

Annual Meeting  
Laboratori Nazionali di Frascati  
June 20, 2024



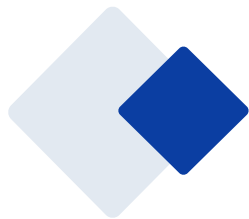
# TA2 TRANSNATIONAL ACCESS TO the Mainz Microtron MAMI

Achim Denig  
JGU Mainz  
Institute for Nuclear Physics

STRONG-2020



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



# MAMI Accelerator

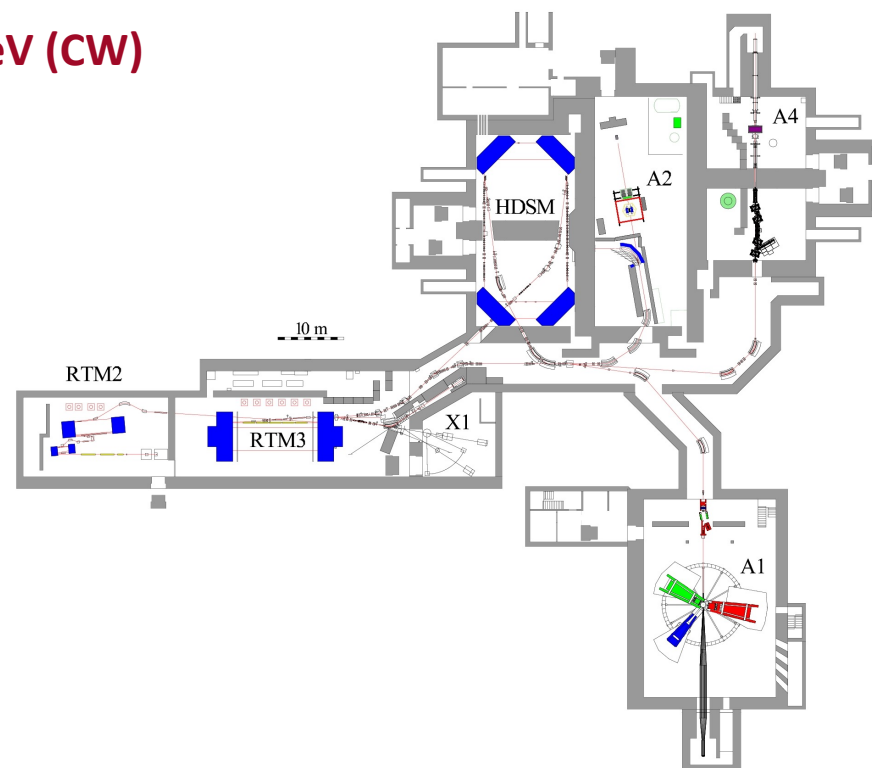


**Electron Accelerator  $E_{\max} = 1.6$  GeV (CW)**

**operated at JGU Mainz**

## Hallmarks

- Intensity max.  $100 \mu\text{A}$
- Resolution  $\sigma_E < 0.100$  MeV
- Polarization 85%





# MAMI Accelerator

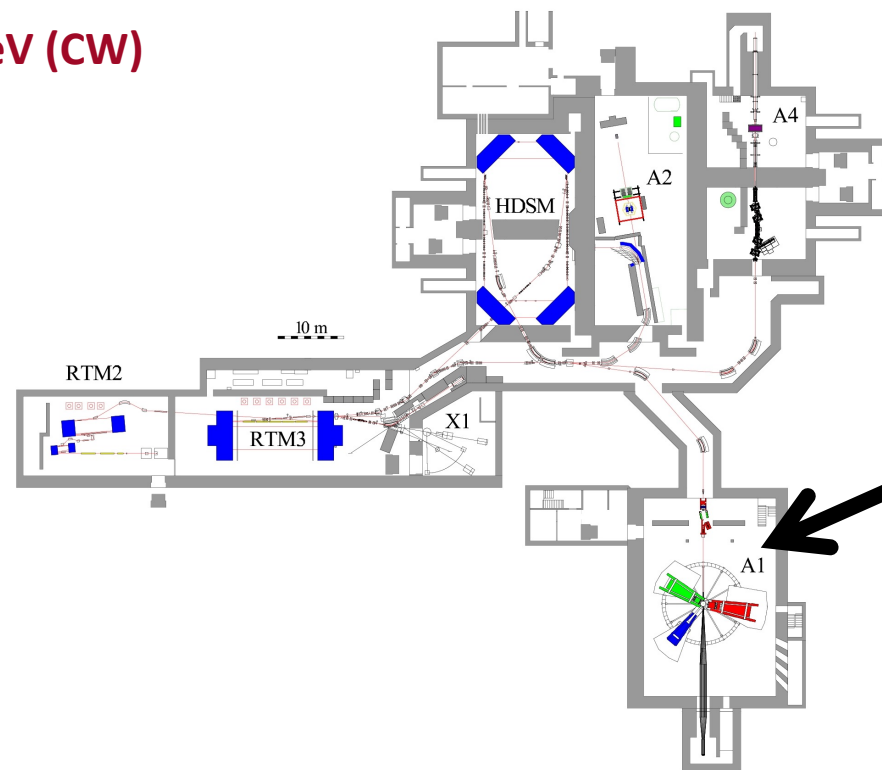


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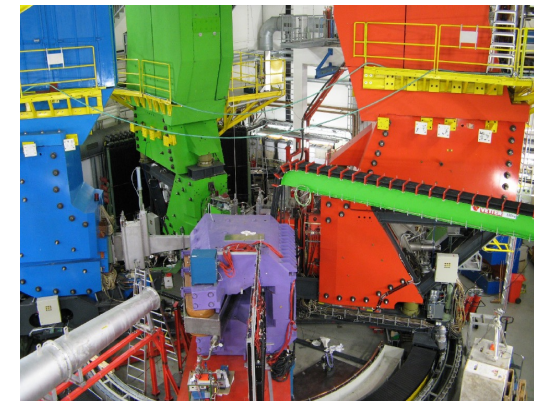
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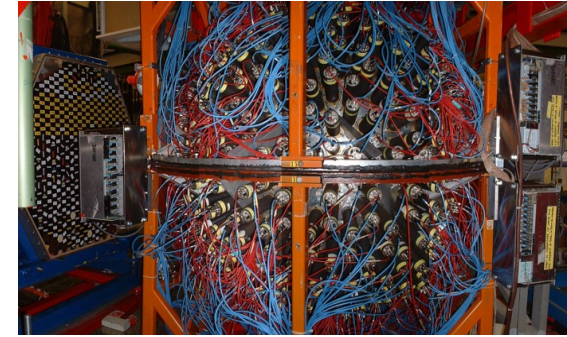


