Intensity measurements using TRIC

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Introduction

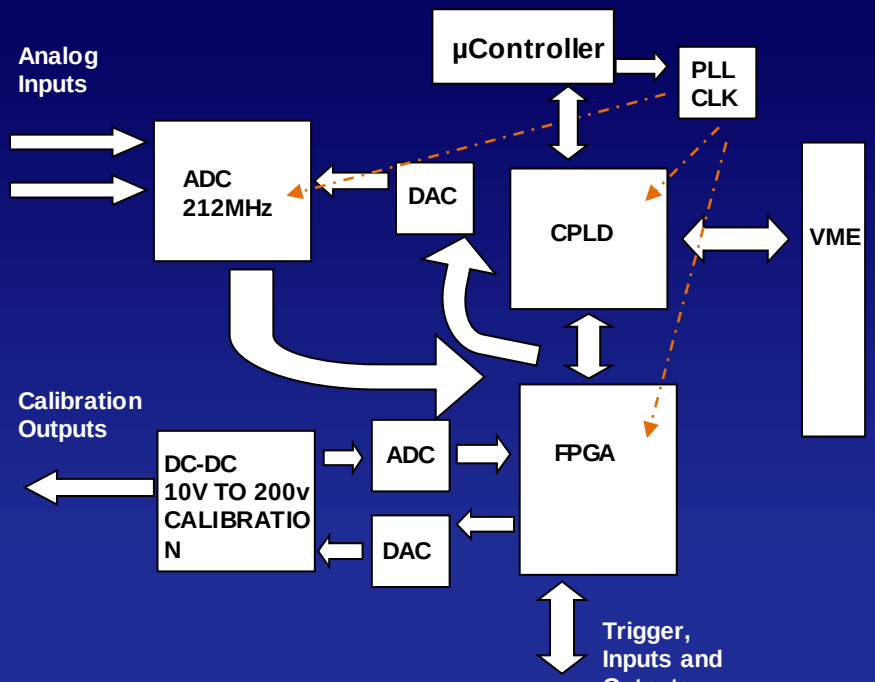
- What is TRIC (TRansformer Integrator Card)?
  - TRIC is a VME64x 6U standard card used to measure beam intensity coming from FBCTs (Fast Beam Current Transformers) in the PS complex.
  - It integrates signals coming from an FBCT using its calibrator as a reference.
  - Calibration can be either on-line (charges, current) or off-line.
  - It offers different integration modes (bunch to bunch, total intensity) with offset suppression.
  - It is remotely managed by software, a FESA class (internal analyzer).

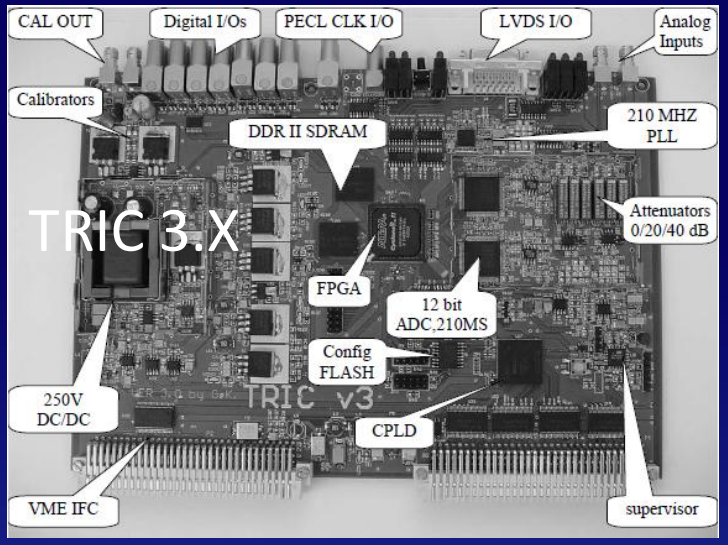
Introduction

Why TRIC?

- Automated calibration
- Remote setup
- Maintainability
- Fast upgrade, FPGA remote programming

Hardware


Analog Inputs
µController
PLL CLK
ADC 212MHz
DAC
CPLD
VME
Calibration Outputs
DC-DC 10V TO 200v CALIBRATION
ADC
DAC
FPGA
Trigger, Inputs and Outputs

