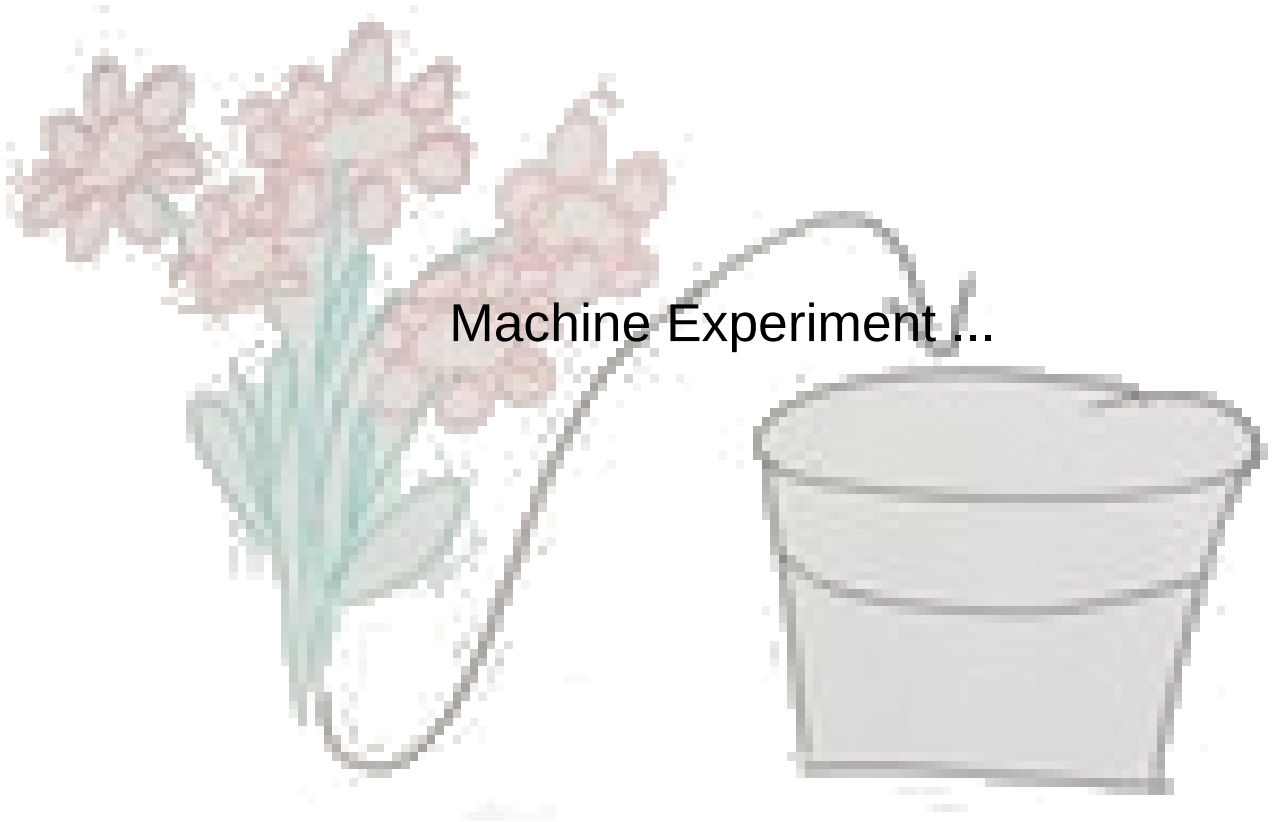
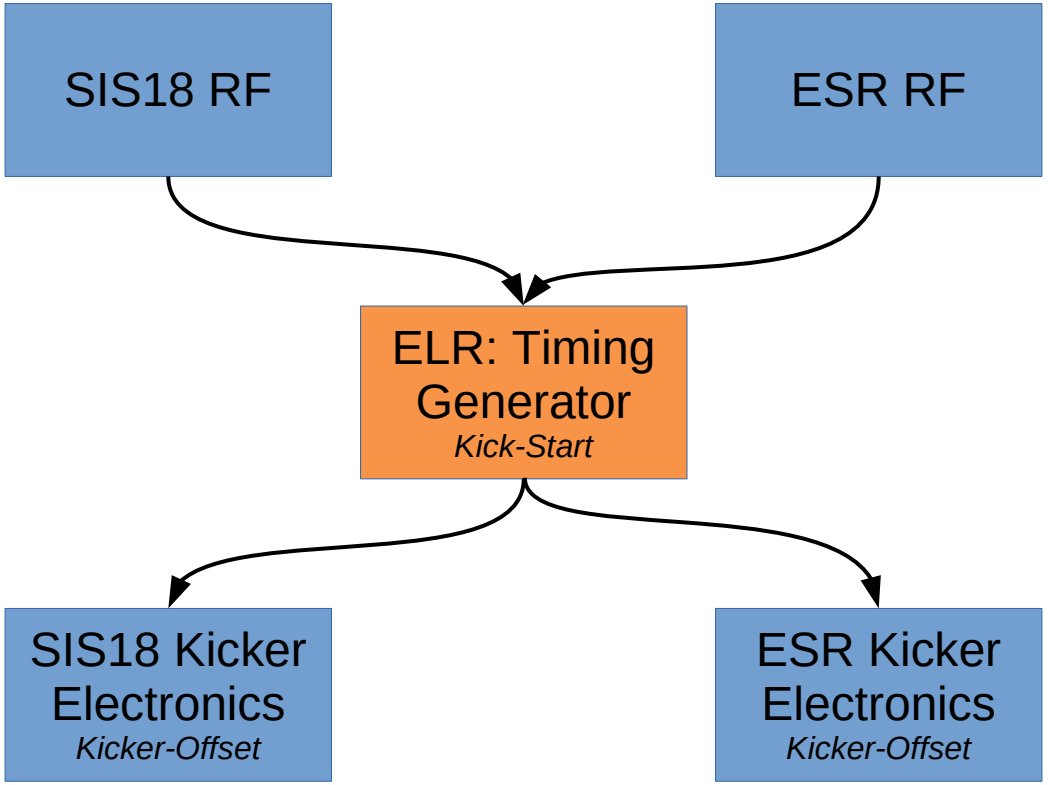
Bunch to Bucket Lite

