OUTLOOK

K.HAYASAKA (NIIGATA UNIV.)

NIIGATA UNIVERSITY
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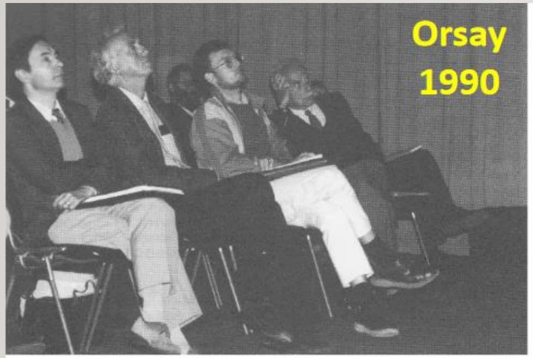
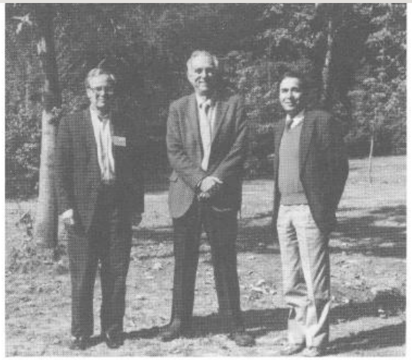
30th anniversary!





Workshop on Tau Lepton Physics
30th Anniversay

Antonio Pich

IFIC, Univ. Valencia - CSIC

The 16th International Workshop on Tau Lepton Physics (TAU2021)
Indiana University (online), 27 September – 1 October 2021

Tau 2021 in figures

- 99 scheduled talks
  - Properties of the tau lepton: 5 talks
  - Test of fundamental symmetries with tau lepton: 26 talks
  - Exclusive and inclusive hadronic tau decays: 11 talks
  - Neutrinos and Dark Matter: 11 talks
  - Proton-proton and e^+e^- colliders: 11 talks
  - Muon g-2: 15 talks
  - Future directions: 20 talks
- 18 posters

Sorry I cannot cover all of them!

What is discussed?

- Properties of the tau lepton:

  Pich's historical review, LU theory, tau mass, Belle II status, muon lifetime

- Test of fundamental symmetries with tau lepton:

  LFV search/theory, EDM, APL/DS search, LUV search

- Exclusive and inclusive hadronic tau decays:

  Theory for tau hadronic decays, HFLAV report

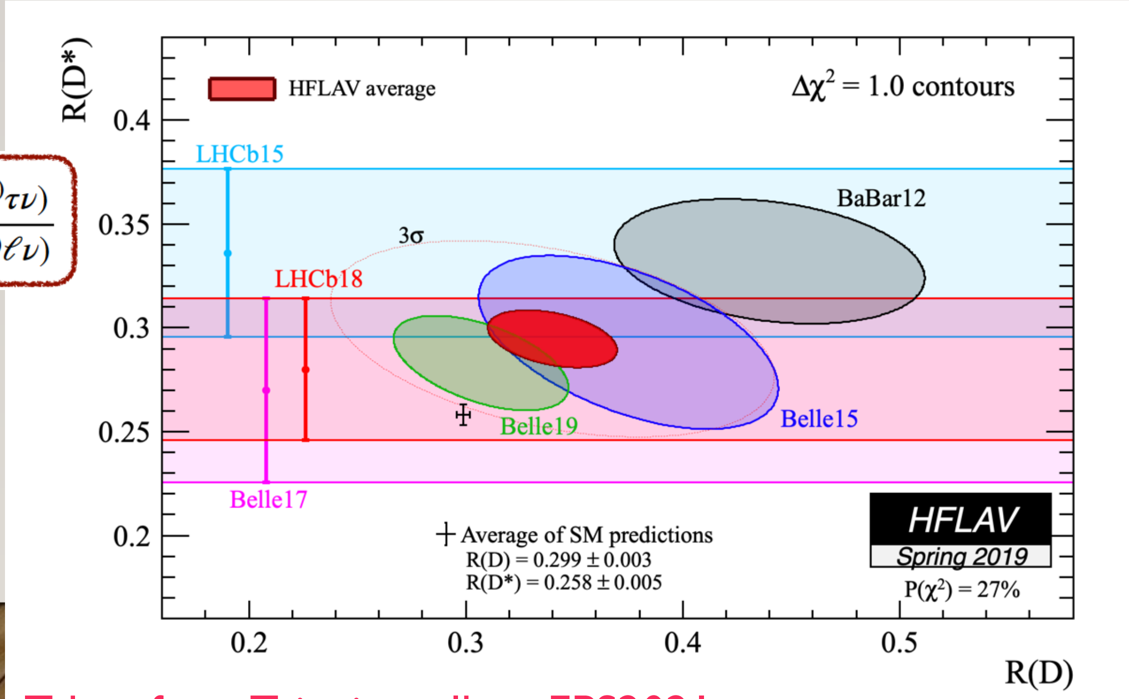
- Neutrinos and Dark Matter: sterile neutrino search,…
- Proton-proton and e^+e^- colliders: e^+e^- results, τ at LHC, simulator, ...
- Muon g-2: FNL result, theory to calc. a_μ
- Future directions: τ/charm factory, μ, ν, Belle II, FCC-ee

My personal view

The exciting era for lepton physics is coming!

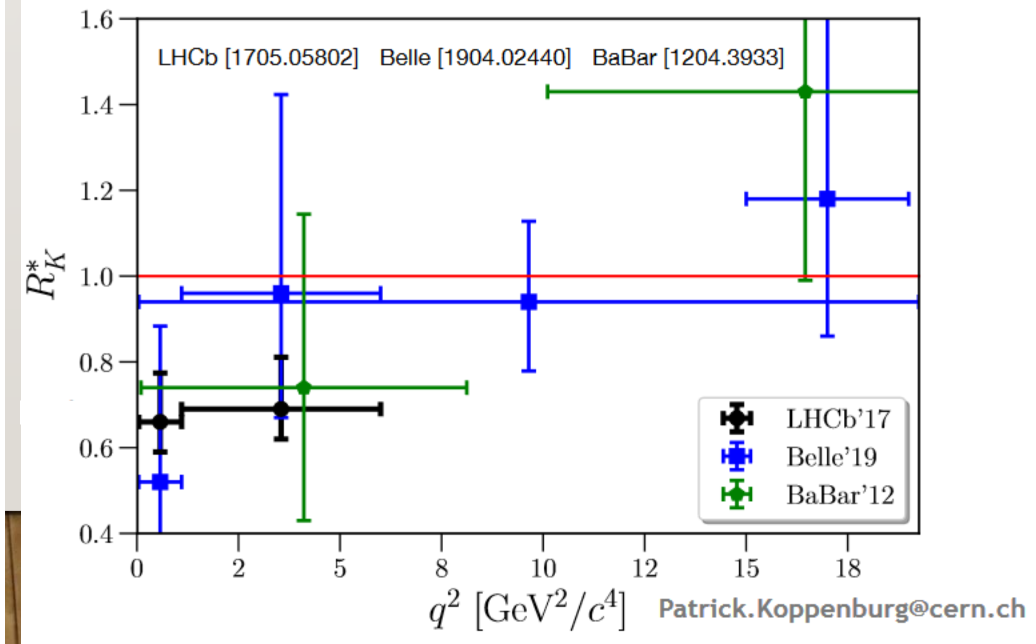
→Anomalies relating to Lepton Universality survive these years.

$$R_{D^{(*)}} = \frac{BR(B \to D^{(*)}\tau\nu)}{BR(B \to D^{(*)}\ell\nu)}$$



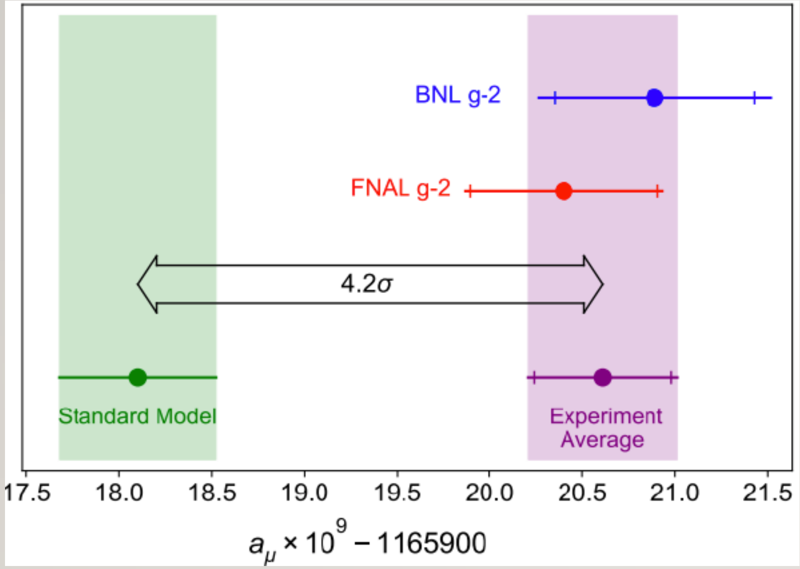
Taken from Teixeira talk at EPS2021

$$R_{K^{(*)}} = \frac{BR(B \to K^{(*)}\mu\mu)}{BR(B \to K^{(*)}ee)}$$

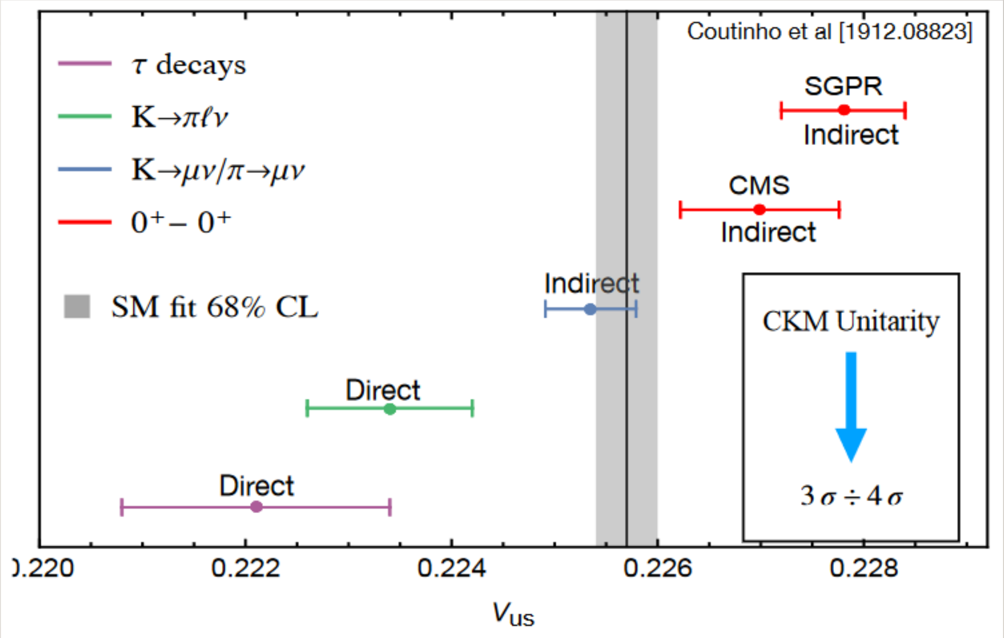


More anomalies relating to leptons

Muon g-2



Vus from various processes



Taken from Teixeira talk at EPS2021

Detailed study of leptons will reveal the hidden New Physics!

Lepton Universality relating to τ decay

Motivation for Lepton Flavour Universality

Lepton Flavour Universality (LFU) requires that the coupling between three charged leptons (g_e , g_μ and g_τ) and W boson is the same.

