



$\tau \rightarrow \ell + \text{hadrons}$ decays at Belle(II)

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On behalf of the Belle II collaboration

Topical workshop on LFV decays of the τ

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Outline

- Motivation, experimental challenges
 - Search for $\tau \rightarrow \ell V^0$ at Belle
 - Search for $\tau \rightarrow \ell \phi$ at Belle II
 - Search for $\tau \rightarrow \ell K_S^0$ at Belle + Belle II and baryon and lepton number violation in $\tau \rightarrow \Lambda(\bar{\Lambda})\pi$ at Belle II
- Conclusion



Why τ decays?



τ pairs produced in the e^+e^- collisions are a unique laboratory to **test the standard model (SM)** through **precision** measurements and **search for non-SM physics!**

- $M_\tau = 1777.09 \text{ MeV}/c^2$
 - heavy enough to decay into final states with hadrons
 - **search for non-SM physics**, possible enhancement due to mass-dependent couplings
- Lifetime: 290.17 fs
 - not a long-lived particle
 - **missing energy** due to neutrinos



The challenges

High precision measurements of the SM properties

- **Control of systematic sources** → excellent understanding of the experiment performance and background description necessary to improve results **mainly systematically limited**



e.g. tau mass, lifetime, branching fractions measurement

< fractions of per mill level

World's leading sensitivities for direct searches

- **Largest data sets** → attain highest luminosity, collect (unique) data set suitable to study rare processes + new techniques to **increase** the signal **efficiency** while keeping background under control



e.g. LFV decays, $\tau \rightarrow \ell \Phi$, $\tau \rightarrow \mu \mu \mu$, ...

< 10^{-8} level

Working at ~~B~~-factories

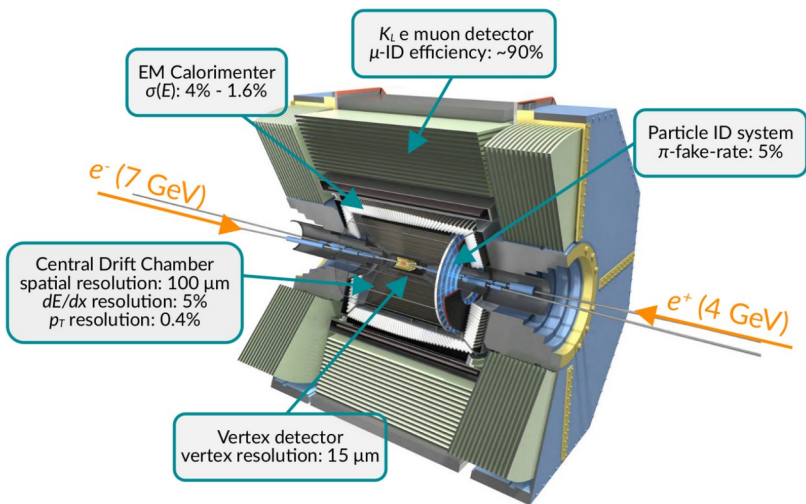
tau

- **Clean environment** at asymmetric energy e^+e^- collider + ~ **hermetic detector**:

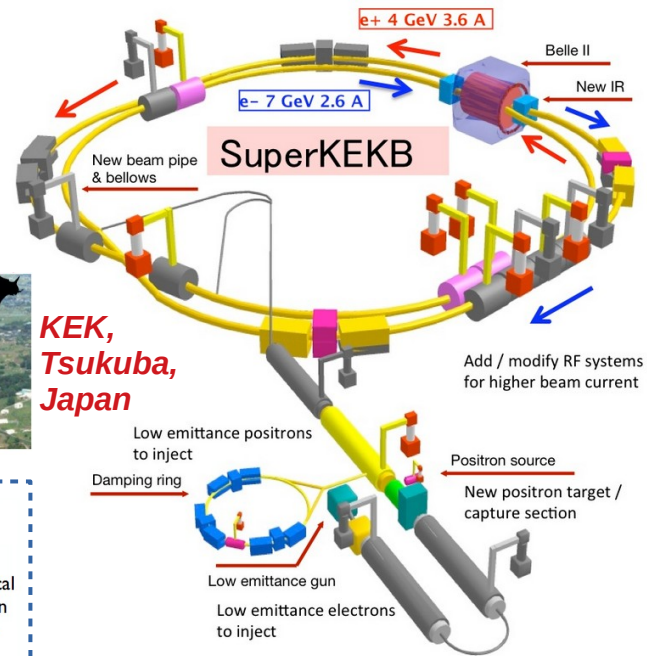
→ at $\sqrt{s} = 10.58 \text{ GeV}$: $\sigma_{bb} \sim \sigma_{\tau\tau} \sim 1 \text{ nb}$, B & τ factory

→ known initial state + efficient reconstruction of **neutrals** (π^0, η), **recoiling system** and **missing energy**

→ specific **low-multiplicity triggers** (previously not available at Belle)



KEK, Tsukuba, Japan



$$L = \frac{\gamma_{\pm}}{2e r_e} \left(1 + \frac{\sigma_y^*}{\sigma_x^*} \right) I_{\pm} \xi_{y\pm} \frac{R_L}{R_{\xi}} \text{ geometrical reduction factors}$$

Labels for the equation:

- Lorentz factor: γ_{\pm}
- beam current: I_{\pm}
- beam-beam parameter: $\xi_{y\pm}$
- beam aspect ratio at the IP: $\frac{\sigma_y^*}{\sigma_x^*}$
- vertical beta-function at the IP: $\beta_{y\pm}^*$
- geometrical reduction factors: $\frac{R_L}{R_{\xi}}$

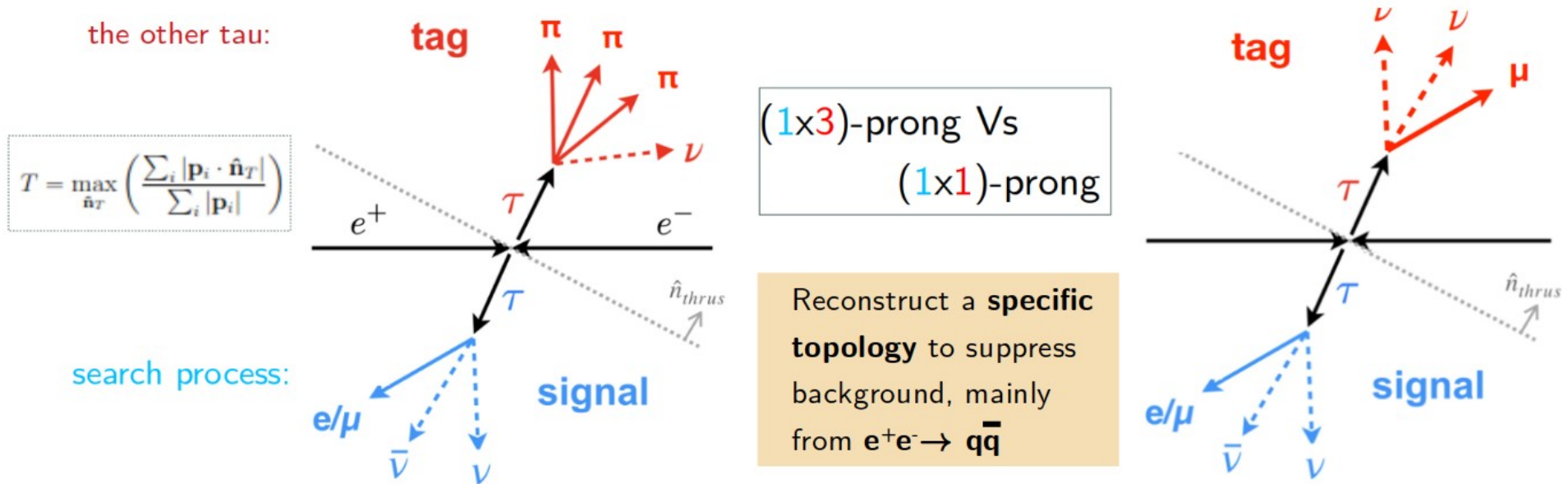
- **GOAL:** 30 x KEKB peak luminosity, $L = 6 \cdot 10^{35} \text{ cm}^{-2}\text{s}^{-1}$ (*nano-beam scheme technique**)
- Collect 50 x Belle → 50 ab^{-1}

• **Accumulated 424 fb^{-1}** (~ Babar, ~ half of Belle) and unique energy scan samples during run 1

• Resumed data taking in February 2024: **run 2 started!**

Tau topologies and signatures

- Tau pairs in $e^+e^- \rightarrow \tau^+\tau^-$ events produced back-to-back in CM system
- Possible to separate them in **two opposite hemispheres** defined by the plane perpendicular to the **thrust axis** \hat{n}_T





THIS IS WHERE YOU
LOST YOUR WALLET?

NO, I LOST IT IN THE PARK.
BUT THIS IS WHERE THE LIGHT IS.

