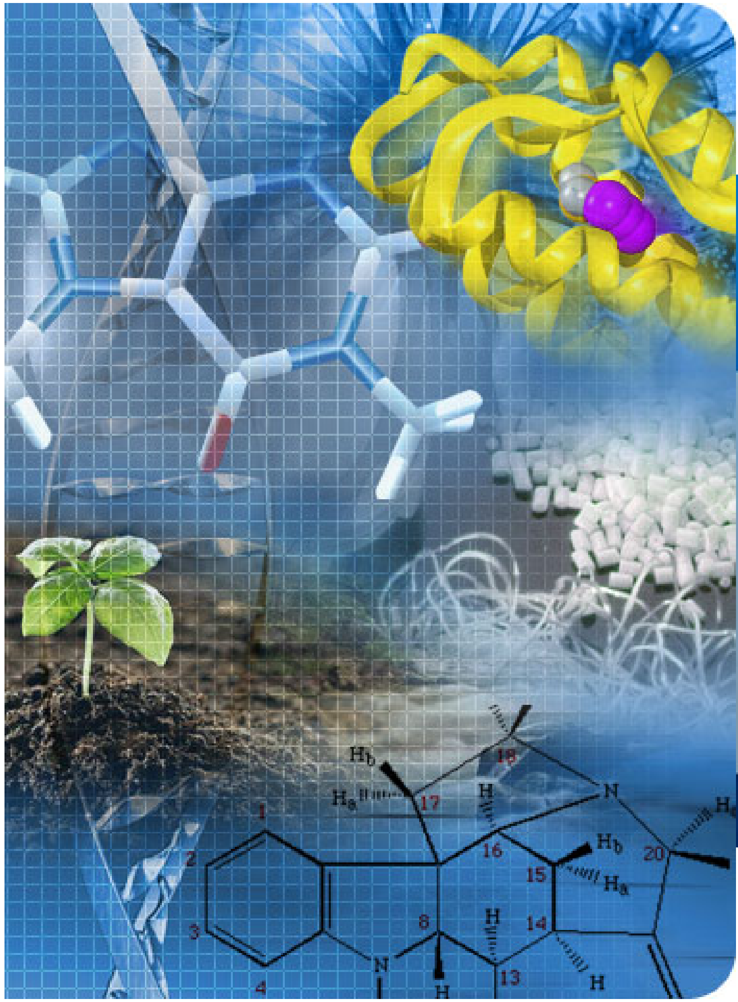

Fast Data Acquisition NMR Experiments

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Bruker Biospin
Rheinstetten, DE

Quick Overview: Fast Methods

FDM (Filter Diagonalisation Method)+	(Mandelshtam & Shaka)
Hadamard+	(Kupce & Freeman)
Red. Dimensionality:	(Szyperski, Wüthrich, Brutscher,
GFT* / MWD- / APSY+	(Gronenborn, Billeter, Markley, ...)
Projection Reconstruction+	(Kupce & Freeman)
Non-Linear Sampling-	(Wagner, Orekhov, Marion, ...)
Ultrafast 2D*	(Frydman, Pelupessy)
Covariance NMR+	(Brüschweiler, ...)
Spectrum Folding	(Sidebottom, Berger, ...)
Sharc NMR	(Sakhaii)
Rapid Pulsing	(Ross, Pervushin, Brutscher,...)
Simultaneous Data Acquisition	(Soerensen, Griesinger, Parella, ...)

* patented   - special software (n.a.)   + software available

Rapid Pulsing: BEST-NMR: References

Schanda et al, J. Am. Chem. Soc. (2005) 127, 8014

Schanda et al, J. Biomol. NMR (2005) 33, 199.

Schanda et al, J. Magn. Reson. (2006) 178, 334.

Schanda et al, Magn. Reson. Chem. (2006) 44, 177.

Schanda et al, J. Am. Chem. Soc. (2006) 128, 9042

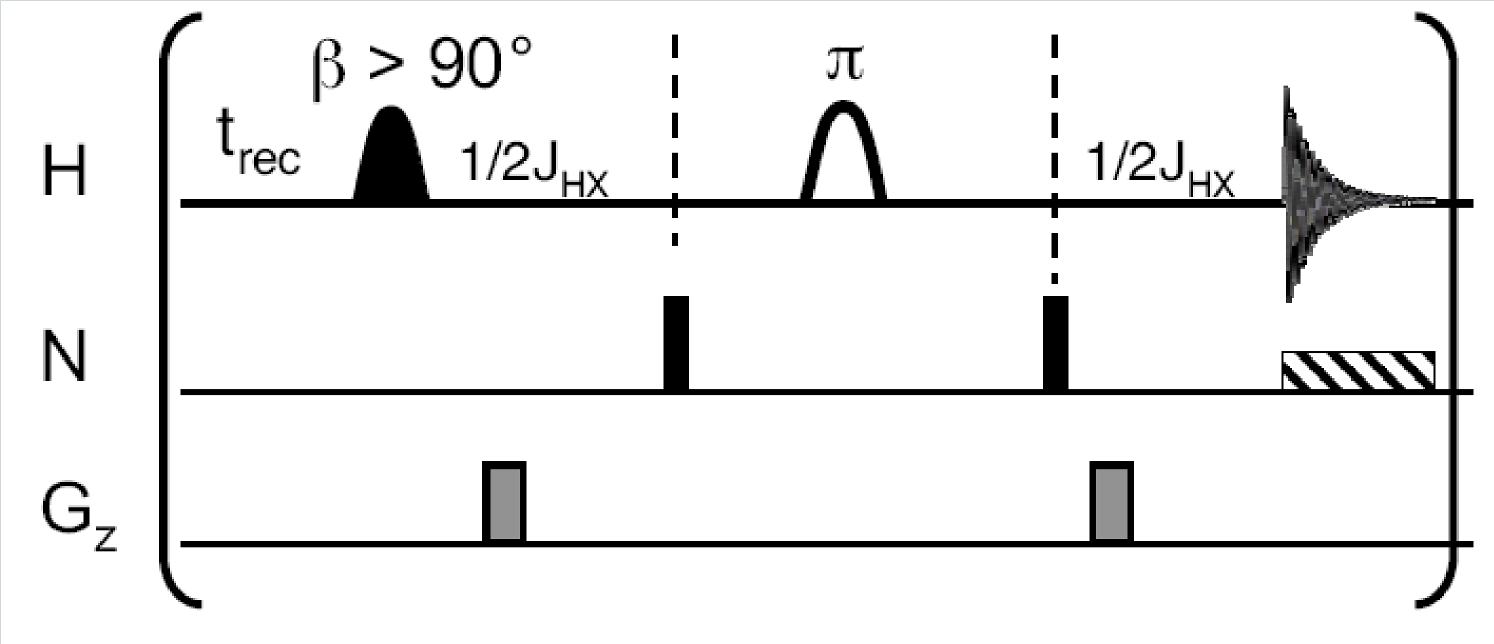
Schanda et al, J. Biomol. NMR (2007) 38, 47.

Schanda et al, Proc. Natl. Acad. Sci. USA (2007) 104, 11257.

Lescop et al, J. Magn. Reson. (2007) 187, 163.

