Pulse Programming

Elements of Pulse Programs

Pulse Programming

Trim Pulses

Flip back pulses

Shaped pulses in triple resonance experiments

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Flip back pulses

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Selective solvent signal dephasing by RF pulses

Purge pulses (spin-lock or trim pulses)

selectively dephase coherences orthogonal to the RF-field (I_x ,I_z) while preserving coherences locked along the RF-field (I_y)

experiments: ^{1}H TOCSY, HSQC-type inverse, triple resonance experiments,...

power levels: **pl10** for ^{1}H TOCSY, others **pl1** (same as hard proton pulses!!, but not more than power level corresponding to 10 μs 90 degree pulse!!)

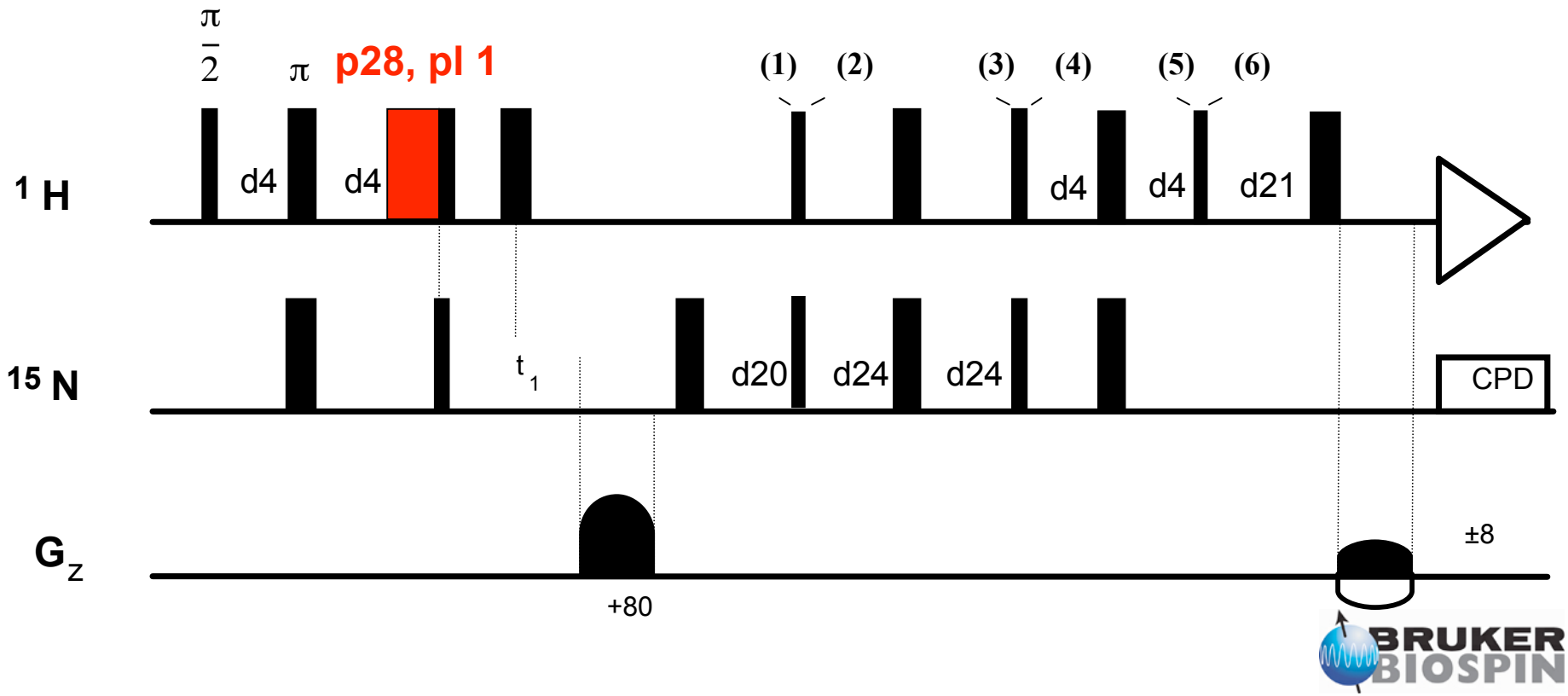
purge pulses: **p17 (=< 2.5ms); p28** (=< 1.0ms, if pl1 set as described above)

Note: make sure that the probe can stand the rather high power level used for the trim pulse. Otherwise the probe is damaged!!

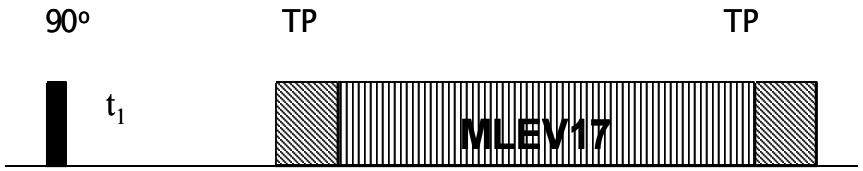
Selective dephasing of solvent signal by RF pulses

Purge pulses (spin-lock- or trim pulses) p28 = < 1.0ms @ pl1 (max. level of pl1 corresponding to 10μs 90 degree pulse)! use p28 only if you have a solvent signal to suppress, try without (p28 = 0.1ms) for inverse probeheads with latest design.

