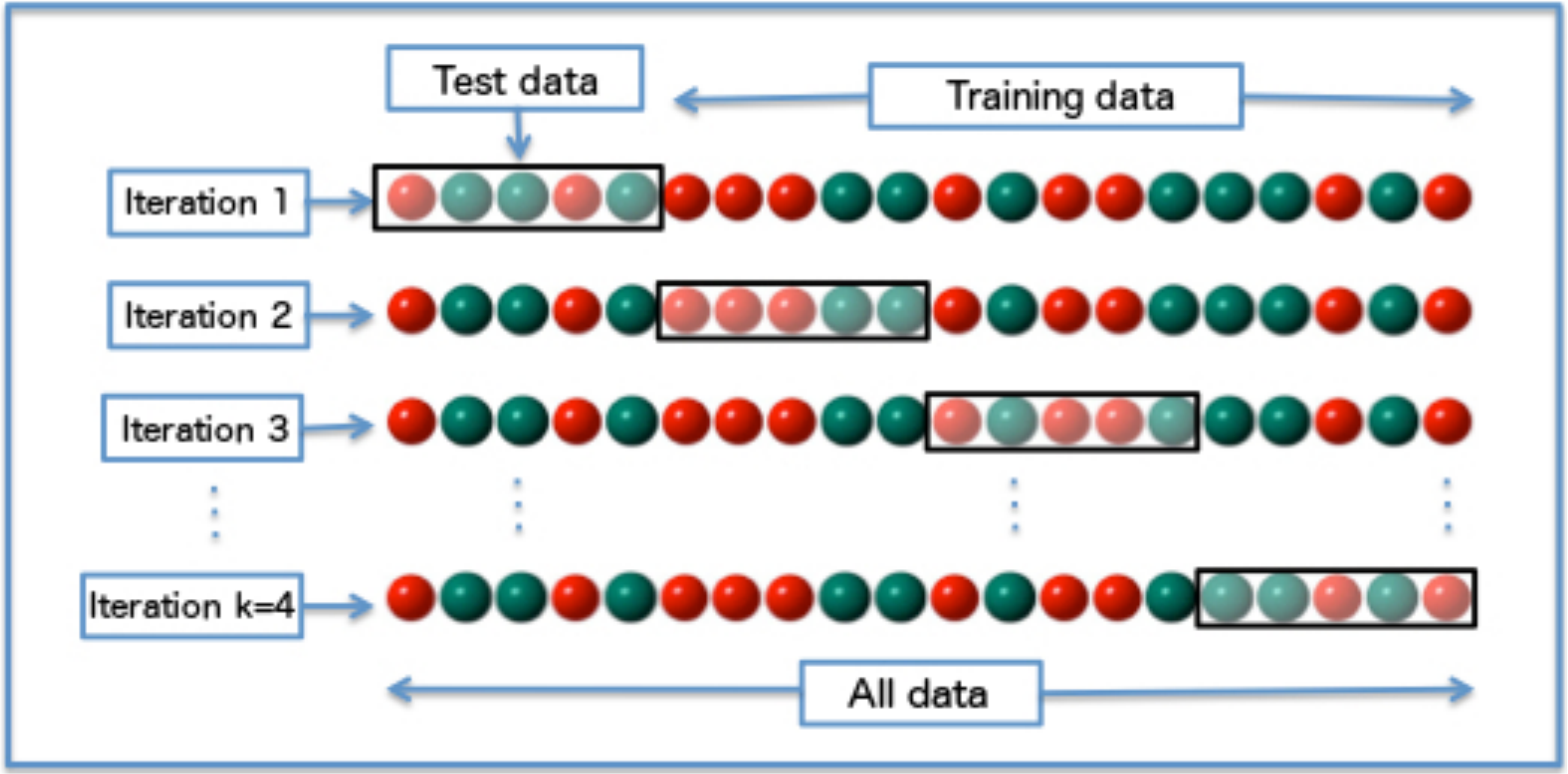
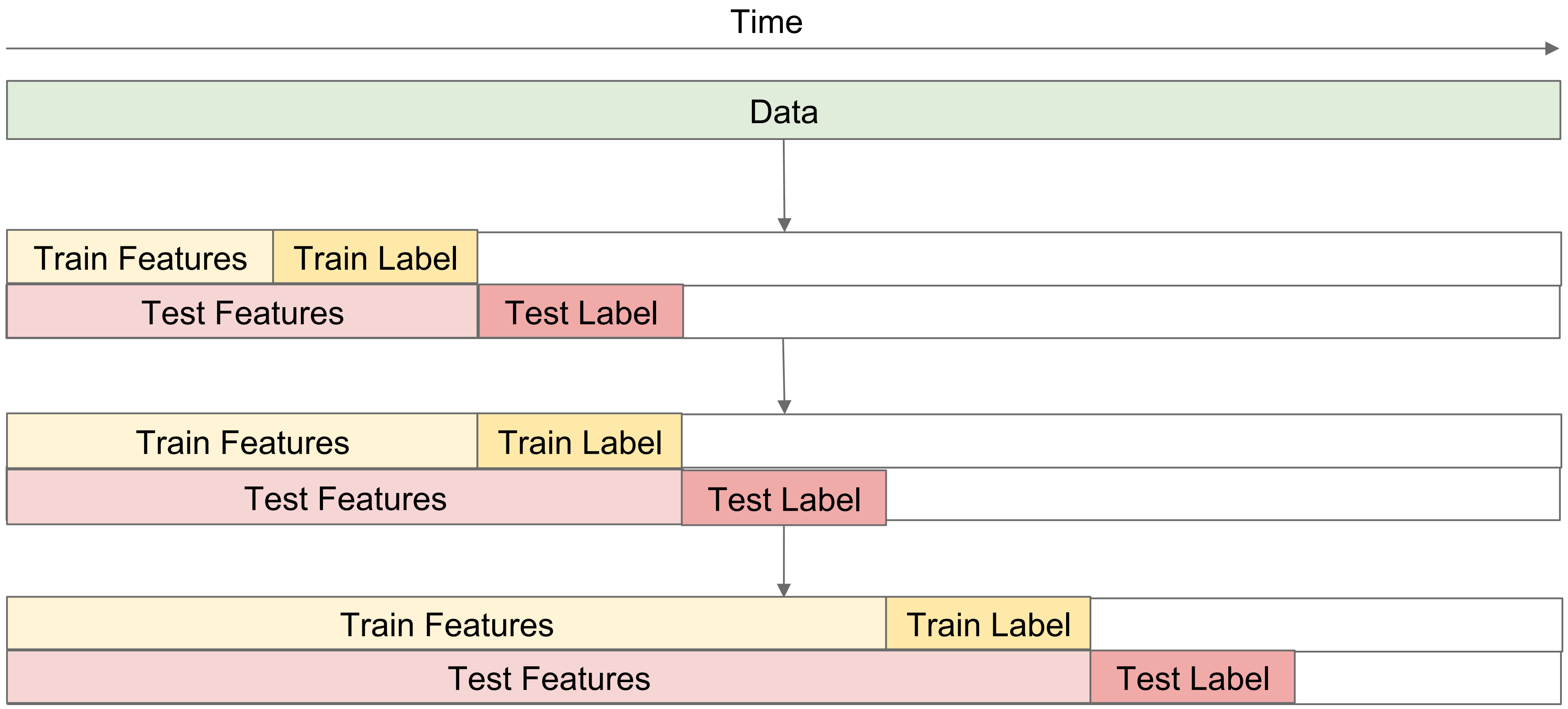
Temporal Cross Validation

Standard Cross Validation



Temporal Cross Validation



Standard vs Temporal

Standard

- Generally used for non-temporal data, such as for image classification
- Uses comparatively more training data and more folds,
- Theoretically reduces variance in error predictions
- Labels and features are **static properties**

Temporal

- Especially important for data with a time component
- Mimics the use of our models in the real world
- Computationally cheaper because of reusability of folds
- Theoretically reduces bias in error predictions on out of sample data
- Labels and features are **aggregations over timespans**

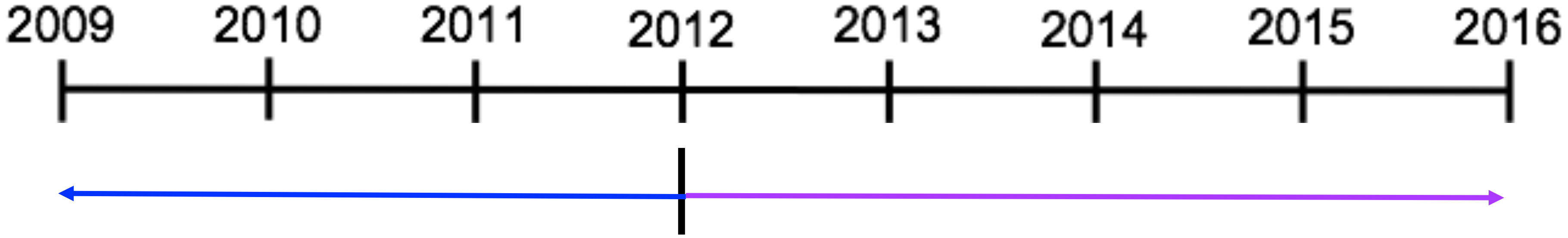
Implementing Temporal Cross Validation

- A series of loops with complicated logic …

Implementing Temporal Cross Validation

Split data at a specific timestamp so that:

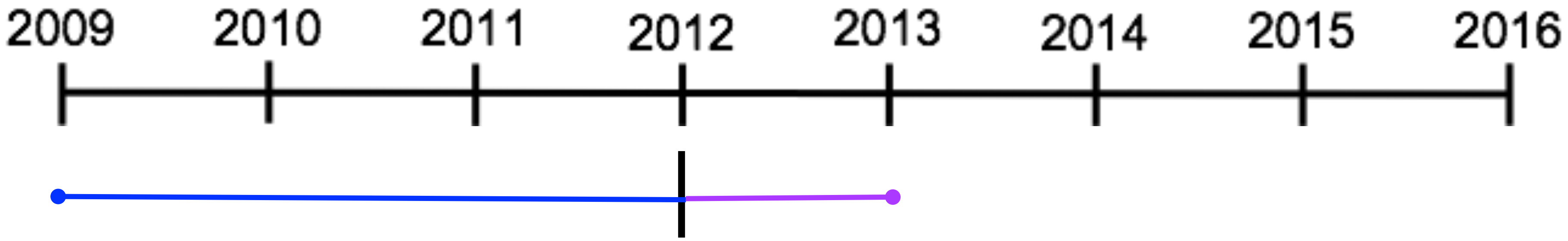
- **features** only incorporate information **before (<)** that timestamp
- **labels** include information **at or later (>=)** than that timestamp



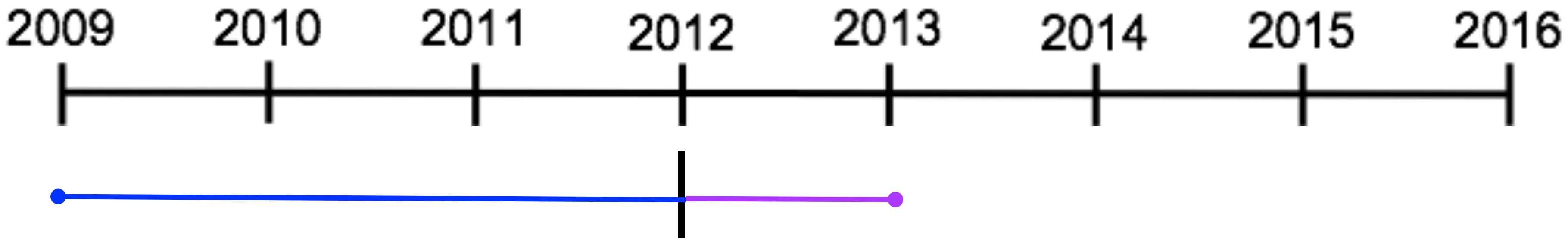
Implementing Temporal Cross Validation

For example:

- **features: As of** January 1, 2012, how many jail bookings did you have in the last four years?
- **labels: Starting** January 1, 2012, do you have a jail booking in the next year?



entity_id	as_of_date	bookings_last_4_yrs	label
1	2012-01-01	3	1
2	2012-01-01	1	0
3	2012-01-01	1	1



entity_id	as_of_date	bookings_last_4_yrs	label
1	2012-01-01	3	1
2	2012-01-01	1	0
3	2012-01-01	1	1

