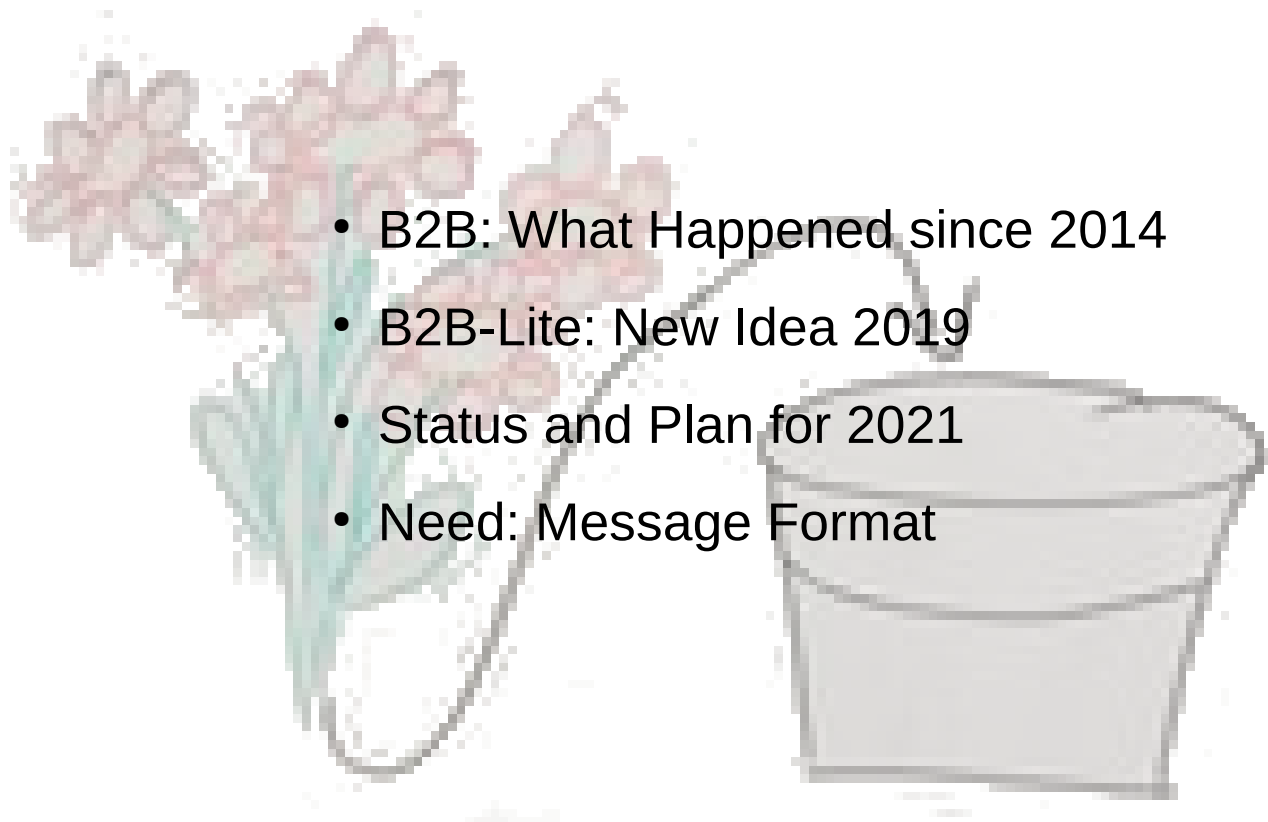# Bunch to Bucket Lite[1]

**Dietrich Beck, Dieter Lens - GSI**

- B2B: What Happened since 2014

- B2B-Lite: New Idea 2019

- Status and Plan for 2021

- Need: Message Format

[1] "Light (… manchmal auch *lite*) ist eine verbreitete Zusatzbezeichnung… Je nach Produkt steht *light* für einen reduzierten Gehalt an Bestandteilen...", siehe https://de.wikipedia.org/wiki/Light-Produkt

# B2B

- transfer 'ring – ring' ('ring – target')
- requires RF phase matching
- old control system: 'timing generator' + long cables
- new control system: distributed solution

1. RF control loop(s) off
2. frequency and phase measurement(s) in RF supply rooms
3. data transfer to central unit
4. calculation by central unit
5. 'frequency beating' or 'phase shift'
6. data transfer to kicker room(s)
7. fire kickers(s)

