Istituto Nazionale di Fisica Nucleare
Sezione di Roma Tre

ROMA TRE
UNIVERSITÀ DEGLI STUDI

LFV τ searches at Belle II: $\tau \to 3\mu$ analysis strategy

On behalf of the Belle II collaboration

Alberto Martini
University & INFN Roma Tre

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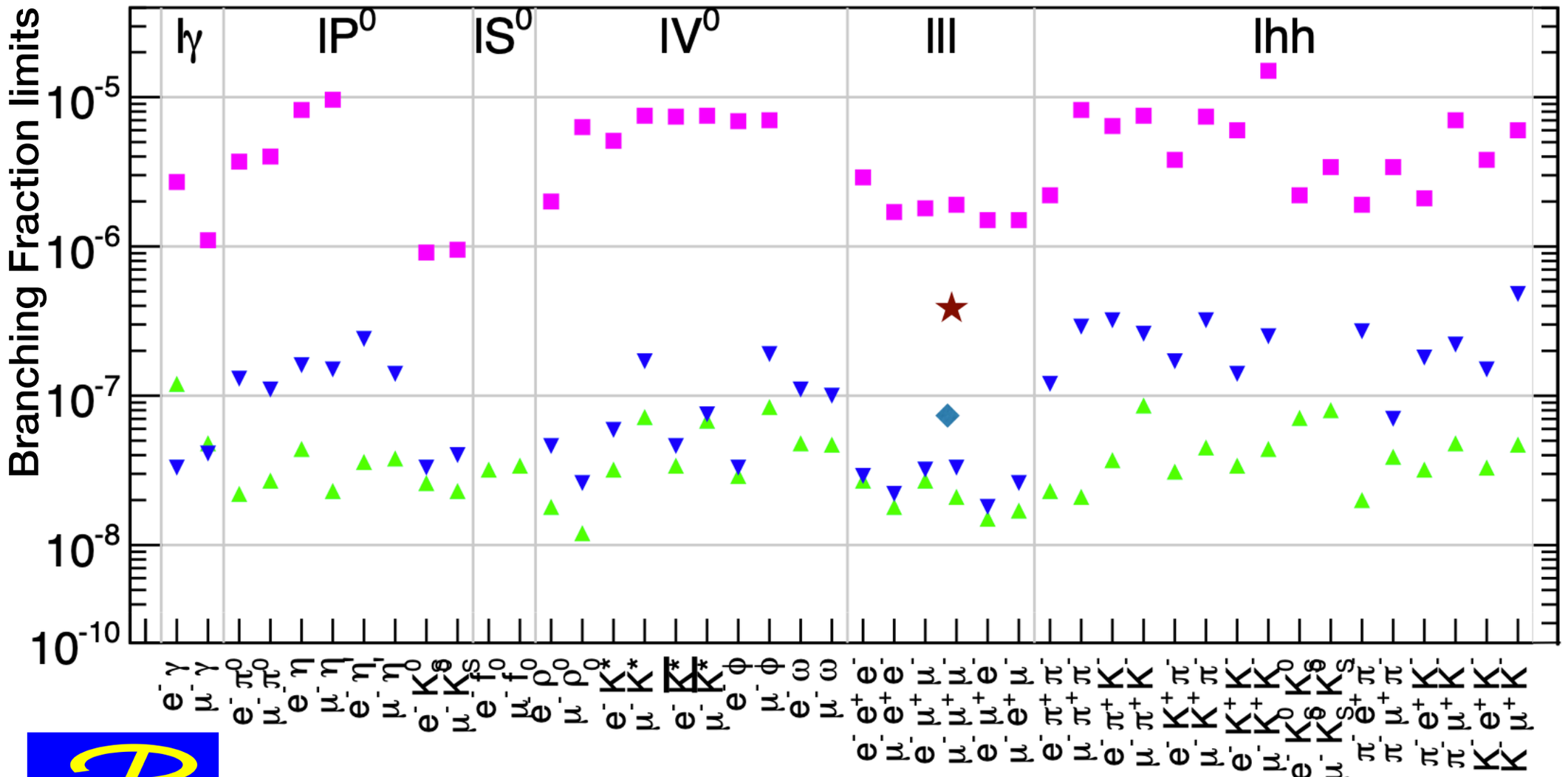
Belle II

Status of the τ LFV searches

Lepton Flavor Violation (LFV) are allowed in various extensions of the Standard Model (SM) but it has never been observed

Advantages of B-factories in τ studies:

- τ produced in pairs
- Well defined initial state energy
- Clean environment
- High hermeticity of the detector



τ LFV golden channels

Search various decay modes:

- $\tau \to \ell\ell\ell$
- $\tau \to \ell K_s, \Lambda h$
- $\tau \to \ell V_0 (\to hh')$
- $\tau \to \ell P^0 (\to \gamma\gamma)$
- $\tau \to \ell hh'$
- $\tau \to \ell\gamma$

