

Dark sector searches at the electron accelerator MESA.

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<https://indico.cern.ch/event/1358446/>



Greetings from Mainz.

Carnival



bistummainz.de



pixopolis.de

Printing & Johannes Gutenberg



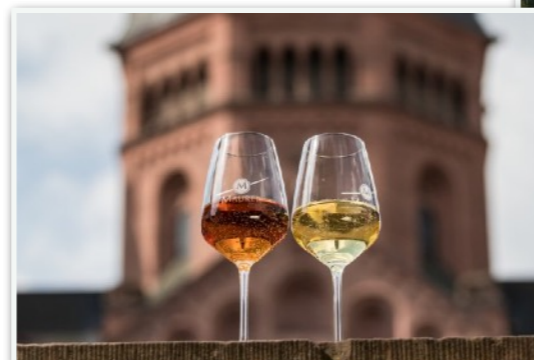
mainz.de

Wine



christophorus-hof.de

mainz-tourismus.com

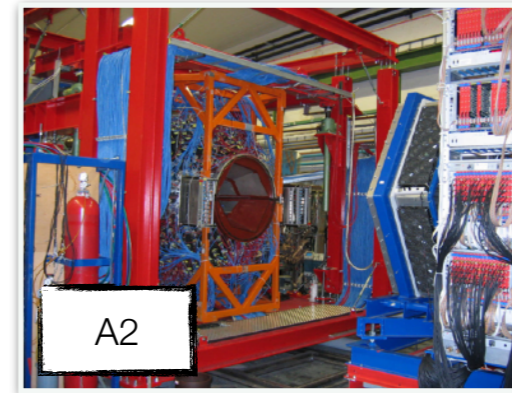
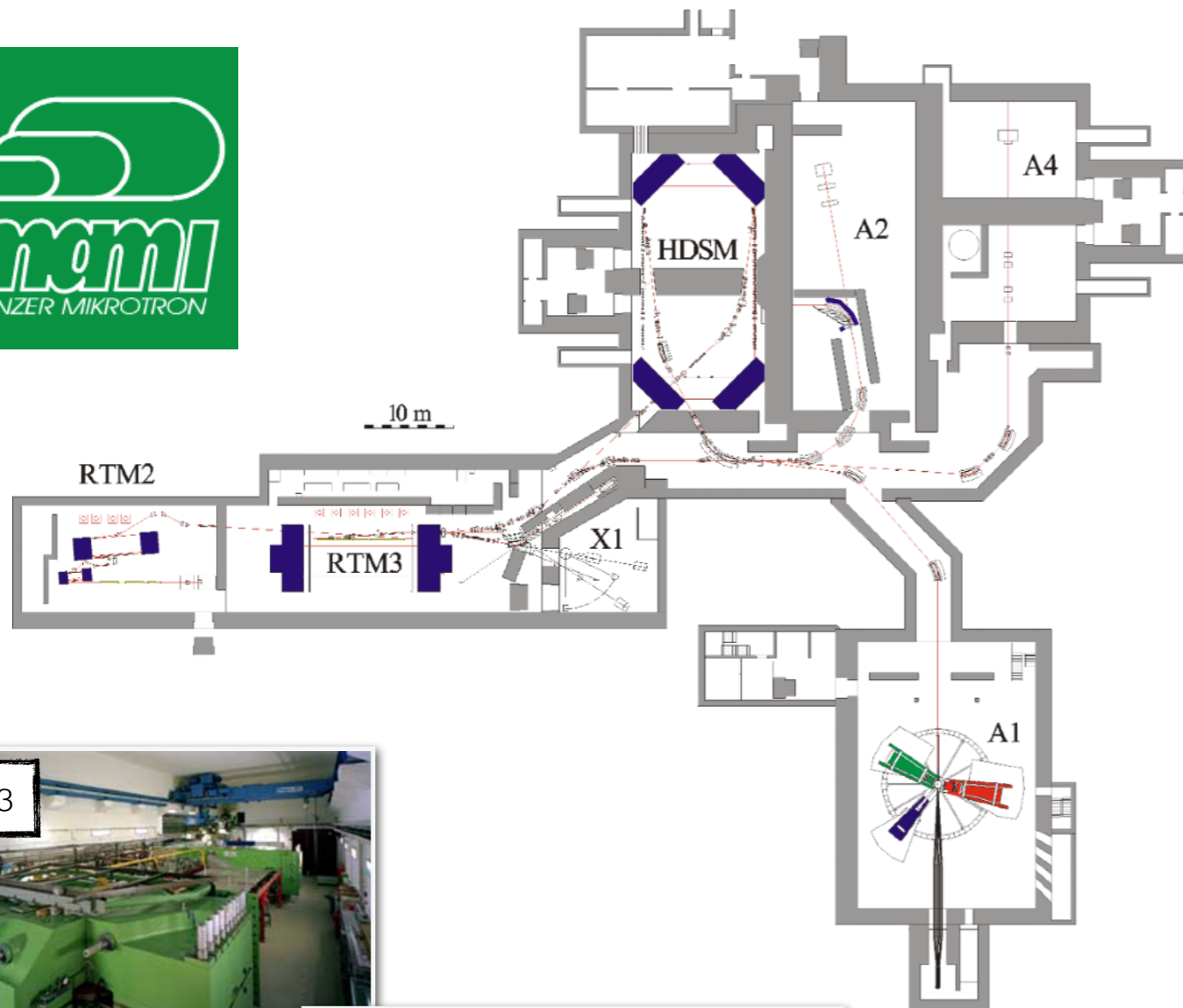


Adobe stock

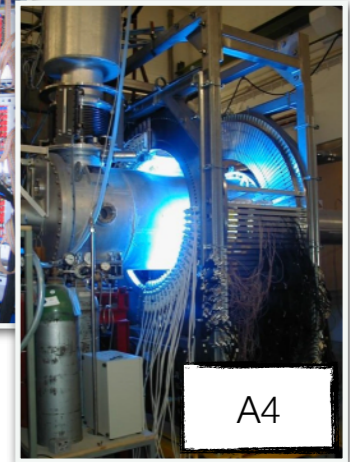


Mainz

Greetings from MAMI.



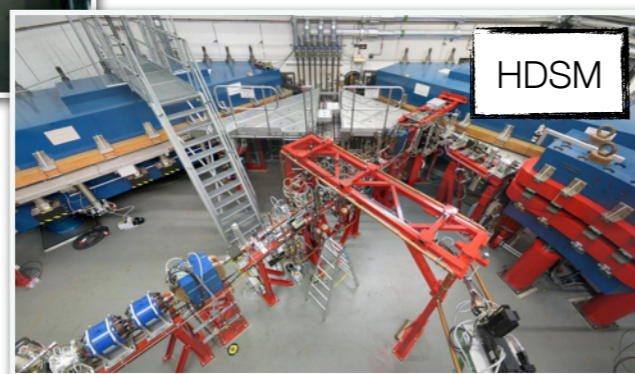
A2



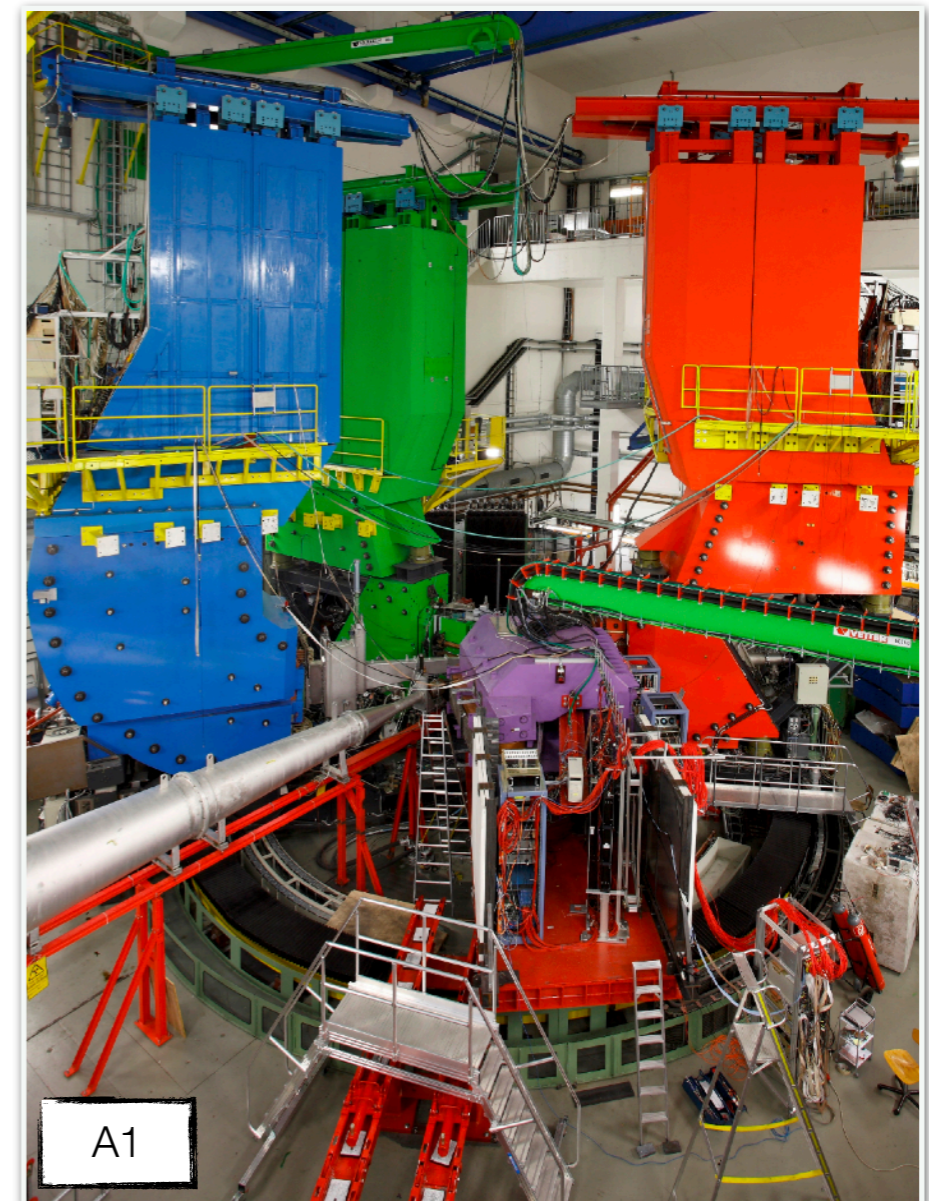
A4



RTM3



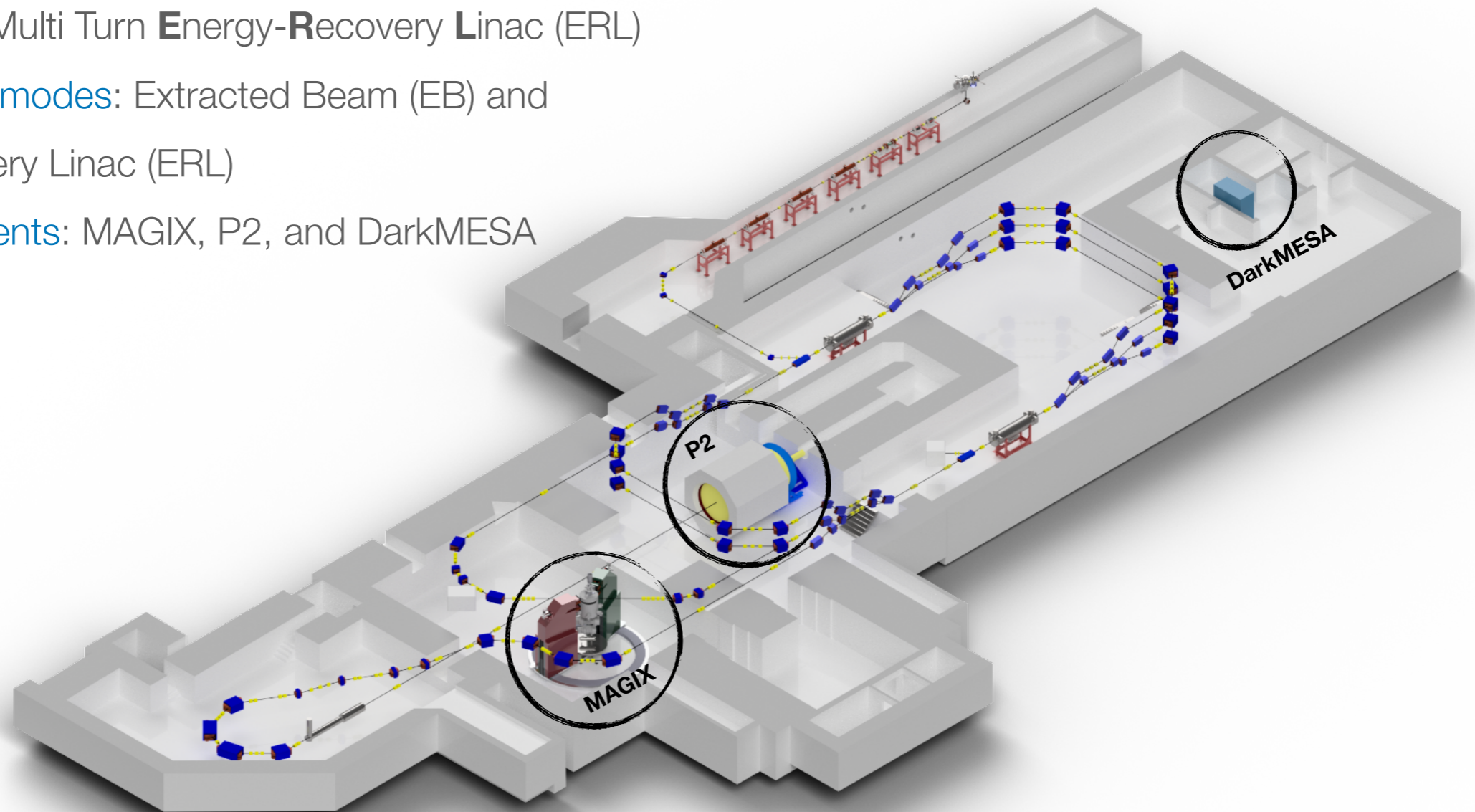
HDSM



A1

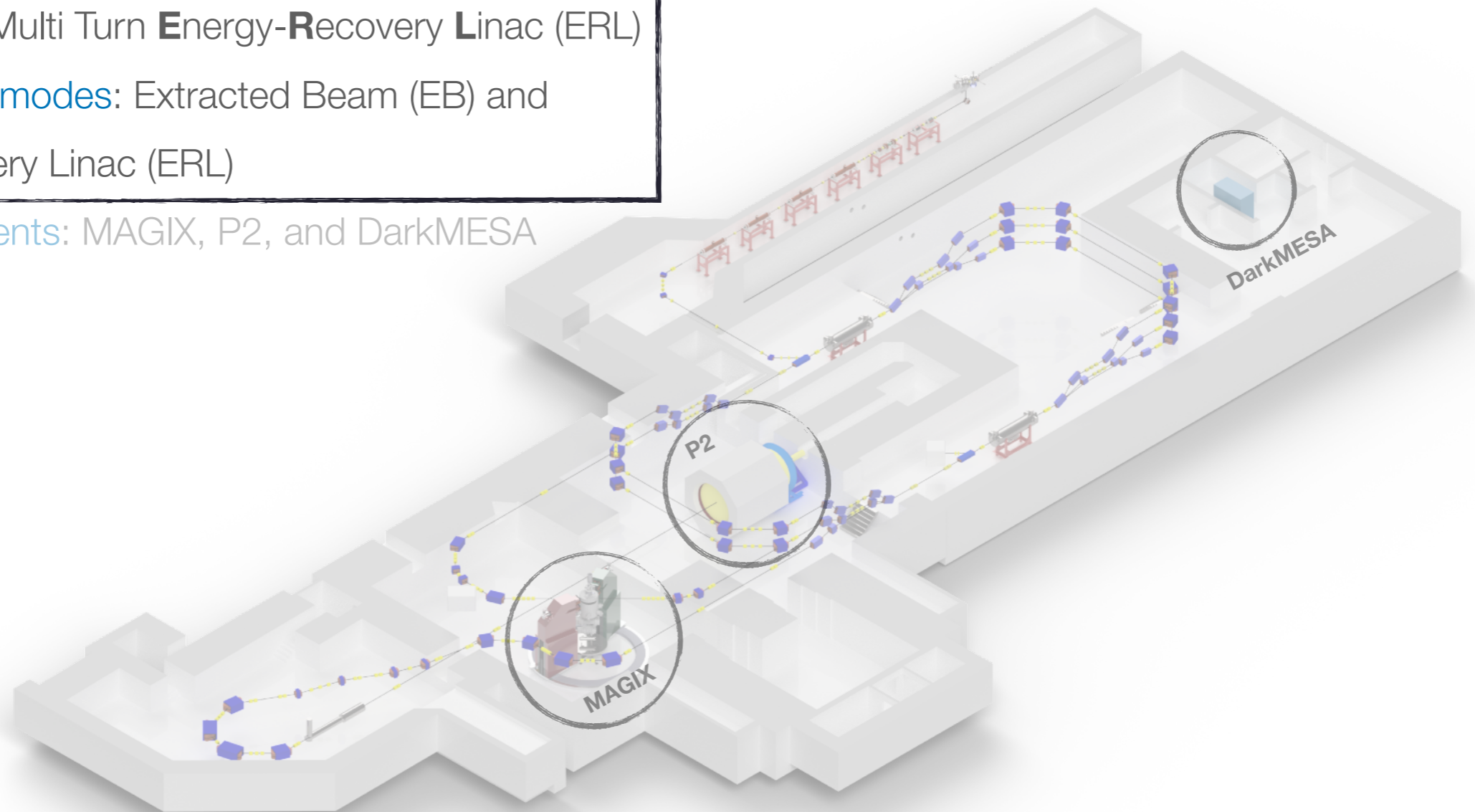
MESA - the new flagship at Mainz.

