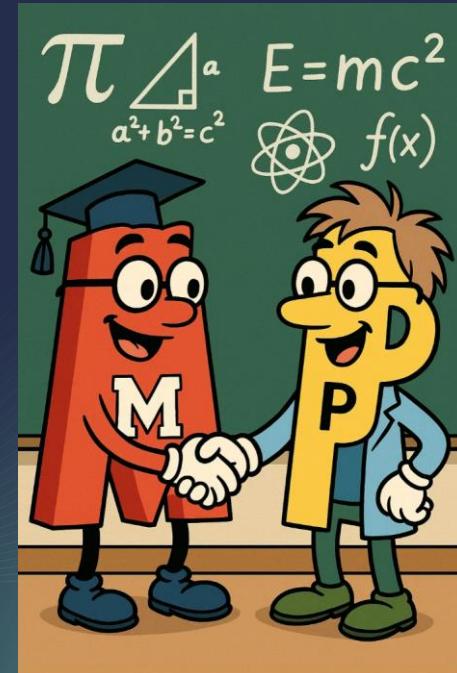




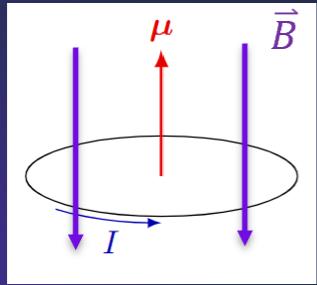
The τ g-2 at future collider

ZeQiang Wang

UCLouvain, CP3



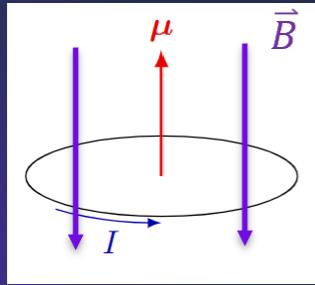
What is g-2?



$$\vec{\mu} = I \vec{A}$$

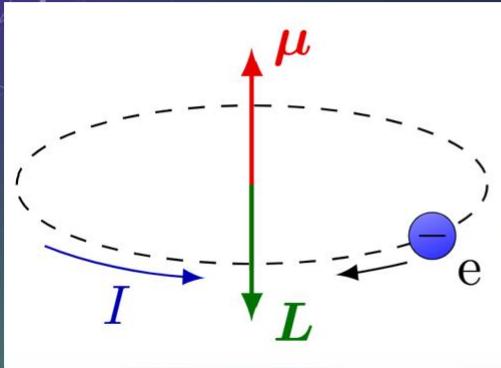
$$E = -\vec{\mu} \cdot \vec{B}$$

What is g-2?



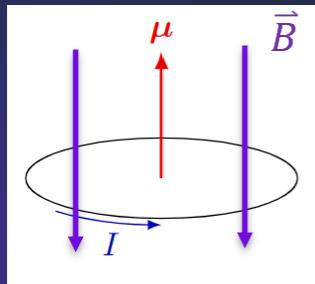
$$\vec{\mu} = I \vec{A}$$

$$E = -\vec{\mu} \cdot \vec{B}$$



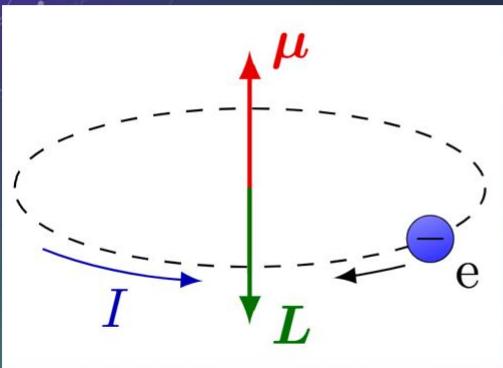
$$\vec{\mu} = -\frac{e}{2m} \vec{L}$$

What is g-2?



