Achim Denig
JGU Mainz
Institute for Nuclear Physics

STRONG-2020 ANNUAL MEETING (2022)

TA2 – TRANSNATIONAL ACCESS TO MAMI

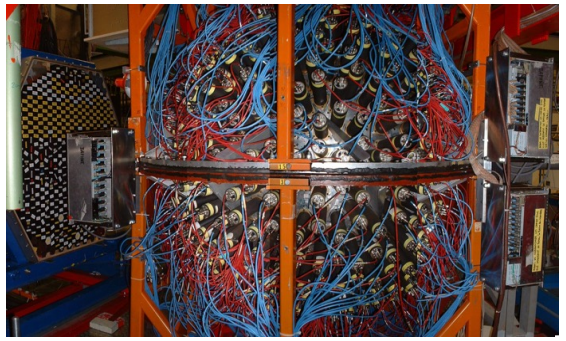
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824093

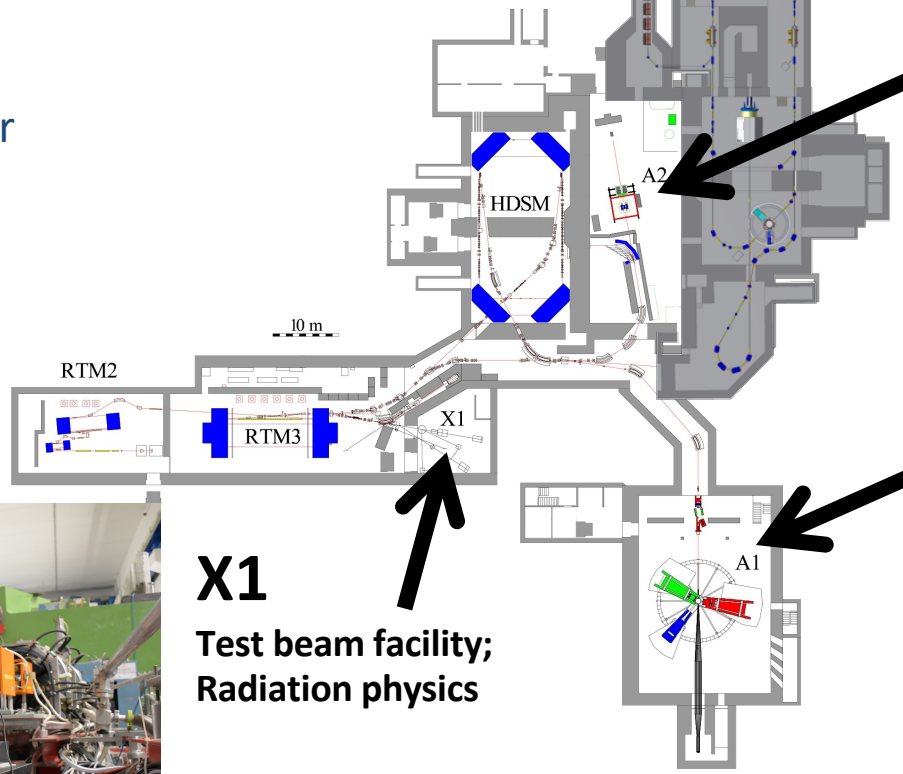
MAMI ELECTRON ACCELERATOR

Electron Accelerator E_{max} =1.6 GeV (CW) operated at JGU Mainz
Hallmarks

- Intensity max. 100 μA
- Resolution σ_E < 0.100 MeV
- Polarization 85%
- Reliability: up to 7000 h / year

MESA

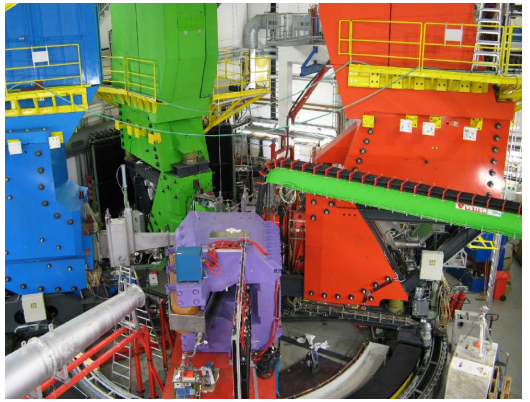




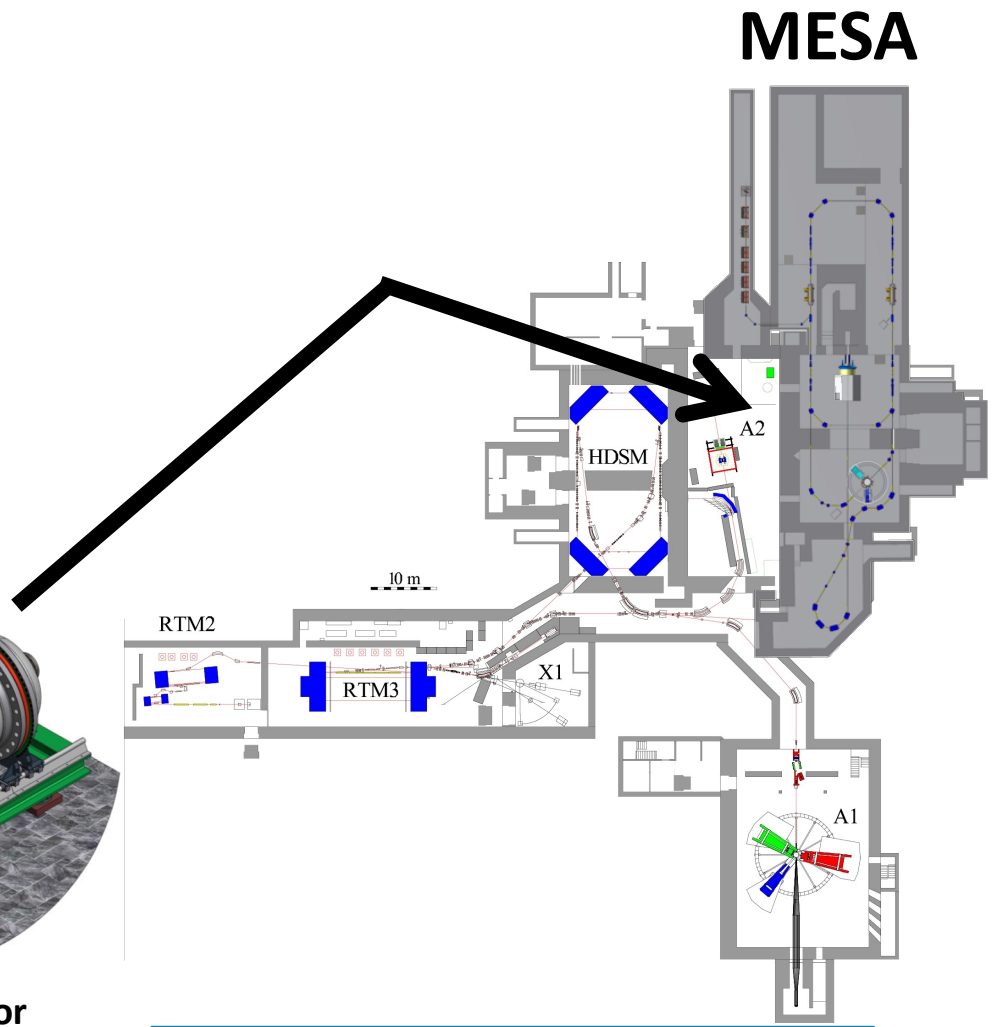
A2 Photon scattering (A2 hall) (Crystal Ball / TAPS calorimeters; Polarized frozen-spin target → currently at Univ. Bonn)

