HYPERTRITON LIFETIME IN EFT

16.09.2022 | Fabian Hildenbrand | IAS-4

$^{3}_{\Lambda}$H Theoretical Framework $\Rightarrow$ Pionless EFT

Shallow S-Wave State

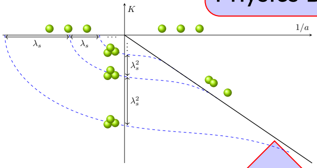
$J^P = \frac{1}{2}^+$

Distinguishable

$^{3}_{\Lambda}\mathrm{H}$

Theoretical Framework $\Rightarrow$ Pionless EFT

Physics Determined by a and Λ_*



Large Scattering Length

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$^3_\Lambda$H Theoretical Framework ⇒ Pionless EFT

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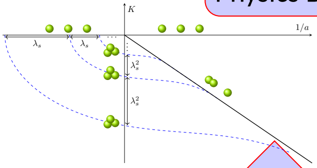

Universal Relations Between Observables

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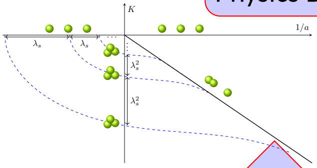

Universal Relations Between Observables

- B_Λ and $< r^2 >$
- B_Λ and τ
- B_Λ and $a_{\Lambda d}$

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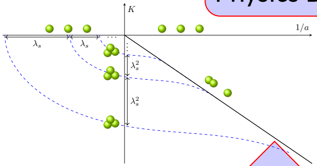

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Pionless EFT

Controllable Uncertainties

Systematic Improvement

$^{3}_{\Lambda}$H Theoretical Framework ⇒ Pionless EFT

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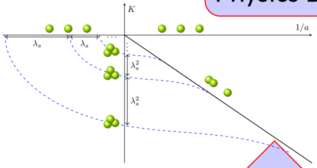

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Large Scattering Length

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Controllable Uncertainties
Systematic Improvement

Shallow S-Wave State

$J^P = \frac{1}{2}^+$

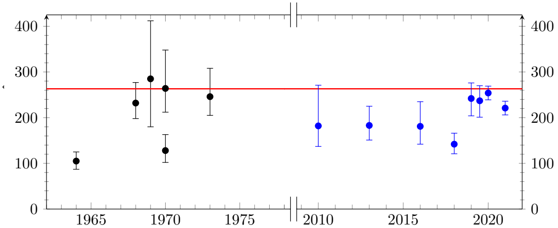
Distinguishable

Boil the tree-body down to two-body EFT

JÜLICH Forschungszentrum

$^3_\Lambda H$ Channels and Isospin Rule

- Two-Body Picture Works
- Calculate Lifetime in a Theory with Fundamental Deuteron
- Focus on B_Λ Dependence



JÜLICH Forschungszentrum

$^3_\Lambda$H Channels and Isospin Rule

$^3_\Lambda\text{H} \mapsto \pi^- + ^3\text{He}$, $^3_\Lambda\text{H} \mapsto \pi^0 + ^3\text{H}$,

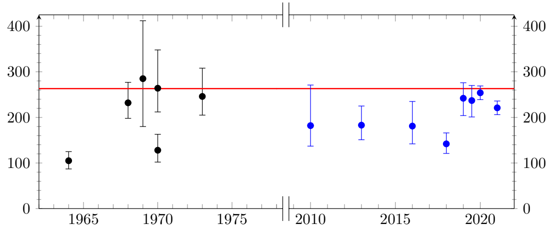
$^3_\Lambda\text{H} \mapsto \pi^- + d + p$, $^3_\Lambda\text{H} \mapsto \pi^0 + d + n$,

~~$^3_\Lambda\text{H} \mapsto \pi^- + p + n + p$~~, ~~$^3_\Lambda\text{H} \mapsto \pi^0 + p + n + n$~~

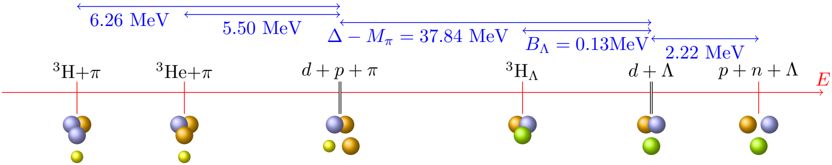
→ Charged and Uncharged Channel Are Related by the $\Delta I = \frac{1}{2}$ Rule
$\Rightarrow$ Calculate only one

- Two-Body Picture Works
- Calculate Lifetime in a Theory with Fundamental Deuteron
- Focus on B_Λ Dependence

