EMMI workshop day 2 wrap-up

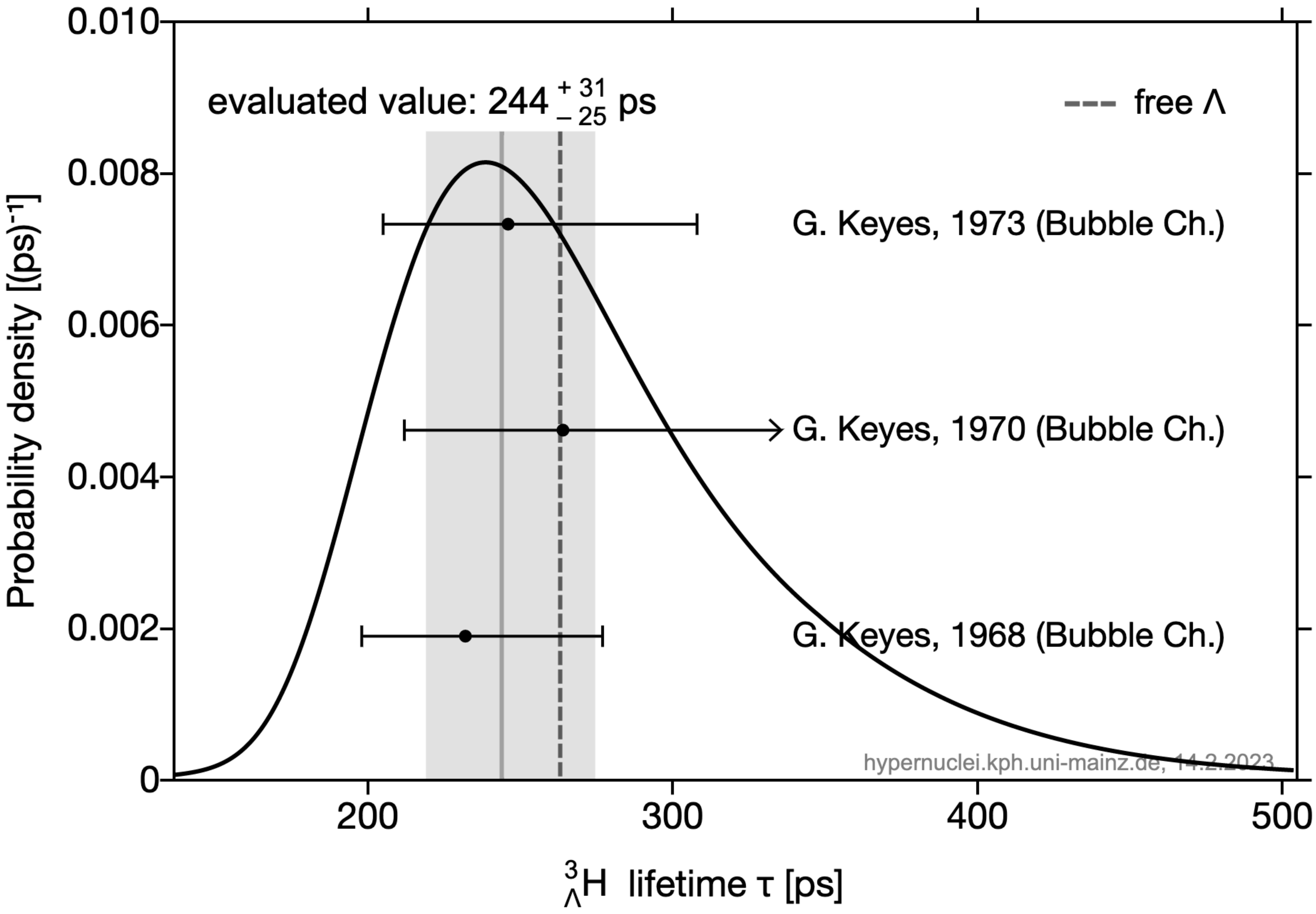
Maximiliano Puccio (CERN)

Bologna 14 Feb 2023

A bit of history

Before Heavy Ions

[Mainz database]

