15 March 2016

THE 2ND JLAB HYPERNUCLEAR WORKSHOP

Spectroscopic Study of Medium Heavy Hypernuclei

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Messages from PAC43

Spectroscopy of ${}^{40}_{\Lambda}$K, ${}^{48}_{\Lambda}$K are most compelling physics.

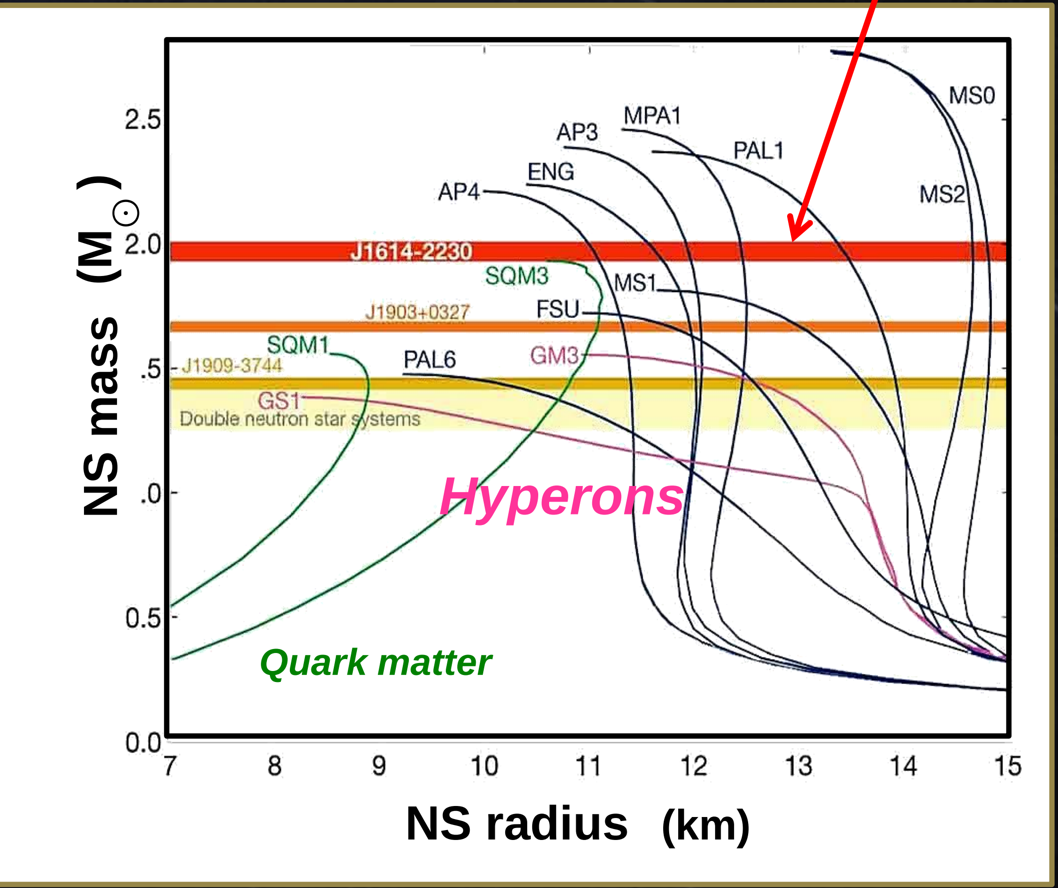
Stronger theoretical connection between Λnn and two M_{sun} NS.

PAC does not convince that
A dependence of B_{Λ} constrains NS EoS

Cannot it truly ?   Or our explanation was not good enough?

Hyperon Puzzle

PSR J1614-2230 (2010) 1.97±0.04 M_{sun}
PSR J0348-0432 (2013) 2.01±0.04 M_{sun}



Hyperons naturally appear at $\rho = 2\sim3\ \rho_0$

EOS w/hyperons is too soft for $2M_{sun}$

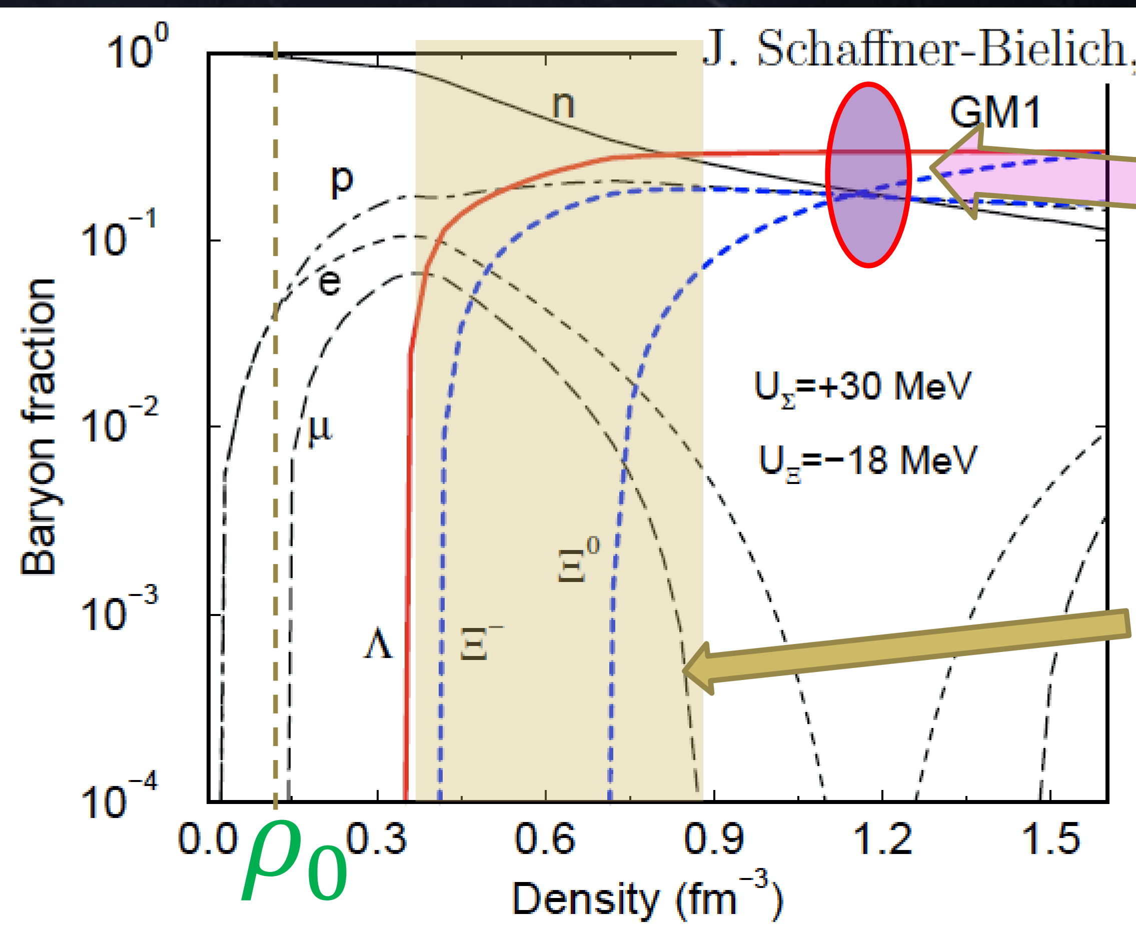
Contradicts observation!

