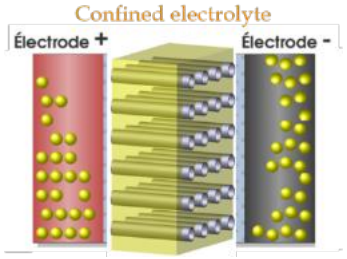
Liquides ioniques sous confinement 1D : vers des batteries à la puissance décuplée?



Q. Berrod, F. Ferdeghini, R. de Oliveira-Silva,
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Laboratoire Léon Brillouin, CEA/DRF/IRAMIS-CNRS, CEA Saclay, Gif-sur-Yvette, France

*: CEA/DRT/LITEN, Département des naomatérieux, Grenoble, France

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Neutron ToF V. Garcia Sakai (ISIS), J. Ollivier (ILL), S. Rols (ILL)
D. Yu, (Ansto), R. Mole (Ansto)

WAXS D. Constantin (LPS, Orsay)

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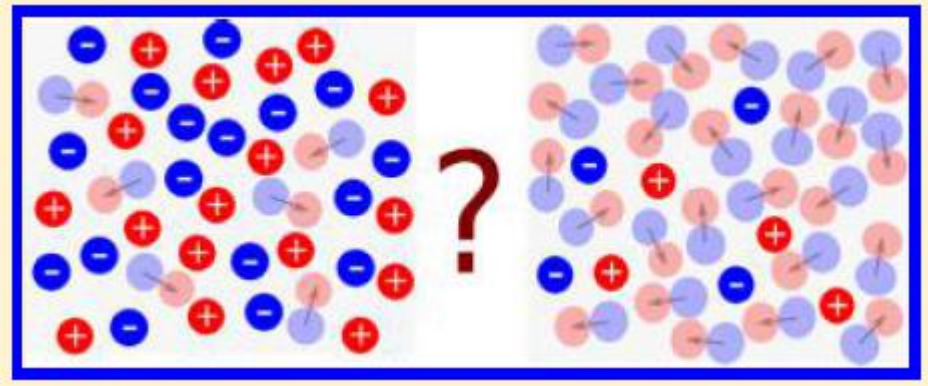
Ionic liquids in bulk and under nanometric confinement

Motivations: Basic Science + Technological Aspects

Ionic Liquids (ILs): salts in the liquid state at RT (pure liquids *i.e.* no co-solvent)



Lee *et al.*,
J. Phys. Chem. Lett., 6, 159 (2015)

Fluid of « free » ions

High [Charges]
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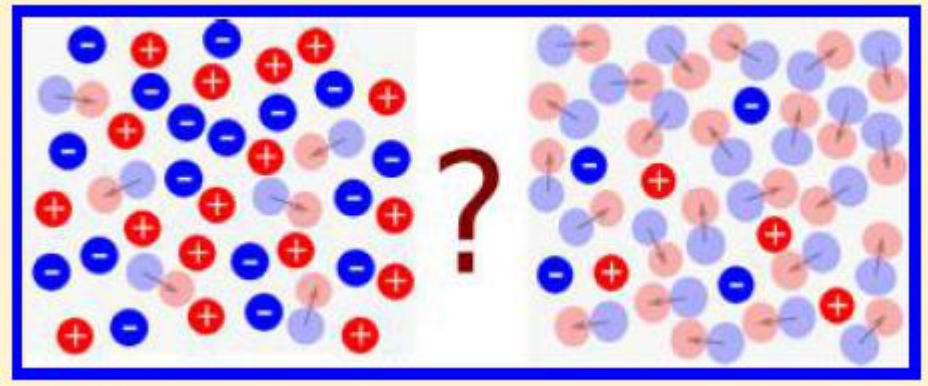

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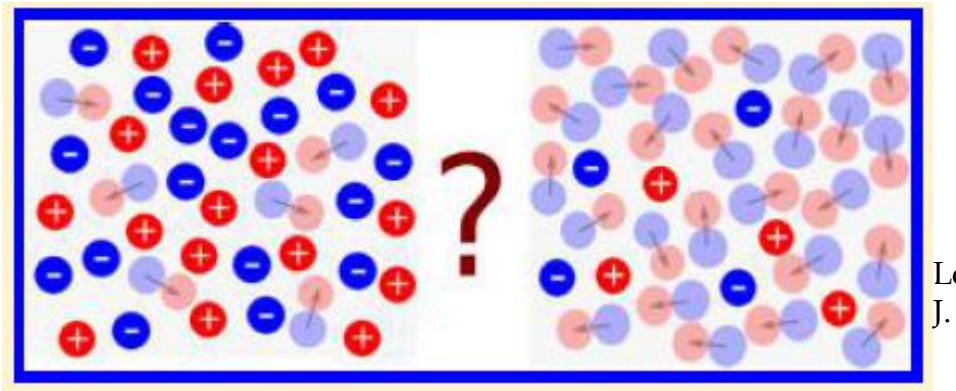

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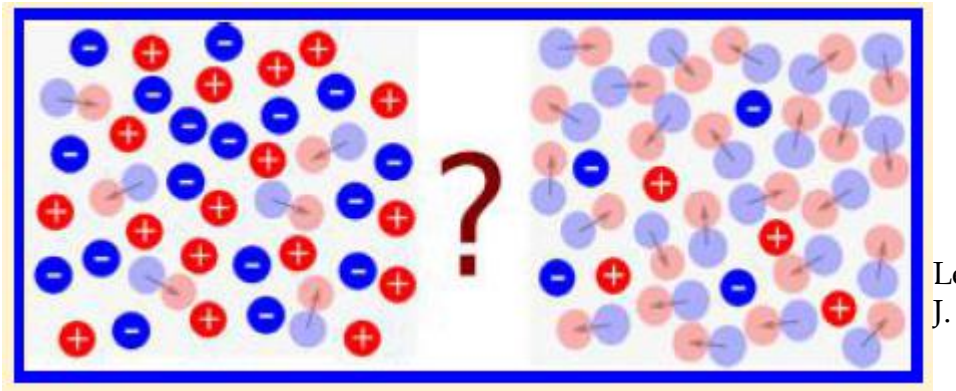

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$$\Lambda \propto \sum_i |z_i| e \mu_i$$

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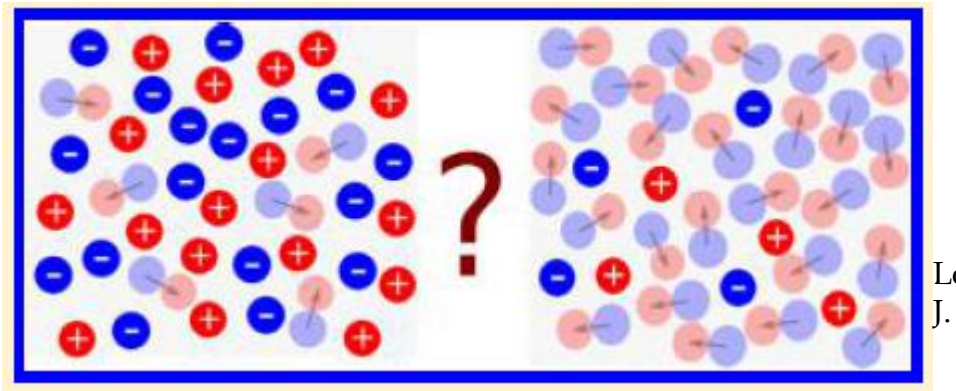

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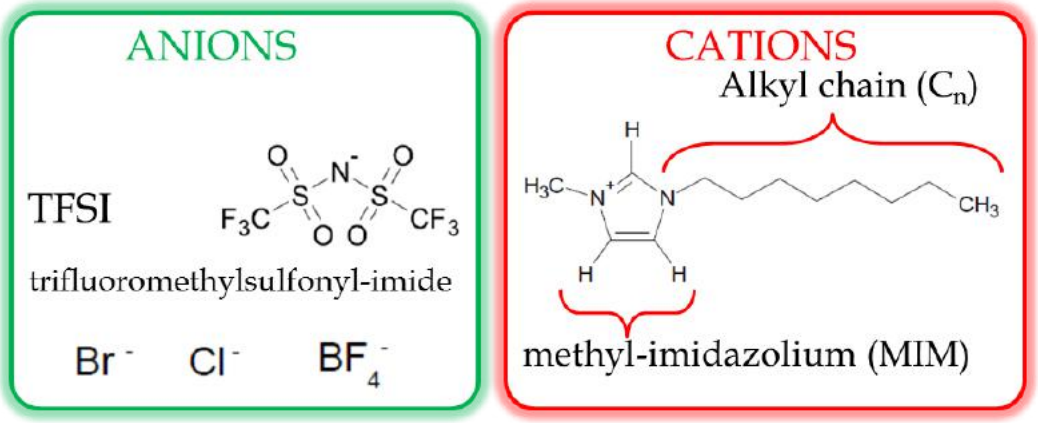

