

# Muffler Modeling Options to Simulate Your Exhaust System

Steven Patterson

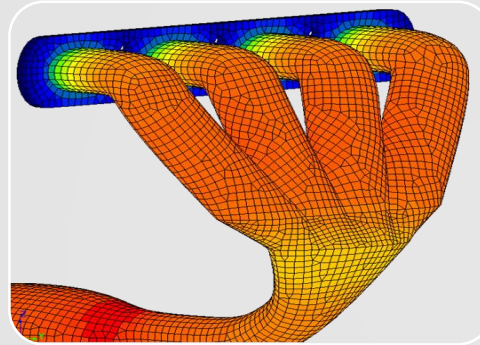
# Agenda

- Introduction to Exhaust Streams
- Motivation for Muffler Modeling
- Muffler Chambers in TAITherm
- Comparison of 3 TAITherm muffler models
  - Using only simple chamber type
  - Using advanced chamber types
  - Using interior geometry and custom setup

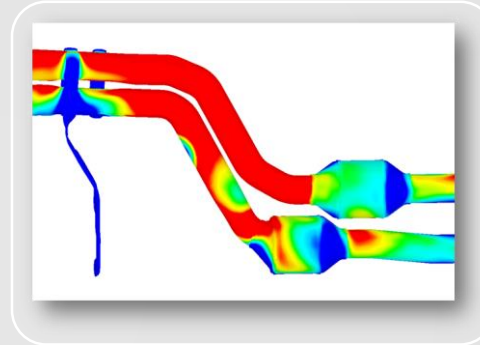
# Exhaust Simulation Methods



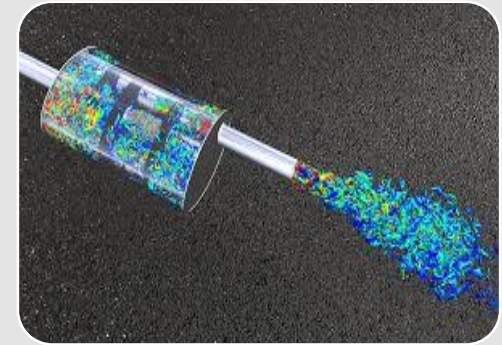
**Assigned Temperatures**  
Constant temperature  
Interpolated  
Part from Thermocouples  
Typically Low resolution



**1D or Fluid Streams**  
Calculated Temperatures  
Higher resolution  
General convection calculations  
Manual setup of many parts



**Exhaust Streams**  
Calculated Temperatures  
Higher resolution  
Exhaust specific convection  
Easy setup  
Run complex geometry or imperfect mesh

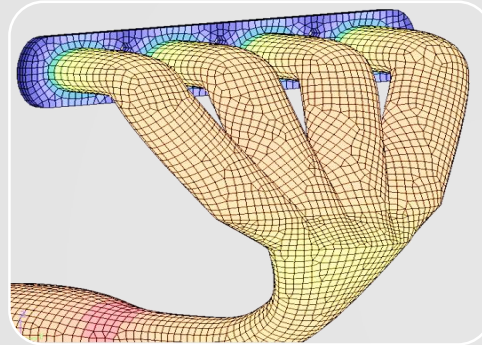


**3D CFD**  
Calculated Temperatures  
Highest Resolution  
Requires fine mesh to resolve heat transfer  
Needs detailed geometry for all parts  
Requires input of heat sources

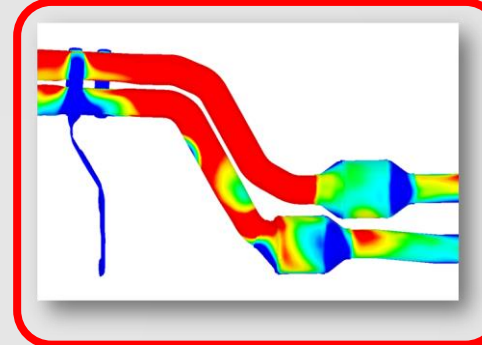
# Exhaust Simulation Methods



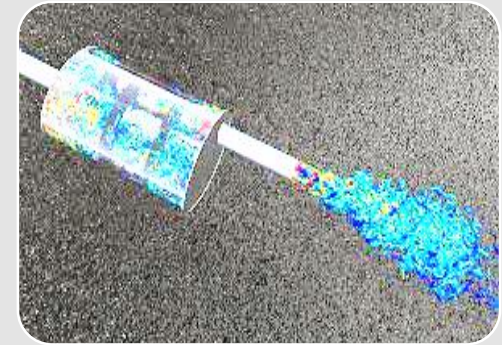
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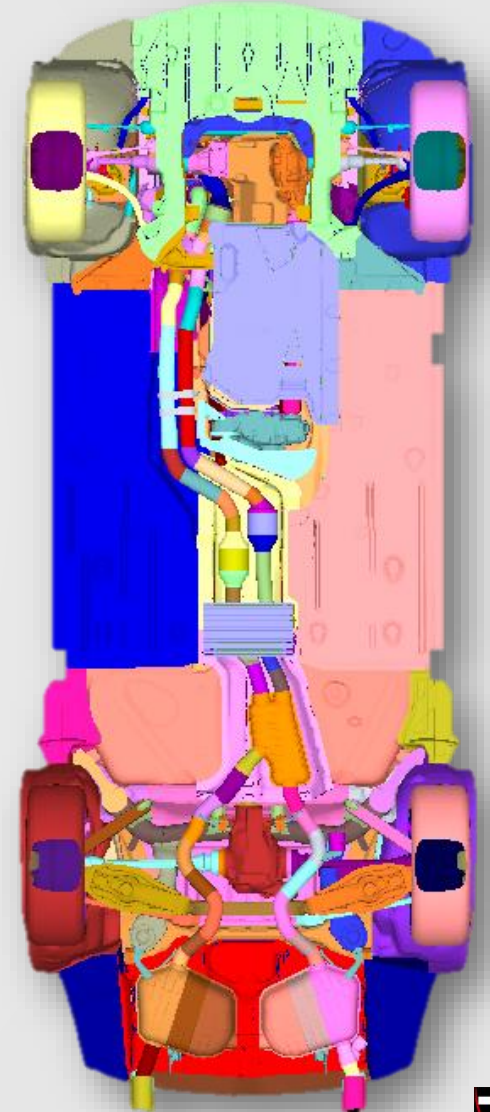
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# Exhaust Streams

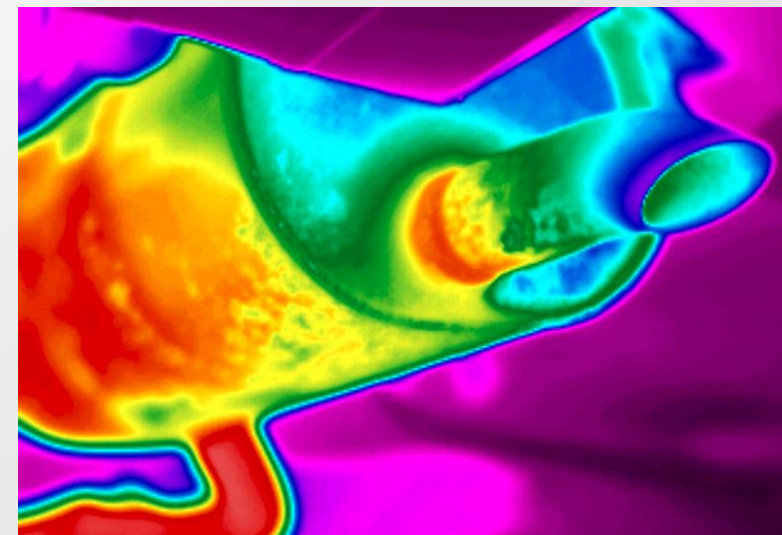
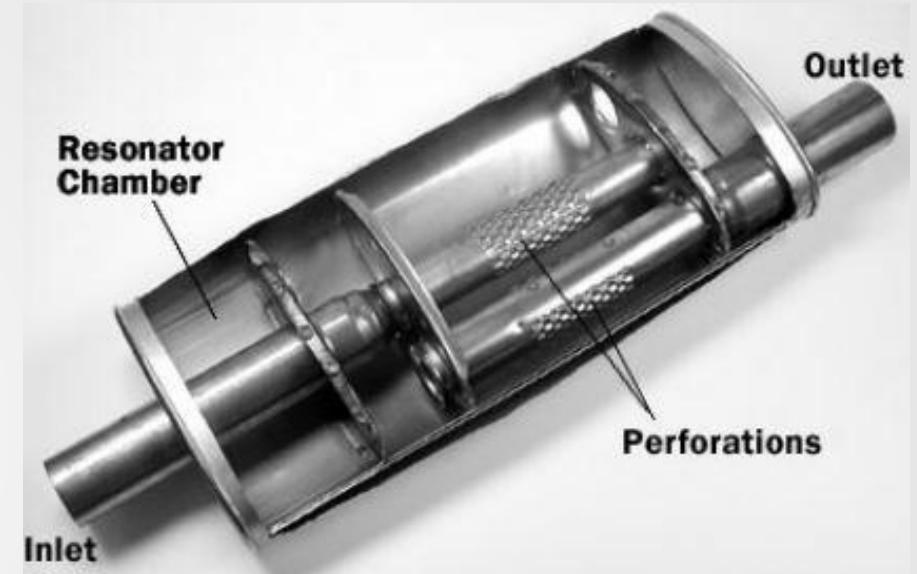
- Thermal prediction of exhaust components is critical
  - Predictions must be fast, accurate & support transient analysis
- Exhaust Streams
  - 1D Convection from 3D Geometry
  - Component Types
    - Catalytic Converters
    - Turbochargers
    - Mufflers
    - Pipes
    - Custom
  - Higher Accuracy
    - Geometric convection effects
    - High resolution 1D networks
    - Increased detail for active components
  - Simplified Setup
    - Engine data integrated with Exhaust Stream
    - Multiple sub-streams for complex exhaust systems
    - Branching & Merging flows





# Fast, Simple Muffler Modeling

- There are many types of muffler styles and designs
- Thermal analysts building underbody models have access to different levels of interior detail
- Different modeling methods are needed for different situations

