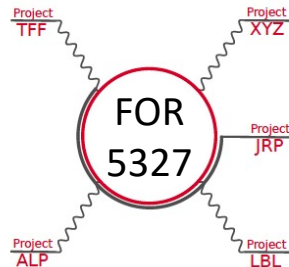




Achim Denig
Institute of Nuclear Physics, JGU Mainz



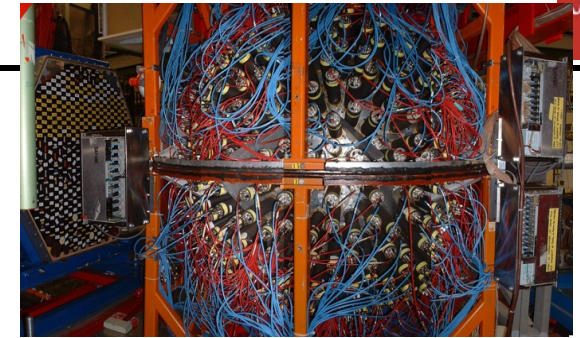
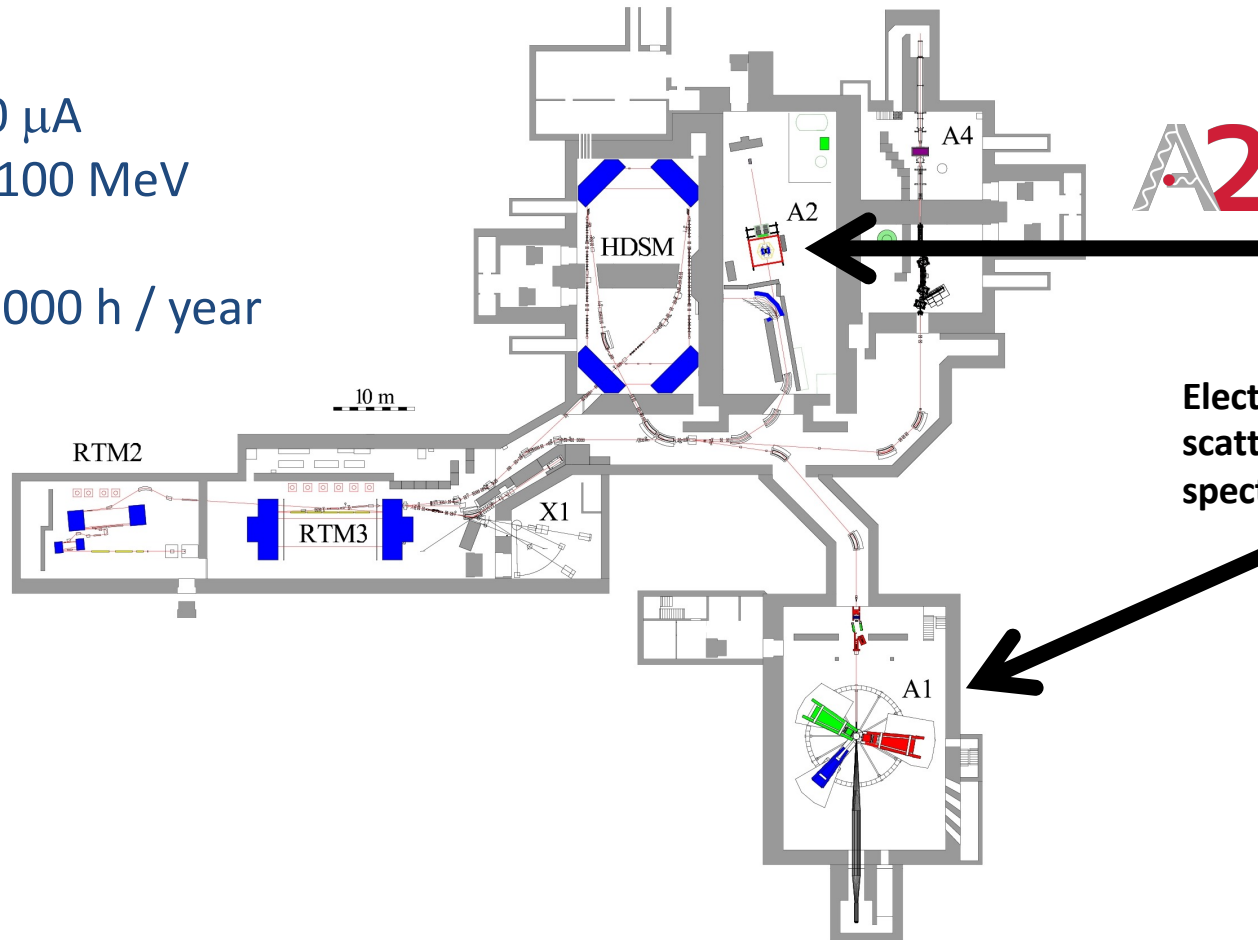
The Mainz Energy-Recovering Superconducting Accelerator MESA - an Overview



The Mainz Microtron MAMI

Electron Accelerator E = 0.185 GeV - 1.6 GeV (CW – 2.45 GHz)
operated at JGU Mainz
Hallmarks

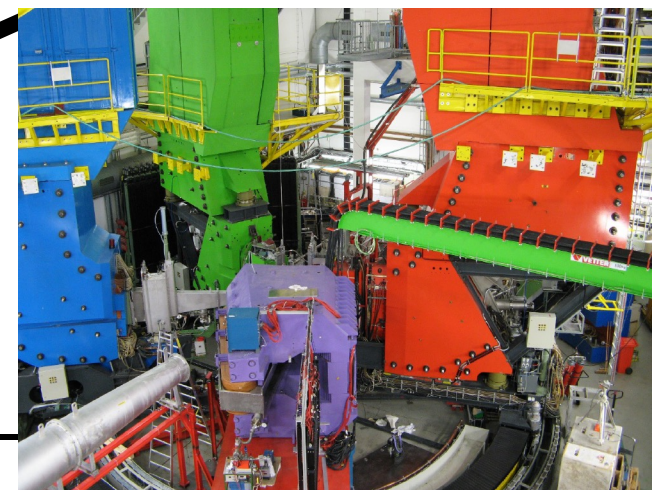
- Intensity max. 100 μA
- Resolution $\sigma_E < 0.100 \text{ MeV}$
- Polarization 85%
- Reliability: up to 7000 h / year



Photon scattering (A2 hall)
 (Crystal Ball / TAPS calorimeters; Polarized frozen-spin target → currently at Univ. Bonn)



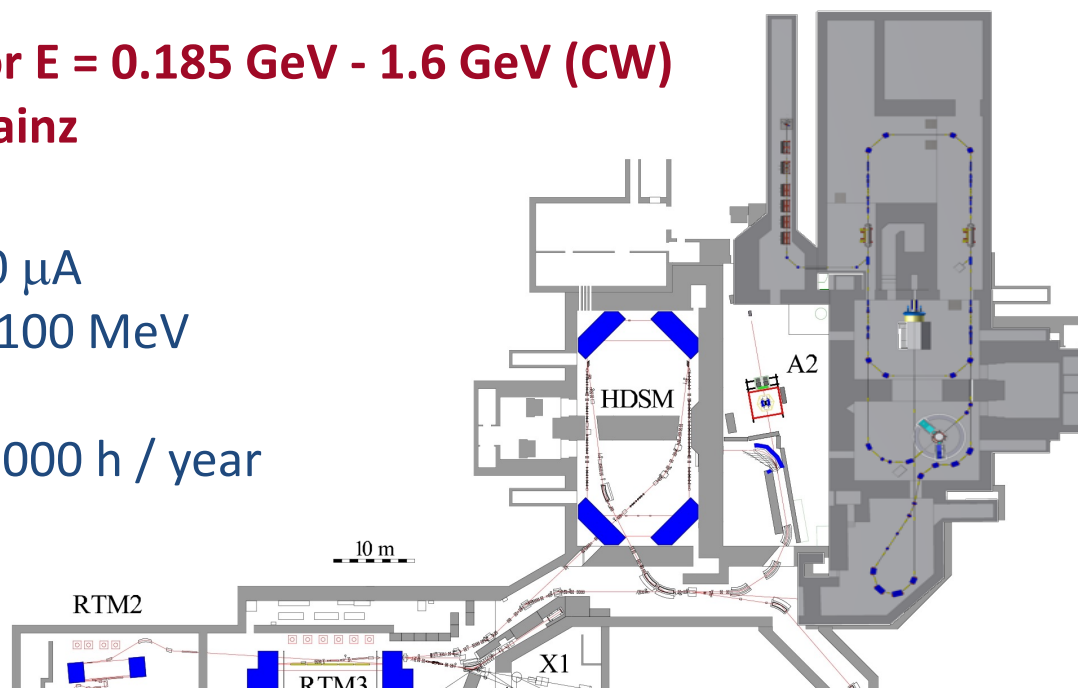
Electron scattering (high resolution spectrometer setup)



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- Reliability: up to 7000 h / year



**New MESA accelerator:
 Beam energies below MAMI energy range !
 Increase of intensities by factor of 10 !
 MESA is an intensity frontier facility**



Oct. 2020



Oct. 2023

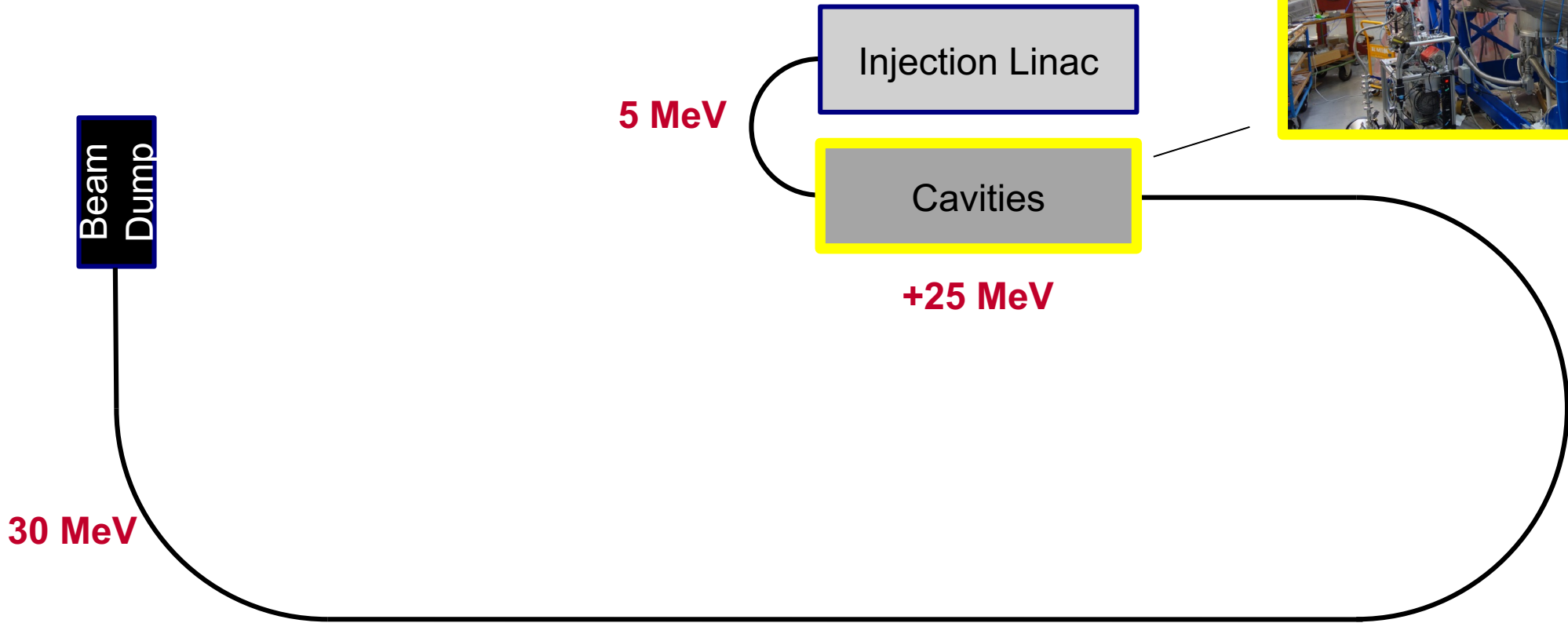
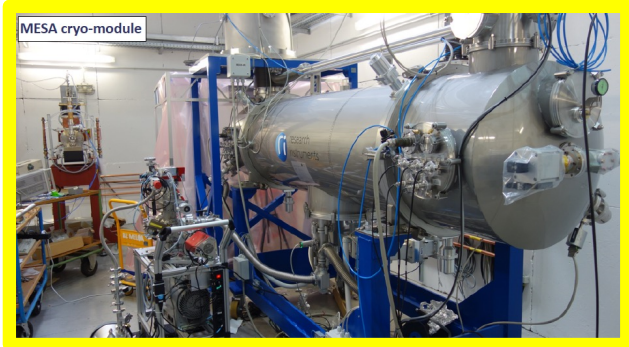
**New experimental hall
 MAMI and MESA
 11m under ground**



Mainz Energy-Recovering Superconducting Accelerator (MESA)

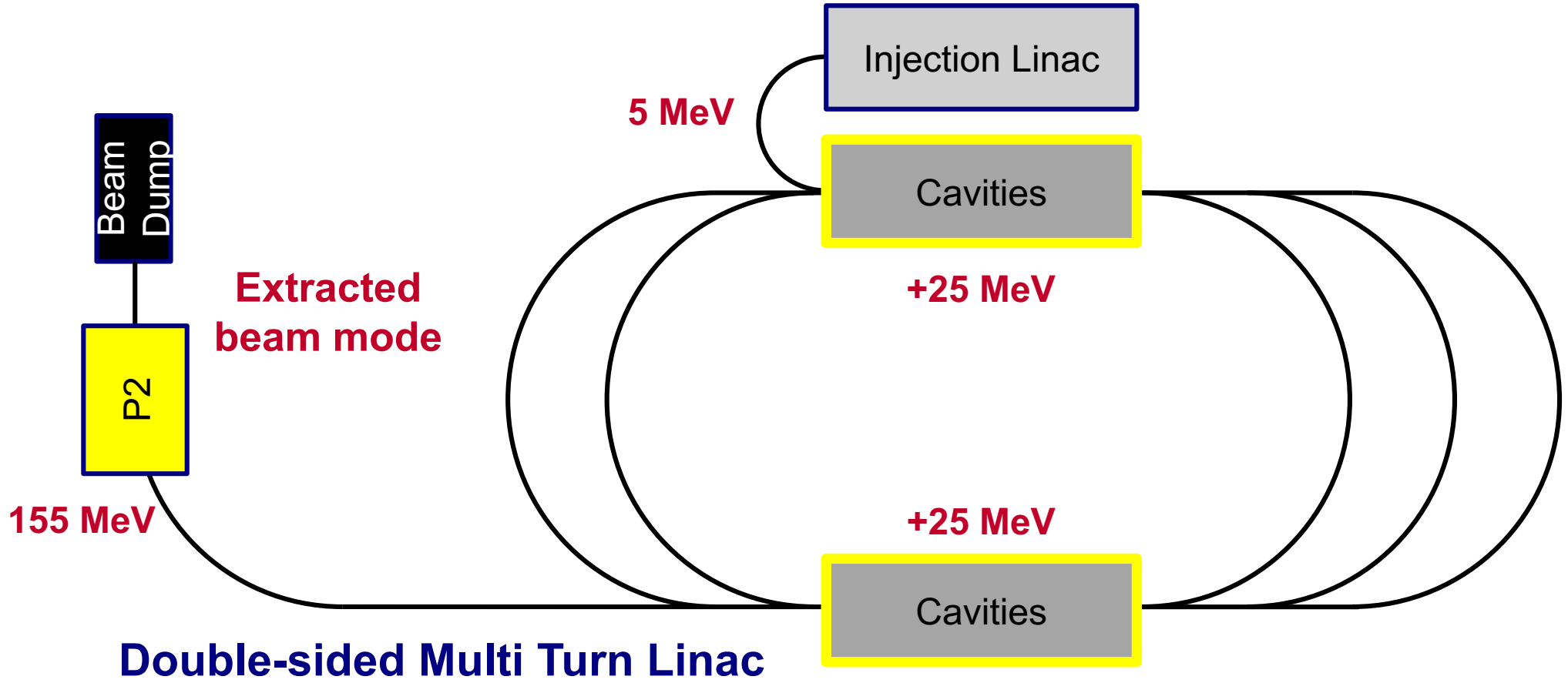
Extracted Beam Mode
beam currents $\sim 150 \mu\text{A}$

Superconducting TESLA-like cavities



Mainz Energy-Recovering Superconducting Accelerator (MESA)

Extracted Beam Mode
beam currents ~ 150 μA

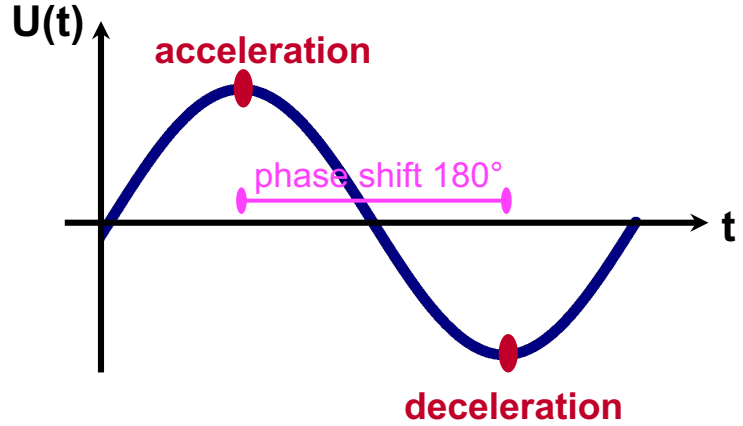
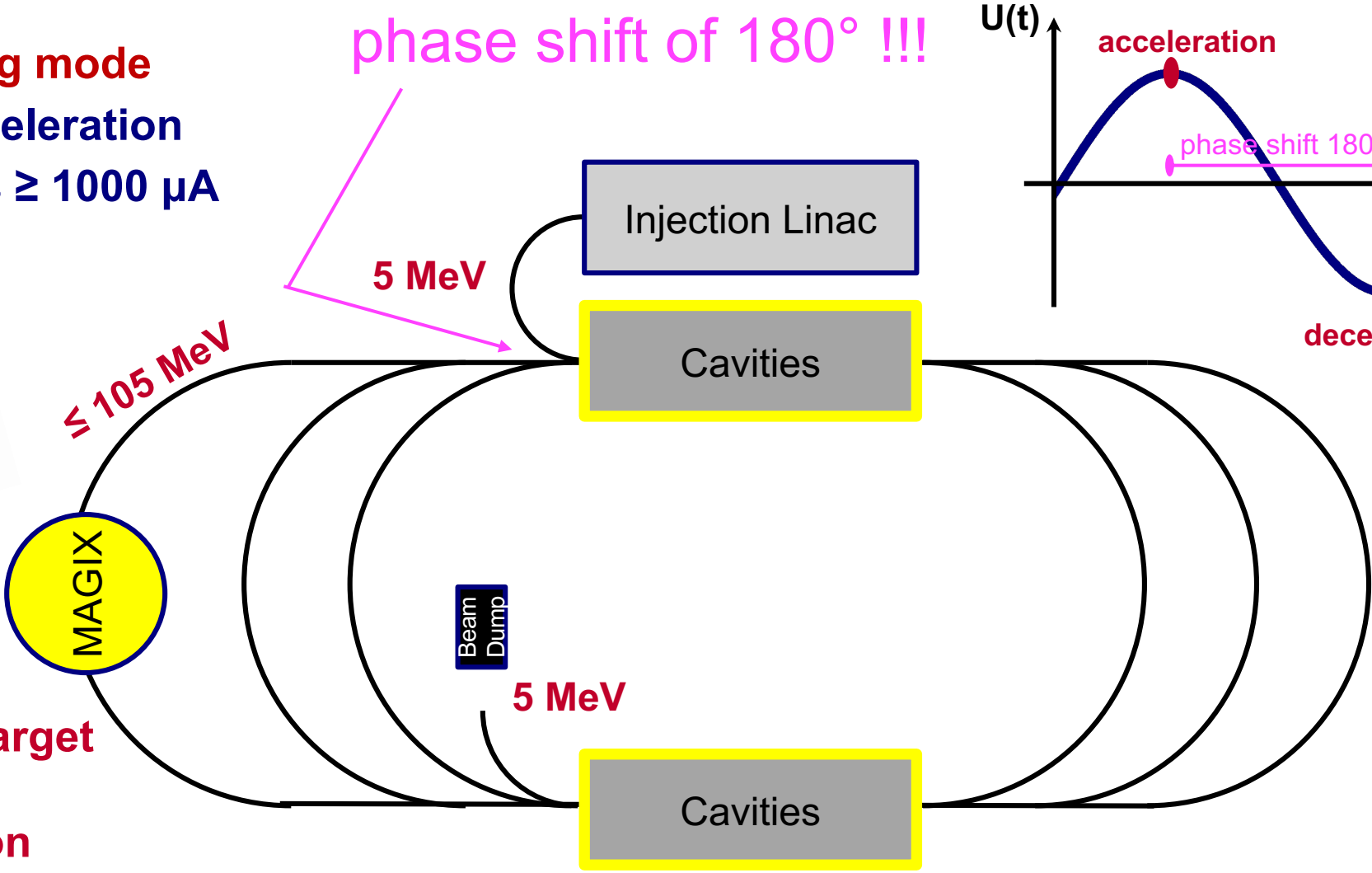


Mainz Energy-Recovering Superconducting Accelerator (MESA)

Energy-Recovering mode
energy-efficient acceleration
▶ high beam currents $\geq 1000 \mu\text{A}$

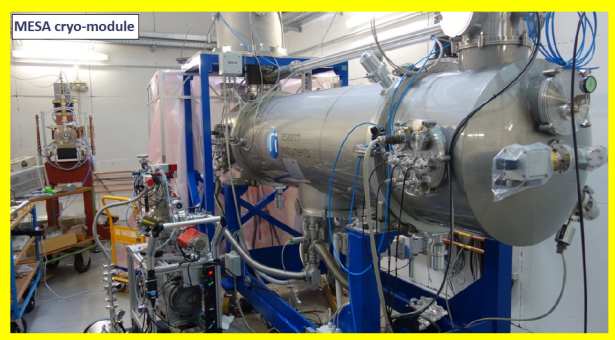


**thin internal MAGIX target
to allow
for ERL recollection**

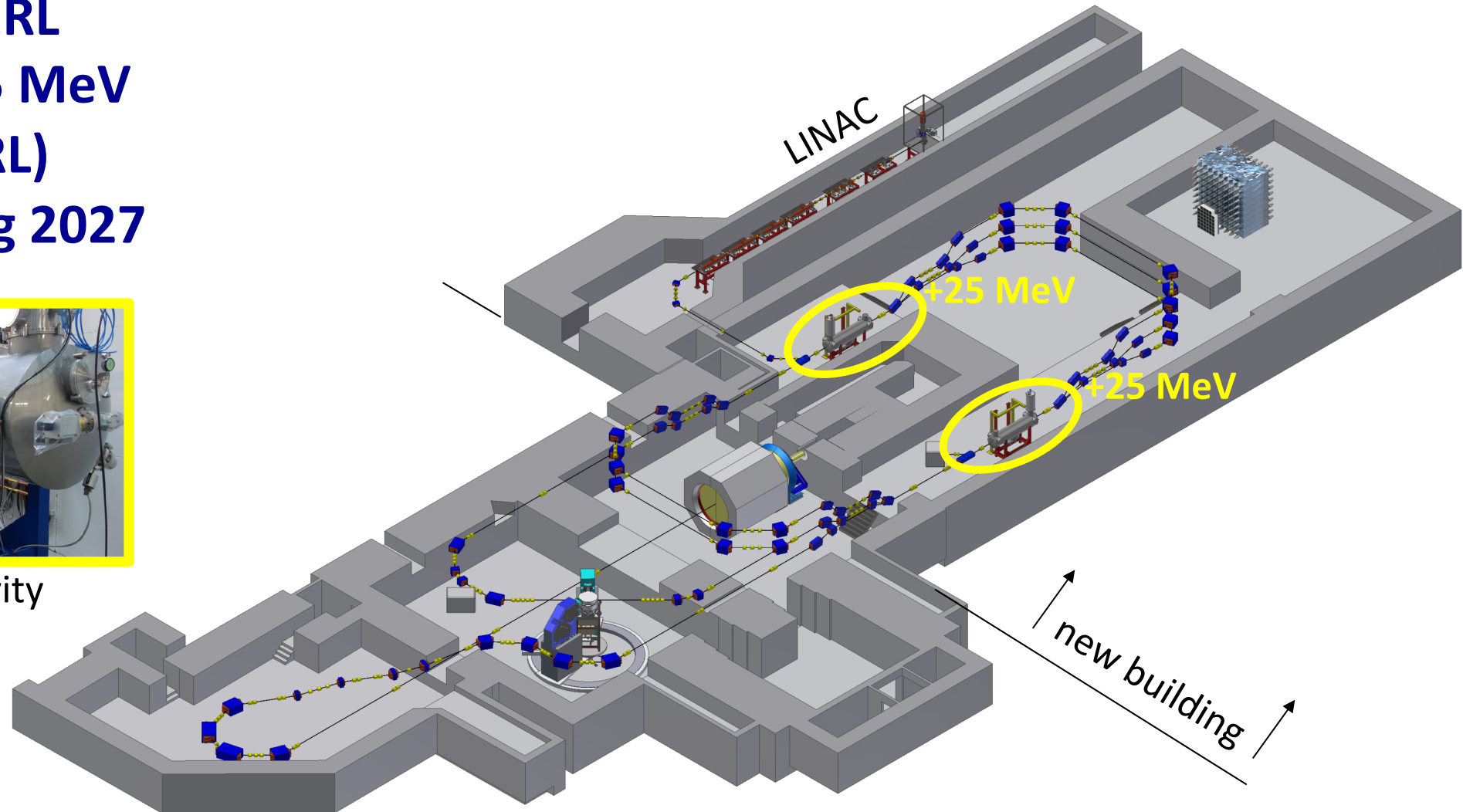


Mainz Energy-Recovering Superconducting Accelerator (MESA)

