Offline Electron Seeding Validation - Update

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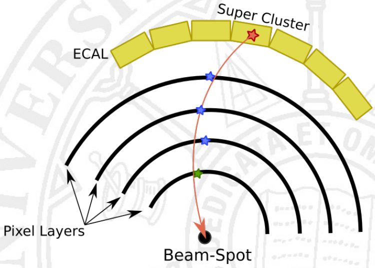
Introduction

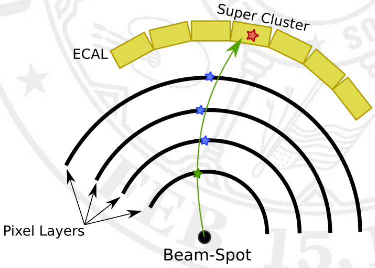
- Our goal is to study **seeding** for the **offline** GSF tracking with the **new pixel detector**.
- Specifically, we want to optimize the new pixel-matching scheme from HLT for use in off-line reconstruction.
- This Talk:
  - Define and demonstrate performance of a GSF-Track "Fake Rate" for:
    - Current offline (Legacy HLT) seeding method with default offline settings
    - New seeding method with HLT settings[1]
    - New seeding method with optimized-for-offline (aka `wide`) settings
  - Show efficiency for prompt electrons specifically

[1] Note: In previous talks I've called this one `narrow`.

N-Hit Electron Seeding

1. Using the beam spot, the SC position, and SC energy, propagate a path through the pixels.
2. Require the first hit to be within a $\delta\phi$ and δz window. ($\delta\phi$ and δR for FPIX)
3. δz window for first hit is huge as SC and beam spot positions give very little information about z.
4. Forget the SC position, and propagate a new track based on the vertex and first hit positions, and the SC energy.
5. Progress one-by-one through the remaining hits in the seed and require each one fit within a specified window around the track.
6. Quit when all hits are matched, or a hit falls outside the window. No skipping is allowed.





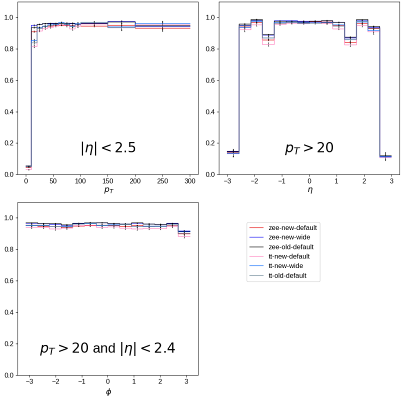
Definitions

- **Sim-Track -** A track from a simulated electron both originating from the luminous region of CMS (beam-spot +- 5σ) and having $|\eta| < 3.0$.
- **ECAL-Driven Seed -** A seed created via a matching procedure between Super-Clusters and General Tracking Seeds (Either from `ElectronSeedProducer` or `ElectronNHitSeedProducer`). Must have $HOE < 0.15$.
- **GSF Track -** A track from GSF-Tracking resulting from an **ECAL-Driven Seed**
- **GSF Tracking Efficiency -** The fraction of **Sim-Tracks** that have a matching **GSF Track** (based on ΔR matching)
- **GSF Tracking Purity -** The fraction of **GSF Tracks** that have a matching **Sim-Track**
- **GSF Tracking Fake Rate -** The fraction of nontruth-matched Super-Clusters which result in at least one **GSF Track**.

Relative Performance - GSF Tracking Efficiency

- Figure shows GSF Tracking efficiency vs kinematic variables of the electron `SimTrack`
- Efficiency is comparable for both DY and $t\bar{t}$ environments and for both algorithms and working points.
- Largest differences appear at low p_T and in the barrel/endcap transition region.

GSF Tracking Efficiency

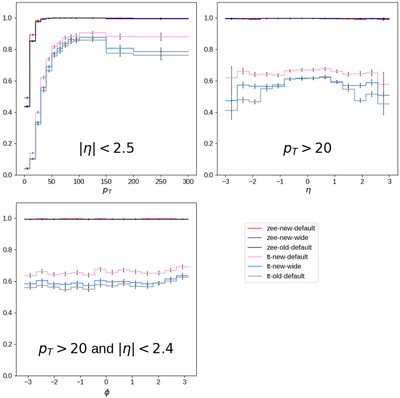


This and the following slide have been show before and are included for completeness

Relative Performance - GSF Track Purity

- Figure shows GSF Tracking purity vs kinematic variables of the `GSFTrack`
- Clearly purity is affected by the higher fake environment in the $t\bar{t}$ sample.
- Note how the `default` working point of the new seeding (red/pink) has significantly better purity than the working point or the old seeding.