**Electron scattering (high resolution spectrometer setup)**



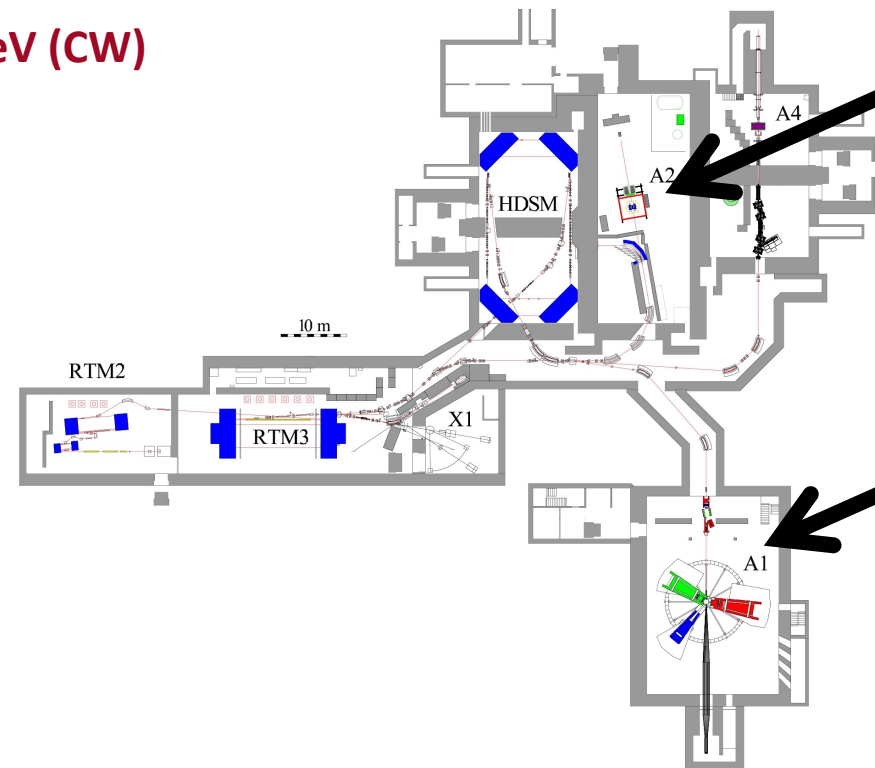


# MAMI Accelerator



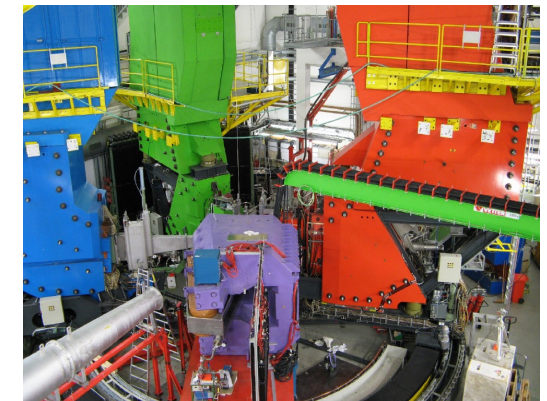
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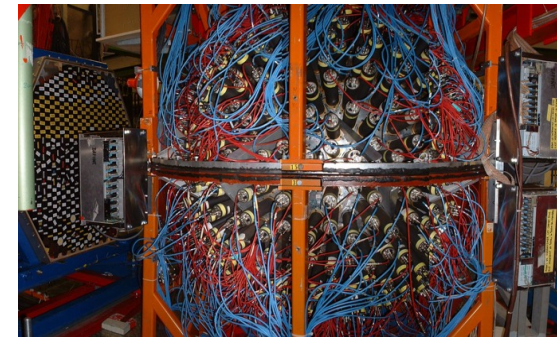
**A2** Photon scattering (A2 hall)  
(Crystal Ball / TAPS calorimeters;  
Polarized frozen-spin target)

**A1** Electron scattering (high resolution spectrometer setup)



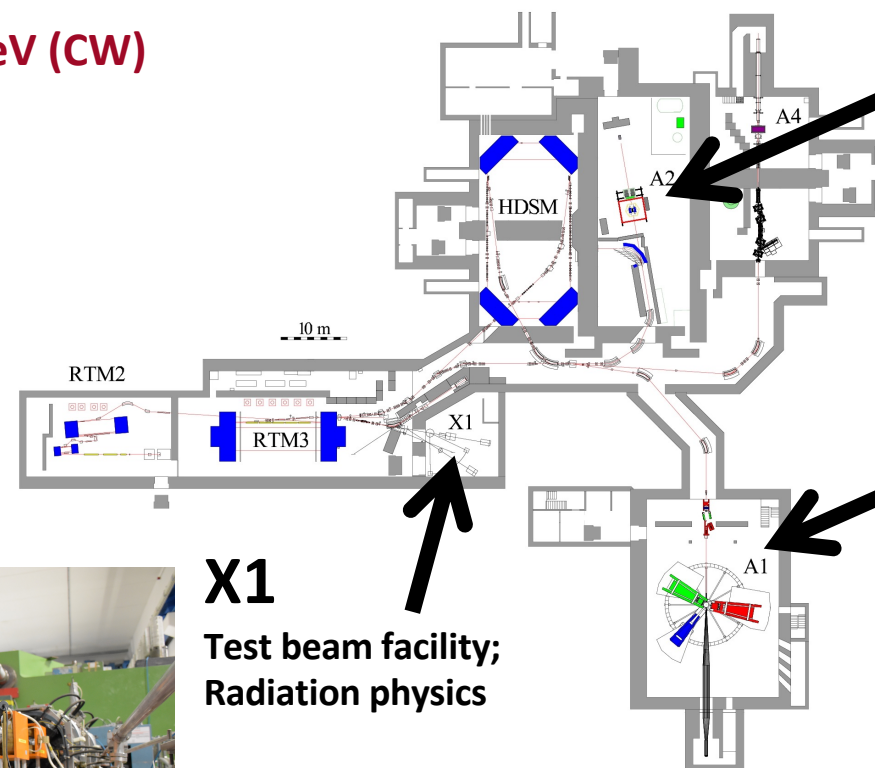


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**A2**

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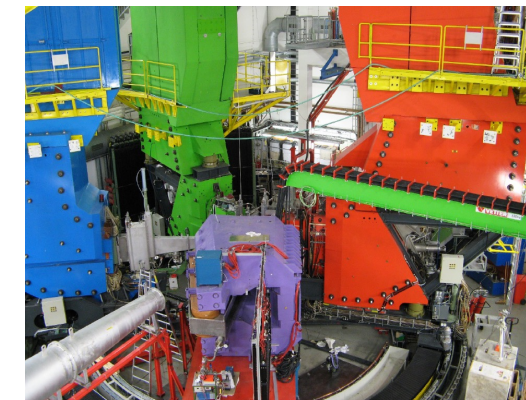
**A1**

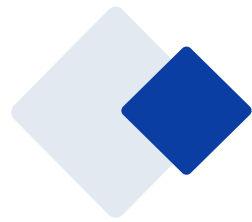


**Electron scattering (high resolution spectrometer setup)**



**X1**  
 Test beam facility;  
 Radiation physics





# MAMI Accelerator

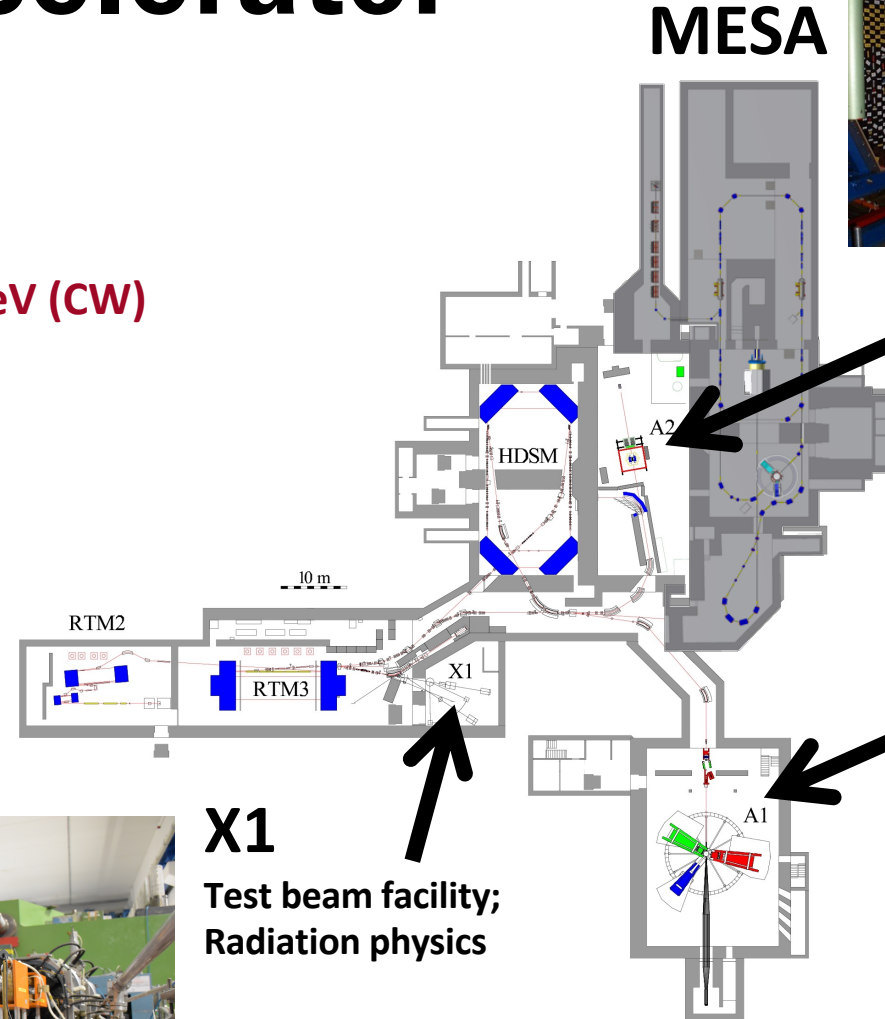


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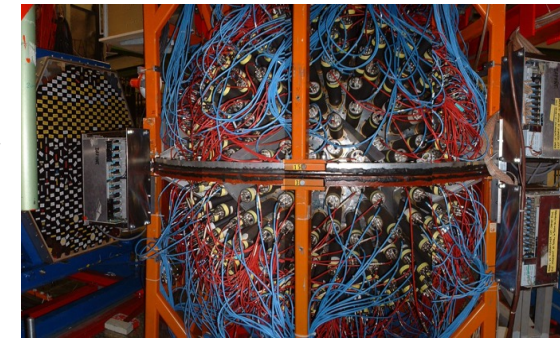
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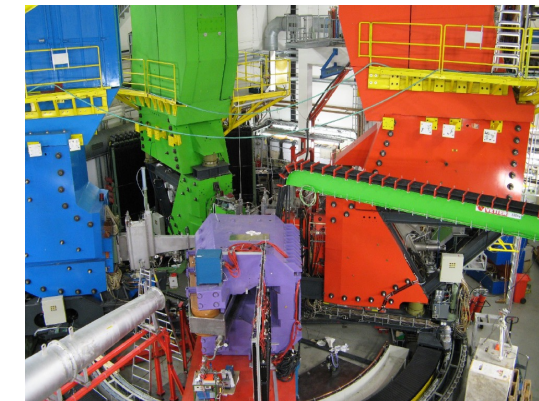


