Application of Super-resolution Techniques in Collider Physics

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Regular Article - Experimental Physics

Towards a computer vision particle flow

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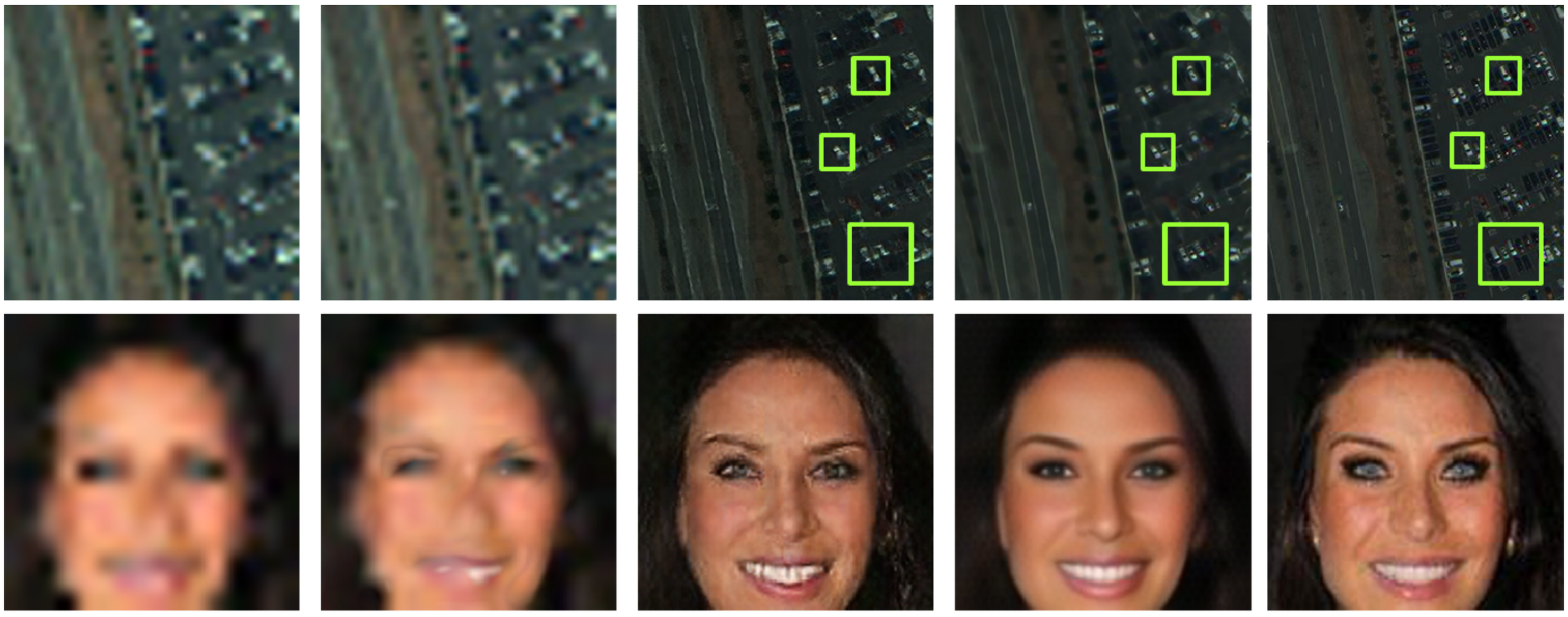
What is super-resolution ?

In the context of images : a systematic algorithm to sharpen the images

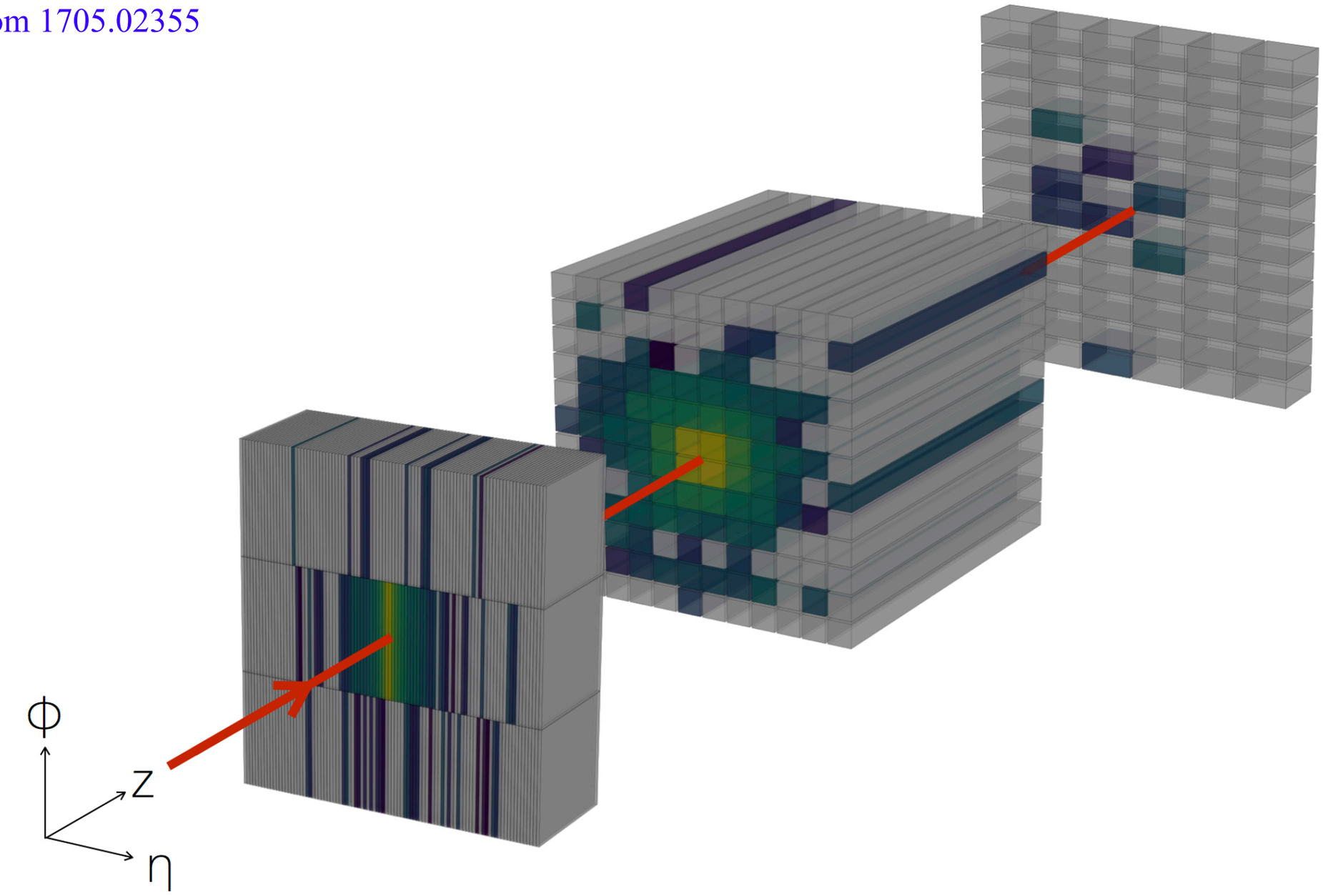


Low Resolution | MSSRNet | SRGAN | Our Method | High Resolution

Ref : DOI:10.1109/ICASSP.2019.8682354. Corpus ID: 145823404

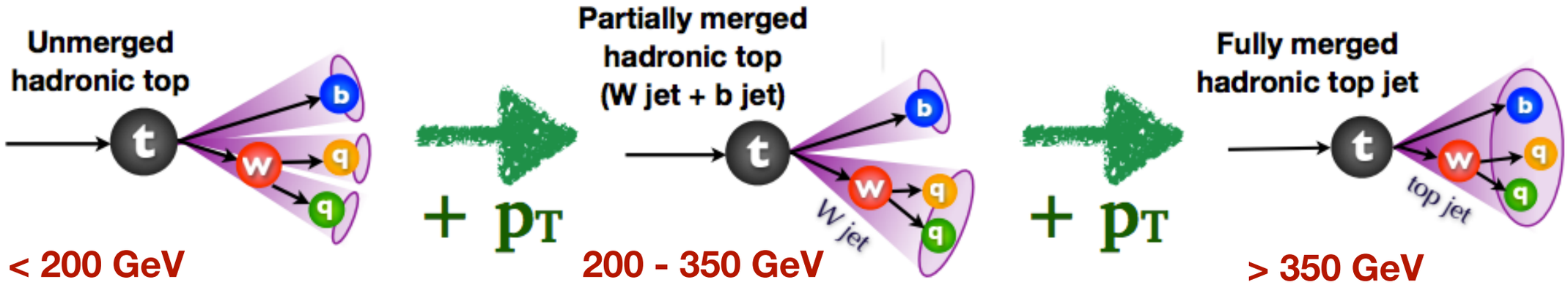
The intrinsic analogy : Calorimeter & Images

