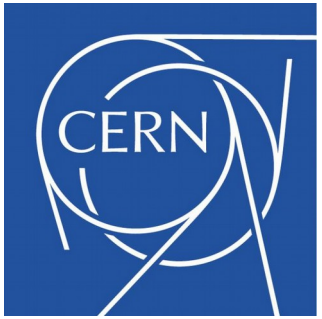


Low energy (LE) timing cuts optimization

Erica Brondolin

How to proceed

- **Identify the problem**
  - Find and check datasample
  - Produce PFOs energy distributions
  - Define “figure(s) of merit”

- **Understand current approach**
  - Current documentation
  - Select variables needed

- **Improving**
  - Produce new correlation plots
  - Introduce new LE timing cuts
  - Evaluate the impact
  - Re-iterate if necessary

Work in progress

- **Outlook**

How to proceed

- **Identify the problem**
  - Find and check datasample
  - Produce PFOs energy distributions
  - Define “figure(s) of merit”

- **Understand current approach**
  - Current documentation
  - Select variables needed

- **Improving**
  - Produce new correlation plots
  - Introduce new LE timing cuts
  - Evaluate the impact
  - Re-iterate if necessary

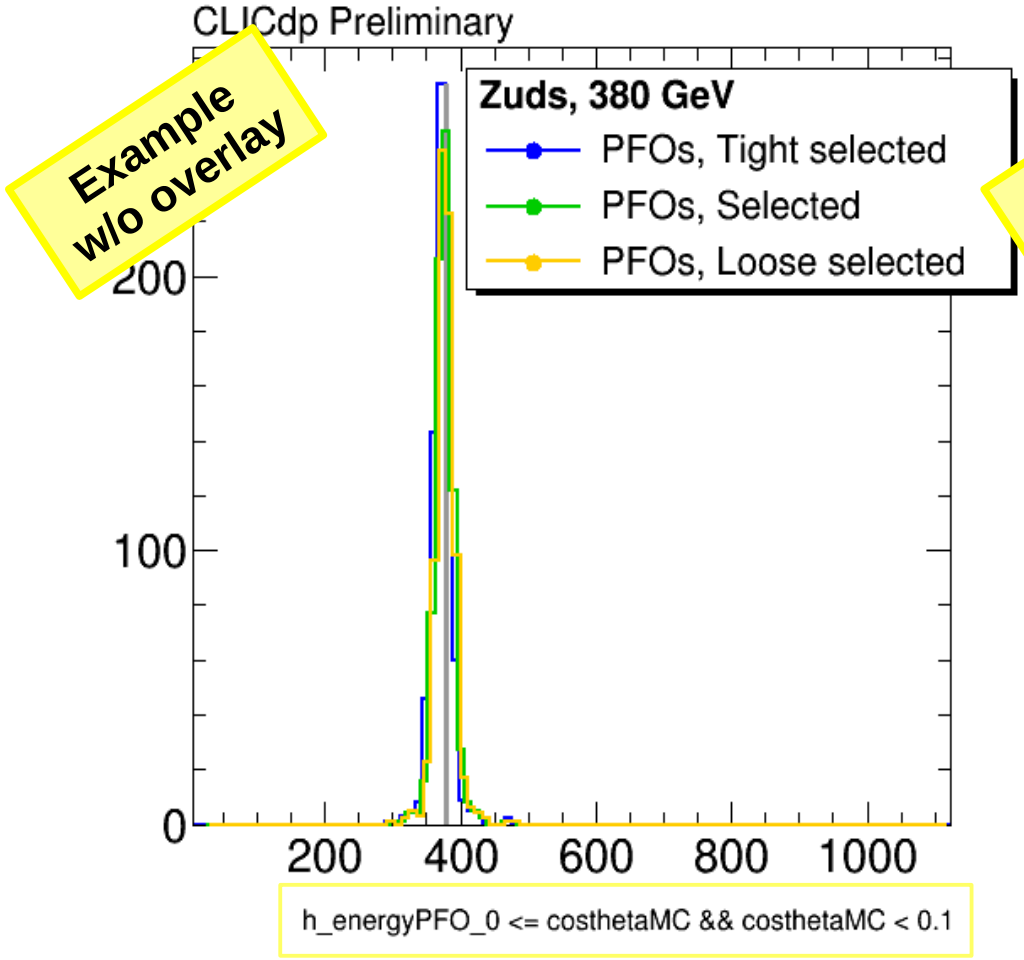
- **Outlook**

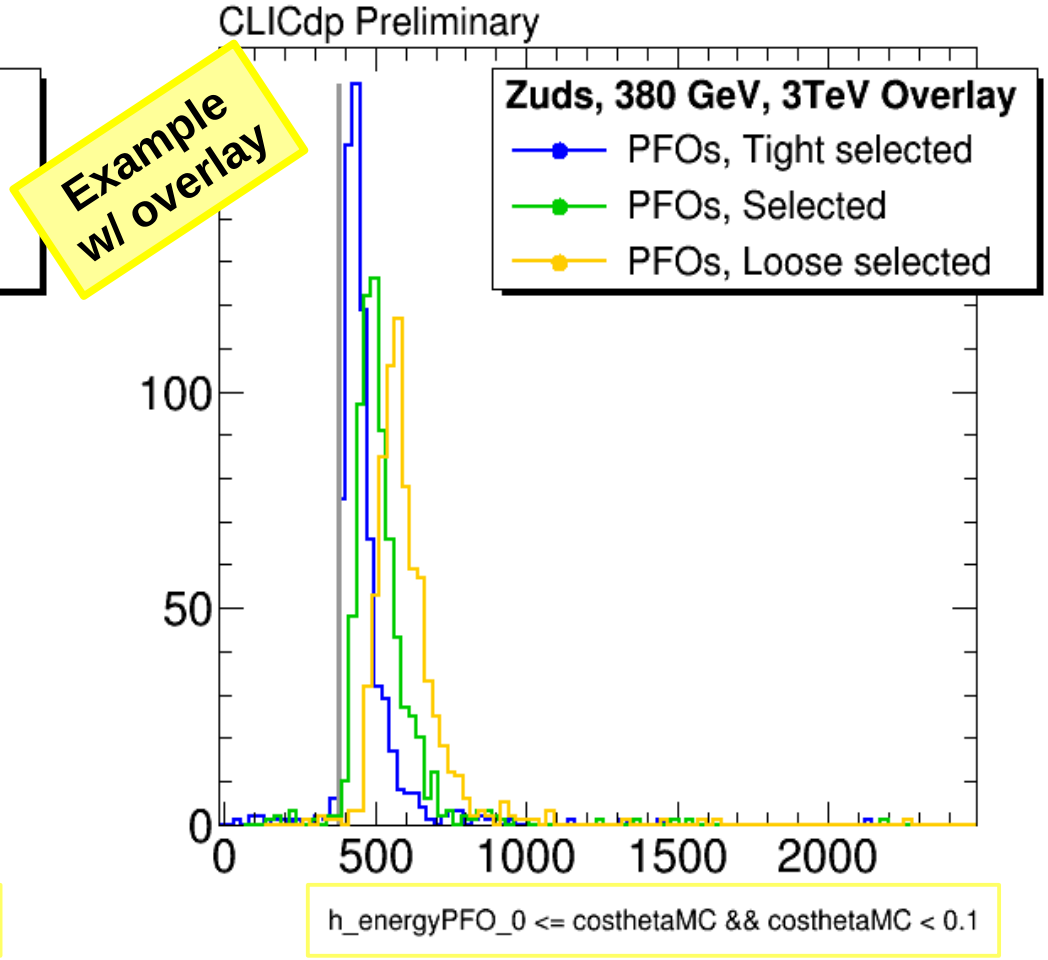
Identify the problem: first steps

- **First sample used: Z → uds**
  - Centre of mass energy = 380 GeV
  - Overlay = 3 TeV
  - Selections used: Loose, Selected, Tight

Nb. cosθ is computed from the generated light quarks

- **Energy distribution for different <u>cosθ</u> bins**

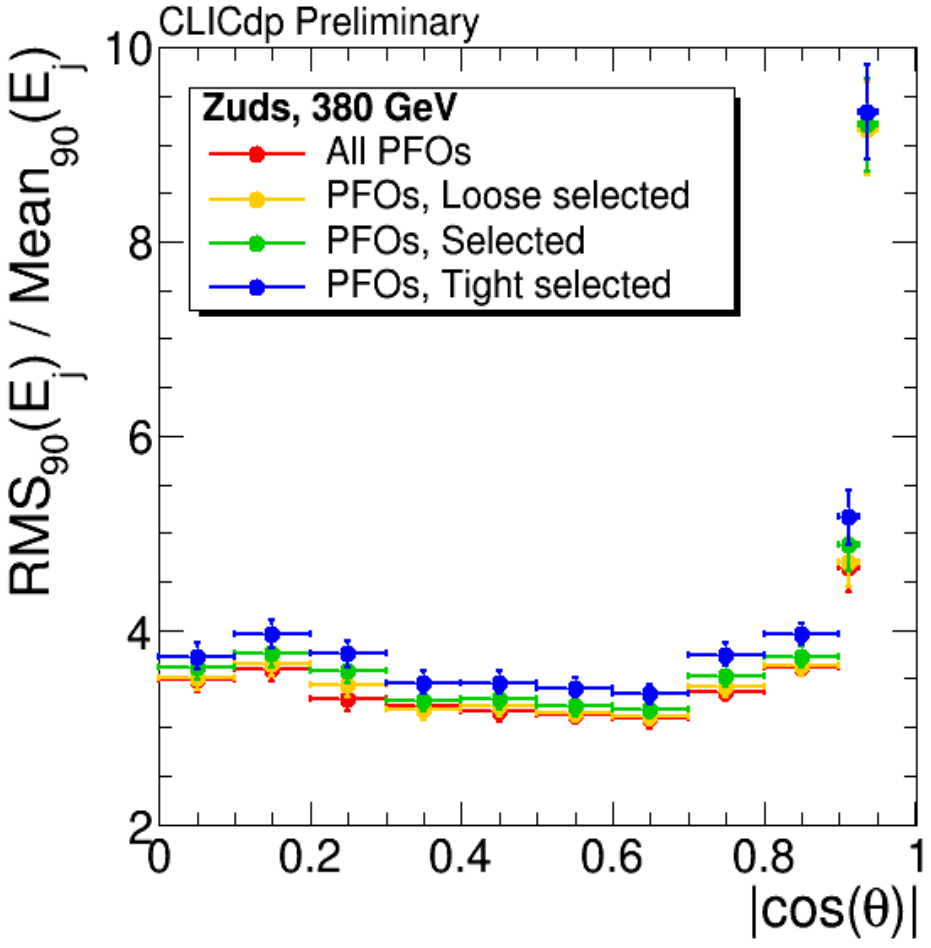


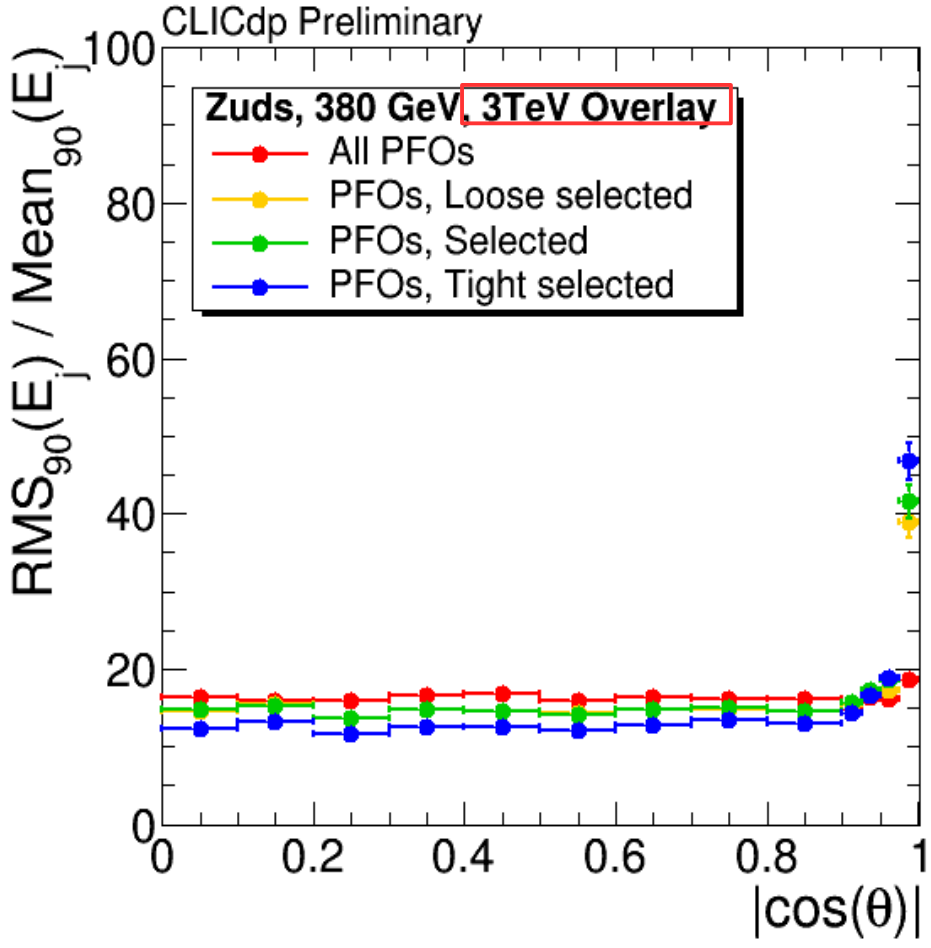


Identify the problem: first steps

- **First sample used: Z → uds**
  - Centre of mass energy = 380 GeV
  - Overlay = 3 TeV
  - Selections used: Loose, Selected, Tight

- **Jet energy resolution for different cosθ bins**

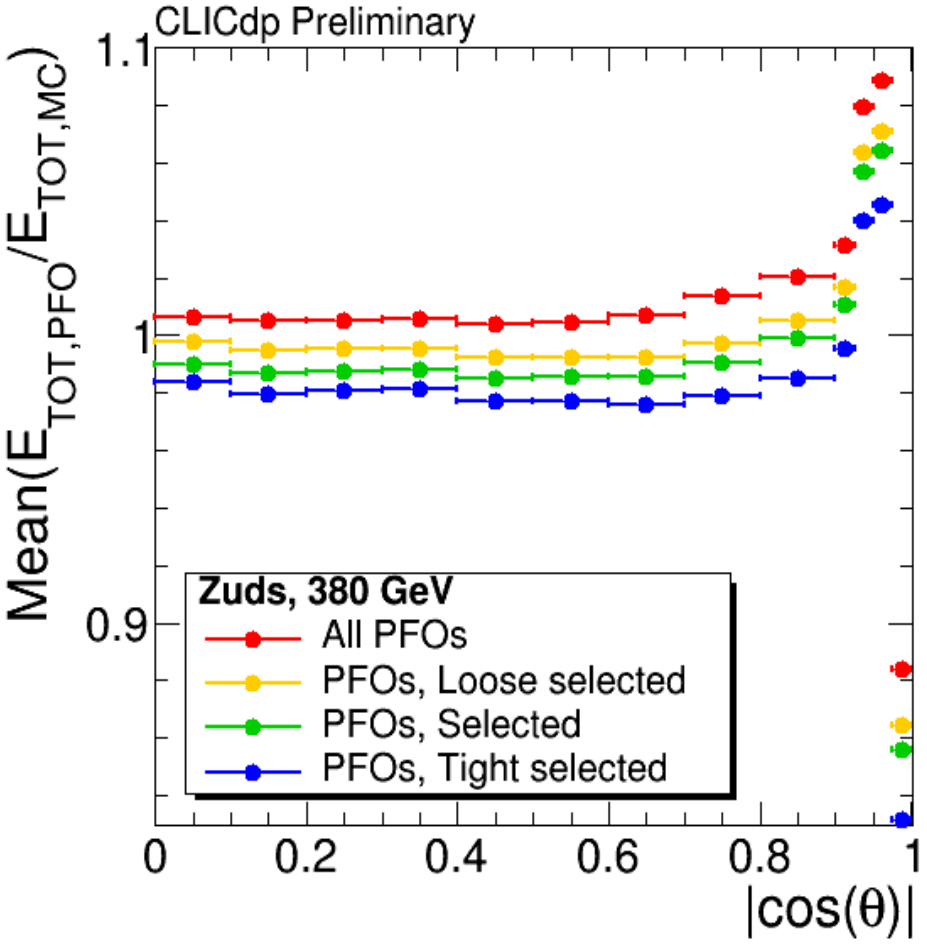


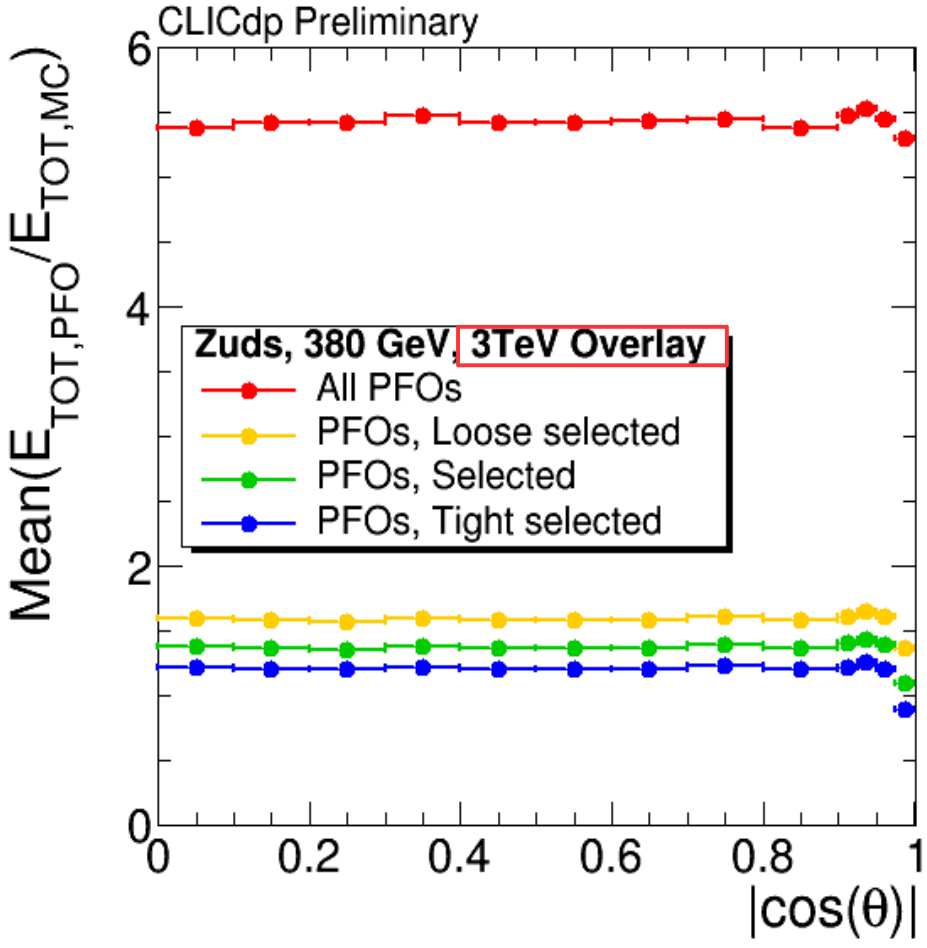


Identify the problem: first steps

- **First sample used: Z → uds**
  - Centre of mass energy = 380 GeV
  - Overlay = 3 TeV
  - Selections used: Loose, Selected, Tight