- requirement: dφ ~ 0.5°
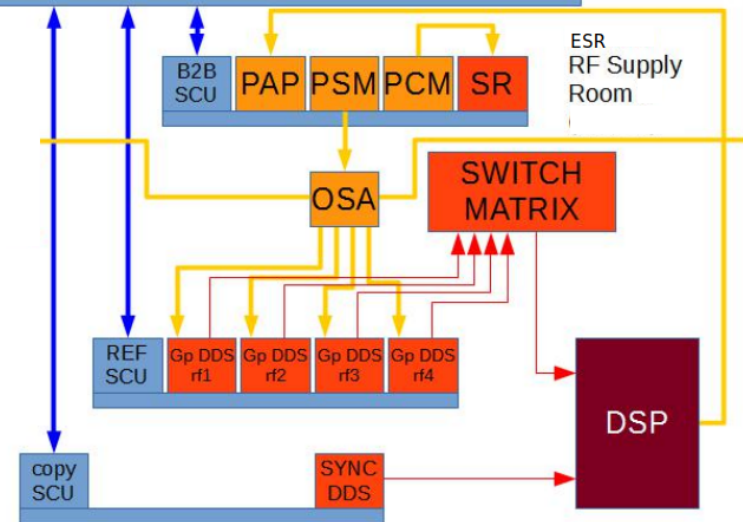- example: SIS18, f ≈ 1.5 MHz ⇒ dφ ≈ 1ns

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# What Happened Since 2014

- 2014, 2015: Kick-Off, conceptual work
- 2016: Technical Concept
- 2017: Technical Concept approved, new work package 'B2B', WP12 development of MHU required, but …
- 2017, spring: activities frozen (no personnel, operation existing facility, ...)
- 2018: frozen ...
- 2019: B2B-lite (plan 'B')

# B2B 2017
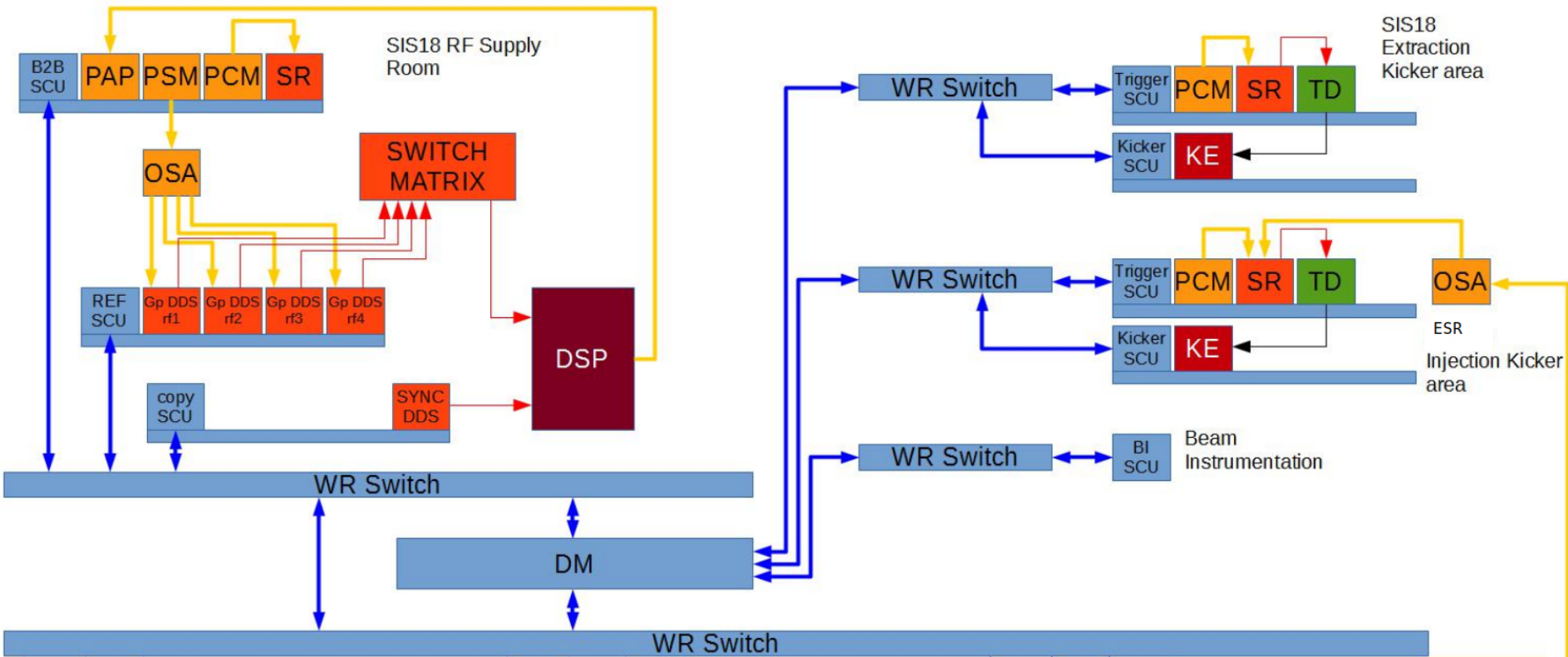


- frequency and phase measurement
- BuTiS as distributed reference clock
- GMT used for data transfer only

# B2B Lite: Background and Idea

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

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

- dφ ≈ 1ns requirement:

Group DDS signals corrected in phase and frequency by different sources
corrections in general unknown to LSA (especially those from real-time loops)