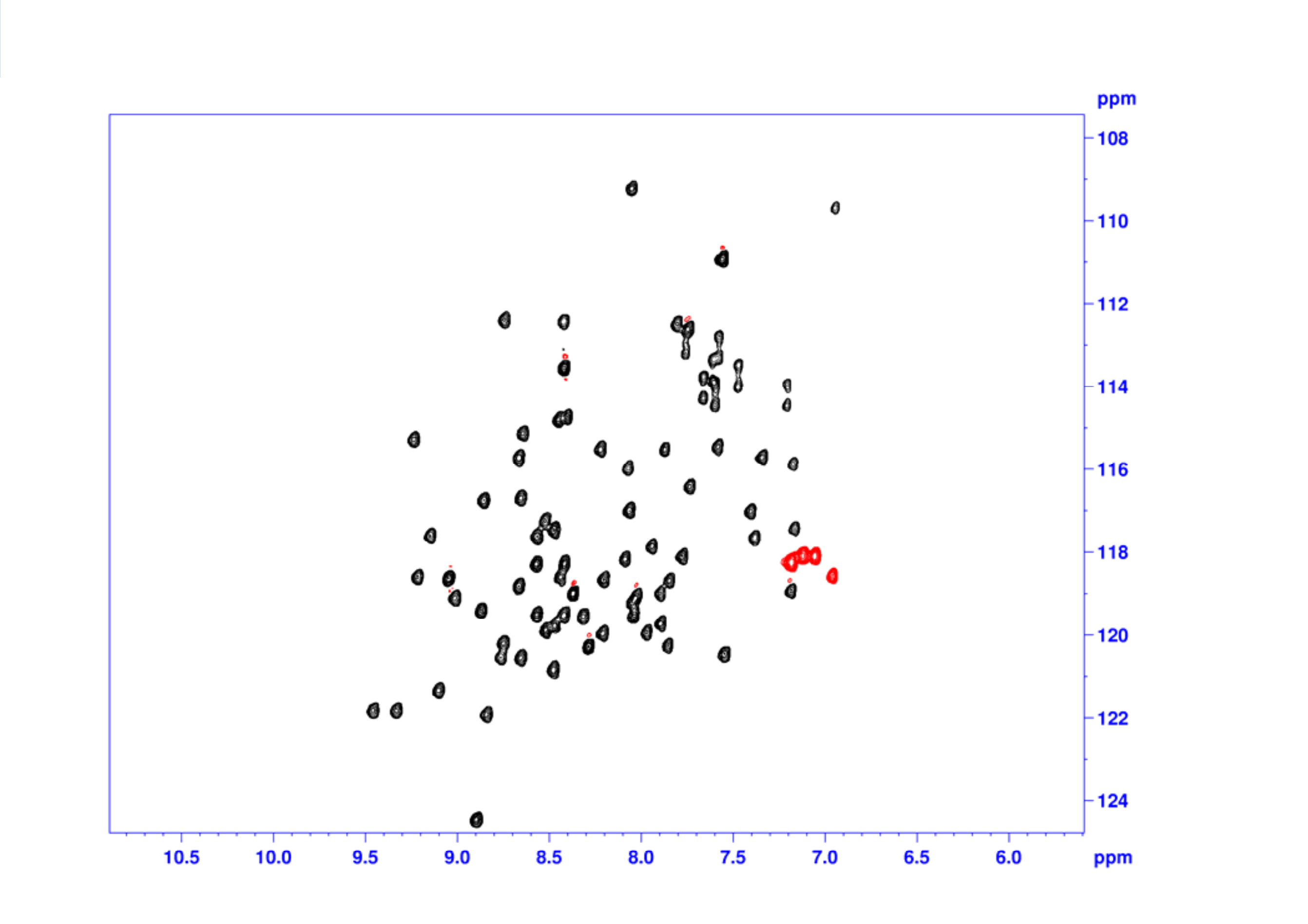
Rapid Pulsing: SOFAST-HMQC (sfhmqcf3gpph)

(Band-Selective Optimized-Flip-Angle Short-Transient)



;p39: f1 channel - 120 degree shaped pulse for excitation
;   Pc9_4_120.1000 (120º)   (3.0ms at 600.13 MHz)
;   (or Q5.1000 (90º)   (2.0ms at 600.13 MHz))
;p40: f1 channel - 180 degree shaped pulse for refocussing
;   Rsnob.1000   (1.0ms at 600.13 MHz)

Rapid Pulsing: SOFAST-HMQC



Relaxation Delay: 40ms
Acquisition Time: 40ms
GARP Decoupling w/1.4 kHz

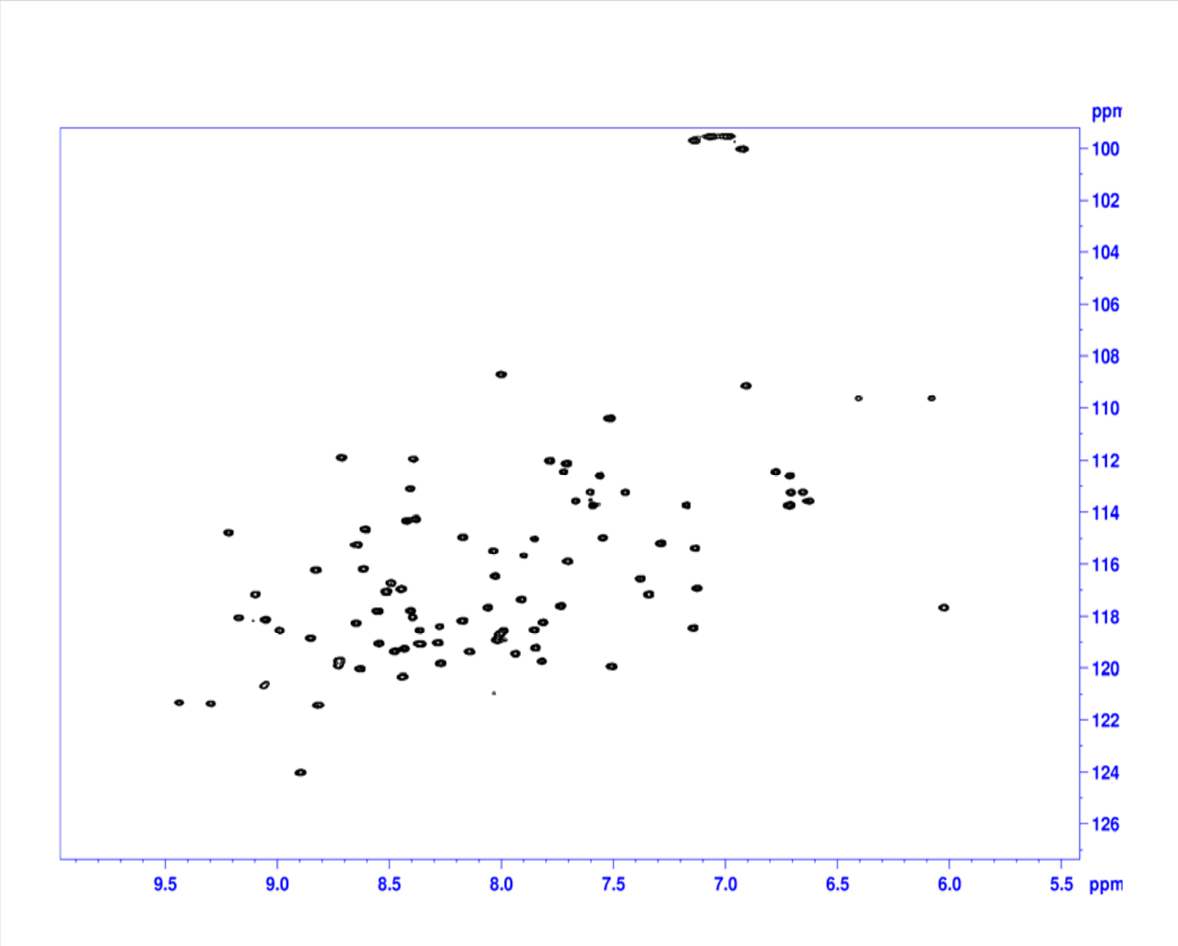
64 complex points, NS=2

experimental time: 28 sec

Avance III 800MHz US^2
5mm TXI (H,C-N) probehead

Ref: P.Schanda, E. Kupce, B. Brutscher J.Biomol.NMR 33 (2005) 199-211

Rapid Pulsing: SOFAST-HMQC (800 MHz /Cryo)



