Semi-tauonic group meeting: Progress on the search of $B^0 \to \pi^- \tau^+ \nu_\tau$ at Belle II

Leonardo Benjamin Rizzuto

Supervisor: Prof. Boštjan Golob

Institut Jožef Stefan and University of Ljubljana

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University *of Ljubljana*
Faculty *of Mathematics and Physics*

Outline:

- Introduction (very brief!)
- Description of my first (preliminary) working example tested on MC signal samples and the two developed approaches developed so far
- Some results obtained with this approaches
- Questions about some not well understood variables
- Conclusions

(Very brief) introduction to this decay channel

Motivation:

- Very interesting semitauonic decay channel that could be used as a crosscheck for testing LFU
- Still no evidence was obtained for it, but the first analysis performed with the full Belle data set (711 fb^{-1}) shows at least that the evidence is to be expected in the future: a significance of 2.4σ was reached and an upper limit at 90% CL was obtained (Belle, Phys. Rev. D 93, 032007 (2016)).

The Belle analysis was performed with the ancestor of FEI algorithm: Full Reconstruction algorithm.

- Hadronic tagging
- Signal side reconstructed in:
  - $\tau \rightarrow \rho \quad \nu_\tau$
  - $\tau \rightarrow e \quad \nu_e \quad \nu_\tau$
  - $\tau \rightarrow \mu \quad \nu_\mu \quad \nu_\tau$
  - $\tau \rightarrow \pi \quad \nu_\tau$

Study of the signal selection

I prepared a preliminary working example for signal side reconstructed only in $\tau \to e \quad \nu_e \quad \nu_\tau$.
Btag is reconstructed with FEI both hadronic and semileptonic.

Actually I have tried two different approaches until now:

Steps followed in the first code:

- After FEI tagging and just selecting the tracks for electrons and pions to construct a Bsig, combine Btag and Bsig to an Y(4S) candidate
- Only the Y(4S) candidates that satisfy the condition of no tracks left in their ROE are saved

In the second code developed I instead do the following:

- After FEI tagging I create the ROE of Btag in which I select the tracks for electrons and pions to construct a Bsig, with the condition that there must be not more than 2 Tracks in the Btag ROE
- combine Btag and Bsig to an Y(4S) candidate
- Construct ROE of Y(4S) and check that there are no tracks in it

Selection criteria

To reconstruct the Btags I was using the **feiv4_2018_MC9_release_02_00_01_phase3** FEI training

For Btag:

- hadronic: $Mbc > 5.273 \;\; GeV \;\; \&\& \; sigProb > 0.088$
- semileptonic: $|cosBY| < 1.175 \;\&\&\; sigProb > 0.095$

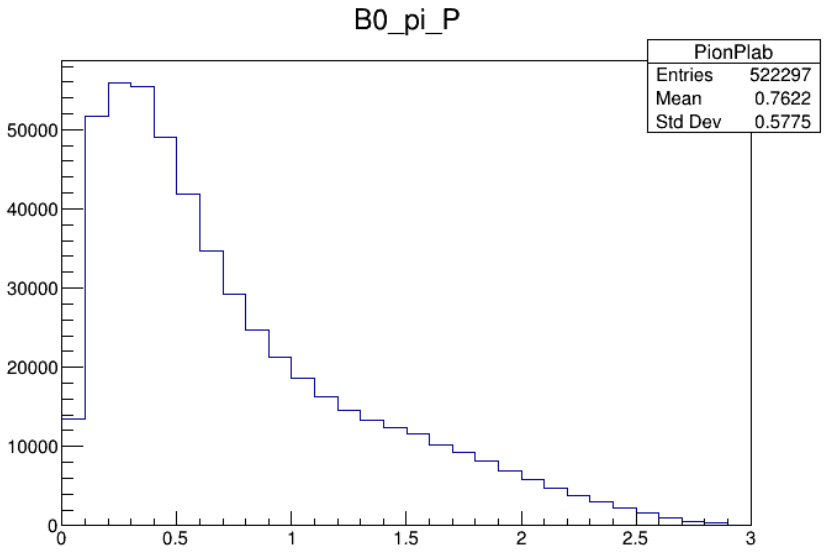
For Bsig:

