# Use of Machine Learning tools: plans from IFCA

COMCHA meeting
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CMS

UC
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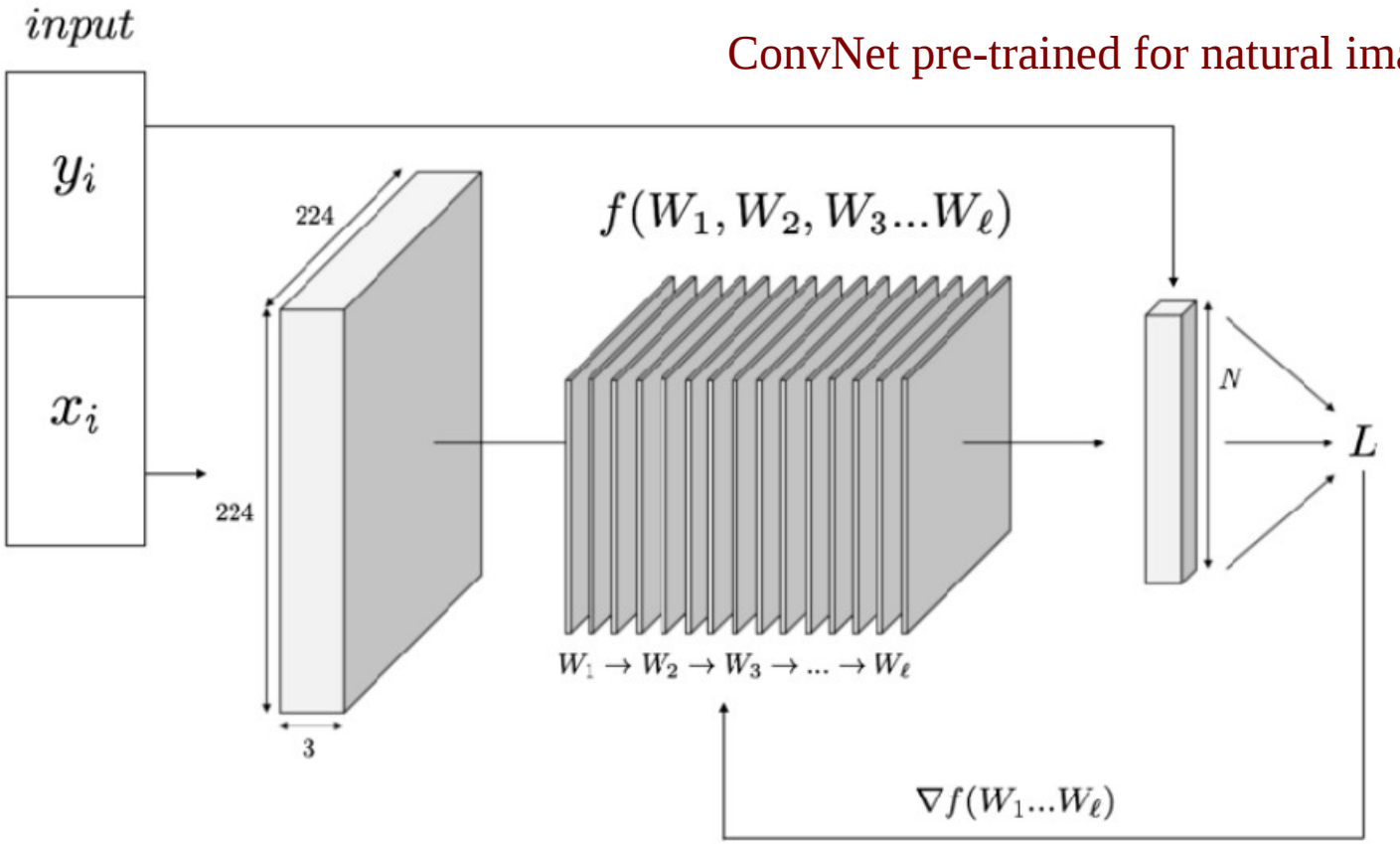
# Introduction and context

- IFCA has a strong group of advanced computing with focus on ML techniques.
  - About 10 people including physicists and software engineers.
  - This has to be added up to the High Energy Physics group.
- Administration of the IFCA Tier2 + HEP Tier3 and other resources:
  - Altamira super computer.
  - Currently 10 new GPUs + 1 old GPU.
  - Cloud resources.
- Also strong involvement in the Open Data group within CMS.
- Several years of expertise in Deep Learning techniques mainly for image classification.
  - Biodiversity. (Mobile application). **arXiv:1706.03736**.
  - High Energy Physics classification. **arXiv: 1708.07034**
  - Working now in medical diagnosis.
- Excellent environment to explore and promote ML tools in the context of HEP.

