

# Exploring the flux pinning performance of bulk FeSe by electron irradiation

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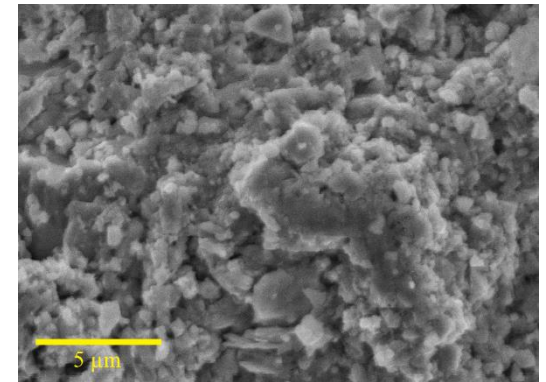
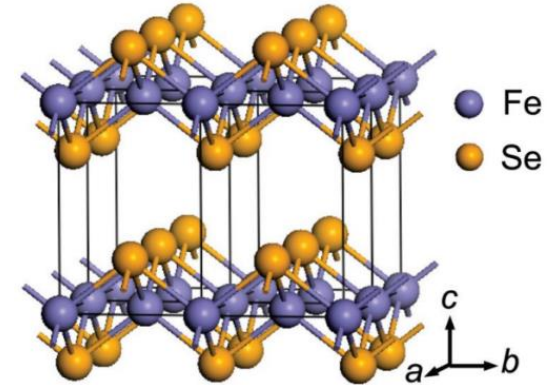
# Polycrystalline Iron based superconductors (FeSe)

- Iron selenide superconductors (FeSe):

- Discovered in 2008
- rare-earth free, non toxic material

- Polycrystalline FeSe:

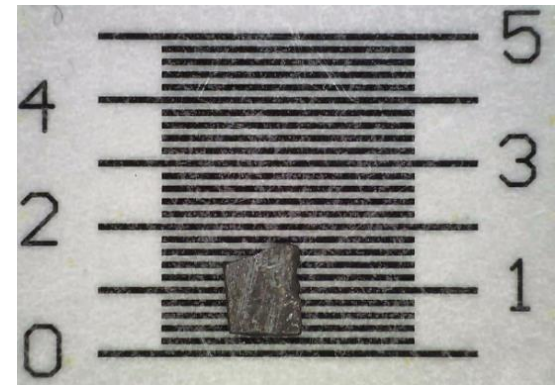
- Ball melted process at 950 °C
- Critical temperature: 8 K
- Well coupled and randomly oriented grains of the order of 1  $\mu\text{m}$
- Presence of a  $\text{Fe}_6\text{Se}_7$  ferromagnetic phase (40% of the volume)



*SEM pictures of polycrystalline FeSe sample*

# Irradiation campaign using SIRIUS and SQUID measurements

- Adding point like irradiation using electron irradiation of 2.5 MeV for 2 different dose:
  - A total dose of  $4 \times 10^{19}$  e<sup>-</sup> or 1.27 C
  - A total dose of  $2 \times 10^{19}$  e<sup>-</sup> or 0.655 C
- Those measurements were done using MPMS SQUID for a high precision at different temperatures (2 to 7 K) and from 7 to -7 T.
- Few irradiated samples were characterized
- 1 unirradiated sample called "Unirr" was also characterized

