Queen Mary
University of London

A brief introduction to…

Techniques for automatic event recognition in MoEDAL

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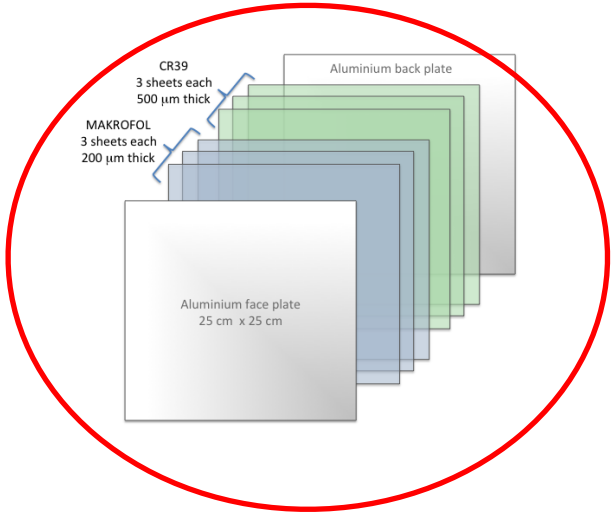
1. What is MoEDAL?

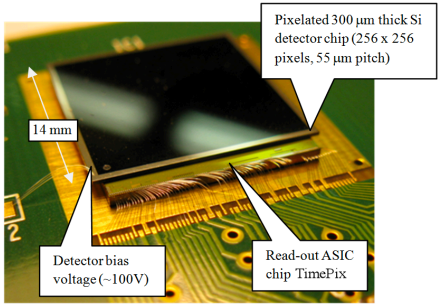
2. What is an event?

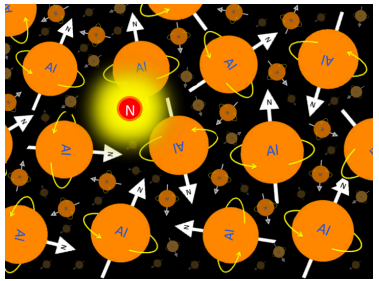
3. Automatic recognition

What is MoEDAL?

- A passive detector of polymer, timepix and aluminium.
- Designed to detect heavily ionising long lived particles.
- Specific focus on magnetic monopoles backed up by an assortment of exotic models.

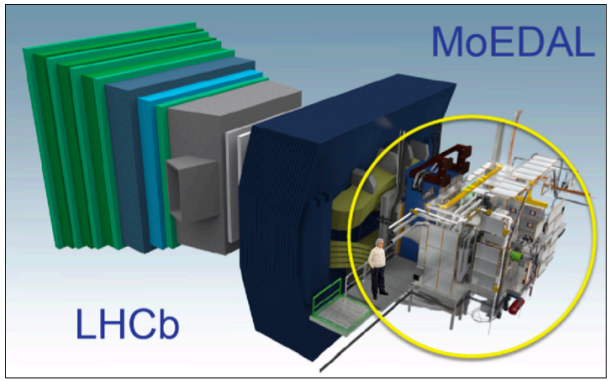


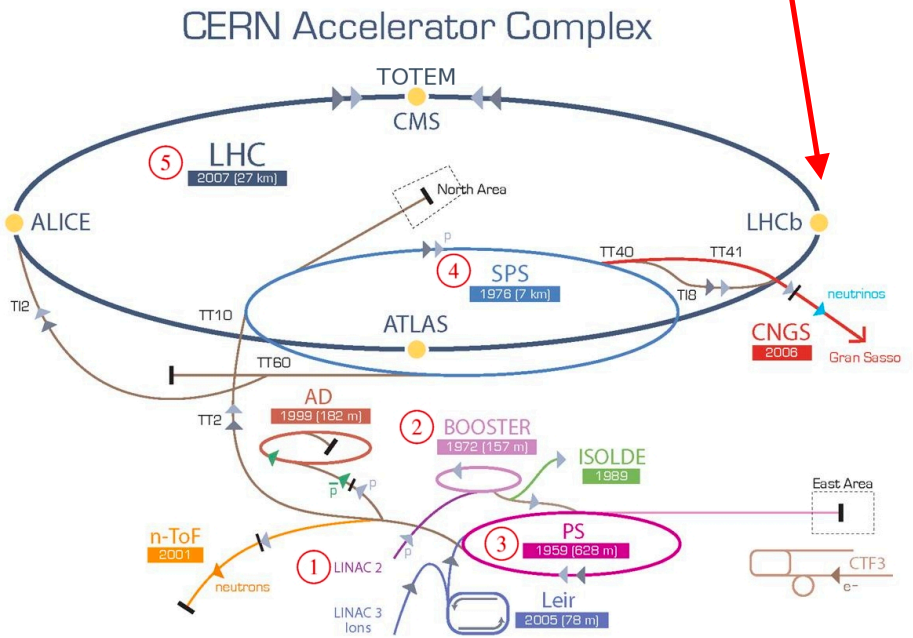




Where is MoEDAL?

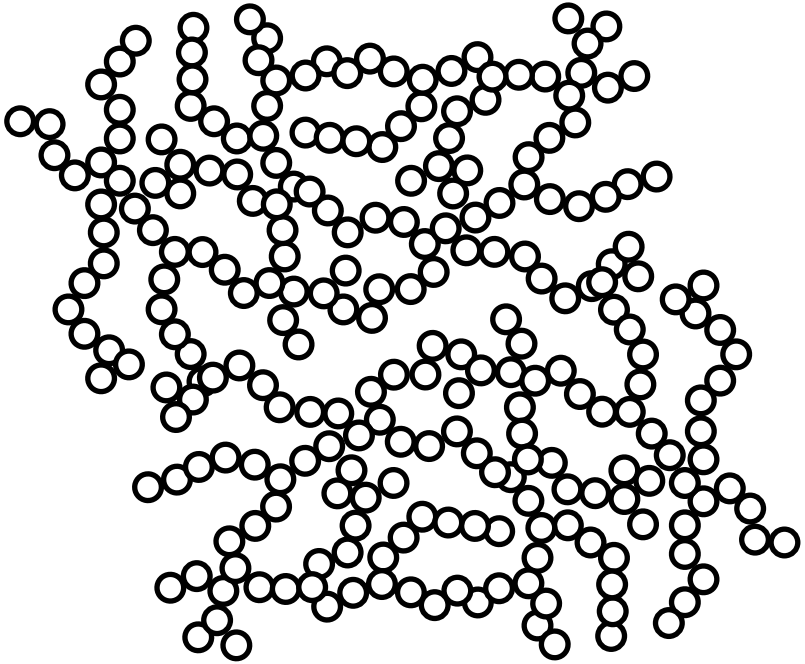
- Point 8 of LHC ring
- Vertex Locator Cavern of LHCb