- **Energy scale for different <u>cosθ</u> bins**

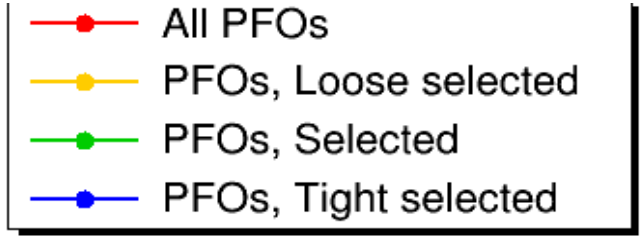


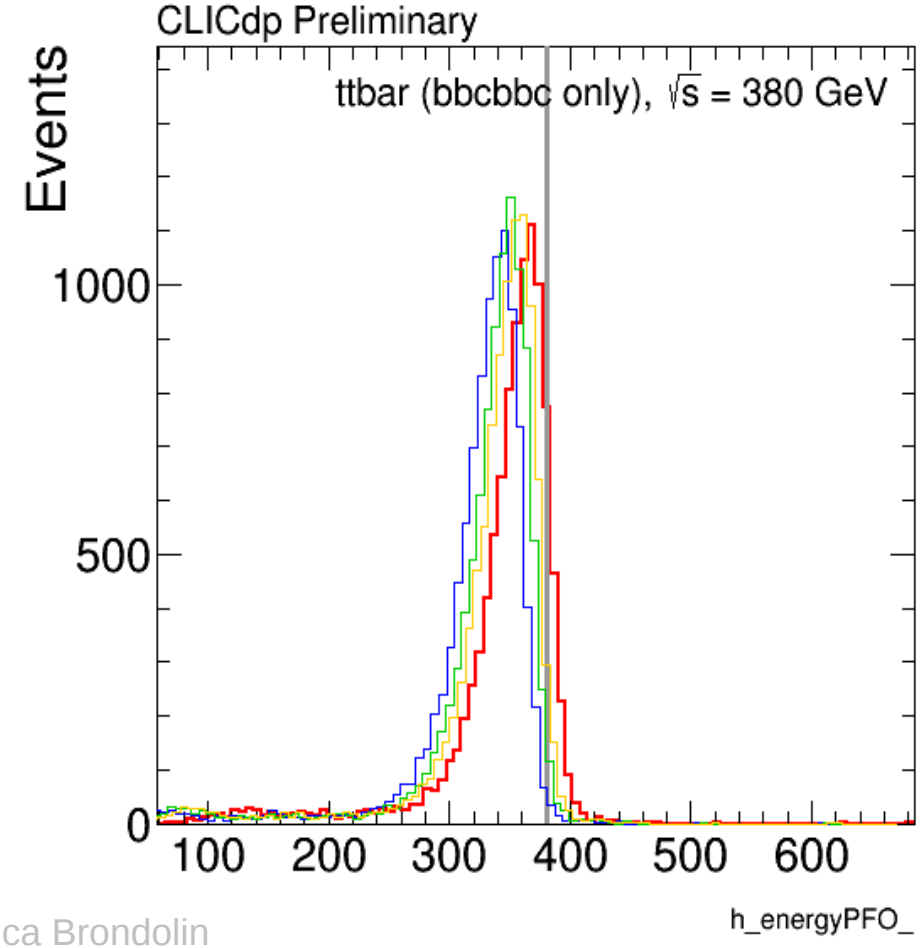


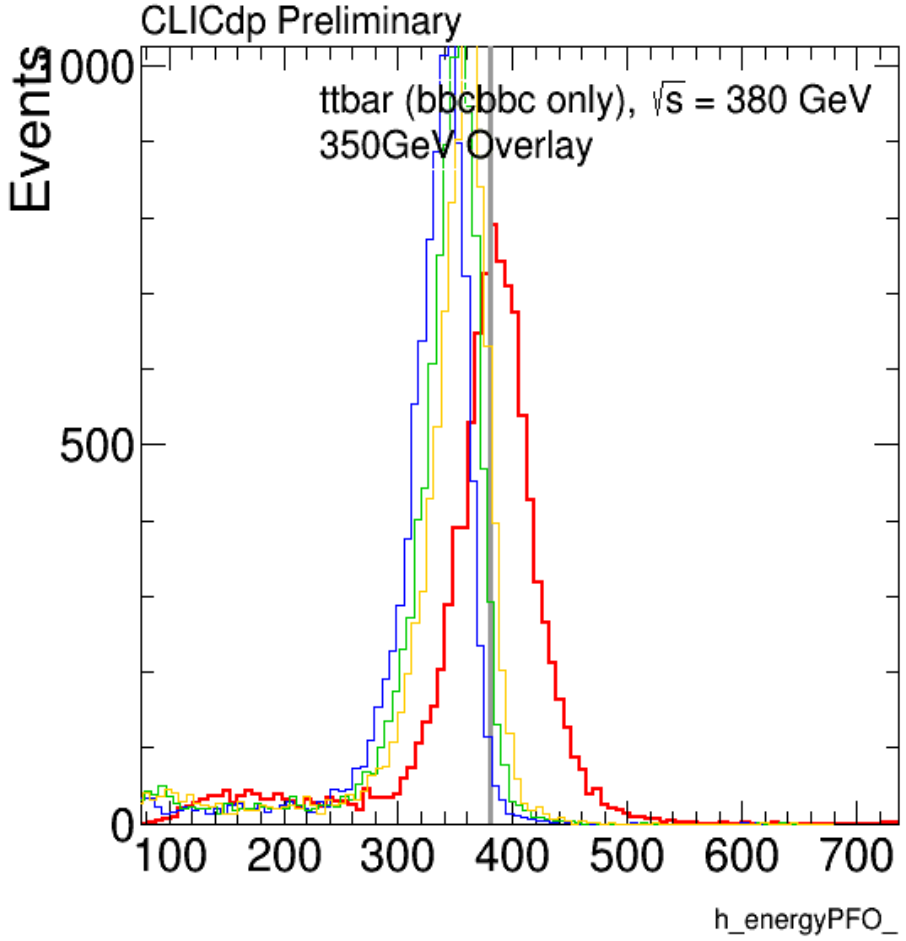
Identify the problem: ttbar (bbcbbc)

- **Second sample used: ttbar (bbcbbc)**
  - Centre of mass energy = 380 GeV + Overlay = 350 GeV
  - Selections used: Loose, Selected, Tight

- **Not possible to compute cosθ easily because top is at rest**
- **Inclusive distribution**



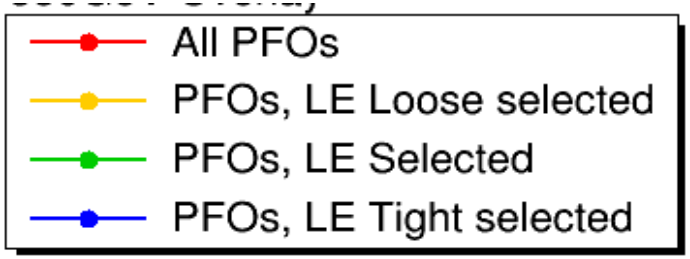


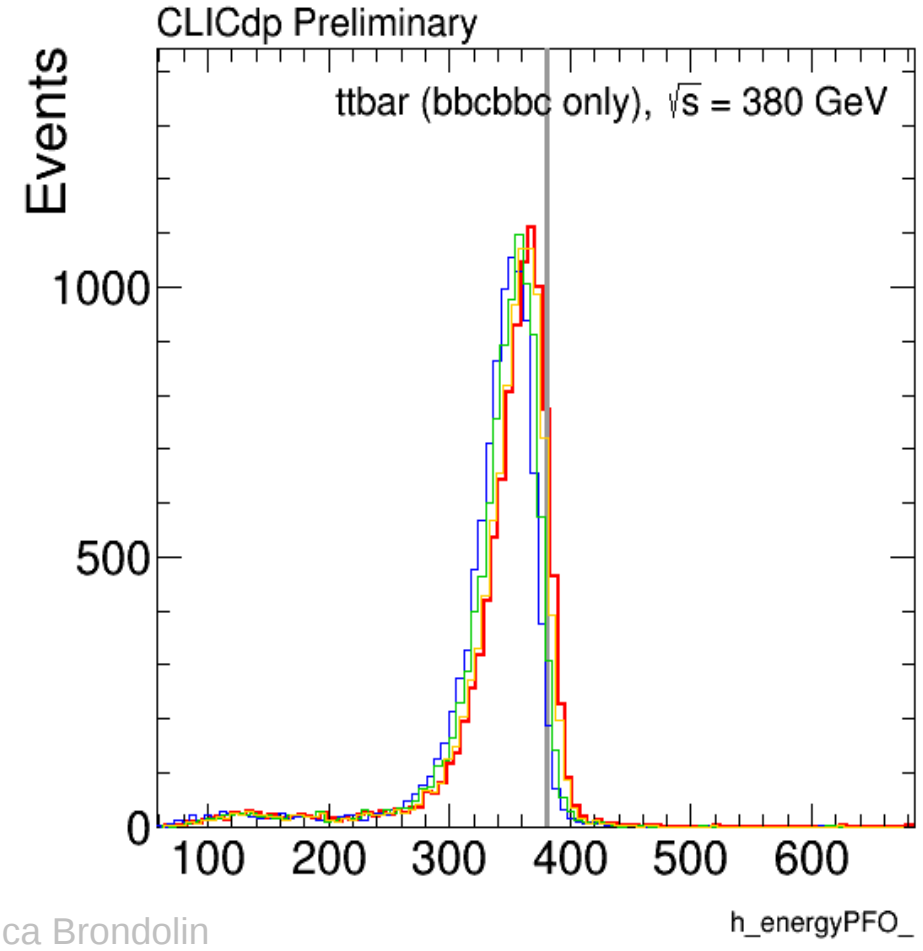


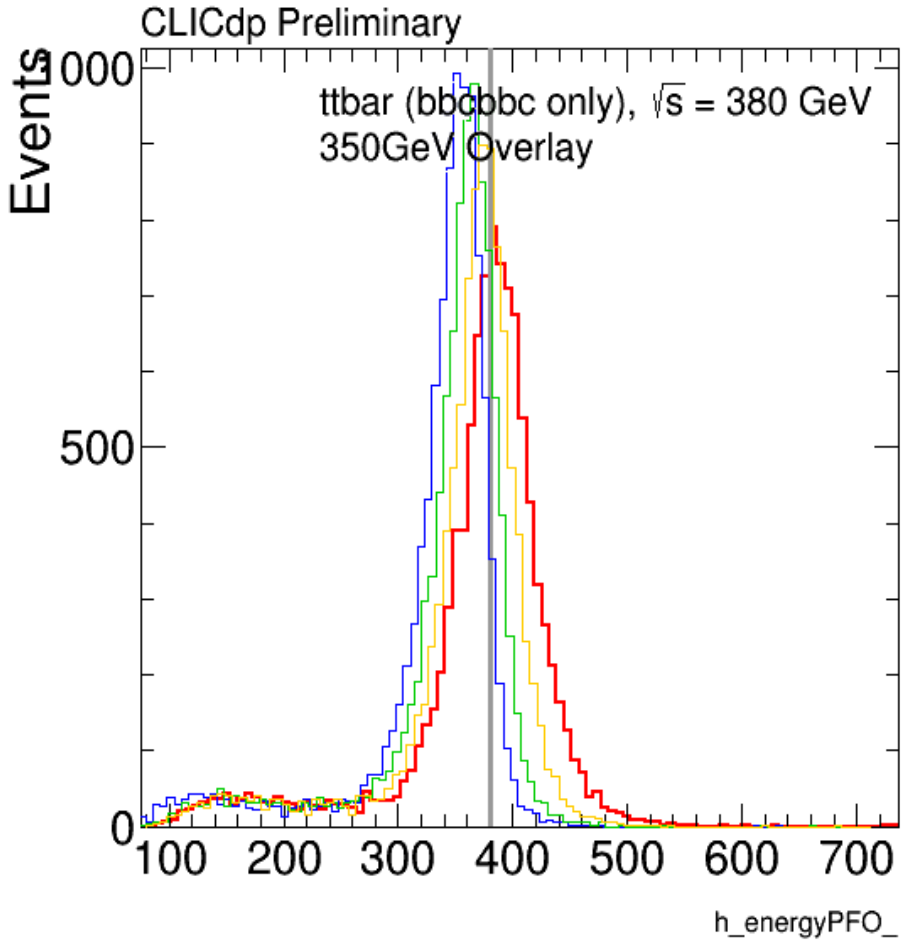
Identify the problem (2): ttbar (bbcbbc)

- **Second sample used: ttbar (bbcbbc)**
  - Centre of mass energy = 380 GeV + Overlay = 350 GeV
  - Selections used: LE Loose, LE Selected, LE Tight

- **Inclusive distribution**
- **LE timing cuts used**
  → differences between HE and LE cuts in backup



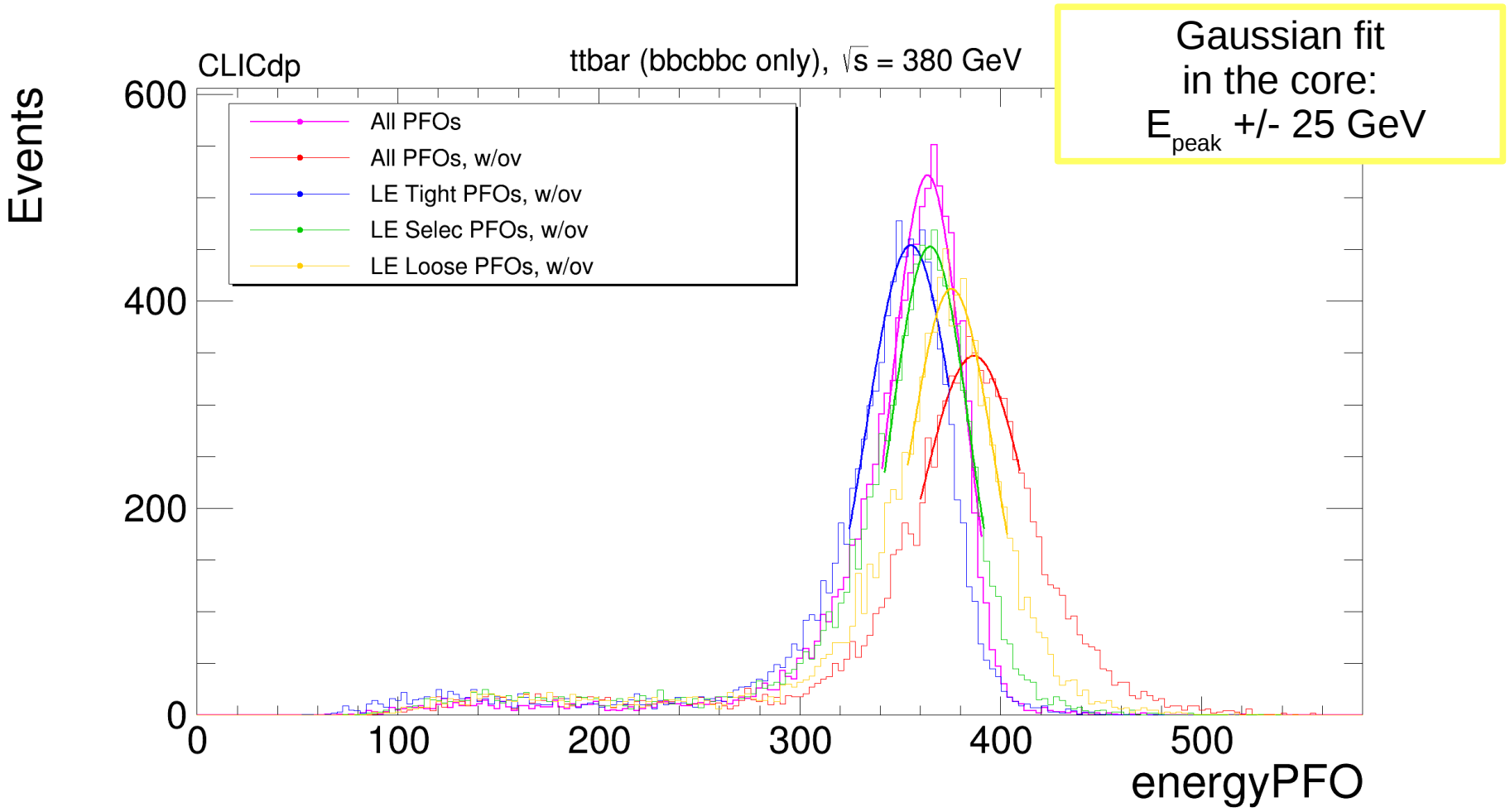




Identify the problem (2): ttbar (bbcbbc)

