Activity for the nuclear target development within NUMEN

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on behalf of
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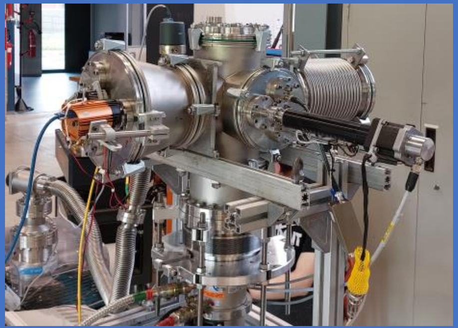
Second meeting on "Targets for Nuclear Physics“, 18-19 May 2026

Institutions

INFN TORINO
Istituto Nazionale di Fisica Nucleare
Sezione di Torino



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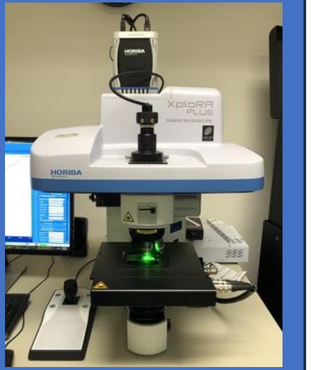

INFN GENOVA

Università di Genova

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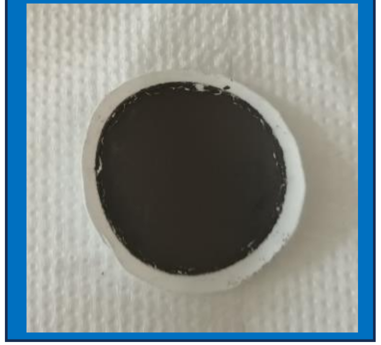
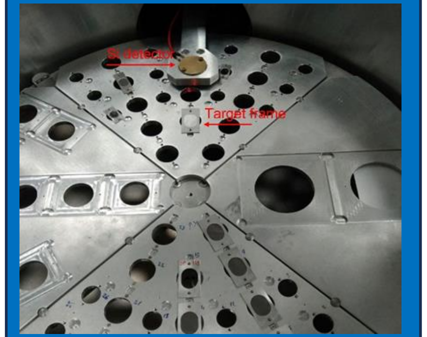


INFN LNS
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali del Sud



INFN LNL
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Legnaro

Outline

- Motivations for the study of new substrates for target deposition
- Commercial C-material foils
- First custom C-material foils
- Preliminary results from measurements of radiation damage

Activity for nuclear targets

The activity finds its motivation in the study of targets for the NUMEN experiment

- ✓ Target of isotopes candidates for 0νββ decays
- ✓ ^{20}Ne and ^{18}O ion beams with 15-60 MeV/u energy and up to 10^{13} pps

→ more than 10^5 W/cm^3 power density in the target

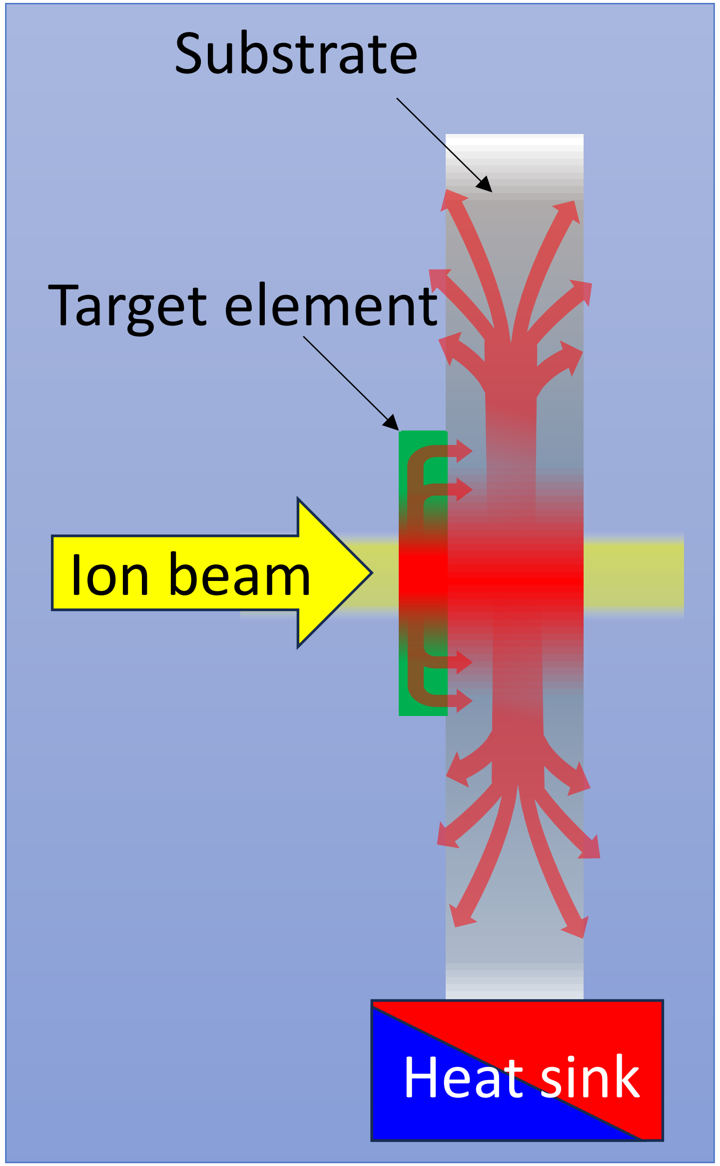
→ high thermal stress

Custom solution for the target

- The thermal stress of the target is addressed with a highly thermally conductive substrate that dissipates heat toward a heat sink.

- The isotope is evaporated on the substrate by e-beam evaporation or thermal evaporation

- ***Highly Oriented Pyrolytic Graphite* (HOPG)** and ***Multilayer Graphene (MLG)*** featuring higher thermal conductivity ($k_{//}$=1500-1900 $Wm^{-1}K^{-1}$), produced in μm-thick foils, are good candidates



Commercial C-material foils

Commercial Carbon foils

HOPG – Optigraph

CVD + HT HP annealing

MLG - Kaneka

Pyrolysis of polyimide film

MLG – ACF/Nanotech

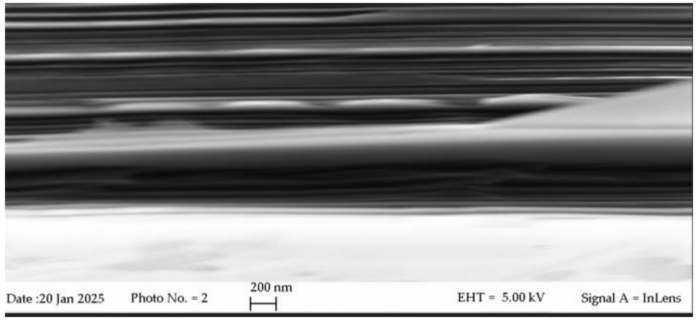
GO and rGO

Material	Calculated density [g/cm^3]	Purity degree /cristallinity	Thickness [μm]	Thermal diffusivity [mm^2/s]	Thermal conductivity [W/(m · K)]	Thickness uniformity by APT (@LNS)
HOPG	2.265	99.9 %/HO	2	1550	2.3	poor
MLG - K	2.272	99 %/HO	1.6	1200	2.0 (l.)	good
MLG - A	2.02	Fair	1-3	1308	1.93 (l.)	good

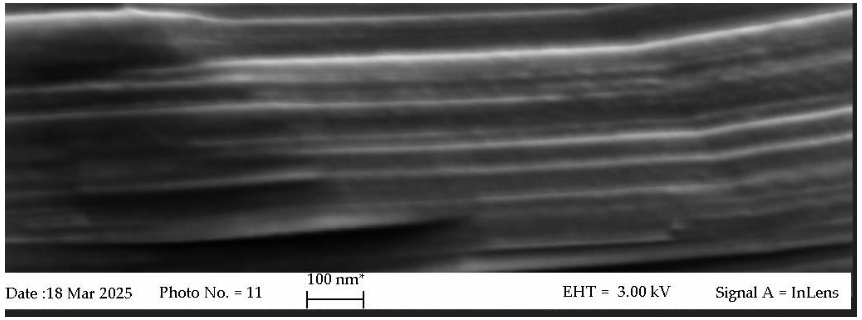
Thermal conductivity measurements till now FAILED!
Only HOPG was measured with the laser flash method

