# The MAGIX experiment at MESA.

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EINN 2025, Paphos, Cyprus, October 28, 2025

https://agenda.infn.it/event/45343/







# **Greetings from Mainz.**





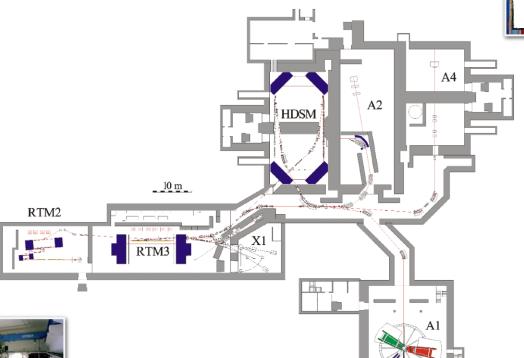


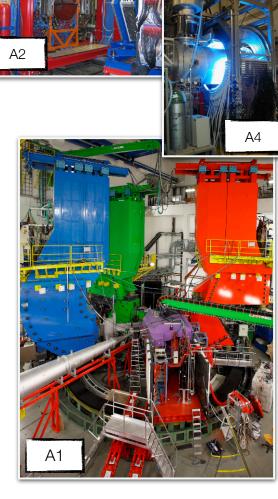




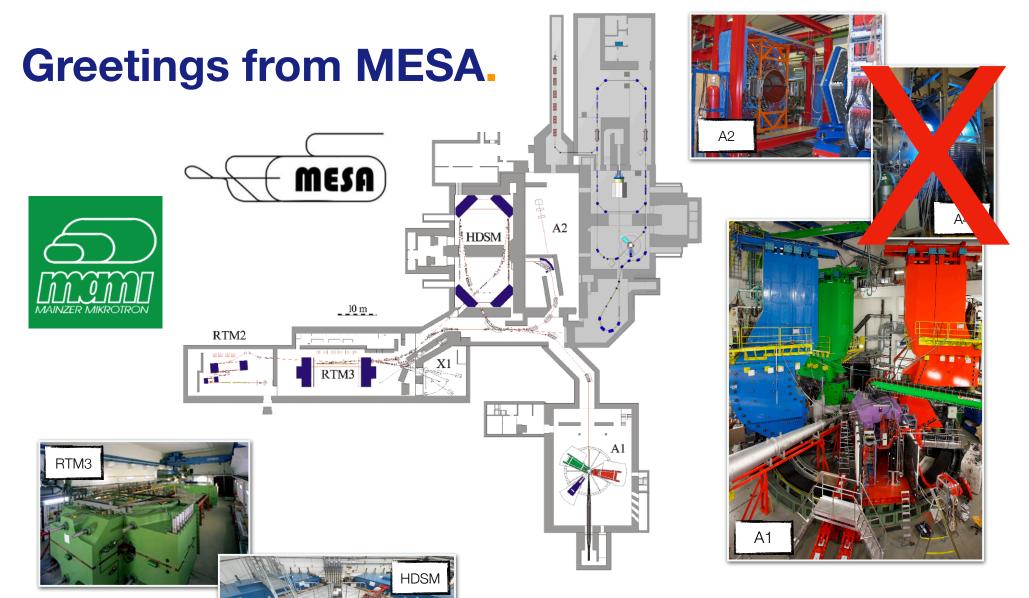
# **Greetings from MAMI.**







- Mainz has a long history of electron accelerators (linac in the 1960s, MAMI since the 1990s)
- **MA**inzer **MI**crotron, energies  $\leq 1600 \, MeV$ , currents  $\geq 100 \mu A$

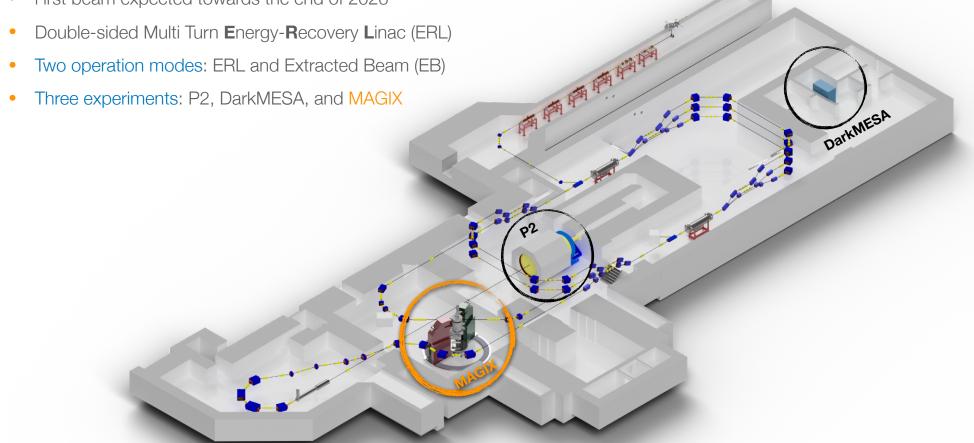


- The A4 experiment has been finished several years ago
- MESA will be the next-generation electron accelerator in Mainz with lower energies and higher intensities compared to MAMI

- Mainz Energy-Recovering Superconducting Accelerator
- Beam energies from 20 MeV to 155 MeV
- Beam currents of  $\geq 1 \, mA$
- First beam expected towards the end of 2026
- Double-sided Multi Turn Energy-Recovery Linac (ERL)
- Two operation modes: ERL and Extracted Beam (EB)

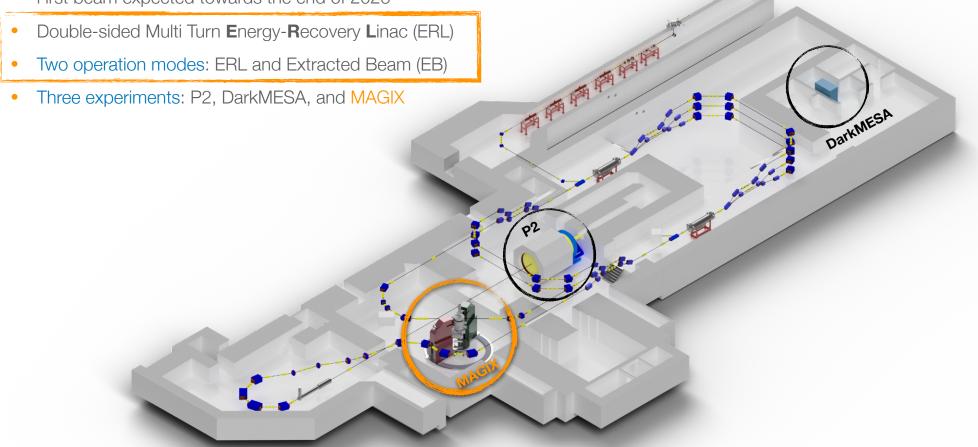


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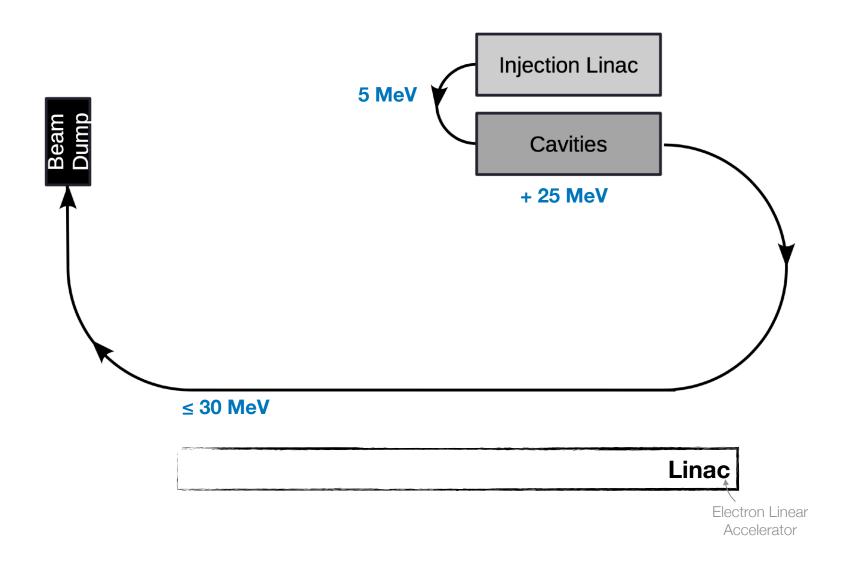


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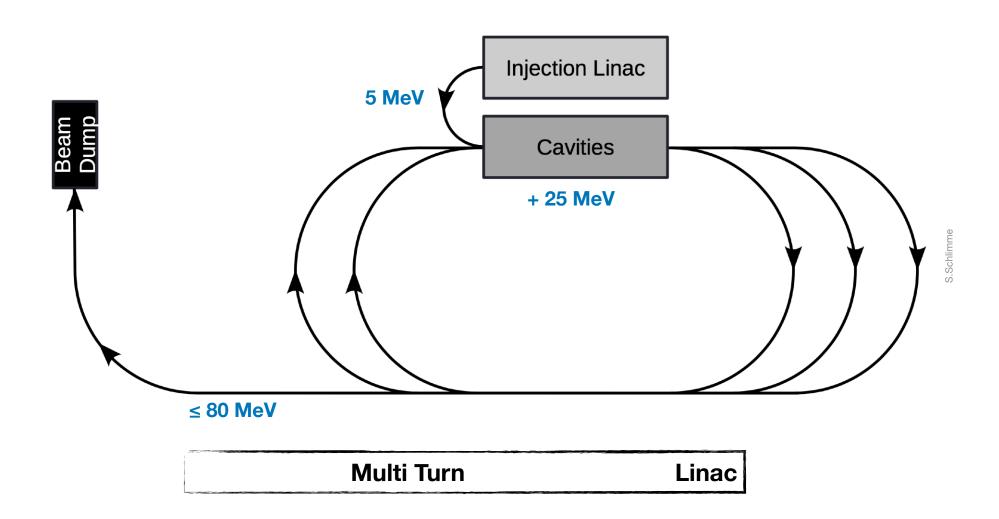