One of most serious problems of nuclear physics

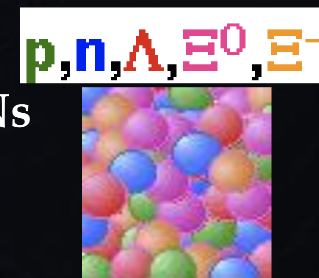
Neutron star and Strange hadronic matter

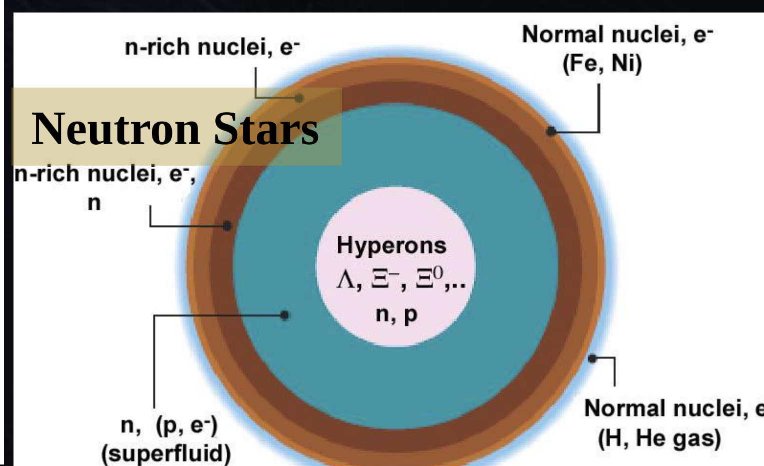
Sym. Nucl. Matter : Limit for size (due to Coulomb force)

