



MAX-PLANCK-INSTITUT
FÜR PHYSIK

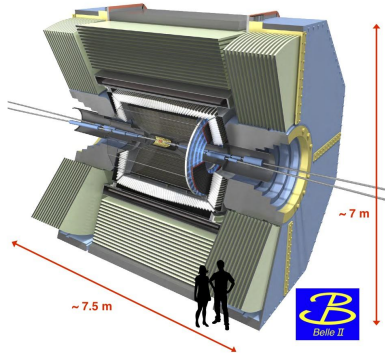
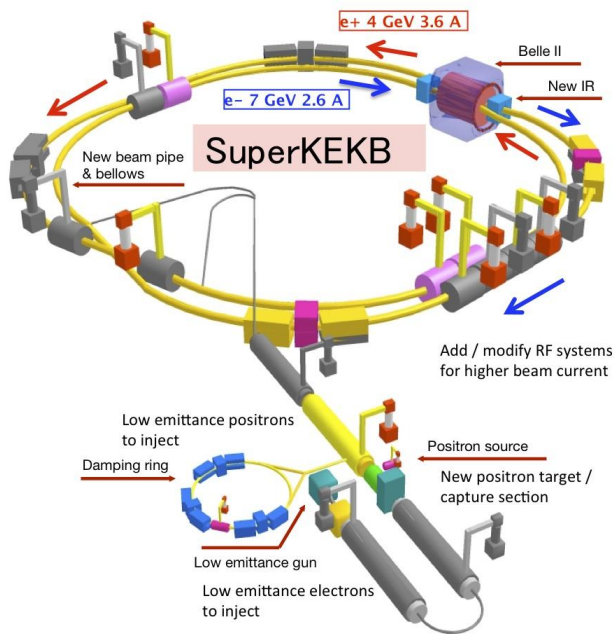


Search for the LFV-Decay $\tau \rightarrow \mu \pi^0$

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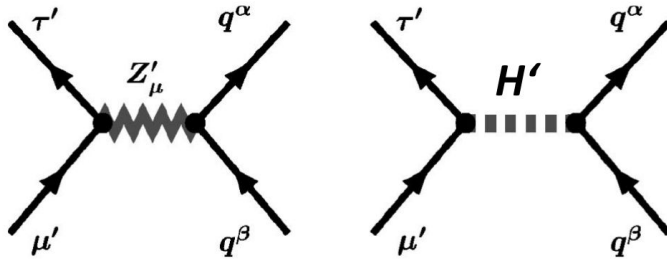
Belle-II-Experiment



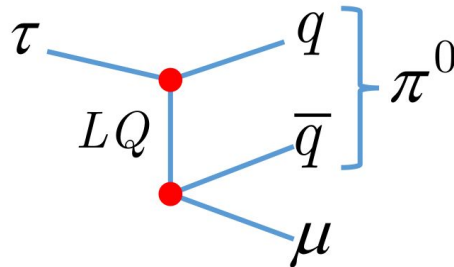
- e-e⁺-Accelerator at Υ (4S)-resonance (10,6 GeV)
- “B-Factory” → $B\bar{B}$ -pairs
background from $u\bar{u}$, $d\bar{d}$, $s\bar{s}$, $c\bar{c}$ -events
- Ideal environment for τ -Pair-Production
→ background mainly from $q\bar{q}$,
signal easy to separate from B-events

LFV-Decay $\tau \rightarrow \mu \pi^0$

New Physics Tree Models



Flavor violating Z and H



Lepto-quarks

- LFV-decay already at tree-level
- All final state particles are measurable
- 2-body decay
→ in tau rest system Pion and Muon have same total momentum
- tau rest system can be estimated directly from decay products (no neutrino)

