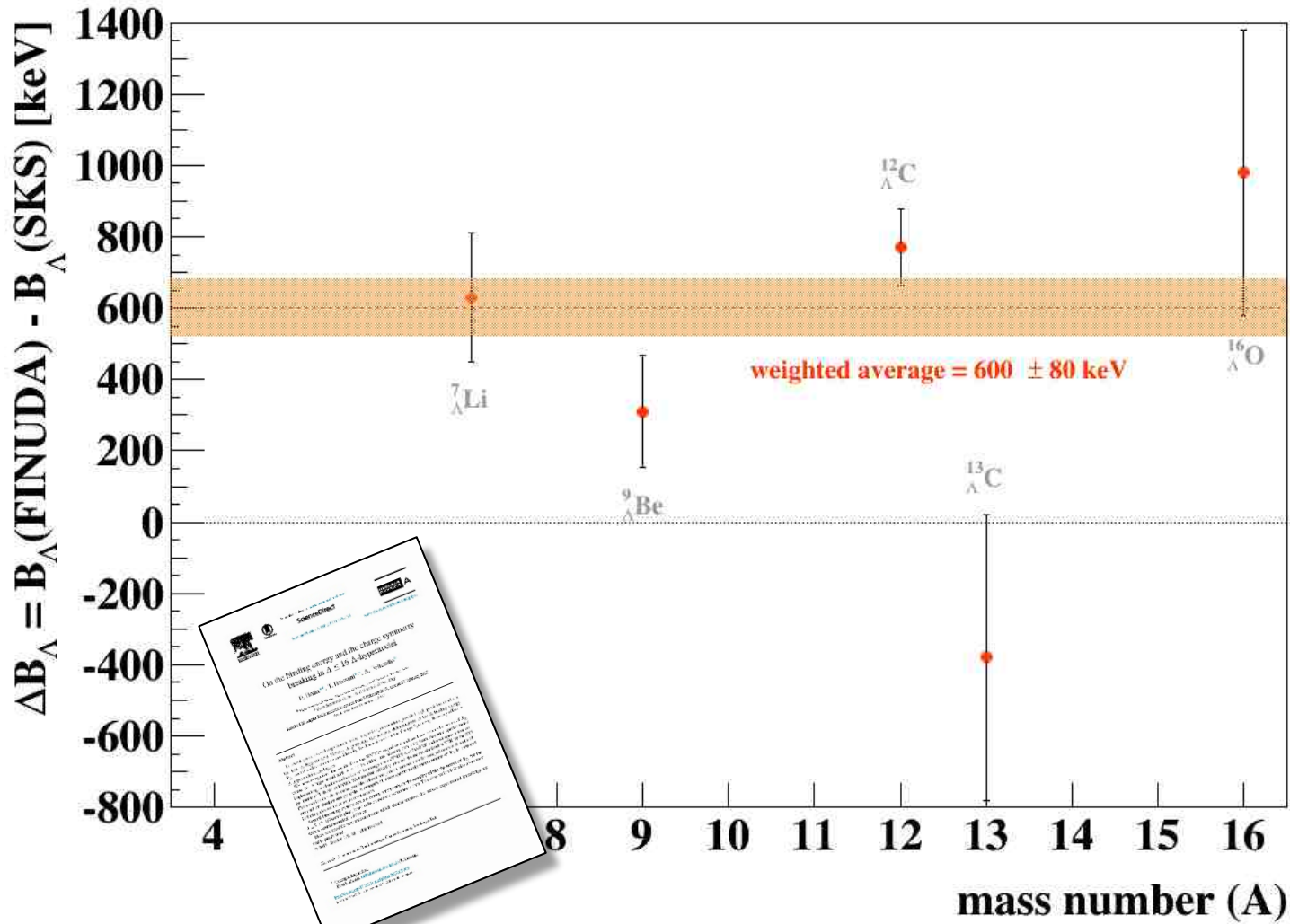
# $B_\Lambda$ for $p$ -shell $\Lambda$ -hypernuclei by FINUDA



# Comparison with SKS @ KEK results



# FINUDA vs. SKS results



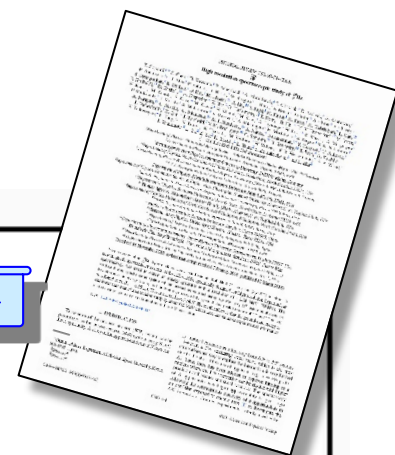
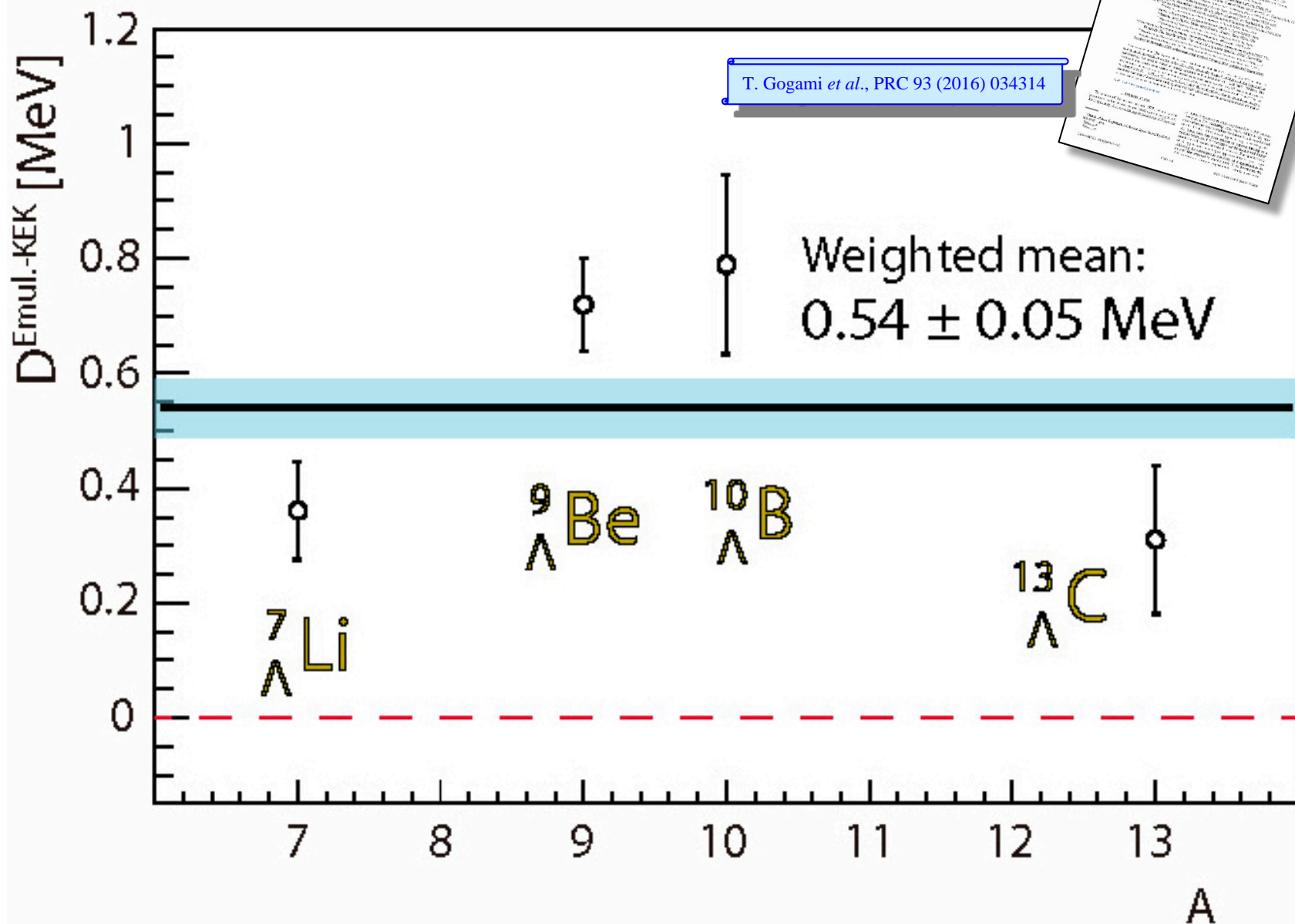
E. Botta, T. Bressani, A.F., NPA 960 (2017) 165



