Addendum to P-521 to the ISOLDE and Neutron Time-of-Flight Committee

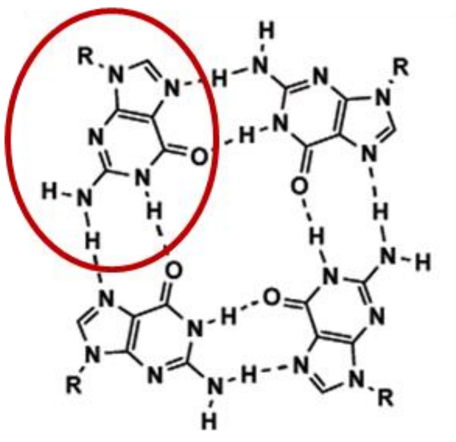
Interaction of Na ions with DNA G-quadruplex structures studied directly with Na beta-NMR spectroscopy

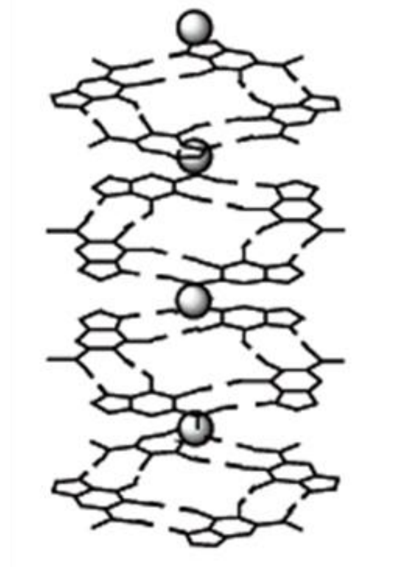
M. Kowalska1, V. Araujo Escalona2, M. Baranowski3, J. Croese1,4, L. Cerato4, M. Bissell4, W. Gins2, F. Gustafsson2, R. Harding1,7, L. Hemmingsen8, H. Heylen1, F. Hofmann8, A. Kanellakopoulos2, V. Kocman9, M. Kozak3, M. Madurga Flores6, G. Neyens1,2, S. Pallada1, J. Plavec9, K. Szutkowski3, M. Walczak10, F. Wienholtz1, J. Wolak3, X.F. Yang11, D. Zakoucky12

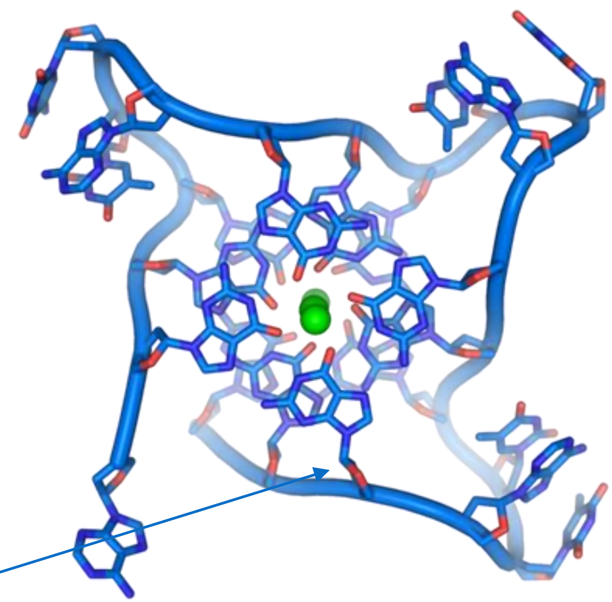
1. EP-Dept, CERN, Geneva, Switzerland
2. IKS, KU Leuven, Leuven, Belgium
3. Faculty of Physics, Adam Mickiewicz University, Poznan, Poland — biophysics, NMR, DNA studies
4. Faculty of Sciences, University of Geneva, Geneva, Switzerland — Biology, DNA studies
5. School of Physics and Astronomy, Manchester University, Manchester, United Kingdom
6. Dept. of Physics and Astronomy, University of Tennessee, Knoxville, Tennessee, USA
7. Department of Physics, University of York, York, United Kingdom
8. Department of Chemistry, University of Copenhagen, Copenhagen, Denmark — biophysics, metal-ion studies@ISOLDE
9. Slovenian NMR Center, National Institute of Chemistry, Ljubljana, Slovenia — chemistry, NMR, G-quadruplex studies
10. School of Physics, Peking University, Beijing, China
11. Poznan University of Technology, Poznan, Poland
12. NPI, Czech Academy of Sciences, Rez, Czech Republic

Motivation: DNA G-quadruplexes

- DNA G-quadruplexes: Formed in guanine-rich DNA fragments
  - ✓ Present in telomeres (ends of chromosomes)
  - ✓ Present in promoter regions of many oncogenes







- Alkali metals in DNA G-quadruplexes
  - ➢ Important for their formation, stability and structural polymorphism
  - ➢ Until recently considered invisible in conventional Na+/K+ NMR

- Goal of IS601: 15 shifts to study Na-DNA interaction using ultrasensitive beta-NMR (5 shifts used already)

