The MESA physics programme

High-intensity low-energy electron accelerator in Mainz

Sören Schlimme
Institute for Nuclear Physics
Johannes Gutenberg University Mainz

via zoom

apologies for my absence today

and please don't mind my neighborhood

The MESA physics programme

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MENU 2023:

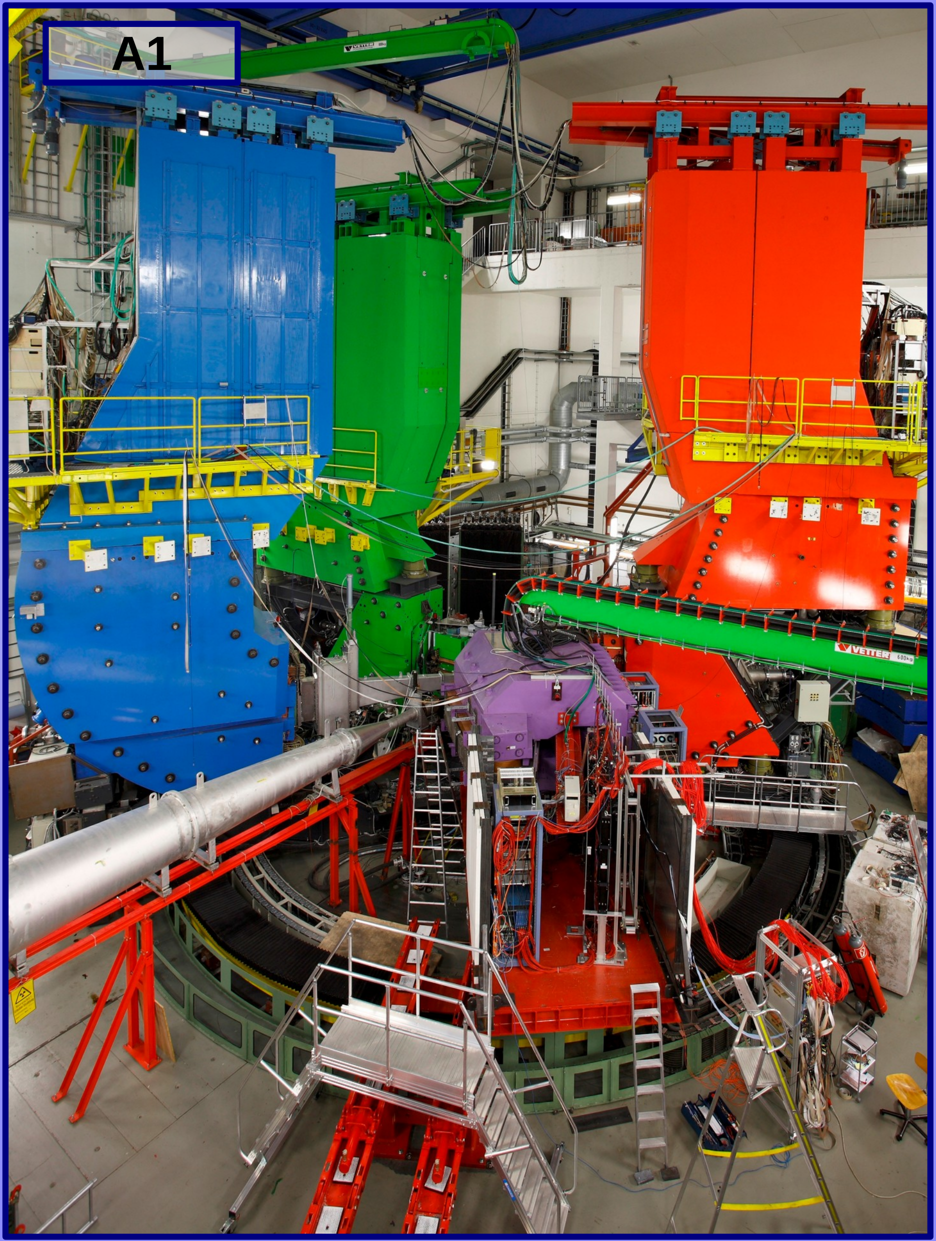
The 16th International Conference on Meson-Nucleon Physics and the Structure of the Nucleon

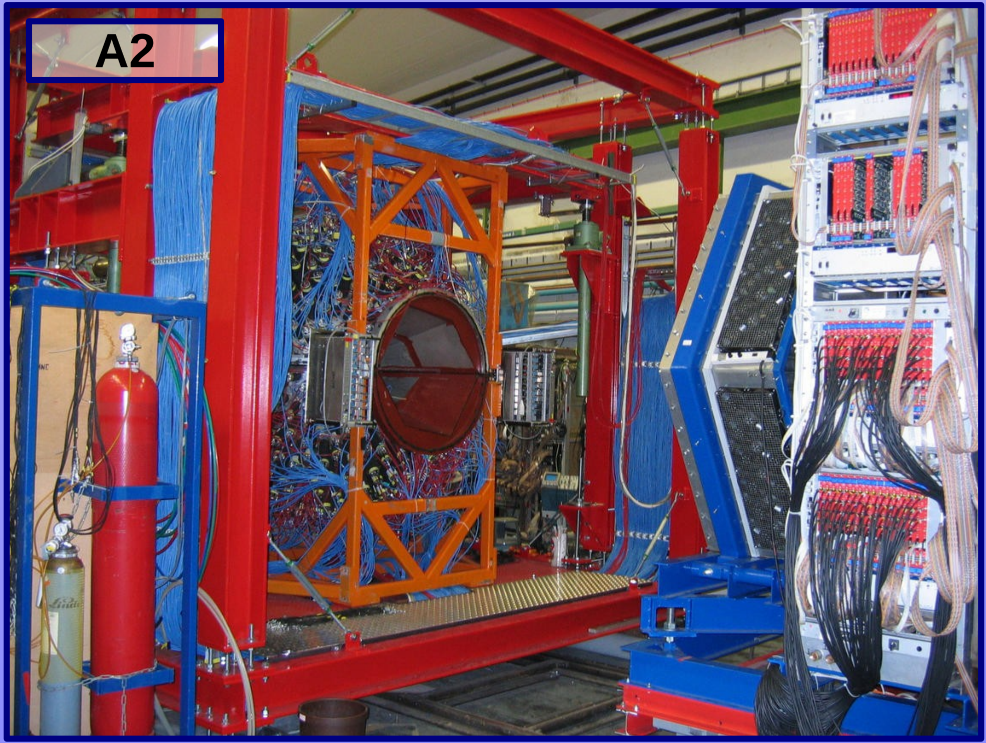
October 16-20, 2023
Mainz, Germany
https://indico.him.uni-mainz.de/event/171/

Cluster of Excellence PRISMA+

- **MESA: Energy Recovery Linac**
- **P2: Parity-violating electron scattering**
- **DarkMESA: Beam dump experiment**
- **MAGIX: Multi-purpose experiment**

Mainz Microtron





Electron accelerators in Mainz

New 1966++
Mainz University Electron Linac (**MUELL**)
~80-300 MeV, pulsed beam

Upgrade 1972++
Mainz Linear Accelerator Improving System (**MALAISE**)
Enhancement of the energy resolution

New 1990++
Mainz Microtron (**MAMI-B**)
Three-staged racetrack microtron cascade
~180-855 MeV, cw beam

Upgrade 2007++
Harmonic double-sided microtron (**MAMI-C**)
Energy increase to ~1600 MeV

New 2024++
Mainz Energy-recovering Superconducting Accelerator (**MESA**)
Double-sided Multi Turn Energy Recovery Linac (ERL)
~20-155 MeV, high-intensity cw beam

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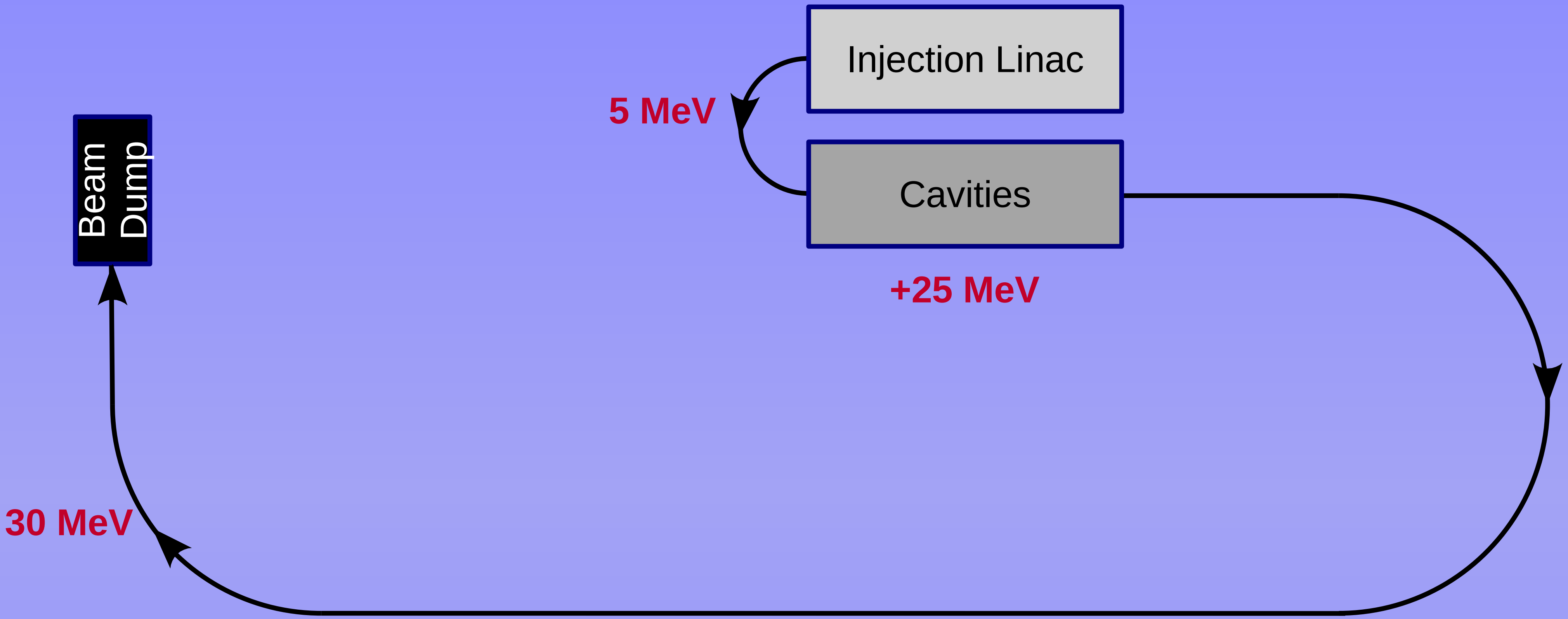
MUELL and **MALAISE**

MAMI

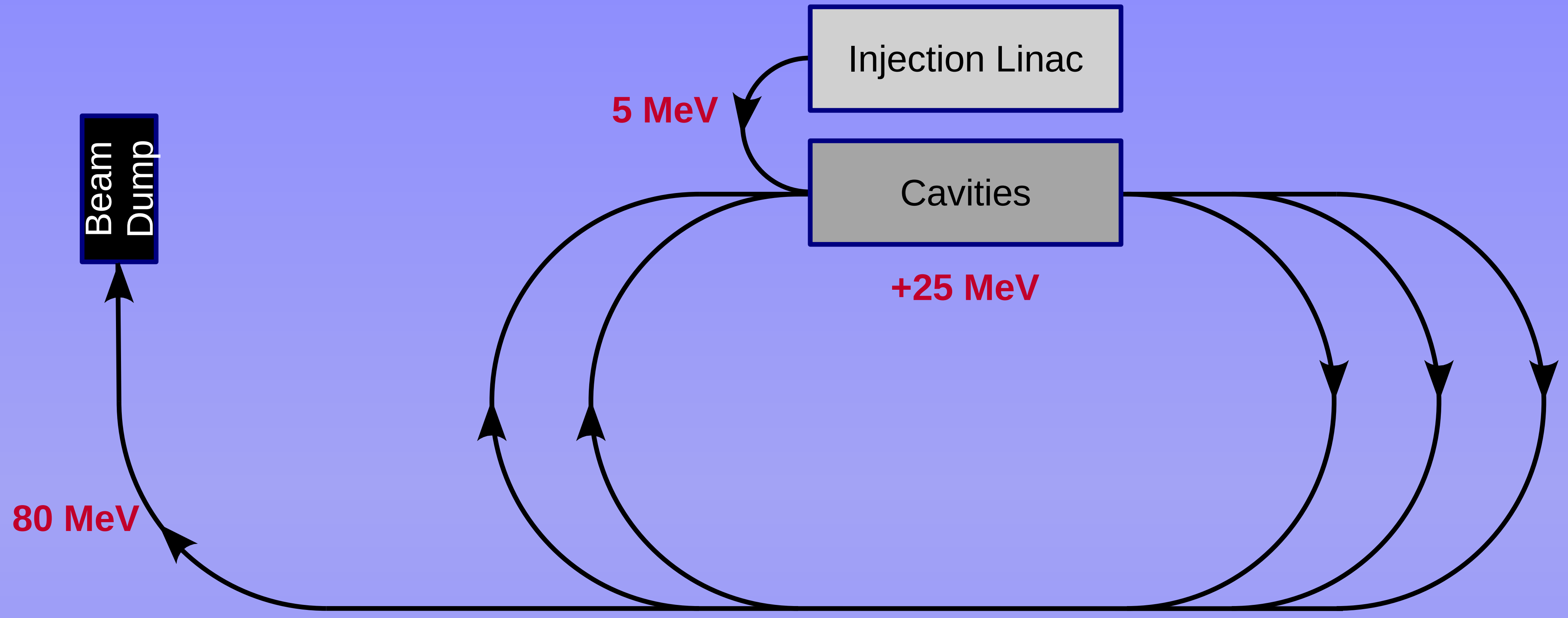
MESA

Let's build MESA 1/6



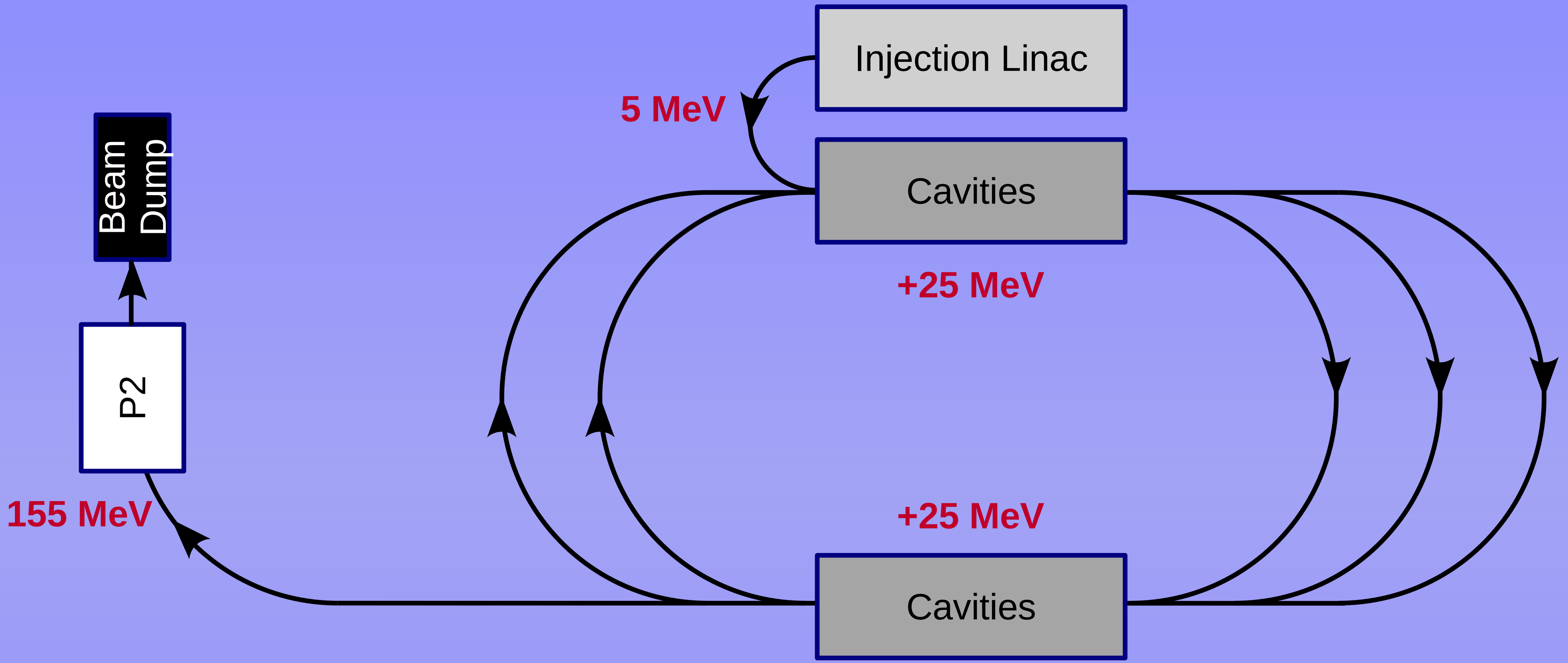
Electron Linear Accelerator (Linac)

Let's build MESA 2/6



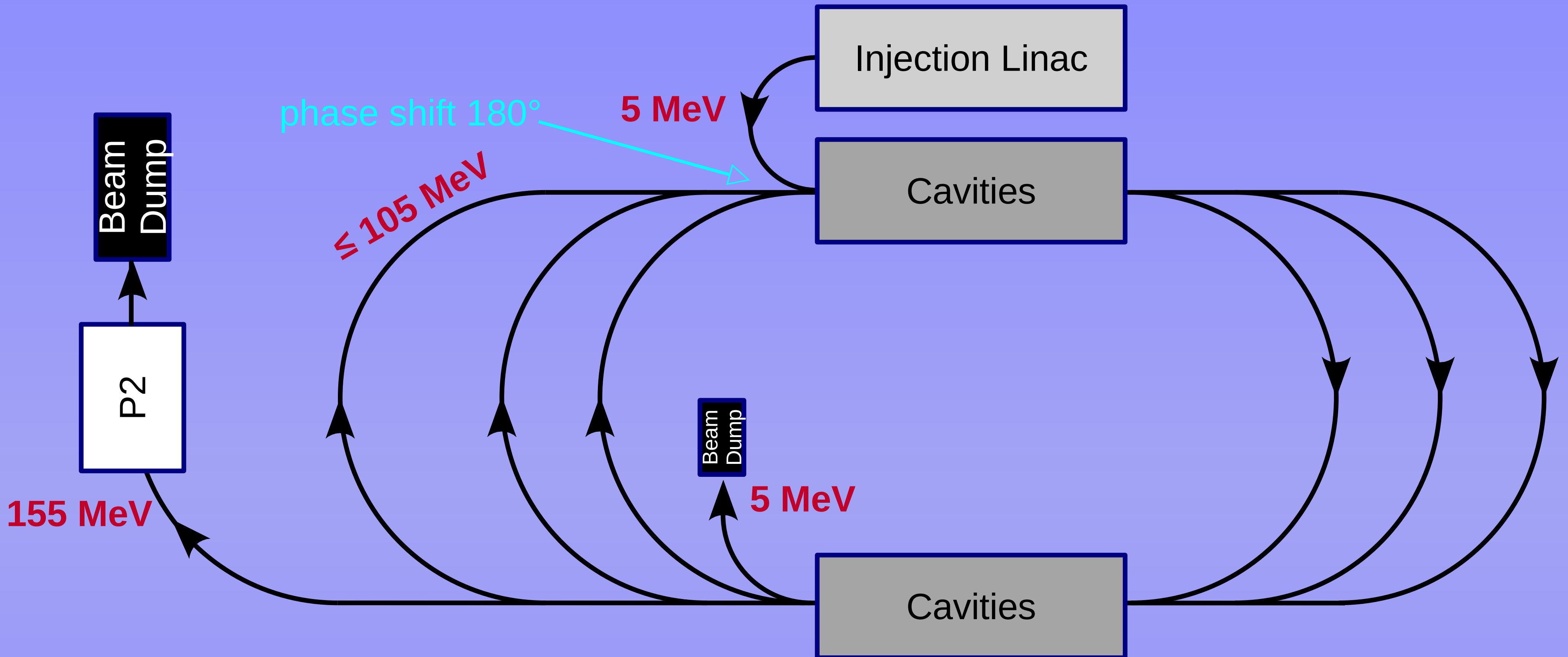
Multi Turn Linac

Let's build MESA 3/6



Double-sided Multi Turn Linac

Let's build MESA 4/6

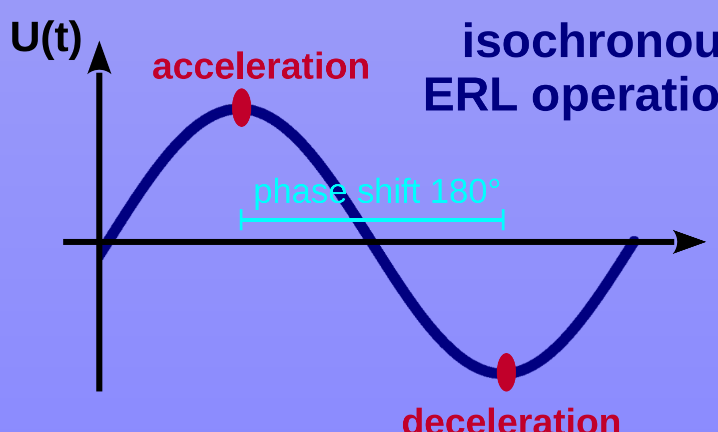


Double-sided Multi Turn Energy Recovery Linac

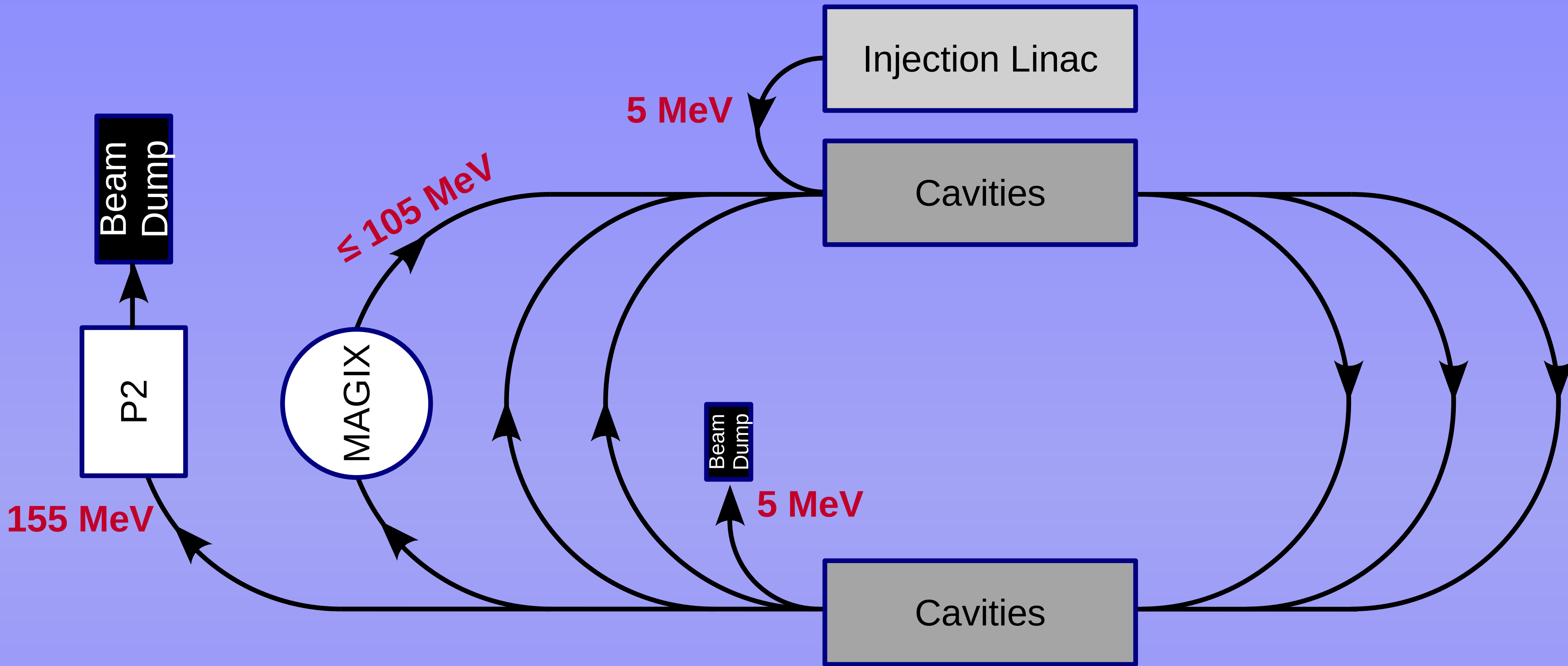
energy-efficient acceleration

▸ high beam currents ≥ 1000 μA (ERL)