Simple → Hard

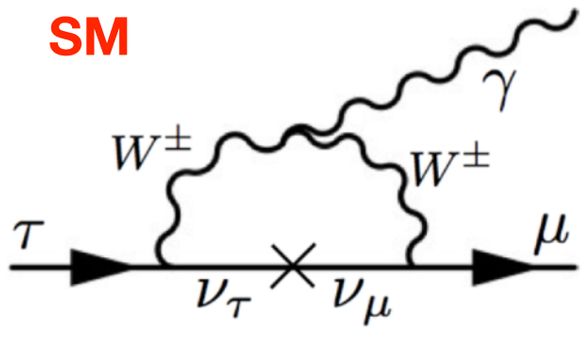
Difficulty of background reduction

→ Very good determination of τ mass and energy + few physical background sources

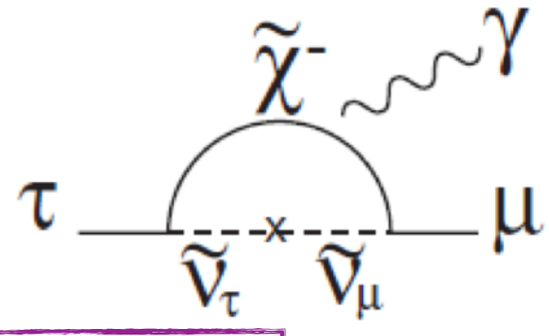
→ Many physical background sources + weak mass and energy determination

Golden channel: $\tau \to \mu\gamma$

SM



SUSY



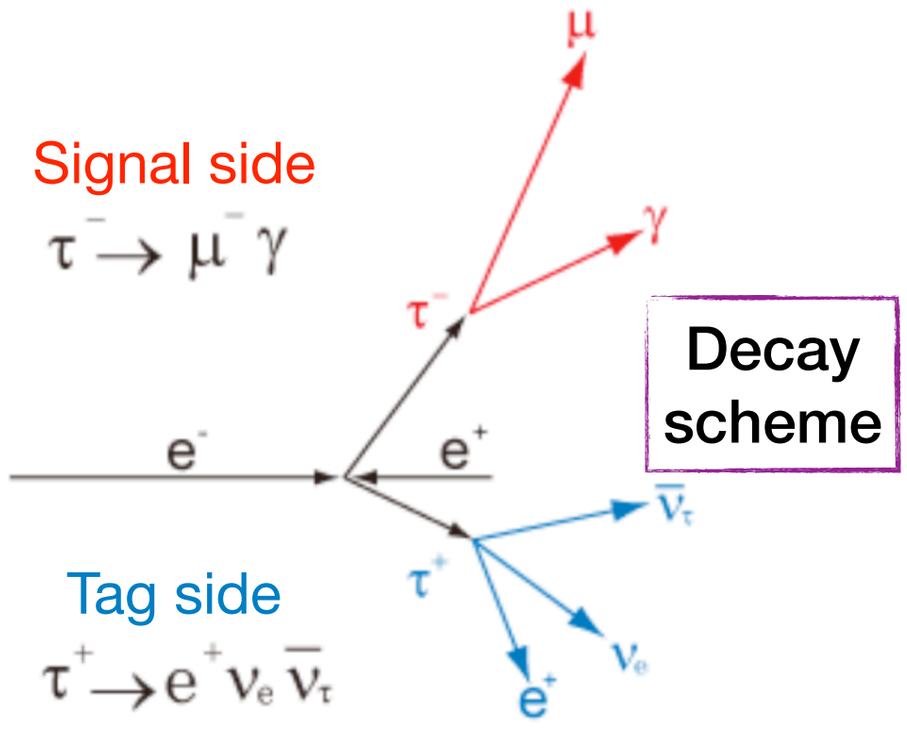
Highest not-SM BF prediction

Signal side

$\tau^- \to \mu^- \gamma$

Tag side

$\tau^+ \to e^+ \nu_e \bar{\nu}_\tau$



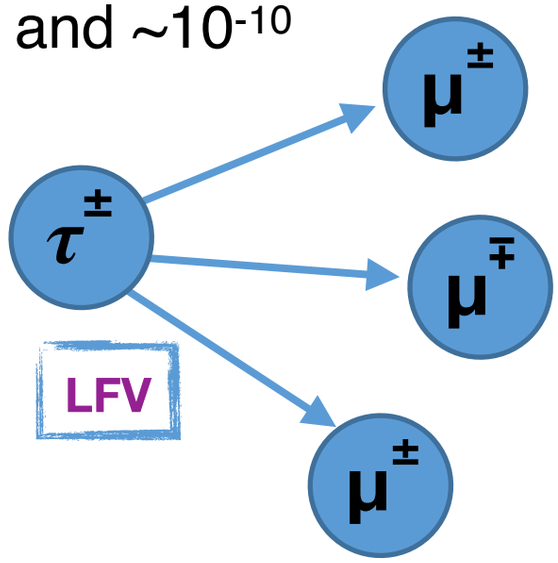
Decay scheme

Analysis motivations: $\tau \rightarrow 3\mu$

Beyond Standard Model branching fraction predictions within ~10^{-7} and ~10^{-10}

↓

Accessible by the ***Belle II experiment w/ luminosity***



Experimental upper limits from **Belle** and **BaBar**:

- Belle: **2.1 x 10^{-8}** @90% confidence level using $\int Ldt = 782 fb^{-1}$
- BaBar: **3.3 x 10^{-8}** @90% confidence level using $\int Ldt = 468 fb^{-1}$

Physics models	$B(\tau \rightarrow \mu\gamma)$	$B(\tau \rightarrow \mu\mu\mu)$
SM + ν mixing	$10^{-49} \sim 10^{-52}$	$10^{-53} \sim 10^{-56}$ [1]
SM+heavy Majorana ν_R	10^{-9}	10^{-10}
Non-universal Z'	10^{-9}	10^{-8}
SUSY SO(10)	10^{-8}	10^{-10}
mSUGRA + seesaw	10^{-7}	10^{-9}
SUSY Higgs	10^{-10}	10^{-7}

BF limits on τ LFV decays allow to discriminate NP models!