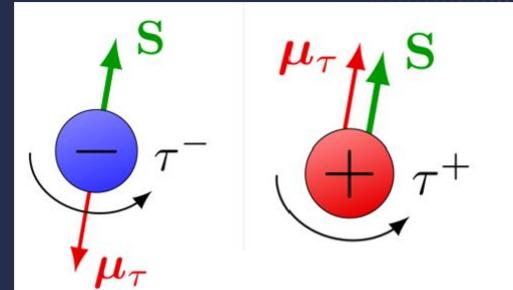
$$\vec{\mu} = I \vec{A}$$

$$E = -\vec{\mu} \cdot \vec{B}$$



$$\vec{\mu} = -\frac{e}{2m} \vec{L} \quad \longrightarrow \quad \vec{\mu} = g \frac{e}{2m} \vec{S}$$

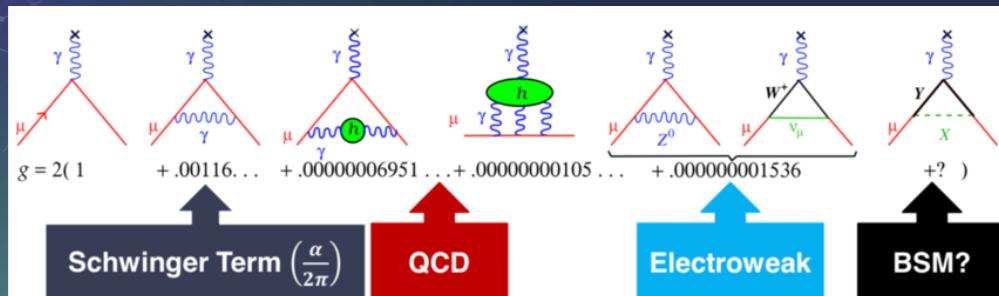
The **g-factor** relates the magnetic dipole moment and its spin angular momentum



What is $g-2$?



Dirac predicts $g=2$



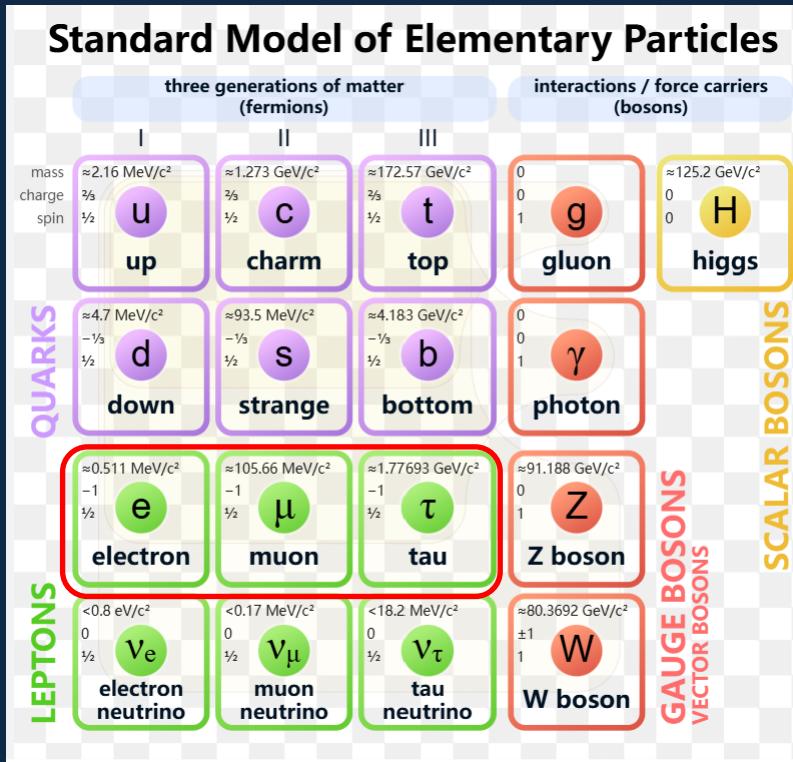
Schwinger gives the term $\frac{\alpha}{2\pi}$