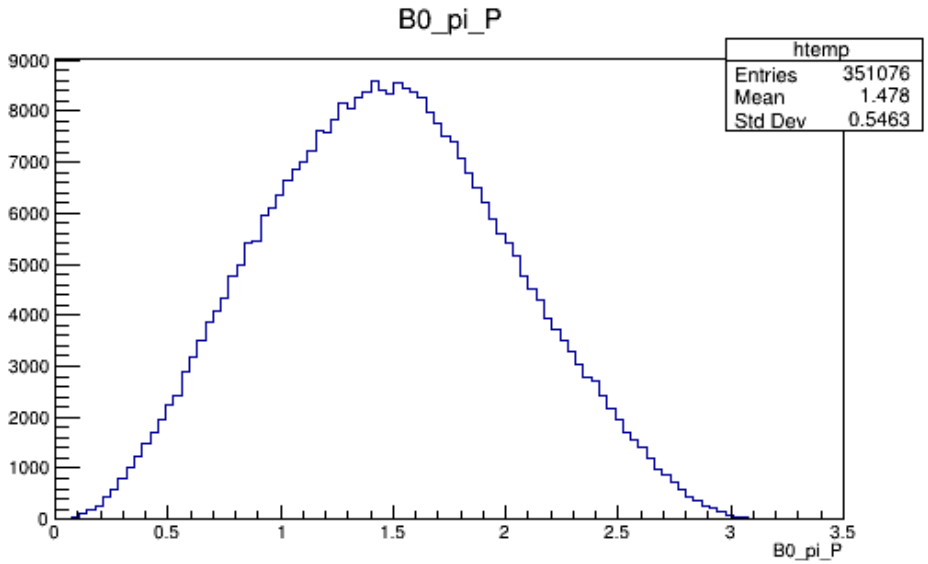
- Only tracks in impact region $dr < 2$ cm and $|dz| < 4$ cm are selected
- Pions with $pID > 0.5$ are selected
- Electrons with $eID > 0.9$ and $p_{lab} > 0.4 GeV$ are selected