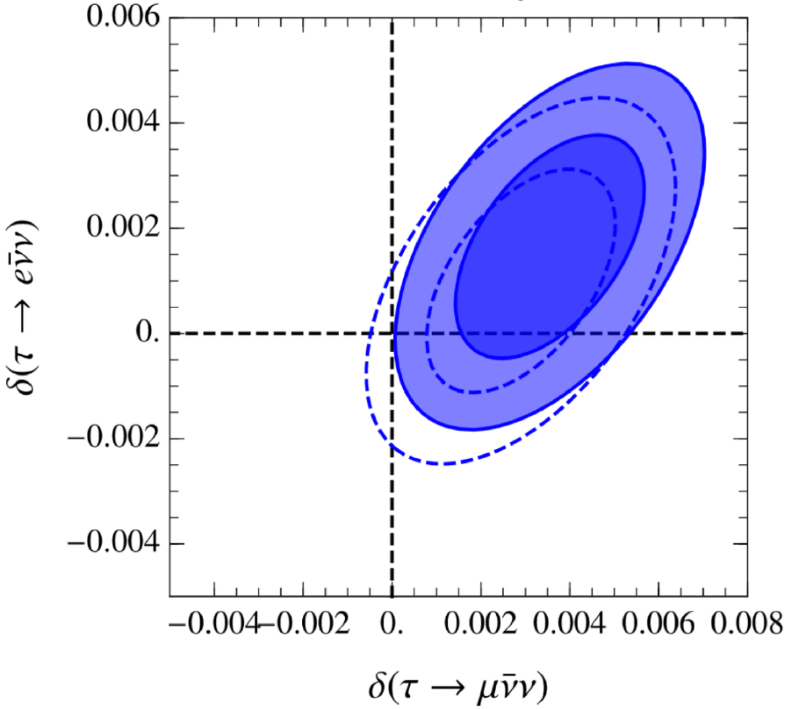
$$\frac{\mathcal{A}_{\rm EXP}(\tau\to\mu\nu\bar{\nu})}{\mathcal{A}_{\rm SM}(\mu\to e\nu\bar{\nu})}=1.0029\pm0.0014$$

$$\frac{\mathcal{A}_{\rm EXP}(\tau\to\mu\nu\bar{\nu})}{\mathcal{A}_{\rm SM}(\tau\to e\nu\bar{\nu})}=1.0018\pm0.0014$$

$$\frac{\mathcal{A}_{\rm EXP}(\tau\to e\nu\bar{\nu})}{\mathcal{A}_{\rm SM}(\mu\to e\nu\bar{\nu})}=1.0010\pm0.0014$$

Several NP models can explain the anomaly:
W', Modified *Wlν* couplings
Z', **Singly-Charged Scalar** …

ref: arXiv:2105.06734



Belle II

Alberto Martini — Prospects for violation of LFU at Belle II — TAU2021 5

Belle II DESY.

Prospects for violation of Lepton Flavour Universality at Belle II

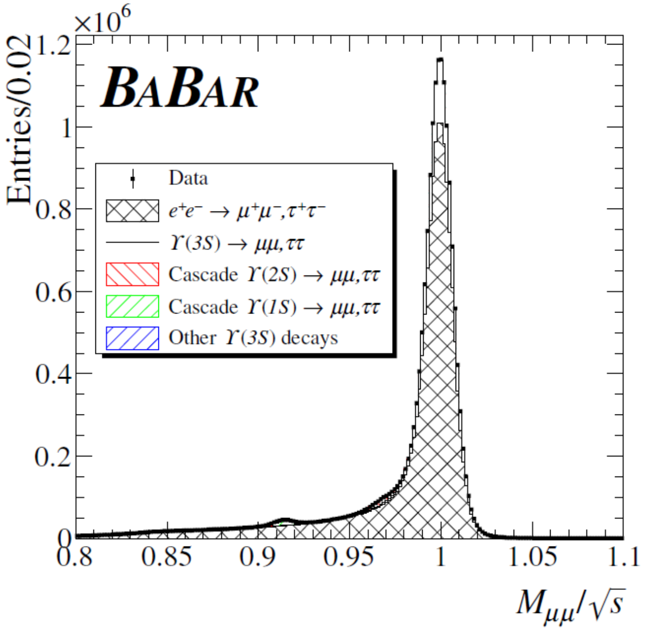
Alberto Martini
DESY (Deutsches Elektronen-Synchrotron)
On behalf of the Belle II collaboration

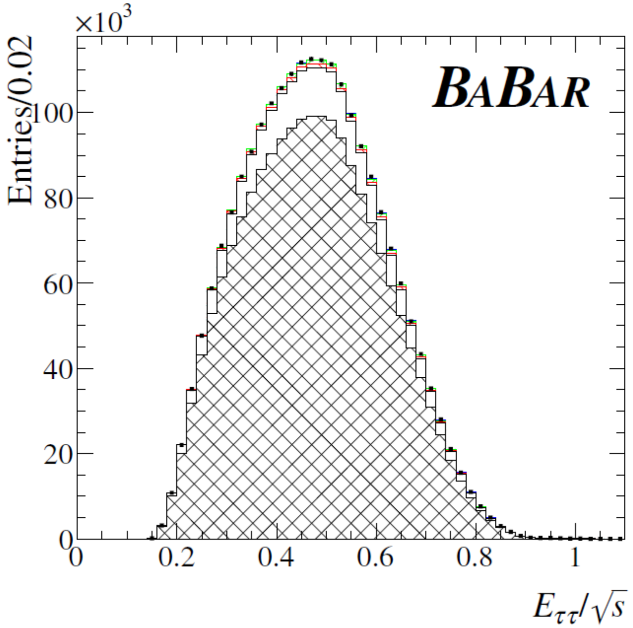
16th International Workshop on Tau Lepton Physics, 27 Sep - 1 Oct 2021, Indiana University

- τ **3x1:** good trigger and LID → final results shows very good **performances: ~4x better than Babar**

Lepton Universality relating to τ production

Fit result





Dominant continuum $e^+e^- \to \ell^+\ell^-$ background (cross-hatched histogram) is mainly visible.

The raw result of the fit $\tilde{R}_{\tau\mu} = N_{\tau\tau}/N_{\mu\mu} = 0.1079 \pm 0.0009$

$$R_{\tau\mu} = \tilde{R}_{\tau\mu} \frac{1}{C_{\text{MC}}} \frac{\varepsilon_{\mu\mu}}{\varepsilon_{\tau\tau}} \cdot (1 + \delta_{B\bar{B}}) = 0.966 \pm 0.008_{\text{stat}} \pm 0.014_{\text{syst}} = 0.966 \pm 0.016_{\text{tot}}$$

Precision measurement of the $\mathcal{B}(\Upsilon(3S) \to \tau^+\tau^-)/\mathcal{B}(\Upsilon(3S) \to \mu^+\mu^-)$ ratio at the BABAR experiment

Alexei Sibidanov

University of Victoria
on behalf of the BABAR collaboration

The 16th International Workshop on Tau Lepton Physics
TAU 2021
(Virtual Edition)
September 27, 2021 – October 1, 2021
Indiana University, Bloomington, USA

This result is published in [Phys.Rev.Lett. **125** (2020) 241801] and a preprint is available [arXiv:2005.01230]. It can be compared with $R_{\tau\mu} = 0.9948$ in the Standard Model (radiation effects are included) as well as the only previous measurement reported by the CLEO collaboration [Phys.Rev.Lett.**98** (2007) 052002]: $R_{\tau\mu} = 1.05 \pm 0.08 \pm 0.05$.

2σ deviation from SM

Vus recent result

Updated preliminary determinations of $|V_{us}|$ with tau decays using the HFLAV fit

2021 update on $|V_{ud}|$ - $|V_{us}|$, HFLAV 2021 prelim., Di Carlo *et al.* 2019 RC

$|V_{ud}|$

- J.C.Hardy & Ii.S.Towner, PRC 102, 045501 (2020)
  - revised experimental inputs
  -

Marciano and Sirlin 2006	2.361 ± 0.038
Seng et al. 2018/2019	2.467 ± 0.022
Czarnecki, Marciano and Sirlin 2019	2.426 ± 0.032
Adopted value for Δ_R^V	2.454 ± 0.019

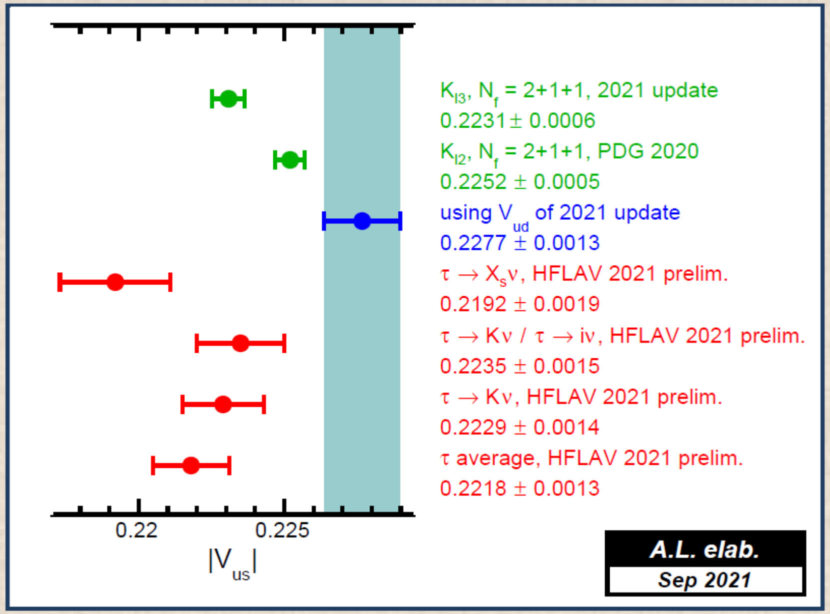
  - increased systematic uncertainty (new nuclear corrections)

$|V_{us}|$ from kaons

- improved K_{e3} radiative corrections, Seng, Gorchteín & Ramsey-Musolf, arXiv:2103.04843 [hep-ph]
- new calculation of $|V_{us}|_{K\ell 3}$ Seng, Galviz, Marciano, Meißner, arXiv:2107.14708 [hep-ph]

$|V_{us}|$ from tau

- using 2021 update $|V_{ud}|$ (minor)
- Di Carlo *et al.* 2019 radiative corrections



- $|V_{ud}|$ - $|V_{us}|_K$ anomaly $\sim 3\,\sigma$
- no scale factor on $|V_{us}|_K$
- $\sim 5\,\sigma$ without increased $|V_{ud}|$ systematics

Alberto Lusiani (SNS & INFN Pisa) – Tau 2021, 27 September 2021 – 1 October 2021 8 / 9

On the result, very slightly, the tau results get close to.

Still, ~ 3σ discrepancy.

Search for the new physics

Two directions:

- Forbidden process search

    LFV , CPV…

- Precise measurement

    LFU , g-2 …

    Key: precise theoretical prediction: How far away from SM prediction?

τ LFV decay at Belle

Upper limits at 90% CL

Upper limit on branching fraction at 90% CL

$$\mathcal{B}(\tau^\pm \to \mu^\pm\gamma) < \frac{\tilde{s}_{90}}{2\epsilon N_{\tau\tau}} = 4.2 \times 10^{-8},$$

$$\mathcal{B}(\tau^\pm \to e^\pm\gamma) < \frac{\tilde{s}_{90}}{2\epsilon N_{\tau\tau}} = 5.6 \times 10^{-8},$$

$B\times10^{-8}$ at 90% CL	BaBar $N_{\tau\tau} = 4.8\times10^8$		Belle $N_{\tau\tau} = 4.8\times10^8$		Belle $N_{\tau\tau} = 9.1\times10^8$	
	Exp	Obs	Exp	Obs	Exp	Obs
$B(\tau \to \mu\gamma)$	8.2	4.4	8.0	4.5	4.9	4.2
$B(\tau \to e\gamma)$	9.8	3.3	12	12	6.5	5.6

- Expected limits: factor 1.5 – 1.7 improved
- Observed limits, $\tau \to \mu\gamma$: Most stringent limit to the date

