X17 Searches at the MAGIX Spectrometer Setup at MESA.

Contribution on behalf of the **MAGIX collaboration**

Sebastian Stengel (sestenge@uni-mainz.de)
Institute for Nuclear Physics, Johannes Gutenberg University Mainz, Germany

„X17 What if?“ Workshop, Frascati, Italy, March 20th, 2026
https://agenda.infn.it/event/49565/

Cluster of Excellence PRISMA++ Precision Physics, Fundamental Interactions and Structure of Matter

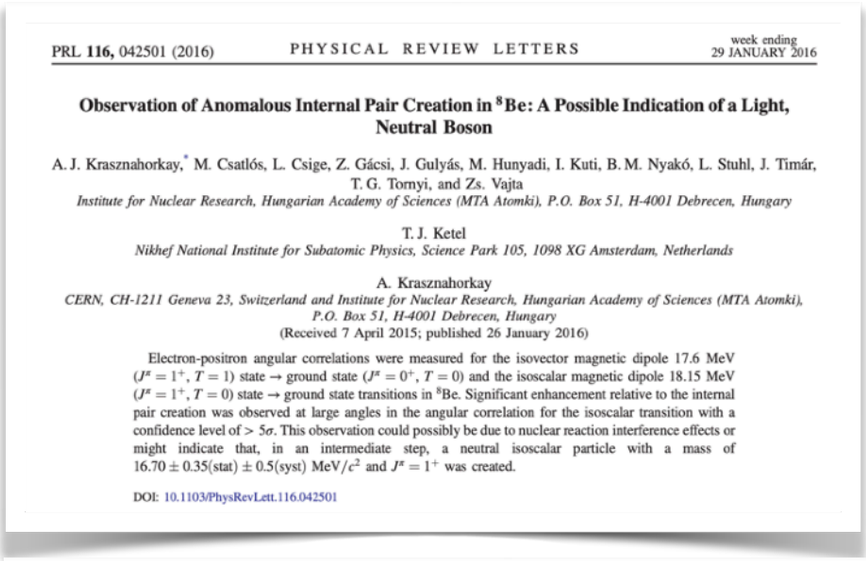
JOHANNES GUTENBERG UNIVERSITÄT MAINZ JG|U

MESA

MAGIX

X17 - to peak or not to peak?

A. J. Krasznahorkay *et al.*, 10.1103/PhysRevLett.116.042501



PRL 116, 042501 (2016) PHYSICAL REVIEW LETTERS week ending 29 JANUARY 2016

Observation of Anomalous Internal Pair Creation in ^{8}Be: A Possible Indication of a Light, Neutral Boson

A. J. Krasznahorkay,* M. Csatlós, L. Csige, Z. Gácsi, J. Gulyás, M. Hunyadi, I. Kuti, B. M. Nyakó, L. Stuhl, J. Timár, T. G. Tornyi, and Zs. Vajta
Institute for Nuclear Research, Hungarian Academy of Sciences (MTA Atomki), P.O. Box 51, H-4001 Debrecen, Hungary

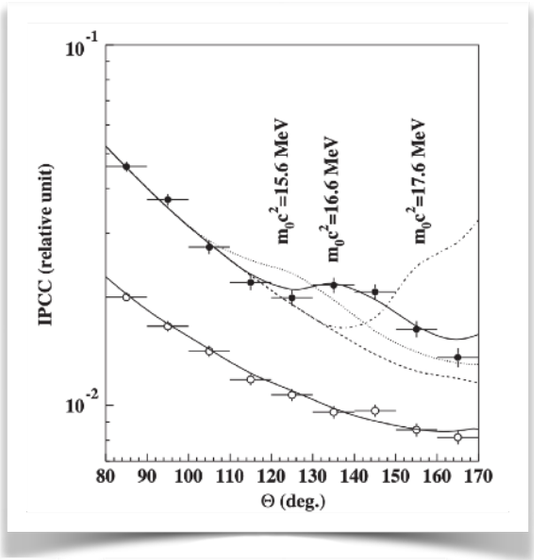
T. J. Ketel
Nikhef National Institute for Subatomic Physics, Science Park 105, 1098 XG Amsterdam, Netherlands

A. Krasznahorkay
CERN, CH-1211 Geneva 23, Switzerland and Institute for Nuclear Research, Hungarian Academy of Sciences (MTA Atomki), P.O. Box 51, H-4001 Debrecen, Hungary

(Received 7 April 2015; published 26 January 2016)

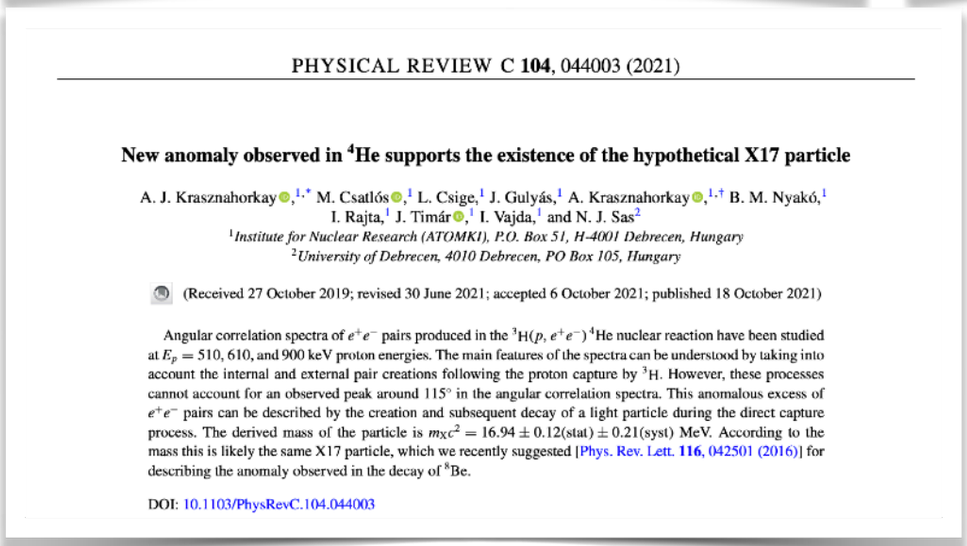
Electron-positron angular correlations were measured for the isovector magnetic dipole 17.6 MeV ($J^\pi = 1^+, T = 1$) state → ground state ($J^\pi = 0^+, T = 0$) and the isoscalar magnetic dipole 18.15 MeV ($J^\pi = 1^+, T = 0$) state → ground state transitions in ^{8}Be. Significant enhancement relative to the internal pair creation was observed at large angles in the angular correlation for the isoscalar transition with a confidence level of $> 5\sigma$. This observation could possibly be due to nuclear reaction interference effects or might indicate that, in an intermediate step, a neutral isoscalar particle with a mass of $16.70 \pm 0.35(\text{stat}) \pm 0.5(\text{syst})$ MeV/c^2 and $J^\pi = 1^+$ was created.

DOI: 10.1103/PhysRevLett.116.042501



- **ATOMKI** (2016): Peak-like anomaly in the angular correlation of the e^+e^- pairs produced in the decays of excited states of ^{8}Be (6.8σ)

A. J. Krasznahorkay *et al.*, 10.1103/PhysRevC.104.044003



PHYSICAL REVIEW C **104**, 044003 (2021)

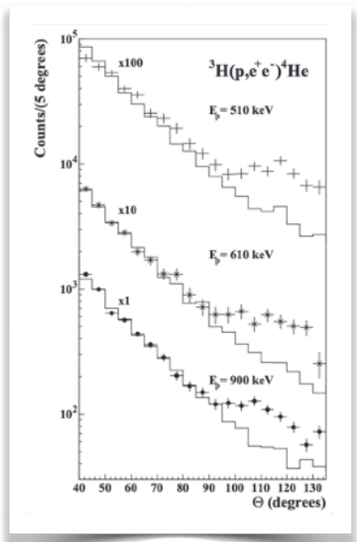
New anomaly observed in ^{4}He supports the existence of the hypothetical X17 particle

A. J. Krasznahorkay,*,† M. Csatlós,† L. Csige,† J. Gulyás,† A. Krasznahorkay,†,† B. M. Nyakó,† I. Rajta,† J. Timár,† I. Vajda,† and N. J. Sas‡
†*Institute for Nuclear Research (ATOMKI), P.O. Box 51, H-4001 Debrecen, Hungary*
‡*University of Debrecen, 4010 Debrecen, PO Box 105, Hungary*

(Received 27 October 2019; revised 30 June 2021; accepted 6 October 2021; published 18 October 2021)

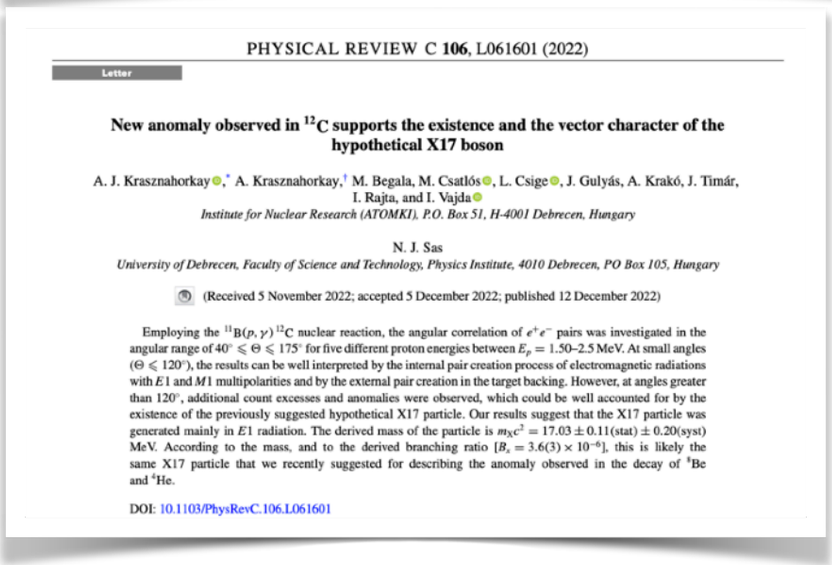
Angular correlation spectra of e^+e^- pairs produced in the ^{3}H$(p, e^+e^-)^4$He nuclear reaction have been studied at $E_p = 510$, 610, and 900 keV proton energies. The main features of the spectra can be understood by taking into account the internal and external pair creations following the proton capture by ^{3}H. However, these processes cannot account for an observed peak around 115° in the angular correlation spectra. This anomalous excess of e^+e^- pairs can be described by the creation and subsequent decay of a light particle during the direct capture process. The derived mass of the particle is $m_Xc^2 = 16.94 \pm 0.12(\text{stat}) \pm 0.21(\text{syst})$ MeV. According to the mass this is likely the same X17 particle, which we recently suggested [Phys. Rev. Lett. **116**, 042501 (2016)] for describing the anomaly observed in the decay of ^{8}Be.

DOI: 10.1103/PhysRevC.104.044003



- **ATOMKI** (2021): Observation of a similar peak-like anomaly in ^{4}He (≥ 6.6σ)

A. J. Krasznahorkay *et al.*, 10.1103/PhysRevC.106.L061601



PHYSICAL REVIEW C **106**, L061601 (2022)

Letter

New anomaly observed in ^{12}C supports the existence and the vector character of the hypothetical X17 boson

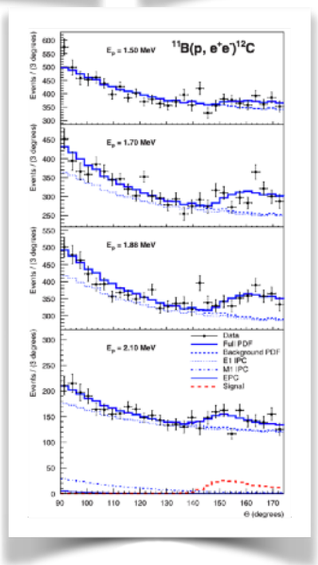
A. J. Krasznahorkay,* A. Krasznahorkay,† M. Begala, M. Csatlós, L. Csige, J. Gulyás, A. Krakó, J. Timár, I. Rajta, and I. Vajda
Institute for Nuclear Research (ATOMKI), P.O. Box 51, H-4001 Debrecen, Hungary

N. J. Sas
University of Debrecen, Faculty of Science and Technology, Physics Institute, 4010 Debrecen, PO Box 105, Hungary

(Received 5 November 2022; accepted 5 December 2022; published 12 December 2022)

Employing the ^{11}B$(p, \gamma)^{12}$C nuclear reaction, the angular correlation of e^+e^- pairs was investigated in the angular range of $40° \leqslant \Theta \leqslant 175°$ for five different proton energies between $E_p = 1.50$–2.5 MeV. At small angles ($\Theta \leqslant 120°$), the results can be well interpreted by the internal pair creation process of electromagnetic radiations with $E1$ and $M1$ multipolarities and by the external pair creation in the target backing. However, at angles greater than 120°, additional count excesses and anomalies were observed, which could be well accounted for by the existence of the previously suggested hypothetical X17 particle. Our results suggest that the X17 particle was generated mainly in $E1$ radiation. The derived mass of the particle is $m_Xc^2 = 17.03 \pm 0.11(\text{stat}) \pm 0.20(\text{syst})$ MeV. According to the mass, and to the derived branching ratio [$B_r = 3.6(3) \times 10^{-6}$], this is likely the same X17 particle that we recently suggested for describing the anomaly observed in the decay of ^{8}Be and ^{4}He.

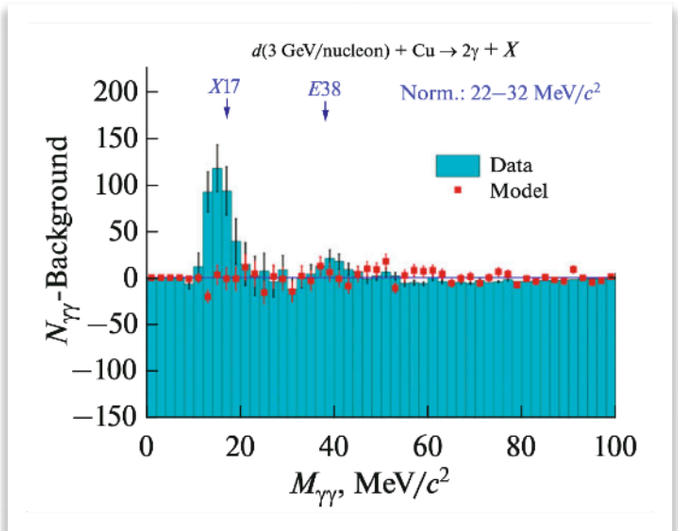
DOI: 10.1103/PhysRevC.106.L061601



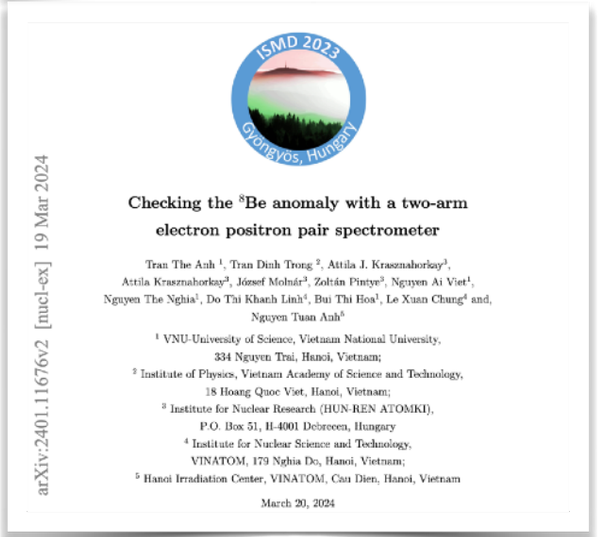
- **ATOMKI** (2022): Observation of a similar peak-like anomaly in ^{12}C

X17 - to peak or not to peak?

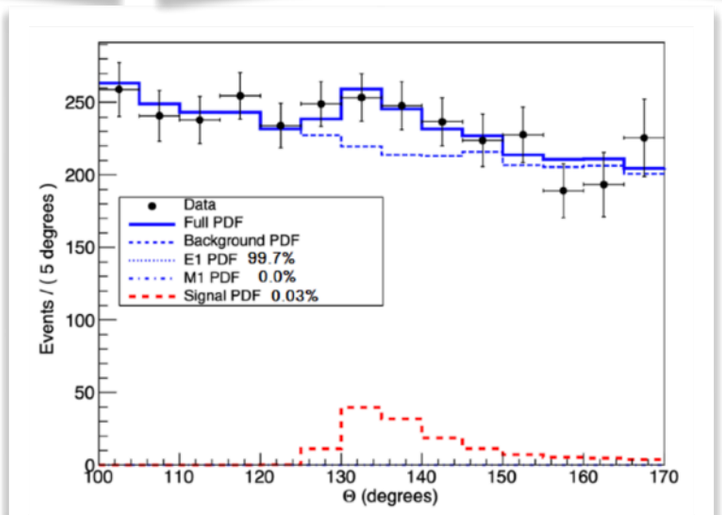
Abamyan *et al.*,10.1134/S1063779624700412



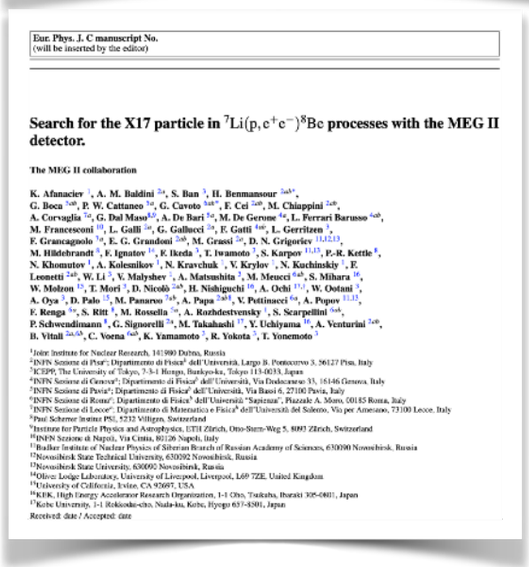
- **JINR** (2024): Peak-like anomaly in the $\gamma\gamma$ invariant mass spectra in d+Cu collisions ($\geq 6\sigma$)



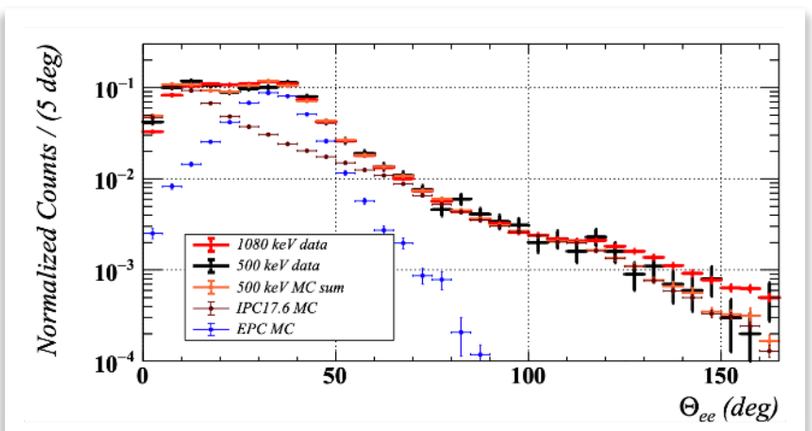
Tran The Anh *et al.*,10.3390/universe10040168 arXiv:2401.11676v2 [nucl-ex] 19 Mar 2024



- **VNU** (2024): Repetition of the ^{8}Be measurement
  -> Observation of a similar peak-like anomaly ($\geq 4\sigma$)



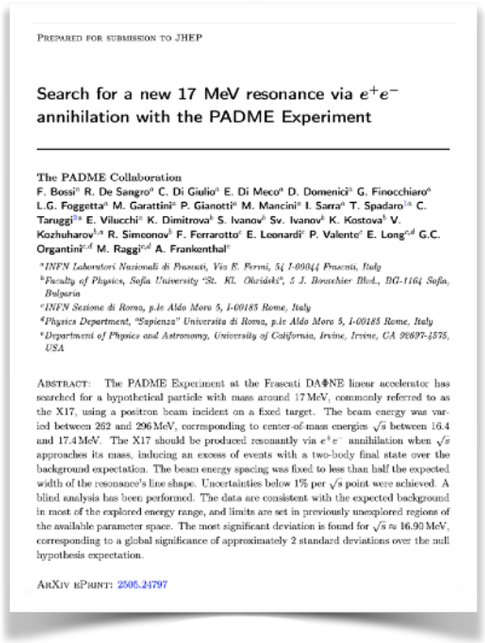
The MEG II collaboration,10.48550/arXiv.2411.07994



- **MEG II** (2024): Repetition of the ^{8}Be measurement
  -> No peak-like anomaly but results compatible within 1.5σ

X17 - to peak or not to peak?

The PADME collaboration,10.1007/JHEP11%282025%29007



Prepared for submission to JHEP

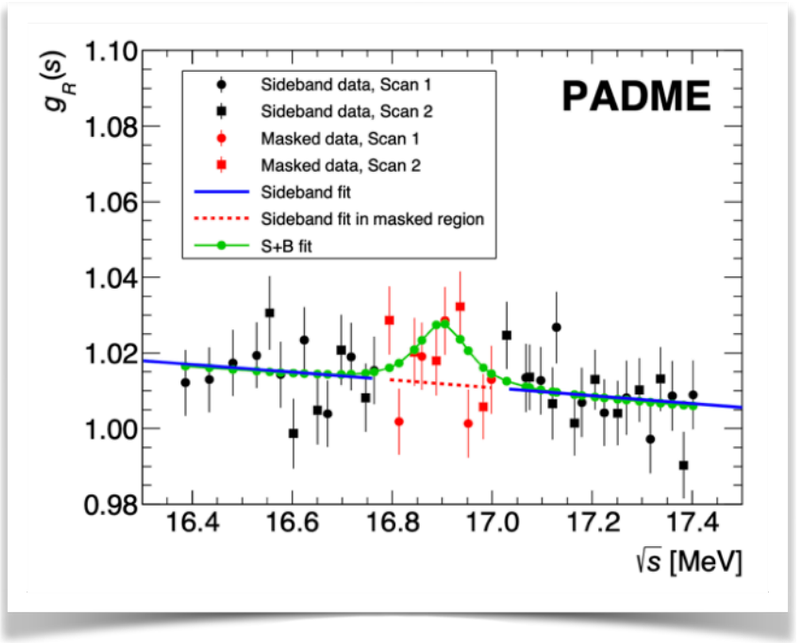
Search for a new 17 MeV resonance via e^+e^- annihilation with the PADME Experiment

The PADME Collaboration
F. Bossi[a] R. De Sangro[a] C. Di Giulio[a] E. Di Meco[a] D. Domenici[a] G. Finocchiaro[a] L.G. Foggetta[a] M. Garattini[a] P. Gianotti[a] M. Mancini[a] I. Sarra[a] T. Spadaro[1,a] C. Taruggi[2,a] E. Vilucchi[a] K. Dimitrova[b] S. Ivanov[b] Sv. Ivanov[b] K. Kostova[b] V. Kozhuharov[1,b] R. Simeonov[b] F. Ferrarotto[c] E. Leonardi[c] P. Valente[c] E. Long[c,d] G.C. Organtini[c,d] M. Raggi[c,d] A. Frankenthal[e]

[a]INFN Laboratori Nazionali di Frascati, Via E. Fermi, 54 I-00044 Frascati, Italy
[b]Faculty of Physics, Sofia University "St. Kl. Ohridski", 5 J. Bourchier Blvd., BG-1164 Sofia, Bulgaria
[c]INFN Sezione di Roma, p.le Aldo Moro 5, I-00185 Rome, Italy
[d]Physics Department, "Sapienza" Universita di Roma, p.le Aldo Moro 5, I-00185 Rome, Italy
[e]Department of Physics and Astronomy, University of California, Irvine, Irvine, CA 92697-4575, USA

Abstract: The PADME Experiment at the Frascati DAΦNE linear accelerator has searched for a hypothetical particle with mass around 17 MeV, commonly referred to as the X17, using a positron beam incident on a fixed target. The beam energy was varied between 262 and 296 MeV, corresponding to center-of-mass energies $\sqrt{s}$ between 16.4 and 17.4 MeV. The X17 should be produced resonantly via e^+e^- annihilation when $\sqrt{s}$ approaches its mass, inducing an excess of events with a two-body final state over the background expectation. The beam energy spacing was fixed to less than half the expected width of the resonance's line shape. Uncertainties below 1% per $\sqrt{s}$ point were achieved. A blind analysis has been performed. The data are consistent with the expected background in most of the explored energy range, and limits are set in previously unexplored regions of the available parameter space. The most significant deviation is found for $\sqrt{s} \approx 16.90$ MeV, corresponding to a global significance of approximately 2 standard deviations over the null hypothesis expectation.

ArXiv ePrint: 2505.24797



- **PADME** (2025): Peak-like anomaly in the invariant mass spectrum of e^+e^- annihilation (1.7σ)

More data would be nice!


MAGIX

MAGIX

MAinz

MESA

Multi-purpose Apparatus

Massima Accuratezza

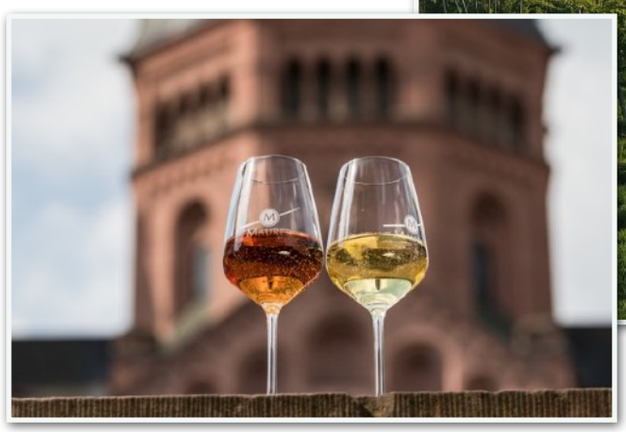
Greetings from Mainz.

bistummainz.de

pixopolis.de

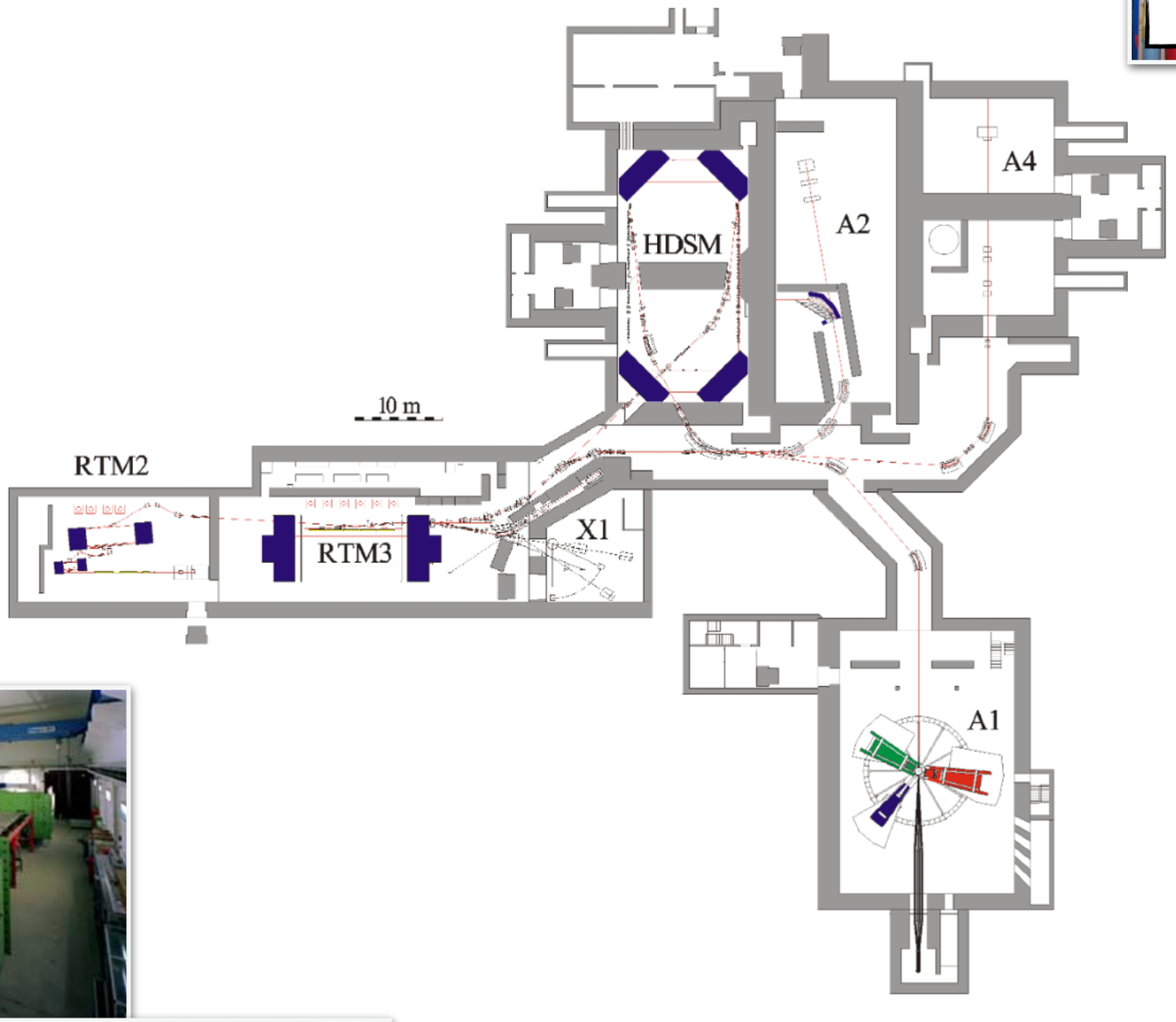
Adobe stock

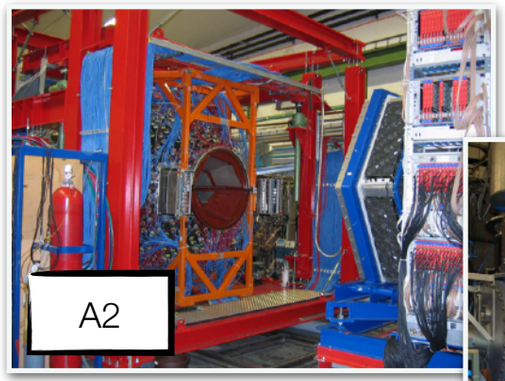
christophorus-hof.de

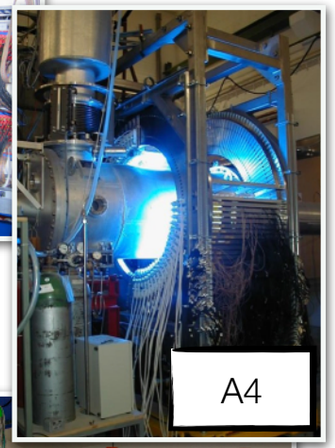


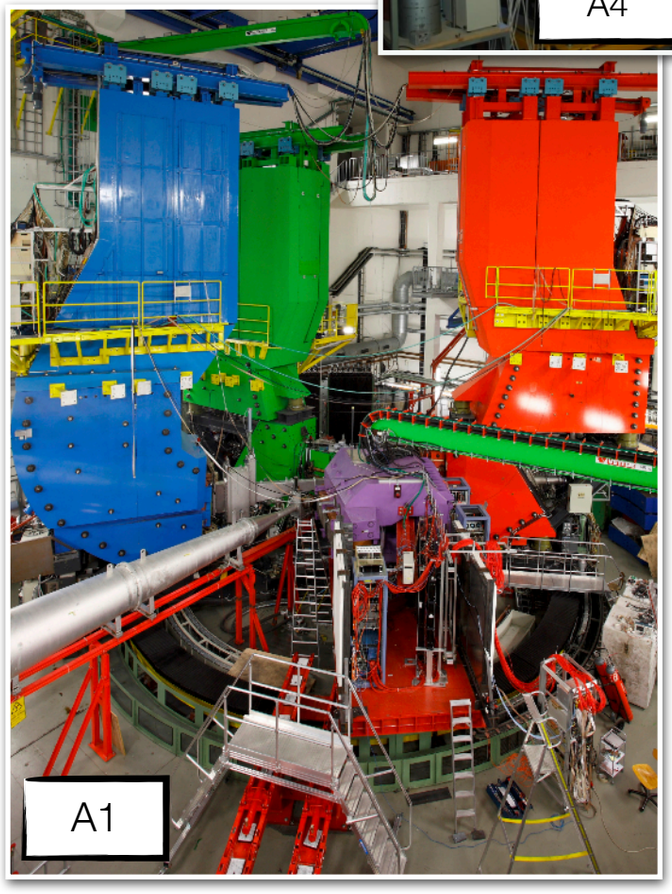
mainz-tourismus.com

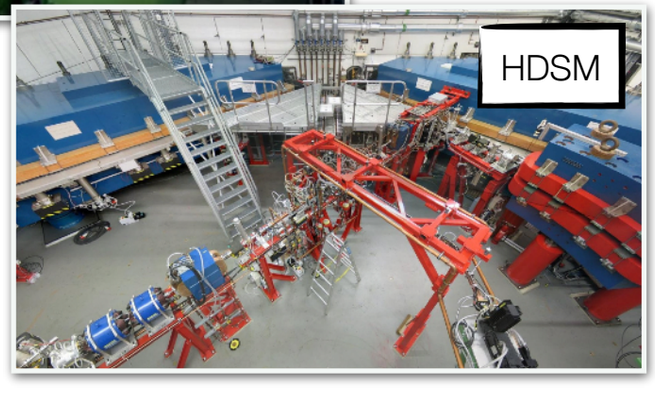
Greetings from MAMI.





