

# **STLCutter.jl**

Pere Antoni Martorell

<http://github.com/pmartorell/STLCutters.jl>

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# Performed tests

Experiments from issue #11

## 1.1. Relative position - robustness test

- ▶ Set of 13 geometries
- ▶ Constant background mesh  $h$ -refinement
- ▶ 17 relative positions ( $\Delta x = 10^{-17:-1}$ )
- ▶ 17 rotation angles ( $\theta = 10^{-17:-1}$ )

## 1.2. Relative position - Poisson test

- ▶ Idem as 1.1. w/ Poisson eq. manufactured solution  $u(x) = x + y - z$

## 2.1. $h$ -refinement - robustness test

- ▶ 1.1. geometries
- ▶ 6 constant  $h$ -refinements

## 2.2. $h$ -refinement - Poisson test

- ▶ Idem as 2.1. w/ Poisson eq. manufactured solution  
 $u(x) = x^2 + y^2 - z^2$

## 3. Large geometry dataset

- ▶ 5k geometries filtered from Thingi10k
- ▶ Unique criterion for background mesh refinement: maximum of 100 divisions per direction

## 1.1. Relative position - Robustness test

### Setup

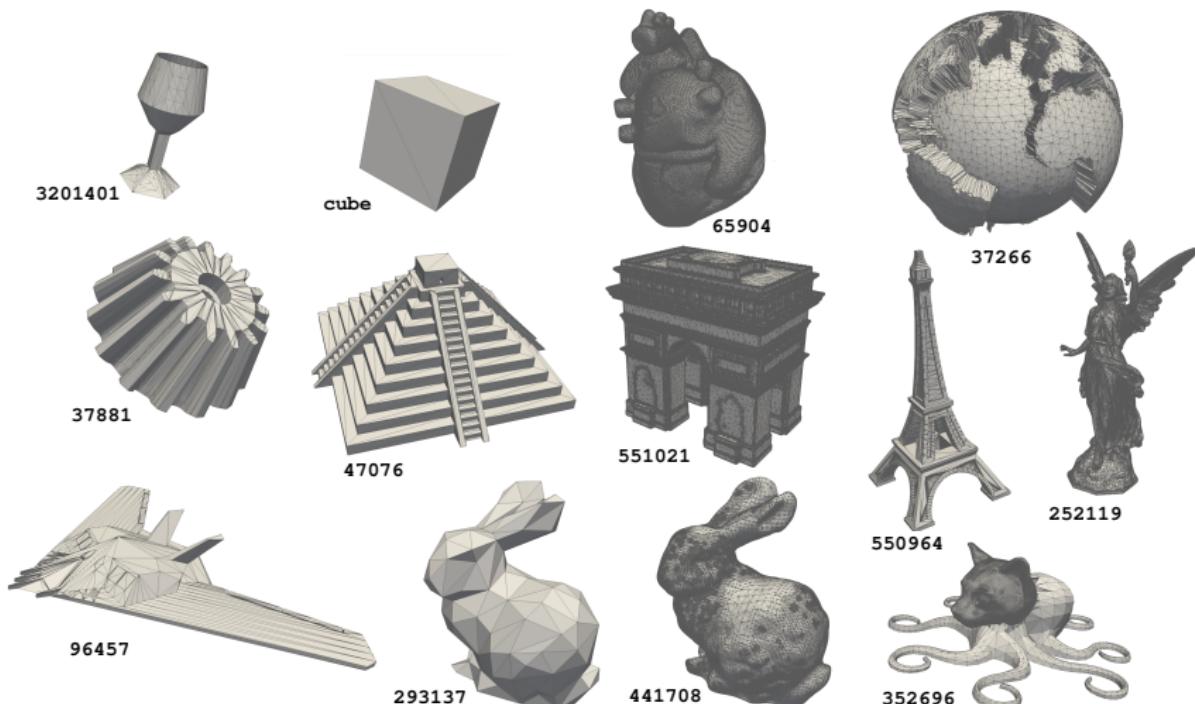
13 STLs; 17 relative positions; 17 rotation angles;  $\{\Delta x, \theta\} = 10^{-17:-1}$