# Let's build MESA (1/7).

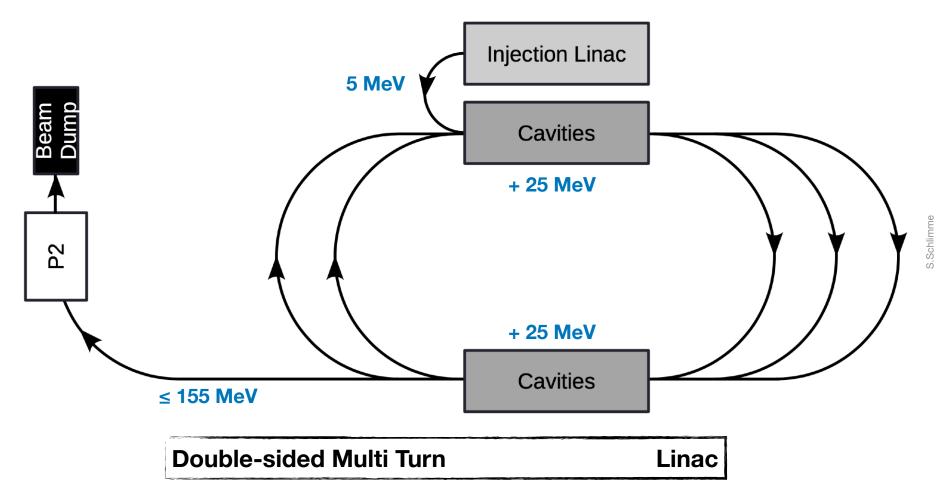


S.Schlimme

# Let's build MESA (2/7).

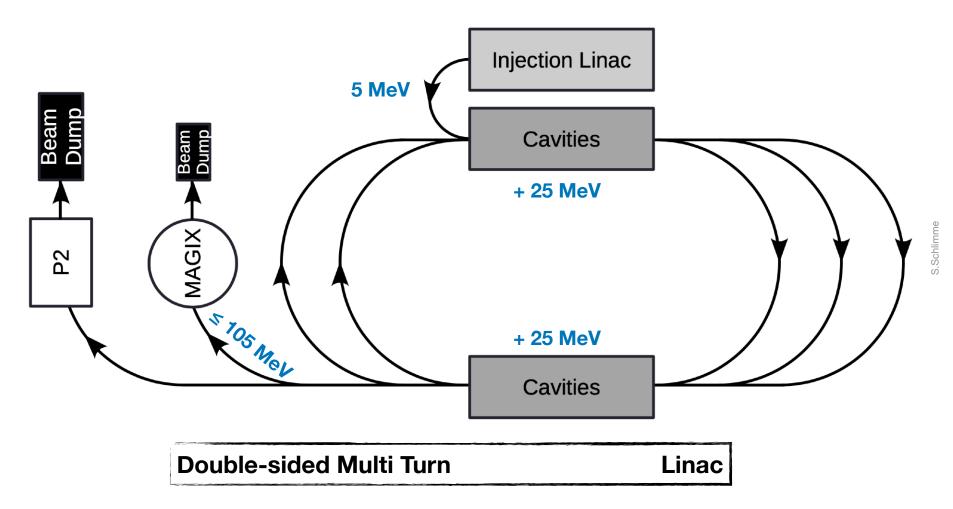


# Let's build MESA (3/7).



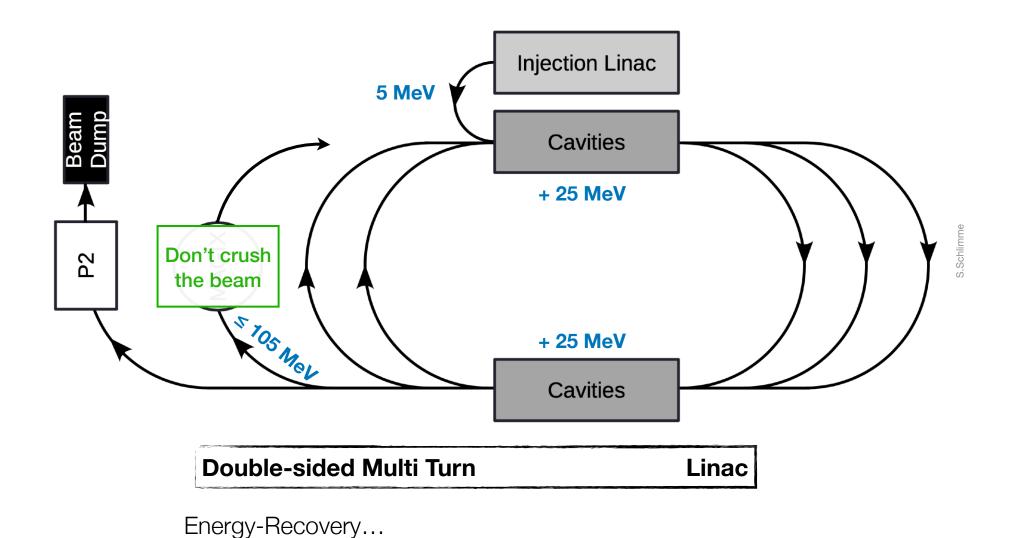
Extracted Beam (EB) mode - P2 experiment

# Let's build MESA (4/7).



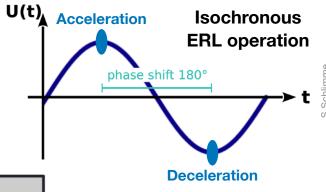
Extracted Beam (EB) mode - MAGIX experiment

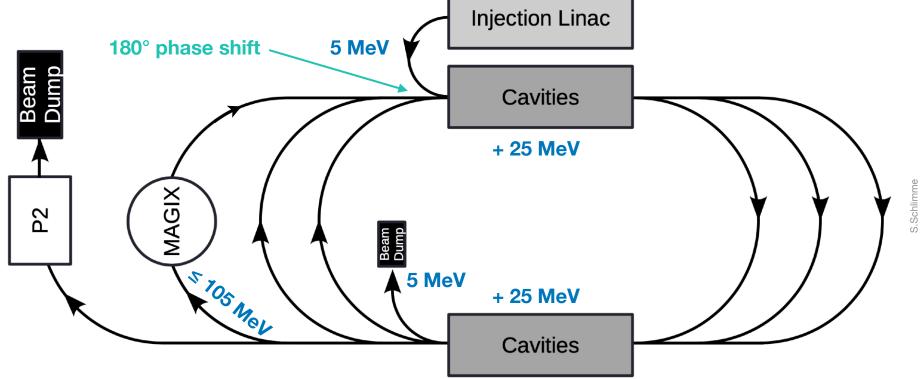
# Let's build MESA (5/7).





# Let's build MESA (6/7).

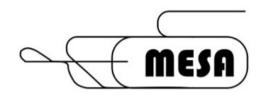


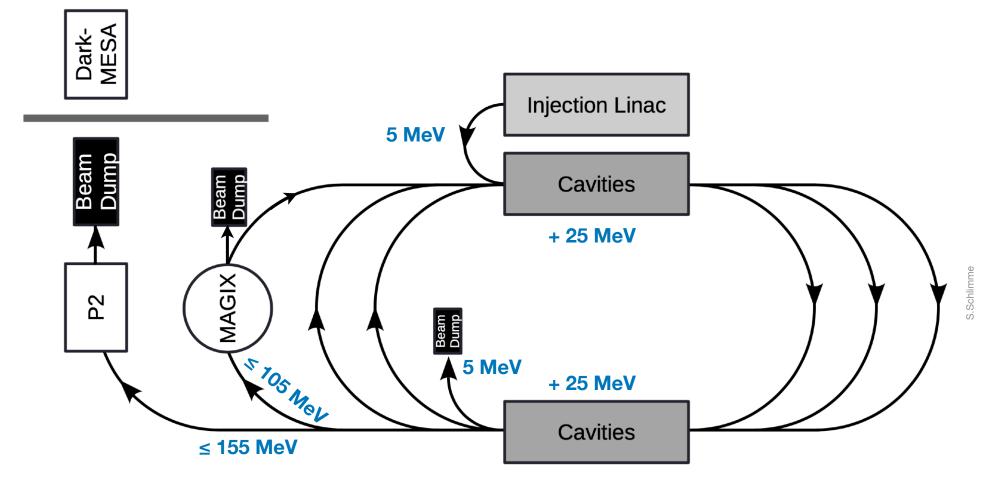


**Double-sided Multi Turn Energy-Recovery Linac** 

Energy-Recovery Linac (ERL) mode - MAGIX experiment

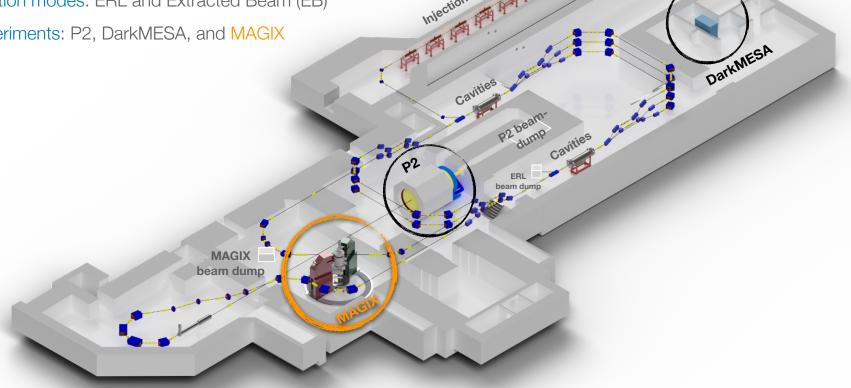
# Let's build MESA (7/7).