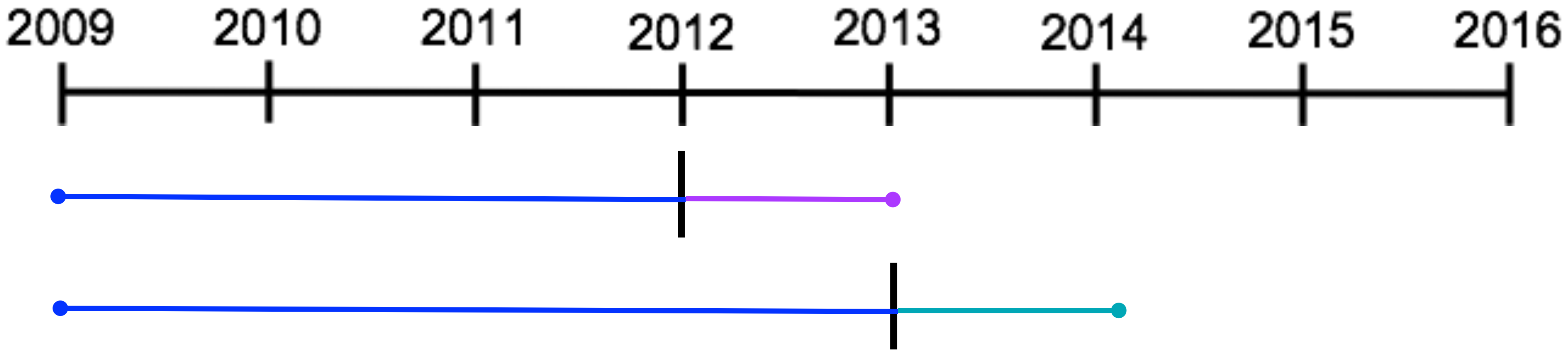
```
SELECT count(*)
  FROM events
 WHERE event_type = ‘booking’
   AND event_date < ‘2012-01-01’
   AND event_date >= (‘2012-01-01 - INTERVAL ‘4 years’)
```

entity_id	as_of_date	bookings_last_4_yrs	label
1	2012-01-01	3	1
2	2012-01-01	1	0
3	2012-01-01	1	1

```
WITH positive_labels AS (
    SELECT entity_id
      FROM events
     WHERE event_type = ‘booking’
       AND event_date >= ‘2012-01-01’
       AND event_date < (‘2012-01-01 + INTERVAL ‘1 year’)
)
SELECT CASE WHEN entity_id IN (positive_labels) THEN 1 ELSE 0 END as label
  FROM entities
```

Finding Train-Test Splits (Timechop)

Split data at a specific timestamp so that **test labels** do not overlap with **training labels**.

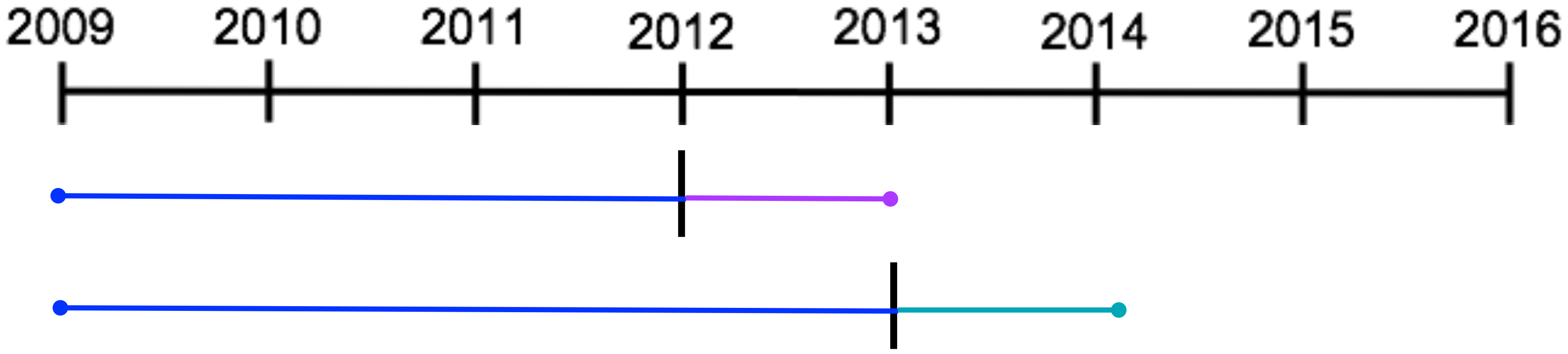


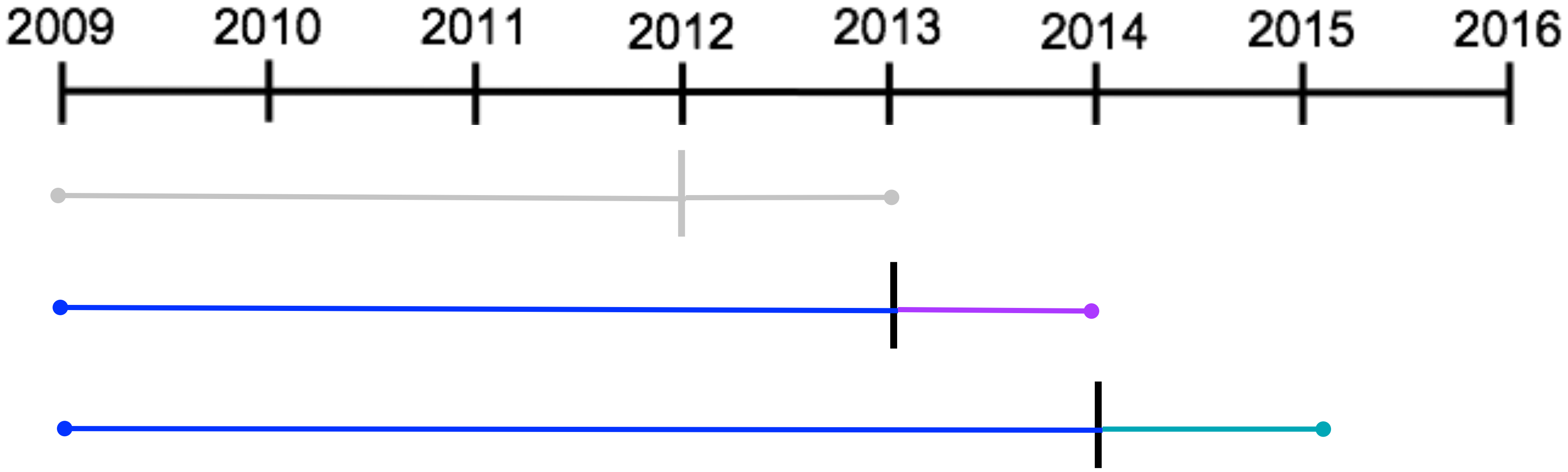
train

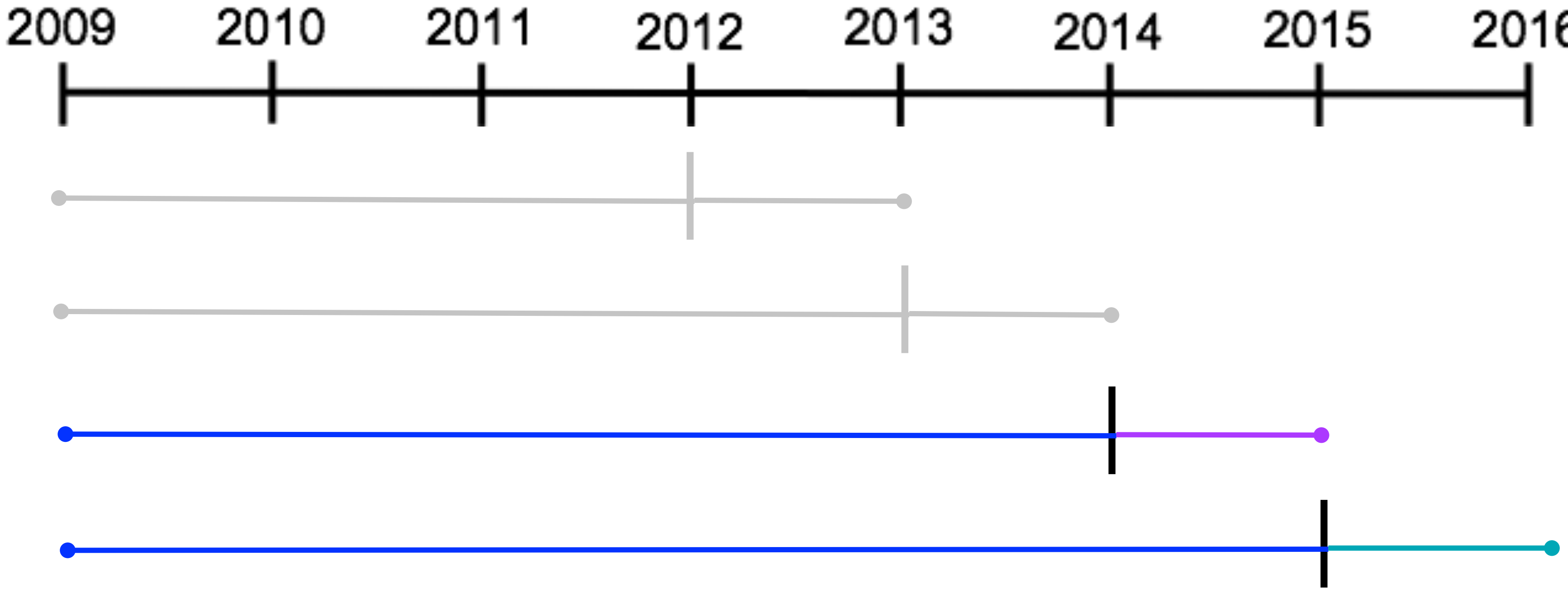
entity_id	as_of_date	bookings_last_4_yrs	label
1	2012-01-01	3	1
2	2012-01-01	1	0
3	2012-01-01	1	1

test

entity_id	as_of_date	bookings_last_4_yrs	label
1	2013-01-01	2	1
2	2013-01-01	2	1
3	2013-01-01	0	0


2009
2010
2011
2012
2013
2014
2015
2016

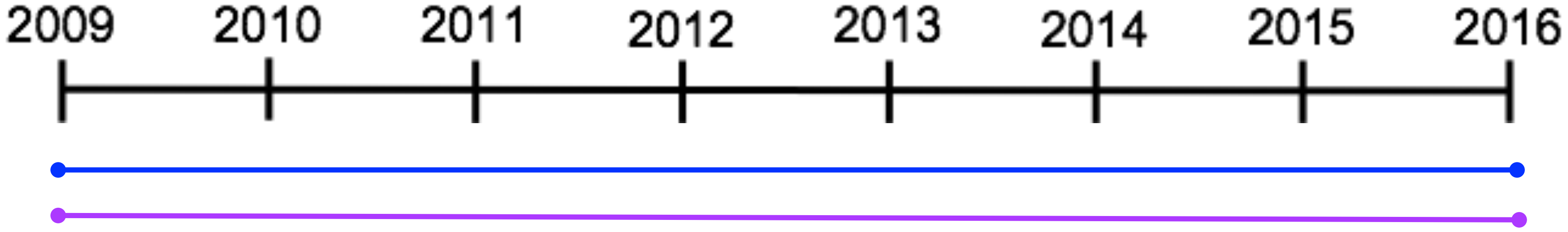

2009
2010
2011
2012
2013
2014
2015
2016


2009
2010
2011
2012
2013
2014
2015
2016

Train-Test Splits: How Much Time for Modeling?

