Integrative Structure Validation Report

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The following software was used in the production of this report:

IHMValidation Version 3.0
Python-IHM Version 2.5
MolProbity Version 4.5.2
ATSAS Version 3.2.1 (r14885)

PDB ID	9A9R | pdb_00009a9r
Structure Title	Chloroplastic protein CP12 from the diatom Thalassiosira pseudonana (tp-CP12, homodimer)
Structure Authors	Bonucci, A.; Wang, T.; Baroudi, H.; Etienne, E.; Gerbaud, G.; Mileo, E.; Yamato, T.; Gontero, B.; Launay, H.; Belle, V.; Receveur-Brechot, V.
Deposited on	2025-04-08

This is a PDB-IHM Structure Validation Report.

We welcome your comments at helpdesk@pdb-ihm.org

A user guide is available at https://pdb-ihm.org/validation_help.html with specific help available everywhere you see the ? symbol.

List of references used to build this report is available here.

1. Overview

1.1. Summary

This entry consists of 1 model(s). A total of 3 dataset(s) were used to build this entry.

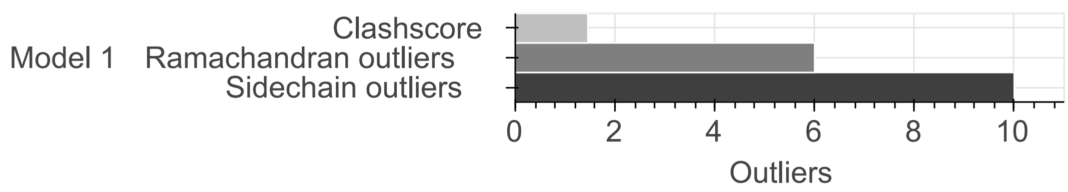
Name	Type	Count
EPR data	Experimental data	1
SAS data	Experimental data	1

Name	Type	Count
De Novo model	Starting model	1

1.2. Overall quality

This validation report contains model quality assessments for all structures, data quality and fit to model assessments for SAS and crosslinking-MS datasets. Data quality and fit to model assessments for other datasets and model uncertainty are under development. Number of plots is limited to 256.

Model Quality: MolProbity Analysis



2. Model Details

2.1. Ensemble information

This entry consists of 0 distinct ensemble(s).

2.2. Representation

This entry has 1 representation(s).

ID	Model(s)	Entity ID	Molecule name	Chain(s) [auth]	Total residues	Rigid segments	Flexible segments	Model coverage/ Starting model coverage (%)	Scale
1	1	1	CP12 domain-containing protein	A	163	-	1-163	100.00 / 100.00	Atomic
				B					

2.3. Datasets used for modeling

There are 3 unique datasets used to build the models in this entry.

ID	Dataset type	Database name	Data access code
1	EPR data	Zenodo	10.5281/zenodo.15117282
2	SAS data	Zenodo	10.5281/zenodo.15117282
3	De Novo model	Zenodo	10.5281/zenodo.15117282

2.4. Methodology and software

This entry is a result of 1 distinct protocol(s).

Step number	Protocol ID	Method name	Method type	Method description	Number of computed models	Multi state modeling	Multi scale modeling
1	1	ab initio modeling	Not available	AlphaFold modelling: Structure prediction for the CP12 homodimer was performed using AlphaFold v2.1.1-Multimer (AF2) and the default databases The sequence of mature CP12 was used in the AF2 input file for multiple sequence alignments (MSAs) lookup and structural template matching. The predicted local distance difference test score (pLDDT,) was used to estimate the per-residue confidence of the models. The percentages of the secondary structure elements of the models were assessed using YASARA View22. Modification of the selected AF2 model was performed using PyMOL by a rotation around N-Ca bond of residue I134 and by respecting the Ramachandran plot. Structure prediction of T. pseudonana PRK was performed using AlphaFold3 webserver (Abramson, J et al. Accurate structure prediction of biomolecular interactions with AlphaFold3. Nature (2024) based on the sequence provided by UNIPROT (entry B8BZ40) devoid of the first 15 residues, which are predicted with a score of 0.96 to form the chloroplast transit peptide by HECTAR v1.3 (https://webtools.sb-roscoff.fr/root?tool_id=abims_hectar HECTAR: A Method to Predict Subcellular Targeting in Heterokonts", Gschloessl et al., BMC Bioinformatics, 2008 (PubMed ID 18811941)) specifically trained for heterokonts.	Not available	False	False

