

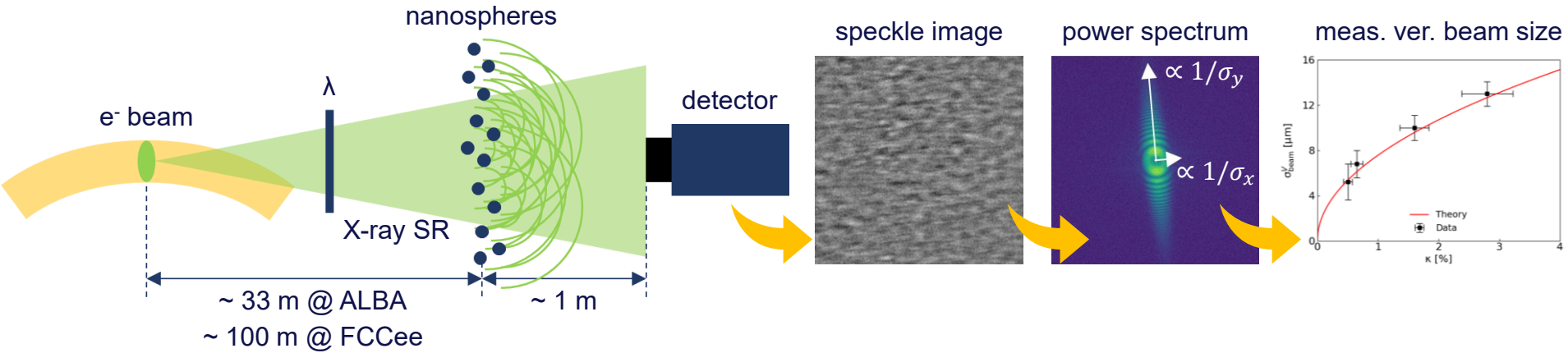
Recent advances and future plans for the HNFS project

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with many thanks to:

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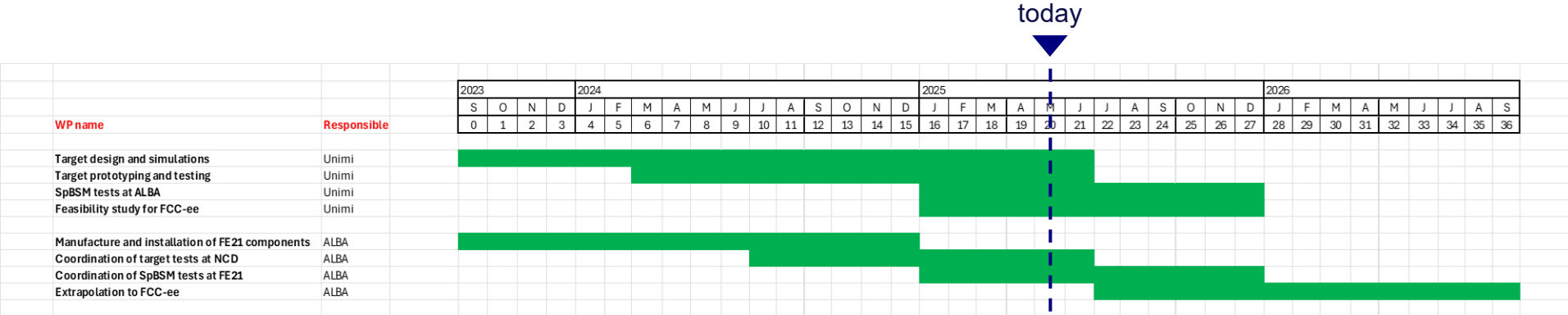
Speckle-based Beam Size Monitor (SpBSM)



Light through a suspension of **nanospheres** forms **speckles**

- validated at ALBA down to $4.5 \mu\text{m}$ beam sizes @ 33 m
- with the angular resolution of the current setup, **FCC-ee source resolvable**

Overview of the HNFS project

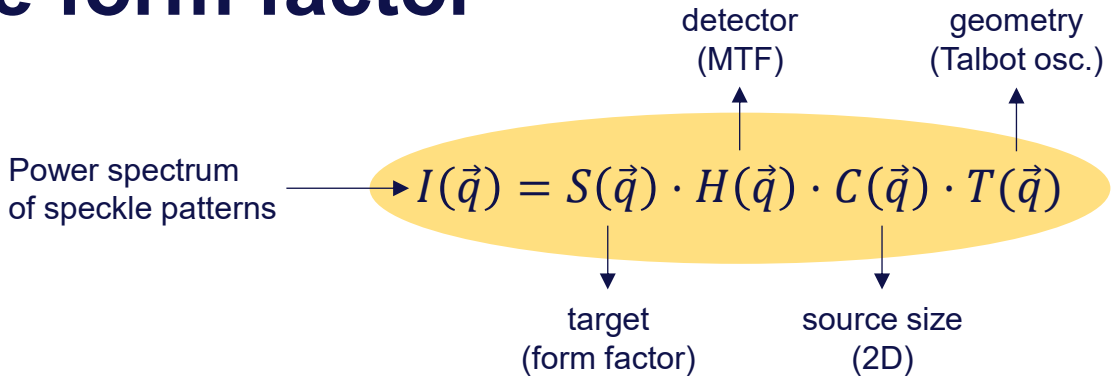


R&D studies to develop and validate at ALBA an **SpBSM instrument compatible with FCC-ee requirements**