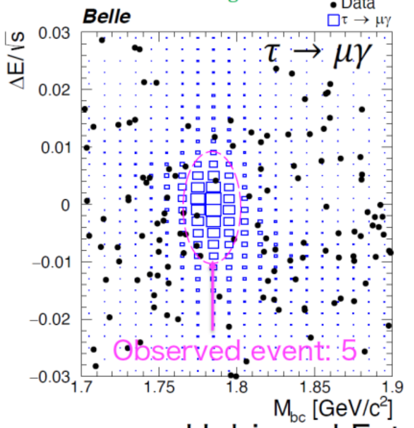
Search for tau LFV/LNV decays at Belle

Tau2021 (ONLINE)
Kenta Uno
Niigata university

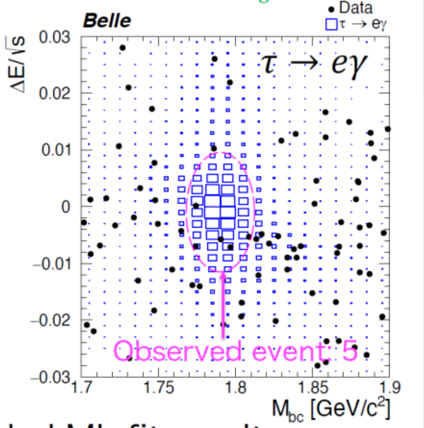
Result

Luminosity: 988 fb^{-1} : $9.1\times10^8 N_{\tau\tau}$

Signal eff. = 3.7% $N_{\rm bkg}^{\rm exp} = 5.8 \pm 0.4$



Signal eff. = 2.9% $N_{\rm bkg}^{\rm exp} = 5.1 \pm 0.4$



Unbinned Extended ML fit result

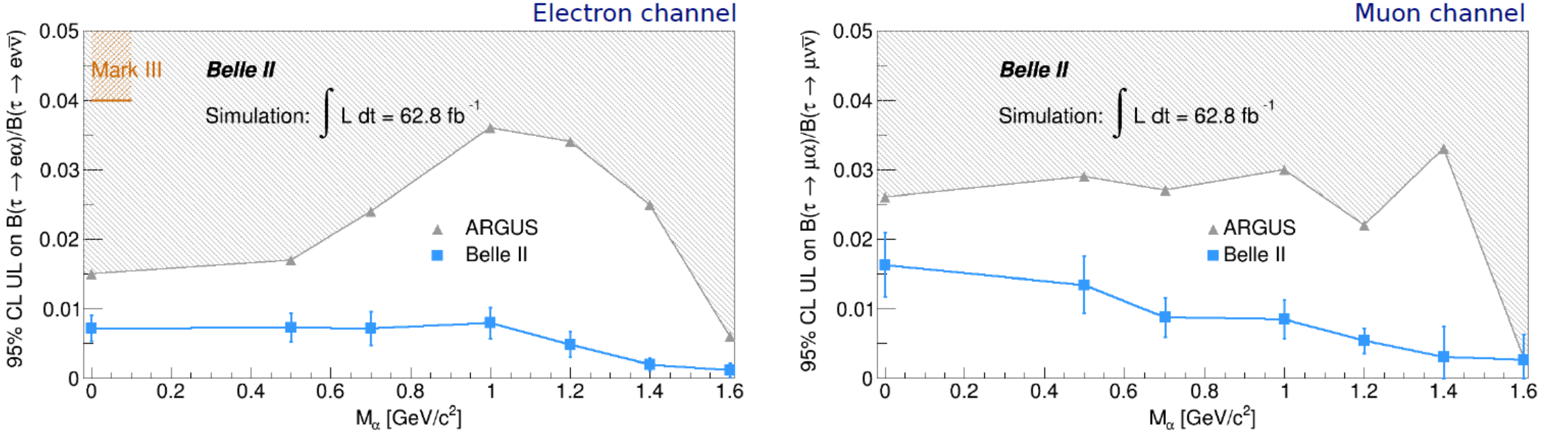
$s = -0.3^{+1.8}_{-1.3}, b = 5.3^{+3.2}_{-2.3}$ $s = -0.5^{+4.4}_{-3.6}, b = 5.5^{+5.2}_{-4.1}$

No significant excess over SM background predictions

τ LFV decay at Belle II

UL: systematic uncertainties

- We provide the UL sensitivity for $Br(\tau \to \ell\alpha)/Br(\tau \to \ell\nu\nu)$ at 95% CL for L_{int} = 62.8 fb^{-1}
- We have identified the sources of dominant systematic uncertainties
  - LID
  - Trigger



- A scenario with reduced systematic effects is expected.

- Search for the LFV decay channels: $\tau \to e\alpha$ and $\tau \to \mu\alpha$ being α a BSM invisible particle.
- This decay appears in several NP model[s] Axion-like particles, Z' gauge boson, etc

First Results and Prospects for the LFV decay $\tau \to \ell\alpha$(invisible) at Belle II

Cinvestav
Alejandro De Yta Hernández (CINVESTAV)
on behalf of the Belle II Collaboration
Belle II

Sep 28th, 2021

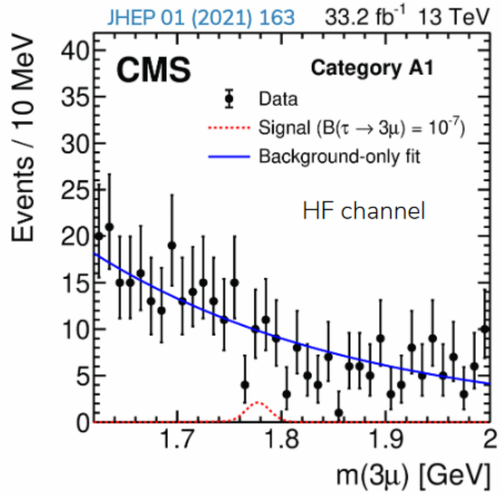
τ LFV decay at LHC

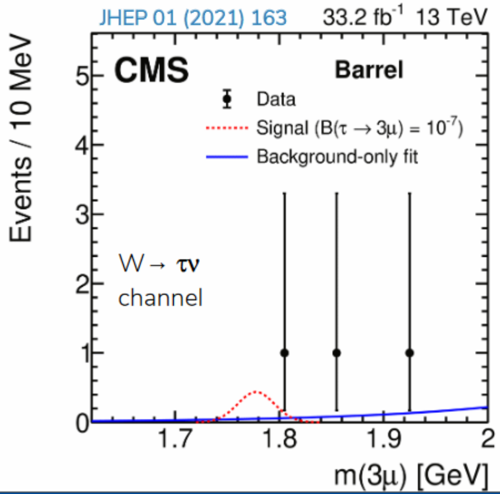
$\tau \rightarrow \mu\mu\mu$ search results

- CMS Results:
  - Observed (Expected) limit is **8.0 (6.9) x 10^{-8}** @ 90% C.L.
    - W boson channel: 20 (13) x 10^{-8} @ 90% C.L.
    - HF channel: 9.2 (10.0) x 10^{-8} @ 90% C.L.

Results comparison	$\tau \rightarrow 3\mu$ **90% CL Limits**
Belle Phys.Lett.B687:139-143 (2010)	2.1×10^{-8}
BaBar Phys.Rev.D81:111101 (2010)	3.3×10^{-8}
LHCb JHEP 02 (2015) 121	4.6×10^{-8} (8 TeV)
ATLAS Eur. Phys. J. C (2016) 76	3.76×10^{-7} ($W \rightarrow \tau\nu$, 8 TeV)
CMS JHEP 01 (2021) 163	8.0×10^{-8} ($W \rightarrow \tau\nu$ and hadrons, 13 TeV)

Best mass resolution categories



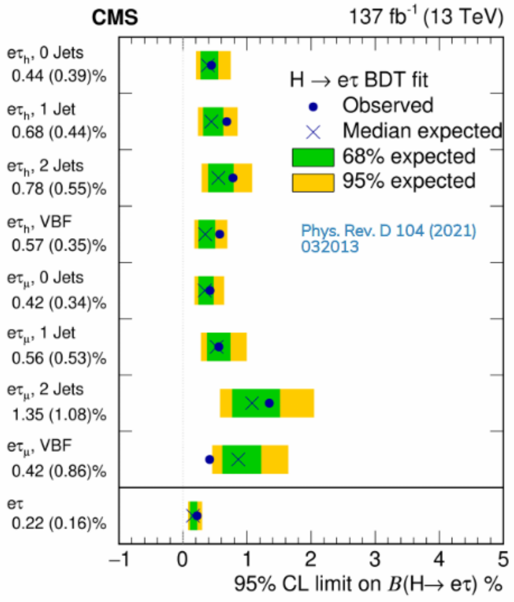


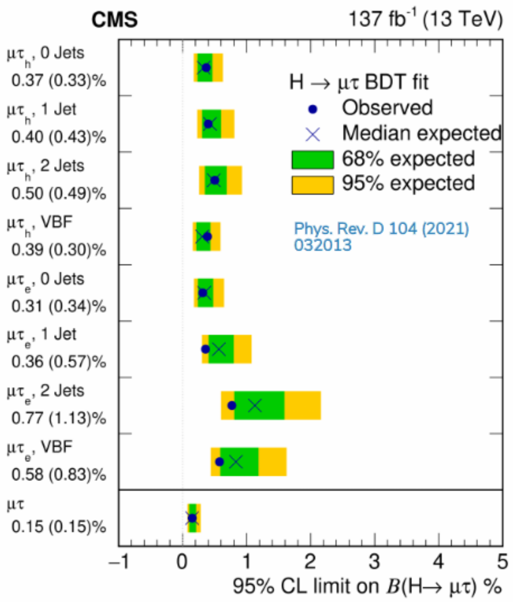
LFV searches at ATLAS and CMS

LFV process at LHC (1)

Results of LFV H search

- 95% C.L. limits on B(H→eτ) and B(H→μτ) and on off-diagonal Yukawa coupling:

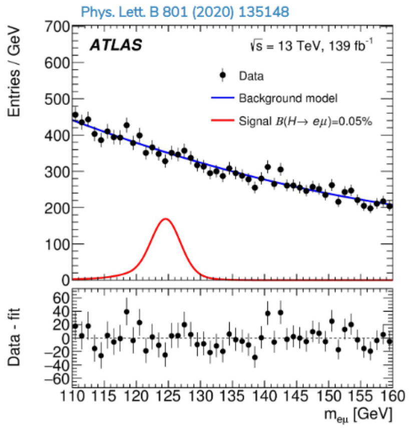


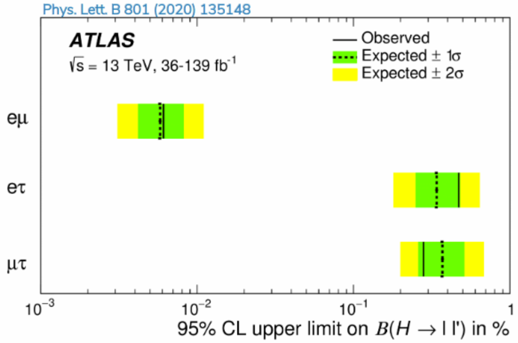


	Observed (expected) upper limits (%)	Best fit branching fractions (%)	Yukawa coupling constraints
$H \to \mu\tau$	<0.15 (0.15)	0.00 ± 0.07	$< 1.11\,(1.10) \times 10^{-3}$
$H \to e\tau$	<0.22 (0.16)	0.08 ± 0.08	$< 1.35\,(1.14) \times 10^{-3}$

Search for LFV H→eμ

- Unbinned fit of the $m_{e\mu}$ mass spectrum, similar to H → μμ and H → γγ analyses.
- Events are separated in 8 categories (Low p_T, VBF, 3 barrel and 3 endcap).
- Background modeled by a Bernstein polynomial of degree two with category-dependent parameters.
- Signal modeled by the sum of a Crystal Ball and a Gaussian distribution.





No excess observed, 95% CL limit is B(H→eμ)<6.1×10⁻⁵ (5.8×10⁻⁵ expected)

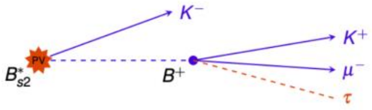
LFV process at LHC (2)

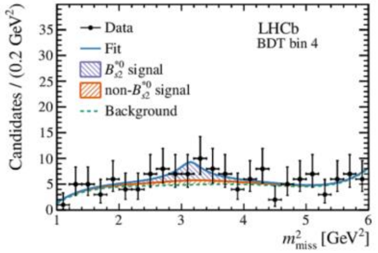
LFV with taus

JHEP 06 (2020) 129 — Run1+2 9fb^{-1}

$B^+ \to K^+\mu^-\tau^+$

- Use $\tau^- \to \pi^-\pi^+\pi^-(\pi^0)\nu_\tau$
- New technique for τ reconstruction: use B^+ from B_{s2}^{*0}
  - B^+ flight direction and energy from mass constrains and PV and $K^+\mu^-$ vertex info
  - K^- momenta (two-fold ambiguity)
  - Resolve the ambiguity requiring missing energy > τ track energy (75% of confidence)
- BDT against combinatorial background
  - Control sample adding a prompt kaon of the same sign as the one in the $K^+\mu^-$ pair (SSK)
- Fit to the missing mass distribution in BDT bins





$\mathcal{B}(B^+ \to K^+\mu^-\tau^+) < 4.5 \times 10^{-5}$ at 95% CL

Comparable with the world-best limit

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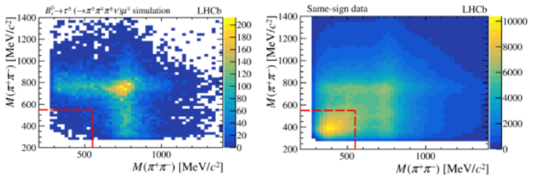
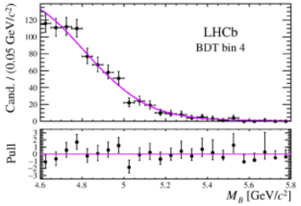
LFV with taus

PRL 123 (2019) 211801 — Run1 3fb^{-1}

$B^0_{(s)} \to \tau^\pm\mu^\mp$

- Use $\tau^- \to \pi^-\pi^+\pi^-(\pi^0)\nu_\tau$
- B mass analytically reconstructed from kinematics constrains
- Background proxy from same-sign data
  - BDT anti-combinatorial + isolation-based BDT
  - Decay time cut to reduce partially reconstructed decays
- 'Final' BDT: Same Sign data vs MC
- Simultaneous fit in bins of BDT and B mass





Most stringent → $\mathcal{B}(B^0 \to \tau^\pm\mu^\mp) < 1.4 \times 10^{-5}$

First limit → $\mathcal{B}(B^0_s \to \tau^\pm\mu^\mp) < 4.2 \times 10^{-5}$

@ 95 % CL

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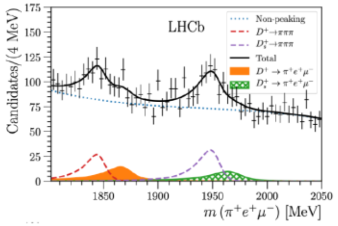
LFV with e, μ

