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# Study of $\tau^- \rightarrow \Lambda \pi^-$ at Belle II Experiment

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# Outline

- Motivation
- Dataset
- Signal MC generation
- Event reconstruction and selection
- Signal Region
- Summary

# Motivation

## ➤ Puzzle ! Asymmetry of matter and anti-matter

- Baryon number violation (BNV)
- CP violation
- Departure from thermal equilibrium

## ➤ Standard Model (SM)

- Baryon number (B)
  - Lepton number (L)
- ➔ **Conserved!**

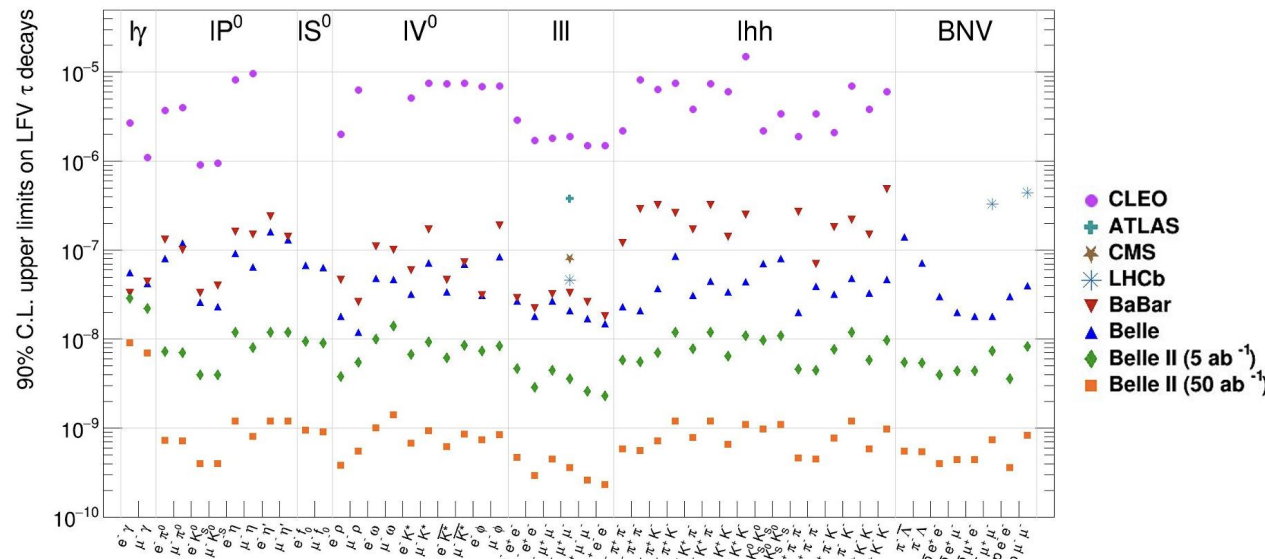
## ➤ $\tau$ decays

- Clean physics environment and Known initial state
- In previous BNV analysis of  $\tau$  decays, the lepton number and flavor are also violated (**LNV & LFV**)

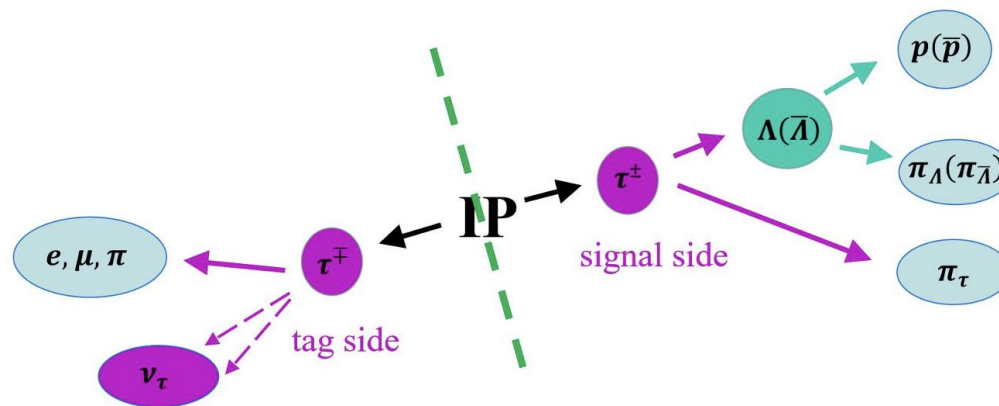
↓  
sensitive probe for  
new physics beyond SM!