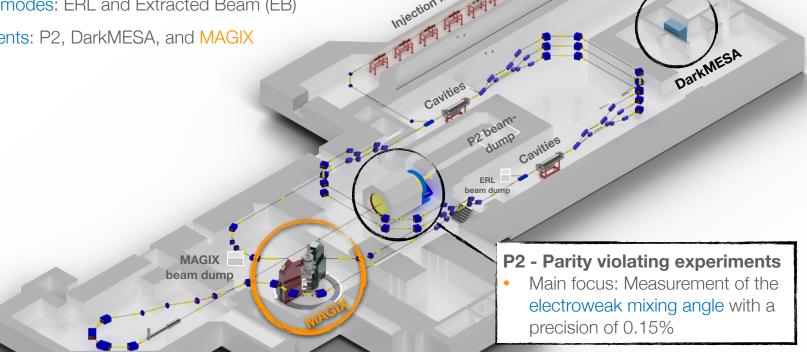
Mainz Energy-recovering Superconducting Accelerator

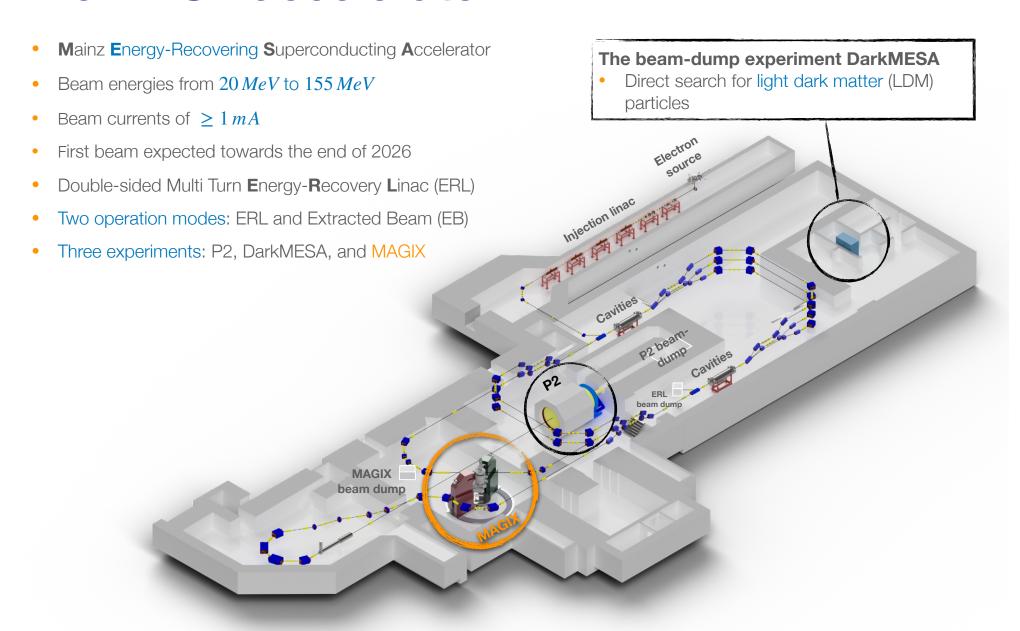
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- Three experiments: P2, DarkMESA, and MAGIX



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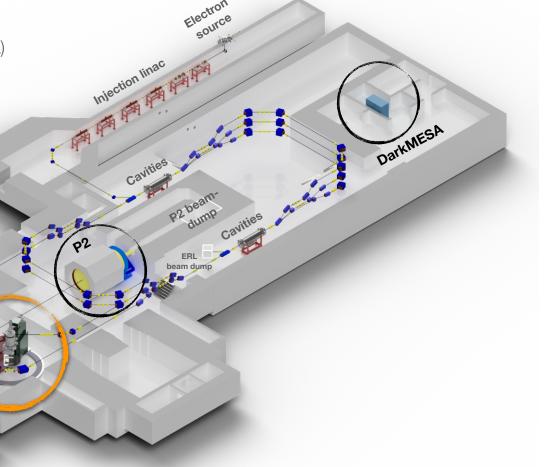




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#### The multi-purpose experiment MAGIX

- Mainly operated in MESA's ERL mode
- Rich physics program in nuclear, particle, and hadron physics
- A compact, next-generation version of the A1 experiment at MAMI



MAGIX

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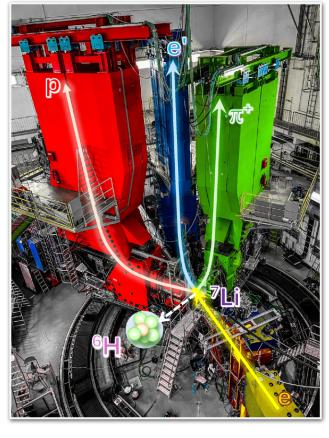
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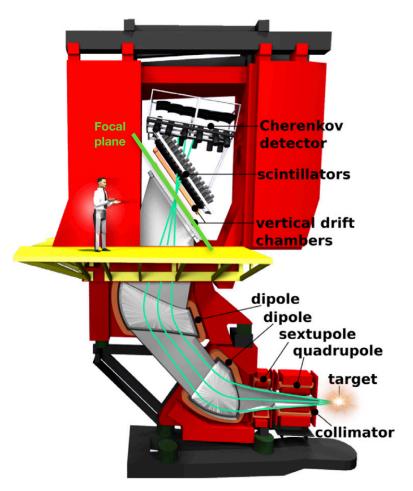


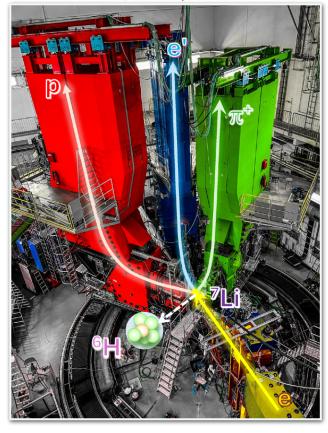
DarkMESA

- Three high-resolution, focusing magnetic spectrometers
- Exceptional momentum resolution of  $\Delta p/p < 10^{-4}$
- Solid angle acceptance of 28msr and momentum acceptance of 25%

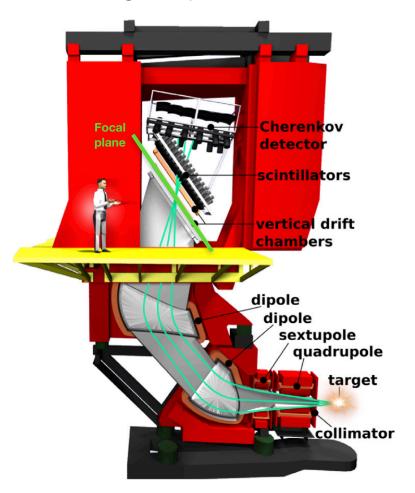


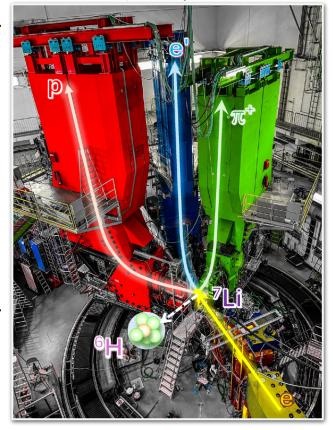
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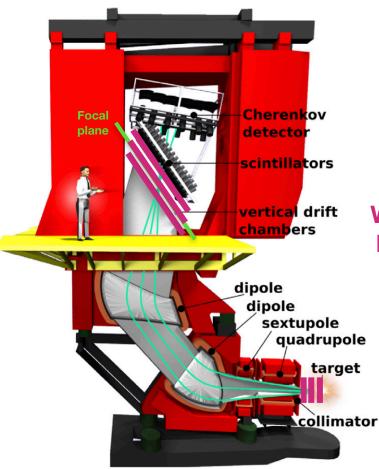




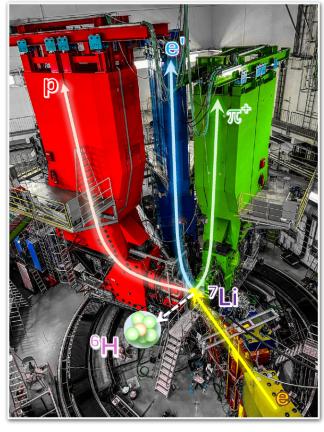
#### **Biggest achievements**

- Measurement of the ground-state energy of <sup>6</sup>H
- High-precision measurement of the proton charge radius
- Search for light massive gauge bosons (dark photons) in the mass range  $40 300 \, MeV/c^2$

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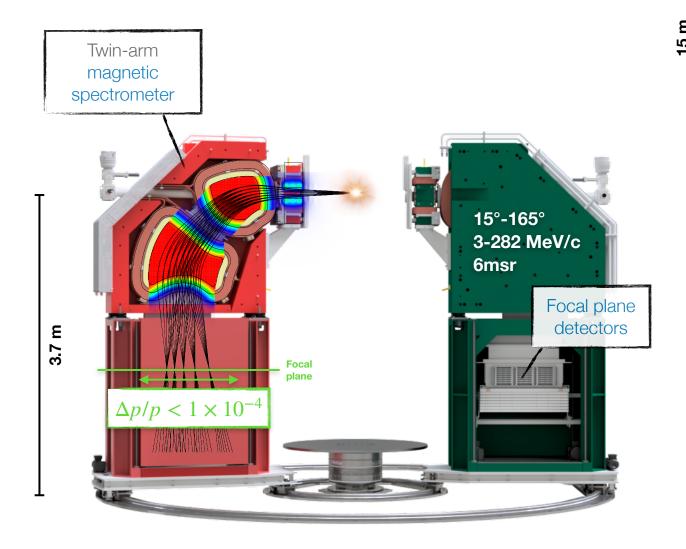
Way too many foils for MESA's low energies!

