Kooperation für Anwendung und Innovation der HAW Hamburg und DESY

GIROS

ADVANCED STRUCTURAL OPTIMIZED PETRA IV GIRDER ASSEMBLY SET-UPS

Insights into the Girder Optimized Structures (GIROS) Project at the DESY Engineering and Innovation Day

19th of June 2025

DESY ZM1:
Katharina Bartsch/Martin Lemke/Torsten Ramm/Normann Koldrack

HAW Hamburg:
Jens Telgkamp/Jaco Beckmann/Nils Müller

DESY.

HAW HAMBURG

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ADDITIVE MANUFACTURING AT HAW HAMBURG

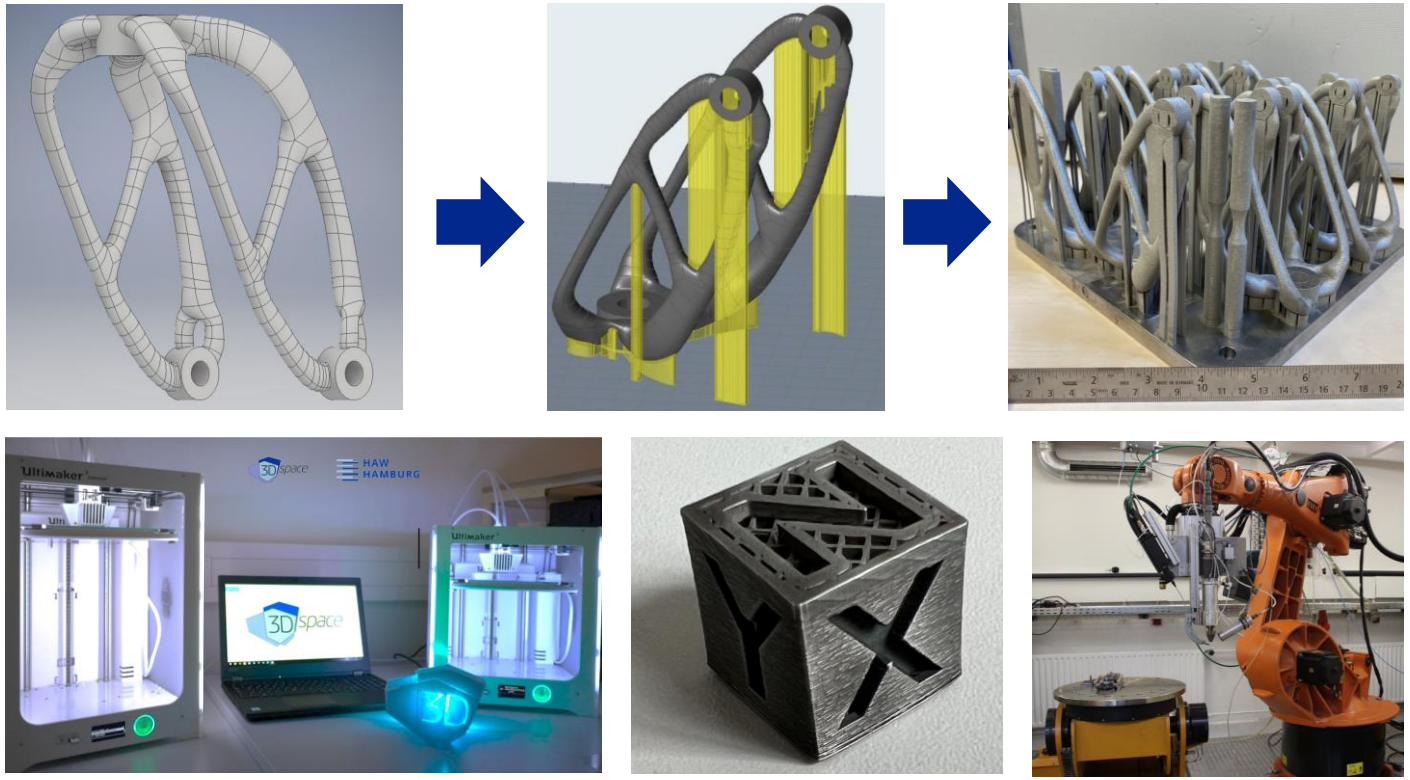
University teaching, Bachelor: ADDFT

- AM technologies (polymers/metals)
- AM process routes

3D Space: Prototyps and components, from and for students with FFF/SLS/DLP

Research:

- Sinter-based process routes (Ti/Al)
- Polymer recycling and quality



Sources: [Haw2025]

Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

SIGNAL

AKROPOLYS
UPCYCLING IN HAMBURG

IFB HAMBURG

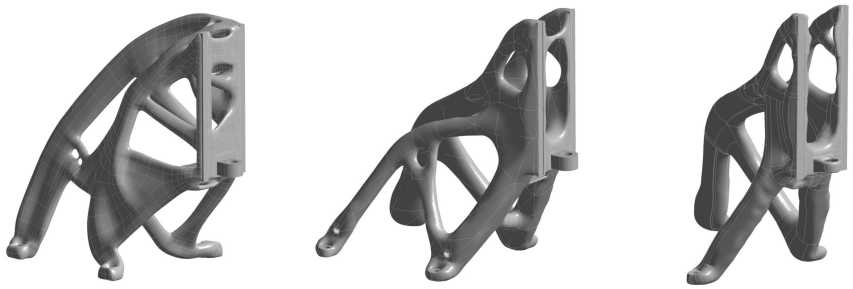
TOPOLOGY OPTIMIZATION AT HAW HAMBURG

CONFIDENTIAL

University teaching, Bachelor: STROP
- Parameter optimization
- Toplogie optimization