Commercial Carbon foils

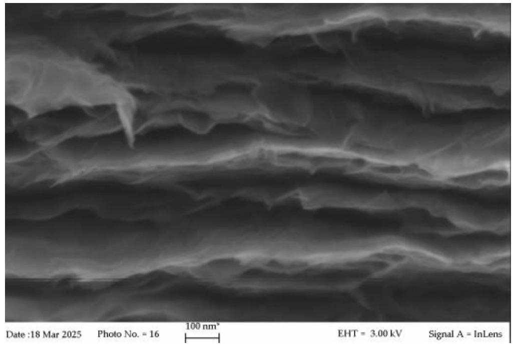
HOPG – Optigraph



MLG - Kaneka



MLG – ACF/Nanotech

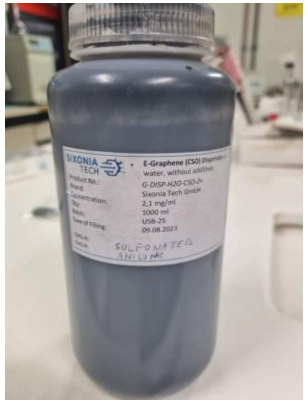


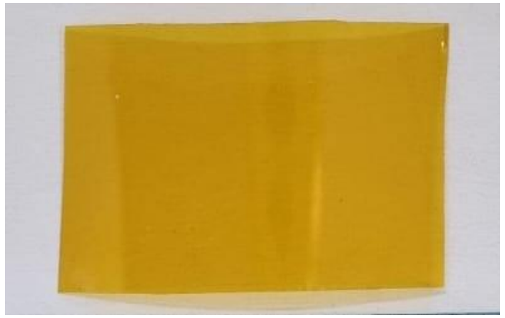
Material	Measured Electrical Conductivity [S/m]	Literature value [S/m]
HOPG	$3.05 \cdot 10^6$	$2.10 \cdot 10^6$
MLG - Kaneka	$2.12 \cdot 10^4$	$1.00 \cdot 10^3$ to $1.00 \cdot 10^4$
MLG - ACF	$2.03 \cdot 10^6$	$1.00 \cdot 10^6$

Custom C-material foils

Custom MLG foil production

Filtration of graphene dispersion



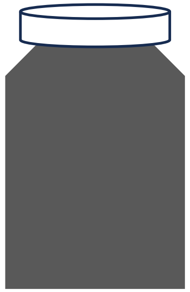


Carbonization followed by graphitization of polyimide film (Kapton)

Reduction of graphene oxide (GO) to reduced graphene oxide rGO

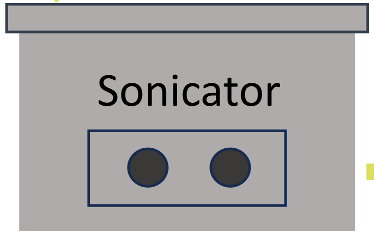
MLG foil production by filtration

Procedure



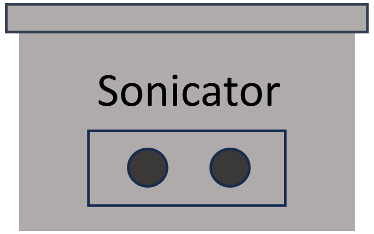
E-graphene dispersion

Concentration 2-3 mg/ml



10 mins

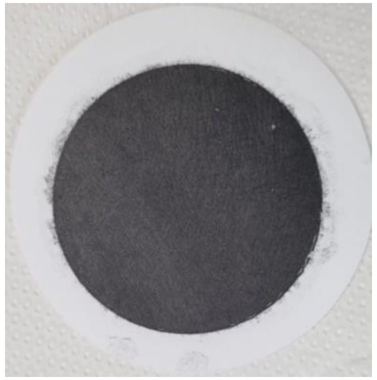
Known volume (V_d) of dispersion diluted with water



few mins

Filtration

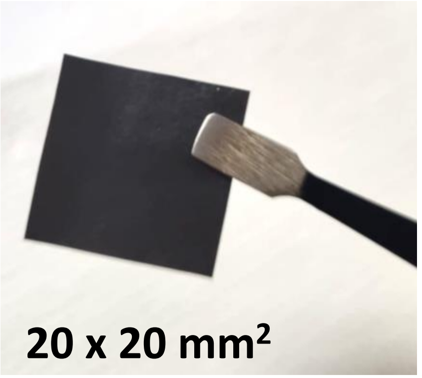
Filters: Nylon
Polytetrafluoroethylene-PTFE,
Mixed cellulose ester -MCE,
Polypropylene-PP



Foils separated from filters

either by peeling off

or by pyrolysis at different temperatures (up to 700 °C)



