Tag and probe tools for data driven corrections

Yuan Zhang

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O2 Analysis tutorial 4.0

Motivation

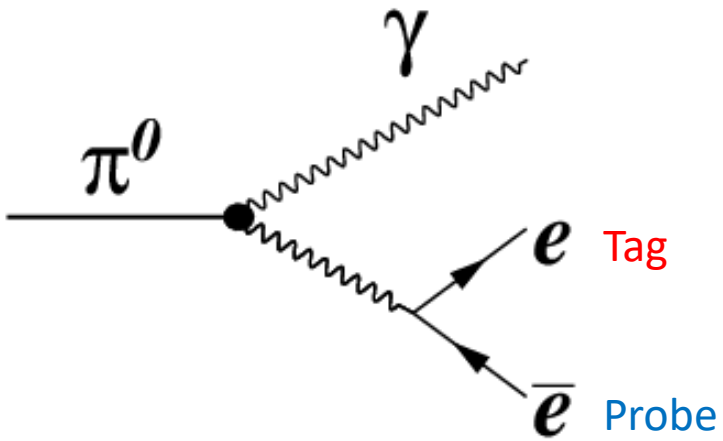
- MC simulation can not describe data well.

- Need data driven calibration.

- A lot of photon converted electrons in electrons sample
- To learn ITS-TPC matching efficiency, we need to exclude photon converted electrons without ITS cuts.

- Use Tag and Probe method

Tag and probe



$$\mathcal{B}\left(\pi^0 \to e^+e^-\gamma(\gamma)\right) = 1.1836(6)\%$$

The lifetime is 8.5 x10 -17s

- The tag and probe method involves selecting a clean sample of electrons from pi0 Dalitz decay.
- One of the electron (the tag) is well-identified.
- Another electrons (the probe) from same pair is used for the TPC and ITS matching efficiency study.
- The photon converted electrons need to be rejected.

Dalitz selection in O2Physics

```
o2-analysis-dq-table-reader -b --configuration json://configuration.json | \
o2-analysis-dq-table-maker -b --configuration json://configuration.json | \
o2-analysis-dq-dalitz-selection -b --configuration json://configuration.json | \
o2-analysis-multiplicity-table -b --configuration json://configuration.json | \
o2-analysis-pid-tof-full -b --configuration json://configuration.json | \
o2-analysis-pid-tof-beta -b --configuration json://configuration.json | \
o2-analysis-pid-tof-base -b --configuration json://configuration.json | \
o2-analysis-ft0-corrected-table -b --configuration json://configuration.json | \
o2-analysis-track-propagation -b --configuration json://configuration.json | \
o2-analysis-trackselection -b --configuration json://configuration.json | \
o2-analysis-pid-tpc -b --configuration json://configuration.json | \
o2-analysis-event-selection -b --configuration json://configuration.json | \
o2-analysis-timestamp -b --configuration json://configuration.json | \
o2-analysis-pid-tpc-base -b --configuration json://configuration.json --aod-writer-json OutputDirector.json
```

- Run the table-maker and table-reader with dalitz-selection task.
- Save the derived table “DielectronsAll” in table-reader and do the tag-probe locally.

Dalitz selection in O2Physics

Dalitz-pairing:

```
"cfgDalitzTrackCuts": "Jpsi_TPCPost_calib_noITSCuts_debug4",
"cfgDalitzPairCuts": "pairDalitz1",
```

Table-maker:

```
"cfgBarrelTrackCuts": "dalitzSelected1",
"processBarrelOnlyWithDalitzBits": "false",
"processBarrelWithDalitzEvent": "true",
```

- processBarrelOnlyWithDalitzBits: run table-maker with dalitz information
- processBarrelWithDalitzEvent: run table-maker with dalitz information and skip events without dalitz tracks

OutputDirector.json

```
{
    "OutputDirector": {
        "debug_mode": true,
        "resfile": "AO2D",
        "OutputDescriptors": [
            {
                "table": "AOD/RTDIELECTRONALL/0"
            }
        ],
        "ntfmerge": 1
    }
}
```

- Save DielectronsAll table to do tag and probe locally.

Dalitz selection

LHC22o pass4: 528021, 528026, 528036, 528094, 528097, 528105, 528107, 528109, 528231, 528232, 528233, 528263, 528266, 528292, 528294, 528316, 528319, 528328, 528329, 528330, 528332, 528336, 528347, 528359, 528379, 528381, 528386, 528448, 528451, 528461, 528463, 528530, 528531, 528534

Pair cut (default)

0 < m < 0.035 GeV/c2

Triangle cut ($\psi pair$ and $\Delta\varphi$) (to reject photon conversion electron):

Reject pairs with ($\Delta\varphi$,$\psi pair$) in triangle (0,-0.8) (0,0.8) (0.12,0)

Track cut (default)

p_T > 1.0 GeV/c, |η| < 0.9

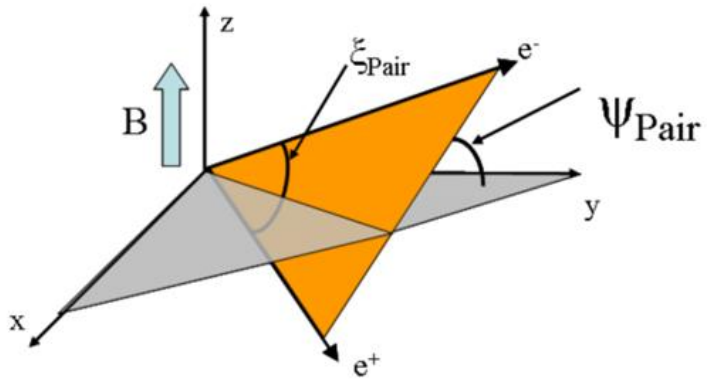
TPCncls > 90, TPCchi2 < 4

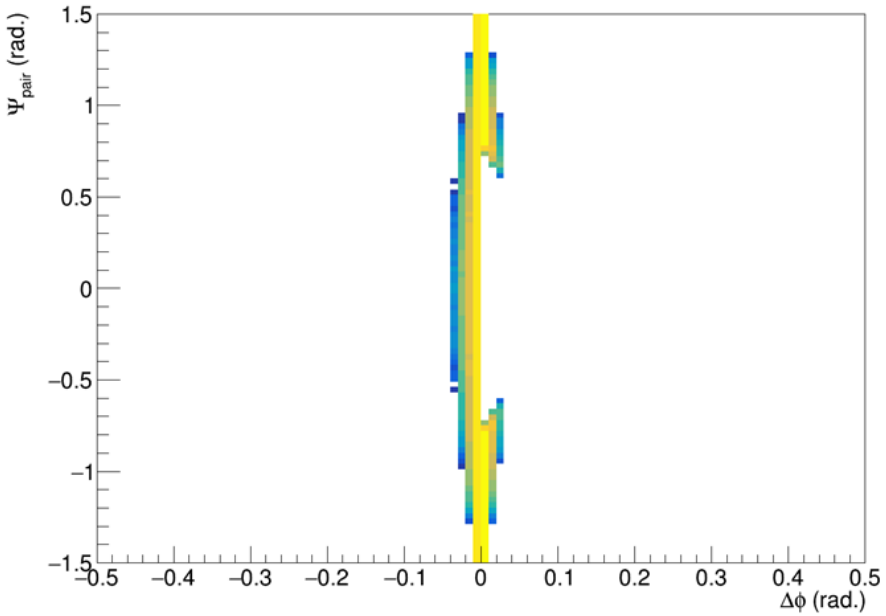
ITSRequirement: ITSMatch (tag)