Beyond SM searches

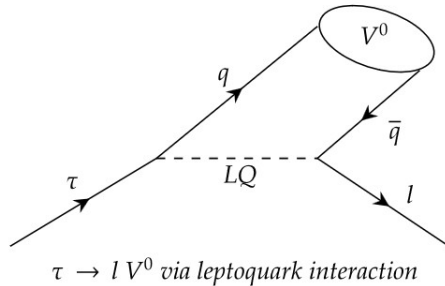


Lepton flavor violation

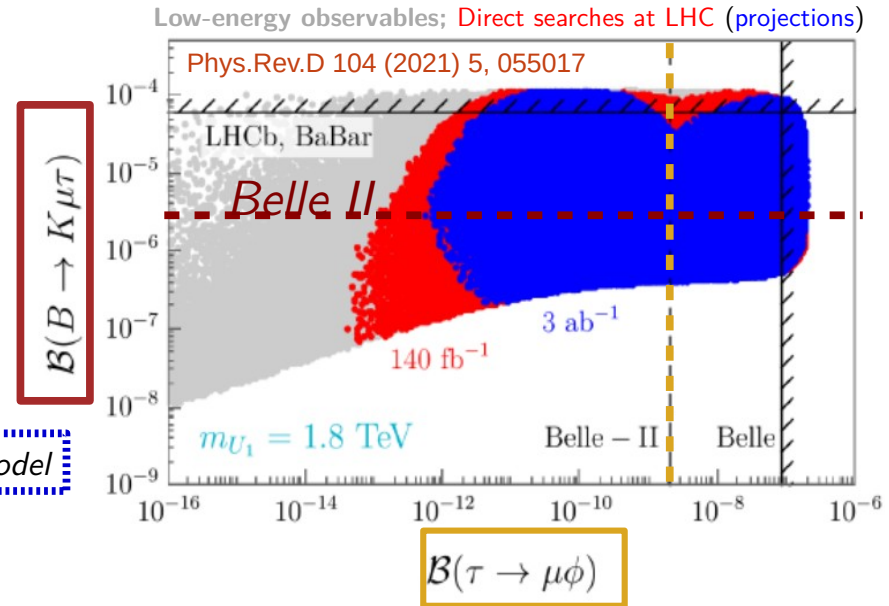
- **Charged Lepton Flavor Violation (LFV)** via SM weak interaction charged currents and neutrino mixing $< O(10^{-50}) \rightarrow$ below any experiment sensitivity
 \rightarrow **observation of LFV decays is *per se* a proof of non-SM physics!**
- Hints of Lepton Flavor Universality (LFU) violation and deviation from SM predictions in rare B decays:
 - $b \rightarrow c l \bar{\nu}$ (τ Vs light leptons), $b \rightarrow s l l \dagger$



New interaction that violates flavor (Z' boson, leptoquark)
 \rightarrow **Special role of the third family**



Simplified U1 leptoquark model

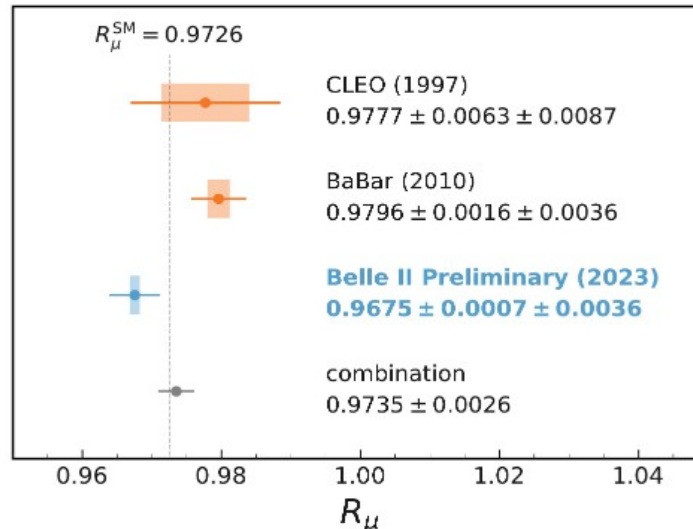
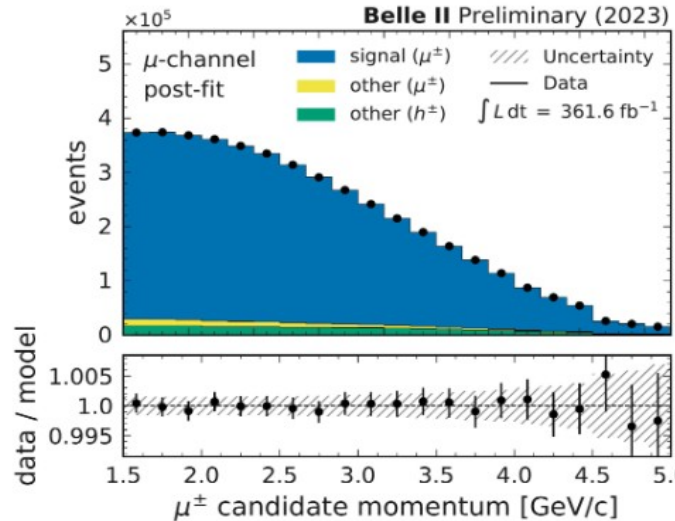
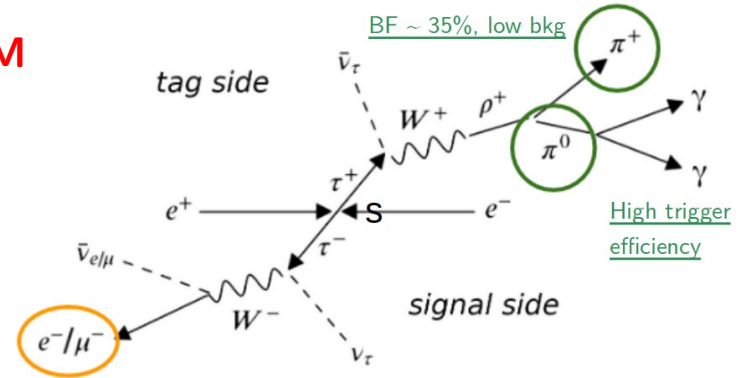


LFU test with τ at Belle II

- In the SM all three leptons have equal coupling strength (g_i) to the charged gauge bosons: LFU \rightarrow may be violated by **new forces** [1]

$$R_\mu = \frac{\mathcal{B}(\tau^- \rightarrow \mu^- \bar{\nu}_\mu \nu_\tau)}{\mathcal{B}(\tau^- \rightarrow e^- \bar{\nu}_e \nu_\tau)} \Rightarrow \left(\frac{g_\mu}{g_e}\right)_\tau^2 = R_\mu \cdot \frac{f(m_e^2/m_\tau^2)}{f(m_\mu^2/m_\tau^2)} = \mathbf{1 \text{ in SM}}$$

- Select 1x1-prong decays, rely on **lepton ID** to identify signal side
- Use neural network to isolate signal and extract R_μ with **template** fit to the lepton momentum distributions

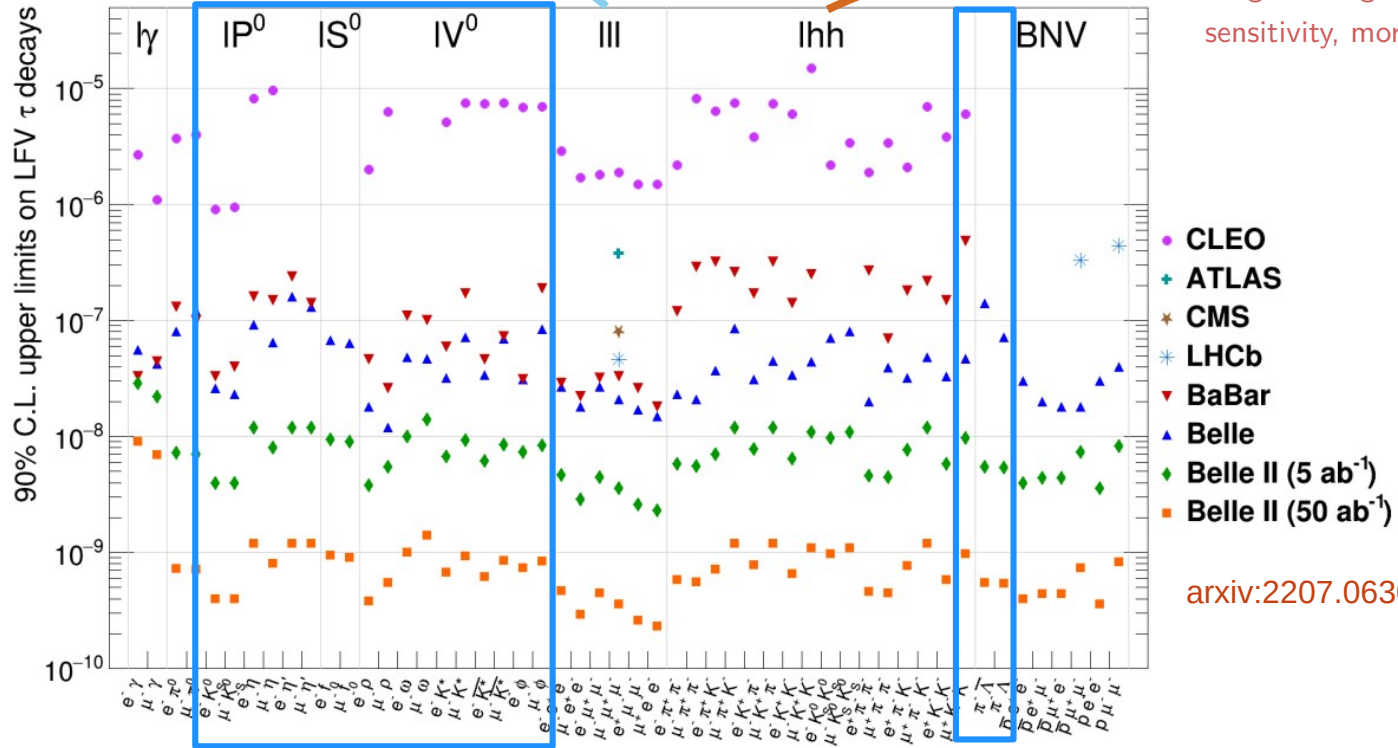


\rightarrow Most precise test of μ -e universality in τ decays from a single measurement, **systematically limited by lepton ID (0.32%)**

