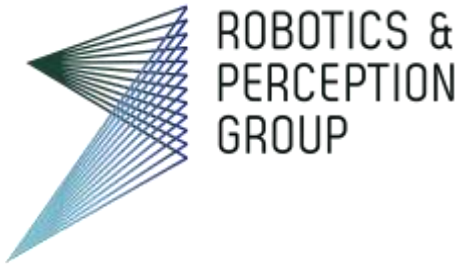
Efficient Event Processing with Geometric Deep Learning

Daniel Gehrig



University of Zurich[UZH]

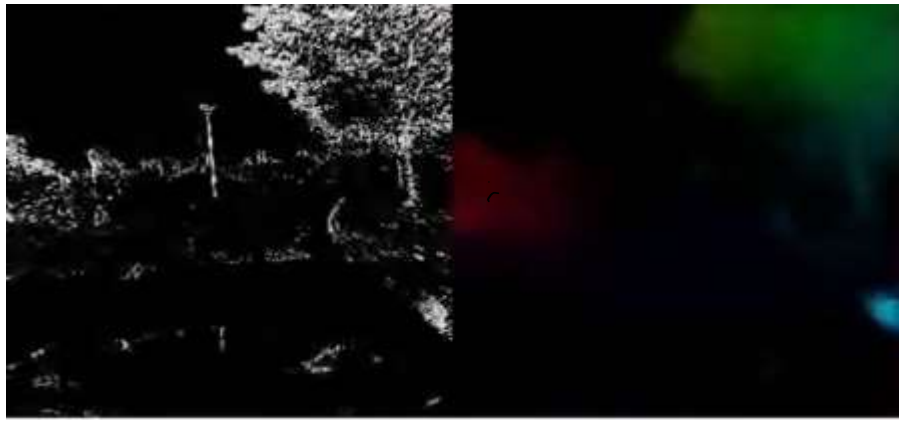
Institute of Informatics

Deep Learning for Event Camera

[1]

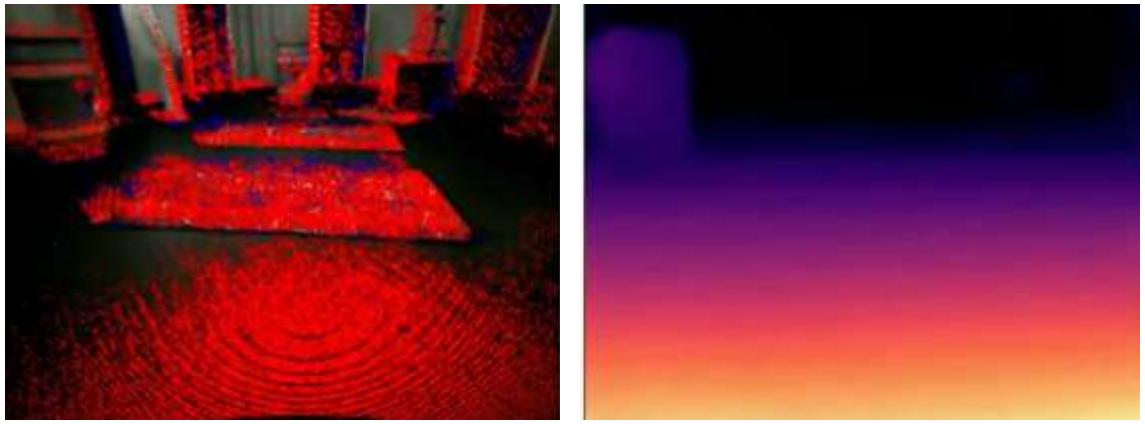
Events

Estimated Flow



Events

Estimated Depth



[2]

[3]

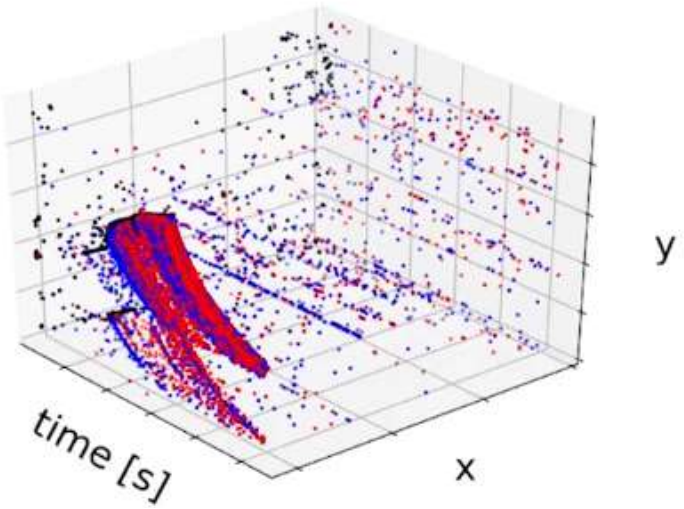
[1] Zhu et al., EV-FlowNet: Self-Supervised Optical Flow Estimation for Event-based Cameras. RSS, 2018

[2] Tulyakov et al., Learning an Event Sequence Embedding for Dense Event-Based Deep Stereo. ICCV, 2019