-3 < TPCnSigmaE < 3

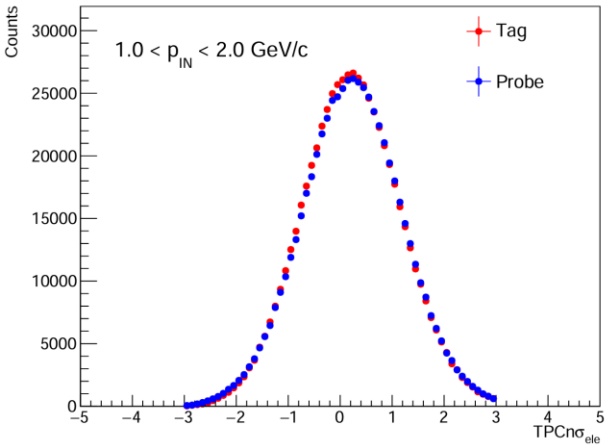
|TPCnSigmaPi| > 3

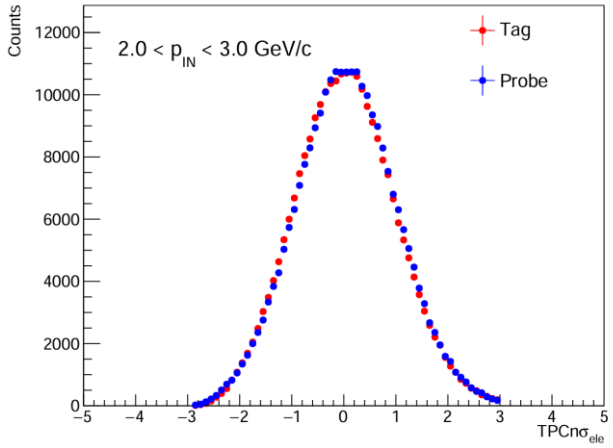
|TPCnSigmaPr| > 3

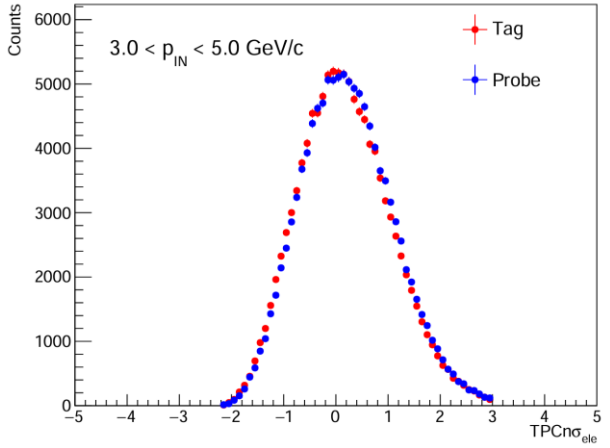


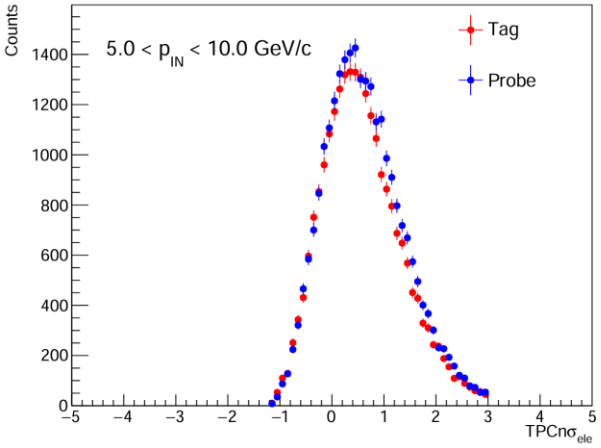


PID performance









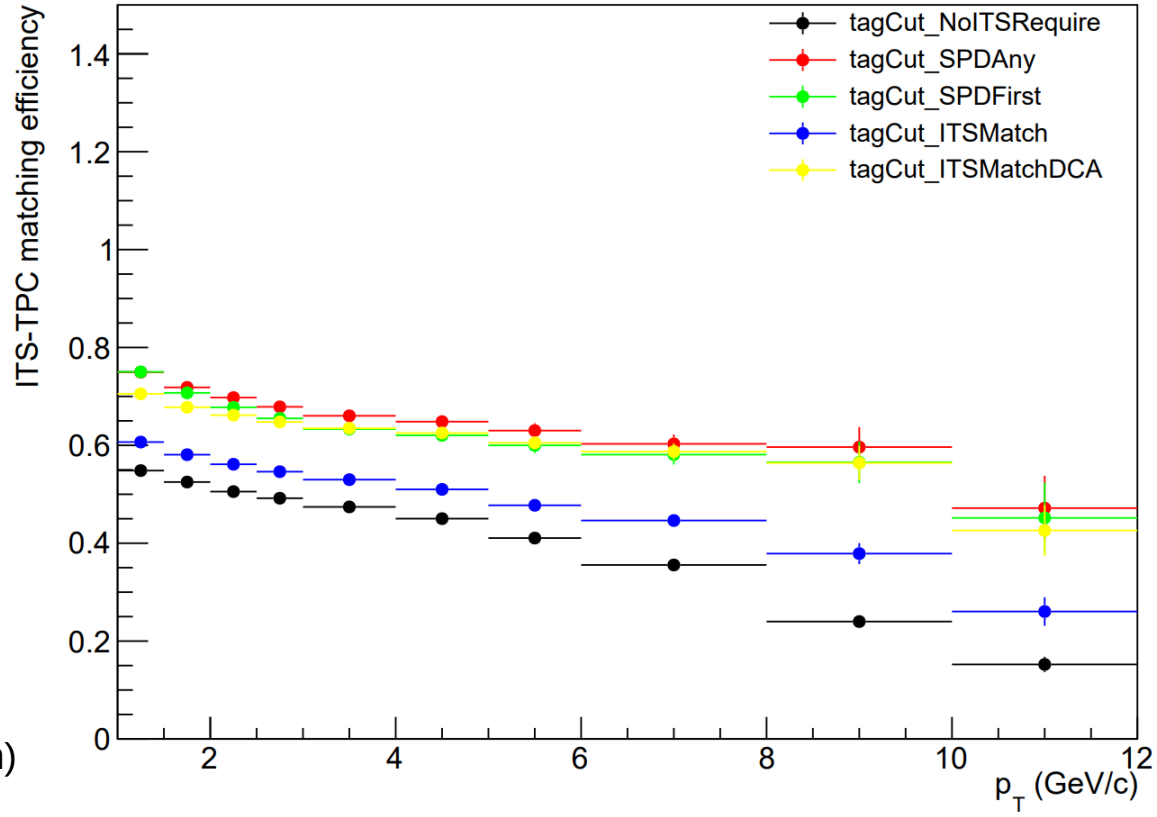
- TPCnSigmaE distribution of tag and probe tracks.
  - Electron purity is high after PID selections