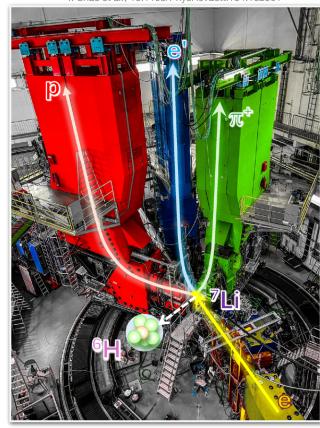


#### **Biggest achievements**

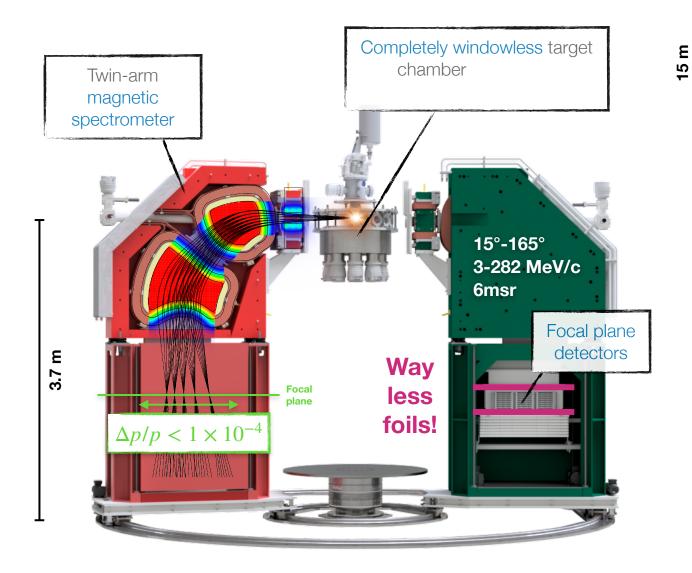
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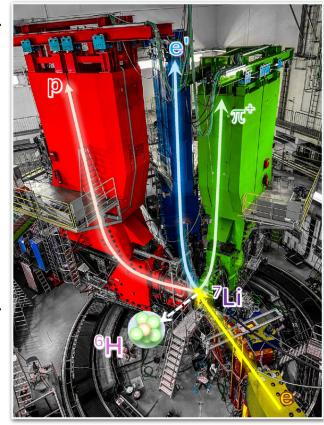
#### MAGIX vs. A1.



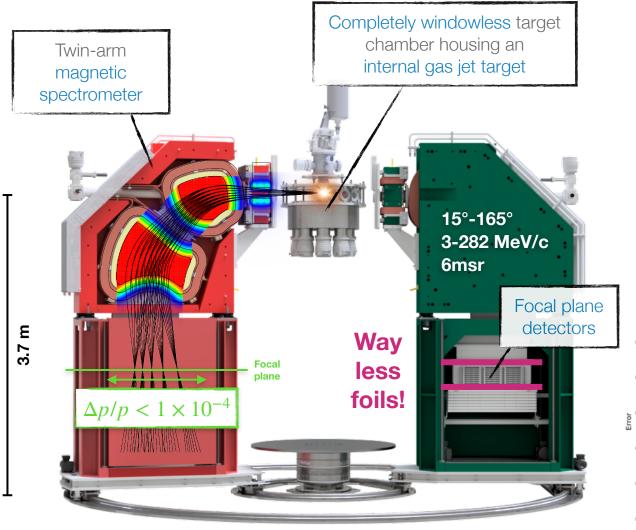


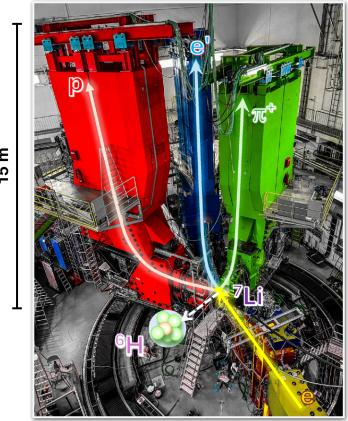
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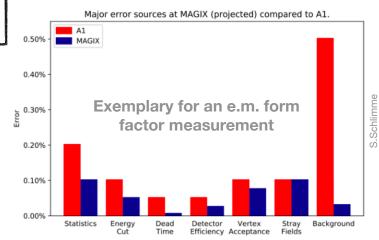




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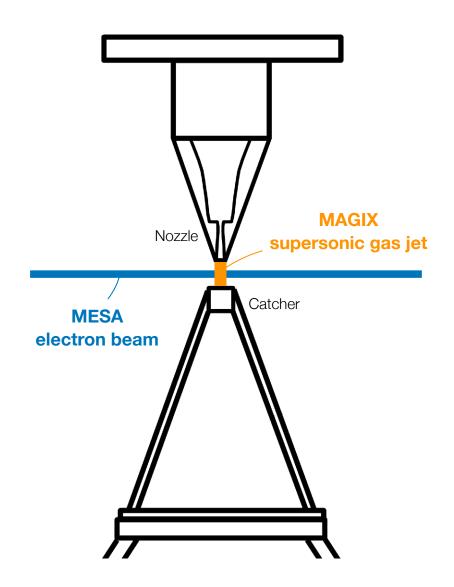






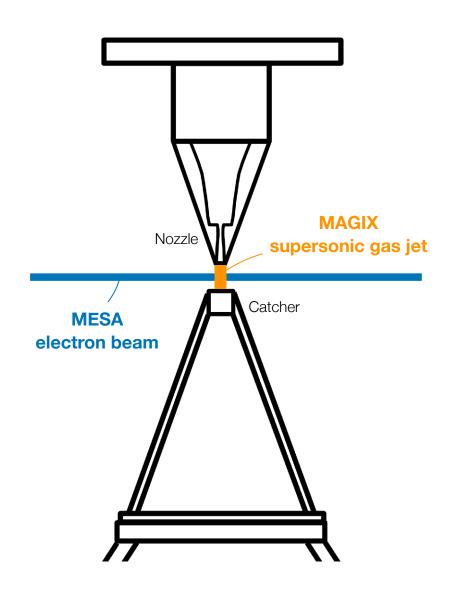
#### The basic idea of MAGIX.

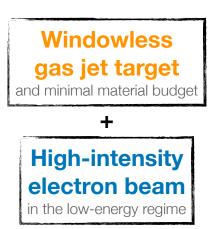




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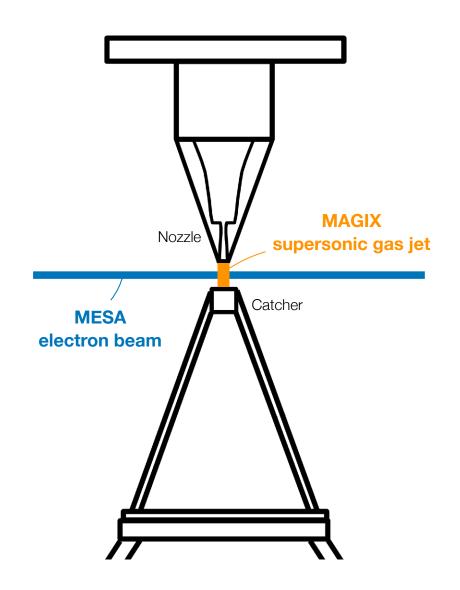


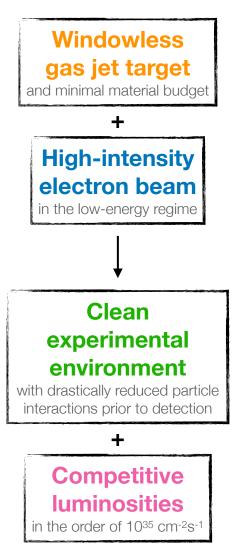




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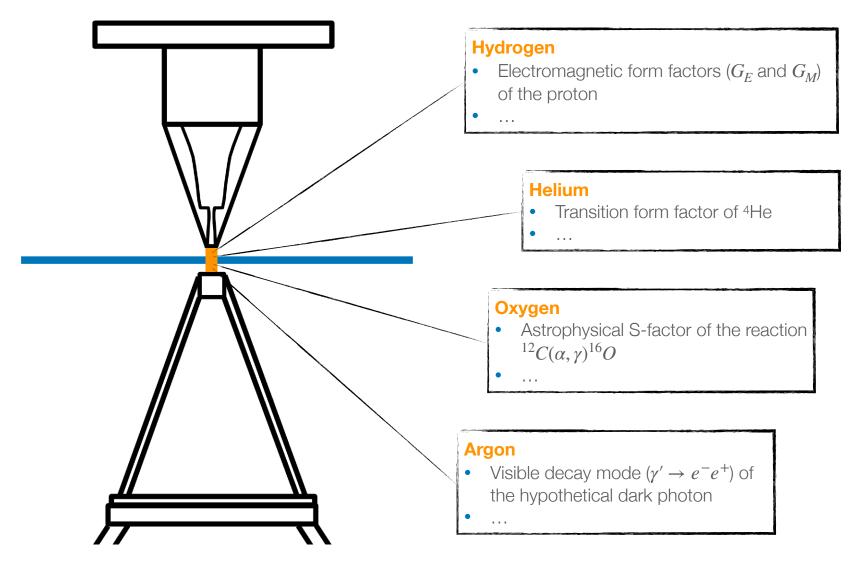




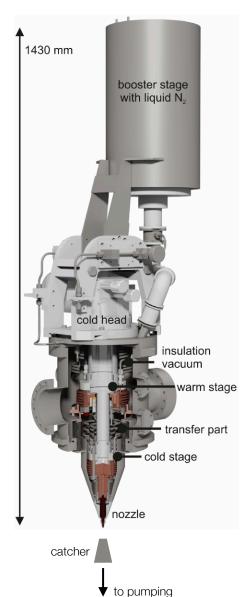


## A versatile physics program.





## The MAGIX gas jet target.

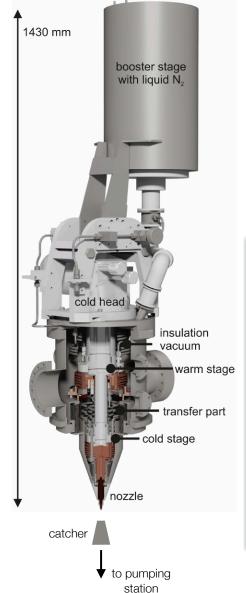


D. Bonaventura

- Developed and constructed by AG Khoukaz at WWU Münster, Germany
- Windowless, thin, point-like jet target

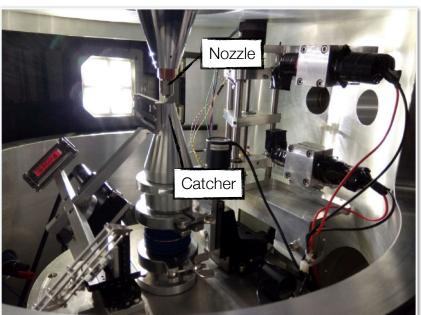
station

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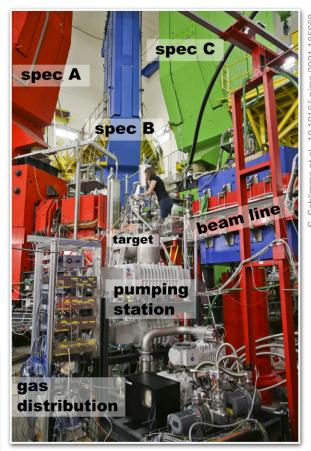


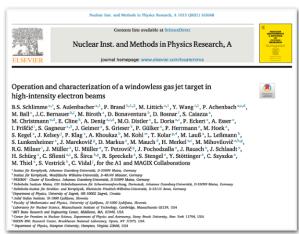
Bonaventura

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- Already commissioned at A1 with hydrogen...