Dietrich Beck, Dieter Lens - GSI



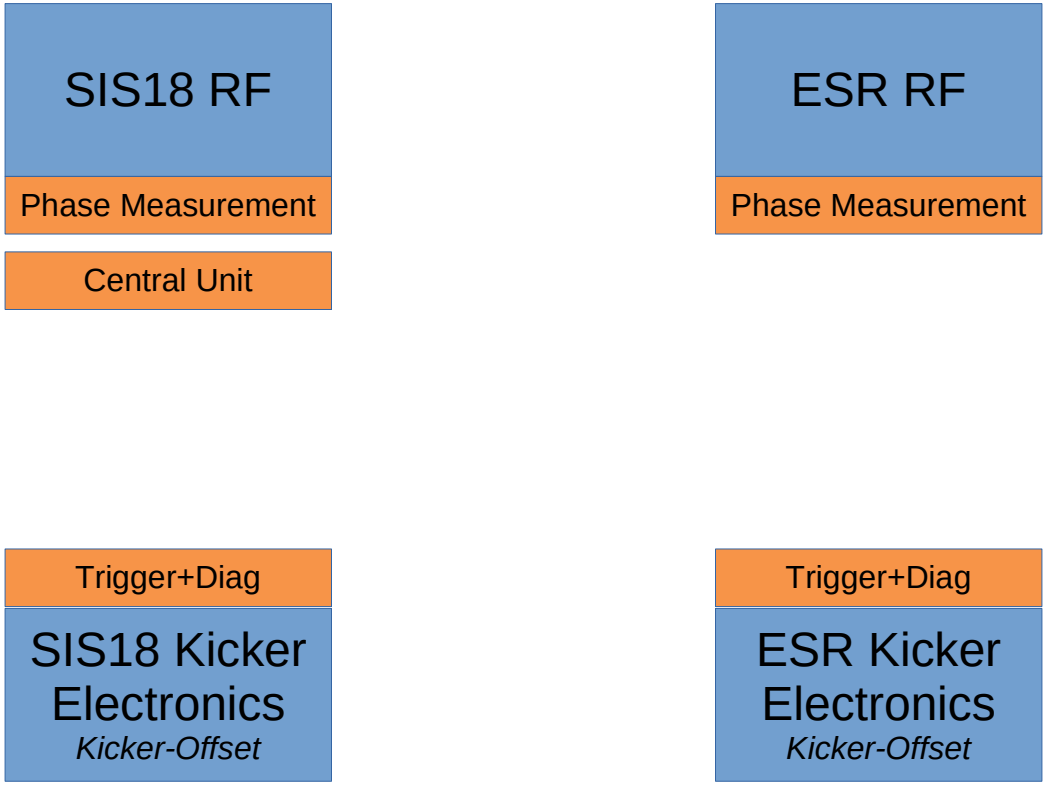
‘Old’ Setup

‘old’ system: analog signals on copper cables

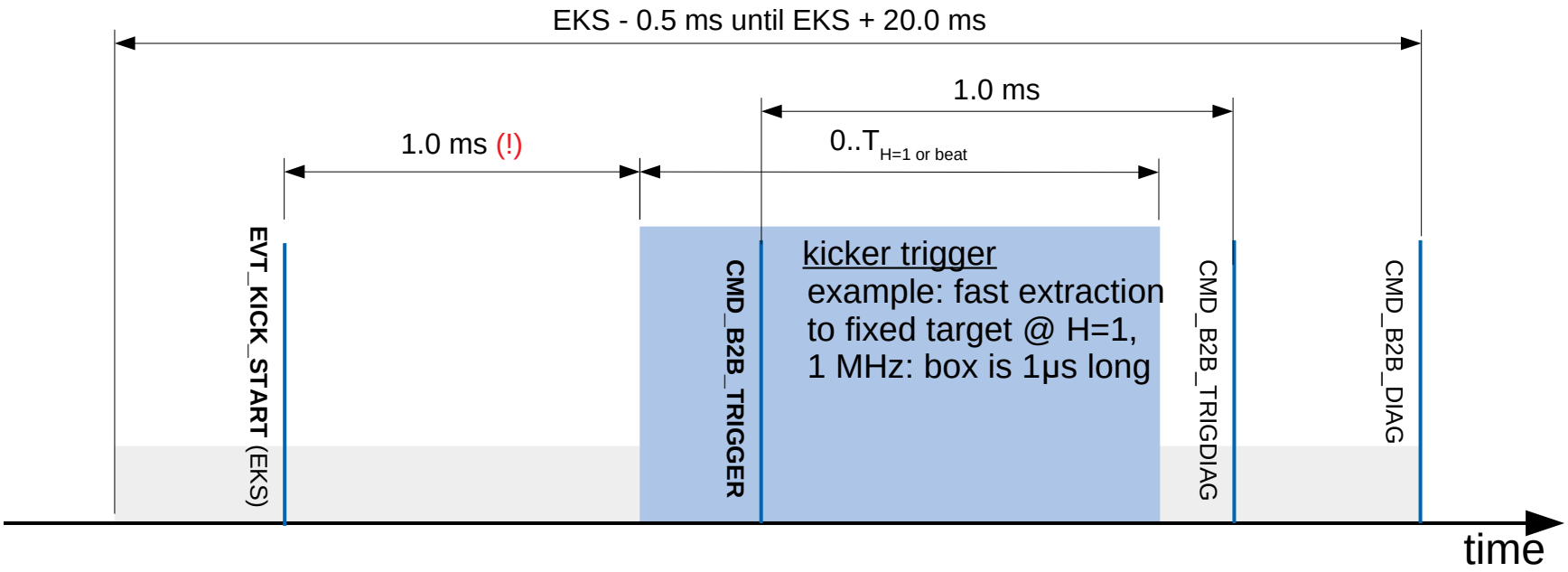


B2B Setup

B2B: distributed, no copper, no analog cables; ParamModi: no value *Kick-Start*



B2B Schedule

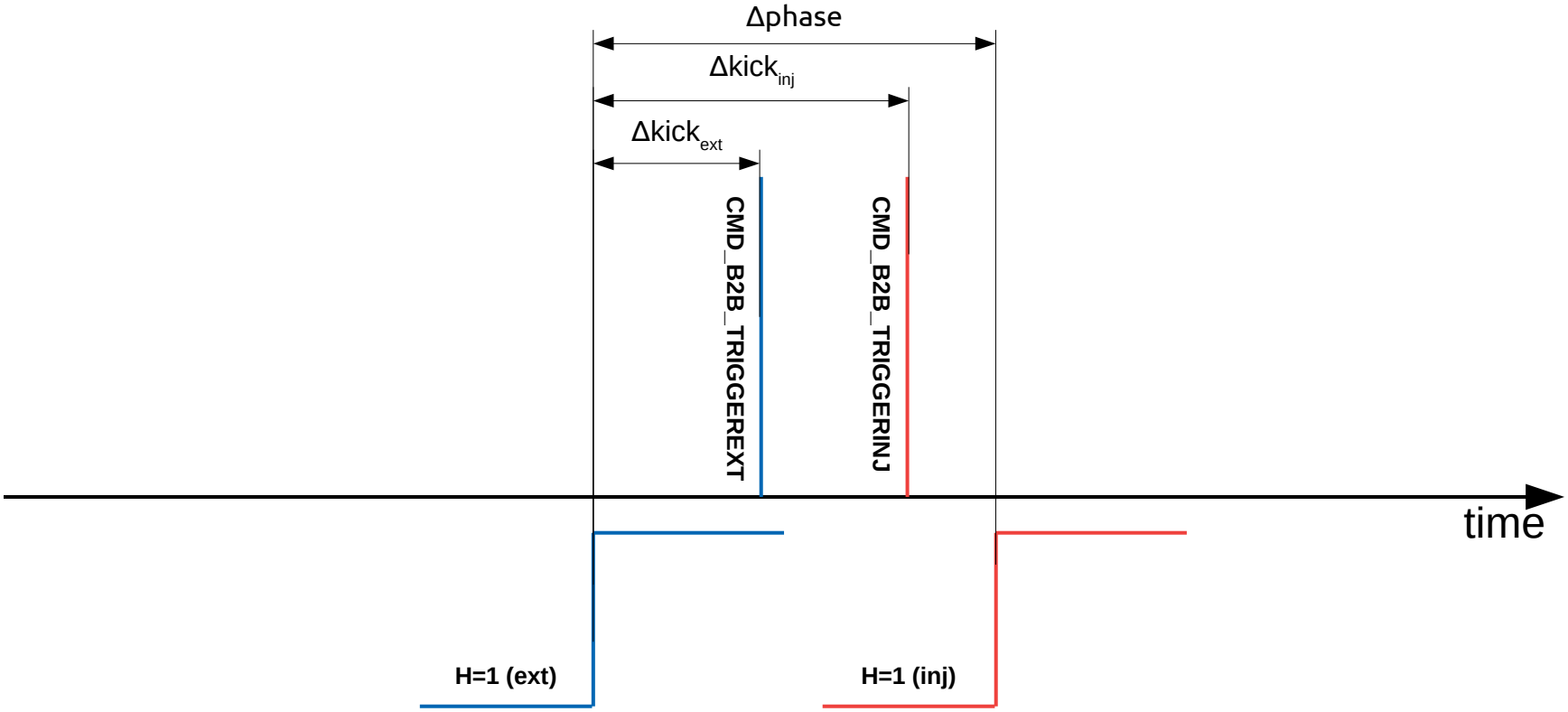