LFV sensitivities

Covered by Justine and Federica's talks

Larger background degrades sensitivity, more challenging

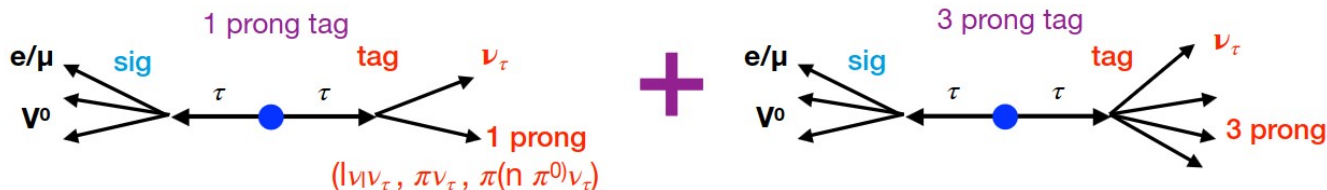


- Belle II expected to provide world's leading limits on many channels

Search for $\tau \rightarrow \ell V^0$ at Belle:

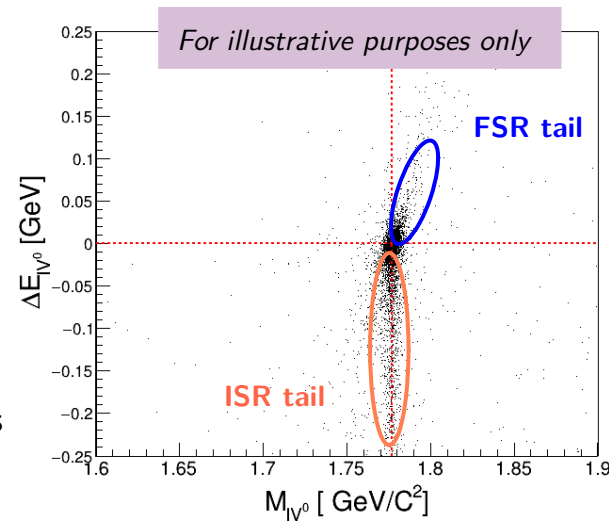
strategy

- Previous search at Belle on 854 fb^{-1} exploiting one-prong tag [1]



Full Belle data set of 980 fb^{-1}
 $\rightarrow 9.05 \times 10^8$ tau pairs

- **Signal side:** reconstruct lepton and $V^0 \in [\rho, \phi, \omega, K^*]$ from invariant mass windows around M_{V^0}
 - Use particle identification (PID) variables, likelihood ratios to identify (veto) leptons and hadrons
- **Tag side:** reconstruct 1 or 3-prong decays
- Exploit kinematics of the signal as *neutrinoless* decays
 - M_{IV^0} expected to peak at known tau mass
 - $\Delta E_{IV^0} = E_{\text{sig}}^* - \sqrt{s}/2$ peaks at 0 \rightarrow up to initial/final state radiation (ISR, FSR) effects
- Count in elliptical signal region (SR) in ΔE_{IV^0} and M_{IV^0} plane



[1] [Phys. Lett. B 699 \(2011\) 251](#)

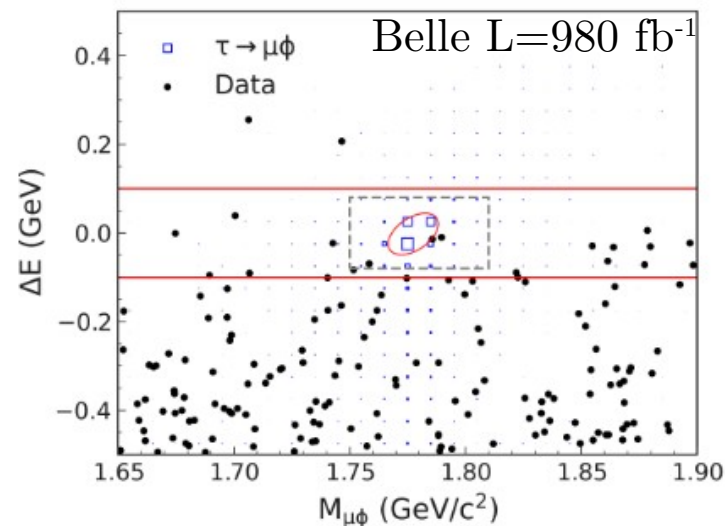
Search for $\tau \rightarrow \ell V^0$ at Belle:

background suppression and yields extraction

- Backgrounds mimic the presence of neutrinos in the tag side (detector inefficiencies), wrong PID in the signal side \rightarrow exploit topology and tag kinematics to reject low-multiplicity: $e^+e^- \rightarrow e^+e^- (\gamma)$, $e^+e^- \rightarrow \mu\mu(\gamma)$, $e^+e^- \rightarrow e^+e^- \Pi$
- Further suppress $\tau \rightarrow 3\pi\nu$ and $ee \rightarrow q\bar{q}$ with BDT
 - use **missing momentum** and **V^0** properties, and **event tag** categorical variables
- Estimate expected background in SR from **sideband interpolation**
 - Model the shape from hadron enhanced data samples scaled to sideband
 - Integrate over the elliptical SR area

\rightarrow **Count number of observed events in data inside SR**

- Dominant systematic uncertainties from tracking and PID (negligible impact compared to the **statistical** one)



(b) $\tau \rightarrow \mu\phi$

Search for $\tau \rightarrow \ell V^0$ at Belle:

results

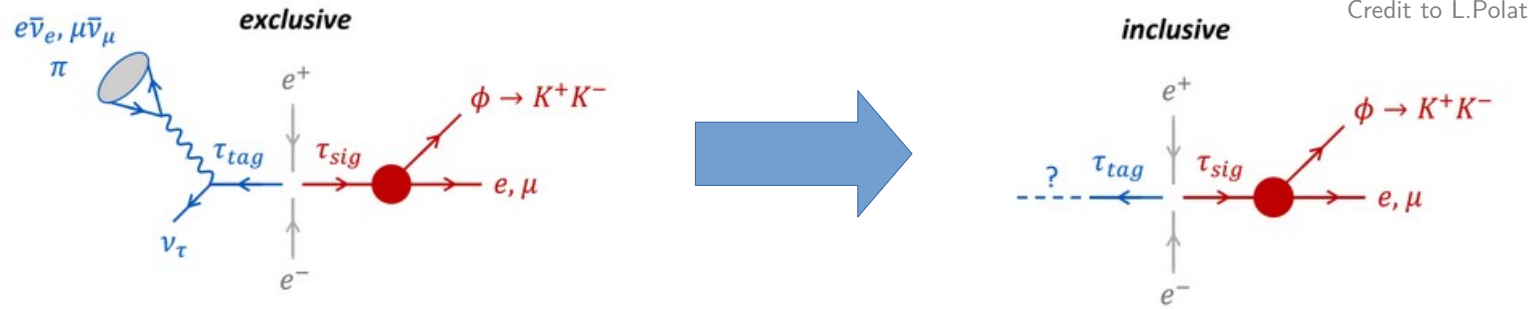
- No significant excess observed \rightarrow set ULs at 90% CL

Mode	ε (%)	N_{BG}	σ_{syst} (%)	N_{obs}	$\mathcal{B}_{\text{obs}} (\times 10^{-8})$
$\tau^\pm \rightarrow \mu^\pm \rho^0$	7.78	$0.95 \pm 0.20(\text{stat.}) \pm 0.15(\text{syst.})$	4.6	0	< 1.7
$\tau^\pm \rightarrow e^\pm \rho^0$	8.49	$0.80 \pm 0.27(\text{stat.}) \pm 0.04(\text{syst.})$	4.4	1	< 2.2
$\tau^\pm \rightarrow \mu^\pm \phi$	5.59	$0.47 \pm 0.15(\text{stat.}) \pm 0.05(\text{syst.})$	4.8	0	< 2.3
$\tau^\pm \rightarrow e^\pm \phi$	6.45	$0.38 \pm 0.21(\text{stat.}) \pm 0.00(\text{syst.})$	4.5	0	< 2.0
$\tau^\pm \rightarrow \mu^\pm \omega$	3.27	$0.32 \pm 0.23(\text{stat.}) \pm 0.19(\text{syst.})$	4.8	0	< 3.9
$\tau^\pm \rightarrow e^\pm \omega$	5.41	$0.74 \pm 0.43(\text{stat.}) \pm 0.06(\text{syst.})$	4.5	0	< 2.4
$\tau^\pm \rightarrow \mu^\pm K^{*0}$	4.52	$0.84 \pm 0.25(\text{stat.}) \pm 0.31(\text{syst.})$	4.3	0	< 2.9
$\tau^\pm \rightarrow e^\pm K^{*0}$	6.94	$0.54 \pm 0.21(\text{stat.}) \pm 0.16(\text{syst.})$	4.1	0	< 1.9
$\tau^\pm \rightarrow \mu^\pm \bar{K}^{*0}$	4.58	$0.58 \pm 0.17(\text{stat.}) \pm 0.12(\text{syst.})$	4.3	1	< 4.3
$\tau^\pm \rightarrow e^\pm \bar{K}^{*0}$	7.45	$0.25 \pm 0.11(\text{stat.}) \pm 0.02(\text{syst.})$	4.1	0	< 1.7