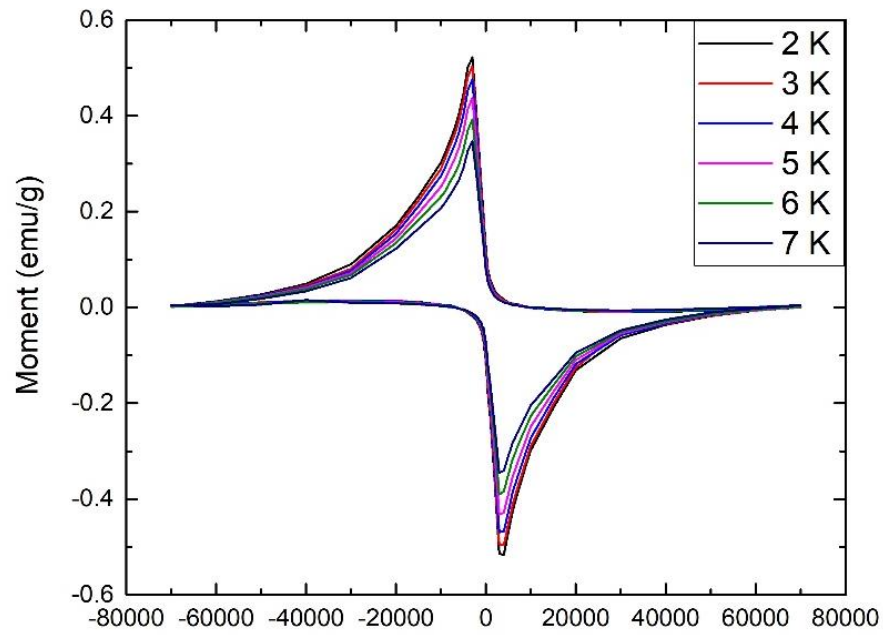


*Polycrystalline FeSe sample  
Area=1.7mm<sup>2</sup>, thickness  $\approx$  0.3 mm*

# Critical state model for polycrystalline FeSe

- Typical asymmetric magnetization loops for a polycrystalline FeSe superconductors at different temperature:

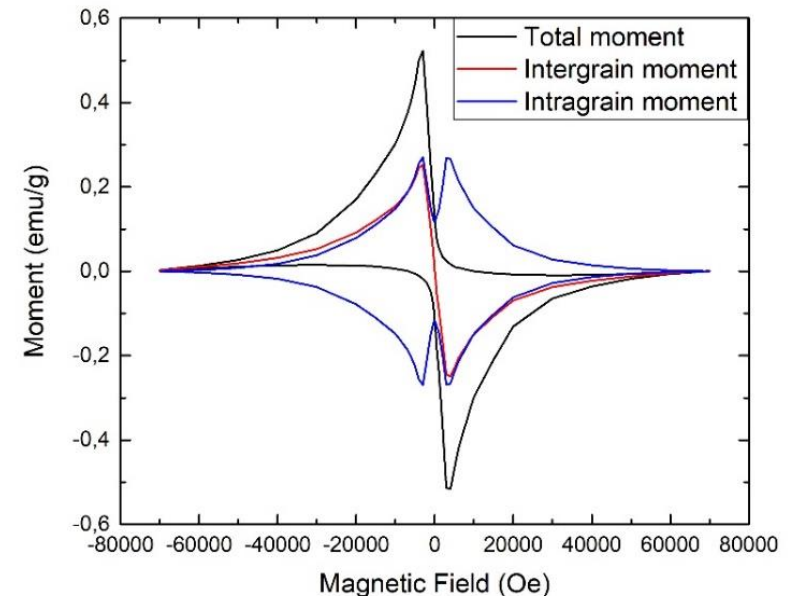
- Very asymmetric magnetization loops...
- ...at each temperature
- A constantly quasi-null moment for a decreasing external field
- The so called Bean critical state model cannot be applied here
- We need to determine the nature of those magnetization loops



Magnetization loops of polycrystalline FeSe

# Critical state model for polycrystalline FeSe

- A sum of 2 different moments:
  - An intergrain moment generated by a intergrain current, **without pinning processes and with a total reversibility**
  - An intragrain moment generated by an intragrain current, **with pinning processes and symmetry with the external field axis**
- For an external magnetic field  $B(T)$ , we can see that:
  - $|M_{\text{intergrain}}(B)| = |M_{\text{intragrain}}(B)|$ .
  - which means 50% of the superconducting volume is allocated for each current

