‘The strong interaction at the frontier of knowledge: fundamental research and applications’

NA5
Josef Pochodzalla
Johannes Gutenberg-Universität Mainz

STRONG-2020 Kick-off meeting
October 23-25, 2019

THEIA: Strange Hadrons and the Equation-of-State of Compact Stars

Networking activity of 24 institutions

Universitat de Barcelona
Univ. Bonn
Univ. Frankfurt
Hebrew University, Jerusalem
Japan Atomic Energy Agency
Johannes Gutenberg University Mainz
Inst. for Phys. and Chem Res. RIKEN
Univ. Tohoku

Institute of Space Sciences Barcelona
GSI Darmstadt
Justus Liebig Universität Gießen
Univ. Heidelberg
Forschungszentrum Jülich
Technical University München
Univ. of Southampton
Univ. Tokyo

Ruhr-Universität Bochum
Frankfurt Institute for Advanced Studies
Hampton University
INFN (Catania, LNF, Torino, Trieste)
Helmholtz Institute Mainz
Nucl. Phys. Institute Rez/Prague
Aristotle Univ. Thessaloniki
Österreichische Akademie der Wissensch. Wien

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824093.

THEIA: Strange Hadrons and the Equation-of-State of Compact Stars

- Experimental and theoretical studies of strange nuclear systems on all scales in energetic collisions with various projectiles e, π^+, π^-, K^-, p, $\bar{p}$, HI
  - (anti-)baryon-baryon and baryon-meson systems
  - hypernuclei and kaonic bound systems
  - neutron stars
- Deliverables:
  - D16.1: Study of A=3 hypernuclei $^3_\Lambda$H and $^3_\Lambda$n → report @ m36
  - D16.2: Study of antihyperons in nuclei; PANDA software tools → demonstrator @ m30
  - D16.3: Theoretical and experimental studies of bound mesonic systems → report @ m30
  - Annual workshops guarantee effective and fruitful interactions
- Milestones
  - MS20: First data taking by WASA@GSI/FAIR @ m24
  - MS21: Design report for antihyperons in nuclei @ m30
  - MS22: SIDDHARTA-2 progress report @ m30

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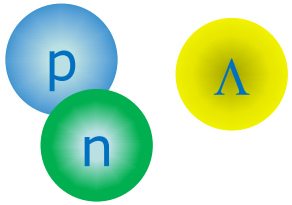
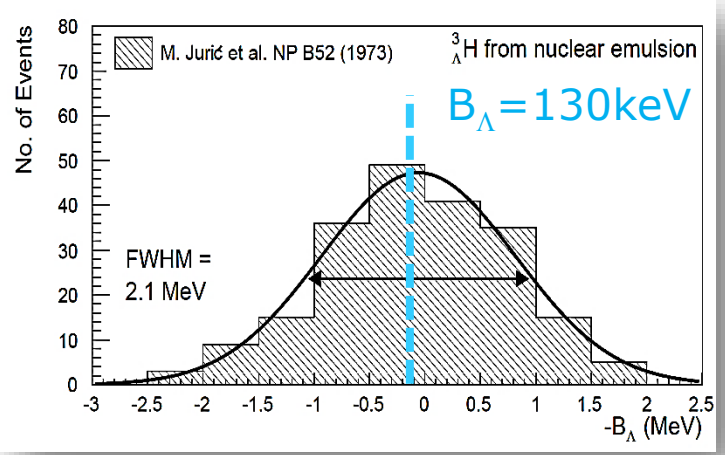
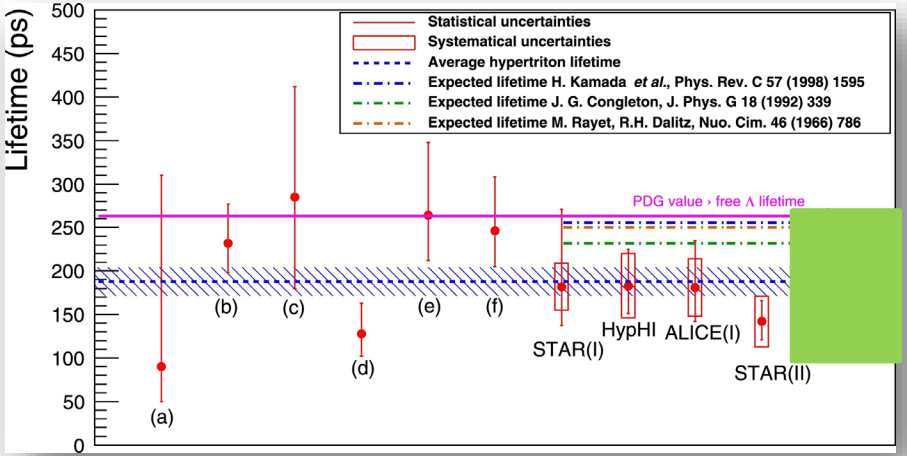
NA5 Task 1
A=3 hypernuclei

- The Hypertriton $^{3}_{\Lambda}$H Puzzle
  - Observation: Binding energy ≈130keV and $\tau(^{3}_{\Lambda}H) \ll \tau(\Lambda)$
  - Characteristic length of two-body s-wave halo system

$$\left\langle \Delta r^2 \right\rangle = \hbar^2 / (4\mu B) \approx 10\,\text{fm} \Rightarrow \tau(^{3}_{\Lambda}H) \simeq \tau(\Lambda)$$







