



MAX-PLANCK-INSTITUT
FÜR PHYSIK

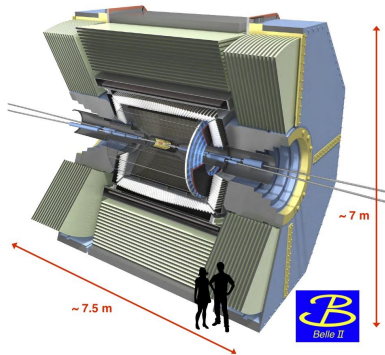
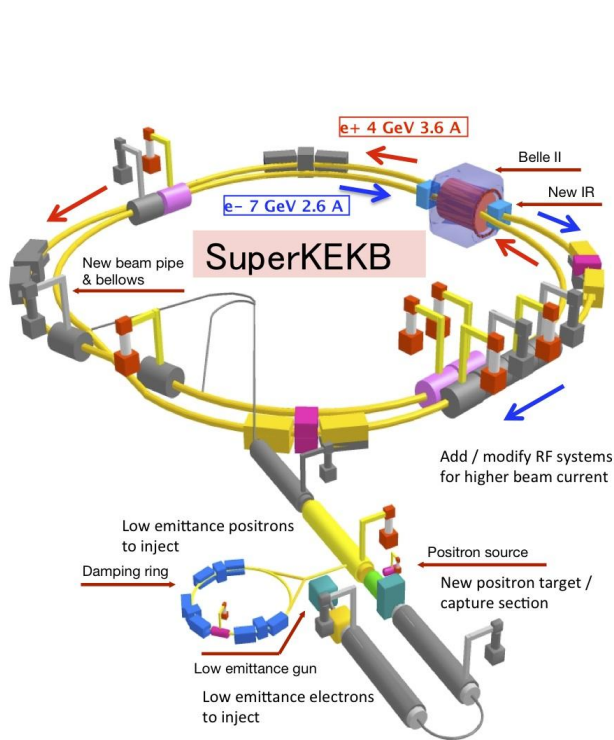


Search for the LFV-Decay $\tau \rightarrow \mu\pi^0$

18.03.2021 DPG-spring-conference

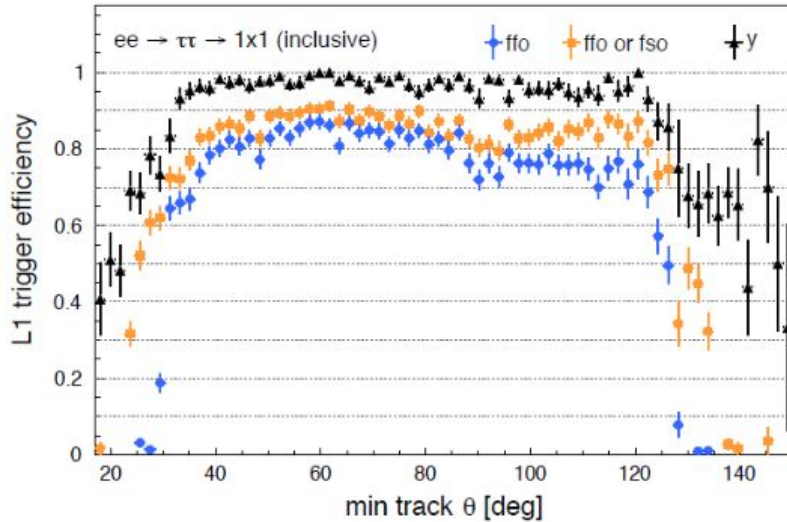
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Belle-II-Experiment



- e-e⁺-Accelerator at Υ (4S)-resonance (10,6 GeV)
 - Pair-Production of B-Mesons
 - Also ideal environment for τ -Pair-Production
- low background, distinct signal from B-events