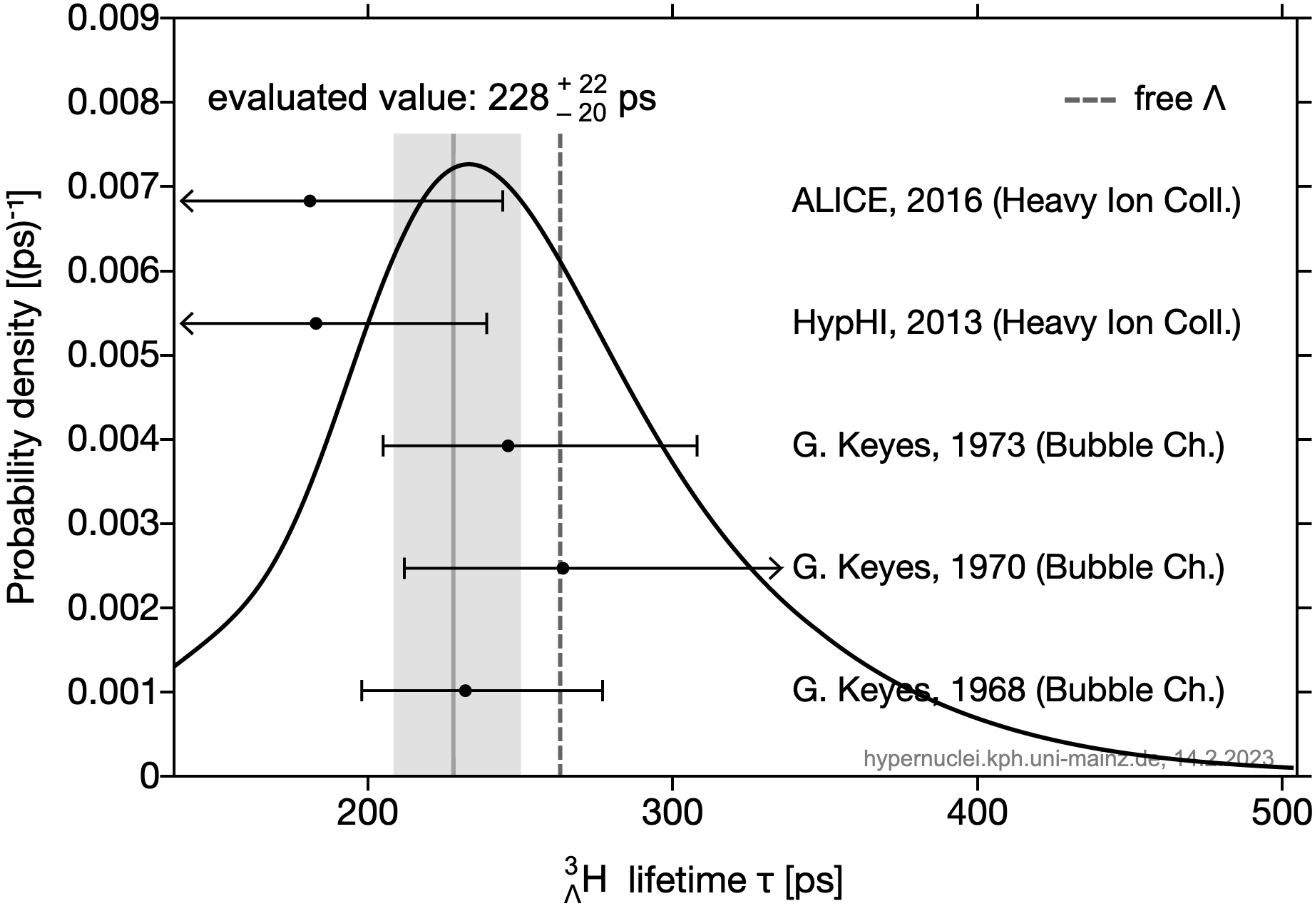


90% Probability

A bit of history

First EMMI workshop, 2015

Mainz database

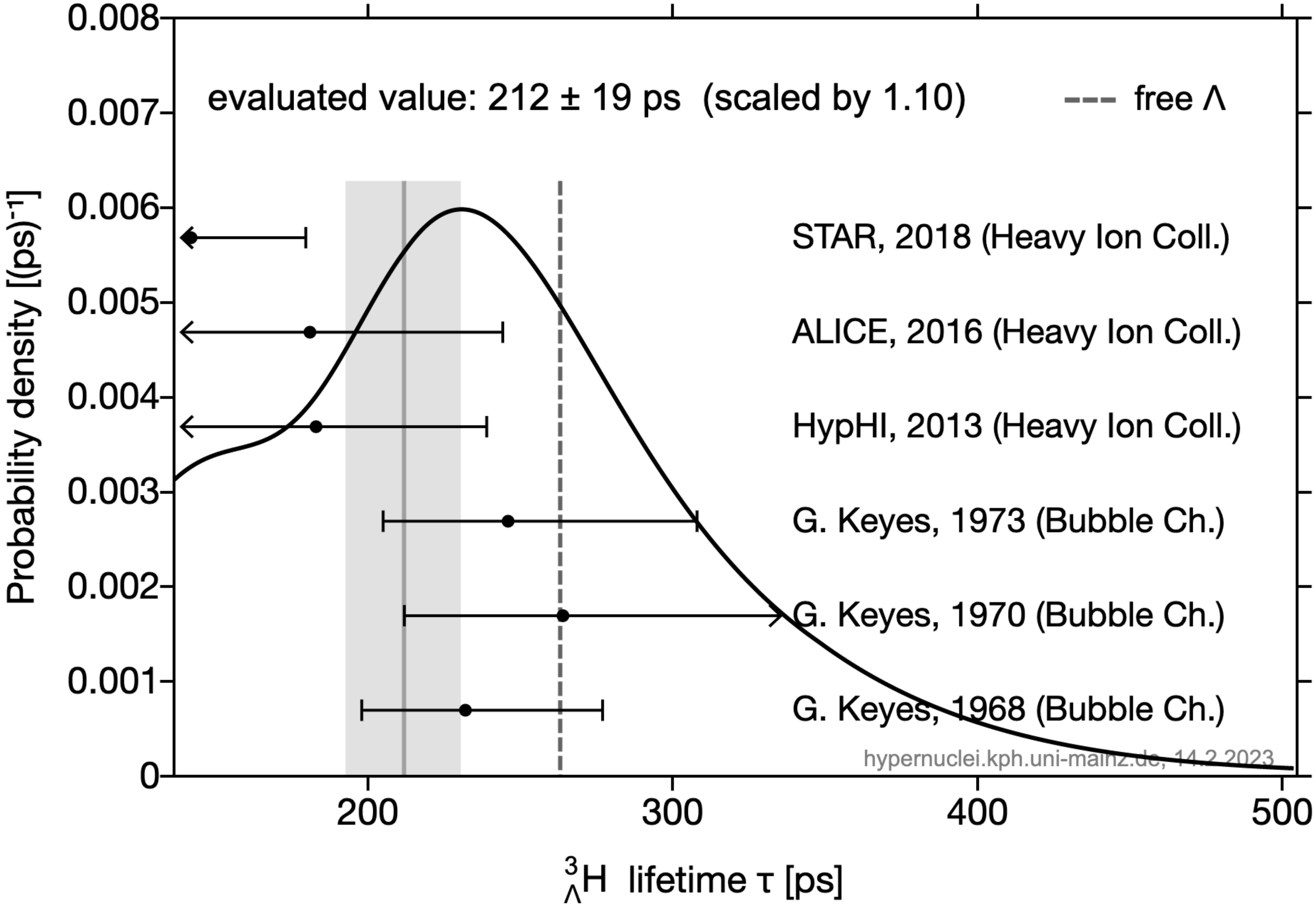


76% Probability

A bit of history

Second EMMI workshop, 2017

Mainz database

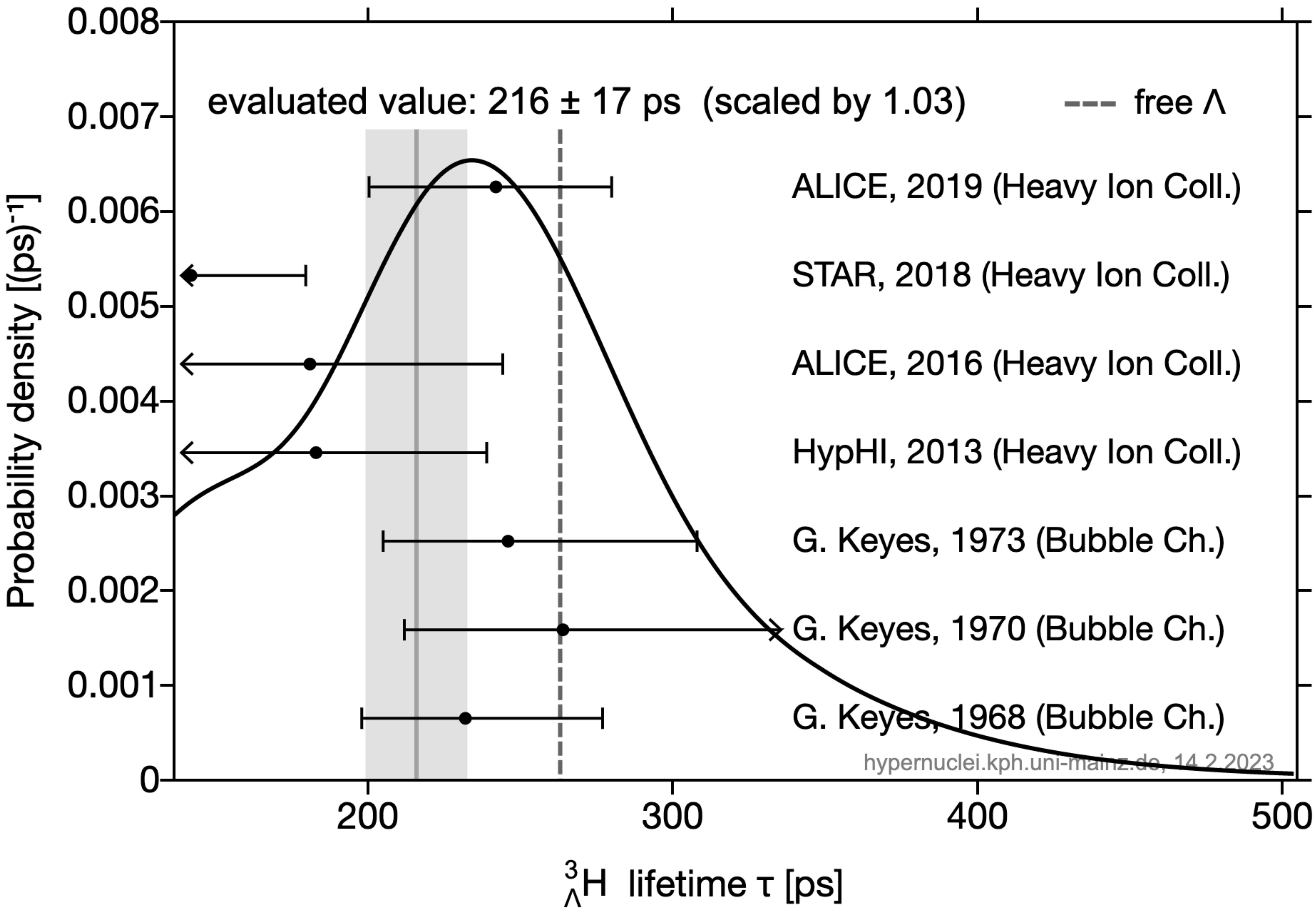


35% Probability

A bit of history

Third EMMI workshop, 2019

Mainz database

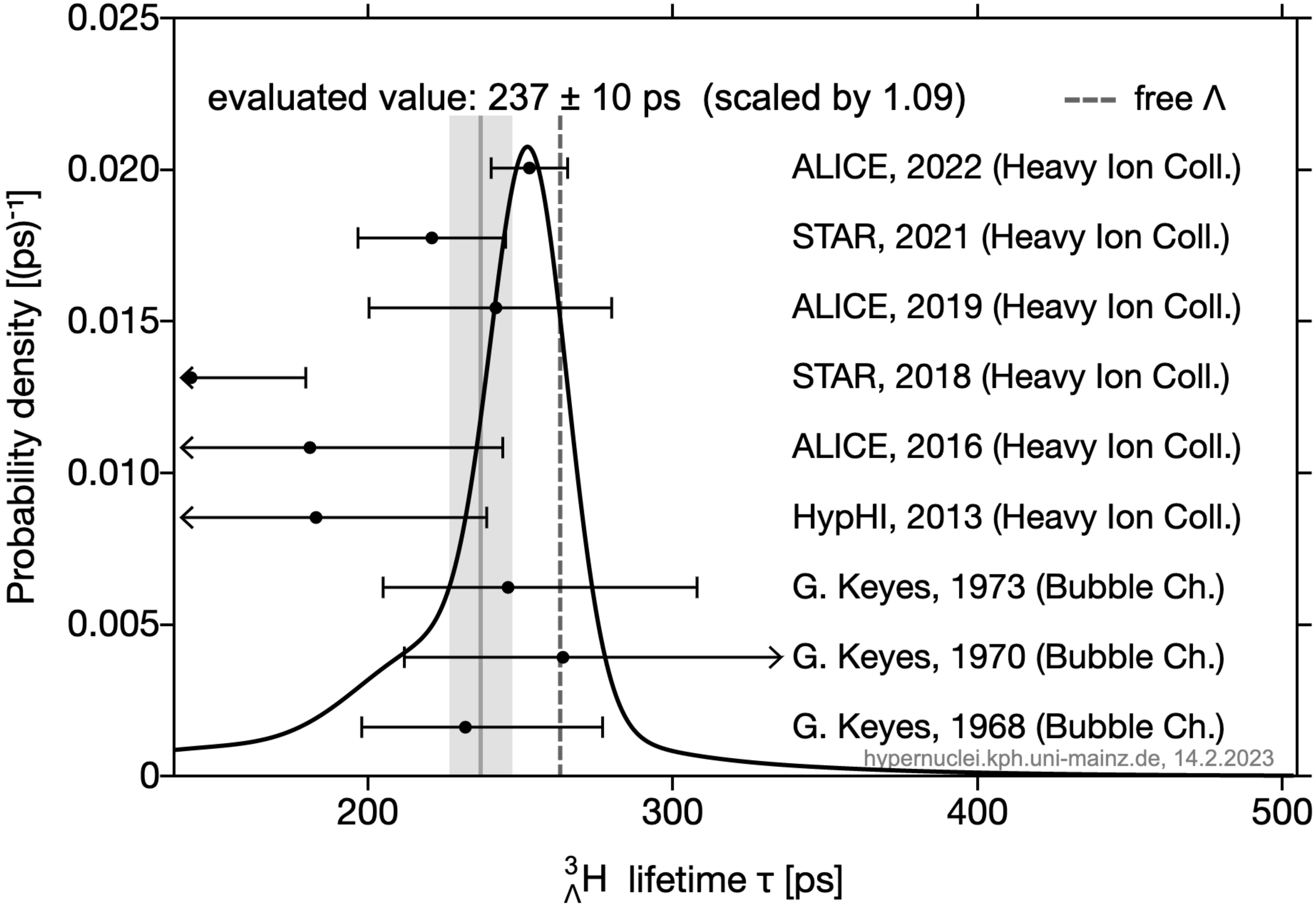


38% Probability

A bit of history

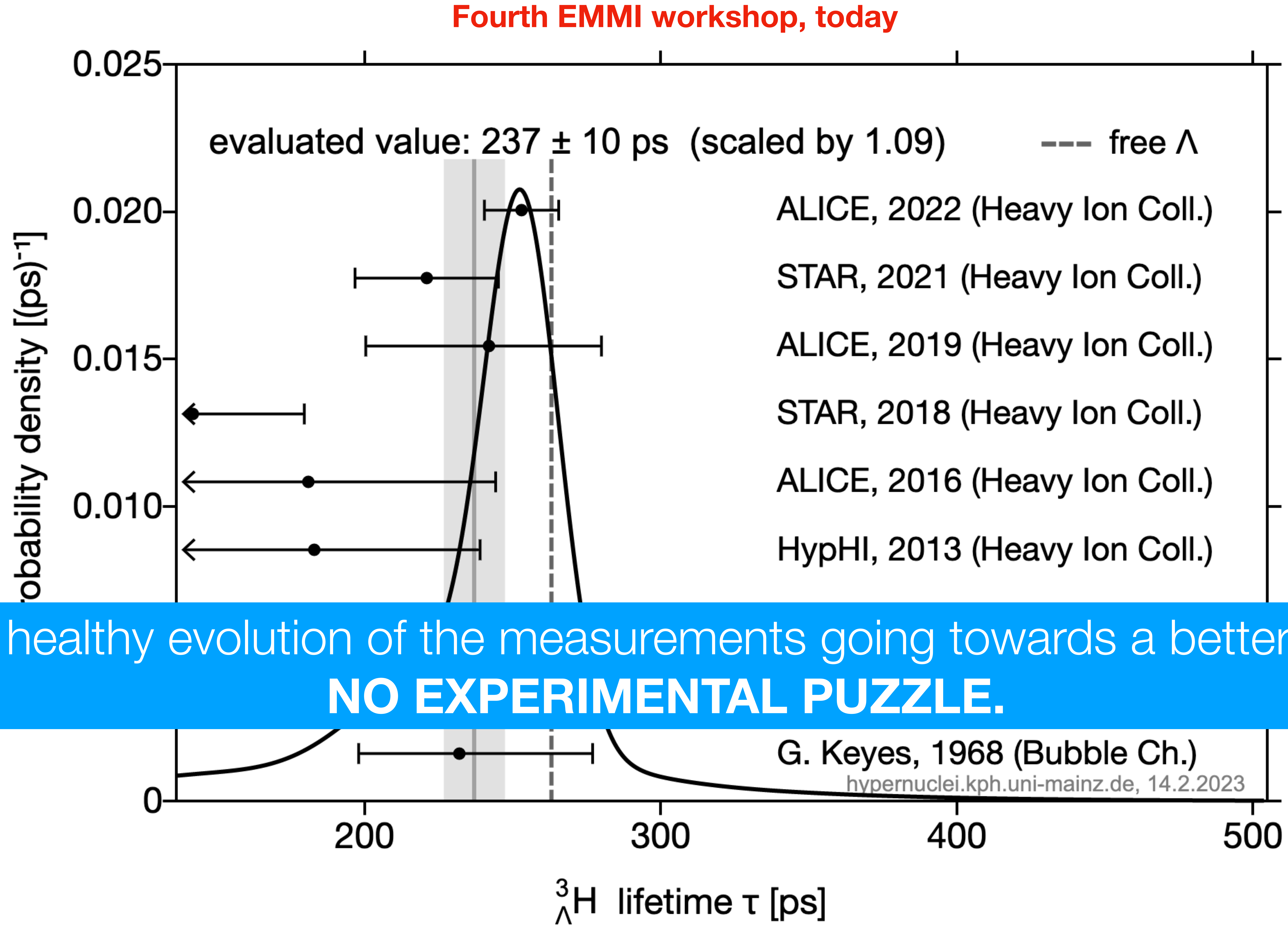
Fourth EMMI workshop, today

Mainz database



30% Probability

Let’s get something straight



[Mainz database]

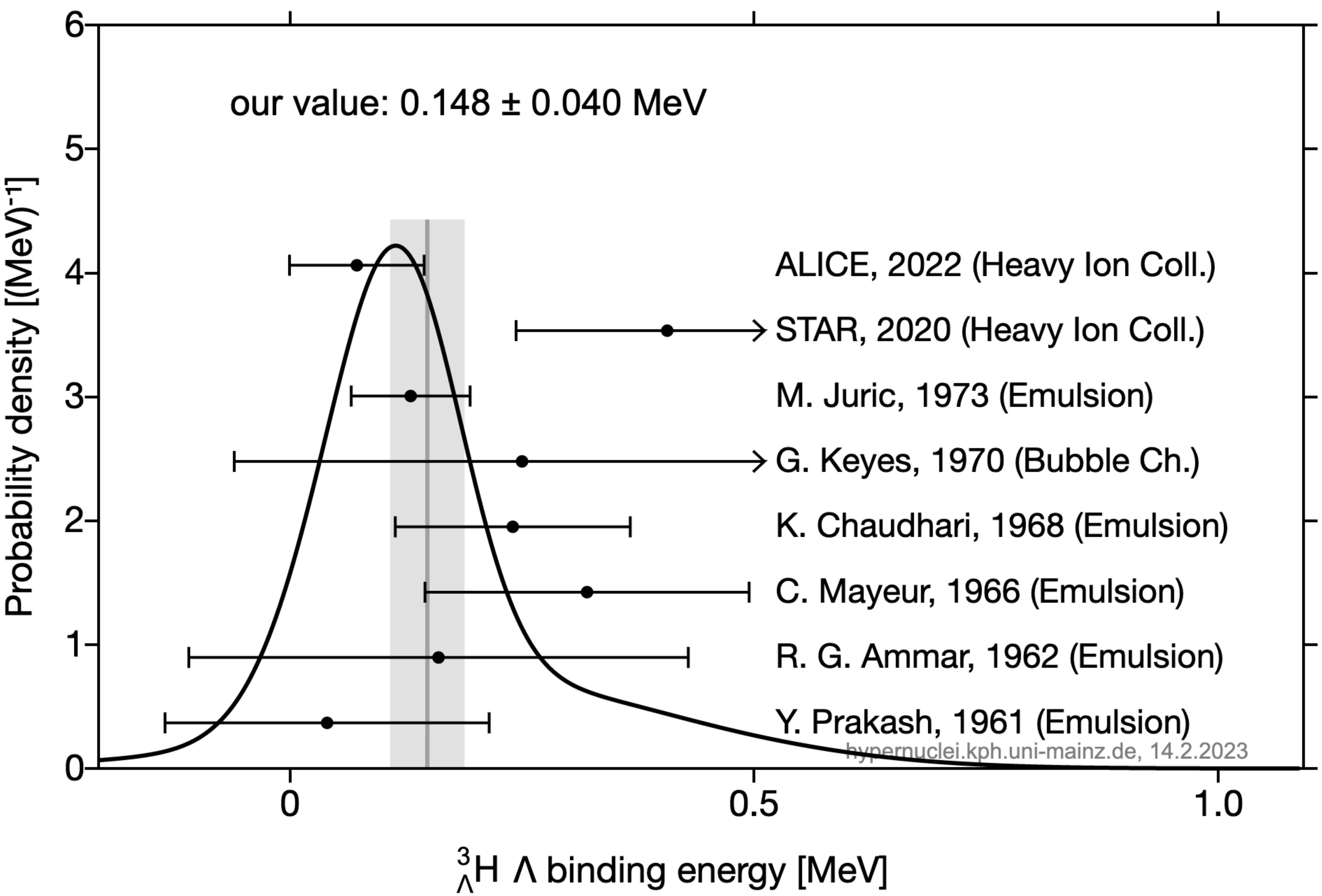
30% Probability

A rather healthy evolution of the measurements going towards a better precision.

NO EXPERIMENTAL PUZZLE.