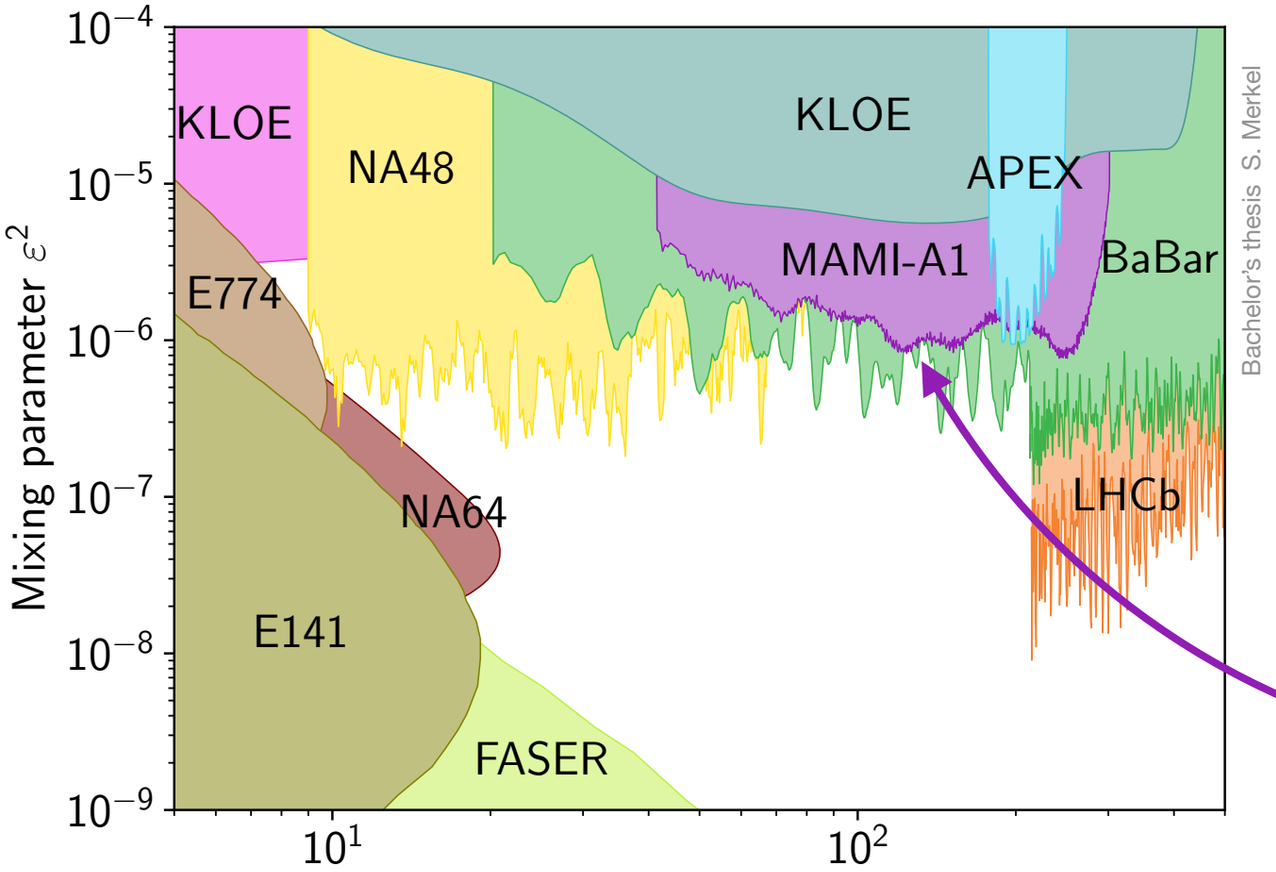




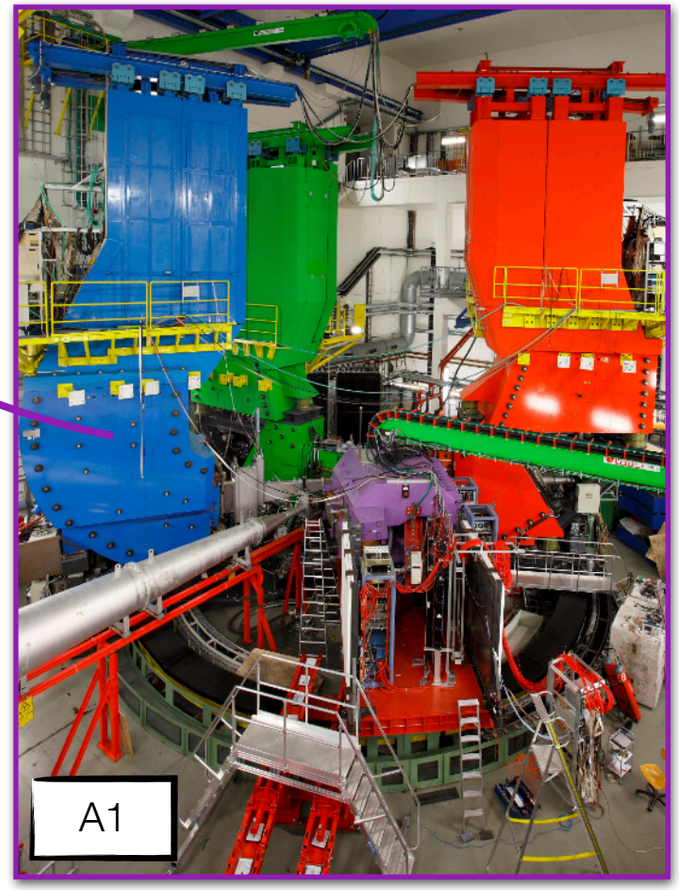


- **MA**inzer **MI**crotron, energies $\leq 1600\,MeV$, currents $\geq 100\mu A$
- Mainz has a long history of electron accelerators (linac in the 1960s, MAMI since the 1990s)

Dark sector searches at MAMI.



Bachelor's thesis S. Merkel



PRL 106, 251802 (2011) PHYSICAL REVIEW LETTERS week ending 24 JUNE 2011

Search for Light Gauge Bosons of the Dark Sector at the Mainz Microtron

H. Merkel, P. Achenbach, C. Ayerbe Gayoso, J. C. Bernauer, R. Böhm, D. Bosnar, L. Debenjak, A. Denig, M. O. Distler, A. Esser, H. Fonvieille, I. Friščić, D. G. Middleton, U. Müller, L. Nungesser, J. Pochodzalla, M. Rohrbeck, S. Sánchez Majos, B. S. Schlimme, M. Schoth, S. Širca, and M. Weinriefer

(A1 Collaboration)

Institut für Kernphysik, Johannes Gutenberg-Universität Mainz, D-55099 Mainz, Germany
Department of Physics, University of Zagreb, HR-10002 Zagreb, Croatia
Jožef Stefan Institute, SI-1000 Ljubljana, Slovenia
Clermont Université, Université Blaise Pascal, CNRS/IN2P3, LPC, BP 10448, F-63000 Clermont-Ferrand, France
Department of Physics, University of Ljubljana, SI-1000 Ljubljana, Slovenia
(Received 21 January 2011; published 22 June 2011)

A new exclusion limit for the electromagnetic production of a light $U(1)$ gauge boson γ' decaying to e^+e^- was determined by the A1 Collaboration at the Mainz Microtron. Such light gauge bosons appear in several extensions of th
matter with standard m
narrow state coupling t
pair mass of 210 MeV/
current and high resolut

DOI: 10.1103/PhysRevLet

Merkel et al., 10.1103/PhysRevLett.106.251802

PRL 112, 221802 (2014) PHYSICAL REVIEW LETTERS week ending 6 JUNE 2014

Search at the Mainz Microtron for Light Massive Gauge Bosons Relevant for the Muon $g-2$ Anomaly

H. Merkel, P. Achenbach, C. Ayerbe Gayoso, T. Beranek, J. Beričič, J. C. Bernauer, R. Böhm, D. Bosnar, L. Correa, L. Debenjak, A. Denig, M. O. Distler, A. Esser, H. Fonvieille, I. Friščić, M. Gómez Rodríguez de la Paz, M. Hoek, S. Kegel, Y. Kohl, D. G. Middleton, M. Mihovilović, U. Müller, L. Nungesser, J. Pochodzalla, M. Rohrbeck, G. Ron, S. Sánchez Majos, B. S. Schlimme, M. Schoth, F. Schulz, C. Sfienti, S. Širca, M. Thiel, A. Tyukin, A. Weber, and M. Weinriefer

(A1 Collaboration)

Institut für Kernphysik, Johannes Gutenberg-Universität Mainz, D-55099 Mainz, Germany
Jožef Stefan Institute, SI-1000 Ljubljana, Slovenia
Department of Physics, University of Zagreb, HR-10002 Zagreb, Croatia
Clermont Université, Université Blaise Pascal, CNRS/IN2P3, LPC, BP 10448, F-63000 Clermont-Ferrand, France
Racah Institute of Physics, Hebrew University of Jerusalem, Jerusalem 91904, Israel
Department of Physics, University of Ljubljana, SI-1000 Ljubljana, Slovenia
(Received 22 April 2014; revised manuscript received 19 May 2014; published 4 June 2014)

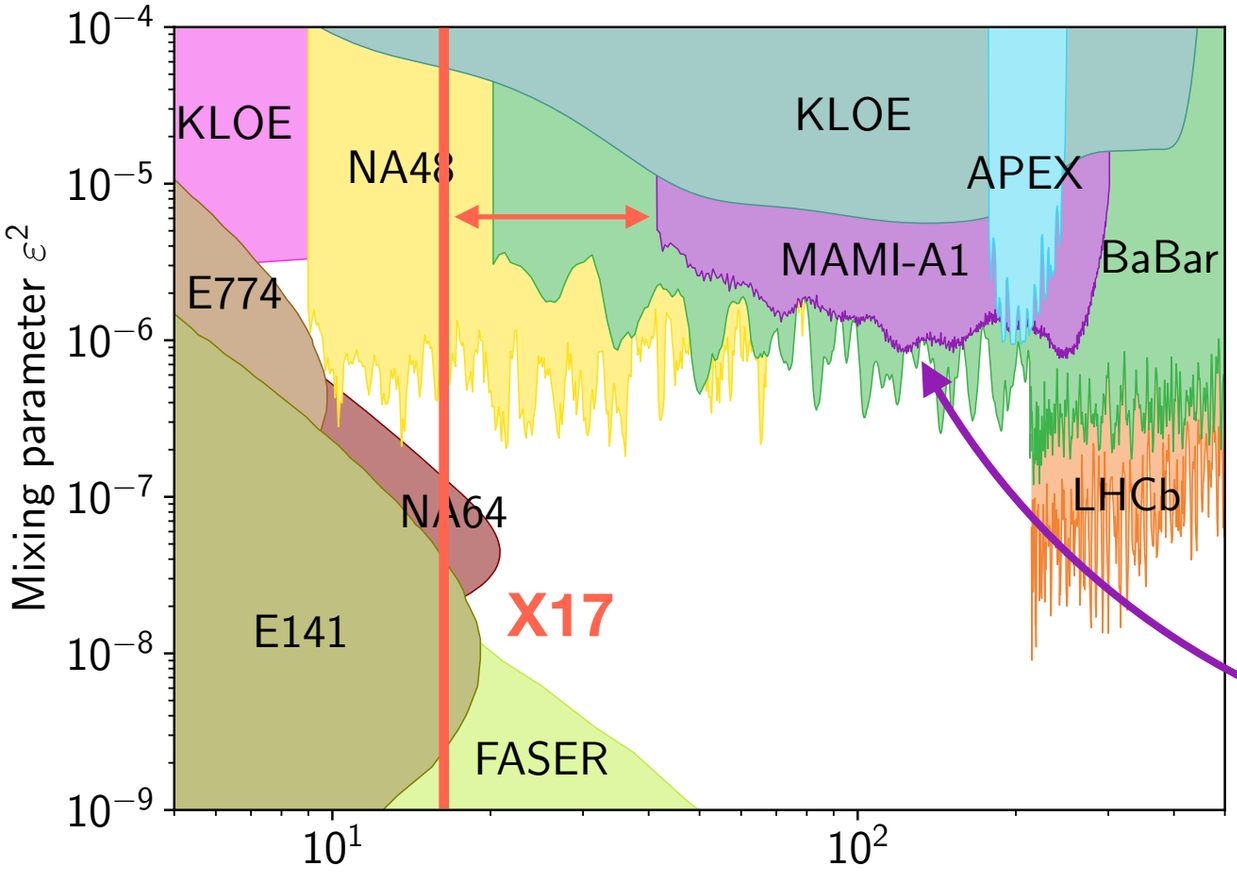
A massive, but light, Abelian $U(1)$ gauge boson is a well-motivated possible signature of physics beyond the standard model of particle physics. In this Letter, the search for the signal of such a $U(1)$ gauge boson in electron-positron pair production at the spectrometer setup of the A1 Collaboration at the Mainz Microtron is described. Exclusion limits in the mass range of 40 MeV/c^2 to 300 MeV/c^2, with a sensitivity in the squared mixing parameter of as little as $\epsilon^2 = 8 \times 10^{-7}$ are presented. A large fraction of the parameter space has been excluded where the discrepancy of the measured anomalous magnetic moment of the muon with theory might be explained by an additional $U(1)$ gauge boson.

DOI: 10.1103/PhysRevLett.112.221802 PACS numbers: 14.70.Pw, 13.40.Em, 25.30.Rw, 95.35.+d

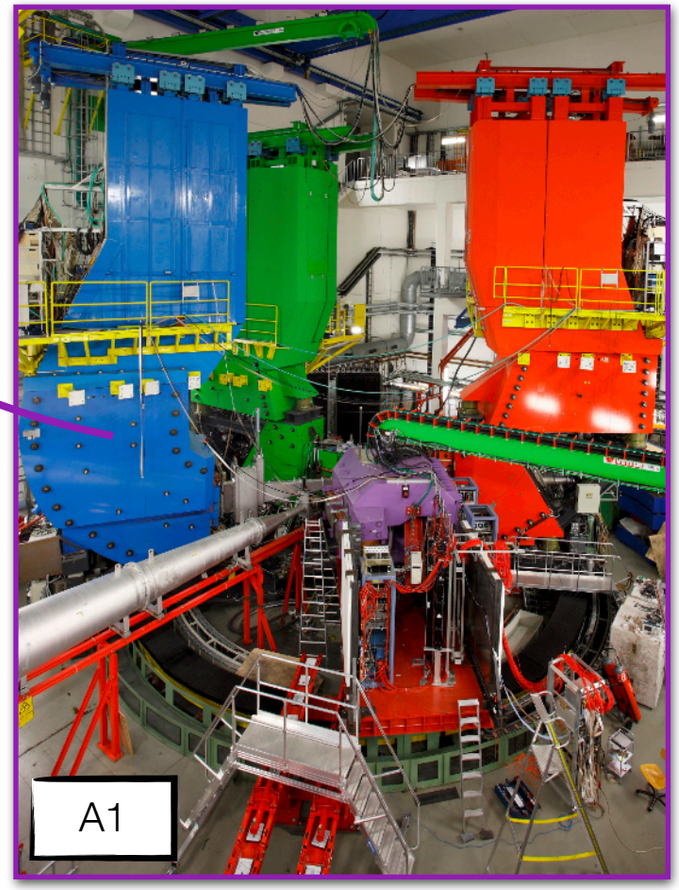
Merkel et al., 10.1103/PhysRevLett.112.221802

- Searches for Light Gauge Bosons of a hypothetical dark sector in 2011 and 2014 giving exclusion limits in the mass range from 40 MeV/c^2 to 300 MeV/c^2

Dark sector searches at MAMI.



Bachelor's thesis S. Merkel



PRL 106, 251802 (2011) PHYSICAL REVIEW LETTERS week ending 24 JUNE 2011

Search for Light Gauge Bosons of the Dark Sector at the Mainz Microtron

H. Merkel, P. Achenbach, C. Ayerbe Gayoso, J. C. Bernauer, R. Böhm, D. Bosnar, L. Debenjak, A. Denig, M. O. Distler, A. Esser, H. Fonvieille, I. Friščić, D. G. Middleton, U. Müller, L. Nungesser, J. Pochodzalla, M. Rohrbeck, S. Sánchez Majos, B. S. Schlimme, M. Schoth, S. Širca, and M. Weinriefer

(A1 Collaboration)

Institut für Kernphysik, Johannes Gutenberg-Universität Mainz, D-55099 Mainz, Germany
Department of Physics, University of Zagreb, HR-10002 Zagreb, Croatia
Jožef Stefan Institute, SI-1000 Ljubljana, Slovenia
Clermont Université, Université Blaise Pascal, CNRS/IN2P3, LPC, BP 10448, F-63000 Clermont-Ferrand, France
Department of Physics, University of Ljubljana, SI-1000 Ljubljana, Slovenia
(Received 21 January 2011; published 22 June 2011)

A new exclusion limit for the electromagnetic production of a light $U(1)$ gauge boson γ' decaying to e^+e^- was determined by the A1 Collaboration at the Mainz Microtron. Such light gauge bosons appear in several extensions of th
matter with standard m
narrow state coupling t
pair mass of 210 MeV/
current and high resolut

DOI: 10.1103/PhysRevLet

Merkel *et al.*, 10.1103/PhysRevLett.106.251802

PRL 112, 221802 (2014) PHYSICAL REVIEW LETTERS week ending 6 JUNE 2014

Search at the Mainz Microtron for Light Massive Gauge Bosons Relevant for the Muon $g-2$ Anomaly

H. Merkel, P. Achenbach, C. Ayerbe Gayoso, T. Beranek, J. Beričič, J. C. Bernauer, R. Böhm, D. Bosnar, L. Correa, L. Debenjak, A. Denig, M. O. Distler, A. Esser, H. Fonvieille, I. Friščić, M. Gómez Rodríguez de la Paz, M. Hoek, S. Kegel, Y. Kohl, D. G. Middleton, M. Mihovilović, U. Müller, L. Nungesser, J. Pochodzalla, M. Rohrbeck, G. Ron, S. Sánchez Majos, B. S. Schlimme, M. Schoth, F. Schulz, C. Sfienti, S. Širca, M. Thiel, A. Tyukin, A. Weber, and M. Weinriefer

(A1 Collaboration)

Institut für Kernphysik, Johannes Gutenberg-Universität Mainz, D-55099 Mainz, Germany
Jožef Stefan Institute, SI-1000 Ljubljana, Slovenia
Department of Physics, University of Zagreb, HR-10002 Zagreb, Croatia
Clermont Université, Université Blaise Pascal, CNRS/IN2P3, LPC, BP 10448, F-63000 Clermont-Ferrand, France
Racah Institute of Physics, Hebrew University of Jerusalem, Jerusalem 91904, Israel
Department of Physics, University of Ljubljana, SI-1000 Ljubljana, Slovenia
(Received 22 April 2014; revised manuscript received 19 May 2014; published 4 June 2014)

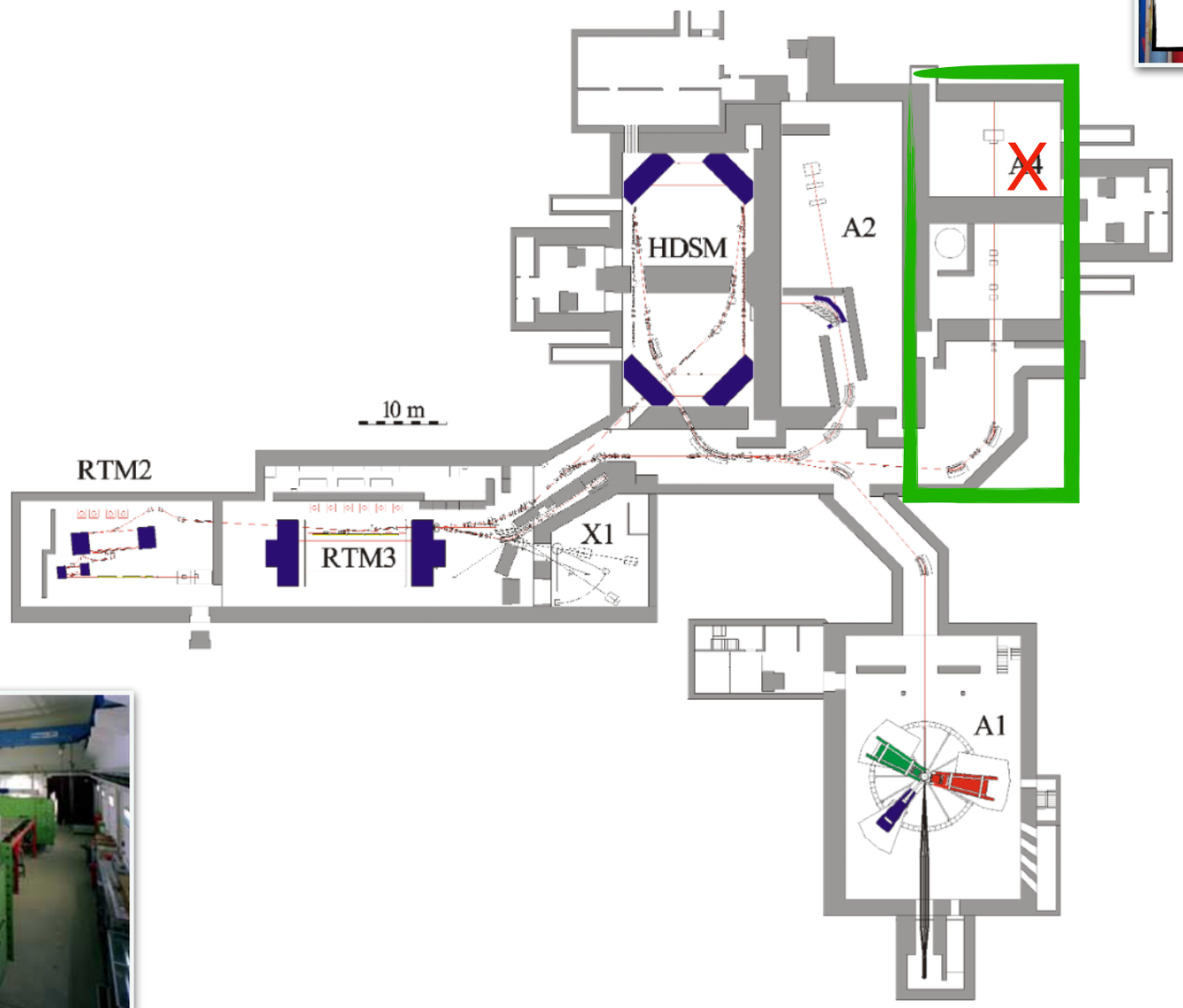
A massive, but light, Abelian $U(1)$ gauge boson is a well-motivated possible signature of physics beyond the standard model of particle physics. In this Letter, the search for the signal of such a $U(1)$ gauge boson in electron-positron pair production at the spectrometer setup of the A1 Collaboration at the Mainz Microtron is described. Exclusion limits in the mass range of 40 MeV/c^2 to 300 MeV/c^2, with a sensitivity in the squared mixing parameter of as little as $\epsilon^2 = 8 \times 10^{-7}$ are presented. A large fraction of the parameter space has been excluded where the discrepancy of the measured anomalous magnetic moment of the muon with theory might be explained by an additional $U(1)$ gauge boson.

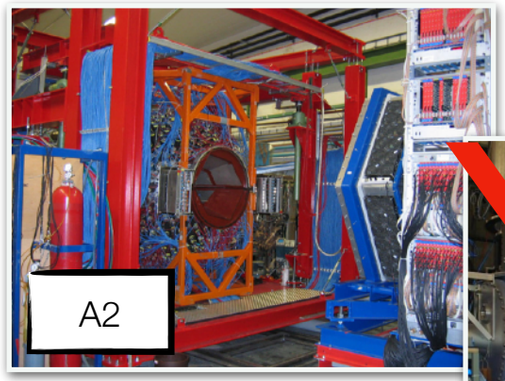
DOI: 10.1103/PhysRevLett.112.221802 PACS numbers: 14.70.Pw, 13.40.Em, 25.30.Rw, 95.35.+d

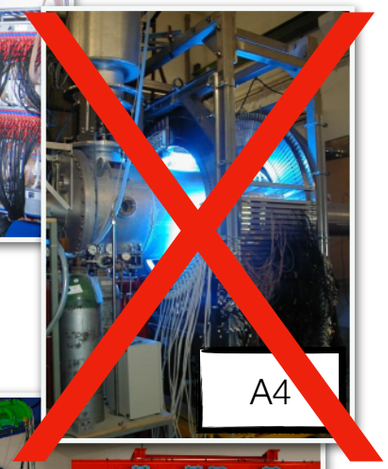
Merkel *et al.*, 10.1103/PhysRevLett.112.221802

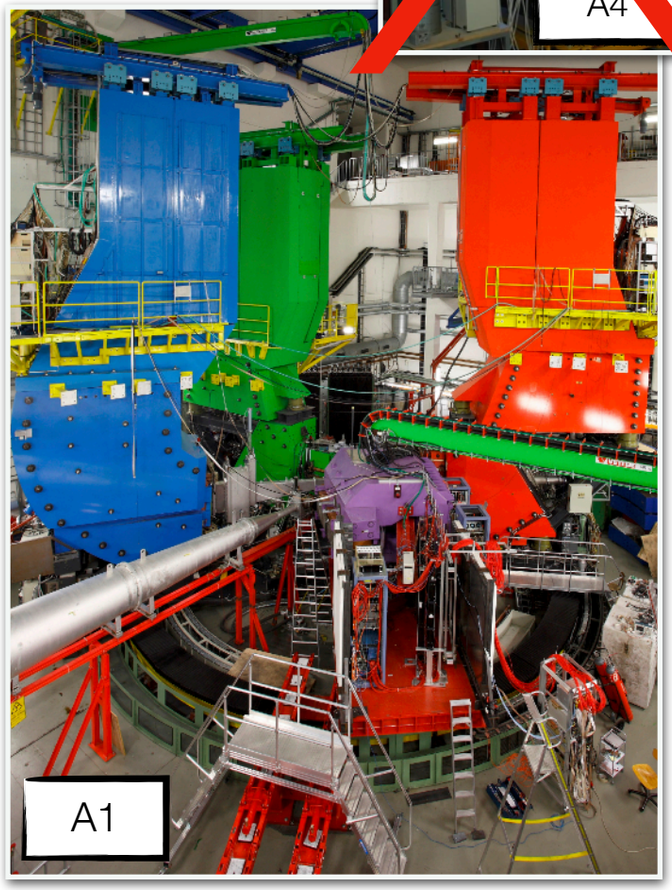
- Searches for Light Gauge Bosons of a hypothetical dark sector in 2011 and 2014 giving exclusion limits in the mass range from $40\,MeV/c^2$ to $300\,MeV/c^2$
- X17 range not accessible at A1@MAMI

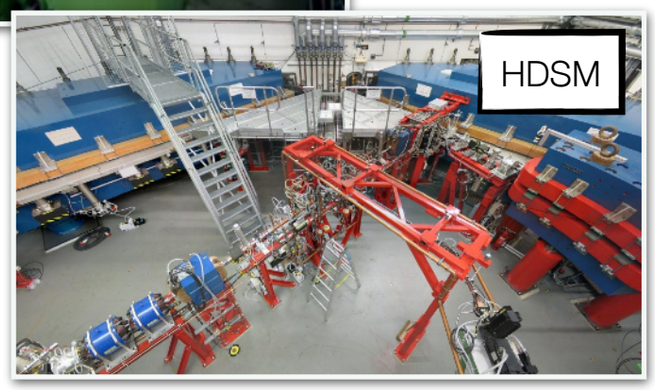
With best wishes from A4.





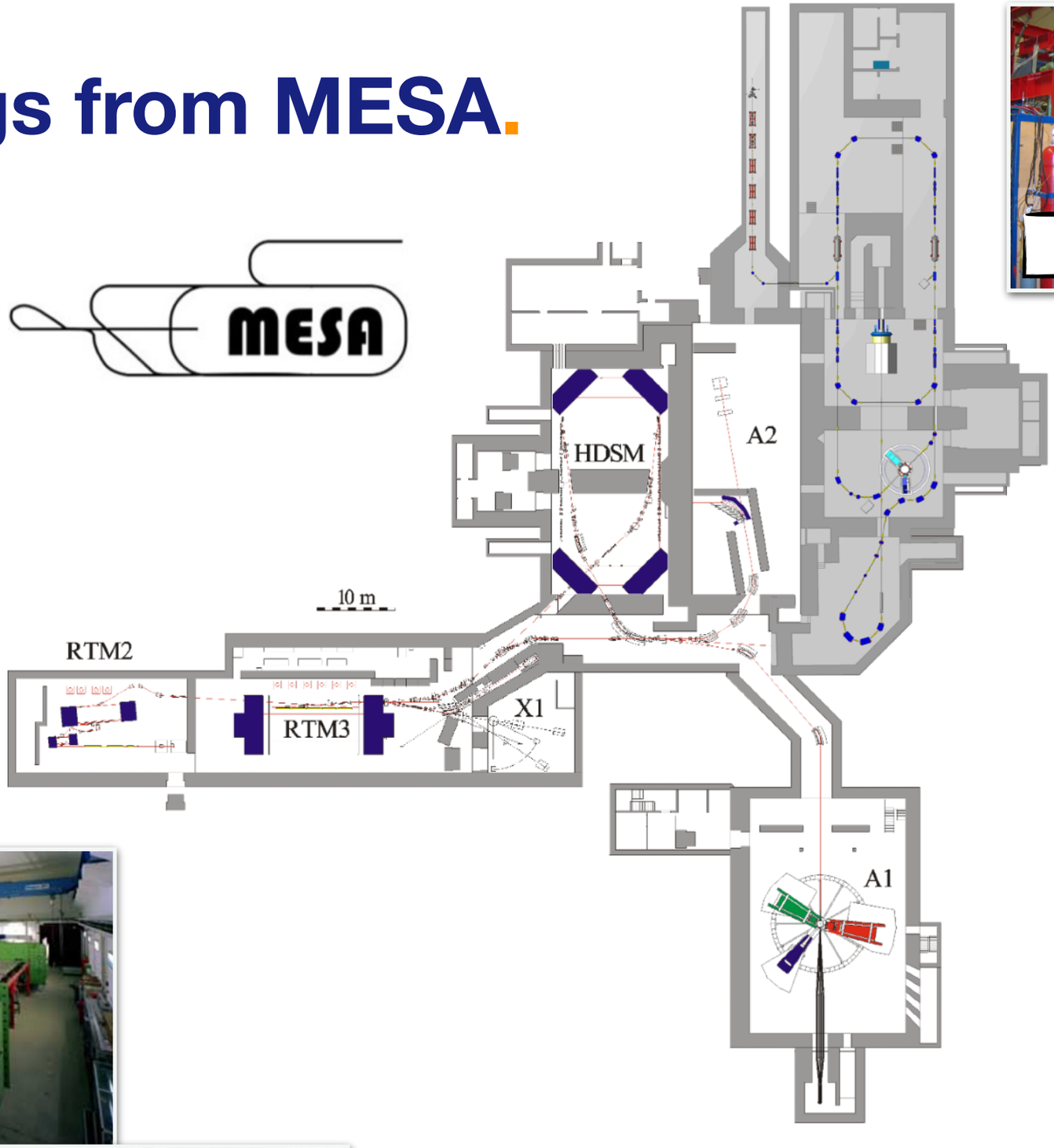


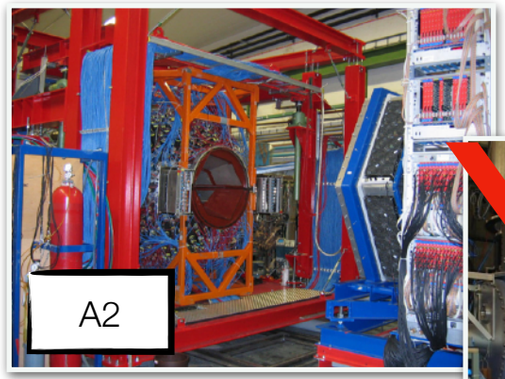


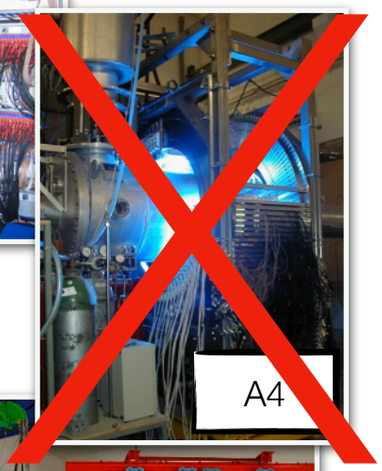


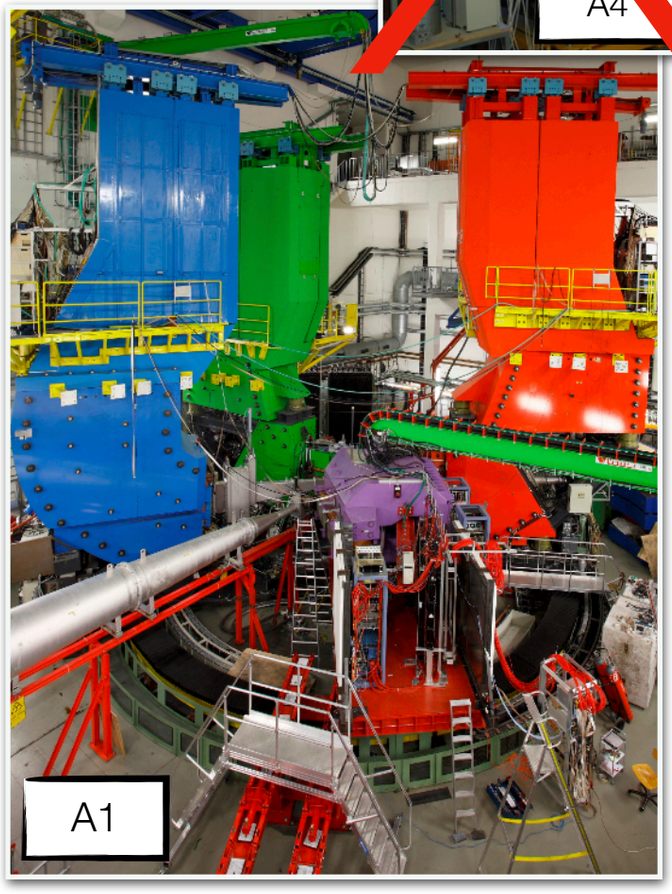
- The A4 experiment has been finished several years ago and its experimental halls are free for something new

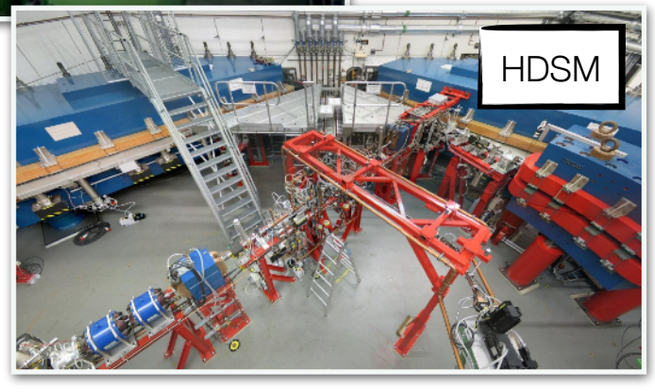
Greetings from MESA.







