Irradiation of 2D materials with swift heavy ions

GANIL Community Meeting 2022

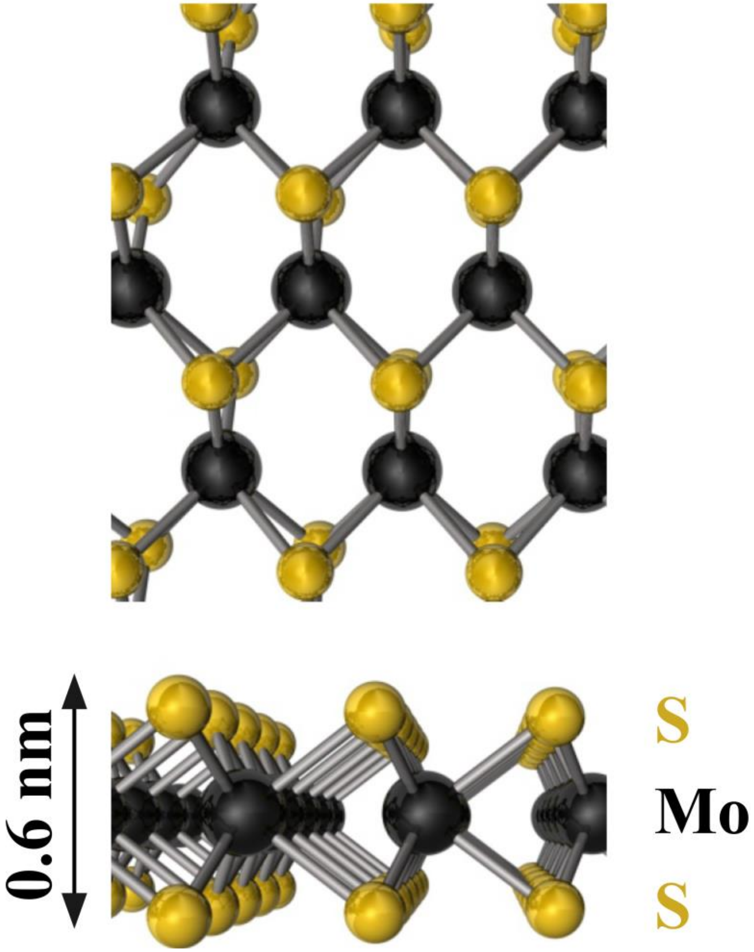
Yossarian Liebsch | AG Schleberger

Universität Duisburg-Essen

What are 2D materials?

- atomically thin crystalline solids
- graphene was discovered in 2004
- large range of potential application
- **graphene** and **MoS_2** was used for most of our work

Why would we irradiate 2D materials with ions?