- **Second sample used: ttbar (bbcbbc)**
  - Centre of mass energy = 380 GeV + Overlay = 350 GeV
  - Selections used: Loose, Selected, Tight

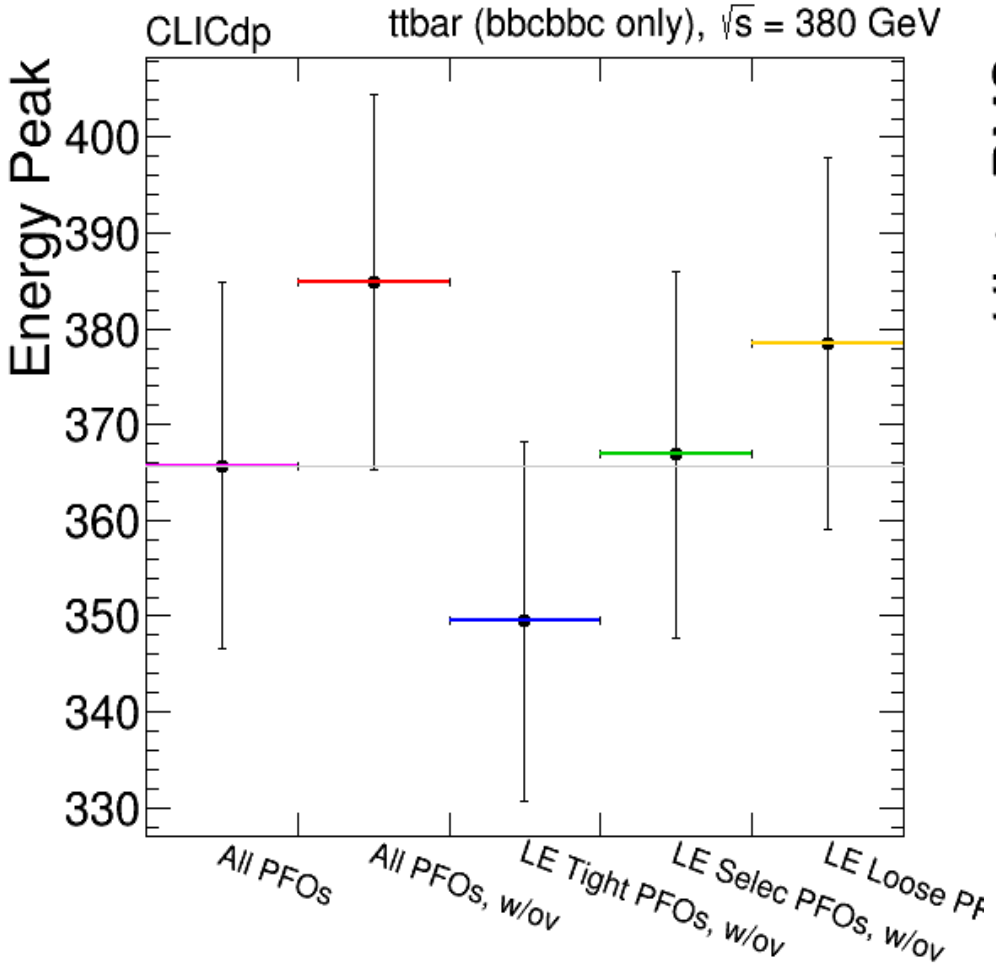
- **Main idea:**
  LE timing cuts w/overlay should reproduce "All PFOs" energy w/o overlay
- **Lot of missing energy due to the b-jets**

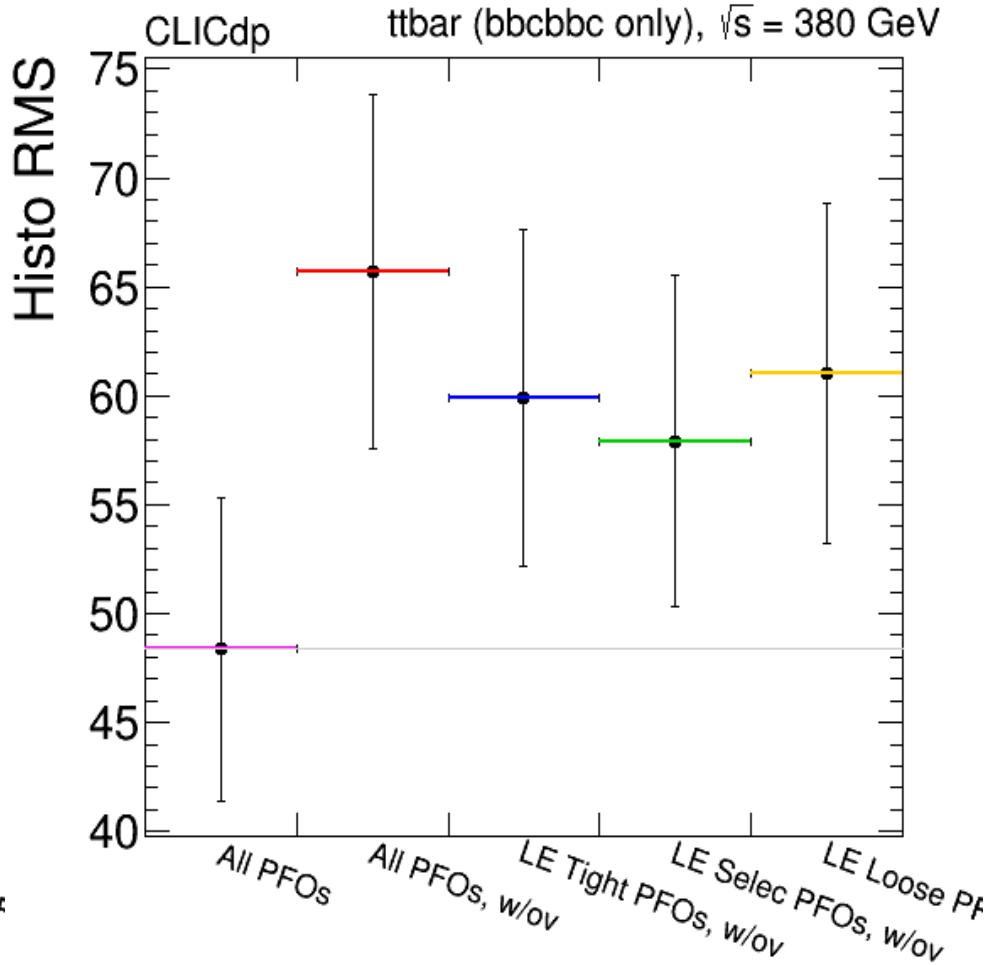


Identify the problem (2): ttbar (bbcbbc)

- **Second sample used: ttbar (bbcbbc)**
  - Centre of mass energy = 380 GeV + Overlay = 350 GeV
  - Selections used: Loose, Selected, Tight

- **Main idea:**
  LE timing cuts w/overlay should reproduce "All PFOs" energy w/o overlay





Identify the problem (2): ttbar (bbcbbc)

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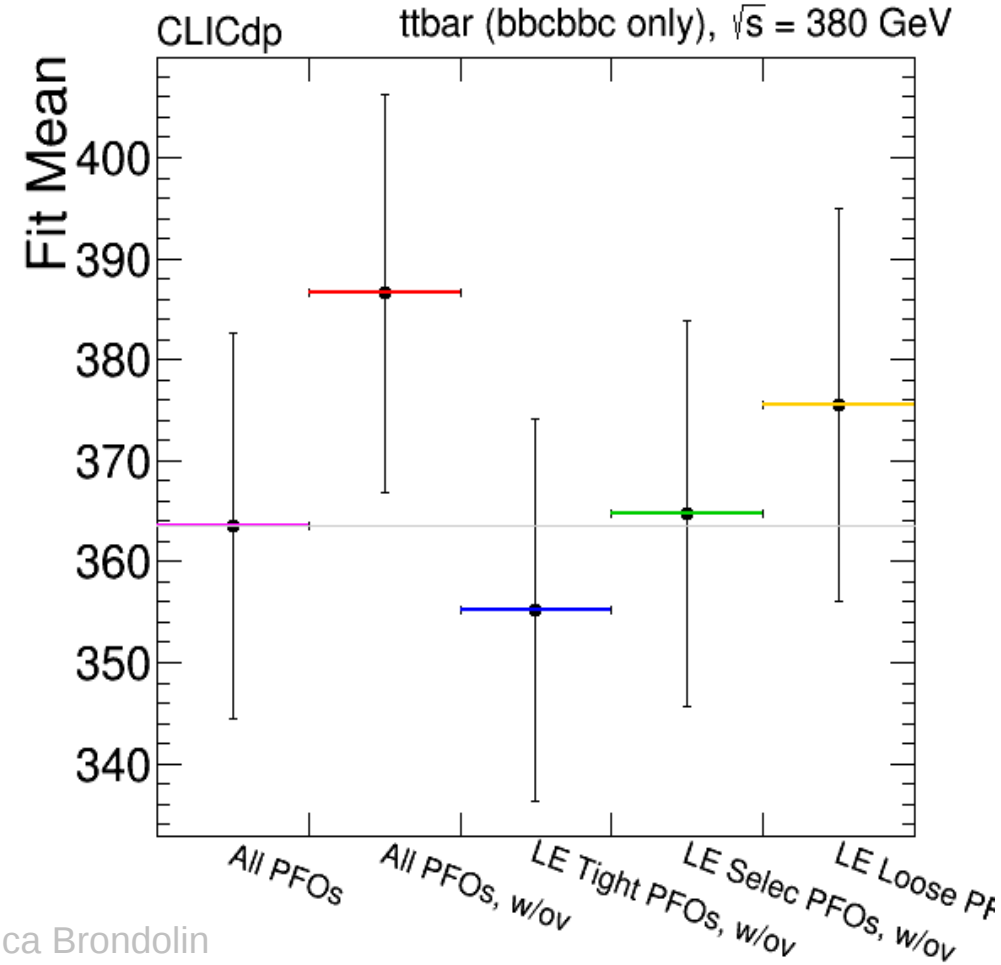
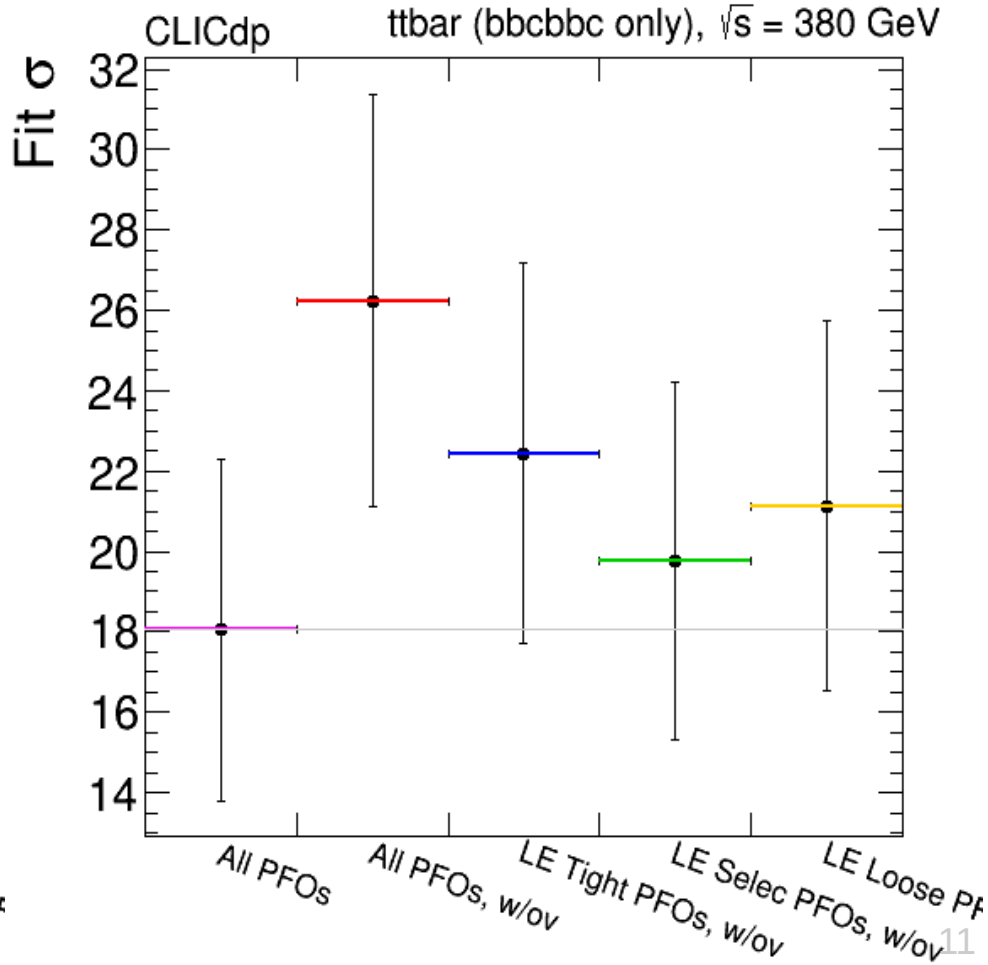
  - Centre of mass energy = 380 GeV + Overlay = 350 GeV
  - Selections used: Loose, Selected, Tight

- **Main idea:**
  LE timing cuts w/overlay should reproduce “All PFOs” energy w/o overlay

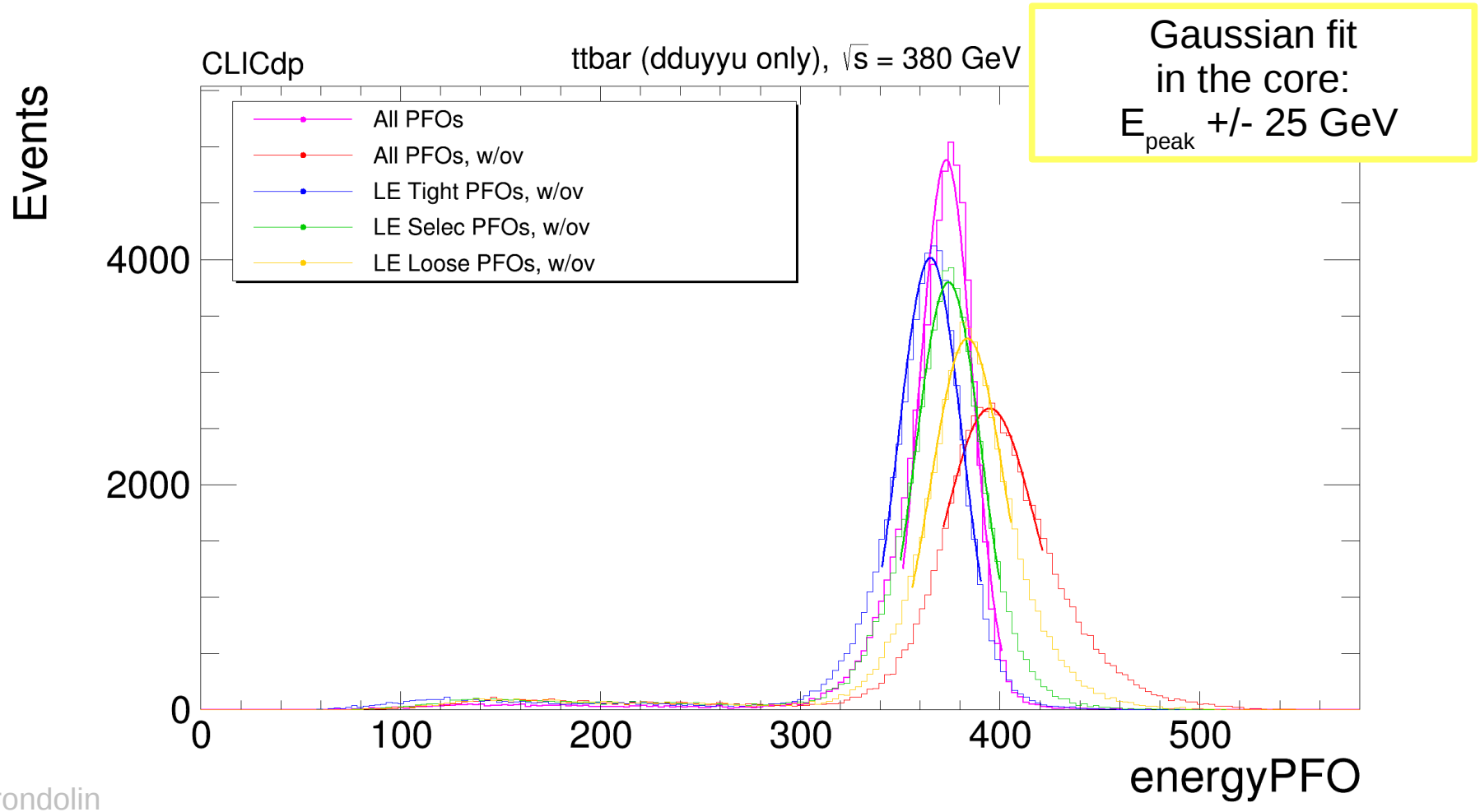




Identify the problem (3): ttbar (dduyyu)

- **Third sample used: ttbar (dduyyu)**
  - Centre of mass energy = 380 GeV + Overlay = 350 GeV
  - More light quarks (y = d,s,b)
  - Selections used: Loose, Selected, Tight