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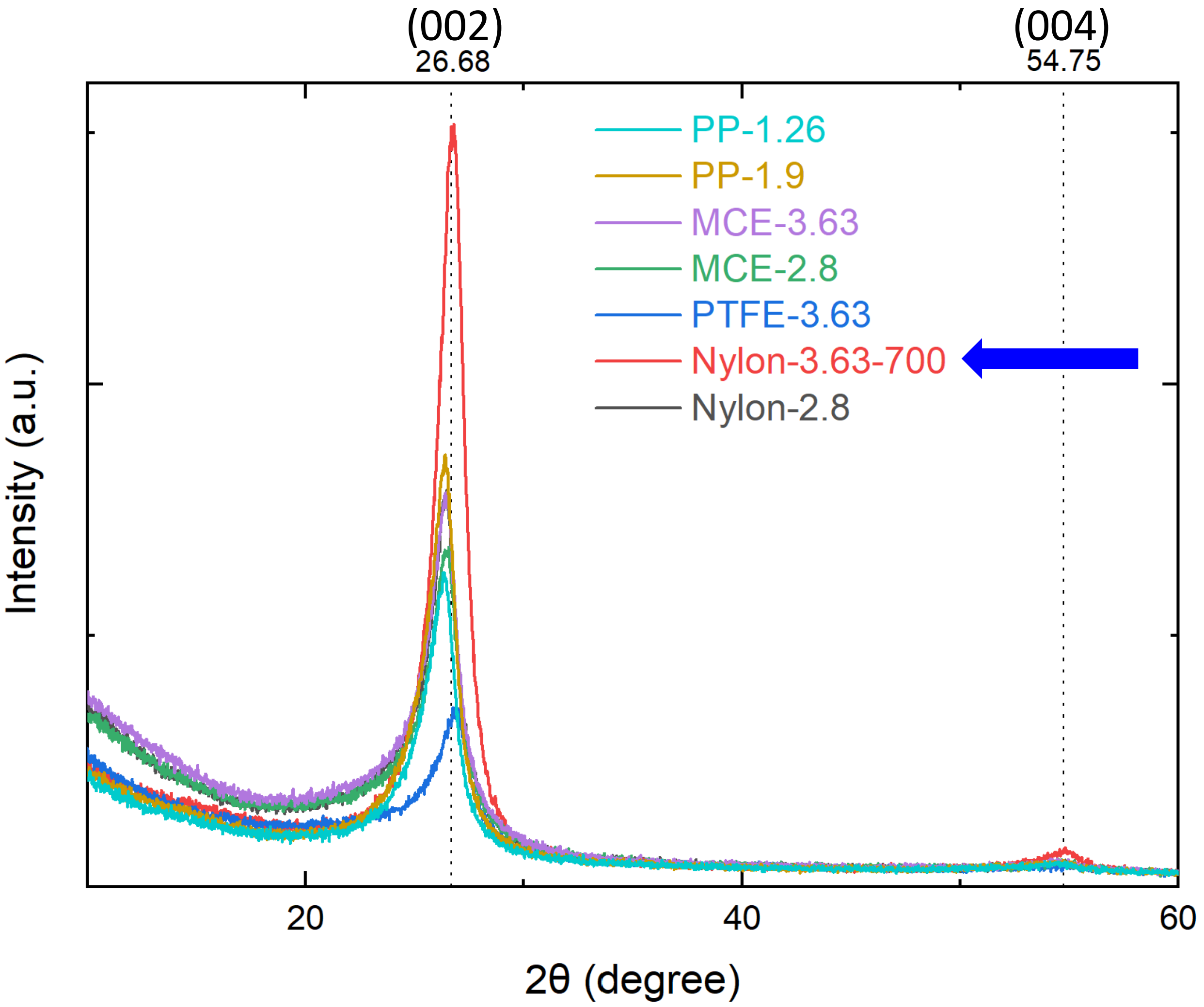
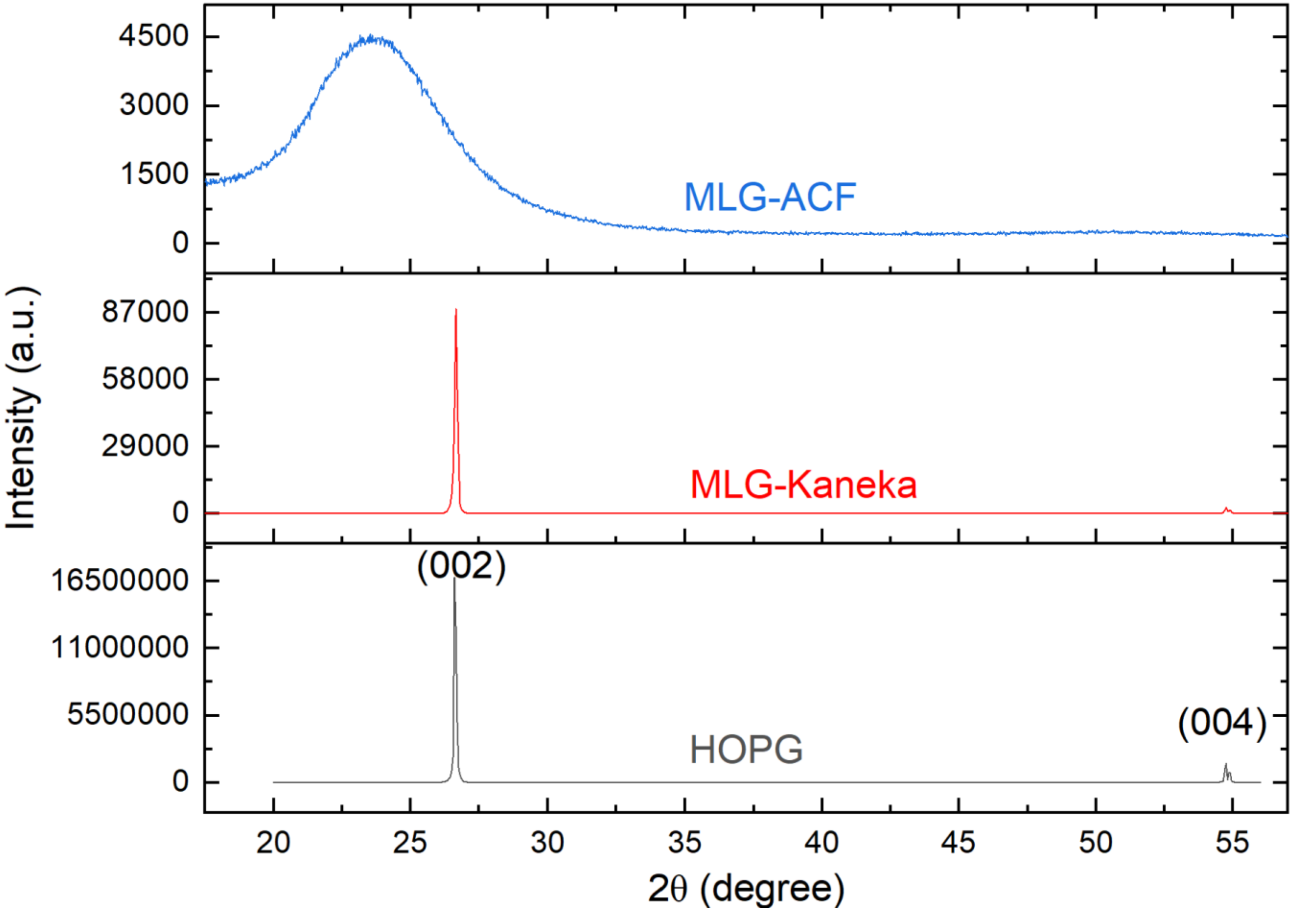
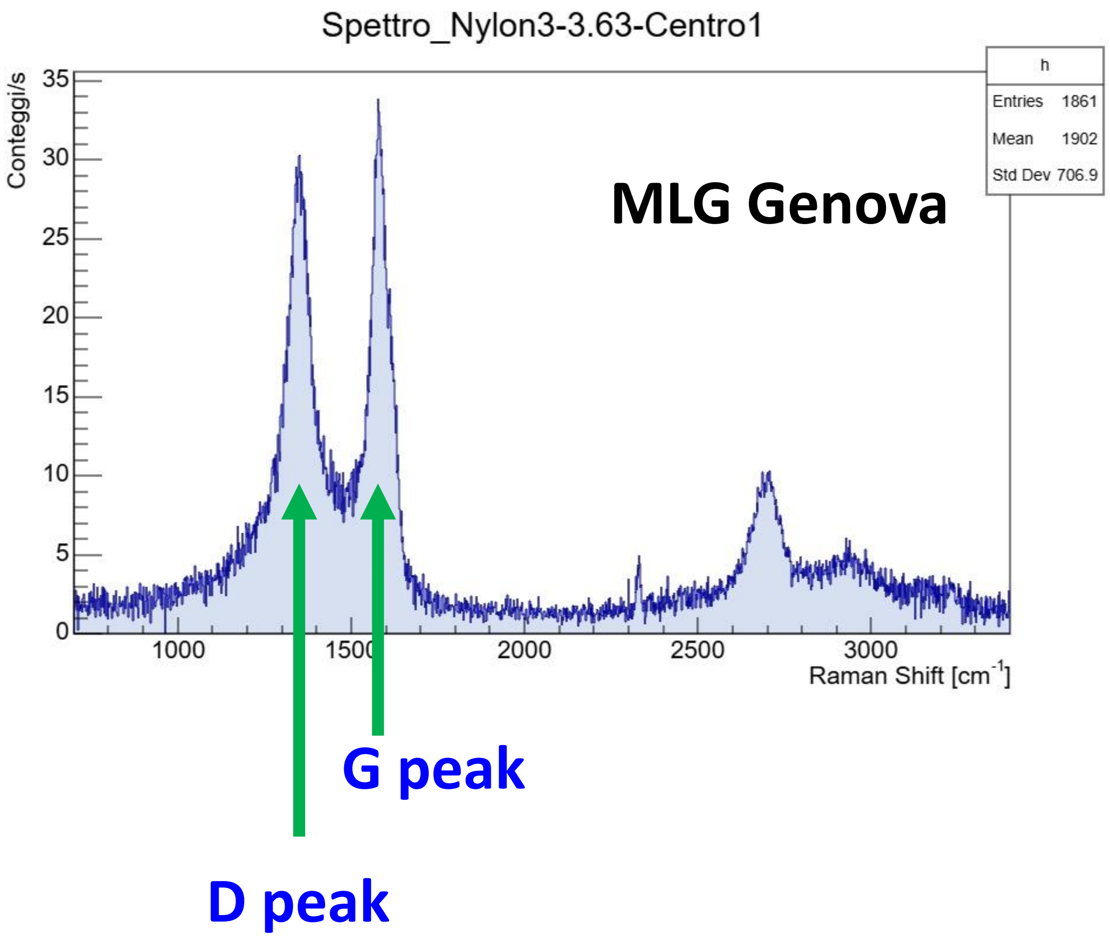
Custom vs Commercial foils – XRD analysis