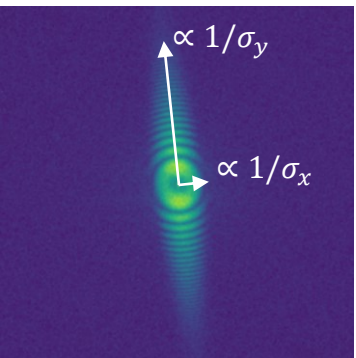
Outline

- Target design and simulations: results for nanospheres
- Overview of samples: nanoclusters, membranes, nanoporous gold
- SAXS characterizations at NCD-SWEET (ALBA)
- Outlook on next activities

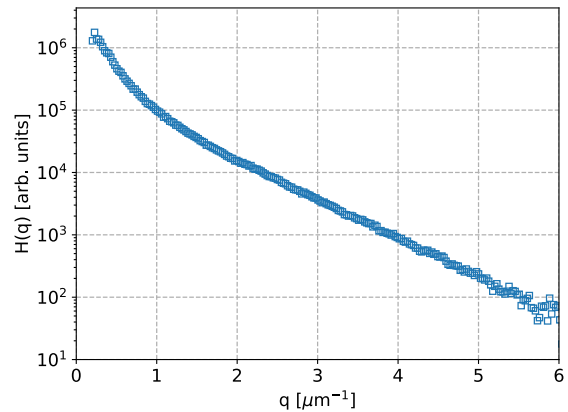
The form factor



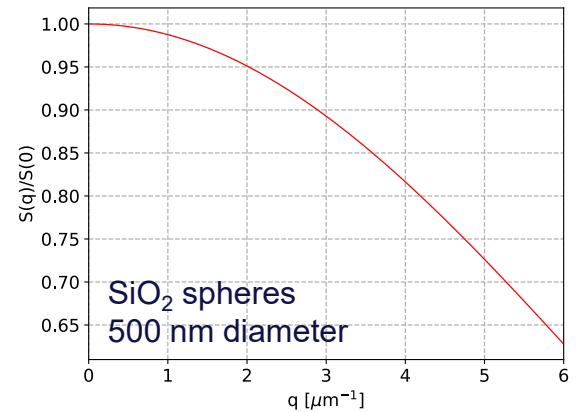
SOURCE + GEOMETRY



DETECTOR RESOLUTION



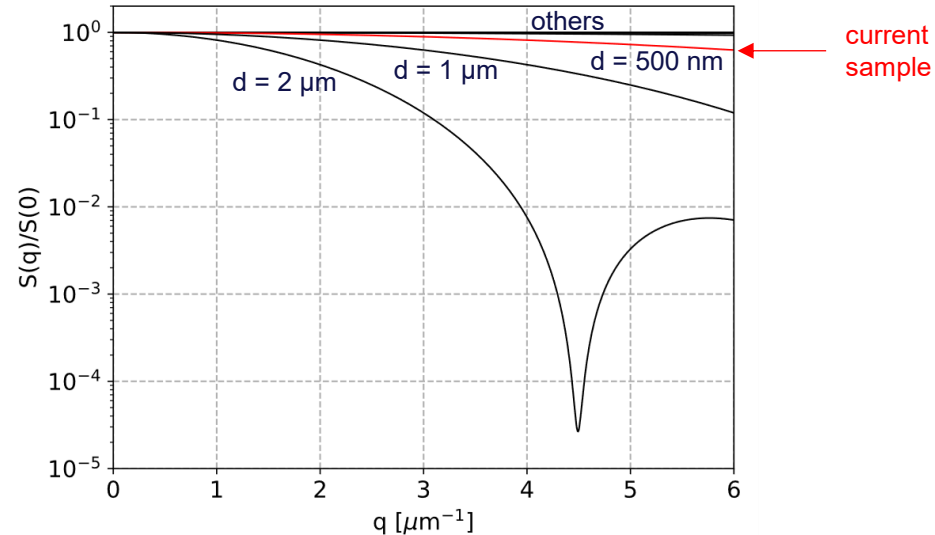
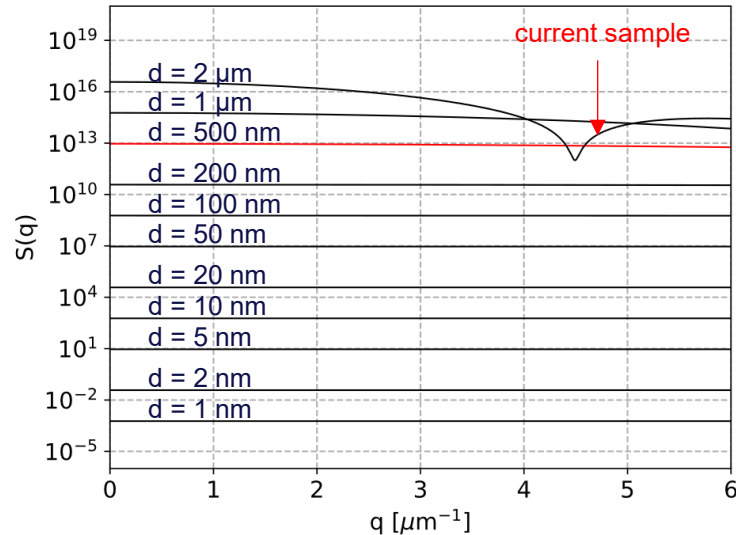
TARGET RESPONSE