Superconducting technology
Recirculating ERL
 $E_{\text{max}} = 105/155 \text{ MeV}$
 $I_{\text{max}} > 1 \text{ mA (ERL)}$
Commissioning 2027

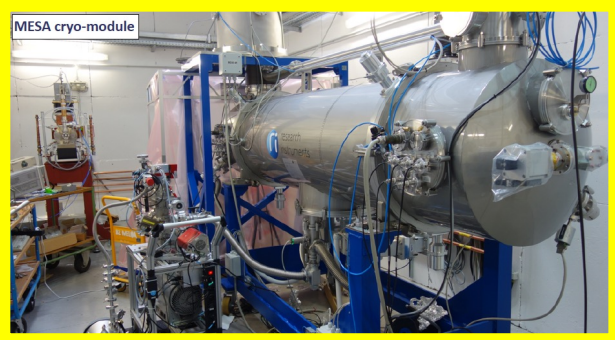


Superconducting cavity

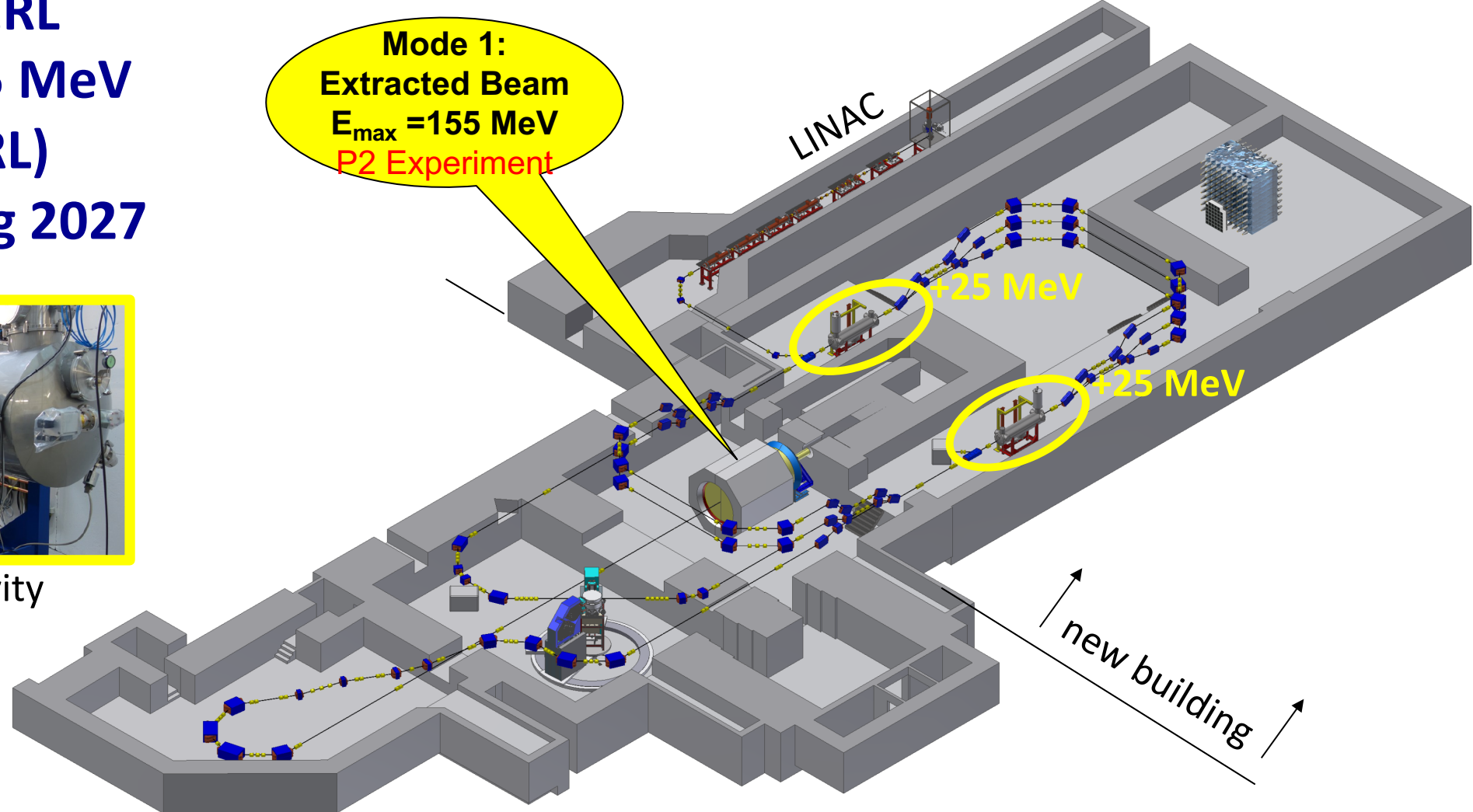


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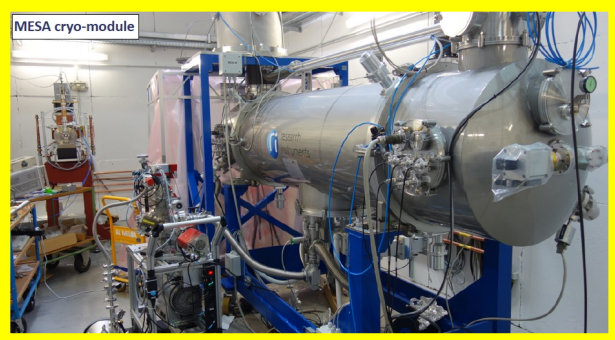


Superconducting cavity

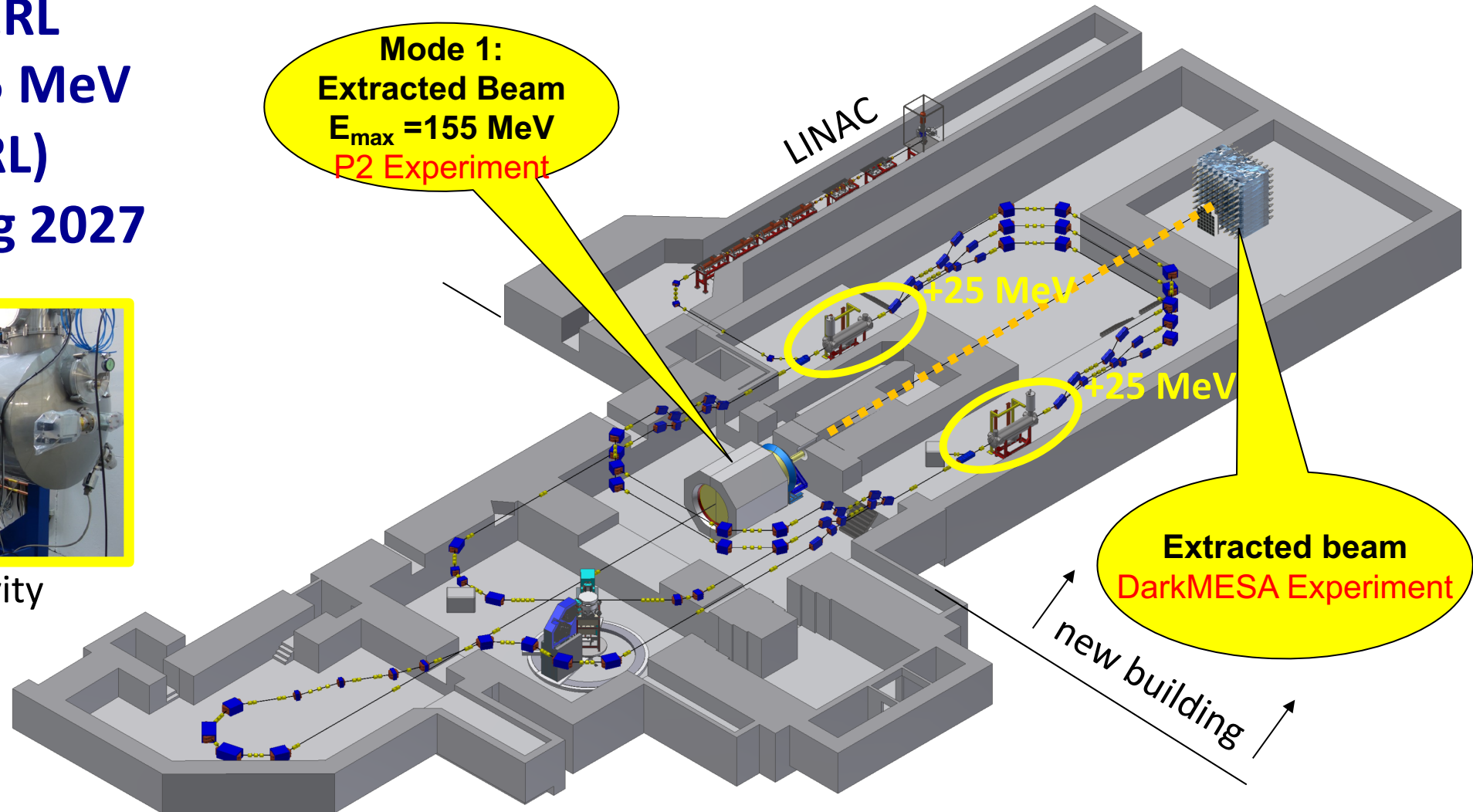


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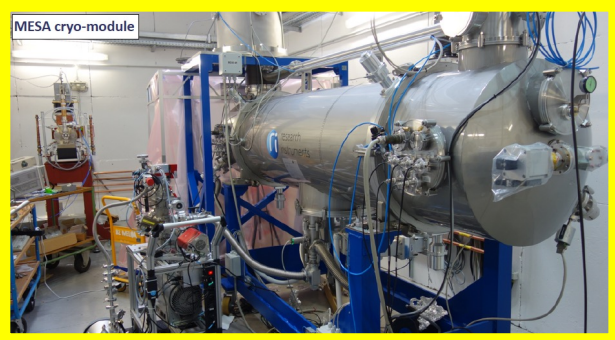
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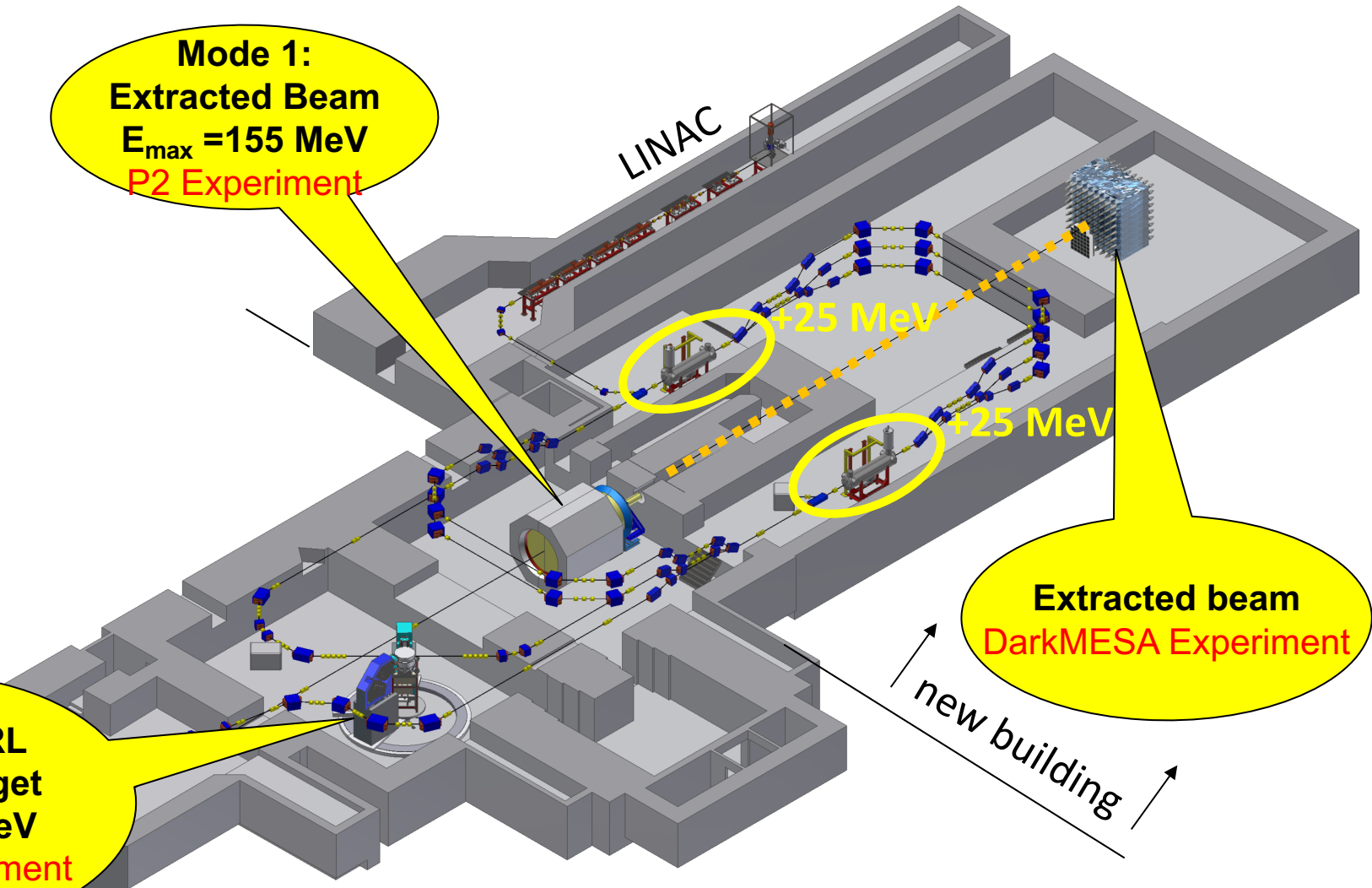
Commissioning 2027



Superconducting cavity

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

Mode 2: ERL
Internal Target
 $E_{\text{max}} = 105 \text{ MeV}$
MAGIX Experiment



Extracted beam
DarkMESA Experiment

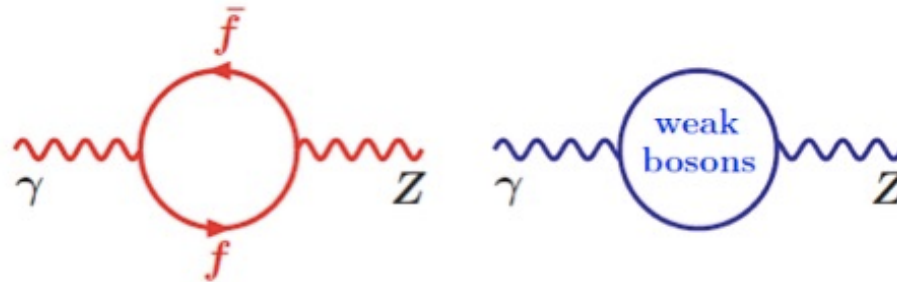
P2
 $\sin^2 \theta_w$

P2 Experiment

MESA Extracted Beam Mode

Measurement of: $\sin^2 \Theta_W = (e/g)^2 = 1 - (M_W/M_Z)^2$

Rad. corrections strongly correlated with quarks, W-Bosons, Higgs, ...

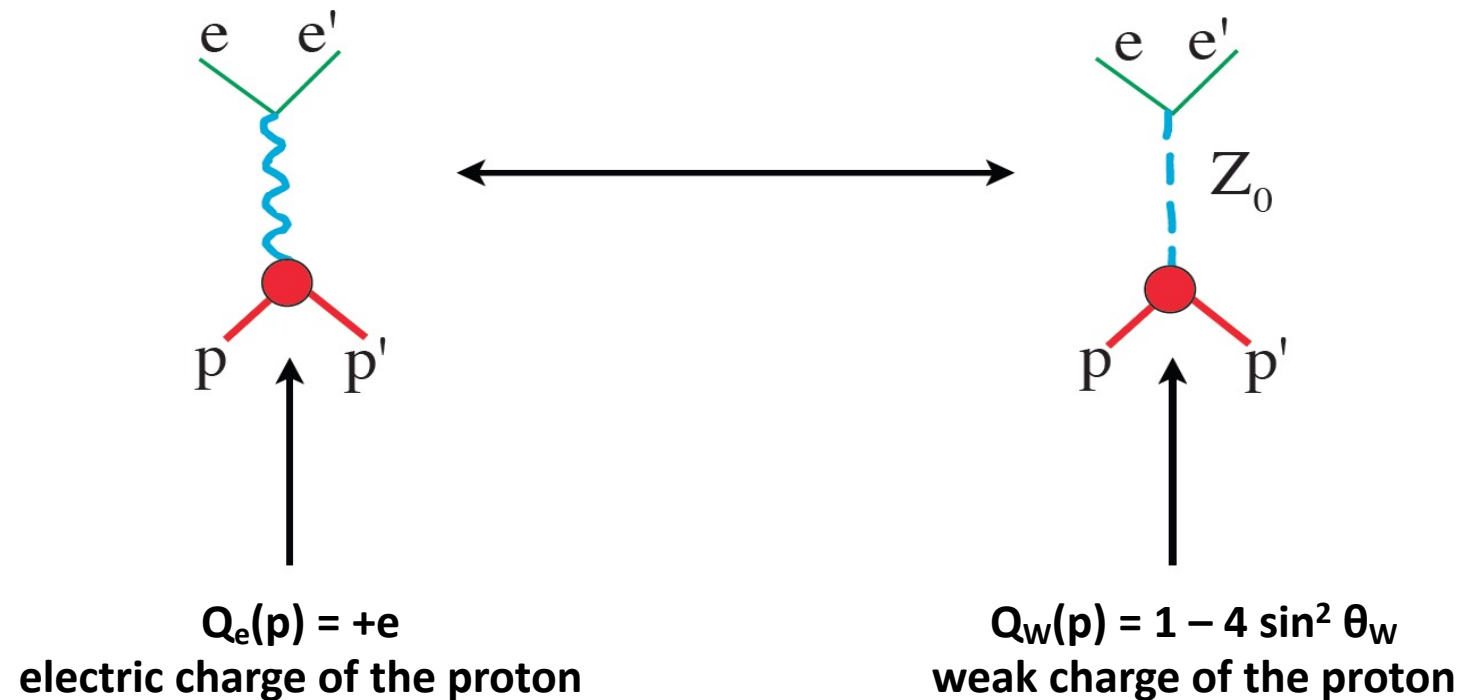


Leads to running (Q^2 dependence) of $\sin^2 \Theta_W \rightarrow$ Precision test of SM

Measurement of the Weak Charge of the Proton

Scattering of longitudinally polarized electrons on unpolarized protons

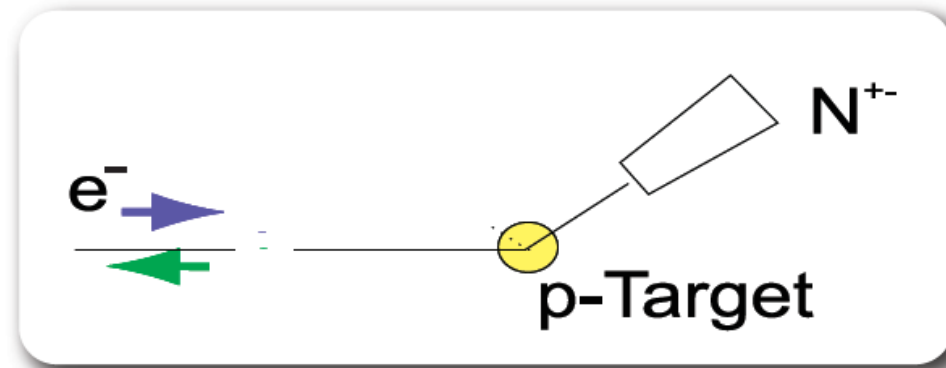
- Z boson exchange in electron-proton scattering introduces **parity-violating effect**
- Measure **parity-violating Left-Right cross section asymmetry A_{LR}**



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- Measure **parity-violating Left-Right cross section asymmetry** A_{LR}

$$A_{LR} = \frac{\sigma(e \uparrow) - \sigma(e \downarrow)}{\sigma(e \uparrow) + \sigma(e \downarrow)} = -\frac{G_F Q^2}{4\sqrt{2}\pi\alpha} (Q_W - F(Q^2))$$

weak charge of proton (pointing to Q_W)
hadron structure (pointing to $F(Q^2)$)

$$Q_W = 1 - 4\sin^2\theta_W(Q^2)$$

Measurement of the Weak Charge of the Proton

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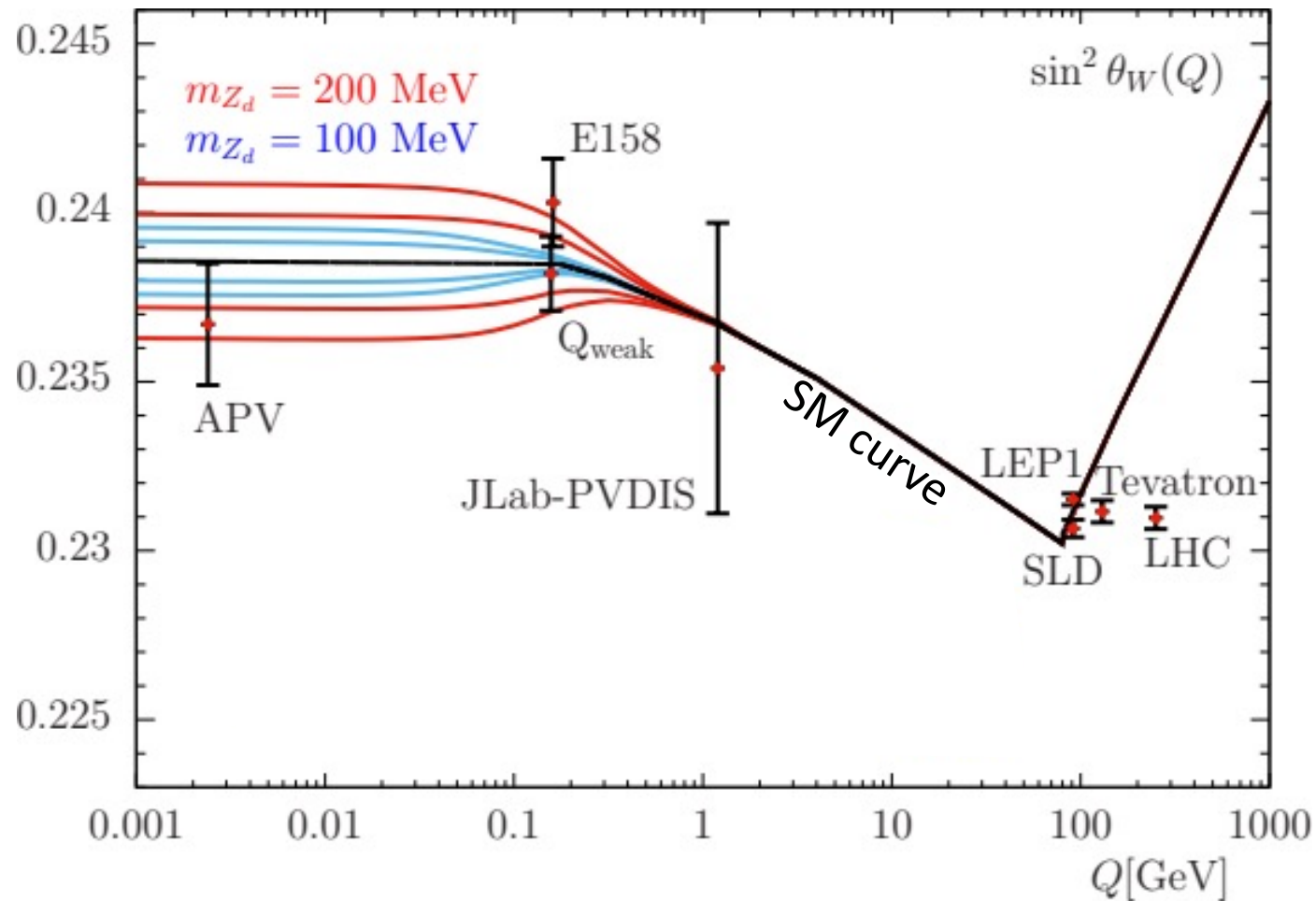
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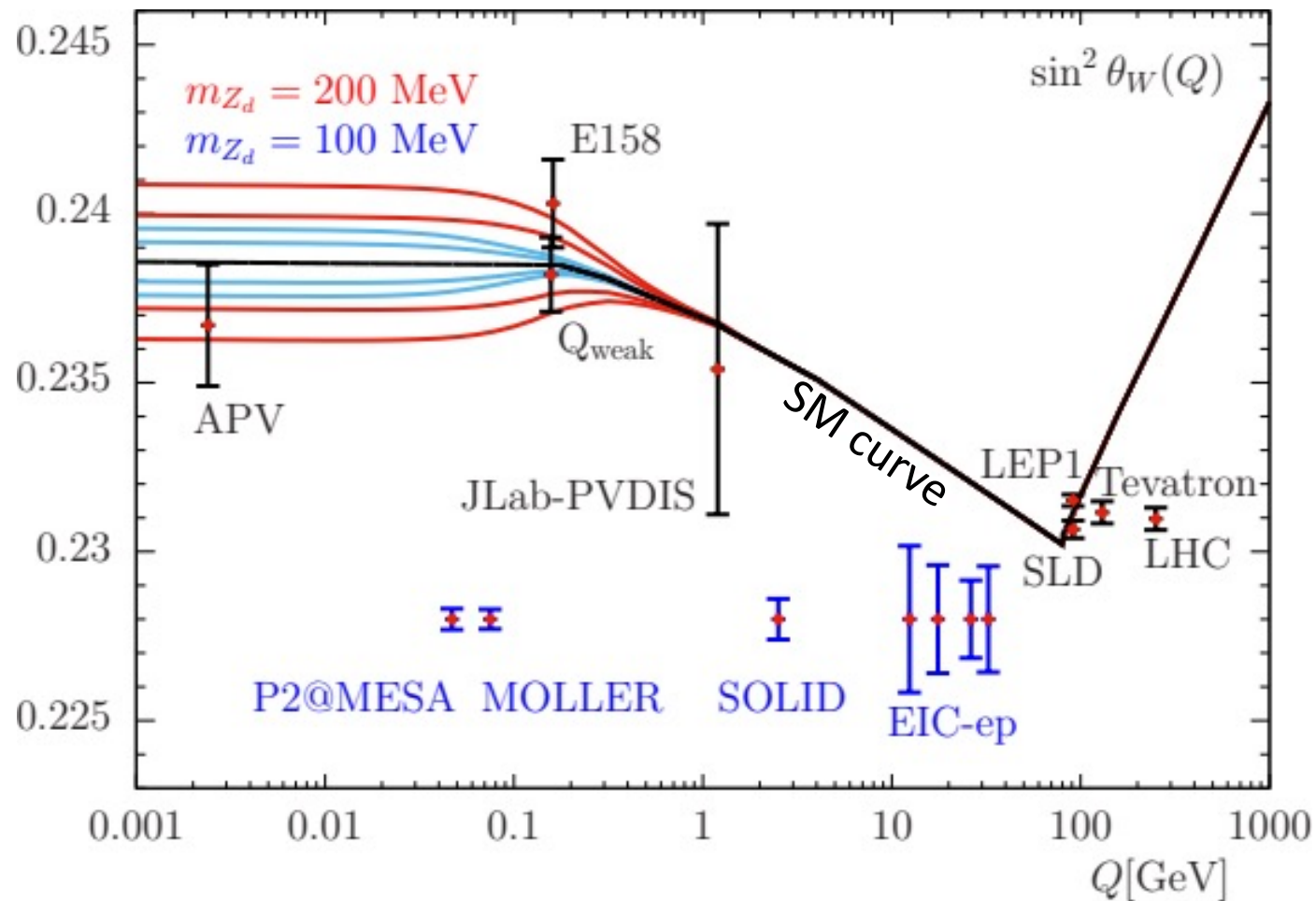
P2@MESA goal:

**Measure parity-violating Left-Right asymmetry A_{LR}
of 20×10^{-9} with 2.4% precision → 0.16% error on $\sin^2\theta_W$**

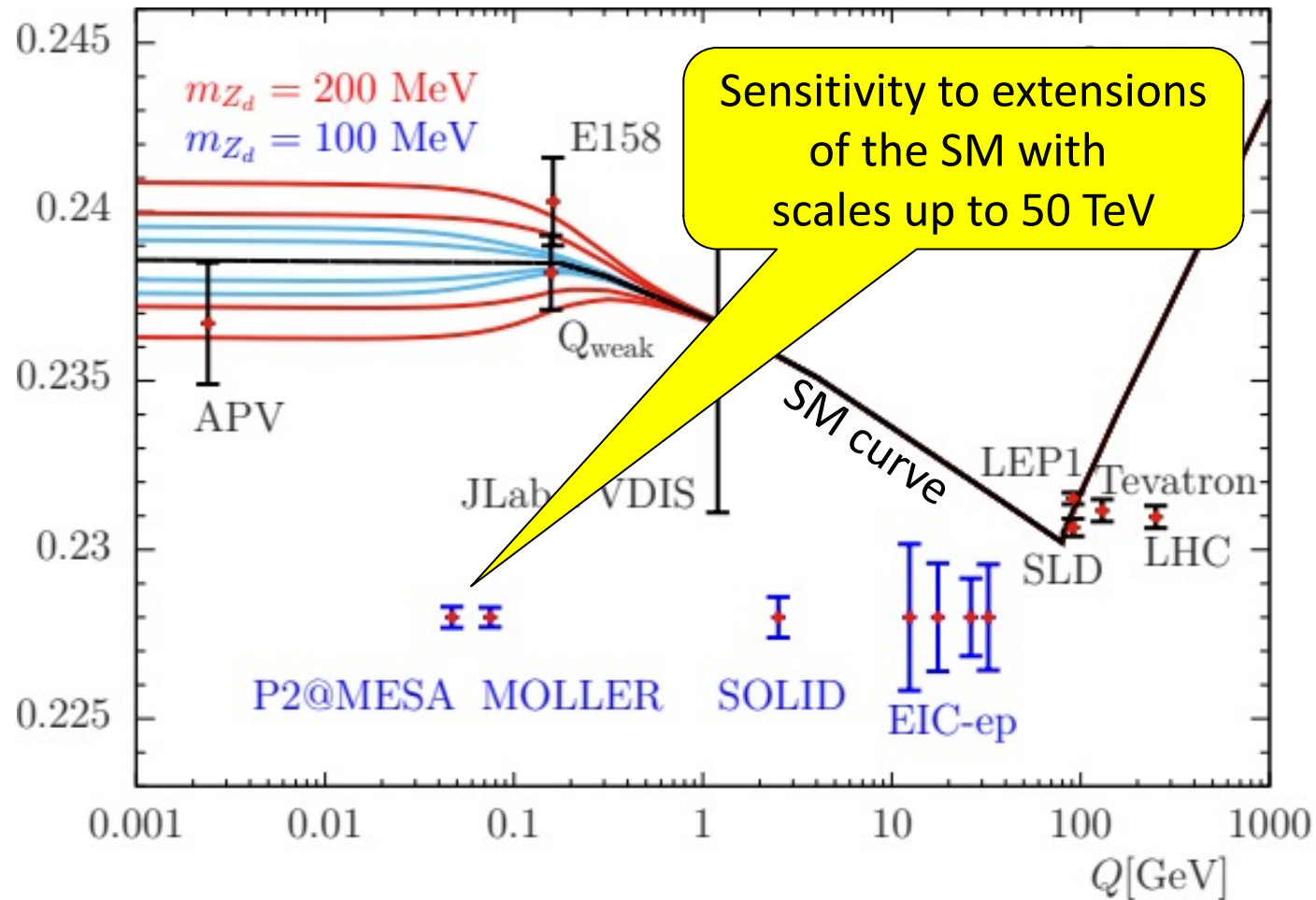
A Low- Q^2 Measurement of $\sin^2\theta_W$ at MESA



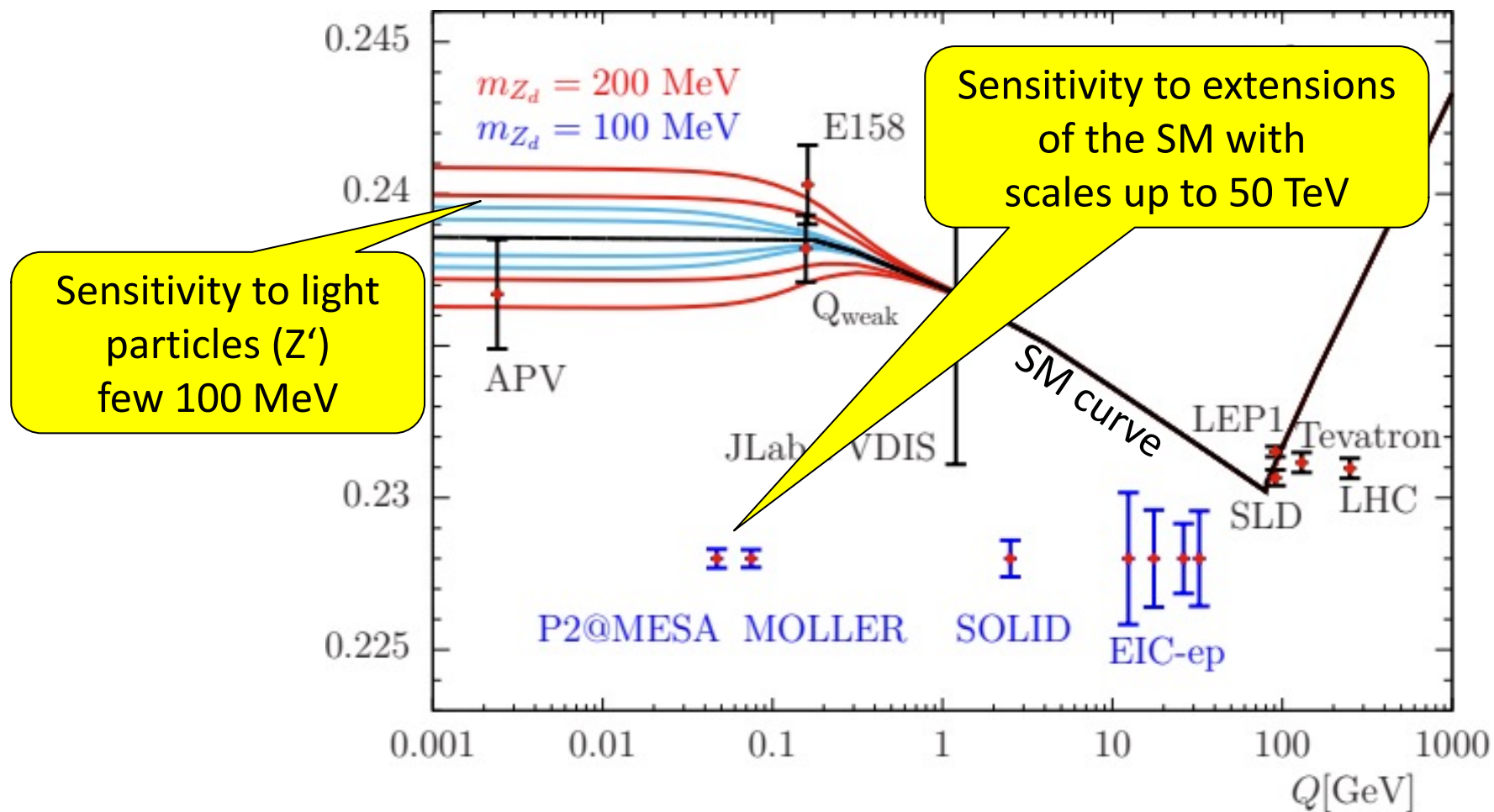
A Low- Q^2 Measurement of $\sin^2\theta_W$ at MESA



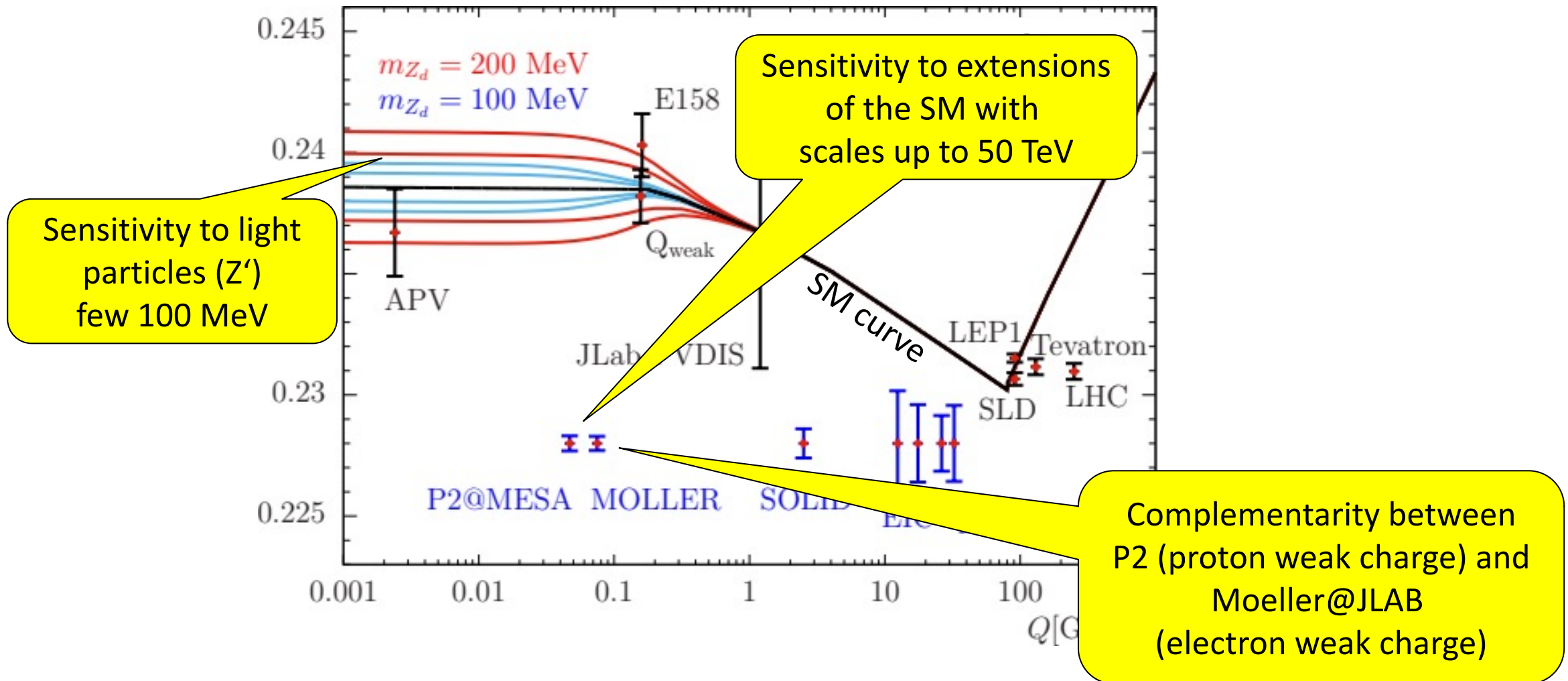
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A Low- Q^2 Measurement of $\sin^2\theta_W$ at MESA



A Low- Q^2 Measurement of $\sin^2\theta_W$ at MESA

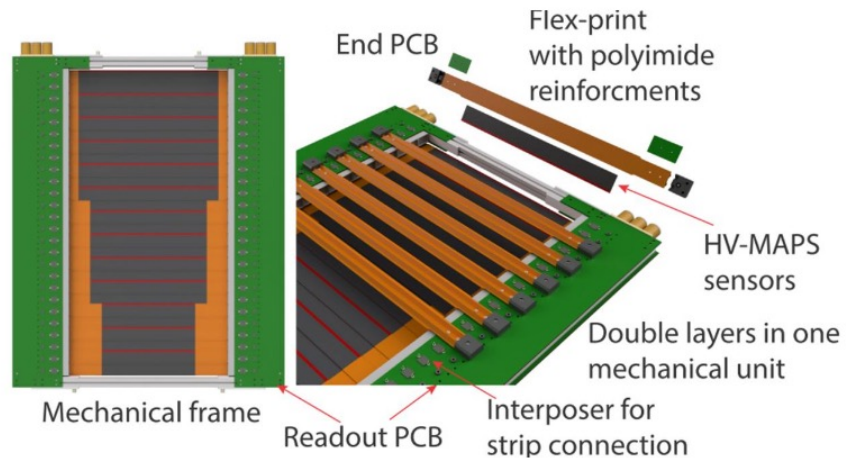


Impressions from the P2 Assembly

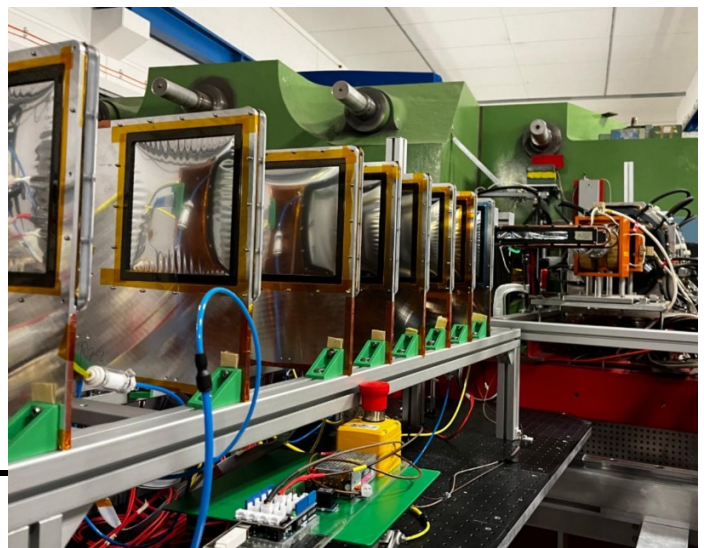
Arrival of the P2 superconducting magnet (11/24)



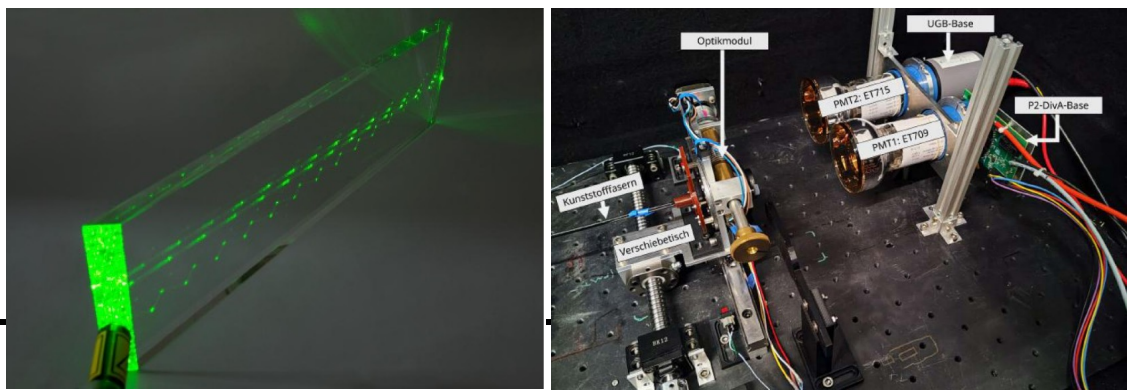
Forward tracker based on HV-MAPS technology



Backward tracker based on MicroMegas



Quartz bars and PMTs characterized



Physics Program of P2 Experiment

Hydrogen

Measurement of parity-violating A_{LR} and **extraction of proton weak charge** → Improvement QWEAK x 3

$$A_{LR} = \frac{\sigma(e \uparrow) - \sigma(e \downarrow)}{\sigma(e \uparrow) + \sigma(e \downarrow)} \propto (1 - 4 \sin^2 \theta_W)$$

^{12}C

Measurement of parity-violating A_{LR} and **extraction of ^{12}C weak charge** → First precision measurement

$$A_{LR} \propto -24 \cdot \sin^2 \theta_W$$

complementary to hydrogen measurement in BSM reach

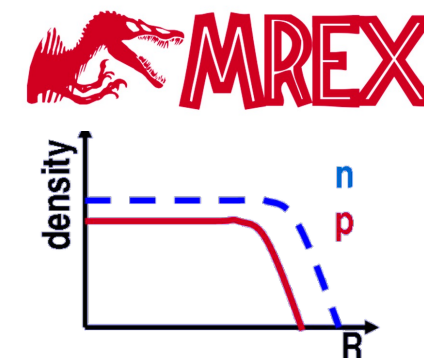
Pb

Measurement of parity-violating A_{LR} and **extraction of weak form factor**

- sensitive to neutron skin thickness
 - related to the Equation of State (EOS)
 - relation to neutron star density
- Improvement upon PREX x 2

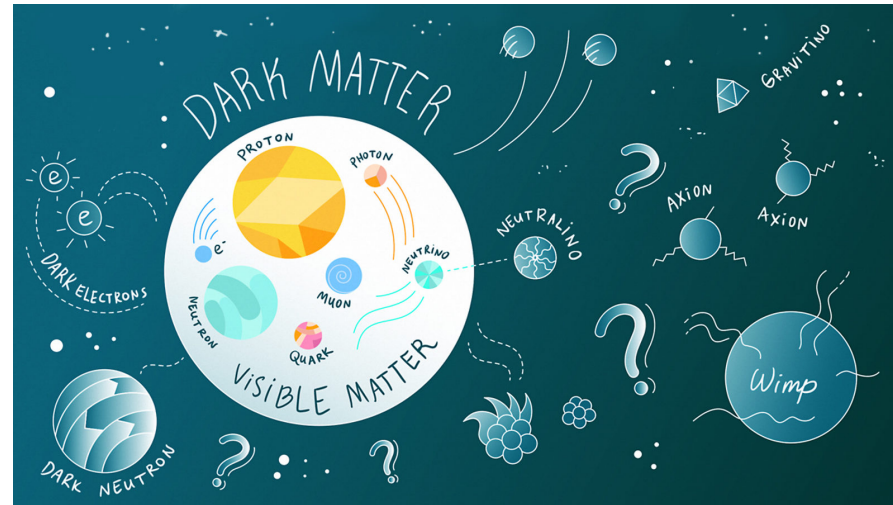
$$A_{LR} \propto \frac{F_{\text{weak}}(Q^2)}{F_{\text{charge}}(Q^2)}$$

dominated by neutrons
 dominated by protons



DarkMESA Experiment

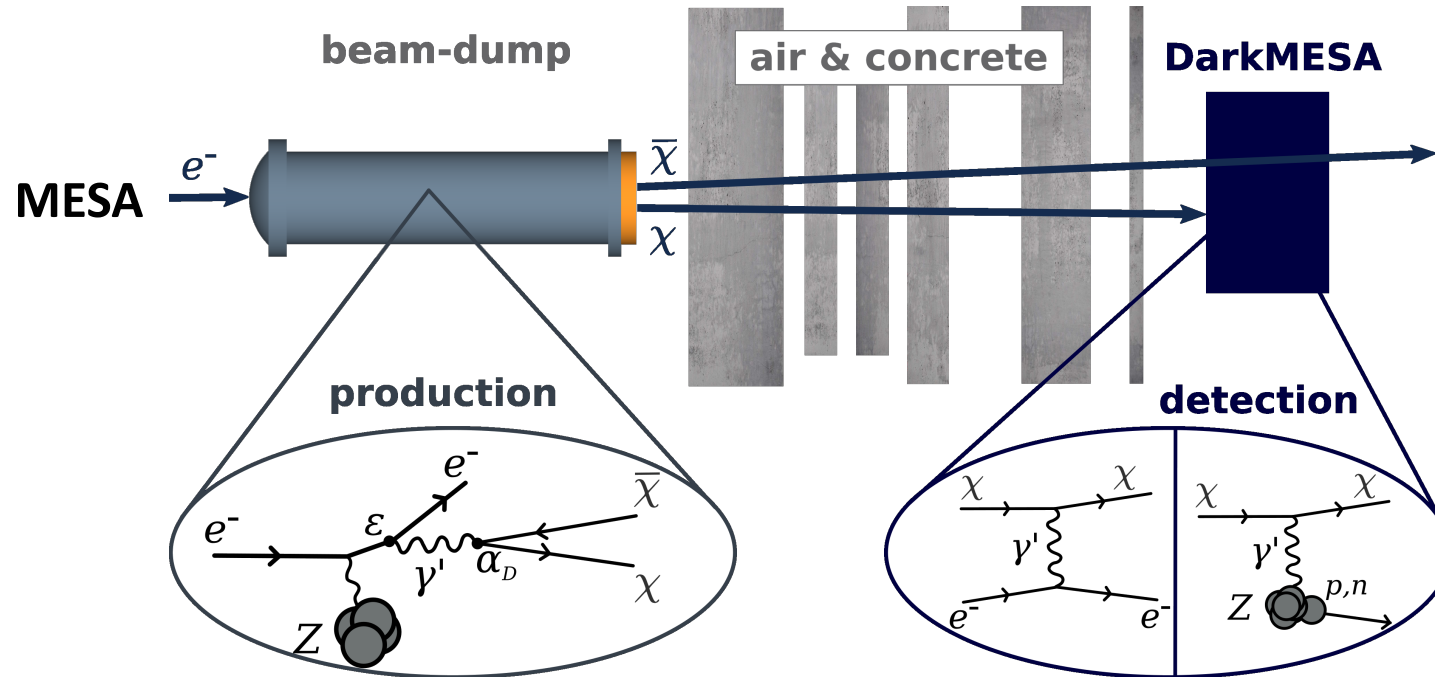
Parasitically running to P2
MESA Extracted Beam Mode



**DARK
MESA**

Beam Dump Experiment DarkMESA

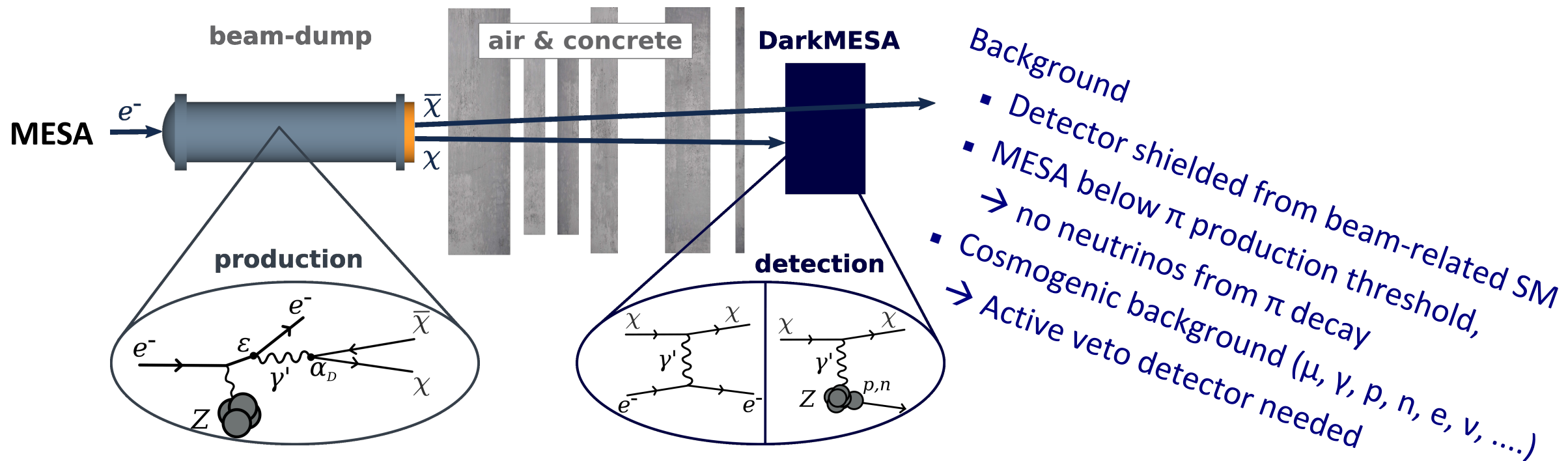
Model 2: $m_{\gamma'}$ $>$ $2m_{DM}$



**Electron Scattering of 3×10^{22} EOT (MESA) on Beam Dump
 → Collimated pair of Dark Matter particles !**

Beam Dump Experiment DarkMESA

Model 2: $m_{\gamma'}$ > $2m_{DM}$



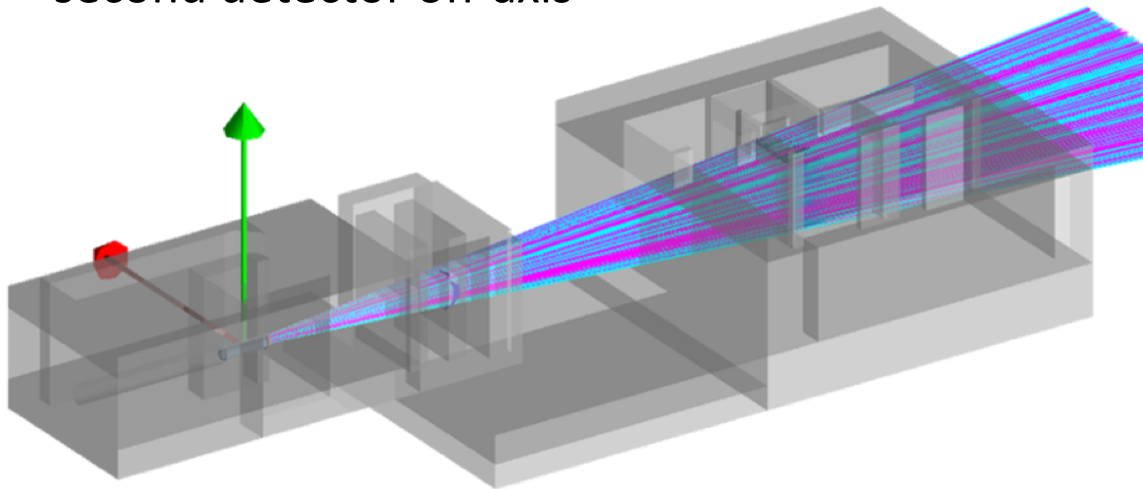
Electron Scattering of 3×10^{22} EOT (MESA) on Beam Dump
 \rightarrow Collimated pair of Dark Matter particles !