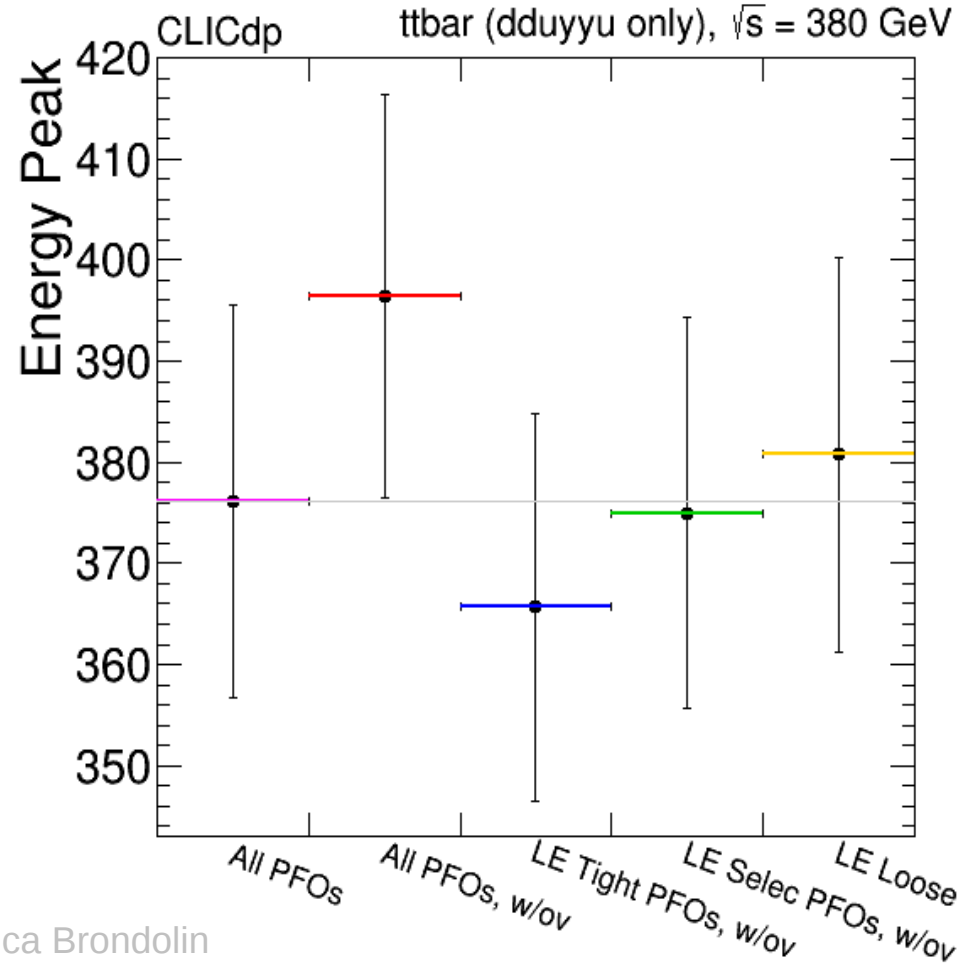
- **Main idea:**
  LE timing cuts w/overlay should reproduce "All PFOs" energy w/o overlay

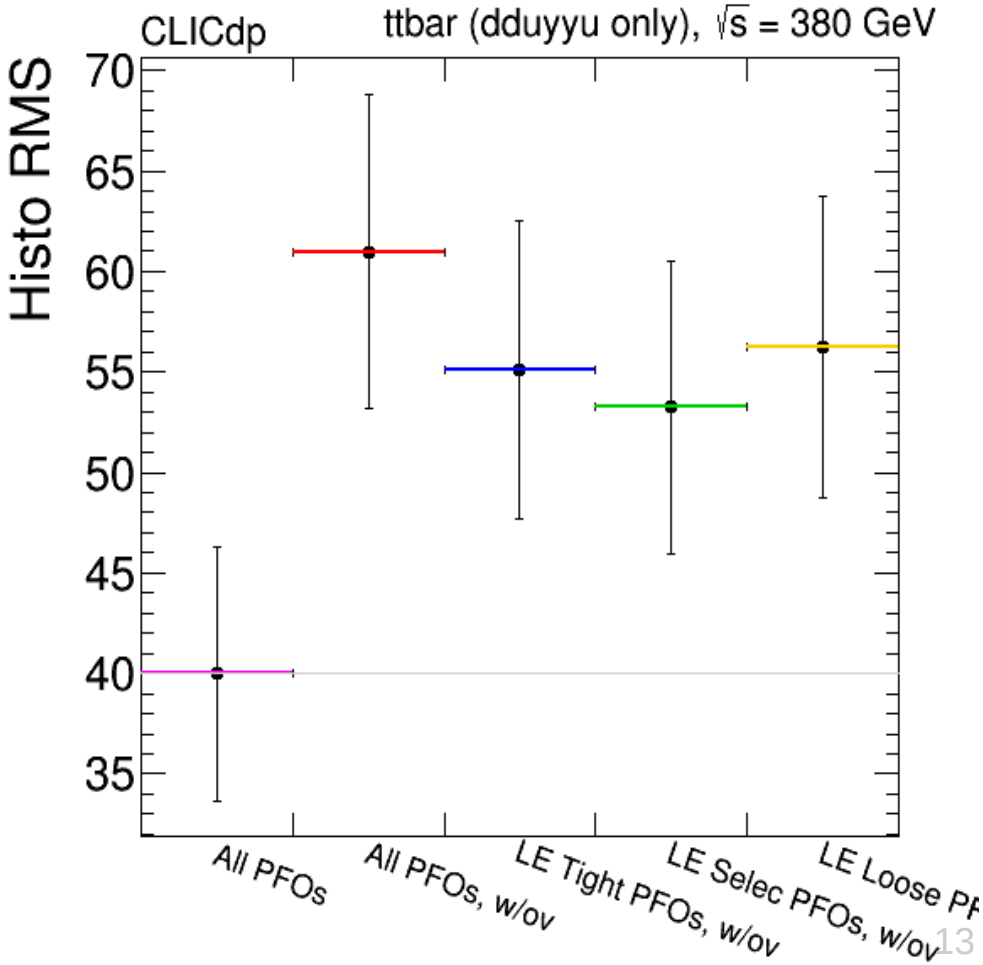


Identify the problem (3): ttbar (dduyyu)

- **Third sample used: ttbar (dduyyu)**
  - Centre of mass energy = 380 GeV + Overlay = 350 GeV
  - More light quarks (y = d,s,b)
  - Selections used: Loose, Selected, Tight

- **Main idea:**
  LE timing cuts w/overlay should reproduce "All PFOs" energy w/o overlay

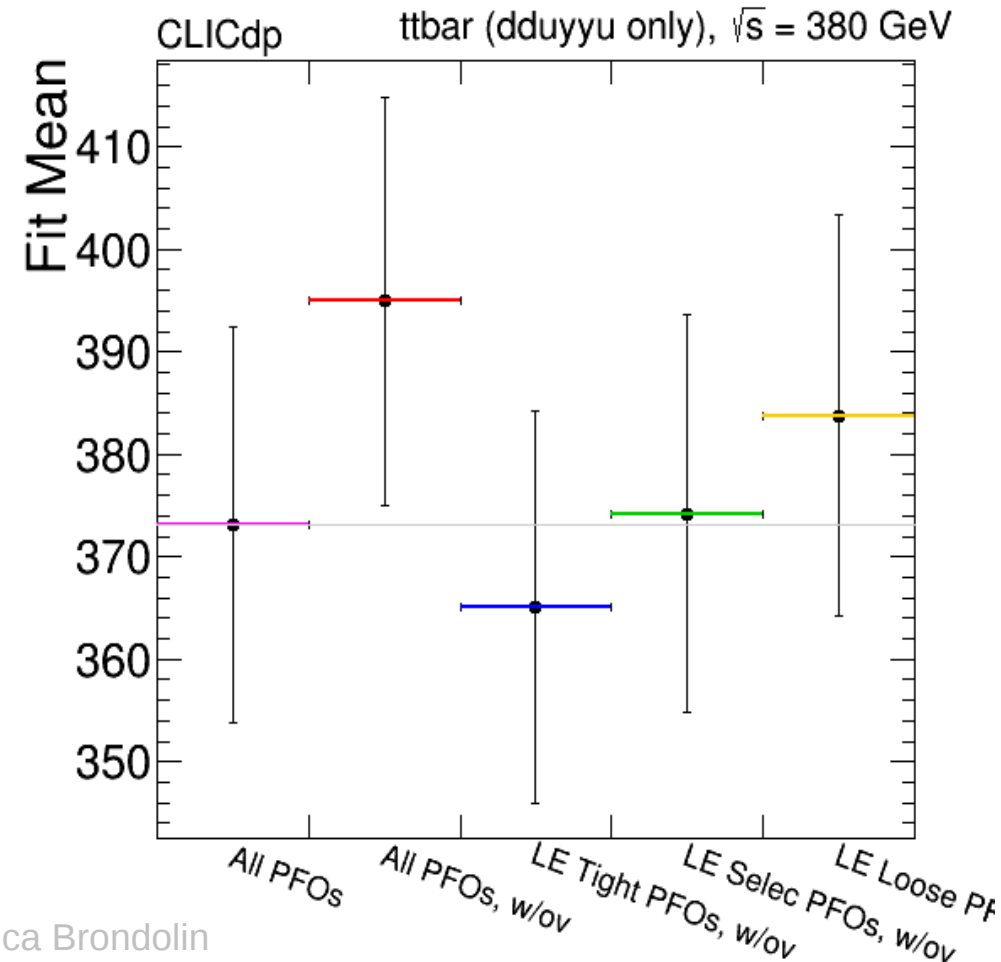


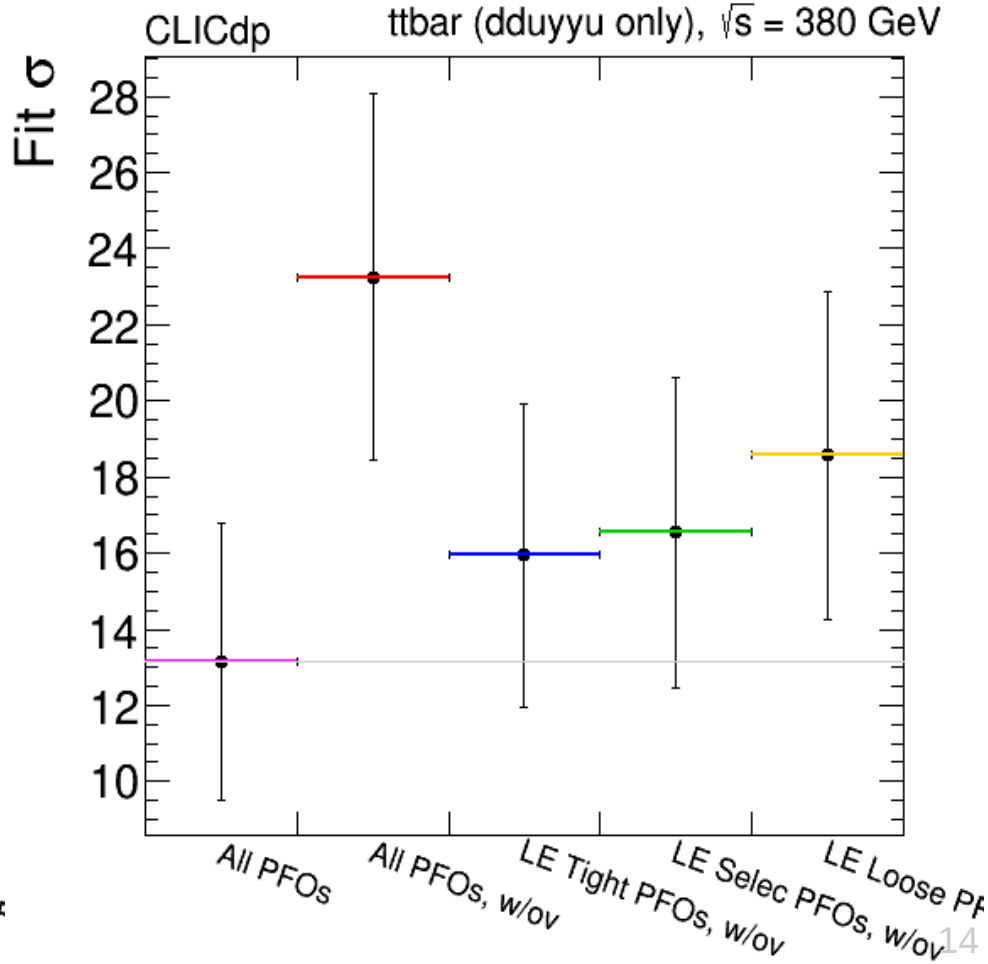


Identify the problem (3): ttbar (dduyyu)

- **Third sample used: ttbar (dduyyu)**
  - Centre of mass energy = 380 GeV + Overlay = 350 GeV
  - More light quarks (y = d,s,b)
  - Selections used: Loose, Selected, Tight

- **Main idea:**
  LE timing cuts w/overlay should reproduce "All PFOs" energy w/o overlay





Identify the problem : summary

- **Sample:**
  - ttbar
  - Centre of mass energy = 380 GeV
  - Overlay = 350 GeV
  - More light quarks → **dduyyu** (with y = d,s,b)
  - REC ProdId #9762 #9763

- **Figure of merit:**
  - Comparison (PFO energy without overlay) vs (PFO energy + cuts with overlay)
  - Look at histo distribution
  - Fit?

How to proceed

- **Identify the problem**
  - Find and check datasample
  - Produce PFOs energy distributions
  - Define “figure(s) of merit”

- **Understand current approach**
  - Current documentation
  - Select variables needed

- **Improving**
  - Produce new correlation plots
  - Introduce new LE timing cuts
  - Evaluate the impact
  - Re-iterate if necessary

- **Outlook**

Current approach: documentation

- **Papers:**
  “Performance of Particle Flow Calorimetry at CLIC”, arXiv:1209.4039
  CDR, Appendix B

- **Useful presentations:**
  https://indico.cern.ch/event/157476/contributions/1406549/attachments/174783/246032/Manchester_CLIC_Review_Oct2011_Thomson.pdf
  https://indico.cern.ch/event/116322/contributions/71526/attachments/53288/76615/WG6_20110126.pdf

- **More updated documentation?**

- **In the code:**
  MarlinReco/Analysis/CLICPfoSelector

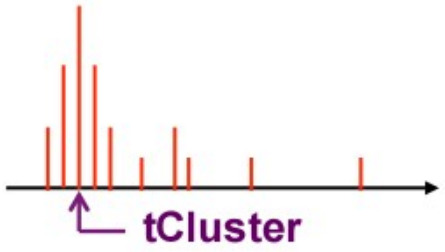
Current approach: documentation

- **Main idea**

Reconstruction in Time

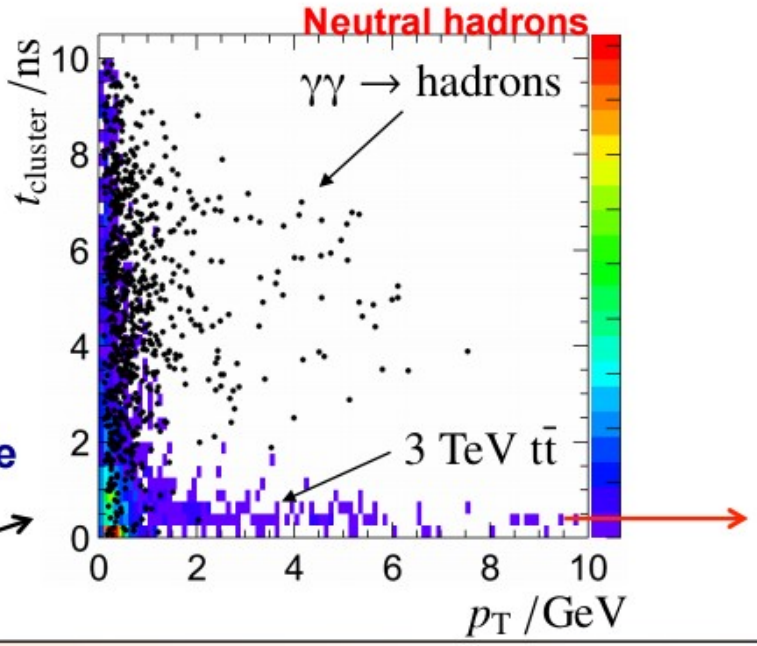
★ After reconstruction have a list of particles (PFOs):
- charged particles – mostly matched to clusters
- photons – EM clusters
- neutral hadrons – clusters

★ High granularity calorimeter - even low energy clusters have many hits
- calculate energy weighted truncated mean time of each cluster
  - calo hit times corrected for time-of-flight (straight-line)
  - sub-ns resolution



- use times to reject clusters
- also can reject associated tracks
  - account for helical propagation time

★ Reject PFOs from background
- e.g. neutral hadrons in Endcap



Mark Thomson CLIC Review, Manchester, October 2011 17

Current approach: documentation

- **Main idea**

PFOSelection

★ Only apply to "low" p_T PFOs
★ Three sets of timing cuts applied in reconstruction
- Loose, Default, Tight

Table B.2

Region	p_T range	time cut
	Photons	
central	$0.75\ \text{GeV} \leq p_T < 4.0\ \text{GeV}$	$t < 2.0$ ns
$\cos\theta \leq 0.975$	$0\ \text{GeV} \leq p_T < 0.75\ \text{GeV}$	$t < 1.0$ ns
forward	$0.75\ \text{GeV} \leq p_T < 4.0\ \text{GeV}$	$t < 2.0$ ns
$\cos\theta > 0.975$	$0\ \text{GeV} \leq p_T < 0.75\ \text{GeV}$	$t < 1.0$ ns
	neutral hadrons	
central	$0.75\ \text{GeV} \leq p_T < 8.0\ \text{GeV}$	$t < 2.5$ ns
$\cos\theta \leq 0.975$	$0\ \text{GeV} \leq p_T < 0.75\ \text{GeV}$	$t < 1.5$ ns
forward	$0.75\ \text{GeV} \leq p_T < 8.0\ \text{GeV}$	$t < 2.0$ ns
$\cos\theta > 0.975$	$0\ \text{GeV} \leq p_T < 0.75\ \text{GeV}$	$t < 1.0$ ns
	charged particles	
all	$0.75\ \text{GeV} \leq p_T < 4.0\ \text{GeV}$	$t < 3.0$ ns
	$0\ \text{GeV} \leq p_T < 0.75\ \text{GeV}$	$t < 1.5$ ns