X1
Test beam facility; Radiation physics

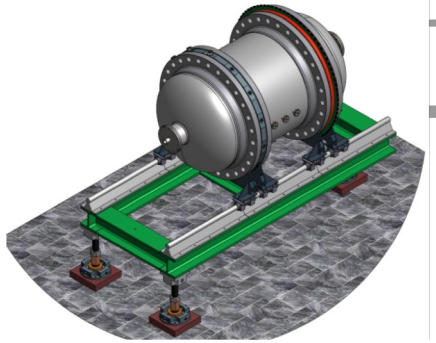
A1 Electron scattering (high resolution spectrometer setup)



MAMI ELECTRON ACCELERATOR



PRES Electron scattering in A2 hall



High pressure active TPC detector in cooperation with PNPI St. Petersburg

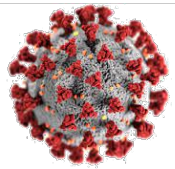
Change of work plan
→ Cooperation presently deferred

THE PAST 12 MONTHS

09/21 Restart of MAMI operation

11/21 01/22 03/22 05/20 07/20 09/22 01/10

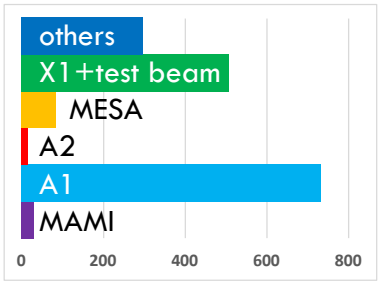
Covid-19 Shutdown

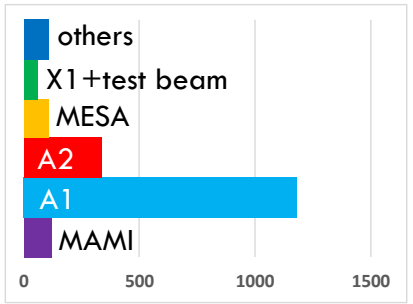


Restart

01/09/21 – 01/19/22: 3569 hours of MAMI operation

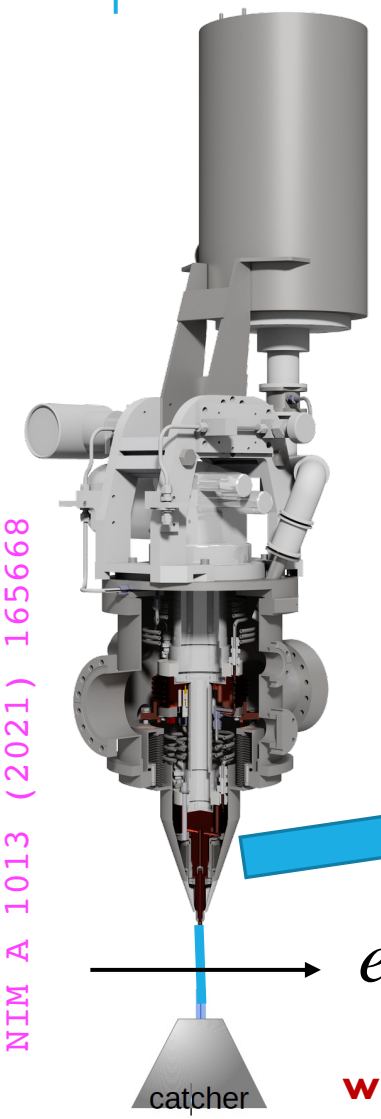
1669 h Data Taking A1, A2, X1, Test beams	Winter Shutdown	1701 h Data Taking A1, A2, X1 Test beams	Sum-mer Shut-down	199 h Data Taking A1, A2, Test beams	Winter Shutdown 12/22 - 03/23





Change of work plan → Longer shutdown

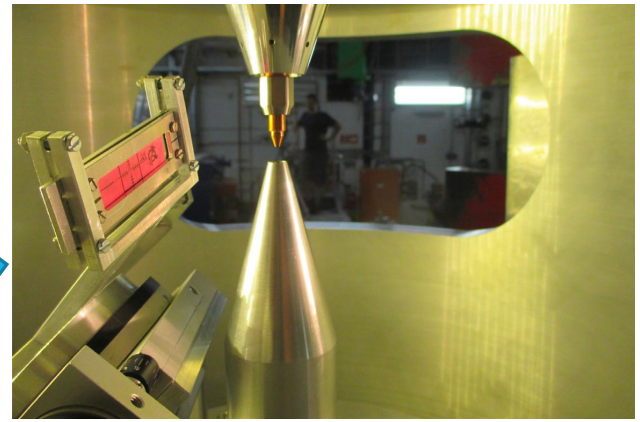
SUPERSONIC GAS-JET TARGET (A1/MAMI, LATER MAGIX/MESA)