Beam Dump Experiment DarkMESA

Full GEANT4 simulation:

P2 target, beam dump, DarkMESA detector volume, walls etc.

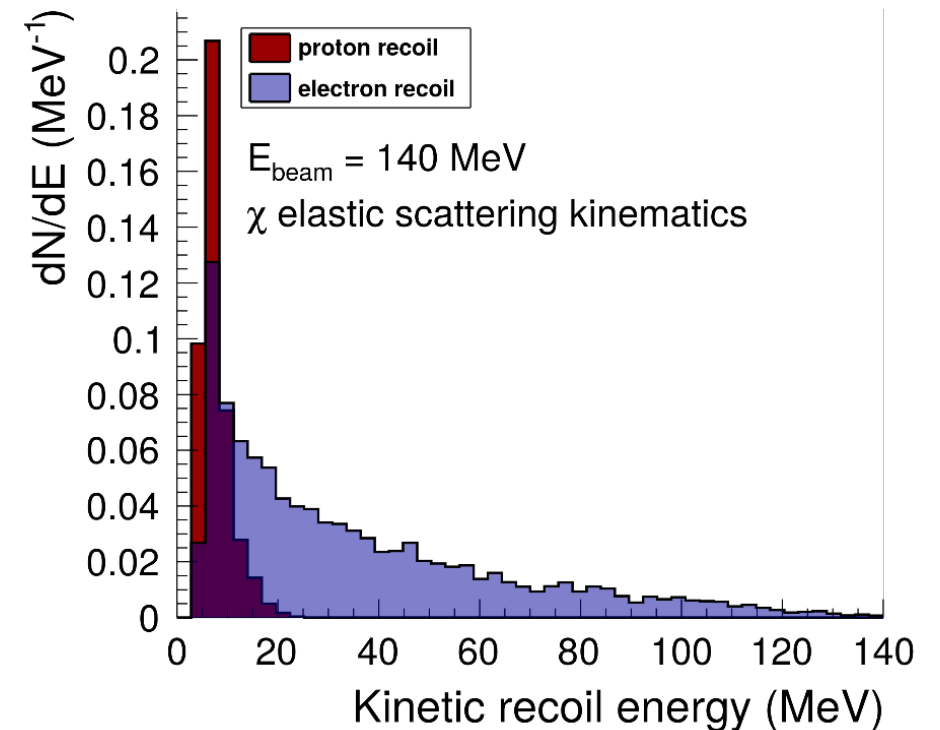
Possibility to place a
second detector off-axis



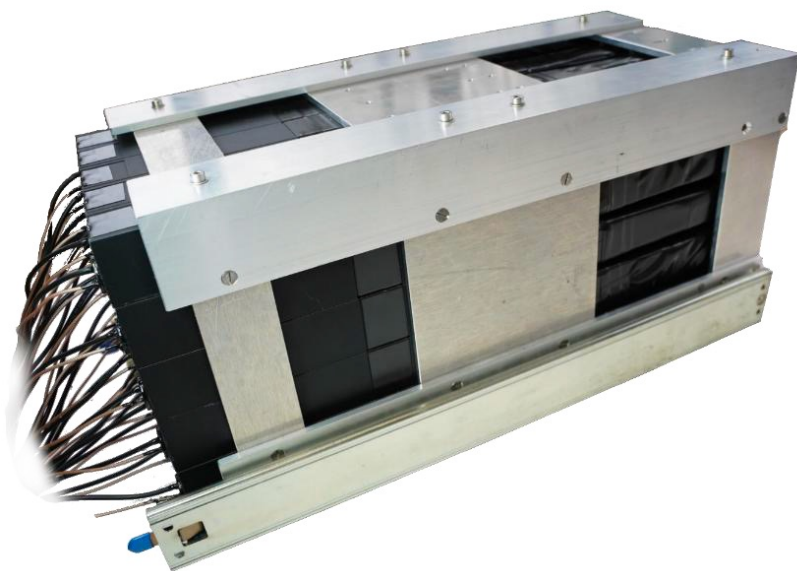
Baseline Concept: Inorganic crystal calorimeter

- Cherenkov (fast, no neutrons)
- Scintillator (higher light yield)

→ LDM interaction with
DarkMESA material (electron recoil)



DarkMESA Phase A Detectors (PbF_2 and $PbWO_4$)



PbF₂ Phase A Detector

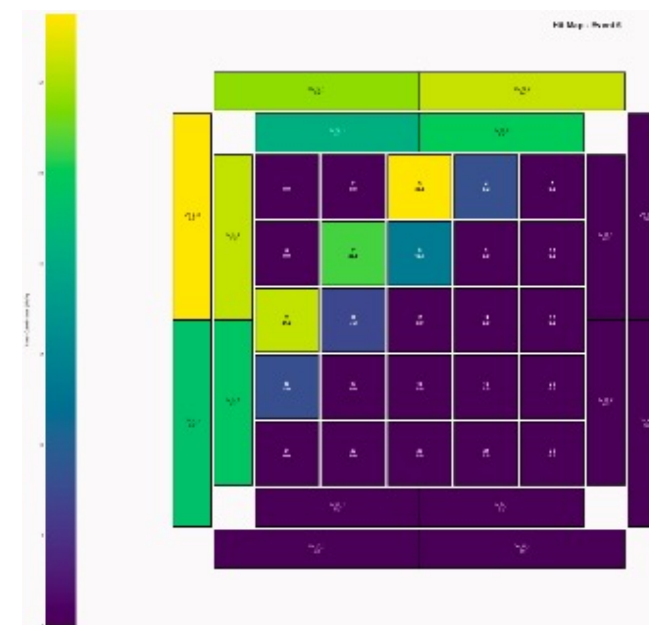
- ☺ Fast signal
- ☹ Limited light yield



PbWO₄ Phase A Detector (on loan from Crytur company)

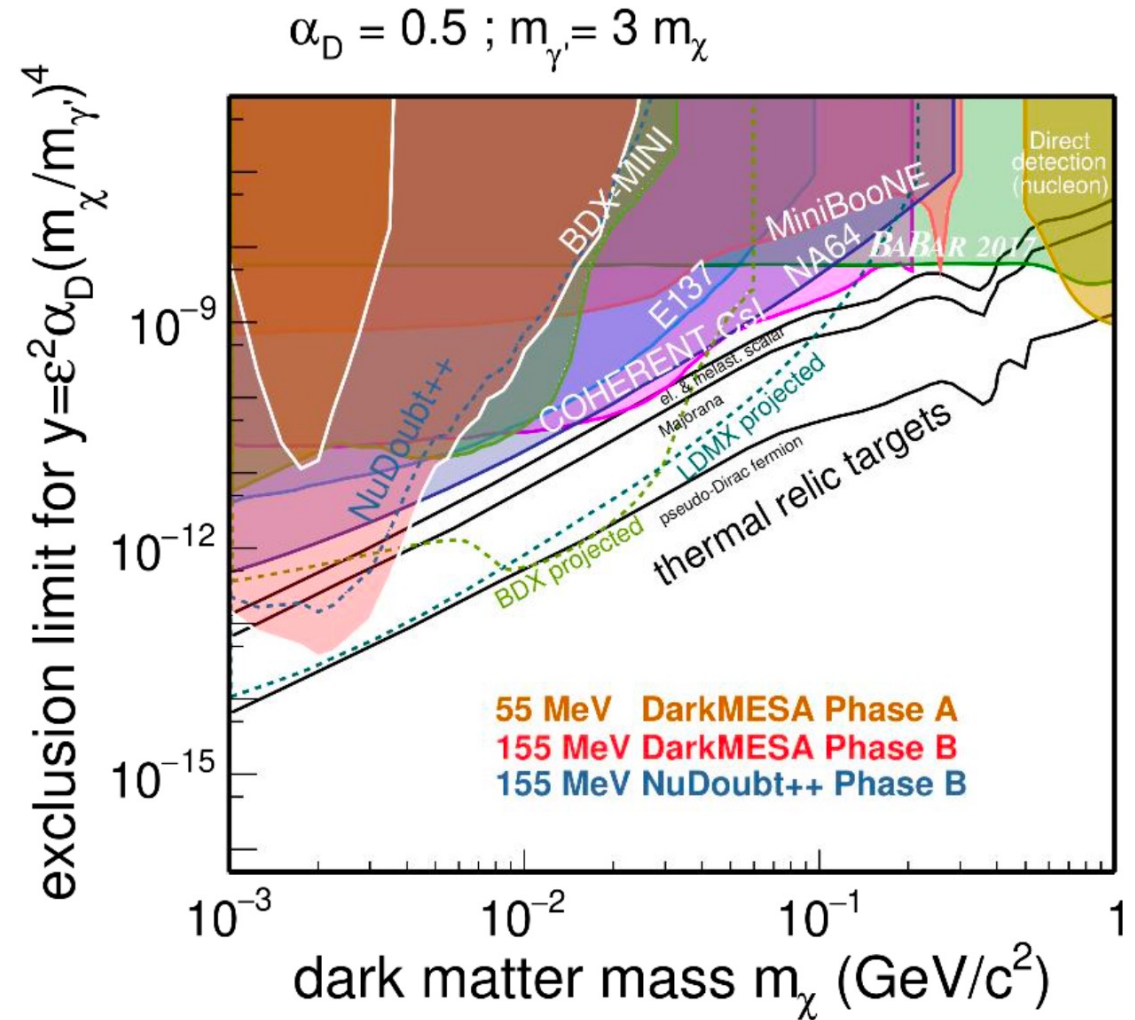
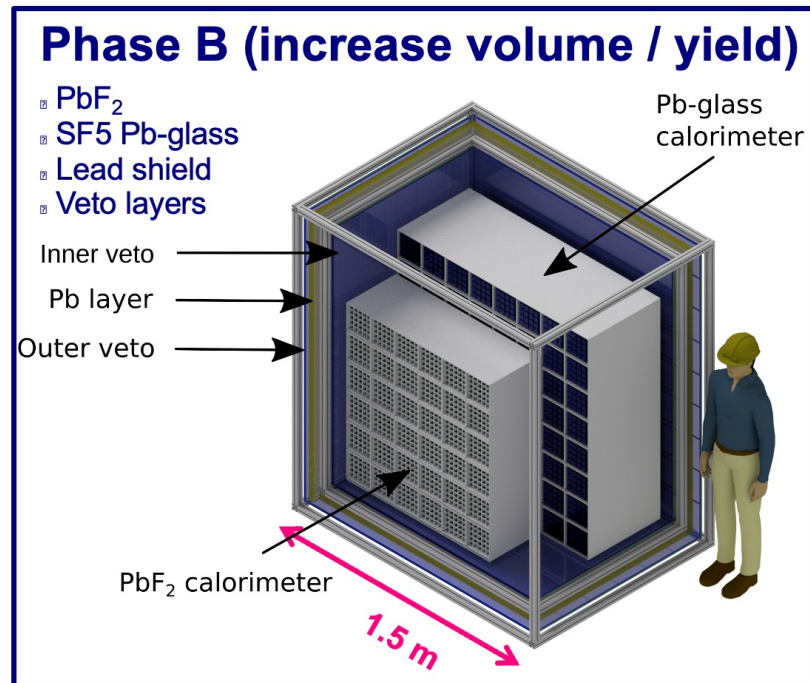
- ☺ Significant light yield
- ☹ Slow signal

Cosmic ray test of full setup



Cosmic veto detector (scintillator bars and Pb shielding)

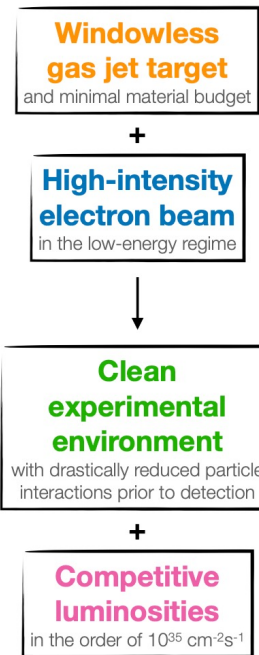
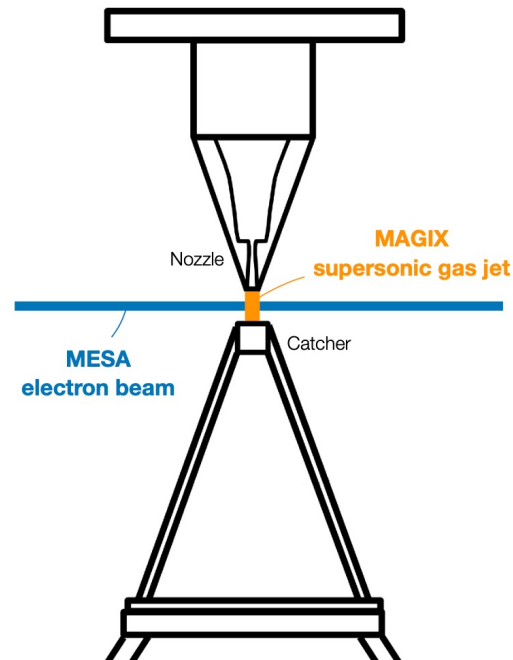
DarkMESA Physics Reach





MAGIX Experiment

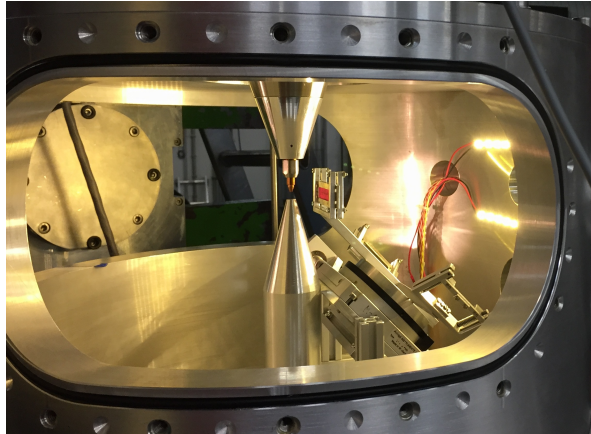
Energy-Recovering Mode (ERL) of MESA



High-Resolution MAGIX Spectrometers

Operation of a high-intensity (polarized) ERL beam
in conjunction with light internal target

→ a novel technique in nuclear and particle physics

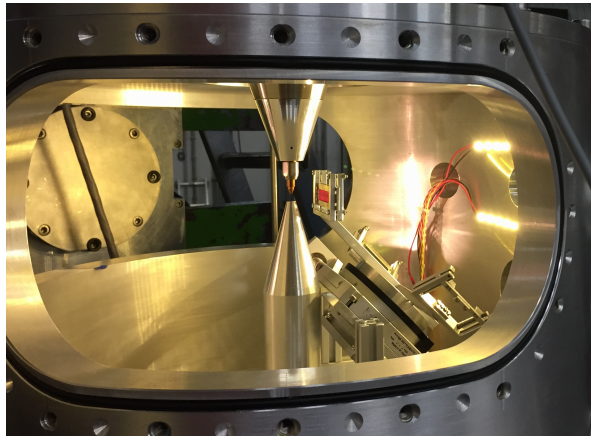


Two identical spectrometers

- Two dipoles each
- One quadrupole each

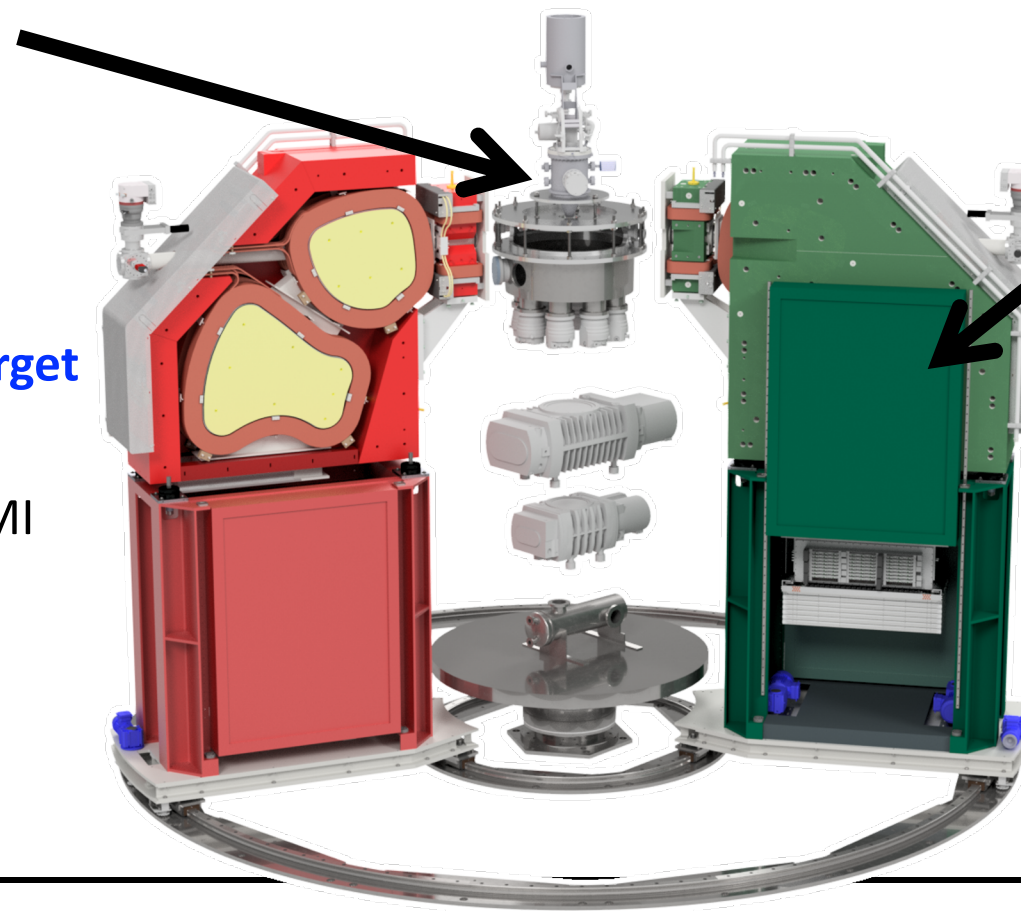
High-Resolution MAGIX Spectrometers

NIM A1013 (2021)



Operation of a high-intensity (polarized) ERL beam
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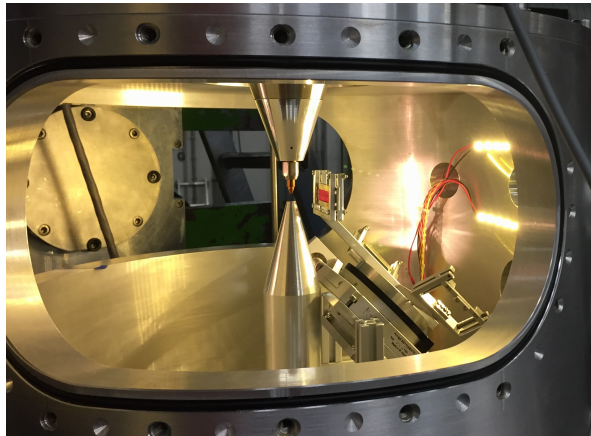
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Supersonic cryogenic gas jet target

- Windowless environment
- Commissioned at A1/MAMI
- Design density $10^{19}/\text{cm}^2$

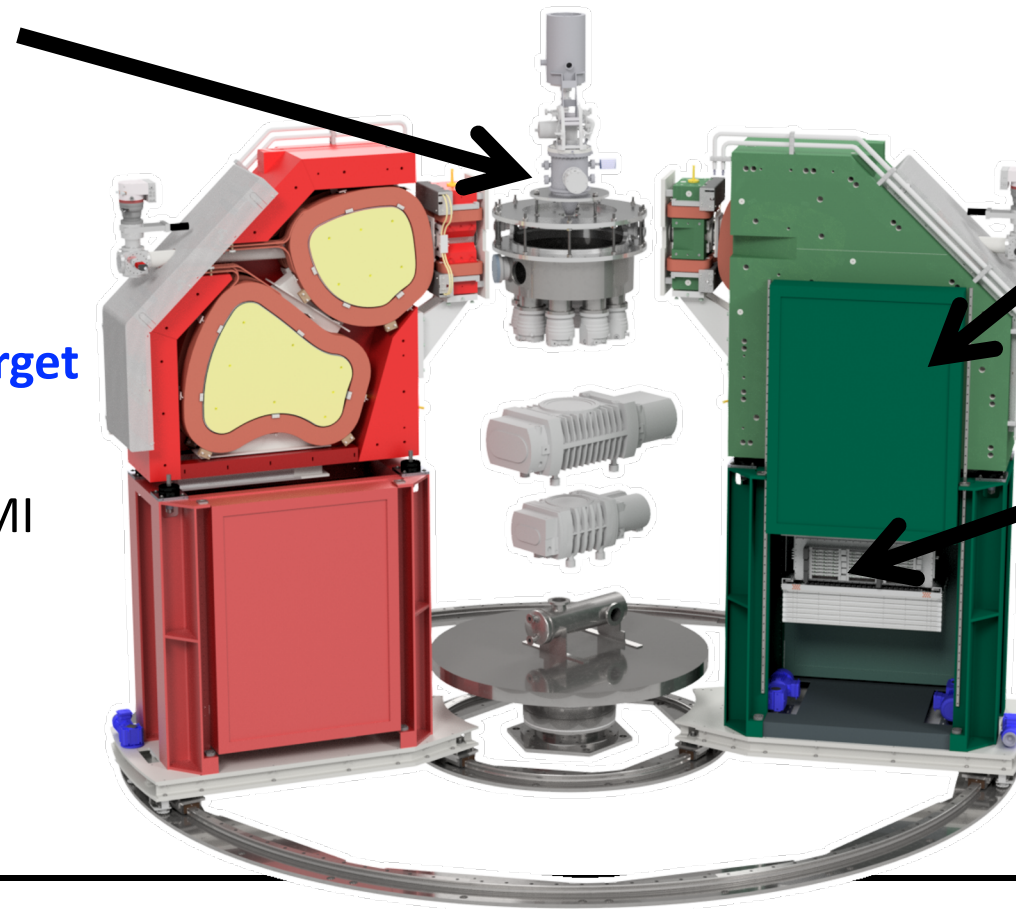
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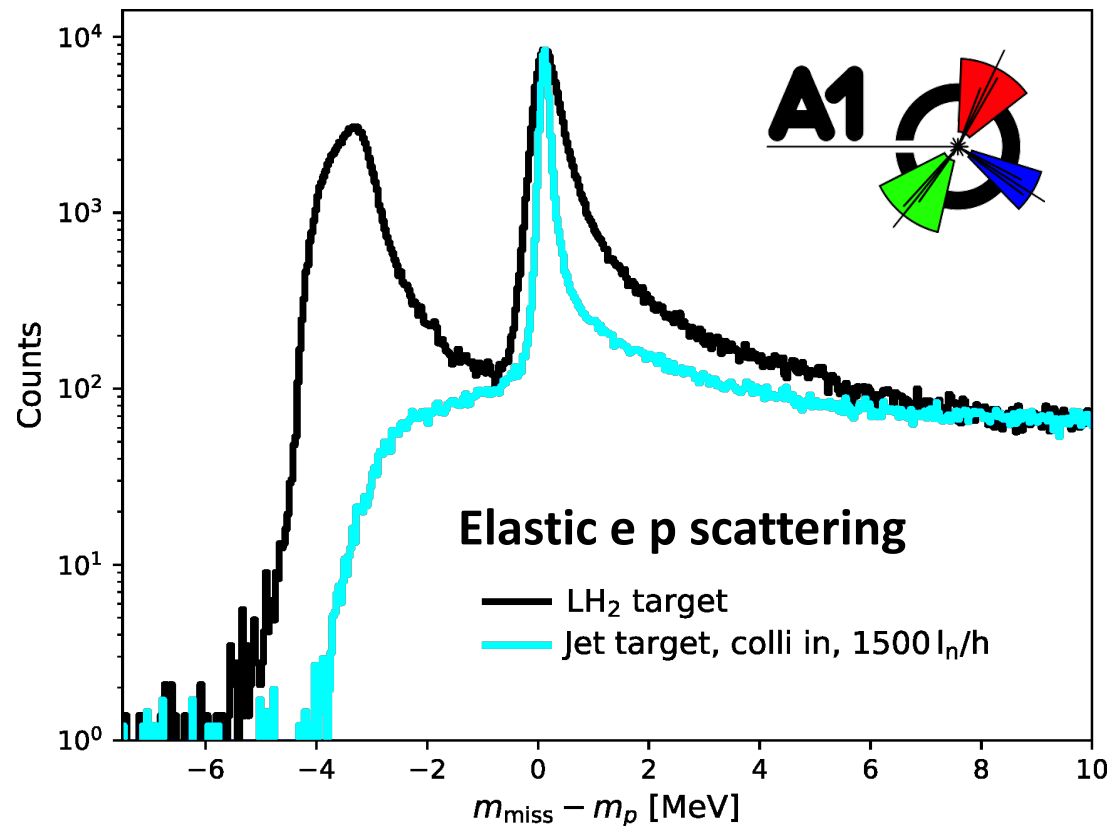
TPC-based focal plane detector