**MESA**



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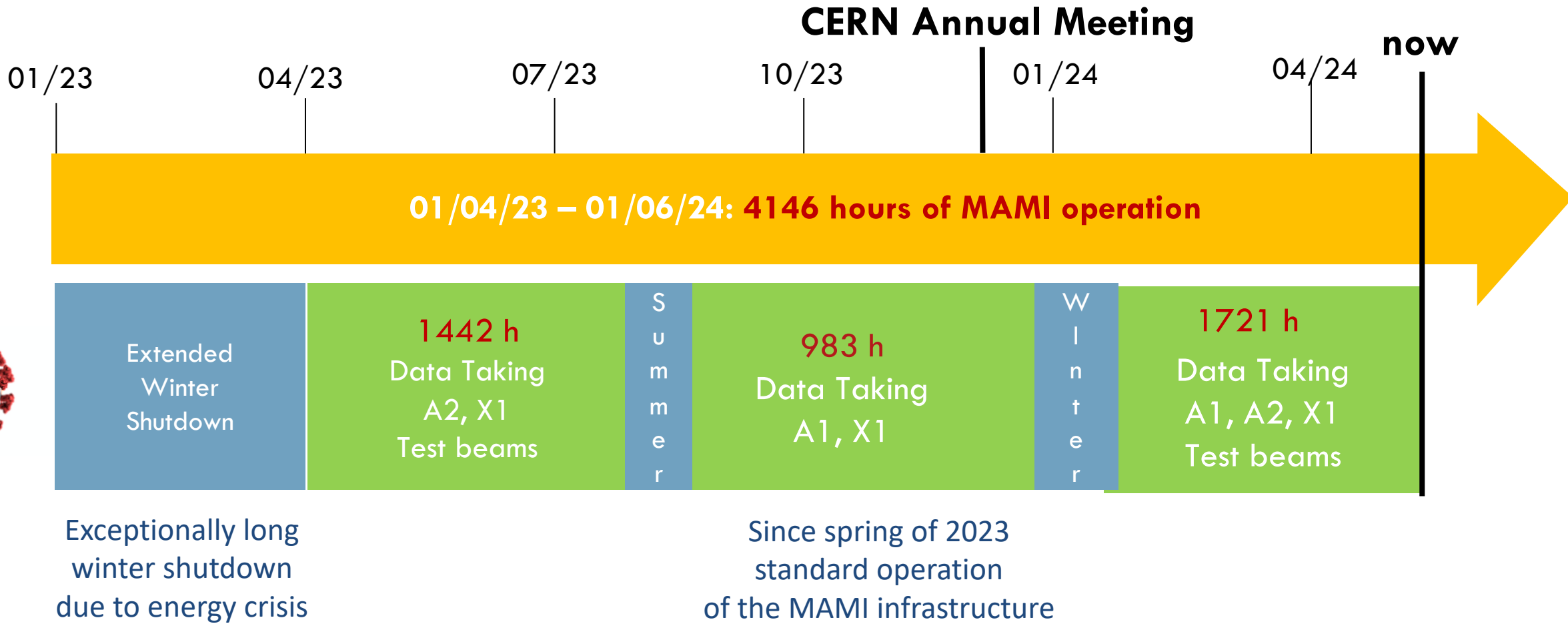
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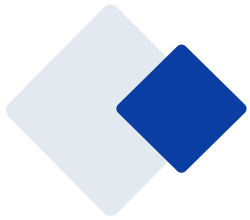
# Data Taking MAMI Accelerator



2138 h of beam time since CERN Annual Meeting







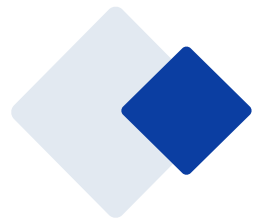
# Outline



- **Progress achieved during the last year**
  - Positron channeling
  - Transverse asymmetries for nuclei
  - Electrons for Neutrinos (e4nu)
- **General comments on MAMI TNA**
- **Outlook for the Future**





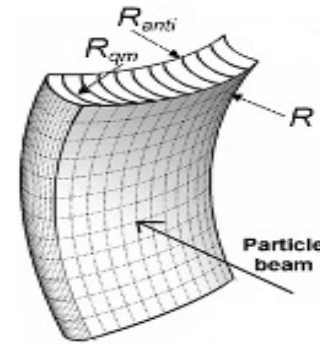
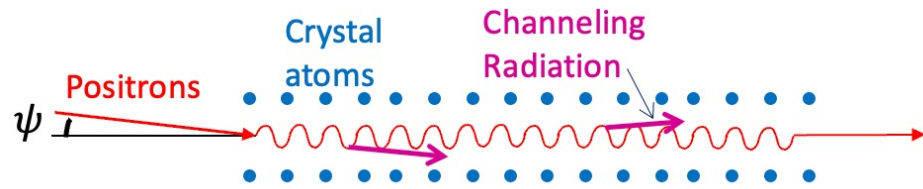


# Positron Channeling (X1)

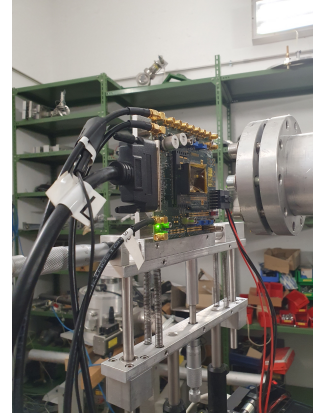
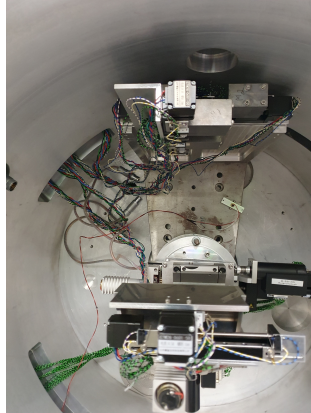
TECHNO-CLS project number: 101046458

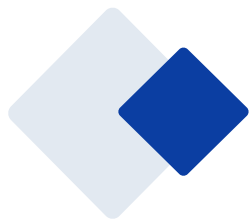


Funded by  
the European Union



Dechanneling length for  $e^+$   $\sim 300 \mu\text{m} = \times 15$  compared to  $e^-$   
New: positron beam line at MAM, now with bent crystals!