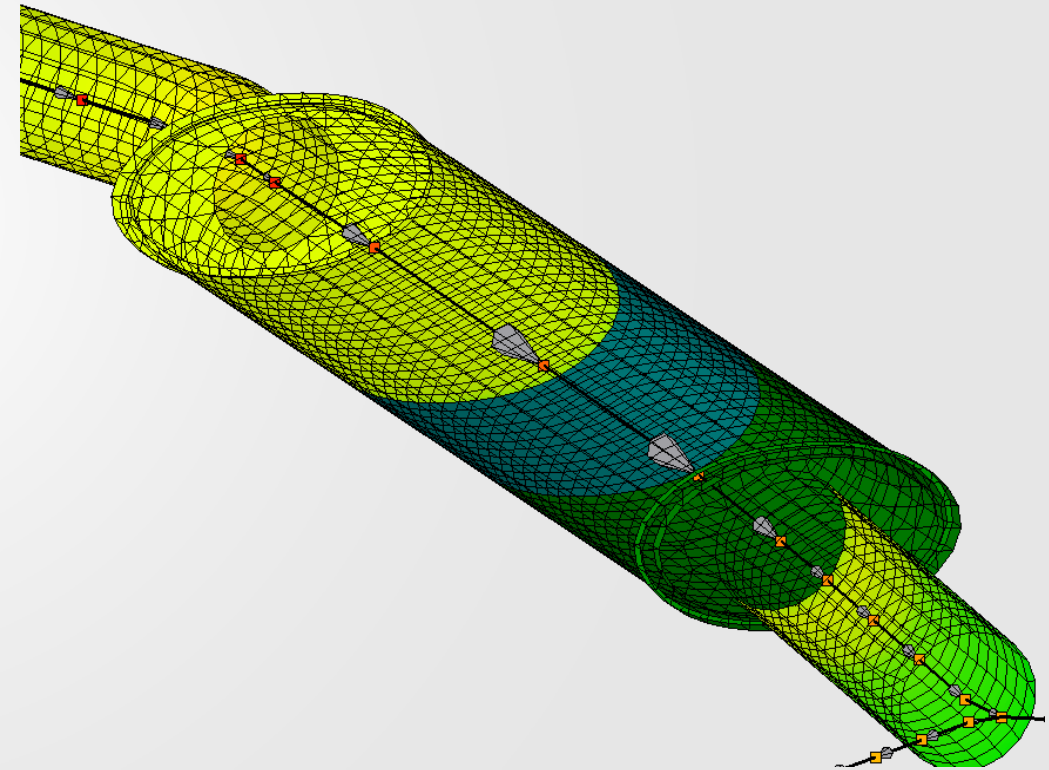


# Muffler Chamber Types in TAITherm

- Simple Chamber
- Uninsulated Pipe
- Insulated Pipe
- Open Chamber

# Muffler Chamber Types: Simple Chamber

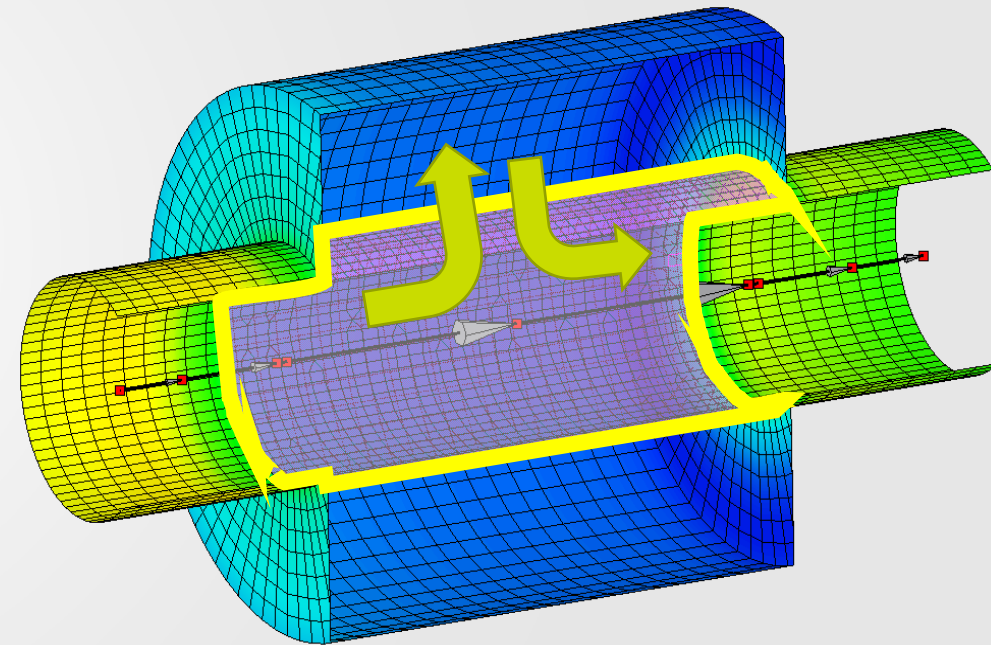
- Chamber type introduced in version 12.4
- Retained for backward compatibility
- Does not support internal geometry





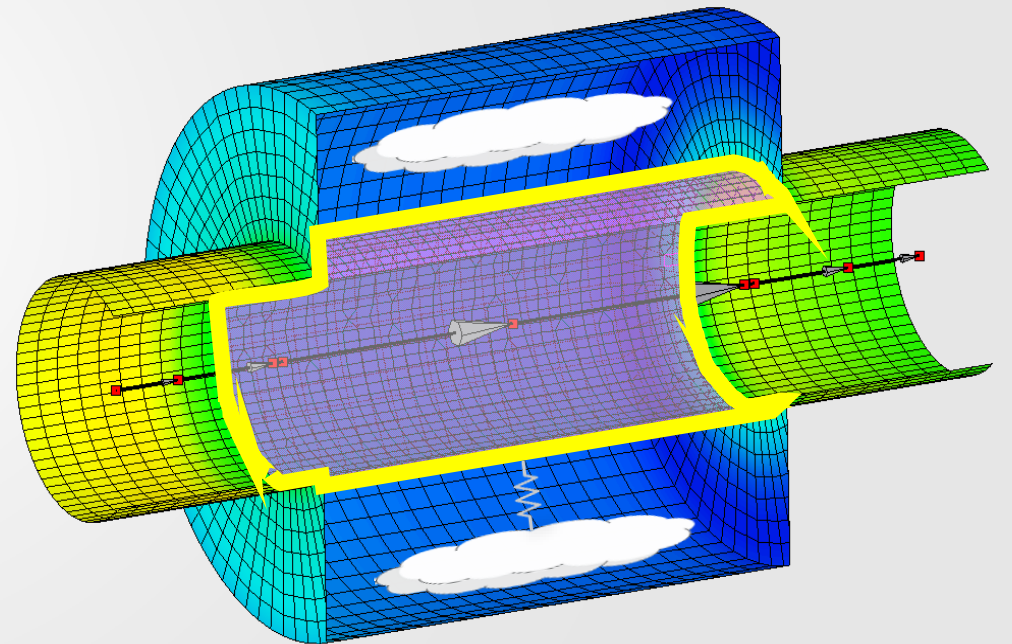
# Muffler Chamber Types: Uninsulated Pipe

- No internal geometry
- Implicitly models a perforated pipe passing through the chamber
- User defines fraction of flow exchange between the pipe and the chamber



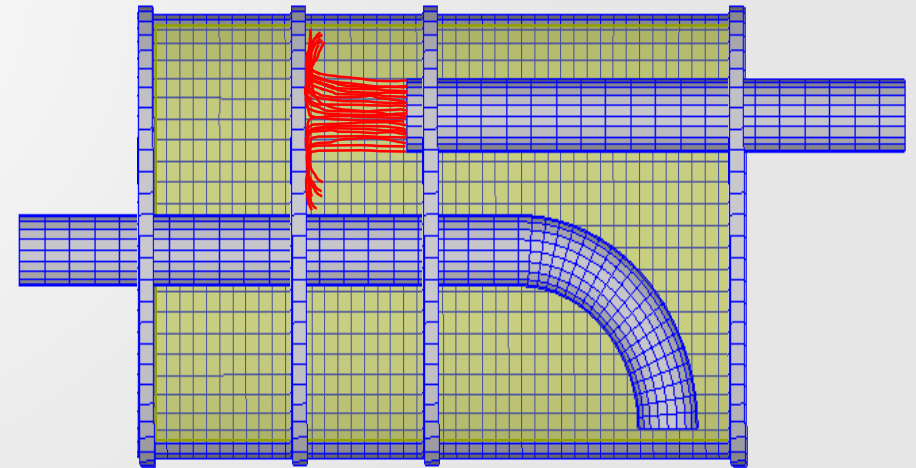
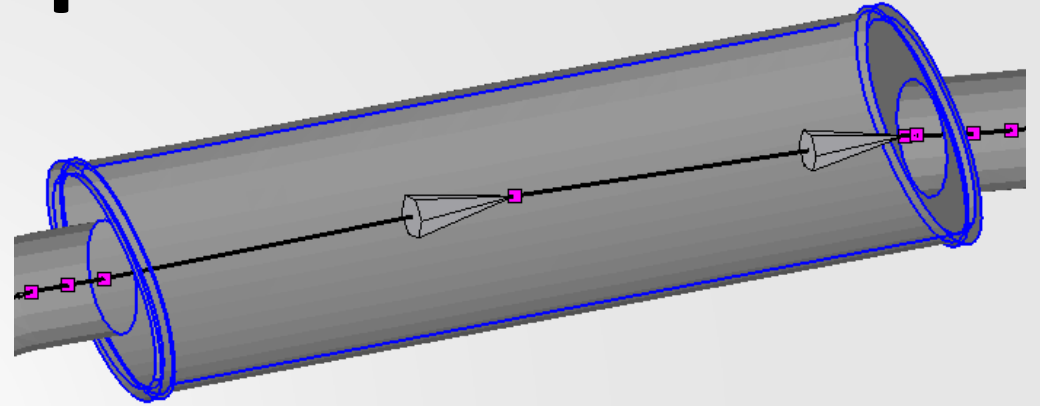
# Muffler Chamber Types: Insulated Pipe

- No internal geometry
- Implicitly models a perforated pipe passing through the chamber and the chamber filled with porous insulation
- User defines fraction of flow exchange between the pipe and the chamber



# Muffler Chamber Types: Open

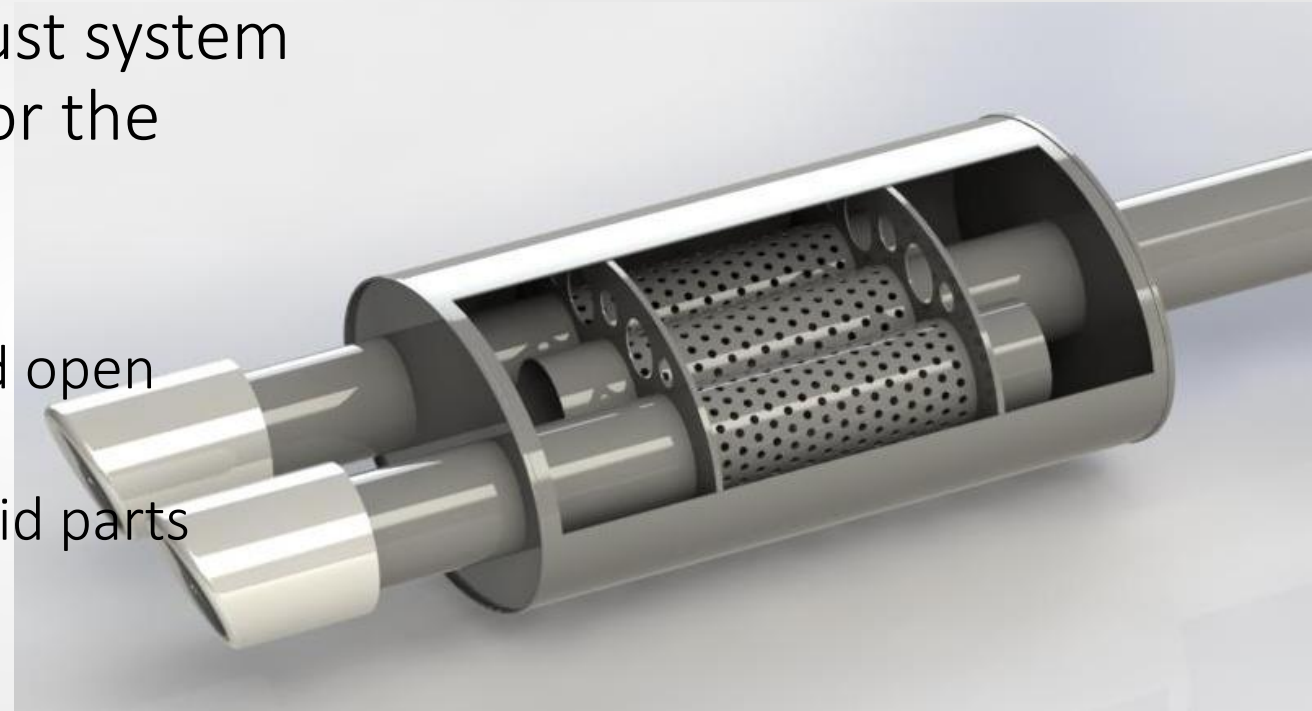
- No internal geometry
- Models flow in a fully open chamber
- Allows convection augmentation for an impingement point