Image from 1705.02355



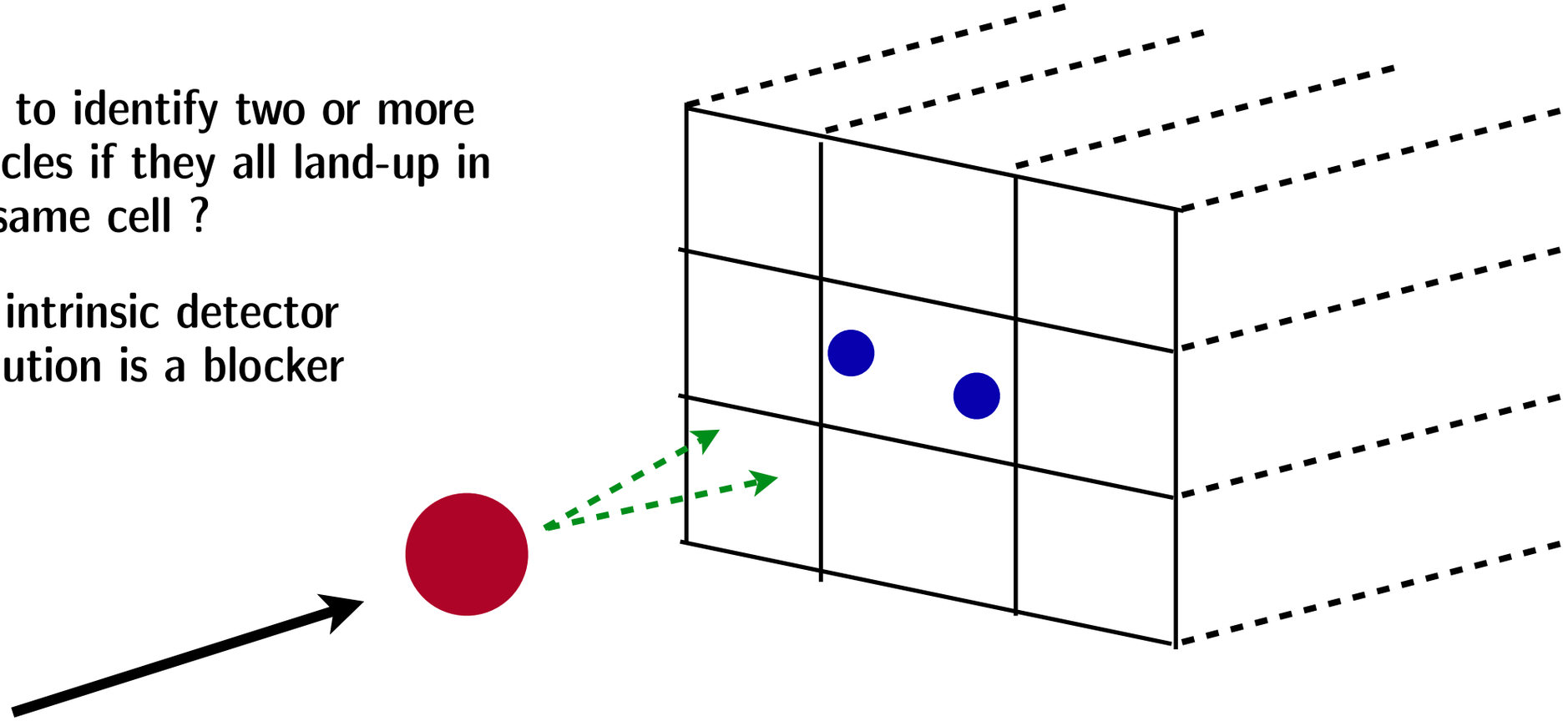
Calorimeter showers have natural representation of a multi channel image and point-cloud

When do intrinsic calorimeter sizes are limiting factors ?

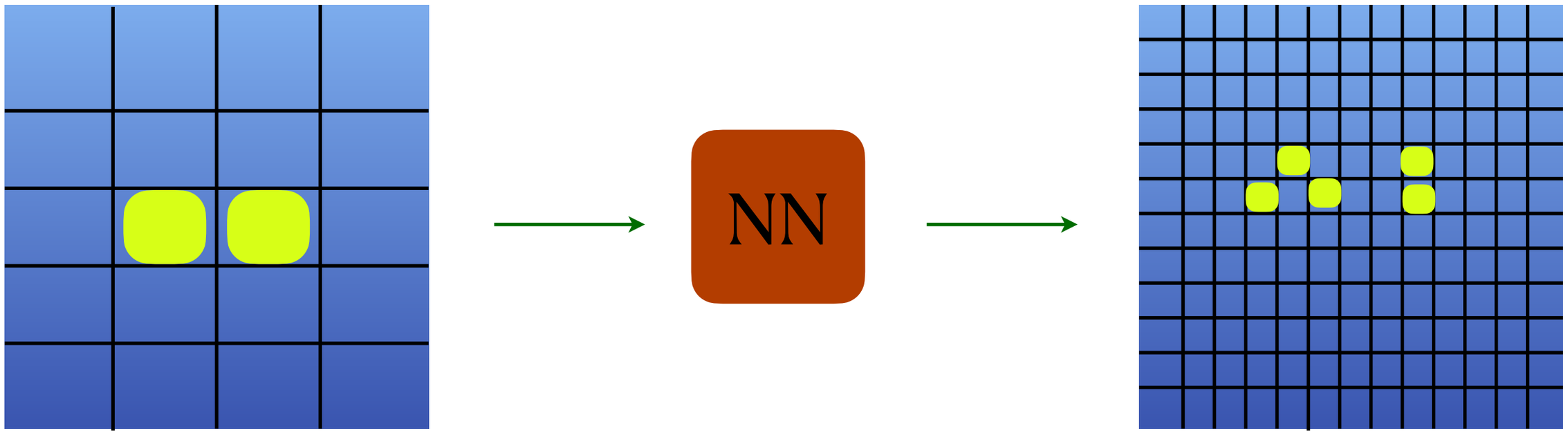


How to identify two or more particles if they all land-up in the same cell ?

The intrinsic detector resolution is a blocker



How ML can help us to overcome the problem ?

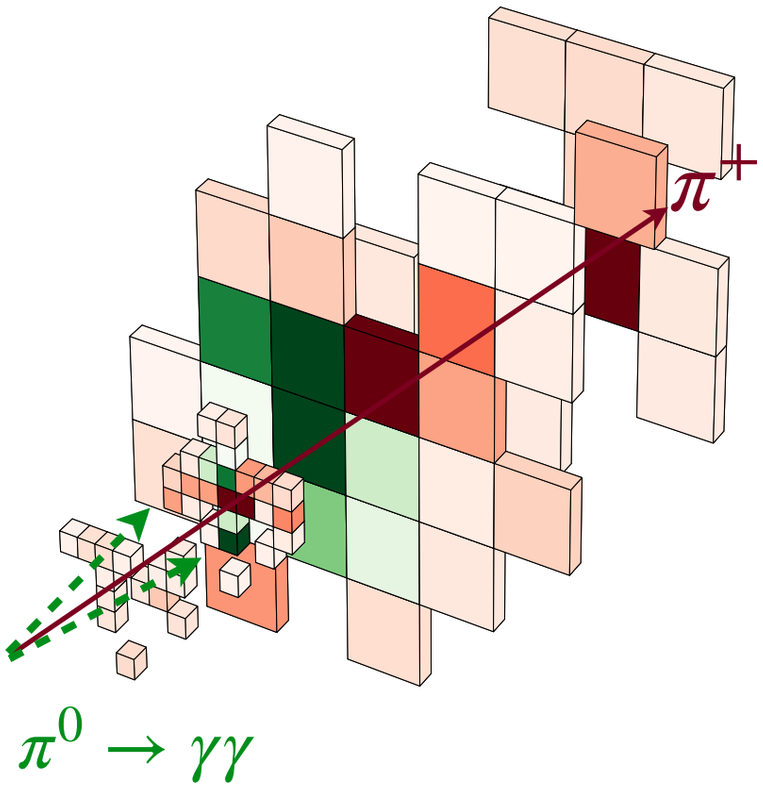


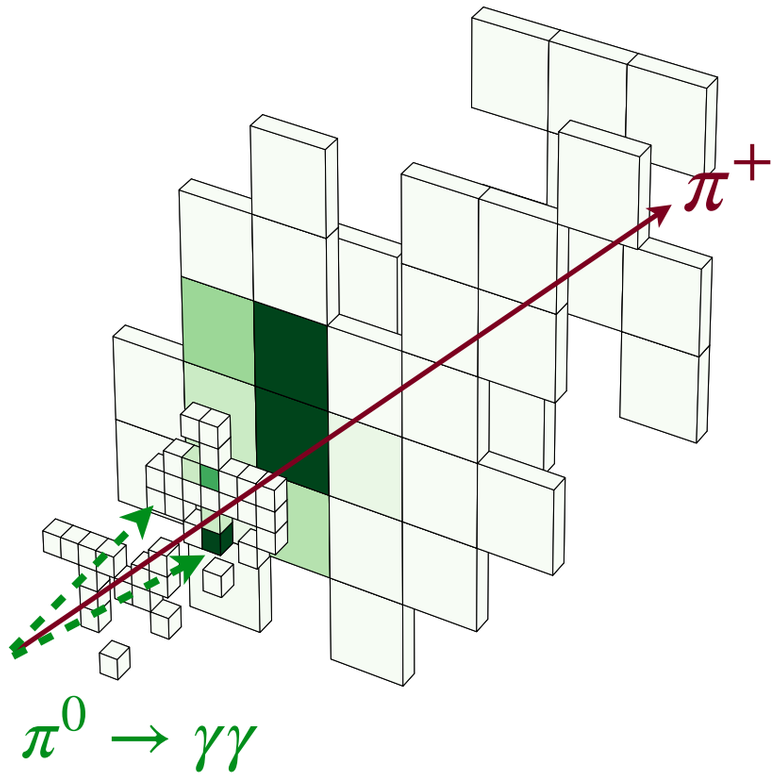
Input

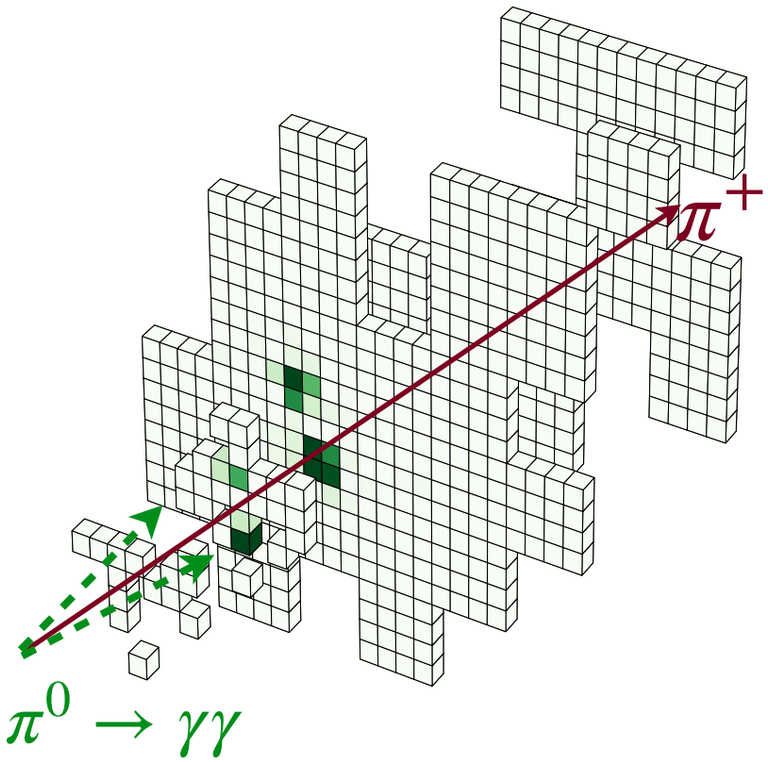
Target

- ☑ Train a NN to teach high resolution shower pattern, starting from the low granularity one.
- ☑ Use it to predict shower profile for a real-life low-resolution measurement.
- ☑ This helps us to decode the shower pattern obtained from LR detector (and recover some physical information.)