S. Schlimme et al., 10.1016/j.nima.2021.165668

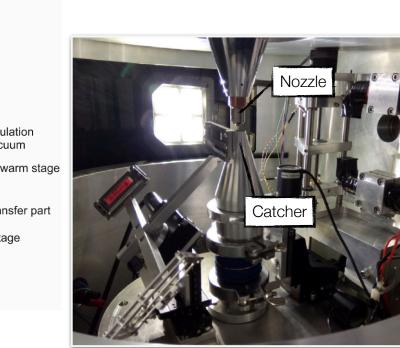




S. Schlimme et al. ,10.1016/j.nima.2021.165668



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S. Schlimme et al., 10.1016/j.nima.2021.165668

https://doi.org/10.1140/epia/s10050-025-01623-4

#### THE EUROPEAN PHYSICAL JOURNAL A



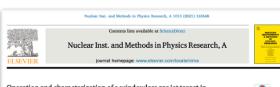
Regular Article - Experimental Physics

#### Measurement of the <sup>40</sup>Ar(e,e') elastic scattering cross section with a novel gas-jet target

M. Littich<sup>1</sup>, L. Doria<sup>1,a</sup>, P. Brand<sup>2</sup>, P. Achenbach<sup>1</sup>, S. Aulenbacher<sup>1</sup>, S. Bacca<sup>1</sup>, J. C. Bernauer<sup>3</sup>, M. Biroth<sup>1</sup>, D. Bonaventura<sup>2</sup>, D. Bosnar<sup>4</sup>, M. Christmann<sup>1</sup>, E. Cline<sup>3,5</sup>, A. Denig<sup>1</sup>, M. Distler<sup>1</sup>, A. Esser<sup>1</sup>, I. Friščić<sup>4</sup>, J. Geimer<sup>1</sup>, P. Gülker<sup>1</sup>, M. Hoek<sup>1</sup>, P. Klag<sup>1</sup>, A. Khoukaz<sup>2</sup>, M. Lauß<sup>1</sup>, S. Lunkenbeimer<sup>1</sup>, T. Manoussos<sup>1</sup>, D. Markus<sup>1</sup>, H. Merkel<sup>1</sup>, M. Mihovilovič<sup>6,7</sup>, U. Müller<sup>1</sup>, J. Pochodzalla<sup>1</sup>, B. S. Schlimme<sup>1</sup>, C. Sfienti<sup>1</sup>, J. E. Sobczyk<sup>1</sup>, S. Stengel<sup>1</sup>, E. Stephan<sup>8</sup> M. Thiel<sup>1</sup>, S. Vestrick<sup>2</sup>, A. Wilczek<sup>8</sup>, L. Wilhelm<sup>1</sup>

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  ür Kernphysik, Johannes Gutenberg-Universität, 55128 Mainz, Germany
- Institut für Kernphysik, Universität Münster, 48149 Münster, Germany
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  Department of Physics, Faculty of Science, University of Zagreb, Zagreb, Croatia
- Laboratory for Nuclear Science, Massachusetts Institute
- <sup>6</sup> Jožef Stefan Institute, 1000 Ljubljana, Slovenia
  <sup>7</sup> Faculty of Mathematics and Physics, University of Ljub
- Institute of Physics, University of Silesia in Katowice,





#### Operation and characterization of a windowless gas jet target in high-intensity electron beams

B.S. Schlimme "", S. Aulenbacher "", P. Brand "", M. Littich ", I. Y. Wang ", I. P. Achenbach "", M. Ball ", J.C. Bernauer ", M. Biroth ", D. Bonaventura ", D. Bonsar ", S. Caiazza ", M. Christmand, E. Cline<sup>1</sup>, A. Denig<sup>8-6</sup>, M.O. Distler<sup>1</sup>, L. Doria<sup>8</sup>, P. Ecker<sup>1</sup>, A. Esser<sup>8</sup>, I. Friščić<sup>1</sup>, S. Gagneur<sup>1,3</sup>, J. Geimer<sup>8</sup>, S. Grieser<sup>1</sup>, P. Gülker<sup>8</sup>, P. Herrmann<sup>8</sup>, M. Hoek<sup>8</sup>, S. Kegel<sup>8</sup>, J. Kelsey<sup>1</sup>, P. Klag<sup>8</sup>, A. Khoukaz<sup>8</sup>, M. Kohl<sup>8</sup>, T. Kolar<sup>8,4</sup>, M. Lauß<sup>8</sup>, L. Leßmann<sup>8</sup>, S. Roget 1, Ressey 7, Rodg 7, R. Olubhart 3, March 1, Roda 1, Restant 1, Lestinath M. Thiel a, S. Vestrick b, C. Vidal , for the A1 and MAGIX Collaboration

for Kernjoyki, Arhamon Gaininkey Diviernalit, b-5509 Mains, Germay for Kernjoyki, Kernjoski Hellinder Billender Gainstein, L-64199 Mains, Corn for Kernjoyki, Kernjoski Hellinder Billender Gainstein, L-64199 Mainser, Cort olie Instituti Mains, G.S. Hideboldsmerson for Schwerisondyrochung, Durch solie Instituti Mains, G.S. Hideboldsmerson for Schwerisondyrochung, Durch solie Institut. Schwarzie oli Zeptop, HE-10002 Zagrab, Croadia Gainstein, G. S. Schwarzie, G. Schwarzie, G. Schwarzie, G. S. Schwarzie, G. S. Schwarzie, G. Schwarzie, G. Schwarzie, G. Schwarzie, G. S. Schwarzie, G. S. Schwarzie, G. Schwar

S. Schlimme et al. ,10.1016/j.nima.2021.165668



33

to pumping

catcher

cold head

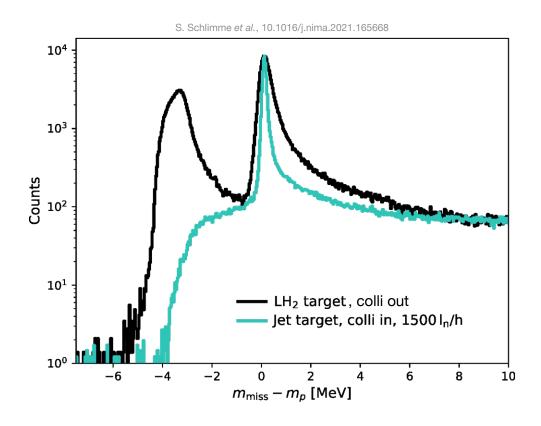
insulation vacuum

transfer part

cold stage

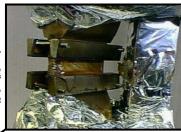
station Sebastian Stengel

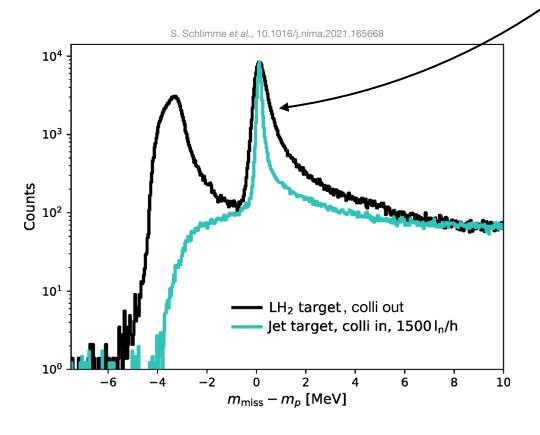
# Benefits of a gas jet target.