## ➤ $\tau^- \rightarrow \Lambda\pi^-$

- Previous Belle result [2]
- Updated study at Belle II



The current experimental status of LFV for forty-eight tau decays [1]



The schematic diagram of the reconstructed  $\tau^- \rightarrow \Lambda\pi^-$  ( $\Lambda\pi^-$ ) signal event [1]

[1] BELLE2-NOTE-PH-2023-012

[2] Y. Miyazaki, et al., (Belle Collaboration), Phys. Lett. B 632, 51 (2006).

# Dataset

Dataset		Version
Signal MC	1M (MC15ri)	light-2409-toyger
Generic MC	40 $fb^{-1}$ (MC15ri) (qqbar & tautau)	

# Signal MC Generation

- The [KKMC](#) software package used for  $e^+e^- \rightarrow \tau^+\tau^-(\gamma)$  simulation
- The [TAUOLA](#) software package used for  $\tau$  decay simulation

$\tau^- \rightarrow \bar{p}^- \eta$	325
$\tau^- \rightarrow \bar{p}^- K^0$	326
$\tau^- \rightarrow e^- \eta'$	327
$\tau^- \rightarrow \mu^- \eta'$	328
$\tau^- \rightarrow \pi^- \Lambda$	329
$\tau^- \rightarrow \pi^- \bar{\Lambda}$	330
$\tau^- \rightarrow K^- \Lambda$	331
$\tau^- \rightarrow K^- \bar{\Lambda}$	332
$\tau^- \rightarrow e^- K^*$	333

- 0.5M signal MC for  $\tau^+$  and  $\tau^-$  respectively (total 1M)

```

0.08711          * c*tau(tau life time) (mm)
1               * switch for long lived (1:no decay, 0:decay)
1               * switch for KKMC-JETSET (1:on, 0:off)
***** Above is for basf *****

BeginX
*****
*
*          ACTUAL DATA FOR THIS PARTICULAR RUN
*****
*indx_____cccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc
*
*  Center-of-mass energy [GeV]
*  1      10.5800      CMSene =xpar( 1) Average Center of mass energy [GeV]
*  2      0.007e0      DelEne =xpar( 2) Beam energy spread [GeV]
*****
*  61      0.7071d0      spinlx  polarization vector beam 1
*  62      0d0          spinly  polarization vector beam 1
*  63      0.7071d0      spinlz  polarization vector beam 1
*  64      0d0          spinlx  polarization vector beam 2
*  65     -0.7071d0      spinly  polarization vector beam 2
*  66      0.7071d0      spinlz  polarization vector beam 2
*****
*
*  Define process
*  415      1          KFFin, Tau
*****
*  901      4          Ihvp  !=1,2,3,4
*****
*  2001      0e0       Jak1  =xpar(71) First Tau decay mask (tau-)
*  2002      329e0     Jak2  =xpar(72) Second Tau decay mask (tau+)
*****
*  2900      1e0       BBB   0: ORIG  1: BBB
*  2901      0e0       EQUALBR
*  2902      2e0       FF2PIRHO
*  2903      1e0       IRCHL3PI
*  2904      0e0       IFKPIPI
*  2905      0e0       IFCURR4PI
*****
EndX
    
```

# Baseline Selection

- $e^+e^- \rightarrow \tau^+\tau^-(\gamma)$

- $\tau^- \rightarrow \Lambda\pi^- \rightarrow p\pi^-\pi^-$

- $\tau^+ \rightarrow e/\mu/\pi\nu\nu$

- **Charged Tracks**

  - Within the detector acceptance range ( $-0.8660 < \cos\theta < 0.9536$ )
  - Transverse momentum ( $p_t > 0.1\text{GeV}/c^2$ )
  - For hadron tracks ( $n\text{CDCHits} > 0$ )