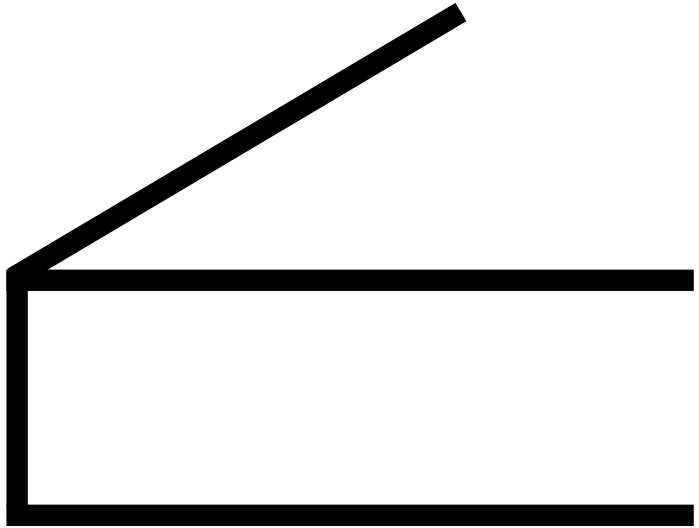


Undamaged polymer

○ = monomer

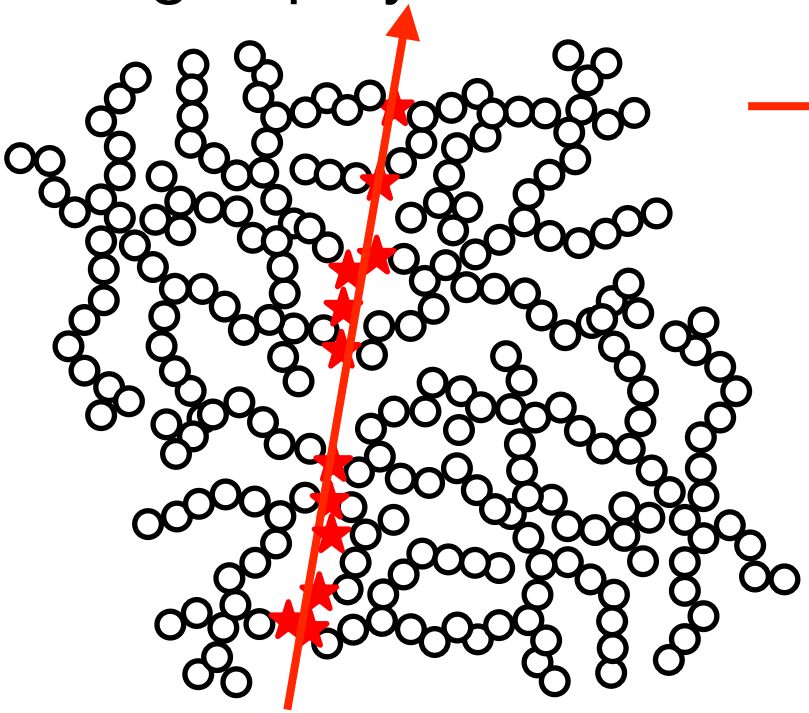


Nano-scale



Micron-scale

Damaged polymer

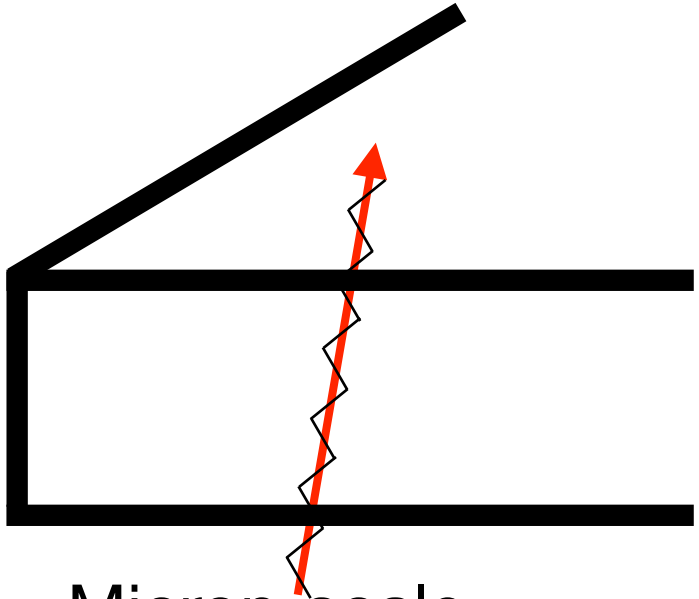


Nano-scale

= monomer

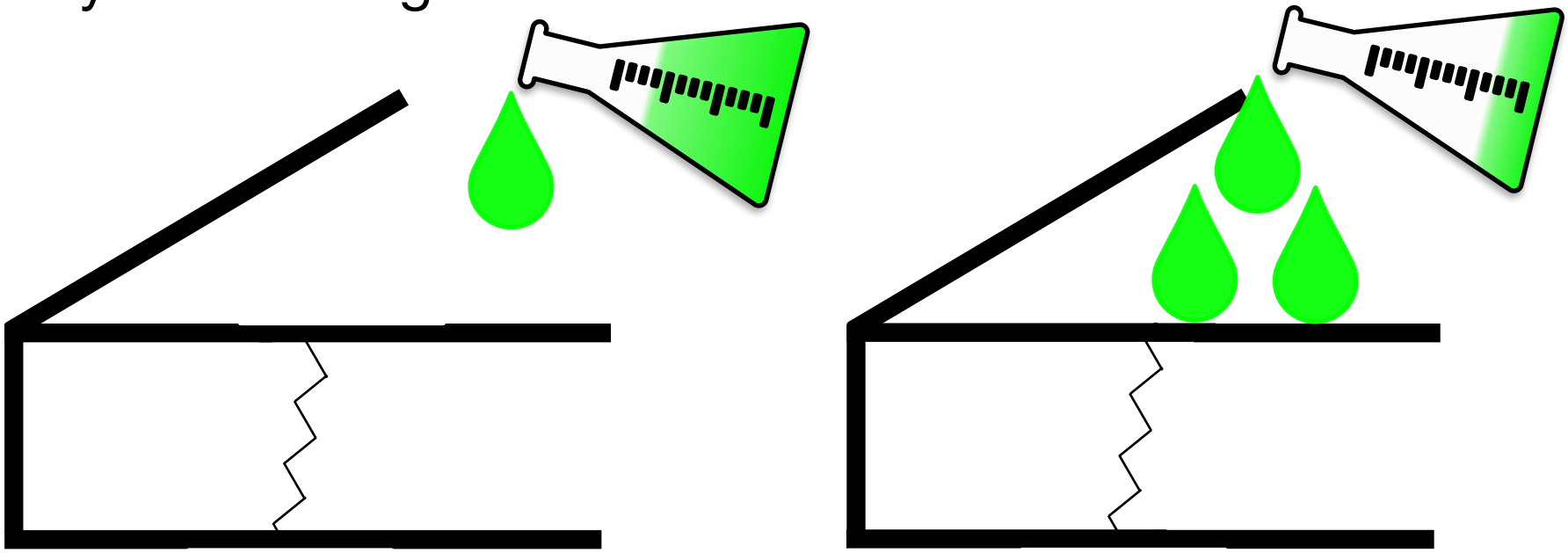
= broken link

= ionising particle trajectory

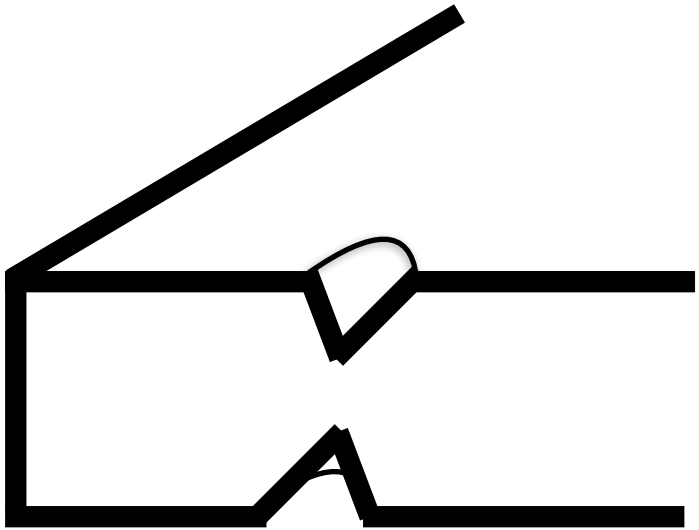


Micron-scale

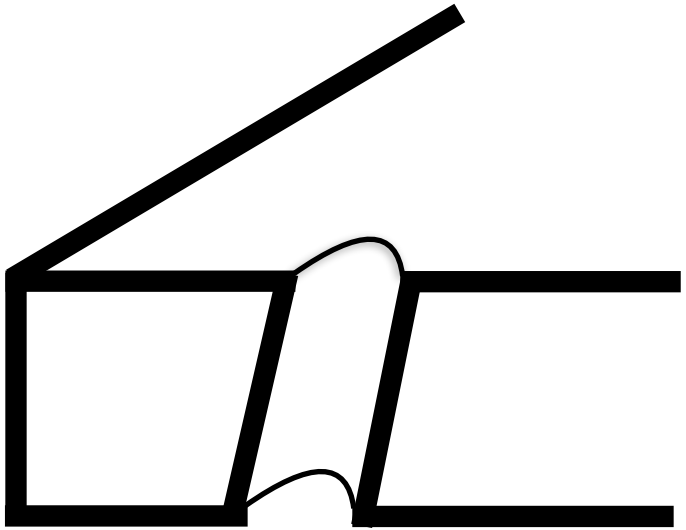
Polymer Etching