Leptonic and Non-Mesonic Decays are Negligible



$^3_\Lambda$H Thresholds and Feynman Diagrams



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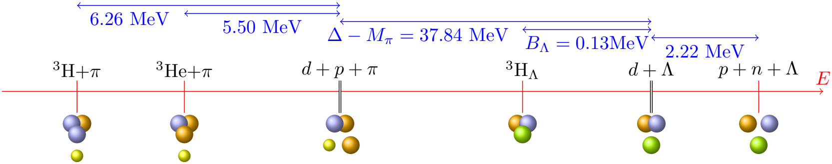
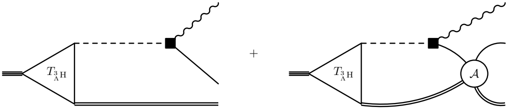


Deuteron Final State



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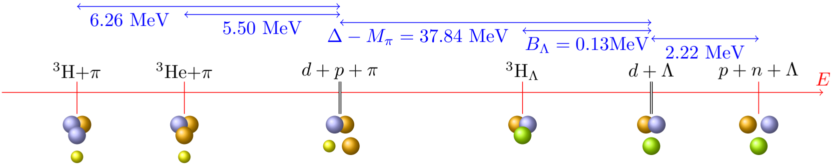
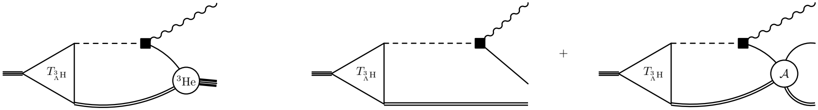
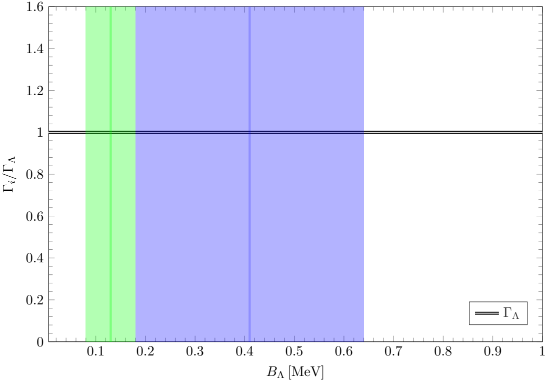


Trinucleon Final State

Deuteron Final State



$^{3}_{\Lambda}$H Hypertriton Width and Branching Ratios



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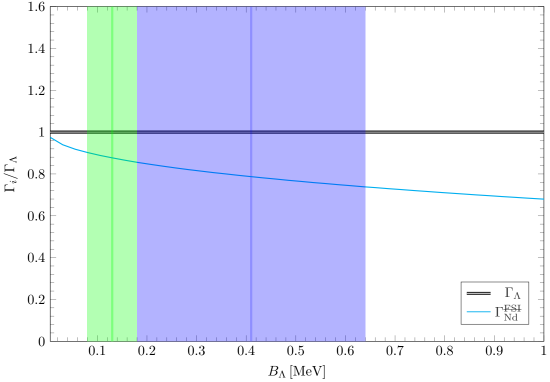

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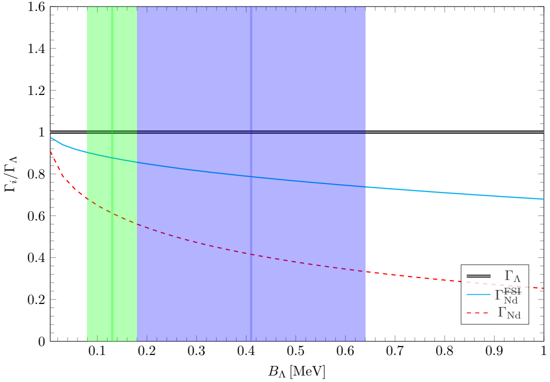

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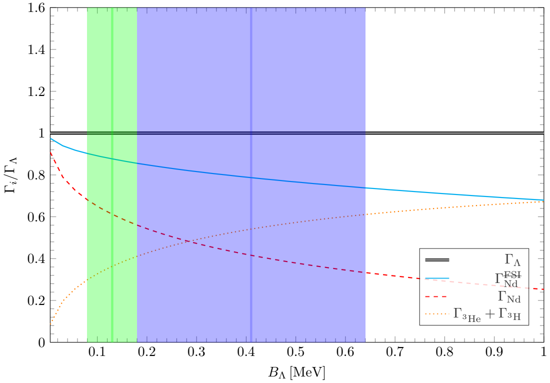

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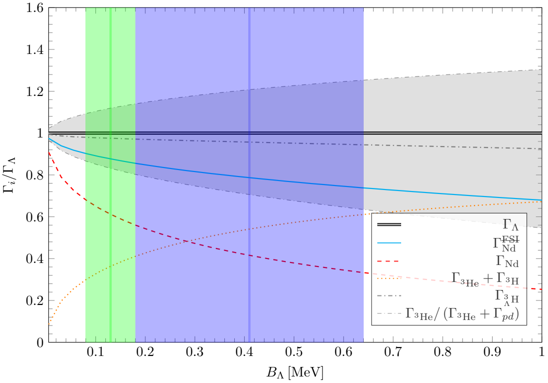