Average 30% improvement from both increased statistics (+ 124 fb⁻¹) and improved analysis (+ 9% efficiency)

$\tau \rightarrow \ell \Phi$ at Belle II

untagged approach



→ **Increase signal efficiency:** reconstruct explicitly only **signal side**, no requirement on the **tag side** (untagged inclusive reconstruction)

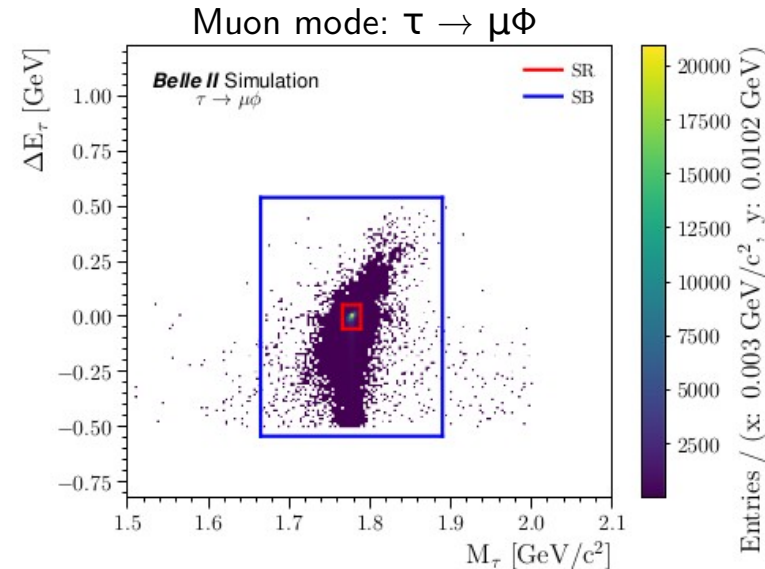
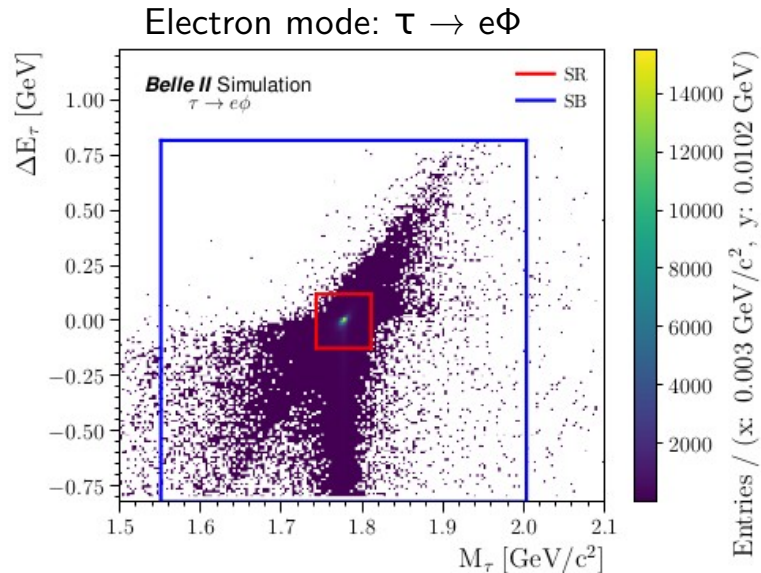
– Exploit signal and event features in **BDT classifiers** to suppress background



- First application for $\tau \rightarrow \ell \Phi$ search on 190 fb^{-1} → Also used for $\tau \rightarrow 3\mu$ search (see Justine's talk)

$\tau \rightarrow \ell\Phi$: strategy

- Signal candidate: two oppositely charged **kaon** candidates with invariant mass at M_Φ and a **lepton** (electron or muon)
 - use of kaonID and muonID as likelihood ratios of different particle hypothesis; BDT-based electronID (uses ECL and CDC information)
- Define **analysis** and **signal** box regions in the the $(M_\tau, \Delta E_\tau)$ plane, in units of fitted signal resolutions modeled on signal simulations.



$\tau \rightarrow \ell\Phi$: background suppression

- Reject radiative dilepton (Bhabha) with **pre-selections based on event geometry**
- Exploit rest of event (ROE), missing momentum and event shape, signal side kinematics in a **BDT classifier** (XGBoost, overtraining checked with log loss function)

- Most discriminating variables related to:
 - Rest Of Event (ROE)** → combines all non-signal tracks and remaining ECL clusters
 - Missing momentum** → good accuracy from Belle II hermetic detector's configuration
 - Topology** → thrust, reduced Fox-Wolfram moment R_2 and CLEO cones (w.r.t. thrust or beam axis)
 - Ranked transverse momenta** of signal side tracks
 - Charged and neutral** particles multiplicities.

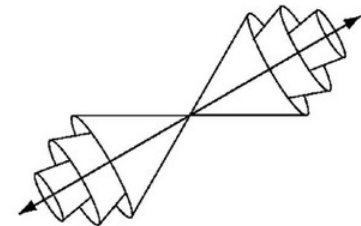
$$R_2 = H_2/H_0, \quad H_l = \sum_{i,j} \frac{|p_i| |p_j|}{s} P_l(\cos \phi_{ij})$$

i, j : final state particles.

ϕ_{ij} : angle between them.

P_l : Legendre polynomial of degree l .

CLEO cones

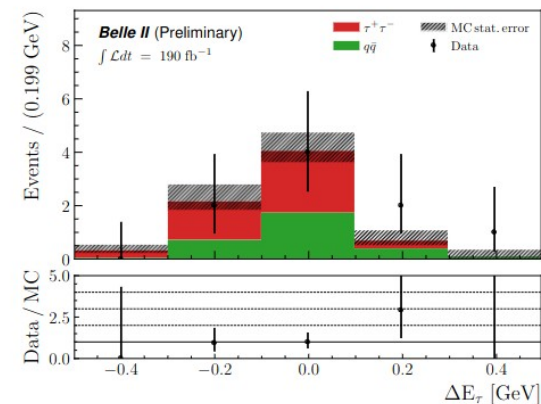
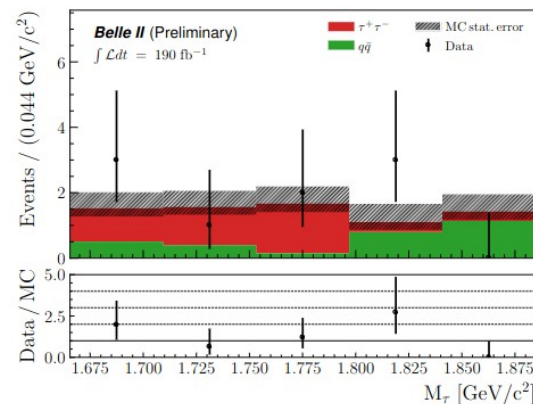
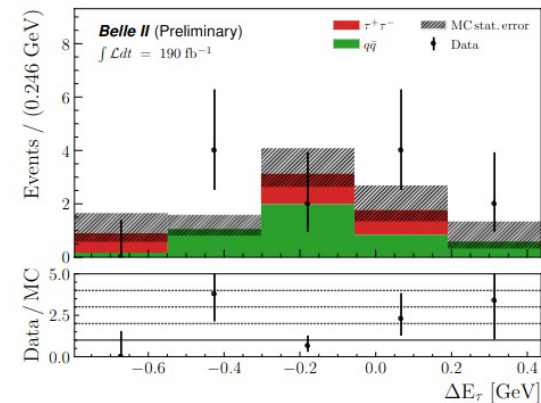
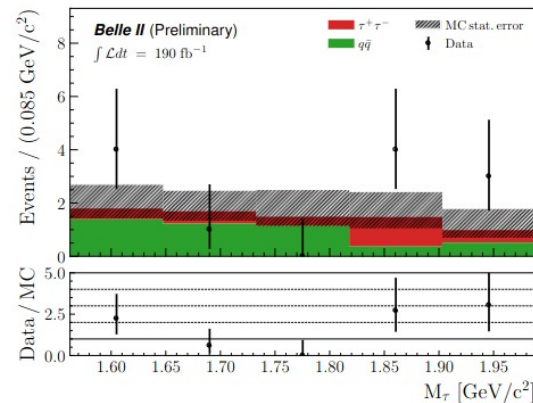


D. M. Asner et al., *Search for Exclusive Charmless Hadronic B Decays*,
Phys. Rev. D 53 1039,
<https://arxiv.org/abs/hep-ex/9508004v1>

- Optimal BDT selection found by minimizing the expected UL inside SR on simulation
- Final signal efficiencies: $\epsilon_{e\Phi} = 6.1\%$, $\epsilon_{\mu\Phi} = 6.5\%$ → 16% improvement wrt tagged approach**

$\tau \rightarrow \ell \Phi$: data validation

- Remaining backgrounds due to **misidentification of hadrons**
 - Electron channel: KKK, K $\pi\pi$, e $\pi\pi$, ee π
 - Muon channel: KKK, KK π , K $\pi\pi$, $\pi\pi\pi$, $\mu\pi\pi$
- Assess systematic uncertainties from data-MC agreement in control samples
 - Largest contribution due to simulation mismodeling, but negligible compare to **statistical** uncertainty



