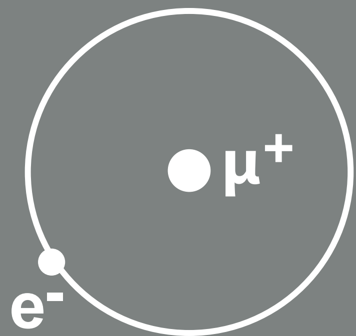
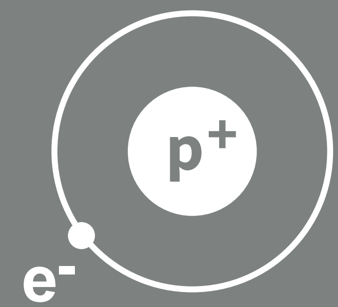
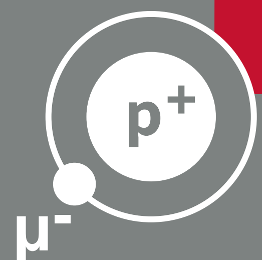


Finite-size Effects & New Physics



Sotiris Pitelis

in collaboration with F. Hagelstein, V. Lensky and V. Pascalutsa



31.07.25

JG|U JOHANNES GUTENBERG UNIVERSITÄT MAINZ

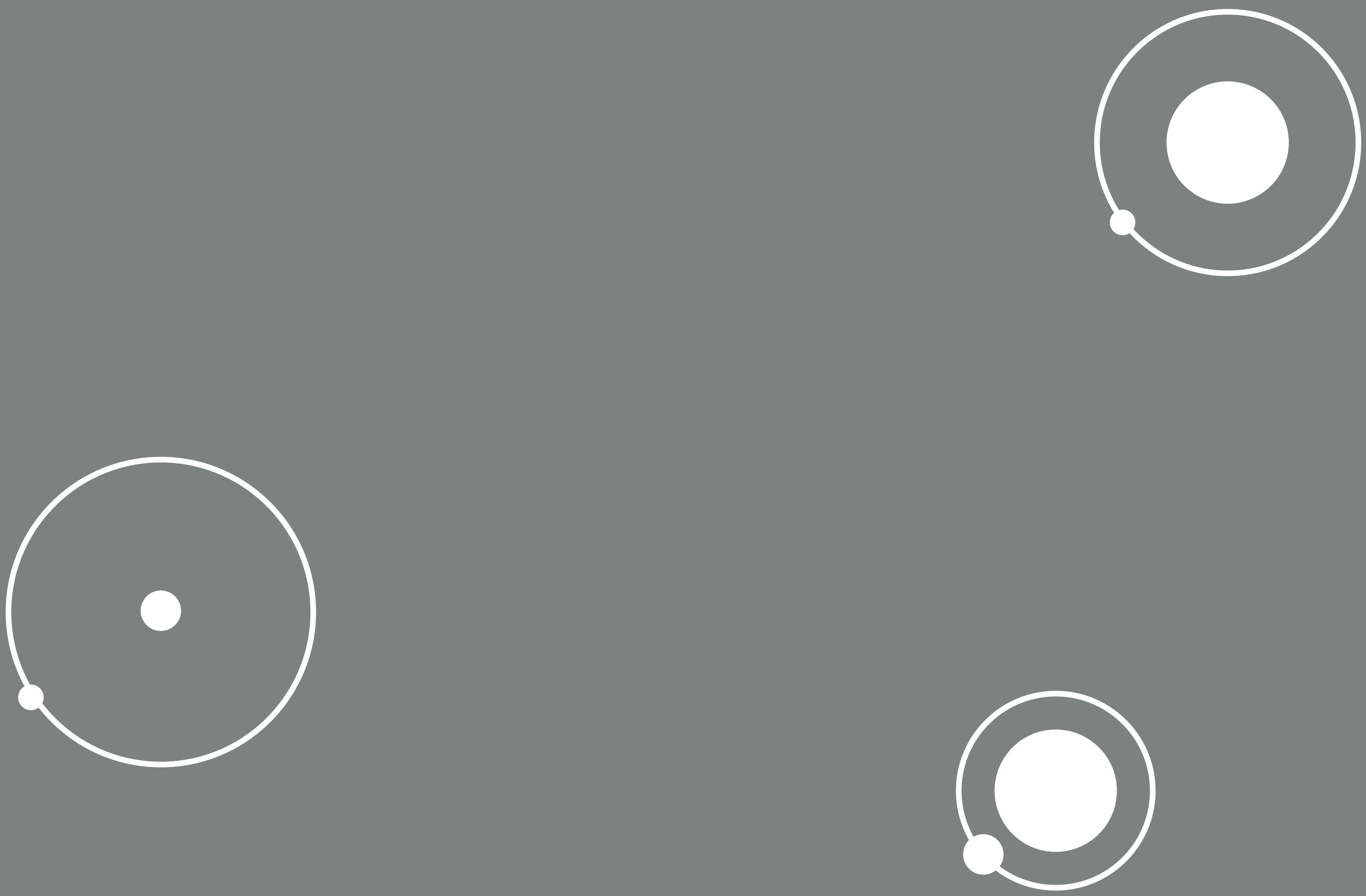
FONDAZIONE BRUNO KESSLER

ECT* EUROPEAN CENTRE FOR THEORETICAL STUDIES IN NUCLEAR PHYSICS AND RELATED AREAS

Emmy Noether-Programm

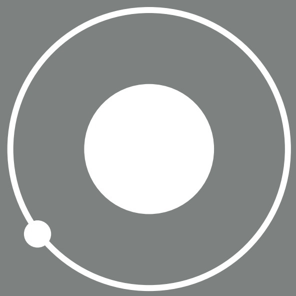
DFG Deutsche Forschungsgemeinschaft

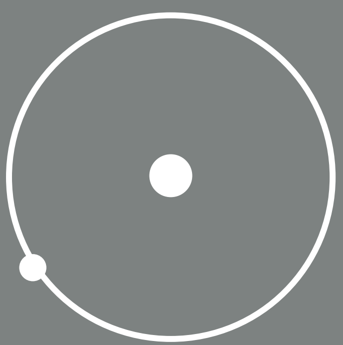
A brief outline



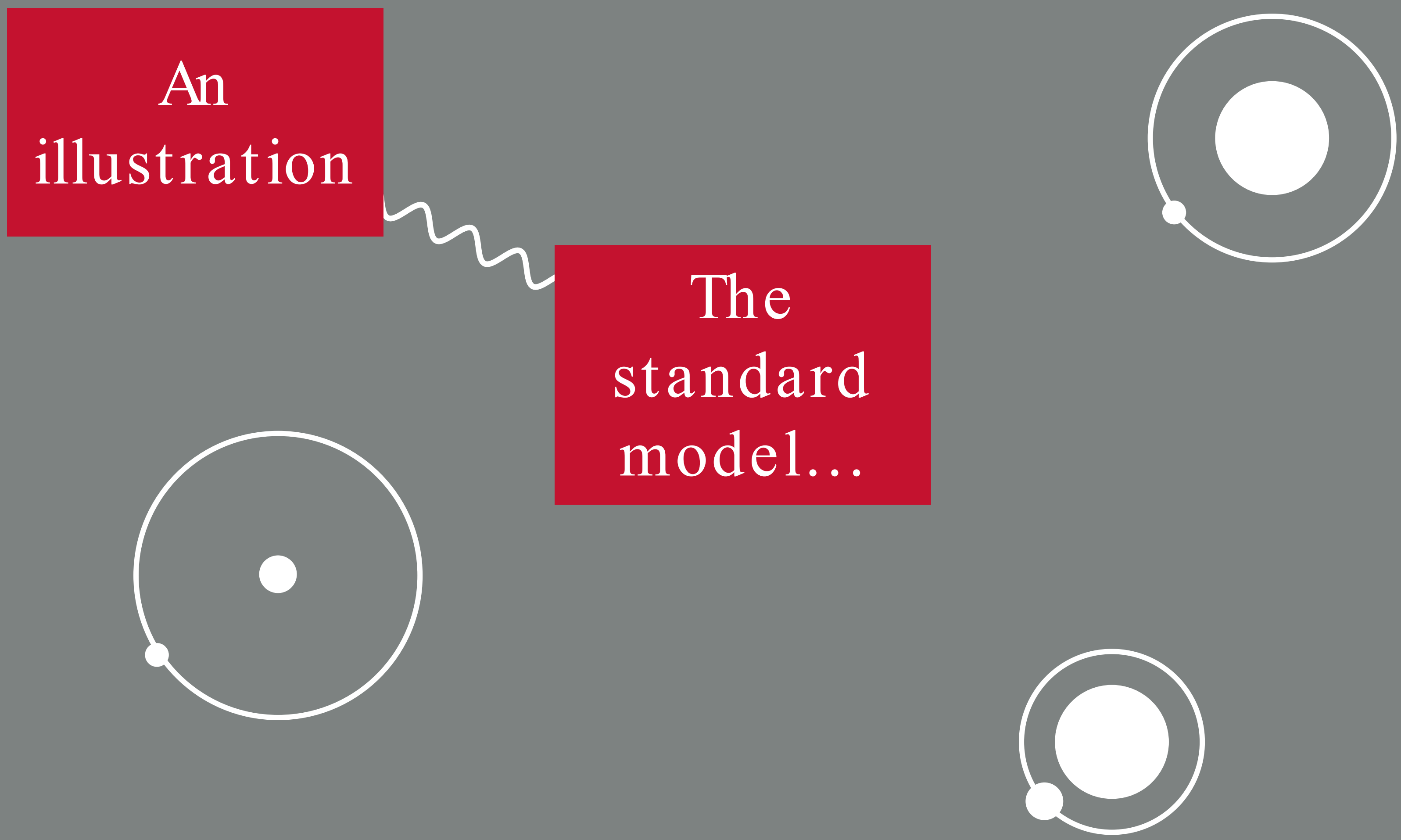
A brief outline

An illustration





A brief outline



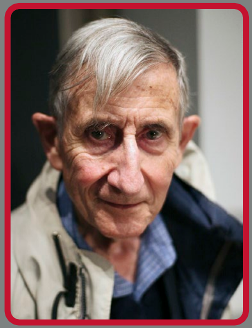
A brief outline

An illustration

The standard model...

...and beyond

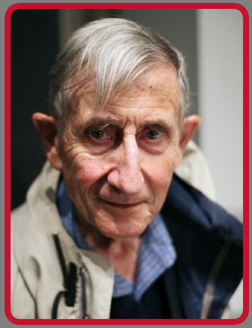
Frontiers of New Physics Searches



"If you look for nature's secrets in only one direction, you are likely to miss the most important secrets…"

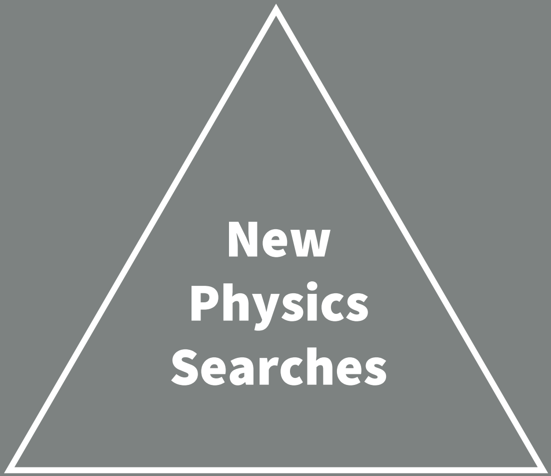
-Freeman Dyson

Frontiers of New Physics Searches

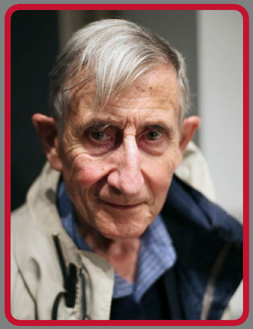


"If you look for nature's secrets in only one direction, you are likely to miss the most important secrets..."

-Freeman Dyson

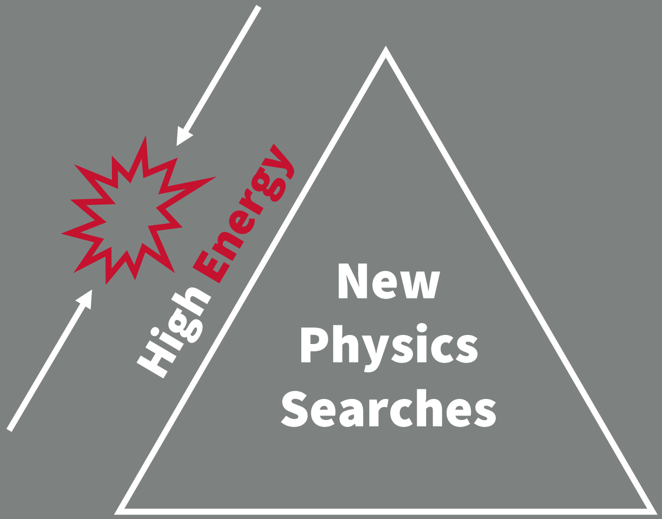


Frontiers of New Physics Searches

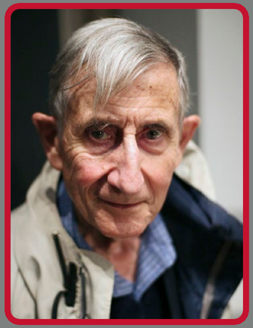


"If you look for nature's secrets in only one direction, you are likely to miss the most important secrets..."

-Freeman Dyson

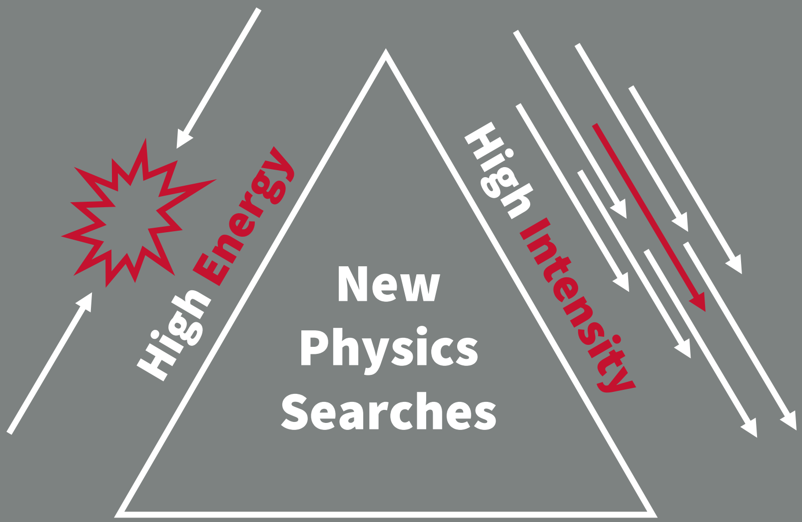


Frontiers of New Physics Searches

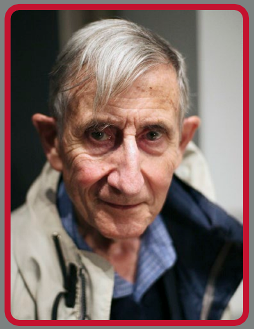


"If you look for nature's secrets in only one direction, you are likely to miss the most important secrets..."

-Freeman Dyson

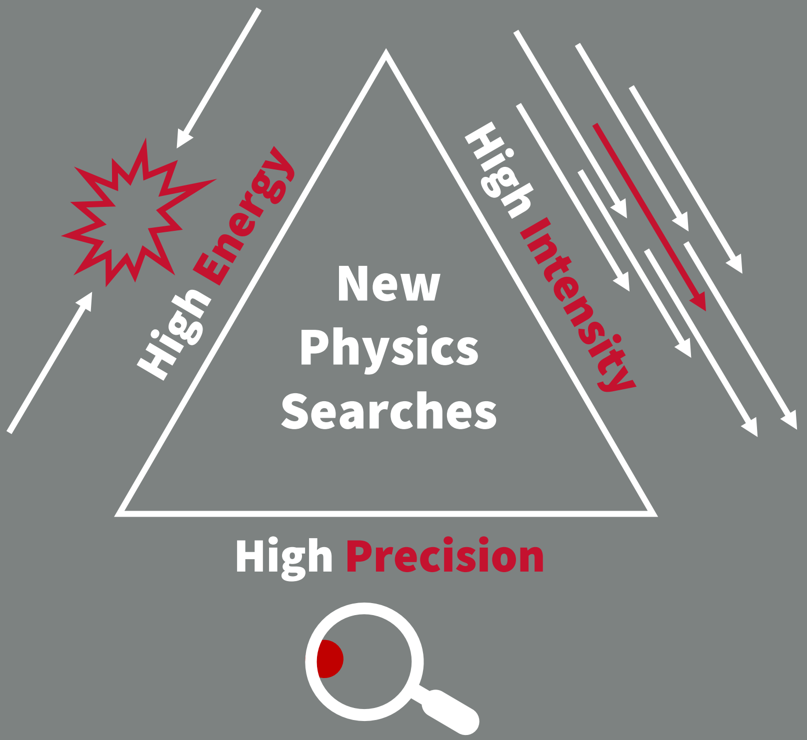


Frontiers of New Physics Searches

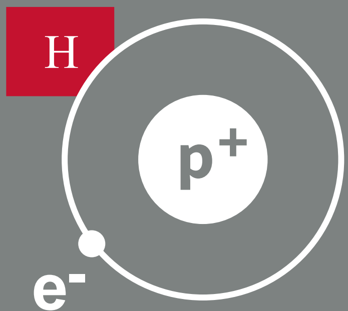


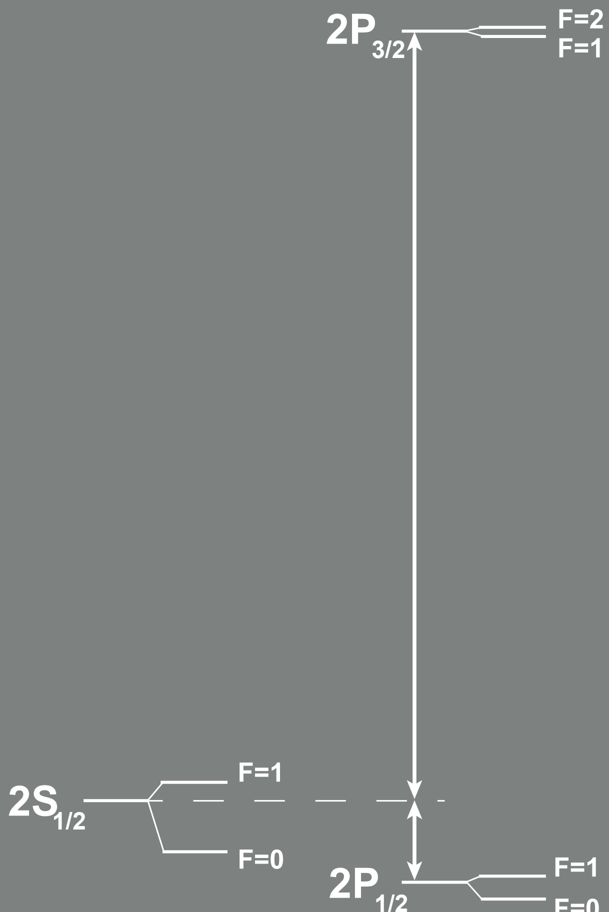
"If you look for nature's secrets in only one direction, you are likely to miss the most important secrets..."