Higer-order quantum effects(QED, electroweak and hadronic contributions) slightly modify g , defining the **anomalous magnetic moment** :

$$a_l = (g - 2)/2$$

Any significant $\Delta a_l = a_l^{\text{exp}} - a_l^{\text{SM}}$ may hints new physics (BSM)

g-2 for charged lepton



g-2 for charged lepton

Standard Model of Elementary Particles								
three generations of matter (fermions)			interactions / force carriers (bosons)					
QUARKS	I	II	III	0	0	0	0	0
	mass ≈2.16 MeV/c ²	mass ≈1.273 GeV/c ²	mass ≈172.57 GeV/c ²	g gluon	g Higgs	γ photon	Z Z boson	W W boson
	charge 2/3 1/2 up	charge 2/3 1/2 charm	charge 2/3 1/2 top	spin 1/2	spin 0	spin 0	spin 0	spin 1
LEPTONS	mass ≈4.7 MeV/c ²	mass ≈93.5 MeV/c ²	mass ≈4.183 GeV/c ²	0	0	0	0	0
	charge -1/3 1/2 down	charge -1/3 1/2 strange	charge -1/3 1/2 bottom	0	0	0	0	0
	mass ≈0.511 MeV/c ²	mass ≈105.66 MeV/c ²	mass ≈1.77693 GeV/c ²	0	0	0	0	0
electron	muon	tau	Z Z boson	W W boson	GAUGE BOSONS VECTOR BOSONS	SCALAR BOSONS	SCALAR BOSONS	SCALAR BOSONS
electron neutrino	muon neutrino	tau neutrino	0	0	0	0	0	0
charge 0 1/2	charge 0 1/2	charge 0 1/2	spin -1 1/2	spin ±1 1	spin -1 1/2	spin 0 1/2	spin 0 1/2	spin 0 1/2



Mass

1 : 207 : 3477

Stable : 2.2×10^{-6} s : 2.9×10^{-13} s

Lifetime

—————>

Measure and calculate g-2
Difficulty

—————>

The current state of $g-2$ of charged Lepton



$$a_e^{\text{SM}} = 0.001159652182032(720)$$

$$a_e^{\text{Exp}} = 0.00115965218059(13)$$

The current state of $g-2$ of charged Lepton



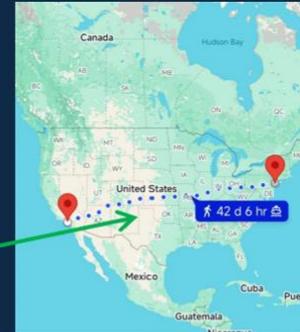
Electron

$$a_e^{\text{SM}} = 0.001159652182032(720)$$

$$a_e^{\text{Exp}} = 0.00115965218059(13)$$



“The precision of AMM like using the width of a human hair to measure the distance from Los Angeles to New York—over 3,000 miles”



1985

pushed precision to 0.13 parts per trillion



Now

The current state of $g-2$ of charged Lepton



Electron

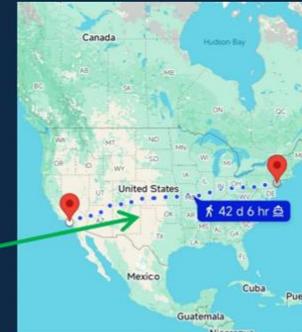
$$a_e^{\text{SM}} = 0.001159652182032(720)$$

$$a_e^{\text{Exp}} = 0.00115965218059(13)$$



“The precision of AMM like using the width of a human hair to measure the distance

The most precise measurement in fundamental particle's property.



1985



 pushed precision to 0.13 parts per trillion



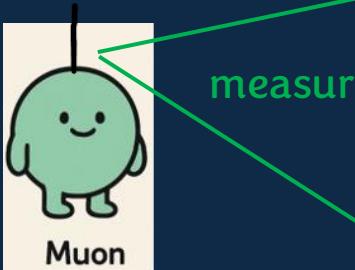
Now

The current state of $g-2$ of charged Lepton



"This is equivalent to measuring the length of a football field to a precision of one-tenth the thickness of a human hair"

$$a_{\mu}^{\text{SM}} = 0.00116591810(43)$$
$$a_{\mu}^{\text{Exp}} = 0.00116592059(22)$$

