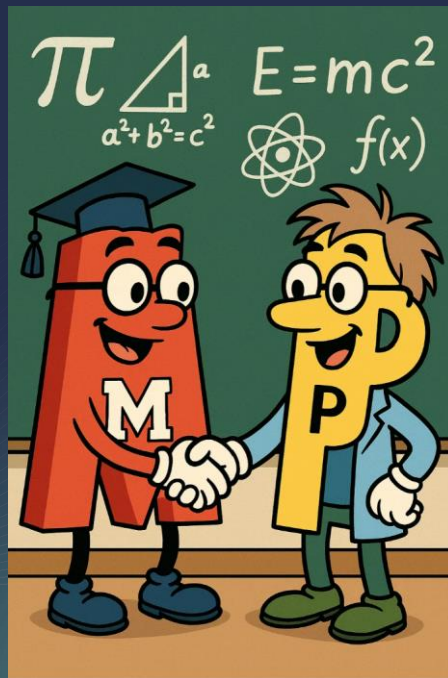




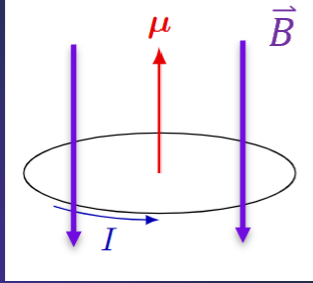
The τ $g-2$ at future collider

ZeQiang Wang

UCLouvain, CP3



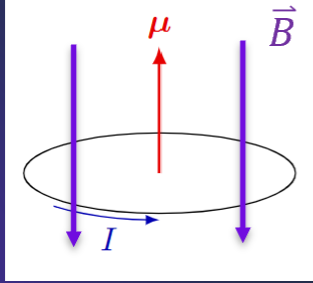
What is g-2?



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

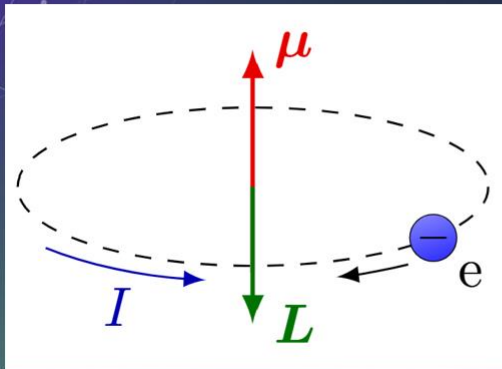
$$E = -\vec{\mu} \cdot \vec{B}$$

What is g-2?



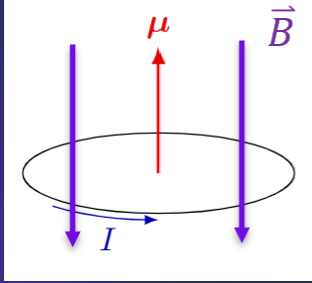
$$\vec{\mu} = I \vec{A}$$

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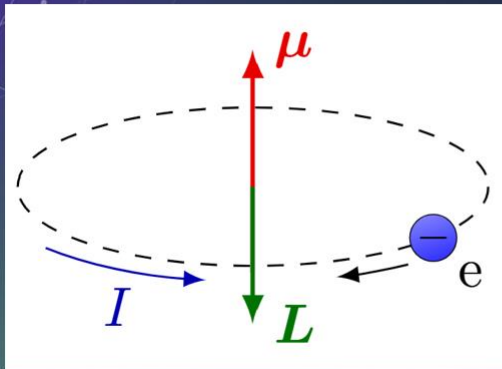
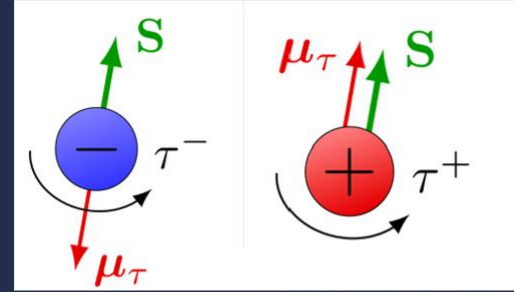
$$\vec{\mu} = -\frac{e}{2m} \vec{L}$$

What is g-2?