# Example Models

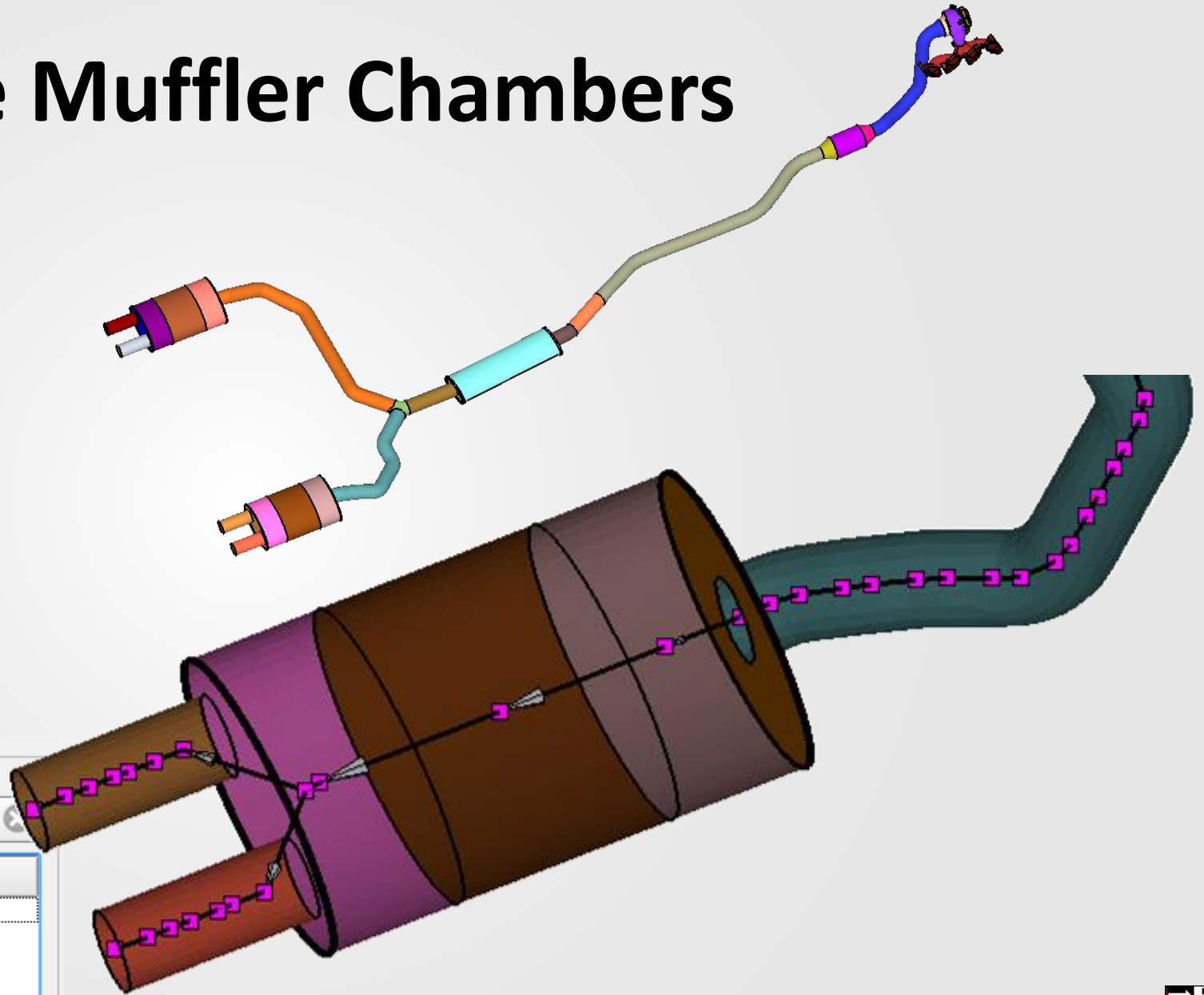
# Example Model Variations

- We will now demonstrate 3 exhaust system models using different methods for the muffler
  - Using 3 simple chambers
  - Using <un>insulated chambers, and open chamber, and impingement
  - Using the interior geometry and fluid parts



# Model 1: Simple Muffler Chambers

- No interior geometry
- 3 Simple Chambers



Current Component Details

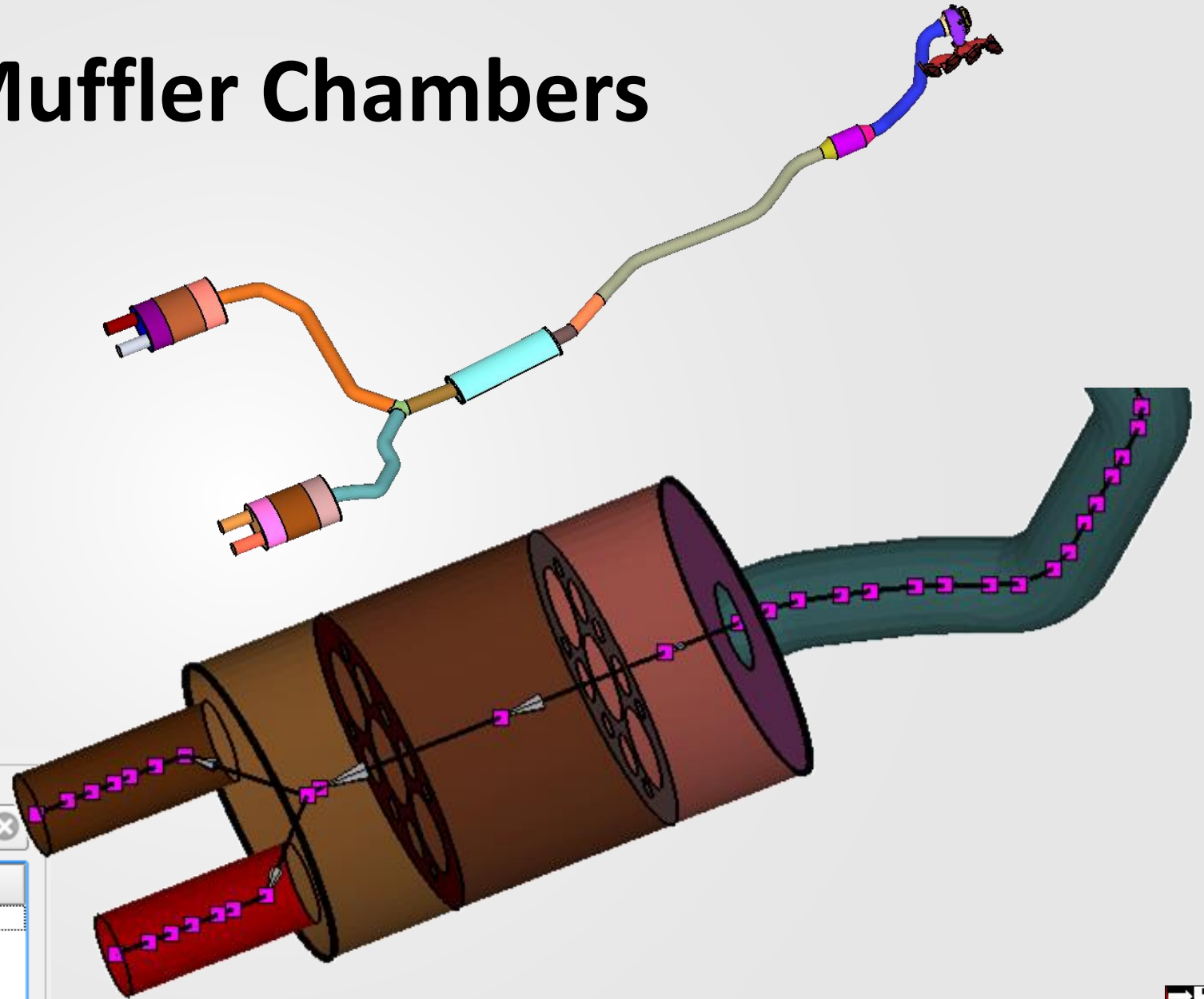
Bounding Parts

ID	Name	Face
+	Simple Chamber	
+	Simple Chamber	
+	Simple Chamber	



# Model 2: New Muffler Chambers

- Include geometry for baffles
- 3 Chambers
- Impingement on back face



Current Component Details

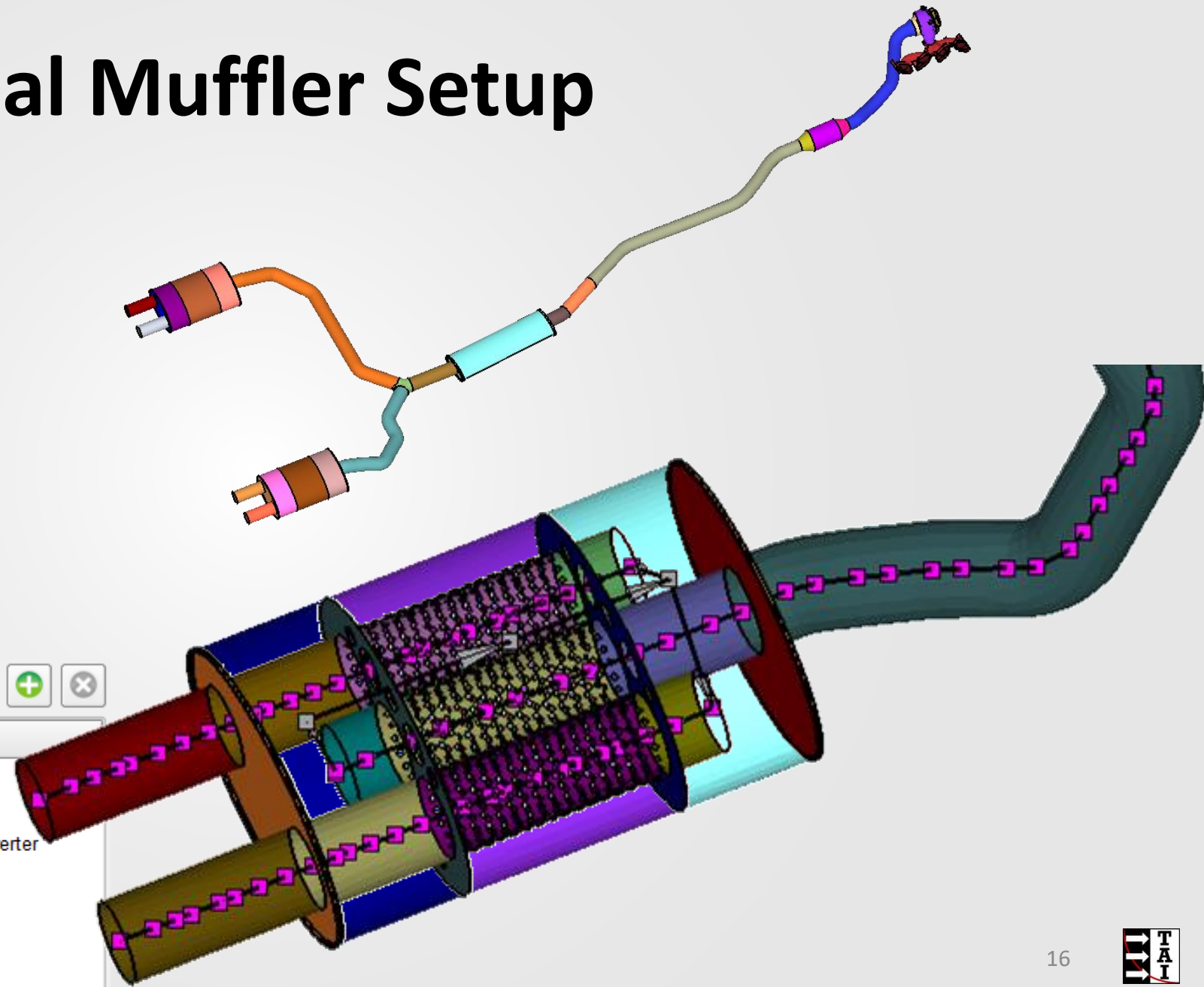
Bounding Parts



ID	Name	Face
+	Open Chamber	
+	Uninsulated Pipe	
+	Uninsulated Pipe	

# Model 3: Manual Muffler Setup

- Include geometry for baffles
- Includes geometry for interior pipes
- Uses Fluid Parts for convection on muffler walls



