STRONG-2020: Project Review
Low energy frontier
28 September 2022

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Low energy frontier: Working groups

JRA- Precision Tests of the Standard Model (PrecisionSM)

NA - Proton Radius European Network (PREN)

NA - LatticeHadrons (LatticeHadrons)

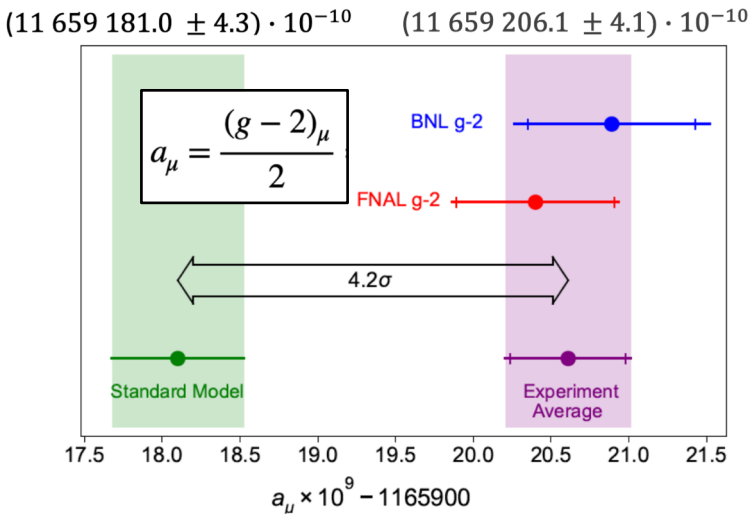
JRA-Light-and heavy- quark hadron spectroscopy (HaSP)

NA - QCD physics at GSI/FAIR (FAIRnet)

NA-Strange Hadrons and the Equation-of-State of Compact Stars (THEIA)

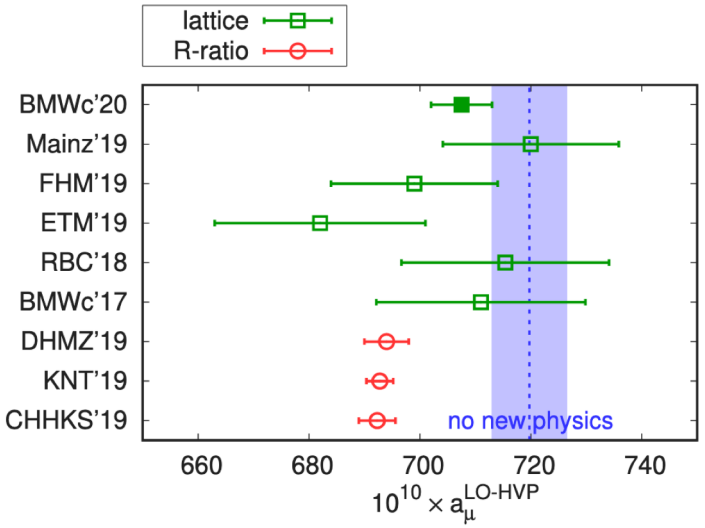
Low energy frontier: Objectives **PrecisionSM**

Precise determination of the muon anomalous magnetic moment (g-2)μ; extraction of the CKM matrix element Vud from beta decay, and of the weak mixing angle from parity-violating electron scattering



B. Abi et al., Muon g-2 Coll. Phys. Rev. Lett. 126, 141801 (2021)

Muon g-2 Theory Initiative Whitepaper Physics Reports 887 (2020) 1-166



Low energy frontier: Activities **PrecisionSM**

Task 1: Hadronic effects in precision tests of the weak sector of SM

reductions in the hadronic uncertainties in Vud and Vus

more precise evaluation of the uncertainties on beta decays that depend on nuclear structure

contributions to 2 Snowmass White Papers, organization of 1 workshop and 3 papers

Task 2: Hadronic effects in precision tests of the electromagnetic sector of the SM