A. Gal, E.V. Hungerford, D.J. Millener, RMP 88 (2016) 035004

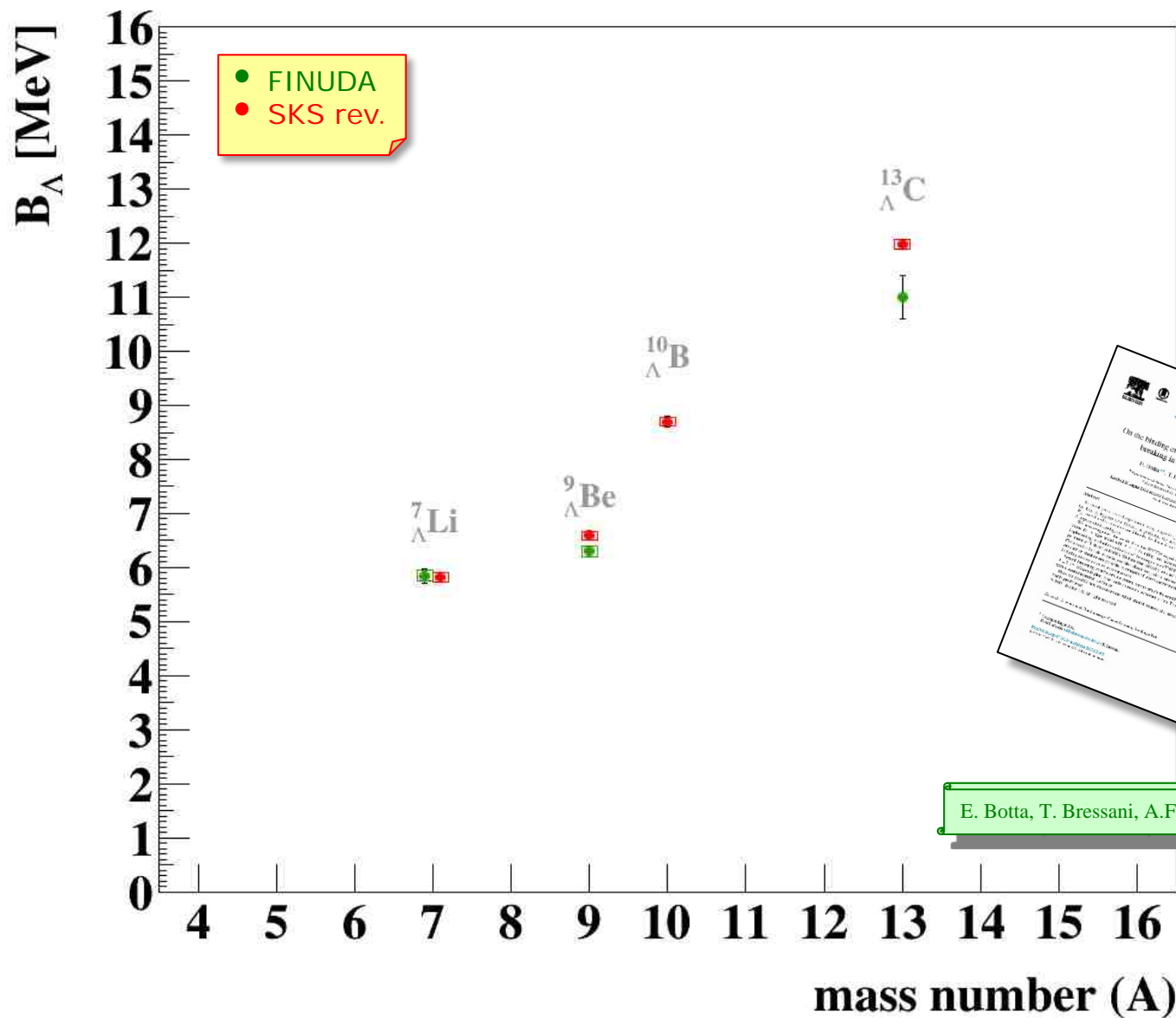
$\Delta B_{\Lambda} = +600$  keV

# SKS vs. emulsions results





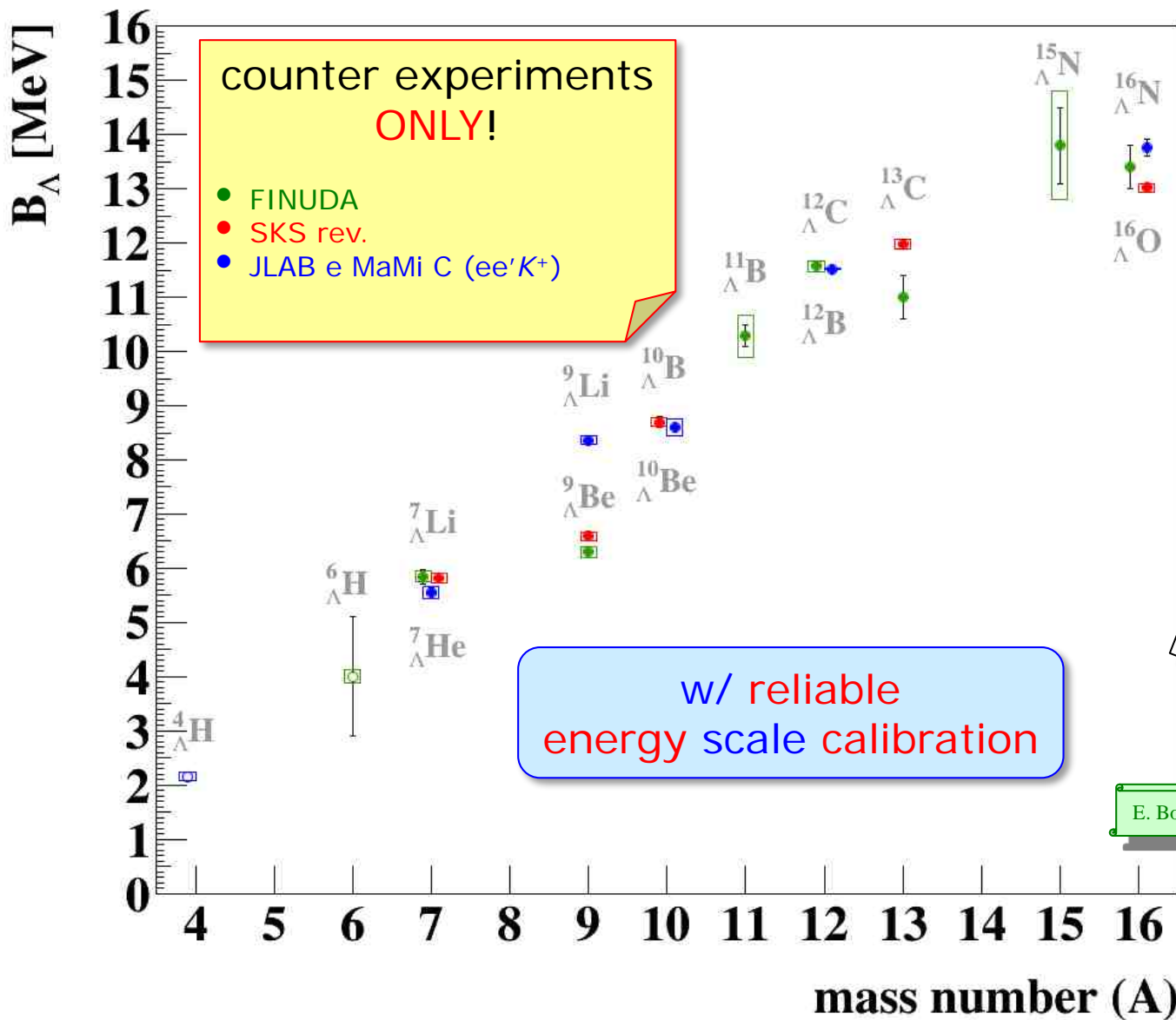
# SKS data revised



E. Botta, T. Bressani, A.F., NPA 960 (2017) 165



# World $\Lambda$ -hypernucleus $B_\Lambda$ compilation

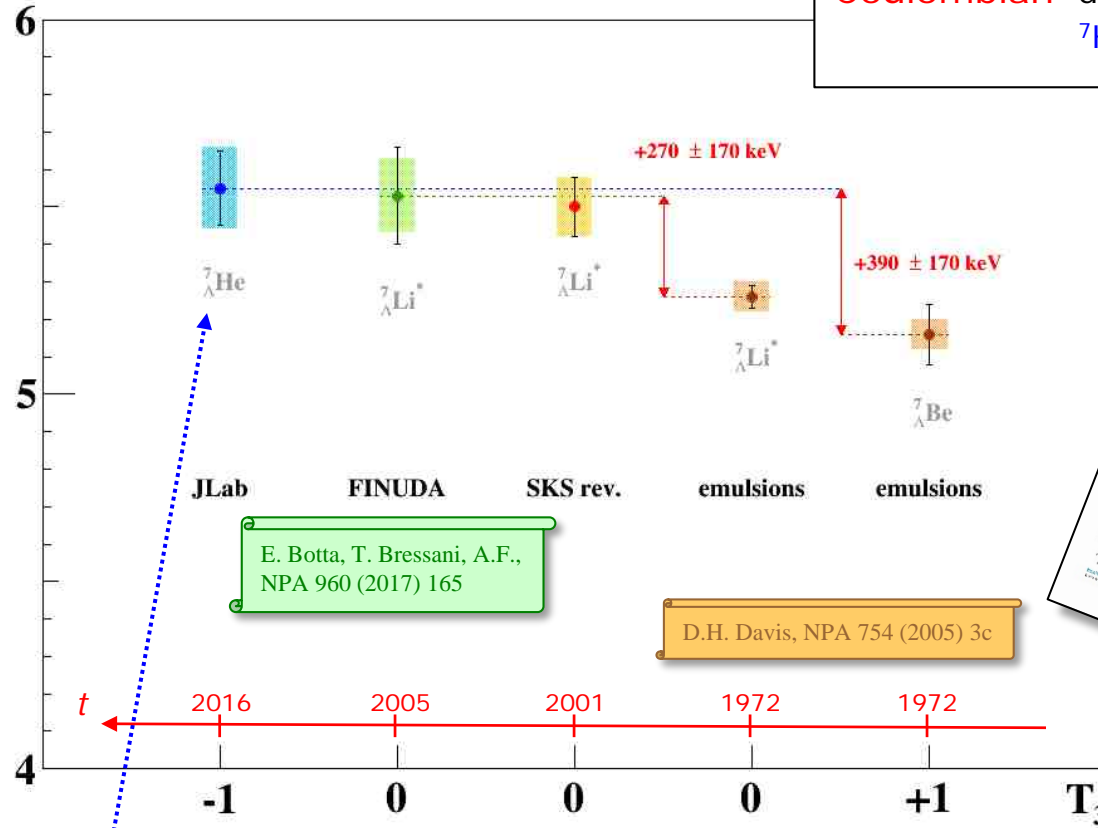


E. Botta, T. Bressani, A.F., NPA 960 (2017) 165

# CSB in $A = 7, T = 1$ $\Lambda$ -hypernuclei?

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$B_\Lambda (A = 7, T = 1 \text{ systems}) [\text{MeV}]$



offset between emulsions and counters experiments values

Coulombian differential shrink of  ${}^7\text{He}_\Lambda$  and  ${}^7\text{Be}_\Lambda$  cores ( $\sim 150$  keV)

E. Hiyama *et al.*, PRC 80 (2009) 054321



E. Botta, T. Bressani, A.F., NPA 960 (2017) 165

D.H. Davis, NPA 754 (2005) 3c

E. Botta, T. Bressani, A.F., NPA 960 (2017) 165

updated value from:

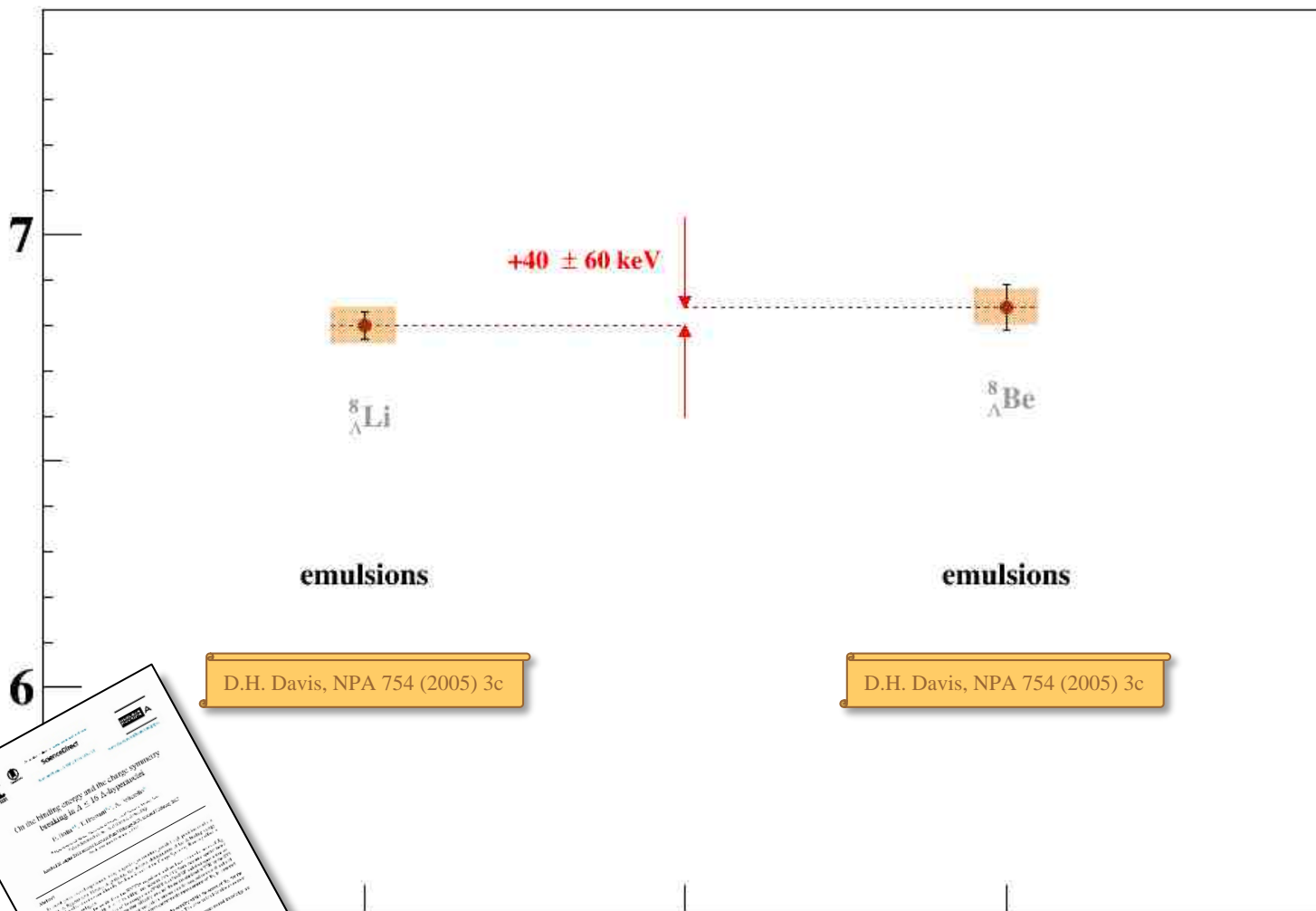
T. Gogami *et al.*, PRC 94 (2016) 021302

th. prediction: -17 keV

A. Gal, PLB 744 (2015) 352

# CSB in $A = 8$ , $T = 1/2$ $\Lambda$ -hypernuclei?

$B_\Lambda$  ( $A = 8$  systems) [MeV]



D.H. Davis, NPA 754 (2005) 3c

D.H. Davis, NPA 754 (2005) 3c

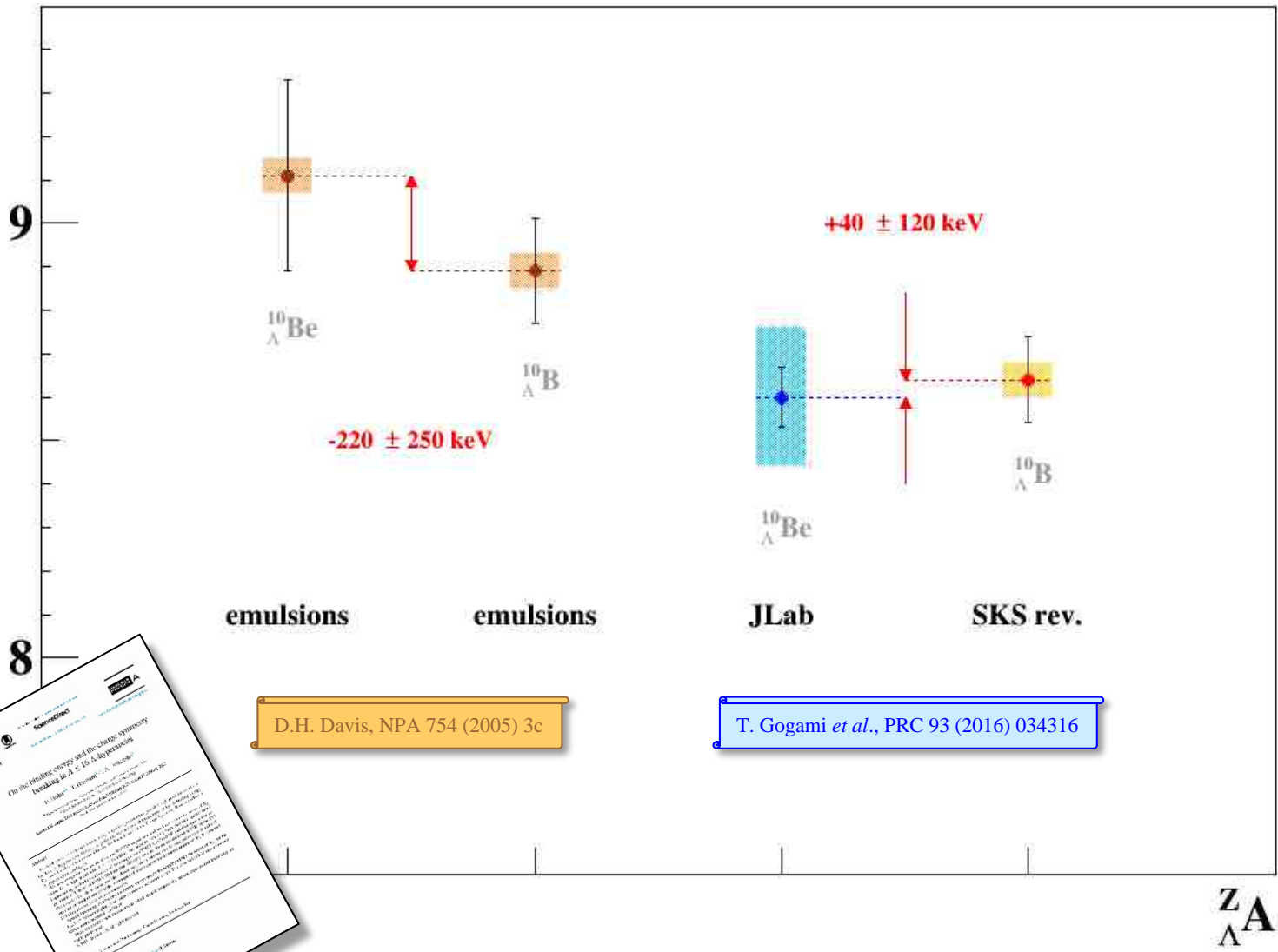
th. prediction: +49 keV

A. Gal, PLB 744 (2015) 352

E. Botta, T. Bressani, A.F., NPA 960 (2017) 165

# CSB in $A = 10, T = 1/2$ $\Lambda$ -hypernuclei?

$B_{\Lambda}$  ( $A = 10$  systems) [MeV]



emulsions

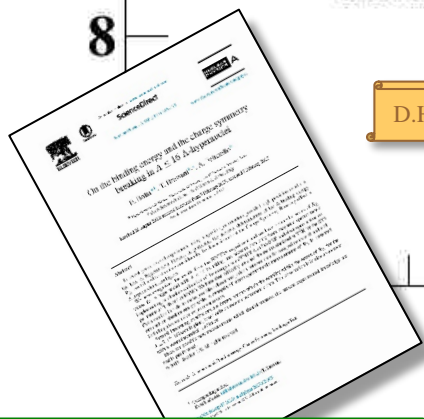
emulsions

JLab

SKS rev.

