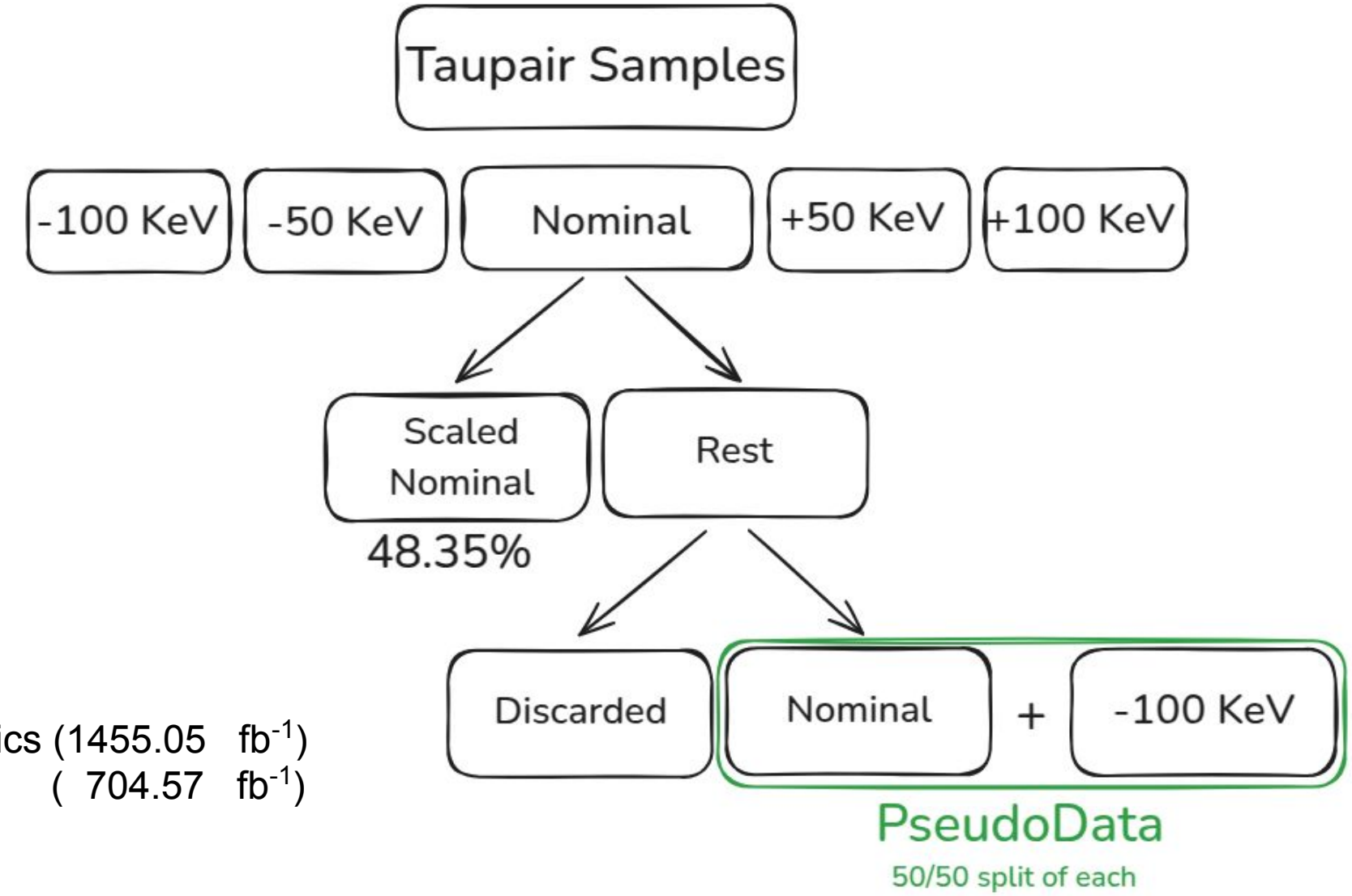
Tau Mass Analysis
Run 1

Raimundo Hoppe

Hamburg, 02.05.2025

Generating the PseudoData



Current taupair samples:

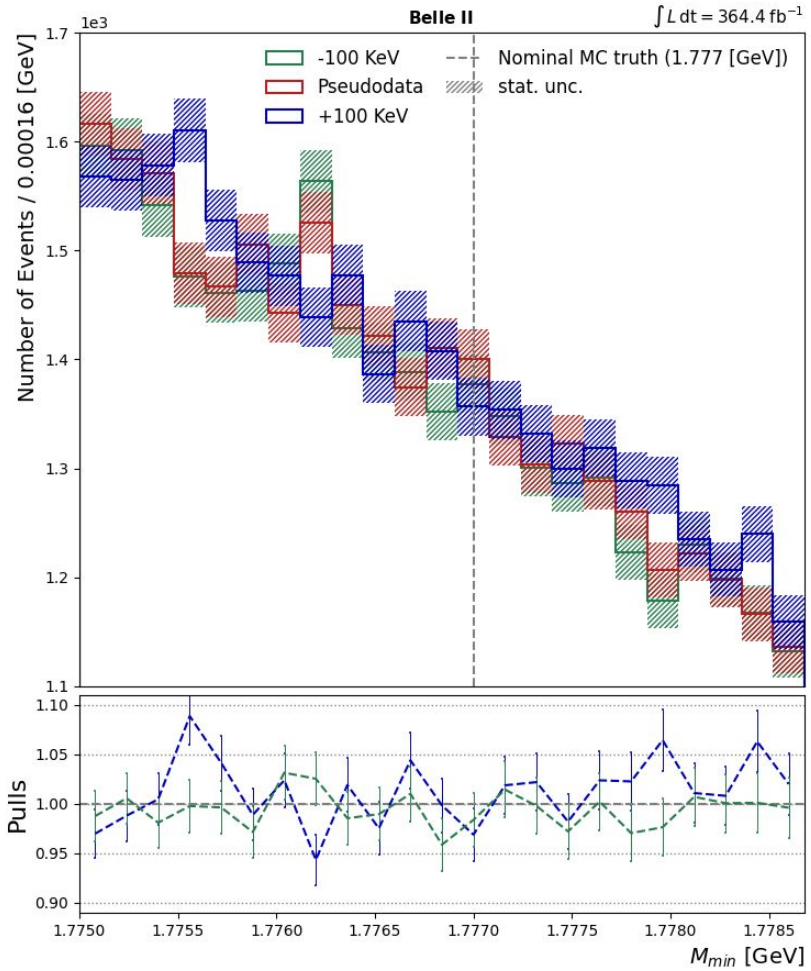
- Nominal ➡ Full MC Statistics (1455.05 fb^{-1})
- Templates ➡ 750M Events (704.57 fb^{-1})