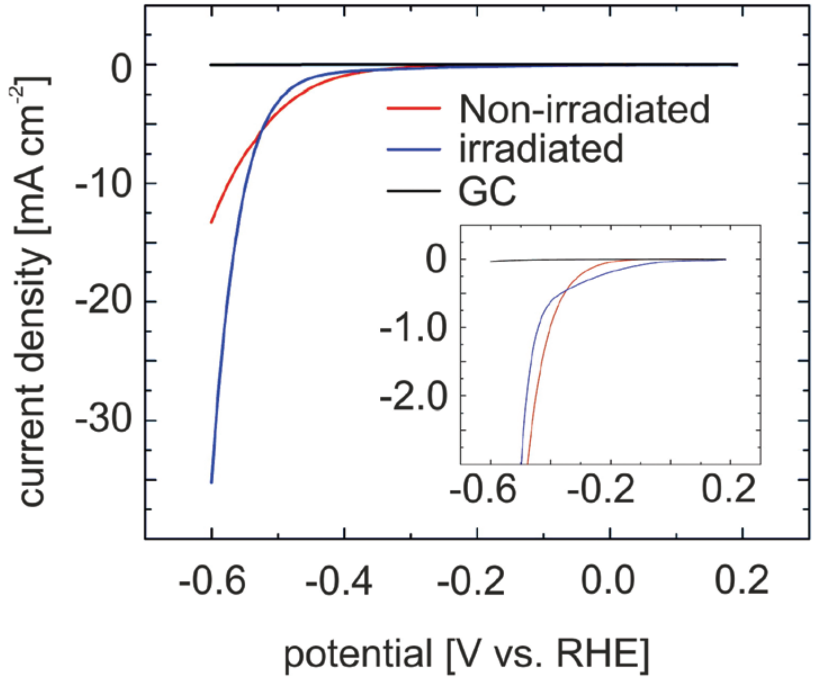


R.Kozubek, PhD thesis

Y.Liebsch

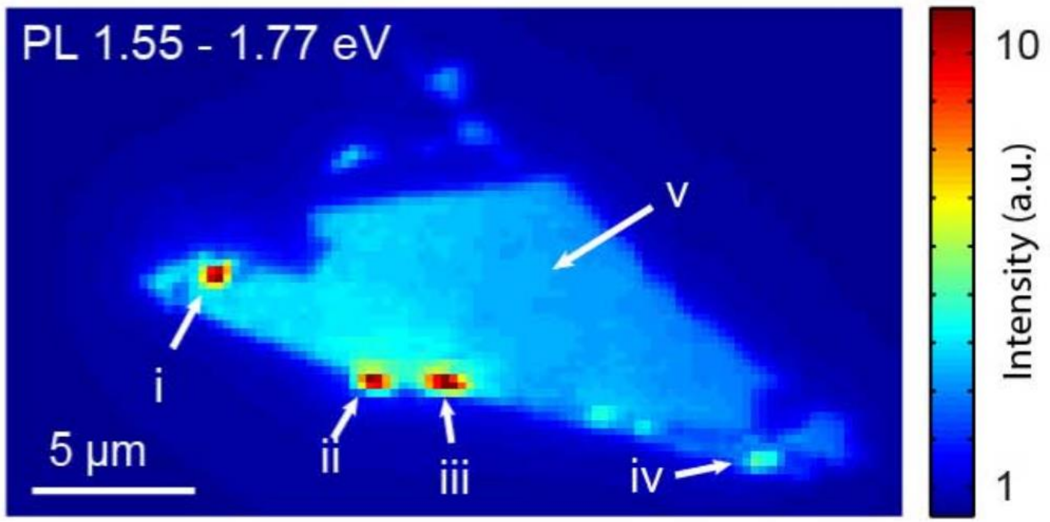
What are 2D materials?

- Single layer MoS_2 as a **catalyst** for hydrogen evolution reaction
- higher catalytic activity after irradiation



Nanoscale **10** (2018), 22908

- Tonndorf *et al*. found **single photon emitters** in 2D WSe_2
- sharp linewidth
- application in quantum devices