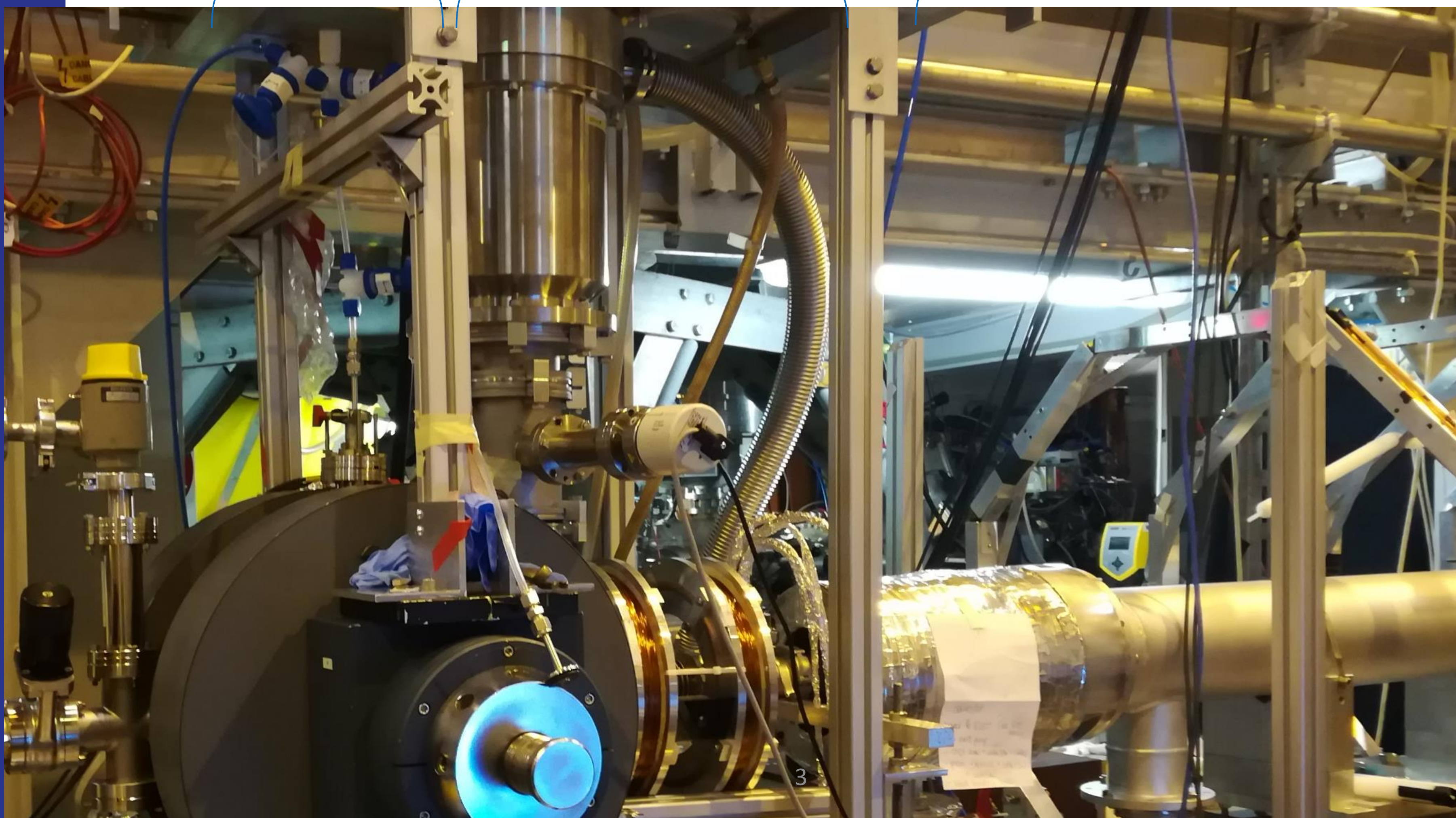
M. Trajkovski et al, J. Am. Chem. Soc. 134, 4132 (2012)

Technique: beta-NMR at VITO beamline

Up to 1e10 increased NMR sensitivity: hyperpolarization and beta-asymmetry detection

Designed, commissioned in 2017:

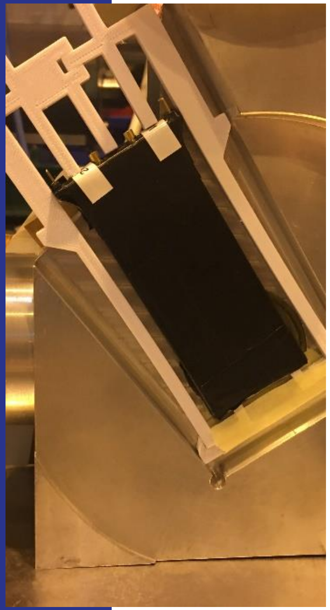
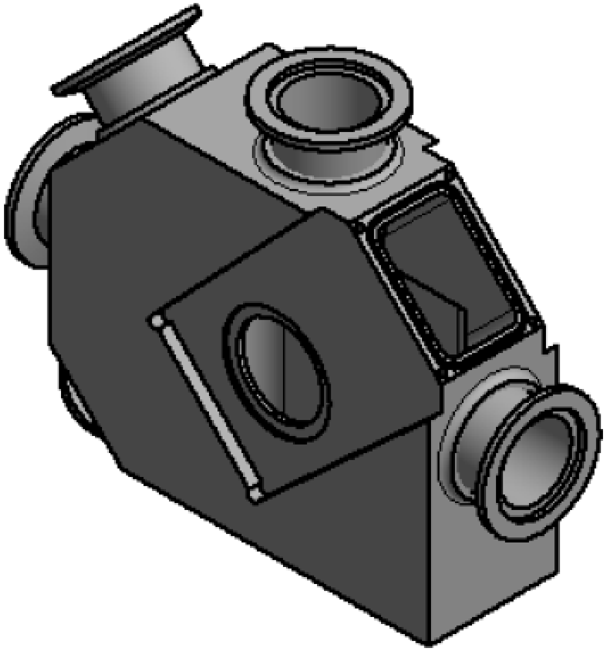
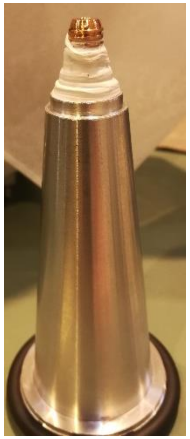
Liquid Beta-NMR | Differential pumping and transitional field | Spin polarization



September 2017 beamtime

Online commissioning of:

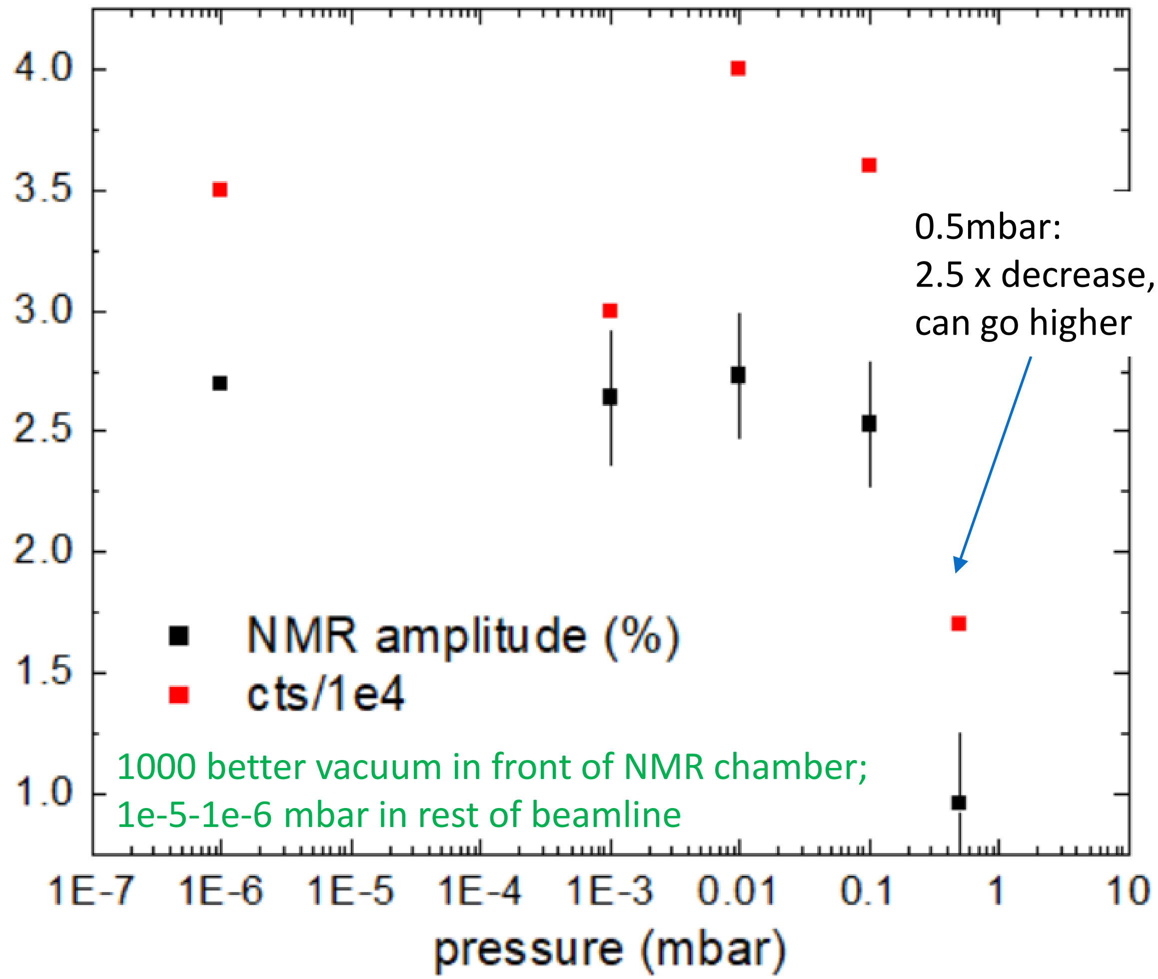
- New compact beta detectors
- New NMR chamber (delayed, arrived 2 days before beamtime; vacuum leak during run)
- Liquid handling system: liquid injected and coating a substrate (30 min)
- Differential pumping system (pinholes arrived with chamber, 1-2mm off center, 1 too thick)
- New transitional magnetic field