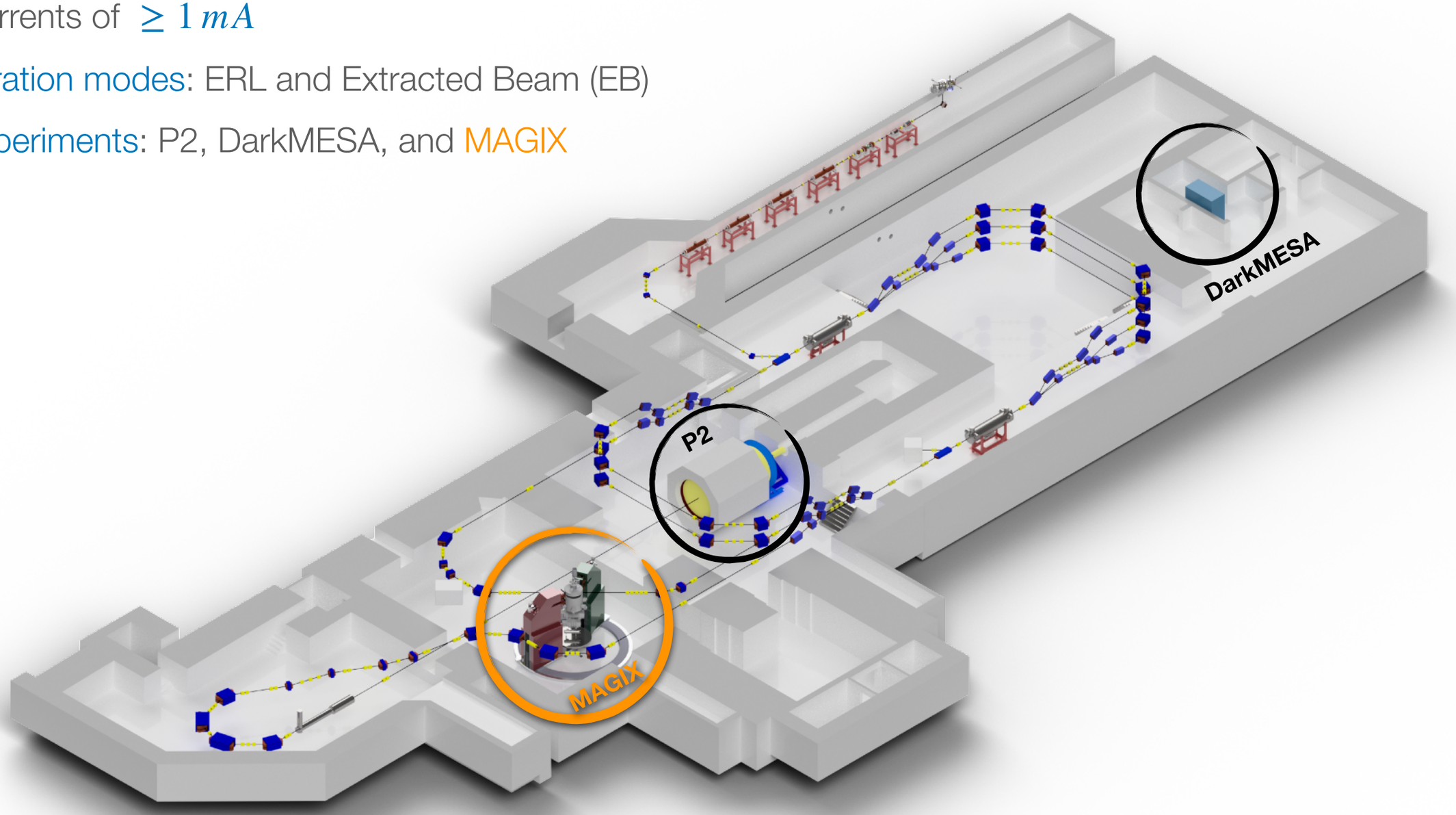




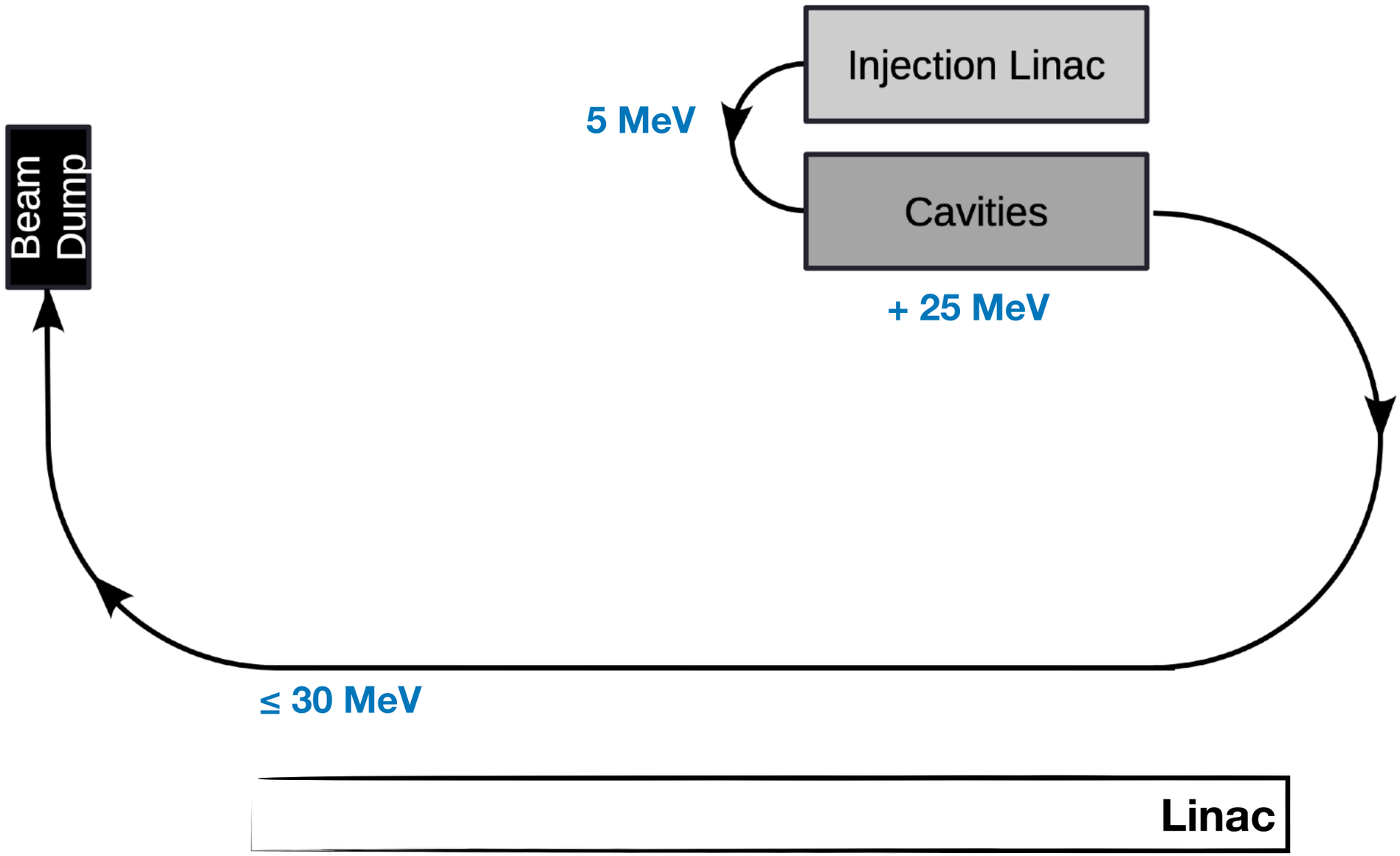
- The A4 experiment has been finished several years ago and its experimental halls are free for something new
- MESA will be the next-generation electron accelerator in Mainz with lower energies but higher intensities compared to MAMI

The low-energy electron accelerator MESA.

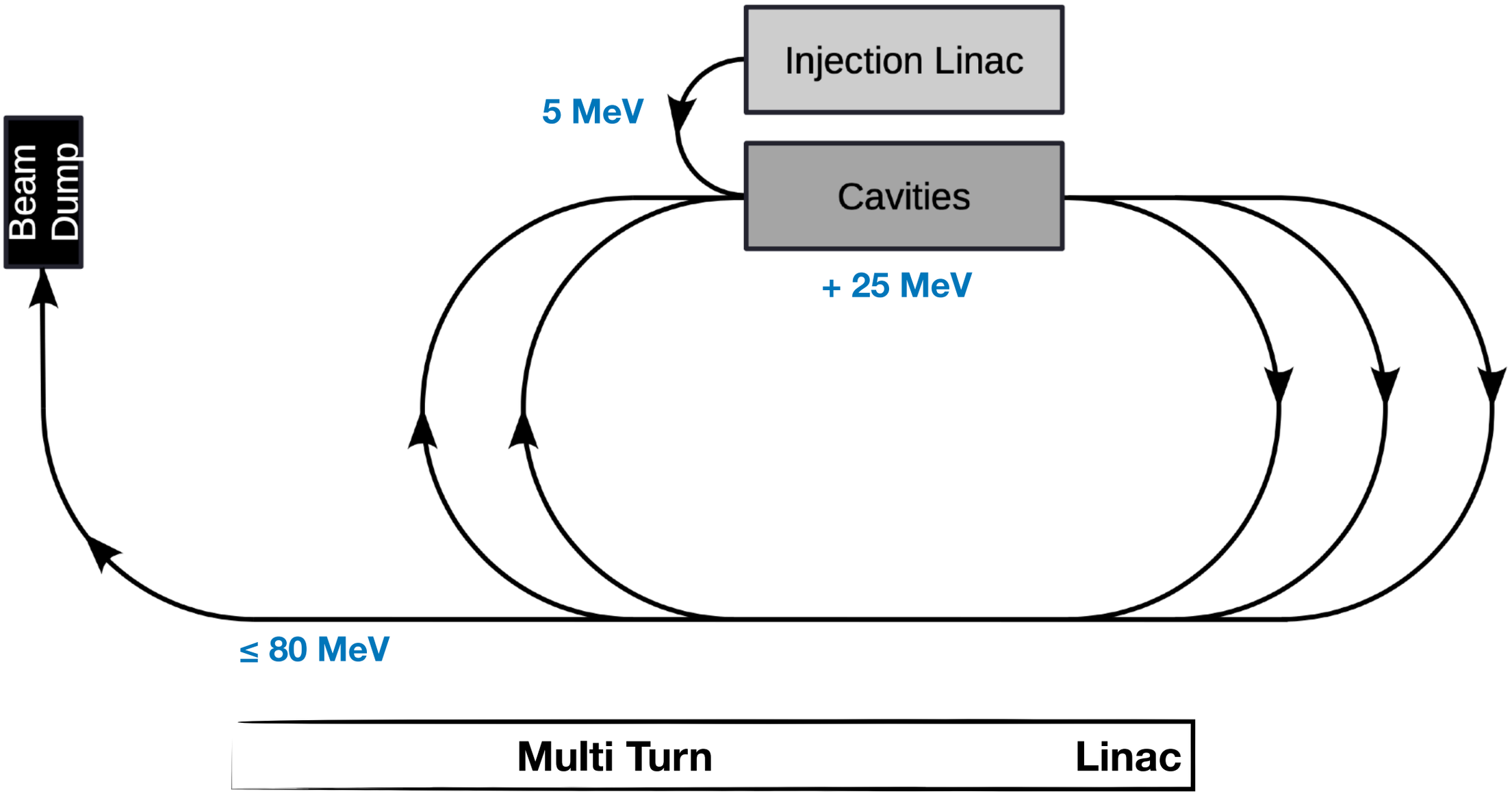
- **M**ainz **E**nergy-Recovering **S**uperconducting **A**ccelerator
- Double-sided Multi Turn **E**nergy-**R**ecovery **L**inac (ERL)
- Beam energies from $20\,MeV$ to $155\,MeV$
- Beam currents of $\geq 1\,mA$
- Two operation modes: ERL and Extracted Beam (EB)
- Three experiments: P2, DarkMESA, and MAGIX



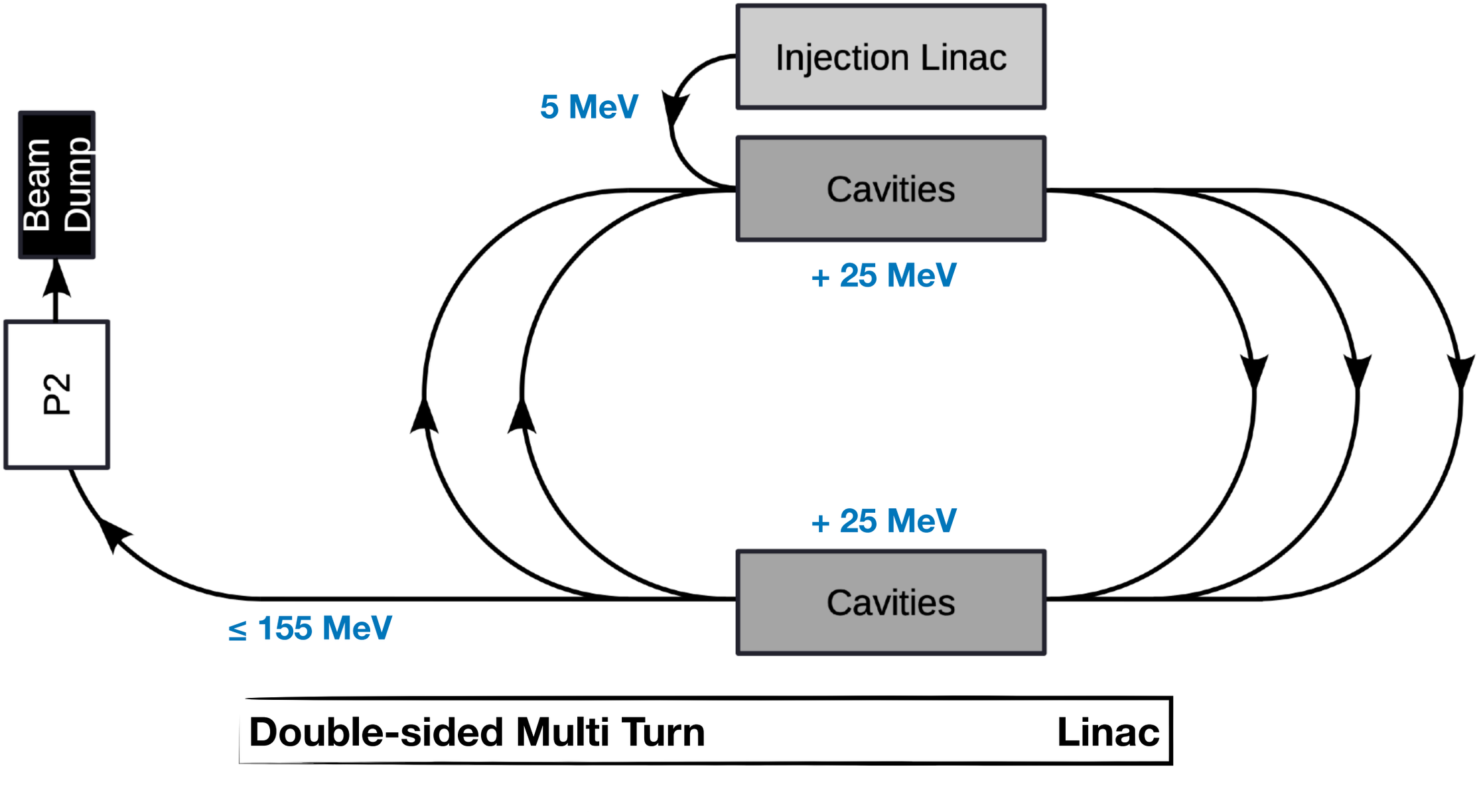
Let’s build MESA (1/7).



Let’s build MESA (2/7).

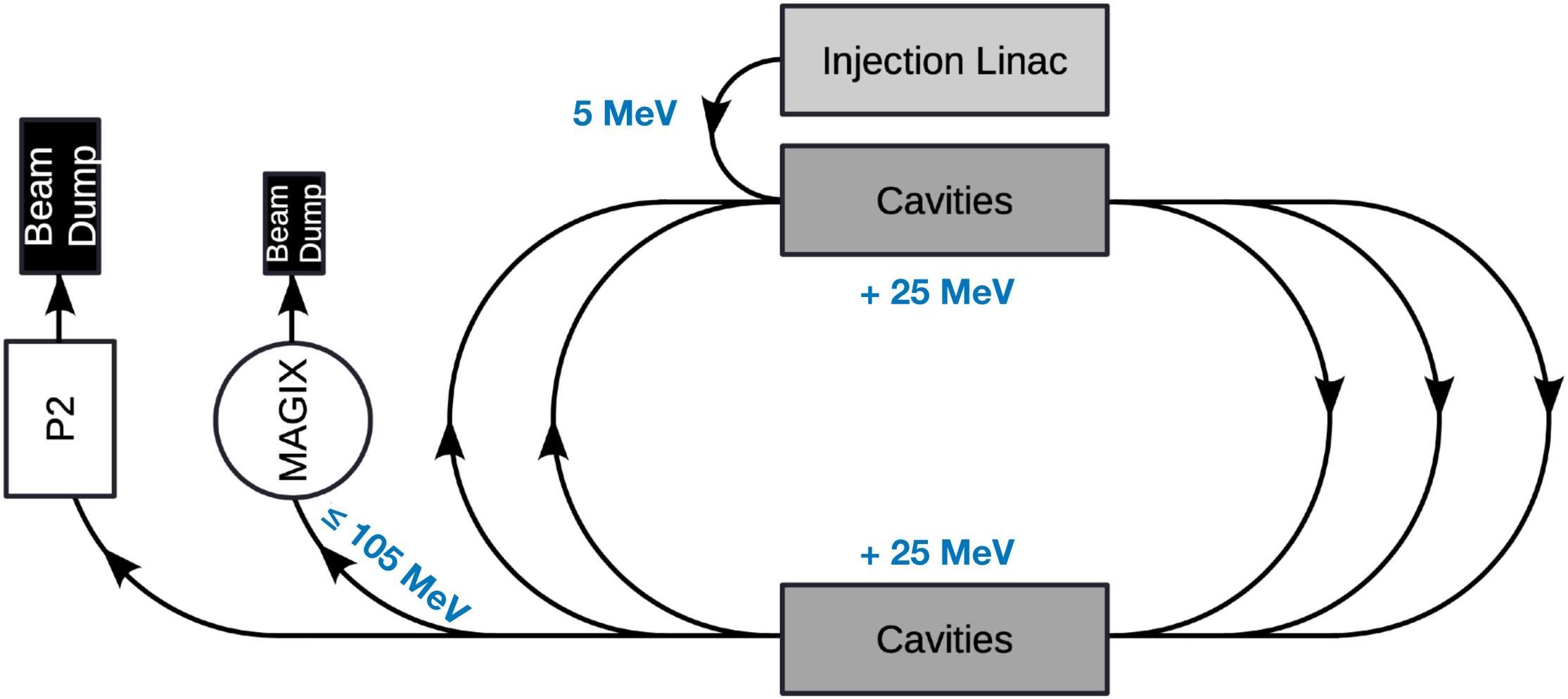


Let’s build MESA (3/7).



Extracted Beam (EB) mode - P2 experiment

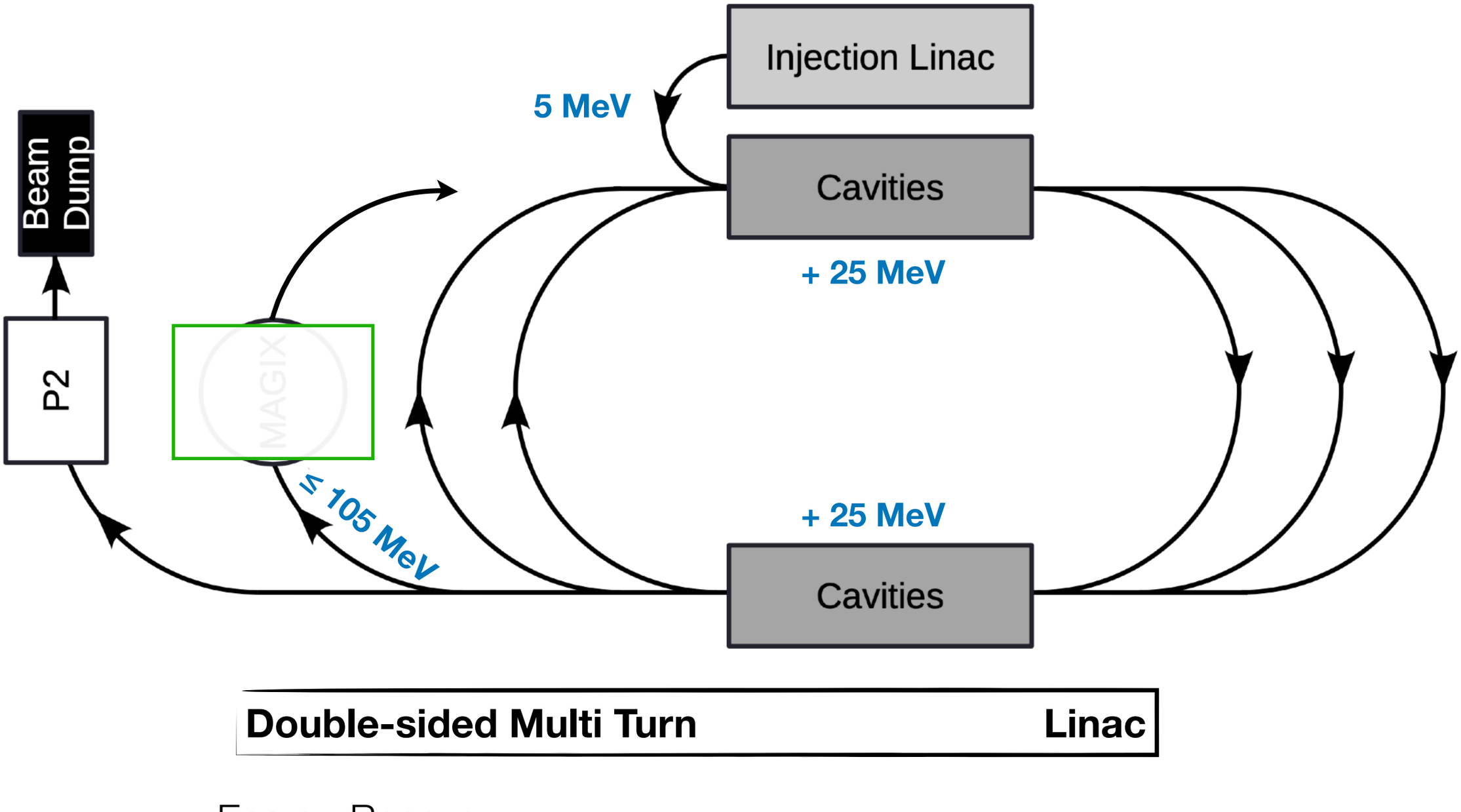
Let’s build MESA (4/7).



Double-sided Multi Turn **Linac**

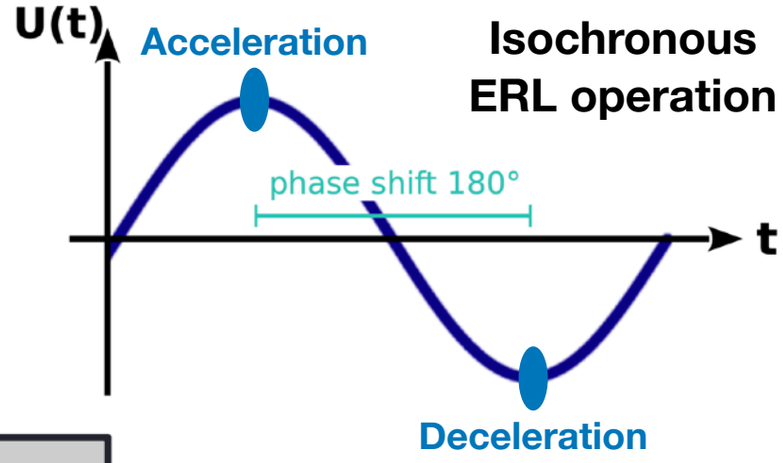
Extracted Beam (EB) mode - MAGIX experiment

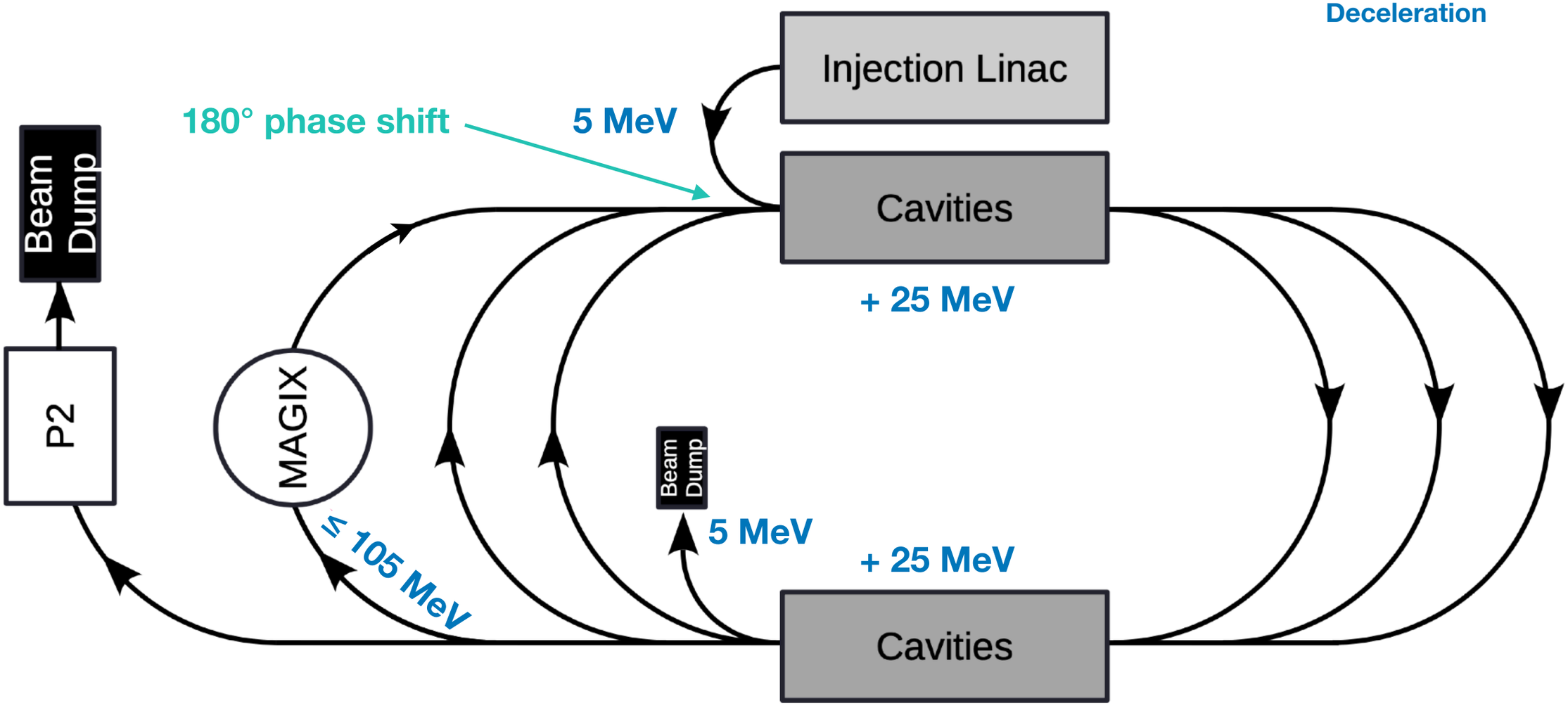
Let’s build MESA (5/7).



Energy-Recovery…

Let's build MESA (6/7).