# HEP example: event image classification

- Final degree project developed by Celia Fernández. Presented at the CMS ML forum.
- Use of a Convolutional Network to classify event images from different processes.

ConvNet pre-trained for natural images.

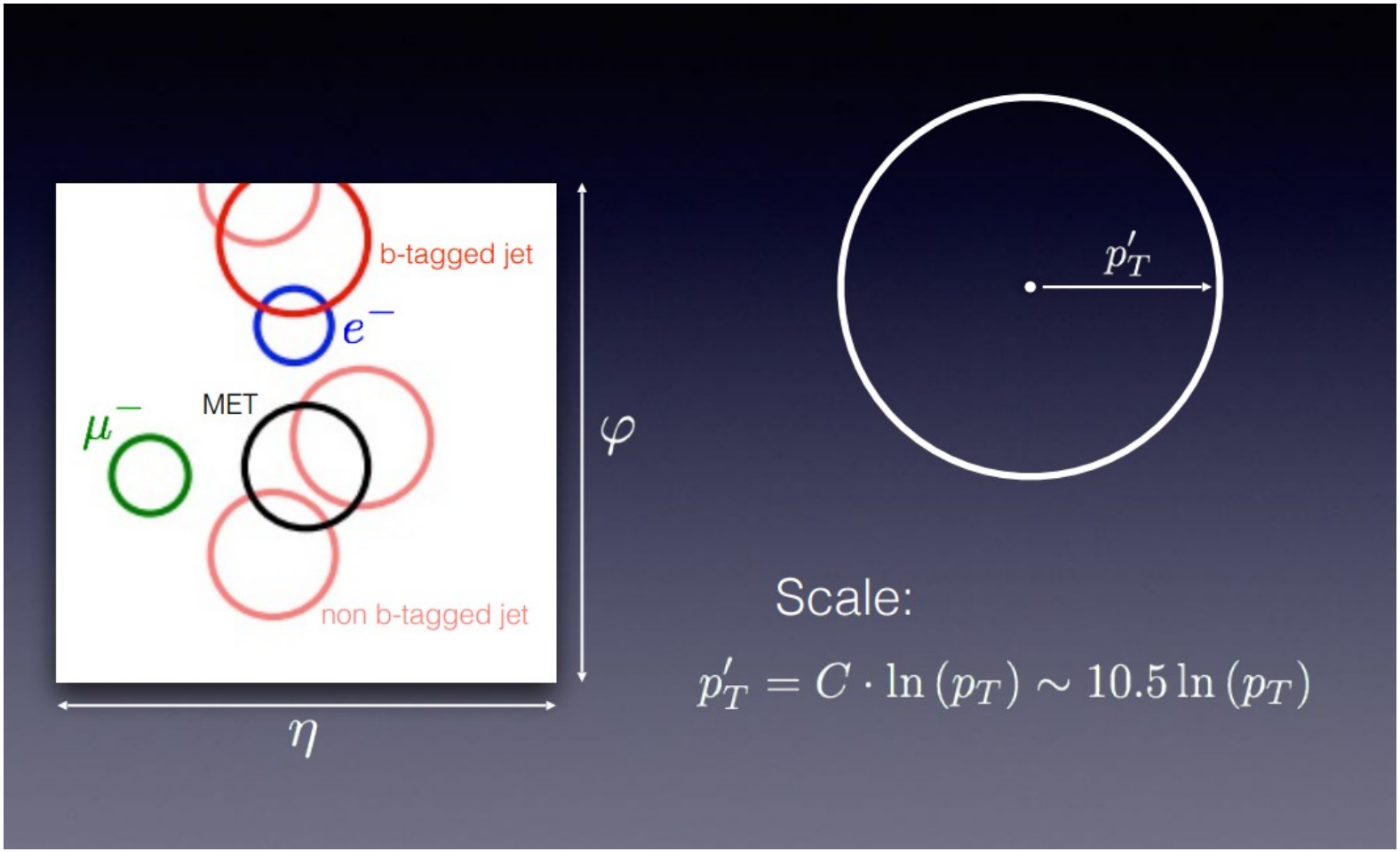



https://indico.cern.ch/event/646782/

**arXiv: 1708.07034**

# HEP example: event image classification

- HEP events are translated into pictures according to a simple geometrical mapping.

