Validation of background contributions for tau pairs at Belle II

Tsovinar Karapetyan (AANL)

Supervisor: Michel Villanueva (DESY)

The Belle II experiment

- Belle II is a detector coupled to the SuperKEKB accelerator.
- It collides electrons and positrons to produce B-mesons
- In the collision also tau pairs are produced, providing a good environment for the study of tau physics.

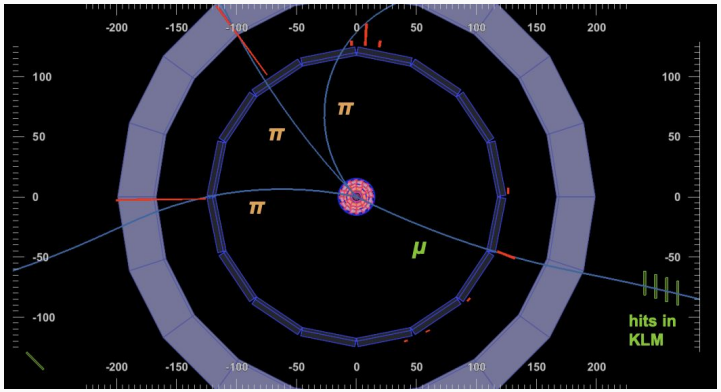
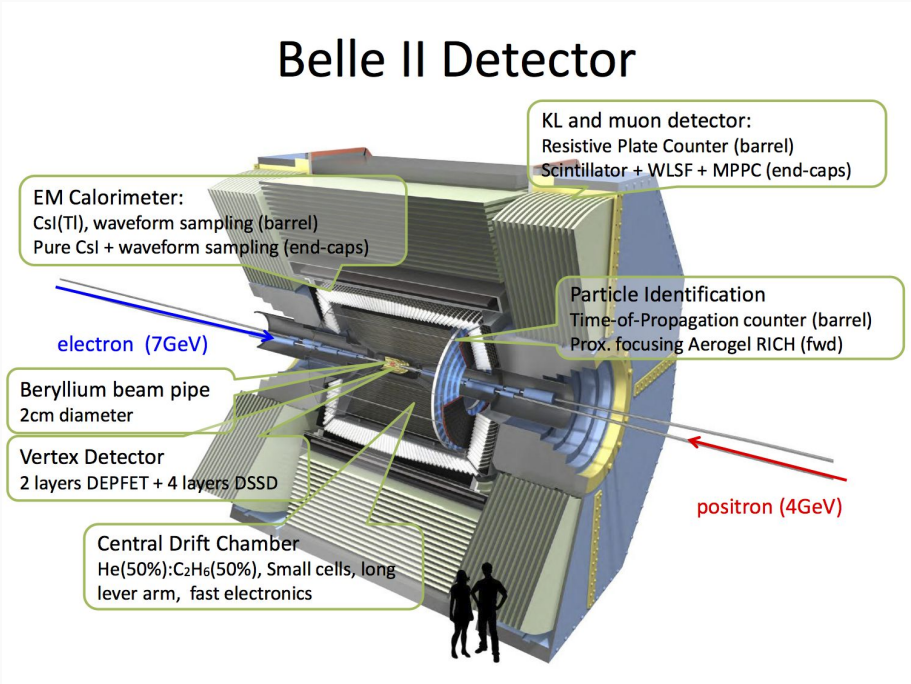


Figure: A pair of tau leptons decaying at Belle II.



Background contribution in tau analysis

Tau pair analyses require to account properly the contamination of non-tau sources, such as

- $q\bar{q}$, q = {u,d,s,c}
- Two-photon events {eehh, eell}
- Bhabha

In a precision measurement the background contributions must be accounted properly.

In particular, we must ensure that the simulation describes correctly the production of all kind of events.