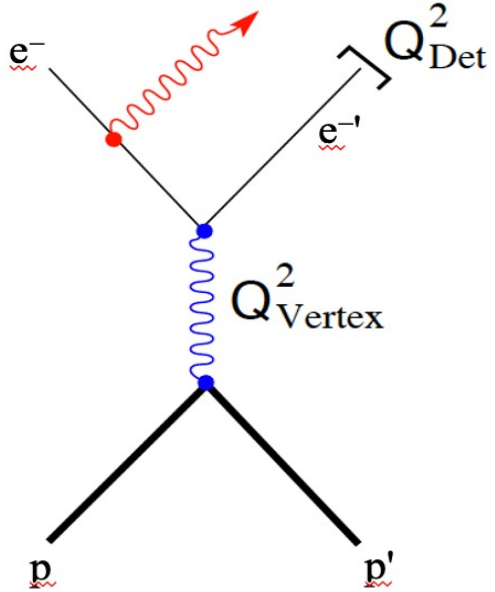
NIM A 1013 (2021) 165668

Construction of a high-density gas jet target in cooperation with University of Münster (A. Khoukaz)

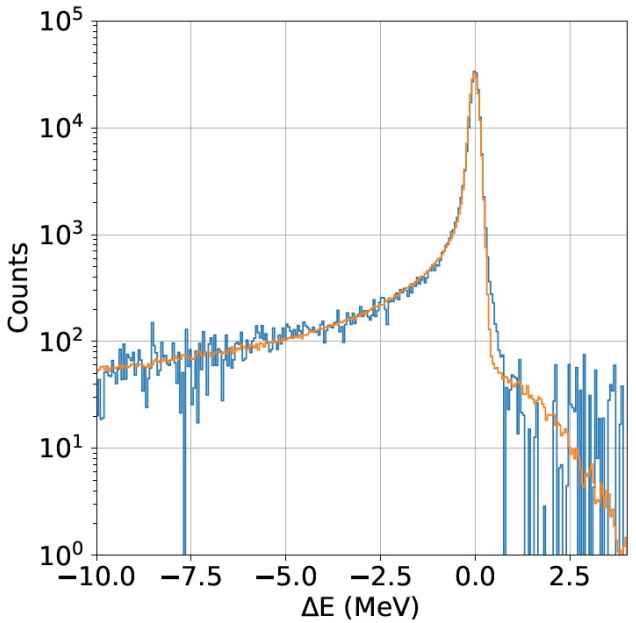
- Future MAGIX experiment at MESA: combination of light gas jet target with ERL electron beam
- Commissioning at A1/MAMI already now
  → Measurement of electron-proton scattering (proton EM factors = flagship project @ Mainz)
  → Most precise determination of proton radius in electron scattering (Bernauer et al. 2010); accuracy limited by scattering of electrons at walls of liquid hydrogen target
- New measurement of G_E with gas jet target via Initial state radiation
  → access low momentum transfer 0.01 GeV^2/c^2



window-less, thin, point-like target !



arXiv:2208.13689

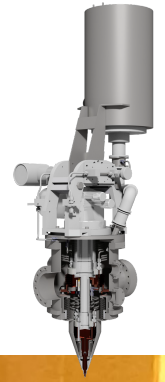


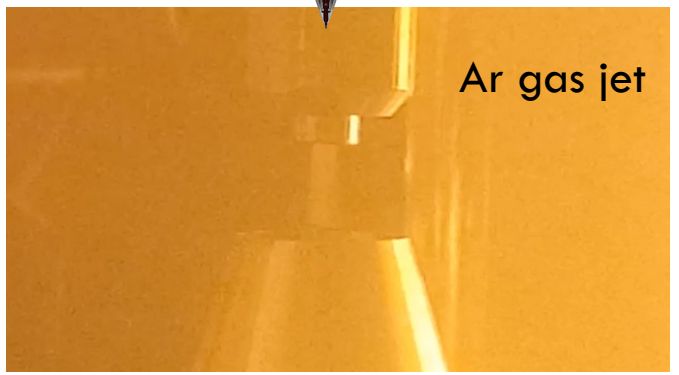
ELECTRONS FOR NEUTRINOS A1

Interpretation of current and future generation of **neutrino experiments** (DUNE,T2K, Hyper-K, Mini-Boone, ...) requires knowledge of **neutrino-nucleus interaction:** **^{12}C, ^{16}O, ^{40}Ar**

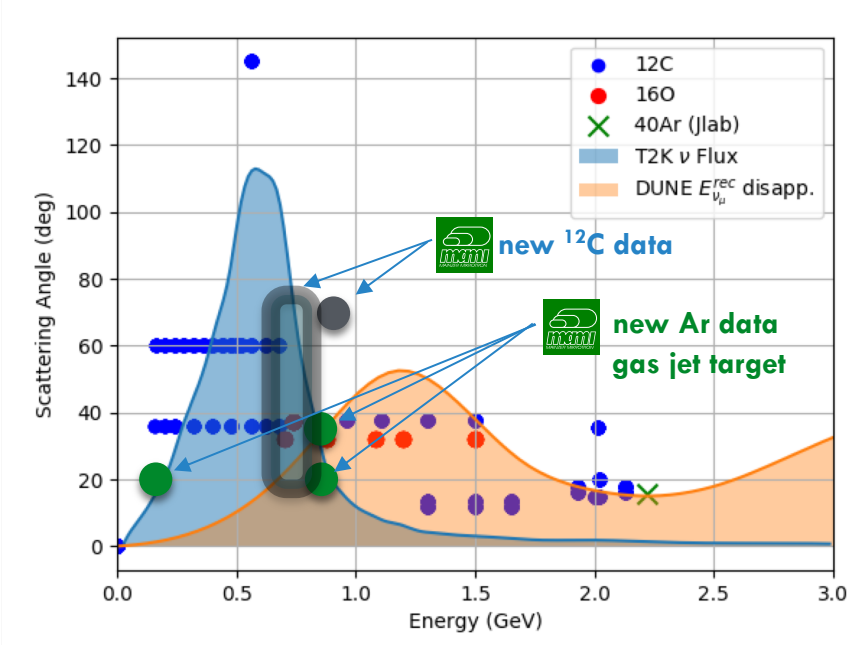
→ **Check and calibrate MC-generators** via dedicated program of **electron-nucleus measurements**

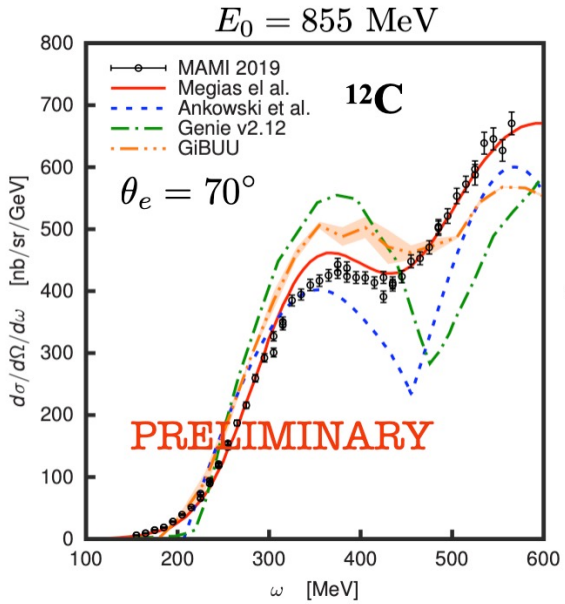
→ **MAMI energy range complementary to program at JLAB**