Asym. Nucl. Matter : Neutron Stars, Strange Hadronic Matter

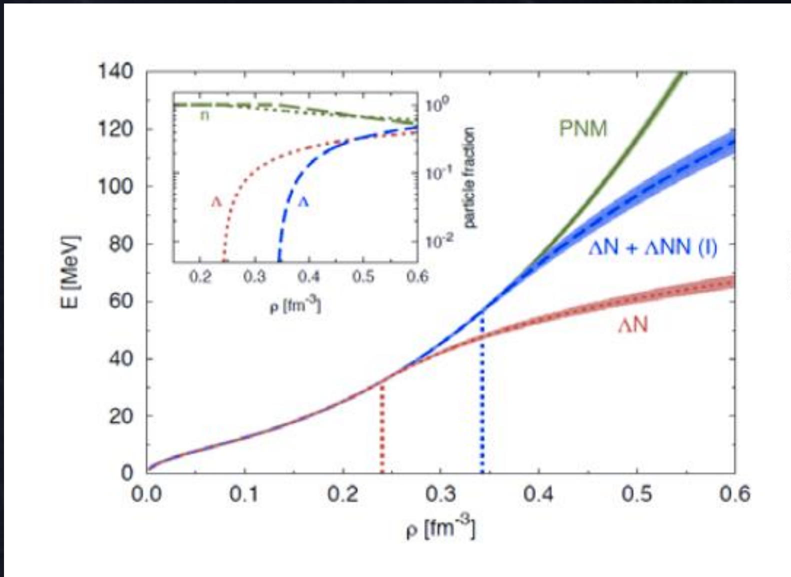


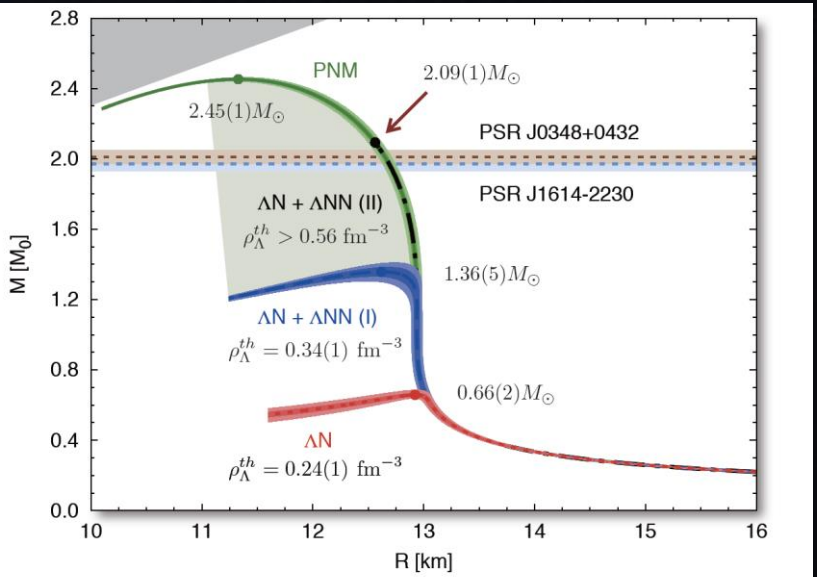
Nu ~ Nd ~ Ns

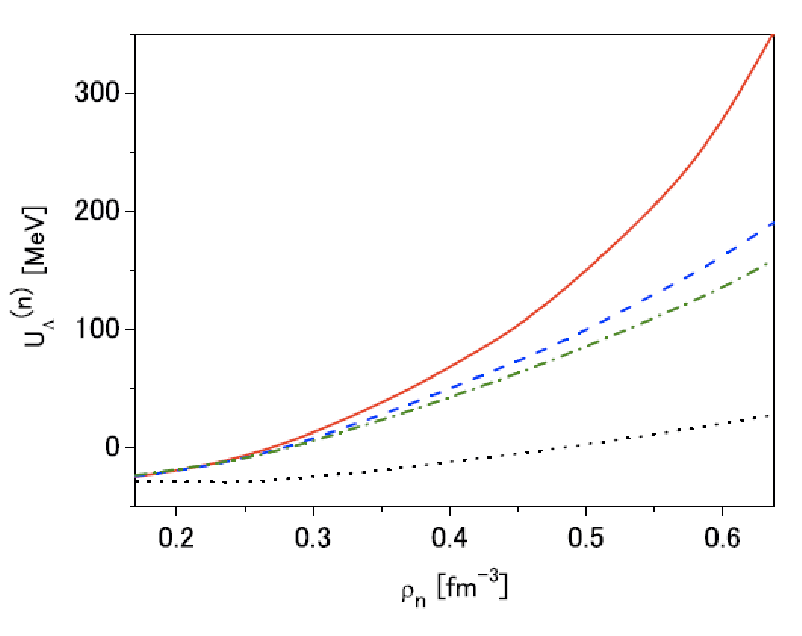


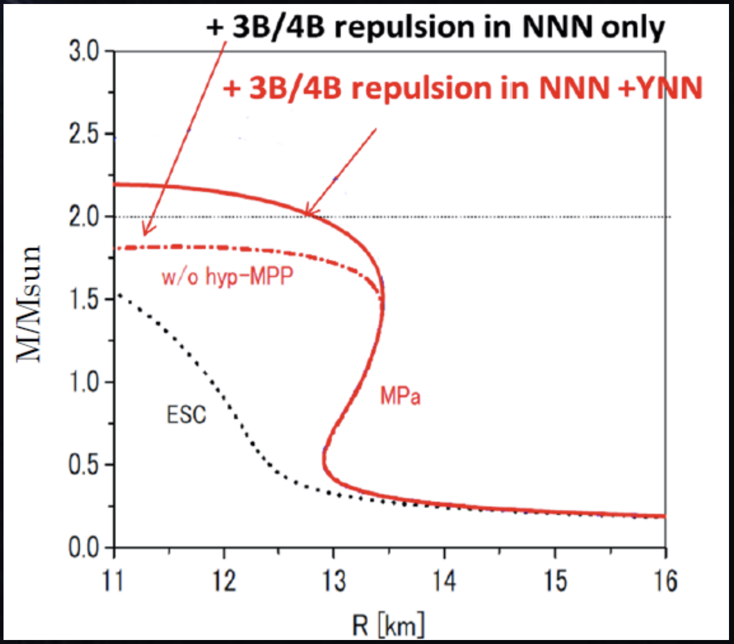


AFDMC by Lonardoni et al. PRL114, (2015) 092301, updated (2016)



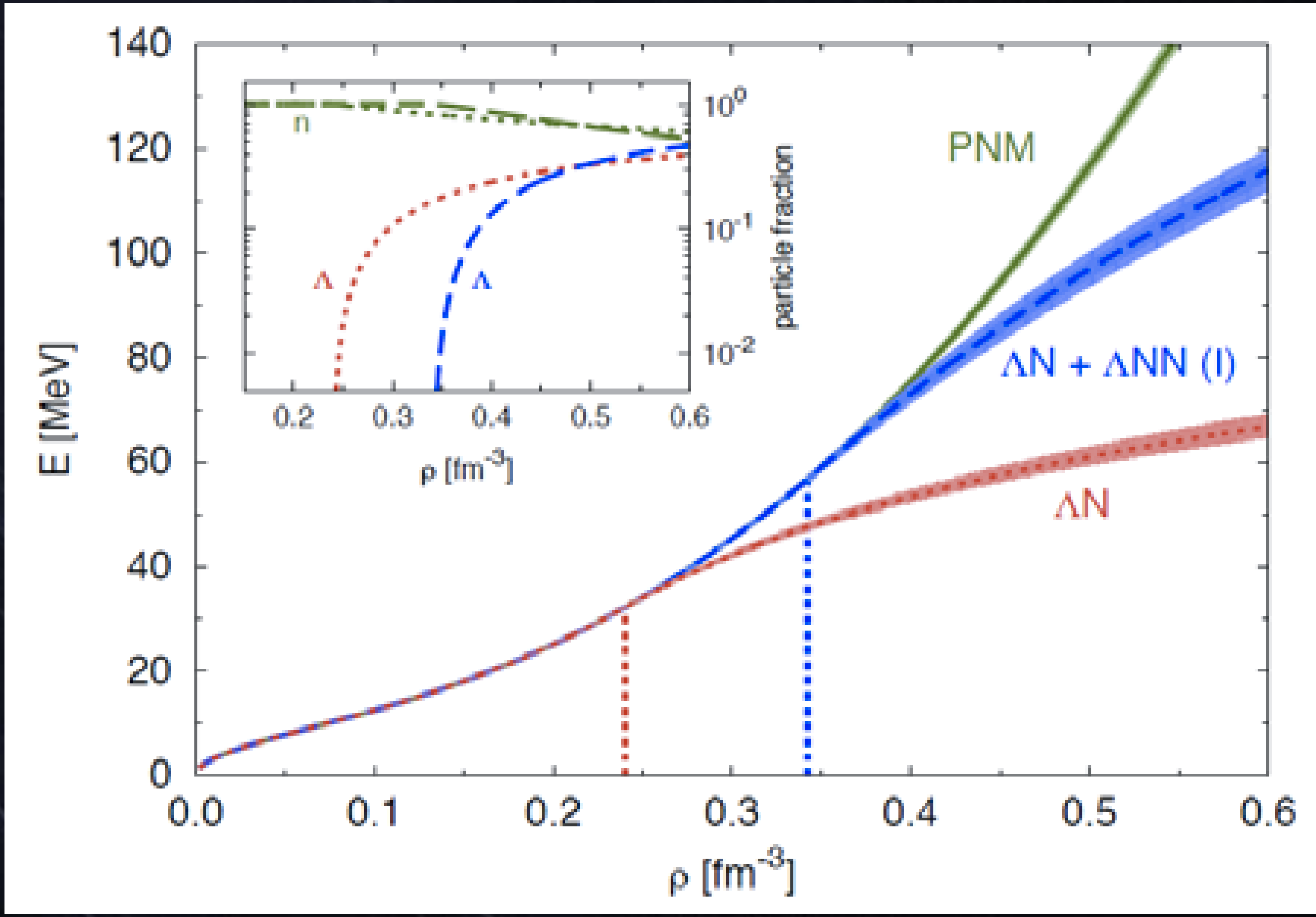






ESC08c + 3B/4B RF : G-Matrix Calc. by Yamamoto et al., PRC 90 (2014) 045805.

