

PFA & Tracking

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Software status

- Two **self-consistent track lists** available:
 - **FSReconTracks**: Ron's cheated track list, for final-state particles with at least 3 SimTrackerHits. Track parameters smeared by FastMC.
 - **Tracks**: Rich et al.'s SeedTracker track list, for primary tracks with $p_T > 1$ GeV, at least 7 real TrackerHits, and an impact parameter < 1 cm in both z and xy .
 - Cuts are not set in stone -- Rich is looking into loosening them.
- Three **ways of extrapolating track** to calorimeter:
 - **LocalHelixExtrapolator**: Extrapolate outermost 3 hits as a helix. Only for tracks with SimTrackerHits (relies on hits having negligible 3D position resolution)
 - **TrackHelixExtrapolator**: Convert track into helix and swim it.
 - **TrackHelixPlusHitExtrapolator**: Convert track into helix and swim it to outermost hit. Adjust for offset between track & hit positions but keep momentum fixed. Continue swimming to calorimeter.
- PFA defaults: FSReconTracks + LocalHelixExtrapolator

What hurts performance?

There are several places where we will take performance hits:

- Preselection cuts remove some tracks.
- Inefficiency & unfindable tracks.
- Extrapolation may go badly wrong (e.g. for kinks)...
- ... and even when it doesn't, resolution may be worse.
- There may be fake tracks.

We want to separate these effects as much as possible.

Effect of preselection cuts

- We can take the cheated FSReconTracks and apply cuts to them to see what happens.
- This isn't exactly the same as the effect on real tracks...
 - Number of SimTrackerHits vs real TrackerHits differs
 - Cut on 3D DOCA to origin rather than on z_0 and d_0 separately
 - Because of FS requirement, we may be cutting out too many tracks (e.g. if a pion went through 7 layers then decayed to a muon that hit 3 layers, we'd lose them both)
- ... but it's probably close.

Cheat tracks: Preselection

Extra cuts	qq100	qq200	qq500	ZZ	
None	3.5%	2.8%	3.5%	4.2%	441
7 hits				4.4%	455
7 hits and IP < 1 cm	3.6%	3.0%	3.4%	4.4%	450
$p_T > 0.2$ GeV				4.2%	458
7 hits and IP < 1 cm and $p_T > 0.2$ GeV			3.4%	4.4%	462
7 hits and IP < 1 cm and $p_T > 1.0$ GeV	3.7%	3.0%	3.4%	5.2%	449

- Effect on energy resolution is minimal.
- **Mass resolution hurt by p_T cut** (and a bit by eliminating secondaries).
- Can recover almost entirely by loosening p_T cut to 200 MeV.

Cheat tracks: Extrapolation

Extra cuts	Extrapolation	ZZ	
None	Cheating 3-hit helix	4.2%	441
None	Track → helix	4.7%	442
None	Track → helix, adjusted for last hit	4.2%	465
7 hits and $IP < 1\text{ cm}$ and $p_T > 0.2\text{ GeV}$	Cheating 3-hit helix	4.4%	462
7 hits and $IP < 1\text{ cm}$ and $p_T > 0.2\text{ GeV}$	Track → helix, adjusted for last hit	4.4%	466

- Just extrapolating as a helix is pretty lousy.
- Correction based on outermost hit fixes problem...
 - ... but **be careful!** These are cheat hits with perfect resolution.

Cheat vs real tracks

Extra cuts	Extrapolation	Tracks	ZZ	qq500	
7 hits and $IP < 1\text{ cm}$ and $p_T > 0.2\text{ GeV}$	Cheating 3-hit helix	FSReconTracks	4.4%	3.4%	462
7 hits and $IP < 1\text{ cm}$ and $p_T > 0.2\text{ GeV}$	Track \rightarrow helix, adjusted for last hit	FSReconTracks	4.4%	3.4%	466
7 hits and $IP < 1\text{ cm}$ and $p_T > 1.0\text{ GeV}$	Cheating 3-hit helix	FSReconTracks	5.2%	3.4%	449
7 hits and $IP < 1\text{ cm}$ and $p_T > 1.0\text{ GeV}$	Track \rightarrow helix, adjusted for last hit	FSReconTracks	5.1%	3.4%	467
7 hits and $IP < 1\text{ cm}$ and $p_T > 1.0\text{ GeV}$	Track \rightarrow helix, adjusted for last hit	Real Tracks	5.2%	4.5%	465

- ... so for **ZZ events** we understand where all of the performance is lost.
- Still a puzzle: What happened to the **qq500 events**?

Barrel vs Forward

Extra cuts	Extrapolation	Tracks	ZZ barrel	ZZ forward	qq500 barrel	qq500 forward	
7 hits and $IP < 1\text{cm}$ and $p_T > 0.2\text{ GeV}$	Track \rightarrow helix, adjusted for last hit	FSReconTracks	4.4%	3.9%	3.4%	3.6%	466
7 hits and $IP < 1\text{cm}$ and $p_T > 1.0\text{ GeV}$	Track \rightarrow helix, adjusted for last hit	FSReconTracks	5.1%	4.2%	3.4%	3.5%	467
7 hits and $IP < 1\text{cm}$ and $p_T > 1.0\text{ GeV}$	Track \rightarrow helix, adjusted for last hit	Real Tracks	5.2%	4.5%	4.5%	4.3%	465

- Curiouser and curiouser: pattern is roughly consistent between barrel and endcap. Is there some problem with real tracking & high-energy jets that doesn't show up for FSReconTracks+cuts?

More on extrapolation

- We correct the helix extrapolation based on the last hit.
- For truth hits that's easy... but what about real hits?
 - Identify the type based on class.
 - HelicalTrack2DHit: Microstrips in OT barrel (about 10cm x 50 μ m). Extrapolate to cylinder, then adjust ϕ while keeping z fixed.
 - HelicalTrackCross: Axial-stereo hit in OT endcap. Extrapolate to disc, then adjust x & y while keeping z fixed.
 - HelicalTrack3DHit: Pixels in vertex detector. Extrapolate to POCA to 3D hit position, then apply 3D offset to hit point.
- Implemented in TrackHelixPlusHitExtrapolator.
- Downside: Code needs to know about all the possible types of TrackerHit (ugly). May not serialize well.

Summary of real tracking

Extra cuts	Extrapolation	Tracks	qq100	qq200	qq500	ZZ	
7 hits and $IP < 1 \text{ cm}$ and $p_T > 0.2 \text{ GeV}$	Track \rightarrow helix, adjusted for last hit	FSRecon Tracks	3.6%	3.0%	3.4%	4.4%	466
7 hits and $IP < 1 \text{ cm}$ and $p_T > 1.0 \text{ GeV}$	Track \rightarrow helix, adjusted for last hit	FSRecon Tracks	3.7%	3.0%	3.4%	5.1%	467
7 hits and $IP < 1 \text{ cm}$ and $p_T > 1.0 \text{ GeV}$	Track \rightarrow helix, adjusted for last hit	Real Tracks	3.8%	3.1%	4.5%	5.2%	465

qq360

We now have another data point between qq200 & qq500:

$\Delta E_{CM}/E_{CM}$	Barrel $ \cos(\theta) < 0.8$	Forward $0.8 < \cos(\theta) < 0.95$
qq100	3.5%	3.4%
qq200	2.8%	2.9%
qq360	2.6%	2.8%
qq500	3.5%	3.8%

Good news! Looks like performance continues to scale well until very high jet energies.