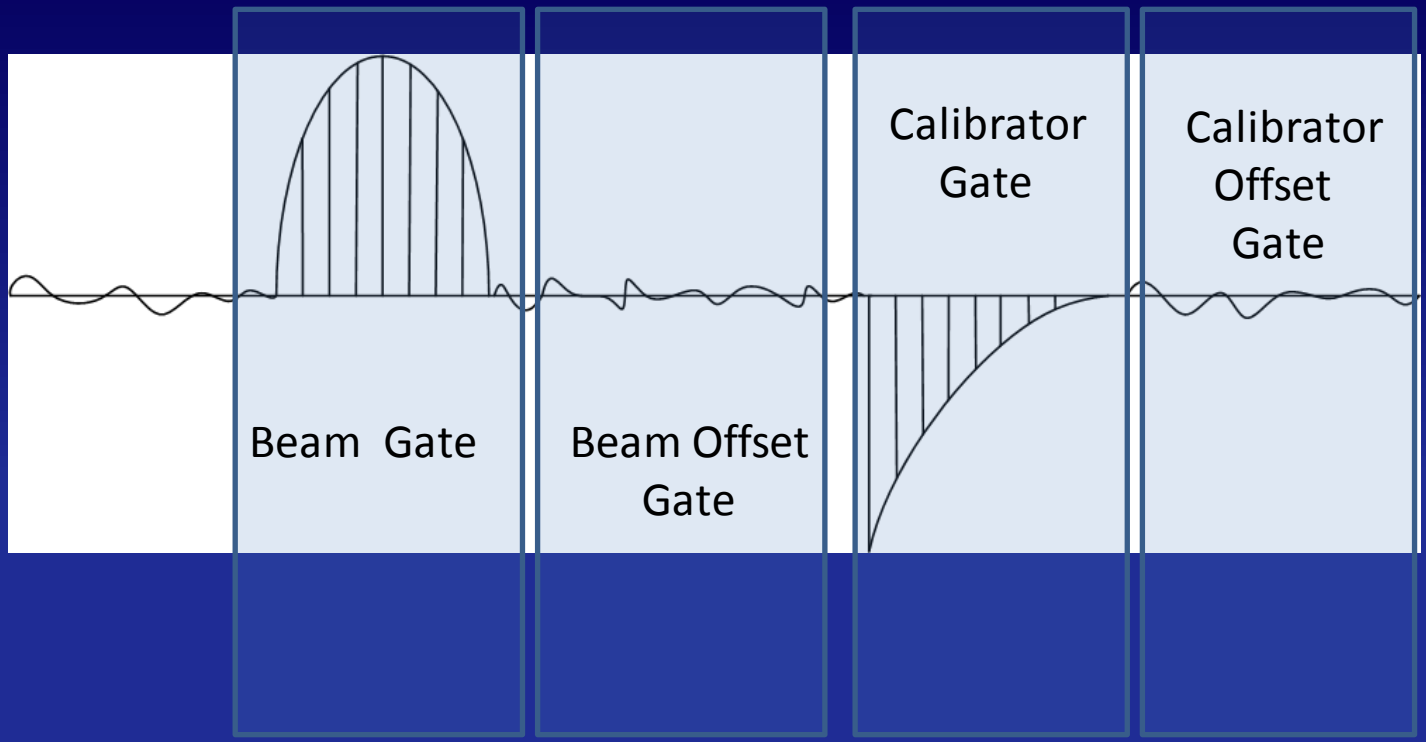

CAL OUT
Digital I/Os
PECL CLK I/O
LVDS I/O
Analog Inputs
Calibrators
DDR II SDRAM
210 MHZ PLL
TRIC 3.X
Attenuators 0/20/40 dB
FPGA
12 bit ADC,210MS
Config FLASH
250V DC/DC
TRIC v3
CPLD
VME IFC
supervisor


TRIC 4
TRIC v4

Measurement principle

$$Q = C \times V \quad \Rightarrow \quad N_{charges\ Cal} = \frac{C \times V}{e}$$

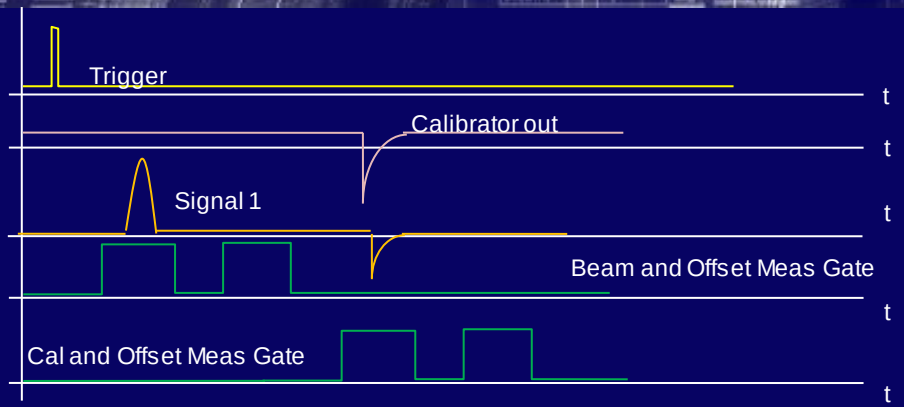
$$N_{charges\ Beam} = N_{charges\ calibration} \times \frac{(Beam\ integral - Offset\ integral)}{(Cal\ integral - Offset\ integral)}$$