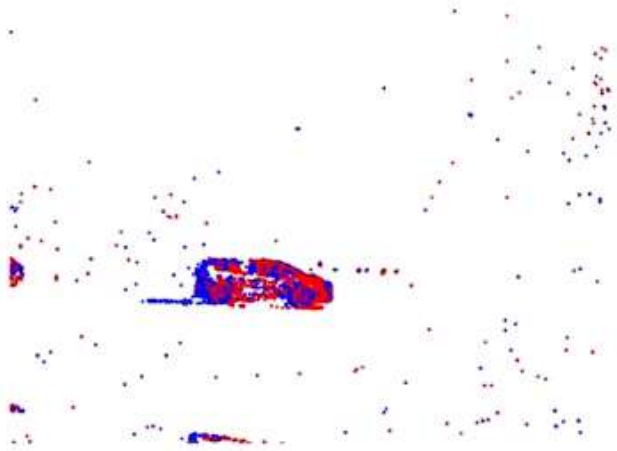
[3] Rebecq et al., High speed and high danymic range video with and event camera. T-PAMI, 2020

Deep Learning for Event Camera

- But can we make event representations that are also efficient, and operate at high temporal resolution?
- Dense representations lead to redundant processing when
  - No events are present
  - When new events arrive in the time window



Events in Space-Time



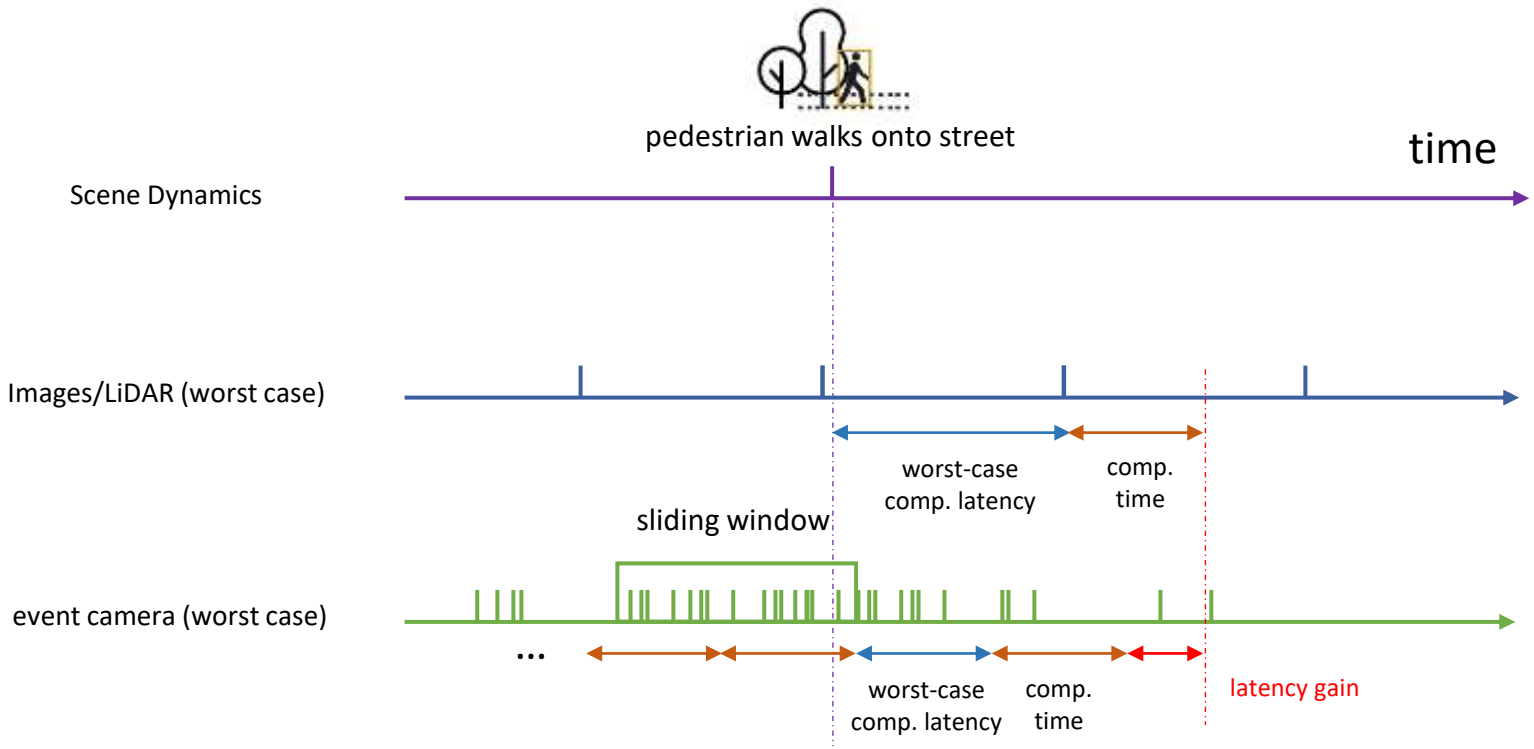
Event Histogram

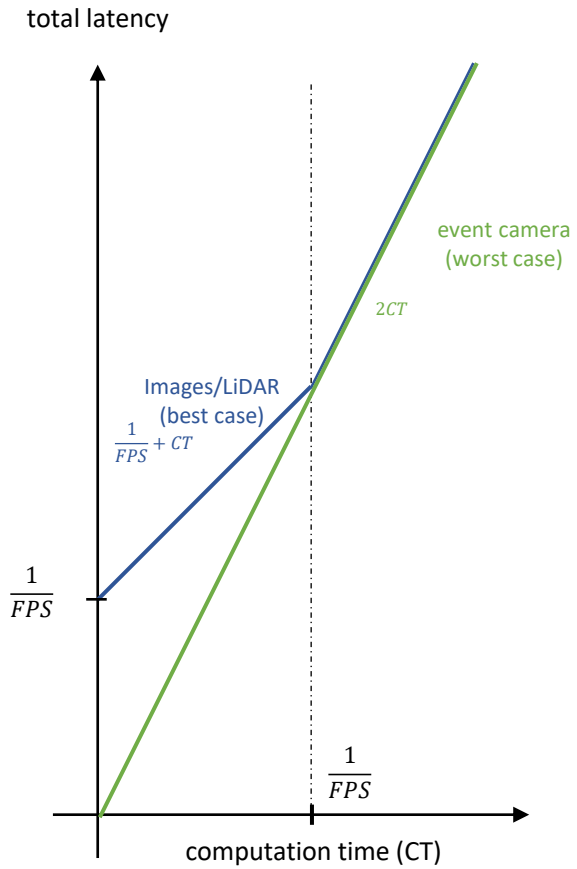
RGB Camera

[1] Messikommer & Gehrig et al., “Event-based Asynchronous Sparse Convolutional Networks ”, ECCV 2020

Why improve efficiency?