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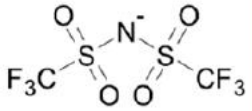
ANIONS

TFSI

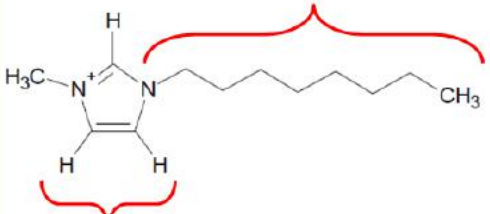


trifluoromethylsulfonyl-imide

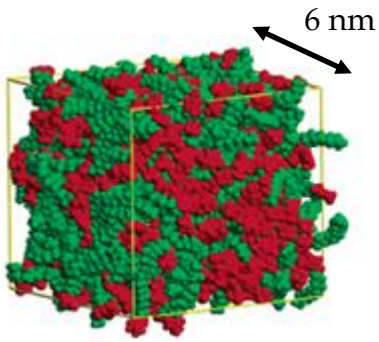
Br^- Cl^- BF_4^-

CATIONS

Alkyl chain (C_n)



methyl-imidazolium (MIM)



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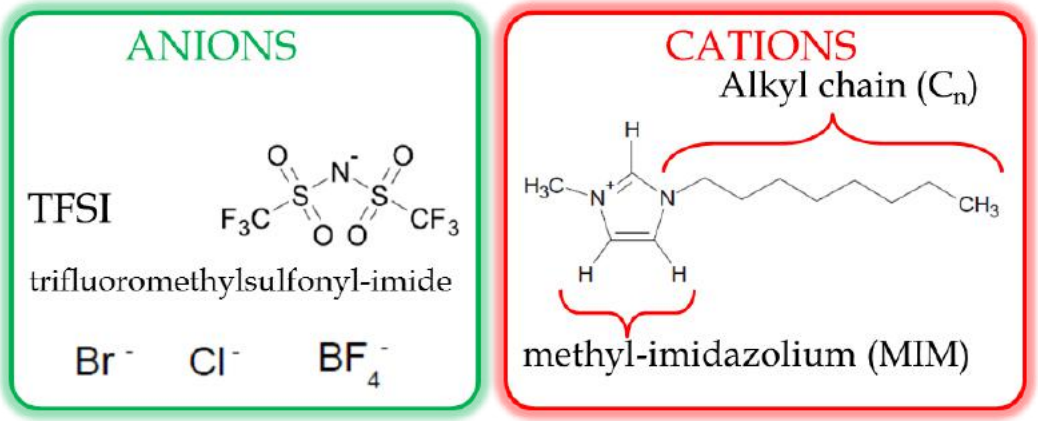
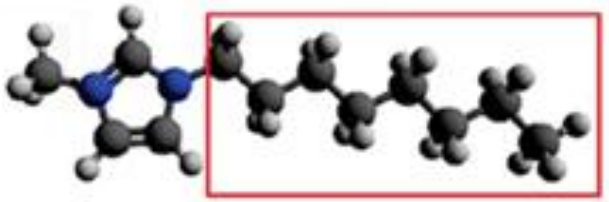
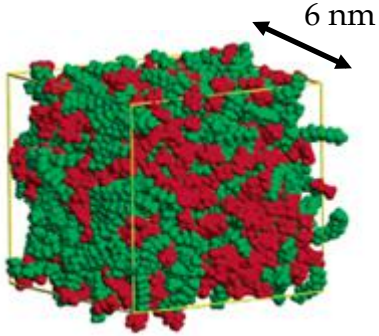


C_8=Octyl

OMIM





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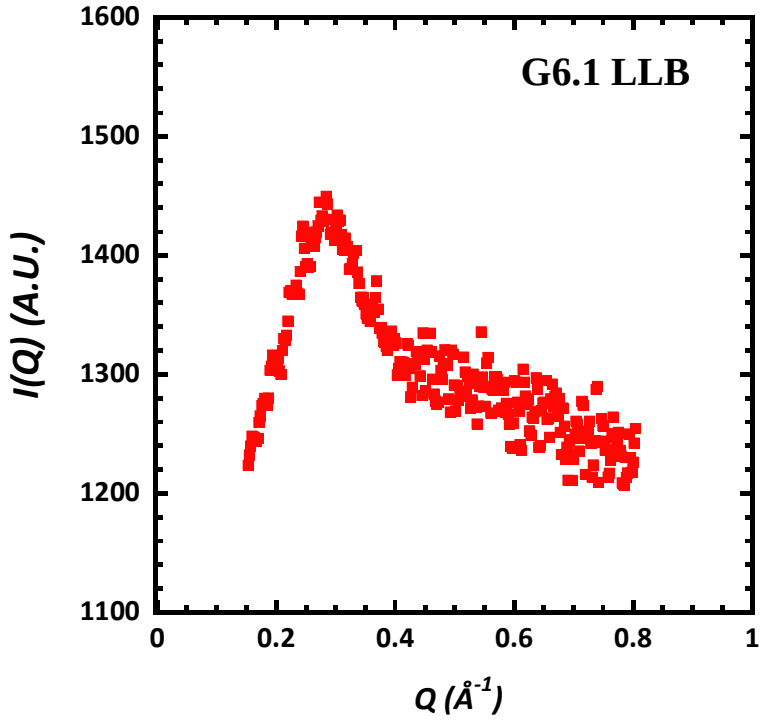
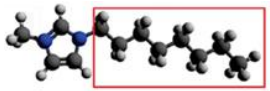


Self-organisation *vs* dynamics:
Hierarchical model

Time of Flight → Side-chains dynamics + Diffusion within aggregates

Dynamical window:
1-50 ps / 1-20 Å



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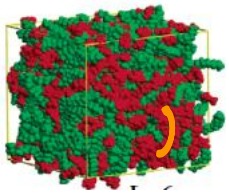

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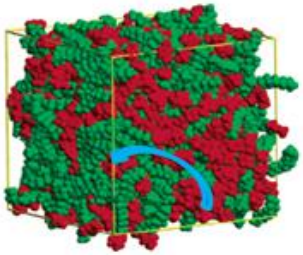

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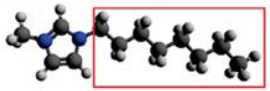

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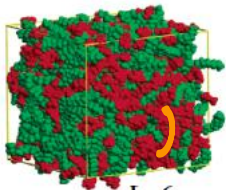

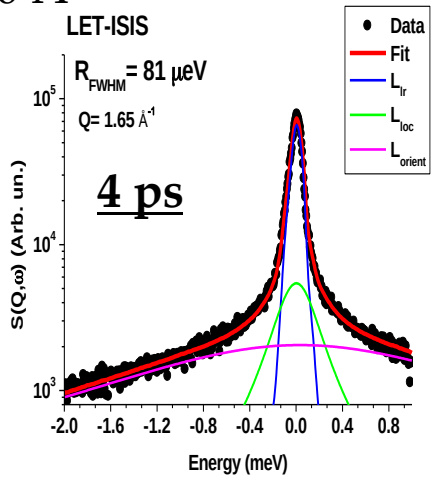

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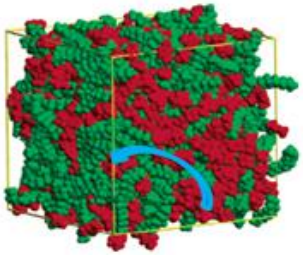

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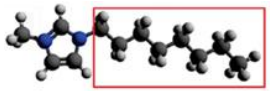

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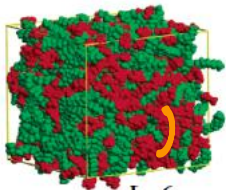