NS EOS with hyperon and 3BRF

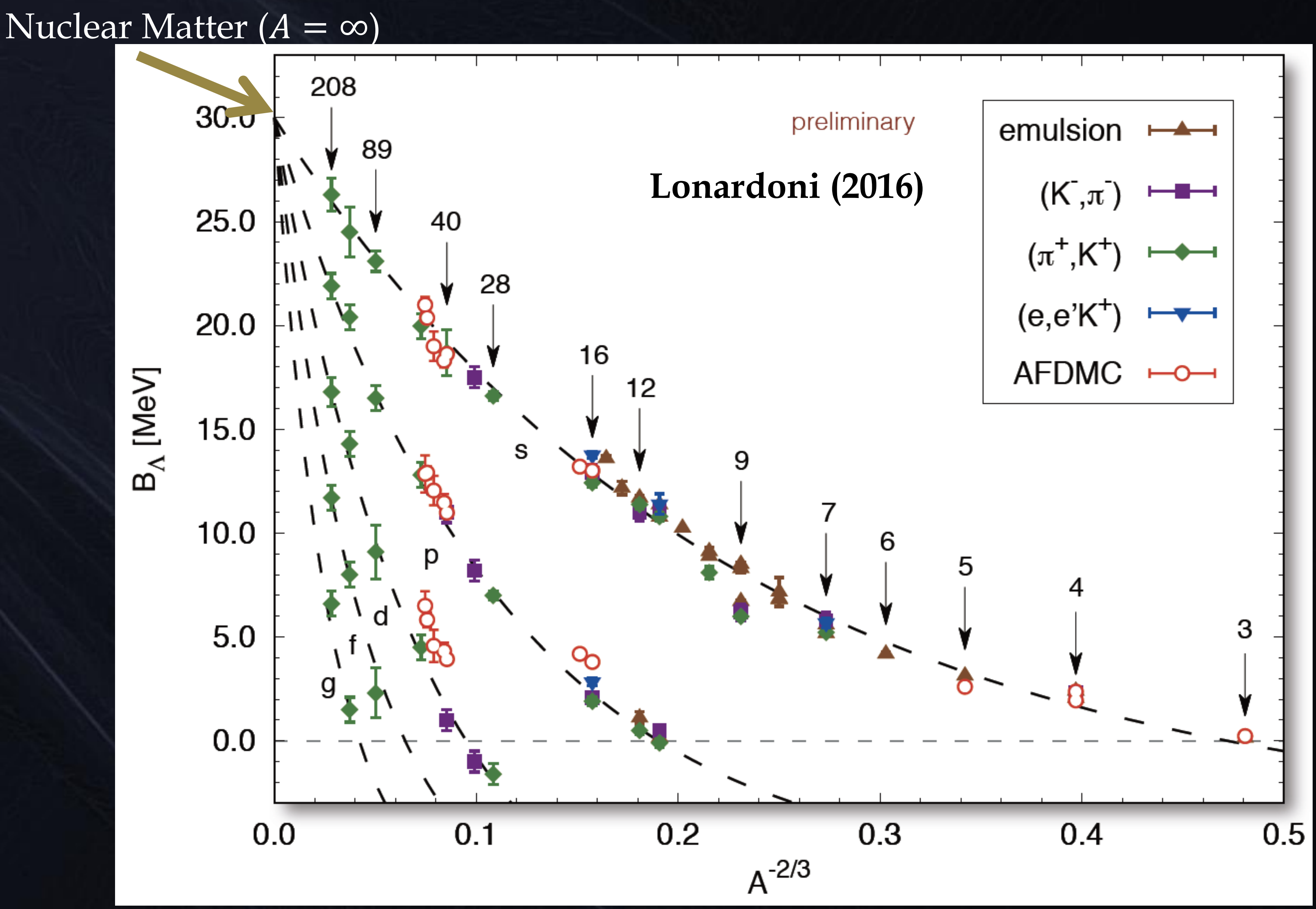


PNM

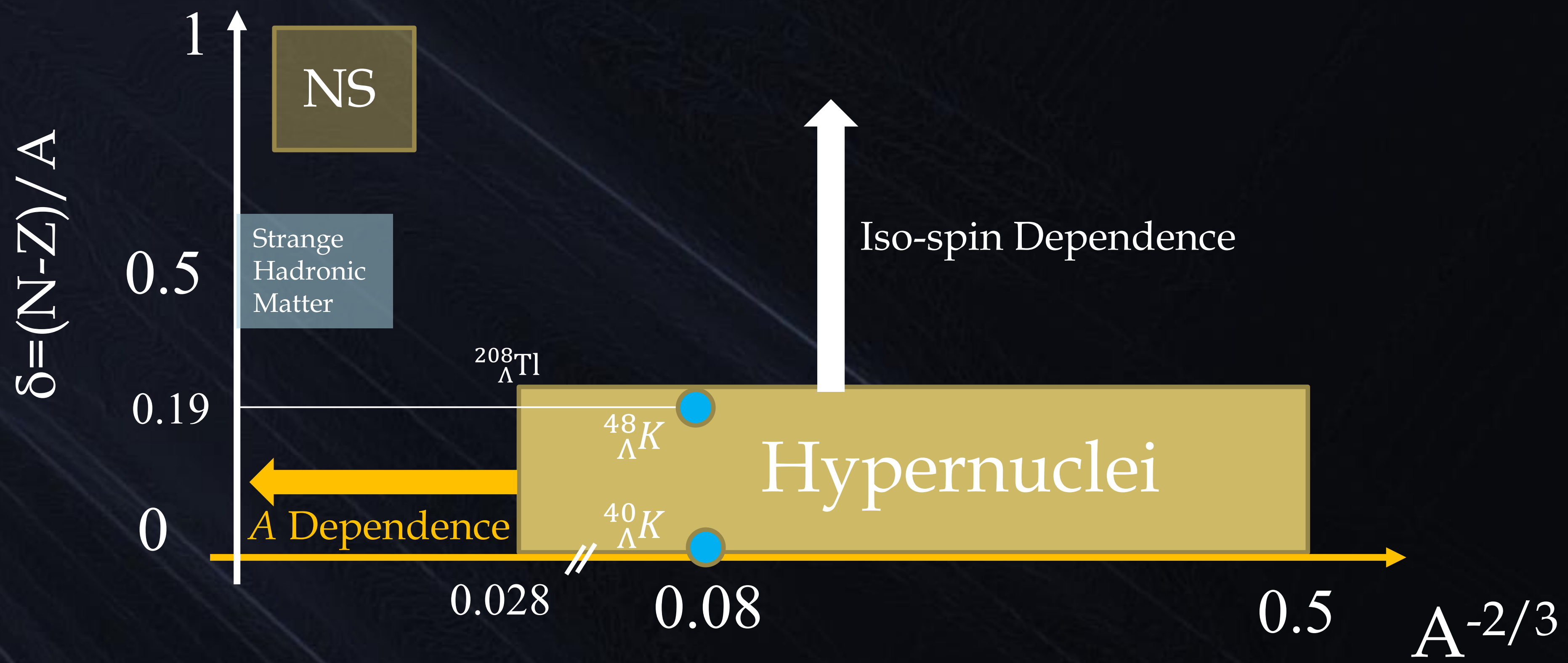
With 3BRF
recover hardness

With Hyperon
too Soft

Mass dependence of B_Λ