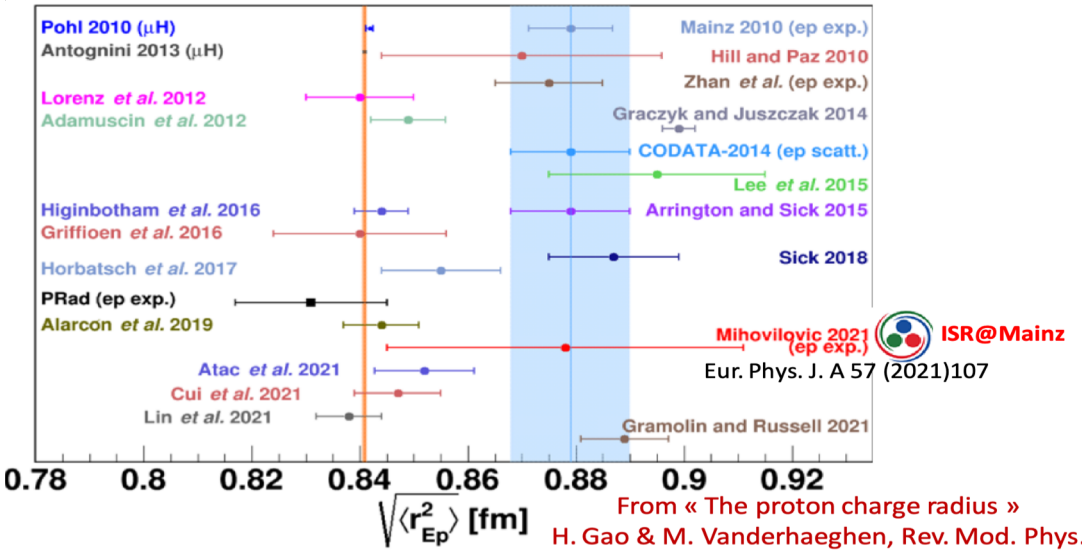
participation in the interpretation of recently released experimental results from the Muon g-2 experiment at Fermilab together with NA-LatticeHadrons

organization of 1 virtual workshop

contribution to 1 Snowmass White Paper

Low energy frontier: Objectives **PREN**

Address the “proton-radius puzzle” via combined data-theory analyses of new results in atomic spectroscopy and very-low momentum transfer lepton-proton elastic scattering at various energies



ISR@Mainz
Eur. Phys. J. A 57 (2021)107

From « The proton charge radius »
H. Gao & M. Vanderhaeghen, Rev. Mod. Phys.
(accepted Sept. 2021), arXiv

Low energy frontier: Activities **PREN**

Task 1: PREN-Collaboration

regular zoom meetings organized with short time visits by postdocs at different groups

Task 2: PREN-Study

progress in terms of experimental and theoretical results: experiment at Mainz for 1S-2S transition in atomic H,D and T in a gas cell, analysis of new transitions in atomic H and D, most recent proton radius value from MPQ Garching team, publication of results from muonic helium-4 ions, comparison between electron and positron elastic scattering off a proton to investigate the Two Photon Exchange question

Task 3: PREN-Conventions

PREN2022 meeting in Paris

Task 4: PREN-Meetings

members of STRONG-2020 taking part in several virtual meetings

Low energy frontier: Objectives **LatticeHadrons**

Development of combined software, data sharing, and methodologies in lattice QCD theory across Europe for hadron spectroscopy and structure, hadrons under extreme conditions, hadrons in the SM and beyond, and novel numerical algorithms and computing for lattice hadron physics

LaVA

Lattice Virtual Academy

Low energy frontier: Activities **LatticeHadrons**

Task 1: Coordinate research secondments, visits and exchanges

no in-person visits and exchanges were possible due to the pandemic. However, a new platform LaVA has been devised and agreed via the web systems of ECT*

Task 2: Arrange thematic workshops

worskhop at Galileo Galilei Insitute for Theoretical Physics in March 28-April 1 2022

online mini-workshop in June 2021

Task 3: Develop software, data sharing and analytic methodologies

mini-symposium at the 2022 PASC conference (June 2022) to refocus and coordinate the lattice comunity access to EuroHPC resources and Exascale computing

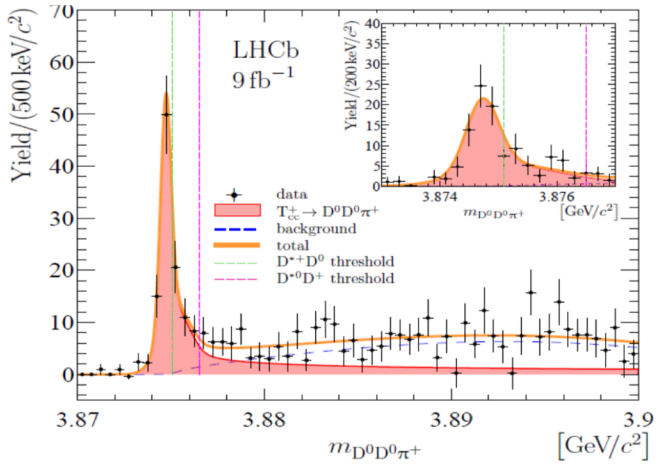
Low energy frontier: Objectives **HaSP**