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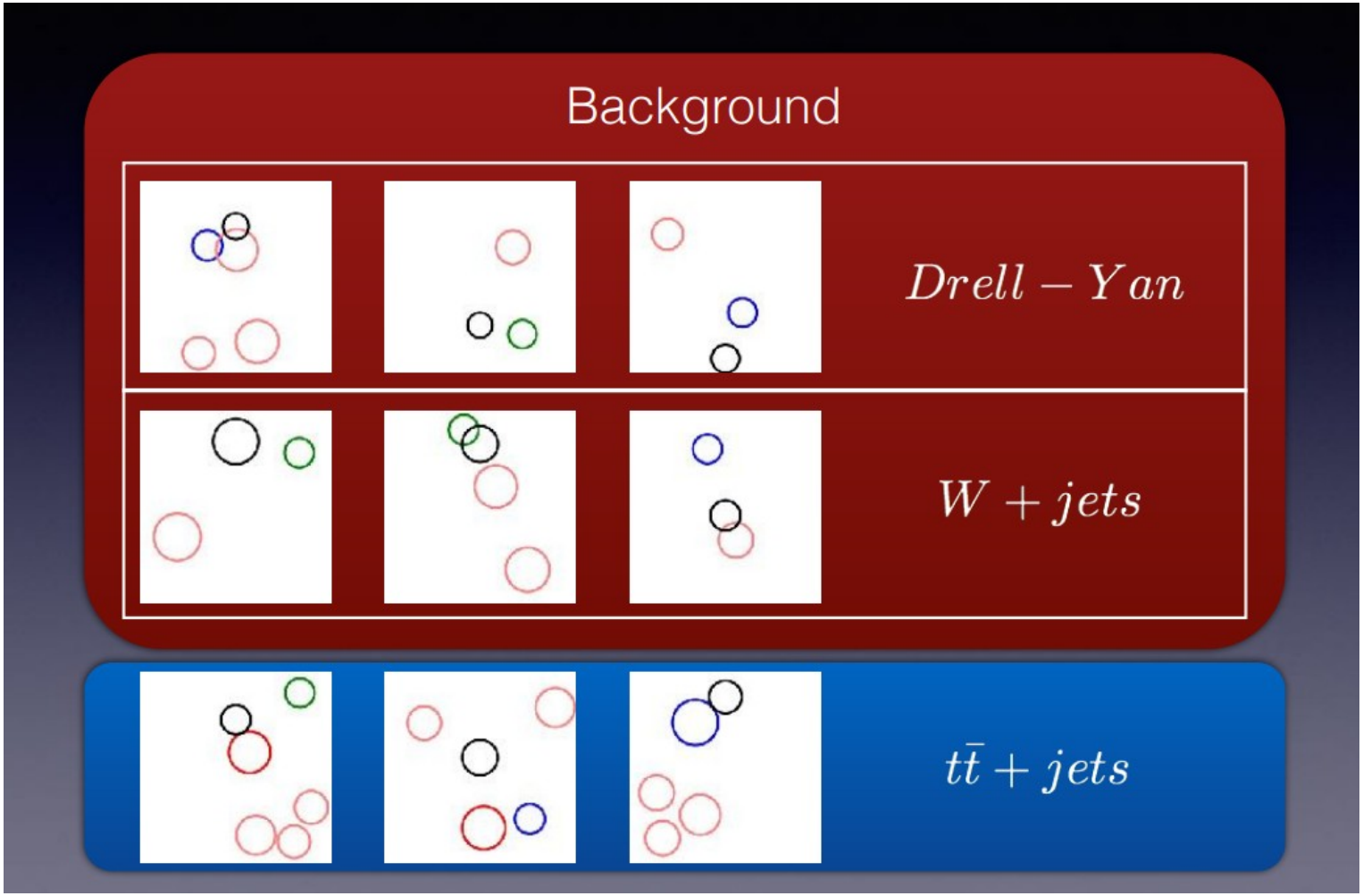
# HEP example: event image classification

- Using these images to treat the background discrimination as an image classification.