Current state of LFV tau-decays

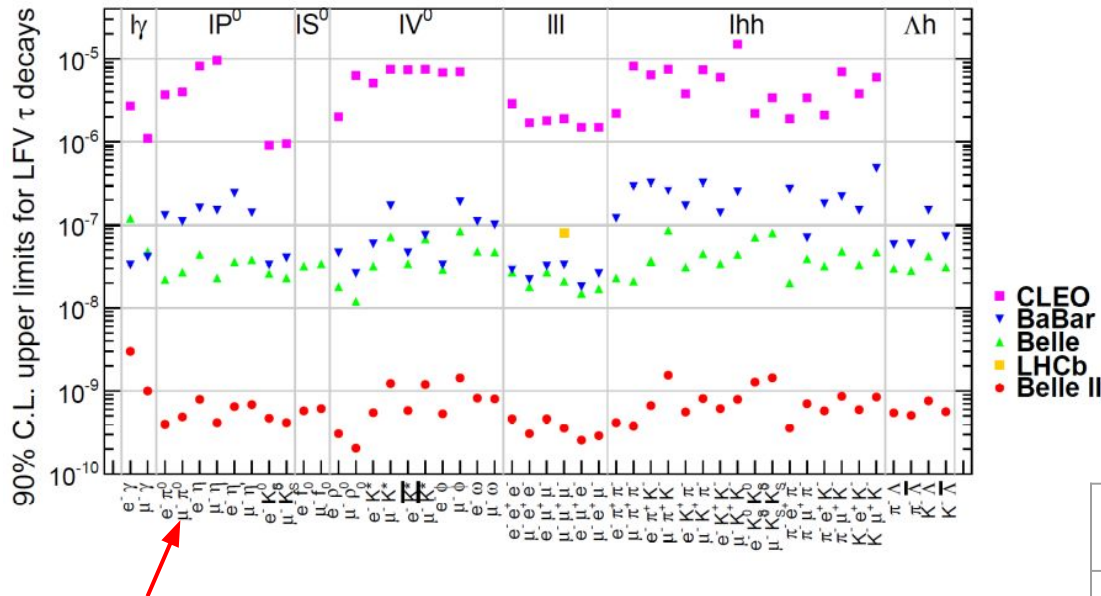


Table 14. Expected limits on several selected τ LFV searches.

Observables	Belle (2014)	Belle II	
		5 ab ⁻¹	50 ab ⁻¹
$\text{Br}(\tau \rightarrow \mu\gamma) [10^{-9}]$	< 45	< 15	< 5
$\text{Br}(\tau \rightarrow e\gamma) [10^{-9}]$	< 120	< 39	< 12
$\text{Br}(\tau \rightarrow \mu\mu\mu) [10^{-9}]$	< 21	< 3	< 0.3
$\text{Br}(\tau \rightarrow eee) [10^{-9}]$	< 27	< 4	< 0.4
$\text{Br}(\tau \rightarrow eKK) [10^{-9}]$	< 33	< 6	< 0.6
$\text{Br}(\tau \rightarrow \mu\pi^0) [10^{-9}]$	< 120	< 34	< 11
$ \Im(\eta_s) (\tau \rightarrow K_S^0\pi\nu)$	0.026	0.010	0.003

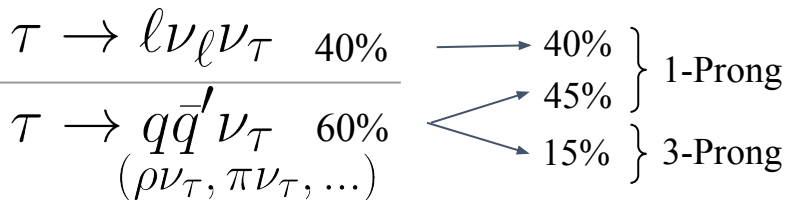
Integrated Luminosity

Belle	Belle II (8.3.2021)
710 fb ⁻¹	94.48 fb ⁻¹

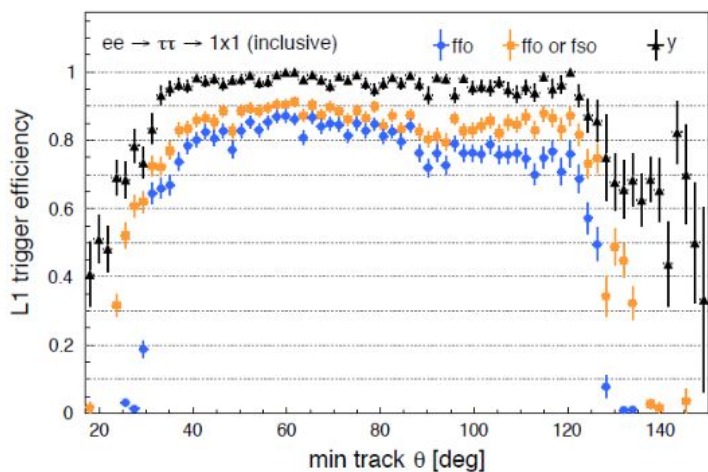
Due to new trigger Belle II already competitive at much lower luminosity compared to Belle