-Freeman Dyson

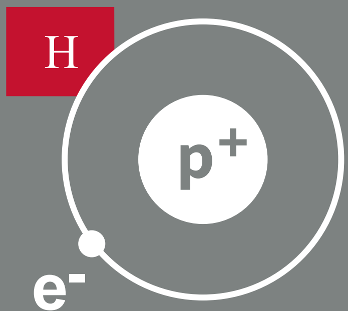


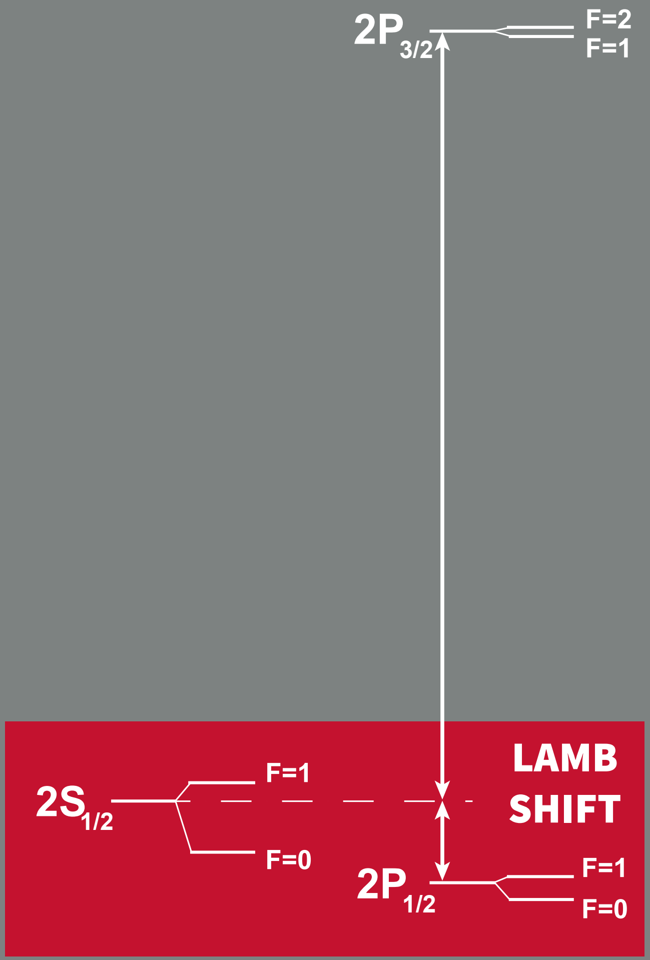
Precision Atomic Spectroscopy



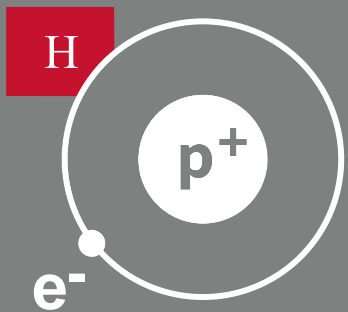


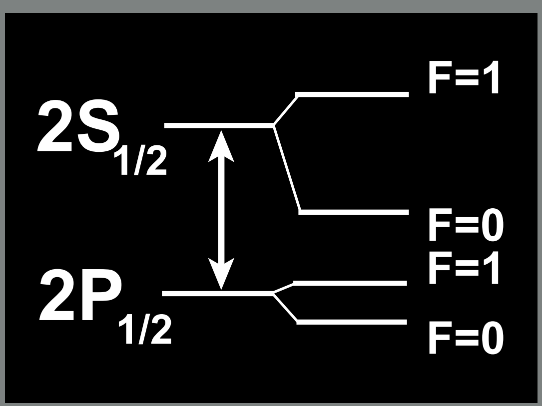
Precision Atomic Spectroscopy



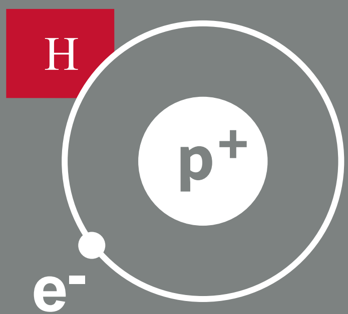


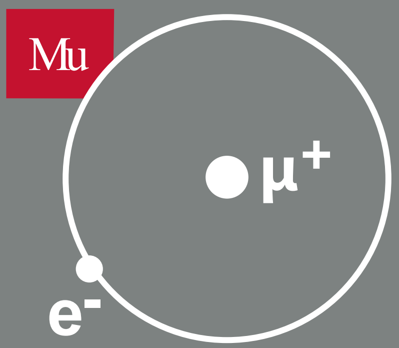
Precision Atomic Spectroscopy

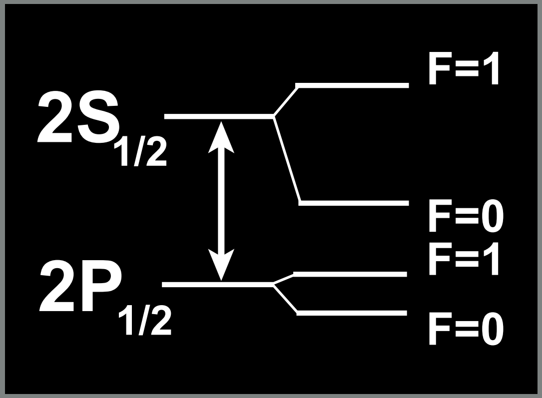




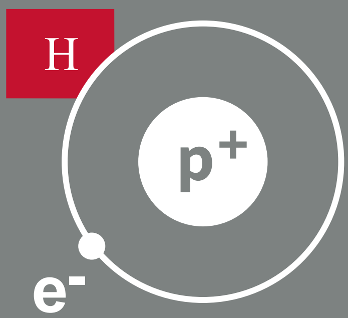
Precision Atomic Spectroscopy

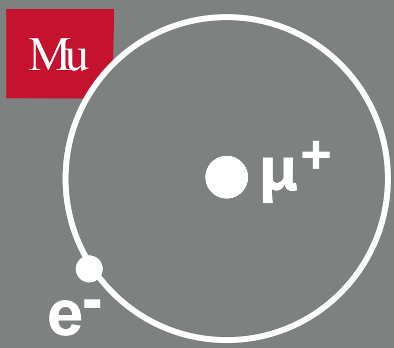


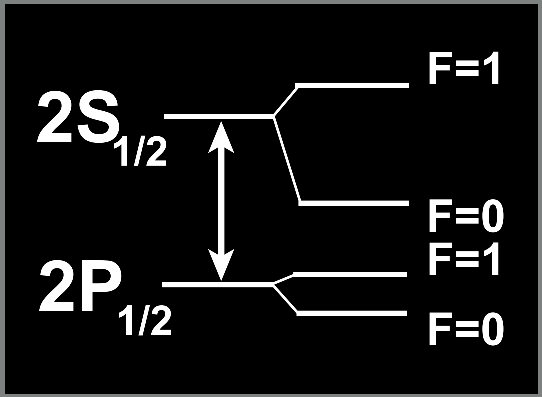


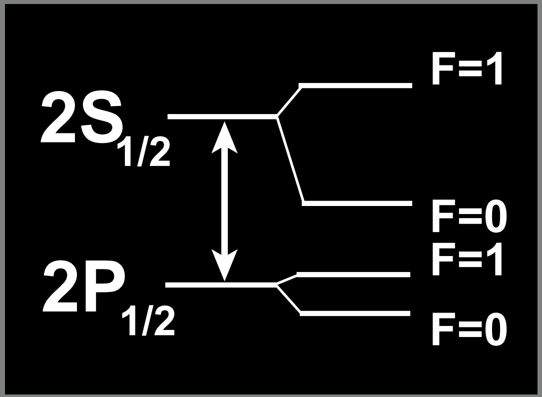


Precision Atomic Spectroscopy

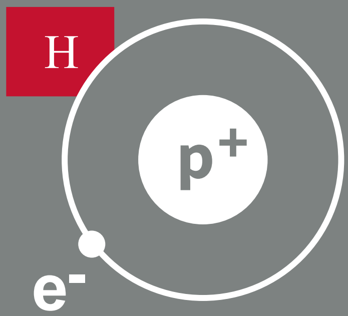


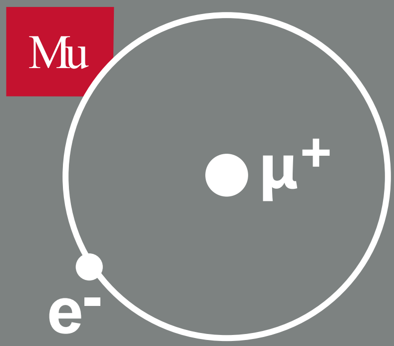


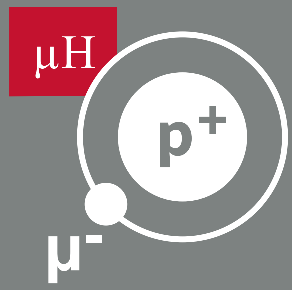


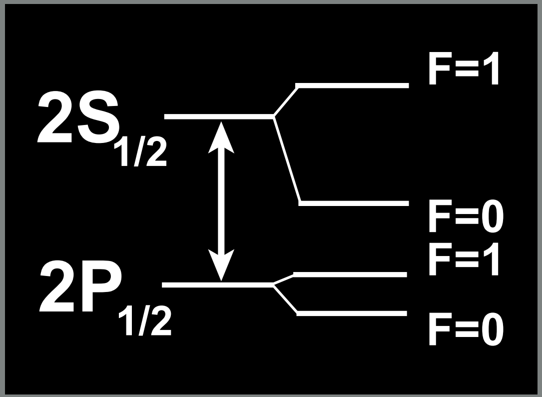


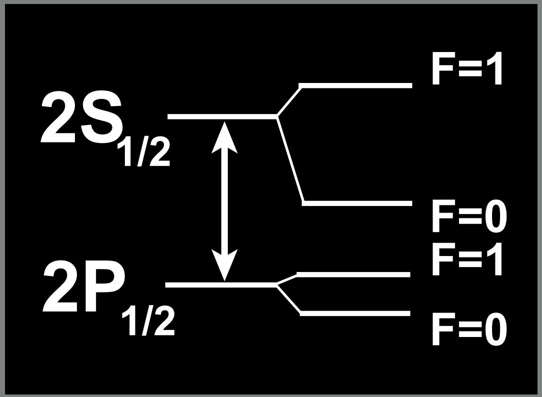
Precision Atomic Spectroscopy



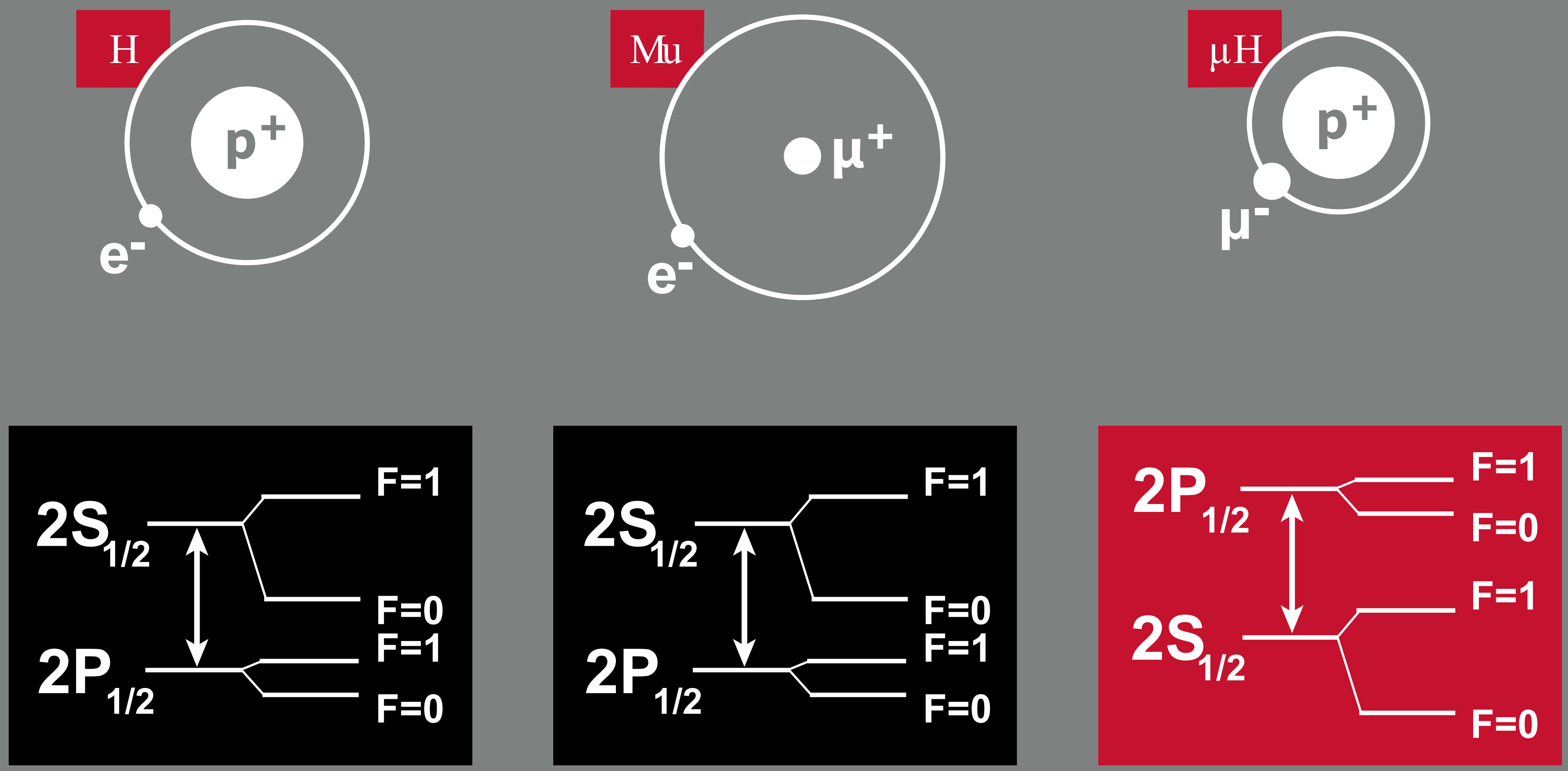




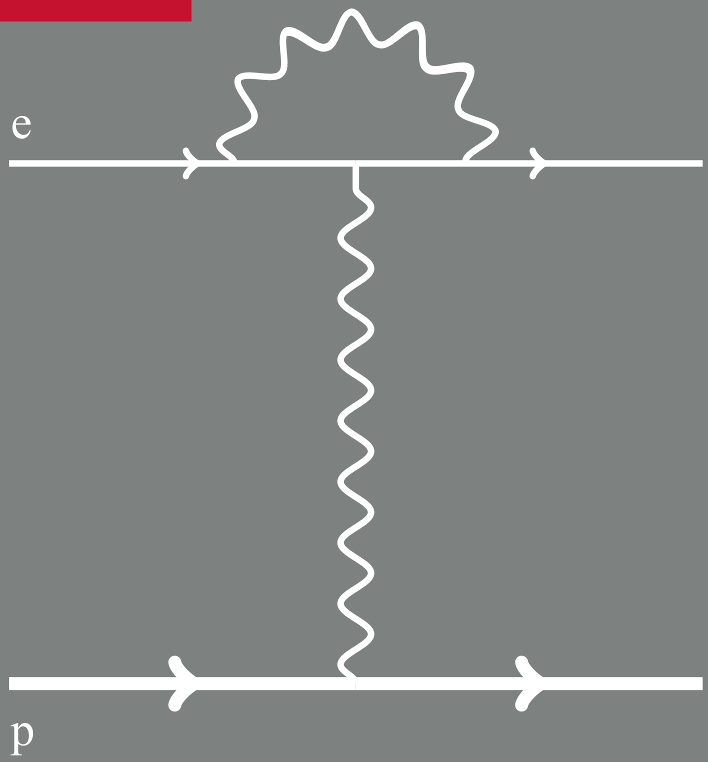




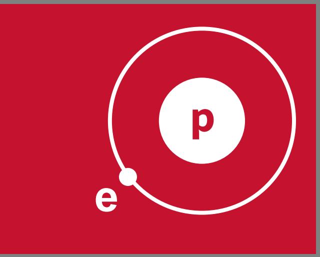
Precision Atomic Spectroscopy

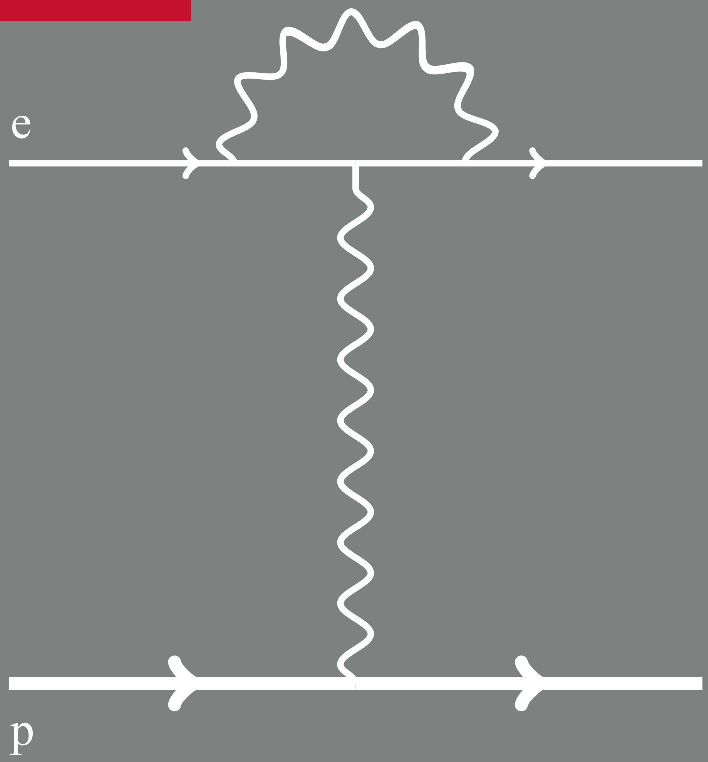


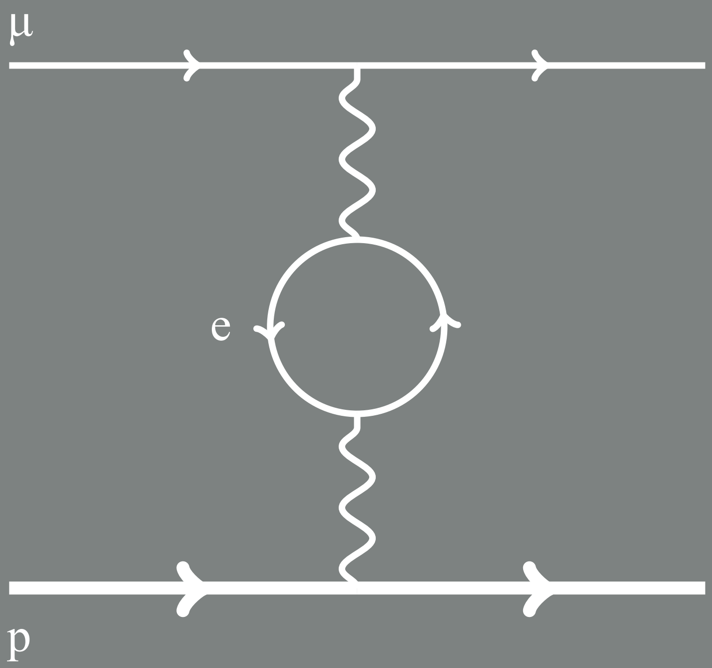
Leading QED Corrections



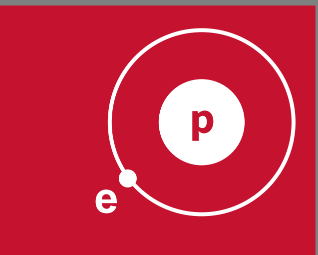
Leading QED Corrections

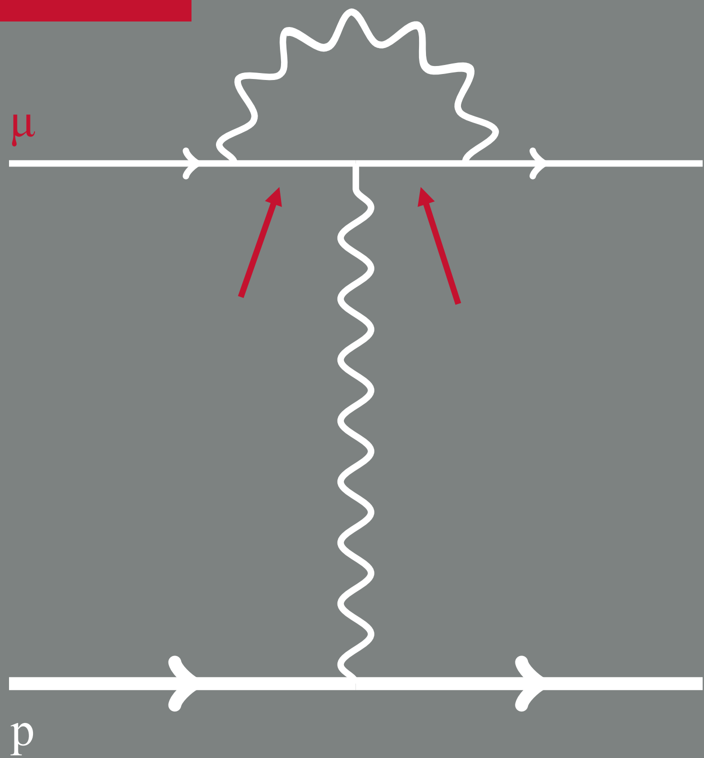


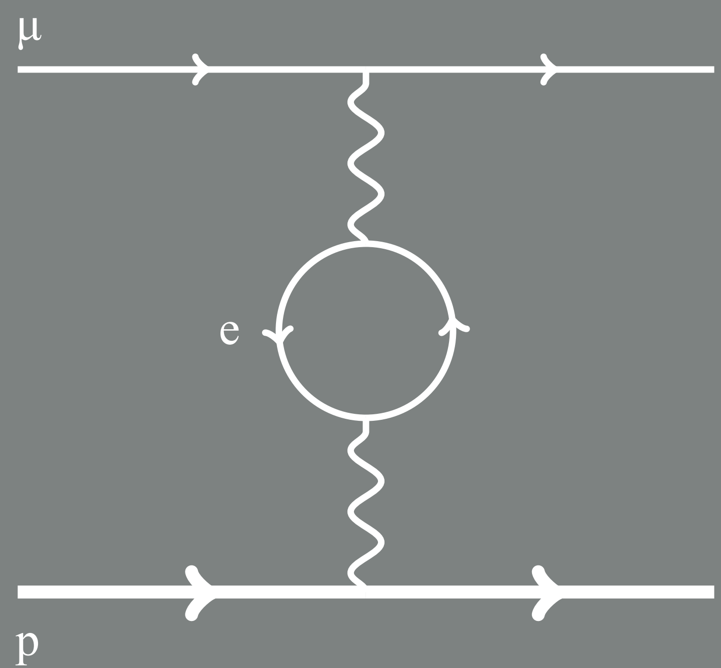




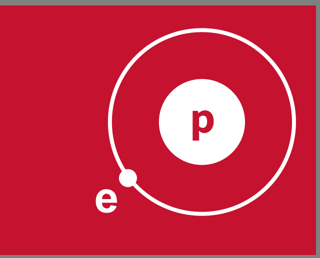
Leading QED Corrections

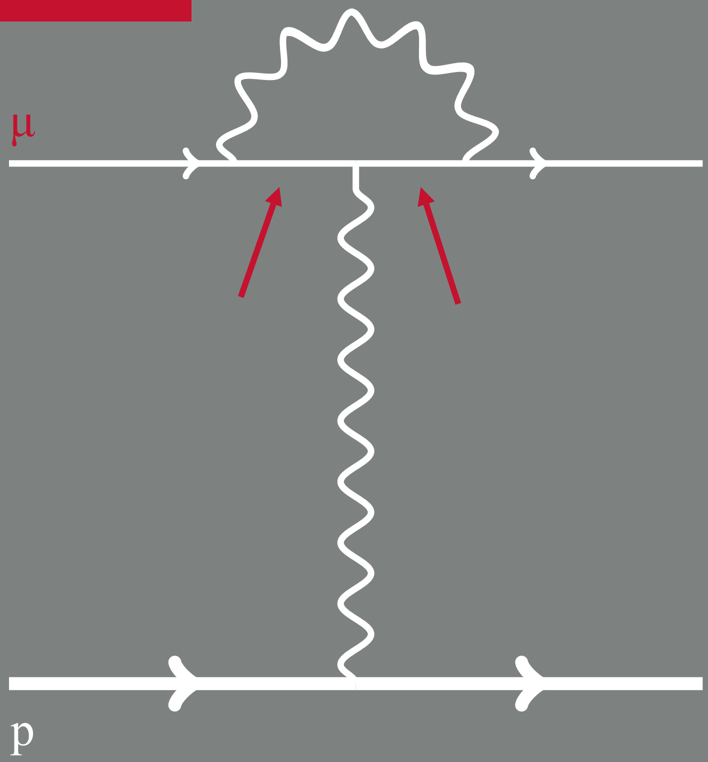


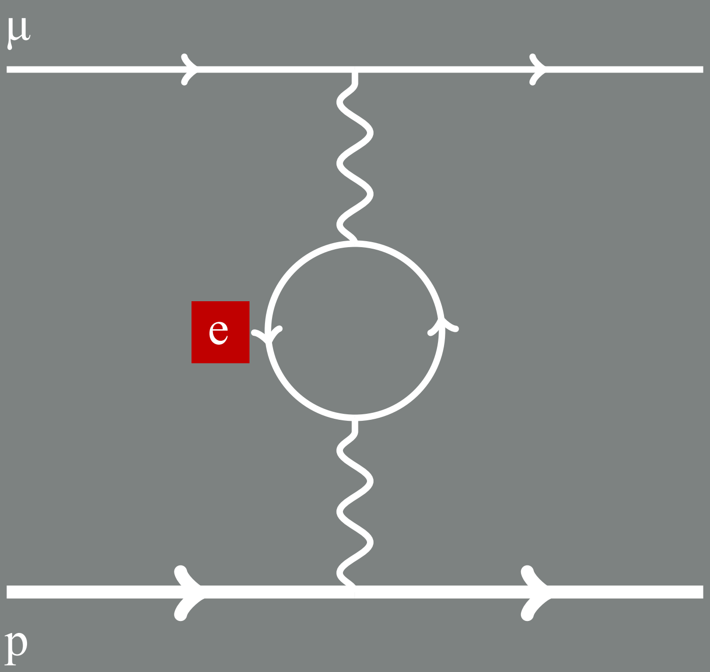




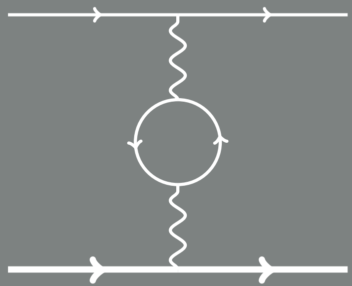
Leading QED Corrections







Electronic Vacuum Polarization in μH

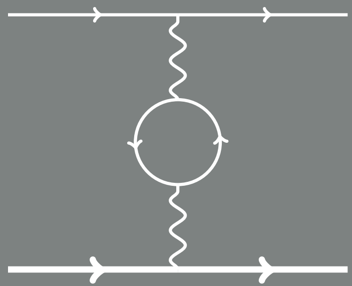


DOI: 10.1103/RevModPhys.96.015001

Sec.	Order	Correction	μH
III.A	$\alpha\,(Z\,\alpha)^2$	$\mathrm{eVP}^{(1)}$	205.007 38
III.A	$\alpha^2\,(Z\,\alpha)^2$	$\mathrm{eVP}^{(2)}$	1.658 85
