CERN

BE Beams Department | Beam Instrumentation

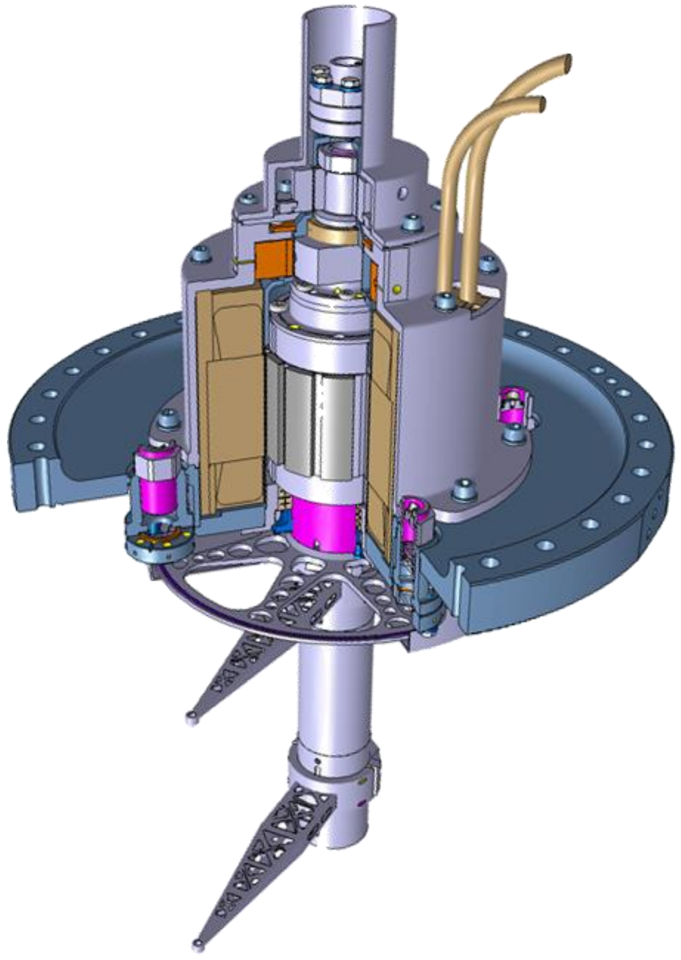
LIU BWS electronics

J. Emery for the Beam Wire-scanner team

BI-TB 26.01.2018

Content

- Wire-Scanner system architecture
- Electronics hardware
- Firmware / Software
- Lab tests
- LIU electronics for the linear scanners
- 2018 milestones



Laboratory tests (January 2018)

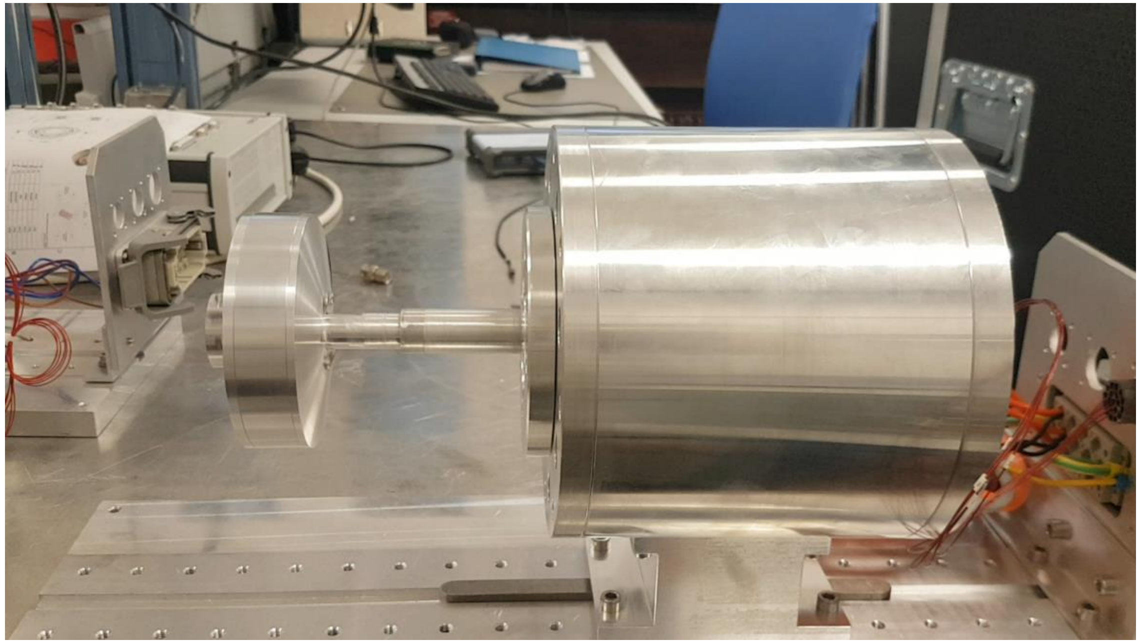
Motor Bench

Intelligent Drive Crate (IDC)

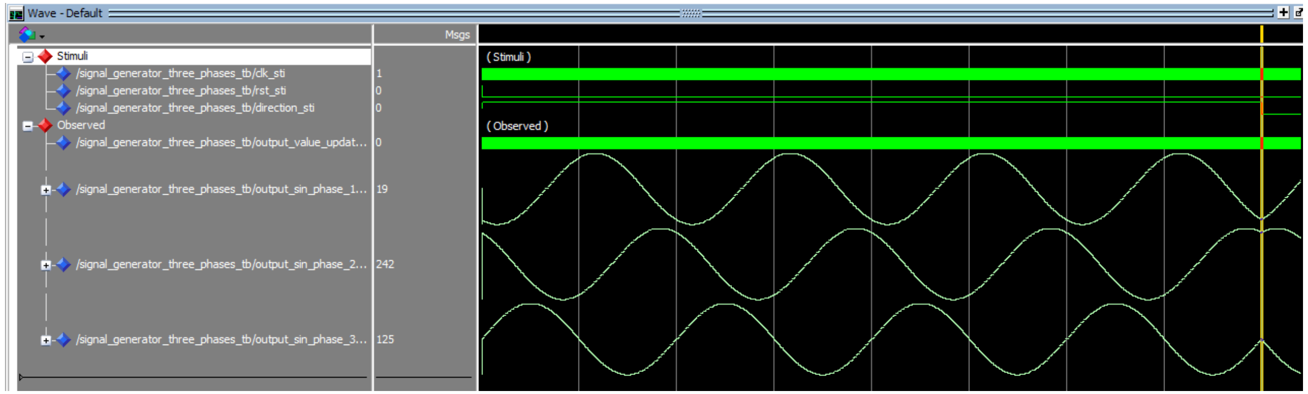
Dspace control system

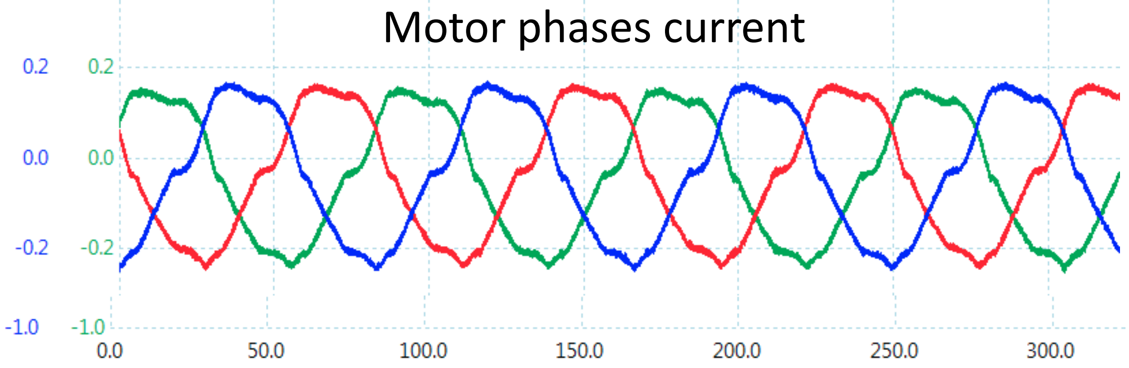
VFC based control system

Laboratory tests: Custom power driver + VFC based control



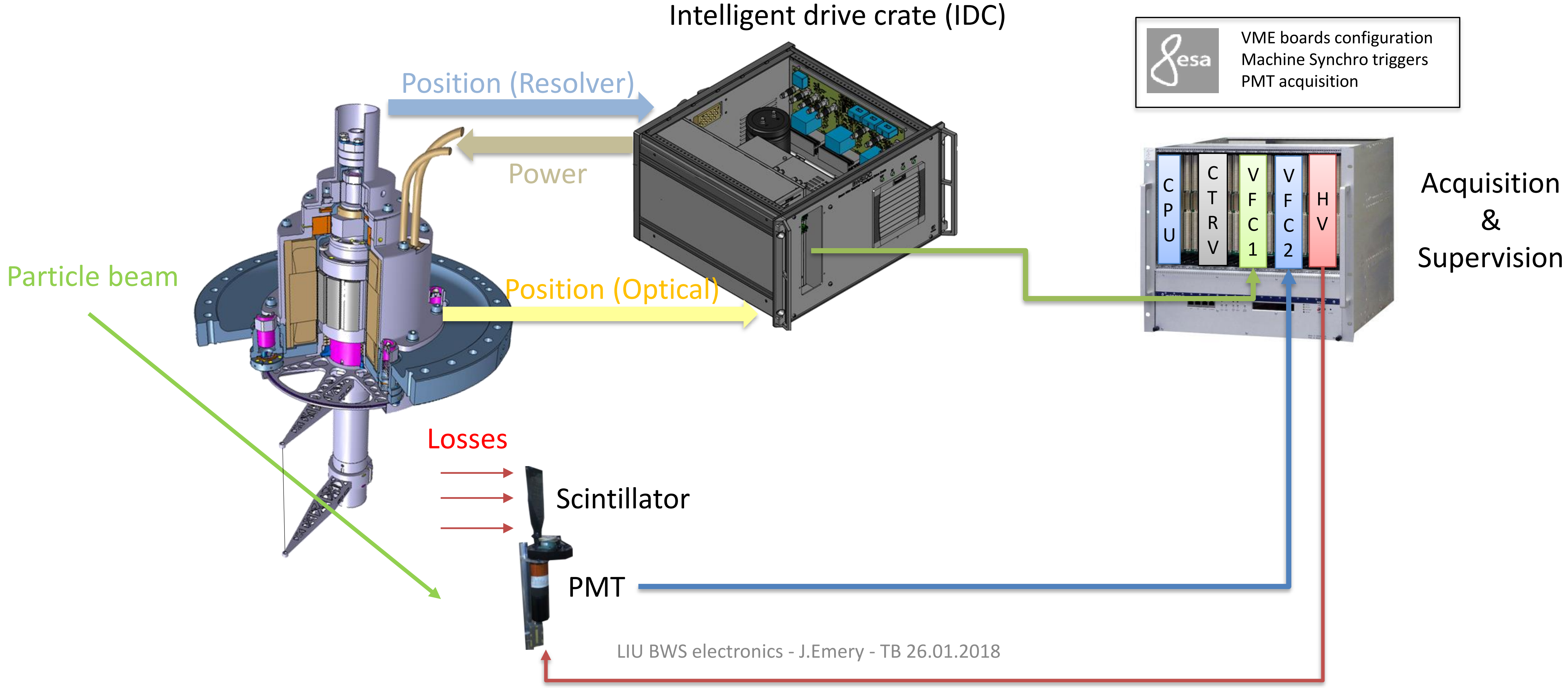
3 phases control signals simulation in VHDL (Modelsim)



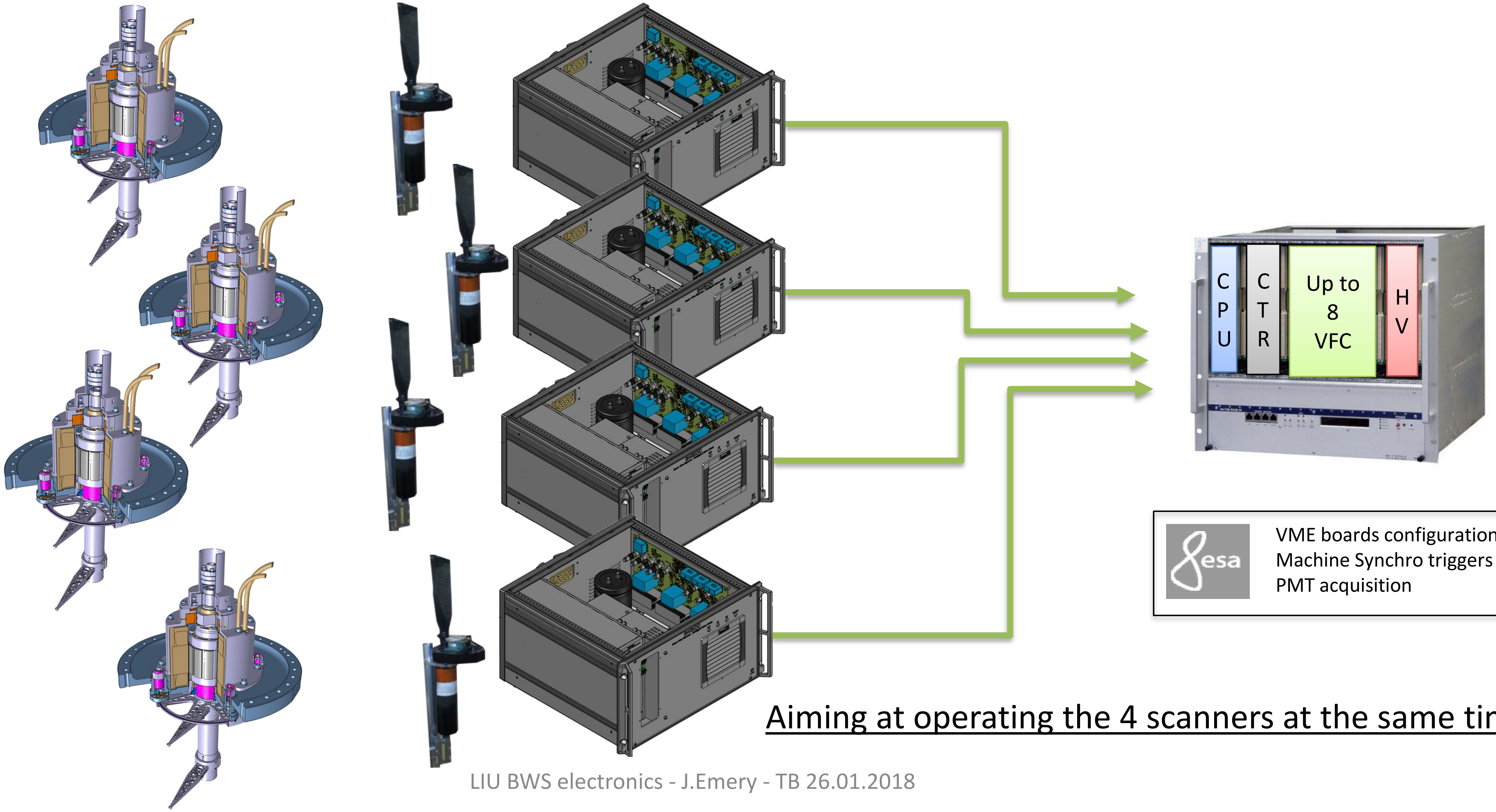


Time [ms]