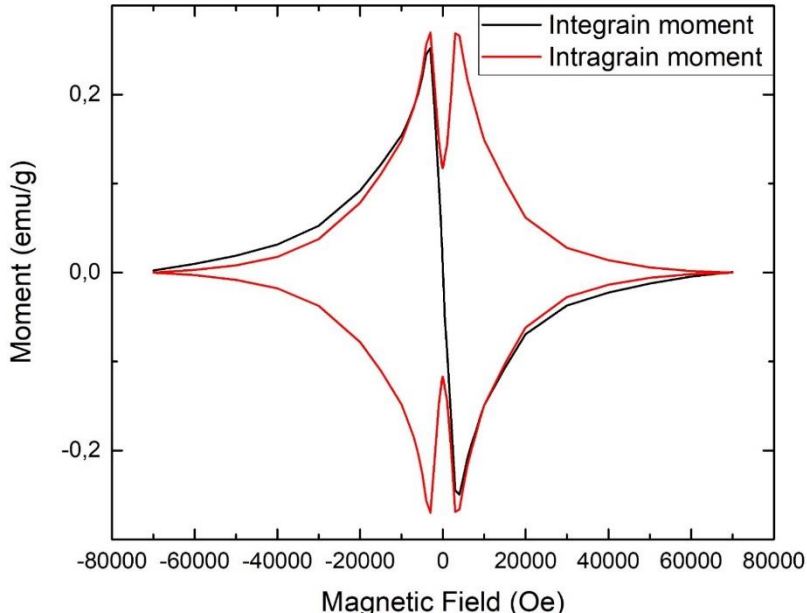


Magnetization loops of polycrystalline FeSe

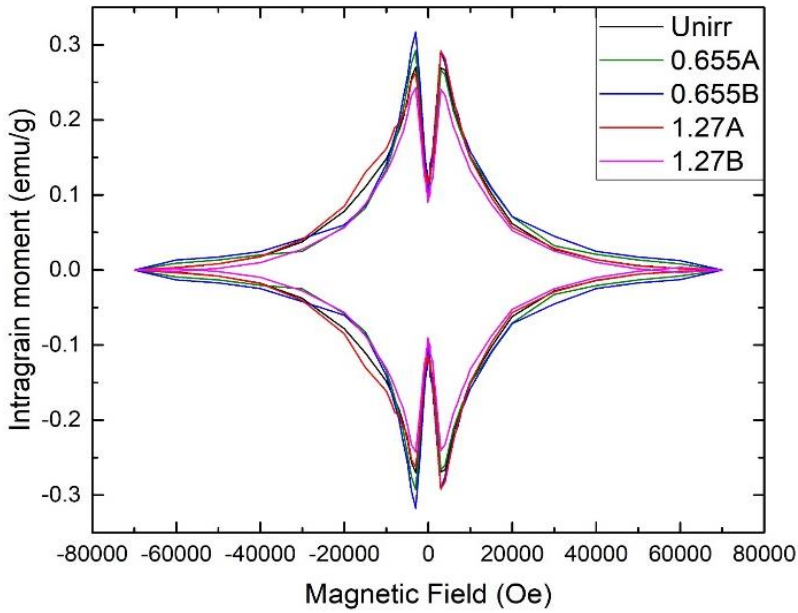


# Critical state model for polycrystalline FeSe

- We know that 60% of the sample is superconductor...
- ... And 50% of it generate the intragrain moment
- Which means just 30% of the total volume of the sample is responsible for the intragrain current.



Intragrain and intergrain magnetization loops at 2 K



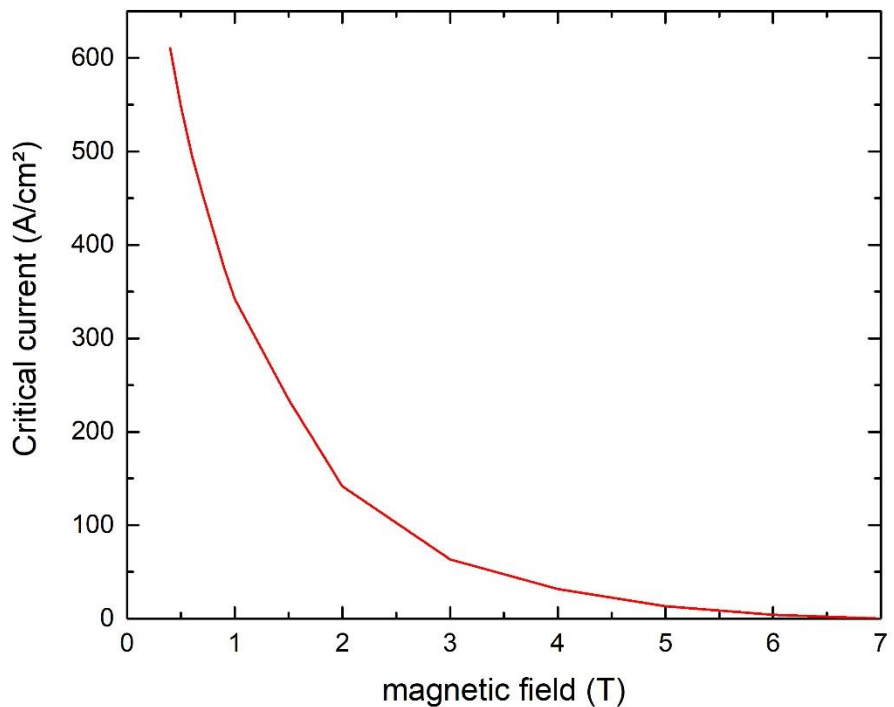
Intragrain moment for each sample at 2 K