New single-track trigger at Belle2

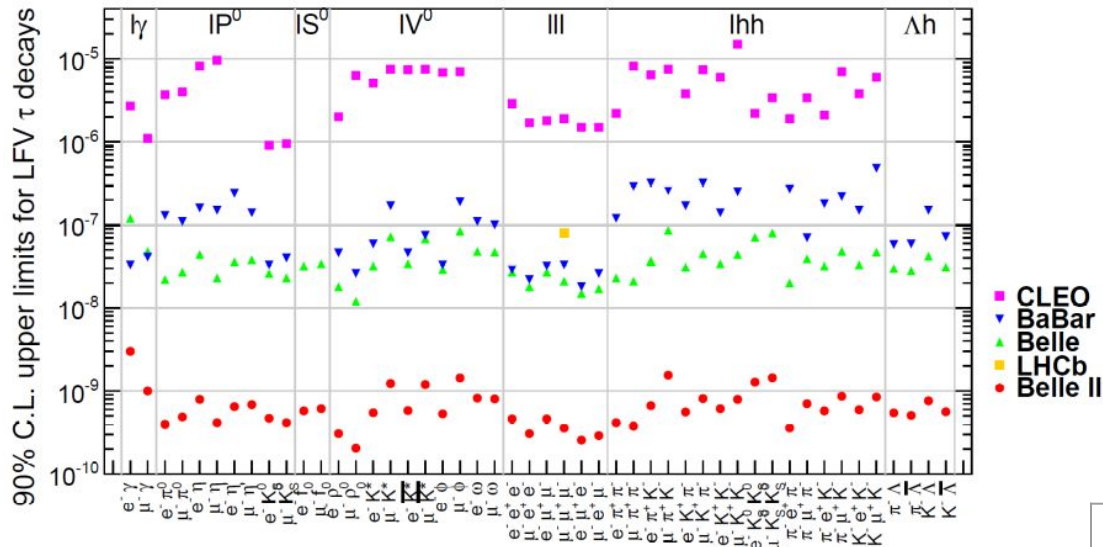


- Greatly improved triggering on single-tracks
- 1-1-Topologies measurements possible
- Improvement in signal-data

Tau-decay modes:

$$\begin{array}{l}
 \tau \rightarrow \ell \nu_{\ell} \nu_{\tau} \quad 40\% \quad \longrightarrow \quad 40\% \\
 \tau \rightarrow q \bar{q}' \nu_{\tau} \quad 60\% \quad \left\{ \begin{array}{l} \longrightarrow 45\% \\ \longrightarrow 15\% \end{array} \right. \\
 \hspace{15em} \left. \begin{array}{l} \text{1-Prong} \\ \text{3-Prong} \end{array} \right\}
 \end{array}$$

Current state of LFV tau-decays



Due to Single-Track-Trigger 1-Prong
only $\frac{1}{5}$ of the luminosity needed

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

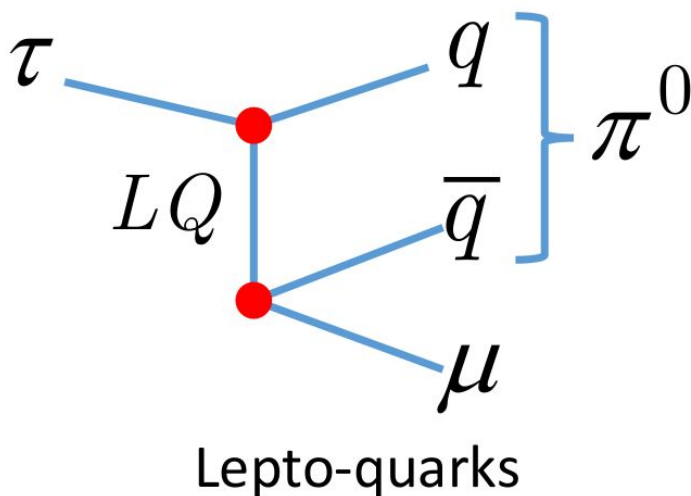
Observables	Belle (2014)	Belle II	
		5 ab ⁻¹	50 ab ⁻¹
Br($\tau \rightarrow \mu\gamma$) [10 ⁻⁹]	< 45	< 15	< 5
Br($\tau \rightarrow e\gamma$) [10 ⁻⁹]	< 120	< 39	< 12
Br($\tau \rightarrow \mu\mu\mu$) [10 ⁻⁹]	< 21	< 3	< 0.3
Br($\tau \rightarrow eee$) [10 ⁻⁹]	< 27	< 4	< 0.4
Br($\tau \rightarrow eKK$) [10 ⁻⁹]	< 33	< 6	< 0.6
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	Belle2 (8.3.2021)
710 fb ⁻¹	94.48 fb ⁻¹