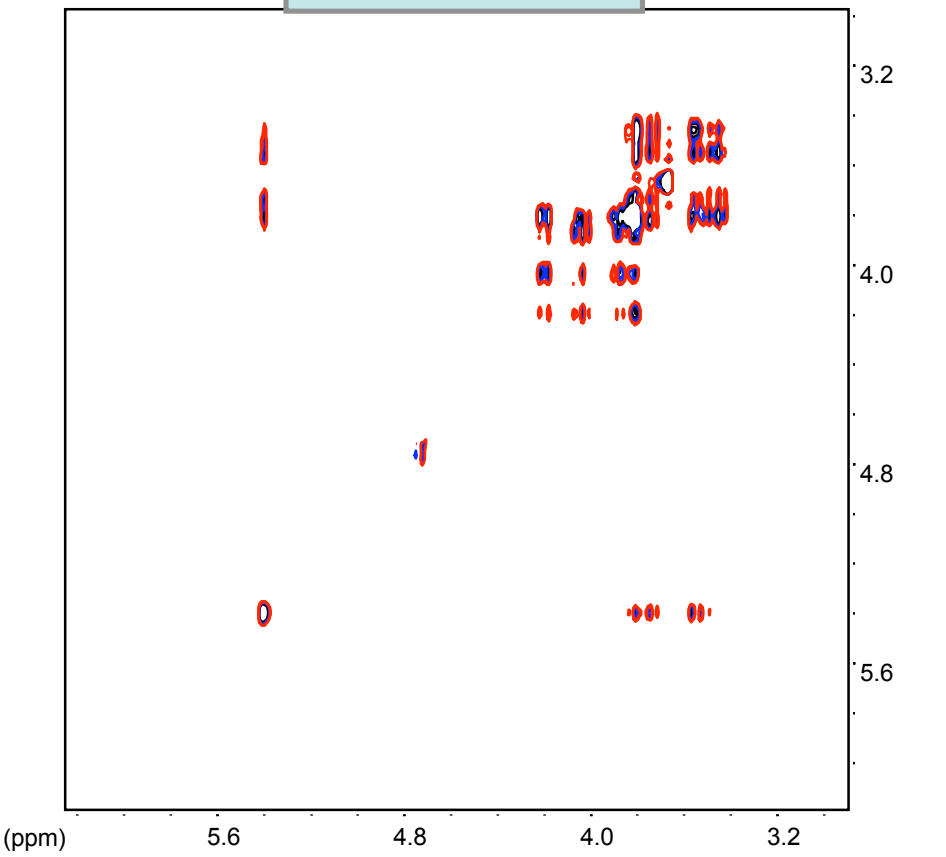
Example: hsqcetgpsi



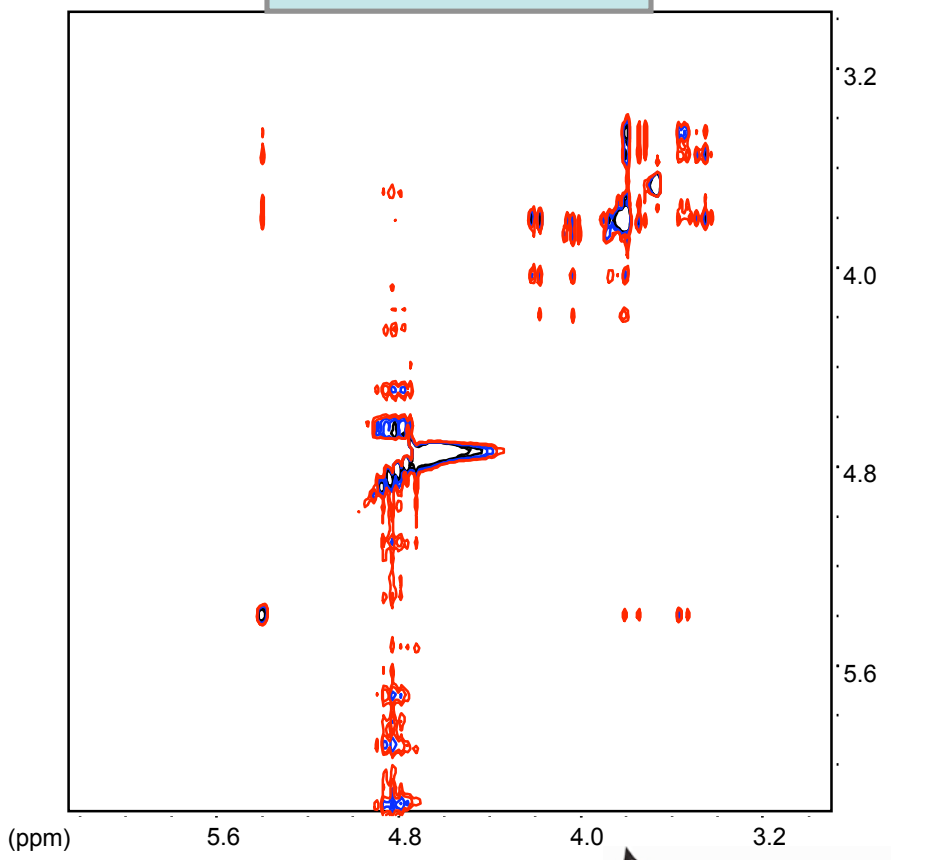
TOCSY experiment: effect of trim pulses



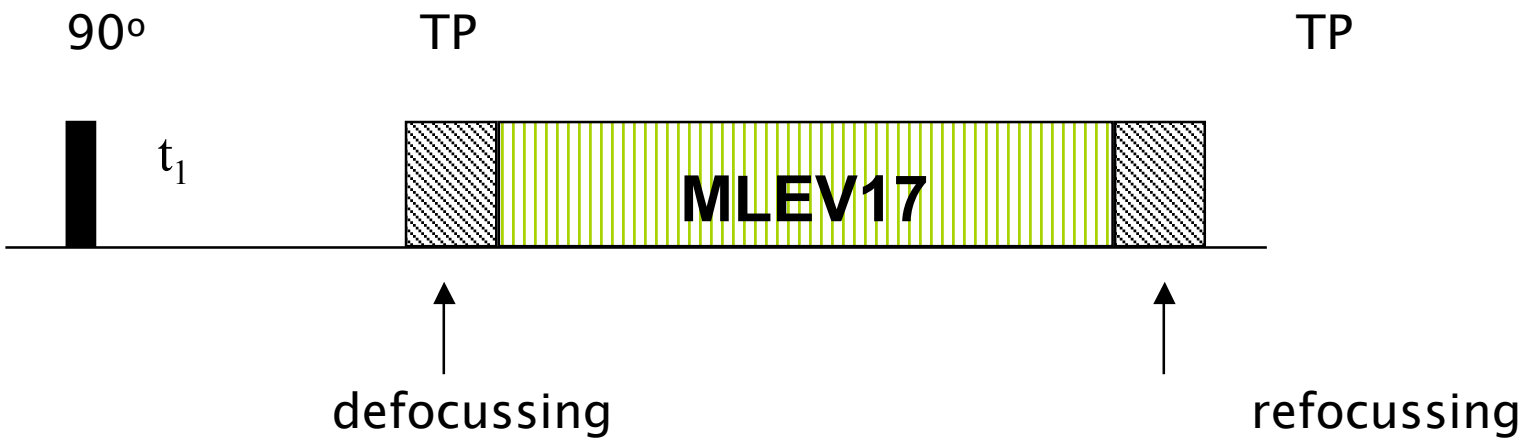
1 trim pulse



2 trim pulses



Effect of trim pulses when presaturation is applied



