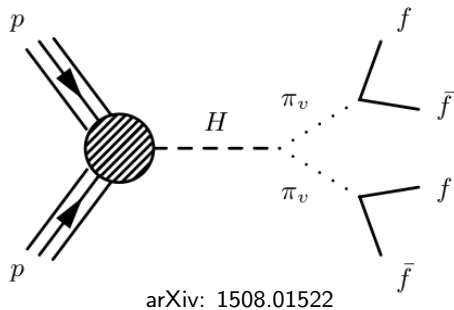


Searching for LL Particles in the CMS Tracker

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π_ν : LL dark neutral scalars

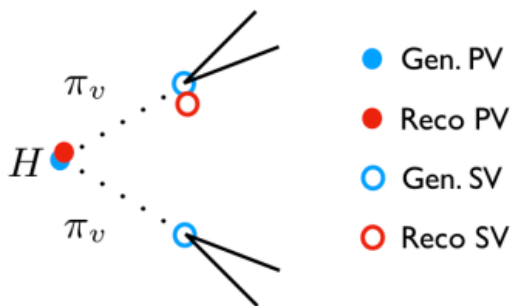
Displaced Vertices

Decays in the tracking system

→ Displaced vertex signature

Conventional reconstruction (algorithms) optimized for prompt decays

→ Low efficiency for displaced secondary vertices (SV)



Displaced Vertices with Graph Networks

Graph network:

→ *Dynamic* graph.

→ Predict displaced vertex position.

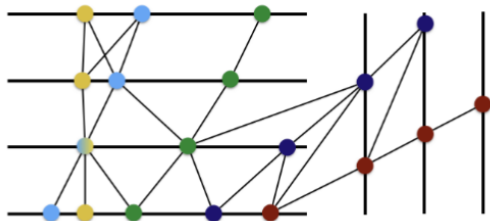
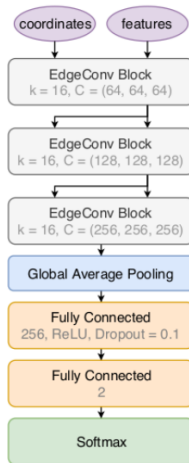
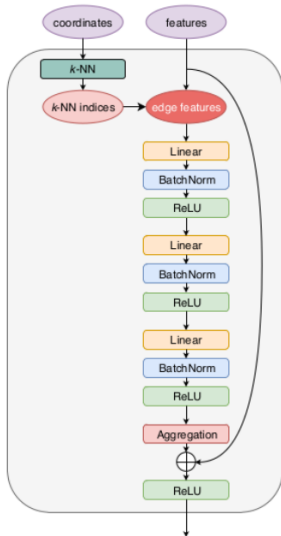


Illustration of a graph representation of track hit data (one tracker hit per node). Hits are connected on adjacent layers if they are compatible according to some criteria.

arXiv: 1508.01522

ParticleNet architecture



(a) ParticleNet

arXiv: 1902.08570v3

MC-simulated data:

- ▶ # Events for training: ~ 28 k
- ▶ # Events for validating: ~ 9 k
- ▶ Selection of RecHits: Taking all hits in the Pixel detector and all matched hits in the Strip detector, s.t. distance is $\Delta R \leq 0.4$ to GenVertex

-- Dataframe --

	GenVertex_x	GenVertex_y	GenVertex_z	RecHits0_x	RecHits0_y	RecHits0_z	\
0	-0.451857	1.424021	0.405141	0.146212	4.612905	2.061922	
1	1.662652	-4.598944	-10.955744	-0.049687	-4.612924	-11.654938	
2	2.765399	5.457177	-15.323605	3.424456	3.148194	-11.017507	
3	-3.667790	-3.934658	-23.687908	-3.518617	-2.181137	-20.270203	
4	2.432257	2.714588	-0.025834	3.440402	2.316579	-0.192514	

	RecHits0_isPixel	RecHits0_isStripMatched	RecHits1_x	RecHits1_y	...	\
0	1	0	-0.409651	4.137804	...	
1	1	0	0.651441	-4.137894	...	
2	1	0	2.776190	3.692204	...	
3	1	0	-3.584929	-2.066302	...	
4	1	0	3.283573	2.588183	...	

ParticleNet doesn't seem to work immediately
 → Benchmark with FCN

Layer (type)	Output Shape	Param #
conv1d_1 (Conv1D)	(None, 1500, 32)	128
conv1d_2 (Conv1D)	(None, 1500, 128)	4224
conv1d_3 (Conv1D)	(None, 1500, 256)	33024
max_pooling1d_1 (MaxPooling1D)	(None, 1, 256)	0
flatten_1 (Flatten)	(None, 256)	0
dense_1 (Dense)	(None, 1024)	263168
dense_2 (Dense)	(None, 256)	262400
dense_3 (Dense)	(None, 64)	16448
dense_4 (Dense)	(None, 32)	2080
dense_5 (Dense)	(None, 3)	99

Total params: 581,571

Trainable params: 581,571

Non-trainable params: 0

Number of Trainings: 10

Training:

(8.94 ± 0.10) RMSE

Validation:

(9.27 ± 0.01) RMSE

- ▶ Change metrics from *accuracy* to *RMSE*.
- ▶ Changing mask:

```
feature_dict['mask'] = ['hit_isStrip'].
```

- ▶

```
feature_dict['points'] = ['hit_x', 'hit_y', 'hit_z']  
feature_dict['features'] = ['hit_isStrip', 'hit_isPixel']
```
- ▶ In the convert-notebook:

```
v['hit_x'] = awkward.JaggedArray.fromcounts(n_hits, _x[mask])  
v['isStrip'] = awkward.JaggedArray.fromcounts(n_hits, _isStrip[mask])
```