Effects of particle size

SiO₂ spheres in water

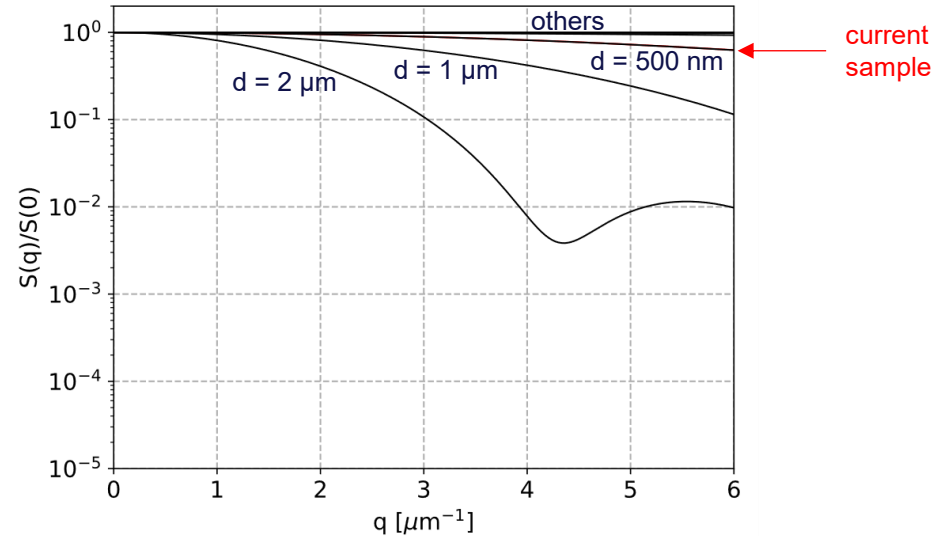
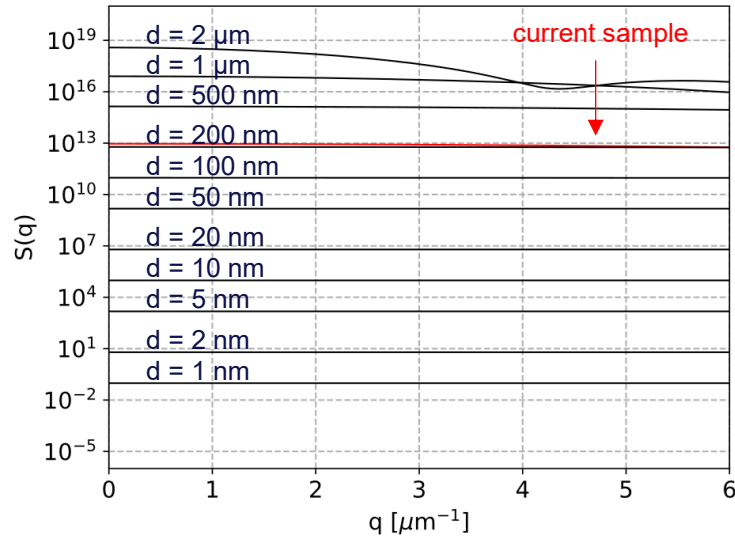
Complex refractive index $n = 1 - \delta + i\beta$ with $\delta = 2.9 \cdot 10^{-6}$ and $\beta = 1.7 \cdot 10^{-8}$



Effects of particle material

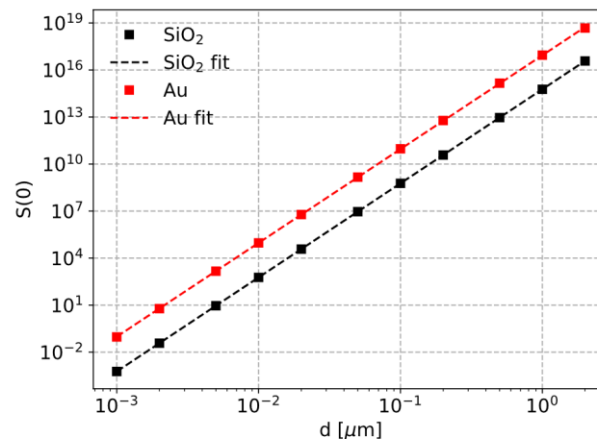
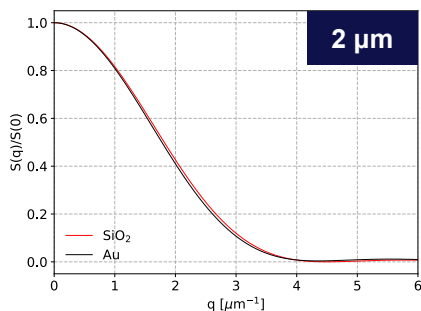
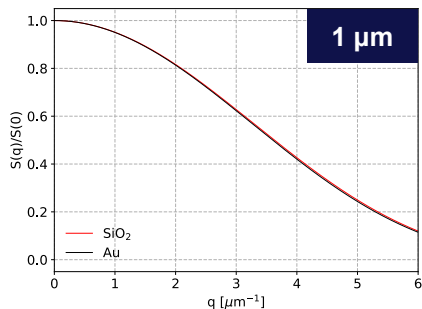
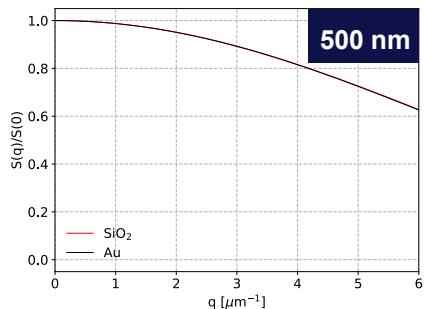
Au spheres in water

Complex refractive index $n = 1 - \delta + i\beta$ with $\delta = 1.8 \cdot 10^{-5}$ and $\beta = 2.8 \cdot 10^{-6}$



Master curves and scaling laws

The normalized form factors are described by **master curves** of the particle size. The normalization factors follow **power laws** of the particle diameter.