Step number	Protocol ID	Method name	Method type	Method description	Number of computed models	Multi state modeling	Multi scale modeling
2	1	sampling	harmonic restrained MD simulations	Harmonic restrained MD simulations were run with the Amber 20 package based on the modified AF2 model. The Amber ff19SB force field was used for the protein, which was immersed into a cubic periodic box filled with water solvent molecules modeled by the OPC model with the LEaP program of AmberTools20. All charged residues were considered in their standard protonation state at pH = 7.0. We added 28 sodium ions to neutralize the simulation box and the total number of atoms became 178352. Nonbonded particle-particle interactions were considered with a distance cutoff of 9 and the long-range electrostatic interactions were treated with the particle mesh Ewald (PME) method. After minimization, heating, and equilibration of the simulation system, several rounds of MD simulations were conducted imposing harmonic restraints on the CA-CA distances across the dimer for respective spin-labeled residues S39, S46, S56, S83, and C150 with a spring force of 30 kcal/(mol2). Each round ran for 100ps with time step of 2 fs at T = 300 K and P = 1 atm. The trajectories and snapshots were saved every 1 ps. The initial/target distances for each CA atom pair were 73 /68 for S39, 57 /43 for S46, 26 / 32 for S56, 51 /64 for S83, 12 /25 for C150, respectively.	1	False	False

Step number	Protocol ID	Method name	Method type	Method description	Number of computed models	Multi state modeling	Multi scale modeling
3	1	sampling	restrained-ensemble MD simulation	The following reMD simulations were run by using a modified version of NAMD 2 with all-atom CHARMM36m protein force field. 25 copies of all-atom MTSL (CYR1 in CHARMM-GUI) spin labels were attached to residues S39, S46, S56, S83 and C150, respectively, with reMD Prepper in vacuum for saving the computational resources. The force field of all-atom CYR1 spin label is provided by CHARMM-GUI. Spatial overlap among the 25 copies of CYR1 spin labels was allowed by neglecting the interactions among them. Five independent all-atom reMD simulations were conducted at 303.15 K with different random number seeds using Langevin dynamics with a damping coefficient of 5 ps-1. Before each reMD production run, we performed minimization and equilibration, during which only sidechain atoms were relaxed, keeping the backbone atom positions with harmonic restraints of 2 kcal/(mol2) imposed on them. For these structural refinement, we switched off the harmonic restraints imposed on the backbone atoms, and conducted production runs of reMD simulations for 2 ns with a time step of 0.5 fs. The long-range electrostatic interactions were treated with the particle mesh Ewald (PME) method and the nonbonded interactions were truncated at a 10 distance cutoff. The distance distributions of each spin label pair were restrained with a force constant of 100 kcal/(mol2) toward the experimental distance distribution histograms with a bin width of 0.025 nm. The atomic coordinates of each reMD production run were saved every 1ps. Since each spin label has 25 copies, a total number of 625 distances for each spin label pair were obtained from a single snapshot of trajectories and a total of 1, 250, 000 data points were yielded for every spin label pair from one single reMD production run.	1435	False	False

Step number	Protocol ID	Method name	Method type	Method description	Number of computed models	Multi state modeling	Multi scale modeling
4	1	Not available	Not available	The saved atomic coordinates of reMD productions were then removed of CYR1 spin-labels, and then used as an ensemble of structures to simulate the SAXS data.	Not available	False	False
5	1	Not available	Not available	DEER distance distributions were extracted from raw experimental data using DeerAnalysis2019 software	Not available	False	False

There are 5 software packages reported in this entry.

ID	Software name	Software version	Software classification	Software location
1	AlphaFold Multimer	2.1.1	model building	https://cosmic-cryoem.org/tools/alphafoldmultimer/
2	Amber	20	refinement	http://ambermd.org/
3	modified version of NAMD	2	refinement	http://www.ks.uiuc.edu/Research/namd/
4	CRYSOL	3.10	data collection	https://www.embl-hamburg.de/biosaxs/crysol.html
5	DeerAnalysis	2019	other	https://epr.ethz.ch/software/older-versions/old_deeranalysis.html

3. Data quality ?

3.1.1. Scattering profile

SAS data used in this integrative model could not be validated as the sasCIF file is currently unavailable or incomplete.