# Benefits of a gas jet target.

<u>Typical</u> liquid H₂ <u>target</u>





- Large energy straggling and multiple scattering
- Background from target foils

# Benefits of a gas jet target.





booster stage with liquid N<sub>2</sub>

10<sup>4</sup>

10<sup>3</sup>

10<sup>2</sup>

insulation vacuum

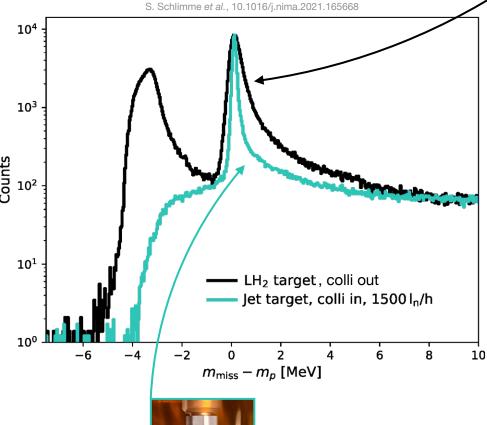
warm stage

transfer part

cold stage

nozzle

to pumping station



- Large energy straggling and multiple scattering
- Background from target foils

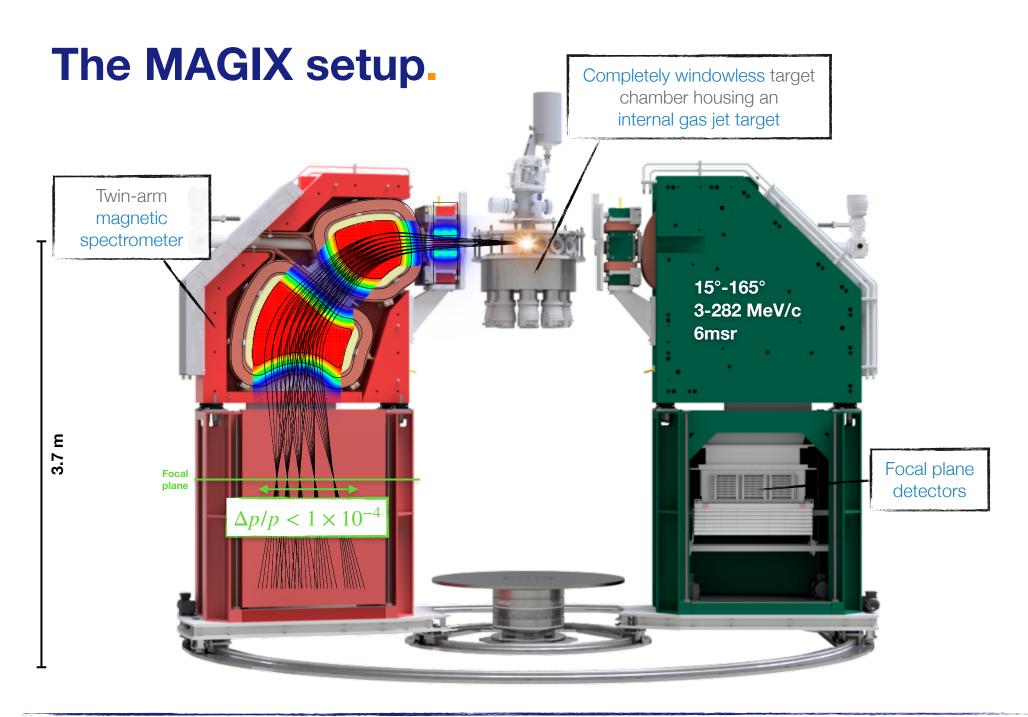
- Sharper elastic peak in electron-proton scattering
- Background effects drastically reduced

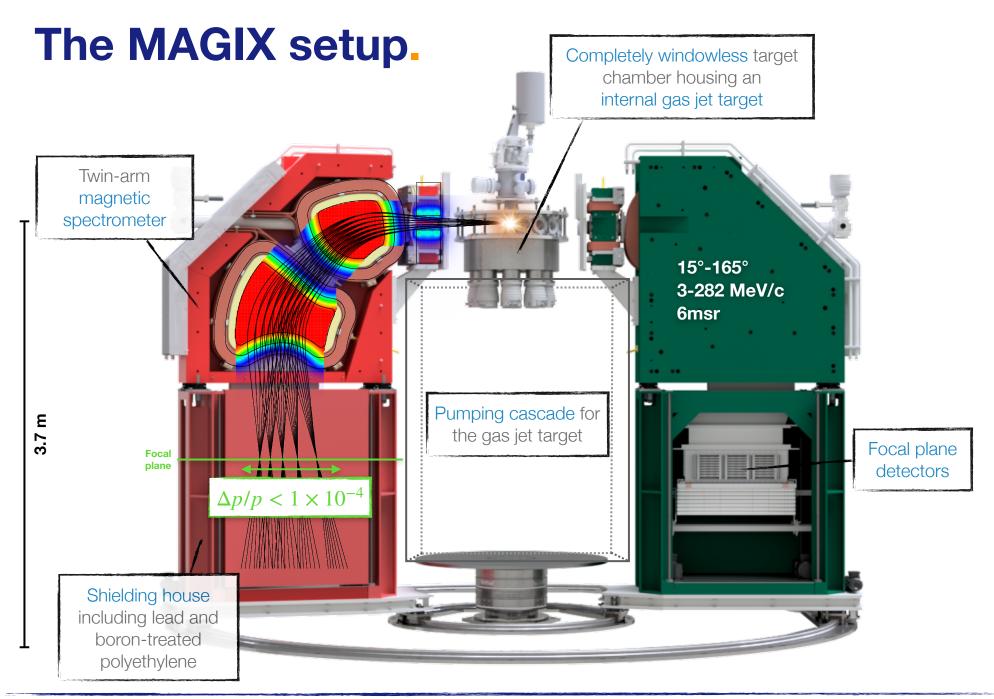
catcher

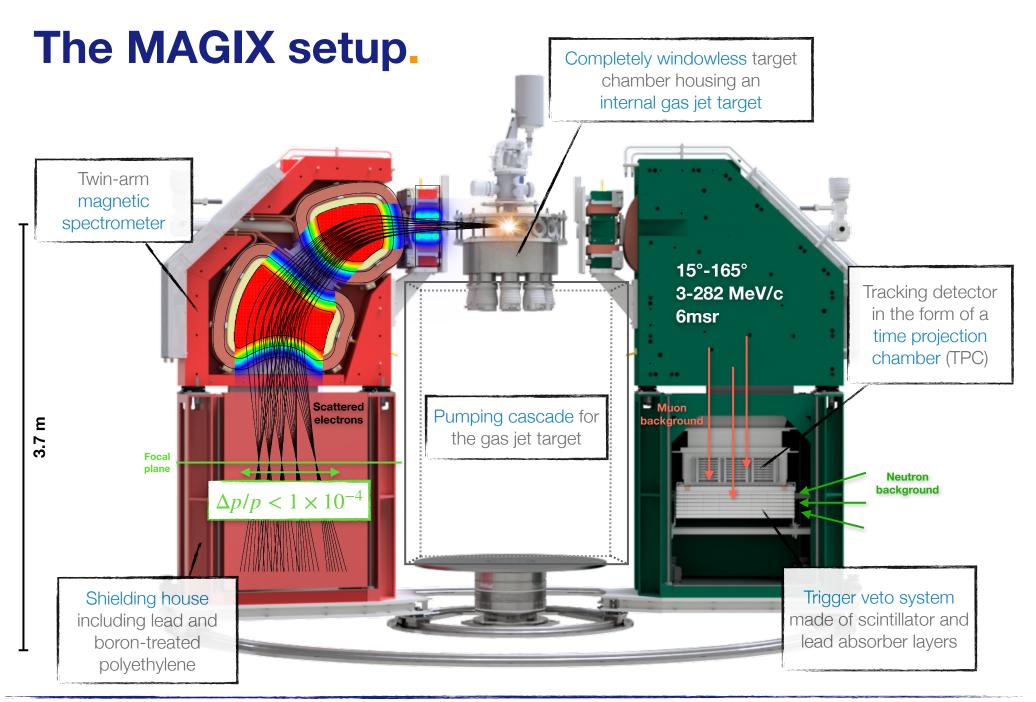
 $H_2$ 

gas jet

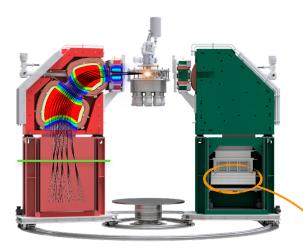
target



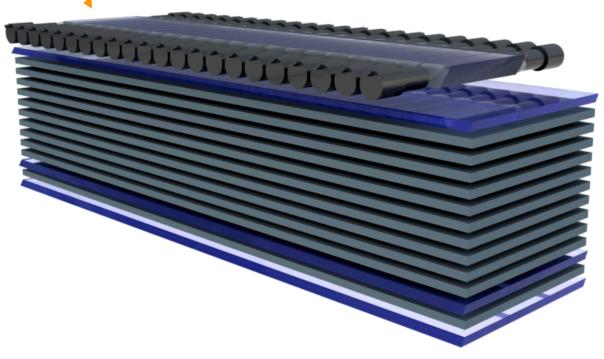




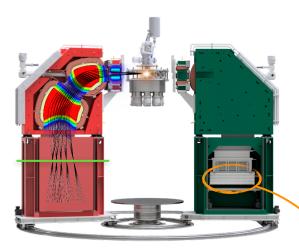
### The MAGIX trigger veto system.



Combine triggering and PID in one modular system

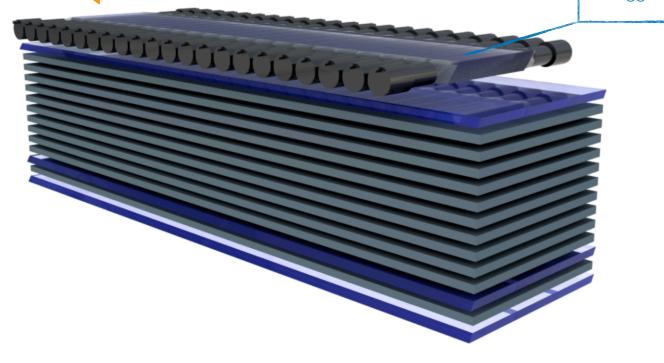


#### The MAGIX trigger veto system.

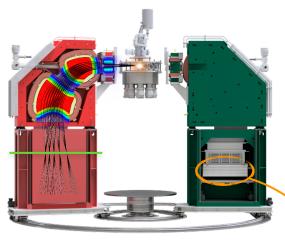


- Combine triggering and PID in one modular system
- Segmented trigger layer at the top, made of plastic scintillators read out by PMTs

Trigger layer



#### The MAGIX trigger veto system.

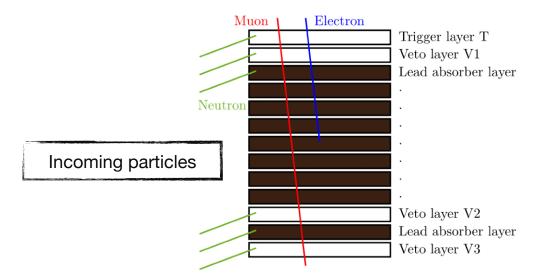


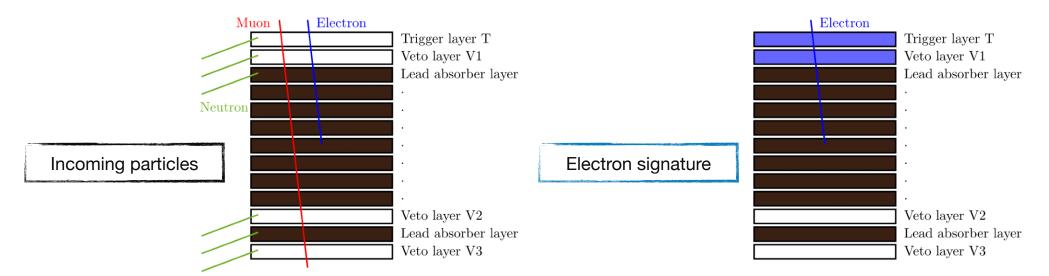
- Combine triggering and PID in one modular system
- Segmented trigger layer at the top, made of plastic scintillators read out by PMTs
- A flexible veto system underneath, built from:
  - Several veto layers, made of plastic scintillators read out by SiPMs
  - Passive lead absorber layers in between

