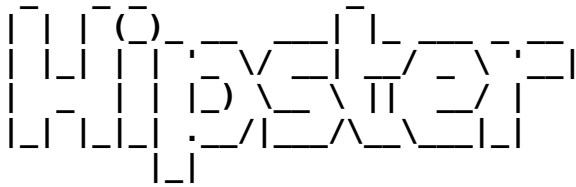




## Searching for monopoles & exotics with

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*Heavily Ionising Particle Standard Toolkit for Event Recognition*

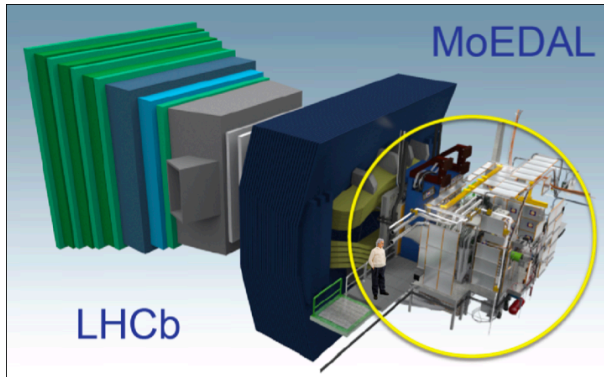
Thomas Charman<sup>1</sup>  
for the MoEDAL Collaboration

<sup>1</sup>t.p.charman@qmul.ac.uk

- What is MoEDAL?
- What do events look like?
- HIPSTER as an effort to analyse events.

# Where is MoEDAL?

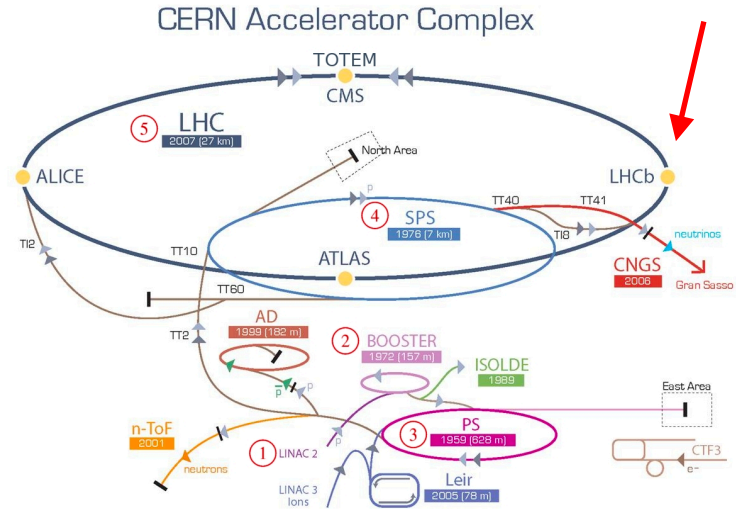
- Point 8 of LHC ring
- Vertex Locator Cavern of LHCb



[https://youtu.be/PYJ2\\_upeGQE](https://youtu.be/PYJ2_upeGQE)



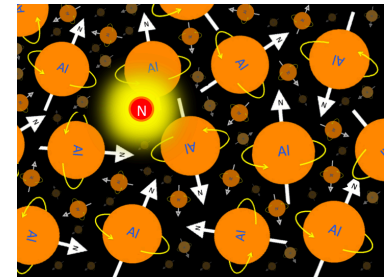
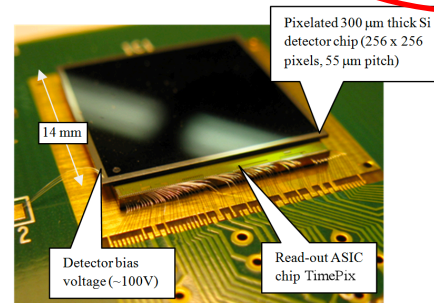
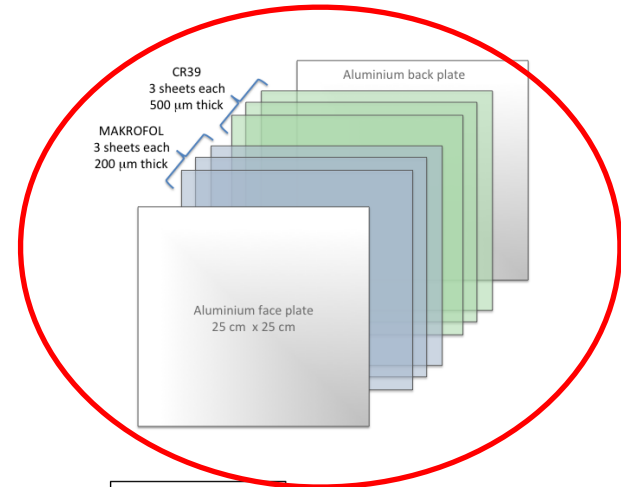
MoEDAL



