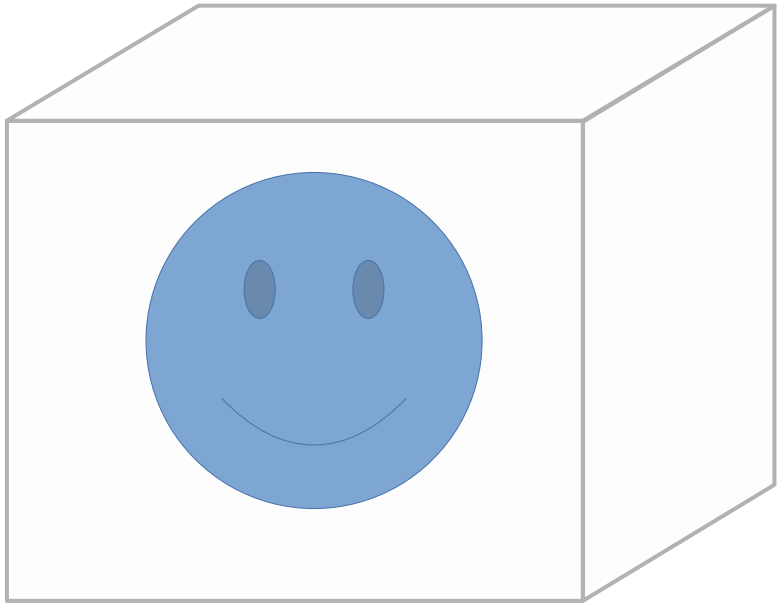
Acquiring EPI volumes: slice timing considerations

We speak about acquiring “a volume” of EPI data in the interval of one TR (say, 2s). That *sounds* like an instantaneous snapshot of the whole volume every TR, like this:



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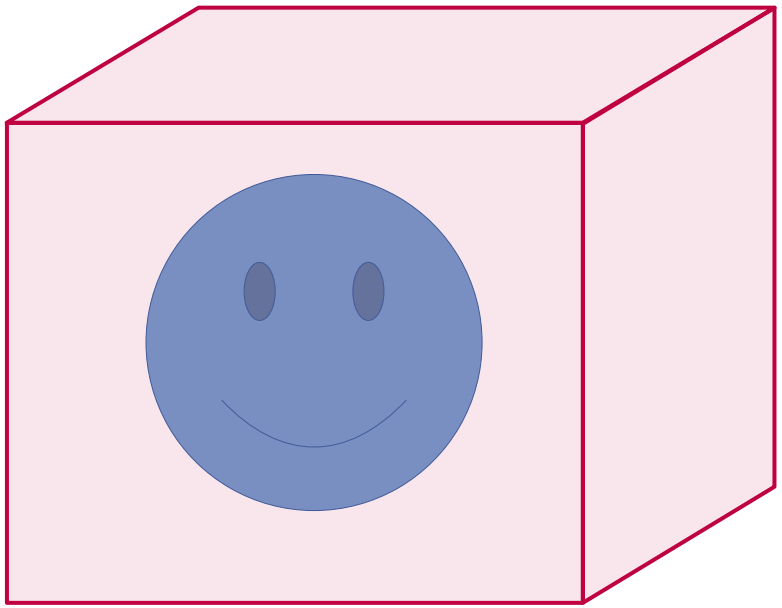

$n = 0$, $t = 0.000$ s

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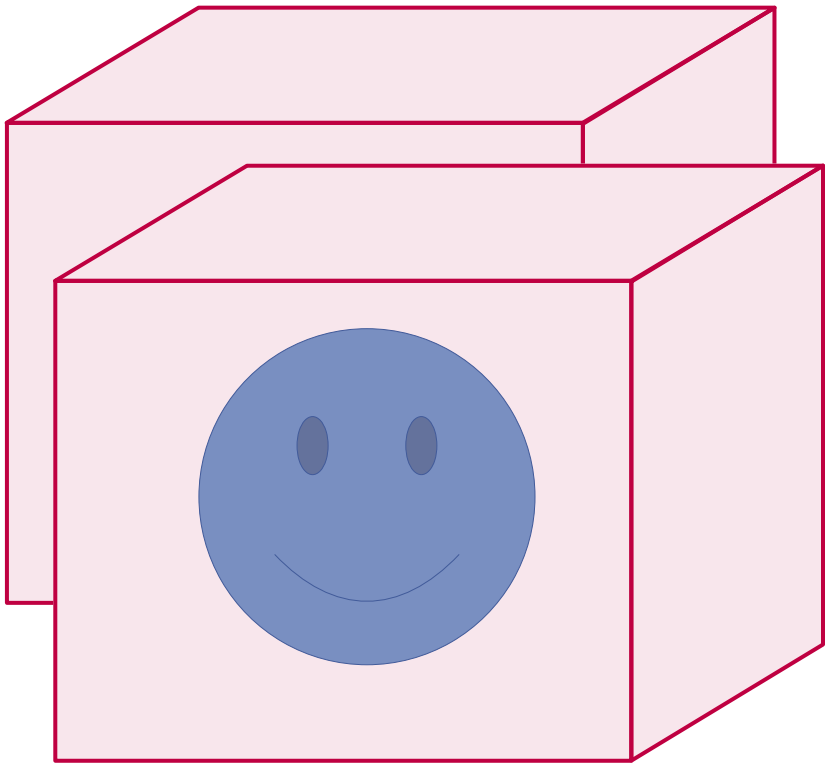