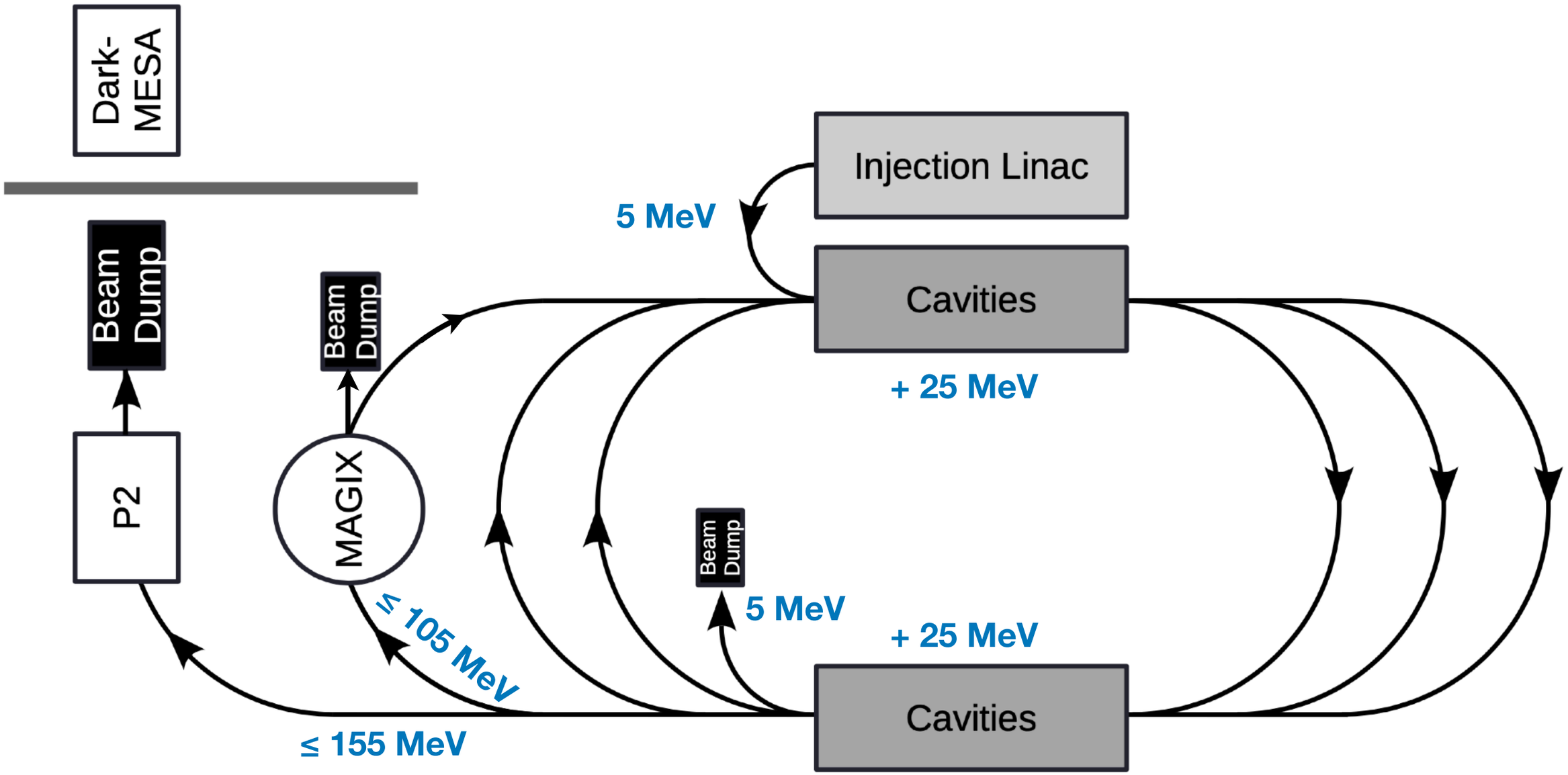




Double-sided Multi Turn Energy-Recovery Linac

Energy-Recovery Linac (ERL) mode - MAGIX experiment

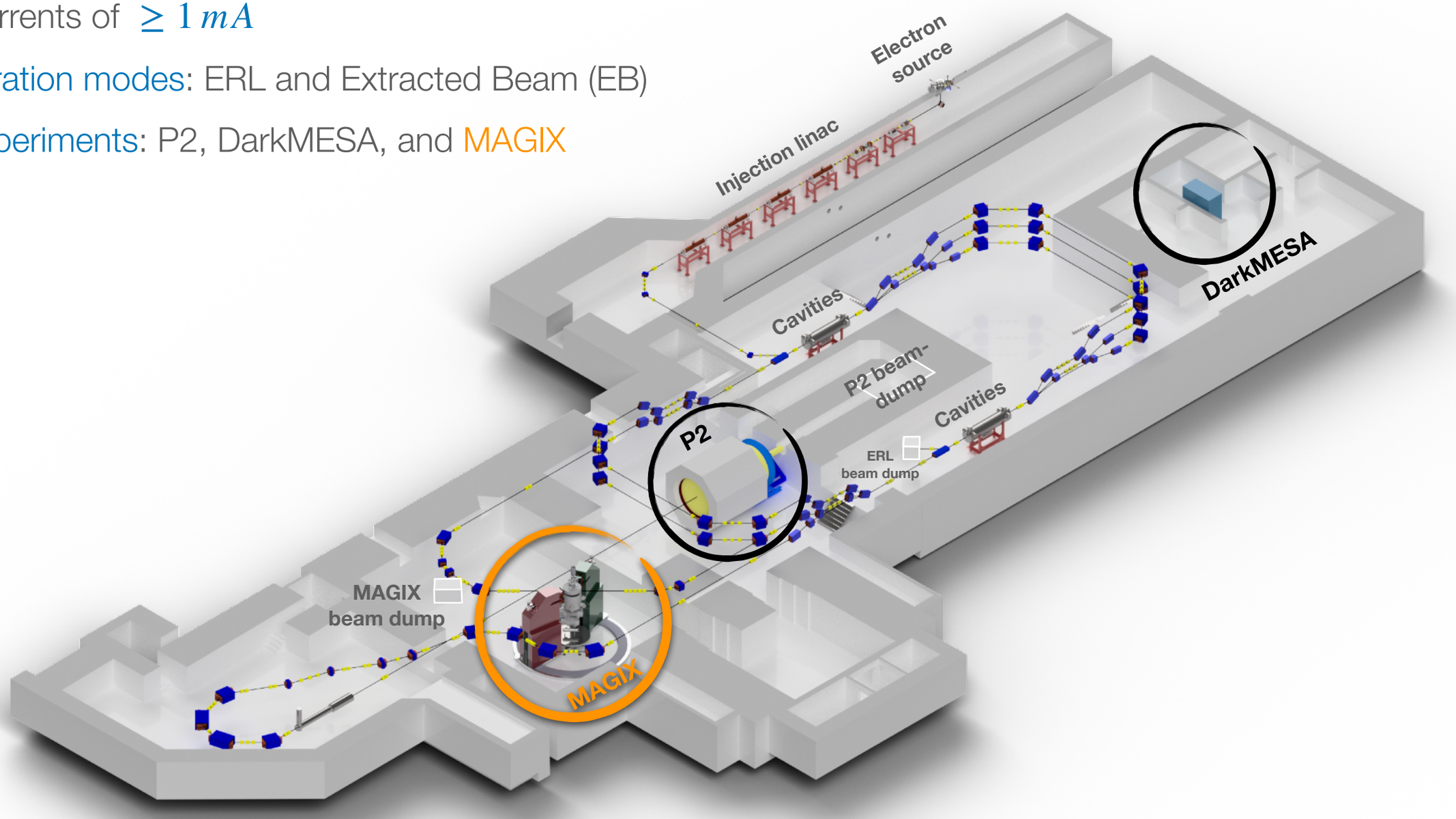
Let's build MESA (7/7).



Mainz **E**nergy-recovering **S**uperconducting **A**ccelerator

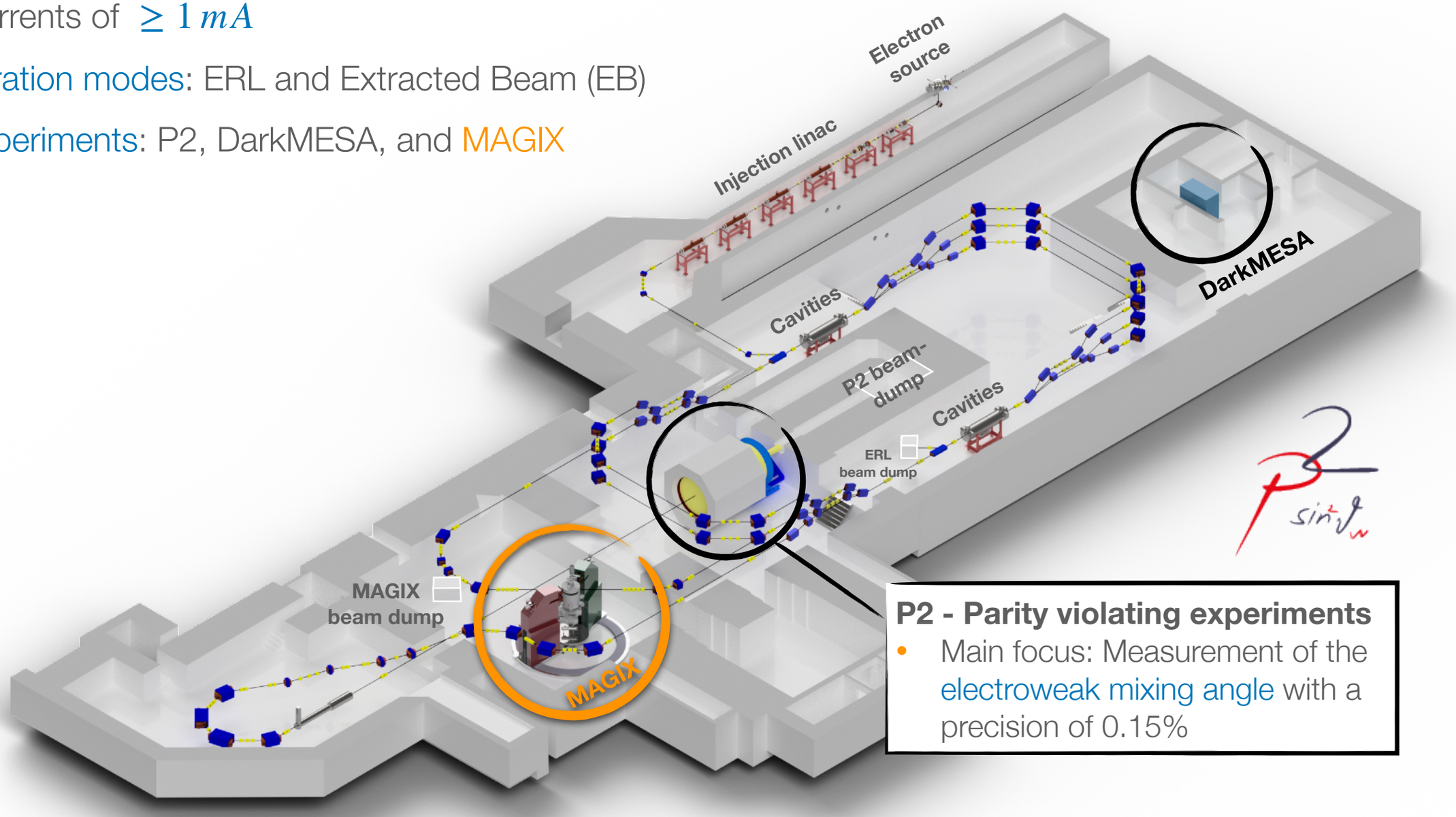
The low-energy electron accelerator MESA.

- **M**ainz **E**nergy-Recovering **S**uperconducting **A**ccelerator
- Double-sided Multi Turn **E**nergy-**R**ecovery **L**inac (ERL)
- Beam energies from $20\,MeV$ to $155\,MeV$
- Beam currents of $\geq 1\,mA$
- Two operation modes: ERL and Extracted Beam (EB)
- Three experiments: P2, DarkMESA, and MAGIX



The low-energy electron accelerator MESA.

- **M**ainz **E**nergy-Recovering **S**uperconducting **A**ccelerator
- Double-sided Multi Turn **E**nergy-**R**ecovery **L**inac (ERL)
- Beam energies from $20\,MeV$ to $155\,MeV$
- Beam currents of $\geq 1\,mA$
- Two operation modes: ERL and Extracted Beam (EB)
- Three experiments: P2, DarkMESA, and MAGIX



P2 - Parity violating experiments

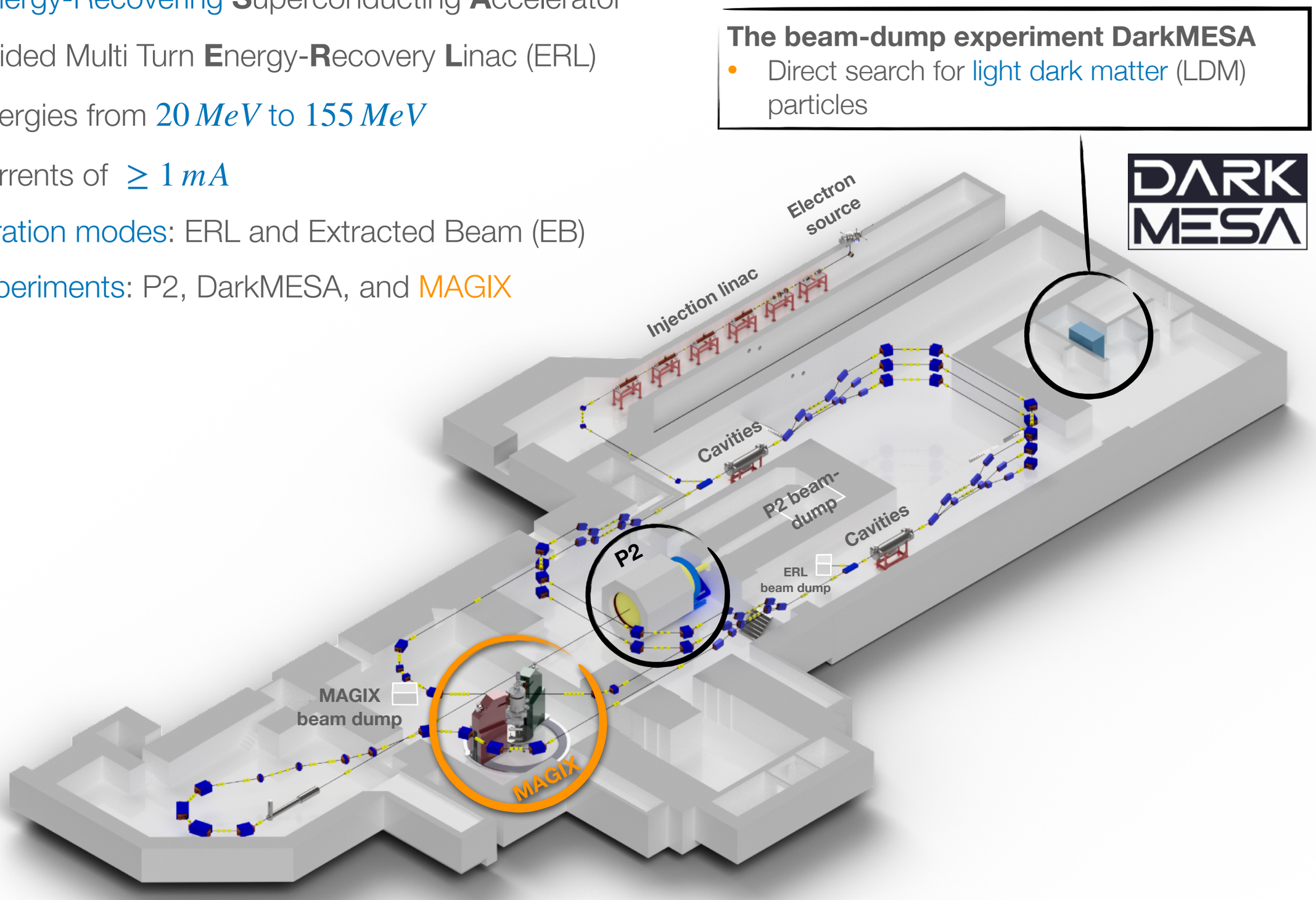
- Main focus: Measurement of the electroweak mixing angle with a precision of 0.15%

The low-energy electron accelerator MESA.

- **M**ainz **E**nergy-Recovering **S**uperconducting **A**ccelerator
- Double-sided Multi Turn **E**nergy-**R**ecovery **L**inac (ERL)
- Beam energies from $20\,MeV$ to $155\,MeV$
- Beam currents of $\geq 1\,mA$
- Two operation modes: ERL and Extracted Beam (EB)
- Three experiments: P2, DarkMESA, and MAGIX

The beam-dump experiment DarkMESA

- Direct search for light dark matter (LDM) particles

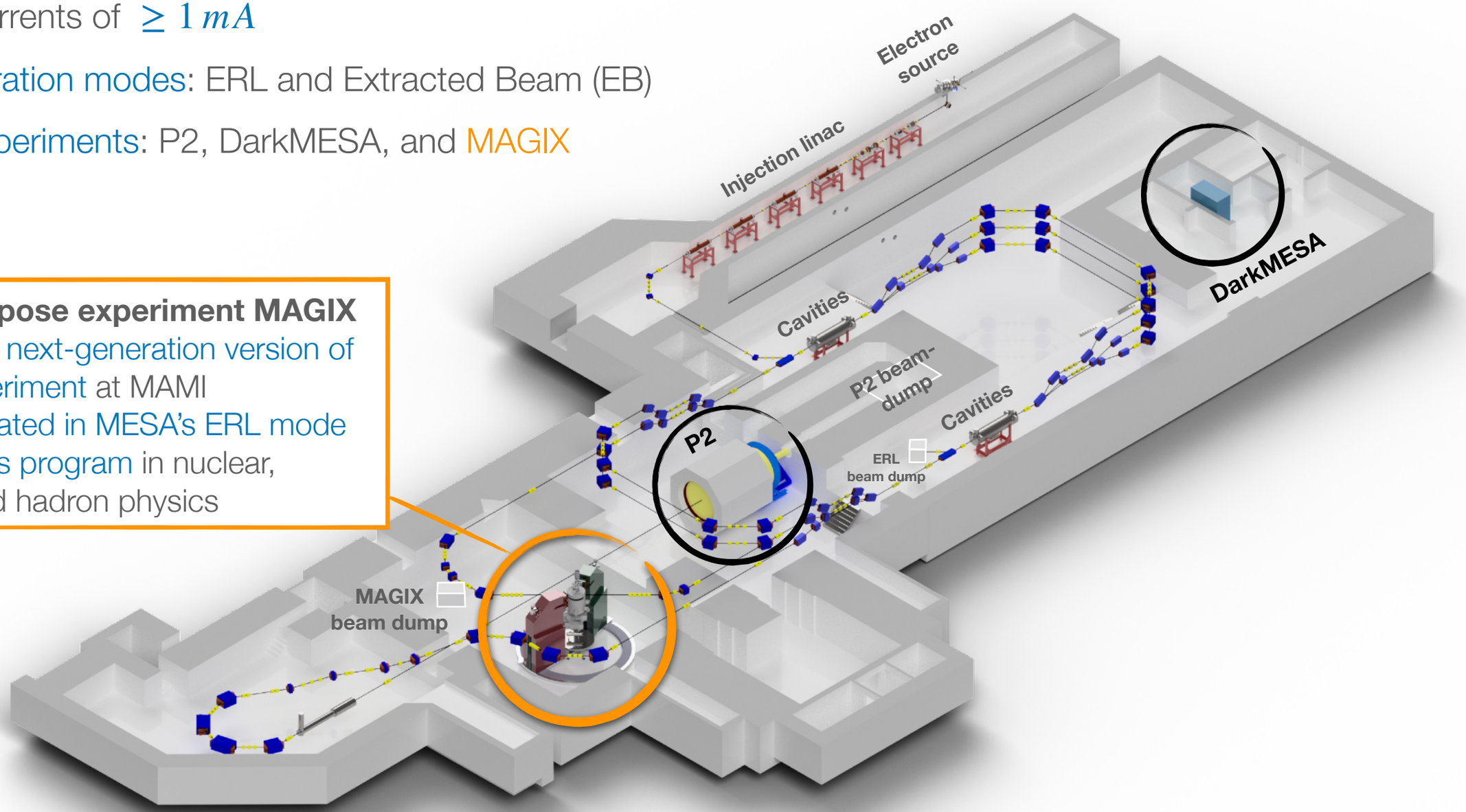


The low-energy electron accelerator MESA.

- **M**ainz **E**nergy-Recovering **S**uperconducting **A**ccelerator
- Double-sided Multi Turn **E**nergy-**R**ecovery **L**inac (ERL)
- Beam energies from $20\,MeV$ to $155\,MeV$
- Beam currents of $\geq 1\,mA$
- Two operation modes: ERL and Extracted Beam (EB)
- Three experiments: P2, DarkMESA, and MAGIX

The multi-purpose experiment MAGIX

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



MAGIX

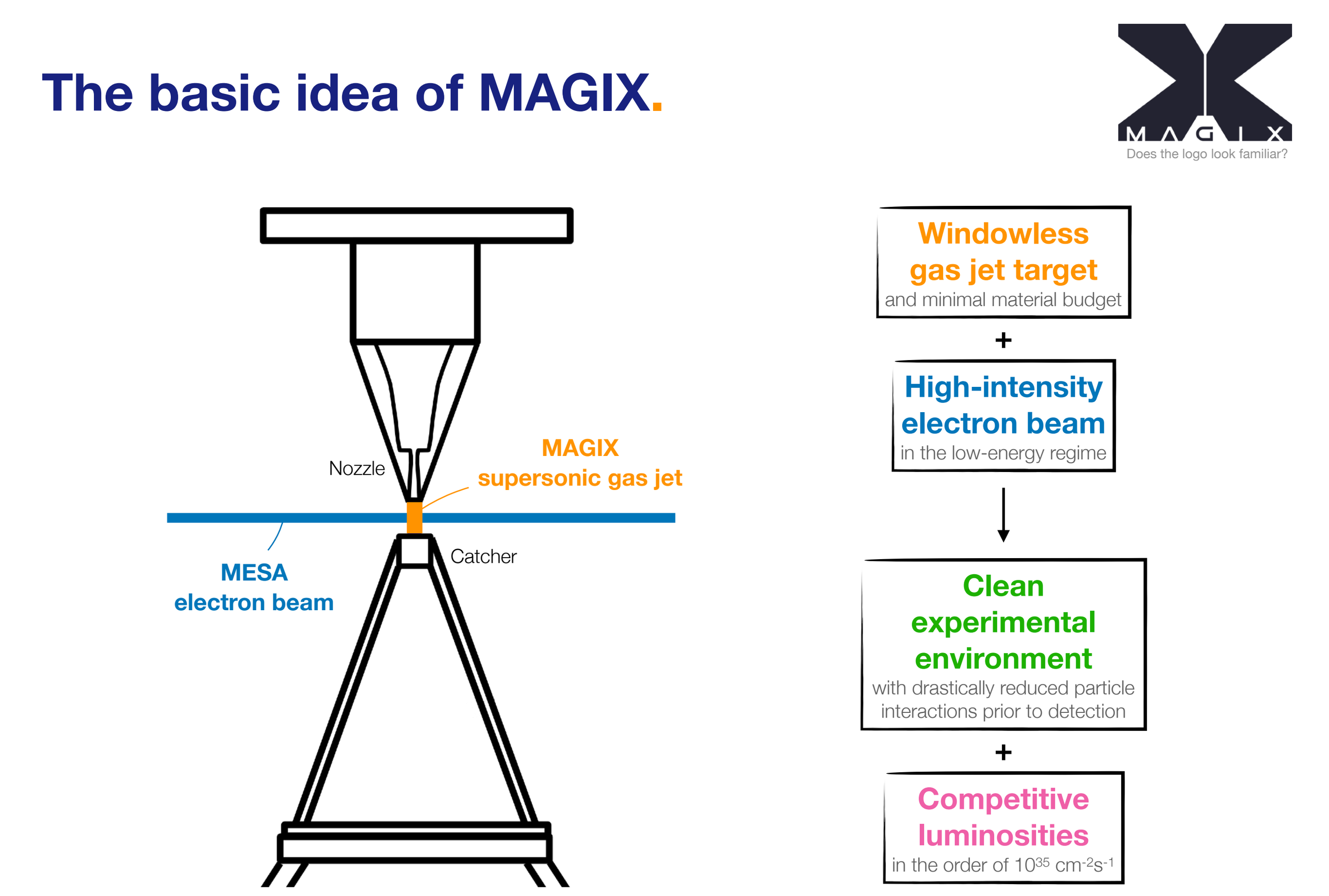
Gas Injection

Gas Internal

Gas Interaction

Grande Innovazione

The basic idea of MAGIX.



Windowless gas jet target
and minimal material budget

+

High-intensity electron beam
in the low-energy regime

↓

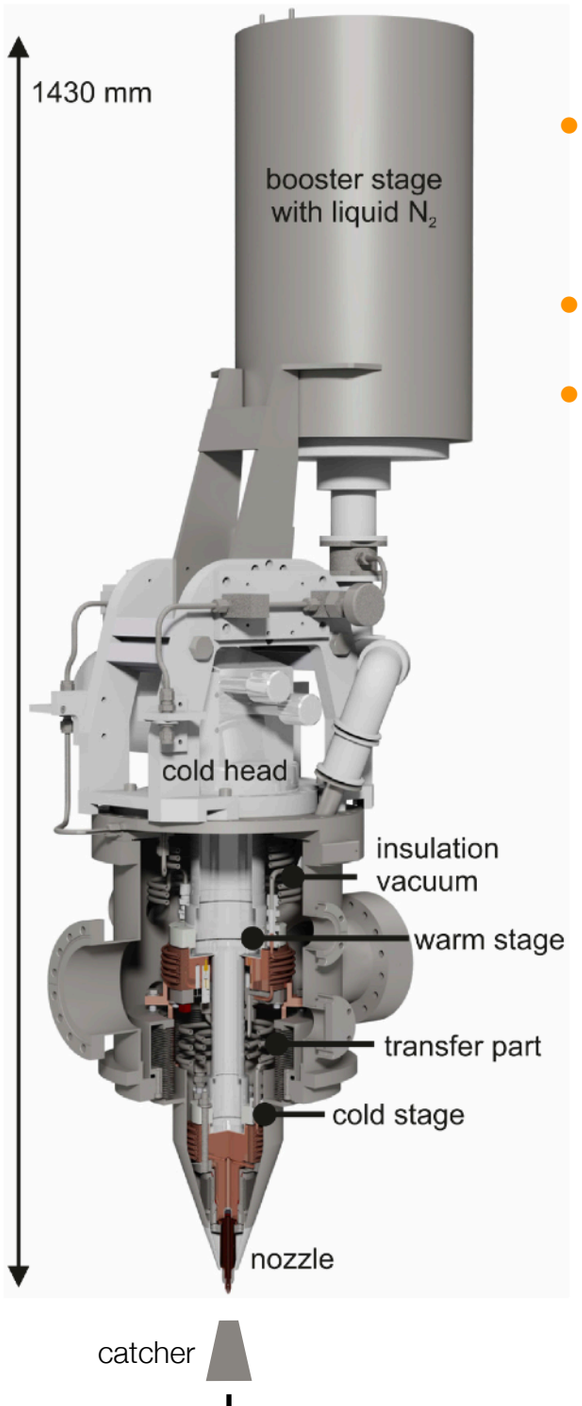
Clean experimental environment
with drastically reduced particle interactions prior to detection

+

Competitive luminosities
in the order of 10^{35} $cm^{-2}s^{-1}$

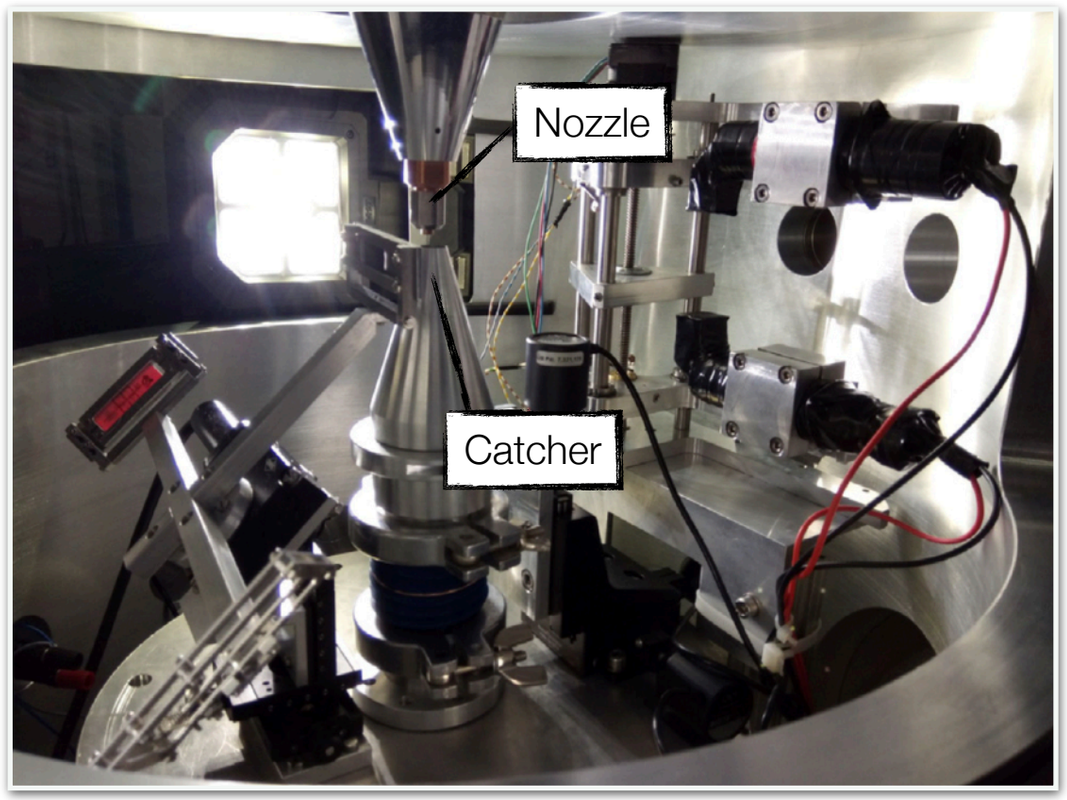
Does the logo look familiar?

The MAGIX gas jet target.

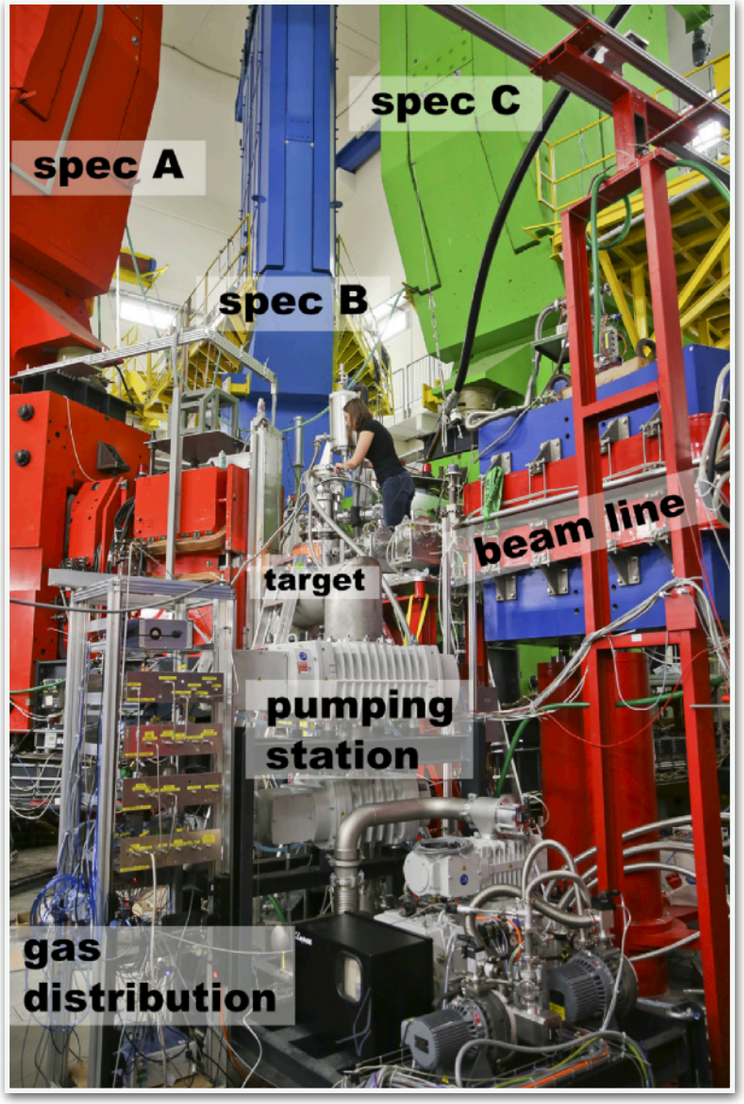


D. Bonaventura

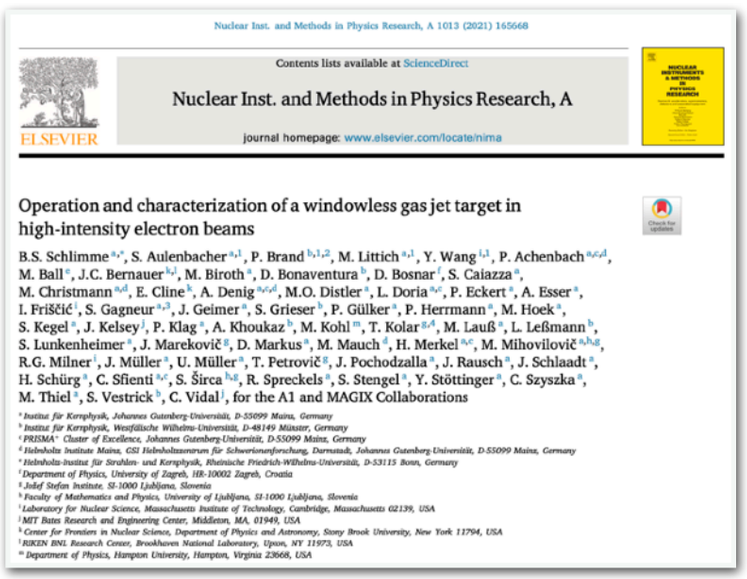
- Developed and constructed by AG Khoukaz at WWU Münster, Germany
- Windowless, thin, point-like jet target
- Already commissioned at A1 with hydrogen…



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



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



Nuclear Inst. and Methods in Physics Research, A 1013 (2021) 165668

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

journal homepage: www.elsevier.com/locate/nima

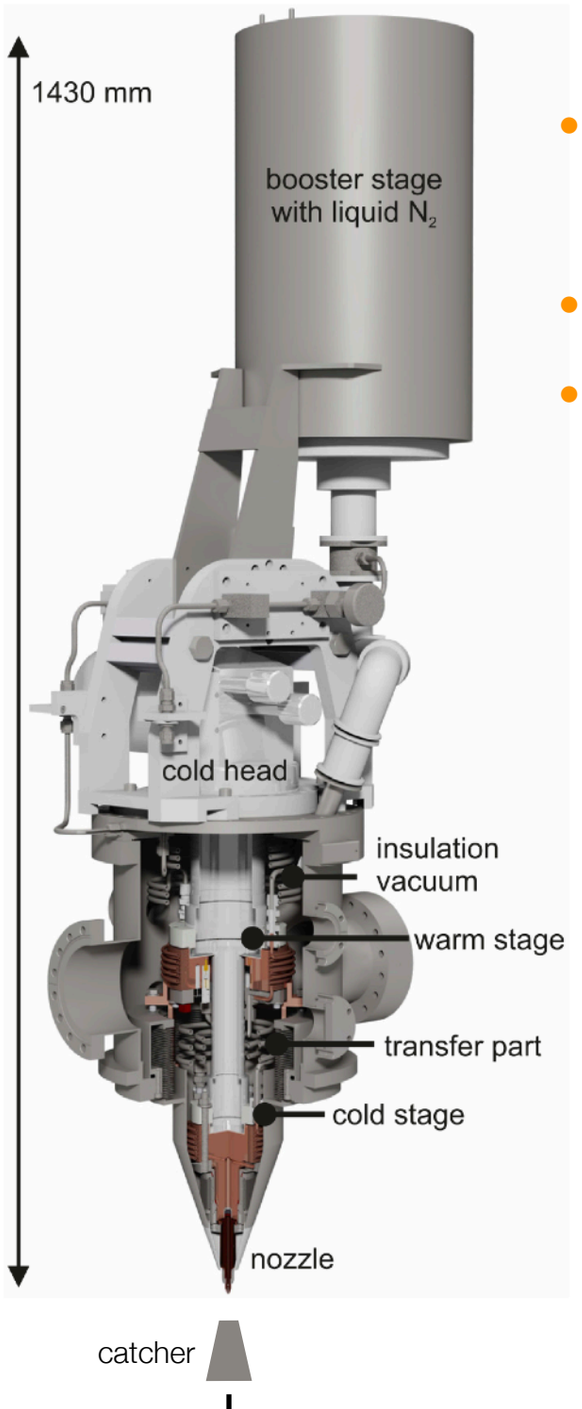
Operation and characterization of a windowless gas jet target in high-intensity electron beams