LIU Wire scanner system architecture



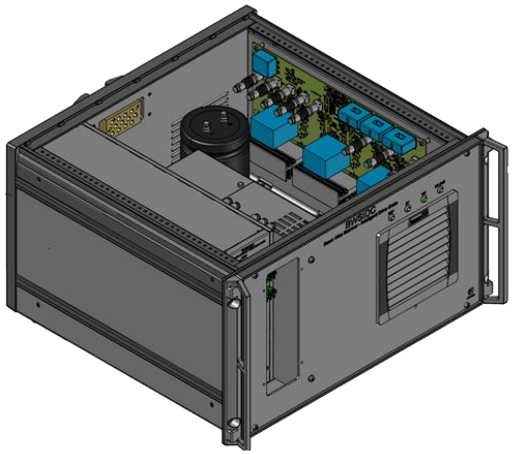
LIU Wire scanner system architecture



VME boards configuration
Machine Synchro triggers
PMT acquisition

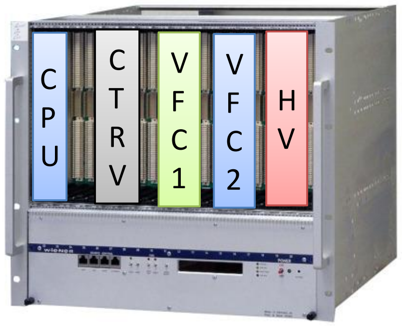
<u>Aiming at operating the 4 scanners at the same time</u>

Hardware item list

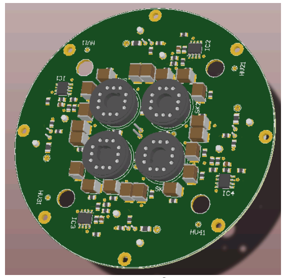


- Scanner controller (IDC):
  - Stand-alone operation of the scanner mechanism
  - Custom design
  - Based on VFC board + 3 custom boards

- Acquisition and Supervision:
  - VME based system
  - 1 VFC to connect to the IDC
  - 1VFC + commercial mezzanine for PMT signals digitalization
  - 1 commercial HV module (ISEG)



- Sensor assembly:
  - Multi-PMT baseboard



Control and power electronics
First implementation (for SPS and PSB)

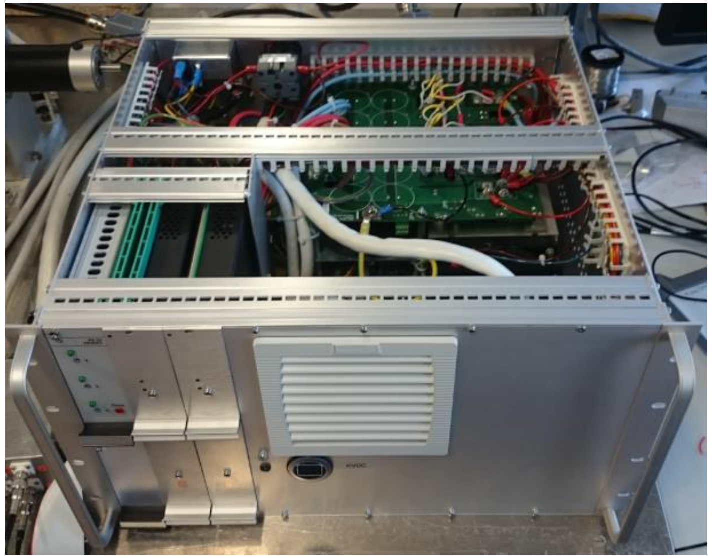
Control Electronic

- 1 pcs. Altera development kit ARRIA V SoC
- 1 pcs. Mezzanie FMC board, CERN J.Emery

3U

Power Unit

- 1pcs. Motor Inverter. Arcel
- 1Pcs. Mesurement board,CERN L.Timeo
- 2pcs. DC bus Power Supply.DeltaElektronika



6U
= 34.5Kg

Filter

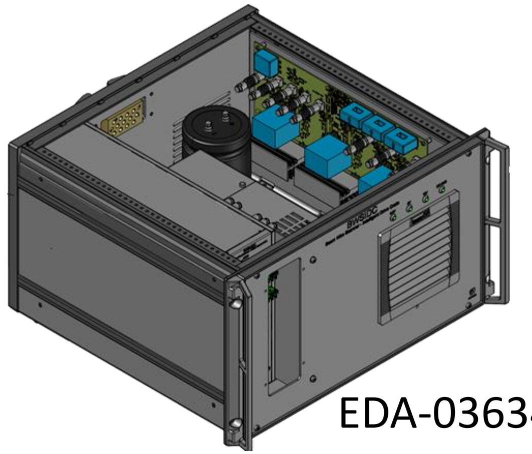
Filter,Schaffner

External Filter

330*100*165mm

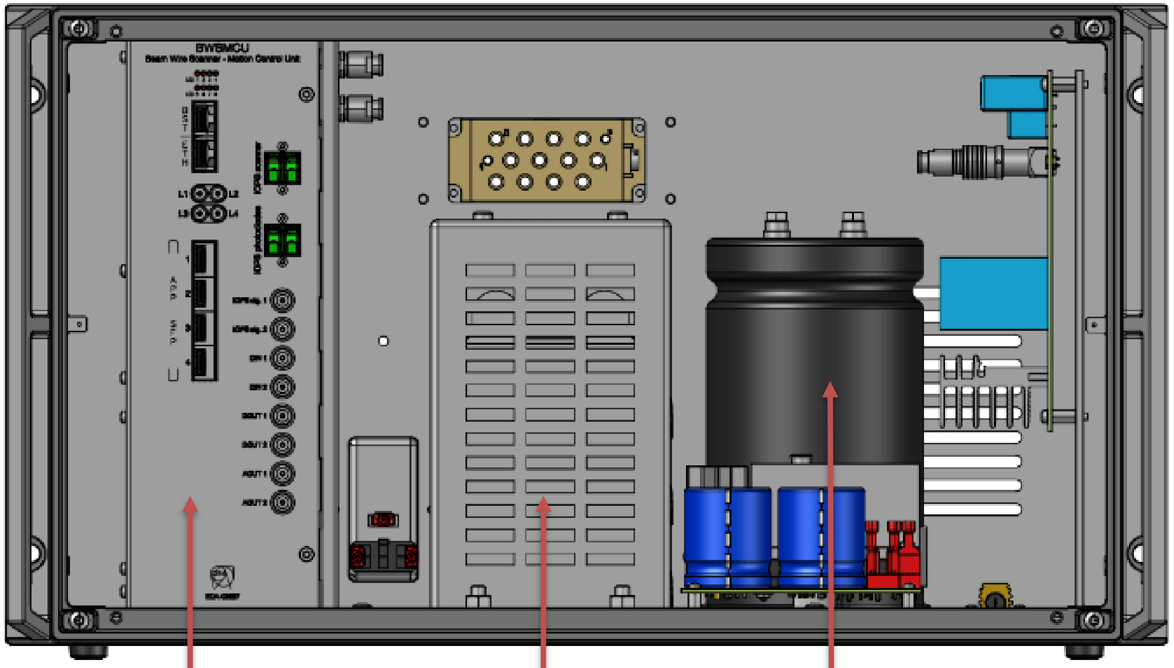
See Patrik Andersson presentation BI-DAY 2017

Intelligent Drive Crate (IDC)



EDA-03634

6U, ≈ 22Kg

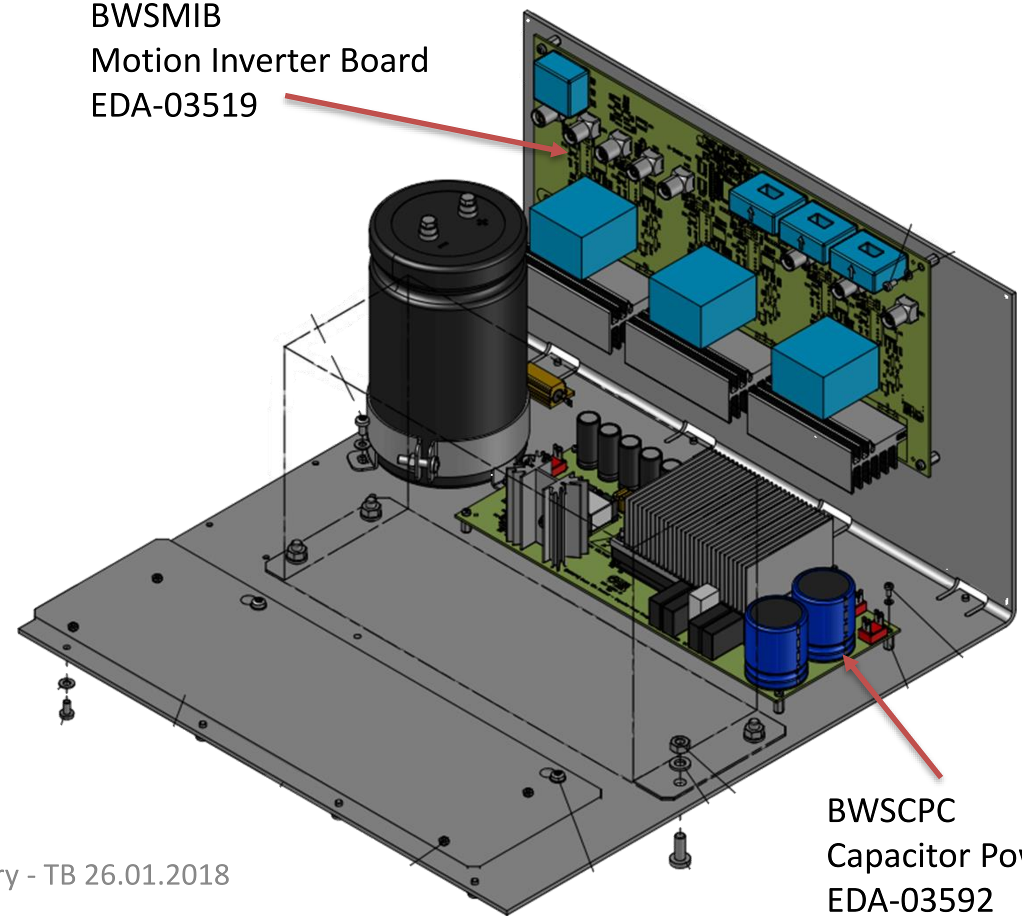


DC-BUS Capacitor

BWSMCU
Motion Control Unit
EDA-03697

Output filter “sinus”

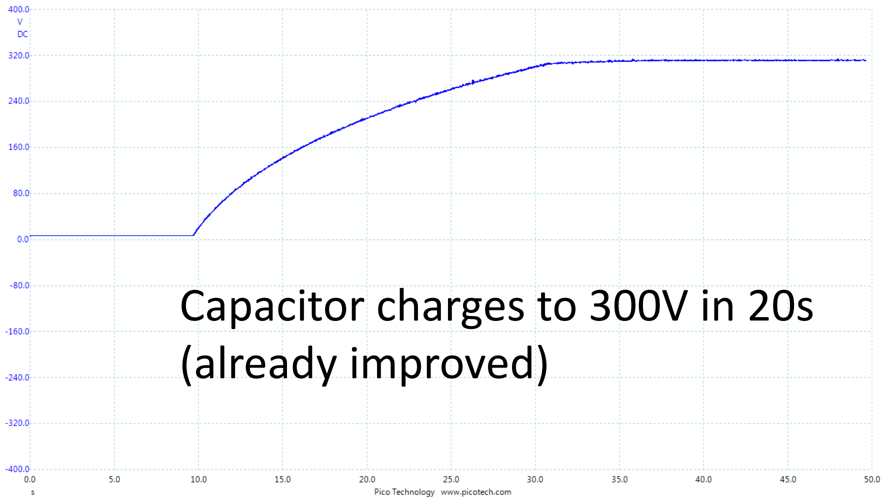
BWSMIB
Motion Inverter Board
EDA-03519



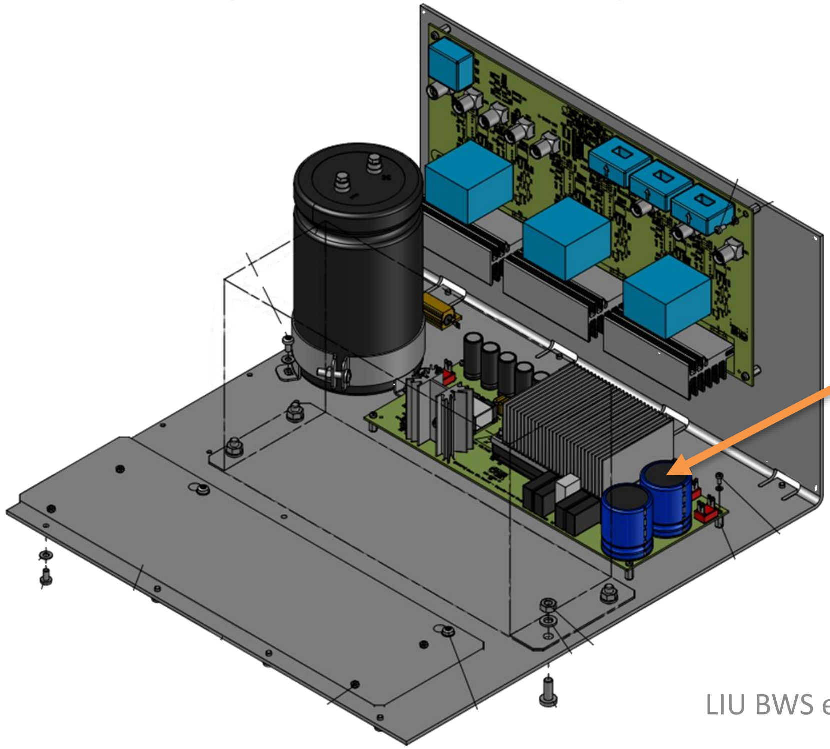
BWSCPC
Capacitor Power Charger
EDA-03592