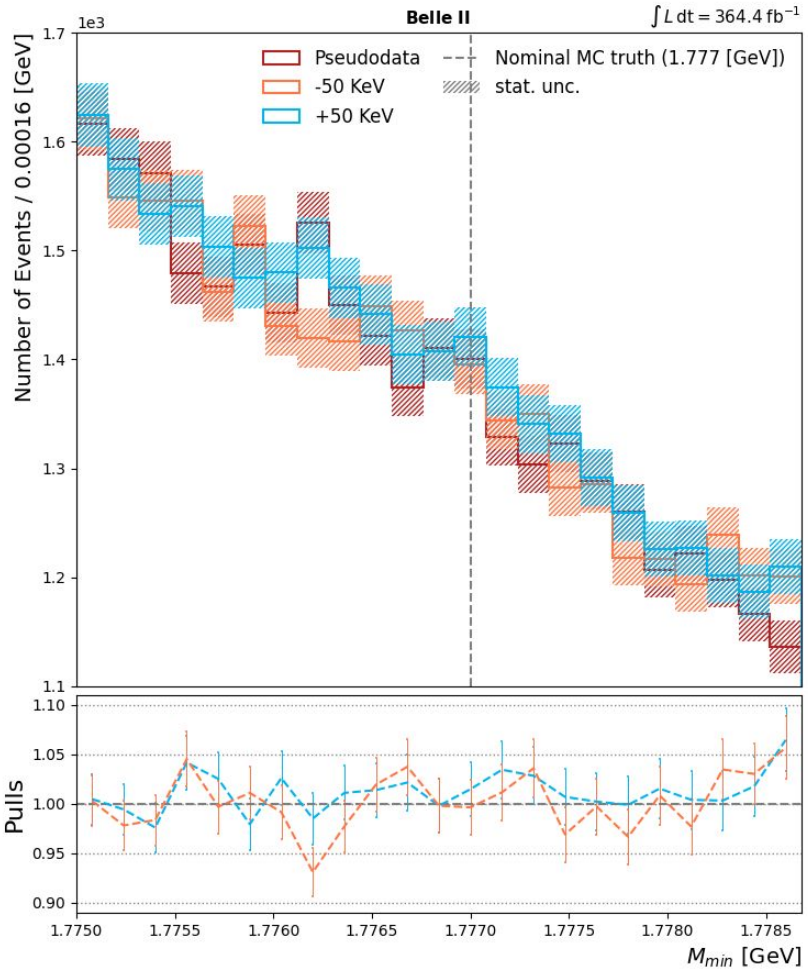
Data ➡ 361.924 fb^{-1}

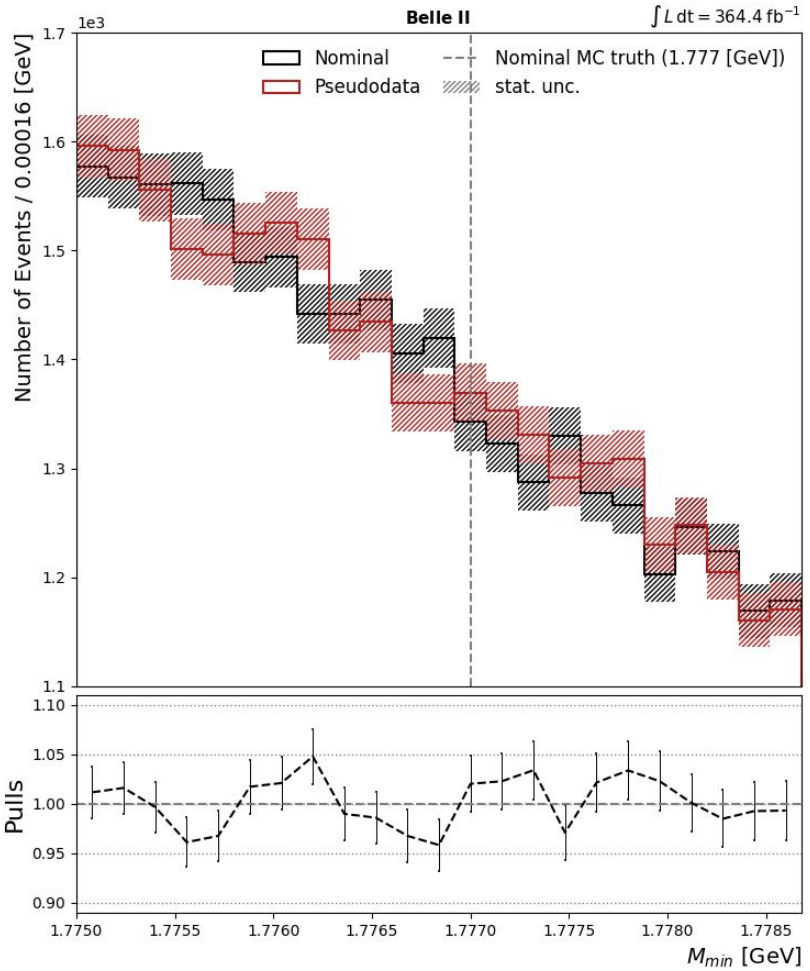
All Taupair Samples end with the <u>almost</u> the same number of events in the root files