Polymer Etching

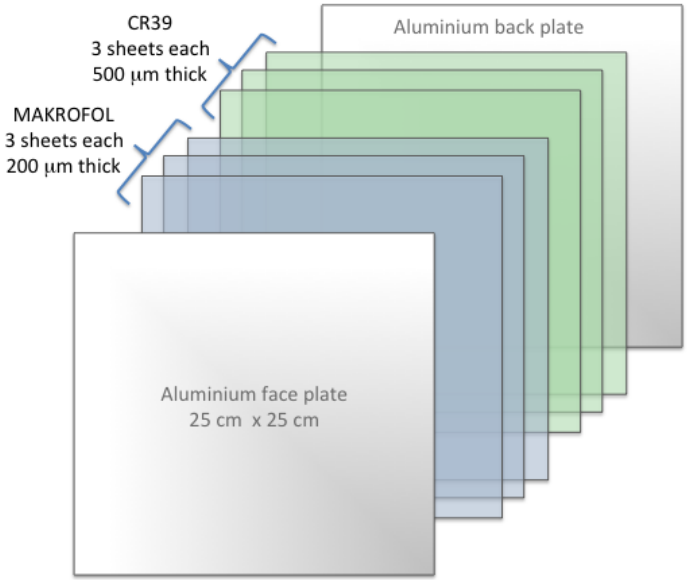


Typical Etching

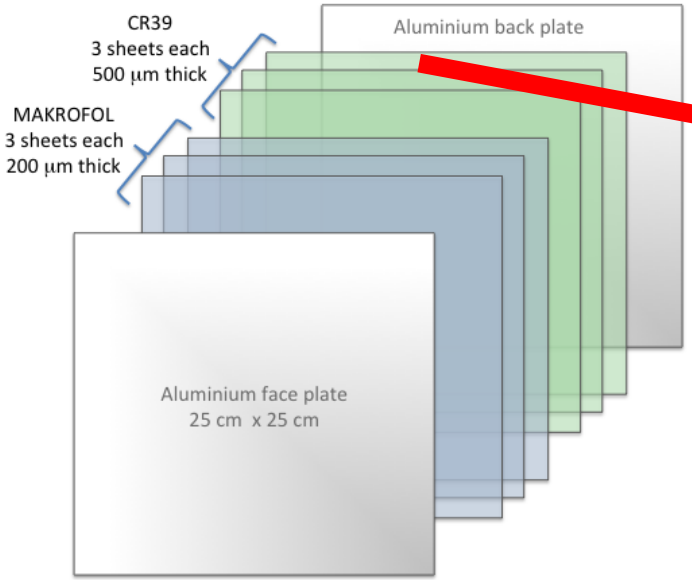


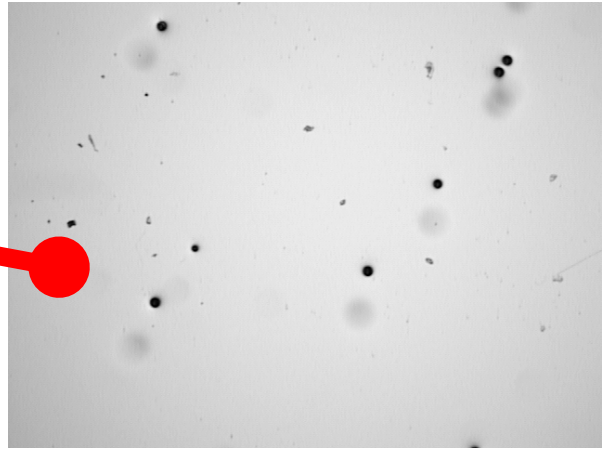
Over Etching

A closer look: Nuclear Track Detector



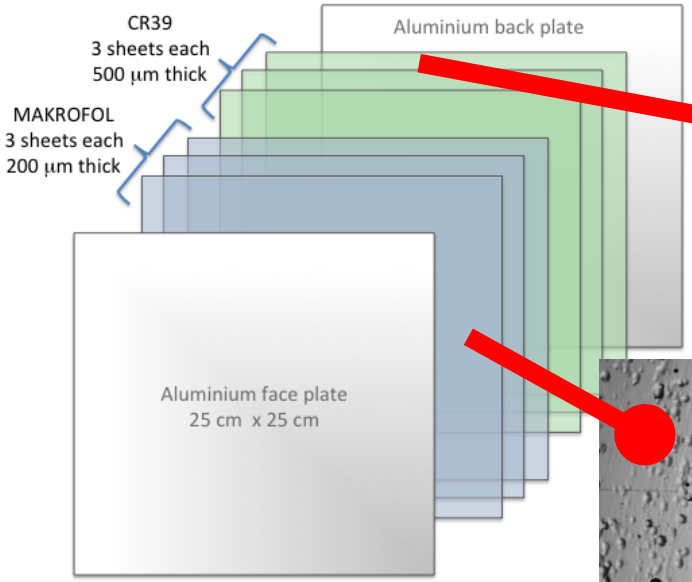
A closer look: Nuclear Track Detector

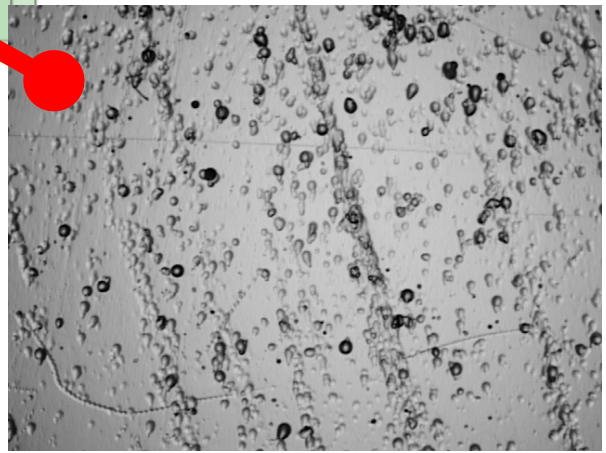


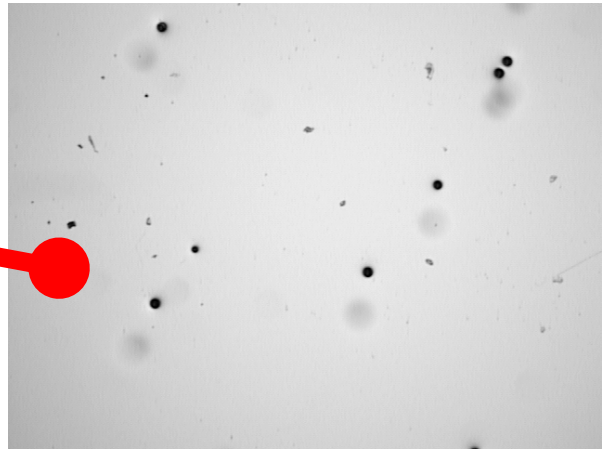


CR39 (above)

A closer look: Nuclear Track Detector