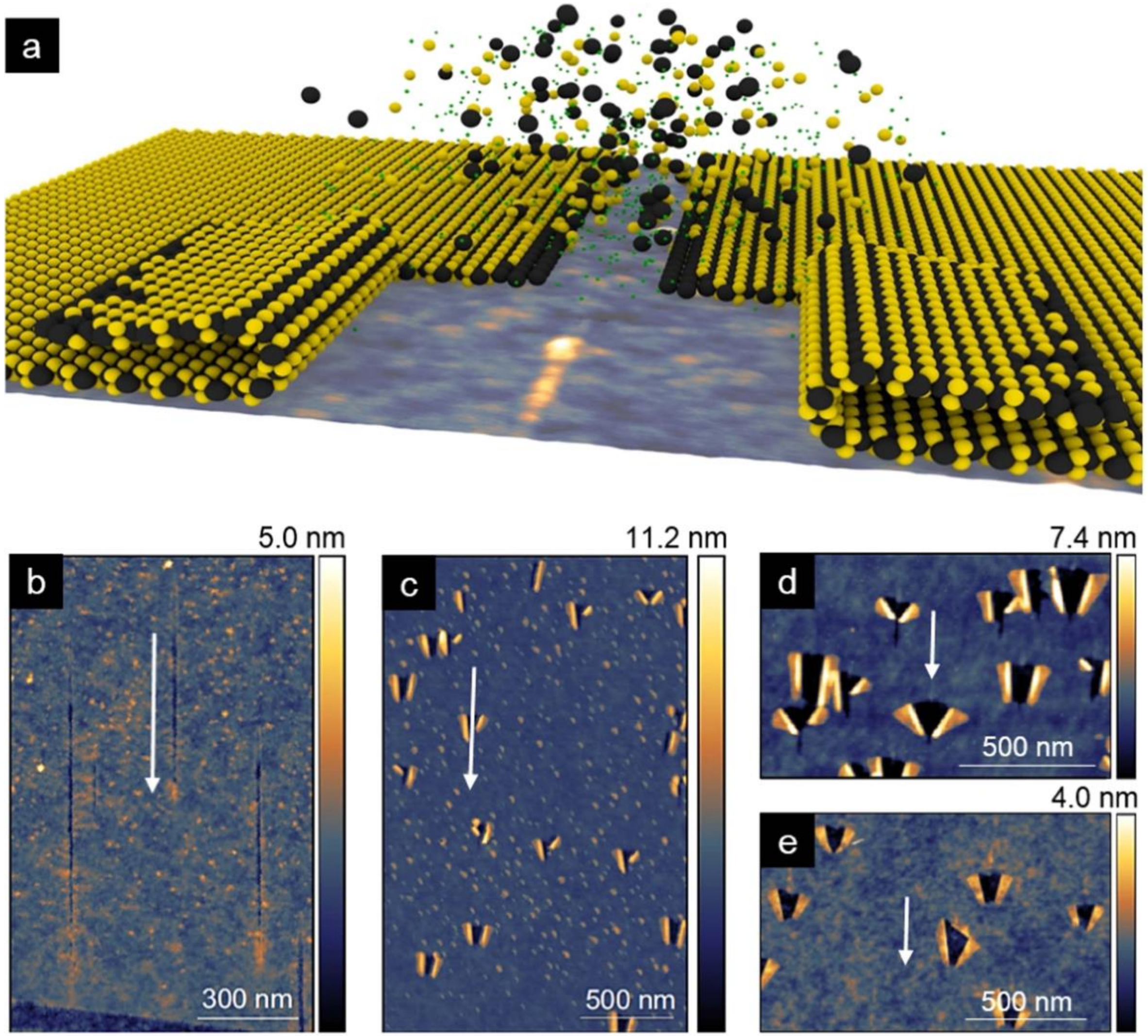


Tonndorf *et al.*,*Optica* **2** (2015) , 347-352

What has been done: Grazing incidence

- irradiation of exfoliated MoS_2 under grazing incidence
- Additionally, multilayer and bulk MoS_2 was irradiated
- Nano hillocks with striking periodicity were found
- **substrate** and material **thickness** are important parameters
- precise **control** of the **angle of incidence** is crucial

Nature Nanotechnology **2** (2007), 290-294
Nature Communications **5** (2014), 3913



2D Materials **4** (2017), 015034

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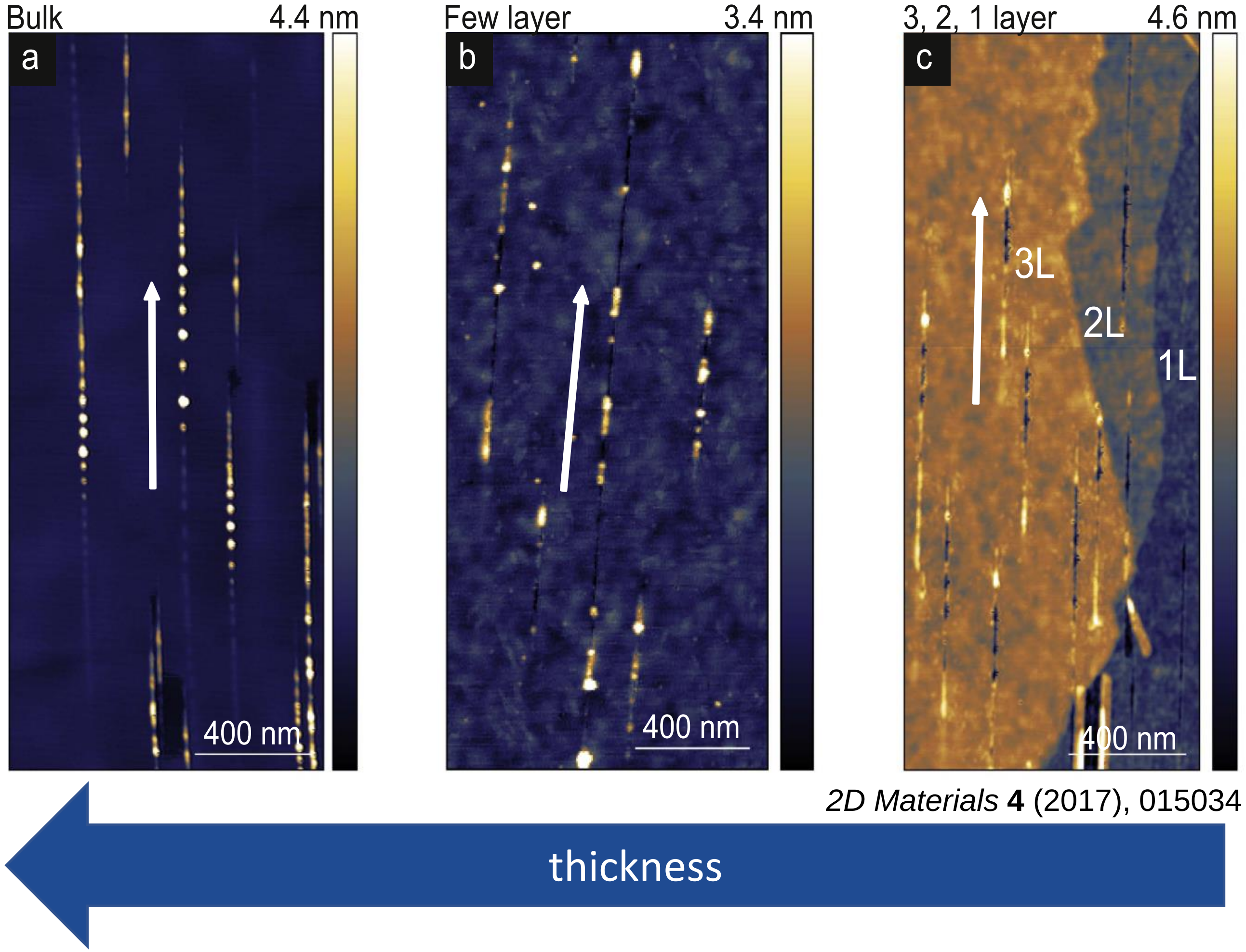
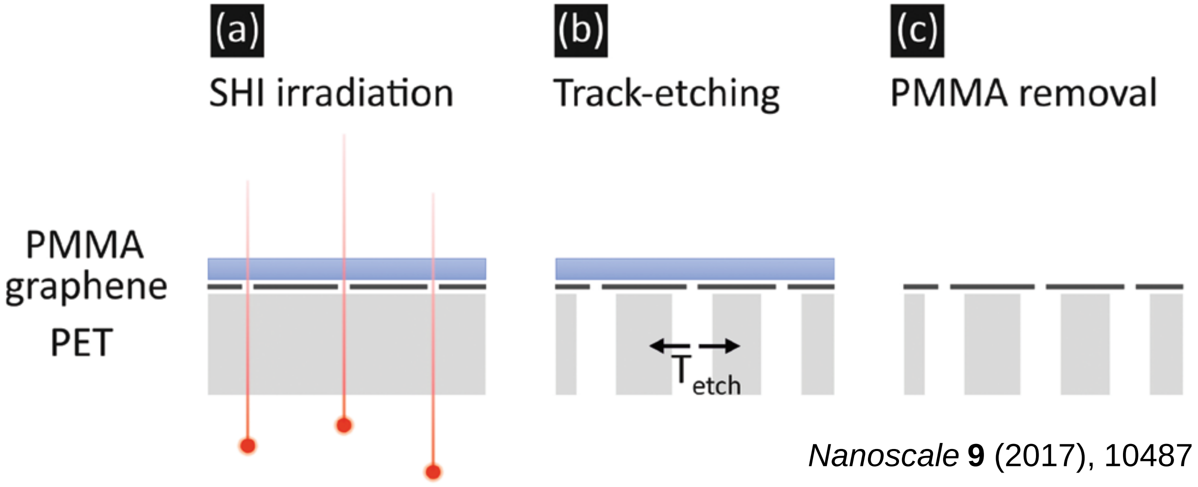


