# Improvements of Rubble Ice Generation In Numerical Simulation of Ice Ridge and Structure Interaction

Adylio Vitarelli Neto

Supervisors: Prof. Robert Bronsart – University of Rostock

MSc. Quentin Hisette – Hamburg Ship Model Basin

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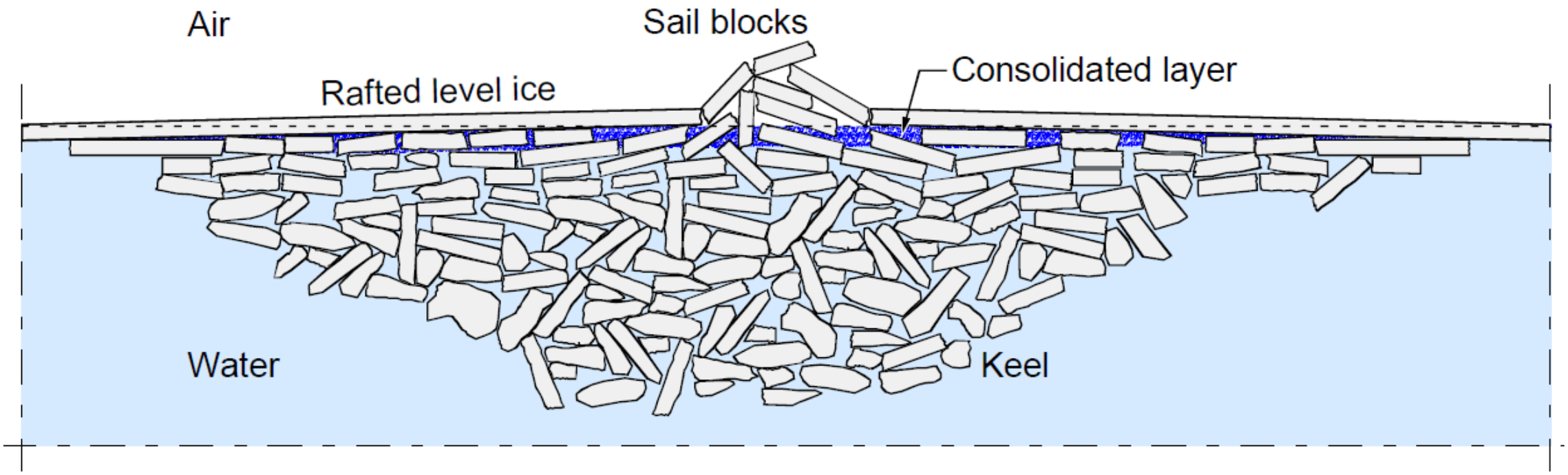
# 1 – Arctic Engineering

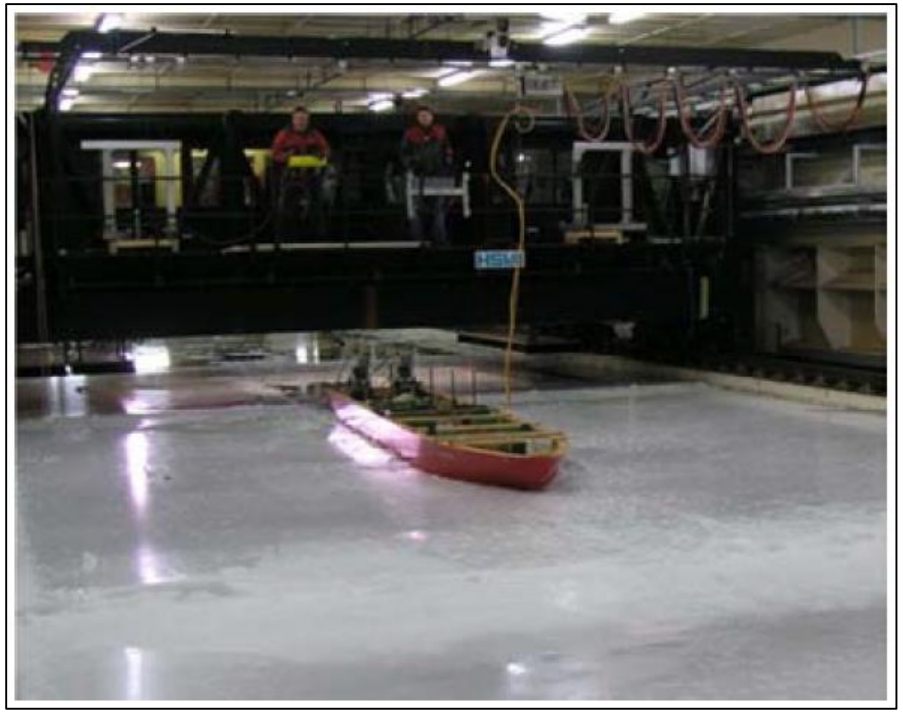
- Application: Ships and offshore structures in Nothern Sea Route
- Ice ridges are the main design criteria for those structures