September 2017 beamtime

- Differential pumping tests: pinhole problems: off center and large beta background

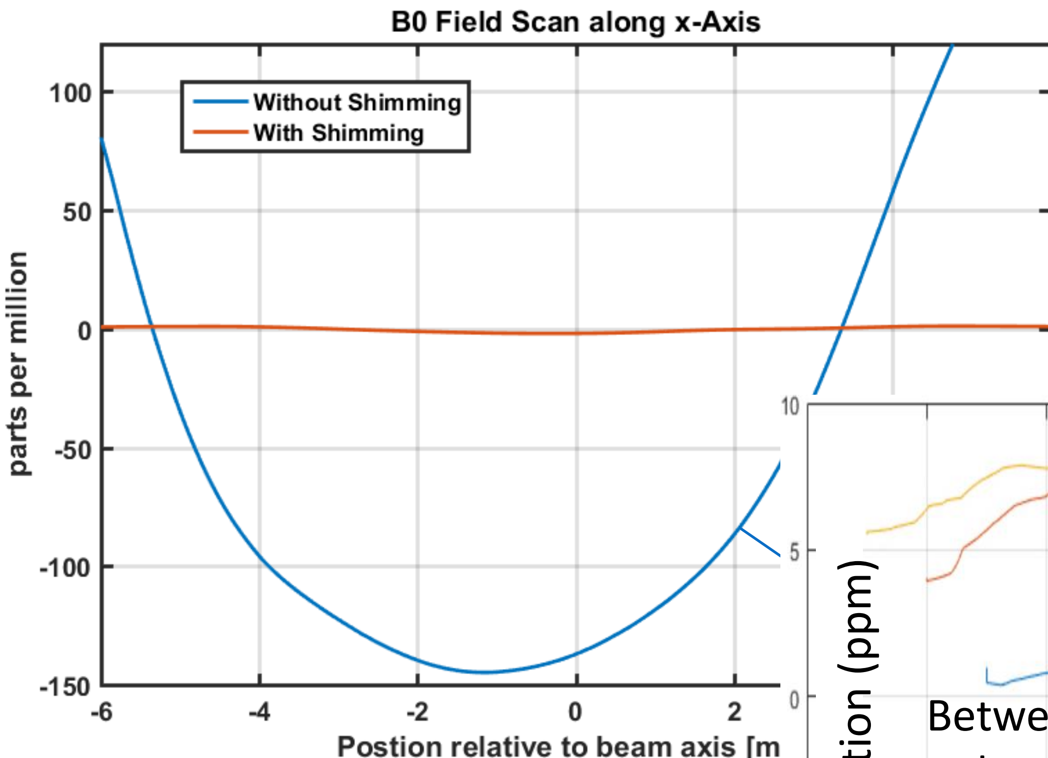
Nevertheless, very good performance:



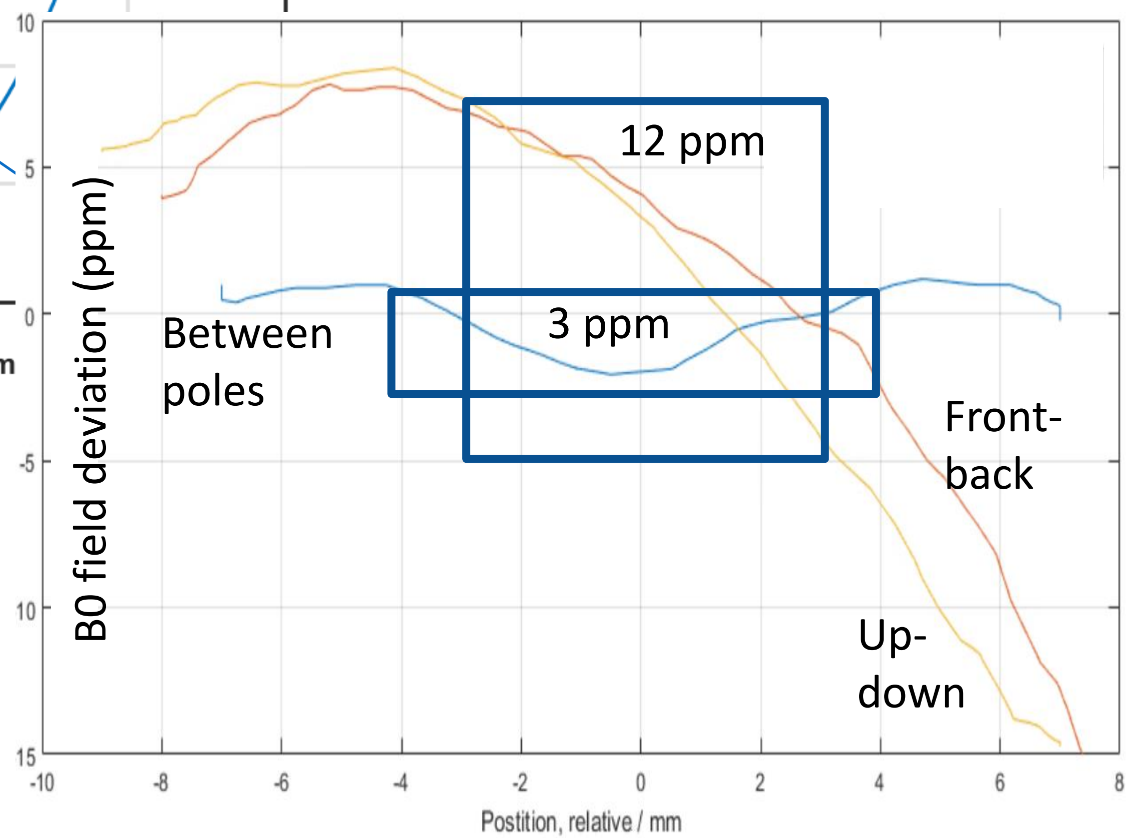
December 2017 beamtime

- Improved stability and tightness of liquid-handling system
- Last pinhole out -> concentrate on resonances in good vacuum

