Search for new physics via the photo-production of tau leptons

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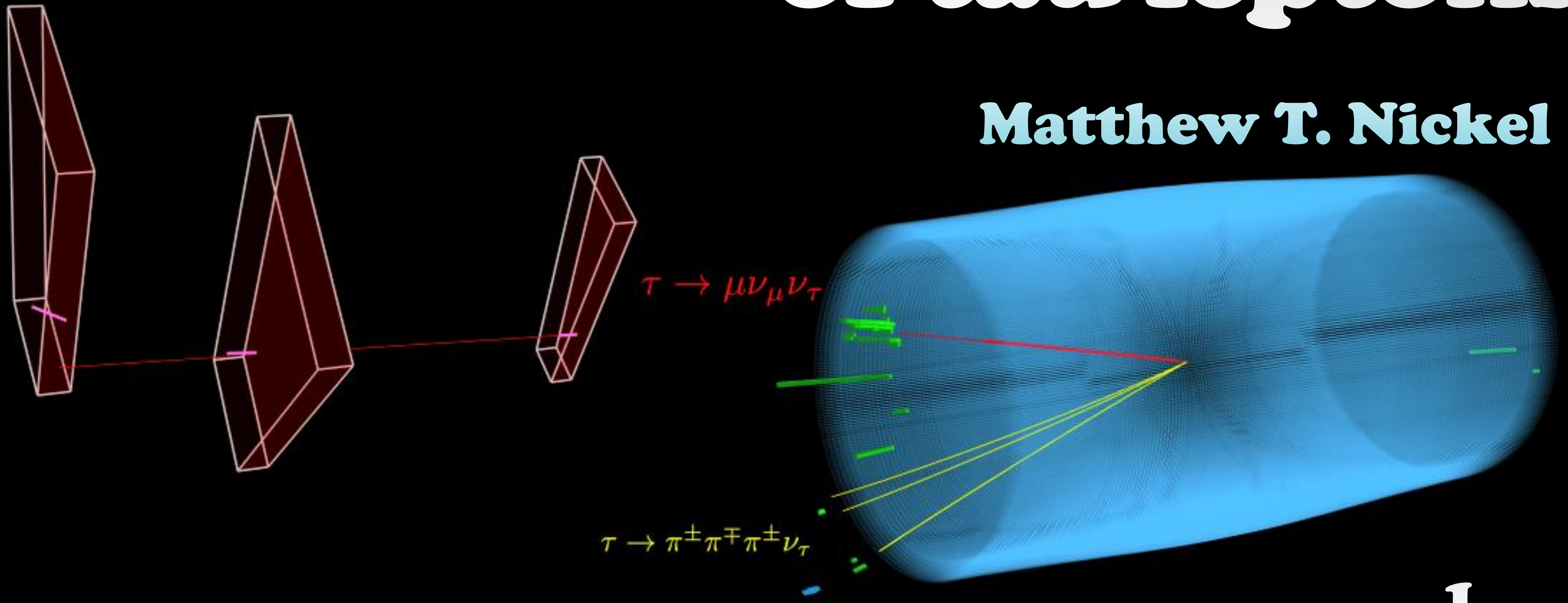
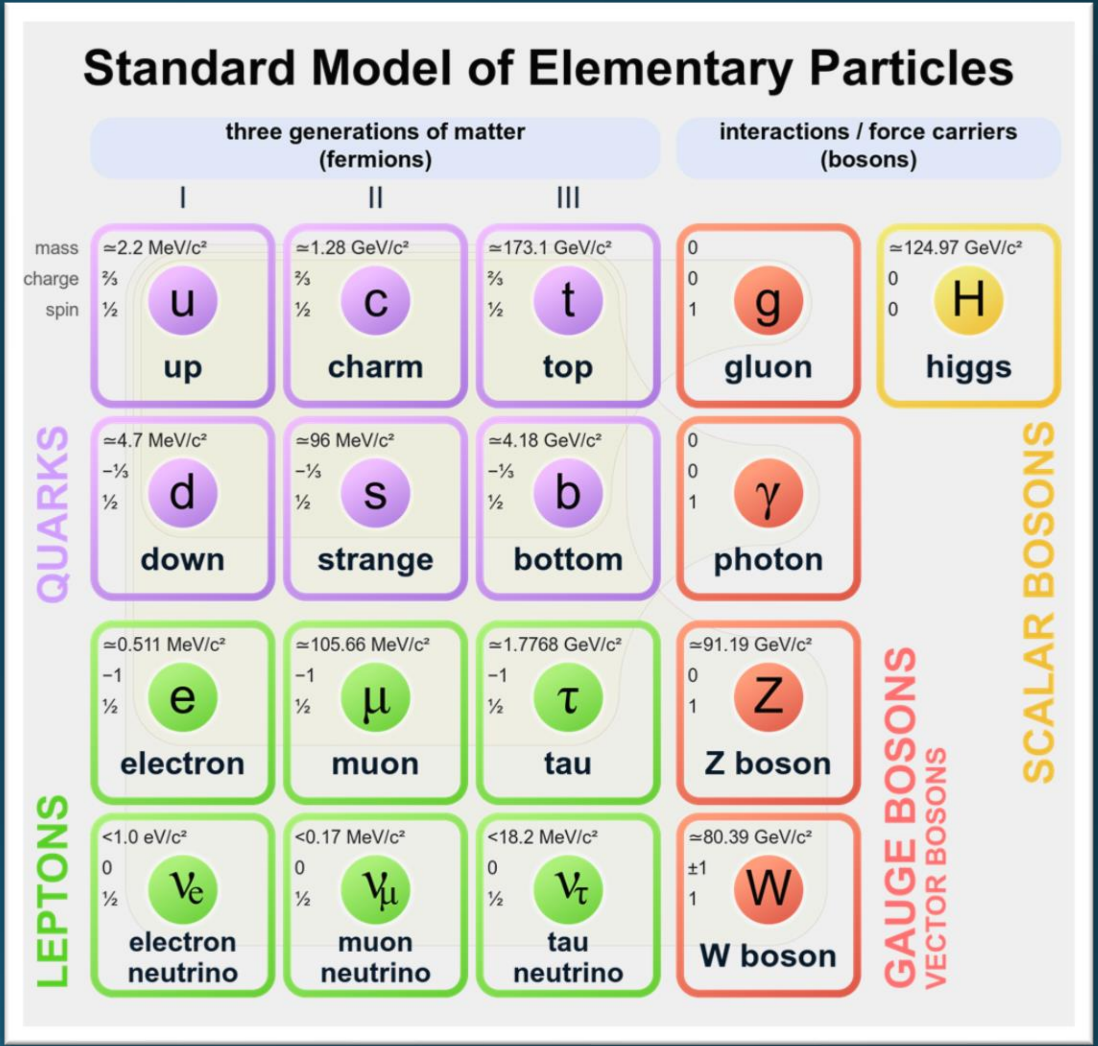