3.4. EPR ?

Validation for this section is under development.

4. Model quality ?

For models with atomic structures, MolProbity analysis is performed. For models with coarse-grained or multi-scale structures, excluded volume analysis is performed.

4.1b. MolProbity Analysis ?

Excluded volume satisfaction for the models in the entry are listed below. The Analysed column shows the number of particle-partice or particle-atom pairs for which excluded volume was analysed.

Standard geometry: bond outliers ?

There are 66 bond length outliers in this entry (2.71% of 2438 assessed bonds). A summary is provided below.

Chain	Res	Type	Atoms	|Z|	Observed (Å)	Ideal (Å)	Model ID (Worst)	Models (Total)
B	161	GLY	C-N	7.41	1.23	1.33	1	1
A	121	TRP	NE1-CE2	7.02	1.45	1.37	1	1
B	135	ARG	CZ-NH2	6.80	1.24	1.33	1	1
B	21	ARG	C-N	6.41	1.42	1.33	1	1
B	118	ARG	C-N	6.23	1.42	1.33	1	1
B	12	LYS	N-CA	5.95	1.57	1.46	1	1
B	51	LYS	C-N	5.93	1.41	1.33	1	1
A	52	VAL	C-N	5.67	1.41	1.33	1	1
B	121	TRP	C-N	5.63	1.41	1.33	1	1
A	156	PHE	C-N	5.59	1.41	1.33	1	1
A	55	LEU	CA-CB	5.57	1.64	1.53	1	1
B	145	GLU	N-CA	5.51	1.56	1.46	1	1
A	136	ALA	CA-C	5.43	1.64	1.52	1	1
A	25	ASP	N-CA	5.41	1.56	1.46	1	1
B	159	ALA	N-CA	5.33	1.56	1.46	1	1
A	151	GLU	C-N	5.20	1.40	1.33	1	1
B	118	ARG	CZ-NH1	5.14	1.25	1.32	1	1
B	76	LEU	CA-CB	5.10	1.63	1.53	1	1
B	98	GLU	C-N	5.10	1.40	1.33	1	1
B	161	GLY	N-CA	5.01	1.53	1.45	1	1
A	108	GLU	C-N	5.01	1.40	1.33	1	1
A	149	GLY	N-CA	4.87	1.53	1.45	1	1
A	37	VAL	N-CA	4.82	1.55	1.46	1	1
B	100	LEU	CA-CB	4.76	1.63	1.53	1	1
A	52	VAL	CA-CB	4.75	1.67	1.54	1	1
B	150	SER	C-N	4.73	1.40	1.33	1	1
A	126	GLU	N-CA	4.68	1.55	1.46	1	1
B	84	PRO	C-N	4.68	1.39	1.33	1	1
B	118	ARG	CZ-NH2	4.66	1.27	1.33	1	1
A	92	ASP	C-N	4.60	1.39	1.33	1	1
A	106	ALA	C-N	4.58	1.39	1.33	1	1
B	149	GLY	CA-C	4.55	1.60	1.52	1	1
A	160	LEU	CA-C	4.50	1.62	1.52	1	1
B	57	GLN	N-CA	4.50	1.54	1.46	1	1
A	71	ALA	C-N	4.45	1.39	1.33	1	1