$D^+_{(s)} \to h^\pm\ell^+\ell'^\mp$, with $\ell = e, \mu$ $h = \pi, K$ — 2016 1.7fb^{-1} — JHEP 06 (2021) 044

- Normalisation $D^+ \to \pi^+\phi(\to \ell^+\ell^-)$
- Fit to the 3-body invariant mass
- Limits set between 1.4×10^{-8} and 6.4×10^{-6}



$B^+ \to K^+\mu^\pm e^\mp$ — Run1 3fb^{-1} — PRL 123 (2019) 241802

- Normalisation $B^+ \to K^+J/\psi(\to \ell^+\ell^-)$

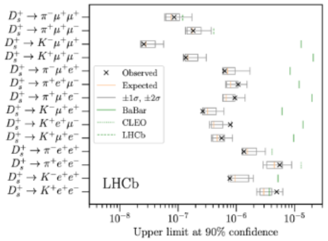
$\mathcal{B}(B^+ \to K^+\mu^-e^+)/10^{-9}$ 7.0
$\mathcal{B}(B^+ \to K^+\mu^+e^-)/10^{-9}$ 6.4
90% C. L.

world-best limits

$B^0_{(s)} \to \mu^\pm e^\mp$ — Run1 3fb^{-1} — JHEP 03 (2018) 078

channel	expected	observed
$\mathcal{B}(B^0_s \to e^\pm\mu^\mp)$	$5.0\,(3.9) \times 10^{-9}$	$6.3\,(5.4) \times 10^{-9}$
$\mathcal{B}(B^0 \to e^\pm\mu^\mp)$	$1.2\,(0.9) \times 10^{-9}$	$1.3\,(1.0) \times 10^{-9}$

world-best limits



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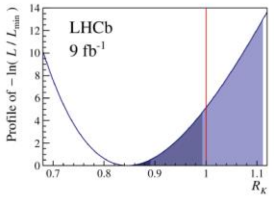
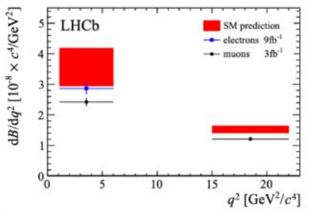
$b \to s\ell\ell$ ratios status

- LHCb recently updated the measurement of R_K using 9fb^{-1}
  - 3.1σ from SM: **evidence of LFU violation**
  - Electron seems to behave more SM like than muons





arXiv:2103.11769

$1.1 < m^2(\ell^+\ell^-) < 6\ \text{GeV}^2$

$$R_K = 0.846^{+0.042}_{-0.039}(\text{stat})^{+0.013}_{-0.012}(\text{sys})$$

$$r_{J/\psi} = 0.981 \pm 0.020(stat + sys)$$
$$R_{\psi(2S)} = 0.997 \pm 0.011(stat + sys)$$

- Other LFU ratio @LHCb:

JHEP 08 (2017) 055

$$R_{K^{*0}} = \begin{cases} 0.66^{+0.11}_{-0.07} \pm 0.03 & \text{for } 0.045 < q^2 < 1.1\ \text{GeV}^2 \\ 0.69^{+0.11}_{-0.07} \pm 0.05 & \text{for } 1.1 < q^2 < 6.0\ \text{GeV}^2 \end{cases}$$

Run1: $2.1\sigma(2.4\sigma)$ from SM

JHEP 05 (2020) 040

$$R_{pK}^{-1} = 1.17^{+0.18}_{-0.16} \pm 0.07 \quad \text{for} \quad 0.1 < m^2(\ell^+\ell^-) < 6\ \text{GeV}^2$$

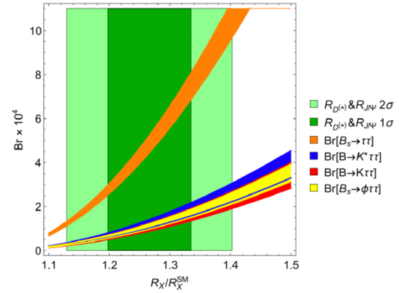
Run1 + 2016: compatible with the SM

- Near future:
  - Update of $R_{K^{*0}}$ with the full data set
  - Ratio measurements with many more decay channels: $R_{K_S}, R_\phi, R_{K\pi\pi}\ldots$

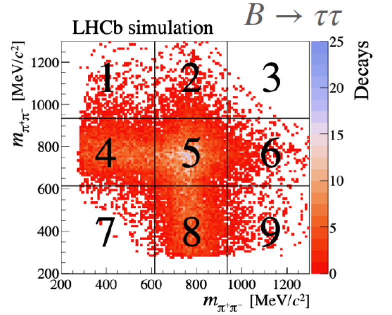
Why not $b \to s\tau^+\tau^-$?

- taus could be the most sensitive to NP, still largely unexplored
- More complex experimentally
  - Neutrinos in the final state, $m(\tau\tau)$ weak discriminant
  - No 4π coverage at LHCb
- Usually searched with : $\tau \to a_1(1260)^-\nu_\tau \to \rho(770)^0\pi^-\nu_\tau \to \pi^-\pi^+\pi^-\nu_\tau$
  - Study intermediate resonance forms cross-shape
- Exploit a large variety of MVA techniques
  - Isolation, selection and fit variables
- Difficult choice of control regions to model the background
  - Pseudo-Dalitz plane: define signal and background boxes

PRL 120 (2018) 181802



$B \to \tau\tau$



Decay	SM prediction	Limits @90% CL
$B^0 \to \tau\tau$	$(2.22 \pm 0.19) \cdot 10^{-8}$	$< 1.6 \cdot 10^{-3}$ (LHCb)
$B_s^0 \to \tau\tau$	$(7.73 \pm 0.49) \cdot 10^{-7}$	$< 5.2 \cdot 10^{-3}$ (LHCb)
$B^0 \to K^{*0}\tau\tau$	$(0.98 \pm 0.10) \cdot 10^{-7}$	Ongoing
$B^+ \to K^+\tau\tau$	$(1.20 \pm 0.12) \cdot 10^{-7}$	$< 2.3 \cdot 10^{-3}$ (BaBar)

LHC + LHCb upgrades → 2x yields for fully hadronic decays!

PRL 118 (2017) 251802 PRL 118 (2017) 031802

LFV process at BESIII

BESIII Summary

- **BESIII has a rich new physics search program**
- **charged LFV with the world largest e^+e^- annihilation J/ψ. Latest results are reported:**
  - $BR(J/\psi \to e\tau) < 7.5\times10^{-8}$ @ 90% C.L. Phys. Rev. D 103, 112007 (2021)
    - The 1st publication with 10B J/ψ sample
  - $BR(J/\psi \to e\mu) < 1.6\times10^{-7}$ @ 90% C.L.
    - With 225M J/ψ sample Phys. Rev. D 87, 112007 (2013)
    - In updates with 10B data: $10^{-9}\sim10^{-8}$
- **Better/more constraints on LFV processes can be expected from BESIII in future.**

...More to come!

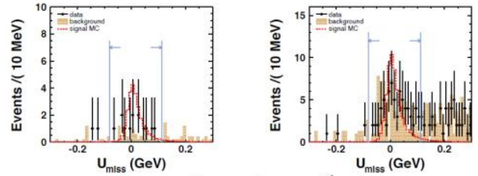
2021/9/28 TAU2021 Dayong Wang 18

BESIII Search for $J/\psi \to e^{\pm}\tau^{\mp}$

- Background from J/ψ resonance and continuum process.

	$N_{bkg}^{J/\psi}$	$N_{bkg}^{cont.}$	N_{bkg}^{total}	N_{data}
Sample I	1.1 ± 0.8	5.8 ± 1.8	6.9 ± 1.9	13
Sample II	25.7 ± 6.4	37.9 ± 11.5	63.6 ± 13.2	69

- Total systematic uncertainty ~ 4%.
- No excess of events is observed over the background.



$U_{miss} = E_{miss} - c|\vec{P}_{miss}|$

Phys. Rev. D 103, 112007 (2021)

2021/9/28 TAU2021 Dayong Wang 12

Search for charged lepton flavor violation at BESIII

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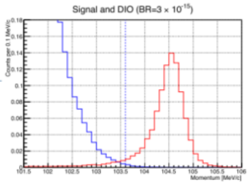
北京大学 PEKING UNIVERSITY

30 Years of Tau International Workshops
The 16th International Workshop on Tau Lepton Physics
TAU 2021
(Virtual edition)
Indiana University, Bloomington, USA
September 27, 2021 - October 1, 2021

Muon LFV

COMET Experiment Sensitivity of μ⁻→e⁻

- COMET Phase-I Target single event sensitivity : **3×10^{-15}**
  - 100 times improvement from SINDRUM-II
  - Phase-II : 2.5×10^{-17} ~ 10^{-18}
- Net acceptance = **4.1%**
  - Online efficiency ~0.99
  - Geometric acceptance + track quality ~0.18
  - 103.6 MeV < p < 106MeV : 0.93
  - 700ns < t < 1170 ns : 0.3
- Background = **0.032**
  - DIO ~ 0.01 (dominant)
  - RPC ~ 0.003, Cosmic <0.01
- Schedule
  - Detector integration by 2023 summer
  - **Engineering run: end of 2023, followed by physics run**



Event selection	Value	Comments
Online event selection efficiency	0.9	Sect. 8.1.1
DAQ efficiency	0.9	
Track finding efficiency	0.99	Sect. 5.4
Geometrical acceptance + Track quality cuts	0.18	
Momentum window (ε_{mom})	0.93	103.6 MeV/c < P_e <106.0 MeV/c
Timing window (ε_{time})	0.3	700 ns < t < 1170 ns
Total	0.041	

Type	Background	Estimated events
Physics	Muon decay in orbit	0.01
	Radiative muon capture	0.0019
	Neutron emission after muon capture	< 0.001
	Charged particle emission after muon capture	< 0.001
Prompt beam	* Beam electrons	
	* Muon decay in flight	
	* Pion decay in flight	
	* Other beam particles	
	All (*) combined	≤ 0.0038
	Radiative pion capture	0.0028
	Neutrons	$\sim 10^{-9}$
Delayed beam	Beam electrons	~ 0
	Muon decay in flight	~ 0
	Pion decay in flight	~ 0
	Radiative pion capture	~ 0
	Antiproton-induced backgrounds	0.0012
Others	Cosmic rays†	< 0.01
Total		0.032

Search for Muon to Electron Conversion at J-PARC – COMET Experiment

MyeongJae Lee (Institute for basic science, Korea)
The 16th International Workshop on Tau Lepton Physics

Status of the Mu2e experiment

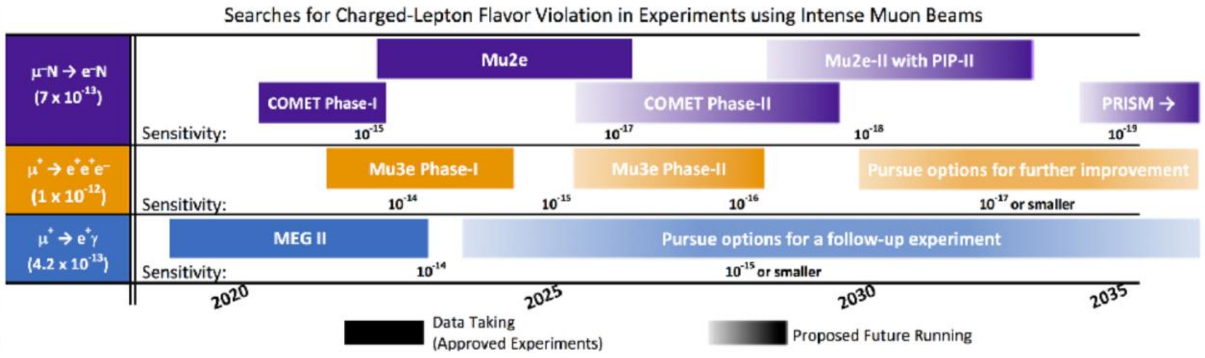
Nam Tran
Boston University
For the Mu2e Collaboration

Summary

- Mu2e will improve sensitivity on μ-e conversion experiment by a factor of 10,000
  - provides discovery capability over wide range of New Physics models
- In construction phase:
  - begin commissioning in 2021
  - First physics run expected in 2025-2026, 1000 times improvement in sensitivity
  - Full dataset from 4-5 years of running
- Start discussing about next phase, Mu2e-II
  - Increase sensitivity by another order of magnitude (see Giani's talk on Oct 1)

COMET International Future Planning

A.Baldini et al., arXiv:1812.06540v1



Rich physics in near and long future for Muon LFV !

Prediction of $\tau \to lll$ at SM + ν oscillation

Based on the work
Eur. Phys. J. C **80,** 506 (2020).