Source: Jensen, A., *et al*. Physical Modeling of First-Year Ice Ridges – Part II: Mechanical properties (2001)

# 1 – Arctic Engineering

- Model ice ridge at HSVA basin



Ship model test [1]

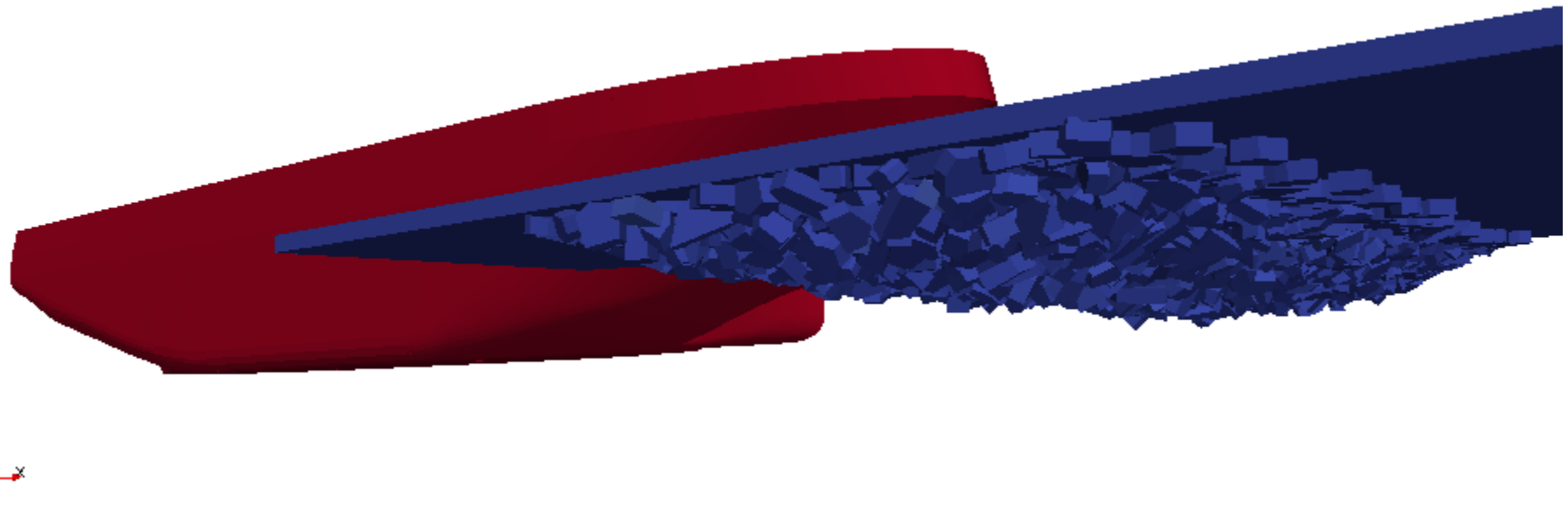
Punch test

Source: [1] Ehle, D., Analysis of Breaking through Sea Ice Ridges for Development of a Prediction Method (2011)

# 2 – Discrete Elements Method (DEM) simulation

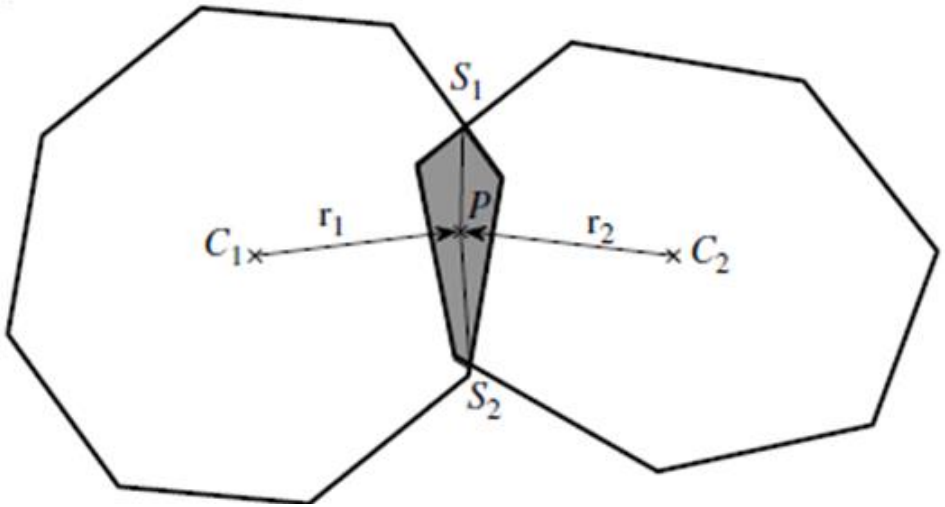
- Full DEM in house algorithm
- Seidel (2016) -> DEM introduction and punch test
- Alekseev (2016) -> Ship simulation