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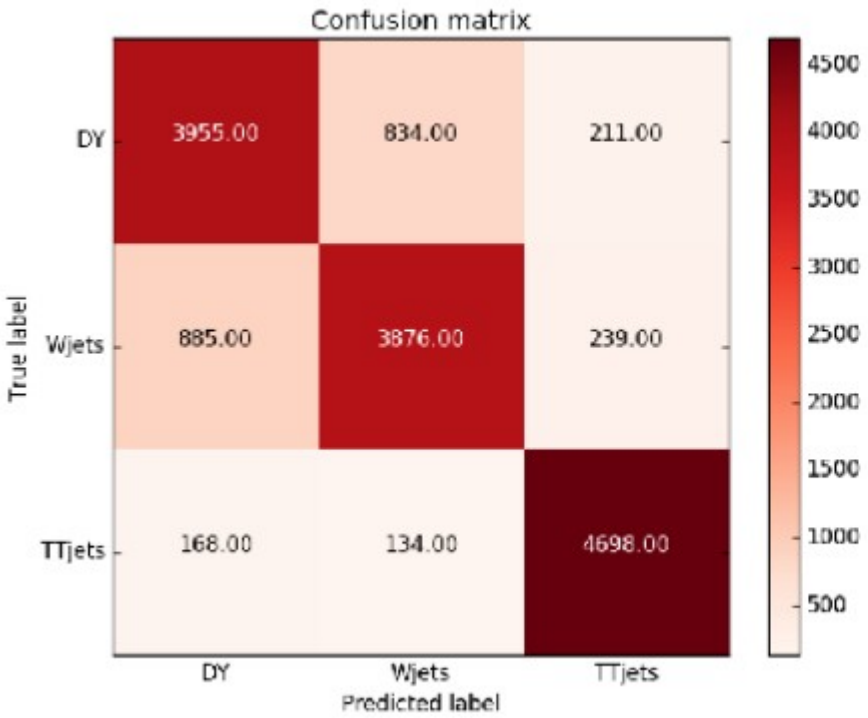


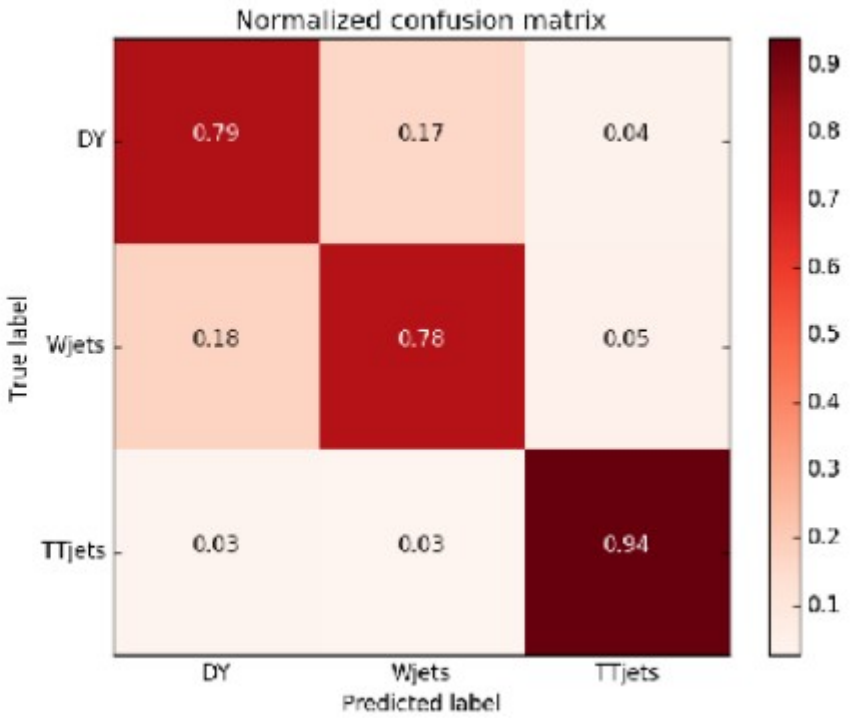


- Probability of choosing the right category: 84% (98% within the two first choices)