New single-track trigger at Belle2

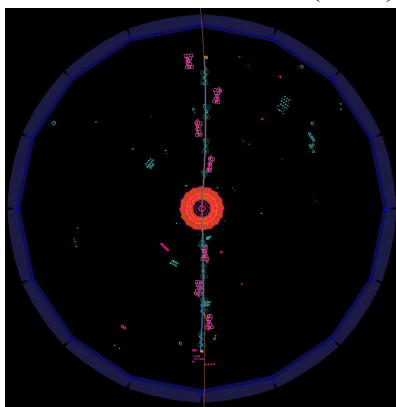
Tau-decay modes:



- Greatly improved triggering on a single charged track in the CDC



Central Drift Chamber (CDC)



- measurements using the 1-1-topology possible
 - Improvement by using 1-prongs as tag lepton instead of 3-prongs
- 5-times more statistics

Expected challenges

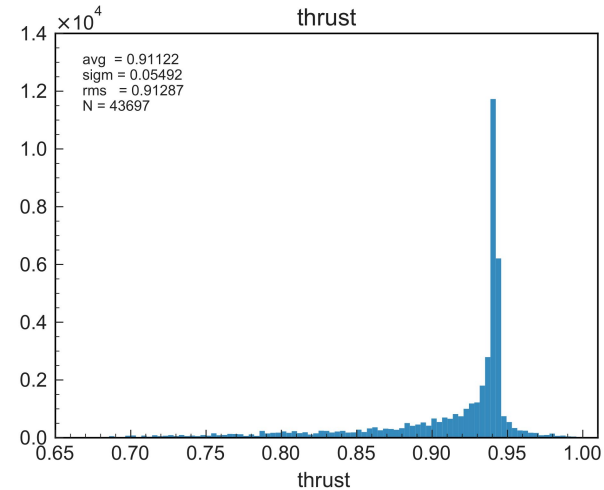
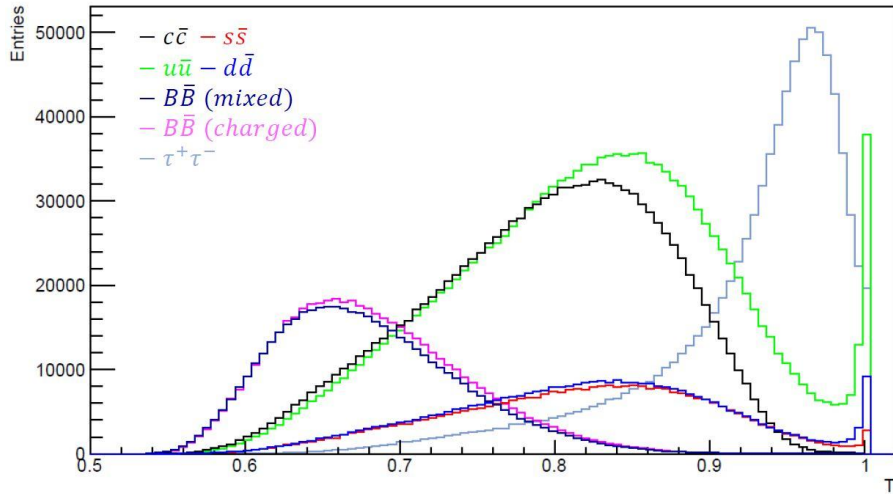
Analysis of 1-1 topologies:

possible approaches

<ul style="list-style-type: none"> • π^0 reconstructed via $\pi^0 \rightarrow \gamma\gamma$ • τ reconstructed via $\tau \rightarrow \mu\pi^0$ 	<p>→ Cut on π^0-mass</p> <p>→ Cut on $[\mu\pi^0]$-mass</p>
<ul style="list-style-type: none"> • generic tau and $q\bar{q}$ background 	<p>→ explicit reconstruction of tau-signal: cut on charged multiplicity, particle identification (high momentum muon)</p>
<ul style="list-style-type: none"> • $B\bar{B}$-background 	<p>→ Cut on event shape variables e.g. thrust</p>