- $\gamma$

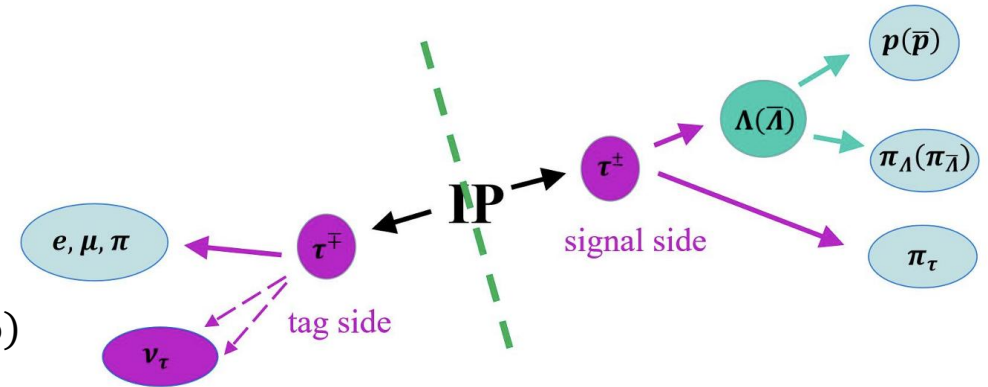
  - Photon energy ( $E > 0.1\text{GeV}$ )
  - Within the detector acceptance range ( $-0.8660 < \cos\theta < 0.9536$ )
  - $\text{clusterNHits} > 1.5$

- **PID**

  - Electronic veto :  $\text{electronID} < 0.9$  for three tracks in the signal side
  - $\text{protonID} > 0.5$
  - $\mathcal{L}(p/\pi) < 0.6$  and  $\mathcal{L}(K/\pi) < 0.4$

  - **Tag side :**

    - $\text{pidChargedBDTScore}_e > 0.9$  regarded as electron
    - $\text{pidChargedBDTScore}_e < 0.9$  and  $\text{muonID\_noSVD} > 0.9$  regarded as muon
    - Tracks with  $\mathcal{L}(p/\pi) < 0.6$  and  $\mathcal{L}(K/\pi) < 0.4$  regarded as pion



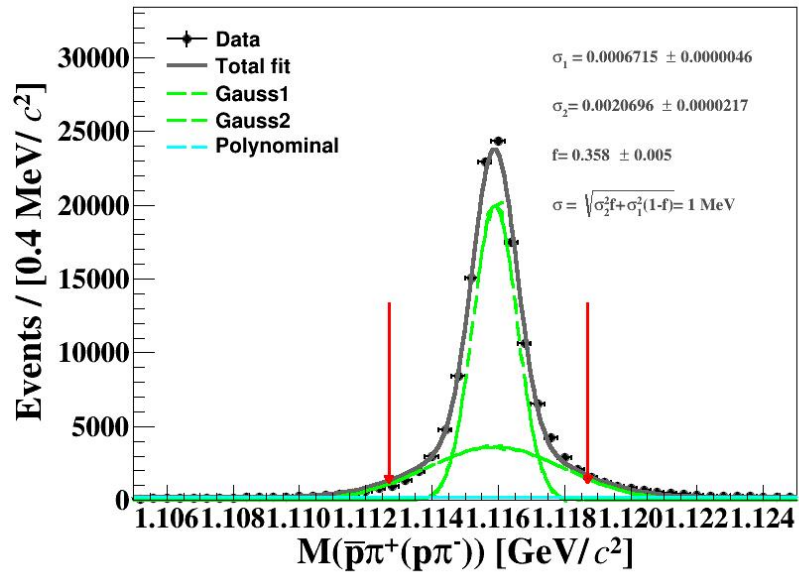
The schematic diagram of the reconstructed  $\tau^- \rightarrow \Lambda\pi^-$  ( $\Lambda\pi^-$ ) signal event<sup>[1]</sup>

- **Other criteria**

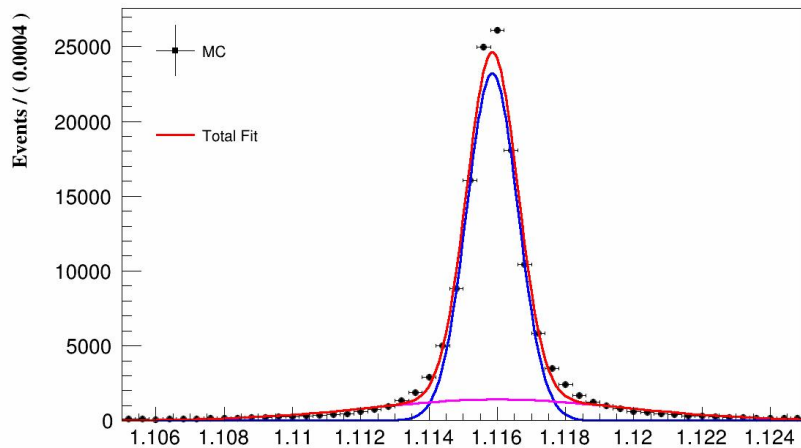
  - Treefit to signal  $\tau$  candidates
  - $n\text{GoodTrack} = 4$