# MoEDAL - Monopole & Exotics Detector at the LHC

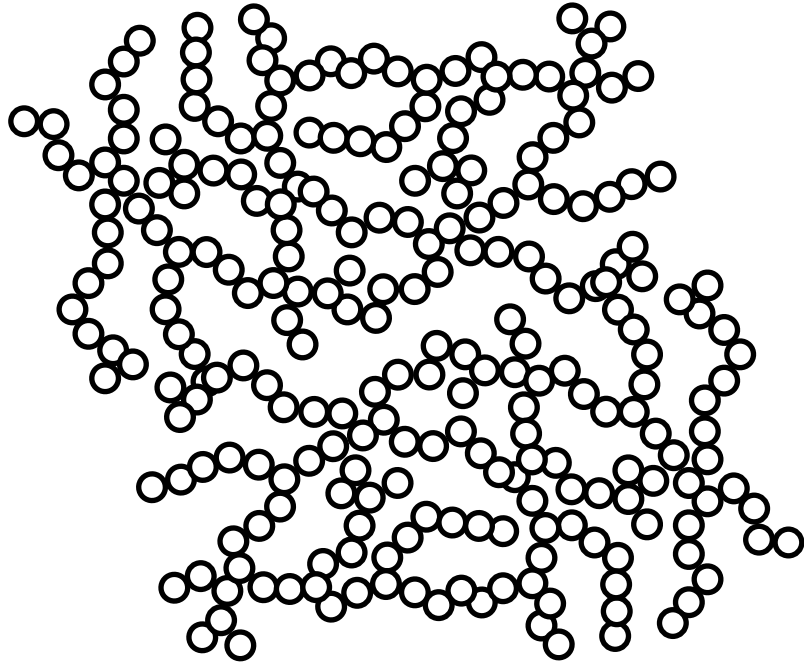
<https://moedal.web.cern.ch/>

- 3 detector types: polymer, timepix and aluminium.
- Designed to detect heavily ionising long lived particles.
- Specific focus on magnetic monopoles backed up by 30+ exotic models.