- Mainz **E**nergy-Recovering **S**uperconducting **A**ccelerator
- High-intensity, low-energy **electron accelerator** currently under construction, first beam expected in 2025
- Double-sided Multi Turn **E**nergy-**R**ecovery **L**inac (ERL)
- **Two operation modes**: Extracted Beam (EB) and Energy-Recovery Linac (ERL)
- **Three experiments**: MAGIX, P2, and DarkMESA

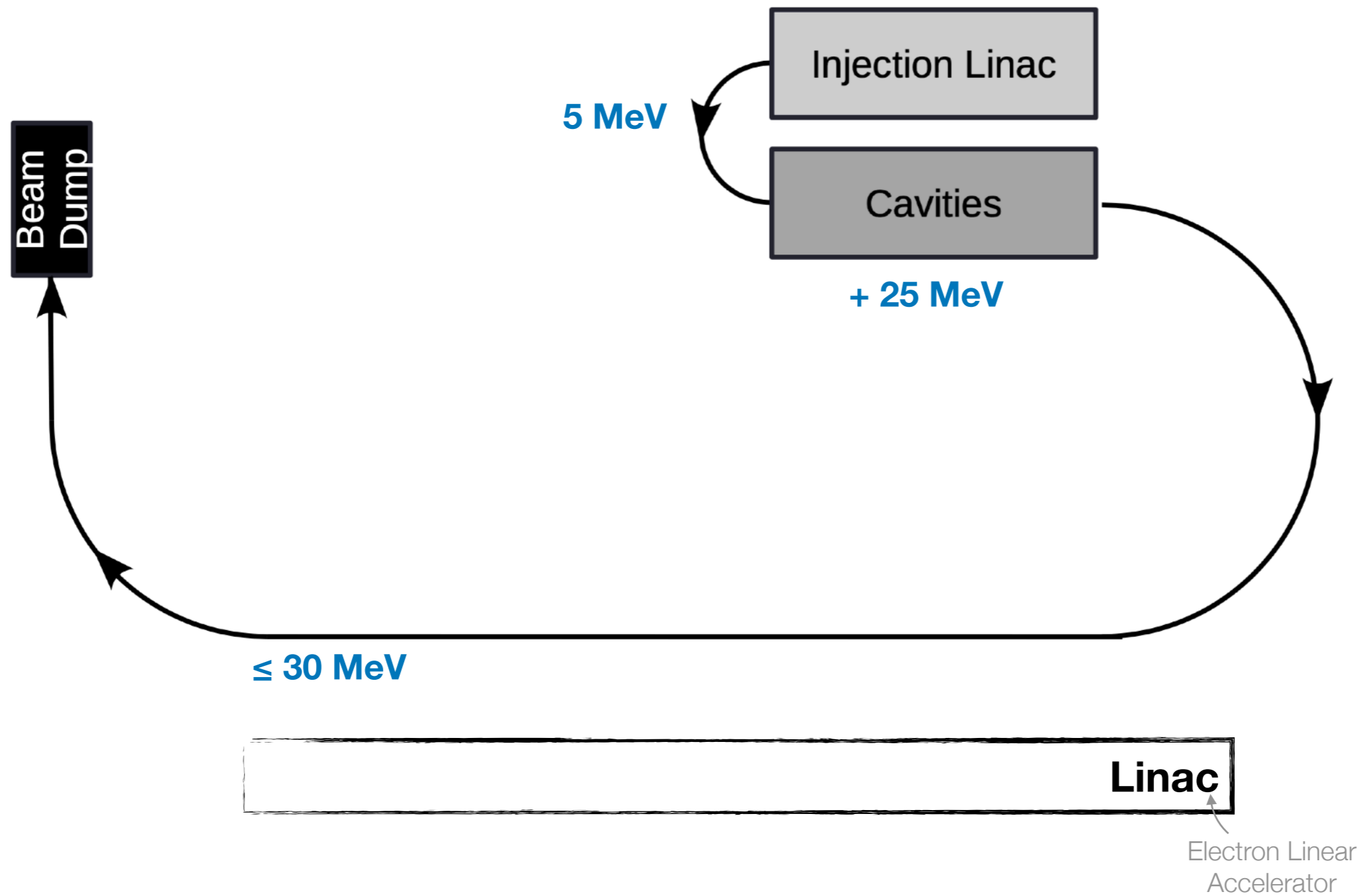


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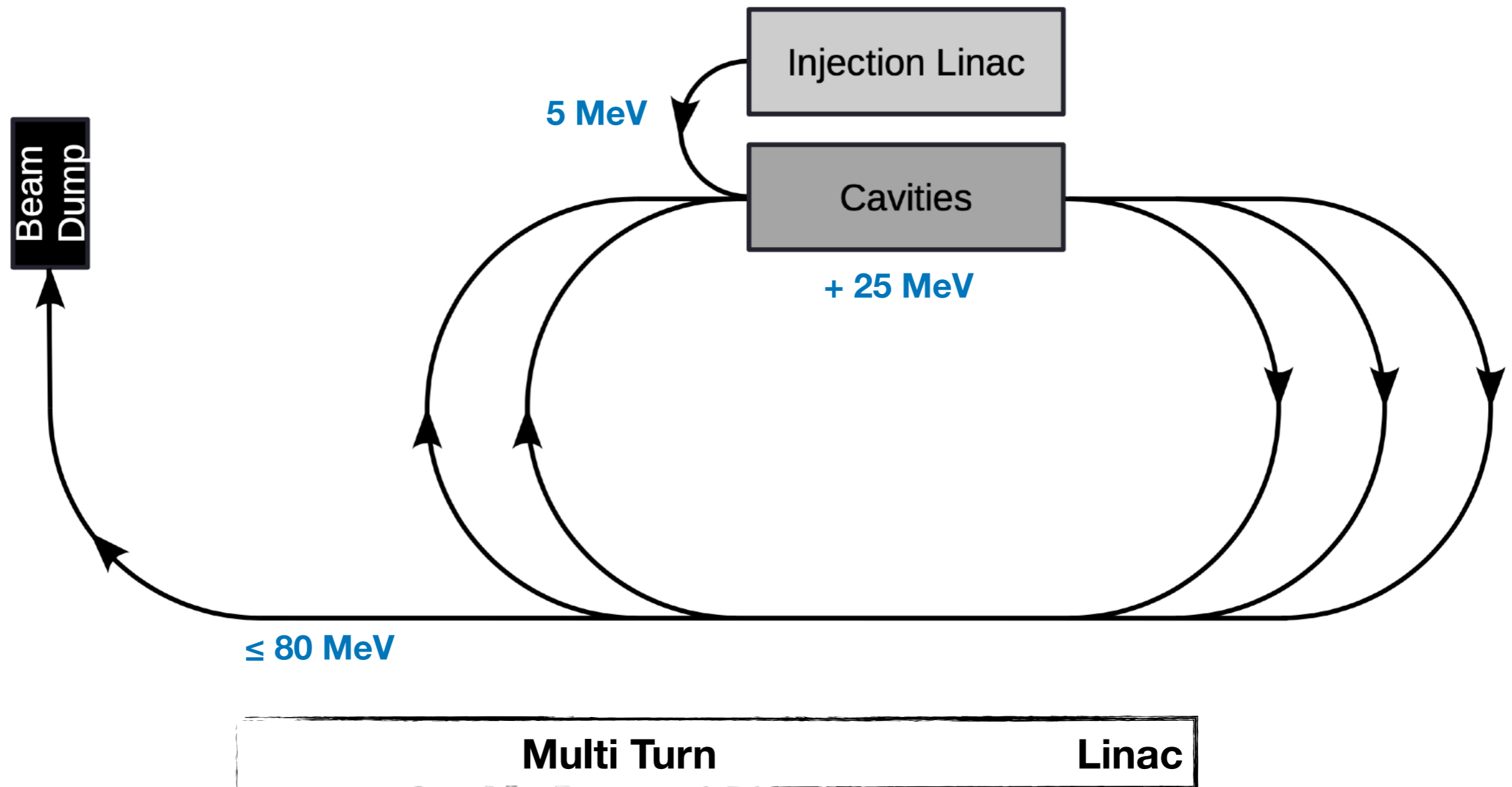
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Let's build MESA (1/7).

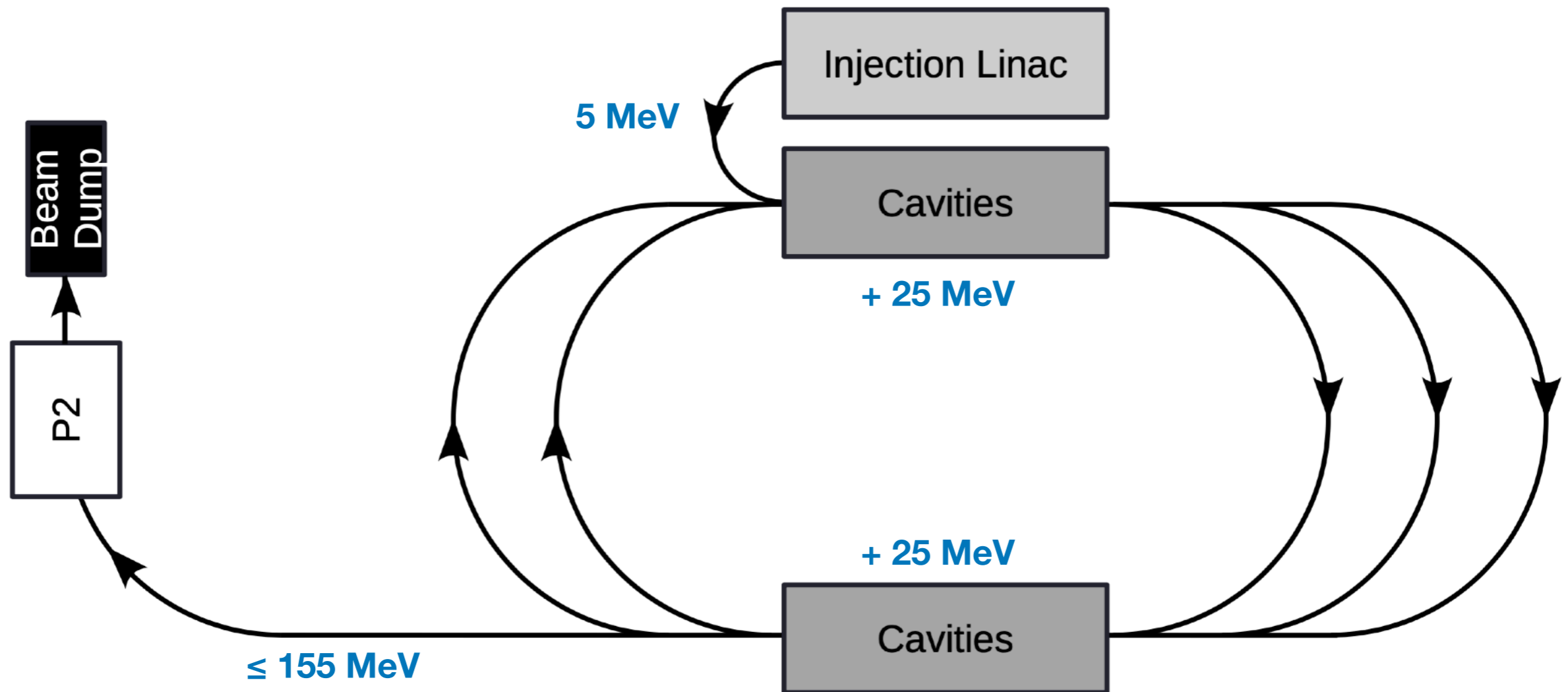


Let's build MESA (2/7).



S.Schlimme

Let's build MESA (3/7).

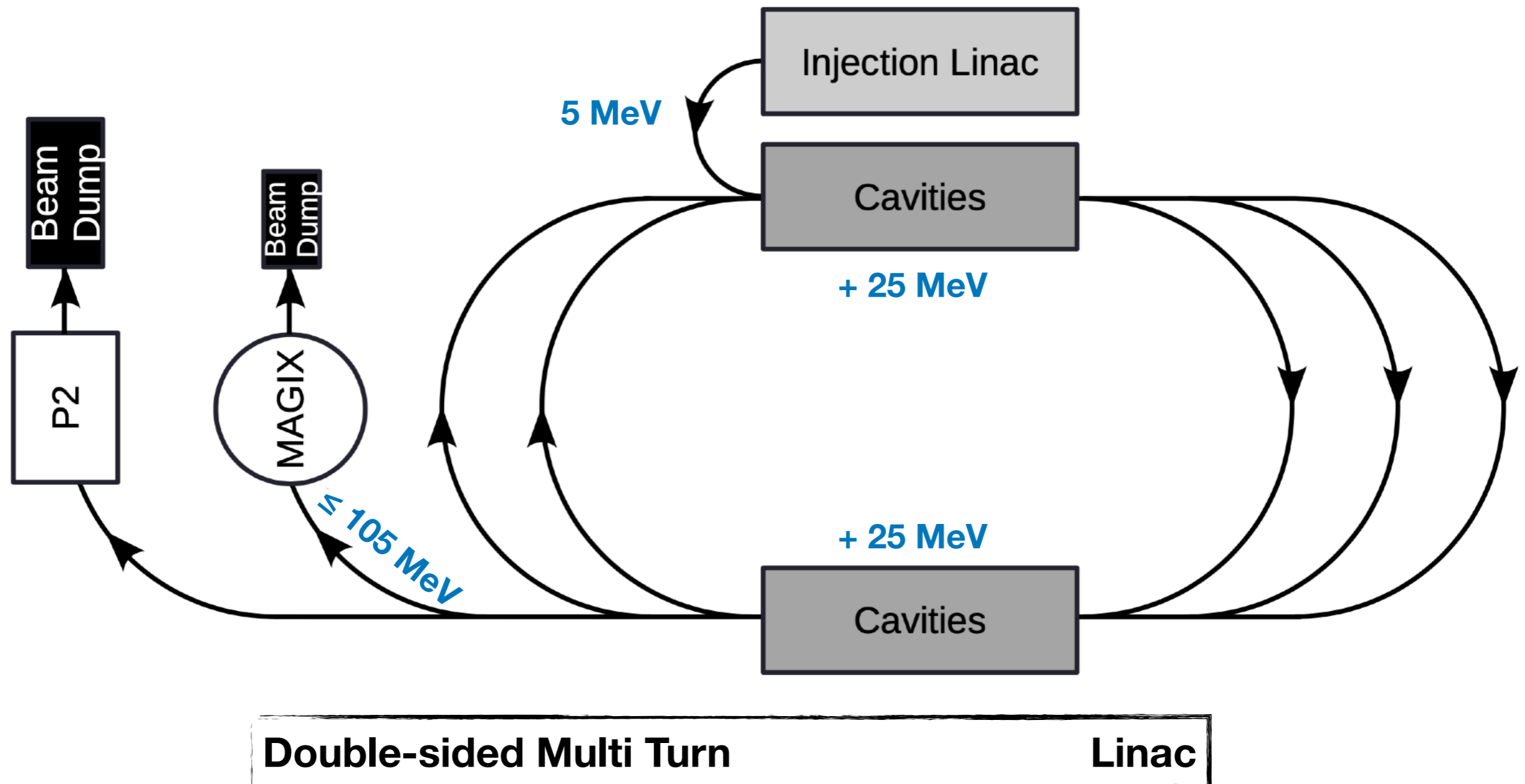


Double-sided Multi Turn

Linac

Extracted Beam (EB) mode - P2 experiment

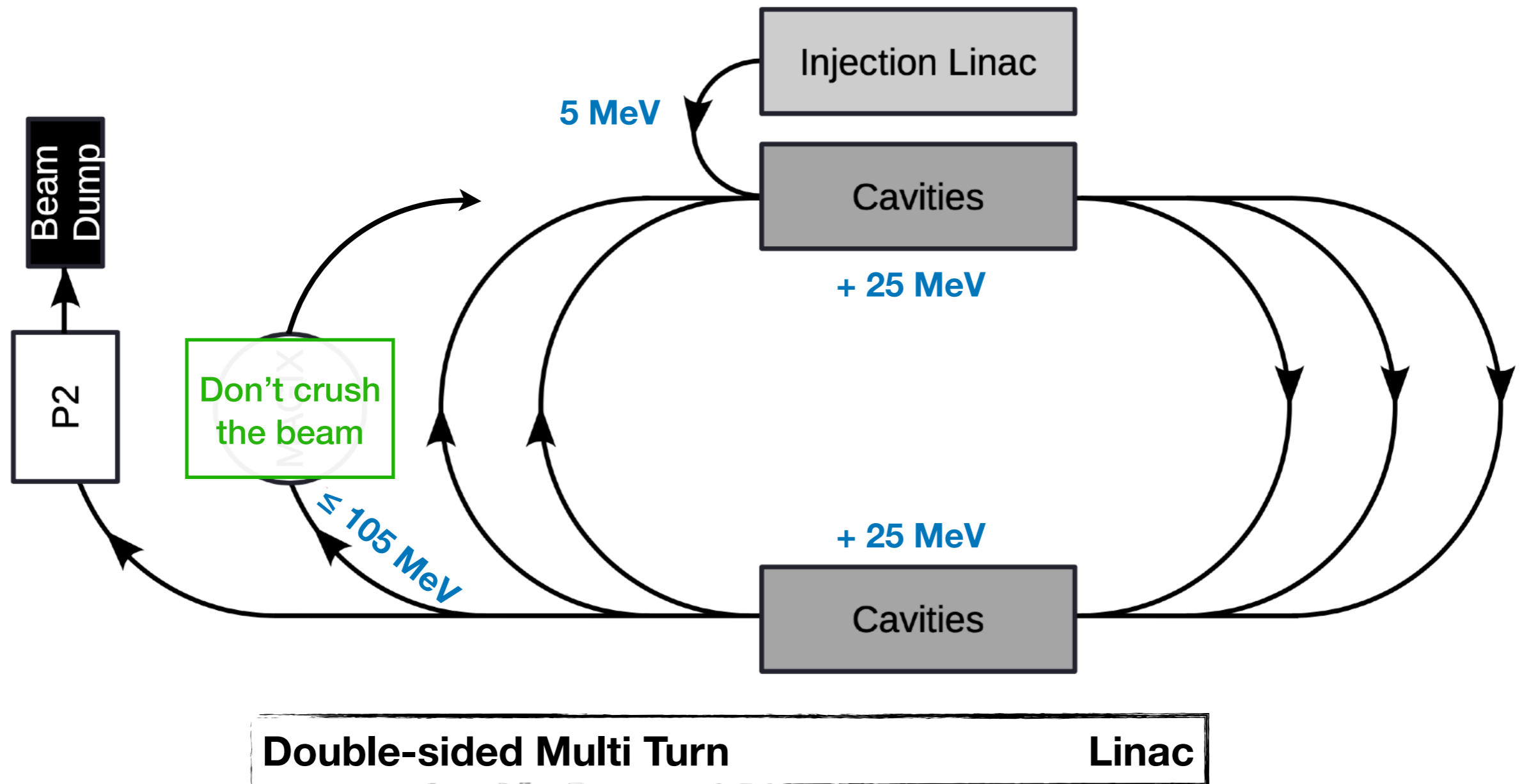
Let's build MESA (4/7).



S.Schlimme

Extracted Beam (EB) mode - MAGIX experiment

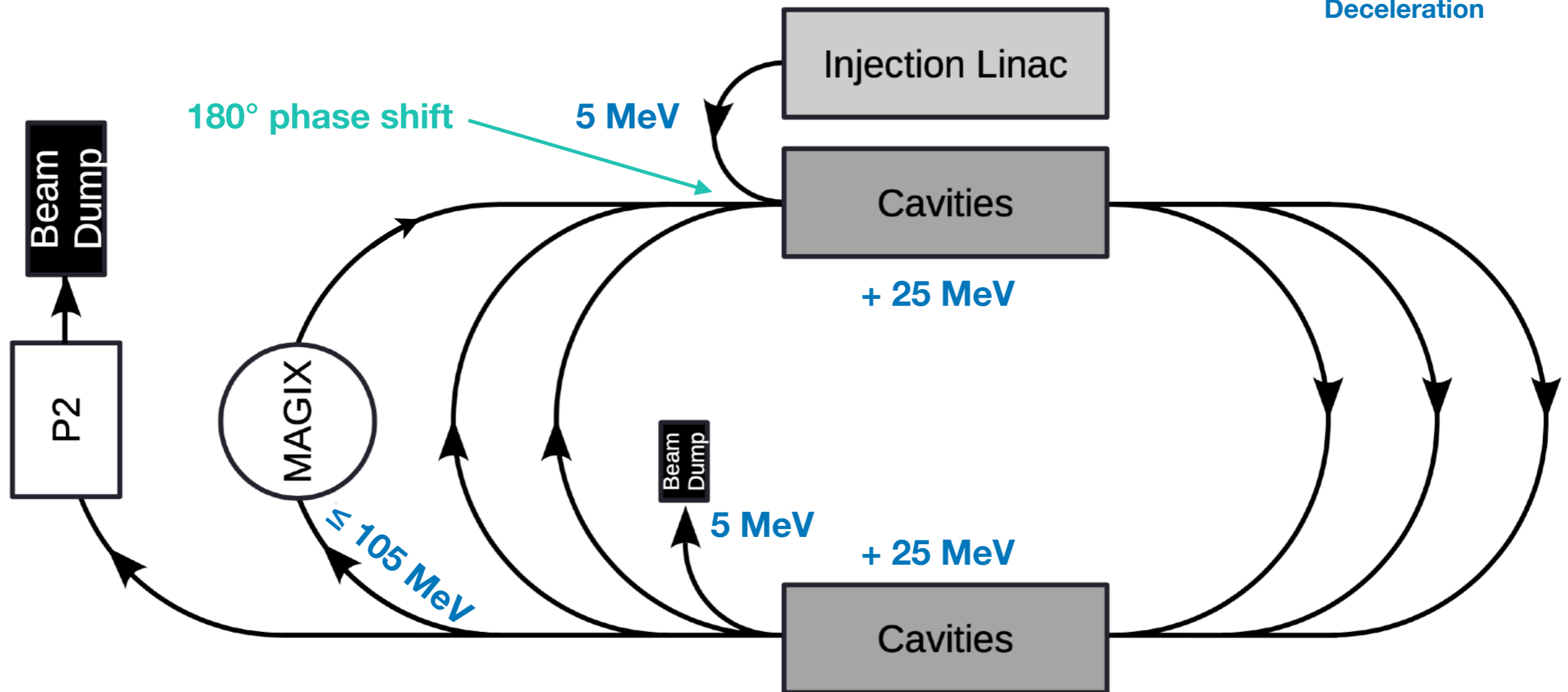
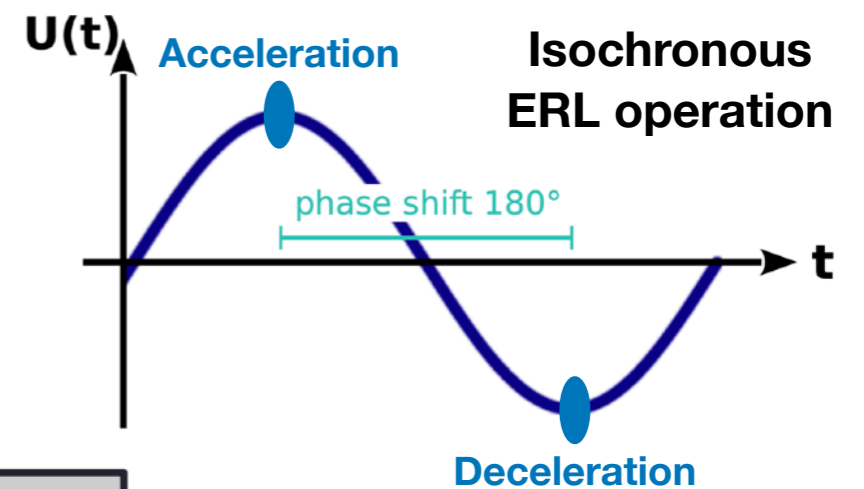
Let's build MESA (5/7).



S.Schlimme

Energy-Recovery...