**Investigate rubble ice geometry**



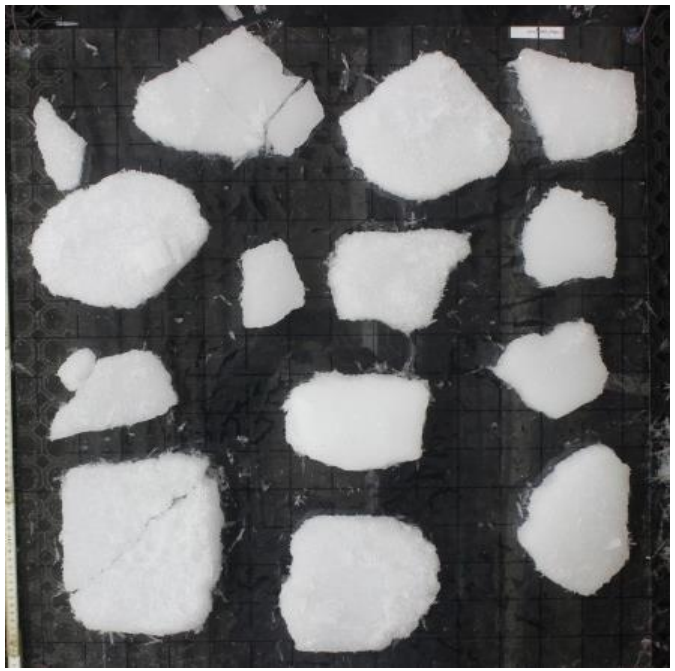
# 2 – Discrete Elements Method (DEM) simulation

- DEM calculates the forces when two elements are interacting
- Inputs for force calculation:
  - Volume of the interaction
  - Position of the CG of the elements and the interaction volume
  - Young's modulus
  - Mechanical properties

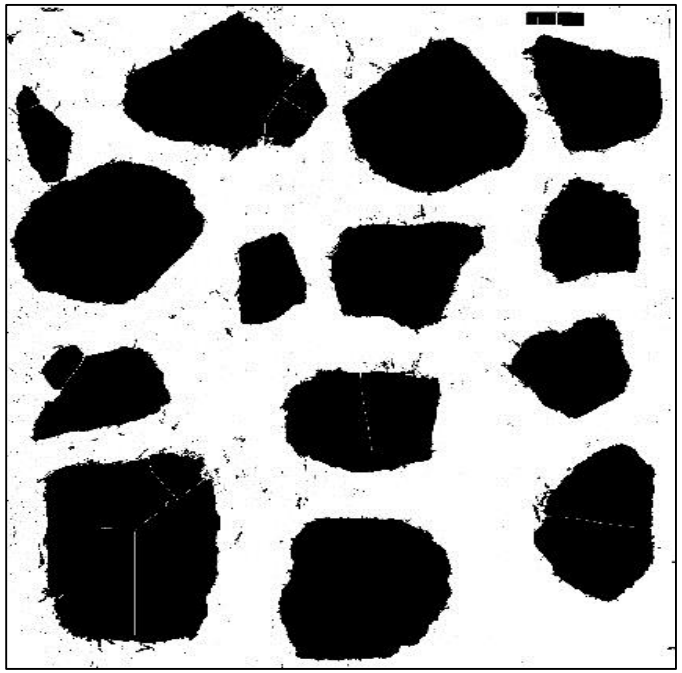



Source: Matuttis & Chen, Understanding the Discrete Element Method, (2014)

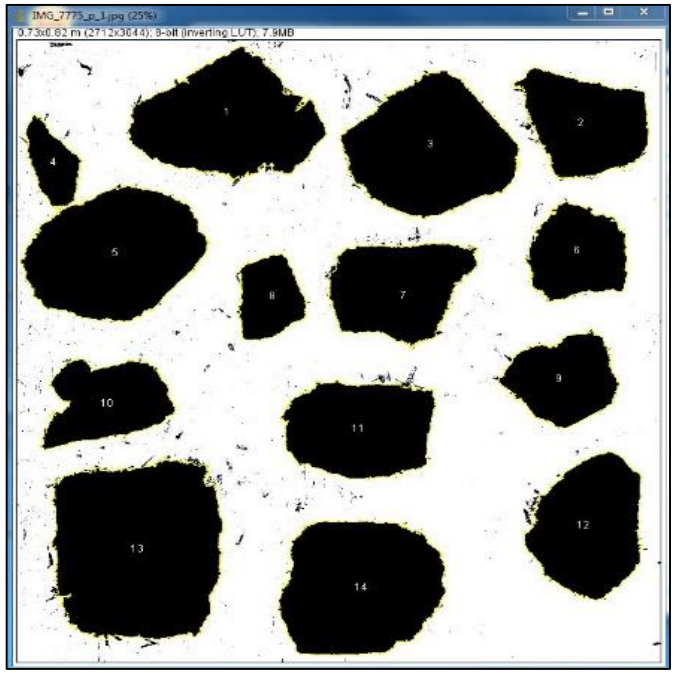
# 3 – Investigation of rubble ice geometry