Ref.
[1]: M. Blanke, et al., Charged Lepton Flavour Violation and (g – 2)μ in the Littlest Higgs Model with T-Parity: a clear Distinction from Supersymmetry, JHEP 0705, 013 (2007).

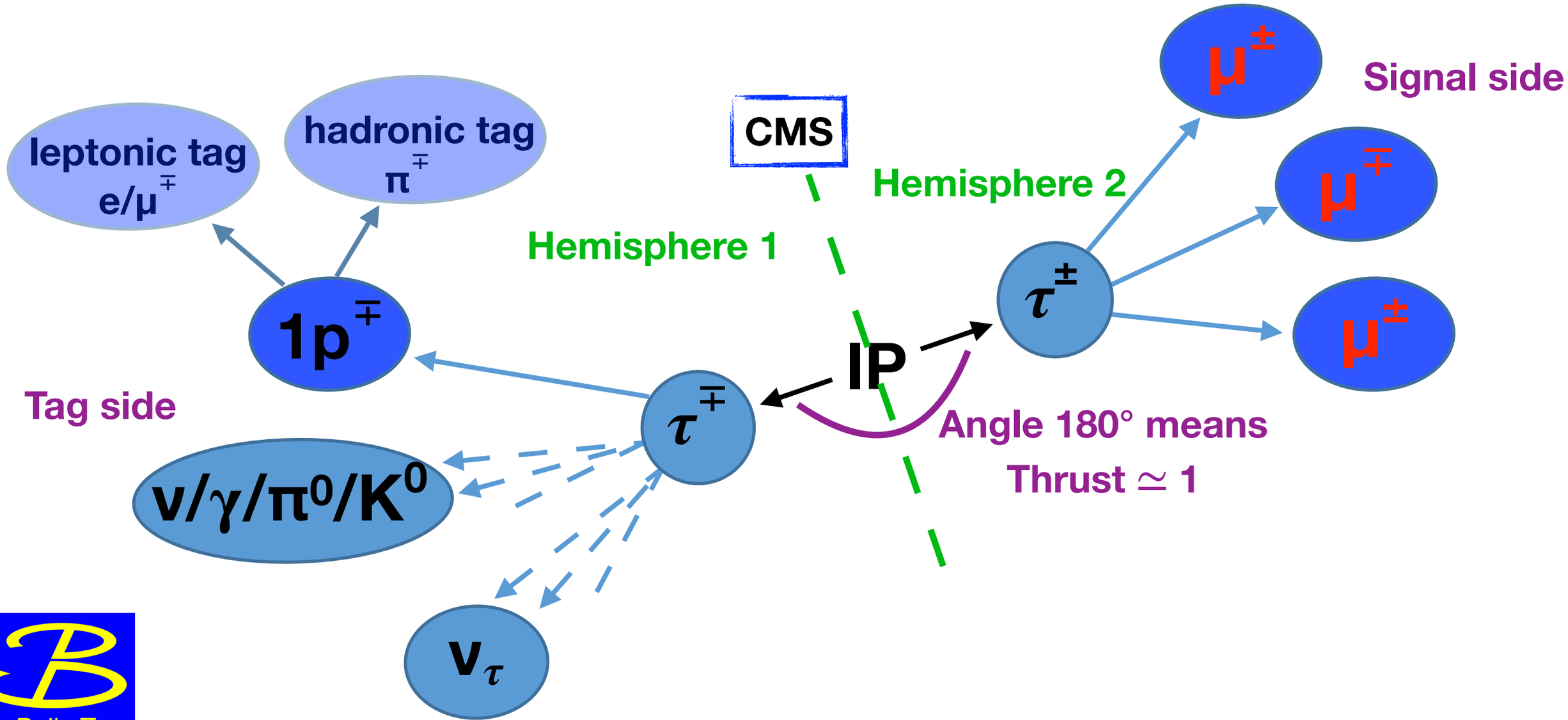
An observation of LFV in τ decays would be a clear signature of NP

Belle II

Signal preselection

Requirement adopted to reconstruct the decay:

- **thrust**: discriminate between spherical and boosted events;
- the two τ point to opposite **hemispheres**;
- Exactly **4 tracks** coming nearby the IP;
- **Signal** tracks loosely identified as **muons**
- **1prong track nature divides the study into leptonic and hadronic tag cases**