- **Computational efficiency is the main source of latency for event-based vision**
- Reducing it can reduce the latency to minimal values

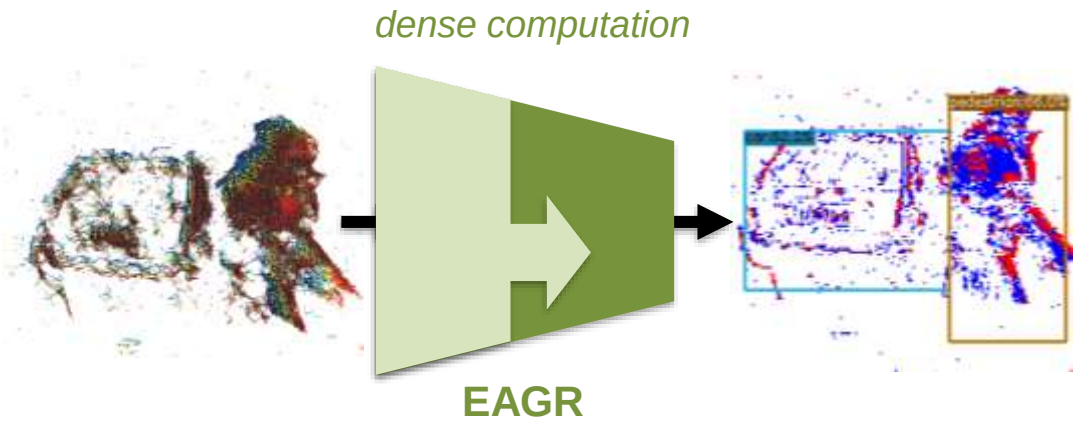




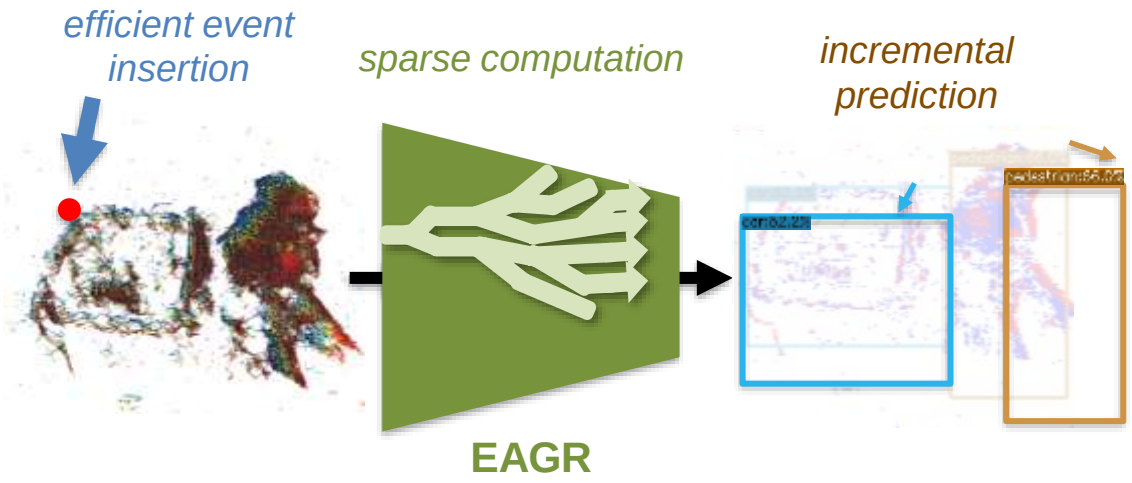
[1] Li et al. “Towards Streaming Perception”, ECCV 2020
[2] Forrai, Miki, Gehrig et al. “Event-based Agile Object Catching with a Quadrupedal Robot”, ICRA 2023
[3] Gehrig et al., “Low-latency Interframe Object Detection with Event Cameras”, submitted

Event-based Graph Neural Networks

- Process events as **spatio-temporally evolving graphs**
  - Sparser than Histograms
  - Efficient construction and event insertion into graph
  - Does not discard time information