B.S. Schlimme [a,*], S. Aulenbacher [a,1], P. Brand [b,1,2], M. Littich [a,1], Y. Wang [i,1], P. Achenbach [a,c,d], M. Ball [e], J.C. Bernauer [b,j], M. Biroth [a], D. Bonaventura [b], D. Bosnar [f], S. Caiazza [a], M. Christmann [a,d], E. Cline [k], A. Denig [a,c,d], M.O. Distler [a], L. Doria [a,c], P. Eckert [a], A. Esser [a], I. Fišić [i], S. Gagneur [a,3], J. Geimer [a], S. Grieser [b], P. Gülker [a], P. Herrmann [a], M. Hoek [a], S. Kegel [a], J. Kelsey [j], P. Klag [a], A. Khoukaz [b], M. Kohl [m], T. Kolar [g,4], M. Lauß [a], L. Leßmann [b], S. Lunkenheimer [a], J. Marekovič [g], D. Markus [a], M. Mauch [d], H. Merkel [a,c], M. Mihovilovič [a,h,g], R.G. Milner [i], J. Müller [a], U. Müller [a], T. Petrovič [g], J. Pochodzalla [a], J. Rausch [a], J. Schlaadt [a], H. Schürg [a], C. Sfienti [a,c], S. Širca [h,g], R. Spreckels [a], S. Stengel [a], Y. Stöttinger [a], C. Szyszka [a], M. Thiel [a], S. Vestrick [b], C. Vidal [i], for the A1 and MAGIX Collaborations

[a] Institut für Kernphysik, Johannes Gutenberg-Universität, D-55099 Mainz, Germany
[b] Institut für Kernphysik, Westfälische Wilhelms-Universität, D-48149 Münster, Germany
[c] PRISMA+ Cluster of Excellence, Johannes Gutenberg-Universität, D-55099 Mainz, Germany
[d] Helmholtz Institute Mainz, GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Johannes Gutenberg-Universität, D-55099 Mainz, Germany
[e] Helmholtz-Institut für Strahlen- und Kernphysik, Rheinische Friedrich-Wilhelms-Universität, D-53115 Bonn, Germany
[f] Department of Physics, University of Zagreb, HR-10002 Zagreb, Croatia
[g] Jožef Stefan Institute, SI-1000 Ljubljana, Slovenia
[h] Faculty of Mathematics and Physics, University of Ljubljana, SI-1000 Ljubljana, Slovenia
[i] Laboratory for Nuclear Science, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA
[j] MIT Bates Research and Engineering Center, Middleton, MA, 01949, USA
[k] Center for Frontiers in Nuclear Science, Department of Physics and Astronomy, Stony Brook University, New York 11794, USA
[l] RIKEN BNL Research Center, Brookhaven National Laboratory, Upton, NY 11973, USA
[m] Department of Physics, Hampton University, Hampton, Virginia 23668, USA

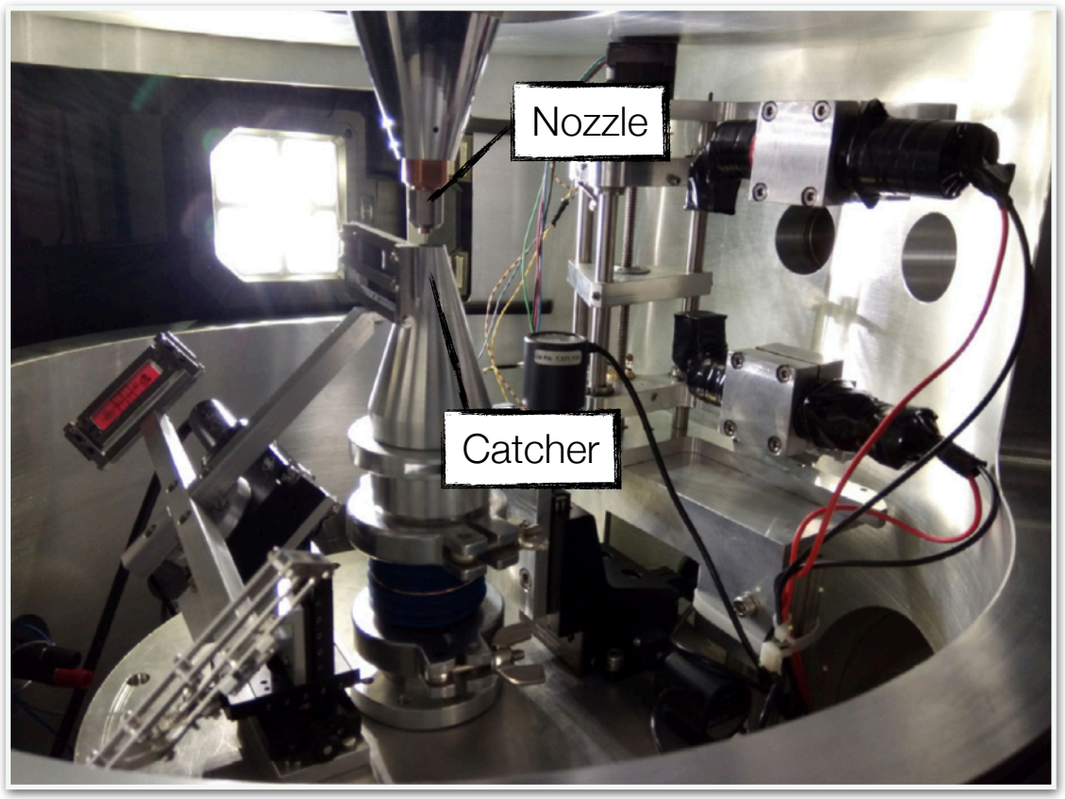
S. Schlimme *et al.* ,10.1016/j.nima.2021.165668

The MAGIX gas jet target.



D. Bonaventura

- Developed and constructed by AG Khoukaz at WWU Münster, Germany
- Windowless, thin, point-like jet target
- Already commissioned at A1 with hydrogen and argon



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

M. Littich *et al.*, *10.1140/epja/s10050-025-01623-4*

Eur. Phys. J. A (2025) 61:152
https://doi.org/10.1140/epja/s10050-025-01623-4

THE EUROPEAN PHYSICAL JOURNAL A

Regular Article - Experimental Physics

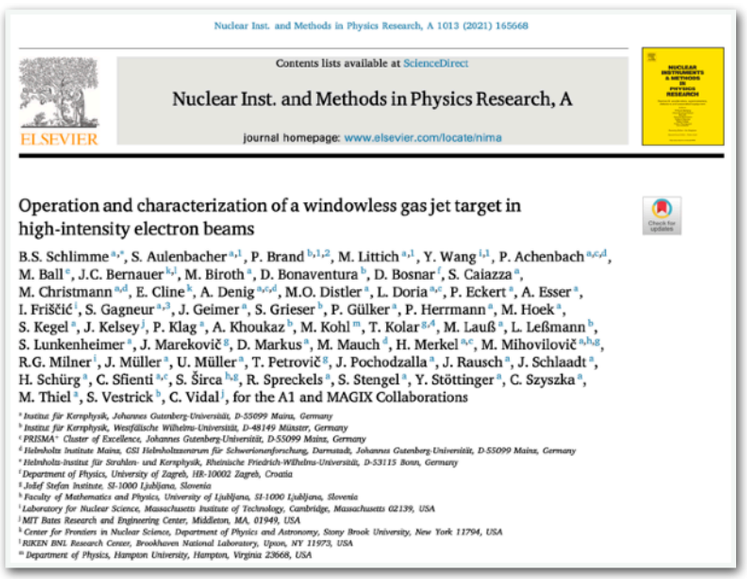
Measurement of the ^{40}Ar(e,e′) elastic scattering cross section with a novel gas-jet target

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

[1] Institut für Kernphysik, Johannes Gutenberg-Universität, 55128 Mainz, Germany
[2] Institut für Kernphysik, Universität Münster, 48149 Münster, Germany
[3] Department of Physics and Astronomy, Center for Frontiers in Nuclear Science, Stony Brook University, New York 11794, USA
[4] Department of Physics, Faculty of Science, University of Zagreb, Zagreb, Croatia
[5] Laboratory for Nuclear Science, Massachusetts Institute
[6] Jožef Stefan Institute, 1000 Ljubljana, Slovenia
[7] Faculty of Mathematics and Physics, University of Ljub
[8] Institute of Physics, University of Silesia in Katowice, 4

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

P. Brand



Nuclear Inst. and Methods in Physics Research, A 1013 (2021) 165668

Contents lists available at ScienceDirect

Nuclear Inst. and Methods in Physics Research, A

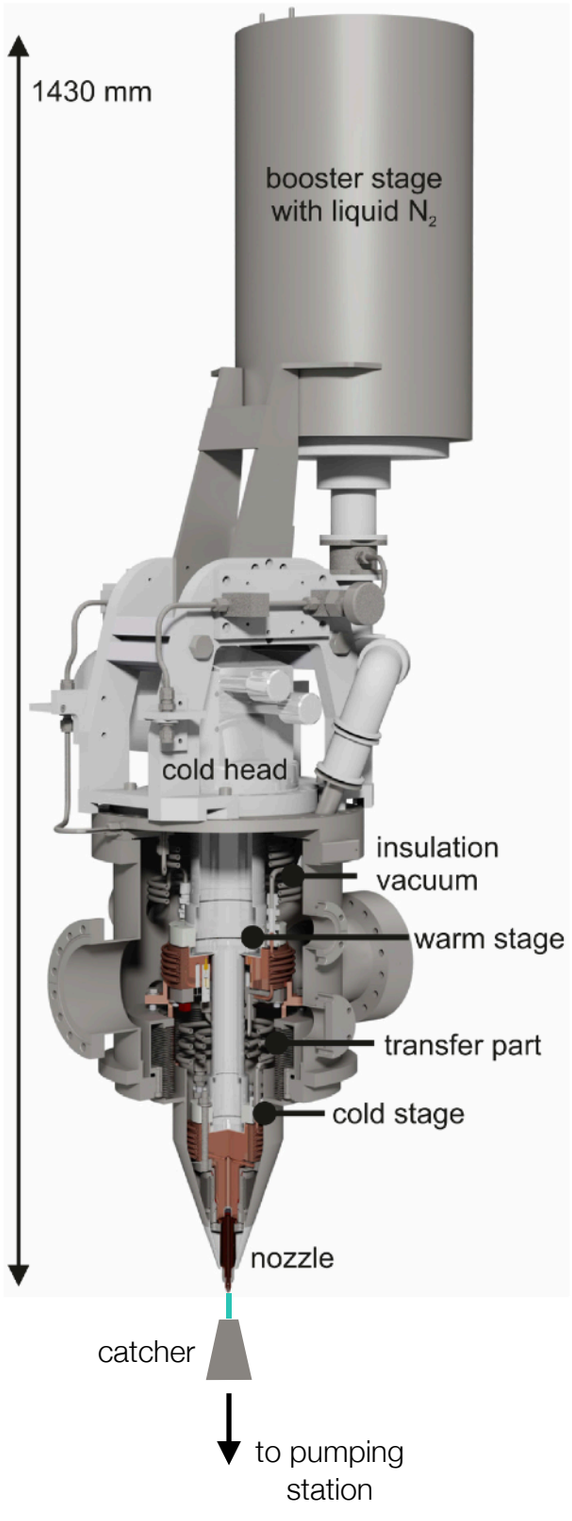
journal homepage: www.elsevier.com/locate/nima

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

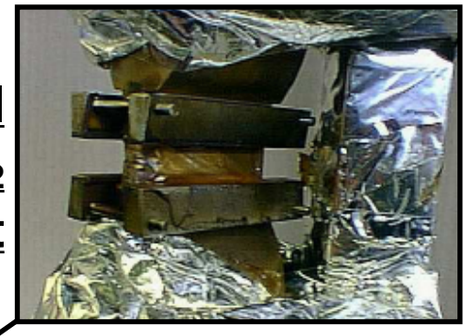
B.S. Schlimme[a,*], S. Aulenbacher[a,1], P. Brand[b,1,2], M. Littich[a,1], Y. Wang[i,1], P. Achenbach[a,c,d], M. Ball[e], J.C. Bernauer[b,j], M. Biroth[a], D. Bonaventura[b], D. Bosnar[f], S. Caiazza[a], M. Christmann[a,d], E. Cline[k], A. Denig[a,c,d], M.O. Distler[a], L. Doria[a,c], P. Eckert[a], A. Esser[a], I. Friščić[i], S. Gagneur[a,3], J. Geimer[a], S. Grieser[b], P. Gülker[a], P. Herrmann[a], M. Hoek[a], S. Kegel[a], J. Kelsey[j], P. Klag[a], A. Khoukaz[b], M. Kohl[m], T. Kolar[g,4], M. Lauß[a], L. Leßmann[b], S. Lunkenheimer[a], J. Marekovič[g], D. Markus[a], M. Mauch[d], H. Merkel[a,c], M. Mihovilovič[a,h,g], R.G. Milner[l], J. Müller[a], U. Müller[a], T. Petrovič[g], J. Pochodzalla[a], J. Rausch[a], J. Schlaadt[a], H. Schürg[a], C. Sfienti[a,c], S. Širca[h,g], R. Spreckels[a], S. Stengel[a], Y. Stöttinger[a], C. Szyszka[a], M. Thiel[a], S. Vestrick[b], C. Vidal[j], for the A1 and MAGIX Collaborations

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

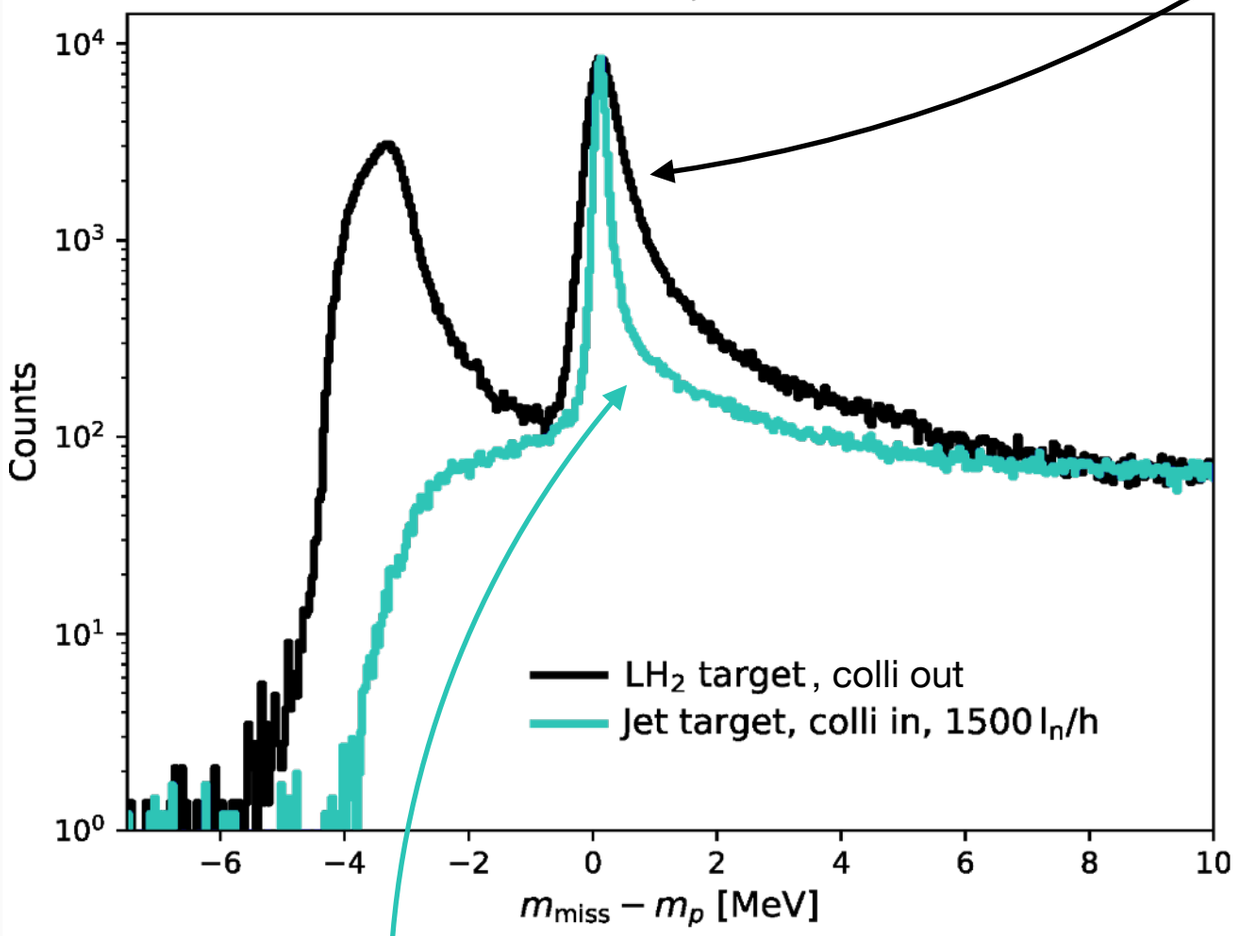
Benefits of a gas jet target.



Typical liquid H_2 target



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



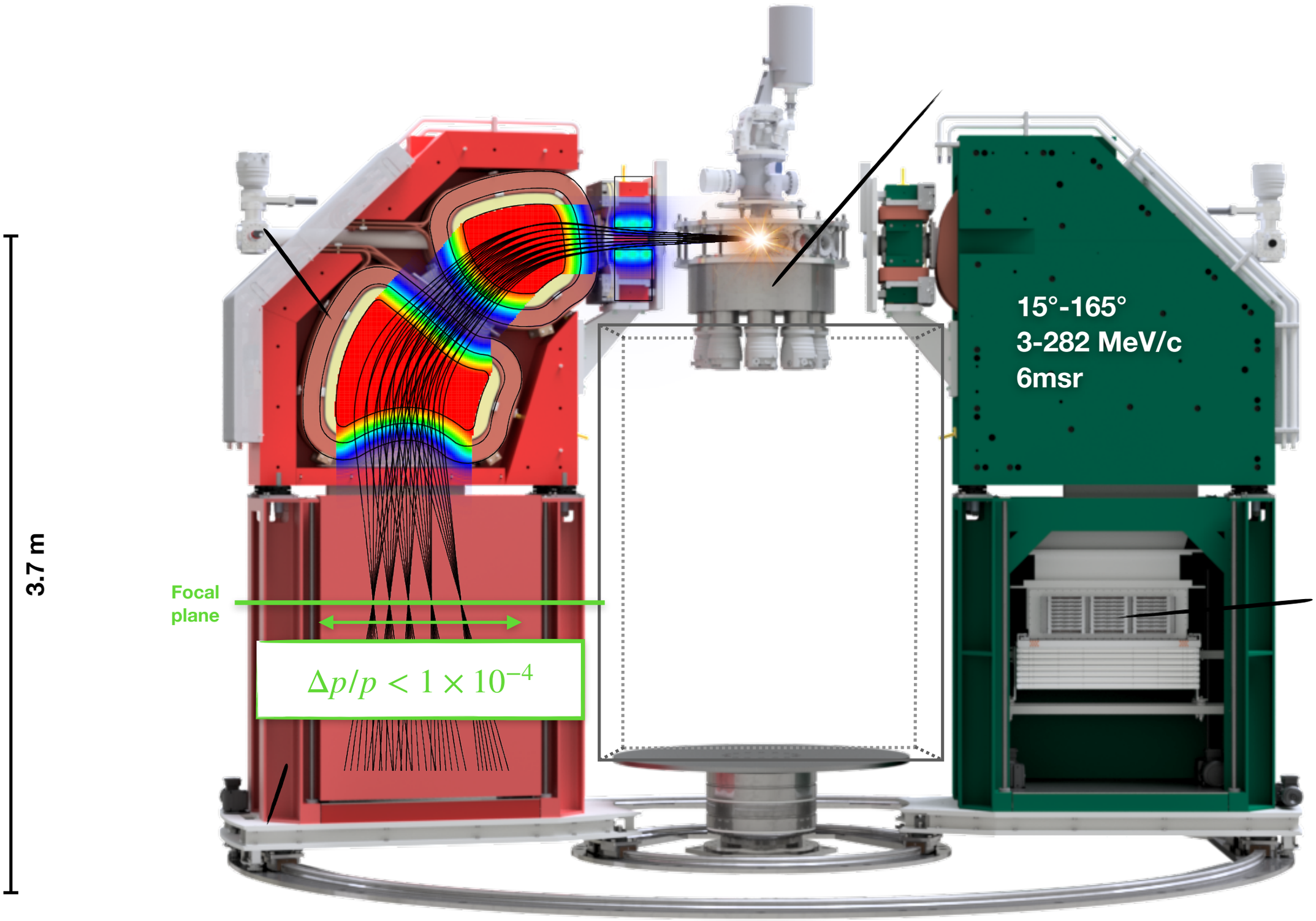
- Large energy straggling and multiple scattering
- Background from target foils/cell

H_2 gas jet target

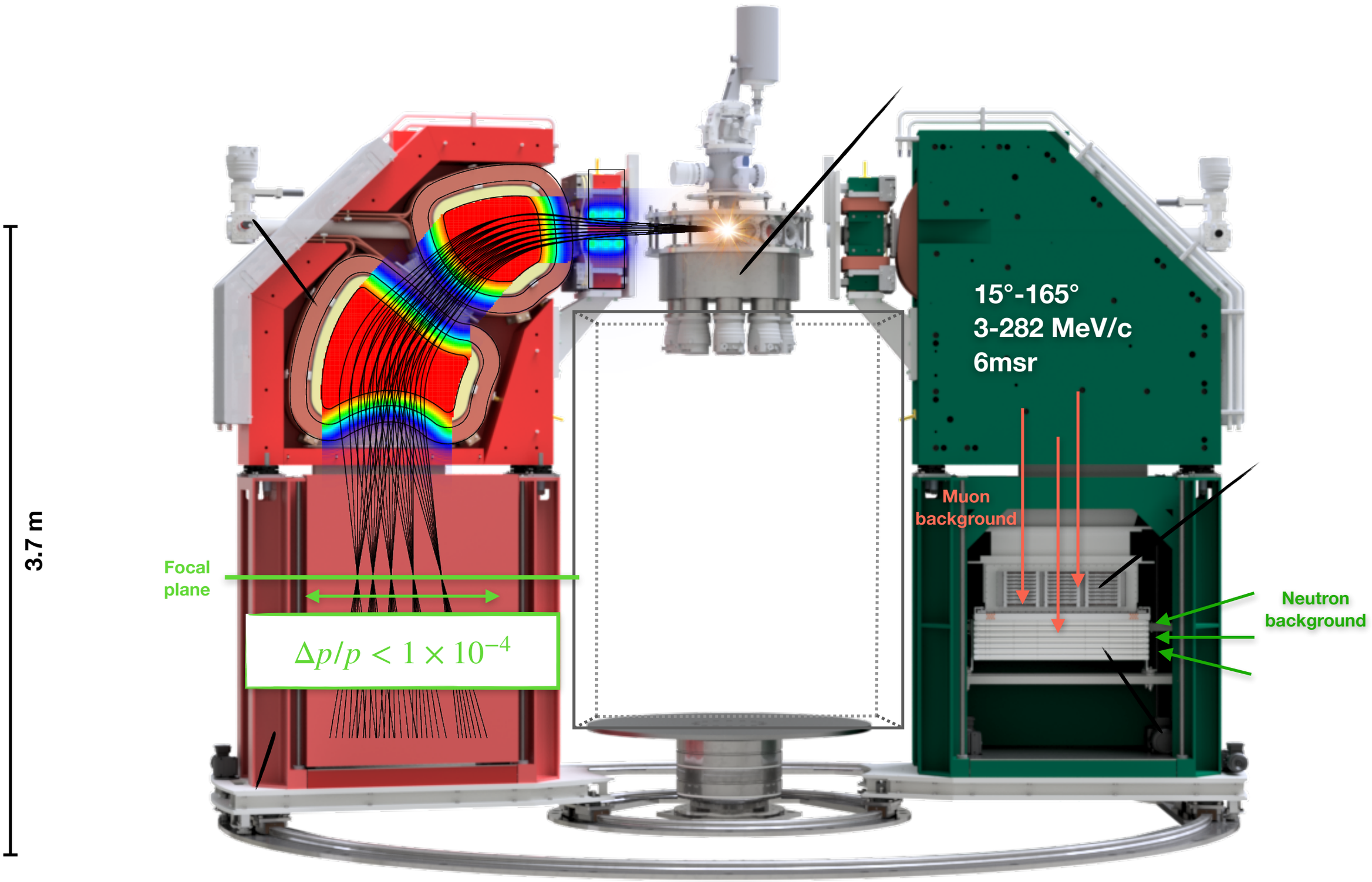
- Sharper elastic peak in electron-proton scattering
- Background effects drastically reduced

D. Bonaventura

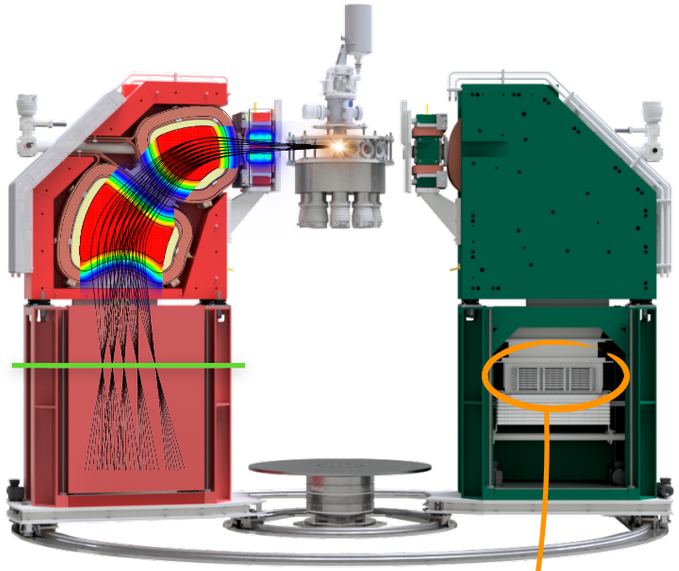
The MAGIX setup.

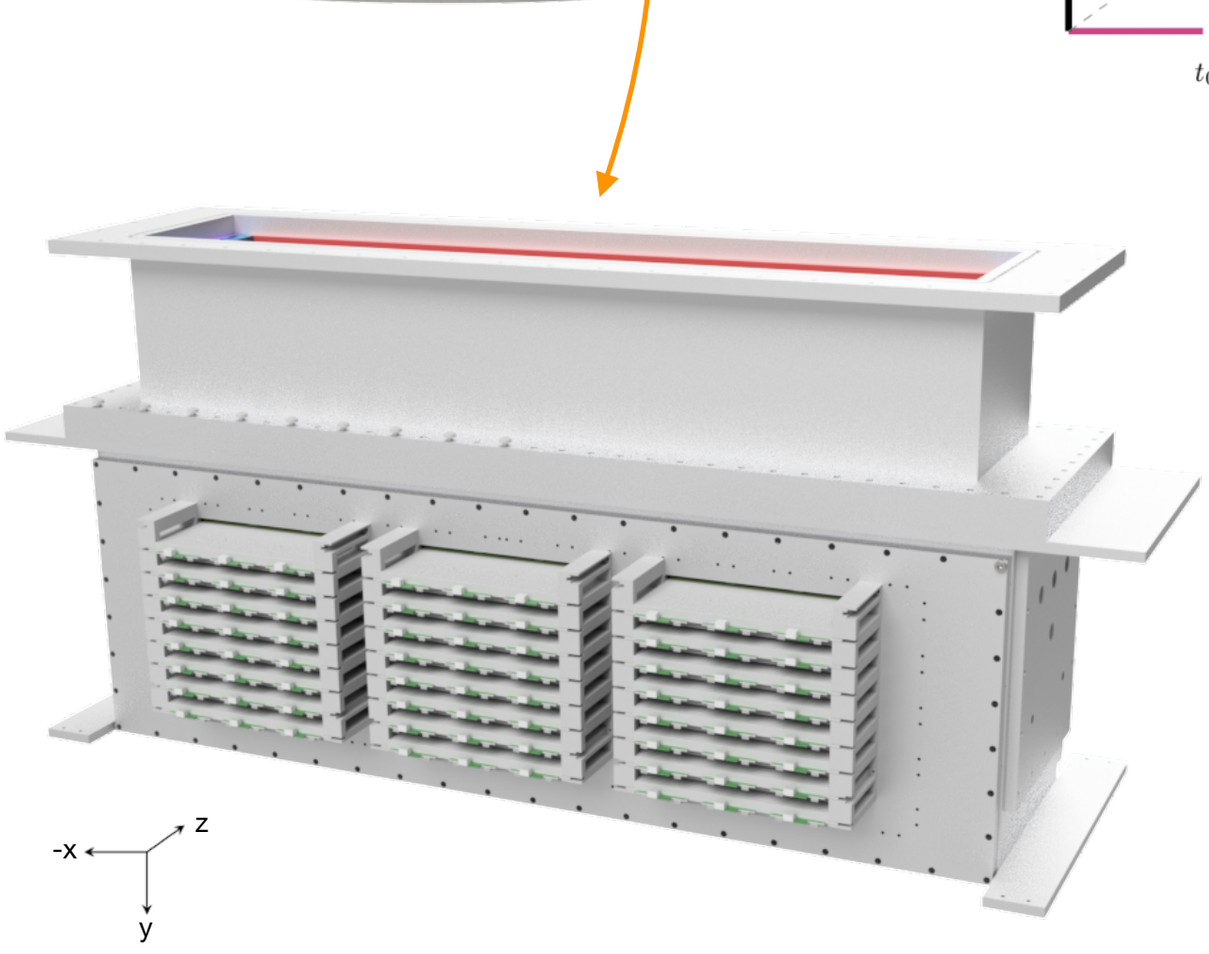


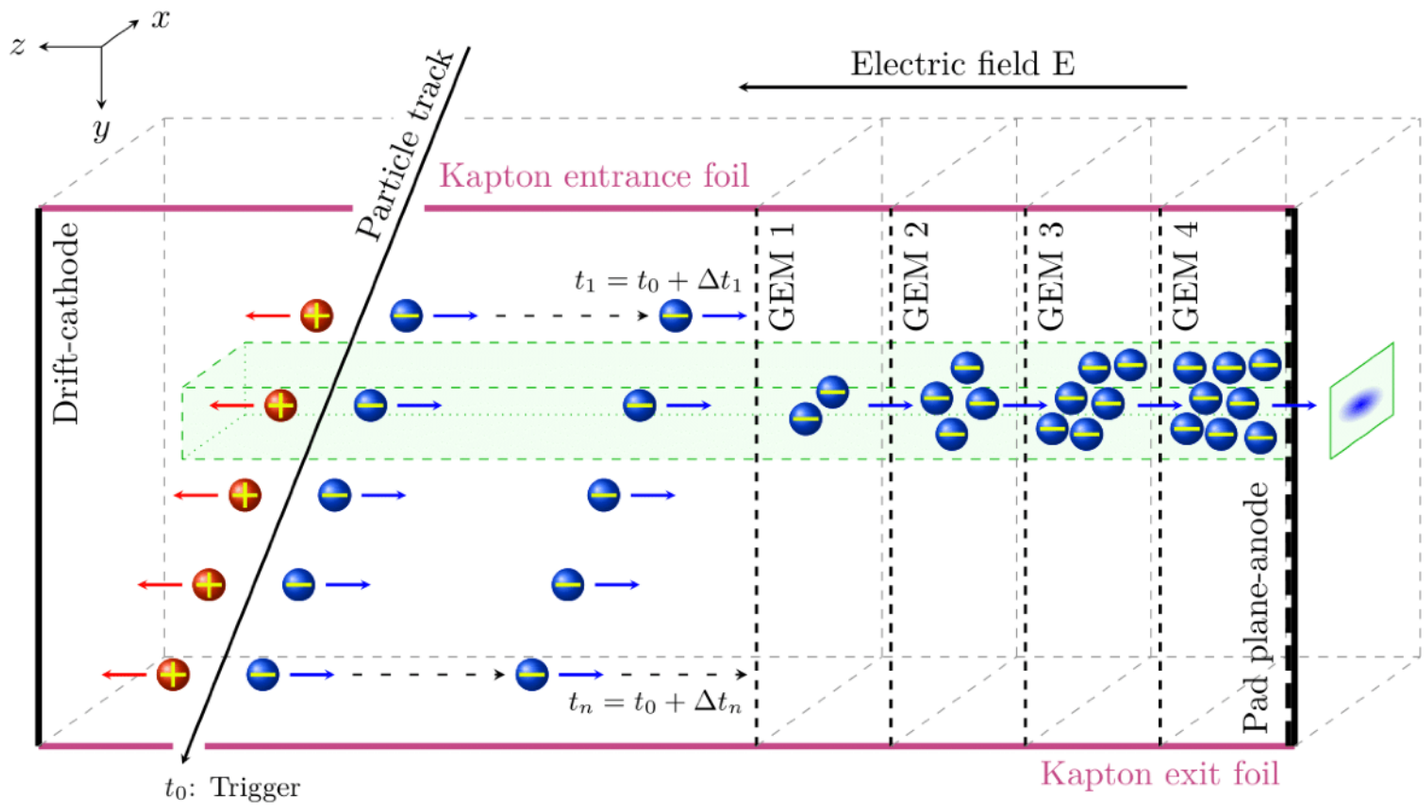
The MAGIX setup.