Start and end times:

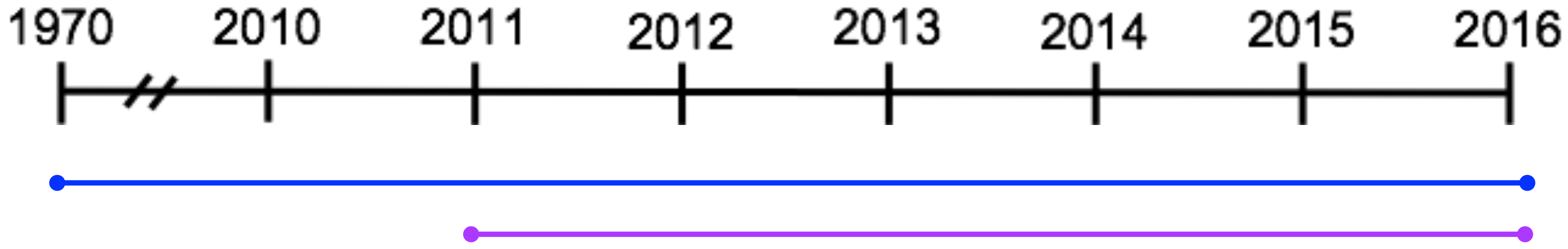
- **feature_start_time**: earliest time in any feature aggregation
- **feature_end_time**: upper limit for data in any feature aggregation
- **label_start_time**: earliest time in any label
- **label_end_time**: upper limit for label data

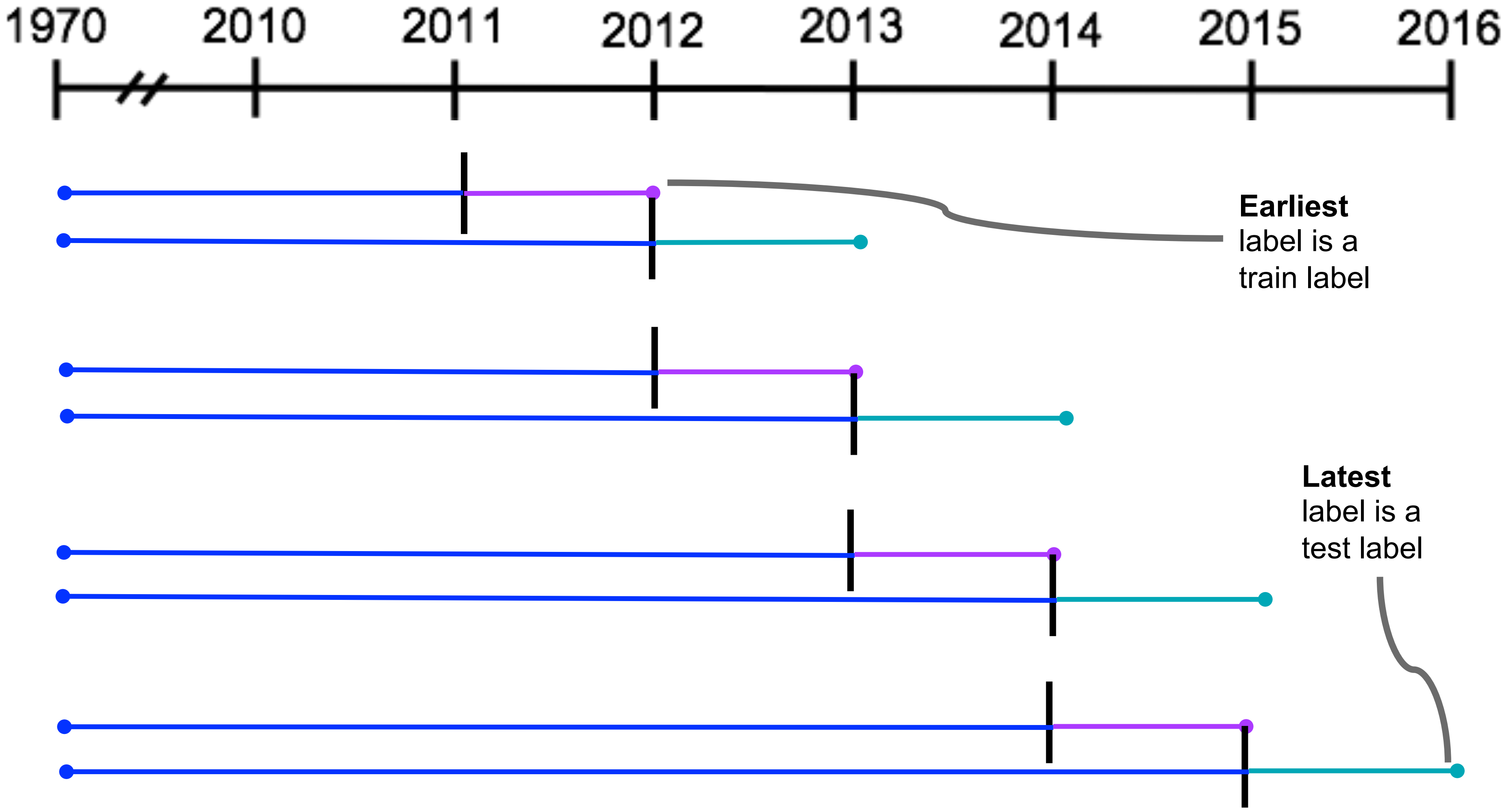


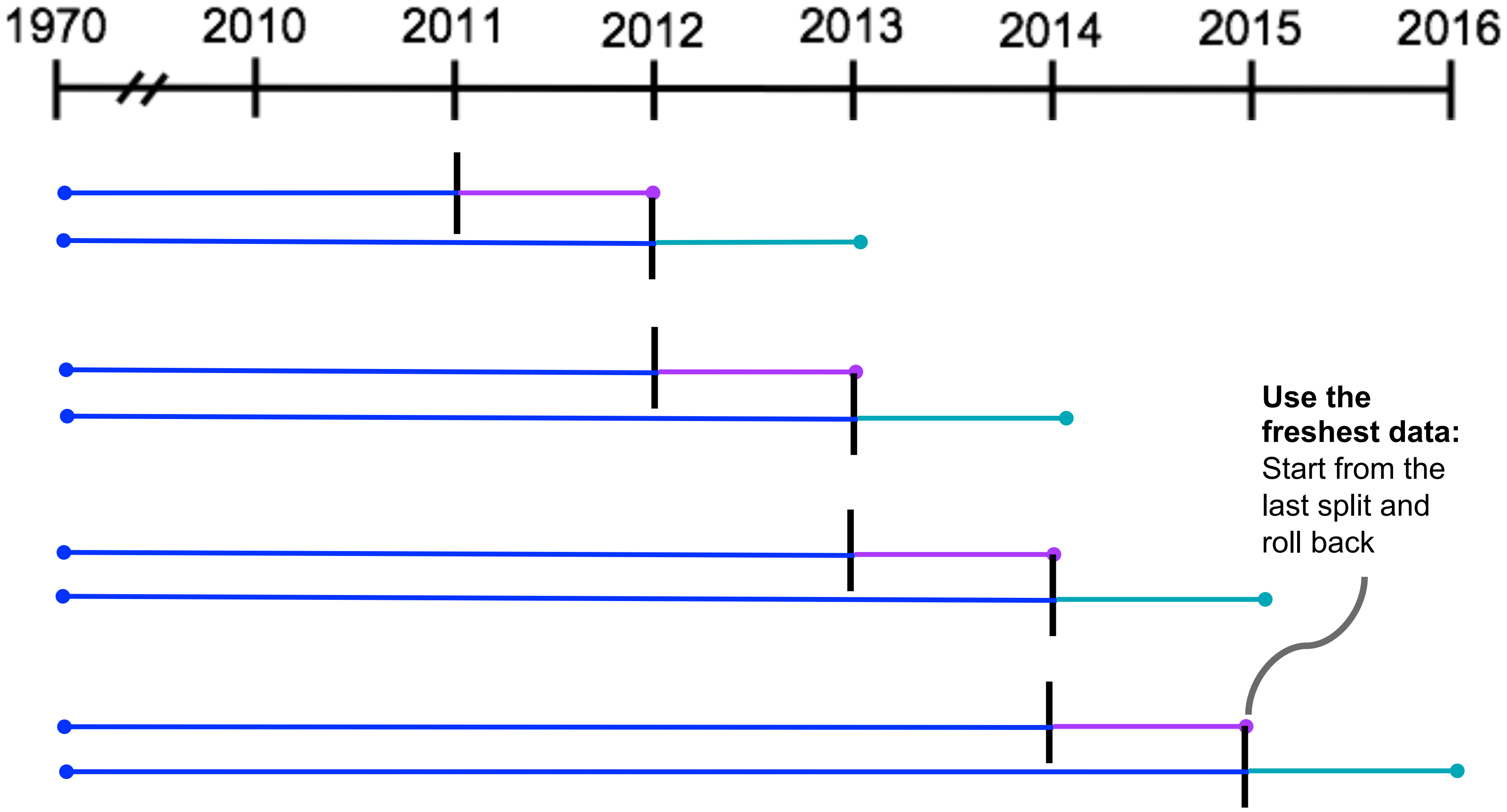
Train-Test Splits: How Much Time for Modeling?

For example:

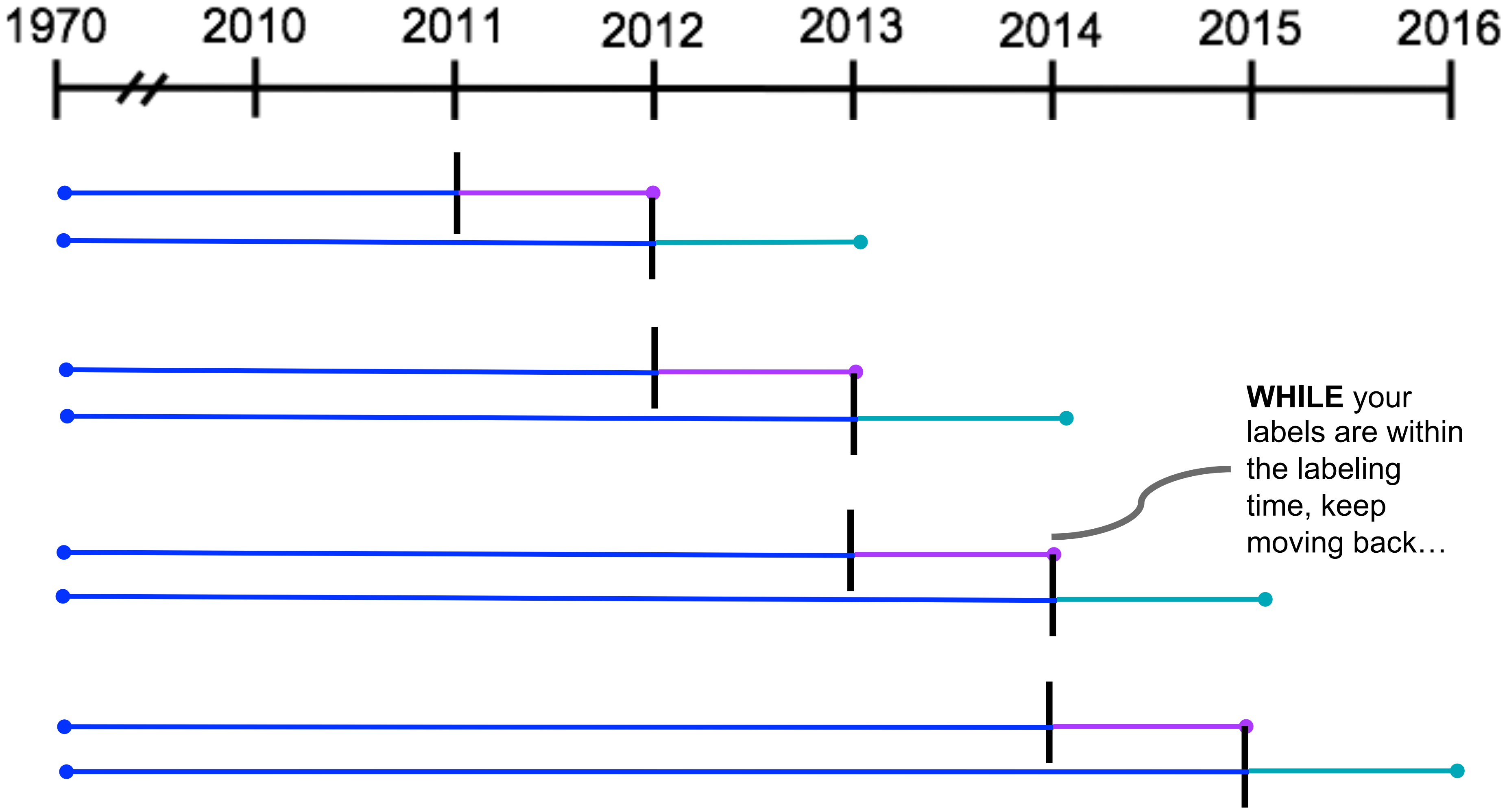
- **feature_start_time**: January 1, 1970
- **feature_end_time**: January 1, 2016
- **label_start_time**: January 1, 2011
- **label_end_time**: January 1, 2016