Development of a common data-theory analysis framework to determine exotic hadrons properties by fitting new experimental data to lattice QCD and effective-field-theory predictions

Doubly charmed tetraquark T_{cc}^{+}

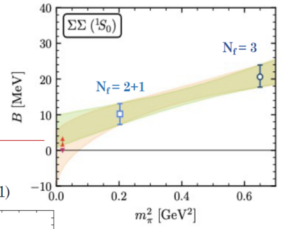
$\delta m_{\rm BW} = -273 \pm 61 \pm 5^{+11}_{-14}$ keV,
$\Gamma_{\rm BW} = 410 \pm 165 \pm 43^{+18}_{-38}$ keV,

relative $D^{*+}D^{0}$ threshold



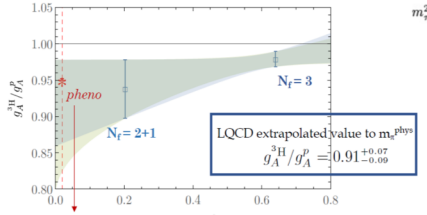
Recent work

Baryon-Baryon interactions, strangeness from 0 to -4
Phys. Rev. D 103, 054508 (2021) @ m_π ~450 MeV



NSC97, χEFT @ NLO

^{3}H axial charge
Phys. Rev. D 103, 074511 (2021)



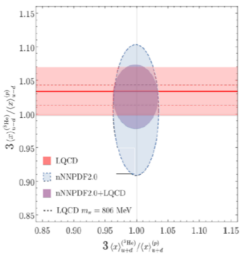
LQCD extrapolated value to m_π^{phys}
$g_A^{^3H}/g_A^p = 0.91^{+0.07}_{-0.09}$

Baroni et al,
PRC 94, 024003 (2016); PRC95 059902 (2017)

$g_A^{^3H}/g_A^p = 0.9511(13)$

Nuclear matrix elements from LQCD
Phys. Rept. **900**, 1 (2020)

Momentum fraction of ^{3}He
Phys. Rev. Lett. 126, 202001 (2021)



Low energy frontier: Activities **HaSP**

Task 1: Precision calculations in non-perturbative QCD (I)

effective field theories (EFTs) for exotic hadrons, for NN interactions, for conventional states, for light mesons dynamics and EFTs of heavy hadrons in matter and finite temperature. Also, study of exotics via hadron decays, semi-inclusive decays or triangle singularities

Task 2: Precision calculations in non-perturbative QCD (II)

determination of the strong coupling constant, study of jets and other nuclear observables, lattice QCD calculations of nuclear systems, exotics and quarkonium in matter, study of atomic nuclei and neutron matter, use of dispersive methods for light resonances

Task 3: Meson Spectroscopy analysis of new and exotic states

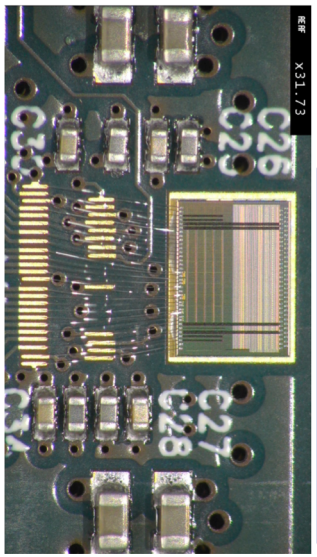
study of light exotic mesons, charmonium, strangeonium and low-lying scalars and strange mesons

Task 4: Baryon Spectroscopy

new experimental data on photo- and electro-induced meson production on protons and deuterons