Relaxation Delay: 100ms
Acquisition Time: 79ms
GARP Decoupling w/690 Hz

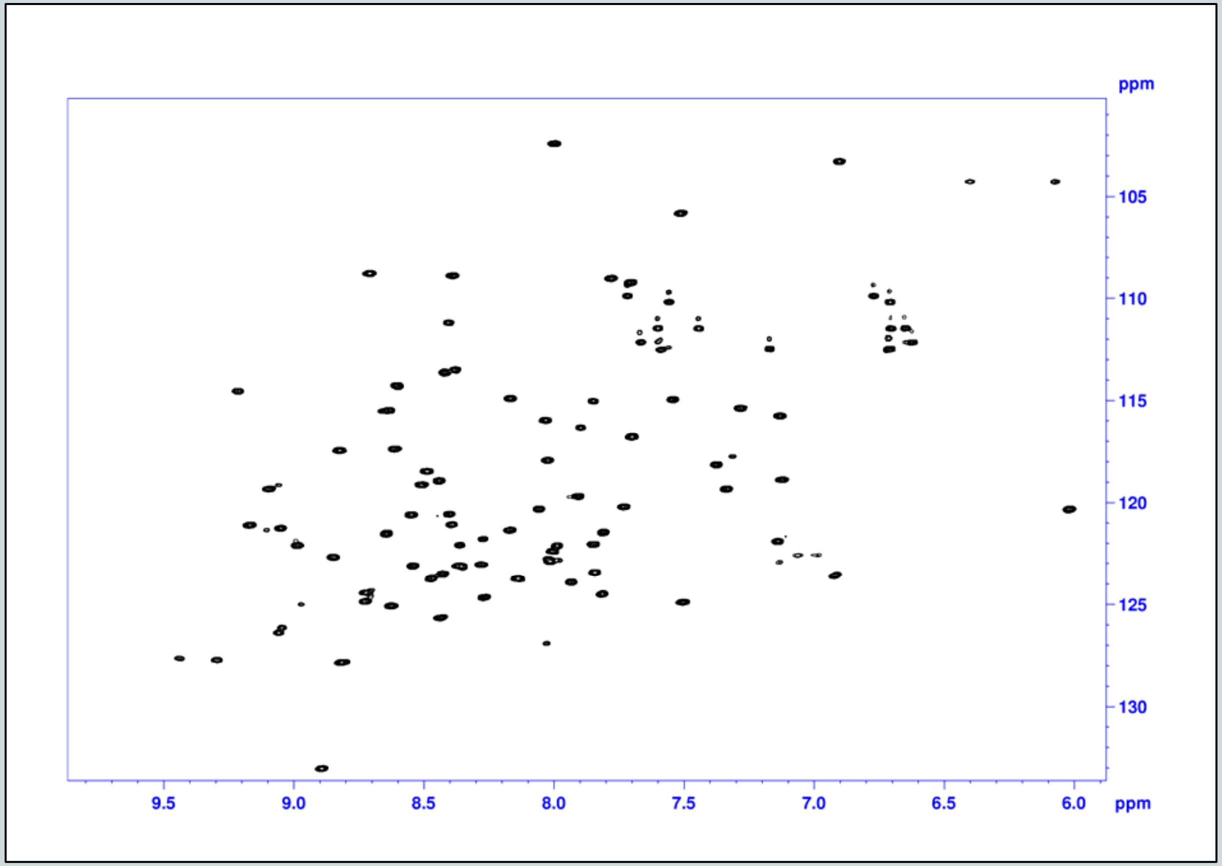
64 complex points, NS=2

experimental time: 57sec

Avance III 800MHz US^2
5mm TXI (H,C-N)
cryogenic probehead
no folding

Ref: P.Schanda, E. Kupce, B. Brutscher J.Biomol.NMR 33 (2005) 199-211

Rapid Pulsing: BEST-HSQC (800 MHz /Cryo)



Relaxation Delay: 200ms
Acquisition Time: 79ms
GARP Decoupling w/690 Hz

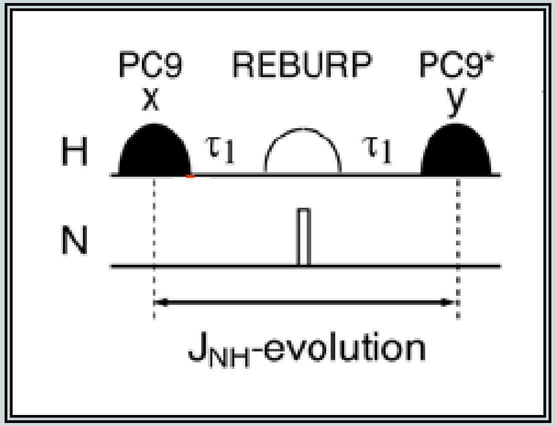
128 complex points, NS=4

experimental time: 360sec

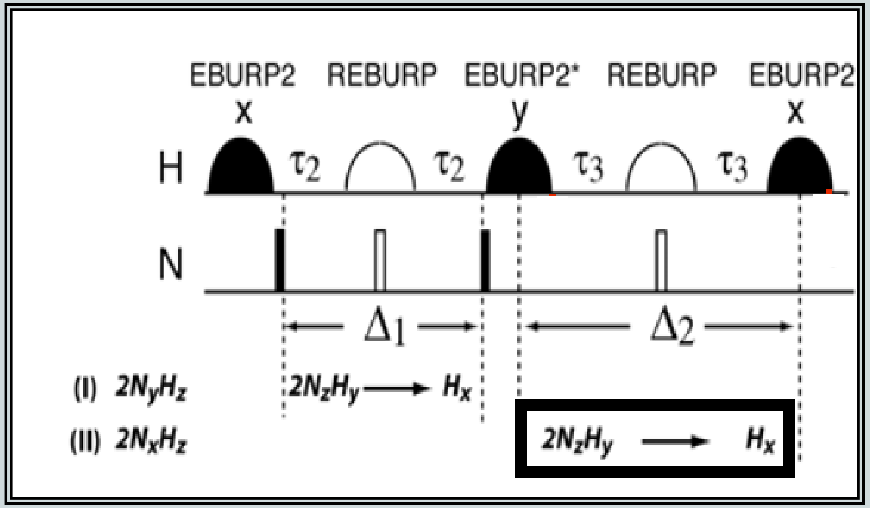
Avance III 800MHz US^2
5mm TXI (H,C-N)
cryogenic probehead
no folding