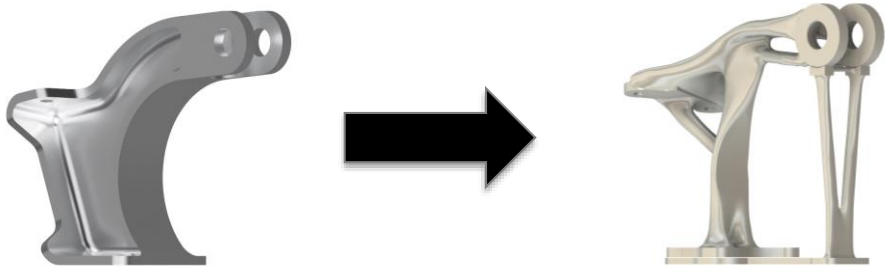
University teaching, Master: TDAF & NLO
- Optimization methods
- Design for additive Manufacturing and Optimization

Research
- Design for sinter-based additive manufacturing
- New optimization- and design algorithms



Source: TDAF-Designs von Müller, Streck, Werth and Andresen [Haw2025]

HEXAGON AUTODESK Fusion 360 nTop Ansys Synera NX SIEMENS



Source: SIGNAL Projekt [Sig2025]

SIGNAL

Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

SIGNAL PROJEKT

Project start: 01. March 2023

Aim:

Development of sinter-based process routes for metallic AM components, cheaper than powder bed processes and ecologically friendly - the focus is on light metals.

HAW SIGNAL Team:

Jaco Beckmann

David Stachg

Fatih Gözüküçük

Jens Telgkamp

SIGNAL

Supported by:

Federal Ministry for Economic Affairs and Climate Action

on the basis of a decision by the German Bundestag

Active partners:

SACS aero space | FEHRMANN MATERIALS | MUT ADVANCED HEATING | Fraunhofer IFAM | element22 | HAW HAMBURG

Associated partners:

DB | SIEMENS | brose Excellence in Mechatronics | Audi | AIRBUS | ZAL | HEXAGON

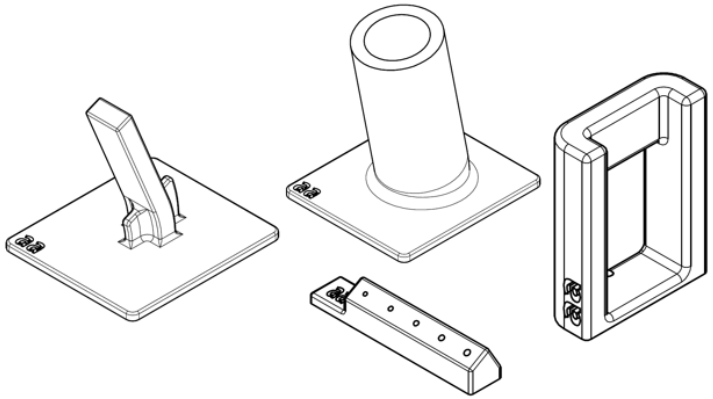
SIGNAL PROJECT

Gefördert durch:
Bundesministerium für Wirtschaft und Klimaschutz
aufgrund eines Beschlusses des Deutschen Bundestages

CONFIDENTIAL

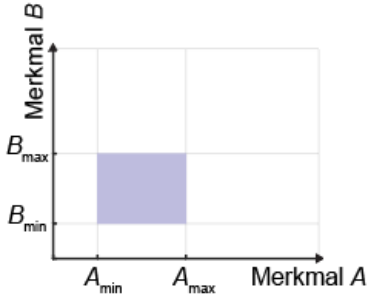
FFF Printer FuseLab FL300M

FGF Printer AIM3D ExAM 255

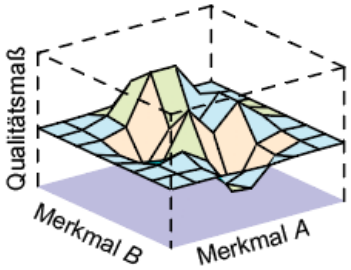


Modified specimen body based on VDI 3405

Source: SIGNAL Projekt [Sig2025]



(a)



(b)

(a) Determination of the process limits
(b) Investigation of the geometric quality

HAWKS Racing Components

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THE BASIS FOR TOPOLOGY OPTIMIZATION

Bionics

Bionic Designs

Topology Optimization

Lattice Structures

Sources: [Vom2025], [Com2025], [Mem2025], [Sig2025], [Gre2025]

BIONICS

Definition of Bionics (also known as biomimetics):

- Transferring natural principles to technology
- “Bionics” is formed by combining the terms biology and technics
  - → Interdisciplinary field of research in which naturally arising processes or structures are adapted to technical developments

Source: [Der2025], [Mem2025]

Prime example: The invention of the aeroplane based on flying birds

Other important inventions based on bionics:

- General applications: Lotus effect, spider silk
- Fasteners: Gecko, burdock, suction cup
- Aircraft construction: Winglet, sharkskin
- Shipbuilding: Sharkskin, floating fern

Sources: [Bio2025], [Zie2025]

BIONIC DESIGNS

Definition of Bionic Designs:
- The use of natural principles to develop high-performance, lightweight structures that are also more durable

→ Modern approach for more efficient lightweight solutions

Generation through optimisations designed to achieve specific goals:

- Topology Optimization
- Generative Design
- Field Optimization

→ The main aim is to recreate natural structures in order to create innovative and sustainable design solutions

Sources: [Bau2025], [Vom2025], [Com2025]

Source: [Lig2025]

Source: [Ame2025]

TOPOLOGY OPTIMIZATION

CONFIDENTIAL

Definition of Topologie Optimization:

