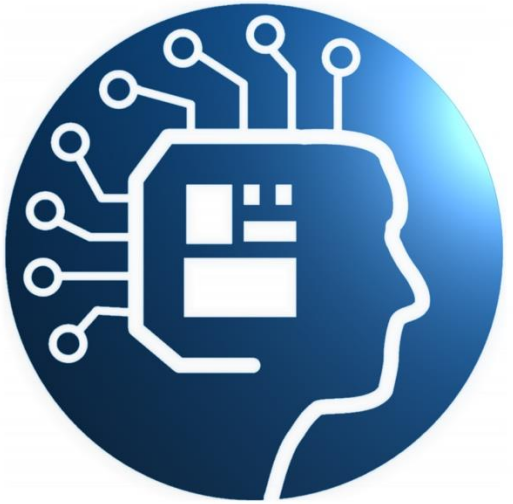
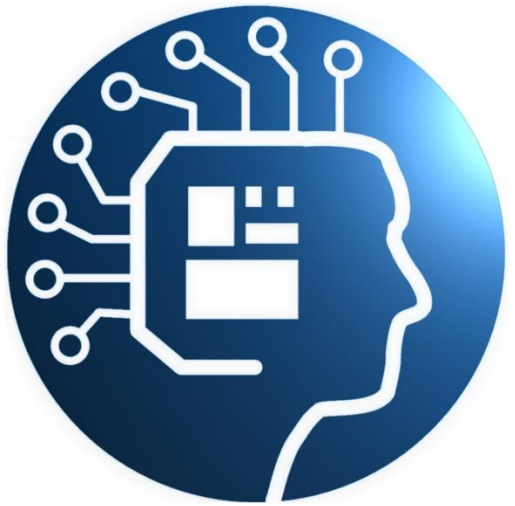
# Welcome Note

Daniele Jahier Pagliari, Politecnico di Torino
daniele.jahier@polito.it



The AMBEATion project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be made of them.

# Meeting Agenda



The AMBEATion project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be made of them.

# Meeting Agenda

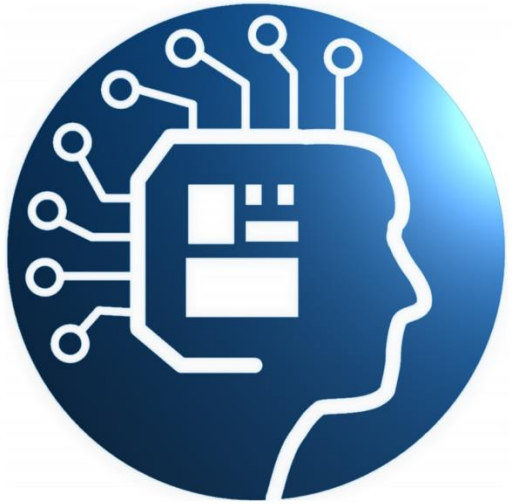
| Start Time | Title | Speaker |
|---|---|---|
| 15:00 | **Welcome Note – Lessons Learned from the AMBEATion Project** | Daniele Jahier Pagliari<br>**Politecnico di Torino** |
| 15:20 | **Effective Analog ICs Floorplanning with Relational Graph Neural Networks and Reinforcement Learning** | Davide Basso<br>**University of Trieste** |
| 15:40 | **Learning to Act like a Pro: Discovering Procedural Models of Expert Workflows for Assistance and Validation** | Antonino Furnari<br>**University of Catania** |
| 16:00 | **The AI Revolution in ST Design Flow** | Michelangelo Grosso<br>**ST Microelectronics** |
| 16:20 | **A Modern Solution for Analog/Mixed-Signal Design** | Marco Inglardi<br>**Synopsys** |
| 16:40 | **A Follow-up to the AMBEATion Project** | Dalibor Barri<br>**ST Microelectronics** |

European Commission

The AMBEATion project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be m ade of them.

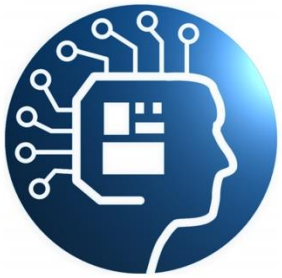
Marie Skłodowska-Curie Actions

# Lessons Learned from the AMBEATion Project



Daniele Jahier Pagliari, Politecnico di Torino
daniele.jahier@polito.it

The AMBEATion project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be made of them.



# The AMBEATion Project

- *Analog/Mixed Signal Back End Design Automation based on Machine Learning and Artificial Intelligence Techniques*

- Marie Skłodowska Curie Research and Innovation Staff Exchange Action (MSCA-RISE)

- Sep. 1st  2021 – Aug. 31st 2025

European Commission

The AMBEATion project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be m ade of them.

Marie Skłodowska-Curie Actions

# AMBEATion's Consortium

Politecnico di Torino

UNIVERSITÀ degli STUDI di CATANIA

ČVUT ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE

life.augmented

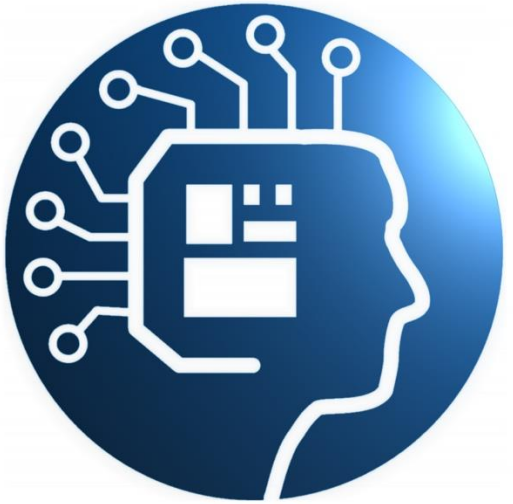
SYNOPSYS®

European Commission

The AMBEATion project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be m ade of them.

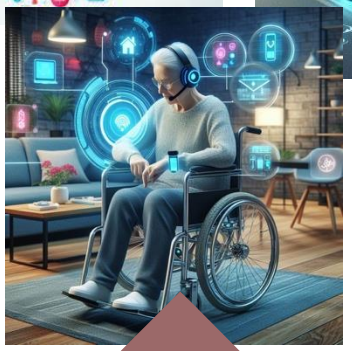
Marie Skłodowska-Curie Actions

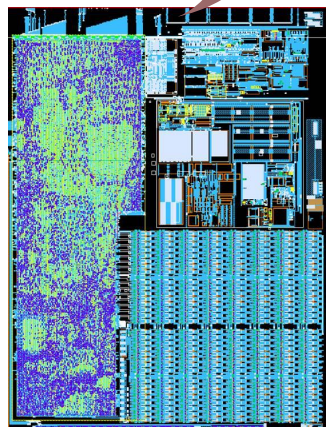
# Context and Motivation



The AMBEATion project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be made of them.