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

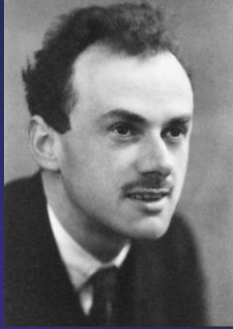
$$E = -\vec{\mu} \cdot \vec{B}$$



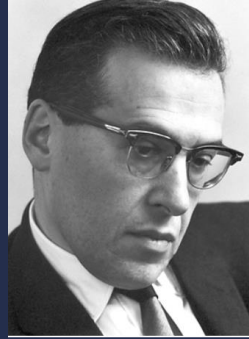
$$\vec{\mu} = -\frac{e}{2m}\vec{L} \quad \longrightarrow \quad \vec{\mu} = g\frac{e}{2m}\vec{S}$$

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

What is g-2?



Dirac predicts $g=2$

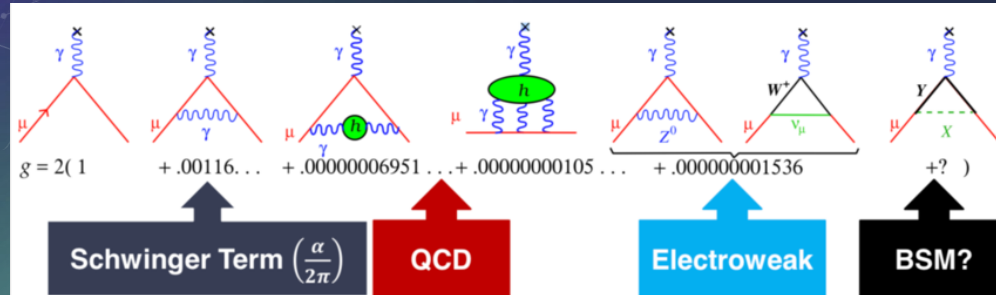


Schwinger gives the term $\frac{\alpha}{2\pi}$

Higher-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 hint new physics (BSM)



g-2 for charged lepton

Standard Model of Elementary Particles

three generations of matter (fermions)						interactions / force carriers (bosons)	
I			II			III	
mass charge spin	$\approx 2.16 \text{ MeV}/c^2$ $\frac{2}{3}$ $\frac{1}{2}$	$\approx 1.273 \text{ GeV}/c^2$ $\frac{2}{3}$ $\frac{1}{2}$	$\approx 172.57 \text{ GeV}/c^2$ $\frac{2}{3}$ $\frac{1}{2}$	0 0 1	$\approx 125.2 \text{ GeV}/c^2$ 0 0		
up			charm			gluon	
down			strange			photon	
bottom			tau			Z boson	
electron			muon			W boson	
electron neutrino			muon neutrino				

QUARKS

LEPTONS

SCALAR BOSONS

GAUGE BOSONS VECTOR BOSONS

g-2 for charged lepton

Standard Model of Elementary Particles

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	u up	c charm	t top	g gluon	H higgs		
	$\approx 4.7 \text{ MeV}/c^2$ $-\frac{1}{3}$ $\frac{1}{2}$	$\approx 93.5 \text{ MeV}/c^2$ $-\frac{1}{3}$ $\frac{1}{2}$	$\approx 4.183 \text{ GeV}/c^2$ $-\frac{1}{3}$ $\frac{1}{2}$	0 0 1			
	d down	s strange	b bottom	γ photon			
	$\approx 0.511 \text{ MeV}/c^2$ -1 $\frac{1}{2}$	$\approx 105.66 \text{ MeV}/c^2$ -1 $\frac{1}{2}$	$\approx 1.77693 \text{ GeV}/c^2$ -1 $\frac{1}{2}$	$\approx 91.188 \text{ GeV}$ 0 1			
	e electron	μ muon	τ tau	Z Z boson			
	$< 0.8 \text{ eV}/c^2$ 0 $\frac{1}{2}$	$< 0.17 \text{ MeV}/c^2$ 0 $\frac{1}{2}$	$< 18.2 \text{ MeV}/c^2$ 0 $\frac{1}{2}$	$\approx 80.3692 \text{ GeV}/c^2$ ± 1 1			
	ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	W W boson			