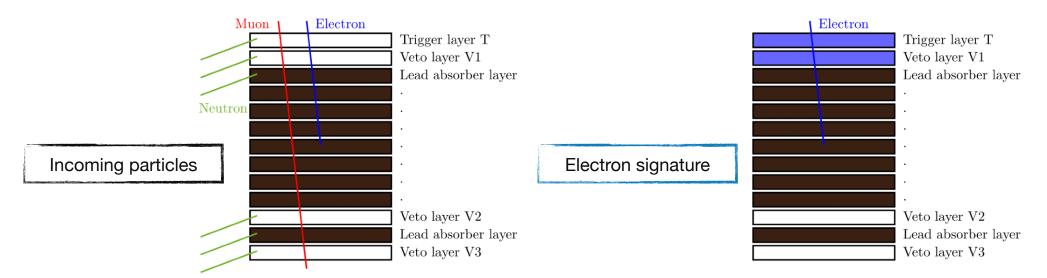
Veto layers

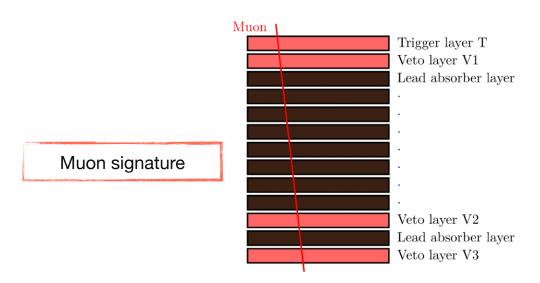
Veto system

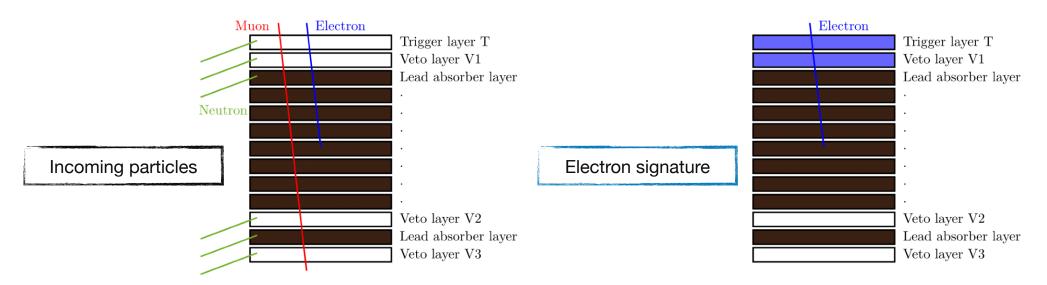
Passive lead absorber layers

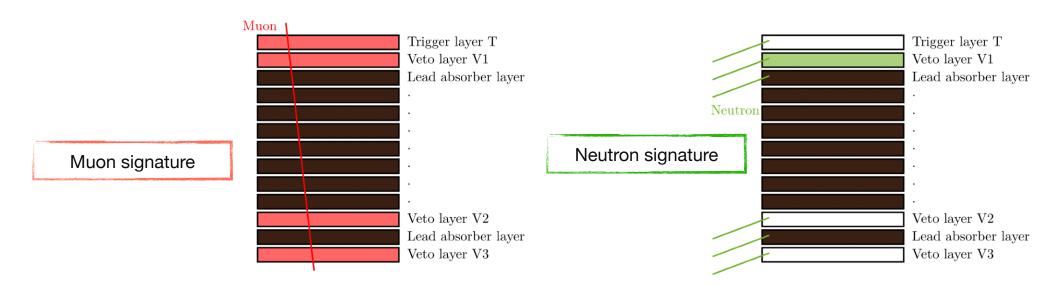


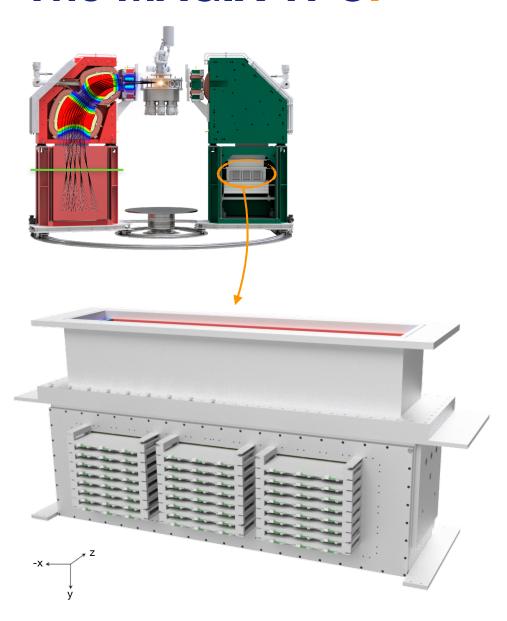


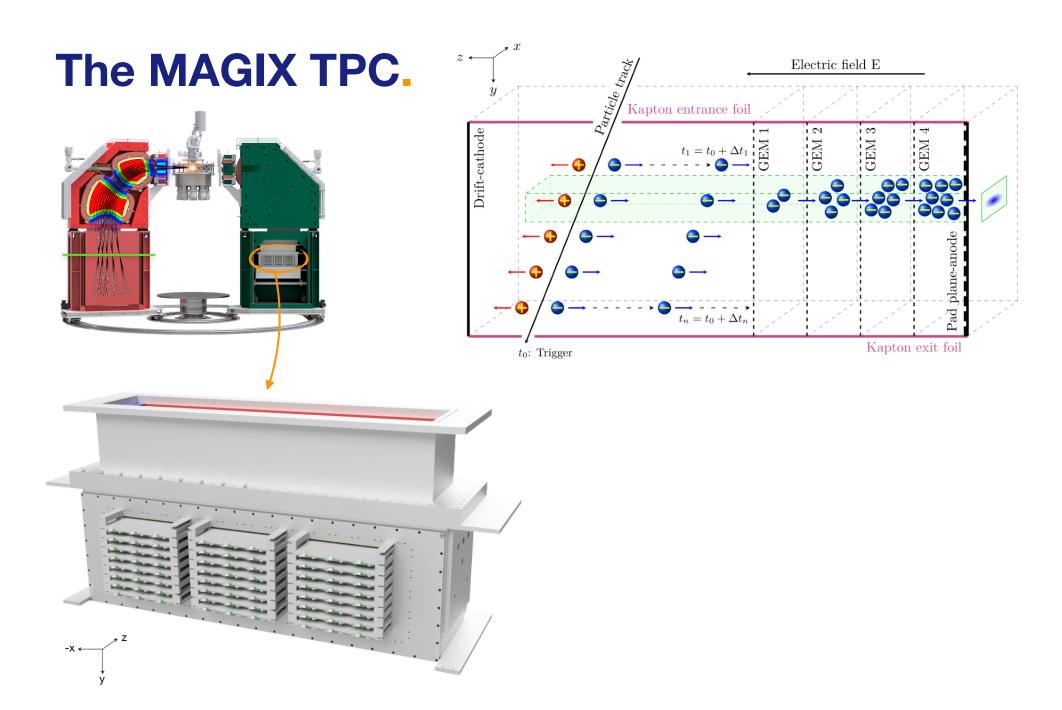


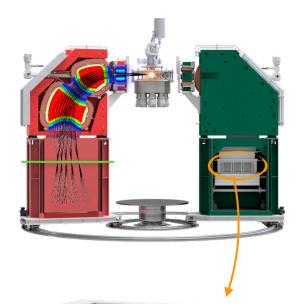


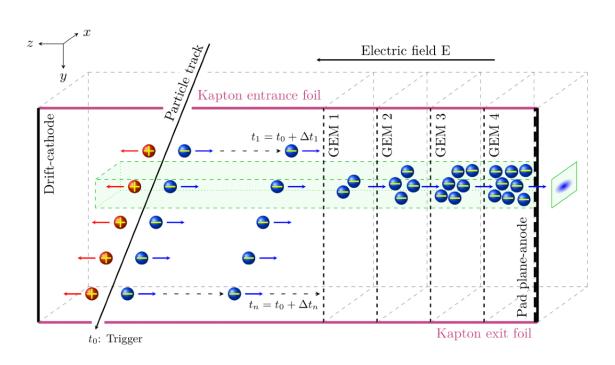


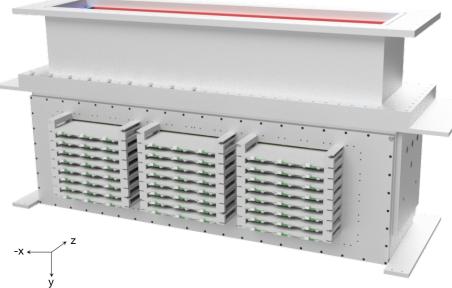




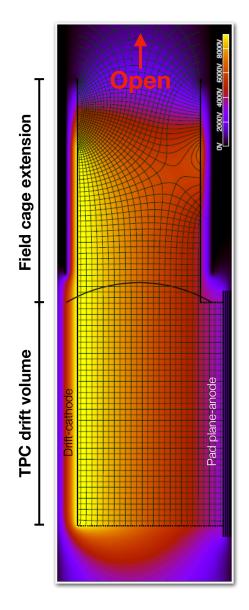


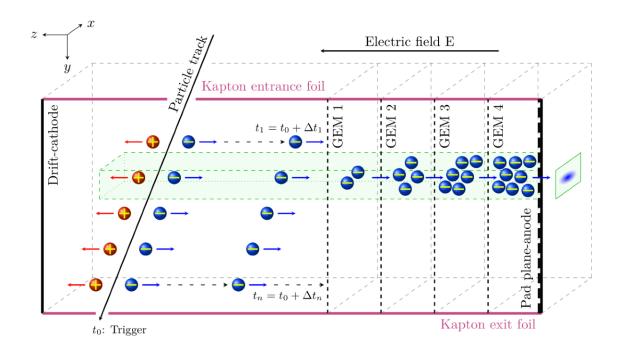




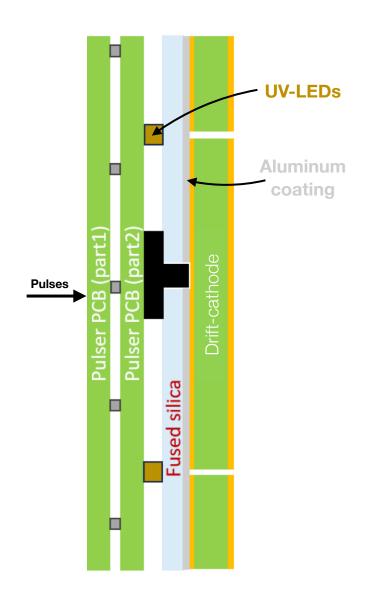


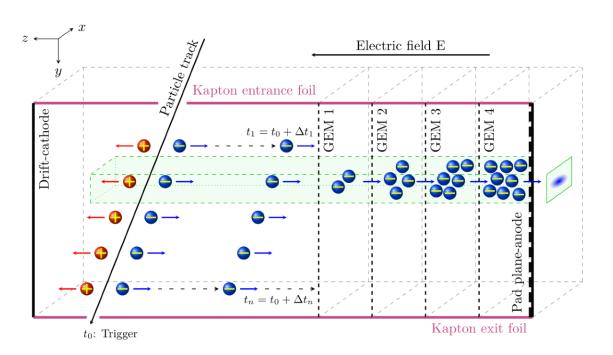
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- Segmented readout at the pad plane-anode
- 3D track reconstruction via projection on pad planeanode (2D) plus drift time (1D)





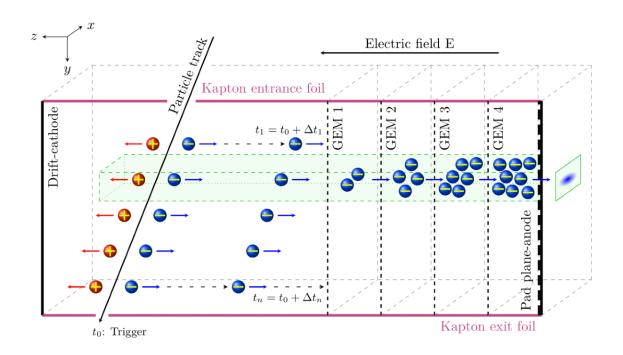
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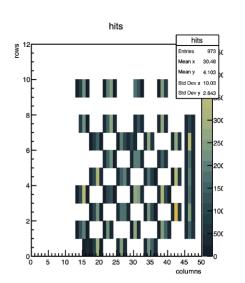


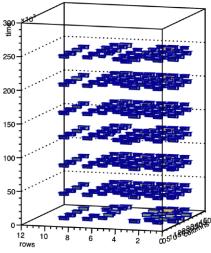


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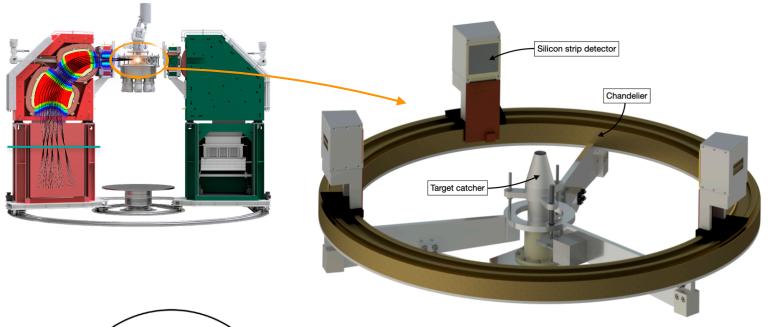


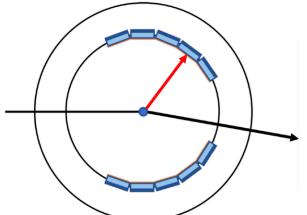




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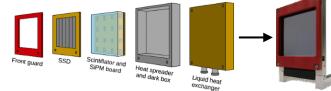
#### Recoil detector array.

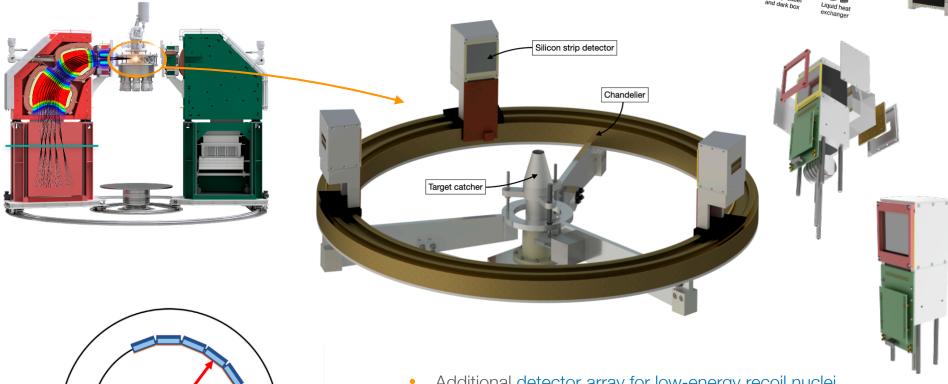




- Additional detector array for low-energy recoil nuclei
- Mounted inside the scattering chamber with no material between reaction vertex and detectors

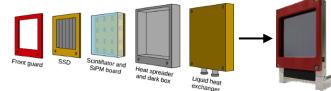
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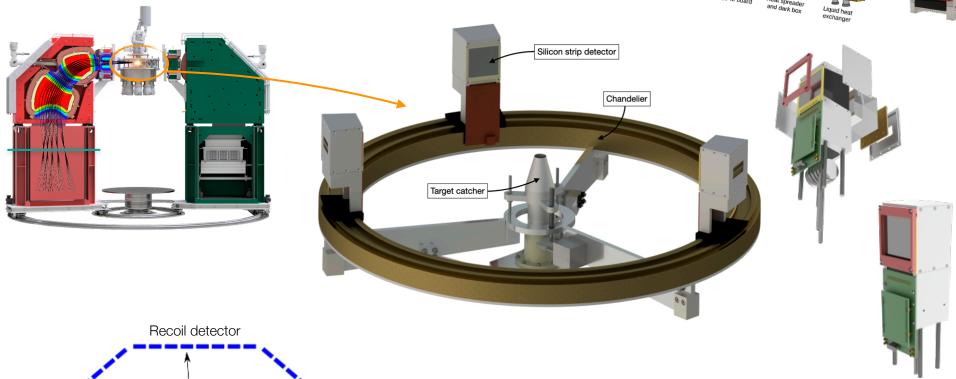




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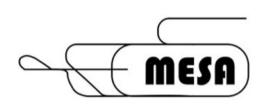
- Recoil detector

  α

  16

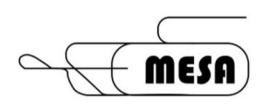
  γ\*

  E'
- Additional detector array for low-energy recoil nuclei