Measured Signal

Sampling = 5 ns max
212 MHz ADC

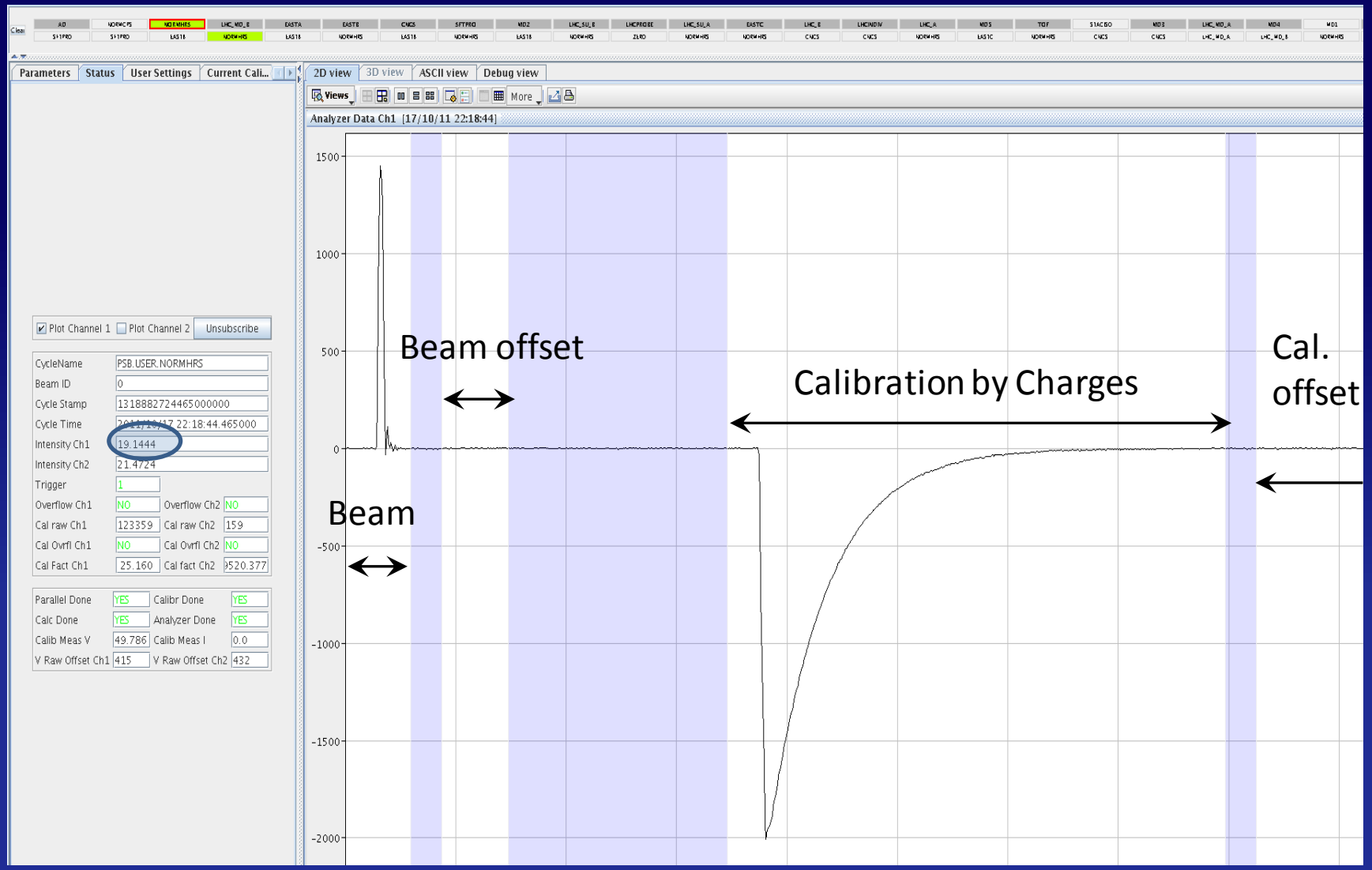
Measurement process



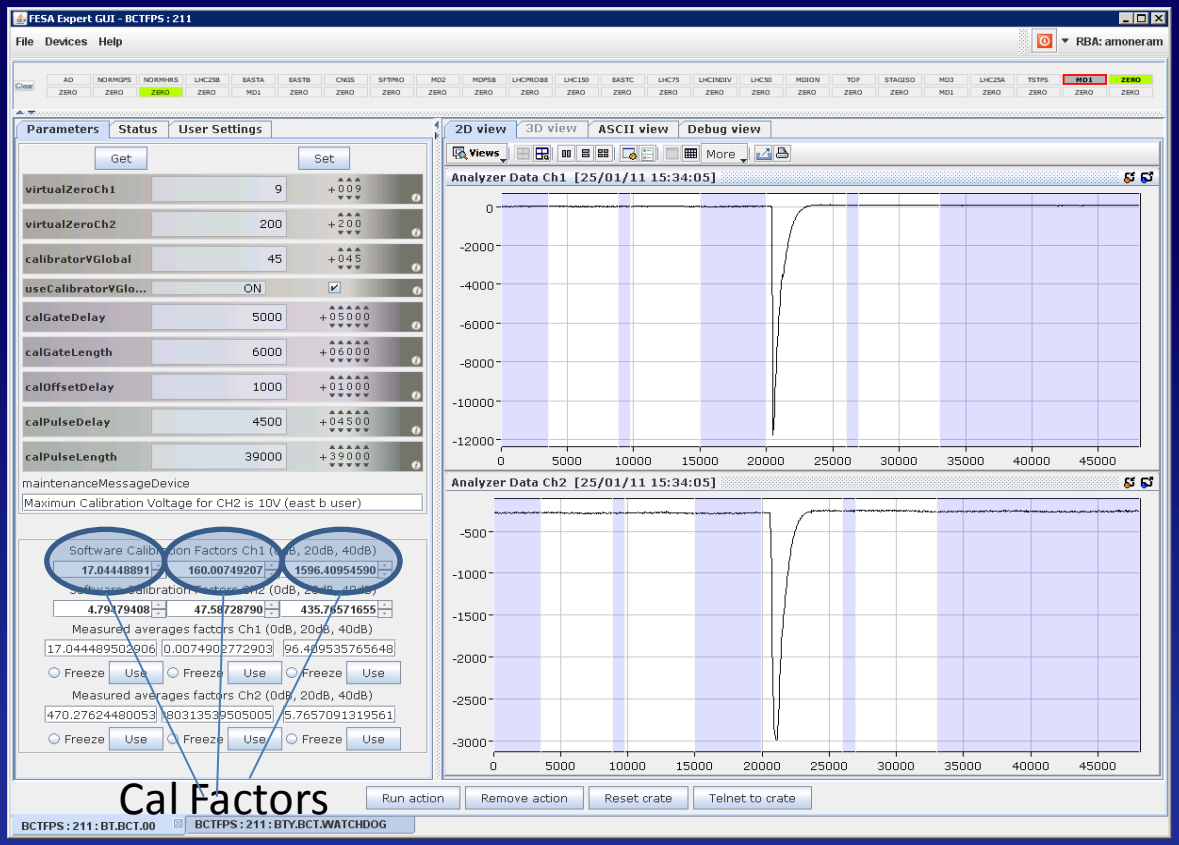
1. Settings from Expert GUI
2. PSB-CPS trigger
3. Beam signal to TRIC
4. Cal signal to FBCT
5. Cal signal to TRIC
6. Intensity calculation

$$N \text{ charges Beam} = N \text{ charges calibration} \times \frac{(\text{Beam integral} - \text{Offset integral})}{(\text{Cal integral} - \text{Cal Offset integral})}$$