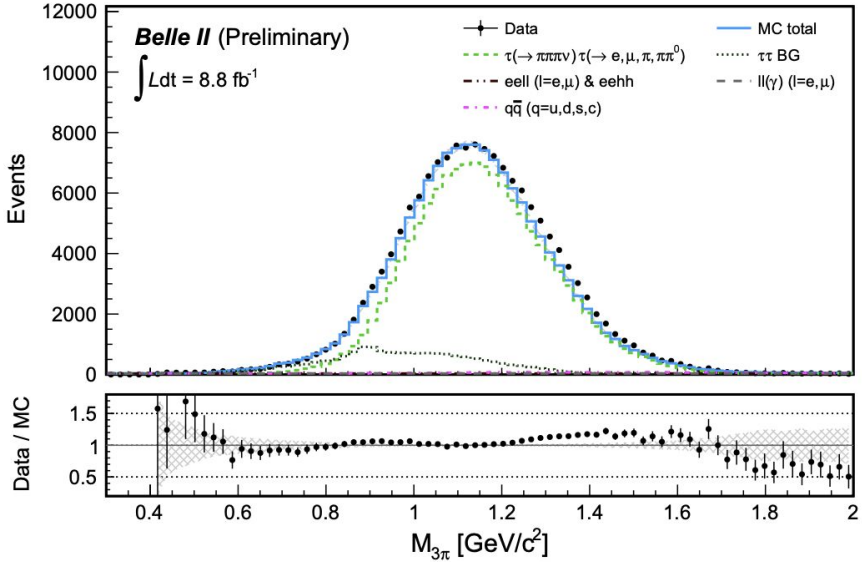
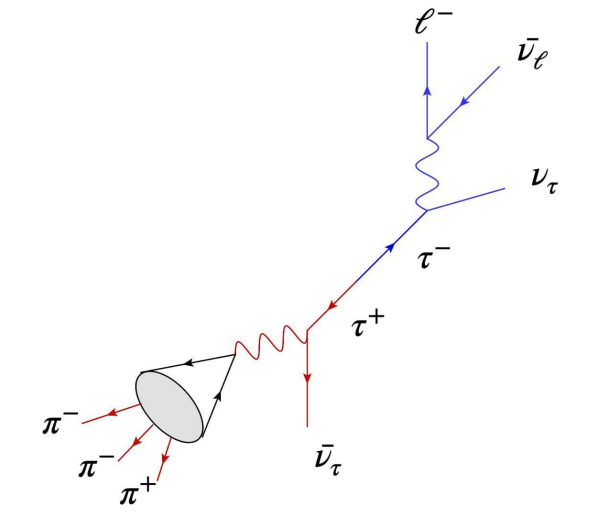


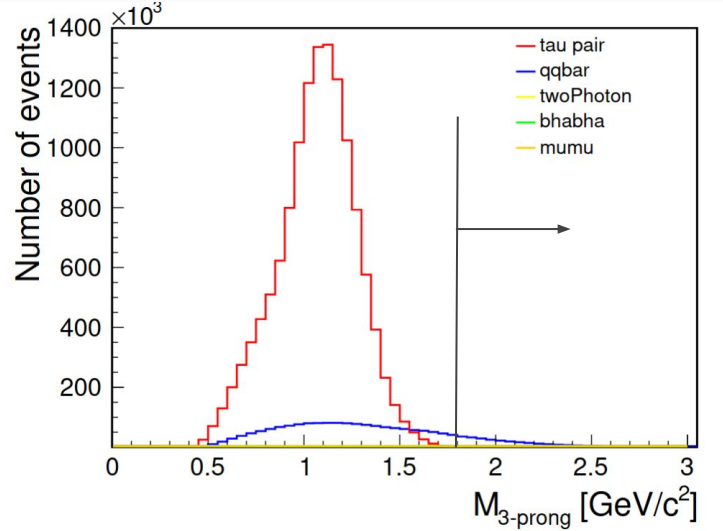
Figure: Invariant mass of 3 pions coming from a tau lepton produced at Belle II (arXiv:2008.04665)

Event selection

- We apply a selection criteria to reconstruct the topology of 3 charged tracks in one side and 1 charged track in the other side.



- To make the data vs MC comparison in a region dominated for the contribution of qqbar events, we apply a cut in the invariant mass of the tag side M > 1.8 GeV.



Events after selection

Distribution of the momentum in the 1 track side at 100 fb^{-1} after applying M > 1.8 GeV in the 3 track side.