Training: On full spatio-temporal graphs

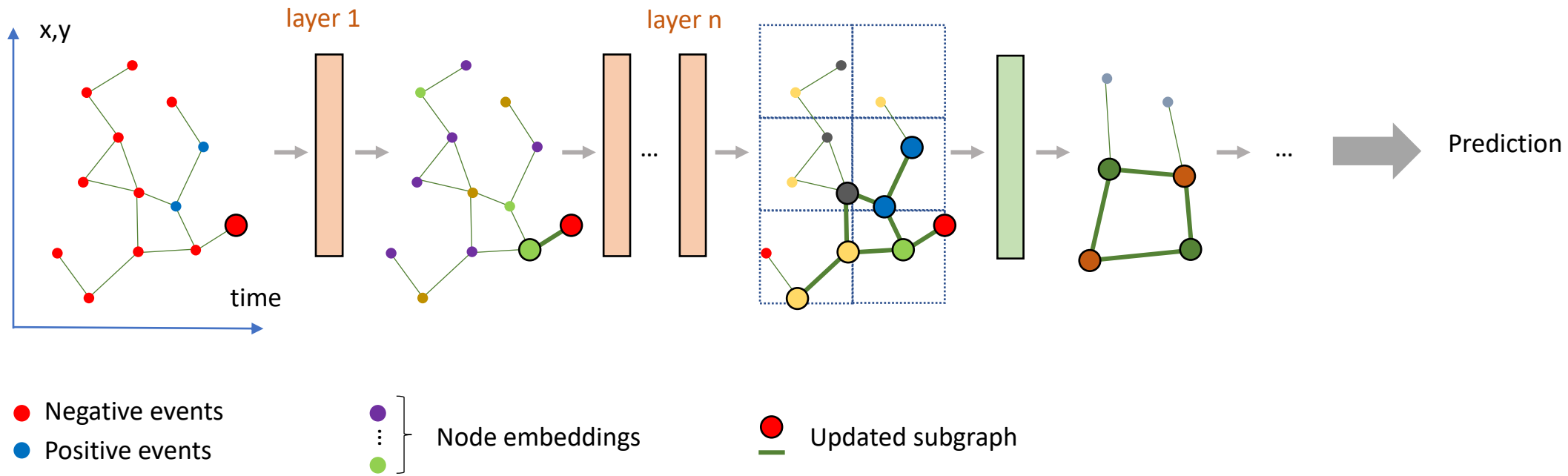


Testing: Event-based and sparse

[1] Li et al., “Graph-based Asynchronous Event Processing for Rapid Object Recognition”, ICCV 2021
[2] Schaefer & Gehrig et al., “Asynchronous Event-based Graph Neural Networks”, CVPR 2022
[3] Gehrig et al., “Pushing the Limits of Asynchronous Graph-based Object Detection with Event Cameras”, arXiv 2022

