



Continuous Benchmarking of Protein Structure Predictions

Juergen Haas, ELIXIR-CH



CASP13, 1st December 2018, Playa del Carmen, MX

www.elixir-europe.org

ELIXIR-EXCELERATE is funded by the European Commission within the Research Infrastructures programme of Horizon 2020, grant agreement number 676559.

CAMEO



CAMEO is a community project

→ CAMEO continuously applies quality assessment criteria established by the protein structure prediction community. Since the accuracy requirements for different scientific applications vary, there is no "one fits all" score. CAMEO therefore offers a variety of scores - assessing different aspects of a prediction (coverage, local accuracy, completeness, etc.) to reflect these requirements.

→ CAMEO is a community project - please feel free to suggest additional/alternative ways how CAMEO can support users and developers of structure prediction.



Join CAMEO today...

We invite developers of prediction methods to participate in the continuous evaluation by registering their servers [REGISTER]. We also invite developers of scoring and evaluation methods to suggest alternative scoring schemes. Please contact us directly.

Servers of the following groups are registered so far:

A. Sali ✎, L. McGuffin ✎, T. Schwede ✎, J. Soeding ✎, D. Baker ✎, A. Fiser ✎, M. Sternberg ✎, Y. Zhang ✎, C. Floudas ✎, S. Tosatto ✎, J. Xu ✎, Y. Zhou ✎, O. Brock ✎, B. Wallner ✎, A. Elofsson ✎, D. Labudde ✎, C. Venclovas ✎, J. Cheng ✎, O. Taştan Bishop ✎, Y. An-Suei ✎, T. Sosnick ✎, C. Kaesar ✎, P. Winn ✎.

Day 0
PDB Pre-release

CAMEO

Target
Selection
Submission

Sequences

3D
Modeling

CAMEO is a community project

→ CAMEO continuously applies quality assessment criteria established by the protein structure prediction community. Since the accuracy requirements for different scientific applications vary, there is no "one fits all" score. CAMEO therefore offers a variety of scores - assessing different aspects of a prediction (coverage, local accuracy, completeness, etc.) to reflect these requirements.

→ CAMEO is a community project - please feel free to suggest additional/alternative ways how CAMEO can support users and developers of structure prediction.

Join CAMEO today...

We invite developers of prediction methods to participate in the continuous evaluation by registering their servers [REGISTER]. We also invite developers of scoring and evaluation methods to suggest alternative scoring schemes. Please contact us directly.

Servers of the following groups are registered so far:

A. Sali ✦, L. McGuffin ✦, T. Schwede ✦, J. Soeding ✦, D. Baker ✦, A. Fiser ✦, M. Sternberg ✦, Y. Zhang ✦, C. Floudas ✦, S. Tosatto ✦, J. Xu ✦, Y. Zhou ✦, O. Brock ✦, B. Wallner ✦, A. Elofsson ✦, D. Labudde ✦, C. Venclovas ✦, J. Cheng ✦, O. Taştan Bishop ✦, Y. An-Suei ✦, T. Sosnick ✦, C. Kaesar ✦, P. Winn ✦.

CAMEO

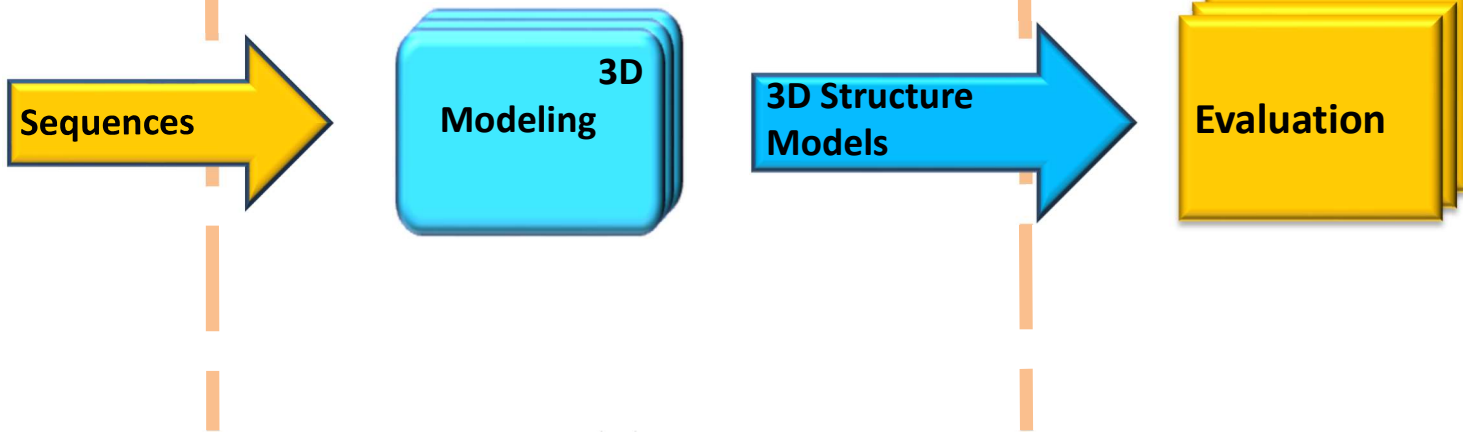
Day 0
PDB Pre-release



Day 4
PDB Release

Target
Selection
Submission

Target
Validation
Scoring



CAMEO is a community project

→ CAMEO continuously applies quality assessment criteria established by the protein structure prediction community. Since the accuracy requirements for different scientific applications vary, there is no "one fits all" score. CAMEO therefore offers a variety of scores - assessing different aspects of a prediction (coverage, local accuracy, completeness, etc.) to reflect these requirements.

→ CAMEO is a community project - please feel free to suggest additional/alternative ways how CAMEO can support users and developers of structure prediction.

Join CAMEO today...

We invite developers of prediction methods to participate in the continuous evaluation by registering their servers [REGISTER]. We also invite developers of scoring and evaluation methods to suggest alternative scoring schemes. Please contact us directly.