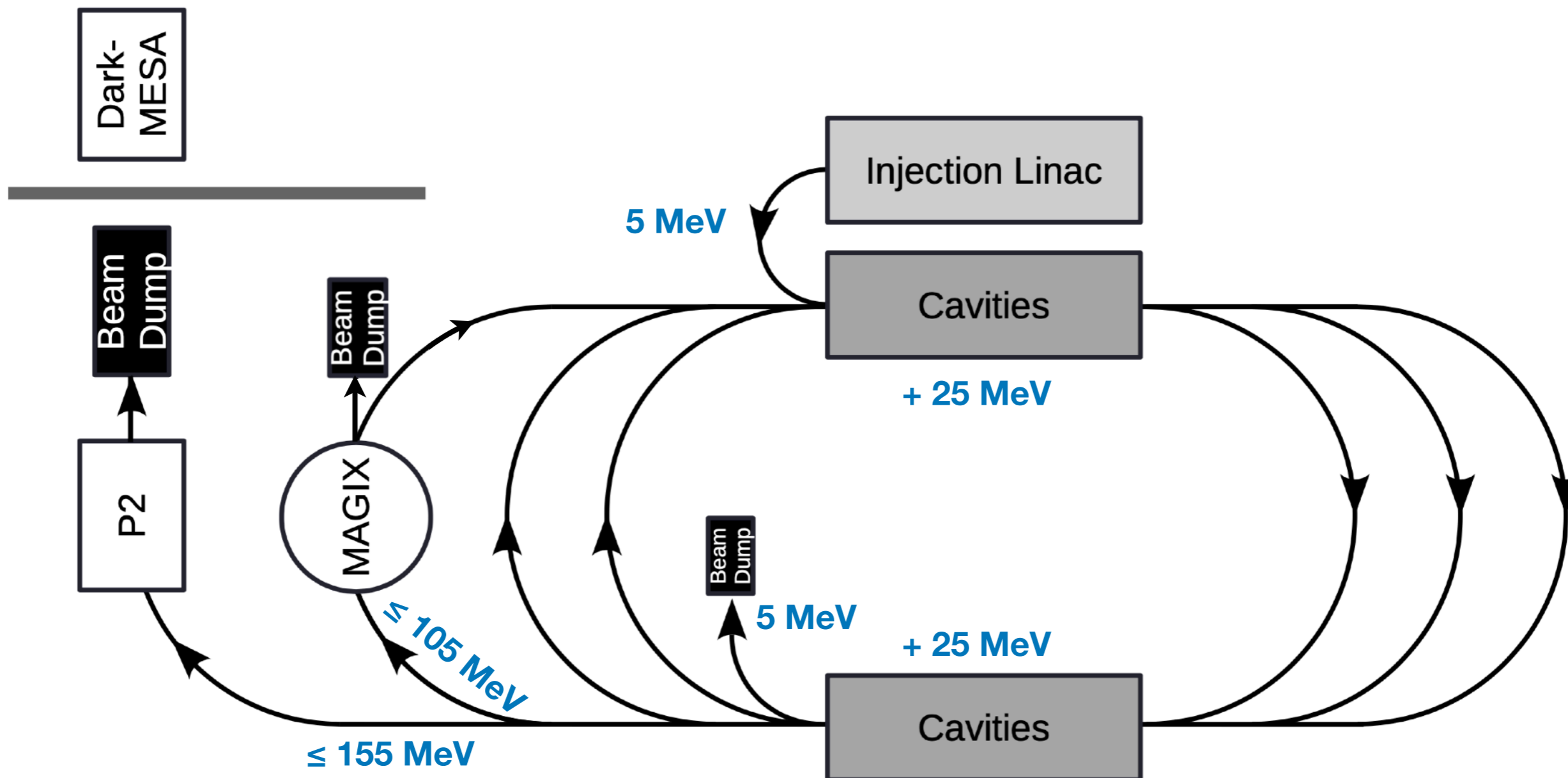
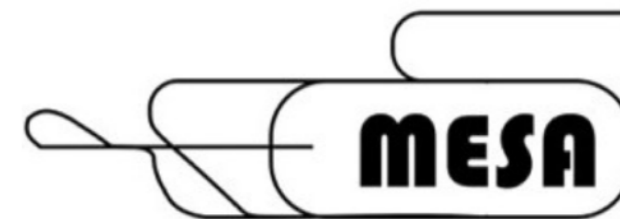
Let's build MESA (6/7).



Double-sided Multi Turn Energy-Recovery Linac

Energy-Recovery Linac (ERL) mode - MAGIX experiment

Let's build MESA (7/7).

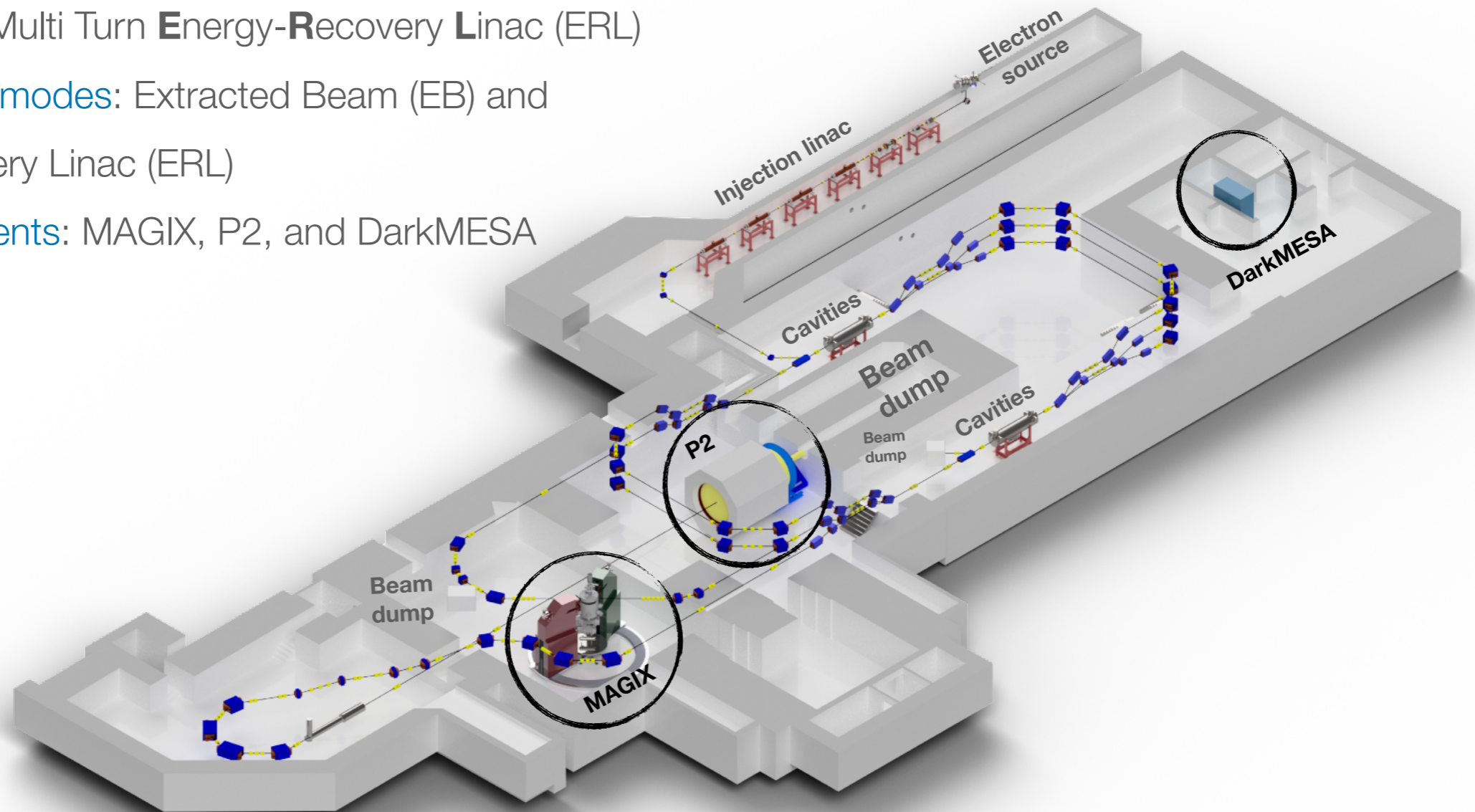


S.Schlimme

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


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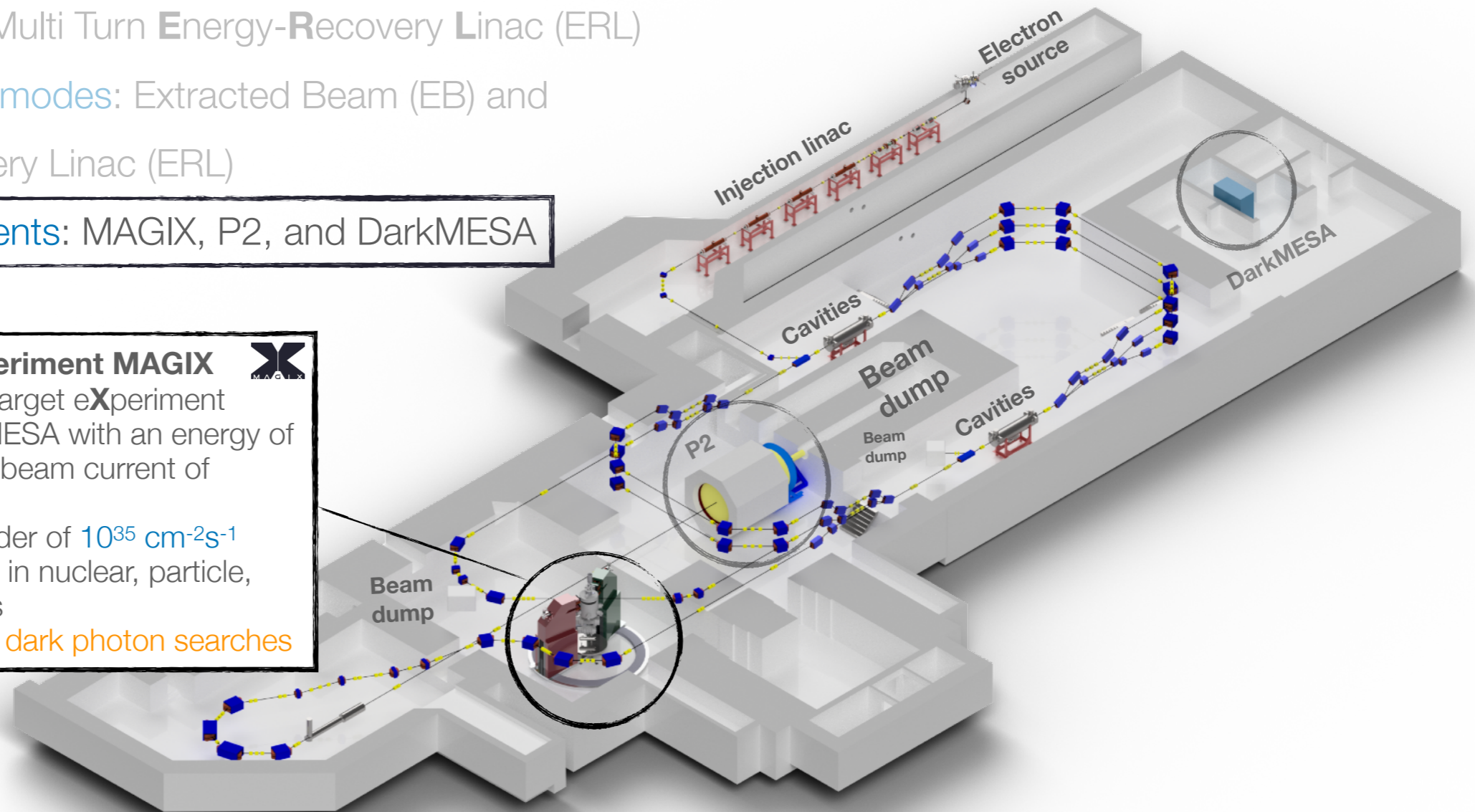


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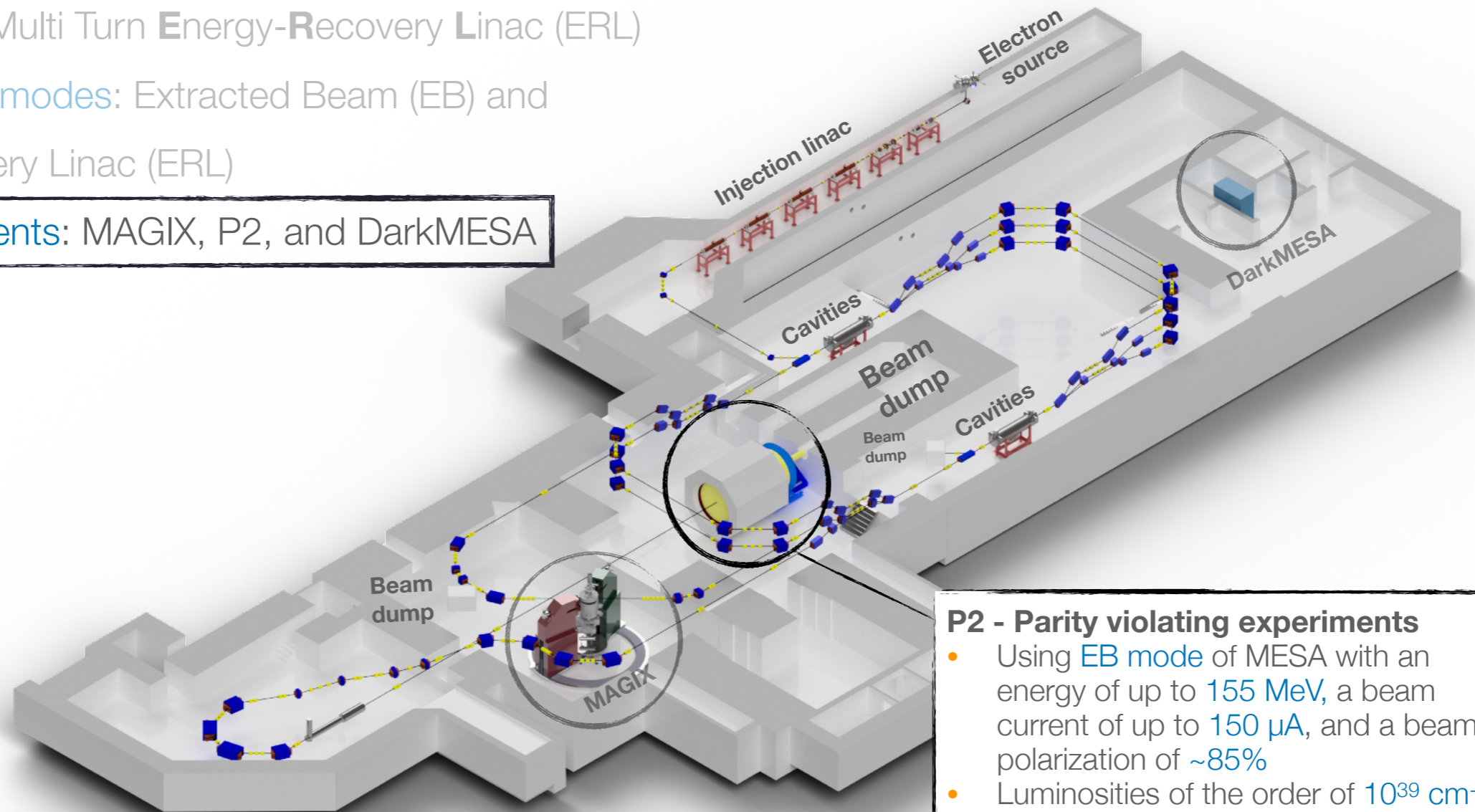
The multi-purpose experiment MAGIX 

- Mainz Gas Injection target eXperiment
- Using ERL mode of MESA with an energy of up to 105 MeV and a beam current of $>1000 \mu\text{A}$
- Luminosities of the order of $10^{35} \text{ cm}^{-2}\text{s}^{-1}$
- Rich physics program in nuclear, particle, and few-body physics
- One focus: dedicated dark photon searches



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P2 - Parity violating experiments

- Using **EB mode** of MESA with an energy of up to **155 MeV**, a beam current of up to **150 μA** , and a beam polarization of **$\sim 85\%$**
- Luminosities of the order of **$10^{39} \text{ cm}^{-2}\text{s}^{-1}$**
- Main focus: Measurement of the **weak mixing angle** with highest precision

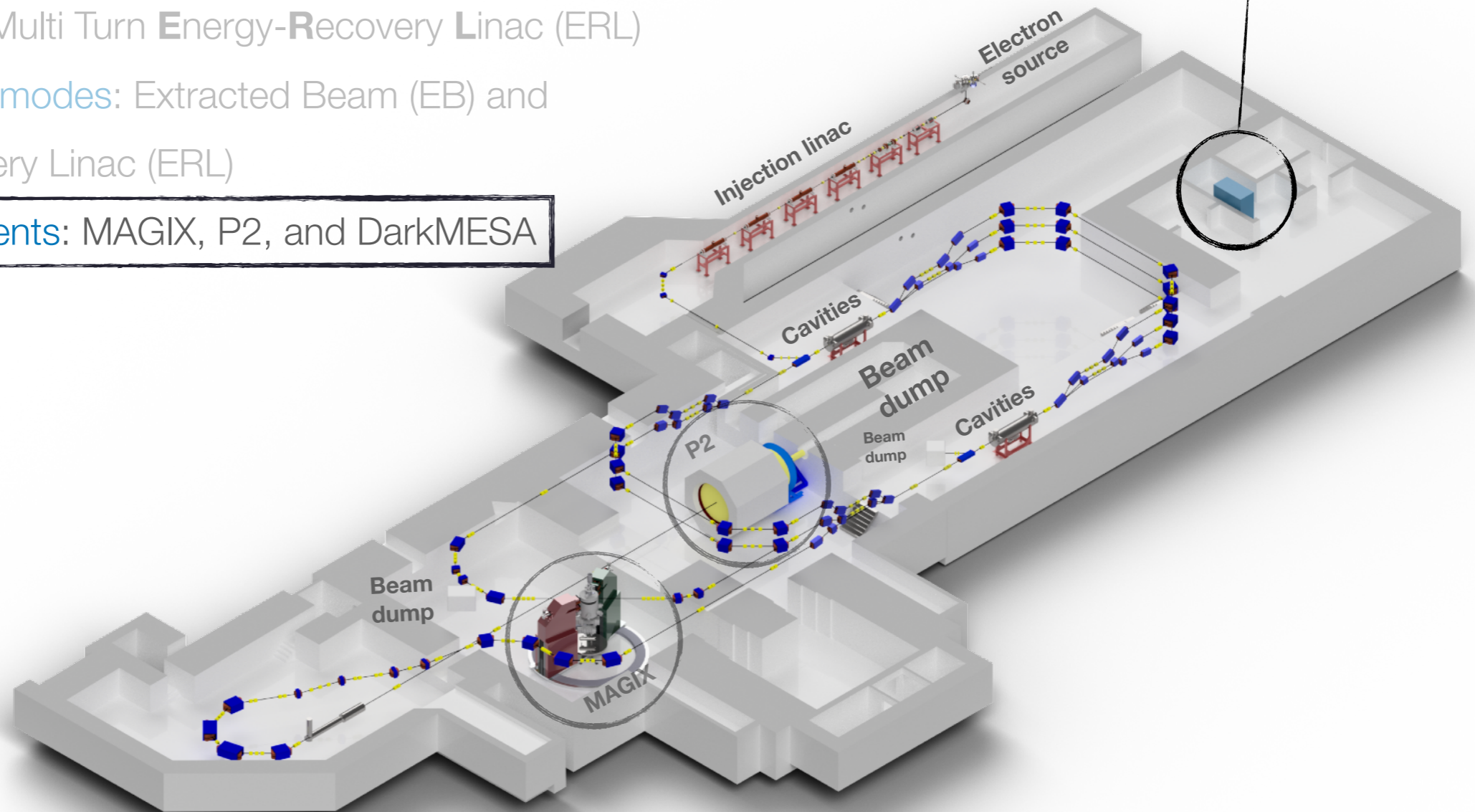
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The beam-dump experiment DarkMESA



- Using P2 beam-dump as a source for hypothetical LDM particles
- Direct search for light dark matter (LDM) particles



MAGIX - A collaboration.