Matching efficiency with different tag cuts

$$eff = \frac{N^{probe}_{TPC+ITSall}}{N^{probe}_{TPC}}$$ ITSall: hit all 7 layers of ITS

Tag ITS Requirement with the below:

1. NoITSRequire:
   - No ITS requirement
2. SPDFirst:
   - at least one hit on the inner most layer
3. SPDAny:
   - at least one hit on the first two layers
4. ITSMatch:
   - any hits on the ITS
5. ITSMatchDCA:
   - any hits on the ITS + DCA(|xy| < 0.1 cm, |z| < 0.15 cm)

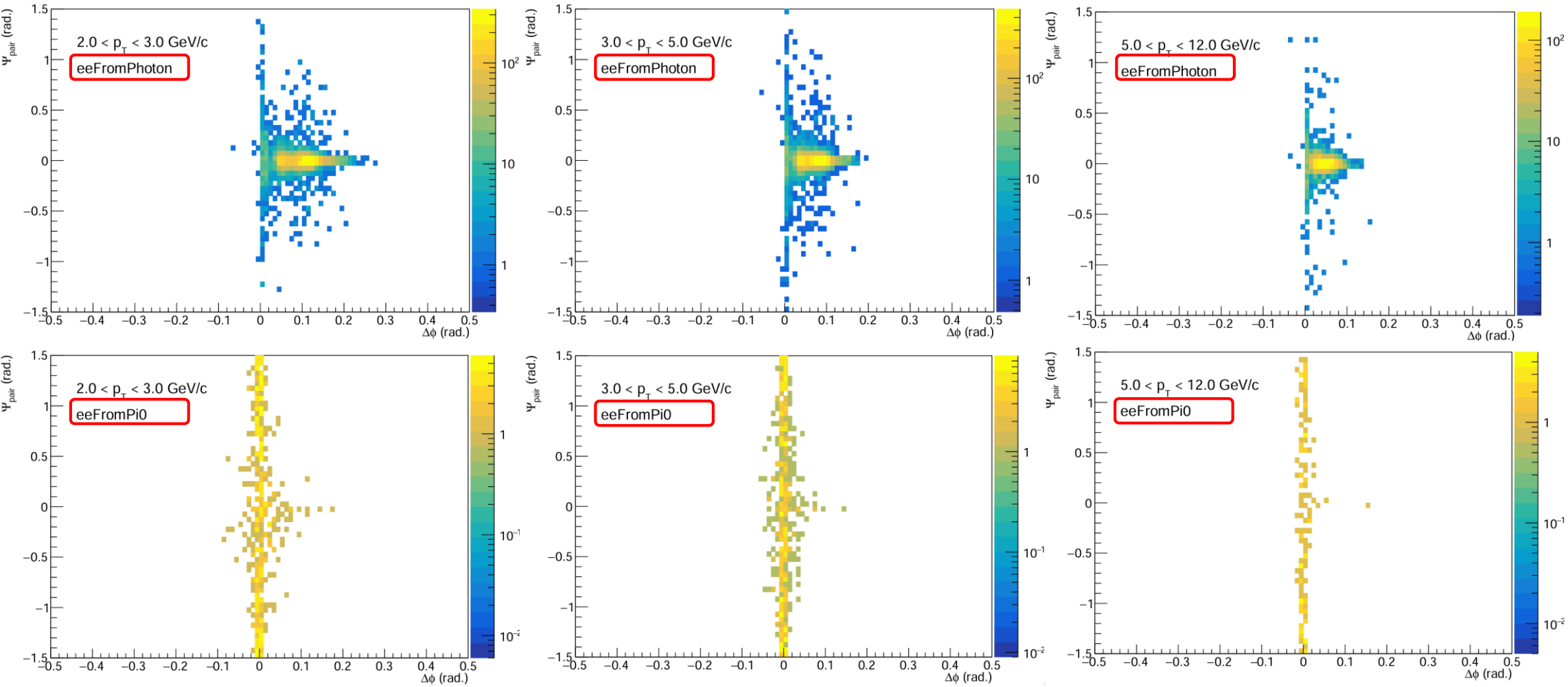


- The matching efficiency of probe will increase if the tag is with a strict ITS requirement.
- The ITS-TPC matching efficiency decrease to very low in high pT.

⬇

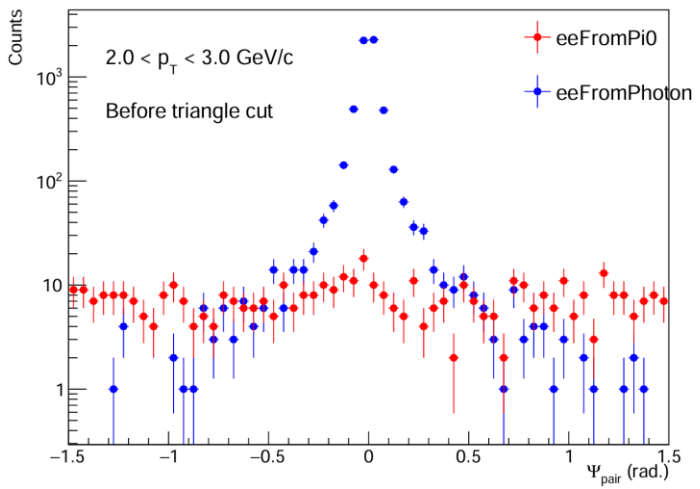
- Photon converted electrons contamination.