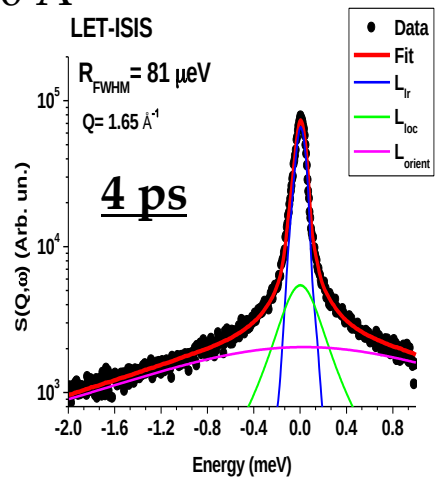

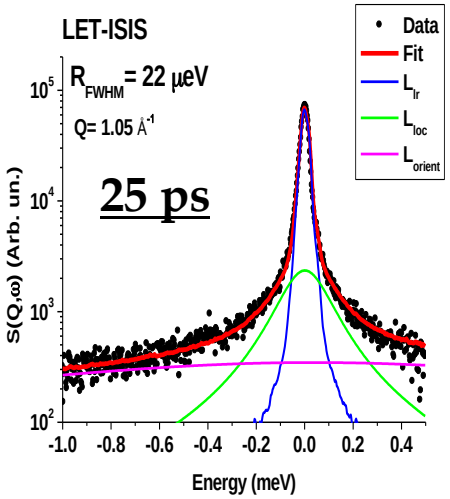

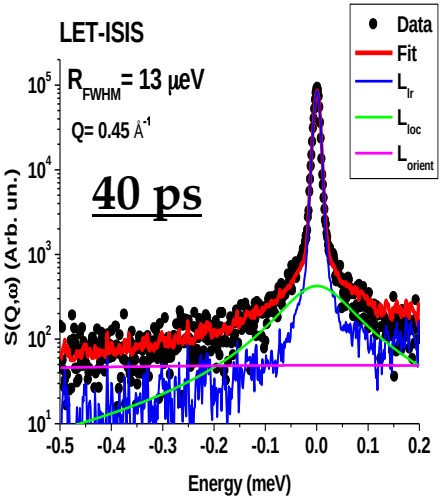

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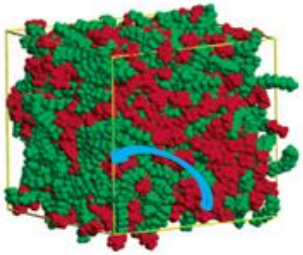

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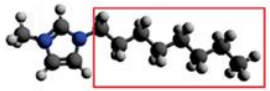

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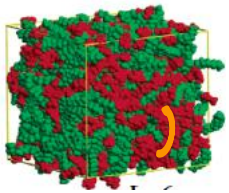

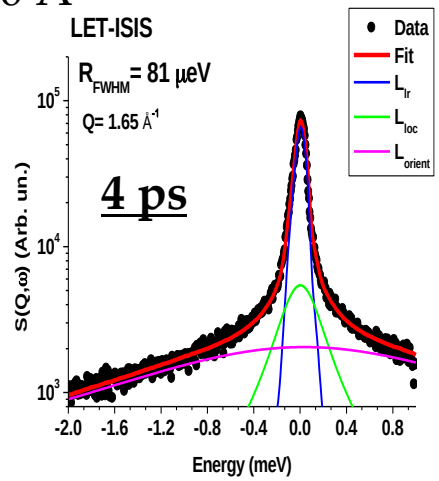

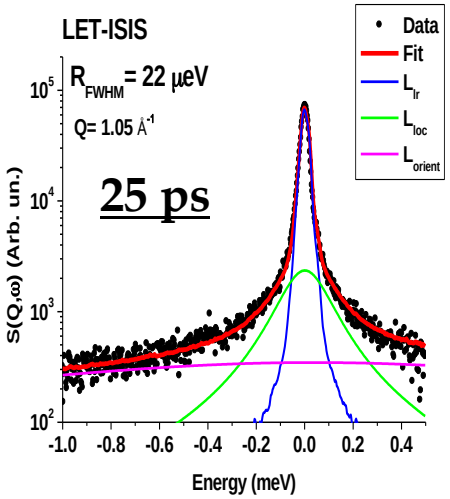

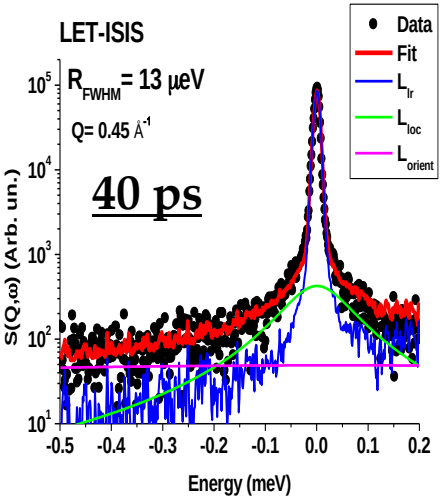

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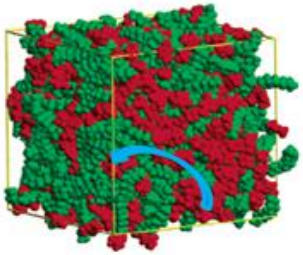

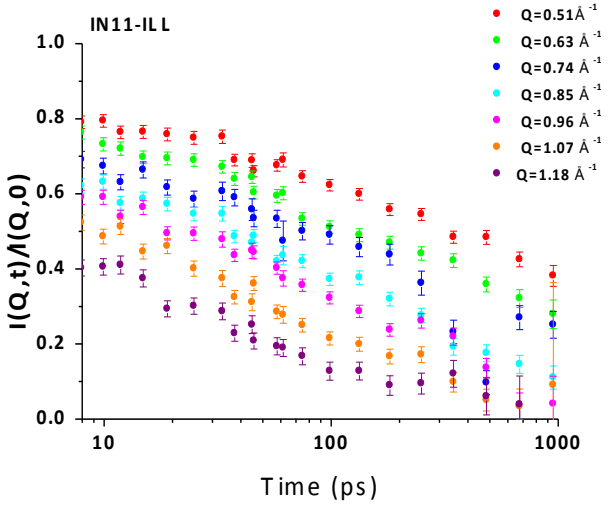

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Time and space multi-scale analysis of translational diffusion

Ferdeghini *et al.*, Nanoscale, 2017

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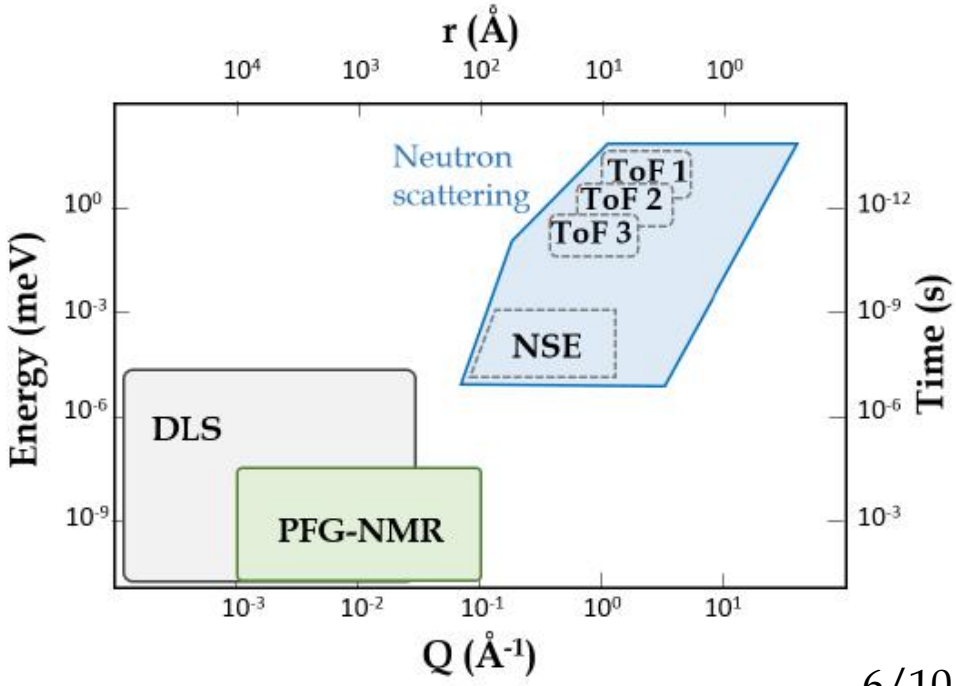