Expert GUI


Parameters
Status
User Settings
Current Cali...
2D view
3D view
ASCII view
Debug view
Views
More
Analyzer Data Ch1 [17/10/11 22:18:44]
Plot Channel 1
Plot Channel 2
Unsubscribe
CycleName
PSB.USER.NORMHRS
Beam ID
0
Cycle Stamp
1318882724465000000
Cycle Time
17 22:18:44.465000
Intensity Ch1
19.1444
Intensity Ch2
21.4724
Trigger
1
Overflow Ch1
NO
Overflow Ch2
NO
Cal raw Ch1
123359
Cal raw Ch2
159
Cal Ovrfl Ch1
NO
Cal Ovrfl Ch2
NO
Cal Fact Ch1
25.160
Cal fact Ch2
9520.377
Parallel Done
YES
Calibr Done
YES
Calc Done
YES
Analyzer Done
YES
Calib Meas V
49.786
Calib Meas I
0.0
V Raw Offset Ch1
415
V Raw Offset Ch2
432
1500
1000
500
0
-500
-1000
-1500
-2000
Beam offset
Calibration by Charges
Cal. offset
Beam

Expert GUI



$$C_{FBCT,DCCT} = stdev\left(100 \cdot \frac{DCCT - FBCT}{DCCT}\right)$$

Measurement System	$C_{FBCT1,DCCT}$	$C_{FBCT2,DCCT}$
TRIC Online Calibration	0.65 %	1.16 %
TRIC Offline Calibration	0.074 %	0.189 %

Measured in Booster and Isolde

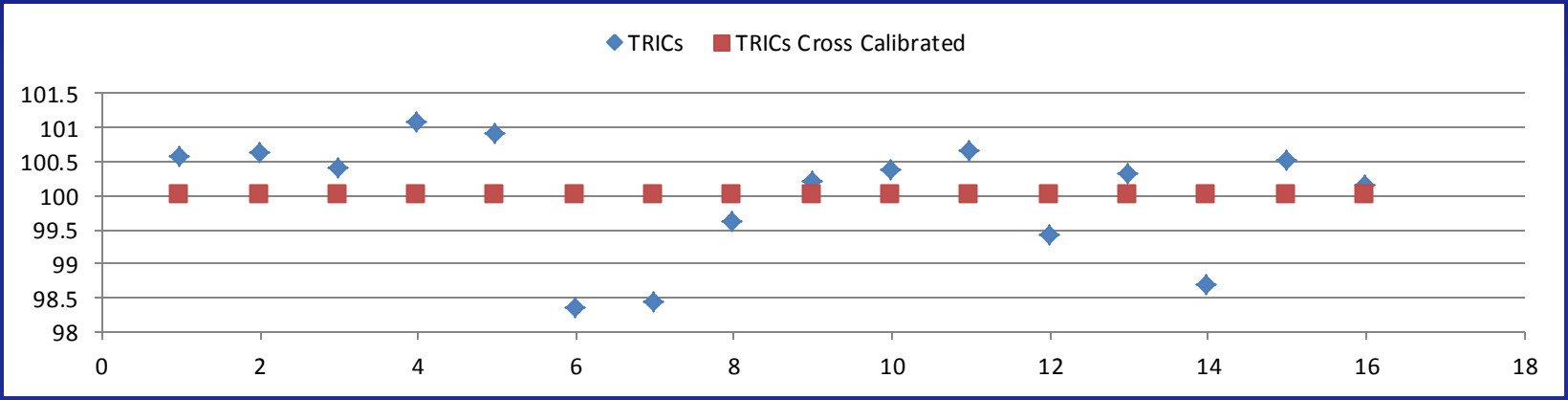
- Cal factors improve the measurement precision
- Are calculated by averaging on-line intensity measurements
- Cal factors for 0dB, 14dB and 28dB attenuation in order to maximize the dynamic range

Cross calibration

- In order to improve the relative precision between the FBCTs we have cross calibrated the TRICs reducing the relative error between them to just TRIC measurement standard deviation (0.25 %) [1], for more info [2].

- The cross calibration procedure starts by sending 1024 calibration pulses from a reference TRIC to the analog inputs of the TRIC been cross-calibrated.

- The measurement results are then averaged in each channel and later on averaged with all the other TRICs. The result of the averaging is the number of charges sent by the reference TRIC but with a lower uncertainty. This value is used to calibrate the other TRICs and to reduce the total uncertainty.