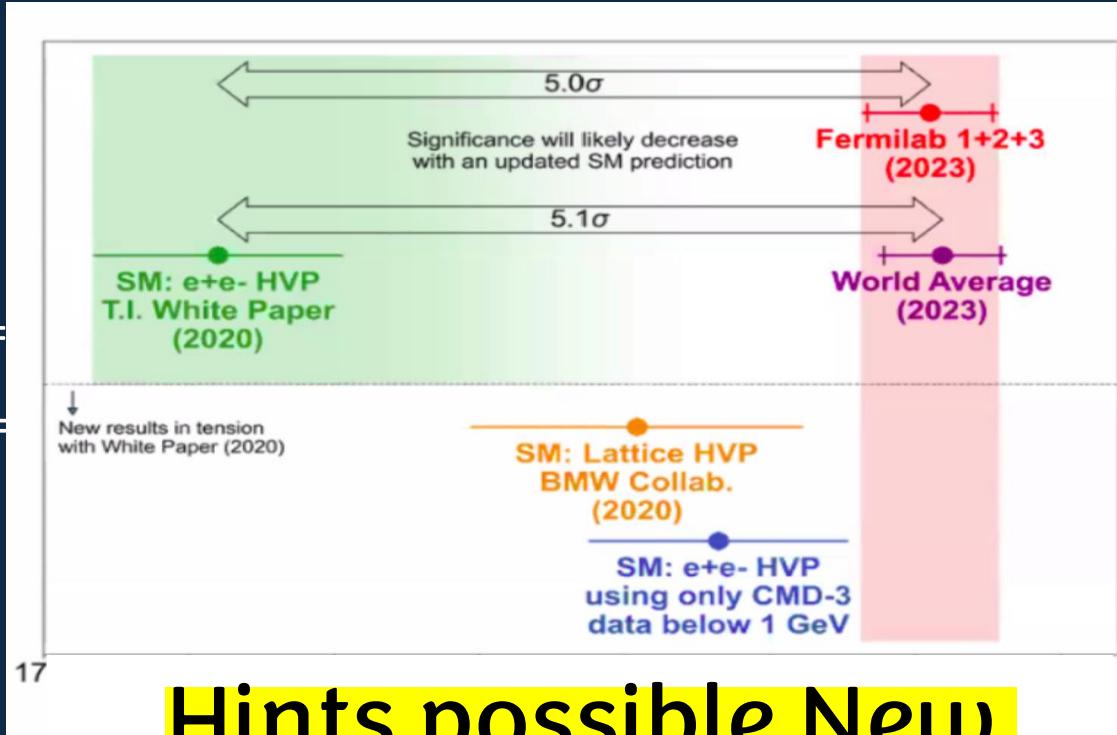


precision to up to 0.2 parts per million



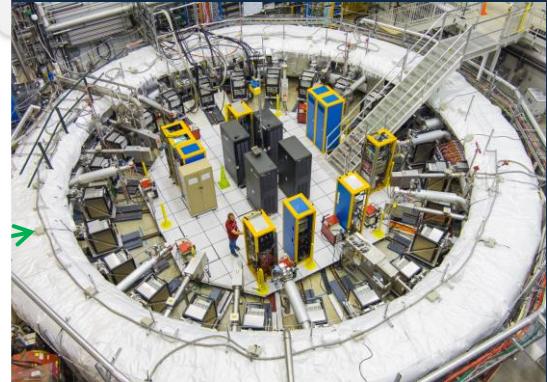
The current state of $g-2$ of charged Lepton

$$a_{\mu}^{\text{SM}} = a_{\mu}^{\text{Exp}}$$



17

Hints possible New Physics



 precision to up to 0.2 parts per million



The current state of $g-2$ of charged Lepton



“Short lifetime prevented precise measurements of its $g-2$,
but large mass hints larger Δa_l deviations may anticipate”