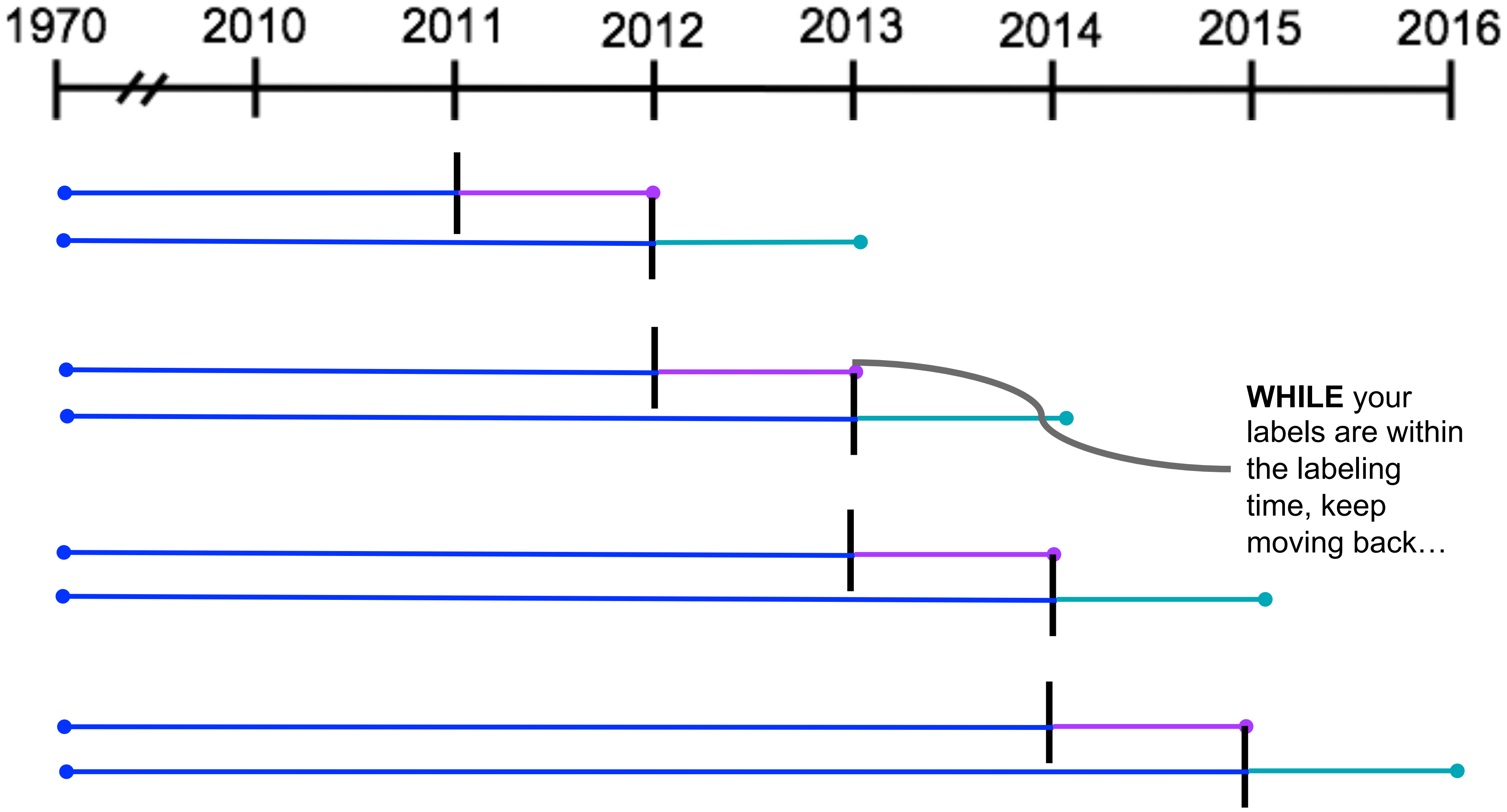

1970
2010
2011
2012
2013
2014
2015
2016
Earliest label is a train label
Latest label is a test label



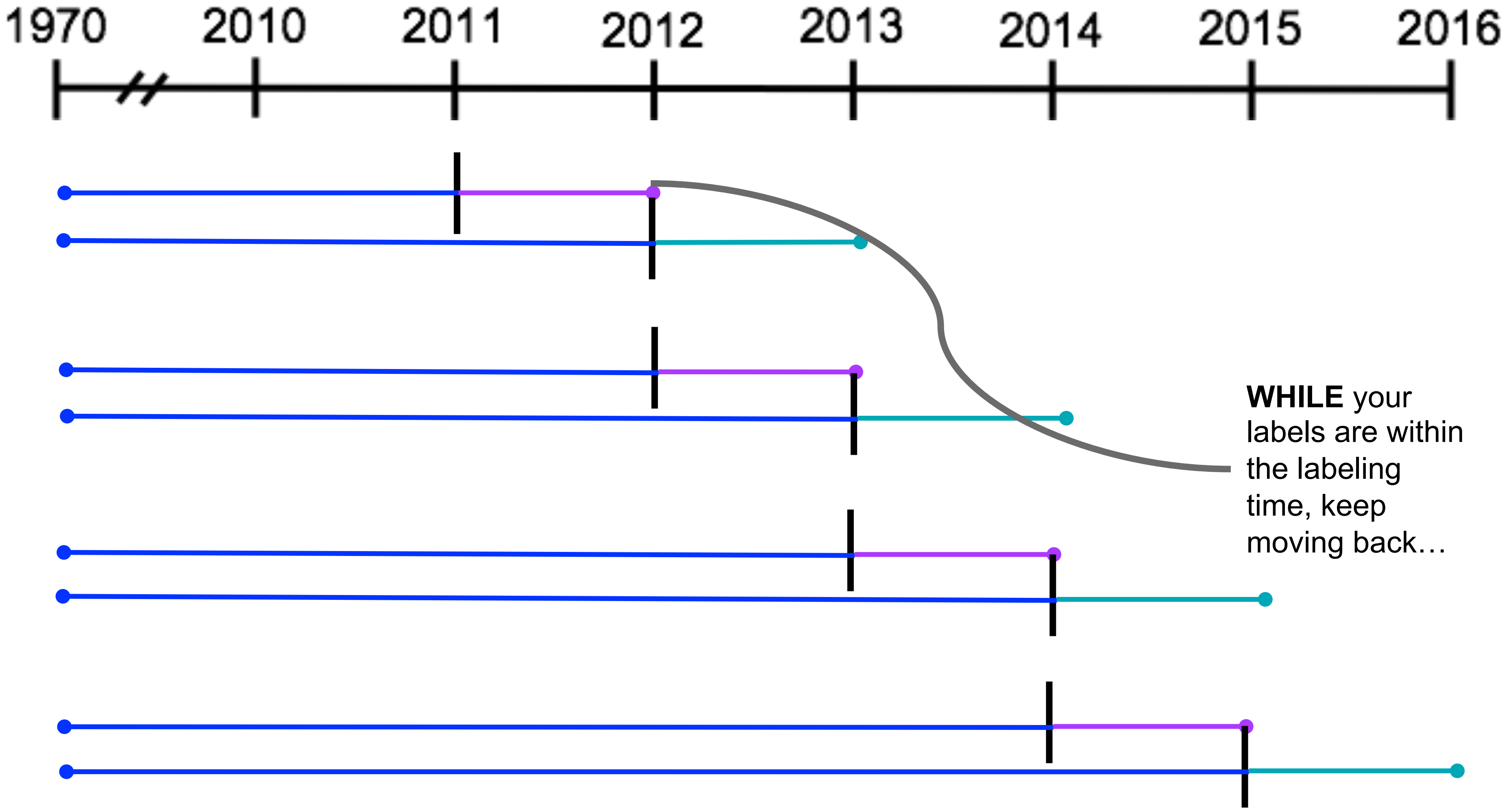
Use the freshest data: Start from the last split and roll back



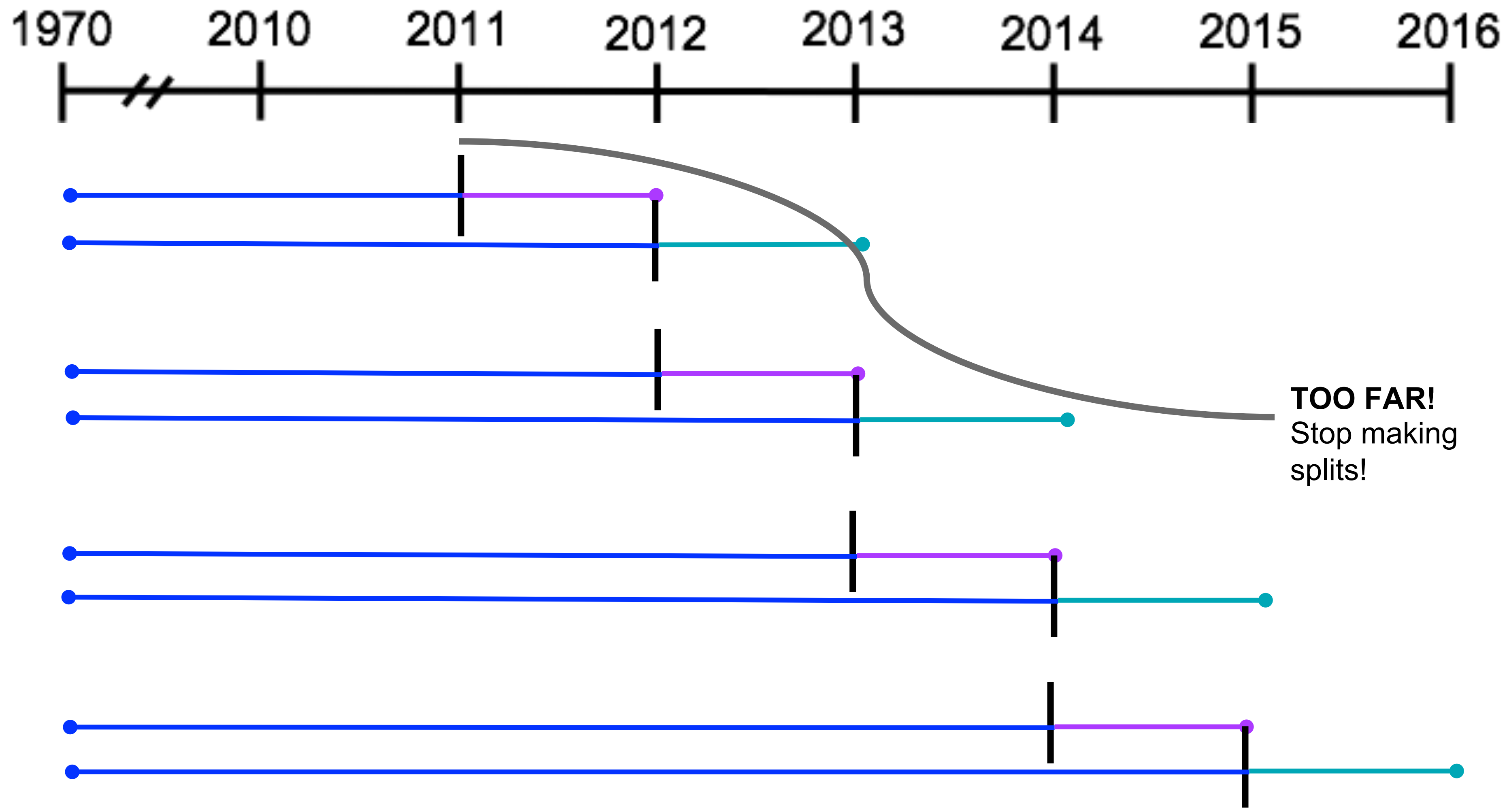
WHILE your labels are within the labeling time, keep moving back…



WHILE your labels are within the labeling time, keep moving back…



WHILE your labels are within the labeling time, keep moving back…

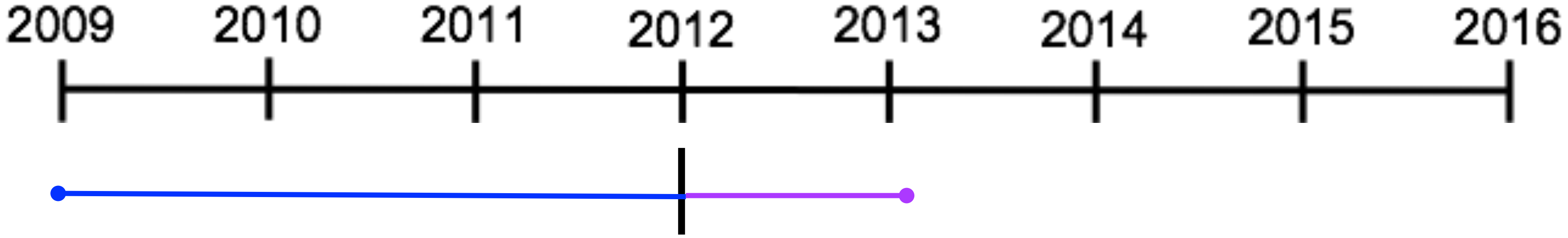

1970
2010
2011
2012
2013
2014
2015
2016
TOO FAR!
Stop making splits!

Configuring Labels

Labels aggregate data over a fixed time period, beginning at the feature label cut point (as of date), and assign a score.

For example:

- Will this property have a housing code violation in the next year?