# Context and Motivation



- **Analog Mixed-Signal (AMS) ICs** are pervasive:
  - Internet of Things (IoT), Smart & Autonomous Driving, Active Assisted Living (AAL)
  - **Digital blocks** → computational tasks
  - **Analog blocks** → power conversion, A/D and D/A conversion, actuation, thermal/voltage/current sensing, signal conditioning, etc.

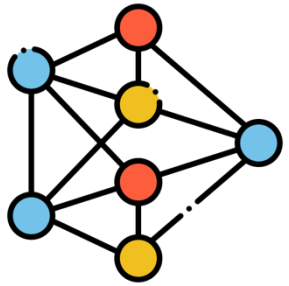
European Commission

The AMBEATion project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be m ade of them.

Marie Skłodowska-Curie Actions

# Context and Motivation

- Digital EDA tools have achieved remarkable levels of back-end automation.
- Analog (and thus AMS) back-end, instead, is still mostly done **manually** by experienced designers.
  - Sensitivity to Well Proximity Effect, Shallow Trench Isolation stress, thermal gradients, mismatch, process variations, etc.
  - More complex constraints: gain, bandwidth, distortion, etc, different for each class of devices.
  - No standard cells…
- Problem studied for decades. What's new?

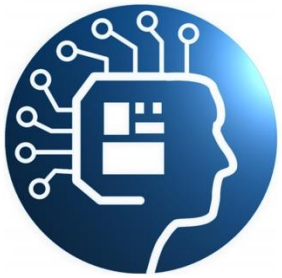


**Question: Can AI and ML help automating AMS BE?**

European Commission

The AMBEATion project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be m ade of them.

Marie Skłodowska-Curie Actions



# State-of-the-Art

- AI and ML have been introduced in the EDA industry since several years:
  - Improve scalability, computational efficiency and QoR in different parts of the digital flow
  - A wide gap still exists within the analog domain [1]

- Some recent initiatives investigated AI/ML for AMS Back-End:
  - US DARPA IDEA Program (ALIGN Project)
  - US NSF
  - Taiwan‘s Ministry of Science and Technology
  - etc.

*[1] B. Nikolic, “ML for analog design: Good progress, but more to do,” in ACM/IEEE MLCAD, 2022*

European Commission

The AMBEATion project has received funding from the European Union’s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be m ade of them.



Marie Skłodowska-Curie Actions

# The AMBEATion Project

- **Objective:** Develop **Electronic Design Automation (EDA)** methodologies, based on AI/ML to enhance the productivity of AMS physical design
  - Increase designers' productivity → Reduce design costs
  - Mainly targeting the AMS **placement** phase.
  - Strong focus on **training, staff education and knowledge exchange** (as per MSCA goals).

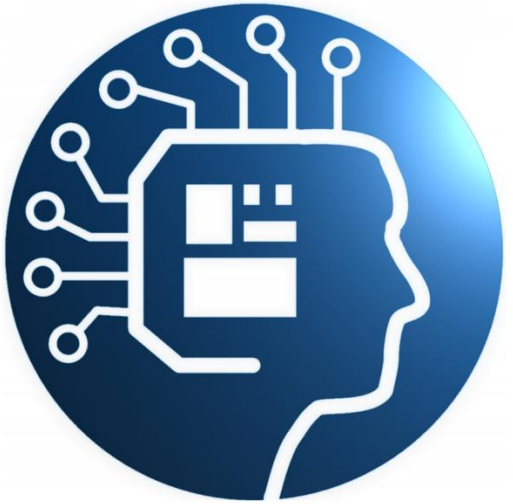
**Project Website:**
**ambeation.polito.it**

European Commission

The AMBEATion project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be m ade of them.

Marie Skłodowska-Curie Actions

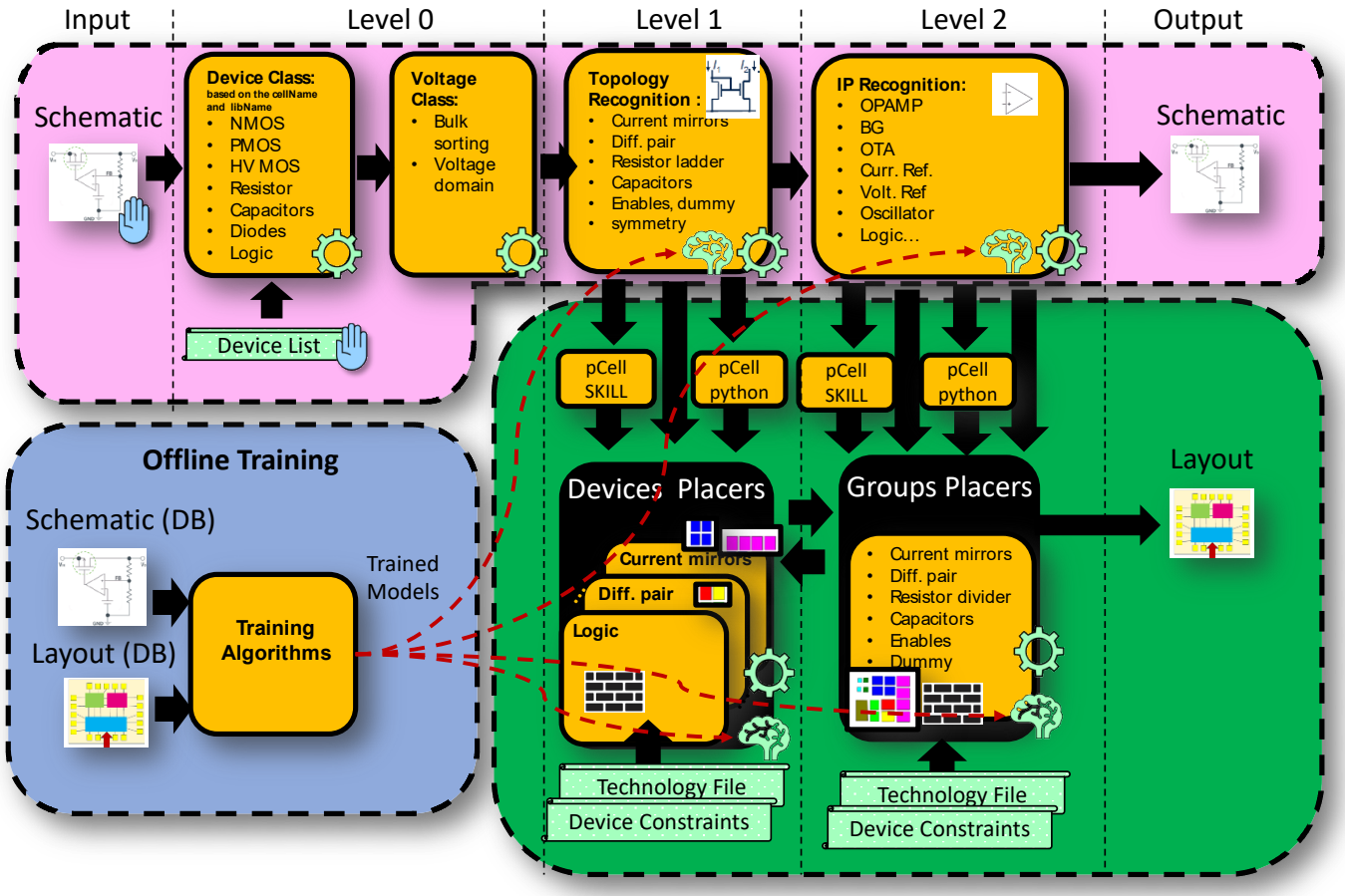
# Current Status and Results



The AMBEATion project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be made of them.