Results obtained with the first approach

Run on $4 \cdot 10^5$ events MC9 BGx0 signal samples using release 02-00-00

Momentum in the lab frame





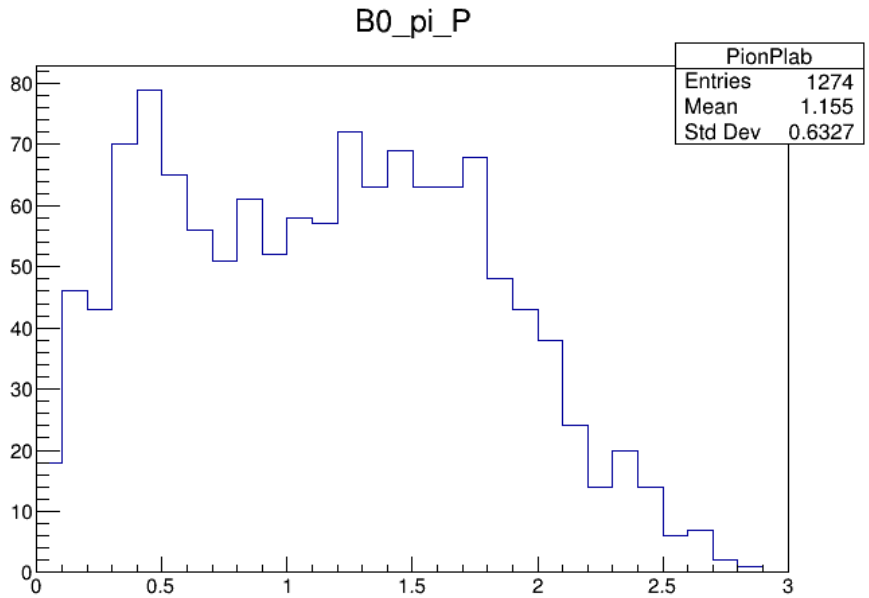
Bsig pions selected with this approach

Bsig pions at generator level

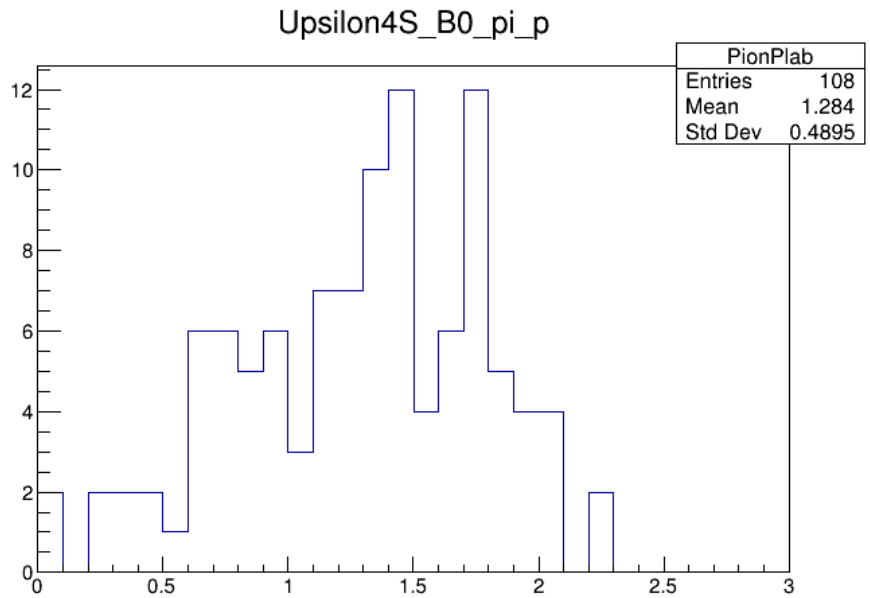
Results obtained with the second approach