At the ice basin



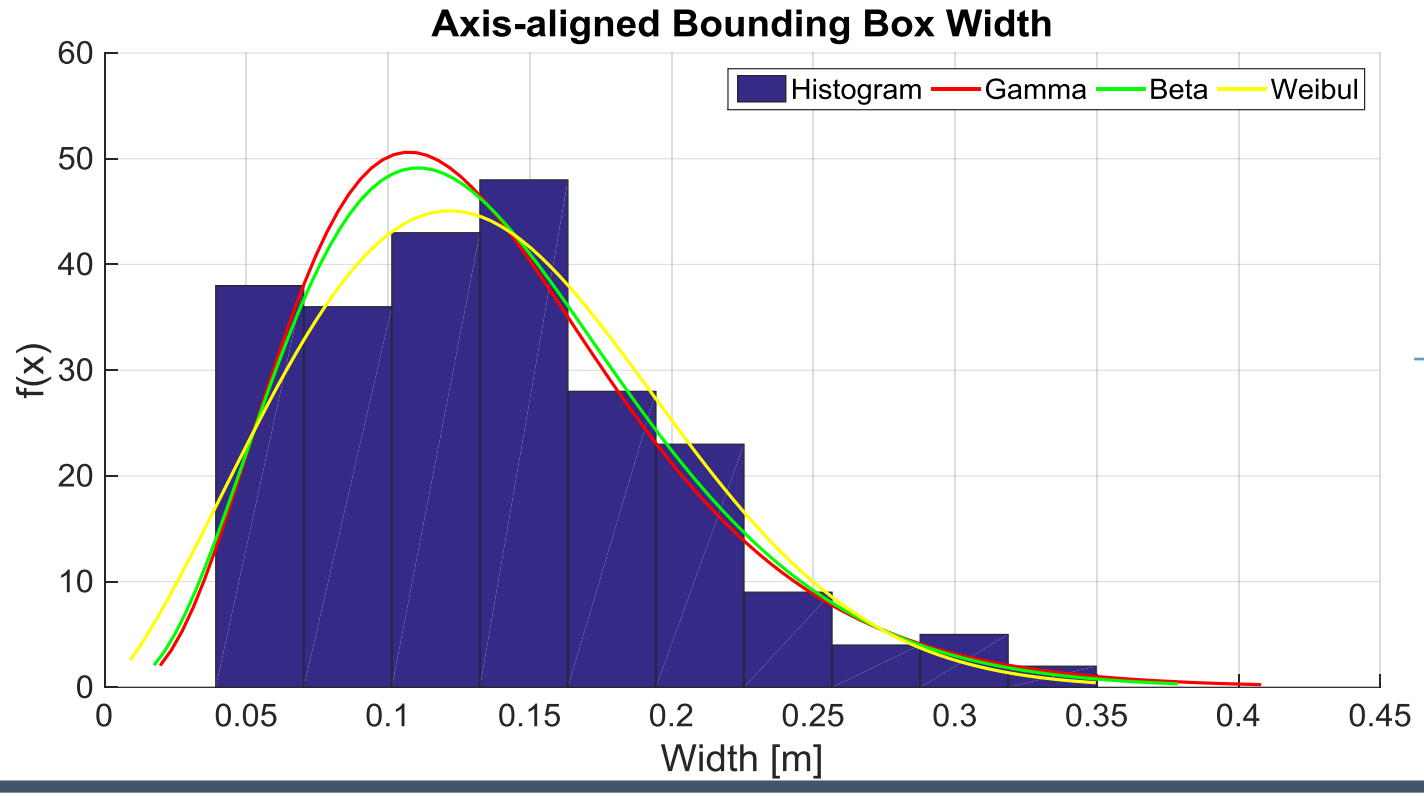
Pre-processed




Post-processed

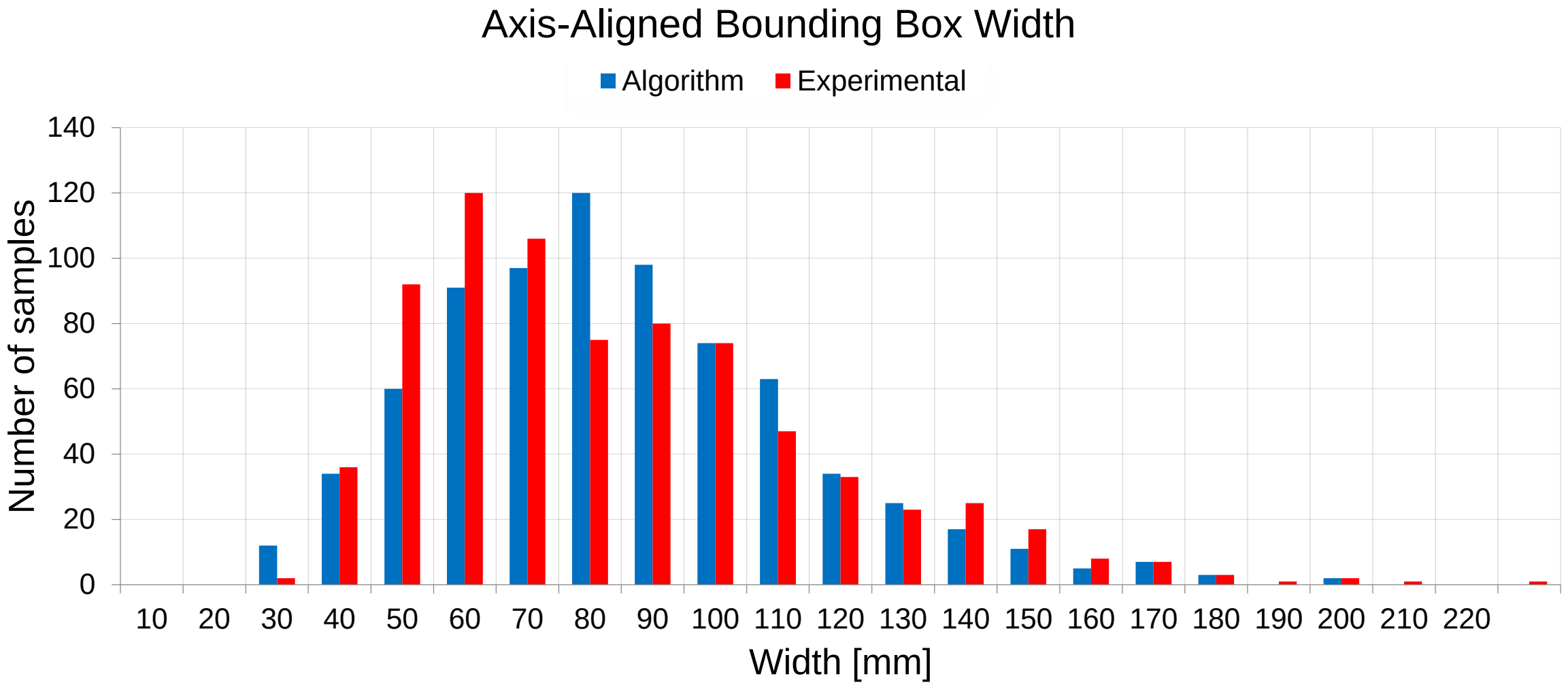
# 4 – Rubble ice measurements processing

- Axis-aligned bounding box height
- Axis-aligned bounding box width
- Number of edges