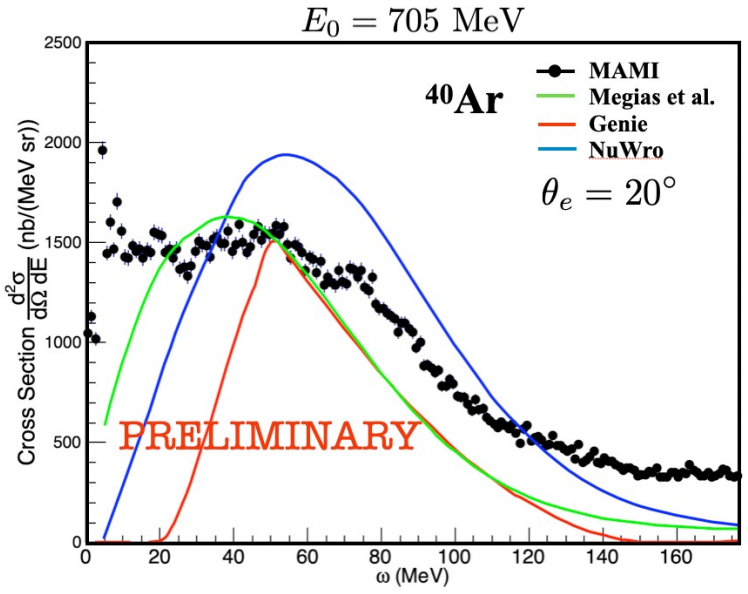




courtesy Sören Schlimme







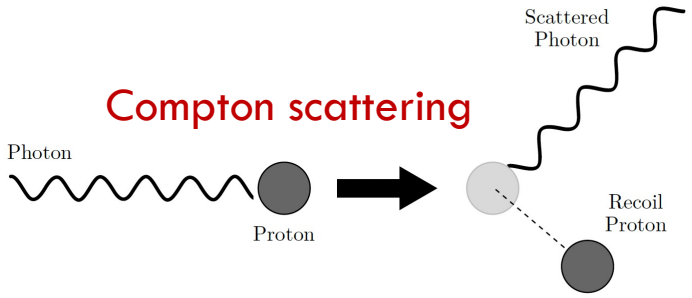
PROTON POLARIZABILITIES @ A2/MAMI

Reaction of nucleon under influence of an EM field provides fundamental information of the nucleon; very sensitive test of theories (H/BχPT, Disp. Rel.).

- Electric Polarizability: α_{E1}
- Magnetic Polarizability: β_{M1}

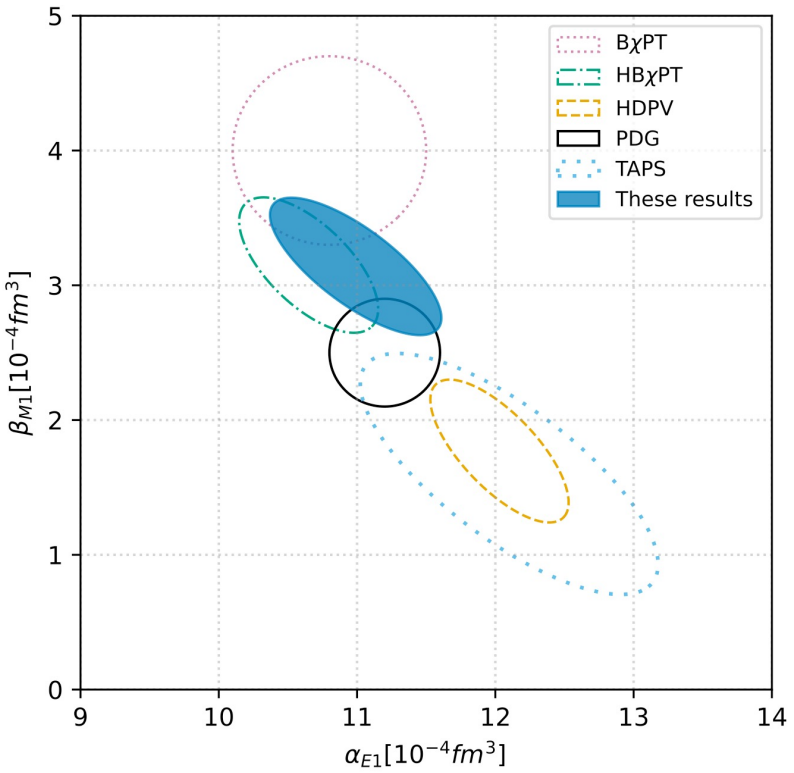
$$H_{\text{eff}}^{(2)} = -4\pi\left[\frac{1}{2}\alpha_{E1}\vec{E}^2 + \frac{1}{2}\beta_{M1}\vec{H}^2\right]$$