- Is the lifetime really as short as it seems? ⇒ new data
- Is B_Λ as small as emulsion data indicate? ⇒ critical review, new data
- Is the naiv theoretical picture correct? ⇒ well-founded calculations

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NA5 Task 1
A=3 hypernuclei

- Hypertriton
  - New data on hypertriton lifetime from ALICE – more will come
  - Improved calculations of hypertriton lifetime
  - New hypertriton mass measurements in HI
  - Prepration for precission mass measurement at MAMI on track

- nnΛ
  - Experiment $^{3}H(e,e'K^{+})^{3}_{\Lambda}n$ successfully performed at Jlab using a tritium target, analysis ongoing
  - Experiment with the WASA detector at FAIR under preparation; beamtime approved for 2021 **(MS20 @ m24)**

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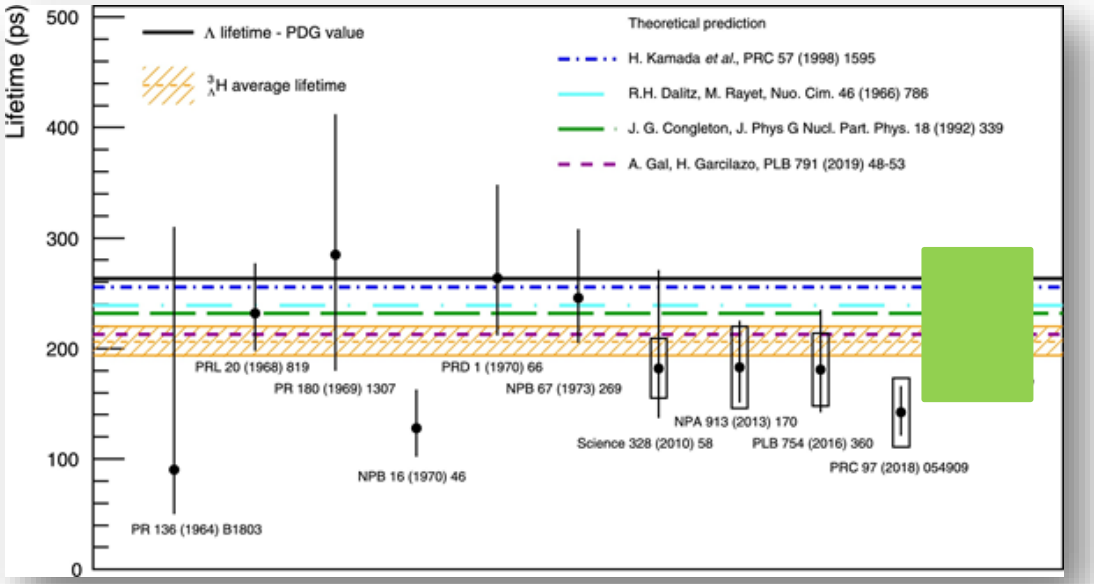
NA5 Task 1
A=3 hypernuclei

- Is the lifetime really so small?
  - new lifetime measurements 2019: ALICE - end Run2

ALICE, PLB 797, 134905 (2019)



- 2020+x: ELPH (γ,K^+)
- 2021: WASA@GSI (FAIR Phase 0)
- 2023: ALICE – end run 3: statistics × 200 stat.; re-analysis of first data planed
- 2020+x: J-PARC-P73 ^{3,4}He(K^-,π^0)$^{3,4}_\Lambda$H (pilot run for 2020 envisaged)

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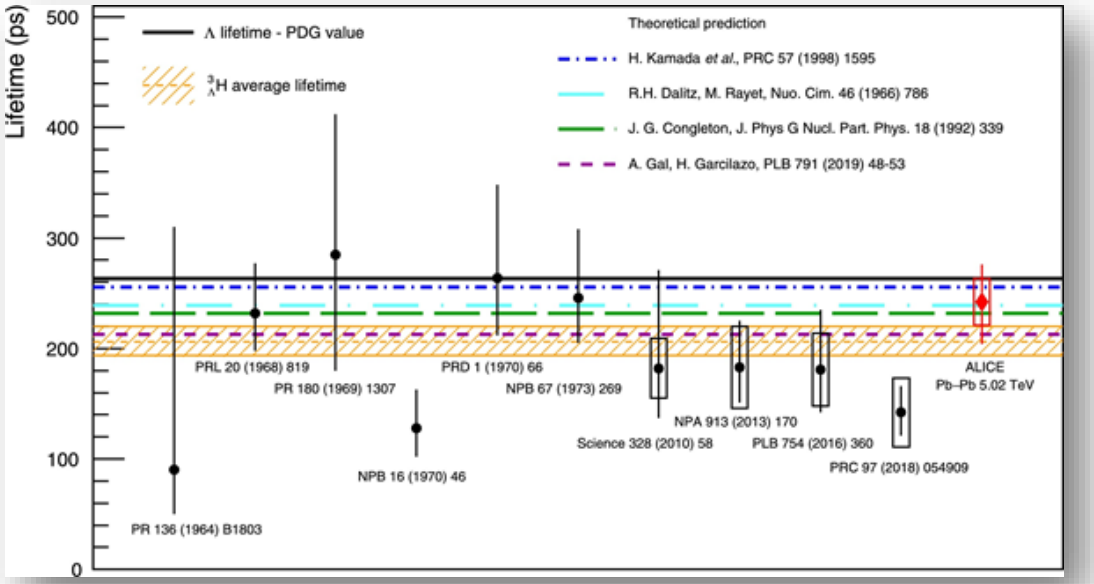