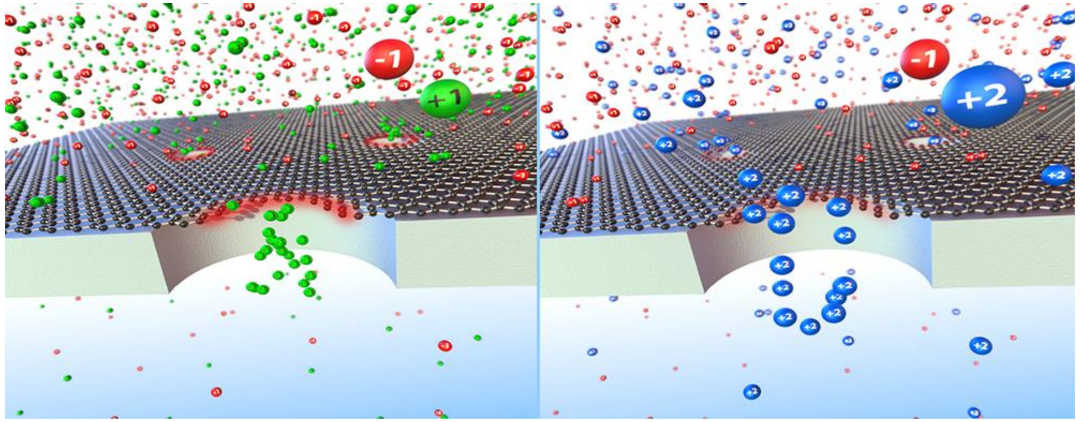
2D Materials **4** (2017), 015034

What has been done: Normal incidence

- perforation of graphene/PET composite membranes
- **SHIs** create **tracks** in relatively thick membranes
- achieved high graphene surface coverage (99.6 %)