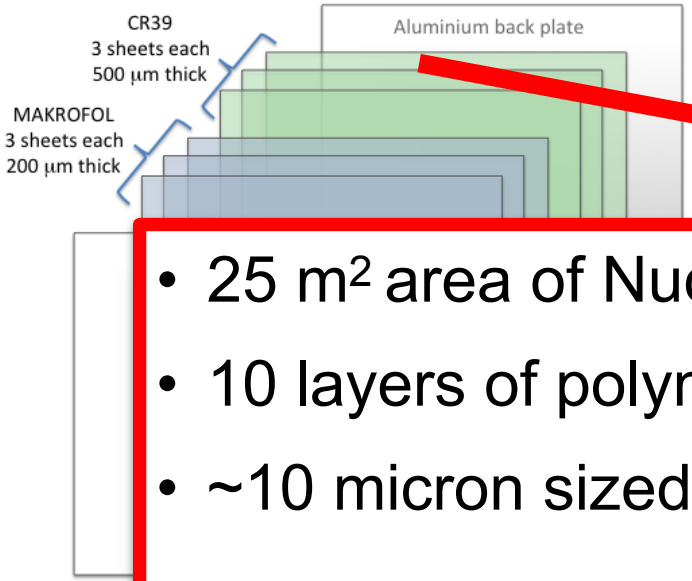


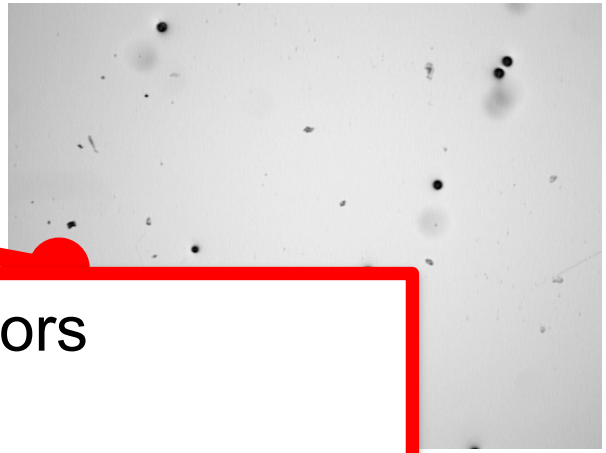


CR39 (above)

Makrofol (left)
Both exposed to Xe ions.

A closer look: Nuclear Track Detector



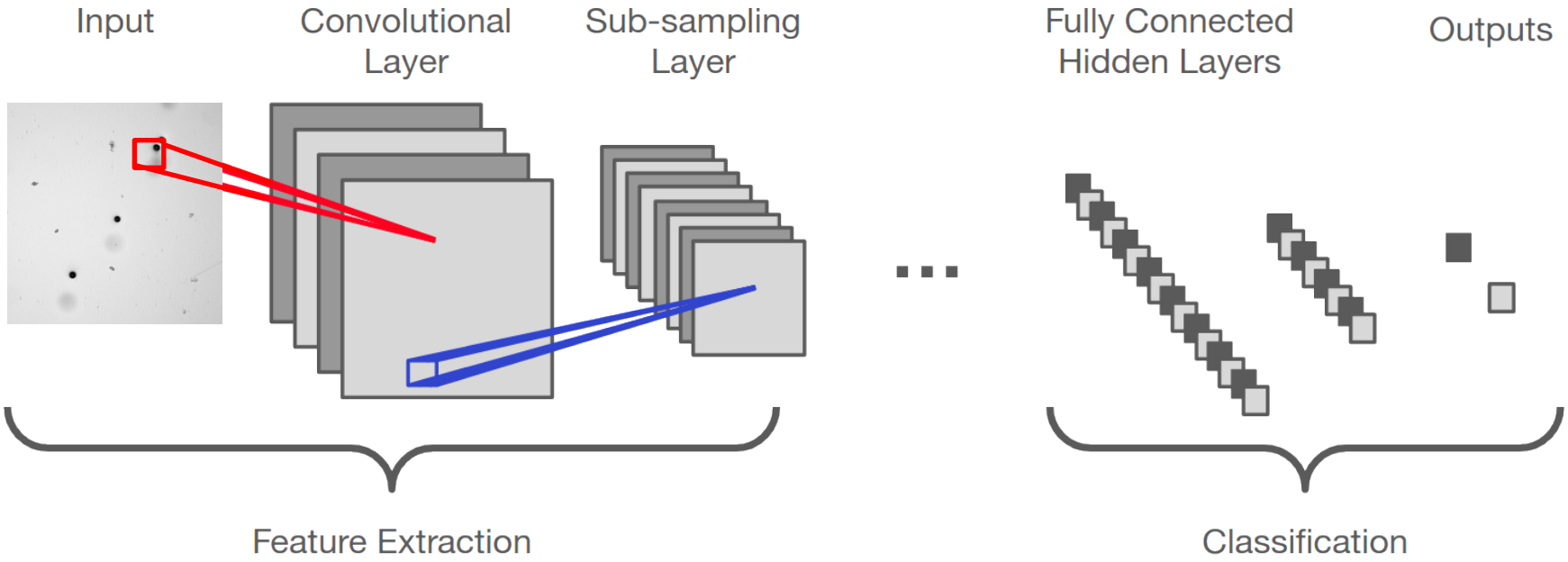


- 25 m^2 area of Nuclear Track Detectors
- 10 layers of polymer per detector
- ~10 micron sized etch pits to search for

How do we search through all of that area?

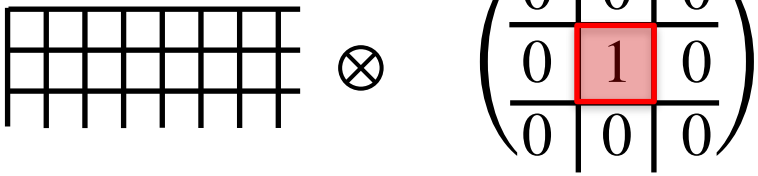
ions.