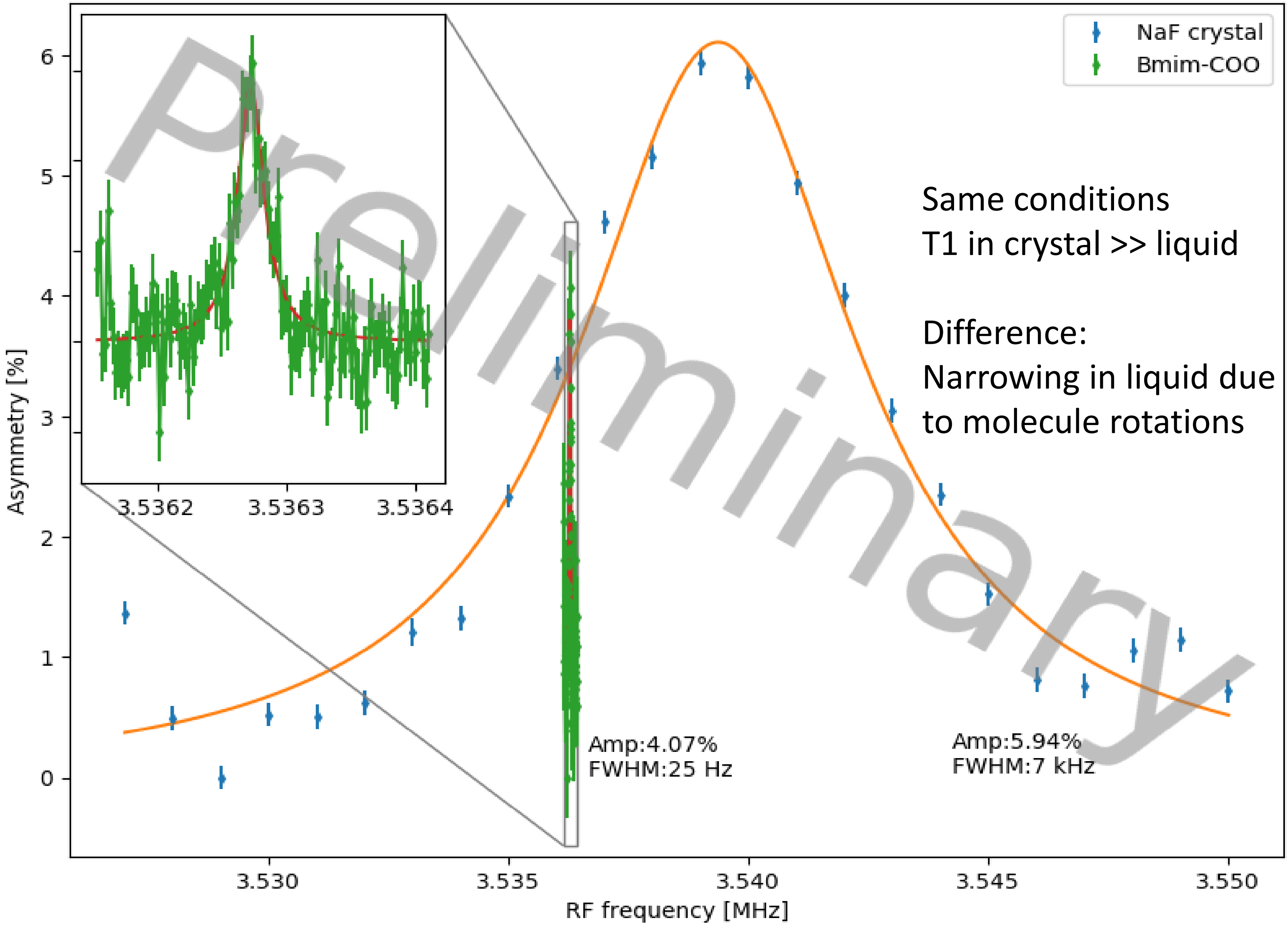
December 2017 beamtime



Improved B-field homogeneity



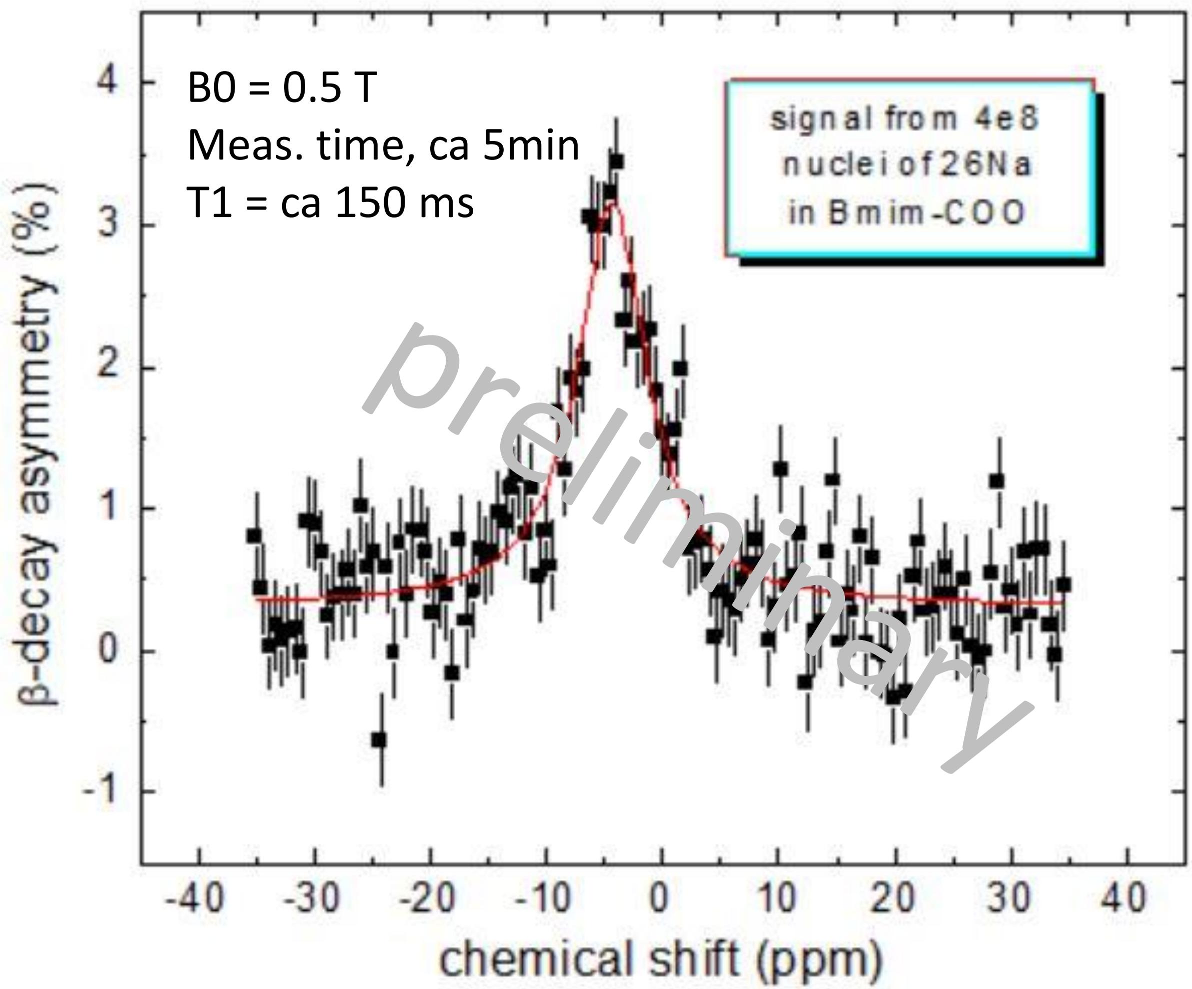
Ionic liquid vs crystal



Same conditions
T1 in crystal >> liquid

Difference:
Narrowing in liquid due to molecule rotations

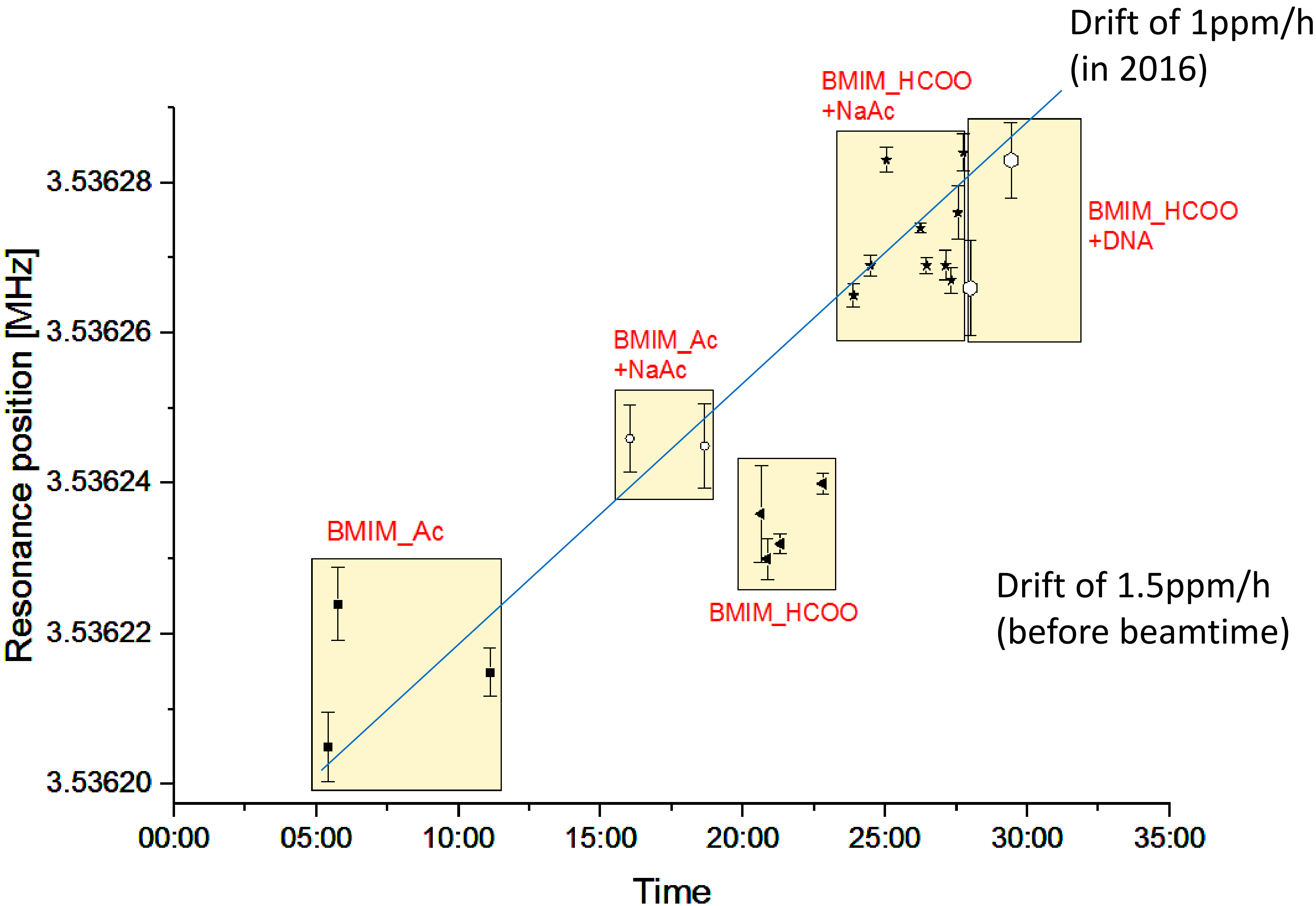
First 26Na NMR in ionic liquids



26Na
T1/2 = 1.1 s
I = 3
$\mu = 2.86\ \mu_N$
Q = - 5 mb

In comparison - 23Na:
I = 3/2
$\mu = +2.21\ \mu_N$
Q = 100 mb
(20x larger!)

December 2017 results



Winter shutdown activities

- Complementary measurements on several ionic liquids with ^{23}Na NMR
- Offline studies of short DNA sequences dissolved in ionic liquids
- Conventional NMR measurements in cell-like PEG solvent

- Modifications to the last differential pumping section to allow studies in 1e-3-1e-2 mbar: pinhole in front of chamber, not inside

- Further improvement in magnetic-field homogeneity
- Improvement of the long-term stability of the magnetic field
- Magnetic field measurement (using NMR probe) during data-taking

- Minimisation of the time required to clean the liquid handling system and inserting new samples

- Addition of temperature control and measurement of the temperature

Online plans for 2018

1st run, 9 shifts:

- Try b-NMR with ISCOOL bunched beam
- 26Na in Emim-DCA to compare to Bmim-COOH: narrower resonance? Longer relaxation time T1?
- 26Na b-NMR of DNA dissolved in Emim-DCA or Bmim-COOH: looking for change in chemical shift, T1
- Same study in another ionic liquid or other DNA