BWSCPC - Capacitor Power Charger - EDA-03592

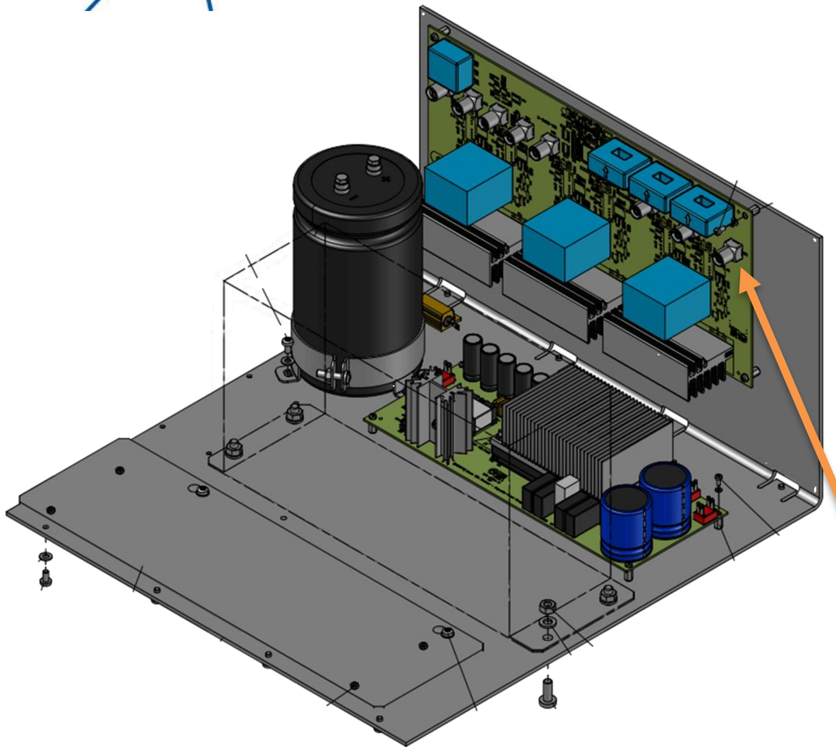
- Charge DC-BUS capacitor up to 500V (was 400V)
- Replace the Delta Electronics 300V supplies (obsolete)
- Increase the charge current from 0.3A to 0.45A RMS
- In the future, increase current to 0.55A for shorter charging time (higher scan cycle rate)
- Version 2 being done at the design office



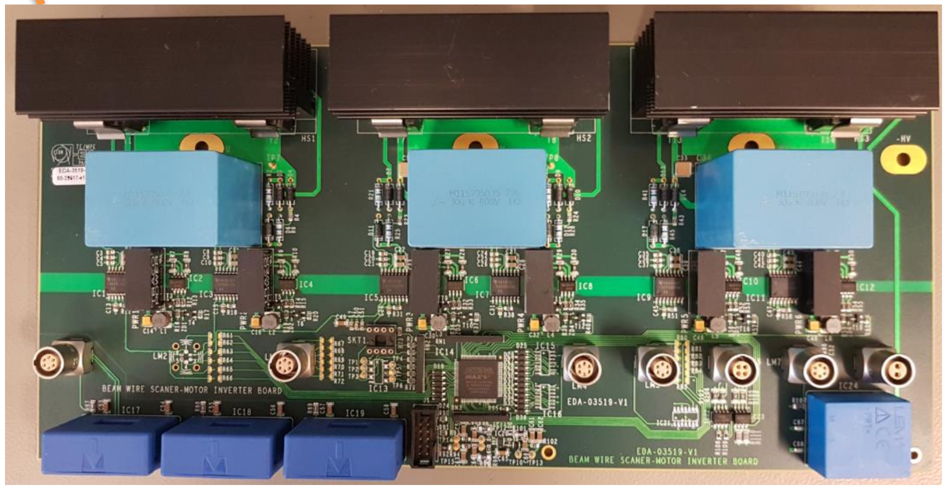
Capacitor charges to 300V in 20s (already improved)



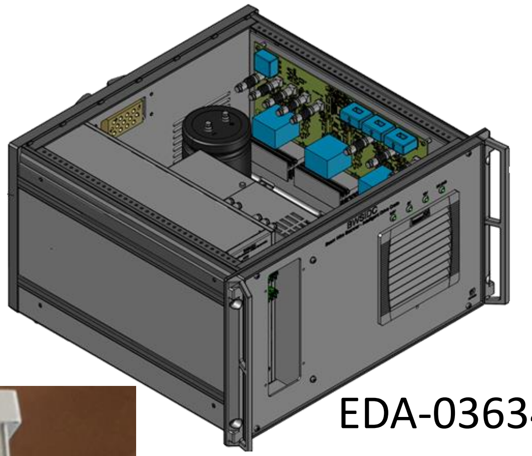
BWSMIB - Motion Inverter Board - EDA-03519



- Motor phases powering by chopping the DC-BUS (PWM control)
- Design for the wire-scanner repetition rate (~every few sec.)
  To reduce size by 3 compared to off the shelf inverter
- CPLD based digital interface and controls
- Also replace DC-BUS control and measure card
- SPI based interface, IGBT protection, faults signalisation, PWM generation (tbc)
- Version 2 to the design office mid-February 2018



Intelligent Drive Crate (IDC)



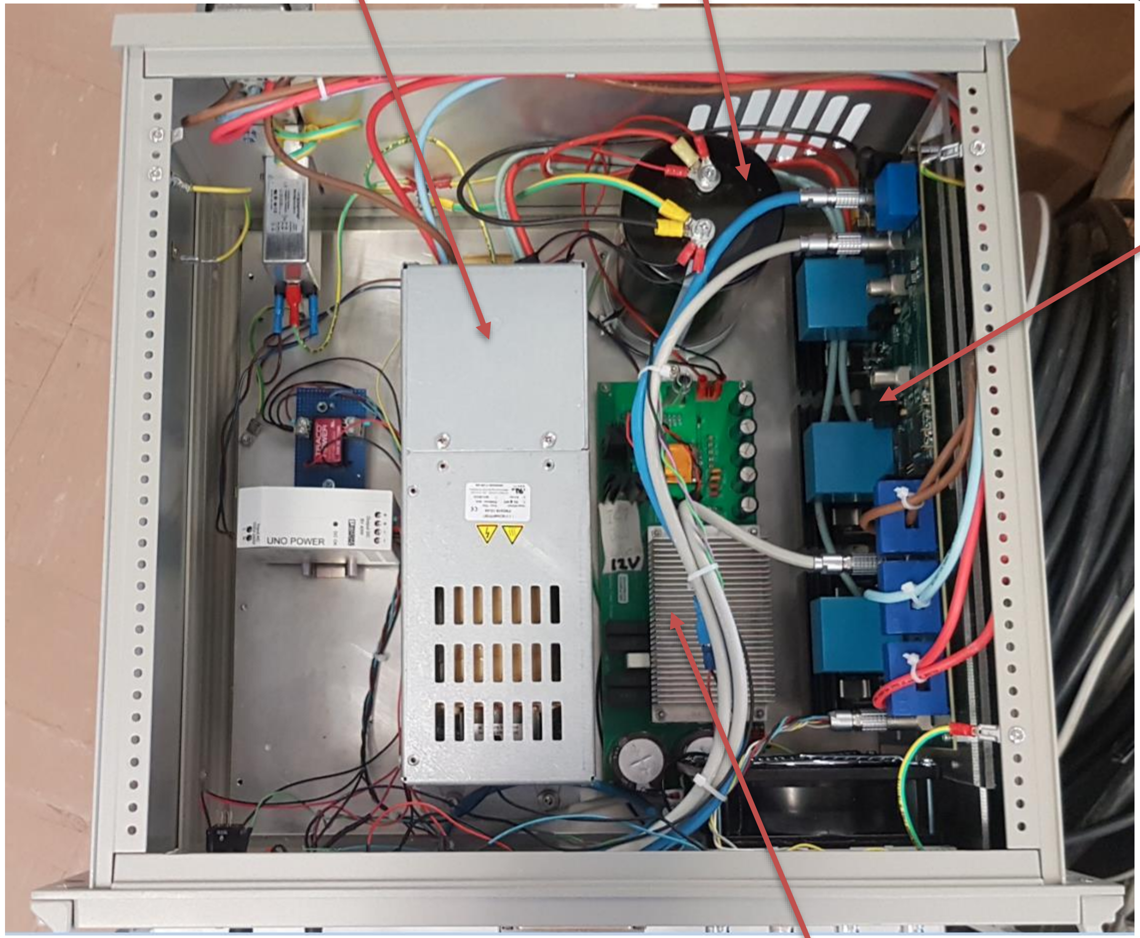
EDA-03634

IDC for external control system “Dspace”

2 new Dspace MicroLabBox Received

Output filter “sinus”