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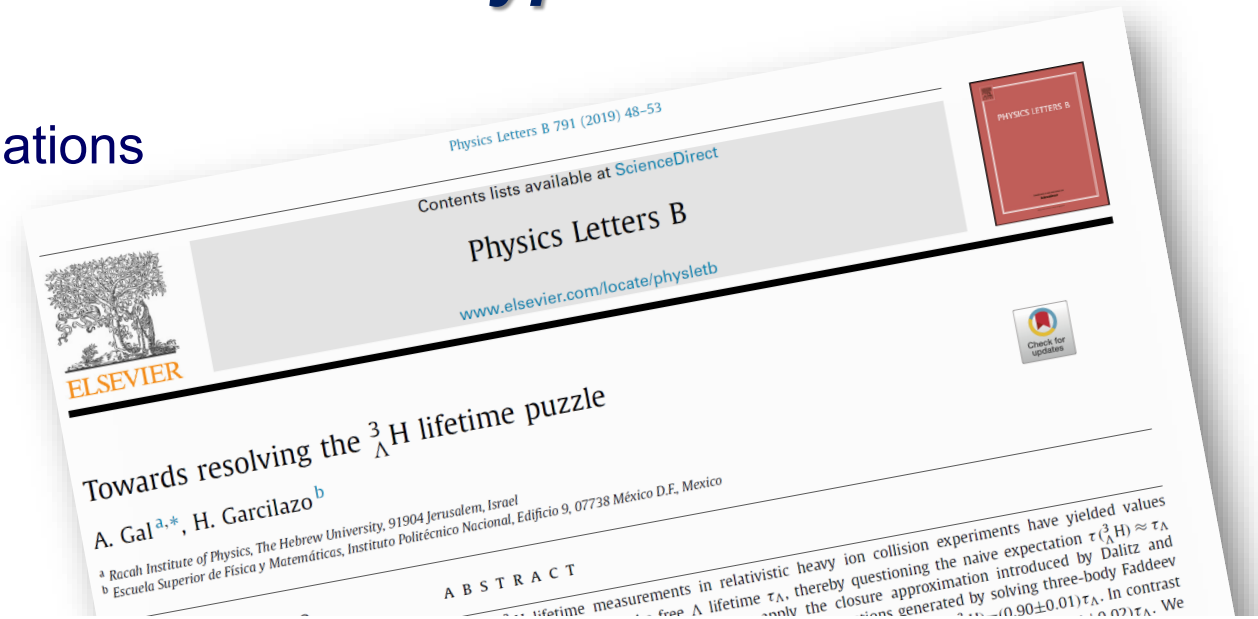
NA5 Task 1
A=3 hypernuclei

- Improved calculations



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Towards resolving the ${}^{3}_{\Lambda}$H lifetime puzzle

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ABSTRACT

Recent ${}^{3}_{\Lambda}$H lifetime measurements in relativistic heavy ion collision experiments have yielded values shorter by (30±8)% than the free Λ lifetime τ_Λ, thereby questioning the naive expectation $\tau({}^{3}_{\Lambda}\mathrm{H}) \approx \tau_\Lambda$ for a weakly bound Λ hyperon. Here we apply the closure approximation introduced by Dalitz and coworkers to evaluate the ${}^{3}_{\Lambda}$H lifetime, using ${}^{3}_{\Lambda}$H wavefunctions generated by solving three-body Faddeev equations. Our result, disregarding pion final-state interaction (FSI), is $\tau({}^{3}_{\Lambda}\mathrm{H}) = (0.90 \pm 0.01)\tau_\Lambda$. In contrast to previous works, pion FSI is found attractive, reducing further $\tau({}^{3}_{\Lambda}\mathrm{H})$ to $\tau({}^{3}_{\Lambda}\mathrm{H}) = (0.81 \pm 0.02)\tau_\Lambda$. We also evaluate for the first time $\tau({}^{3}_{\Lambda}\mathrm{n})$, finding it considerably longer than τ_Λ, contrary to the shorter lifetime values suggested by the GSI HypHI experiment for this controversial hypernucleus.