- calibration: phase shift
- beam phase control: phase shift
- K.O. (slow) extraction: frequency shift
- radial loop (might come in future): frequency shift
- ...

assumption: B2B transfer is not used with K.O. extraction
other frequency shifts are set to zero during B2B transfer ⇒ **B2B Lite**

- 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: Background and Idea

- with control loops off, DDS frequencies match known LSA values
- <u>no frequency measurement required</u>

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

- $d\varphi \approx 1ns$ requirement:
- a White Rabbit Timing Receiver is good enough

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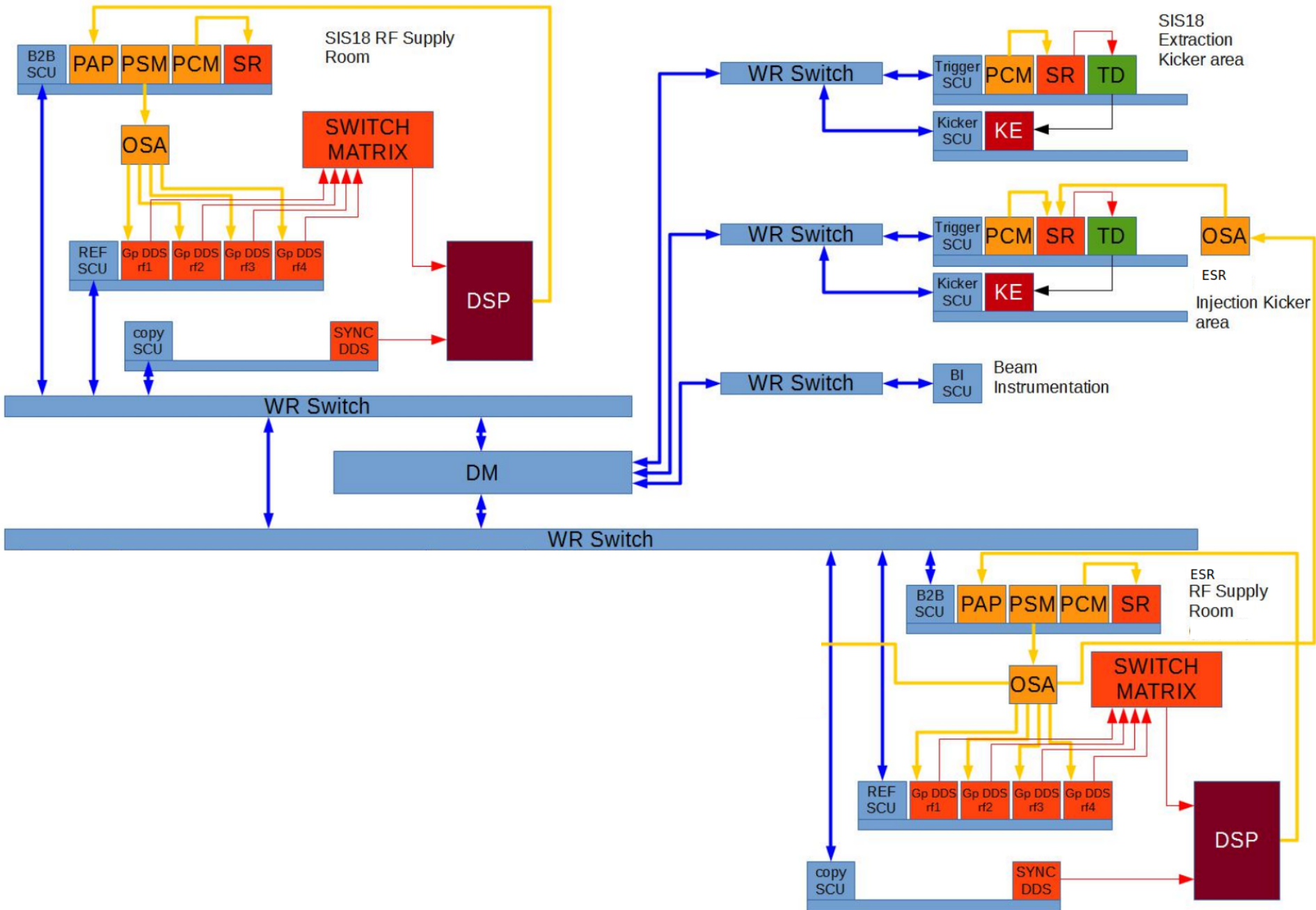- 'Phase Shift' requires development at RRF