DC-BUS Capacitor

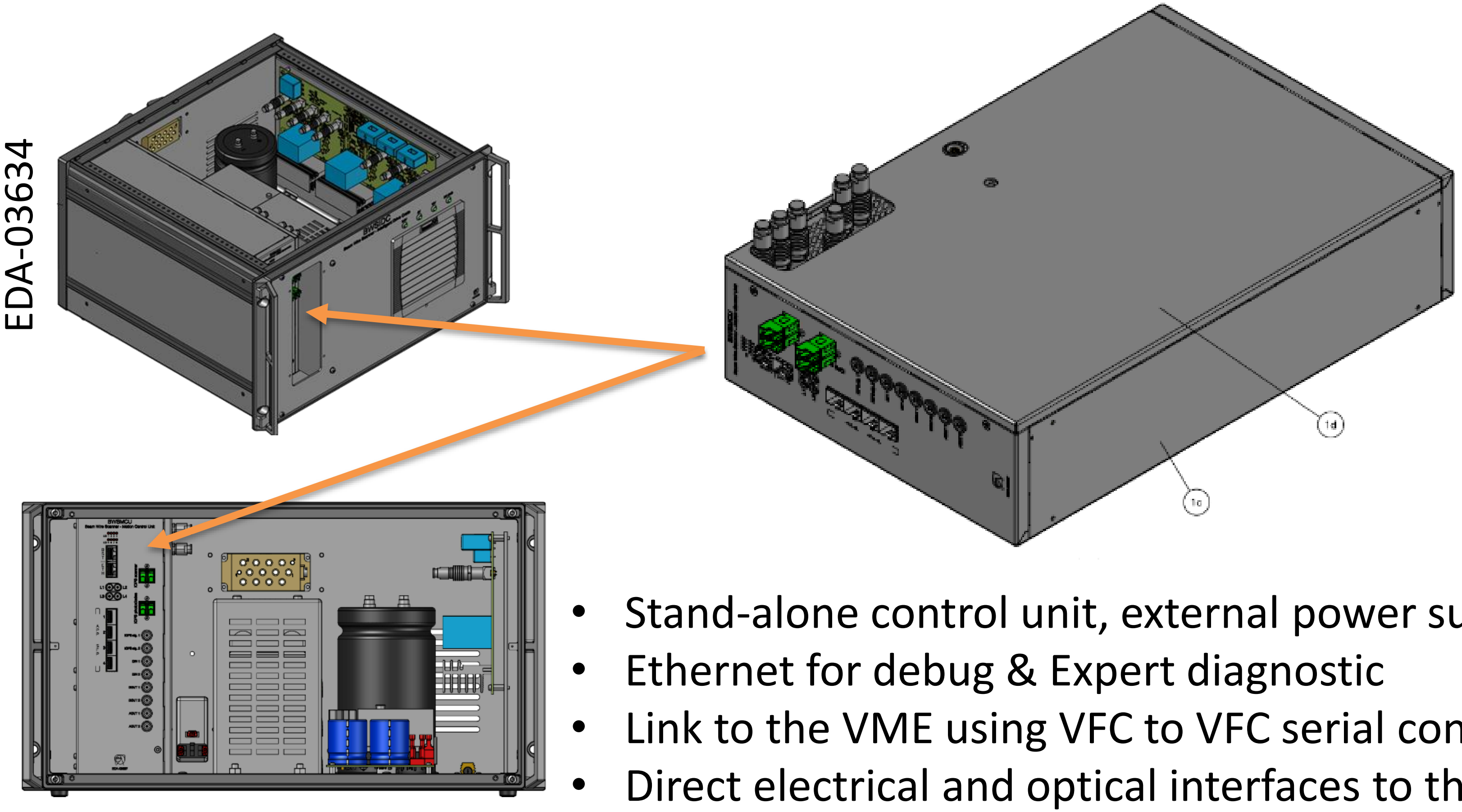


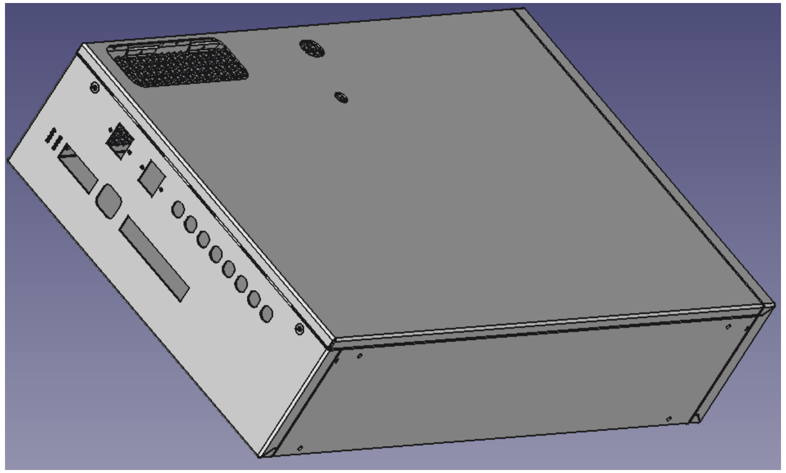
BWSMIB
Motion Inverter Board
EDA-03519

BWSCPC Capacitor Power Charger

BWSMCU Motion Control Unit EDA-03697

EDA-03634



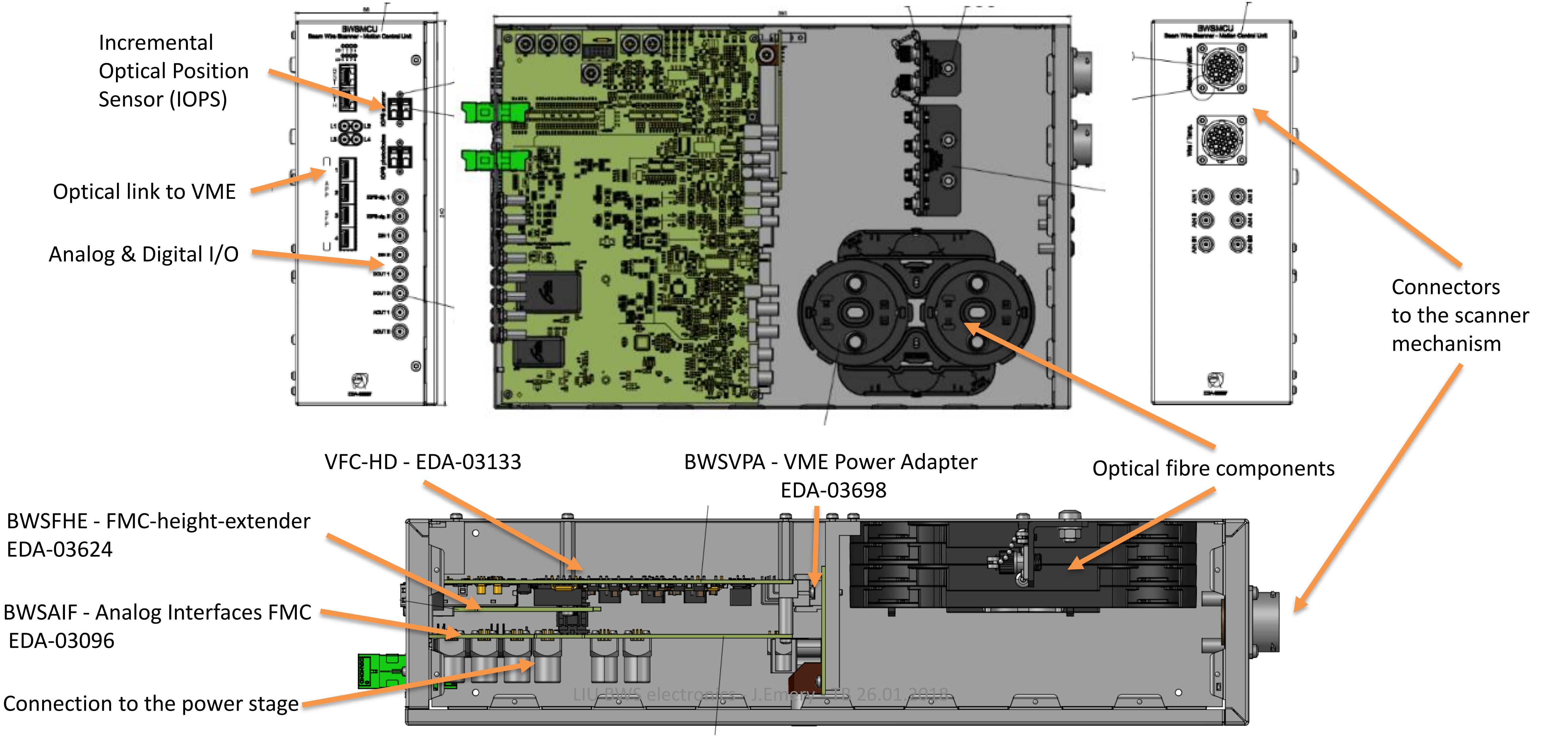


STEP MODEL

- Stand-alone control unit, external power supplies
- Ethernet for debug & Expert diagnostic
- Link to the VME using VFC to VFC serial connection
- Direct electrical and optical interfaces to the scanner
- Interfaces to the power stage (inverter)
- Numerous analog and digital I/O (isolated)
- Easy assembly and maintenance

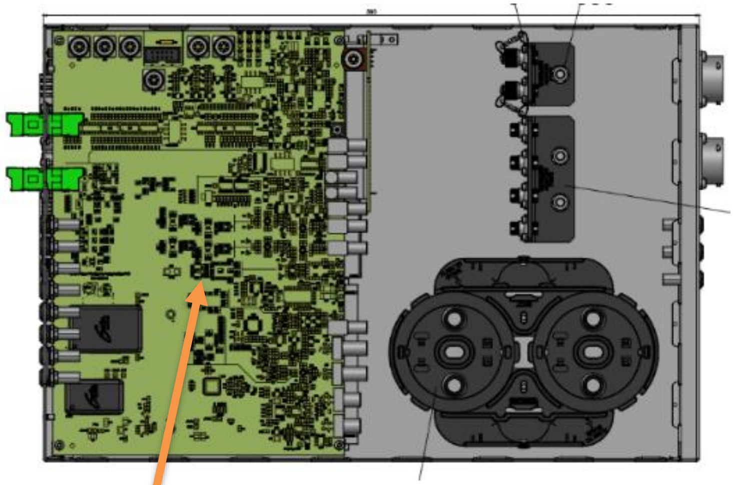
Motion Control Unit (MCU)

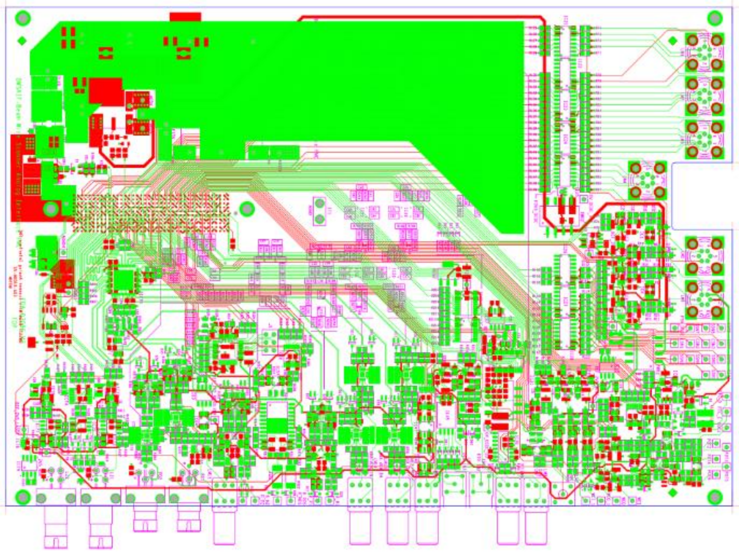
EDA-03697

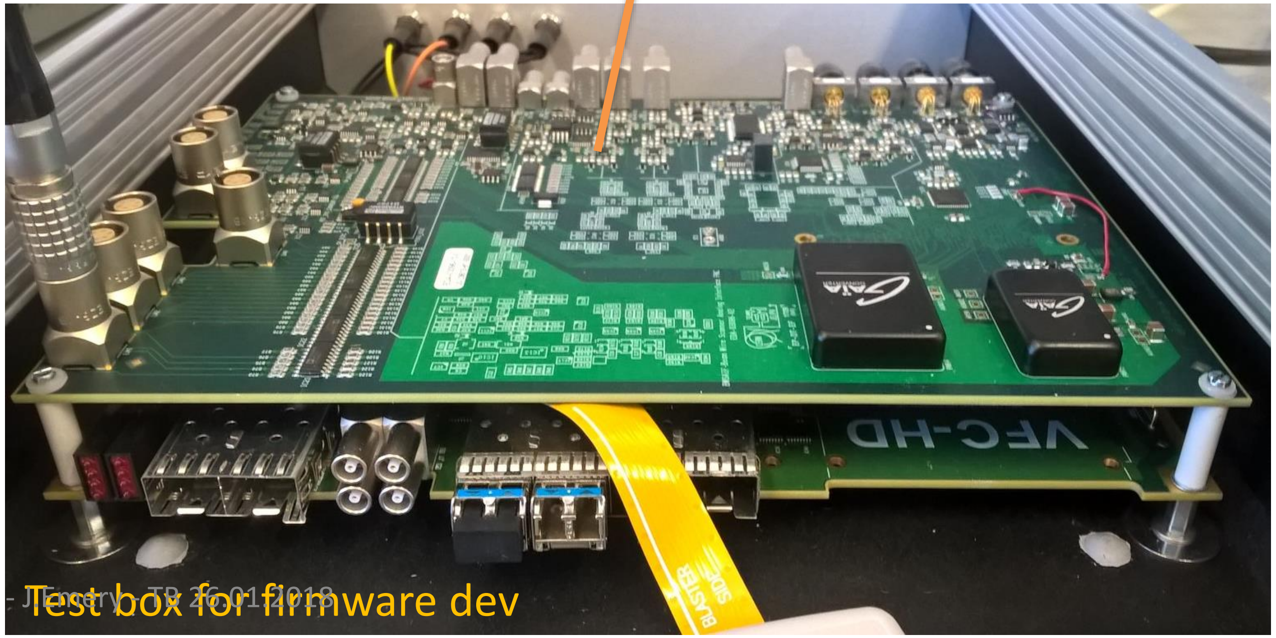


(BWSAIF)
Beam Wire Scanner - Analog Interfaces FMC

- Interfaces to scanner sensors (Resolver, IOPS, Wire, PTC)
- Interfaces to the power stage (PWM, SPI, I and V)
- Too large mezzanine for the FMC standard on VFC-HD
- Custom FMC height extender
- Version 2 to the design office mid-February 2018

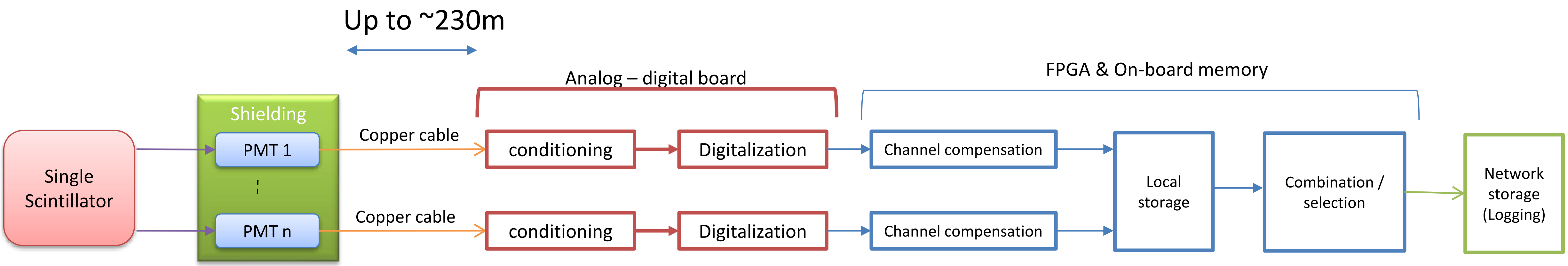






Test box for firmware dev

Secondary shower sensing

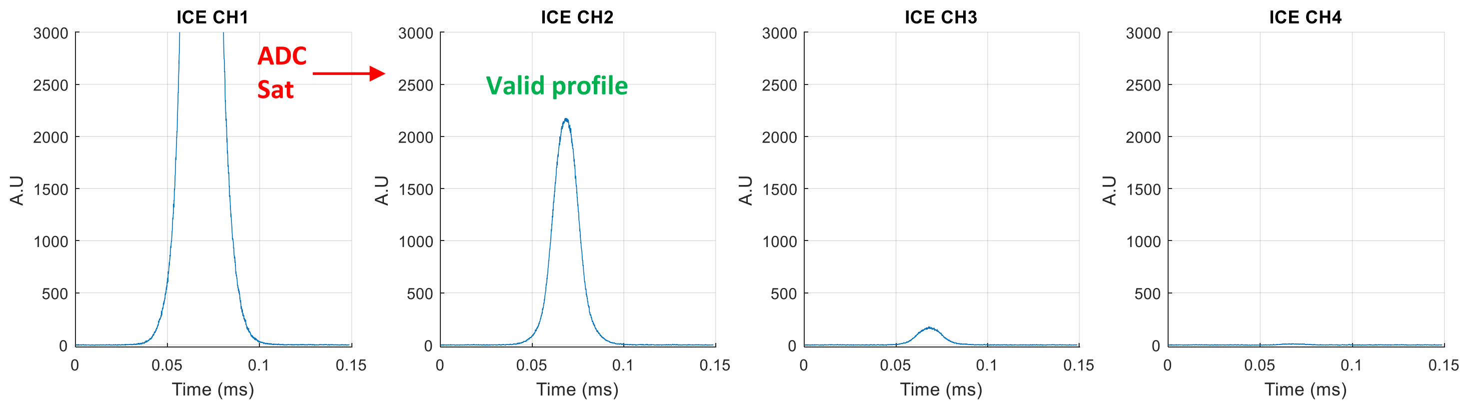


- Similar sensor as today: Scintillator + PMT
- Moving filters replaced by fixed filter and 4 PMTs
- Signal digitalization at the surface using direct digitalization on VFC
- Channel compensation, sensors combination and data reduction to be developed this year using field measurement (starting with scopes)
- Take advantage of the FBCT experience with similar architecture

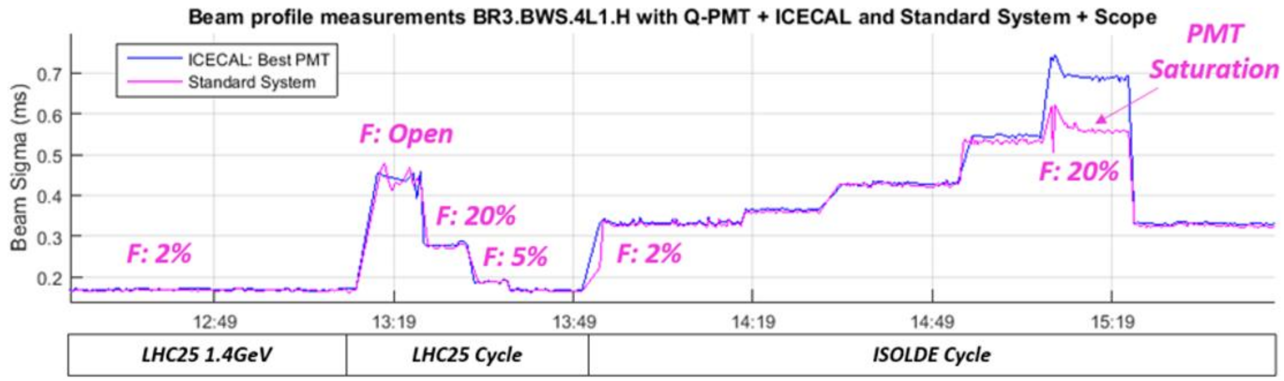
PSB Prototype Beam Tests: Results

HDR techniques evaluation: Multi-PM system

- Parallel acquisition of 4 channels with different dynamics adapted to PMT working points.
  - PMTs operate on linear range & with no saturation.
  - Static HV and Filter configuration: Operation in LHC25ns and ISOLDE cycles.
- Low noise tunnel digitalization with ICECAL Front-end & GBT link to surface.