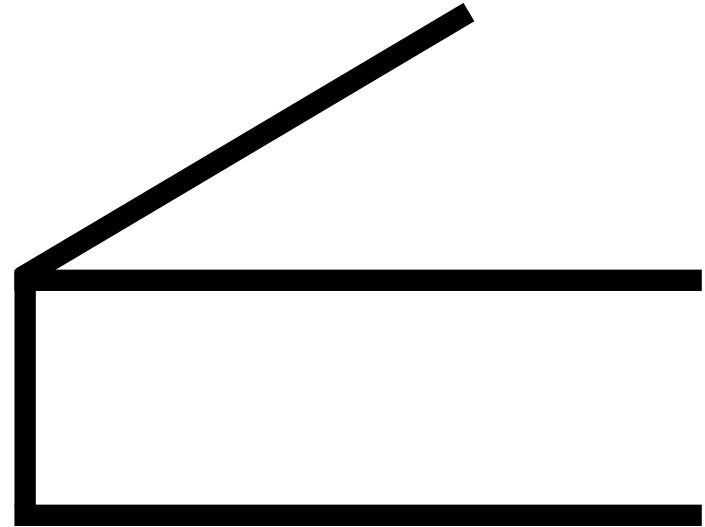


# Undamaged polymer

○ = monomer



Nano-scale



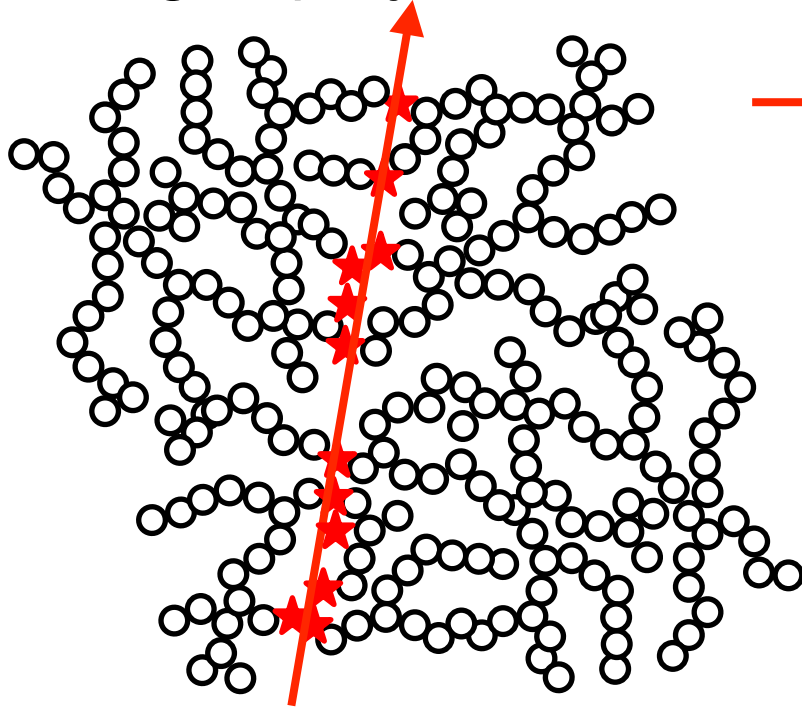
Micron-scale

# Damaged polymer

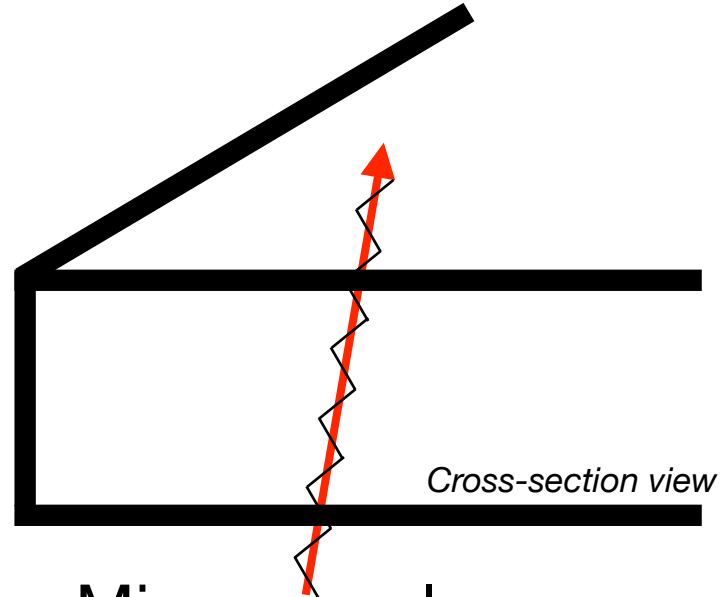