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

**GSI**

# 23 Dec 2019 – Phase Match via Frequency Beating
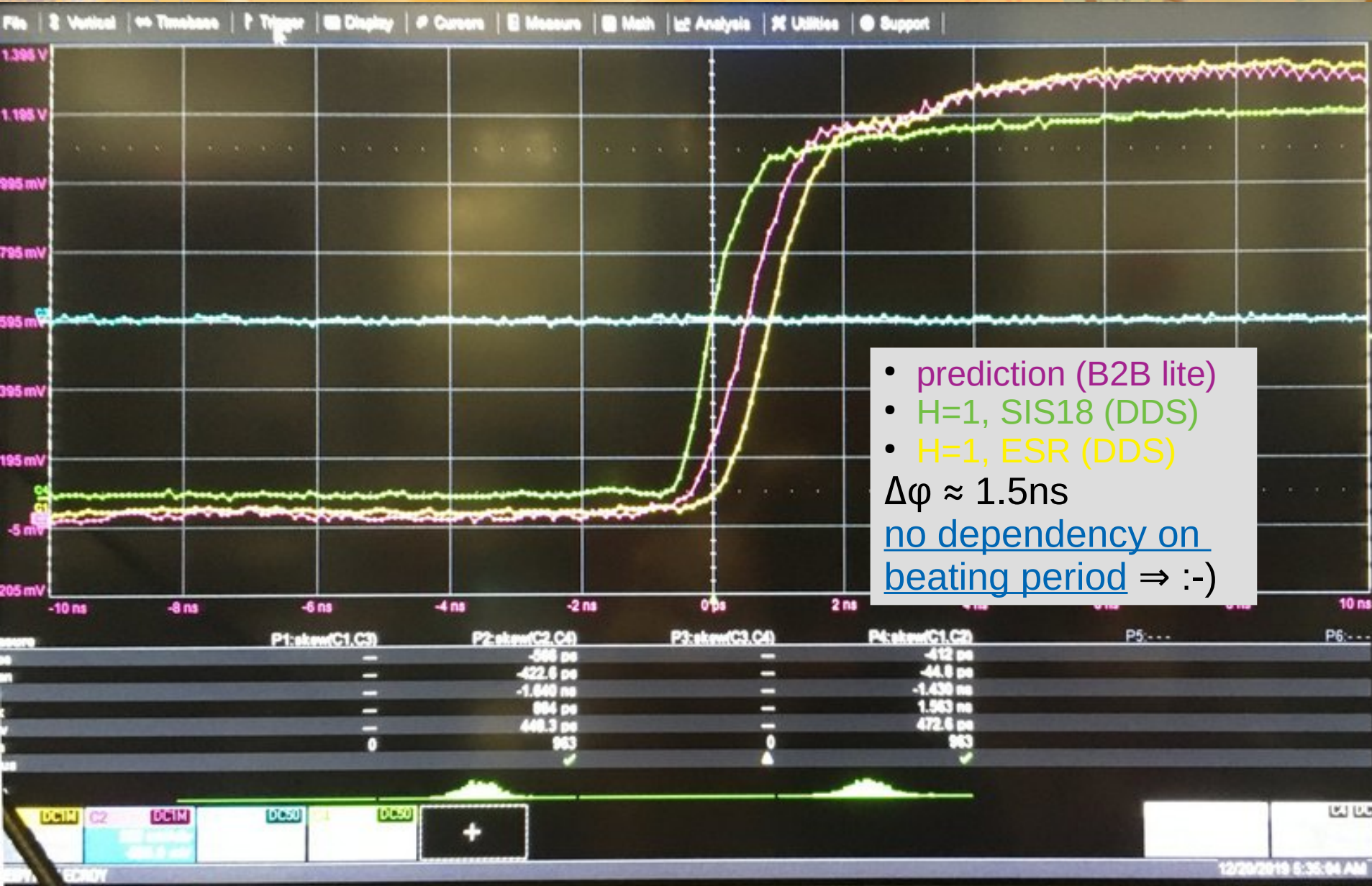


- prediction (B2B lite)
- H=1, SIS18 (DDS)
- H=1, ESR (DDS)

Δφ ≈ 1.5ns
no dependency on beating period ⇒ :-)