# 1.1. Relative position - Robustness test

## Setup

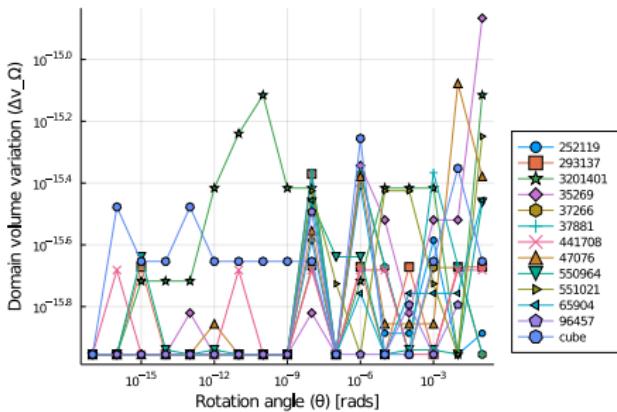
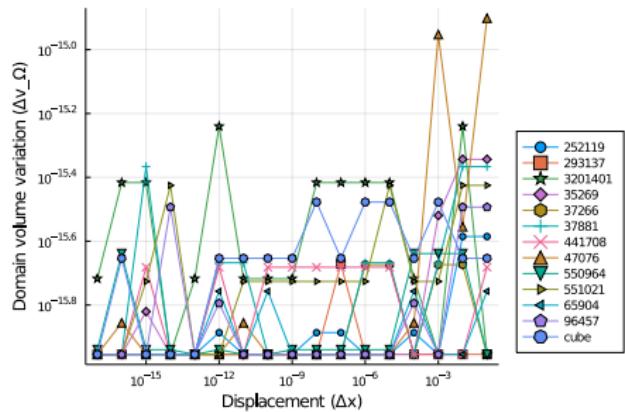
13 STLs; 17 relative positions; 17 rotation angles;  $\{\Delta x, \theta\} = 10^{-17:-1}$



# 1.1. Relative position - Robustness test

## Domain volume variation

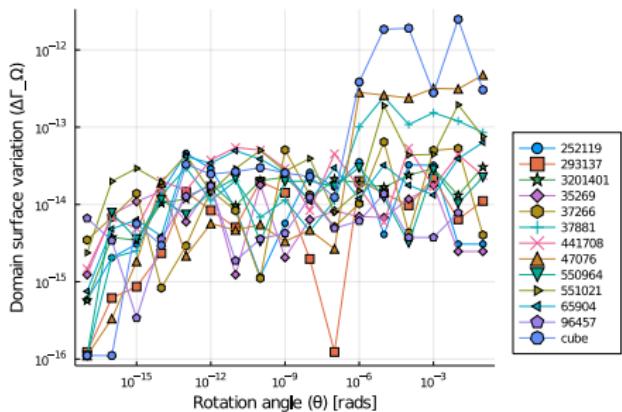
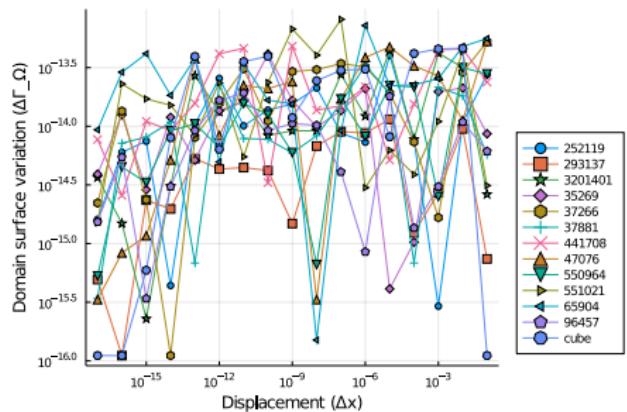
► Maximum volume variation  $< 10^{-14}$



# 1.1. Relative position - Robustness test

## Domain volume variation

- Maximum volume variation  $< 10^{-11}$
- Rotations introduce more rounding errors at planes