A case for calorimeter super-resolution





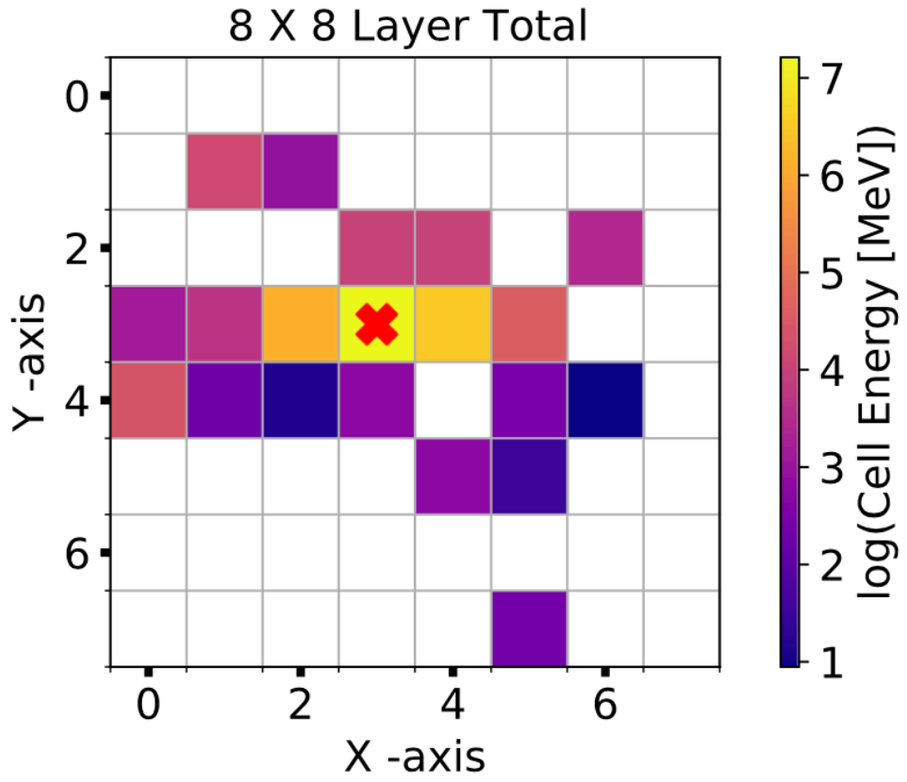


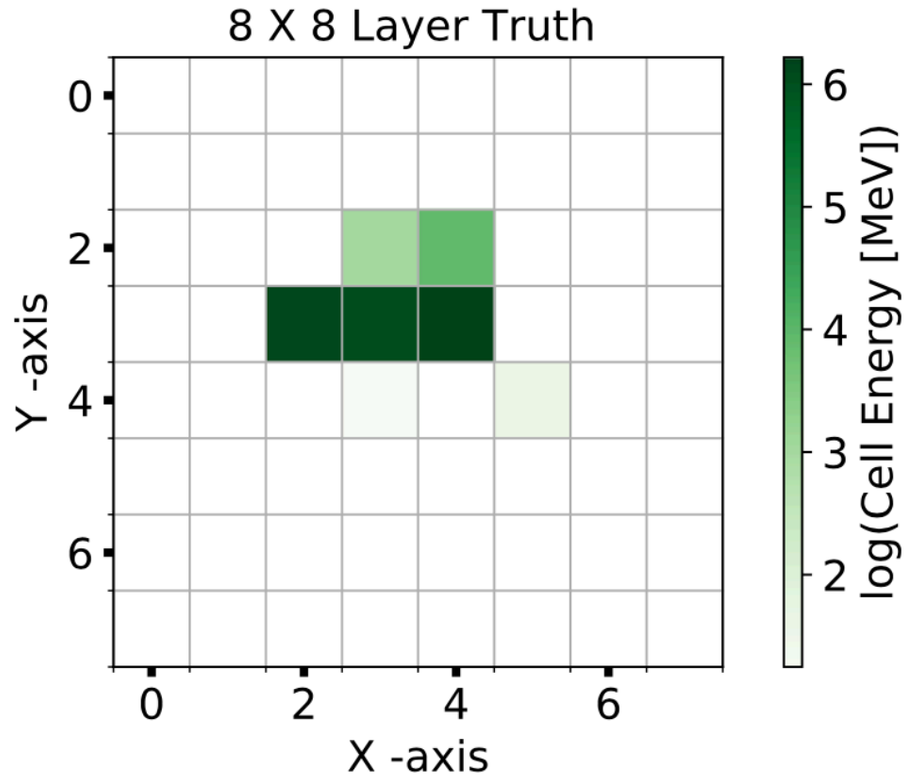
8 X 8 Low Res detector

32 X 32 High Res detector

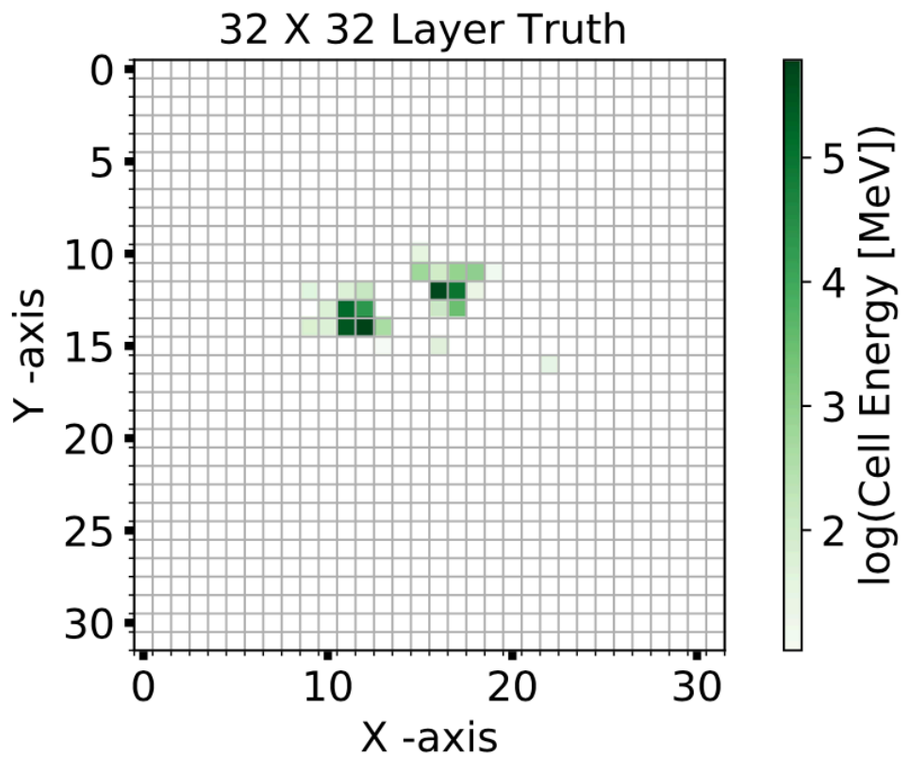
A higher resolution calorimeter has the ability to capture multi-prong decay pattern in showers.

What we aim to learn ?