# Critical state model for polycrystalline FeSe

- Now let us apply the so-called extended Bean model which extracts the critical current from the intragrain moment (using the factor of the sample's volume we computed just before). Using the following formula [Chen et al., 1989]:

$$J_c = \frac{\Delta M_{\text{intragrain}}}{a \left(1 - \frac{a}{3b}\right)} \times \left(\frac{100}{30}\right)$$

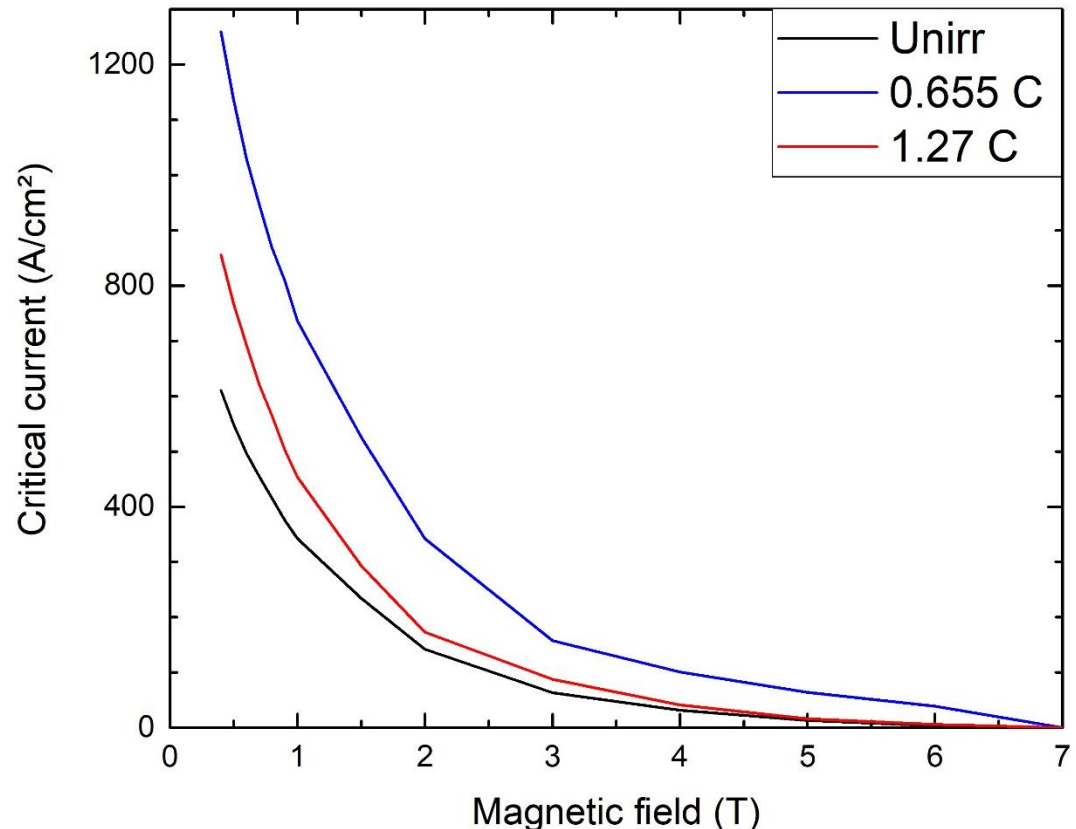
Where  $\Delta M$  is the thickness of the magnetization loop,  $a$  is the width of the sample and  $b$  its length.