D.H. Davis, NPA 754 (2005) 3c

T. Gogami *et al.*, PRC 93 (2016) 034316



th. prediction:  $-136$  keV

E. Botta, T. Bressani, A.F., NPA 960 (2017) 165

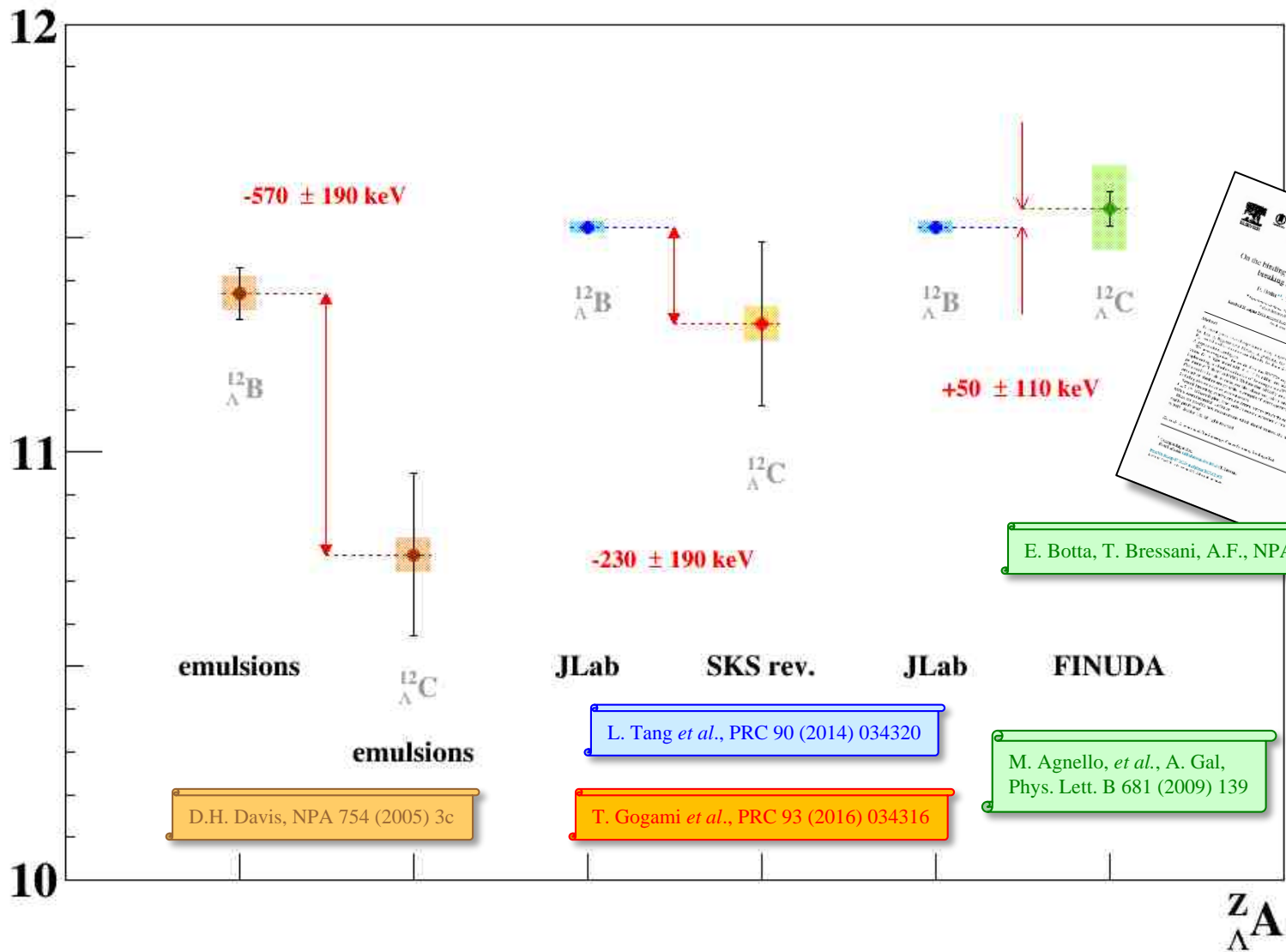
A. Gal, PLB 744 (2015) 352

$Z_A$



# CSB in $A = 12, T = 1/2$ $\Lambda$ -hypernuclei?

$B_{\Lambda}$  ( $A = 12$  systems) [MeV]