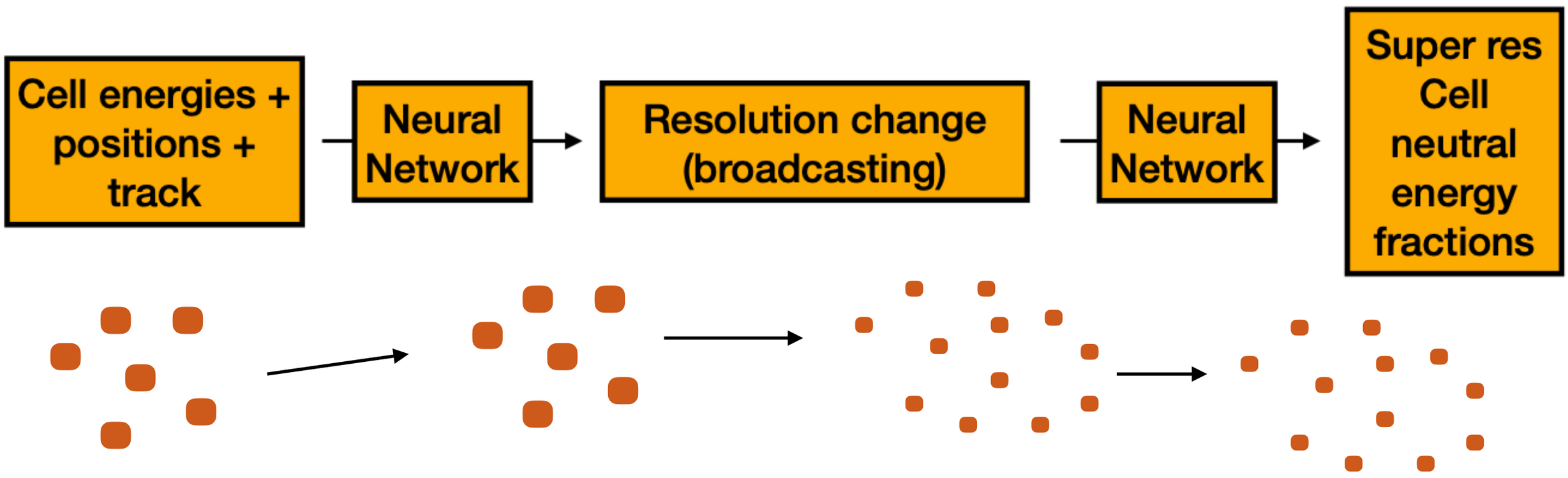


Separating the pi+ and two photons is a challenging experimental task



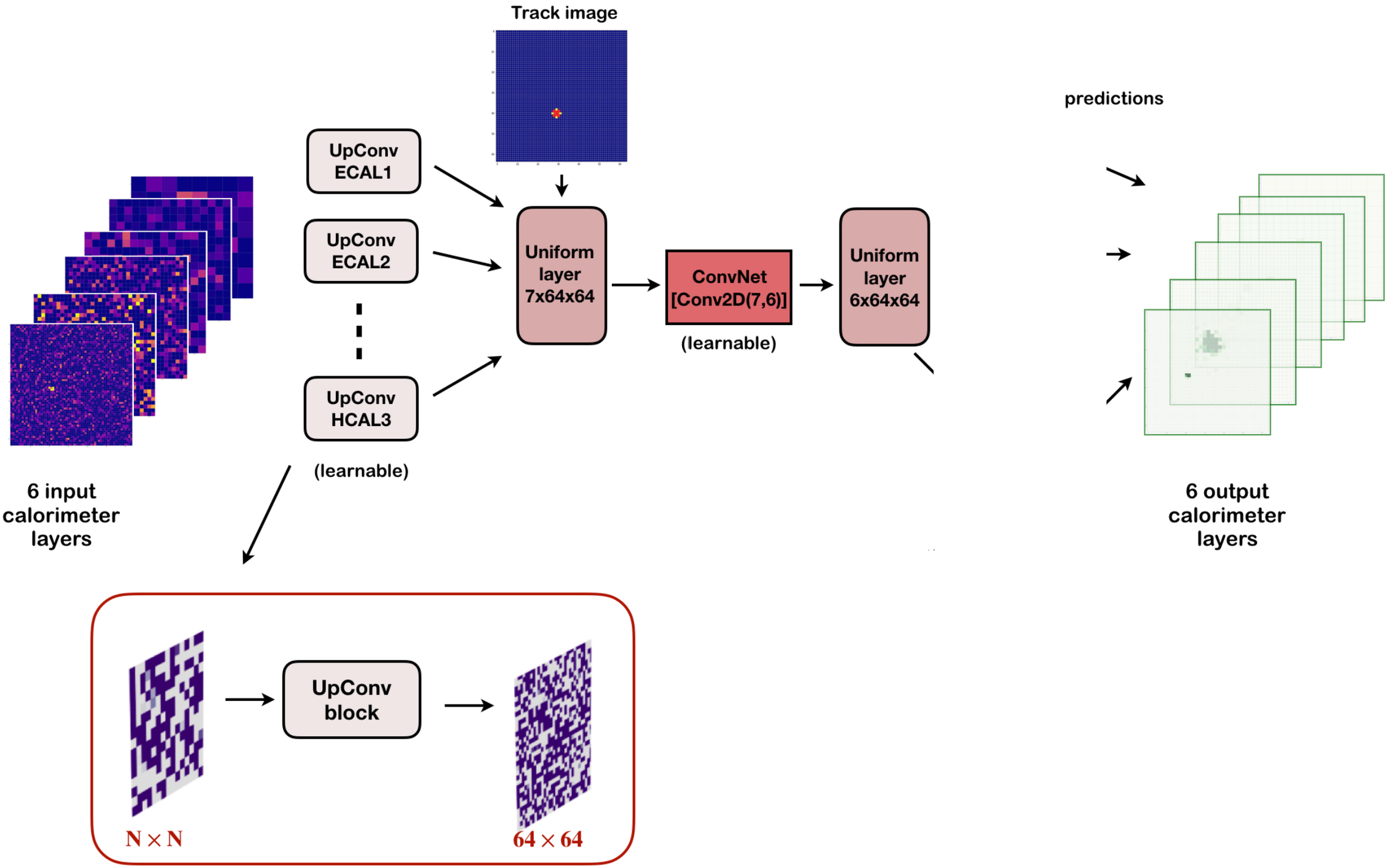
The proposed NN structure

Common network structure for super-resolution task



$$L_{event}^{\text{super-res}} = \frac{1}{E_{tot}} \sum_{c} E_c \sum_{s=0}^{us^2} (f_t^{sc} - f_d^{sc})^2$$