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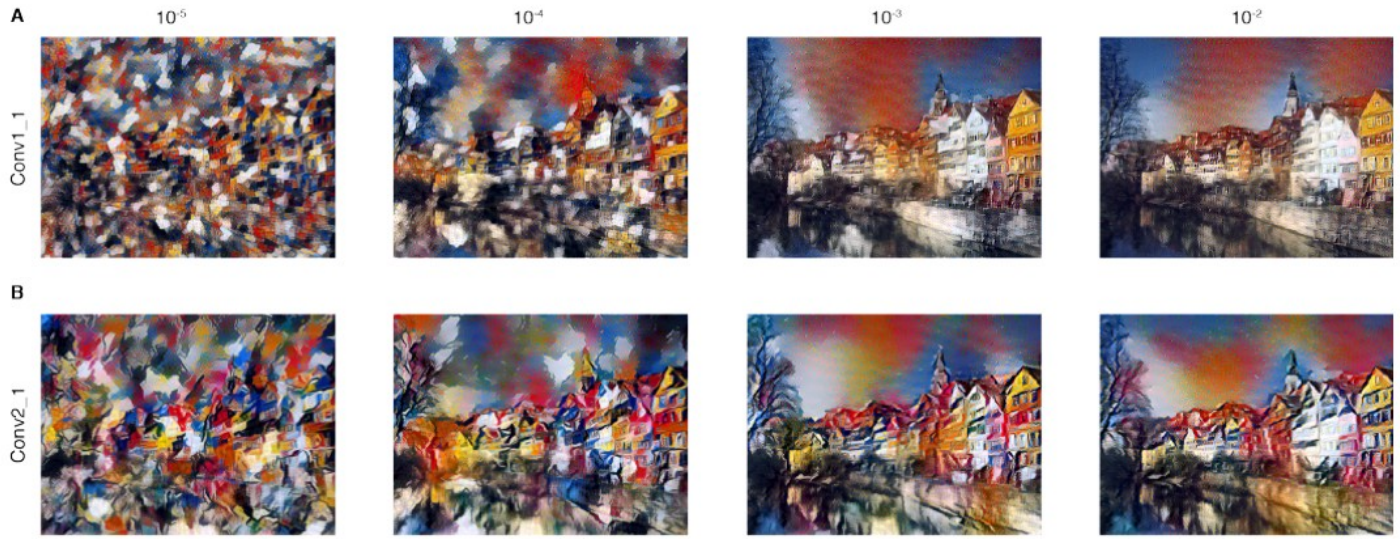
# HEP example: realistic MC generation

- This is currently a Final Degree Project (Mario Señas) to be presented in September.
- Learning local correlation patterns to produce realistic MonteCarlo simulations.


**Based on arXiv:1508.06576**

# HEP example: realistic MC generation

- The “style”of an artist is encapsulated in the local correlations among pixels.
- The content produces larger-scale correlations among distant pixels.
- Convolutional networks learn local correlations in the first layers/filters.
- Idea is to consider MC simulation as a real image and data as an “artist/detector” vision.
  - Detector effects in real data introduce local correlations in the observables.
  - We train with data to learn these local features and then apply to real MC.




$$\mathcal{L}_{total}(\vec{p},\vec{a},\vec{x}) = \alpha\mathcal{L}_{content}(\vec{p},\vec{x}) + \beta\mathcal{L}_{style}(\vec{a},\vec{x})$$

**Based on arXiv:1508.06576**

# HEP example: realistic MC generation

- In order to map processes into pixel maps where correlations make sense:
  - We make two categories of observables: simple and composed.
  - Both of them are used in a 2D table. Size of each pair map into a pixel colour.

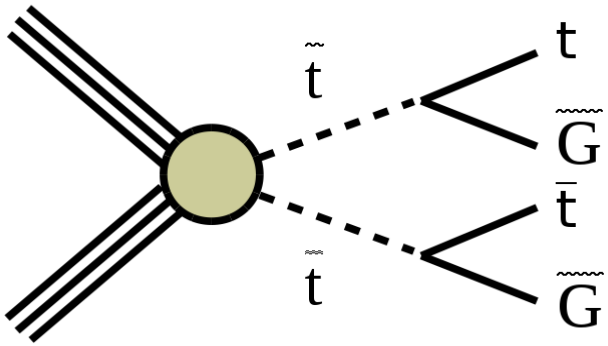
| | MET | N Jet | MT2 | HT | MT | ... | ... | ... | ST |
|---|---|---|---|---|---|---|---|---|---|
| Jet1 pt | | | | | | | | | |
| Jet1 phi | | | | | | | | | |
| Jet1 eta | | | | | | | | | |
| Jet2 pt | | | | | | | | | |
| Jet2 phi | | | | | | | | | |
| ... | | | | | | | | | |
| Lep1 pt | | | | | | | | | |
| ... | | | | | | | | | |
| Lep2 eta | | | | | | | | | |

Work ongoing...