# The AMBEATion Flow

- Mix of *top-down* (digital-like) and *bottom-up* philosophies
- Two sections: schematic and layout
  - Plus offline training for ML
  - Organized in levels (input, device, group, etc).
- Industrial I/O formats:
  - OA, CDL, GDS-II.




European Commission

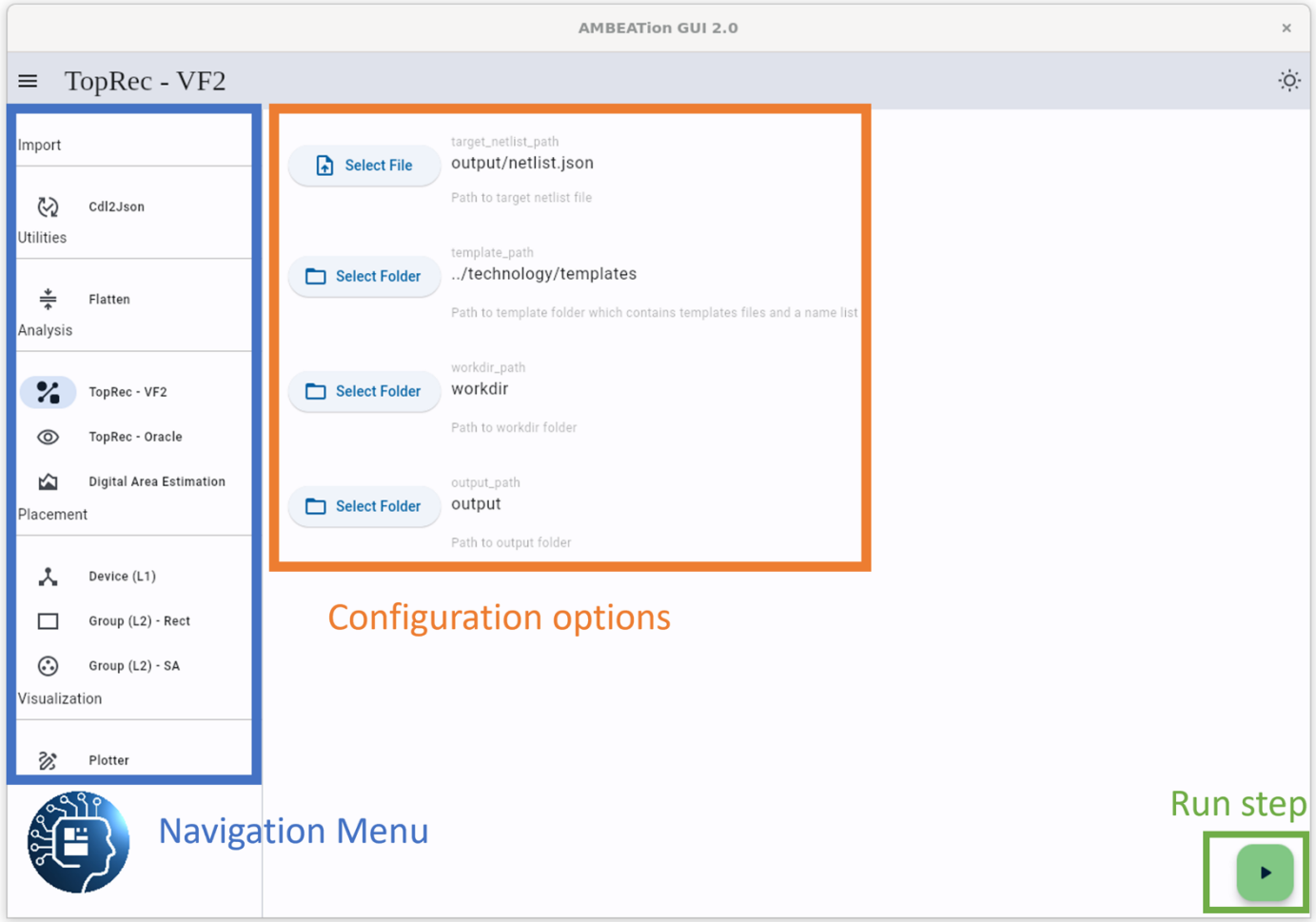
The AMBEATion project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be m ade of them.



Marie Skłodowska-Curie Actions

# The AMBEATion Autoplacer Tool

- Implementation of the flow shown in previous slides
- Entirely Python-based
- Modular interconnection of independent SW components using JSON-based internal DB files.
- Simple GUI and CLI




European Commission

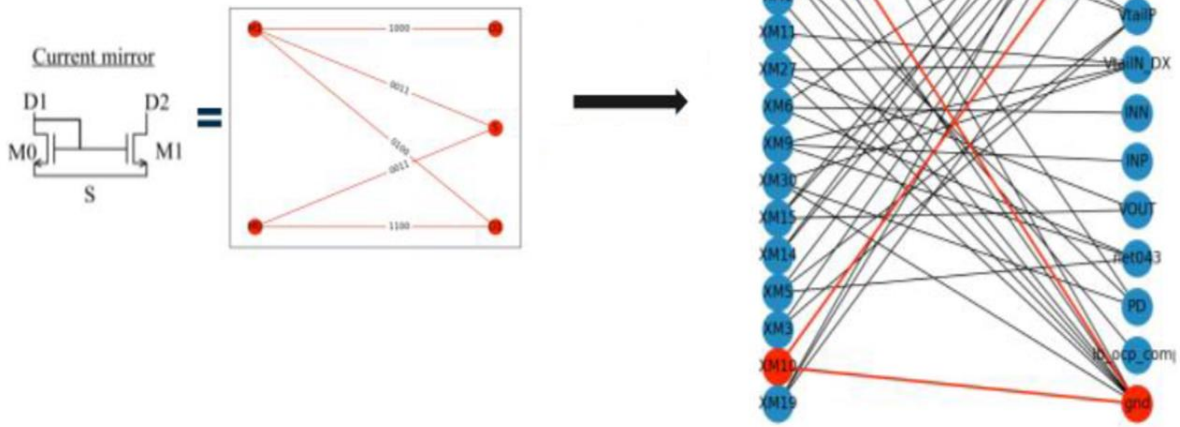
The AMBEATion project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be m ade of them.