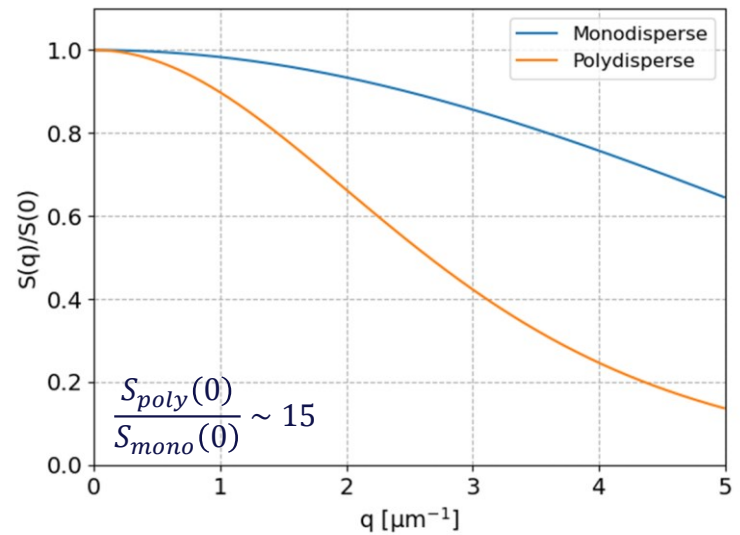
$$S(0) = c \cdot d^\alpha$$

$\alpha = 6$
c depends on material
and wavelength

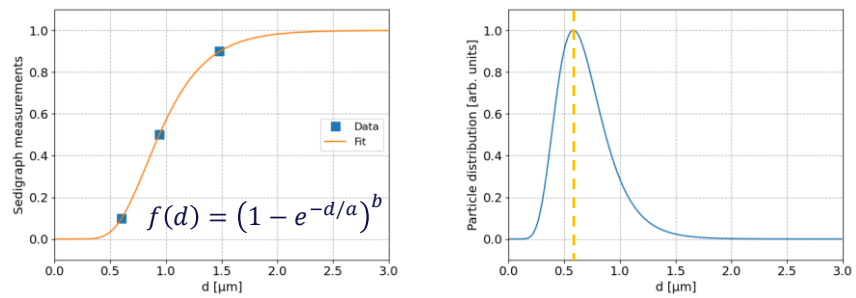
Effects of polydispersity

In a polydispersed sample, larger spheres give stronger contributions, often resulting in a more intense yet narrower form factor.

$$S_{poly}(\vec{q}) = \frac{\int n(r)S_r(\vec{q}) dr}{\int n(r)dr}$$

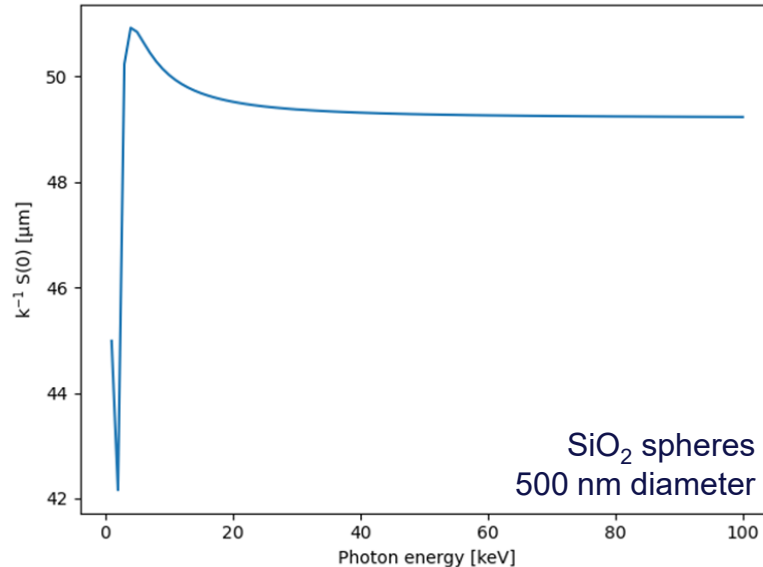


Size distribution $n(r)$ obtained from sedigraph data:



Varying the photon energy

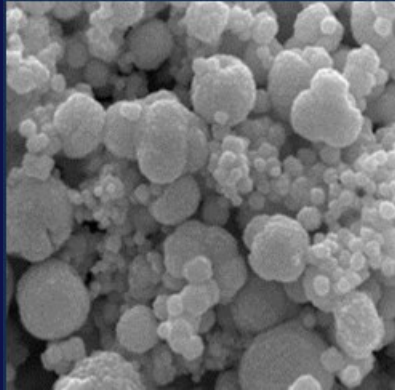
The form factor of spherical nanoparticles exhibit **'achromaticity'** upon rescaling $|S(0)|$ by the radiation wavenumber $k=2\pi/\lambda$.