## 1.2. Relative position - Poisson test

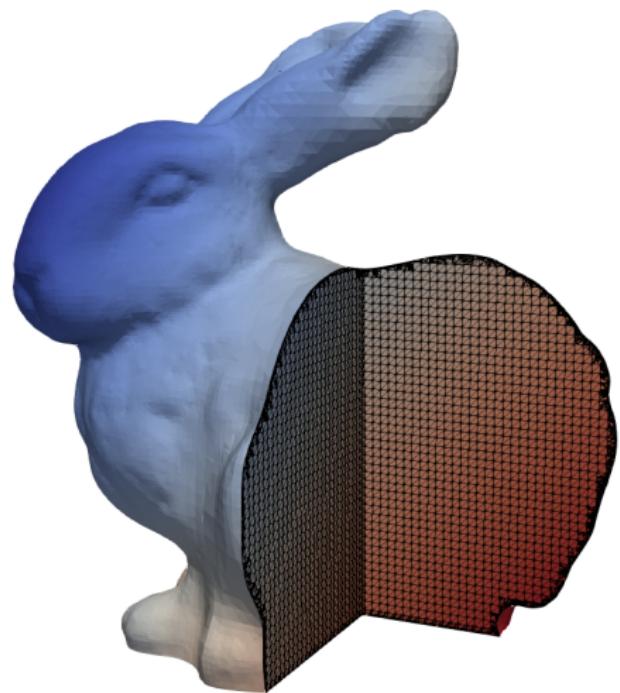
### Setup

- ▶ Same configurations as 1.1.
- ▶ Poisson eq. w/ manufactured solution

$$-\Delta u = f,$$

$$u(x) = x + y - z$$

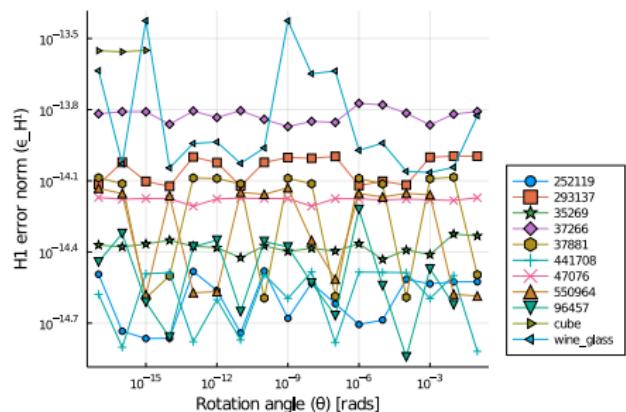
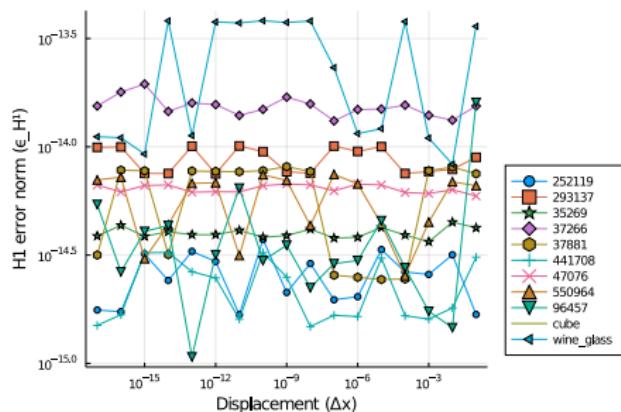
- ▶ AgFEM w/ aggregate threshold 0.5



# 1.2. Relative position - Poisson test

## H1 error norm

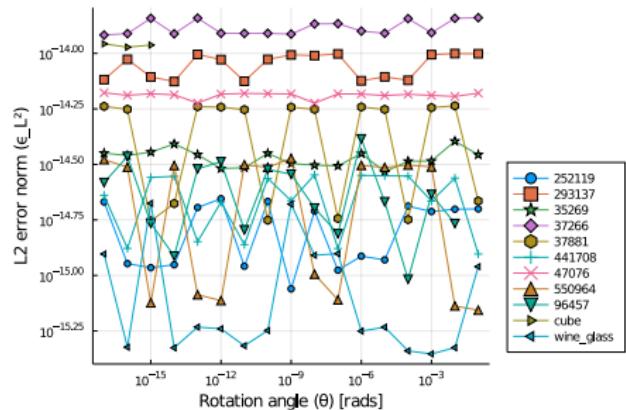
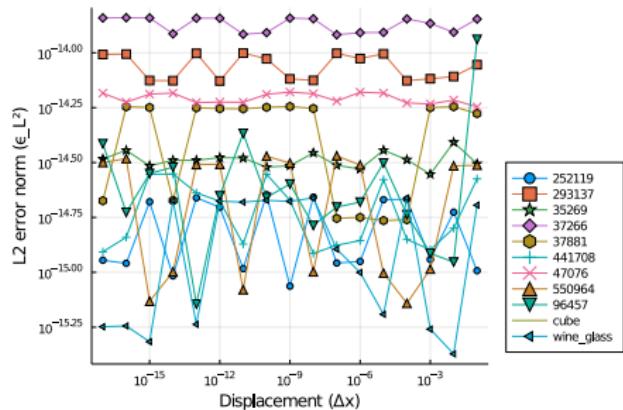
- Maximum H1 error norm  $< 10^{-12}$
- Minor variations on rotation/displacement



## 1.2. Relative position - Poisson test

### L2 error norm

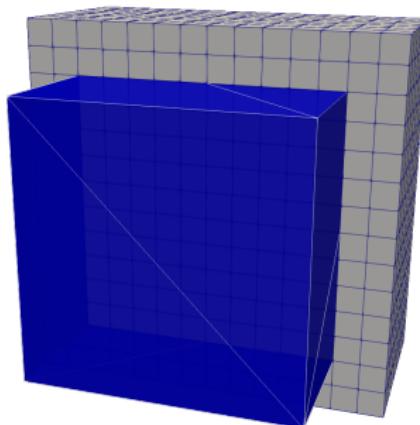
- Maximum L2 error norm  $< 10^{-13}$
- Minor variations on rotation/displacement



## 2.1. *h*-refinement - Robustness test

### Setup

- ▶ 13 geometries from 1.1.
- ▶ 6 refinement sizes:  $N_{max} = 14 \cdot 2^{0:5}$