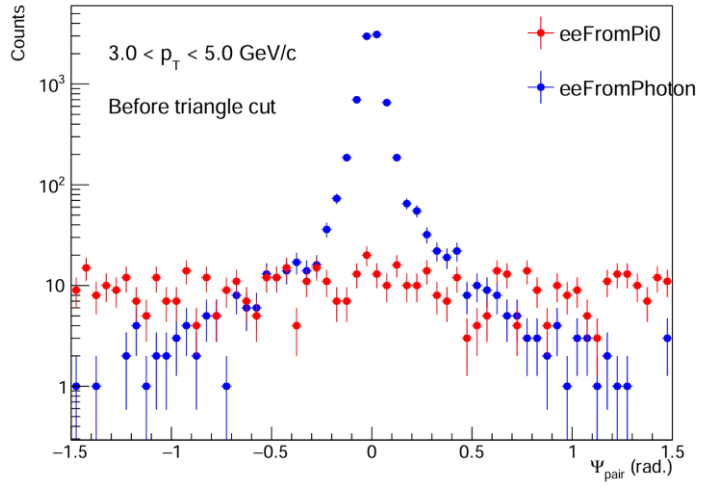
Check triangle cut in MC

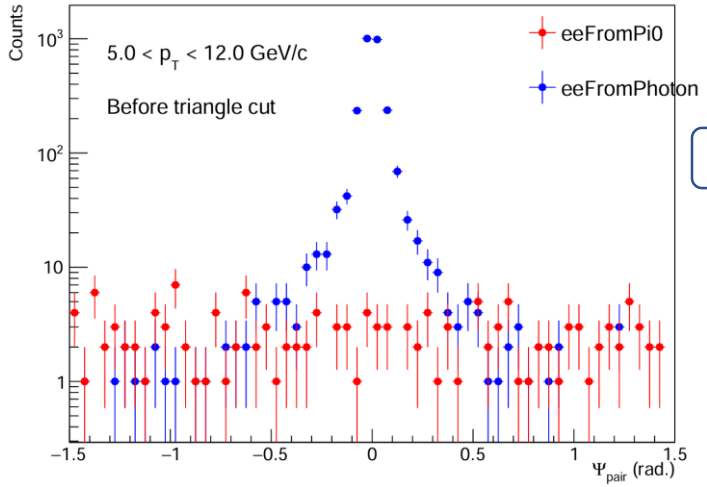


- The $\psi pair$ and $\Delta\varphi$ distribution are different between electron pairs from photon conversion and dalitz decay.

