Searching for heavy Majorana neutrinos in τ four-body decays

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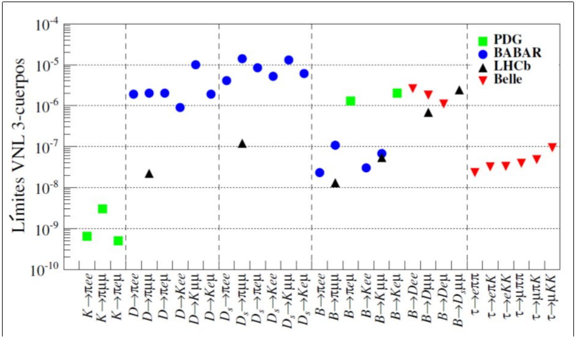
Searches in LNV Accelerators

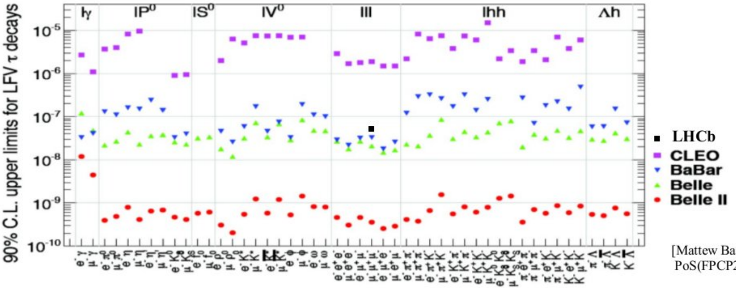


The Searches are

- $(barion) \to barion + lepton + lepton$
- $(lepton) \to lepton + barion + barion$

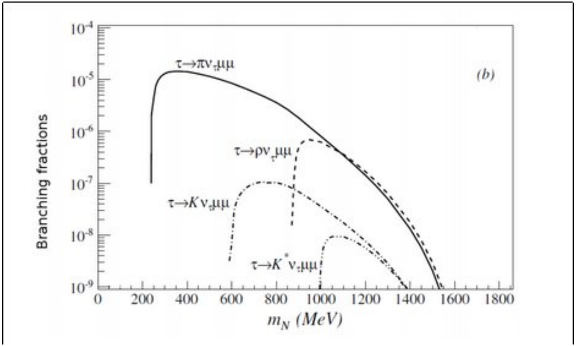
All of them are decay to three bodies.

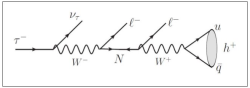
Searches in LFV in τ



[Mattew Barrett PoS(FPCP2015)049]

LNV in four body decay

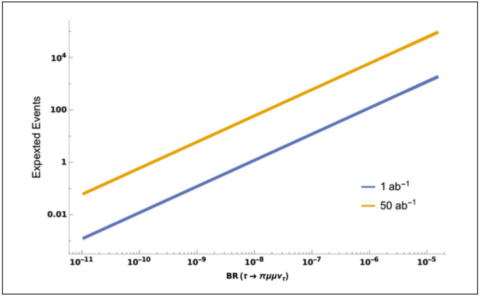




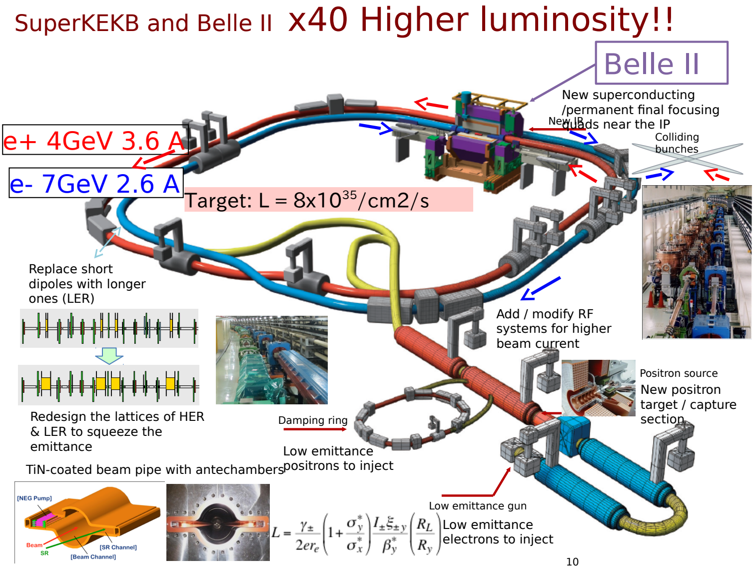
These violate the total lepton number $\Delta L = 2$ and can be induced by the exchange of Majorana neutrinos[1].