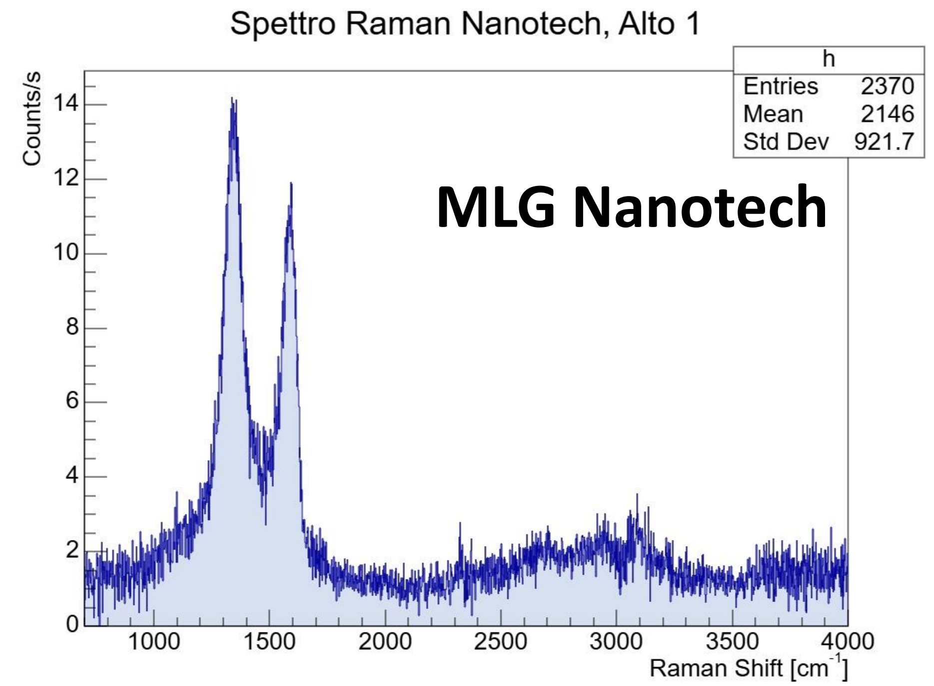


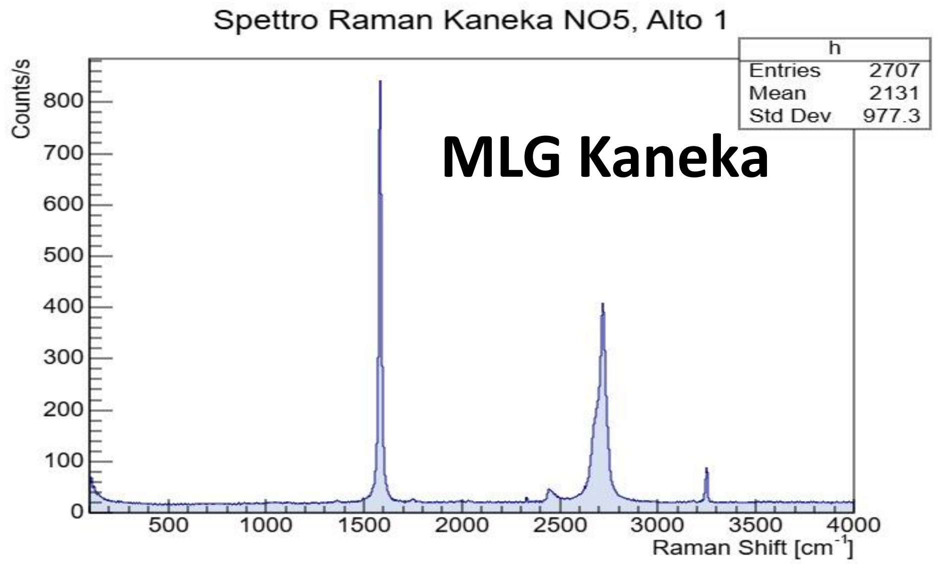


A post-annealing treatment of 700 °C for just 10 minutes improves cristallinity

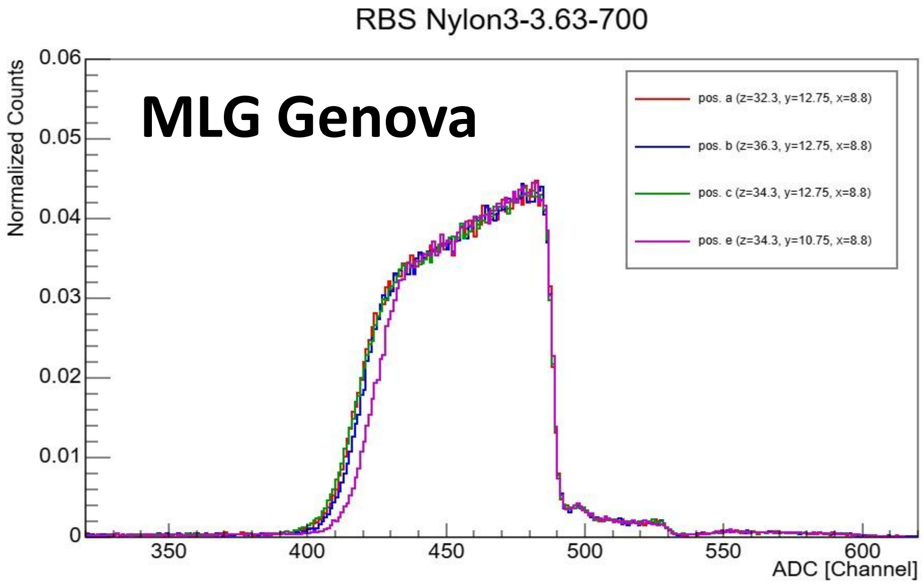
Custom vs Commercial foils – Raman analysis



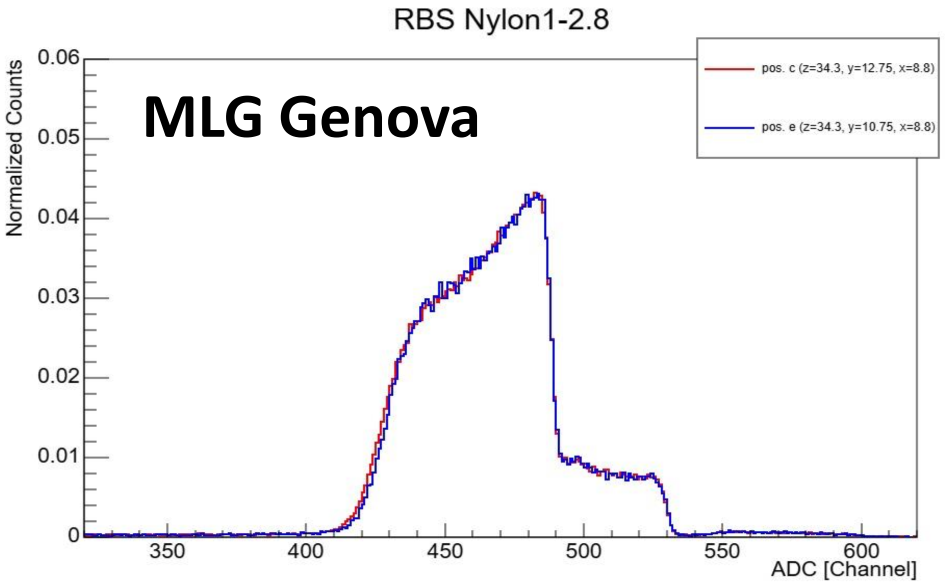




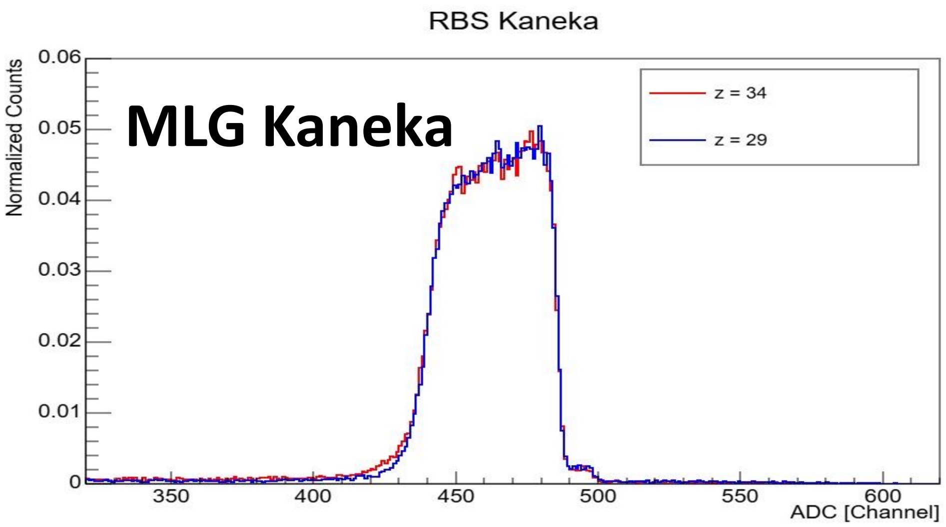
Custom vs Commercial foils – EBS analysis