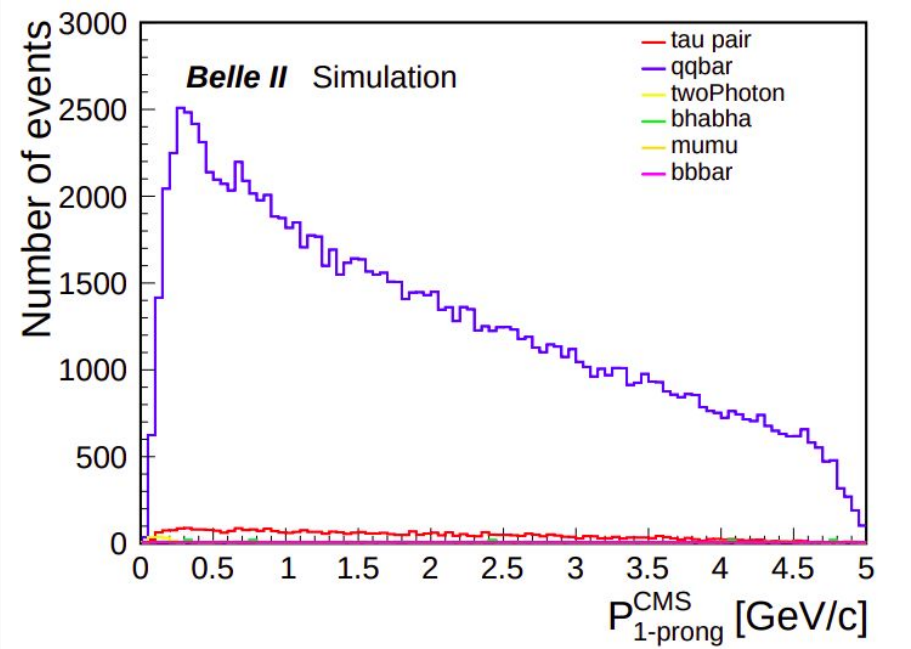


Table with number of events at 8.76 fb^{-1}

Event type	Number of events
qqbar	10931 +/- 31
Tau pair	395 +/- 6
twoPhoton	46 +/- 2
bhabha	4 +/- 1
BBbar	5 +/- 1
mumu	13 +/- 1