A bit of history

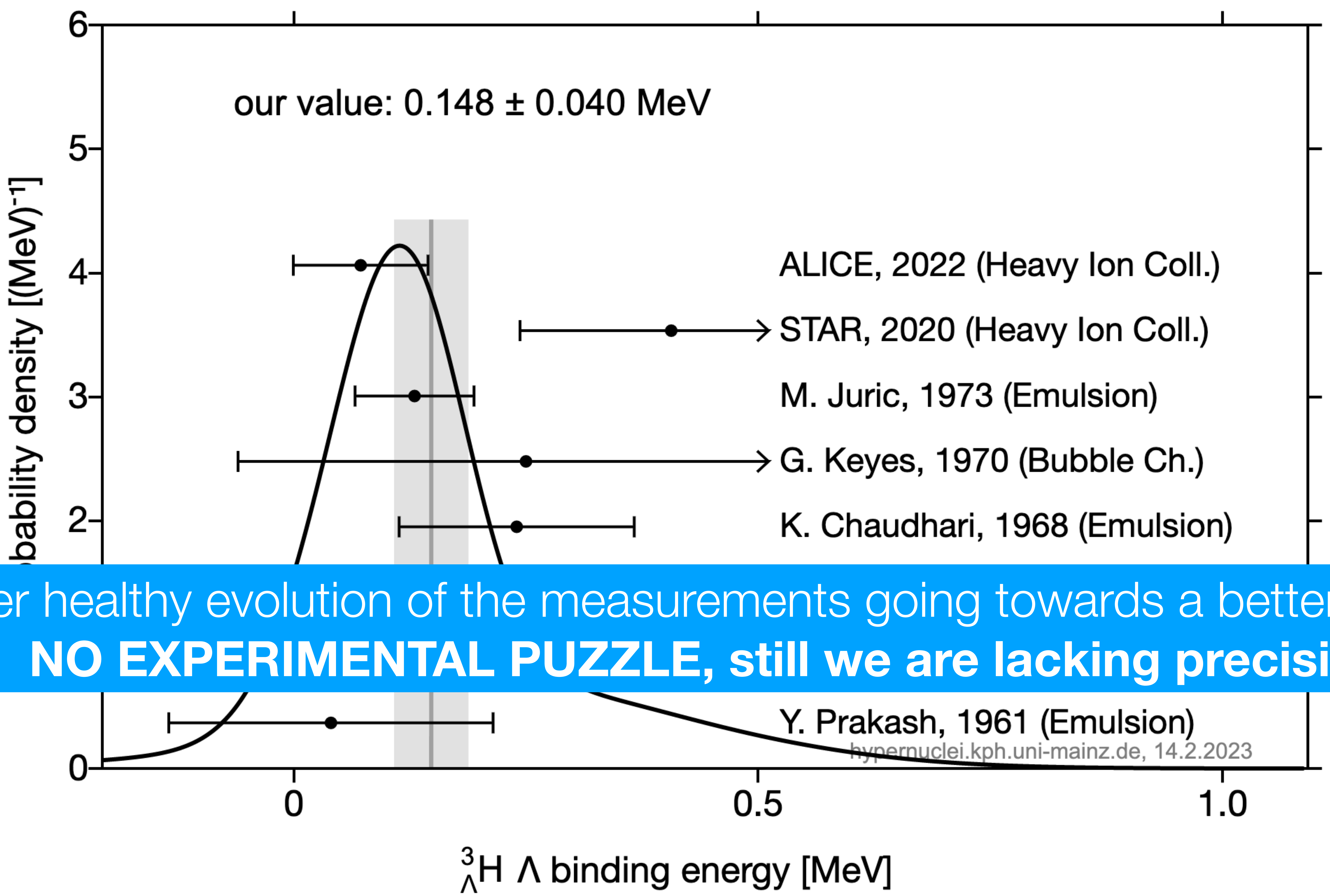
Mainz database



57% Probability

A bit of history

Mainz database



57% Probability

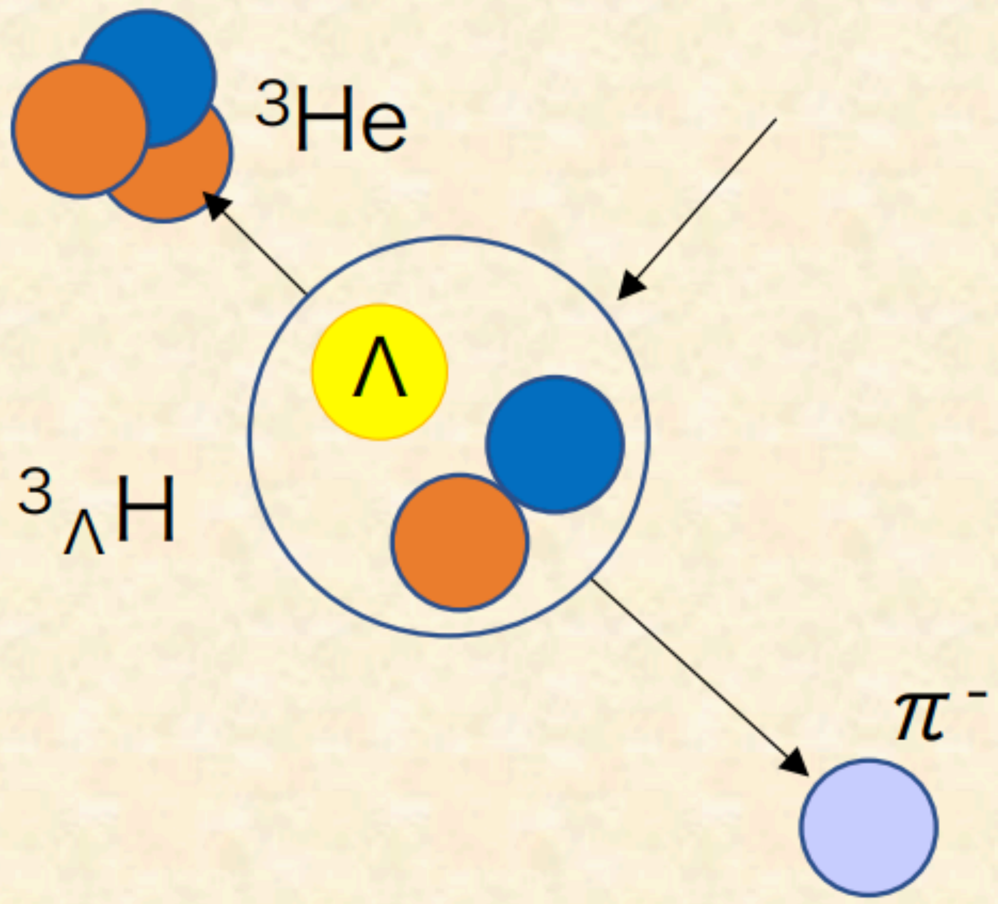
A rather healthy evolution of the measurements going towards a better precision.
NO EXPERIMENTAL PUZZLE, still we are lacking precision

Perspective for more precise hypertriton binding energy

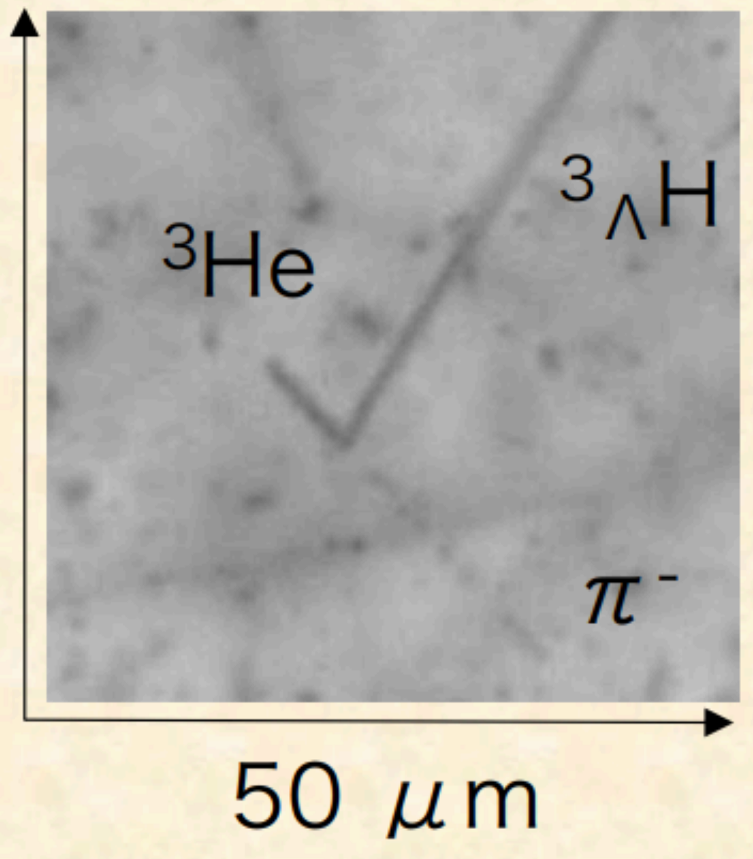
J-PARC, T. Saito

Hypertriton search with Mask R-CNN

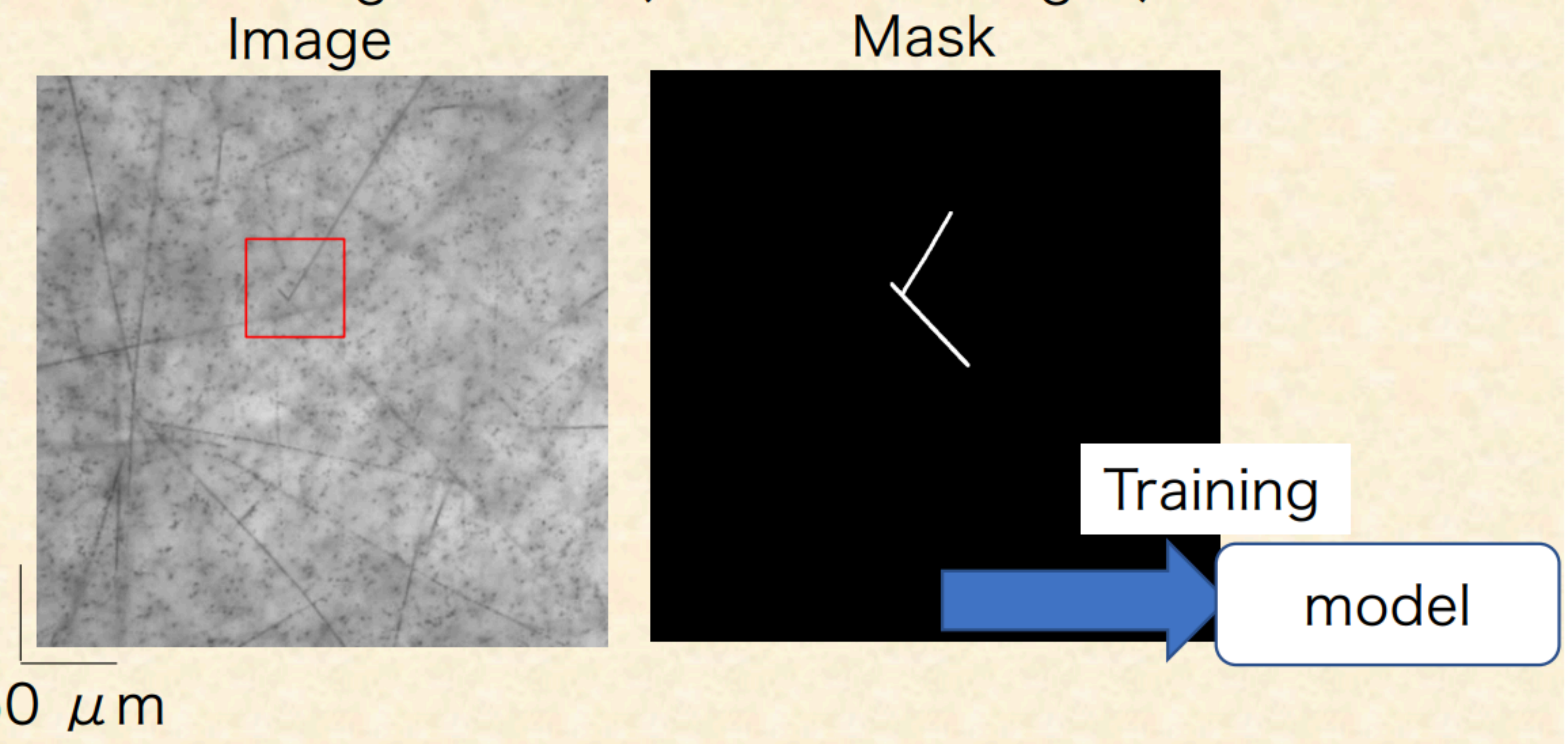
Two body decay of $^{3}_{\Lambda}H$



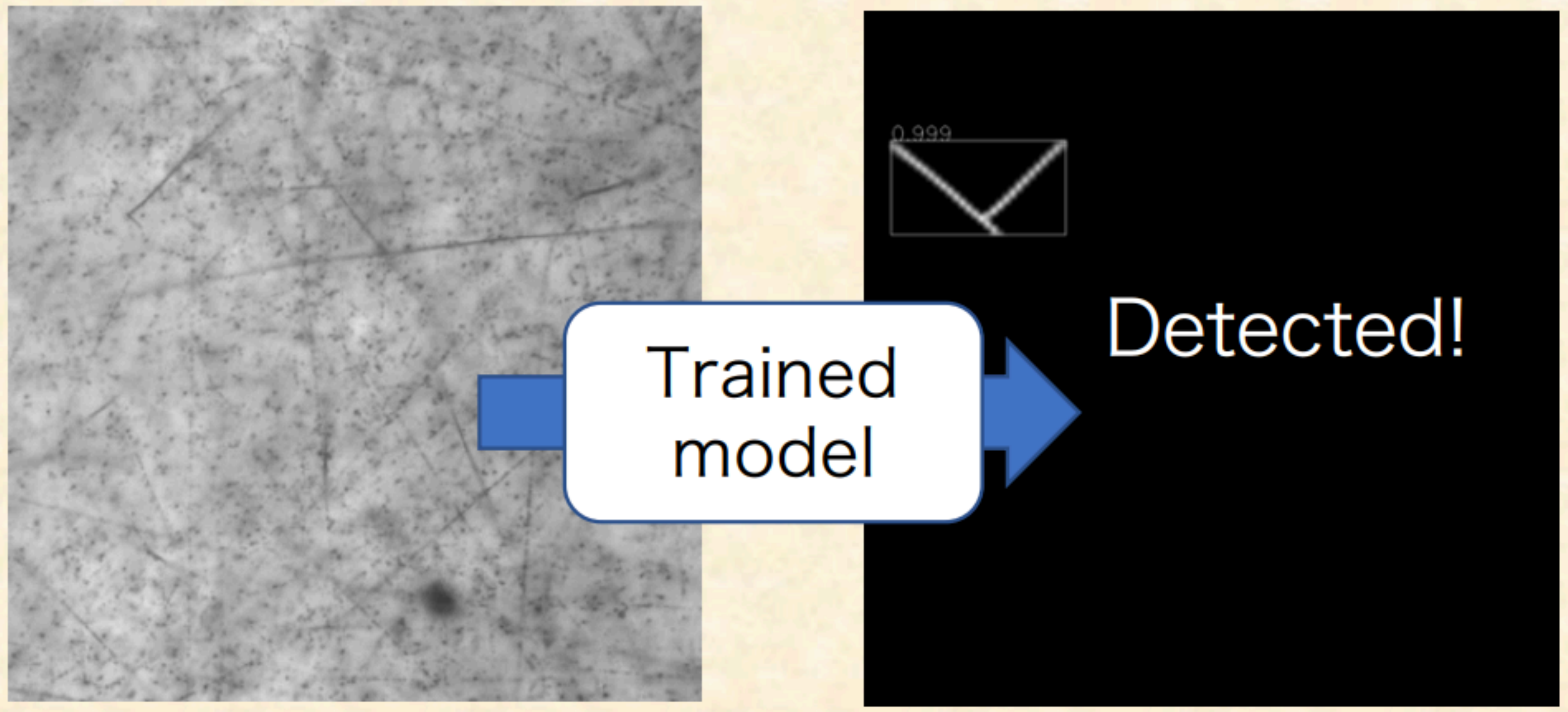
Simulated image



Training dataset (Simulated images)



Real image



Projected precision: 28 keV

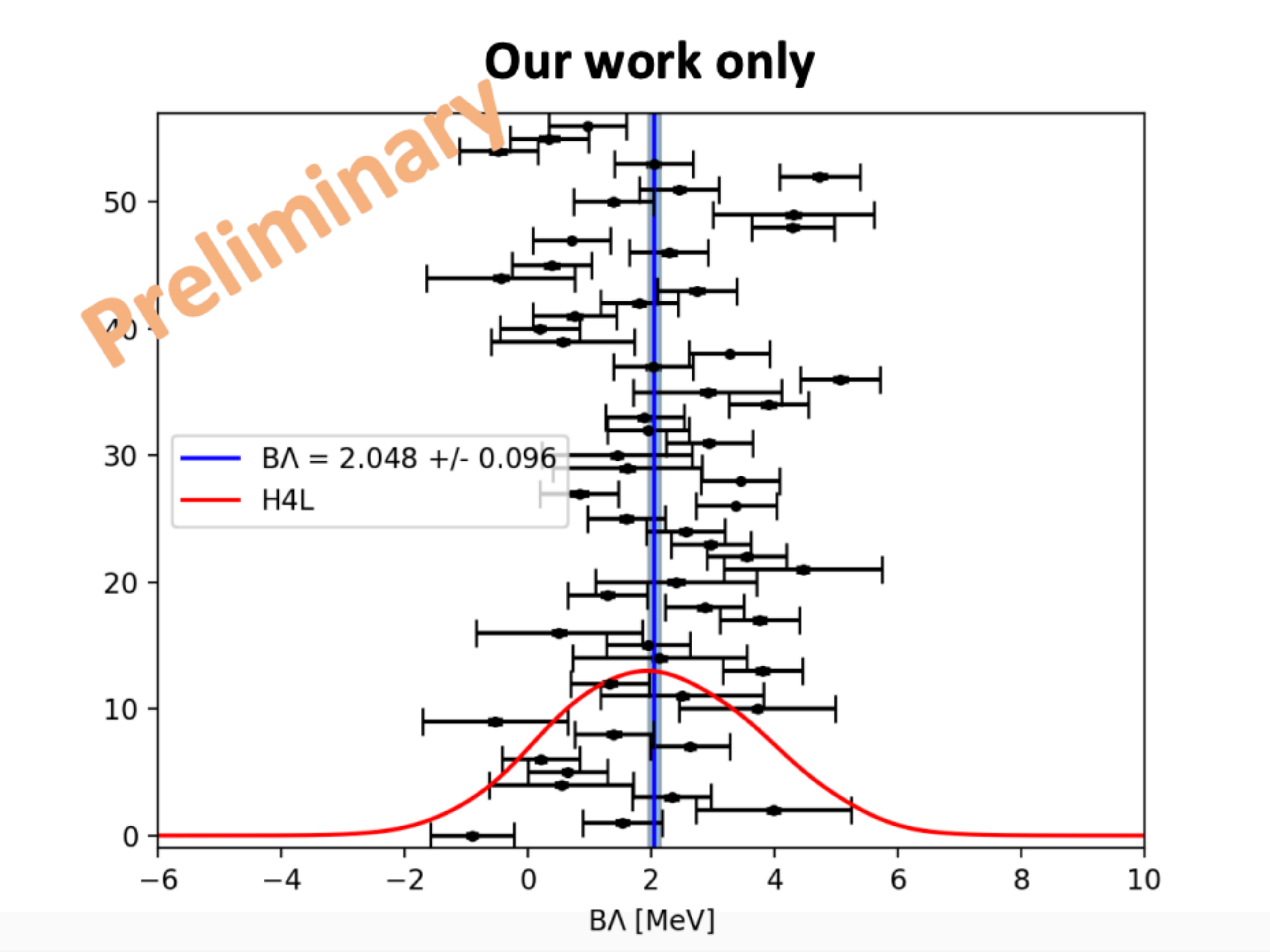
Ayumi Kasagi. Ph.D. thesis (2023)