- Exploiting as many synergies as possible
- Currently 47 members in 11 locations

The beam-dump experiment DarkMESA

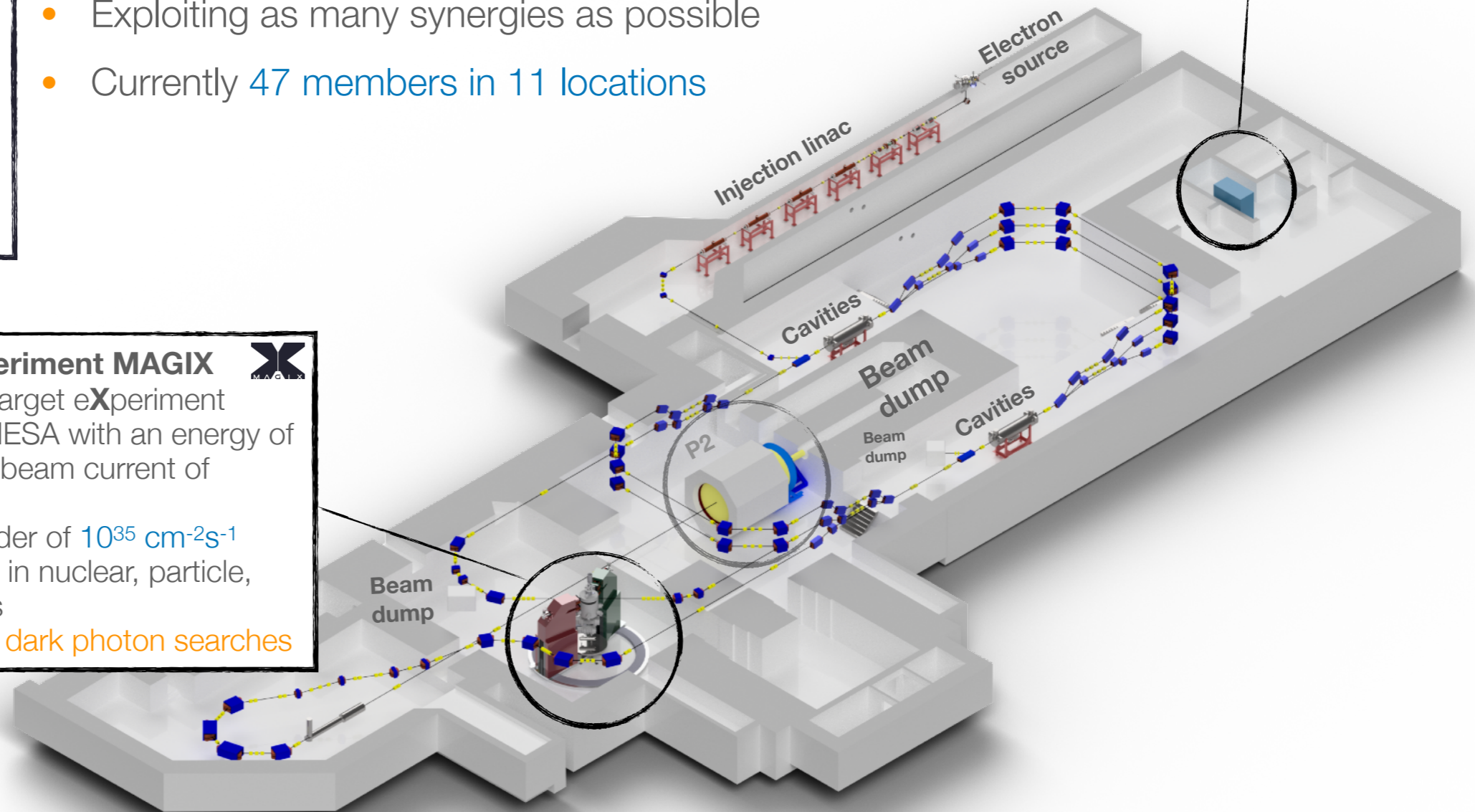


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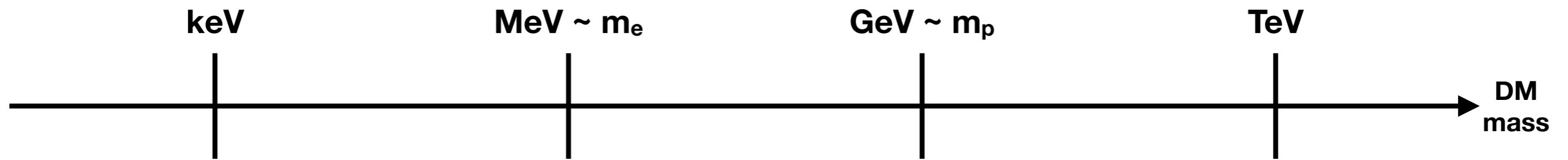
The multi-purpose experiment MAGIX



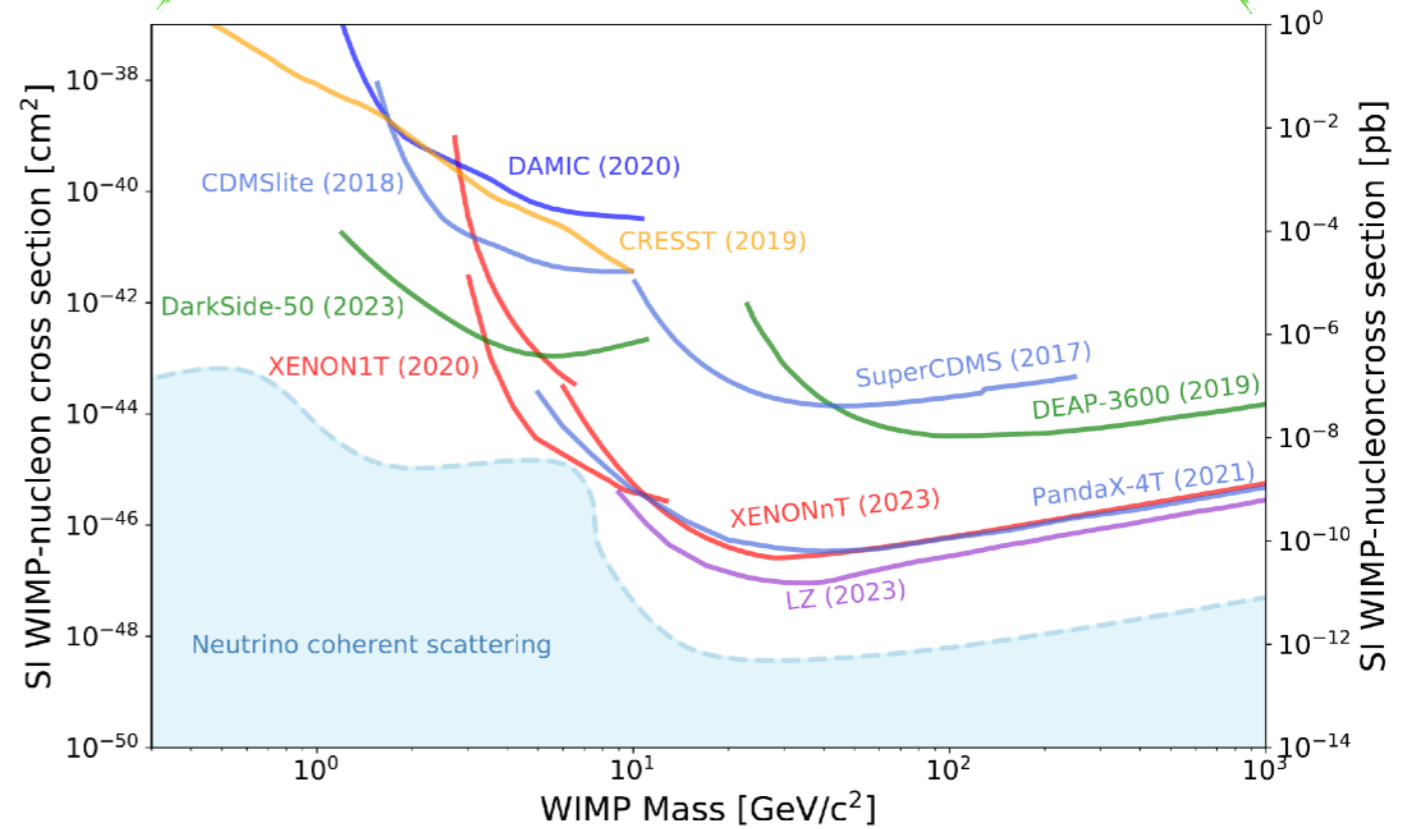
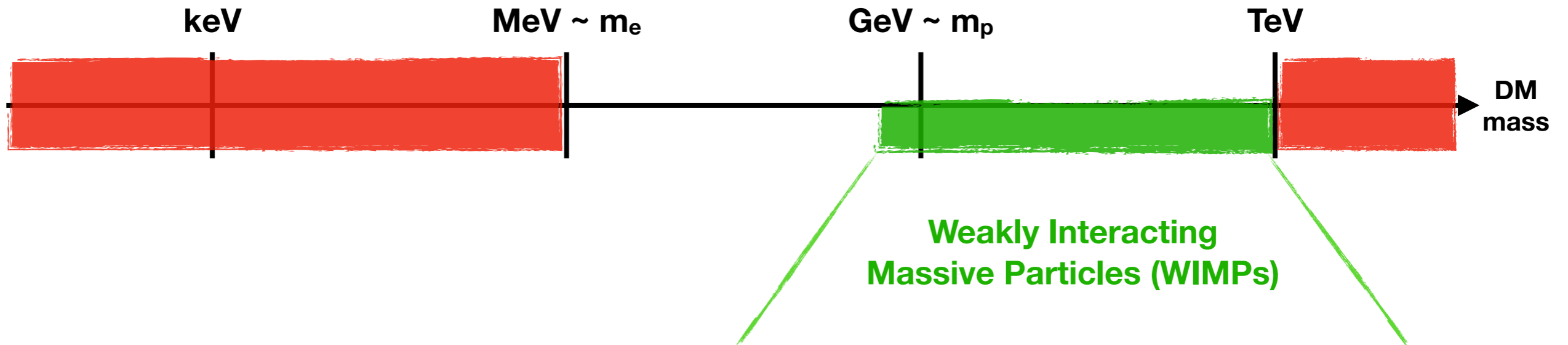
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Dark matter searches.

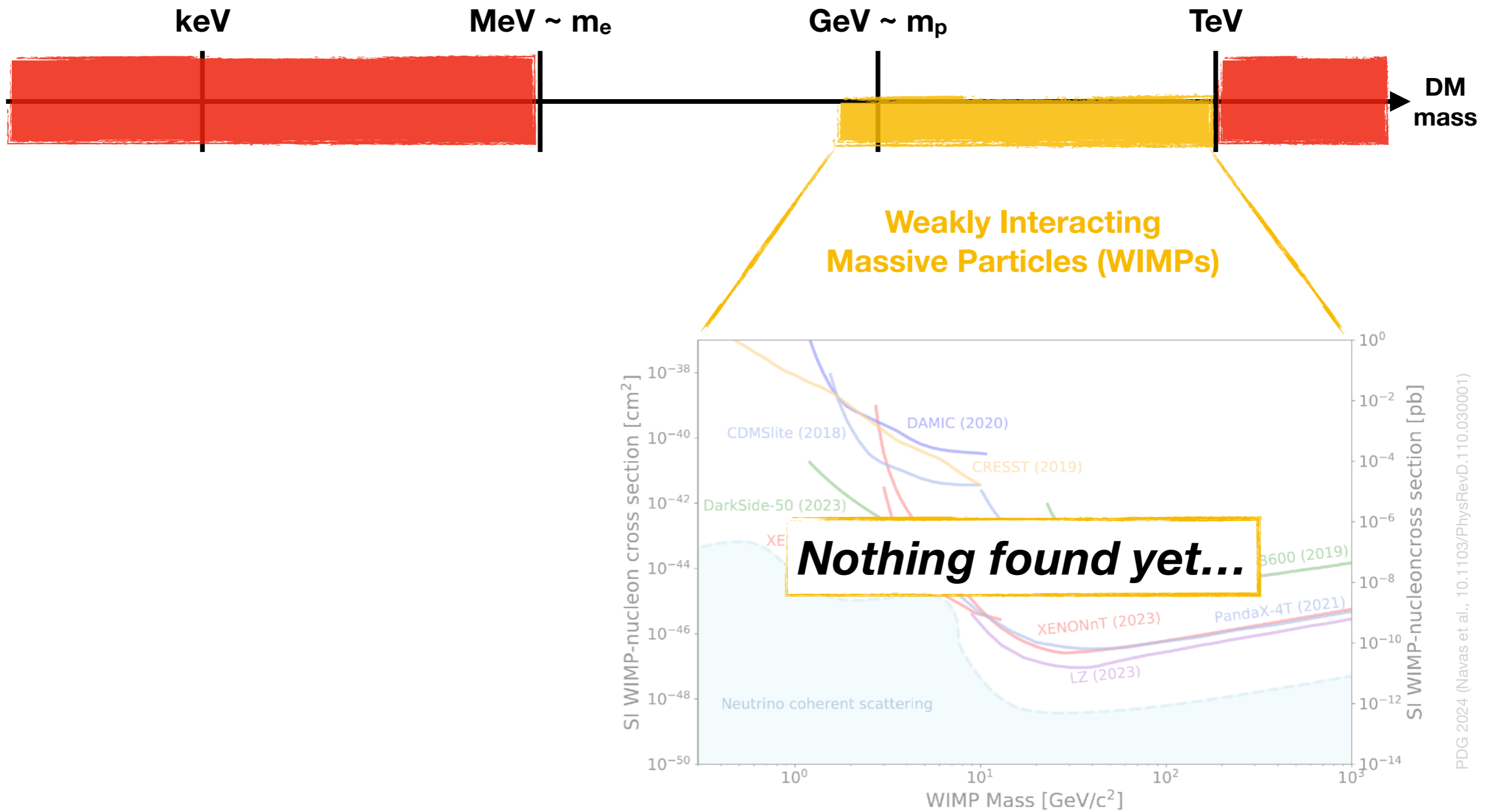


Dark matter searches.



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

Dark matter searches.



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

Dark matter searches.



Light Dark Matter (LDM)

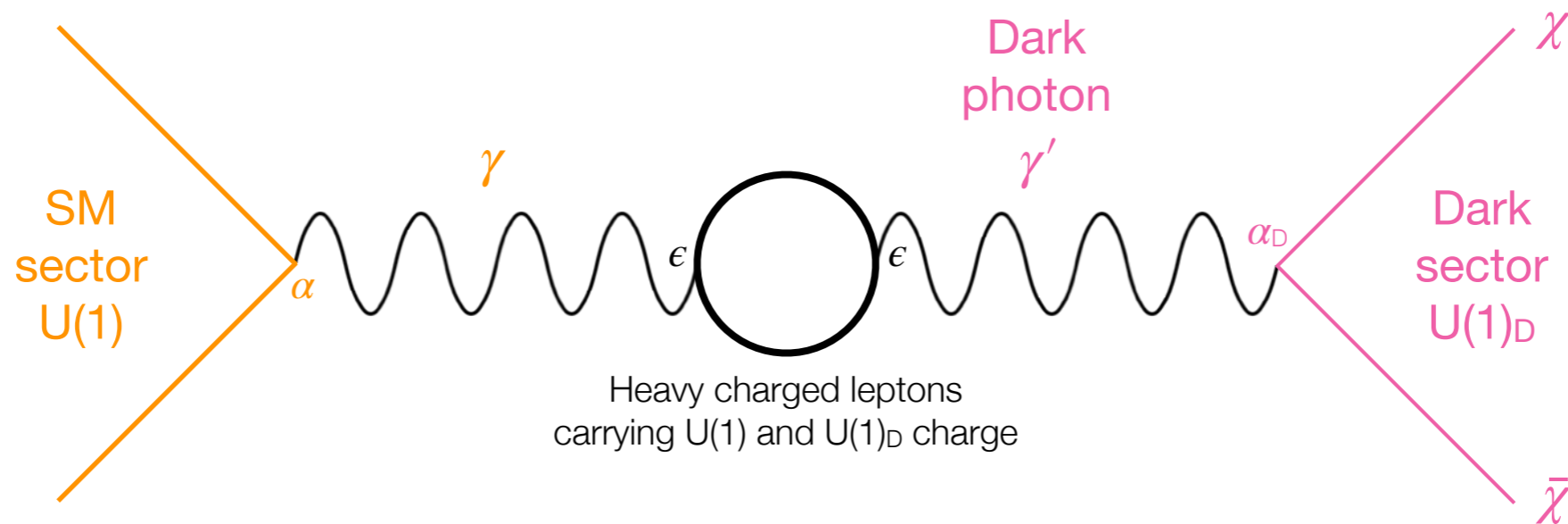
- Interest has shifted towards lower masses
- Related: idea of rich but unexplored **dark sector** that communicates with the SM through one (or more) dark mediator particles

Dark matter searches.



Light Dark Matter (LDM)

- Interest has shifted towards lower masses
- Related: idea of rich but unexplored **dark sector** that communicates with the SM through one (or more) dark mediator particles
- Popular mediator model: **Dark photon γ'** that couples e.g. via kinetic mixing



Dark matter searches.



Light Dark Matter (LDM)

- Interest has shifted towards lower masses
- Related: idea of rich but unexplored dark sector that communicates with the SM through one (or more) dark particles

Complementary dark sector searches

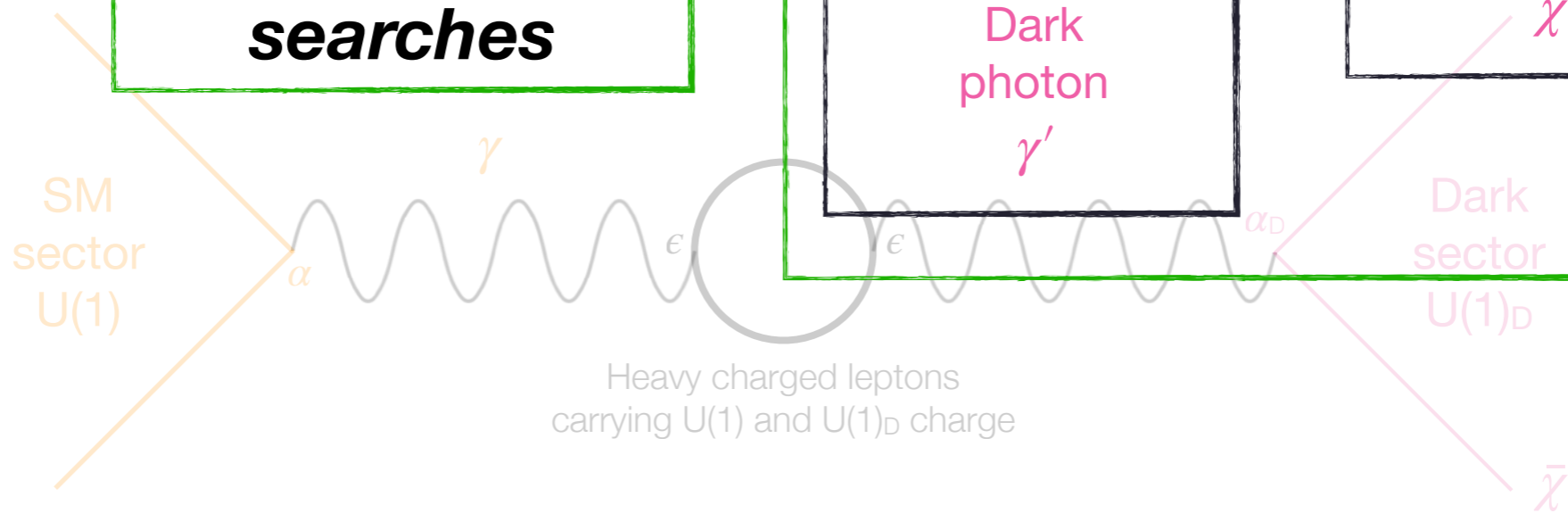


Dark photon
 γ'



χ

Dark sector
 $U(1)_D$

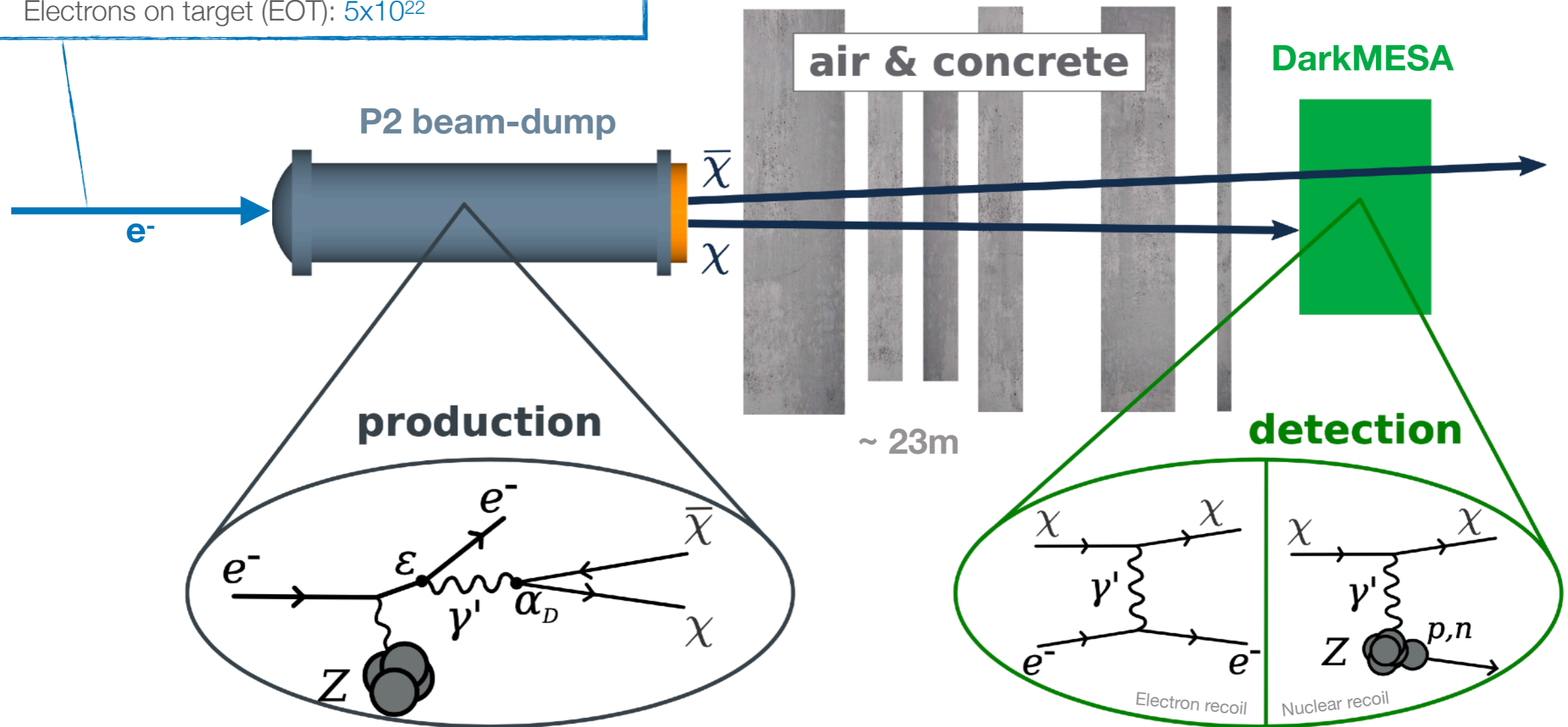


Heavy charged leptons carrying $U(1)$ and $U(1)_D$ charge

DarkMESA.

