Reporting Summary

Nature Research wishes to improve the reproducibility of the work that we publish. This form provides structure for consistency and transparency in reporting. For further information on Nature Research policies, see our Editorial Policies and the Editorial Policy Checklist.

Statistics

For all statistical analyses, confirm that the following items are present in the figure legend, table legend, main text, or Methods section.

n/a  Confirmed

☐  The exact sample size (n) for each experimental group/condition, given as a discrete number and unit of measurement

☐  A statement on whether measurements were taken from distinct samples or whether the same sample was measured repeatedly

☐  The statistical test(s) used AND whether they are one- or two-sided

☐  Only common tests should be described solely by name; describe more complex techniques in the Methods section.

☐  A description of all covariates tested

☐  A description of any assumptions or corrections, such as tests of normality and adjustment for multiple comparisons

☐  A full description of the statistical parameters including central tendency (e.g. means) or other basic estimates (e.g. regression coefficient) AND variation (e.g. standard deviation) or associated estimates of uncertainty (e.g. confidence intervals)

☐  For null hypothesis testing, the test statistic (e.g. F, t, r) with confidence intervals, effect sizes, degrees of freedom and P value noted Give P values as exact values whenever suitable.

☐  For Bayesian analysis, information on the choice of priors and Markov chain Monte Carlo settings

☐  For hierarchical and complex designs, identification of the appropriate level for tests and full reporting of outcomes

☐  Estimates of effect sizes (e.g. Cohen’s d, Pearson’s r), indicating how they were calculated

Our web collection on statistics for biologists contains articles on many of the points above.

Software and code

Policy information about availability of computer code

Data collection  EPU 1.1.4

Data analysis  MotionCor 2, CTFFIND 4, RELION 3.1, Resmap 1.1.4, MODELLER 10.1, Chimera 1.13, COOT 0.8.9, PHENIX 1.19 (real_space_refine, MolProbity 4, Pymol 2.5)

For manuscripts utilizing custom algorithms or software that are central to the research but not yet described in published literature, software must be made available to editors and reviewers. We strongly encourage code deposition in a community repository (e.g. GitHub). See the Nature Research guidelines for submitting code & software for further information.

Data

Policy information about availability of data

All manuscripts must include a data availability statement. This statement should provide the following information, where applicable:

- Accession codes, unique identifiers, or web links for publicly available datasets
- A list of figures that have associated raw data
- A description of any restrictions on data availability

Map and model have been deposited in the EMDB and PDB with the accession codes: EMG-33501 and 7XKF. [http://dx.doi.org/10.2741/pdb7XKFpdb]. The coordinates (SYSS) for Tcv. tepidum LH1-AC is available at PDB. All other data are available from the authors upon reasonable request.
Field-specific reporting

Please select the one below that is the best fit for your research. If you are not sure, read the appropriate sections before making your selection.

- [x] Life sciences
- [ ] Behavioural & social sciences
- [ ] Ecological, evolutionary & environmental sciences

For a reference copy of the document with all sections, see nature.com/documents/nr-reporting-summary-flat.pdf

Life sciences study design

All studies must disclose on these points even when the disclosure is negative.

- **Sample size**: Sample sizes of Cryo-EM data are given in Methods, Supplementary Table 1, and Supplementary Figure 3. All intact particles were considered and the sample size was sufficient to obtain high resolution.
- **Data exclusions**: No data were excluded from the analysis, except for badly picked or low resolution particles in the cryo-EM data sets.
- **Replication**: All experiments were confirmed with at least two replications as detailed in Methods. We also performed averaging over a large number of independent particle images on single particle cryo-EM as detailed in Supplementary Table 1.
- **Randomization**: Randomization was not relevant to this study, which is standard in the single particle analysis.
- **Blinding**: Blinding was not relevant to this study, which is standard in the single particle analysis.

Reporting for specific materials, systems and methods

We require information from authors about some types of materials, experimental systems and methods used in many studies. Here, indicate whether each material, system or method listed is relevant to your study. If you are not sure if a list item applies to your research, read the appropriate section before selecting a response.

| Materials & experimental systems | Methods |
|-------------------------------|---------|
| n/a                           | n/a     |
| [x] Antibodies                | [x] ChiP-seq |
| [x] Eukaryotic cell lines     | [x] Flow cytometry |
| [x] Palaeontology and archaeology | [x] MRI-based neuroimaging |
| [x] Animals and other organisms |         |
| [x] Human research participants |         |
| [x] Clinical data             |         |
| [x] Dual use research of concern |       |