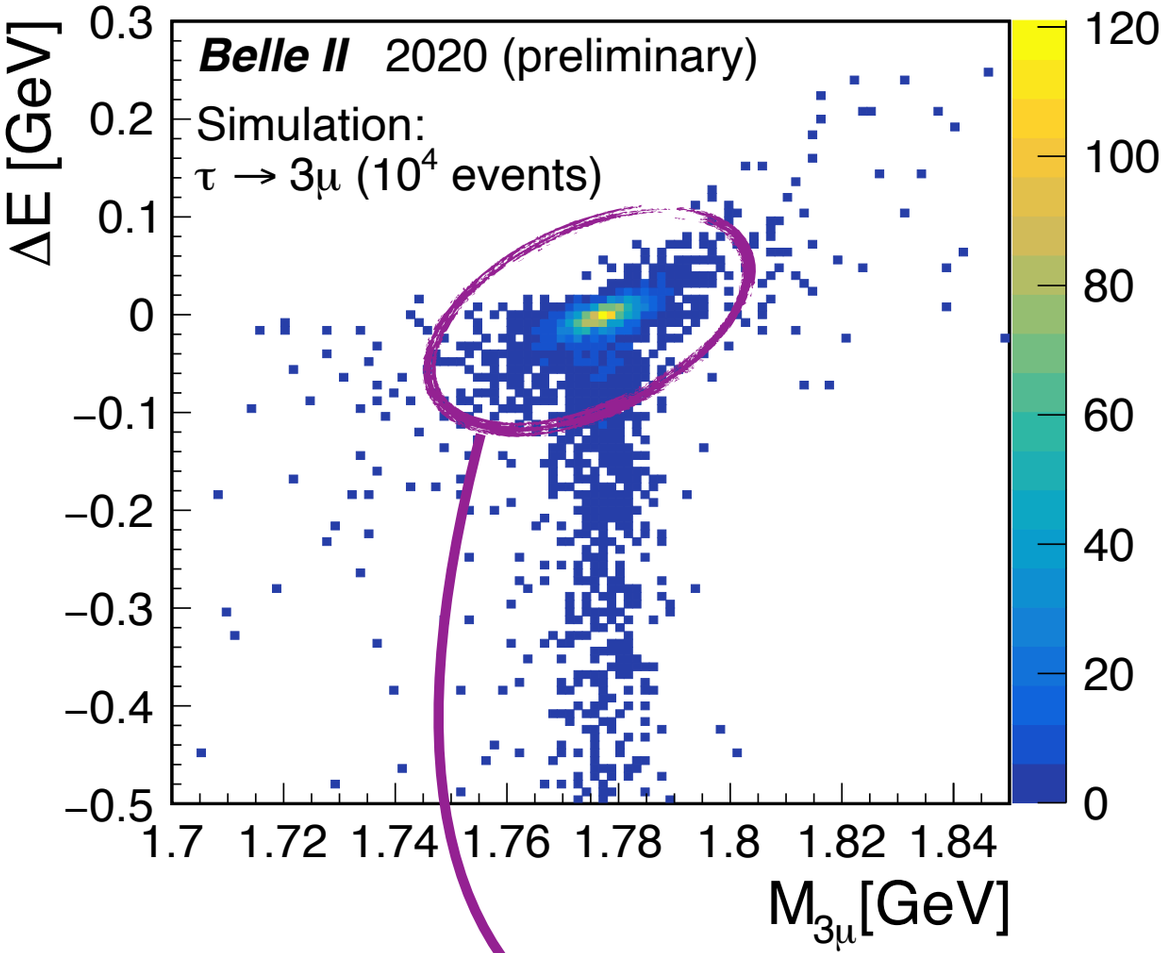
Signal determination: signal region

Signal identification in LFV τ analysis is usually done using a τ mass and ΔE selection