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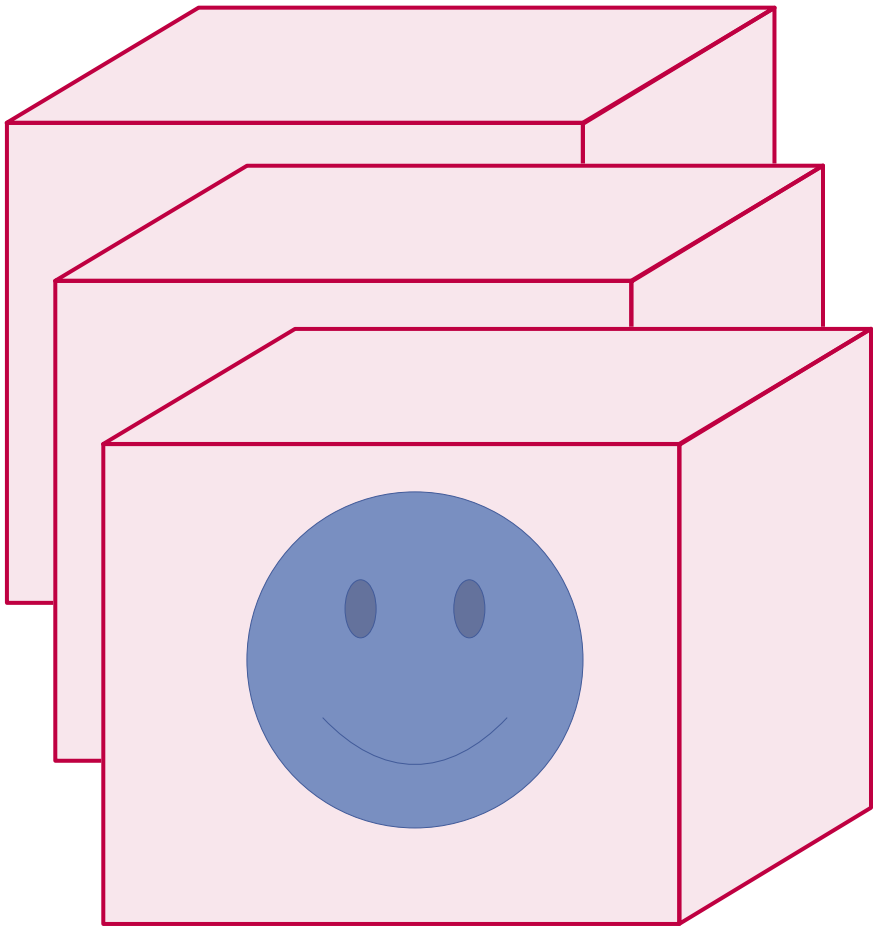


$n = 0$, $t = 0.000$ s

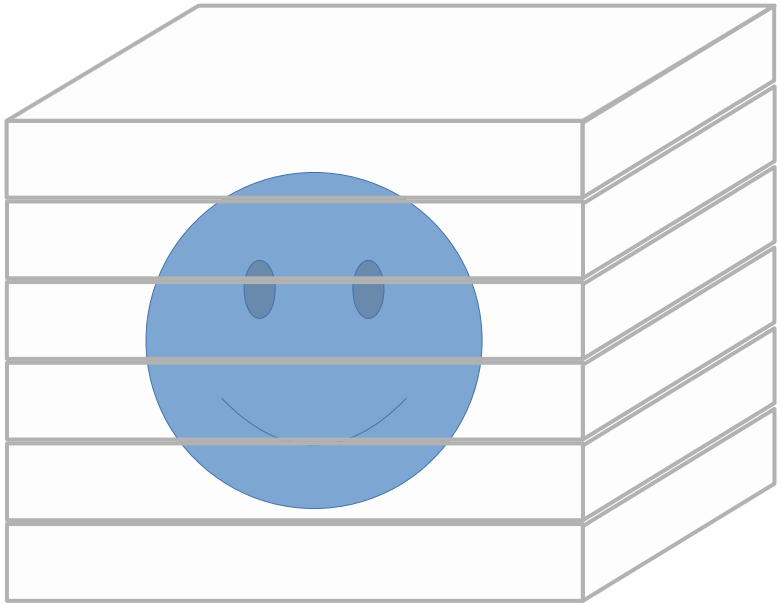
$n = 1$, $t = 2.000$ s

$n = 2$, $t = 4.000$ s

...

Acquiring EPI volumes: slice timing considerations

But in reality, a volume is acquired slice-by-slice throughout the TR interval. Moreover, the ordering is typically *not* sequential, but like this:



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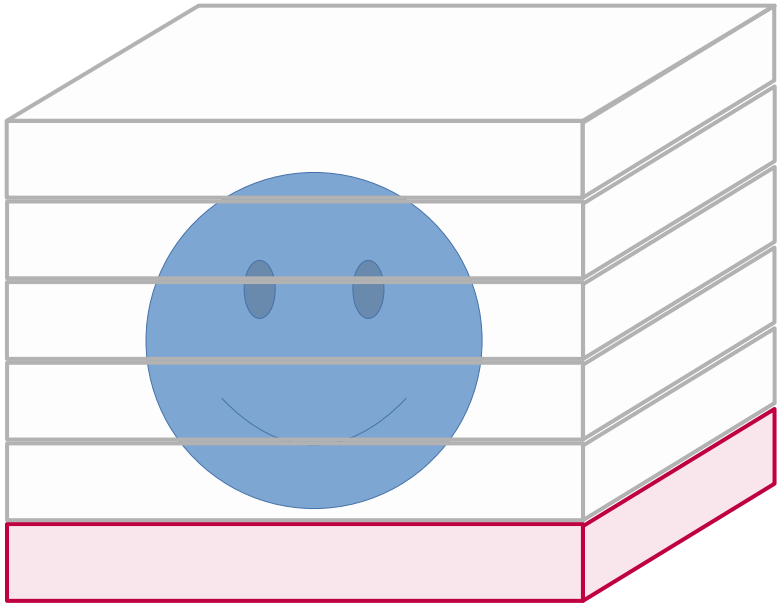

