Reconstructing top quarks with deep learning at the Large Hadron Collider

Dortmund Data Science Center
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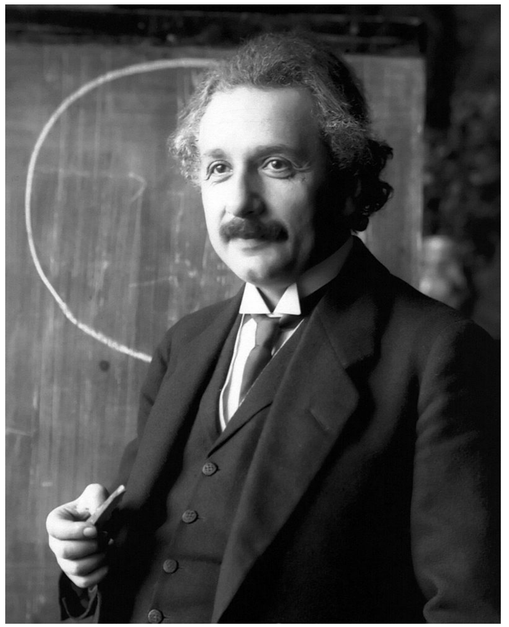
Experimentelle Physik IV

based on
arXiv:1907.11181

Top quarks at the Large Hadron Collider



$E = mc^2$

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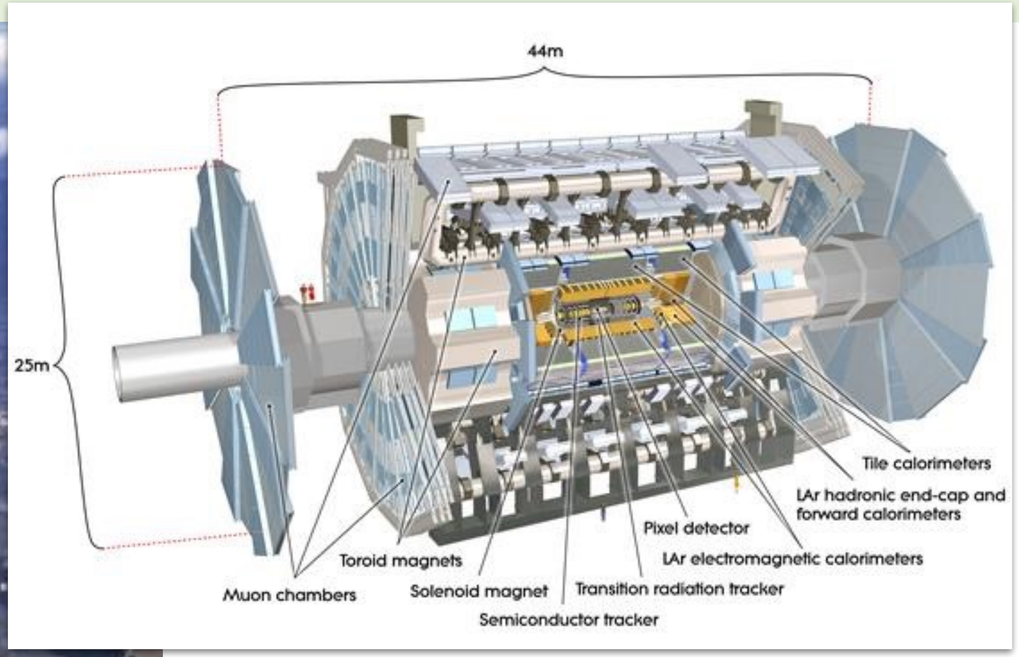