# B2B 2017

# B2B Lite

# B2B Lite



SIS18 RF Supply Room

SIS18 Extraction Kicker area

ESR Extraction Kicker Area

Beam Instrumentation

ESR RF Supply Room
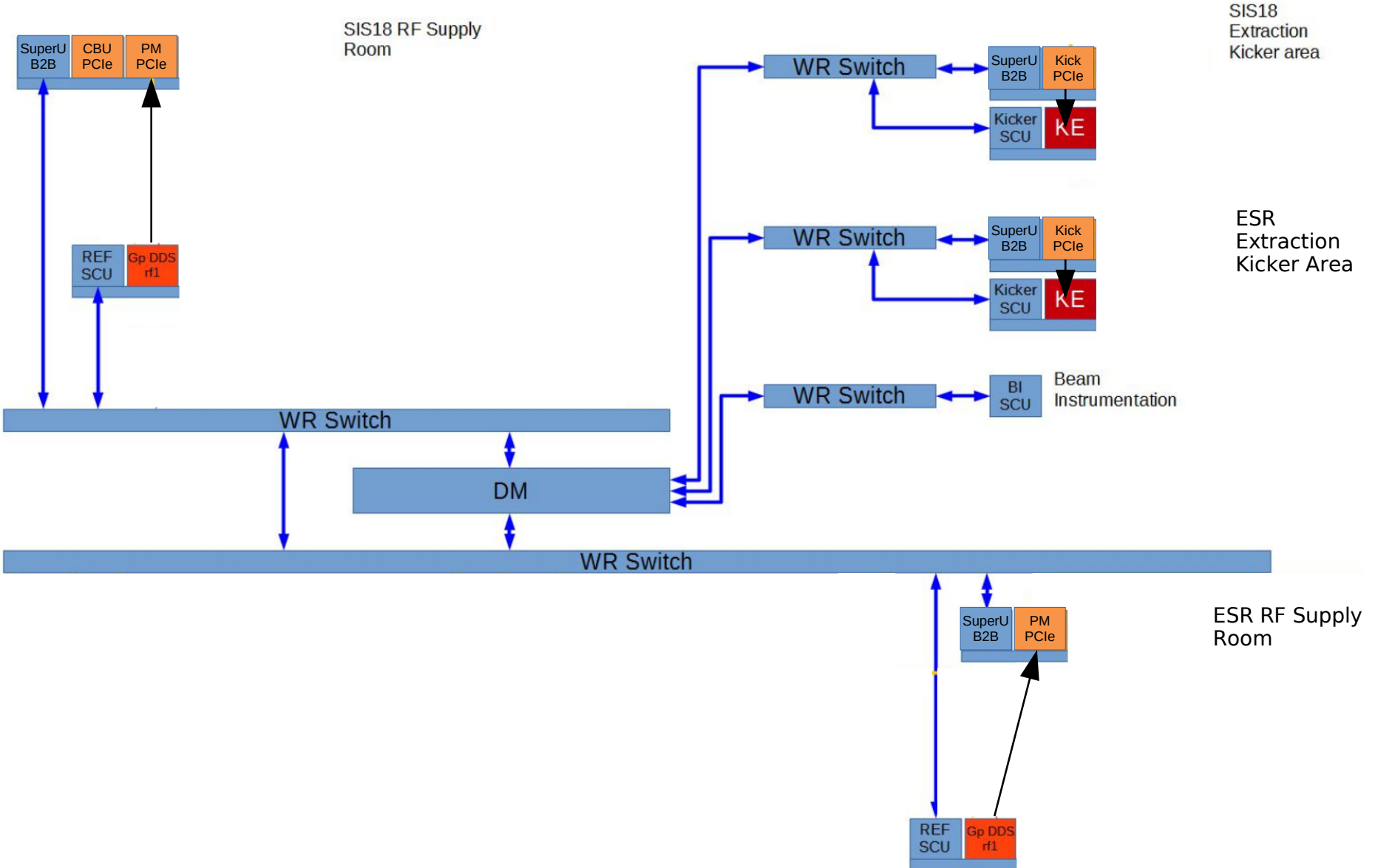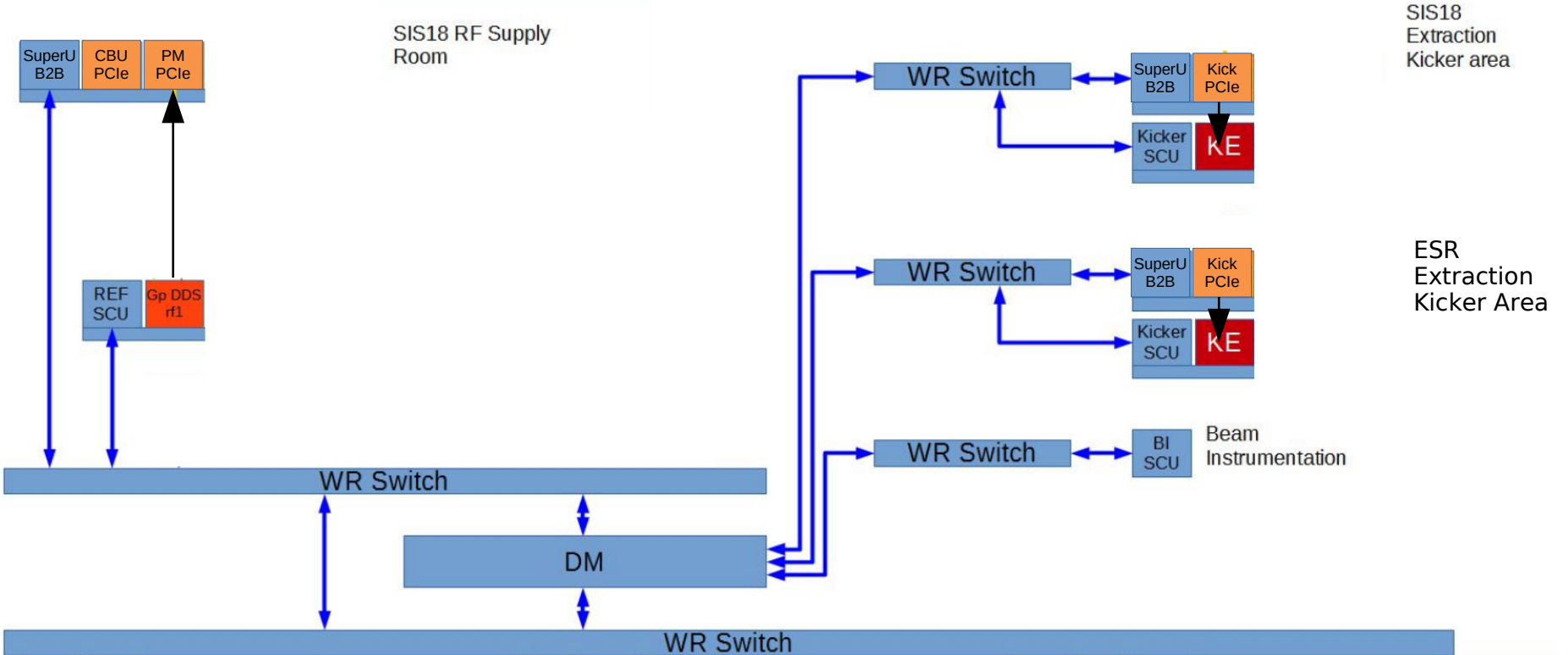
## GOTS (GSI Off-The-Shelf)