Nanoscale **9** (2017), 10487



ACS Omega, **6** (2021) 2487 *Langmuir* **36** (2020), 7400

- high water permeation
- varying degrees of ion selectivity

→ high **mechanical stability**, while having the **advantages of graphene**

for graphene oxide see: *J.Phys.Chem.Lett.* **11** (2020), 6025

What are we doing: Charge state experiment

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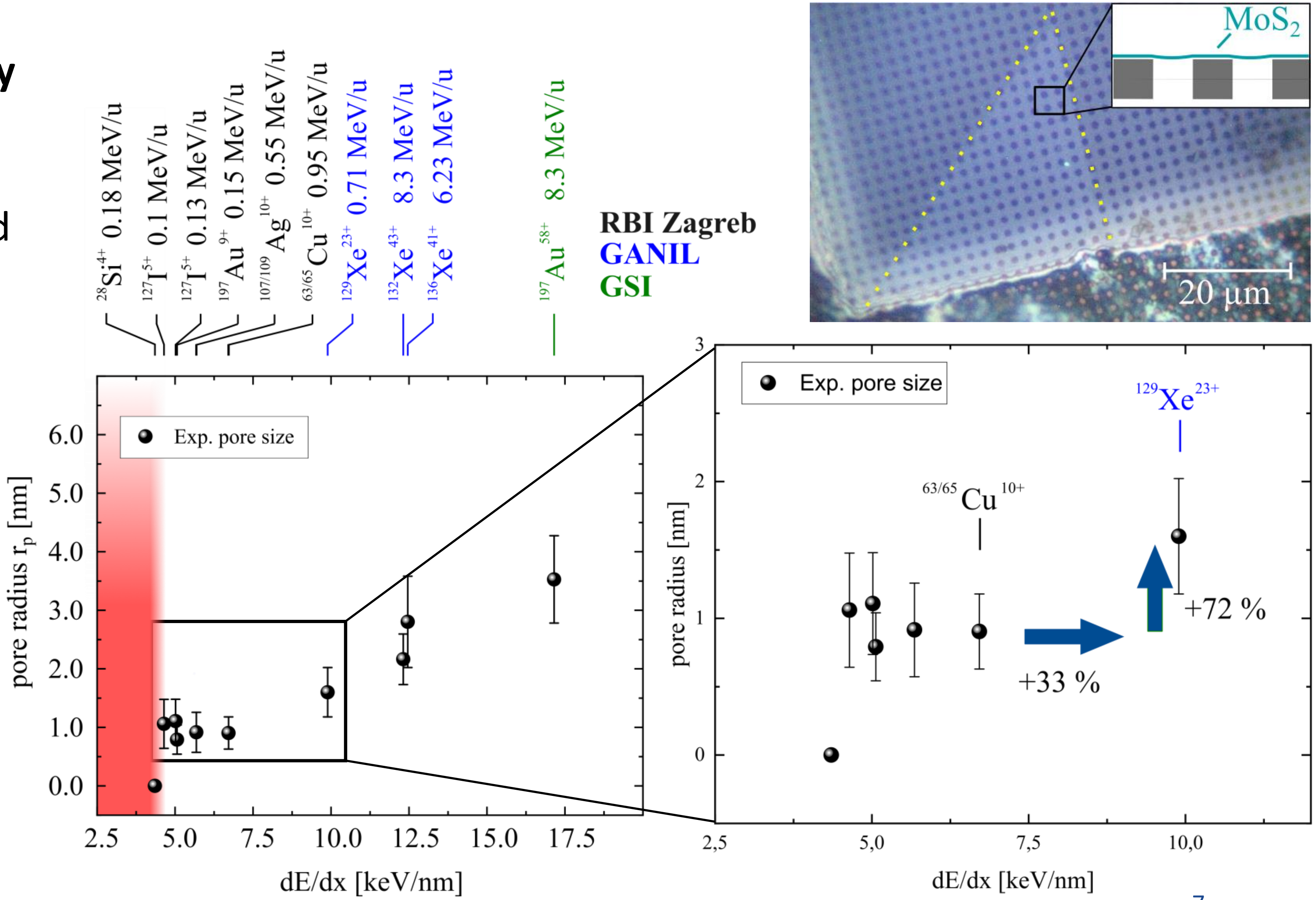
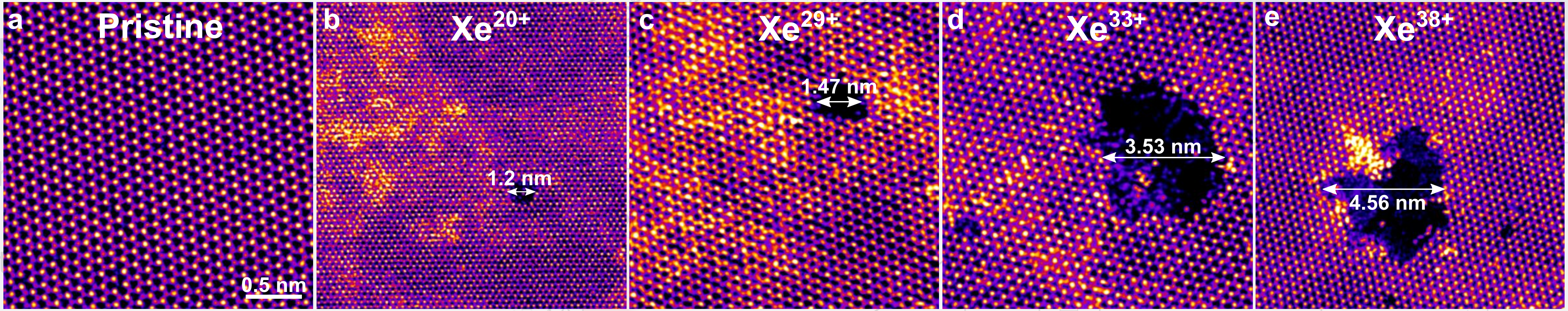
- pore **creation processes** and **energy deposition**
- **suspended SL-MoS_2** was perforated by a variety of ions
- threshold for pore creation
- steep increase in pore radius