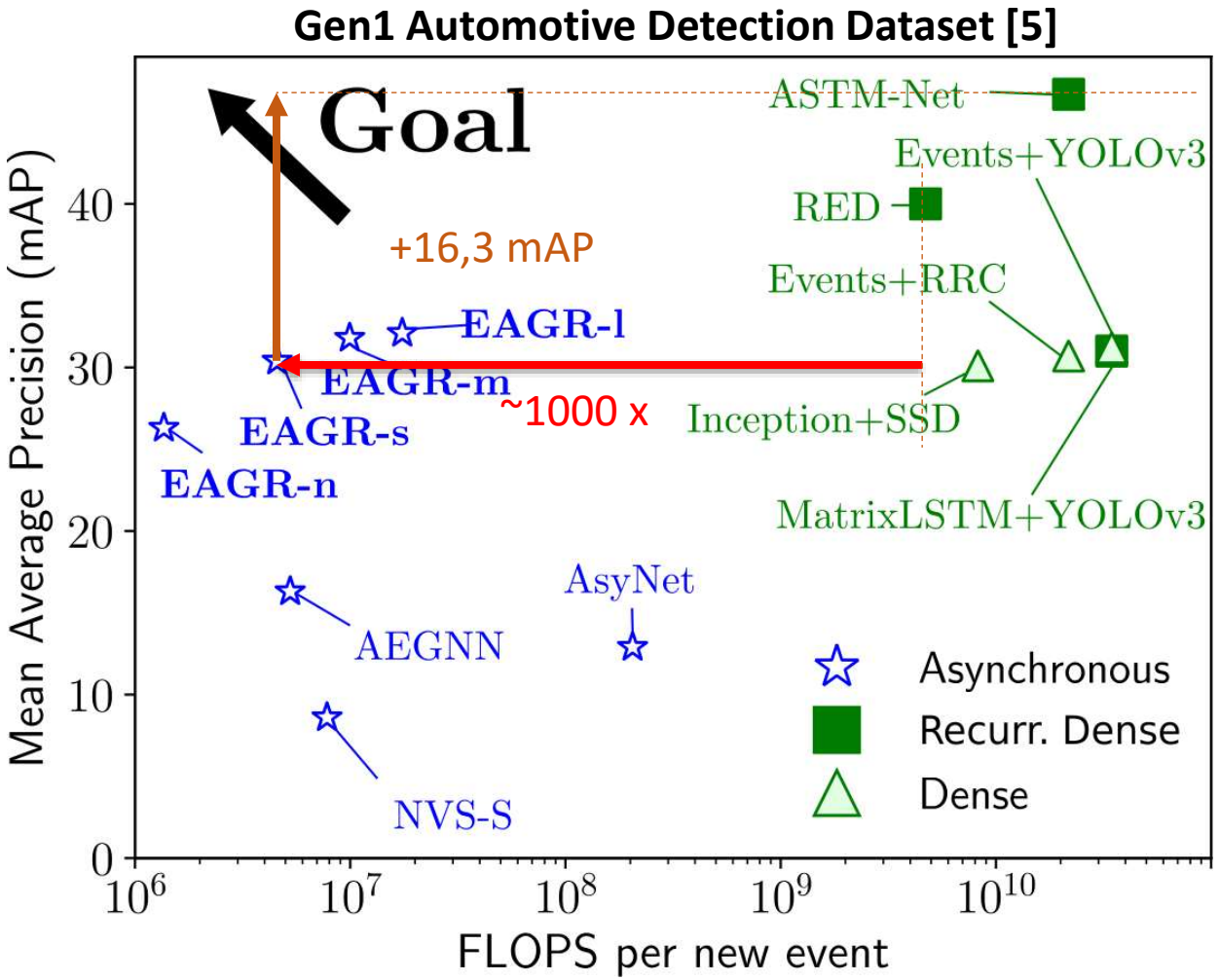
Event-based Graph Neural Networks

- During training, the GNN processes events synchronously.
- During testing, deploy GNN asynchronously: First initialize densely, then update **only small subgraph**



[1] Li et al., “Graph-based Asynchronous Event Processing for Rapid Object Recognition”, ICCV 2021
[2] Schaefer & Gehrig et al., “Asynchronous Event-based Graph Neural Networks”, CVPR 2022
[3] Gehrig et al., “Pushing the Limits of Asynchronous Graph-based Object Detection with Event Cameras”, arXiv 2022

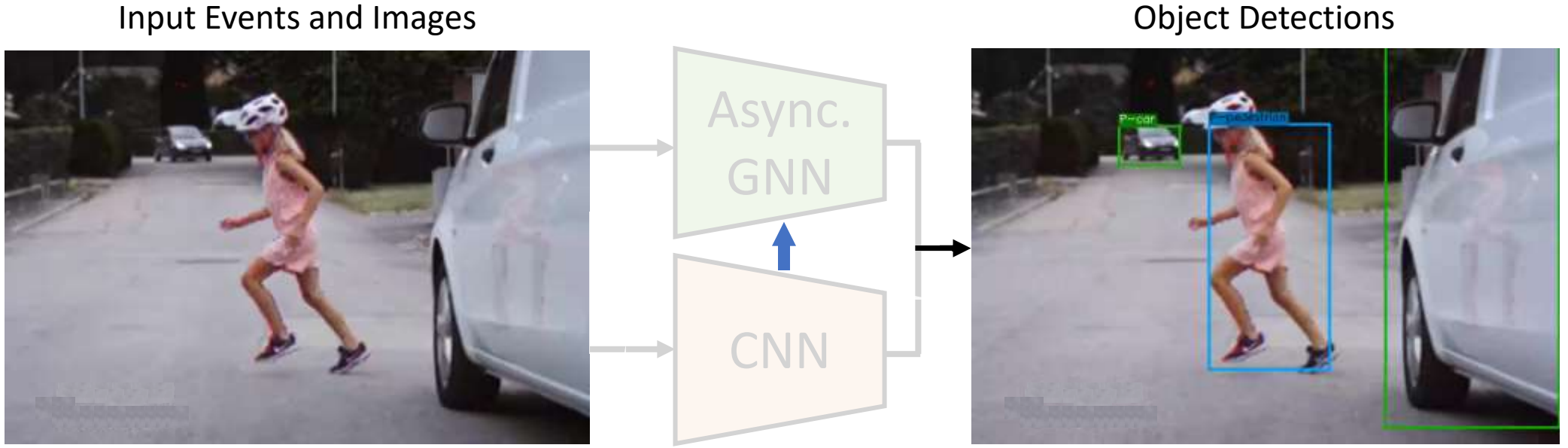
Performance vs. Efficiency



[1] Messikommer et al., “Event-based Asynchronous Sparse Convolutional Networks”, ECCV 2020
[2] Li et al., “Graph-based Asynchronous Event Processing for Rapid Object Recognition”, ICCV 2021
[3] Schaefer & Gehrig et al., “Asynchronous Event-based Graph Neural Networks”, CVPR 2022
[4] Gehrig et al., “Pushing the Limits of Asynchronous Graph-based Object Detection with Event Cameras”, arXiv 2022
[5] de Tournemire et al., “A Large Scale Event-based Detection Dataset for Automotive”, arXiv, 2020