Marie Skłodowska-Curie Actions

# Zoom-in #1: Topology Recognition

- Find topologies (CM, DP, etc) in a bipartite graph representation of a netlist
- Classic approach: convert topology template to bipartite graph too, and apply subgraph isomorphism
  - e.g. VF2/VF3 algorithms




- Main limitation: ex. time for large netlists (hours/template)

European Commission

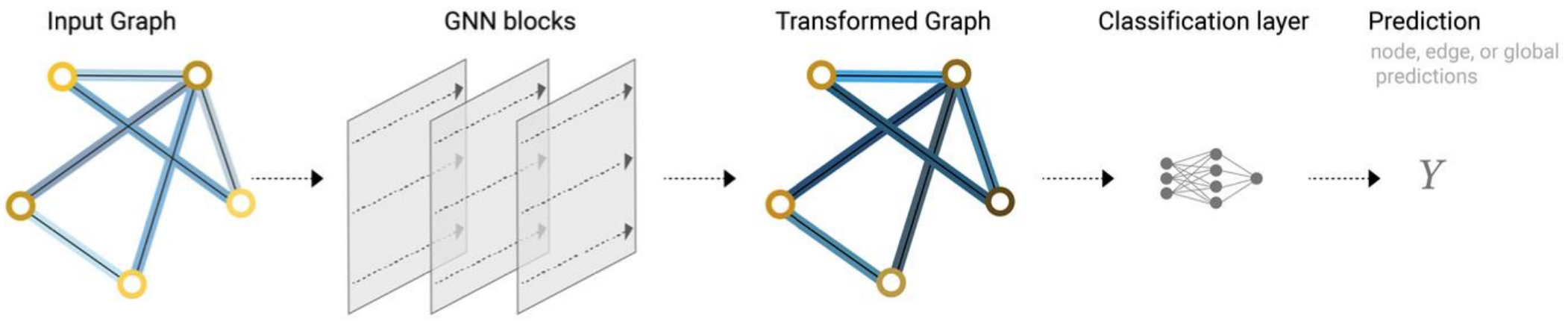
The AMBEATion project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be m ade of them.



Marie Skłodowska-Curie Actions

# Zoom-in #1: Topology Recognition

- ML-based approach: apply Graph Neural Network (GNN) to target netlist and assign “probability of being part of a topology” to each node.




- Faster but possibly inaccurate…

[source] https://distill.pub/2021/gnn-intro/

European Commission

The AMBEATion project has received funding from the European Union’s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be m ade of them.



Marie Skłodowska-Curie Actions

# Zoom-in #1: Topology Recognition

- AMBEATion's Solution:
  - Hybrid GNN + VF2 approach
  - Use GNN to quickly identify cells belonging to a topology with "high-probability"
  - Filter-out false positives with deterministic algorithm (VF2)
- Example of results (on CMs):

| Metric | VF2 | RGCN (with pre-processing) | RGCN + VF2 |
|---|---|---|---|
| **Accuracy** | 99.99% | 99.48% | 99.99% |
| **Precision** | 96.41% | 30.62% | 96.62% |
| **Recall** | 98.60% | 99.48% | 99.48% |
| **Execution Time** | 10h 54min | 60s | 1min 57s |

European Commission

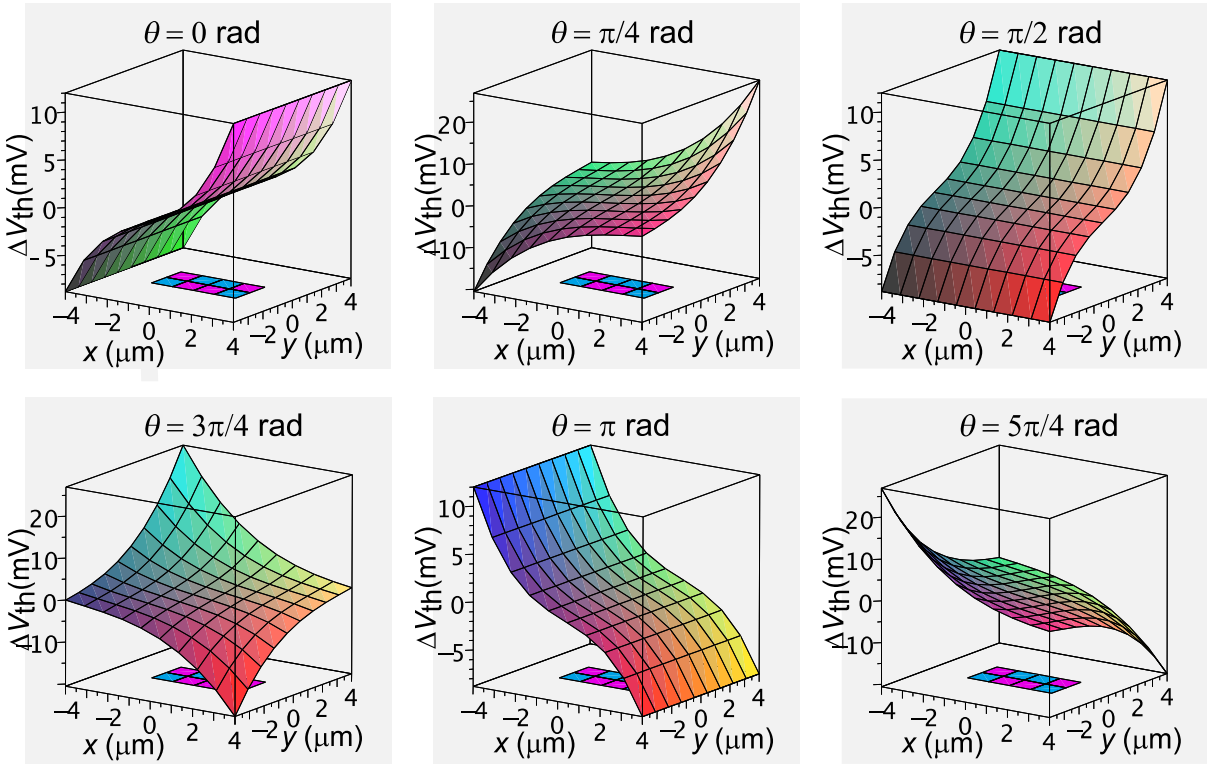
The AMBEATion project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be m ade of them.