Run on $4 \cdot 10^5$ events MC9 BGx0 signal samples using release 02-00-00

Momentum of Bsig pions selected with this approach in the lab frame



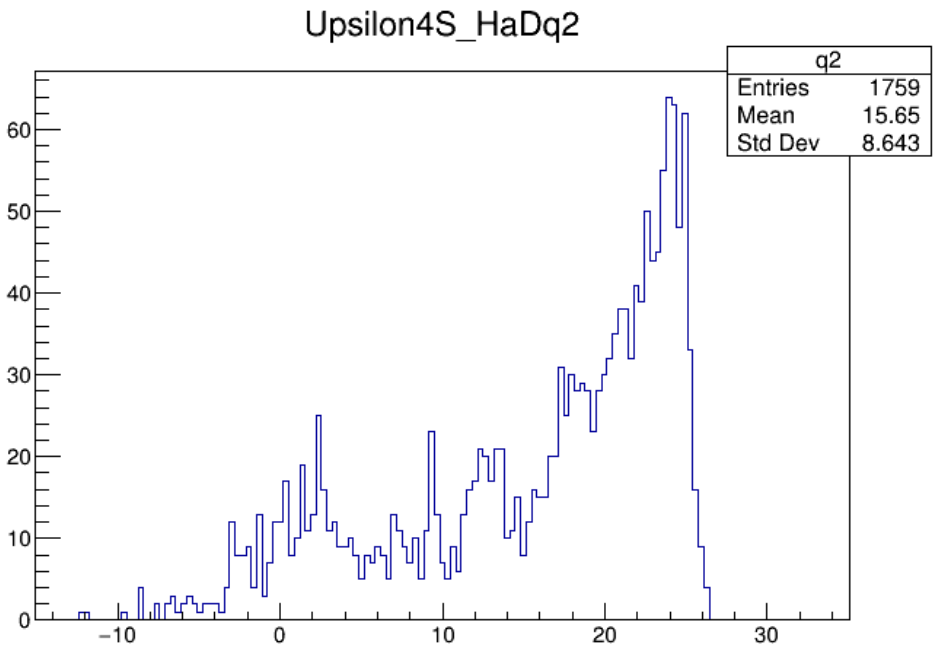
before combining Bsig with the Btag

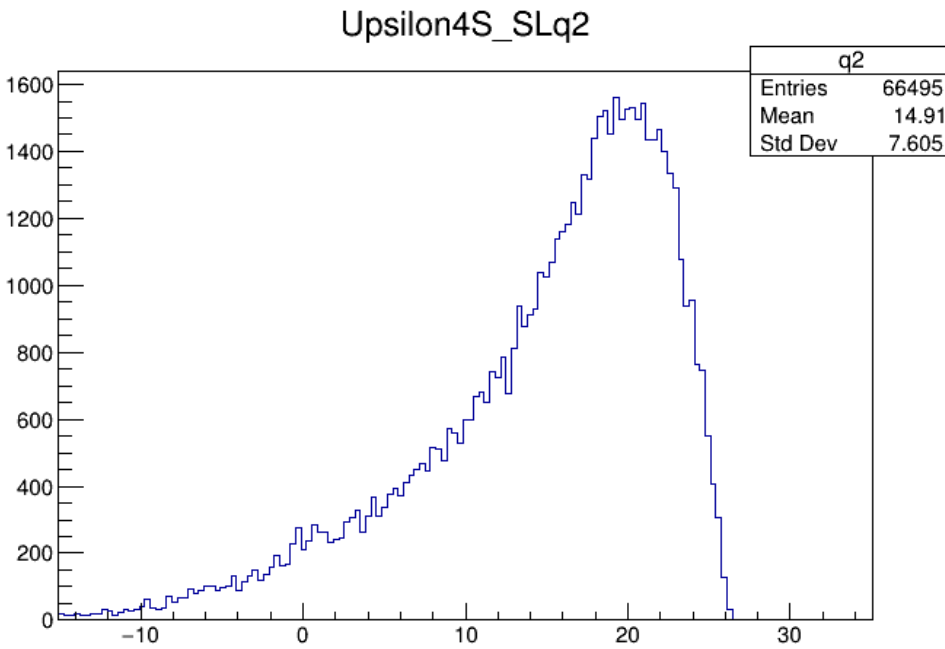


after combining Bsig with the Btag

Other variables: q^2

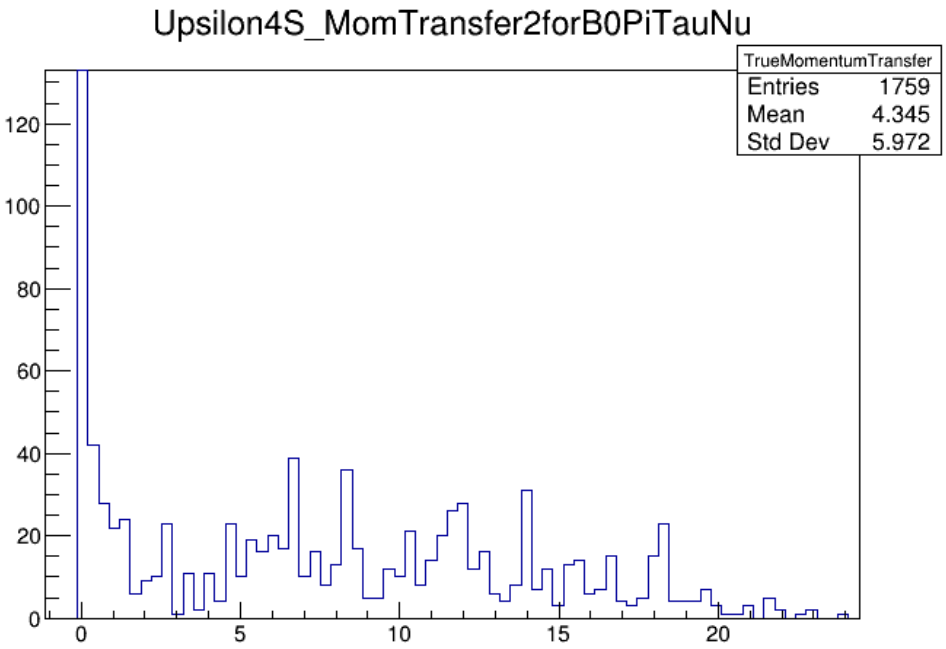
Defined in the same way as Racha's

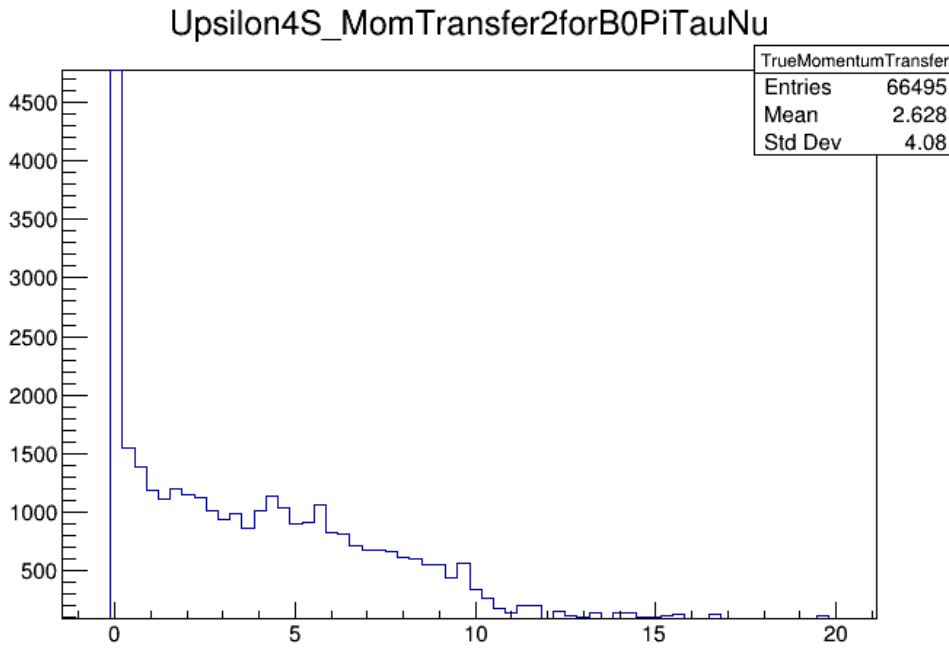




Other variables: mcMomTransfer2

Basf2 defined variable that calculates the true momentum transfer to lepton pair in a B(semi -) leptonic B meson decay but in this way: q = $p_{Bsig} - p_{meson}$





Other variables: UniqueSignal

Developed specifically for FEI (so it works only on FEI reconstructed particles...maybe only B mesons?)

- It loops through the particle list and checks which candidate is a true candidate associated with an MCParticle and does so uniquely (discarding those candidates which were reconstructed with less info).
- used with generic samples to discard duplicates of FEI correctly reconstructed Bmesons
- I tried it as well on my signal MC samples but without success (it returns always 0)
- does it work only when the MC samples are of the same type of the ones used for the FEI training? Or as it is defined it is foreseen to work only on generic MC samples?