Problem:

The two trim pulses are acting as B_1-gradients.

First TP is defocussing residual water in inhomogeneous regions.

This water has not been presaturated.

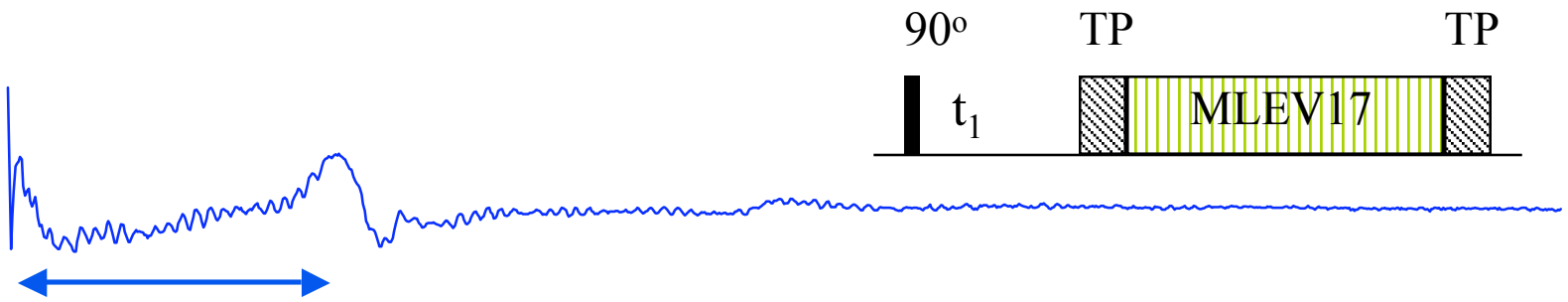
Second TP is refocussing that water.