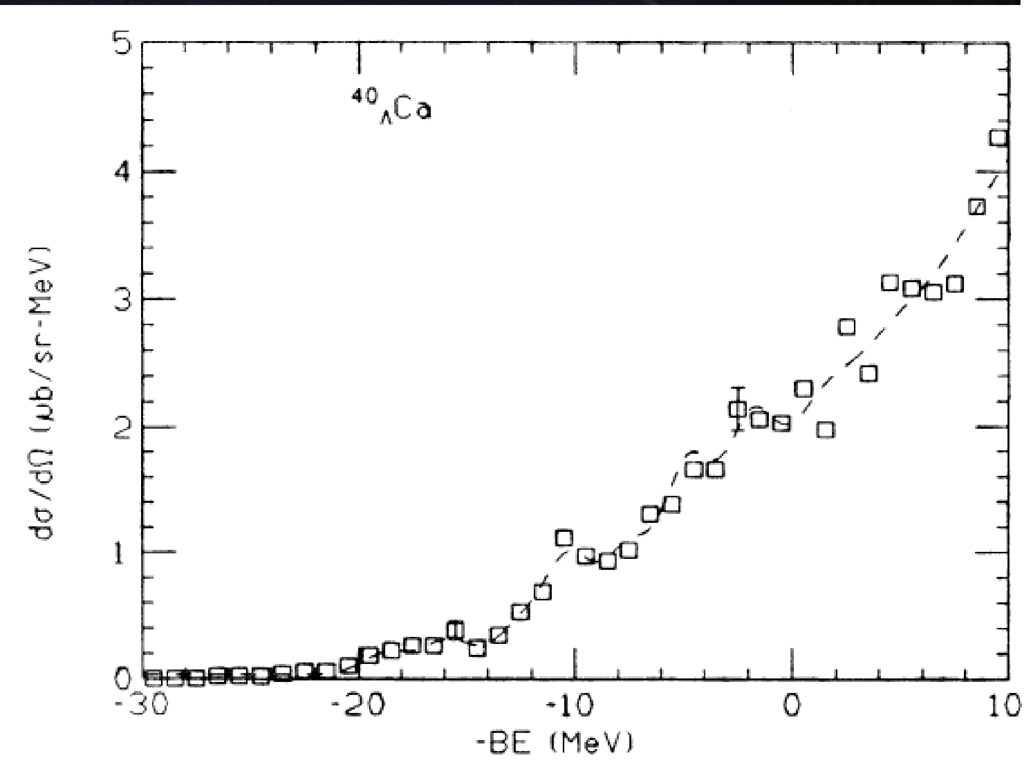


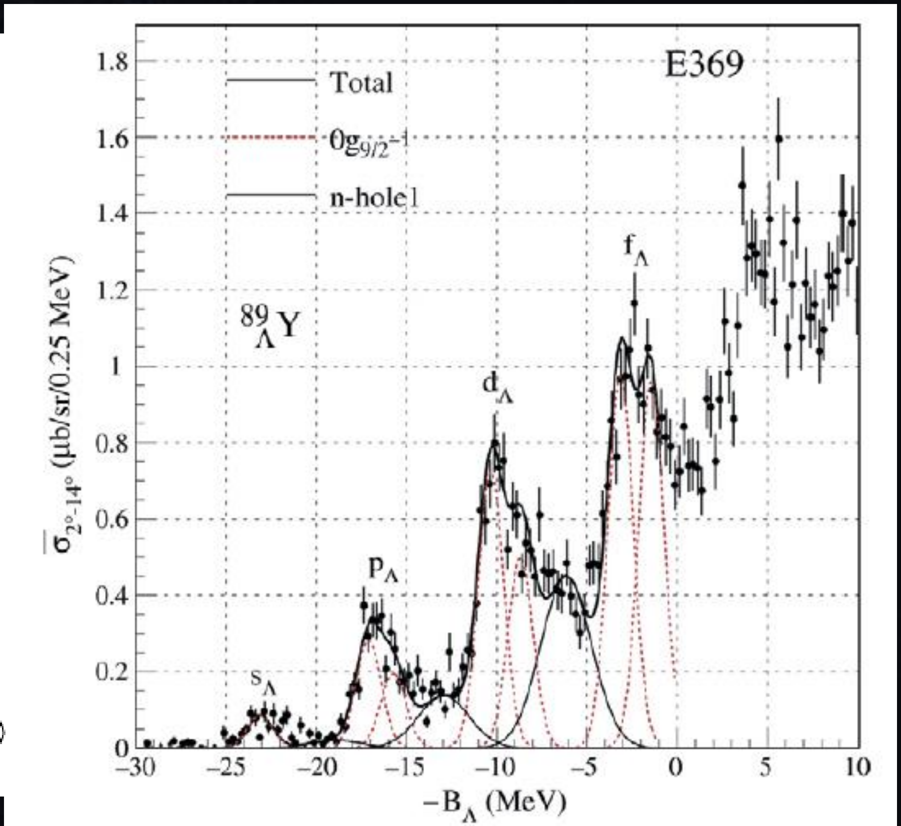
NS EOS with hyperon and 3BRF



Key issues : *A* Dependence
Iso-spin Dependence of 3BRF

Mid-heavy data from (π,K) exp.