Exhaust Components



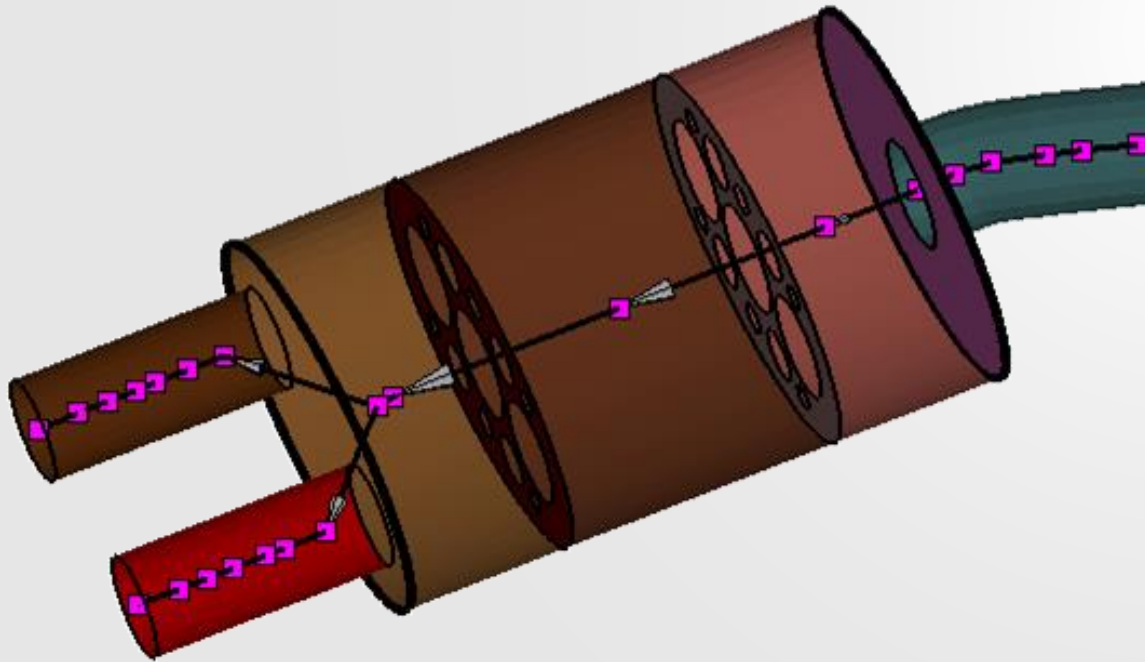
Name	Type
manifold	Pipe
turbo	Turbocharger
pipesToSilencer	Pipe
cat	Catalytic Converter
silencer	Muffler
pipes_silencerIntoMufflers	Pipe
pipes_lhs_tail1	Pipe
pipes_lhs_tail2	Pipe
pipes_rhs_tail1	Pipe
pipes_rhs_tail2	Pipe

# Model 2: Muffler Chambers

Model Setup

# Model 2: Muffler Chambers

- Defined 3 Chambers



Properties Components Stream Points Sub-Streams Distribu

Exhaust Components

Name	Type
pipes_rhs_tail1	Pipe
pipes_rhs_tail2	Pipe
muffler_rhs	Muffler
muffler_lhs	Muffler

Current Component Details

Bounding Parts

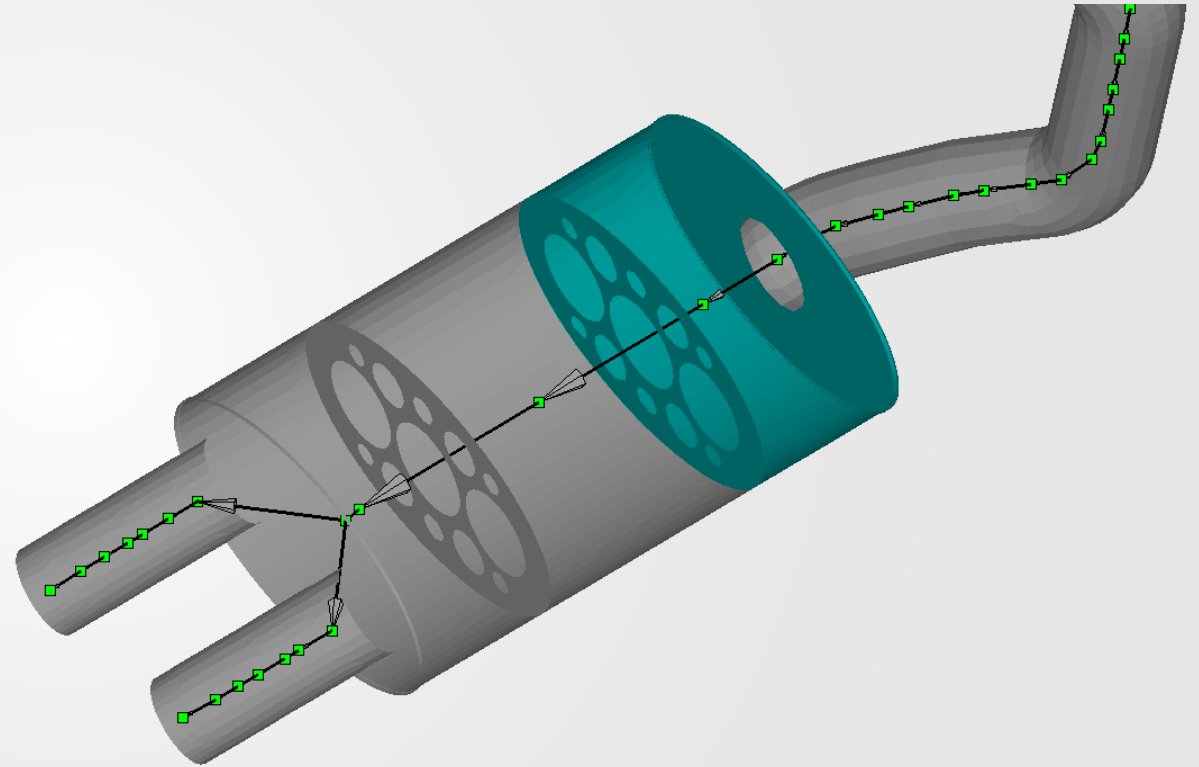
ID	Name	Face
Open Chamber		
840	chamber_3_rhs	Back
858	baffle_2_rhs	Back
859	muffler_back_end_rhs	Back
Uninsulated Pipe		
839	muffler_front_end_rhs	Back
842	baffle_1_rhs	Front
854	chamber_1_rhs	Back
Uninsulated Pipe		
842	baffle_1_rhs	Back
855	chamber_2_rhs	Back
858	baffle_2_rhs	Front

Current Sub-Component Details

Perforation %

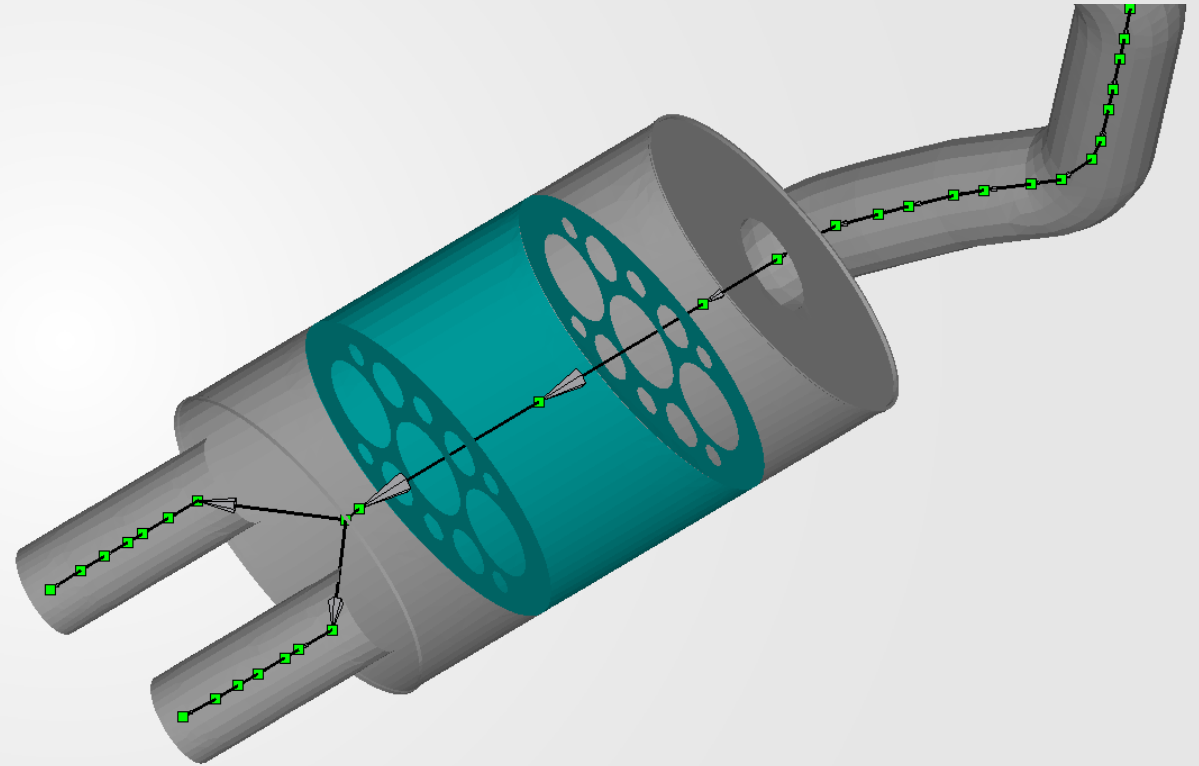
# Model 2: Muffler Chambers

- Chamber 1
- Uninsulated Pipe



# Model 2: Muffler Chambers

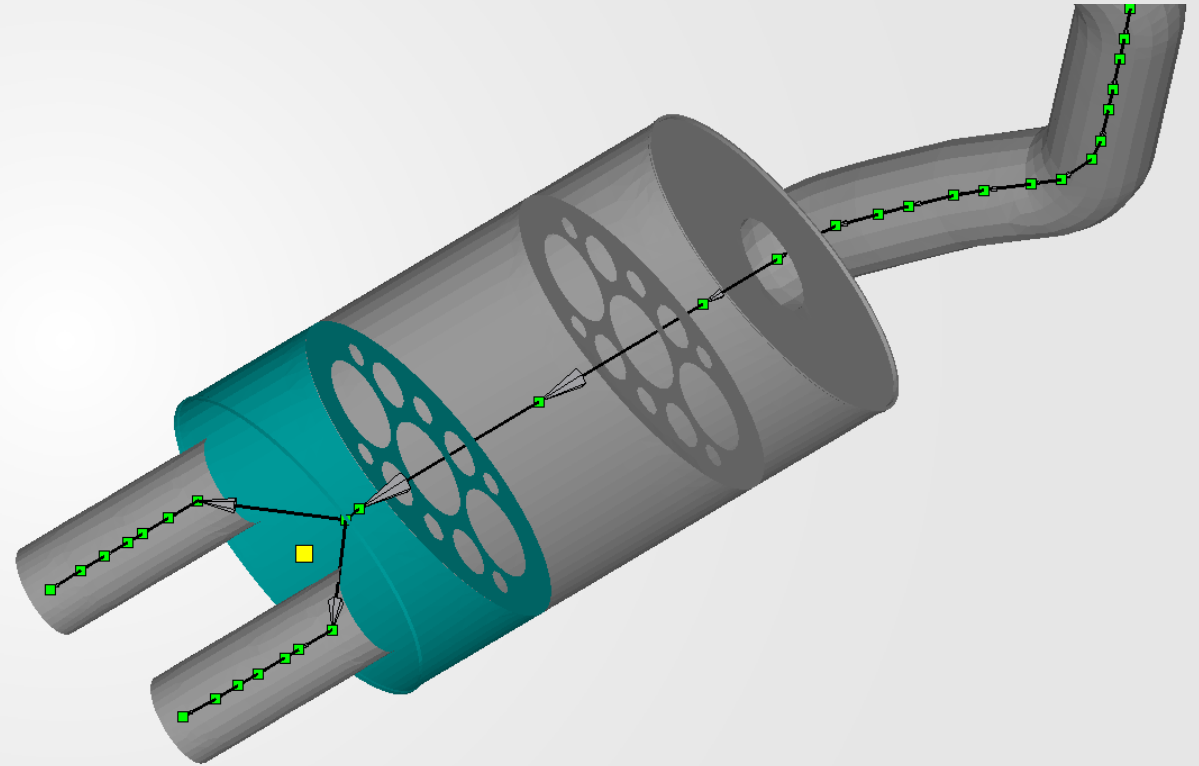
- Chamber 2
- Uninsulated Pipe





# Model 2: Muffler Chambers

- Chamber 3
- Open Chamber



# Model 2: Muffler Chambers

- Chamber 3
- Impingement

Current Component Details

Bounding Parts

ID	Name	Face
Open Chamber		
840	chamber_3_rhs	Back
858	baffle_2_rhs	Back
859	muffler_back_end_rhs	Back