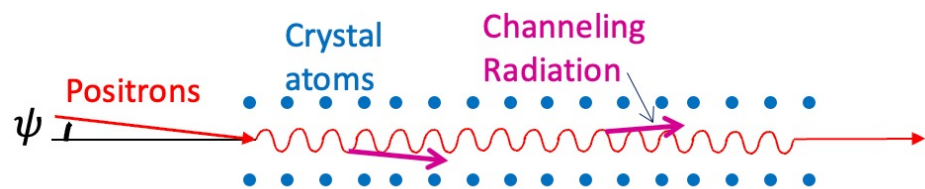


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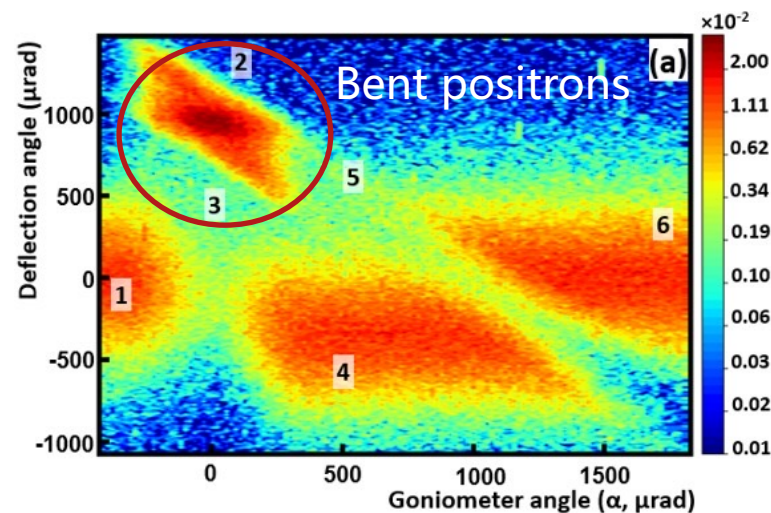
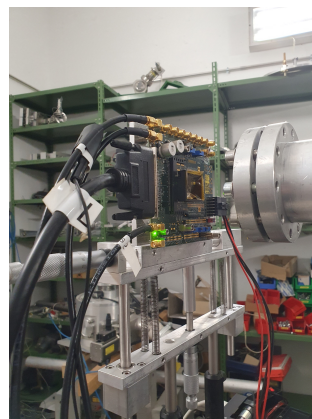
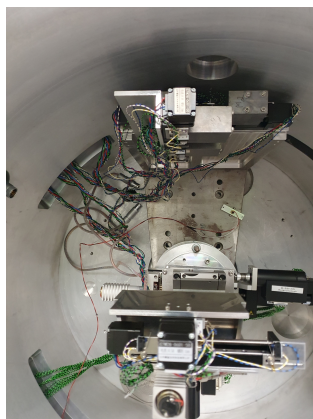
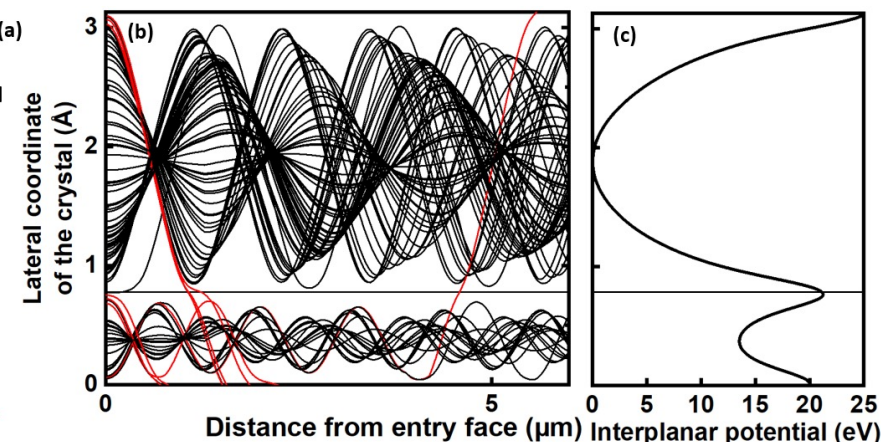
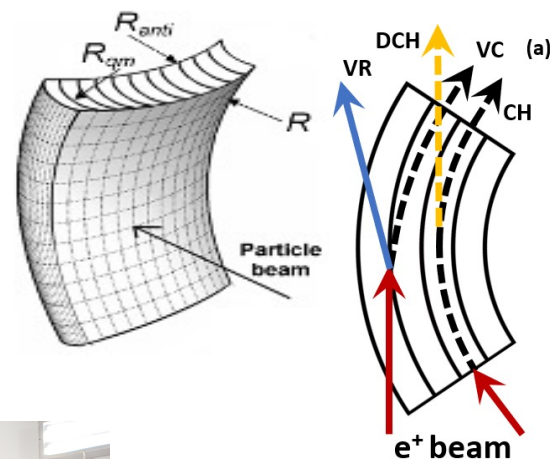
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New: positron beam line at MAM, now with bent crystals!



855 MeV electron beam  
arXiv:2404.08459

First highly efficient deflection of sub-GeV  
positrons in bent crystal worldwide!

→ Important applications for crystal light sources, bending and accelerator technologies, ...

# Transverse Asymmetries Nuclei (A1)



- arise from interference of one- and two-photon exchange amplitude
- allow to access of imaginary part of  $2\gamma$  exchange amplitude:

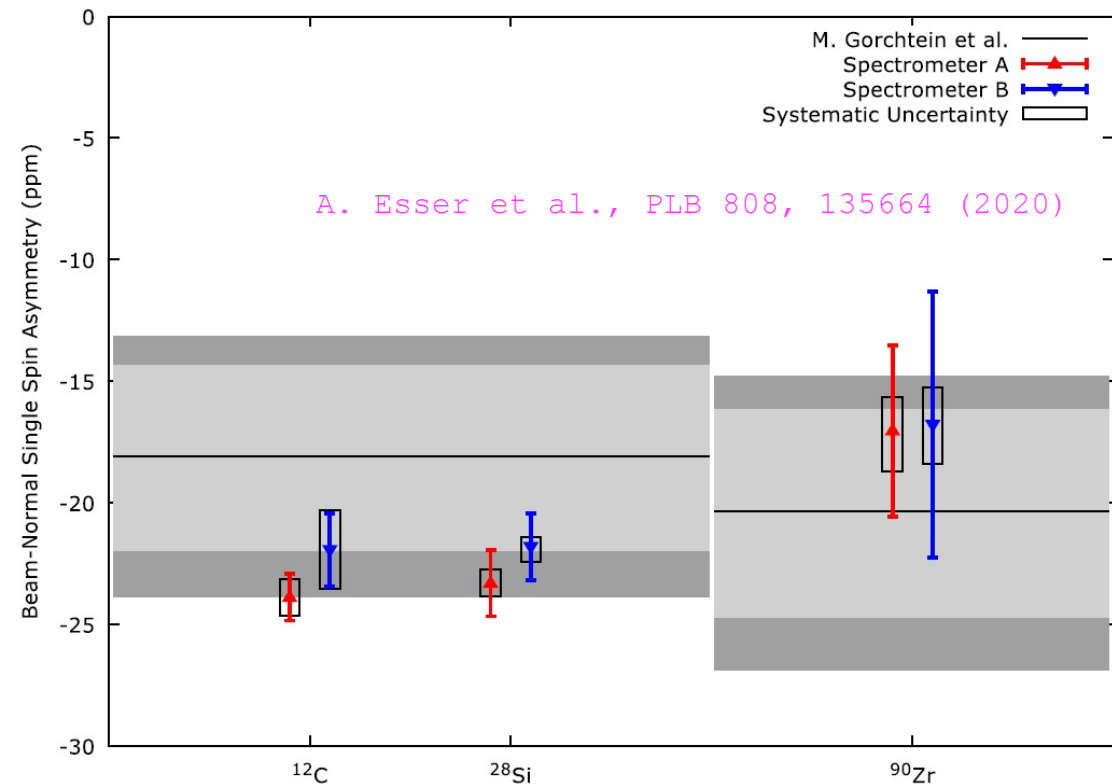
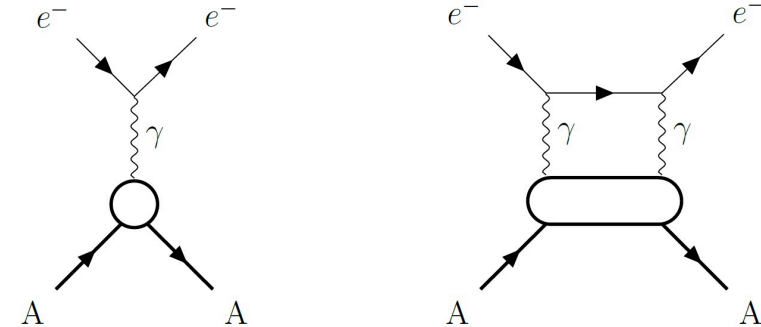
$$A_n = \frac{2\Im(\mathcal{M}_\gamma^* \mathcal{M}_{\gamma\gamma})}{|\mathcal{M}_\gamma|^2}$$

## Why interesting ?

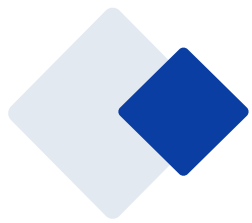
- constrain systematic uncertainties in high-precision parity-violating electron scattering experiments (e.g. neutron skin, weak charge of the proton)
- good agreement between data and theory for lighter targets, but dramatic difference for  $^{208}\text{Pb}$

new systematic study at A1@MAMI  
of intermediate and heavy mass nuclei

study of Z-dependence will be completed  
with new experimental campaign on  $^{208}\text{Pb}$  now