Cut on Event-Shape: Thrust

Thrust (T)



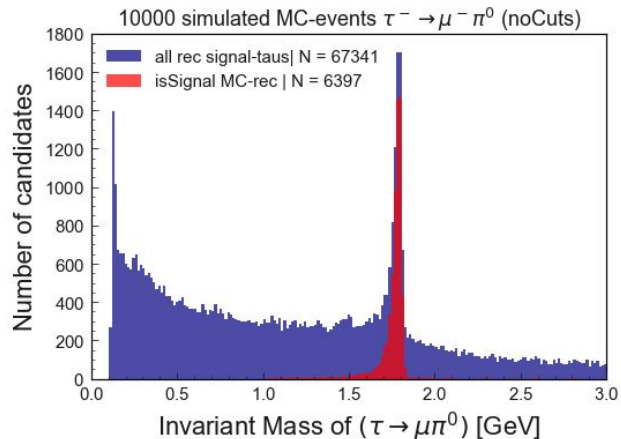
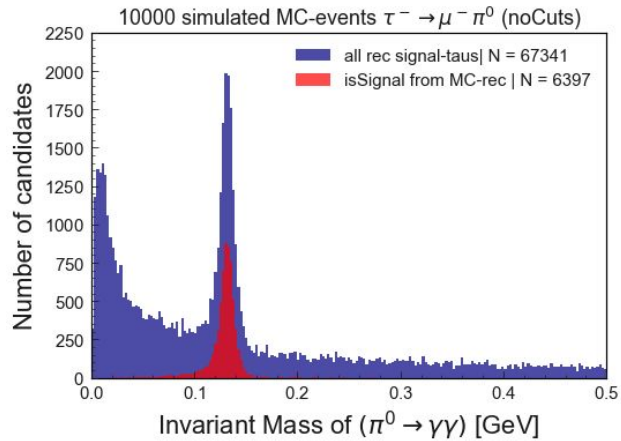
MC-data:
 $\tau \rightarrow \mu \pi^0$

$$\hat{T} = \max \left(\sum_i \frac{\vec{p}_i \cdot \vec{T}}{|\vec{p}_i|} \right)$$

- Taus have high momentum: jet-like
- Low-momentum (“spherical”) B-Mesons can be eliminated by Thrust-Cut



First look, π^0 and τ -reconstruction



generated 10 000 MC-sample with decay:

$$e^+e^- \rightarrow [\tau^- \rightarrow \mu\pi^0][\tau^+ \rightarrow \text{SM-decay}]$$