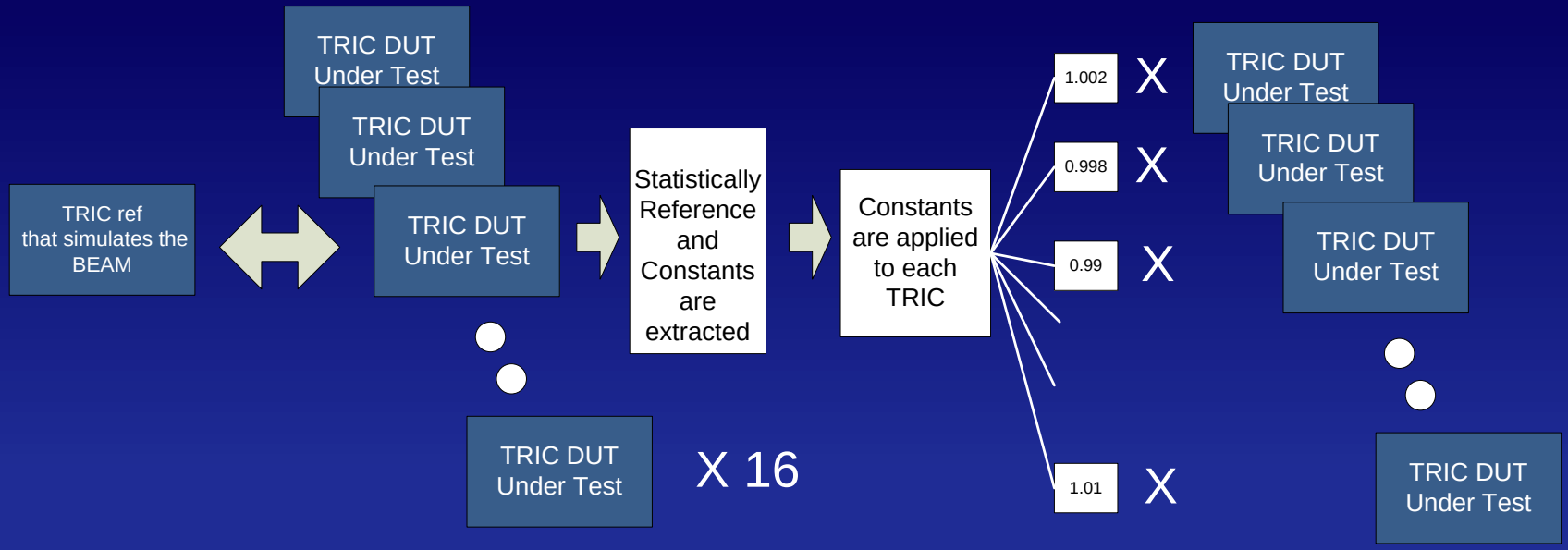


[1] Lab Measurement with the TRIC ref's pulse as input

[2] DIPAC 2011, Upgrade of the PCB/CPS Fast Intensity Measurements

Cross calibration

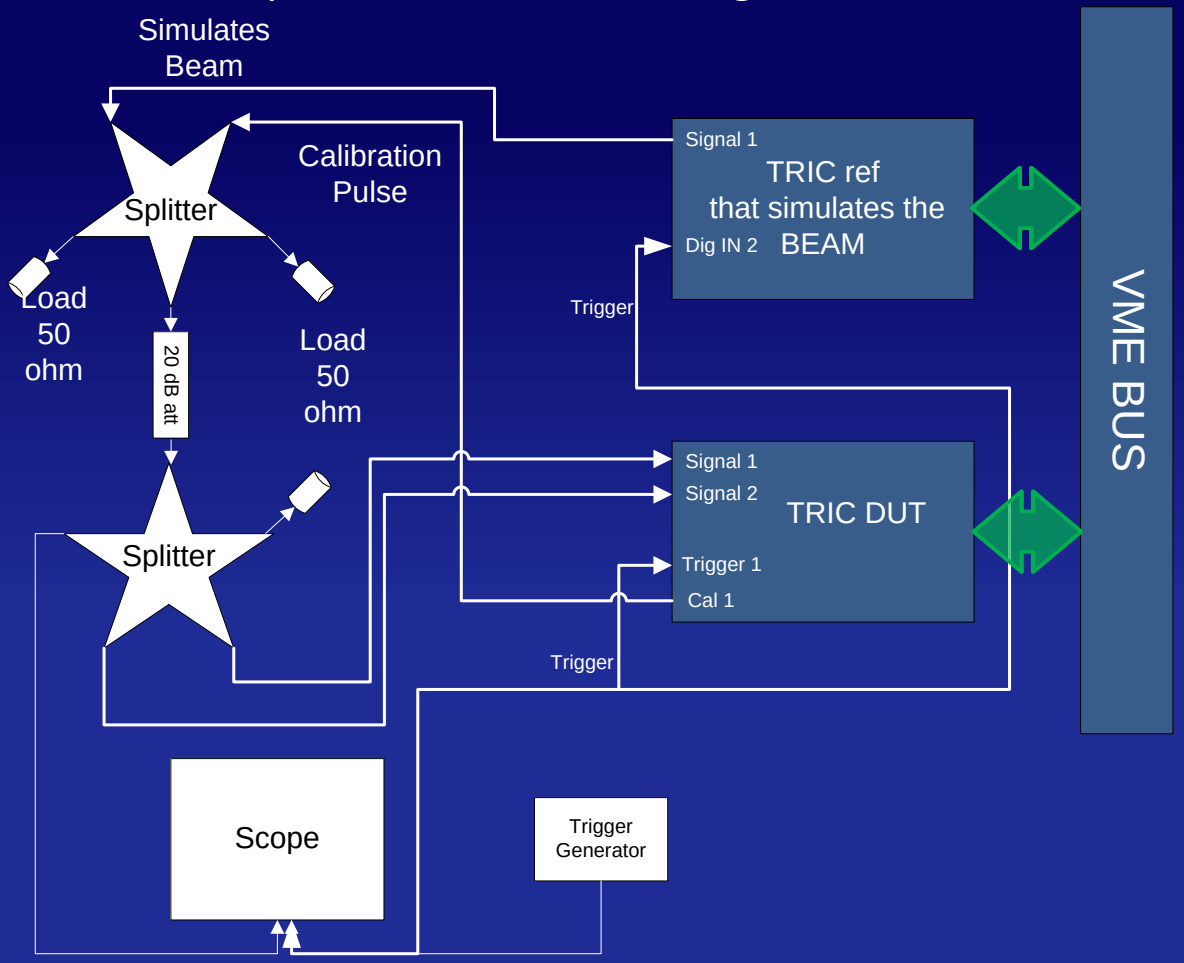
1024 measurements for each card



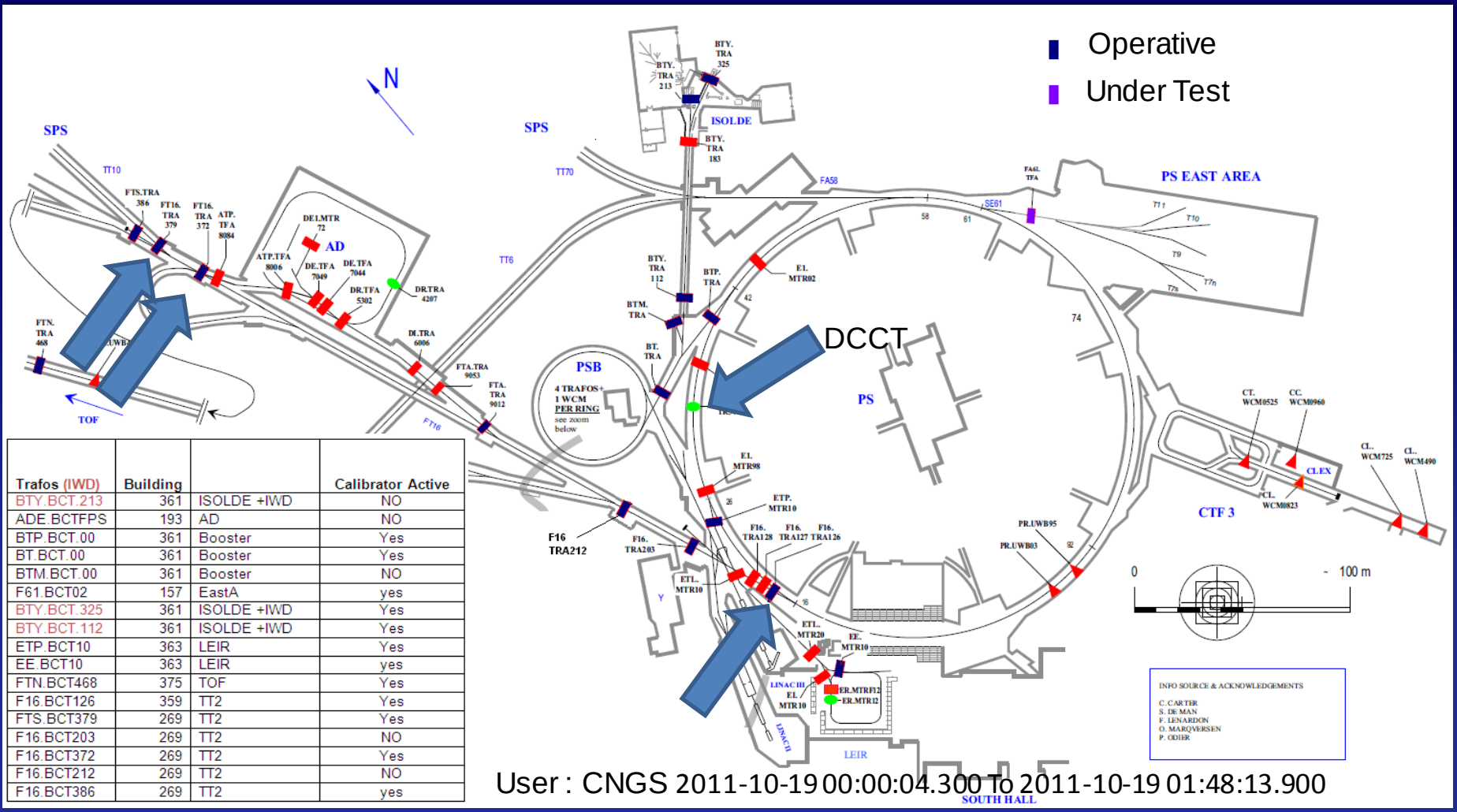
Cross calibration set up

This set up is repeated for all the TRICs resulting in a calibration constant that gives us the deviation for each TRIC in respect to the TRICs' average.

1. Process starts with a C program "testric".
2. TRIC ref sends a calibration pulse which simulates the beam.
3. Signal is received on the TRIC DUT for both channels.
4. TRIC Under Test sends its calibration pulse.
5. Sends measurement results via VME.
6. The program "testric" saves the data and repeats the process 1024 times to have the average value of the measurement; all the data is stored in one file.