→ varying **charge state**, constant $\boldsymbol{E_{kin}}$



What are we doing: Charge state experiment

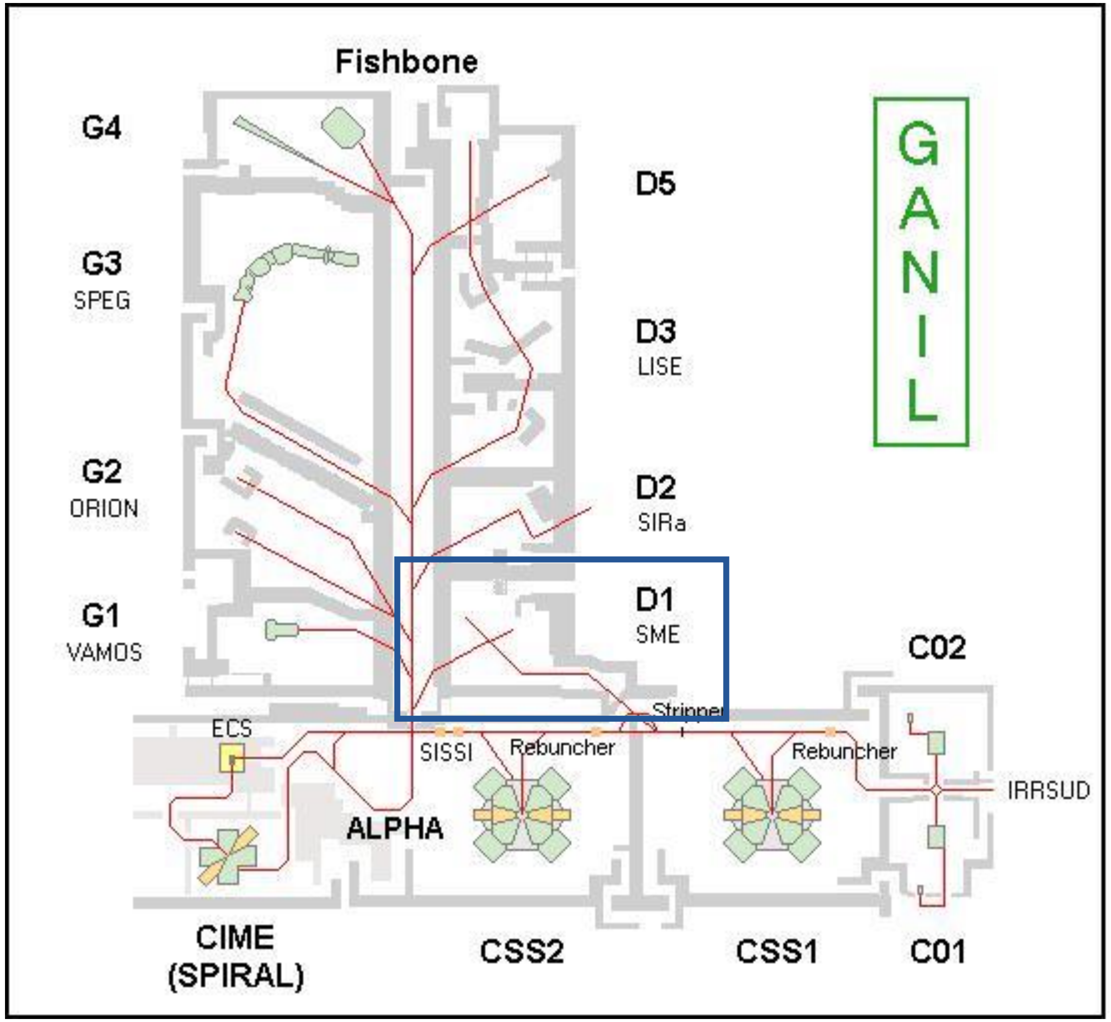
Irradiation of MoS_2 with **highly charged ions**