The MAGIX TPC.

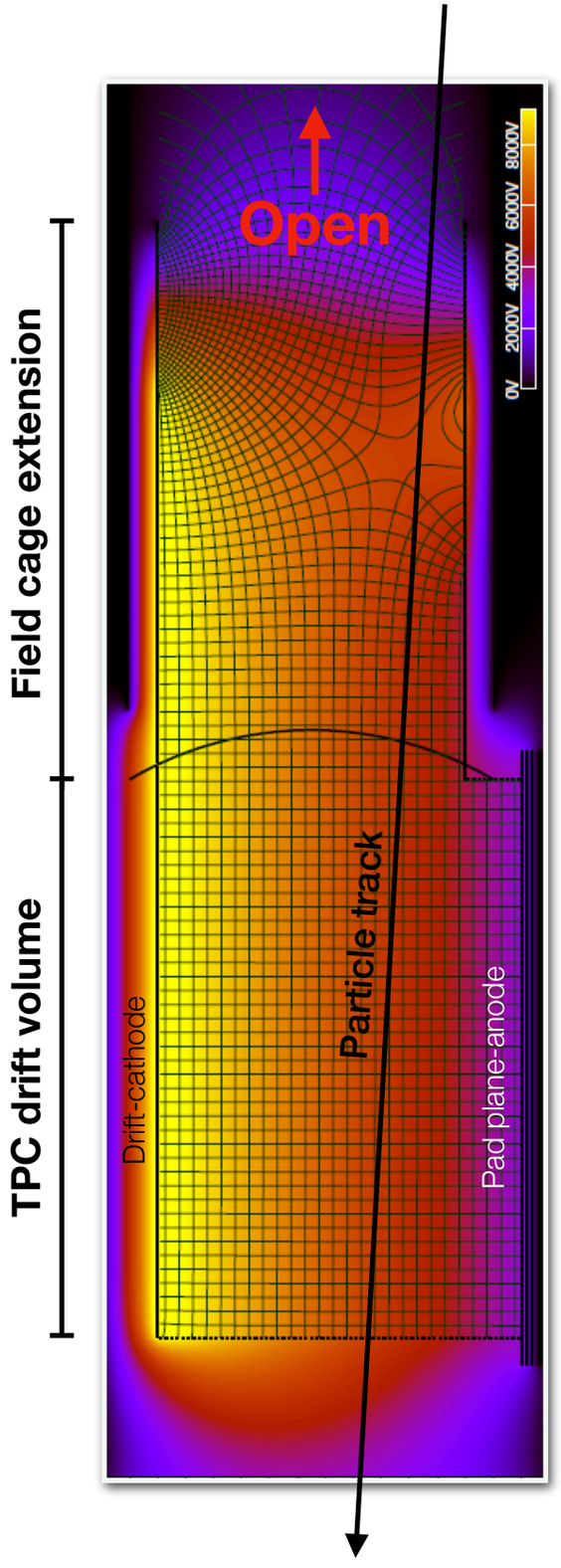


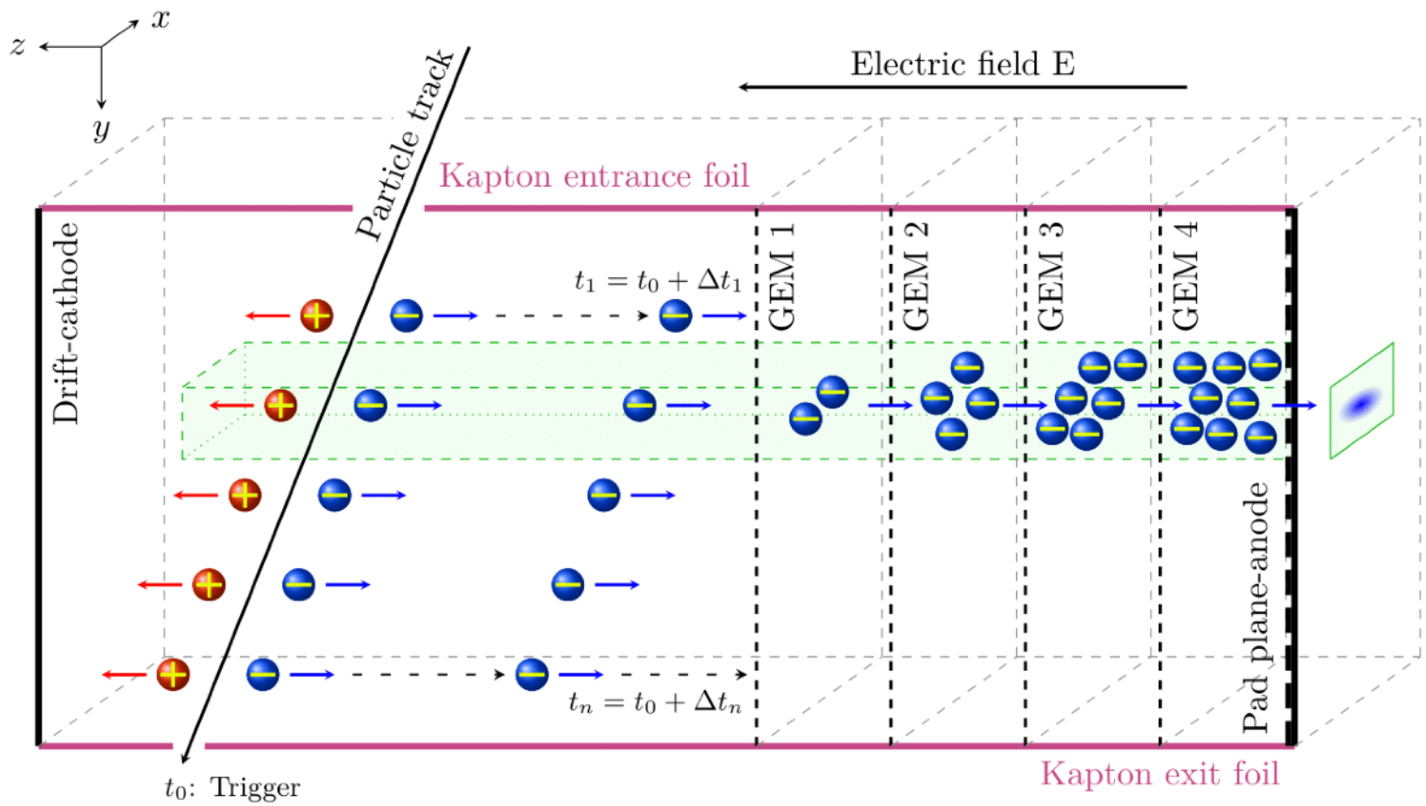




- TPC based on a stack of four Gas Electron Multipliers (GEMs)
- Segmented readout at the pad plane-anode
- 3D track reconstruction via projection on pad plane-anode (2D) plus drift time (1D)
- Expected accuracy in the focal plane coordinates: $\Delta x = 100 \mu m$ and $\Delta\theta = 3.5 mrad$

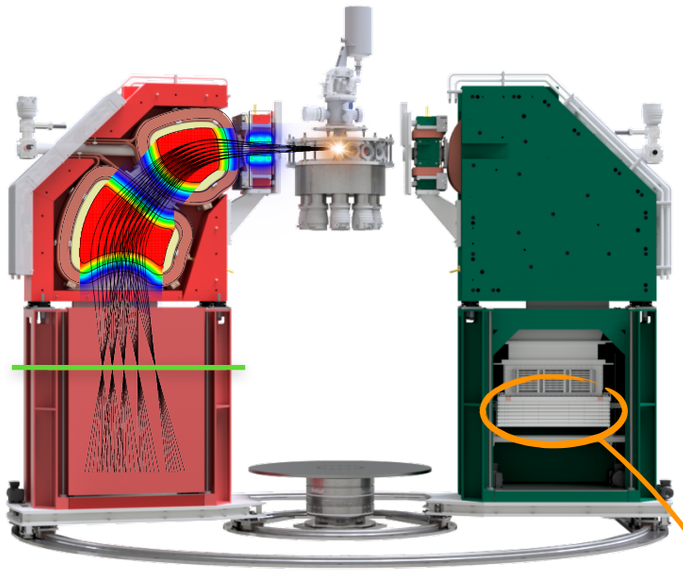
The MAGIX TPC.



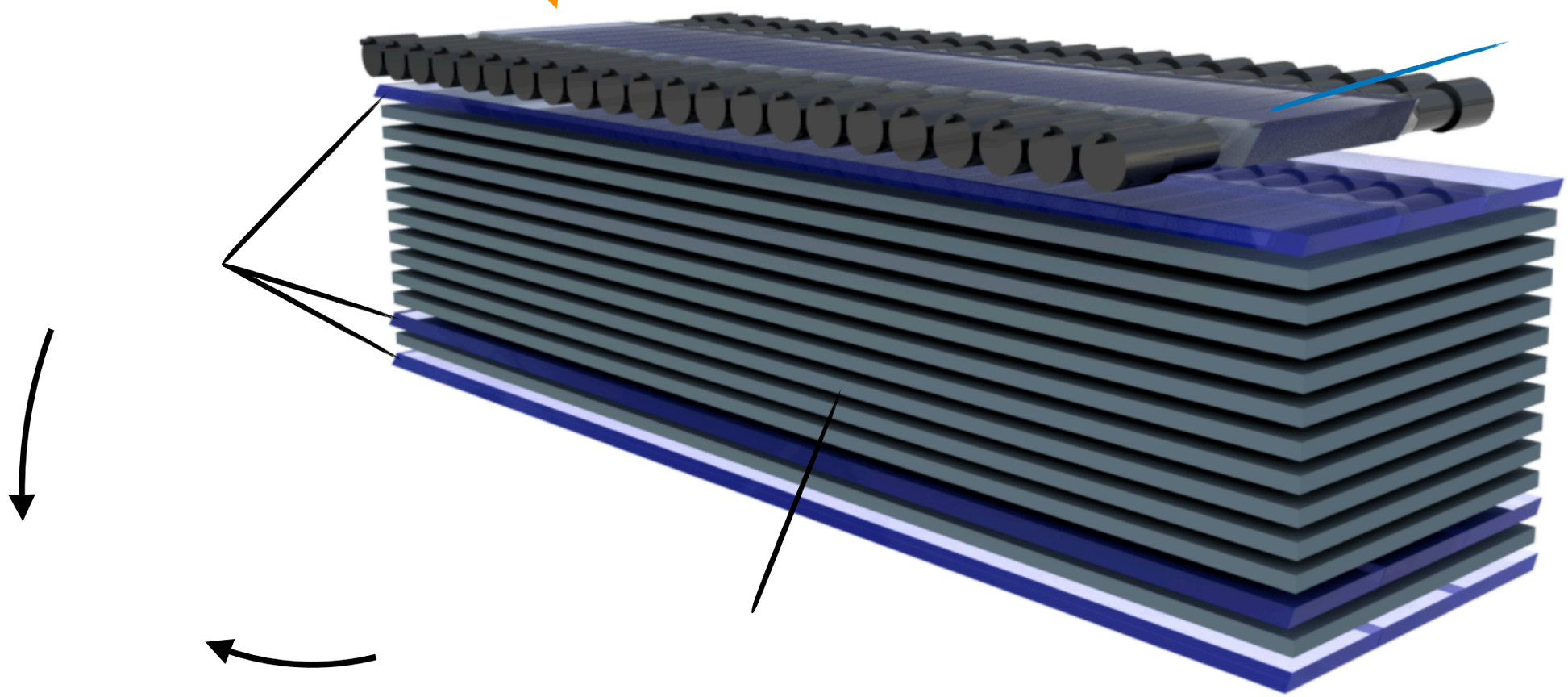


- TPC based on a stack of four Gas Electron Multipliers (GEMs)
- Segmented readout at the pad plane-anode
- 3D track reconstruction via projection on pad plane-anode (2D) plus drift time (1D)
- Expected accuracy in the focal plane coordinates: $\Delta x = 100\mu m$ and $\Delta\theta = 3.5mrad$
- Novel open field cage design to minimize the material budget

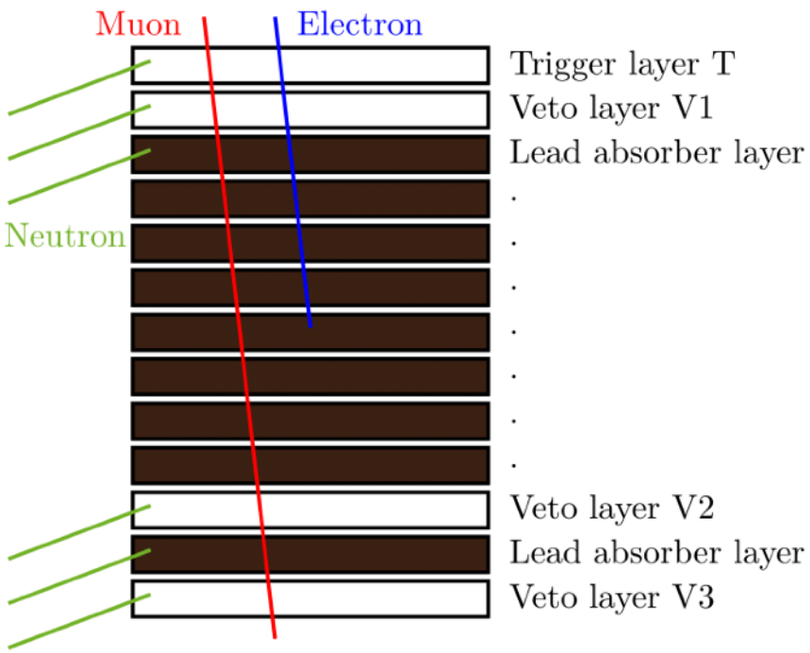
The MAGIX Trigger Veto System.

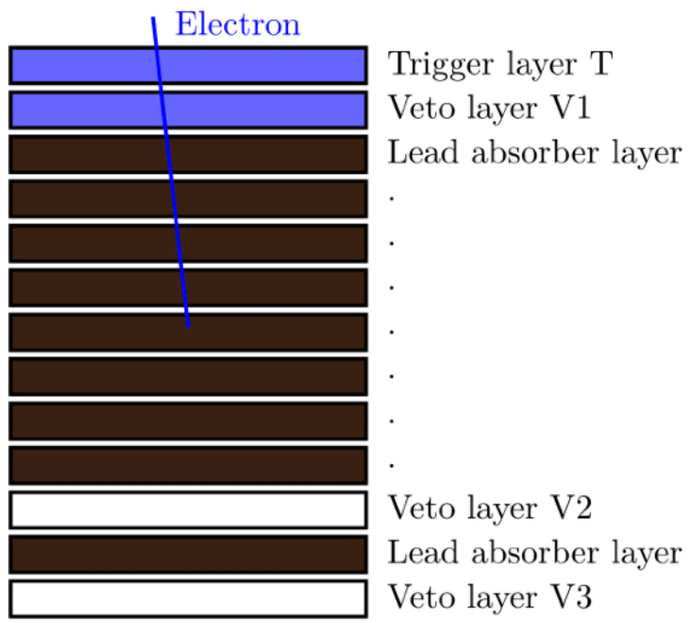


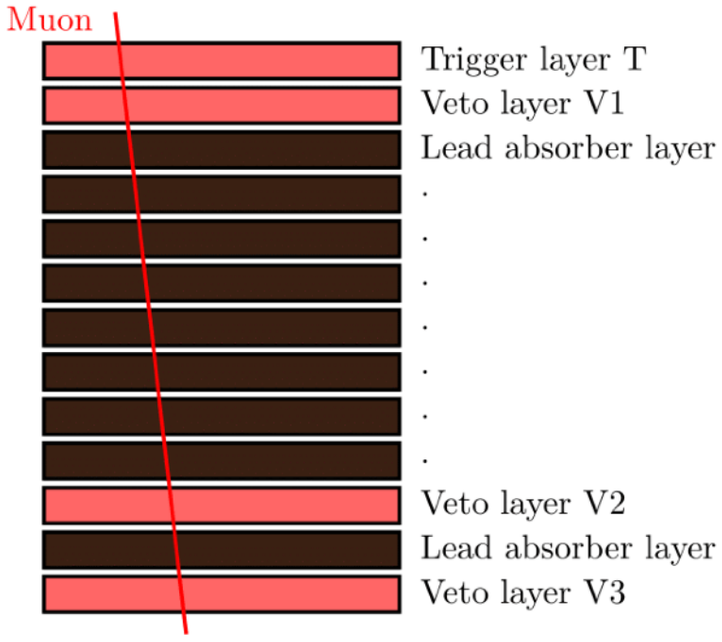
- Combine triggering and PID in one modular system
- Segmented trigger layer at the top, made of plastic scintillators read out by PMTs
- A flexible veto system underneath, built from:
  - Several veto layers, made of plastic scintillators read out by SiPMs
  - Passive lead absorber layers in between

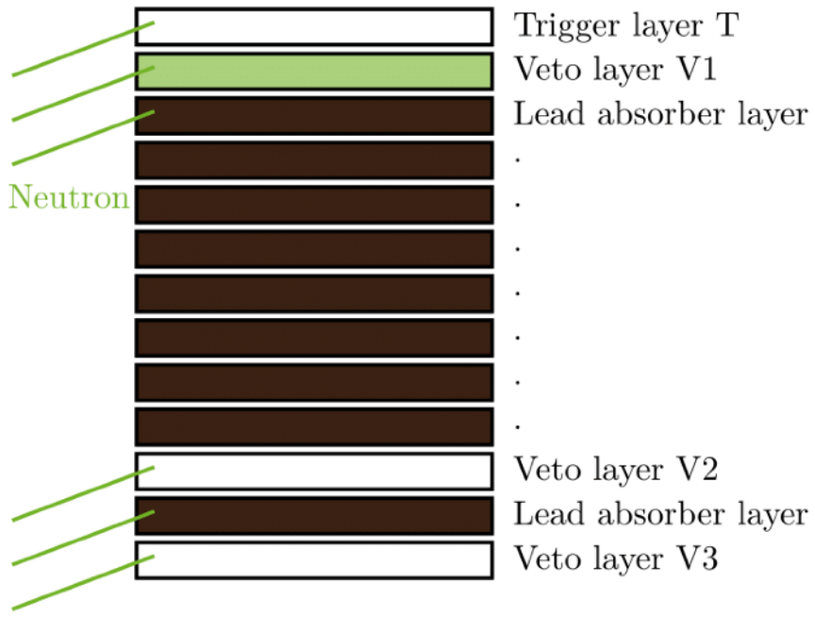


Working principle of the trigger veto system.

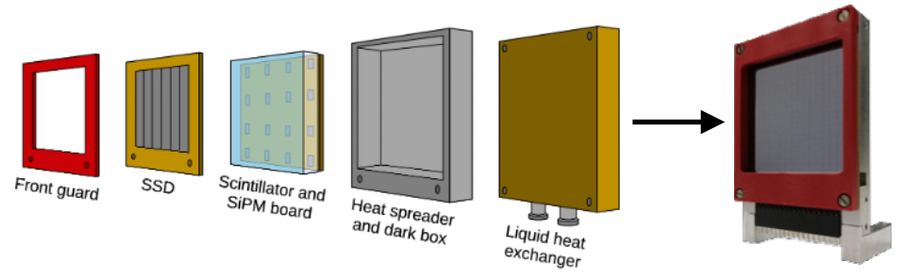


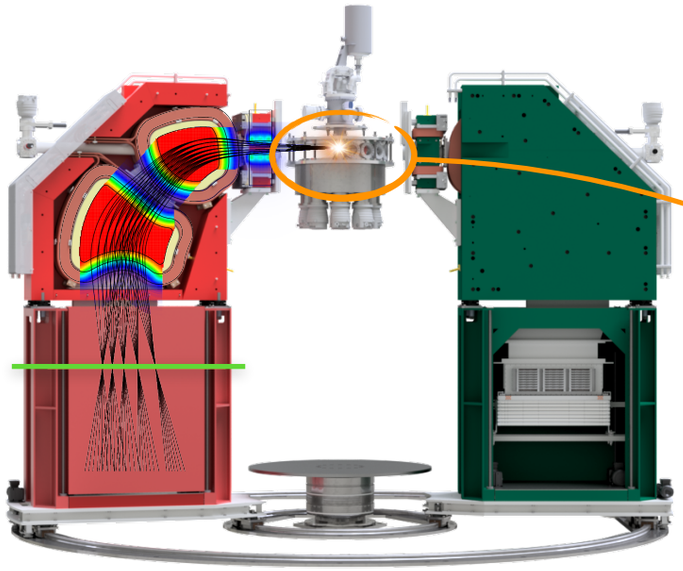


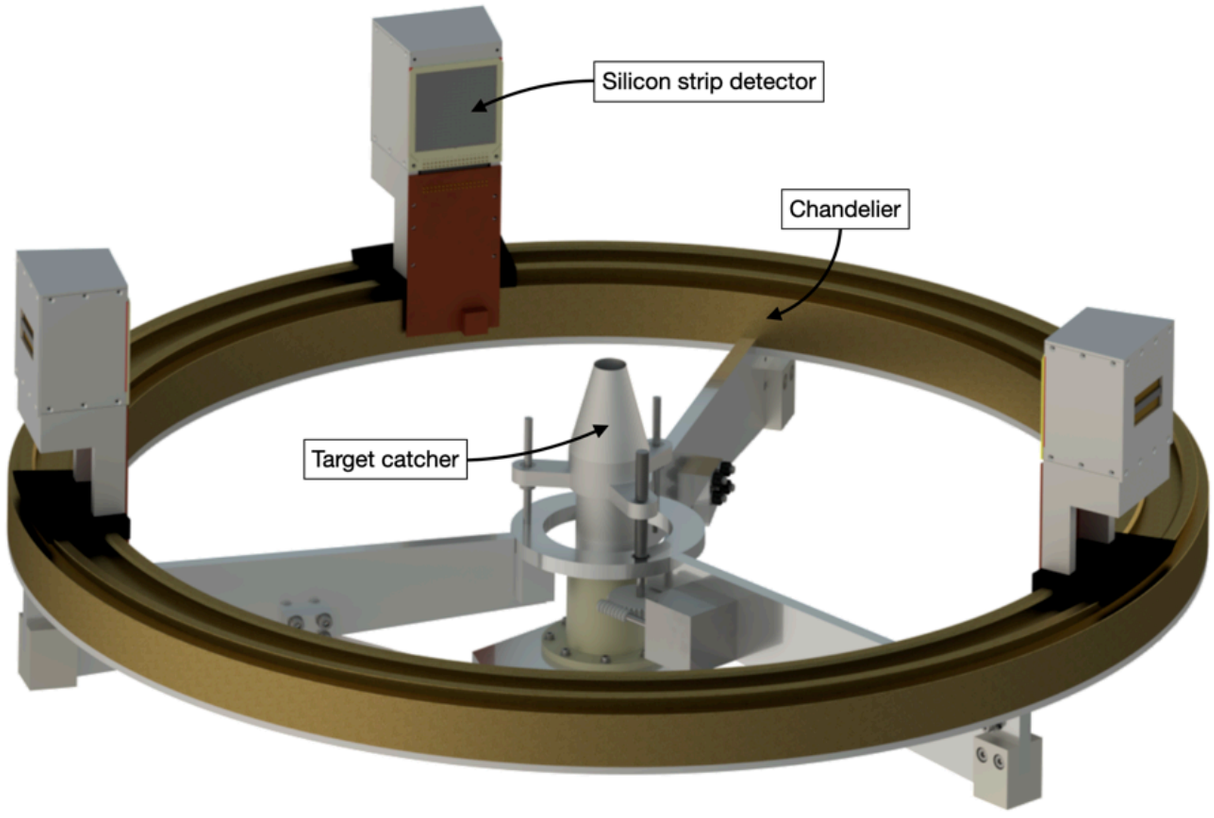




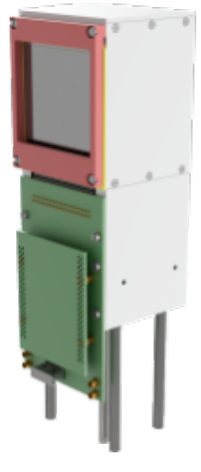
Recoil detector array.

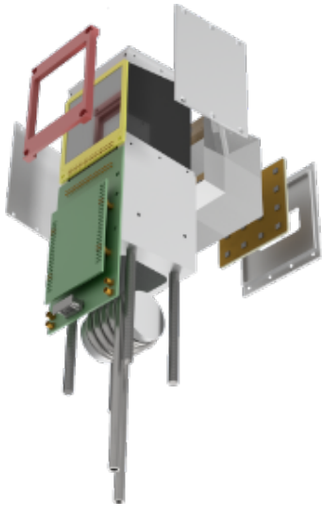






- Additional detector array for low-energy recoil nuclei
- Mounted inside the scattering chamber with no material between reaction vertex and detectors
- Individual detectors built from silicon strip + scintillation detectors





MAGIX

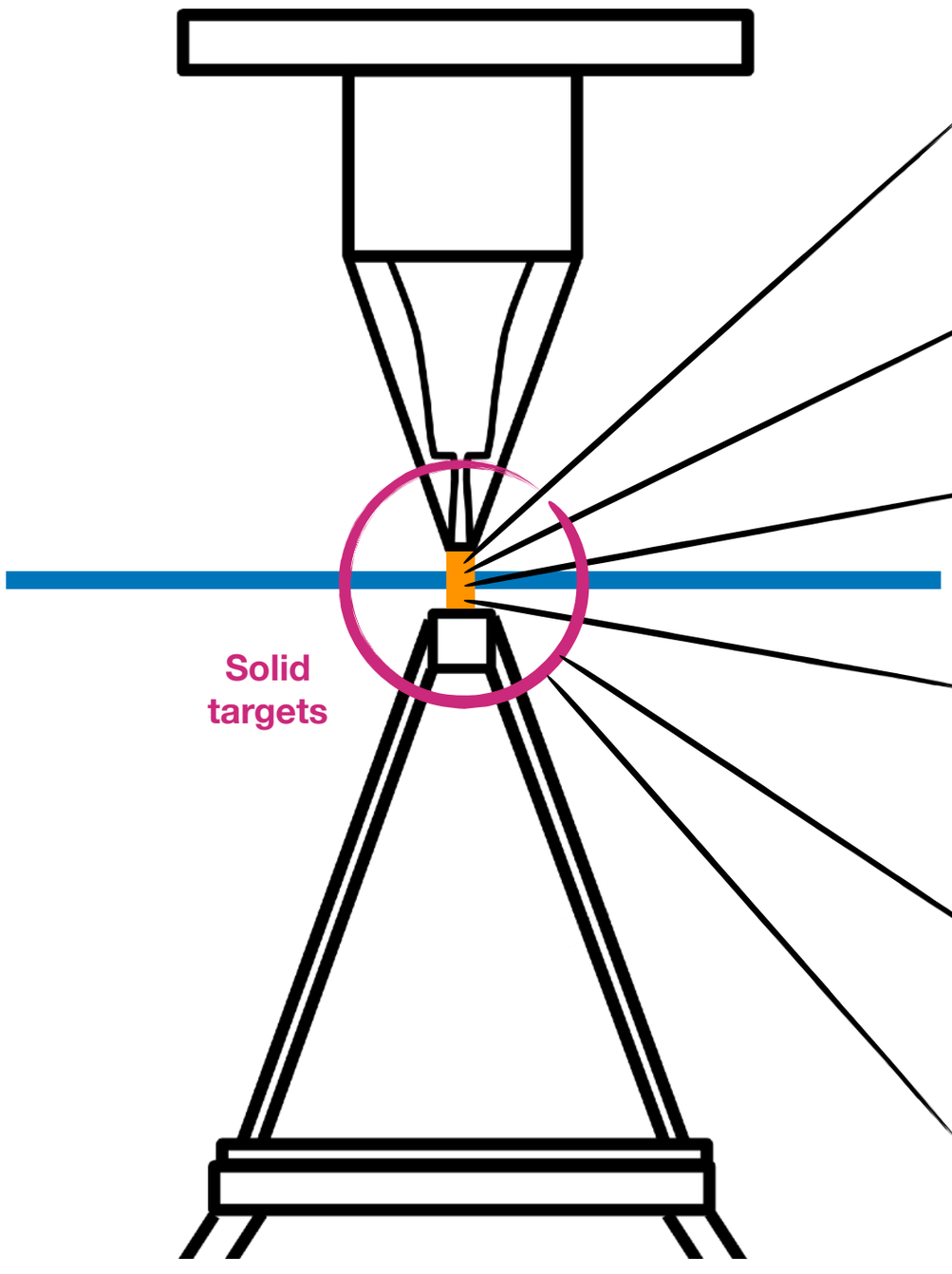
EXperiment

Exploration

Excellence

Exattezza

A versatile physics program.



Hydrogen
- Electromagnetic form factors (G_E and G_M) of the proton
- …

Helium
- Transition form factor of ^{4}He
- …

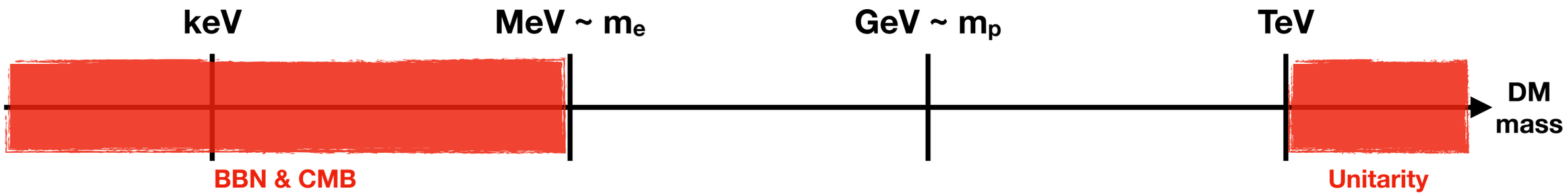
Oxygen
- Astrophysical S-factor of the reaction $^{12}C(\alpha,\gamma)^{16}O$
- …

Deuterium, Argon, Xenon, …
- …

Carbon
- Transition form factor of the Hoyle state in ^{12}C
- …

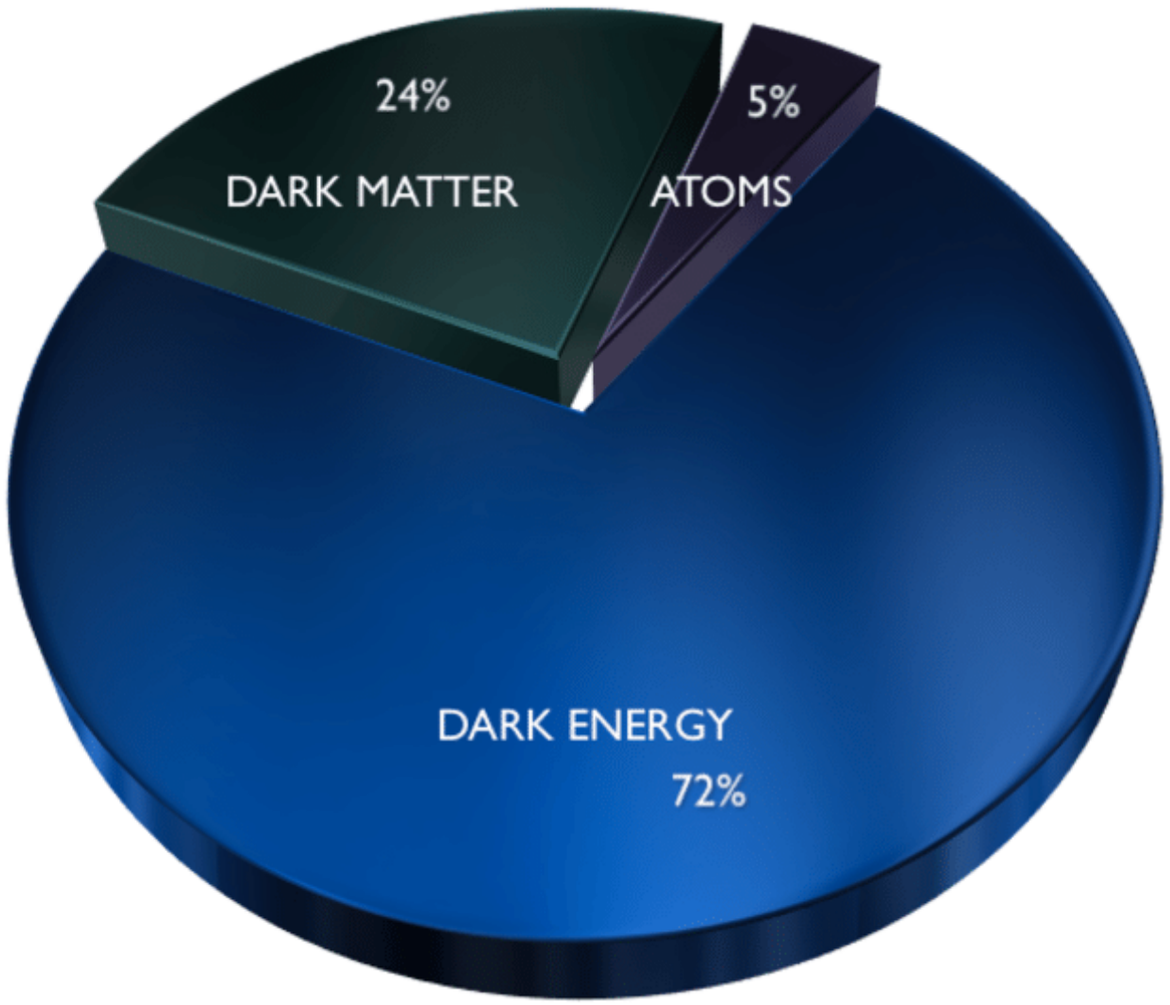
Tantalum
- Visible decay mode ($\gamma' \rightarrow e^- e^+$) of the hypothetical dark photon
- …

Dark sector searches.