III.A	$\alpha^3\,(Z\,\alpha)^2$	$\mathrm{eVP}^{(3)}$	0.007 52
III.B	$(Z, Z^2, Z^3)\,\alpha^5$	light by light eVP	−0.000 89(2)
III.C	$(Z\,\alpha)^4$	recoil	0.057 47
III.D	$\alpha\,(Z\,\alpha)^4$	relativistic with $\mathrm{eVP}^{(1)}$	0.018 76
III.E	$\alpha^2\,(Z\,\alpha)^4$	relativistic with $\mathrm{eVP}^{(2)}$	0.000 17

⋮

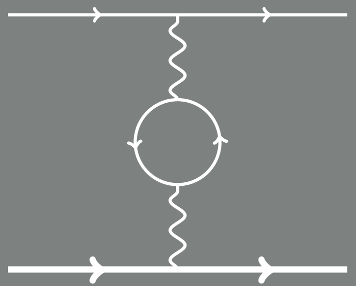
Electronic Vacuum Polarization in μH



DOI: 10.1103/RevModPhys.96.015001

Sec.	Order	Correction	μH
III.A	$\alpha\,(Z\,\alpha)^2$	eVP$^{(1)}$	205.007 38
III.A	$\alpha^2\,(Z\,\alpha)^2$	eVP$^{(2)}$	1.658 85
III.A	$\alpha^3\,(Z\,\alpha)^2$	eVP$^{(3)}$	0.007 52
III.B	$(Z, Z^2, Z^3)\,\alpha^5$	light by light eVP	−0.000 89(2)
III.C	$(Z\,\alpha)^4$	recoil	0.057 47
III.D	$\alpha\,(Z\,\alpha)^4$	relativistic with eVP$^{(1)}$	0.018 76
III.E	$\alpha^2\,(Z\,\alpha)^4$	relativistic with eVP$^{(2)}$	0.000 17
⋮			
III	E_{QED}	point nucleus	206.034 4(3)

Electronic Vacuum Polarization in μH



DOI: 10.1103/RevModPhys.96.015001

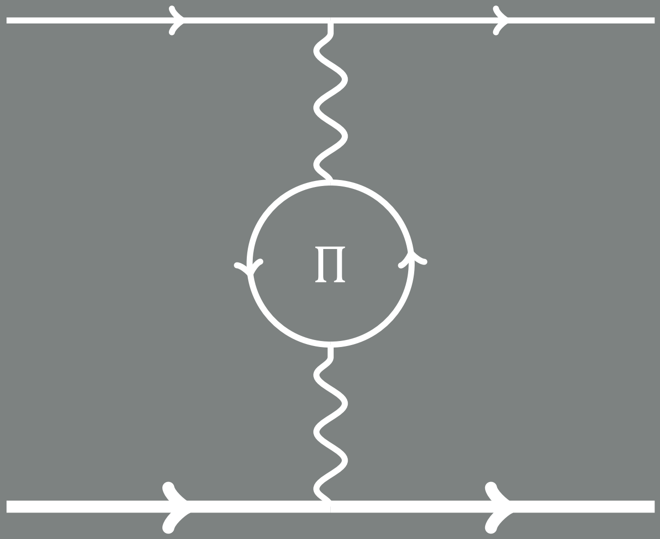
Sec.	Order	Correction	μH
III.A	$\alpha\,(Z\,\alpha)^2$	eVP$^{(1)}$	205.007 38
III.A	$\alpha^2\,(Z\,\alpha)^2$	eVP$^{(2)}$	1.658 85
III.A	$\alpha^3\,(Z\,\alpha)^2$	eVP$^{(3)}$	0.007 52
III.B	$(Z, Z^2, Z^3)\,\alpha^5$	light by light eVP	−0.000 89(2)
III.C	$(Z\,\alpha)^4$	recoil	0.057 47
III.D	$\alpha\,(Z\,\alpha)^4$	relativistic with eVP$^{(1)}$	0.018 76
III.E	$\alpha^2\,(Z\,\alpha)^4$	relativistic with eVP$^{(2)}$	0.000 17

⋮

III	E_{QED}	point nucleus	206.034 4(3)

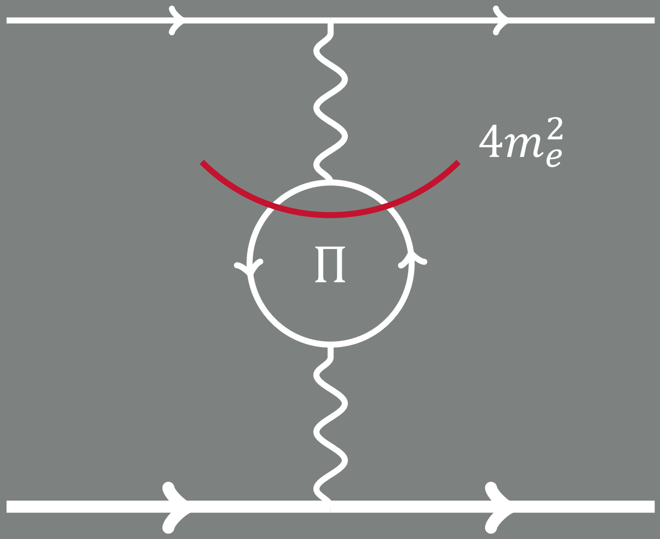
Dispersive Calculation of the eVP Contribution

$$E^{\langle \mathrm{eVP} \rangle}_{2P-2S} = -\frac{(Z\alpha)^4 m_r^3}{2\pi} \int_{4m_e^2}^{\infty} \mathrm{d}t \, \frac{\alpha \, \mathrm{Im}\Pi(t)}{\left(\sqrt{t} + Z\alpha m_r\right)^4}$$