Template in MVA

➡ 160 KeV Bins | No Smoothing

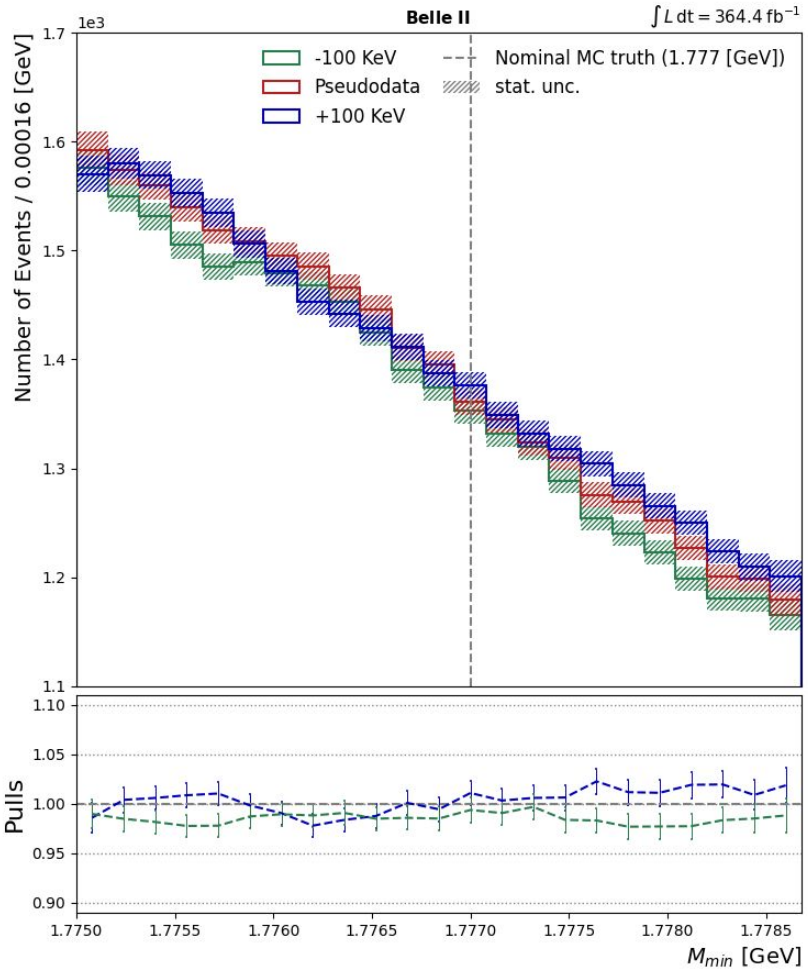


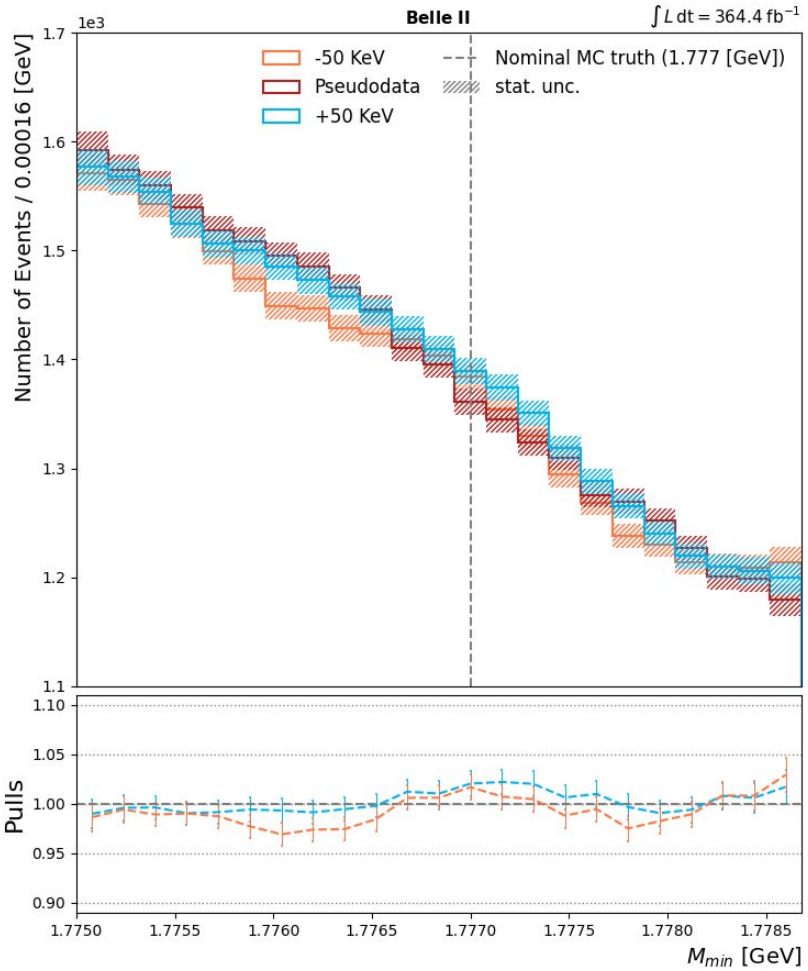


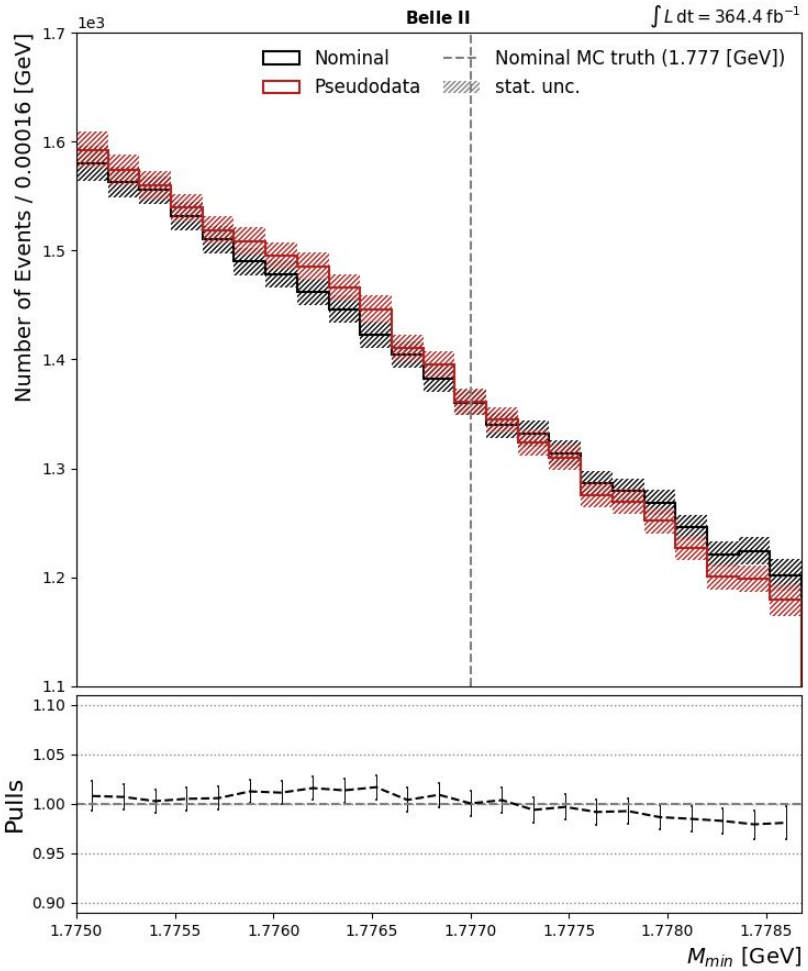


Template in MVA

➡ 160 KeV Bins

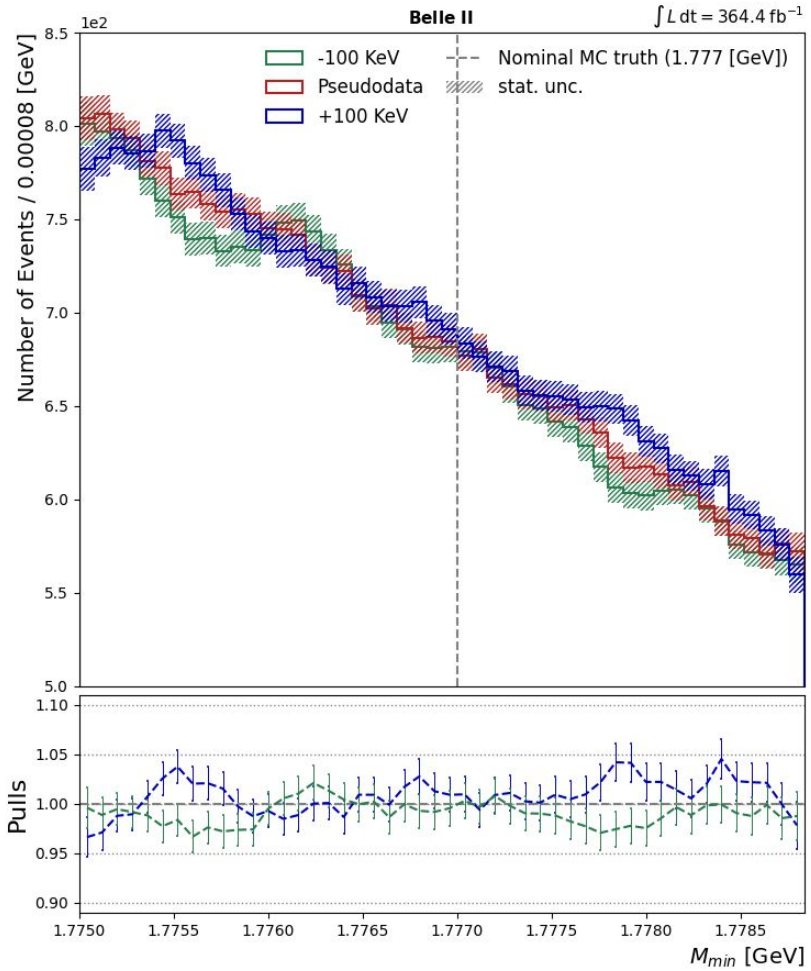


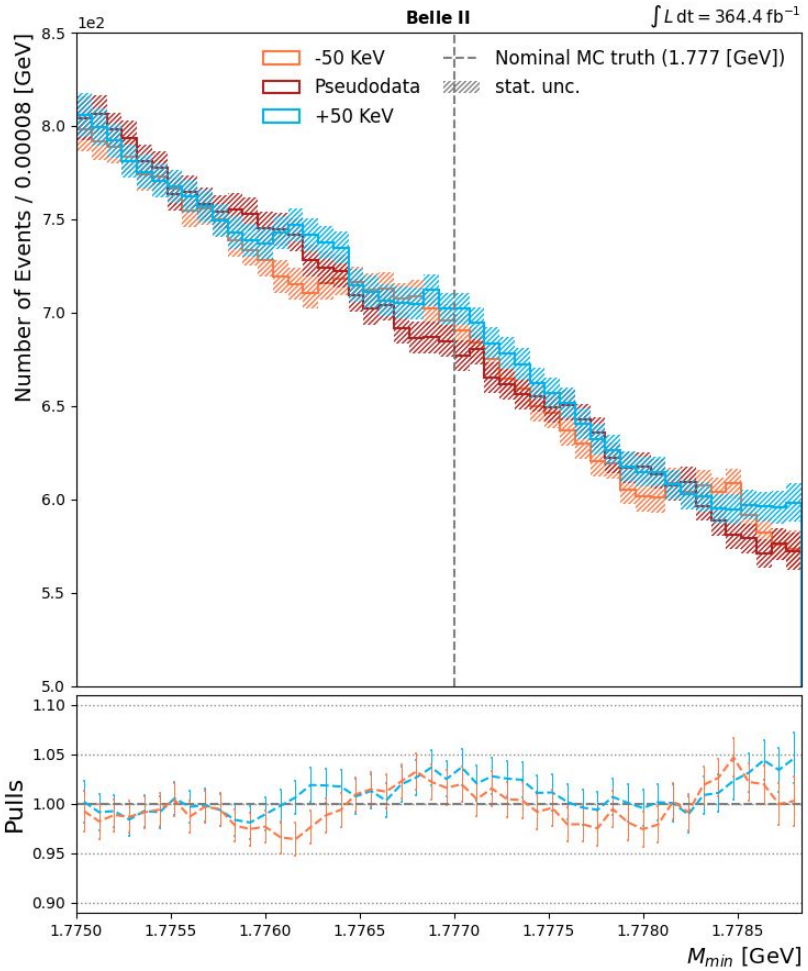


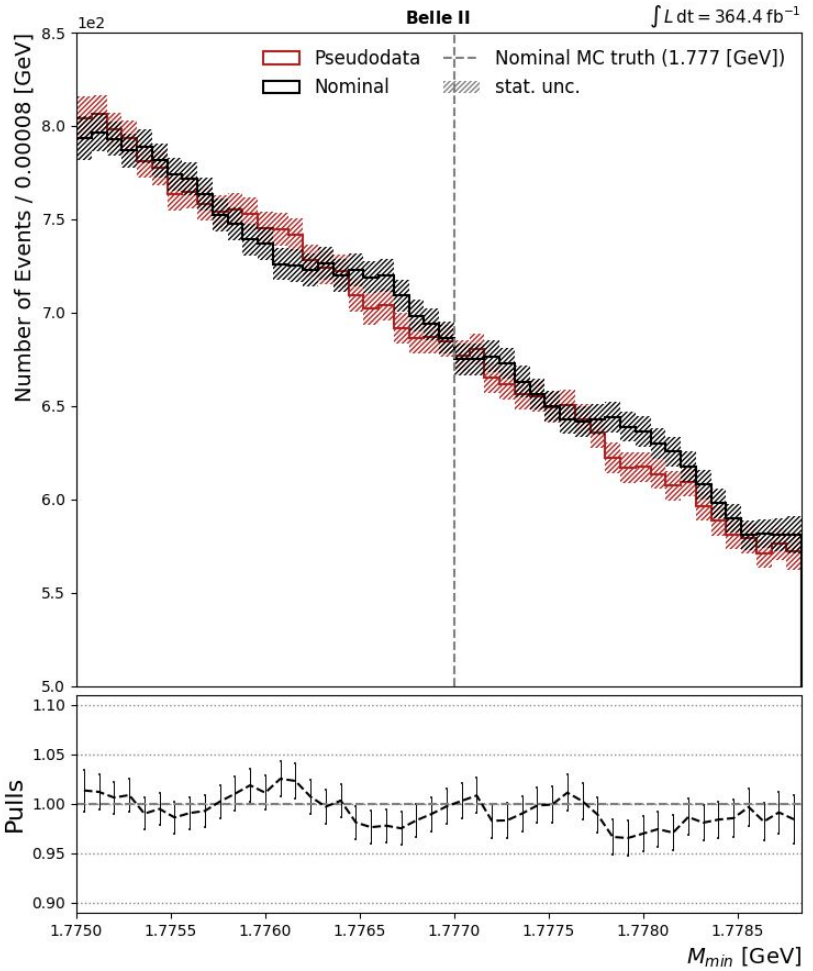


Template in MVA

➡ 80 KeV Bins

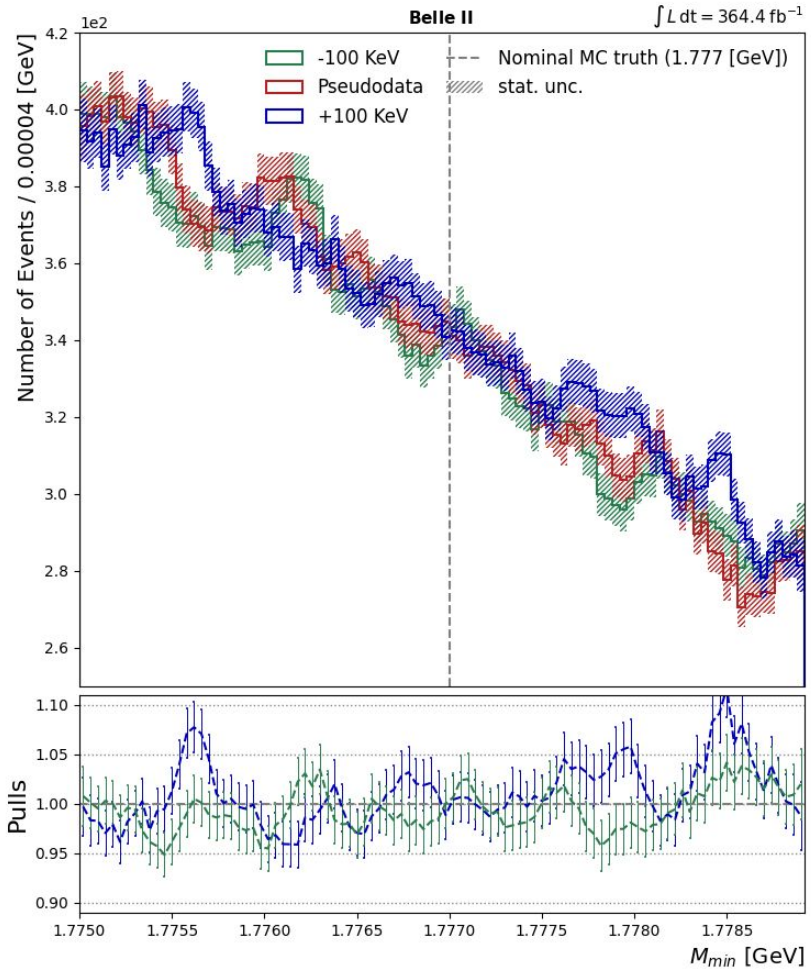


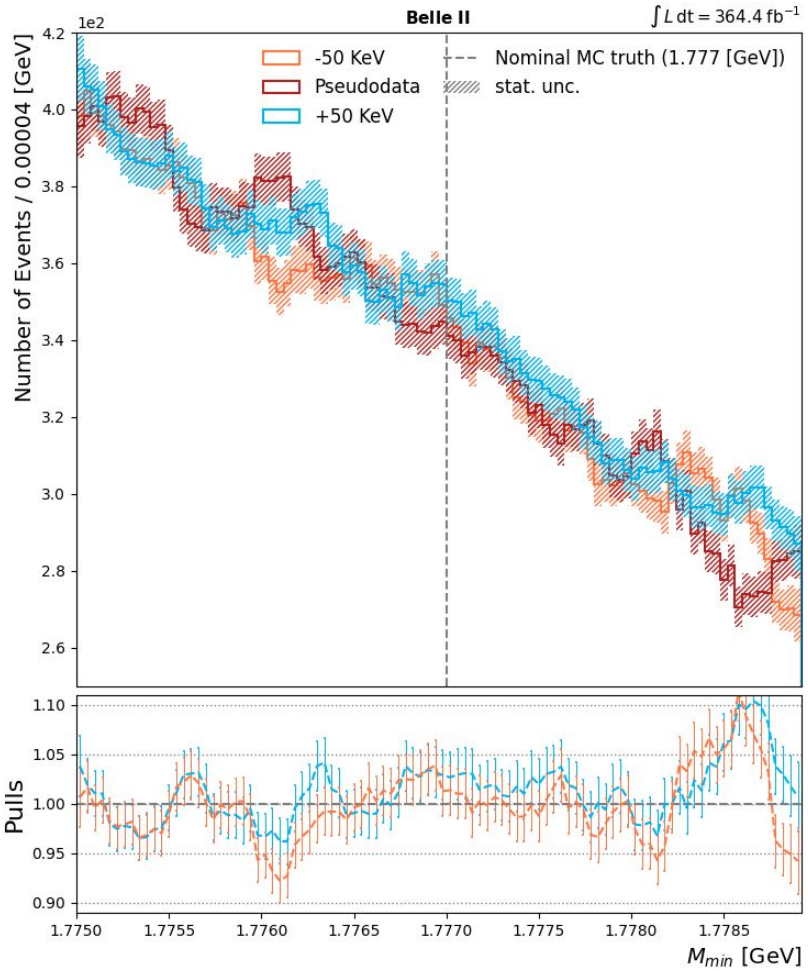


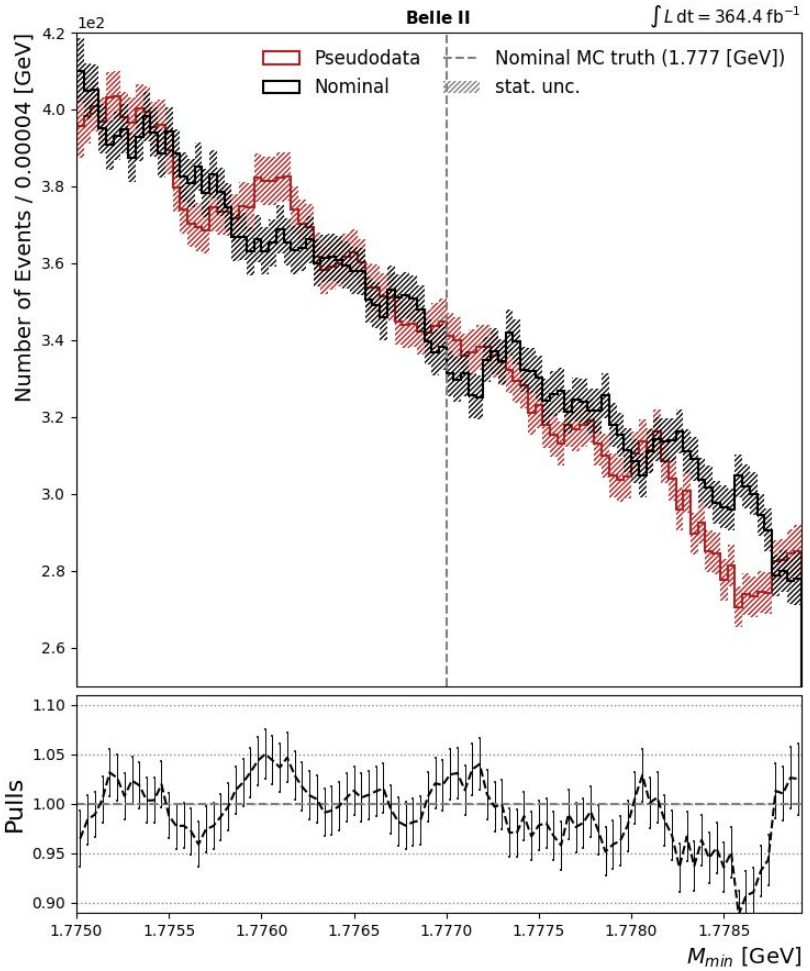


Template in MVA

➡ 40 KeV Bins

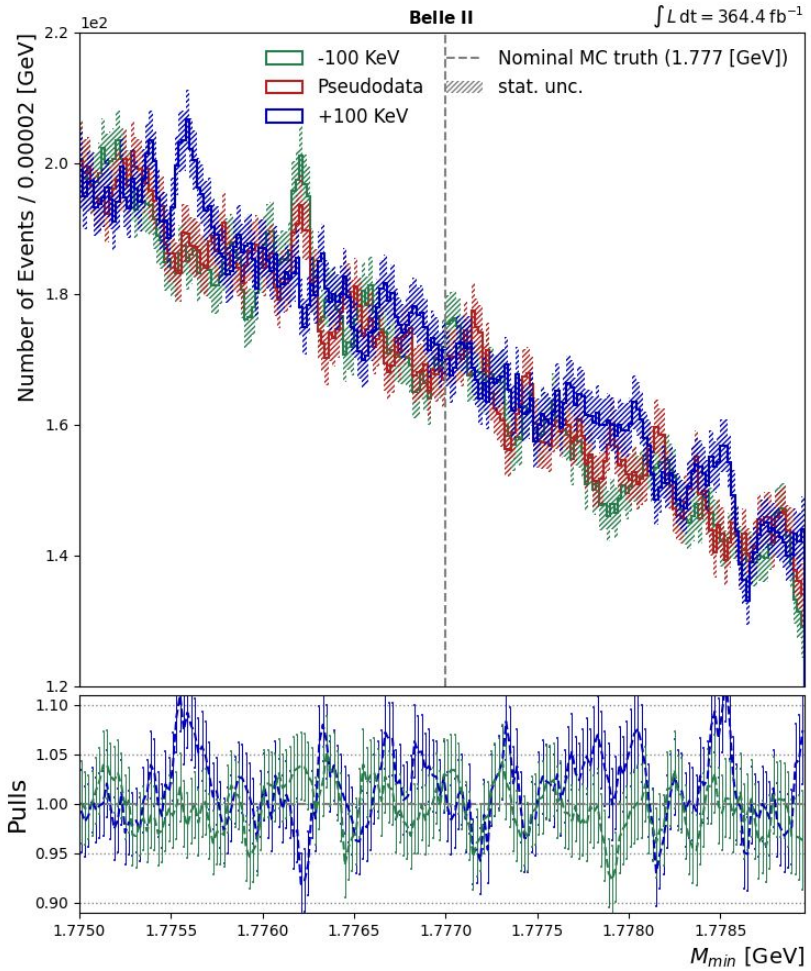


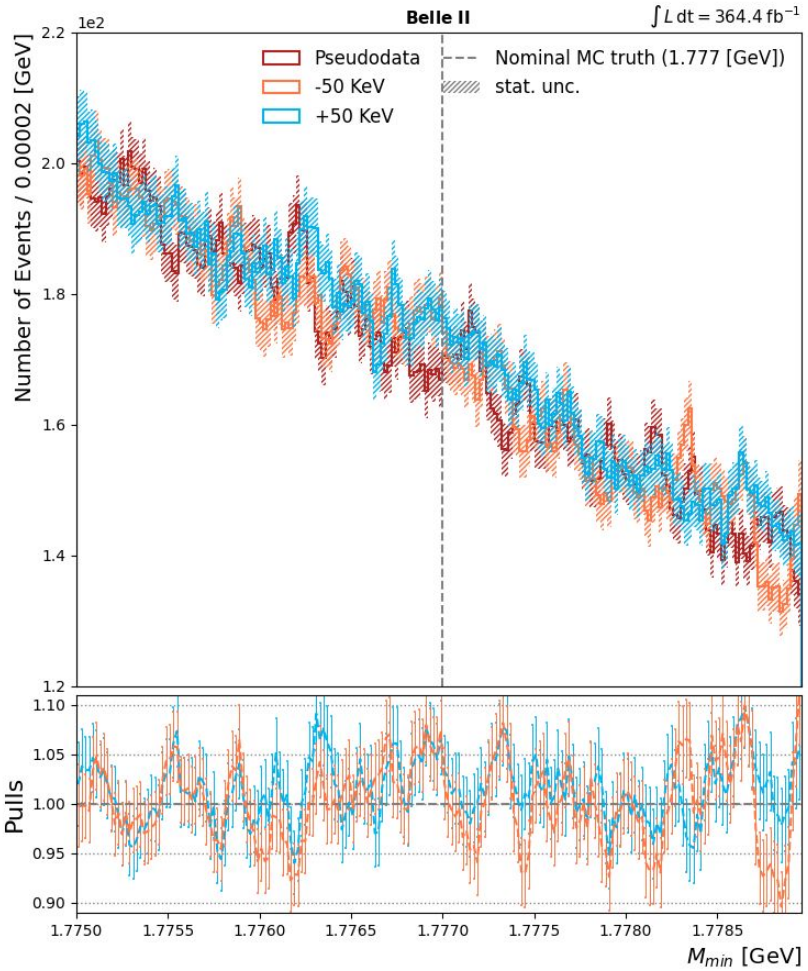


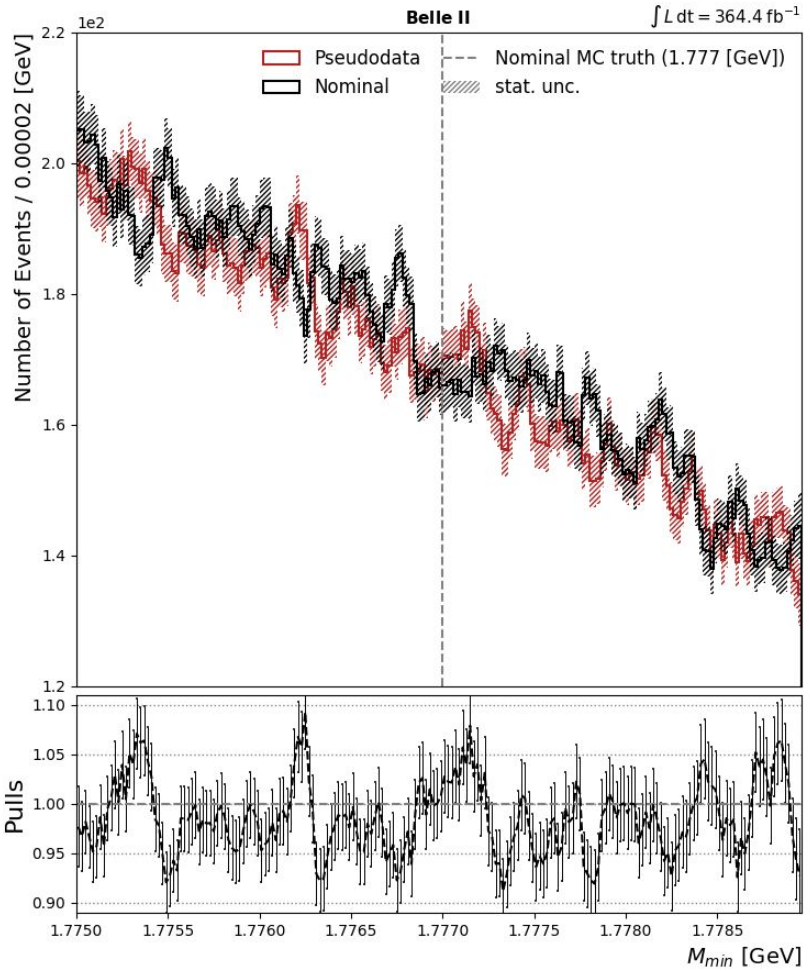


Template in MVA

➡ 20 KeV Bins







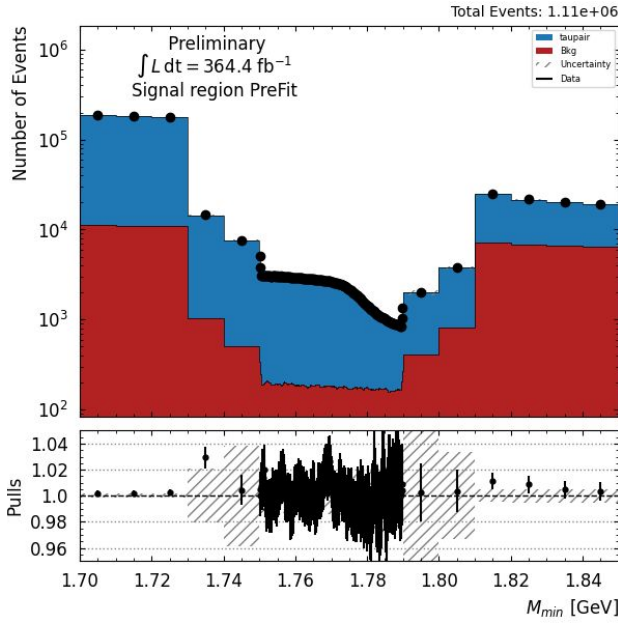
Template Fitting

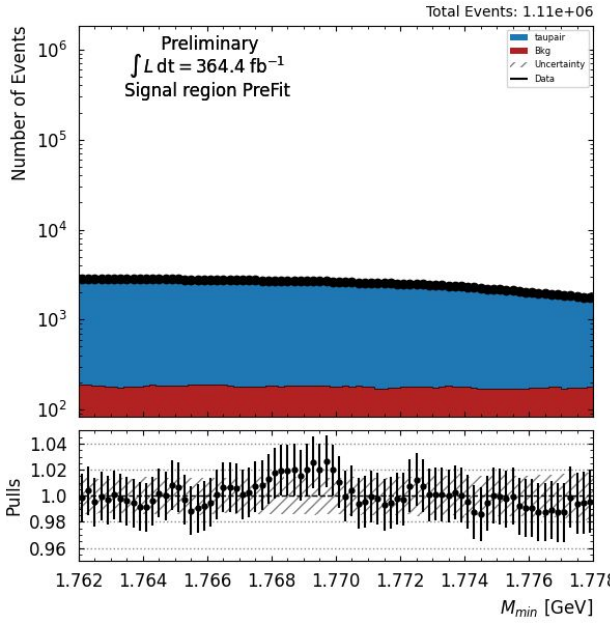
➡ 20 KeV Bins

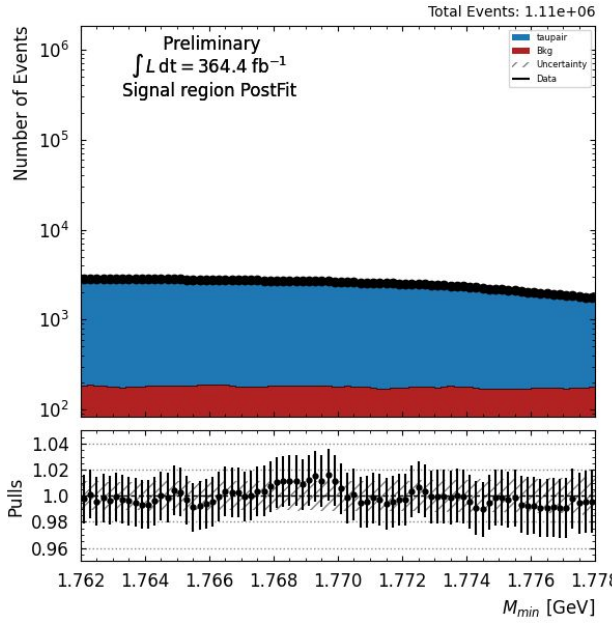
PreFit

PostFit

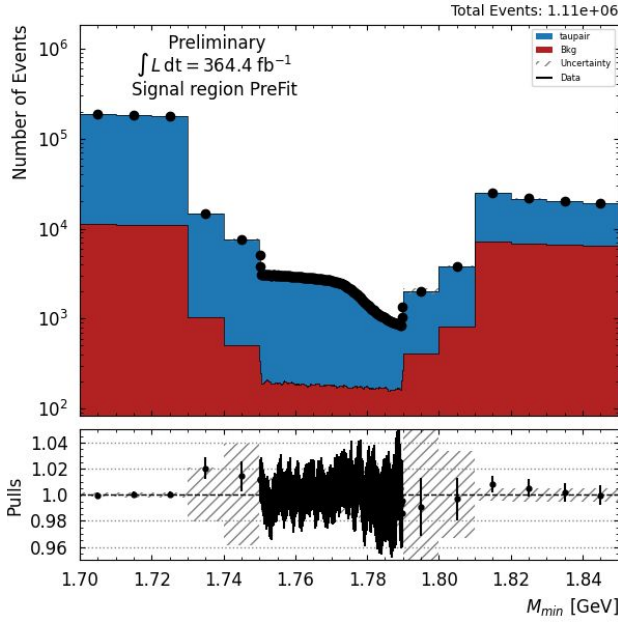
Nominal