The DarkMESA concept.

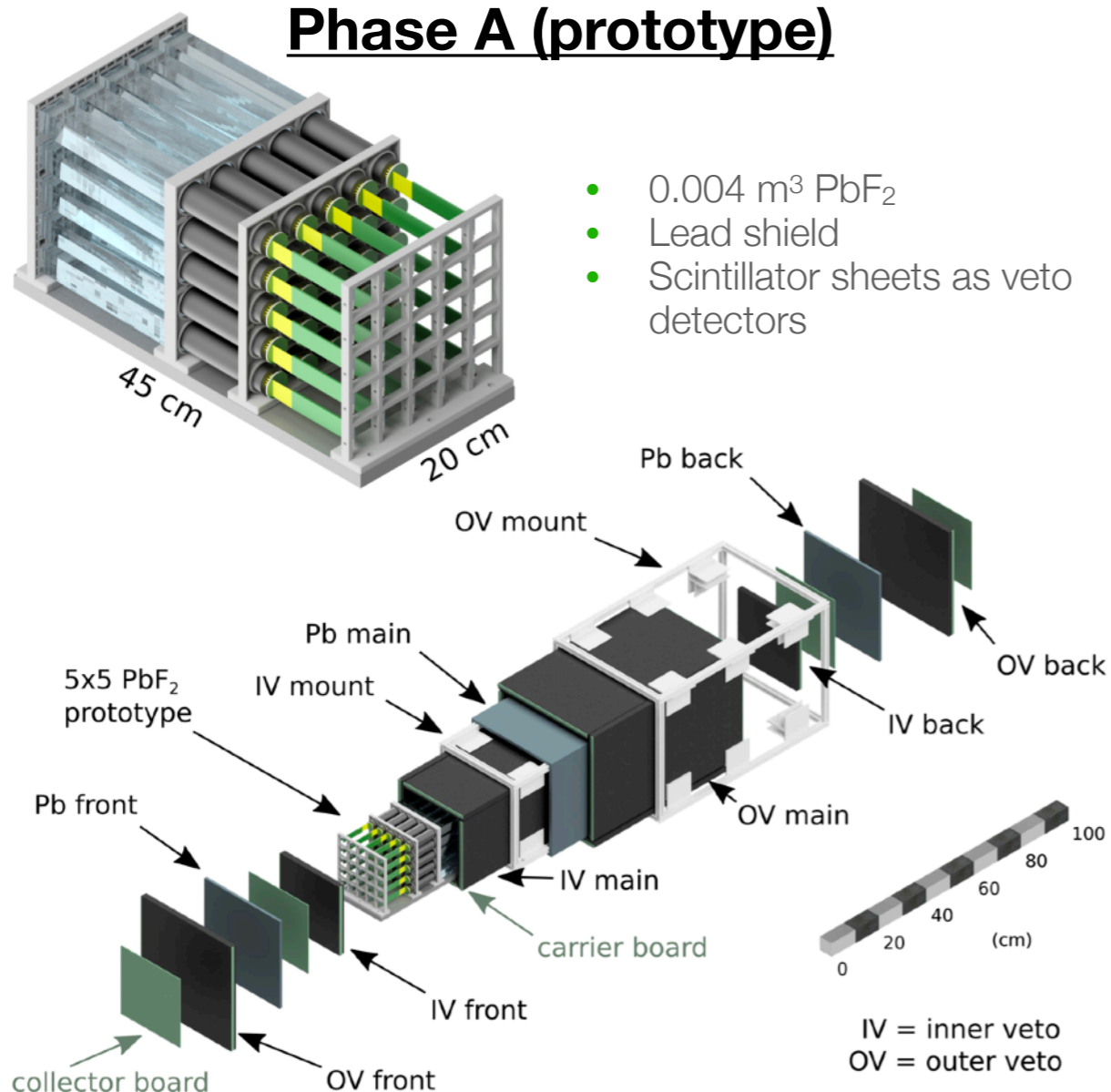
- 16,000 hours of high-intensity beam on the dump
- Beam energy below the pion production threshold
- Beam current: $150\mu\text{A}$
- Electrons on target (EOT): 5×10^{22}



M. Christmann, PhD thesis, 10.25358/openscience-9076

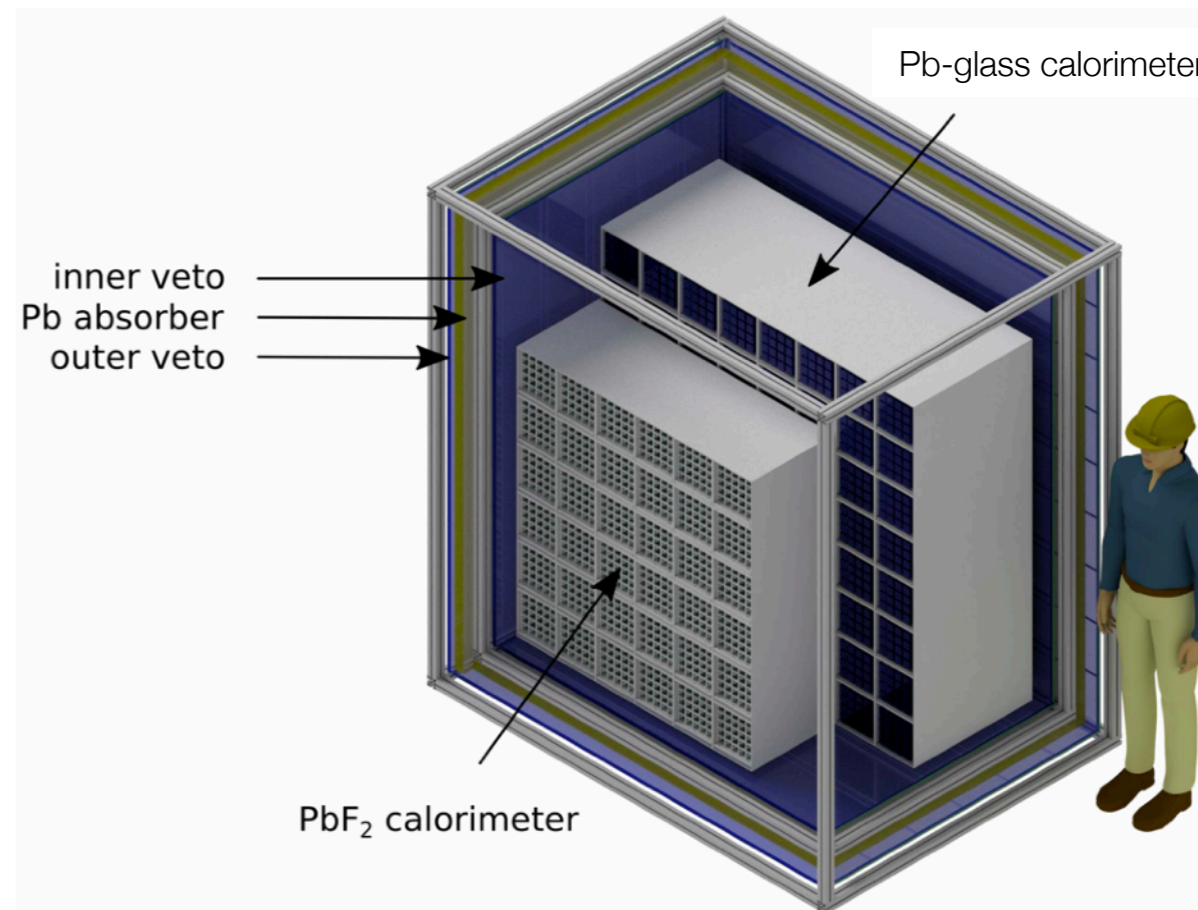
DarkMESA - detector stages.

Phase A (prototype)



Phase B (increased volume)

- 0.120 m³ PbF₂ and 0.580 m³ SF5 Pb-glass
- Lead shield
- Scintillator sheets as veto detectors



Phase C (range extension, different options)

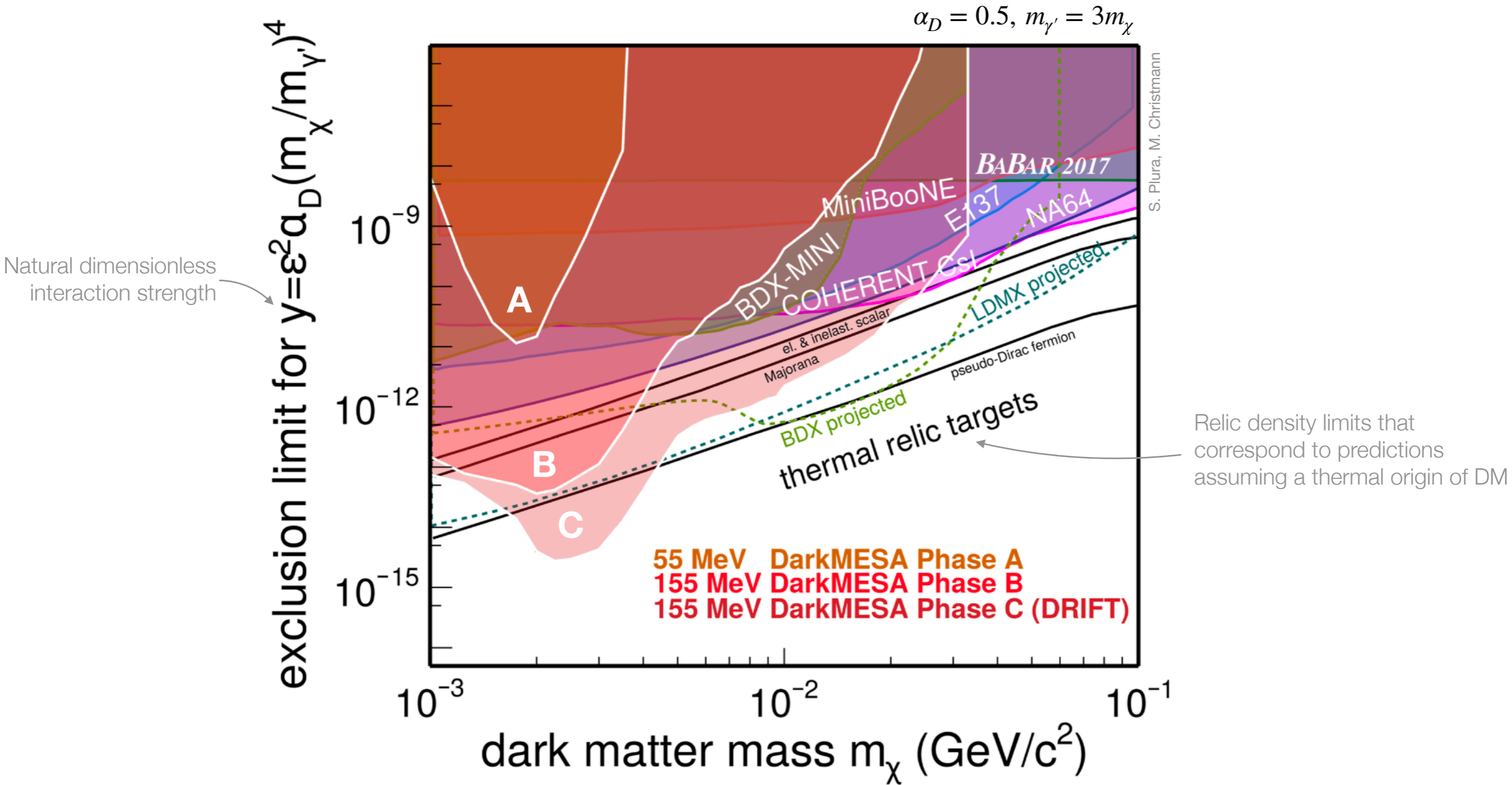
Radiation protection glass

Time-projection-chamber (DarkMESA DRIFT)

Liquid scintillators (NuDoubt++)

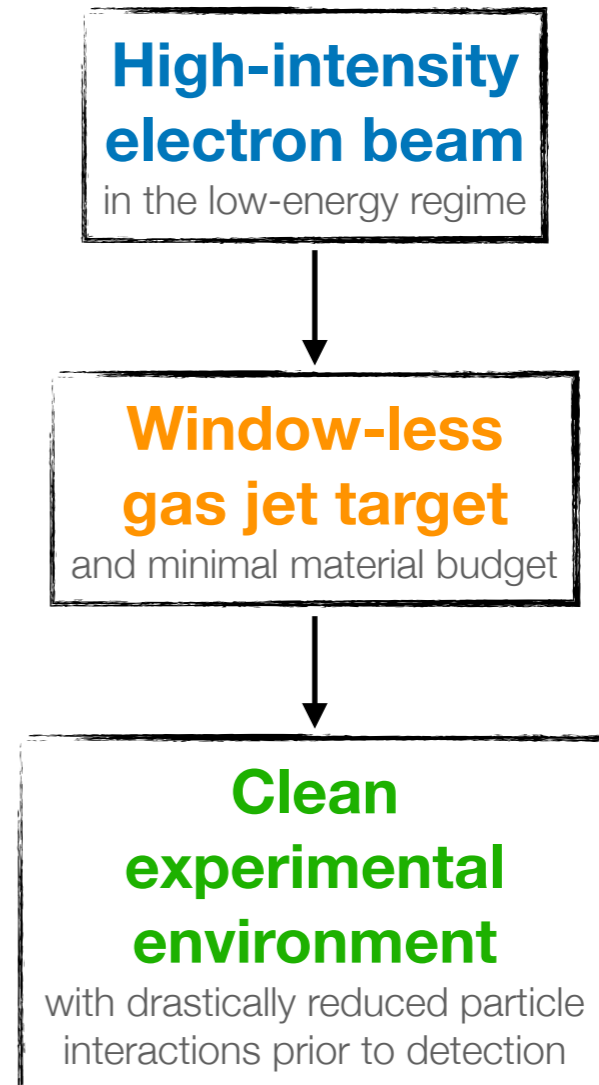
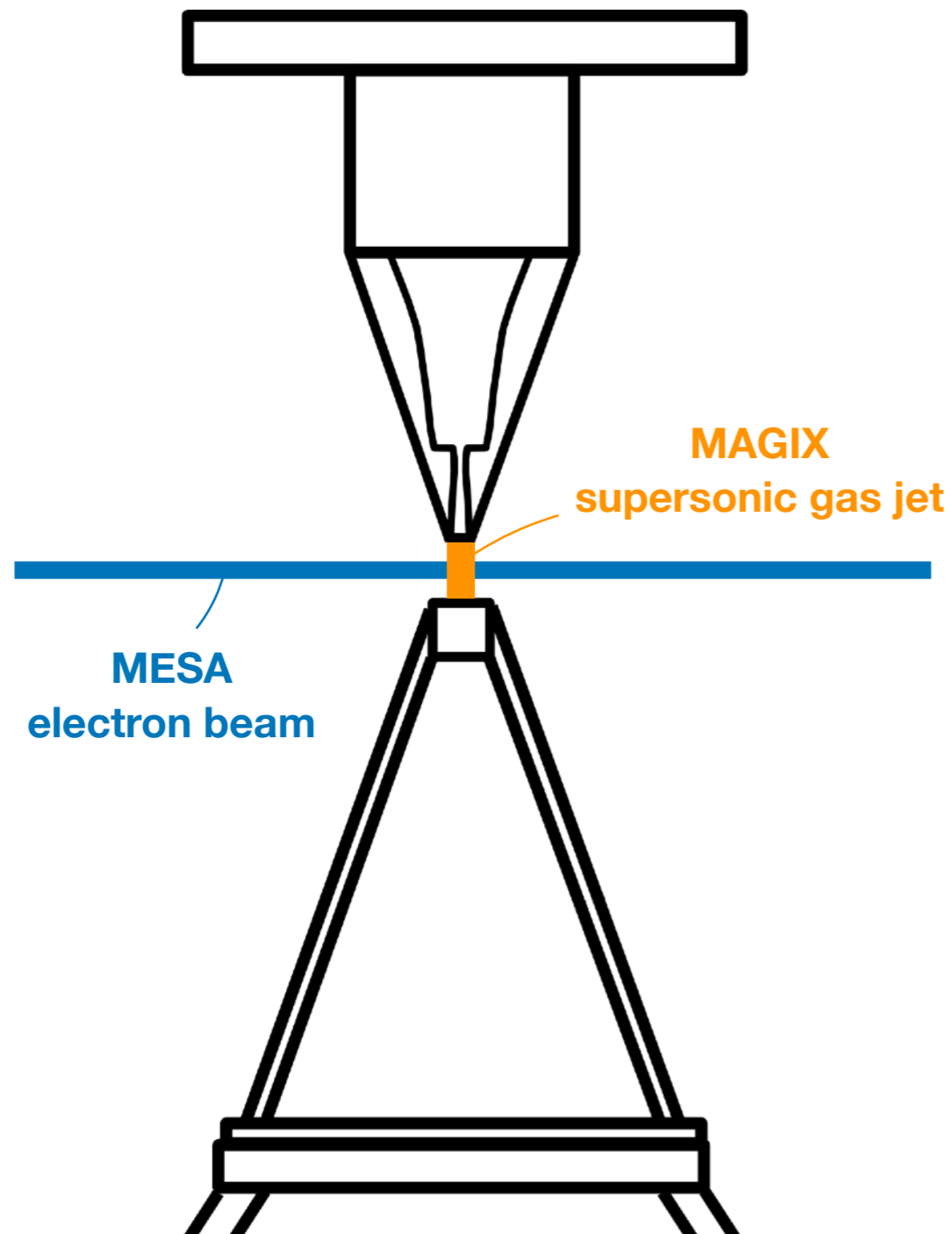
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DarkMESA - expected sensitivity.