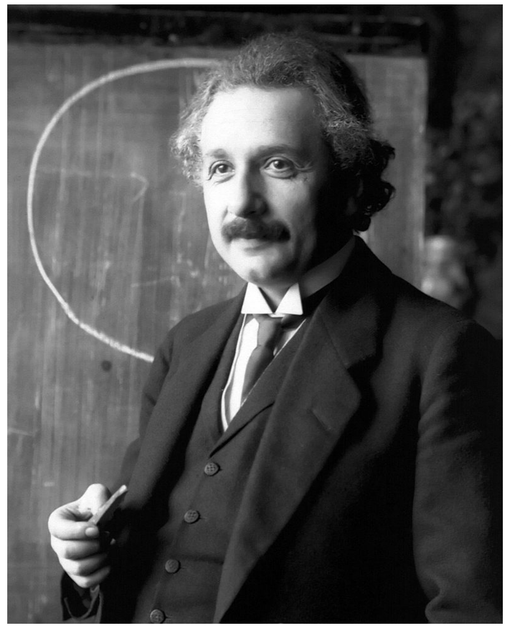

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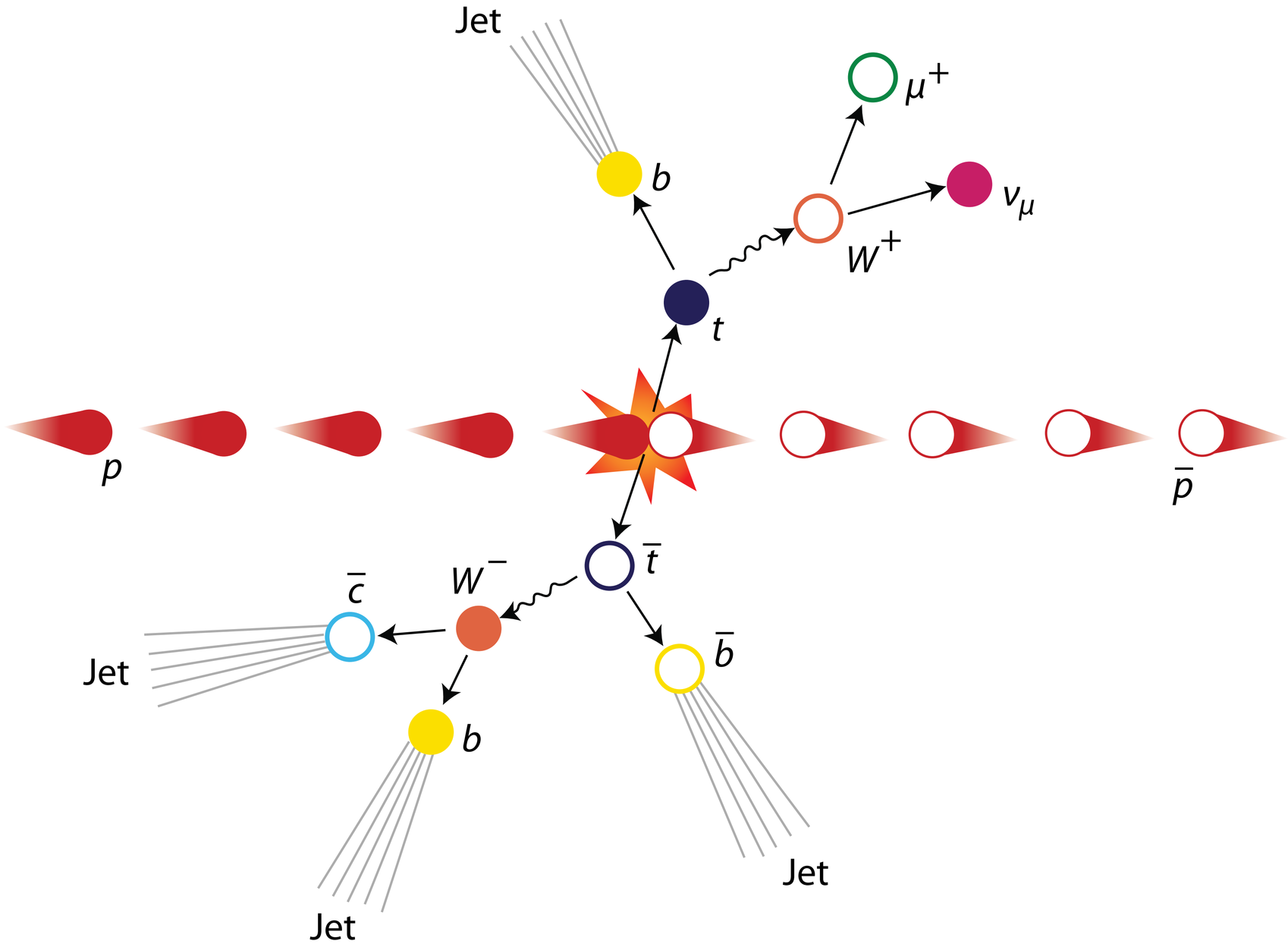
Detection of top quarks and the issue of jet combinatorics