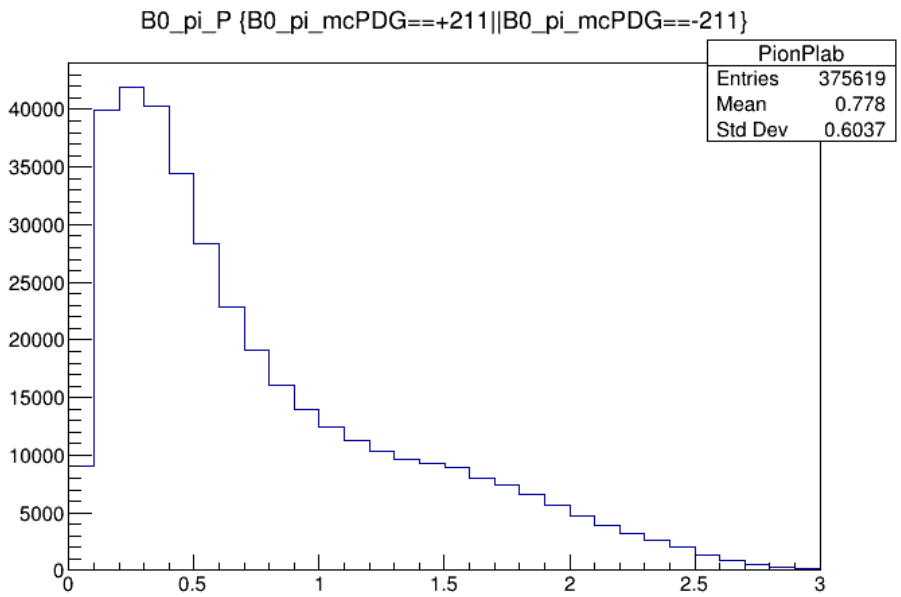
CONCLUSIONS:

- First (partial and preliminary) working example for the study of this channel developed!
- Second approach seems to be promising, but need more statistics
- Still some variables has to be checked and understood
- When everything is becoming clear possible to implement also the other τ decay channels
- Then one can start doing some proper physics and also background studies!

