

Upgrade of PS complex BCTs

Status and outlook

Lars Søyby

On the behalf of:

**Maxim Andersen, Juan Carlos Allica, David Belohrad,
Franco Lenardon, Lars Jensen, P. Odier.**

Outlook

- BCT overview and upgrades
- **Introducing TRIC**
- Upgrades for the Linac's and Booster injection
- **New FBCT for PSB and PS extraction lines**
- LEIR, PSB, PS DCCT's
- **Summery**

Upgrades

- **Why:**

- In order to improve the accuracy of the measured transfer efficiencies, we try to improve the relative accuracy of our intensity measurements.

- **FBCTs**

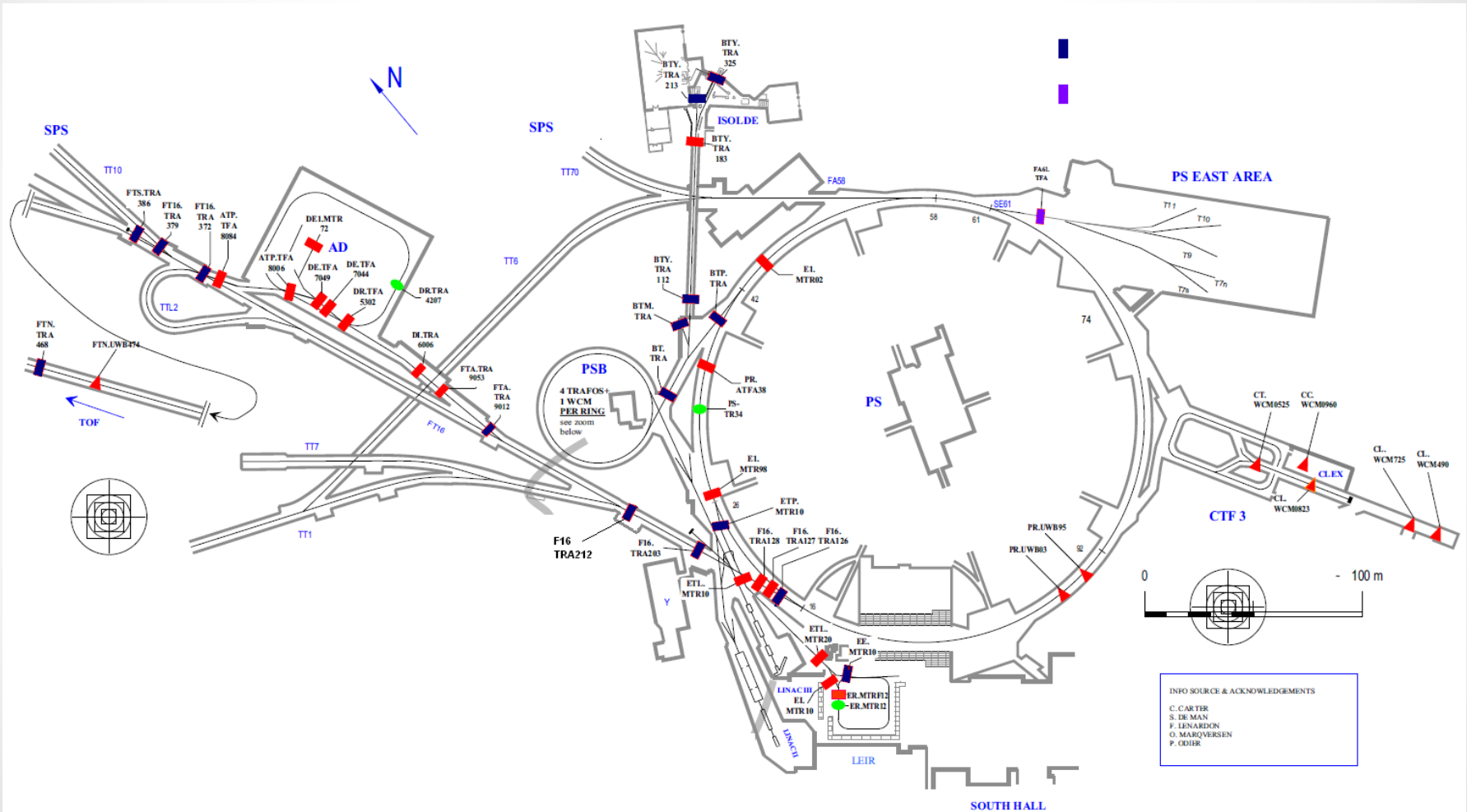
- **From:** Devices with different mechanical structure and magnetic properties, with little knowledge of their performance
- **To:** Same toroid everywhere (Linac different from H.E. transfer lines) , same mechanical structure, and well know performances with respect to beam position and bunch length dependency. Same cable type everywhere.
- New radiation hard FE electronics

- **Acquisition system, FBCTs**

- **From:** Analogue integrators, with complicated timing and no remote control and diagnostic.
- **To:** Single unit, cross calibrated VME cards with onboard calibrator, remote control, acquisition. **TRIC**

- **DCCTs**

- Consolidation analogue electronic, new ADC and CPU, upgrade of FESA class.