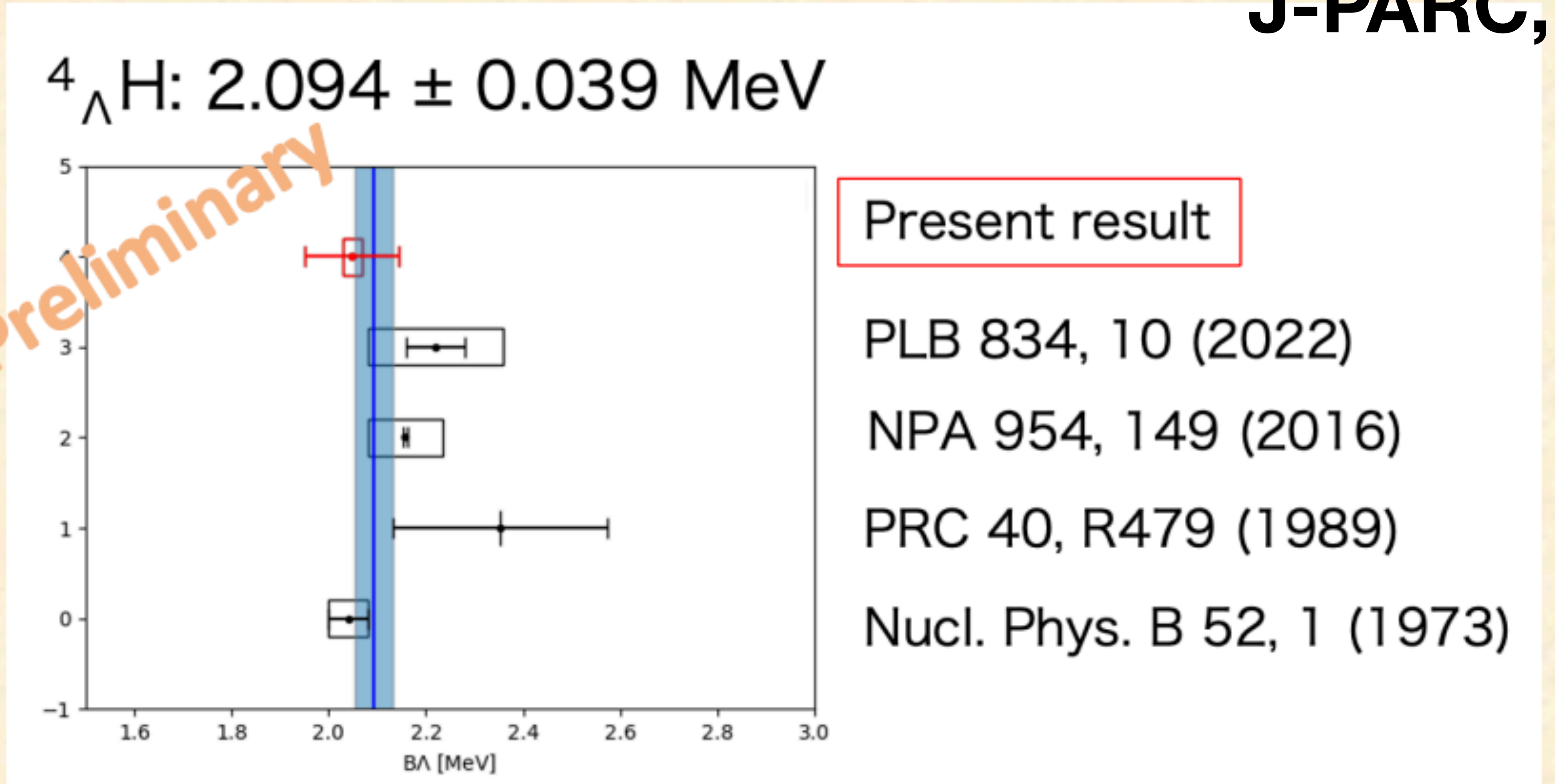
Perspective for more precise hypertriton binding energy

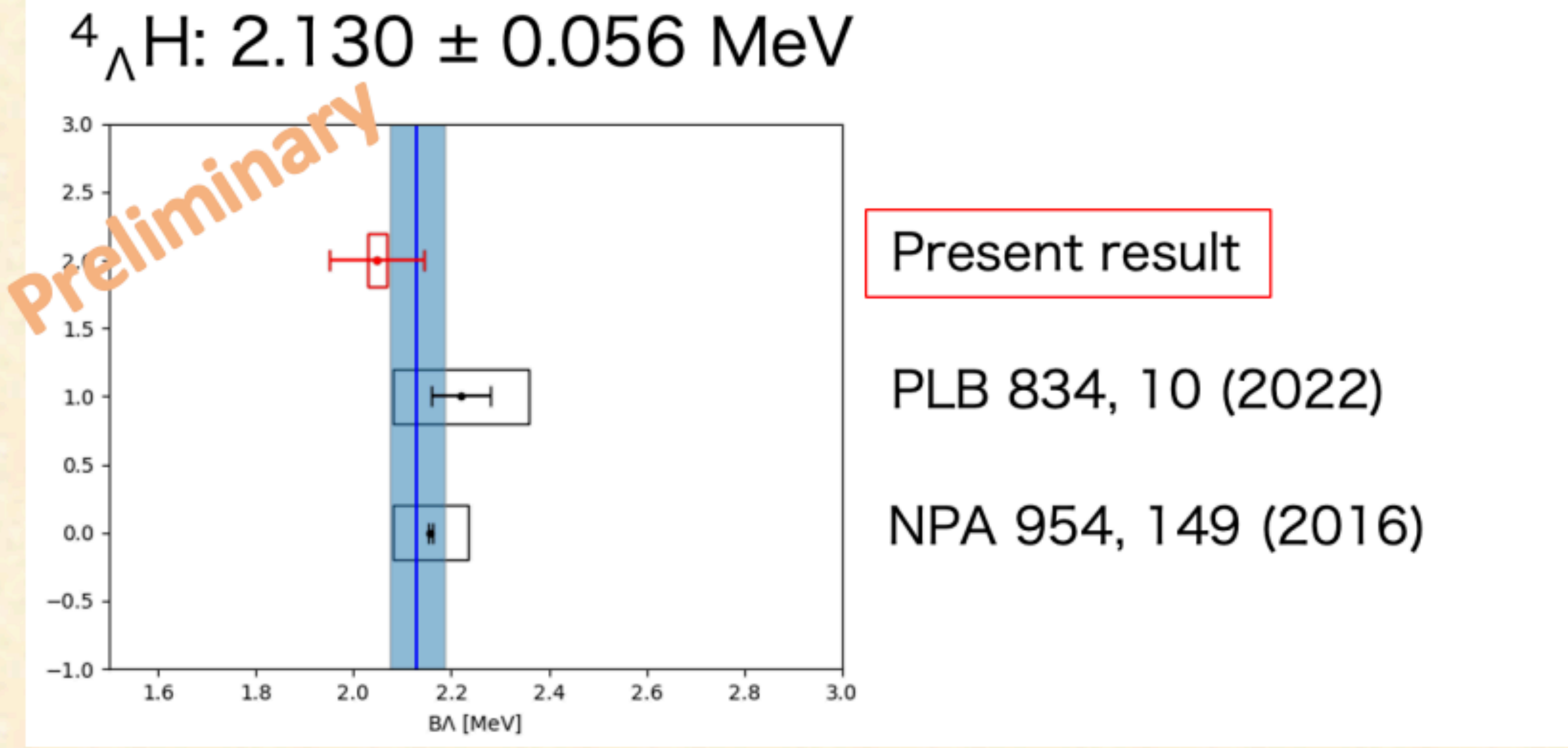
J-PARC, T. Saito

Binding energy for $^{4}_{\Lambda}H$

- Mass with range of ^{4}He
- **Emulsion calibration (density and shrinkage) for each event**
- Checking coplanarity and inner-product
- **Only 0.4 % of the entire data**







Similar analysis for hypertriton (to be published soon)

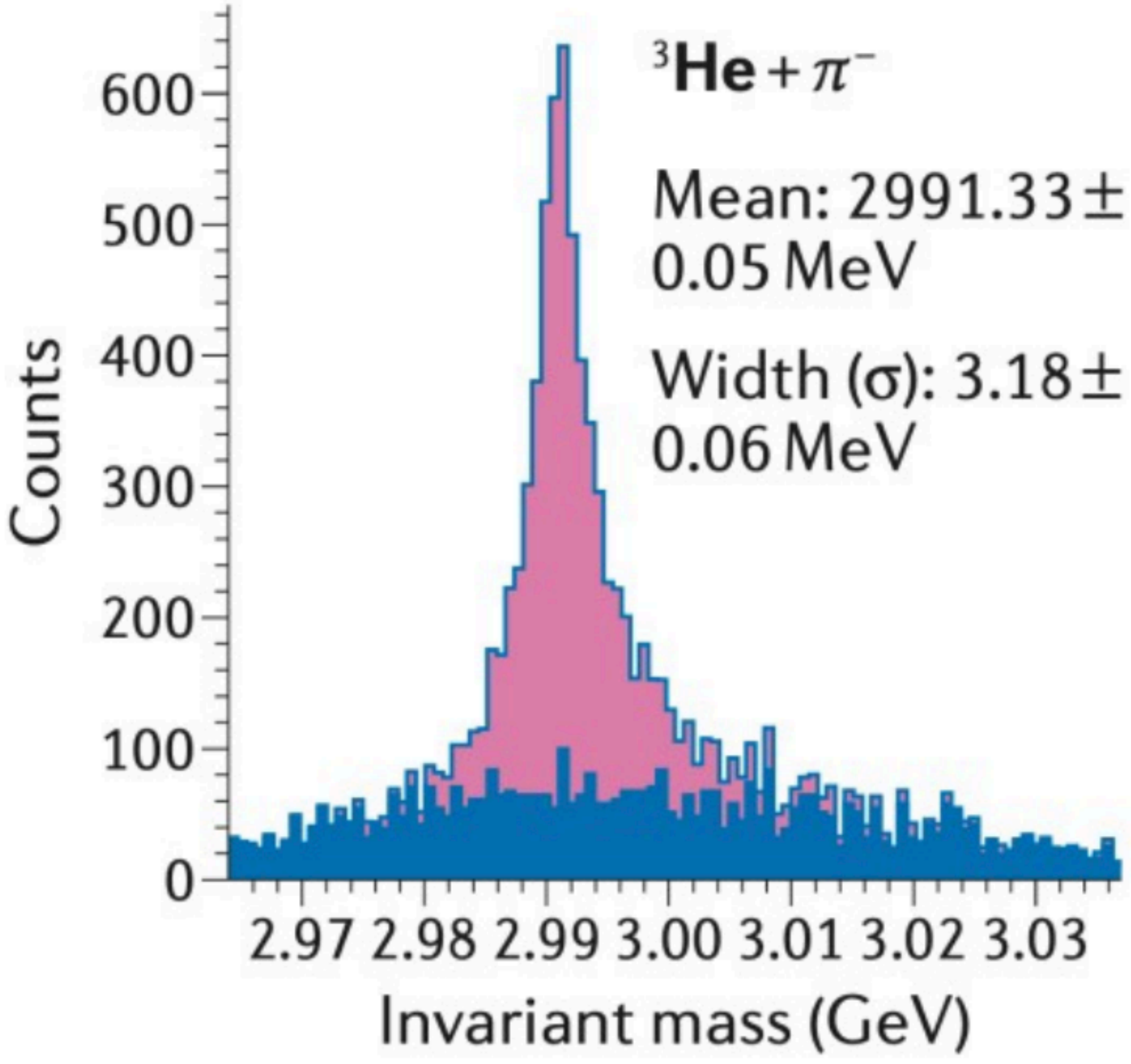
Ayumi Kasagi. Ph.D. thesis (2023)