Servers of the following groups are registered so far:

A. Sali ✦, L. McGuffin ✦, T. Schwede ✦, J. Soeding ✦, D. Baker ✦, A. Fiser ✦, M. Sternberg ✦, Y. Zhang ✦, C. Floudas ✦, S. Tosatto ✦, J. Xu ✦, Y. Zhou ✦, O. Brock ✦, B. Wallner ✦, A. Elofsson ✦, D. Labudde ✦, C. Venclovas ✦, J. Cheng ✦, O. Taştan Bishop ✦, Y. An-Suei ✦, T. Sosnick ✦, C. Kaesar ✦, P. Winn ✦.

Day 0
PDB Pre-release

Day 4
PDB Release

CAMEO

Target
Selection
Submission

Target
Validation
Scoring

Sequences

3D -
Structure
Prediction

3D Models

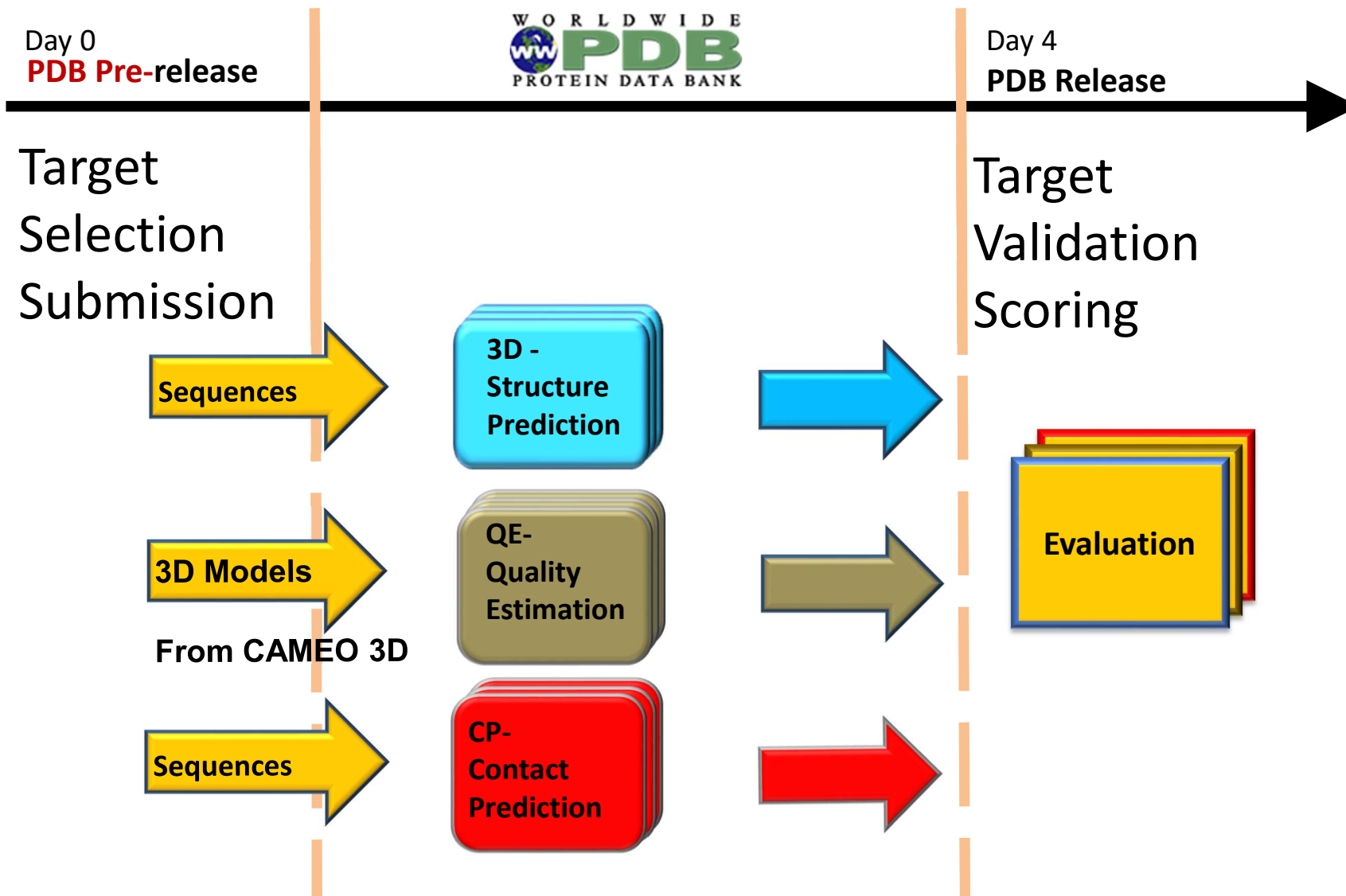
QE-
Quality
Estimation

From CAMEO 3D

Sequences

CP-
Contact
Prediction

Evaluation



Related Complementary Efforts

CAMEO

Weekly Continuous fully Automated Model EvaluatiOn
6'462 targets in 360 weeks
fully automated assessment
<https://cameo3d.org>

CASP

Community Wide Experiment on the Critical Assessment of Techniques for Protein Structure Prediction
Human expert assessment of ~100 target proteins per 2-year season
<http://PredictionCenter.org>

Related Complementary Efforts

CAMEO

Weekly Continuous fully Automated Model EvaluatiOn
6'462 targets in 360 weeks
fully automated assessment
<https://cameo3d.org>

CASP

Community Wide Experiment on the Critical Assessment of Techniques for Protein Structure Prediction
Human expert assessment of ~100 target proteins per 2-year season
<http://PredictionCenter.org>

CAPRI

Critical Assessment of PRedicted Interactions
46 CAPRI prediction Rounds were completed with a total of 159 targets
<http://www.capri-docking.org>

D3R / CELPP

Assessment of protein-ligand interactions / computer-aided drug discovery tools
3 rounds of challenges
<https://drugdesigndata.org>