L2	L3	L4	LEIR	PSB	PS / TT2	ADE
LI.TRA02	ITL.TRA05	L4L.BCT.1213	ETL.MTR10	BI.BCT10	PR.ATFA38	FTA.TRA9012
LI.TRA06	ITF.TRA15	L4L.BCT.3103	ETL.MTR20	BI.BCT20 *4	PR.TDC34	FTA.TRA9053
LA.TRA07	ITF.TRA25	L4L.BCT.4013	EI.MTR10	BR.TFA	FT16.TRA126	TRA6006
LT.TRA10	ITH.MTR41	L4L.BCT.4040	ER.MTRF12	BR.TMD	FT16.TRA127	DR.TFA.5302
LTE.TRA15		L4L.BCT.5010	ER.MTR12	BR.TSW	FT16.TRA128	DE.TFA7049
LTS.TRA12		L4C.BCT.0117	EE.MTR10	BR.TDC	FT16.TRA203	
LTS.TRA14		L4P.BCT.0117	ETP.MTR10	BT.BCT10	FT16.TRA212	
LT.TRA20		L4T.BCT.0107		BTP.BCT10	FT16.TRA372	
LT.TRA30		L4T.BCT.0673		BTM.BCT10	FT16.TRA379	
LT.TRA40		L4T.BCT.1043		BTY.BCT112	FTD.TRA386	
LTB.TRA50		L4T.BCT.1243		BTY.BCT183	FTN.TRA468	
LTB.TRA60		L4T.BCT.1553		BTY.BCT213	FT61.TRA	
LBS.TRA62		L4Z.BCT.0293		BTY.BCT325		
LBS.TRA64						
LBE.TRA65						

Used with L4
Acq to BOR

New FBCT

With TRIC

Will be equipped with TRIC in LS1

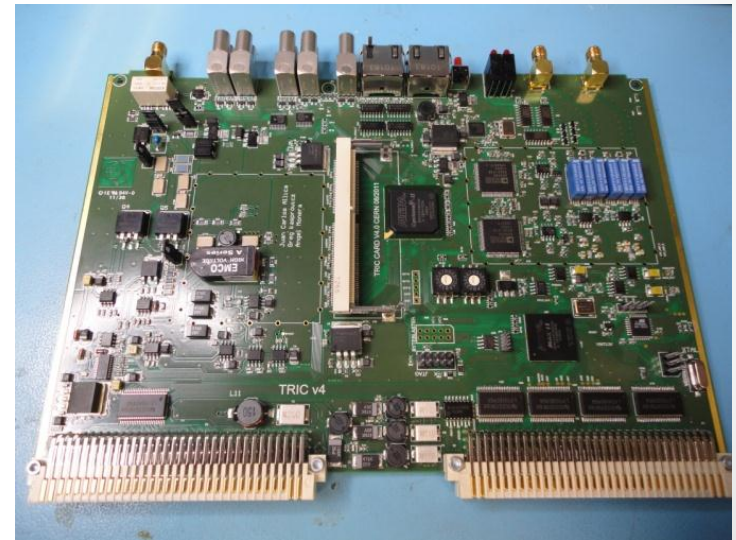
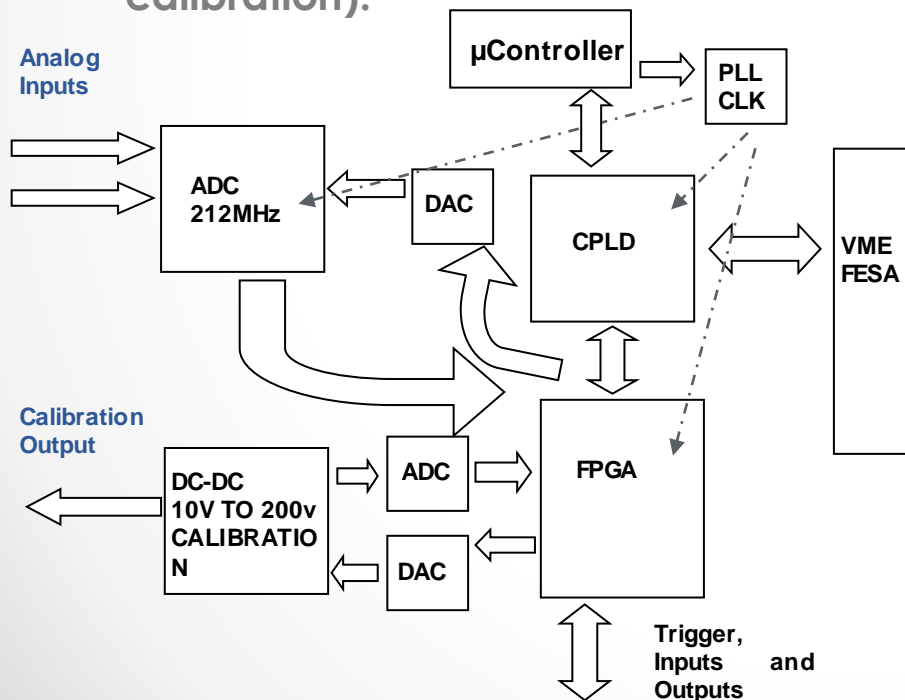
DCCT