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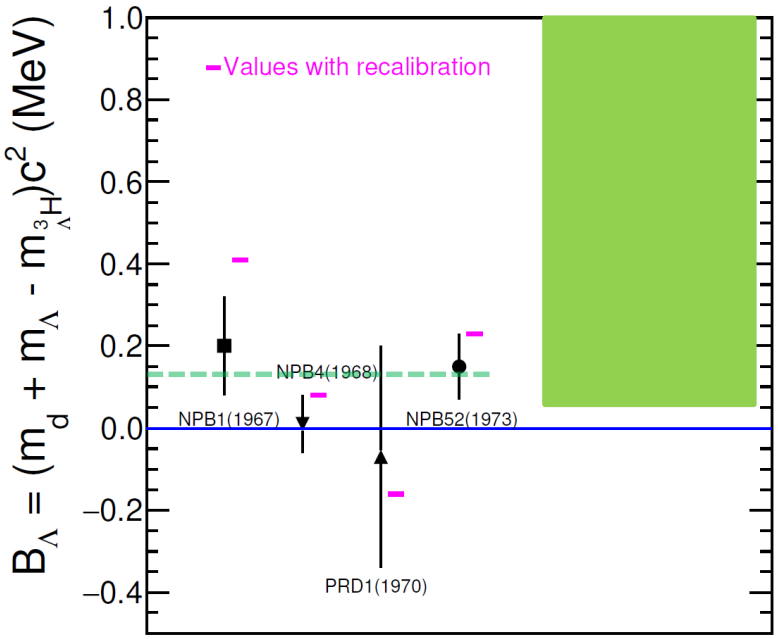
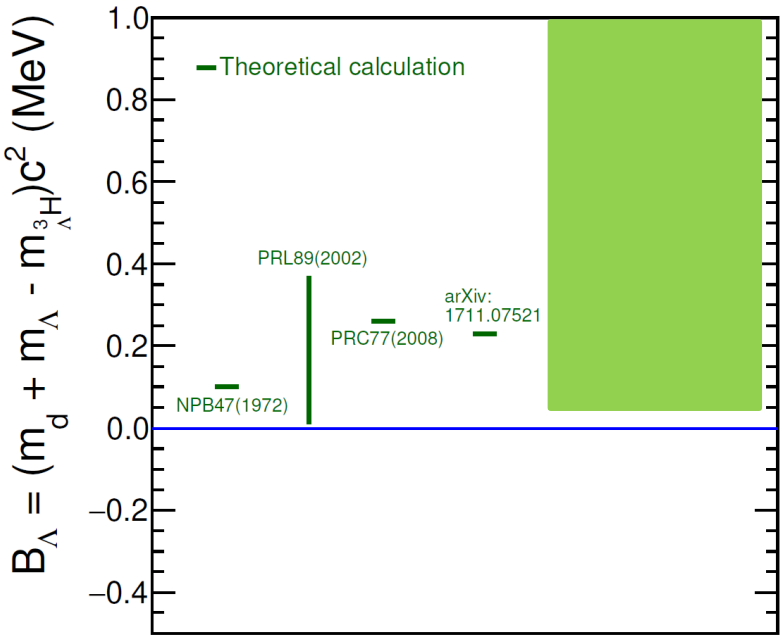
NA5 Task 1
A=3 hypernuclei

- Is $B_\Lambda(^3_\Lambda H)$ really so small?
  - Re-calibration of B_Λ from emulsion due to Λ mass changes ??
  - New data from STAR

Peng Liu *et al.*, arXiv:1908.03134 [nucl-ex]

STAR Collaboration, arXiv:1904.10520 [hep-ex]





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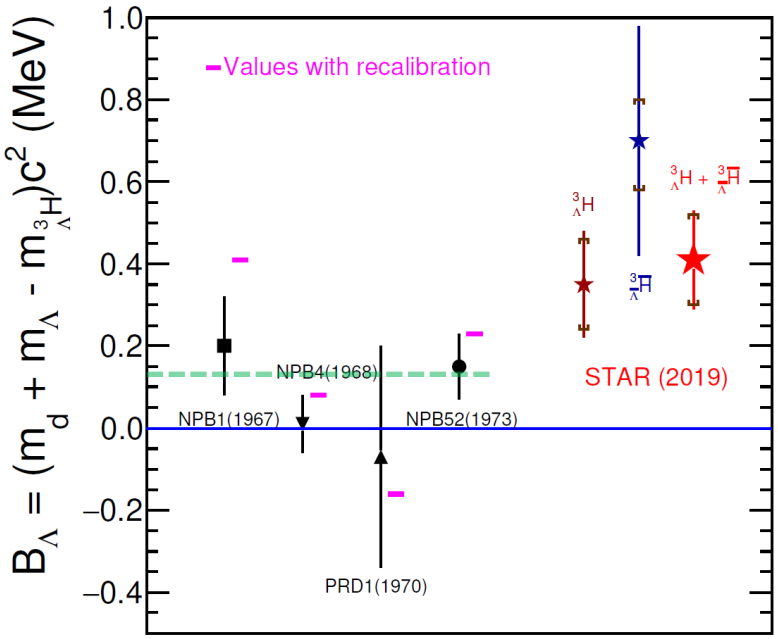