Intragrain critical current of polycrystalline FeSe at 2 K

# Critical current of irradiated polycrystalline FeSe

- By applying the same model on irradiated sample we can compare them at 2 K:

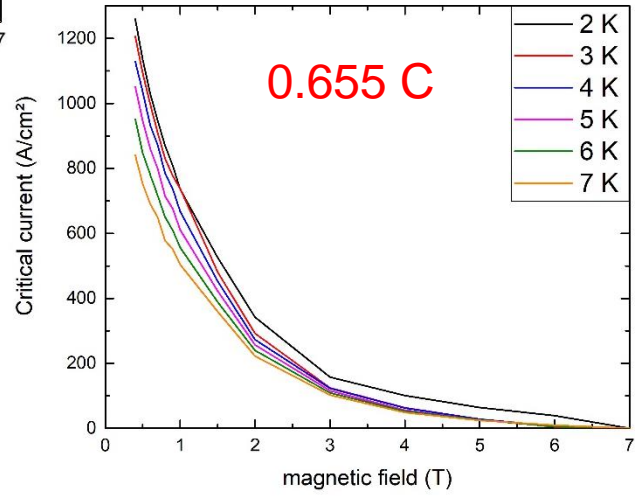
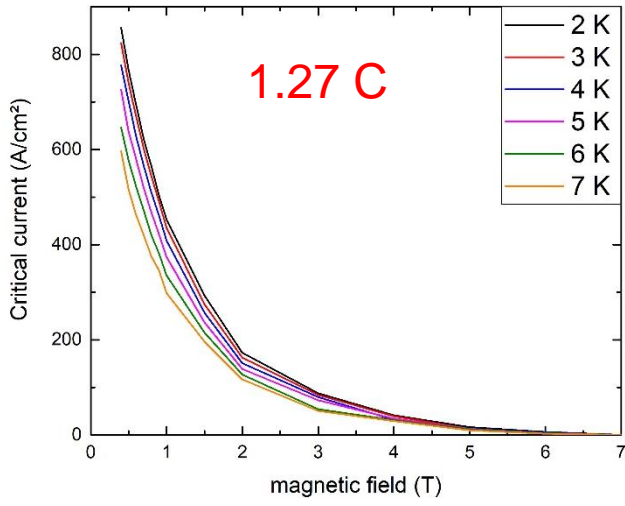
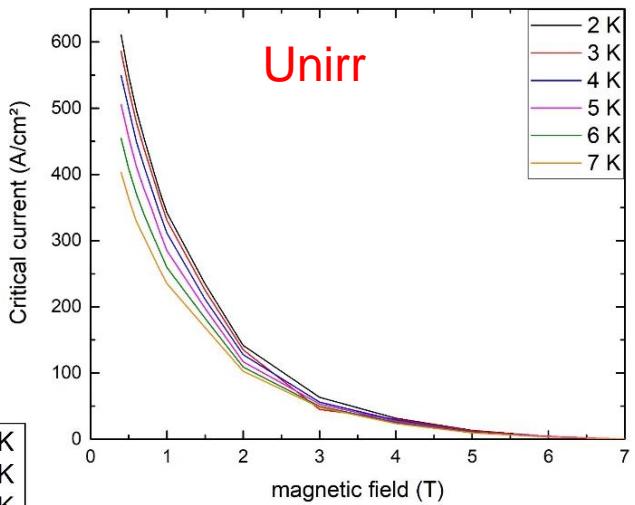


Critical current of polycrystalline FeSe samples at 2 K



# Critical current of irradiated polycrystalline FeSe

- Let us have a look on the temperature dependency for each irradiation dose:



Top: Critical current of the unirradiated sample  
 Left: Critical current of the 1.27 C sample  
 Right: Critical current of the 0.655 C sample

# Conclusion

- Conclusion

- We developed a new model to extract the Intragrain critical current of a polycrystalline superconductor
- We have seen the influence of the irradiation on a FeSe polycrystalline sample:
  - A "medium" dose increases the critical current
  - A "high" dose starts to lowering the critical current, comparing at "medium" dose

- What next?