Dispersive Calculation of the eVP Contribution

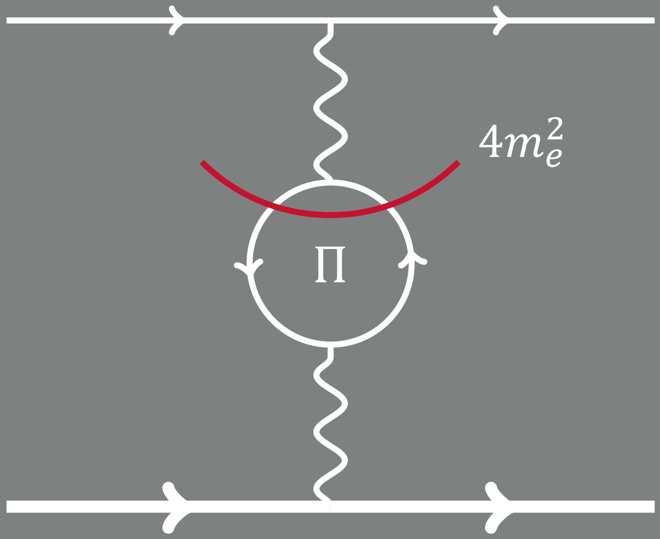
$$E_{2P-2S}^{\langle \mathrm{eVP} \rangle} = -\frac{(Z\alpha)^4 m_r^3}{2\pi} \int_{4m_e^2}^{\infty} \mathrm{d}t \, \frac{\alpha \, \mathrm{Im}\Pi(t)}{\left(\sqrt{t} + Z\alpha m_r\right)^4}$$



Dispersive Calculation of the eVP Contribution

$$E_{2P-2S}^{\langle \mathrm{eVP} \rangle} = -\frac{(Z\alpha)^4 m_r^3}{2\pi} \int_{4m_e^2}^{\infty} \mathrm{d}t \, \frac{\alpha \, \mathrm{Im}\Pi(t)}{\left(\sqrt{t} + Z\alpha m_r\right)^4}$$

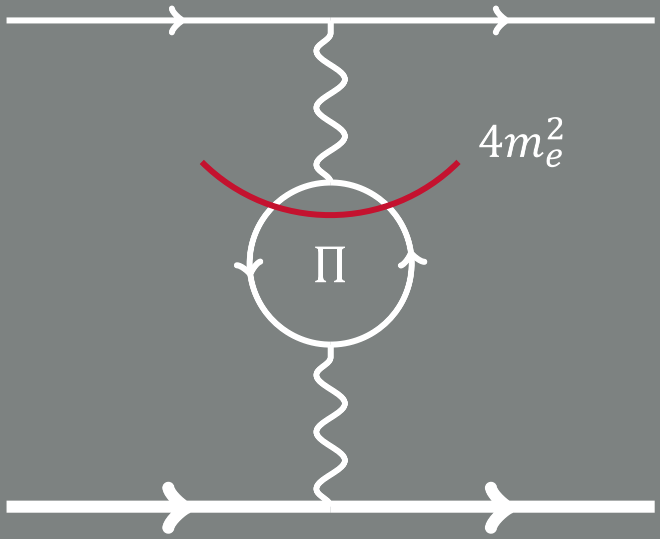
$$= -\frac{\alpha (Z\alpha)^4 m_r^3}{4m_e^2} \frac{1}{2\pi} \int_{1}^{\infty} \mathrm{d}t \, \frac{\mathrm{Im}\Pi(4m_e^2 \, t)}{\left(\sqrt{t} + \frac{m_r}{2 \, m_e} Z\alpha\right)^4}$$



Dispersive Calculation of the eVP Contribution

$$E_{2P-2S}^{\langle\mathrm{eVP}\rangle} = -\frac{(Z\alpha)^4 m_r^3}{2\pi}\int_{4m_e^2}^{\infty}\mathrm{d}t\,\frac{\alpha\,\mathrm{Im}\Pi(t)}{\left(\sqrt{t}+Z\alpha m_r\right)^4}$$

$$= -\boxed{\frac{\alpha(Z\alpha)^4 m_r^3}{4m_e^2}}\frac{1}{2\pi}\int_1^{\infty}\mathrm{d}t\,\frac{\mathrm{Im}\Pi(4m_e^2\,t)}{\left(\sqrt{t}+\frac{m_r}{2\,m_e}Z\alpha\right)^4}$$

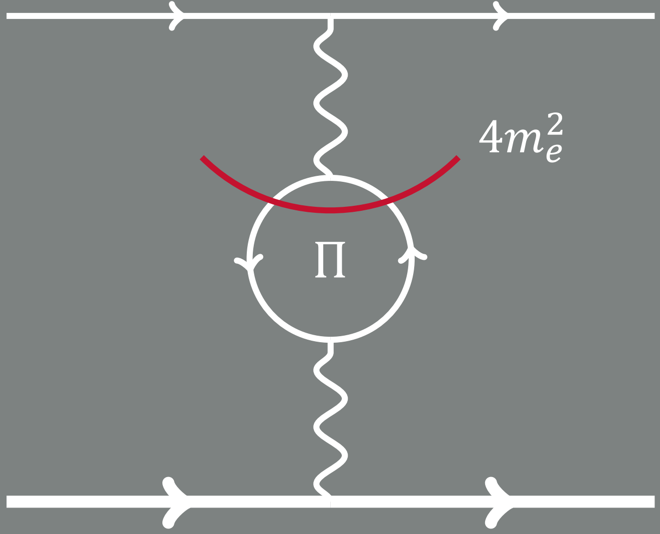


Dispersive Calculation of the eVP Contribution

$$E^{\langle \mathrm{eVP} \rangle}_{2P-2S} = -\frac{(Z\alpha)^4 m_r^3}{2\pi} \int_{4m_e^2}^{\infty} \mathrm{d}t \, \frac{\alpha \, \mathrm{Im}\Pi(t)}{\left(\sqrt{t} + Z\alpha m_r\right)^4}$$

$\alpha\,(Z\,\alpha)^2$?

$$= -\frac{\alpha (Z\alpha)^4 m_r^3}{4m_e^2} \frac{1}{2\pi} \int_1^{\infty} \mathrm{d}t \, \frac{\mathrm{Im}\Pi(4m_e^2\, t)}{\left(\sqrt{t} + \frac{m_r}{2\, m_e} Z\alpha\right)^4}$$



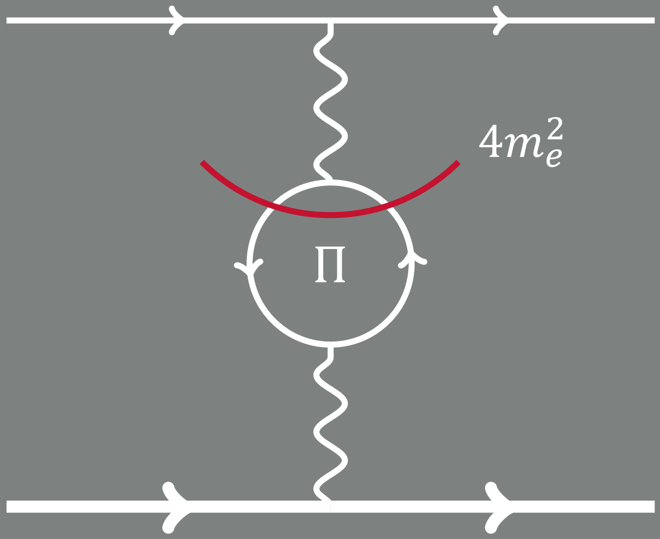
Dispersive Calculation of the eVP Contribution

$$E_{2P-2S}^{\langle \mathrm{eVP} \rangle} = -\frac{(Z\alpha)^4 m_r^3}{2\pi} \int_{4m_e^2}^{\infty} \mathrm{d}t \, \frac{\alpha \, \mathrm{Im}\Pi(t)}{\left(\sqrt{t} + Z\alpha m_r\right)^4}$$

$\alpha (Z\alpha)^2$?

$$= -\frac{\alpha (Z\alpha)^4 m_r^3}{4 m_e^2} \frac{1}{2\pi} \int_1^{\infty} \mathrm{d}t \, \frac{\mathrm{Im}\Pi(4m_e^2\, t)}{\left(\sqrt{t} + \frac{m_r}{2\, m_e} Z\alpha\right)^4}$$

$\frac{m_r}{2\, m_e} Z\alpha \rightarrow \kappa$



Dispersive Calculation of the eVP Contribution

$$E_{2P-2S}^{\langle \mathrm{eVP} \rangle} = -\frac{(Z\alpha)^4 m_r^3}{2\pi} \int_{4m_e^2}^{\infty} \mathrm{d}t \, \frac{\alpha \, \mathrm{Im}\Pi(t)}{\left(\sqrt{t} + Z\alpha m_r\right)^4}$$

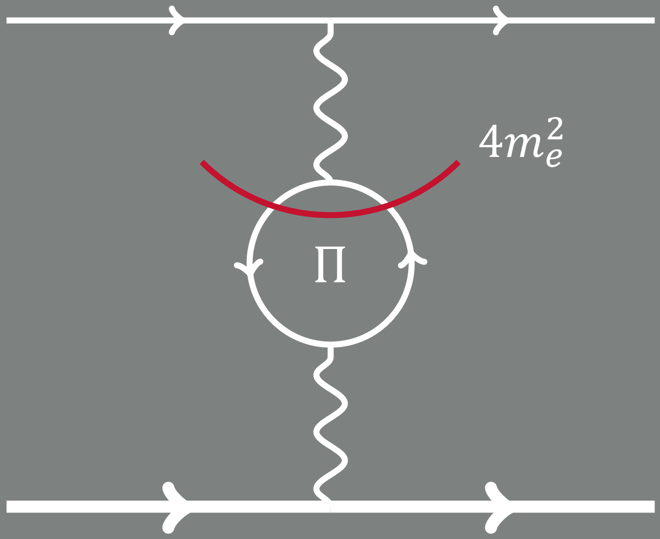
$\alpha(Z\alpha)^2$?

$$= -\frac{\alpha(Z\alpha)^4 m_r^3}{4m_e^2} \frac{1}{2\pi} \int_1^{\infty} \mathrm{d}t \, \frac{\mathrm{Im}\Pi(4m_e^2\, t)}{\left(\sqrt{t} + \frac{m_r}{2\, m_e} Z\alpha\right)^4}$$

κ

$$= \alpha(Z\alpha)^2 \kappa^2 m_r$$

$$\times \frac{1}{3\kappa^5} \left(1 + \frac{\kappa(2\kappa^6 - 13\kappa^4 + 44\kappa^2 - 24)}{12\pi(1-\kappa^2)^2} - \frac{15\kappa^4 - 20\kappa^2 + 8}{4\pi(1-\kappa^2)^{\frac{5}{2}}} \mathrm{ArcCos}\, \kappa \right)$$



Dispersive Calculation of the eVP Contribution

$$E^{\langle \mathrm{eVP}\rangle}_{2P-2S} = -\frac{(Z\alpha)^4 m_r^3}{2\pi}\int_{4m_e^2}^{\infty} \mathrm{d}t\,\frac{\alpha\,\mathrm{Im}\Pi(t)}{\left(\sqrt{t}+Z\alpha m_r\right)^4}$$

$\alpha(Z\alpha)^2$?

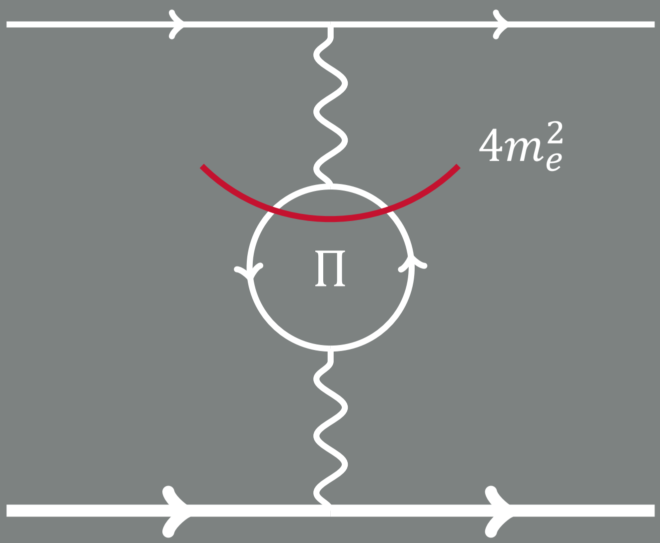
$$= -\frac{\alpha(Z\alpha)^4 m_r^3}{4m_e^2}\,\frac{1}{2\pi}\int_1^{\infty}\mathrm{d}t\,\frac{\mathrm{Im}\Pi(4m_e^2\,t)}{\left(\sqrt{t}+\frac{m_r}{2\,m_e}Z\alpha\right)^4}$$

$\frac{m_r}{2\,m_e}Z\alpha \rightarrow \kappa$

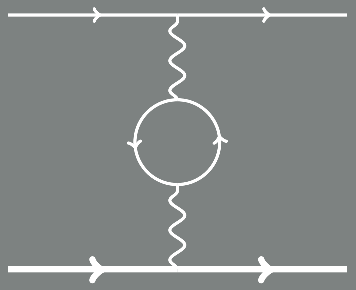
$$= \alpha(Z\alpha)^2\kappa^2 m_r$$

$$\times \frac{1}{3\kappa^5}\left(1+\frac{\kappa(2\kappa^6-13\kappa^4+44\kappa^2-24)}{12\pi(1-\kappa^2)^2}\;\frac{15\kappa^4-20\kappa^2+8}{4\pi(1-\kappa^2)^{\frac{5}{2}}}\mathrm{ArcCos}\,\kappa\right)$$

(almost) constant as κ changes

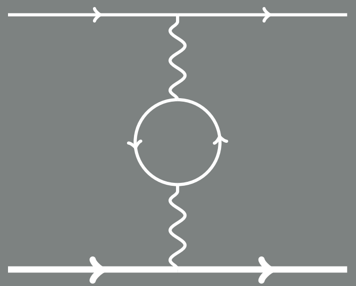


The eVP Contribution Across Different Systems



$$E_{2P-2S}^{\langle \mathrm{eVP} \rangle} \propto \alpha (Z\alpha)^2 \kappa^2 m_r, \qquad \kappa = \frac{m_r}{2m_e} Z\alpha$$

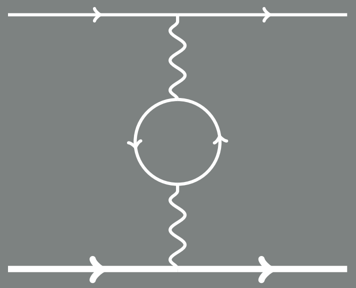
The eVP Contribution Across Different Systems



$$E_{2P-2S}^{\langle \mathrm{eVP} \rangle} \propto \alpha (Z\alpha)^2 \kappa^2 m_r, \qquad \kappa = \frac{m_r}{2m_e} Z\alpha$$

System	m_r [MeV]	κ	$\kappa^2 m_r$ [MeV]
Mu	0.509	$0.498\, Z\alpha$	6.71×10^{-6}

The eVP Contribution Across Different Systems

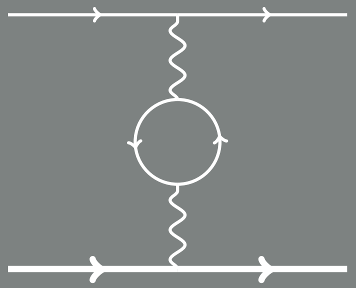


$$E_{2P-2S}^{\langle \mathrm{eVP} \rangle} \propto \alpha (Z\alpha)^2 \kappa^2 m_r, \qquad \kappa = \frac{m_r}{2m_e} Z\alpha$$

$$Z\alpha \simeq \frac{1}{137}$$

System	m_r [MeV]	κ	$\kappa^2 m_r$ [MeV]
Mu	0.509	$0.498\, Z\alpha$	6.71×10^{-6}

The eVP Contribution Across Different Systems

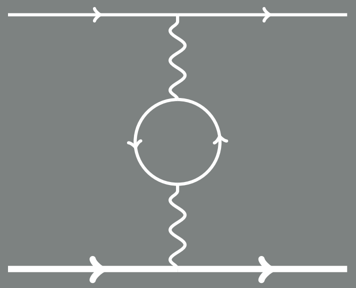


$$E_{2P-2S}^{\langle \mathrm{eVP} \rangle} \propto \alpha (Z\alpha)^2 \kappa^2 m_r, \qquad \kappa = \frac{m_r}{2m_e} Z\alpha$$

$$Z\alpha \simeq \frac{1}{137}$$

System	m_r [MeV]	κ	$\kappa^2 m_r$ [MeV]
Mu	0.509	$0.498\, Z\alpha$	6.71×10^{-6}
H	0.511	$0.500\, Z\alpha$	6.79×10^{-6}

The eVP Contribution Across Different Systems

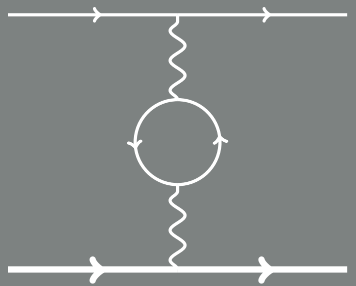


$$E_{2P-2S}^{\langle \text{eVP} \rangle} \propto \alpha (Z\alpha)^2 \kappa^2 m_r, \qquad \kappa = \frac{m_r}{2m_e} Z\alpha$$

$$Z\alpha \simeq \frac{1}{137}$$

System	m_r [MeV]	κ	$\kappa^2 m_r$ [MeV]
Mu	0.509	$0.498\ Z\alpha$	6.71×10^{-6}
H	0.511	$0.500\ Z\alpha$	6.79×10^{-6}
μH	94.965	$92.9\ Z\alpha$	43.66

The eVP Contribution Across Different Systems



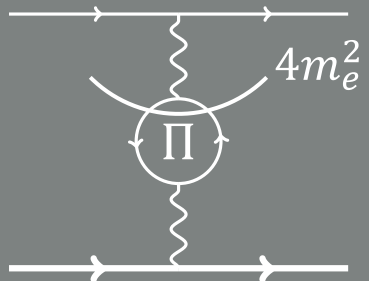
$$E_{2P-2S}^{\langle \mathrm{eVP} \rangle} \propto \alpha (Z\alpha)^2 \kappa^2 m_r, \qquad \kappa = \frac{m_r}{2m_e} Z\alpha$$

$$Z\alpha \simeq \frac{1}{137}$$

System	m_r [MeV]	κ	$\kappa^2 m_r$ [MeV]
Mu	0.509	$0.498\ Z\alpha$	6.71×10^{-6}
H	0.511	$0.500\ Z\alpha$	6.79×10^{-6}
μH	94.965	$92.9\ Z\alpha$	43.66

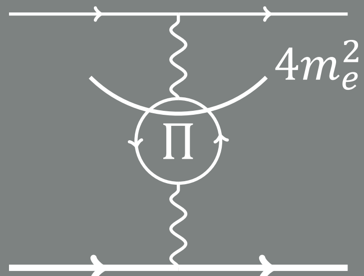
$\alpha\,(Z\,\alpha)^2$!