E. Botta, T. Bressani, A.F., NPA 960 (2017) 165

L. Tang *et al.*, PRC 90 (2014) 034320

T. Gogami *et al.*, PRC 93 (2016) 034316

M. Agnello, *et al.*, A. Gal, Phys. Lett. B 681 (2009) 139

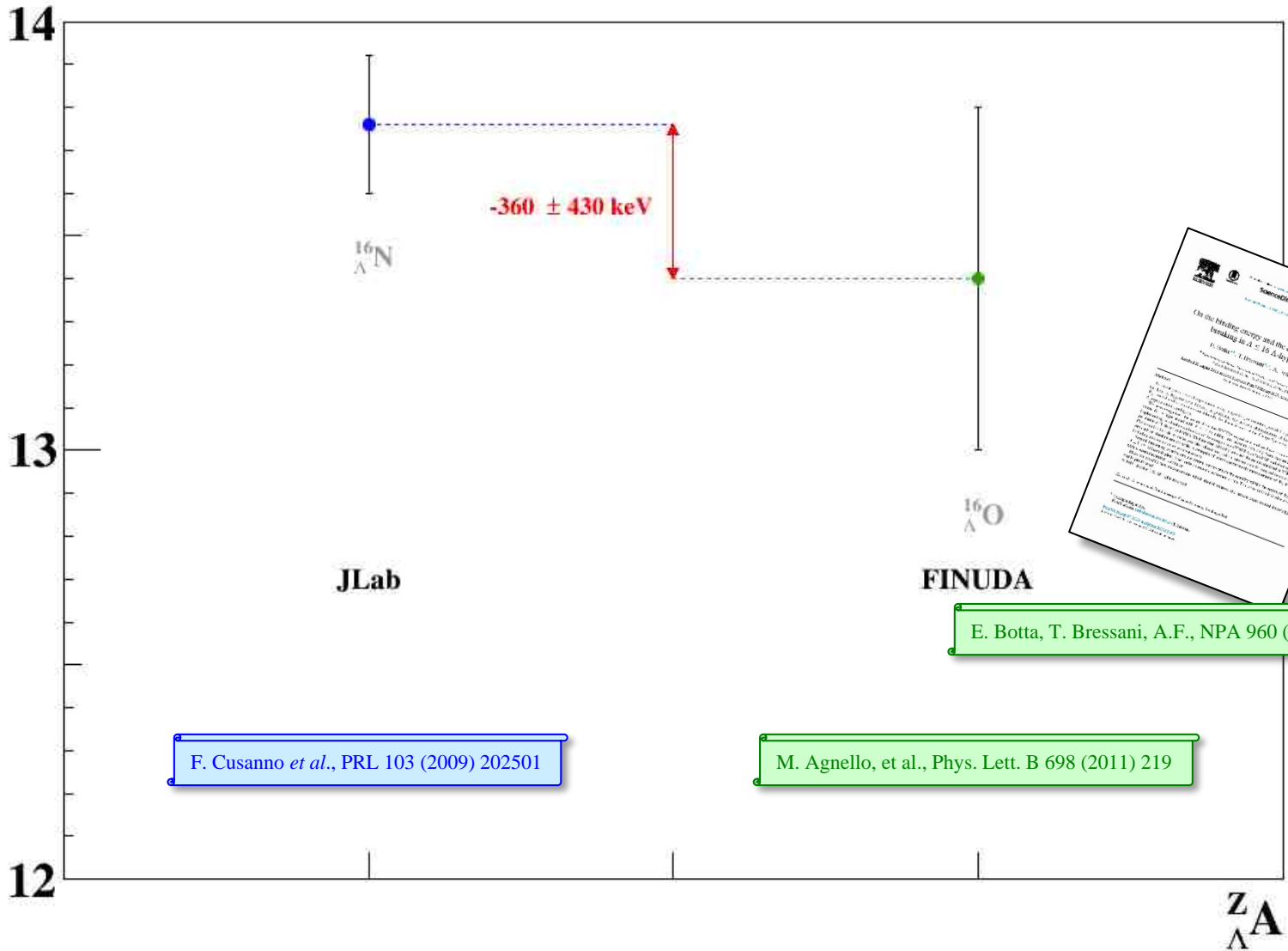
D.H. Davis, NPA 754 (2005) 3c

A. Gal, PLB 744 (2015) 352

th. prediction:  $\leq +50$  keV