- grey box, extraction: flat-top required from EKS -0.5 ms until EKS + 20.0 ms
- grey box, injection: same, but for injection level instead of flat-top
- blue box, trigger for kickers: t_{min} = EKS + 1ms, t_{max} = EKS + 1ms + $T_{H=1 \text{ or beat}}$
- (border case: trigger @ EKS for simplified kicker tests)

- CMD_B2B_TRIGGERDIAG: measured kick time (electronics, magnet) delivered 1ms after trigger
- CMD_B2B_DIAG: measured skew between H=1 signals and kick time, H=1 frequencies measurement

B2B Adjustments

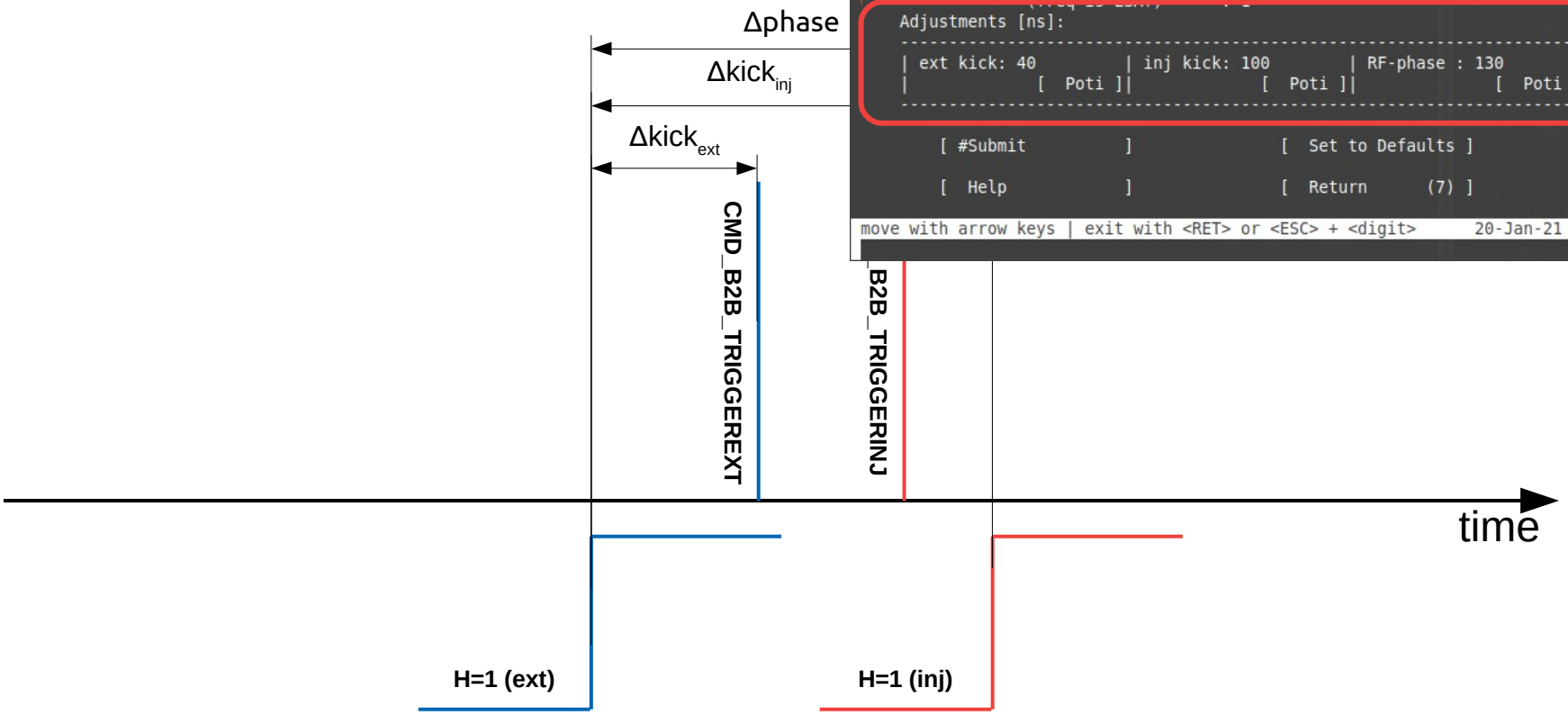
real life: time-of-flight, delays (cables, kicker …), location of cavities ...