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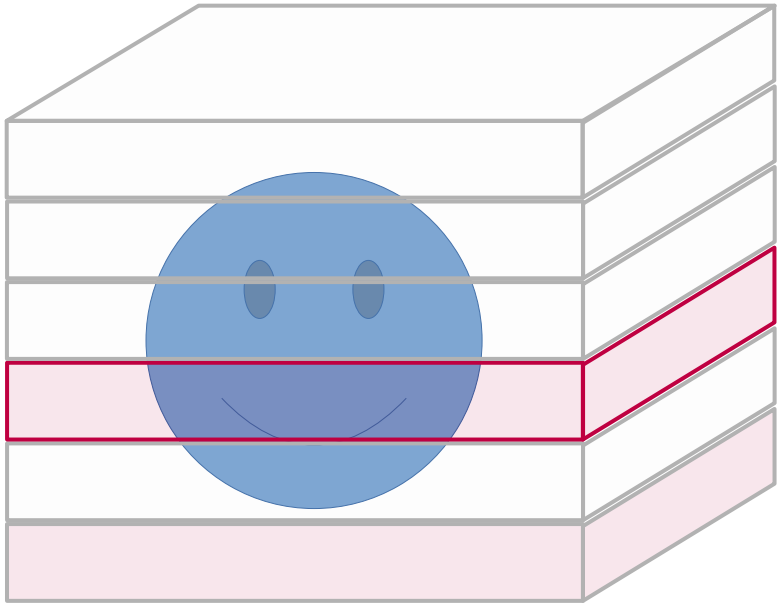

$k = 2$, $t = 0.333$ s

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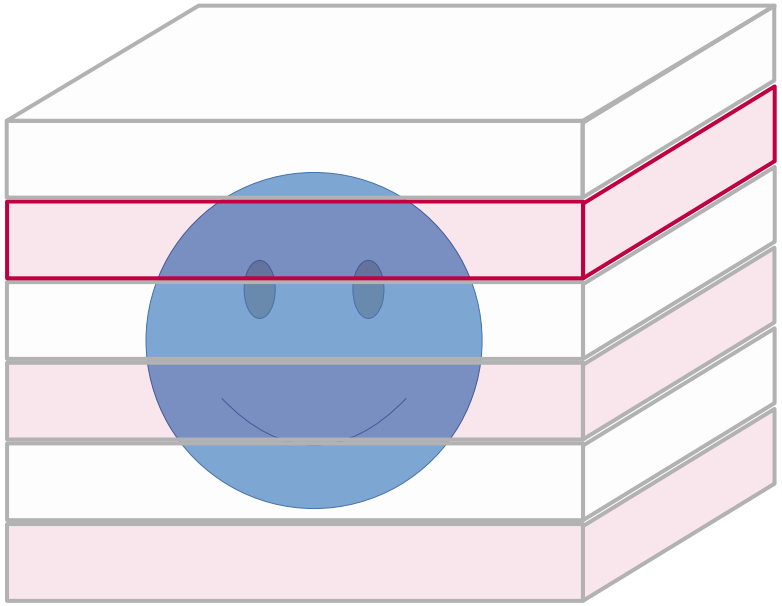

$k = 4$, $t = 0.667$ s

Acquiring EPI volumes: slice timing considerations

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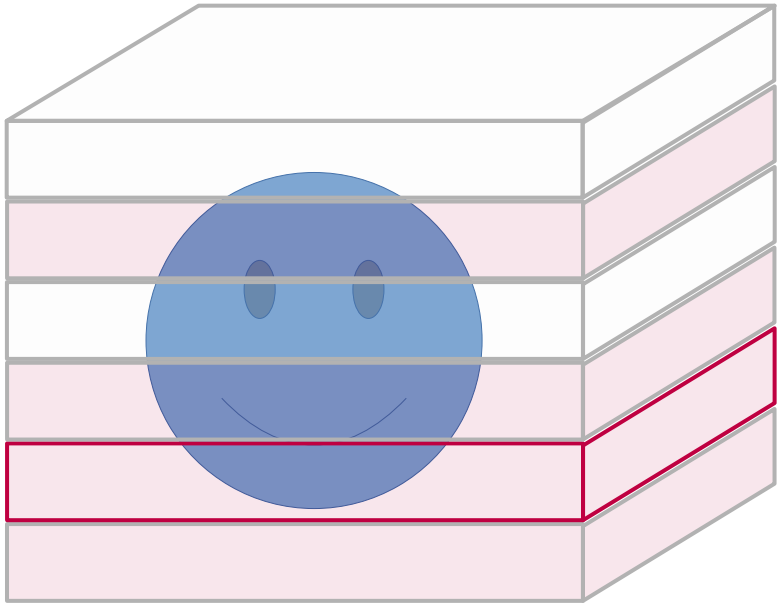