Solution:

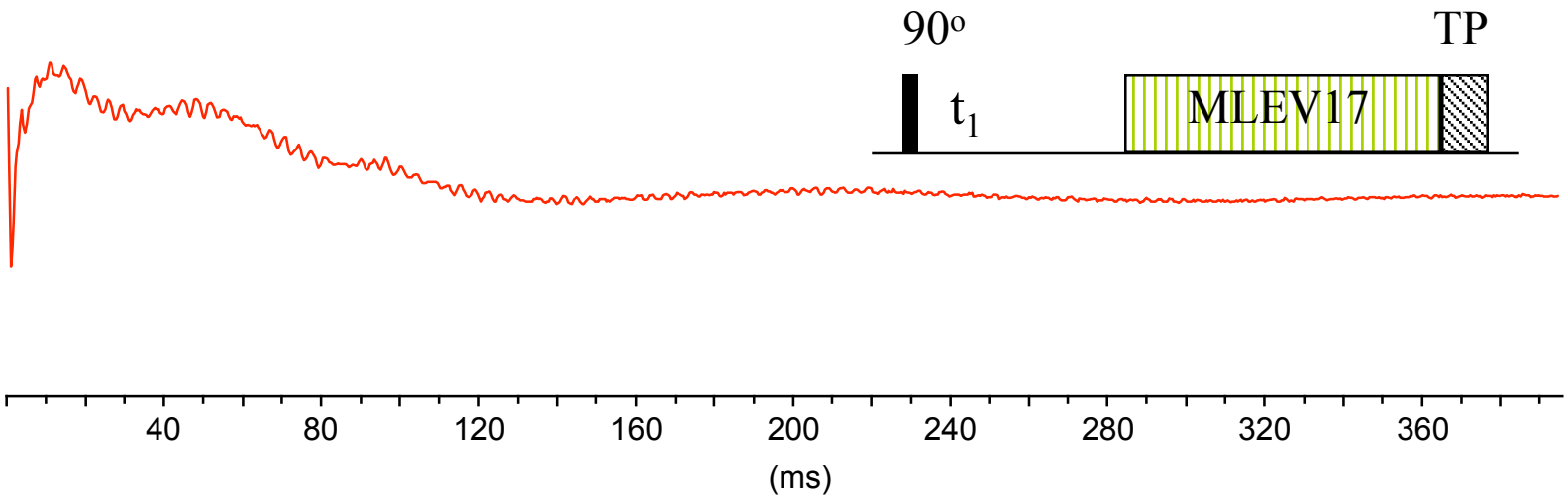
remove first trim pulse

TOCSY experiment: effect of trim pulses

first serial file of TOCSY experiment with presaturation



echo signal after 100ms = length of spinlock



Keeping the water magnetization along the +z axis

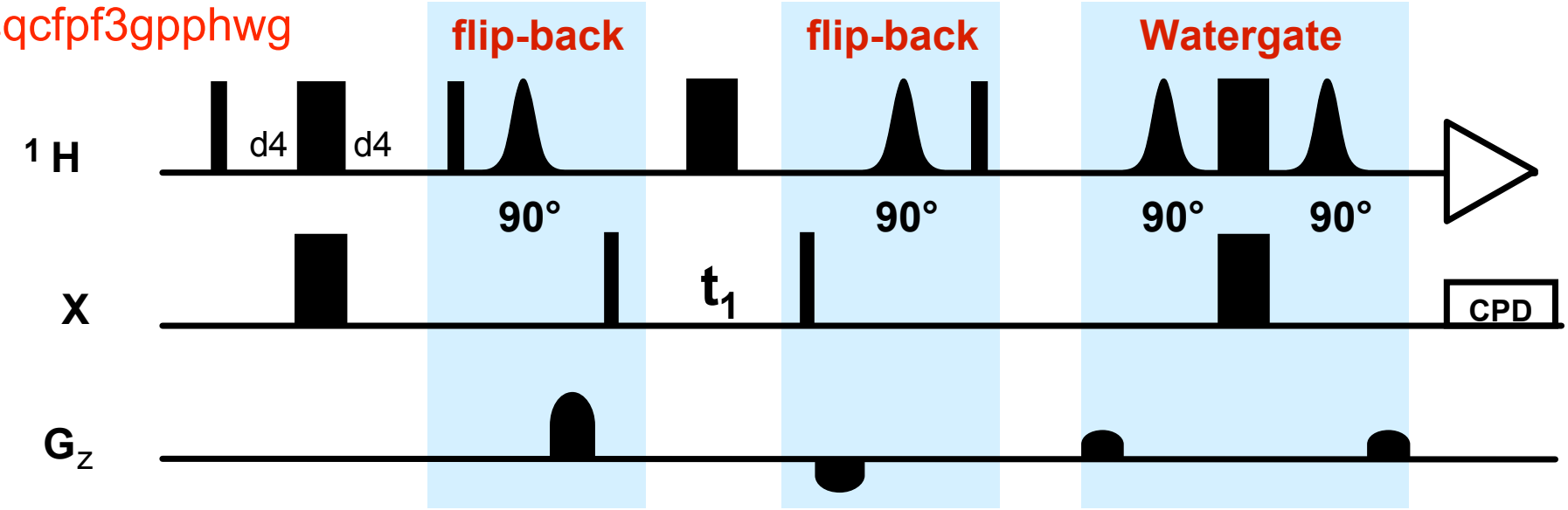
Common element in heteronuclear correlation experiments to improve WATERGATE

- **flip-back pulses** throughout the pulse sequence (prior to WATERGATE) to re-align transverse water magnetization along +z axis
- Pulse sequence names: …**fp**… with the following parameters:

selective on-resonant flip-back pulse: **p11** 1 - 2ms, the shorter the broader
shape of the flip-back pulse: **spnam1** sinc or rectangular pulse
power of the flip-back pulse: **sp1** calculate selective 90° pulse in stdisp (might be optimized in gs-mode)