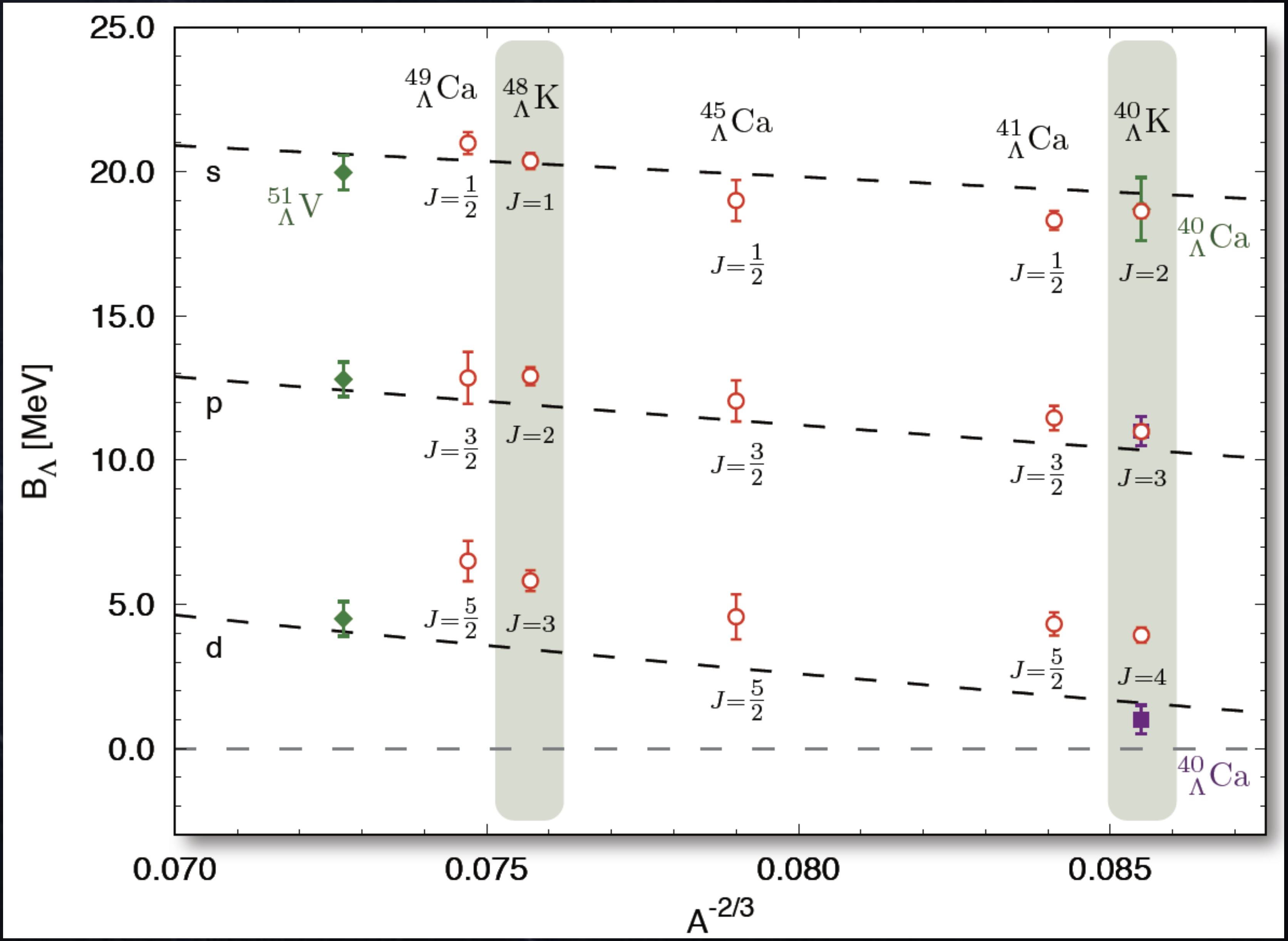




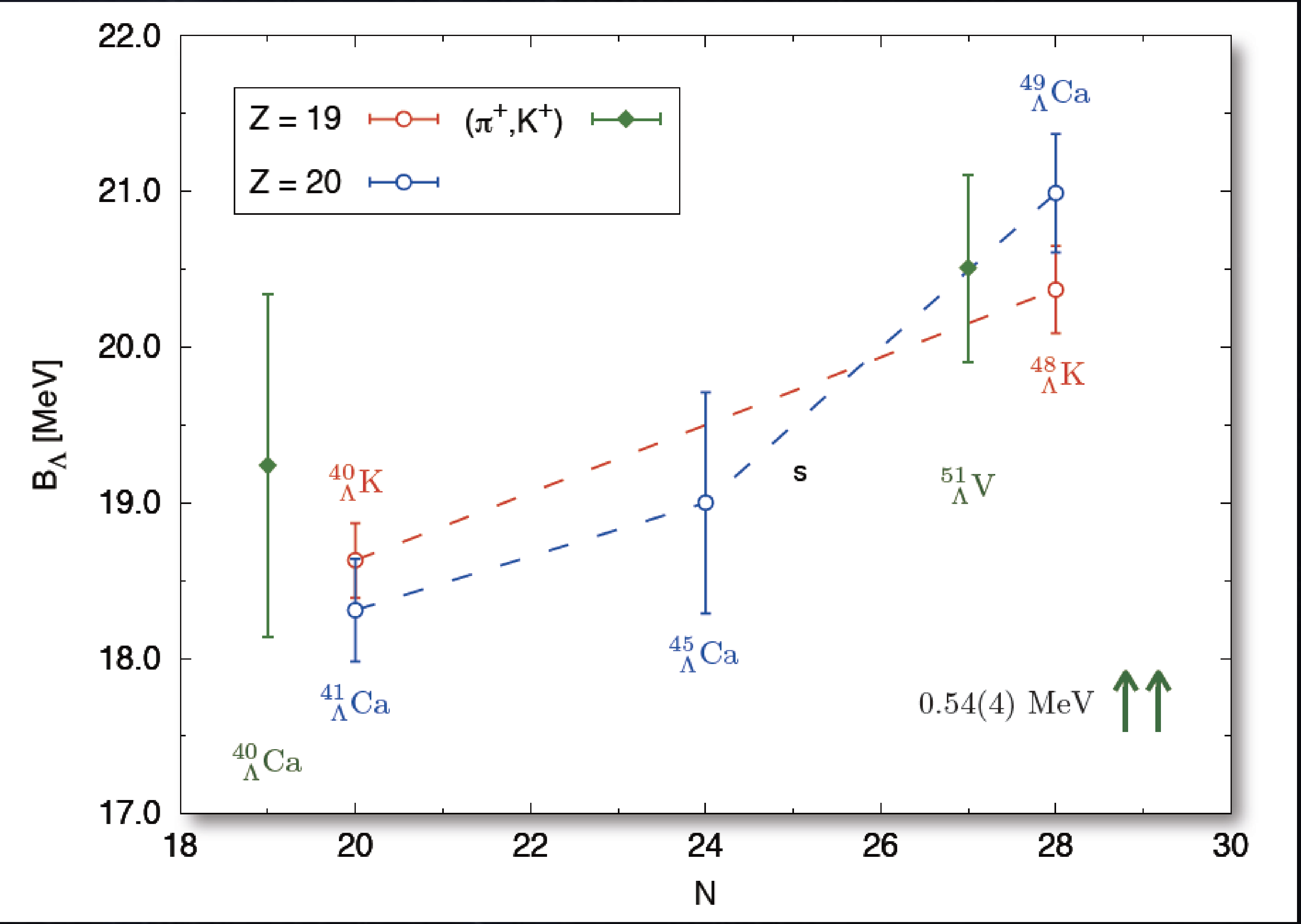
P.H.Pile et al. PRL 20 (1991) 2585.

H.Hotchi et al. PRC 64 (2001) 044302.

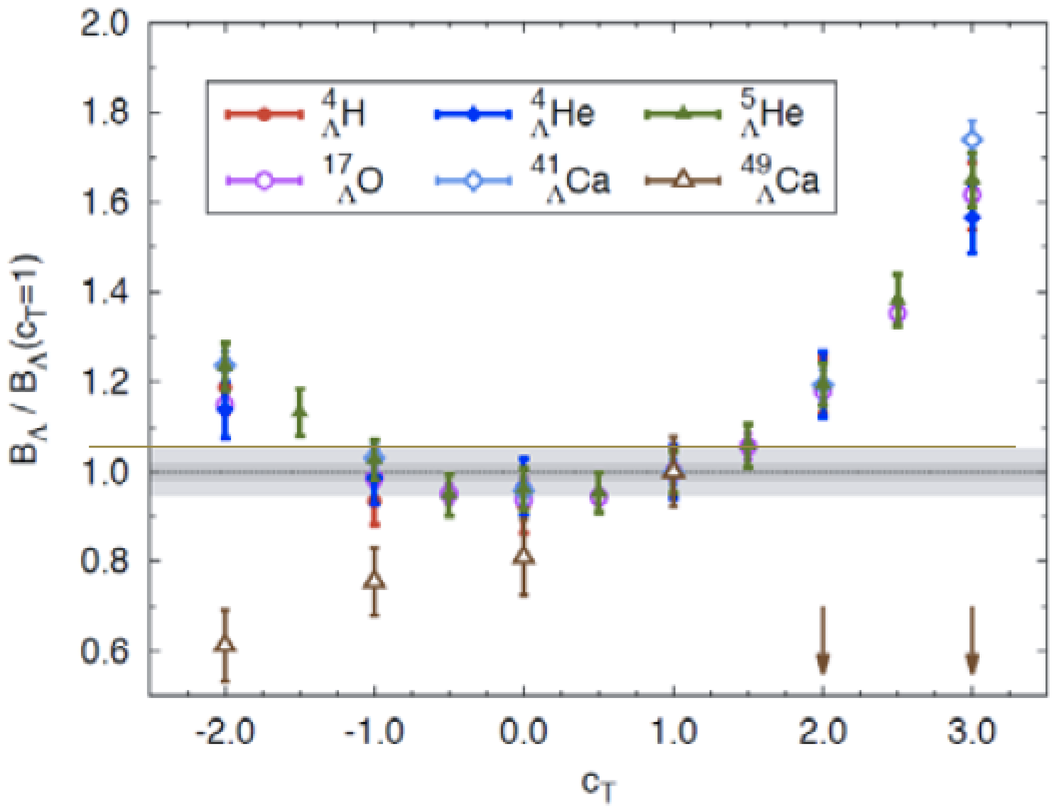
Mass dependence of $B_\Lambda(s_\Lambda, p_\Lambda, d_\Lambda)$



N dependence of B_Λ(gs)