isochronous ERL operation



Let's build MESA 5/6



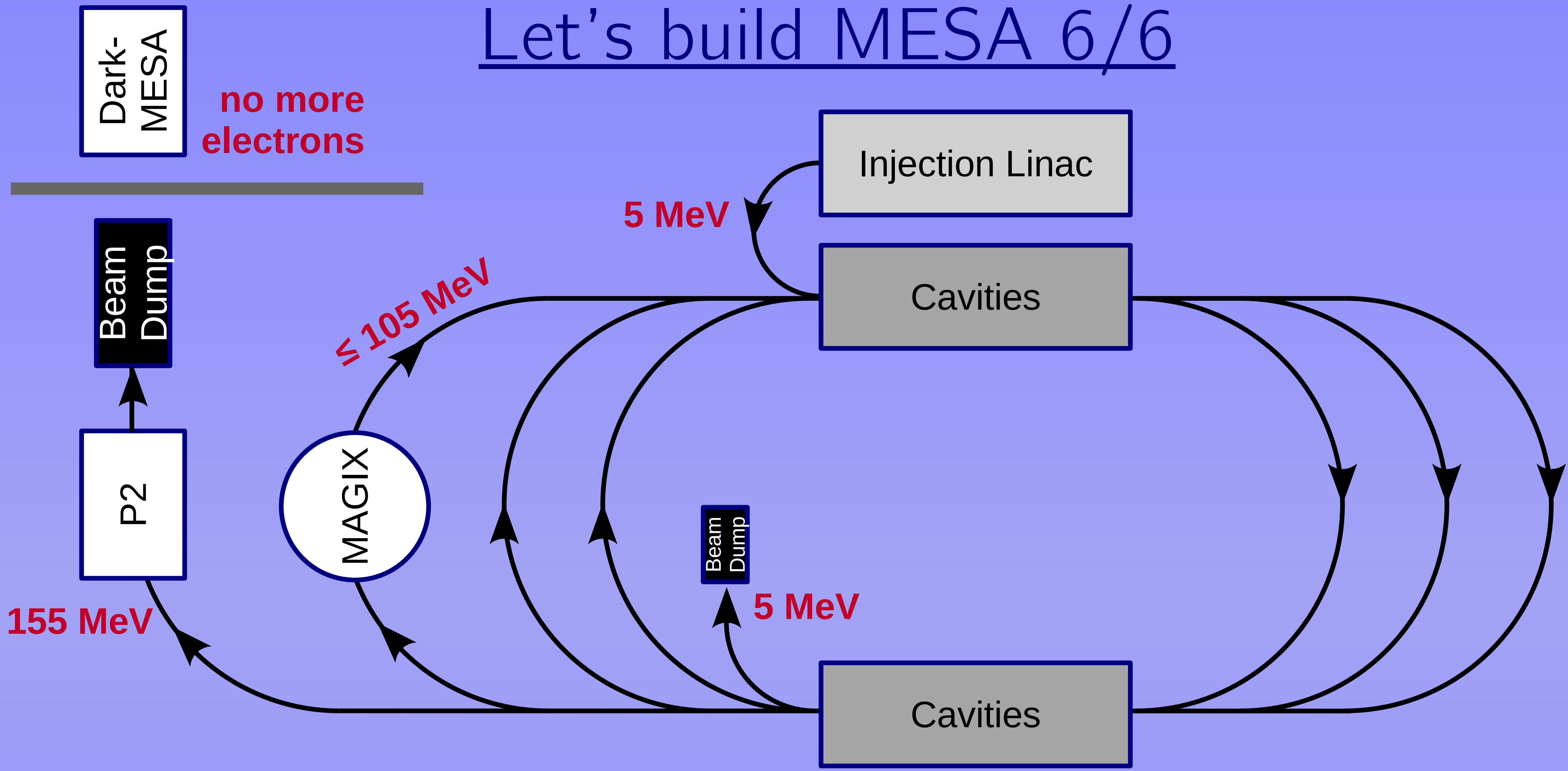
Double-sided Multi Turn
Energy Recovery Linac

- **with internal target experiment**

thin target – don't disturb the beam too much for 'ERL recollection'...

- **→ minimal effects from E-loss and multi-scattering →high resolution**
- **high beam intensity →large luminosity**

Let's build MESA 6/6

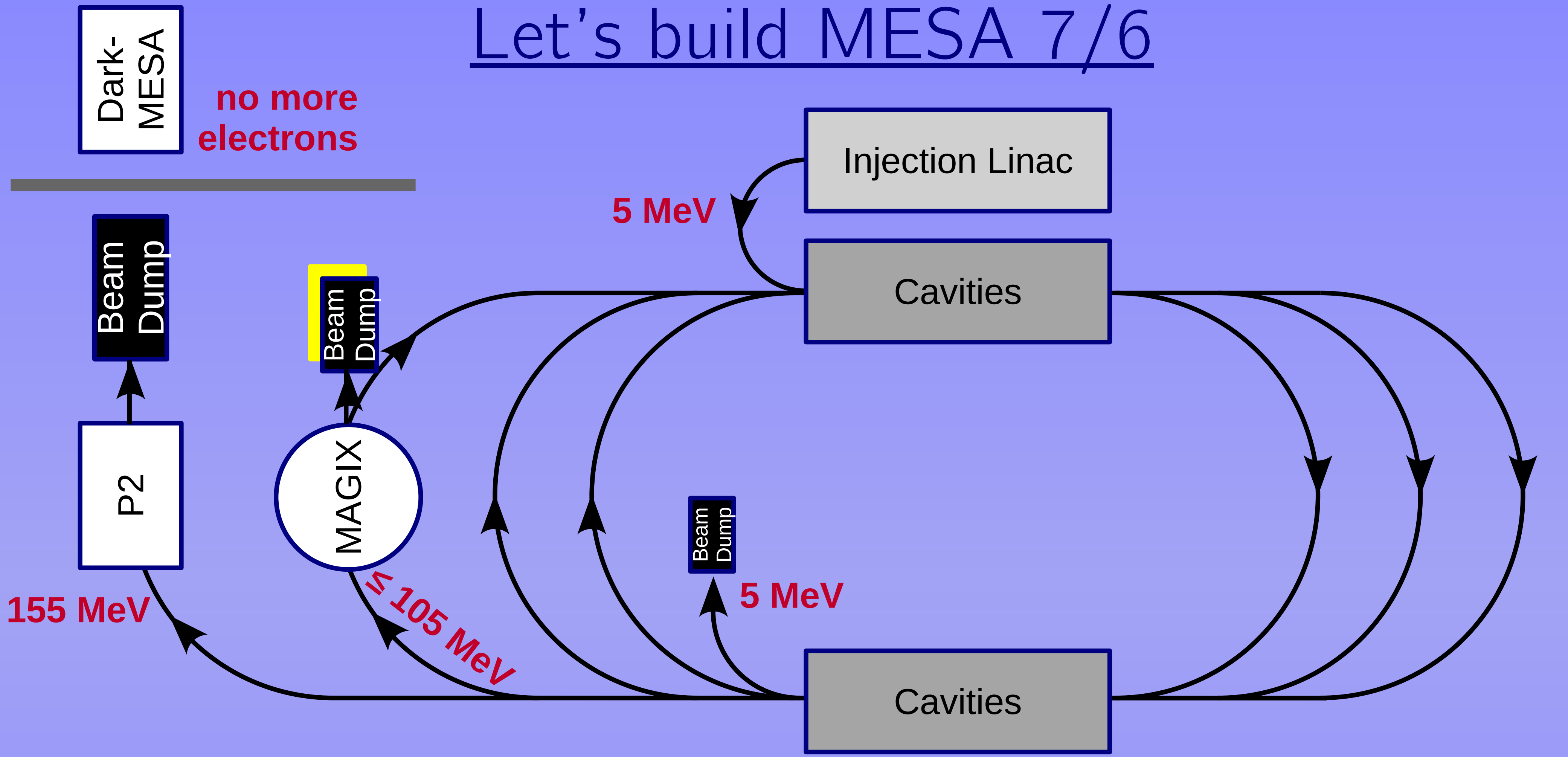


Double-sided Multi Turn Energy Recovery Linac

- **with internal target experiment**
- **with extracted beam experiment**
  - **and beam dump experiment**

Obviously, great experimental opportunities!

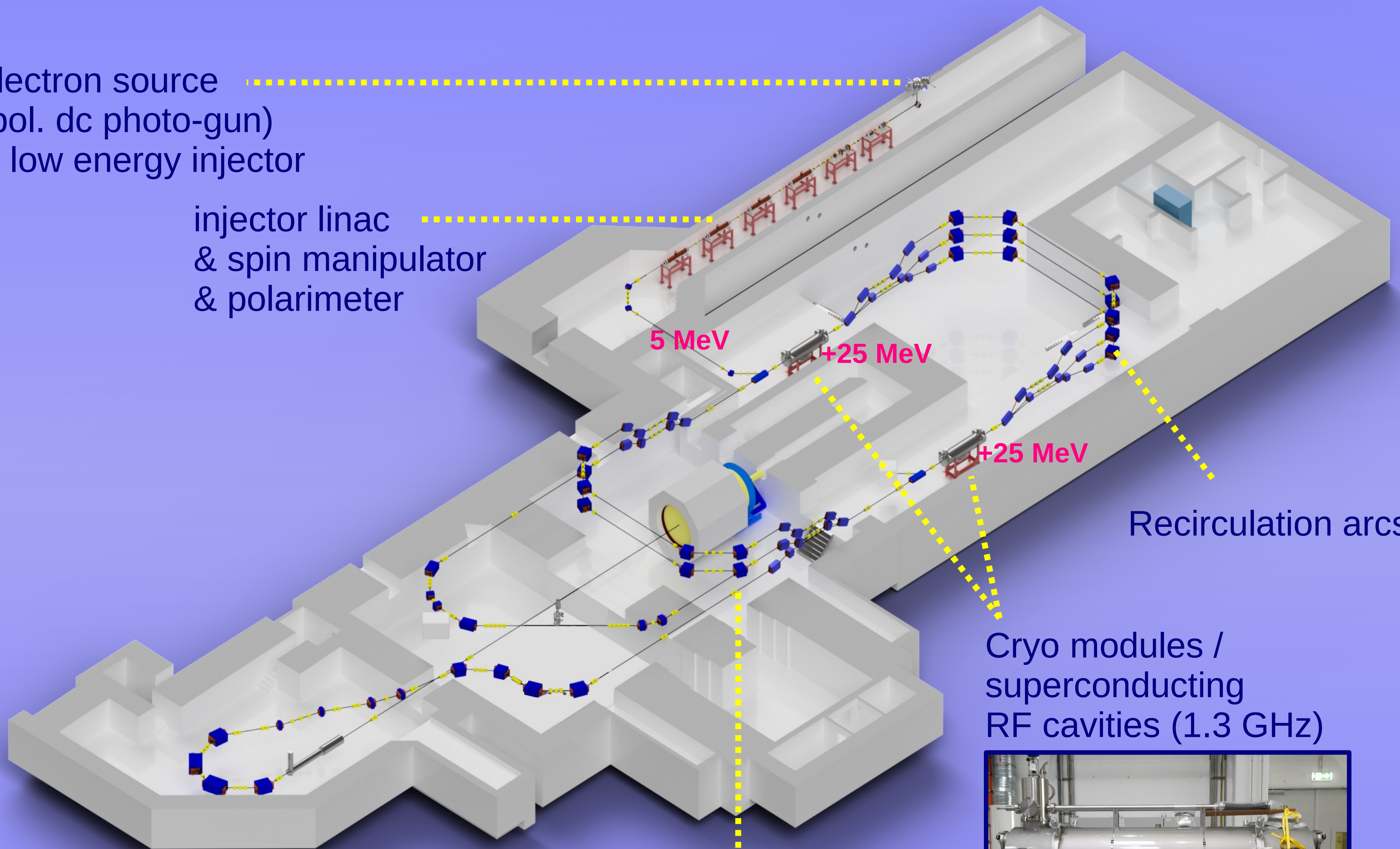
Let's build MESA 7/6



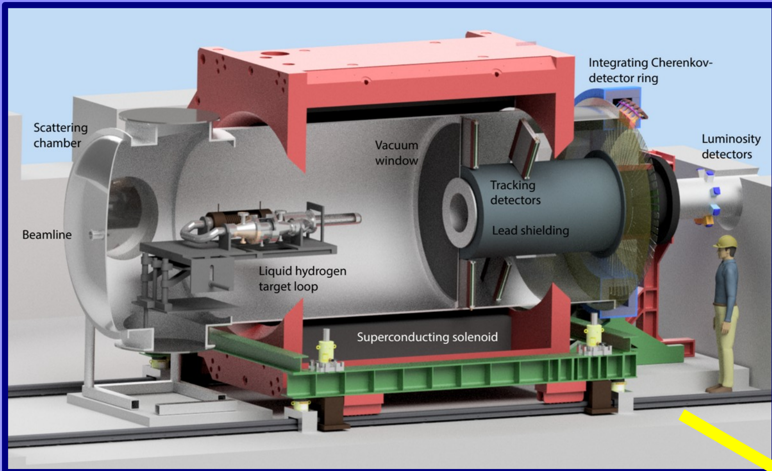
MAGIX when beneficial:

- **extracted beam mode, including beam dump**
  - **useful at the early stage of the accelerator**
  - **possibility to use thicker targets**

MESA: Mainz Energy-Recovering Superconducting Accelerator

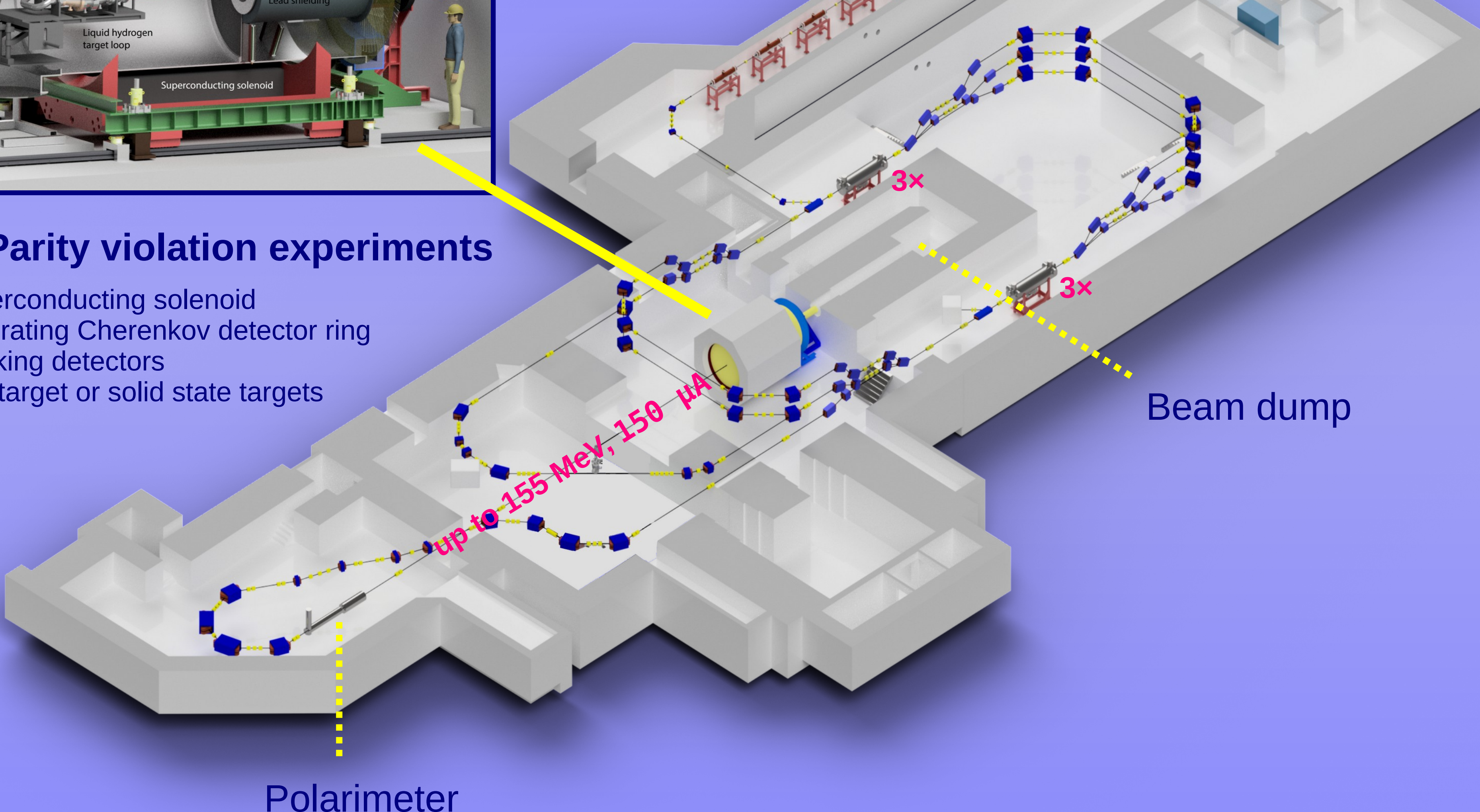


MESA EB-mode: P2

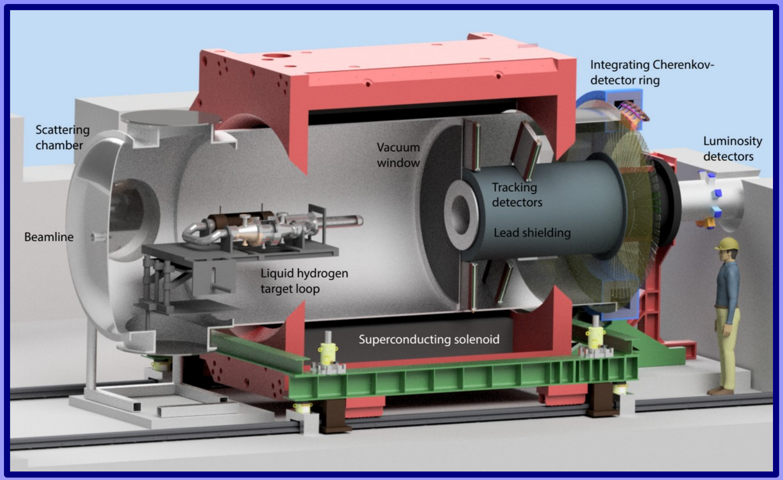


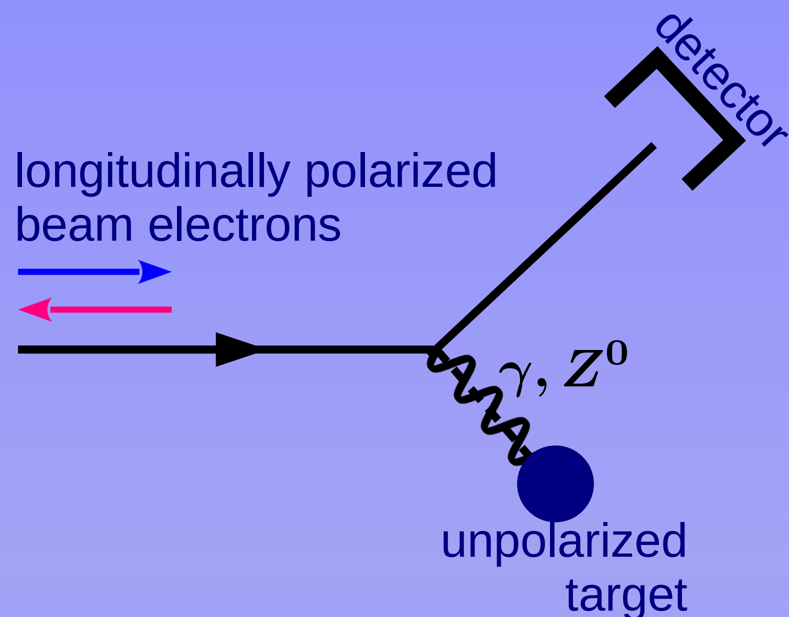
P2 - Parity violation experiments

- Superconducting solenoid
- Integrating Cherenkov detector ring
- Tracking detectors
- LH2 target or solid state targets



Parity Violating Electron Scattering





P2 - Parity violation experiments

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$$\boldsymbol{A_{\mathrm{PV}}} = \frac{\boldsymbol{\sigma^{+}} - \boldsymbol{\sigma^{-}}}{\boldsymbol{\sigma^{+}} + \boldsymbol{\sigma^{-}}} = \ldots$$

Multi-talent !

flip the helicity with 1kHz:
+ - + - + - - + ...

~85% beam polarization

Physics programme at P2

in a nutshell

- **Hydrogen** at **forward angles:**
  $A_{\mathrm{PV}} \rightarrow Q_W(p) \rightarrow \sin^2\theta_W \rightarrow$ BSM physics?