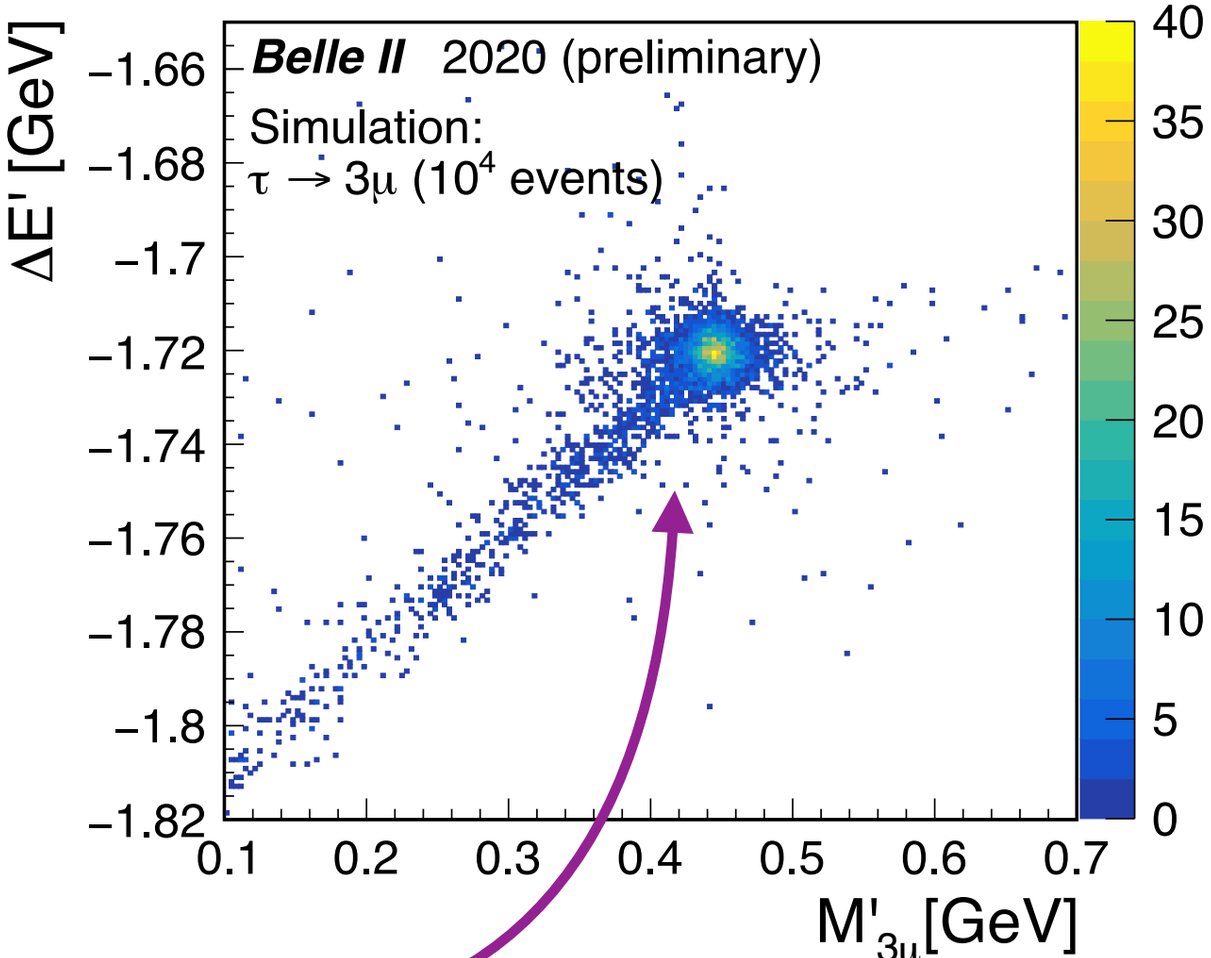
$$\Delta E \equiv E_\tau - E_{beam}$$

$E_\tau \rightarrow E_{3\mu}$, $E_{beam} \rightarrow \sqrt{s}/2$

ΔE VS M of signal τ



ΔE' VS M' of signal τ



$$\begin{pmatrix} M'_{3\mu} \\ \Delta E' \end{pmatrix} = \begin{pmatrix} cos\theta & sin\theta \\ -sin\theta & cos\theta \end{pmatrix} \begin{pmatrix} M_{3\mu} \\ \Delta E \end{pmatrix}$$ **with** $\theta \simeq 75°$

Background rejection: signal side

The most powerful discriminating variable between signal and background is the μID →usage of a different&optimised cut-based approach

Momentum ranges:

- **p_μ<0.7 GeV**: μ do not reach the μ detector (KLM)
- **0.7<p_μ<1 GeV**: μ reach KLM but not many layers are crossed
- **p_μ>1 GeV**: μ reach KLM and many layers are crossed