Marie Skłodowska-Curie Actions

# Zoom #2: Device Placer

- Novel Simulated Annealing (SA)-based placement algorithm to minimize systematic device **mismatch** (due to known parasytic effects).
- Based on approximating the gradient of mismatch w.r.t. (x, y) involved devices distances as a polynomial
- Graphs: $\Delta V_{th}$ as an example of parameter influenced by mismatch



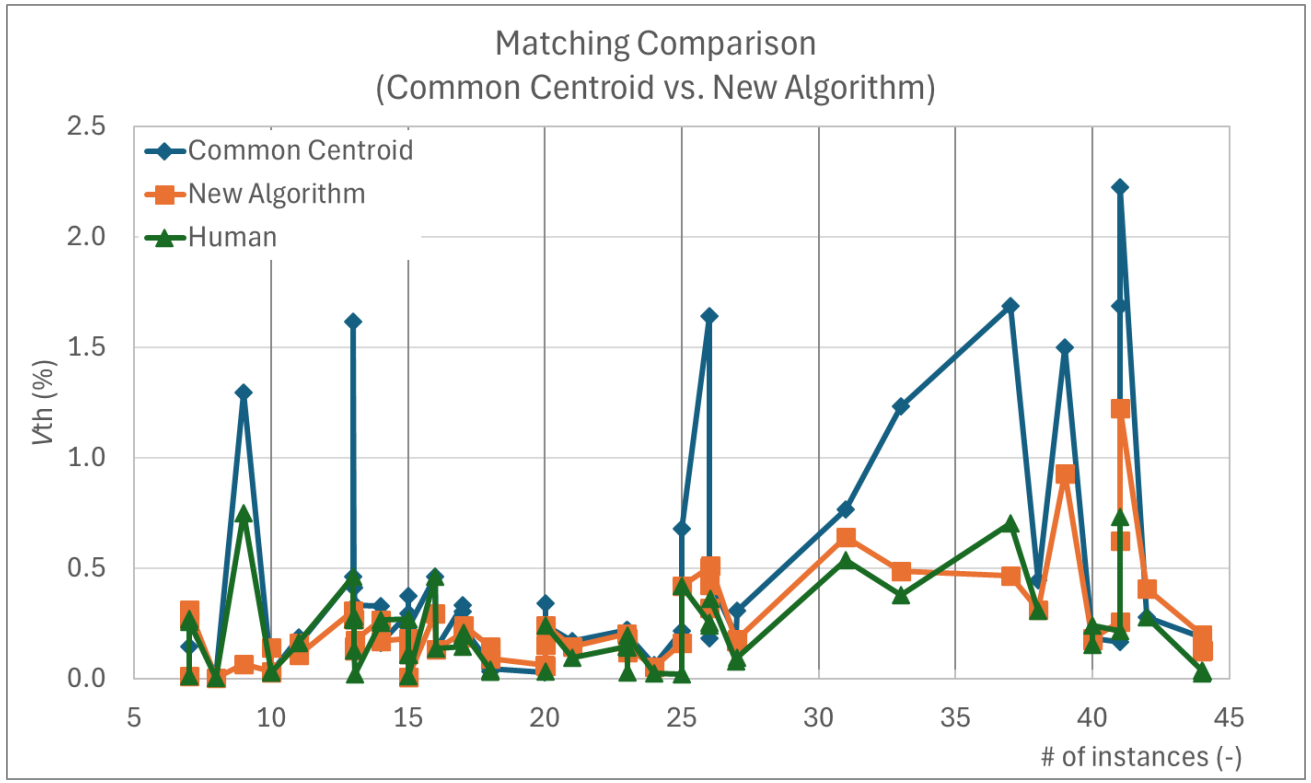

European Commission

The AMBEATion project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be m ade of them.

Marie Skłodowska-Curie Actions

# Zoom #2: Device Placer

- Results consistently better than previous algorithm (Common Centroid) and often comparable with human-made layouts in terms of matching.

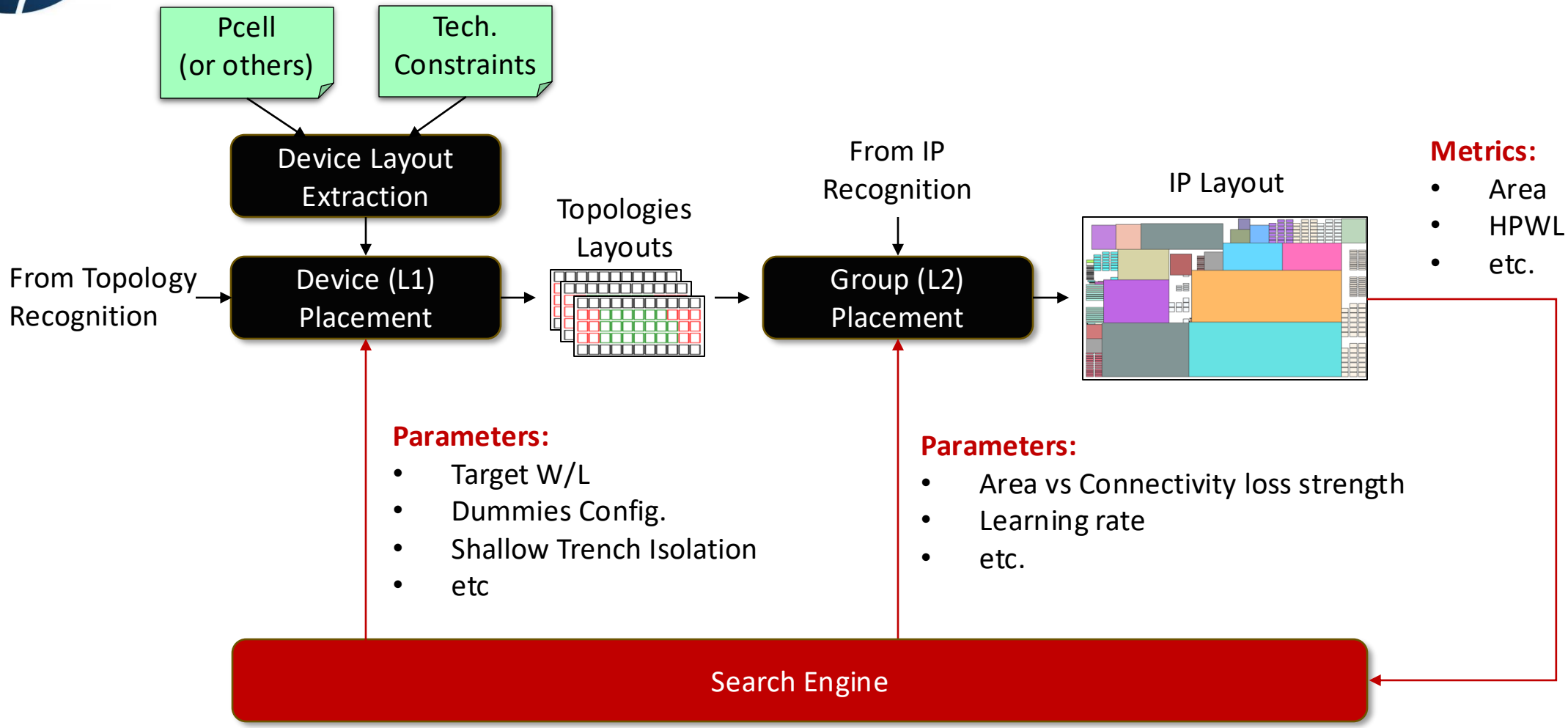



European Commission

The AMBEATion project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be m ade of them.