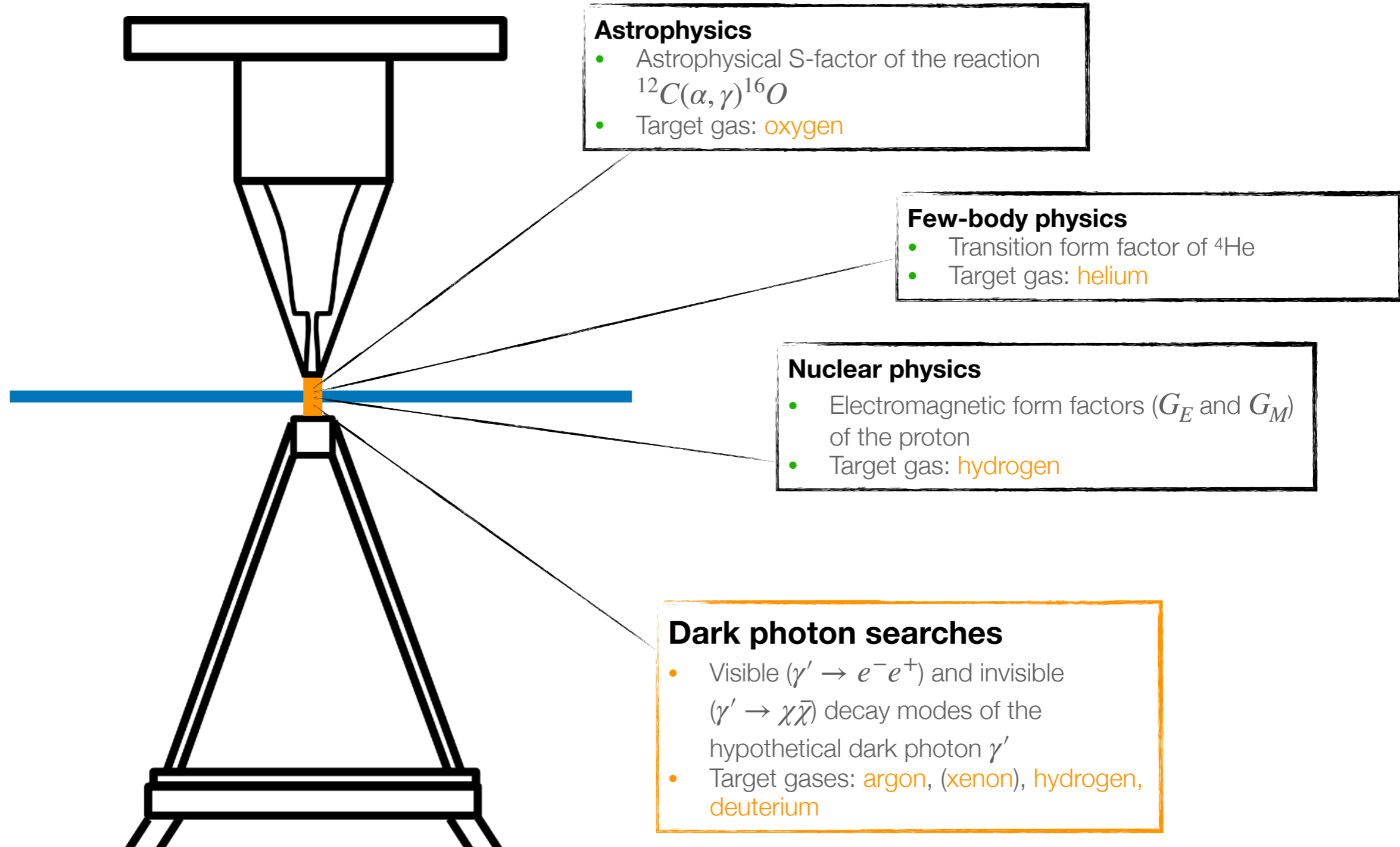


MAGIX.

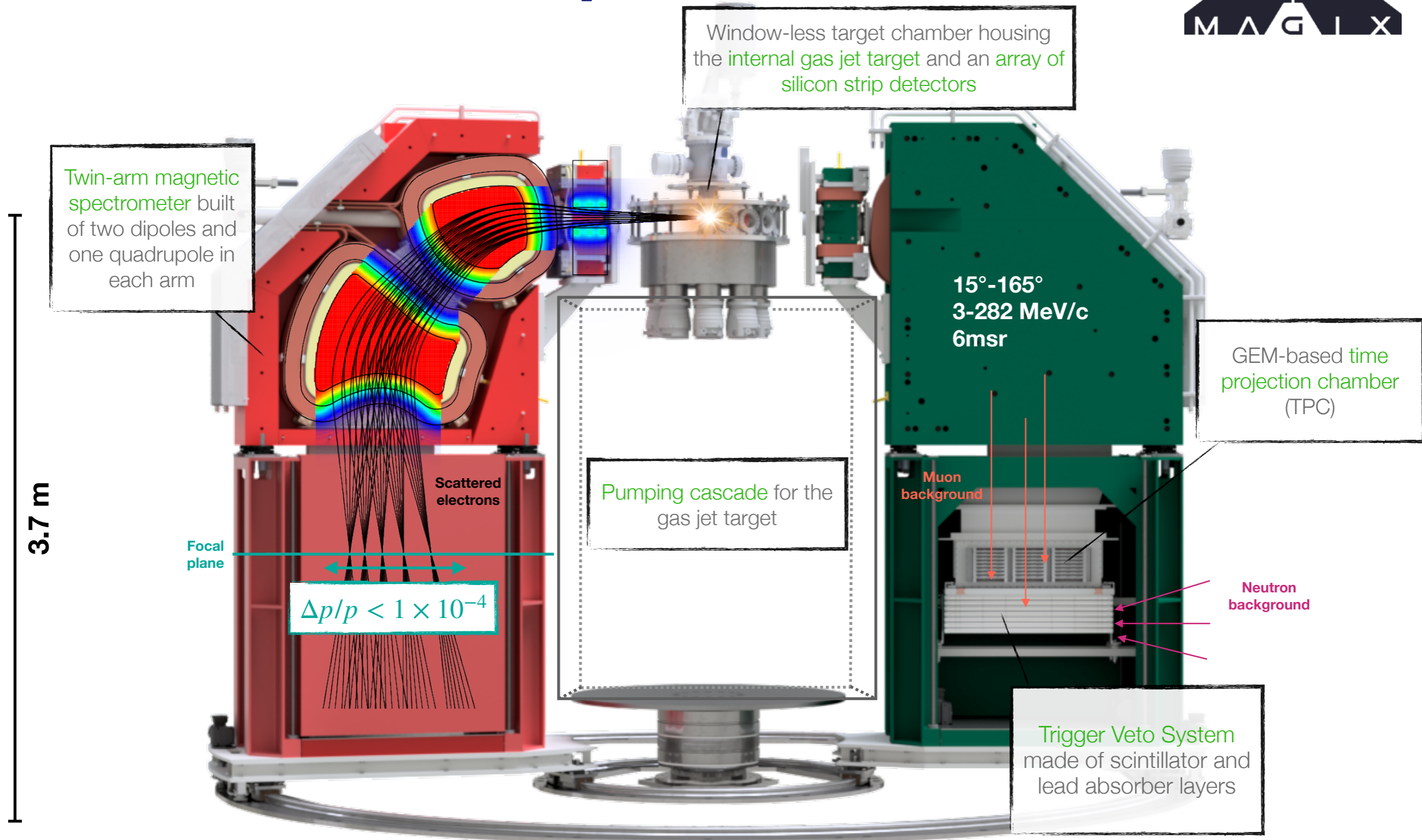
The basic idea of MAGIX.



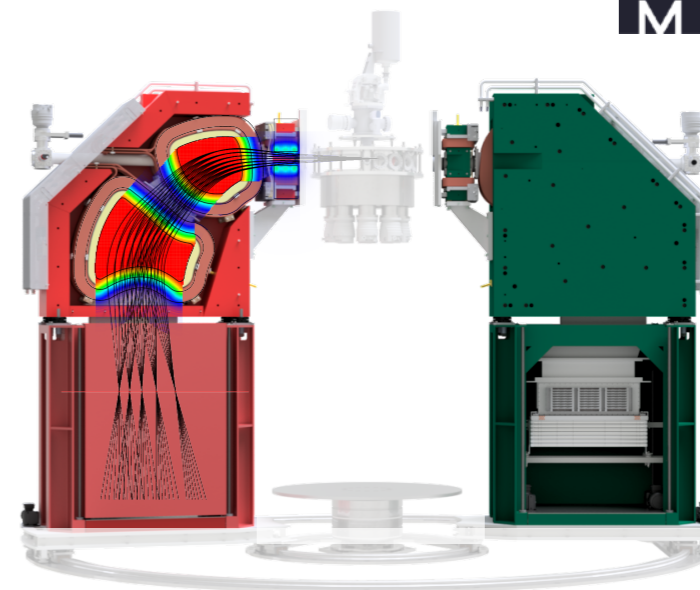
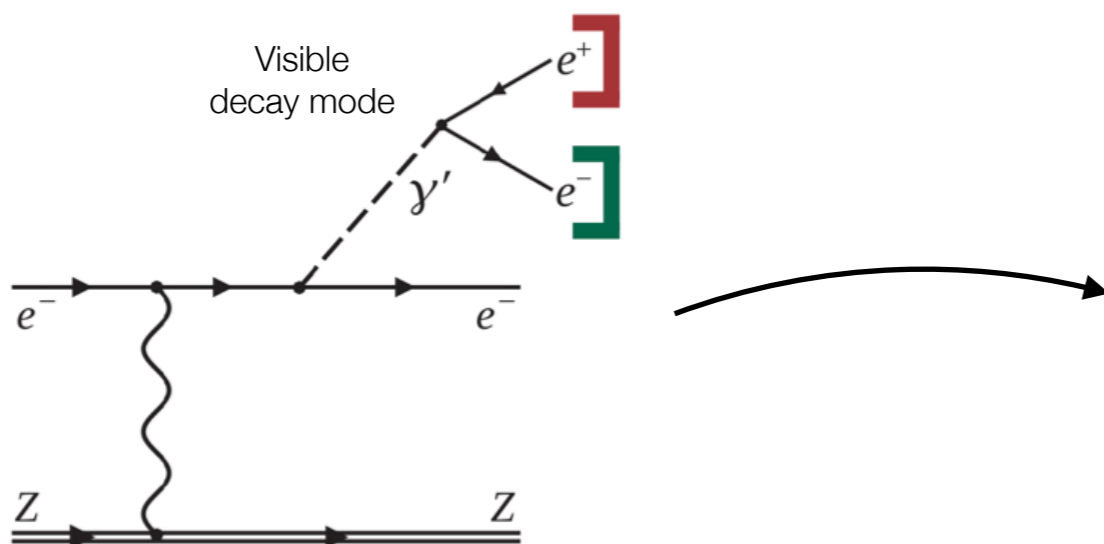
The MAGIX physics program.



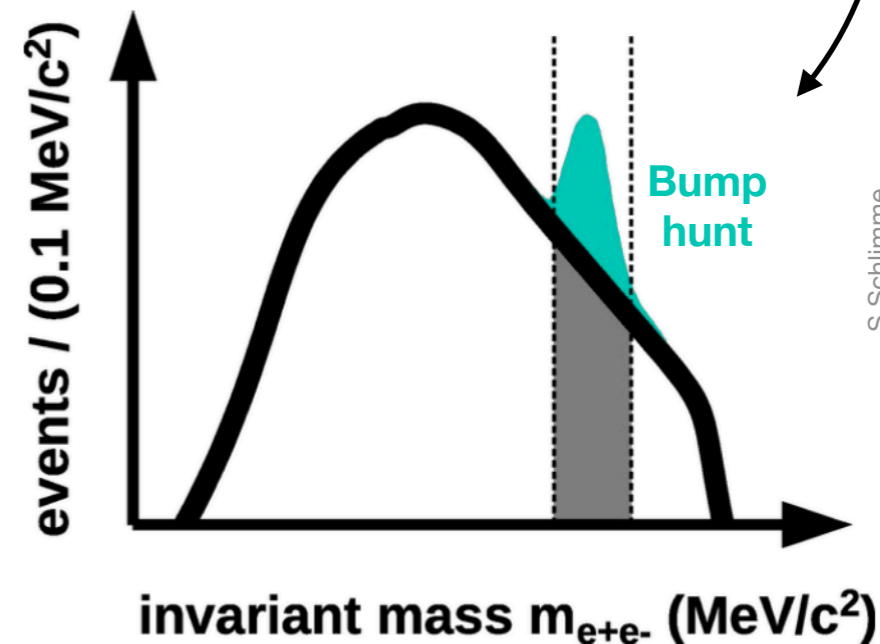
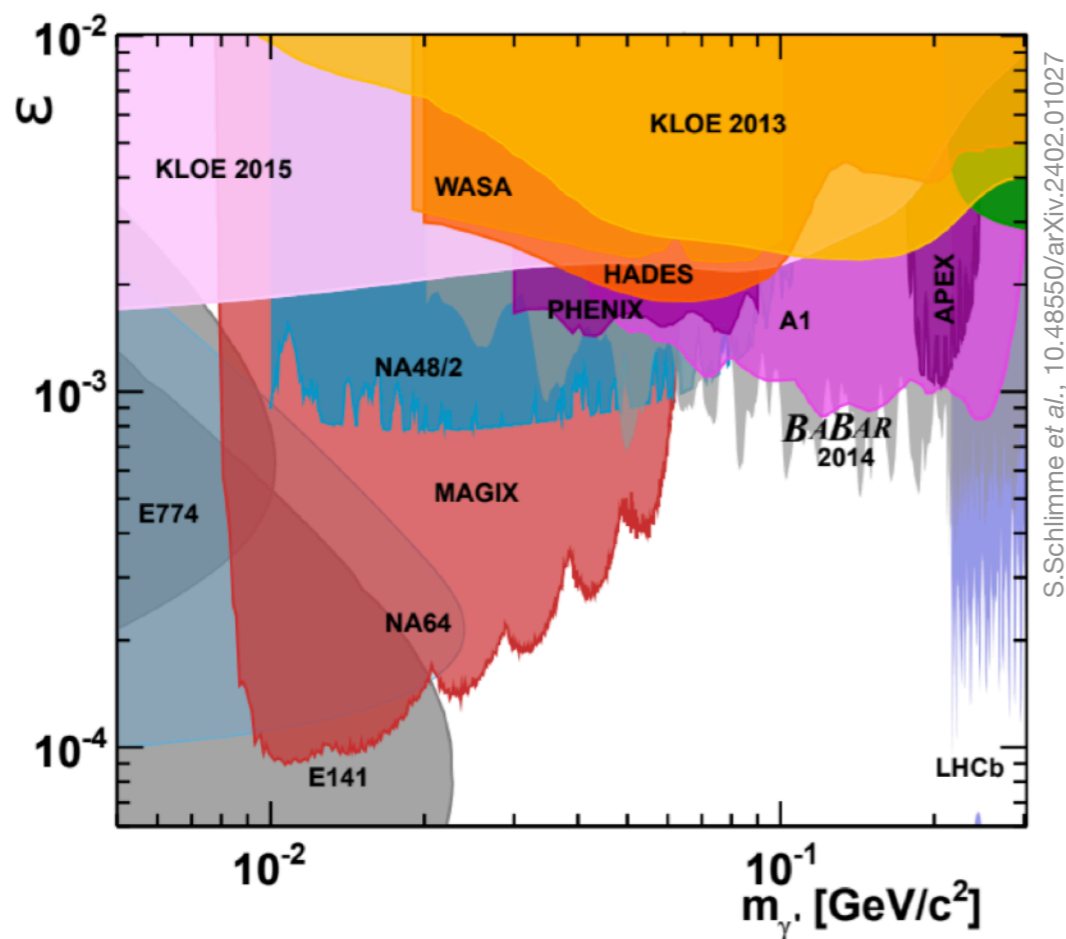
The MAGIX setup.



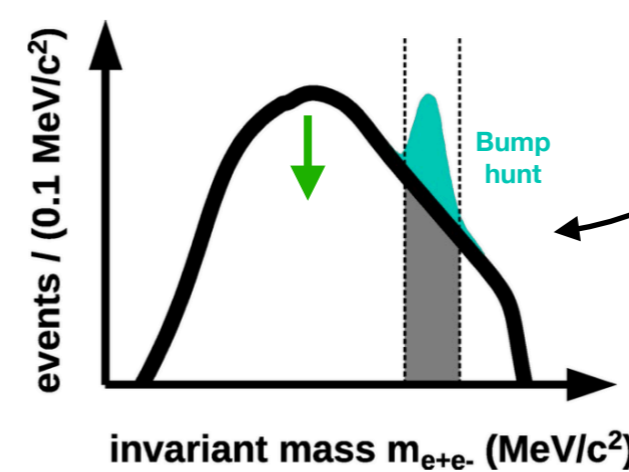
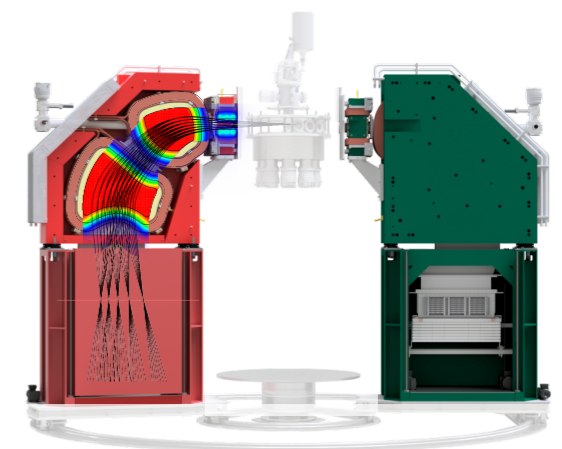
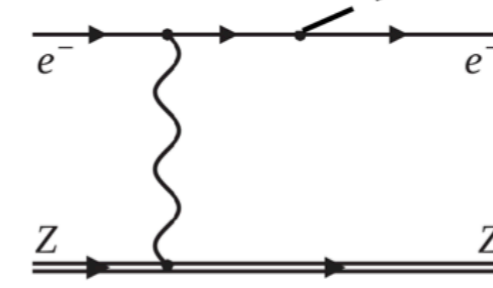
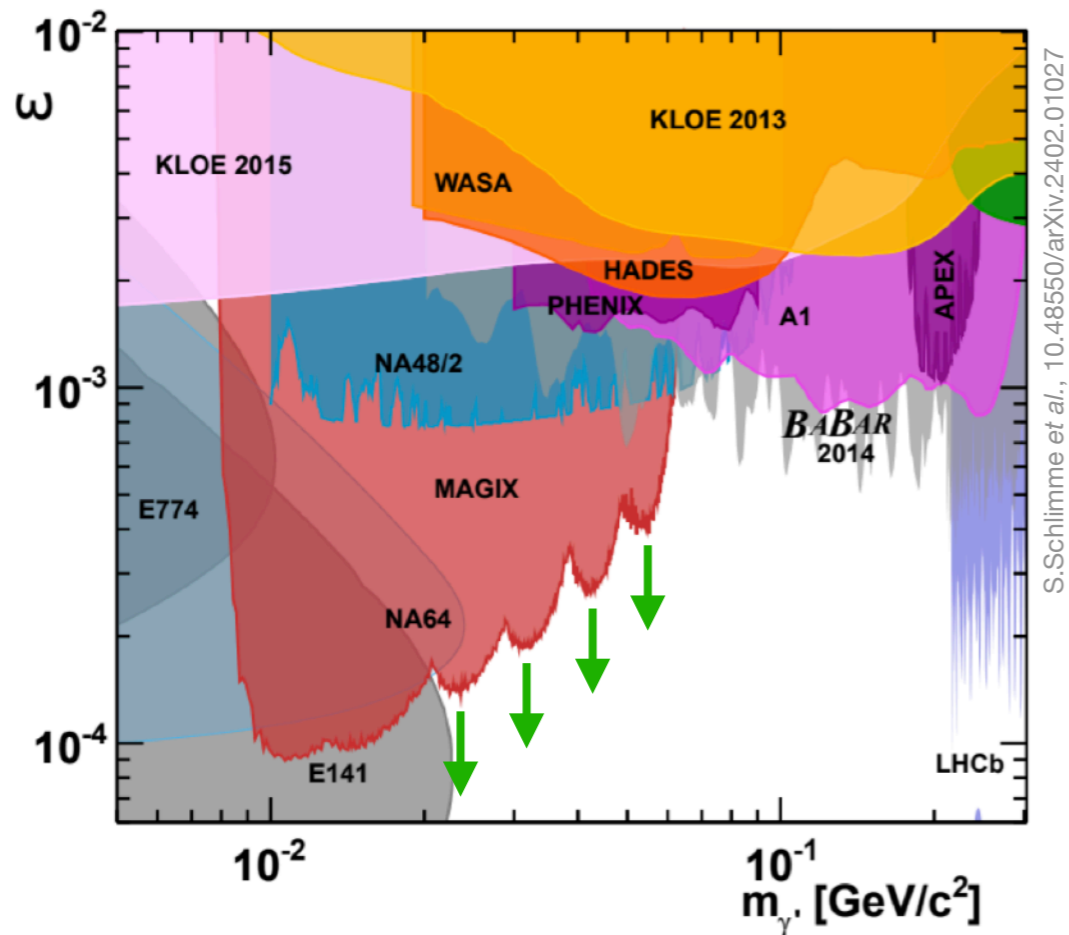
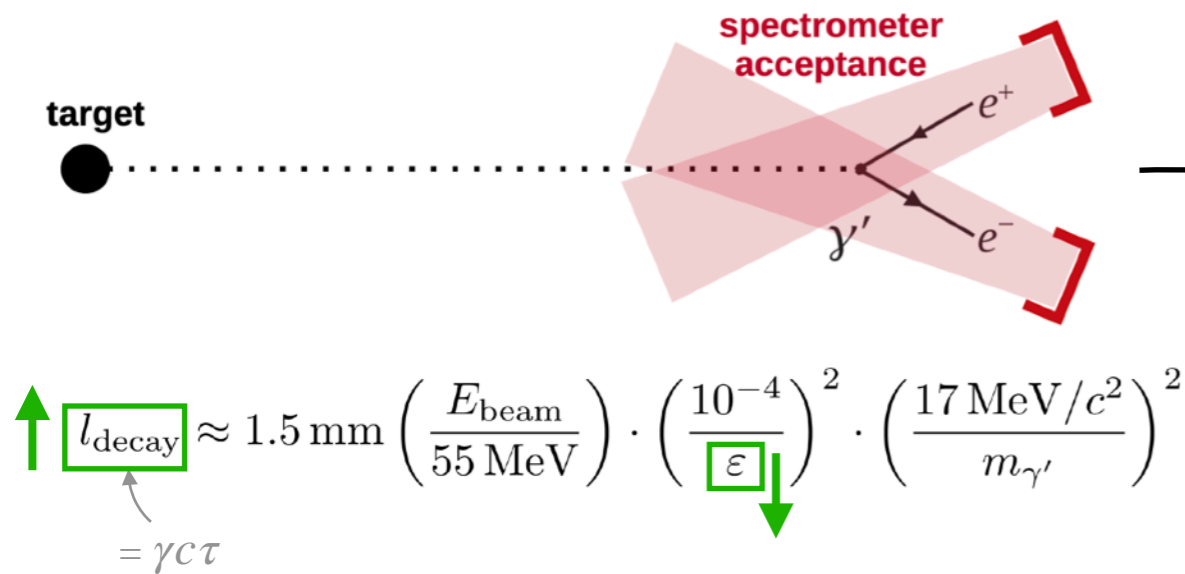
Dark photon - visible decay.