Total of 69 BCTs

TRIC acquisition system

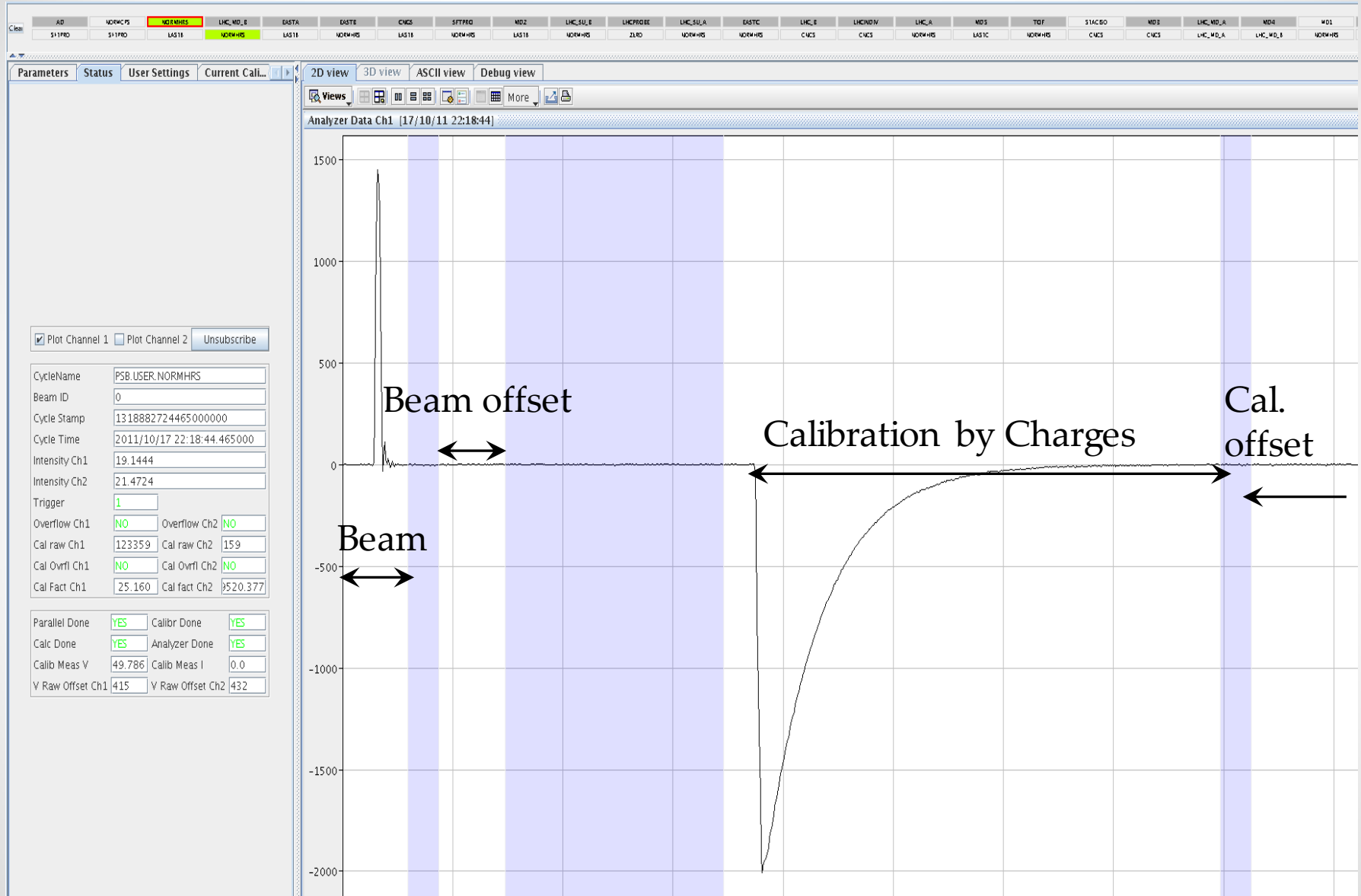
TRIC acquisition system

- TRIC is a VME64x 6U standard Card used to Measure Beam intensity using signals coming from the FBCT (Fast Beam Current Transformers) in the PS complex
- Integrates In digital domain signals using its on board calibrator as a reference.