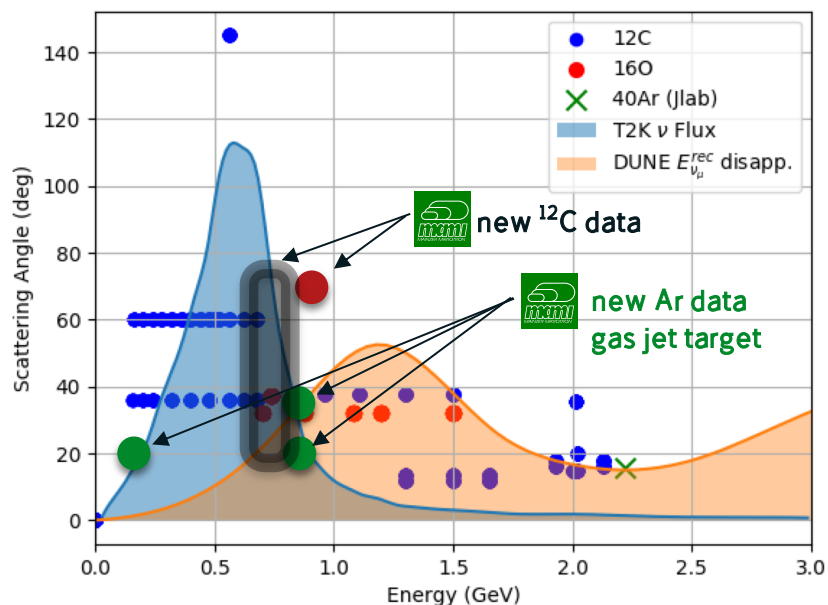
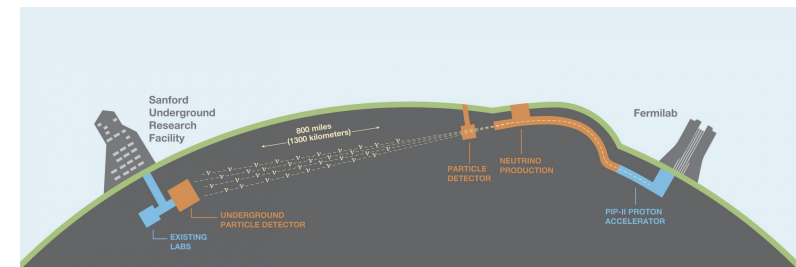
# e4nu: Electrons for Neutrinos (A1)



Interpretation of neutrino experiments (DUNE, T2K, Hyper-K, Mini-Boone, ...) requires knowledge of neutrino-nucleus interaction ( $^{12}\text{C}$ ,  $^{16}\text{O}$ ,  $^{40}\text{Ar}$ )

→ **Electron scattering to validate neutrino cross section models**

- Precision test of the nuclear models
- Precision test of the “neutrino generator” codes
- Precision test of modern ab-initio nuclear theory







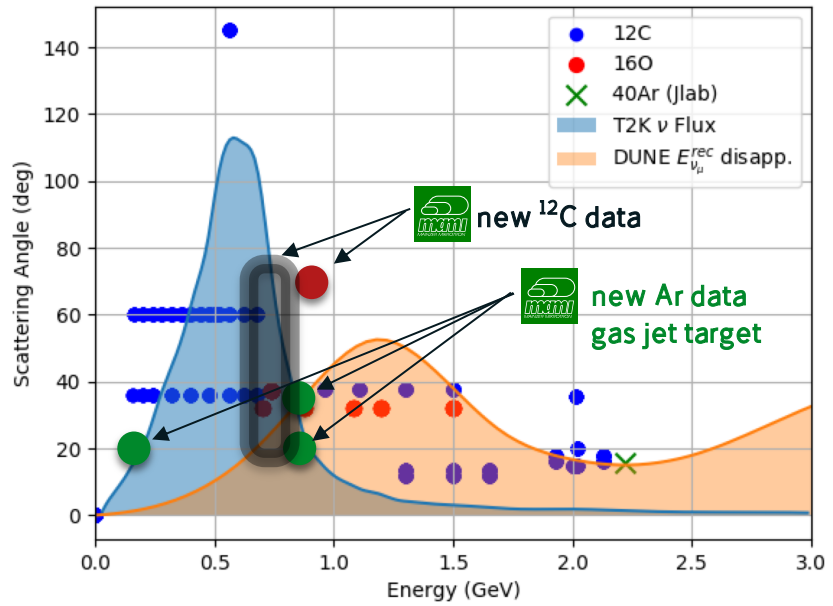
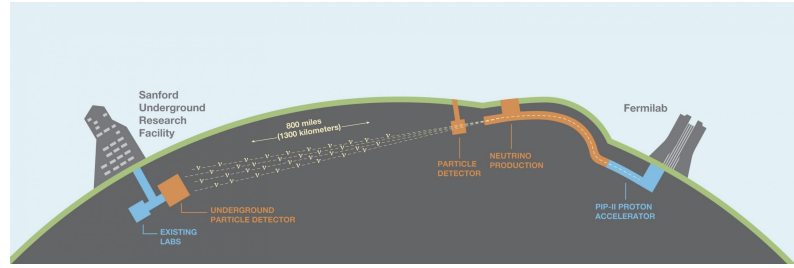
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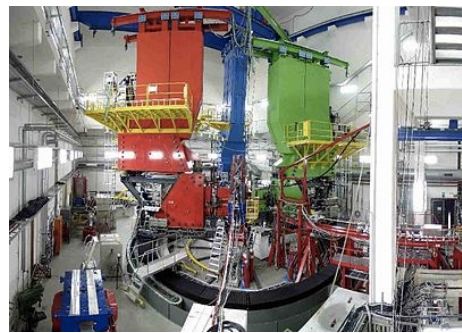
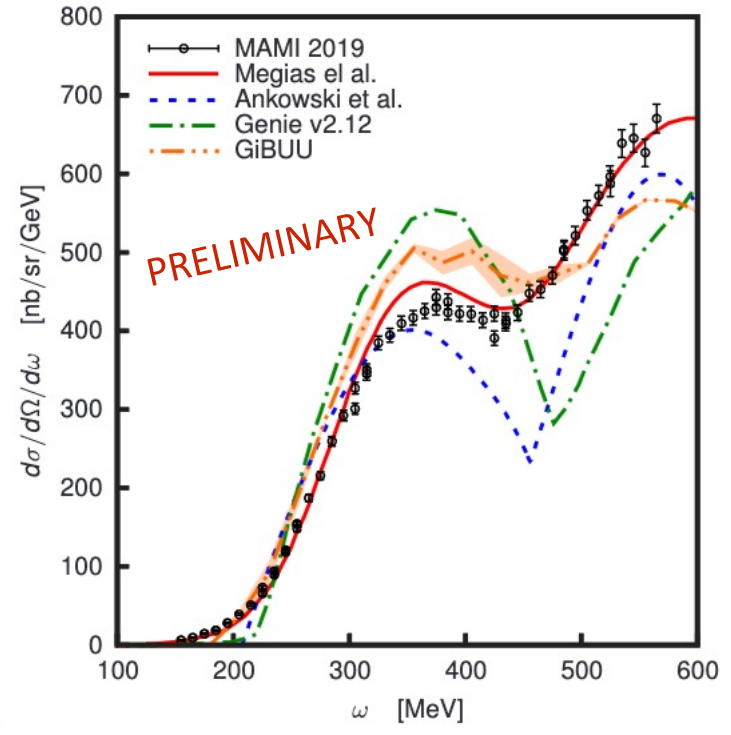
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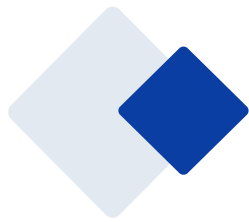
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## $^{12}\text{C}(e,e')$ @ MAMI (855 MeV)



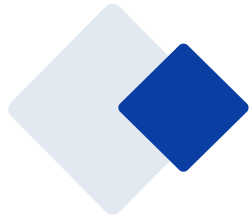
Near future: exclusive reactions



# TNA MAMI during STRONG2020



- Covid pandemic with very severe consequences for MAMI operation  
→ long shut-down periods in 2020 and 2021 with improvements starting in 2022 only
- Energy crisis (as a consequence of war in Ukraine) in winter of 2022/23 lead again to a long shutdown of MAMI
- Starting from spring of 2023, MAMI operation again in full swing with continuous data taking periods, interrupted only by short winter/summer breaks
- Overwhelming fraction of TNA travels and user's access since 2023  
→ good news: we could provide the access as proposed in GA in 2019 !



