Zero-bias new particle searches in UPCs

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UPC and CEP processes:

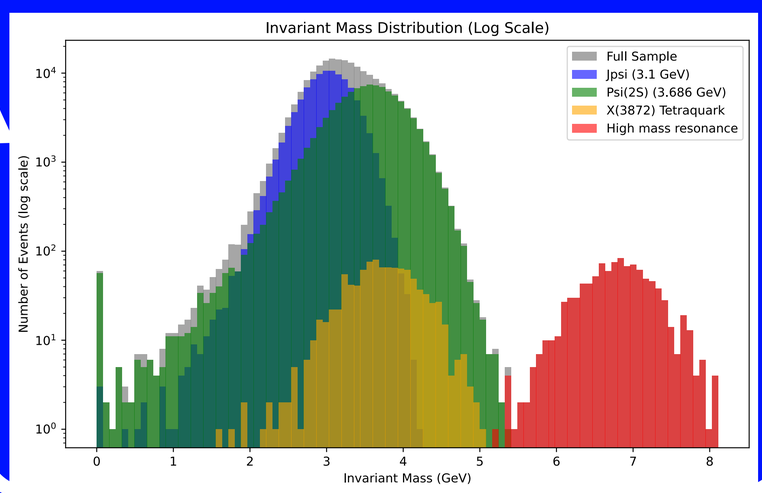
- Rapidity gaps (no particles) on both side of the detector
- Low multiplicities involved (in exclusive UPCs measurements, multiplicities considered do not surpass six tracks events)
- Very clean environment, suitable for studies of New Physics
- In the case of UPCs, low p_{T} of the vector meson in the process $\gamma + \mathrm{Pb} \rightarrow \mathrm{VM}$ [1]

Opportunity for anomaly detection:

- Anomaly detection in particle physics usually refers to online triggering, e.g. triggers for calorimeters
- We explore the possibility that anomaly detection can be used at the offline level in analyses, on the full data set for UPC and CEP processes

Toy simulations:

- Built a very simple cocktail with typical UPC-like kinematics for J/ψ and ψ'
- Added signals of new physics, i.e. $X(3872)$ and a (unknown) particle with high mass 6.9 GeV

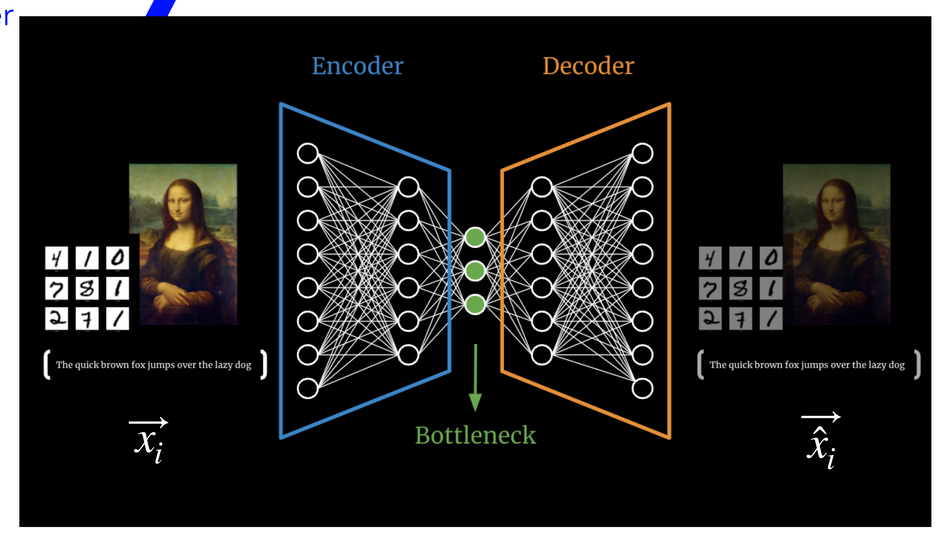


Autoencoders:

- Two neural networks, encoder+decoder
- Very similar to zipping+unzipping a folder
- In this analogy, the unzipped folders are identical to the folders that were zipped
- Discrepancies result in *reconstruction errors*
- Preferred choice for a figure of merit for the reconstruction error is the *mean squared error (MSE):*

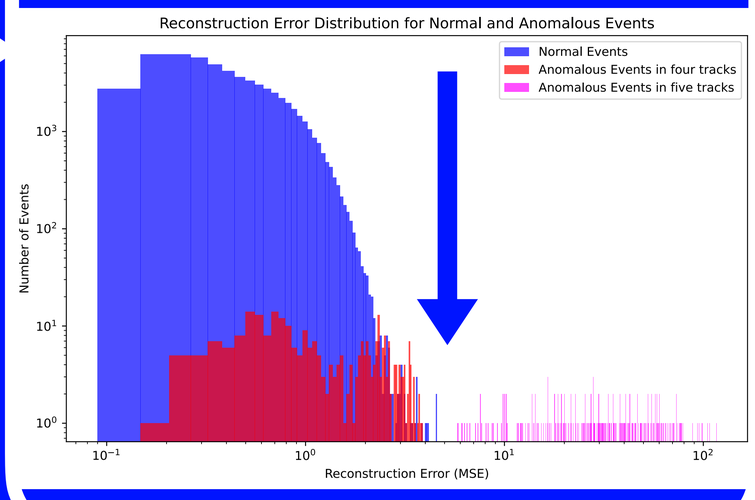
$$\mathrm{MSE} = \frac{1}{\sigma}\sum_{i=1}^{\sigma}(x_i - \hat{x}_i)^2 \quad [2]$$

Autoencoders are perfect for anomaly detection



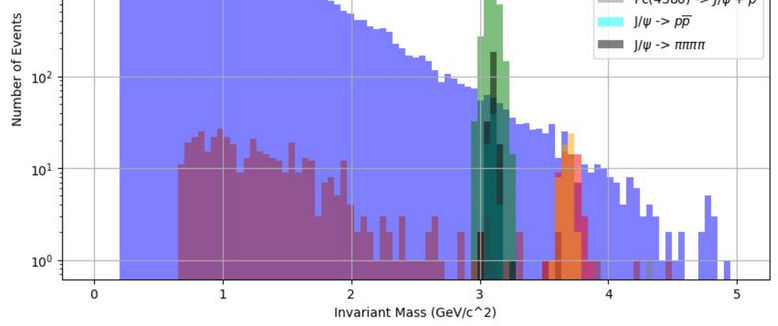
How New Physics behaves: [3]

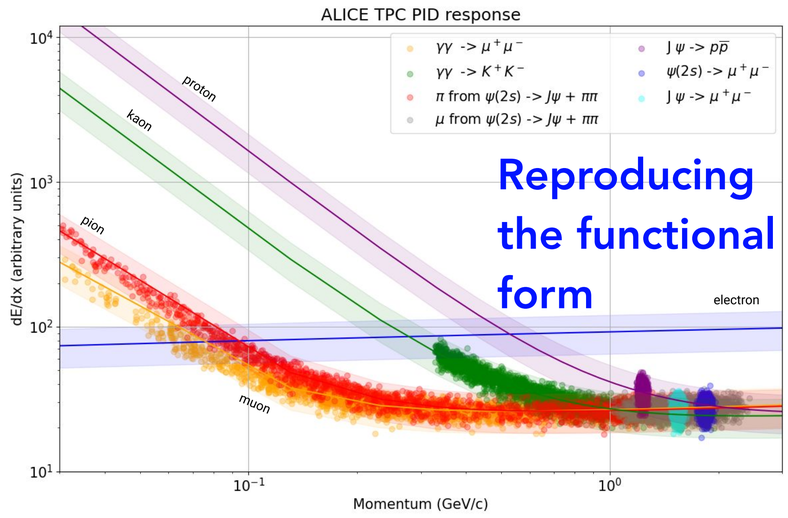
- Very well separated with high MSEs



Creating a more realistic particle cocktail:

- Cocktail includes all UPC processes measured by ALICE
- $J/\psi \rightarrow \mu\mu$, $\psi' \rightarrow \mu\mu$, $\gamma\gamma \rightarrow \mu\mu$, $\gamma + (\gamma/pomeron) \rightarrow KK$, $\psi' \rightarrow J/\psi + \pi\pi$, $J/\psi \rightarrow p\bar{p}$
- Added additional exotic processes e.g. $J/\psi \rightarrow \pi\pi\pi\pi$, and $P_C(4380) \rightarrow J/\psi + p$
- In this exercise, realistic PID capabilities are also applied
- Model specialised for TPC-like data taking conditions, but far more general than just TPC-like conditions
- Input to the autoencoder is based just on the number of tracks, and the number of particles satisfying the PID selection criteria for a certain particle species (a particle can satisfy multiple PID requirements)

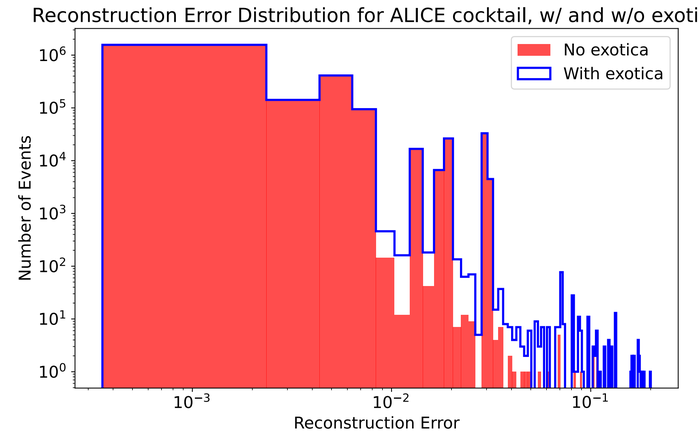


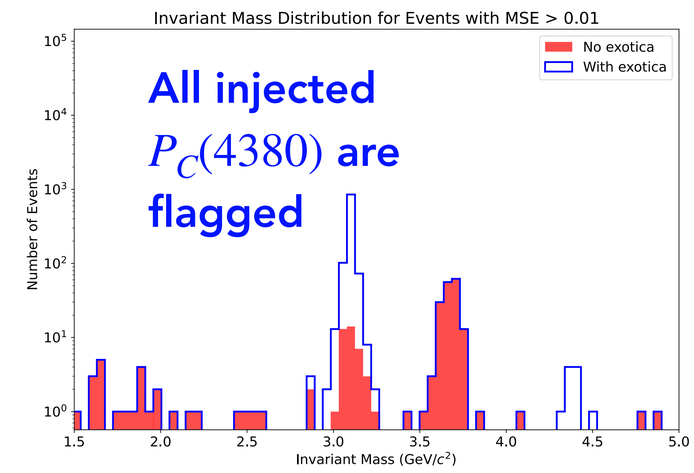


Reproducing the functional form

How this cocktail behaves:

- Red: standard cocktail without exotica, blue curve: with exotica
- Three peaks at larger masses ($J/\psi \rightarrow \pi\pi\pi\pi$, $\psi' \rightarrow J/\psi + \pi\pi$, $P_C(4380) \rightarrow J/\psi + p$)
- Since the background is very clean at larger masses it is possible to single out the peaks
- By studying the topology of the outstanding events it is possible to look for either New Physics or new decay channels [4]





All injected $P_C(4380)$ are flagged

Conclusions - the advantages of this approach:

- Only one pass through the entire data set to find any new particle or physics process
- Zero-bias: no cuts applied, no selection of a privileged phase space or topology
- If new processes appear, a dedicated cut-based analysis may follow to increase statistics

[1] A. J. Baltz et al., *Phys.Rept.* 458 (2008) 1-171
[2] U. Michelucci, arXiv:2201.03898
[3] S.Ragoni, J.Seger, C.Anson, arXiv:2411.00903
[4] S.Ragoni, B.Kinkaid, J.Seger, C.Anson, D.Tlusty, arXiv:XXXX.XXXX, paper in preparation