$$a_\tau^{\text{SM}} = 0.00117721(5)$$

$$a_\tau^{\text{Exp}} = 0.0009^{+0.0032}_{-0.0031}$$

The current state of $g-2$ of charged Lepton

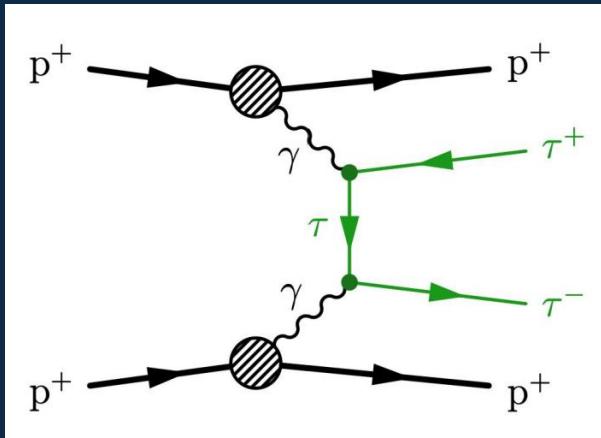


$$a_{\tau}^{\text{SM}} = 0.00117721(5)$$

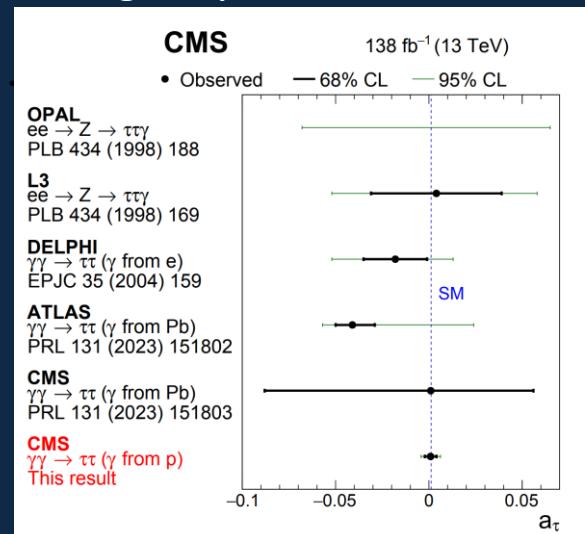
$$a_{\tau}^{\text{Exp}} = 0.0009^{+0.0032}_{-0.0031}$$

“Short lifetime prevented precise measurements of its $g-2$, but large mass hints larger Δa_L deviations may anticipate”

LHC probes magnetic moments through $\gamma\gamma \rightarrow \tau\tau$



Improving LEP limits on tau $g-2$ by a factor of five!!



The current state of $g-2$ of charged Lepton



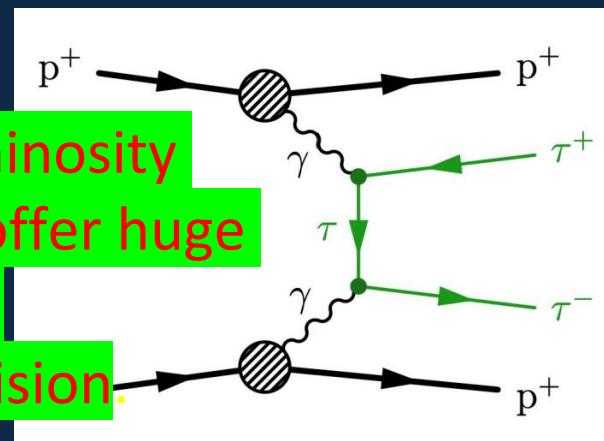
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$$a_{\tau}^{\text{SM}} = 0.00117721(5)$$

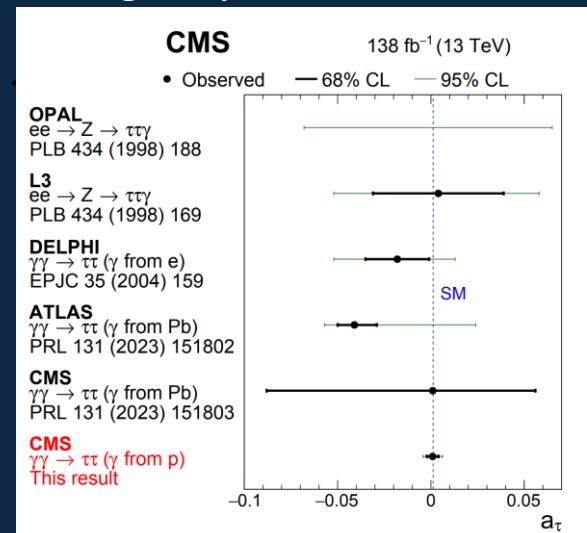
$$a_{\tau}^{\text{Exp}} = 0.0009^{+0.0032}_{-0.0031}$$

High-energy and luminosity future colliders will offer huge improvements in tau production and precision.