1 : 207 : 3477

Mass

Stable : $2.2 \times 10^{-6} \text{ s}$: $2.9 \times 10^{-13} \text{ s}$

Lifetime

Measure and calculate g-2
Difficulty

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



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

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

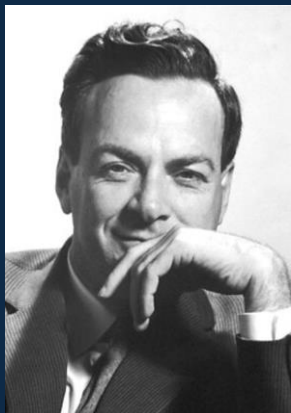
The current state of $g-2$ of charged Lepton



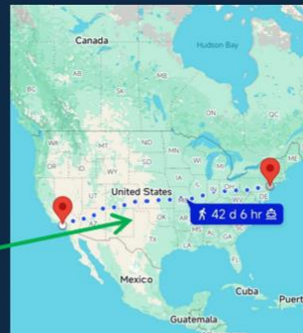
Electron

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

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



“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



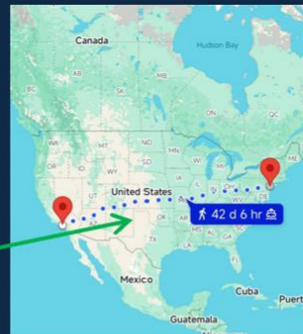
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1985



pushed precision to 0.13 parts per trillion

Now

The most precise measurement in fundamental particle's property.

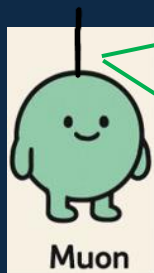
The current state of $g-2$ of charged Lepton



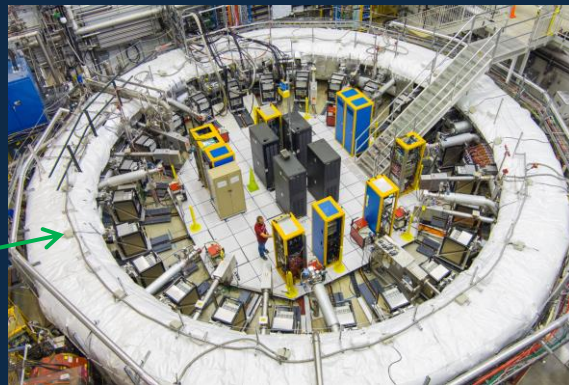
“This is equivalent to measuring the length of a football field to a precision of one-tenth the thickness of a human hair”