$\tau \rightarrow \ell\Phi$: yields extraction

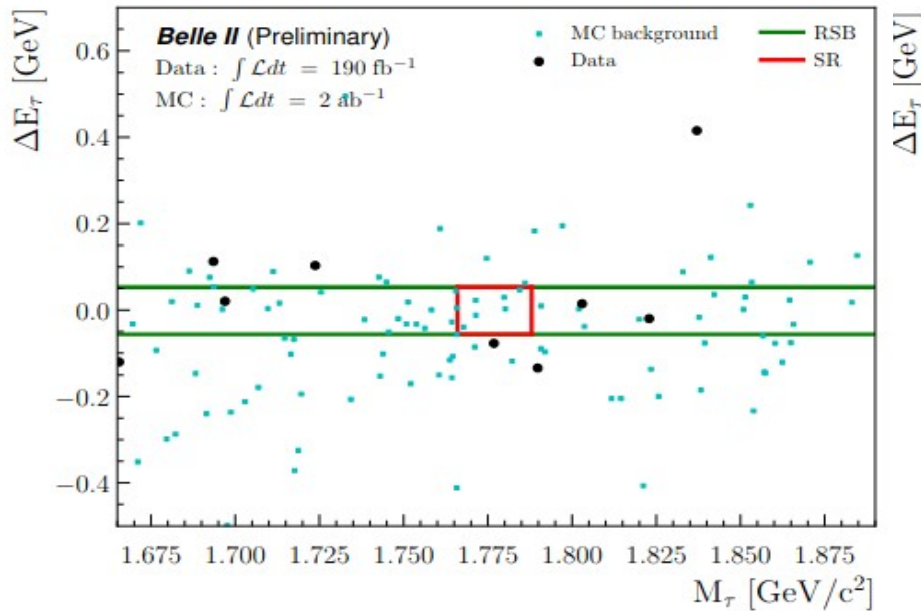
- Poisson counting experiment approach in **signal regions** in M_τ and

$$\Delta E_\tau = E_{\text{sig}}^* - \sqrt{s}/2 \text{ plane}$$

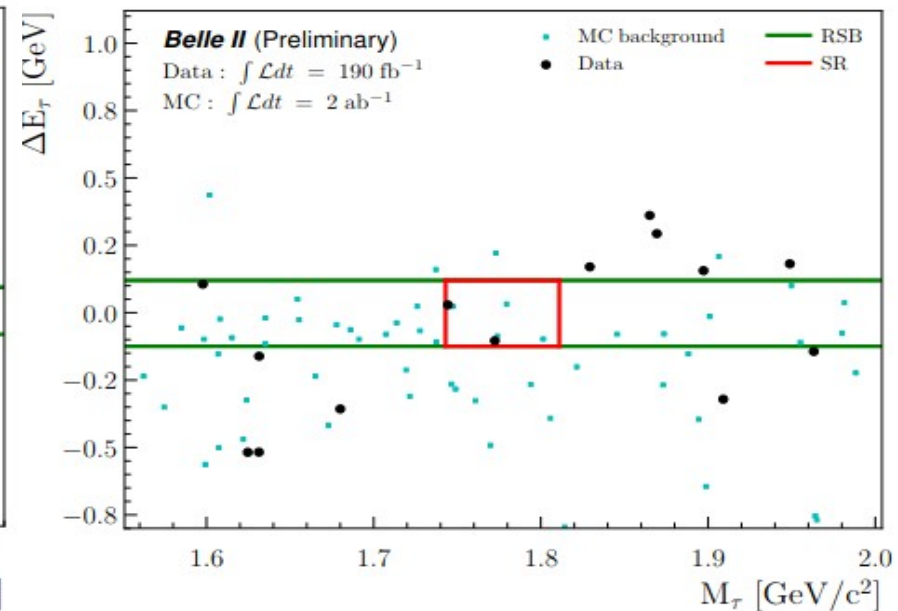
→ expected background N_{exp} evaluated from data **reduced sidebands** with scaling from simulation

Result	Region	Mode	
		$e\phi$	$\mu\phi$
N_{exp}	SR	$0.23^{+0.55}_{-0.21}$ stat	$0.36^{+0.39}_{-0.23}$ stat
N_{obs}	SR	$2.0^{+2.6}_{-1.3}$ stat	$0.0^{+1.8}_{-0.0}$ stat

Muon mode: $\tau \rightarrow \mu\Phi$



Electron mode: $\tau \rightarrow e\Phi$



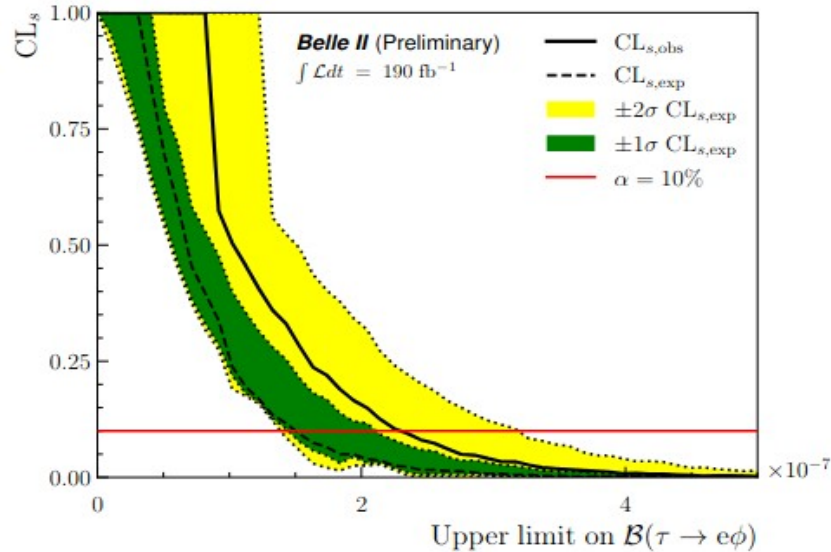
$\tau \rightarrow \ell\Phi$: results

- No significant excess in **190 fb⁻¹**
- Set 90% CL upper limits on the BF with CL_s method:
$$\mathcal{B}_{\text{UL}}(\tau \rightarrow \ell\phi) = \frac{N_{\text{obs}} - N_{\text{exp}}}{L \times 2\sigma_{\tau\tau} \times \varepsilon_{\ell\phi}},$$

Electron mode: $\tau \rightarrow e\Phi$

Observed: $\mathcal{B}_{\text{UL}}(\tau \rightarrow e\Phi) = 23 \times 10^{-8}$

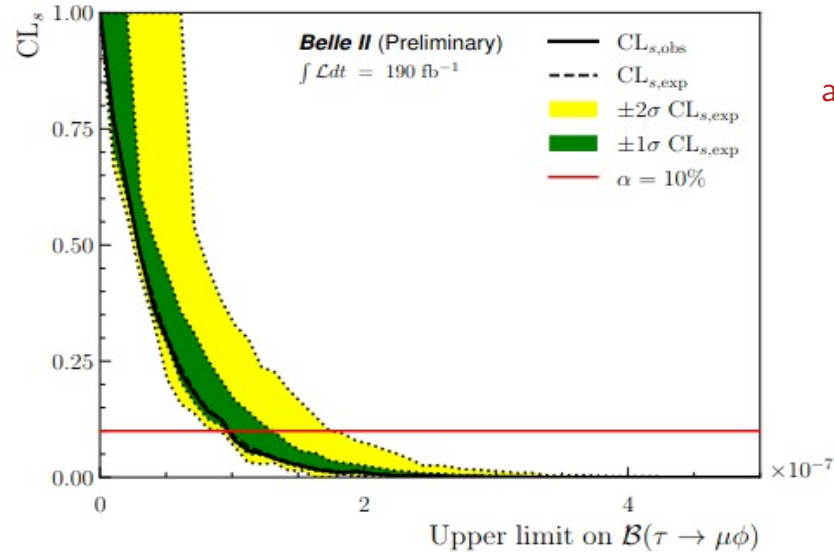
Expected: $\mathcal{B}_{\text{UL}}(\tau \rightarrow e\Phi) = 15 \times 10^{-8}$



Muon mode: $\tau \rightarrow \mu\Phi$

Observed: $\mathcal{B}_{\text{UL}}(\tau \rightarrow \mu\Phi) = 9.7 \times 10^{-8}$

Expected: $\mathcal{B}_{\text{UL}}(\tau \rightarrow \mu\Phi) = 9.9 \times 10^{-8}$



Results not competitive yet

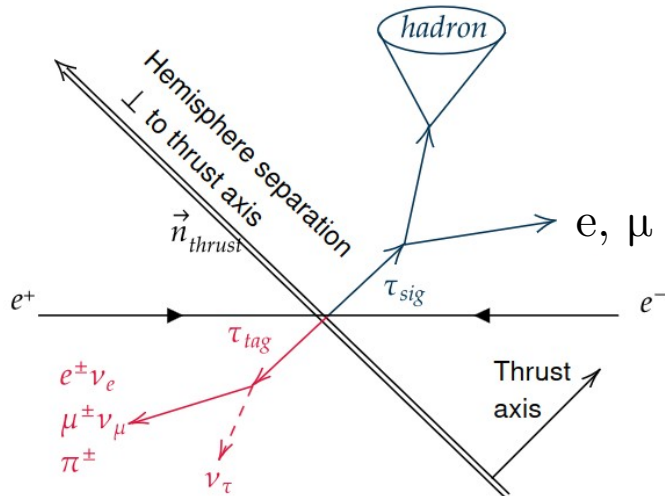
→ successful first application of **untagged approach** in τ -pair analysis at Belle II