Standard Model

$$
\begin{aligned}
\mathcal{L} = &-\frac{1}{4}F_{\mu\nu}F^{\mu\nu} \\
&+ i\bar{\psi}\not{D}\psi + h.c. \\
&+ \psi_i y_{ij}\psi_j\phi + h.c. \\
&+ |D_\mu\phi|^2 - V(\phi)
\end{aligned}
$$



Almost all fundamental interactions described by these

Issues in The Standard Model

- Standard Model has been extremely successful in describing all current collider data
- There have been a few measurements that are in tension with the standard model
- Most notably the anomalous magnetic moment of the muon a_μ
- If discrepancy of a_μ is due to new physics, then a_τ would be 280 times more sensitive to NP due to increased mass

Anomalous Magnetic Moment of Leptons

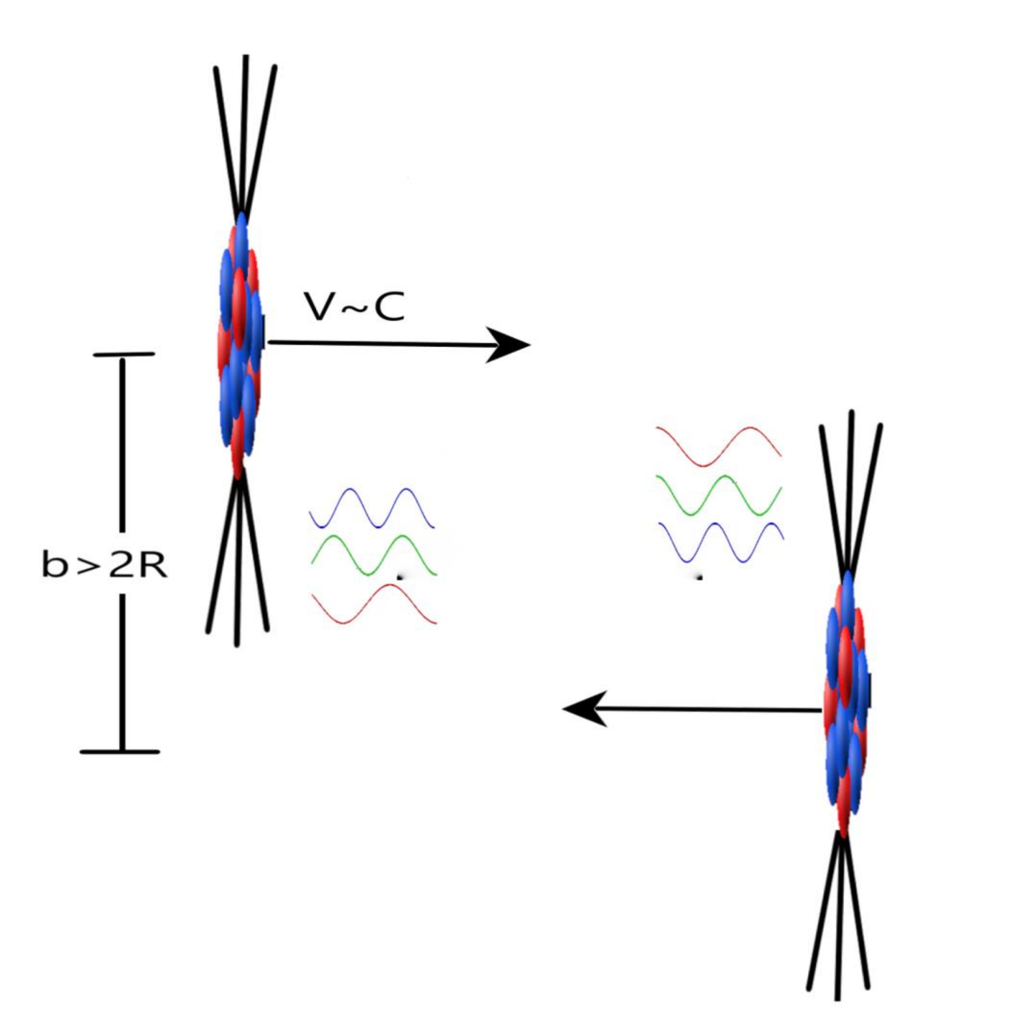
$$\overrightarrow{\mu_l} = g_l \left(\frac{q}{2m}\right) \vec{S}$$