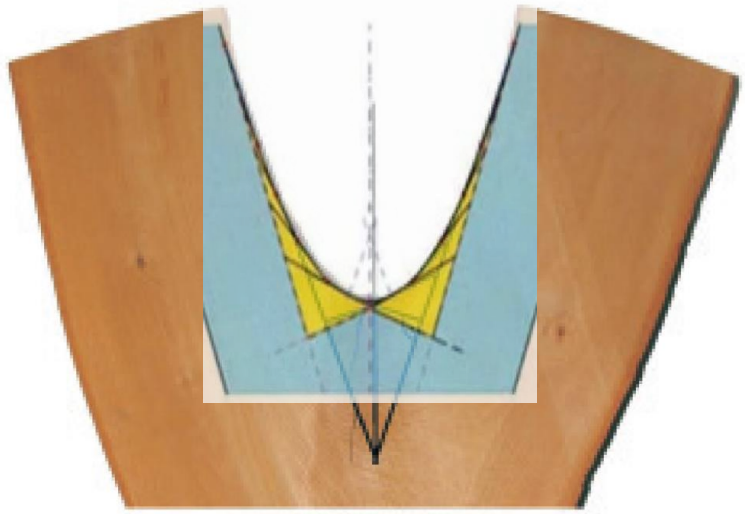
Computer-based calculation of a favourable topology for components under mechanical load

Based on the principle of tree or bone growth:

- Material forms at highly stressed areas
- Notch stresses are avoided as far as possible, which in turn leads to significantly reduced stresses in the component

→ Rounded curves are generated by using the “method of tension triangles” in order to obtain significantly better structures than it is the case with conventional engineering designs

→ Combining Topology Optimization with the design freedom of Additive Manufacturing offers many possibilities!



Sources: [Mat2005], [Mat2008], [Küf2007], [Sig2025]

Source: [Haw2025]

TOPOLOGY OPTIMIZATION

Optimization formulation:

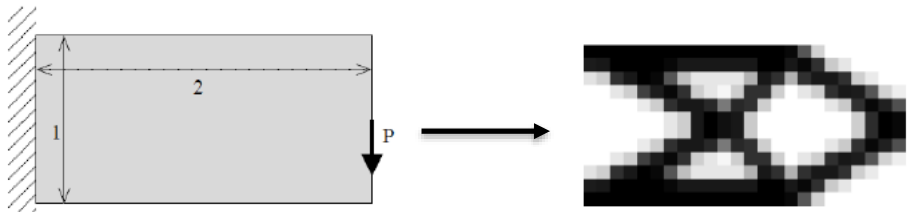
$$\min_{\rho,U} : \Phi(\rho, U)$$
$$s.t. : V(\rho) \leq V^*$$
$$: g_i(\rho, U) \leq g_i^*, \quad i = 2, ..., M$$
$$: \rho_{min} \leq \rho \leq \rho_{max}$$
$$: \mathbf{K}(\rho)\mathbf{U} = \mathbf{F}$$

Objective function

Constraints

Box constraints

State equation (FE)



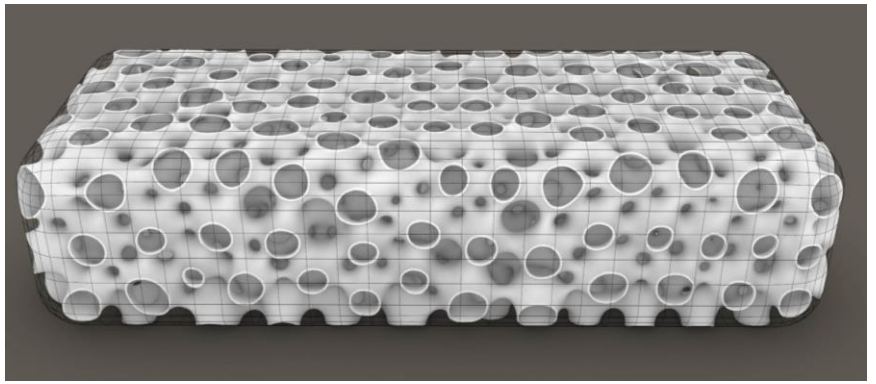
Source: [Dtu2025] [Aut2025]

LATTICE STRUKTUREN

Definition of Lattice Structures:
Cellular lattice structures integrated within a component, similar to the composition of the human bone

Application areas:
- Lightweight designs
- Heat exchanger
- Energy absorber

Additive manufacturing is particularly suitable for producing the lattice structures
→ Challenge: Selecting the right lattice structure for the corresponding application and manufacturing process before integrating it appropriately into the component design



Sources: [Spe2025], [Gre2025]

Source: [Nto2025]

Source: [Ame2025]

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GIROS PROJECT

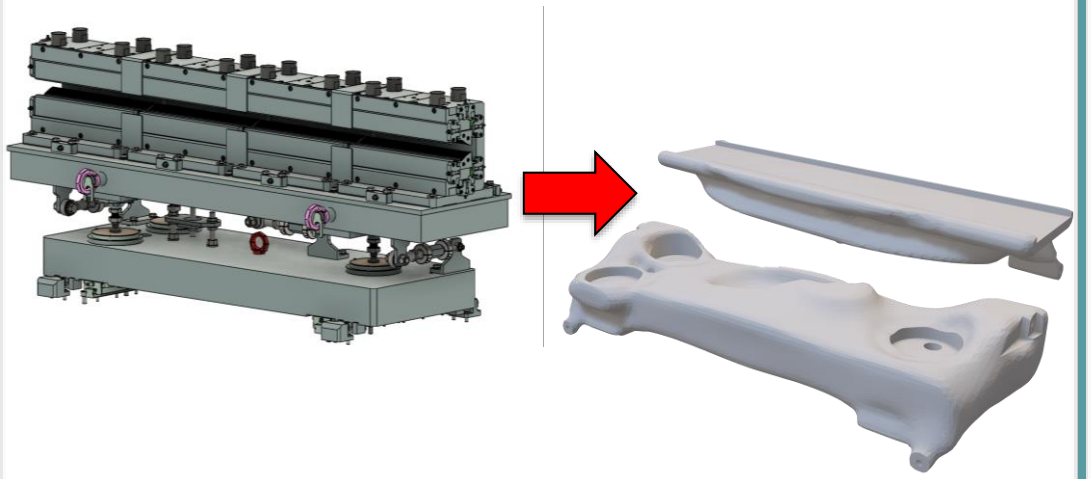
CONFIDENTIAL

Project start: 01. January 2025

Aim:

Development of design concepts for DESY PETRA IV Girder assembly set-ups by applying emerging optimization algorithms - the focus is on aluminium.