Chain	Res	Type	Atoms	|Z|	Observed (Å)	Ideal (Å)	Model ID (Worst)	Models (Total)
A	74	ASP	C-N	4.45	1.39	1.33	1	1
A	71	ALA	CA-C	4.42	1.62	1.52	1	1
A	90	ALA	CA-C	4.38	1.62	1.52	1	1
B	132	VAL	C-N	4.35	1.39	1.33	1	1
A	89	SER	N-CA	4.34	1.54	1.46	1	1
A	30	MET	SD-CE	4.30	1.90	1.79	1	1
B	104	ARG	N-CA	4.27	1.54	1.46	1	1
B	123	THR	N-CA	4.26	1.54	1.46	1	1
A	135	ARG	CD-NE	4.26	1.40	1.46	1	1
A	40	LYS	CA-CB	4.26	1.62	1.53	1	1
B	105	ALA	C-O	4.25	1.15	1.23	1	1
B	111	GLY	C-N	4.24	1.39	1.33	1	1
B	21	ARG	N-CA	4.23	1.54	1.46	1	1
A	103	ALA	CA-C	4.23	1.61	1.52	1	1
A	73	ALA	C-N	4.22	1.39	1.33	1	1
B	106	ALA	N-CA	4.21	1.54	1.46	1	1
B	75	ASP	CG-OD2	4.16	1.33	1.25	1	1
B	88	SER	CA-C	4.16	1.61	1.52	1	1
A	18	SER	CB-OG	4.15	1.50	1.42	1	1
A	40	LYS	N-CA	4.12	1.54	1.46	1	1
B	59	LEU	CB-CG	4.11	1.61	1.53	1	1
A	67	ASP	C-N	4.10	1.39	1.33	1	1
A	146	LEU	CB-CG	4.09	1.61	1.53	1	1
A	119	LEU	CA-C	4.08	1.61	1.52	1	1
A	139	ASP	N-CA	4.08	1.54	1.46	1	1
A	55	LEU	C-N	4.08	1.39	1.33	1	1
A	141	GLU	N-CA	4.08	1.54	1.46	1	1
A	142	SER	CA-CB	4.07	1.61	1.53	1	1
B	44	VAL	CA-C	4.05	1.61	1.52	1	1
A	92	ASP	CB-CG	4.05	1.62	1.52	1	1
B	55	LEU	CB-CG	4.01	1.61	1.53	1	1

Standard geometry: angle outliers ?

There are 209 bond angle outliers in this entry (6.34% of 3298 assessed bonds). A summary is provided below. The output is limited to 100 rows.

Chain	Res	Type	Atoms	|Z|	Observed (Å)	Ideal (Å)	Model ID (Worst)	Models (Total)
B	74	ASP	CA-CB-CG	13.12	125.72	112.60	1	1
A	135	ARG	CD-NE-CZ	9.27	137.37	124.40	1	1
A	21	ARG	NE-CZ-NH1	8.94	130.44	121.50	1	1
A	35	ASN	CA-CB-CG	8.75	121.35	112.60	1	1
A	50	ALA	N-CA-CB	8.55	97.58	110.40	1	1
A	68	GLN	OE1-CD-NE2	8.25	114.35	122.60	1	1
A	132	VAL	C-N-CA	7.57	135.32	121.70	1	1
B	25	ASP	CA-CB-CG	7.54	120.14	112.60	1	1
A	132	VAL	CA-CB-CG1	7.37	122.92	110.40	1	1
A	107	THR	CA-CB-OG1	7.35	120.62	109.60	1	1
A	41	ALA	N-CA-CB	7.19	99.61	110.40	1	1
A	123	THR	CA-CB-OG1	7.13	120.30	109.60	1	1
A	139	ASP	CA-CB-CG	7.07	119.67	112.60	1	1
A	69	VAL	CA-CB-CG1	6.98	122.26	110.40	1	1
A	121	TRP	CG-CD2-CE2	6.78	115.33	107.20	1	1
A	35	ASN	OD1-CG-ND2	6.74	115.86	122.60	1	1
B	135	ARG	NH1-CZ-NH2	6.70	128.02	119.30	1	1
B	13	PHE	C-N-CA	6.56	133.51	121.70	1	1
B	138	LEU	C-N-CA	6.54	133.47	121.70	1	1
B	87	GLY	C-N-CA	6.30	133.04	121.70	1	1
B	132	VAL	CA-CB-CG2	6.28	121.08	110.40	1	1
A	94	SER	C-N-CA	6.27	132.99	121.70	1	1
A	75	ASP	C-CA-CB	6.23	121.93	110.10	1	1
A	155	LYS	C-N-CA	6.19	132.84	121.70	1	1
A	5	ALA	N-CA-CB	6.11	101.23	110.40	1	1
B	130	SER	O-C-N	6.08	113.28	123.00	1	1
B	119	LEU	C-CA-CB	6.07	121.63	110.10	1	1
A	45	ASP	CA-CB-CG	6.06	118.66	112.60	1	1
B	133	ASP	CA-CB-CG	6.05	118.65	112.60	1	1
A	133	ASP	CA-CB-CG	6.03	118.63	112.60	1	1
B	75	ASP	N-CA-CB	6.00	100.30	110.50	1	1
A	38	ALA	N-CA-CB	5.99	101.41	110.40	1	1
B	60	THR	CA-CB-CG2	5.95	120.61	110.50	1	1
A	53	LYS	N-CA-CB	5.90	100.46	110.50	1	1
A	128	ALA	C-CA-CB	5.88	119.31	110.50	1	1