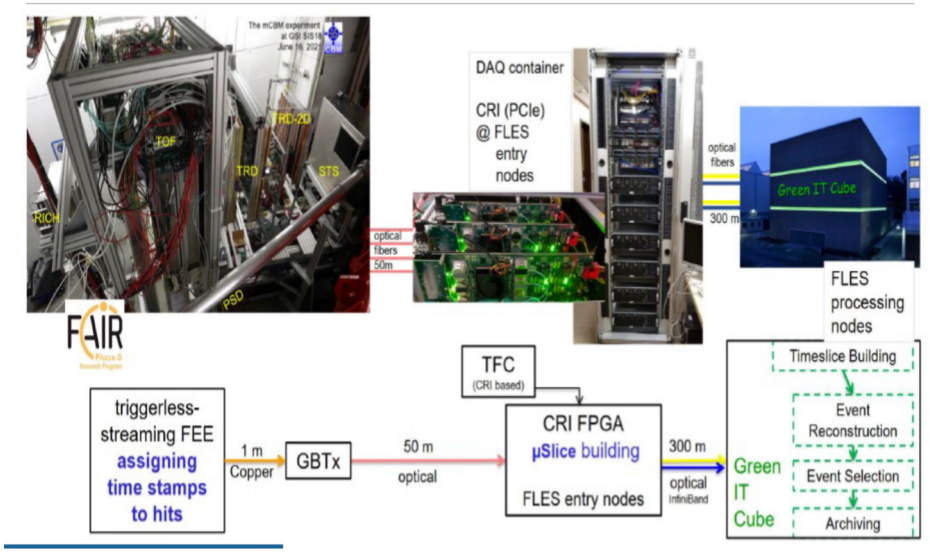
Low energy frontier: Objectives **FAIRnet**

Multi-prong improved data selection plus distributed physics analysis for rare signal events under high background conditions in anti-p-p, anti-p-A, and A-A collisions for the PANDA and CBM experiments at the future FAIR facility



Specification	Min	Max	Unit
Input capacitance	2	17	pF
Max rate per strip		40	kHz
Input charge	1	40	fC
Noise		1500	e^-
Preamp peaking time	50	≥ 100	ns
Channels per chip	64		
Reference clock		160	MHz
Charge resolution	8		bits
Time resolution (pk-pk)		6.25	ns
Time resolution (r.m.s.)		1.8	ns
Power consumption		256	mW
Chip dimensions	4.5 × 3.5		mm^2
Pads position	On two sides only		

The mCBM experiment at SIS18



Low energy frontier: Activities **FAIRnet**

Task 1: Front-end, DAQ and On-line

a prototype for the Application-Specific Integrated Circuit (ASIC) for readout of the Silicon Strip Detectors for PANDA was delivered and is being tested; an AMC board for high-speed data collection was delivered and is being tested; a paper on reconstruction algorithm for EMC spectrometer of PANDA was published

Task 2: Demonstrator

several test beam campaigns with the mCBM experiment have taken place

Task 3: Data analysis challenge

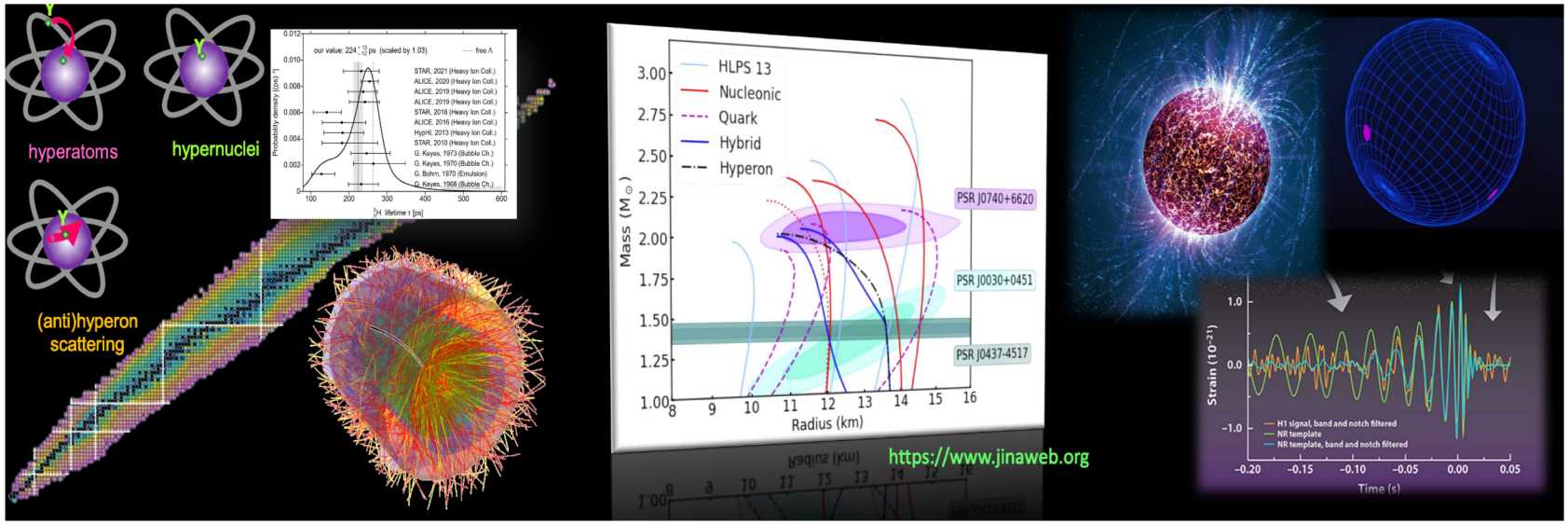
progress in the preparation of the CBM event reconstruction software chain, with updates to the CAD and GEANT geometries of the CBM experiment implemented and also prospective topics within PANDA were simulated. A paper on PANDA detector was published