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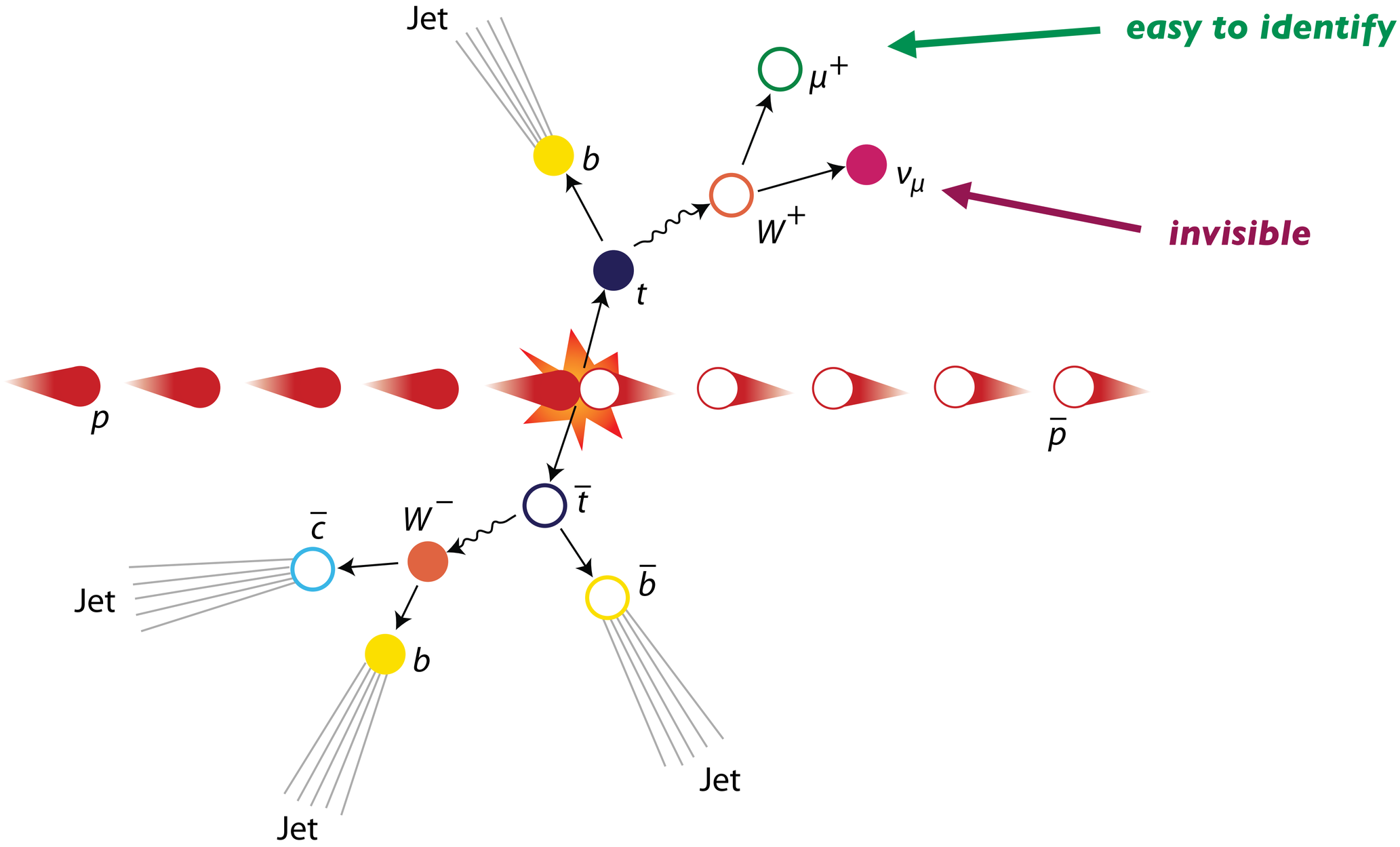