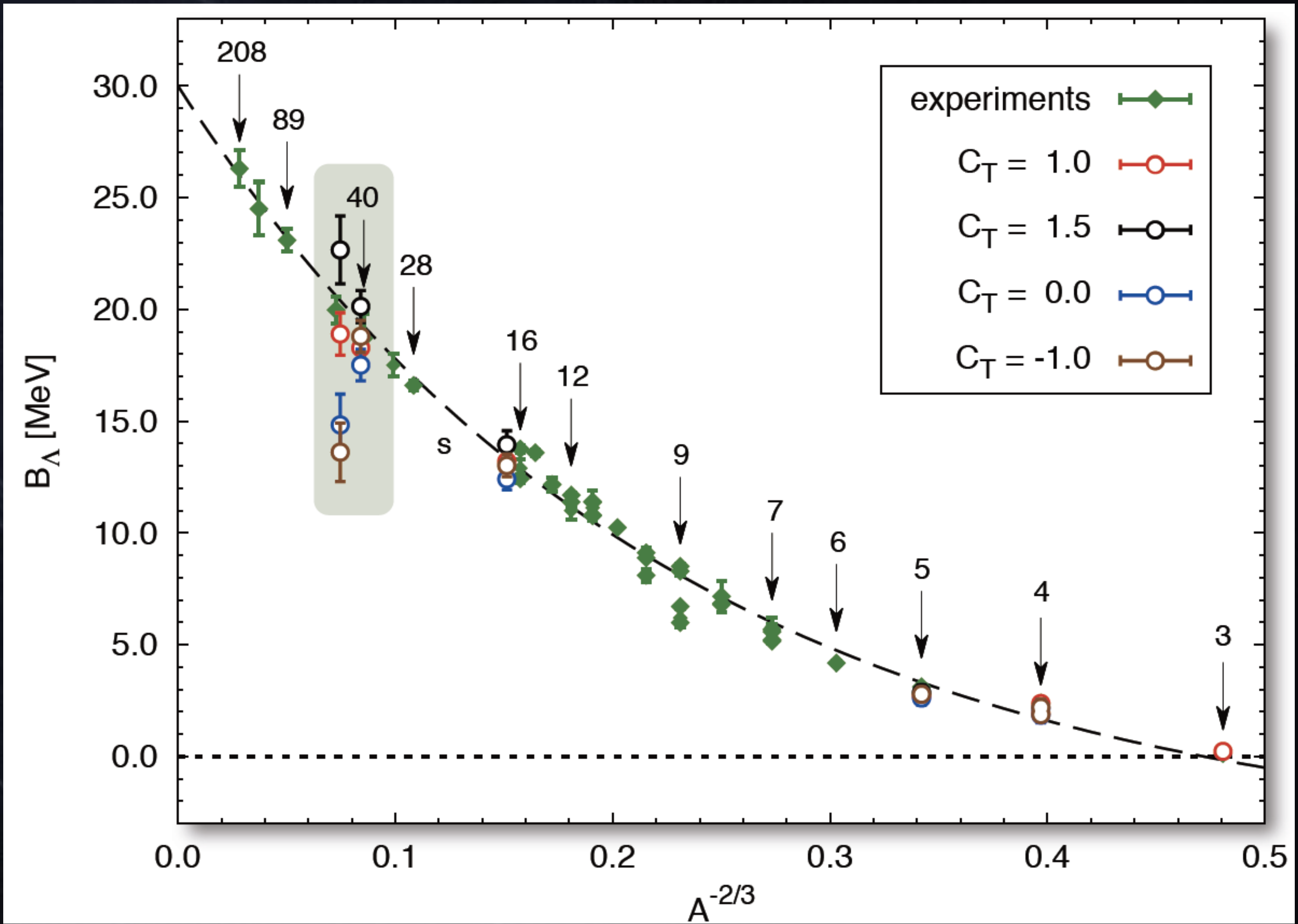
Λnn/Λnp dependence of B_Λ



Presented at PAC43

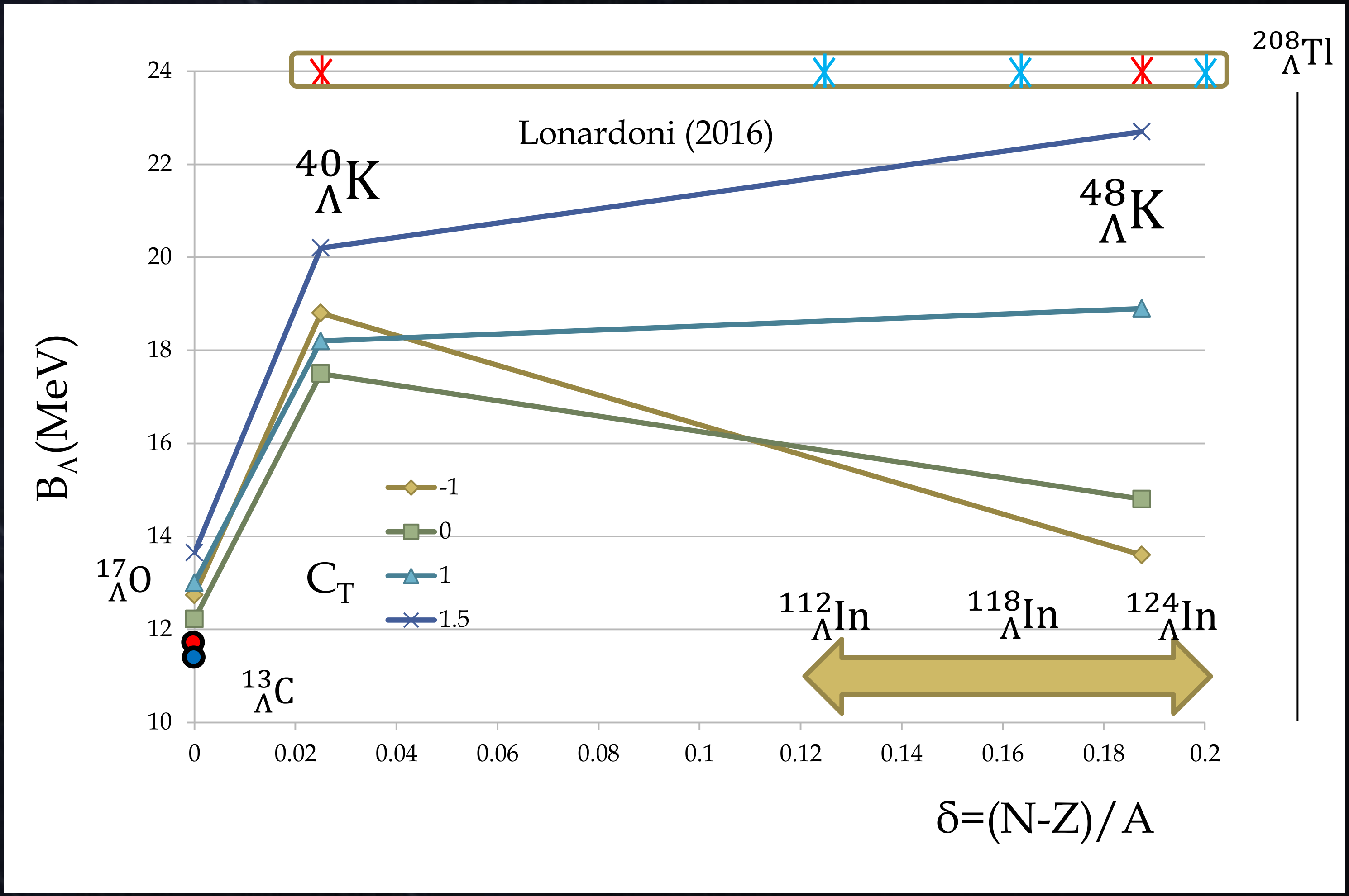
Figure 2-10: Λ separation energies normalized with respect to the $C_T = 1$ case as a function of C_T. Grey bands represent the 2% and 5% variations of the ratio B_Λ/B_Λ ($C_T = 1$). Brown vertical arrows indicate the results for ^{49}Ca in the case of $C_T = 2$ and $C_T = 3$, outside the scale of the plot.