○ = monomer

★ = broken link

→ = ionising particle trajectory



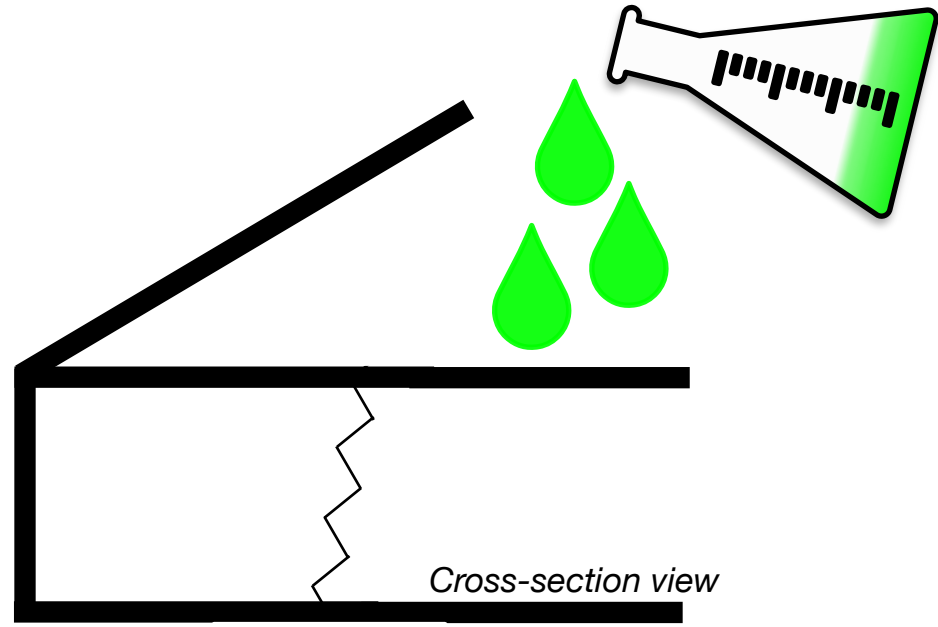
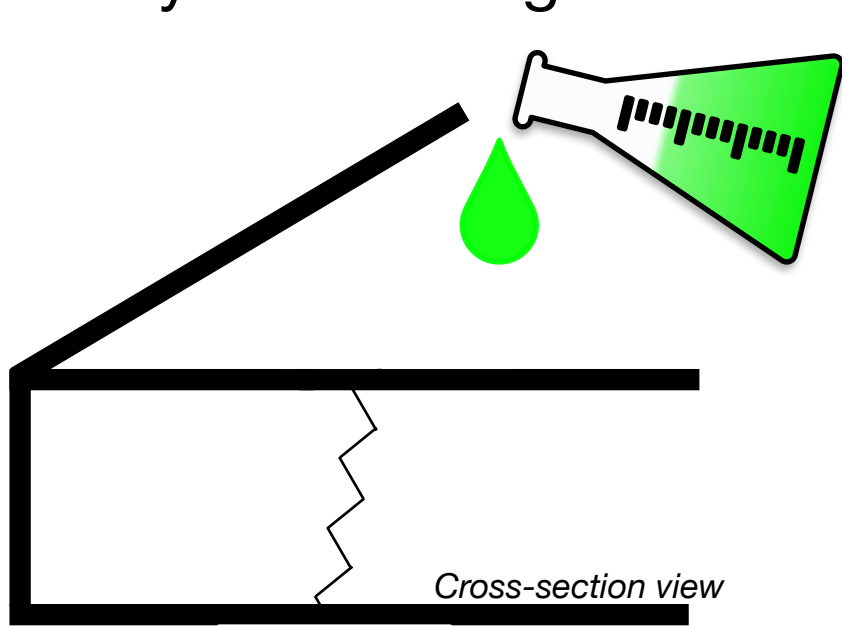
Nano-scale