Ref: E.Lescop, P.Schanda, B. Brutscher J.Mag.Res 187 (2007) 163-169

Rapid Pulsing: BEST-NMR: Building Blocks

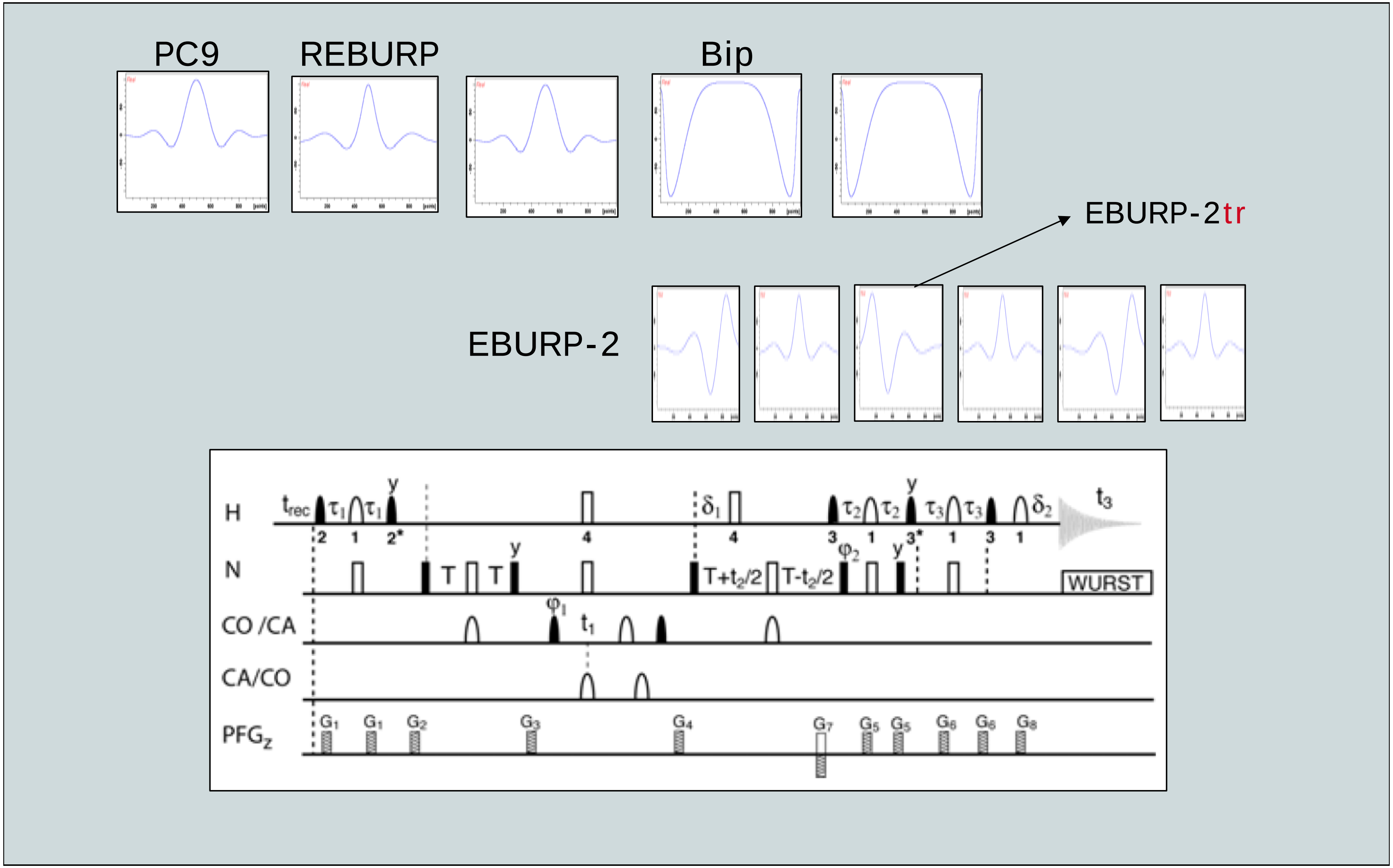


Time optimized INEPT transfer
(Kupce and Freeman, J. Magn.Res 102A, 1993, 122ff)



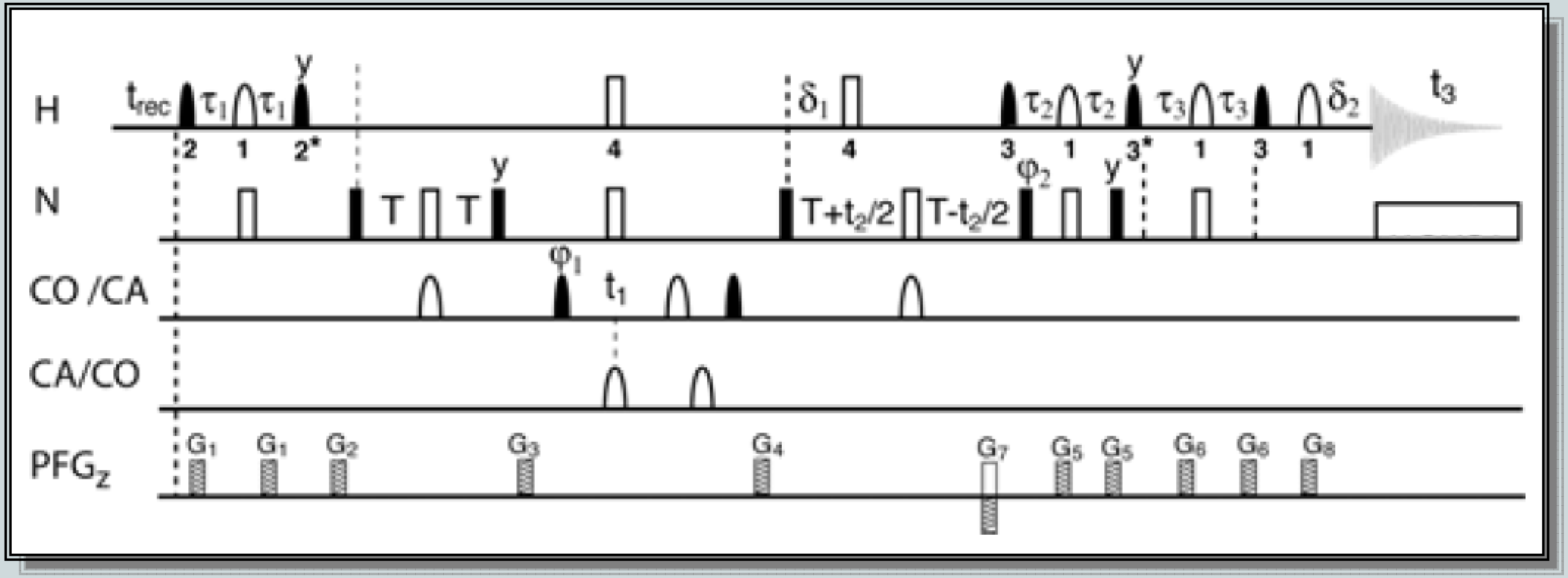
Planar Mixing
(Geen and Freeman, J. Magn.Res 93, 1991, 93ff)

Rapid Pulsing: BEST-NMR: Shaped Pulses



Rapid Pulsing: BEST-NMR: Example

BEST-HNCA/HNCO



Procedure: scaling/calculation of rf-powers; interactive optimization of parameters by evaluation of on-line FT in continous observation mode.

Other parameters identical to „classical“ HNCx „out-and-back“ style experiments.

Rapid Pulsing: BEST-NMR Implementation(s)

```
.....
"spoff2=0"
"spoff3=0"
"spoff5=bf2*(cnst21/1000000)-o2"
"spoff8=0"

"spoff25=bf1*(cnst19/1000000)-o1"
"spoff26=bf1*(cnst19/1000000)-o1"
"spoff27=bf1*(cnst19/1000000)-o1"
"spoff28=bf1*(cnst19/1000000)-o1"
"spoff29=bf1*(cnst19/1000000)-o1"
"spoff30=0"

...
 p29:gp3
  d16
  (p41:sp27 ph2):f1

  p16:gp4
  d16

  (p21 ph3):f3
  d23
  (center (p14:sp3 ph1):f2 (p22 ph1):f3 )
  d23
  (p21 ph2):f3

  p16:gp5
  d16

  (p13:sp2 ph4):f2
  d0
  (center (p44:sp30 ph1) (p14:sp5 ph1):f2 (p22 ph7):f3 )
  d0
  4u
  (p14:sp3 ph1):f2
  DELTA
  (p14:sp5 ph1):f2
  4u
  (p13:sp8 ph1):f2
```

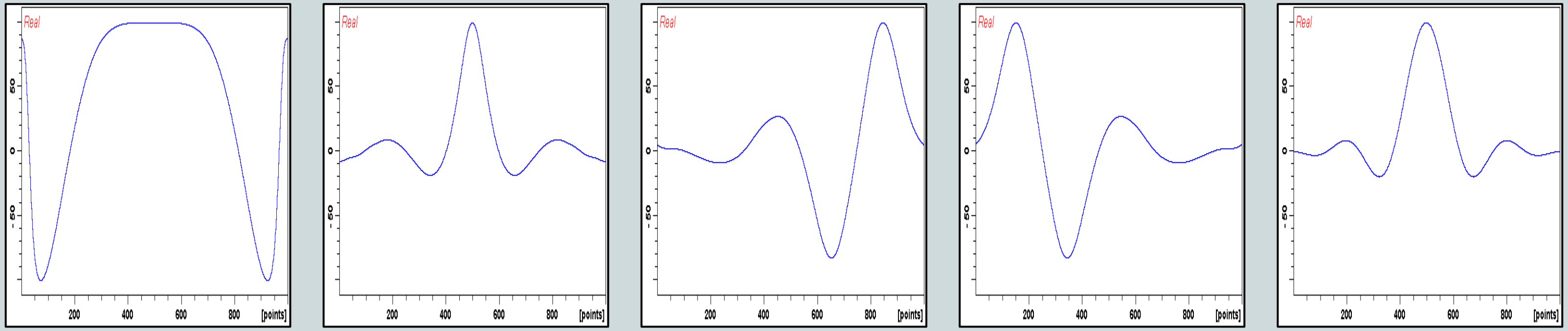
Offset Calculations

Extended
Shaped Pulse Array

Rapid Pulsing: BEST-NMR: Shaped Pulses

Pulse Program Comment

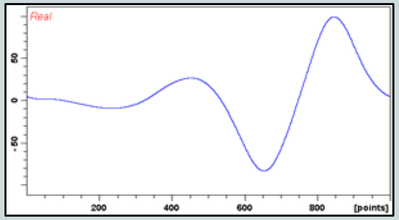
```
;p41: f1 channel -  90 degree shaped pulse for excitation
;                   Pc9_4_90.1000                           (3.0ms at 600.13 MHz)
;p42: f1 channel - 180 degree shaped pulse for refocussing
;                   Reburp.1000                             (2.0ms at 600.13 MHz)
;p43: f1 channel -  90 degree shaped pulse for excitation
;                   Eburp2.1000/Eburp2tr.1000               (1.92ms at 600.13 MHz)
;p44: f1 channel - 180 degree shaped pulse for refocussing
;                   Bip720,50,20.1                          (200us at 600.13 MHz)
```