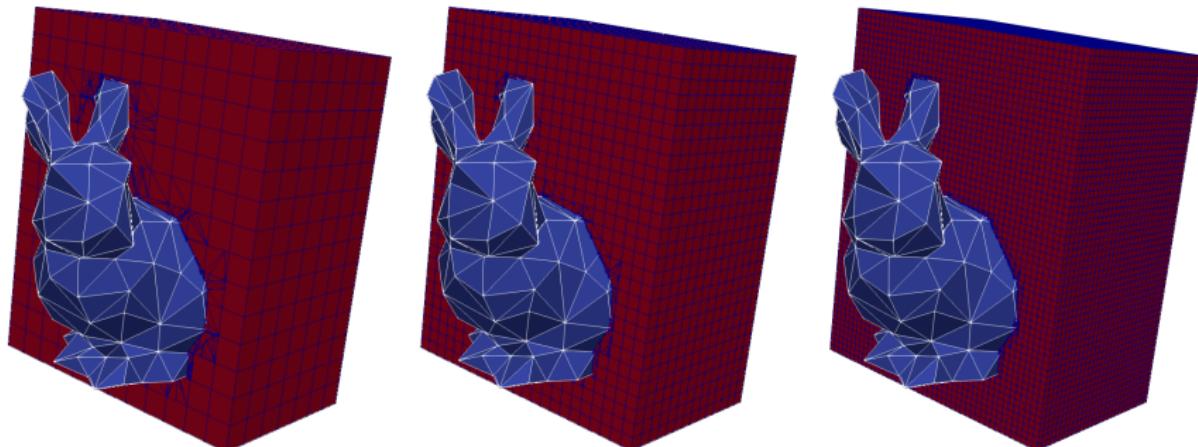


**NOTE 1:** The  $N_{max}$  is multiple of 14 to force the STL faces and background cell faces to be aligned, thus stress more the algorithm. As the background mesh is expanded 0.2 in each direction of the STL's bounding box.

## 2.1. $h$ -refinement - Robustness test

### Setup

- ▶ 13 geometries from 1.1.
- ▶ 6 refinement sizes:  $N_{max} = 14 \cdot 2^{0:5}$

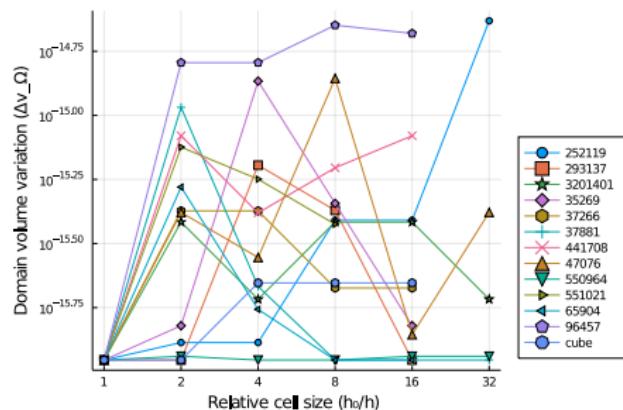
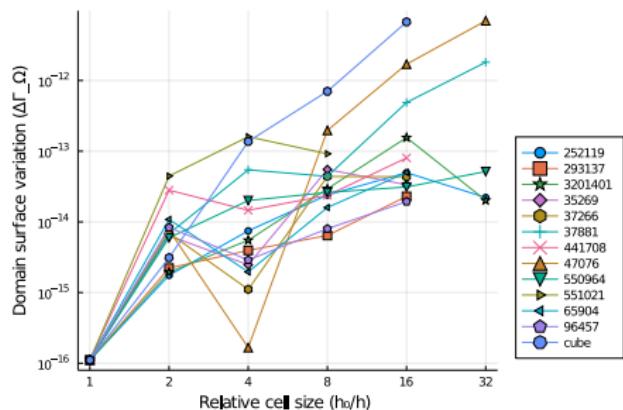


**NOTE 2:** In order to keep the background cell aspect ratio,  $N_{max}$  is the number of divisions on the largest side of the bounding box.

## 2.1. $h$ -refinement - Robustness test

### $h$ -refinement

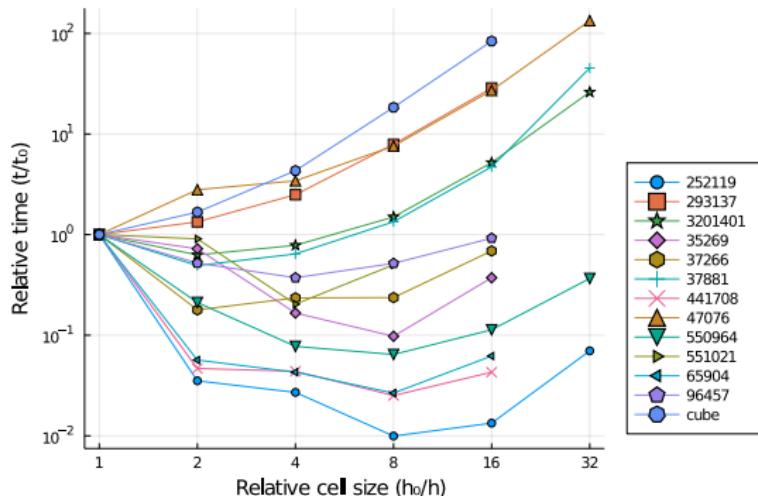
- Surface variation increases with  $1/h$  ( $\Delta\Gamma < 10^{-11}$ )
- Volume is constant at refinement ( $\Delta V < 10^{-14}$ )



## 2.1. $h$ -refinement - Robustness test

### CPU time with $h$ -refinement

- Not precise measure (single runs)
- Tend to be linear after first complexity reduction