- 4 * SuperMicro
- 5 * PCIe TR
- 2 * Reference SCU, DDS H=1 signal
- 4 * LEMO cable (~ 0,5m)

## ToDo

- SuperU: get SuperMicro IPC
- CBU: Central B2B Unit, LM32 Firmware
- PM: Phase Measurement, LM32 Firmware
- Kick: Kicker Trigger, LM32 Firmware (?)
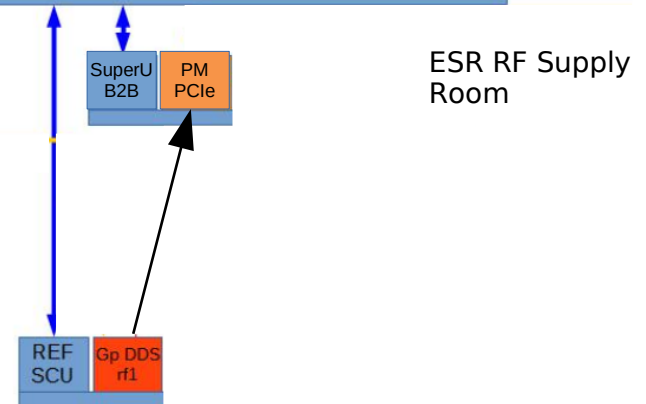
# B2B Lite: Procedure
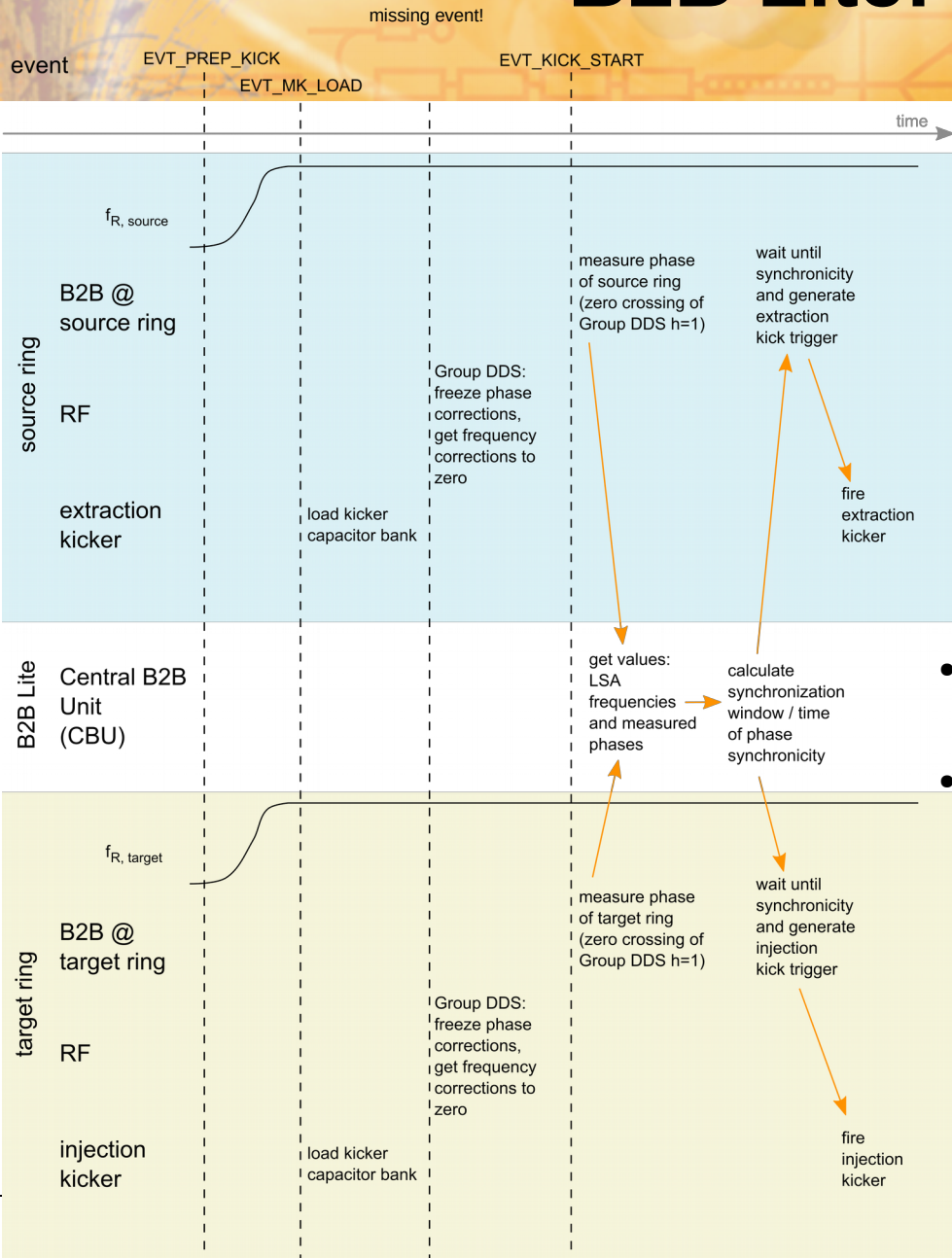