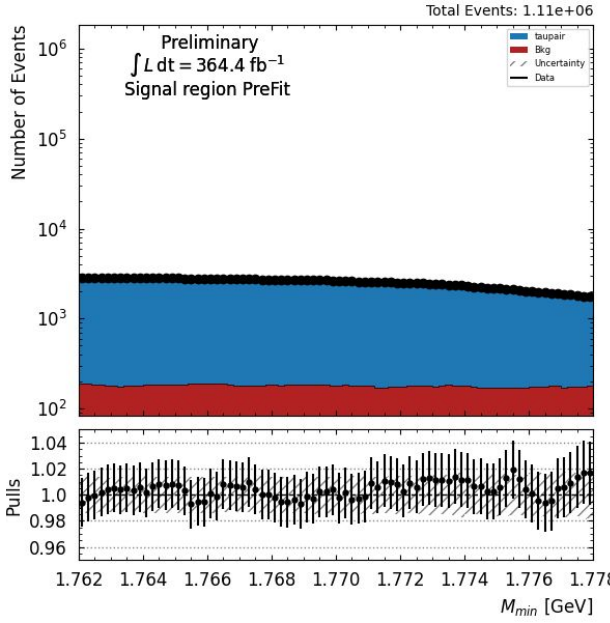


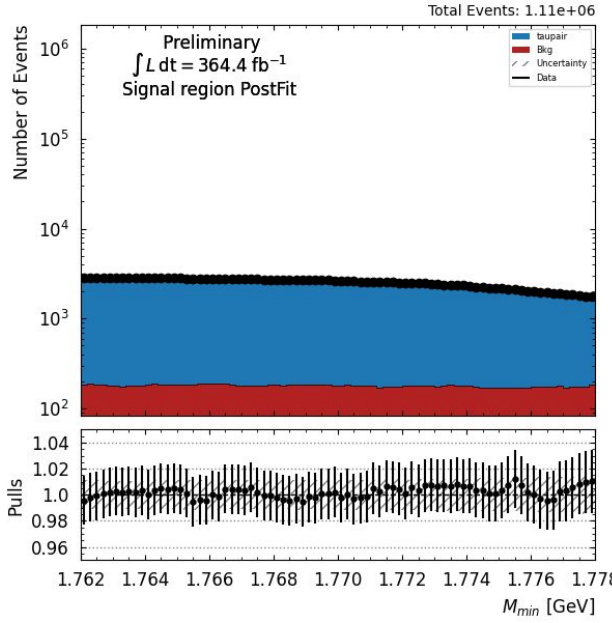




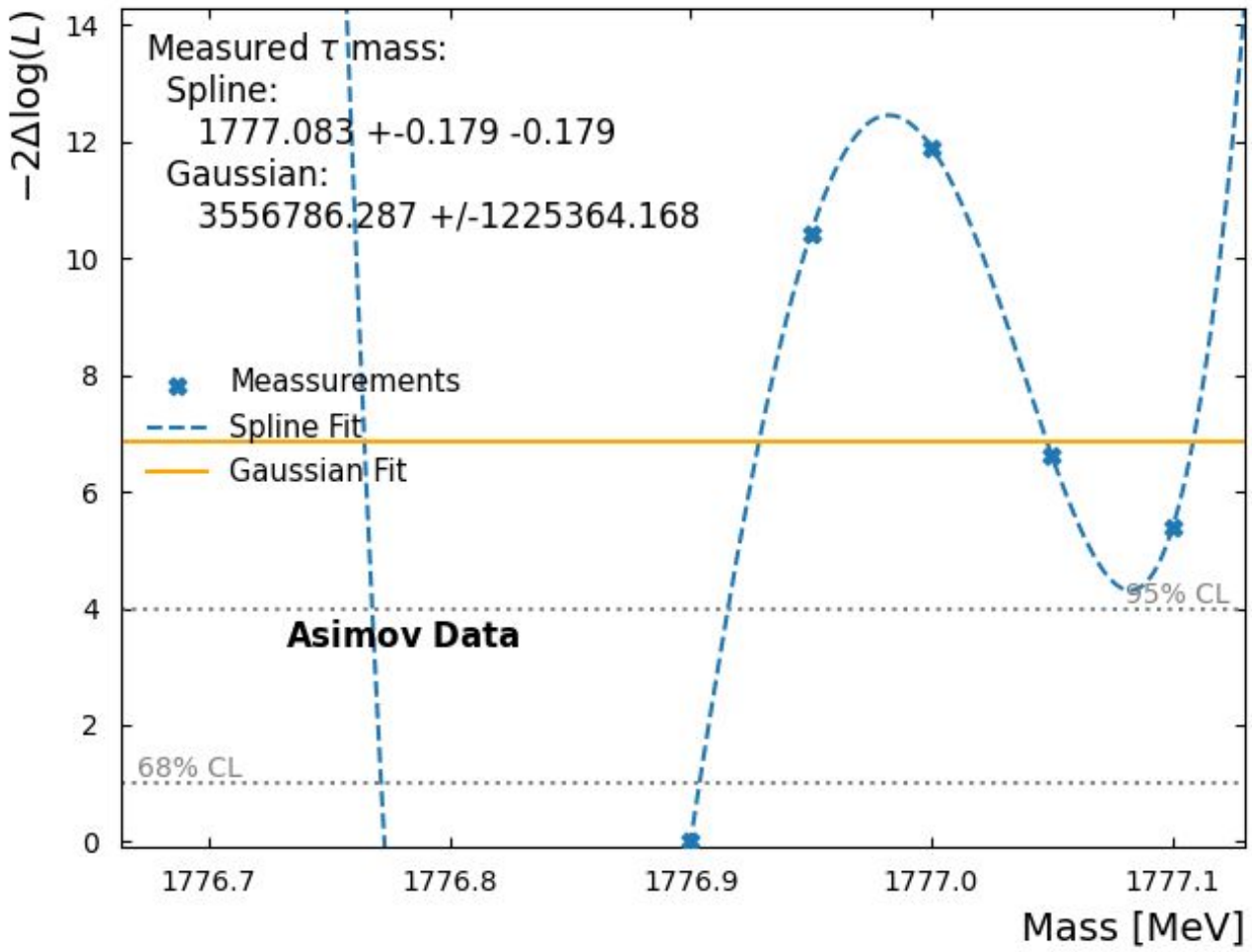
-100 KeV







Template Fitting with smoothed distributions ➡ 20 KeV Bins



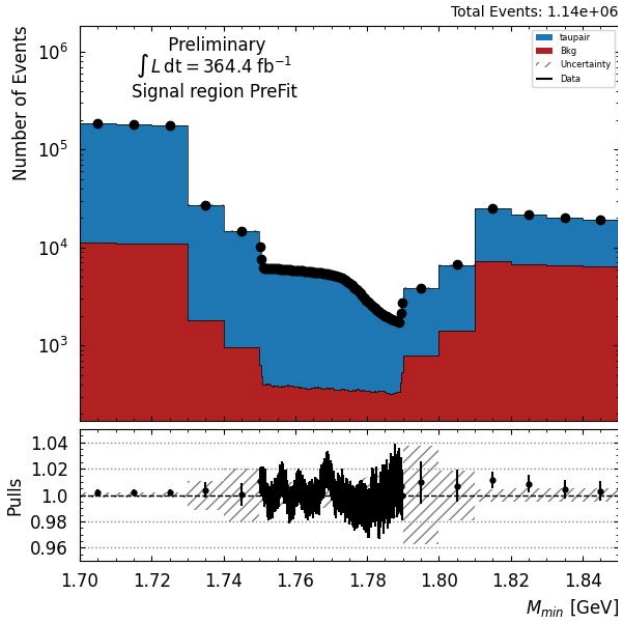
Template Fitting

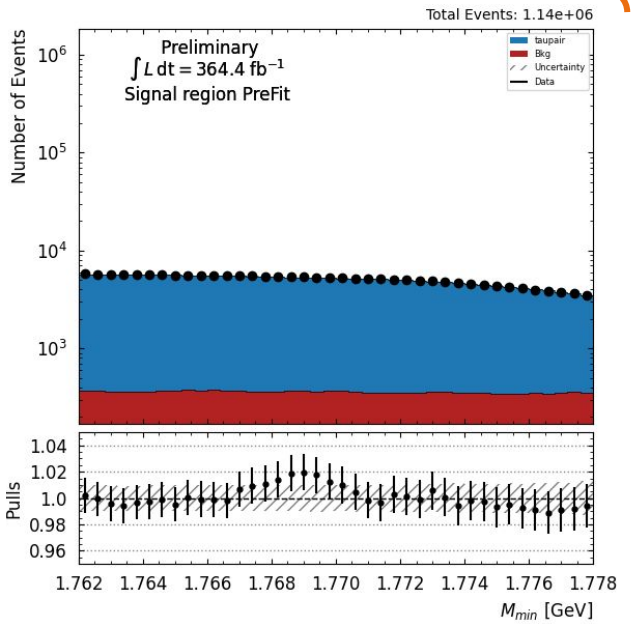
➡ 40 KeV Bins

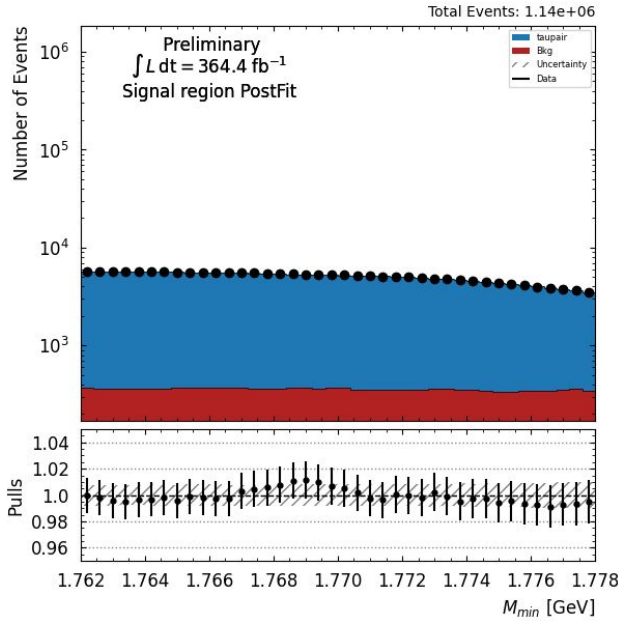
PreFit

PostFit

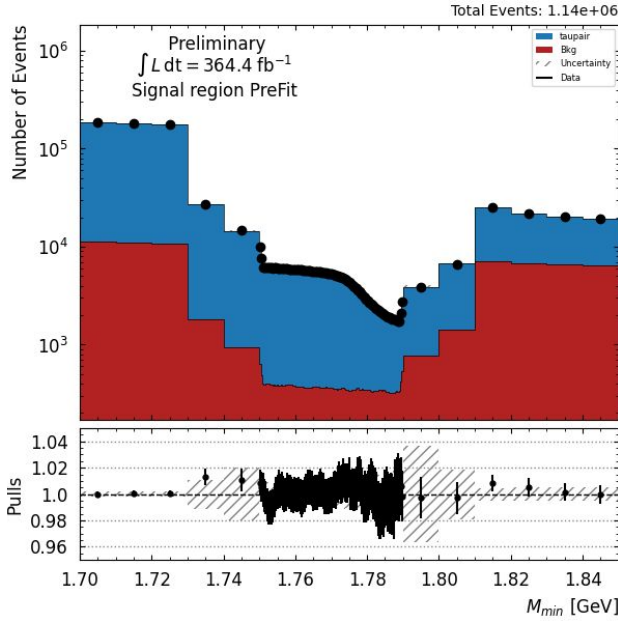
Nominal

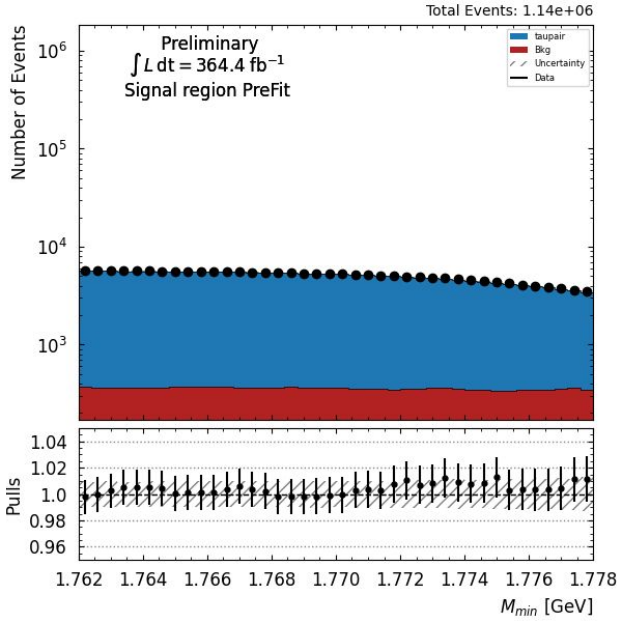


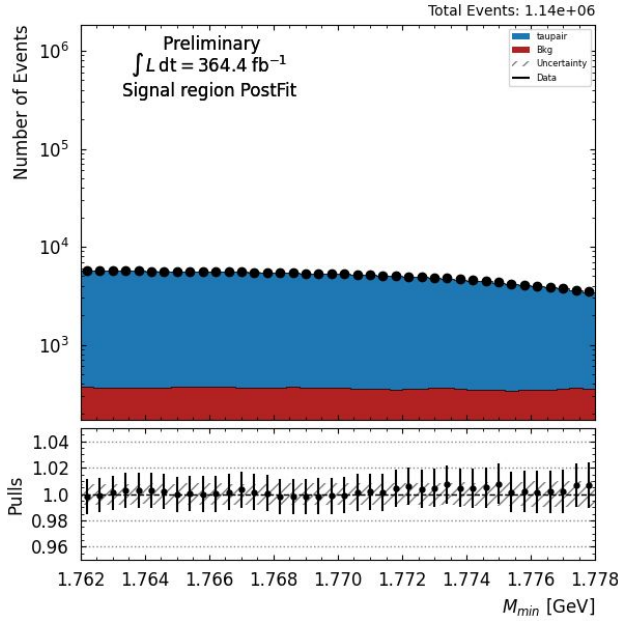




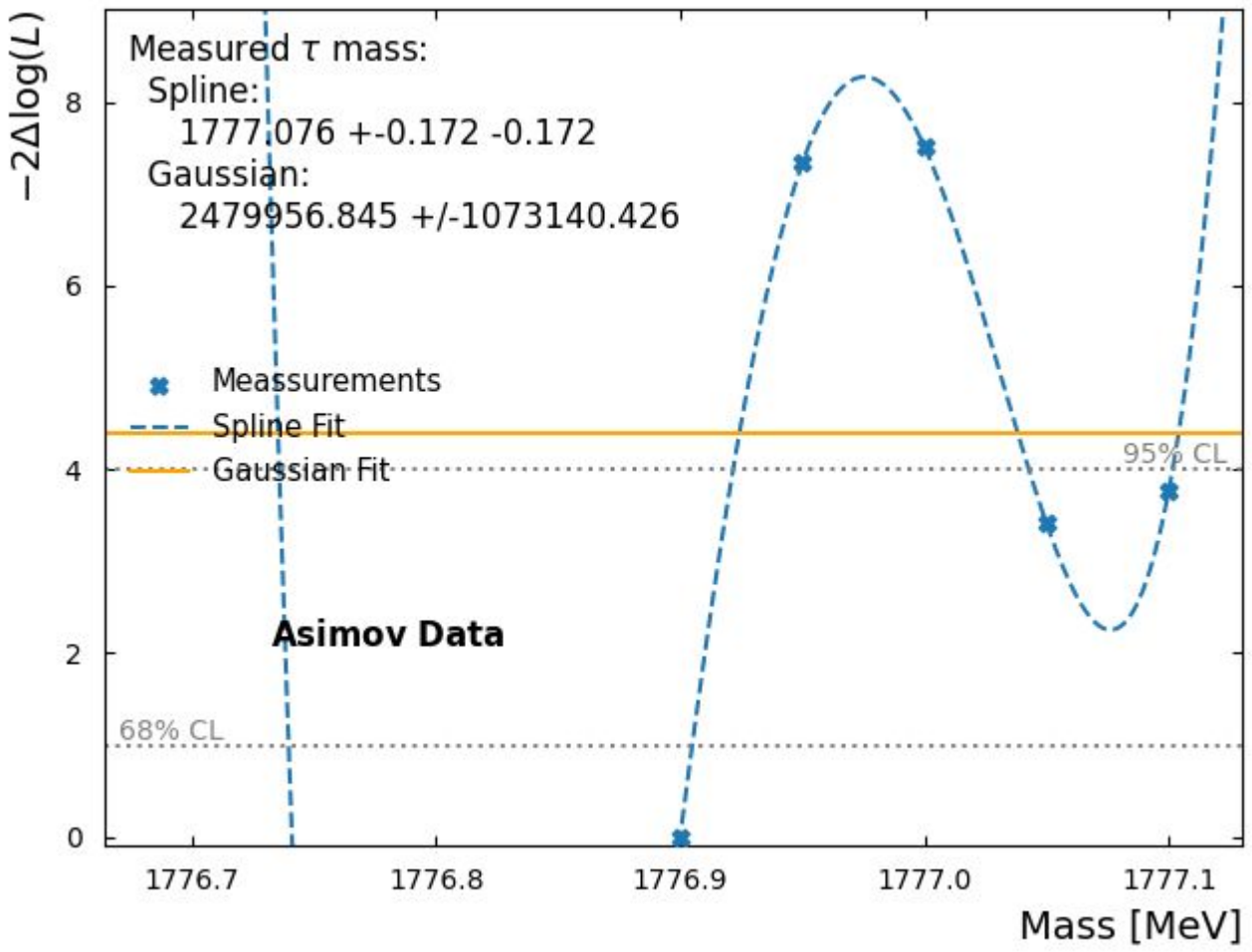
-100 KeV







Template Fitting with smoothed distributions ➡ 40 KeV Bins



Backup

Template Slide

```
Scale taupair Nominal sample to Templates 48.35%
NEvents (Not Weighted):
      taupair_m100:  3670414
      taupair_m50:  3670834
      taupair_p50:  3677471
      taupair_p100:  3674045
      PseudoData:  3670691
Template Mean: 3672691.0
Nominal:  3672152
Scale diff 1.00

NEvents (Weighted):