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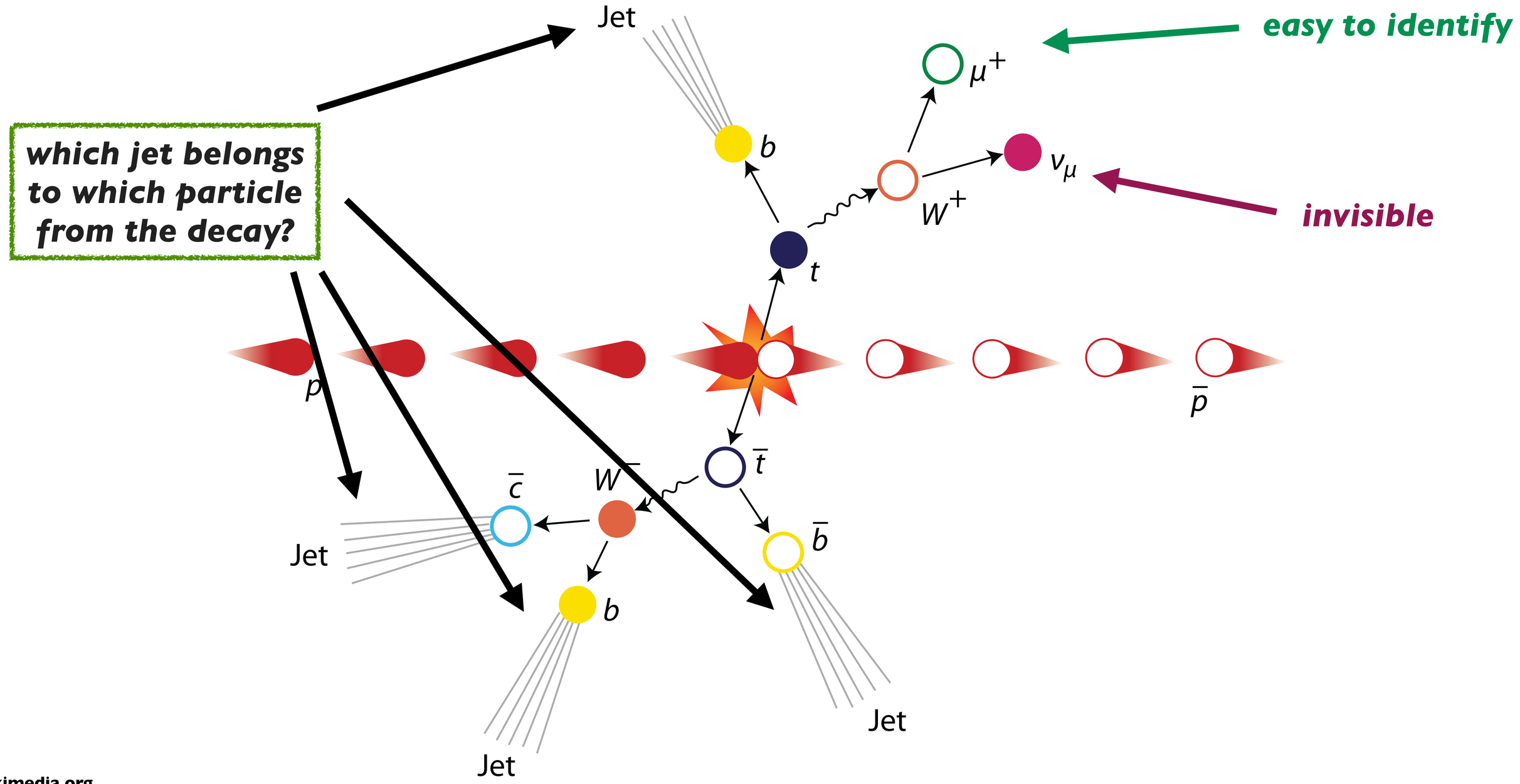

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Standard algorithm vs. deep learning

Standard algorithm

A likelihood-based reconstruction algorithm for top-quark pairs and the KLFitter framework

Johannes Erdmann[a,b], Stefan Guindon[a,c], Kevin Kröninger[a], Boris Lemmer[a], Olaf Nackenhorst[a], Arnulf Quadt[a], Philipp Stolte[a]