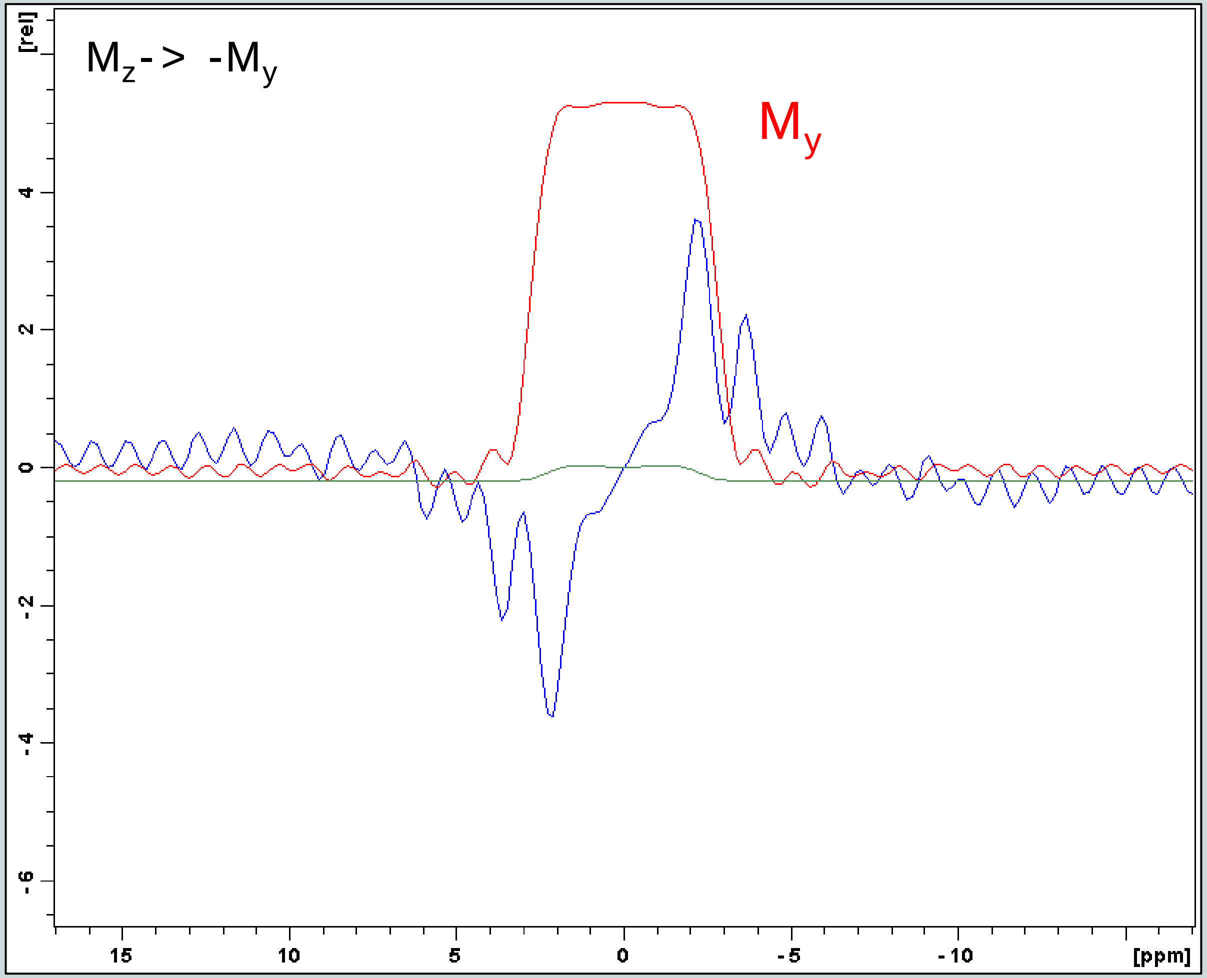


Shaped pulses from Standard Library

Scaling of pulses is necessary for other field strengths ⟹ Probe/Solvent Tables

Rapid Pulsing: BEST-NMR: Shaped Pulses

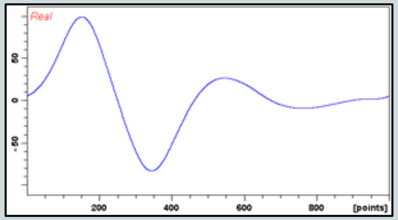


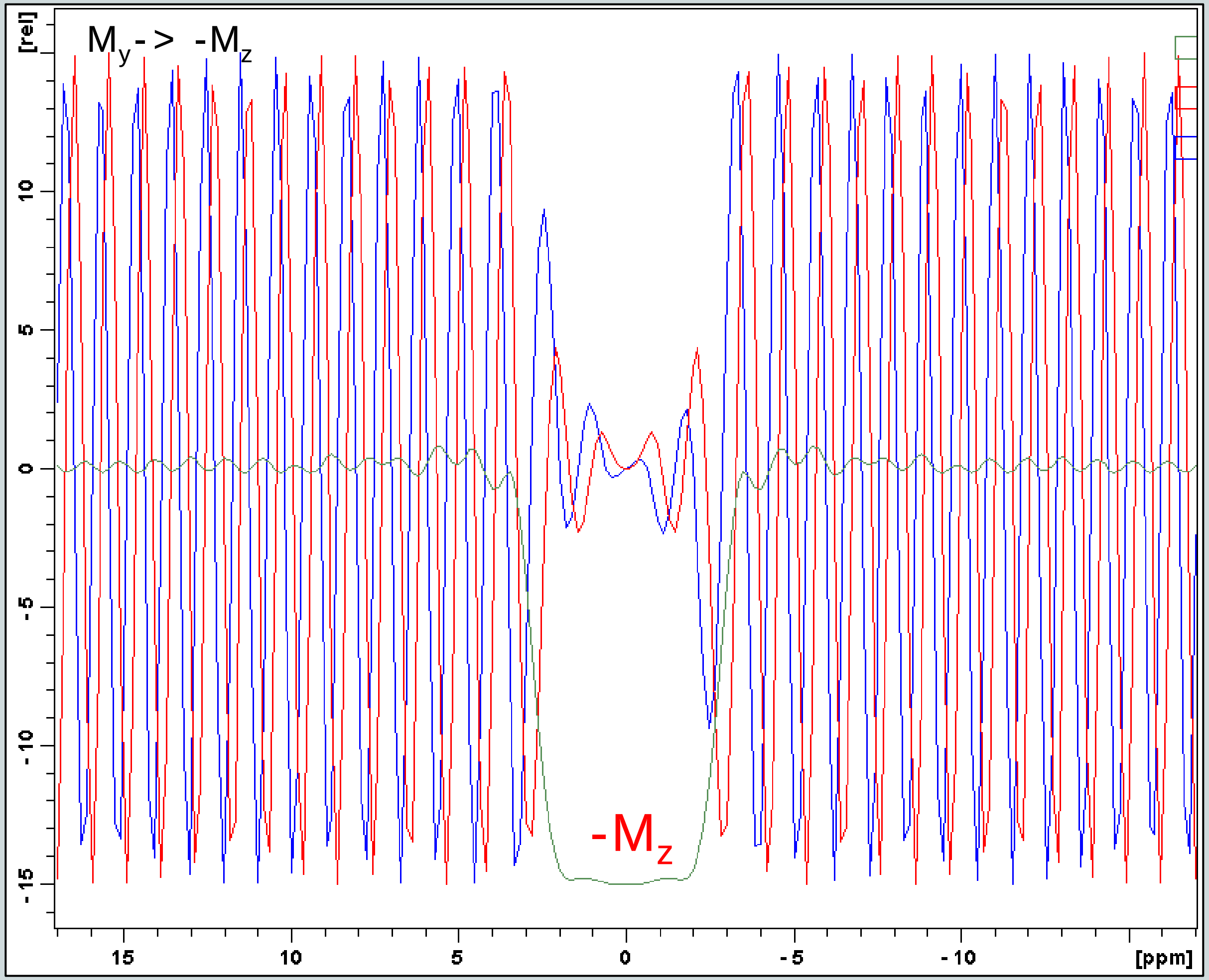


Simulation:
Eburp2.1000 ;
duration: 1920 usec;
2.133 kHz rf-field;
Start: M_z magnetization