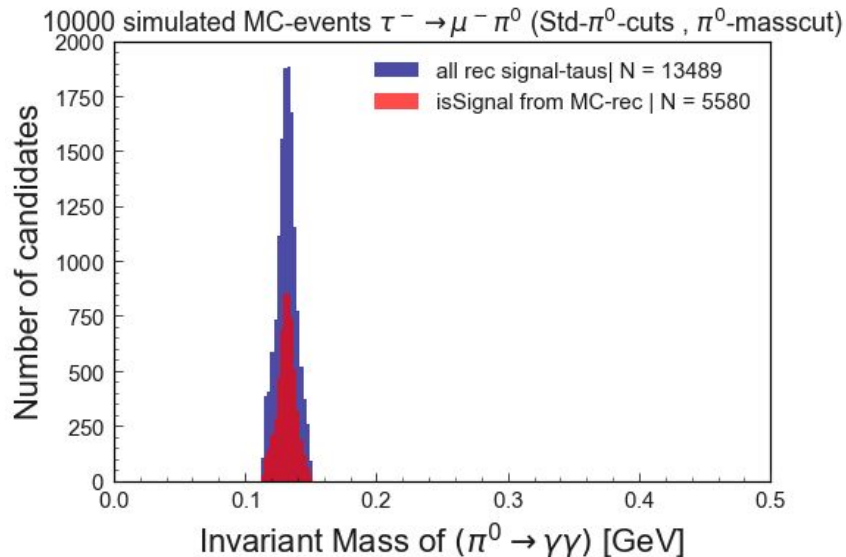
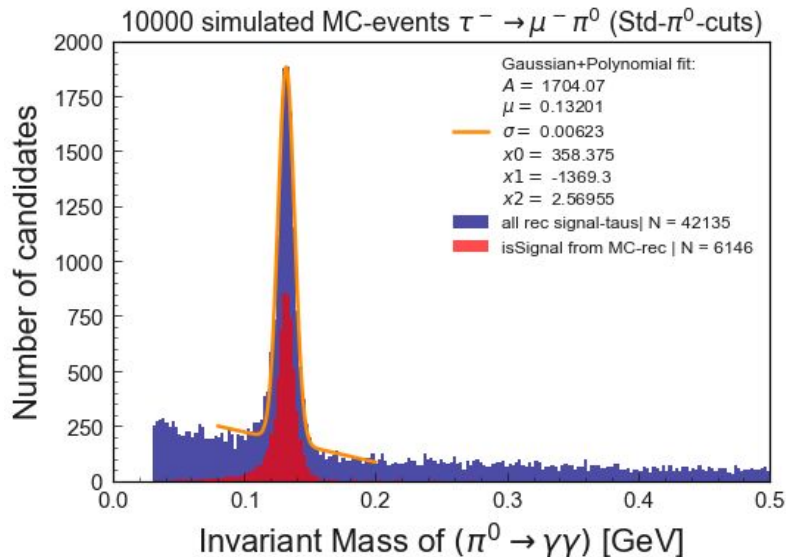
→ Sharp signal peak visible

→ ~60% of signal can be reconstructed

Cut on $[\pi^0 \rightarrow \gamma\gamma]$ -invariant mass (MC)

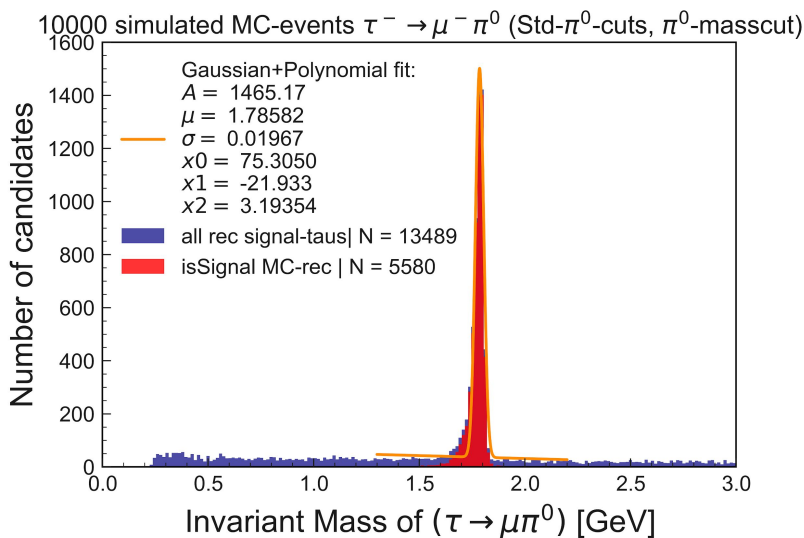
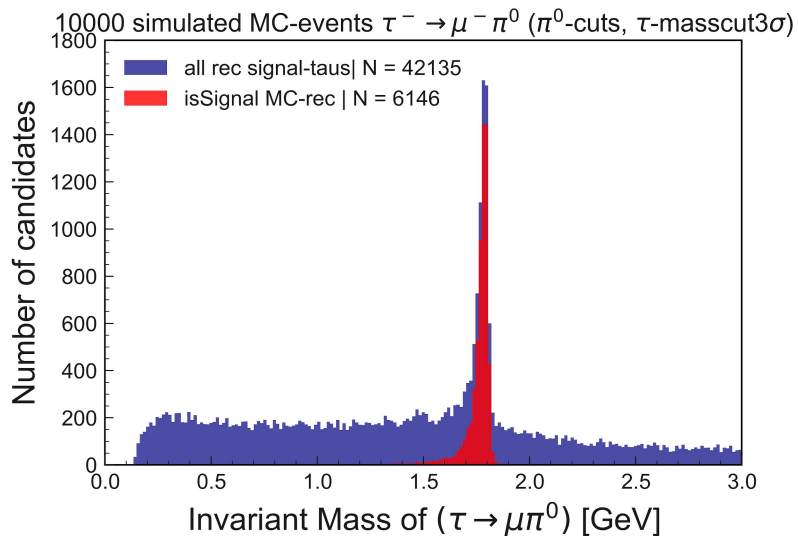
Standard Belle2-Cuts for π^0 to exclude events from detector-specific dead regions