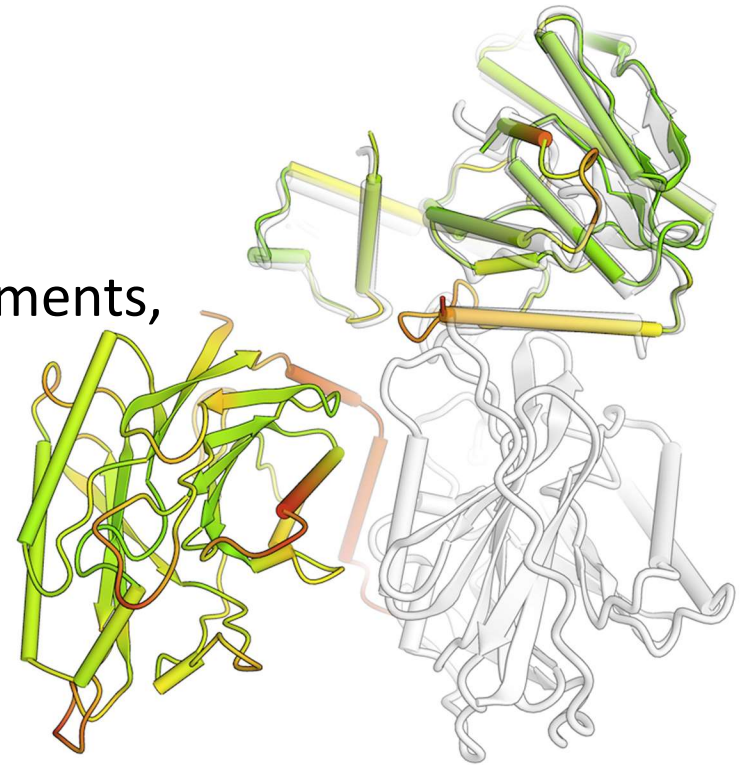


CAMEO is Unique

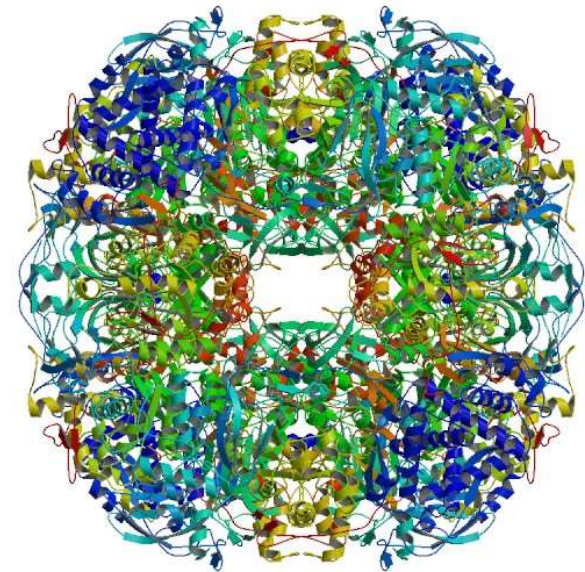
- Continuous: Every Week – Large Number Of Targets, Fast Feed-back.
- Fully Automated: No Human Intervention. Reproducible.
- Open: Modular Platform – Open For New Scores / New Fields.
- Metrics: Scoring Of Different Aspects – No “One Score Fits All”.
- Audience: Method Developers, Peer Reviewers (Papers, Grants).

Unsupervised Evaluation

3D Scoring Must Be Invariant To Domain Movements,
i.e. Superposition Independent.

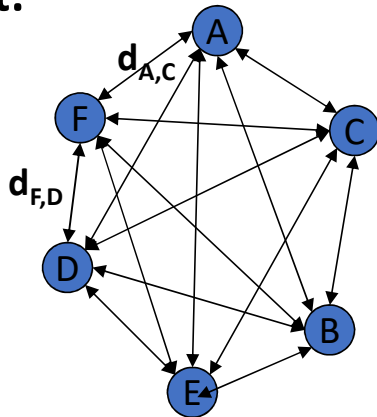


Automatically Evaluate Quaternary Structure, i.e.
Stoichiometry And Relative Orientation

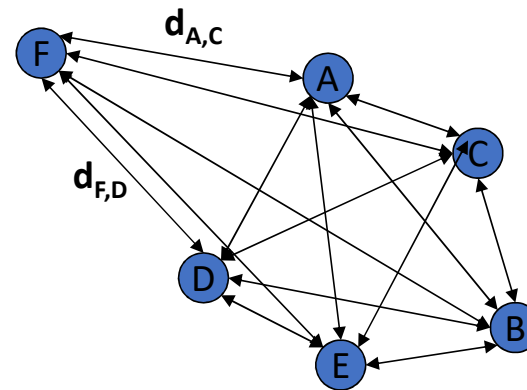


Unsupervised Evaluation

Target:



Prediction:

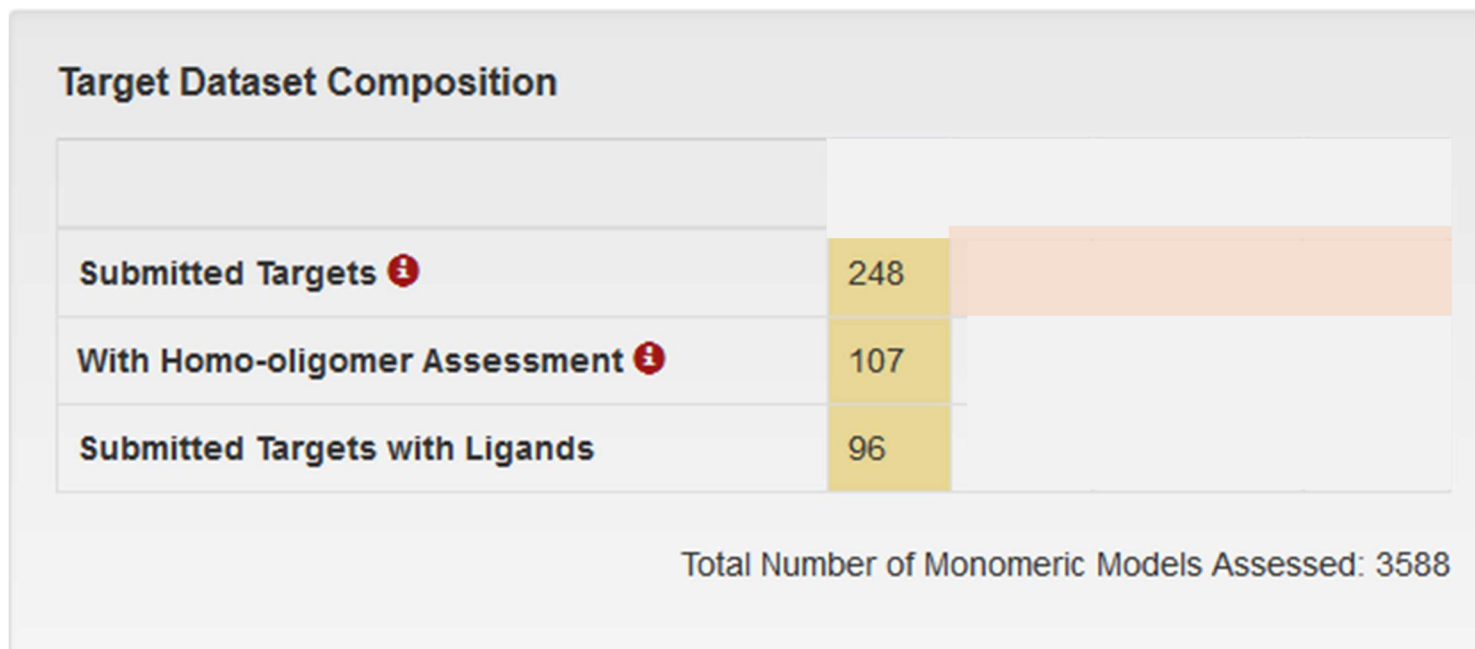


Local Distance-difference-test (IDDT)
Fraction Of Correctly Predicted Inter-atomic Distances For Each Atom To Its Neighbors Within Certain Error Thresholds

$$IDDT = \frac{\sum_{cutoff}^{0.5,1,2,4} \left(\begin{cases} 1 & \text{if } |d_{i,j}^{Target} - d_{i,j}^{Prediction}| < cutoff \\ 0 & \text{otherwise} \end{cases} \right)}{4 * \text{number of distances } d_{i,j}^{Target}}$$

See also: CAD score by C. Venclovas

Content 3D – 3 Months



Based on average IDDT: Easy ≥ 75

Medium $50 < \text{IDDT} < 75$

Hard < 50

Content 3D – 3 Months

Target Dataset Composition

	Any	Easy	Medium	Hard
Submitted Targets ⓘ	248	47	126	75
With Homo-oligomer Assessment ⓘ	107	29	53	25
Submitted Targets with Ligands	96	16	59	21

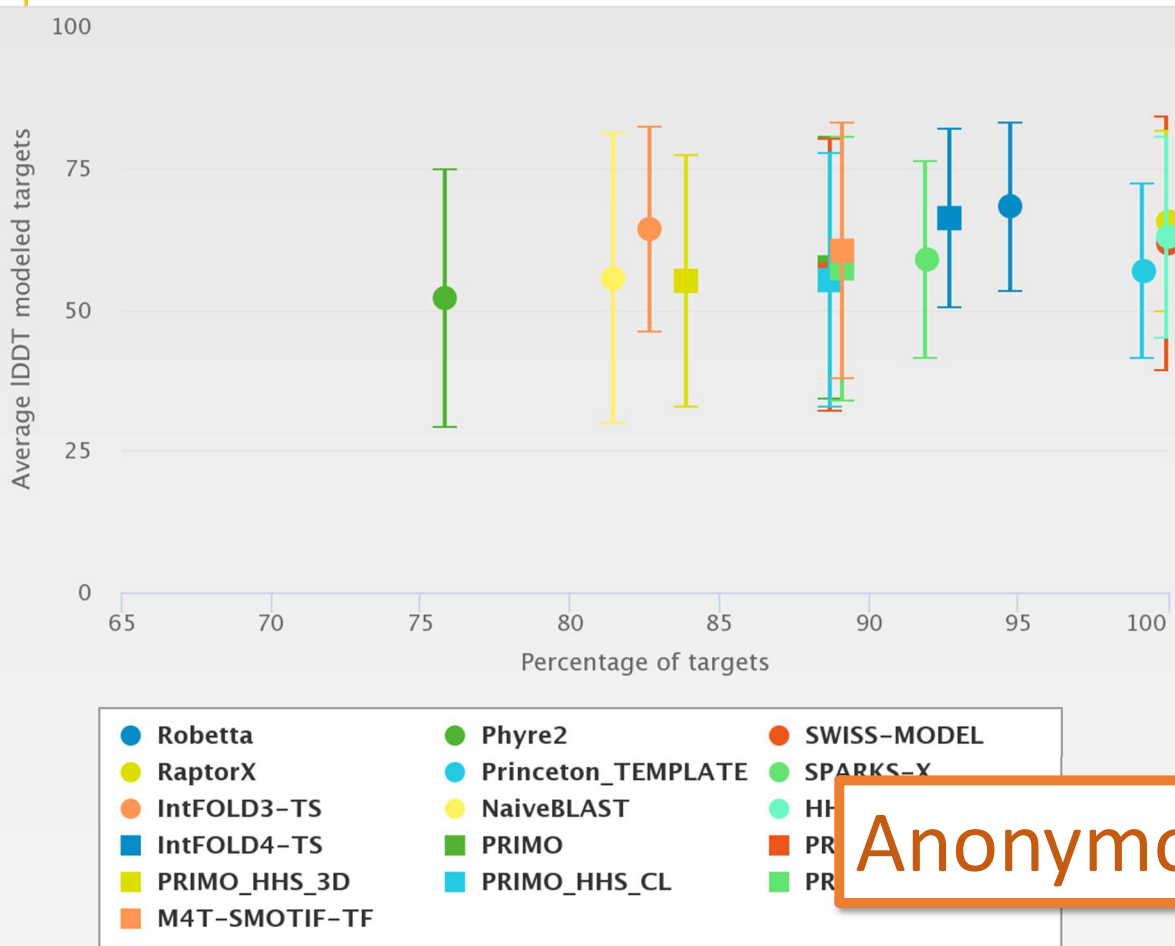
Total Number of Monomeric Models Assessed: 3588