Scanner SN:64 (2017/06/28 MD2375)



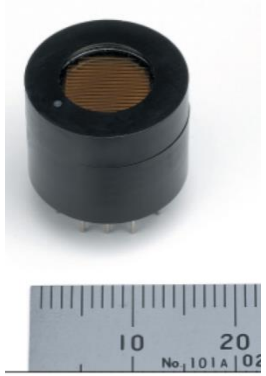
Scint. photon yield varied by 1e3:

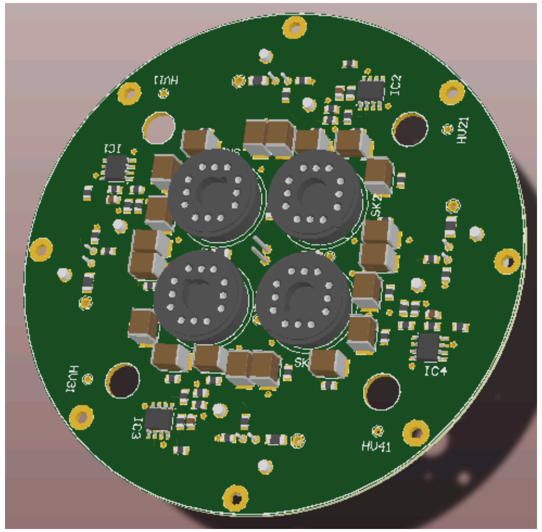
- STD
  - Required filter changes
- HDR
  - Static configuration
  - PMTs saturation free
  - Redundancy
  - Detector x-validation

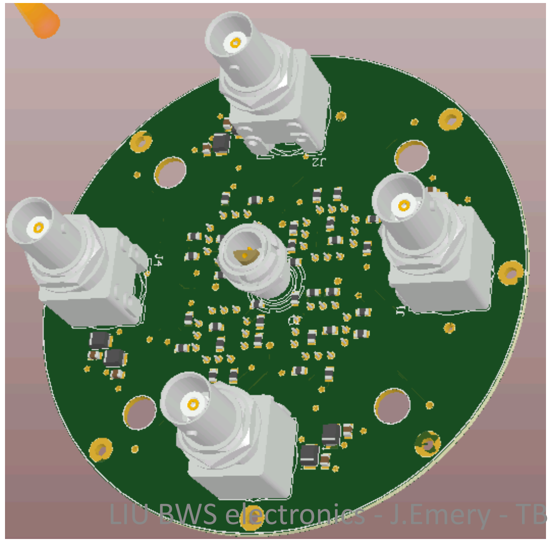
See Jose Sirvent presentation LIU review

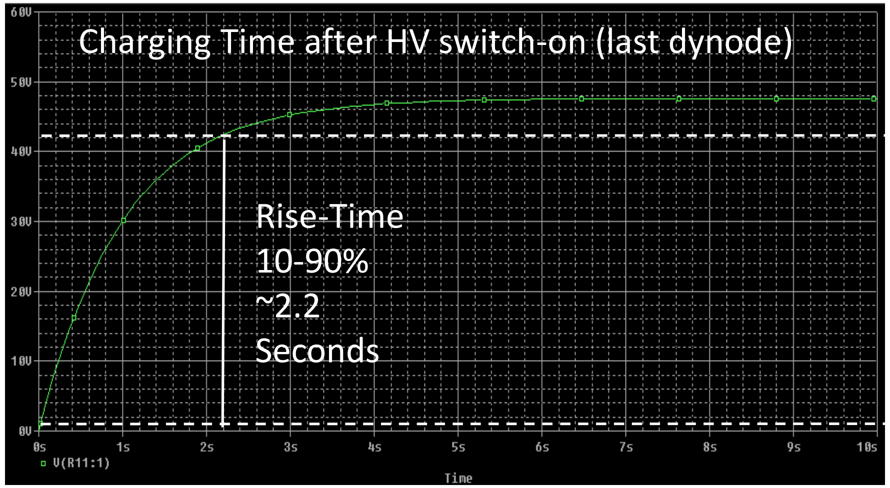
Secondary shower sensing based on Quad PMT assembly

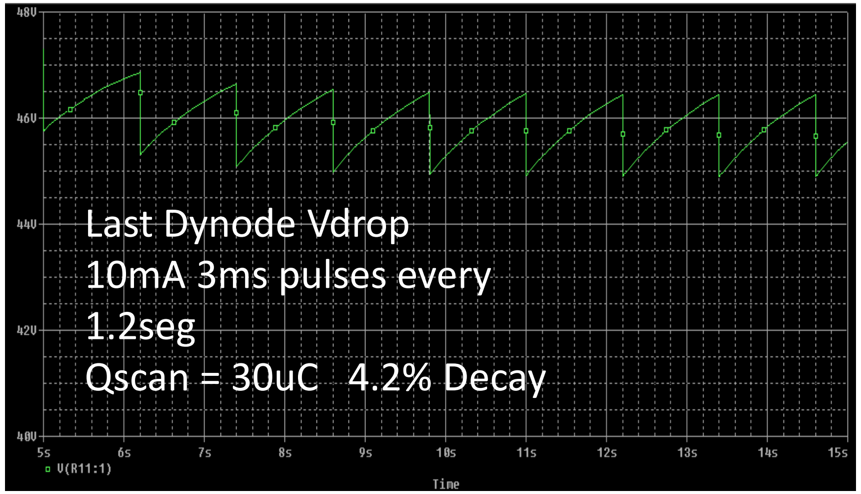
R9880U











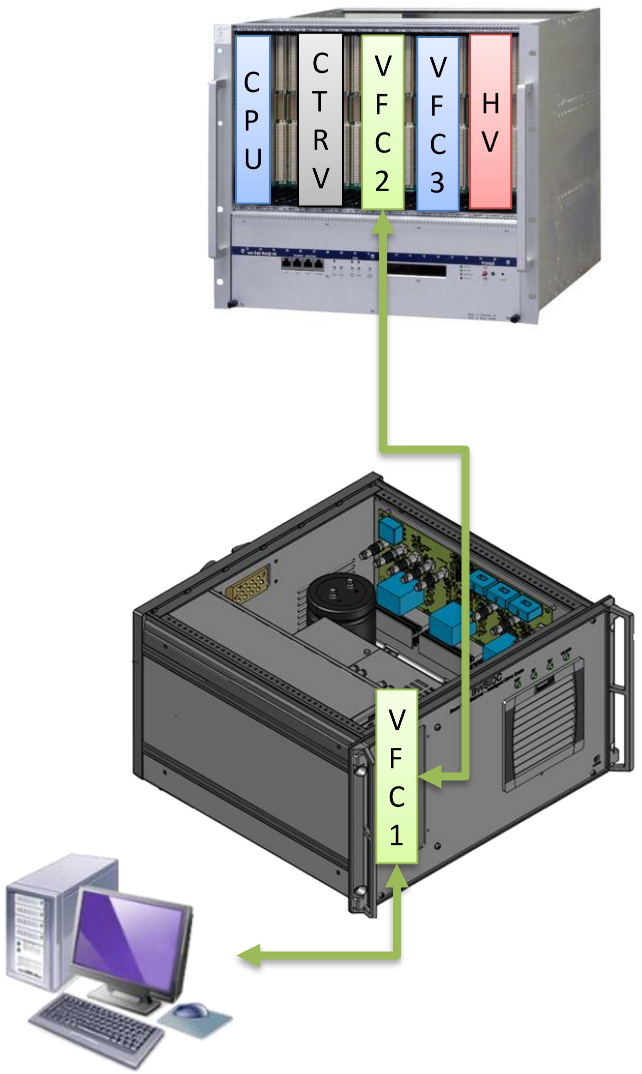
Firmware

- VFC 1 inside the drive (coding on-going):
  - Scanner motion, power stage, sensors (Resolver, IOPS, Wire, PTC) processing
  - Partial use of the existing code of the DevKit version (used in SPS and PSB)
  - Link to the power motor stage (ready)
  - Link to the VFC 2 using serial link cores developed by Cedric Vulliez (TS)
  - Link to distant expert application over Ethernet (collaboration to start in Feb)

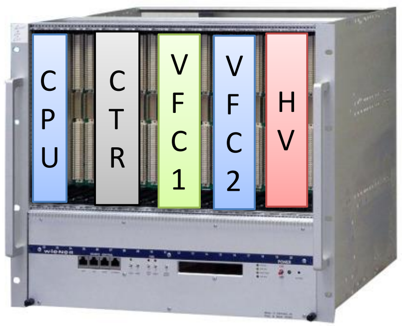
- VFC 2 (starts March 2018):
  - Scan trigger, configuration and exposes motion and sensor data to the CPU

- VFC 3 (to be start soon):
  - PMT acquisitions and processing on 4 parallel channels, exposes data to the CPU
  - Record the 4 channels and decides which one to keep
  - Reuse code from other instruments under investigation (FBCT)

- CPLD of the motor power stage (coding on-going):
  - Powering sequence of the board, error management and components protection



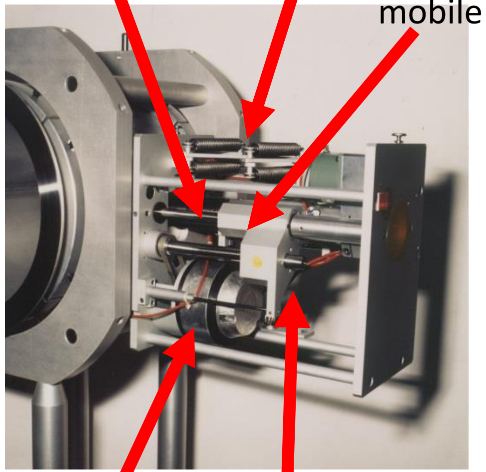
Software



VME boards configuration
Machine Synchro triggers
PMT acquisition

- One crate controls 4 scanners (8 VFC), but needs test for it:
  - Many use cases (data, repetition rate, processing)
  - Data size (PPM) and data transfer (VME and FESA)
  - Data fitting of large number of bunches
  - Potentially offline processing of the optical encoder (large data set)
- A first technical specification to be produced soon with detailed scenarios.
- Implementation could start when Firmware for the VME on-going (Mid-2018, to be agreed)

LIU control system for the Linear scanners LHC



Potential reuse of the LIU control system for the linear scanner in the LHC:

- Motivated by limitations of
  - Today's architecture (scanner multiplexed)
  - Reliability issues (motor power stage, scanner staying IN)
  - Add high precision optical encoder (linear)
  - Various options without electronics changes
- From only firmware change to major mechanical change (still outside vacuum)

	Description	mechanics	motor	cables	Firmware & control	Performance (to check)
1	Keep same hardware	-	-	-	largest (PMSM to DC)	More reliability (power stage)
2	Change motor & resolver	low	DC -> PMSM	Pull new	medium	+Potentially faster speed
3	Change motor & ball screw	medium	DC -> PMSM	Pull new	low	+Faster speed
4	Change to linear motor (direct drive + lin encoder)	larger	DC -> linear	Pull new	low	+higher performance (stability?)

Milestones for 2018

Milestone for the electronics control:

- Feb — Design modification on various board
- Mar — Start working on the VME side (TS)
- Apr — Pre-serie production and assembly
  Production test bench for power stage & charger (Stagiaire)
- June — System validation using calibration bench (Bld. 867)
  Motion optimization (to lower stress on mechanics and power stage)
  Partial production launch of 30-40 units
- Sep — System validation using installed PS scanner prototype
  Complete production launch of 30-40 units

Milestone for the acquisition system:

- End 2017 — Final acquisition baseline
- Sep 2018 — Detector side validation (multiPMT concept) in all machines
- End 2018 — Digitalization electronics validation with beam
  Production launch of 20-30 units

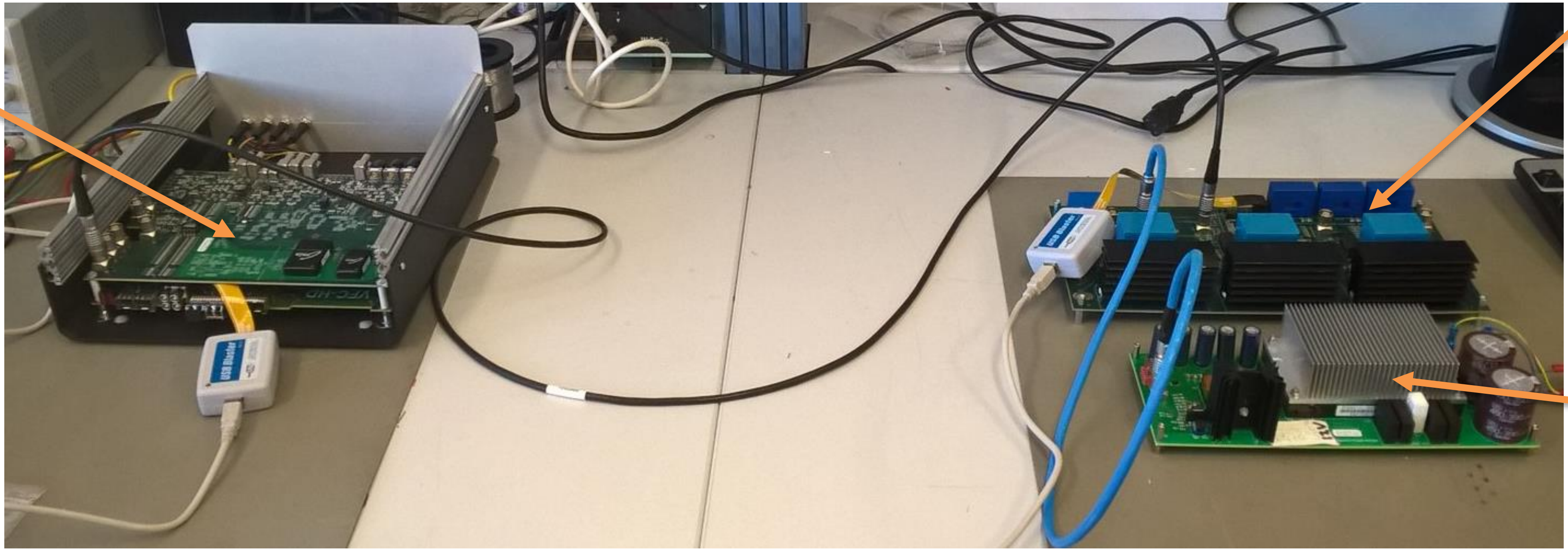
CONTROL SYSTEM LAB TESTS

CERN

First board to board connections (2017)