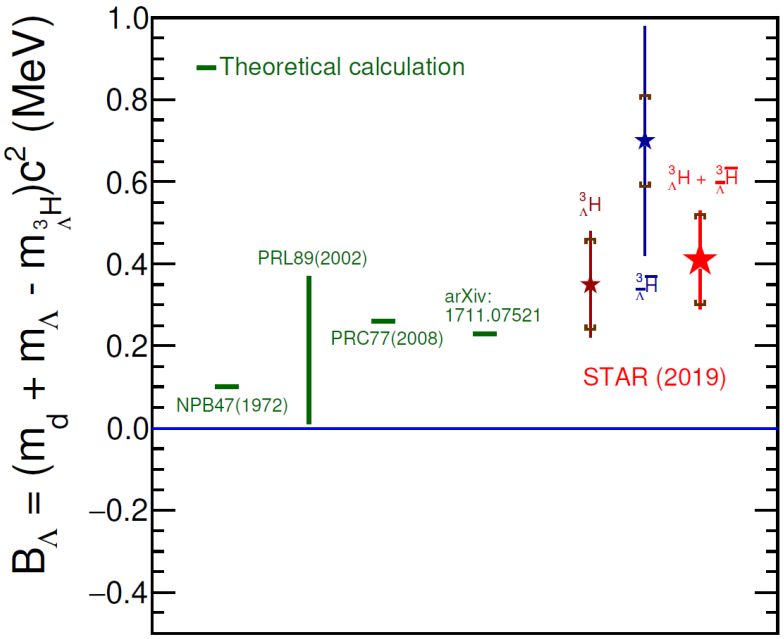

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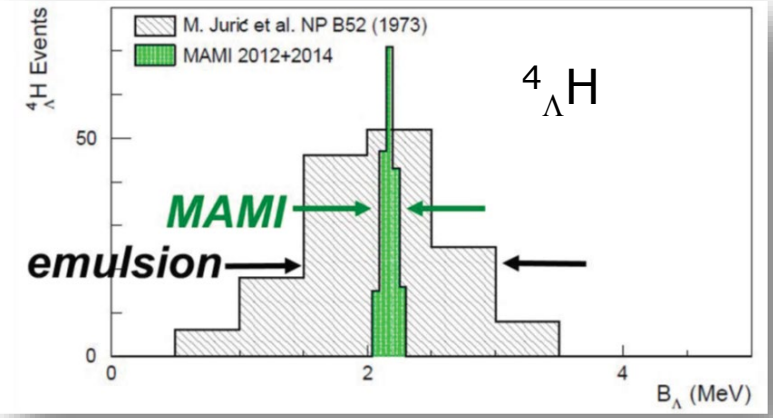
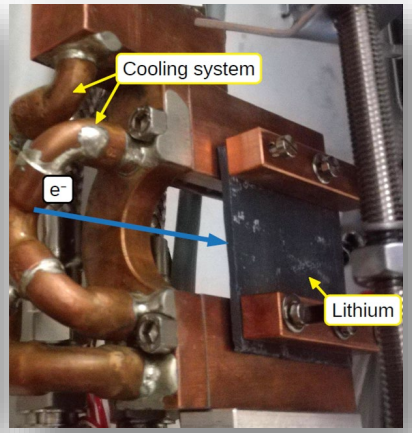
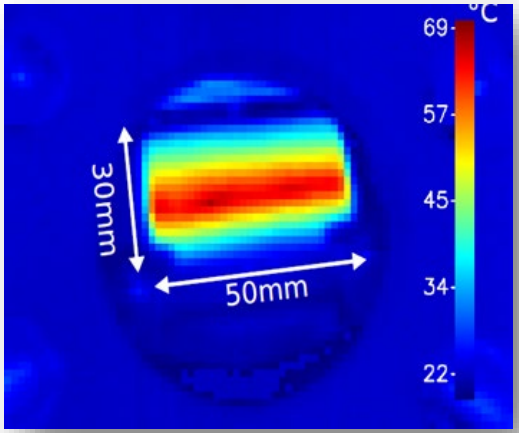
NA5 Task 1
A=3 hypernuclei

- Towards a precision mass measurement at MAMI
  - MAMI has pioneered the π^- decay spectroscopy method for $^4_\Lambda$H
  - For $^3_\Lambda$H:
    - Higher luminosity required $\Rightarrow$ 5cm Li target@10μA ✓
    - Precise *absolute* calibration of spectrometers $\Rightarrow$ interference of undulator radiation March/April 2020
    - Measurement end 2020/beginning 2021







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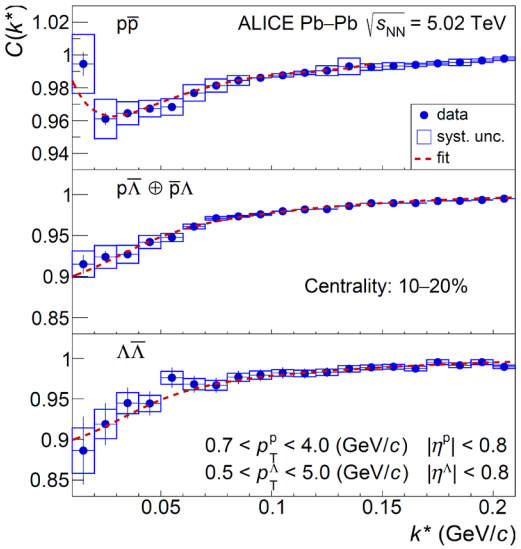
NA5 Task 2
Antihyperons in Nuclei

- Baryon-antibaryon two-body interactions can be studied by two-particle correlation functions in HI
- $\bar{P}$ANDA will measure the effective potential of $\bar{\Lambda}$ hyperons by the exclusive ^{20}Ne($\bar{p}$,$\bar{\Lambda}\Lambda$) reaction during DAY-1 stage



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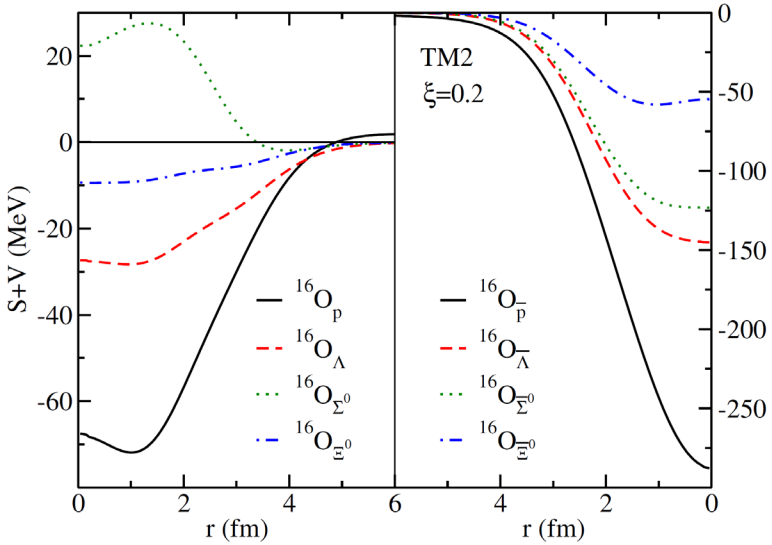
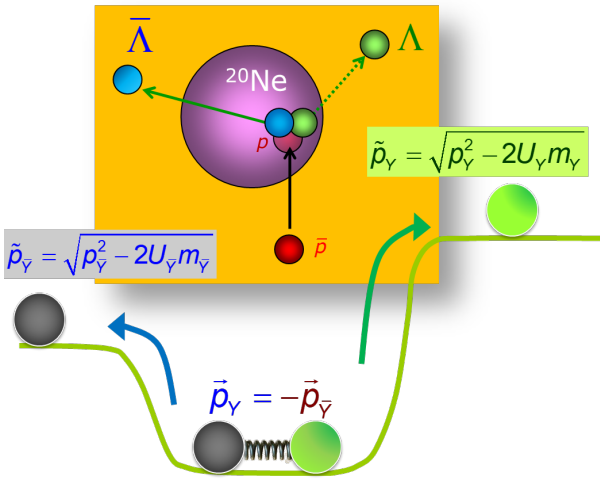