Chain	Res	Type	Atoms	|Z|	Observed (Å)	Ideal (Å)	Model ID (Worst)	Models (Total)
A	8	ASP	CA-CB-CG	5.81	118.41	112.60	1	1
B	7	LEU	CA-C-O	5.79	110.96	120.80	1	1
B	37	VAL	CA-CB-CG2	5.77	100.60	110.40	1	1
A	21	ARG	NH1-CZ-NH2	5.73	111.85	119.30	1	1
B	156	PHE	CA-CB-CG	5.72	119.52	113.80	1	1
B	104	ARG	CA-C-N	5.71	127.63	116.20	1	1
B	8	ASP	OD1-CG-OD2	5.70	109.22	122.90	1	1
B	140	GLU	C-N-CA	5.67	131.91	121.70	1	1
B	121	TRP	C-N-CA	5.67	131.90	121.70	1	1
A	156	PHE	N-CA-CB	5.66	100.88	110.50	1	1
A	59	LEU	C-CA-CB	5.64	99.39	110.10	1	1
B	151	GLU	N-CA-CB	5.59	100.99	110.50	1	1
B	65	GLU	C-CA-CB	5.58	120.71	110.10	1	1
A	112	GLN	OE1-CD-NE2	5.56	117.04	122.60	1	1
B	19	GLU	C-N-CA	5.54	131.66	121.70	1	1
B	107	THR	C-N-CA	5.47	131.55	121.70	1	1
B	121	TRP	CG-CD2-CE3	5.46	139.36	133.90	1	1
B	55	LEU	C-N-CA	5.44	131.49	121.70	1	1
B	34	ASP	C-N-CA	5.43	111.93	121.70	1	1
A	141	GLU	C-N-CA	5.41	131.43	121.70	1	1
A	135	ARG	NE-CZ-NH1	5.39	126.89	121.50	1	1
A	63	LYS	C-N-CA	5.37	131.37	121.70	1	1
A	132	VAL	CG1-CB-CG2	5.34	99.04	110.80	1	1
B	157	GLN	OE1-CD-NE2	5.30	117.30	122.60	1	1
A	69	VAL	C-CA-CB	5.27	121.41	111.40	1	1
B	67	ASP	C-CA-CB	5.27	120.11	110.10	1	1
A	143	LEU	C-CA-CB	5.26	120.09	110.10	1	1
B	35	ASN	OD1-CG-ND2	5.25	117.35	122.60	1	1
A	42	PRO	N-CD-CG	5.24	111.07	103.20	1	1
B	115	PRO	N-CA-CB	5.21	108.73	103.00	1	1
B	24	TRP	CA-CB-CG	5.18	123.43	113.60	1	1
B	116	GLN	OE1-CD-NE2	5.17	117.43	122.60	1	1
B	154	GLU	CA-C-O	5.16	112.03	120.80	1	1
B	58	MET	CA-C-O	5.15	112.04	120.80	1	1
A	33	SER	CA-CB-OG	5.15	121.40	111.10	1	1