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

2-Body decays



- LFV-decay with no loops 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)



Expected challenges



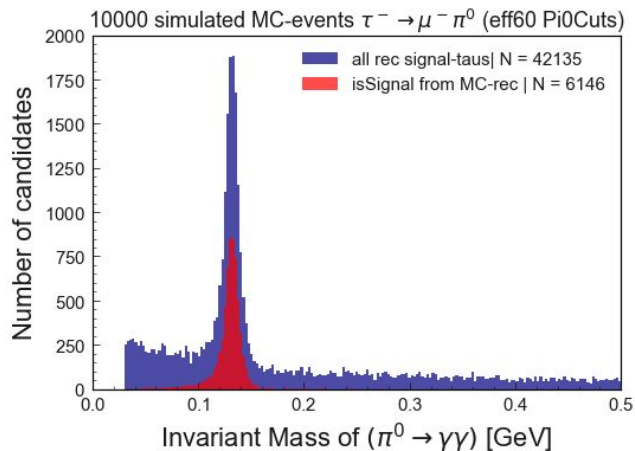
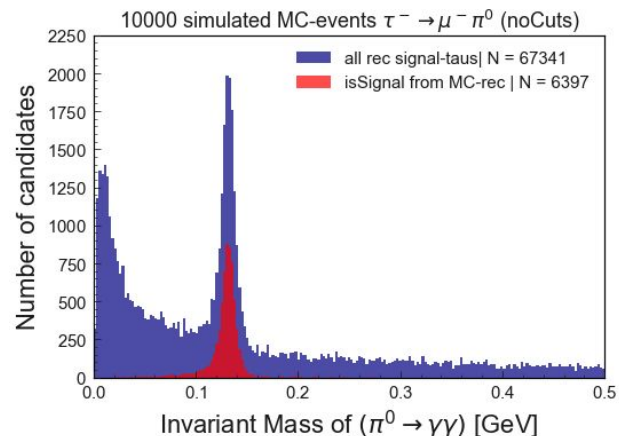
Analysis of 1-1 and 1-3 topologies:

possible approaches

<ul style="list-style-type: none">• First π^0 has to be reconstructed via $\pi^0 \rightarrow \gamma\gamma$	→ Cut on invariant π^0 -mass
<ul style="list-style-type: none">• BB-background	→ Cut with event shape variables e.g. thrust
<ul style="list-style-type: none">• generic tau and qq background	→ explicit reconstruction



First look, π^0 -reconstruction



generated 10 000 MC-sample with decay:

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

Used recommended eff60 π^0 -cuts:

Fill gammas:

$$[[\text{clusterNHits}>1.5] \text{ and } [0.2967< \text{clusterTheta}<2.6180]]$$

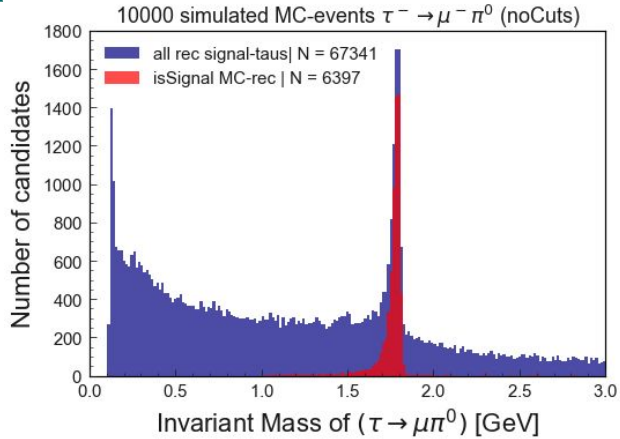
and

$$[[\text{clusterReg}==1 \text{ and } E>0.0225] \text{ or } [\text{clusterReg}==2 \text{ and } E>0.020] \text{ or } [\text{clusterReg}==3 \text{ and } E>0.020]]$$