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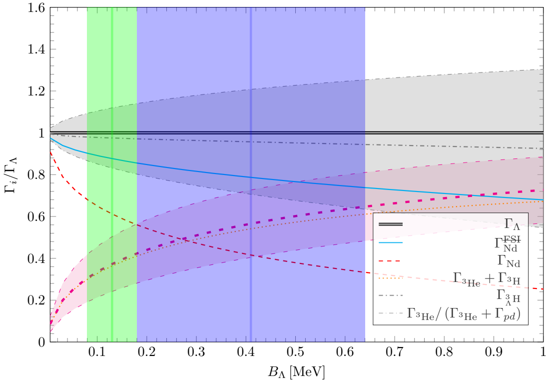


- $\Gamma_{^3_\Lambda H}$ Barely Depends on B_Λ
- Final State Interactions are Important
- $\Gamma_{^3\text{He}}/(\Gamma_{^3\text{He}} + \Gamma_{pd})$ Depends Strongly on B_Λ
- STAR Branching ratio 0.32(5)(8)

Emulsion Data: $R = \Gamma_{^3\text{He}}/(\Gamma_{^3\text{He}} + \Gamma_{pd}) = 0.3 - 0.4$

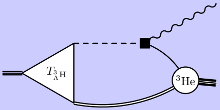
$^{3}_{\Lambda}H$ Pionic Final State Interaction

Work by Perez-Obiol and Gal suggest significant contribution from Pionic final states

Perez-Obiol (2020),Gal(2019)

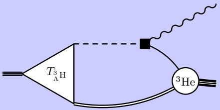
Different Type of calcalution
only has 2 body decay channel
uses Branching ratio as input
Contribution $0.10 - 0.15\Gamma_\Lambda$

Choose this channel!



- only two particles in FSI
- FSI is momentum locked
- not much data available
- direct comparison possible

$^{3}_{\Lambda}$H Pionic Final State Interaction



Watson-Migdal approach for FSI adds interaction between ^{3}He and π^-

$$\Gamma_{^3\mathrm{H}} = \frac{G_F^2 M_\pi^4}{\pi}\,\frac{\bar{k} M_{^3\mathrm{H}}}{M_{^3\mathrm{H}}+\omega_{\bar{k}}}\,\bar{Z}_{^3_\Lambda\mathrm{H}}(B_\Lambda)\bar{Z}_{^3\mathrm{H}}\left(B_{^3\mathrm{H}}\right)\left(A_\pi^2+\frac{1}{9}\left(\frac{B_\pi}{M_\Lambda+m}\right)^2\bar{k}^2\right)\left|I_q\left(\bar{k},B_\Lambda\right)\right|^2$$

$$\int_{Loop}\left|g^2 G_{\pi t}\left(\Delta - m_\pi\,,0\right)\right|^2$$

with $iG_{\pi t}\left(p_0\,,\boldsymbol{p}\right) = \frac{\pi}{\mu_{\pi t} g^2}\,\frac{-i}{-\gamma_{\pi t}+\sqrt{-2\mu_{\pi t}\left(p_0-\frac{\boldsymbol{p}^2}{2(M_\pi+M_{He})}+i\epsilon\right)}} \Rightarrow \Gamma^{\pi FSI}_{^3\mathrm{H}} = (1+\mathrm{cor})\Gamma_{^3\mathrm{H}}$ cor $= 0.06$ Maximal contribution

$^{3}_{\Lambda}\mathrm{H}$

Hypertriton Width and Branching Ratios

Our Results:

- $\Gamma_{^{3}_{\Lambda}H}(0.13) = (1.03 \pm 0.15)\Gamma_{\Lambda}$
- $\Gamma_{^{3}_{\Lambda}H}(0.41) = (1.03 \pm 0.25)\Gamma_{\Lambda}$
- $R(0.13) = 0.38 \pm 0.05$
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Consistent:

- Calculation by Congleton for Γ and R
- Calculation by Kamada for Γ and R
- Emulsion Data $0.05\text{MeV} \lesssim B_\Lambda \lesssim 0.2\text{MeV}$

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Slight Tension:

- STAR results Branching ratio $R = 0.32 \pm 0.05 \pm 0.08$

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Good part:

- EFT systematic improvment possible
- Go to NLO or three-body

Summary

- Elegant theory with few input parameters
- Branching ratio as results and not as input
- Consistent results with a fundamental deuteron including the full three-body phase space
- Branching ratio favors small binding energies
- Systematic improvement possible in the future