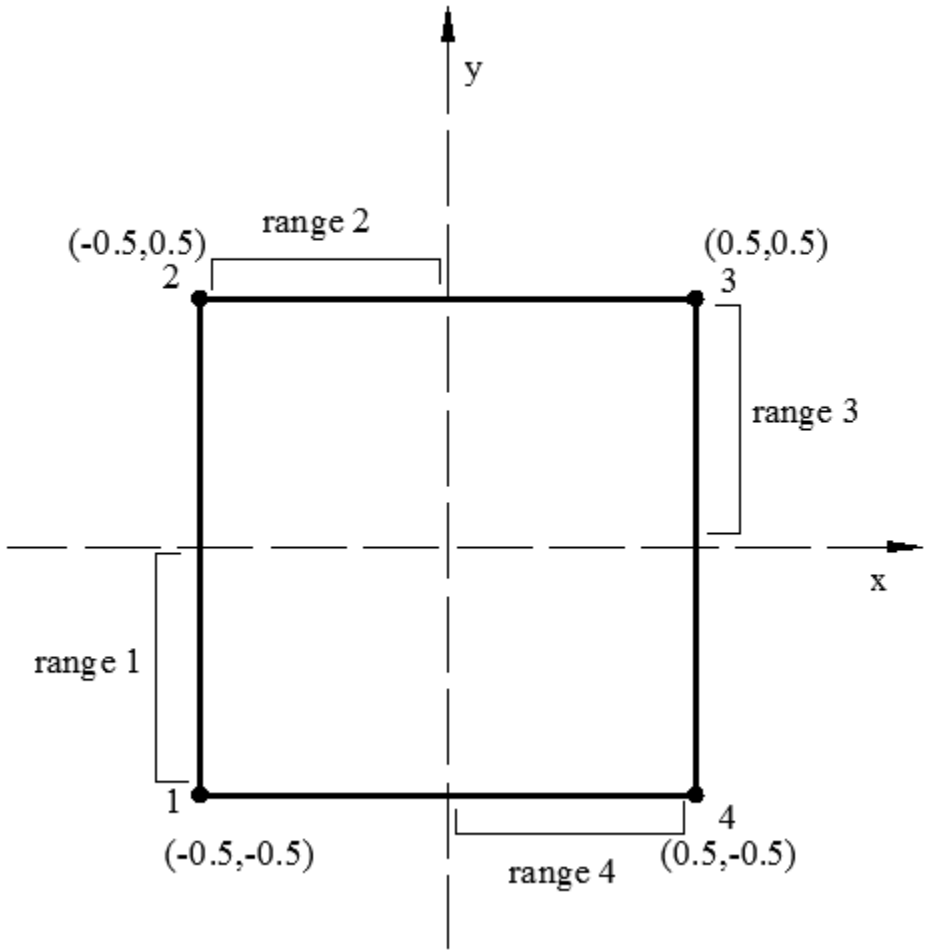

**Shape parameters**

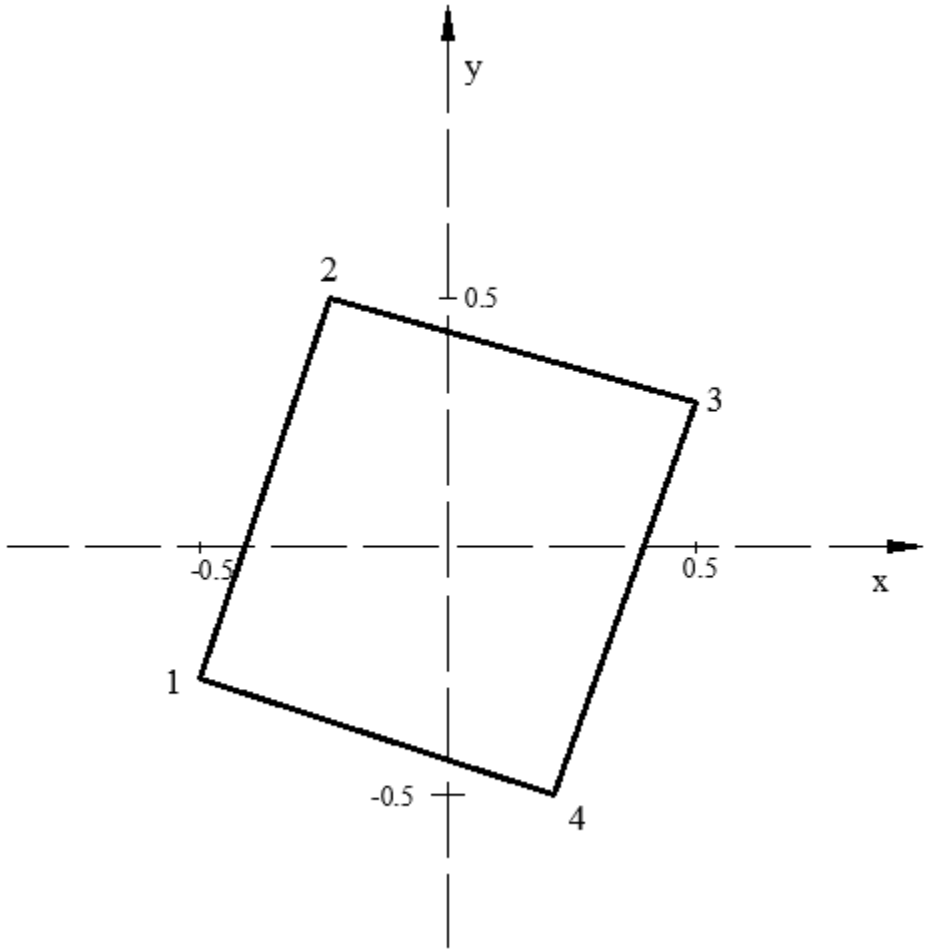
# 4 – Rubble ice measurements processing