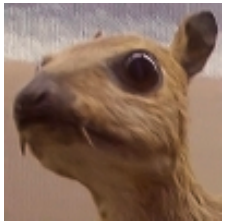
Convolutional Neural Networks



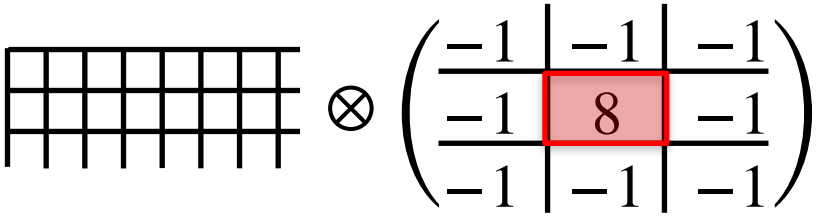
A closer look: Feature Extraction

- Convolutional layer:
  - Edge detection
  - Gaussian blurring
  - High contrast filter
- Sub-sampling layer:
  - Maxpool



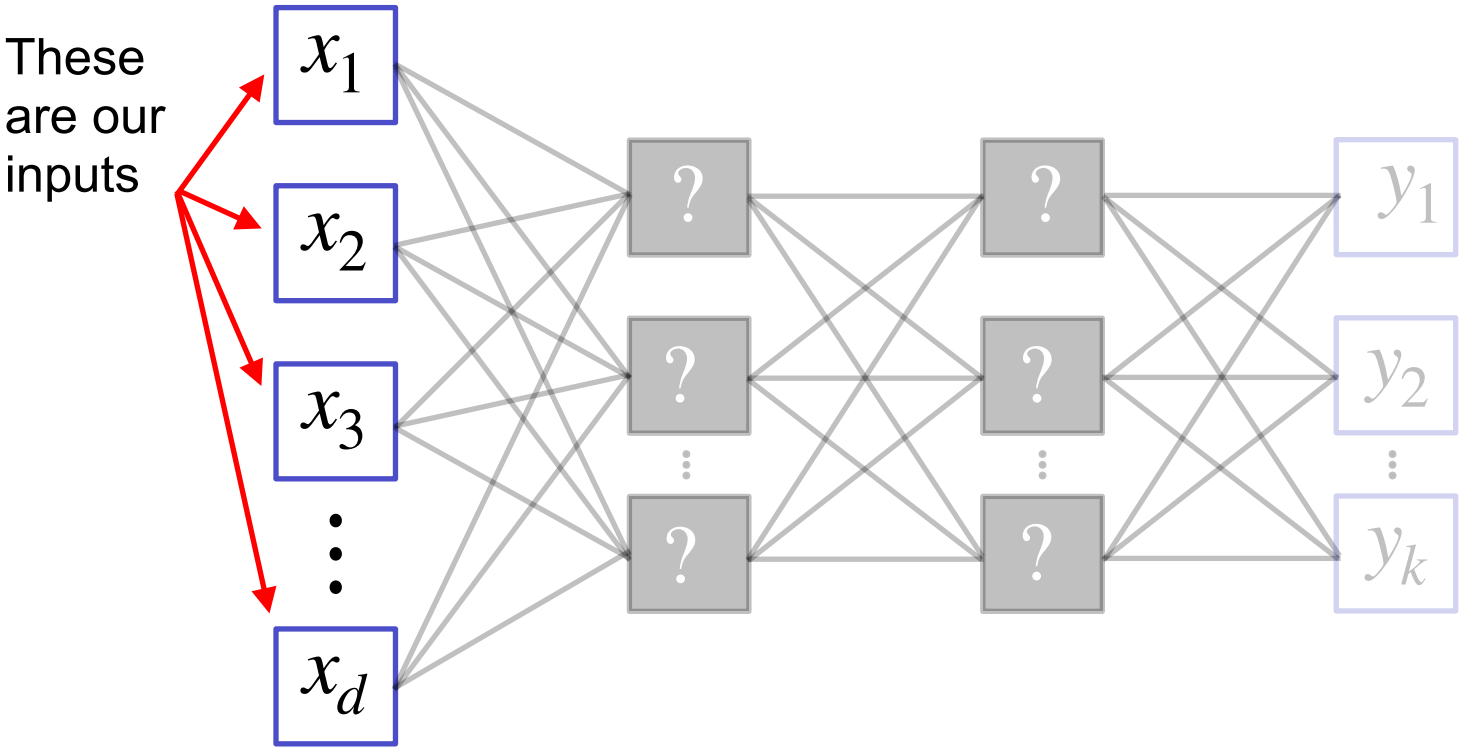


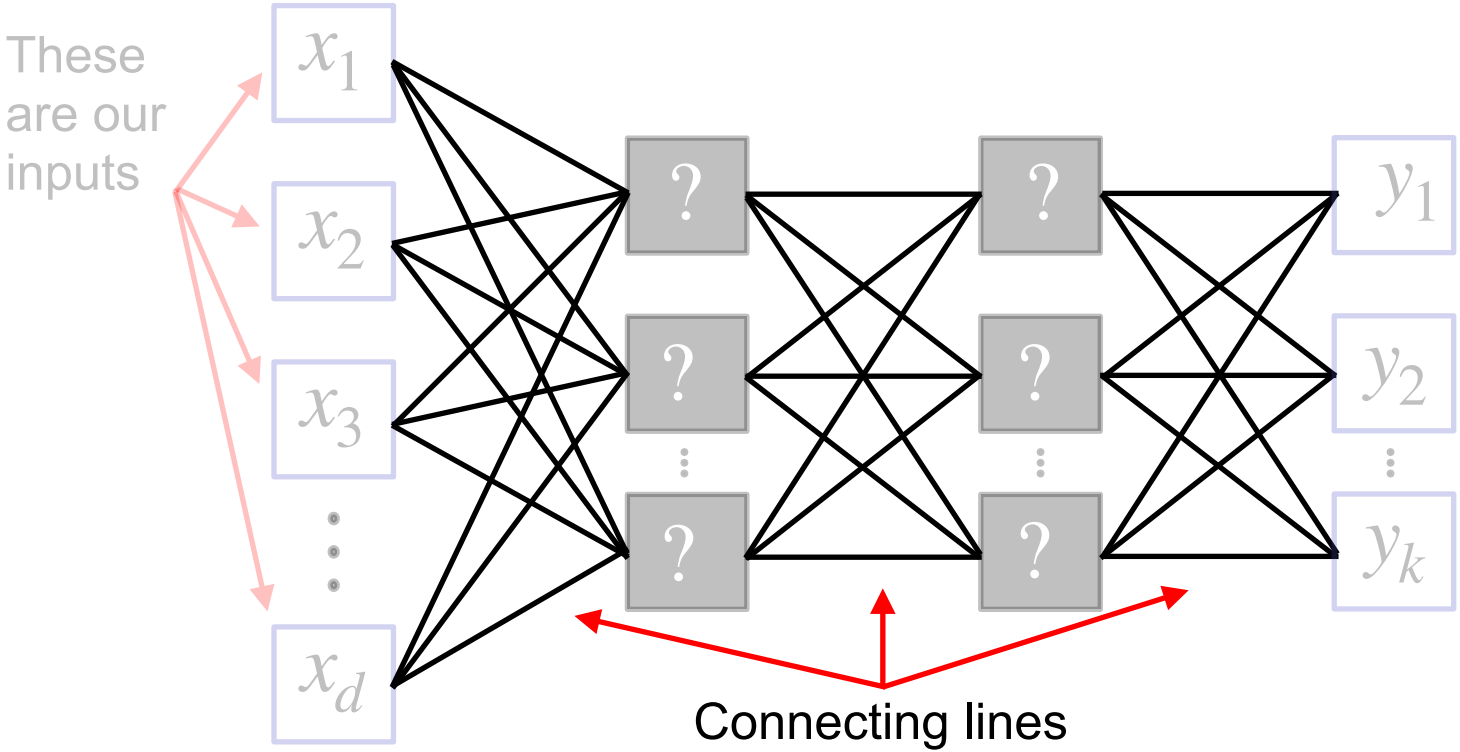