- three ‘free’ parameters for adjustments
- can be set independently
- all values are relative to the rising edge of H=1 (extraction)

B2B Adjus

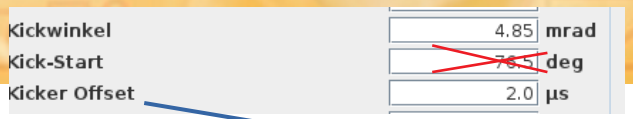
real life: time-of-flight, delays (cables, kicker




```
Terminal
File  Edit  View  Search  Terminal  Help
I V T P A R ---------------------------------------------- GB, DB 1989-2020
                        Transfer from SIS18
                        -------------------
   Comment           : SID-7
   Mode              : 4             (0: off; 1: EKS, 2: B2E; 3: B2C; 4: B2B)
   Injection to Ring : 1             (1: ESR)

   Extraction   H=1 frequency [Hz]  : 1343929.0
                harmonic number     : 2
   Injection    H=1 frequency [Hz]  : 2687758.000000000
                harmonic number     : 1
                (freq is LSA?)      : 1

   Adjustments [ns]:
   ------------------------------------------------------------------------
   | ext kick: 40         | inj kick: 100        | RF-phase : 130        |
   |            [  Poti ]|            [  Poti ]|             [  Poti ]|
   ------------------------------------------------------------------------

       [ #Submit          ]             [  Set to Defaults ]

       [  Help            ]             [  Return      (7) ]

move with arrow keys | exit with <RET> or <ESC> + <digit>      20-Jan-21 22:17
```

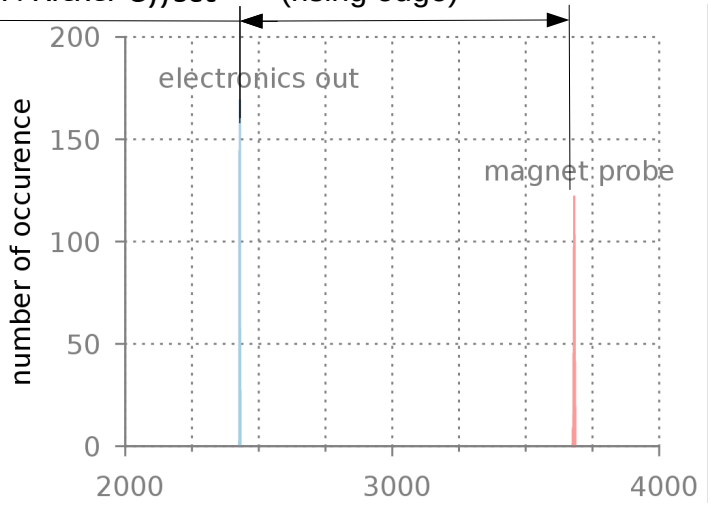
- three ‘free’ parameters for adjustments
- can be set independently
- all values are relative to the rising edge of H=1 (extraction)

RF Triggered Extraction: Kicker Timing



ParamModi : *Kicker Offset*

magnet response (rising edge)