- 10^{-4} momentum resolution
- Requires spatial resolution of $O(100 \mu\text{m})$
- Open field cage
- GEM readout

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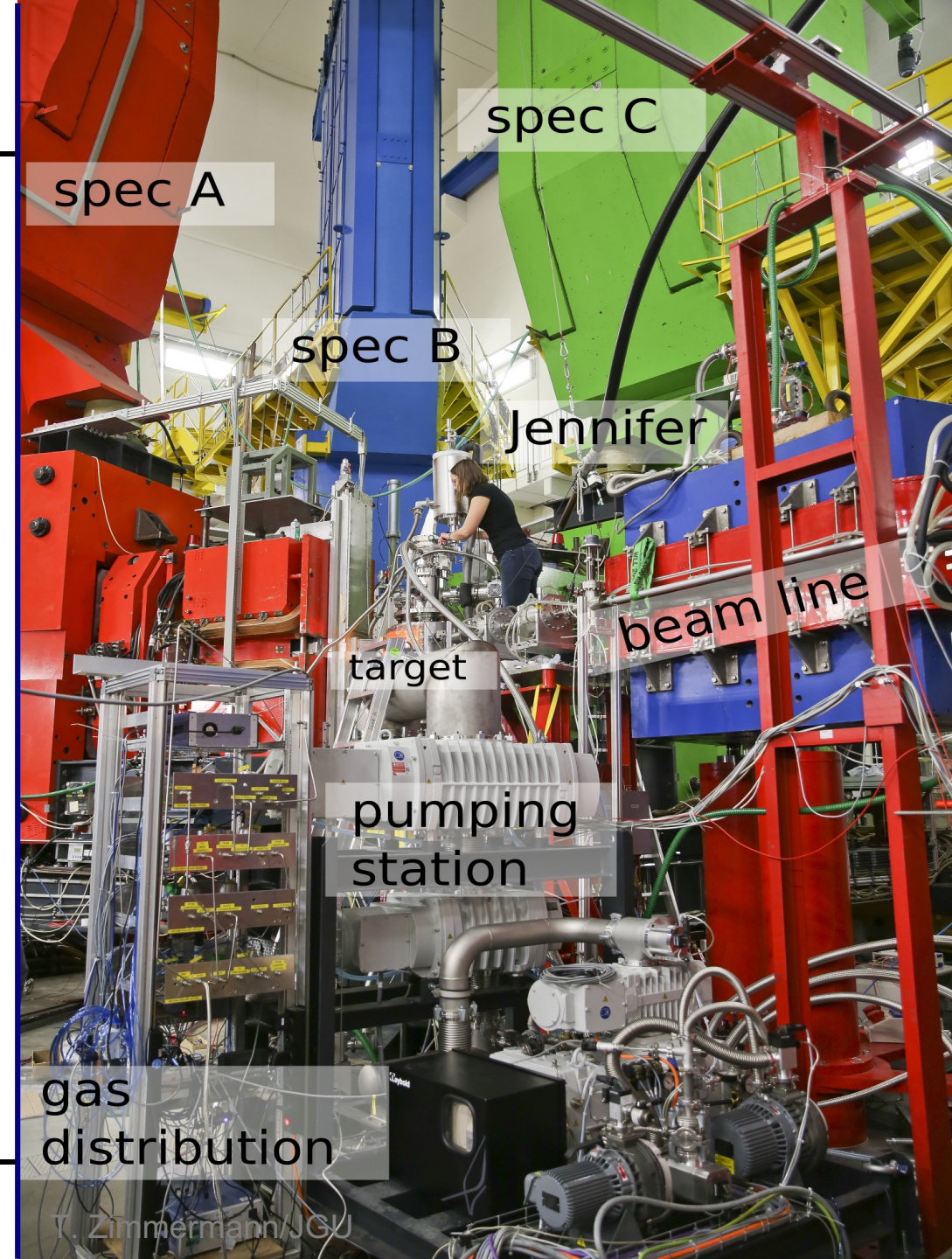
MAGIX Gas Jet Target



Gas Jet Target commissioned at A1/MAMI

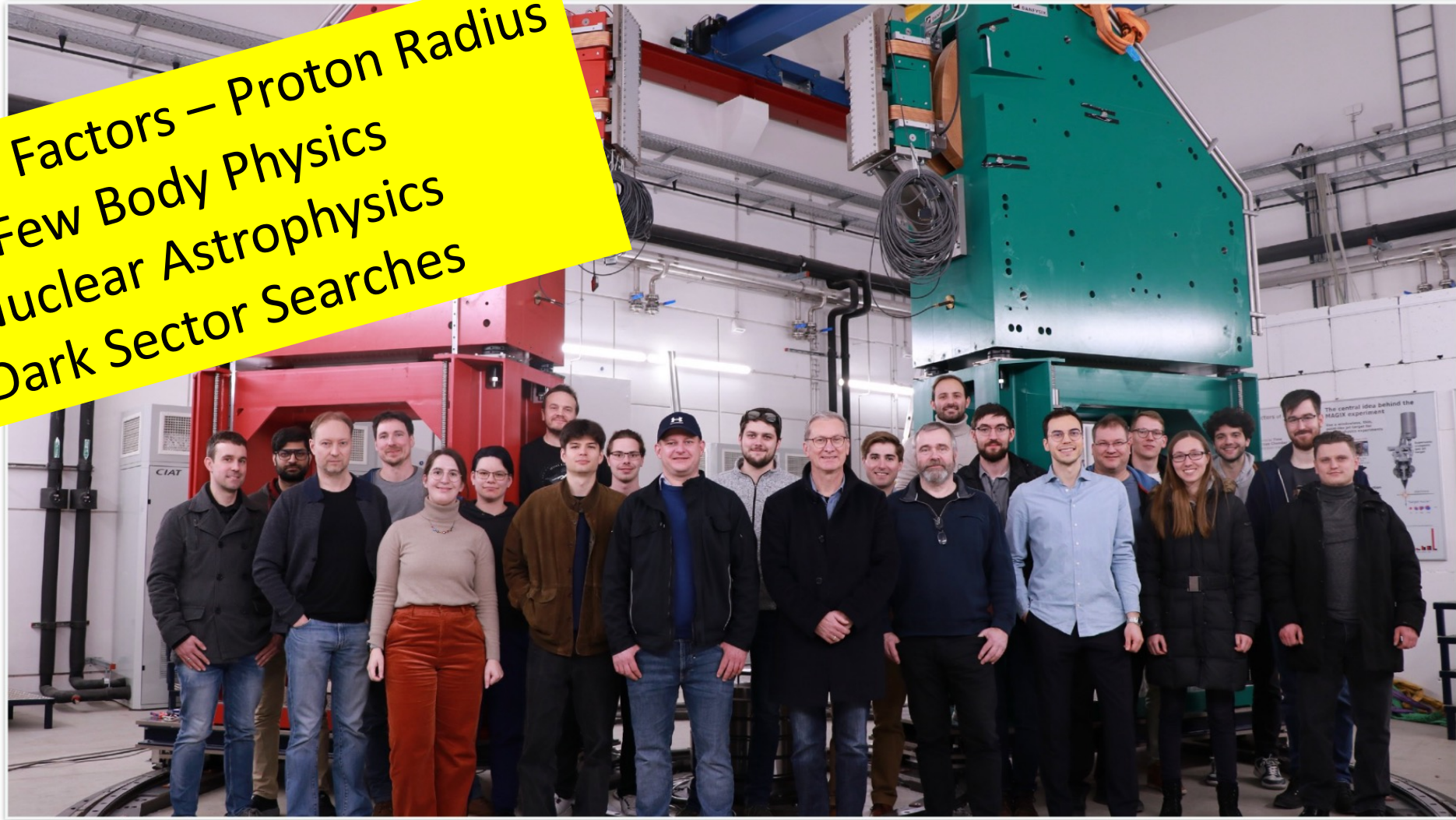
→ Windowless design

→ Much less background from scattering (target walls!) compared to liquid hydrogen LH₂ target



MAGIX Spectrometers almost fully installed

EM Form Factors – Proton Radius
Few Body Physics
Nuclear Astrophysics
Dark Sector Searches



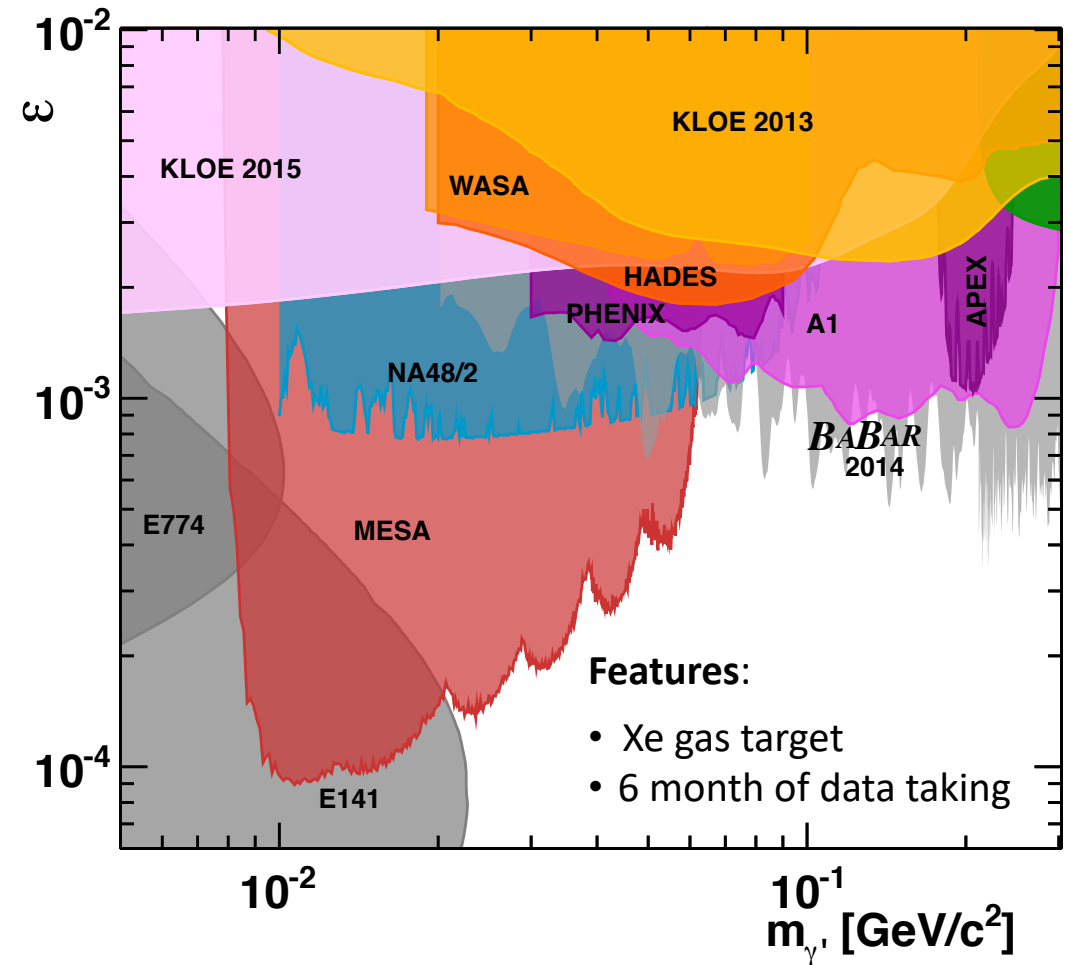
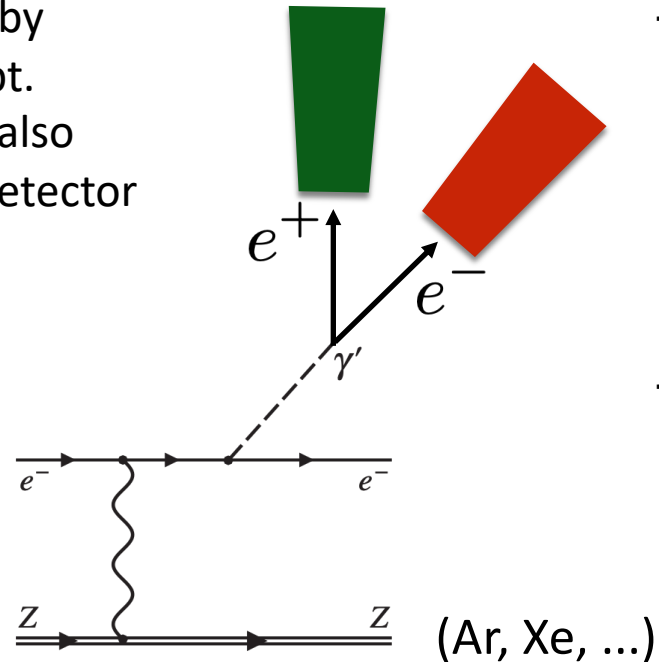
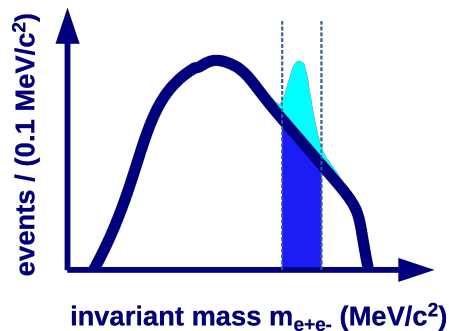
Dark Photon Search at MAGIX

Model 1: $m_{\gamma'} \ll 2m_{DM}$

Dark Photon decaying into SM particles

– coupling ε

- Method pioneered by A1/MAMI and APEX/JLAB
- Parameter range motivated by X17 anomaly of ATOMKI expt.
- Invisible dark photon decay also possible thanks to Si recoil detector

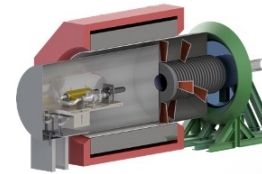


Conclusions

- **New MESA electron accelerator** (increase in intensity x 10 wrt. MAMI) currently being **constructed at Mainz**
- Energy-Recovery Linac mode: innovative and „green“ technique!
- **3 experiments** under construction:
 - Parity-violation experiment **P2**
 - Versatile **MAGIX** spectrometer
 - Beam dump experiment **DarkMESA**

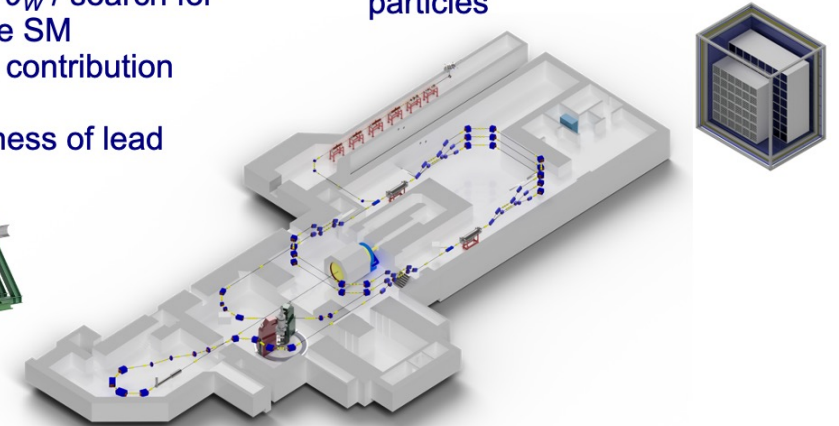
P2 – Parity Violation Experiments

- 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



S. Schlimme



MAGIX – Versatile Electron Scattering Experiment

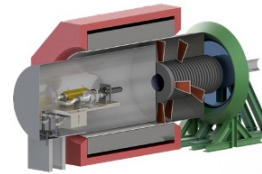
- Structure of Nucleons and Nuclei
- Few-Body Systems
- Nuclear Astrophysics
- Dark Sector Searches

Conclusions

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 - Energy-Recovery Linac mode: innovative and „green“ technique!
 - **3 experiments** under construction:
 - Parity-violation experiment **P2**
 - Versatile **MAGIX** spectrometer
 - Beam dump experiment **DarkMESA**
- **High intensity and low energy enabling exciting precision experiments**
- **New collaborators very welcome**

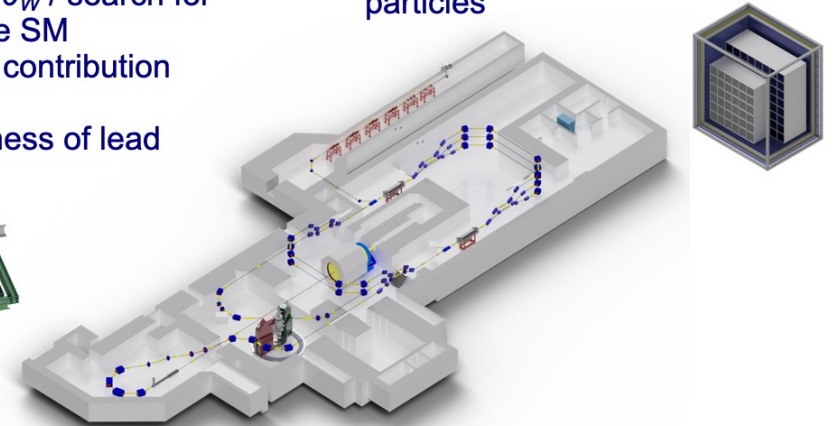
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- neutron skin thickness of lead



DarkMESA – Beam Dump Experiment

- quest for dark matter and other exotic particles



S. Schlimme



MAGIX – Versatile Electron Scattering Experiment

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






Rinaldo Baldini
1943 - 2026



30 Years ago
Karlsruhe, Nov. 1 and 2, 1996
Considered as the start of PhiPsi conference series

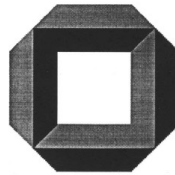
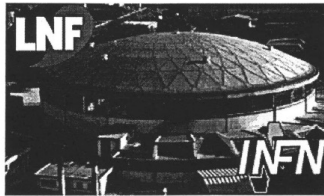
Thanks a lot to
Anna, Andrea, Alberto,
Angela, Alberto for organizing
PhiPsi26 and for hospitality!

>30 more years to come



30 Years ago
Karlsruhe, Nov. 1 and 2, 1996
Considered as the start of PhiPsi conference series

Backup



WORKSHOP ON

'HADRON PRODUCTION CROSS SECTIONS AT DAΦNE'

Karlsruhe, Germany, November 1 and 2, 1996

TOPICS:

Running fine structure constant and electroweak precision tests
 Status and perspectives of $g-2$ measurement
 Hadronic contribution to $g-2$
 Status of R measurements at low energies
 R measurements at DAΦNE, charm/ τ and B factories
 Bhabha cross sections and Monte Carlo programs
 Luminosity and energy measurements at electron-positron colliders
 Machine considerations for DAΦNE

SPEAKERS INCLUDE

R. Baldini (Frascati)	F.A. Berends (Leiden)	S. Eidelman (Novosibirsk)
P. Franzini (Frascati)	W. Hollik (Karlsruhe)	F. Jegerlehner (DESY-IfH)
K. Jungmann (Heidelberg)	J. Gasser (Bern)	E. Mirkes (Karlsruhe)
M. Piccolo (Frascati)	B. Pietrzyk (Annecy)	M. Placidi (CERN)
M.E. Biagini (Frascati)		

SCIENTIFIC ORGANISATION

P. Franzini	Rome and Frascati
W. Hollik	Karlsruhe
W. Kluge	Karlsruhe
J. H. Kühn	Karlsruhe
J. Lee-Franzini	Frascati
Th. Müller	Karlsruhe
G. Pancheri	Frascati

INFORMATION AND REGISTRATION

G. Cataldi, A. Denig, U. v. Hagen
 Institut für Experimentelle Kernphysik
 Postfach 3640
 D 76021 Karlsruhe
 e-mail: workshop@iekpkloe3.fzk.de

K. Jungmann	Status and Perspectives of Muon $g-2$	1
W. Hollik	The running coupling constant $\alpha(M_Z)$ and electroweak precision tests.....	46
F. Jegerlehner	The hadronic contribution to $g-2$	86
F.A. Berends	Bhabha cross sections and Monte Carlo programs.....	110
H. Burkhardt	Beam lifetime and the very forward Bhabha cross section.....	139
G. Cabibbo	Luminosity and energy measurements at DAΦNE.....	154
A. Höcker	Vector spectral functions determined in τ decays.....	184
H. Hu	R values at BES2 with Monte Carlo simulation.....	220
J. Gasser	Pion form factor and chiral perturbation theory.....	260
E. Mirkes	Predictions for exclusive tau decays.....	286
R. Baldini	Form factors and exclusive final states.....	316
S. Bellucci	$\eta \rightarrow \pi^0 \pi^0 \gamma \gamma$ to one loop chiral perturbation theory.....	359
A. Courau	Quasi-real Compton scattering as a continuous calibration for the KLOE detector.....	377
A. Czarnecki	Electroweak corrections to the muon anomalous magnetic moment.....	391
B. Krause	Higher-order hadronic contributions to the anomalous magnetic moment of leptons.....	402
T. Teubner	Extracting α_s from electron-positron annihilation around 10 GeV.....	411
S. Eidelman	Status of R measurements at low energies.....	430
M. Piccolo	Potential improvements at charm/ τ and B factories.....	474
P. Franzini	R measurements at KLOE.....	500
B. Pietrzyk	Luminosity measurements at LEP.....	533
M. Placidi	The beam energy at LEP1.....	564
M.E. Biagini	Machine considerations for DAΦNE.....	608

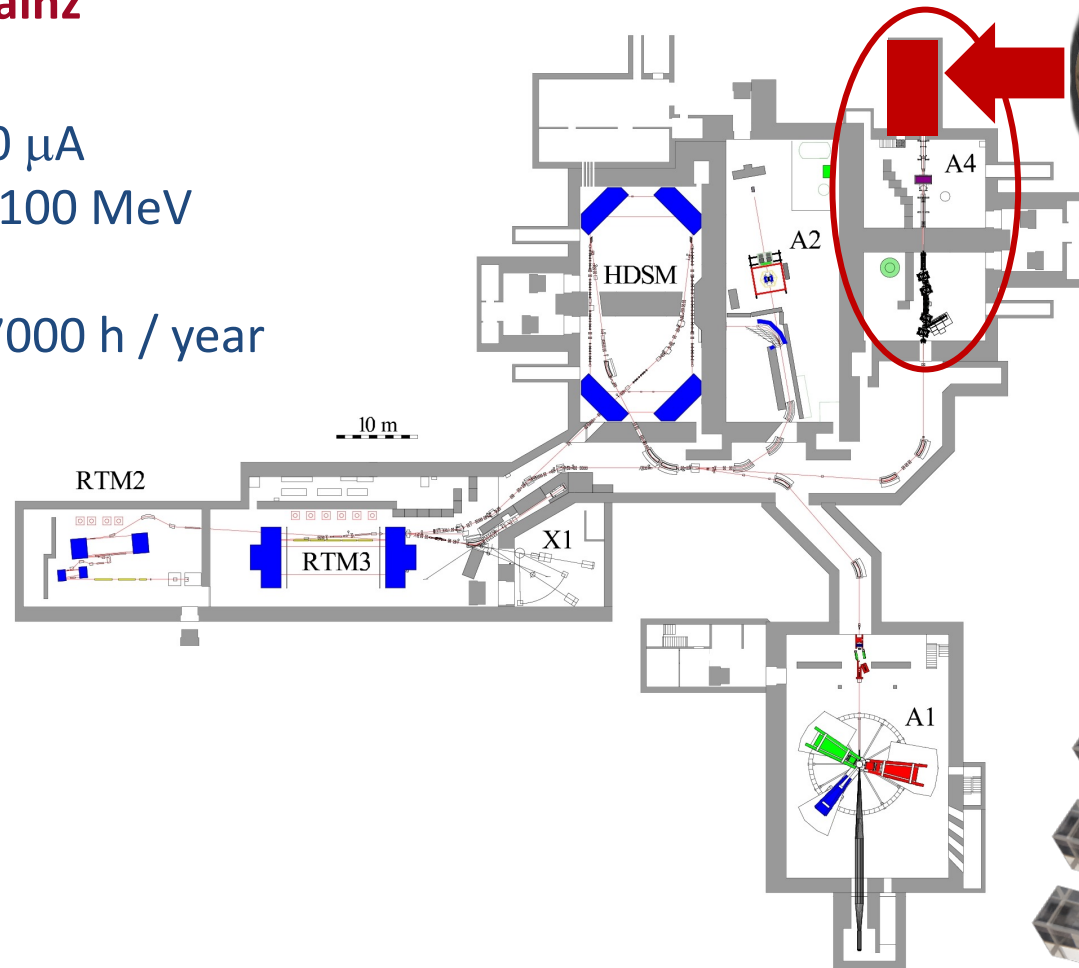
Workshop summary talk

G. Pancheri	Hadron production cross-sections at DAΦNE.....	653
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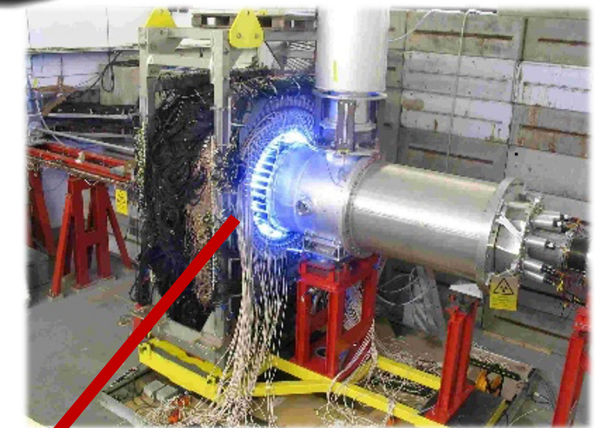
The Mainz Microtron MAMI