3σ -Cut: $0.1137 \text{ GeV} < \text{invM}(\pi^0) < 0.1503 \text{ GeV}$



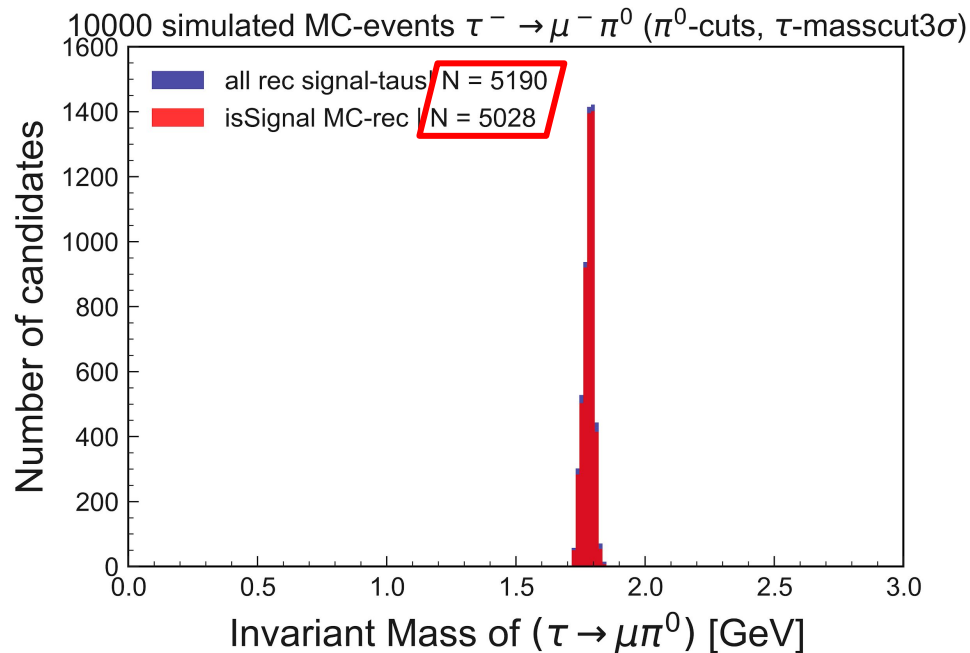
Cut on $[\pi^0 \rightarrow \gamma\gamma]$ -invariant mass (MC)

3σ -Cut: $0.1137 \text{ GeV} < \text{invM}(\pi^0) < 0.1503 \text{ GeV}$



Cut on $[\tau \rightarrow \mu\pi]$ -invariant mass (MC)

3σ -Cut: $1.7268 \text{ GeV} < \text{invM}(\tau \rightarrow \mu\pi^0) < 1.8448 \text{ GeV}$



→ 50% of signal can be reconstructed

→ almost all data is from signal (97%)

→ goal: get close to 0% BG or signal extraction by multivariable-methods

No background yet!



Summary: Search for LFV decay $\tau \rightarrow \mu \pi^0$



- More signal tau decays to analyze due to single-track-trigger with tag- τ being a 1-prong instead of 3-prong from traditional analyses
- 2-body-decay with fully reconstructed final state
- $B\bar{B}$ -, $q\bar{q}$ -background
- Cuts on invariant Mass, Thrust

- Next: Analysis on SM-tau-decay, $q\bar{q}$ -event MC-s with realistic BG
- Hope for 400 fb^{-1} by mid-2022: surpassing Belle-results