Based on average IDDT: **Easy** ≥ 75

Medium $50 < \text{IDDT} < 75$

Hard < 50

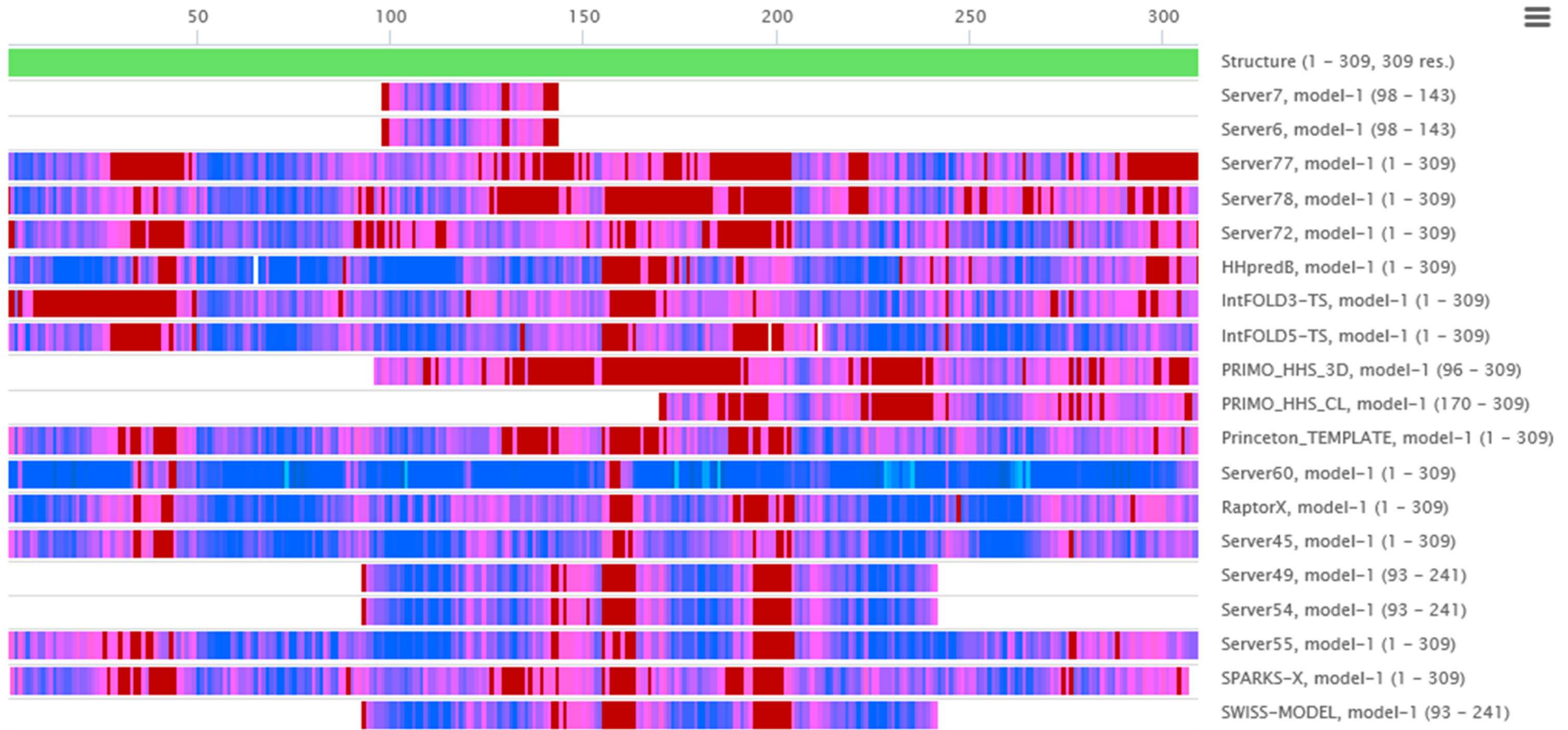
CAMEO-3D: All Targets Performance



- Common Subset
 - Disadvantage For Best Server
 - Hard Targets Drop Out
- Binary Comparison Table
- All Scores Per Target

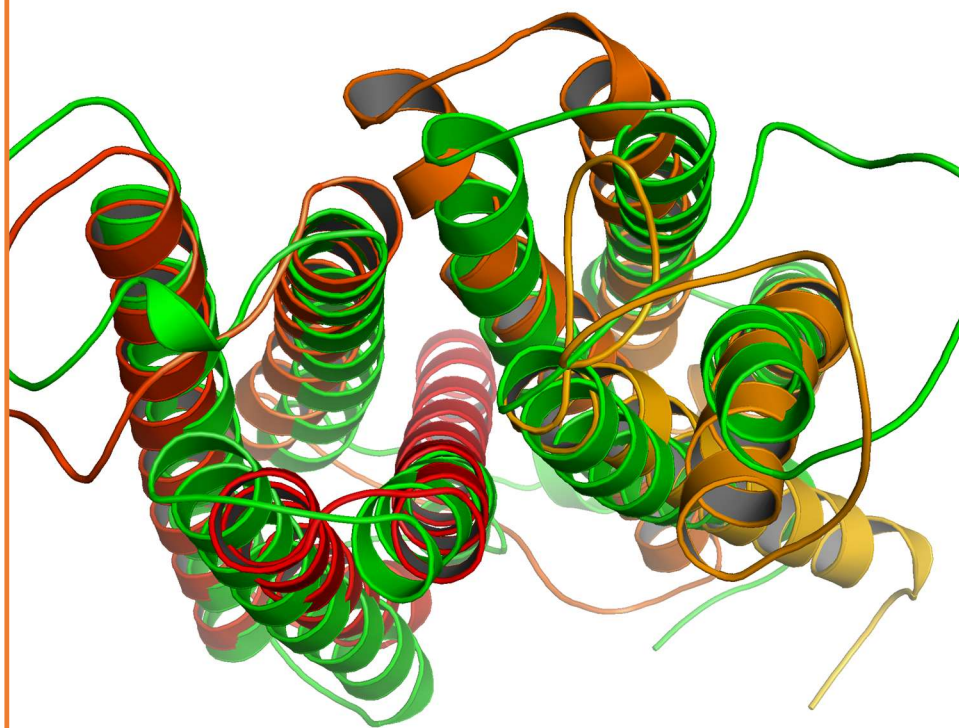
Anonymous Servers are crucial!