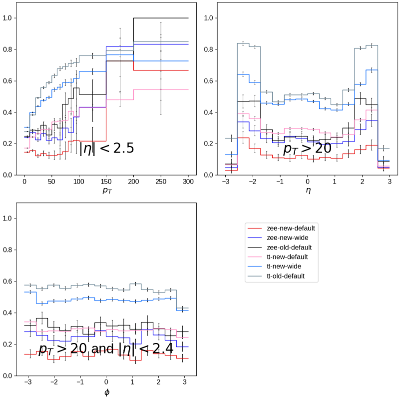
GSF Tracking Purity



Relative Performance - GSF Tracking Fake Rate

- Figure shows GSF Tracking fake rate vs kinematic variables of the supercluster
- Supercluster must have $HOE < 0.15$, so fake are presumably from mostly photons or π^0
- There is a clear reduction in the fake rate with respect to the old method in both the `default` and `wide` working points.
- Seen in both $Z \to ee$ and $t\bar{t}$

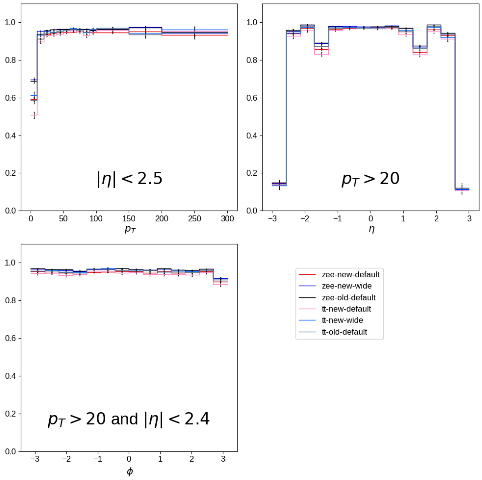
GSF Tracking Fake Rate



Relative Performance - Prompt Efficiency

- The fraction of prompt electrons that match a GSF-Track
- Biggest improvements, again, happen at low p_T and in the barrel/endcap transition region
- Note the change in the first bin relative to the overall efficiency (Slide 5). Large non-prompt contribution at low p_T.

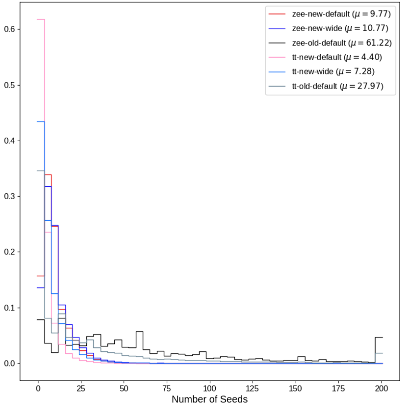
Prompt GSF Tracking Efficiency



Relative Performance - Seed Multiplicity

- A single supercluster can potentially produce many seeds if it matches with many nearby tracks, however only one of these can be from the electron.
- Reducing the number of overall seeds while still producing *the* correct one is desirable from a computational perspective.
- The new seeding scheme (`wide` WP) reduces the number of seeds by a factor of 3.8 for $t\bar{t}$ and 5.6 for $Z \rightarrow ee$.

Number of Electron Seeds Per Event



Overall Performance

Integrating over all tracks with $p_T > 20\text{GeV}$ and $\eta < 2.4$ yields the performance numbers below.