„Onboard“ Simulation program *NMRSIM*
(Bloch Simulator data exported as dataset into TOPSPIN; plot exported as png-file)

Rapid Pulsing: BEST-NMR: Shaped Pulses

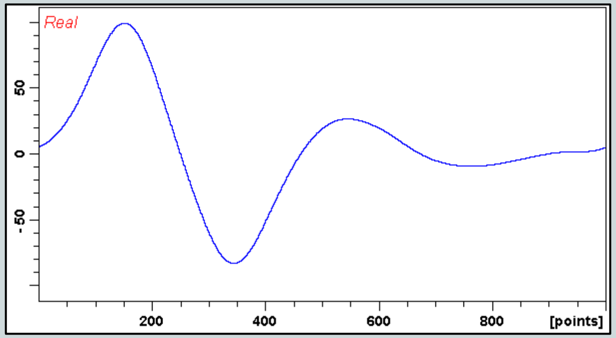




Simulation:
Eburp2tr.1000 ;
duration 1920 usec;
2.133 kHz rf-field;

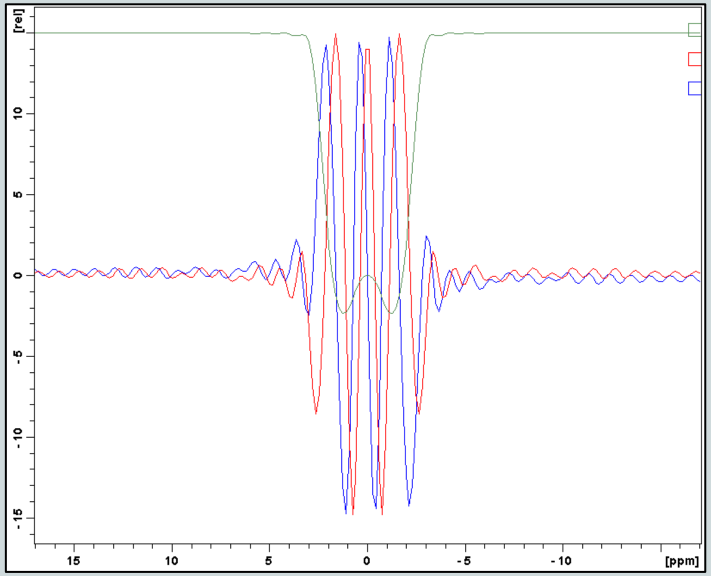
Start: $+M_y$ magnetization

Rapid Pulsing: BEST-NMR: Shaped Pulses



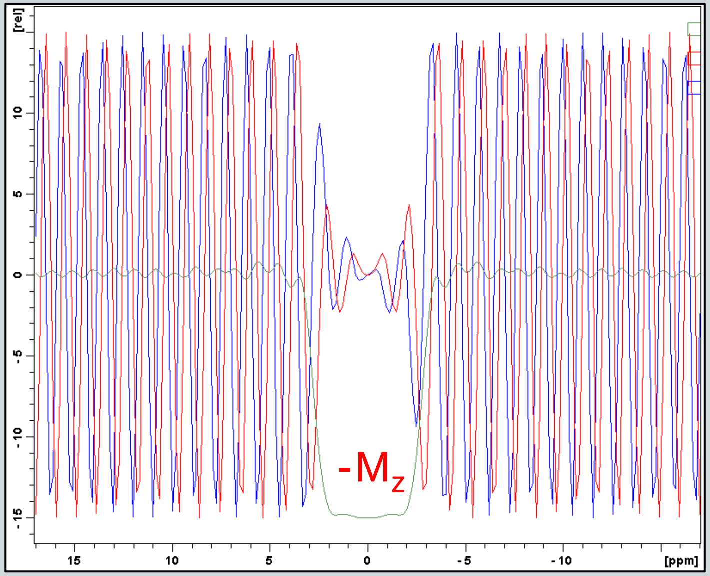
Simulation:
Eburp2tr.1000 ; duration 1920 usec;
2.133 kHz rf-field;
a) starting at $+M_z$ magnetization
b) starting at $+M_y$ magnetization

a)



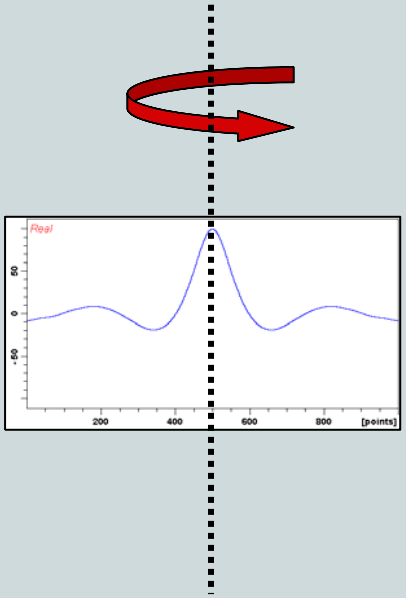
$M_z \rightarrow -M_y$

b)



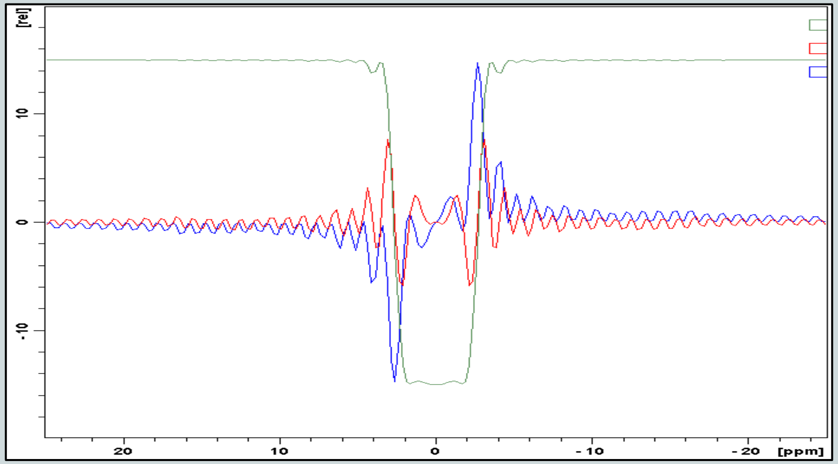
$M_y \rightarrow -M_z$

Rapid Pulsing: BEST-NMR: Shaped Pulses

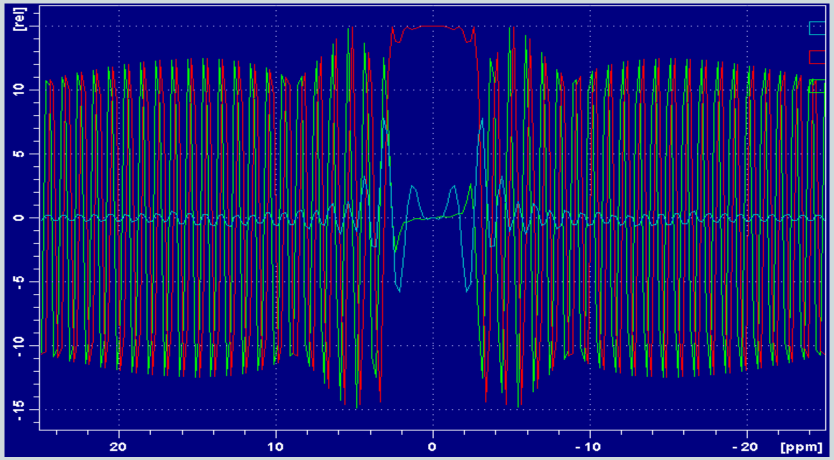


Simulation:
Reburp.1000 ;
duration 2000 usec; 3.133 kHz rf-field;