Identity



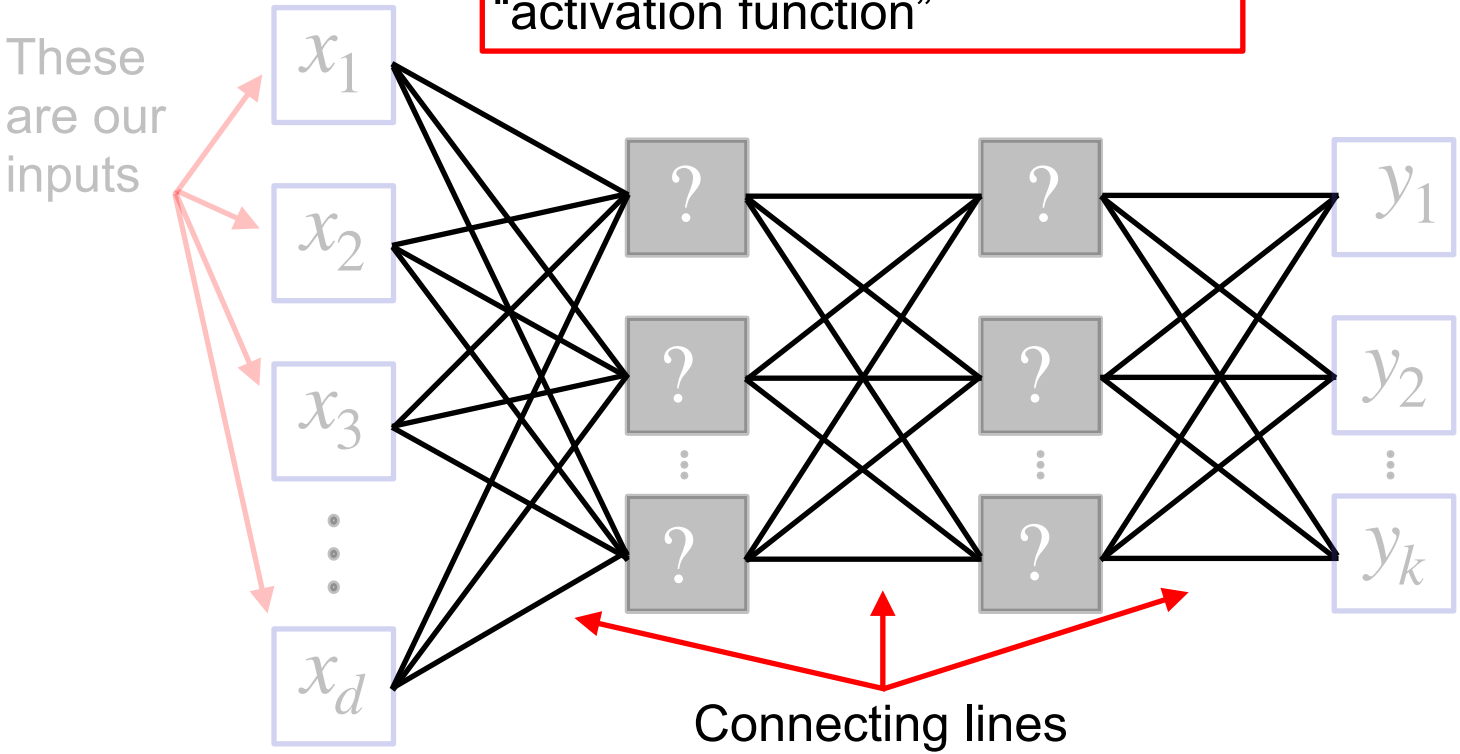
Edge Detection

A closer look: Classification




These are our inputs
x_1
x_2
x_3
x_d
?
?
?
?
?
?
y_1
y_2
y_k
Connecting lines indicate weighting

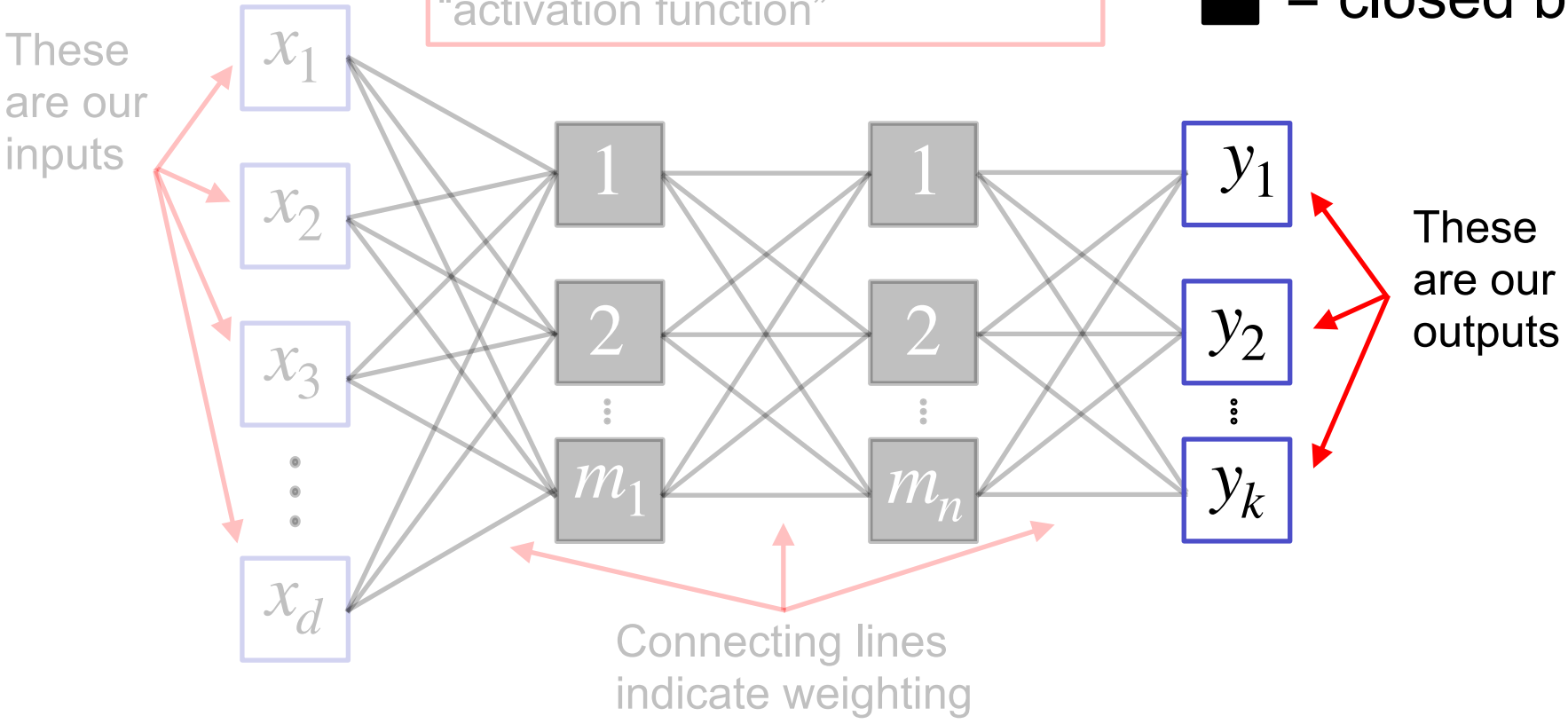
Lines collected at a node are summed and passed through an "activation function"