HSQC with water-flip-back pulses & WATERGATE:

hsqcfpf3gpphwg

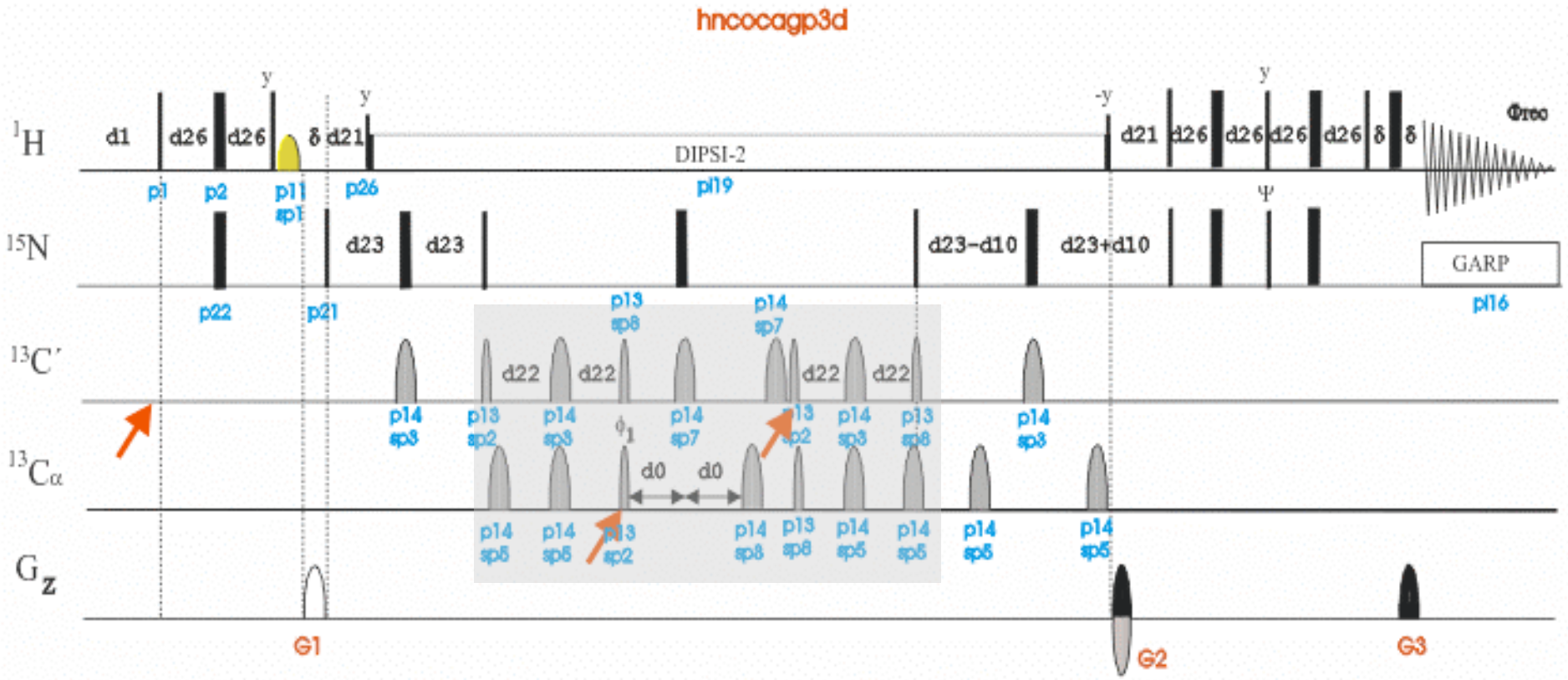


Trim Pulses

Flip back pulses

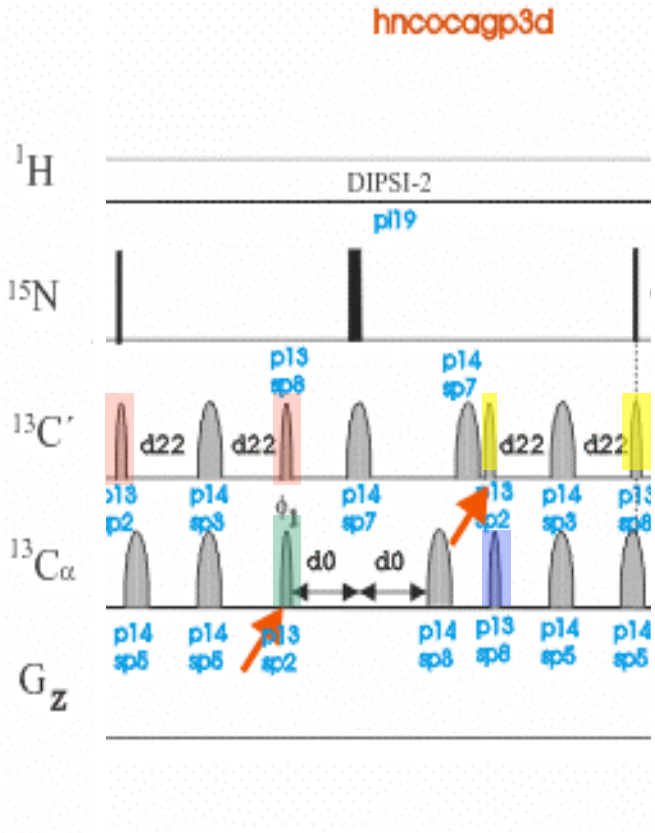
Shaped pulses in triple resonance experiments