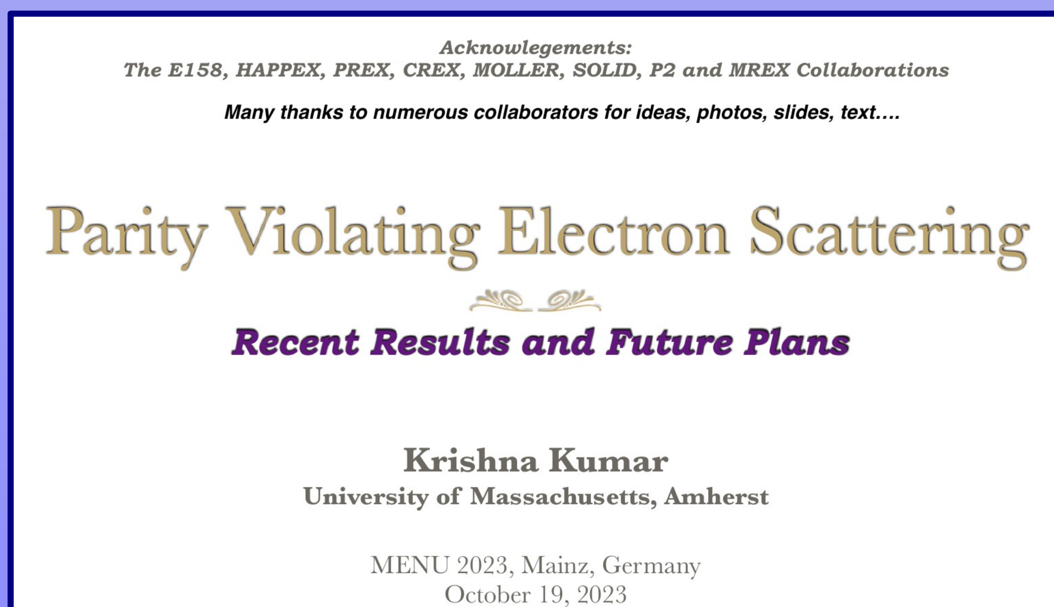
$$\sin^2\theta_W \approx \frac{1-Q_{\mathrm{W}}}{4}$$

Proton structure - << 1 at small Q^2

$$A_{\mathrm{PV}} = \frac{G_{\mathrm{F}} Q^2}{4\sqrt{2}\pi\alpha_{\mathrm{em}}} \left(Q_{\mathrm{W}} - F(Q^2)\right)$$

main objective:
precise measurement of the
weak mixing angle θ_W as a test for physics beyond the SM

next talk:



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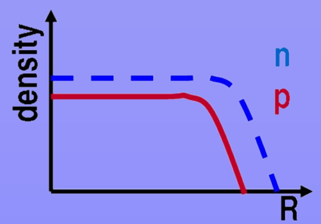
Hadronic structure of proton sizable at not-so-small Q²

- **Hydrogen + Deuterium** at **backward angles:**
  $A_{\mathrm{PV}} \rightarrow$ axial FF + strange contribution to magnetic FF

- **Carbon**:
  $A_{\mathrm{PV}} \rightarrow Q_W(^{12}C) = -24 \sin^2\theta_W$
  Complementary sensitivity to BSM physics

- **Lead**:
  $A_{\mathrm{PV}} \rightarrow F_{\mathrm{weak}}(Q^2)$
  $\rightarrow$ neutron radius
  $\rightarrow$ neutron skin thickness
  related to the
  $\rightarrow$ symmetry energy - nuclear Equation of State,
  e.g., $\rightarrow$ modeling of neutron stars



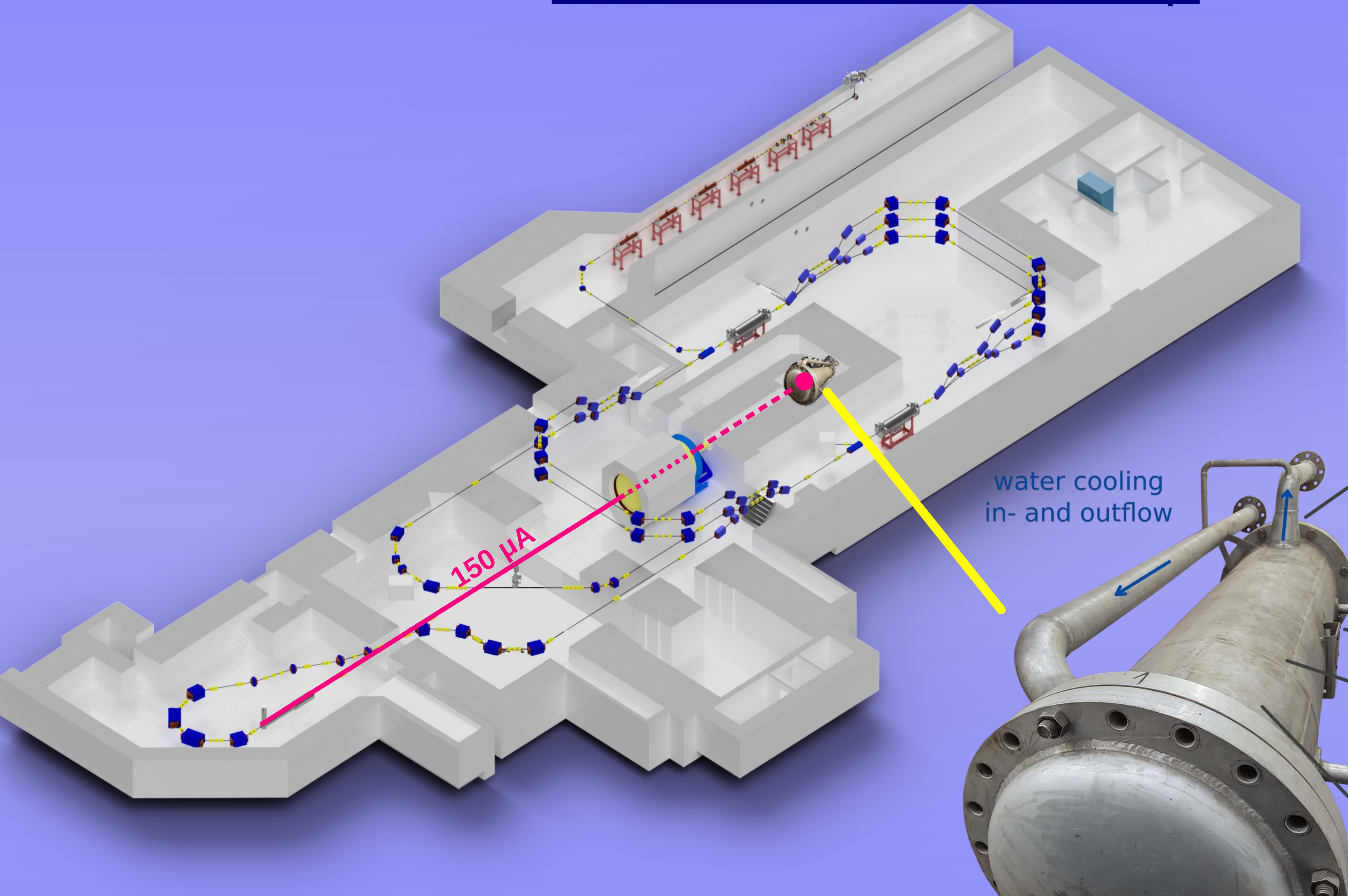
Dominated by neutrons

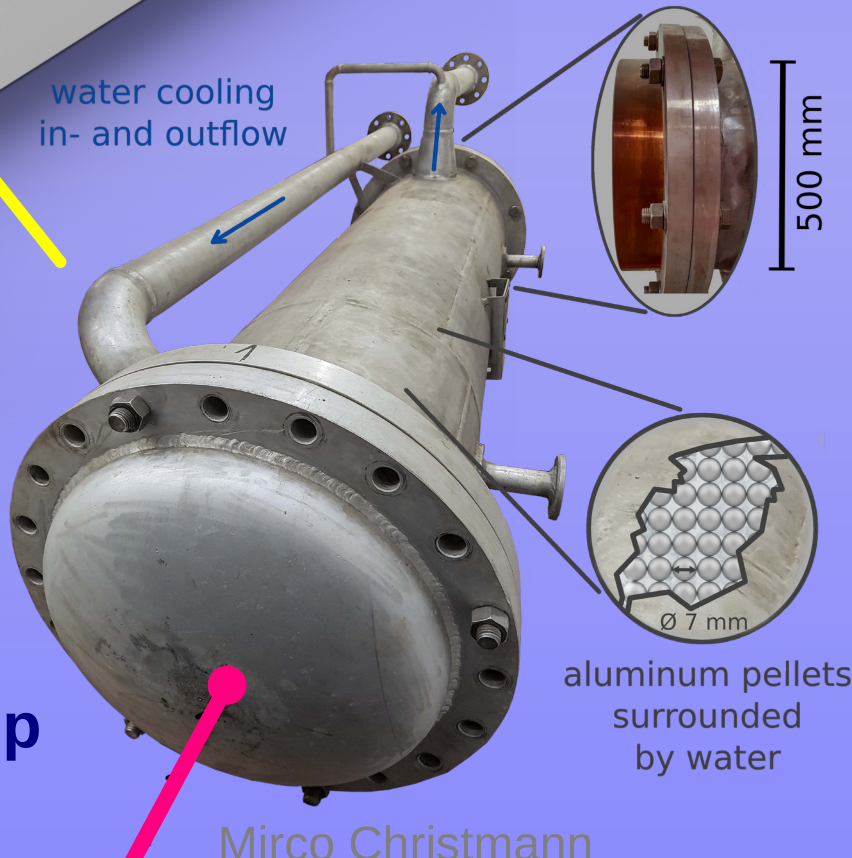
$$A_{\mathrm{PV}} = \frac{G_{\mathrm{F}} Q^2}{4\sqrt{2}\pi\alpha_{\mathrm{em}}} \frac{F_{\mathrm{weak}}(Q^2)}{F_{\mathrm{charge}}(Q^2)}$$

Dominated by protons, ~known

M. Thiel *et al.*, J.Phys.G 46 (2019) 9

The P2 Beam Dump

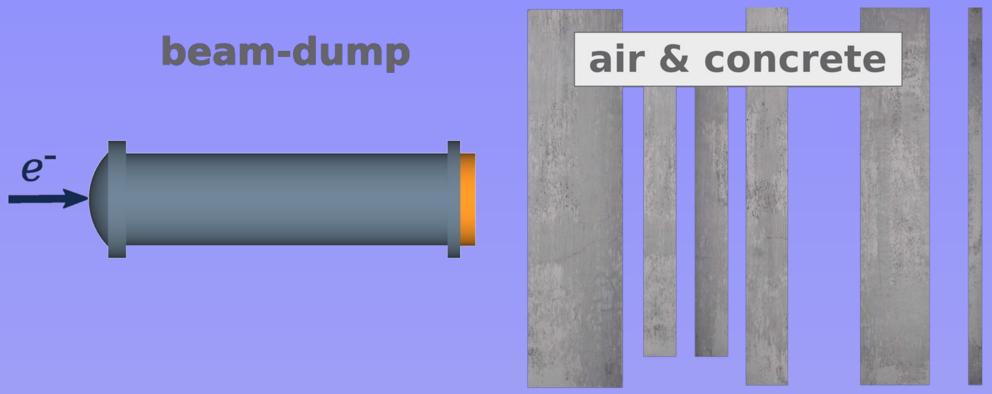




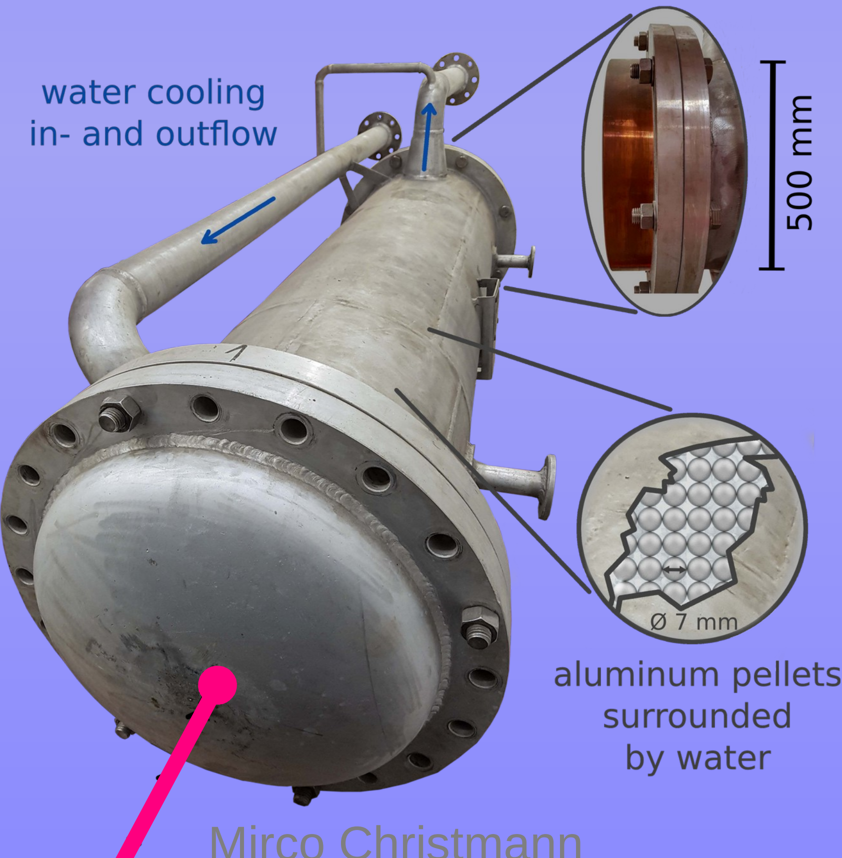
~ 16 000 hours of high intensity beam on the dump

(150 MeV, 150 µA, $5 \cdot 10^{22}$ Electrons On Target)

The P2 Beam Dump



big beam dump
function: stop all particles



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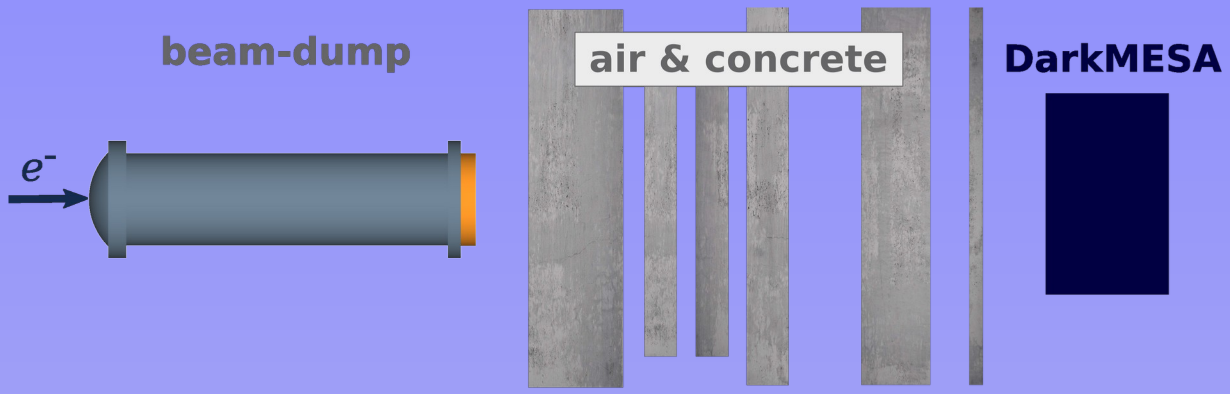

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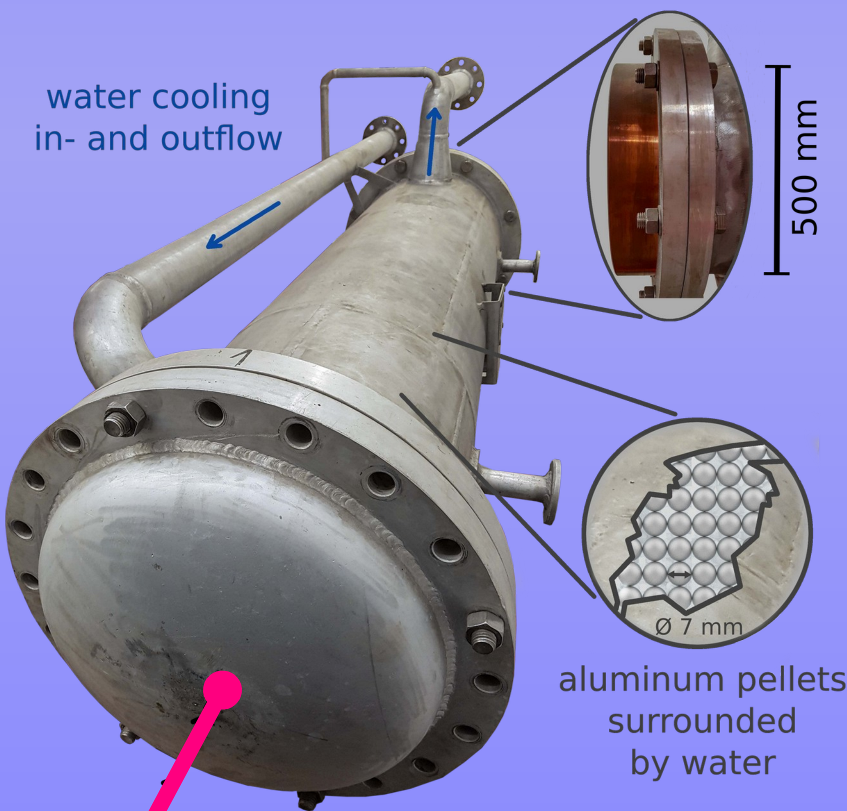
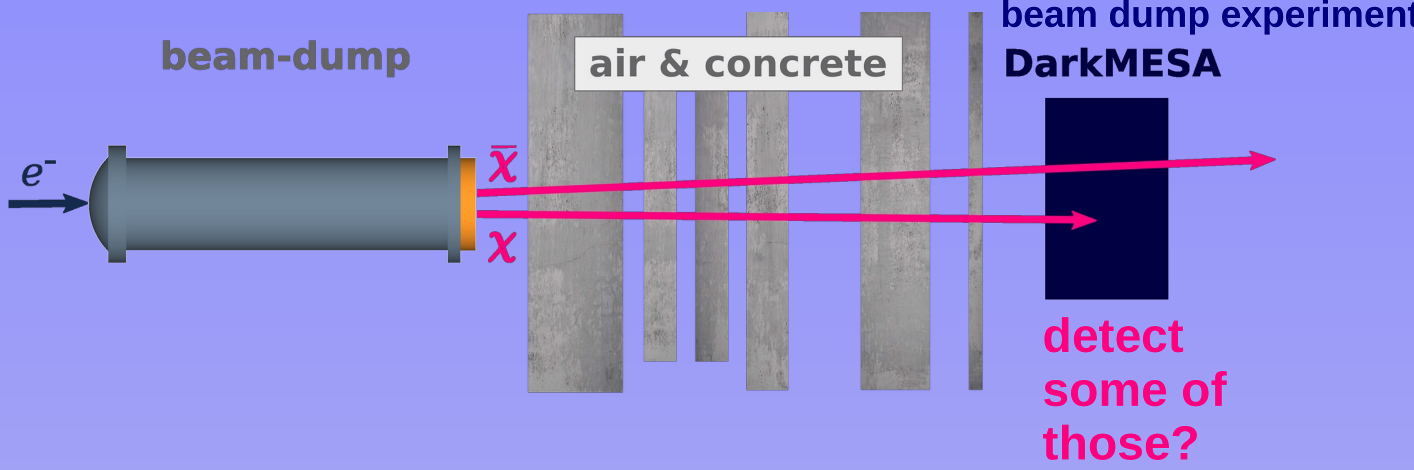


Mirco Christmann

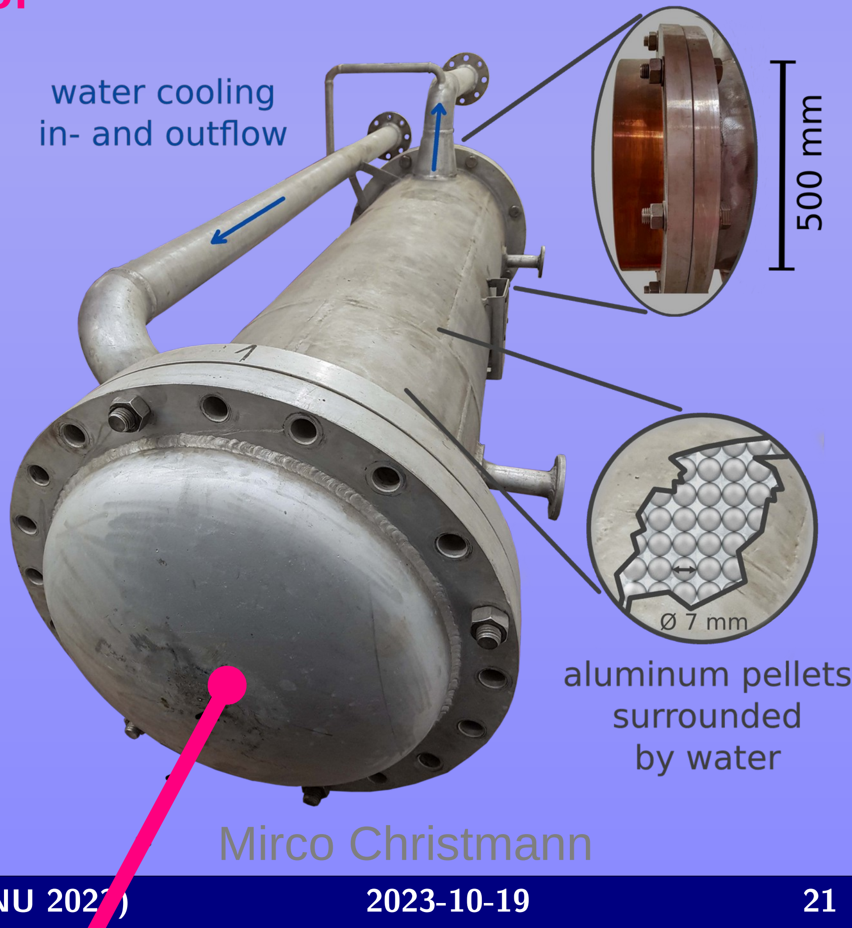
The P2 Beam Dump



big beam dump
function: stop all particles

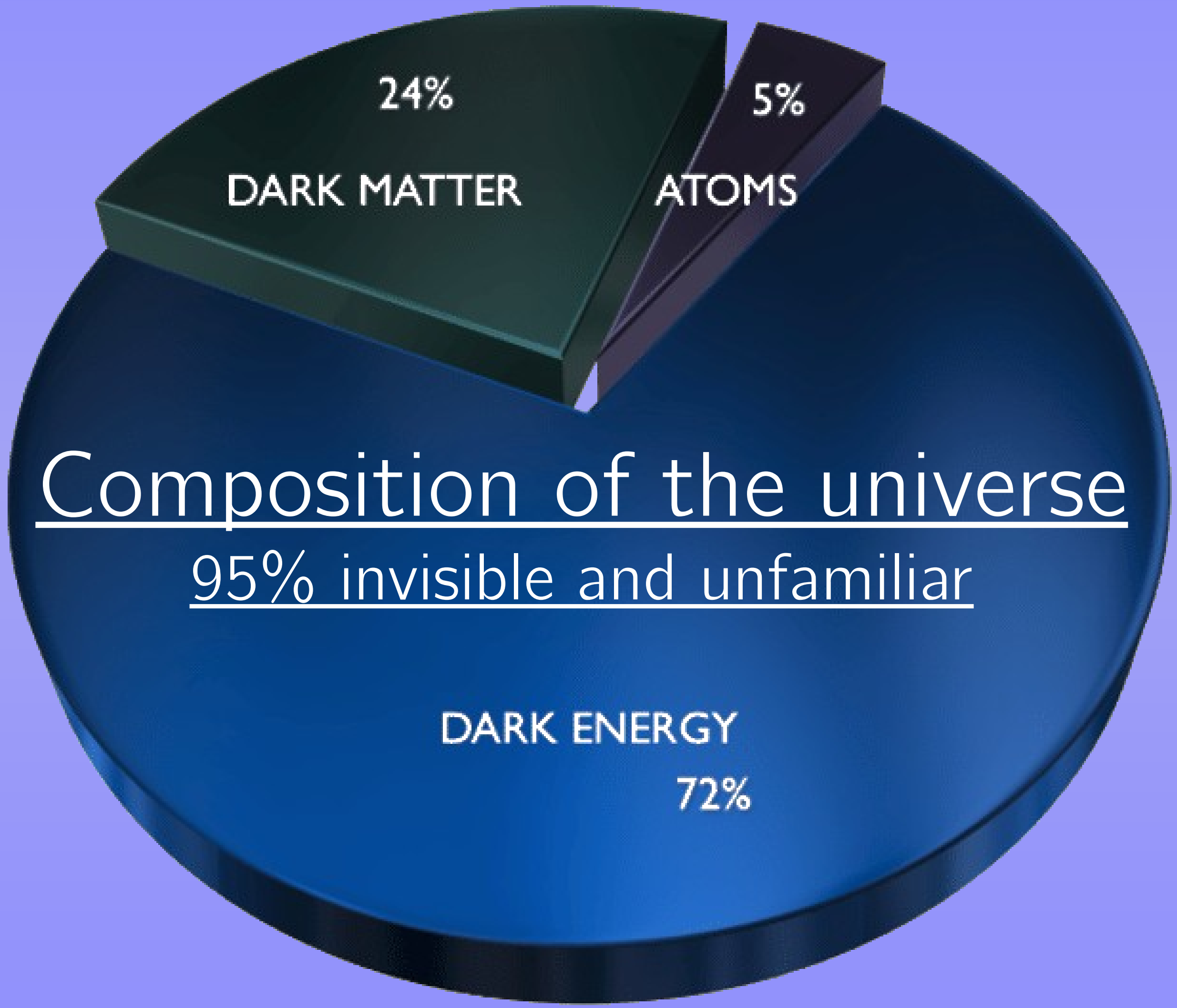
reinterpretation:
big fat target

mystical particles may be produced and may traverse the dump



Physics at DarkMESA: Light dark matter searches

Some say:



M. Hüdaverdi *et al.*, 10.1109/RAST.2011.5966901

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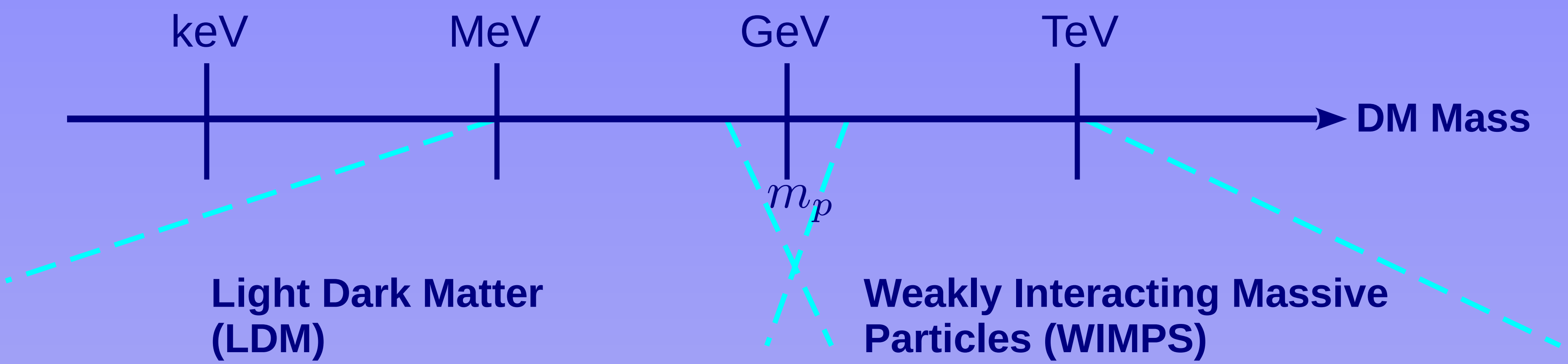
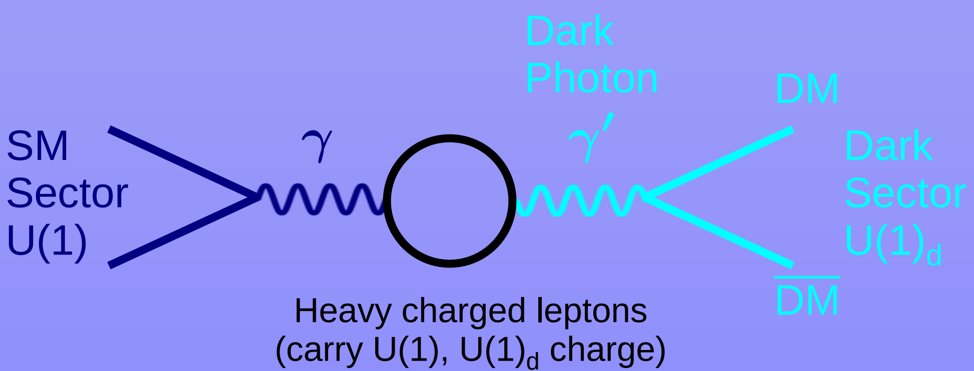


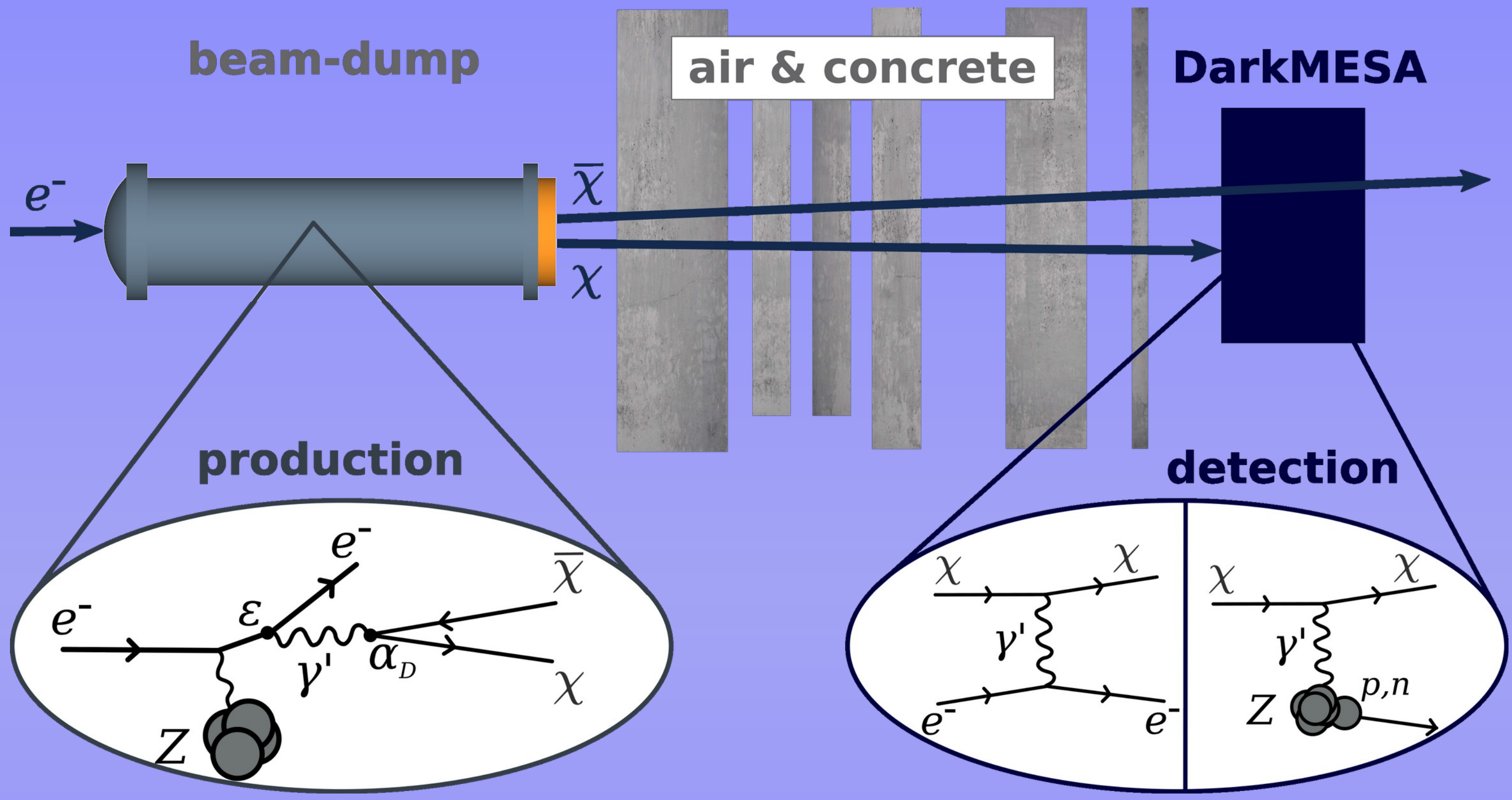
- Speculation that dark matter might be "light" has gained interest
- Related: idea of rich but unexplored ***dark sector***, which communicates with SM through one (or more) dark mediator particles

nothing found yet.



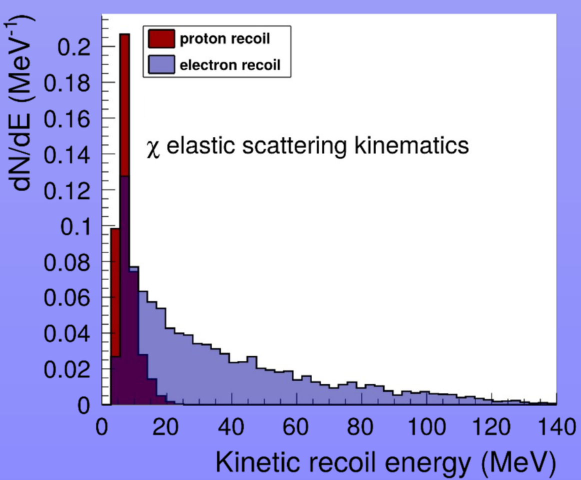
coupling: e.g. through kinetic mixing

Light dark matter searches at DarkMESA



contrast to underground experiments:

- DM particles can have reasonable amount of kin. energy
- recoiling electrons / nuclei as well!
  - simple detection

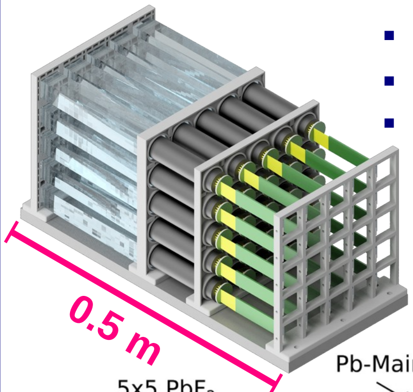


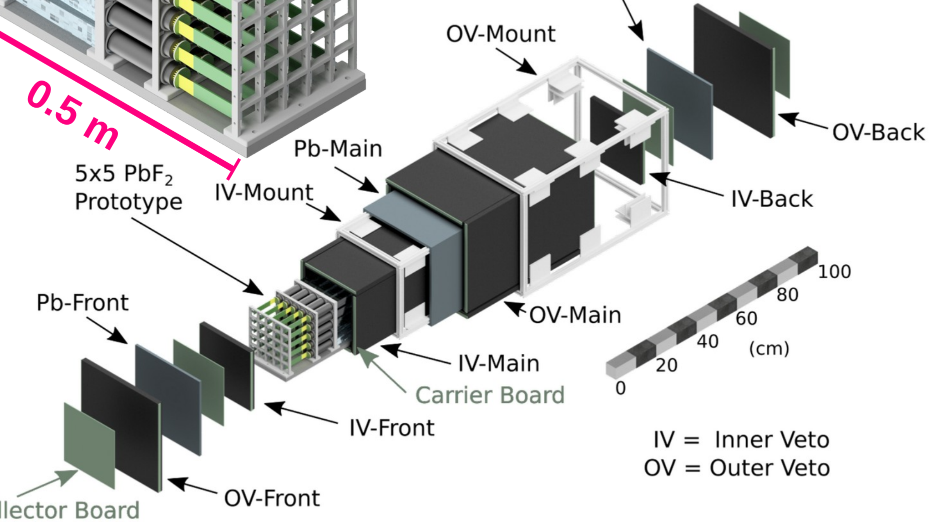
Mirco Christmann

DarkMESA - detector stages

Phase A (prototype)

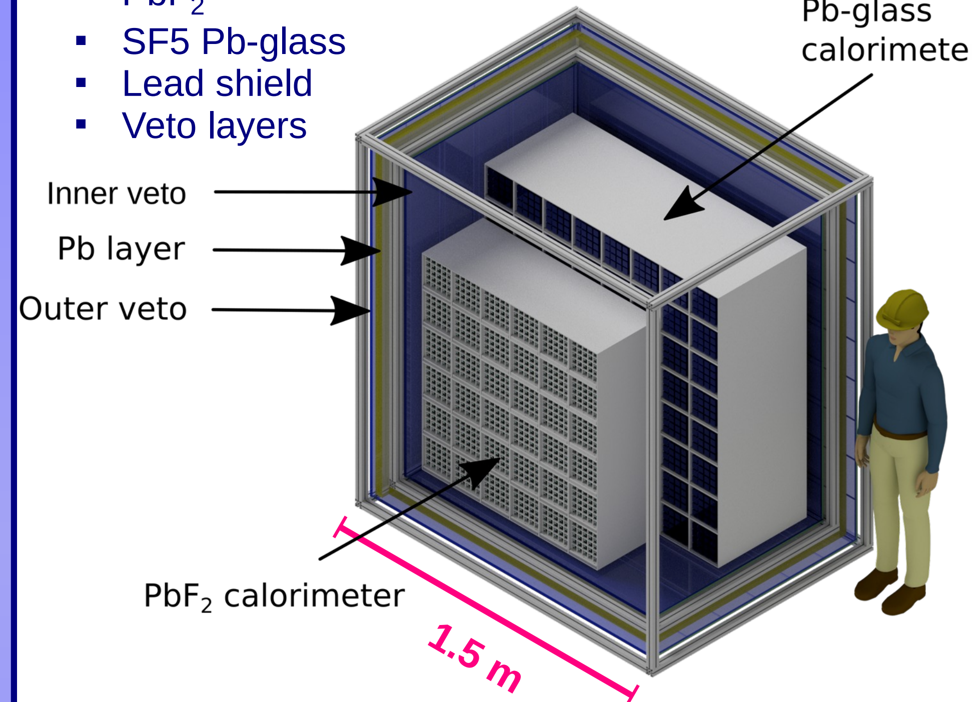
- $0.004\ m^3\ PbF_2$
- Lead shield
- Scintillator bars as veto detector





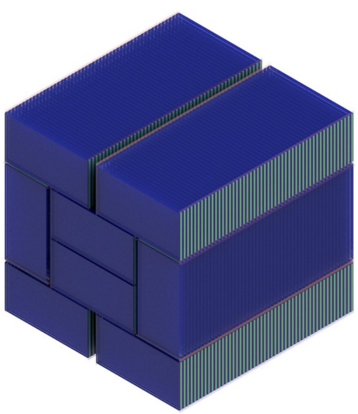
Phase B (increase volume / yield)

- PbF_2
- SF5 Pb-glass
- Lead shield
- Veto layers



Phase C (range extension)

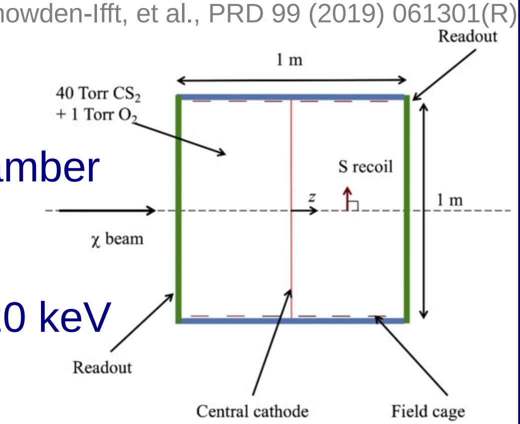
options



Radiation protection glas
e.g., SCHOTT-RD30
Moderate cost: 137 k€ / m^3
High density: 3.13 g / cm^3

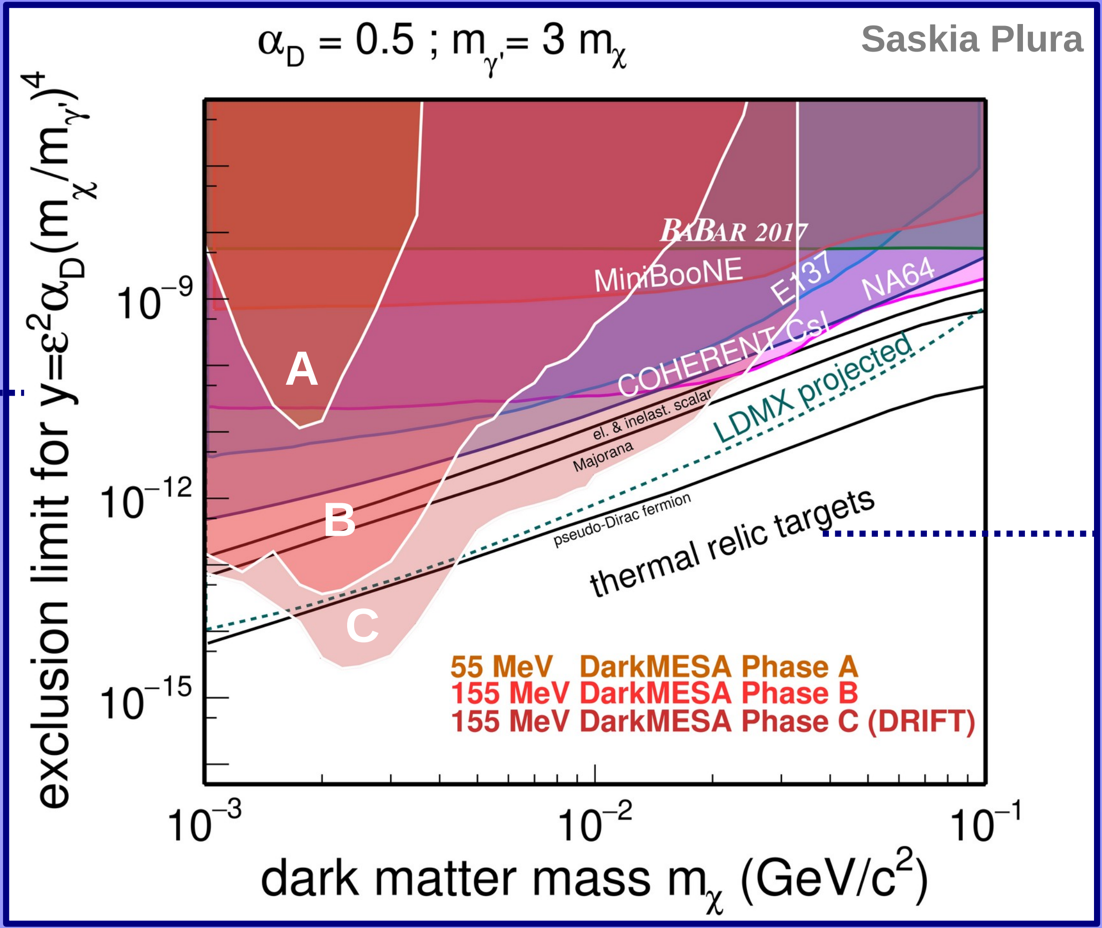
DRIFT -Time Projection Chamber
CS_2 at 50 mbar
$\sim$1 m^3 active volume
Nuclear recoil threshold: 20 keV

D. P. Snowden-Ifft, et al., PRD 99 (2019) 061301(R)



⇒ Extended parameter space

DarkMESA - expected sensitivity



Natural dimensionless **interaction strength**

Relic density limits:

correspond to predictions assuming a thermal origin of the DM

The DarkMESA Experiment
– Maik Biroth (presentation - Tuesday)

Search for Light Dark Matter with the DarkMESA Experiment
– Saskia Plura (poster - Wednesday)

Possibility to probe other DM models using same data set, e.g., ALPs

- P2 / MREX: Several highly prestigious physics objectives
- DarkMESA: A highly specialized search experiment

complement:
versatile and flexible
electron scattering experiment

Multi-purpose experiment MAGIX

Mainz Gas Injection Target Experiment

Multi-purpose experiment MAGIX

Mainz Gas Injection Target Experiment

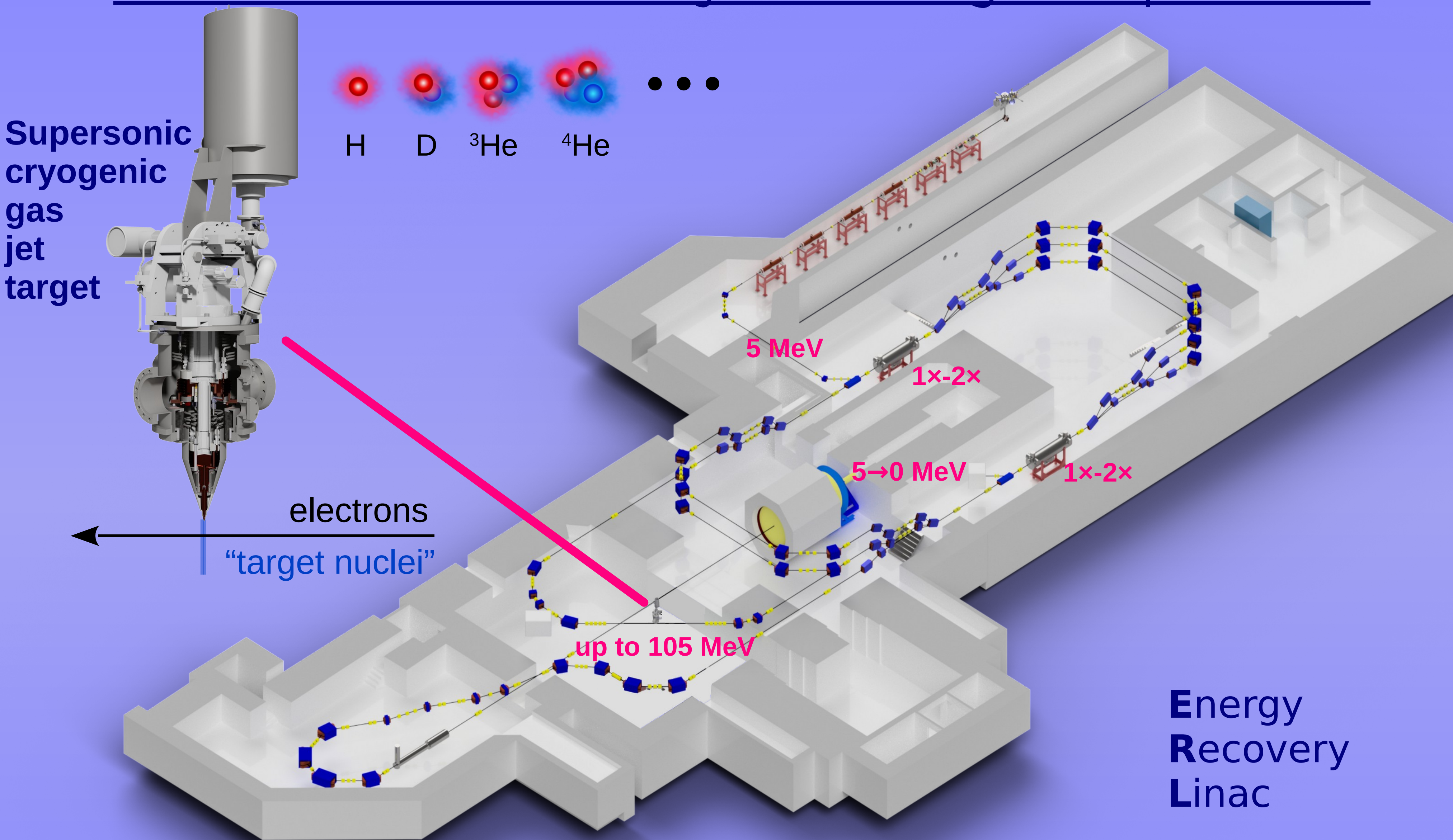
Multi-purpose experiment MAGIX

typical target (LH2)