27 September 2021 – 16th International Workshop on Tau Lepton Physics

$\tau \to \mu\mu\mu$ at a rate of one out of 10^{14} tau decays?

Patrick Blackstone | in collaboration with
Matteo Fael (KIT)
Emilie Passemar (IU, JLAB)

INDIANA UNIVERSITY BLOOMINGTON

That's peculiar...

Eur. Phys. J. C 8, 513–516 (1999)
DOI 10.1007/s100529901088

Lepton flavor changing in neutrinoless τ decays

Xuan-Yem Pham[a]

Laboratoire de Physique Théorique et Hautes Energies, Paris CNRS, Université P. et M. Curie, Université D. Diderot

Received: 29 October 1998 / Published online: 11 March 1999

Abstract. Neutrino oscillations, as recently reported by the Super-Kamiokande collaboration, imply that lepton numbers could be violated, and $\tau^\pm \to \mu^\pm + \ell^+ + \ell^-, \tau^\pm \to \mu^\pm + \rho^0$ are some typical examples. We point out that in these neutrinoless modes, the GIM cancelation is much milder with only a logarithmic behavior $\log(m_j/m_k)$ where $m_{j,k}$ are the neutrino masses. This is in sharp contrast with the vanishingly small amplitude $\tau^\pm \to \mu^\pm + \gamma$ strongly suppressed by the quadratic power $(m_j^2 - m_k^2)/M_W^2$. In comparison with the hopelessly small branching ratio $B(\tau^\pm \to \mu^\pm + \gamma) \approx 10^{-40}$, the $B(\tau^\pm \to \mu^\pm + \ell^+ + \ell^-)$ could be larger than 10^{-14}. The latter mode, if measurable, could give one more constraint to the lepton mixing angle $\sin 2\theta_{jk}$ and the neutrino mass ratio m_j/m_k, and therefore is complementary to neutrino oscillation experiments.

Results

One final MOR application in phase space integration to get leading order in m_ℓ/m_L, we find

$$\Gamma(L \to \ell\ell\ell) = \frac{G_F^2 \alpha^2 m_L^5}{(4\pi)^5} \left| \sum_{i=2}^{3} U_{Li}^* U_{\ell i} \frac{\Delta m_{i1}^2}{M_W^2} \right|^2$$
$$\times \left[\log^2 x_L + 2 \log x_L - \frac{1}{6} \log x_\ell + \frac{19}{18} + \frac{17}{18}\pi^2 - \frac{1}{\sin^2\theta_W}\left(\log x_L + \frac{11}{12} \right) + \frac{3}{8 \sin^4 \theta_W} \right]$$

Note: Final expression is independent of m_1 due to absence of neutrino mass logarithms!

Conclusions

- Can $Br(L \to 3\ell)$ be as large as 10^{-14} in the Standard Model with PMNS neutrino mixing? Unfortunately, no.
- There are no unregulated $\log m_i$ divergences in the neutrino mass.
- If near- or distant-future experiments (Mu3e, Belle II, HL-LHC) see these processes, it will certainly evidence the existence of New Physics beyond $\mathrm{SM} + m_\nu \neq 0$ (and hopefully betray its nature).

τ EDM at Belle

Obtained results

- EDM results

Mode	$\mathrm{Re}(d_\tau)(10^{-17}$ ecm)	$\mathrm{Im}(d_\tau)(10^{-17}$ ecm)
$e\mu$	$-3.2 \pm 2.5 \pm 3.6$	$0.6 \pm 0.4 \pm 1.8$
$e\pi$	$0.7 \pm 2.3 \pm 4.8$	$2.4 \pm 0.5 \pm 2.2$
$\mu\pi$	$1.0 \pm 2.2 \pm 4.3$	$2.4 \pm 0.5 \pm 2.6$
$e\rho$	$-1.2 \pm 0.8 \pm 1.0$	$-1.1 \pm 0.3 \pm 0.6$
$\mu\rho$	$0.7 \pm 1.0 \pm 2.2$	$-0.5 \pm 0.3 \pm 0.8$
$\pi\rho$	$-0.6 \pm 0.7 \pm 1.0$	$0.4 \pm 0.3 \pm 1.2$
$\rho\rho$	$-0.4 \pm 0.5 \pm 0.9$	$-0.3 \pm 0.3 \pm 0.4$
$\pi\pi$	$-2.2 \pm 4.3 \pm 5.2$	$-0.9 \pm 0.9 \pm 1.2$

- By adding the statistical and systematic errors quadratically, we obtain the weighted average of EDM and its error

$$\mathrm{Re}(d_\tau) = (-0.62 \pm 0.63) \times 10^{-17}\ \text{ecm},$$
$$\mathrm{Im}(d_\tau) = (-0.40 \pm 0.32) \times 10^{-17}\ \text{ecm}.$$

Previous results

$$\mathrm{Re}(d_\tau) = (1.15 \pm 1.70) \times 10^{-17}\ e\,\text{cm},$$
$$\mathrm{Im}(d_\tau) = (-0.83 \pm 0.86) \times 10^{-17}\ e\,\text{cm}$$

- Consistent with zero EDM
- ~2.7 times smaller error than the previous results
- Systematic errors are comparable with the statistical errors.

Summary

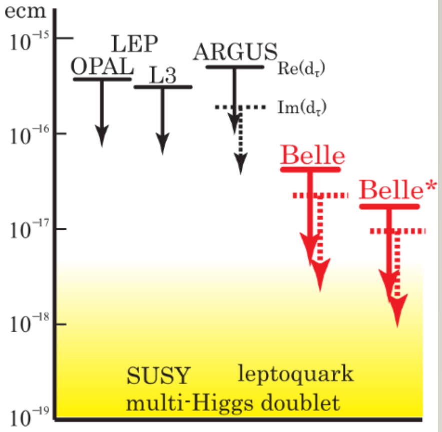
- We have analyzed 833 fb^{-1} of Belle data to measure the electric dipole moment of tau lepton.
  - With optimal observable method
  - 28 times more data than in the previous analysis by Belle
- Obtained the result consistent with zero EDM

$$\mathrm{Re}(d_\tau) = (-0.62 \pm 0.63) \times 10^{-17}\ \text{ecm},$$
$$\mathrm{Im}(d_\tau) = (-0.40 \pm 0.32) \times 10^{-17}\ \text{ecm}.$$

  - 95% confidence intervals

$$-1.85 \times 10^{-17} < \mathrm{Re}(d_\tau) < 0.61 \times 10^{-17}\ \text{ecm},$$
$$-1.03 \times 10^{-17} < \mathrm{Im}(d_\tau) < 0.23 \times 10^{-17}\ \text{ecm}.$$

  - Detector modeling limits our result
  - Good event vertex resolution to obtain tau direction information will improve the sensitivity for future analysis.



Electric dipole moment of the tau lepton at Belle

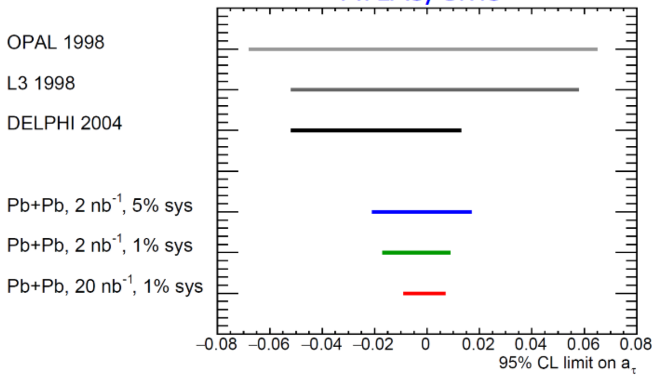
Kenji Inami (Nagoya university)
2021/9 at international workshop on tau physics
Ref: arXiv 2108.11543 [hep-ex]

τ MDM measurement at LHC

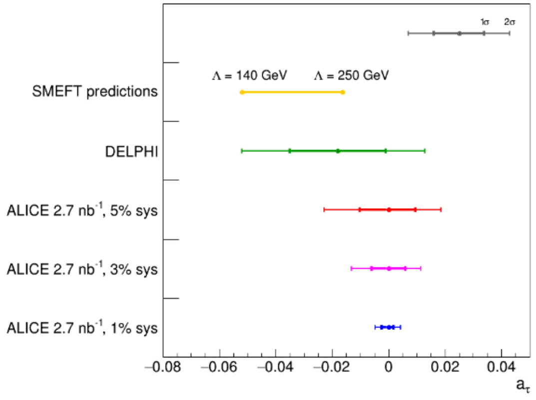
Conclusions

- ATLAS/CMS statistics from Run2 can be used to improve a_τ limits
- ALICE can help to extend a_τ measurements down to low p_T
- precision is limited by systematic uncertainties
- Expected limits on a_τ at least x2 better compared to DELPHI results

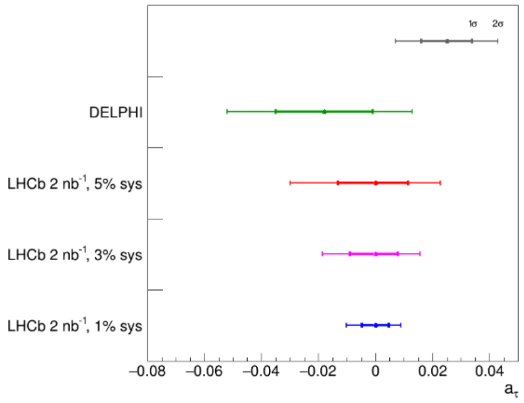
ATLAS/CMS



ALICE



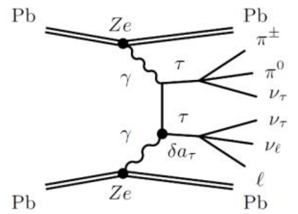
LHCb



This work was supported by the Russian Foundation for Basic Research (RFBR, 21-52-14006) and the Austrian Science Fund (FWF, I 5277-N)

Feasibility of tau g-2 measurements with ultraperipheral collisions of heavy ions

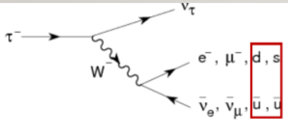
Evgeny Kryshen[1]
in collaboration with Nazar Burmasov[1], Paul Buehler[2] and Roman Lavicka[2]
[1] NRC KI "Petersburg Nuclear Physics Institute", Gatchina, Russia
[2] Stefan Meyer Institute for Subatomic Physics, Vienna, Austria



The 16th International Workshop on Tau Lepton Physics
1 October 2021

Tau hadronic decay: theory

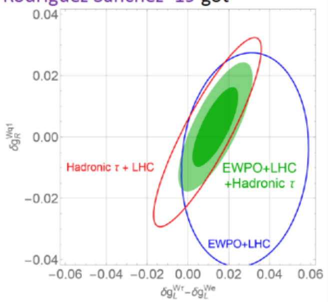
- Since the hadronic decays include QCD process, detailed theoretical analysis of the process is important for the SM prediction.



Beyond the SM

Combining inclusive & exclusive semileptonic τ decays, Cirigliano-Falkowski-González Alonso-Rodríguez Sánchez '19 got
(Only ΔS=0)

$$\mathcal{L}_{\rm eff} = -\frac{G_F V_{ud}}{\sqrt{2}}\Big[\left(1+\epsilon_L^\tau\right)\bar{\tau}\gamma_\mu(1-\gamma_5)\nu_\tau\cdot\bar{u}\gamma^\mu(1-\gamma_5)d$$
$$+\epsilon_R^\tau\,\bar{\tau}\gamma_\mu(1-\gamma_5)\nu_\tau\cdot\bar{u}\gamma^\mu(1+\gamma_5)d$$
$$+\bar{\tau}(1-\gamma_5)\nu_\tau\cdot\bar{u}\left[\epsilon_S^\tau-\epsilon_P^\tau\gamma_5\right]d$$
$$+\epsilon_T^\tau\,\bar{\tau}\sigma_{\mu\nu}(1-\gamma_5)\nu_\tau\cdot\bar{u}\sigma^{\mu\nu}(1-\gamma_5)d\Big]+\text{h.c.},\quad(1)$$



$$\Lambda\sim v\left(V_{uD}\epsilon_i\right)^{-1/2}$$ ~ 2 TeV @90%CL ←

$$\begin{pmatrix}\epsilon_L^\tau-\epsilon_L^e+\epsilon_R^\tau-\epsilon_R^e\\ \epsilon_R^\tau\\ \epsilon_S^\tau\\ \epsilon_P^\tau\\ \epsilon_T^\tau\end{pmatrix}=\begin{pmatrix}1.0\pm1.1\\ 0.2\pm1.3\\ -0.6\pm1.5\\ 0.5\pm1.2\\ -0.04\pm0.46\end{pmatrix}\cdot10^{-2}$$

Exclusive hadronic tau decays within and beyond the Standard Model

(See Sergi Gonzàlez-Solís' talk at CHARM2020 on this subject)

Thanks to all my collaborators in this topic

Pablo Roig
Cinvestav (Mexico City)
The 16th International Workshop on Tau Lepton Physics (TAU2021) (Indiana, Virtual Edition)