k = 1, t = 1.000 s

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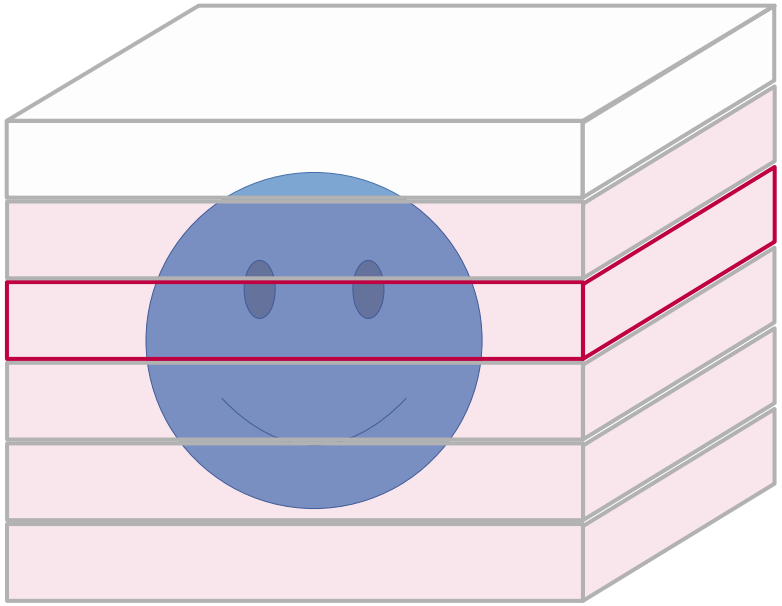

k = 3, t = 1.333 s

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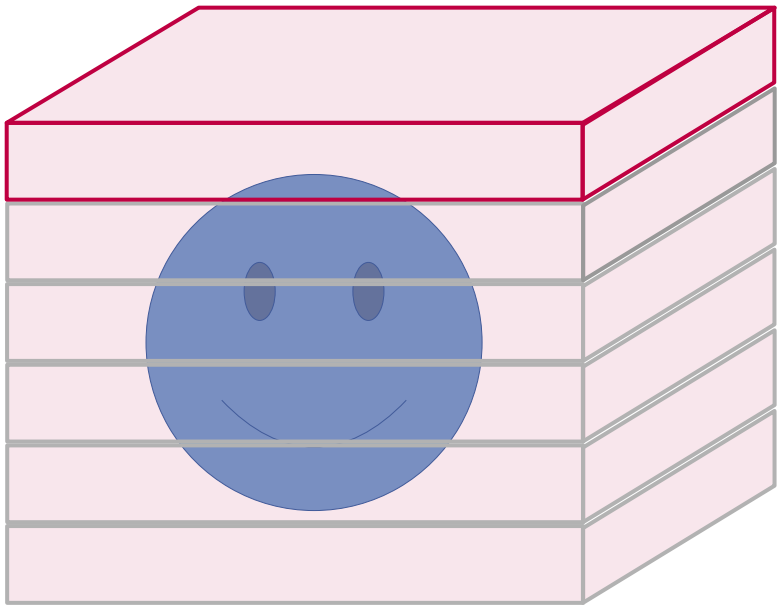

k = 5, t = 1.667 s

Acquiring EPI volumes: slice timing considerations

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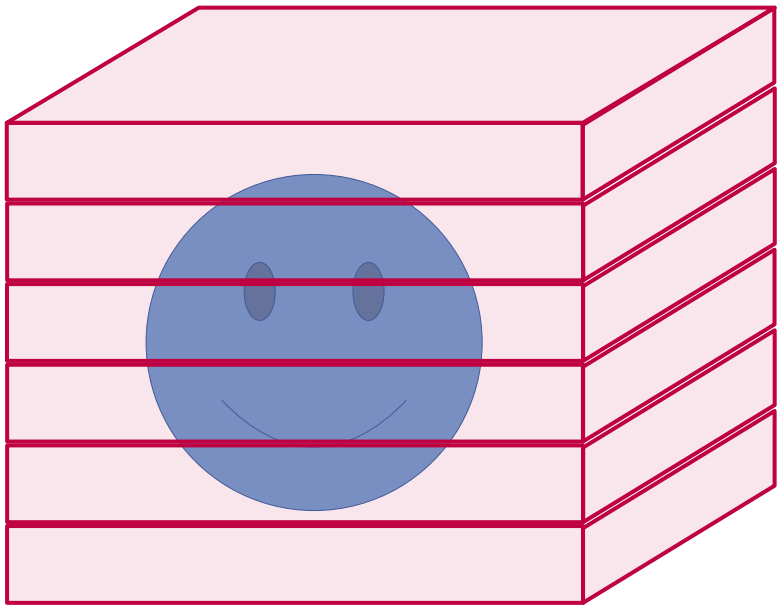