Girder Optimized Structures



GIROS

KAI

Partners:

HAW HAMBURG

DESY.

Software:

Ansys

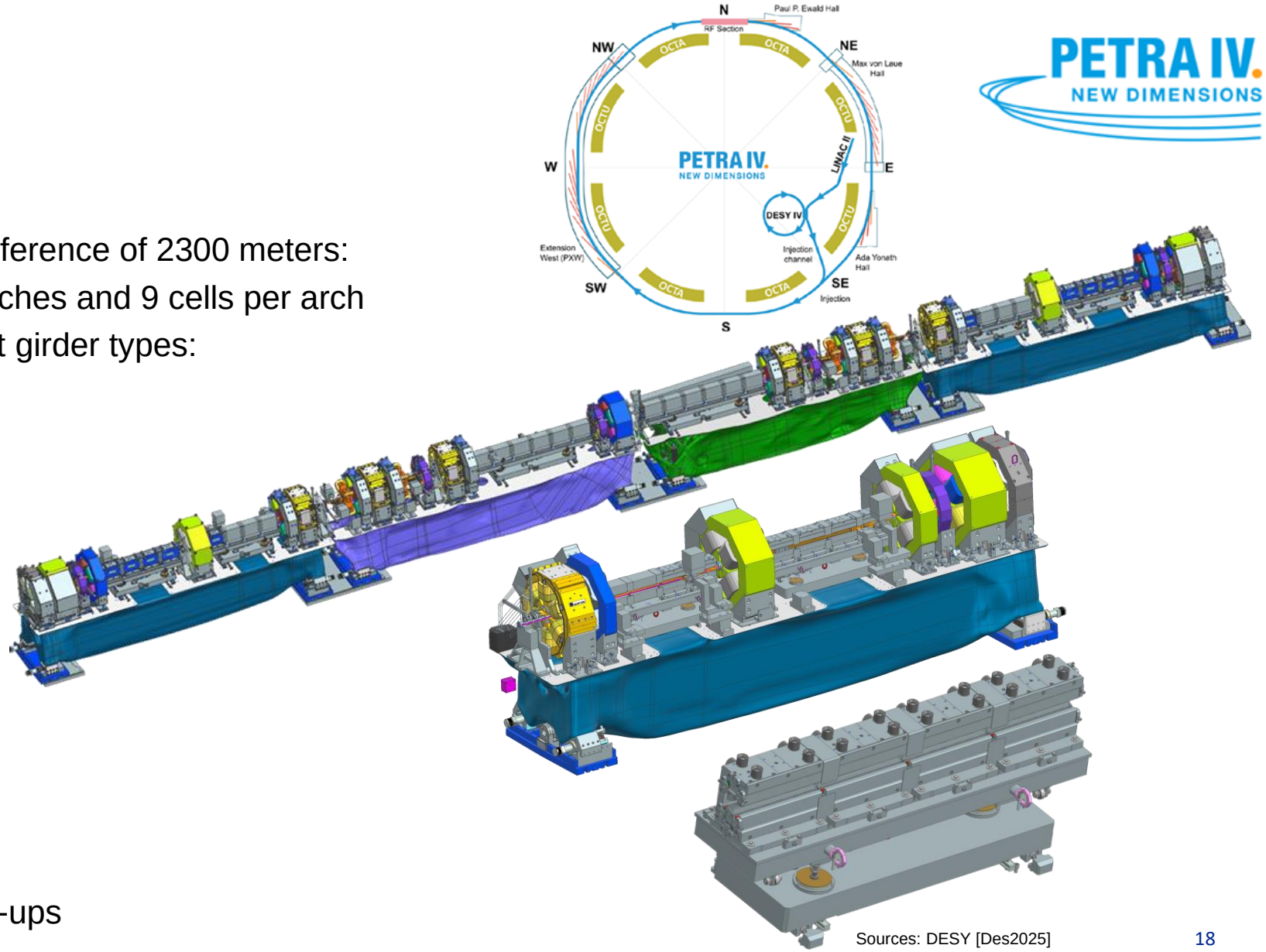
MSC Apex Generative Design

nTop

PETRA IV ACCELERATOR

PETRA IV Circular tunnel has a circumference of 2300 meters:

- Girders are built in a circle with 8 arches and 9 cells per arch
- Four girders per cell, with 4 different girder types:
  - 72x Alpha
  - 72x Beta
  - 72x Gamma
  - 72x Delta
  - → In total 288 Girder
- Girder dimension:
  - 800 mm high
  - 900 mm wide
  - 4000-4700 mm long
- Girder total weight is 12 tons:
  - 5 tons for the Girder itself
  - 7 tons for the assembly set-ups