HNCOCA


hncocagp3d
^{1}H
^{15}N
^{13}C'
^{13}Cα
G$_z$
d1
d26
d26
δ
d21
DIPSI-2
d21
d26
d26
d26
d26
δ
δ
Φrec
p1
p2
p11
sp1
p26
p19
Ψ
d23
d23
d23-d10
d23+d10
GARP
p22
p21
pl16
p13
sp8
p14
sp7
d22
d22
d22
d22
p14
sp3
p13
sp2
p14
sp3
ϕ_1
p14
sp7
d0
d0
p13
sp2
p14
sp3
p13
sp8
p14
sp3
p14
sp5
p14
sp5
p13
sp2
p14
sp8
p13
sp8
p14
sp5
p14
sp5
p14
sp5
G1
G2
G3

Time reversed 90° shaped pulses

HNCOCA

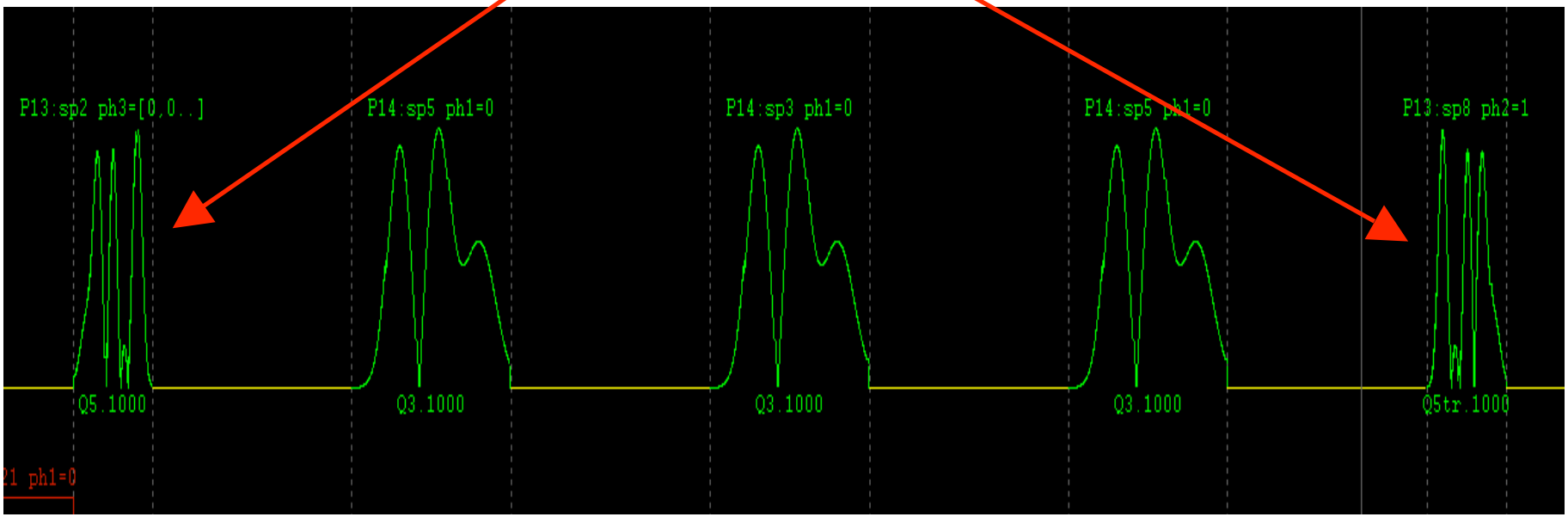


(p21 ph1):f3
(p13:sp2 ph3):f2
4u
(p14:sp5 ph1):f2
DELTA3
(p14:sp3 ph1):f2
4u
(p14:sp5 ph1):f2
DELTA3
(p13:sp8 ph2):f2 time reversed
4u
30u fq=cnst23(bf ppm):f2
(p13:sp2 ph4):f2
d28
(p14:sp3 ph1):f2
d28
(p13:sp8 ph2):f2 time reversed
d0
(center (p14:sp7 ph1):f2 (p22 ph8):f3)
d0

(p14:sp3 ph1):f2
DELTA4
(p14:sp7 ph1):f2
4u
(p13:sp2 ph9):f2
d28
(p14:sp3 ph1):f2
d28
(p13:sp8 ph10):f2 time reversed
4u
30u fq=cnst21(bf ppm):f2
(p13:sp2 ph2):f2
DELTA3
(p14:sp5 ph1):f2
4u
(p14:sp3 ph1):f2
DELTA3
(p14:sp5 ph1):f2
4u
(p13:sp8 ph1):f2 time reversed
(p21 ph1):f3