NIM A 748 (2014) 18
arXiv:1312.5595

Basic idea: For each possible combination …

- use particle energies and flight directions
- assign to top-quark decays
- compare to known particle masses

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Deep learning

- 36 million simulated LHC collisions
- Dataset: 1 true & many wrong combinations for each simulated LHC collision
- Input: particle energies and flight directions

Binary classification problem

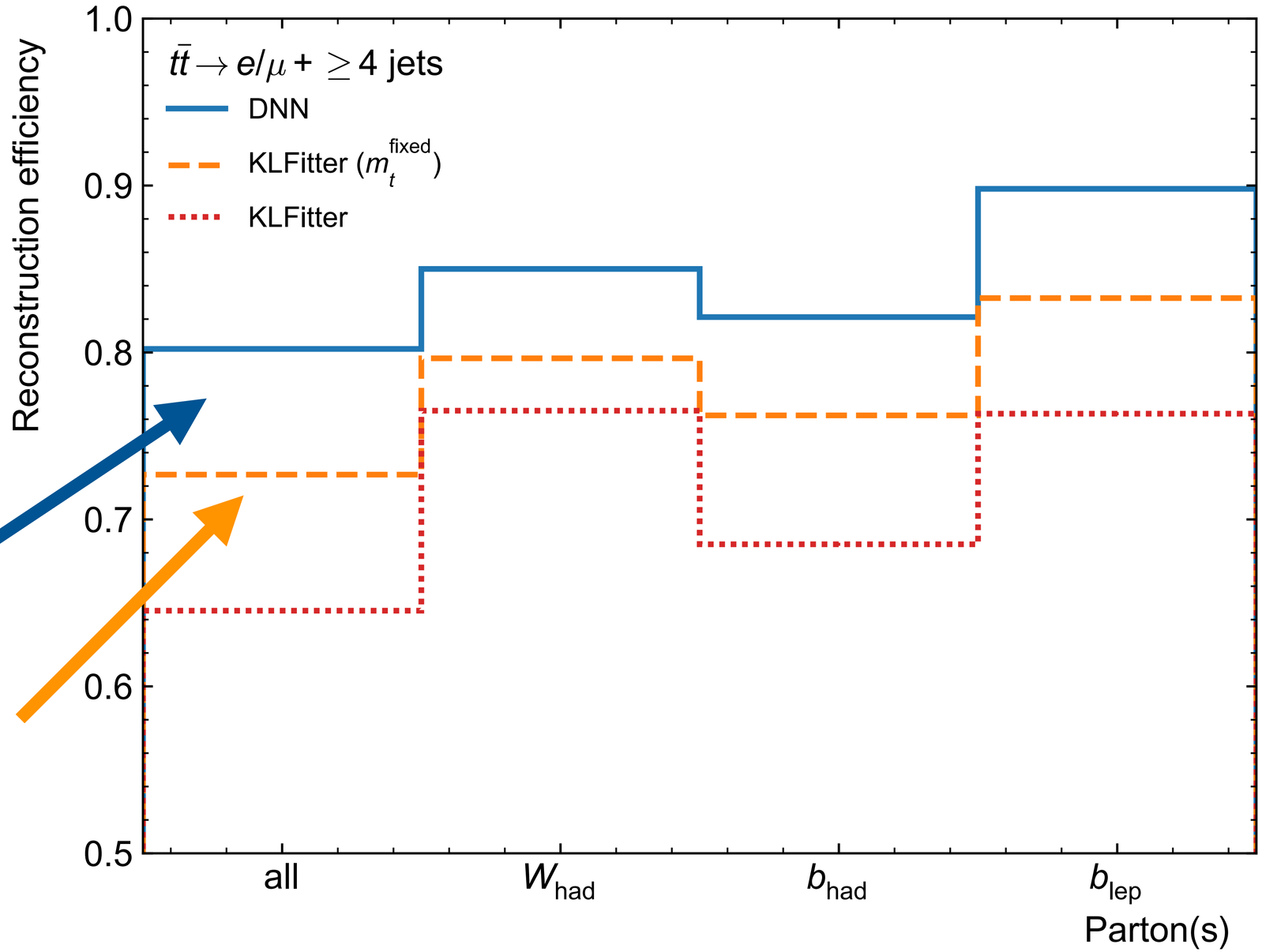
- Separate true and wrong combinations
- For each LHC collision:
  - choose combination with largest output

How often do we pick the right combination?