Outperformers

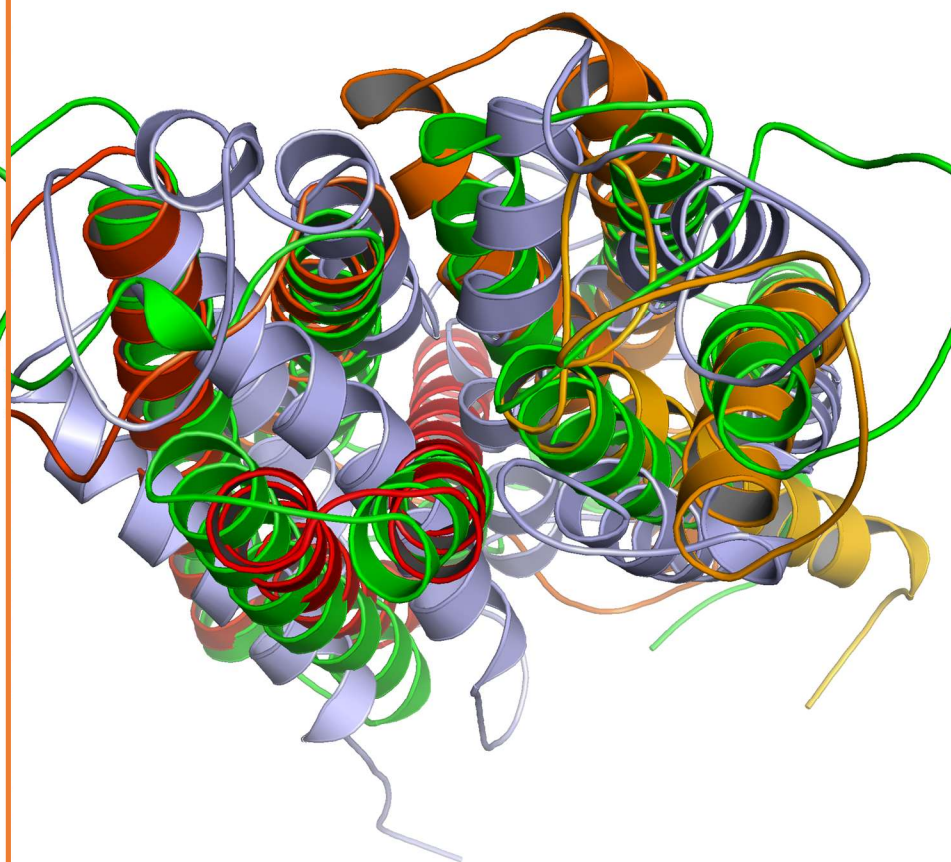


Outperformers

Server60 – IDDT: 59.24



HHpred – IDDT: 34.88



2018-11-17_0000062_1 | [6a2j \[A\]](#)

3D Target Distribution – 1 Year

Target Dataset Composition

	Any	Easy	Medium	Hard
Submitted Targets 	998	180	511	307
With Homo-oligomer Assessment 	381	85	194	102
Submitted Targets with Ligands	393	71	219	103

Total Number of Monomeric Models Assessed: 22598

Based on average IDDT: **Easy** ≥ 75 **Medium** between 50 and 75 **Hard** < 50

3D Current Efforts – Target Validation 1/2

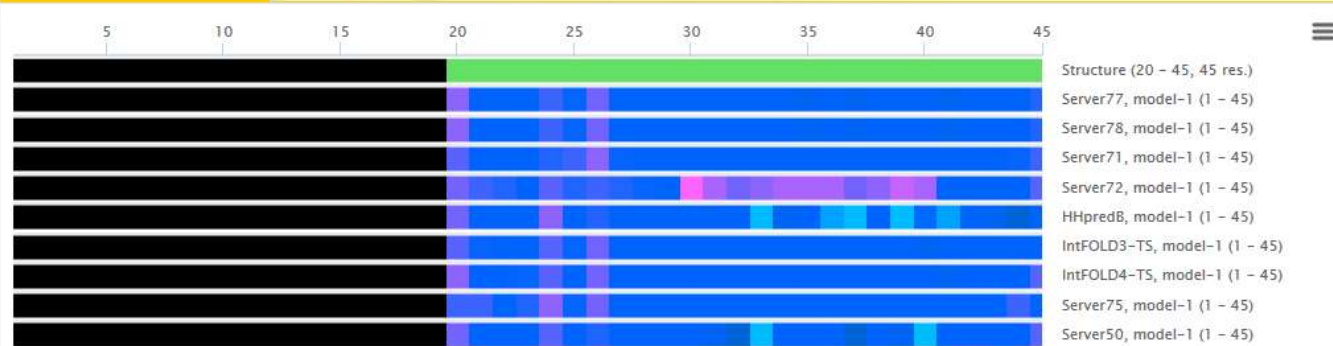
2018-11-17_0000009_2 (5xln_B)

Title Crystal structure of the TRS_UNE-T and 4EHP complex
Method X-RAY DIFFRACTION; 1.9 Å
Target Sequence [Sequence](#)
Target Structure [Chain B](#)
Quaternary State HETERO-Oligomer
Oligo Target Structure [Biounit 1](#)