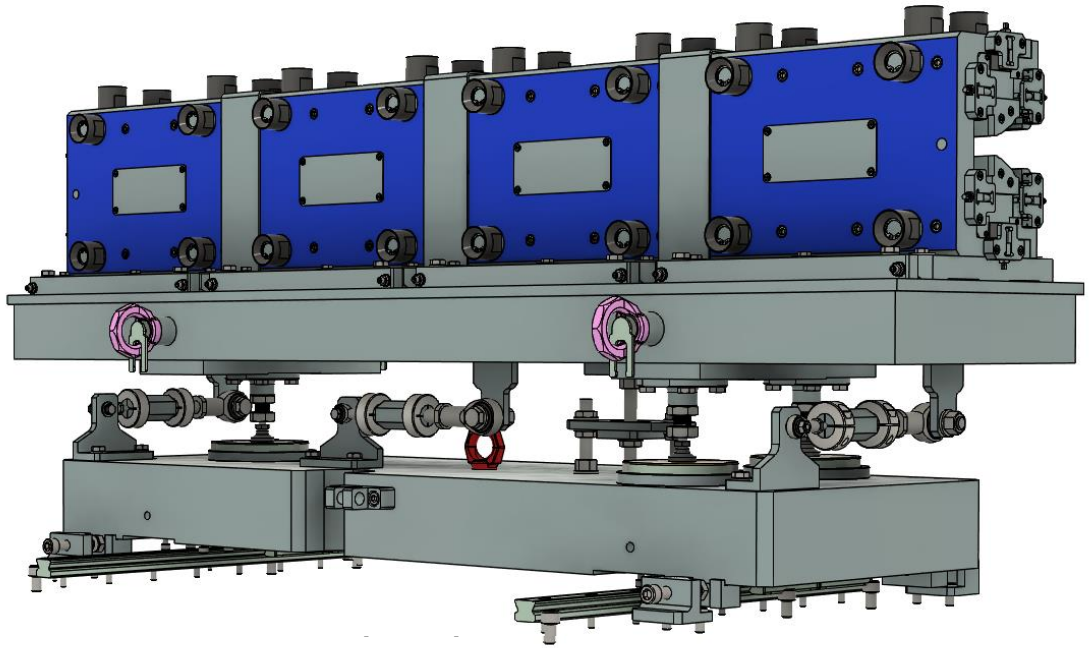
Sources: DESY [Des2025]

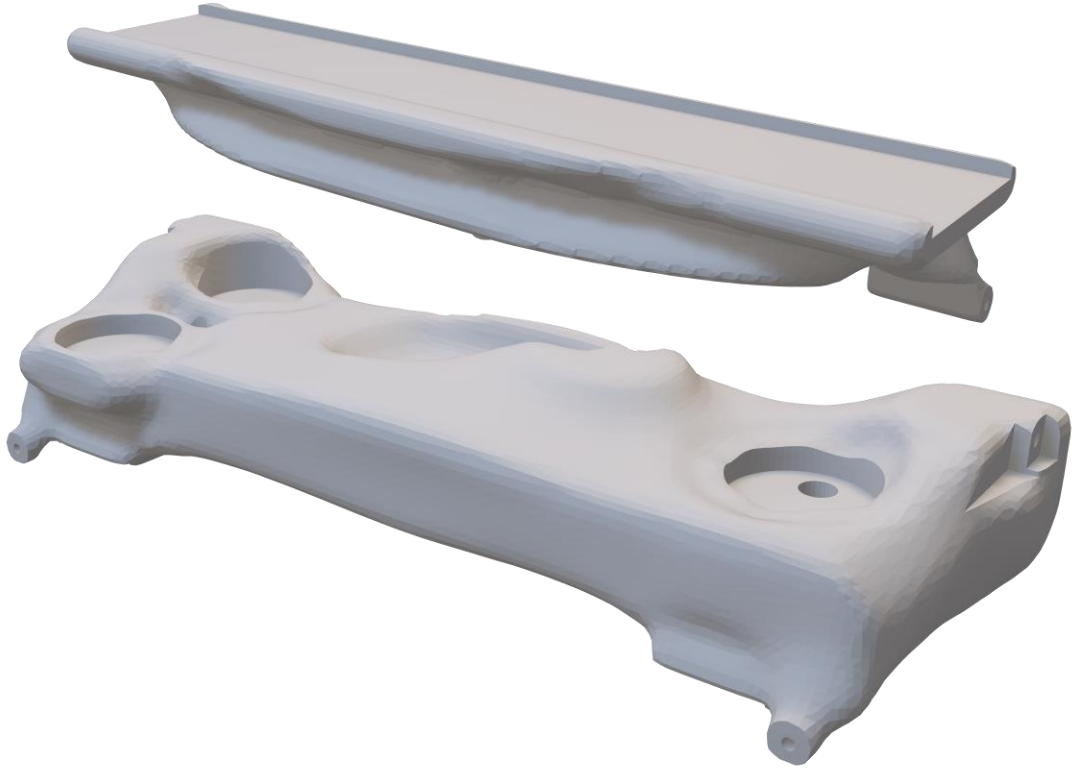
PETRA IV GIRDER AUFBAUTEN

CONFIDENTIAL

Requirements for optimized assembly set-ups for the PETRA IV Girder:

- Lightweight form construction: Weight reduction
- Lightweight material construction: Replacing steel with aluminium
- Frequency optimization: Higher than 100 Hz
- Function integration: Combine all assembly set-up components





THANKS FOR YOUR ATTENTION!

GIROS

HAW HAMBURG

FEEL FREE TO GET IN TOUCH:

JACO BECKMANN
JACO.BECKMANN@HAW-HAMBURG.DE

ZENTRALE MECHANIK 1 AT DESY

Katharina Bartsch
Martin Lemke
Torsten Ramm
Normann Koldrack

GIROS

KAI

DESY.

HAW HAMBURG

QUELLEN

[Haw2025] HAW Hamburg (2025): Interne Dokumente

[Sig2025] SIGNAL Projekt (2025) – BMWK gefördertes Projekt im Zeitraum 2023-2026.

[Gir2025] GIROS Projekt (2025) – KAI Seed gefördertes Projekt im Zeitraum Januar bis Dezember 2025.

[3ds2025] 3D Space (2025): Interne Dokumente

[Des2025] DESY (2025): Interne Dokumente

[Mat2008] Claus Matthek (2008): Zugdreiecke als Universalform, Karlsruher Institut für Technologie.

[Mat2005] Claus Matthek (2005): A most simple graphic way to reduce notch stresses by growth, Karlsruher Institut für Technologie.