B2B Lite: changes happen only 'under the hood'
replacement for 'timing generator'
we will swap 1 Lemo cable in each kicker room

- model and LSA: no change for 2021
later: CBU data supply
- Data Master: no change
kicker control: no change

# Communication in Hard Real-Time

**B2B 2017**

- VLANs
- unicast Ethernet
- re-sending of messages via Data Master

**White Rabbit Switch is not an IT Switch**

- VLANs; recommended, but they are implemented and used differently
- unicast Ethernet; uuuhhh, don't use!
- Zitat MA@INN: "Ich bin immer wieder beeindruckt wie man bestehende (IT) Standards ignorieren kann."

**B2B Lite**

- ~6 messages per transfer (+ optional verbosity)
- proposal: no dedicated VLAN (traffic volume shall be considered by DM/LSA anyhow)
- only the **ECA** shall be used as broadcast target
- **which message format shall be used by B2B?**

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# Message Format Options
## (Priority in Brackets)

### Identical Treatment as Other Equipment (-1)

- pro: fits LSA/model concept
- con: internal communication not part of model or LSA make rules
- B2B similar to DM; components not linked to equipment like magnets

### Dedicated Format ID (1)

- pro: parts of 64bit EvtId can be recycled to increase payload
- con: 0x2..0xf: reduces remaining number of future formats by 1
- (0x0: 'burnt' anyhow)
- con: its less straight-forward for others to subscribe to these data (just in case)

### Internal GID und EvtNo (2)

- GID *0x400-0xfff* and EvtNo *0xfa0-0xfff* reserved for GMT internal stuff
- pro: GMT internal business
- con: its less straight-forward for others to subscribe to these data (just in case)

### Dedicated GID and EvtNo (1)

- GID: s.th. like *SIS18_B2B_ESR*
- EvtNo: s.th. like *CMD_B2B_COM_01..32* (similar to *CMD_RF_SWITCH_01..32*)
- pro: straight-forward for others to subscribe to these data (just in case)
- con: might trigger lengthy discussions

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# Backup Slides...

# Trigger Decision Module

**B2B 2017**

- B2B only requests to fire the kicker to TDM
- TDM fires the kicker

a) upon request of B2B

b) upon request of MPS

- requirements of MPS and B2B are tightly coupled

**B2B Lite**

- TDM as specified by 'B2B 2017'
  OR (to be discussed)
- B2B fires the kicker directly. Here, TDM only passes the B2B trigger signals through with a fixed, known delay.
  Pro: i) better separation of functions, TDM under responsibility of MPS
       ii) for B2B, SIS100 is treated like all the other machines