Start: $+M_{y/z}$ magnetization



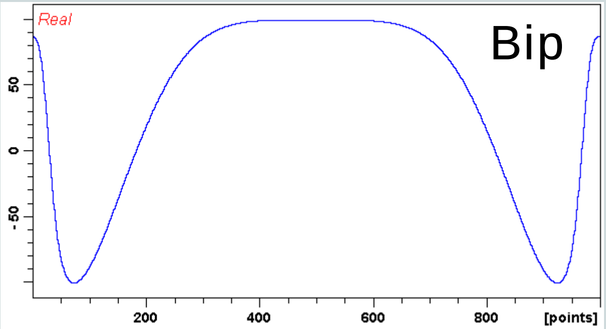
Inversion

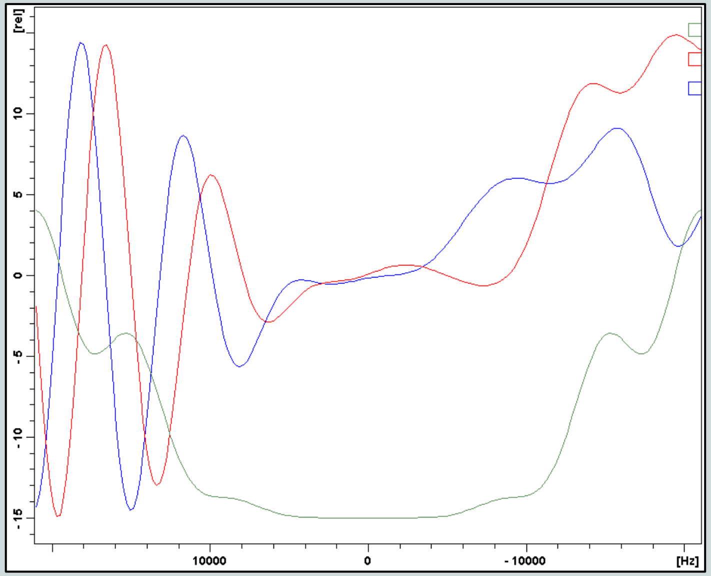


Refocussing

Bruker BioSpin

Rapid Pulsing: BEST-NMR: Shaped Pulses





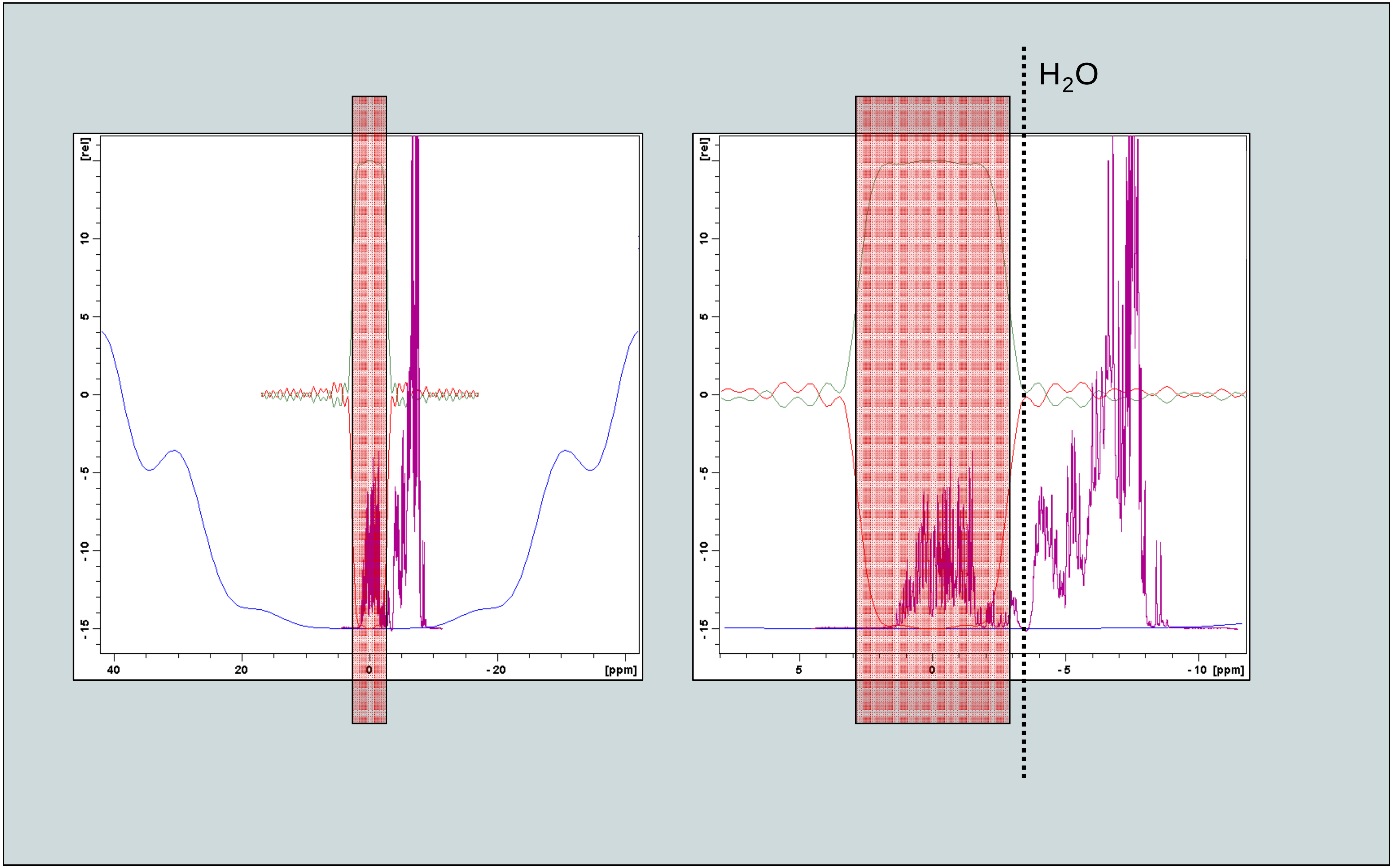
M_z -> $-M_z$

Simulation/Calculation: Bip720,50,20.1 ; duration 200usec; 10kHz rf-field; starting at $+M_z$ magnetization

(cave: pulse is „pseudo"-adiabatic)