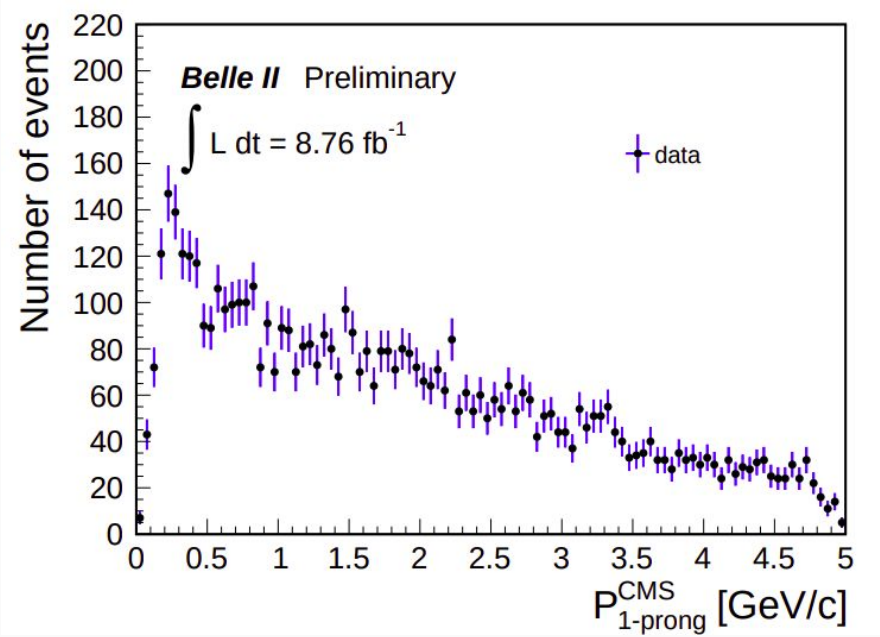
Estimation of the correction factor

We make the comparison of the events between MC and data recorded by Belle II

Correction factor

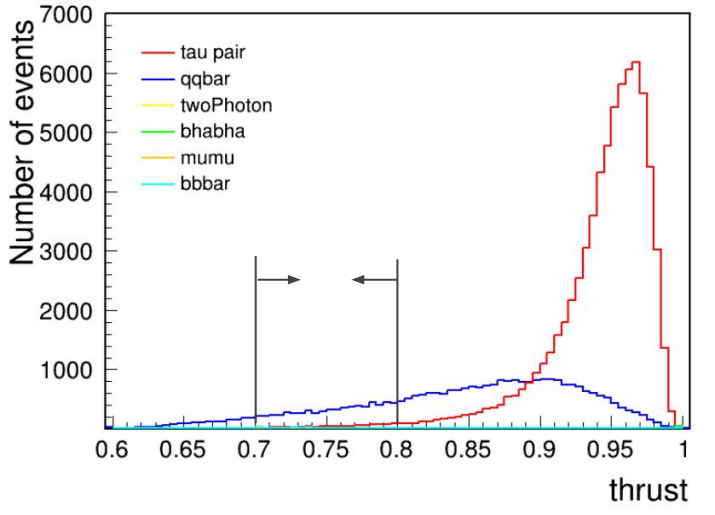
$$f_{qq} = \frac{N^{data} - N^{MC}_{non-qq}}{N^{MC}_{qq}}$$

$$f_{qq} = \frac{5935 \pm 77 - 457 \pm 6}{10931 \pm 31} = 0.501 \pm 0.007$$

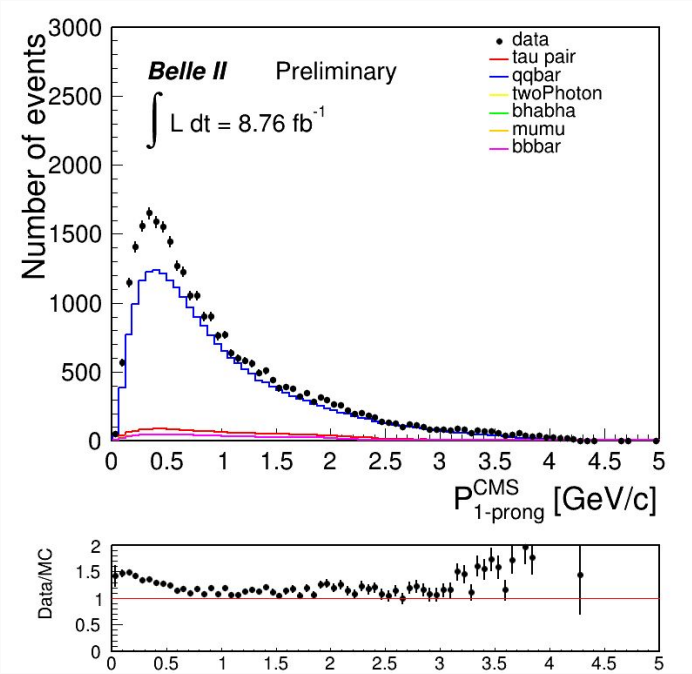


Validation of the scale factor

To validate the scale factor we make a new selection of thrust between 0.7 and 0.8. Then we make the data vs MC comparison with the scale factor applied.



After applying the correction factor the agreement between data and MC is better after 0.5 GeV.



Conclusions

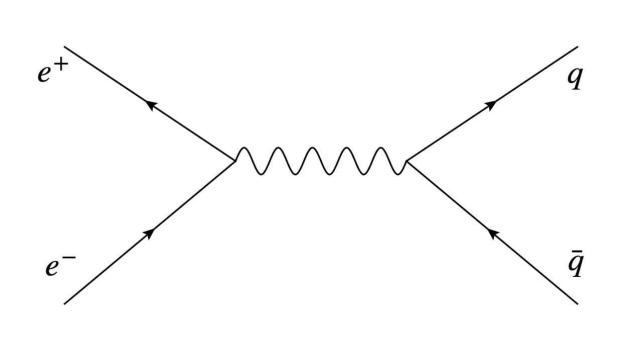
- We have applied a selection for tau pair in regions where qqbar expected to be the main contribution.
- For the determination of correction factor we use a dataset with invariant mass of tag side larger than 1.8 GeV.
- We have determined that the correction factor of qqbar is 0.501 +/- 0.007.
- To validate the correction factor we use an independent dataset with thrust between 0.7 to 0.8.
- In the validation we found a good agreement for the momentum of the 1prong track after 0.5 GeV/c^2.
- From 0 up to 0.5 GeV/c^2 agreement is not good. Further investigation is required.