Compton scattering

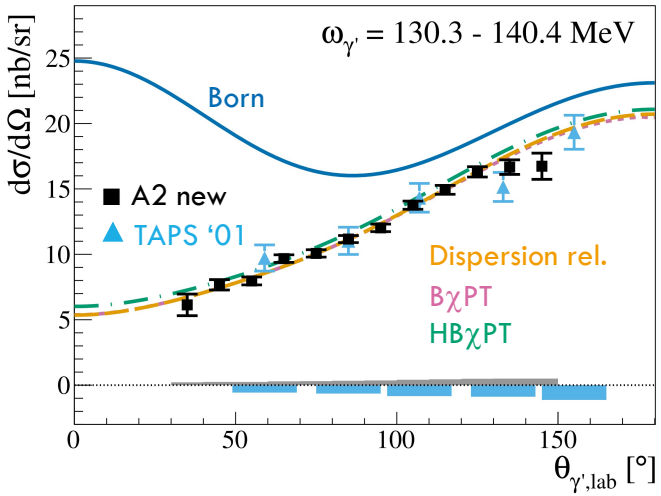


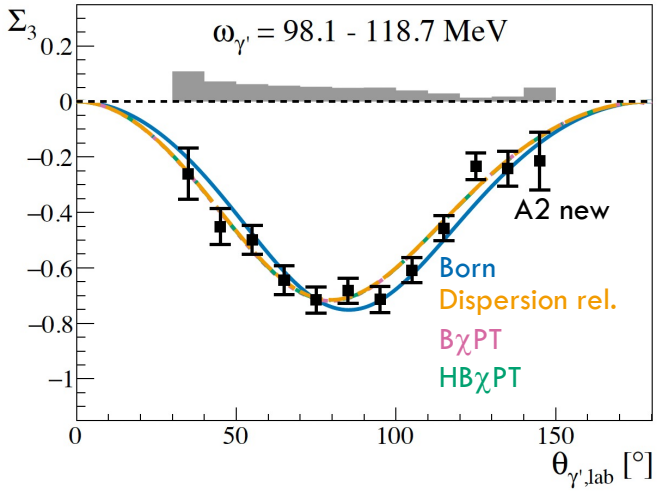
- in addition 4 Spin Polarizabilities

PRL 128 (2022) 132503



Exploit linear beam polarization to measure asymmetry $\Sigma_3 \equiv \frac{d\sigma^{\perp} - d\sigma^{\parallel}}{d\sigma^{\perp} + d\sigma^{\parallel}}$



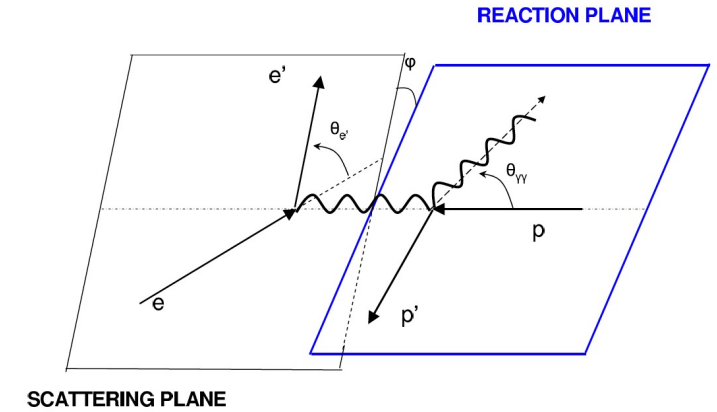


	stat	syst.	spin polar.	model dep.
α_{E1}	10.99 ± 0.16	± 0.47	± 0.17	± 0.34
β_{M1}	3.14 ± 0.21	± 0.24	± 0.20	± 0.35

- Uncertainty as for previous PDG world average!
- New MAMI data (together with asym. Σ_{2x}, Σ_{2z}) allowed for a fit to all 6 LO proton polarizabilities

PRL 129 (2022) 102501

PROTON GENERALIZED POLARIZABILITIES @ A1/MAMI



Accessible via Virtual Compton Scattering:

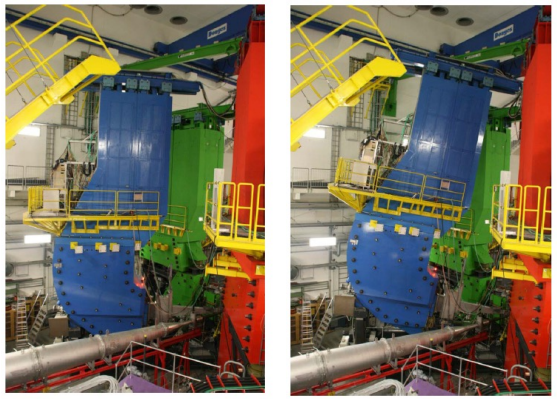
Virtuality of photon gives access to Generalized Polaribilitiess :
$\alpha_E(Q^2)$; $\beta_M(Q^2)$ (+ 4 spin GPs)

→ mapping out the spatial distribution of the polarization densities

→ Fourier transform of densities of electric charges and magnetization of a nucleon deformed by an applied EM field

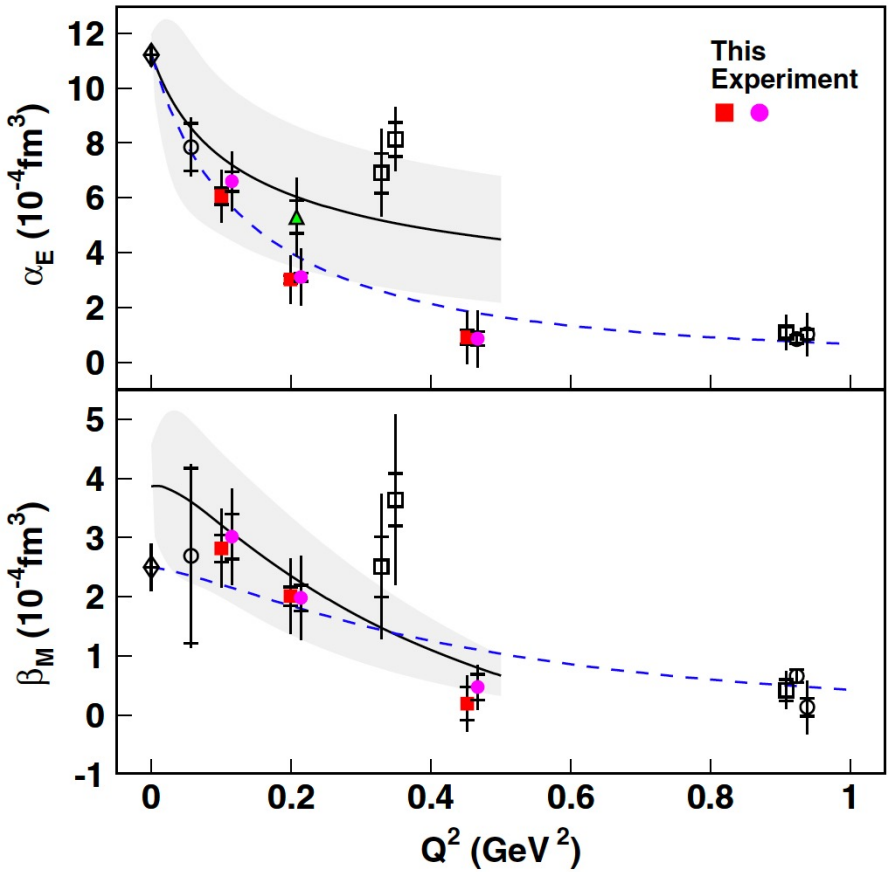
New MAMI data in two measurement campaigns:

- Detailed understanding of systematics (4 PhD students)
- Out of plane (oop) measurement to access kinematic range, in which higher order terms small and extraction possible
- Final extraction according to LEX (low energy expansion) and DR
- First extration of N-Δ transition FF via gamma channel



in plane oop (8.5°)

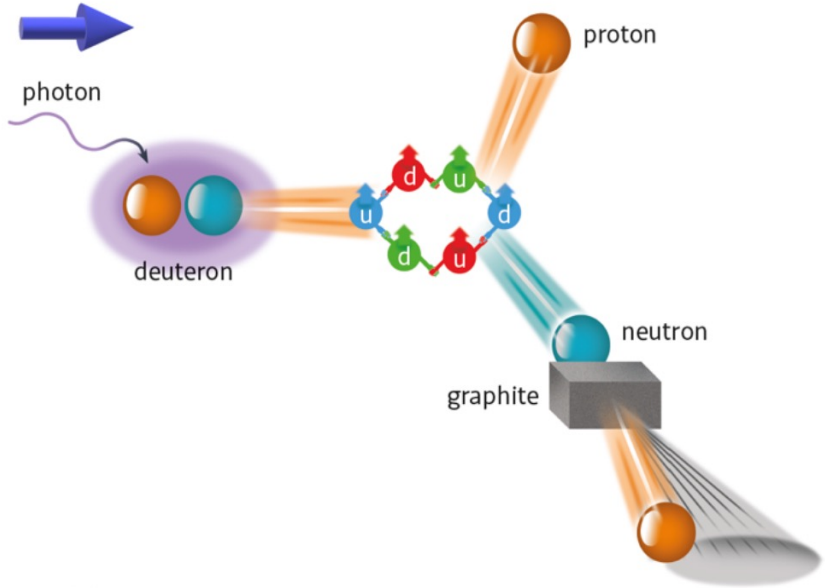
PRL123 (2019) 192302



PHOTODISINTEGRATION OF THE DEUTERON AT A2/MAMI SEARCHING FOR THE d*(2318) HEXAQUARK IN PHOTOPRODUCTION

First measurement of polarization transfer from circularily-polarized photon to the neutron in deuterium photodisintegration

- Large acceptance nucleon polarimeter (graphite)
- Photon energy range 370 – 700 MeV
- Final state neutron angular coverage 45° - 120°

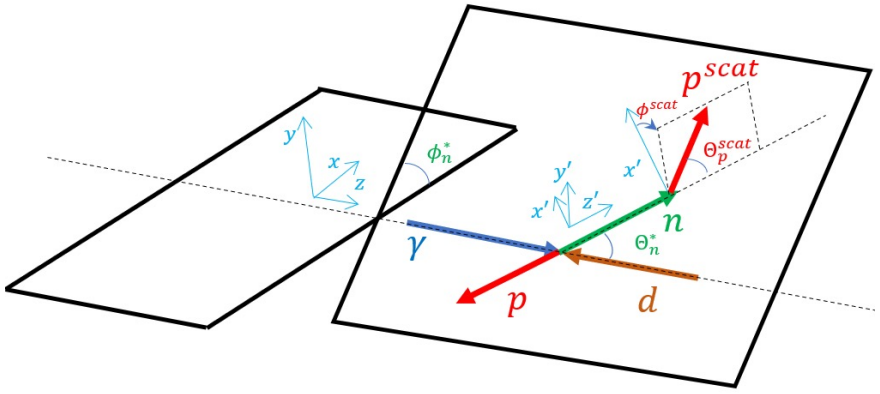


circular photon polarization — projection of nucleon polarization

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_0 \cdot [1 + C^n_{x'} \cdot P^{\odot}_{\gamma} \cdot P_{x'} + ...],$$

Born — spin tranfer observable

arXiv:2206.12299v2



PRL124 (2020) 132001

In comparison to previous measurement of induced polarisation P_n^y

- resonant phase motion at around 2.3 GeV
- New $C^n_{x'}$ data seems not in agreement with theoretical estimates using nucleon-nucleon resonances only

→ Signature of d*(2318) hexaquark state seen at WASA@COSY ?

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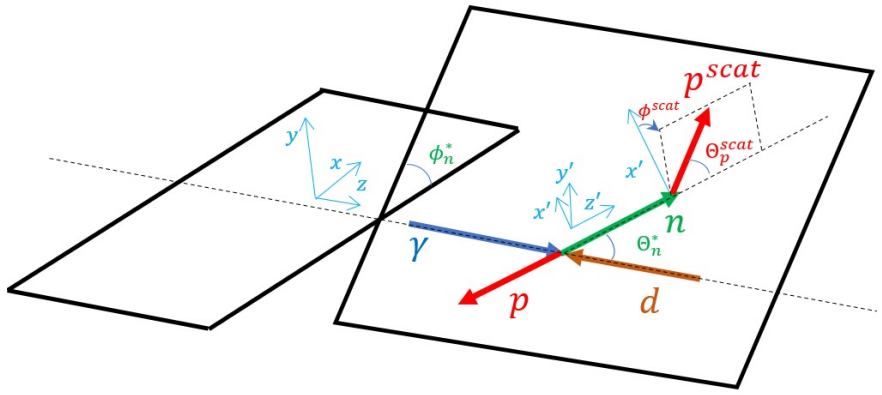

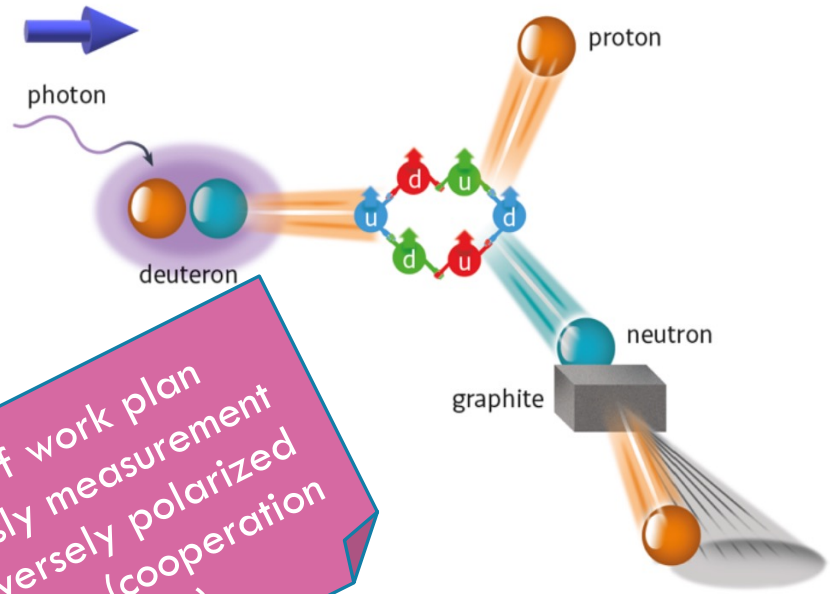

arXiv:2206.12299

Change of work plan
→ Previously measurement with transversely polarized target foresen (cooperation with Dubna)