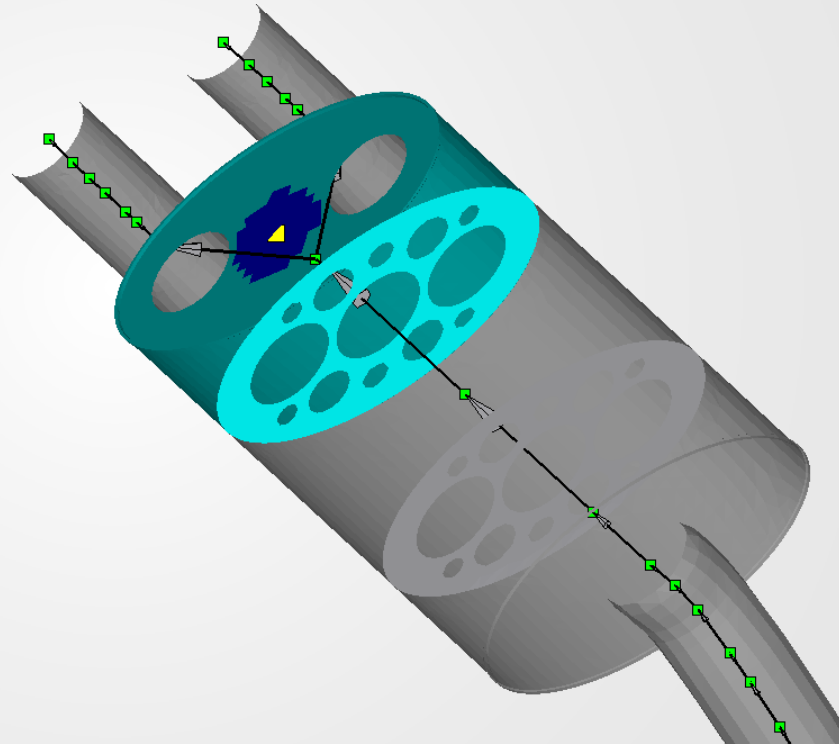
Current Sub-Component Details

Enable Impingement

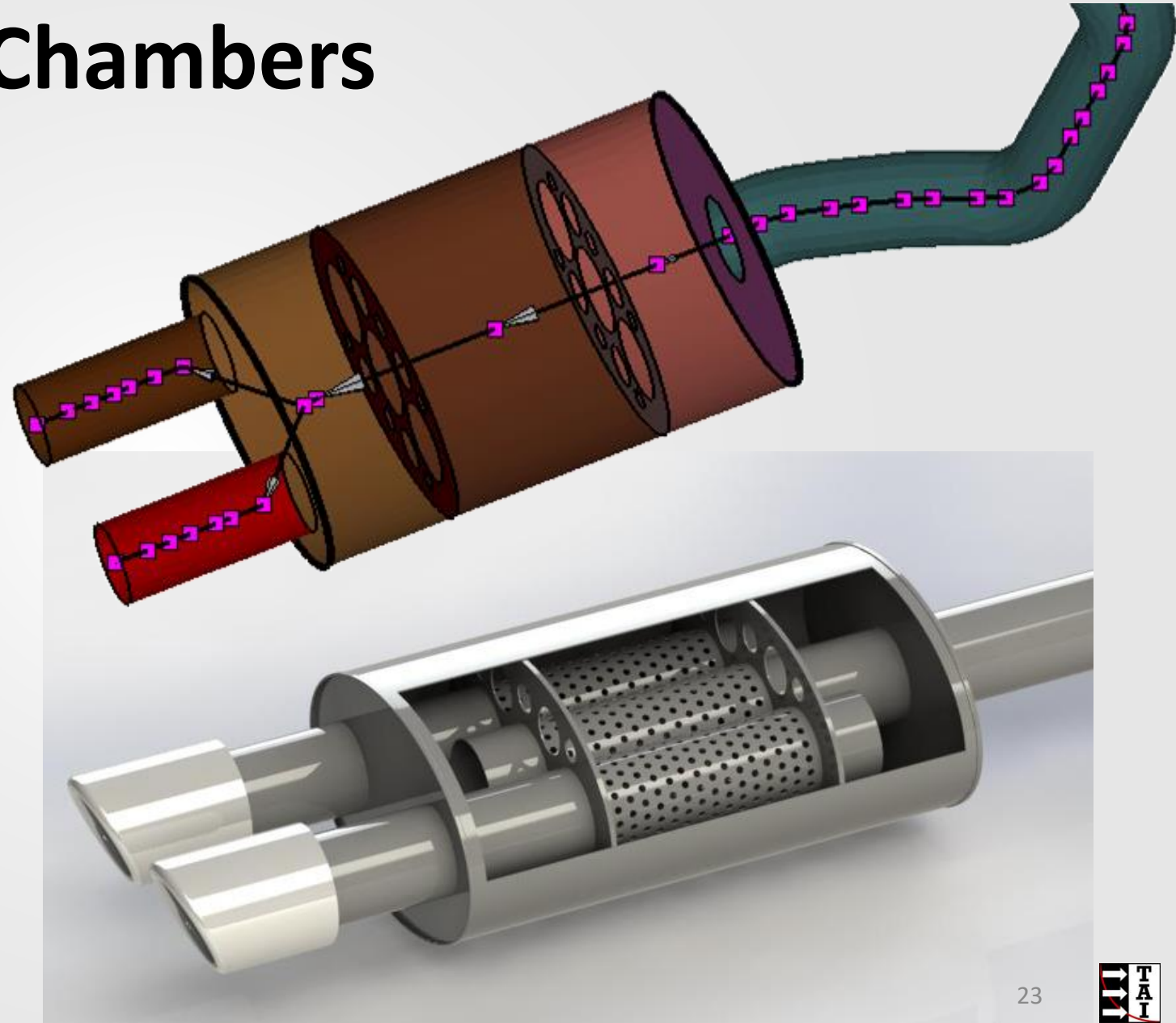
Impingement Point

X (mm)	Y (mm)	Z (mm)
3570.74	712.891	-193.207

Impingement Radius (mm) 30



# Model 2: Muffler Chambers

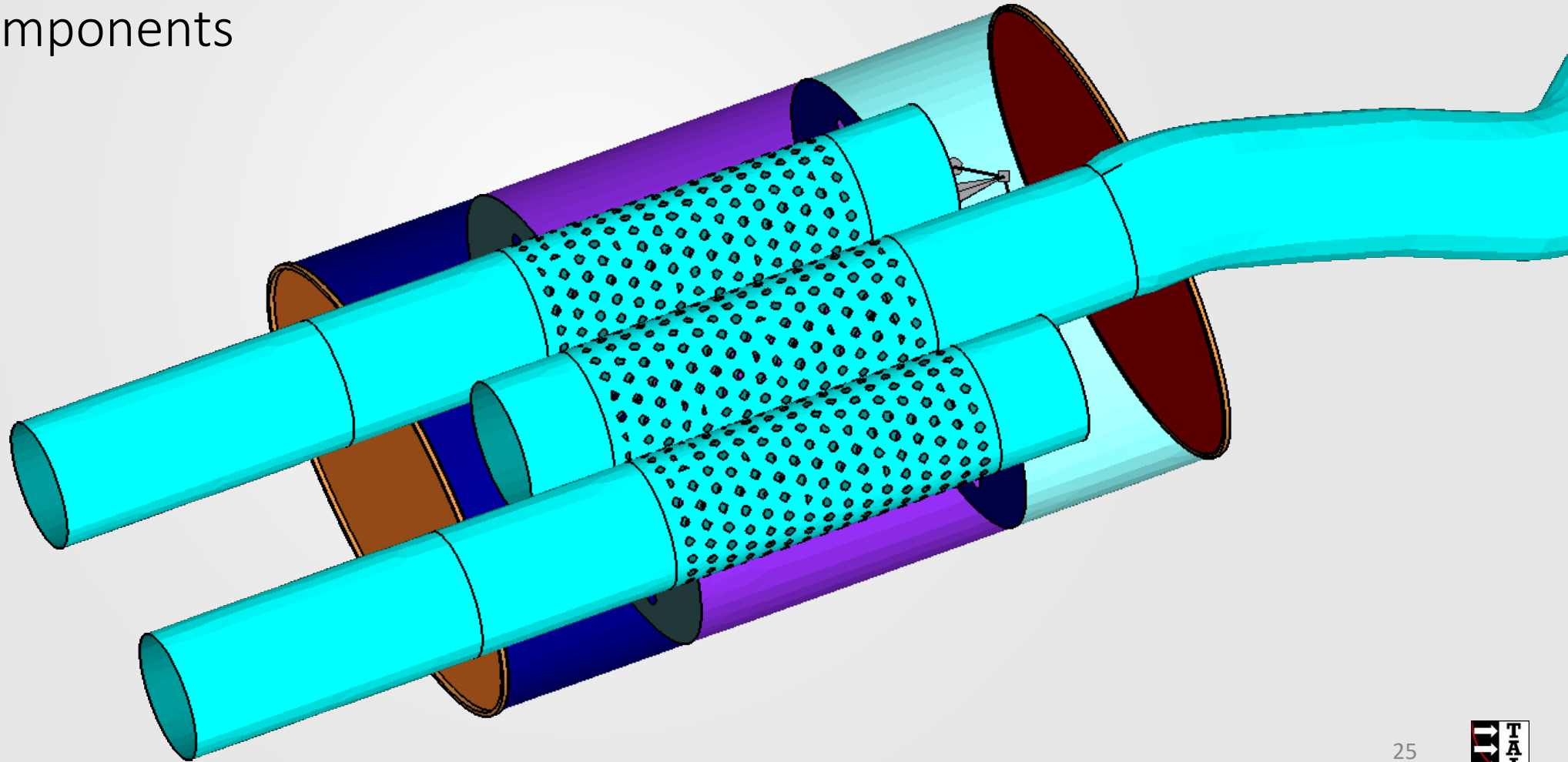


# Model 3: Full Interior

Model Setup

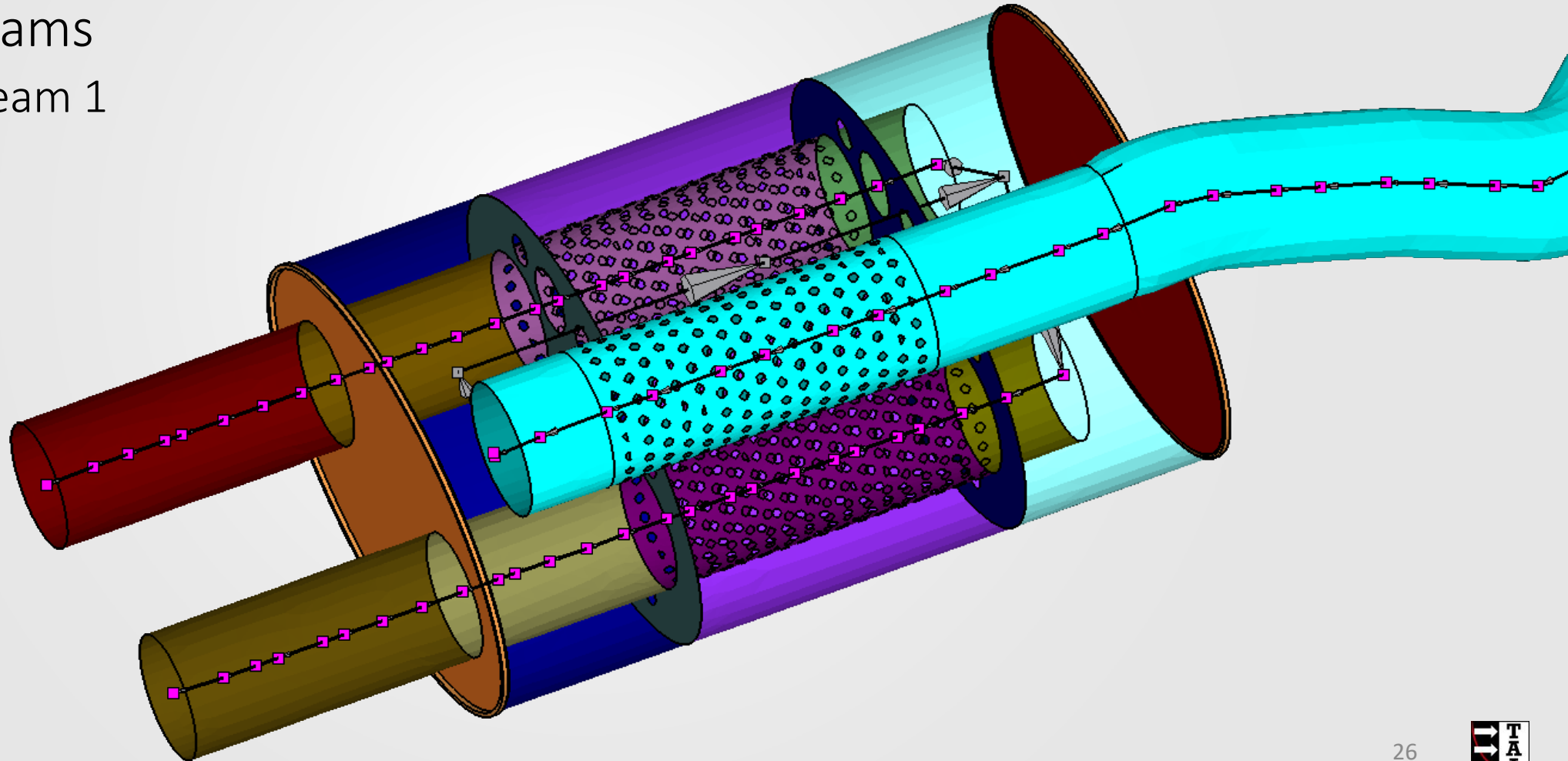
# Model 3: Manual Muffler Setup

- 3 Pipe Components