- ~~background from target foils~~
- ~~large energy loss straggling and multiple small angle scattering~~
- ~~target length acceptance issues~~

<u>Ma</u>inz <u>G</u>as <u>I</u>njection Target E<u>x</u>periment

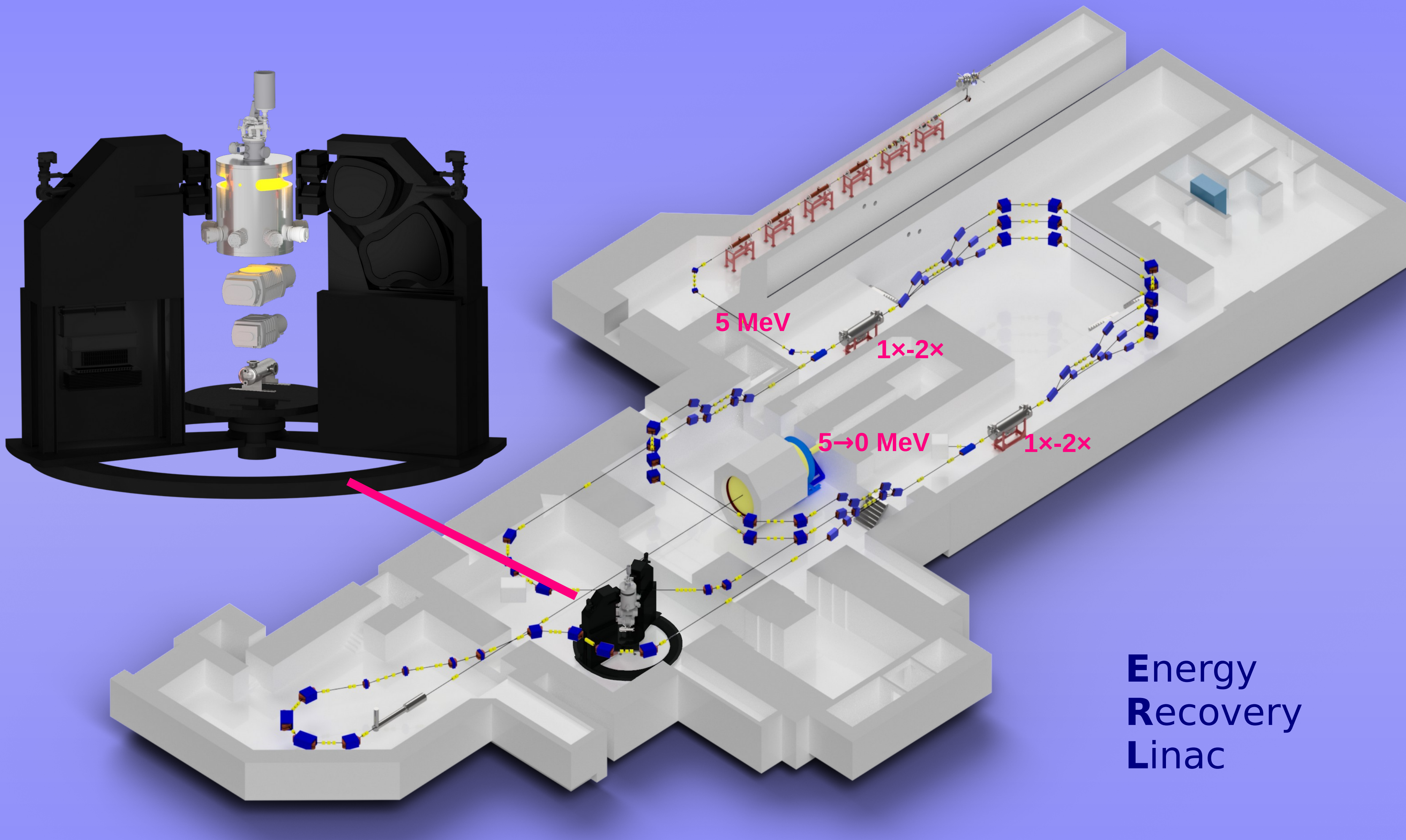
MAGIX: MAinz Gas Injection target eXperiment



Energy
Recovery
Linac

```
P2/DM-EB mode:    ~155 MeV,   150 μA
   MX-EB mode:  20-105 MeV, < 150 μA
    ERL mode:  30-105 MeV, 10000 μA
```