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

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



measure

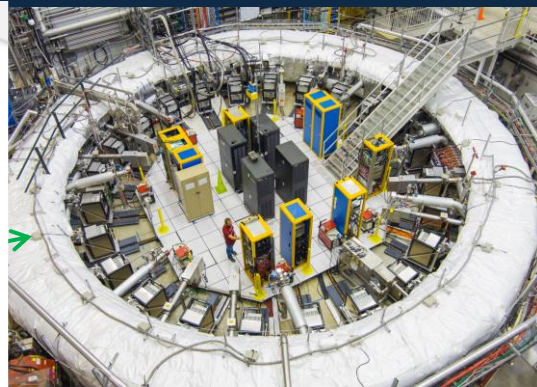
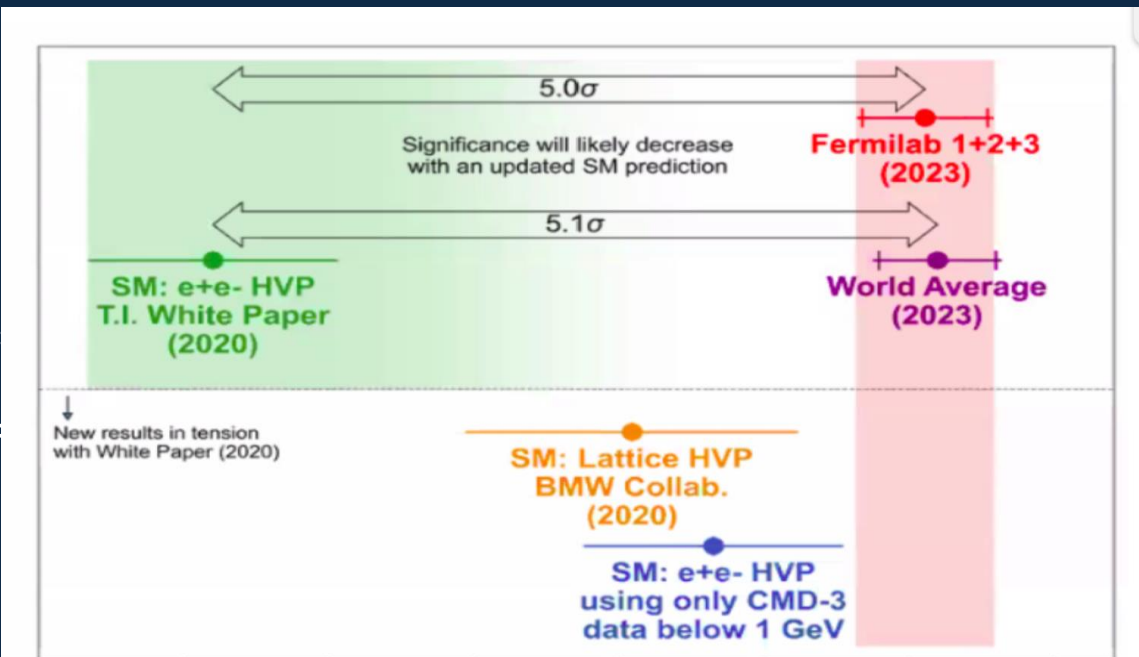


precision to up to 0.2 parts per million



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

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



precision to up to 0.2 parts per million



Hints possible New Physics

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

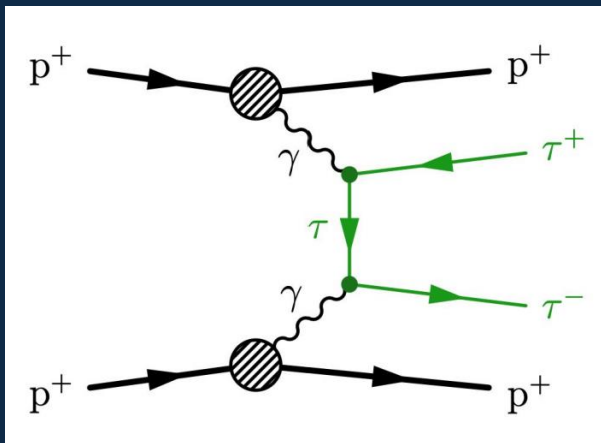


“Short lifetime prevented precise measurements of its $g-2$, but large mass hints larger Δa_l deviations may anticipate”

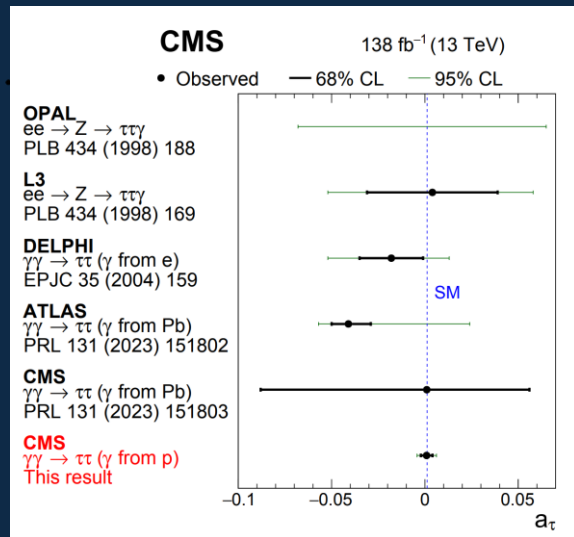
$$a_\tau^{\text{SM}} = 0.00117721(5)$$

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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