Measurements with a calibration constant

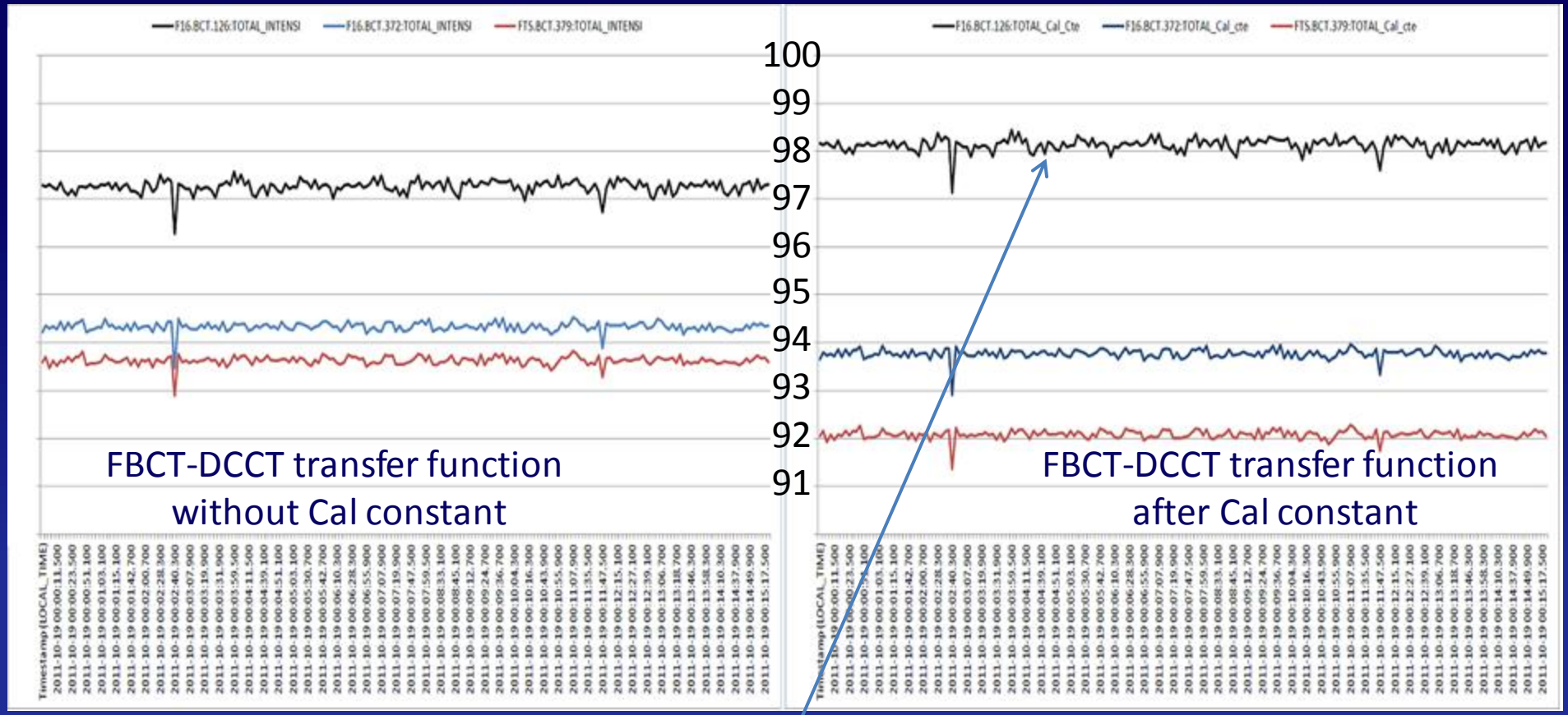


Trafos (IWD)	Building		Calibrator Active
BTY.BCT.213	361	ISOLDE +IWD	NO
ADE.BCTFPS	193	AD	NO
BTP.BCT.00	361	Booster	Yes
BT.BCT.00	361	Booster	Yes
BTM.BCT.00	361	Booster	NO
F61.BCT02	157	EastA	yes
BTY.BCT.325	361	ISOLDE +IWD	Yes
BTY.BCT.112	361	ISOLDE +IWD	Yes
ETP.BCT10	363	LEIR	Yes
EE.BCT10	363	LEIR	yes
FTN.BCT468	375	TOF	Yes
F16.BCT126	359	TT2	Yes
FTS.BCT379	269	TT2	Yes
F16.BCT203	269	TT2	NO
F16.BCT372	269	TT2	Yes
F16.BCT212	269	TT2	NO
F16.BCT386	269	TT2	yes

User : CNGS 2011-10-19 00:00:04.300 To 2011-10-19 01:48:13.900

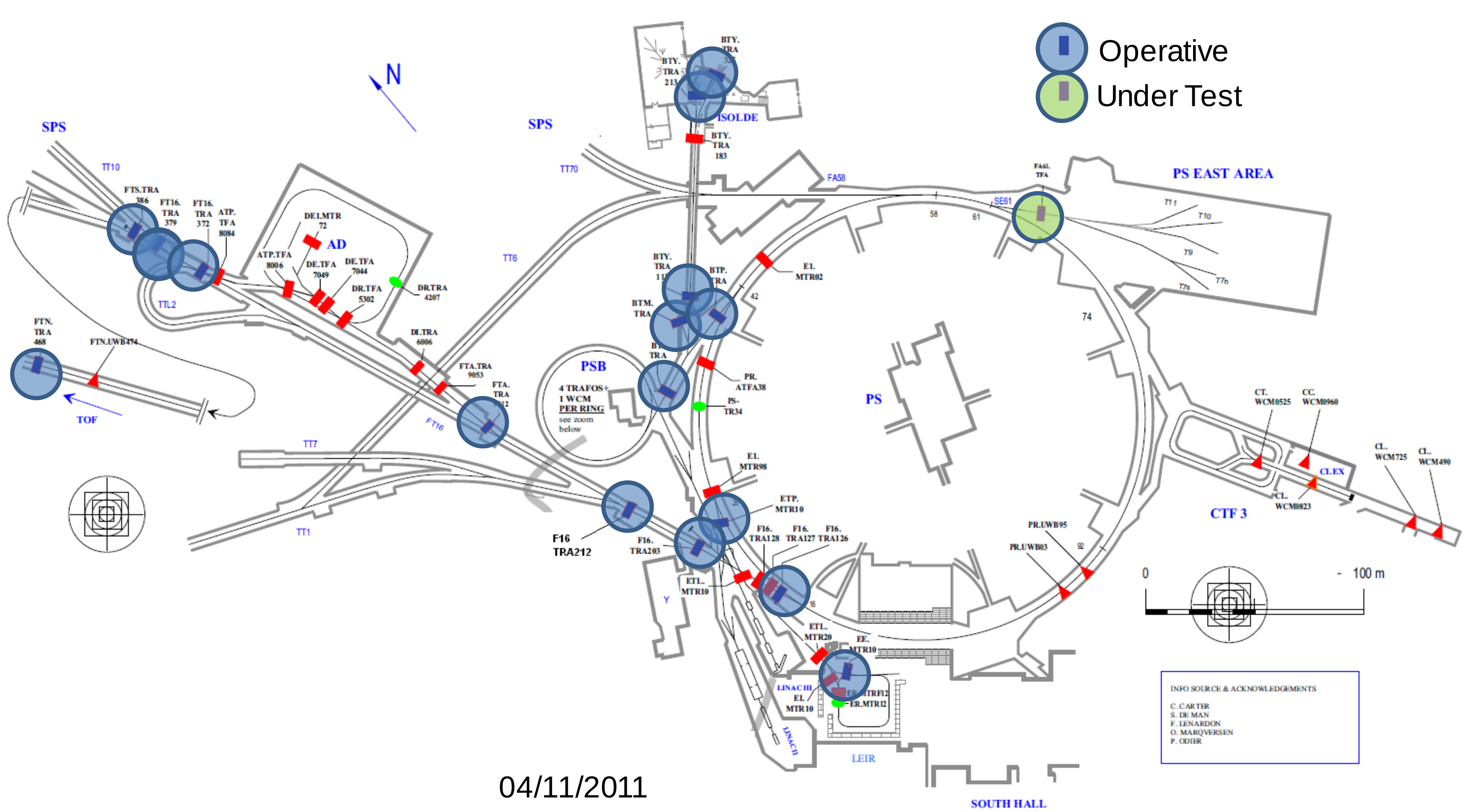
Measurements with a calibration constant

User : CNGS 2011-10-19 00:00:04.300 To 2011-10-19 01:48:13.900



F16.BCT: difference between non cross-cal and cross-cal is 1% when comparing with DCCT.