VFC based control system

Motion Inverter Board



Capacitor Power Charger

Link between the Motion Control Unit and the Motion Inverter Board validated (Robust SPI)

Signal start DC-BUS sent from VFC-HD to Capacitor Power Charger

Link fully simulated in VHDL: - Transaction Level Modeling (TLM), random fault injection, reporting, etc…

Laboratory tests (January 2018)

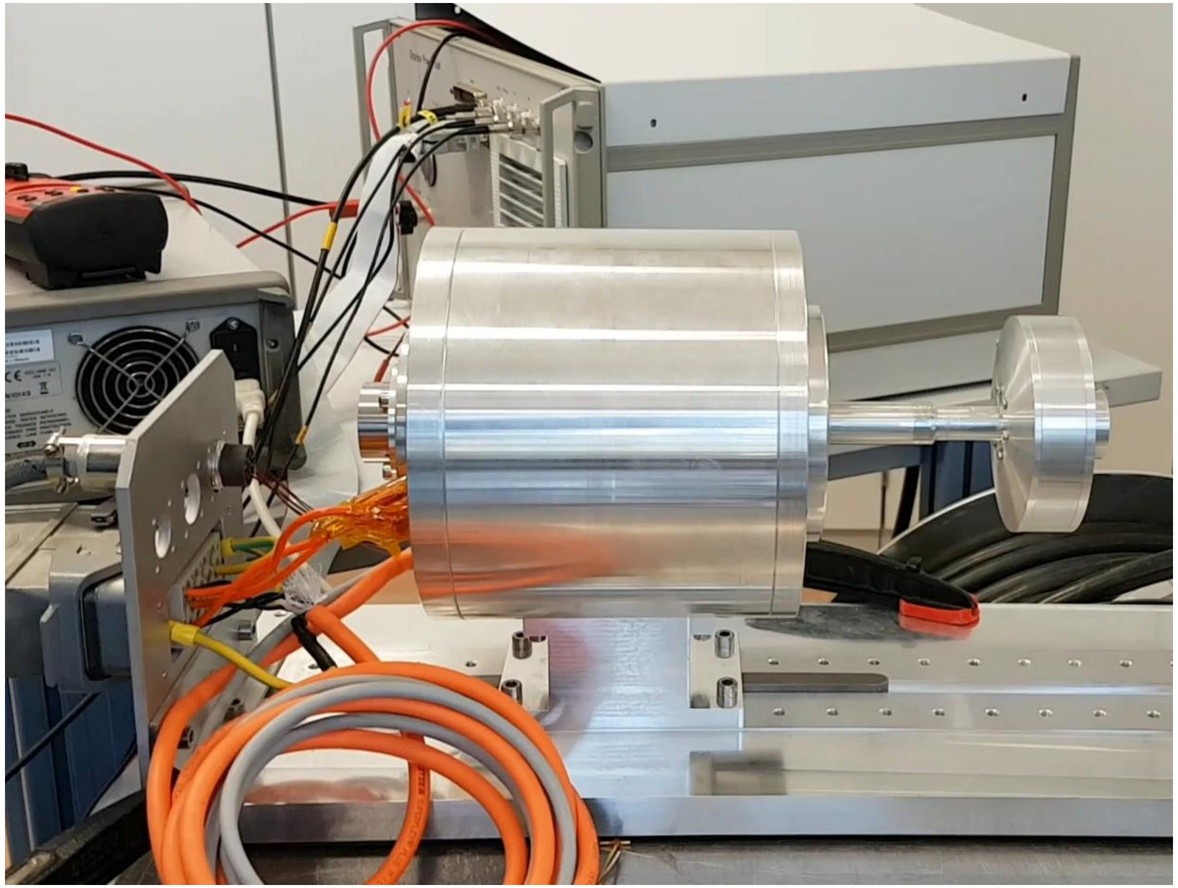
Dspace
control system

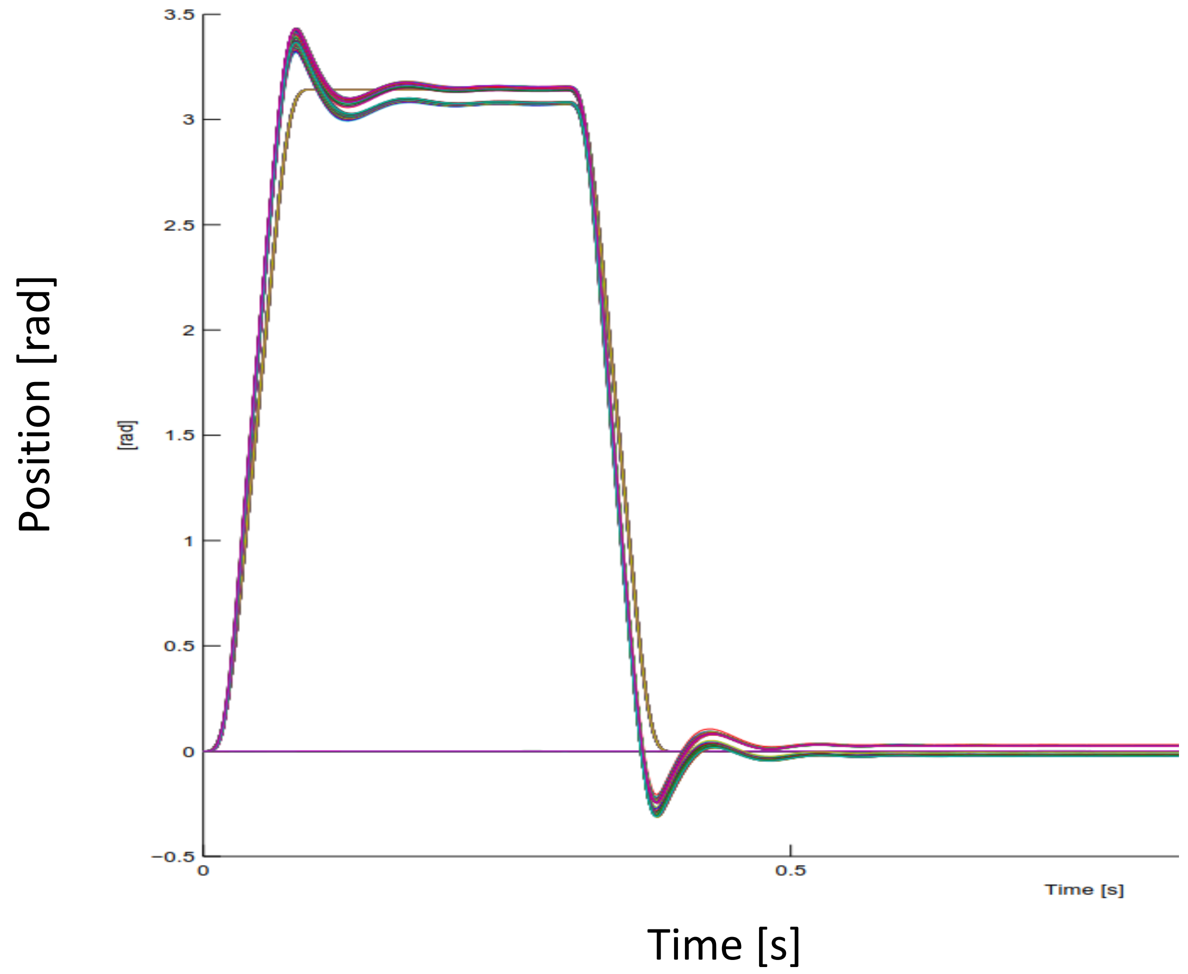
Motor Bench

VFC based
control system

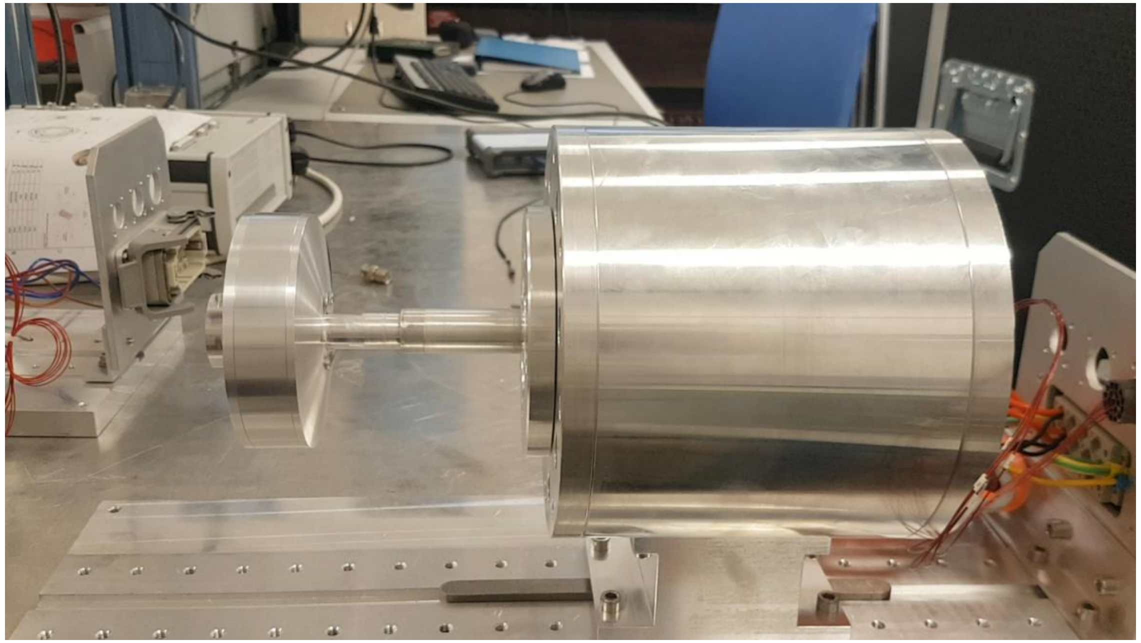
Intelligent Drive
Crate (IDC)

Laboratory tests:
Custom power driver + Dspace control

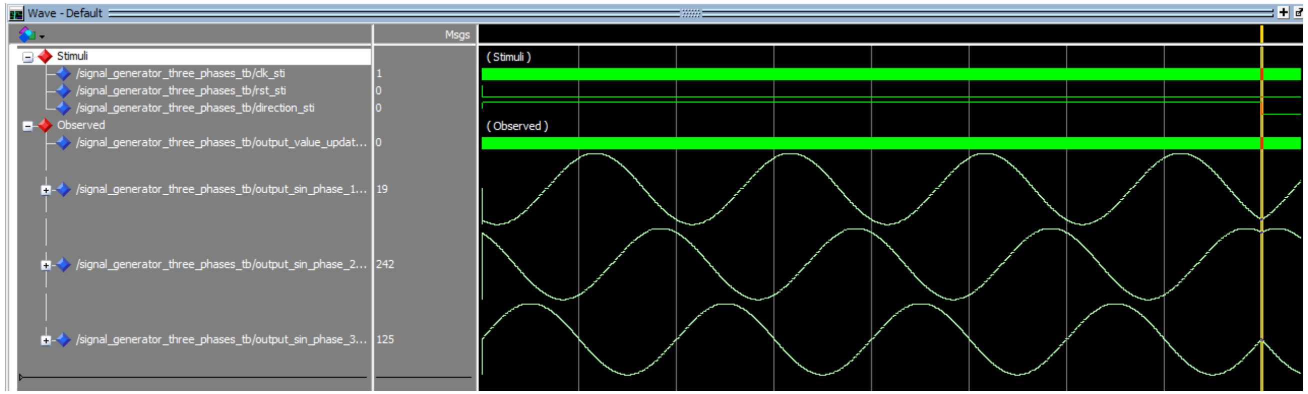




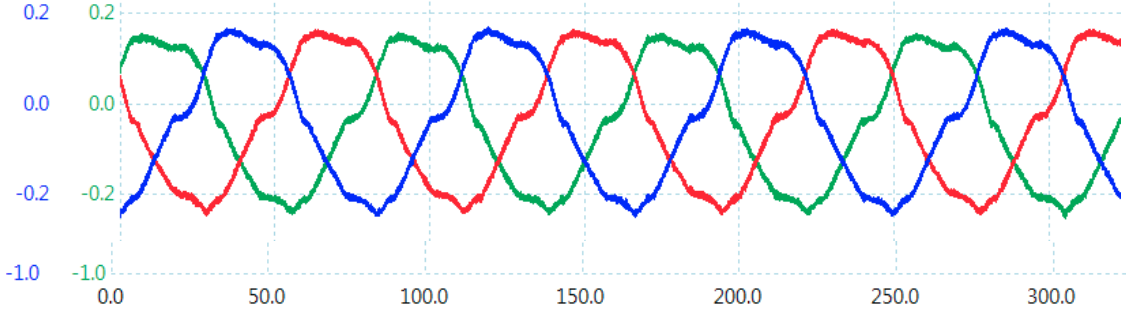
Laboratory tests:
Custom power driver + VFC based control



3 phases control signals simulation in VHDL (Modelsim)