Task 4: Education and outreach

few teaching activities and laboratory visits for schoolchildren

Low energy frontier: Objectives **THEIA**

Address the “neutron stars hyperon puzzle” through combined theoretical and experimental studies of (anti)hypernuclei and bound strange-meson systems produced in hadronic collisions at various center-of-mass energies



Low energy frontier: Activities **THEIA**

Task 1: A=3 hypernuclei

progress for hypernuclei ${}^{3}_{\Lambda}\mathrm{H}$ and ${}^{4}_{\Lambda}\mathrm{H}$, as well as for determining the existence of a neutral A=3 hypernucleus nnΛ

Task 2: Study of antihyperons in nuclei at PHASE-1 of PANDA

the PANDA Phase-one program including the possible measurement of antihyperons in nuclei was published

Task 3: Theoretical and experimental studies of bound mesonic systems

experimental advances were performed at DAFNE with the SIDDHARTA-2 setup, as well as with AMADEUS

Task 4: Role of mini antiproton-proton collider at FAIR for strangeness nuclear physics

work left for the upcoming period

Task 5: Annual workshops

the HYP2022 conference (June2022) took place in Prague, whereas two web-seminars with weekly talks were held online

Low energy frontier: Impact

The role of STRONG-2020 together with the European infrastructures is fundamental for tackling the long-standing puzzles in the low-energy frontier of the strong interaction, such as the proton radius puzzle and the neutron star puzzle

The low-energy frontier has a wide and ambitious program that involves VA-, JRA- and NA-projects. The embedment of the numerical ab-initio calculations of QCD on the lattice with the European hadron community via NA-LatticeHadrons and JRA-HaSP will have a large impact on the precision computation of hadron spectroscopy and structure, hadrons under extreme conditions, hadrons in the standard model and beyond.

Low energy frontier: Impact

In particular,

JRA-HaSP has made already an impact developing and applying effective field theories to quarkonia, exotic hadrons, hadronic transitions and decays, and hadrons in dense matter, confronting the precise theoretical calculations with experimental observables. This procedure will also allow precision test of the standard model with hadronic observables.

JRA- PrecisionSM has improved the treatment of electro-weak box diagrams, which contribute to all SM-Tests involving weak interactions like in beta decay, Vud and parity violating electron scattering. The JRA has collected the specifications from the community and defined the user interfaces for the dissemination of the theory results.

Low energy frontier: Impact

The two main puzzles to be addressed in the low-energy frontier, that is the proton radius puzzle and the neutron star puzzle, are still relevant, and further developments have been done during the second reporting period. Those include theoretical and experimental studies of the lightest hypernuclei, so as to give an answer to the hypertriton puzzle, as well as the analysis of bound strange-mesonic systems at AMADEUS and SIDDHARTINO, delivered by NA-THEIA.

As for the proton radius puzzle network, NA-PREN, only individual work on understanding and improving the knowledge of some systematic effects has been possible due to the COVID-19 crisis. Online meetings have been held and an in-person meeting took place in summer 2022. A similar situation occurred for the NA-LatticeHadrons, with a large convention of the community hindered by the COVID-19 crisis.

Related to data analysis and acquisition, new systems such as mCBM and digital algorithms, are still being developed by NA-FAIRnet, so as to comply with the needs of PANDA and CBM experiments at FAIR, and they will have an impact to avoid bottlenecks at FAIR.