Thank you

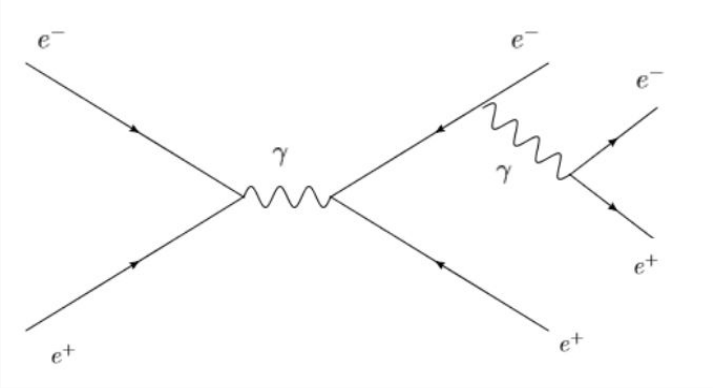
Backup

Sources of background in tau pair reconstruction

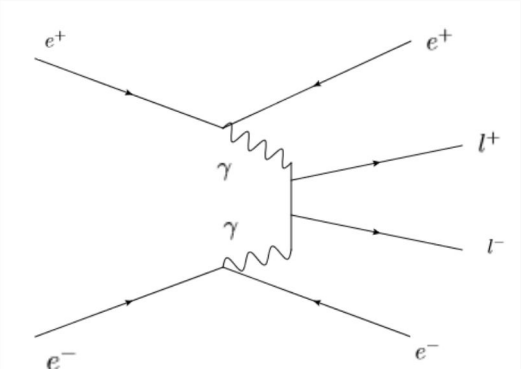
qqbar



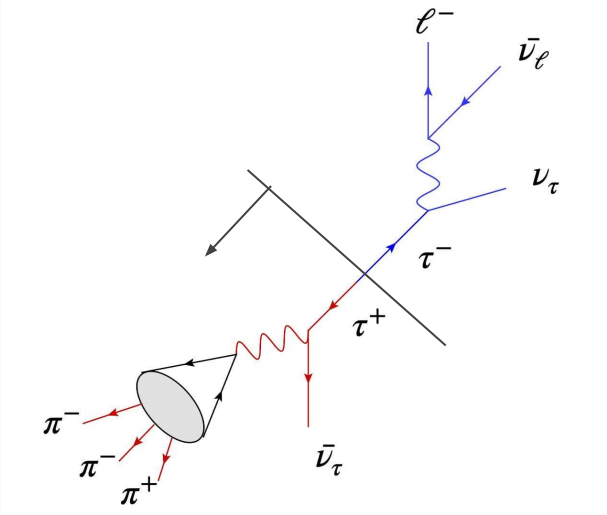
Bhabha



TwoPhoton



Event selection



3x1 prong decays of tau:
Signal: 1 track
Tag: 3 tracks

Tracks:
|dr| < 1 cm
-3 < dz < 3 cm

We apply scale factor for tracks 0.99976

3 prong:
0 < Tracks E/P < 0.8

Event Selection
0.9 < thrust < 0.99
2.5 < Visible CMS Energy < 10.2 GeV

We require that events fire lml triggers.