TR = 2s

$k = 5, t = 1.667$ s

$k = 4, t = 0.667$ s

$k = 3, t = 1.333$ s

$k = 2, t = 0.333$ s

$k = 1, t = 1.000$ s

$k = 0, t = 0.000$ s

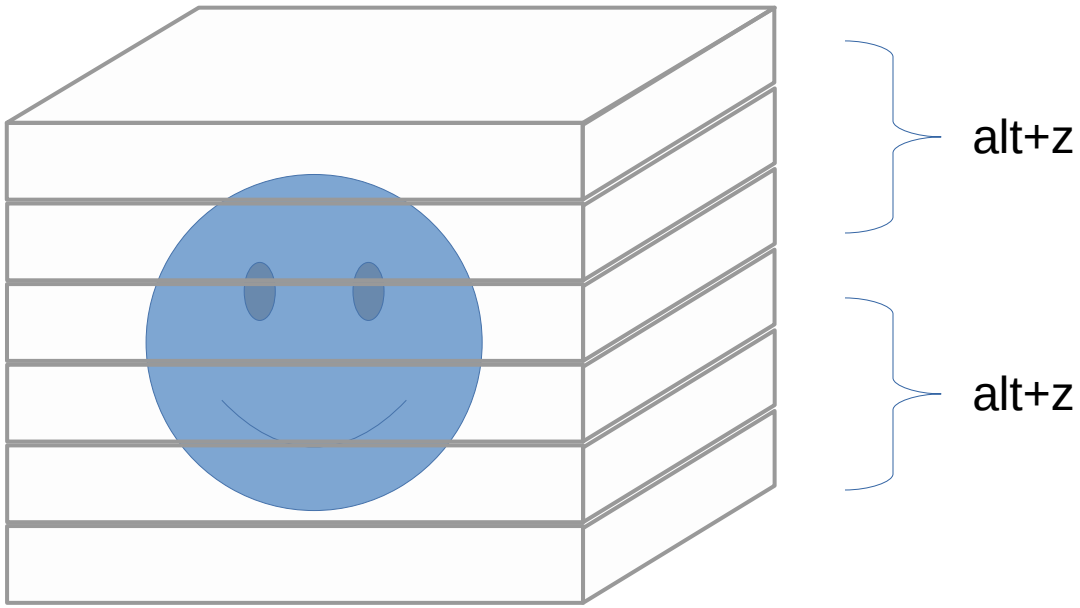
Note the ≈ TR/2 time difference between all neighboring slices.

The slice selection pattern is called **interleaved**. This is done to reduce signal contamination from neighboring slices by acquiring them approximately ½ TR apart in time.

This particular slice selection alternates upward through the *z*-axis, so it is abbreviated **alt+z.**

Acquiring EPI volumes: slice timing considerations

In the special case of **multiband acquisitions**, multiple subsets of the slices are acquired simultaneously, where each set could use alt+z timing and MB factor = 2, for example.

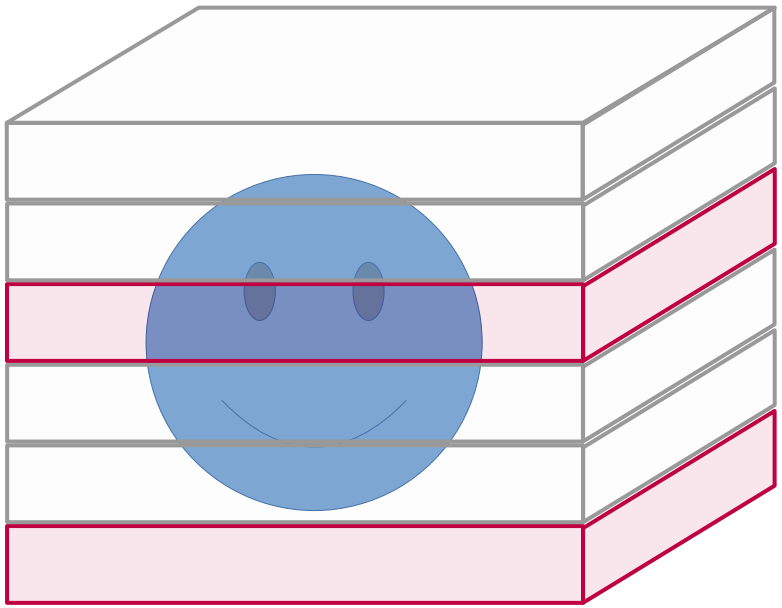


Because the bands are acquired simultaneously, a volume is acquired in half of the time.

Acquiring EPI volumes: slice timing considerations

In the special case of **multiband acquisitions**, multiple subsets of the slices are acquired simultaneously, where each set could use alt+z timing and MB factor = 2, for example.

MB factor = 2, TR = 1s



k = 3, *t* = 0.000 s (like k = 0)

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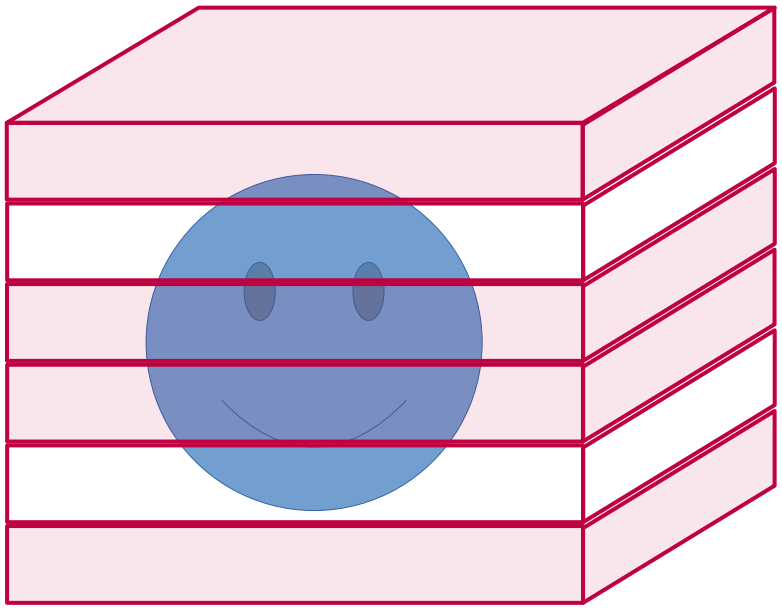