[Küf2007] Georg Küffner (2007): Bionik - Der Baum als Vorbild für stabile Technik, Frankfurter Allgemeine Zeitung. https://www.faz.net/aktuell/technik-motor/technik/bionik-der-baum-als-vorbild-fuer-stabile-technik-1485860.html

[Sph2025] Spherene (2025): https://spherene.ch/

[Mem2025] Memon (2025): https://www.memon.eu/blog/was-ist-bionik

[Vor2025] Vomreiter (2025): https://vomreiter.at/blogs/news/wie-die-natur-die-technik-inspiriert

[Dtu2025] Technical University of Denmark (2025): DCAMM TO PhD course

[Ame2025] Created picture by https://www.americanforests.org/article/last-look-garret-suhrie/ and ChatGPT

QUELLEN

[Com2025] Compamed (2025): https://www.compamed.de/de/services/Bionik_Es_w%C3%A4re_sch%C3%B6n,_wenn_die_Menschen,_die_im_Bereich_Medizintechnik_arbeiten,_h%C3%A4ufiger_einen_Blick_in_die_Natur_werfen_w%C3%BCrden

[Gre2025] Green up your Future (2025): https://www.green-up-your-future.de/was-ist-bionik/

[Der2025] Der Standard (2025): https://www.derstandardde./consent/tcf/story/2000133299453/bionik-dinge-welche-die-natur-erfunden-hat

[Bau2025] Baubiologie (2025): https://baubiologie.de/wissen/baubiologie-magazin/handwerk-im-bau-ausbau/bionik-und-baubiologie/

[Lig2025] Lightbau (2025): Ein Leitfaden zu modernen Optimierungsmethoden im Leichtbau https://lightbau.de/bionisches-design-ein-leitfaden-zu-modernen-optimierungsmethoden-im-leichtbau/

[Nto2025] Ntop (2025): https://www.ntop.com/software/capabilities/lattice-structures/

[Bio2025] Biokon (2025): https://www.biokon.de/bionik/was-ist-bionik/

[Zie2025] Ziehl-Abbegg (2025): https://www.ziehl-abegg.com/glossar/bionik-biomimetik#:~:text=Die%20Bionik%20(auch%20Biomimetik%20oder,in%20kreativen%20technischen%20Konstruktionen%20adaptiert.

[Aut2025] Automotivepowertraintechnologyinternational (2025): https://www.automotivepowertraintechnologyinternational.com/features/powertrain-focus-czinger-21c-the-3d-printed-hypercar.html

ANHANG

- SIGNAL Projekt
- TDAF Master Modul

SIGNAL PROJEKT (BMWK TECHNOLOGIETRANSFERPROGRAMM LEICHTBAU)

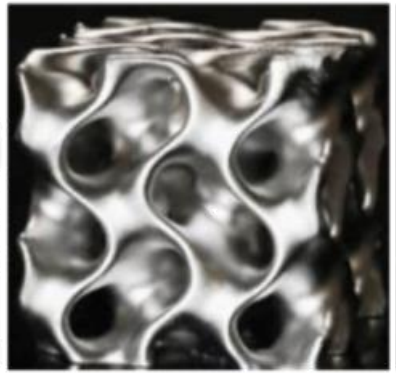
Gefördert durch:

Bundesministerium
für Wirtschaft
und Klimaschutz

aufgrund eines Beschlusses
des Deutschen Bundestages

Technologien / Prozessketten in SIGNAL:

MoldJet



Gelcasting

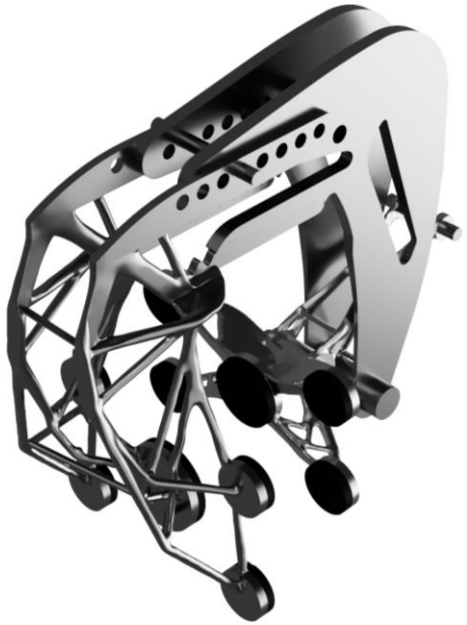
Cold Metal Fusion

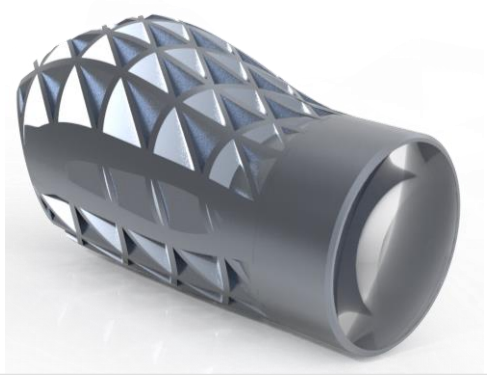
FFF/FGF

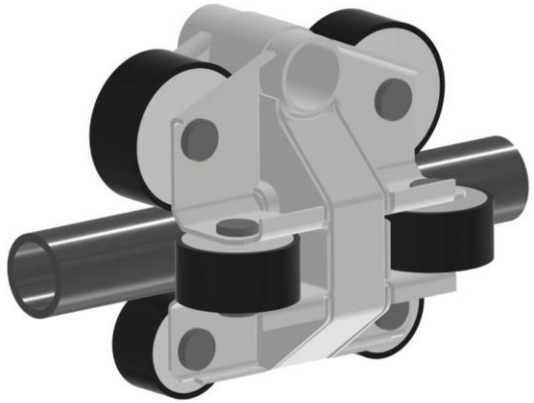
Binder Jetting
LMM (Incus)