EBS of a sample with annealing at 700°C



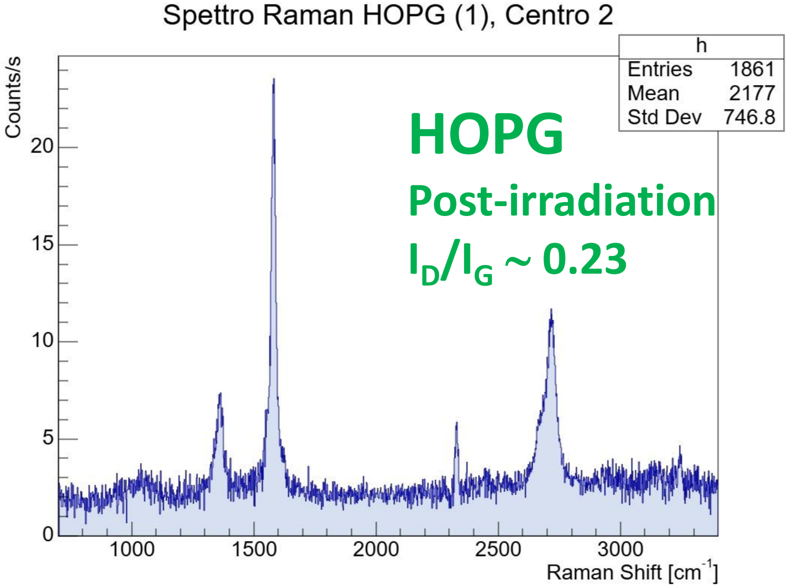
EBS of a sample without annealing at 700°C

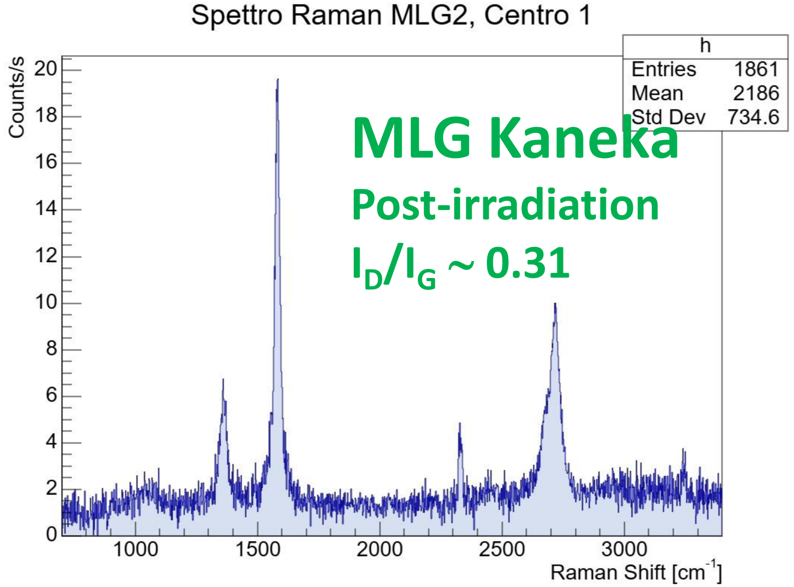


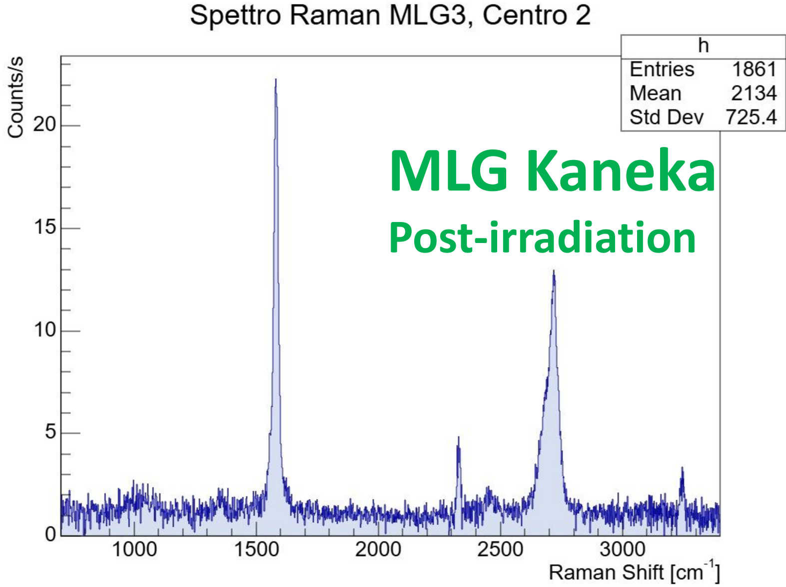
The non-uniformity of MLG Genova doubles compared to MLG Kaneka

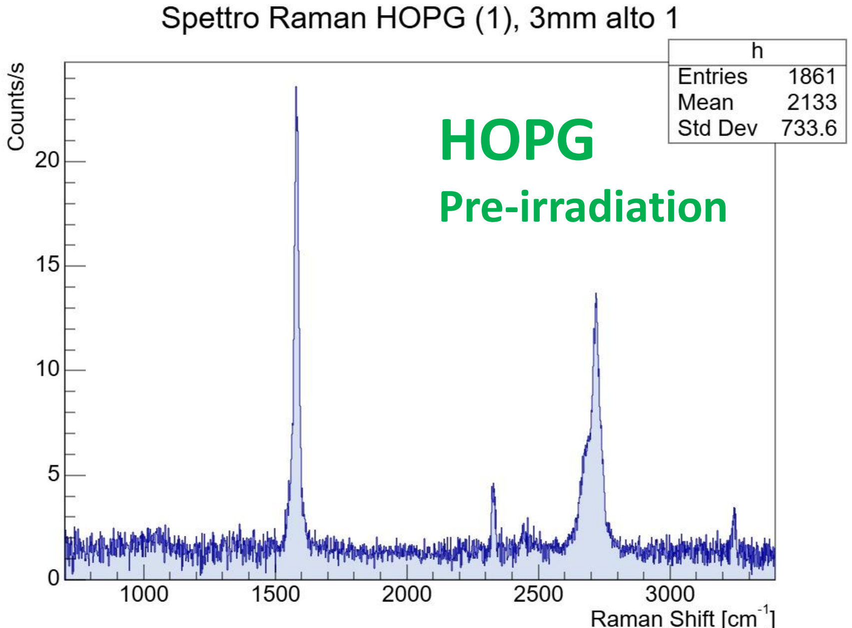
Preliminary results from measurements of radiation damage