Current approach: documentation

- **Translate into code**

```
<group name="PfoSelector">
  <!--Selects Pfos from full PFO list using timing cuts-->
  <!--ChargedPfoLooseTimingCut-->
  <parameter name="ChargedPfoLooseTimingCut" type="float">3 </parameter>
  <!--ChargedPfoNegativeLooseTimingCut-->
  <parameter name="ChargedPfoNegativeLooseTimingCut" type="float">-1 </parameter>
  <!--ChargedPfoNegativeTightTimingCut-->
  <parameter name="ChargedPfoNegativeTightTimingCut" type="float">-0.5 </parameter>
  <!--ChargedPfoPtCut-->
  <parameter name="ChargedPfoPtCut" type="float">0 </parameter>
  <!--ChargedPfoPtCutForLooseTiming-->
  <parameter name="ChargedPfoPtCutForLooseTiming" type="float">4 </parameter>
  <!--ChargedPfoTightTimingCut-->
  <parameter name="ChargedPfoTightTimingCut" type="float">1.5 </parameter>
  <!--CheckKaonCorrection-->
  <parameter name="CheckKaonCorrection" type="int">0 </parameter>
  <!--CheckProtonCorrection-->
  <parameter name="CheckProtonCorrection" type="int">0 </parameter>
  <!--ClusterLessPfoTrackTimeCut-->
  <parameter name="ClusterLessPfoTrackTimeCut" type="float">10 </parameter>
  <!--CorrectHitTimesForTimeOfFlight-->
  <parameter name="CorrectHitTimesForTimeOfFlight" type="int">0 </parameter>
  <!--DisplayRejectedPfos-->
  <parameter name="DisplayRejectedPfos" type="int">1 </parameter>
  <!--DisplaySelectedPfos-->
  <parameter name="DisplaySelectedPfos" type="int">1 </parameter>
  <!--FarForwardCosTheta-->
  <parameter name="FarForwardCosTheta" type="float">0.975 </parameter>
  <!--ForwardCosThetaForHighEnergyNeutralHadrons-->
  <parameter name="ForwardCosThetaForHighEnergyNeutralHadrons" type="float">0.95 </parameter>
  <!--ForwardHighEnergyNeutralHadronsEnergy-->
  <parameter name="ForwardHighEnergyNeutralHadronsEnergy" type="float">10 </parameter>
  <!--HCalBarrelLooseTimingCut-->
  <parameter name="HCalBarrelLooseTimingCut" type="float">20 </parameter>
  <!--HCalBarrelTightTimingCut-->
  <parameter name="HCalBarrelTightTimingCut" type="float">10 </parameter>
  <!--HCalEndCapTimingFactor-->
  <parameter name="HCalEndCapTimingFactor" type="float">1 </parameter>
  <!--Input PFO Collection-->
  <parameter name="InputPfoCollection" type="string" lcioInType="ReconstructedParticle">PandoraPFOs </parameter>
  <!--KeepKShorts-->
  <parameter name="KeepKShorts" type="int">1 </parameter>
```

- **Entire list of parameters and values for HE vs LE in backup**

Current approach: variables needed

- Event Num
- Num PFO tracks
- Num clusters

- PFO particle Id
- PFO charge
- PFO momentum components (px,py,pz,pT)
- PFO cosθ
- PFO energy
- PFO cluster time (*)

(*) if more than one clusters, take the one with min time

How to proceed

- **Identify the problem**
  - Find and check datasample
  - Produce PFOs energy distributions
  - Define “figure(s) of merit”

- **Understand current approach**
  - Current documentation
  - Select variables needed

- **Improving**
  - Produce new correlation plots
  - Introduce new LE timing cuts
  - Evaluate the impact
  - Re-iterate if necessary

- **Outlook**

Work in progress

Improving: correlation plots

- **Main idea:**

Creating new processor called 'CLICPfoSelectorAnalysis', which creates a TTree with the PFO variables used in the CLIC selection and produce scatter plots of PFO cluster time vs PFO pT for:
- different particle “class”:
Photons, charged particles, neutral hadrons
- different cosθ regions:
central, forward

- **Prototype:**

https://github.com/ebrondol/MarlinReco/tree/addCLICPfoSelTree

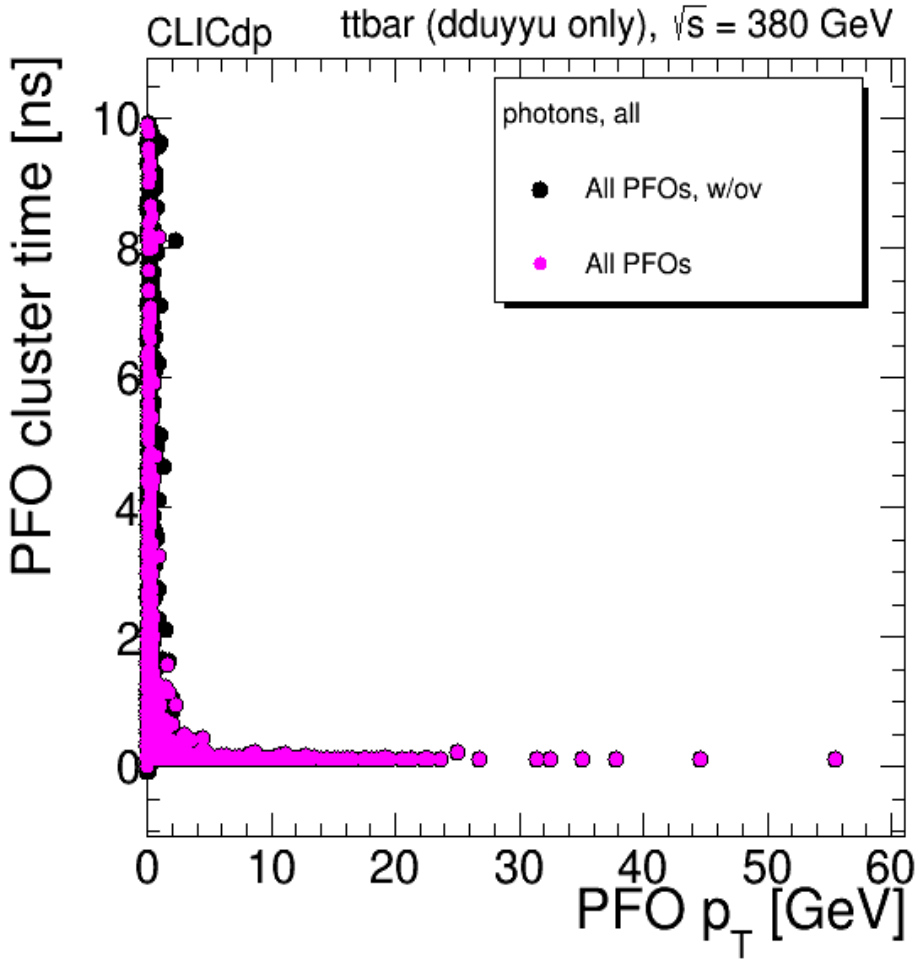
- **Sample used:**
  - ttbar
  - Centre of mass energy = 380 GeV
  - Overlay = 350 GeV
  - More light quarks → dduyyu (with y = d,s,b)
  - 100 events

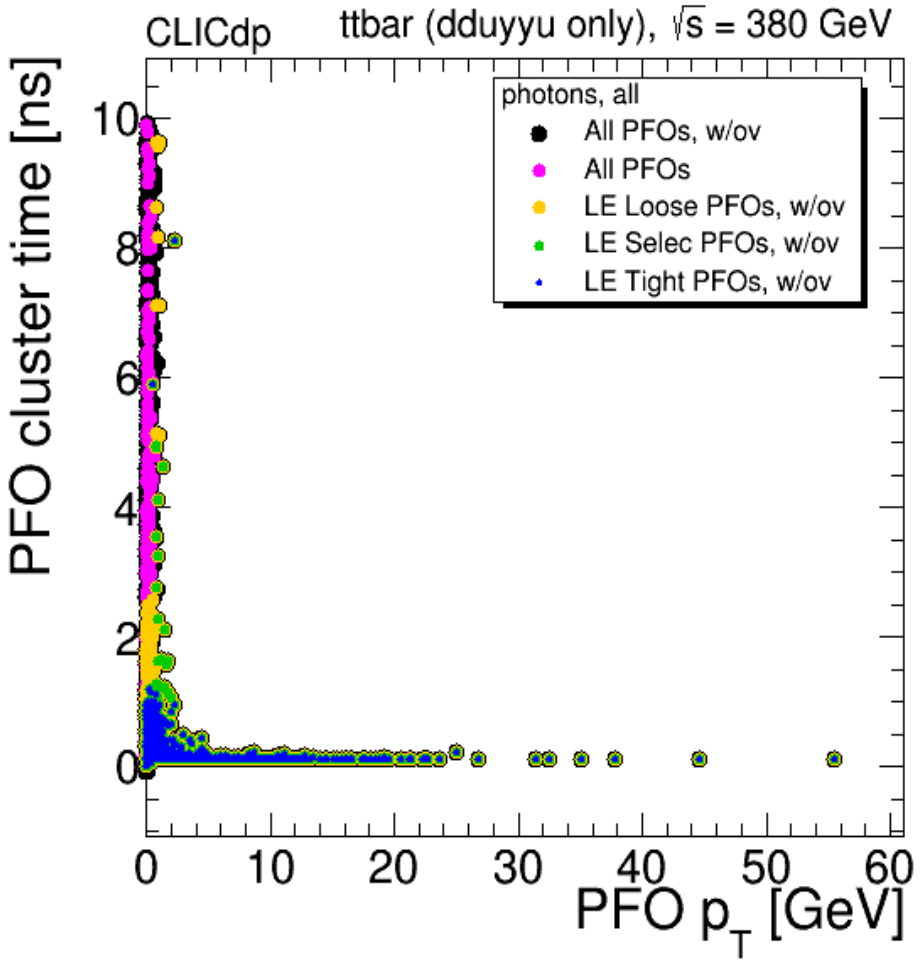
  → This sample is particularly challenging!

- **Entire set of plots:**
  http://ebrondol.web.cern.ch/ebrondol/CLIC/EnergyStudies/ttbar/380GeV/dduyyu/