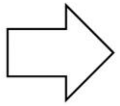
EINIGE BEISPIELE AUS TDAF

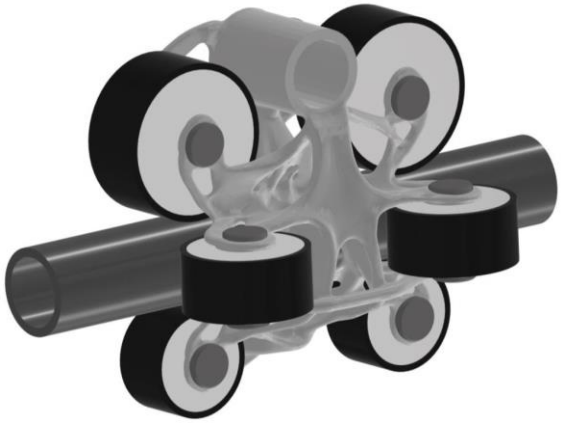
Einige Beispiele für TDAF Bauteile:







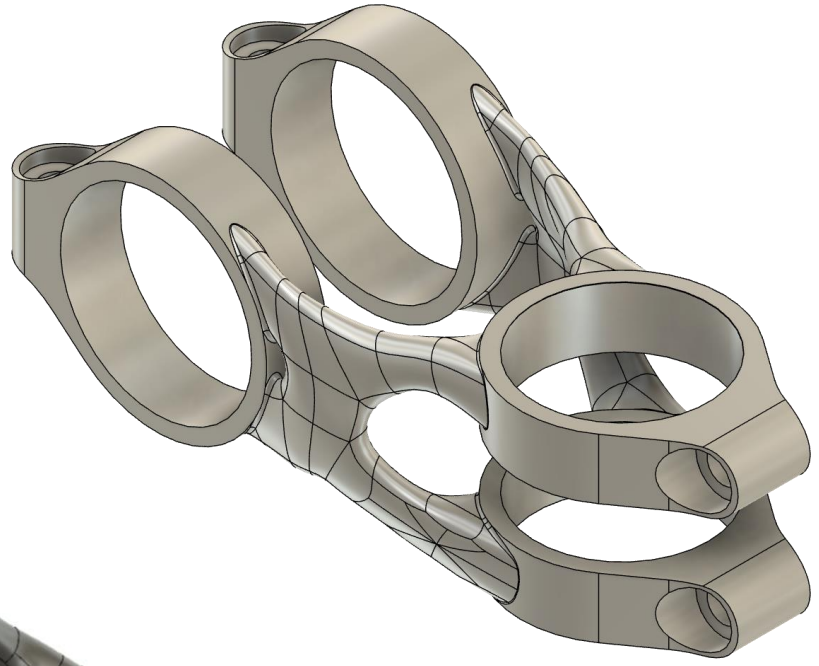




Sources: TDAF students teams, with friendly approval

EINIGE BEISPIELE AUS TDAF

Einige Beispiele für TDAF Bauteile:

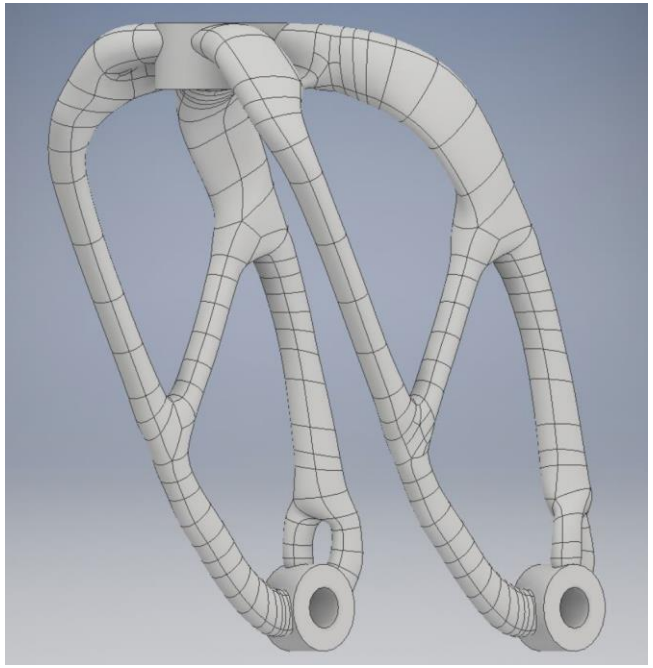


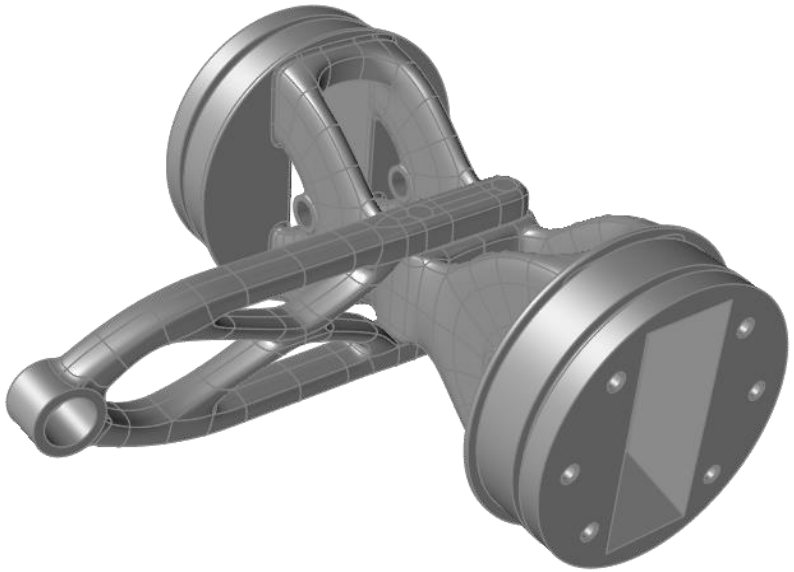
☑ Die Komplexität der Bauteile variiert stark!
Die Tiefe der jeweils erwarteten Detaillierung/Analyse muss angepasst werden!