$\Delta kick_{ext}$

CMD_B2B_TRIGGEREXT

H=1 (ext)

time

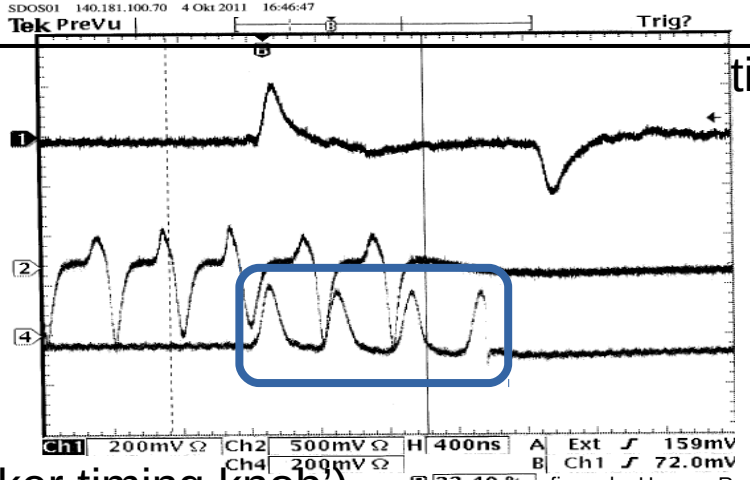


figure by Hannes Reeg

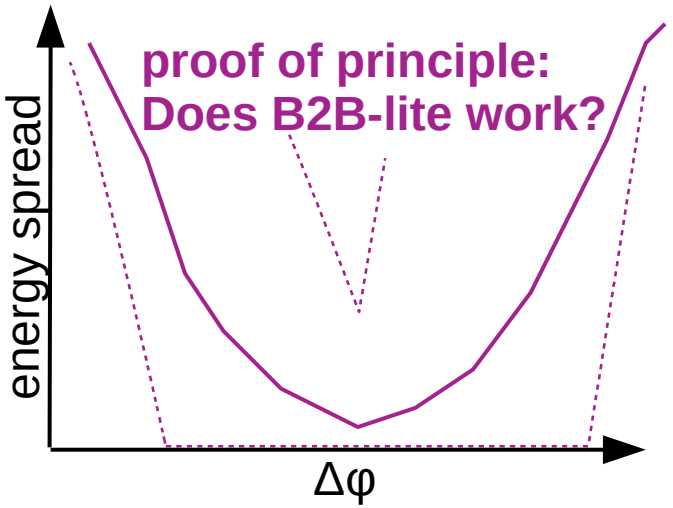
- $\Delta kick_{ext}$: B2B
- 'Kicker Offset': ParamModi
- (injection works the same)
- (we need to agree, who turns which 'kicker timing knob')

Diagnostics and ‘Program’

SIS18 extraction kicker adjustment
- can be done by extracting the beam anywhere
- FCT after SIS18

ESR injection kicker adjustment
- can be done with ‘bunch-to-coasting beam’ into ESR
- FCT in ESR (?)

relative RF phase
- ‘bunch-2-bucket’
- FCT + analysis in ESR
- estimate energy/momentum spread
- energy spread as a function of relative phase
  - for various beating frequencies ...
- ...



ESR extraction ?
- in principle possible
- selection of FCT needs to be considered only ‘nice to have’

Other

H=1 frequencies and harmonic numbers must be supplied manually to the B2B system; no control system integration yet

adjustment of kicker timing: B2B or ParamModi?

‘Doppelschussverfahren’ not implemented with B2B (but straight forward!)

viewing/analysis of analog signals: how and from where (HKR, office?)

swap cables in SIS18+ESR kicker rooms

help with setting up and modifying patterns; a higher rate would be extremely helpful: maybe shorten pattern length for ESR?

parallel operation of other patterns from SIS18 with fast RF-triggered extraction should be possible (only the revolution frequency at flat-top and kicker-offset needs to be set once)