# $\Lambda$ reconstruction

➤  $\tau^- \rightarrow \Lambda \pi^- \rightarrow p \pi^- \pi^-$



Fitted distribution of  $\Lambda$

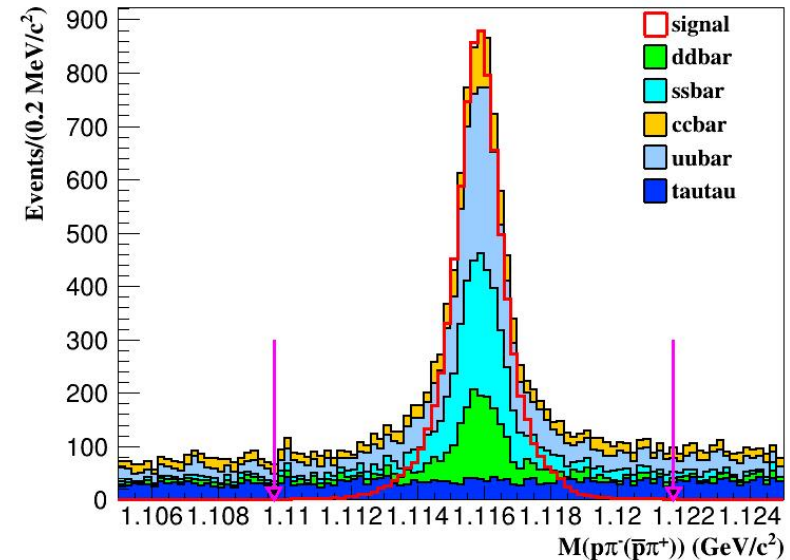


Yan's result

Li & Chen's result

➤  $\Lambda \rightarrow p \pi^-$

- Nominal mass:  $1.1156 \text{ GeV}/c^2$
- Mass windows approximately  $\pm 6 \text{ MeV}/c^2$  (corresponding to  $3\sigma$ )
- $\varepsilon = 12.69\%$