J. Phys. Chem. Lett., **10** (2019) 904–910

varying **charge state**, constant E_{kin}

What we are doing: Charge state experiment



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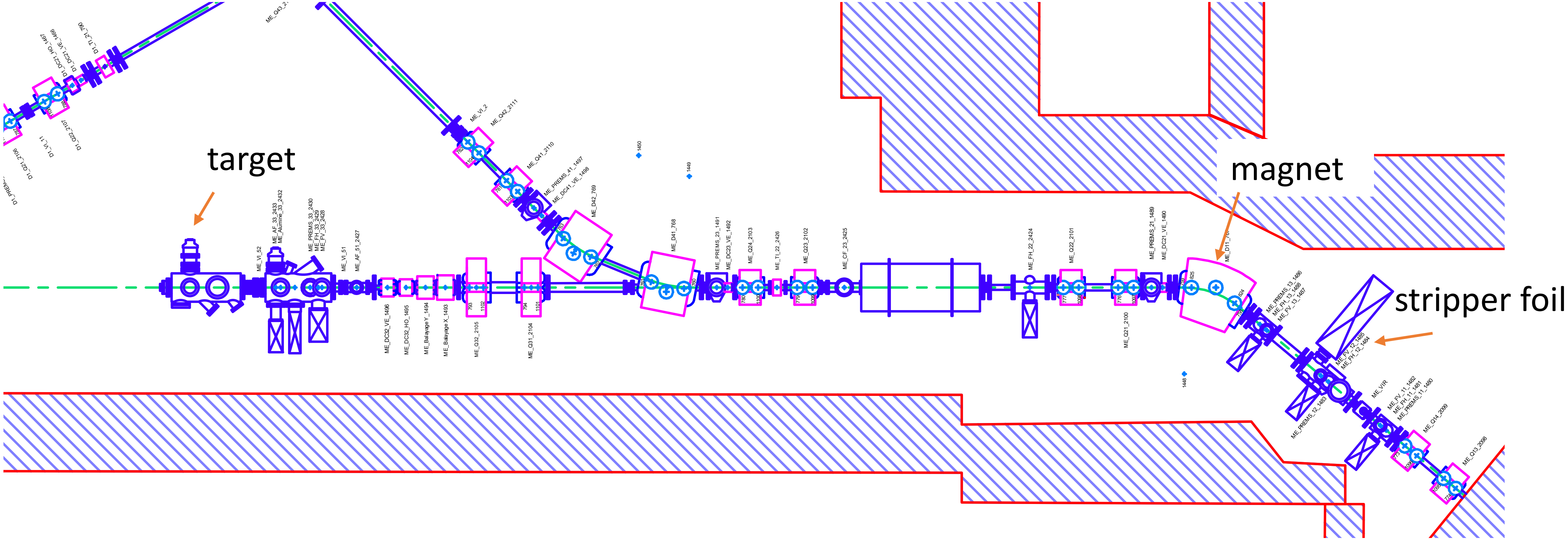


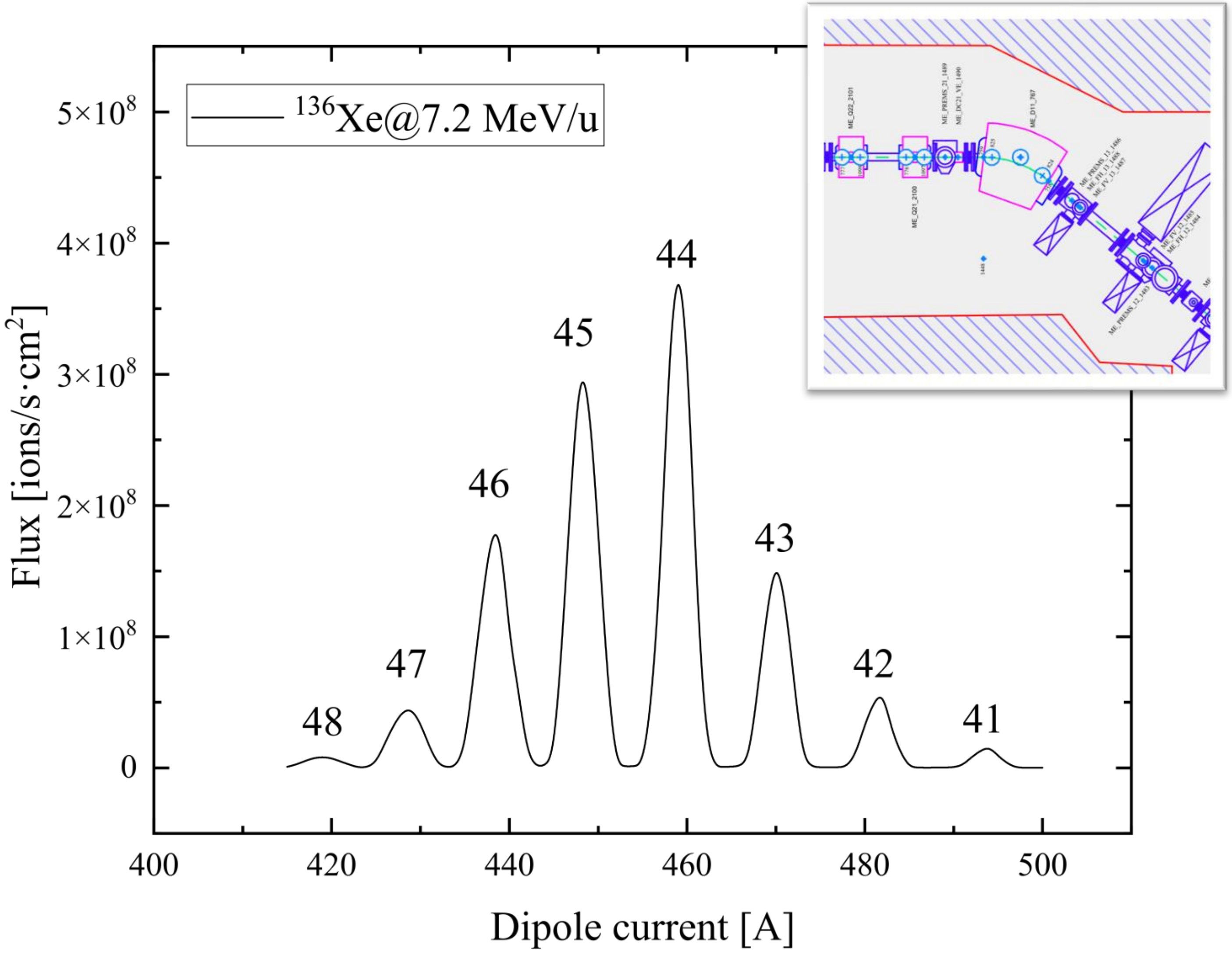
What are we doing: Charge state experiment