PRL124 (2020) 132001

In comparison ... ious measurement of induced polarisation P_n^y

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- New $C^n_{x'}$ data seems not in agreement with theoretical estimates using nucleon-nucleon resonances only

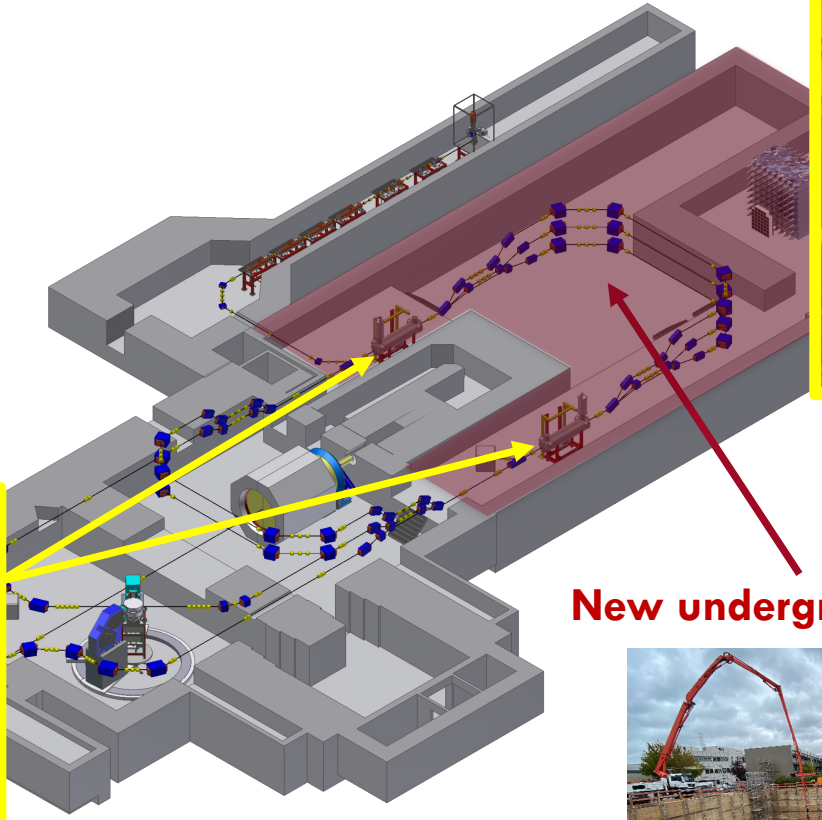
→ Signature of d*(2318) hexaquark state seen at WASA@COSY ?

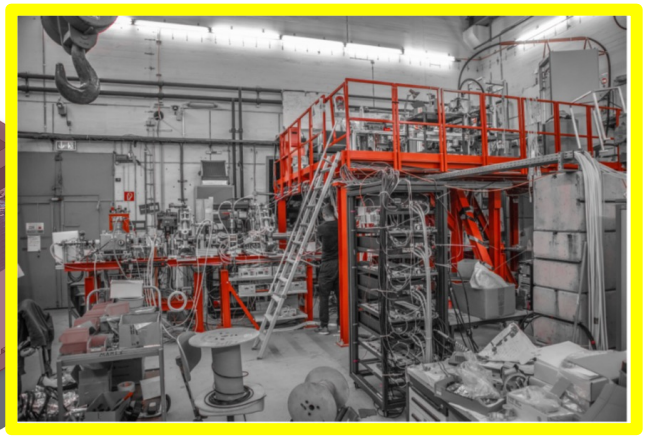
MESA ACCELERATOR

Cluster of Excellence PRISMA+

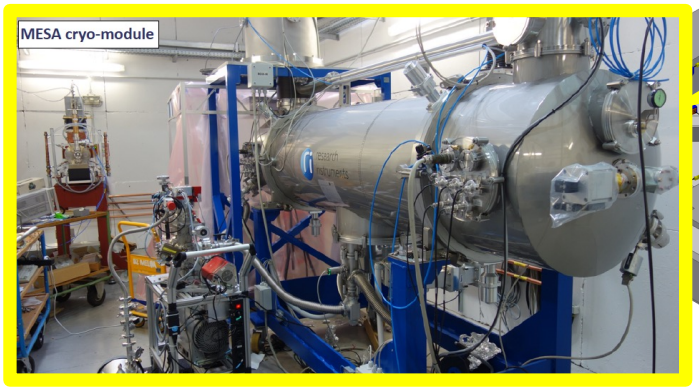
Key parameters MESA:

- Max. beam energy 155 MeV
- Beam current >1 mA
- Energy-recovering (ERL) mode
- Superconducting cavities
- Start commissioning 2024
- New research building (par. 91b GG)
- Can run in parallel to MAMI





Polarized Source Test Setup



Cryomodules successfully tested

New underground experimental hall (par. 91b GG)