# CSB in $A = 16$ , $T = 1/2$ $\Lambda$ -hypernuclei?

$B_{\Lambda}$  ( $A = 16$  systems) [MeV]

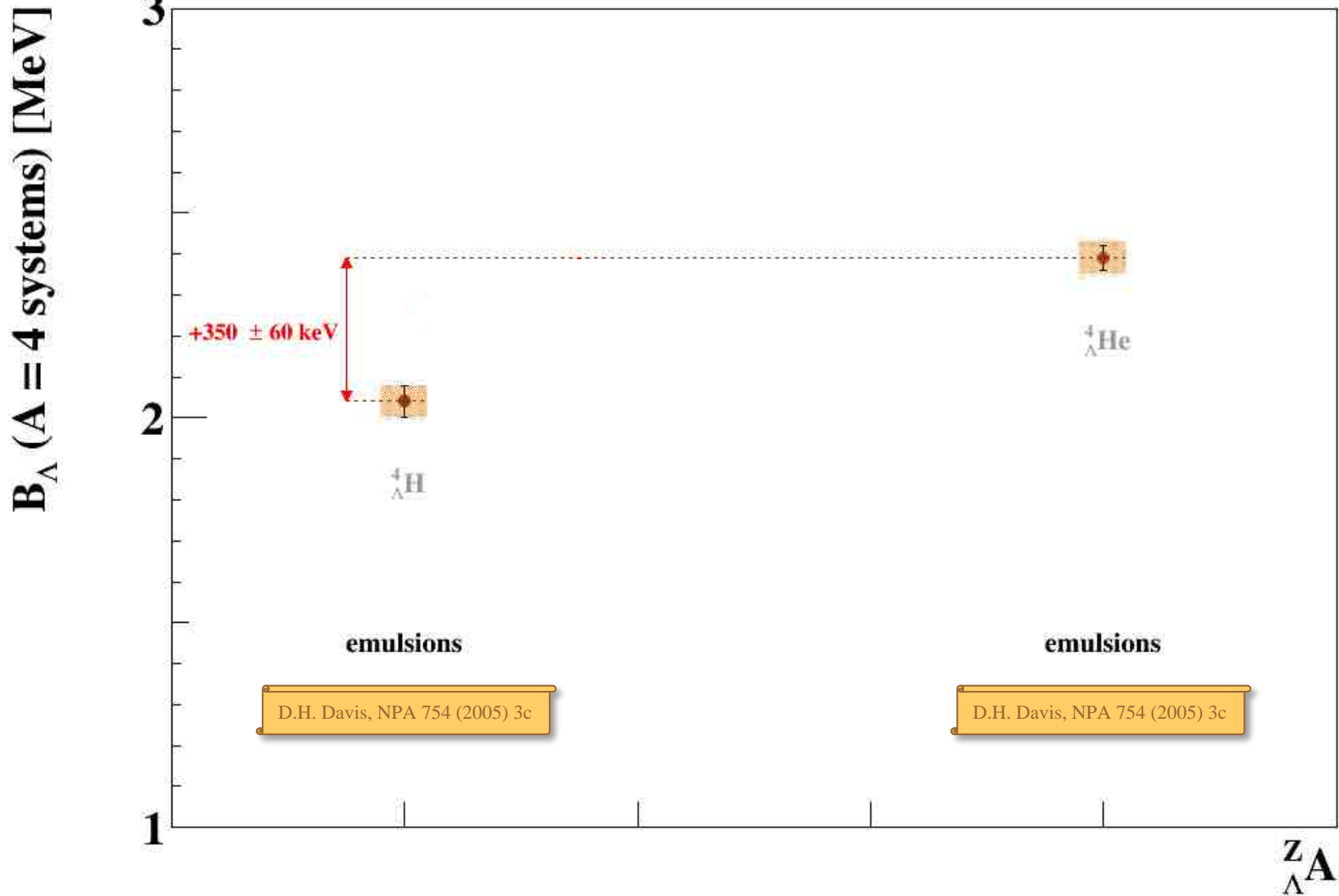


E. Botta, T. Bressani, A.F., NPA 960 (2017) 165

F. Cusanno *et al.*, PRL 103 (2009) 202501

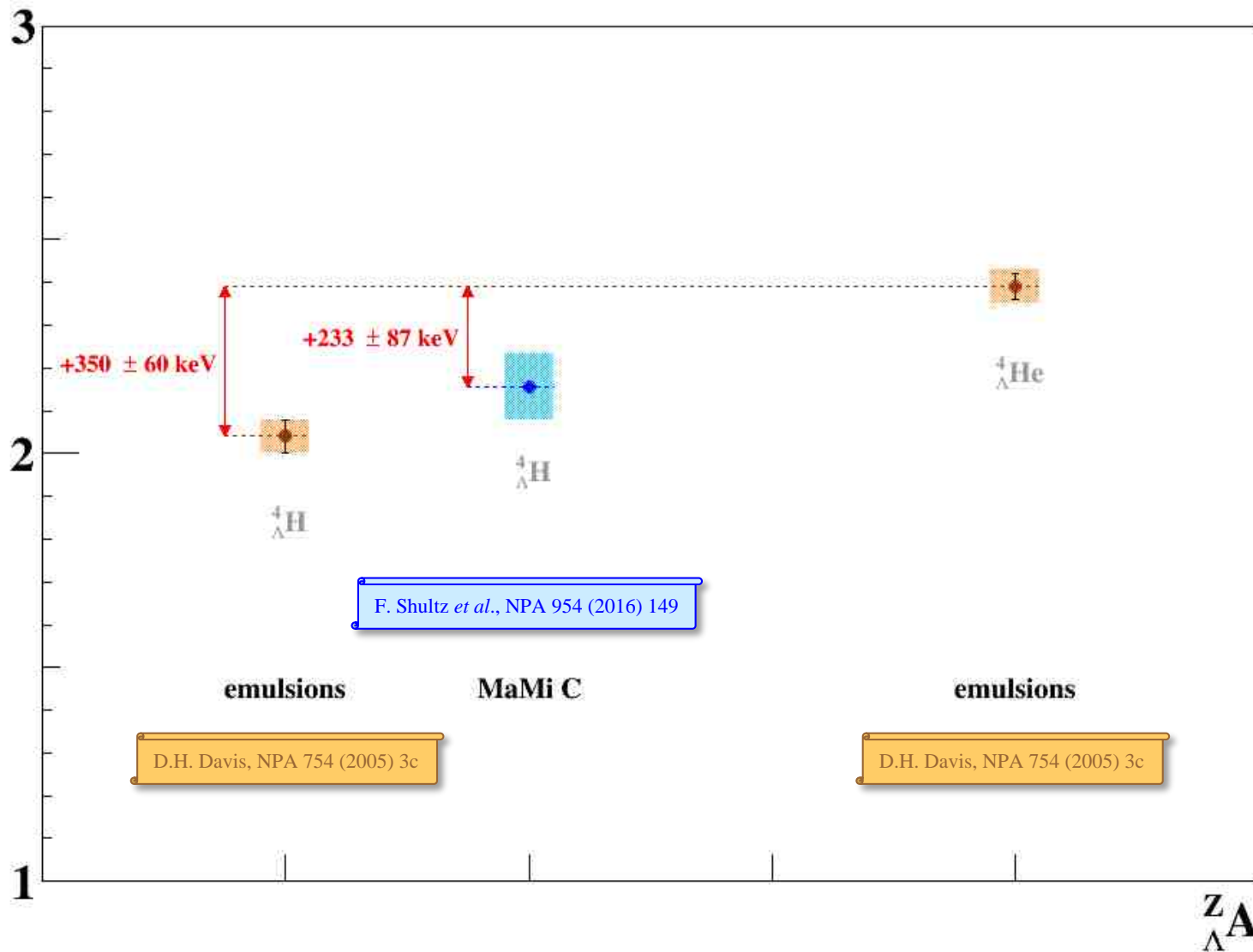
M. Agnello, *et al.*, Phys. Lett. B 698 (2011) 219