      taupair_m100:  1918179.5448214835
      taupair_m50:  1918399.039246043
      taupair_p50:  1921867.5737598555
      taupair_p100:  1920077.1263823775
      PseudoData:  1917631.9134186548
Template Mean: 1919231.04
Nominal:  1916651.84
Scale diff 1.00
```

```
New_binning = np.concatenate([
                    np.arange(1.7,1.75,0.01)[:-1],
                    np.arange(1.75,1.79,0.0004)[:-1],
                    np.arange(1.79,1.85,0.01),
                    ])
```

Source	Uncertainty [MeV/c^2]
Knowledge of the colliding beams:	
Beam-energy correction	0.07
Boost vector	< 0.01
Reconstruction of charged particles:	
Charged-particle momentum correction	0.06
Detector misalignment	0.03
Fit model:	
Estimator bias	0.03
Choice of the fit function	0.02
Mass dependence of the bias	< 0.01
Imperfections of the simulation:	
Detector material density	0.03
Modeling of ISR, FSR and τ decay	0.02
Neutral particle reconstruction efficiency	≤ 0.01
Momentum resolution	< 0.01
Tracking efficiency correction	< 0.01
Trigger efficiency	< 0.01
Background processes	< 0.01
Total	0.11

Template Fitting

Generate Templates from the Full Nominal taupair sample

```
template_df[Template]["Mmin"] = df["taupair"]["Mmin"]
                +(n*0.000_05+0.000_001*np.random.Normal(0, 1, size=len(template_df[Template])))
```

N* 50 KeV

+/- 2 KeV

To Test:

Template Fitting with:

- Full MC Statistics (1455.05 fb^{-1})
- 250M Events (234.69 fb^{-1})
- 750M Events (704.57 fb^{-1})

Data ➡ 361.924 fb^{-1}

Templates Generated for ±50, ±100, ±150 [KeV]

Selection Definitions

2023 Belle II Tau mass selection (a.k.a. Cut Based)

$1.7 \leq M_{min} \leq 1.85$

$N_{\gamma}^{1-prong} = N_{\gamma}^{3-prong} = 0$

$N_{\pi^0}^{1-prong} \leq 1$

$N_{\pi^0}^{3-prong} = 0$

$Thrust \in [0.87, 0.97]$

$E_{vis}^{CMS} \in [2.5, 9]$

$\theta_{miss}^{CMS} \in [0.5, 2.7]$