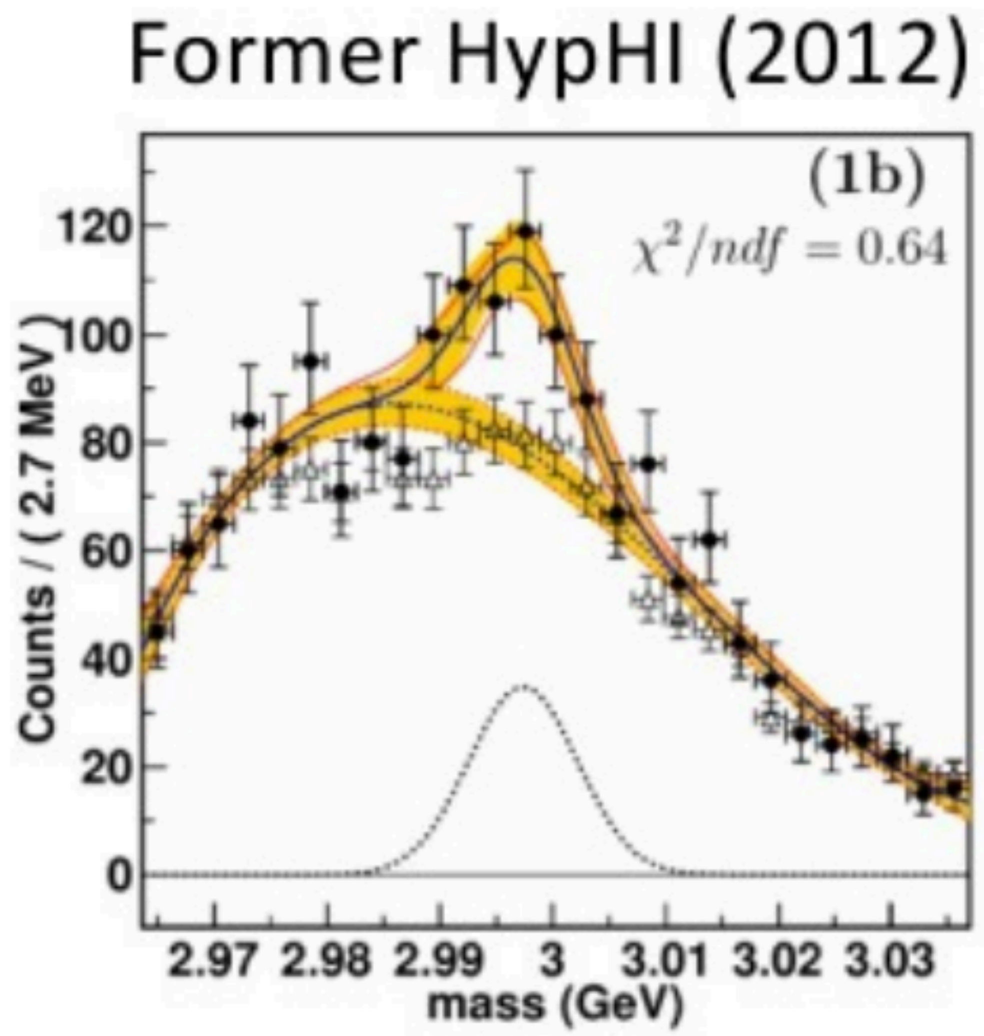
WASA-FRS HypHI prospective

Expected performances

C. Rappold

- **Expected results by updated MC simulations:**





  - 4 days measurement

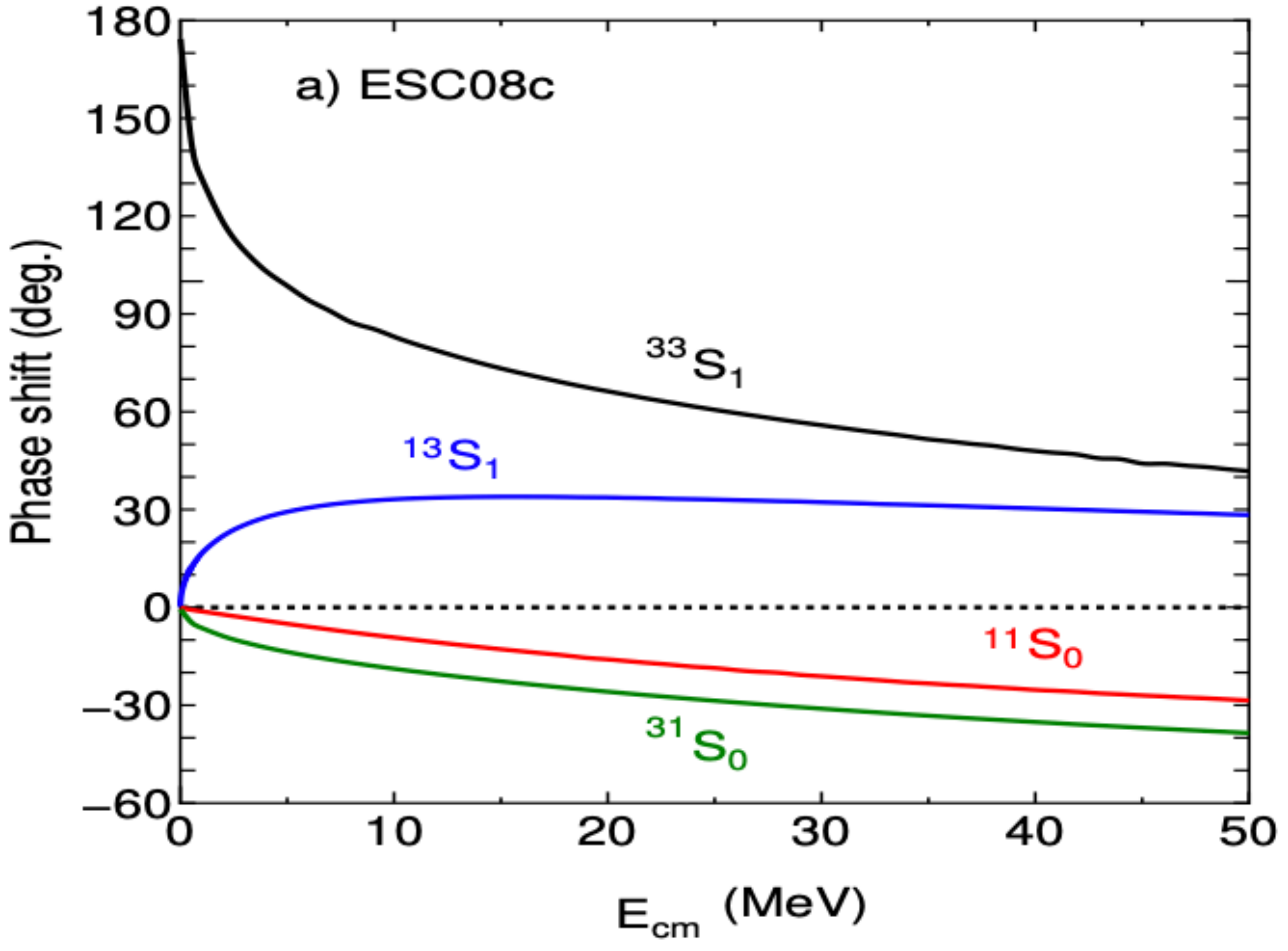
[T.R,Saito et al., Nature Reviews Physics 3, 803-813 (2021)]

- **Mass resolution**
  - 3.2 MeV/c² (1 T field)
  - 1.5 times better than HypHI
- **Statistics**
  - ~ 5800 in the peak for 4 days
  - 38 times more than HypHI
- **Expected Lifetime accuracy**
  - 8 ps
  - 5 times better than HypHI

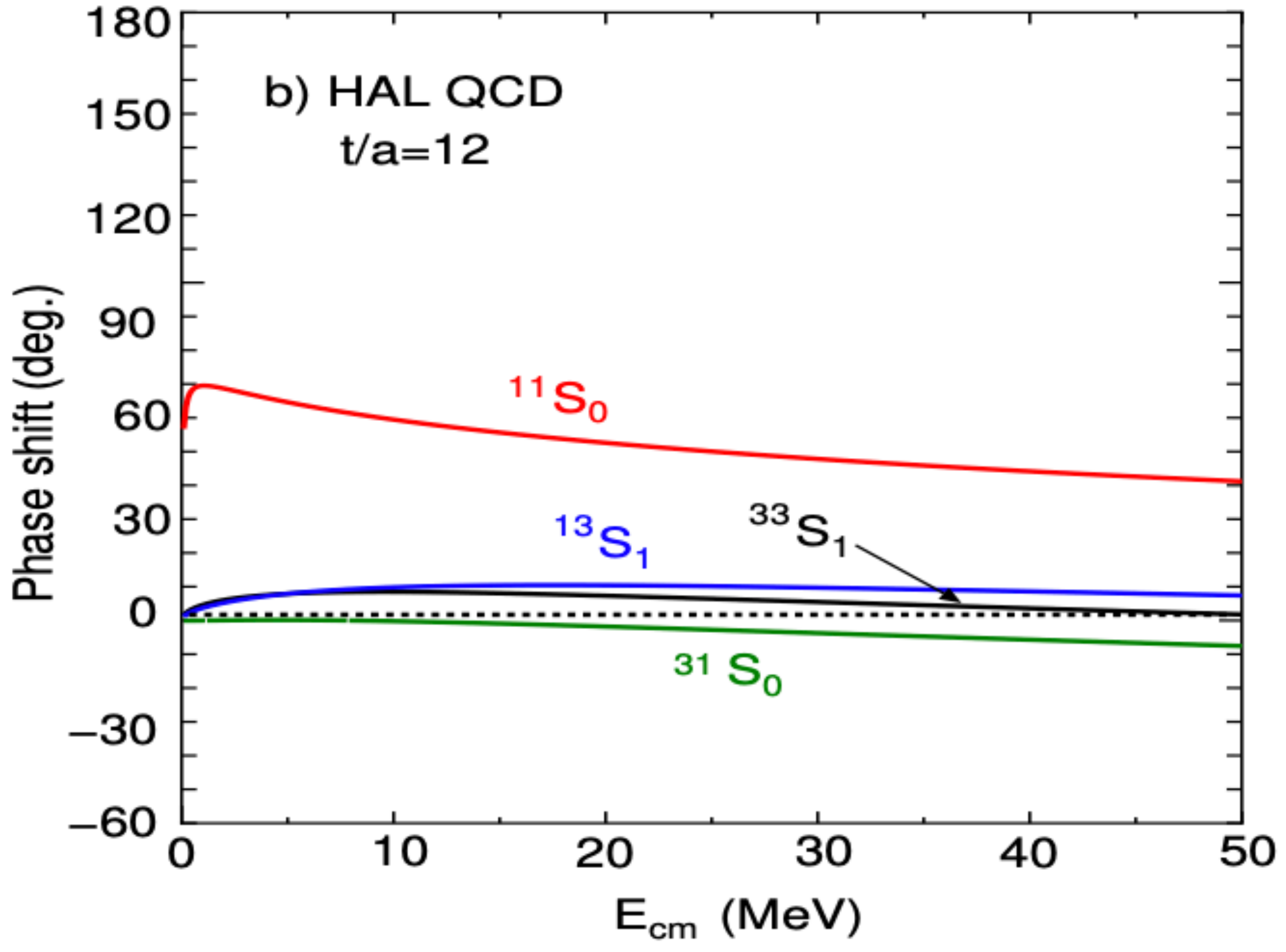
Multi-strange hypernuclei: theory calls

A. Gal

ΞN s-wave model interactions



Nijmegen ESC08c version



HAL-QCD version

Hiyama et al. PRL 124 (2020) 092501: A≤4 Ξ hypernuclei

Substantial model dependence

HAL-QCD: LQCD calculation at $m_{\pi(K)}$=146(525) MeV

Sasaki et al. NPA 998 (2020) 121737

Inoue et al. AIPCP 2130 (2019) 020002: V_{Ξ}^{LQCD}=4±2 MeV

Kohno, PRC 100 (2019) 024313: $V_{\Xi}^{EFT} \approx$ 10 MeV

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Measurement of s-wave Xi hypernucleus required

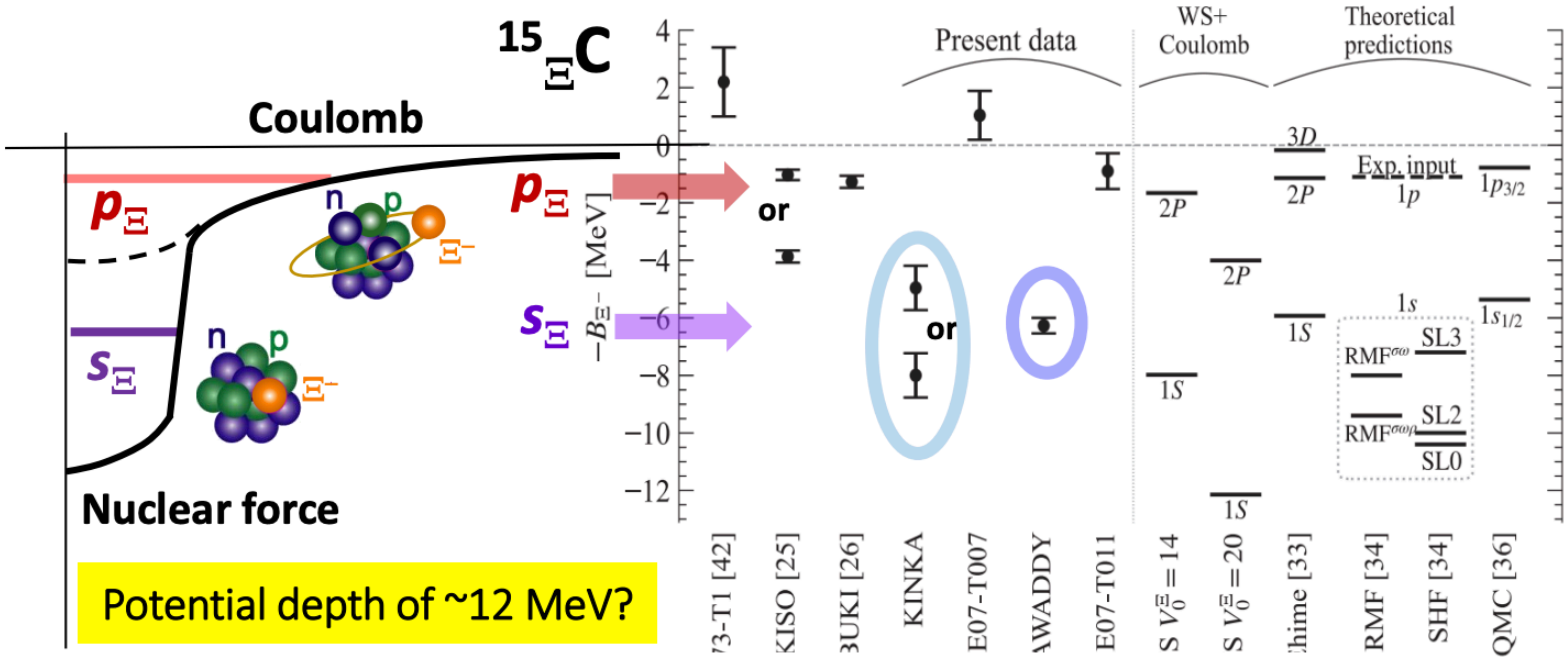
Experiment answer?

H. Tamura

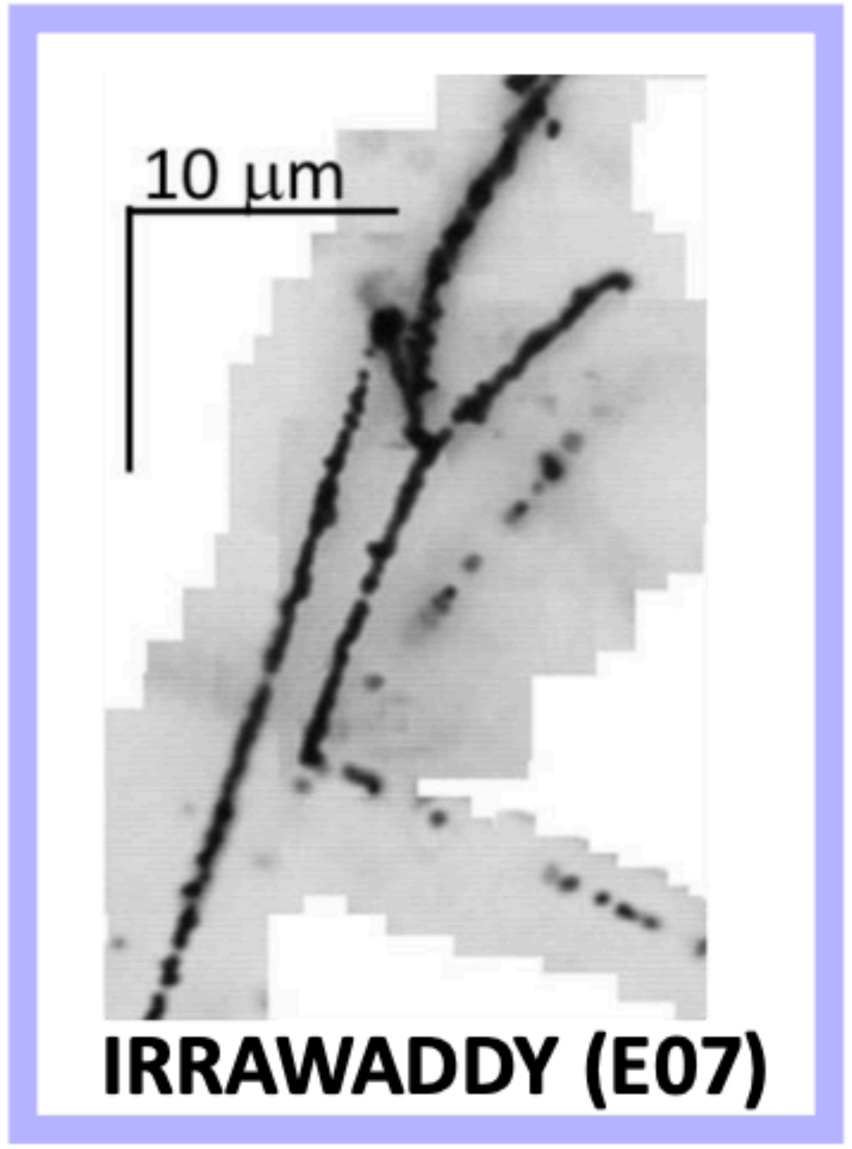
Observation of *s*-state Ξ hypernucleus ?