# Model 3: Manual Muffler Setup

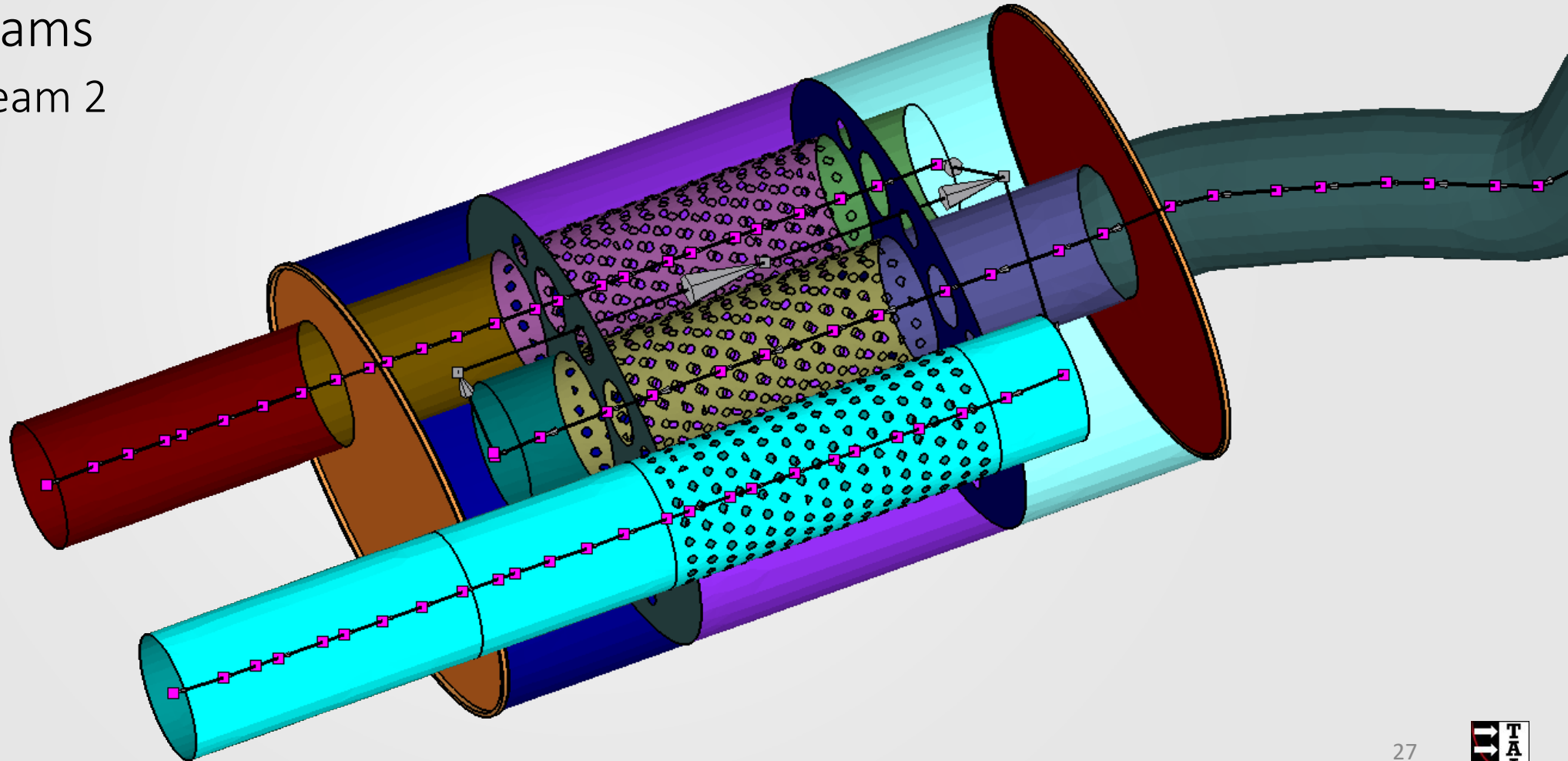
- 3 Substreams
  - Substream 1





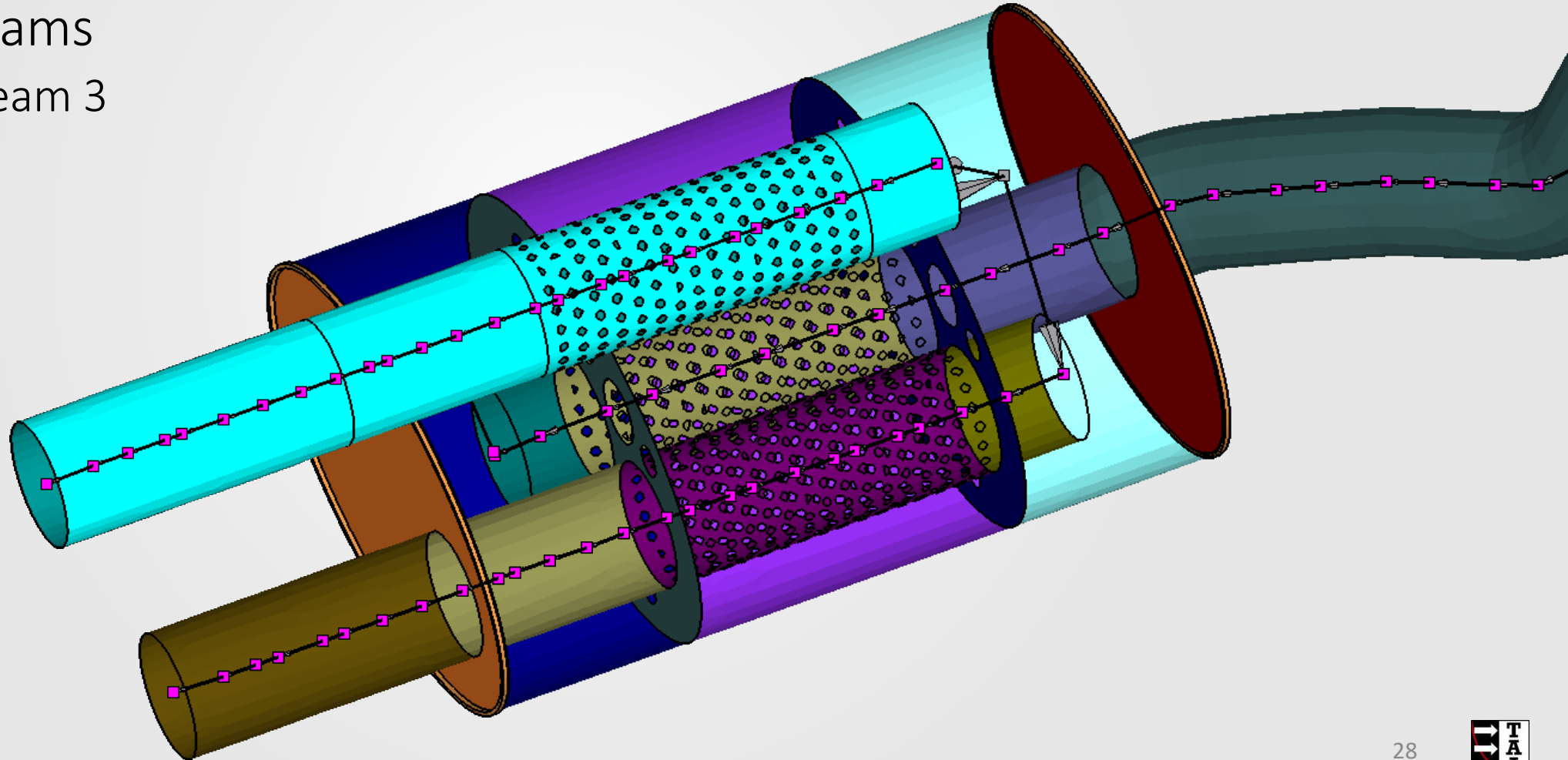
# Model 3: Manual Muffler Setup

- 3 Substreams
  - Substream 2



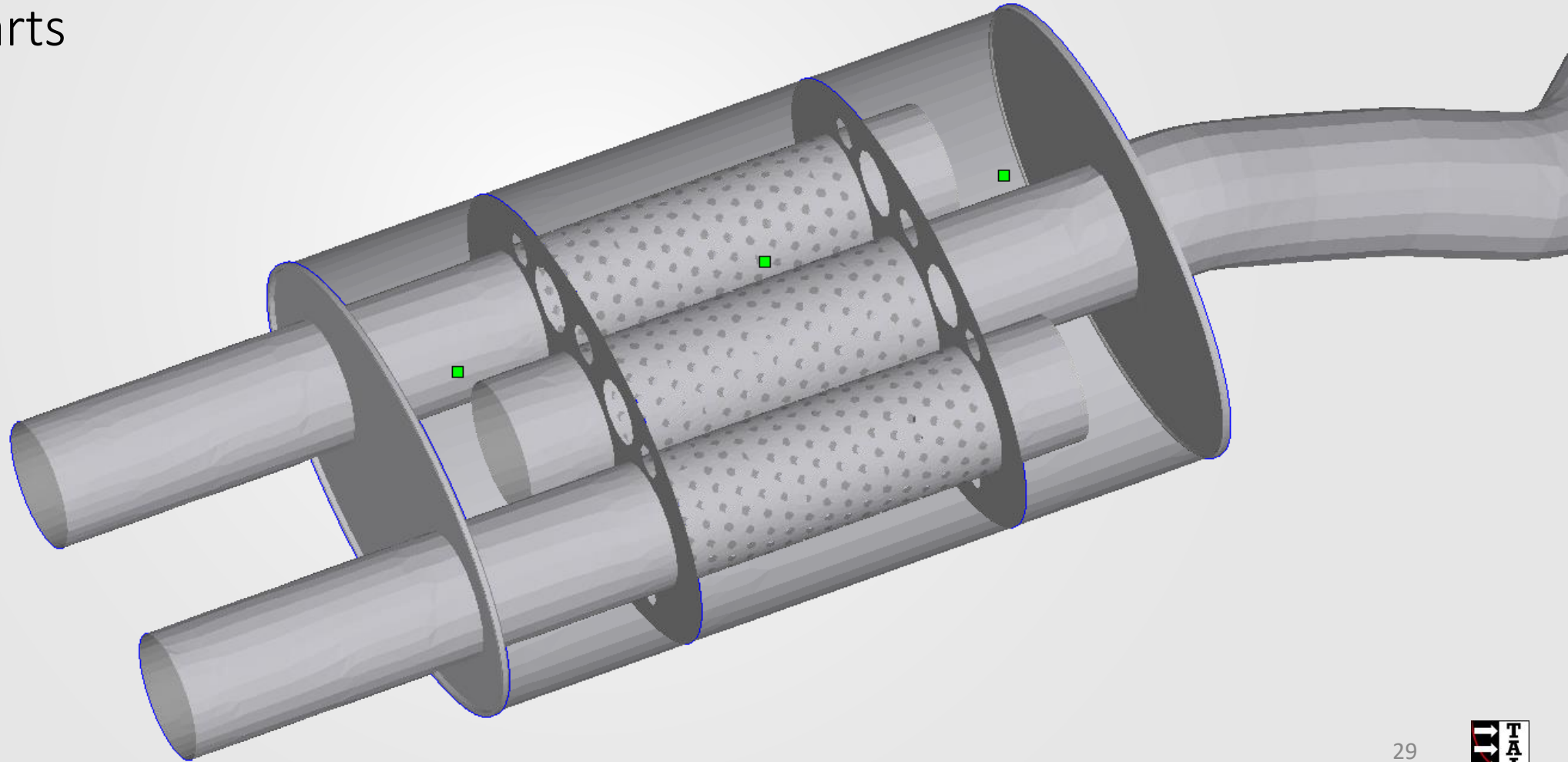
# Model 3: Manual Muffler Setup

- 3 Substreams
  - Substream 3



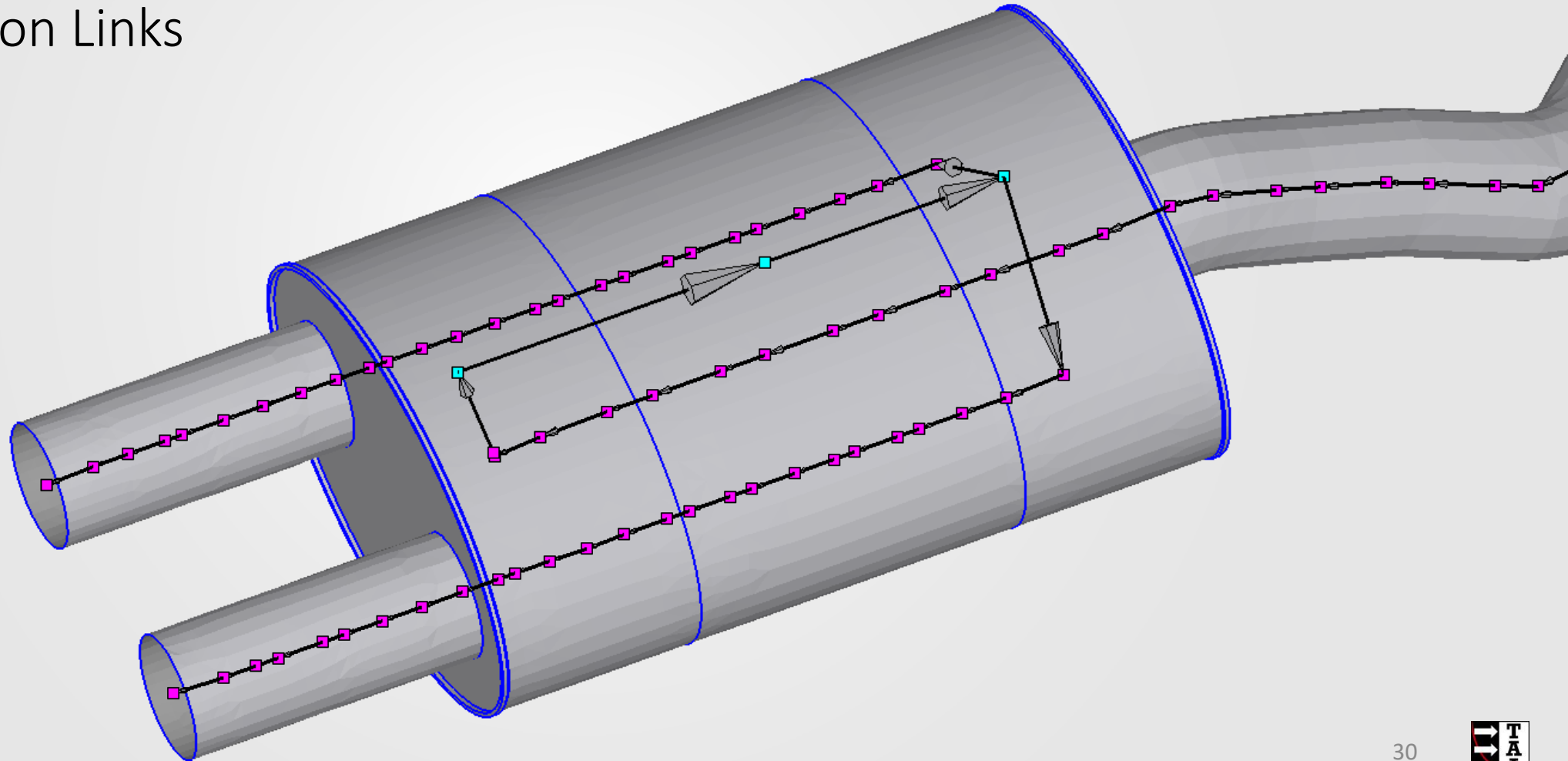
# Model 3: Manual Muffler Setup

- 3 Fluid Parts



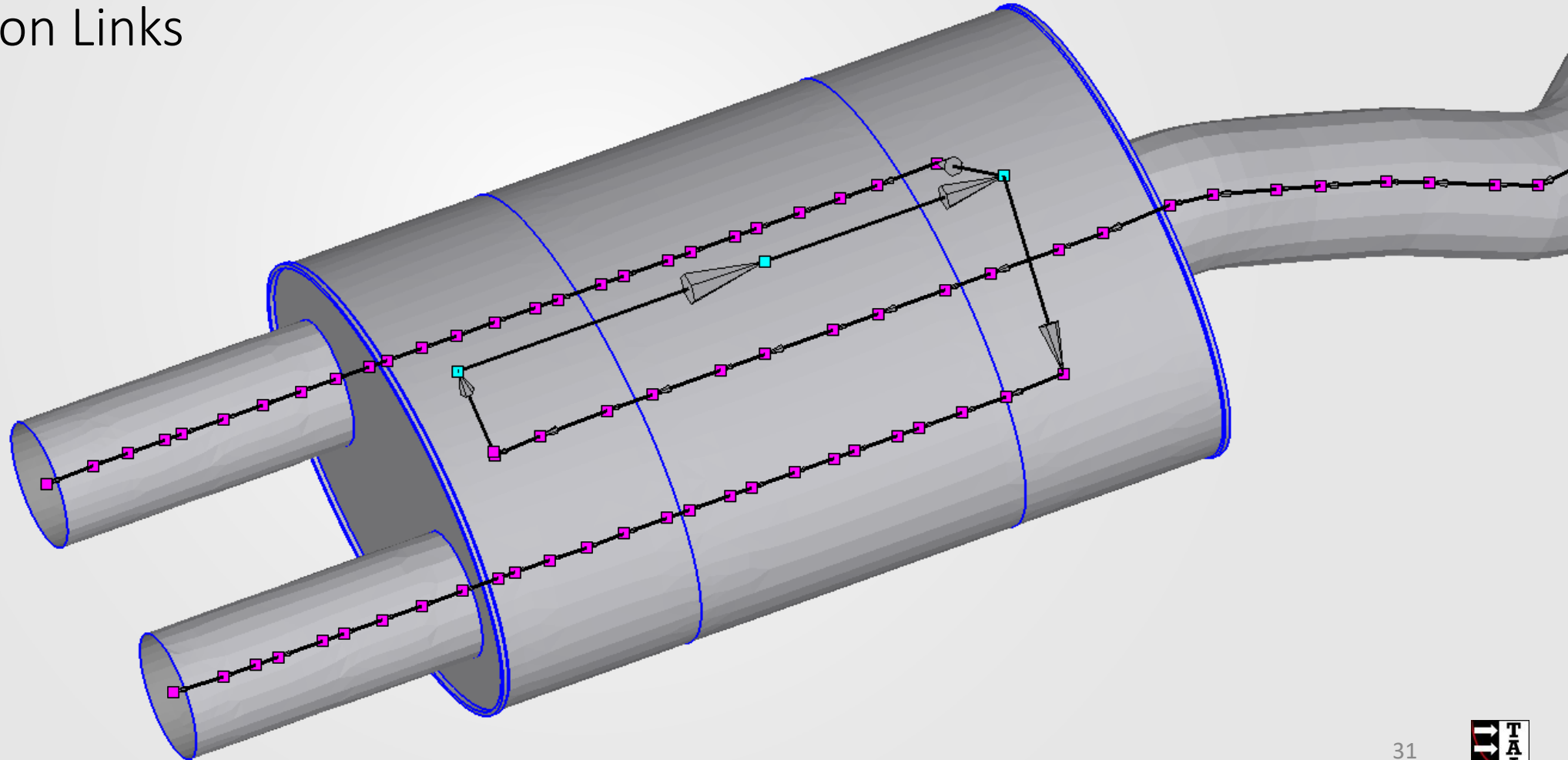
# Model 3: Manual Muffler Setup

- 5 Advection Links



# Model 3: Manual Muffler Setup

- 5 Advection Links



# Library Convection

- Muffler is not part of “Exhaust Stream” in this model
- Use Library Convection with flow from the Fluid Parts

TAITherm Library Convection

Automatic

Automatically mixed natural and forced convection

Fluid Temperature (°C)

Value

Curve

Routine

Fluid

From Altitude

1006: ex\_muffler\_rhs\_aft

Flow Speed (L/min)