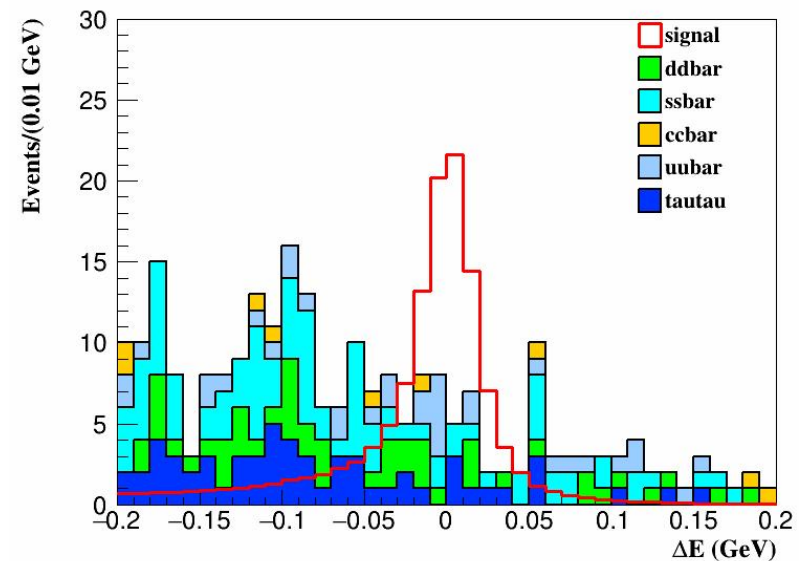
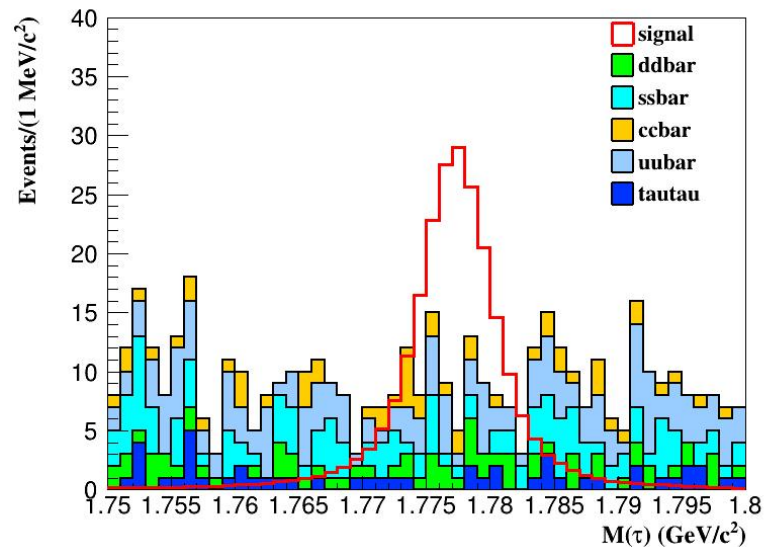
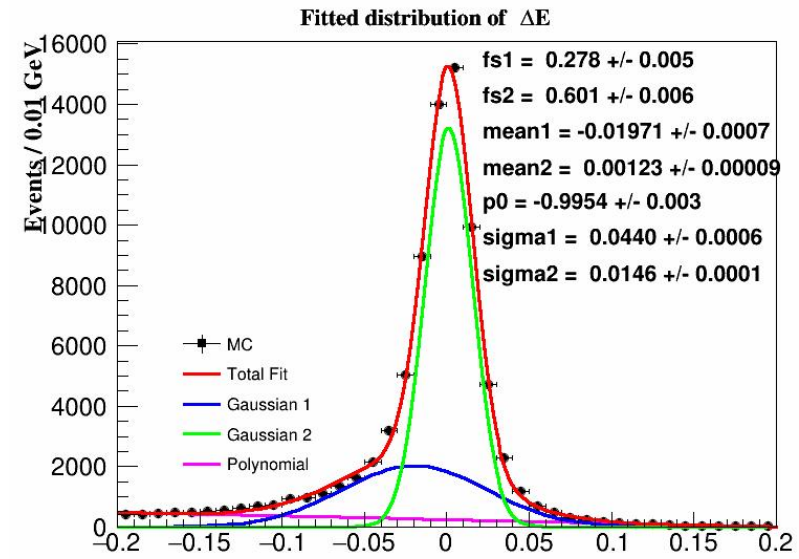
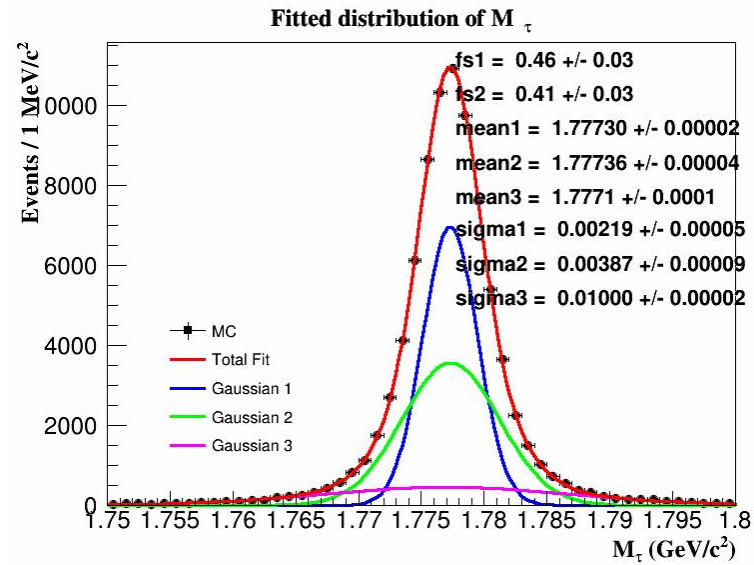


(Signal events scaled to half the number of Bkg events for better comparison)