[1] Castro, G. López and Quintero, N., Phys. Rev. D 85, 076006.

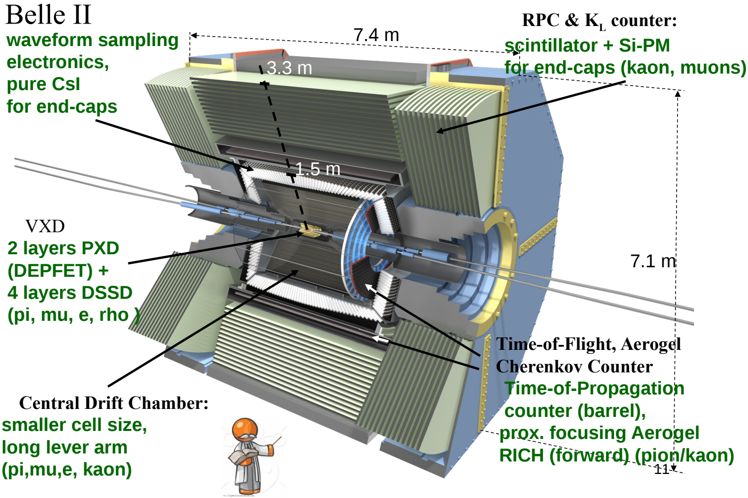
We can go as low as 10^{-8} for Belle II, and 10^{-6} in Belle.



SuperKEK improvements



Belle II Detector



40 billion of tau expected in the full run

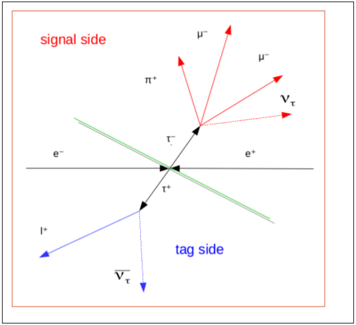
Introduction

The studied processes are:

- $\tau^- \to K^+ \mu^- \mu^- \nu_\tau$
- $\tau^- \to K^{*+} \mu^- \mu^- \nu_\tau$
- $\tau^- \to \pi^+ \mu^- \mu^- \nu_\tau$
- $\tau^- \to \rho^+ \mu^- \mu^- \nu_\tau$

To generate the sample we use a phase space model and we do not take into account the lifetime of the majorana neutrino

Tagging



We separate the event in two sides the tag region, wher we use one charged track, and the signal region in this case at least three charged tracks.

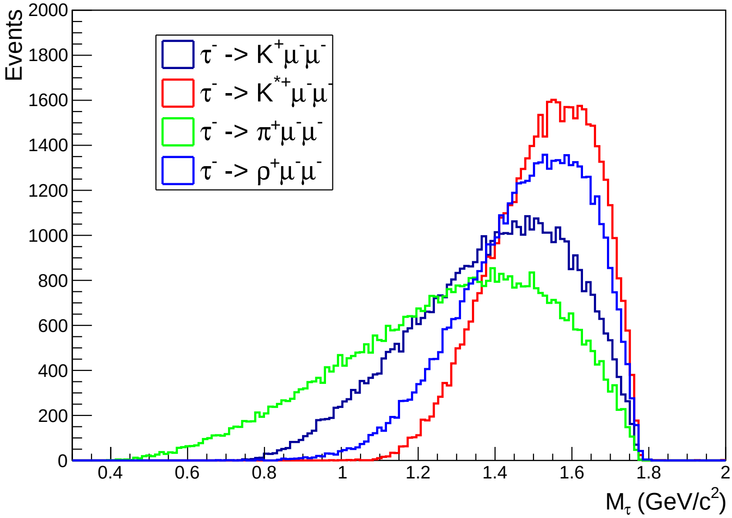
Monte Carlo production

MC signal events were generated in KKMC and Taula, we generate 5×10^4 events for each channel. At this moment, we are working with generated MC level. So we can observe some distributions, for example:

- Invariant mass of τ's
- ΔE

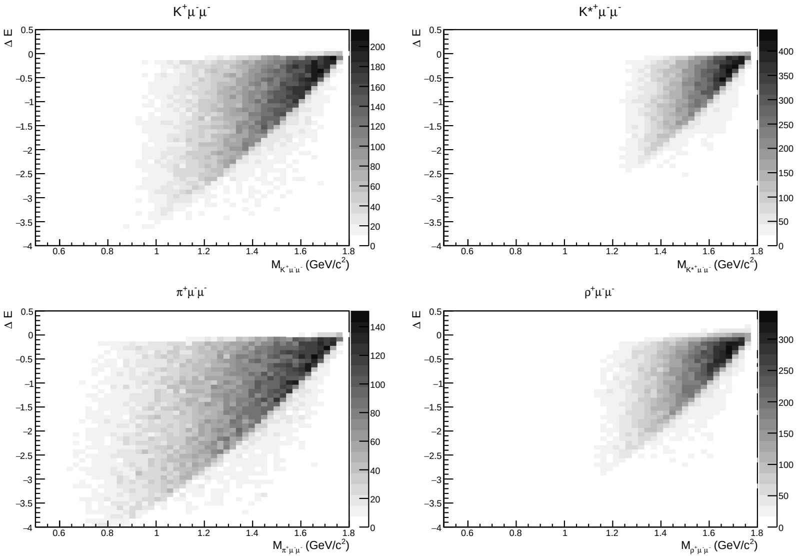
To generate the ntuples the cuts in decays with missing energy is very important, the invariant mass window is big and that produce a larger number of candidates, around $O(10^6)$ per 90K events in background sample.

Invariant mass



In this case the mass is not as the same in the tau since we are missing the ν_τ

Invariant mass vs ΔE



Preselection cuts

To generate the ntuples for background sample we use differrente generatos depending of the process, also beam background is taking into account, this one affect recontruction quality.

Background process	Cross-section [nb]	Generator
$e^+e^- \rightarrow B^+B^-$ (Charged)	0.525	EvtGen, PYTHIA
$e^+e^- \rightarrow B^0\bar{B}^0$ (Mixed)	0.525	EvtGen, PYTHIA
$e^+e^- \rightarrow u\bar{u}$ (uubar)	1.61	KKMC
$e^+e^- \rightarrow d\bar{d}$ (ddbar)	0.40	KKMC
$e^+e^- \rightarrow s\bar{s}$ (ssbar)	0.38	KKMC
$e^+e^- \rightarrow c\bar{c}$ (ccbar)	1.30	KKMC
$e^+e^- \rightarrow \tau^-\tau^+$ (taupair-generic)	1.30	KKMC

Since we have the initial energy $e + e-$ and the final energy we can reduce background using this condition

- $|\text{deltae}| < 2.5$ GeV
- $M_\tau < 1.8$ GeV

Preselection efficiency

We generated 50K events for each channel and after these cuts, the efficiencies are:

Event type	events out	ϵ_{ps}
$\tau^- \to K^+\mu^-\mu^-\nu_\tau$	44999	89.99 %
$\tau^- \to K^{*+}\mu^-\mu^-\nu_\tau$	44761	89.52%
$\tau^- \to \pi^+\mu^-\mu^-\nu_\tau$	41897	83.79%
$\tau^- \to \rho^+\mu^-\mu^-\nu_\tau$	46875	93.75%

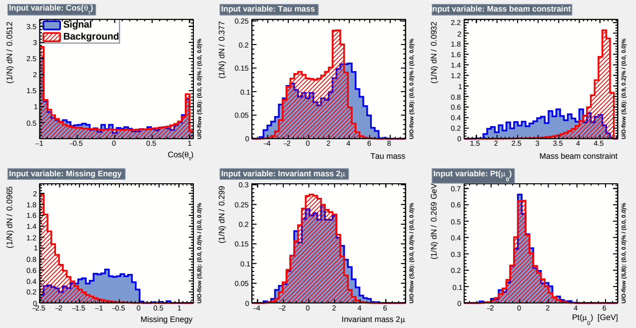
Background process	Generated	Possible candidates		
		$\tau^- \to K^+\mu^-\mu^-\nu_\tau$	$\tau^- \to K^{*+}\mu^-\mu^-\nu_\tau$	$\tau^- \to \pi^+\mu^-\mu^-\nu_\tau$
$e^+e^- \to B^+B^-$	90,000	63,135	212,723	83,077
$e^+e^- \to B^0\bar{B}^0$	90,000	56,358	200,681	75,253
$e^+e^- \to u\bar{u}$	88,957	106,344	183,164	134,932
$e^+e^- \to d\bar{d}$	88,947	105,945	183,365	131,138
$e^+e^- \to s\bar{s}$	85,308	121,364	194,380	148,150
$e^+e^- \to c\bar{c}$	87,958	144,550	339,791	167,939
$e^+e^- \to \tau^+\tau^-$	90,000	18,343	7,034	20,394

The most noisy channel is the K* mode due that we are not aplying cut in k* candidates.