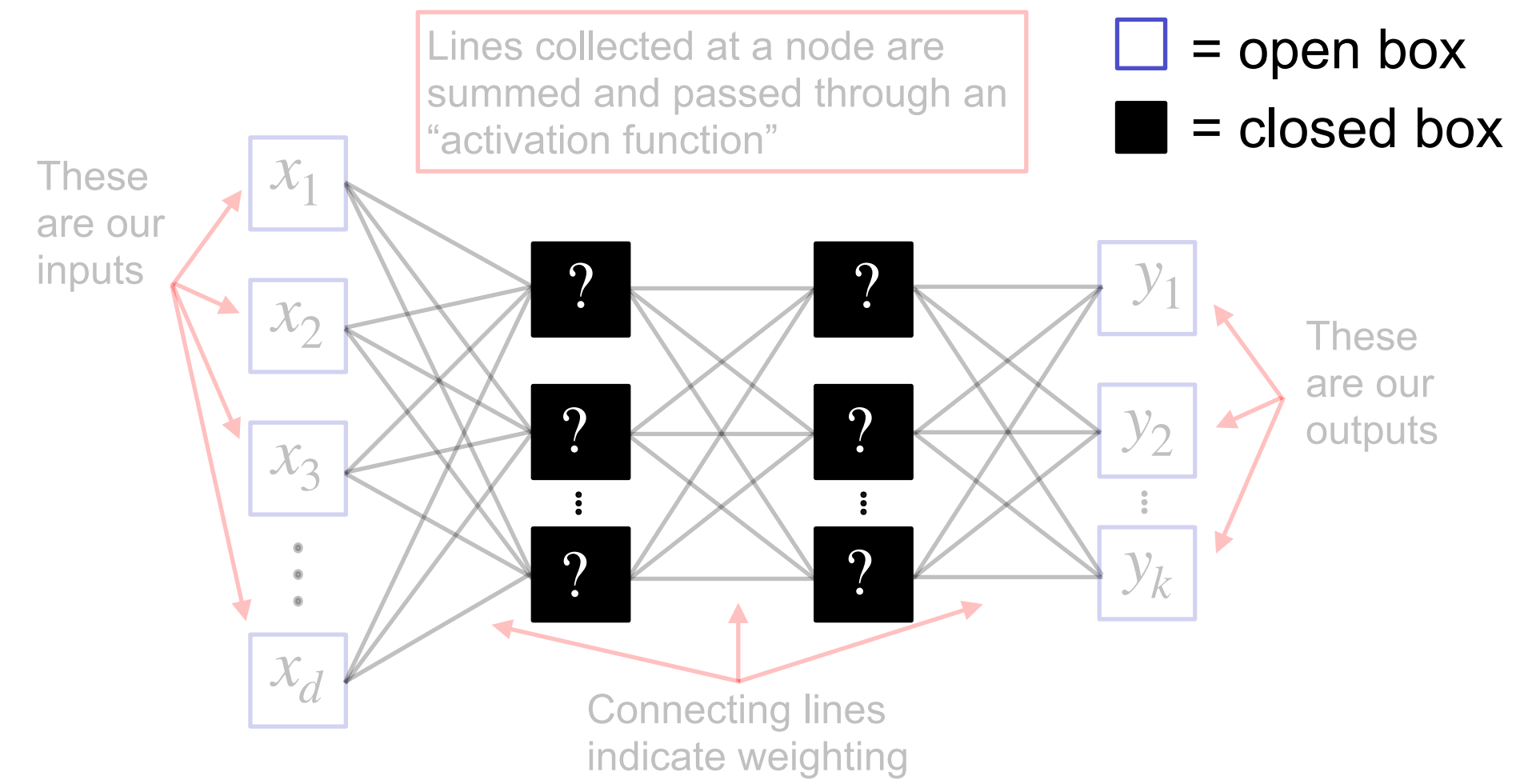


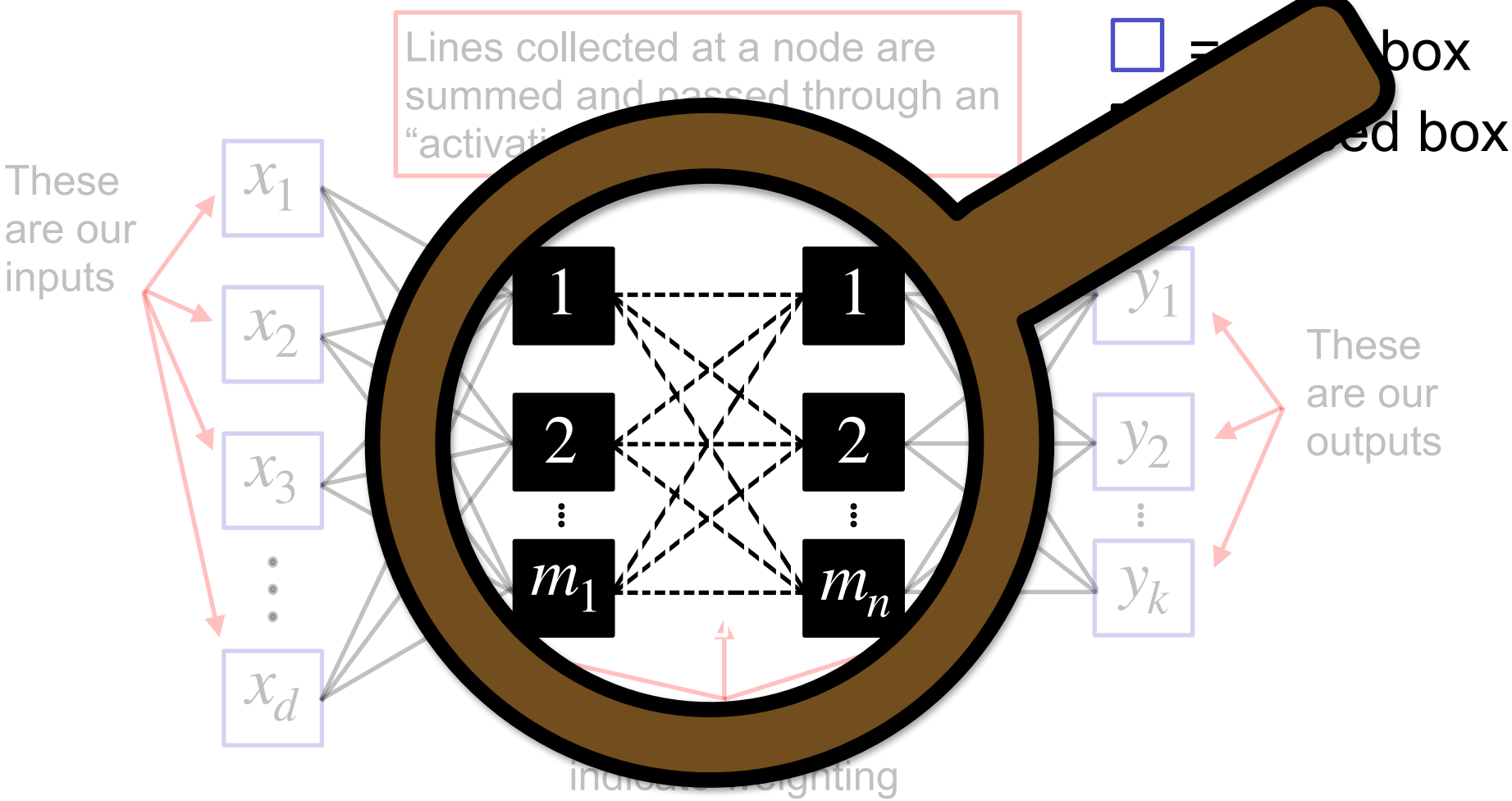
Lines collected at a node are summed and passed through an "activation function"