Submitted model details

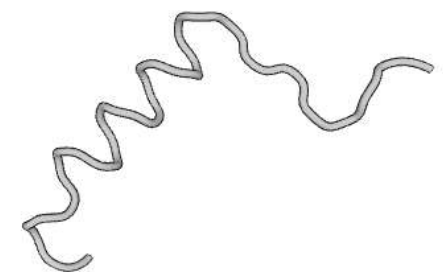
IDDT local scores - Model 1

Coverage - All models



3D Prediction

Target Structure



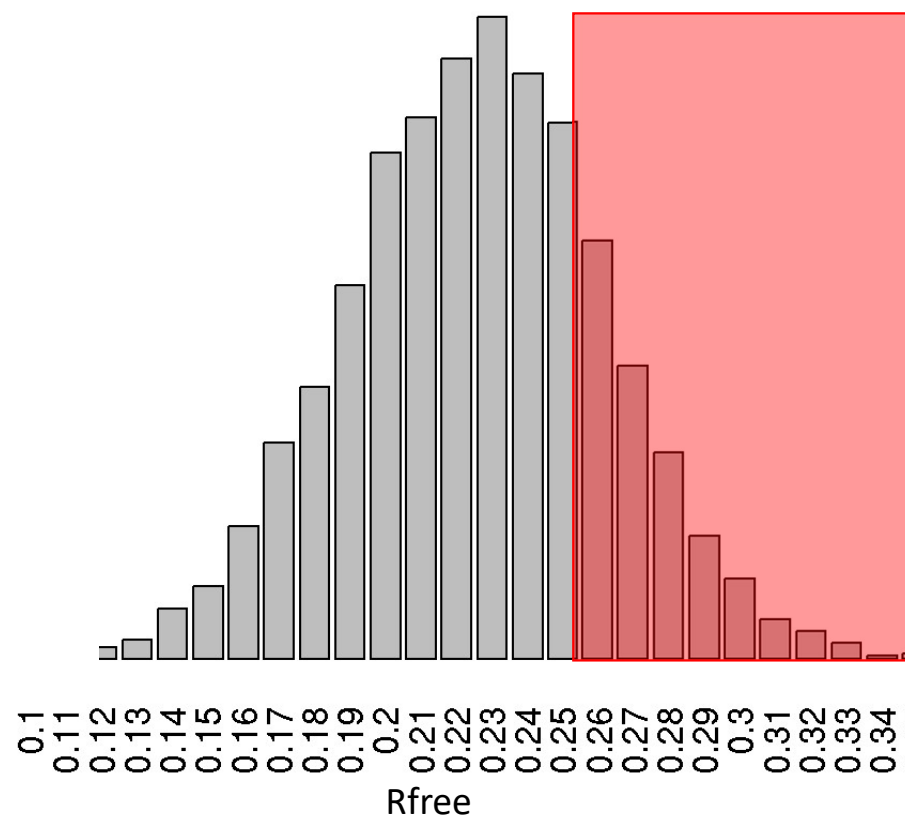
3D Current Efforts - Target Validation 2/2

- $R_{\text{free}} < 0.25$ / $R < 0.3$

80

- R Before/After Refinement < 0.1
- Ramachandran Outliers $< 2\%$
- RSRZ outliers $< 20\%$
- Non-reproducible R factor

6-months < 10



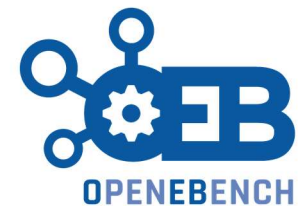
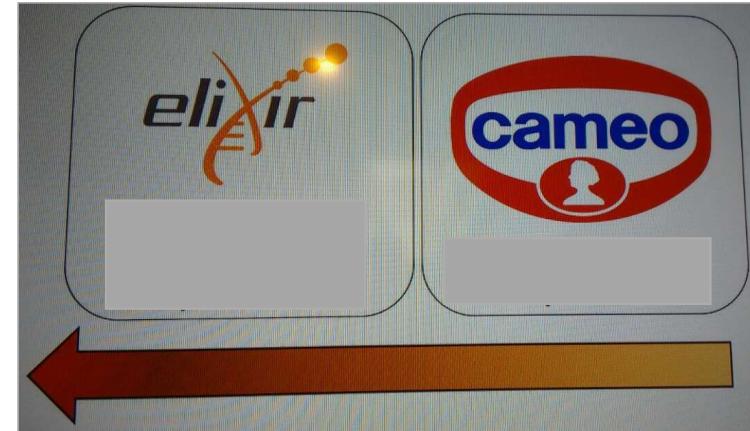
CAMEO goes ELIXIR

OpenEBench:

community-driven ELIXIR benchmarking infrastructure

Supporting and interconnecting scientific benchmarking and technical monitoring of bioinformatics tools, web-services and workflows.

- Level 1 – “Share Lead Scores”
 - Contribution to OEB Data Model
 - Provide Weekly data
- Level 2 – “Computing Metrics for Communities – BYO”
 - Prototype Ready with Cancer Genome Atlas (TCGA)
- Level 3 – “Host Benchmarking Efforts for Communities”
 - In Planning - Sustainability And Long-term Commitment
 - CAMEO Being Ported to NextFlow



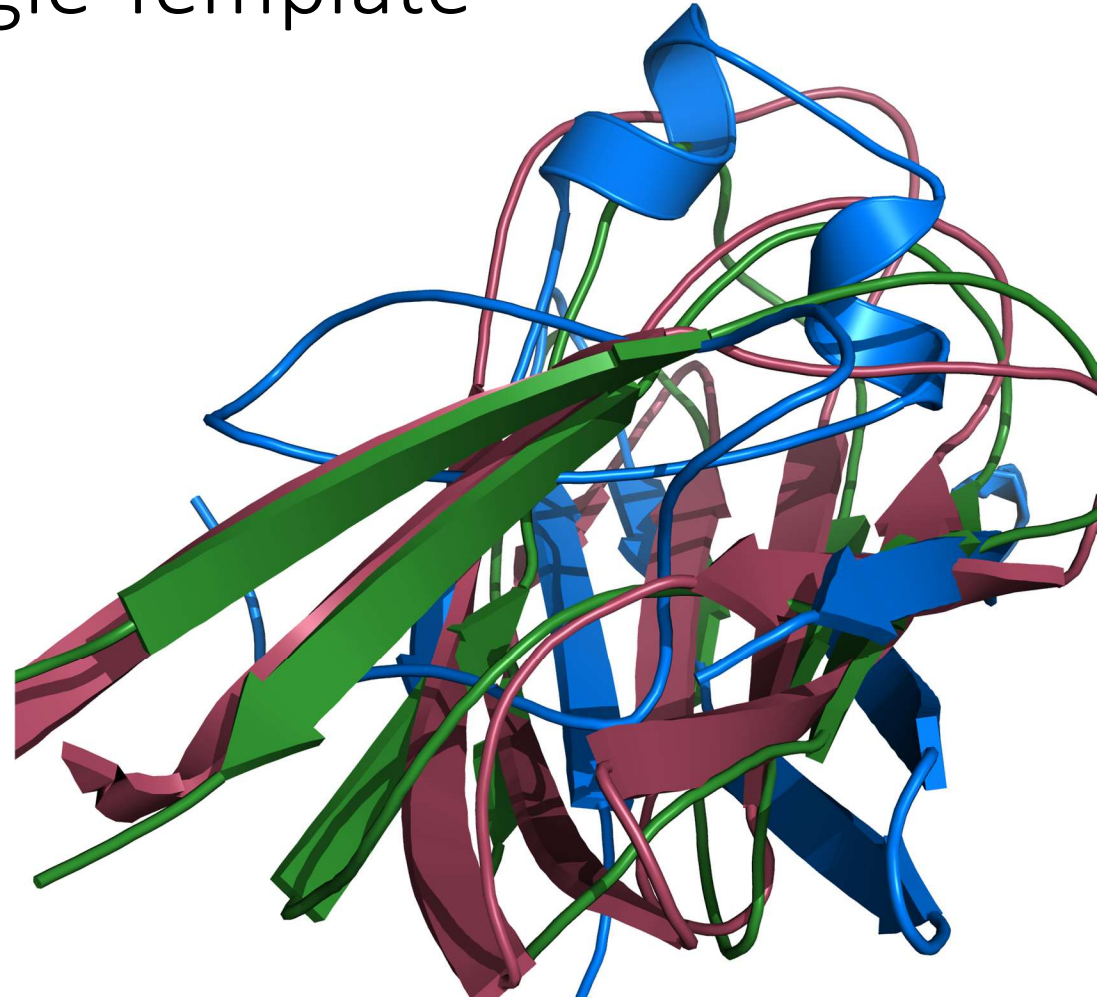
Capella S, et.al. (2017) *bioRxiv* 181677