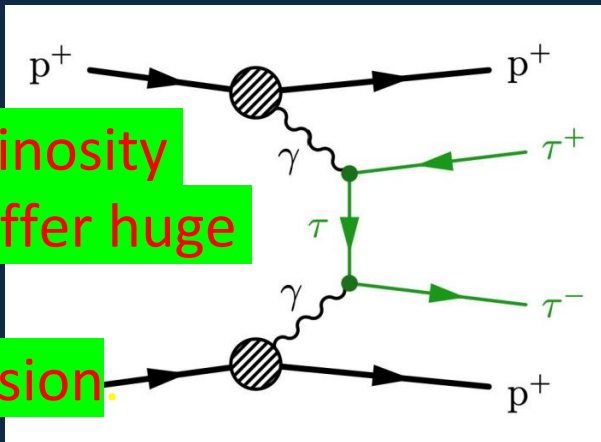
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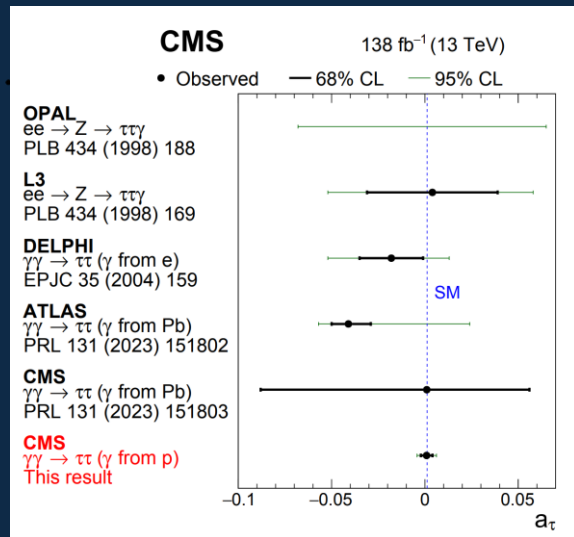
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LHC probes magnetic moments through $\gamma\gamma \rightarrow \tau\tau$

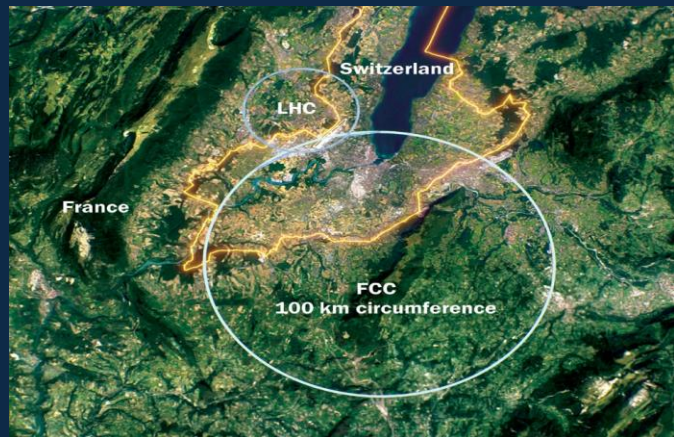
High-energy and luminosity future colliders will offer huge improvements in tau production and precision.



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



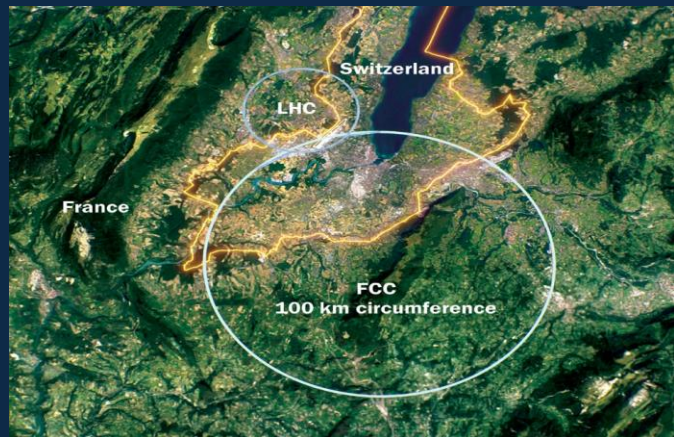
The future collider



Why FCC-ee?