Exclusive hadronic tau decays within and beyond the Standard Model *Virtual, Indiana University*	*Pablo Roig Garcés* 08:00 - 08:25
Radiative correccions to $\tau\to P\nu$ and its consequences for tests of the SM and New Physics *Virtual, Indiana University*	*Gabriel Lopez Castro* 08:25 - 08:45
Radiative two-pion tau decays and the T-odd asymmetries *Virtual, Indiana University*	*Zhi-Hui Guo* 08:45 - 09:05
Deriving experimental constraints on the scalar form factor in the second-class $\tau\to\eta\pi\nu$ mode *Virtual, Indiana University*	*Bachir Moussallam* 09:05 - 09:25
On the scalar πK form factor beyond the elastic region *Virtual, Indiana University*	*Frederic Noël* 09:25 - 09:45
Updated determinations of |Vus| with tau decays using the HFLAV fit *Virtual, Indiana University*	*Alberto Lusiani* 09:45 - 10:05
Break *Virtual, Indiana University*	10:05 - 10:20
Precision measurements on dipole moments of the tau and hadronic multi-body final states *Virtual, Indiana University*	*Dr Fabian Krinner* 10:20 - 10:40
Resonances in hadronic three-body decays of τ *Virtual, Indiana University*	*Mikhail Mikhasenko* 10:40 - 11:00
Reconciling the FOPT and CIPT predictions for the hadronic tau decay rate *Virtual, Indiana University*	*Andre Hoang* 11:00 - 11:20
The strong coupling from an improved tau vector isovector spectral function *Virtual, Indiana University*	*Diogo Boito* 11:20 - 11:40
New results on the use of the operator product expansion in finite-energy sum rules for light-quark correlators *Maarten Golterman*	

τ→ηπν

Introduction:

- Second-class currents [S.Weinberg, PR 112,1375(1958)] (V^{ud}_μ, A^{ud}_μ have definite G-parity): selection rules in isospin limit
  - → $\tau \to \eta\pi\nu_\tau$ mode is clean example

    $G^{-1} V^{ud}_\mu G = +V^{ud}_\mu$

    $G|\eta\pi\rangle = -|\eta\pi\rangle)$
  - → Isospin breaking in SM: $O((m_d - m_u)/m_s, e^2)$
  - → Exp. upper limit $BF_{\eta\pi} < 9.9 \times 10^{-5}$ [Babar, PR D83, 032002 (2010)]
  - → It would be very useful to have a good theoretical estimate of SM contribution

2/20

τ → ηπν decay width

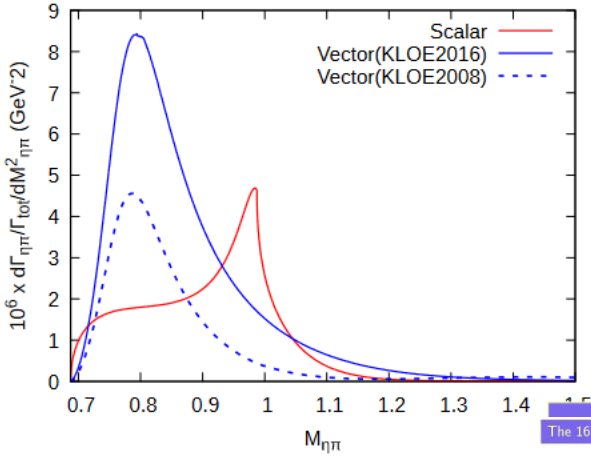
- Energy distribution

$$\frac{d\Gamma_{\tau\to\eta\pi\nu}}{ds} = \frac{G_F^2 V_{ud}^2 S_{EW}}{384\pi^3} \frac{\sqrt{\lambda_{\eta\pi}(s)}\, m_\tau^3}{s^3} \left(1 - \frac{s}{m_\tau^2}\right) \left[|f_+^{\eta\pi}(s)|^2 \lambda_{\eta\pi}(s) \left(1 + \frac{2s}{m_\tau^2}\right) + 3|f_0^{\eta\pi}(s)|^2 \Delta_{\eta\pi}^2 \right]$$

- Results:

$BF_V \simeq 2.6 \times 10^{-6}$

$BF_S \simeq 1.5 \times 10^{-6}$



The 16th International Workshop on Tau Lepton Physics (TAU2021)

université PARIS-SACLAY IJCLab Irène Joliot-Curie

Deriving experimental constraints on the scalar form factor in the second-class $\tau \to \eta\pi\nu$ mode

Bachir Moussallam

based on work with:
S. Descotes-Genon
M. Albaladejo
Junxu Lu

Bloomington, Sept.27-Oct.1

Muon g-2 session

- TAU2018 (10 taks:4 hours) → TAU2021(15 talks: 6hours)

Introduction	William Marciano	Vondelkerk, Amsterdam	08:30 - 09:15
Hadronic vacuum polarization	Christoph Lehner	Vondelkerk, Amsterdam	09:15 - 09:40
Hadronic light-by-light	Harvey Meyer	Vondelkerk, Amsterdam	09:40 - 10:05
Historical Overview	Bradley Lee Roberts	Vondelkerk, Amsterdam	10:30 - 11:00
E989 @ FNAL	Anna Driutti	Vondelkerk, Amsterdam	11:00 - 11:20
E34 @ KEK	Tsutomu Mibe	Vondelkerk, Amsterdam	11:20 - 11:40
Auxiliary measurements, esp. mumu/mup in Muonium; MuSEUM experiment	Shimomura	Vondelkerk, Amsterdam	11:40 - 12:00
Search for the Electric Dipole Moment and anomalous magnetic moment of the tau lepton at tau factories	Xin Chen	Vondelkerk, Amsterdam	12:00 - 12:20
Experimental input from e+e- machines to hadronic contribution to muon (g-2)	Boris Shwartz	Vondelkerk, Amsterdam	12:20 - 12:40
e+e- for g-2 light-by-light	Yuping Guo	Vondelkerk, Amsterdam	12:40 - 13:00

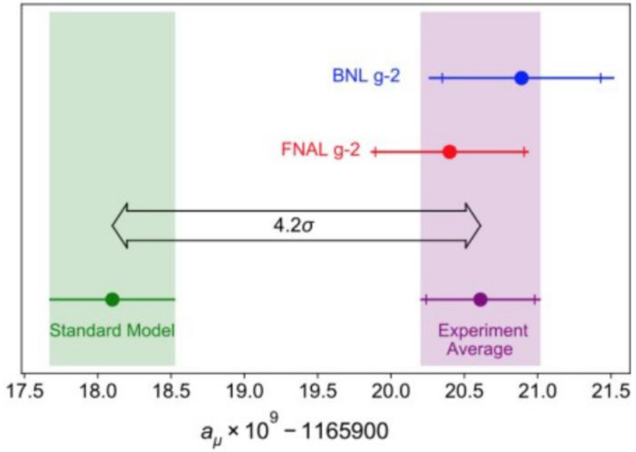
First Result from the New Muon g-2 Experiment at Fermilab	James Stapleton	Virtual, Indiana University	10:00 - 10:25
Theory overview	Gilberto Colangelo	Virtual, Indiana University	10:25 - 10:50
HVP contributions to the muon's anomalous magnetic moment from lattice QCD	Aida El-Khadra	Virtual, Indiana University	10:50 - 11:15
Measuring hadronic corrections to the muon g-2 at BESIII	Achim Denig et al.	Virtual, Indiana University	11:15 - 11:35
Break		Virtual, Indiana University	11:35 - 11:50
The pseudoscalar poles contributions to the muon g-2	Pablo Sanchez Puertas	Virtual, Indiana University	11:50 - 12:10
A dispersive estimate of the f0(980) contribution to g-2	Igor Danilkin	Virtual, Indiana University	12:10 - 12:30
Two-photon physics at KLOE-2	Dario Moricciani	Virtual, Indiana University	12:30 - 12:50
Lunch		Virtual, Indiana University	12:50 - 13:20
Calculating HLbL on the Lattice	Christoph Lehner	Virtual, Indiana University	13:20 - 13:40
HLbL in muon g-2 at large loop momenta	Antonio RODRIGUEZ SANCHEZ	Virtual, Indiana University	13:40 - 14:00
Two-pion contribution to hadronic vacuum polarization	Peter Stoffer	Virtual, Indiana University	14:00 - 14:20
New τ-based evaluation of the hadronic contribution to the vacuum polarization piece of the muon anomalous magnetic	Jesus Alejandro Miranda Hernandez		
Break		Virtual, Indiana University	14:40 - 14:55
Perturbative heavy quark contributions to the anomalous magnetic moment of the muon	Philip David Kennedy	Virtual, Indiana University	14:55 - 15:15
A continuum determination of the strong isospin-breaking contribution to the muon anomalous magnetic moment	Kim Maltman		
Probing New Physics with the leptonic g-2	Paride Paradisi	Virtual, Indiana University	15:35 - 15:55
Probing violation of CP & T invariance	Ikaros Bigi	Virtual, Indiana University	15:55 - 16:15

Muon g-2: FNAL result

The Run 1 a_μ Result

- We have determined a_μ to an unprecedented 460 ppb precision!
- The Run 1 result
  - 6% of ultimate data sample
  - 15% smaller error than BNL
  - 3.3σ tension with SM

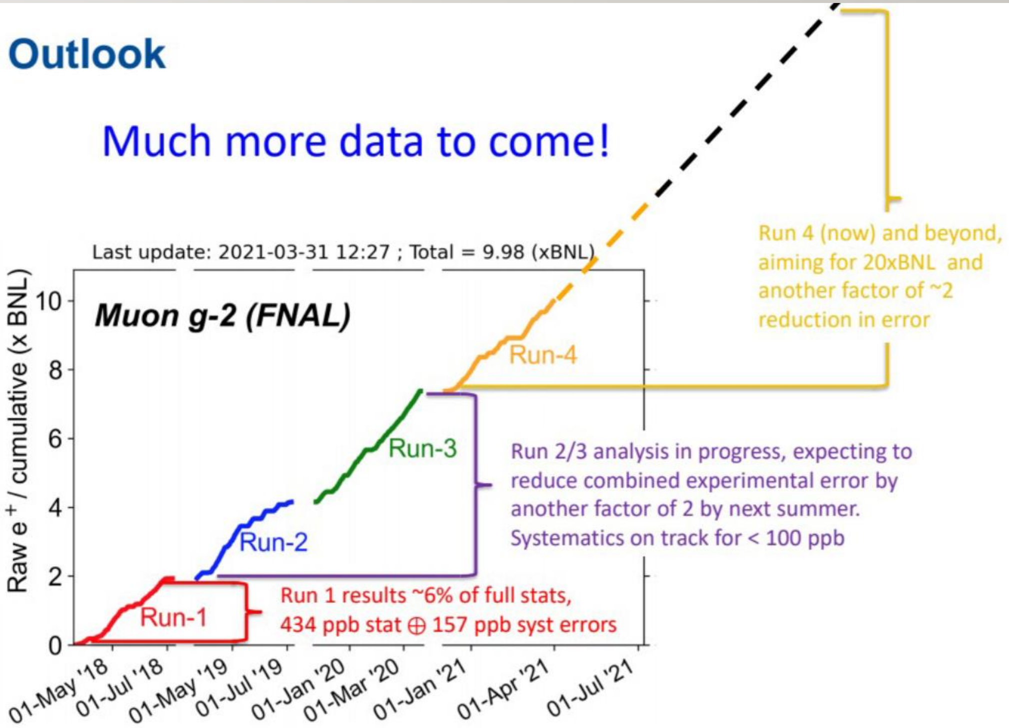
$$a_\mu(\text{FNAL}) = 116\,592\,040(54) \times 10^{-11}$$



- After 20 years, we confirm the BNL experimental results!
- Combining BNL/FNAL and comparing to theory → 4.2σ tension

Outlook

Much more data to come!