TRIC deployment



04/11/2011

TRIC deployment

TRICs currently installed

Trafos (IWD)	Building	Area	Cal Constant	On-line Cal
ADE.BCTFPS	193	AD	1.001857255	NO
BT.BCT.00	361	Booster	1.003668495	Yes
BTM.BCT.00	361	Booster	1.003144575	NO
BTP.BCT.00	361	Booster	1.006215261	Yes
BTY.BCT.112	361	ISOLDE +IWD	0.996025536	Yes
BTY.BCT.213	361	ISOLDE +IWD	1.005648197	NO
BTY.BCT.325	361	ISOLDE +IWD	1.010488715	Yes
EE.BCT10	363	LEIR	to update	yes
ETP.BCT10	363	LEIR	0.100399118	Yes
F16.BCT126	359	TT2	1.008978695	Yes
F16.BCT203	269	TT2	0.984291892	NO
F16.BCT212	269	TT2	to update	NO
F16.BCT372	269	TT2	0.994004397	Yes
F16.BCT386	269	TT2	to update	Yes
F61.BCT02	157	EastA	1.006336858	yes
FTS.BCT379	269	TT2	0.983478171	Yes

Outlook

	FCBT	Date	
PS to AD:	TRA.9053	2012	
	TRA6006	2012	
AD:	TFA.5302	2012	
	DE.TFA7049	2012	
LINAC3	ITL.TRA05	2012	
	ITF.TRA15	2012	
	ITF.TRA25	2012	
	ITH.MTR41	2012	
LEIR	ETL.MTR10	2012	
	ETL.MTR20	2012	
	EI.MTR10	2012	
	ER.MTRF12	2012	
L4 3MeV	L4L.BCT.3113	2012	CHOPPER
	L4L.BCT.4013	2012	CHOPPER
	L4L.BCT.	2012	ML
	L4L.BCT.	2012	ML

Outlook

- Introduce certain hardware modifications to reduce the thermal and electromagnetic noise (new DC-DC converter in new version TRIC 4).
- Replace the old FBCTs (some are more than 30 years old) in order to have a standard set TRIC + FBCT for the intensity measurements.

Conclusions

- TRIC has become the new standard for the beam intensity measurement in the PS complex.
- TRIC 4 prototype manufacturing and 30 boards buch intended for 1st Q 2012.
- 17 units currently installed in total, 30 units expected to be installed for LINAC3, LINAC4, AD and LEIR.

Thank You ☺ , Questions ??

ADC Analog Devices AD9430

Resolution
Q = FSR/N => 1.5/2^10.6
Q = 966.43 µV

Clock Oscillator

Model CCPD-034 is a 162.000MHz to 250.000MHz LVPECL

Phase Jitter: 12kHz~80MHz

0.5ps typ., 1ps RMS max

FEATURES

SNR = 65 dB @ f_{IN} = 70 MHz @ 210 MSPS
ENOB of 10.6 @ f_{IN} = 70 MHz @ 210 MSPS (–0.5 dBFS)
SFDR = 80 dBc @ f_{IN} = 70 MHz @ 210 MSPS (–0.5 dBFS)
Excellent linearity:
DNL = ±0.3 LSB (typical) Differential Non Linearity
INL = ±0.5 LSB (typical) Integral Non Linearity
2 output data options:
Demultiplexed 3.3 V CMOS outputs each @ 105 MSPS
Interleaved or parallel data output option
LVDS at 210 MSPS
700 MHz full-power analog bandwidth
On-chip reference and track-and-hold
Power dissipation = 1.3 W typical @ 210 MSPS
1.5 V input voltage range
3.3 V supply operation
Output data format option
Data sync input and data clock output provided
Clock duty cycle stabilizer

TRIC Specs

Parameter	Value
Number of independent ADC and calibrator channels	2
ADC ENOB	9.7
Linearity	0.2%
Input Low Pass Filter cut-off frequency	30MHz, 7-th order LC filter
Measurement ranges	-0.5..+0.5V ; 0, 20, 40dB attenuation
Over voltage protection	Yes, both channels, clipping at +/- 5.3V
Sampling rate	212.5MHz
Remote firmware upgrade	Yes, conFigure FLASH update and direct FPGA configuration
Measurement gate length (PSB mode)	20ns…8.5s, 10ns step
Measurement gate delay (PSB mode)	20ns…8.5s, 10ns step
Input offset compensation	Yes, before (offset DAC) and after ADC conversion (BLR)
Calibration pulse amplitude (current mode)	0..2A at 50Ohm load
Calibration pulse rise time (current mode)	<15ns
Calibration pulse time (current mode)	100ns…~1ms
Calibration pulse amplitude (charge mode)	0..200V
Calibration pulse charge (charge mode)	10nF 5% capacitor: 0..2µC
Calibration mode	Before or after measurement
Remote control of all the functions (including calibration procedure)	Yes, embedded VME controller running LynxOS
Digital inputs	6 x (LV)TTL, LEMO connectors, over voltage protected
Digital outputs	10x TTL, LEMO connectors, over voltage protected
Dedicated high speed interface	Yes, 8 channel bi-directional LVDS
Communication interface	VME 64X mechanical form, 24bit address, 32bit data
Burst VME transfers support	Yes
Programmable logic resources	~20,000 Logic Entities(LE) of FPGA + 570 LE of CPLD
On-board RAM	Yes (xxxxxxxxxx)

Cross correlation

	F16.BCT.126:TOTAL_Cal_Cte	*F16.BCT.372:TOTAL_Cal_cte*	*FTS.BCT.379:TOTAL_Cal_cte*	*PR.DCBEFEJE_1:INTENSITY*
F16.BCT.126:TOTAL_Cal_Cte	1			
F16.BCT.372:TOTAL_Cal_cte	0.998889921	1		
FTS.BCT.379:TOTAL_Cal_cte	0.998917324	0.99976406	1	
PR.DCBEFEJE_1:INTENSITY	0.998687858	0.999484239	0.999425024	1