Sample	Working Point	Efficiency	Purity	Fake Rate
$Z \to ee$	new-default	$86.57 \pm 0.27\%$	$90.58 \pm 0.28\%$	$69.67 \pm 0.91\%$
	new-wide	$87.90 \pm 0.27\%$	$90.31 \pm 0.28\%$	$76.45 \pm 0.91\%$
	old-default	$87.95 \pm 0.27\%$	$90.19 \pm 0.28\%$	$79.40 \pm 0.91\%$
$t\bar{t}$	new-default	$86.95 \pm 0.77\%$	$60.56 \pm 0.65\%$	$31.40 \pm 0.53\%$
	new-wide	$88.30 \pm 0.77\%$	$54.35 \pm 0.61\%$	$49.95 \pm 0.52\%$
	old-default	$88.07 \pm 0.77\%$	$52.25 \pm 0.60\%$	$56.87 \pm 0.52\%$

- The HLT default settings (`narrow`) of the new pixel matching scheme yield non-trivially better purity at the loss of some efficiency with respect to both the old seeding and the `wide` working point.
- The `wide` working point of the new seeding matches the `old-seeding` within errors except for purity is $\approx 2\%$ better in the $t\bar{t}$ sample

Conclusions & Outlook

- The new seeding algorithm has been optimized to have better or comparable performance to the current Offline seeding method in all investigated metrics including
  - GSF Tracking Efficiency
  - GSF Tracking Purity
  - GSF Tracking Fake Rate
  - Number of Seeds
- Unless there are objections, propose to move forward with implementing the new algorithm as the default in the next available CMSSW release.

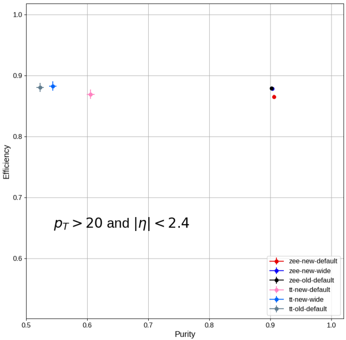
Analysis and ploting code is available at https://git.fangmeier.tech/caleb/EGamma_ElectronTrackingValidation

Additional plots are available at https://eg.fangmeier.tech/seeding_studies_2018_06_20_17/hists.html

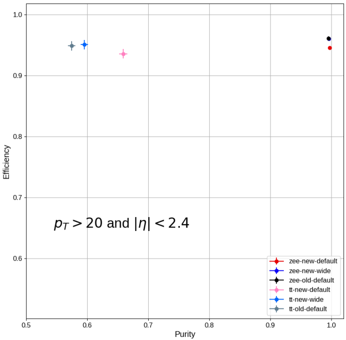
BACKUP

Overall Performance

GSF Tracking Performance (Hit Matched)



GSF Tracking Performance (ΔR Matched)



Matching Window Parameters

		narrow	default (HLT)	wide	extra-wide
Hit 1	dPhiMaxHighEt	**0.025**	**0.05**	**0.1**	**0.15**
	dPhiMaxHighEtThres	20.0	20.0	20.0	20.0
	dPhiMaxLowEtGrad	-0.002	-0.002	-0.002	-0.002
	dRzMaxHighEt	9999.0	9999.0	9999.0	9999.0
	dRzMaxHighEtThres	0.0	0.0	0.0	0.0
	dRzMaxLowEtGrad	0.0	0.0	0.0	0.0
Hit 2	dPhiMaxHighEt	**0.0015**	**0.003**	**0.006**	**0.009**
	dPhiMaxHighEtThres	0.0	0.0	0.0	0.0
	dPhiMaxLowEtGrad	0.0	0.0	0.0	0.0
	dRzMaxHighEt	**0.025**	**0.05**	**0.1**	**0.15**
	dRzMaxHighEtThres	30.0	30.0	30.0	30.0
	dRzMaxLowEtGrad	-0.002	-0.002	-0.002	-0.002
Hit 3+	dPhiMaxHighEt	**0.0015**	**0.003**	**0.006**	**0.009**
	dPhiMaxHighEtThres	0.0	0.0	0.0	0.0
	dPhiMaxLowEtGrad	0.0	0.0	0.0	0.0
	dRzMaxHighEt	**0.025**	**0.05**	**0.1**	**0.15**
	dRzMaxHighEtThres	30.0	30.0	30.0	30.0
	dRzMaxLowEtGrad	-0.002	-0.002	-0.002	-0.002

`NHit` Seeding window parameters. Bold designates modified values.

Samples

- /ZToEE_NNPDF30_13TeV-powheg_M_120_200/RunIISummer17DRStdmix-NZSFlatPU28to62_92X_upgrade2017_realistic_v10-v1
- /TT_TuneCUETP8M2T4_13TeV-powheg-pythia8/RunIISummer17DRStdmix-NZSFlatPU28to62_92X_upgrade2017_realistic_v10-v2