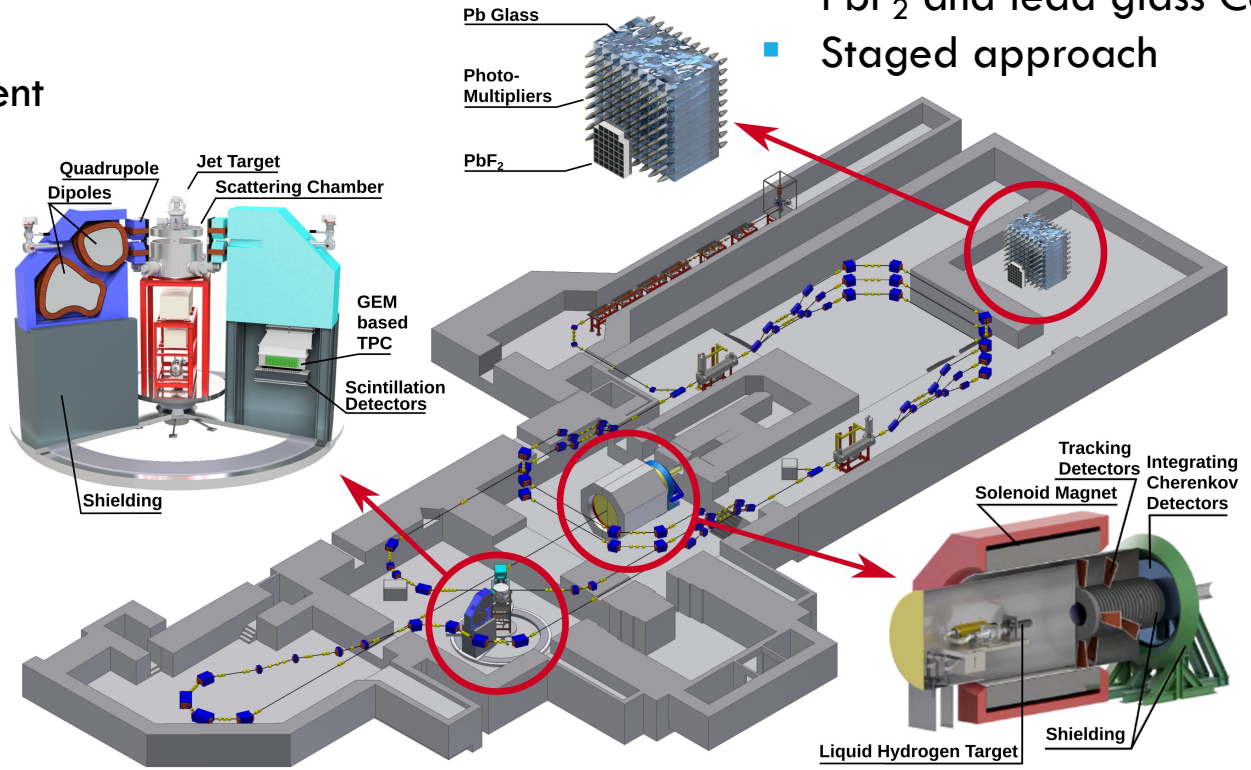
MESA EXPERIMENTS

MAGIX experiment

- Operated in ERL mode of MESA
- Double-arm spectrometers
- Internal gas target experiment
- Gas jet target commissioned at A1/MAMI already

DarkMESA

- Beam dump experiment
- Direct detection of light dark matter
- PbF_2 and lead glass Cerenkov calorimeter
- Staged approach



P2

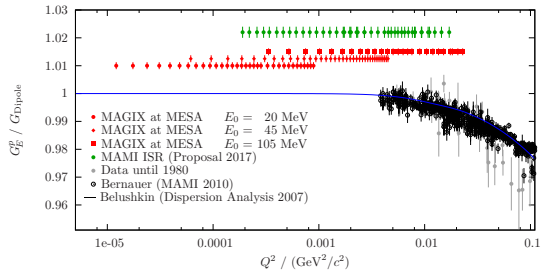
- Extracted beam mode
- Parity violation experiment
- 10^{22} Electrons / a
- $\sin^2\theta_W$ and neutron skin

Main components of MAGIX and P2 presently constructed in industry and assembled in house (funding via major research instrumentation program of federal government)

Phase 1 detecctor for DarkMESA almost ready.

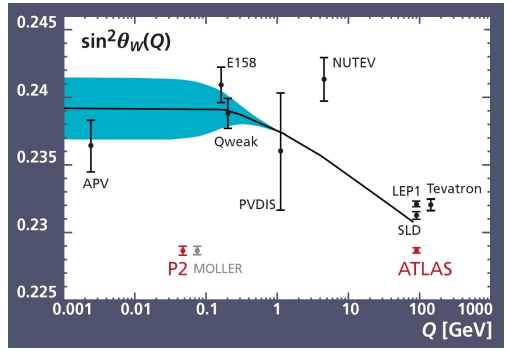
MESA PHYSICS PROGRAM

From Nuclear Physics to Hadron and Particle Physics



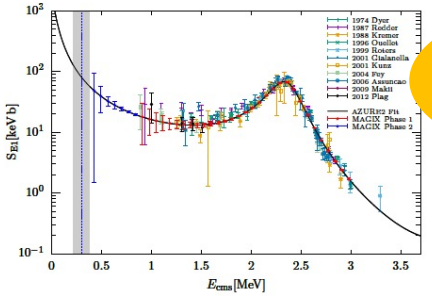
Low Q^2 EM Form Factor p,n (MAGIX)

Precision Measurement of $\sin^2\theta_W$ via p,^{12}C (P2)



Neutron Skin Pb (P2-MREX)

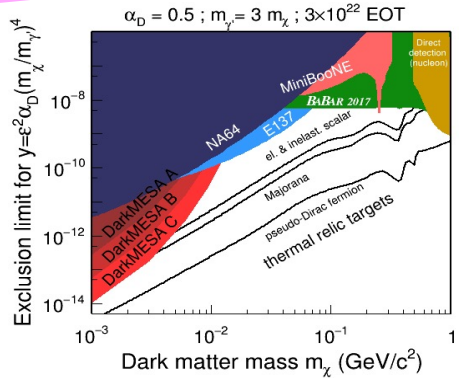
Search for Dark Photon and Axions (MAGIX)



$^{12}C\ (\alpha,\gamma)\ ^{16}O$ (MAGIX)

Few Body Physics (MAGIX)

Light Dark Matter direct detection (DarkMESA)



SUMMARY AND OUTLOOK: TRANSNATIONAL ACCESS TO MAMI

- After 1.5 years of severe constraints due to Covid19 pandemic, beam operation in standard conditions have been resumed in September 2021
  → ~4000 h of beam time since then

- Diverse and successful program of beam times at A1, A2, X1, MESA test beams
  → impressive publication output (could show only a small fraction in this talk)

- Energy crisis due to Ukraine war: so far no restrictions requested by University management
  → shutdown between 12/22 and 03/23

- Ukraine war with severe impact on A2 future physics program: Polarized frozen-spin target and PRES experiment → modifications to run plan

- Construction of MESA accelerator and MESA experiments MAGIX, P2, DarkMESA continuing successfully

- Significant increase of visits via TNA since spring/summer of 2022; will continue in upcoming months
  → extension of STRONG2020 of 6 ... 12 additional months (beyond 11/23) would be helpful !