$\Xi^- + {}^{14}N \rightarrow {}^{15}_{\Xi}C$ *M. Yoshimoto et al., Prog. Theor. Exp. Phys. 2021, 073D02*

IRRAWADDY (E07)	${}^5_\Lambda He + {}^5_\Lambda He + {}^4He + n$: 6.27±0.27 MeV
KINKA (KEK E373)	${}^9_\Lambda Be + {}^5_\Lambda He + n$: 8.00±0.77 or 4.96±0.77 MeV



Potential depth of ~12 MeV?



Caution:
Theories seem to agree with the data, but they used the BNL suggestion of U_Ξ ~ -15MeV.

Why Ξ survives until it cascades down to the 0s orbit ??

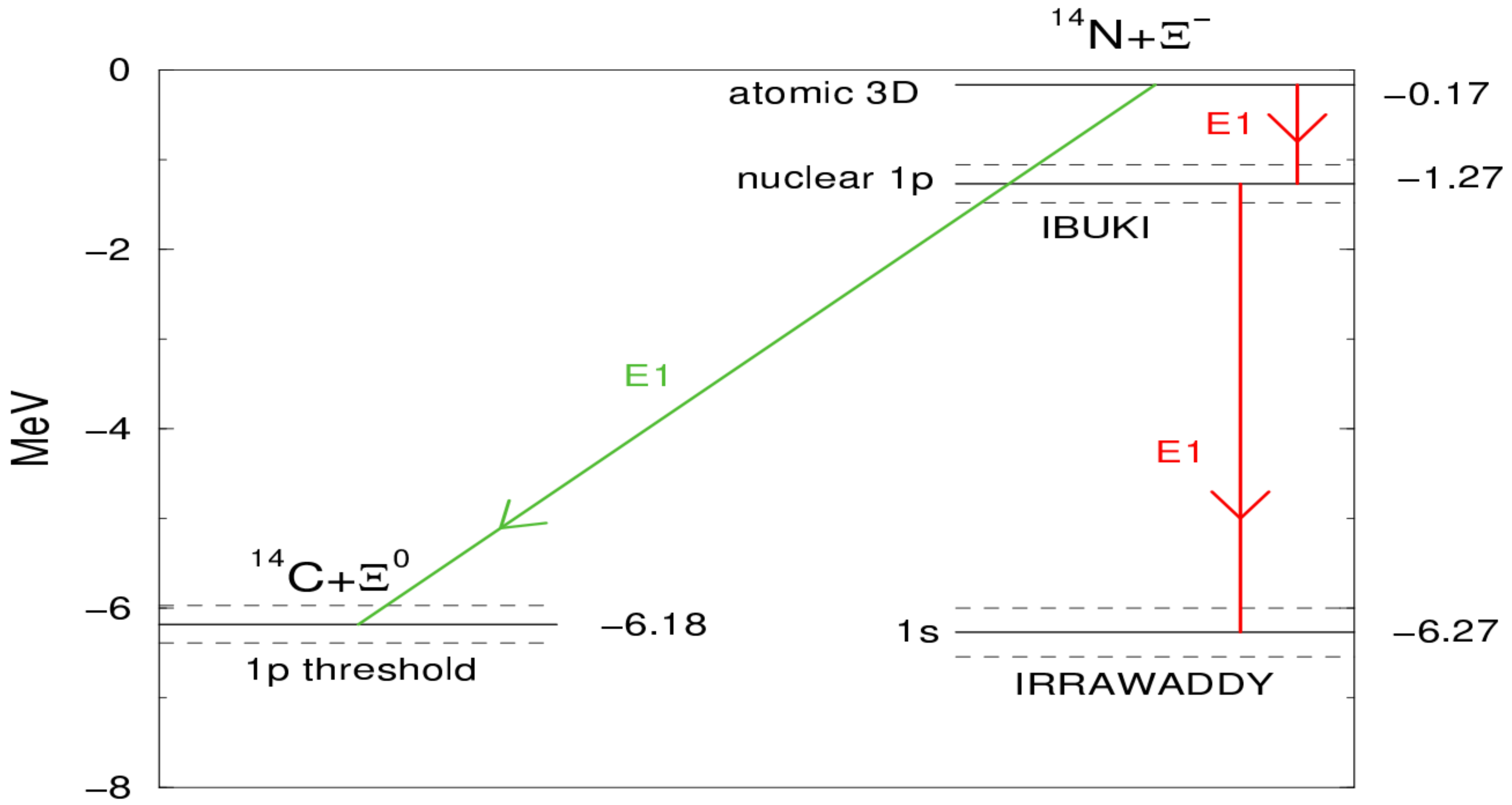
=> Gal's talk

ΞN→ΛΛ in Nijmegen/ HAL QCD => Ξ absorption mainly at 3D / 2P orbits
Observation of s states => **extremely weak ΞN→ΛΛ interaction?**

Or maybe not?

A. Gal

$1s_{\Xi^-}$ **reinterpreted as** $1p_{\Xi^0}$



Friedman-Gal, PLB 837 (2023) 137640

Ξ^0 **relevance unique to** ^{14}**N, not in** ^{12}**C or** ^{16}**O.**

$\Xi^- p \leftrightarrow \Xi^0 n$ **ch. exch. induces** $^{14}N+\Xi^-_{1p} \leftrightarrow {}^{14}C+\Xi^0_{1p}$ **mixing.**

$^{14}N+\Xi^-_{3D}$ **decays by E1 to both** $^{14}N+\Xi^-_{1p}$, $^{14}C+\Xi^0_{1p}$.

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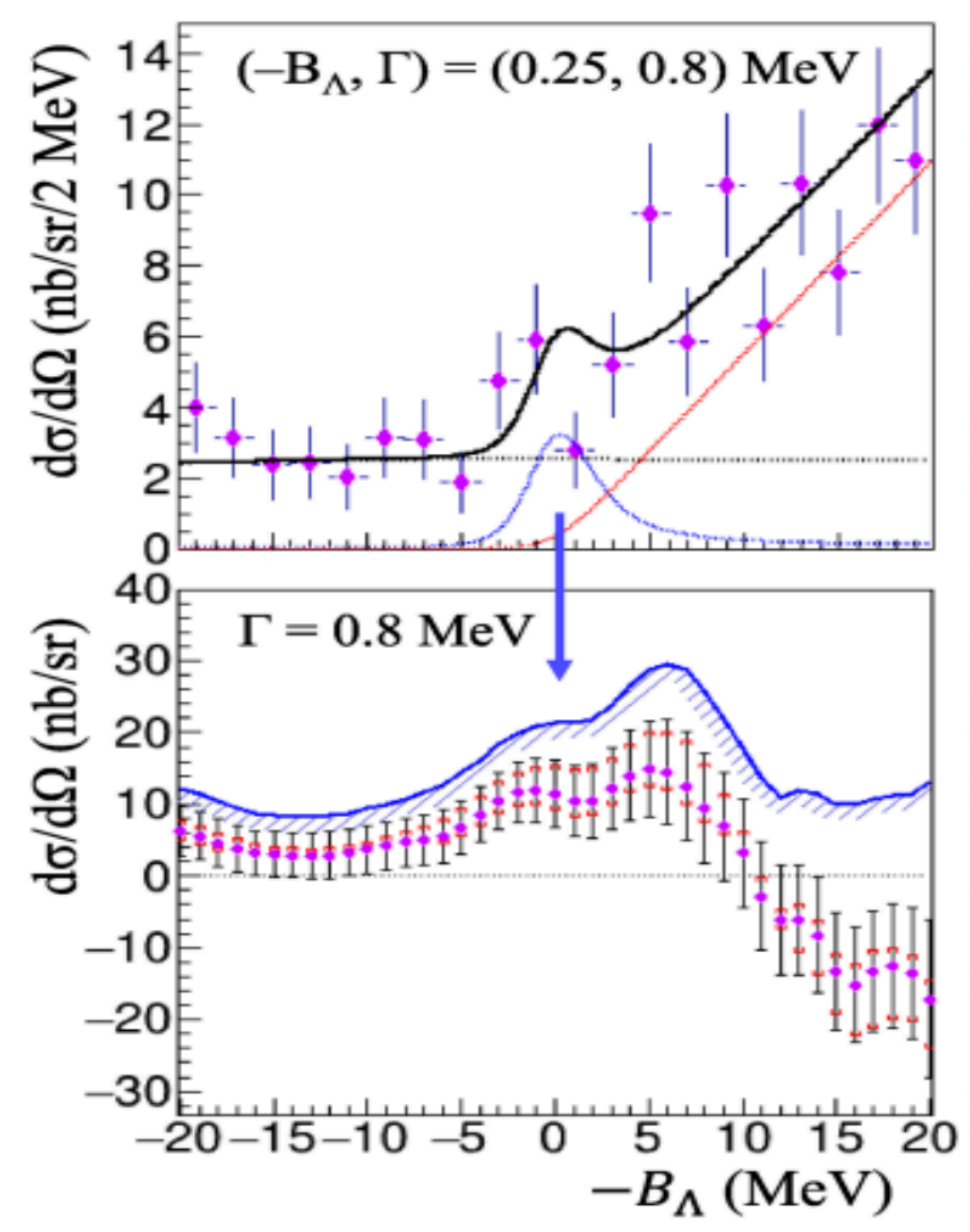
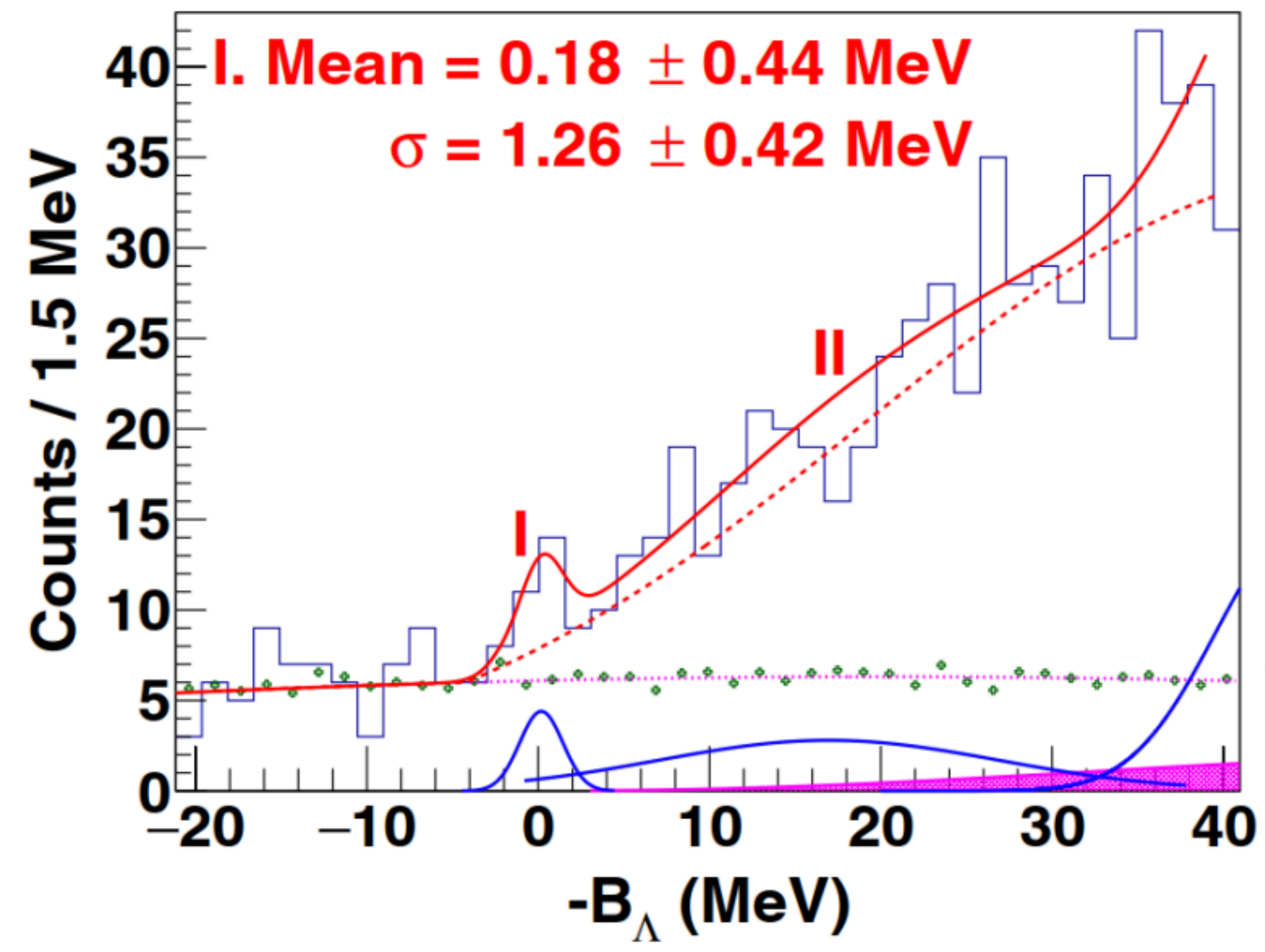
Studies at JLab for LambdaNN

Sho Nagao





- Expected resolution σ = 1.3 MeV, δE = 0.4 MeV
- No robust peak (2.7σ)
- Upper-limits 21 nb sr^{-1} (90% C.L.)

Not only hypernuclei

H. Clement

Outlook and Open Problems

- Size of $d^*(2380)$
  - $\Rightarrow$ elm excitation of d^* $\quad ed \rightarrow ed^* \rightarrow ed\pi^0\pi^0$
- Observation at other installations
  - HADES @ GSI: but no full 4π
  - IHEP ?? $\quad e^+e^- \rightarrow \bar{d}\, d^*$ at 4.3 – 4.6 GeV ??
  - KEK, JPARC, LHCb, others ???
- Astrophysical relevance? (M. Bashkanov, York)
- Are there more (exotic) dibaryons?
  - D_{30} mirror state of d^*
  - strange, charmed and beautiful dibaryons??