Motor phases current



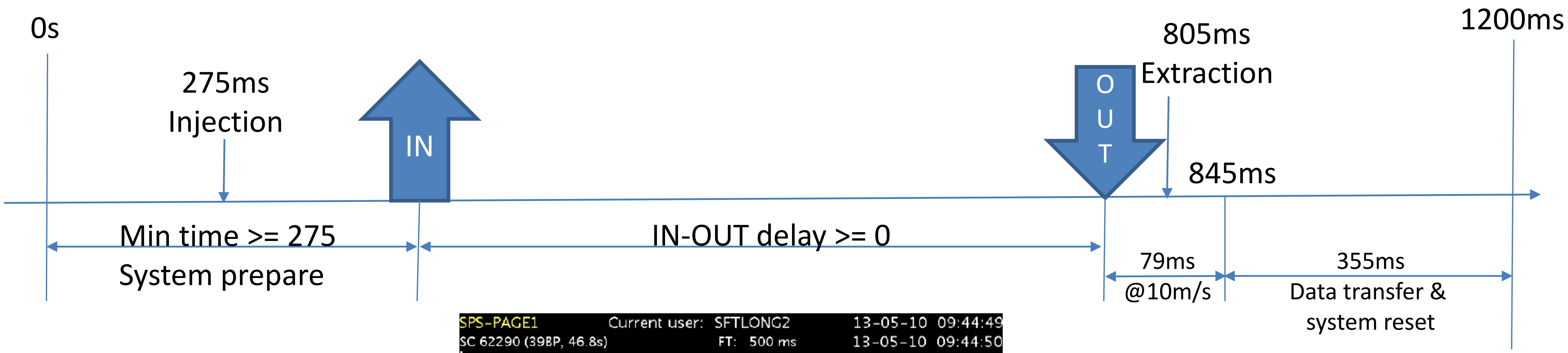
Time [ms]

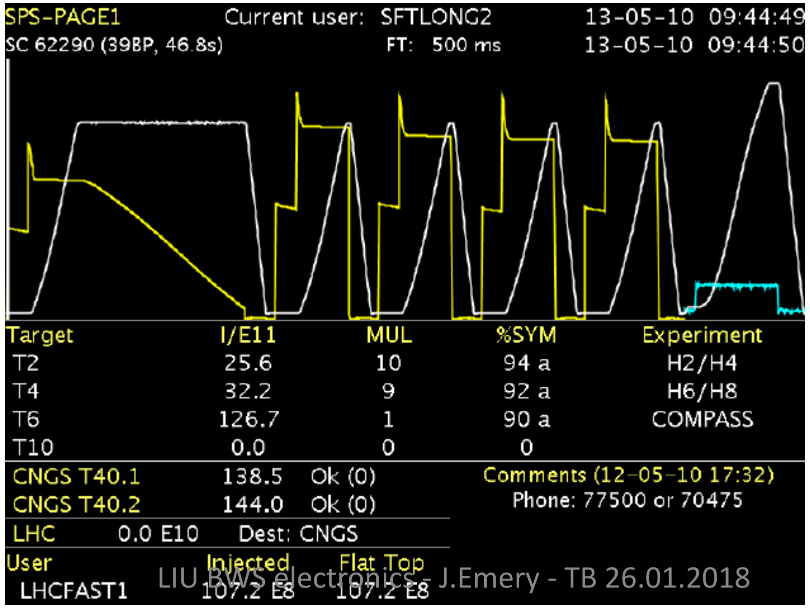
ADDITIONAL SLIDES

Functional system features

- Operate at various nominal speeds (1 m/s to 20m/s)
  For the resolver position:
  20 [m/s] -> 48 [ms] -> 767 pts
  1 [m/s] -> 570 [ms] -> 9119 pts
- One scan cycle per basic period (one IN/OUT)
  Adjustable in/out time, managed by the scanner itself
- Up to 5 scan cycle per user in the SPS
- Target repetition rate: every basic period (tbc)
- Scanner identification by the electronics
  (for simplified calibration management)

One BWS cycle per PSB basic period (1.2s)



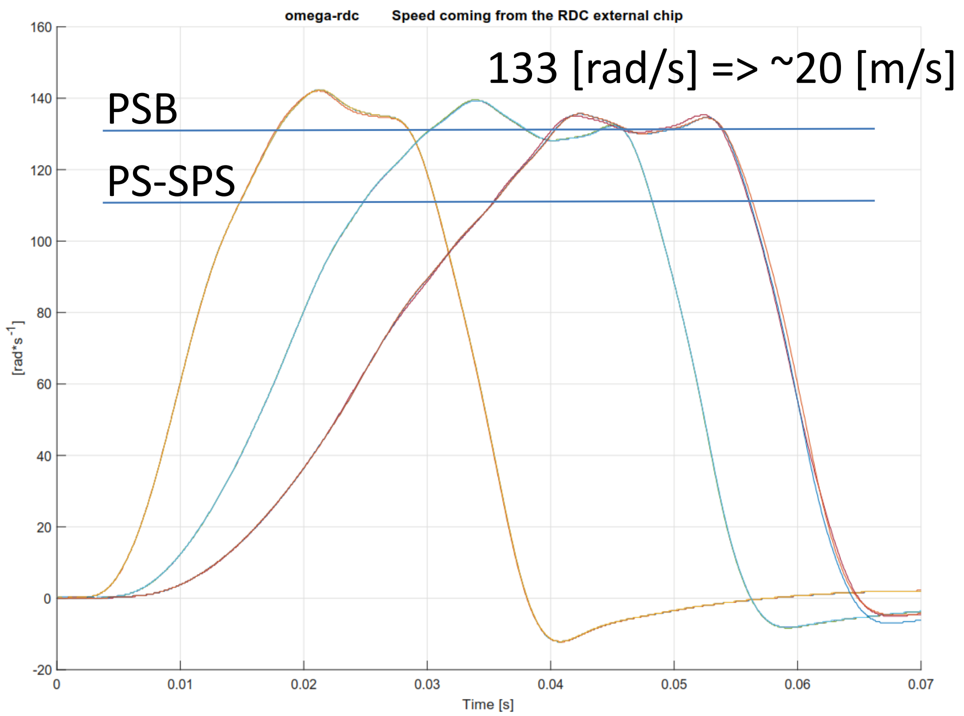


Hardware items status

EDA	Designation	Description	Status	Planning
EDA-03592	BWSCPC	BWS – Capacitor Power Charger	V1 – tested	V2 at design office
EDA-03519	BWSMIB	BWS – Motor Inverter Board	V1 – under test	V2 for mid-February
EDA-03096	BWSAIF	BWS – Analog Interface FMC	V1 – under test	V2 for mid-February
EDA-03624	BWSFHE	BWS – FMC Height Extender	V1 - tested	V2 at design office
EDA-03698	BWSVPA	BWS – VME Power Adapter	V1 to test	
tbd	BWSPSA	BWS – Particle Shower Acquisition	First design ready	V1 at design office
EDA-03634	BWSIDC	BWS – Intelligent Drive Crate	V1 under construction	
EDA-03697	BWSMCU	BWS – Motion Control Unit	V1 under construction	

Motion performance optimisation (2017 studies)

- First motion strategy investigation this year (2017)
- Next step, impact evaluation on the scanner precision (2018)



Angular speed during a measure cycle, ‘IN’ part

Asymmetric motion strategies:

First to second:
Longer stoke and ~ acceleration / 2

First to third:
Longer stroke ~ acceleration / 3

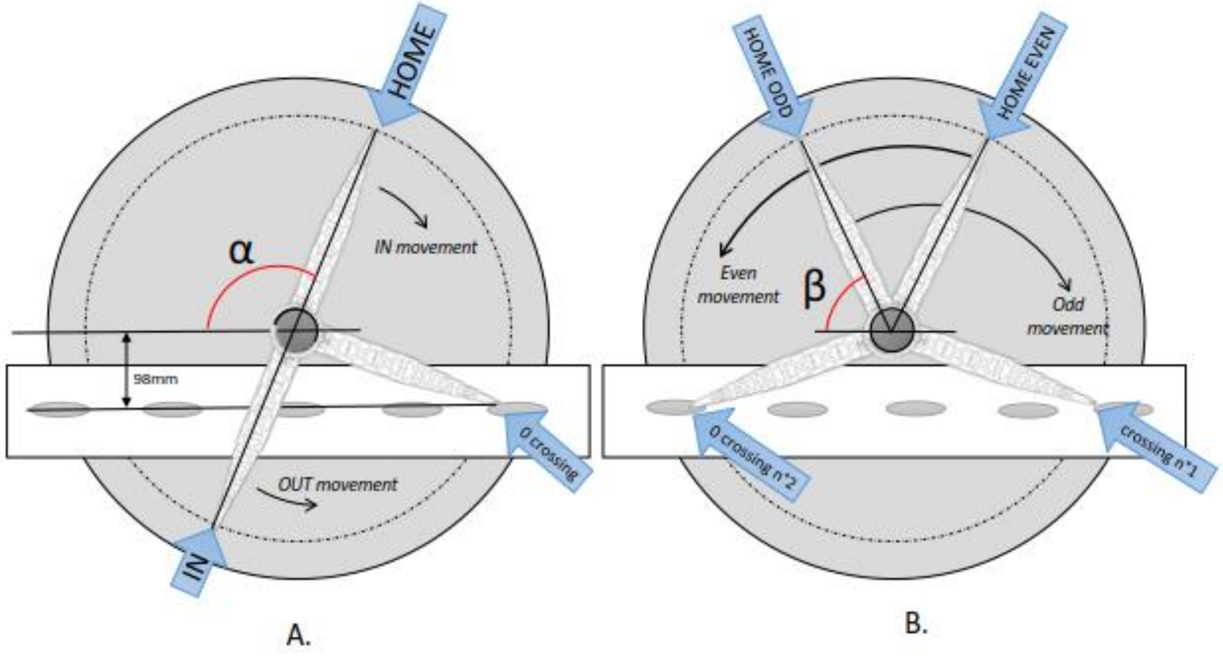
110 [rad/s] for SPS

Motor design (nominal spec)
Max ~160 [rad/s] => 29[m/s] tang.

Motion performance optimisation (2018 studies)

- <u>Study of different motion strategies:</u>
  - Lower the stress on the scanner mechanics, while keeping the nominal speed.
-
  - Evaluate the impact of suppressing the constant speed
    (to lower eventual wire vibration).
-
  - Increase the nominal speed to unsure a high projected speed.

  => Effect on the accuracy/precision of the scanner to be answered in 2018.