**Electron Accelerator $E = 0.185 \text{ GeV} - 1.6 \text{ GeV}$ (CW – 2.45 GHz)
operated at JGU Mainz
Hallmarks**

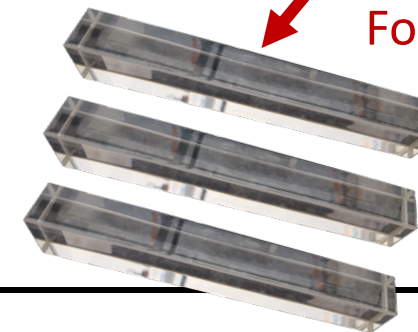
- Intensity max. $100 \mu\text{A}$
- Resolution $\sigma_E < 0.100 \text{ MeV}$
- Polarization 85%
- Reliability: up to 7000 h / year



Former A4 beam dump:
Al, H₂O, Cu → 20 X₀

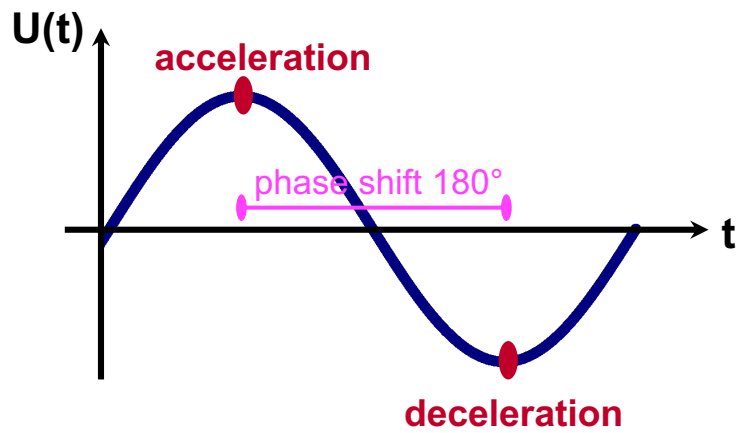
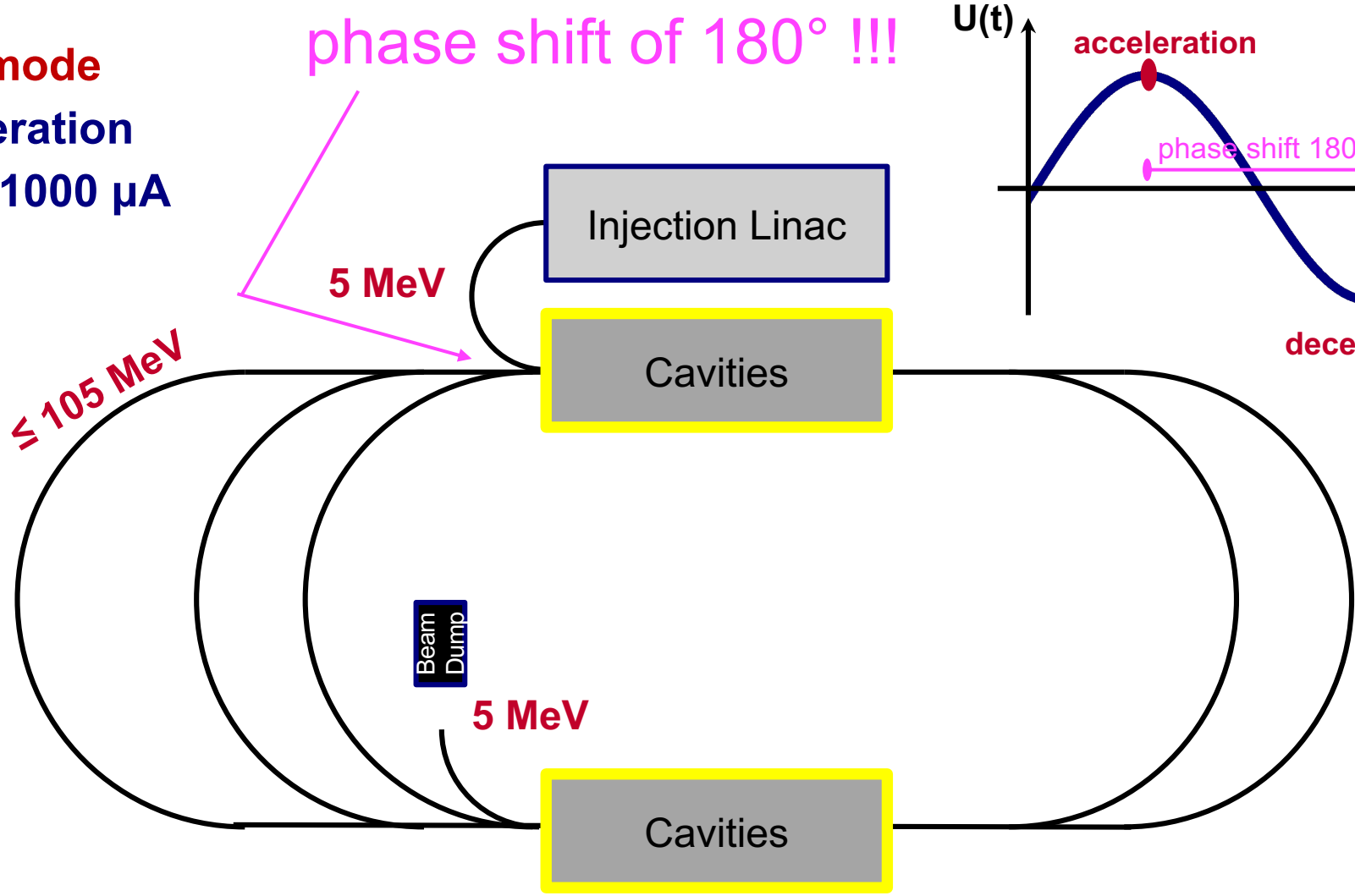


Former A4 experiment:
1000 PbF₂ crystals
and PMTs

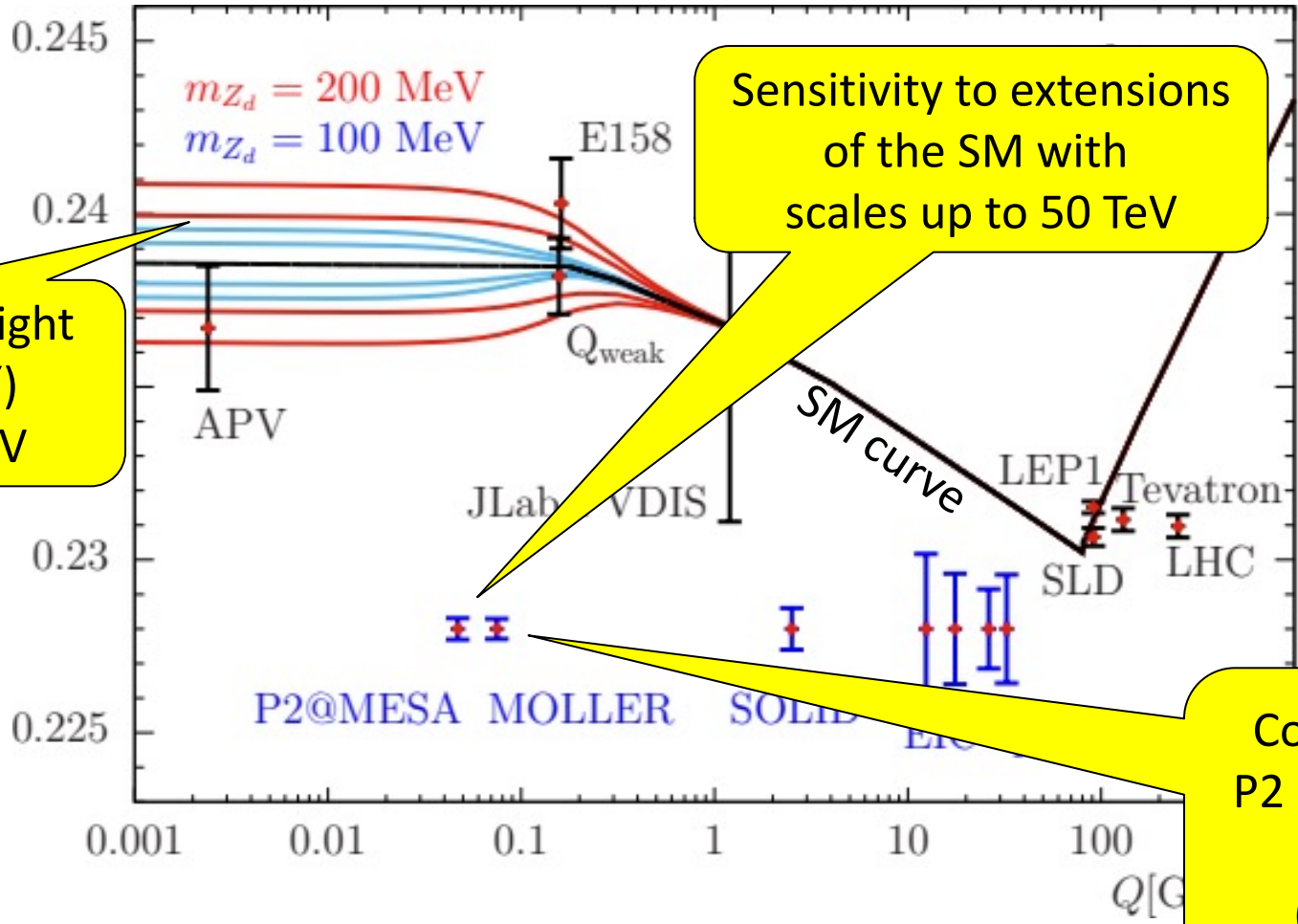


Mainz Energy-Recovering Superconducting Accelerator (MESA)

- Energy-Recovering mode**
- energy-efficient acceleration**
- ▶ **high beam currents $\geq 1000 \mu\text{A}$**



A Low- Q^2 Measurement of $\sin^2\theta_W$ at MESA



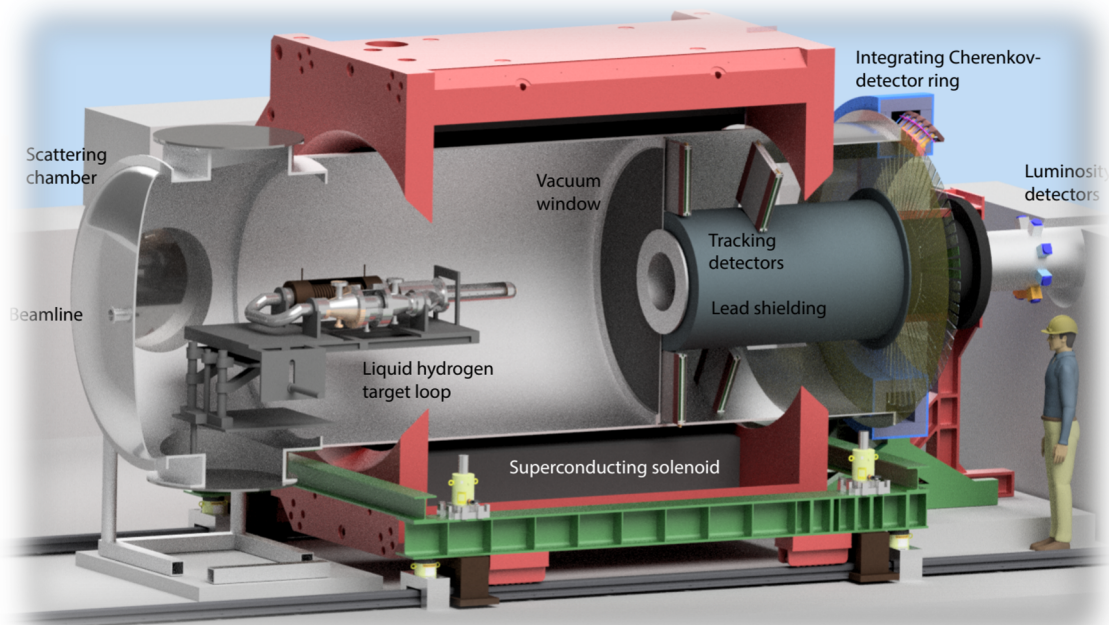
Sensitivity to light particles (Z') few 100 MeV

Sensitivity to extensions of the SM with scales up to 50 TeV

Complementarity between P2 (proton weak charge) and Moeller@JLAB (electron weak charge)

P2 Experiment

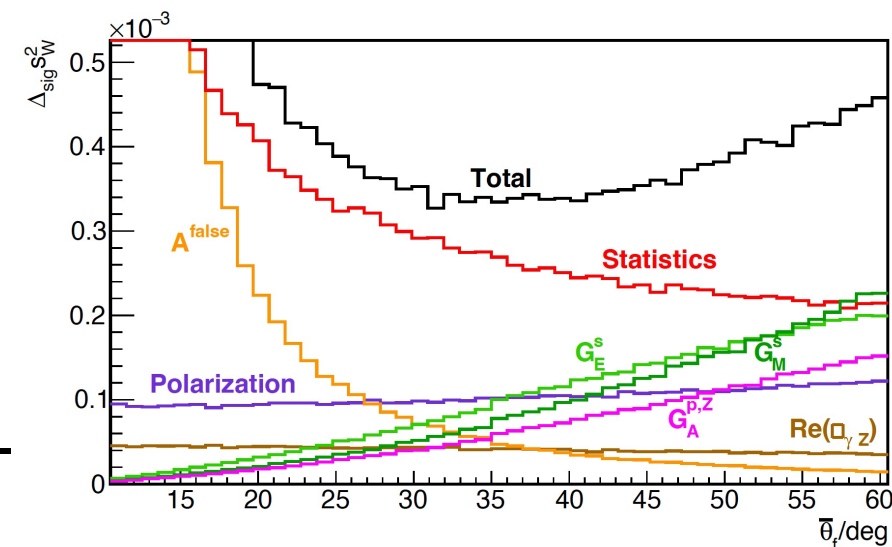
arXiv: 1802.04759



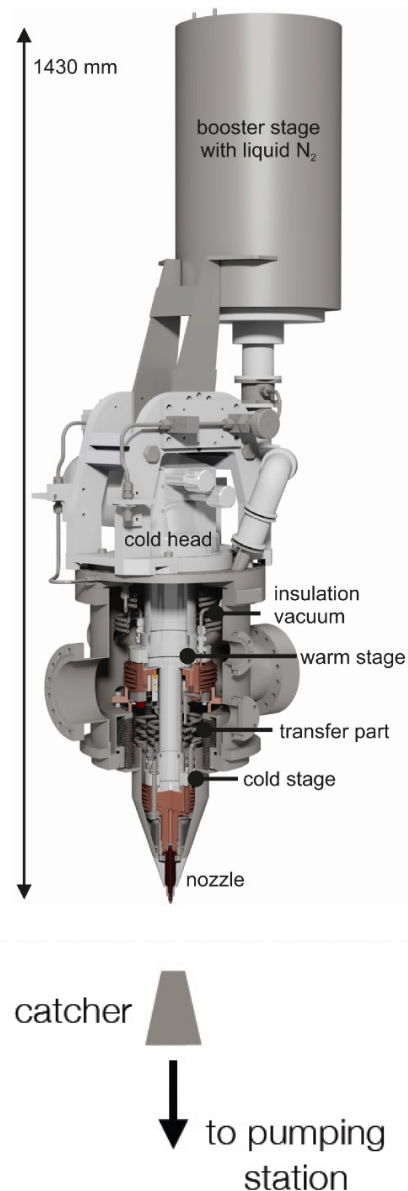
P2 - Parity violation experiments $\rightarrow 3 \cdot 10^{22}$ EOT (!)

- Superconducting solenoid
- Integrating Cherenkov detector ring
- Tracking detectors (HV-MAPS & MicroMegas)
- Chain of polarimeters (90% polarization)
- LH₂ target (60cm) and solid state targets (¹²Ca, ²⁰⁸Pb)

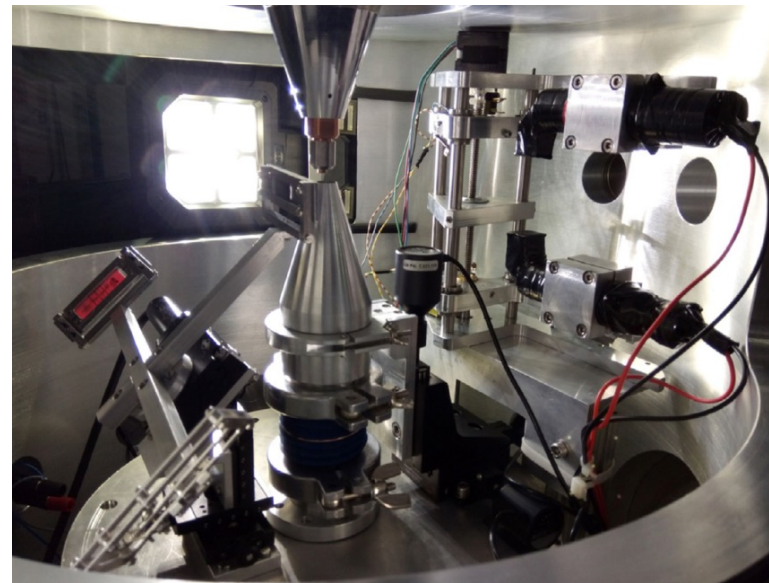
E_{beam}	155 MeV
θ_f	35°
$\delta\theta_f$	20°
s_W^2	0.23116
$\Delta_{\text{exp}} s_W^2$	$3.7 \cdot 10^{-4}$ (0.16%)
$\Delta_{\text{exp, stat}} s_W^2$	$3.1 \cdot 10^{-4}$ (0.13%)
$\Delta_{\text{exp, P}} s_W^2$	$0.7 \cdot 10^{-4}$ (0.03%)
$\Delta_{\text{exp, false}} s_W^2$	$0.6 \cdot 10^{-4}$ (0.03%)
$\Delta_{\text{exp, t.w.}} s_W^2$	$1.2 \cdot 10^{-4}$ (0.05%)
$\Delta_{\text{exp, t.p.}} s_W^2$	$0.1 \cdot 10^{-4}$ (0.00%)
$\Delta_{\text{exp, } \square_{\gamma Z}} s_W^2$	$0.4 \cdot 10^{-4}$ (0.02%)
$\Delta_{\text{exp, nucl. FF}} s_W^2$	$1.2 \cdot 10^{-4}$ (0.05%)



MAGIX Gas Jet Target



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



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^{1,3}, P. Achenbach^{a,c,d}, M. Ball^e, J.C. Bernauer^{d,1}, M. Biroth^a, D. Bonaventura^b, D. Bosnar^f, S. Caiazza^g, M. Christmann^{a,d}, E. Cline^h, A. Denig^{a,c,d}, M.O. Distler^g, L. Doria^{a,c}, P. Eckert^g, A. Esser^g, I. Frišić¹, S. Gagneur^{a,2}, J. Geimer^g, S. Grieser^g, P. Gülker^g, P. Herrmann^g, M. Hoek^g, S. Kegel^g, J. Kelsey¹, P. Klag^g, A. Khoukaz^g, M. Kohl¹, T. Kolar^{g,h}, M. Lauß^g, L. Leßmann^g, S. Lunkenheimer^g, J. Marekovič^g, D. Markus^g, M. Mauch^g, H. Merkel^{a,c}, M. Mihovilović^{a,h,g}, R.G. Milner¹, J. Müller^g, U. Müller^g, T. Petrovič^g, J. Pochodzalla^g, J. Rausch^g, J. Schlaadt^g, H. Schürg^g, C. Sienti^{a,c}, S. Širca^{h,g}, R. Spreckels^g, S. Stengel^g, Y. Stöttinger^g, C. Szyszka^g, M. Thiel^g, S. Vestrick^g, C. Vidal¹, 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 Helmholtz Zentrum 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 Jozef Stefan Institute, SI-1000 Ljubljana, Slovenia

^h Faculty of Mathematics and Physics, University of Ljubljana, SI-1000 Ljubljana, Slovenia

¹ Laboratory for Nuclear Science, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA

² MIT Bates Research and Engineering Center, Middletown, MA, 01949, USA

³ Center for Frontiers in Nuclear Science, Department of Physics and Astronomy, Stony Brook University, New York 11794, USA

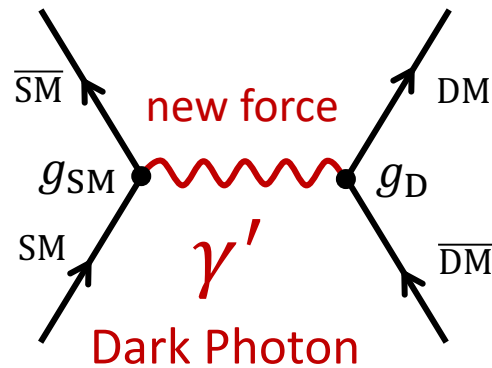
⁴ RIKEN BNL Research Center, Brookhaven National Laboratory, Upton, NY 11973, USA

⁵ Department of Physics, Hampton University, Hampton, Virginia 23668, USA

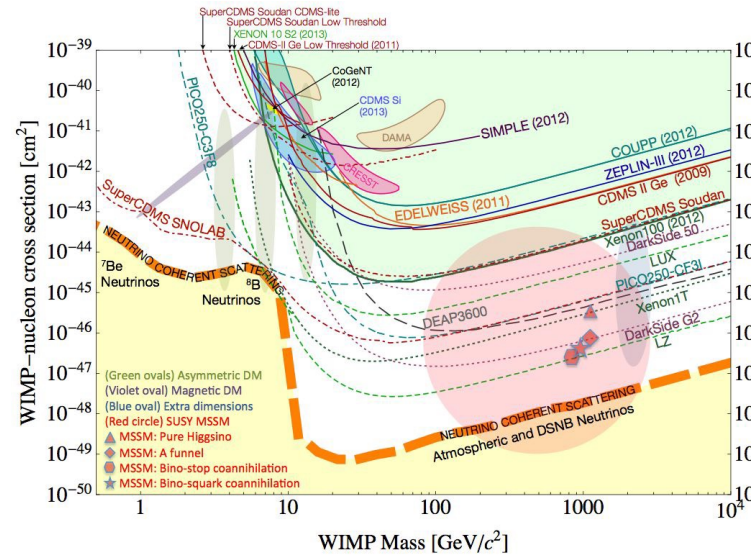
Light Dark Matter (LDM)

Light Dark Matter

$$\text{MeV} < m_{\text{DM}} < \sim \text{GeV}$$

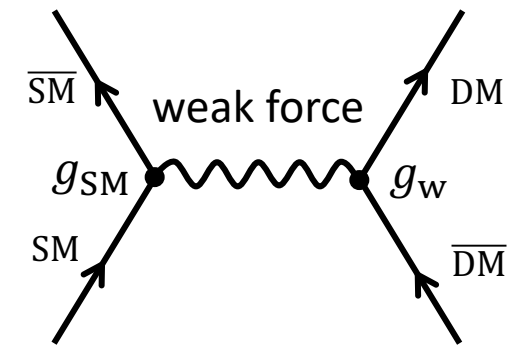


- Thermal relic targets exist for the MeV-GeV mass scale
- LDM requires a beyond SM force
- Rich phenomenology of portals: vector, higgs, neutrino, axion



WIMPs

$$\text{GeV} < m_{\text{DM}} < \sim \text{TeV}$$



- Matching relic abundance for the electroweak mass scale
- WIMPs require only SM interaction
- No positive evidence after LHC and galactic DM searches

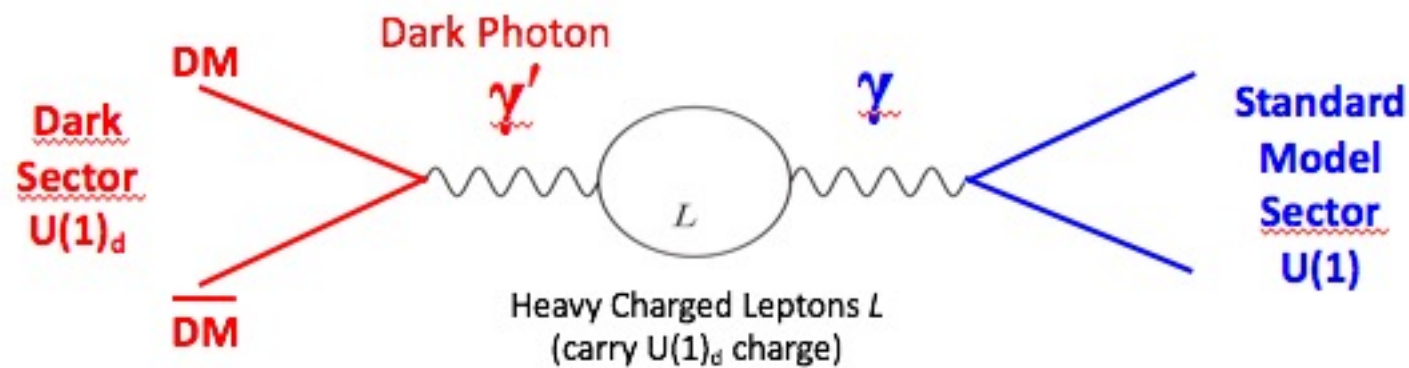
Vector Mediator: Dark Photon

Model 1: $m_{\gamma'} \ll 2m_{DM}$

Dark Photon decaying into SM particles – coupling ϵ
 → MAGIX visible decay

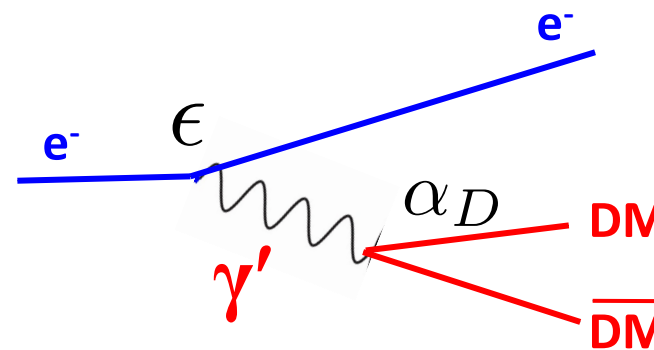
$$\frac{1}{2} \epsilon_Y F_{\mu\nu}^Y F'^{\mu\nu}$$