MAGIX: MAinz Gas Injection target eXperiment



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Recovery
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P2/DM-EB mode:    ~155 MeV,   150 µA
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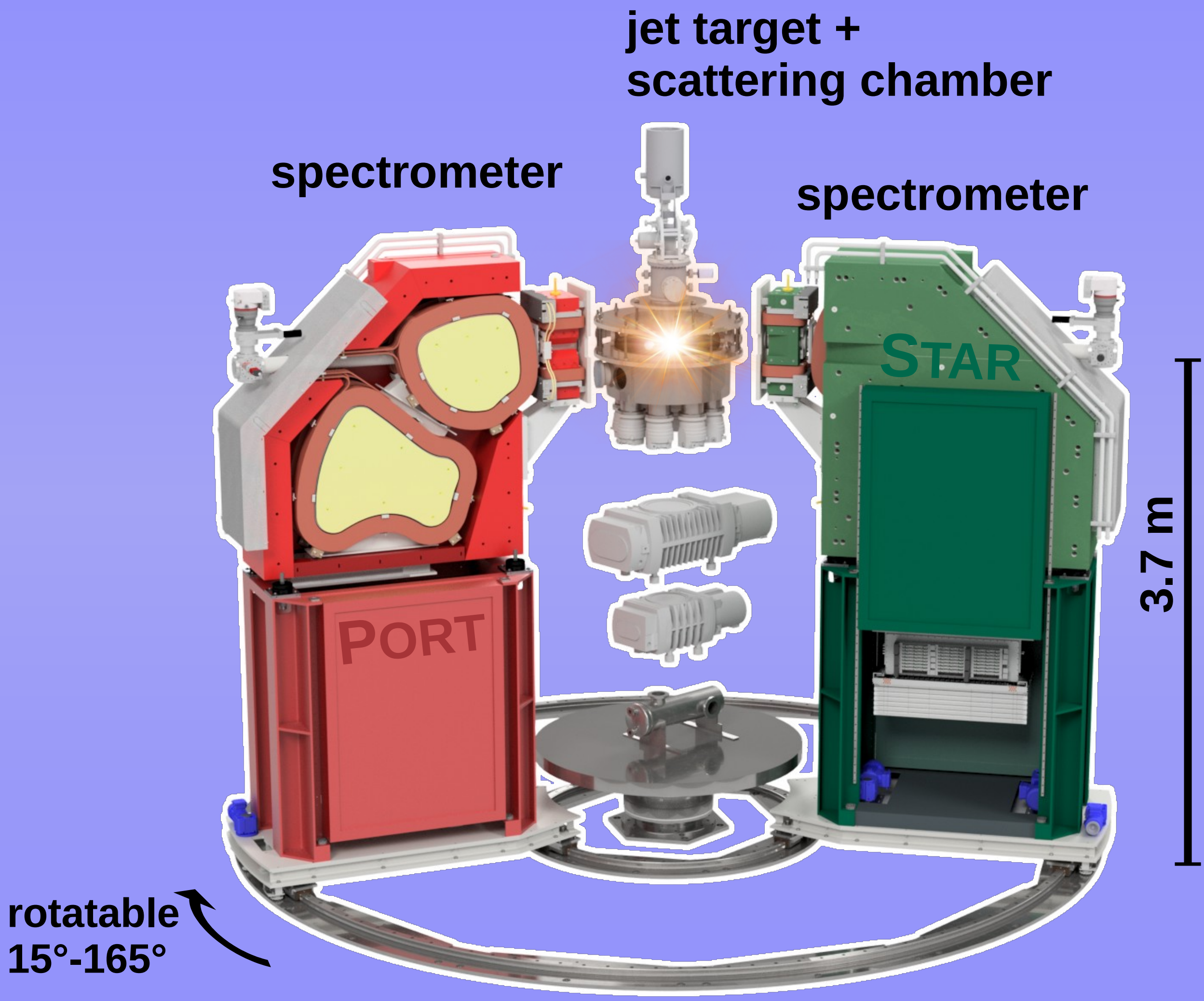
```

StarPort Spectrometer Setup



Electron/positron detection, magnet system, optics

- **quadrupole** followed by two 45° **dipoles**
- double-focusing with a horizontal **focal plane (FP)**

coordinates at vertex

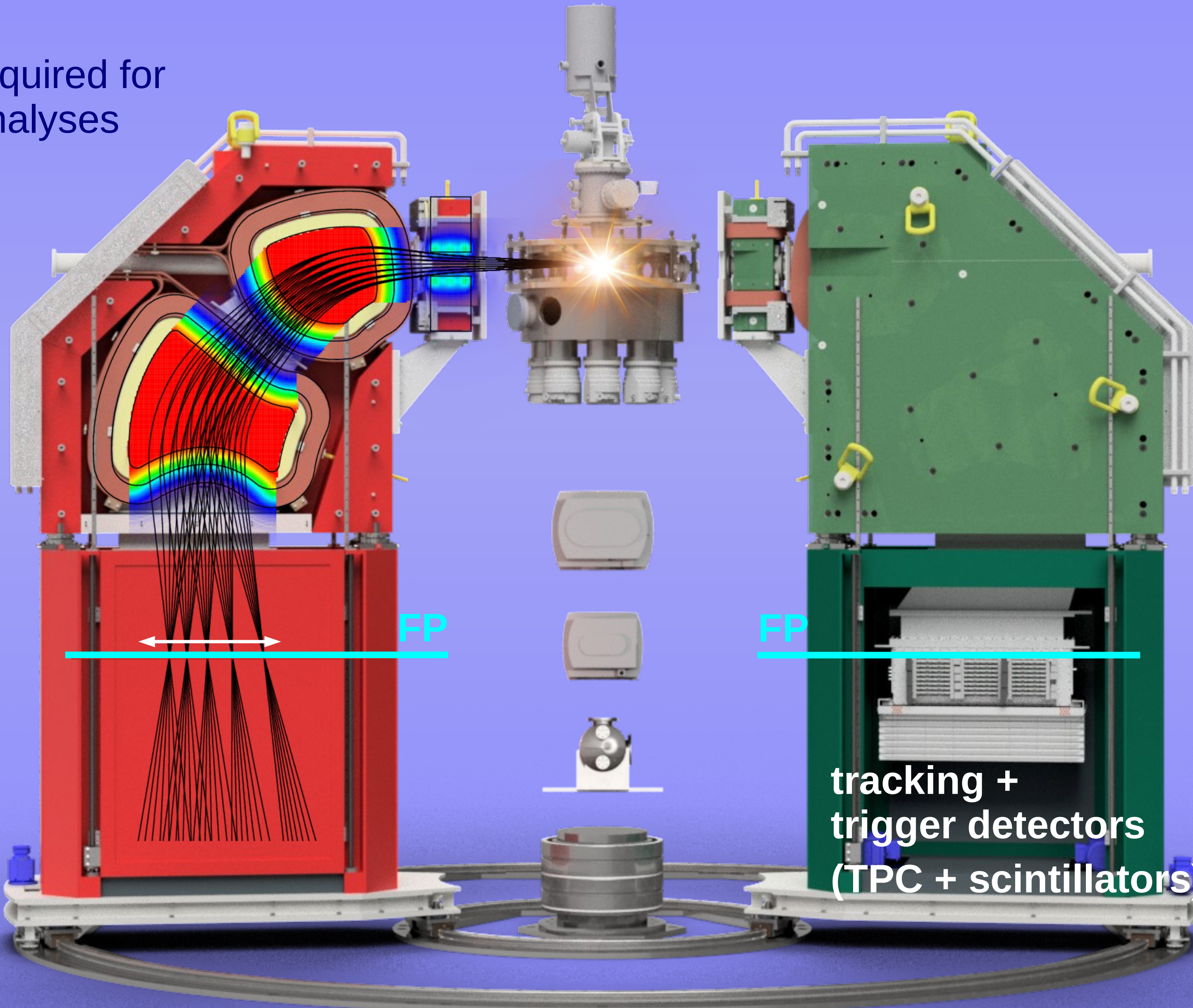
(optics) ↓ ↑ **(optics)$^{-1}$**

required for analyses

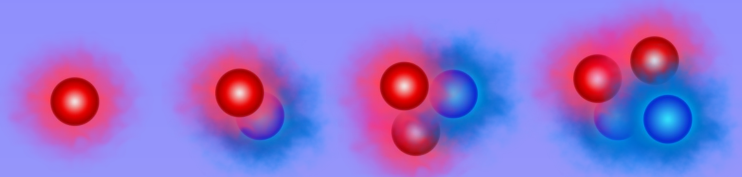
coordinates at FP

measurable

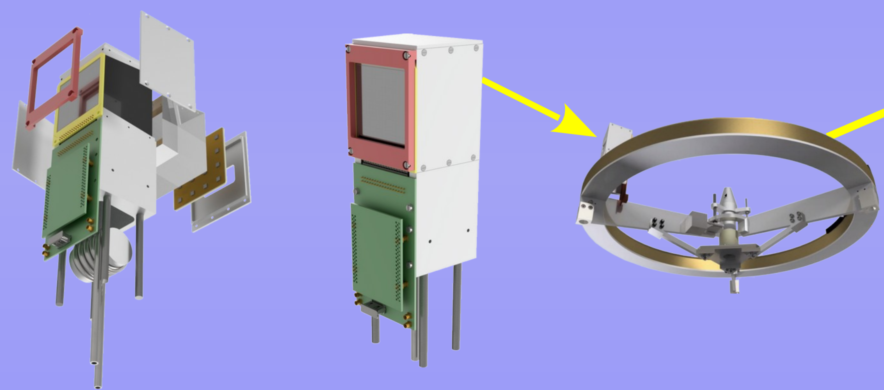
| particle momentum | ≙ hit position in FP_x



Additional recoil detectors



detection of low-energy recoil nuclei

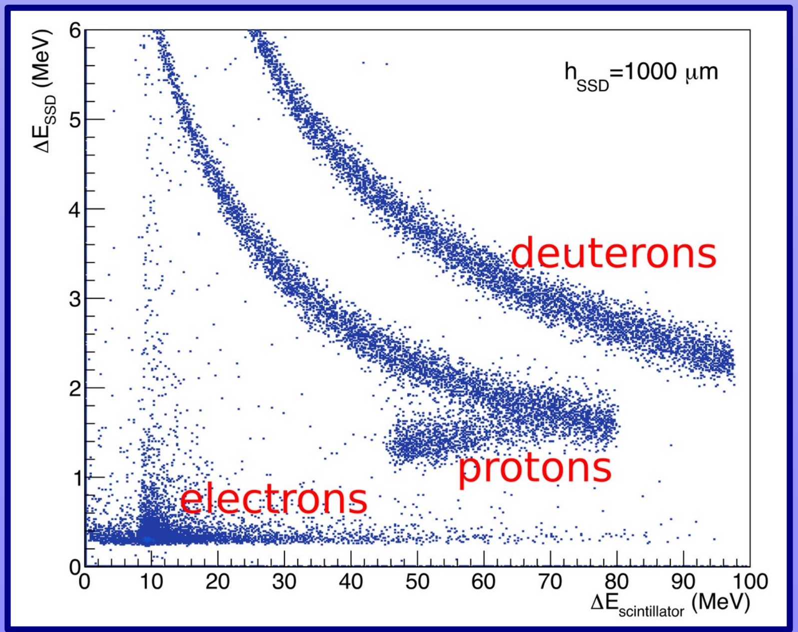


Maik Biroth

Silicon Strip + Scintillation Detector

prepared for a comprehensive physics programme

Andzrej Wilczek



The MAGIX Physics Programme

*[...], the Mainz Gas Injection Target Experiment (**MAGIX**) is a multipurpose spectrometer for a precise determination of the **proton charge radius** and **dark matter searches**.*

https://science.osti.gov/-/media/np/nsac/pdf/202310/October-4-LRP-Report.pdf

Physics at MAGIX: Structure of nucleons and nuclei

use point-like, structure-less electron

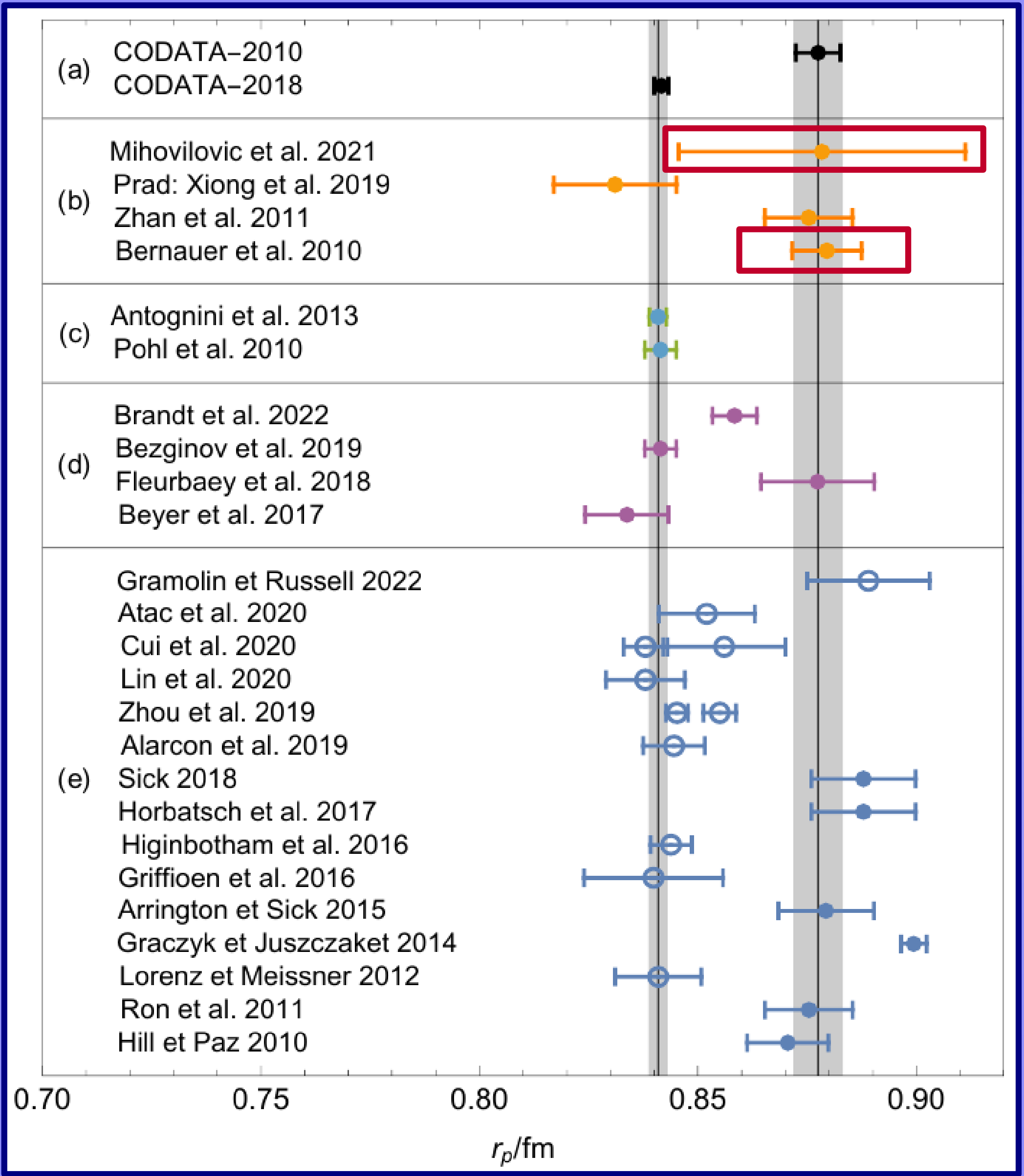
to study structure of nucleons and nuclei

measure e.m. form factors, extract charge radii, join the proton radius puzzle club

Proton radius puzzle

discrepancy between different determinations of the proton radius

13 years later, experts still disagree.



MAMI / A1

(a) 7-std jump
(b) electron scattering
(c) muonic hydrogen (error bars ×5)
(d) electronic hydrogen
(e) reanalyses: mostly data from (b)
open circles: extrapolation variations.

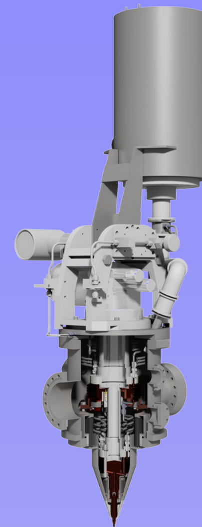
unconsidered effects,
new physics,
experimental / analysis issues ?!

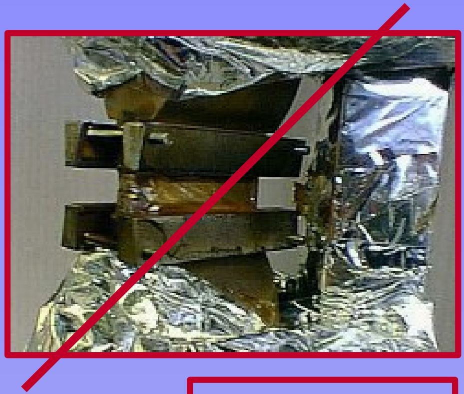
call for dedicated, improved data

Th. Walcher, arXiv:2304.07035 [physics.atom-ph] (2023)

Proton radius puzzle

discrepancy between different determinations of the proton radius





MAMI / A1

MAGIX

plan: comprehensive data set of unpolarized cross-section measurements

- measurements at lower Q^2 (~beam energy)
- significant background reduction (gas-jet target)

$$\left\langle r_p^2 \right\rangle = -6\hbar^2 \left. \frac{\mathrm{d}G_E}{\mathrm{d}Q^2} \right|_{Q^2=0}$$

unconsidered effects,
new physics,
experimental / analysis issues ?!

call for dedicated, improved data

scattering experiments, *e* and *μ*,
each with different beam / systematics:

ULQ²

PRoton Radius

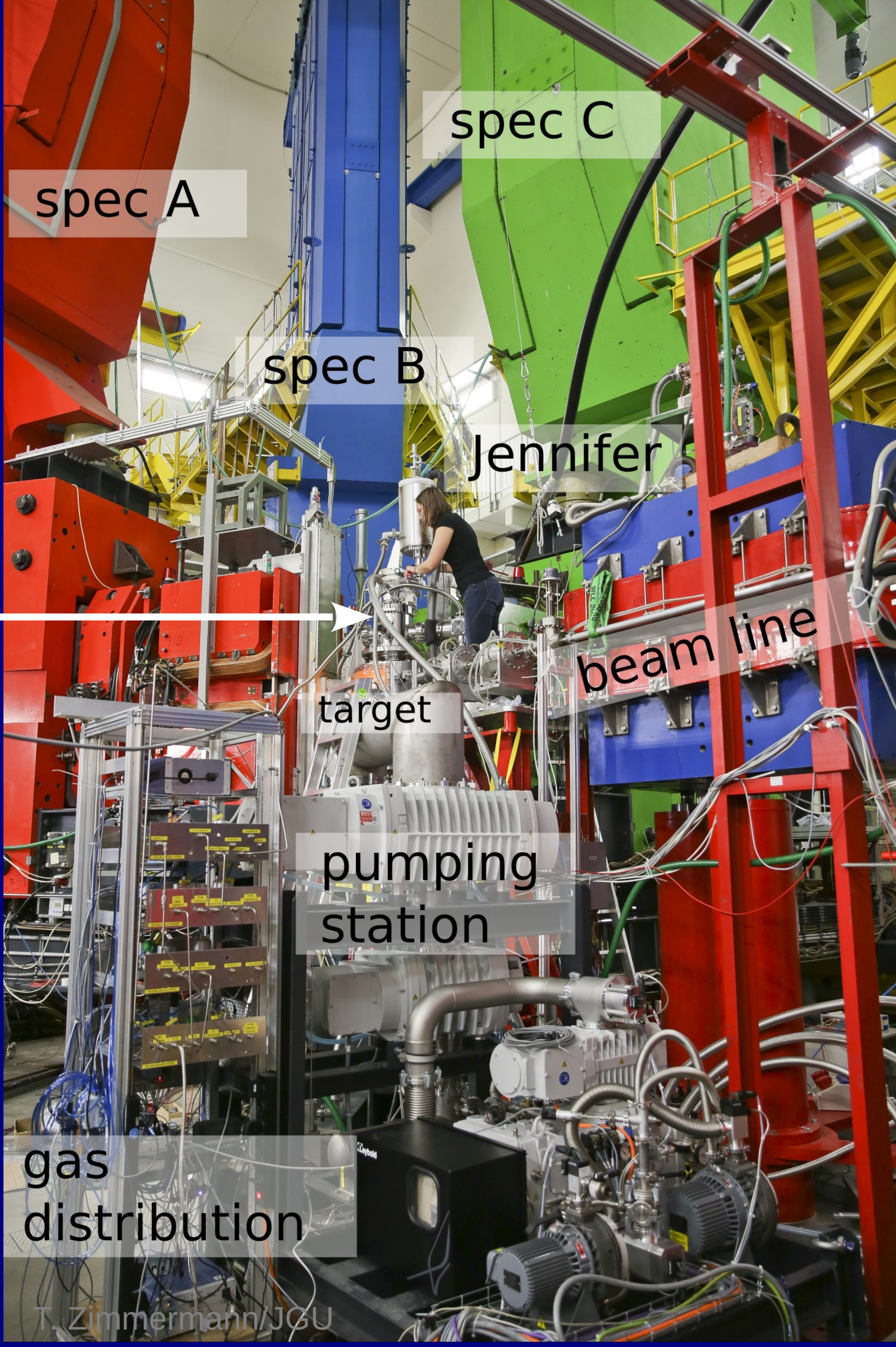
MUSE

AMBER
Apparatus for Meson and Baryon Experimental Research

The MAGIX jet target at

proton FF measurements

AG Khoukaz / Münster



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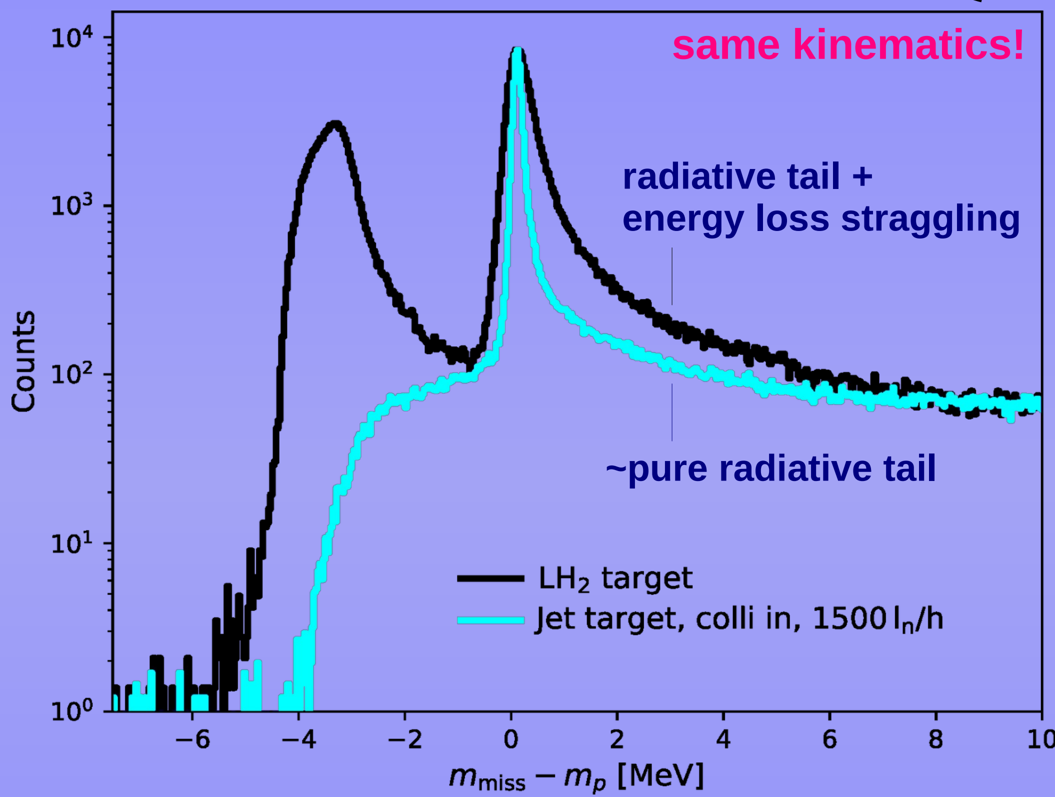
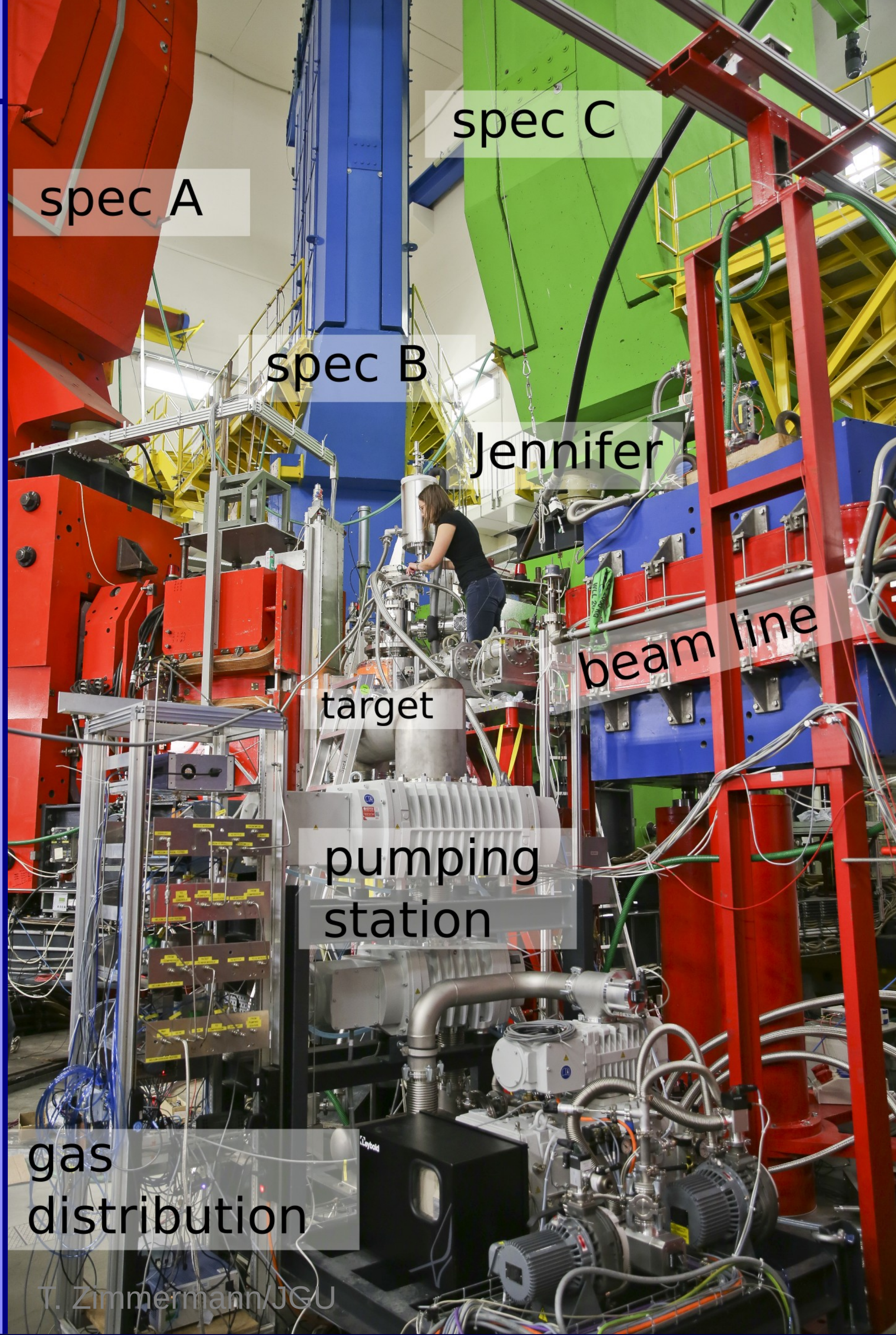


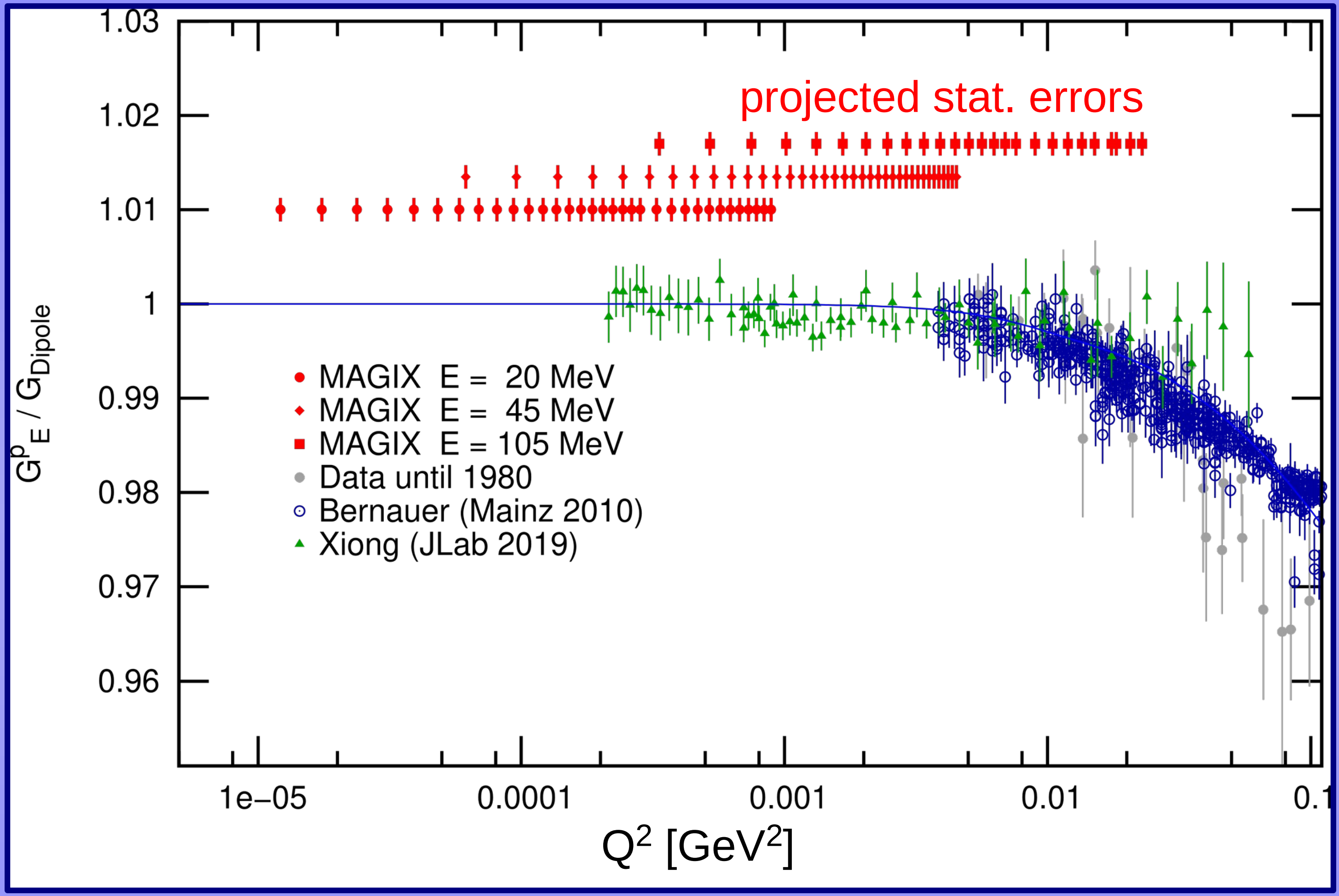
B.S. Schlimme *et al.*, NIMA **1013** (2021) 165668
Y. Wang *et al.*, PRC **106** (2022) 044610

Promising results.
However, we were statistically limited.

We need higher beam intensities!



Electric proton form factor at MAGIX

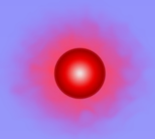


H. Merkel

Coverage from $\mathbf{Q^2 = 1 \cdot 10^{-5}}$ **to 0.03 GeV^2** $\Rightarrow$ **proton radius!**

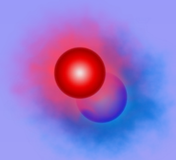
Beyond proton charge radius

H



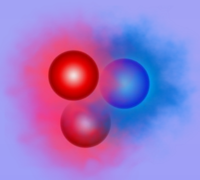
$G_{\mathrm{M}}^2(Q^2) \leftrightarrow$ magnetization distribution
$r_{\mathrm{M}}, r_{\mathrm{Zemach}}$

D



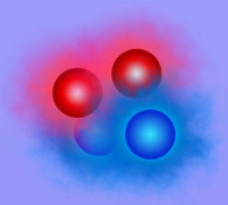
$A(Q^2), B(Q^2), r_d$
spin 1 → 3 elastic e.m. FFs
expensive

^{3}He



spin 1/2 → 2 elastic e.m. FFs
ultra-expensive

^{4}He

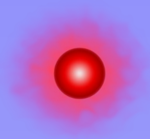


spin 0 → 1 elastic e.m. FFs, $r_{^4\mathrm{He}}$
almost boring...

⋮

Significant improvement of existing data is possible at low momentum transfers

Beyond proton charge radius

H


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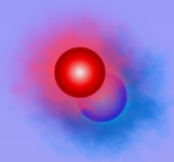

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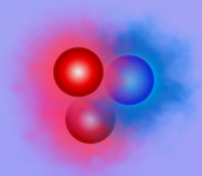

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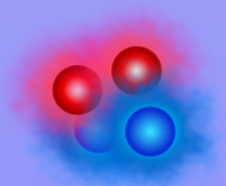


spin 0 $\rightarrow$ 1 elastic e.m. FFs, $r_{^4\mathrm{He}}$
almost boring...

⋮

elastic,
elastic,
elastic...

let's get excited*
... or break something !

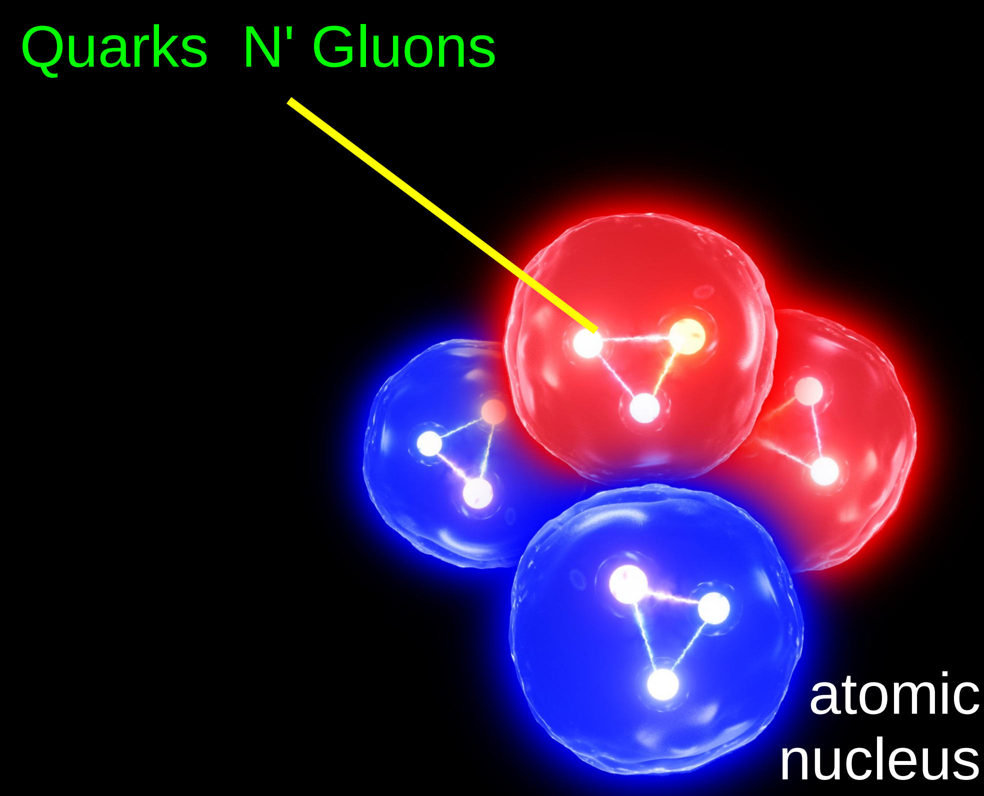
INELASTIC
SCATTERING

Physics at MAGIX: Few-body systems

Physics within a nucleus

can, in principle, be derived

- **based on QCD** (theory of strong interaction between quarks - mediated by gluons)
  limited direct applicability: non-perturbative in low-E regime; → lattice-QCD (promising tool)



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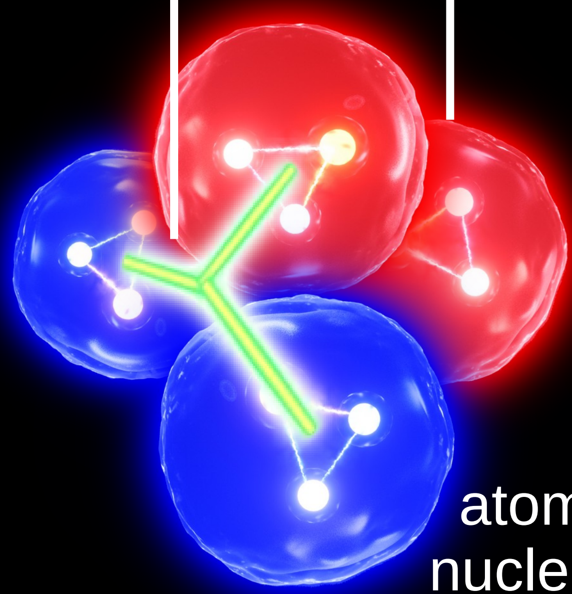
can be described
- **using traditional / phenomenological potentials** (CD-Bonn, Argonne V18, Nijmegen I+II, ...)
  - protons, neutrons as degrees of freedom
  - drawbacks: difficult to assign theoretical errors, implement gauge and chiral symmetry, ...
  - connection to QCD not obvious at all

non-relativistic system of nucleons,
interacting via nuclear forces



atomic
nucleus

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- **using Chiral Effective Field Theory (χEFT)**
  - protons, neutrons, pions as effective DOF
  - starts from most general Lagrangian consistent with all symmetries & conservation laws of QCD