# GMT: Linked to GPS and RF Clock System BuTiS
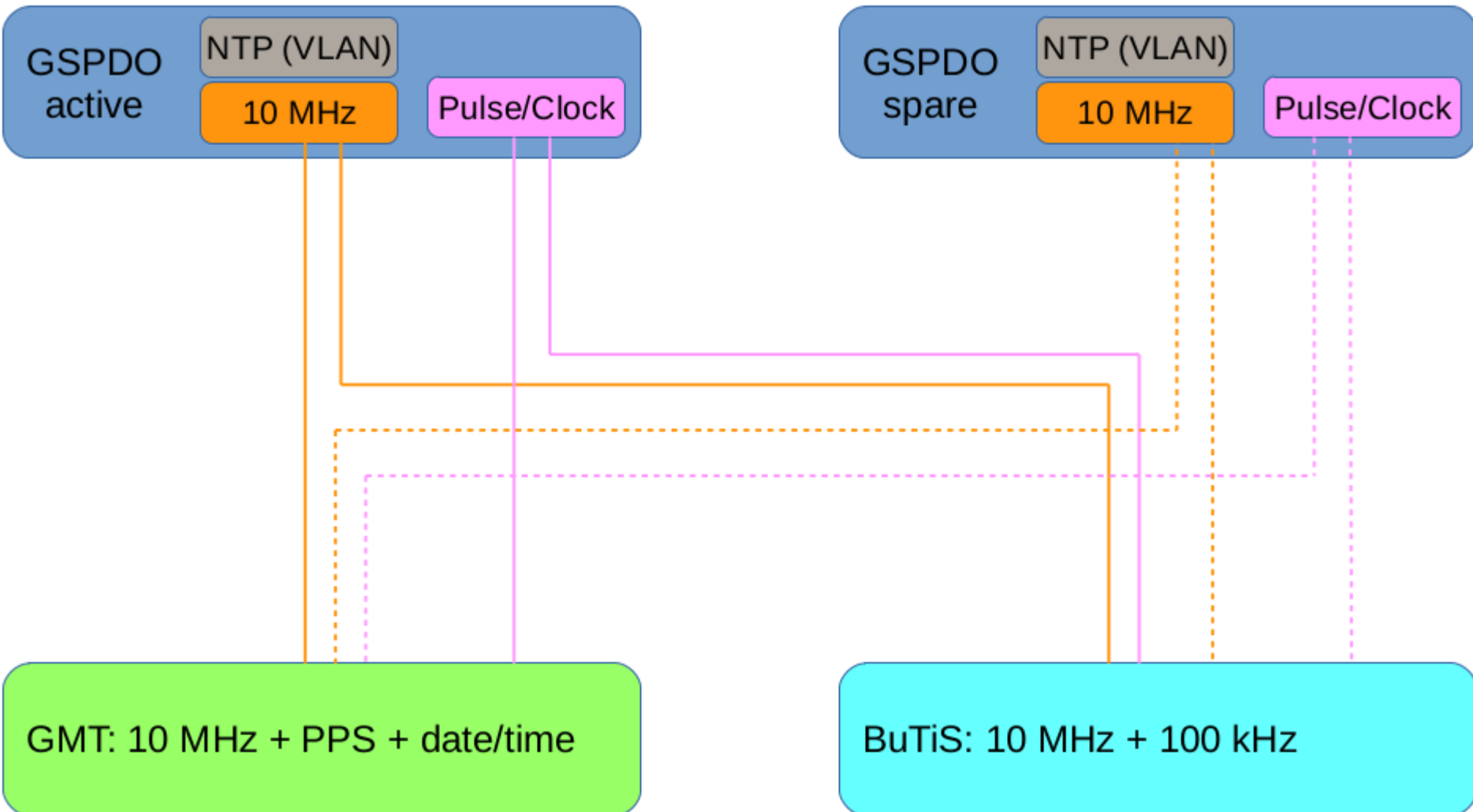
# Primer: Event Condition Action Unit (ECA)



- <u>Event</u>: DM telegram
- <u>Condition</u>: index
- <u>Action</u>: configured, executed on-time

Front-End Computer

host

OS

user-space

user program ('FESA')

EB library/API

kernel-space

driver

bus bridge

timing receiver

FPGA

driver

channel → MSI

channel → *receiver*

channel → lemo out

ECA

filter
(condition)

t=x?

on-time
action

Data Master

broadcast telegrams
- index
- deadline (ns)
- ...

'event'

1 ns resolution
(order matters!)

# B2B 2017

## Frequency beating method

**Step 4**
- Calculate synchronization window for both synchrotrons and DM
- Reproduce the signal of the target RF revolution frequency at the source synchrotron

**Step 3**
Gather data from two synchrotrons

**Step 2**
Collect data locally

**Step 1**
Begin synchronization
Freeze stabilization

**Step 5**
Generate the trigger signals

**Step 6**
Fire injection/extraction kickers

**Synchronization window**

RF frequency

Flattop

f + **Δf**

f

**Δf**

**Phase shift**

**Frequency detune**

The emergency kickers can be triggered at any time by MPS

*time*

**Step 1**
Begin synchronization
Freeze stabilization

**Step 5**
Generate the trigger signals

**Step 6**
Fire injection/extraction kickers

**Step 2**
Collect data locally

**Step 4**
- Calculate synchronization window for both synchrotrons and DM at the source synchrotron
- Reproduce the signal of the target RF revolution frequency at the source synchrotron
- Shift the RF phase

**Step 3**
Gather data from two svnchrotrons

## RF phase shift method

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