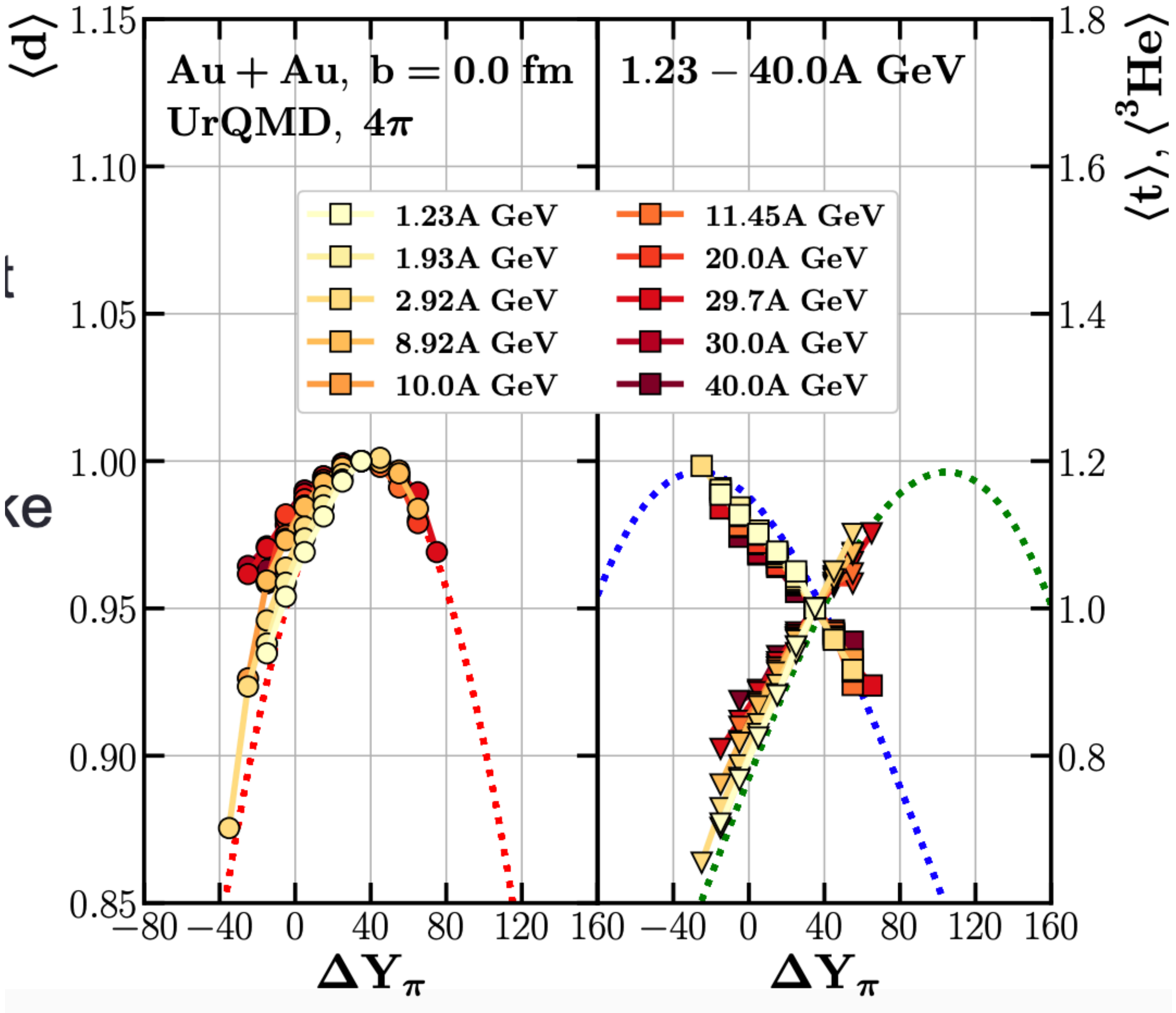
H. Clement Dibaryon - Molecule versus Hexaquark 28

Production models

Coalescence or not Coalescence?

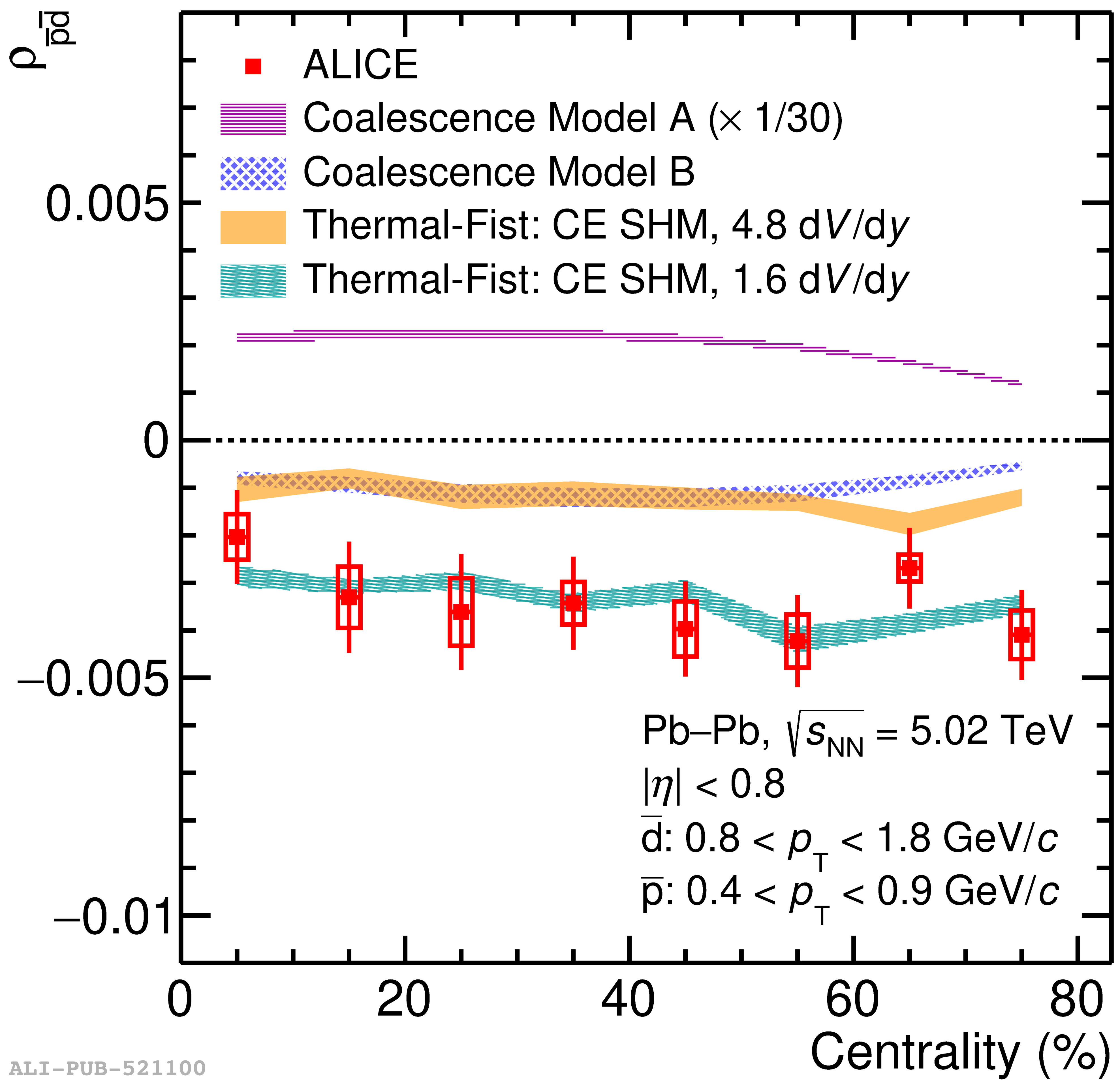
Tom Reichert

A. Kittiratpattana et al. 2210.11699 [nucl-th]



Event by event selection of collisions with large isospin imbalance can help to distinguish between statistical hadronisation (SHM) and coalescence!

arXiv:2204.10166



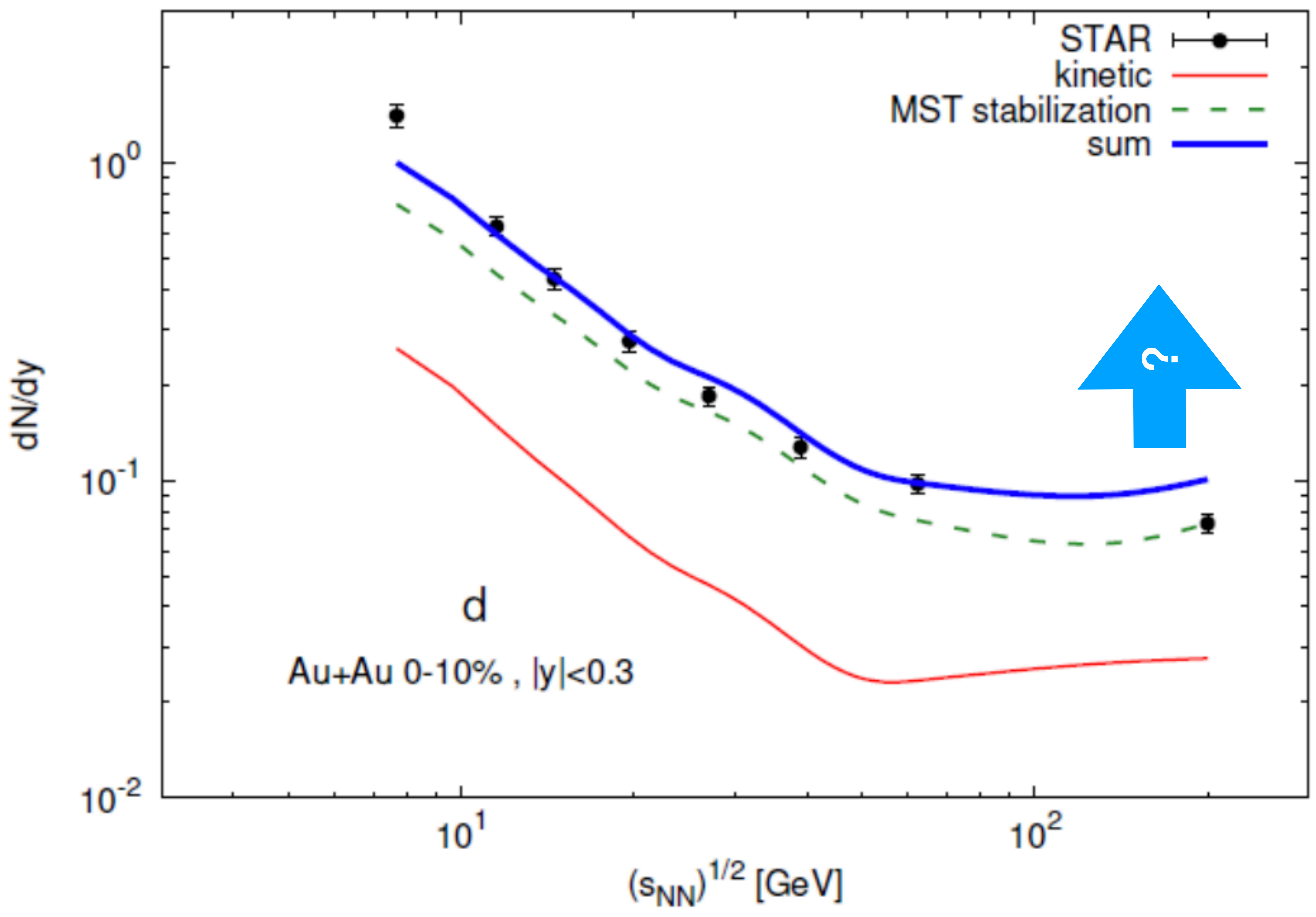
Caution: canonical correction in SHM can introduce correlations due to the conservation of quantum numbers.

Kinetic production + MST

Kinetic vs. potential deuteron production

E. Bratkovskaya

Excitation function dN/dy of deuterons at midrapidity

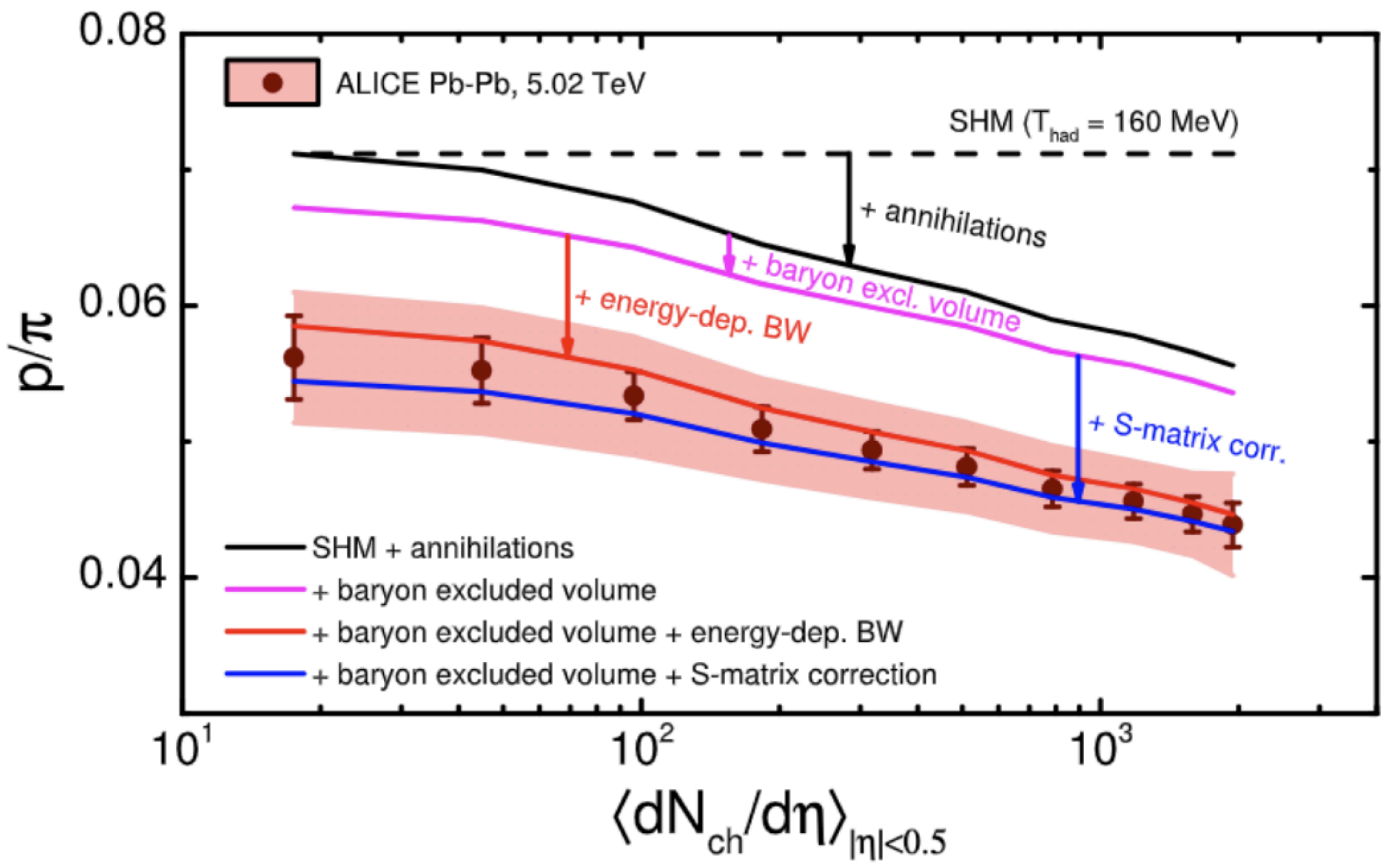


- PHQMD provides a good description of STAR data on d yield at midrapidity
- The potential mechanism is dominant for d production at all energies!