  - power counting scheme, that specifies which terms are required at a desired accuracy
  - predictive low-energy theory, various applications

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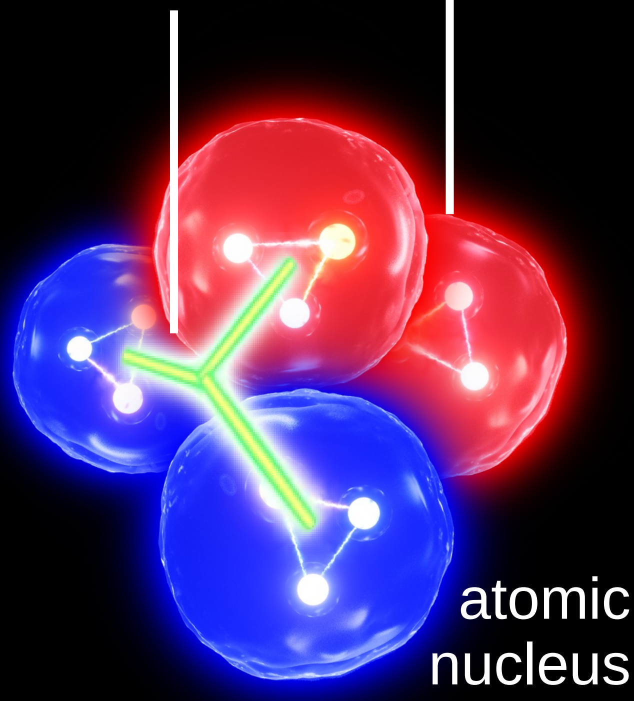

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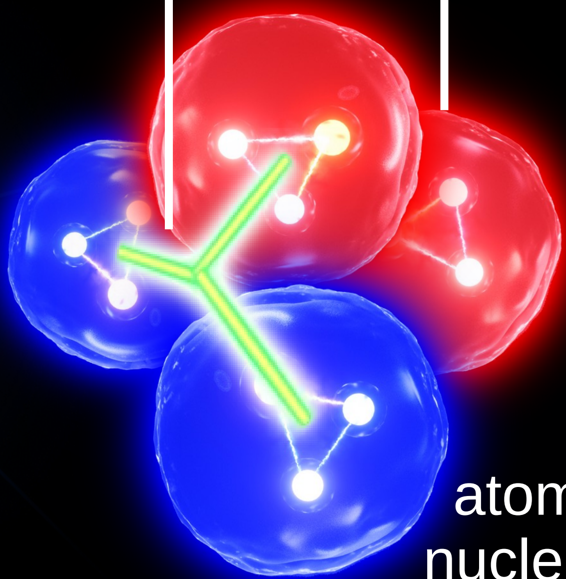
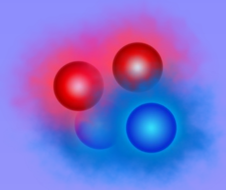


atomic nucleus

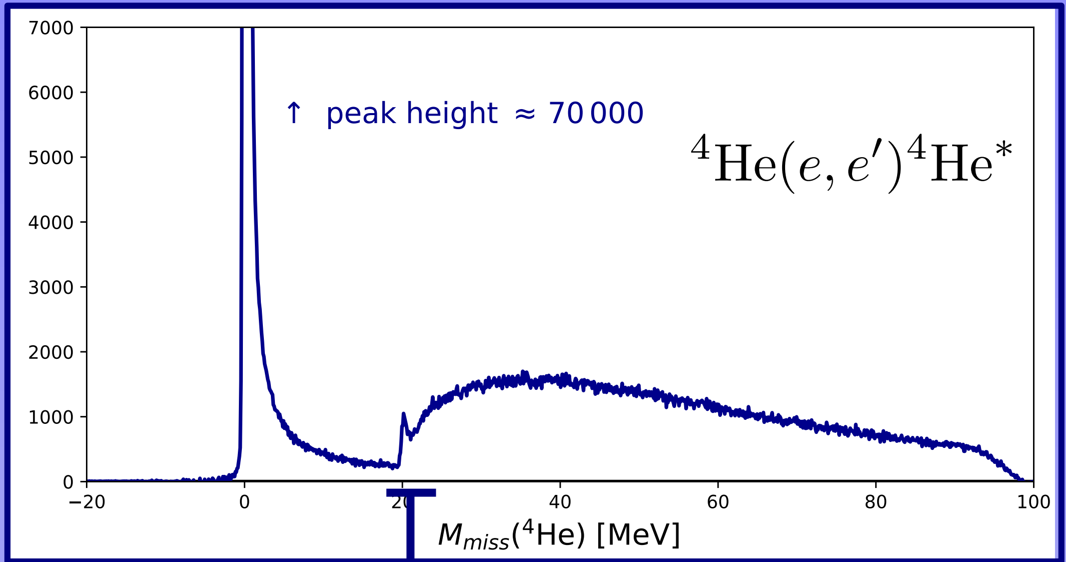
- With great power comes great responsibility:
  test the theory in the low energy regime

study the excitation of light nuclei with e.m. probe

Helium - inclusive



^{4}He: benchmark nucleus for our understanding of the **nuclear forces** and the **few-body methods** used to solve the Schrödinger equation



transition FF: ground state (0^+) to first excited state (0^+)

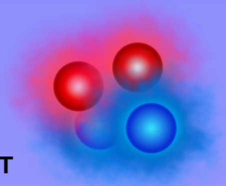
PHYSICAL REVIEW LETTERS **130,** 152502 (2023)

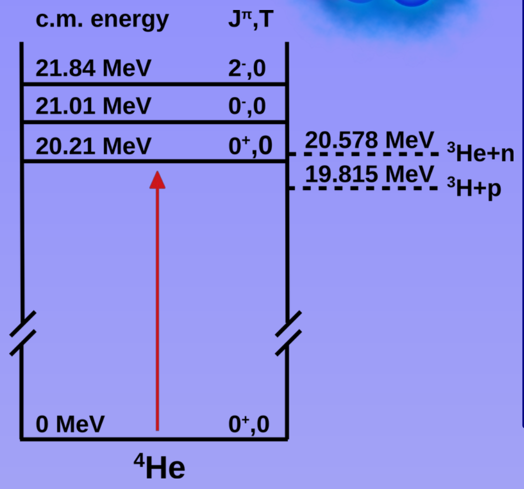
Editors' Suggestion | Featured in Physics

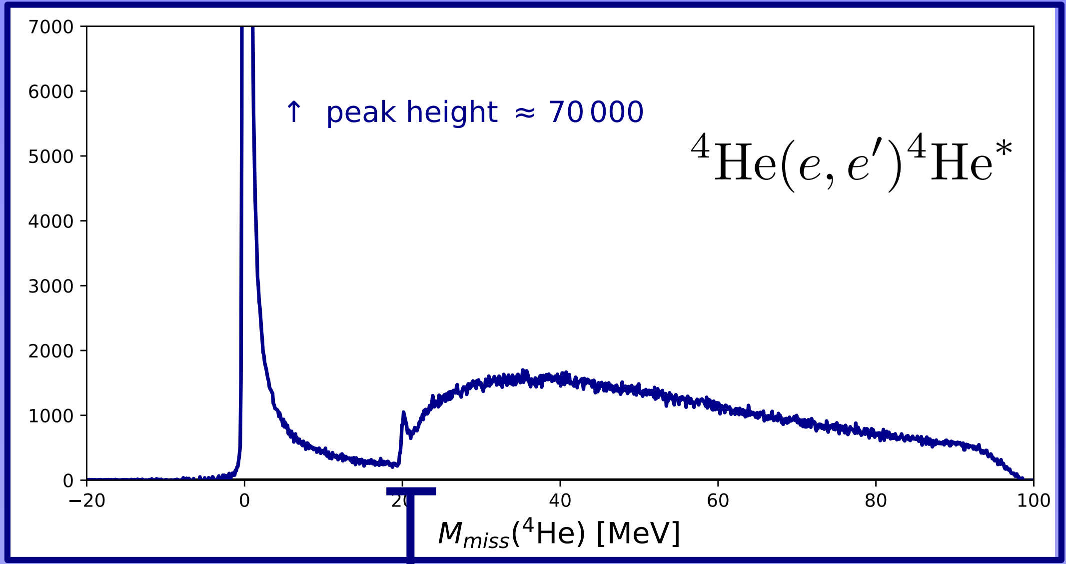
Measurement of the α-Particle Monopole Transition Form Factor Challenges Theory: A Low-Energy Puzzle for Nuclear Forces?

S. Kegel,[1] P. Achenbach,[1] S. Bacca,[1,2] N. Barnea,[3] J. Beričič,[4] D. Bosnar,[5] L. Correa,[6,1] M. O. Distler,[1] A. Esser,[1] H. Fonvieille,[6] I. Friščić,[5] M. Heilig,[1] P. Herrmann,[1] M. Hoek,[1] P. Klag,[1] T. Kolar,[7,4] W. Leidemann,[8,9] H. Merkel,[1] M. Mihovilovič,[1,4] J. Müller,[1] U. Müller,[1] G. Orlandini,[8,9] J. Pochodzalla,[1] B. S. Schlimme,[1] M. Schoth,[1] F. Schulz,[1] C. Sfienti,[1,*] S. Širca,[7,4] R. Spreckels,[1] Y. Stöttinger,[1] M. Thiel,[1] A. Tyukin,[1] T. Walcher,[1] and A. Weber[1]

Helium - inclusive

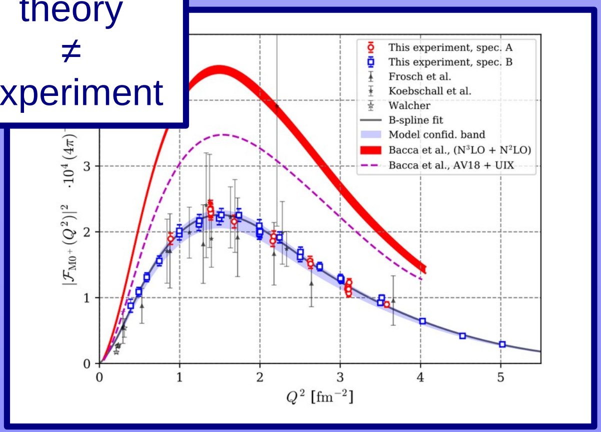






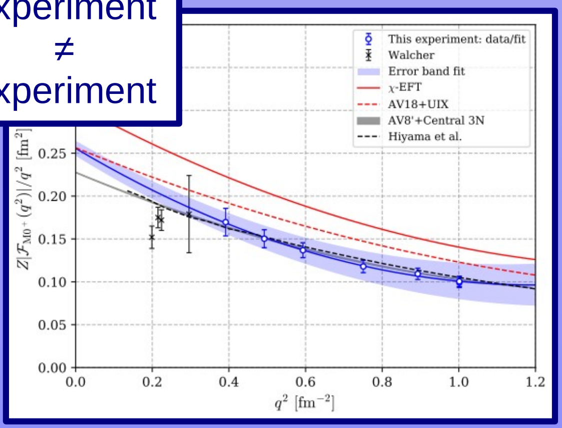
transition FF: ground state (0⁺) to first excited state (0⁺)

theory ≠ experiment

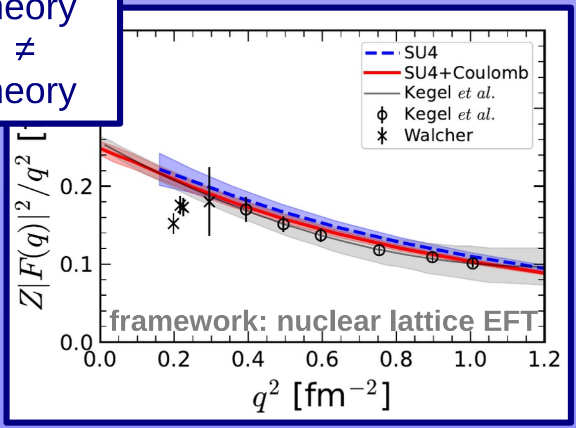


experiment ≠ experiment

S. Kegel *et al.*, PRL 130 (2023) 15



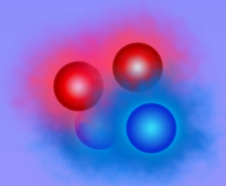
theory ≠ theory

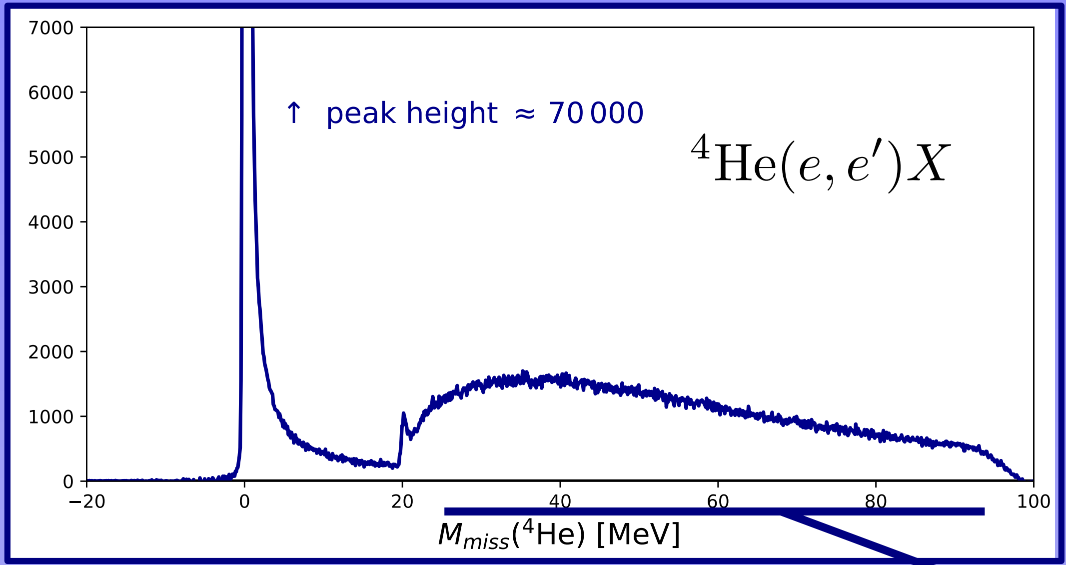


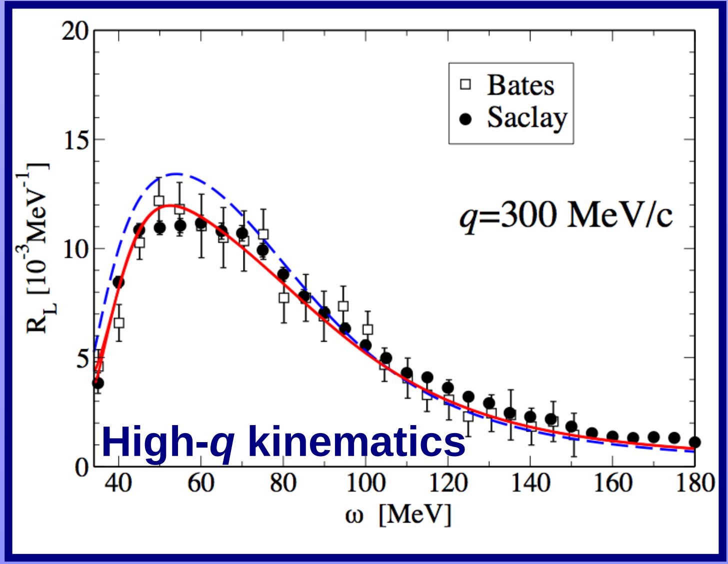
U.-G. Meißner et al., arXiv:2309.01558 [nucl-th] (2023)

Ideal conditions at MAGIX! ⇒ low-q measurement

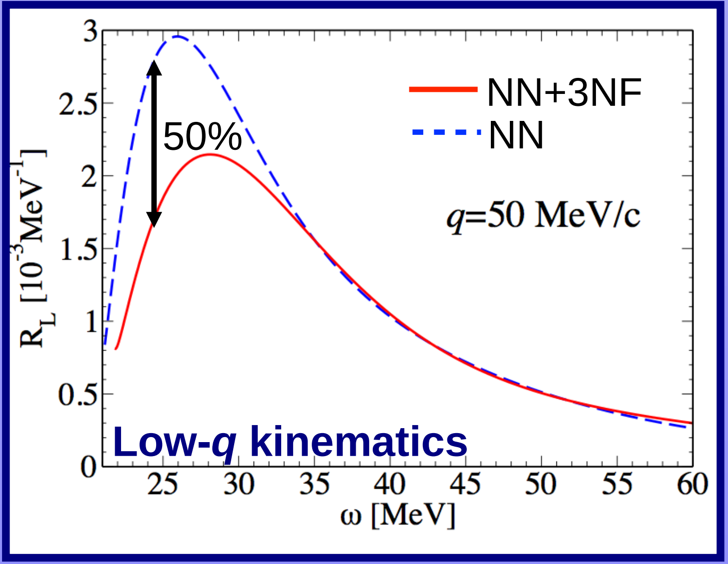
Helium - inclusive







Theory agrees with experiment



Strong 3NF effect at low q predicted

Longitudinal response ^{4}He(e,e')X

⇒ provide low-q measurement at MAGIX!

Bacca et al., Phys. Rev. Lett. 102 (2009) 162501

Few-body systems: key reactions

	reaction	objection
▪ *d* breakup	*D*(*e,e'*), *D*(*e,e'p*)	polarizabilities → nucl. structure corr. in muonic atoms
▪ ^{3}He inclusive	^{3}He(*e,e'*)	el. FF, radius, structure functions, R_L
▪ ^{3}He exclusive	^{3}He(*e,e'p/d*)*d/p*	MEC, 3NF
▪ ^{4}He exclusive	^{4}He(*e,e'p/d*)	dσ/dΩ, ...
▪ ^{4}He inclusive	^{4}He(*e,e'*)	el. FF, radius, structure functions, R_L, 3NF
▪ ^{4}He monopole	^{4}He(*e,e'*)^{4}He*	transition FF, 3NF, E, Γ, r_{Tr}, R_{Tr}
▪ ^{12}C Hoyle	^{12}C(*e,e'*)^{12}C*	transition FF, ..., ↔ cluster EFT
▪ ^{16}O inclusive	^{16}O(*e,e'*)	R_L, Coulomb sum rule ↔ coupled-cluster theory
▪ ^{40}Ar inclusive	^{40}Ar(*e,e'*)	structure functions ↔ e4ν

- **perform measurements on key reactions to study different aspects of few-body systems**
- **supply high-precision data for benchmarking and calibration of theory**

Physics at MAGIX: Study of reaction cross sections of astrophysical interest

To model stars and explain the element abundances accurately, precise cross-section estimates are required

Cross section measurements in the lab:

- particle energies of interest are small
- often tiny cross sections
- often dominated by background

Stellar nucleosynthesis

Helium burning of a main sequence star:

$$3\underline{\alpha} \longrightarrow {}^{12}\mathrm{C} + 2\gamma$$

triple-alpha process

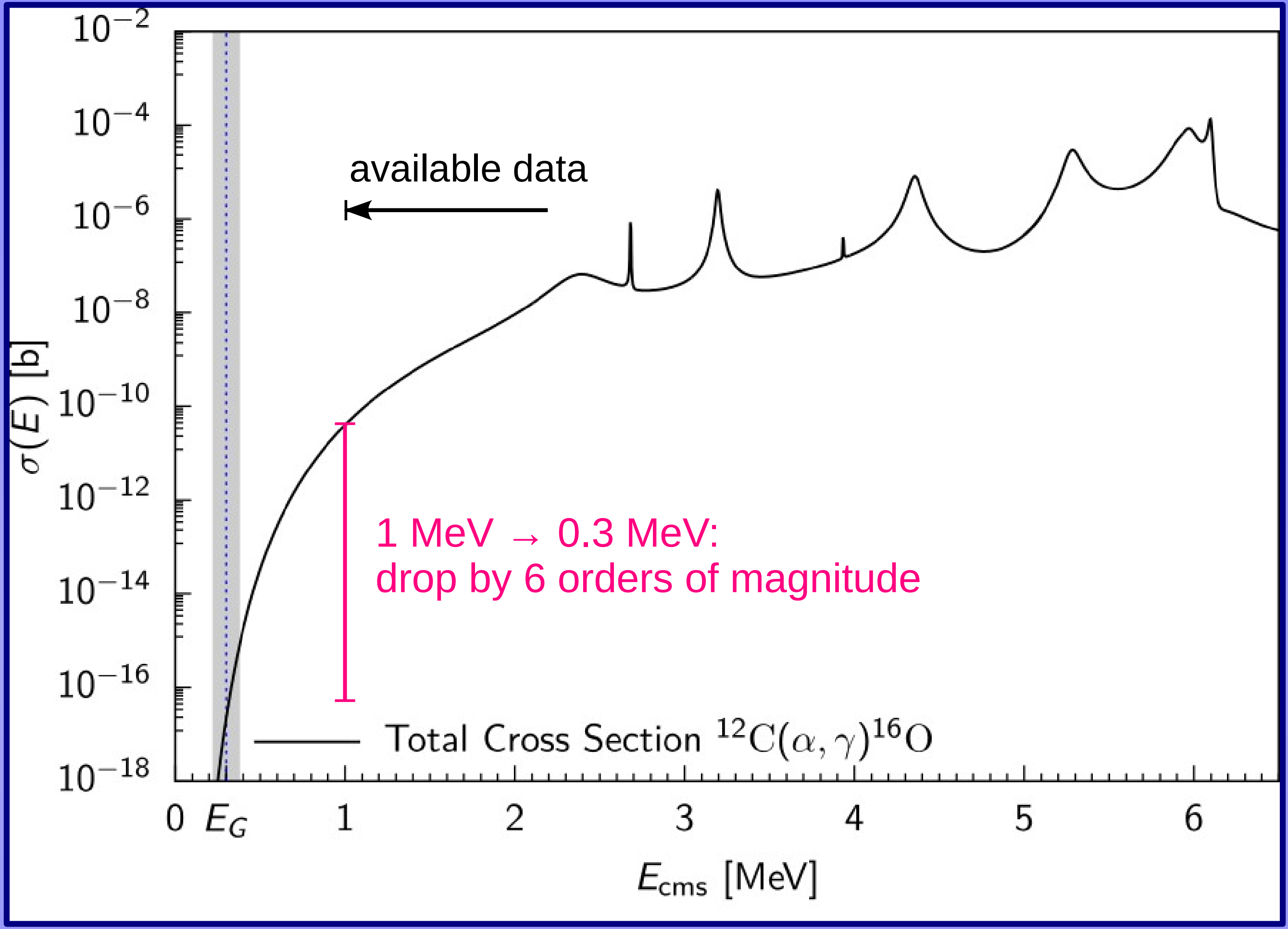
$$^{12}\mathrm{C} + \underline{\alpha} \longrightarrow {}^{16}\mathrm{O} + \gamma$$

radiative alpha particle capture by a carbon nucleus

competition for the alphas
→ C / O - ratio

- 3α-process is known
- **^{12}C + α → ^{16}O + γ:** one of most important reactions to describe nucleosynthesis in burning of a star
- Outcome of competition determines ^{12}C / ^{16}O ratio
  - dominant role in subsequent processes + nuclear abundances!

Alpha-particle capture by a carbon nucleus



- Data available down to 1 MeV
  - best data: underground laboratories, e.g. LUNA (Gran Sasso)
- Needed:
  σ at the 'Gamow peak', $E_{c.m.}$ = 300 keV (T = $2 \cdot 10^8$ K)
- extrapolation → theory dependence

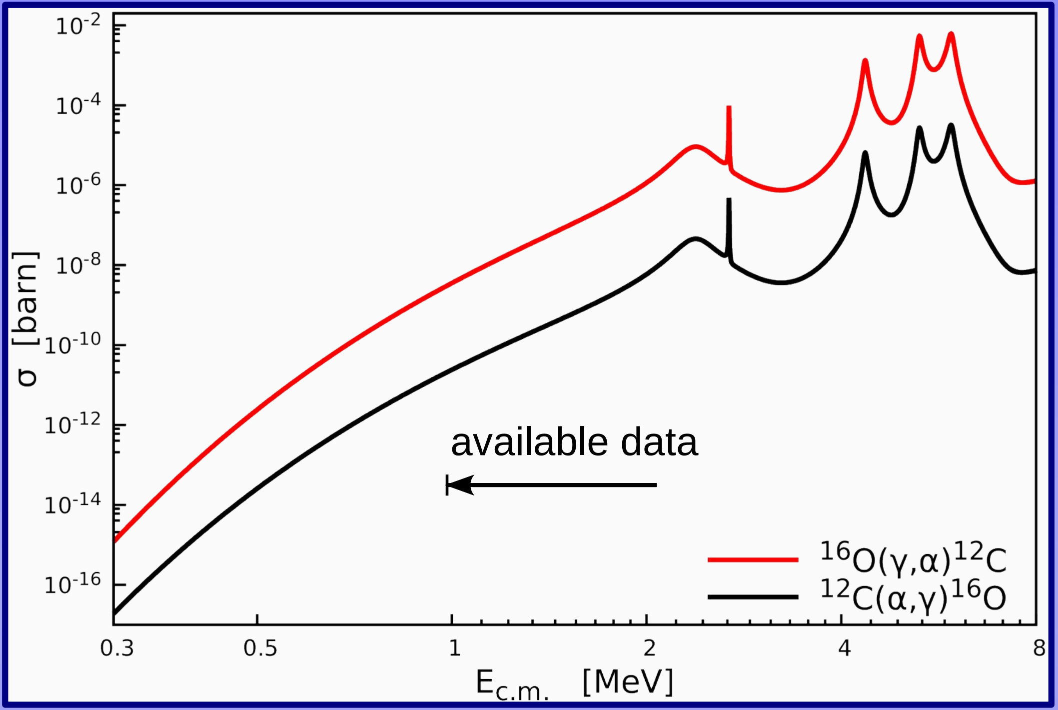
Measurement of the time reversed reaction at MAGIX

study $^{12}\mathrm{C}(\alpha,\gamma)^{16}\mathrm{O}$ **α-capture process**

by $^{16}\mathrm{O}(\gamma,\alpha)^{12}\mathrm{C}$ **~time reversed reaction**

(the cross-sections are directly related)

compare I. Friščić, T. W. Donnelly, R. G. Milner, Phys. Rev. C100, 025804 (2019)



- Time reversal → gain of 50× in CS (spin weight and phase space)
- No γ-beam, but electrons:

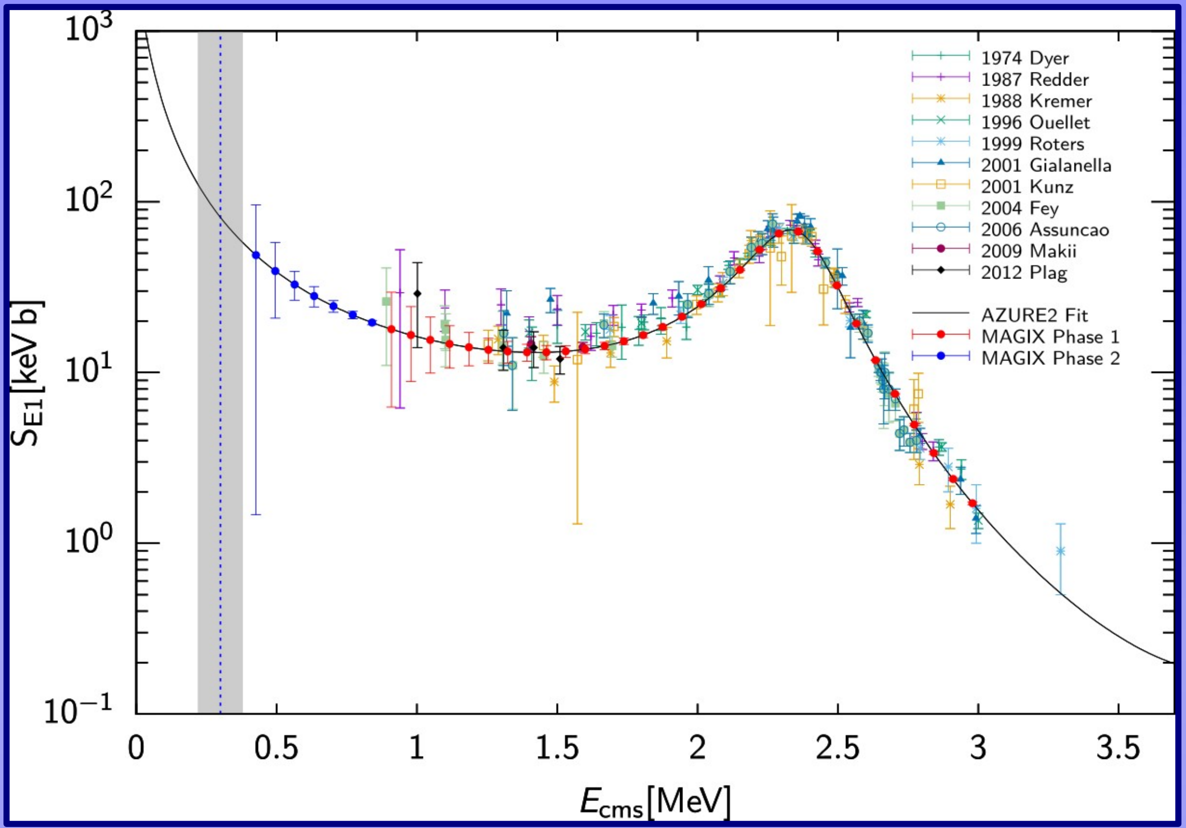
$$^{16}\mathrm{O}(e,e'\alpha)^{12}\mathrm{C}$$

$$\Leftrightarrow {}^{16}\mathrm{O}(\gamma^*,\alpha)^{12}\mathrm{C}$$

kinematics: quasi-real photon, $\gamma^* \approx \gamma$

Sensitivity

Stefan Lunkenheimer



C.S. as function of $E_{c.m.}$

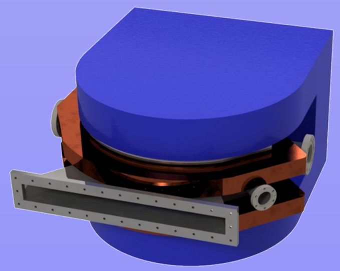
tunneling probability in fusion process

$$\boxed{\sigma(E) = \frac{1}{E} e^{-\frac{2\pi Z_1 Z_2 \alpha c}{v}} \cdot S(E)}$$

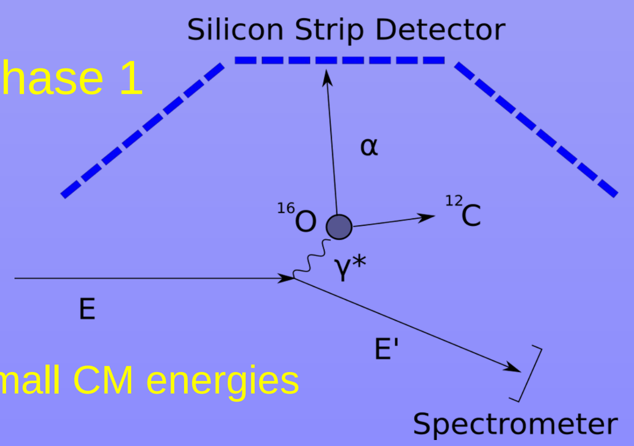