The plateau depends on the size and material of the nanospheres

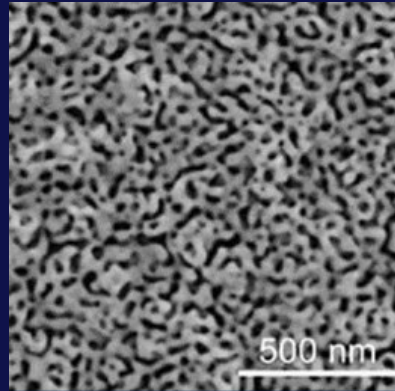
Nanostructured targets under investigation

Nanoclusters



Produced & ready

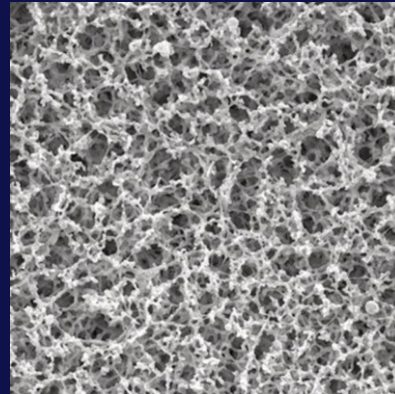
Nanoporous gold



Courtesy of S. Mazzoni

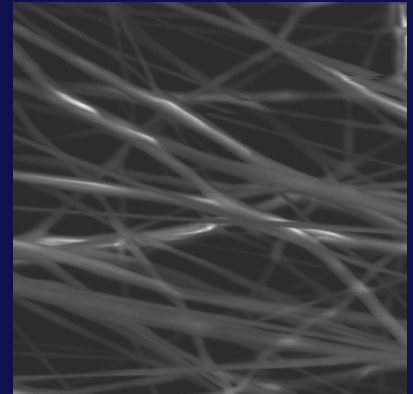
Purchased & ready

Solid membranes



Purchased & ready

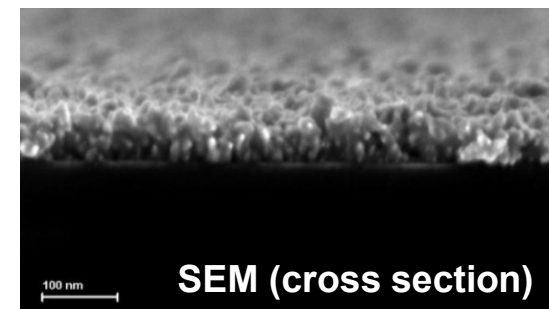
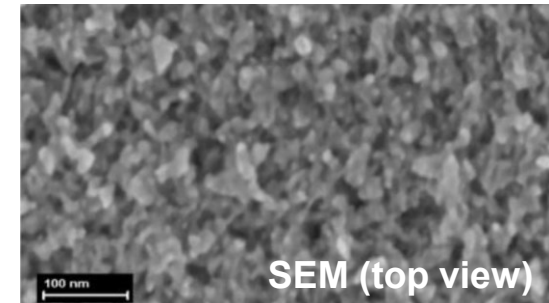
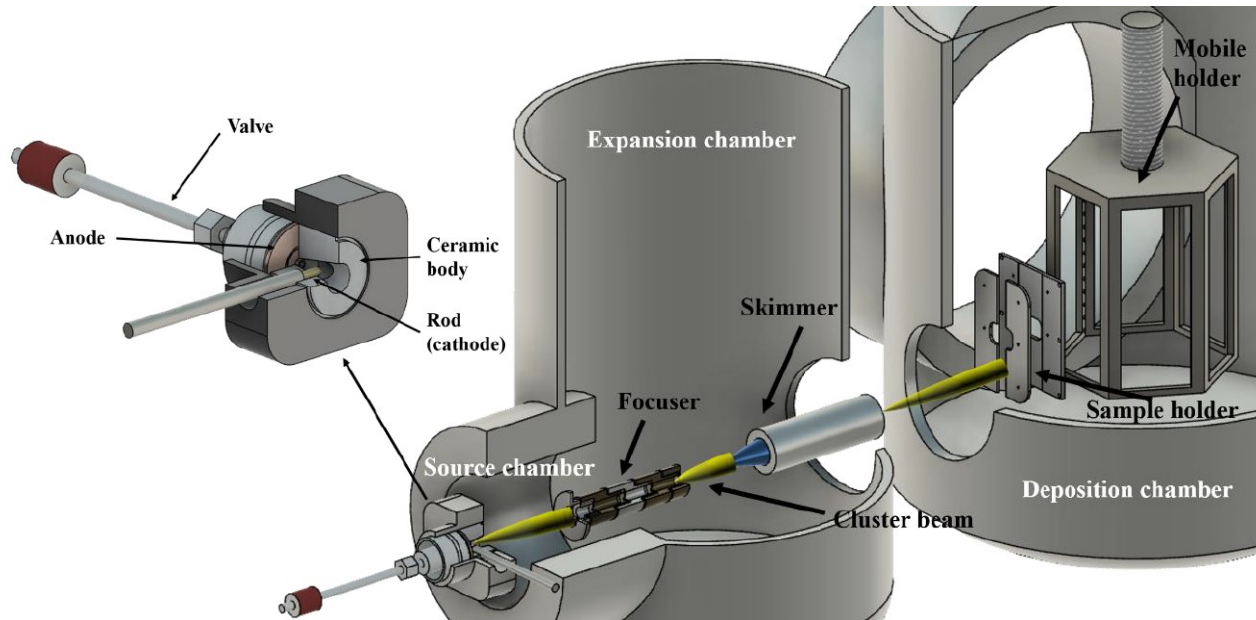
Nanowires



Purchased,
under investigation

Production of nanocluster-based targets

Supersonic Cluster Beam Deposition (SCBD): clusters produced in the source chamber are aerodynamically focused and deposited on the substrate.