Sept 30, 2021 Muon g-2 Run 1 Result

First Results from the New Muon g-2 Experiment at Fermilab

μ g-2

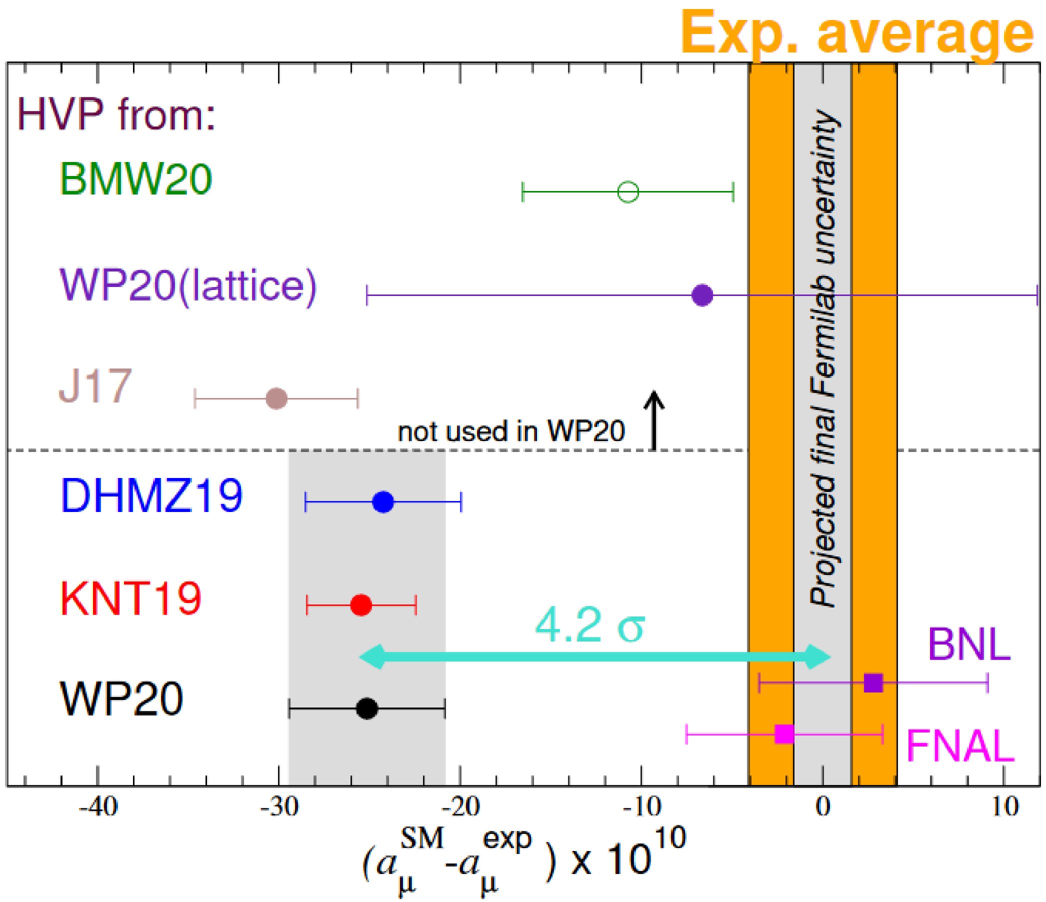
James Stapleton
for the Muon g-2 Collaboration
Sep 30, 2021

Fermilab

Muon g-2: theory summary

Present status of $(g-2)_\mu$, experiment vs SM

After the Fermilab result



Introduction HVP to $(g-2)_\mu$ HLbL to $(g-2)_\mu$ Conclusions

White Paper (2020): $(g-2)_\mu$, experiment vs SM

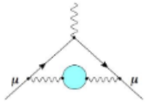
Contribution	Value $\times 10^{11}$
HVP LO (e^+e^-)	6931(40)
HVP NLO (e^+e^-)	−98.3(7)
HVP NNLO (e^+e^-)	12.4(1)
HVP LO (lattice BMW(20), *udsc*)	7075(55)
HLbL (phenomenology)	92(19)
HLbL NLO (phenomenology)	2(1)
HLbL (lattice, *uds*)	79(35)
HLbL (phenomenology + lattice)	90(17)
QED	116 584 718.931(104)
Electroweak	153.6(1.0)
HVP (e^+e^-, LO + NLO + NNLO)	6845(40)
HLbL (phenomenology + lattice + NLO)	92(18)
Total SM Value	116 591 810(43)
Experiment	116 592 061(41)
Difference: $\Delta a_\mu := a_\mu^{exp} - a_\mu^{SM}$	251(59)

The $(g-2)_\mu$ in the Standard Model: calculation of hadronic contributions

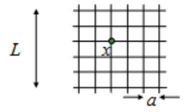
Gilberto Colangelo

TAU2021, Indiana University (virtual)
Sept 27-Oct 1, 2021

Muon g-2: lattice



HVP Comparison



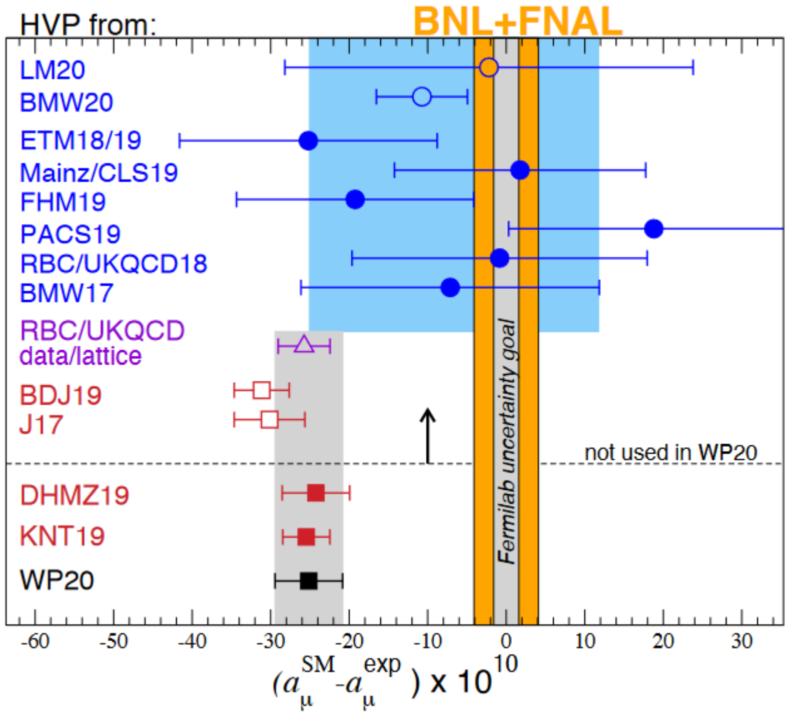
$$a_\mu^{SM} = a_\mu^{HVP} + [a_\mu^{QED} + a_\mu^{Weak} + a_\mu^{HLbL}]$$

Lattice QCD + QED

hybrid: combine data & lattice

data driven

+ unitarity/analyticity constraints



- Introduction to LQCD
- How to compute HVP with LQCD
- Systematic errors
- Results for each contribution
- Windows in Euclidean time ➠ detailed comparisons
- Summary and Outlook: a path forward

[T. Aoyama et al, arXiv:2006.04822, Phys. Repts. 887 (2020) 1-166.]

Future experiment: Prospect for Belle II

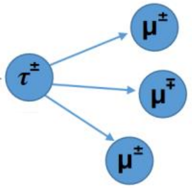
$\tau \to \mu\mu\mu$

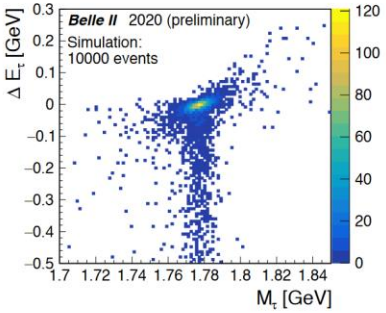
Signal-background discrimination using kinematics of the event

μID - the most powerful discriminating variable

Momentum dependent optimisation of the muID requirement

- $P_\mu < 0.7$ GeV
  - μ do not reach the μ detector (KLM)
- $0.7 < P_\mu < 1$ GeV
  - μ reach KLM but not many layers are crossed
- $P_\mu > 1$ GeV
  - μ reach KLM and many layers are crossed





Other requirement used @Belle but not @Belle II:

- μ veto on tag track
- $P_\mu > 0.6$ GeV

Two independent variables:

$$M_\tau = \sqrt{E^2_{\mu\mu\mu} - P^2_{\mu\mu\mu}}$$

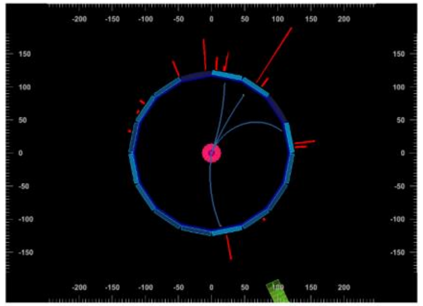
$$\Delta E = E^{CMS}_{\mu\mu\mu} - E^{CMS}_{beam}$$

- For signal → ΔE close to 0 and $M_{\mu\mu\mu}$ close to τ mass

Higher efficiency is foreseen @Belle II than @Belle or @BaBar

Summary

e^+e^- annihilation data is ideal for precision measurements and NP searches in τ physics!

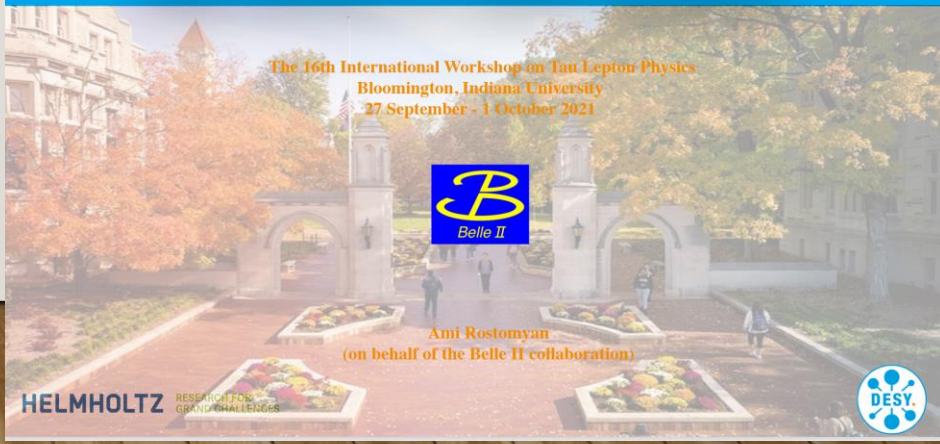


Belle II experiment started

- Achieved world record luminosity $L = 3.1 \times 10^{34} \text{cm}^{-2}\text{s}^{-1}$
- Will provide the world largest number (5x10^10) of $e^+e^- \to \tau^+\tau^-$ events
- **Precision measurements**
  - promising results on **τ mass, lifetime and LFU** with the early data
- **NP searches**
  - **$\tau \to \mu\mu\mu$** shows the potential of LFV searches @ Belle II
- Many more analysis in progress

Belle II will be the major player in τ physics in the near future!

Future directions on τ physics with Belle II



Future experiments: Super Tau Charm Factory

Summary

- **Super τ-c Facility** (STCF):
  - e^+e^- collision with $E_{cm} = 2 - 7$ GeV, $L > 0.5 \times 10^{35}$ cm^{-2}s^{-1}
- **STCF is one of the crucial precision frontier**
  - rich of physics program
  - unique for physics with c quark and τ leptons,
  - important playground for study of QCD, exotic hadrons and search for new physics.
- **Complementary to Belle-II and LHCb in understanding the QCD/EW models and searching for new physics**
- **Project organization is setup and a working group is toward for CDR/TDR**
- **An International collaboration is essential for promoting the project.**

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Summary, physics

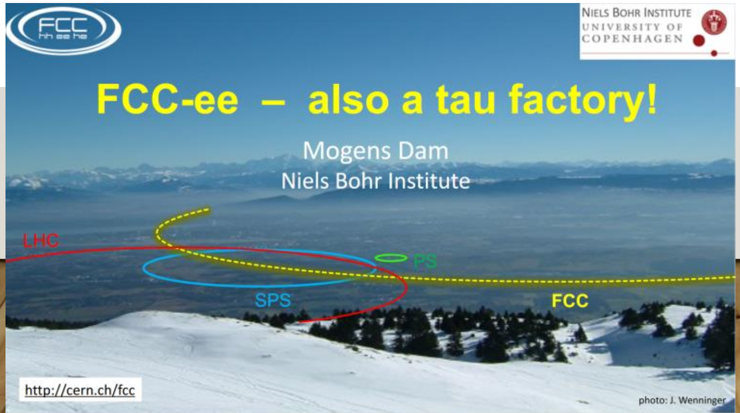
- The world largest statistics of τ leptons collected by Belle and *BABAR* opens new era in the precision tests of the Standard Model, search for the effects of New Physics and precision studies of low energy QCD.
  Belle II is the main player in τ studies in the nearest future.
- Nonzero average polarization of single τ at the SCTF make it to be competitive to Belle II player in τ lepton studies regardless smaller expected statistics (by a factor of 2.2).
- Vast research program of the proper precise study of hadronic τ decays taking into account spin-spin correlation term requires great effort and competition between at least two e^+e^- experiments (Belle II and SCTF).
- The physics program of the SCTF is further developed to unveil rich potential of the e^- beam polarization option.