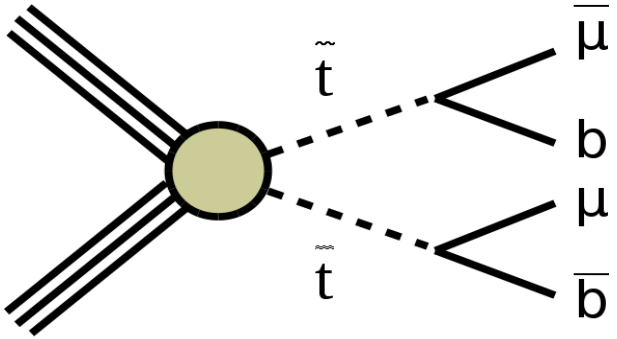
**Based on arXiv:1508.06576**

# Plans for displaced vertex/track reconstruction

- IFCA group has an increasing interest in searches including displaced tracks/leptons.
  - Expertise both in SUSY and EXO searches in conventional prompt-signatures.
  - Also expertise in b-tagging algorithms.
- Starting now involvement within the new timing detectors for the CMS upgrade.
- Already contributing in the context of the Yellow Report for the European Strategy.
- Two PhD students (Celia Fernández, Pedro Fernández) with focus on this activity.



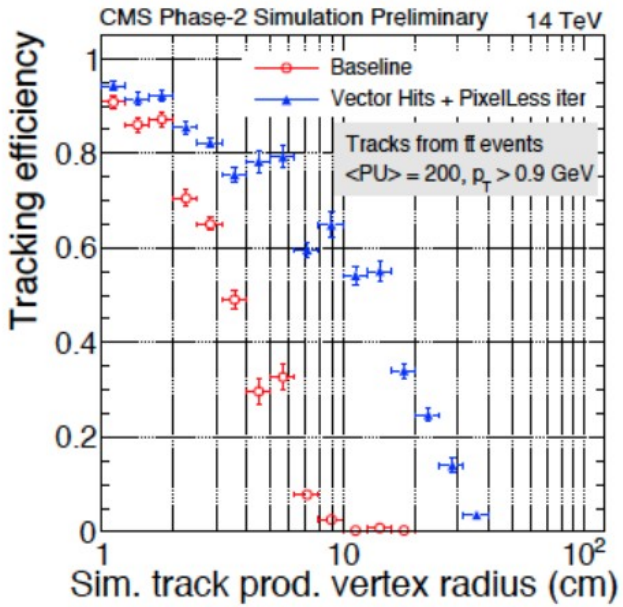

GMSB stop

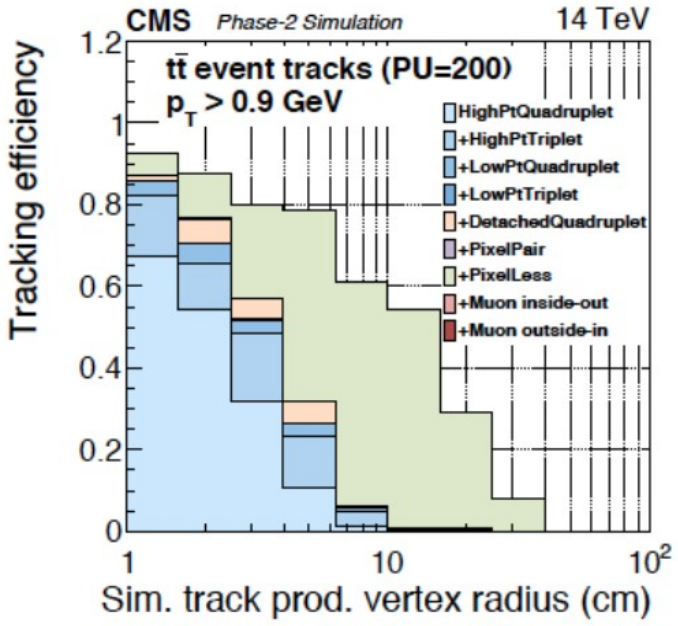



RPV stop

# Plans for displaced vertex/track reconstruction

- Vertex and displaced tracks have very low efficiency (even lower for HL-LHC)
- Plan to work in the application of Deep Algorithms to reconstruct/identify these tracks.
  - Both including the timing and only with spatial information.
- Two PhD students (Celia Fernández, Pedro Fernández) with focus on this activity.
- Using Deep CSV (convolutional network for b-tag identification) as a starting point.
- **Exploration and first steps being carried out right now.**



# Conclusions

- IFCA HEP group is increasingly getting into the use of Machine Learning tools.
- Great synergies with the Advanced Computing group with expertise on the subject.
- Computing resources also available at IFCA to perform studies/work.
- Several exploration examples have been already developed.
- Facing now the first large project to reconstruct displaced tracks w/wo timing information.