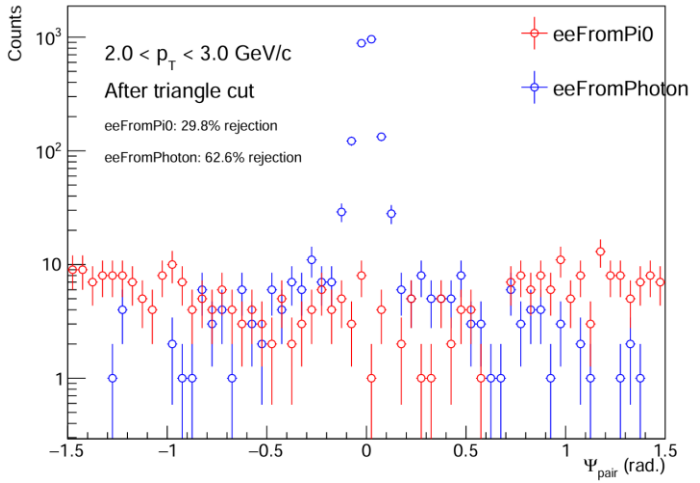
Check triangle cut in MC

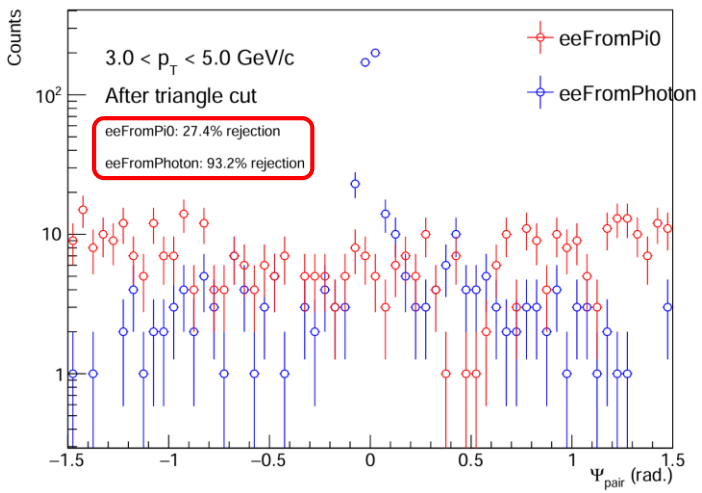


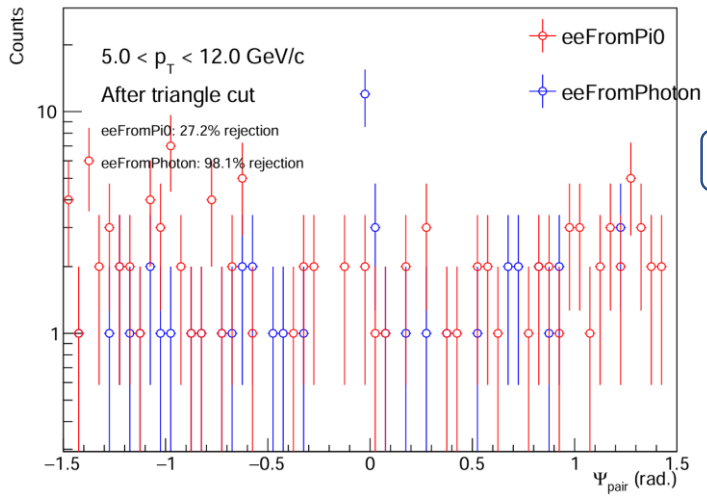




Before triangle cut



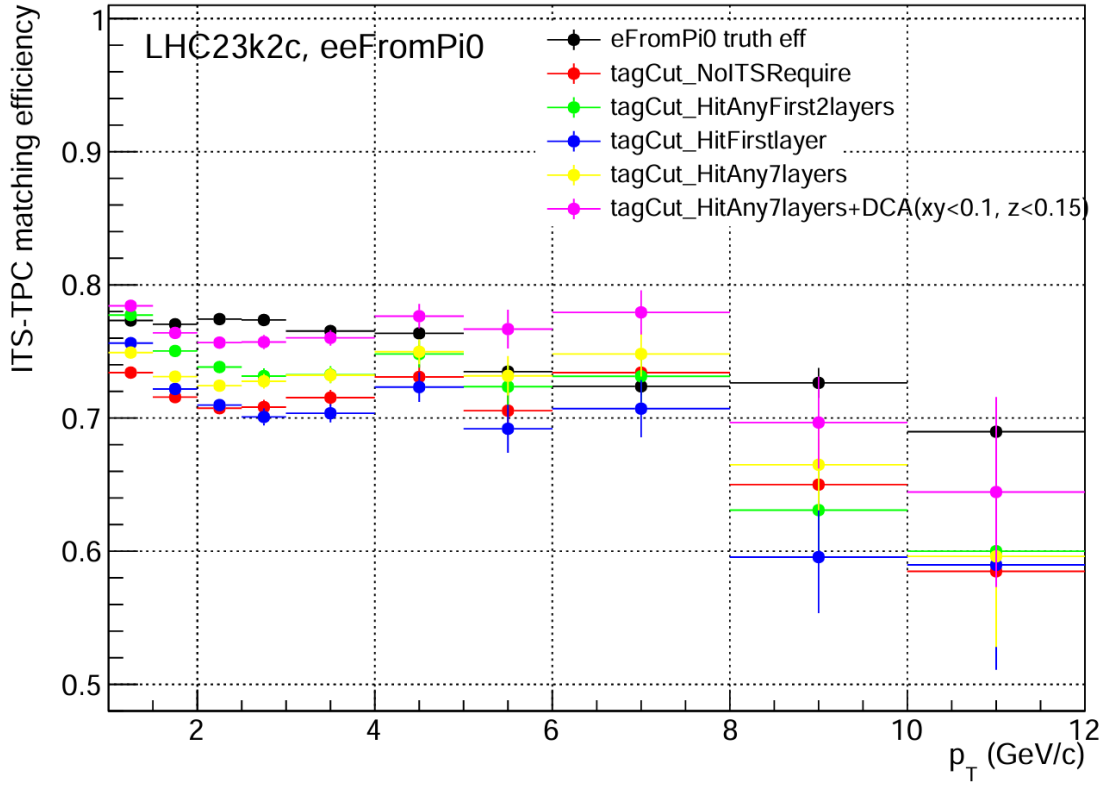




After triangle cut

- The $\psi pair$ distributions before and after triangle cut are shown.
- Large fraction of photon converted electrons are rejected (> 90% in middle and high pT), but still a lot of leftovers

Check using MC



- Electron pairs from pi0 decay are selected.
  - Apply tag cut on one leg and use the other as probe to check ITS-TPC matching efficiency.
- The efficiency of probe leg are similar with all electrons from pi0.
- Slight correlation between matching efficiency of probe with tag cuts.
  - Further checks needed.

Select pure electrons using J/ψ

LHC22o_pass4_minBias_medium:

526641, 526964, 527041, 527240

Pair cut (default)

2.84 < m < 3.2 GeV/c2

Track cut (default)

pT > 1.0 GeV/c, |η|<0.9

TPCncls > 90, TPCchi2 < 4

ITSRequirement: ITSMatch (Tag)

-3 < TPCnSigmaE < 3

|TPCnSigmaPi| > 3

|TPCnSigmaPr| > 3

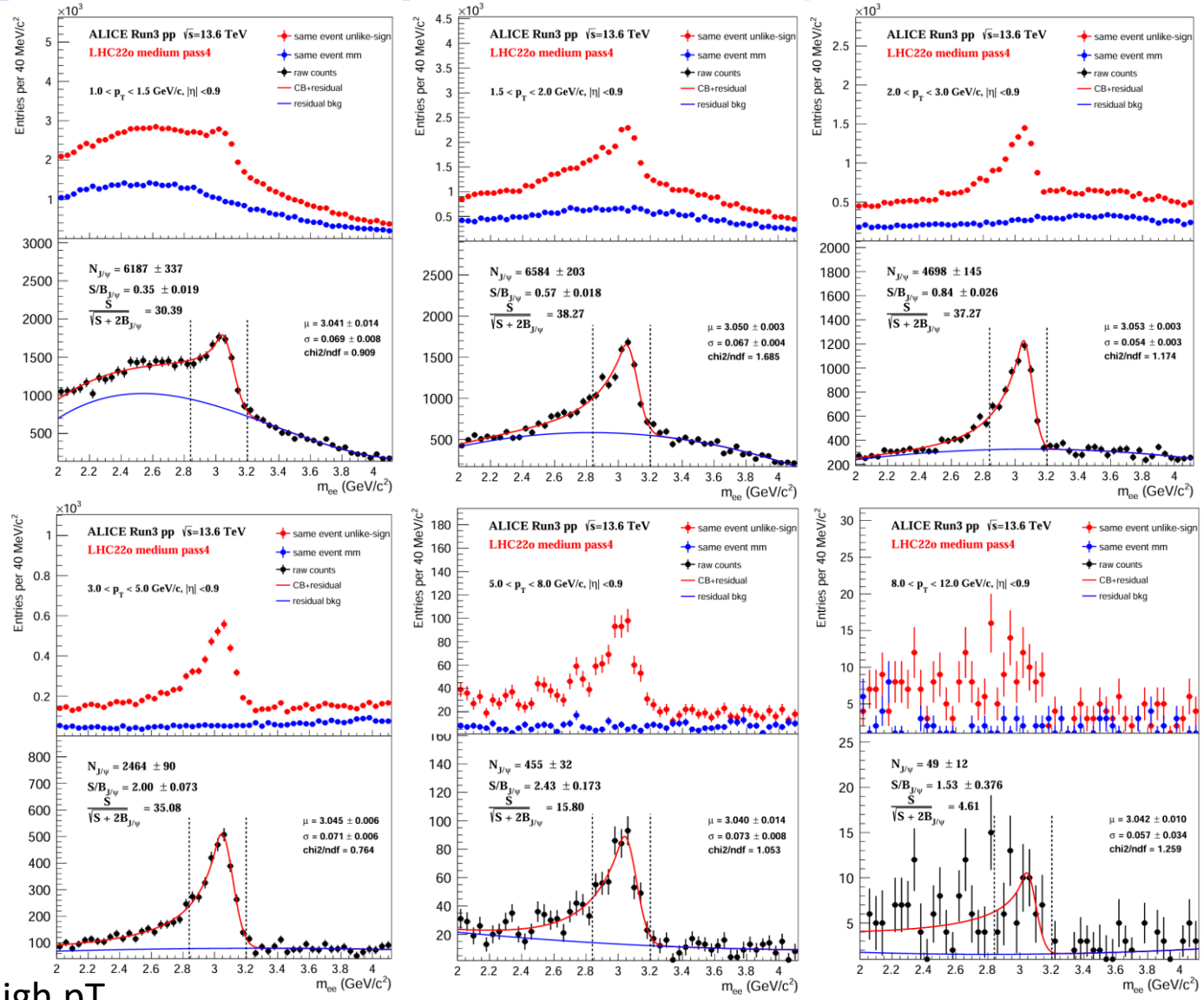
Prefilter cut:

pT > 0.15 GeV/c, |η| < 0.9

TPCncls > 70, TPCchi2 < 4

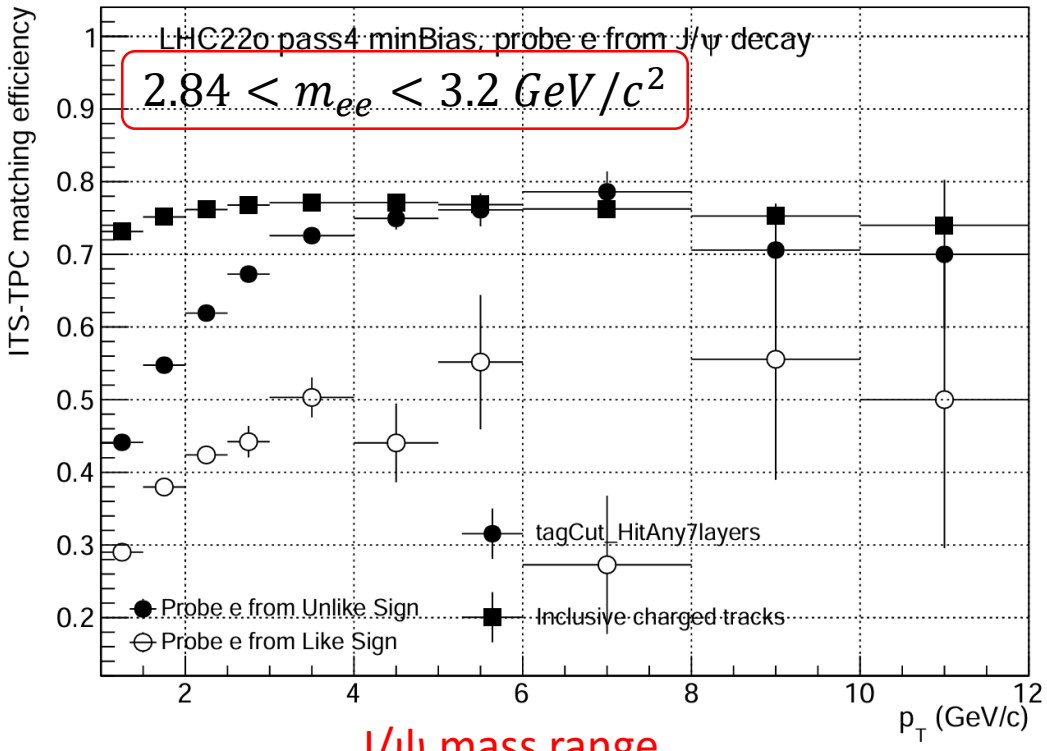
|TPCnSigmaE| < 3

Exclude $m_{ee} < 0.35\ GeV/c^2$

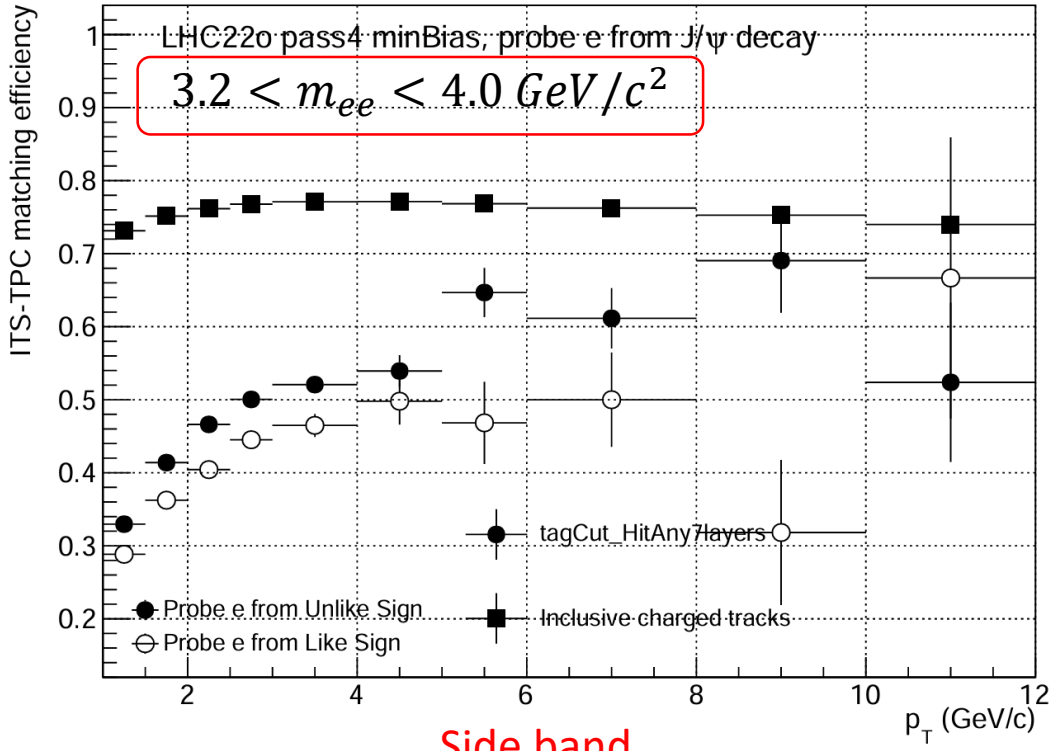


➢ The S/B is ~0.35 in low pT, but can reach to ~2.43 in high pT.