Combining with Images

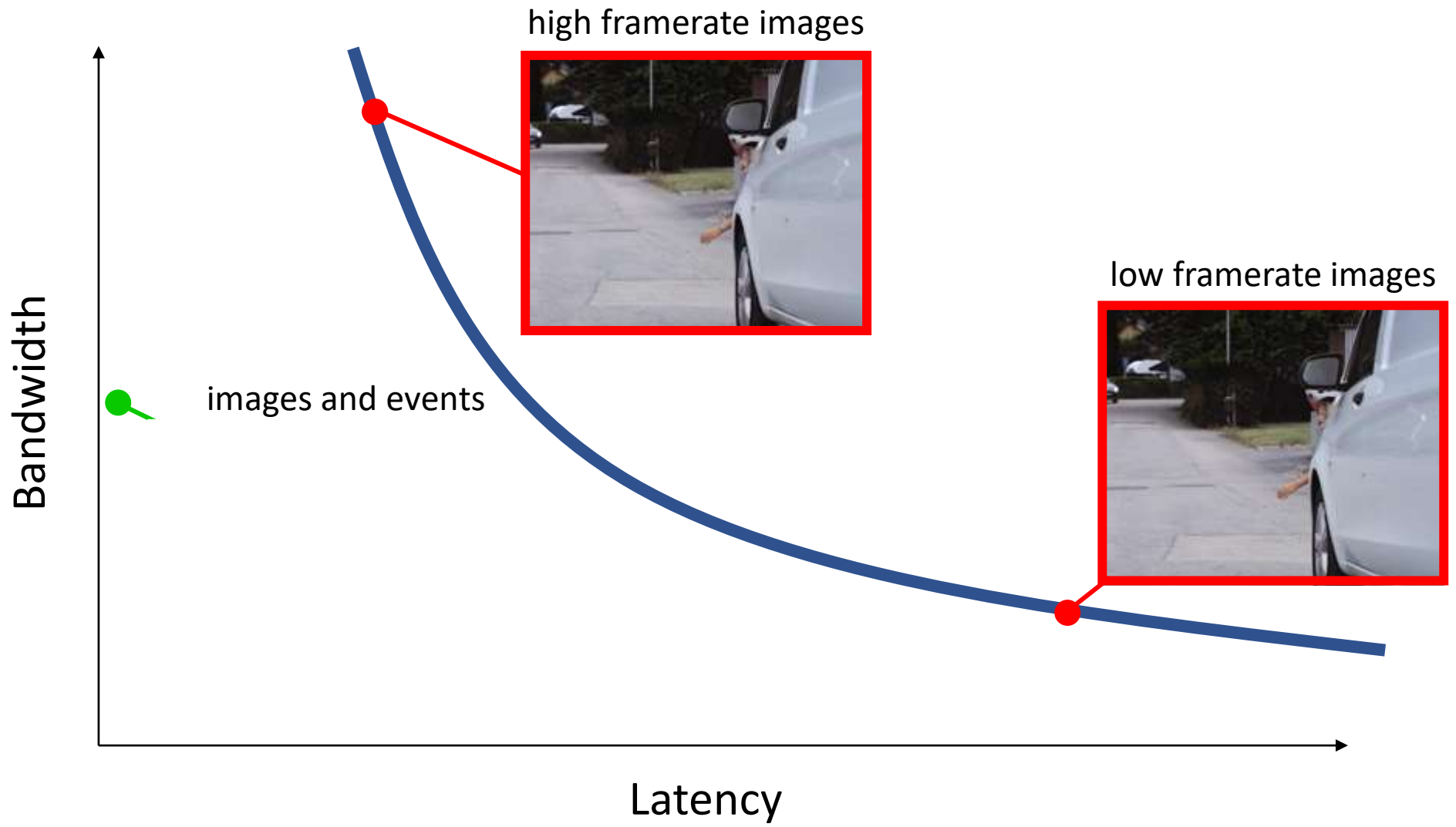
- Event cameras are “blind”, when no motion is present, and contain only binary information
- Combining them with images helps to address these issues.
- Directed feature sharing between CNN and GNN enables **async. reuse of image features**



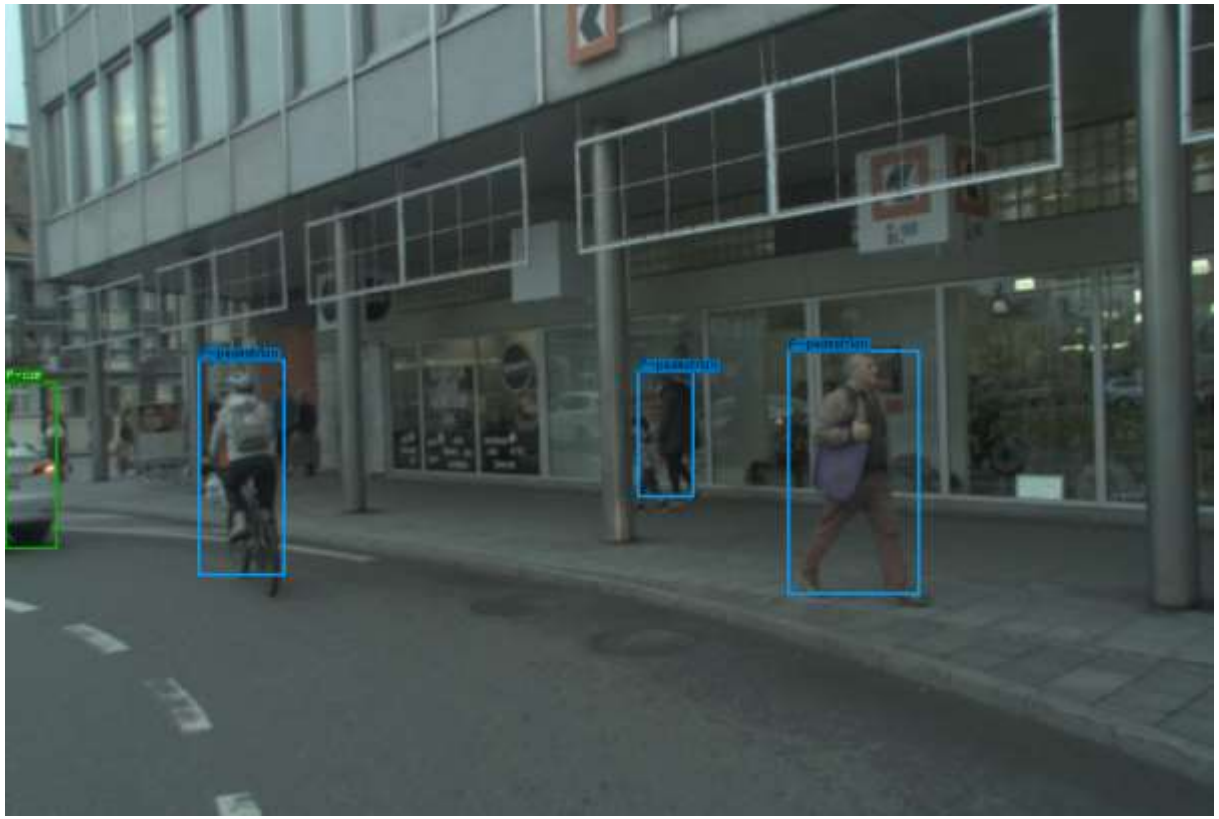
using events and images boosts worst-case mAP by 2.6 mAP over purely image-based