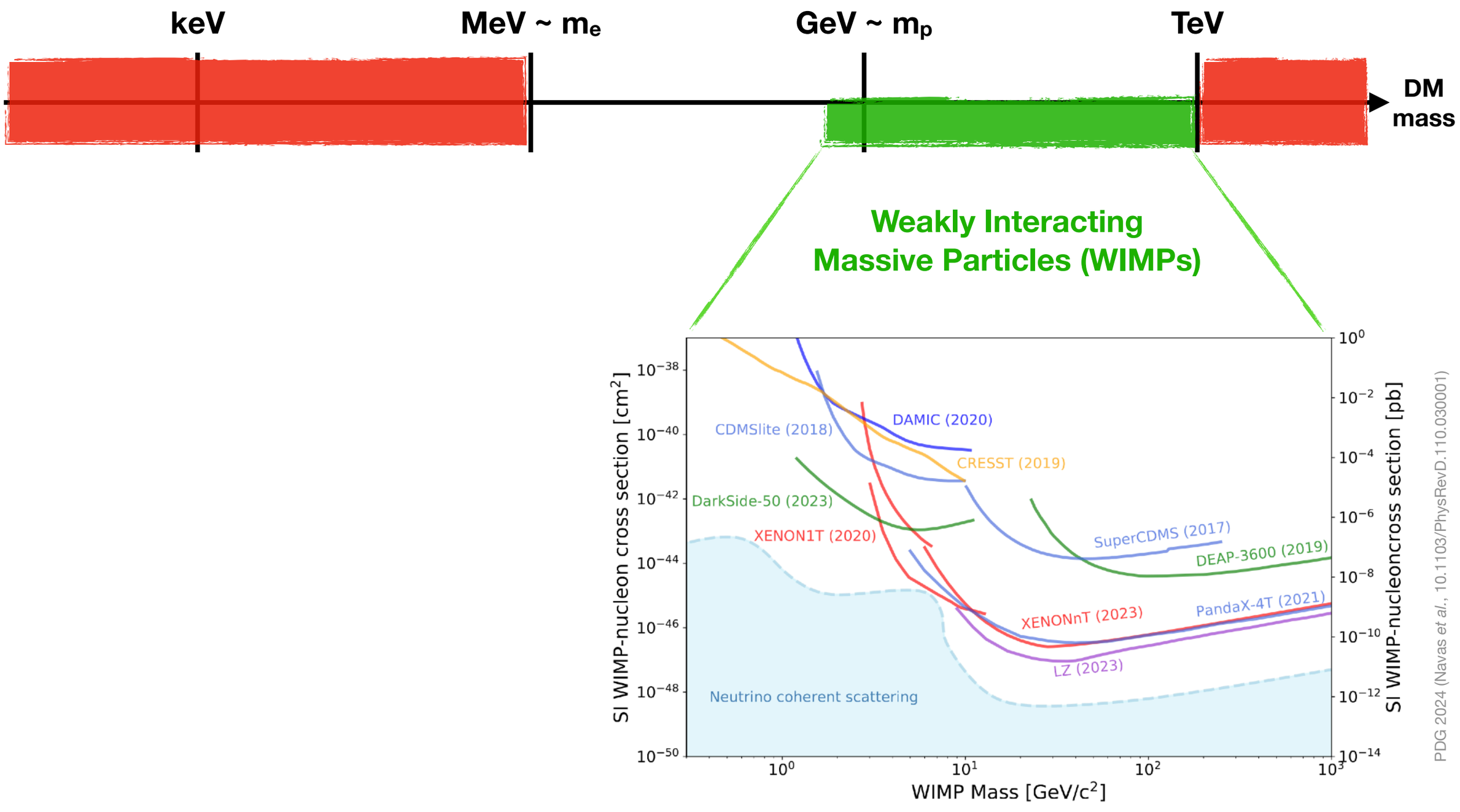
Nollett and Steigman, 10.1103/PhysRevD.89.083508

Griest and Kamionkowski, 10.1103/PhysRevLett.64.615



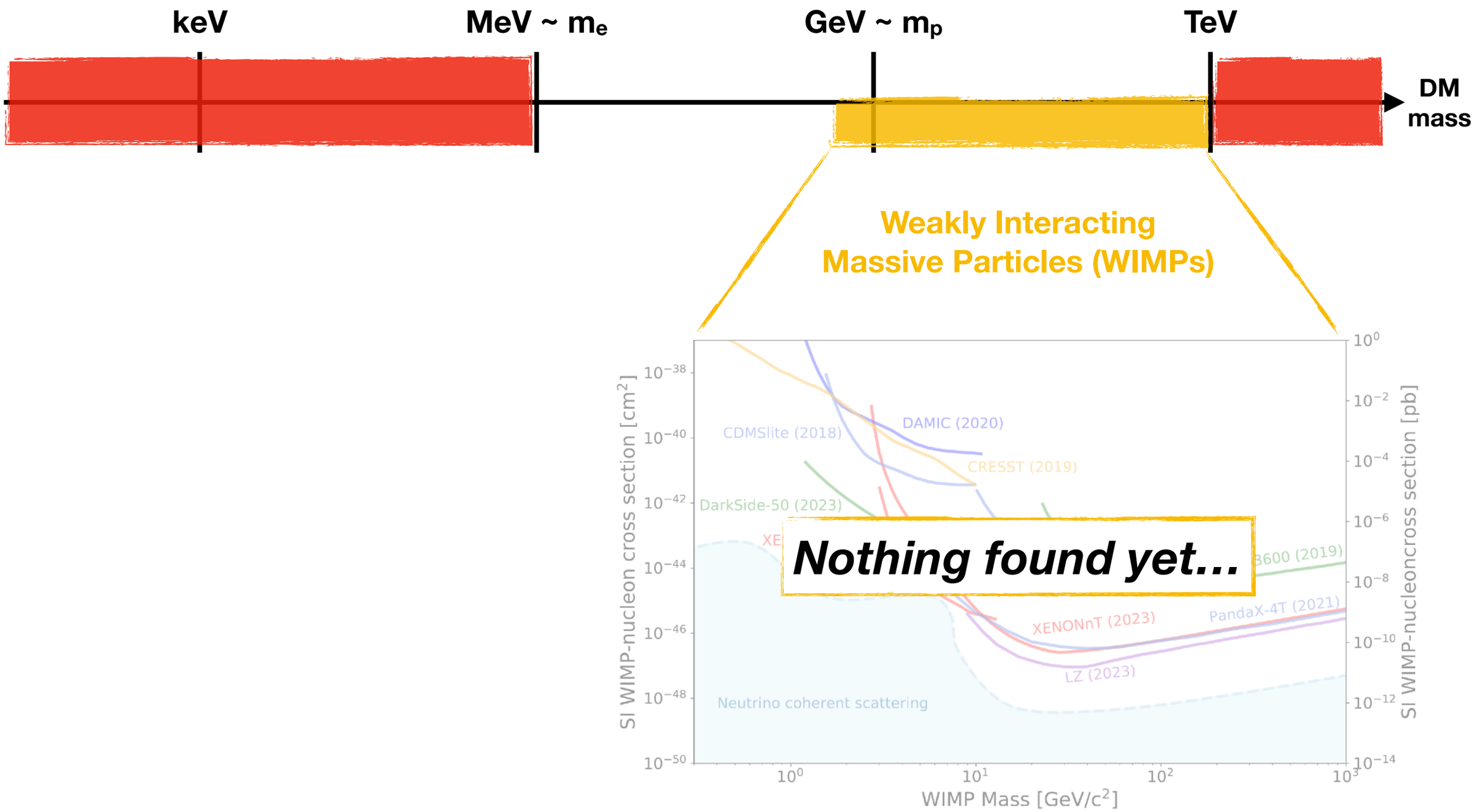
https://www.researchgate.net/figure/Estimated-distribution-of-matter-and-energy-in-the-Universe_fig2_353762159

Dark sector searches.

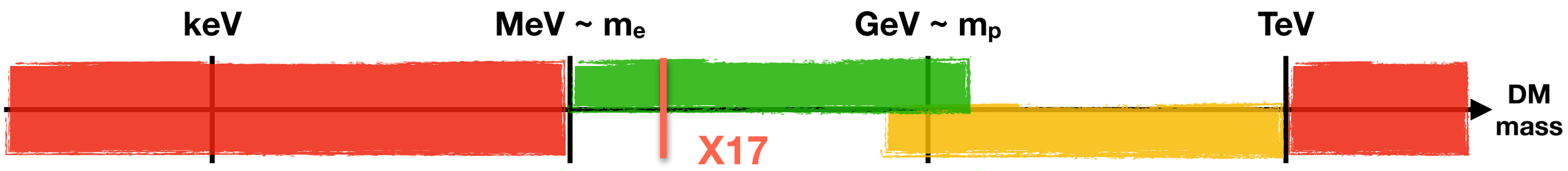


PDG 2024 (Navas *et al.*, 10.1103/PhysRevD.110.030001)

Dark sector searches.

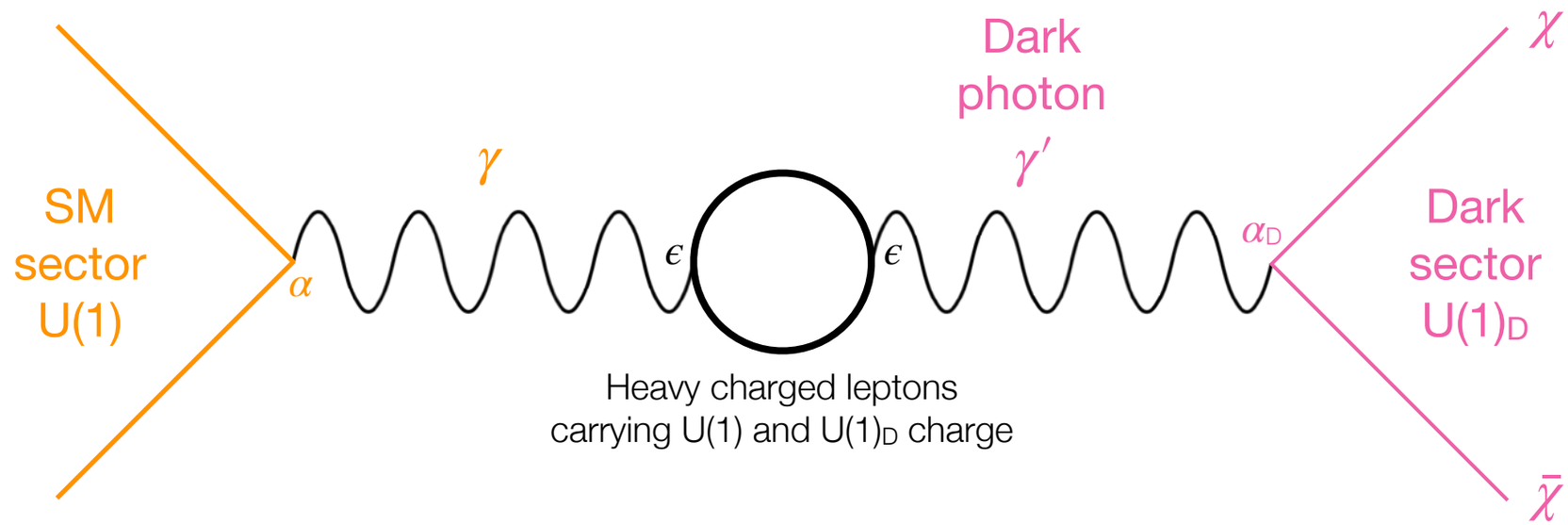


Dark sector searches.

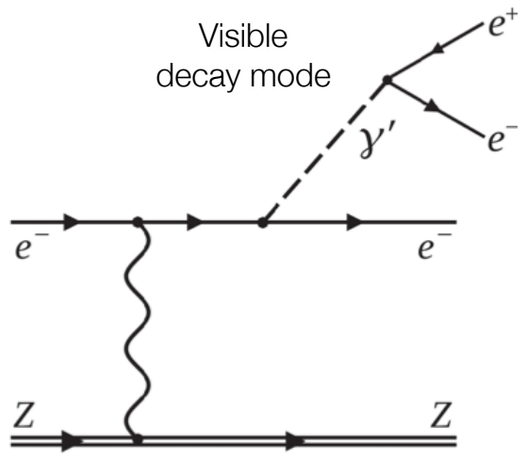


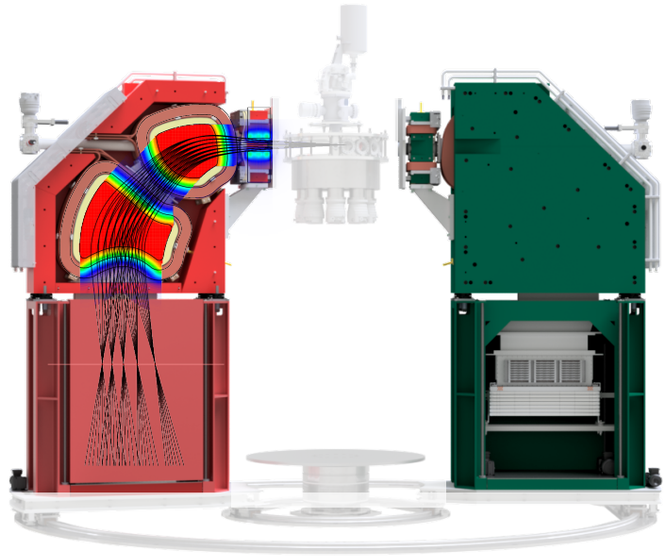
Light Dark Matter (LDM)

- Dark sector that communicates with the SM through one (or more) dark mediator particles?
- Popular mediator model: Dark photon γ' with a mass m_X that couples e.g. via kinetic mixing

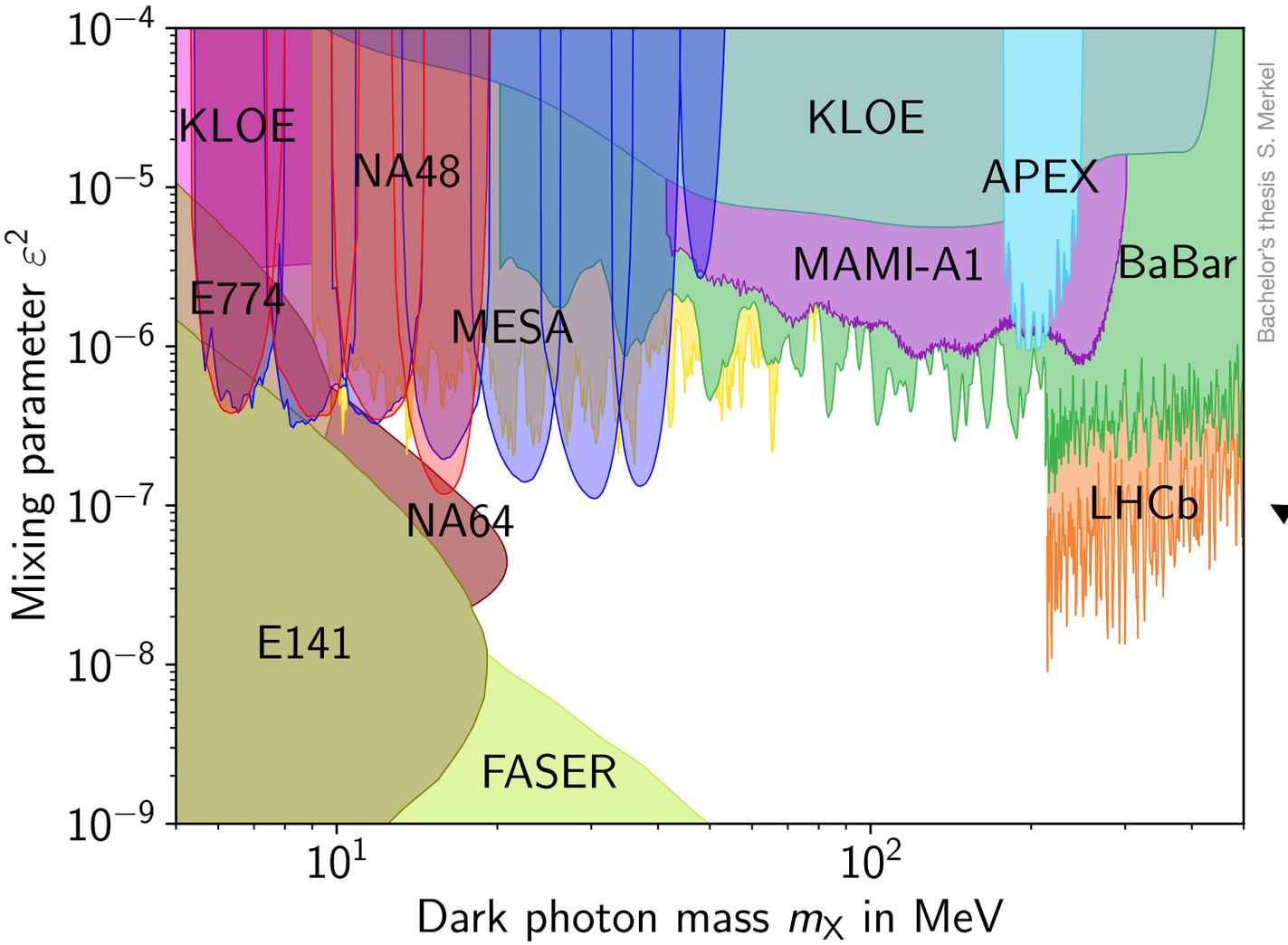


Dark photon - visible decay.

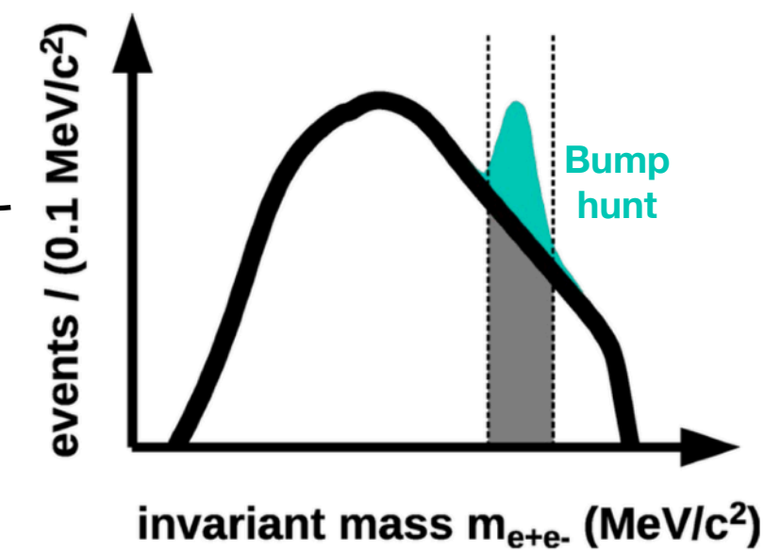




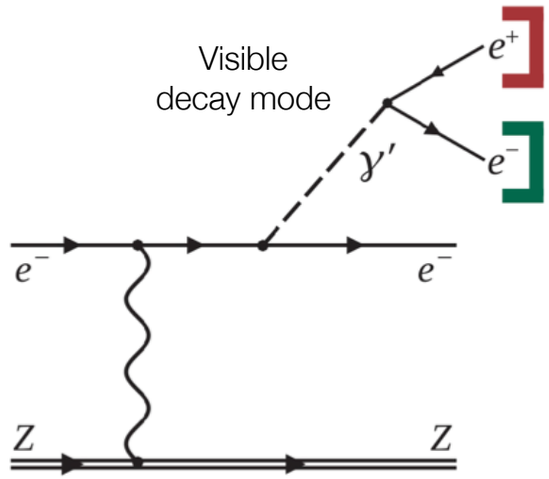
Coincidence measurement
between both spectrometers

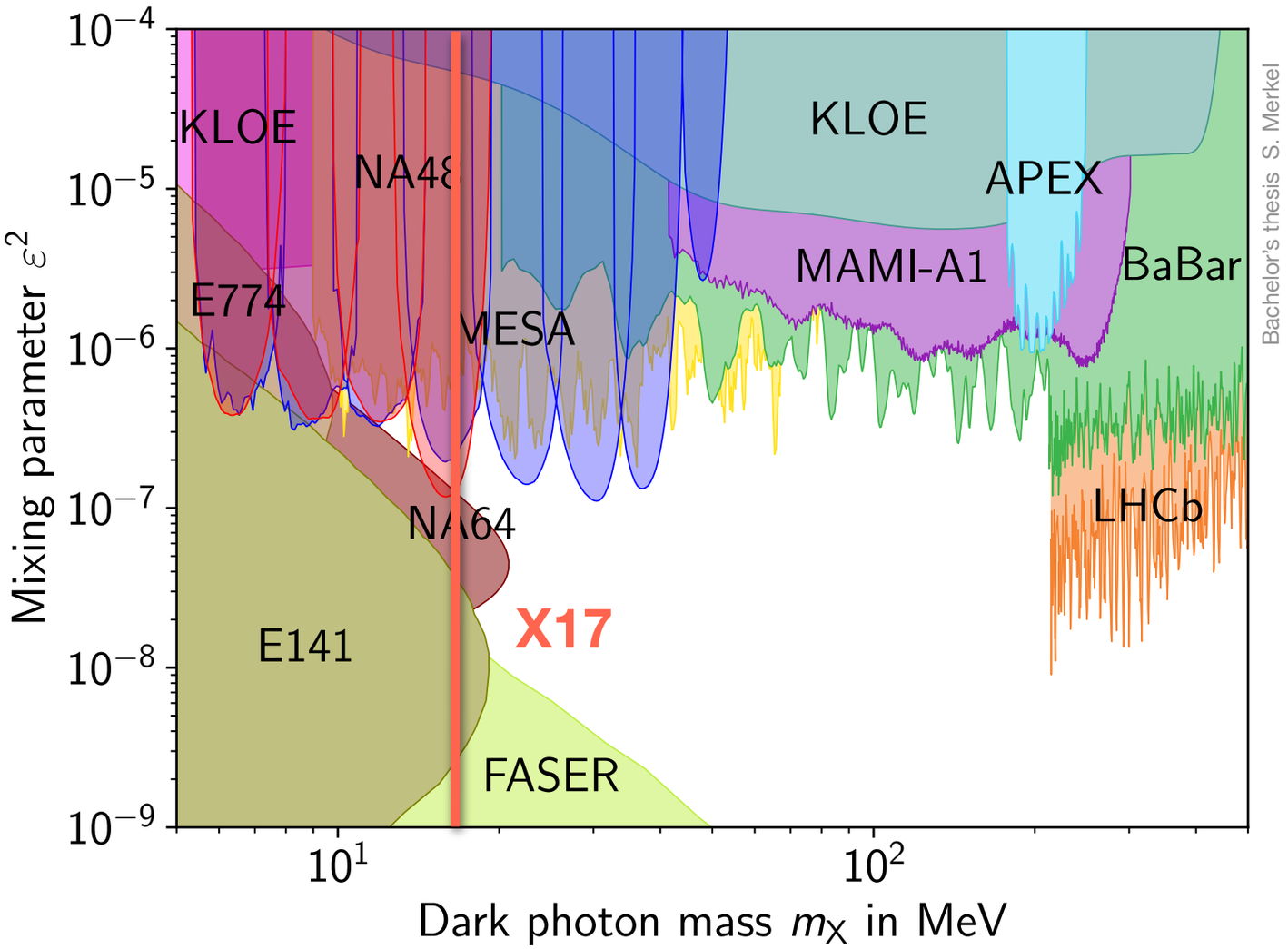


Bachelor's thesis S. Merkel



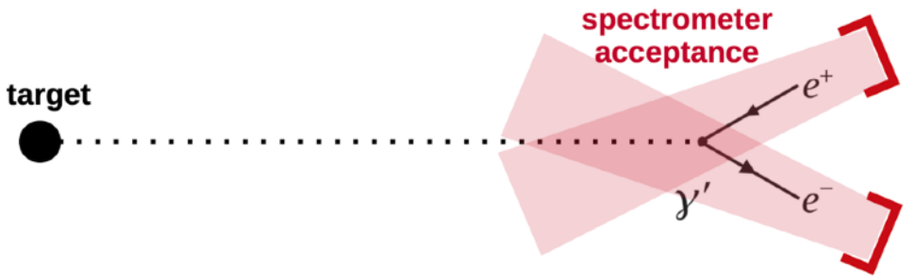
Dark photon - visible decay.

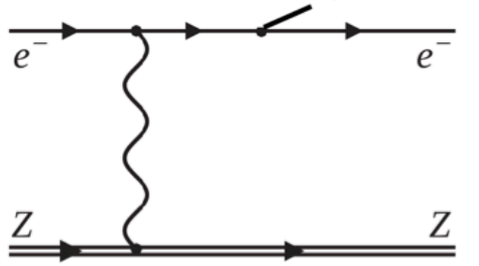


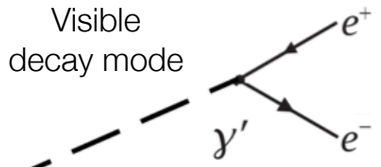


- **MESA in commissioning phase**: EB mode with $100\mu A$ beam current and beam energies of 55MeV and 105MeV
- **Solid target**: stack of 17 tantalum foils (^{181}Ta) with $1\mu m$ thickness each, spaced 2.5mm apart
- 2σ confidence level
- Background included
- 2 weeks per run
- X17 range covered!

Dark photon - displaced vertex.

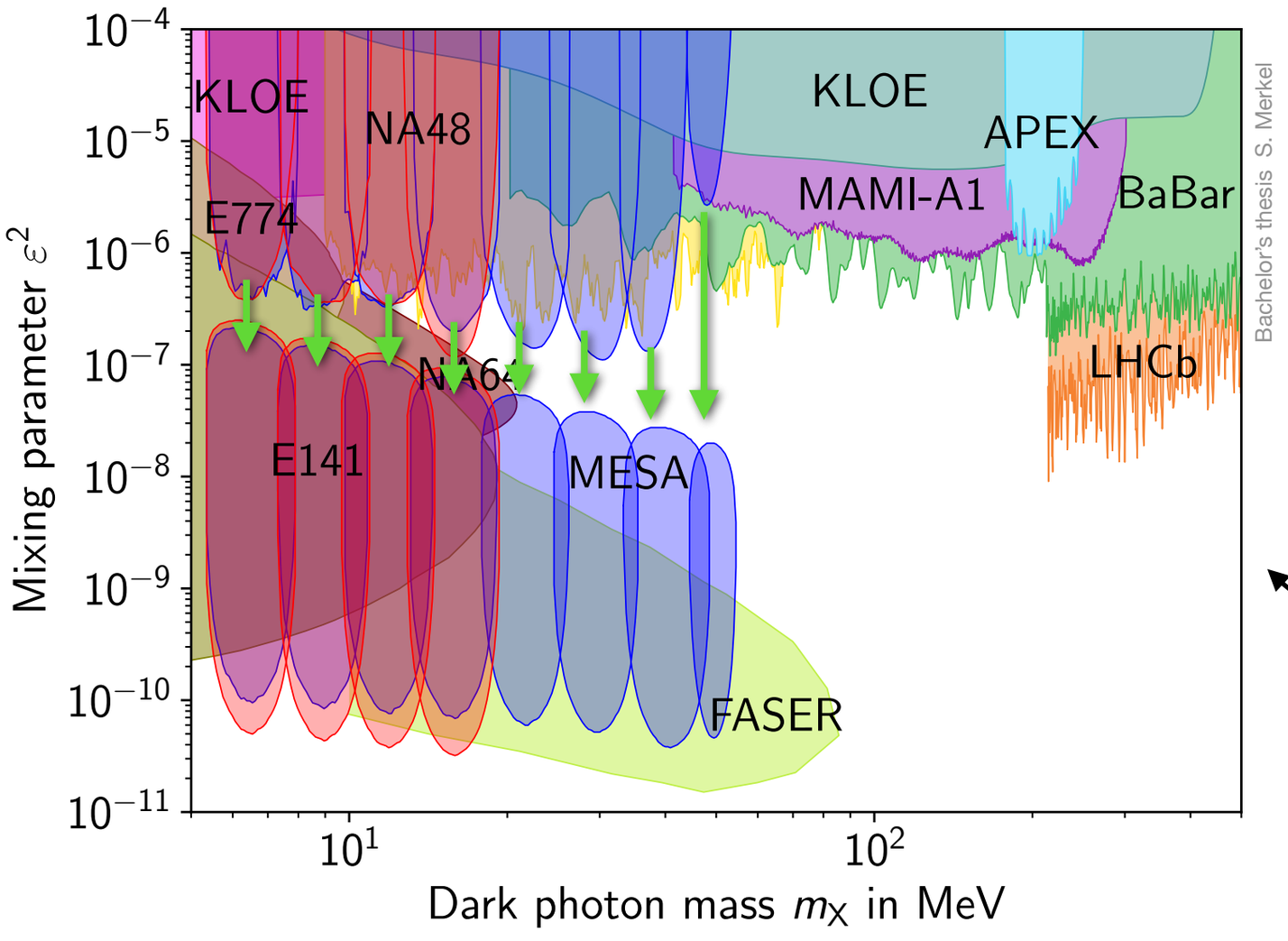




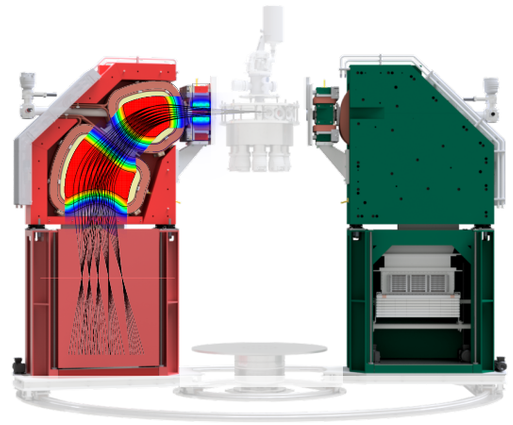


$$l_{\text{decay}} \approx 1.5\,\text{mm}\left(\frac{E_{\text{beam}}}{55\,\text{MeV}}\right)\cdot\left(\frac{10^{-4}}{\varepsilon}\right)^2\cdot\left(\frac{17\,\text{MeV}/c^2}{m_{\gamma'}}\right)^2$$