$M_{miss}^2 \in [0, 54]$

$p_{miss}^{CMS} \in [0.05, 3.5]$

$p_T \, {}^{3-prong}_{Leading} >= 0.6 \; GeV$

$p_T \, {}^{3-prong}_{Subleading} > 0.2 \; GeV$

$p_T \, {}^{3-prong}_{trailing} >= 0.1 \; GeV$

MVA Training Selection

$1.6 < M_{min}$

$Thrust \in [0.87, 0.97]$

$M_{miss}^2 \in [0, 54]$

$E_{vis}^{CMS} \in [4, 9]$

Template Slide

-

Variable Distributions ➡ Training Sample Cuts

Navid's

Raimundo's

1-prong Number of photons

Template Slide

First

Second

Template Slide

- After correcting a

Mass peak Fit PDF Selection Systematic

- Put the mass fits and explain how the error is calculated

Skewed student T

Bifurcated Gaussian

Template Slide

First

Second

Second

Template Slide

First

Second

A

B

Template Slide

Data

MC

- Template

Template Slide

- Template

Cos(θ)

Momentum

Data

MC

Template Slide

	Backward	Central	Forward
A			
B			

Backward

Backward

Backward

3-prong
leading pt

2D Reweighting

3-prong leading pt

Before

After

+3* Reweight Error

Normal Fitting

➡ 250M Events

	-150 KeV	-100 KeV	-50 KeV	Nominal	+50 KeV	+100 KeV	+150 KeV
Uncorrected [KeV]							

- Scalar correction: 621.32 +/- 38.11 [KeV]

PDG τ Mass: 1776.930+/-0.090 [MeV]

Template Fitting ➡ Cut Based

250M Events

750M Events

Full MC (~1550M Events)

PDG τ Mass: 1776.930+/-0.090 [MeV]

Template in MVA

➡ 20 KeV Bins

Normal Fitting ➡ MVA - Simple Model

	-100 KeV	-50 KeV	Nominal	+50 KeV	+100 KeV
Uncorrected [KeV]					

➡ **250M Events**

Average $\chi^2=$

	-100 KeV	-50 KeV	Nominal	+50 KeV	+100 KeV
Uncorrected [KeV]					

➡ **Scaled to Data**

Average $\chi^2=$

	-100 KeV	-50 KeV	Nominal	+50 KeV	+100 KeV
Uncorrected [KeV]					

➡ **750M Events**

Average $\chi^2=$

	-100 KeV	-50 KeV	Nominal	+50 KeV	+100 KeV
Uncorrected [KeV]					

➡ **Full MC**

Average $\chi^2=$

PDG τ Mass: 1776.930+/-0.090 [MeV]

Template Fitting

PreFit

PostFit

Nominal

-100 KeV