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k = 3, *t* = 0.000 s (like k = 0)

k = 2, *t* = 0.333 s

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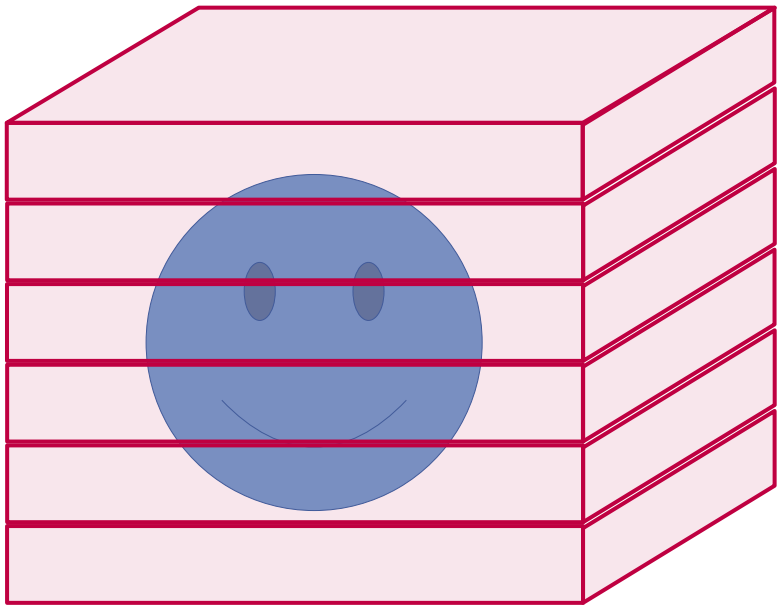

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alt+z

k = 2, *t* = 0.333 s

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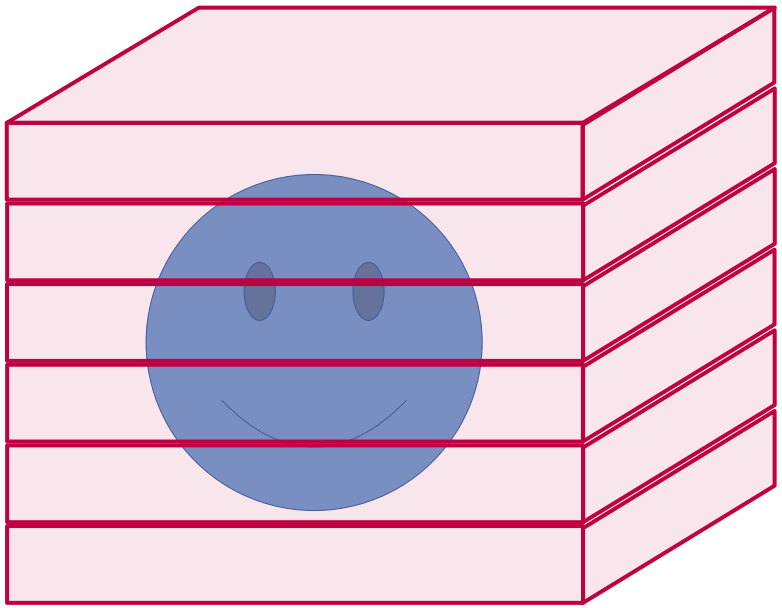