Velocity Value

Velocity Curve

Volume Flow Value

Volume Flow Curve

Mass Flow Value

Mass Flow Curve

Flow from Fluid

4: ex\_muffler\_rhs\_fore

Forced Length (mm) 223.2

Length (mm) 87.4872

Width (mm) 223.2

Height (mm) 143.943

Set to Part Sizes

Flow Area (mm<sup>2</sup>) 30000

Multiplier (CAF) 1.0

OK Cancel

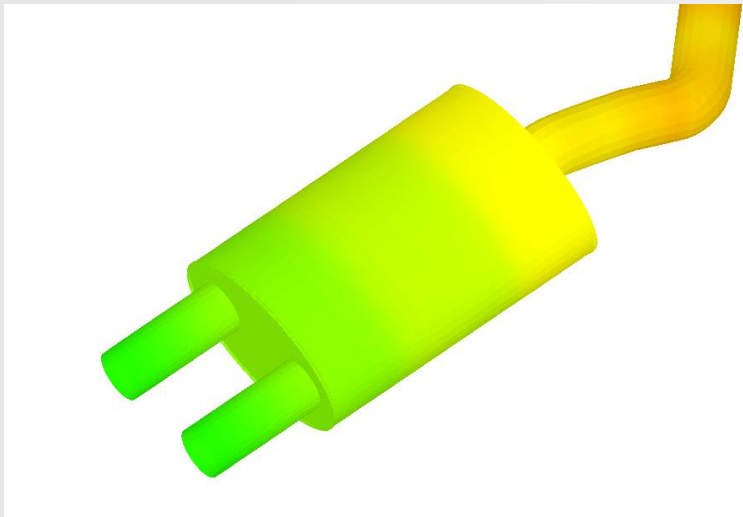


# Results

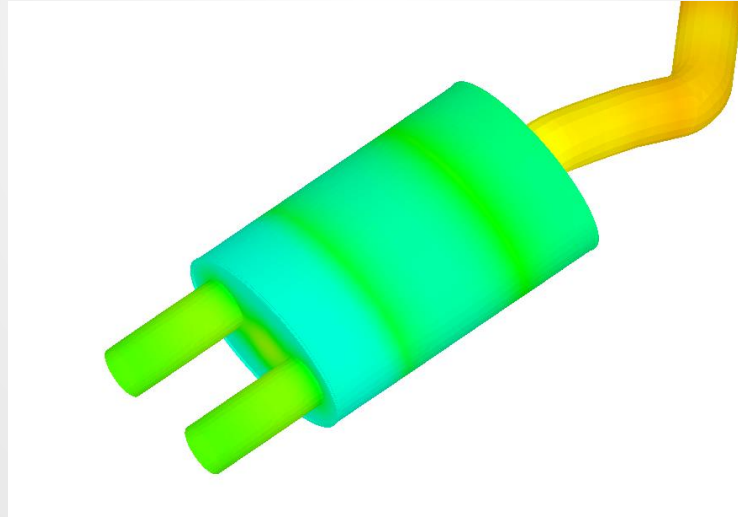
# Muffler Comparison

- Temperatures are different when baffles are included

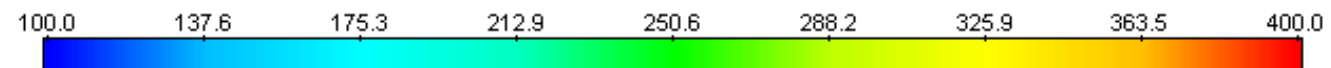
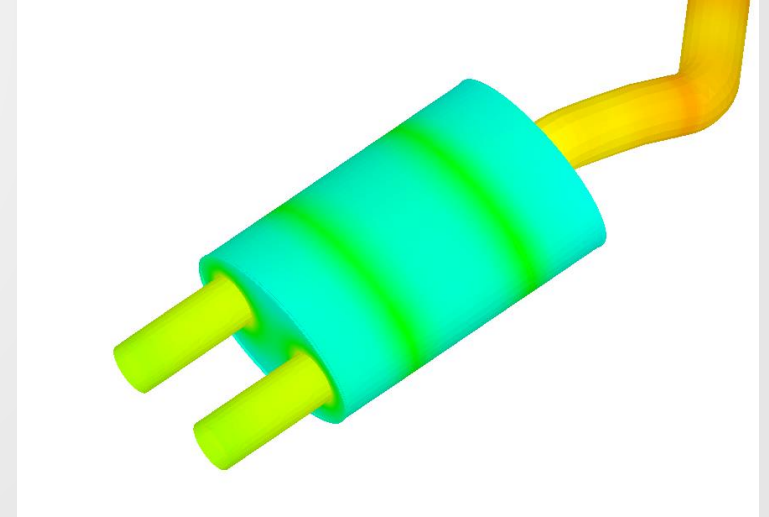
Simple Chambers



Open Chamber with Impingement



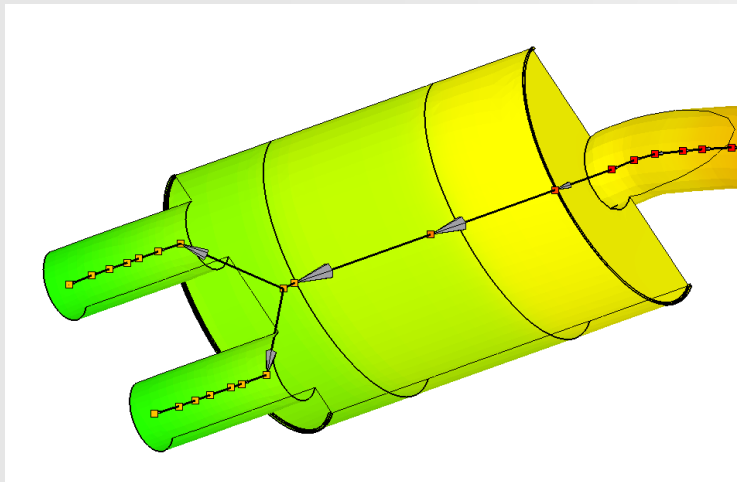
Custom with Interior Pipes



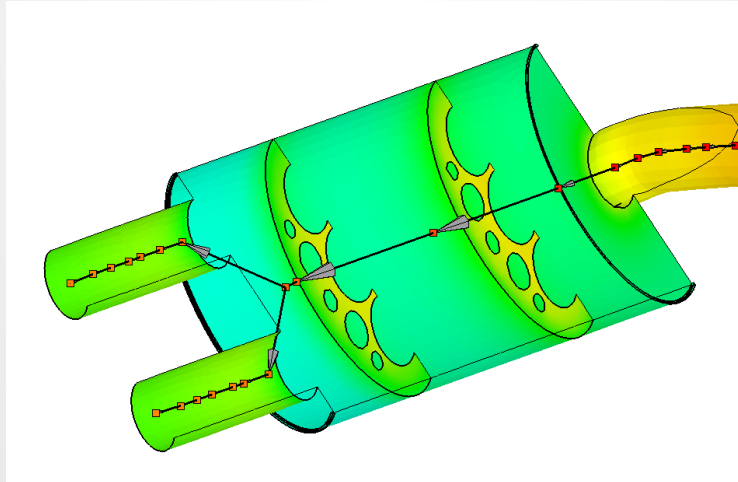
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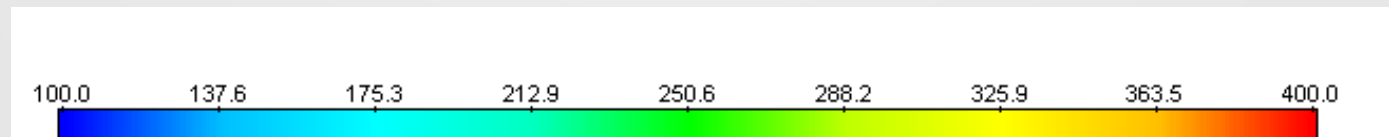
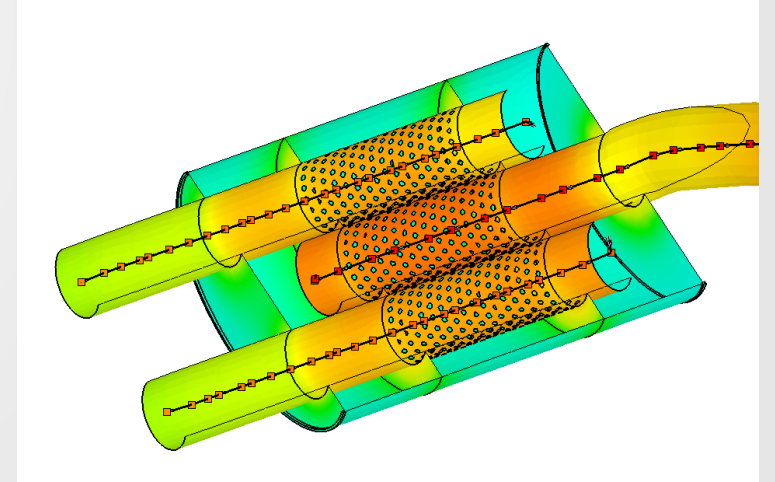
Simple Chambers



Open Chamber with Impingement

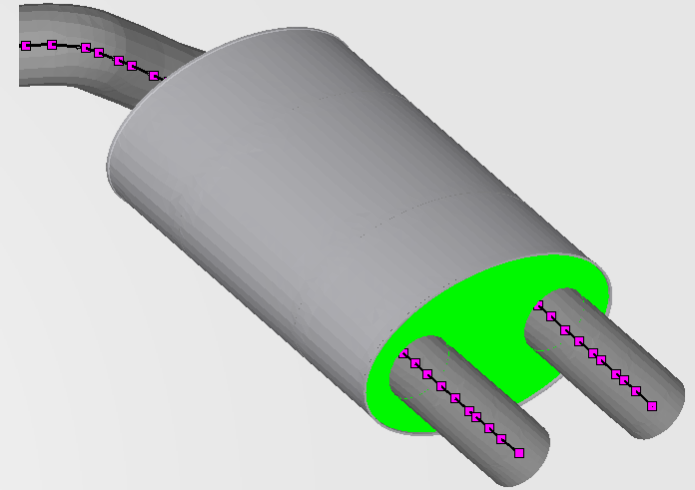


Custom with Interior Pipes

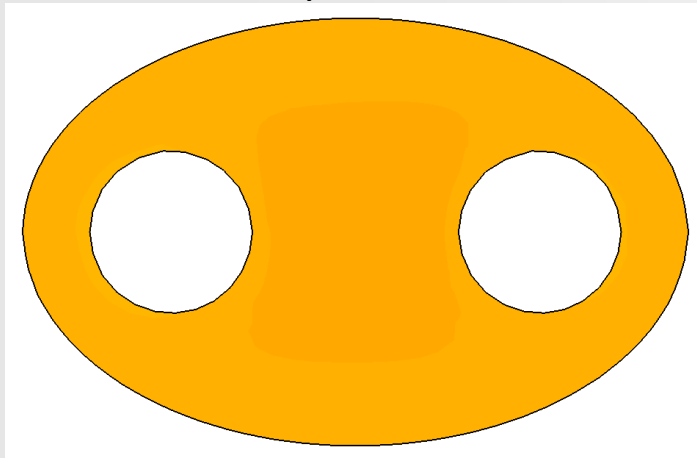


# Muffler Back

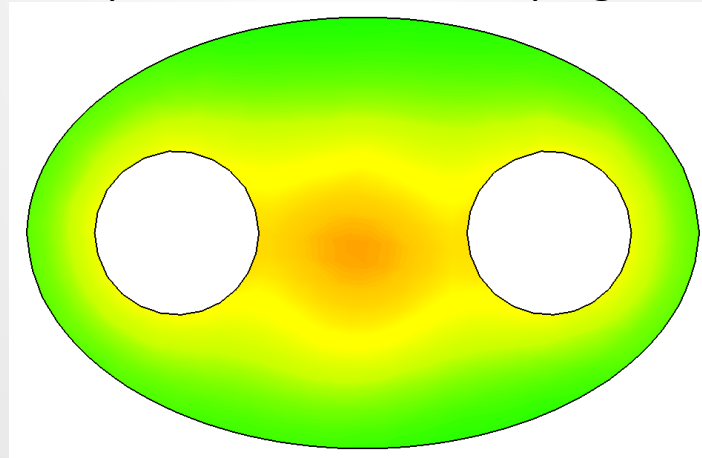
	Part 864 muffler_end_back (front max)	Part 864 muffler_end_back (front avg)
Simple Chamber	275.3	274.7
Open Chamber with Impingement	276.3	224.5
Custom with Interior Pipes	279.1	228.9



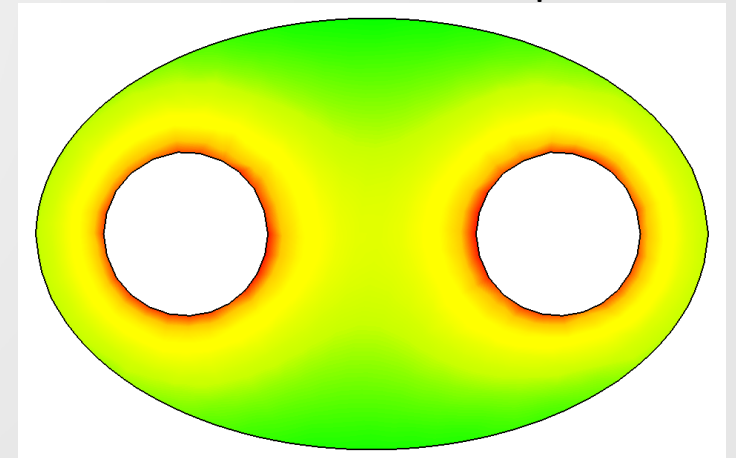
Simple Chambers



Open Chamber with Impingement



Custom with Interior Pipes



# Questions?

# Technical Support Site

- <https://support.thermoanalytics.com>
  - Search FAQ
  - Download Tutorials
  - See Examples
  - Watch Webinar Recordings
  - Request Support
    - Securely upload large files
    - View support requests
    - Or email:  
[techsupport@thermoanalytics.com](mailto:techsupport@thermoanalytics.com)
  - Download Software
  - Post Feature Requests
    - Vote or comment on posted requests