Optimization of the μID cuts on 3 momentum ranges

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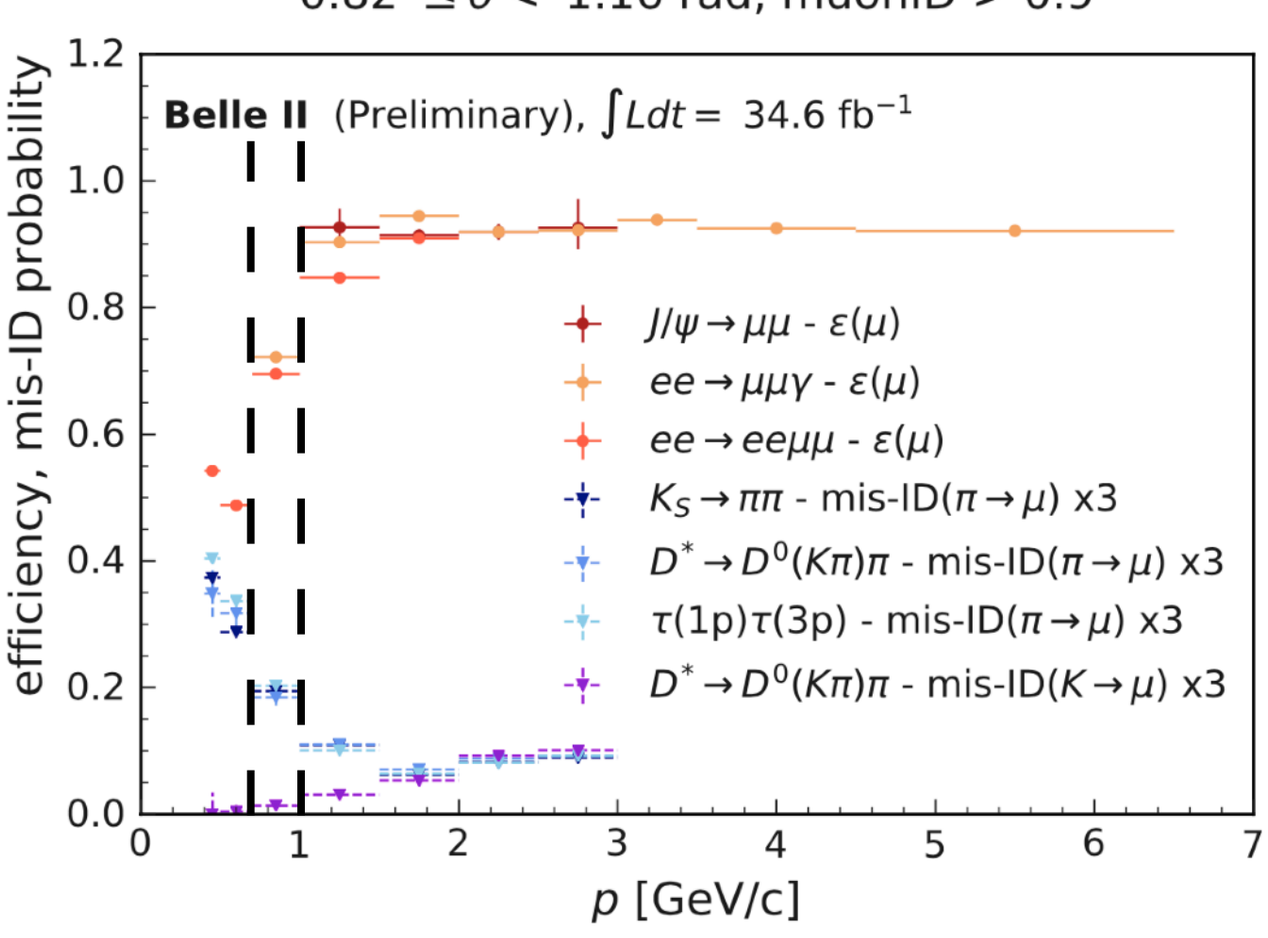
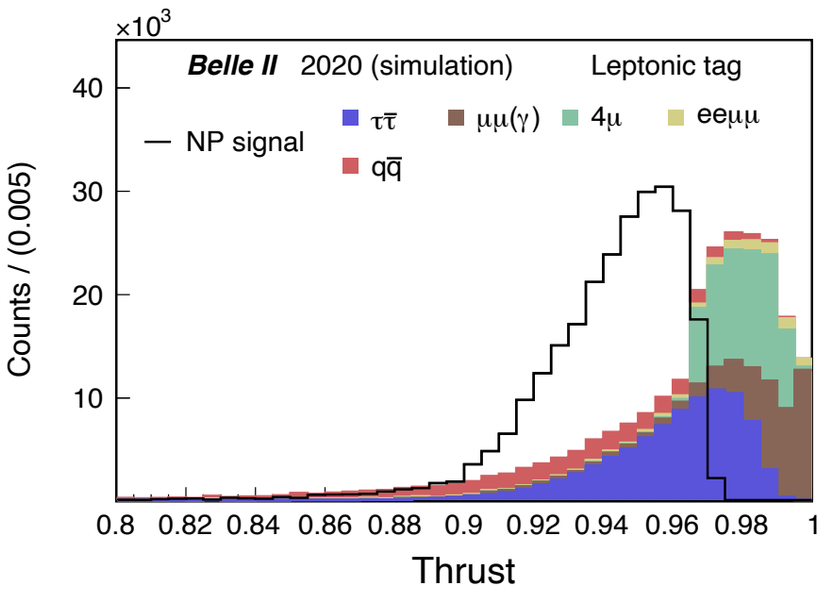
Extract the best combination of cuts for the analysis (*not done by Belle/BaBar*)