then $\pi^0 \rightarrow \gamma\gamma$ with $0.03<\text{InvM}$

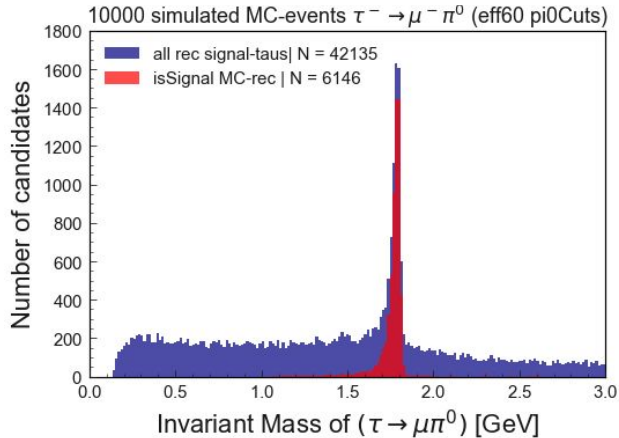


First look, tau-reconstruction



→ Sharp signal peak visible

→ ~60% of signal can be reconstructed



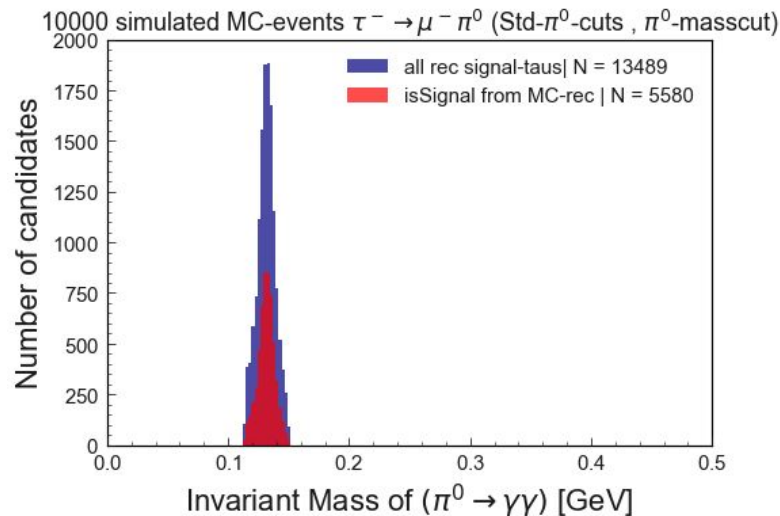
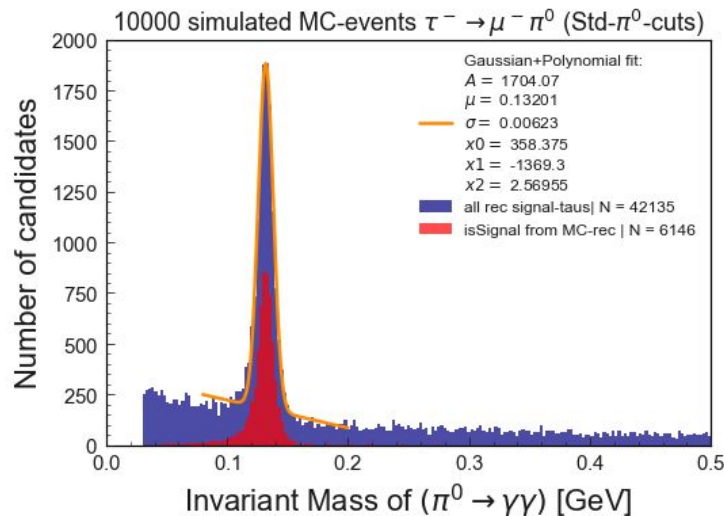
new single-track trigger