Holdom [1986]



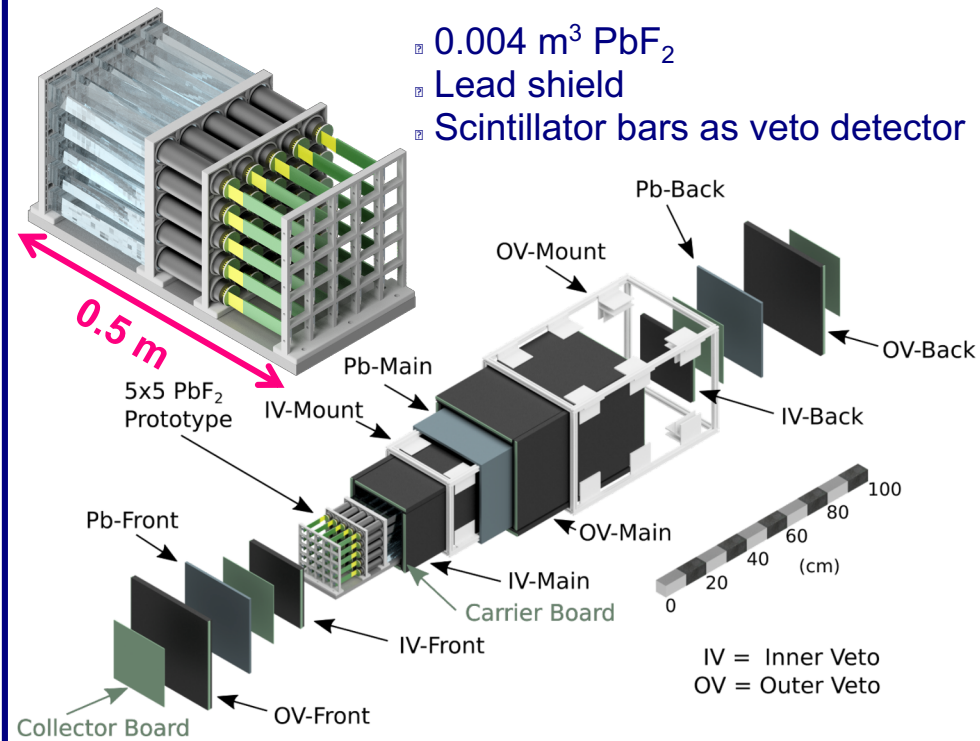
Model 2: $m_{\gamma'} > 2m_{DM}$

Dark Photon decaying into Dark Matter
 → MAGIX invisible decay and DarkMESA

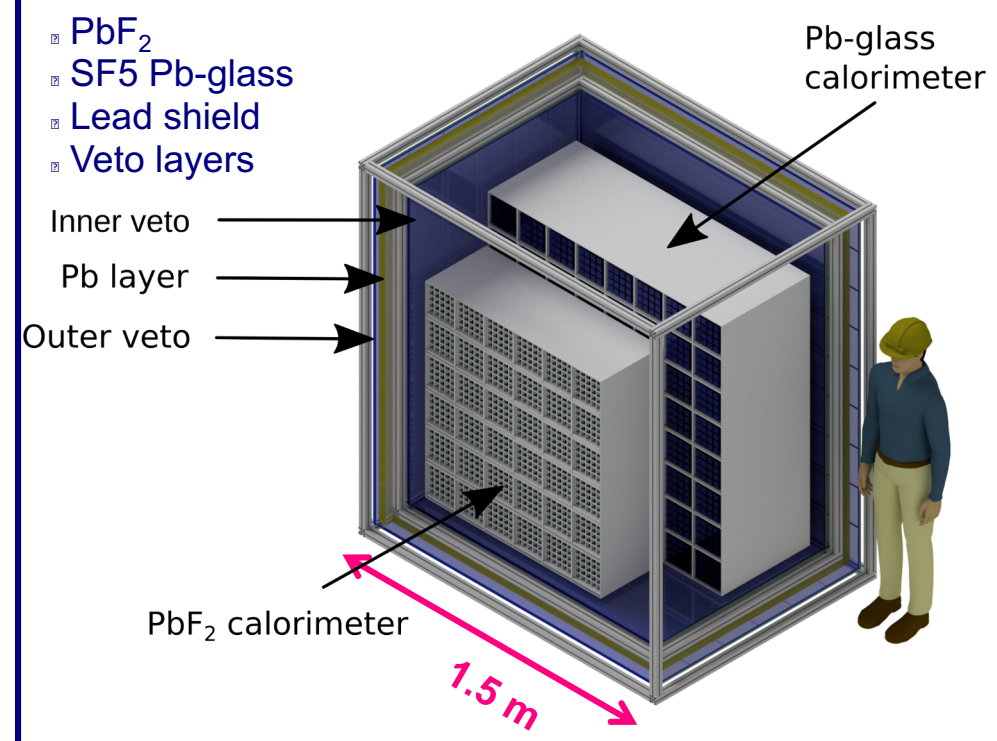


Detector Concept for DarkMESA

Phase A (prototype)



Phase B (increase volume / yield)

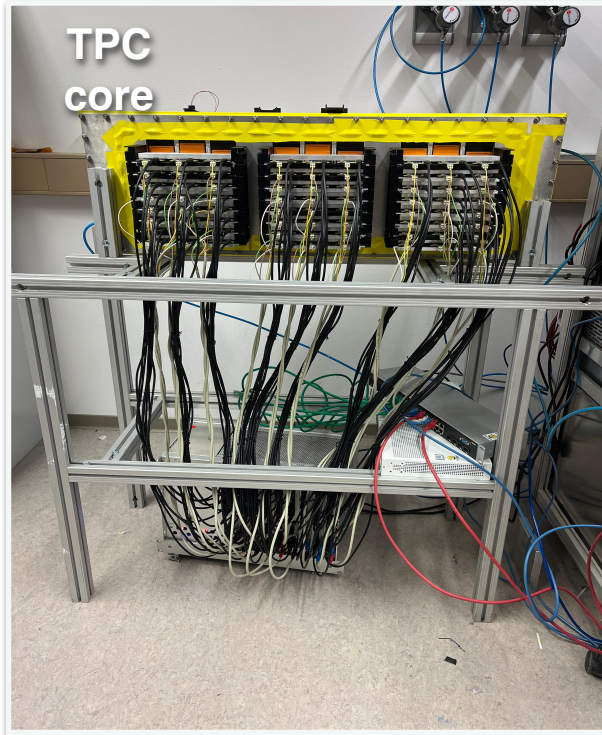


Phase C (range extension – various options)

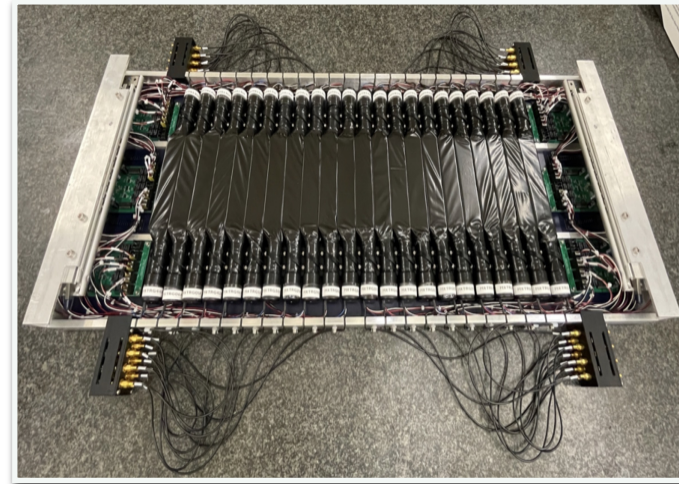
Larger Calorimeter
(e.g. based on PbWO₄ crystals)

Opaque scintillator
technology

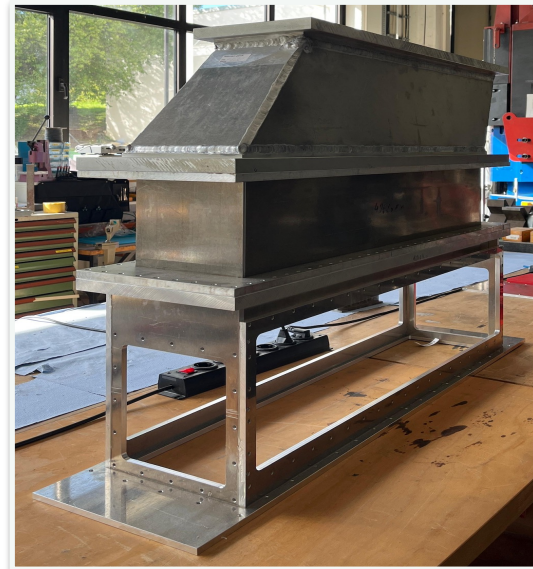
MAGIX Spectrometers almost fully installed



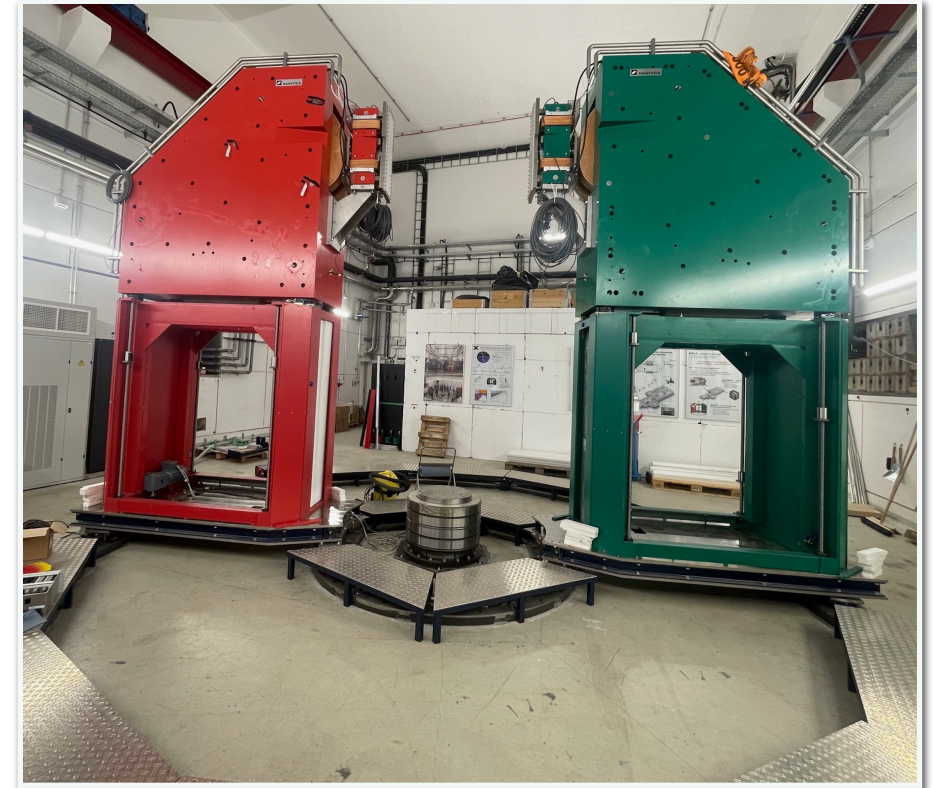
TPC detector with GEM readout



Trigger detector



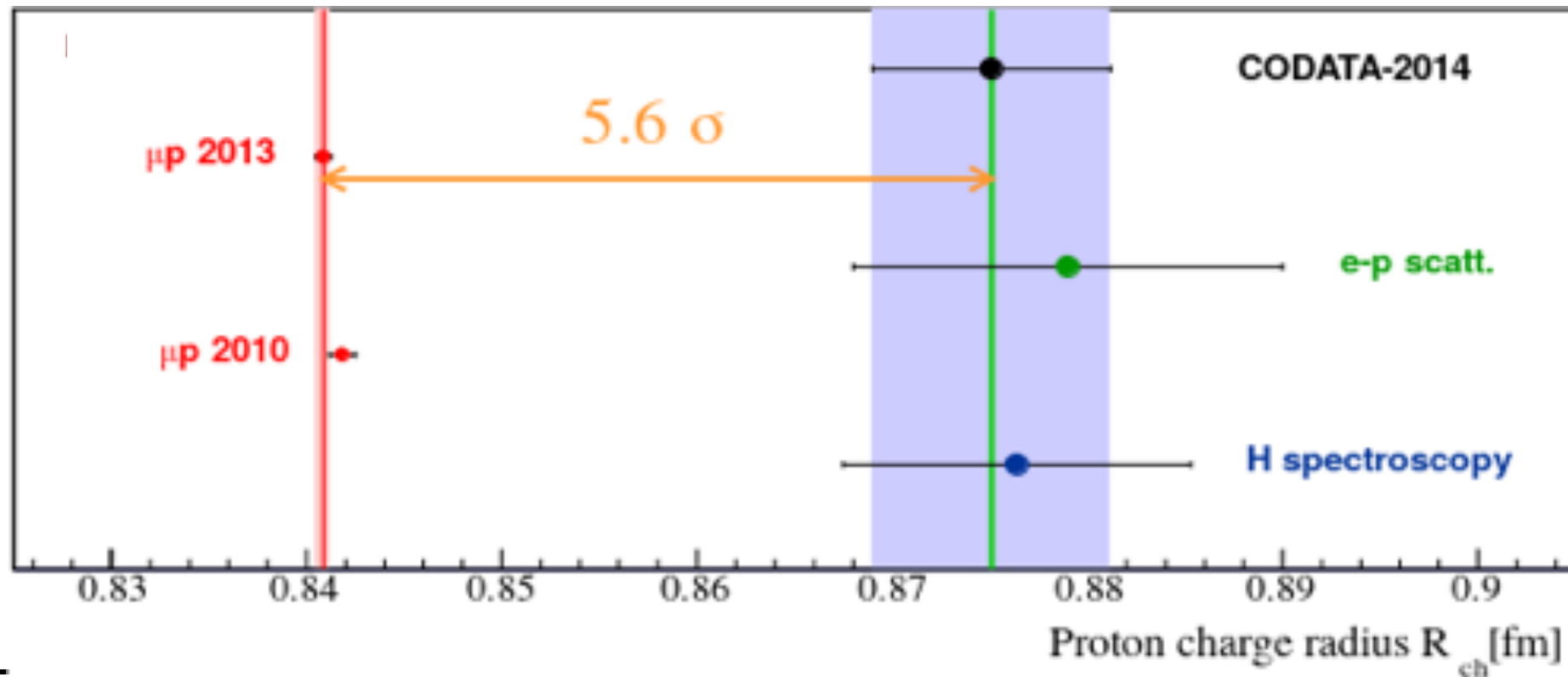
TPC frame



Two identical spectrometers (before insertion of trigger and veto detectors)

EM Form Factors and the Proton Radius (Puzzle ?)

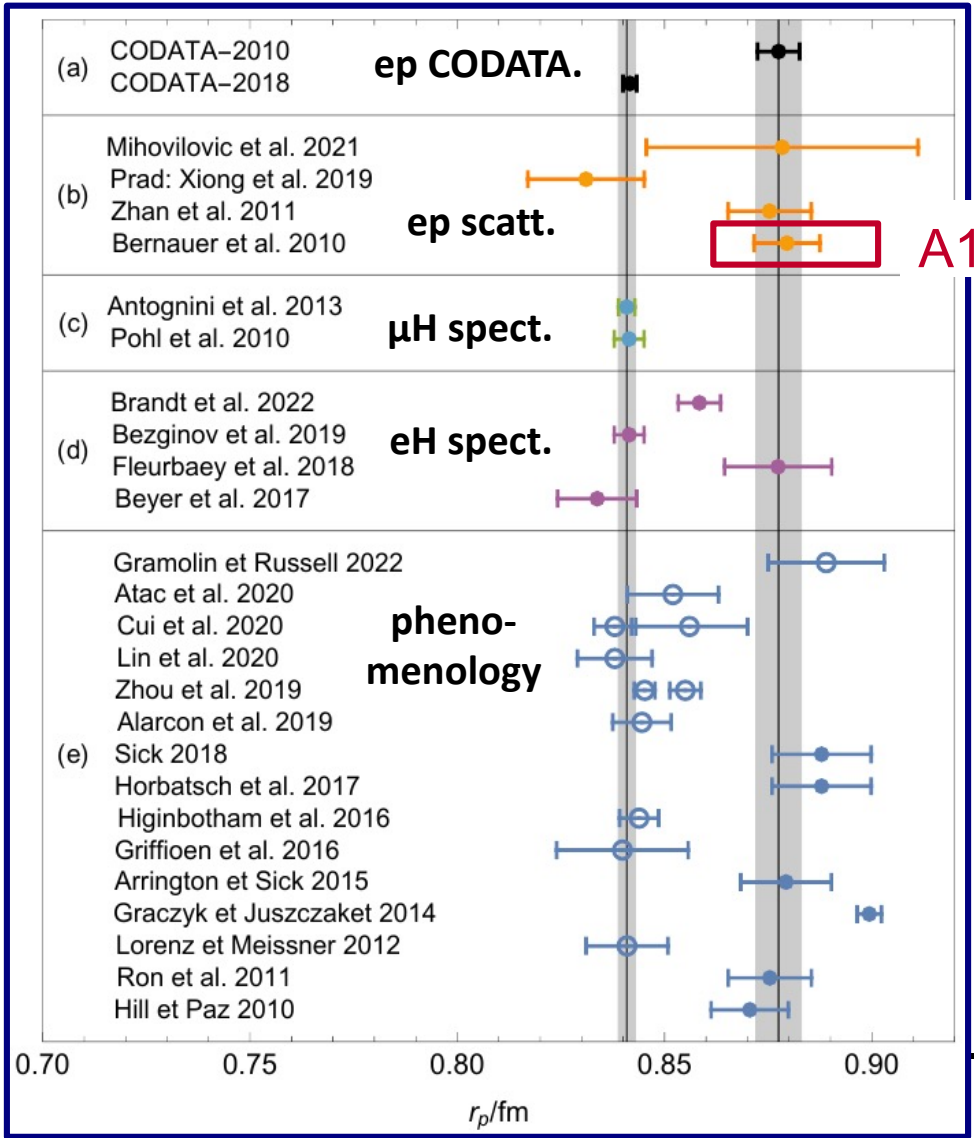
Discrepancy between proton radius extractions from **muonic hydrogen spectroscopy** and **electron scattering/electronic hydrogen spectroscopy** (Situation 2016)



The Proton Radius (Puzzle ?)

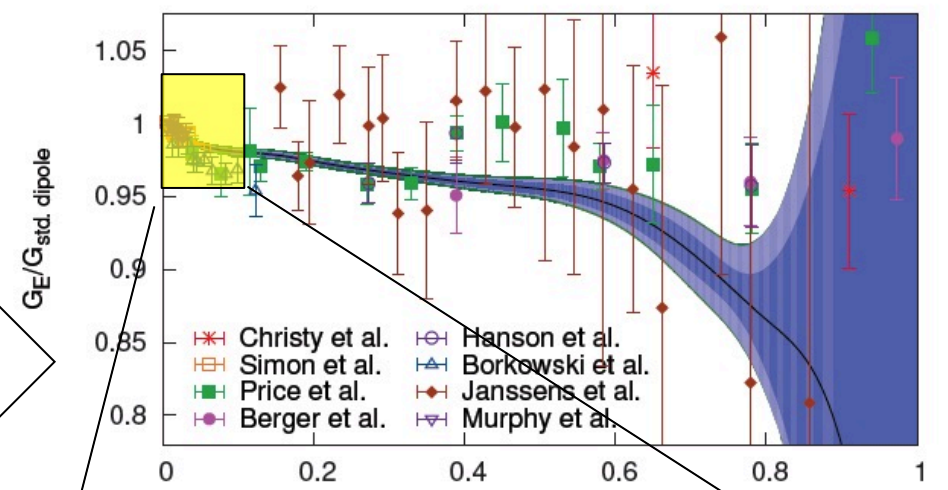
arXiv:2304.07035

Situation 2023



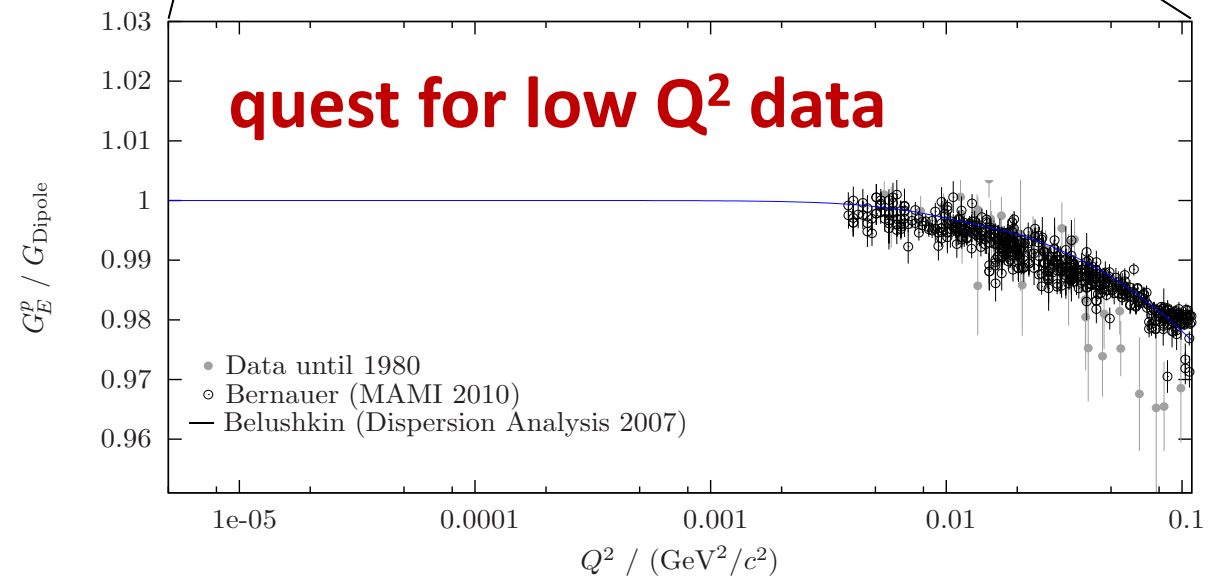
A1/MAMI

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_{\text{Mott}} \frac{1}{\epsilon(1+\tau)} [\epsilon G_E^2(Q^2) + \tau G_M^2(Q^2)]$$



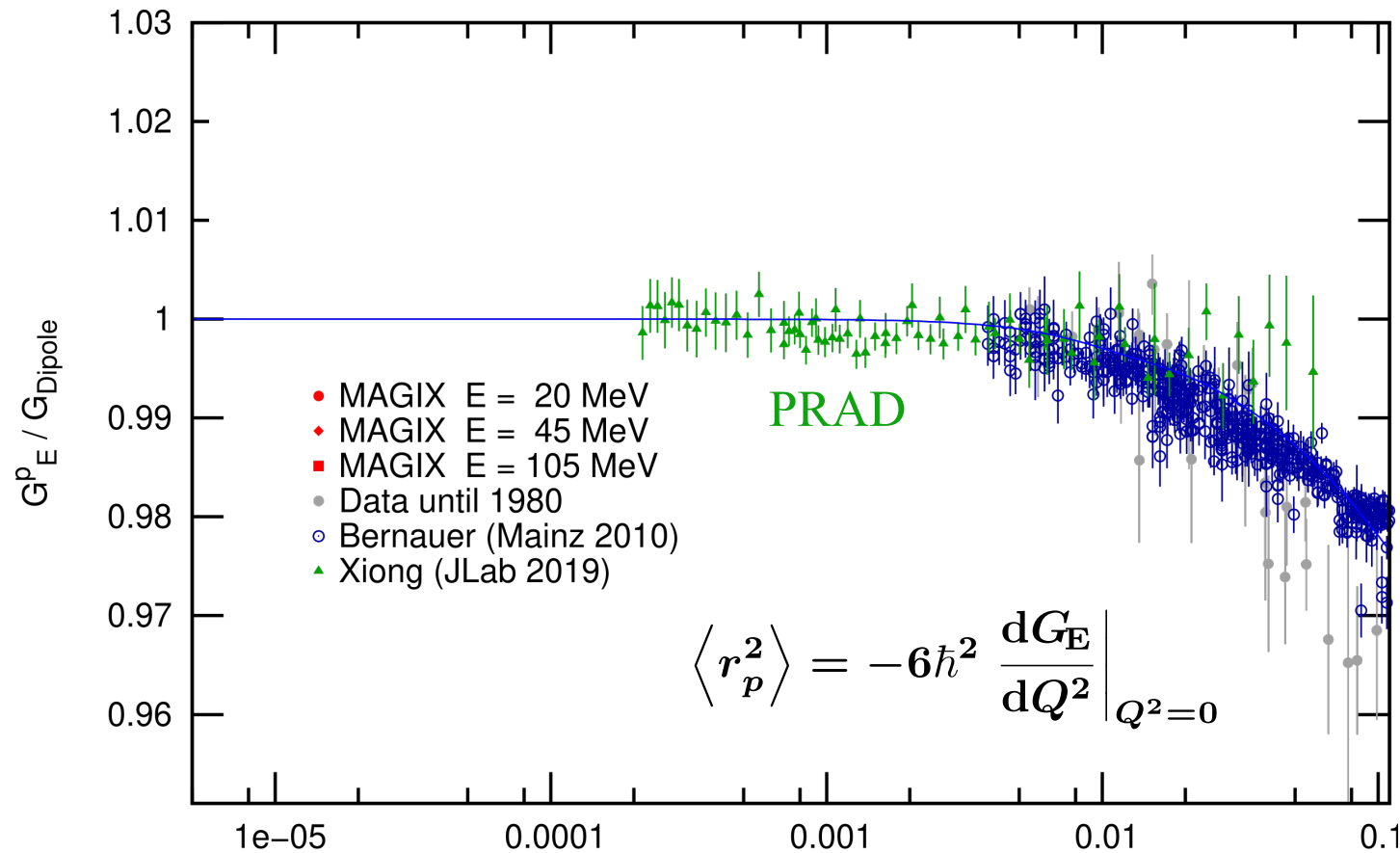
$$\langle r_p^2 \rangle = -6\hbar^2 \left. \frac{dG_E}{dQ^2} \right|_{Q^2=0}$$

quest for low Q^2 data

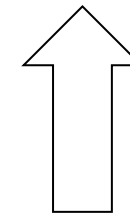
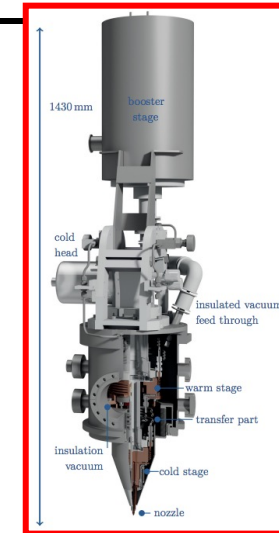


Electromagnetic Form Factors at MAGIX

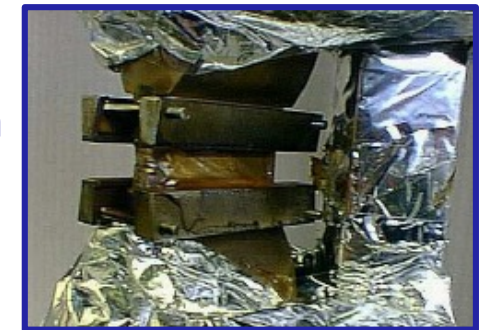
MAGIX: Coverage from $Q^2 = 1 \cdot 10^{-5}$ to 0.03 GeV^2
→ proton charge and magnetic radius!