- A second campaign is planned at GANIL for a heavy ion irradiation (1 GeV Pb ions)
- New experiments are necessary to confirm those results and to see if the properties will continue to decrease at higher dose



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# Thank you for your attention!

## Please ask your questions!



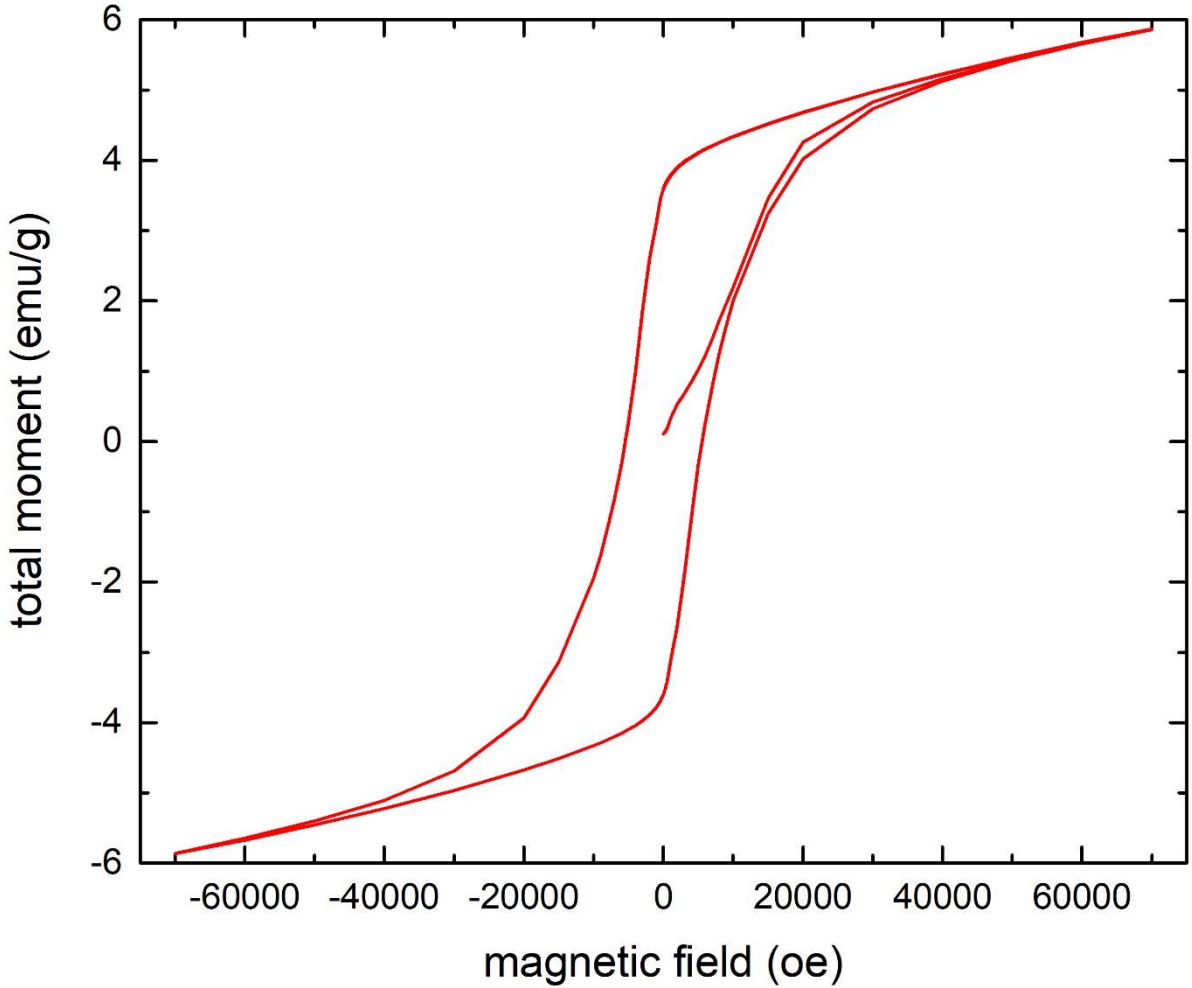
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Superconducting and ferromagnetic moments for the unirradiated sample at 2 K