The general image based networks

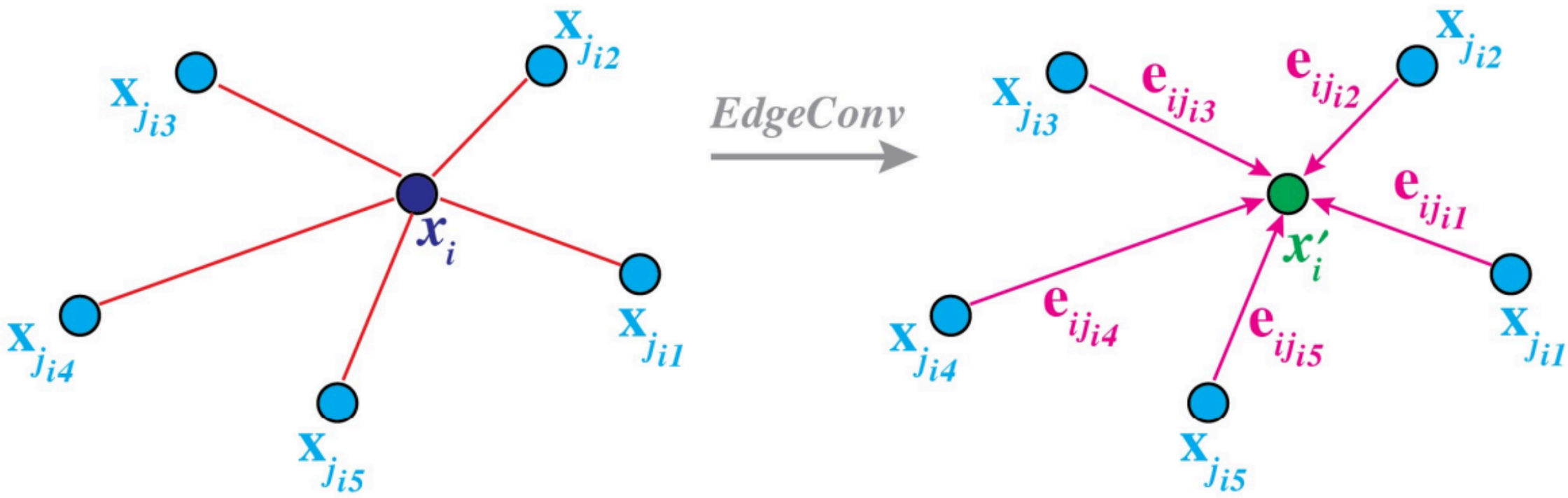


The graph network

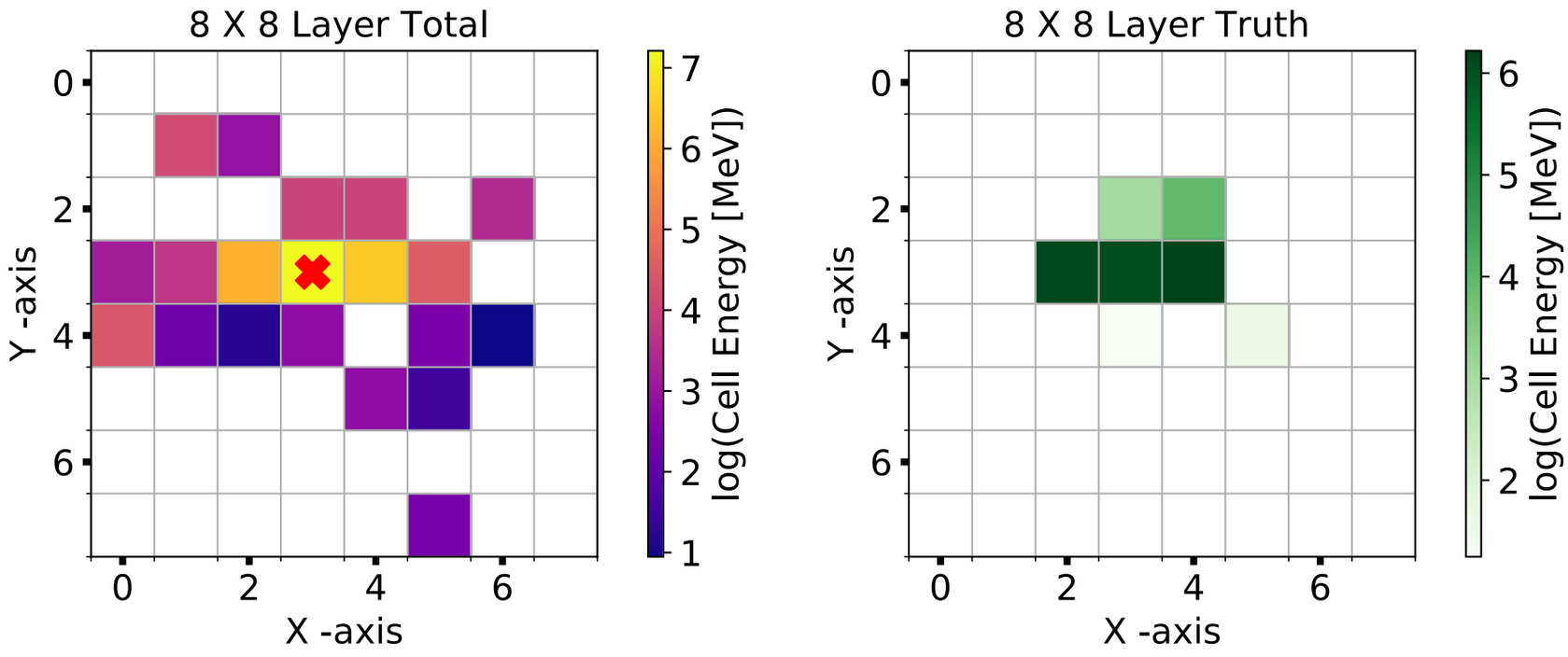
https://arxiv.org/pdf/1801.07829.pdf

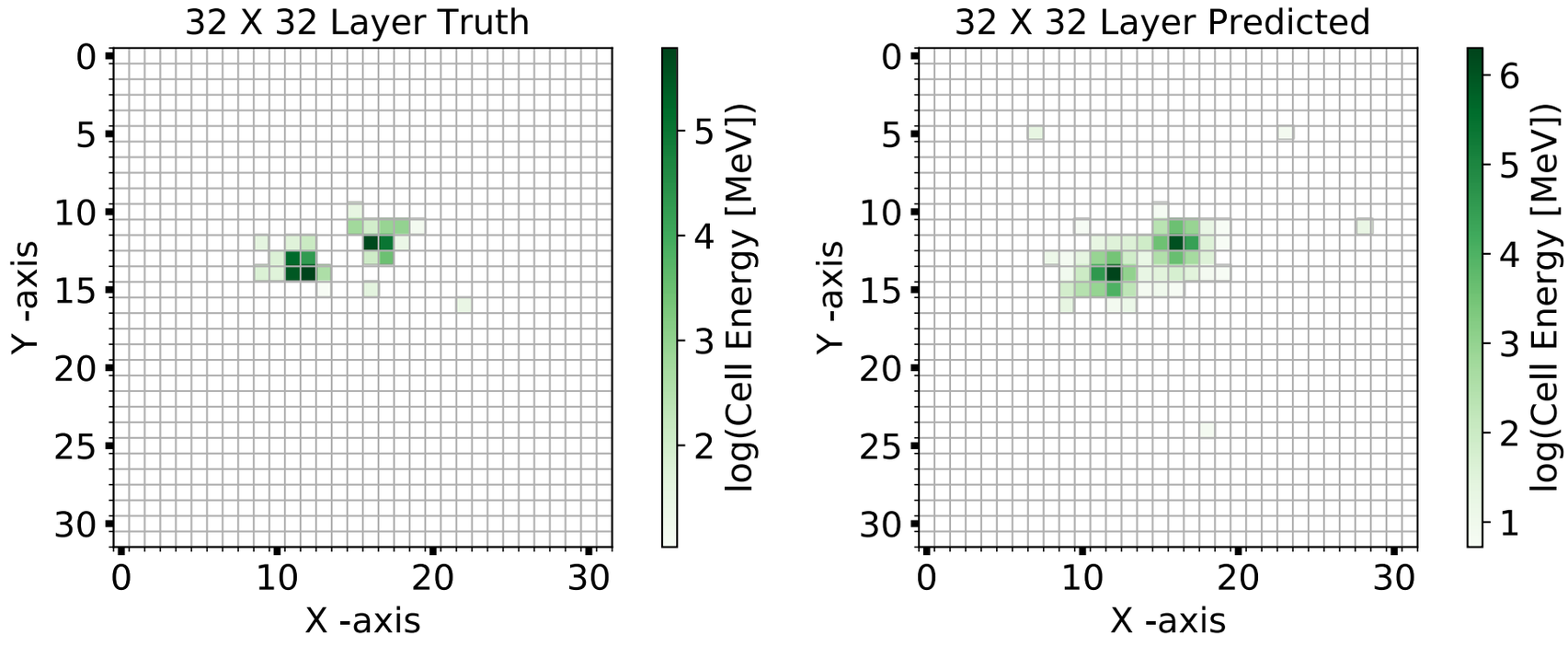
In a graph, each node can "learn" about the state of neighboring node through message passing operation

A general GNN has a NodeNetwork + an EdgeNetwork : updates the nodes and edge features through message-passing operation