Coincidence measurement between both spectrometers



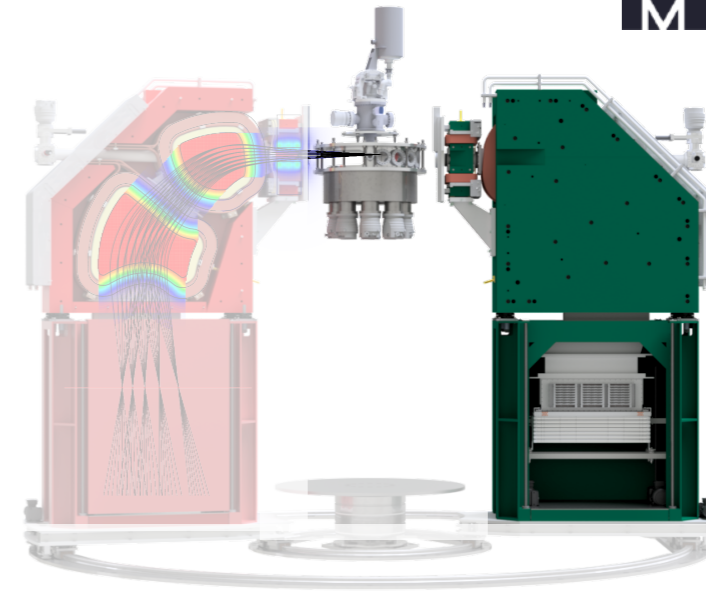
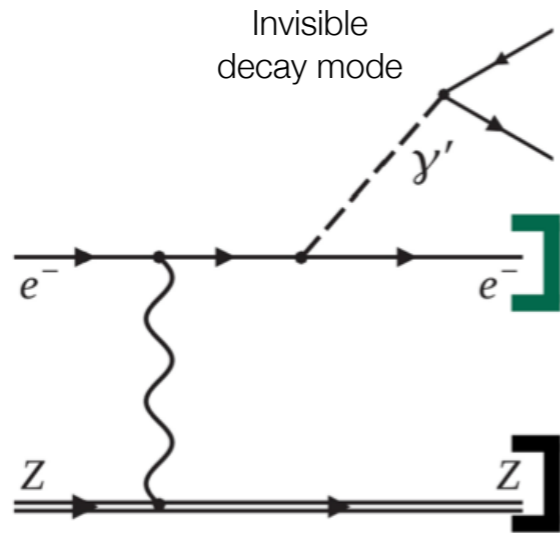
Dark photon - displaced vertex.



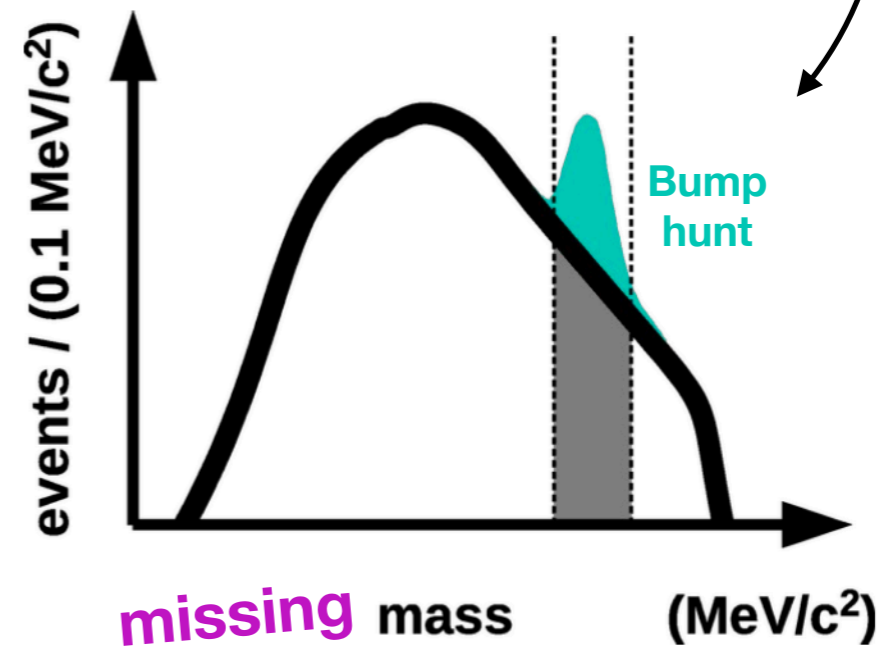
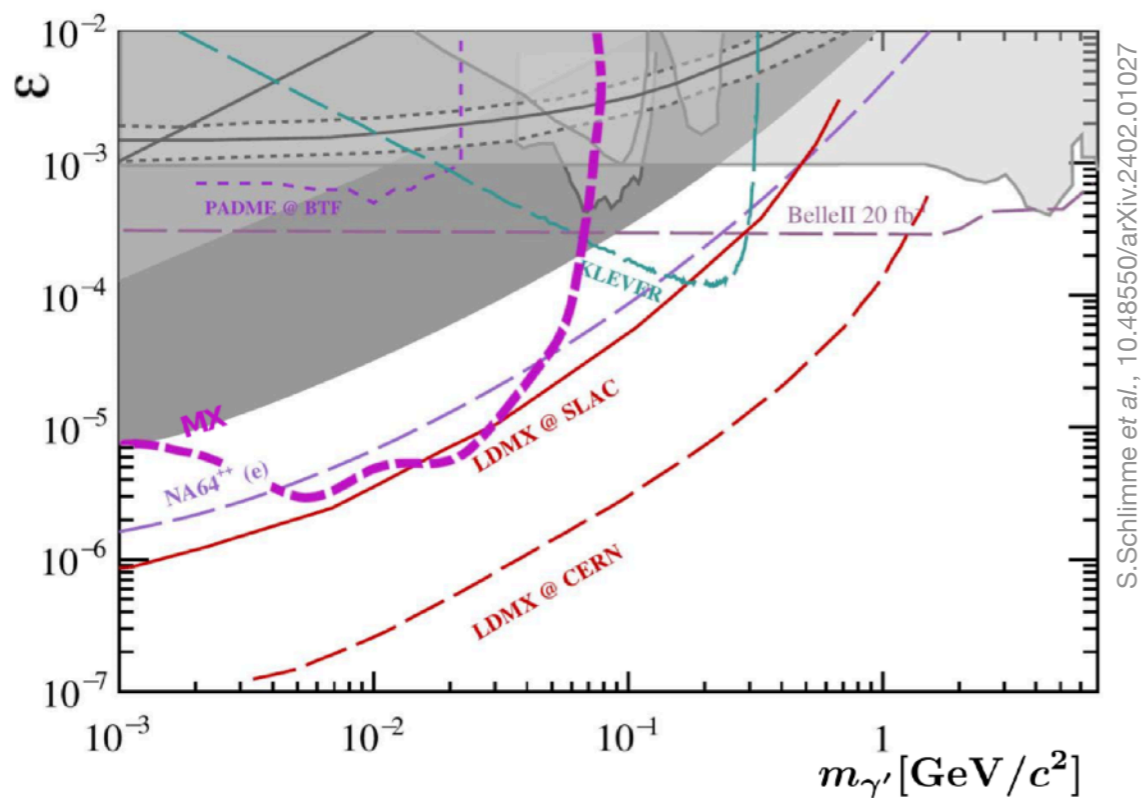
Coincidence measurement between both spectrometers



Dark photon - invisible decay.



Coincidence measurement between one spectrometer and the silicon strip detectors



Dark photon - effective neutron target.



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

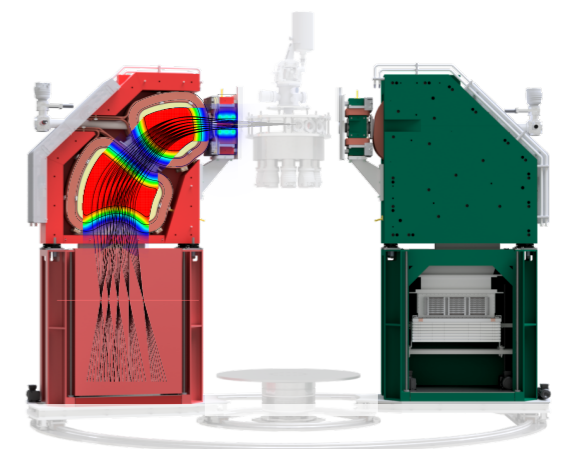
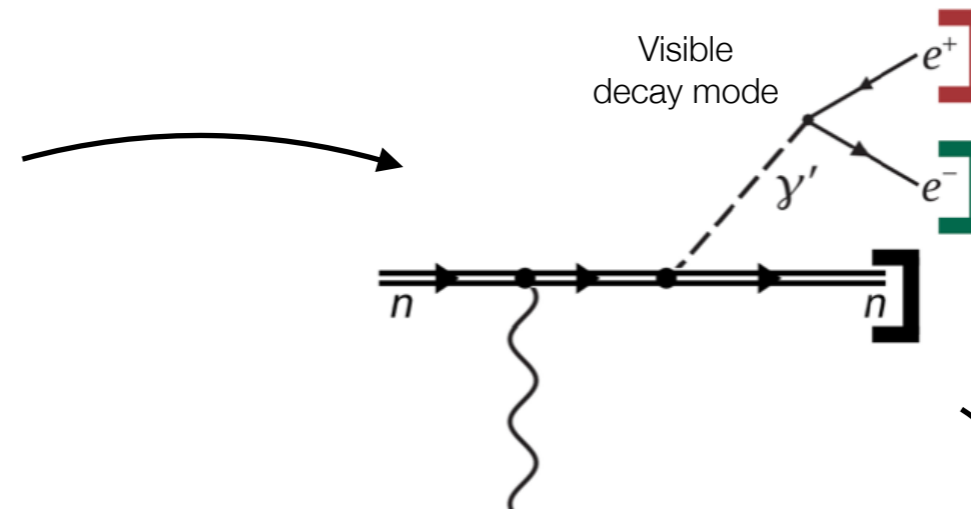
X17 Discovery Potential in the $\gamma N \rightarrow e^+ e^- N$ Process at Electron Scattering Facilities

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)

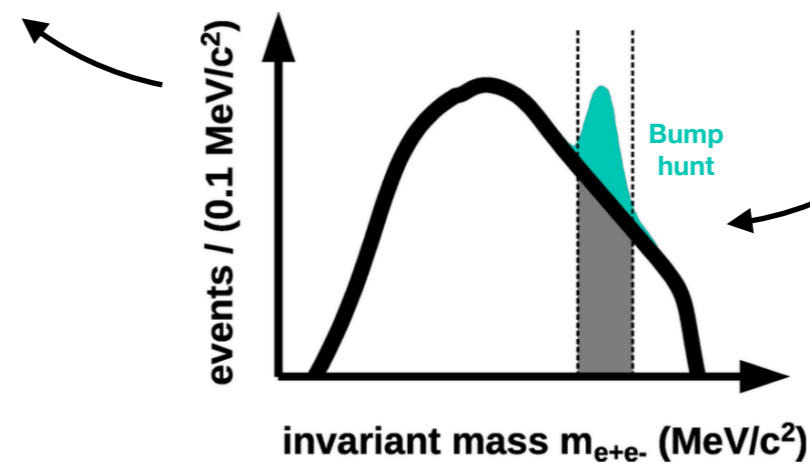
Low-mass dark sector searches with deuteron photodisintegration

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

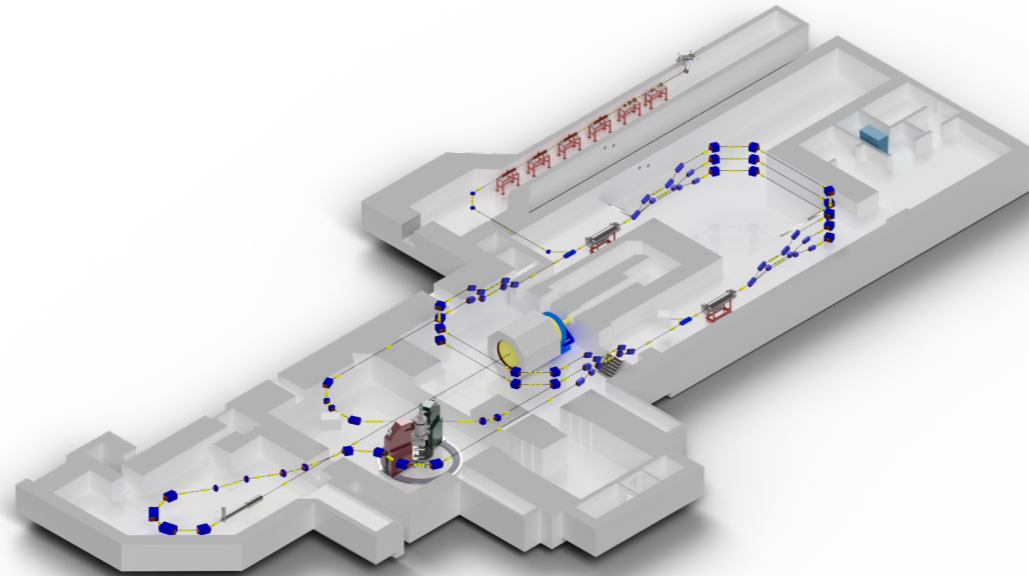
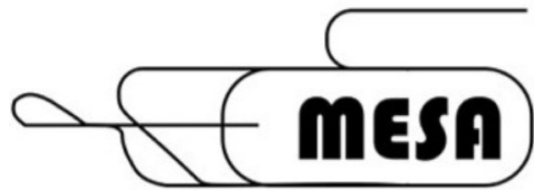


Coincidence measurement between both spectrometers

No exclusion limits yet

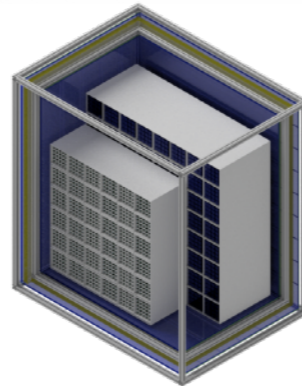


Summary



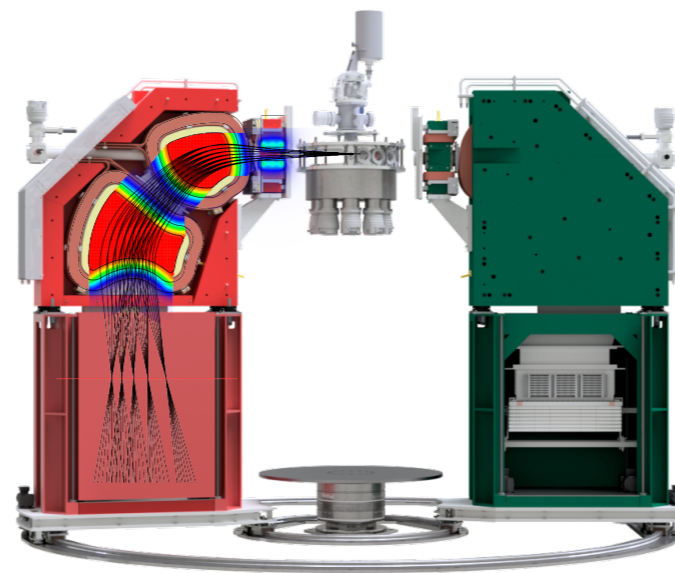
MESA

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



DarkMESA

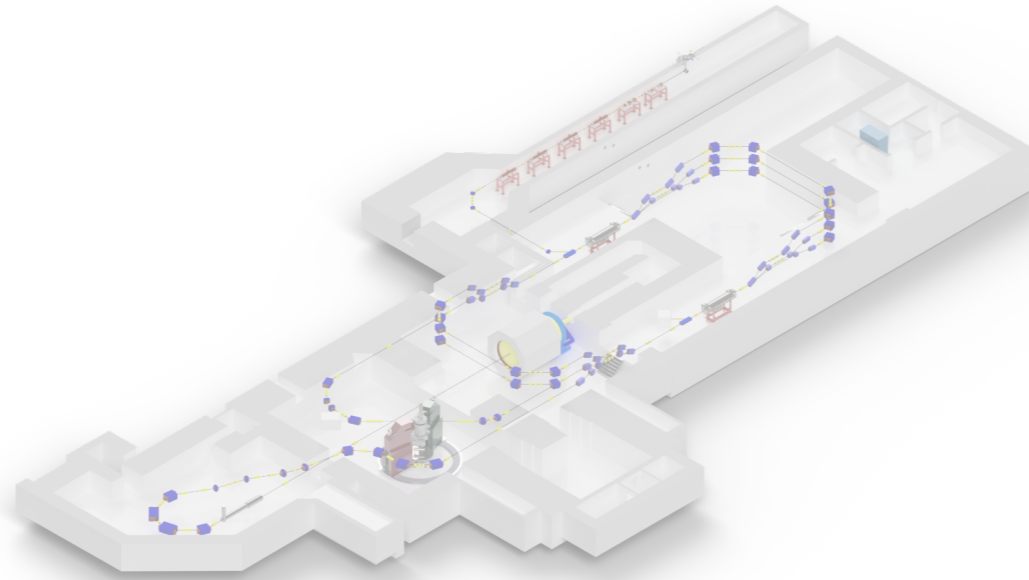
- Beam-dump experiment directly looking for LDM particles



MAGIX

- High-resolution, two-spectrometer setup utilizing an internal gas jet target
- Varied and rich physics program, including investigations of both visible and invisible decay modes of the dark photon

Summary



MESA

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- Two modes: energy-recovery linac mode and extracted beam mode
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DarkMESA

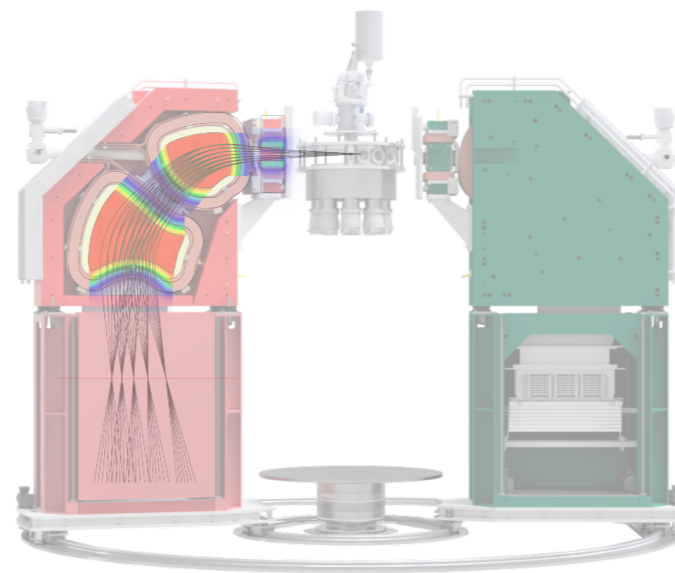


Thanks for your attention!

experiment directly
articles

MAGIX

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Contact

Institute for Nuclear Physics
Johannes Gutenberg University Mainz
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55128 Mainz
Germany