Hyperparameter optimization:
- 5 hidden layers with 512, 256, 128, 64, 32 nodes
- Batch size: 12,000
- Learning rate (Adam) 0.01
- L_2 regularization: 10^{-8}

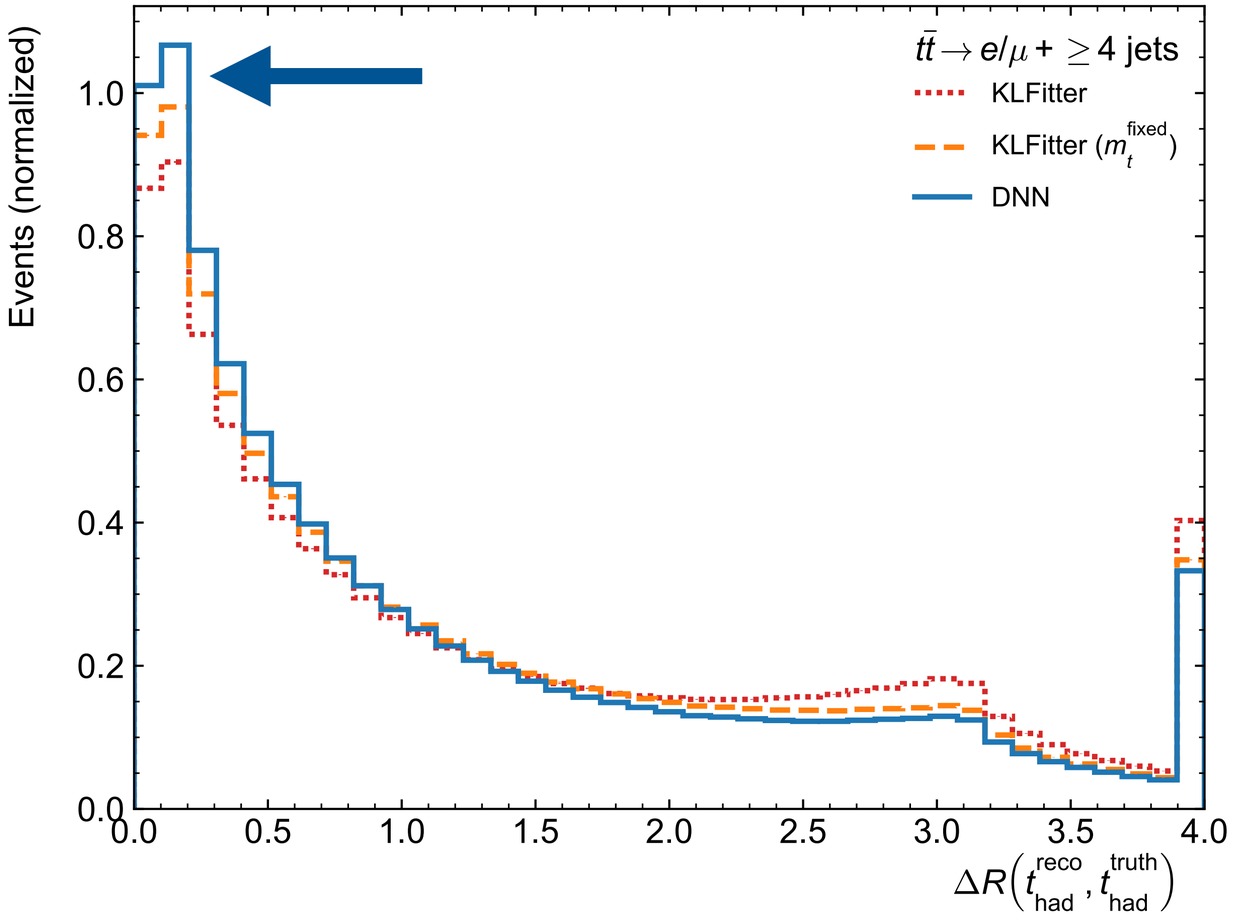
Correct combination in 80.2%

Improvement over best version of the standard algorithm (72.7%)