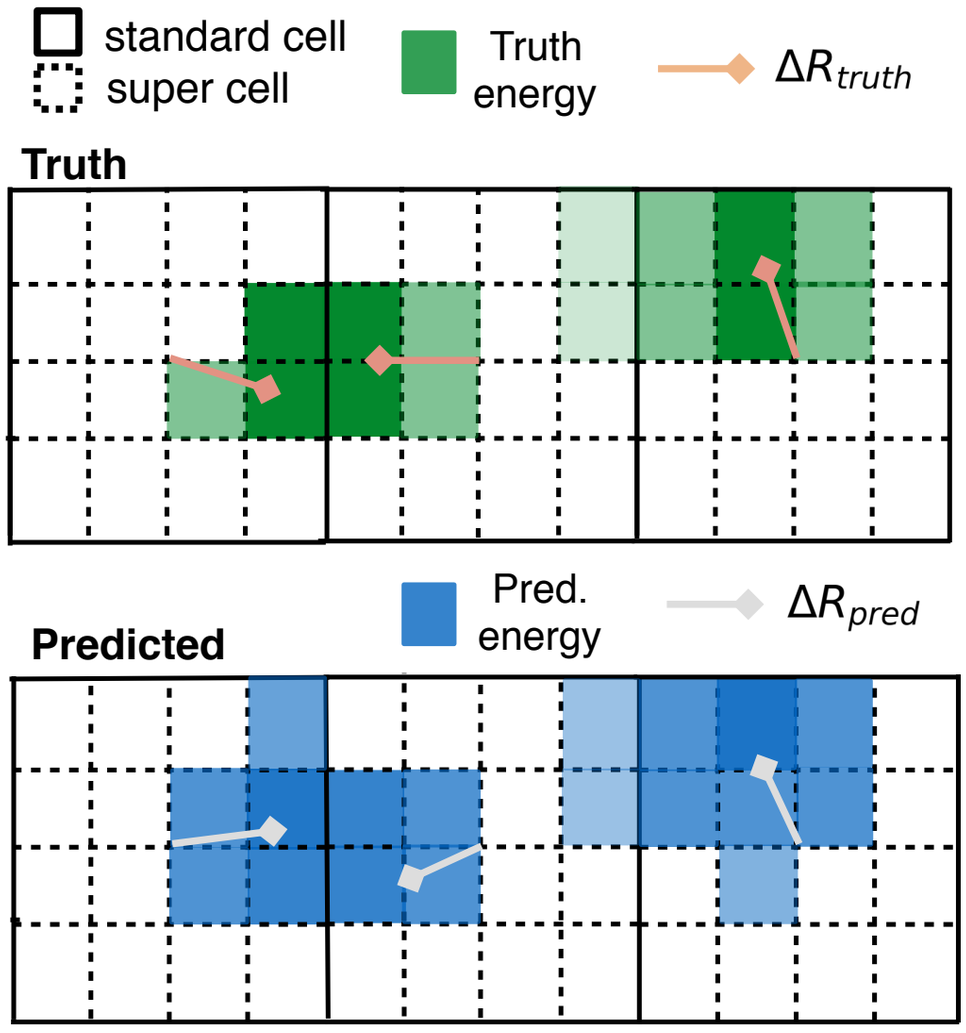


An event display for super-res prediction

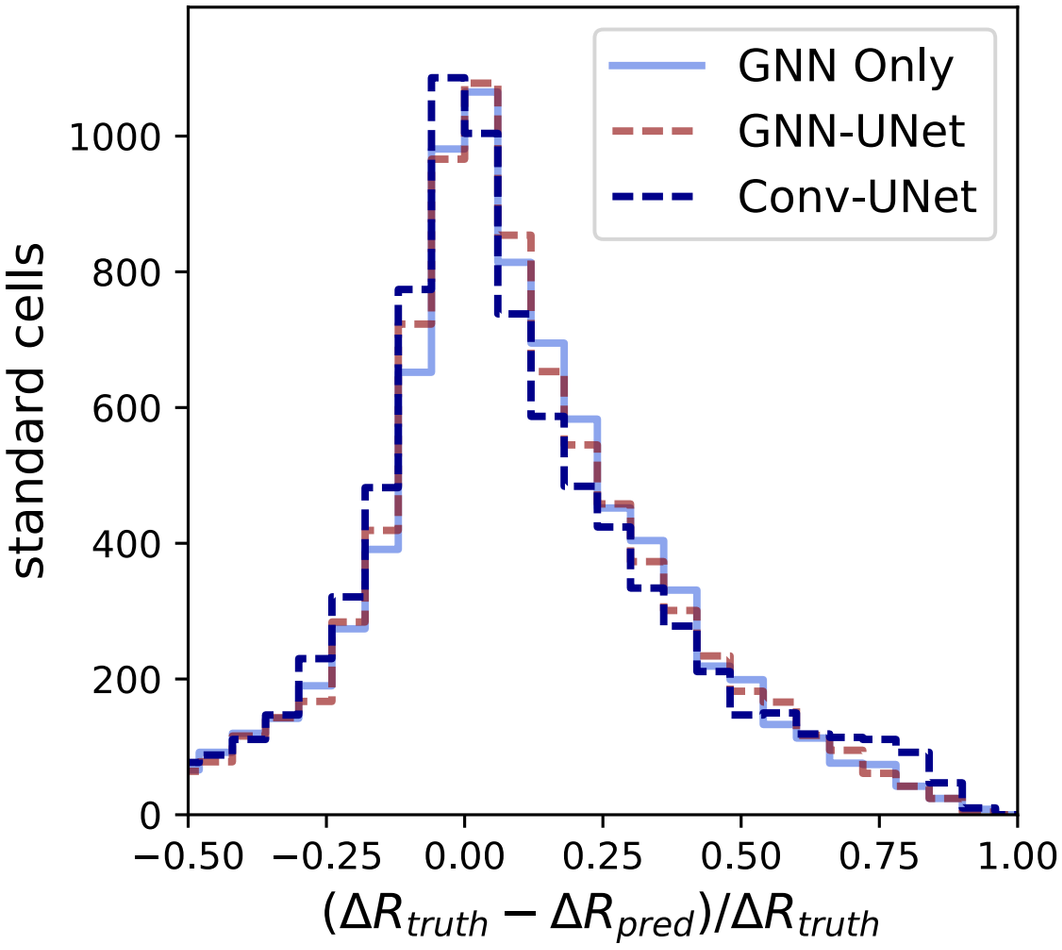




A closer look to super-res prediction

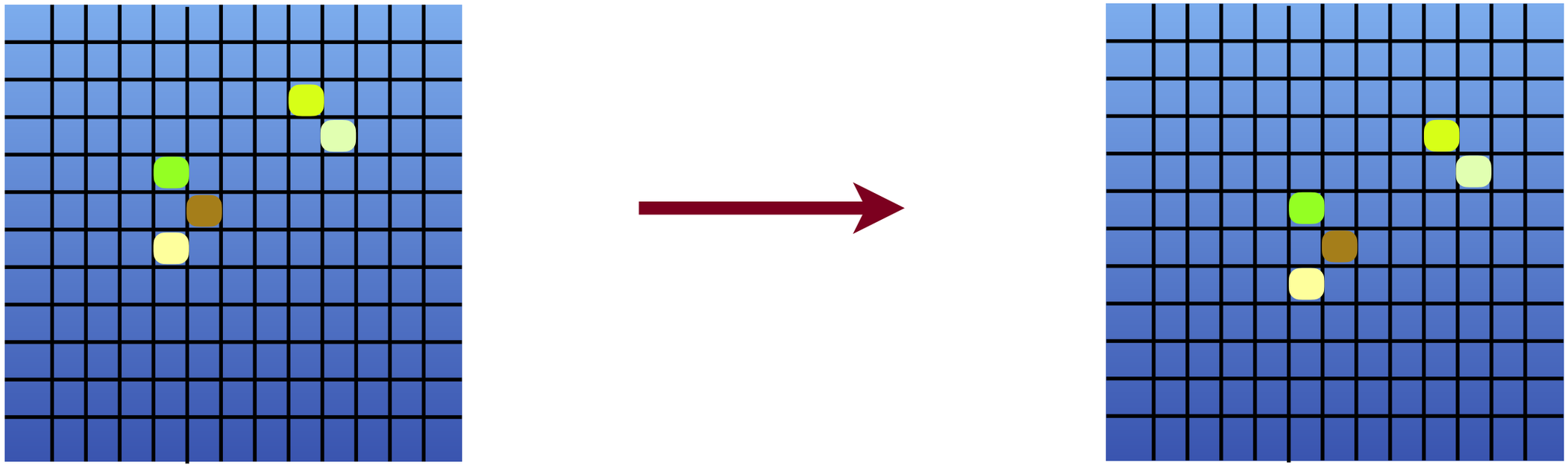


The approximate position of the barycenter is correctly predicted

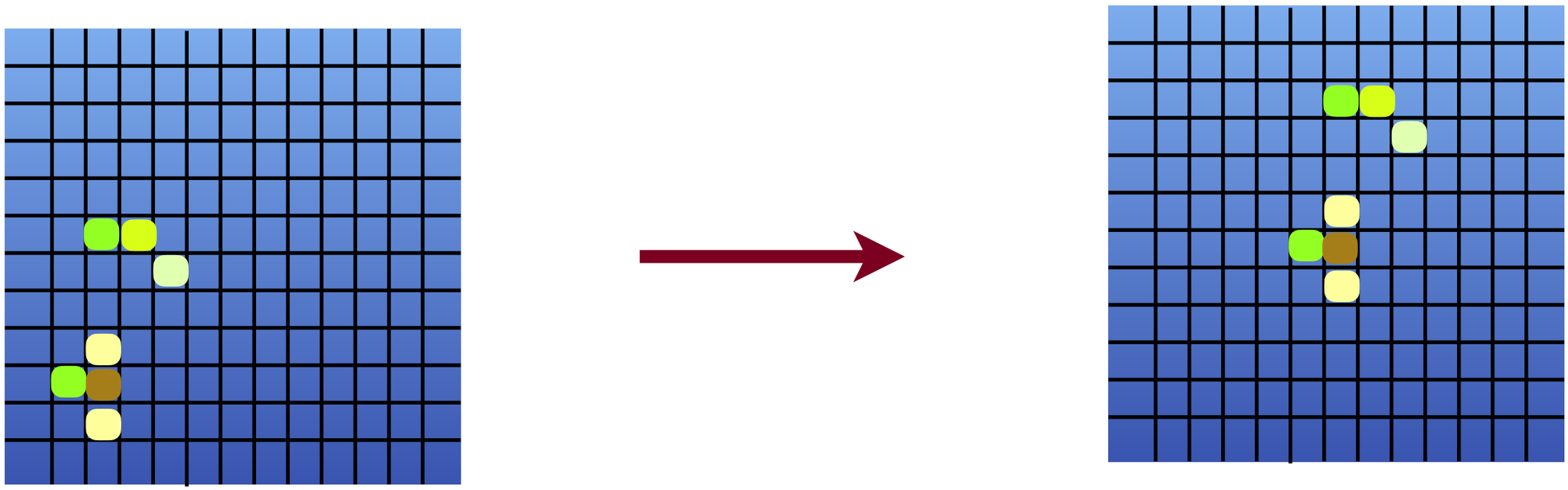


The statistical performance on A test sample

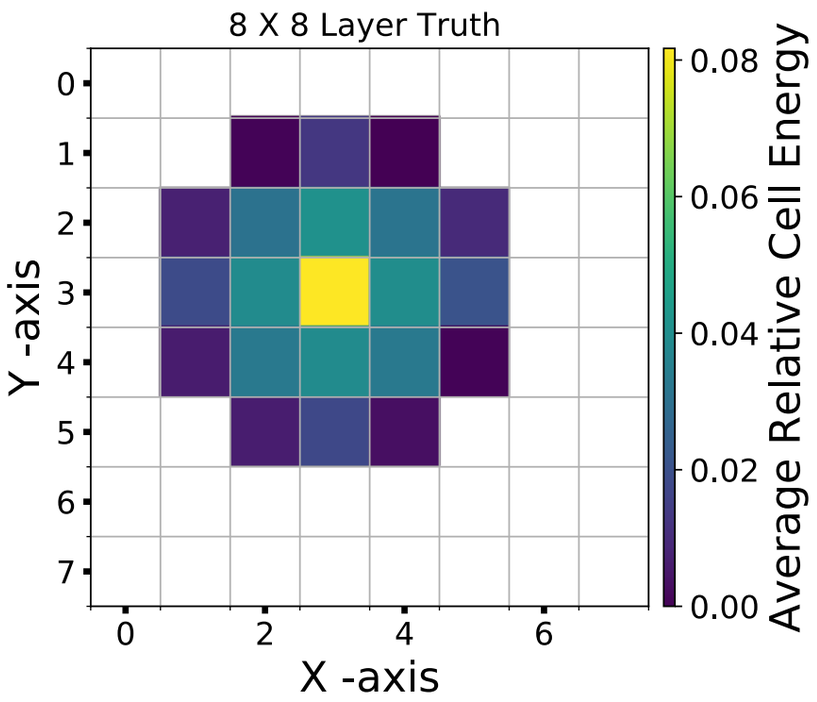
A statistical quantification of two-prong decay