- Irradiation with $^{136}Xe_{43+}$@7.2 MeV/u
- **single charge states** were chosen with the **magnet**
- suspended SL-MoS_2 has been irradiated with 8 different charge states

$$Cu_{10+} \longrightarrow Xe_{23+} : \Delta E_{pot} = 5.5\, keV$$

$$Xe_{41+} \longrightarrow Xe_{48+} : \Delta E_{pot} = 41.7\, keV$$

- STEM measurements are still work in progress



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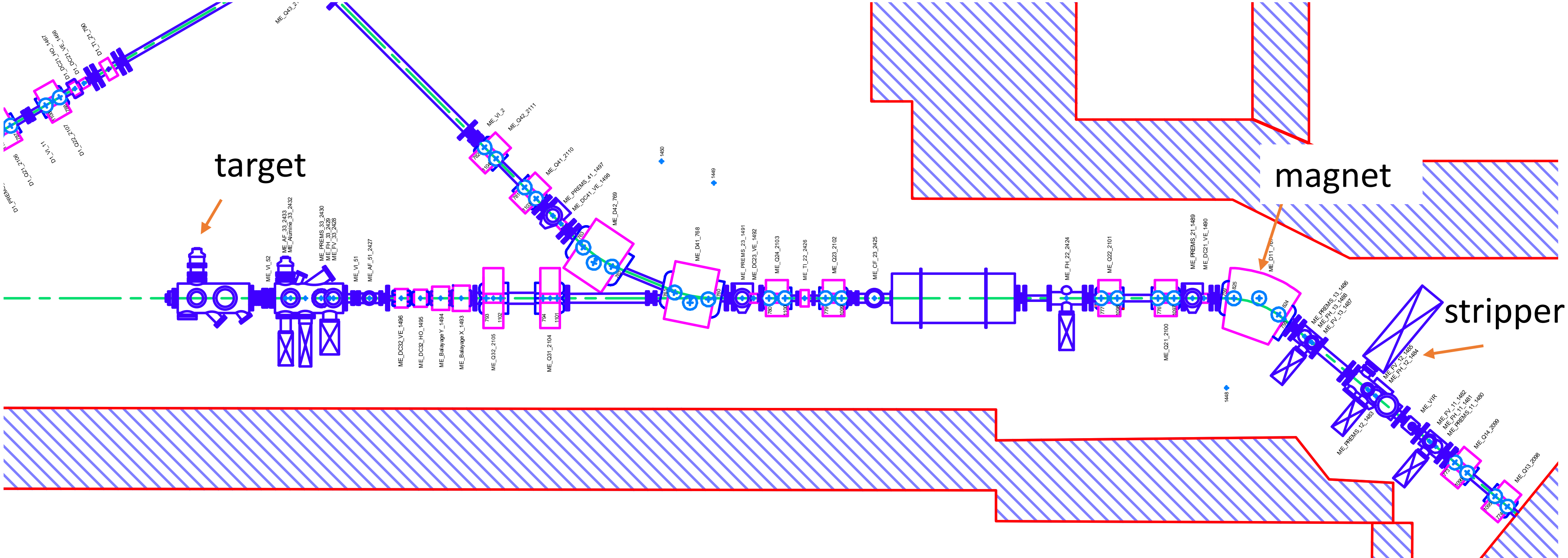
What would help us in the future?

We aim to study the stopping power of ultrathin (up to single layer), suspended materials.

- Beam diagnostics **after the target** needed

adding diagnostics or moving the target



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