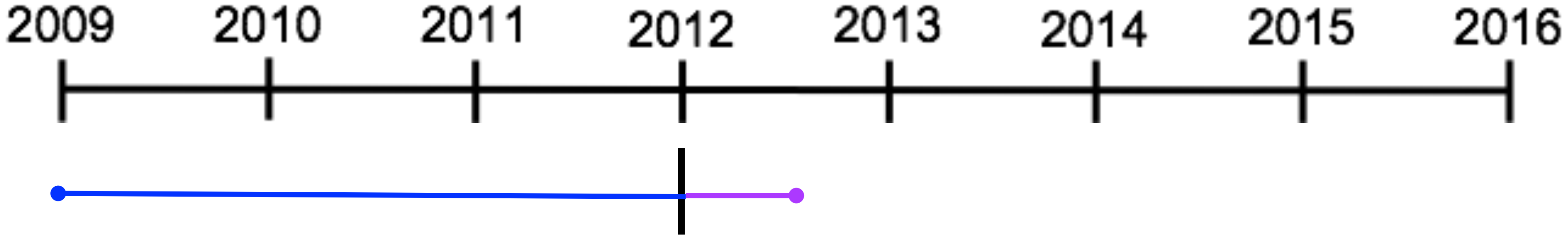


Configuring Labels

Labels aggregate data over a fixed time period, beginning at the feature label cut point, and assign a score.

For example:

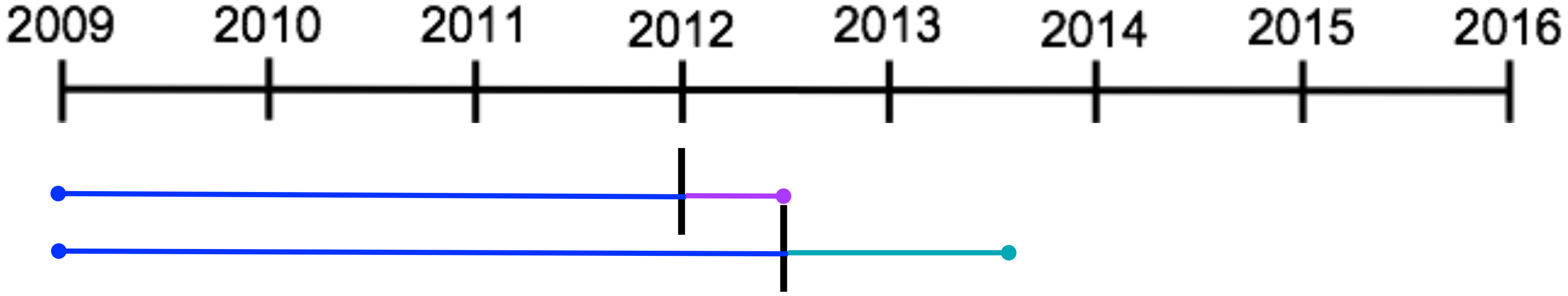
- Will this property have a housing code violation in the next year?
- How many bookings will this person have in the next six months?



Configuring Labels

The length of time aggregated into the label is the **label timespan.** It can be configured separately for train and test labels.

- **train_label_timespan**: how much time is aggregated into labels in the training matrix?
- **test_label_timespan**: how much time is aggregated into labels in the test matrix?



train

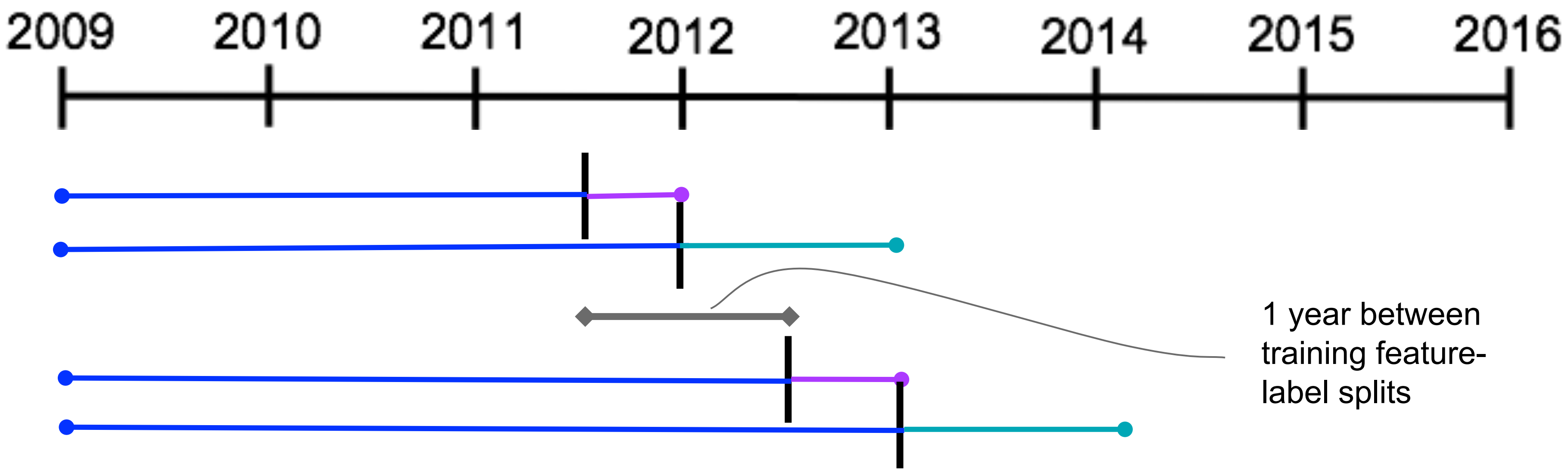
entity_id	as_of_date	bookings_last_4_yrs	label
1	2012-01-01	3	1
2	2012-01-01	1	0
3	2012-01-01	1	1

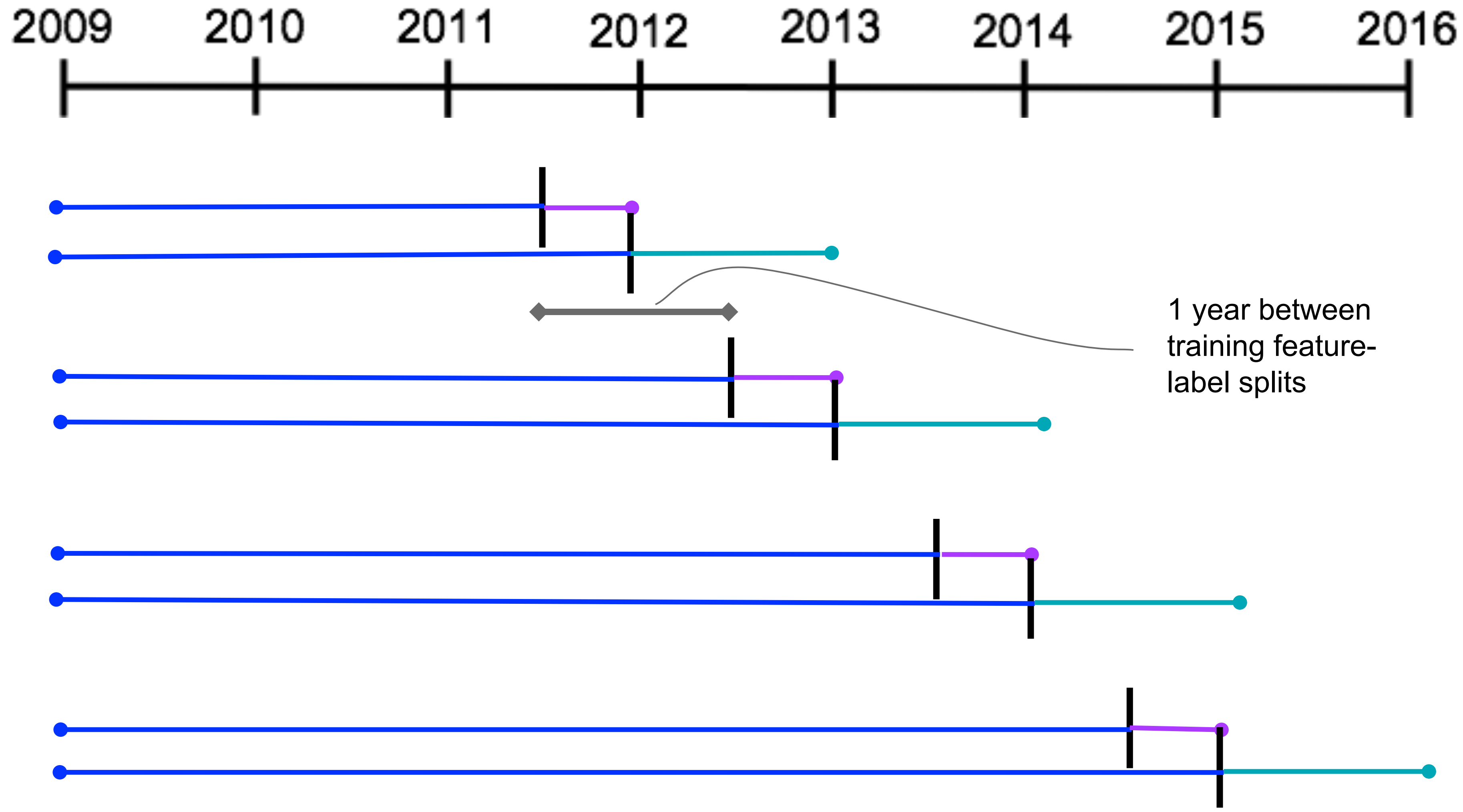
test

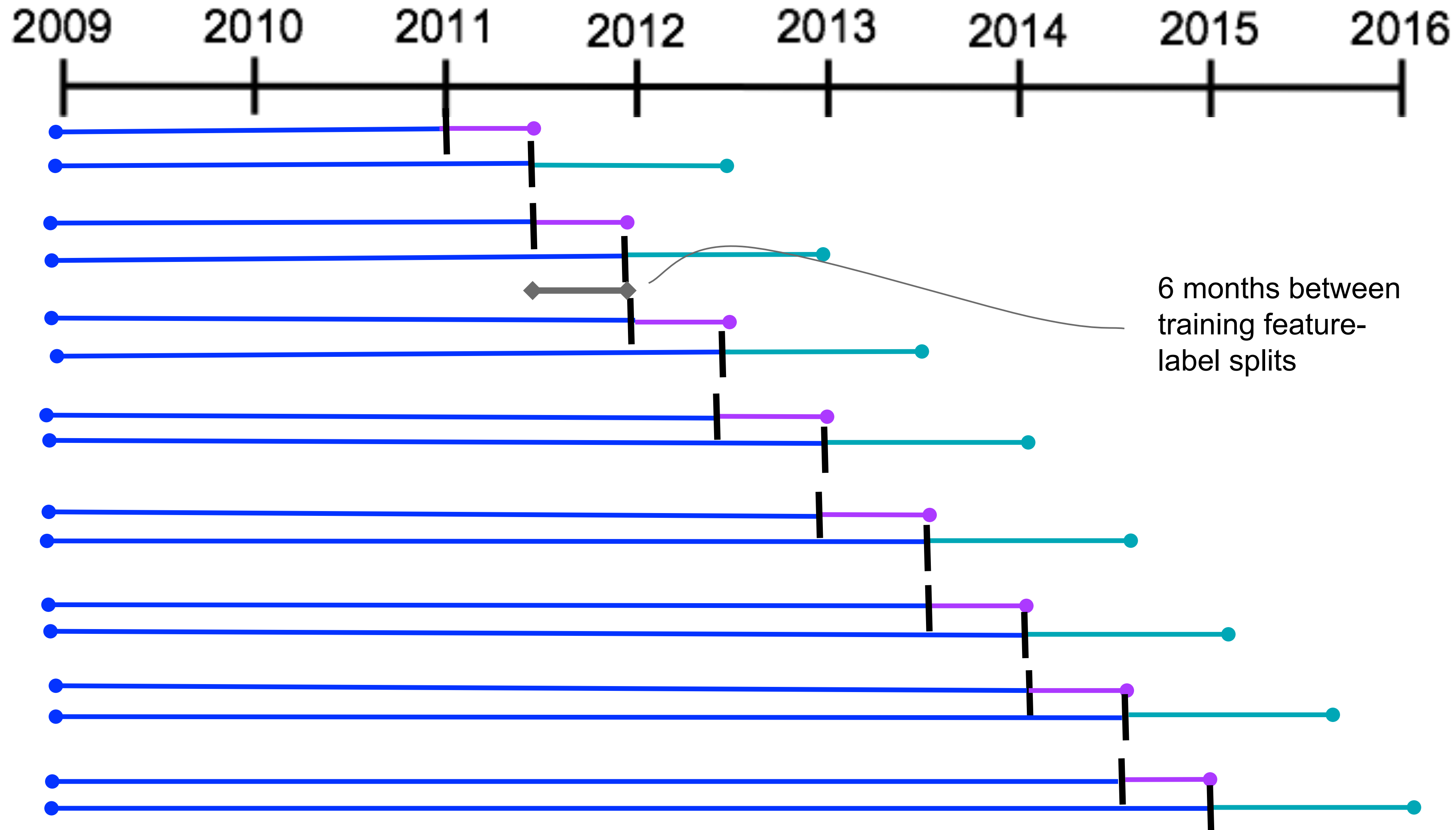
entity_id	as_of_date	bookings_last_4_yrs	label
1	2012-07-01	3	1
2	2012-07-01	1	1
3	2012-07-01	0	1

How often to retrain the model?