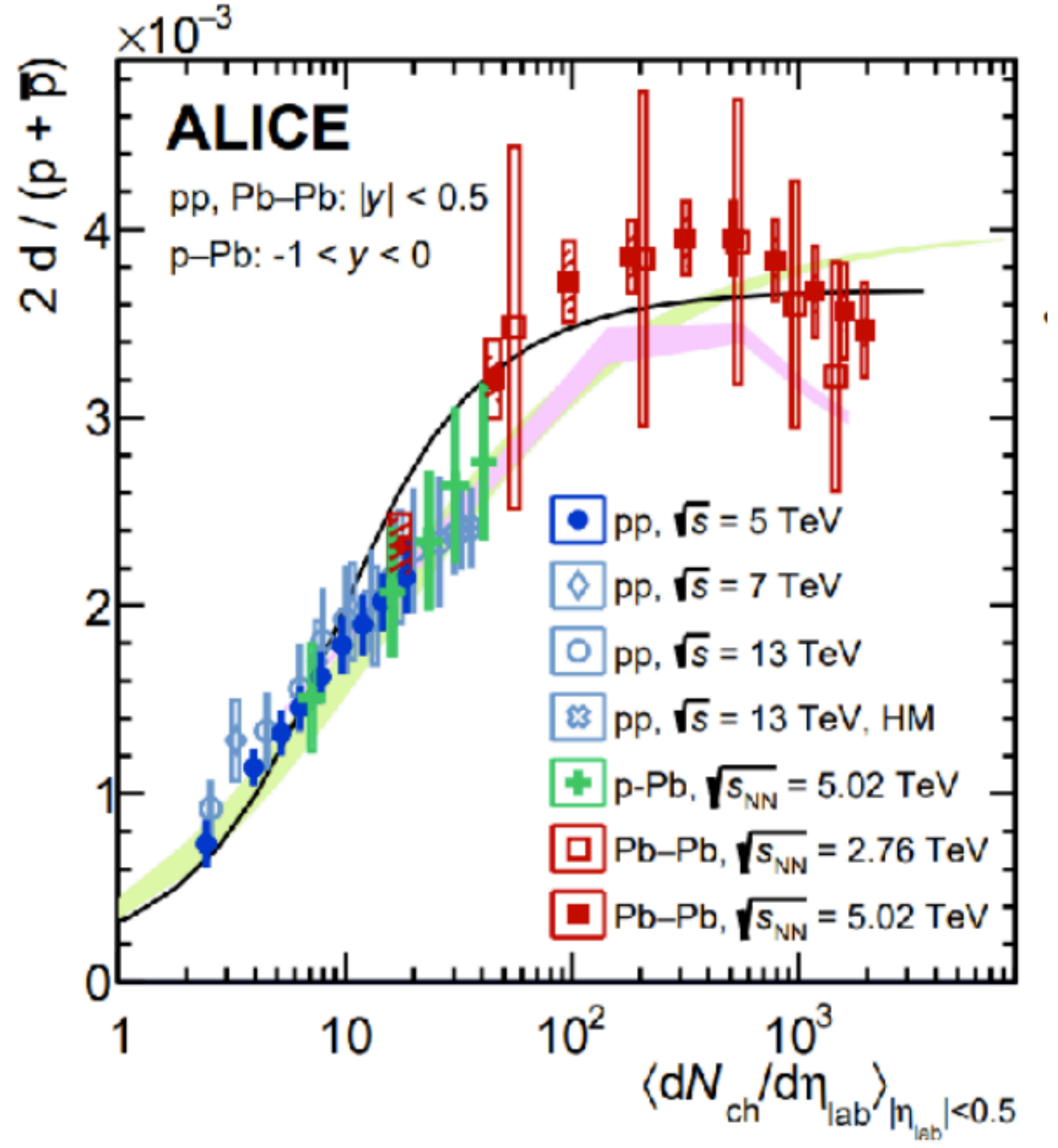
The role of annihilations in the (anti)nuclei yields

V. Koch

This is what is shown in the paper



Baryon annihilation and other mechanisms are complementary

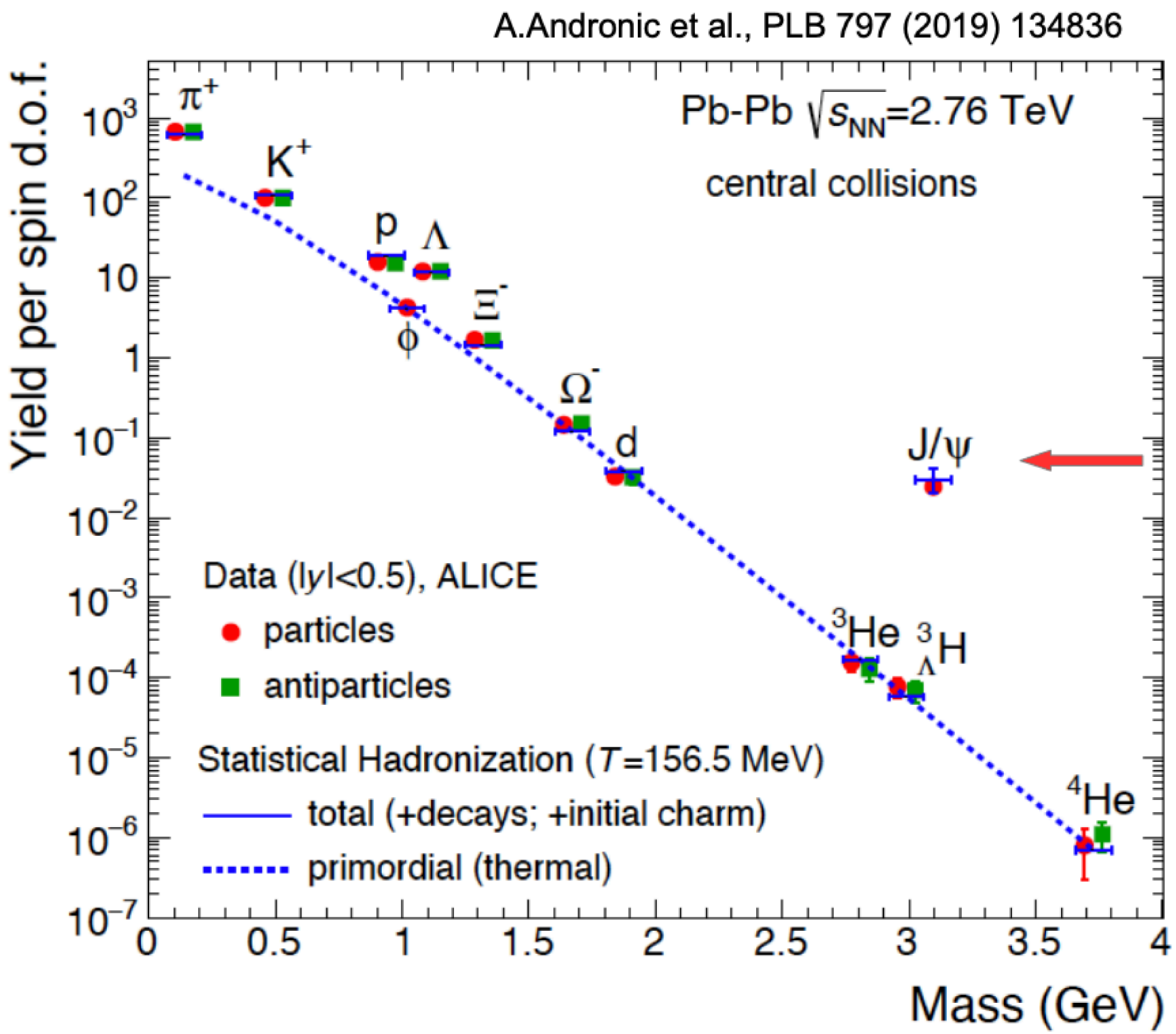


It explain antiprotons!

Will it work for antinuclei?

Beyond u,d,s: charm baryons and molecules

J. Stachel



enhancement factor is 900 for J/ψ

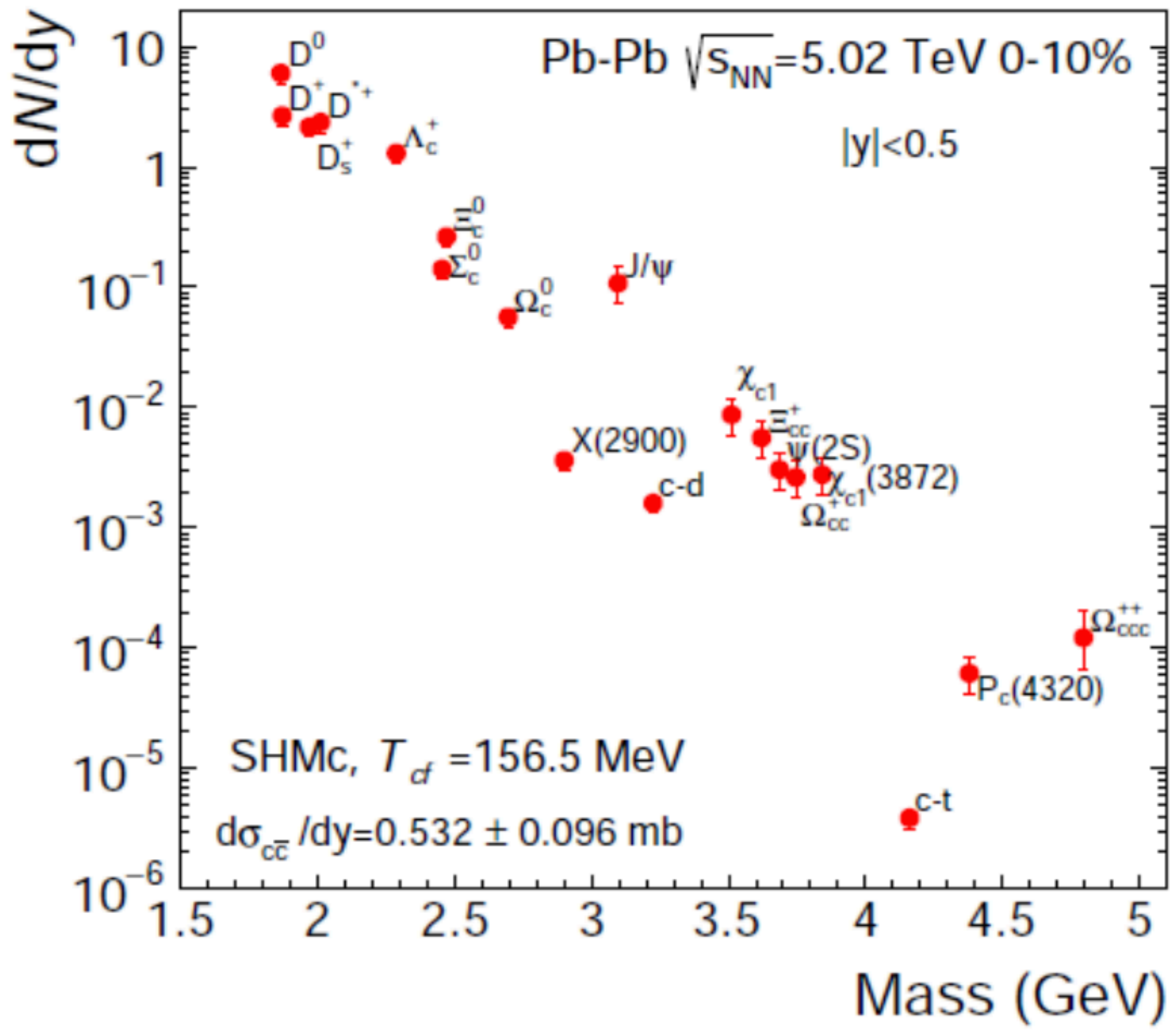
Beyond u,d,s: charm baryons and molecules

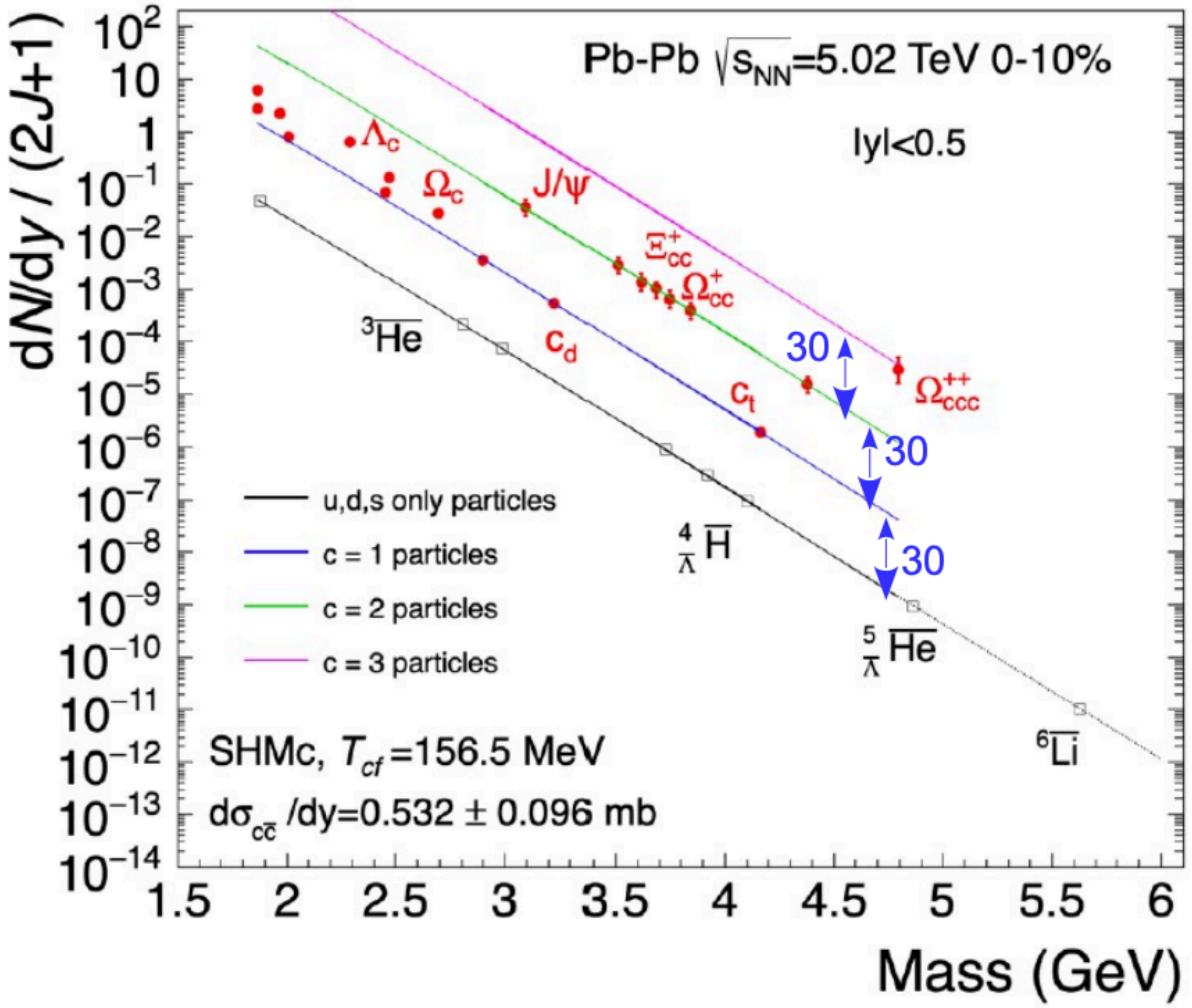
J. Stachel

the multi-charm hierarchy

open and hidden charm hadrons, including exotic objects, such as X-states, c-deuteron, c-triton, pentaquark, Ω_{ccc}

A. Andronic et al., JHEP07 (2021) 035





emergence of a unique pattern, due to g_c^n and mass hierarchy
perfect testing ground for deconfinement for LHC Runs3 and beyond

Thanks a lot for the interesting workshop