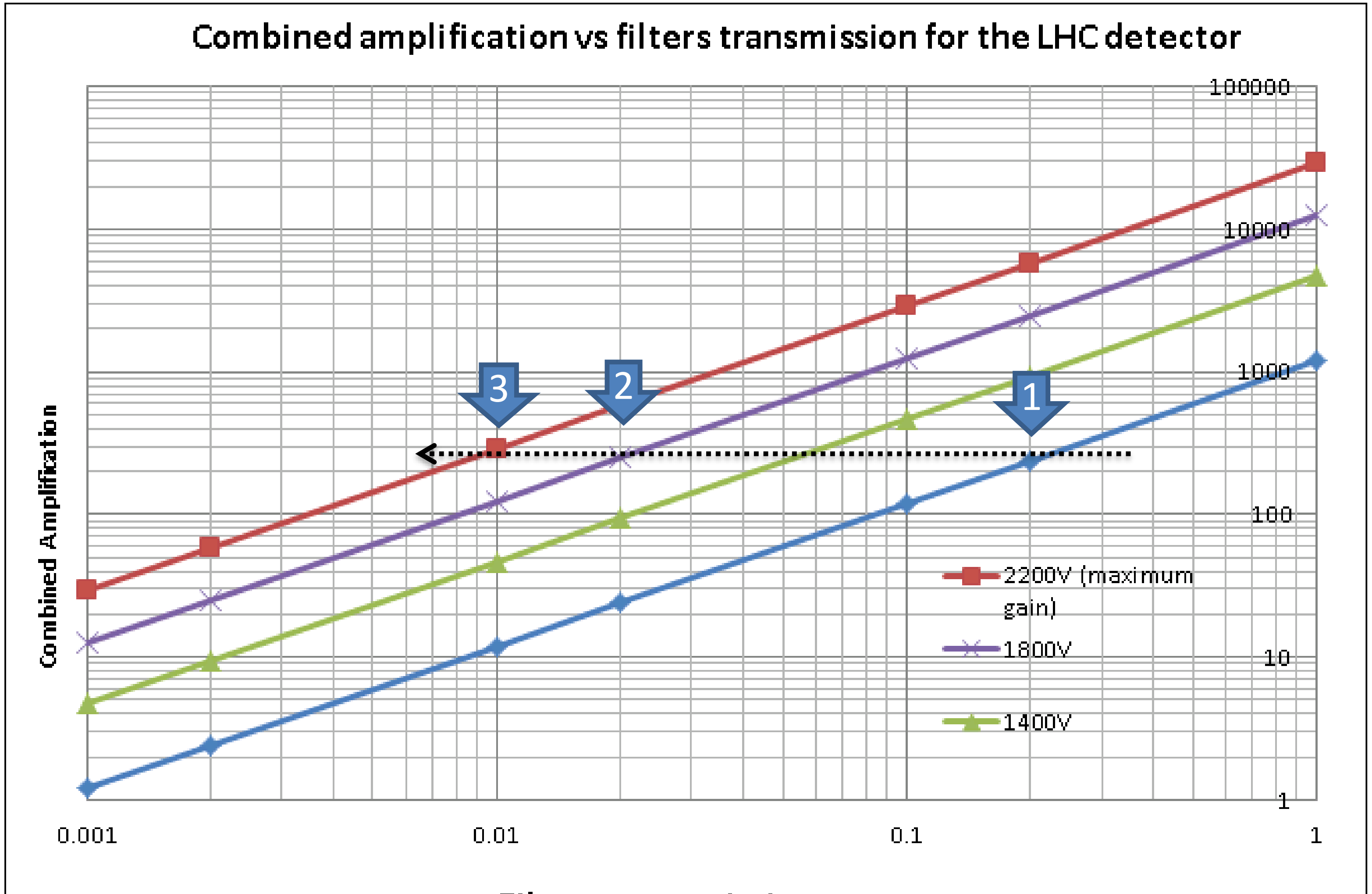


A. Classical approach

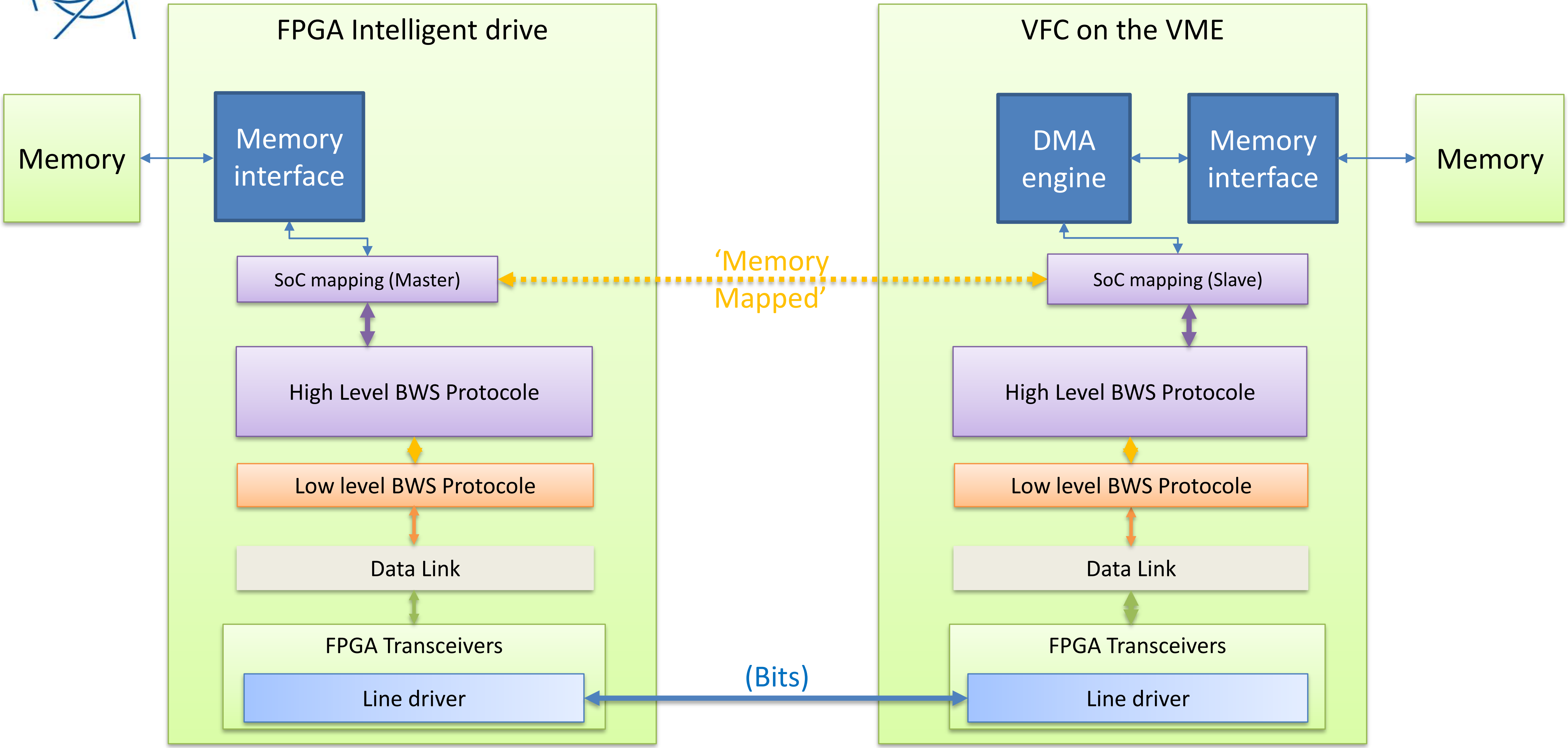
B. 2 crossing strategy:
Time between crossing 1 & 2: 15 [ms]
=> Potentially useful for operation

Secondary shower sensing

Secondary particules detector

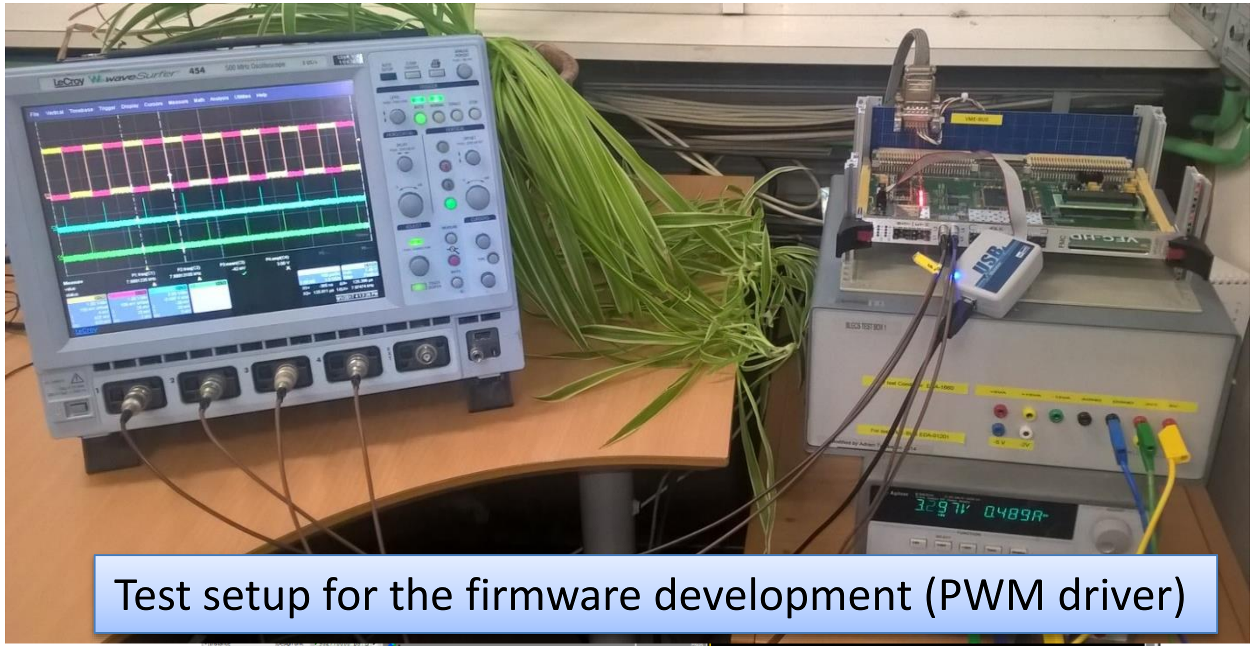


Data collection after a measurement

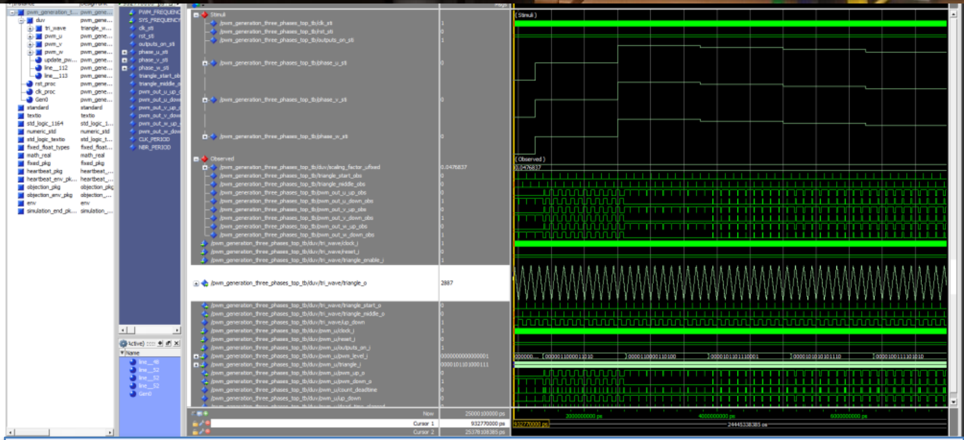


Electronics developments: VFC firmware

- Setup in the office for stand alone use (no VME backplane)
- Already testing first interface to the power board (see picture)
- Development on-going to be able to tests new coming mezzanine
- Code from the SPS prototype to be partialy rewritten for reliability, efficiency and cleanness of the code
- VFC specific interfaces to be written or reused from other on-going projects



Test setup for the firmware development (PWM driver)



VHDL simulation of the new code

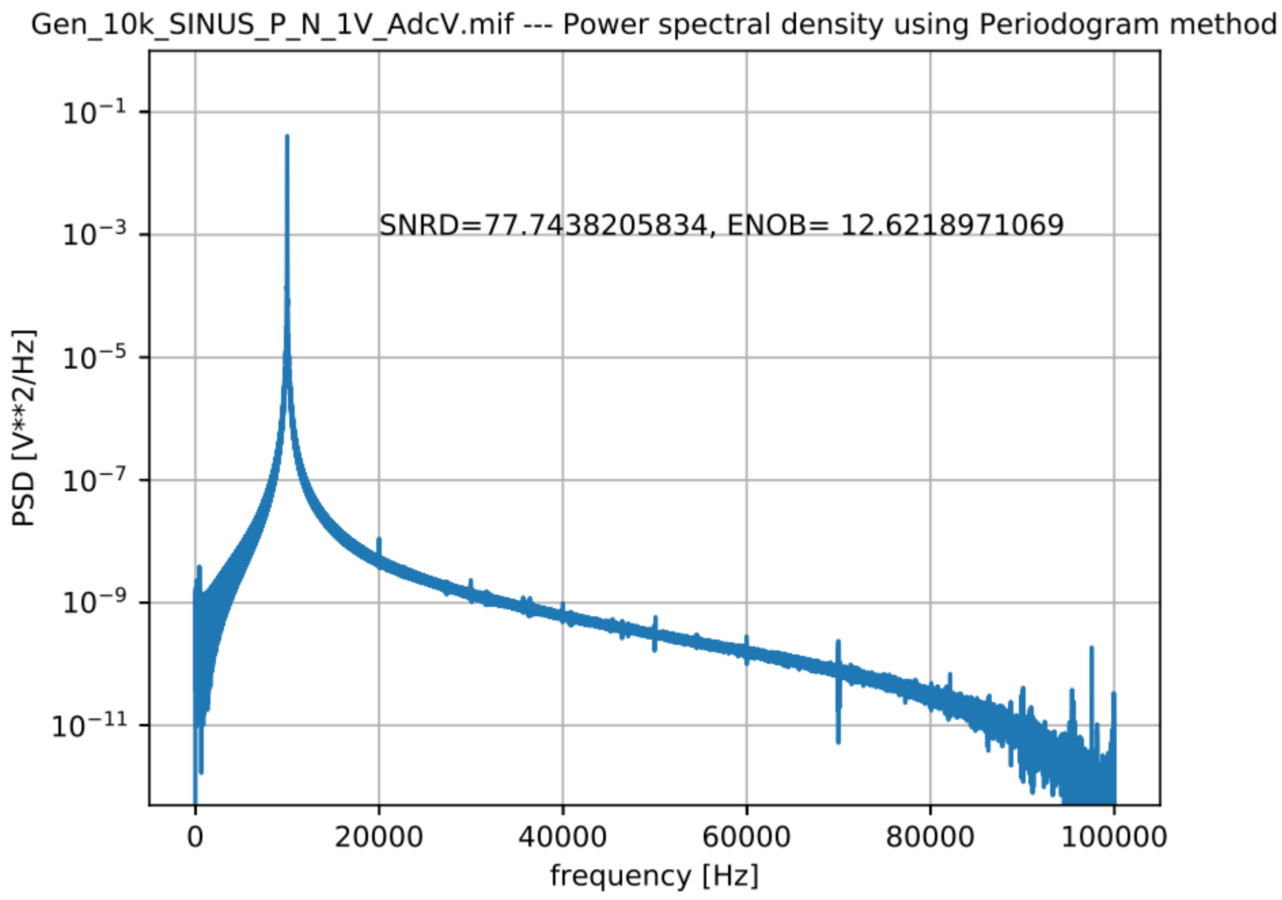
BWSAIF - Analog Interfaces FMC – Board validation tests

Part functioning:

- Power supplies
- Isolated digital I/O
- Isolated interfaces to the inverter
- Scanner Serial number interface
- Slow ADCs for the inverters

To do:

- Resolver interface
- DACs
- Fast ADC
- High res ADC

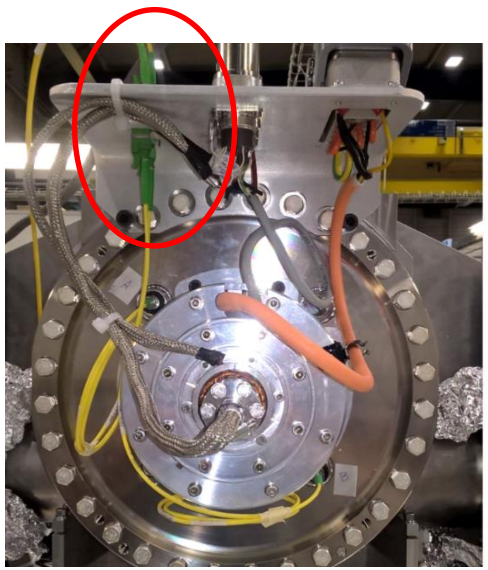


New version needed:
Slot schedule in the design office December 2017

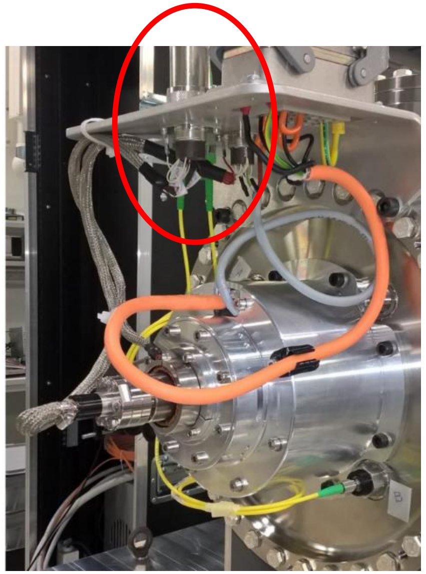
Power Spectral Density
ADC 16 bits dedicated to the measure of one motor phase current

Serial number assignment and reading from the surface

- Hardware encoding of an unique serial number
- Cabled on the scanner connector
(9 bits of information)
- Red from the surface electronics at any time
- Could be red automatically during the calibration process
- Calibration tables will have this number referenced in the files
- Will be used to unsure to correct assignment of the calibration table
- Remove any doubt over time
- Can be used by the electronics to adapt its behavior in function of the machine



BSM19-15



BSM19-7

Machine (3 bits)	Version (2 bits)	Scanner number (4 bits)
0. LAB 1. PSB 2. PS 3. SPS 4. LHC 5. --free 6. --free 7. ISS	0. Rev 0 1. Rev 1 2. Rev 2 3. Rev 3	0 - 15