You can retrain models after any arbitrary amount of time, called the **model update frequency.** For example...

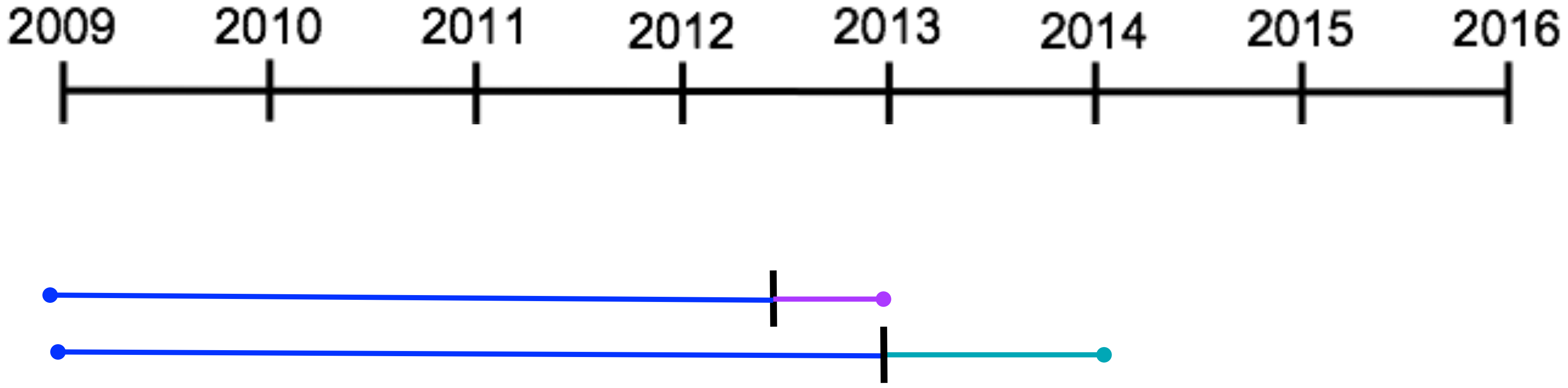



2009
2010
2011
2012
2013
2014
2015
2016
1 year between training feature-label splits


2009
2010
2011
2012
2013
2014
2015
2016
6 months between training feature-label splits

How many rows to put in the matrix?

So far, all of the matrices have one row per entity. We train on one time (July 1, 2012) and test on one time (January 1, 2013).



train

entity_id	as_of_date	bookings_last_4_yrs	label
1	2012-07-01	3	1
2	2012-07-01	1	0
3	2012-07-01	1	1

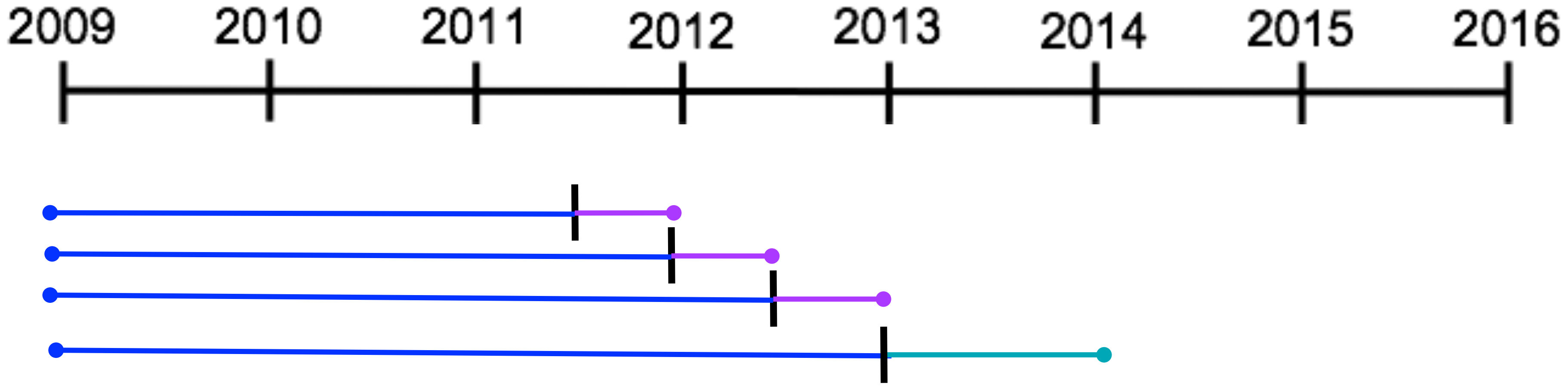
test

entity_id	as_of_date	bookings_last_4_yrs	label
1	2013-01-01	3	1
2	2013-01-01	1	1
3	2013-01-01	0	1

Temporal "oversampling"

So far, all of the matrices have one row per entity. We train on one time (January 1, 2012) and test on one time (July 1, 2012).

But we can train the **same model** on multiple dates….



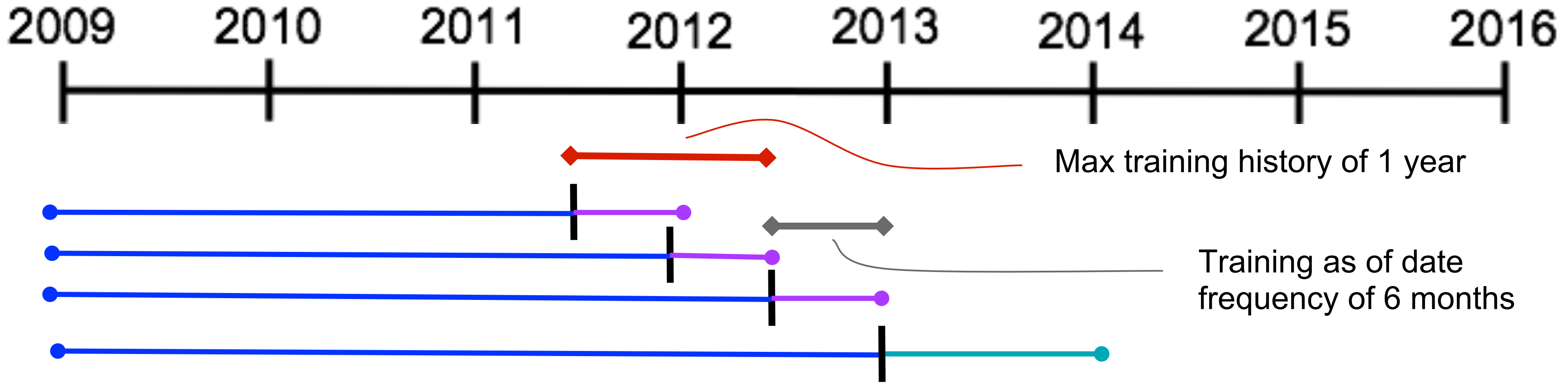
train

entity_id	as_of_date	bookings_last_4_yrs	label
1	2011-07-01	3	1
1	2012-01-01	2	1
1	2012-07-01	4	1
2	2011-07-01	0	1
2	2012-01-01	1	0
2	2012-07-01	0	0
3	2011-07-01	1	1
3	2012-01-01	1	0
3	2012-07-01	2	1

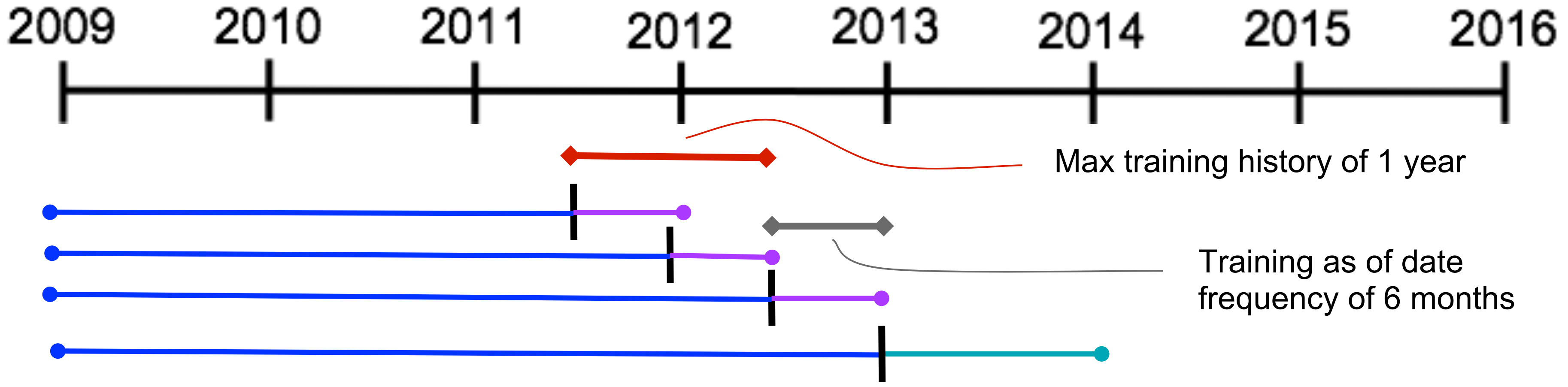
Configuring Temporal Parameters (Timechop)

How many as of dates are in a training matrix depends on 2 parameters:

- **training_as_of_date_frequency**: how much time between dates
- **max_training_history**: how much time between first and last training as of dates (at most)


2009
2010
2011
2012
2013
2014
2015
2016
Max training history of 1 year
Training as of date frequency of 6 months

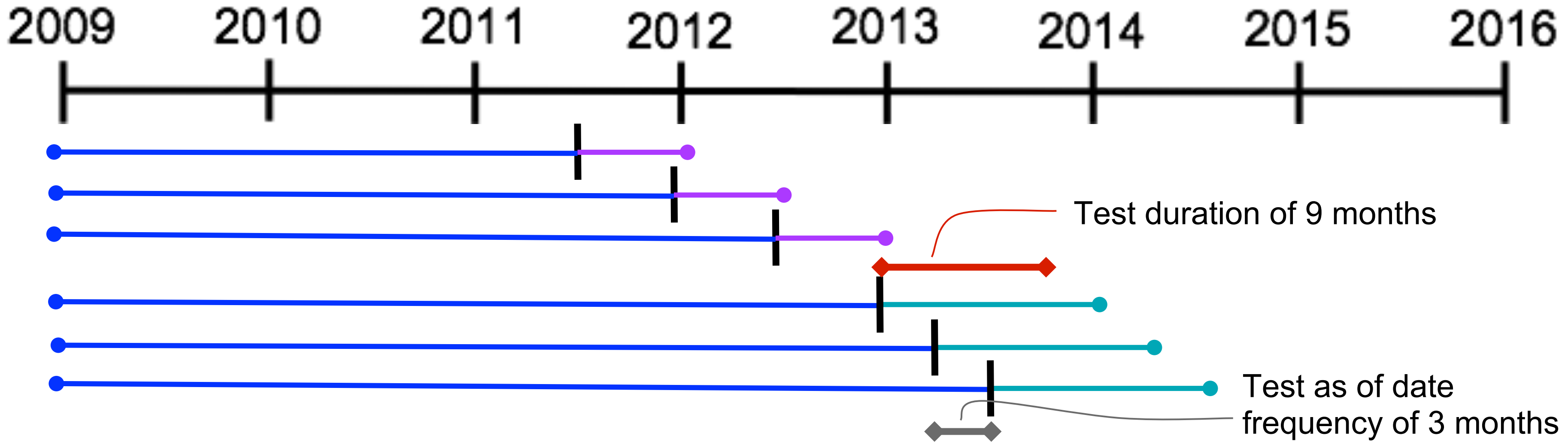
```
last_as_of_date = 2013-01-01
as_of_date_frequency = 6 months
earliest_possible_as_of_date = 2013-01-01 - 1 year
as_of_dates = []
current_as_of_date = last_as_of_date
WHILE current_as_of_date >= earliest_possible_as_of_date:
    as_of_dates.append(current_as_of_date)
    current_as_of_date = current_as_of_date - as_of_date_frequency
```