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

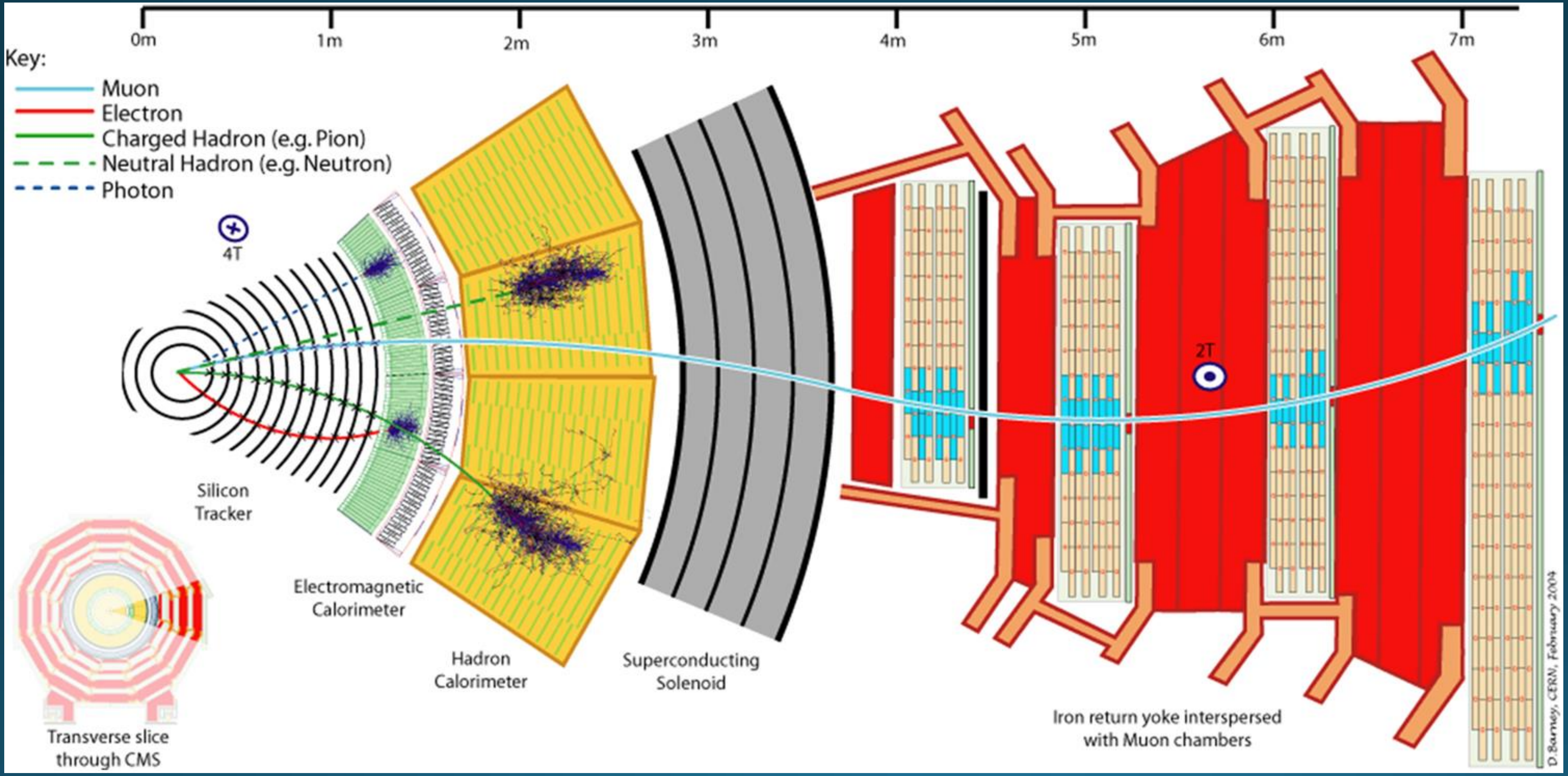
- **Anomalous Magnetic Moment of electron a_e is one of the most precise measurements in SM**
- **Both Theory and Experiment are measured less than 1 part per billion and agree.**
- **a_μ has 3.7σ discrepancy between theory and experiment**
- **a_τ can be measured through photo-production cross-section**

Ultra Peripheral Collisions

Photon Energy	$\sim\gamma\hbar c/R$	**178 GeV**
Max p_T	$\sim\hbar c/R$	**30 MeV**
Photon Rates	$\sim Z^4$	**45 M times pp flux**