## 2.2. $h$ -refinement - Poisson test

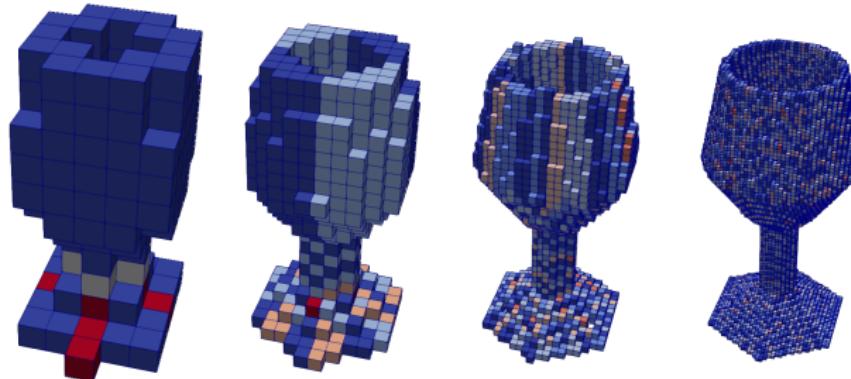
### Setup

- ▶ Same configurations as 2.1.
- ▶ Poisson eq. w/ manufactured solution

$$-\Delta u = f,$$

$$u(x) = x^2 + y^2 - z^2$$

- ▶ AgFEM w/ aggregate threshold 0.5

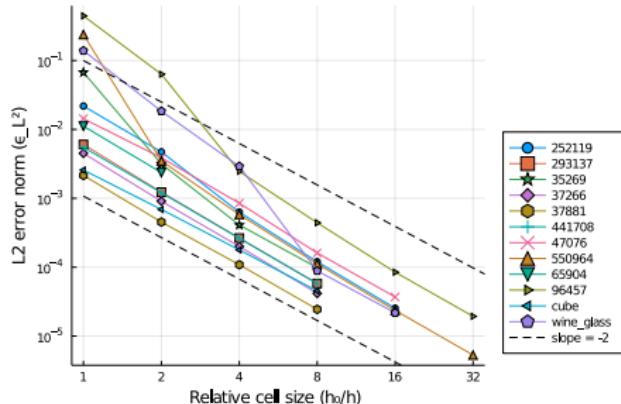
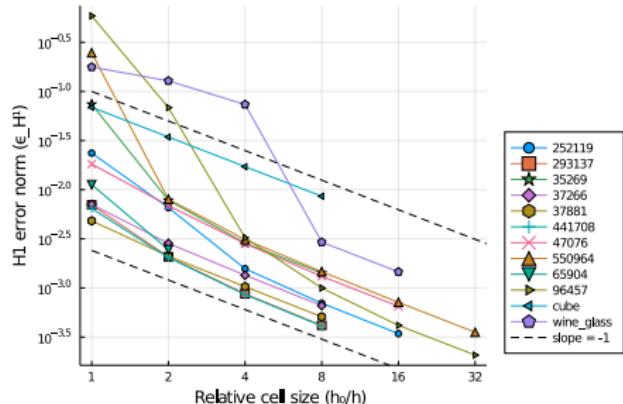


Cell aggregation in thin walls

## 2.2. $h$ -refinement - Poisson test

### FE convergence with $h$

- H1 and L2 error norms tend to the convergence slope



### 3. Large geometry dataset

#### Setup

- ▶ 5052 geometries filtered from Thingi10k
- ▶  $N_{max} = 100$  (unique  $h$ -refinement criterion)



### 3. Large geometry dataset

#### Summary

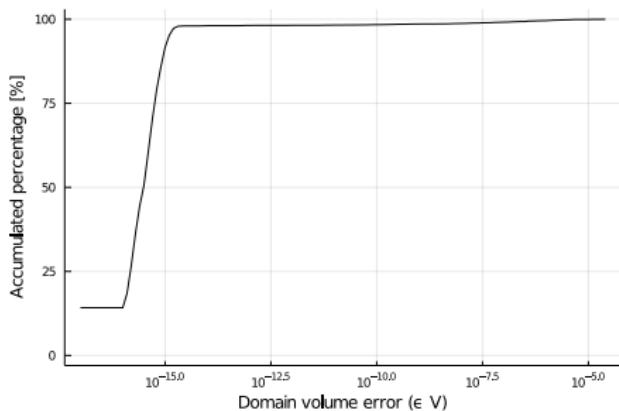
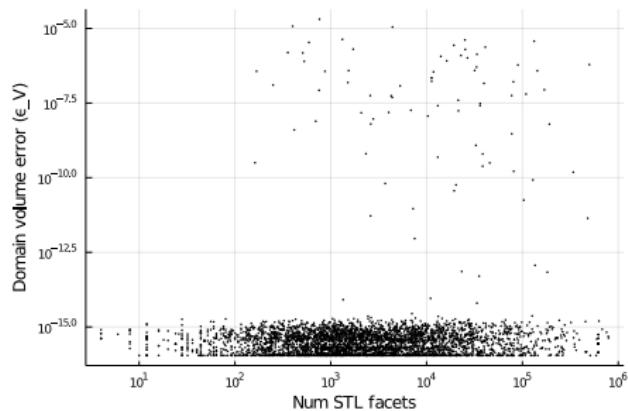
```
Total: 5052
  └── Not available: 312
  └── Load error: 7
  └── Available: 4733
      ├── Launched on HPC: 4169
      │   ├── Success: 4078
      │   ├── Large volume error: 58
      │   └── Not ended: 33
      ├── Pending: 657
      └── Degenerate: 4
```