Jaroslava Hrtánková and Jirí Mareš



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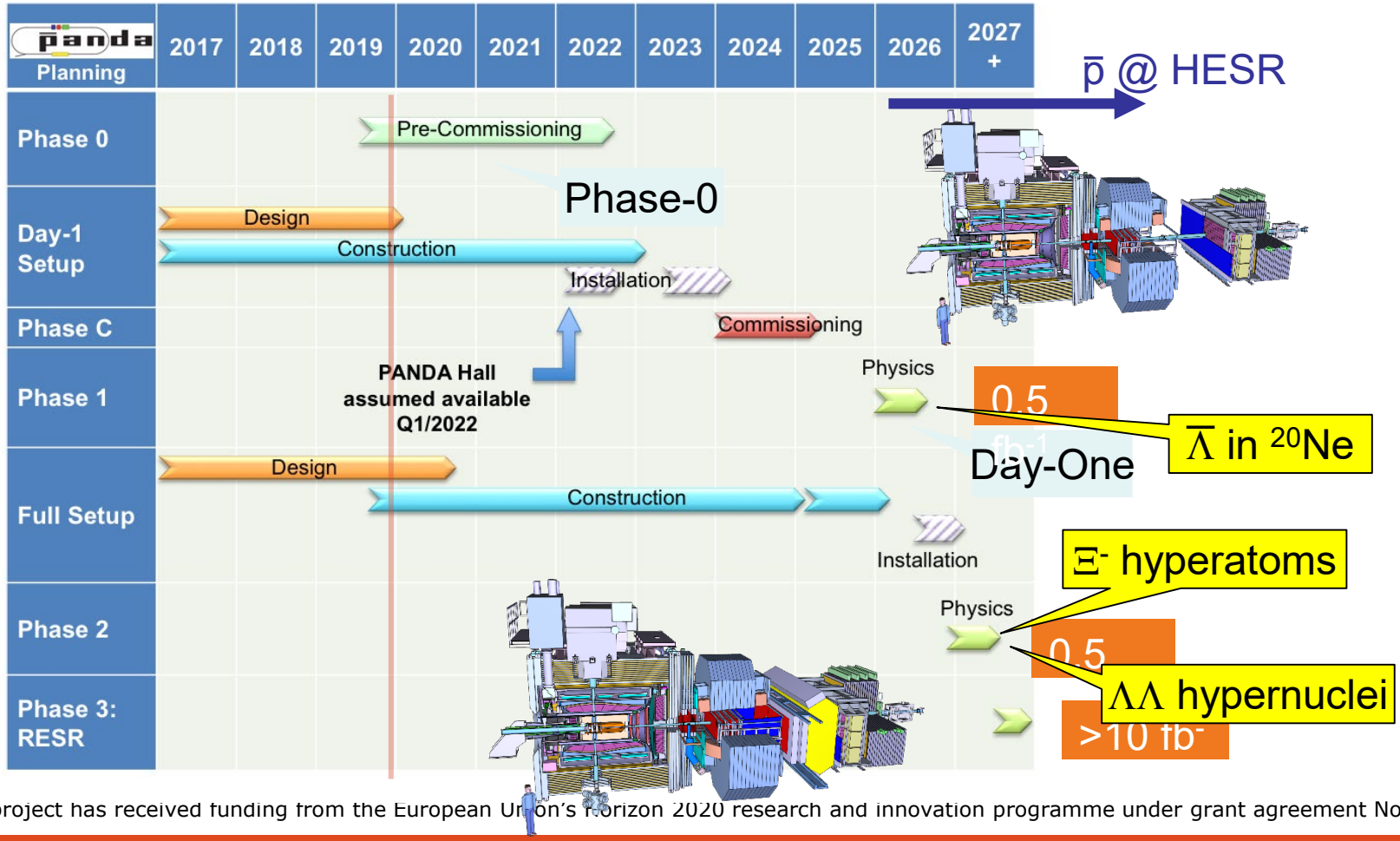
NA5 Task 2
Antihyperons in Nuclei