□ = open box

■ = closed box



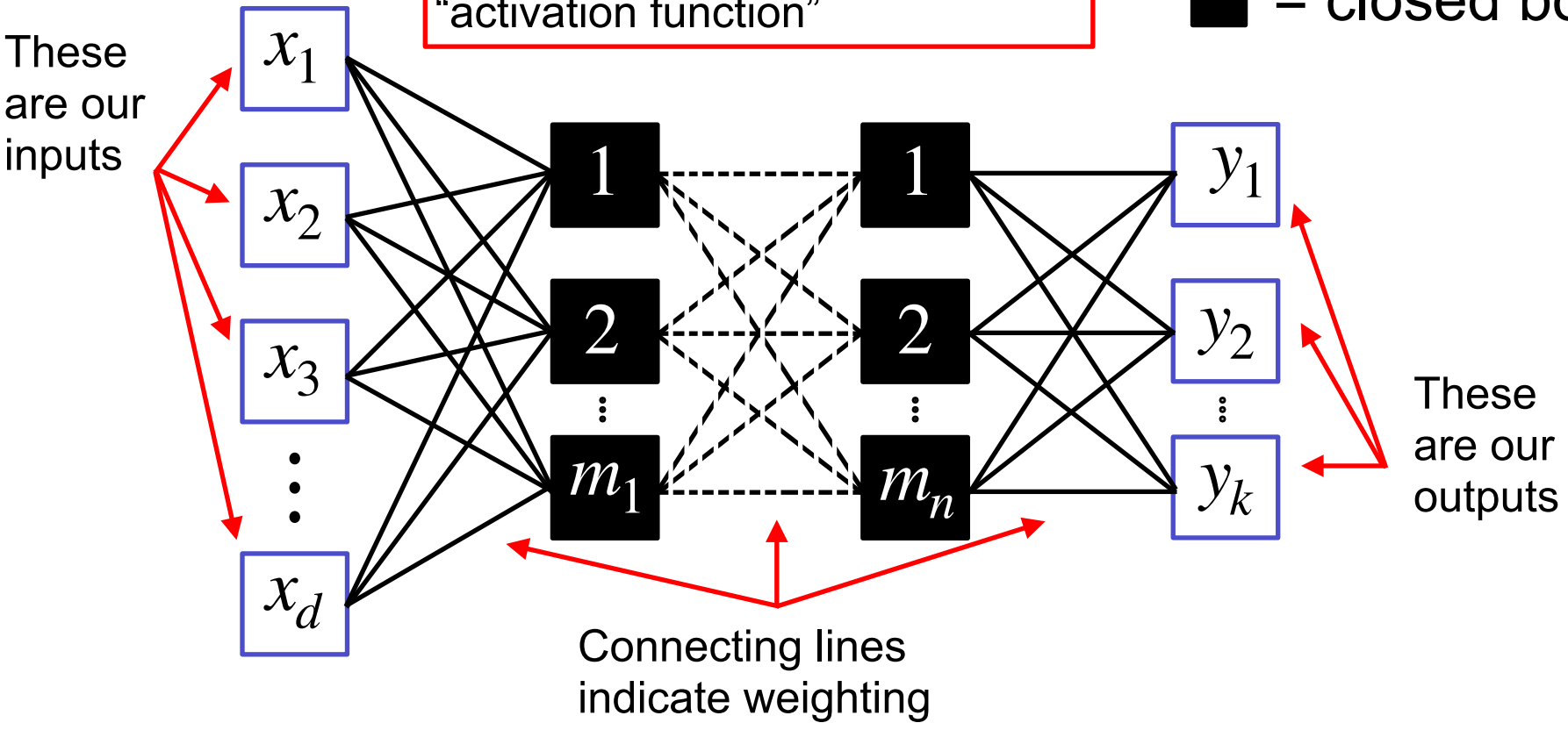

Lines collected at a node are summed and passed through an "activation function"
= open box
= closed box
These are our inputs
x_1
x_2
x_3
x_d
?
?
?
?
?
?
y_1
y_2
y_k
These are our outputs
Connecting lines indicate weighting


Lines collected at a node are summed and passed through an "activati
box
ed box
These are our inputs
x_1
x_2
x_3
x_d
1
2
m_1
1
2
m_n
y_1
y_2
y_k
These are our outputs
indicate weighting

Lines collected at a node are summed and passed through an "activation function"

= open box

= closed box



Lines collected at a node are summed and passed through an "activation function"

These are our inputs

$$\mathcal{O}\left(\sum_{j_n=0}^{m_n} w_{kj_n}\mathcal{H}_n\left(\ldots\mathcal{H}_2\left(\sum_{j_1=0}^{m_1} w_{j_2j_1}\mathcal{H}_1\left(\sum_{i=0}^{d} w_{j_1i}x_i\right)\right)\ldots\right)\right) = y_k(\boldsymbol{x},\boldsymbol{w})$$

These are our outputs

Connecting lines indicate weighting

Lines collected at a node are summed and passed through an "activation function"

These are our inputs

These are our outputs

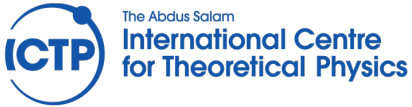
$$\mathcal{O}\left(\sum_{j_n=0}^{m_n} w_{kj_n}\mathcal{H}_n\left(\ldots\mathcal{H}_2\left(\sum_{j_1=0}^{m_1} w_{j_2j_1}\mathcal{H}_1\left(\sum_{i=0}^{d} w_{j_1i}x_i\right)\right)\ldots\right)\right) = y_k(\boldsymbol{x},\boldsymbol{w})$$

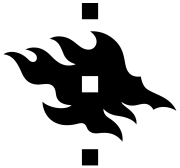
Connecting lines indicate weighting

Summary

- MoEDAL is the:
  Monopoles & Exotics Detector At the LHC
- Events in the Nuclear track detectors appear as etch pits
- We use convolutional neural networks to automatically detect events

Thank you! t.p.charman@qmul.ac.uk





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