Configuring Temporal Parameters (Timechop)

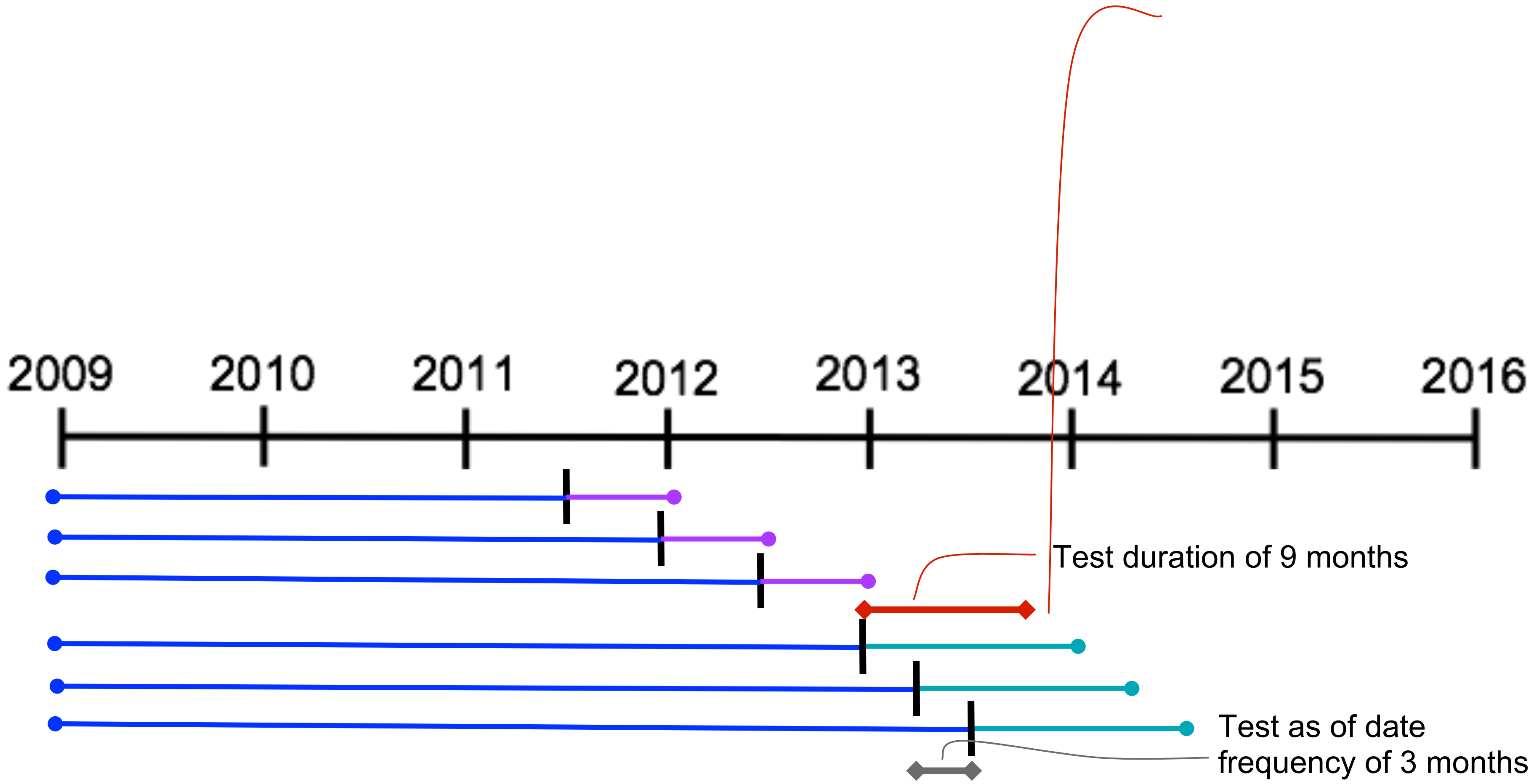
The same controls exist for test matrices, allowing you to include multiple test dates for the same model:

- **test_as_of_date_frequency**: how much time between dates
- **test_duration**: how much time between first and last test as of dates



2009
2010
2011
2012
2013
2014
2015
2016
Test duration of 9 months
Test as of date frequency of 3 months

Same loop, but roll **forward** this time, and don't forget to **always use <**


2009
2010
2011
2012
2013
2014
2015
2016
Test duration of 9 months
Test as of date frequency of 3 months

test

entity_id	as_of_date	bookings_last_4_yrs	label
1	2013-01-01	3	1
1	2013-04-01	3	1
1	2013-07-01	4	1
2	2013-01-01	0	1
2	2013-04-01	1	0
2	2013-07-01	0	0
3	2013-01-01	1	1
3	2013-04-01	3	0
3	2013-07-01	3	1

All the Temporal Parameters

```
temporal_config:
  feature_start_time: '1995-01-01' # earliest date included in features
  feature_end_time: '2015-01-01'   # latest date included in features
  label_start_time: '2012-01-01' # earliest date for which labels are avialable
  label_end_time: '2015-01-01' # day AFTER last label date (all dates in any model are < this date)
  model_update_frequency: ['6month’] # how frequently to retrain models
  training_as_of_date_frequencies: ['1day’] # time between as of dates for same entity in train matrix
  test_as_of_date_frequencies: ['3month’] # time between as of dates for same entity in test matrix
  max_training_histories: ['6month', '3month'] # length of time included in a train matrix
  test_durations: ['0day', '1month', '2month'] # length of time included in a test matrix
  training_label_timespans: ['1month'] # time period across which outcomes are labeled in train matrices
  test_label_timespans: ['7day'] # time period across which outcomes are labeled in test matrices
```

Warnings

- ALWAYS USE >= AND <
- Test your temporal code: Start with a simple configuration where **you can write out the expected results** without code, and make sure your code produces the right dates
- Test your feature code: Start with a few people and a few features that you made up, calculate the expected matrices by hand and check them against the matrices your code makes

Sources of Temporal Leakage

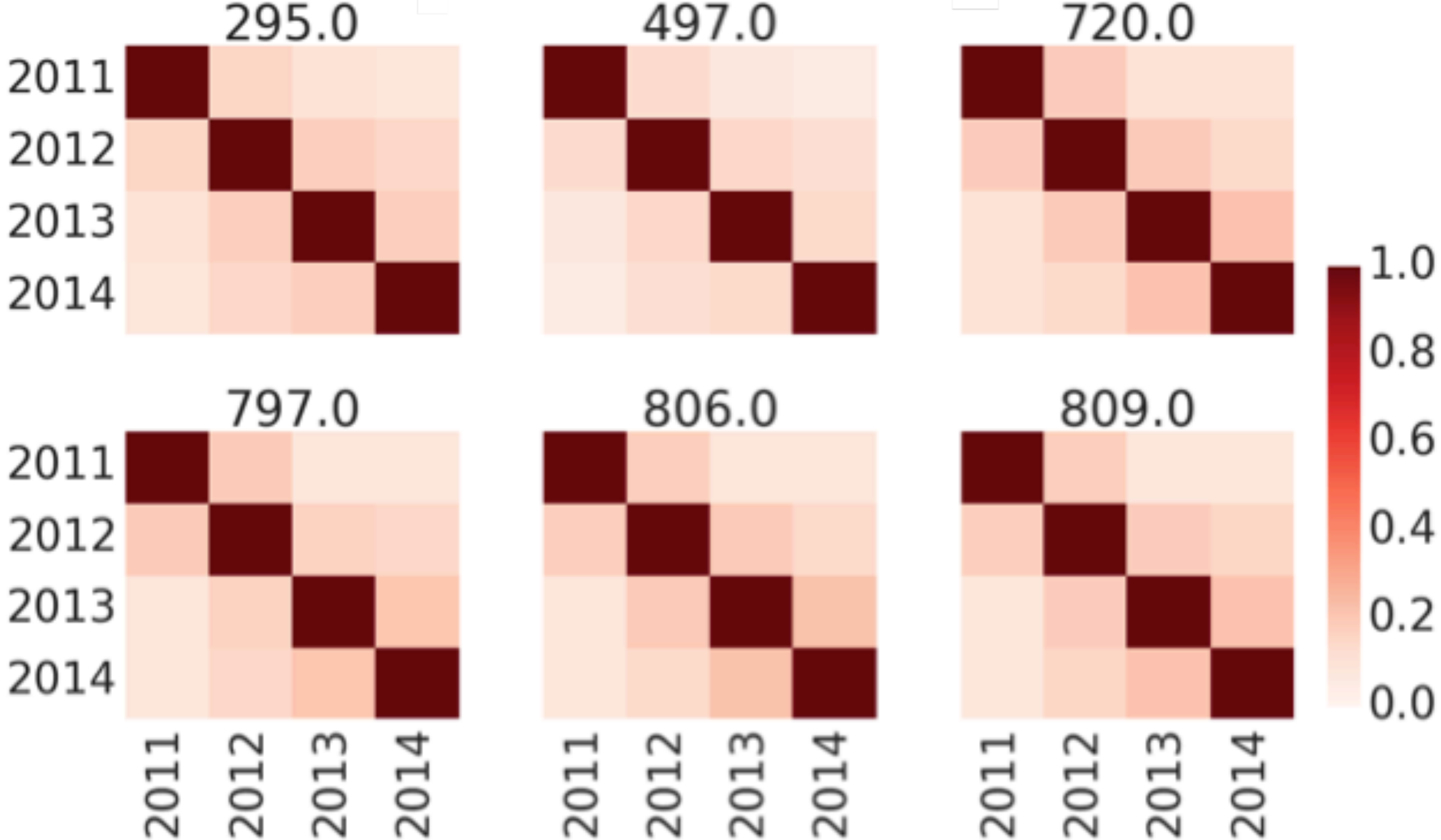
Obvious:

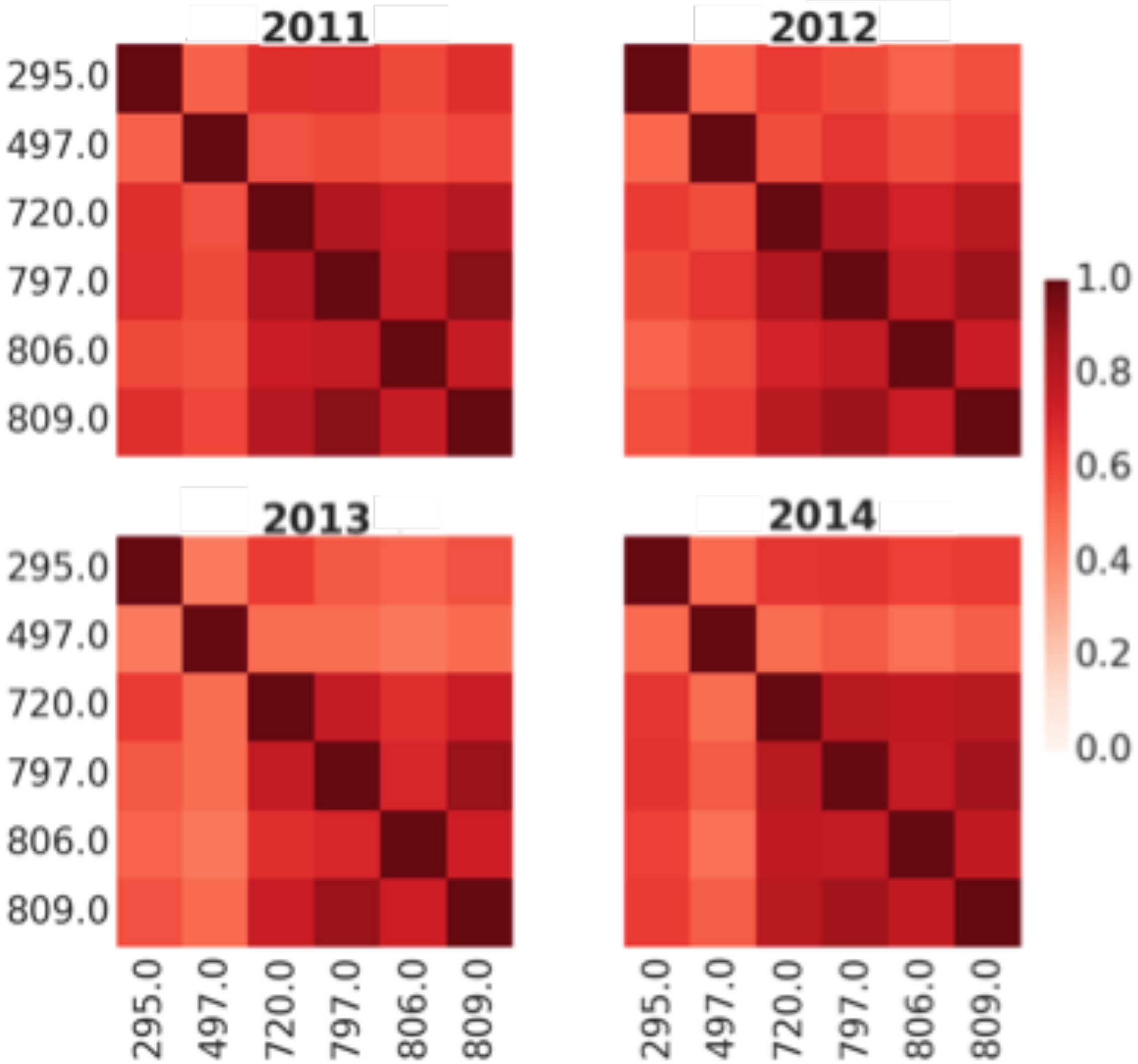
- Train and test labels aggregate data from overlapping times
- Labels and features aggregate data from overlapping times