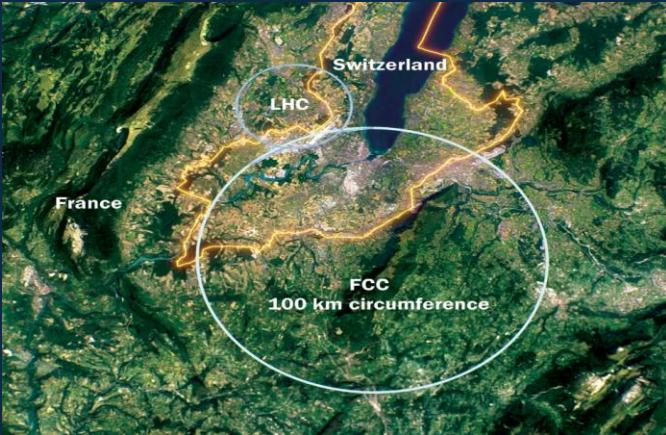
LHC probes magnetic moments through $\gamma\gamma \rightarrow \tau\tau$



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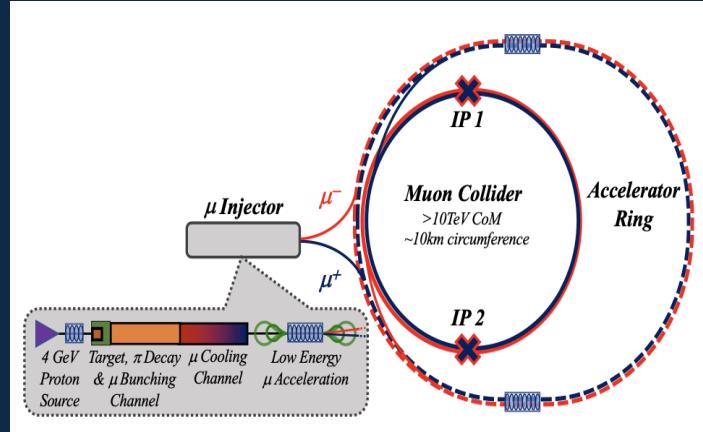
The future collider



Why FCC-ee?

- Super high Luminosity at GeV scale
- High Precision Measurements
- Relatively Mature Technology
- Low hadronization background
- Clean experimental environment
- EPA(Equivalent Photon Approximation)
-