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k = 1, *t* = 0.667 s

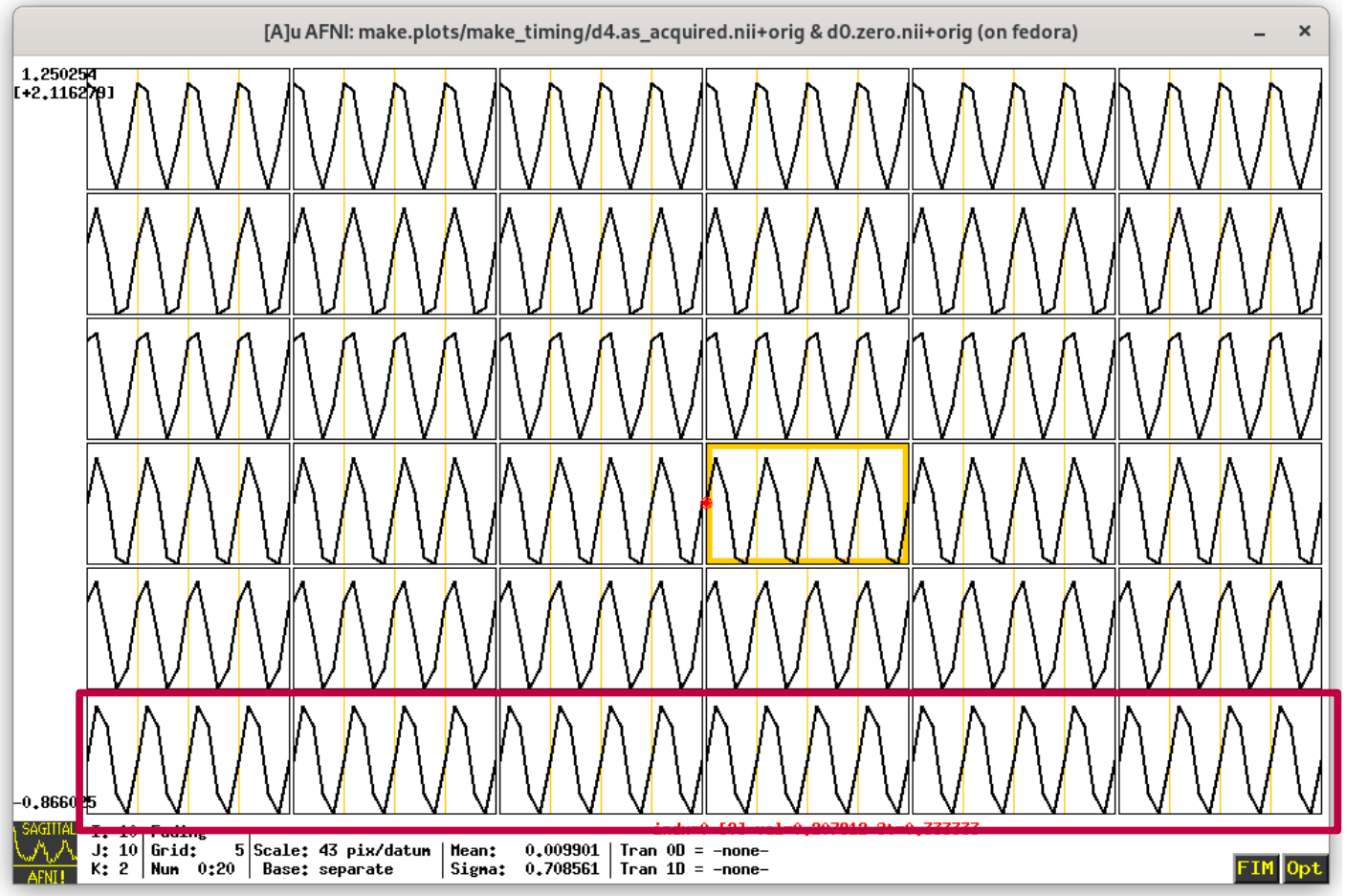
k = 0, *t* = 0.000 s

Note the smaller but still nonzero time difference between all neighboring slices.

Because the bands are acquired simultaneously, a volume is acquired in half of the time.

Acquiring EPI volumes: slice timing considerations

How does slicewise acquisition affect the *time series*? Consider a subject with identical time series at every voxel.
Because each slice is acquired at a **different** time, the sampled time series will differ across slices.
This can affect the results of linear regression modeling.



The later a slice is acquired, the later the (black) curve is sampled.

$k = 5$, $t = 1.667$ s

$k = 4$, $t = 0.667$ s

$k = 3$, $t = 1.333$ s

$k = 2$, $t = 0.333$ s

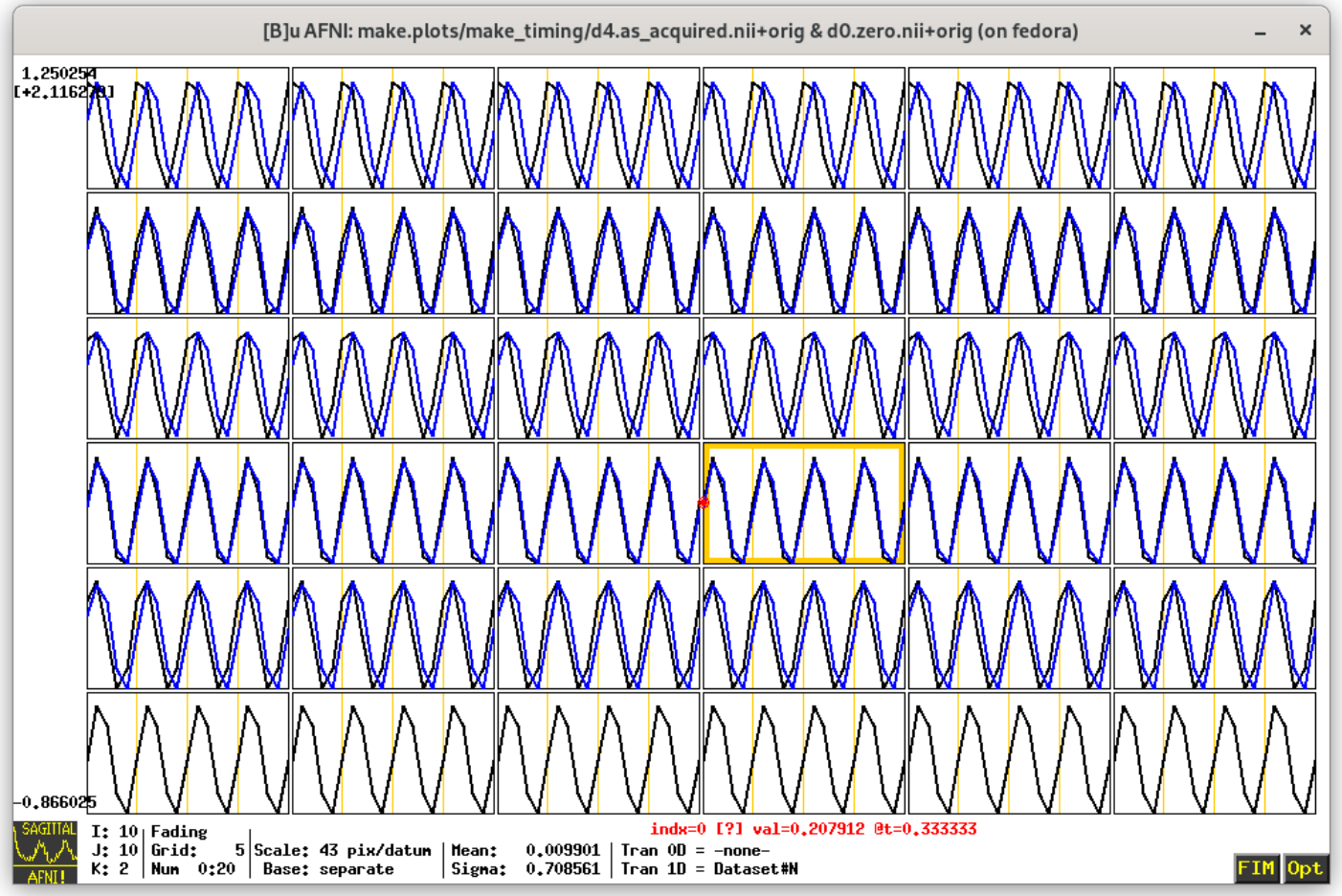
$k = 1$, $t = 1.000$ s

$k = 0$, $t = 0.000$ s

Each slice is identical across all voxels in that slice.