Compact Muon Solenoid



https://cds.cern.ch/record/2270046/plots

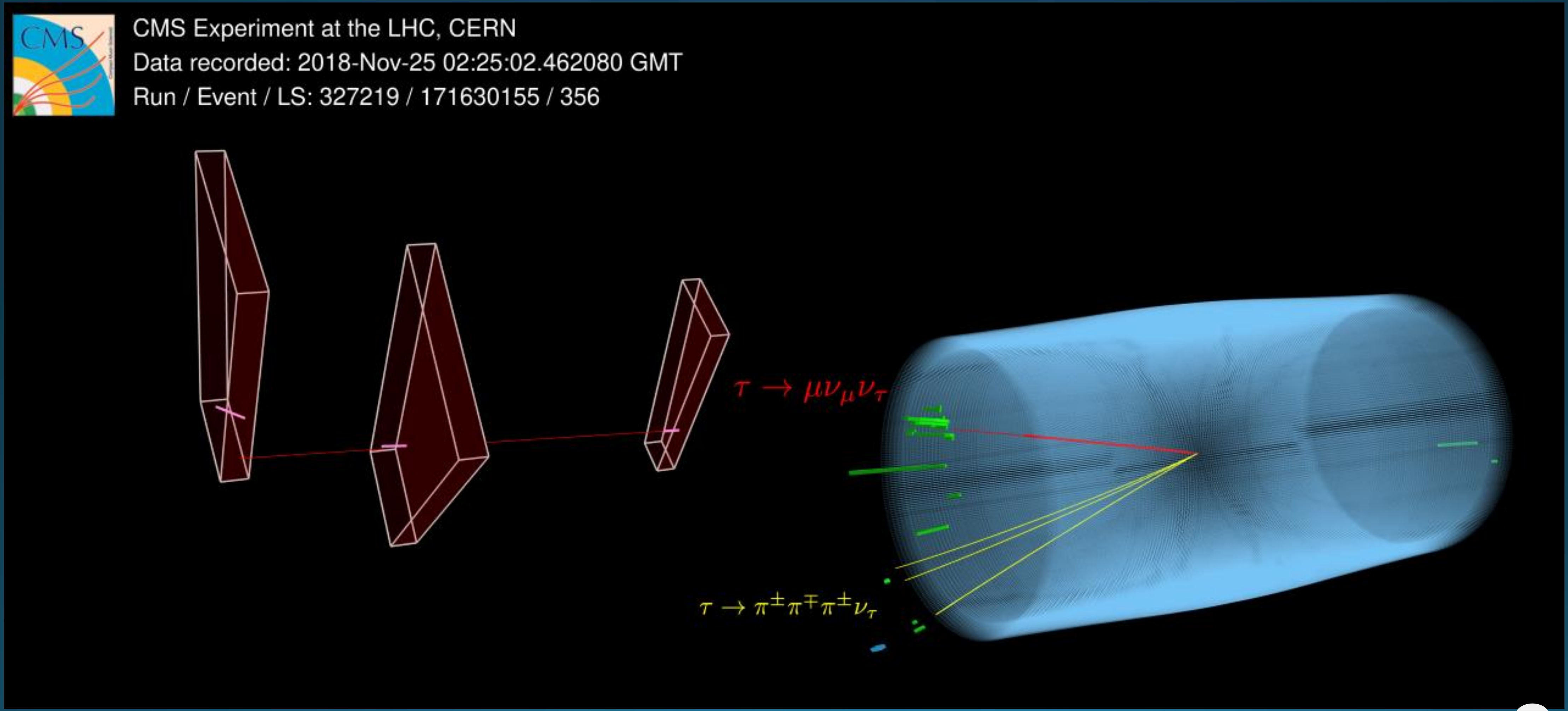
We propose measuring the cross section of the process $\gamma\gamma \rightarrow \tau\,\tau$ using the heavy ion data from the CMS experiment at the LHC.

Tau decays

		τ Decay Mode	Branching Fraction (%)
Leptonic		$\tau^\pm \to e^\pm + \bar{\nu}_e + \nu_\tau$	17.84 ± 0.04
		$\tau^\pm \to \mu^\pm + \bar{\nu}_\mu + \nu_\tau$	17.41 ± 0.04
Hadronic	One-prong	$\tau^\pm \to \pi^\pm + (\geq 0\ \pi^0) + \nu_\tau$	49.46 ± 0.10
		$\tau^\pm \to \pi^\pm + \nu_\tau$	10.83 ± 0.06
		$\tau^\pm \to \rho^\pm(\to \pi^\pm + \pi^0) + \nu_\tau$	25.52 ± 0.09
		$\tau^\pm \to a_1(\to \pi^\pm + 2\pi^0) + \nu_\tau$	9.30 ± 0.11
		$\tau^\pm \to \pi^\pm + 3\pi^0 + \nu_\tau$	1.05 ± 0.07
		$\tau^\pm \to h^\pm + 4\pi^0 + \nu_\tau$	0.11 ± 0.04
Hadronic	Three-prong	$\tau^\pm \to \pi^\pm + \pi^\mp + \pi^\pm + (\geq 0\pi^0) + \nu_\tau$	14.57 ± 0.07
		$\tau^\pm \to \pi^\pm + \pi^\mp + \pi^\pm + \nu_\tau$	8.99 ± 0.06
		$\tau^\pm \to \pi^\pm + \pi^\mp + \pi^\pm + \pi^0 + \nu_\tau$	2.70 ± 0.08