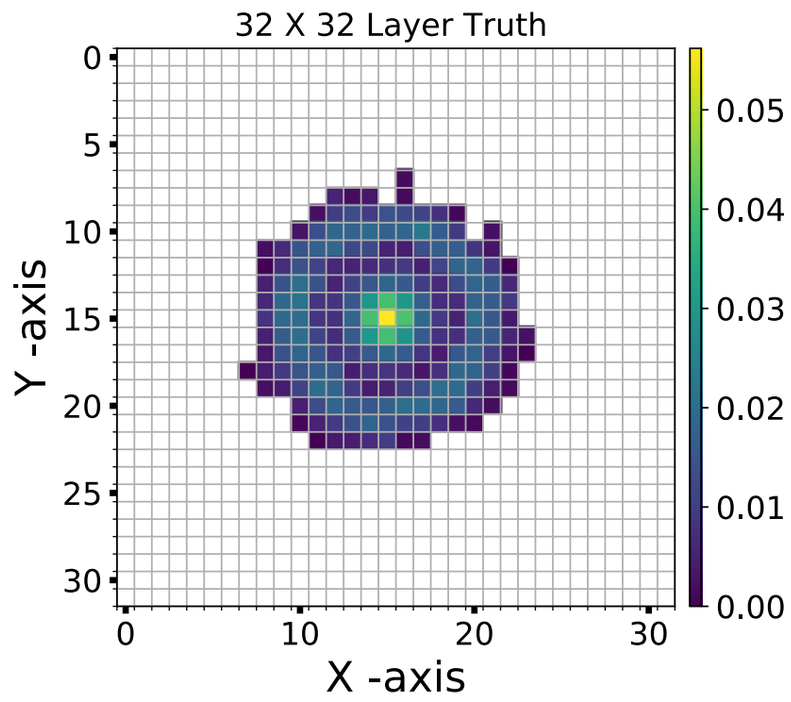


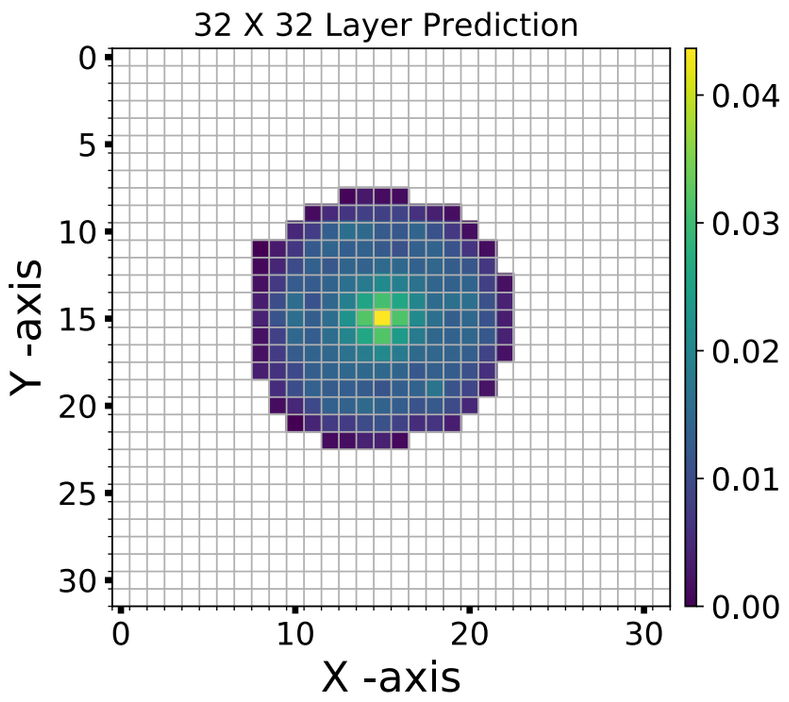
Centered around highest energetic cell



An average of many centered images

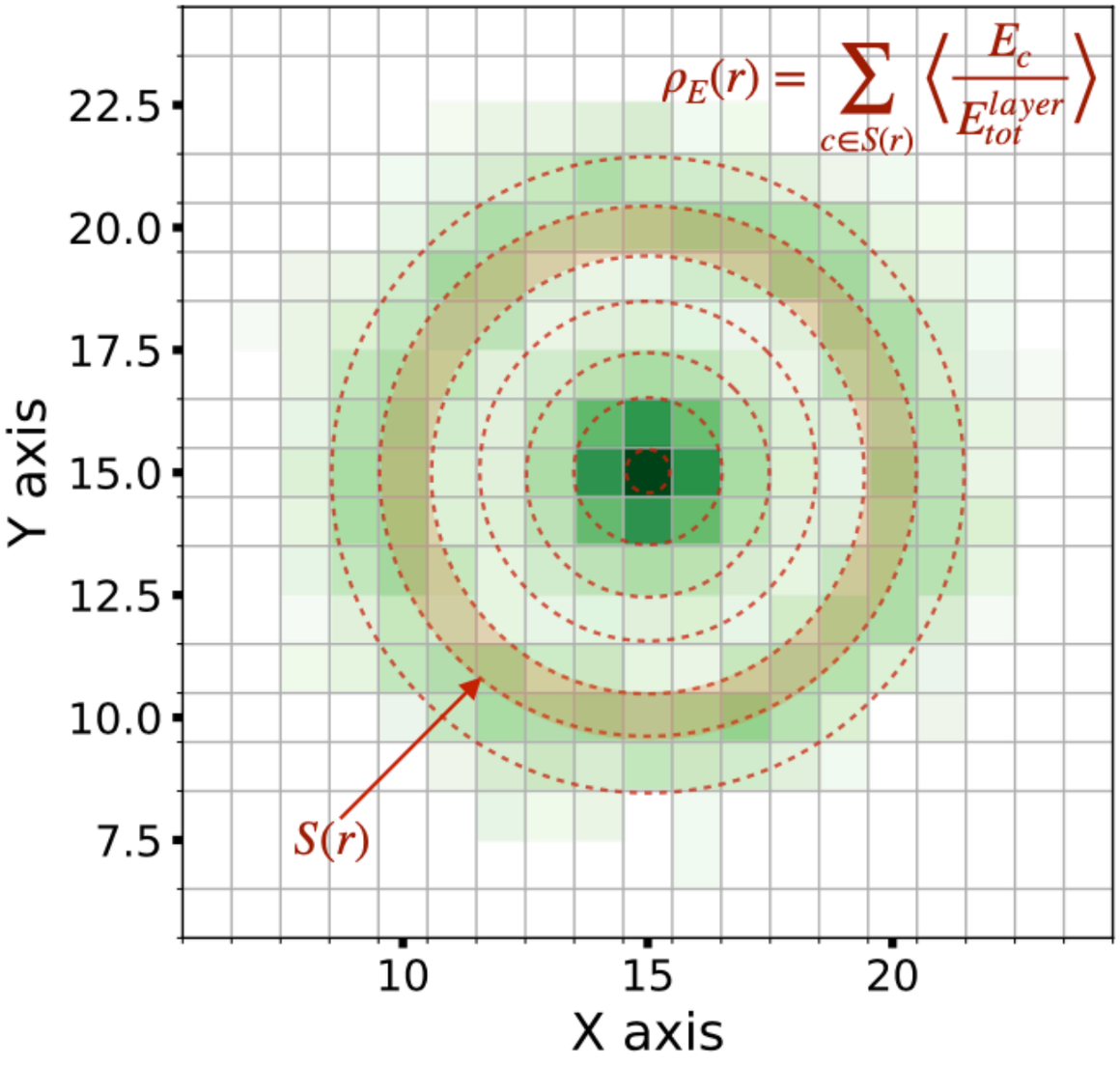


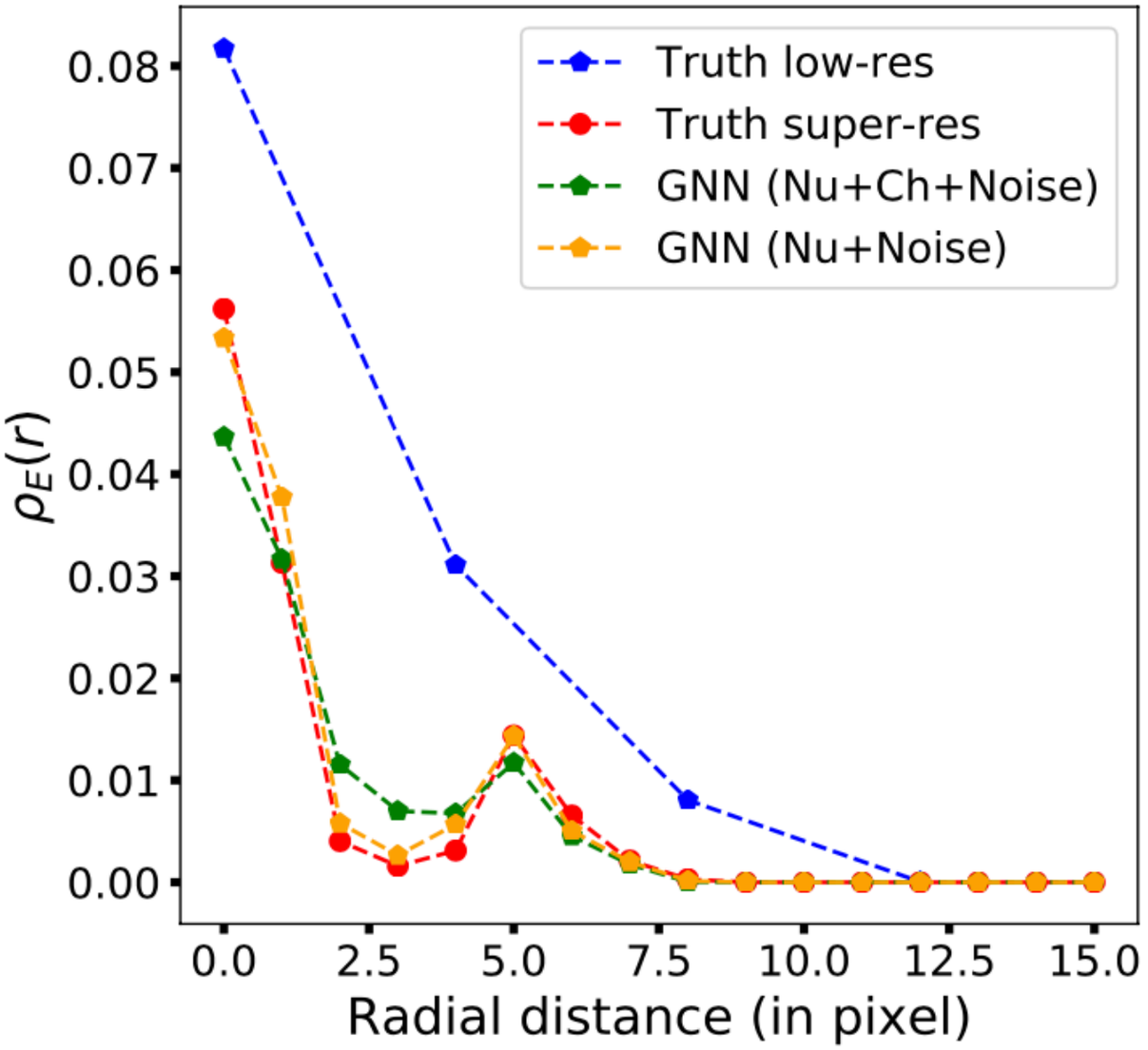




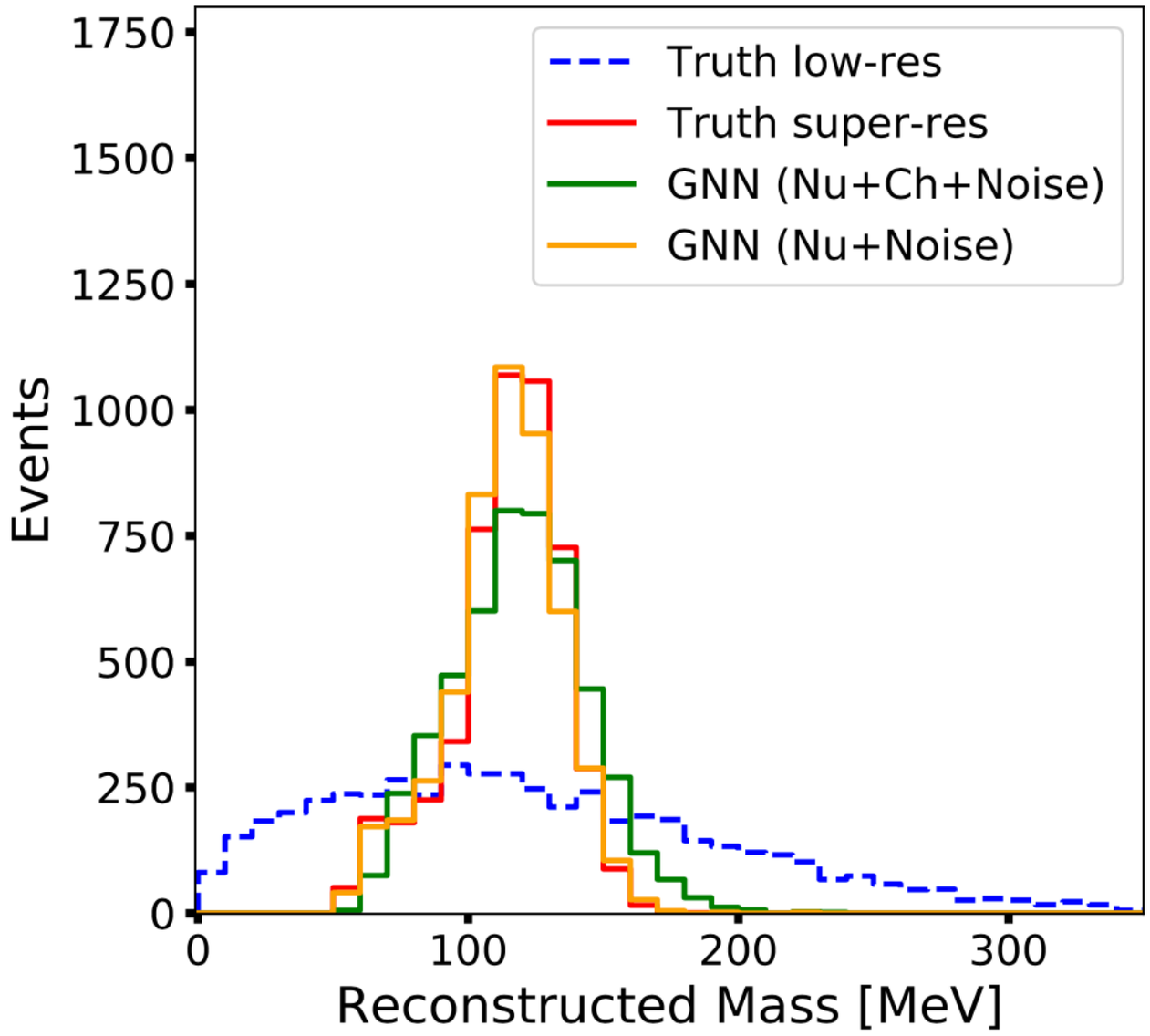
A secondary rim is present in super-resoluted image, but absent in the low-res