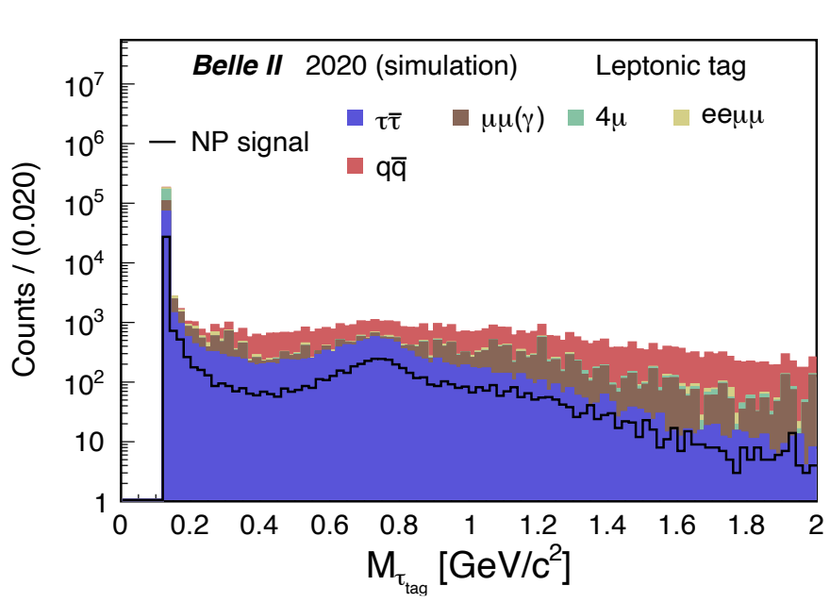


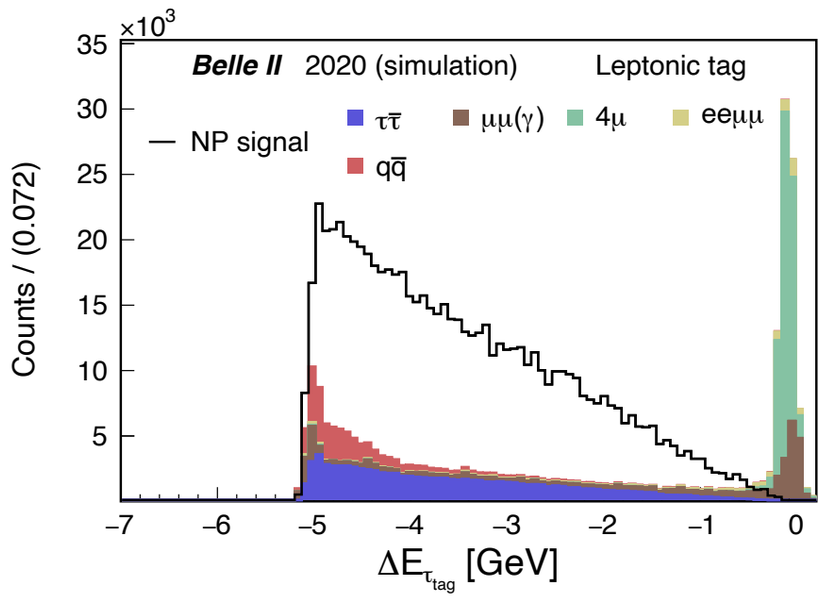
Background rejection: tag side

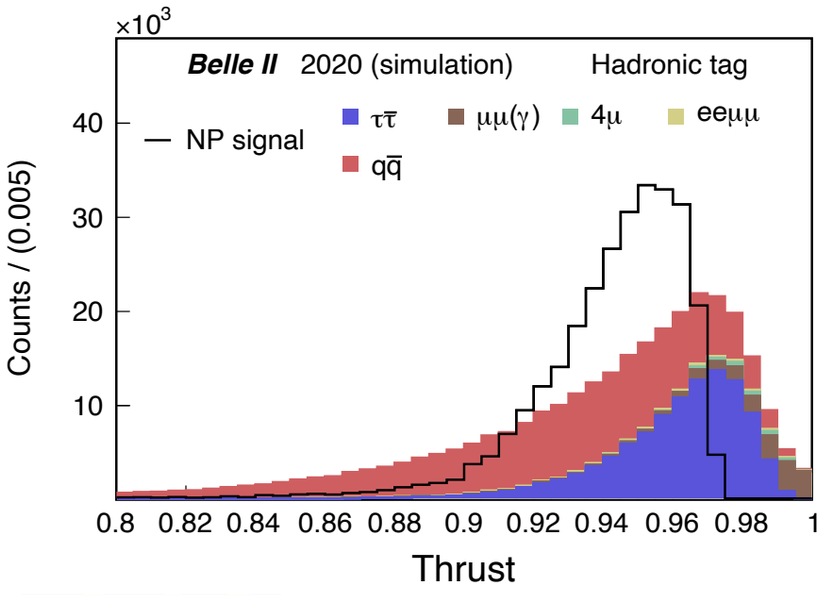
Several other cuts on event and tag side variables further reduce background contributions

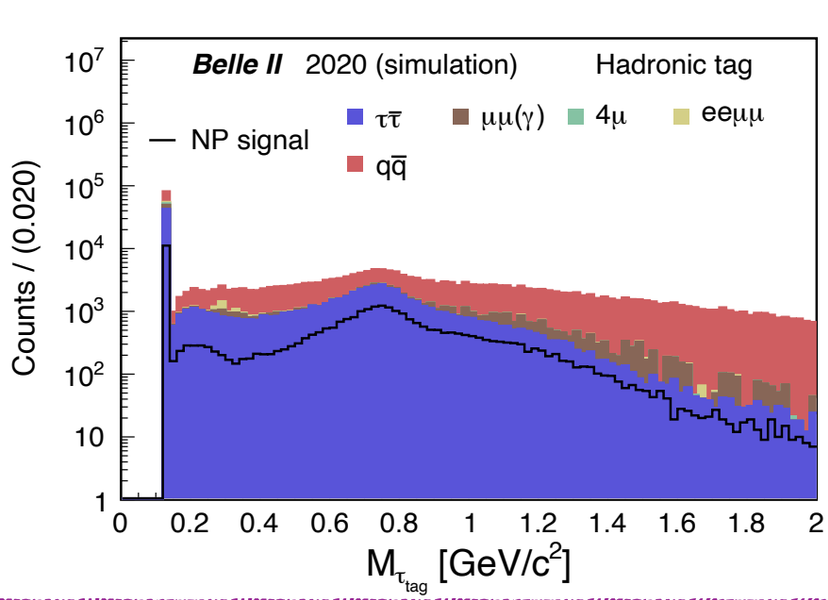
Extract the best combination of cuts for the analysis (*not done by Belle/BaBar*)