Irradiated samples @ GANIL





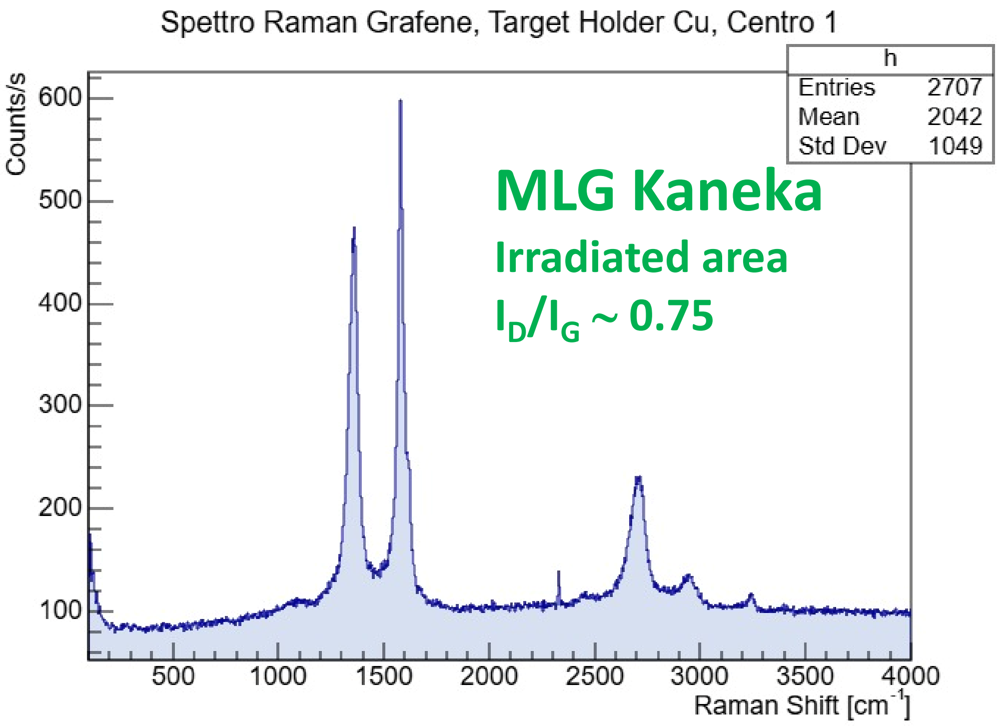


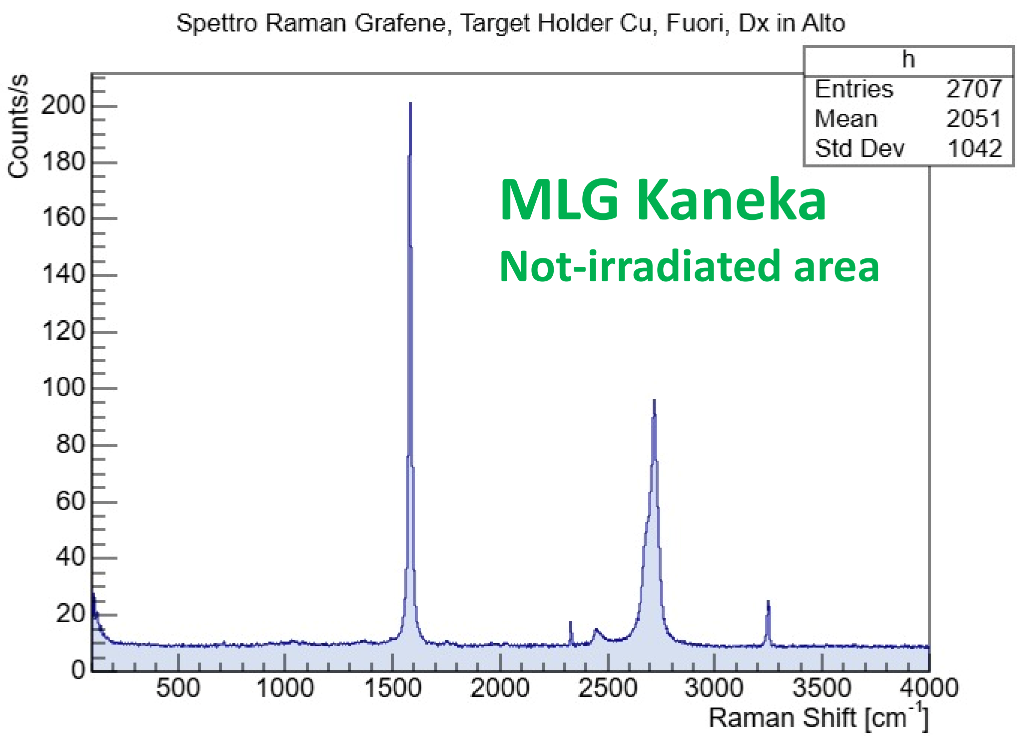


Irradiation with $^{20}Ne^{9+}$ beam, 14 MeV/u
Each sample is inside a target holder at room temperature
HOPG, 140 min. with a ~245 enA beam current
MLG Kaneka 2, 135 min. with a ~ 245 enA beam current
MLG Kaneka 1, 120 min. with a ~ 125 enA beam current

Thanks to Henning Lebius for the continuous support at GANIL

Irradiated sample @ GANIL

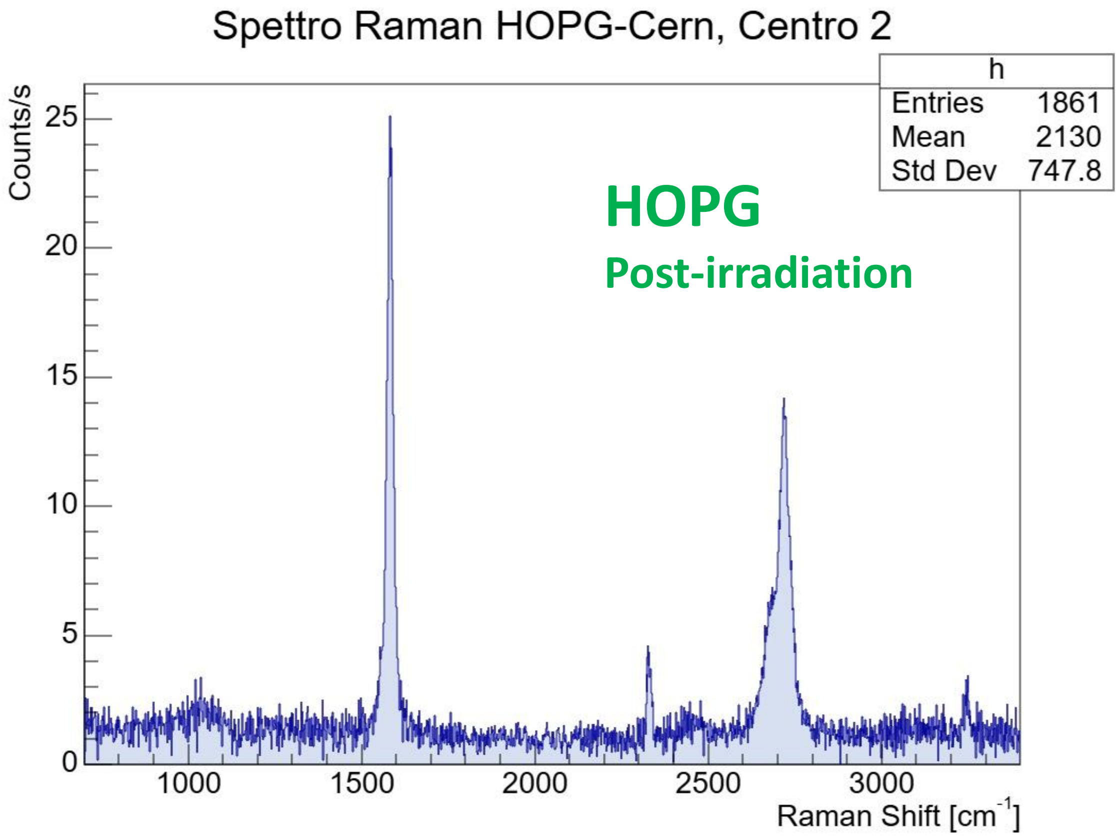




Irradiation with $^{20}Ne^{9+}$ beam, 14 MeV/u
Sample inside a target holder kept at cryogenic temperature
MLG Kaneka, 27 hours with a ~ 200 enA beam current

Thanks to Henning Lebius for the continuous support at GANIL

Irradiated sample @ CERN



Irradiation with a 24 GeV/c proton beam (~ $7.5 \cdot 10^{11}$ p/spill)
Fluence: $2.4 \cdot 10^{15}$ p/cm^2
Sample inside a target holder at room temperature

Conclusion and Future work

The first samples produced in Genova are encouraging

Post-annealing treatment of MLG Genova improves crystallinity

- Production of new samples with a longer post-annealing
- Applying pressure during the synthesis