ITS-TPC matching efficiency using eFromJ/ψ



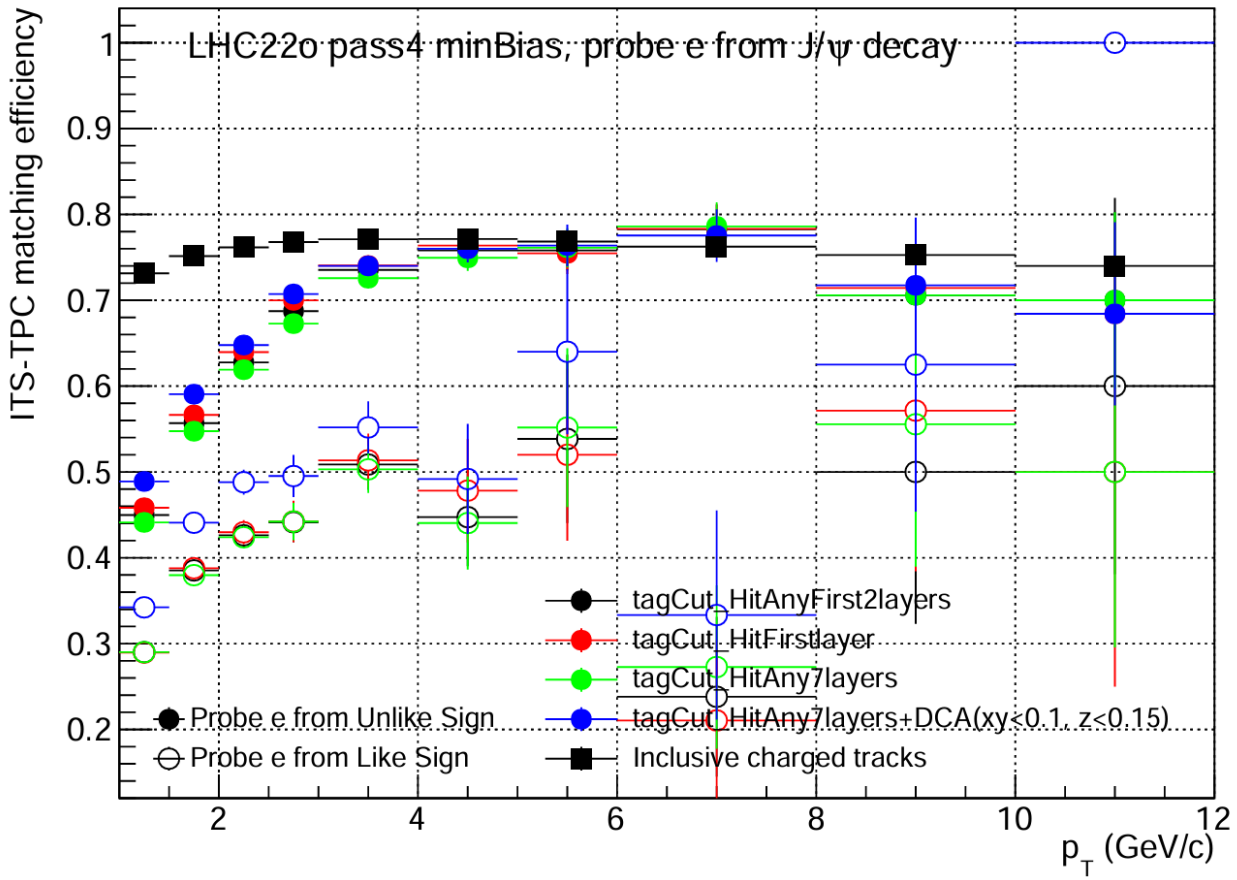
J/ψ mass range



Side band

- ITS-TPC matching efficiency of probe e from unlike-sign pair is close to that of inclusive charged tracks in high pT.
- Efficiency is low in low pT because of the low S/B.

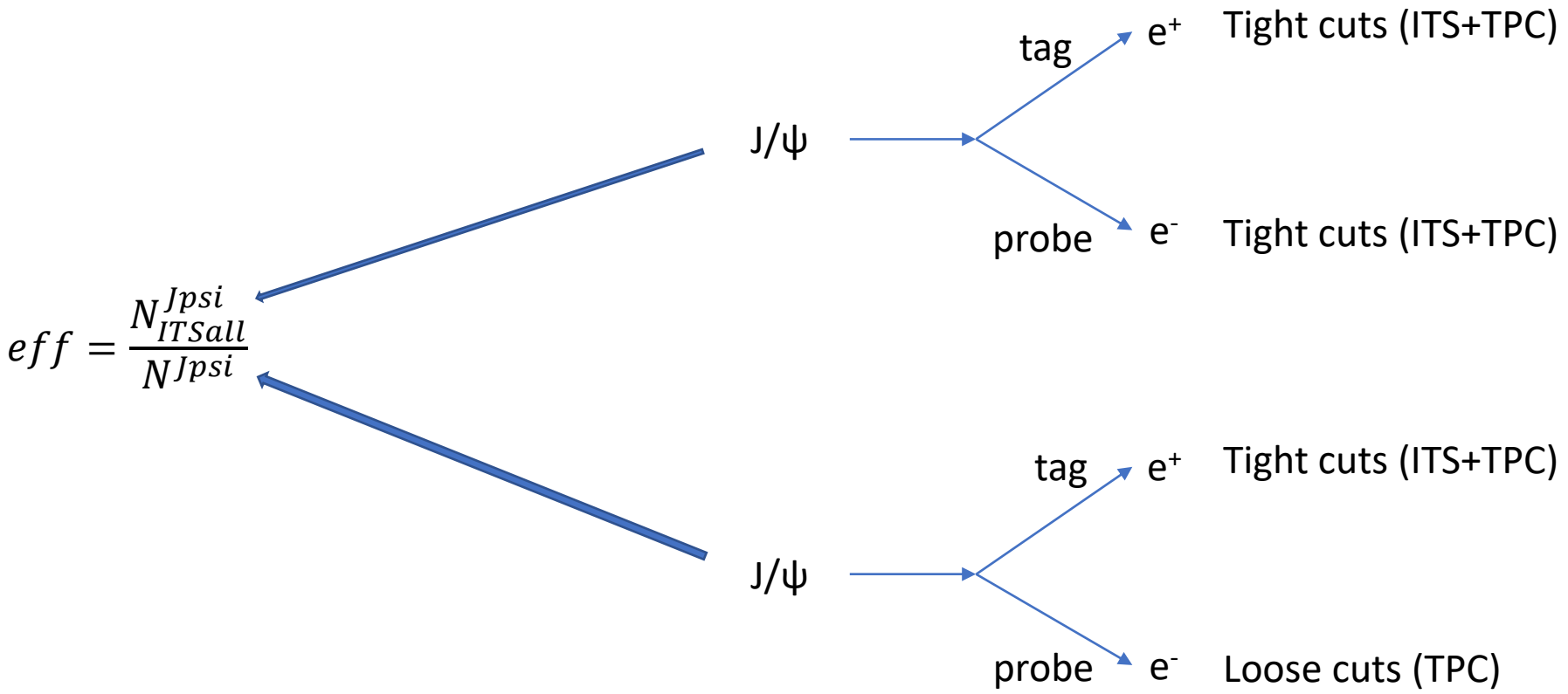
ITS-TPC matching efficiency with different tag cuts



- ITS requirement on the tag will not influence the matching efficiency of the probe too much.

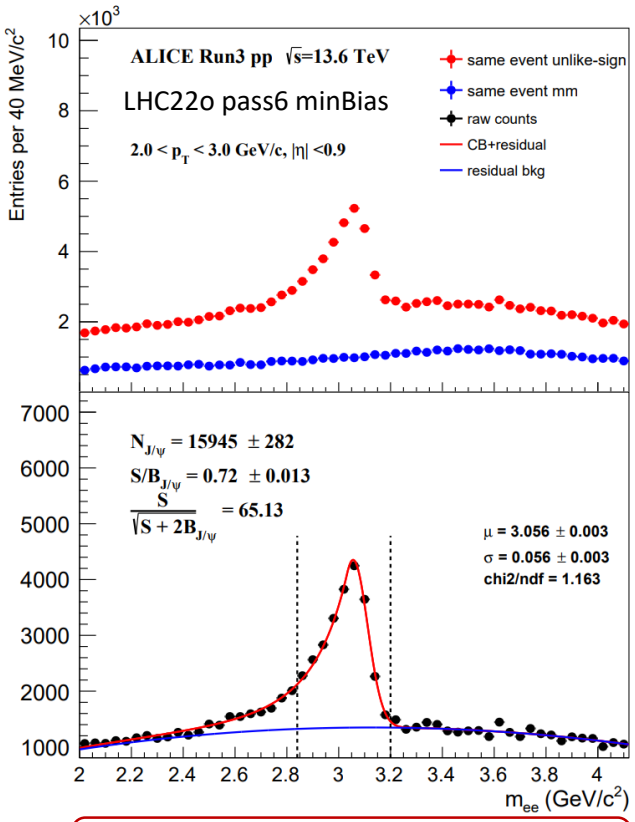
Tag and probe using J/ψ counts

- To avoid the influence of photon converted electrons, ITS-TPC matching efficiency can also be calculated by directly using tag and probe method to J/ψ counts.