Acquiring EPI volumes: slice timing considerations

Correcting for differential slice timing: **`3dTshift -tzero 0 ...`**
→ We can perform **slice timing correction** to adjust each time series to appear *as if* it had been acquired at the same time in each slice, via interpolation (blue time series); here, each slice is adjusted to time=0s.

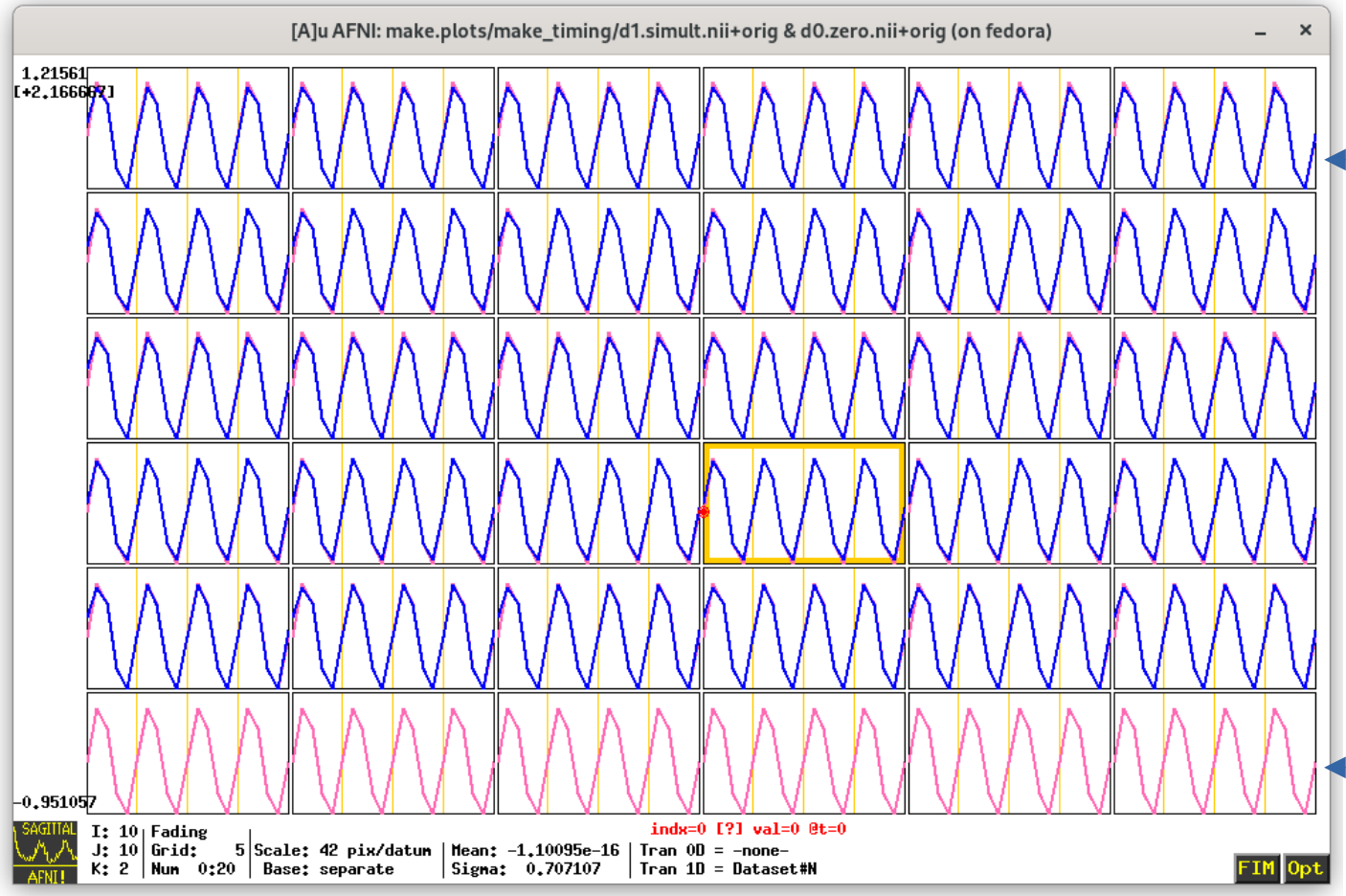


The later a slice is acquired, the later the (black) curve is sampled, hence it looks “left-shifted” compared to the corrected (blue) curve.

The corrected (blue) curves *should* look more like the one at slice k=0 (for: 3dTshift -tzero 0).

Acquiring EPI volumes: slice timing considerations

Correcting for differential slice timing: **`3dTshift -tzero 0 ...`**
→ In an ideal case, the adjusted time series looks the same as an "instantaneous volume" acquisition would (pink line, for reference).
→ In reality, motion spikes and other noise features present challenges, as they get blurred across time (hence we despike first).



Compare the ideal (pink) and 3dTshift adjusted (blue) curves:

At k=5 the curves do **not** match exactly, even without noise.

At k=0 the curves match.