Marie Skłodowska-Curie Actions

# Zoom-in #3: Device/Group Placement



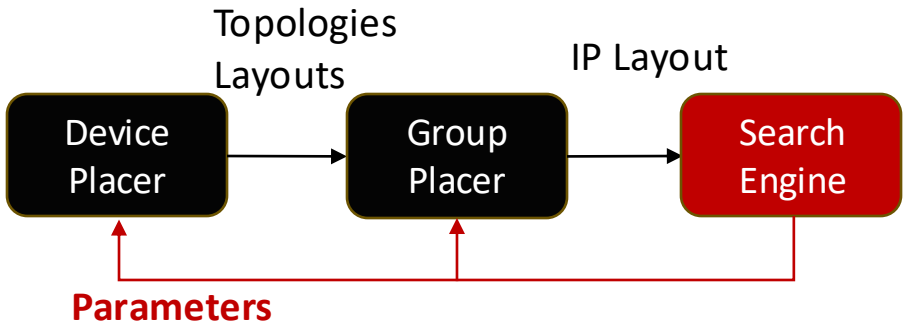

European Commission

The AMBEATion project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be m ade of them.

Marie Skłodowska-Curie Actions

# Zoom-in #3: Device/Group Placement

- **Alternative Group Placer Implementations**:
  - Rectangle Placer (baseline)
  - Simulated Annealing
  - Non-Linear Programming




- **Search Engine**:
  - Bayesian Optimization
  - Reinforcement Learning (with NN-based reward model)

European Commission

The AMBEATion project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be m ade of them.

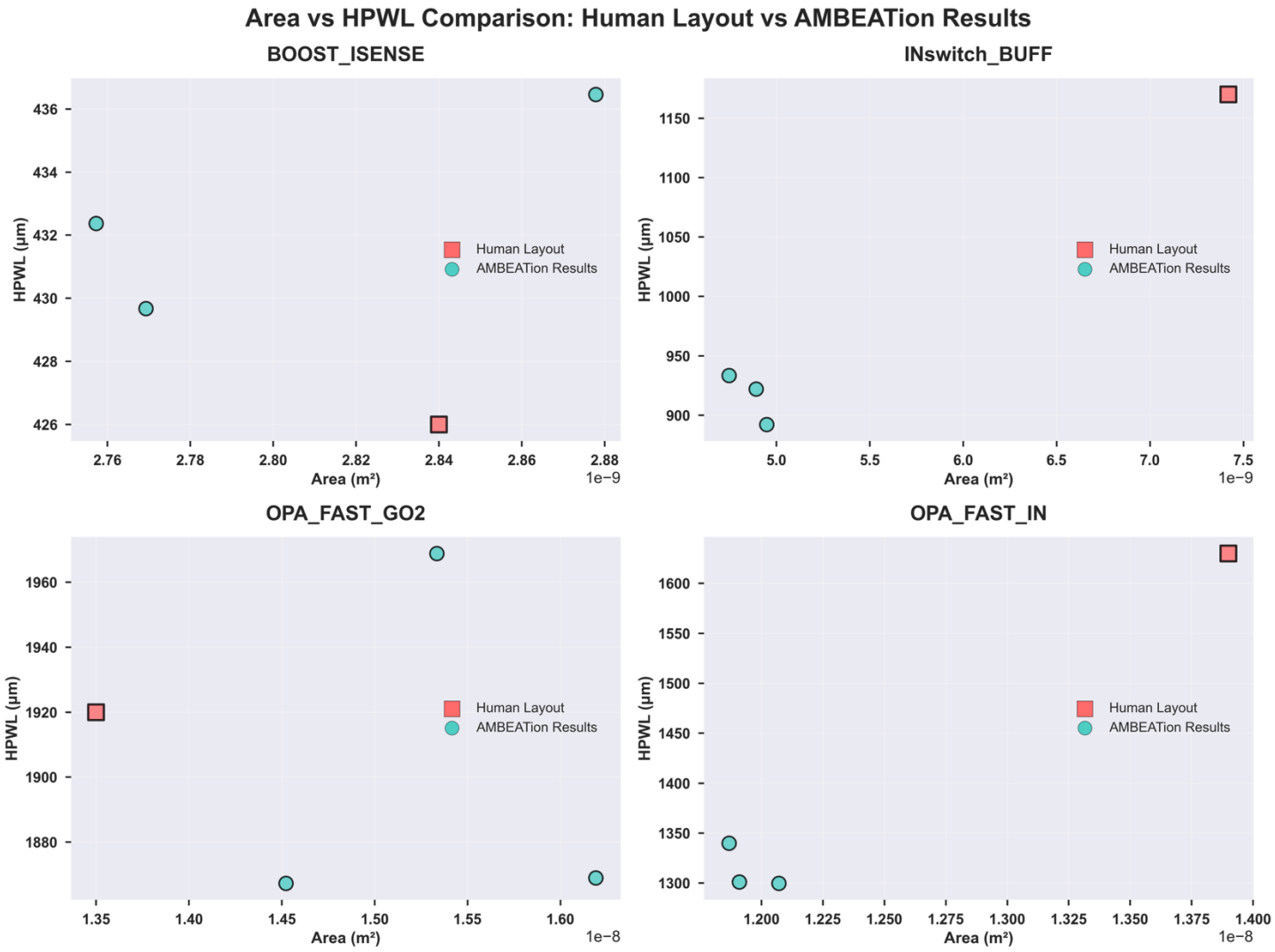
Marie Skłodowska-Curie Actions

# Zoom-in #3: Device/Group Placement

- Results:

  - Flow outputs are **Pareto-optimal** or **dominating** human-made layout (w.r.t. the considered metrics)

  - These are still relatively small circuits (200/300 devices).