The peak D was measured in the ion-irradiated samples

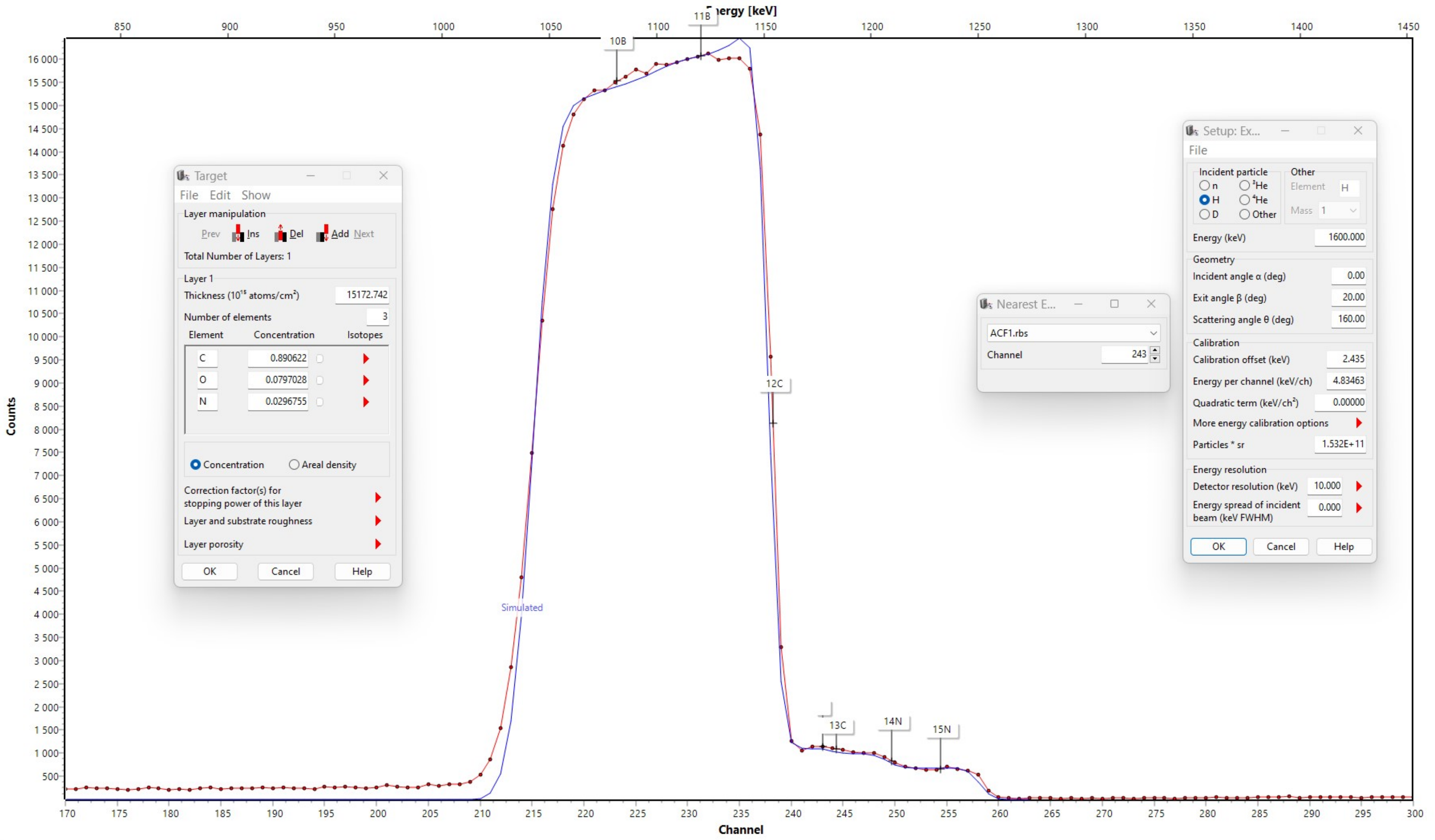
The peak D was not measured in the proton-irradiated sample

- Correlation between the induced defects and the thermal conductivity

Solve the problem of measuring the thermal conductivity!

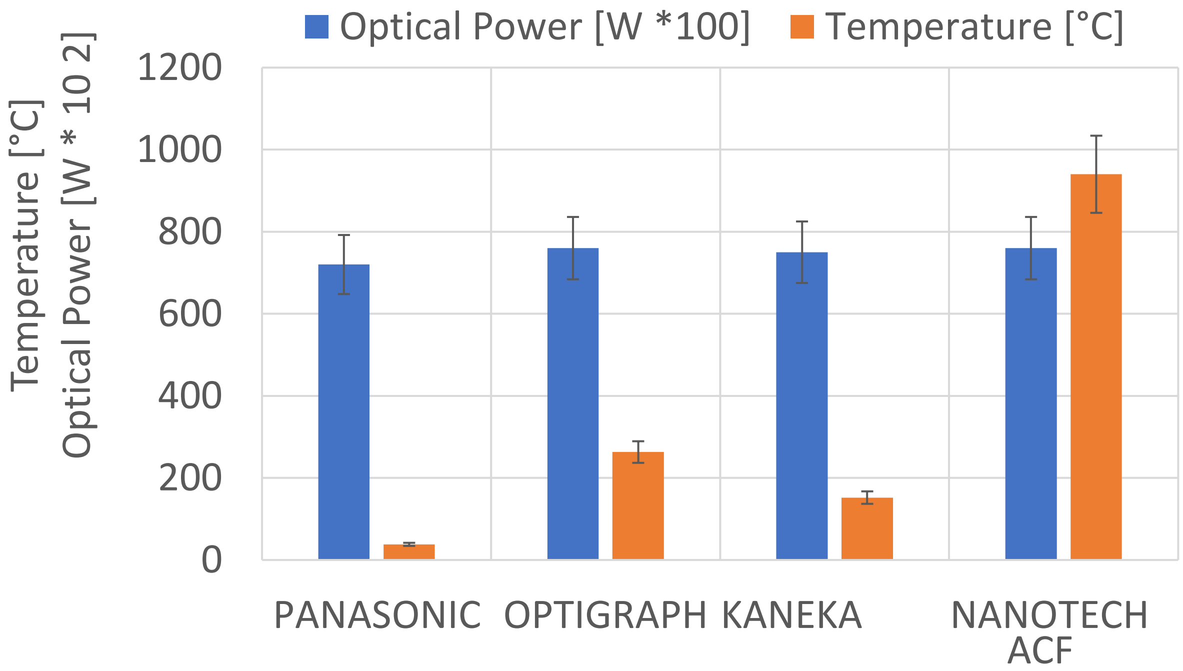
SPARES

RBS of MLG Kaneka



Temperature of heated samples

- Graphyte PANASONIC: 10 μm thick
- HOPG OPTIGRAPH: 2 μm thick
- MLG KANEKA: 1.5 μm thin
- MLG NANOTECH, MLG ACF: 1.5 μm thin