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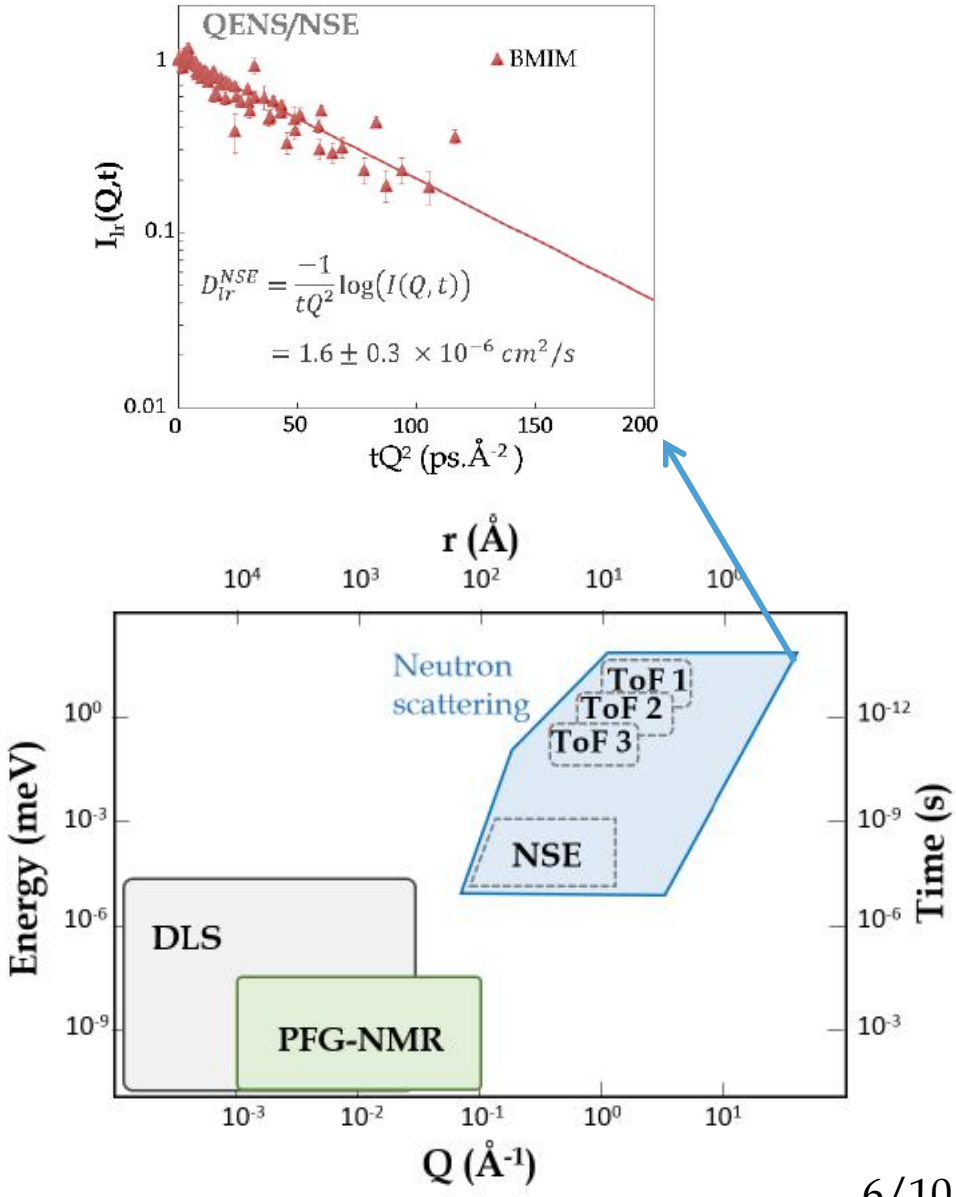

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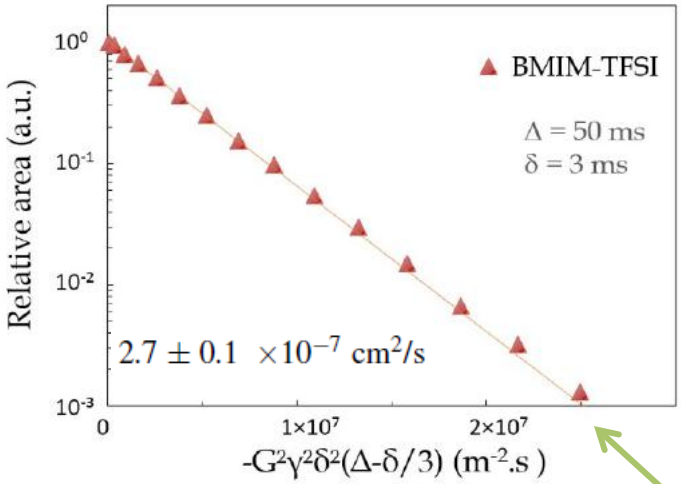

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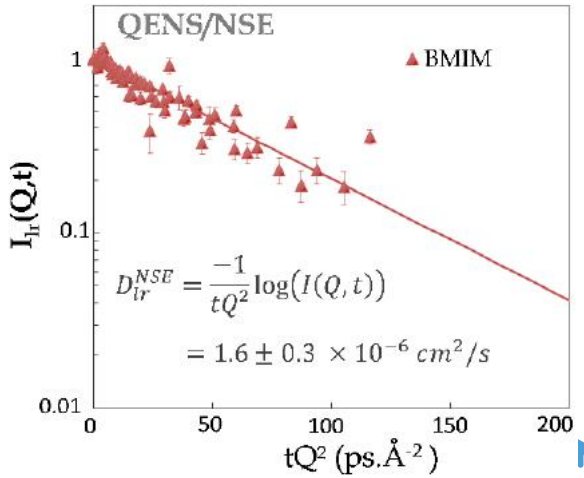

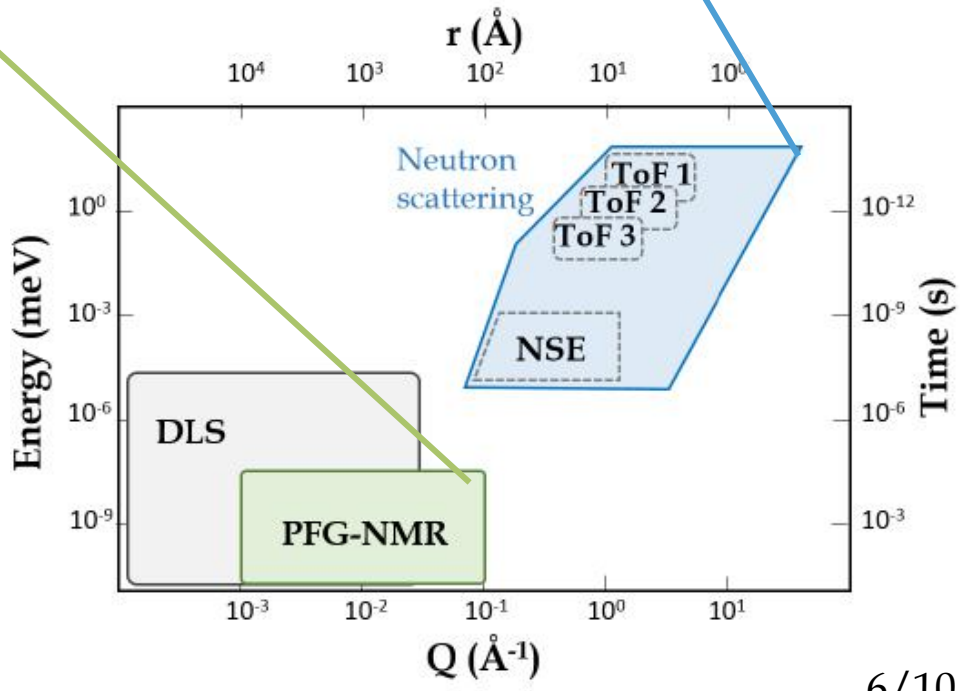

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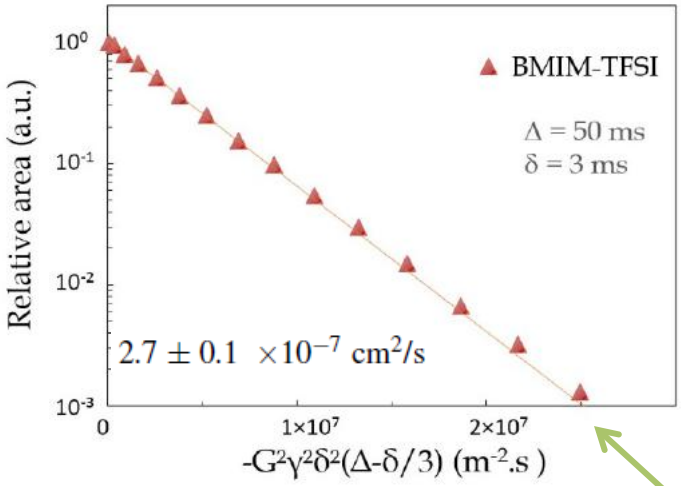