**MAGIX:
truly
windowless
gas target**



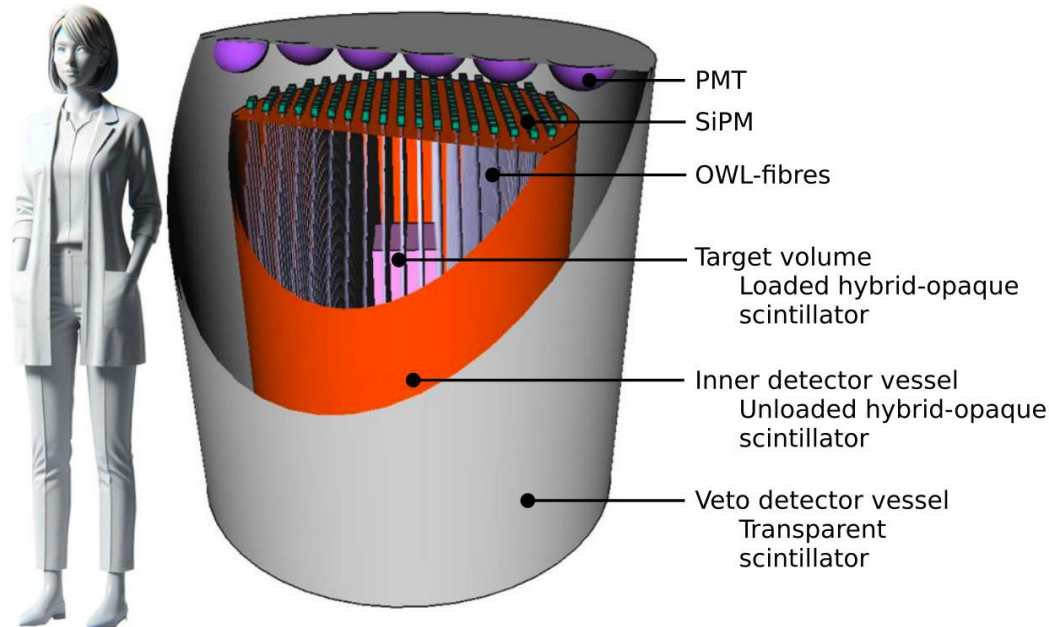
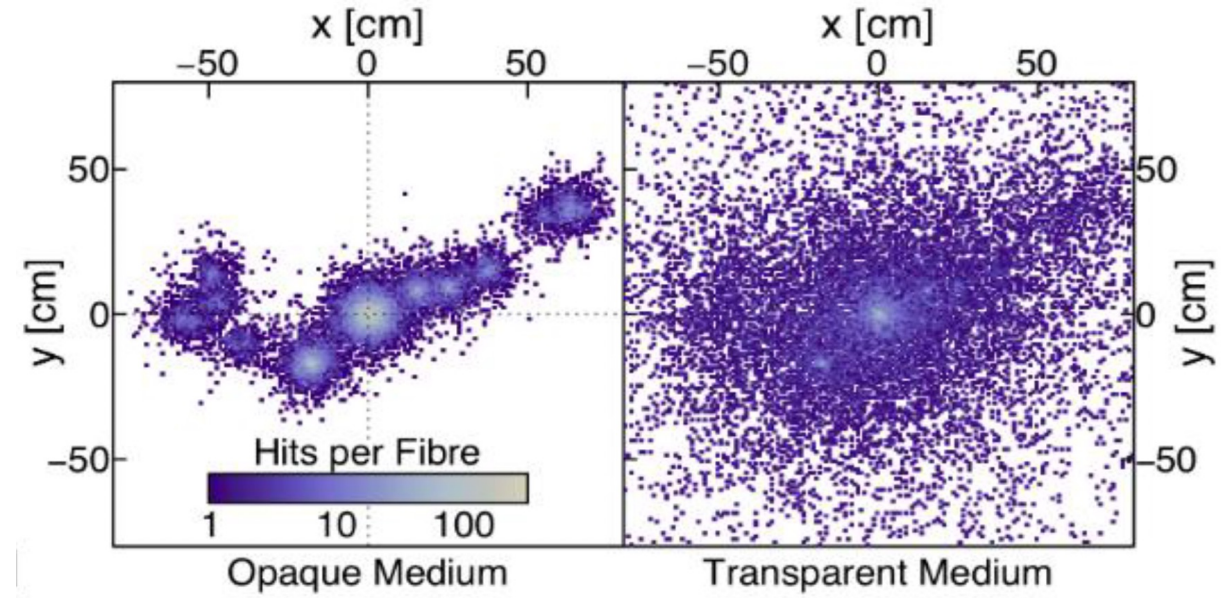
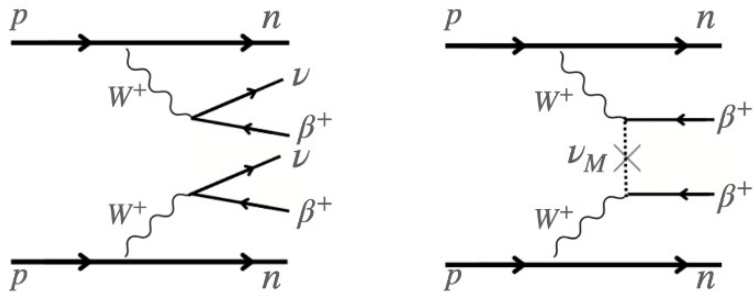
**A1 data:
scattering on
 LH_2 target
target walls**



Opaque Scintillators – Synergy with NuDoubt++

NuDoubt++ - an experiment to look for (neutrino-less) double beta+ decays

Technology choice: opaque liquid scintillator; readout via grid of scintillating fibres

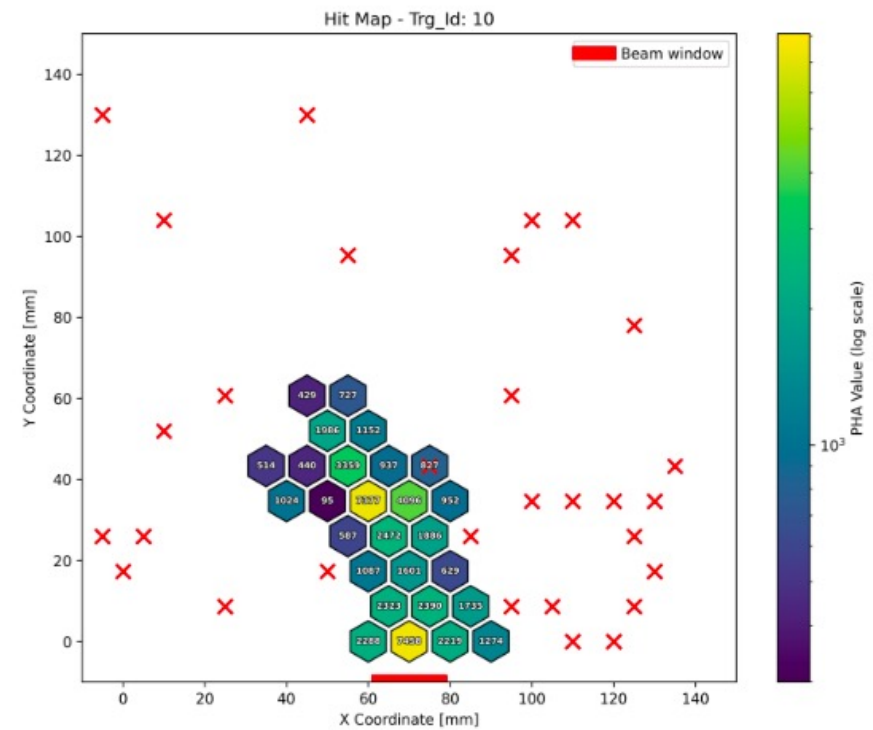
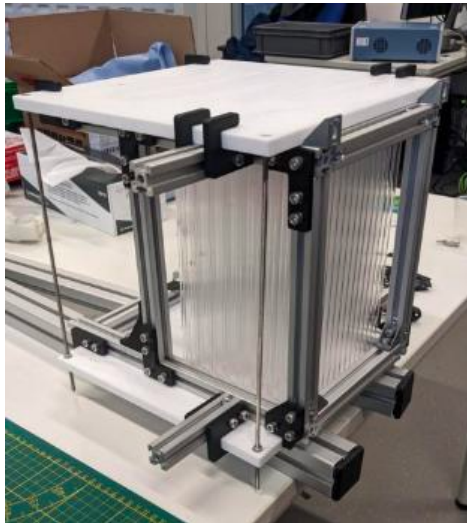


Opaque medium
(1 ... 20% wax):
Signal confined, PID

Transparent medium:
signal washed out

Opaque Scintillators for DarkMESA

Prototype test at MAMI (Nov. 2025)
with 7 – 14 MeV electrons



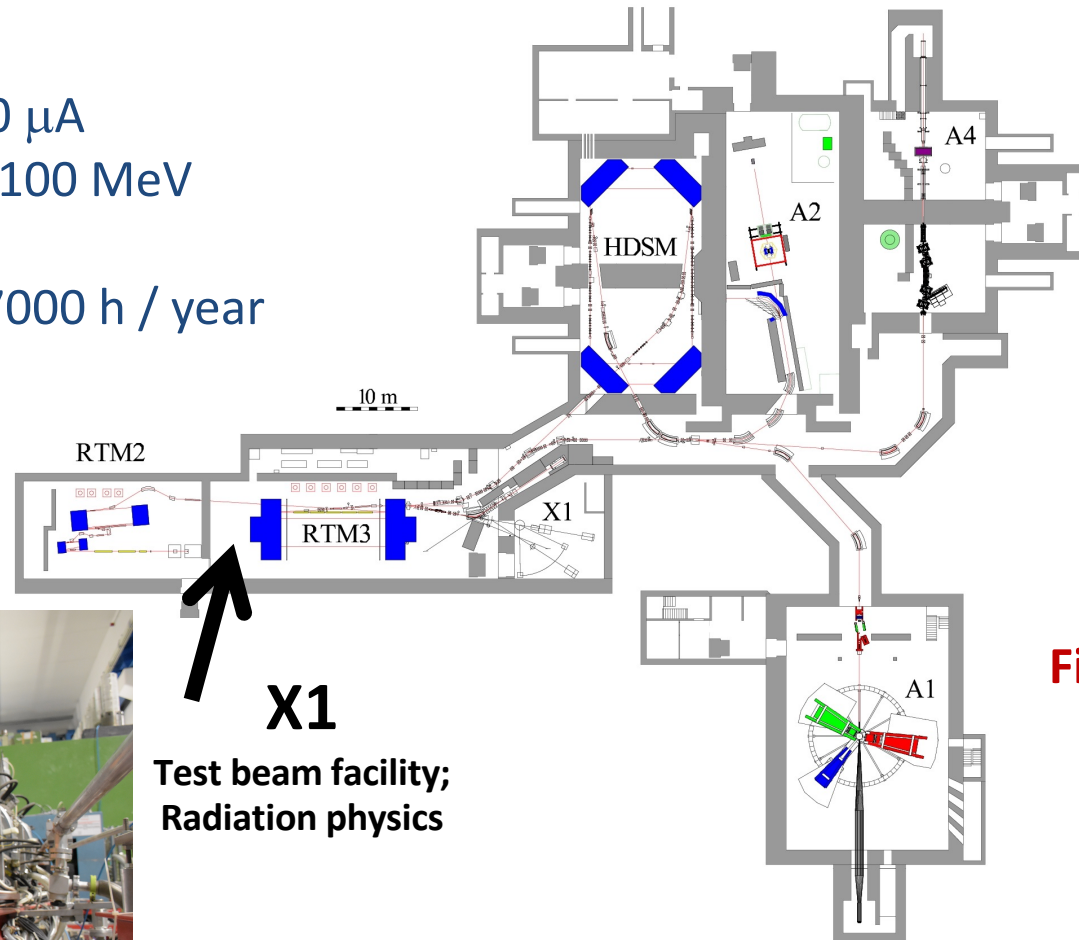
↑
MAMI electrons

Successfully tested electron tracking in opaque liquid scintillator
Option to use Gd-loaded scintillator for veto detector

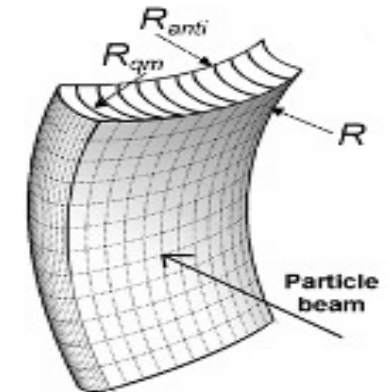
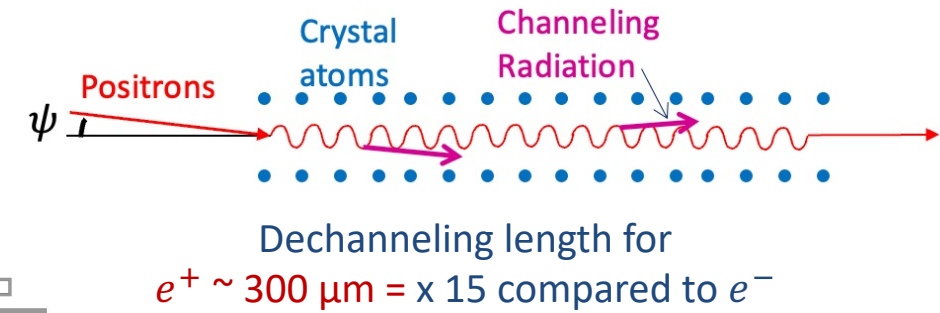
The Mainz Microtron MAMI

**Electron Accelerator $E = 0.185 \text{ GeV} - 1.6 \text{ GeV}$ (CW – 2.45 GHz)
operated at JGU Mainz
Hallmarks**

- Intensity max. $100 \mu\text{A}$
- Resolution $\sigma_E < 0.100 \text{ MeV}$
- Polarization 85%
- Reliability: up to 7000 h / year



X1
Test beam facility;
Radiation physics



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

Phys. Rev. Lett. 135 (2025) 205002

History of Accelerator Physics at Mainz

1957 Foundation of the Institute for Nuclear Physics JGU Mainz
Founding director: Prof. Herwig Schopper (1924-2025)

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

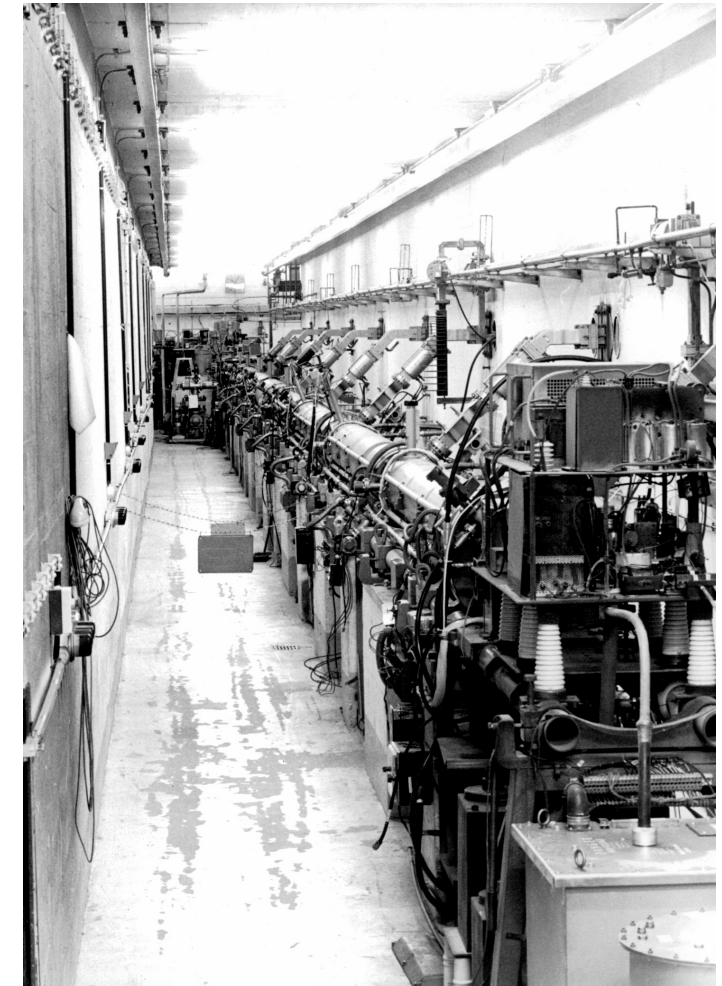
NEW

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

2027++ Mainz Energy-recovering Superconducting Accelerator (**MESA**)
Double-sided Multi Turn Energy Recovery Linac (ERL)
~20-155 MeV, high-intensity cw beam



Few Body Physics at MAGIX

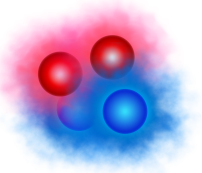
MAGIX provides ideal environment for precision Few Body Physics

→ Elastic scattering: improved determination of charge radii (d, ^3He , ^4He) from e^- scattering

→ Inelastic processes as input for reduced model uncertainties of two-photon corrections and test of χEFT theory

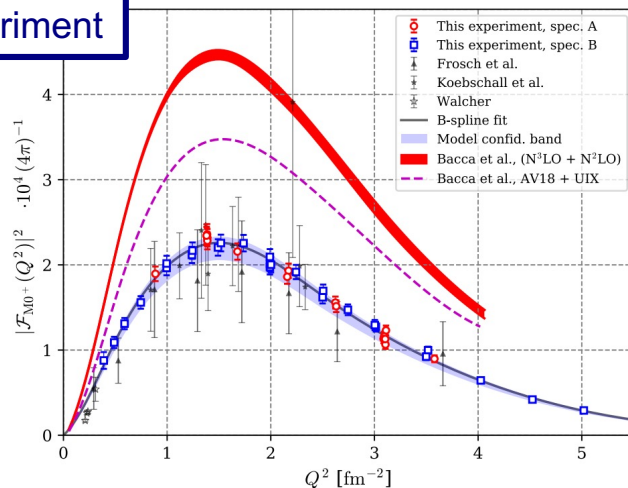
Example:

^4He monopole TFF recently measured at A1/MAMI: Q^2 dependence of $e^- \ ^4\text{He} (0^+) \rightarrow e^- \ ^4\text{He}^* (0^+)$

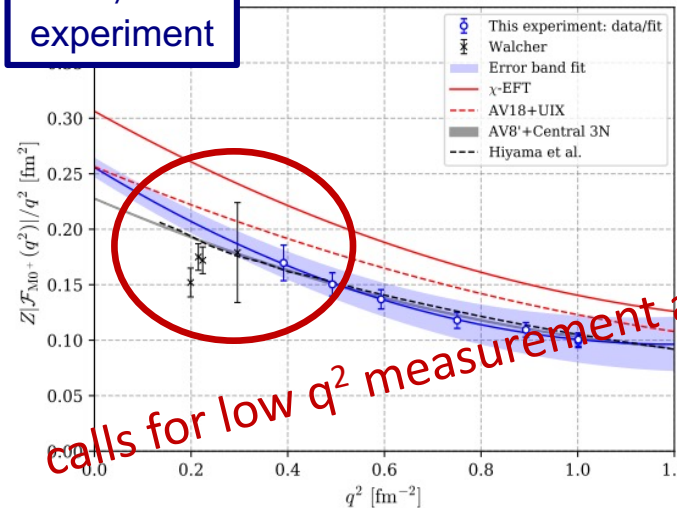


Kegel et al. [A1] PRL2023

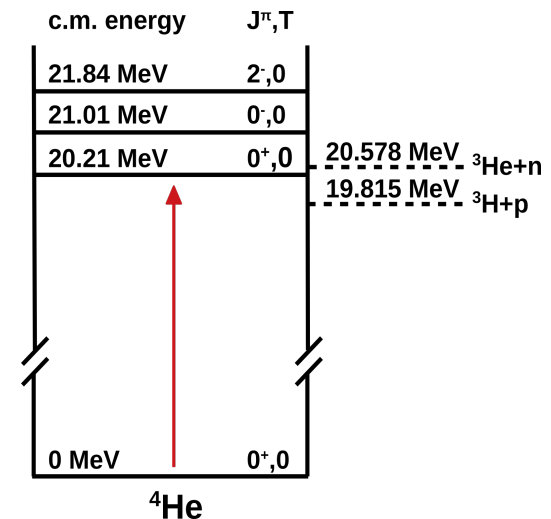
χEFT theory
≠
experiment



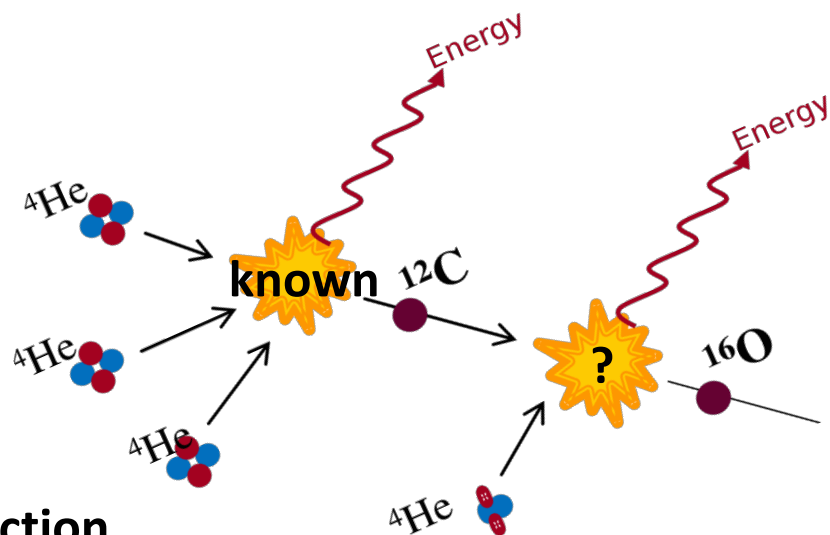
experiment
≠
experiment



calls for low q^2 measurement at MAGIX



Nuclear Astrophysics Reactions at MAGIX



Cross section
as function of $E_{\text{c.m.}}$

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

Compton
wave length

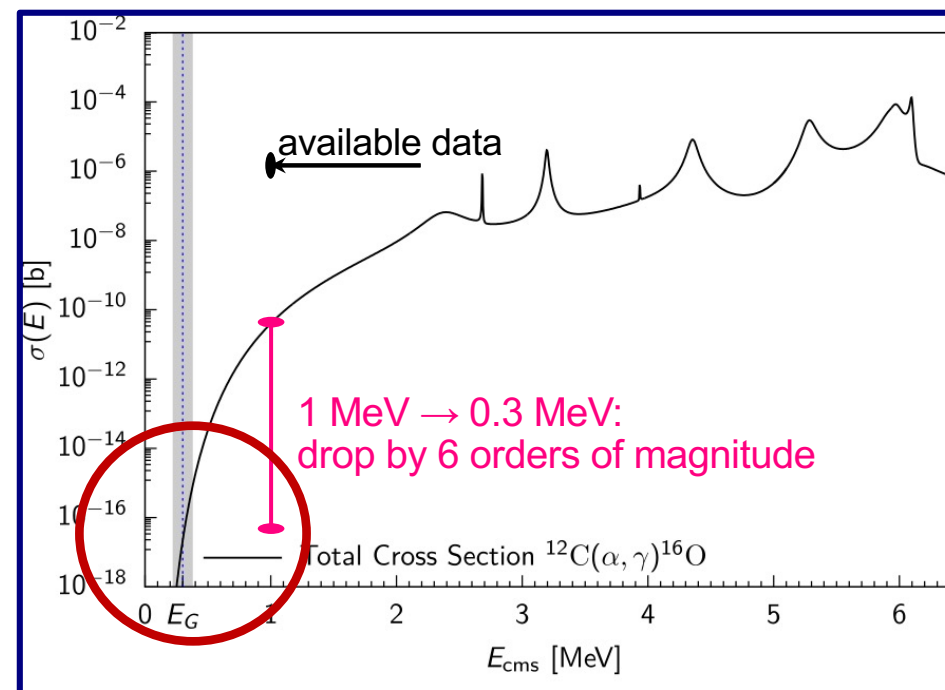
Tunneling
probability
in fusion process

„S factor“

unknown nuclear physics \rightarrow needs to be known at Gamow Peak ~ 0.3 MeV

${}^{12}\text{C}(\alpha, \gamma){}^{16}\text{O}$ reaction

- Of fundamental importance for star burning
- Determines ${}^{12}\text{C} / {}^{16}\text{O}$ abundance
- Influences the nucleosynthesis of heavy elements



$^{16}\text{O}(\gamma, \alpha)^{12}\text{C}$ Reaction at MAGIX

- Inverse reaction: $^{16}\text{O}(\gamma, \alpha)^{12}\text{C}$
- Chose kinematics with quasi-real photon
- Factor of 100 improvement in cross section wrt. original reaction
- Simulation of process
- Development of Si-detector for α particle detection