CAMEO-3D – Best Single Template

Target 2018-10-20_00000020_1
(5YLO_B, red)

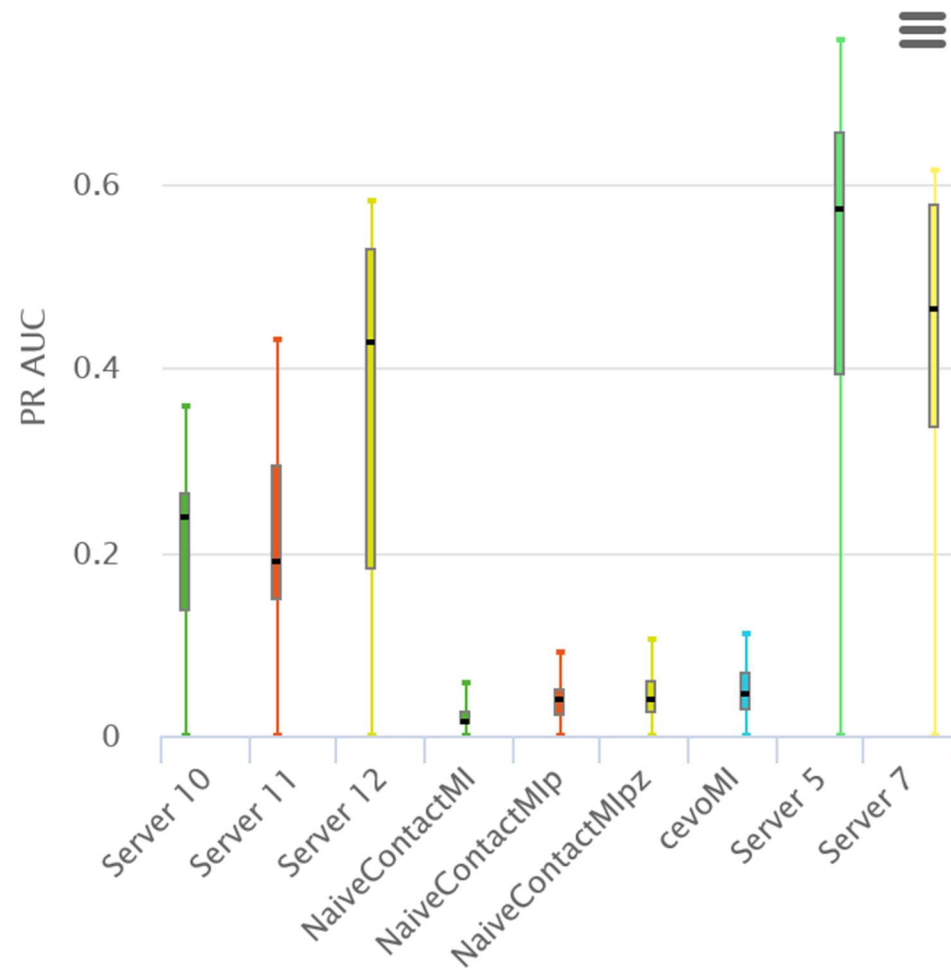
- Best Server (blue): IDDT 32
- Best Template (green): IDDT 47

Methods: TMALIGN + Modeller



CAMEO CP – New Baselines

- CCMPred (server10)
- EVCouplings (server11)
- PConsC4 (server12)





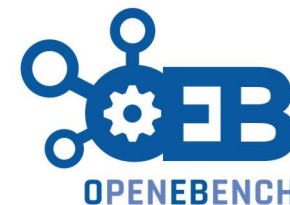
Summary

- Engaging Community Crucial
 - ELIXIR 3DBioInfo Community
 - CAMEO WorkShop @BC2, Basel 2017
 - Benchmarking Session @ISMB 2018
 - Benchmarking Session @ECCB18
- Weekly Public Data – Ready for Publication
 - Web Aggregators and Download, 360 weeks
- Current CAMEO Efforts around
 - Target Validation + Scoring
 - Modernizing Code Base

Reference: Proteins. **(2018)**, 86, 387-398. [DOI: 10.1002/prot.25431]

Outlook

- Continuously Expose Evaluations to OpenEBench
 - Level 1 – Share Data for Integrated View
- Portable Workflows Employing Containers
 - OpenEBench Level 3 – Executing Workflows
- New CAMEO category
 - Including Ligands
 - Hetero-oligomers
- Add Scores
 - Oligo-IDDT
 - CAD-Score
- Release Regular Benchmarks (DOI) – [ModelArchive.org](https://modelarchive.org)



Reference: Proteins. **(2018)**, 86, 387-398. [DOI: 10.1002/prot.25431]

Acknowledgements

- Dario Behringer, Rafal Gumienny,
Xavier Robin, Anna Smolinski, Flavio Ackermann
- Schwede lab
- Torsten Schwede
- ELIXIR WP2 team
- CAMEO Participants



Reference: Proteins. **(2018)**, 86, 387-398. [DOI: 10.1002/prot.25431]