# CSB in $A = 4$ , $T = 1/2$ $\Lambda$ -hypernuclei?



# CSB in $A = 4$ , $T = 1/2$ $\Lambda$ -hypernuclei?

$B_{\Lambda}$  ( $A = 4$  systems) [MeV]

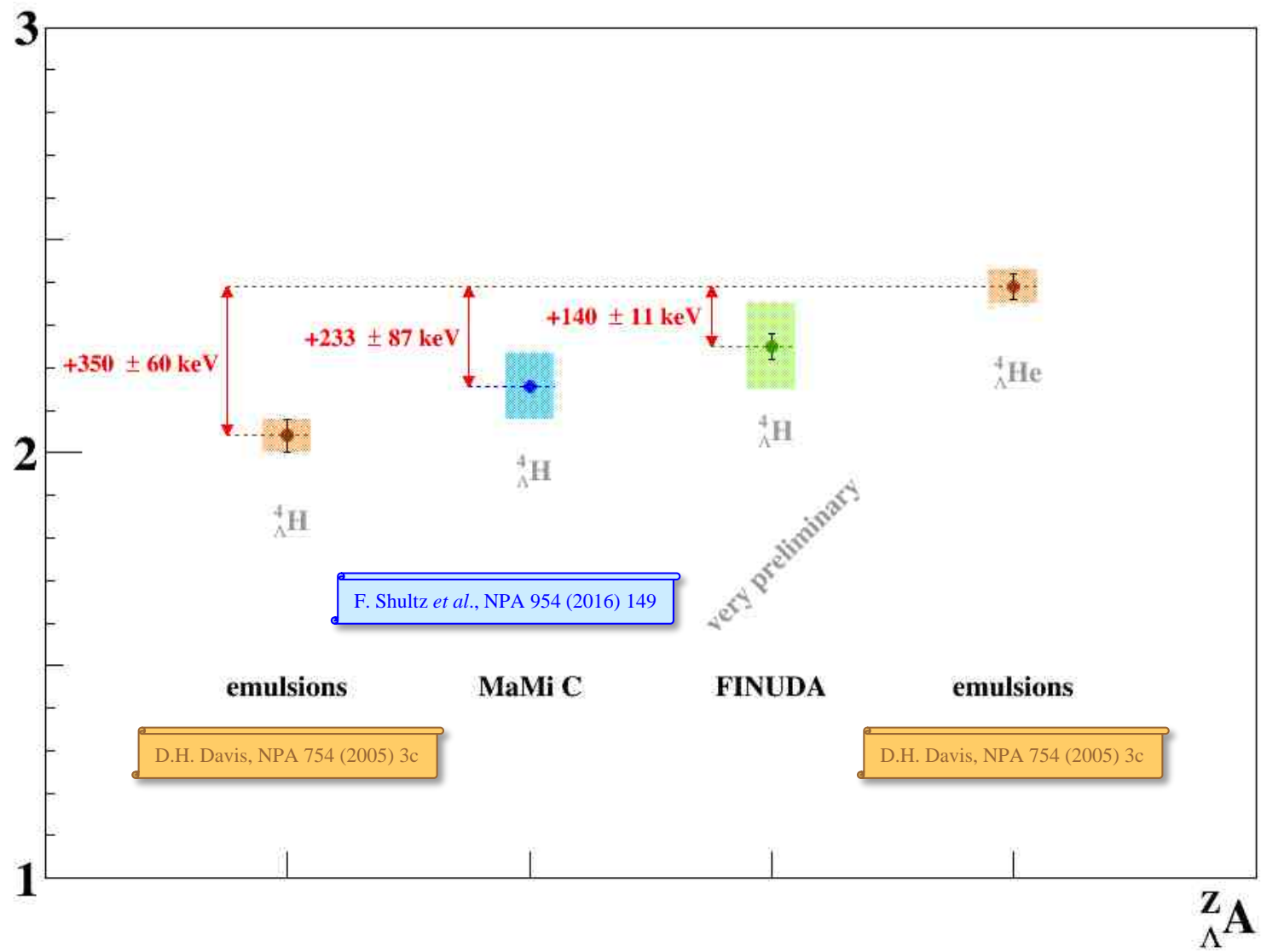


th. prediction: +226 keV

A. Gal, PLB 744 (2015) 352

# CSB in $A = 4$ , $T = 1/2$ $\Lambda$ -hypernuclei?

$B_\Lambda$  ( $A = 4$  systems) [MeV]