**NOTE:** As shown in next slides large volume error is due to small facets.

### 3. Large geometry dataset

#### Volume error

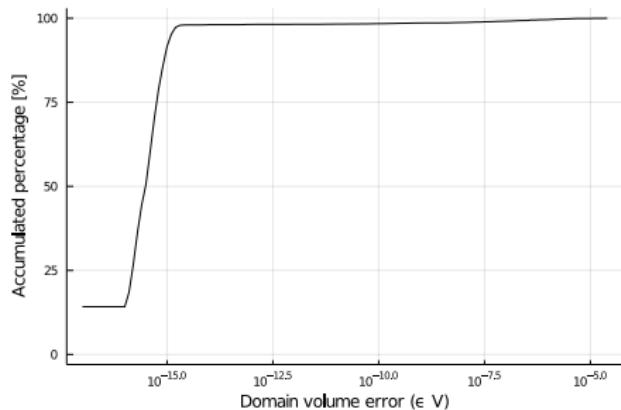
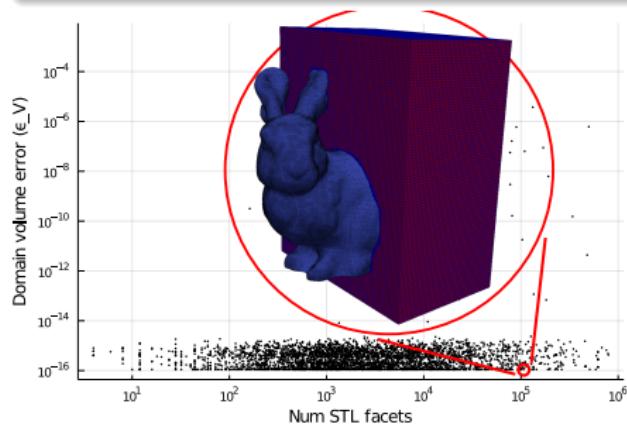
- $\epsilon_V = V_{IN} + V_{OUT} - V_{BBOX}$
- 98.6% of 4136 is below  $10^{-9}$
- All STLs above  $10^{-9}$  contain small facets



### 3. Large geometry dataset

#### Volume error

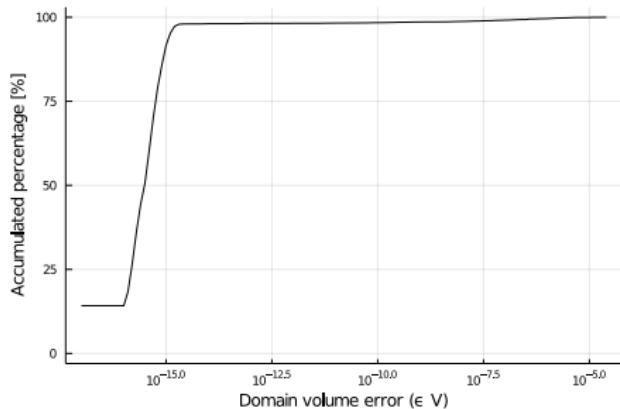
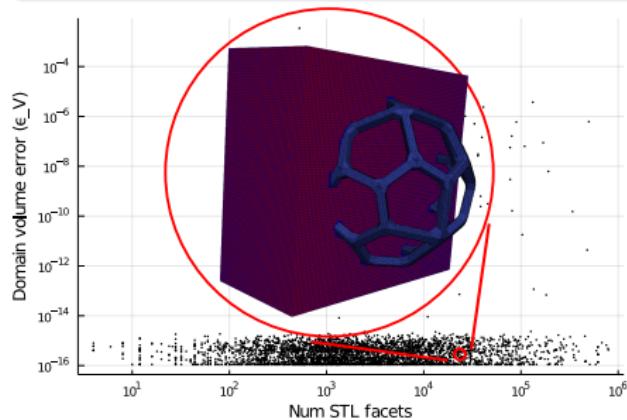
- $\epsilon_V = V_{IN} + V_{OUT} - V_{BBOX}$
- 98.6% of 4136 is below  $10^{-9}$
- All STLs above  $10^{-9}$  contain small facets