One-Photon-Exchange Potentials

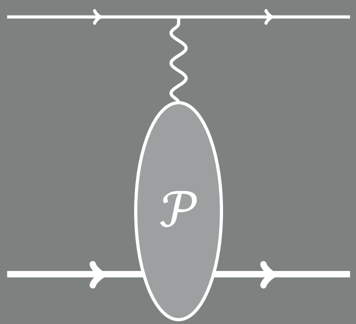


$$E_{2P-2S}^{\langle \mathrm{eVP}\rangle} = -\frac{(Z\alpha)^4 m_r^3}{2\pi}\int_{4m_e^2}^{\infty} \mathrm{d}t\, \frac{a\, \mathrm{Im}\Pi(t)}{\left(\sqrt{t} + Z\alpha m_r\right)^4}$$

One-Photon-Exchange Potentials

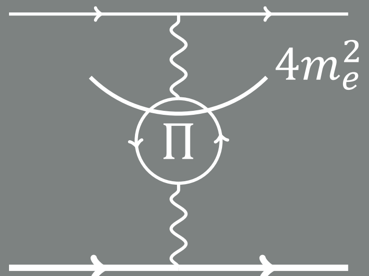


$$E_{2P-2S}^{\langle \mathrm{eVP} \rangle} = -\frac{(Z\alpha)^4 m_r^3}{2\pi} \int_{4m_e^2}^{\infty} \mathrm{d}t \, \frac{a \, \mathrm{Im}\Pi(t)}{\left(\sqrt{t} + Z\alpha m_r\right)^4}$$

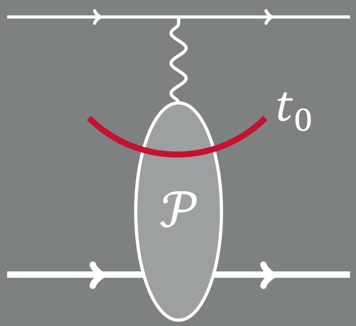


$$E_{2P-2S}^{\langle \mathrm{OPE} \rangle} = -\frac{(Z\alpha)^4 m_r^3}{2\pi} \int_{t_0}^{\infty} \mathrm{d}t \, \frac{\mathrm{Im}\mathcal{P}(t)}{\left(\sqrt{t} + Z\alpha m_r\right)^4}$$

One-Photon-Exchange Potentials

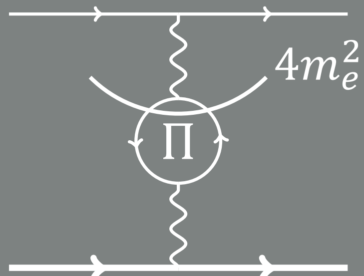


$$E_{2P-2S}^{\langle \mathrm{eVP} \rangle} = -\frac{(Z\alpha)^4 m_r^3}{2\pi} \int_{4m_e^2}^{\infty} \mathrm{d}t \, \frac{a \, \mathrm{Im}\Pi(t)}{\left(\sqrt{t} + Z\alpha m_r\right)^4}$$

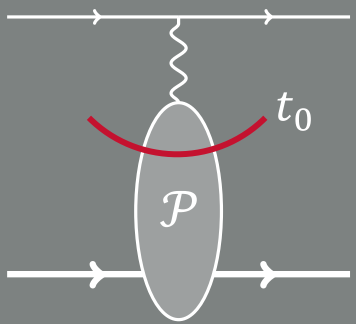


$$E_{2P-2S}^{\langle \mathrm{OPE} \rangle} = -\frac{(Z\alpha)^4 m_r^3}{2\pi} \int_{t_0}^{\infty} \mathrm{d}t \, \frac{\mathrm{Im}\mathcal{P}(t)}{\left(\sqrt{t} + Z\alpha m_r\right)^4}$$

One-Photon-Exchange Potentials



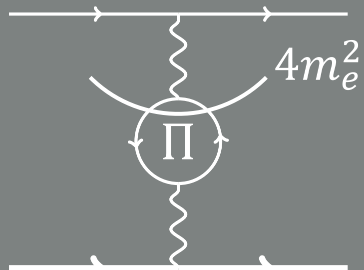
$$E_{2P-2S}^{\langle \mathrm{eVP} \rangle} = -\frac{(Z\alpha)^4 m_r^3}{2\pi} \int_{4m_e^2}^{\infty} \mathrm{d}t \, \frac{a \, \mathrm{Im}\Pi(t)}{\left(\sqrt{t} + Z\alpha m_r\right)^4}$$



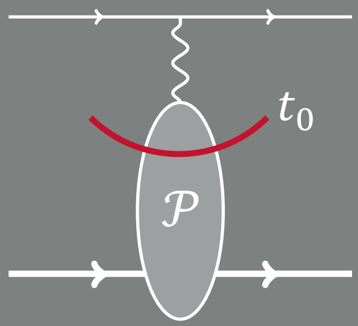
$$E_{2P-2S}^{\langle \mathrm{OPE} \rangle} = -\frac{(Z\alpha)^4 m_r^3}{2\pi} \int_{t_0}^{\infty} \mathrm{d}t \, \frac{\mathrm{Im}\mathcal{P}(t)}{\left(\sqrt{t} + Z\alpha m_r\right)^4}$$

$$\kappa = \frac{m_r}{\sqrt{t_0}} Z\alpha$$

One-Photon-Exchange Potentials



$$E^{\langle \mathrm{eVP} \rangle}_{2P-2S} = -\frac{(Z\alpha)^4 m_r^3}{2\pi} \int_{4m_e^2}^{\infty} \mathrm{d}t \, \frac{\alpha \, \mathrm{Im}\Pi(t)}{\left(\sqrt{t} + Z\alpha m_r\right)^4}$$

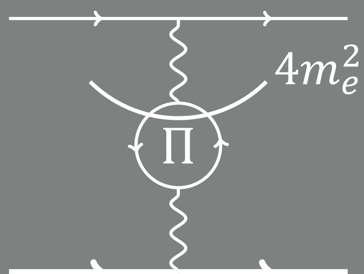


$$E^{\langle \mathrm{OPE} \rangle}_{2P-2S} = -\frac{(Z\alpha)^4 m_r^3}{2\pi} \int_{t_0}^{\infty} \mathrm{d}t \, \frac{\mathrm{Im}\mathcal{P}(t)}{\left(\sqrt{t} + Z\alpha m_r\right)^4}$$

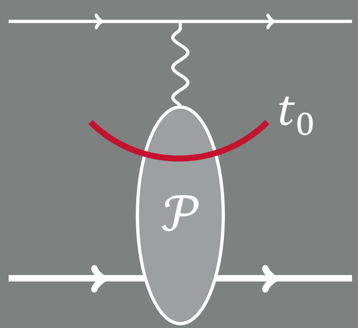
$\kappa = \frac{m_r}{\sqrt{t_0}} Z\alpha$

larger m_r, smaller t_0 } larger $\kappa \to$ enhancement!

One-Photon-Exchange Potentials



$$E_{2P-2S}^{\langle \mathrm{eVP} \rangle} = -\frac{(Z\alpha)^4 m_r^3}{2\pi} \int_{4m_e^2}^{\infty} \mathrm{d}t \, \frac{\alpha \, \mathrm{Im}\Pi(t)}{\left(\sqrt{t} + Z\alpha m_r\right)^4}$$



$$E_{2P-2S}^{\langle \mathrm{OPE} \rangle} = -\frac{(Z\alpha)^4 m_r^3}{2\pi} \int_{t_0}^{\infty} \mathrm{d}t \, \frac{\mathrm{Im}\mathcal{P}(t)}{\left(\sqrt{t} + Z\alpha m_r\right)^4}$$

$$\kappa = \frac{m_r}{\sqrt{t_0}} Z\alpha$$

larger m_r
smaller t_0

Contributions can be enhanced depending on the system's m_r!

Finite-Size Corrections

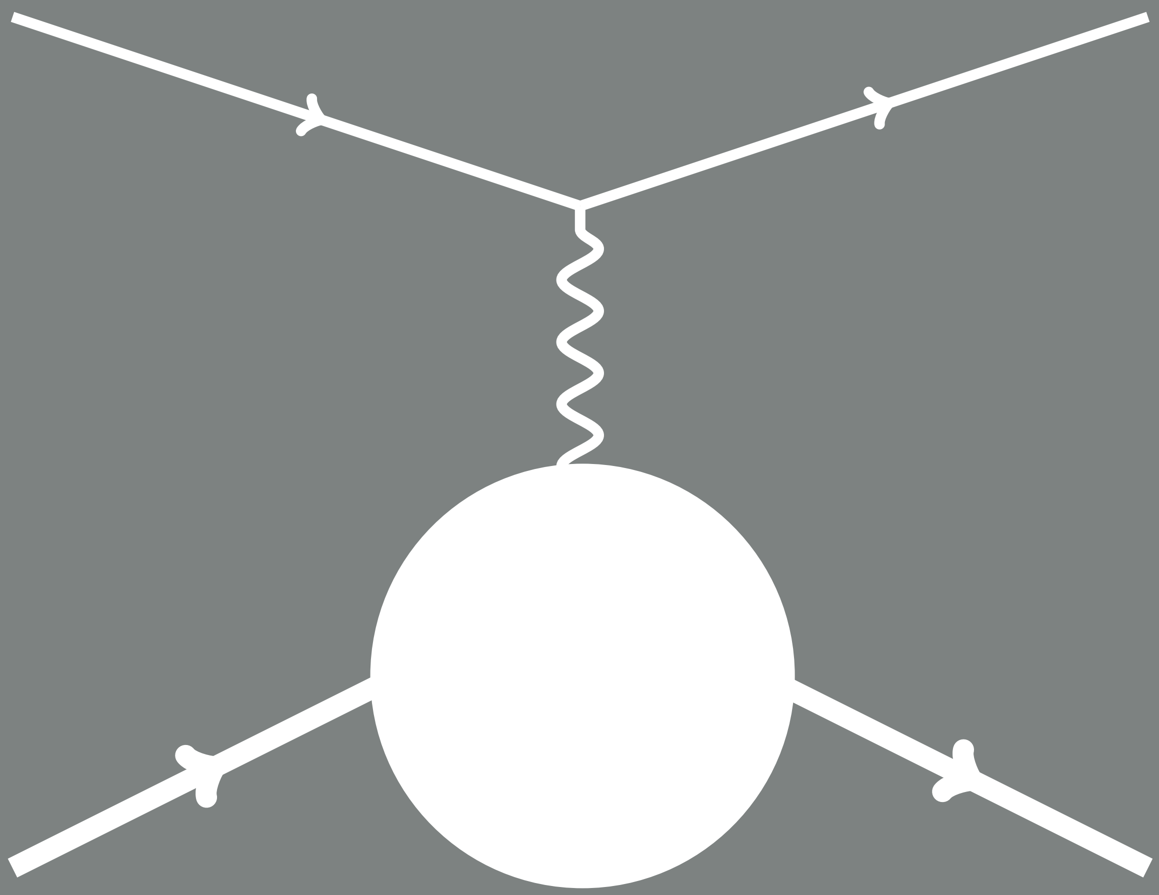
$$E_{2P-2S}^{\langle \mathrm{FS} \rangle} = \int_0^\infty \mathrm{d}Q \, w(Q) \, G_E(Q^2)$$

DOI:10.1103/PhysRevA.91.040502

Finite-Size Corrections

$$E_{2P-2S}^{\langle \mathrm{FS} \rangle} = \int_0^\infty \mathrm{d}Q \, w(Q) \, G_E(Q^2)$$

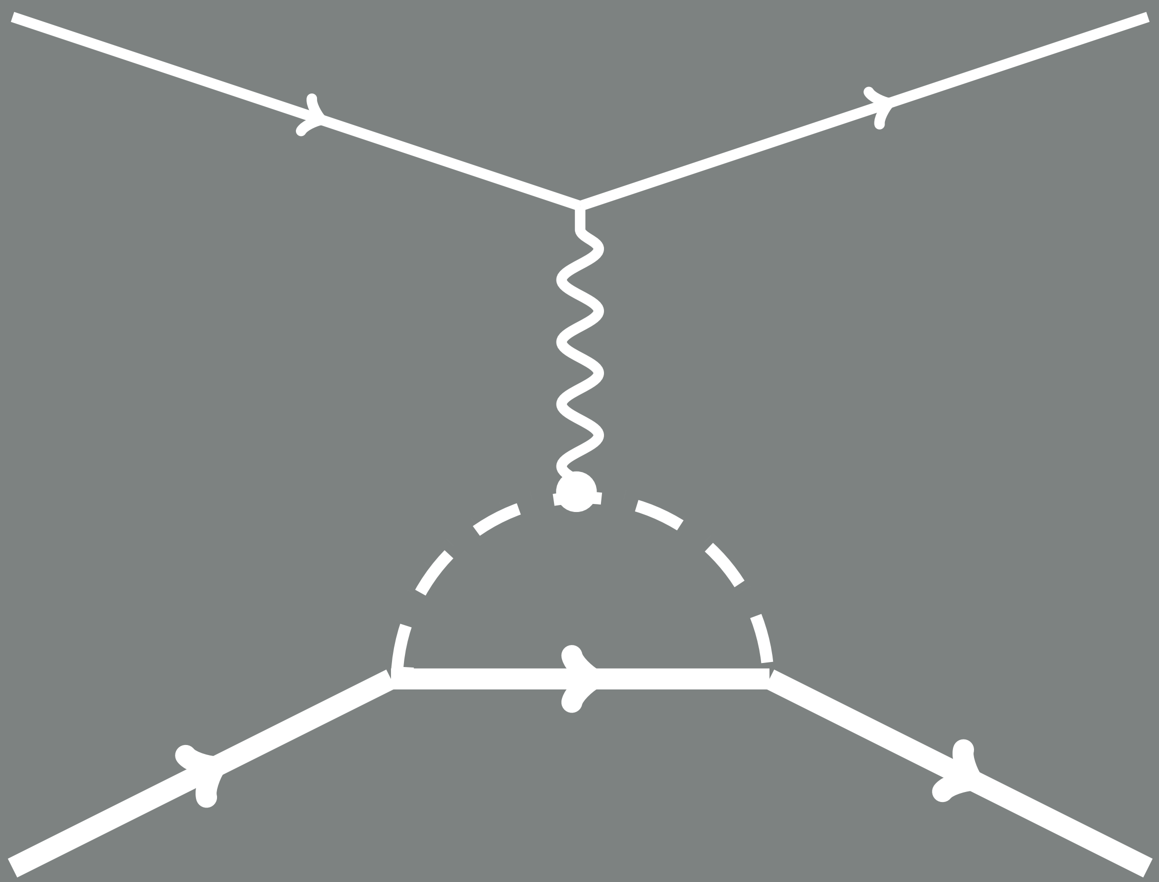
DOI:10.1103/PhysRevA.91.040502



Finite-Size Corrections

$$E_{2P-2S}^{\langle \mathrm{FS} \rangle} = \int_0^\infty \mathrm{d}Q \, w(Q) \, G_E(Q^2)$$