https://cds.cern.ch/record/2306444/files/CERN-THESIS-2013-465.pdf

Our Signal



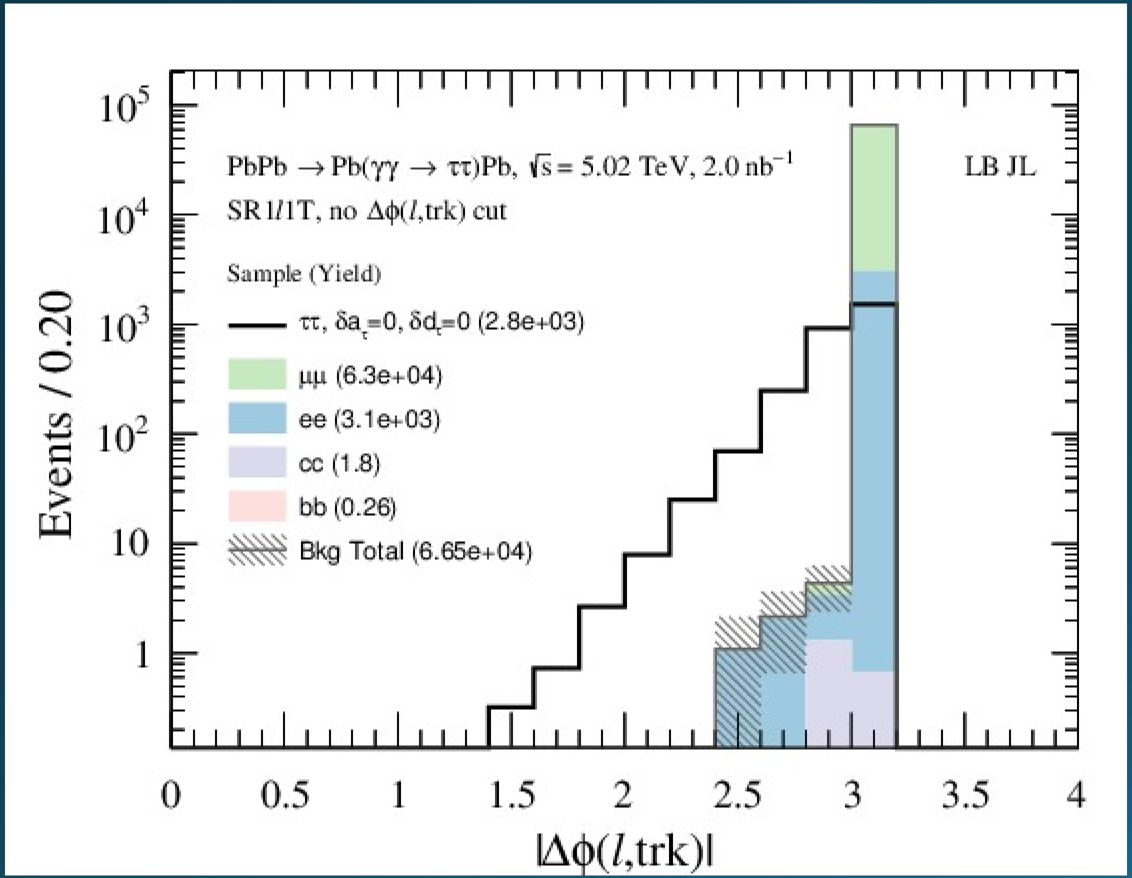
CMS Experiment at the LHC, CERN
Data recorded: 2018-Nov-25 02:25:02.462080 GMT
Run / Event / LS: 327219 / 171630155 / 356
$\tau \rightarrow \mu\nu_\mu\nu_\tau$
$\tau \rightarrow \pi^\pm\pi^\mp\pi^\pm\nu_\tau$