Backup Slides

ruth@tsl023: ~

File Edit View Search Terminal Help

```
      ___ ___ ___  ___ ___ ___ _  ___  _
     | _ )_  ) _ )/ __|_ _/ __/ |( _ )| |_ ___
     | _ \/ /| _ \\__ \| |\__ \ |/ _ \|  _/ _ \
     |___/___|___/|___/___|___/_|\___/ \__\___/ (_) (_) (_)

--- Status ----------- SID  1,          'bunch 2 bucket', #transfer    30 ---
events   :   PME   PMI   PRE   PRI   KTE   KTI   KDE   KDI   PDE   PDI @ 100.0 ms
required:     X     X     X     X     X     X     X     X     X     X
received:     X     X     X     X     X     X     X     X     X     X
late     :
error    :                                               X

--- Set Values ---------------------------------------------------------------
ext: kick  corr  -47 ns; gDDS     594174.163416 Hz,     1683.008218 ns, H = 2
     next gDDS step @ LSA value   594174.209982 Hz
inj: kick  corr  -47 ns; gDDS    1188298.454509 Hz,      841.539427 ns, H = 1
     next gDDS step @ LSA value  1188298.501075 Hz
B2B: phase corr    0 ns,               0.000°
     Beating ----------------------------------------------------------------
     ext                         1188348.326832 Hz,       841.504109 ns
     inj                         1188298.454509 Hz,       841.539427 ns
     diff                              0.015°               0.035318 ns
     beating                         49.871929 Hz,  20051359.916860 ns
     ext                                              23828.000008 periods
     inj                                              23827.000000 periods
     calc delta [@1ns]              -0.003° [ 0.428°]    -0.006654 ns

--- Get Values ---------------------------------------------------------------
ext: 'kick delay'   electronics  2430 ns, magnet  3677 ns, RF bonus 7407181 ns
inj: 'kick delay'   electronics    UNKWN, magnet    UNKWN, RF bonus 7407181 ns
ext: 'kick-gDDS [ns]'  act  -47, ave(sdev)  -47.613( 0.495), minmax  -48,   -47
inj: 'kick-gDDS [ns]'  act  -46, ave(sdev)  -47.323( 0.541), minmax  -48,   -46

--- B2B Diagnostics ------------------ #ext    30, #inj    30, #B2B    30 ---
ext: 'gDDS       [ns]' act    0, ave(sdev)   -0.613( 0.495), minmax   -1,    0
inj: 'gDDS       [ns]' act    1, ave(sdev)   -0.323( 0.541), minmax   -1,    1
B2B: 'phase      [ns]' act   -1, ave(sdev)   -0.290( 0.529), minmax   -1,    1
     'phase-corr [ns]' act   -1, ave(sdev)   -0.290( 0.529), minmax   -1,    1
ext: 'gDDS        [°]' ave(sdev)   -0.131( 0.106), minmax   -0.214,    0.000
inj: 'gDDS        [°]' ave(sdev)   -0.069( 0.116), minmax   -0.214,    0.214
B2B: 'phase       [°]' ave(sdev)   -0.062( 0.113), minmax   -0.214,    0.214
     'phase-corr  [°]' ave(sdev)   -0.062( 0.113), minmax   -0.214,    0.214

--- RF Diagnostics @ 20.0 ms --------------------- #ext    30, #inj    30 ---
ext: 'gDDS raw   [ns]' act    0, ave(sdev)   -0.290( 0.461), minmax   -1,    0
inj: 'gDDS raw   [ns]' act    0, ave(sdev)   -0.097( 0.396), minmax   -1,    1
ext: 'gDDS       [Hz]' ave(sdev)594174.172042(0.002975), diff  0.008626
     'gDDS       [Hz]' calc     594174.163416 - best guess
     'LSA        [Hz]' calc     594174.186699 - proposed safe value
inj: 'gDDS       [Hz]' ave(sdev)1188298.460258(0.004516), diff  0.005750
     'gDDS       [Hz]' calc     1188298.454508 - best guess
     'LSA        [Hz]' calc     1188298.477791 - proposed safe value
```

ruth@tsl023: ~

File Edit View Search Terminal Help

```
I V T P A R ---------------------------------------------- GB, DB 1989-2020
                            Transfer from SIS18
                            -------------------
    Comment            : SID-1#
    Mode               : 4            (0: off; 1: EKS, 2: B2E; 3: B2C; 4: B2B)
    Injection to Ring  : 1            (1: ESR)

    Extraction   H=1 frequency [Hz]  : 594174.200000000
                 harmonic number     : 2
    Injection    H=1 frequency [Hz]  : 1188248.600000000
                 harmonic number     : 1
                 (freq is LSA?)      : 1
    Adjustments [ns]:
    ----------------------------------------------------------------------
    | ext kick: -47         | inj kick: -46         | RF-phase : 0         |
    |             [  Poti ]|             [  Poti ]|             [  Poti ]|
    ----------------------------------------------------------------------

        [  Submit          ]              [  Set to Defaults ]

        [  Help            ]              [  Return      (7) ]

move with arrow keys | exit with <RET> or <ESC> + <digit>      15-Jan-21 15:00
```

B2B Lite: Background and Idea

- with control loops off, Group DDS frequencies match known LSA values
- no frequency measurement required