- $\bar{P}$ANDA schedule



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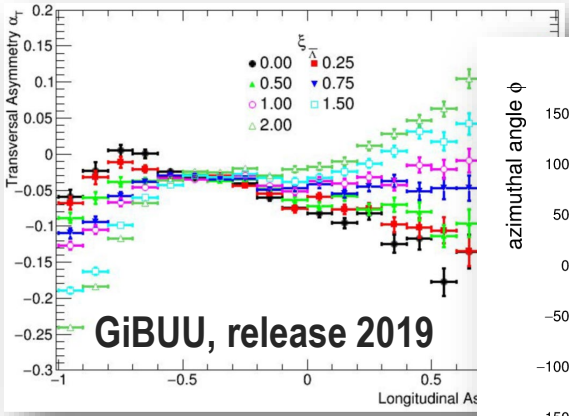
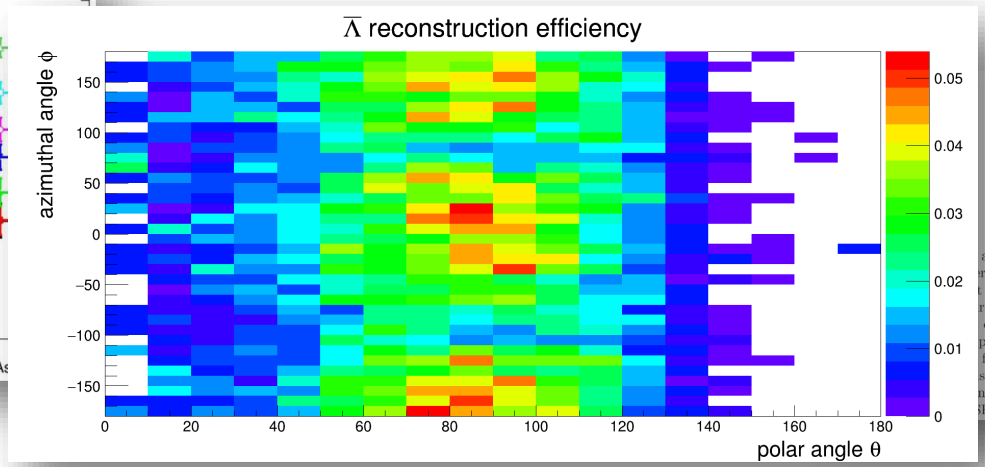
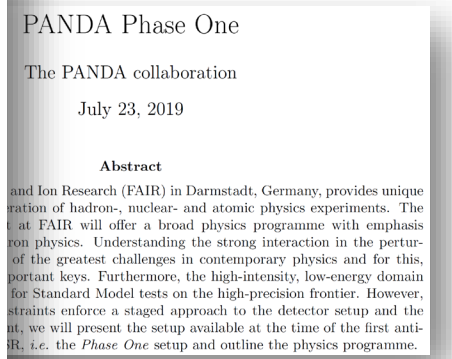
NA5 Task 2
Antihyperons in Nuclei

- Progress in 2019
  - High statistics event samples generated with GiBUU
    - Next step: check with other transport models
  - Integration in PANDA reconstruction software started (PhD thesis)
  - PANDA Phase One paper under internal review by collaboration
  - **MS21 @ m30** well within reach






PANDA Phase One

The PANDA collaboration

July 23, 2019

Abstract

and Ion Research (FAIR) in Darmstadt, Germany, provides unique
eration of hadron-, nuclear- and atomic physics experiments. The
at FAIR will offer a broad physics programme with emphasis
ron physics. Understanding the strong interaction in the pertur-
of the greatest challenges in contemporary physics and for this,
portant keys. Furthermore, the high-intensity, low-energy domain
for Standard Model tests on the high-precision frontier. However,
straints enforce a staged approach to the detector setup and the
ut, we will present the setup available at the time of the first anti-
R, *i.e.* the *Phase One* setup and outline the physics programme.

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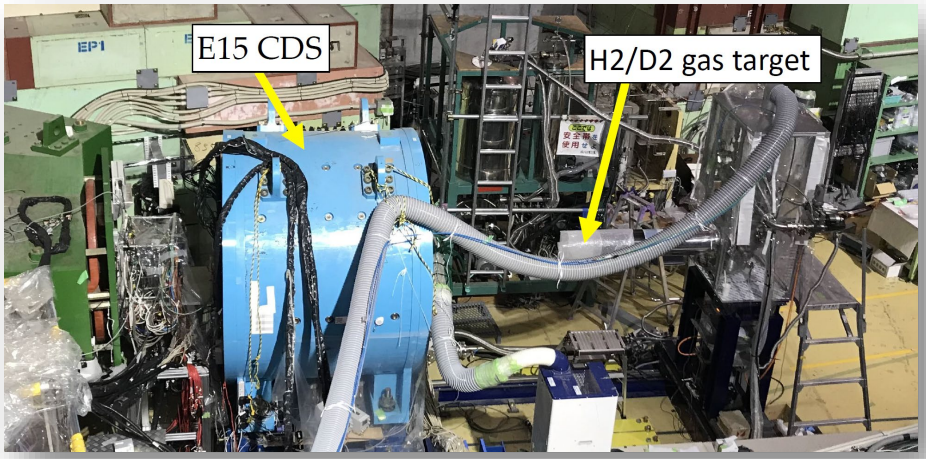
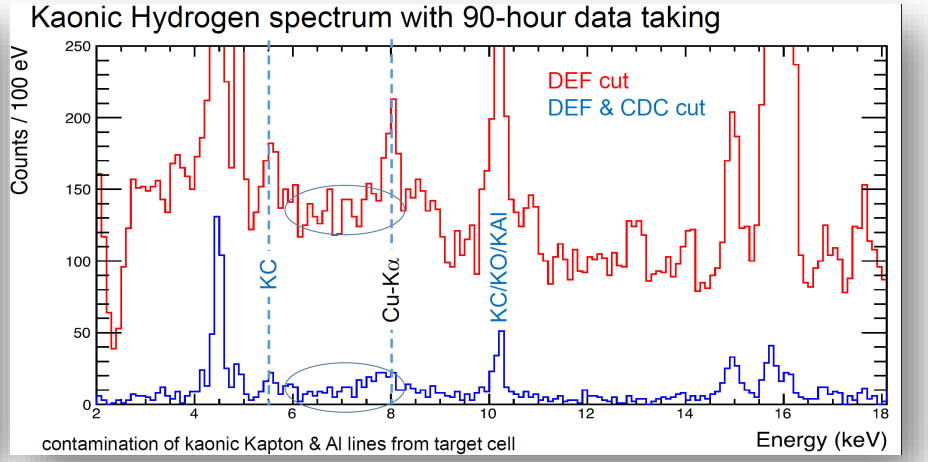
NA5 Task 3