### 3. Large geometry dataset

#### Volume error

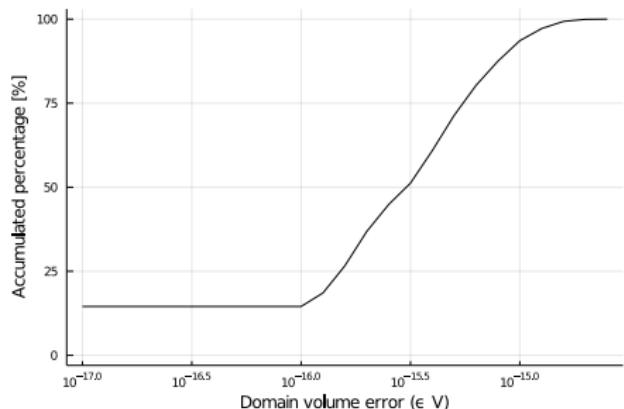
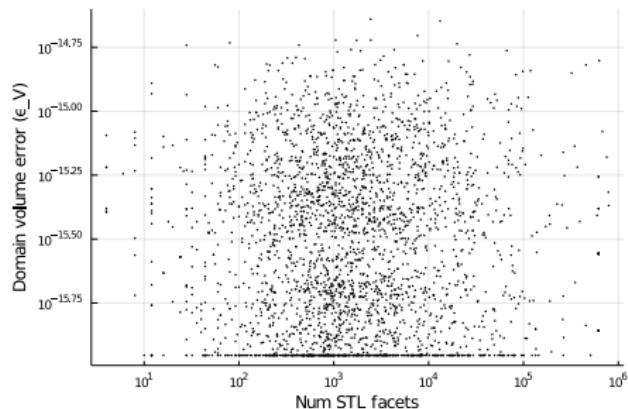
- $\epsilon_V = V_{IN} + V_{OUT} - V_{BBOX}$
- 98.6% of 4136 is below  $10^{-9}$
- All STLs above  $10^{-9}$  contain small facets



### 3. Large geometry dataset

#### Volume error [filtering STLs with small facets]

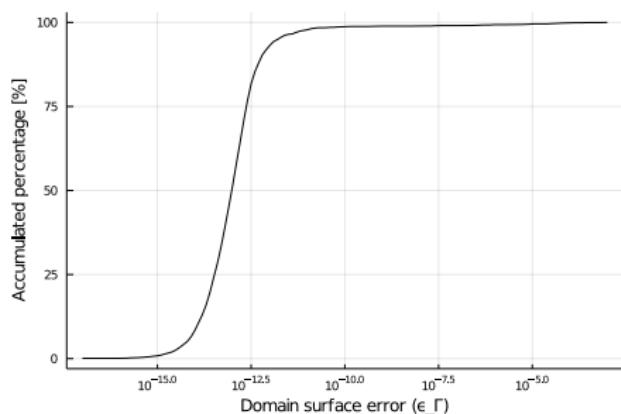
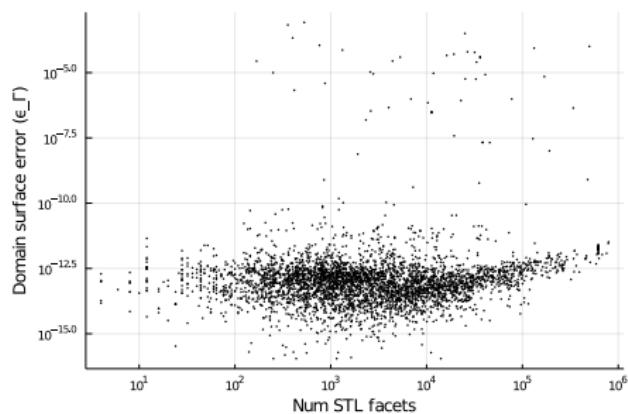
- $\epsilon_V = V_{IN} + V_{OUT} - V_{BBOX}$
- 100% is below  $10^{-14}$



### 3. Large geometry dataset

#### Surface error

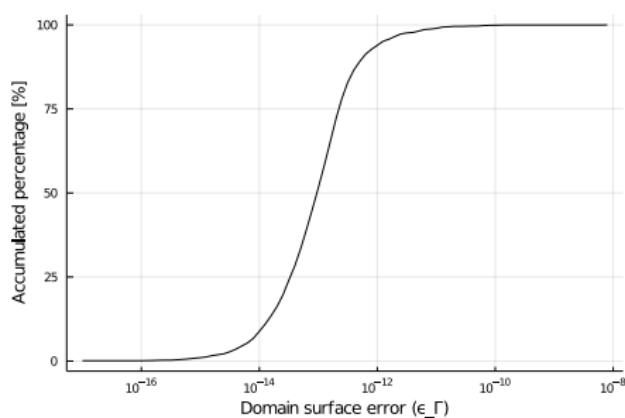
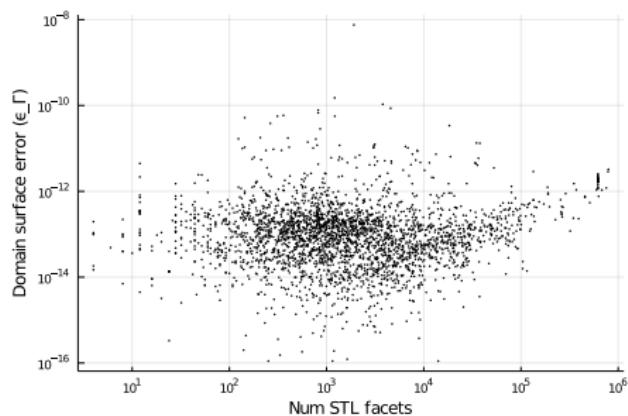
- $\epsilon_{\Gamma} = \Gamma - V_{STL}$
- 98.9% of 4136 is below  $10^{-9}$
- (almost) all STLs above  $10^{-9}$  contain small facets