The future collider



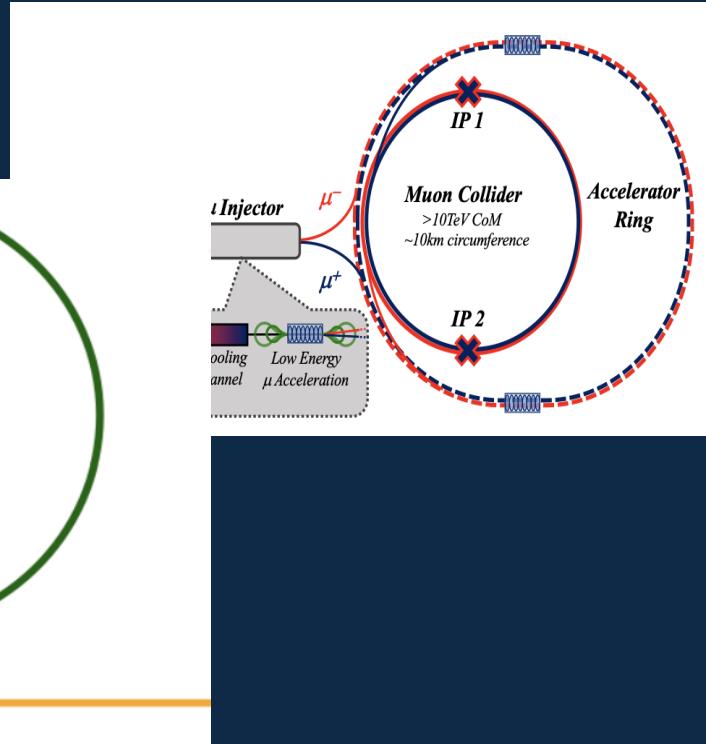
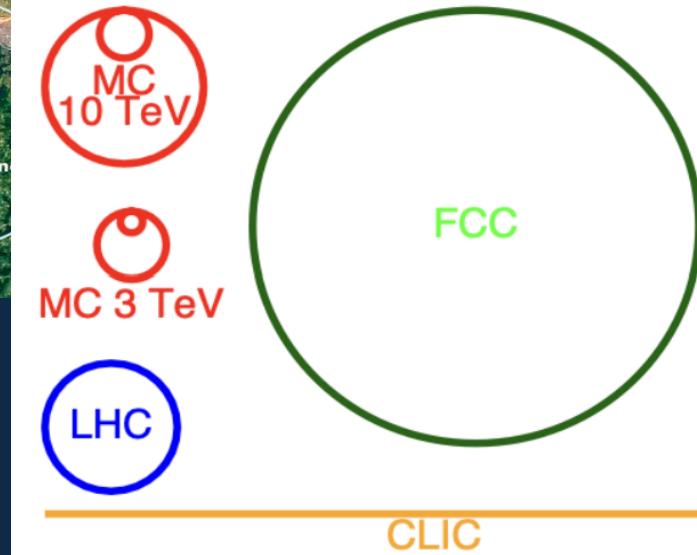
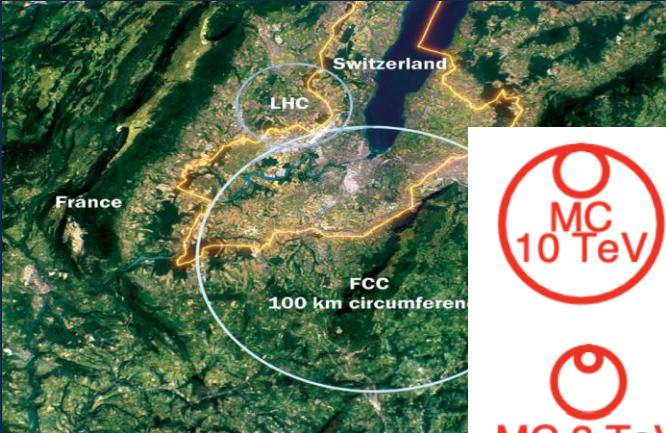
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-

Why Muon Collider?

- High-energy and Luminosity
- A promising candidate for the energy frontier at TeV scale
- ECM efficient in $\mu^+\mu^-$ annihilation
- Less radiation than e^+e^- collider
- Much smaller beam-energy spread
- A smaller and a circular machine is possible
-

The future collider



- Both high luminosity FCC-ee and high energy muon collider can offer a stronger sensitive environment to investigate new physics affecting the tau anomalous magnetic moment.

The tau g-2 based on SMEFT framework

- $e^+e^- \rightarrow \tau^+\tau^-$
- $\gamma\gamma \rightarrow \tau^+\tau^-$ (EPA)



Process Electron Colliders (FCC-ee)

The tau g-2 based on SMEFT framework

- $e^+e^- \rightarrow \tau^+\tau^-$
- $\gamma\gamma \rightarrow \tau^+\tau^-$ (EPA)



Process Electron Colliders (FCC-ee)

All possible high-energy processes at Muon Collider:

- $\mu^+\mu^- \rightarrow \tau^+\tau^-$
- $\mu^+\mu^- \rightarrow \tau^+\tau^- h$ ($\mu^+\mu^- \rightarrow \tau^+\tau^- Z$)



Offer a direct and highly sensitive
for measuring for tau g-2

- $\mu^+\mu^- \rightarrow \mu^+\mu^-\tau^+\tau^-$
- $\mu^+\mu^- \rightarrow \tau^+\tau^-\bar{\nu}\nu$
- $\mu^+\mu^- \rightarrow \mu^+\tau^-\bar{\nu}_\tau\nu_\mu (\mu^-\tau^+\bar{\nu}_\mu\nu_\tau)$



Large cross-section driven by VBF

The tau g-2 based on SMEFT framework

- $e^+e^- \rightarrow \tau^+\tau^-$
- $\gamma\gamma \rightarrow \tau^+\tau^-$ (EPA)



Process Electron Colliders (FCC-ee)

All possible high-energy processes at Muon Collider:

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Offer a direct and highly sensitive
for measuring for tau g-2

- $\mu^+\mu^- \rightarrow \mu^+\mu^-\tau^+\tau^-$
- $\mu^+\mu^- \rightarrow \tau^+\tau^-\bar{\nu}\nu$
- $\mu^+\mu^- \rightarrow \mu^+\tau^-\bar{\nu}_\tau\nu_\mu(\mu^-\tau^+\bar{\nu}_\mu\nu_\tau)$



Large cross-section driven by VBF

Improve the signal-to-background ratio and keep
enough events

Considering the detection efficiency of MC.