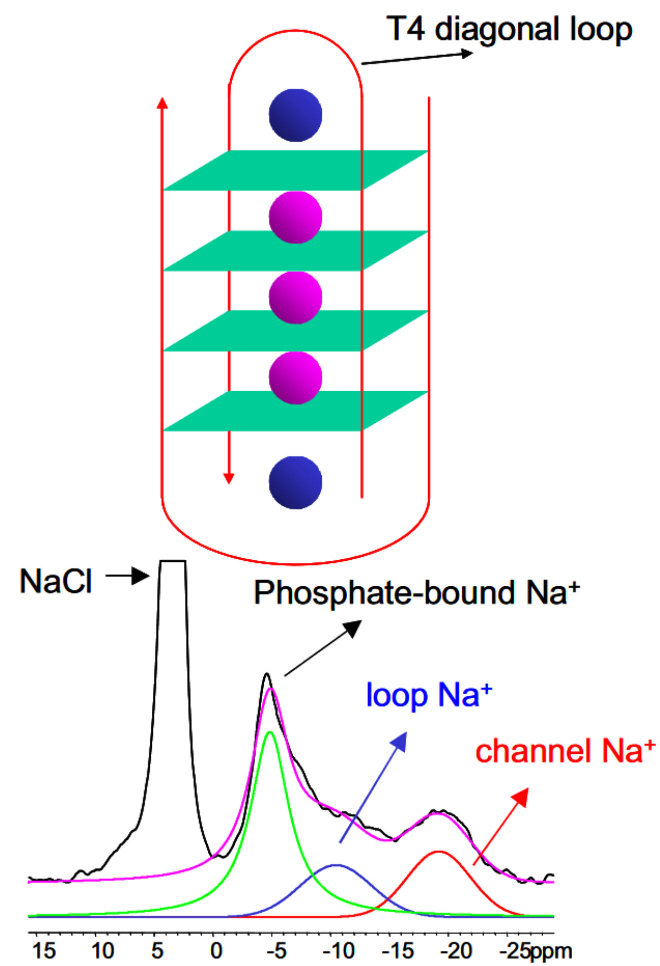
2nd run, 9 shifts:

- Systematic G-quadruplex study in best ionic liquid (identified during 1st run):
  - Change DNA concentration and or T1
- G-quadruplex study in PEG at 1e-3 (or 1e-2)mbar

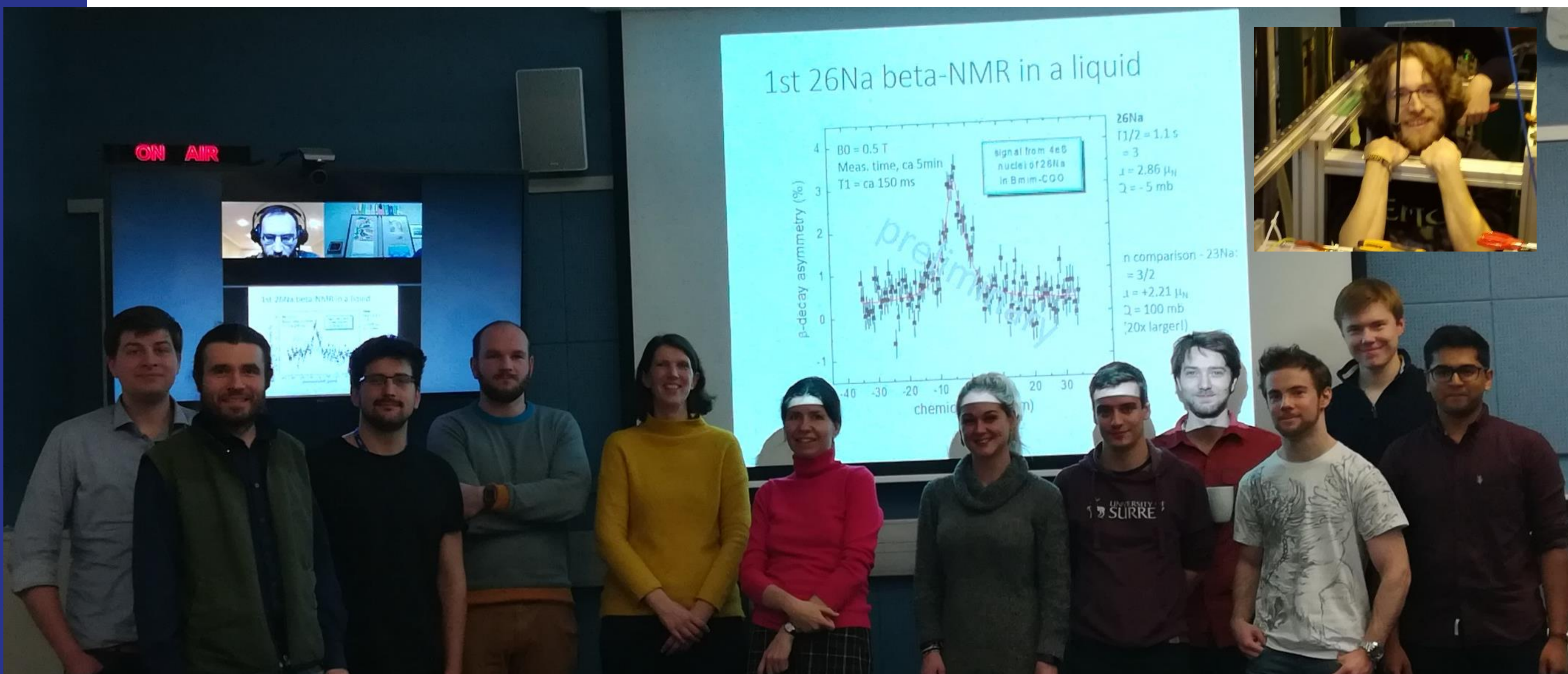
Beam request:

- 26Na from Ti, Ta, or UC with surface ionization
- HRS, ISCOOL in bunch tune
- 8 additional shifts needed (10 still left from 2017)

Resolution of our system is good enough for expected chemical shifts, based on rare 23Na NMR studies:



Thank you



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