Compton wave length

"S-factor" unknown nuclear physics

angular structure
→ multipole decomposition (E1, E2)

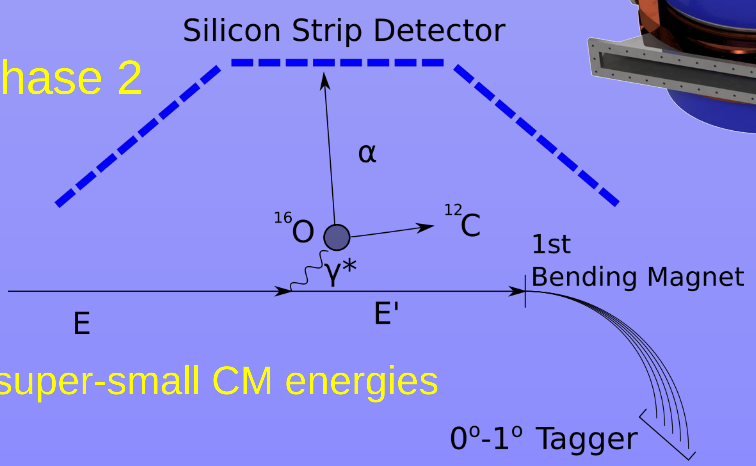


● Phase 1



small CM energies

● Phase 2



super-small CM energies

Study of reaction cross sections of astrophysical interest - key reactions

use the **time-reversed technique**
to measure cross-sections of various
radiative alpha, proton, and
neutron capture reactions

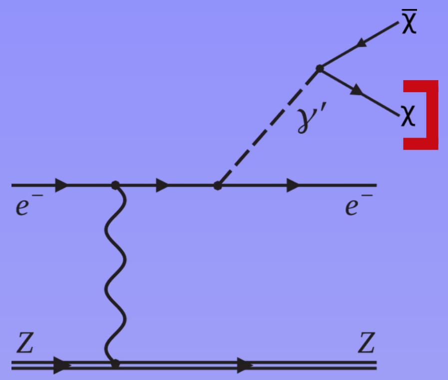
$^{12}C\,(\alpha,\gamma)^{16}O$	C/O - ratio (*holy grail of astroparticle physics*)
$^{24}Mg(\alpha,\gamma)\,^{28}Si$	significant within silicon-burning phase in late evolution
$^{24}Mg(\gamma,\alpha)^{20}Ne$	of massive stars prior to core collapse
$^{15}N(p,\gamma)^{16}O$	key process in CNO cycle; benchmark reaction
$d(p,\gamma)^{3}He$	rate of deuterium burning, primordial deuterium abundance
$^{86}Rb(n,\gamma)^{87}Rb$	^{86}Rb: branching point in the s-process within massive AGB stars
$^{204}Tl(n,\gamma)^{205}Tl$	^{204}Tl: branching point in the s-process

*"versatile and flexible
electron scattering experiment"*

Physics at MAGIX:
Dark sector searches

Dark sector searches at MAGIX

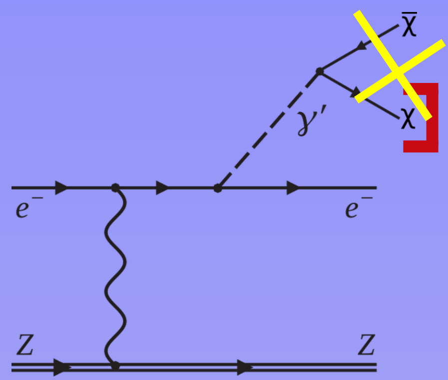
Search for Light Dark Matter



few events / very few SM background contributions

Dark sector searches at MAGIX

Search for Light Dark Matter



few events / very few SM background contributions

DP **cannot decay to LDM particles** if mass of DM is too large.
May decay to lepton pairs (here: e+e-).

Dark sector searches at MAGIX

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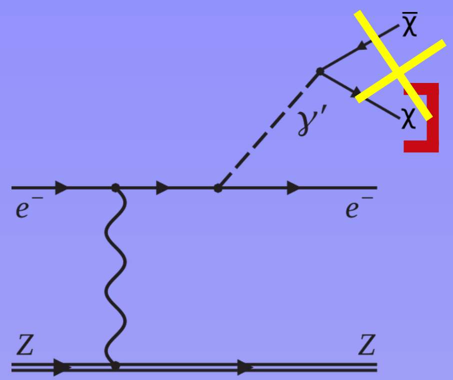

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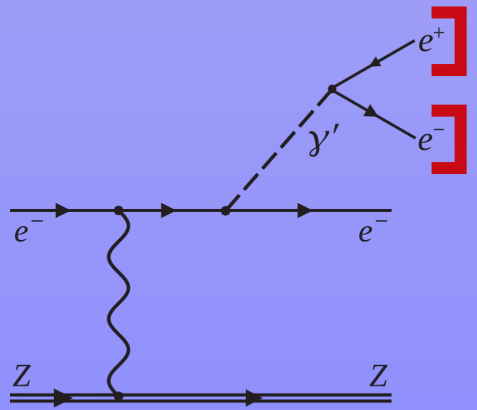
Complementary investigations:

Search for Dark Photons



visible decay

look for DP decay to SM particles

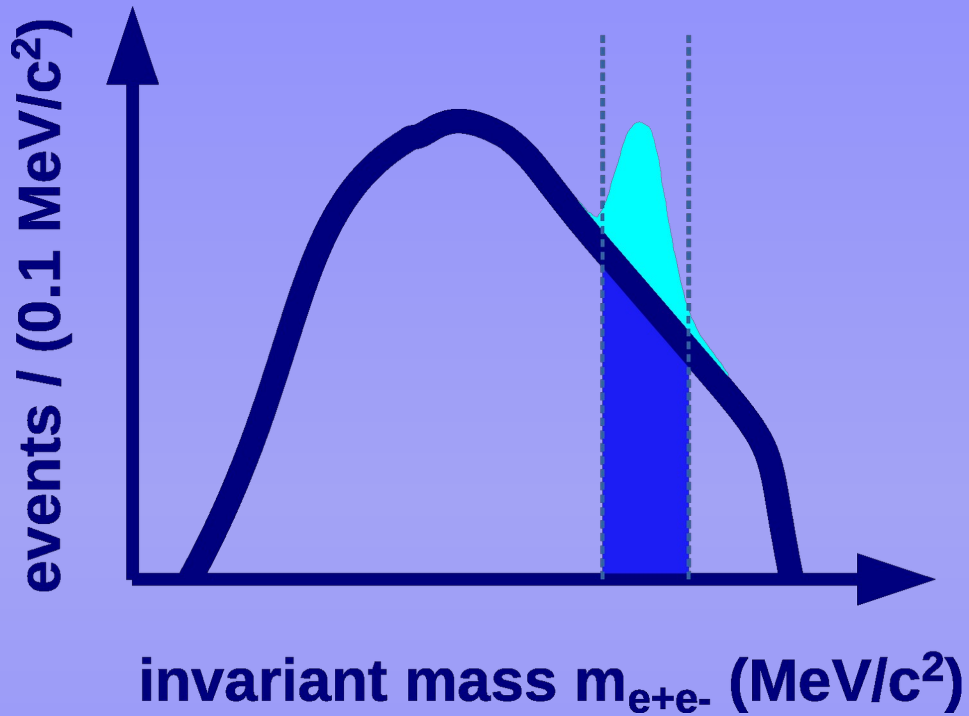
two free parameters (kinetic mixing model):

- $m_{\gamma'}$: mass of the dark photon
- ϵ: mixing parameter

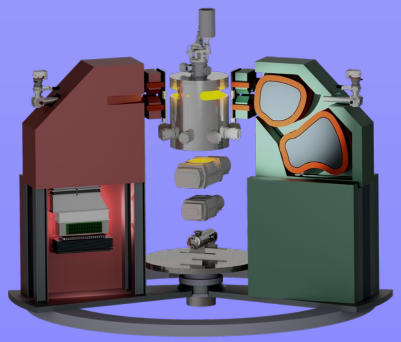
parameterizes strength of the coupling of DP to ordinary SM matter: $\epsilon^2 = \alpha'/\alpha$
(α the QED fine structure constant)

few events / significant SM background contributions

Dark Photon - Visible Decay



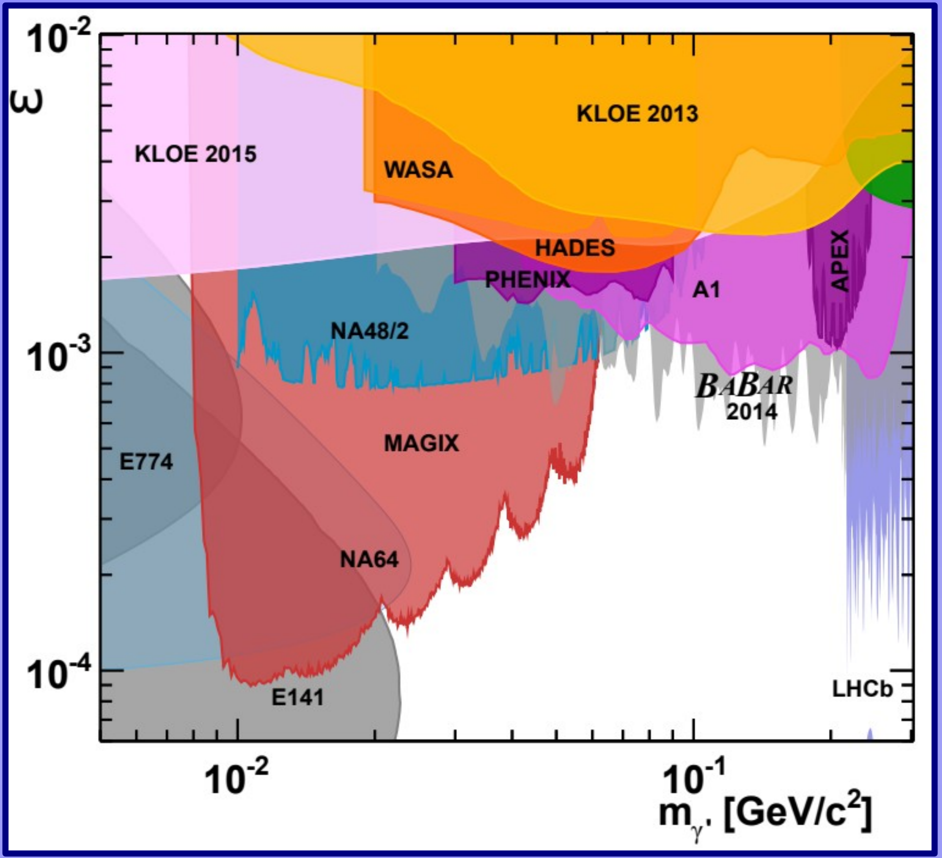
$$m_{\gamma'} = m_{e^+e^-} = \sqrt{(p_{e^+} + p_{e^-})^2}$$



BUMP HUNT

A **sharp peak** (limited by resolution) in the measured invariant mass spectrum, sitting **on a large but smooth background** dominated by irreducible QED background and accidental coincidences.

Dark Photon - Visible Decay: Expected sensitivity



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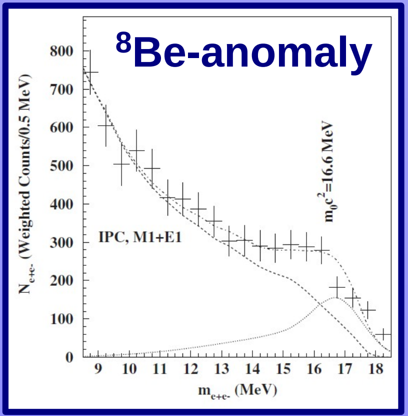
Competitive sensitivity in an interesting parameter range

e.g., **X17 particle**:
signal anomaly in excited ^{8}Be, ^{4}He, and ^{12}C atomic transitions
⇒ vector boson candidate with mass around 17 MeV, ε^2 ~ 10^{-7}



^{8}Be: A.J. Krasznahorkay *et al.*, Phys. Rev. Lett. 116 (2016) 042501
^{4}He: A.J. Krasznahorkay *et al.*, arXiv:1910.10459v1 (2019) [nucl-ex]
^{12}C: A.J. Krasznahorkay *et al.*, Phys. Rev. C 106 (2022) L061601

Great Competition

4 scenarios

We are the first to find it there

Spectacular!

4 scenarios

We are the first to find it there

Spectacular!

We are not the first to find it there

Verify the discovery, study the reaction mechanism, ...

4 scenarios

We are the first to find it there
Spectacular!

We are not the first to find it there
Verify the discovery, study the reaction mechanism, ...

We are the first to not find it there
At least we were the first!

4 scenarios

We are the first to find it there

Spectacular!

We are not the first to find it there

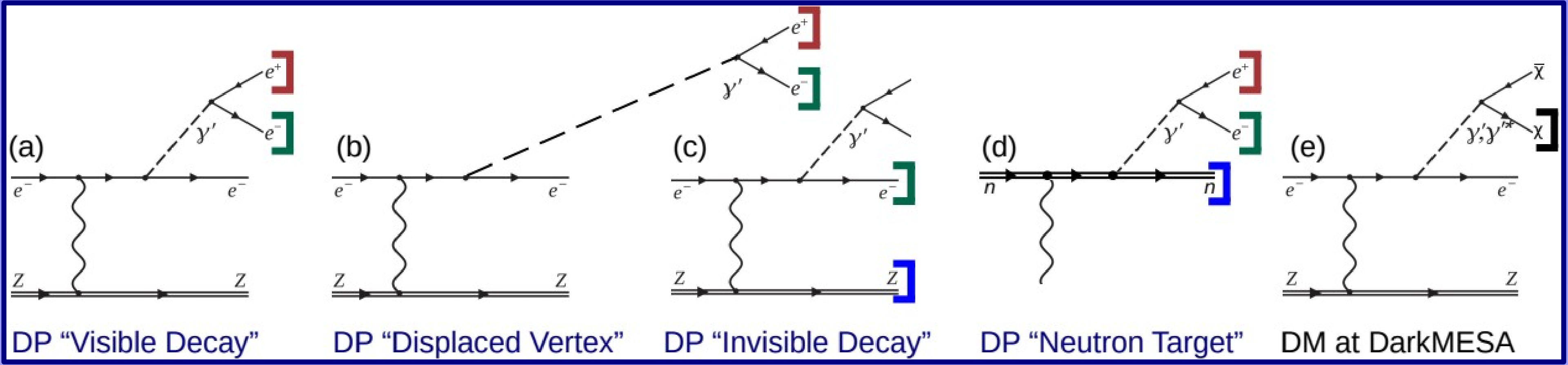
Verify the discovery, study the reaction mechanism, ...

We are the first to not find it there

At least we were the first!

We are not the first to not find it

Different search strategies



(a) just discussed

(b) small coupling or mass
→ long-lived dark photon
→ displaced vertex
move target outside spectrometer acceptance → increase S/N ratio

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

(c) missing mass of electron+nucleus:
DP detection independent of favorite decay channel (e.g. $\bar{\chi}\chi$)

(d) recent studies: enhanced sensitivity on a *neutron target*
(motivated by 'X17 couplings')
C. J. G. Mommers and M. Vanderhaeghen, arXiv:2307.02181 [hep-ph]

(e) complemented by DarkMESA's direct DM search

SUMMARY

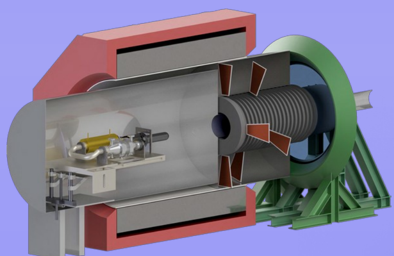
MESA – Electron Energy Recovery Linac

- up to 105 MeV and ≥ 1000 μA (ERL)
- up to 155 MeV and 150 μA (EB)

Exciting experimental program in nuclear, hadron and particle physics

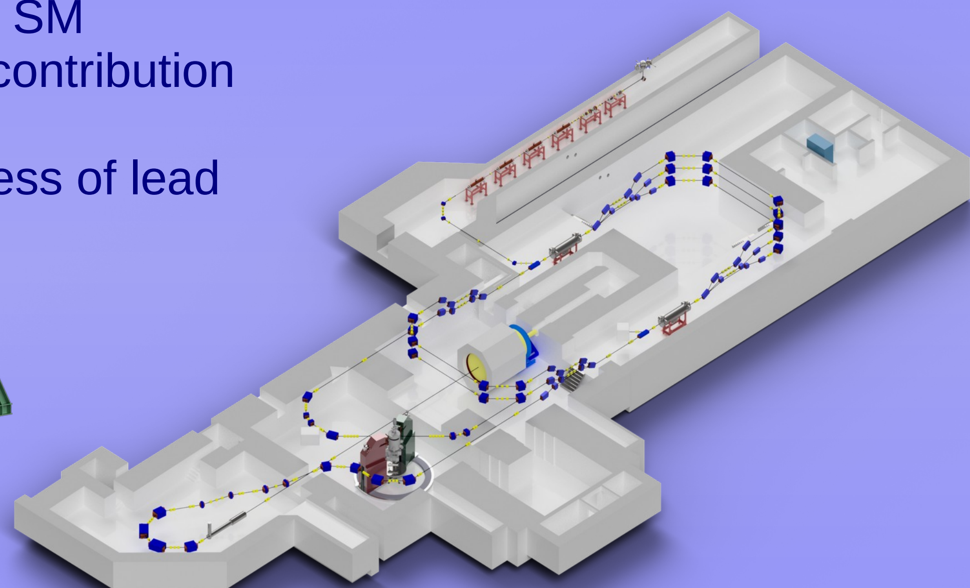
P2 – Parity Violation Experiments

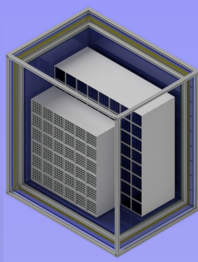
- prec. meas. of $\sin^2\theta_W$ / search for physics beyond the SM
- axial FF + strange contribution to magnetic FF
- neutron skin thickness of lead

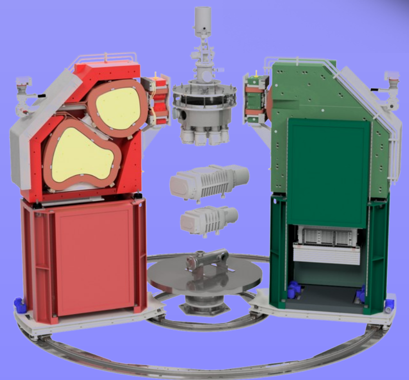


DarkMESA – Beam Dump Experiment

- quest for dark matter and other exotic particles







MAGIX – Versatile Electron Scattering Experiment

- Structure of Nucleons and Nuclei
- Few-Body Systems
- Nuclear Astrophysics
- Dark Sector Searches

First experiments Q1/2025

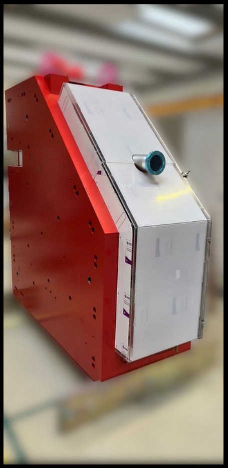
https://www.mesa.uni-mainz.de

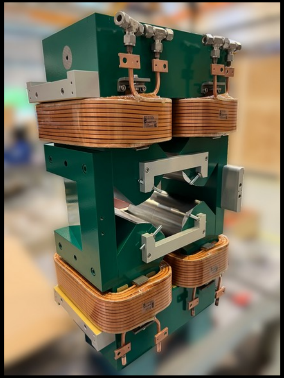
https://www.blogs.uni-mainz.de/fb08p2

https://magix.uni-mainz.de

schlimme@uni-mainz.de

https://magix.uni-mainz.de as well :)





RECENT IMPRESSIONS