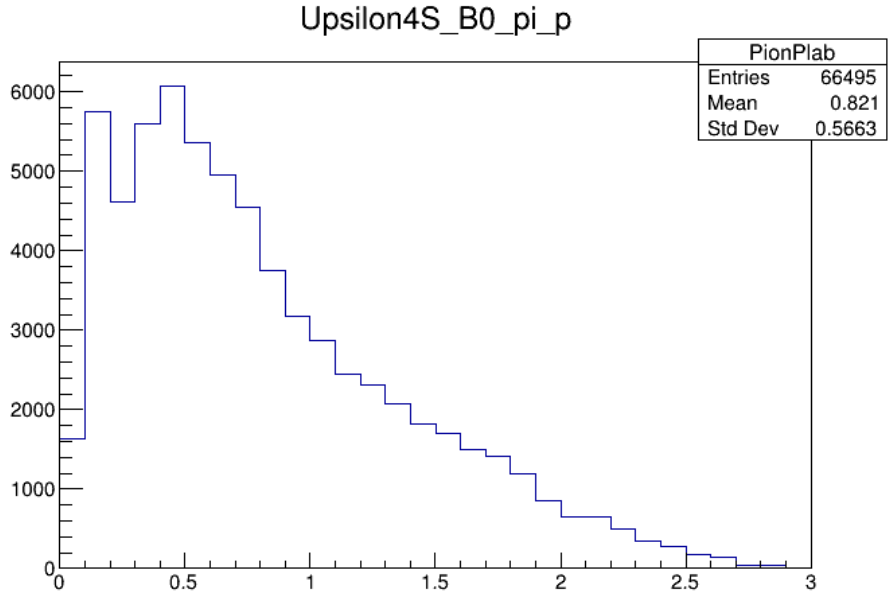
BACKUP SLIDES

Results obtained with the first approach

Momentum in the lab frame



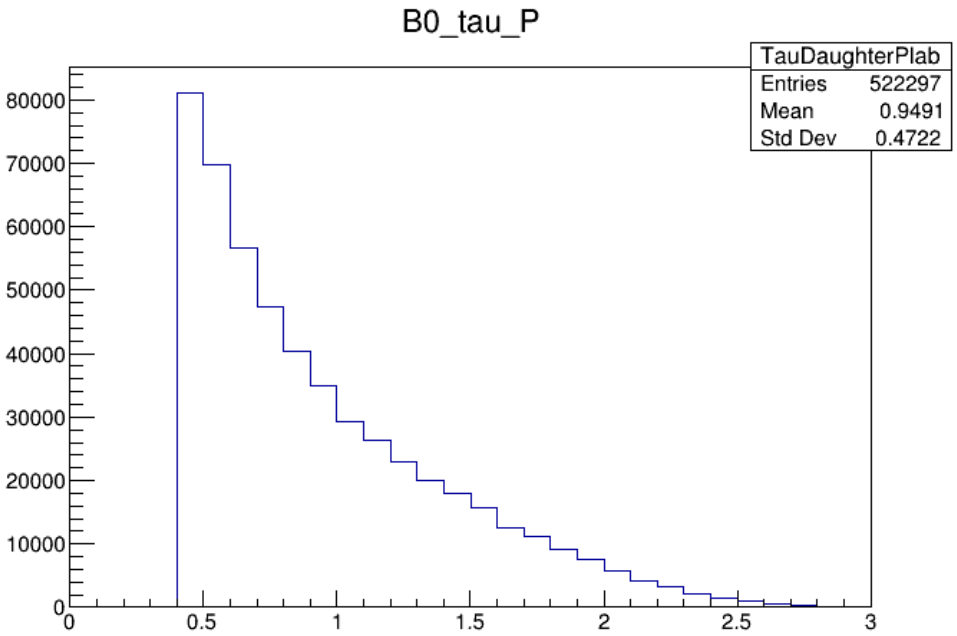
Truth matched Bsig pions



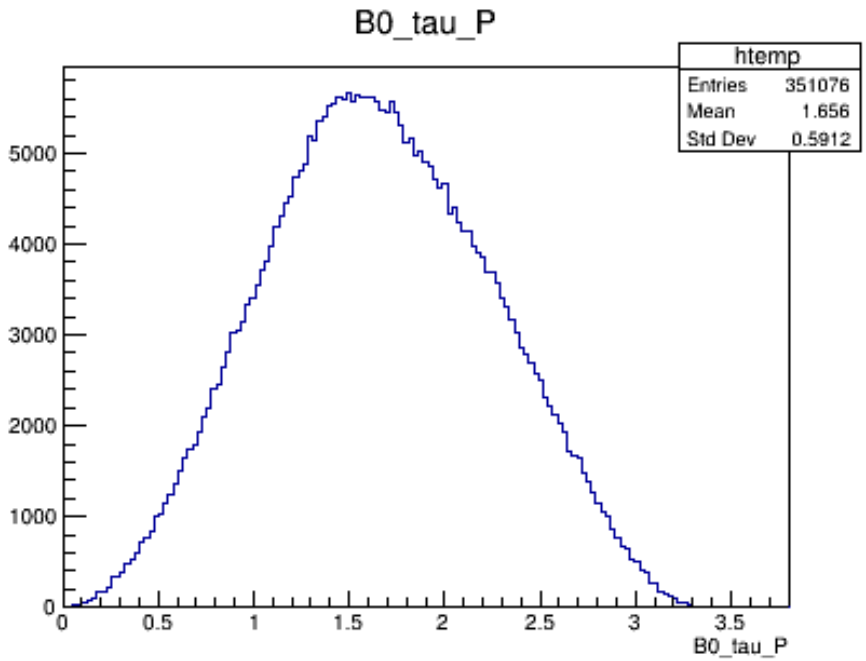
Bsig pions after combining to an Y(4S)