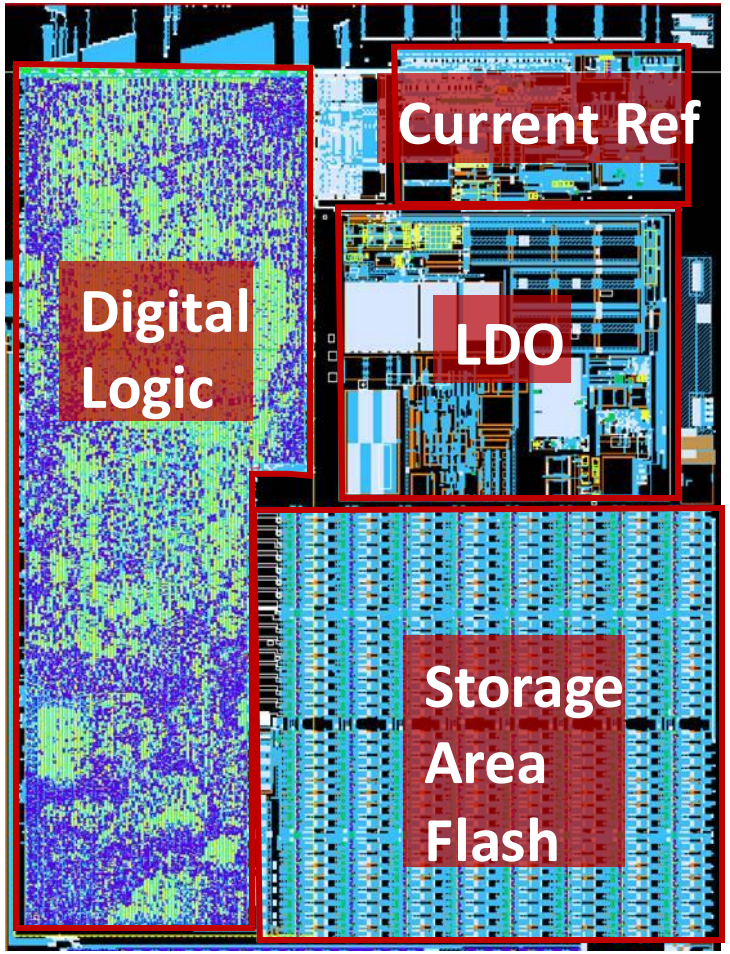
European Commission

The AMBEATion project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be m ade of them.

Marie Skłodowska-Curie Actions

# Zoom-in #4: Digital Placeability

- Analog-on-top AMS ICs can contain large digital blocks:
  - Placed with SotA EDA tools in dedicated layout regions
  - Often requires multiple iterations between analog and digital teams




European Commission

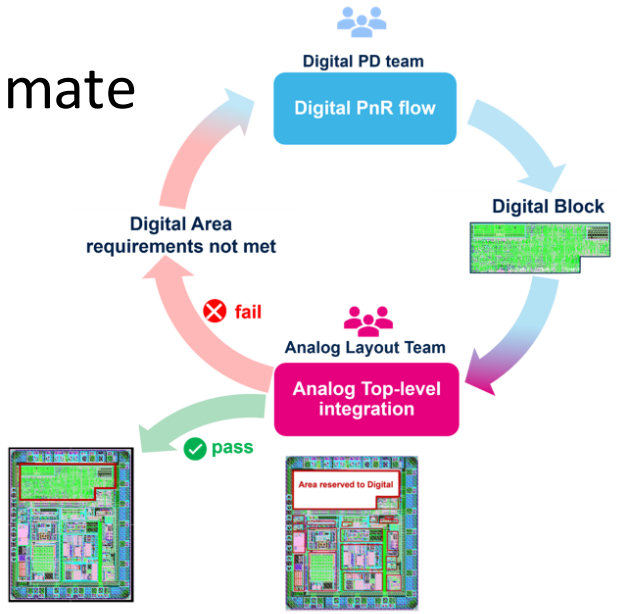
The AMBEATion project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be m ade of them.

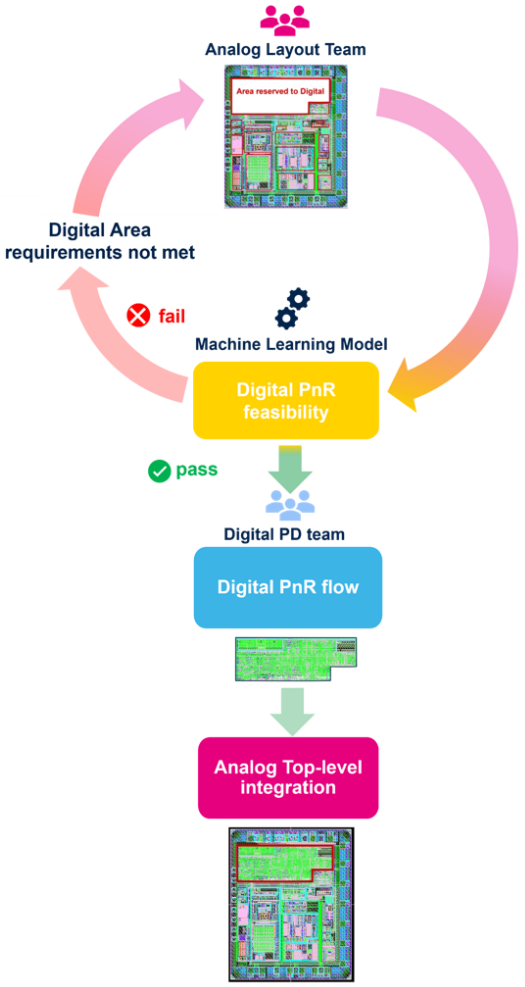
Marie Skłodowska-Curie Actions

# Zoom-in #4: Digital Placeability

- **Proposed Approach:** Use a ML model to estimate "placeability" of digital blocks from:
  - Given layout area (and shape)
  - Simple circuit + technology features

- **Goal:** avoid costly design iterations



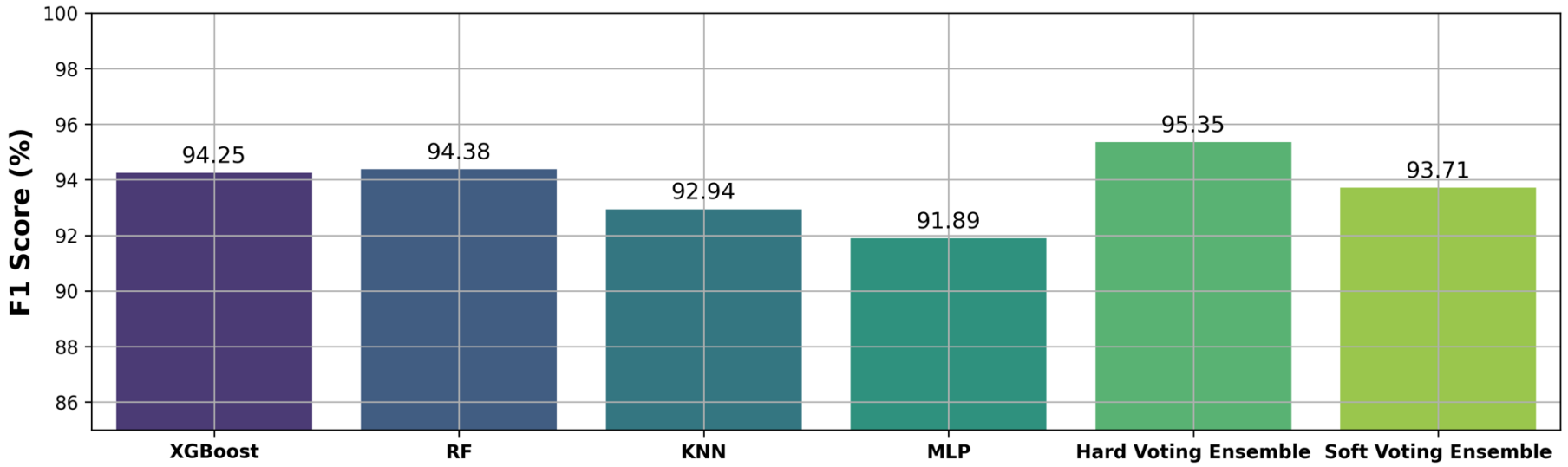

European Commission

The AMBEATion project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be m ade of them.