Less obvious:

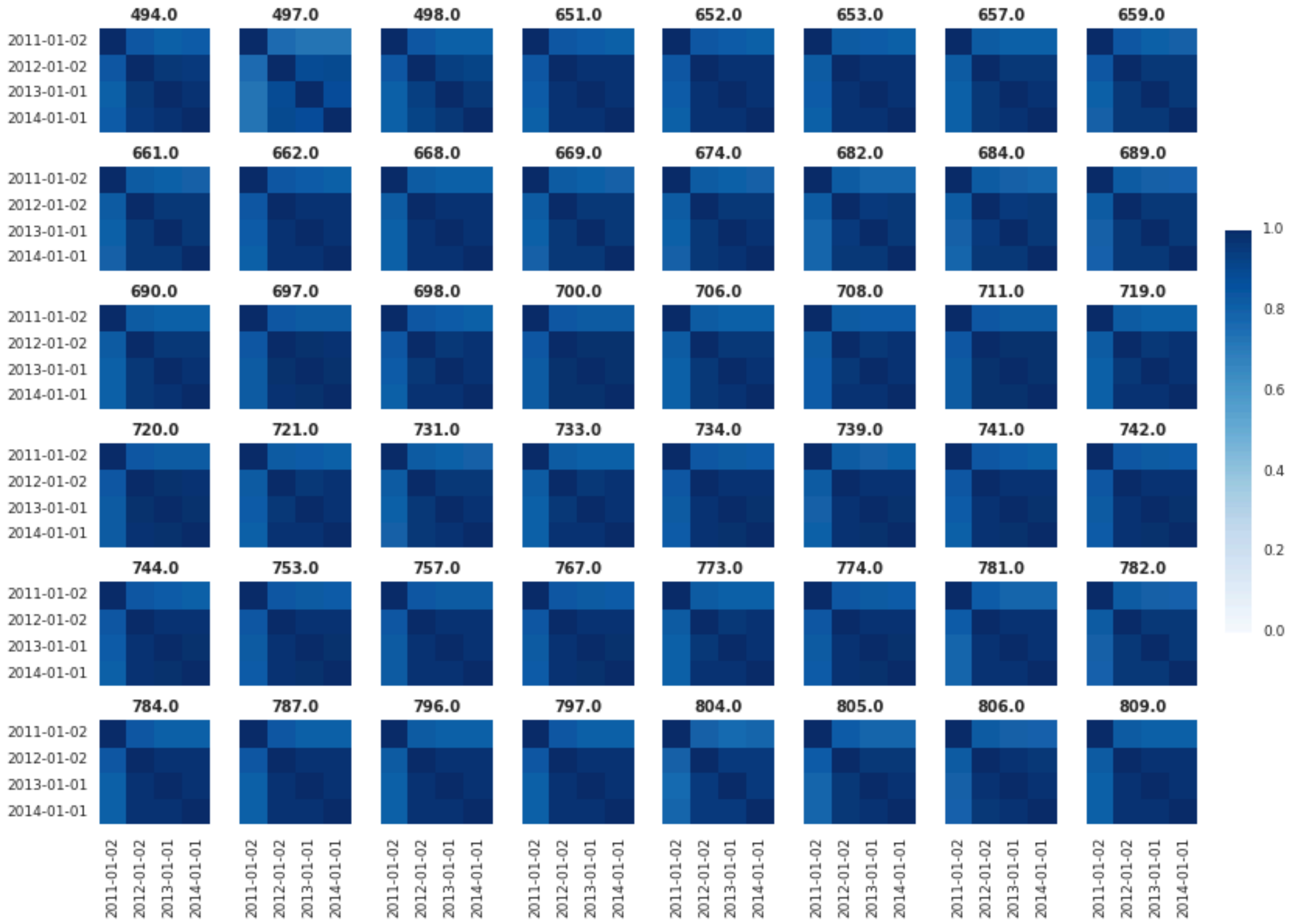
- Cohorts: People not known in the data until later are included in earlier models

Temporal Model Evaluation

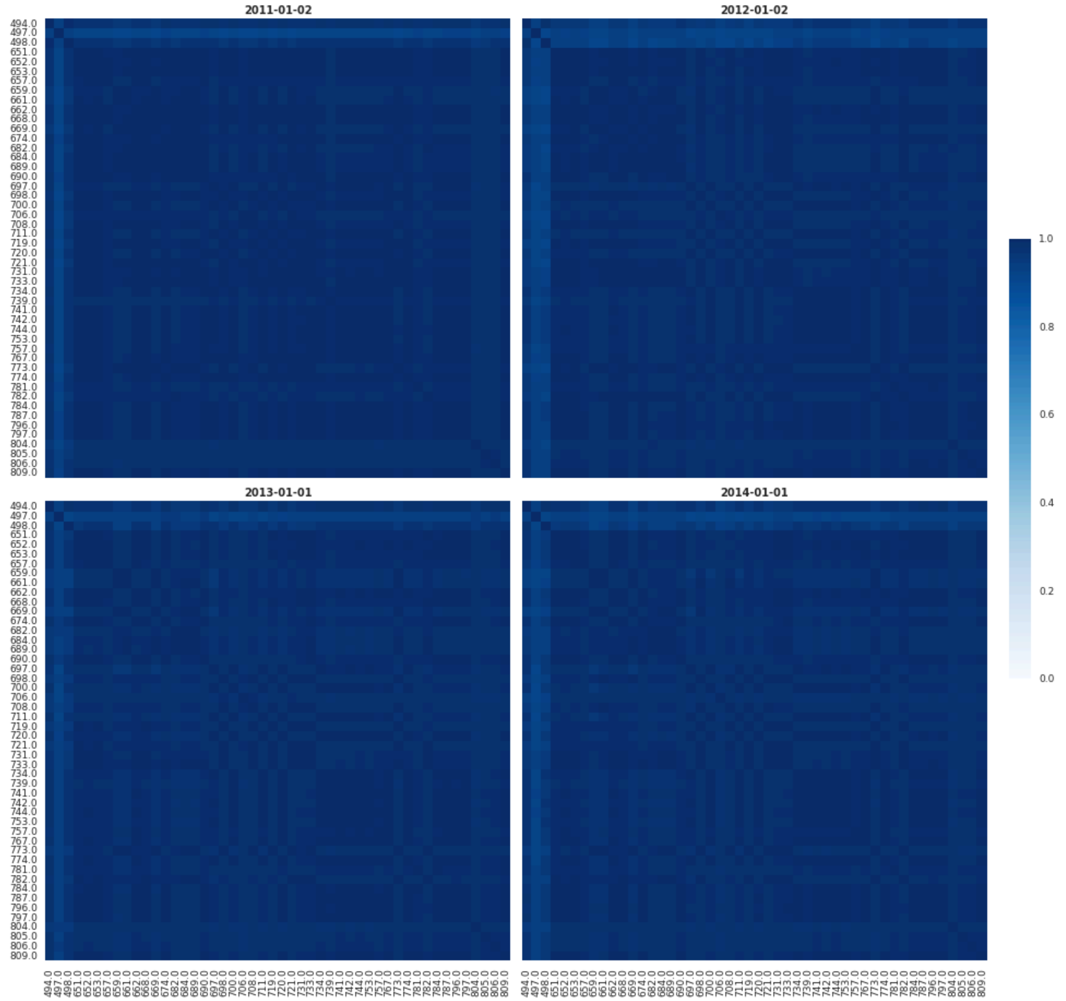

295.0
497.0
720.0
797.0
806.0
809.0
2011
2012
2013
2014
1.0
0.8
0.6
0.4
0.2
0.0

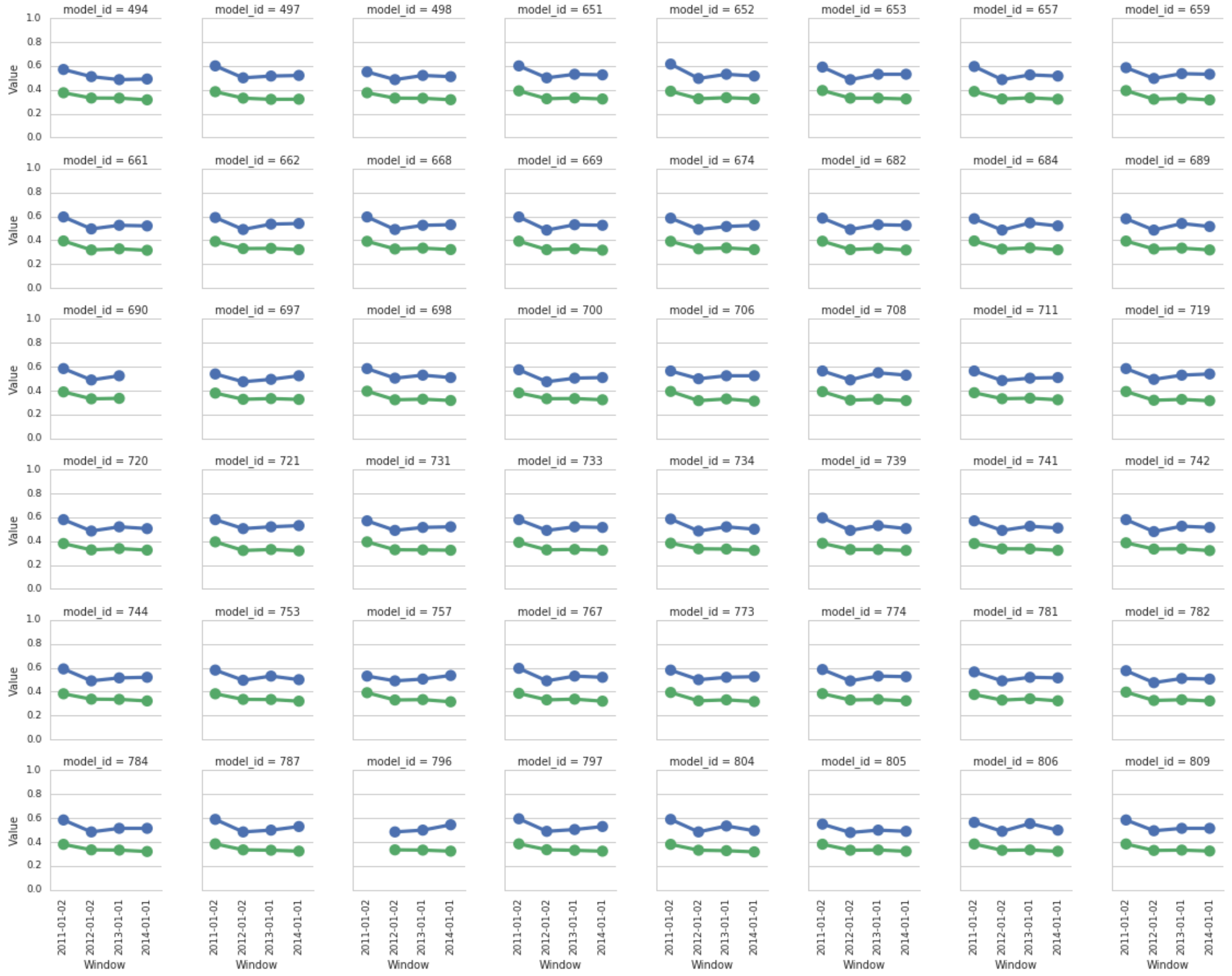

2011
2012
2013
2014
295.0
497.0
720.0
797.0
806.0
809.0
1.0
0.8
0.6
0.4
0.2
0.0

FEATURE IMPORTANCE RANK CORRELATION, WITHIN MODELS



FEATURE IMPORTANCE RANK CORRELATION, BETWEEN MODELS





● precision_200_abs
● precision_1000_abs