↓
 exploited for world's best result on $\tau \rightarrow 3\mu$
 (see Justine's talk)

Search for $\tau \rightarrow \ell K_S^0$ at Belle and Belle II

- First analysis for LFV search on the combined data set **Belle (980 fb⁻¹) + Belle II, run 1 (424 fb⁻¹)**

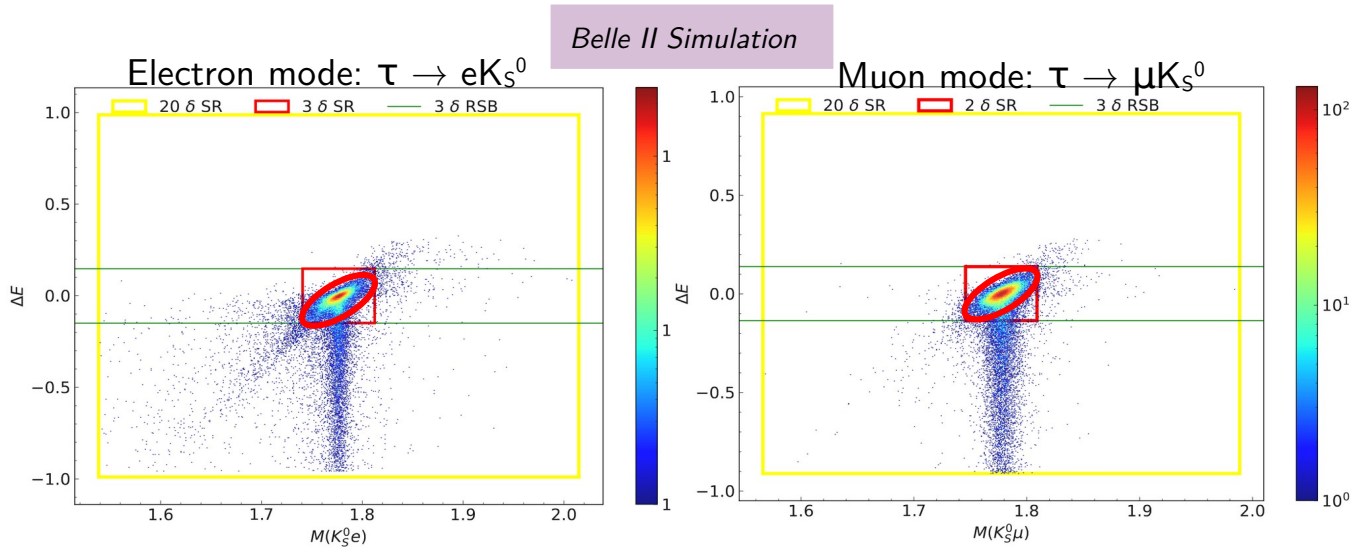
Experiment	Luminosity [fb ⁻¹]	UL at 90% CL [x10 ⁻⁸] (expected)		Ref.
		eK _S ⁰	μK _S ⁰	
BaBar	469	3.3	4.0	Phys. Rev. D, 79 (2009)
Belle	671	2.6	2.3	Physics Letters B, Vol. 692, 1, (2010)
Belle + Belle II	1404	< 2	< 2	This analysis! NOT UNBOXED YET



- Reconstruct signal in one-prong tag approach
- Use lepton ID to distinguish two channels and tag sides
- BDT-based selection to reject main background from $e^+e^- \rightarrow q\bar{q}$

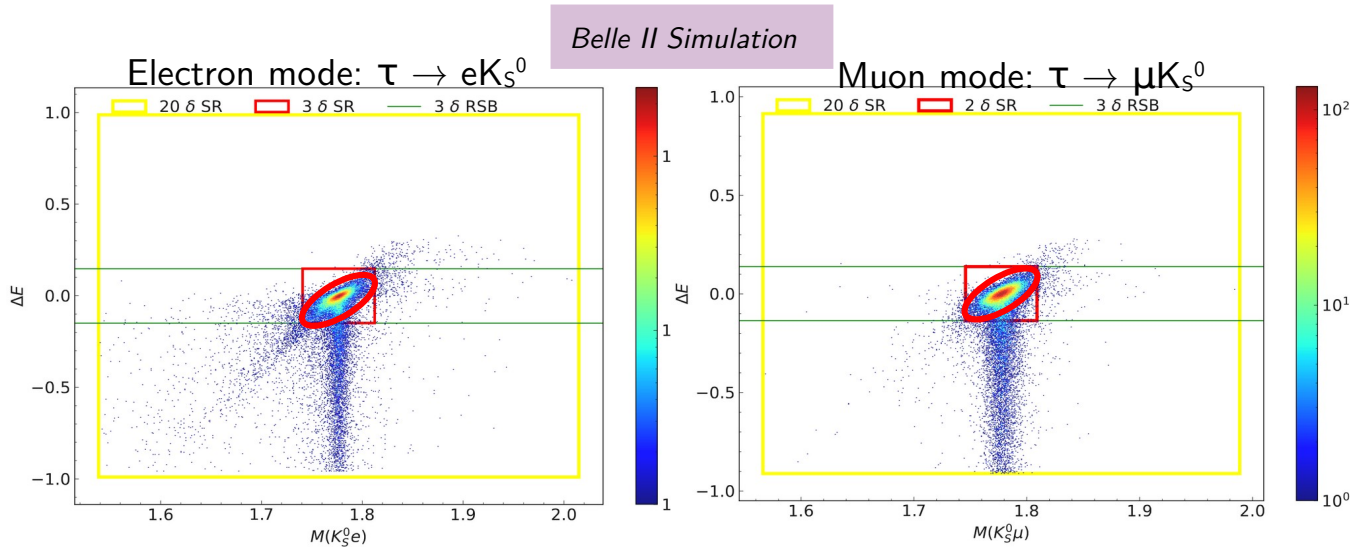
$\tau \rightarrow \ell K_S^0$: strategy

- Define region for **analysis optimization** in $(M_{\ell K_S}, \Delta E)$ plane, hide **signal region** (SR) and use **sidebands** (RSB) for data validation
- Tag-type dependent pre-selections against radiative dilepton and four-lepton final states
- Exploit tag side, missing momentum and event shape properties + K_S^0 properties from signal side to train a **BDT** against $ee \rightarrow q\bar{q}$ → final **efficiencies** $> 10\%$ for both channels
- Expected number of events N_{exp} in SR after final selections extracted by a linear fit to 6 bins of $M_{\ell K_S}$ in the **RSB** and scaled by the ratio $A_{\text{ell}}/A_{\text{rect}}$



$\tau \rightarrow \ell K_S^0$: strategy

- Define region for **analysis optimization** in $(M_{\ell K_S}, \Delta E)$ plane, hide **signal region** (SR) and use **sidebands** (RSB) for data validation
- Tag-type dependent pre-selections against radiative dilepton and four-lepton final states
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- Expected number of events N_{exp} in SR after final selections extracted by a linear fit to 6 bins of $M_{\ell K_S}$ in the **RSB** and scaled by the ratio A_{ell}/A_{rect}



- **Count the number of event in SR ellipse after unboxing, N_{obs} (still blinded)**

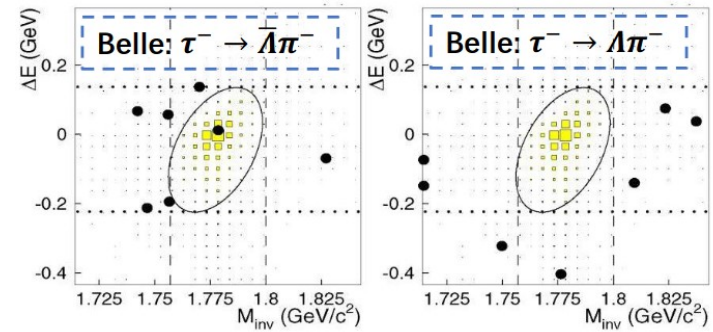
$$\mathcal{B}(\tau^- \rightarrow \ell K_S^0) = \frac{N_{obs}^? - N_{exp}}{2\epsilon_{\ell K_S^0} \mathcal{L} \sigma_{\tau\bar{\tau}}}$$

- Statistically limited \rightarrow estimate expected upper limit at 90% CL including **systematics** uncertainties exploiting **CLs method** in a Poisson counting experiment model

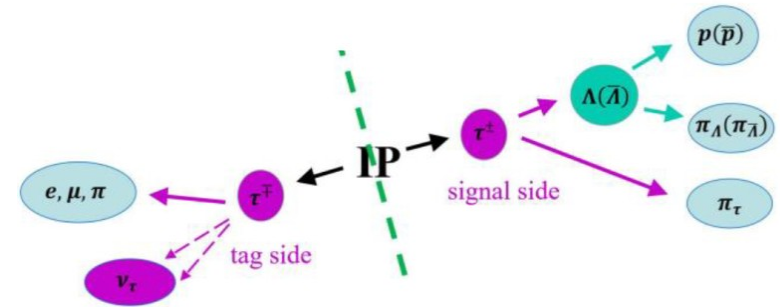
Search for $\tau^- \rightarrow \Lambda(\bar{\Lambda})\pi^-$