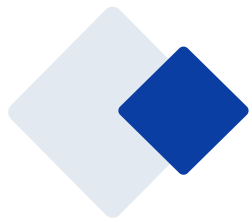
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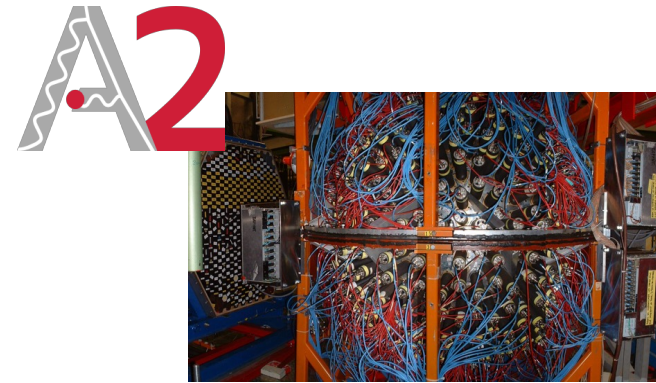
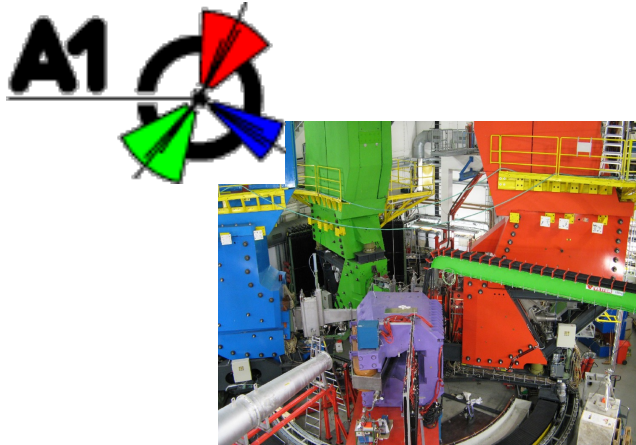
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## Messages learnt:

- **conservative approach regarding beam hours proposed initially**
- **flexibility of utmost importance to provide access to European users**
- **it is possible to deliver also in difficult times**



# Scientific Highlights TNA MAMI



- Program of transverse asymmetry measurements
- Campaign of e4nu measurements ( $^{12}\text{C}$ ,  $^{16}\text{O}$ ,  $^{40}\text{Ar}$ )
- Development of a gas jet target for various nuclei
- Measurement of EM form factor at low  $Q^2$
- Generalized polarizability measurement
- Polarization transfer measurements on nuclei
- ...

- Compton scattering program for p polarizabilities
- Double polarization observables in  $\gamma p \rightarrow p\pi^0/n\pi^+$
- Investigation of  $\pi$  and  $\pi\pi$  channels from deuteron
- Investigation of  $d^*(2380)$  hexaquark candidate
- Meson transition form factor measurements
- ...





# Additional Highlights STRONG2020



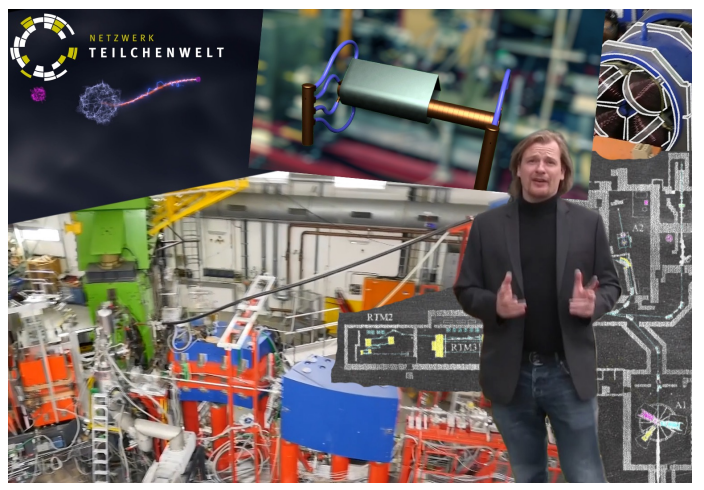
Outreach activities for high school students  
Mainz Physics Academy  
and many more outreach activities



A1 measurement of  $^4\text{He}$  transition FF  
in disagreement with nuclear theory



Development virtual MAMI tour





**NEW**

# Upcoming new MESA Accelerator

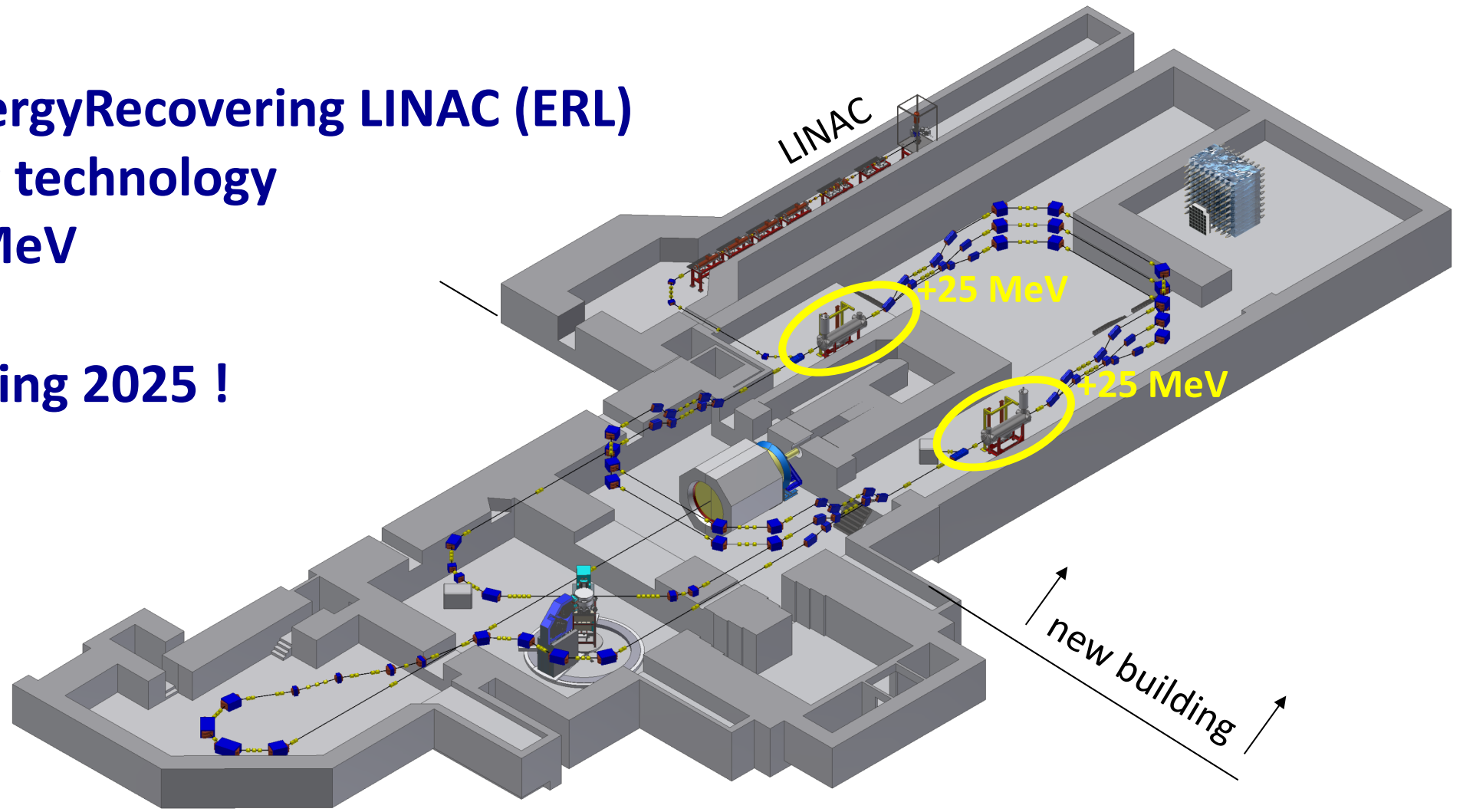
Recirculating EnergyRecovering LINAC (ERL)

Superconducting technology

$E_{max} = 105/155 \text{ MeV}$

$I_{max} > 1 \text{ mA (ERL)}$

Start of Data Taking 2025 !