Results obtained with the first approach

Momentum in the lab frame



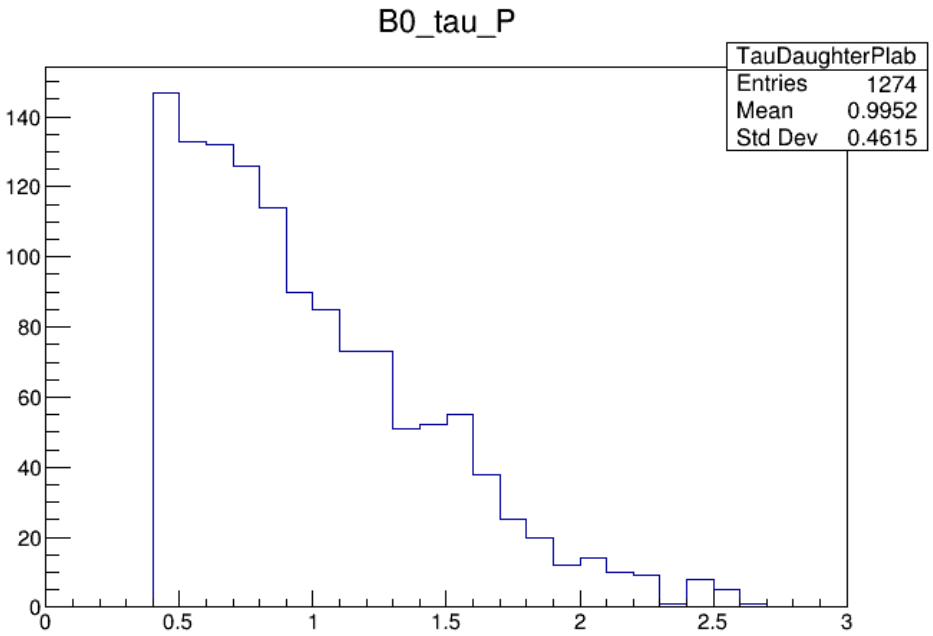
Bsig tauons selected with this approach



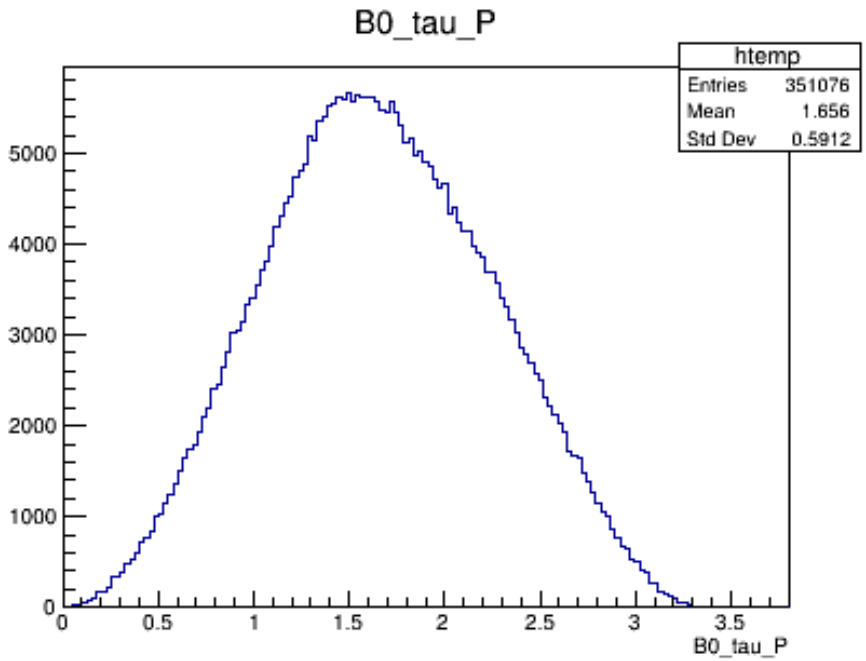
Bsig tauons at generator level

Results obtained with the second approach

Momentum in the lab frame



Bsig tauons selected with this approach



Bsig tauons at generator level

Other variables: mcMomTransfer2 (Definition)

```
double particleMCMomentumTransfer2(const Particle* part)
   {
     // for B meson MC particles only
     const MCParticle* mcB = part->getRelated<MCParticle>()

     if (!mcB)
       return -999.9;

     TLorentzVector pB = mcB->get4Vector();

     std::vector<MCParticle*> mcDaug = mcB->getDaughters();

     if (mcDaug.empty())
       return -999.9;

     // B -> X l nu
     // q = pB - pX
     TLorentzVector pX;

     for (unsigned i = 0; i < mcDaug.size(); i++) {
       const MCParticle* mcTemp = mcDaug[i];

       if (abs(mcTemp->getPDG()) <= 16)
         continue;

       pX += mcTemp->get4Vector();
     }

     TLorentzVector q = pB - pX;

     return q.Mag2();
   }
```