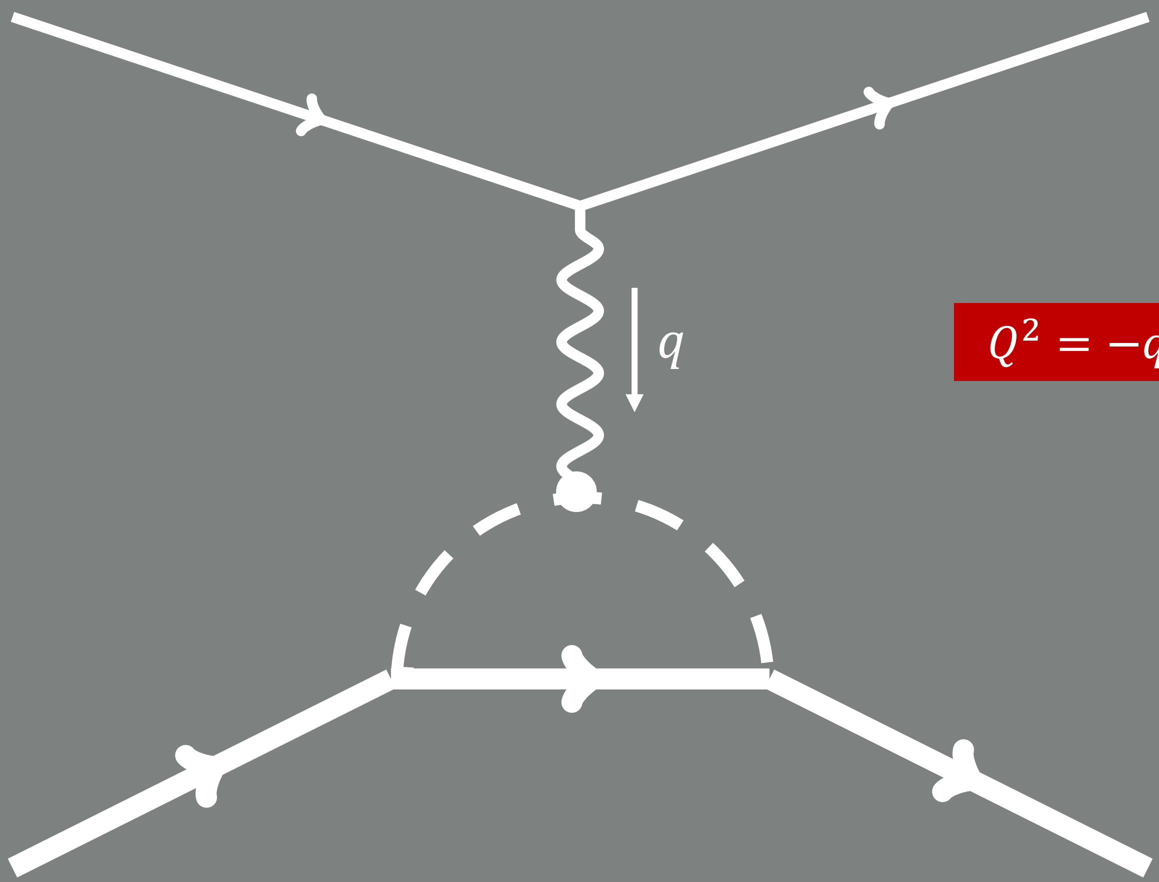
DOI:10.1103/PhysRevA.91.040502



Finite-Size Corrections

$$E_{2P-2S}^{\langle \mathrm{FS} \rangle} = \int_0^\infty \mathrm{d}Q \, w(Q) \, G_E(Q^2)$$

DOI:10.1103/PhysRevA.91.040502



$Q^2 = -q^2$

Finite-Size Corrections

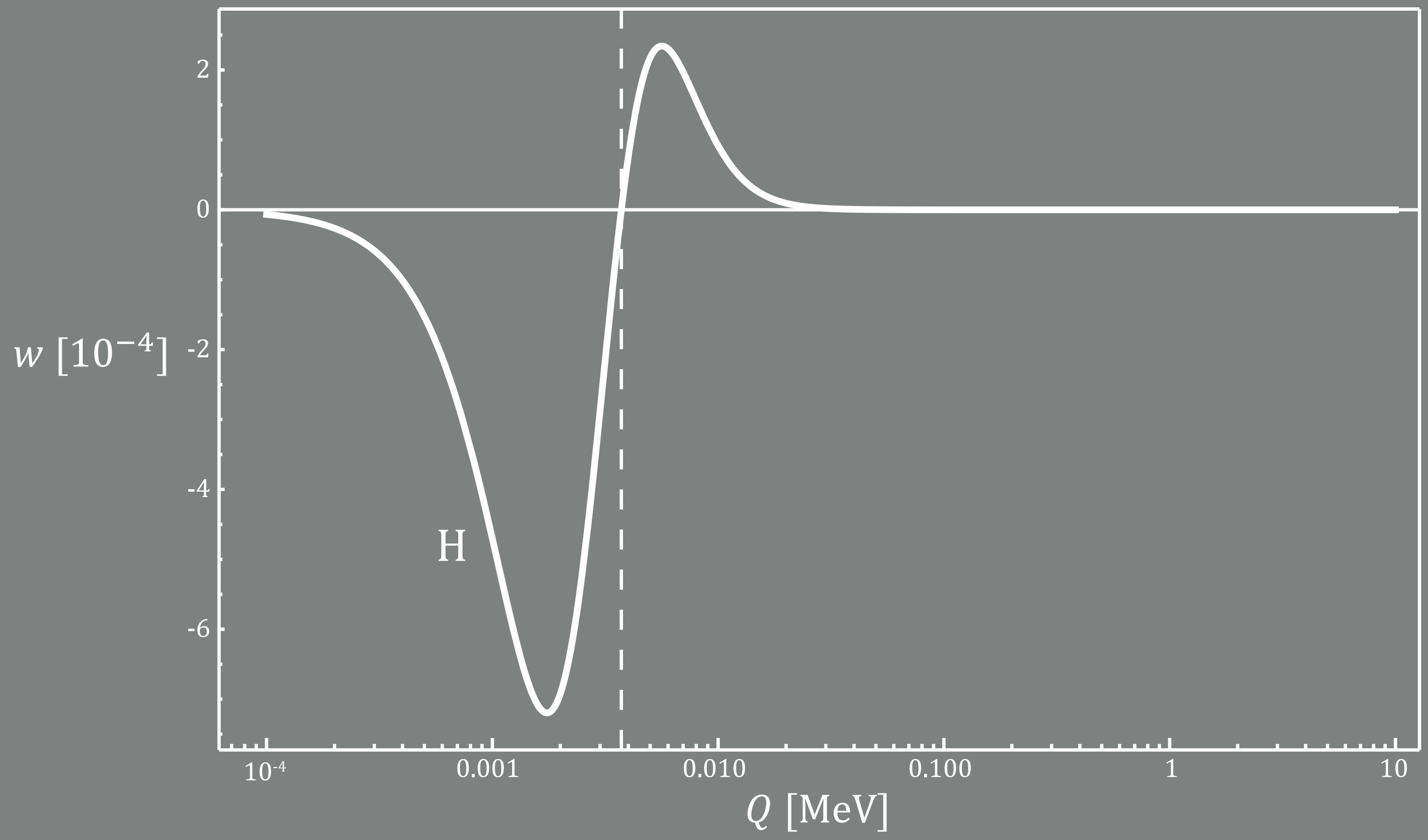
$$E_{2P-2S}^{\langle \mathrm{FS} \rangle} = \int_0^\infty \mathrm{d}Q \, w(Q) \, G_E(Q^2)$$

DOI:10.1103/PhysRevA.91.040502

Finite-Size Corrections

$$E^{\langle FS \rangle}_{2P-2S} = \int_0^\infty \mathrm{d}Q \, w(Q) \, G_E(Q^2)$$

DOI:10.1103/PhysRevA.91.040502

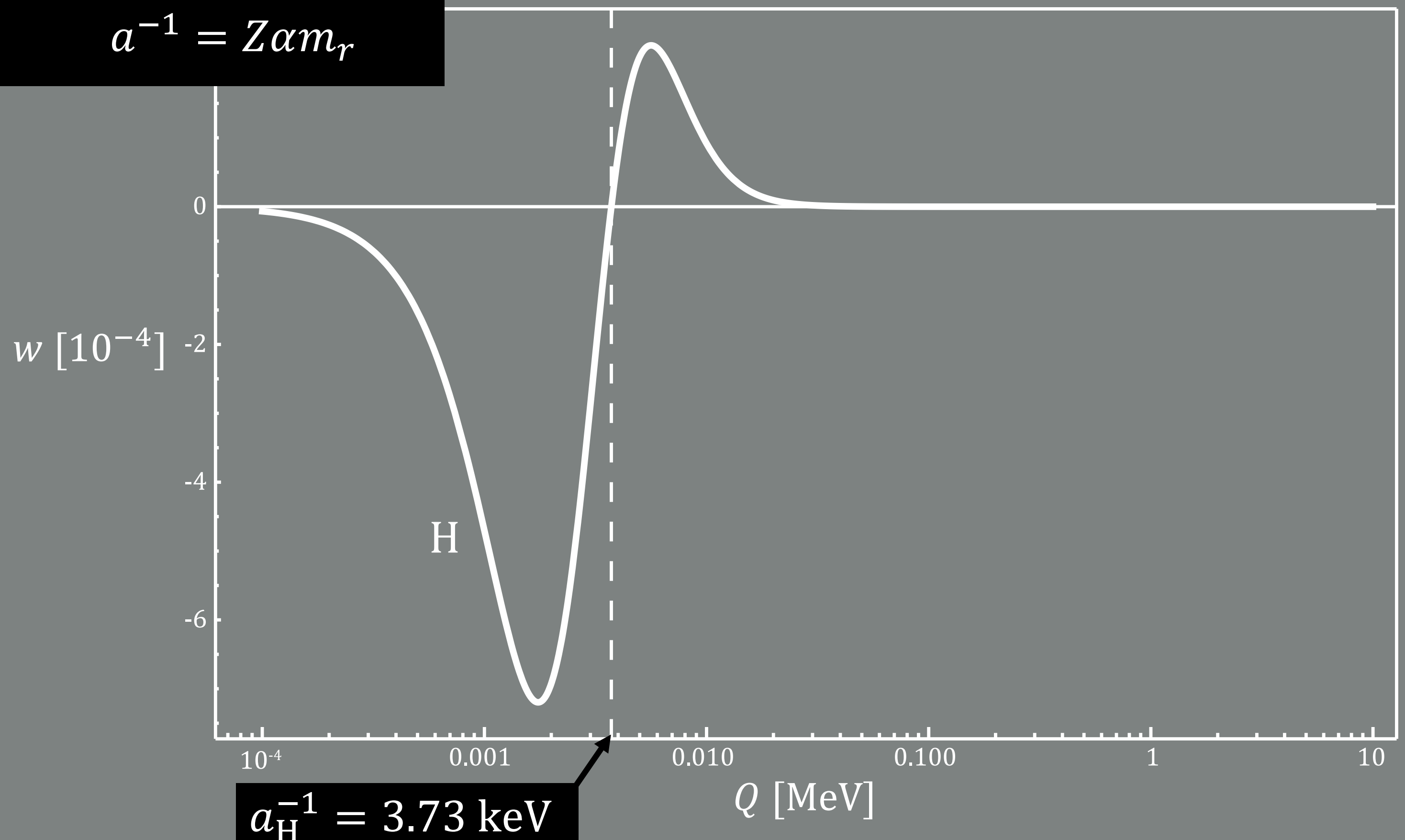


Finite-Size Corrections

$$E^{\langle \mathrm{FS} \rangle}_{2P-2S} = \int_0^\infty \mathrm{d}Q\, w(Q)\, G_E(Q^2)$$

DOI:10.1103/PhysRevA.91.040502

Inv. Bohr radius:
$a^{-1} = Z\alpha m_r$

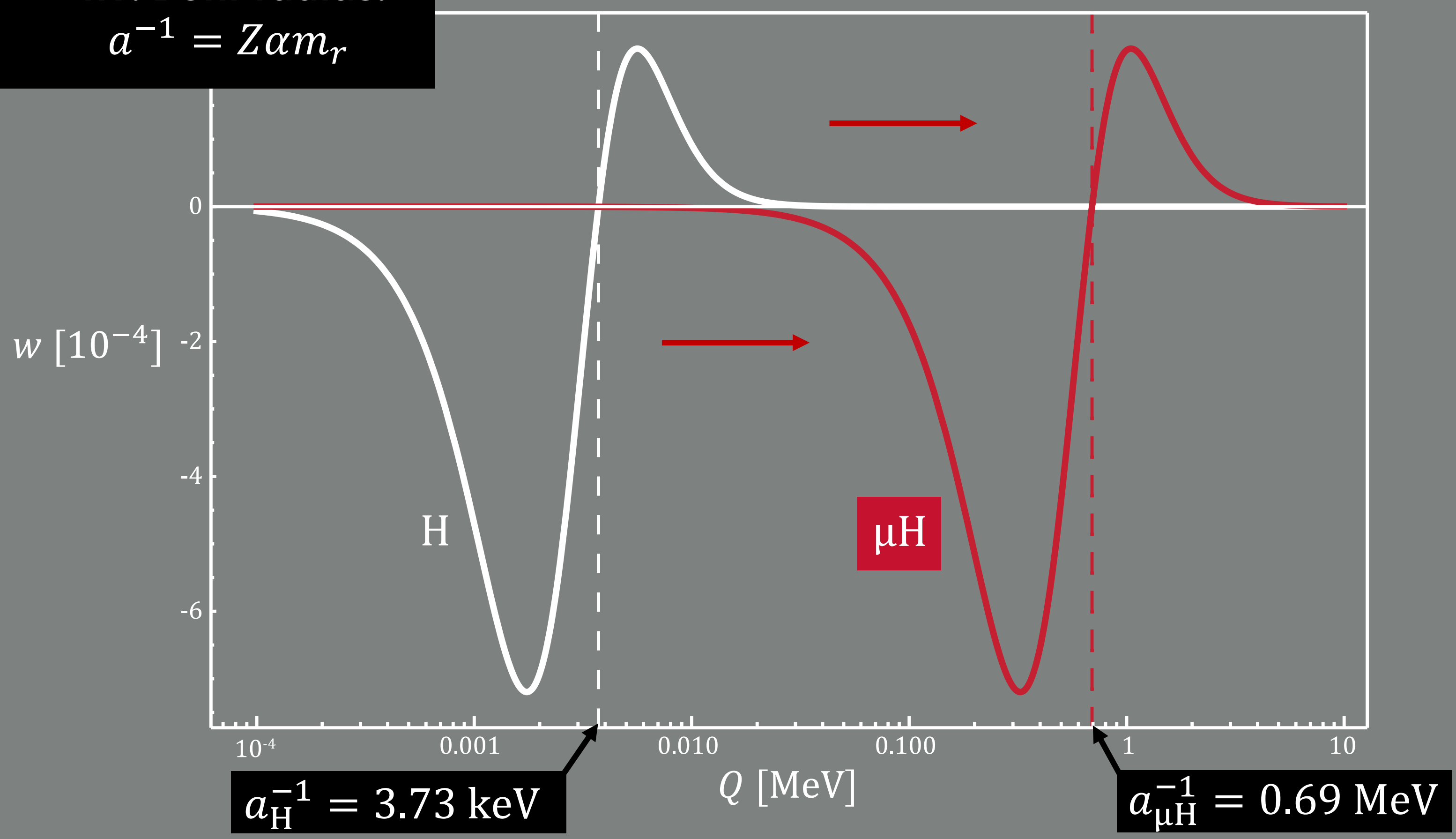


Finite-Size Corrections

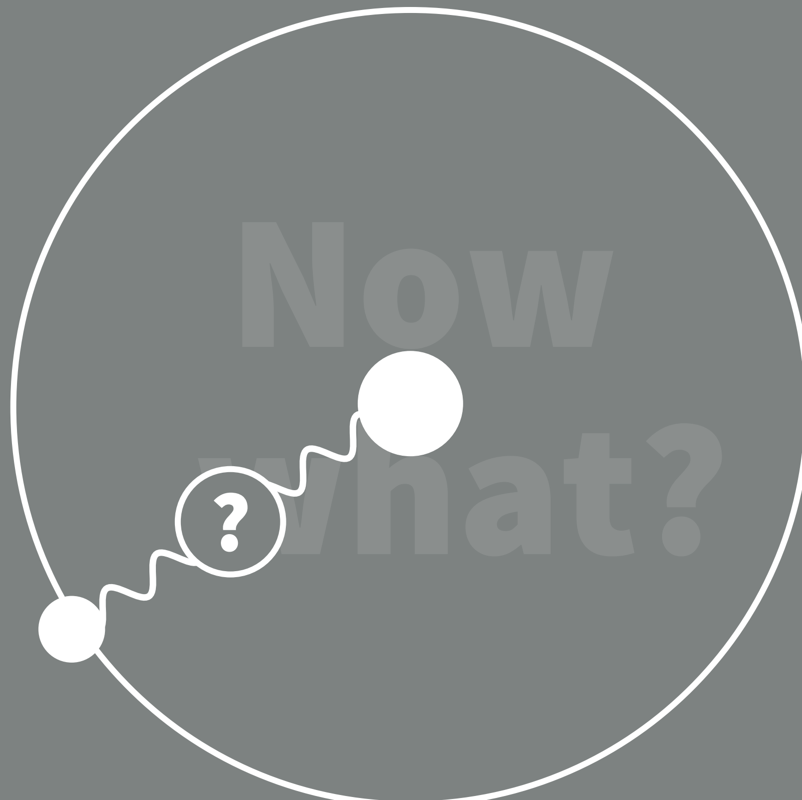
$$E^{\langle FS \rangle}_{2P-2S} = \int_0^\infty \mathrm{d}Q\, w(Q)\, G_E(Q^2)$$