Future experiments: much more future

Summary

- From 5 x 10^{12} Z decays, FCC-ee will produce **1.7 x 10^{11} $\tau^+\tau^-$ pairs**
- Factor ~3 higher statistics than Belle2 projection; plus higher boost (γ = 25)
  - Boost is advantageous for many studies
- Potential for very precise $\sin^2\theta_W$ determination via τ **polarisation** measurement
- Improve **Lepton universality test** by 1-2 orders of magnitude down to at least $\mathcal{O}(10^{-4})$ level [$\mathcal{O}(10^{-4})$ statistically]
  - Substantial improvement in **τ lifetime**
  - Substantial improvement in **τ branching fractions**
  - Potential for improved measurement of **τ mass**
- Improved sensitivity to **lepton flavour violating Z decays** by factor **$\mathcal{O}(10^{3-4})$**
  - Sensitivities down to **10^{-9}**
- Searches for **lepton flavour violating τ decays**; sensitivites comparable to Belle2
  - Range from **$\lesssim 10^{-10}$** to **few x 10^{-9}**
- Plus hadronic branching ratios and spectral functions, α_s, ν_τ mass, …
- Prospects for very precise lepton universality τ lepton tests in b-physics
- And of course Higgs, etc…

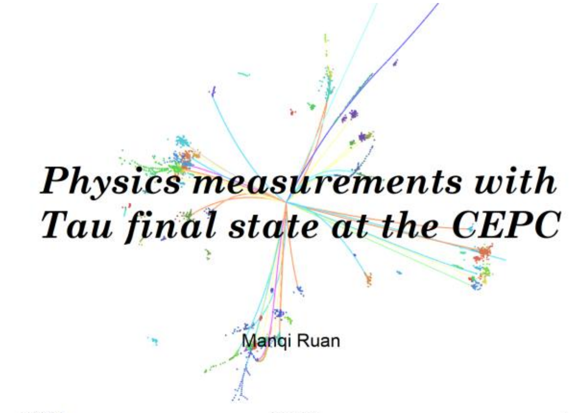
1st October, 2021 30



Summary

- CEPC, a precision & upgradable Higgs/W/Z factory, and a Discover machine!
  - Boost the Higgs/EW precision by ~ 10 times w.r.t HL-LHC/current boundary
  - Huge potential on QCD, Flavor, BSM
- Tau is critical for CEPC physics: we estimated the accuracy for multiple physics benchmarks with tau in their final states
  - Higgs→tautau; relative accuracy of 0.8%
  - Z→bb, Bc→Tauv; relative accuracy of o(1%)
  - Z→bb, b→stautau; sensitive to Br ~ 1E-6
- A dedicated tau finding algorithm, TAURUS has been developed at the CEPC baseline detector. It has a tau finding performance of:
  - Efficiency of 80% and purity of 85% at qqH, H->tautau and WW->tauvqq events.
  - Efficiency of 60% and purity of 75% at Z->bb, Bc->Tauv events.
  - Efficiency of 25% and purity of 30% at Z->bb, Bs->Tautau events.

13/7/2021 Firs 26



Future Experiments: muon

Summary

- In the J-PARC E34 experiment, measurement of muon $g-2$ and EDM is planned with a method different from BNL/FNAL.
  - Re-accelerated thermal μ^+.
  - Beam storage with no electric field.
  - The 300 MeV/c momentum μ^+ beam opens an opportunity for the compact storage region with highly uniform magnetic field.
  - The decay e^+ tracking detector can work in pile-up environment and measure $\vec{p}_{e^+}$, which is required for the $g-2$/EDM determination.
- Construction of the beam line has been started and other components of the experiment are also moved to the construction phase.
- The experiment aims to start data taking from 2025.

MUON $g-2$/EDM MEASUREMENT AT J-PARC

G. P. Razuvaev on behalf of E34

BUDKER INSTITUTE OF NUCLEAR PHYSICS
NOVOSIBIRSK STATE UNIVERSITY

TAU 2021
1 October 2021

Conclusions

https://web.infn.it/MUonE/

- The new method proposed by MUonE to determine a_μ^{HLO} is independent and competitive with the latest evaluations.
- A parasitic Run will be performed at CERN to test the DAQ system in October-November 2021.
- A Test Run of 3 weeks is foreseen at CERN in 2022. The aim of the Test Run will be to verify the detector design, to evaluate the analysis strategy, study the systematic effects and possibly to perform a measurement of $\Delta\alpha_{lep}(t)$.
- Beyond the Test Run: we are planning a first measurement to be performed in 2023-24: a ~2% (stat) measurement of a_μ^{HLO} can be achieved by adding 10 stations to the existing prototype, with a running time of 4 months.

Contacts: riccardonunzio.pilato@phd.unipi.it

Summary

- Mu2e-II is a proposed upgrade to Mu2e with strong physics motivations in either Mu2e scenario
- PIP-II will provide the possibility of a x10 improvement over the expected Mu2e sensitivity
- Mu2e-II experimental conditions will face technological challenges for all detector systems
  - Working groups already started Monte Carlo studies to address most of the issues
  - Various projects (also LDRDs) already started and others have been proposed
- Our first goal is to deliver a strong conceptual design for the US Snowmass-2022 process
- **If approved, Mu2e-II expects to start data taking in the early 2030's**
- **More info: http://mu2eiiwiki.fnal.gov**

16th International Workshop on Tau Lepton Physics

Status of the Mu2e-II experiment

Gianantonio Pezzullo
Yale University
on behalf of the Mu2e-II collaboration

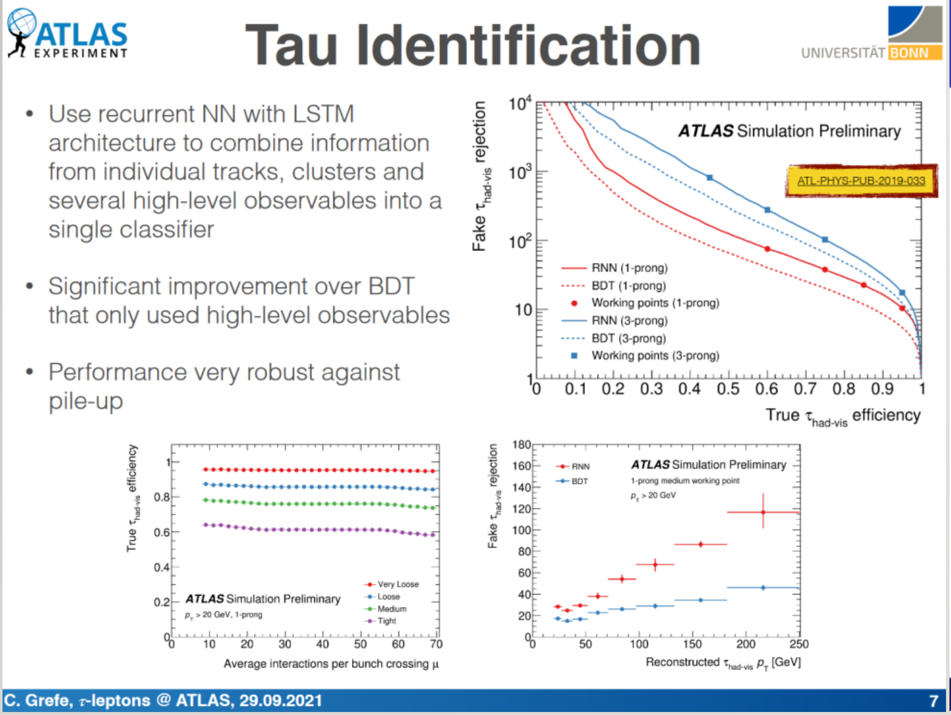
Status of the MUonE experiment

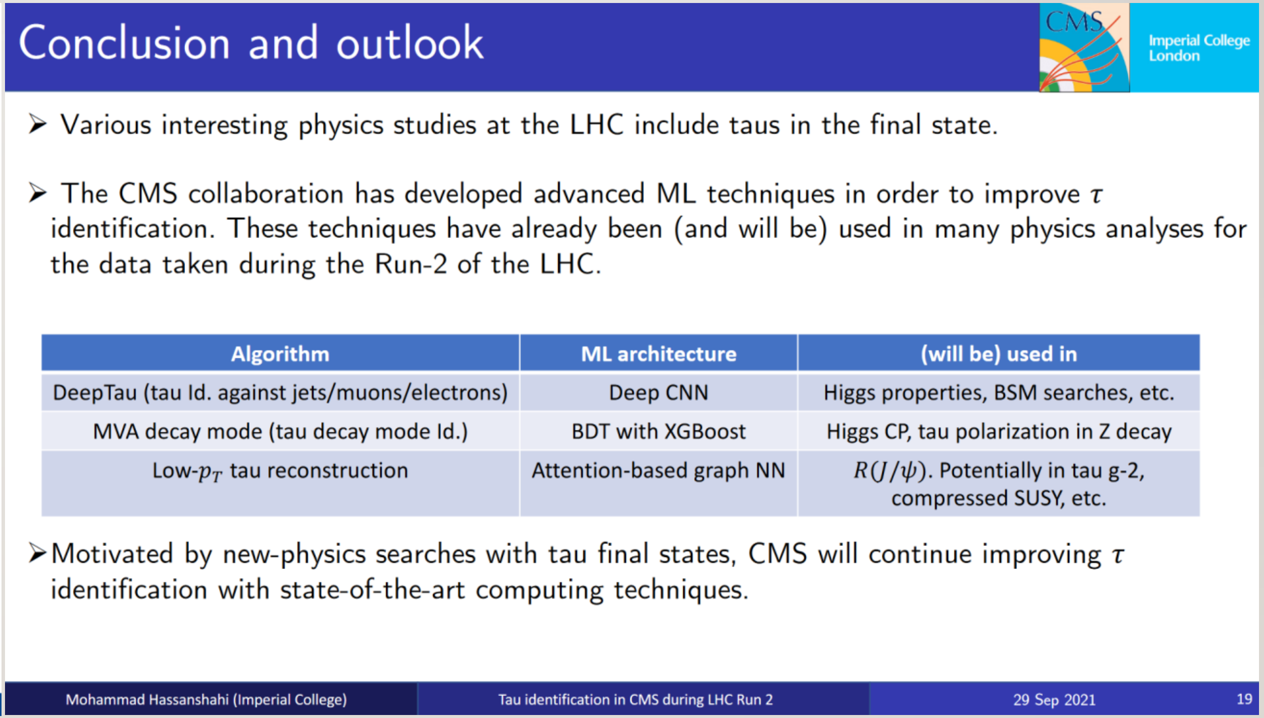
Riccardo Nunzio Pilato
University and INFN Pisa

16th International Workshop on Tau Lepton Physics
1st October 2021

New techniques, Machine Learning and so on…

- Thanks to the recent development information science / computing performance, Machine Learning technique drastically increase detection/PID efficiency and so on.





Conclusion and outlook

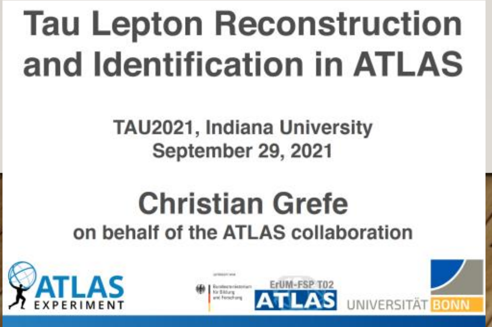
CMS Imperial College London

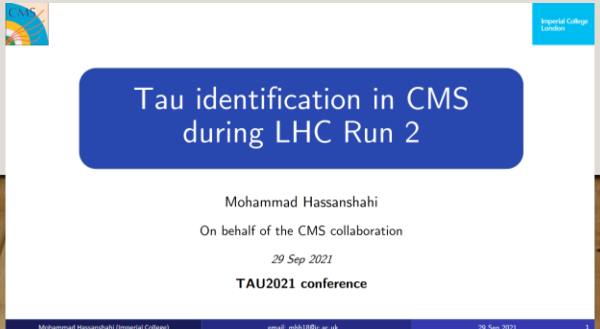
- ➤ Various interesting physics studies at the LHC include taus in the final state.
- ➤ The CMS collaboration has developed advanced ML techniques in order to improve τ identification. These techniques have already been (and will be) used in many physics analyses for the data taken during the Run-2 of the LHC.

Algorithm	ML architecture	(will be) used in
DeepTau (tau Id. against jets/muons/electrons)	Deep CNN	Higgs properties, BSM searches, etc.
MVA decay mode (tau decay mode Id.)	BDT with XGBoost	Higgs CP, tau polarization in Z decay
Low-p_T tau reconstruction	Attention-based graph NN	$R(J/\psi)$. Potentially in tau g-2, compressed SUSY, etc.

- ➤ Motivated by new-physics searches with tau final states, CMS will continue improving τ identification with state-of-the-art computing techniques.

Mohammad Hassanshahi (Imperial College) Tau identification in CMS during LHC Run 2 29 Sep 2021 19





Also, many analyses introduce selection based on ML. Such a gain obtained by ML may lead us to the New physics much faster than expected.

Let's enjoy (tau) lepton physics this exciting era!

Looking forward to seeing you and hearing the new result at the next workshop!!

I am sorry that I cannot mention all talks…

In particular, I am sorry that I cannot mention ν activities at all. So sorry.