### 3. Large geometry dataset

#### Surface error [filtering STLs with small facets]

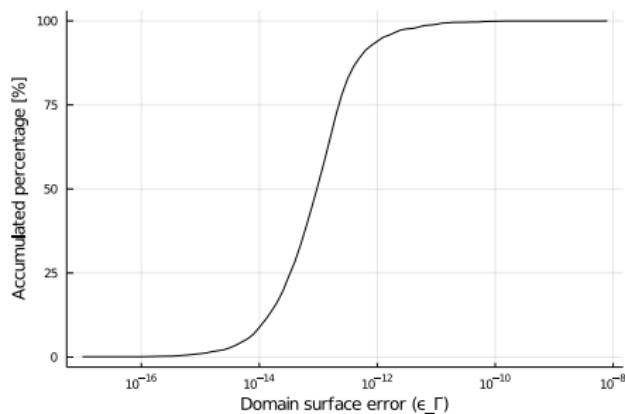
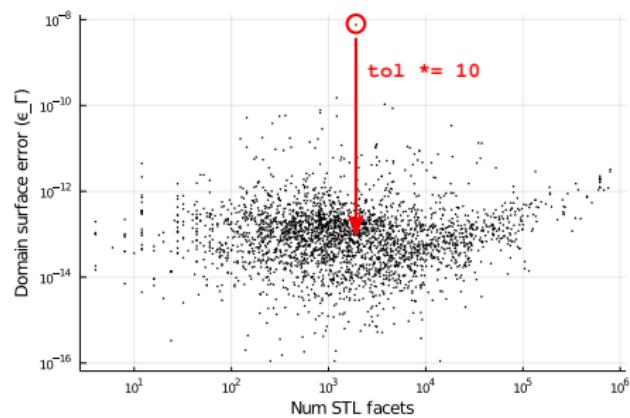
- $\epsilon_{\Gamma} = \Gamma - V_{STL}$
- 99.9% is below  $10^{-9}$
- One outlier can be moved by increasing the tolerance



### 3. Large geometry dataset

#### Surface error [filtering STLs with small facets]

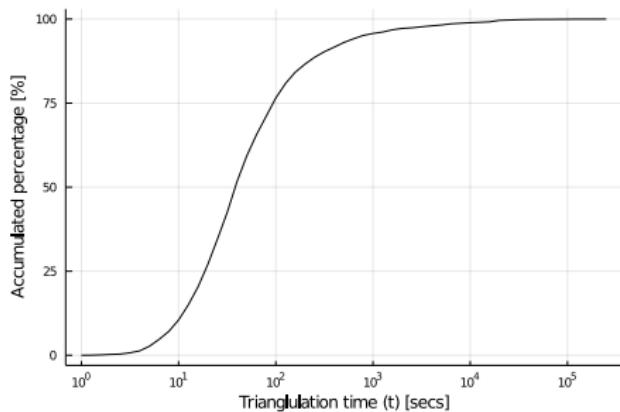
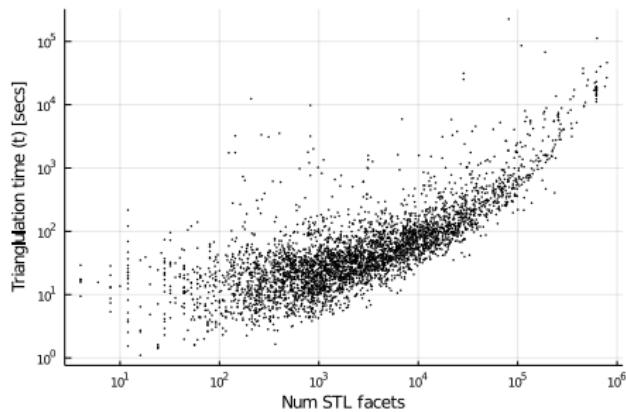
- $\epsilon_{\Gamma} = \Gamma - V_{STL}$
- 99.9% is below  $10^{-9}$
- One outlier can be moved by increasing the tolerance



### 3. Large geometry dataset

#### CPU time

- ▶ Not precise measure (different machines, single runs)
- ▶ Increasing with the number of STL facets



# Conclusions and pending work

## Conclusion so far

- ▶ Issues are depending on the geometry
- ▶ Most of problematic geometries can be found *a priori*

## Ongoing work

- ▶ Detect true degenerated geometries
- ▶ Run Gridap