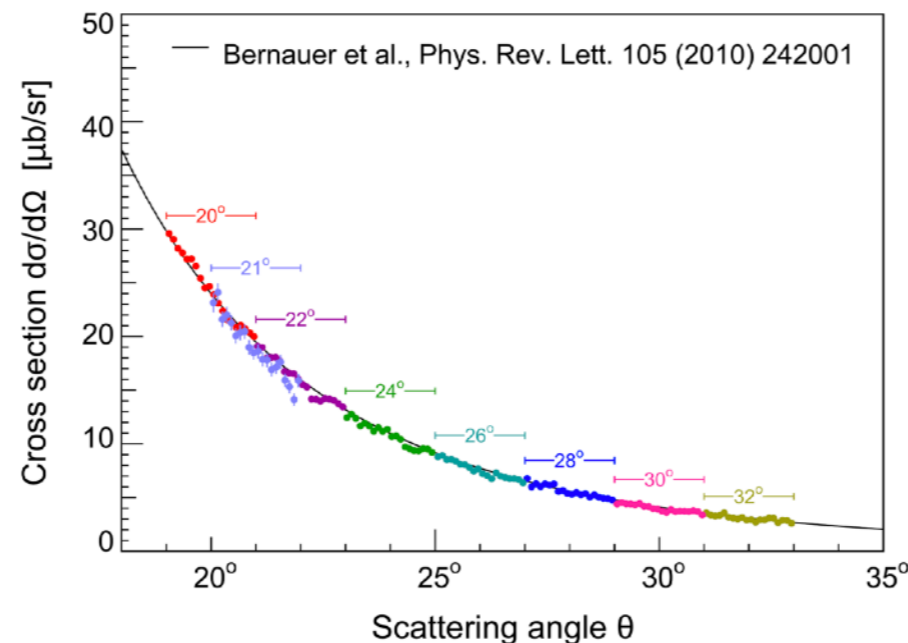
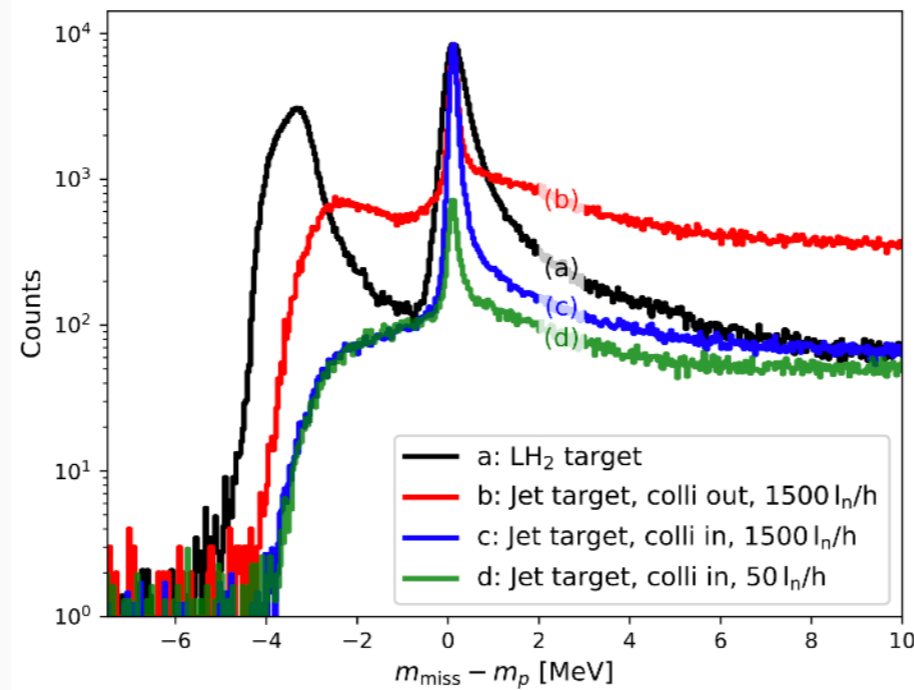
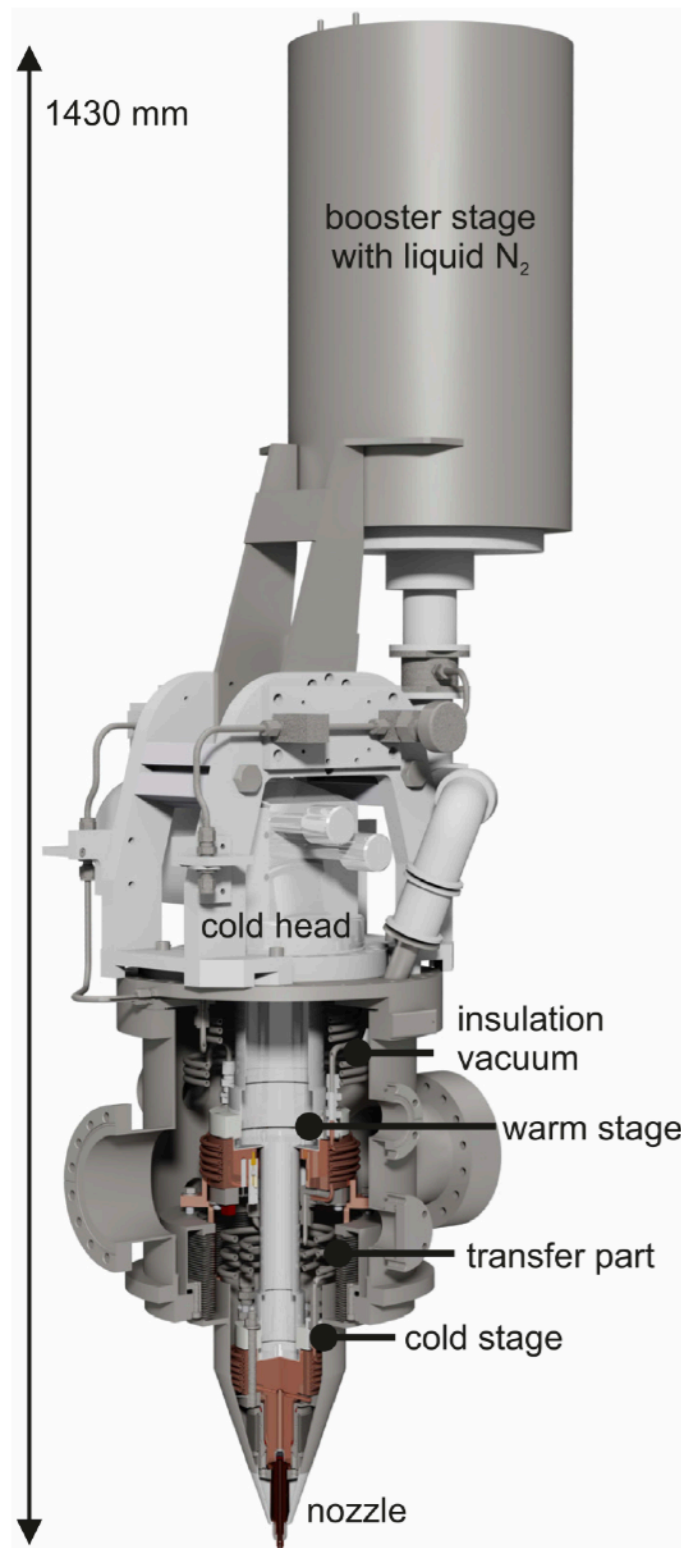
www.kernphysik.uni-mainz.de

Sebastian Stengel
MAGIX Collaboration
sestenge@uni-mainz.de

www.magix.uni-mainz.de

**Backup
slides.**

The MAGIX gas jet target.



Nuclear Inst. and Methods in Physics Research, A 906 (2018) 120–126

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A cryogenic supersonic jet target for electron scattering experiments at MAGIX@MESA and MAMI

S. Grieser^a, D. Bonaventura, P. Brand, C. Hargens, B. Hetz, L. Leßmann, C. Westphälinger, A. Khoukaz

^aInstitut für Kernphysik, Wilhelm-Klemm-Str. 9, 48149 Münster, Germany

S. Grieser *et al.*, 10.1016/j.nima.2018.07.076

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

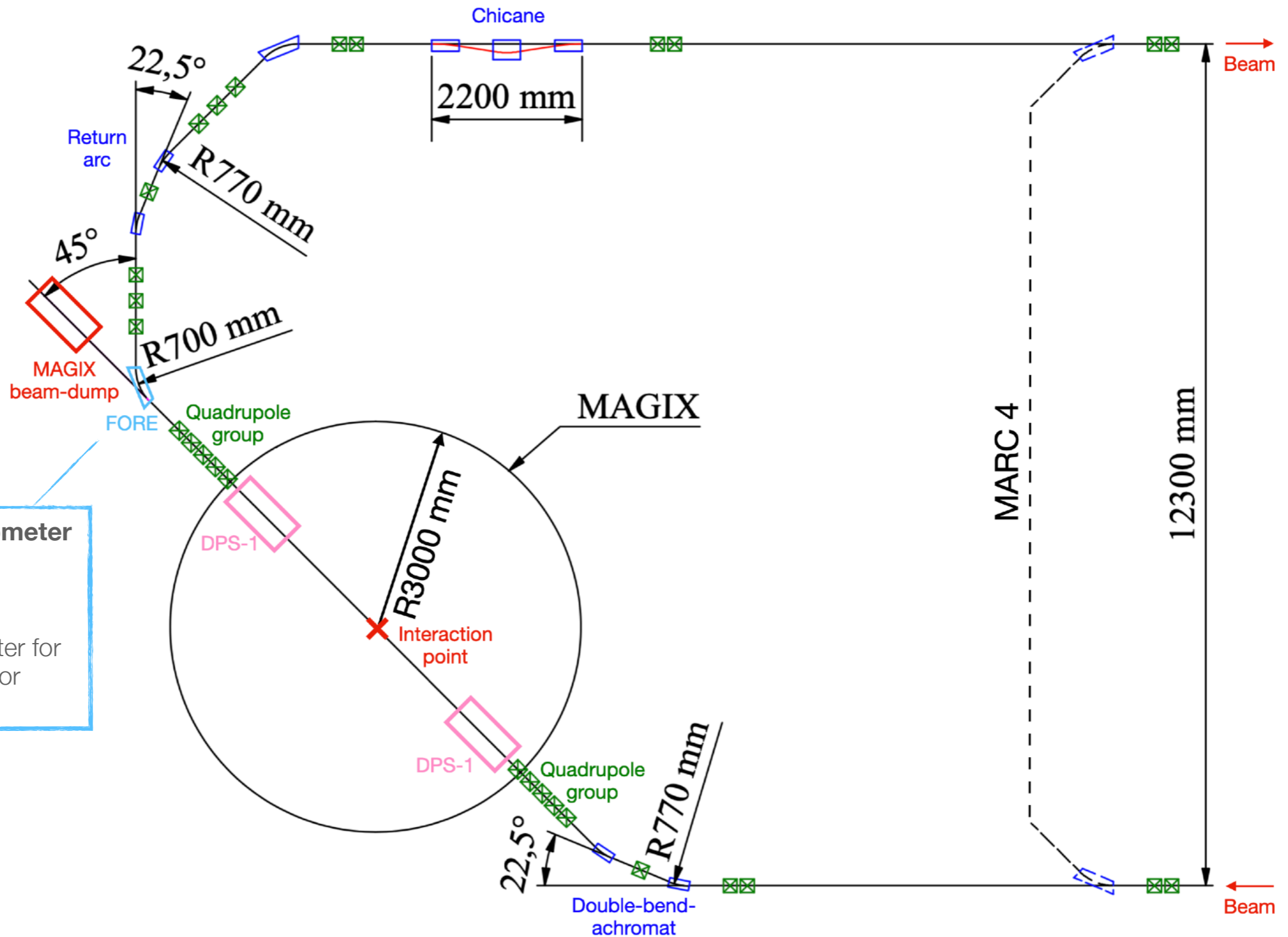
B.S. Schlimme^{a,*}, S. Aulenbacher^{a,1}, P. Brand^{b,1,2}, M. Littich^{a,1}, Y. Wang^{1,1}, P. Achenbach^{a,c,d}, M. Ball^e, J.C. Bernauer^{k,1}, M. Biroth^a, D. Bonaventura^b, D. Bosnar^l, S. Caiazza^a, M. Christmann^{a,d}, E. Cline^k, A. Denig^{a,c,d}, M.O. Distler^a, L. Doria^{a,c}, S. Eckert^a, A. Esser^a, I. Friščić¹, S. Gagneur^{a,3}, J. Geimer^a, S. Grieser^b, P. Gülker^a, P. Herrmann^a, M. Hoek^a, S. Kegel^a, J. Kelsey¹, P. Klag^a, A. Khoukaz^b, M. Kohl^m, T. Kolar^{a,4}, M. Lauß^a, L. Leßmann^b, S. Lunkenheimer^a, J. Mareković^a, D. Markus^a, M. Mauch^d, H. Merkel^{a,c}, M. Mihovilović^{a,b,5}, R.G. Milner¹, J. Müller^a, U. Müller^a, T. Petrović⁸, J. Pochodzalla^a, J. Rausch^a, J. Schlaadt^a, H. Schürig^a, C. Sfonti^{a,c}, S. Širca^{b,6}, R. Spreckels^a, S. Stengel^a, Y. Stöttinger^a, C. Szyska^a, M. Thiel^a, S. Vestrick^b, C. Vidal¹, for the A1 and MAGIX Collaborations

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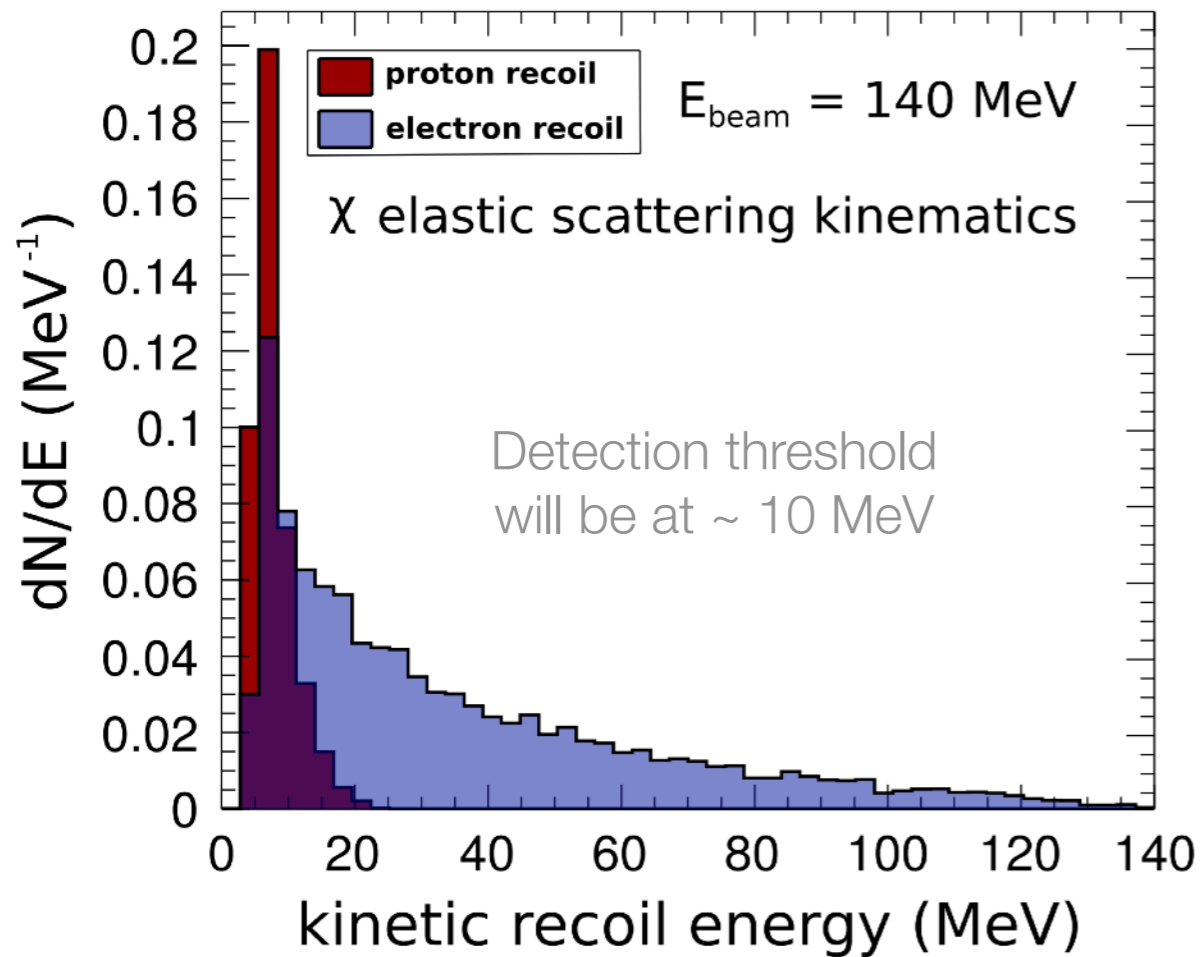
The beam layout of MAGIX.



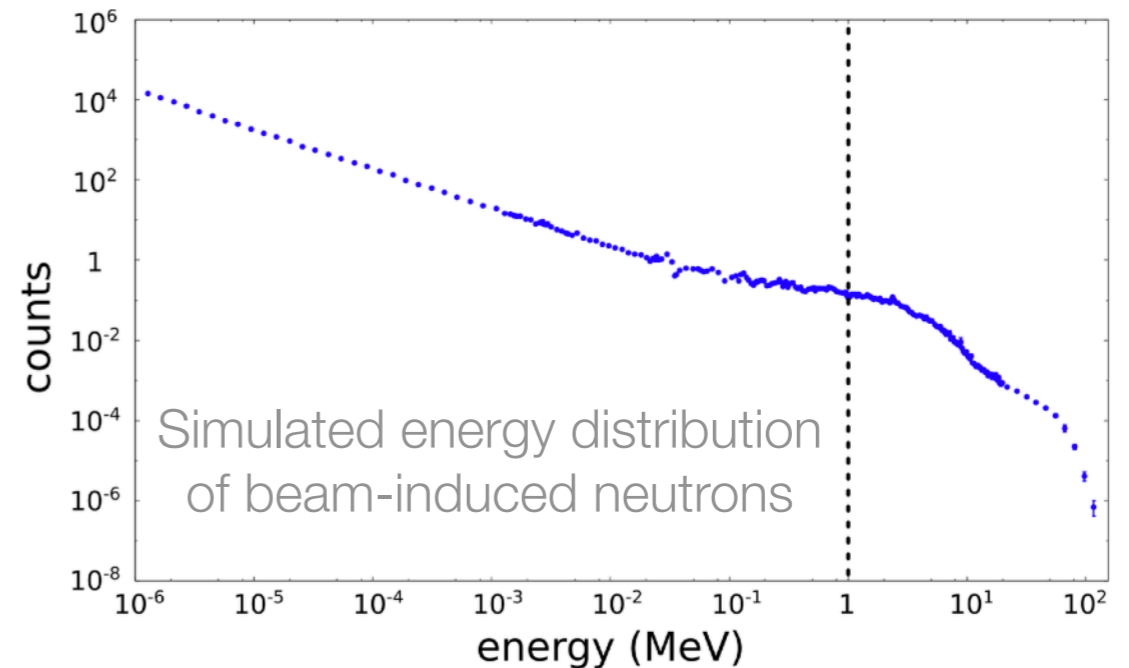
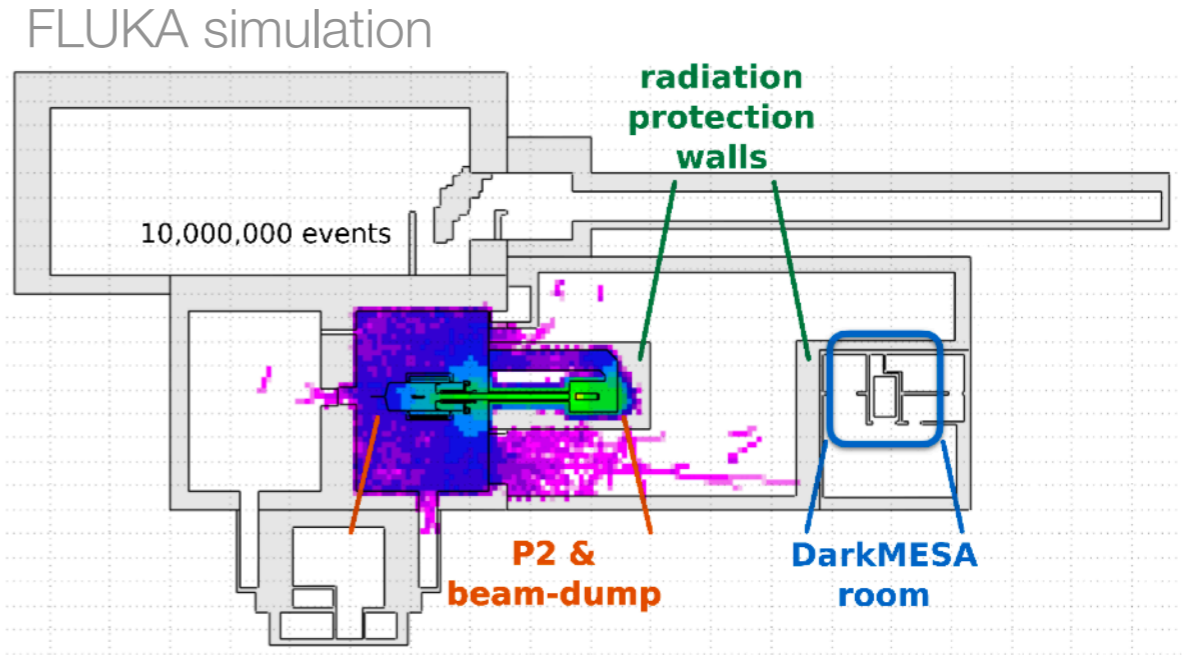
The forward spectrometer FORE

- Bending dipole
- Luminosity monitor
- Forward spectrometer for astrophysical S-factor measurement

DarkMESA - detection threshold and neutron background studies.



M. Christmann, PhD thesis, 10.25358/openscience-9076



DarkMESA - expected sensitivity 2.