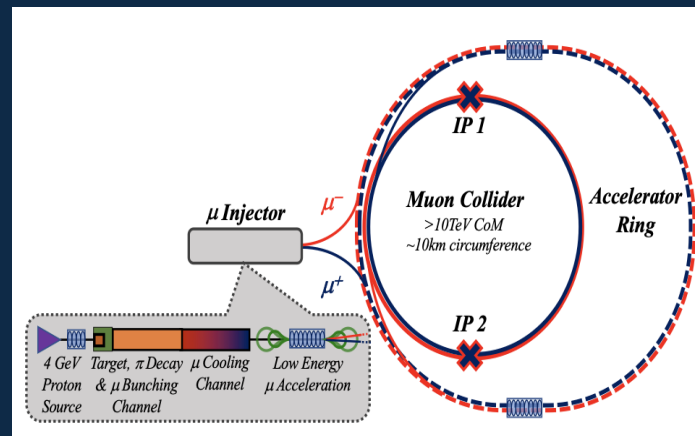
- Super high Luminosity at GeV scale
- High Precision Measurements
- Relatively Mature Technology
- Low hadronization background
- Clean experimental environment
- EPA(Equivalent Photon Approximation)
-

The future collider



Why FCC-ee?

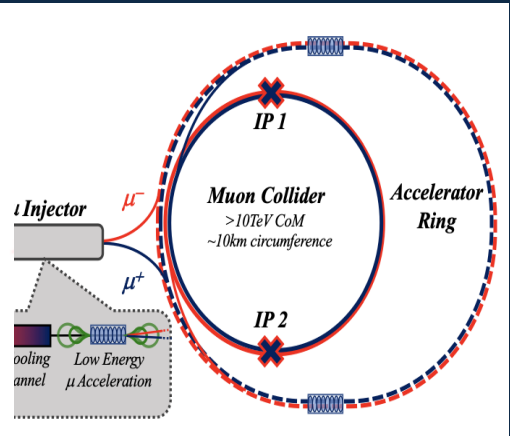
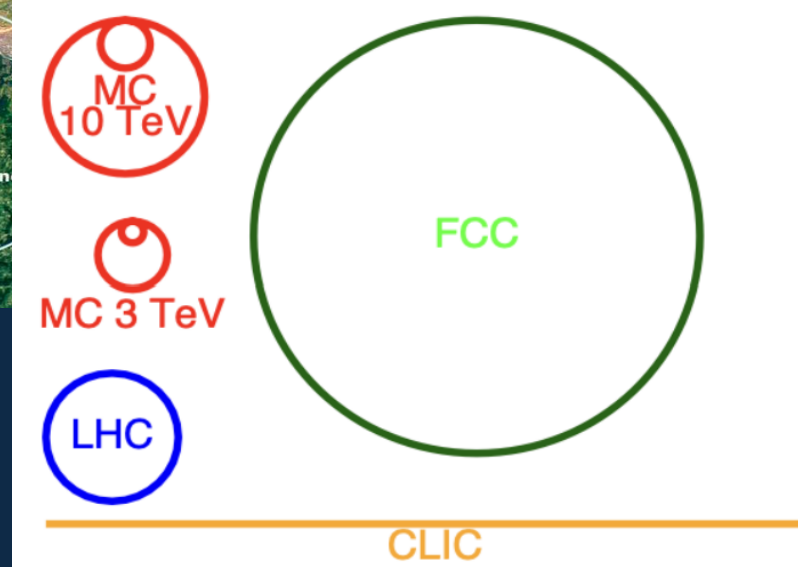
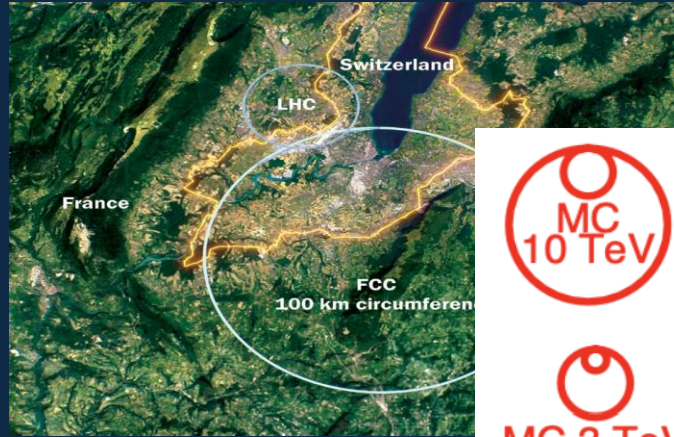
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-



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

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



Process Electron Colliders (FCC-ee)

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



Large cross-section driven by VBF

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

Considering the detection efficiency of MC.