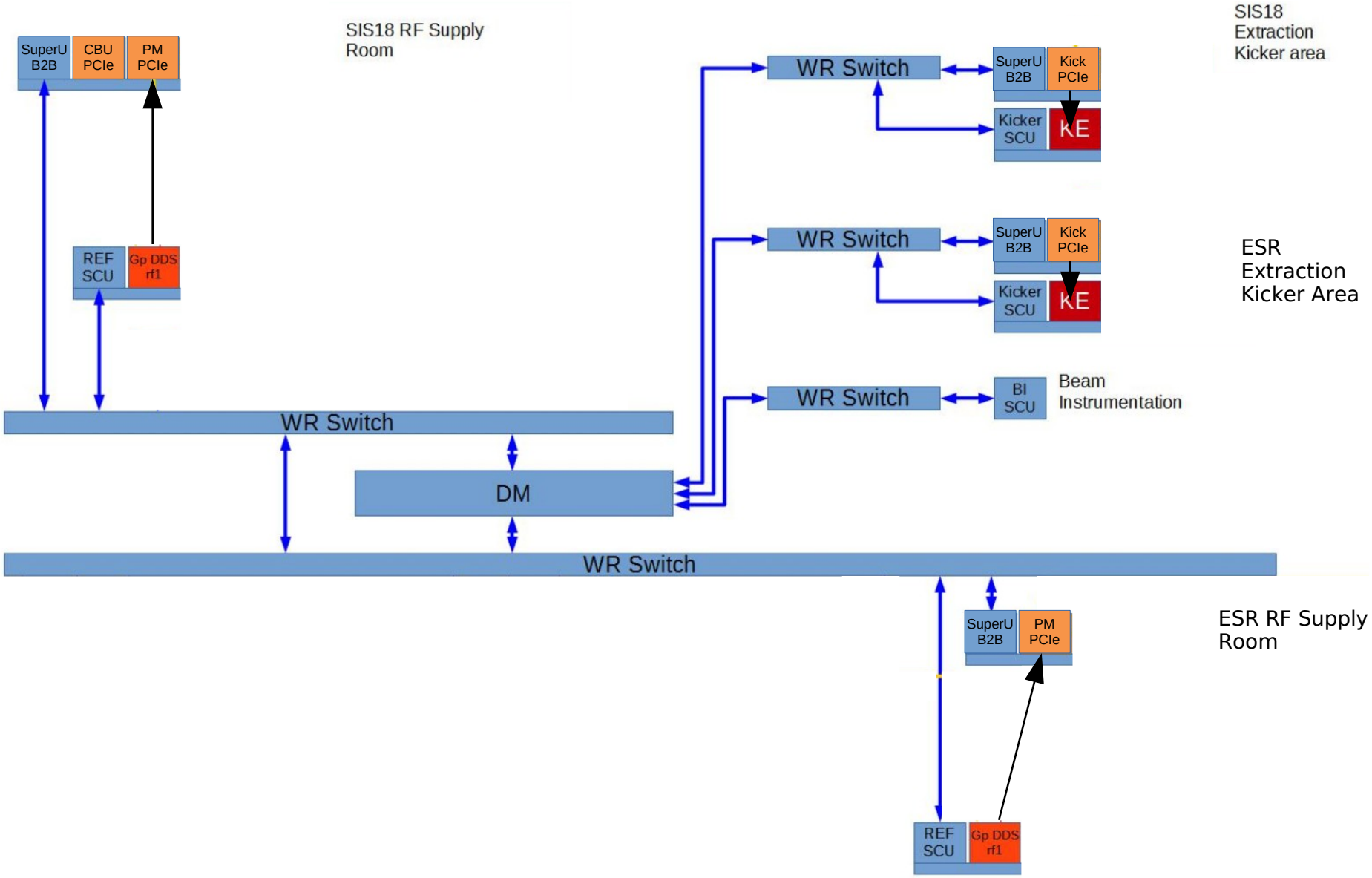
- White Rabbit and BuTiS share the same reference clock
- identical propagation of time
- it does not matter where and how we measure/reproduce signals[1]

- dφ ≈ 1ns requirement:
- a White Rabbit Timing Receiver is good enough

- ‘Frequency Beating’ can be done without hardware development!
- ‘Phase Shift’ requires development at RRF

[1] subtle differences in terms of ‘phase noise’ or ‘frequency drift’ are on the 1-digit-picosecond-scale and irrelevant here

B2B Lite


SIS18 RF Supply Room
SuperU B2B
CBU PCIe
PM PCIe
REF SCU
Gp DDS rf1
WR Switch
DM
WR Switch
SIS18 Extraction Kicker area
WR Switch
SuperU B2B
Kick PCIe
Kicker SCU
KE
WR Switch
SuperU B2B
Kick PCIe
Kicker SCU
KE
ESR Extraction Kicker Area
WR Switch
BI SCU
Beam Instrumentation
SuperU B2B
PM PCIe
REF SCU
Gp DDS rf1
ESR RF Supply Room