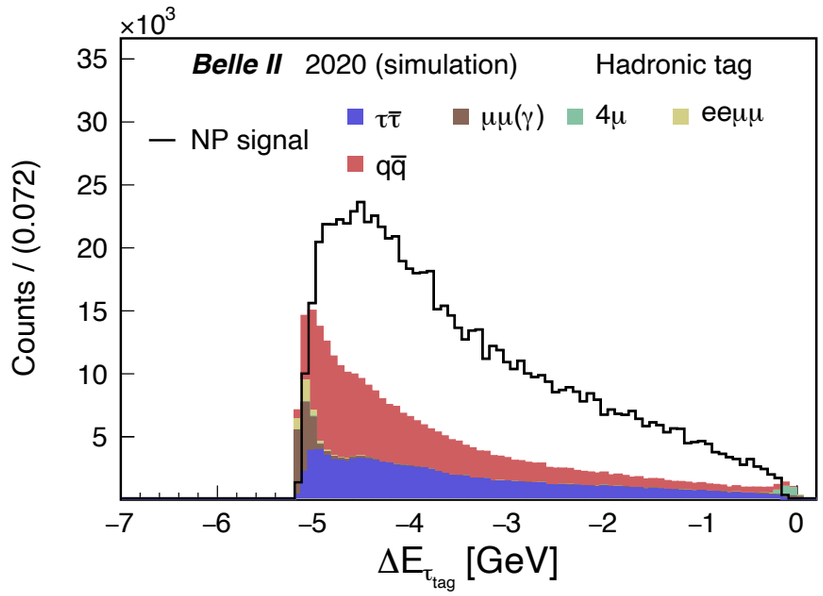






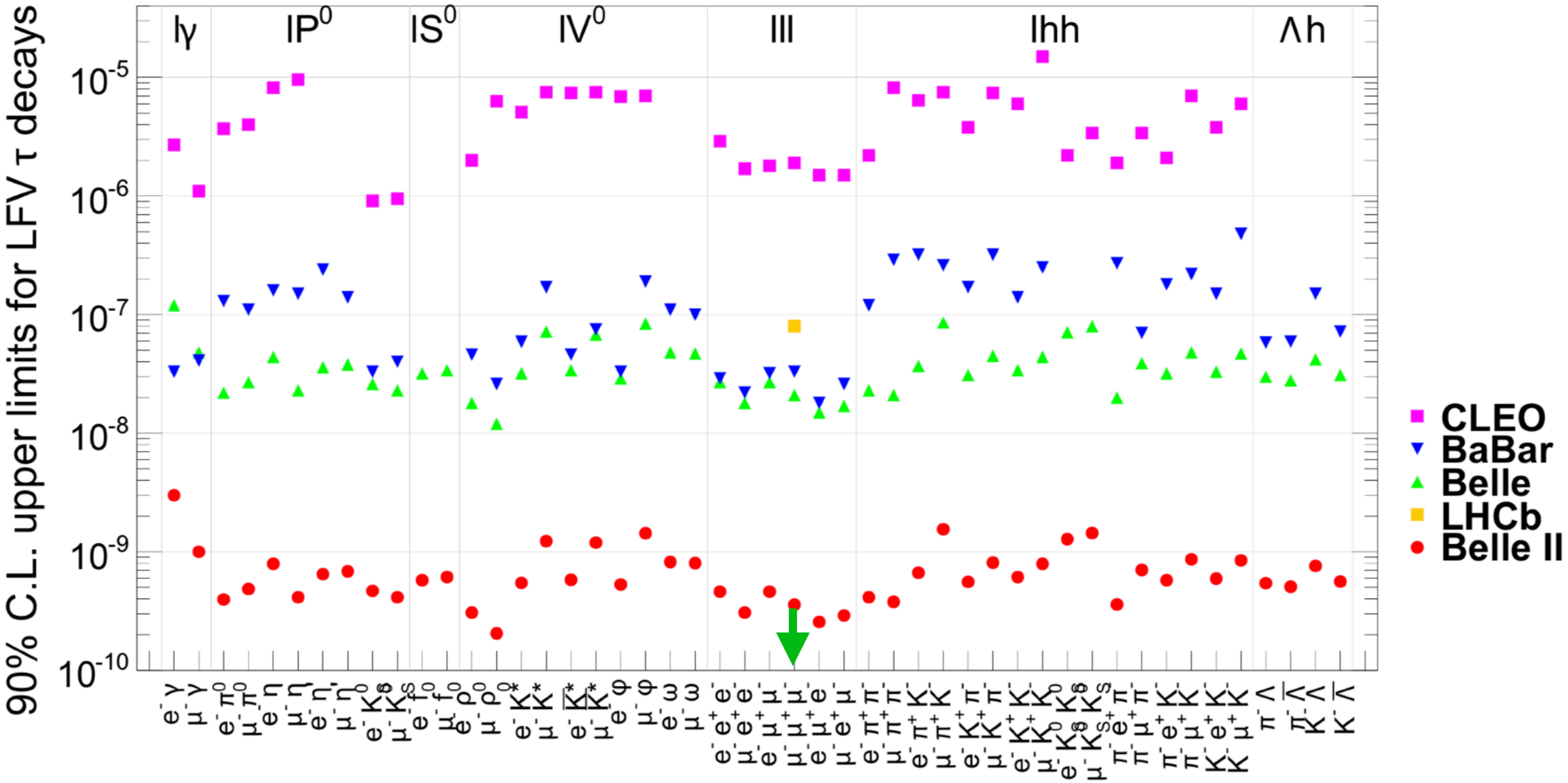






No signal region cuts are applied here

Expected limits results



Belle II is expected to improve the results of previous B-factory by a factor ~100 with statistics only but…

With a better analysis strategy the results can be even better… and they are coming soon!

Conclusions

- **The Belle II experiment will be able to search for many LFV τ decays** within the next years **thanks to advantages** provided by the B-factory

- Several NP contributions are accessible by Belle II → the aim is to further **improve existing limits and search for NP hints**

- **τ → 3μ channel is very promising**
  - New optimised analysis is being performed @ Belle II
  - Improved μID algorithm is expected to improve previous results

- **Final results are on the way → let's wait for more data to come!**