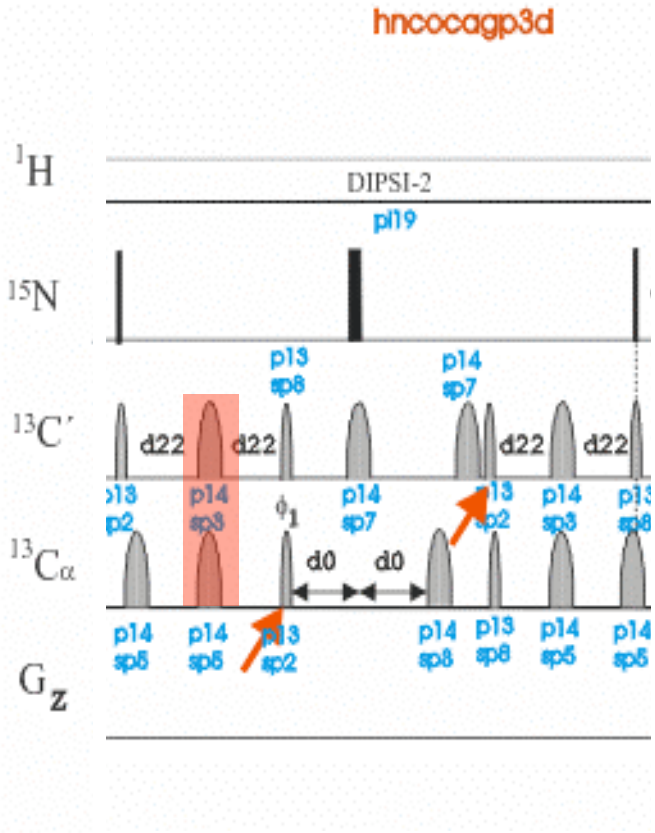
Time reversed 90° shaped pulses

Time reversed pulses



Simultaneous 180° shaped pulses

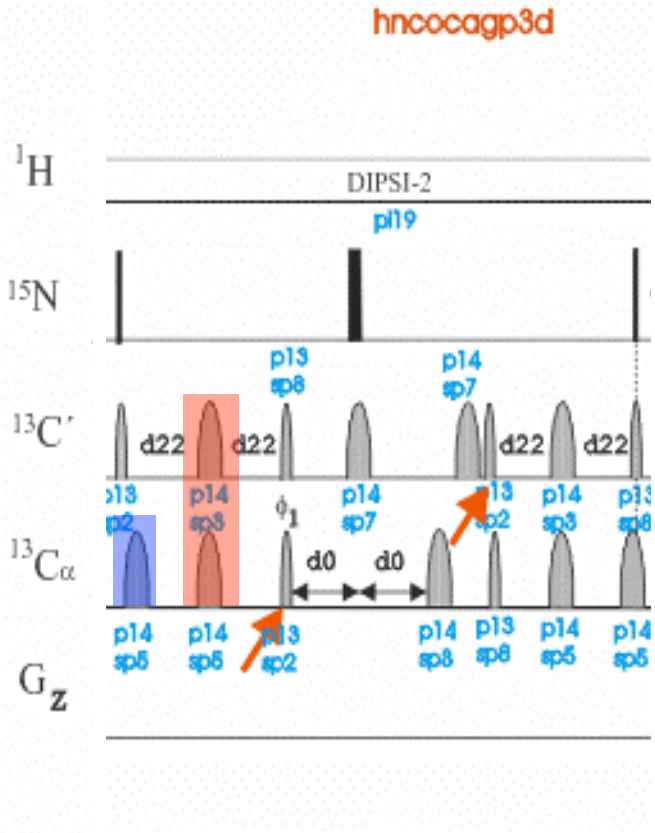
HNCOCA



(p21 ph1):f3
(p13:sp2 ph3):f2
4u
(p14:sp5 ph1):f2
DELTA3
(p14:sp3 ph1):f2
4u
(p14:sp5 ph1):f2
DELTA3
(p13:sp8 ph2):f2
4u
30u fq=cnst23(bf ppm):f2
(p13:sp2 ph4):f2
d28
(p14:sp3 ph1):f2
d28
(p13:sp8 ph2):f2
d0
(center (p14:sp7 ph1):f2 (p22 ph8):f3)
d0