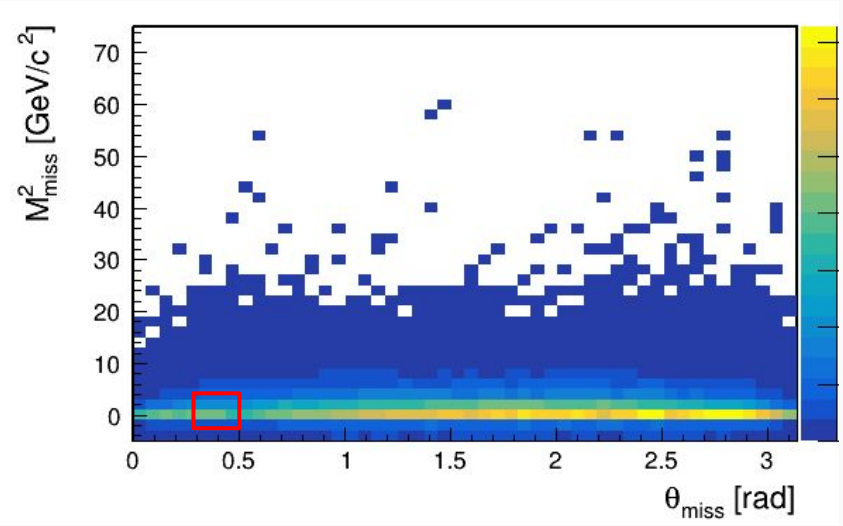
[f"lml{i}" for i in (1, 2, 4, 6, 7, 8, 9, 10, 12)]

Additional cuts

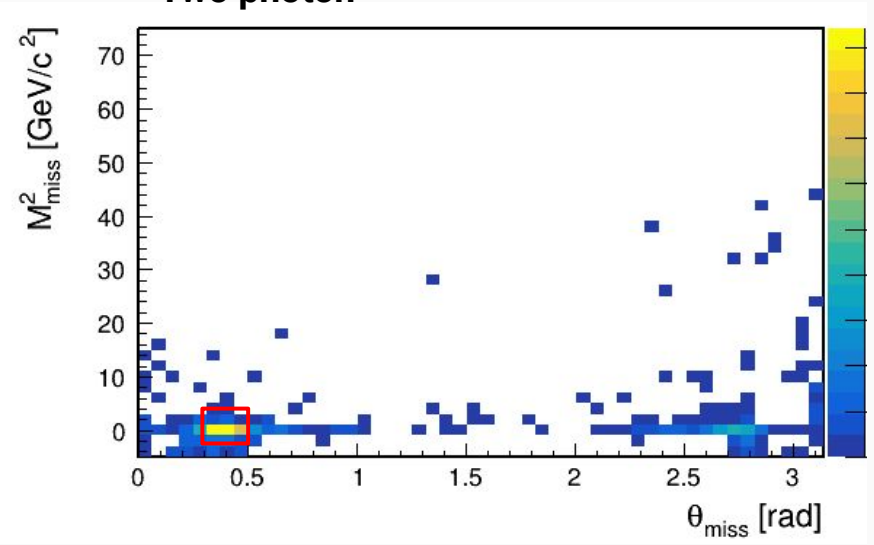
0.3 < Theta of missing momentum in CMS > 0.5
missing mass squared < -1 GeV^2
missing mass squared > 2 GeV^2