DOI:10.1103/PhysRevA.91.040502

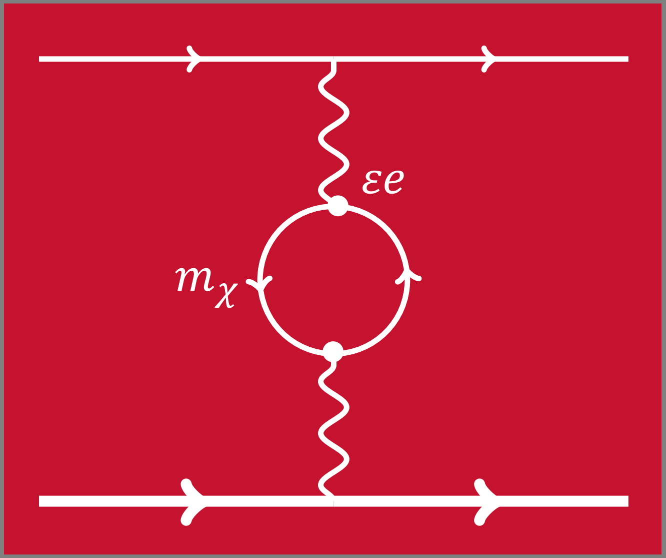
Inv. Bohr radius:
$a^{-1} = Z\alpha m_r$



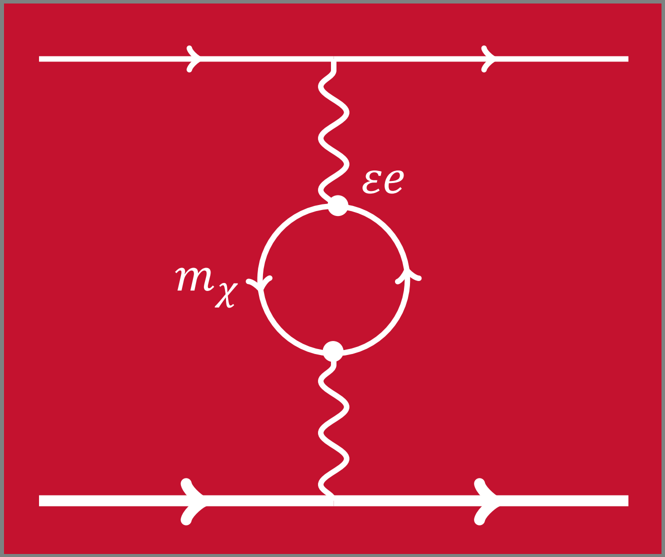
Now what?


Now what?
?