**A low-energy precision machine for particle, hadron, nuclear physics !**

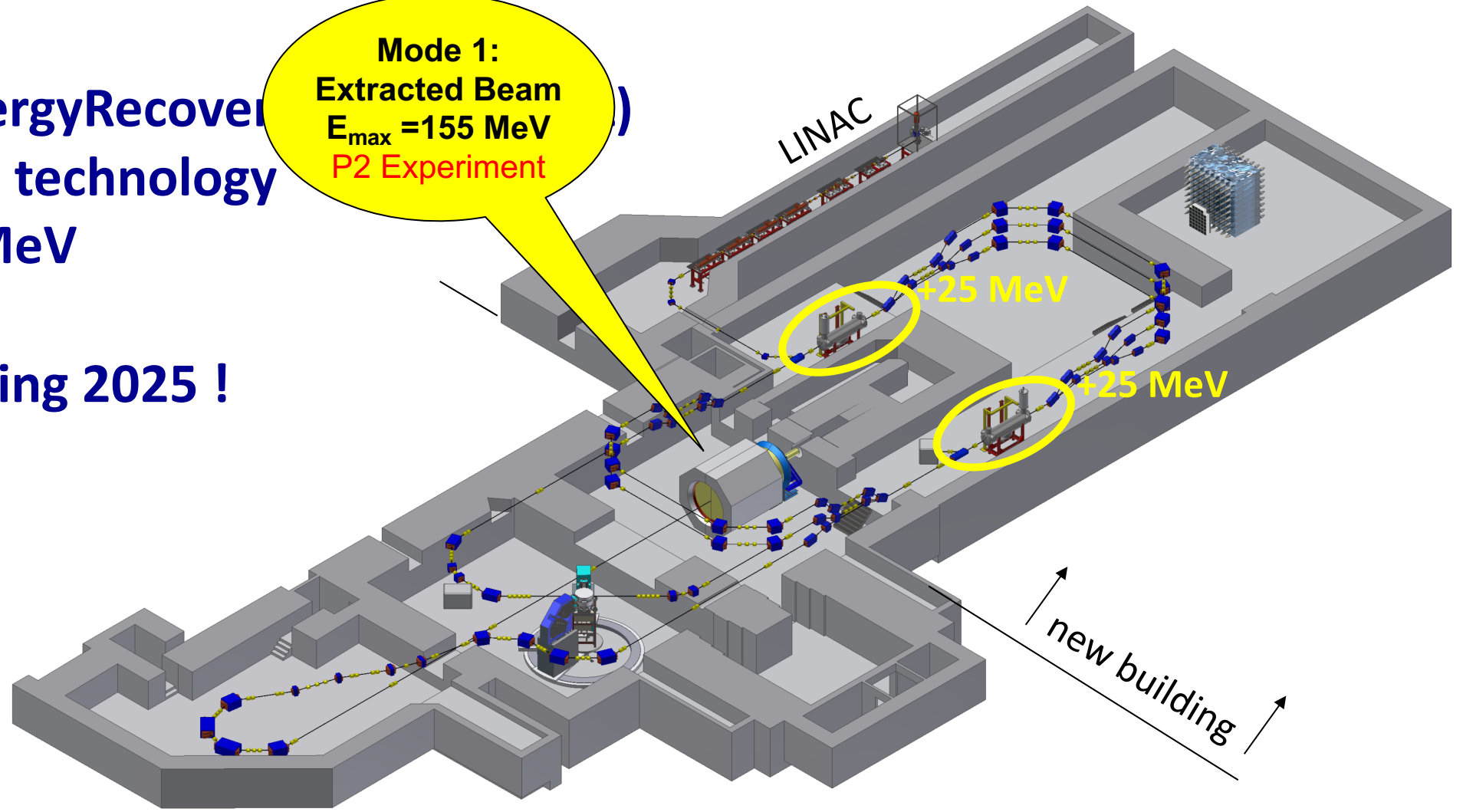


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 Superconducting technology  
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Mode 1:  
 Extracted Beam  
 $E_{max} = 155 \text{ MeV}$   
 P2 Experiment



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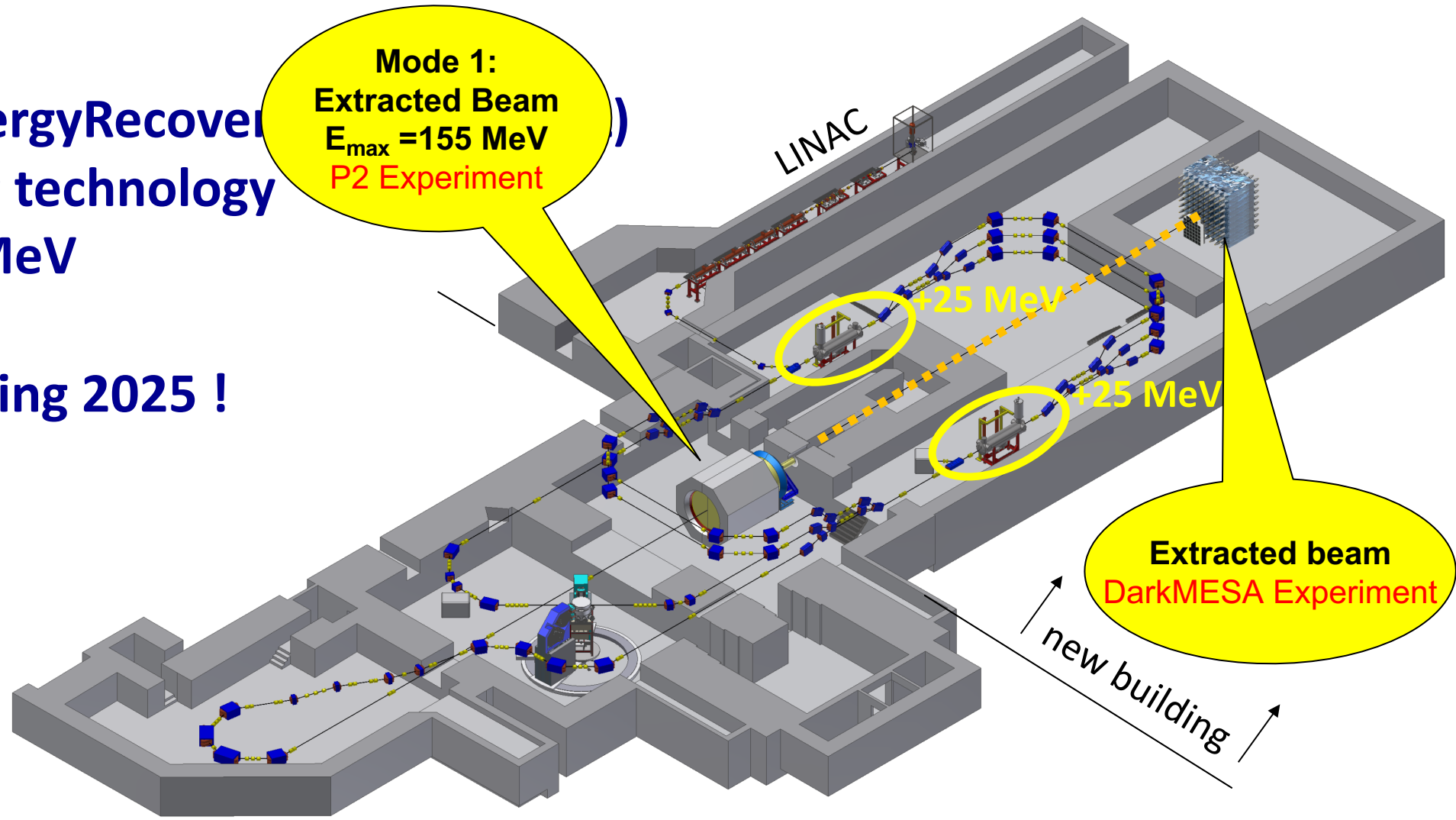