We are removing events inside the red box for cleaning Twophoton

qqbar



Two photon



Events scale to the data luminosity of 8.76 fb^{-1}

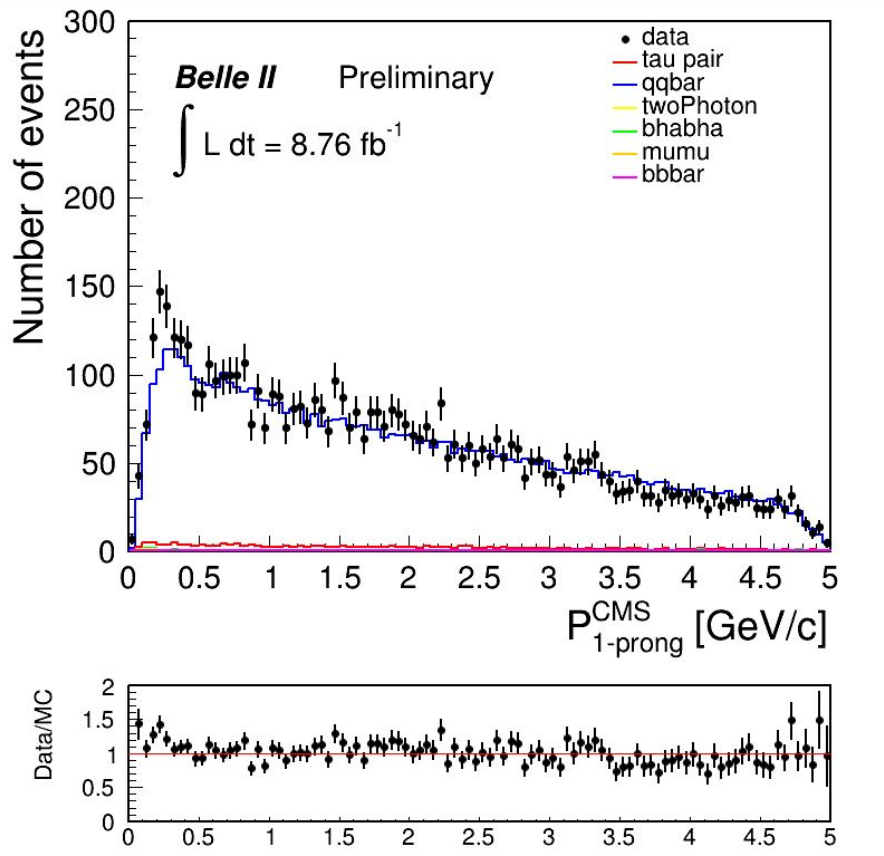
Table with number of events at 100 fb^{-1}

Event type	Number of events
qqbar	124778 +/- 353
Tau pair	4511 +/- 67
twoPhoton	522 +/- 23
bhabha	41 +/- 6
BBbar	58 +/- 8
mumu	147 +/- 12

Table with number of events at 8.76 fb^{-1}

Event type	Number of events
qqbar	10931 +/- 31
Tau pair	395 +/- 6
twoPhoton	46 +/- 2
bhabha	4 +/- 1
BBbar	5 +/- 1
mumu	13 +/- 1

Data vs MC after correction factor

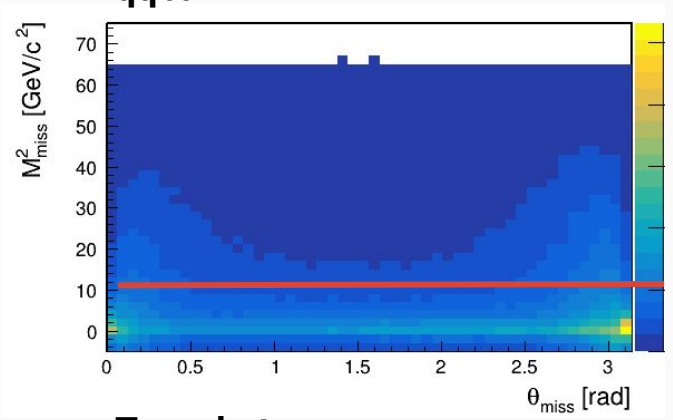


This is the distribution of data vs MC after applying correction factor. Agreement in distributions is good. Here we use events that are above 1.8 GeV in the invariant mass of the tag side.

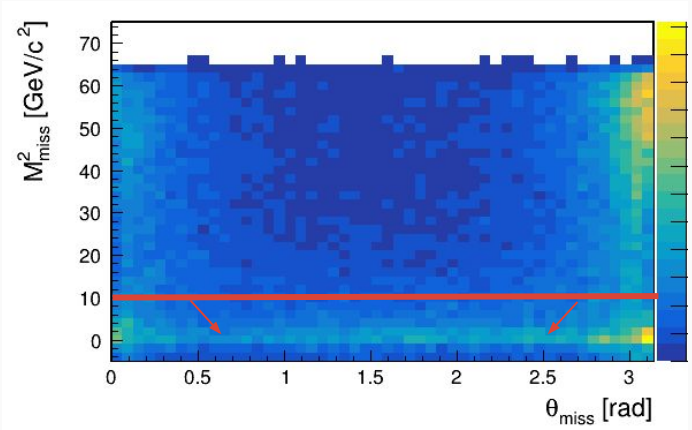
Additional cuts on validation sample

There is contamination of events from an unknown source on the region of large missing invariant mass. We apply a cut of $M^2_{miss} < 10\ GeV^2$ to remove such events.

qqbar



Data



Two photon