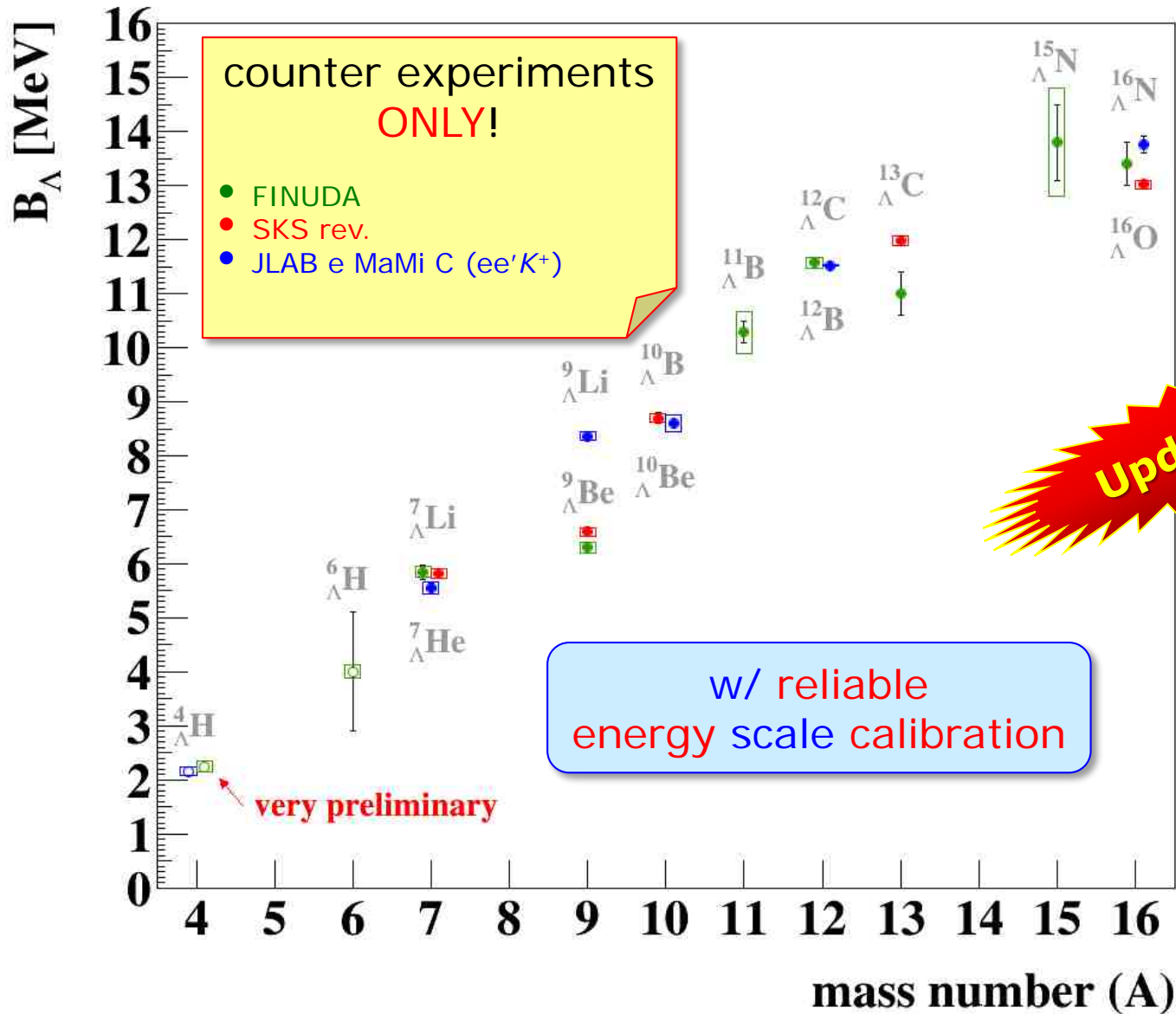


th. prediction: +226 keV

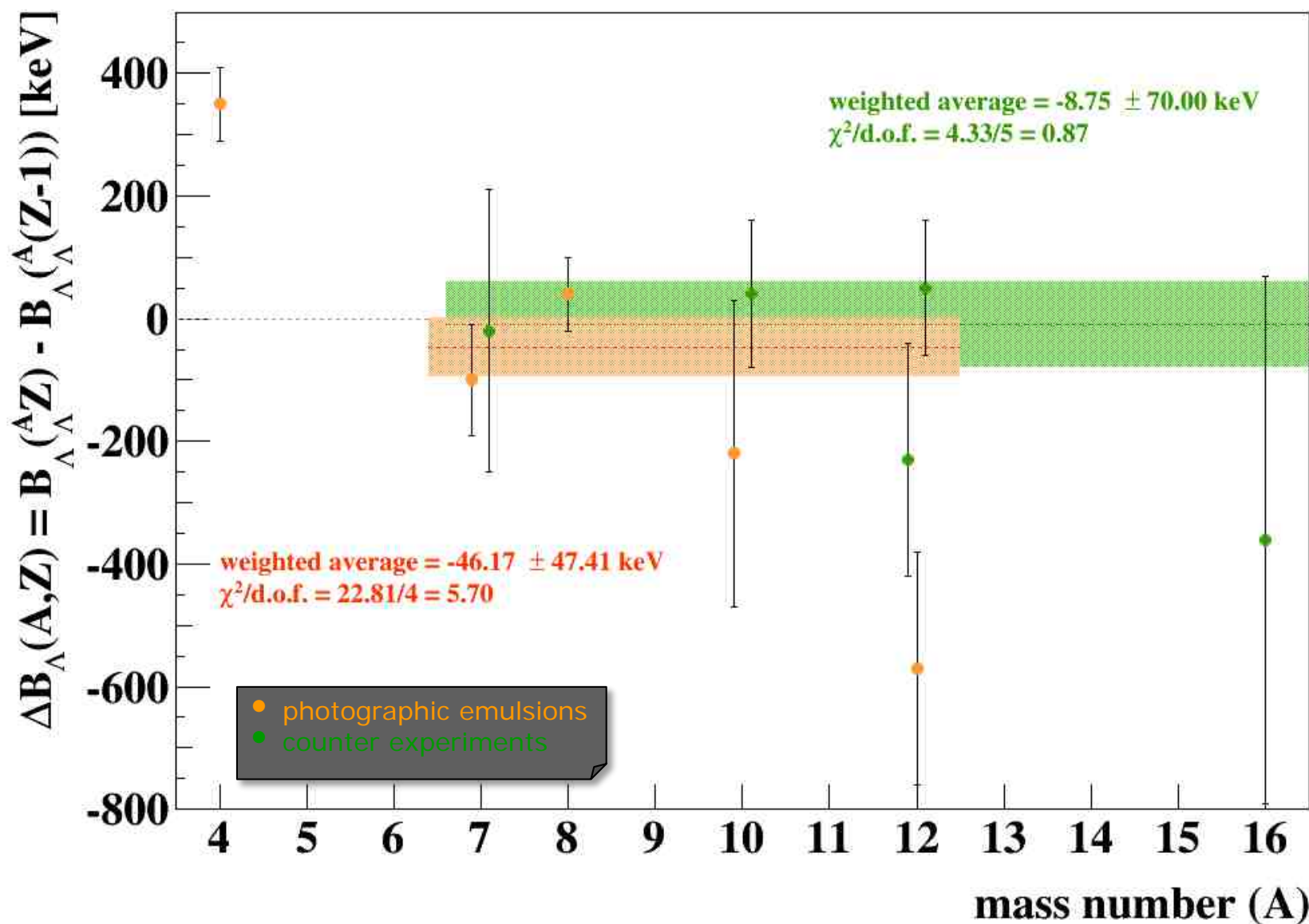
A. Gal, PLB 744 (2015) 352



# World $\Lambda$ -hypernucleus $B_\Lambda$ compilation



# $\Delta B_{\Lambda}$ (counter exp.) vs. $\Delta B_{\Lambda}$ (emulsions)



# Summary

- 👁 The **FINUDA** experiment provided a set of **precise** and **accurate** measurements of  $B_\Lambda$  for several  **$p$ -shell  $\Lambda$ -hypernuclei** and for a pair of  **$s$ -shell  $\Lambda$ -hypernuclei**
- 👉 The comparison of the  $B_\Lambda$  values for members of  **$p$ -shell  $\Lambda$ -hypernucleus iso-multiplets** **doesn't support** the hypothesis of a (strong) **violation of the charge symmetry** in the strong hyperon-nucleon interaction
- 👉 Also for the observed  **$s$ -shell  $\Lambda$ -hypernuclei** the **importance** of the charge **symmetry breaking effect** seems to be **significantly reduced**
- ❖ An **extensive** campaign of **high quality** and **high statistics** **new measurements** would be highly desirable