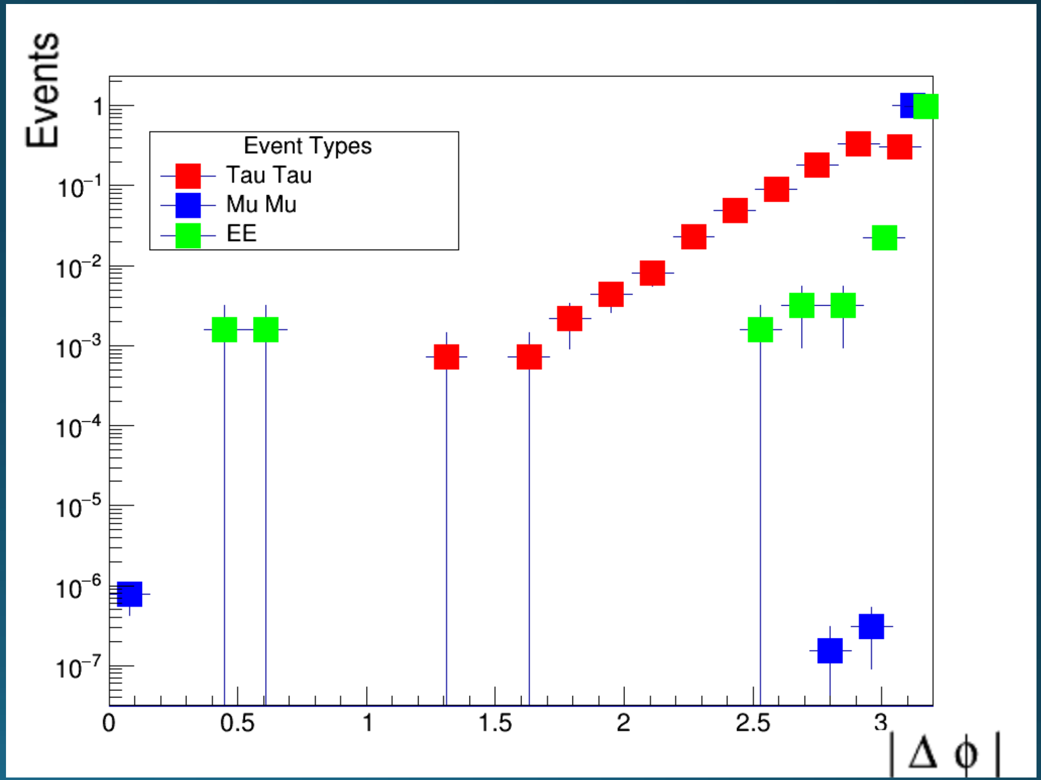
Proposed selection cuts

Requirement	$\tau\tau$ (0,0)	$\tau\tau$ (0.005,0)	$\tau\tau$ (−0.01,0)	$\mu\mu$	ee	bb	cc	ss	uu	dd
1 lepton + 1 track analysis (SR1ℓ1T)										
$\sigma \times \mathcal{L}$	1139800	1195060	1056400	844080	844080	2999	604080	37754	604080	37754
$\sigma \times \mathcal{L} \times \epsilon_{\text{filter}}$	241140	253920	226300	844080	844080	2999	604080	37754	604080	37754
1ℓ plus 1 track	20492.2	21619.3	19348.4	263443	3299.3	5.4	2905.0	0.3	5.4	0.2
$p_T^{e/\mu} > 4.5/3$ GeV, $\lvert\eta^{e/\mu}\rvert < 2.5/2.4$	3659.9	3882.7	3582.8	79043	3118.9	1.1	4.8	0.0	0.0	0.0
2 tracks, $p_T^{\text{trk}} > 0.5$ GeV, $\lvert\eta^{\text{trk}}\rvert < 2.5$	3324.5	3535.9	3256.9	78973	3117.8	1.0	3.0	0.0	0.0	0.0
$\lvert\Delta\phi(\ell, \text{trk})\rvert < 3$	1519.7	1605.7	1468.3	0.9	5.3	0.7	1.8	0.0	0.0	0.0
$m_{\ell,\text{trk}} \notin \{[3, 3.2], [9, 11]\}$ GeV	1275.1	1353.6	1242.3	0.9	5.3	0.2	1.2	0.0	0.0	0.0
$p_T^{\ell} \leq 6.0$ GeV	1197.7	1262.3	1154.7	0.9	0.0	0.2	1.2	0.0	0.0	0.0
$p_T^{\ell} > 6.0$ GeV	77.3	91.3	87.6	0.0	5.3	0.0	0.0	0.0	0.0	0.0