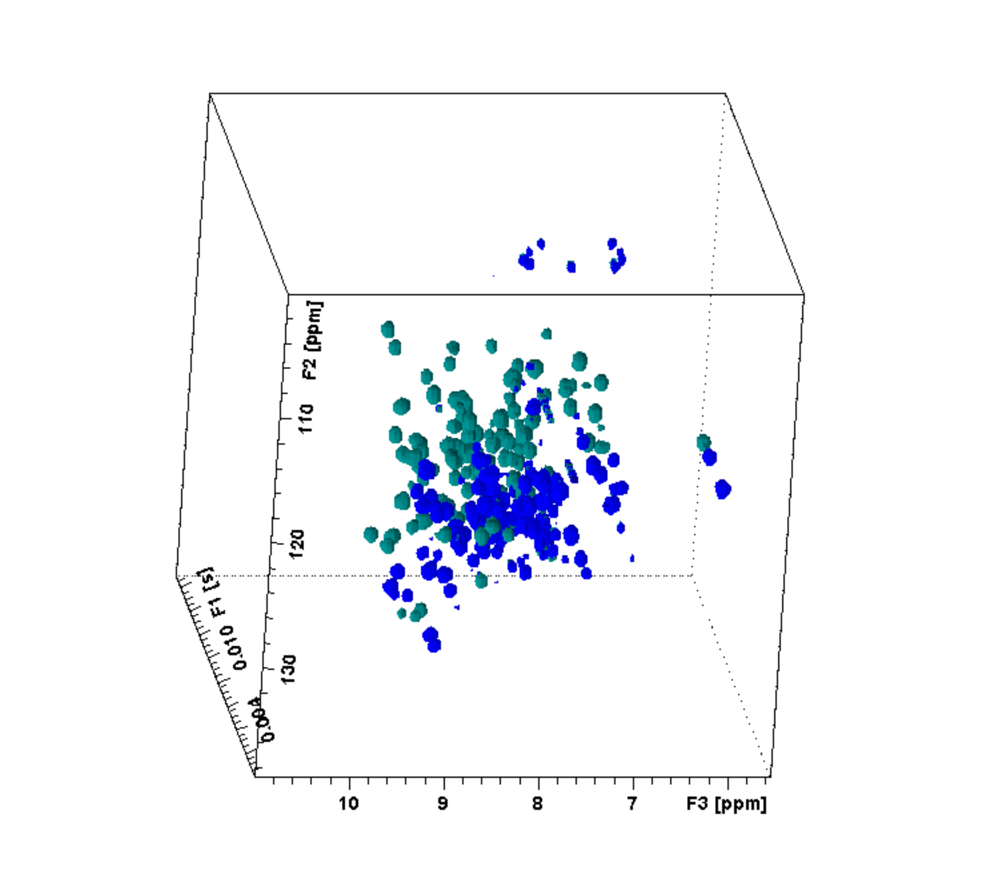
(Broadband inversion pulses: Shaka et al., J. Magn.Res. 151, 2001, 269ff)

Rapid Pulsing: BEST-NMR: Shaped Pulses



Bruker BioSpin

Rapid Pulsing: BEST-NMR Implementations



Example: 3D BEST-HNCACB

b_hncogp3d
b_hncoigp3d

b_hncagp3d
b_hncaigp3d

b_hncacbgp3d
b_hncacbigp3d

b_hncocagp3d
b_hncocacbgp3d

Ref: E.Lescop, P.Schanda, B. Brutscher J.Mag.Res 187 (2007) 163-169

4D BEST-HNCOCA (800 MHz /Cryo)

Spectrum | ProcPars | AcquPars | Title | PulseProg | Peaks | Integrals | Sample | Structure | Fid

Installed probe: not defined

Experiment
Width
Receiver
Nucleus
Durations
Power
Program
Probe
Lists
Wobble
Lock
Automation
Miscellaneous
User
Routing

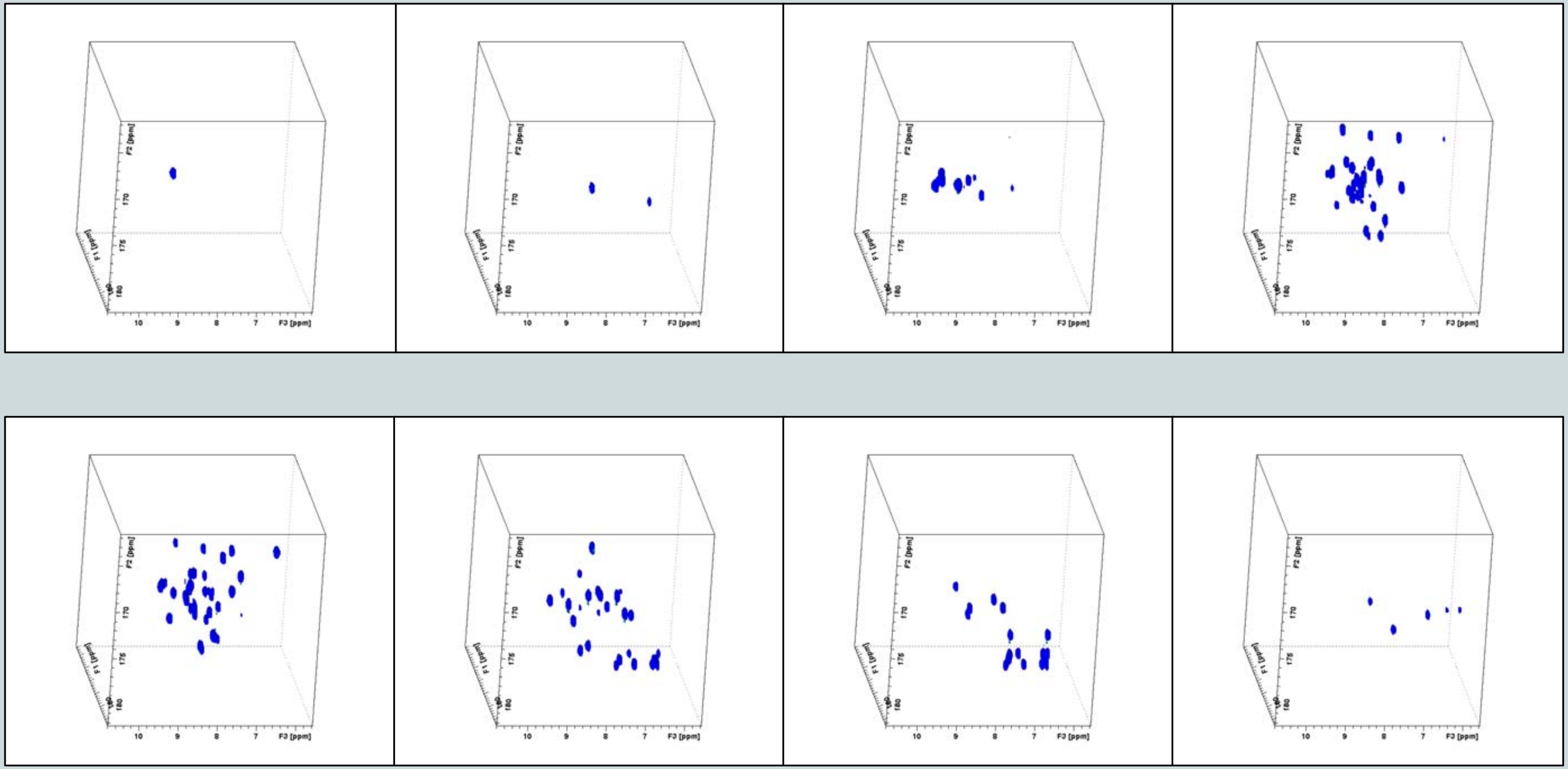
	F4	F3	F2	F1
▼ Experiment				
PULPROG	b_hncocagp4d.t1.be			
AQ_mod	DQD			
FnMODE		Echo-Antiecho	States-TPPI	States-TPPI
TD	1024	32	32	32
NS	4			
DS	100			
TD0	1			
▼ Width				
SW [ppm]	13.9500	38.5431	20.7083	31.0625
SWH [Hz]	11160.714	3125.000	4166.667	6250.000
IN_F [µs]		320.00	240.00	160.00
AQ [s]	0.0459700	0.0051200	0.0038400	0.0025600
FIDRES [Hz]	10.899135	97.656250	130.208328	195.312500
FW [Hz]	125000.00			
► Receiver				
▼ Nucleus 1				
NUC1	1H	15N	13C	13C
O1 [Hz]	3758.63	9688.13	34601.71	34601.71
O1P [ppm]	4.698	119.506	172.000	172.000
SFO1 [MHz]	800.0537586	81.0780501	201.2073347	201.2073347
BF1 [MHz]	800.0500000	81.0683620	201.1727330	201.1727330

4D BEST-HNCOCA (800 MHz /Cryo)

```
....
d16 pl12:f2
  4u BLKGRAD
  go=2 ph31 cpd2:f2
  d11 do:f2 mc #0 to 2
     F1PH(rd32 & rp4 & rp5 & ip3, id31)
     F2PH(rd33 & rp6 & rp31 & ip4 & ip5, id32 & dp4 & dp5)
     F3EA(igrad EA & ip8*2, id33 & ip6*2 & ip31*2)
exit
```

Extension of pulse program syntax to 4D

4D BEST-HNCOCA (800 MHz /Cryo)



„124“ cubes taken at 8 discrete ^{15}N frequencies

Ref: E.Lescop, P.Schanda, B. Brutscher J.Mag.Res 187 (2007) 163-169; extension to 4D by ber/rwe

Thank You !