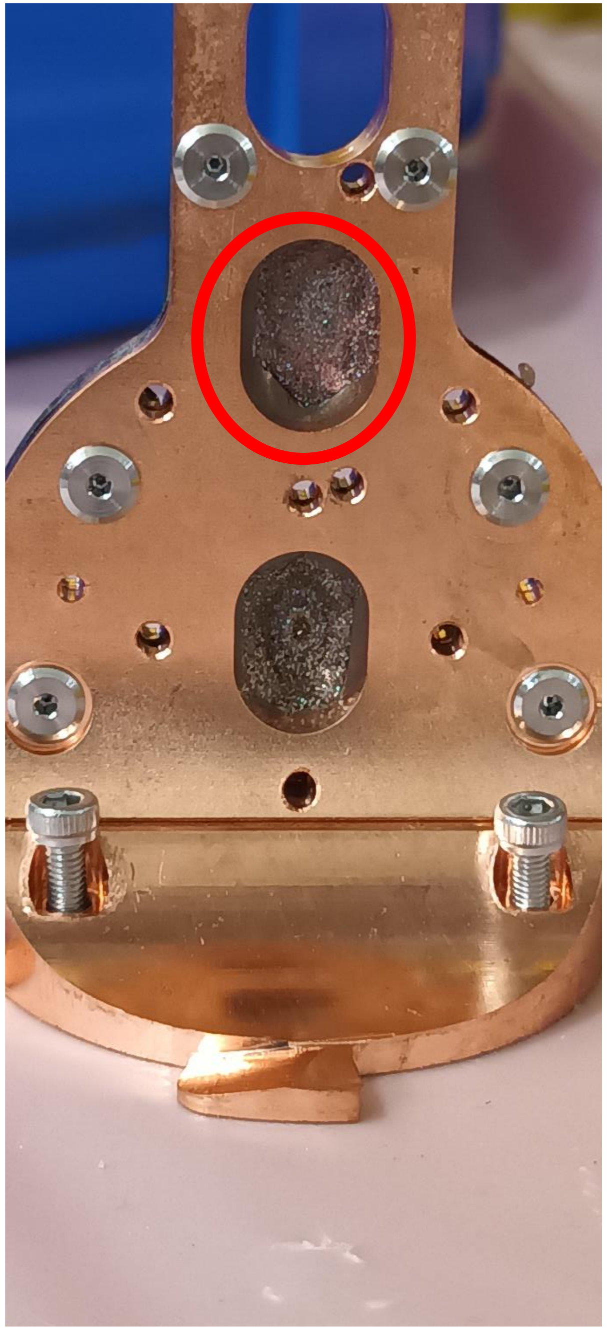


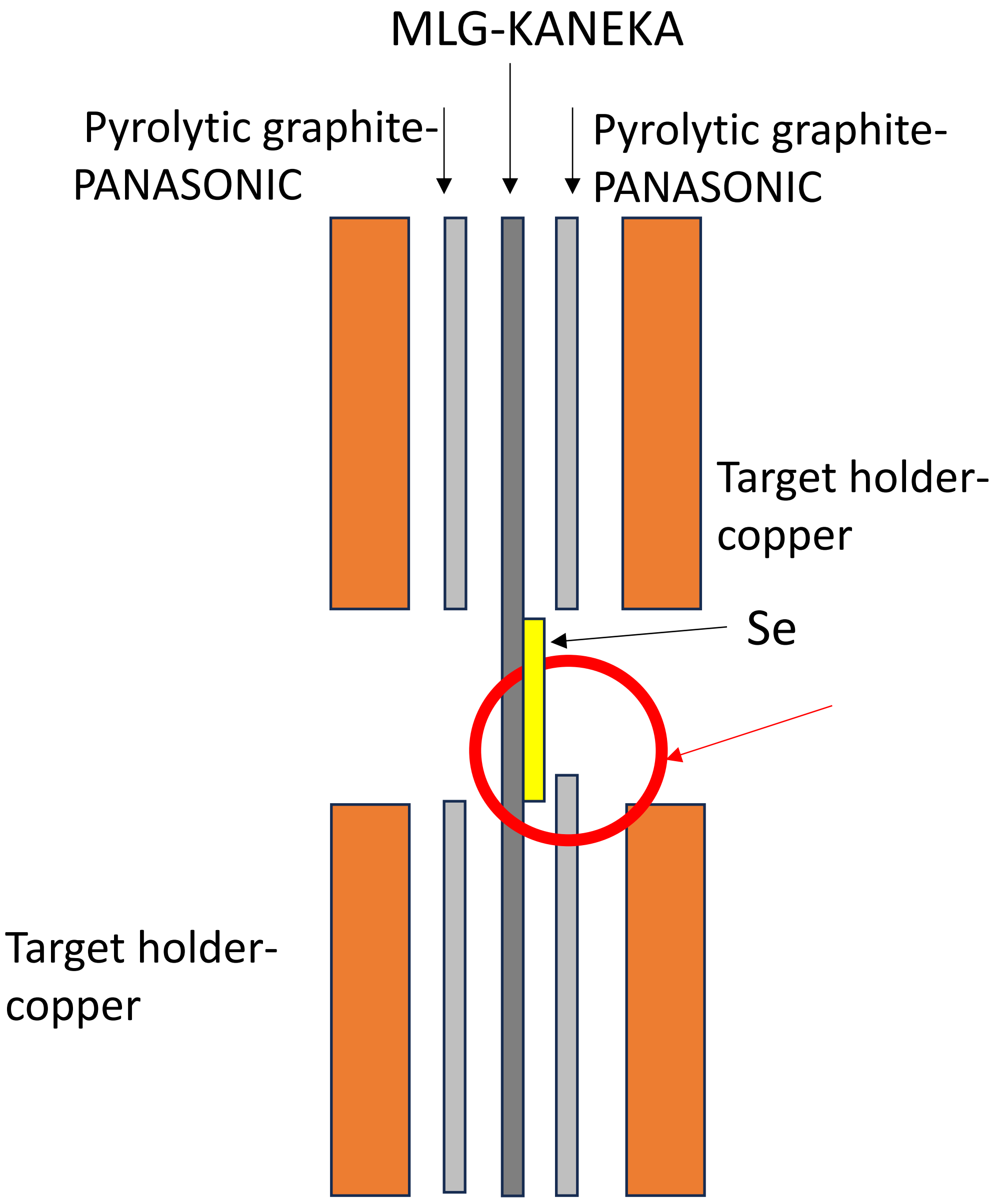
• PGS- PANASONIC	~1700 W/(m·K)
• HOPG-OPTIGRAPH	~1900 W/(m·K)
• MLG-KANEKA	~1800 W/(m·K)
• MLG-NANOTECH(ACF)	~1500-1900 W/(m·K)

Cooled samples

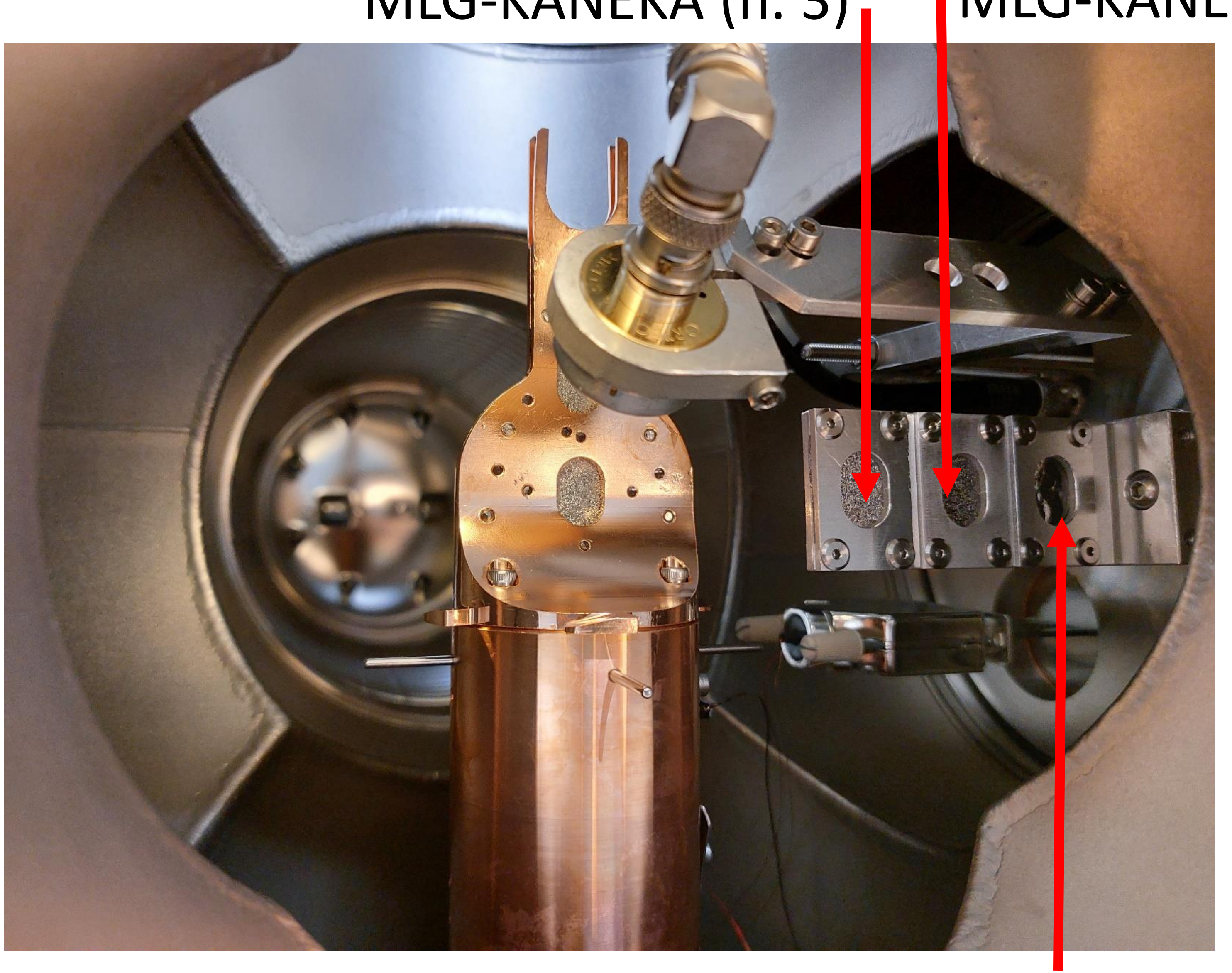
Se +MLG-KANEKA

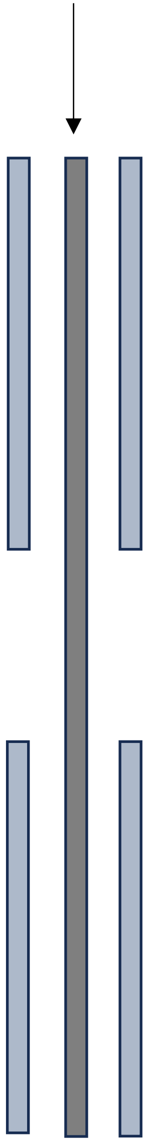
MLG-KANEKA (n. 4)





Samples at room temperature





Experimental setup installed at GANIL