[1] Gehrig et al., “Pushing the Limits of Asynchronous Graph-based Object Detection with Event Cameras”, arXiv 2022, **ongoing research**
[2] Gehrig et al., “Low-latency Interframe Object Detection with Event Cameras”, submitted

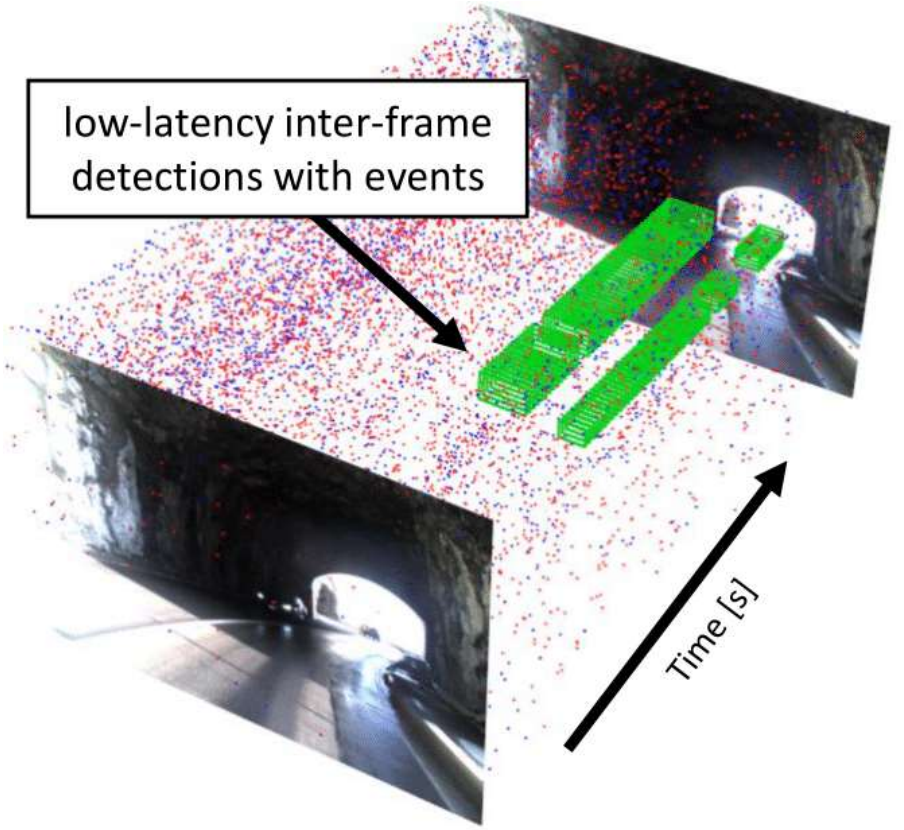
Bandwidth Latency Tradeoff



Results



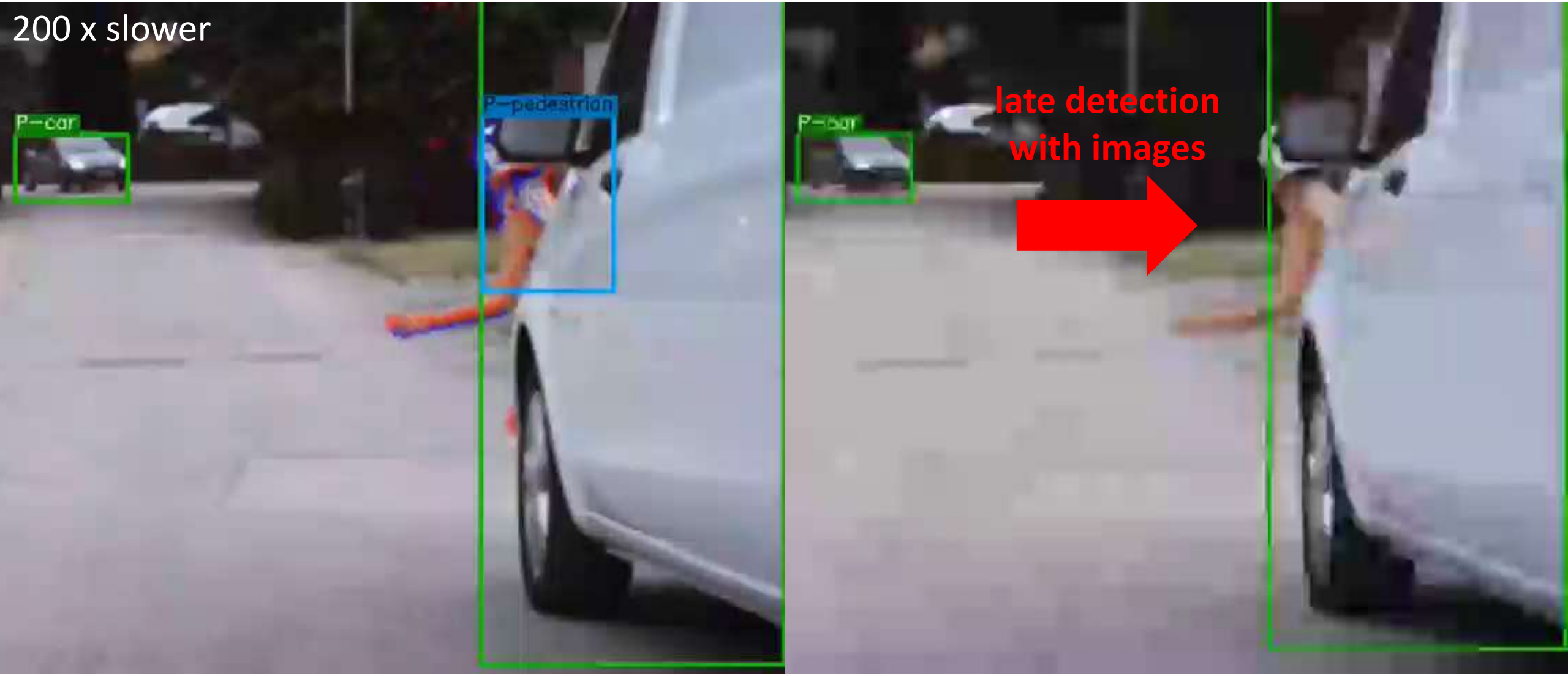
High-Rate Detections



Boost of worst-case mAP by 2.6 mAP over purely image-based at same bandwidth

Event and Image-based: EAGR (this work)

Image-based: YOLOX [3]



Event and Image-based: EAGR (this work)

Image-based: YOLOX


P-car