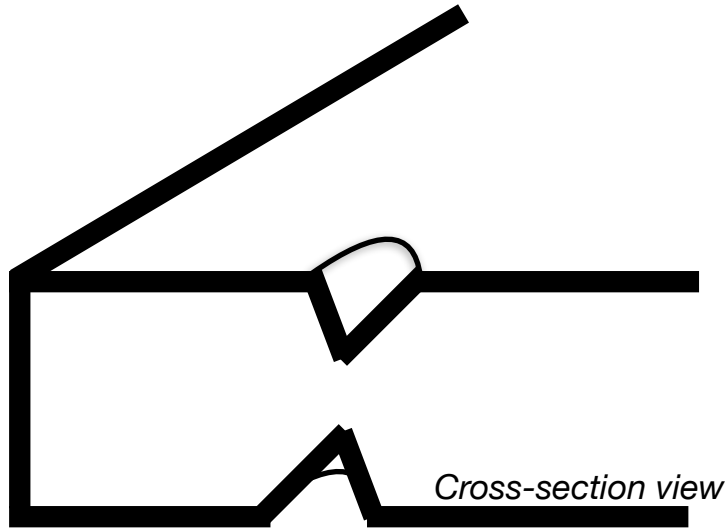
Micron-scale

*Cross-section view*

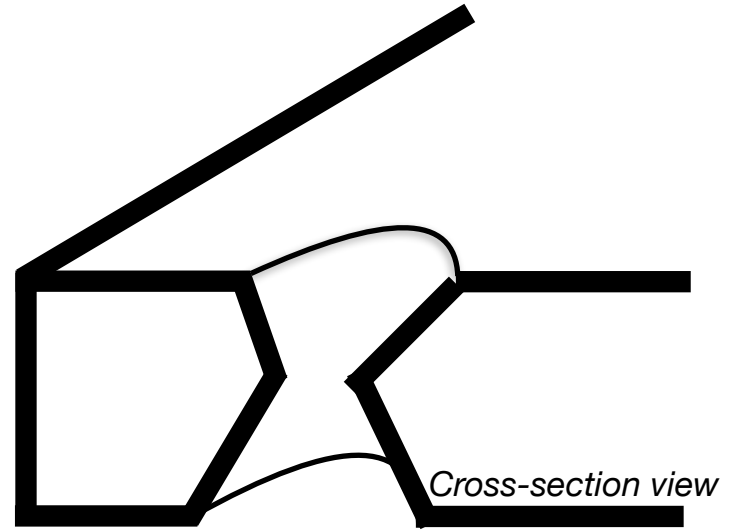
# Polymer Etching



# Polymer Etching



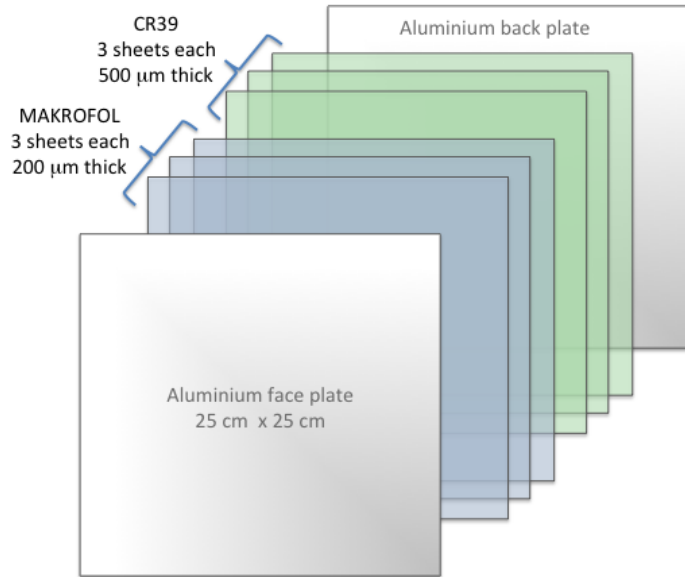
Etching