BDT variables

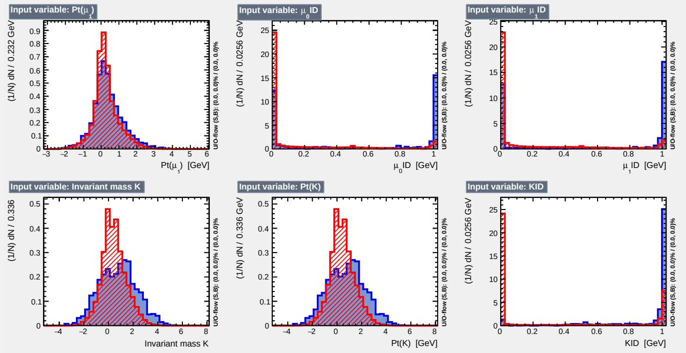
We used the next variables to applied the BDT for $\tau^- \to K^+\mu^-\mu^-\nu_\tau$ with the **(ccbar)** sample

- $\mathrm{Cos}(\theta_\tau)$
- Tau mass
- M_{bc}
- ΔE
- $\mathrm{M}_{2\mu}$
- $\mathrm{Pt}(\mu_0)$



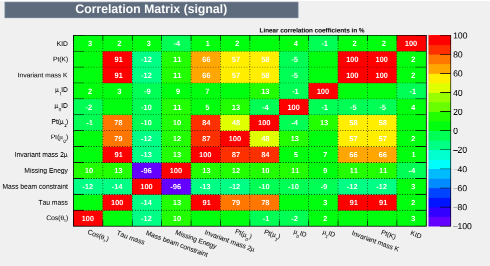
As expected the most powerfull variables are the energy and the mass contraint

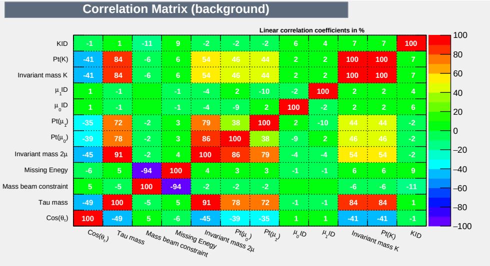
- $Pt(\mu_0)$
- μ_0ID
- μ_1ID
- M(K)
- Pt(K)
- KID



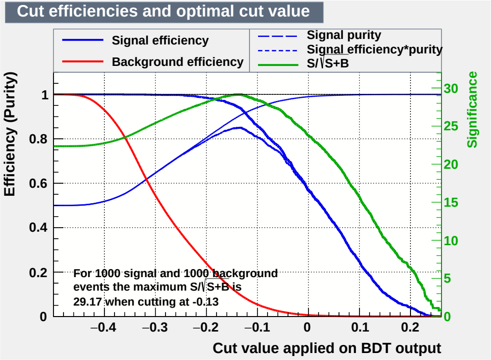
Here again we notice the pid are the most discriminating

The matrix correlation and efficiency





Summary



Background process	$S/\sqrt{S+B}$
$e^+e^- \rightarrow B^+B^-$ (Charged)	29.90
$e^+e^- \rightarrow B^0\bar{B}^0$ (Mixed)	29.89
$e^+e^- \rightarrow u\bar{u}$ (uubar)	29.37
$e^+e^- \rightarrow d\bar{d}$ (ddbar)	29.59
$e^+e^- \rightarrow s\bar{s}$ (ssbar)	28.81
$e^+e^- \rightarrow c\bar{c}$ (ccbar)	29.17
$e^+e^- \rightarrow \tau^-\tau^+$ (taupair-generic)	29.65

These result for the $\tau^- \rightarrow K^+\mu^-\mu^-\nu_\tau$, similarly for the other channels. This is the first approximation to the analysis.

conclusion and perspectives

- Improve the selection variables and look for more.
- Apply other methods beside BDT.
- Use a more realistic model for the decays.
- Include the electron modes channels.