Nanocluster-based targets

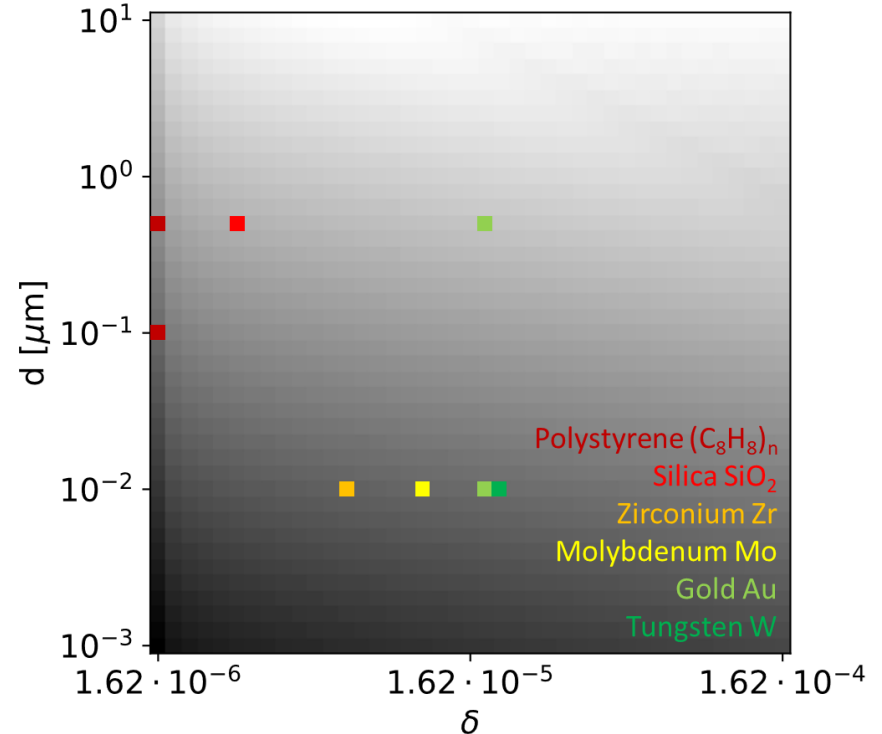
4 different materials, each in **two different thicknesses**:

- Au, 87 nm and 196 nm
- Mo, 89 nm and 300 nm
- W, 87 nm and 173 nm
- Zr, 89 nm and 205 nm

For each material, **5 different supports**:

- paper 60 μm
- paper 100 μm
- PET 30 μm
- PET 110 μm
- glass 160 μm

S(0): survey of the n-d domain



2025-01-08 $\text{WO}_x(\text{Ar})$ $\mu_b = 0.178$
 $T_h = 173 \text{ nm}$

2025-01-07 $\text{WO}_x(\text{Ar})$ $\mu_b = 0.0908$
 $T_h = 87 \text{ nm}$

2024-11-28-E2 $\text{MoO}_x(\text{Ar})$ $\mu_b = 0.3201$
 $T_h = 300 \text{ nm}$

2025-01-02 $\text{MoO}_x(\text{Ar})$ $\mu_b = 0.1013$
 $T_h = 89 \text{ nm}$

2024-11-21 $\text{Au}(\text{Ar})$ $\mu_b = 0.742$
 $T_h = 89 \text{ nm}$

2024-11-25 $\text{Au}(\text{Ar})$ $\mu_b = 1.526$
 $T_h = 196 \text{ nm}$

2024-11-28-E1 $\text{ZrO}_x(\text{Ar})$ $\mu_b = 0.185$
 $T_h = 204 \text{ nm}$

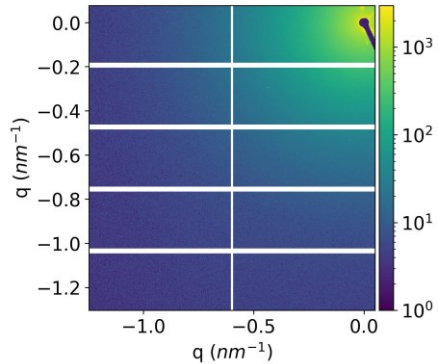
2024-11-27 $\text{ZrO}_x(\text{Ar})$ $\mu_b = 0.9731$
 $T_h = 87 \text{ nm}$

SAXS experiments at NCD-SWEET (ALBA)

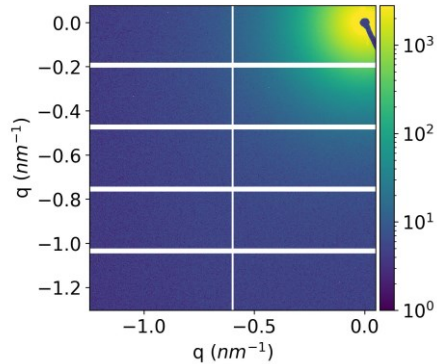
- 10 keV photon energy
- Pilatus3 S 1 M, 1043 x 921 (VxH) pixels, pixel size 172 x 172 μm^2 at 6.583 m from targets, different exposure times 1, 2, 5, and 10 s
- Nanostructured targets on a holed support
- Nanoparticles in a 2 mm capillary (10- μm -thick walls), blank with MilliQ water