- Baryon number violation (BNV) required for explaining matter antimatter asymmetry
- Baryon and lepton numbers conserved in the SM, might be violated in beyond SM scenarios
- Previous search on 154 fb^{-1} at Belle [1] set limits at 90% CL of $0.72 (1.4) \times 10^{-7}$ for $\text{BR}(\tau^- \rightarrow \Lambda(\bar{\Lambda})\pi^-)$

	$\tau^- \rightarrow \Lambda\pi^-$		$\tau^- \rightarrow \bar{\Lambda}\pi^-$	
	initial state	final state	initial state	final state
B	0	1	0	-1
L	1	0	1	0
<i>B - L</i>	-1	1	-1	-1
$\Delta(B - L)$	2		0	



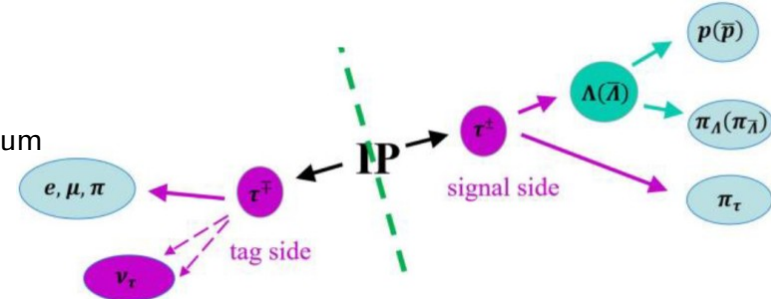
- Reconstruct exactly 4 charged tracks (total null charge) in one-prong tag approach
- Apply loose pre-selections and MVA classifier to isolate signal
- Poisson counting experiment technique in elliptical signal regions SR in M_τ and $\Delta E_\tau = E_{\text{sig}}^* - \sqrt{s}/2$ plane



[1] Physics Letters B, Volume 632, 1 (2006)

$\tau^- \rightarrow \Lambda(\bar{\Lambda})\pi^-$: strategy

- Particle hypothesis likelihood ratio (proton Vs pion, pion Vs kaon) for signal identification: confined around M_Λ with flight distance at least twice its uncertainty
 - Lepton identification to distinguish tag side
- Reject $e^+e^- \rightarrow e^+e^-(\gamma)$, $e^+e^- \rightarrow \mu\mu-(\gamma)$, $e^+e^- \rightarrow e^+e^- hh$ requiring missing momentum and tag side track separation, thrust >0.9 and limit photon multiplicities
- Use MVA with to reject $e^+e^- \rightarrow q\bar{q}$ and $e^+e^- \rightarrow \tau^+\tau^-$
- Final signal efficiencies of **$>9.5\%$** for $\tau^- \rightarrow \Lambda(\bar{\Lambda})\pi^-$ with **1 (0.5) expected events** in SR, evaluated from sidebands and rescaled according to simulation



$$\mathcal{B}(\tau^- \rightarrow \Lambda\pi^-) = \frac{N_{obs}^? - N_{exp}}{2\epsilon_{sig}\mathcal{L}\sigma_{\tau\bar{\tau}}\mathcal{B}(\Lambda \rightarrow p\pi)}$$

- **Count the number of event in SR ellipse after unboxing, N_{obs}**
- Compute upper limit in a Bayesian approach including **systematic uncertainties** (PID dominant contribution), negligible compared to statistical \rightarrow Expect world's leading limits $< 5 \times 10^{-8}$

Summary and outlook

Study of LFV decays $\tau \rightarrow \ell + \text{hadrons}$ ongoing at Belle II \rightarrow Run 2 started, with more data possible to improve LFV channels

- Devised new strategies to boost signal efficiency keeping the background under control
 - First proof of concept in $\tau \rightarrow \ell \Phi$, [Pub.Conf. arxiv:2305.04759](#)
 - Improving hadron ID performance, exploit MVA methods
- Increasing the available statistics by combining with Belle data set, first combined analysis for $\tau \rightarrow \ell K_S^0$
- Expect world's best limit on BNV and LNV decays $\tau \rightarrow \Lambda(\bar{\Lambda})\pi$



- Other channels not considered/favorite?
- Other inputs from experiments?

Thanks for your attention!

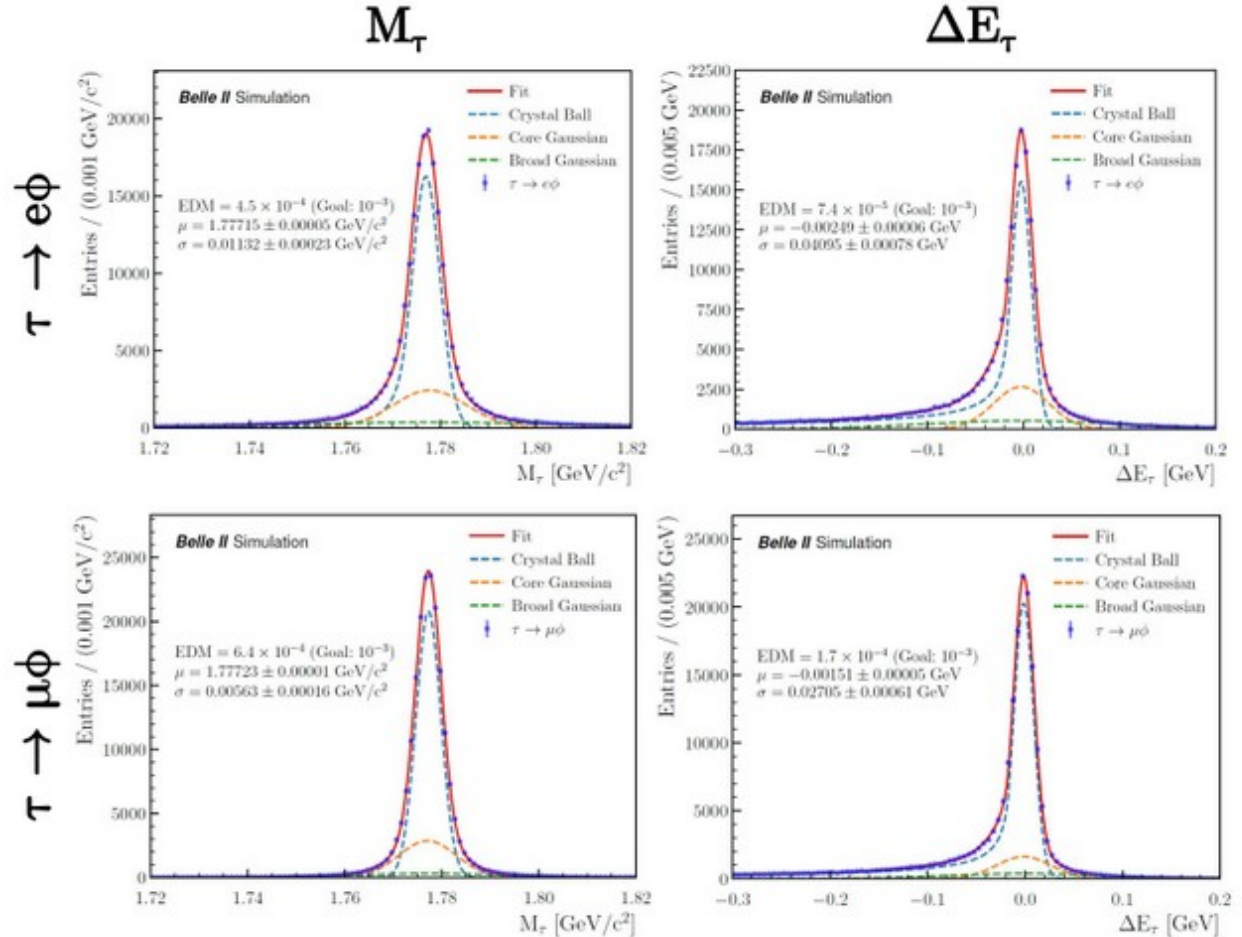




backup

$\tau \rightarrow \ell \Phi$: fitted signal resolutions

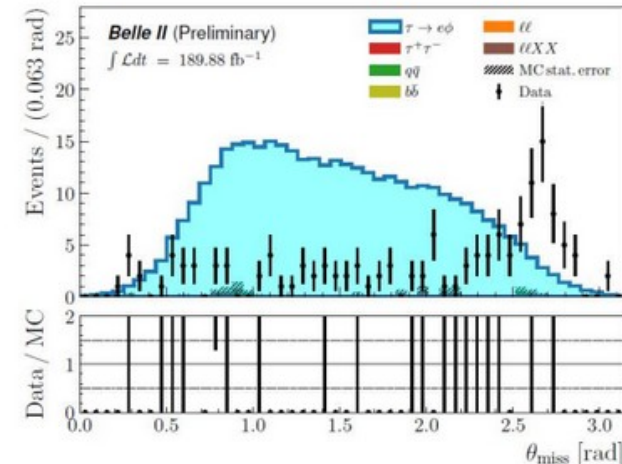
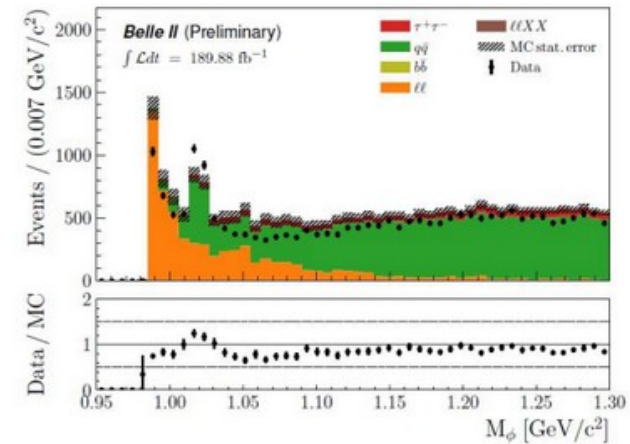
- Fit both variables with (a, b: parameters of the fit):
 - a*Crystal Ball + b*Core Gaussian + (1-a-b)*Broad Gaussian
- Total sigma: weighted sum of the three components' sigmas.