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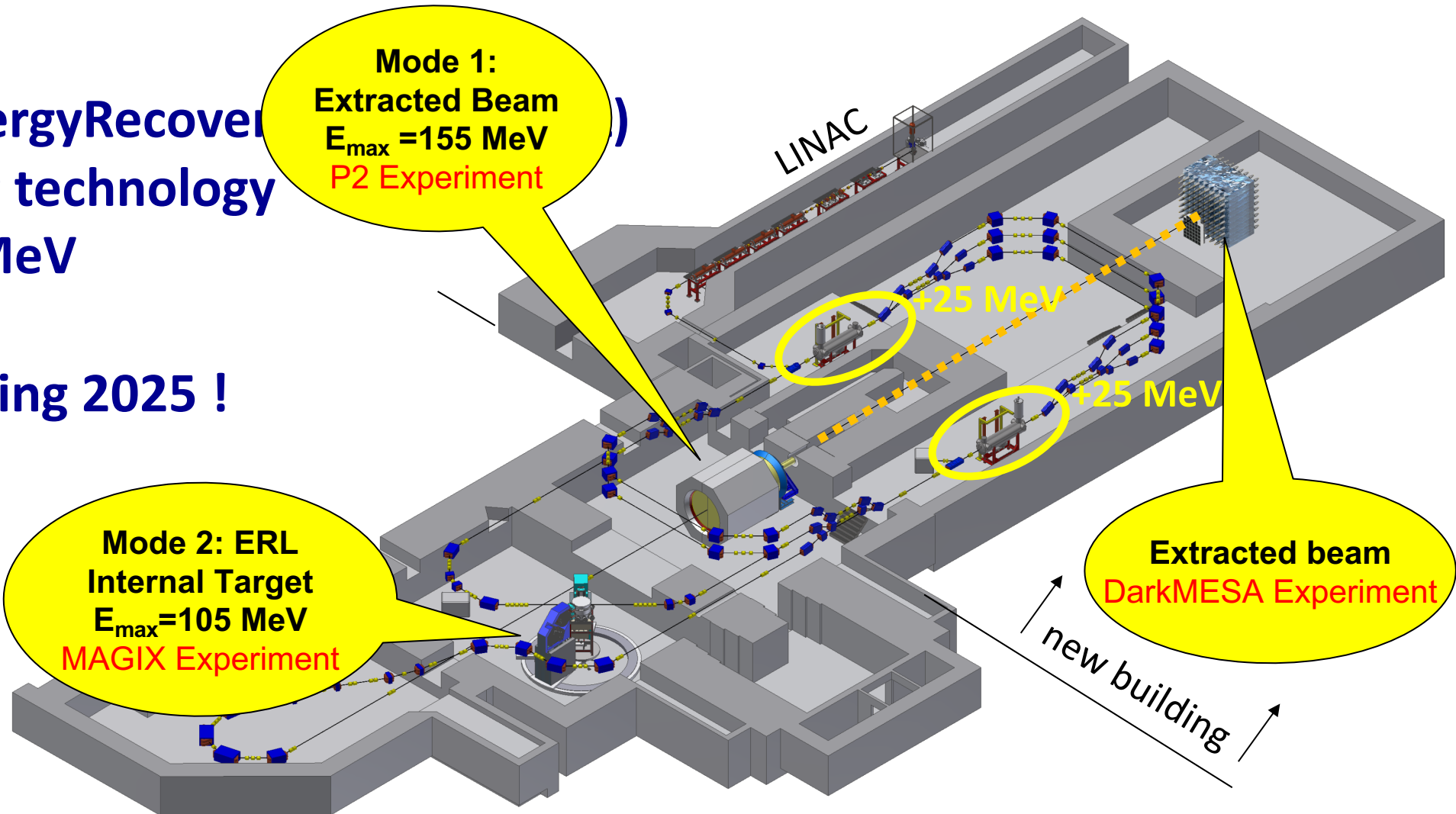
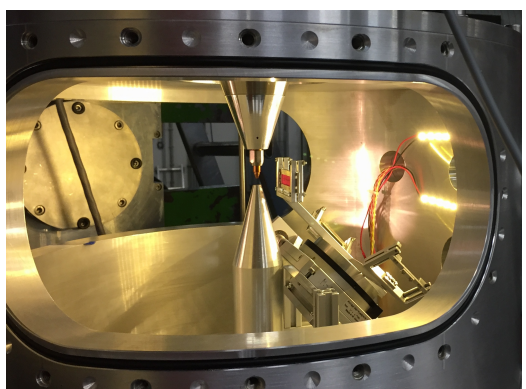




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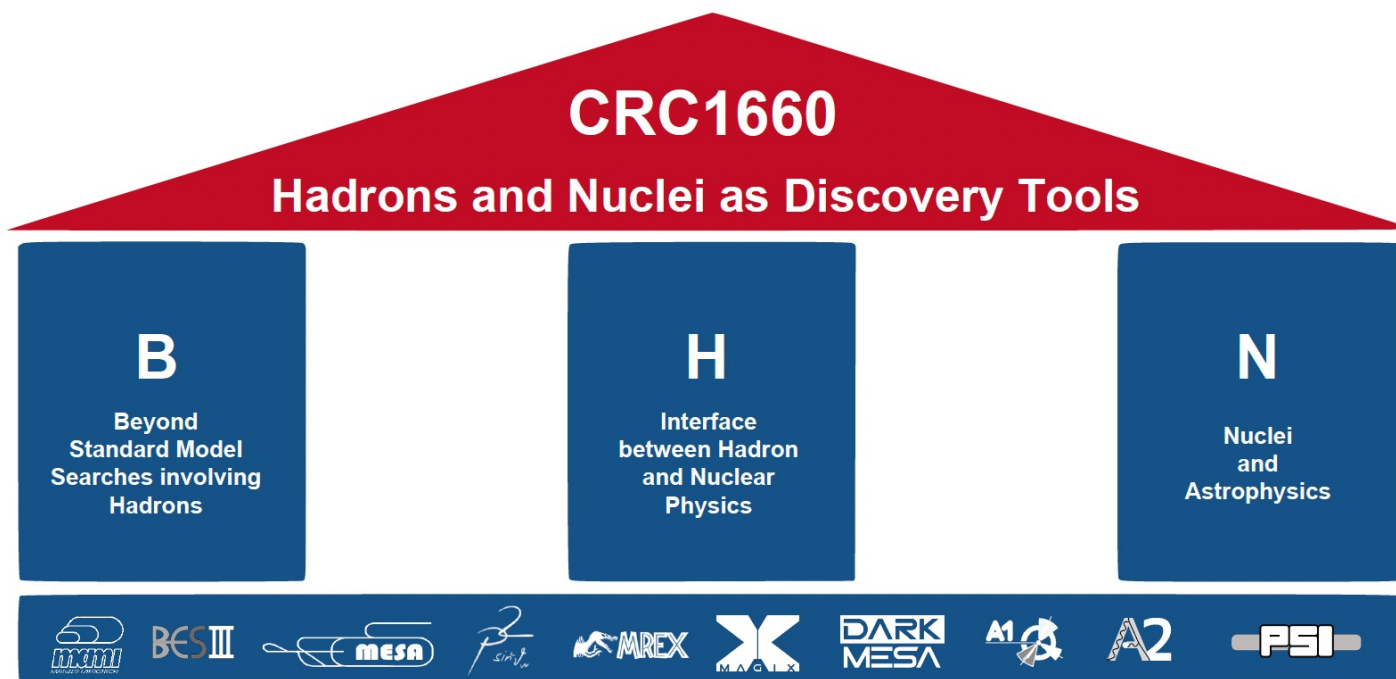
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**NEW**

# New CRC1660 @ Mainz

**DFG**

- May 29: Decision by DFG to fund new **Collaborative Research Center (CRC)** at Mainz
- 13 projects run by 26 principal investigators (spokespersons: C. Sfienti and M. Vanderhaeghen)
- Funding for 6.5 postdocs and 28 PhD students (theory and experiment)
- Start: October 2024 for ~4 years
- Interdisciplinary approach in particle, hadron and nuclear physics
- Very strong focus on experiments at MESA

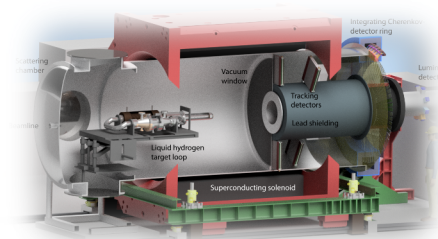


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*P2 Sfiuti***CRC1660****Hadrons and Nuclei as Discovery Tools****B**

Beyond  
Standard Model  
Searches involving  
Hadrons

**H**

Interface  
between Hadron  
and Nuclear  
Physics

**N**

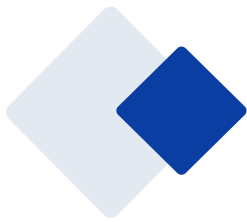
Nuclei  
and  
Astrophysics

**MAGIX****MAGIX experiment @ MESA**

EM Nucleon Form Factors  
Few Body Physics  
→ Nucleon Structure  
  
Search for Dark Mediator  
→ BSM physics  
  
Nuclear Reactions  
→ Nuclear Astrophysics

**BESIII***P2 Sfiuti***DARK MESA**





**Thank you !**  
**Very much looking forward to  
continuing Mainz TNA  
activities on European level !**