Courtesy of E. Solano

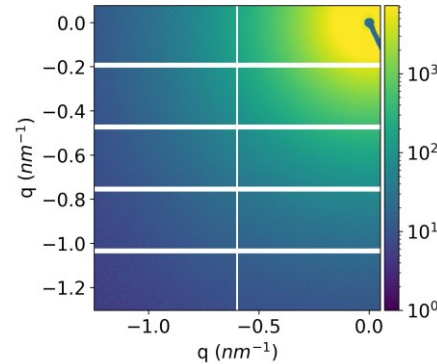
pilatus_ZrOx_glass_ZrOx_3895_0003.edf



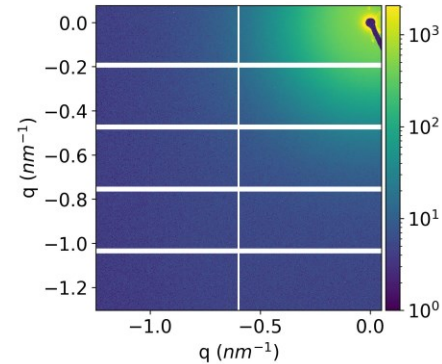
pilatus_MoOx_glass_MoOx_3901_0003.edf



pilatus_Au_glass_Au_3869_0003.edf



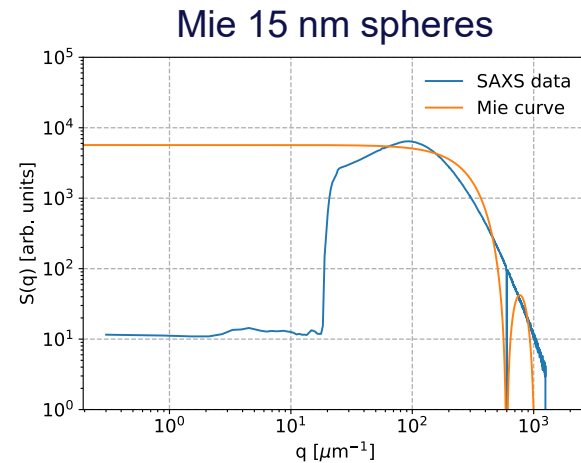
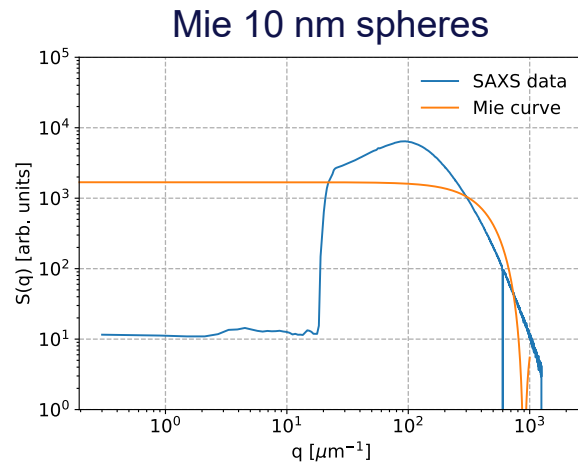
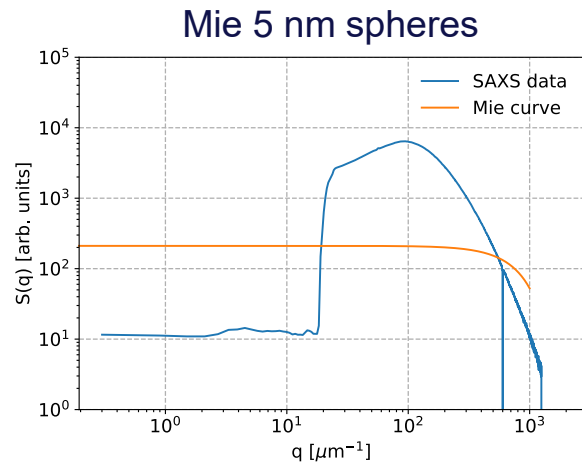
pilatus_W_glass_W_3880_0003.edf