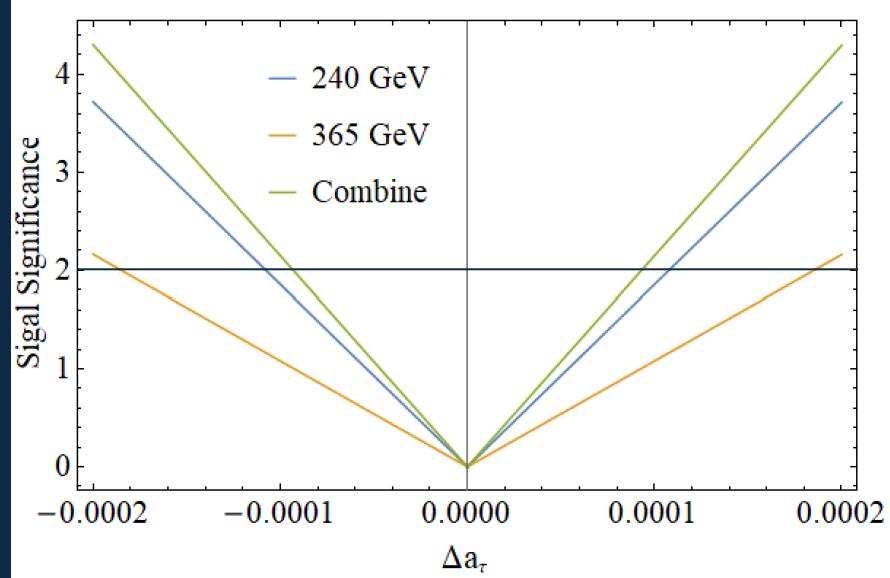
Optimize the cuts selection: Pt and $M(\tau^+\tau^-)$ Analysis

Potential mistags of process

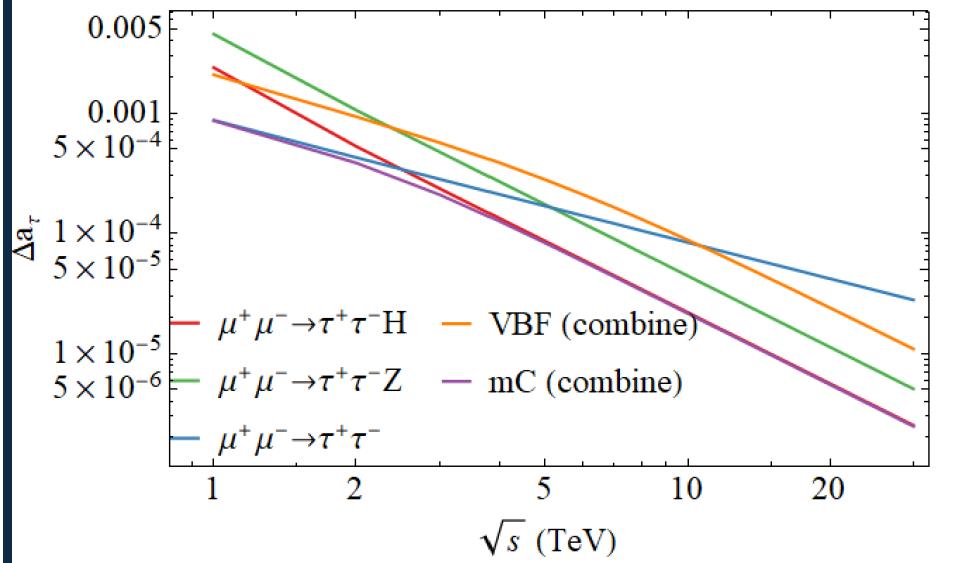
The $g-2$ of Tau at future collider

The combination of multiple processes and the sensitivity of Δa_τ

FCC-ee



Muon collider



Thanks!