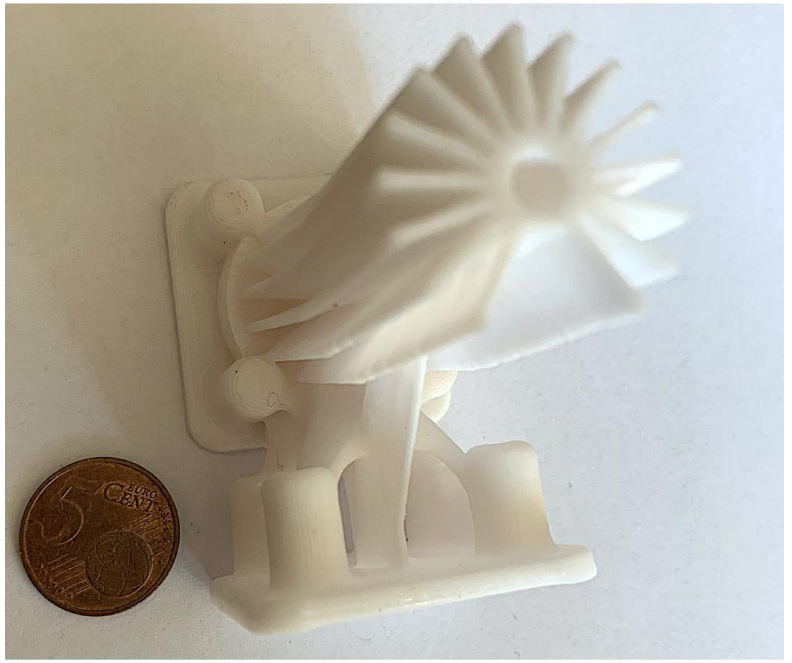
Sources: TDAF students teams, with friendly approval

EINIGE BEISPIELE AUS TDAF

Einige Beispiele für TDAF Bauteile:





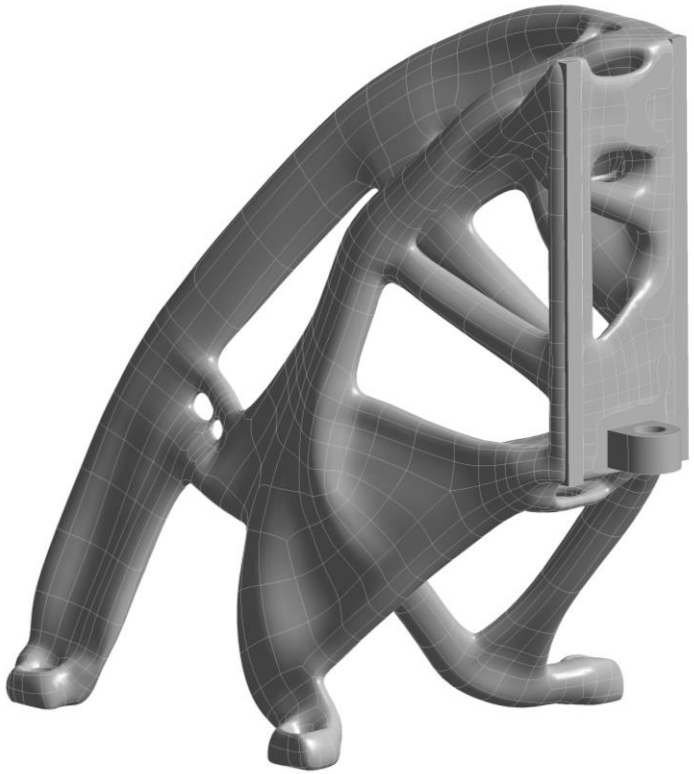


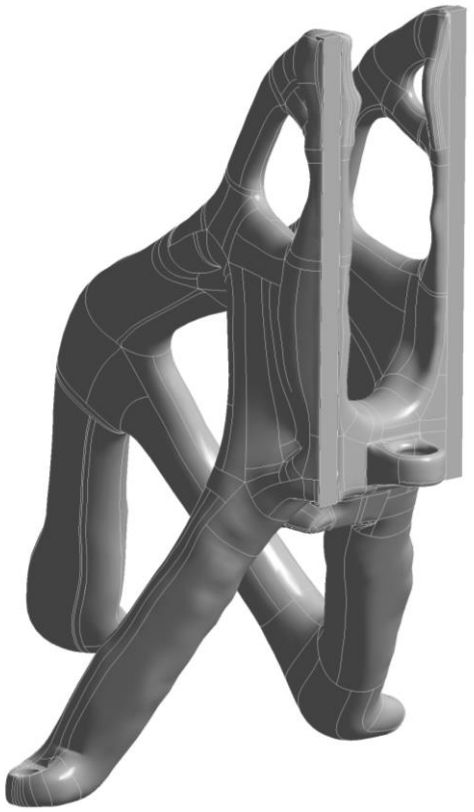
☑ Die Teams werden zur Zusammenarbeit mit FabLabs und zur Herstellung von Anschauungsprototypen ermutigt.

Sources: TDAF students teams, with friendly approval

EINIGE BEISPIELE AUS TDAF

Einige Beispiele für TDAF Bauteile:





☑ Trend: Hersteller von Optimierungssoftware setzen auf unterschiedliche Solver.
Unsere Studierenden erleben die Unterschiede

Sources: TDAF students teams, with friendly approval

TDAF MASTERMODUL
FREIE WAHL DER TOOLS IN DEN KONSTRUKTIONSTEAMS

Beispiele für Konstruktionsaufgaben und von den Teams benutze Tools:

- Steifigkeitsoptimierte Mikroskophalterung: nTop, NX SIEMENS, Ansys, 3DSPARK, Netfabb
- E-Scooter Struktur: HEXAGON, AUTODESK FUSION, 3DSPARK
- Einpresswerkzeug: Synera, NX SIEMENS, 3DSPARK, Ansys, Netfabb, Ultimaker Cura
- Kfz-Tuning-Federbein: AUTODESK FUSION, Ansys, simufact, 3DSPARK
- … (schon ca. 65 Projekte in sieben Semestern durchgeführt)