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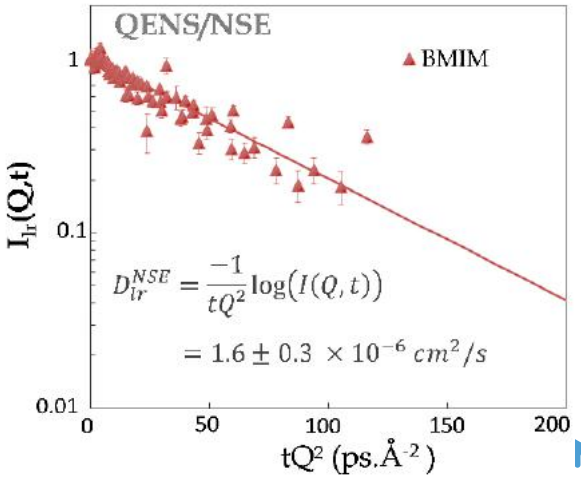
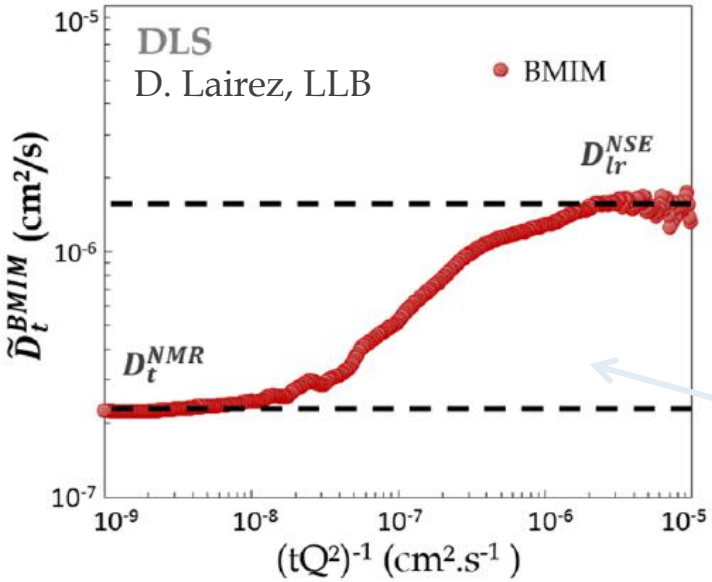
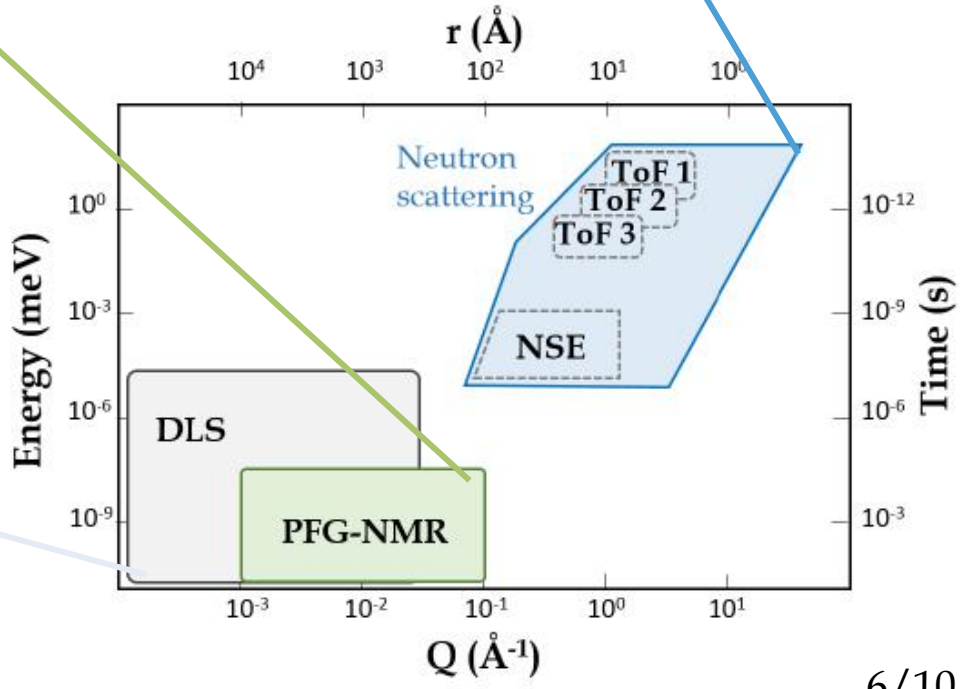


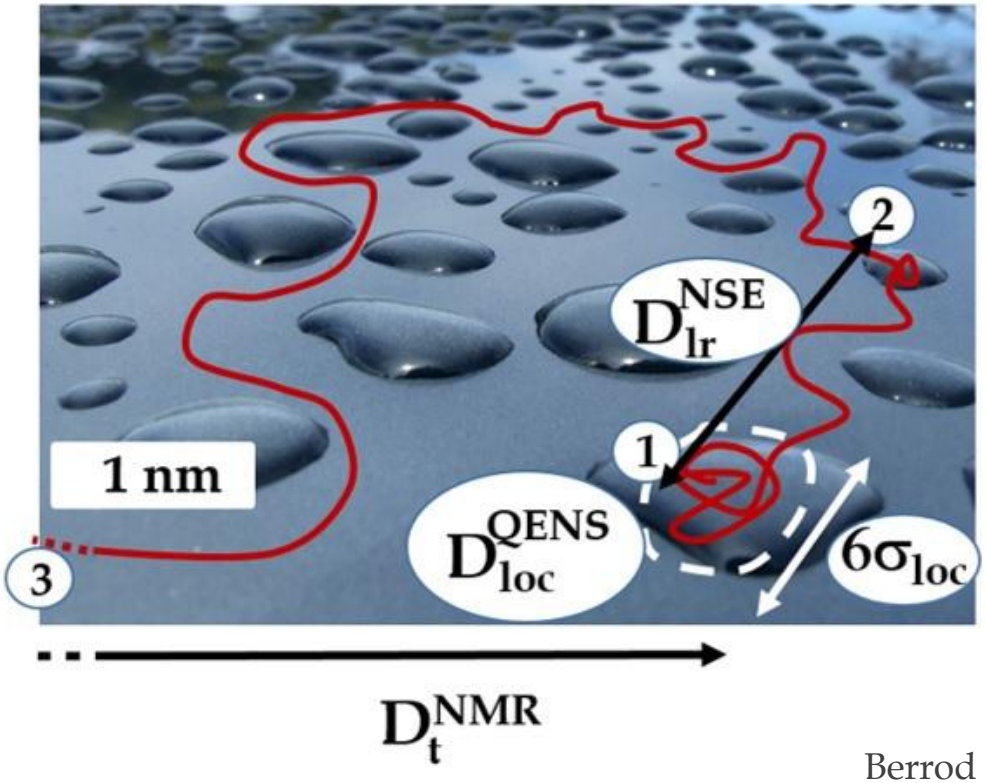
Nanoparticle diffusion probe followed by DLS





Contribution to the debate on the nature of the Ils:

Strong or weak electrolyte? both views are right… just a matter of scale of observation



Berrod *et al.*, Sci. Rep., 2017

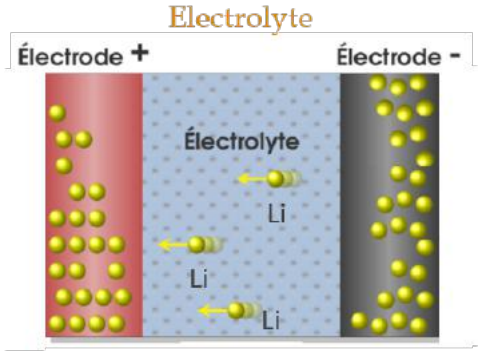
Neutron:

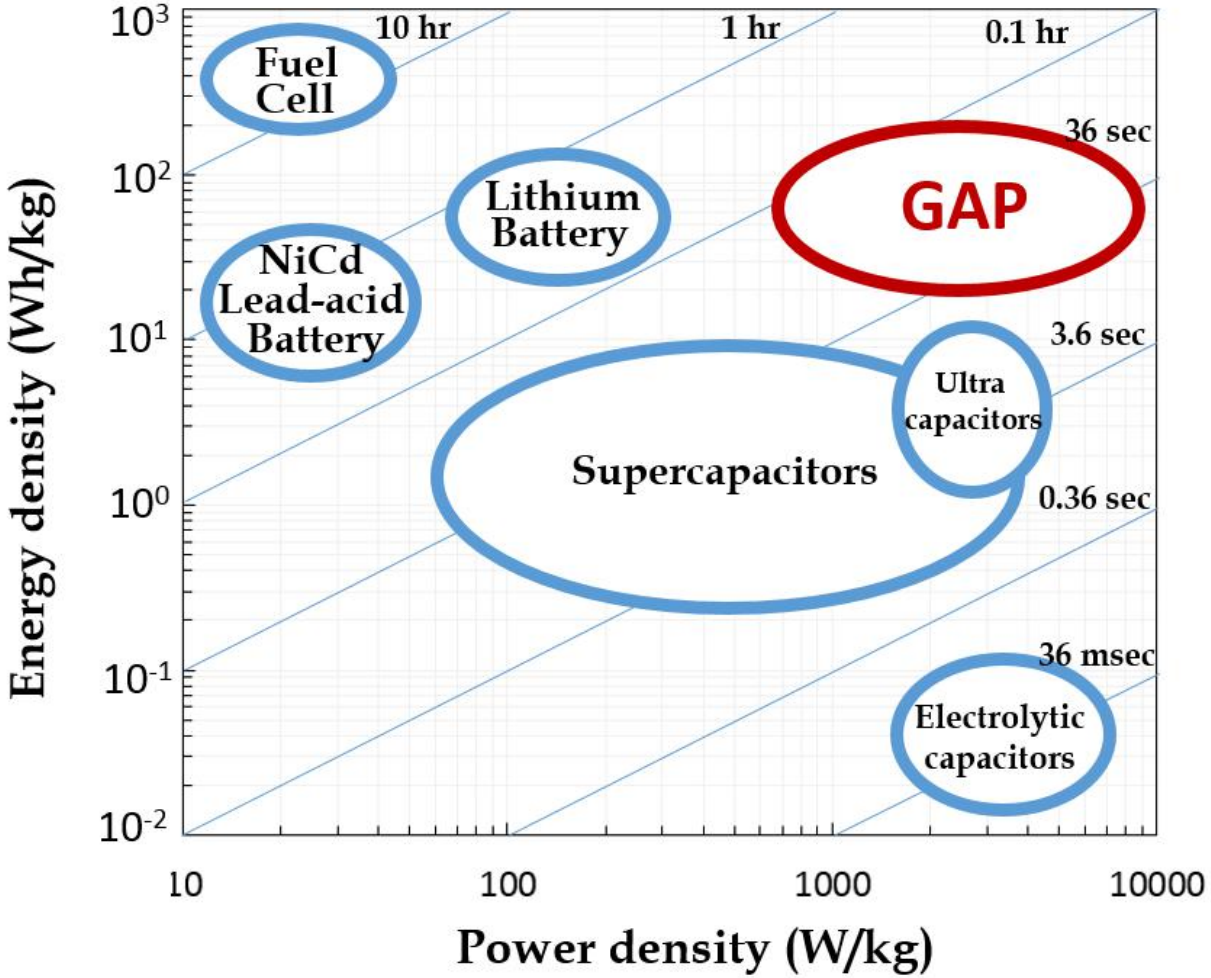
- ToF: 1 nm/ps diffusive processes inside an aggegate (1)
  NB: Since we measure Q and w, we can determine its size.
- NSE: 10 nm/10 ns: diffusive processes in between agreggates ((1) to (2))

PFG-NMR:

- µm/ms diffusive processes ((2) to (3)) also in between aggregate but rate limited by the presence of local (nm/ns) transient potential barriers due to the formation/destruction of the nanometric self-assembly structures.

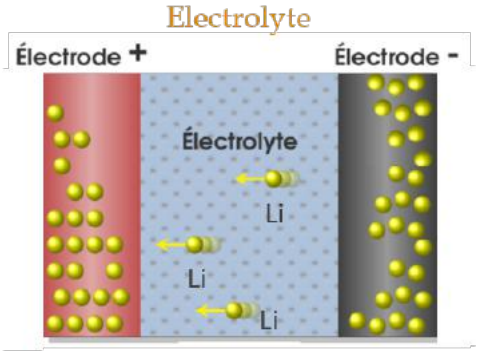
Technological aspects: ILs as batteries electrolytes

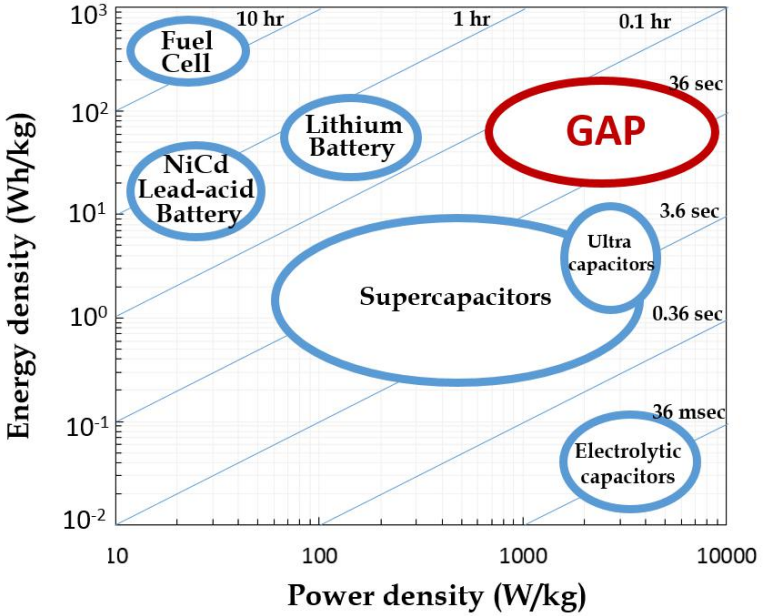




Technological aspects: ILs as batteries electrolytes

Ils: low volatily, excellent electrochemical stability, low flammability.





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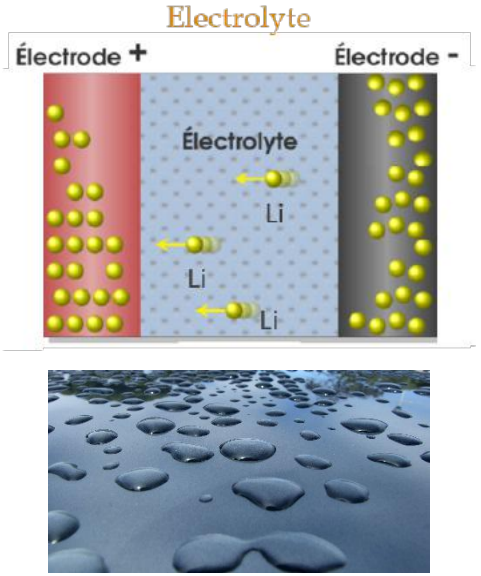
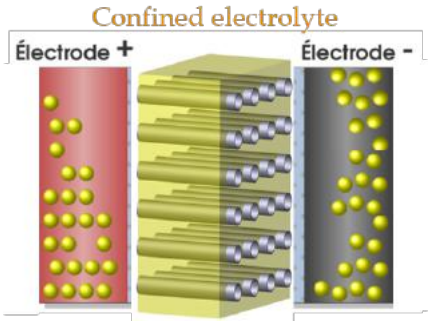
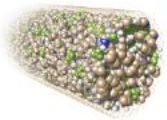
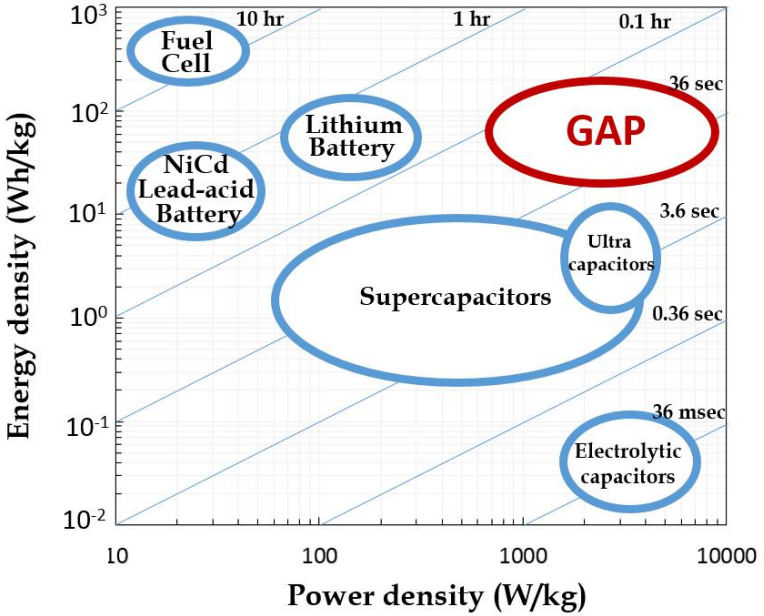






Confine the electrolyte within a macroscopically Oriented porous structure: CNT based composite membrane



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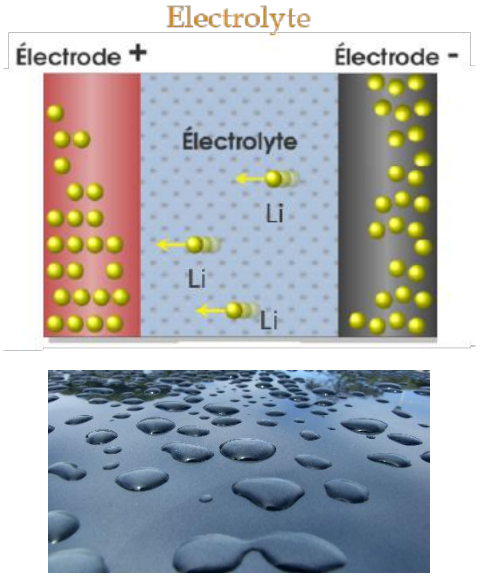