https://arxiv.org/abs/1908.05180

Acoplanarity of taus





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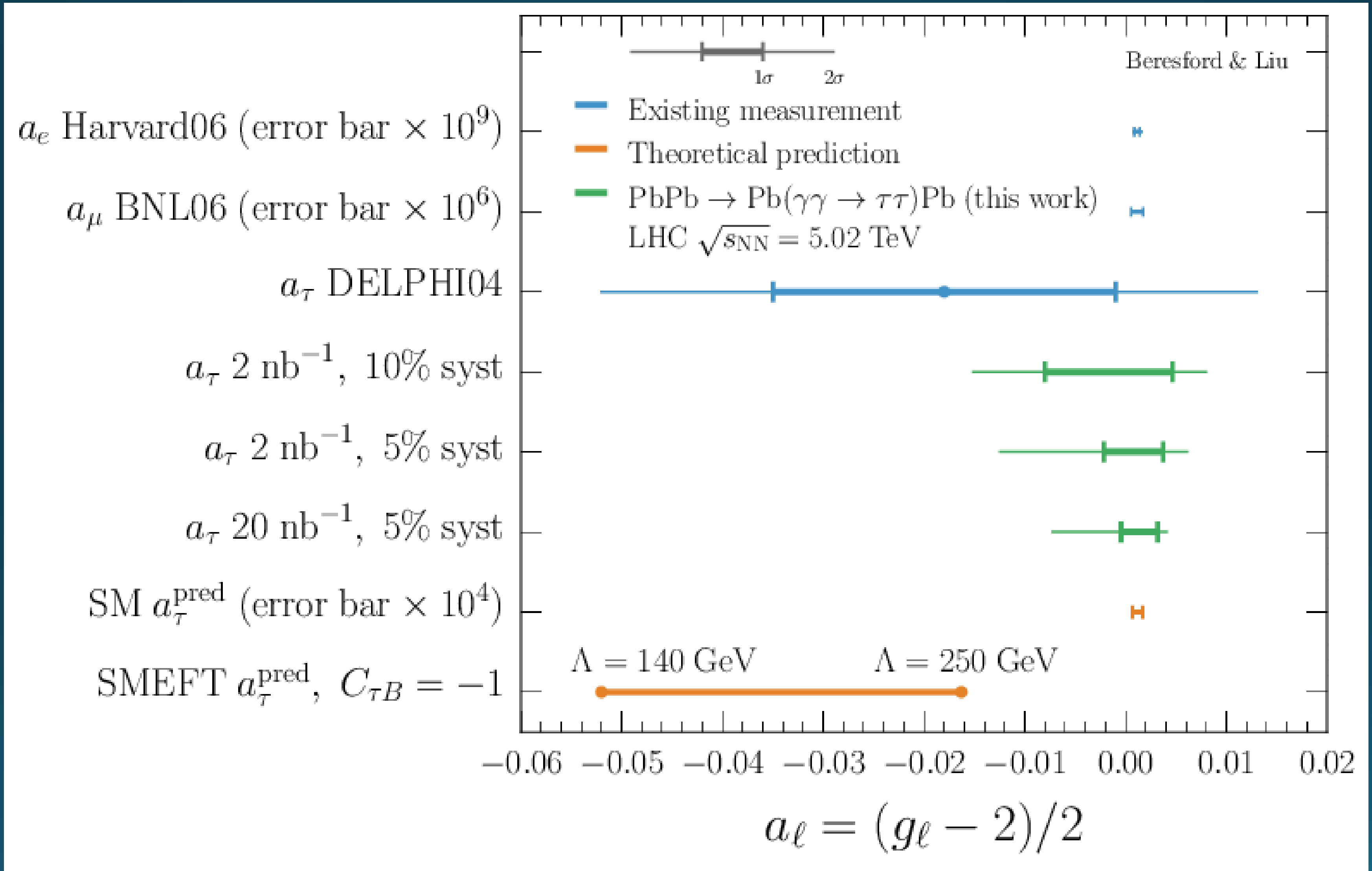
Normalized to Unity

We improve a_τ measurement



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Summary

- Standard Model is extremely accurate
- Only a few experiments are in tension with SM… a_μ
- a_τ is an even better test of the Standard Model
- This measurement is difficult but manageable using UPC
- Current Progress is promising but still much more work to do

Our Wonderful Group

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Questions?

Backups