Λnn/Λnp dependence of B_Λ



Λnn/Λnp dependence of B_Λ

Could be determined with an accuracy of <100keV at JLab



Targets avaiablity

JLab has a 800mg/cm^2 thick ^{48}Ca target for CREX exp.,
but it was oxidized and surface condition is not good.
Furthermore, it is too thick for our experiment.
(Eloss effects are 500keV for both e′ and K$^+$)

Making a new 100mg/cm^2 ^{48}Ca costs roughly $50K.

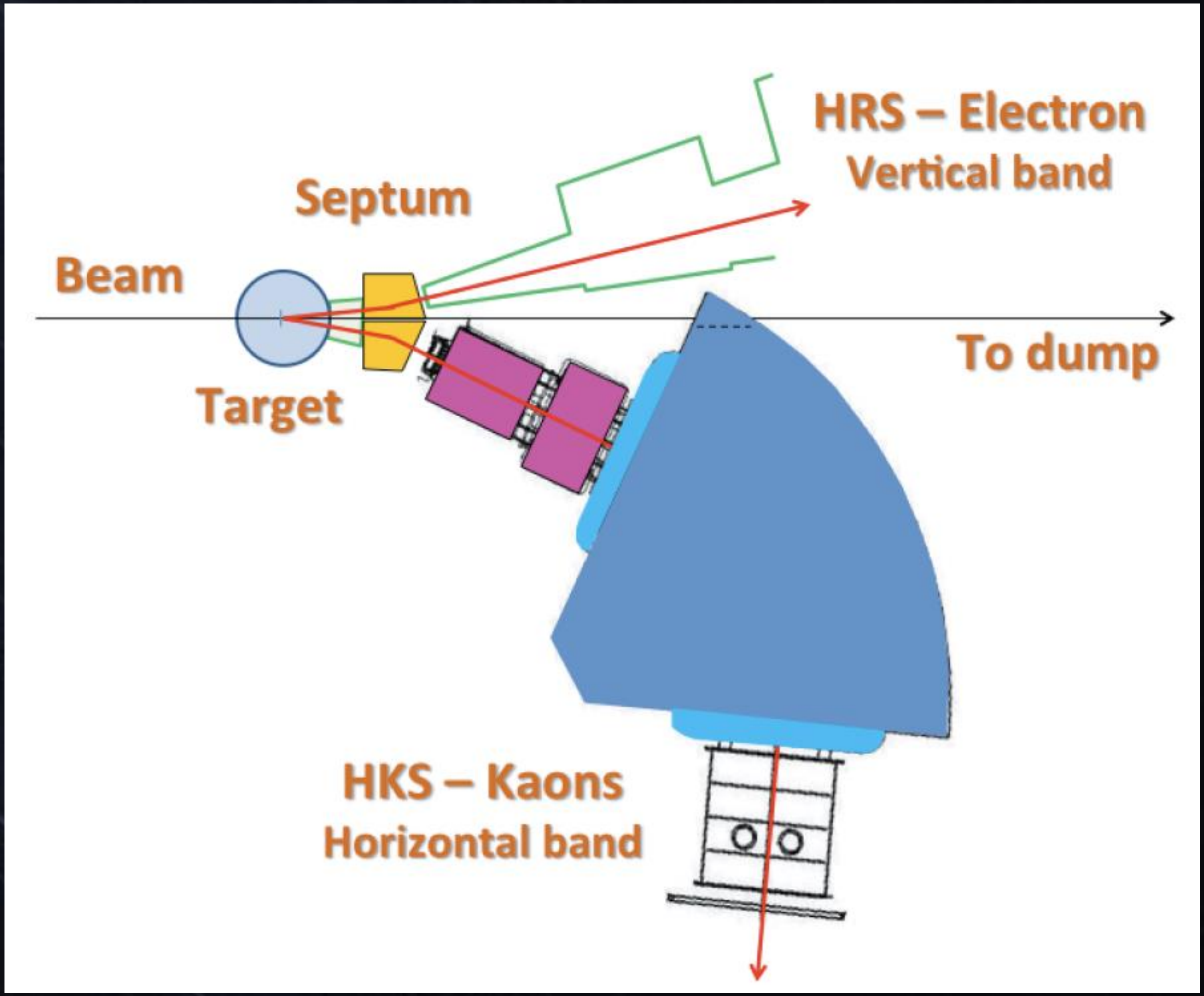
^{40}Ca is one order less expensive.

^{112,114,116,118,120,122,124}Sn 100mg/cm^2 cost $3K for each.

^{112,114}Sn purities are ~70atom%, others >90atom%.

	Li	Ca	Sn	Pb
Melting Point (°C)	181	842	232	323
Heat Cond. (W/(m*K))	85	201	67	35

Proposed Setup



K(HKS) x HRS (e′)

Only **JLab** : Beam + Spectrometers for $(e,e'K^{+})$

Beamtime estimation

	Beam Current (mA)	Target Thick (mg/cm^2)	Assumed CS (nb/sr)	Expected Yield(/h)	Beam Time (h) For 200ev.	BG (/MeV/h) for 250MHz	S/N
${}^{40}_{\Lambda}K$	50	50	10	1.7	230	0.43	4.0
${}^{48}_{\Lambda}K$	50	50	10	1.4	278	0.42	3.5
Calib.					167		
Sub Total					675		
${}^{112}_{\Lambda}In$	40	100	40	2.0	101	0.89	2.2
${}^{118}_{\Lambda}In$	40	100	40	1.9	106	0.89	2.1
${}^{124}_{\Lambda}In$	40	100	40	1.8	112	0.88	2.0
Sub Total					319		

675 h = 28.1 PAC days
Isospin dep of 3BRF

319 h = 13.3 PAC days
Additional constraint for isospin dep of 3BRF and *A* dependence, too.

Summary

PAC43 recognized that measurements of ${}^{40}_{\Lambda}$K, ${}^{48}_{\Lambda}$K proposal should be re-submitted with more theoretical works to bridge Λnn interaction and hyperon puzzle.

Theoretical efforts with AFDMC and AMD are in progress to predict B_Λ reliable medium heavy hypernuclei. Based on these efforts, Λnn interaction model can be applied to NS to solve the hyperon puzzle.

Measurement of B_Λ for ${}^{40}_{\Lambda}$K, ${}^{48}_{\Lambda}$K with a precision of <100 keV can be achievable with a reasonable beamtime (<30 PAC days with calibrations).

It will provide the first data for isospin dependence of ΛNN force.

In order to have better constraints on **iso-spin dependence** of Λnn interaction can be further constraint by the experiment on Sn isotope targets. Though further theoretical efforts are necessary, it will also provide data for ***A*** **dependence**.