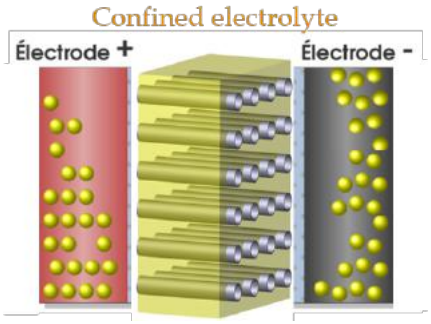

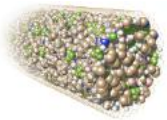

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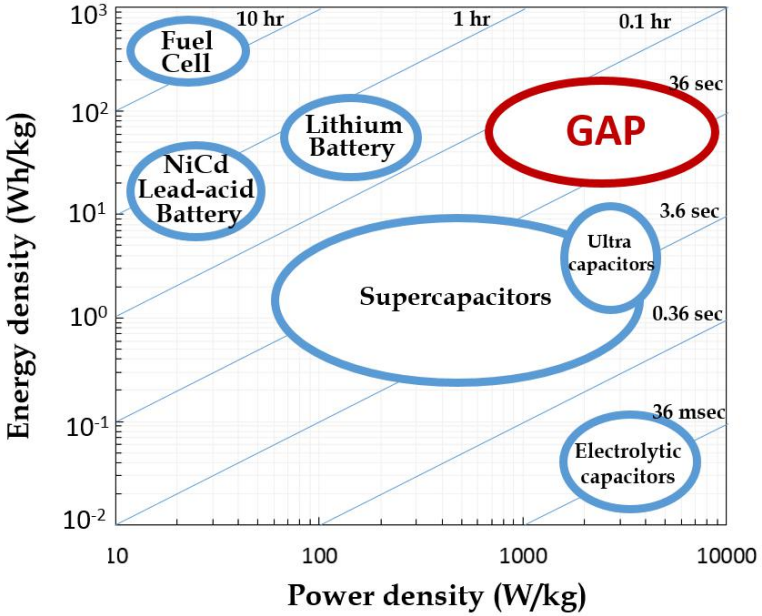
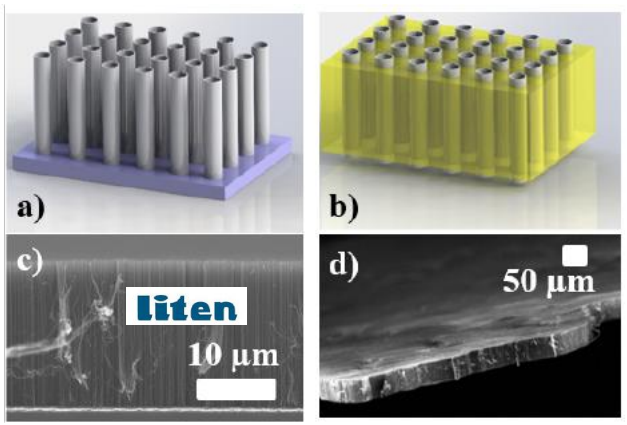
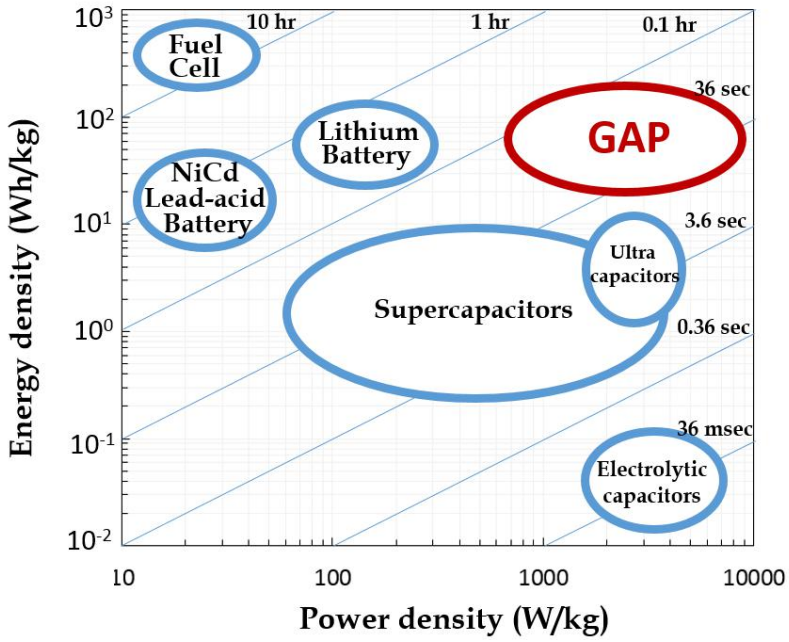


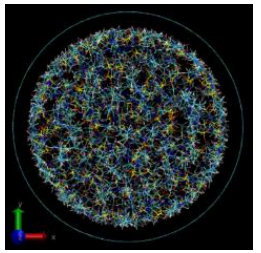
~ 3.10^{11} tips/cm²
~ 4 nm diameter
~ 100 µm thick



Berrod *et al.*, Nanoscale, 2016

Ils+ Li^+ confined in CNT membrane





P. Judeinstein, LLB
B. Coasne, LiPhy, Grenoble

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Neat IL (No lithium salt):

- **Self-diffusion coefficient**
- **Ionic condutivity**

Increased by a factor ~3

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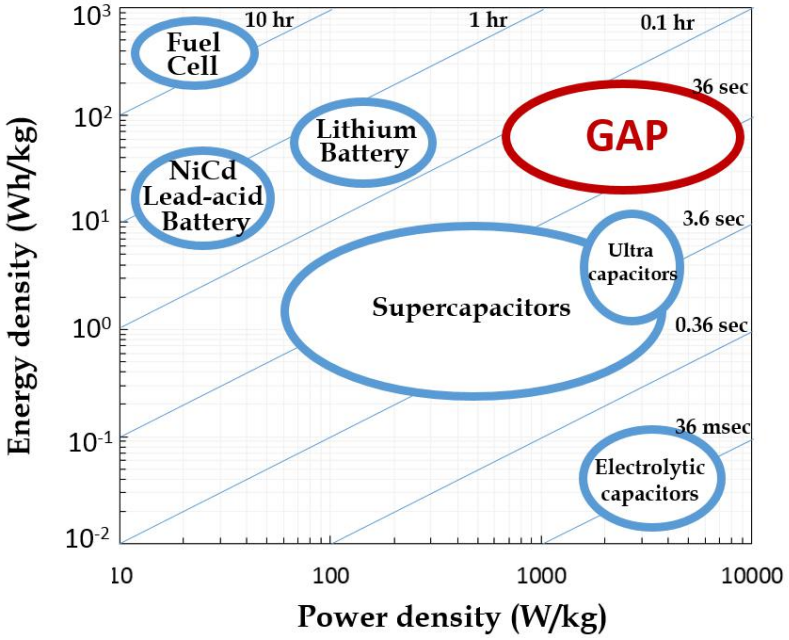

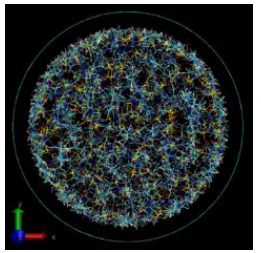

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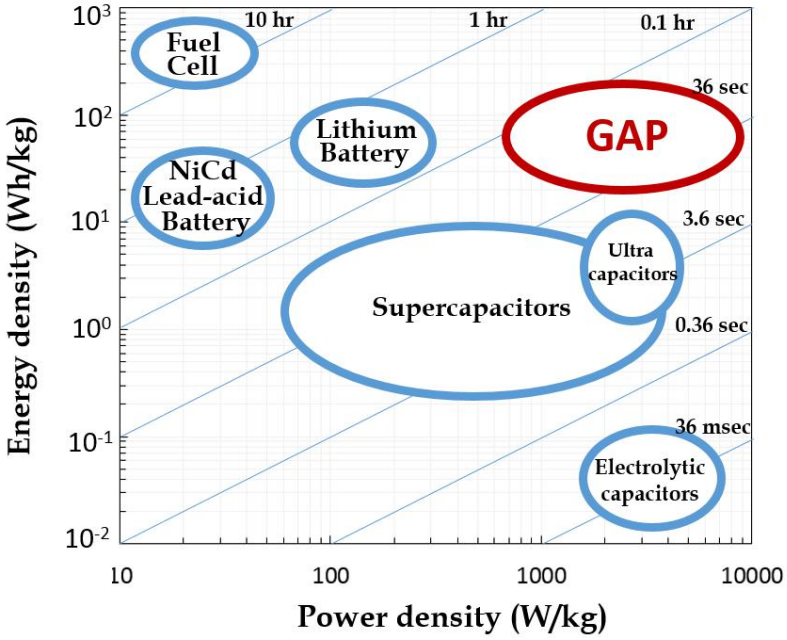