Marie Skłodowska-Curie Actions

# Zoom-in #4: Digital Placeability

- Results on 106 PnR runs from **47** designs, containing on average **42k** gates, targeting **BCD8sp** STMicro technology
- Methodology details: per-design data split, custom feature extraction and data augmentation, etc.

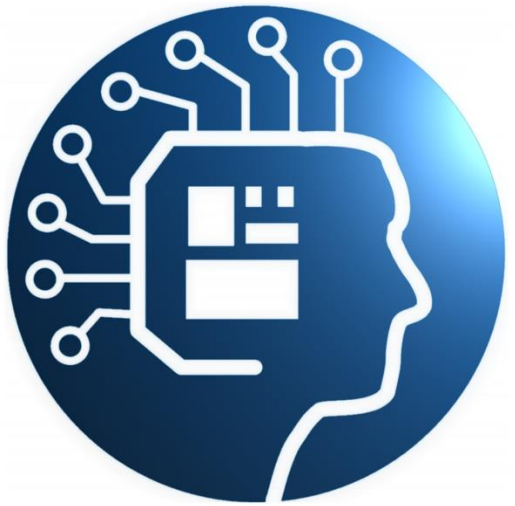



European Commission

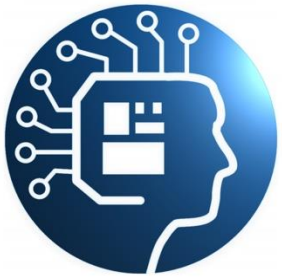
The AMBEATion project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be m ade of them.

Marie Skłodowska-Curie Actions

# Lessons Learned



The AMBEATion project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be made of them.



# Lessons Learned

- After approximately 4 years, reflecting on the key challenges encountered when trying to implement an AI-centric project in the AMS IC design domain…

- Three key lessons learned:

1. **Transitioning from a research prototype to a practically usable tool is difficult**
2. **The “language barrier” can be hard to overcome.**
3. **IC companies still lack a real “data-driven” culture**

**Disclaimers:**
- Entirely personal view
- The industrial teams involved in AMBEATion did whatever they could to overcome these challenges

European Commission

The AMBEATion project has received funding from the European Union’s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be m ade of them.

Marie Skłodowska-Curie Actions

# Lessons Learned

## 1. Transitioning from research prototype to “product”

- Well-known problem for AI-based projects in other domains, particularly critical in this one

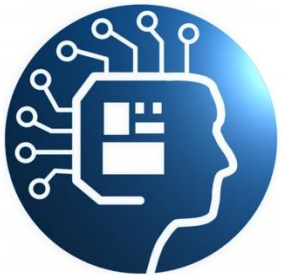
- Issues of **reliability/repeatablity of results, computational cost, data quality/quantity** (see Lesson #3), **scalability**, **technology independence,** etc.

- But also, more practically:
  - Your design might achieve great metrics but still not “look good” to an analog designer (missing constraints, or just ”artistic preference”)
  - Compatibility with industrial EDA flows is key for adoption, and not easy to achieve.

European Commission

The AMBEATion project has received funding from the European Union’s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be m ade of them.

Marie Skłodowska-Curie Actions



# Lessons Learned

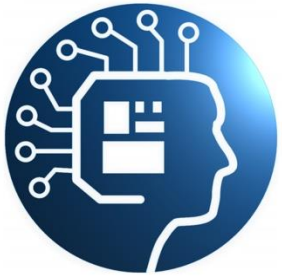
## 2. The “language barrier” can be hard to overcome.

- Very few people have expertise in both AI/ML and IC design (especially analog)
- Experts in each of the two domains speak very different languages.
- Analog design choices can sometimes be difficult to formalize as algorithmic/quantitative. Maybe that’s why AI could work?
- **MSCA-RISE initiatives exist for this exact purpose!**

European Commission

The AMBEATion project has received funding from the European Union’s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be m ade of them.

Marie Skłodowska-Curie Actions



# Lessons Learned

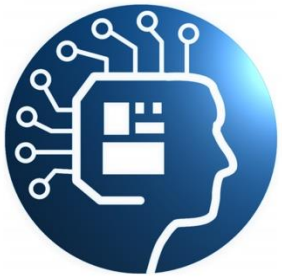
## 3. IC companies still lack a real “data-driven” culture

- AI/ML algorithms are extremely data hungry
- High-quality augmented/synthetic data generation is non-trivial
- Collecting data with sufficient **quantity** and **quality** has proven extremely difficult.
  - **Siloed projects/teams**, no centralized data infrastructure
  - Data deemed unuseful often overwritten.
- Example: Digital Placeability ML model trained on **85 passing, 21 failing** designs.
  - Data imbalance issue.

European Commission

The AMBEATion project has received funding from the European Union’s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be m ade of them.

Marie Skłodowska-Curie Actions



# Conclusion

- Lots remain to be done to integrate ML techniques in EDA (especially for analog/AMS).
- AMBEATion's results, while preliminary, can hopefully motivate future research efforts in this area…
- …and provide useful 'guidelines' for IC companies to develop their future AI-centered agenda (see later talks).

European Commission

The AMBEATion project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be m ade of them.

Marie Skłodowska-Curie Actions

# Questions?

Contact: daniele.jahier@polito.it

Selection of Project Publications:


- *G. E. Aliffi et al., "AMBEATion: Analog Mixed-Signal Back-End Design Automation with Machine Learning and Artificial Intelligence Techniques," DATE 2024*
- *F. Daghero et al., "Machine Learning-based feasibility estimation of digital blocks in BCD technology," IEEE DTTIS 2024*
- *G. Faraone et al, "Machine Learning-based feasibility estimation of digital blocks for improved productivity in Analog-on-Top Back-End design flows", DAC 2024 (Industrial Session Poster).*
- *F. Daghero et al, ""Predicting Digital Layout Success in Analog-on-Top Designs using Machine Learning", IEEE NewCAS 2025 (in press).*
- *D. Barri et al, ""AMBEATion: New Algorithm for Generation IC Matched Structures with Respecting Linear and Non-linear Gradient Parameter Effects," IEEE AE 2024.*



European Commission

The AMBEATion project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 101007730. Results reflect only the author's view. The Agency is not responsible for any use that may be m ade of them.

Marie Skłodowska-Curie Actions