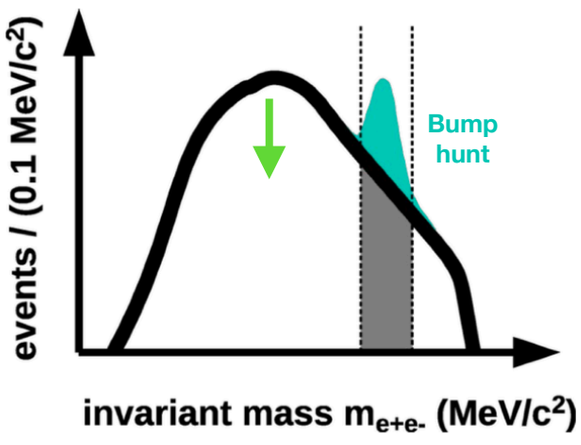
$= \gamma c\tau$



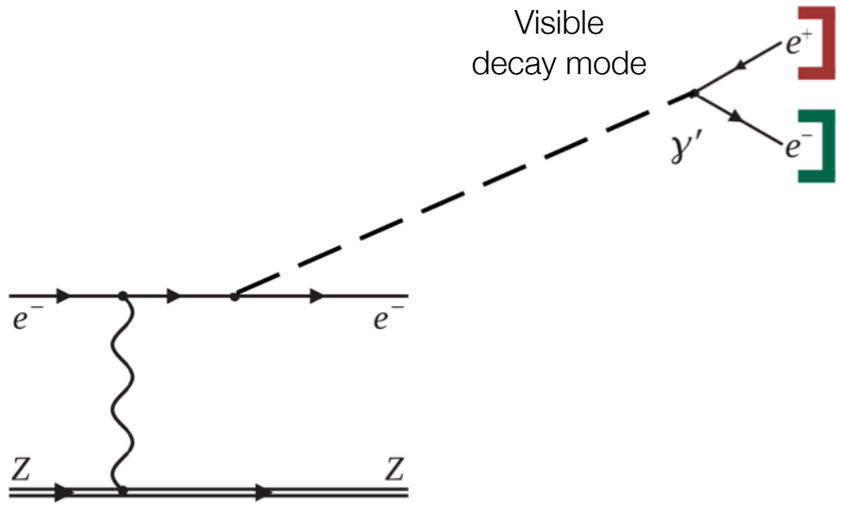
Bachelor's thesis S. Merkel

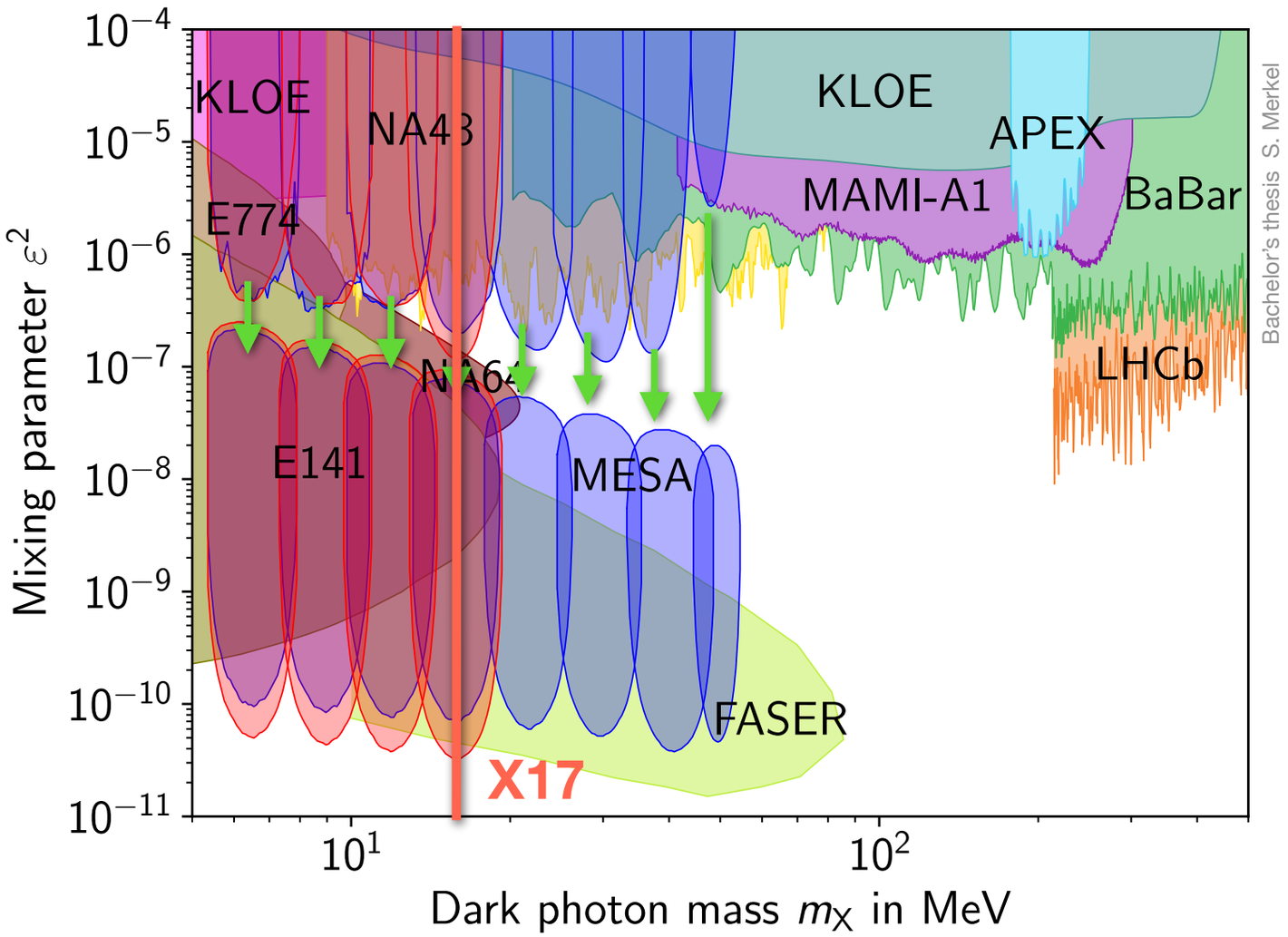


Coincidence measurement
between both spectrometers



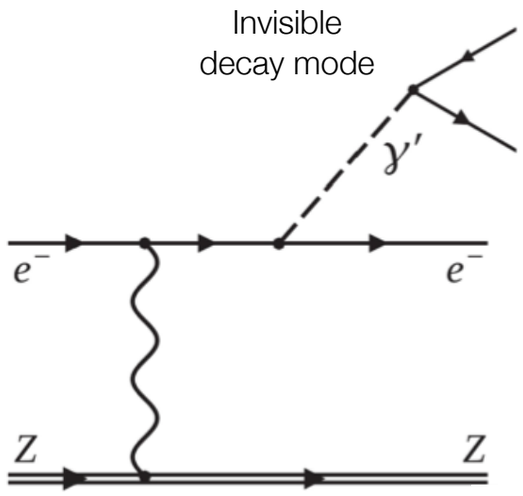
Dark photon - displaced vertex.

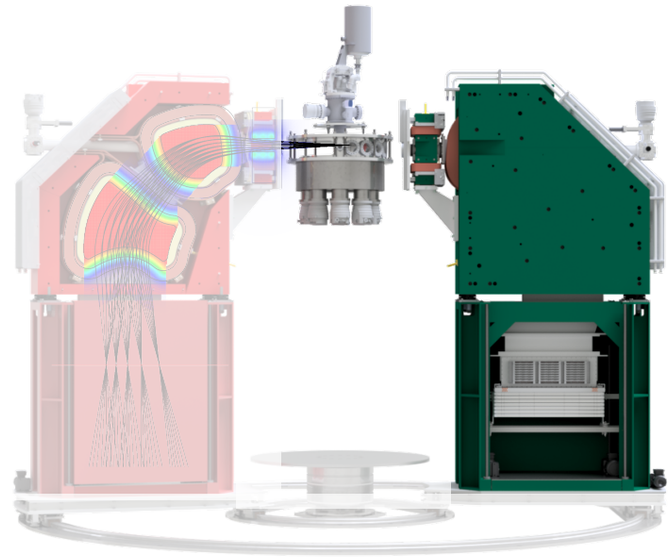




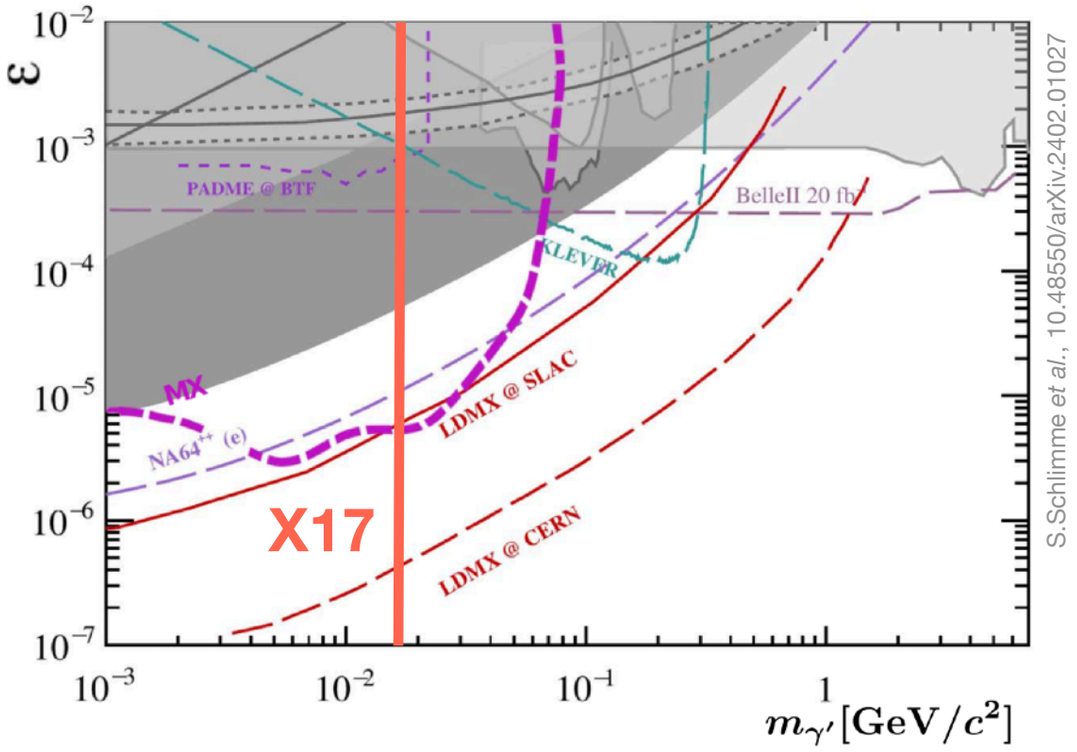
- **MESA in commissioning phase**: EB mode with $100\mu A$ beam current and beam energies of 55MeV and 105MeV
- **Solid target**: stack of 17 tantalum foils (^{181}Ta) with $1\mu m$ thickness each, spaced 2.5mm apart
- 2σ confidence level
- Background not included
- 2 weeks per run
- X17 range covered!

Outlook - invisible dark photon decay.

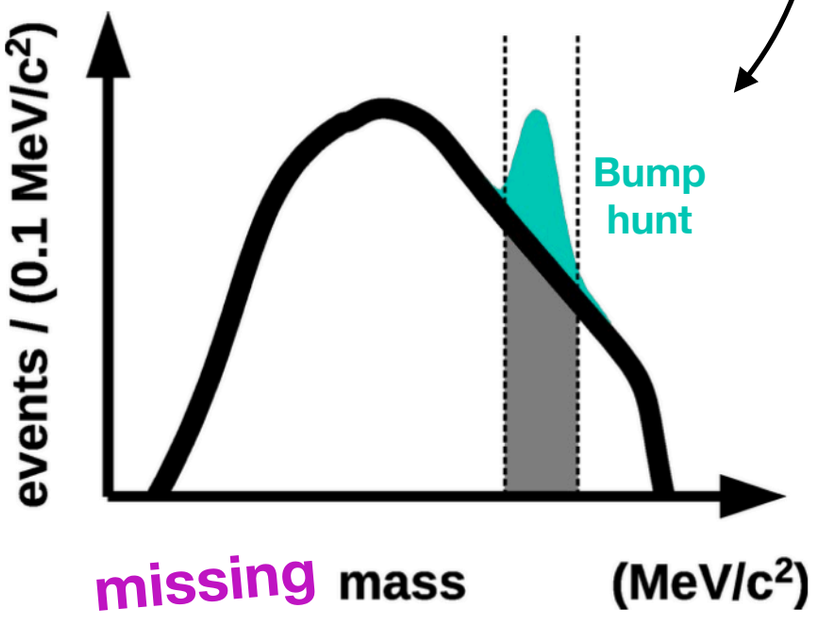




Coincidence measurement between one spectrometer and the silicon strip detectors



S.Schlimme *et al.*, 10.48550/arXiv.2402.01027



Outlook - effective neutron target.

PHYSICAL REVIEW LETTERS **128,** 091802 (2022)

X17 Discovery Potential in the $\gamma N \to e^+e^-N$ Process at Electron Scattering Facilities

Johannes Backens and Marc Vanderhaeghen
Institut für Kernphysik and PRISMA⁺ Cluster of Excellence, Johannes Gutenberg-Universität, D-55099 Mainz, Germany

PHYSICAL REVIEW D **109,** 095010 (2024)

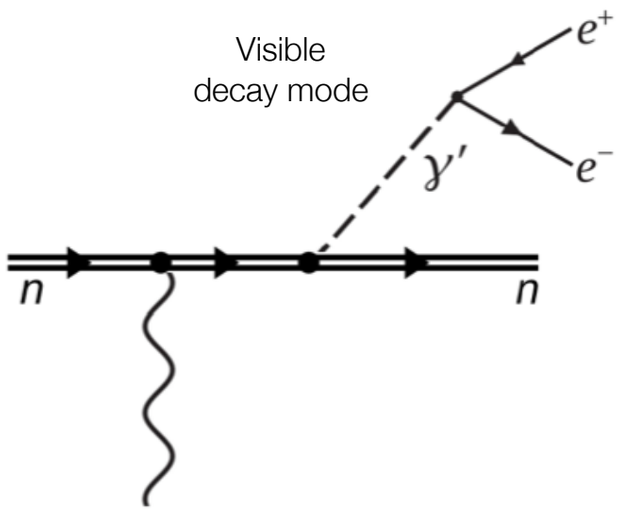
Low-mass dark sector searches with deuteron photodisintegration

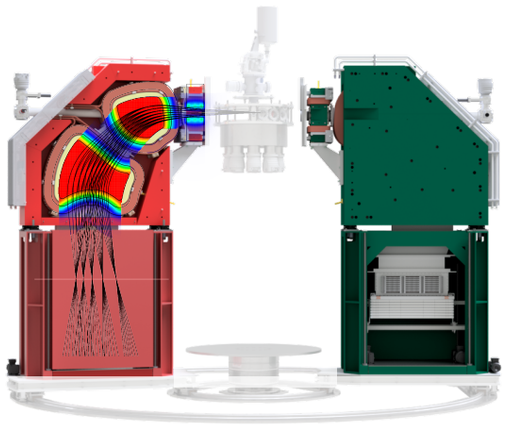
Cornelis J. G. Mommers* and Marc Vanderhaeghen
Institut für Kernphysik and PRISMA⁺ Cluster of Excellence, Johannes Gutenberg-Universität, D-55099 Mainz, Germany

EPJ Web of Conferences **303,** 05004 (2024) https://doi.org/10.1051/epjconf/202430305004
MENU 2023

X17 discovery potential in $\gamma d \to e^+e^-pn$ at MAGIX@MESA

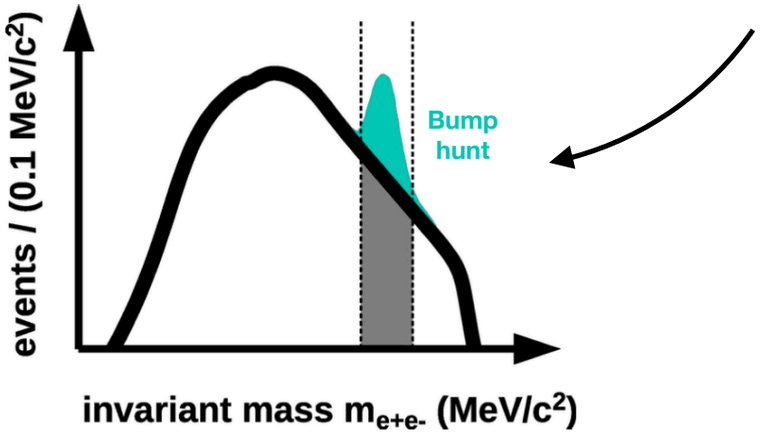
Cornelis J.G. Mommers[1,*] and *Marc* Vanderhaeghen[1]
[1]Institut für Kernphysik and PRISMA+ Cluster of Excellence, Johannes Gutenberg-Universität, D-55099 Mainz, Germany





Coincidence measurement
between both spectrometers

No exclusion
limits yet

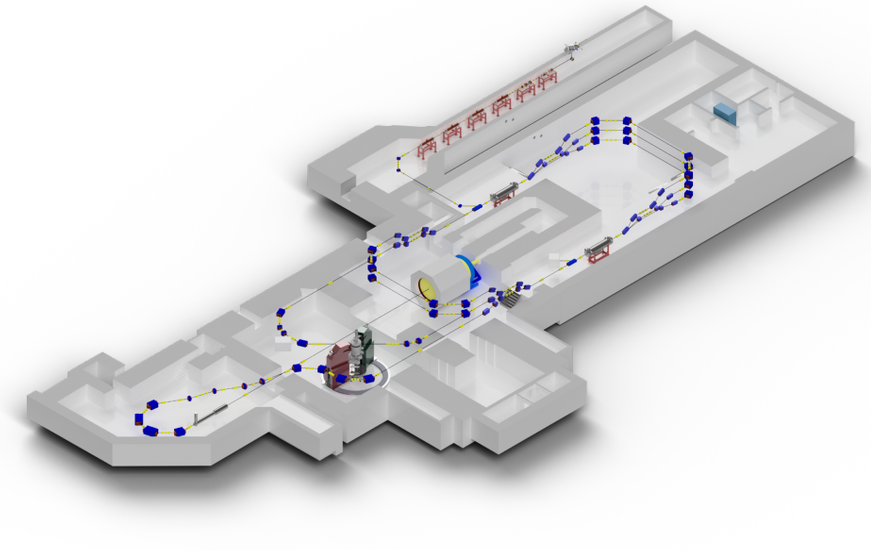


The MAGIX Experiment at MESA.

Target

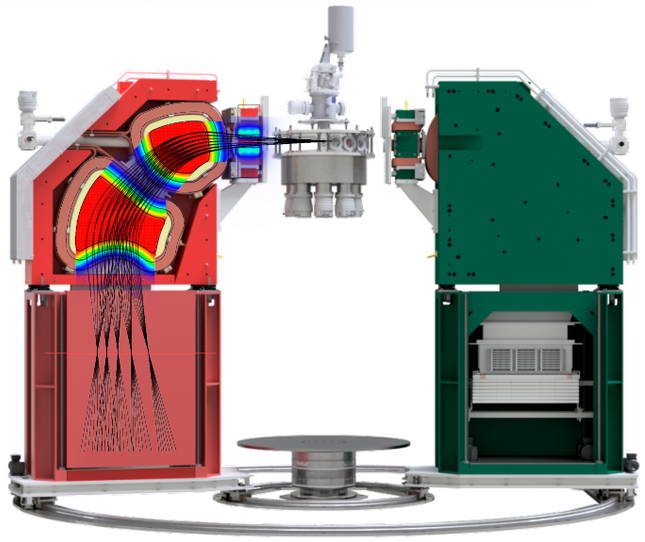
MAinz	**G**as **I**njection	**EX**periment
MESA	Gas Internal	Exploration
Multi-purpose Apparatus	Gas Interaction	Excellence
Massima Accuratezza	Grande Innovazione	Exattezza

Summary



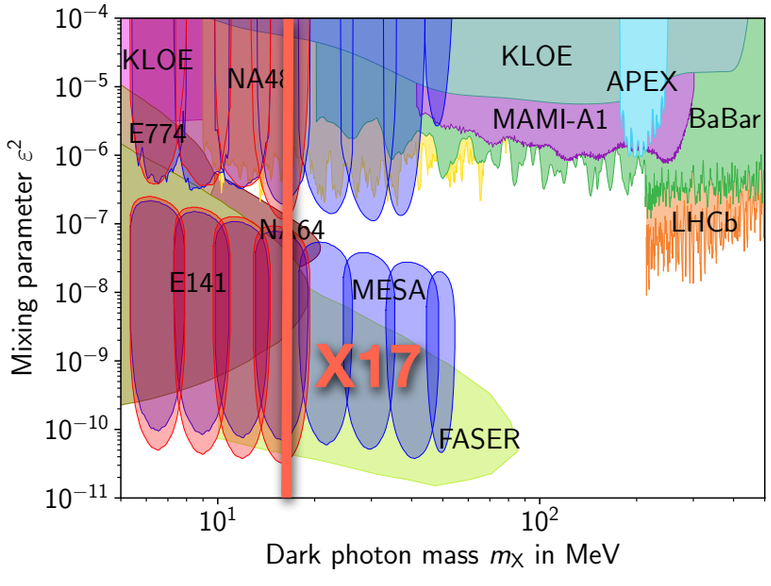
MESA

- New high-intensity, low-energy electron accelerator
- Two modes: energy-recovery linac mode and extracted beam mode
- Exciting experimental program



MAGIX

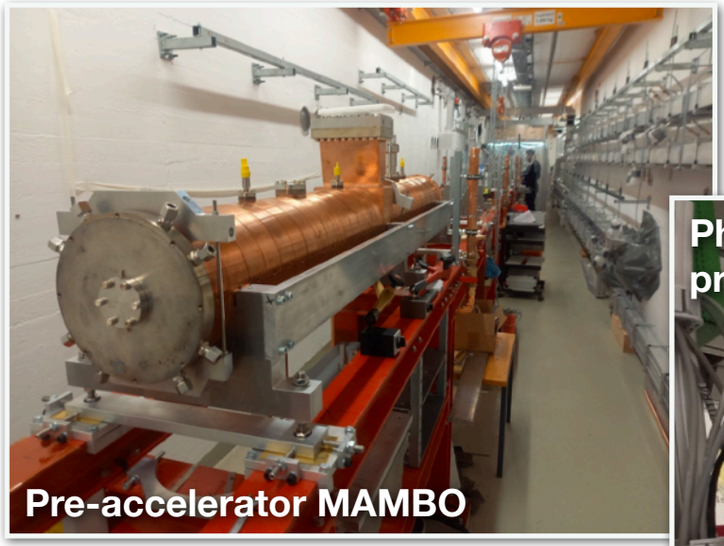
- High-resolution, two-spectrometer setup utilizing an internal gas jet target
- Varied and rich physics program in nuclear, particle, and few-body physics

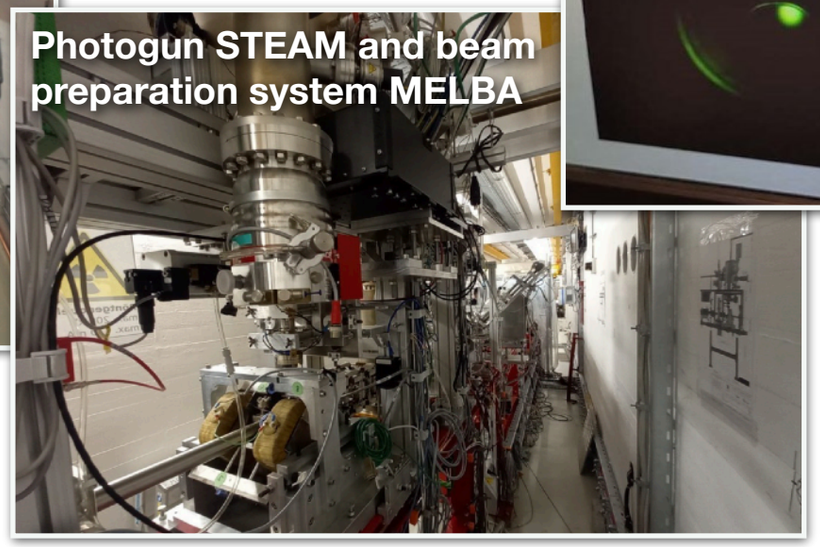


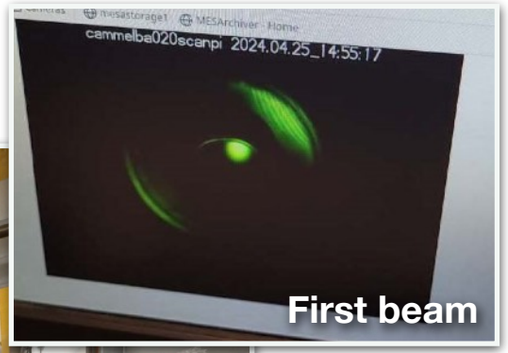
X17 searches

- Several dark photon searches (visible, displaced vertex, …) are planned at MAGIX, all of which cover the interesting X17 range

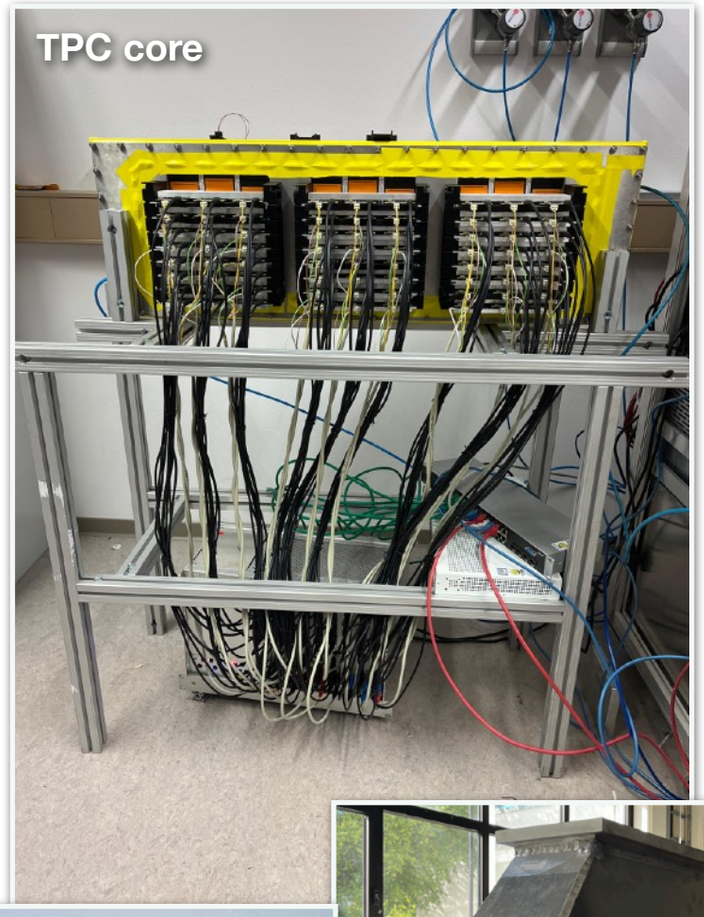
Impressions.

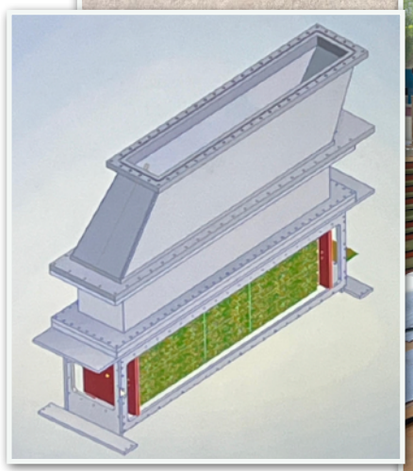


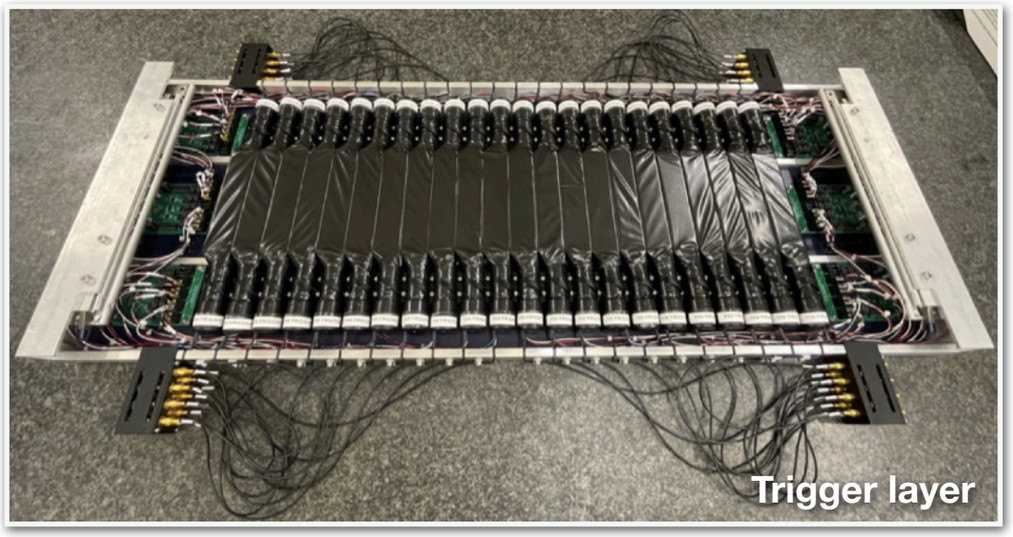


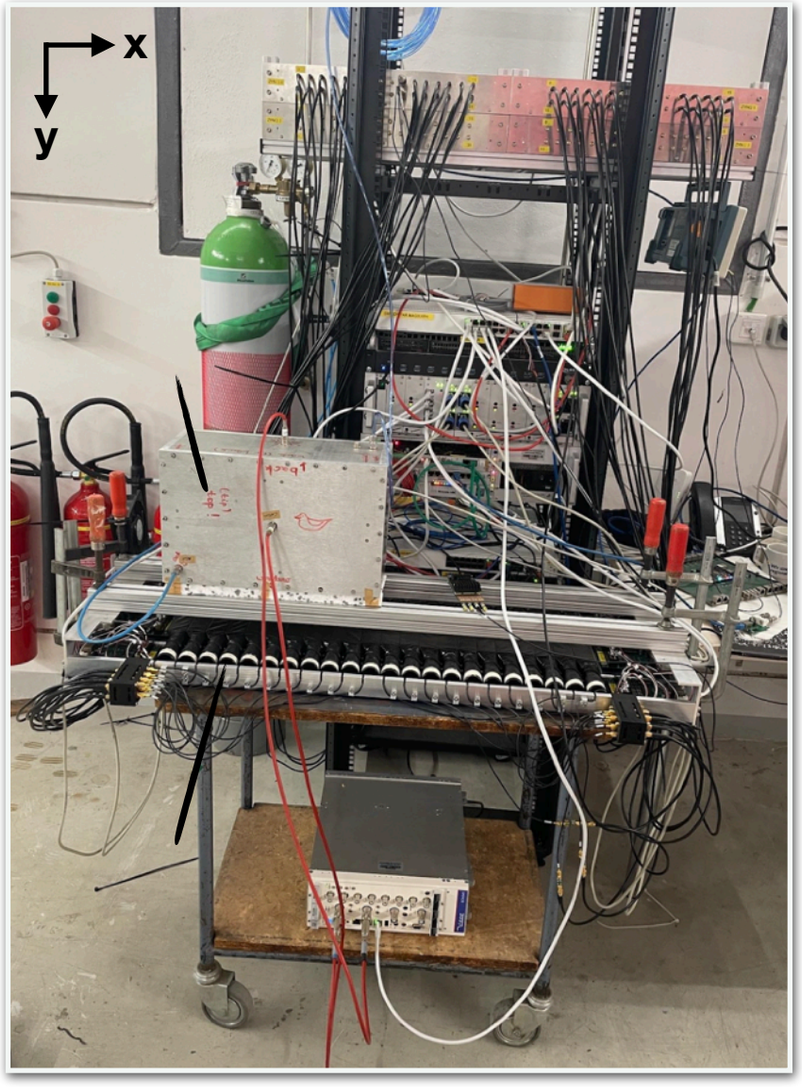


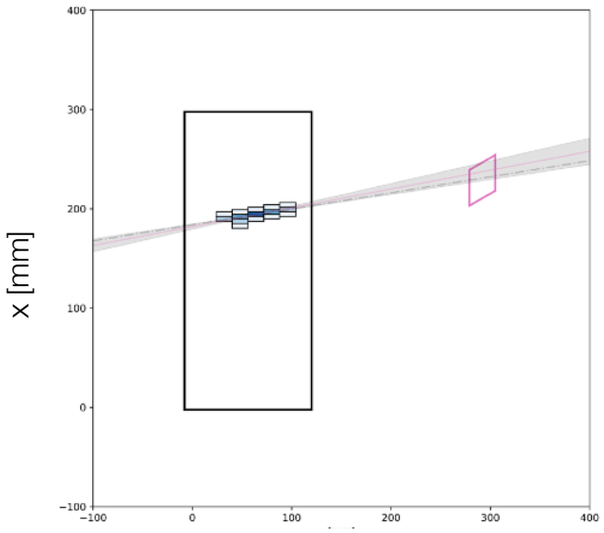
Impressions.

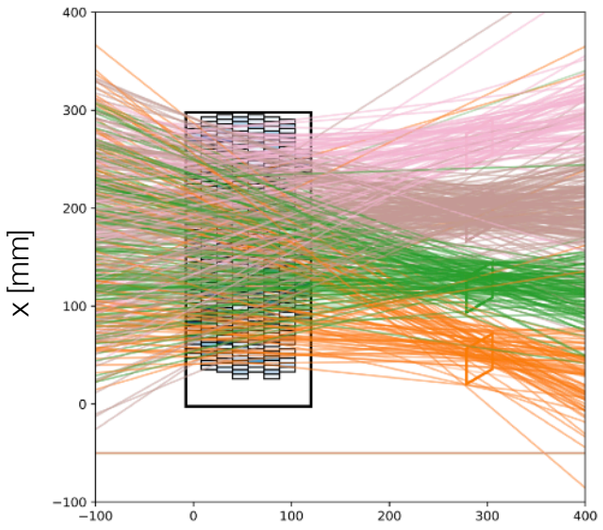












Impressions.

Thank you for your attention!

Contact

Institute for Nuclear Physics
Johannes Gutenberg University Mainz
Johann-Joachim-Becher-Weg 45
55128 Mainz
Germany

www.kernphysik.uni-mainz.de

Sebastian Stengel
MAGIX Collaboration
sestenge@uni-mainz.de

www.magix.uni-mainz.de