Chain	Res	Type	Atoms	|Z|	Observed (Å)	Ideal (Å)	Model ID (Worst)	Models (Total)
A	121	TRP	CD2-CE2-NE1	5.14	100.71	107.40	1	1
A	128	ALA	O-C-N	5.14	131.22	123.00	1	1
B	75	ASP	CA-CB-CG	5.13	107.47	112.60	1	1
B	12	LYS	C-CA-CB	5.12	119.83	110.10	1	1
B	24	TRP	O-C-N	5.12	114.81	123.00	1	1
A	35	ASN	N-CA-CB	5.10	101.84	110.50	1	1
A	137	PRO	CA-N-CD	5.06	104.92	112.00	1	1
B	30	MET	C-N-CA	5.05	130.80	121.70	1	1
B	88	SER	O-C-N	4.99	130.98	123.00	1	1
A	110	PHE	CA-C-O	4.97	112.35	120.80	1	1
B	143	LEU	CD1-CG-CD2	4.97	99.86	110.80	1	1
A	69	VAL	CA-CB-CG2	4.96	101.97	110.40	1	1
B	37	VAL	C-N-CA	4.96	130.62	121.70	1	1
A	135	ARG	NE-CZ-NH2	4.96	114.74	119.20	1	1
A	96	MET	C-CA-CB	4.92	119.46	110.10	1	1
B	36	SER	CA-C-O	4.92	112.43	120.80	1	1
A	35	ASN	O-C-N	4.92	130.87	123.00	1	1
A	36	SER	C-N-CA	4.92	130.55	121.70	1	1
B	152	ALA	O-C-N	4.91	115.14	123.00	1	1
A	23	LEU	CD1-CG-CD2	4.88	100.07	110.80	1	1
B	131	PRO	C-N-CA	4.87	130.47	121.70	1	1
B	144	ILE	C-N-CA	4.87	112.94	121.70	1	1
A	9	ALA	CA-C-O	4.84	129.03	120.80	1	1
A	121	TRP	CB-CG-CD2	4.84	133.57	126.80	1	1
A	13	PHE	O-C-N	4.83	115.27	123.00	1	1
B	93	ASP	CA-C-O	4.80	112.63	120.80	1	1
A	76	LEU	C-N-CA	4.78	130.30	121.70	1	1
A	56	CYS	CA-CB-SG	4.77	103.42	114.40	1	1
A	60	THR	OG1-CB-CG2	4.77	99.76	109.30	1	1
B	135	ARG	NE-CZ-NH2	4.75	114.92	119.20	1	1

Too-close contacts

The following all-atom clashscore is based on a MolProbity analysis. All-atom clashscore is defined as the number of clashes found per 1000 atoms (including hydrogen atoms). The table below contains clashscores for all atomic models in this entry.

Model ID	Clash score	Number of clashes
1	1.45	7

There are 7 clashes. The table below contains the detailed list of all clashes based on a MolProbity analysis. Bad clashes are >= 0.4 Angstrom.

Atom 1	Atom 2	Clash(Å)	Model ID (Worst)	Models (Total)
A:47:GLU:O	A:51:LYS:HE2	0.49	1	1
B:110:PHE:CD2	B:116:GLN:HB3	0.47	1	1
A:103:ALA:HB1	A:121:TRP:CZ2	0.46	1	1
A:107:THR:HG23	A:112:GLN:HA	0.46	1	1
A:66:LEU:HD11	A:70:LYS:HE2	0.45	1	1
B:110:PHE:CD2	B:116:GLN:CB	0.42	1	1
A:12:LYS:HE2	A:13:PHE:CE1	0.41	1	1

Torsion angles: Protein backbone

In the following table, Ramachandran outliers are listed. The Analysed column shows the number of residues for which the backbone conformation was analysed.

Model ID	Analysed	Favored	Allowed	Outliers
1	322	279	37	6

There are 6 unique backbone outliers. Detailed list of outliers are tabulated below.

Chain	Res	Type	Models (Total)
A	36	SER	1
A	133	ASP	1
A	137	PRO	1
B	18	SER	1
B	44	VAL	1
B	130	SER	1

Torsion angles : Protein sidechains

In the following table, sidechain rotameric outliers are listed. The Analysed column shows the number of residues for which the sidechain conformation was analysed.

Model ID	Analysed	Favored	Allowed	Outliers
1	256	214	32	10

There are 10 unique sidechain outliers. Detailed list of outliers are tabulated below.

Chain	Res	Type	Models (Total)
A	55	LEU	1

Chain	Res	Type	Models (Total)
A	67	ASP	1
A	94	SER	1
A	109	GLU	1
A	151	GLU	1
B	22	VAL	1
B	68	GLN	1
B	85	SER	1
B	98	GLU	1
B	150	SER	1

5. Fit to Data Used for Modeling Assessment

SAS data used in this integrative model could not be validated as the sasCIF file is currently unavailable or incomplete.

5.4. EPR

Validation for this section is under development.

6. Fit to Data Used for Validation Assessment

Validation for this section is under development.

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