# $\tau$ reconstruction

➤  $\tau^- \rightarrow \Lambda \pi^-$

- Nominal mass:  $1.777 \text{ GeV}/c^2$



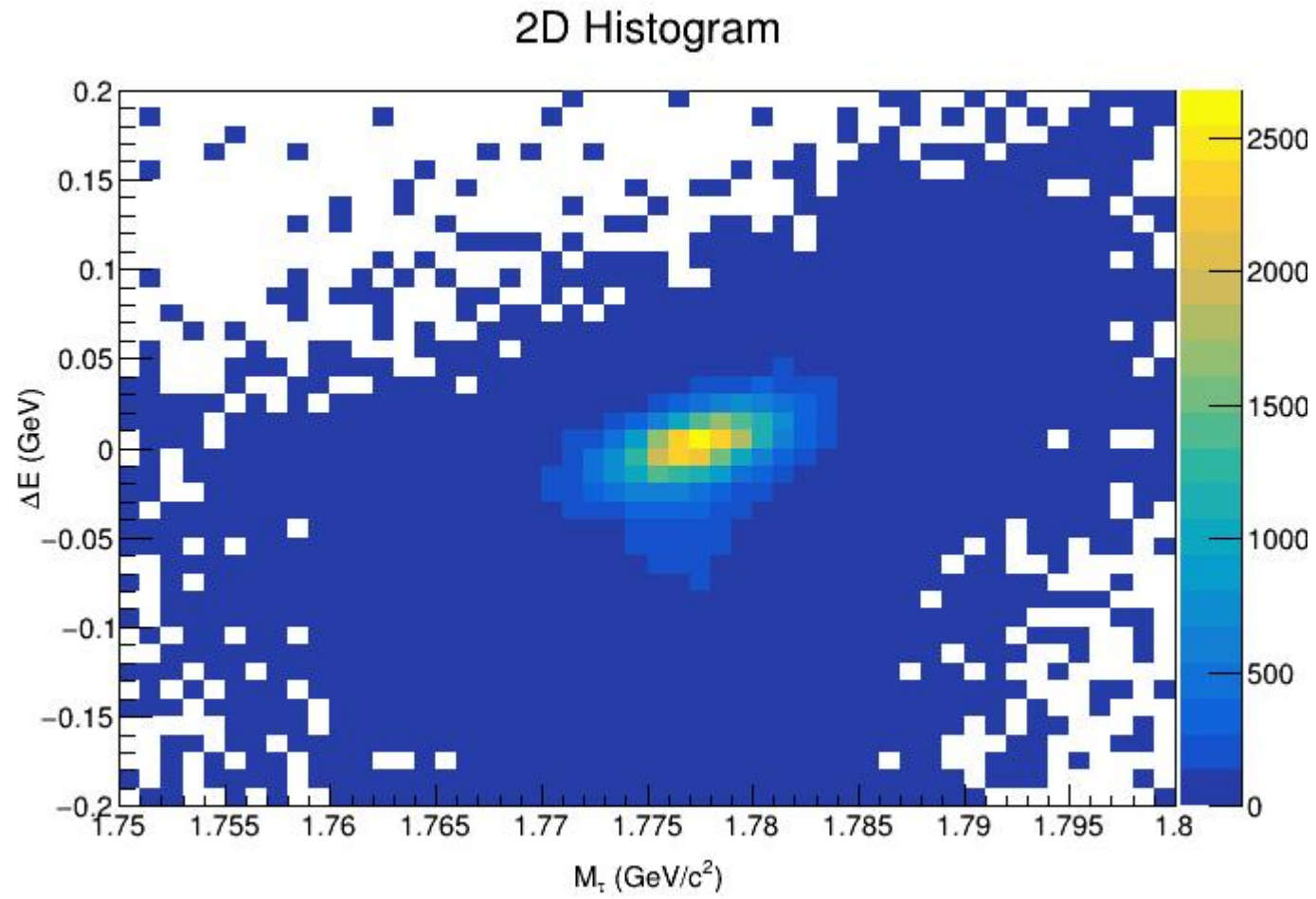
(Signal events scaled to half the number of Bkg events for better comparison)



# Signal Region

➤  $\tau^- \rightarrow \Lambda\pi^-$

- True signal events locate around  $(m_\tau, 0)$  point on the  $M_\tau - \Delta E$  plane



# Summary

- Motivation
- Generate Signal MC
- Event Reconstruction
- Basic Event Selection
- Signal Region
- Gains ...



Thanks for your attention!