P-car
P-car

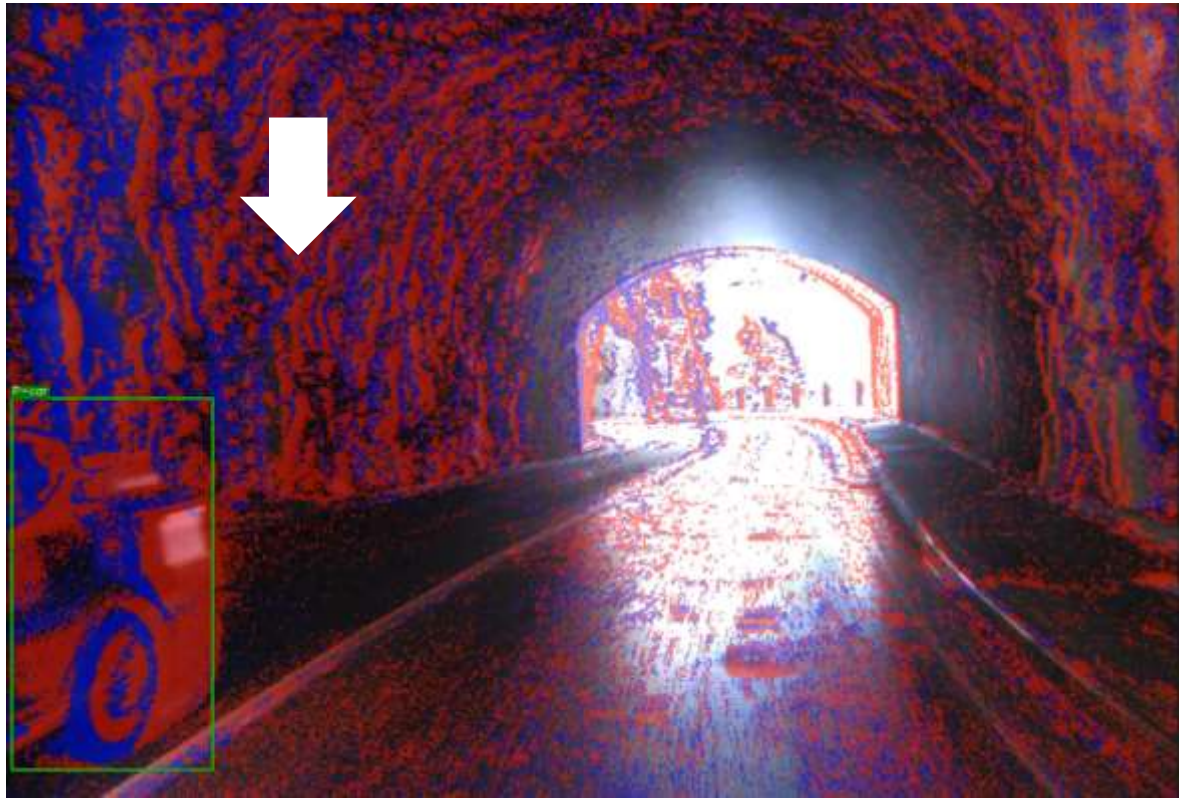

100 x slower
P—car
P—car

Event- and Images-based Object Detector

Event and Image-based: EAGR (this work)

Image-based: YOLOX [1]

Qualitative Results: HDR scenarios



Event and Image-based: DAGr (this work)

Image-based: YOLOX [1]

[1] Ge et al. “YOLOX: Exceeding YOLOX Series in 2021”, arXiv, 2023

Qualitative Results: HDR scenarios

Event and Image-based: DAGr (this work)

Image-based: YOLOX [1]

[1] Ge et al. “YOLOX: Exceeding YOLOX Series in 2021”, arXiv, 2023

https://dsec.ifi.uzh.ch/dsec-detection/

Thank you for listening!