on tag-side: 1-prongs and 3-prongs

→ high statistics

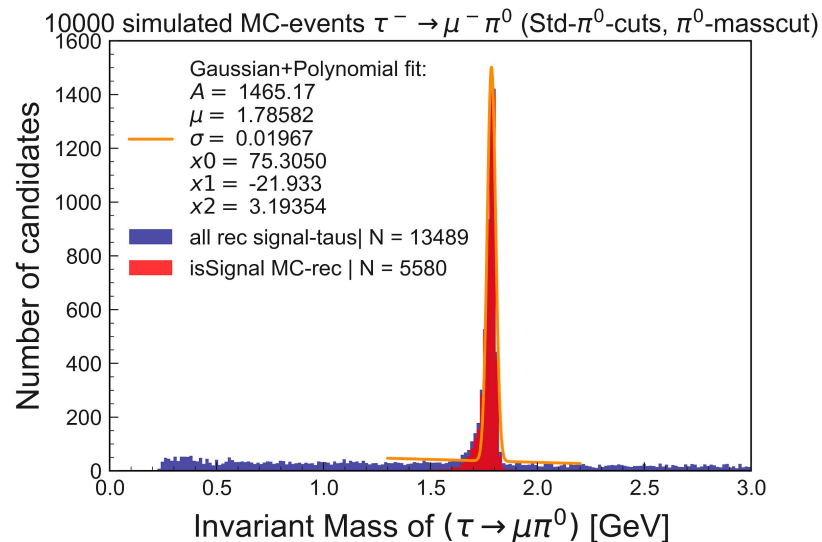
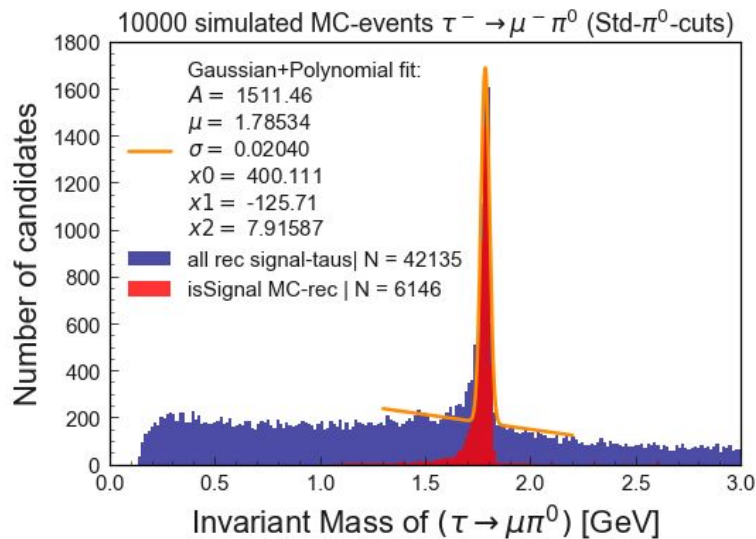
Cut on $[\pi^0 \rightarrow \gamma\gamma]$ -invariant mass (MC)

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



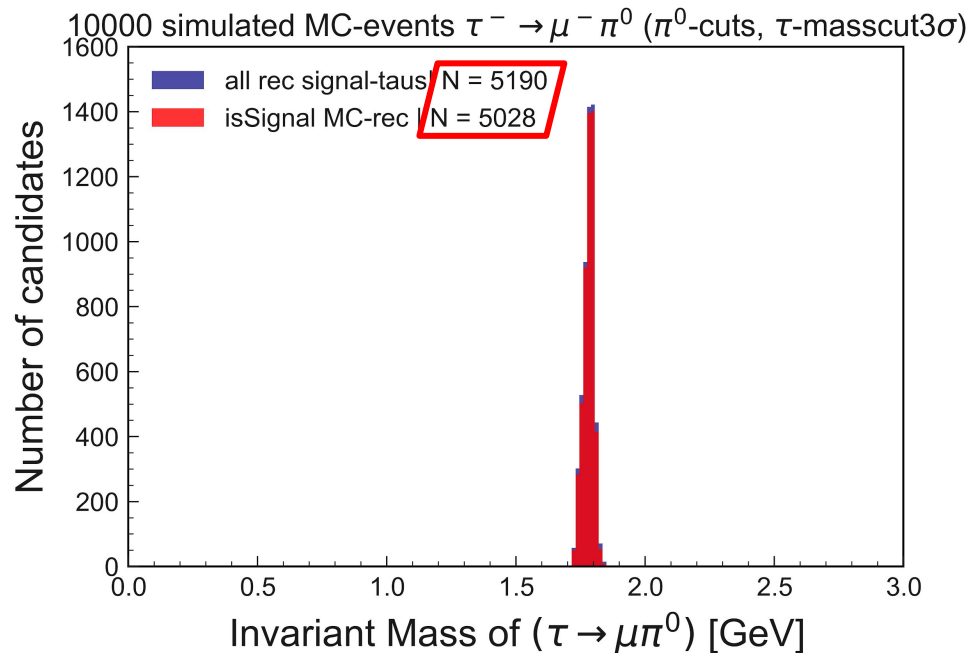
Cut on $[\pi^0 \rightarrow \gamma\gamma]$ -invariant mass (MC)