Dark Matter Fermion



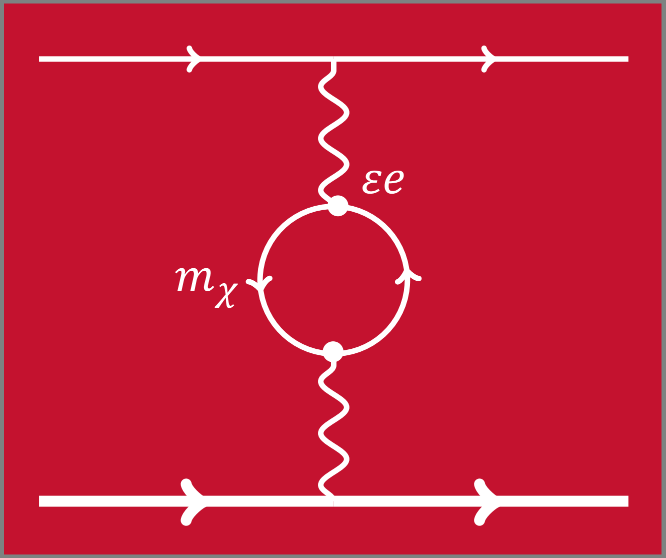
Dark Matter Fermion



Lamb Shift Measurements

Mu: 4.3309(105) μeV
H: 4.37483(1) μeV
μH: 202.3706(23) meV

Dark Matter Fermion

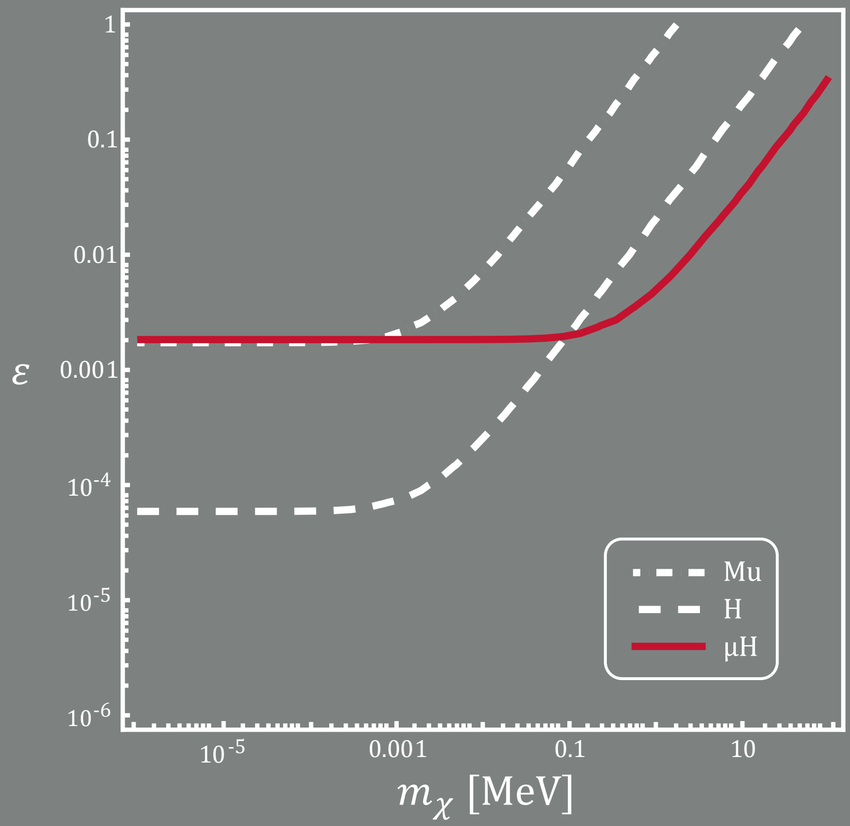


Lamb Shift Measurements

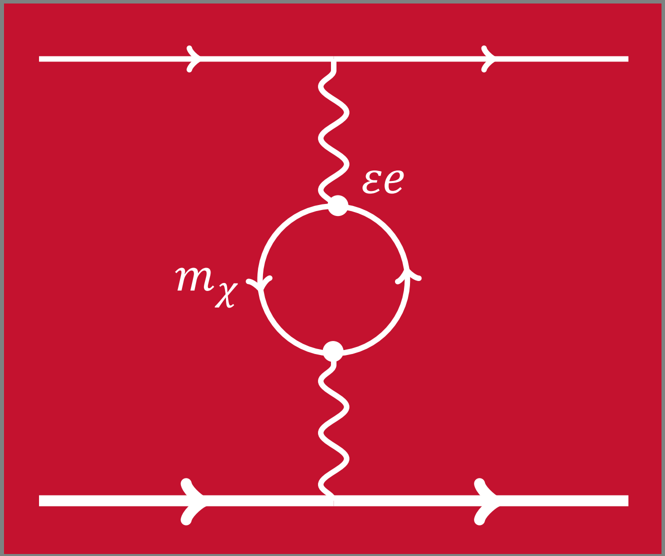
Mu: 4.3309(105) μeV

H: 4.37483(1) μeV

μH: 202.3706(23) meV

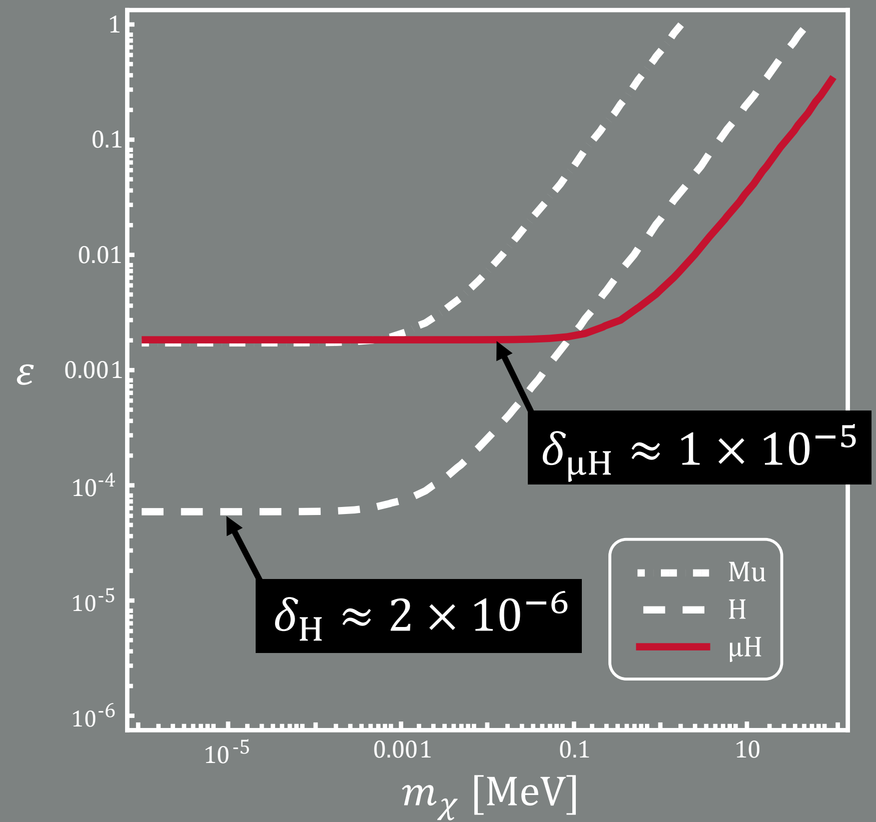


Dark Matter Fermion

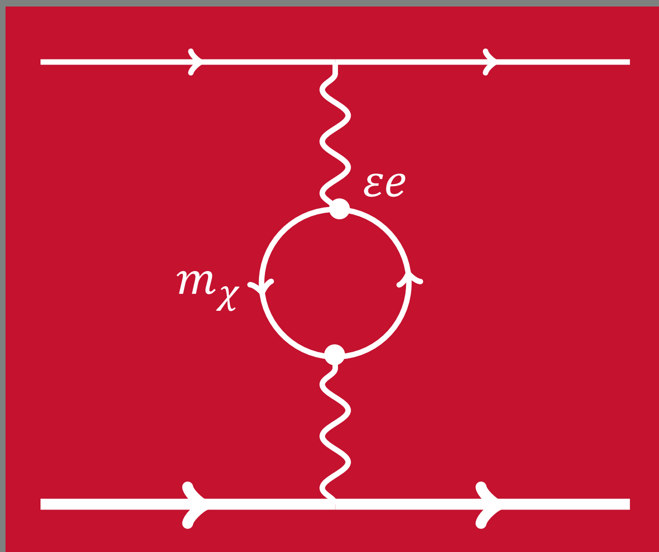


Lamb Shift Measurements

Mu: 4.3309(105) μeV
H: 4.37483(1) μeV
μH: 202.3706(23) meV



Dark Matter Fermion

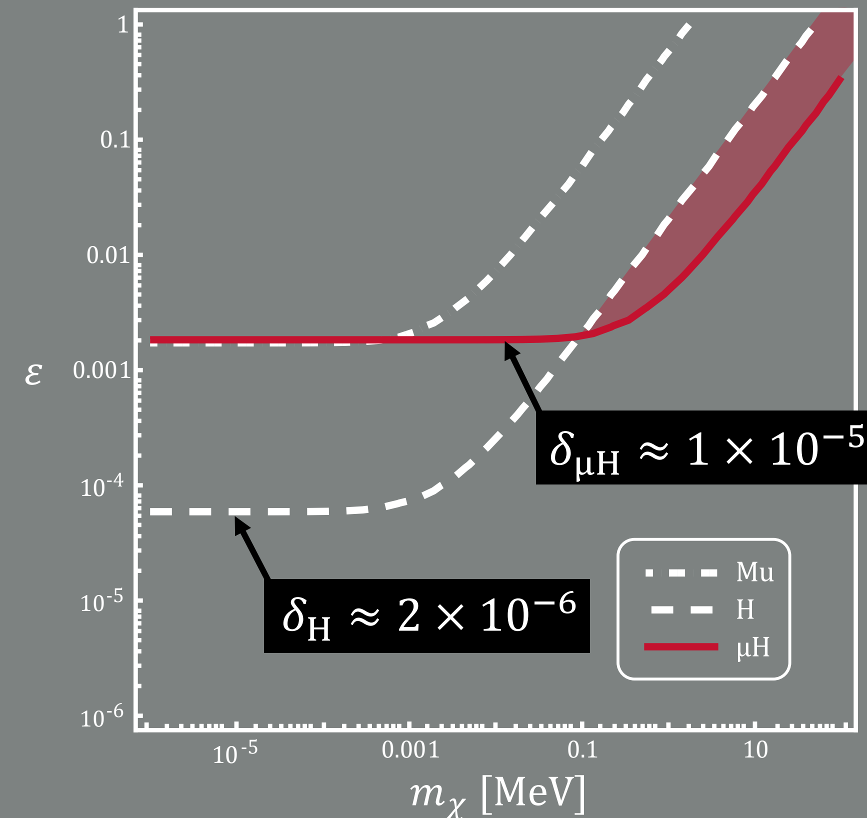


Lamb Shift Measurements

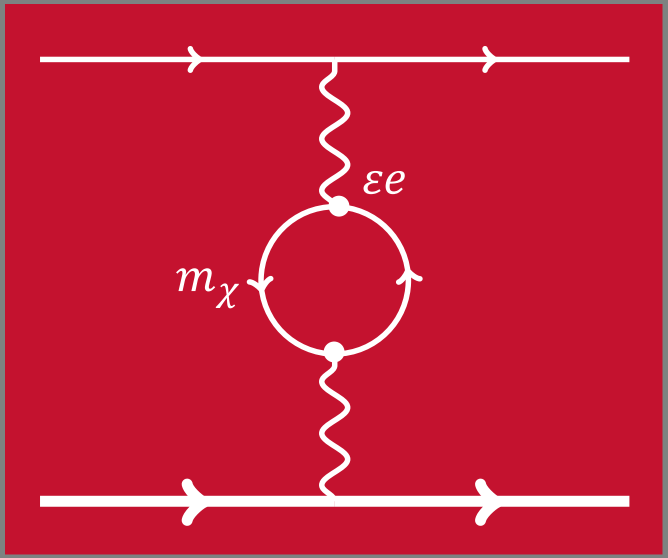
Mu: 4.3309(105) μeV

H: 4.37483(1) μeV

μH: 202.3706(23) meV



Dark Matter Fermion

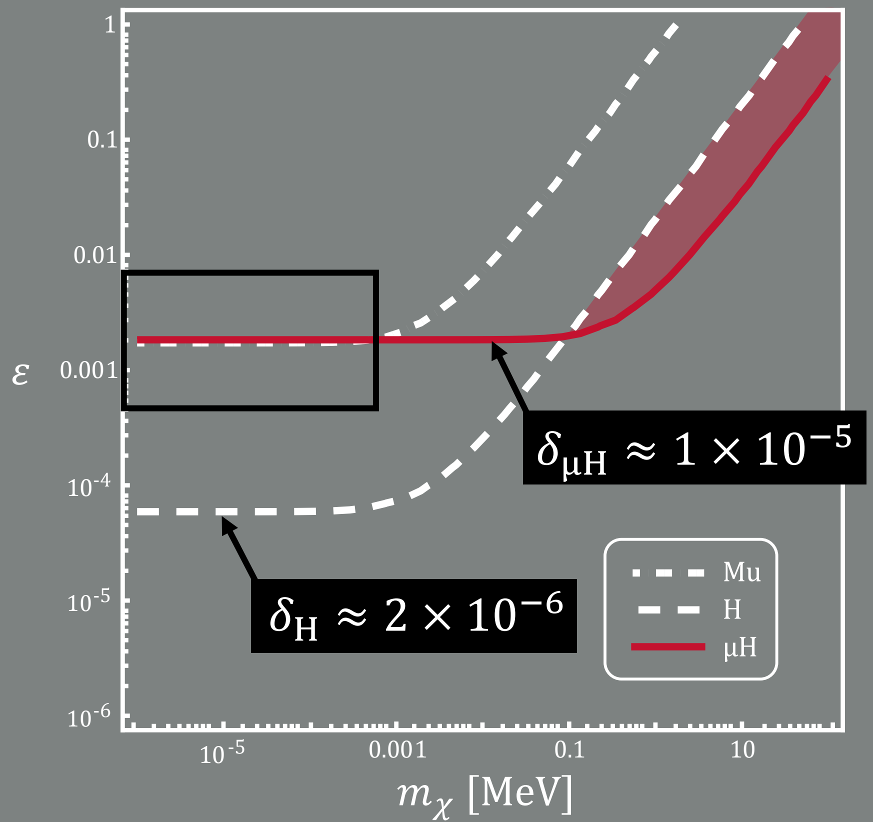


Lamb Shift Measurements

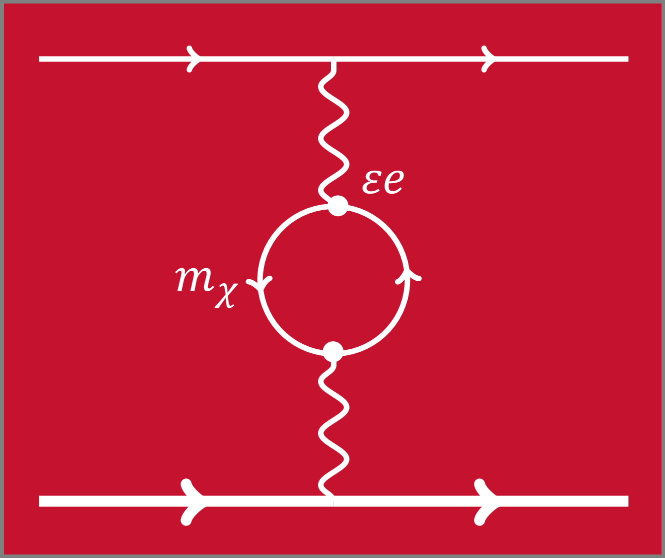
Mu: 4.3309(105) μeV

H: 4.37483(1) μeV

μH: 202.3706(23) meV

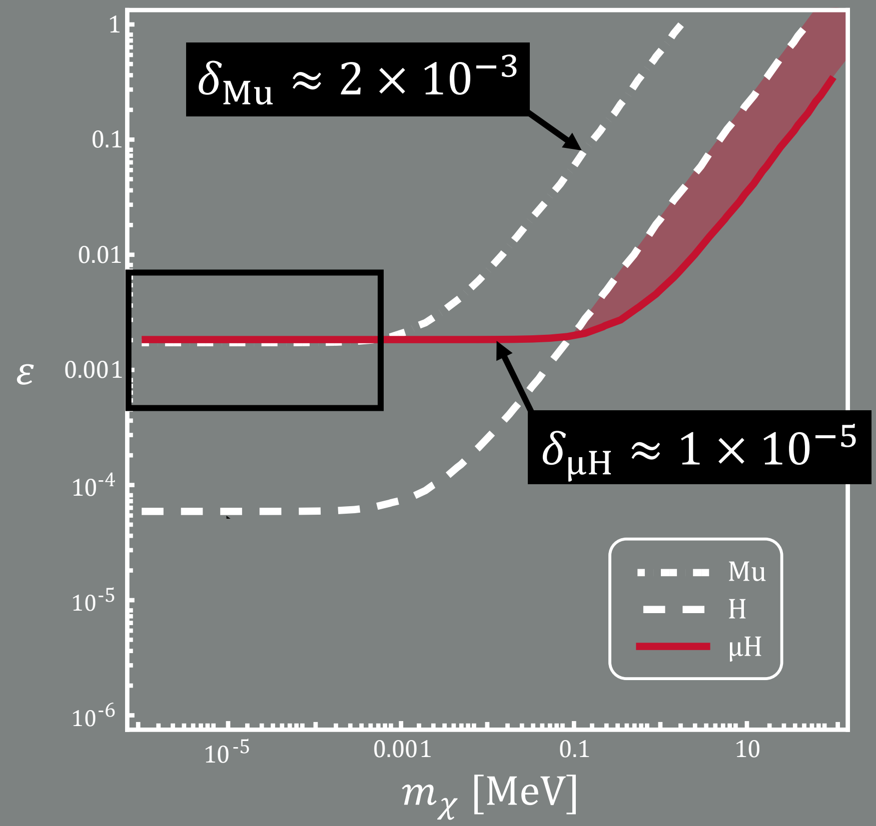


Dark Matter Fermion

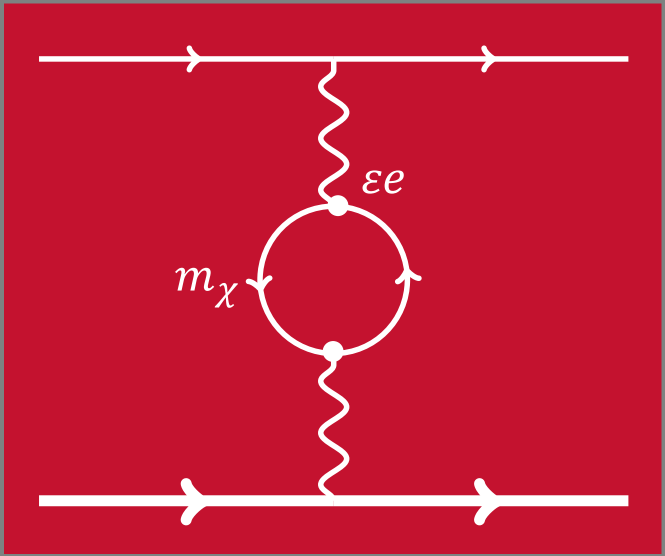


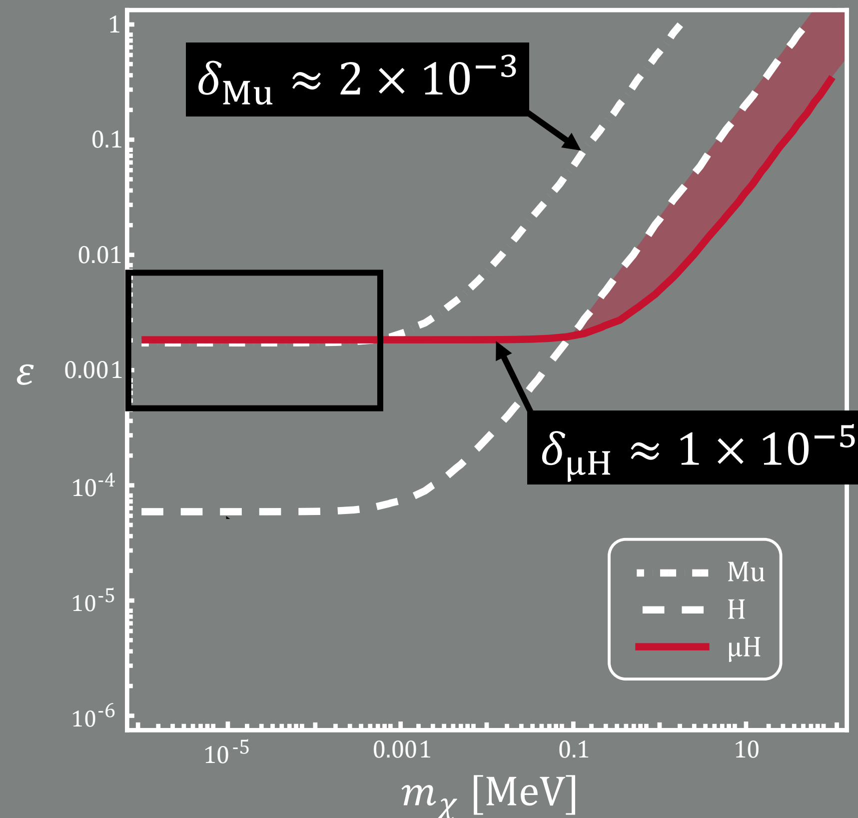
Lamb Shift Measurements

Mu: 4.3309(105) μeV
H: 4.37483(1) μeV
μH: 202.3706(23) meV



Dark Matter Fermion





Lamb Shift Measurements

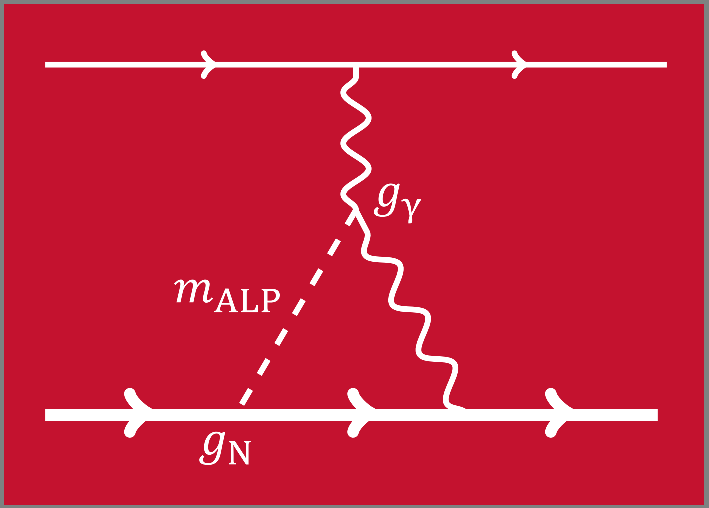
Mu: 4.3309(105) μeV

H: 4.37483(1) μeV

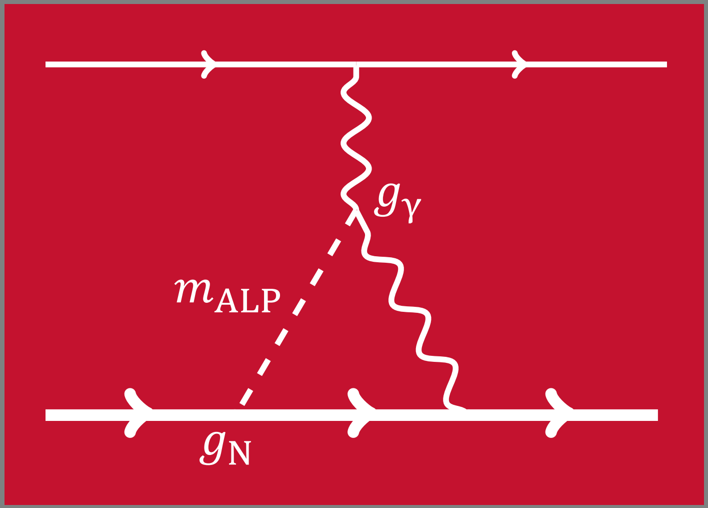
μH: 202.3706(23) meV

Sensitivity depends on experimental precision, Bohr radius, BSM parameters

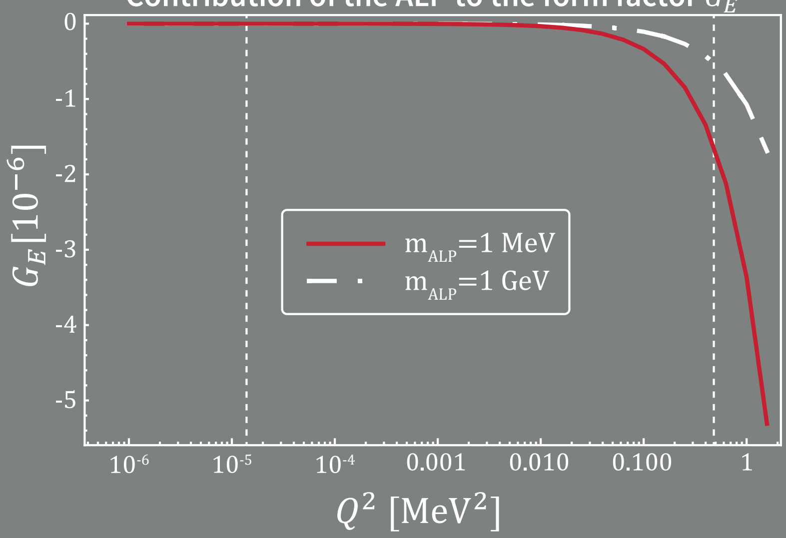
Axion-Like Particle



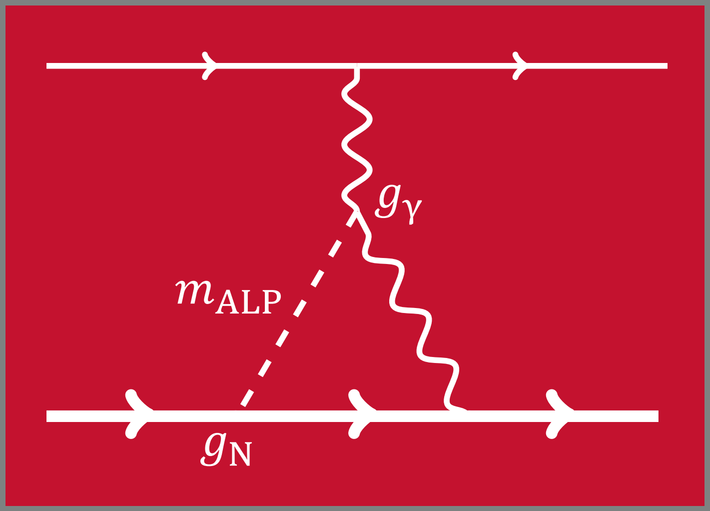
Axion-Like Particle

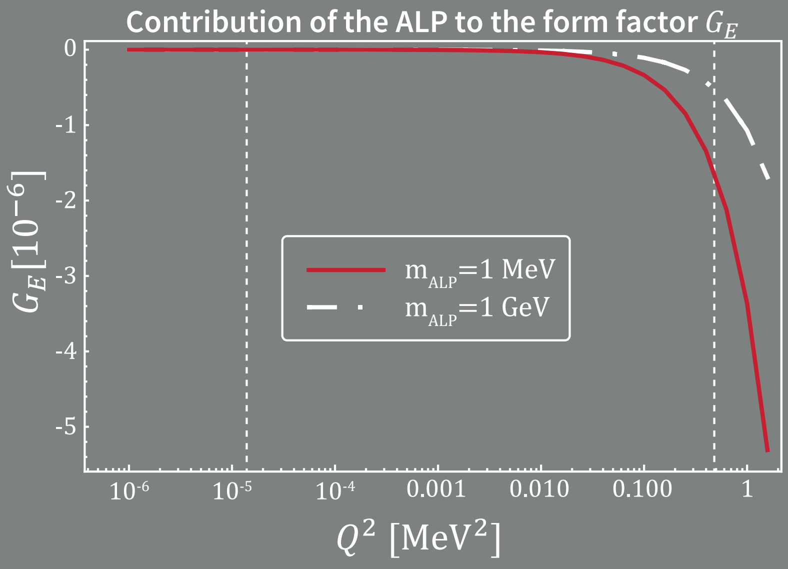


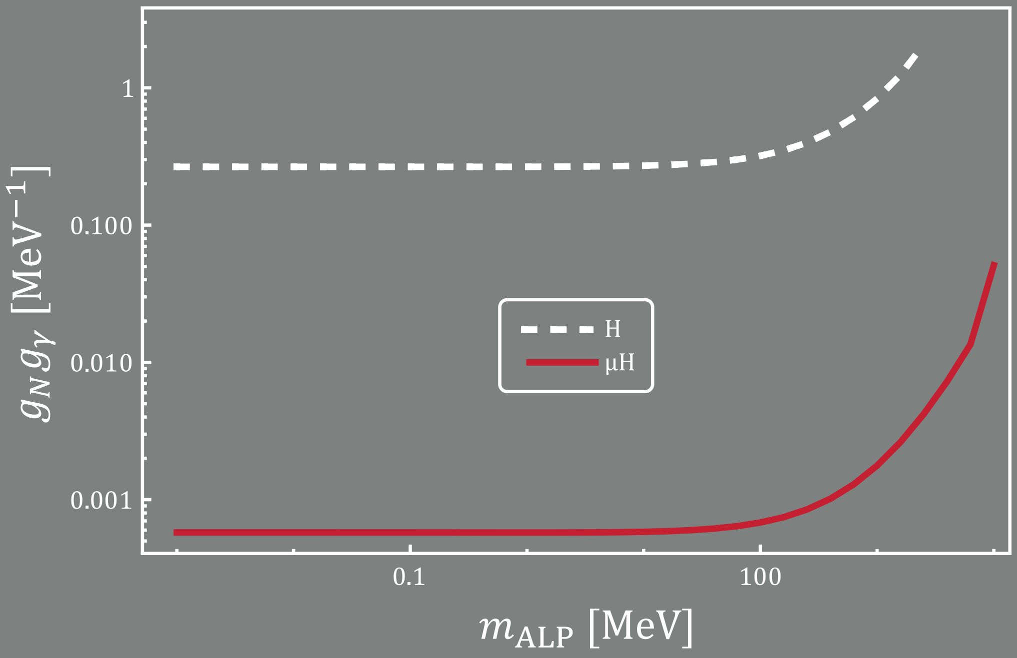
Contribution of the ALP to the form factor G_E



Axion-Like Particle

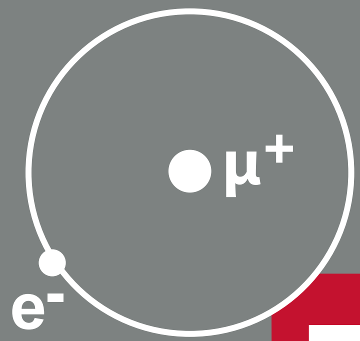






Conclusions

- Contributions to spectroscopy observables may be enhanced depending on the bound state
- Need to be careful with finite-size contributions that can’t be seen in scattering
- Precision atomic spectroscopy holds potential for New Physics searches
- Sensitivity to New Physics depends on energy transition, experimental precision, (exotic) atom, BSM model
- Variety of (exotic) systems with different scales



Thank you!