# 5 – Generation of rubble ice in the simulation

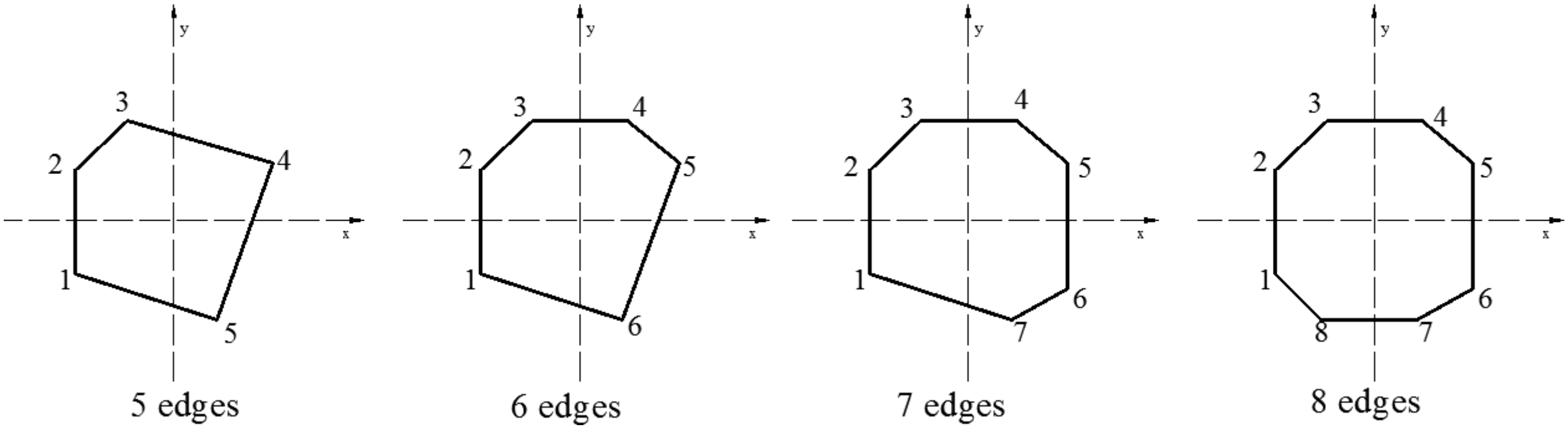
## 1) Generate a unit square



# 5 – Generation of rubble ice in the simulation

2) Create the polygon accordingly to the number of edges

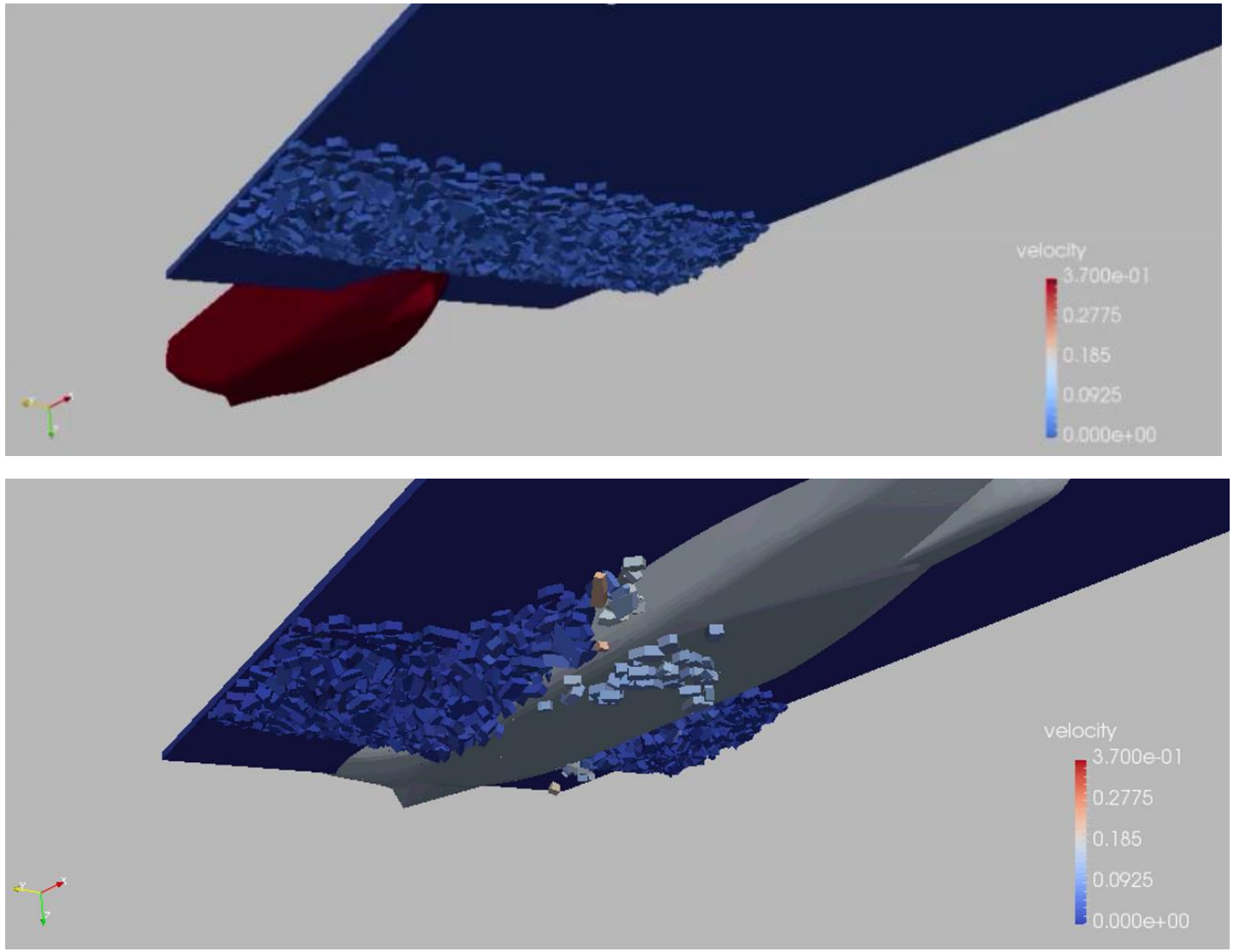


# 5 – Generation of rubble ice in the simulation

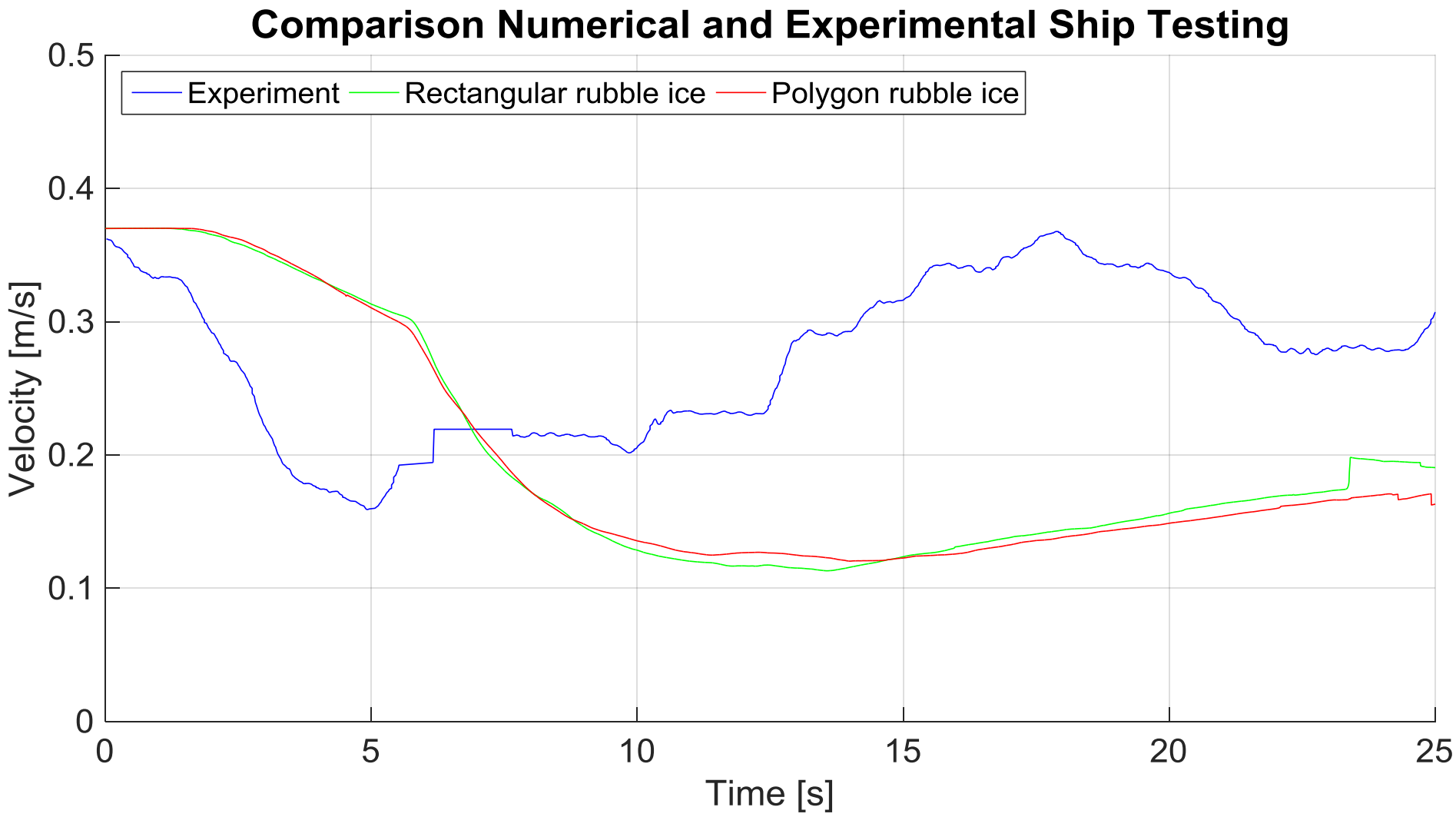
- Centre the polygon at the origin
- Add thickness -> User input
- Triangulated mesh
- Calculate the following properties:
  - Mass
  - Volume
  - Wetted surface area
  - Moment of inertia

# 6 – Punch Test

# 7 – Ship Simulation



# 7 – Ship Simulation



# 8 – Conclusion

- Experimental data analysis of model scale rubble ice geometry
- Influence of the rubble ice geometry in Discrete Elements Methods simulation
- Different friction model for punch and ship simulation