- Mounted inside the scattering chamber with no material between reaction vertex and detectors
- Individual detectors built from silicon strip + scintillation detectors
- Important for studying reactions like  $^{12}C(\alpha, \gamma)^{16}O$



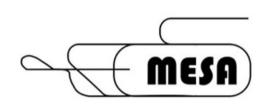


 The low-energy, high-intensity electron accelerator MESA is currently being built and the first beam is expected towards the end of 2026



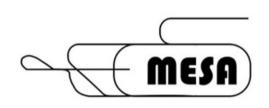


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- MAGIX is a multi-purpose electron scattering experiment that will be operated in MESA's ERL mode; MAGIX is designed for a rich physics program in nuclear, hadron, and particle physics





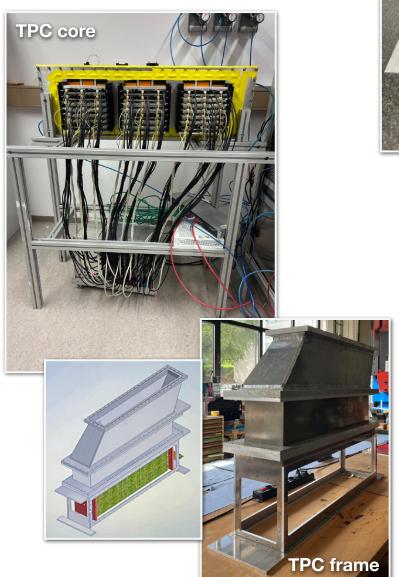
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- The focal plane detectors of MAGIX encompass the MAGIX TPC for tracking and the MAGIX trigger veto system for triggering and PID; additional recoil detectors will be installed inside the scattering chamber

# Impressions.







# Impressions.



Thanks for your attention!

#### **Contact**

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# Backup slides.

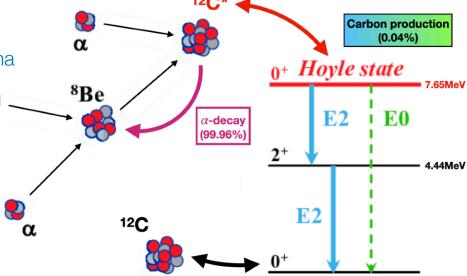
#### The first measurement at MAGIX.

- MAGIX can also be operated in MESA's EB mode, and during MESA's commissioning phase, this is even without an alternative
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The Hoyle state is a specific excited state of <sup>12</sup>C that is critical in carbon production as it facilitates the triple-alpha process in stars



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- The Hoyle state is a specific excited state of <sup>12</sup>C that is critical in carbon production as it facilitates the triple-alpha process in stars
- MAGIX can study the E0 monopole transition via inelastic electron scattering on a <sup>12</sup>C target