Improving: correlation plots

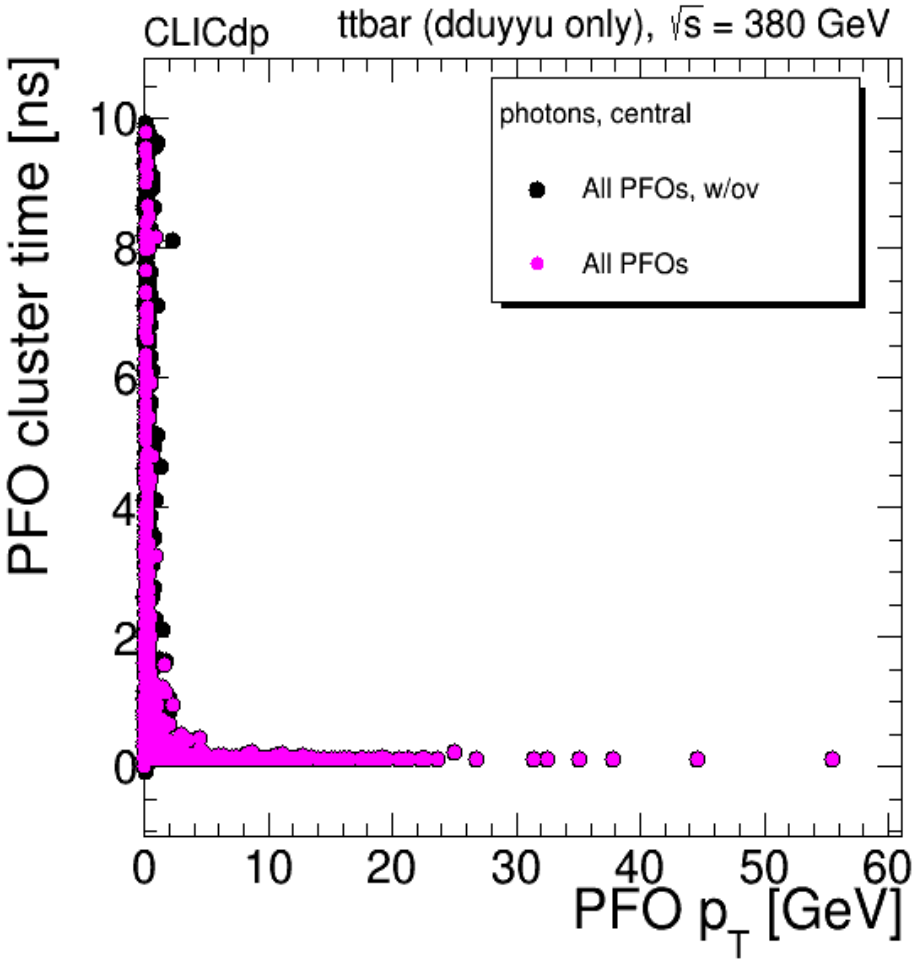
- **Photons, all**

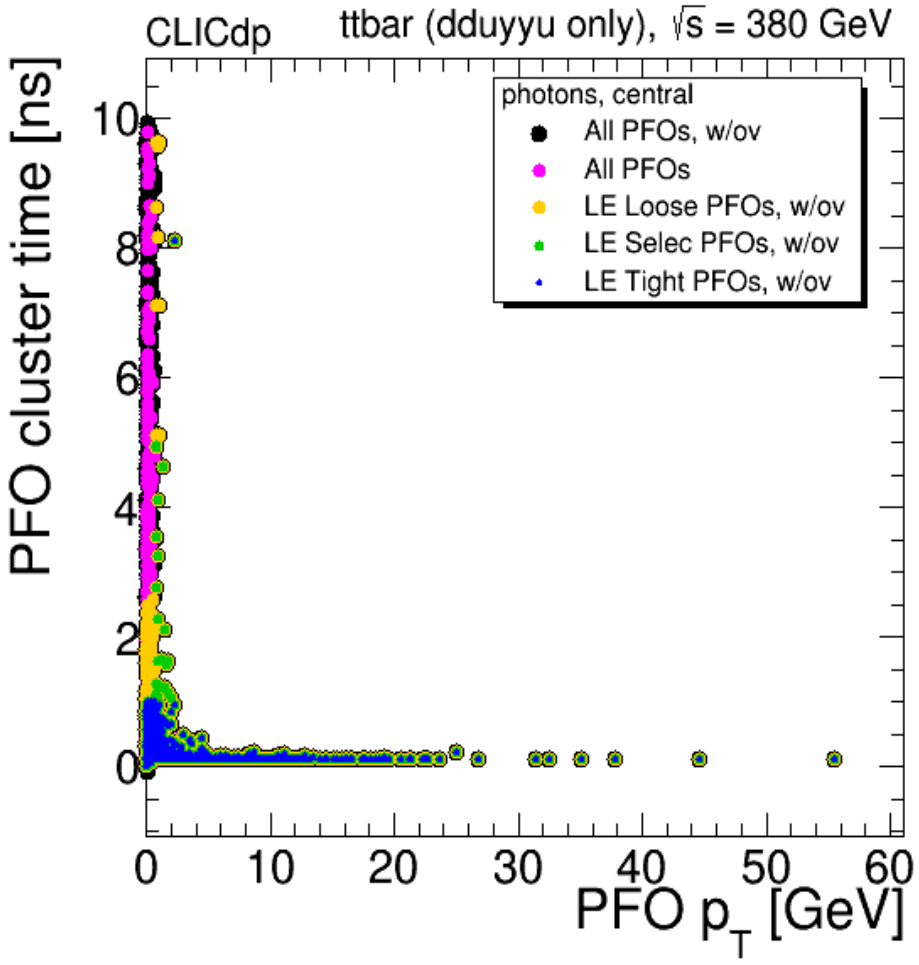




Improving: correlation plots

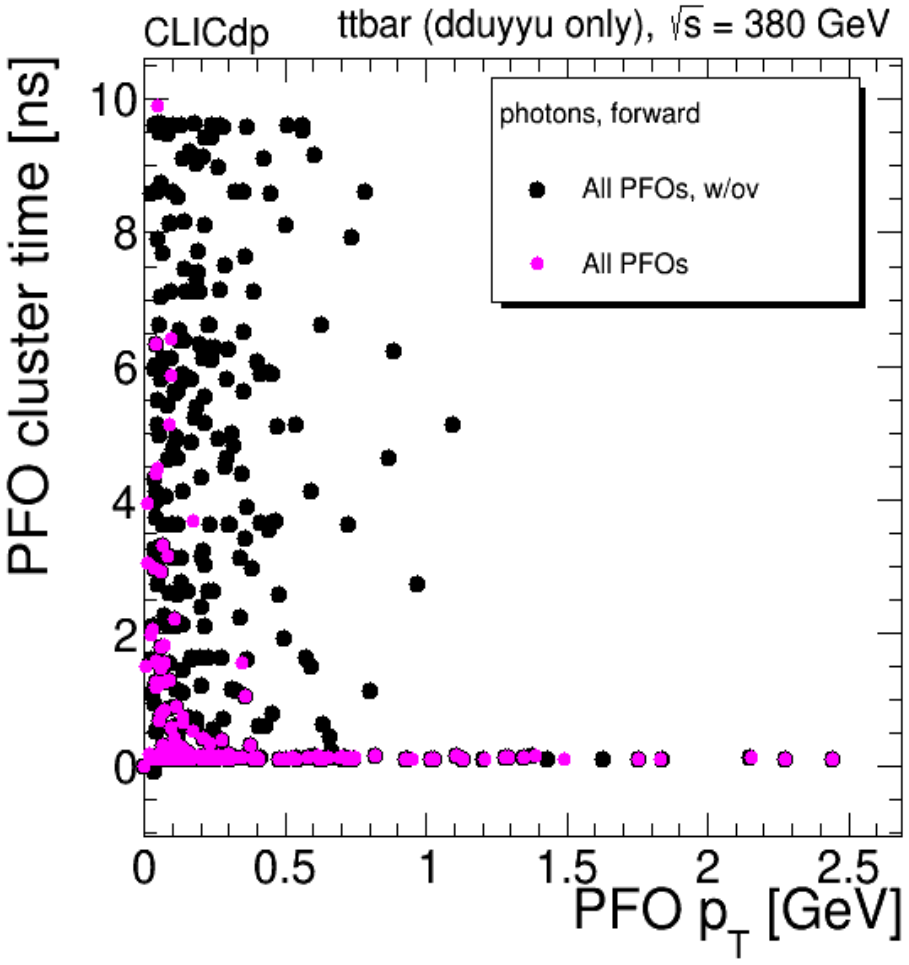
- **Photons, cosθ < 0.975**

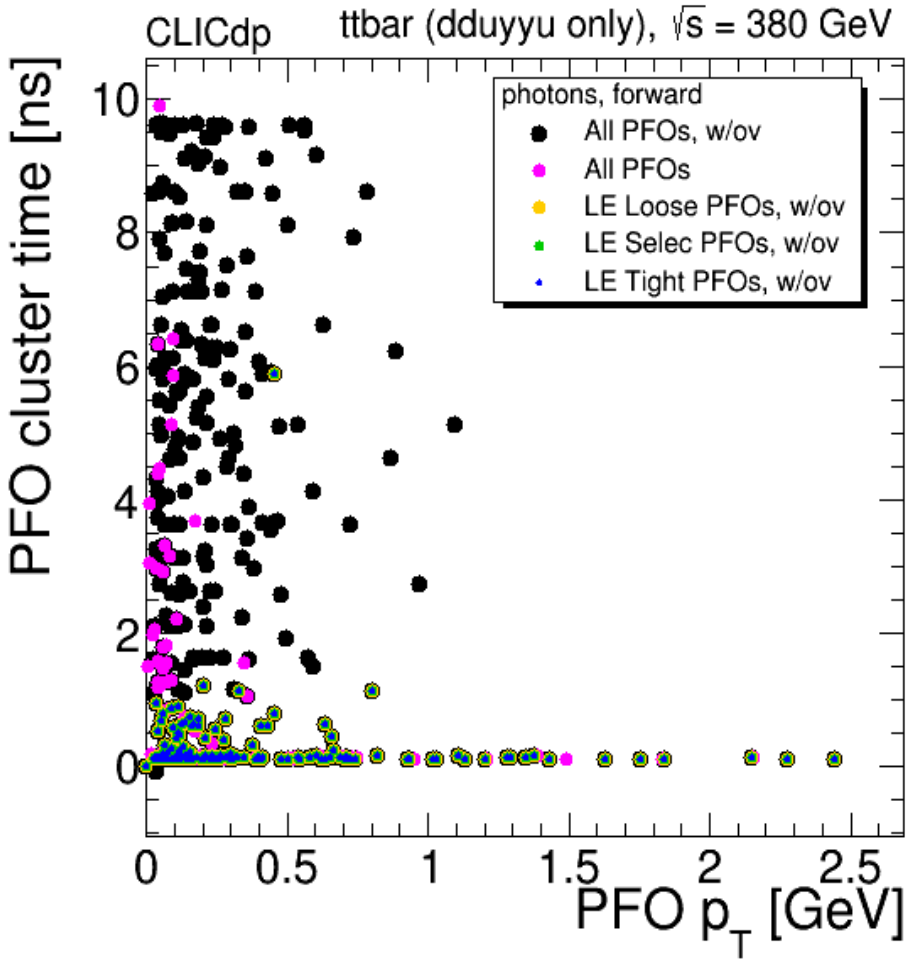




Improving: correlation plots

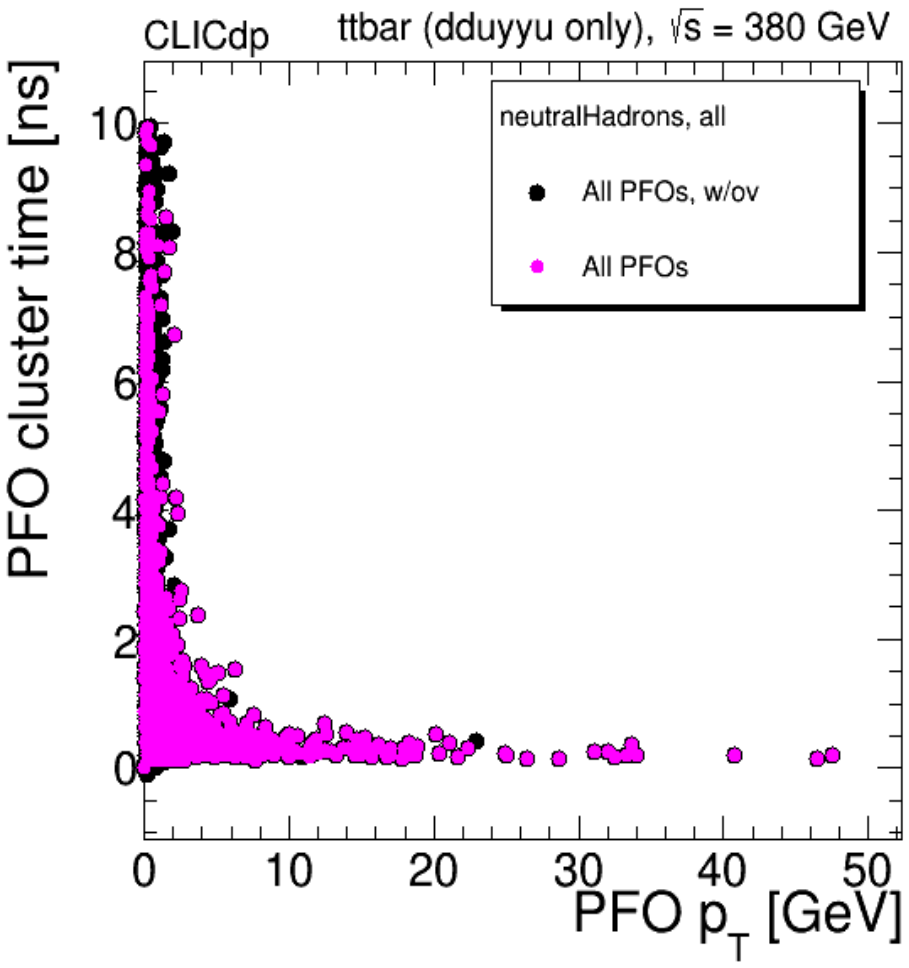
- **Photons, cosθ ≥ 0.975**

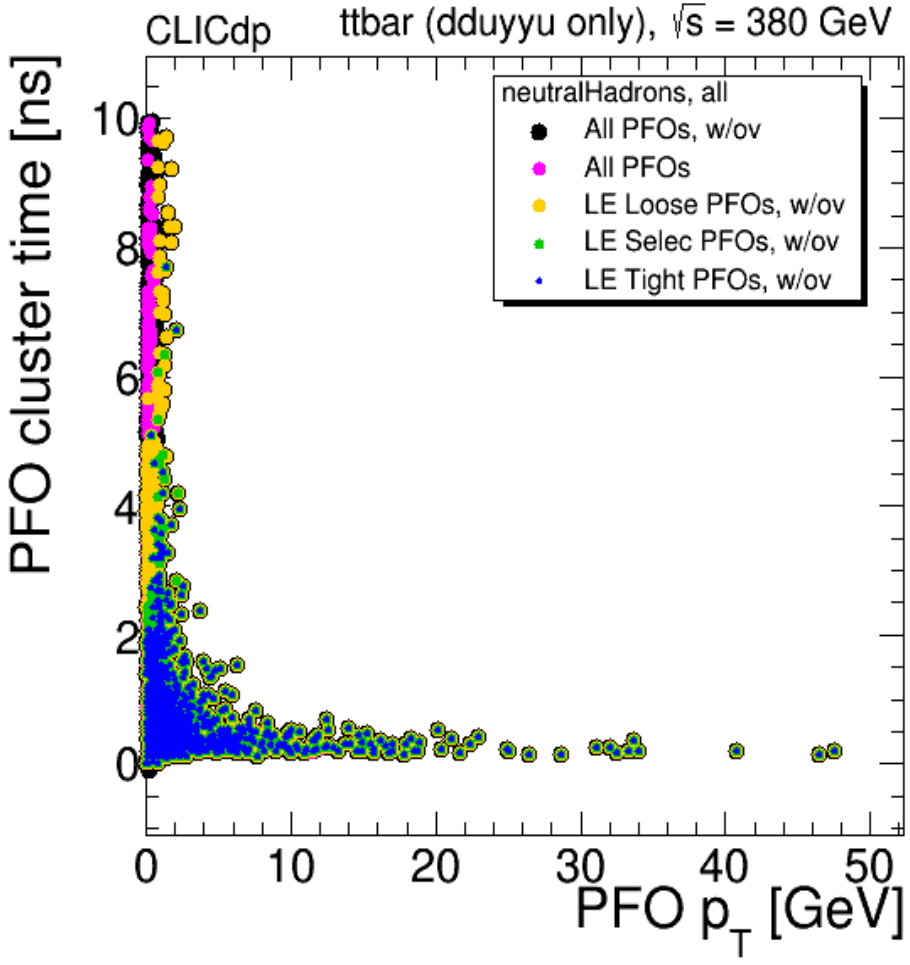




Improving: correlation plots

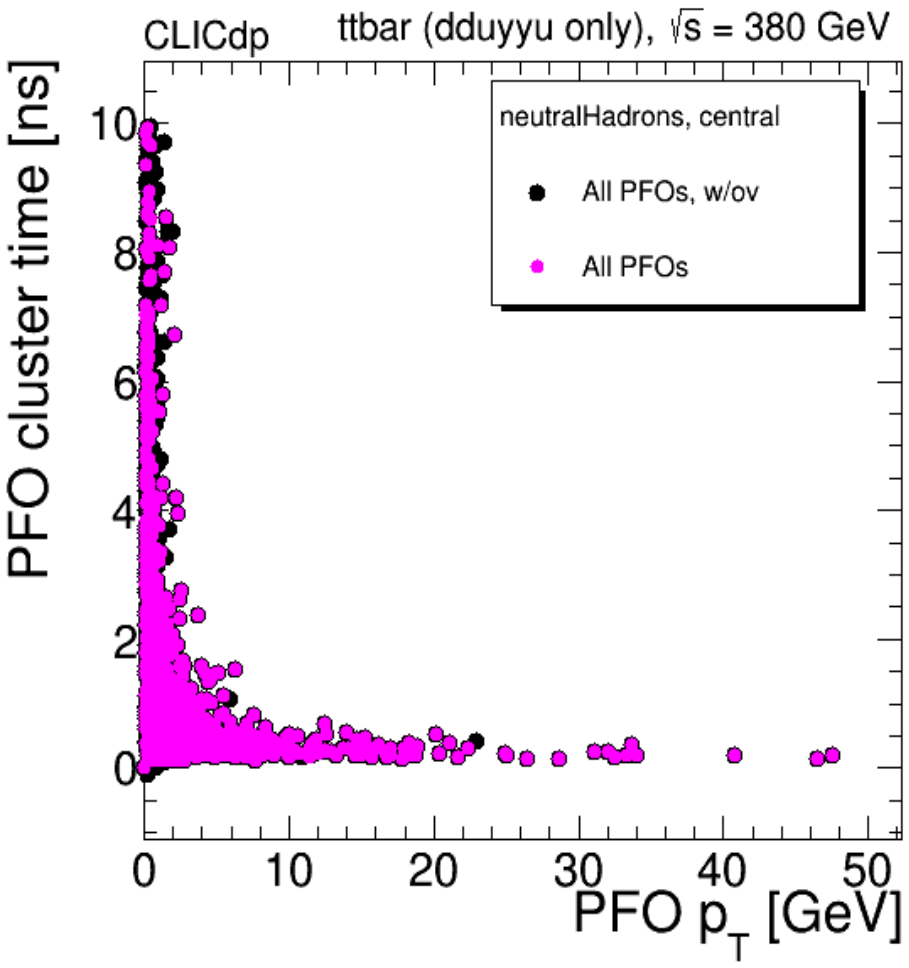
- **Neutral hadrons, all**

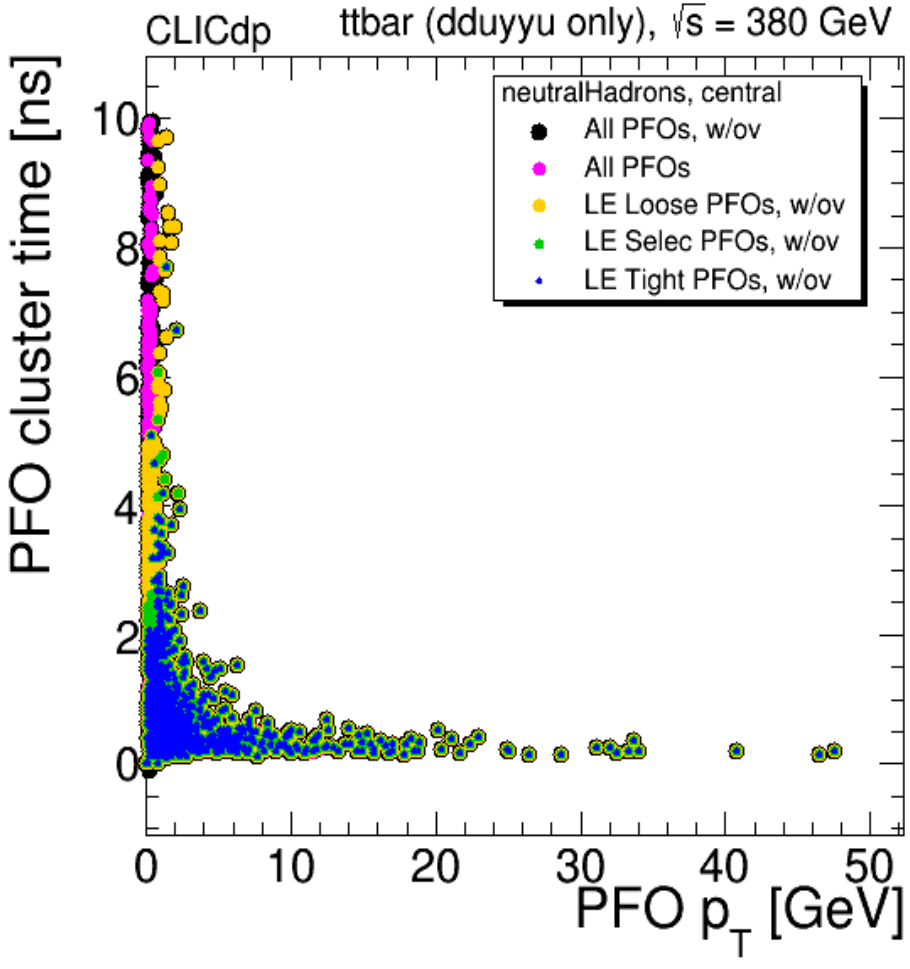




Improving: correlation plots