SAXS: Au nanoclusters

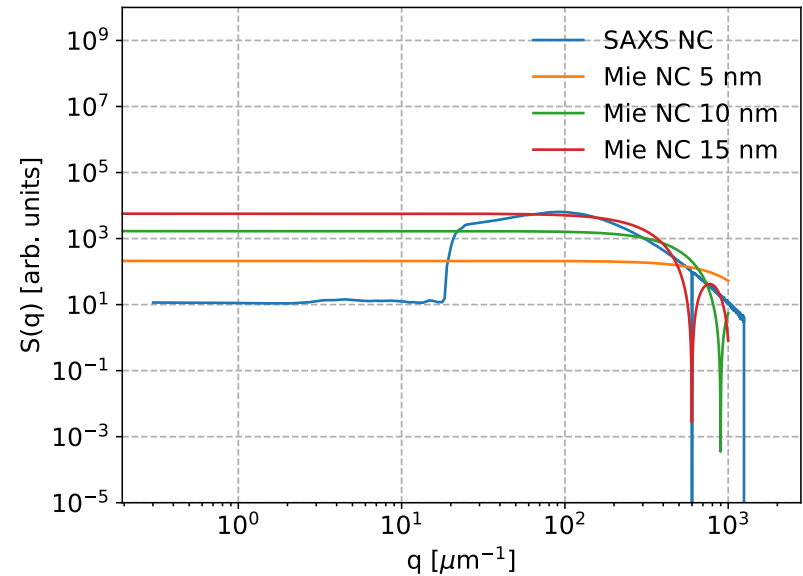
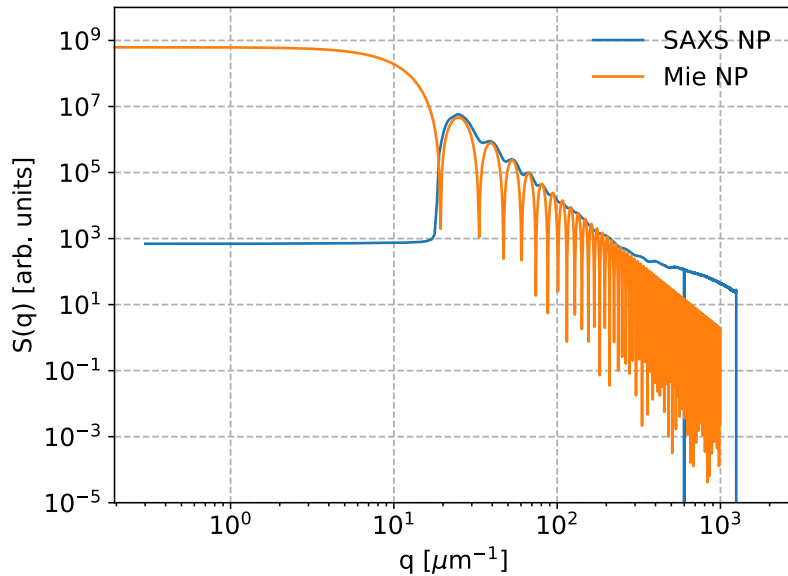
Data are compatible with Au nanoclusters with size between **10 nm** and **15 nm**.

Peak at $q = 100 \mu\text{m}^{-1}$ might be a signal of a **spinodal-like structure** due to **surface diffusion** during NC deposition \rightarrow still under investigation



SAXS: Au nanoclusters vs SiO₂ nanospheres

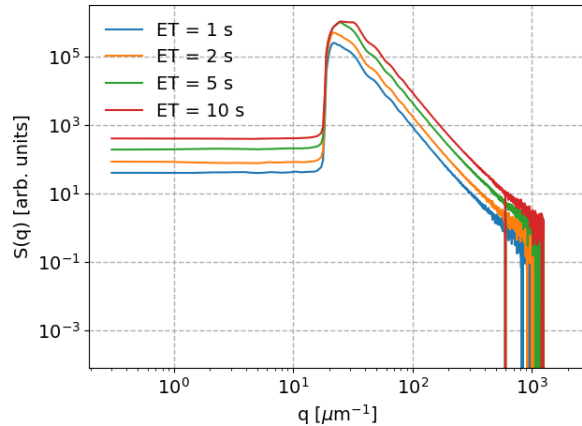
NCs should be **at least 10 times bigger** to match the signal level generated by 500 nm SiO₂ NPs, since $|S(0)| \sim d^6$.



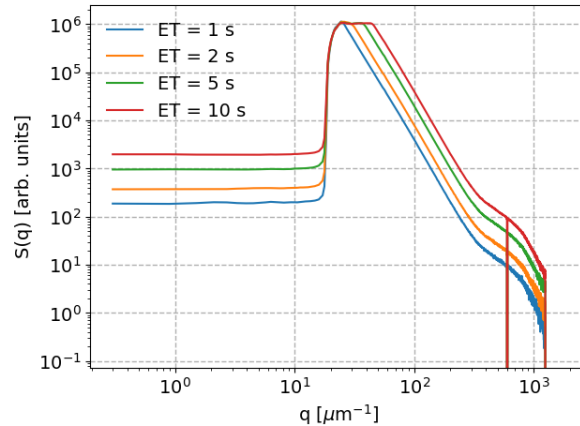
SAXS: membranes and nanoporous gold

Membranes and nanoporous gold generate higher signal levels, in some cases even reaching saturation, thanks to the larger pore size → possible **good alternatives** to NPs.

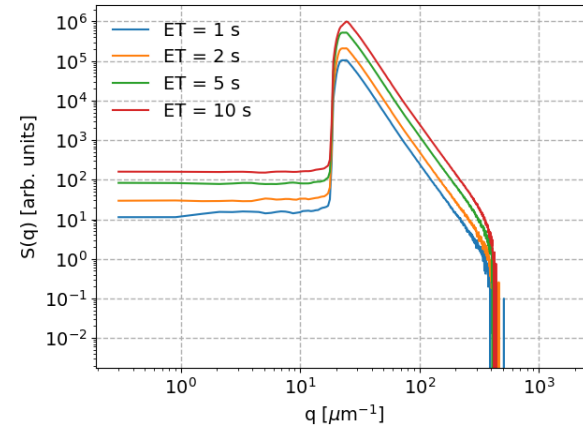
PC membrane, nominal pore size 200 nm



Millipore membrane HV, nominal pore size 450 nm



Nanoporous gold disk, producer: Heraeus



Ongoing and future works

- Production of nanostructured targets with **alternative techniques**
- Numerical studies on **nano-cylinders**
- Experimental investigations on **silver nanowires (NWs)**
- Production of **NW-based targets**
- Test targets at **speckle beamline FE21 @ ALBA** (currently under completion, first experiments ~ **summer 2025**)



“It might be easy or difficult, but come on – surely there must be a way to do it!”



Thank you
for your attention.