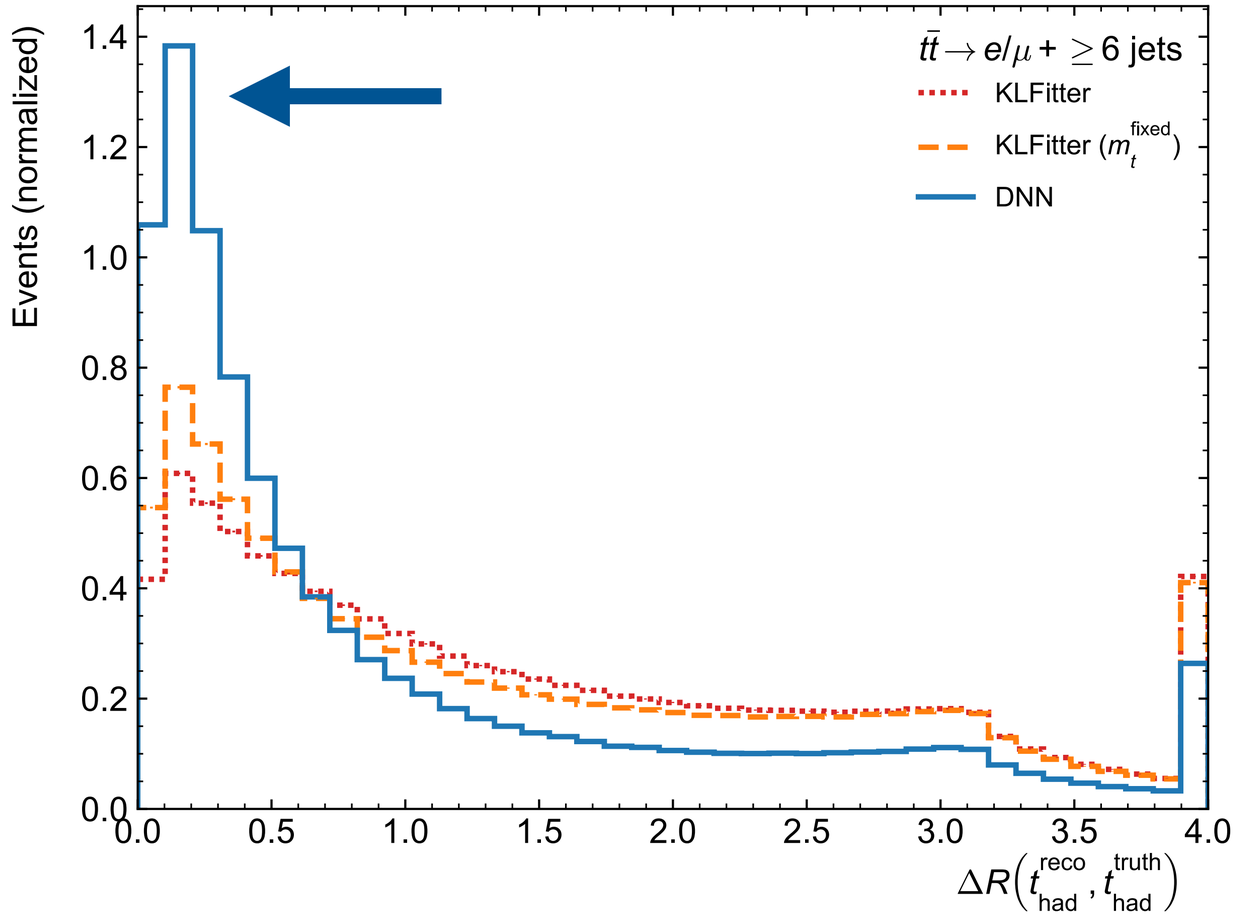
The harder the problem, the larger the improvement

Correct combination of 4 jets out of 4
$\Longrightarrow$ 4!/2 = 12 combinations



(= difference in top-quark direction)

Correct combination 4 jets out of 6
$\Longrightarrow$ 6!/4 = 180 combinations



(= difference in top-quark direction)