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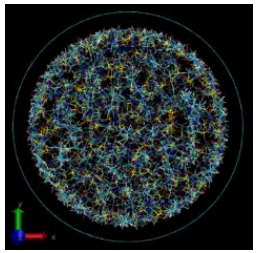

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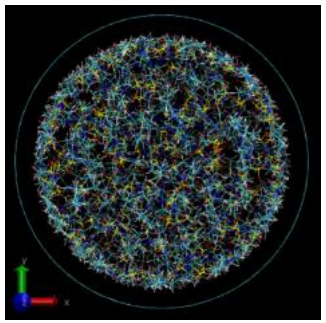
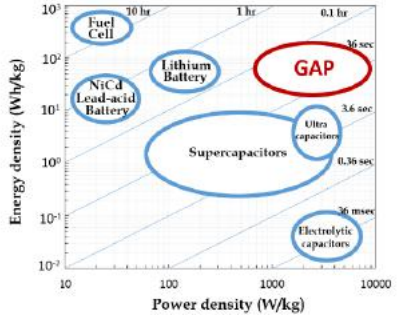
Conclusion / Perspectives

Physics of Ils in Bulk



IL in CNT confinement

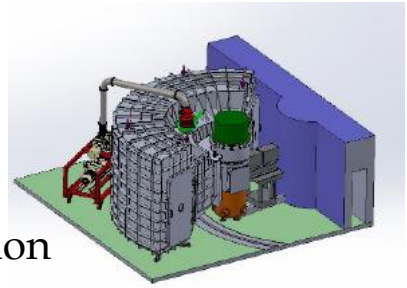


Boost the Power of Li Batteries

Scientific Case on Sharp:

Take advantage of the high conting rate to developp "Pump-Probe" experiments (Electric field, THz, Laser…)

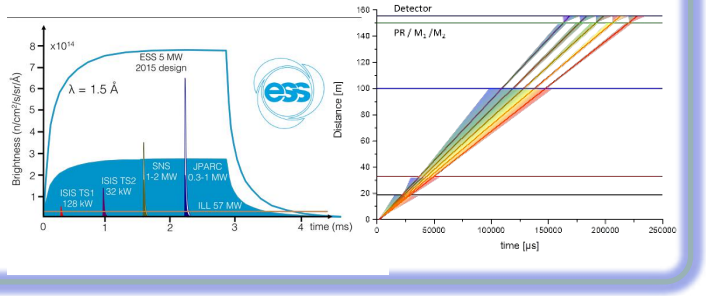
Ex: Relaxation of Li+ coordination sphere upon electrolyte/excitation



Extend the Sharp expertise gain to C-SPEC: ESS Cold ToF spectrometer (LLB/TUM Munich)

- Breathtaking counting rate: Pump Probe exp.
- ESS: Low Frequency (14 Hz)
  Long pulse (3 ms)

Routine Multiple (7-10) Wavelengths Acquisition.



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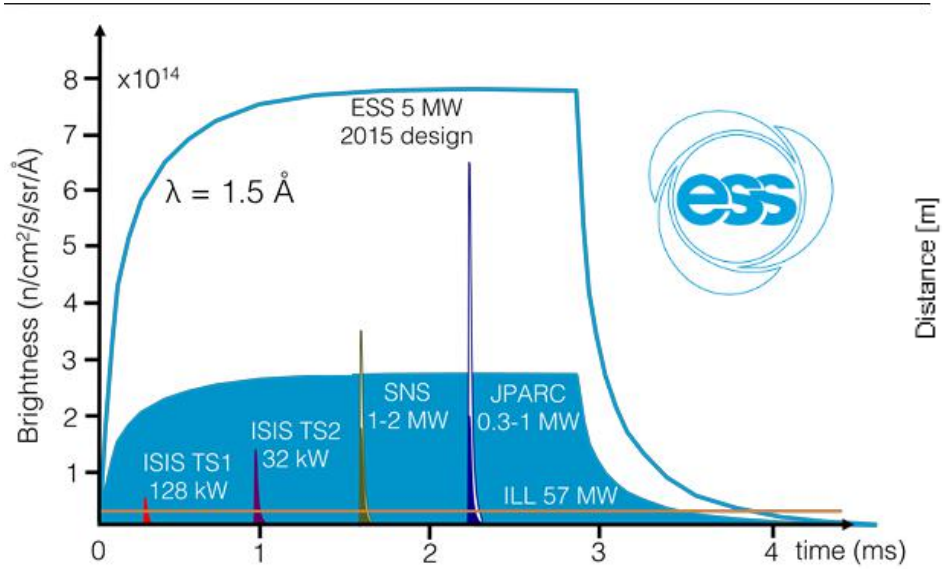

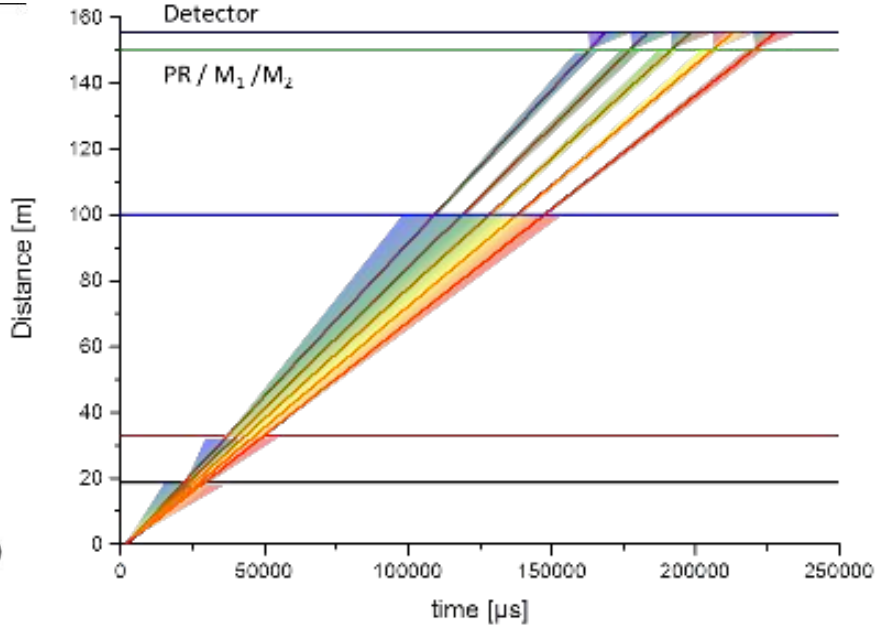

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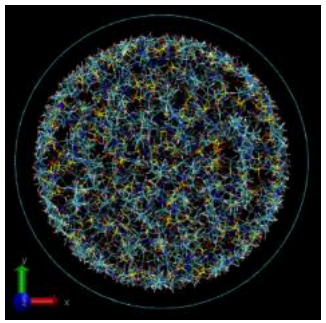

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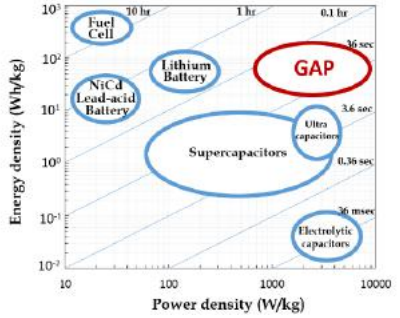

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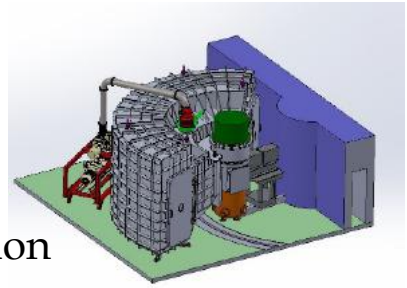

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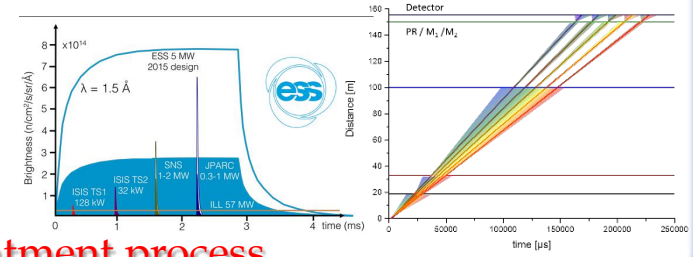
Important to get prepared to a challenging data treatment process.