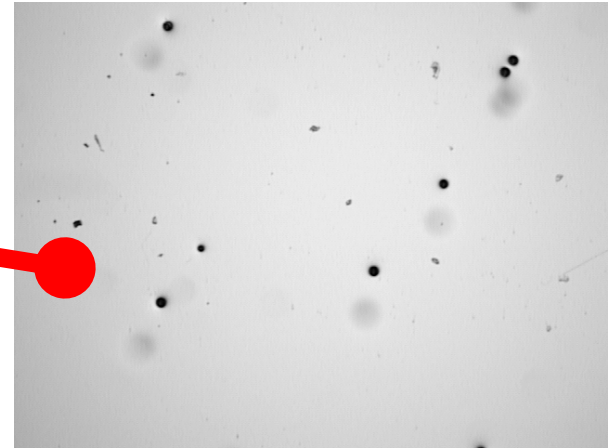
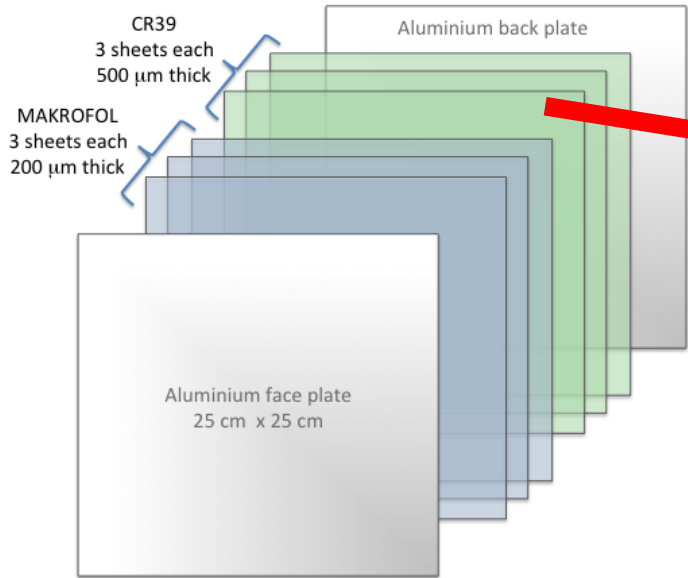
Continued Etching



# A closer look: Nuclear Track Detector

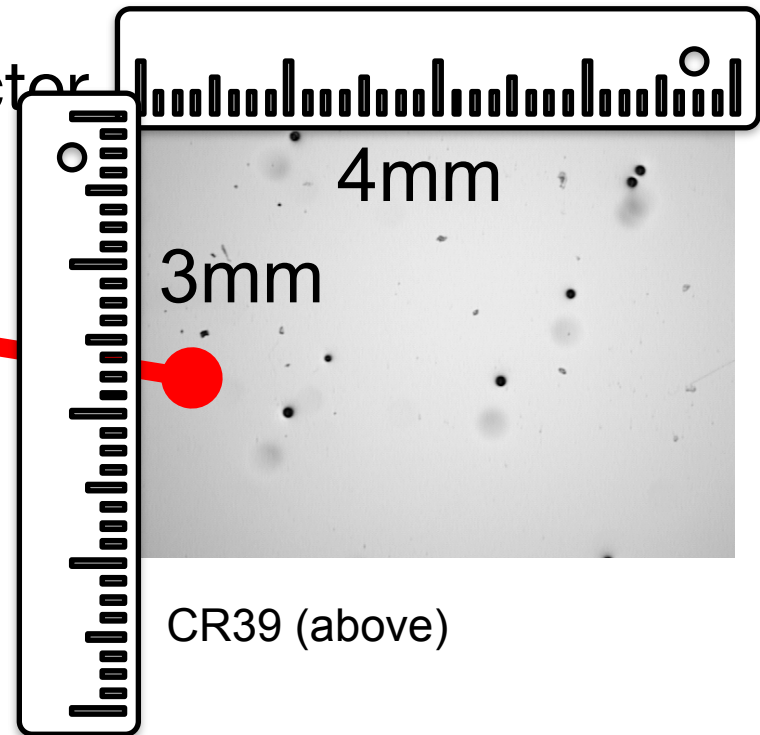
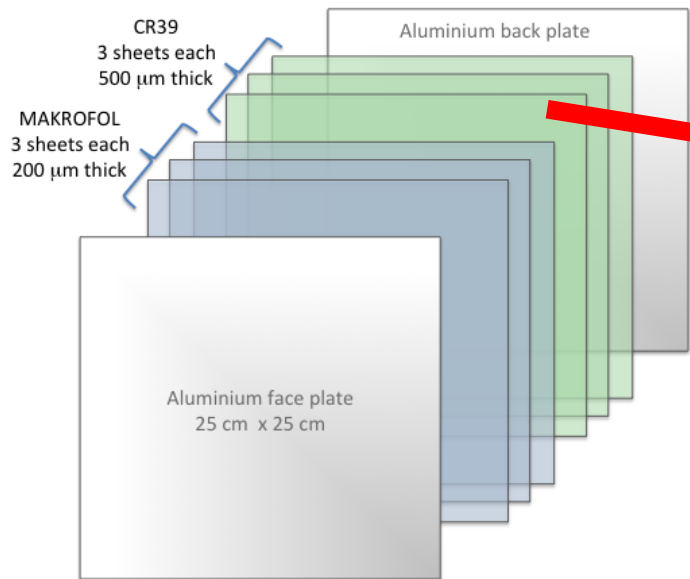