$\tau \rightarrow \ell\Phi$: data driven suppression

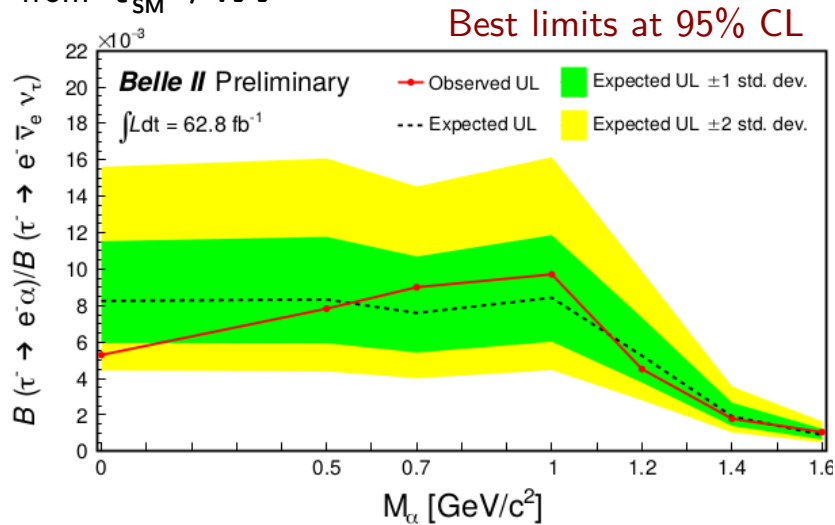
- Remaining contamination observed in data control regions for the electron mode
 - V^0 -photoproduction process $e^+e^- \rightarrow e^+e^-\phi \rightarrow$ **not simulated**
 - data driven veto applied to the electron channel requiring a single electron candidate in the event and constraining the event topology (2nd moment CLEO cone, angle between tau flight direction and reconstructed momentum)
- Final signal efficiencies: Electron = 6.1 %, Muon = 6.5%
- Dominant systematics due to simulation mismodeling, negligible compared to statistical uncertainty

Affected quantity	Source	Mode	
		$e\phi$	$\mu\phi$
$\mathcal{E}_{\ell\phi}$	Particle identification	0.8%	0.3%
	Tracking efficiency		0.9%
	Trigger efficiency	0.4%	0.9%
	Signal variable mismodeling	15.2%	8.5%
N_{exp}	Momentum scale	0.6%	0.4%
L	Luminosity	0.6%	
$\sigma_{\tau\tau}$	Tau-pair cross section	0.3%	



Also dark searches, chiral Belle...and other tests

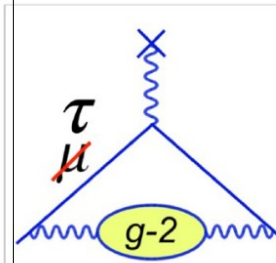
- τ decays to **new LFV bosons**, possible ALP candidates [1]
- Search for $\tau \rightarrow l\alpha$ decays with $l=e$ or μ looking for bumps in normalized lepton energy spectrum over irreducible background from $\tau_{SM} \rightarrow l\nu\nu$



- Possible SuperKEKB upgrade with **polarized electron beam** [2] \rightarrow precision electroweak physics and non-SM searches!
 - Use tau polarimetry for 0.5% precision (BaBar method [3])

$$P_\tau = P \frac{\cos \theta}{1 + \cos^2 \theta} - \frac{8G_{FS}}{4\sqrt{2}\pi\alpha} g_V^\tau \left(g_A^\tau \frac{|\vec{p}|}{p^0} + 2g_A^e \frac{\cos \theta}{1 + \cos^2 \theta} \right).$$

- Unprecedented precision on *edm* and MDM of the τ



$$a_\tau^{\text{BSM}} \sim a_\mu^{\text{BSM}} \left(\frac{m_\tau}{m_\mu} \right)^2 \sim 10^{-6}$$

Current bound in tau $\sim \mathcal{O}(10^{-2})$

Chiral Belle reach $\sim \mathcal{O}(10^{-5})$ with 50ab^{-1}

- Test Bell Inequality violation (non-locality of quantum mechanics) with $e^+e^- \rightarrow \tau\tau$?
 \rightarrow Measure τ spin orientation with polarimeter-vector method,
arXiv:2311.17555 M. Fabbrichesi et al.

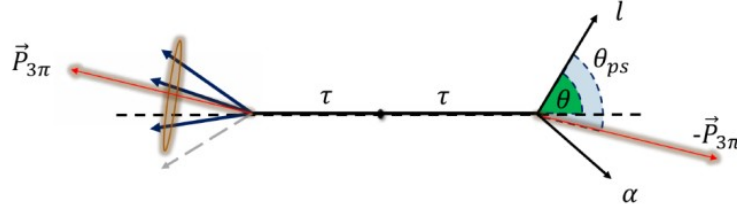
[1] M. Bauer, et al. Phys. Rev. Lett. 124, 211803 (2020)

[2] arXiv: 2205.12847 , [3] PRD 108 (2023) 092001

Invisible boson in LFV τ decays

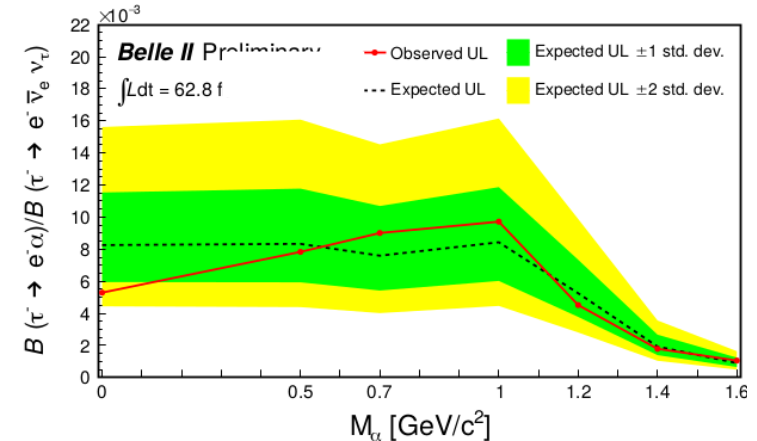
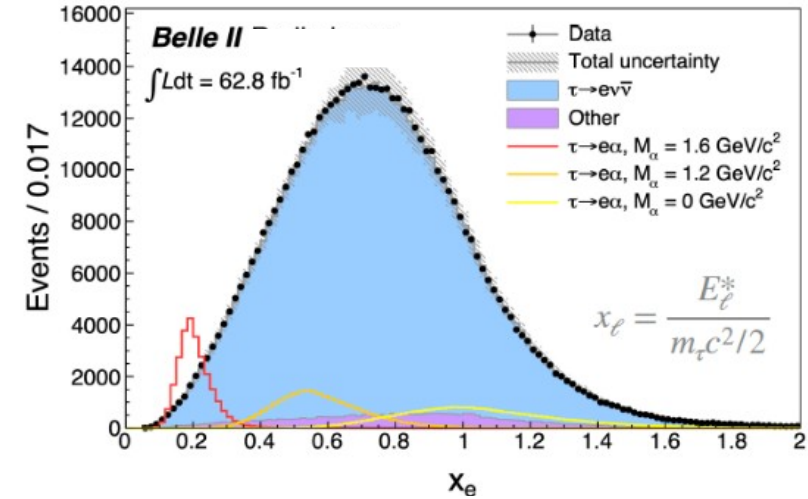
PRL 130 (2023) 181803

- τ decays to **new LFV bosons** (ALPs) predicted in many models [1]
- Search for the process $e^+e^- \rightarrow \tau_{\text{sig}} (\rightarrow l\alpha) \tau_{\text{tag}} (\rightarrow 3\pi\nu)$, with $l=e$ or $l=\mu$



- Approximate τ_{sig} pseudo-rest frame as $E_{\text{sig}} \sim \sqrt{s}/2$ and $\hat{p}_{\text{sig}} \approx -\vec{p}_{\tau_{\text{tag}}} / |\vec{p}_{\tau_{\text{tag}}}|$
- Two-body decay: search a bump in normalized lepton energy x_l spectrum over irreducible background from $\tau_{\text{SM}} \rightarrow l\nu\nu$
- No signal found in $62.8 \text{ fb}^{-1} \rightarrow$ set 95% CL upper limits on BF ratios of $BF(\tau_{\text{sig}} \rightarrow l\alpha)$ normalized to $BF(\tau_{\text{SM}} \rightarrow l\nu\nu)$

Between 2-14 times more stringent than previous limits (ARGUS, 1995 [2])



[1] M. Bauer, et al. Phys. Rev. Lett. 124, 211803 (2020)

[2] ARGUS Collaboration, Z. Phys. C 68, 25 (1995)