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

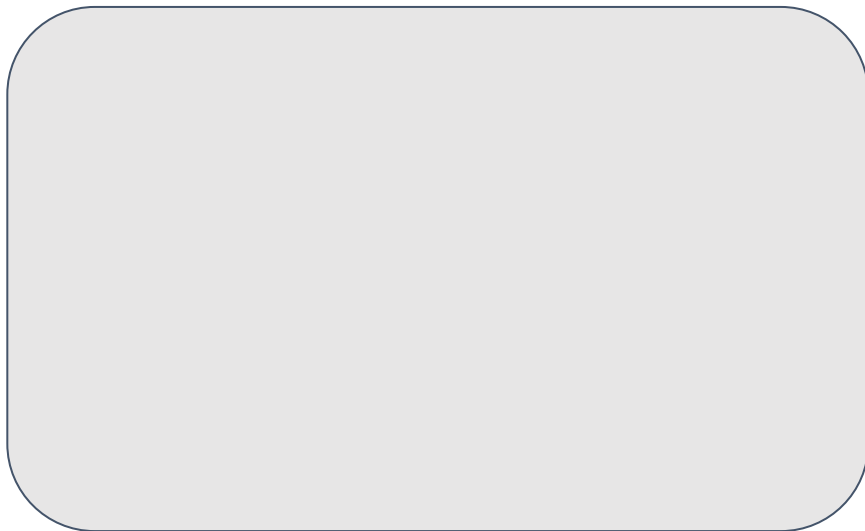


→ 50% of signal can be reconstructed

→ almost all data is from signal

Cut on $[\tau \rightarrow \mu\pi]$ -invM on generic tau-BG

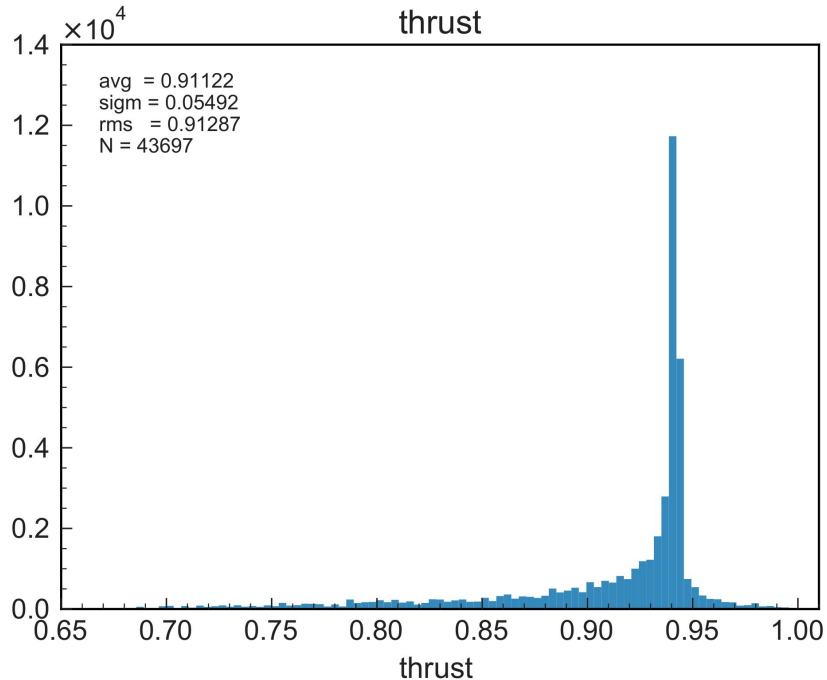
3σ -Cut: $1.7268 \text{ GeV} < \text{invM}(\tau \rightarrow \mu\pi^0) < 1.8448 \text{ GeV}$



- Background is cut by *%

MC-Data with background , before and after invM-Cuts

Cut on Event-Shape: Thrust



- Taus have high momentum
- Thrust $\neq 1$ because of neutrinos

→ Low-momentum B-Mesons
can be eliminated by Thrust-Cut



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



- Increased data due to single-track-trigger with 1-1-topology
- 2-body-decay with fully reconstructed final state
- BB-, qq-background
- Cuts on invariant Mass, Thrust