Study of bound kaonic systems

- E57@J-PARC performed 3-day pilot run
  - All detectors worked well; S/N as expected
  - Kα X-ray transitions from ^{4}He are observed as expected (90/80)
  - Kα events of hydrogen less than expected 🤔
  - Further beam time request foreseen for 2021





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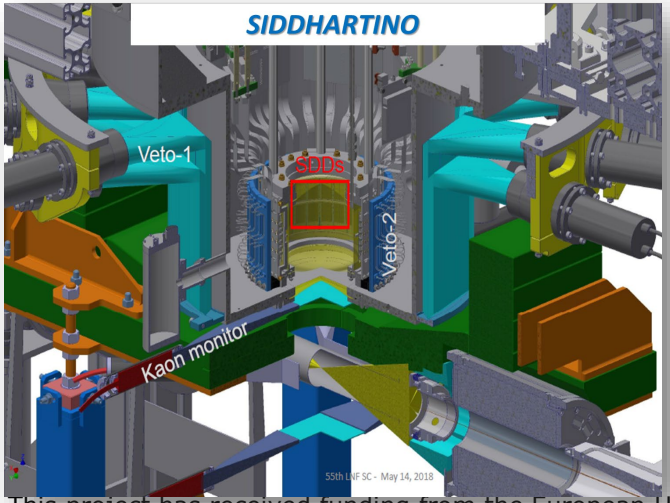
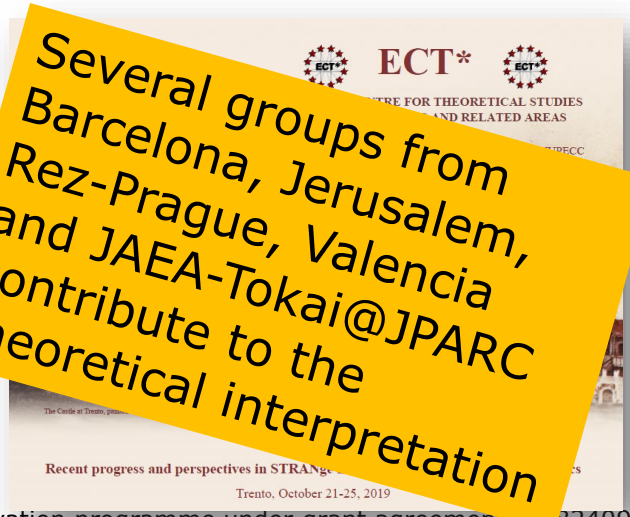
NA5 Task 3

Study of bound kaonic systems

- SIDDHARTA-2 at DAΦNE **(MS22 @ m30)**
  - Phase 1: SIDDHARTINO: measurement of K-^{4}He (8 SDD arrays)
  - Phase 2: after DAΦNE operating condition is comparable with SIDDHARTA ones *kaonic deuterium* (48 SDD arrays)
    - End 2019/beginning 2020: installation of 48 SDD arrays
    - Until June 2020: kaonic deuterium run (~300 pb^{-1})
    - Autumn 2020: restart to collect 500 pb^{-1}





Several groups from Barcelona, Jerusalem, Rez-Prague, Valencia and JAEA-Tokai@JPARC contribute to the theoretical interpretation

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THEIA Workshops

- Further planning
  - 2020 Crete ?
  - 2021 Prague
  - 2022 ECT*

Theia-Strong2020 Workshop 2019 https://indico.gsi.de/event/8950/

25-29 November 2019
Technik Museum Speyer
Europe/Berlin timezone

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schupp@uni-mainz.de

THEIA is a networking activity within the STRONG-2020 Project which is funded by the EU Framework Programme for Research and Innovation, Horizon 2020.

The cooperation of world-leading experimentalists and theoreticians in the field of strangeness nuclear physics with experts of the neutron star community in astrophysics within the networking activity THEIA will allow to critically assess the status of our present understanding, to determine the impact of terrestrial observations for the hadronic EOS, and to identify possible new avenues to follow.

The annual workshops organized by THEIA aim to provide a platform for the early exchange of new ideas and scientific results, leading to interlinked and complementary future activities. Particularly significant is the participation of groups from Japan since the facility J-PARC provides unique pion and kaon beams for the experiments in this field and which, therefore, complements the research infrastructure available in Europe.

HIM HELMHOLTZ Helmholtz-Institut Mainz

JOHANNES GUTENBERG UNIVERSITÄT MAINZ JG|U

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This project has received funding from the

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Summary

- Significant progress in strangeness nuclear physics
- All deliverables are on track
- Milestones are within reach
  - Caveat: WASA@GSI may be slightly shifted beyond m24
- Started to setup a webpage dedicated to THEIA activities, reports, publications, …

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