Simultaneous 180° shaped pulses

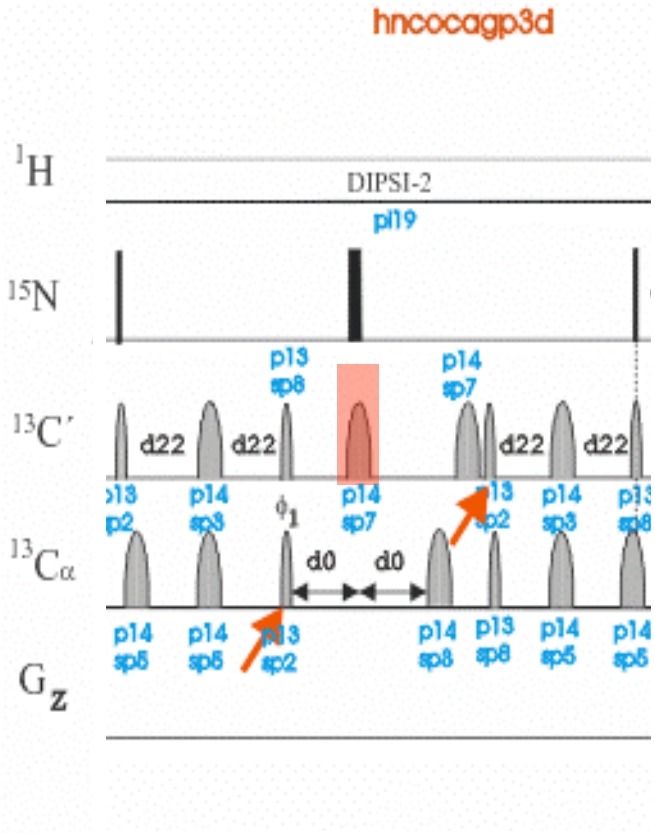
HNCOCA



(p21 ph1):f3
(p13:sp2 ph3):f2
4u
(p14:sp5 ph1):f2
DELTA3
(p14:sp3 ph1):f2
4u
(p14:sp5 ph1):f2
DELTA3
(p13:sp8 ph2):f2
4u
30u fq=cnst23(bf ppm):f2
(p13:sp2 ph4):f2
d28
(p14:sp3 ph1):f2
d28
(p13:sp8 ph2):f2
d0
(center (p14:sp7 ph1):f2 (p22 ph8):f3)
d0

Single 180° shaped pulses

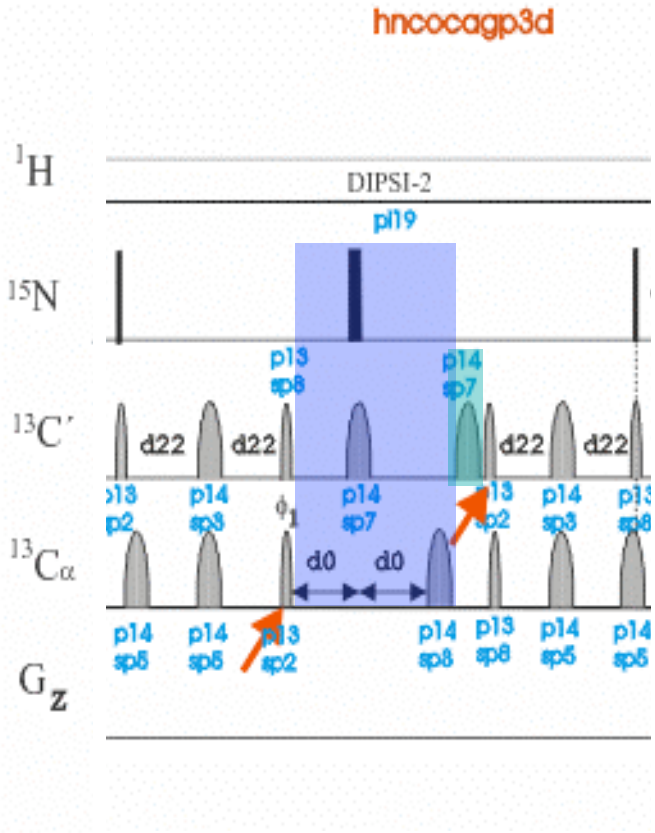
HNCOCA



(p21 ph1):f3
(p13:sp2 ph3):f2
4u
(p14:sp5 ph1):f2
DELTA3
(p14:sp3 ph1):f2
4u
(p14:sp5 ph1):f2
DELTA3
(p13:sp8 ph2):f2
4u
30u fq=cnst23(bf ppm):f2
(p13:sp2 ph4):f2
d28
(p14:sp3 ph1):f2
d28
(p13:sp8 ph2):f2
d0
(center (p14:sp7 ph1):f2 (p22 ph8):f3)
d0

Refocused phase evolution during t_1:180° shaped pulses

HNCOCA



(p21 ph1):f3
(p13:sp2 ph3):f2
4u
(p14:sp5 ph1):f2
DELTA3
(p14:sp3 ph1):f2
4u
(p14:sp5 ph1):f2
DELTA3
(p13:sp8 ph2):f2
4u
30u fq=cnst23(bf ppm):f2
(p13:sp2 ph4):f2
d28
(p14:sp3 ph1):f2
d28
(p13:sp8 ph2):f2
d0
(center (p14:sp7 ph1):f2 (p22 ph8):f3)
d0
(p14:sp3 ph1):f2
DELTA4 d0*2+larger(p14,p22)-p14
(p14:sp7 ph1):f2

Shaped pulses in Triple Resonance Experiments

- Pairs of 90^{o} pulses: final pulse is time-reversed
- Compensation for phase evolution during t_1: spin-echo
- BS compensation for 180^{o} pulses: pair of 180^{o} pulses