# A closer look: Nuclear Track Detector

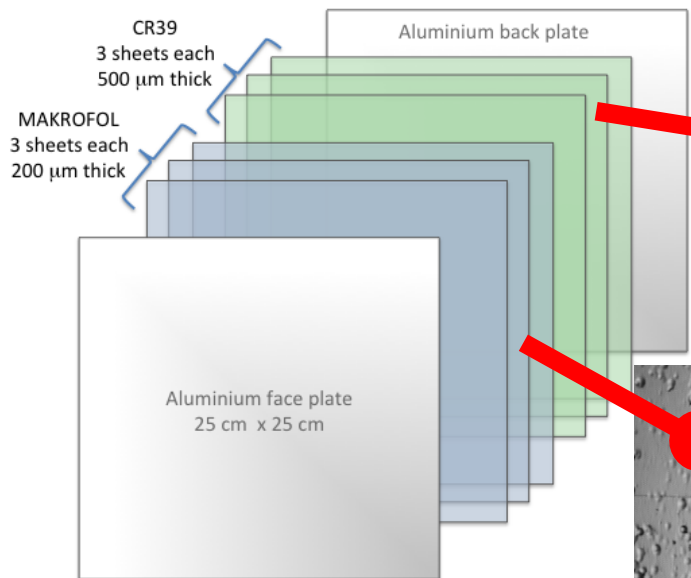


CR39 (above)

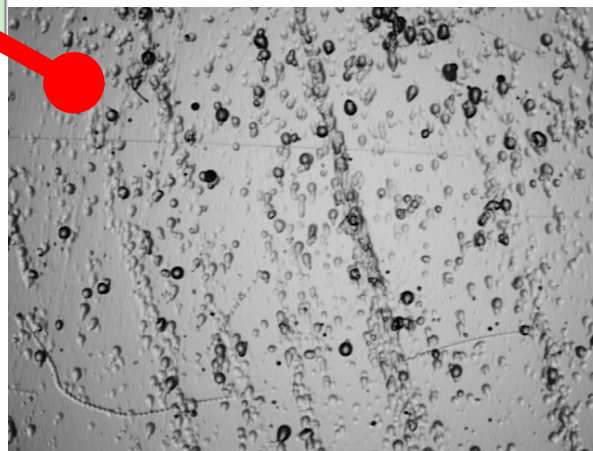
# A closer look: Nuclear Track Detector



# A closer look: Nuclear Track Detector



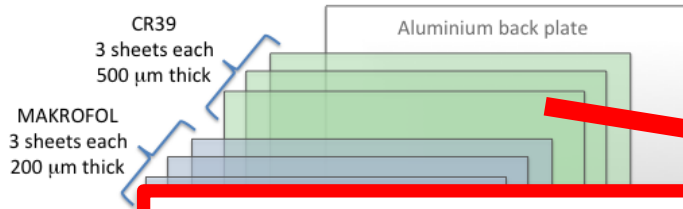
CR39 (above)



Makrofol (left)

Exposed to 13 GeV Xe ions  
 $\sim 100$  ions/cm<sup>2</sup>

# A closer look: Nuclear Track Detector



- $\sim 25 \text{ m}^2$  area of Nuclear Track Detectors
- 10 layers of polymer per detector
- $\sim 30$  micron sized etch pits to search for

*How do we search through all of that area?*

e ions.