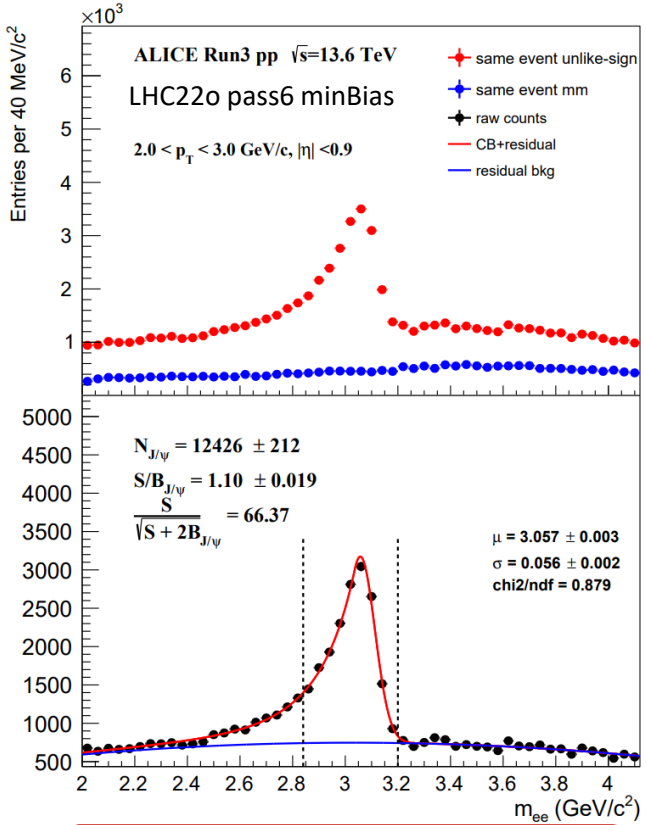


- Raw counts of J/ψ with probe leg after ITS cut are used as nominator.
- Raw counts of J/ψ with probe leg without ITS requirement are used as denominator

Tag and probe using J/ψ counts



Probe w/o ITS requirement

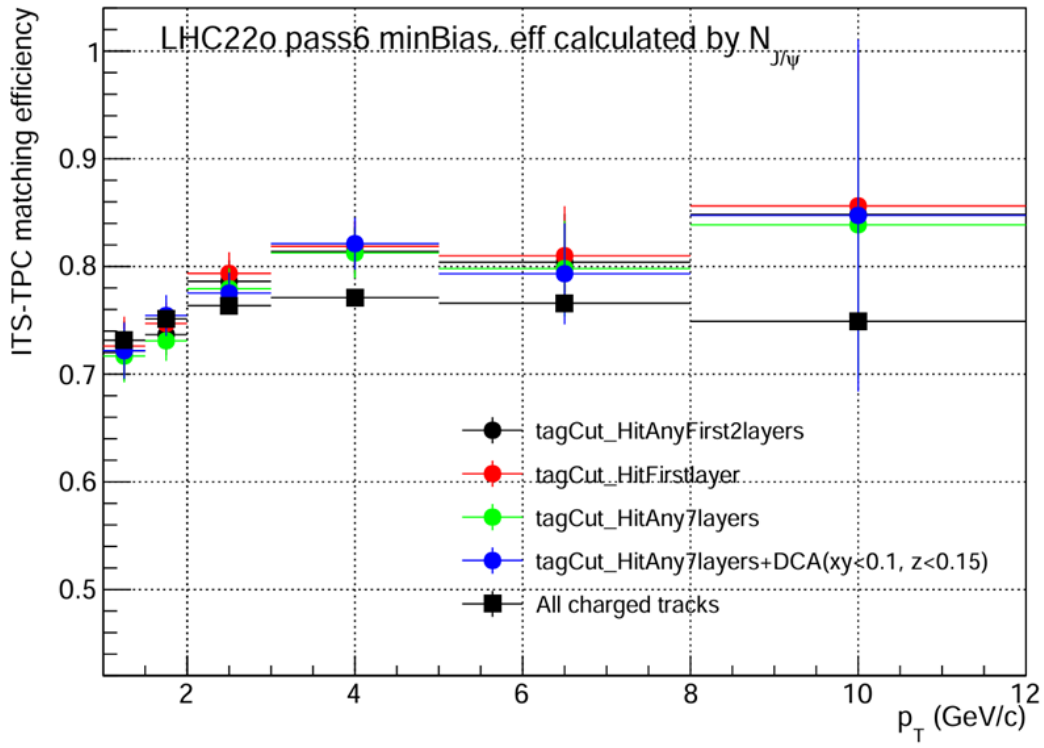


Probe w ITSall

$$eff = \frac{N_{ITSall}^{Jpsi}}{N^{Jpsi}}$$

- ITS-TPC matching efficiency can be calculated by raw counts of J/ψ by changing the ITS requirement on one leg.
- Will be influenced by the systematic uncertainty of signal extraction.

ITS-TPC matching efficiency



- ITS requirement on the tag will not influence the matching efficiency of the probe too much.

Summary

- The ITS-TPC matching efficiency is measured using tag and probe method.
  1. Using the dalitz selection to select pure primary electrons.
     - Some photon converted electrons left.
  2. Using J/ψ signal to select primary electrons.
     - Efficiency are similar with inclusive charged tracks in high pT.
     - Efficiency is lower in low pT because of the low S/B.
  3. Using tag and probe to J/ψ directly.
     - Get similar efficiency with inclusive charged tracks.
     - Will be influenced by the systematic uncertainty from signal extraction.

Back up

Code of DalitzSelection

1. runTrackSelection<gkTrackFillMap>(groupedFilteredTracks);

```
for (auto& track : tracksBarrel) {
  uint8_t filterMap = uint8_t(0);
  VarManager::FillTrack<TTrackFillMap>(track);
  int i = 0;
  for (auto cut = fTrackCuts.begin(); cut != fTrackCuts.end(); ++cut, ++i) {
    if ((*cut).IsSelected(VarManager::fgValues)) {
      filterMap |= (uint8_t(1) << i);
    }
  }
  if (filterMap) {
    fTrackmap[track.globalIndex()] = filterMap;
  }
} // end loop over tracks
```

Code of DalitzSelection

2. runDalitzPairing<pairType, gkTrackFillMap>(groupedFilteredTracks, groupedFilteredTracks);

```
int icut = 0;
auto trackCut = fTrackCuts.begin();
for (auto pairCut = fPairCuts.begin(); pairCut != fPairCuts.end(); pairCut++, trackCut++, icut++) {
  if (!(twoTracksFilterMap & (uint8_t(1) << icut))) {
    continue;
  }
  if ((*pairCut).IsSelected(VarManager::fgValues)) {
    fDalitzmap[track1.globalIndex()] |= (uint8_t(1) << icut);
    fDalitzmap[track2.globalIndex()] |= (uint8_t(1) << icut);
    if (fQA) {
      fHistMan->FillHistClass(Form("Pair_%s_%s", (*trackCut).GetName(), (*pairCut).GetName()), VarManager::fgValues);
    }
  }
}
```

3.

```
for (auto& track : tracks) { // Fill dalitz bits
  dalitzbits(fDalitzmap[track.globalIndex()]);
}
```