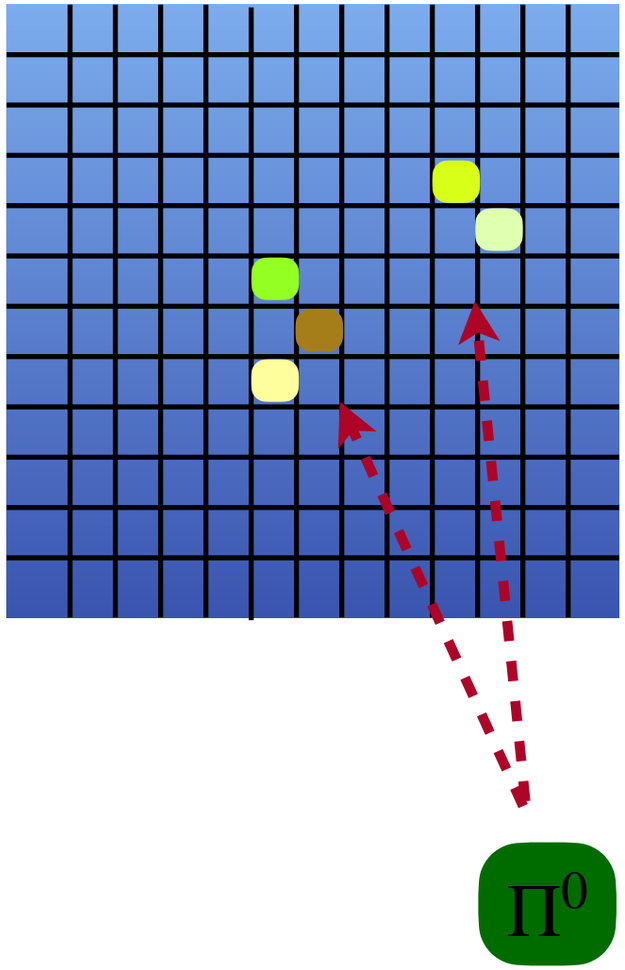
The integrated profile





The mass distribution





Invariant mass from reconstructed 4-vectors.

and .. we are not alone

High Energy Physics - Phenomenology

[Submitted on 22 Dec 2020 (v1), last revised 3 Feb 2021 (this version, v2)]

How to GAN Higher Jet Resolution

Pierre Baldi, Lukas Blecher, Anja Butter, Julian Collado, Jessica N. Howard, Fabian Keilbach, Tilman Plehn, Gregor Kasieczka, Daniel Whiteson

Astrophysics > Cosmology and Nongalactic Astrophysics

[Submitted on 13 Oct 2020]

AI-assisted super-resolution cosmological simulations

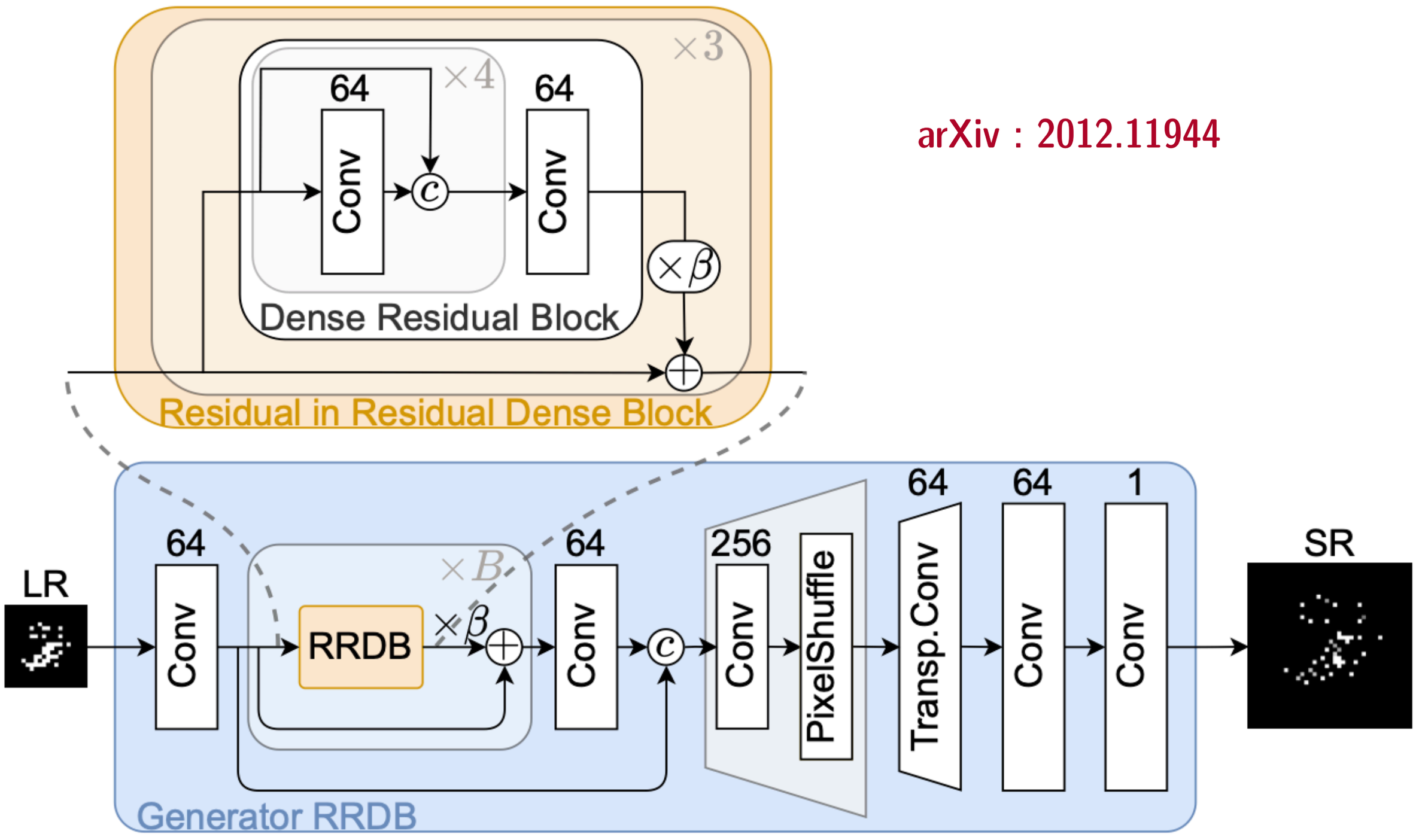
Yin Li, Yueying Ni, Rupert A. C. Croft, Tiziana Di Matteo, Simeon Bird, Yu Feng

Deep learning methods for super-resolution reconstruction of turbulent flows

Physics of Fluids **32**, 025105 (2020); https://doi.org/10.1063/1.5140772

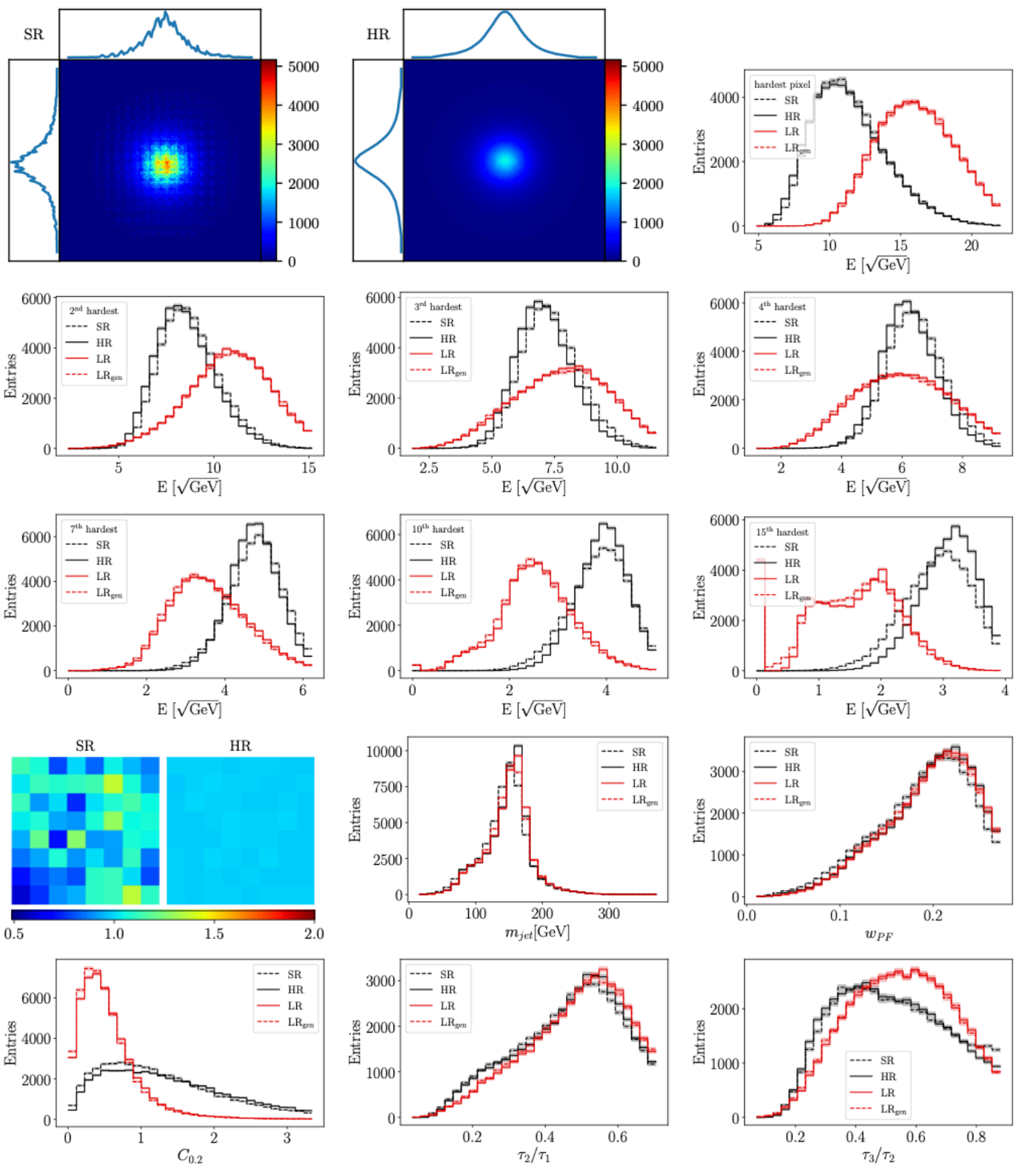
Bo Liu, Jiupeng Tang, Haibo Huang[a], *and* Xi-Yun Lu

Just a bit closer look at SR generative model



arXiv : 2012.11944

Just a bit closer look at SR generative model



arXiv : 2012.11944

Summary

Generalized Super-resolution techniques are powerful tool to extract more physical information from a given data.

In context of particle physics, these techniques can be applied to any problem which suffers from the issue of intrinsic resolution of measuring devices.

The techniques we develop for HEP applications are readily usable for other branches like astronomy etc ...