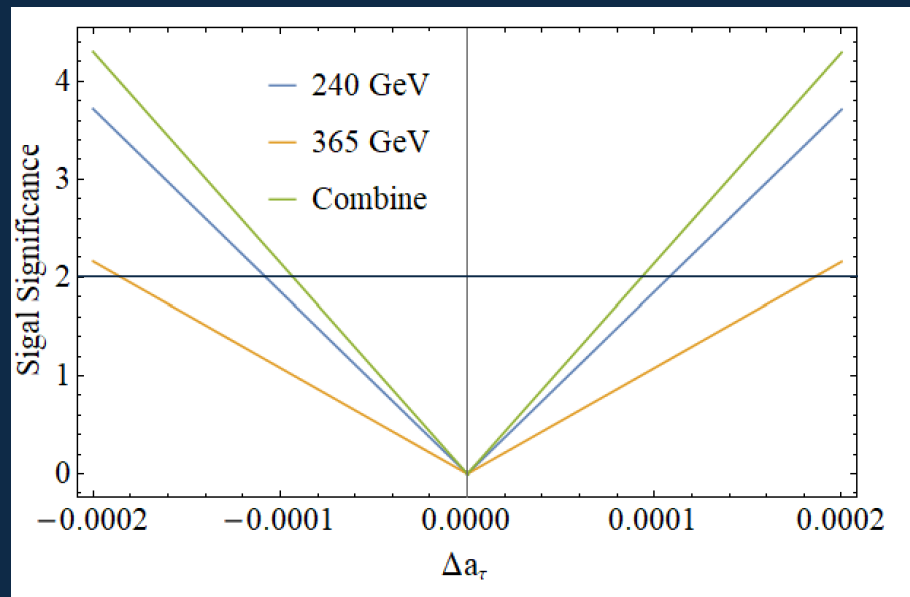
Optimize the cuts selection: Pt and M($\tau^+\tau^-$) Analysis

Potential mistags of process

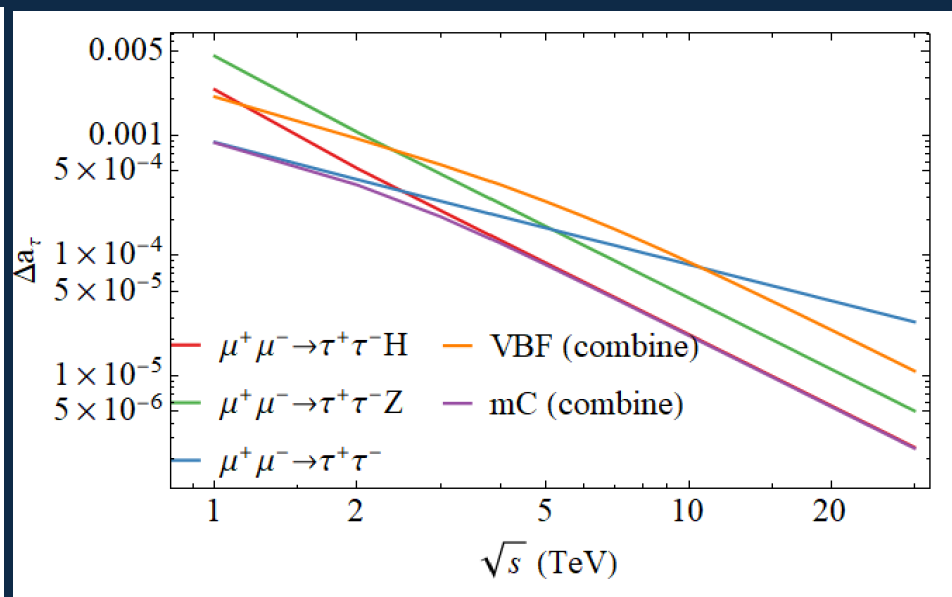
The g-2 of Tau at future collider

The combination of multiple processes and the sensitivity of Δa_τ

FCC-ee



Muon collider



Thanks!