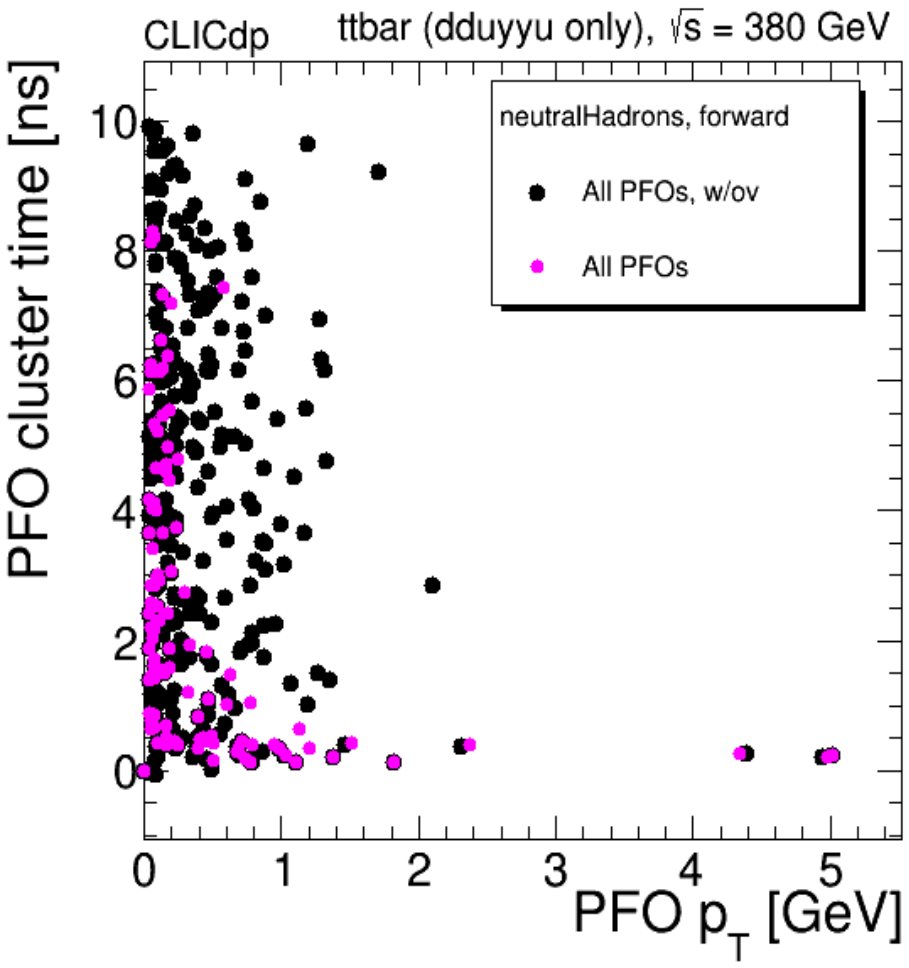
- **Neutral hadrons, cosθ < 0.975**

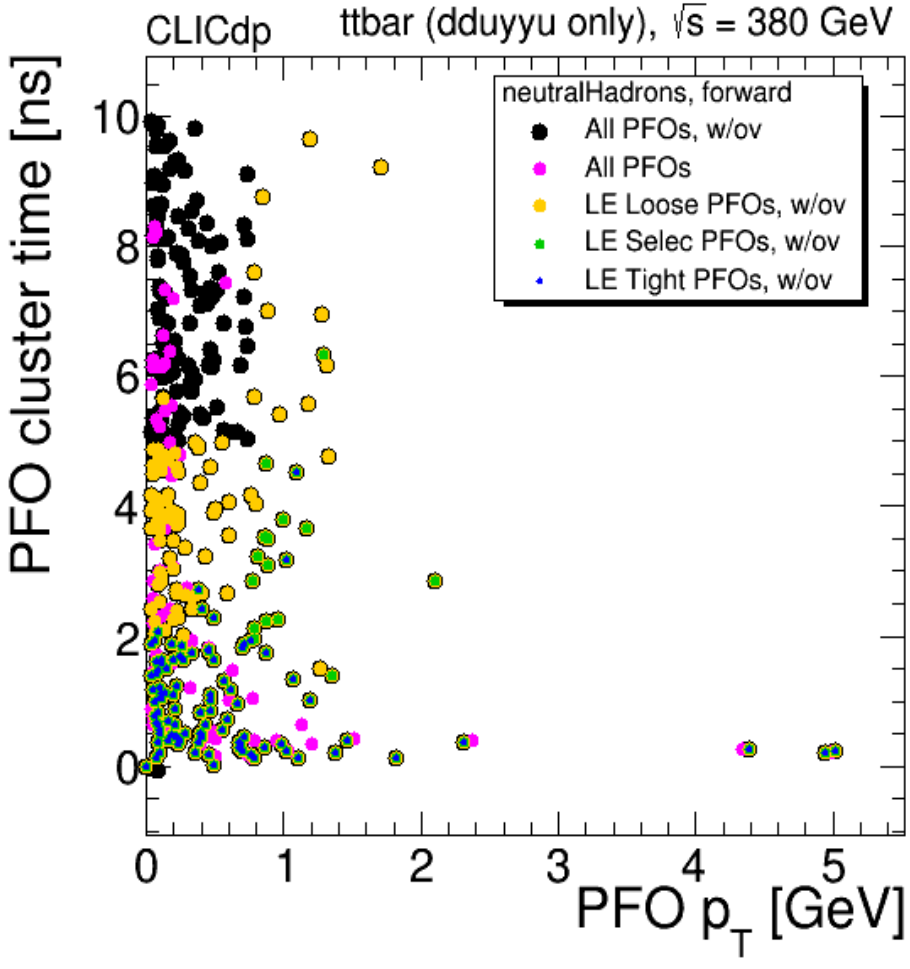




Improving: correlation plots

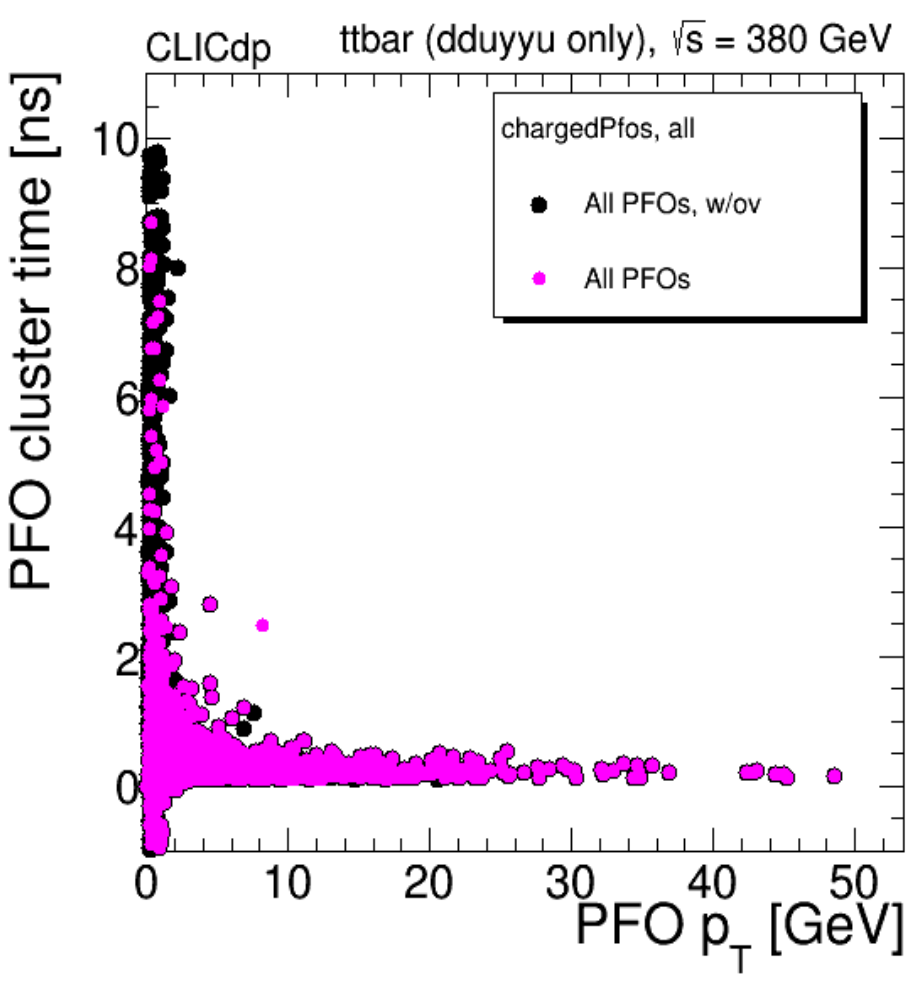
- **Neutral hadrons, cosθ ≥ 0.975**

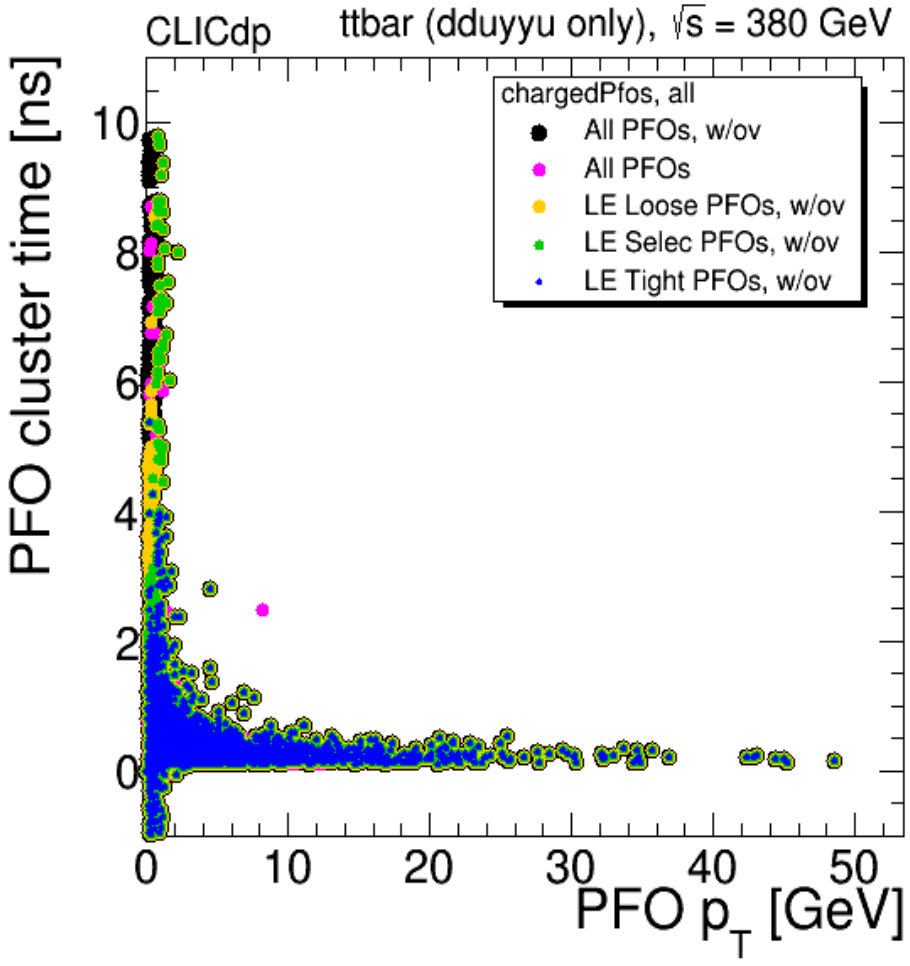




Improving: correlation plots

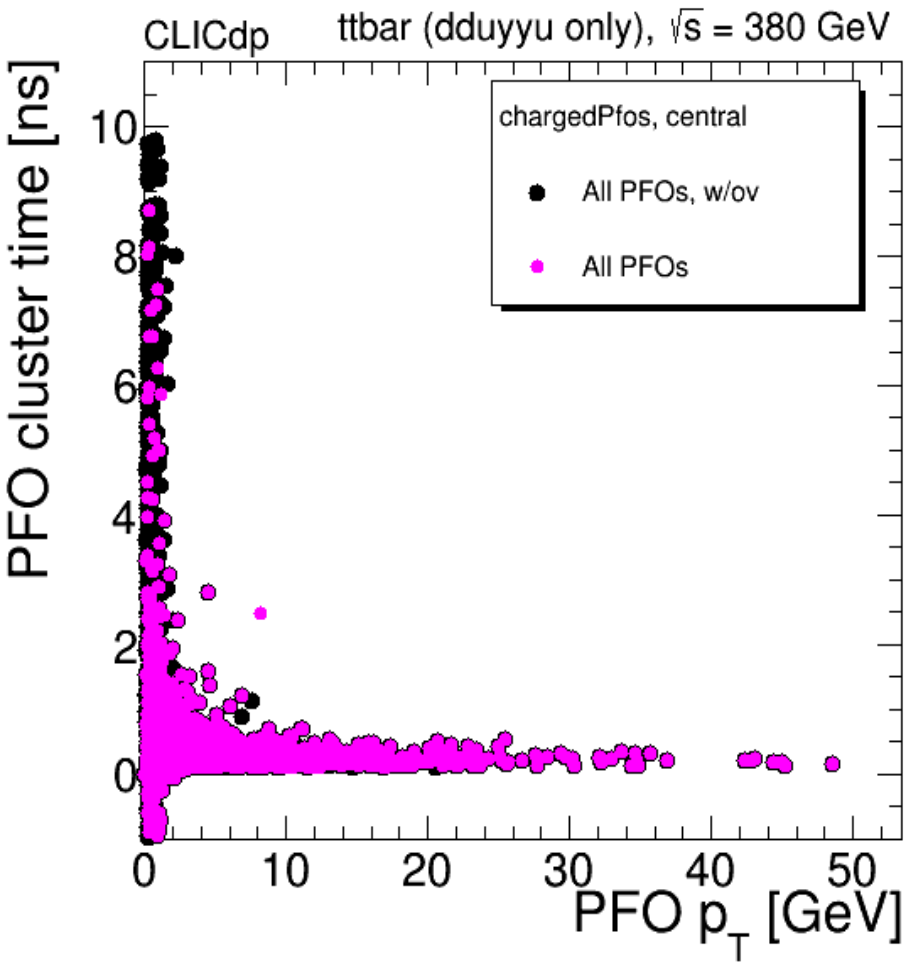
- **Charged PFOs, all**

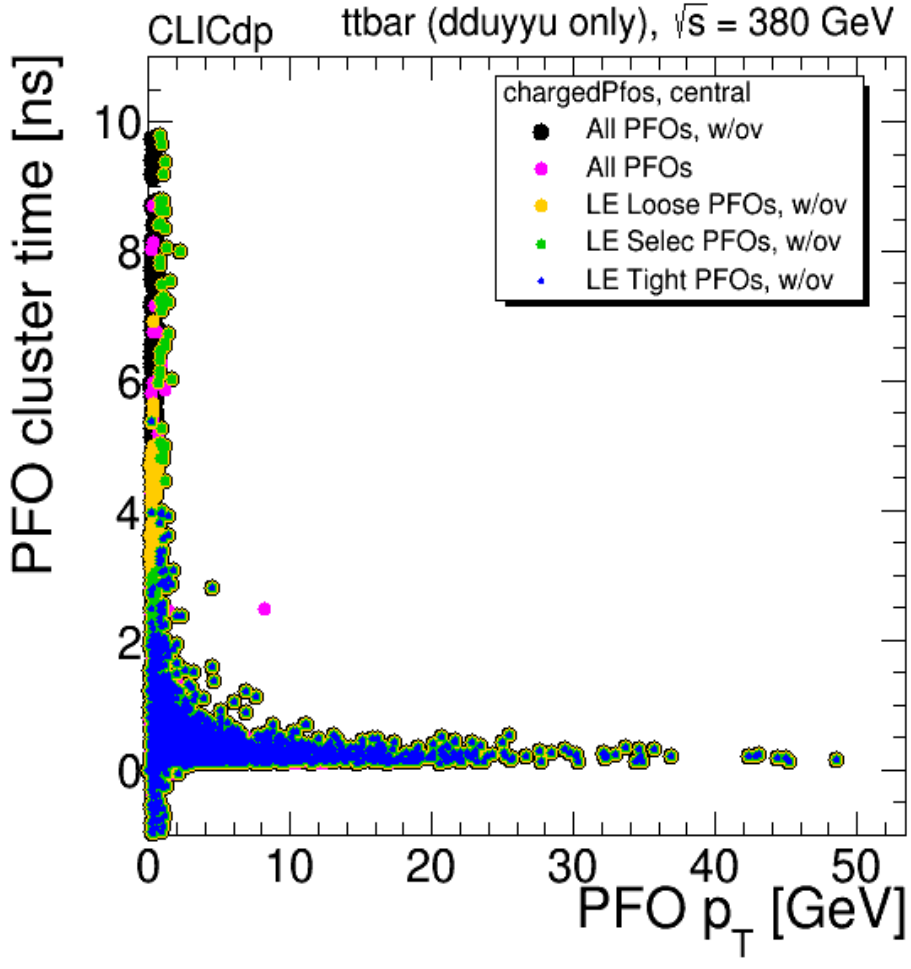




Improving: correlation plots

- **Charged PFOs, cosθ < 0.975**

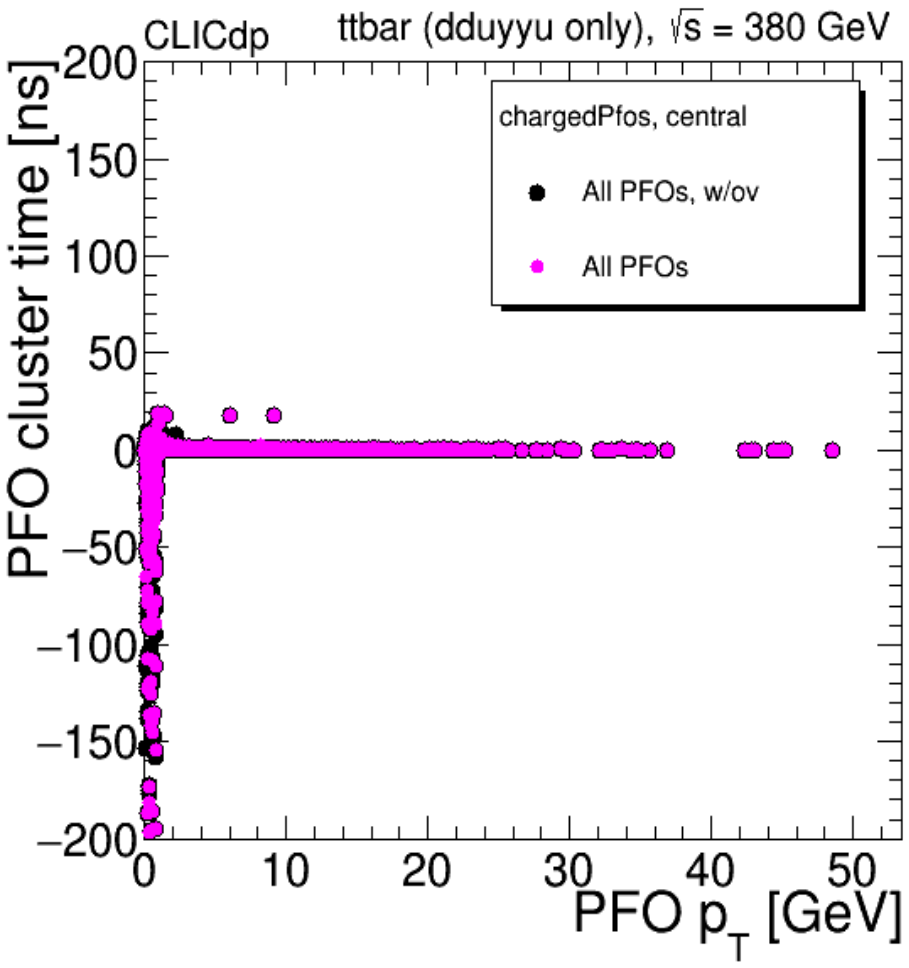


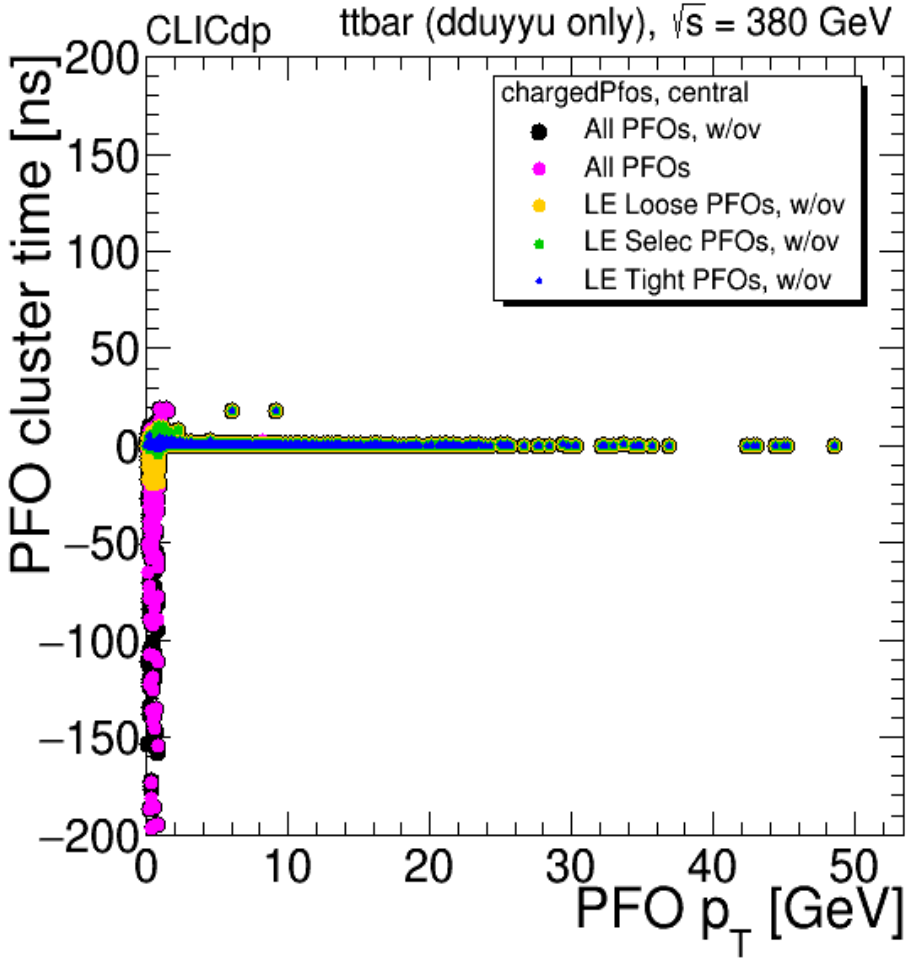


… zooming out ...