# Hipster

Heavily Ionising Particle Standard Toolkit for Event Recognition

Adrian Bevan, Thomas Charman, Krzysztof Furman, Jon Hays

- Hipster is a toolkit built on top of TensorFlow/NumPy
- Provides models for machine learning  
MLP, DNN, CNN, Gaussian mixture models + more
- Easy to use and has few dependencies



# Hipster

## Heavily Ionising Particle Standard Toolkit for Event Recognition

- Contains HEP style plotting/histogram manipulation
- Basic modelling tools, used to generate fake images for MoEDAL
- Basic image manipulation functionality e.g. image stitching algorithms
- Optional compatibility with ROOT and LabVIEW



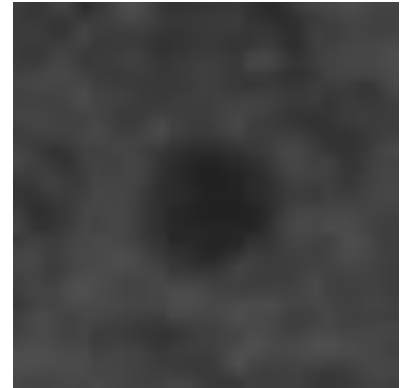
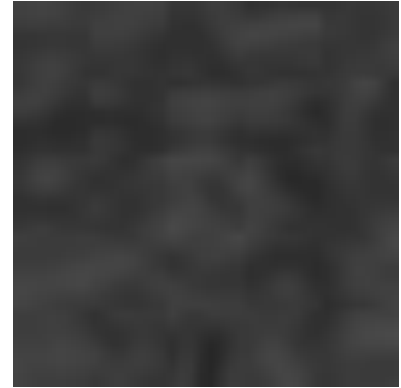
# Performance

**80% accuracy classifying etch pits in NTDs**



# Performance

**80% accuracy classifying etch pits in NTDs**

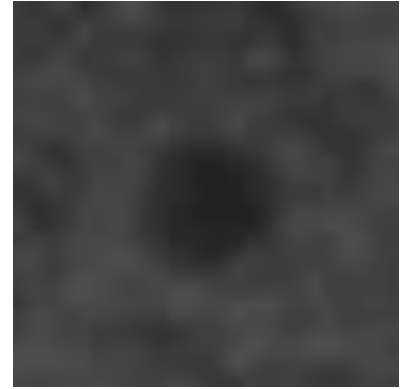


# Performance

**80% accuracy classifying etch pits in NTDs**

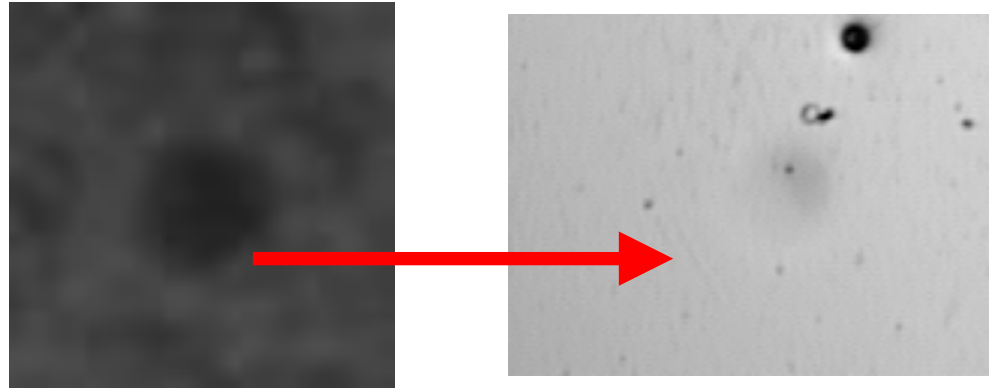
Issues with this result:

- Small dataset size  $O(500)$  images
- Etch pits poorly resolved by scanner
- Sub-optimal etching conditions



# Future Improvements

- New larger dataset
- Modelling of LHC background in hipster to circumvent reliance on Zooniverse
- 3D data: laser scans of polymer provide 3D map of surface



# The collaboration



# HIPSTER - Available soon on PyPI/Github

- Migration from cern gitlab imminent

*Thank you for listening, questions?*



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@ThomasCharman