Improving: correlation plots

- **Charged PFOs, cosθ < 0.975**

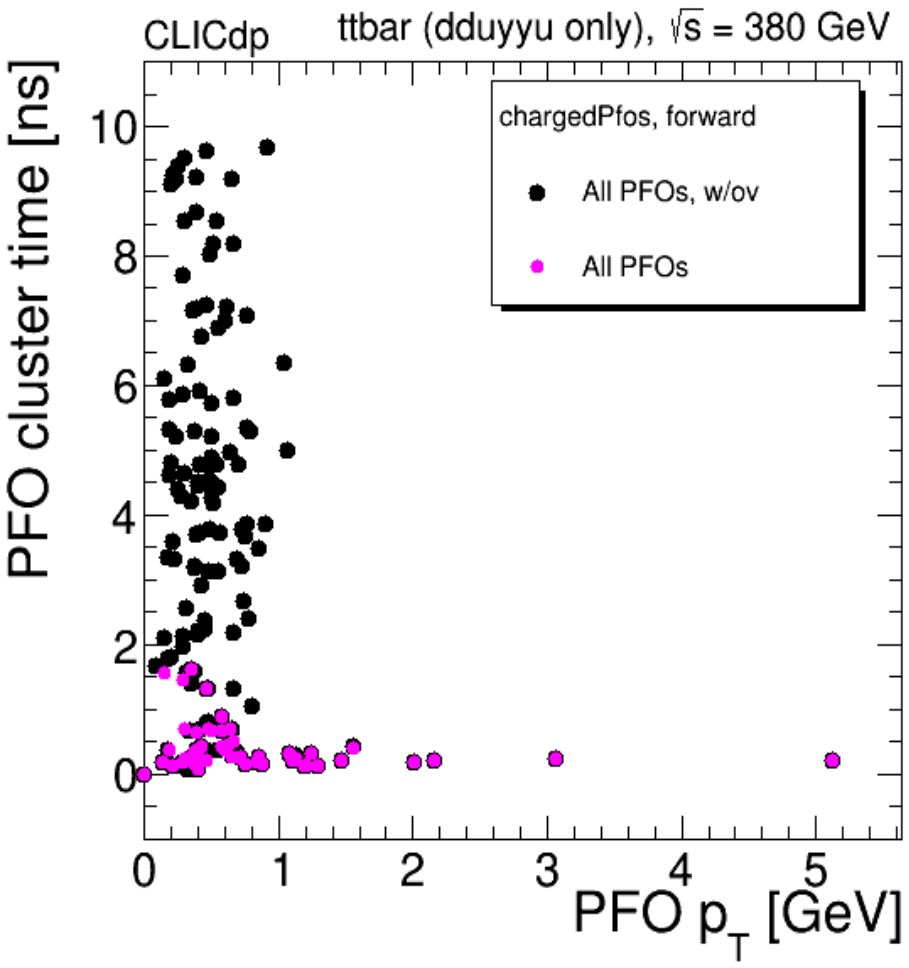


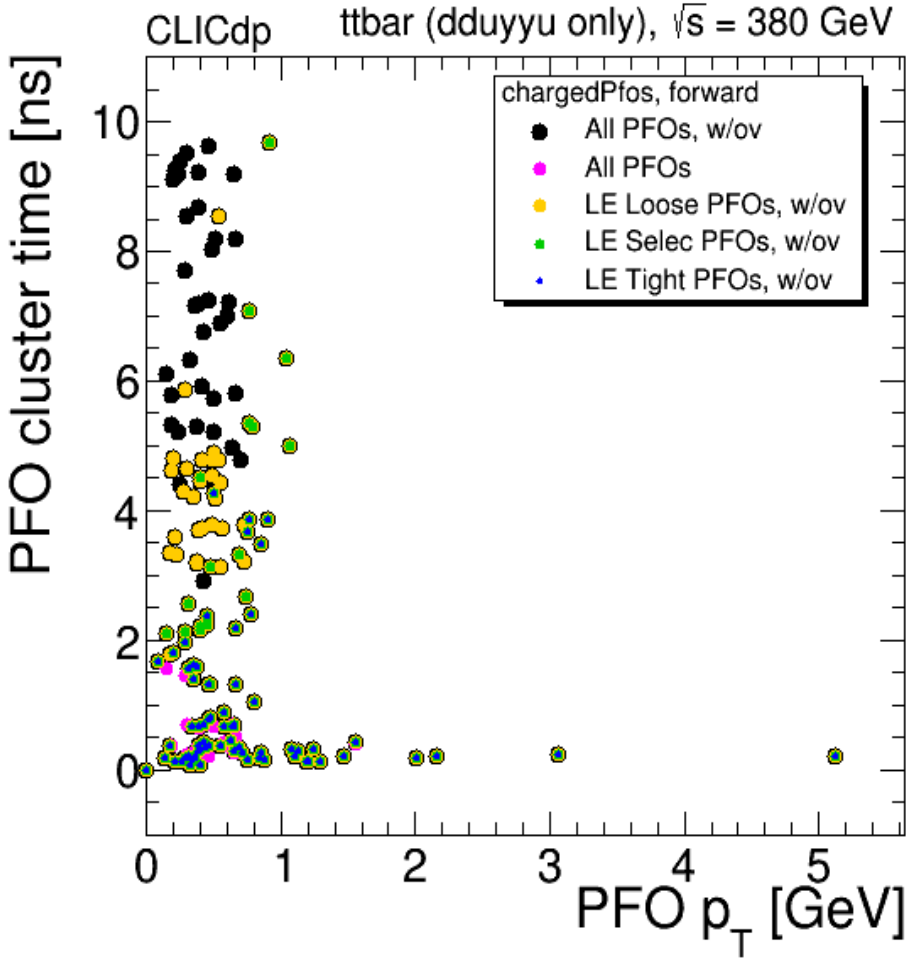


- **Expected?**
  → Maybe worth a double check in the cluster time correction using tracks
- **Why not selected in any LE selection?**

Improving: correlation plots

- **Charged PFOs, cosθ ≥ 0.975**





- **Tighter cut?**

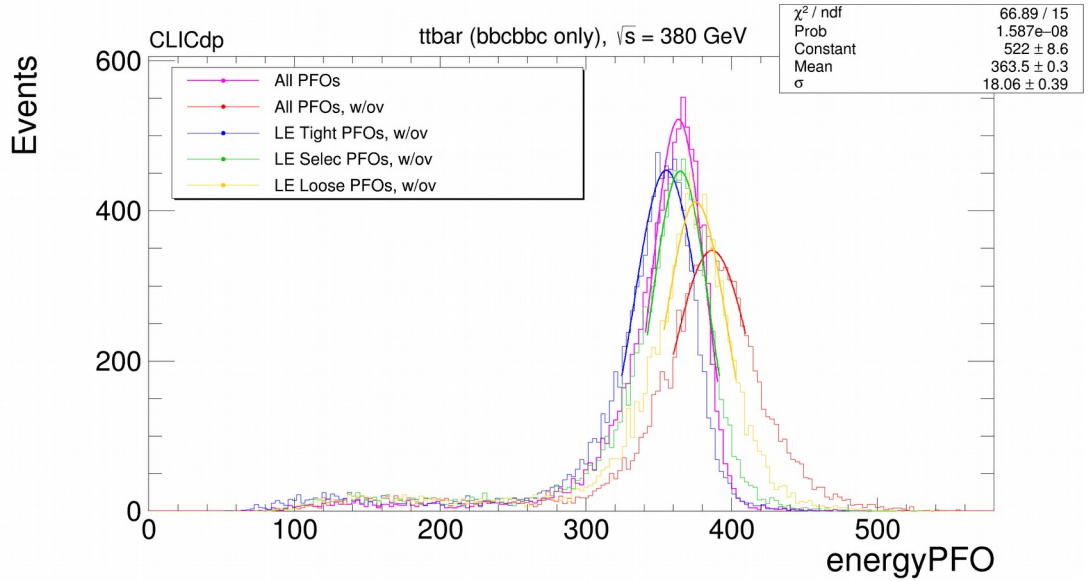
How to proceed

- **Identify the problem**
  - Find and check datasample
  - Produce PFOs energy distributions
  - Define “figure(s) of merit”

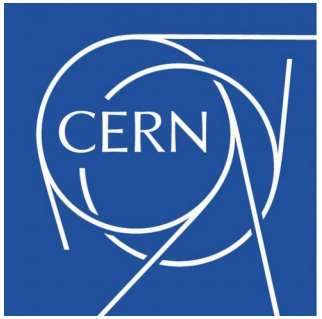
- **Understand current approach**
  - Current documentation
  - Select variables needed

- **Improving**
  - Produce new correlation plots
  - Introduce new LE timing cuts
  - Evaluate the impact
  - Re-iterate if necessary

- **Outlook**

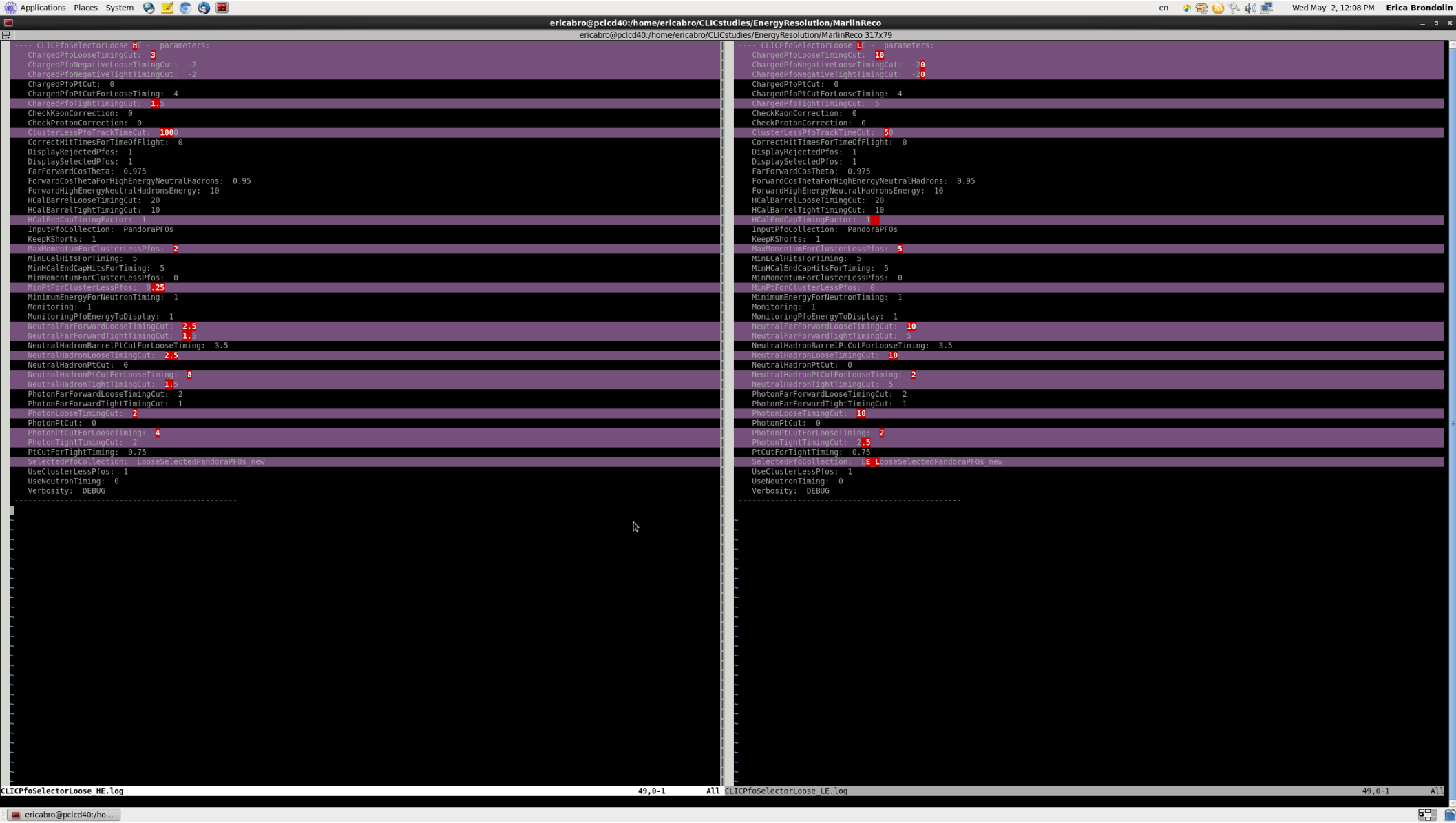


Open to suggestions:
- Better Figure of merit?
- Other documentation?
- Input on new LE selection?
- More statistics? Less?

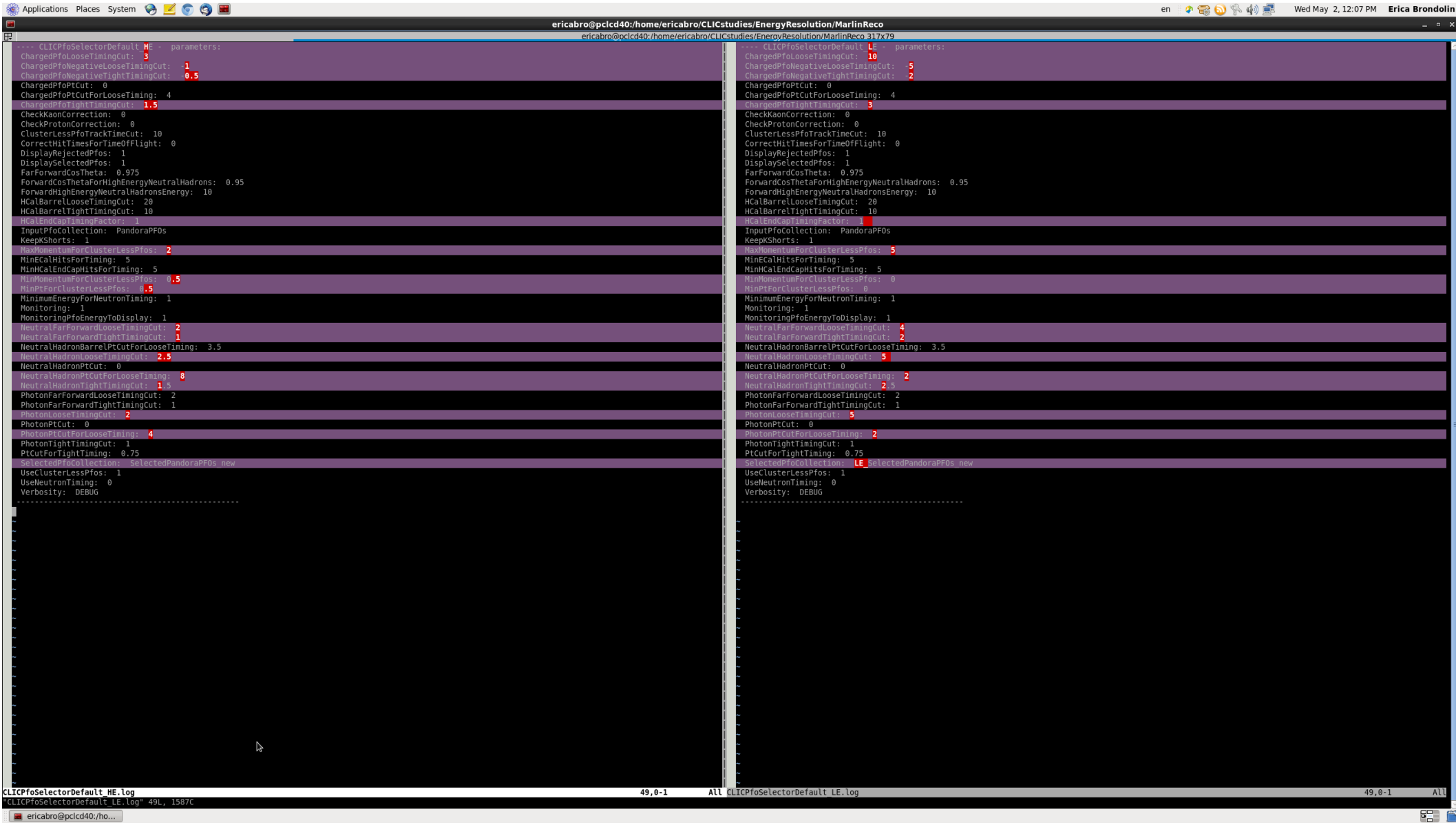


Thank you for the attention!

HE vs LE (Loose)



HE vs LE (Default)



HE vs LE (Tight)