- Calibration can be either **on-line** (charges, **current**) or **off-line**.
- Different Integration modes (Parallel, Linac) both with offset suppression.
- It is remotely managed by Software, FESA class (gates, internal Analyzer, calibration).

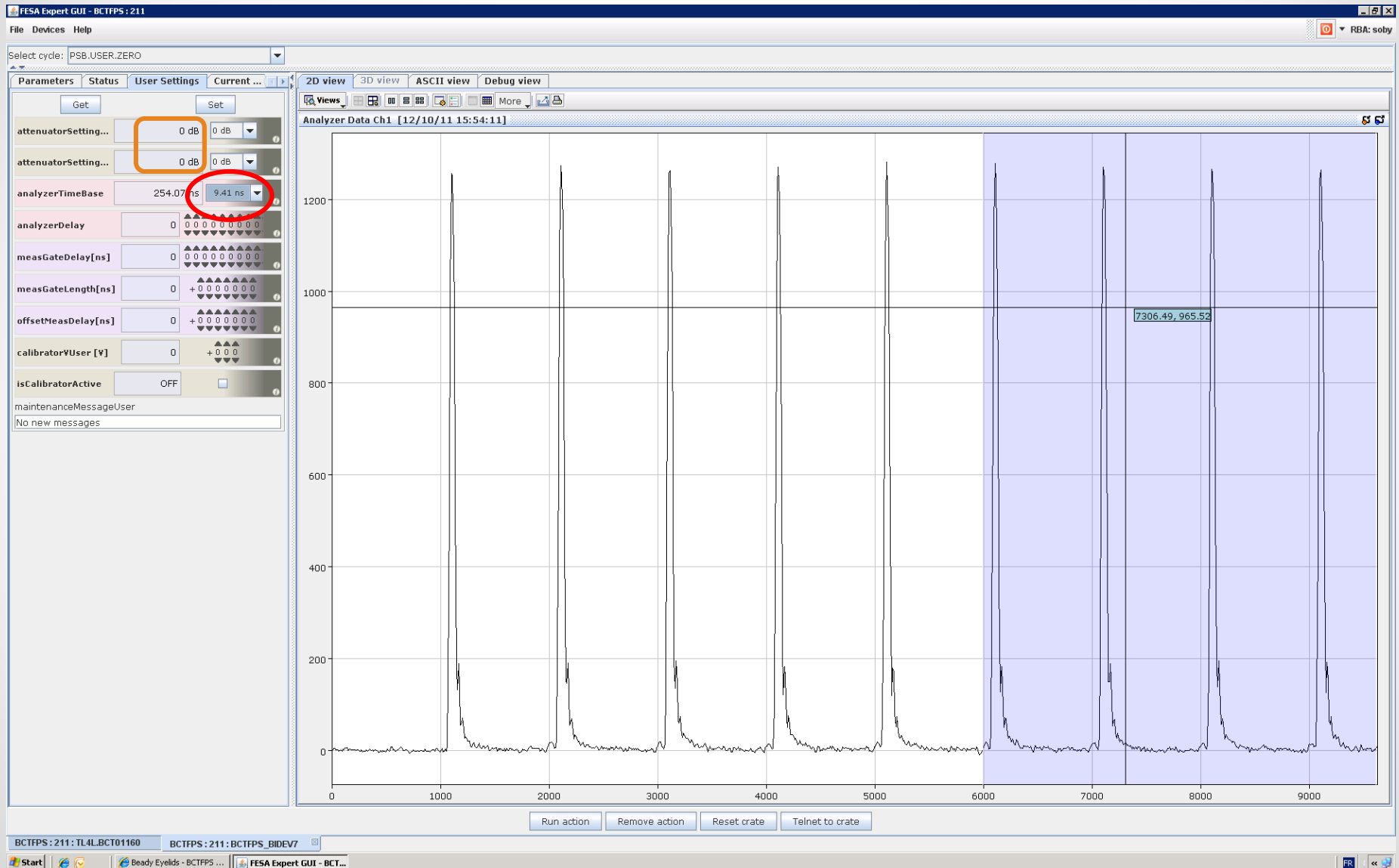


212 MHz ADC, 12bit

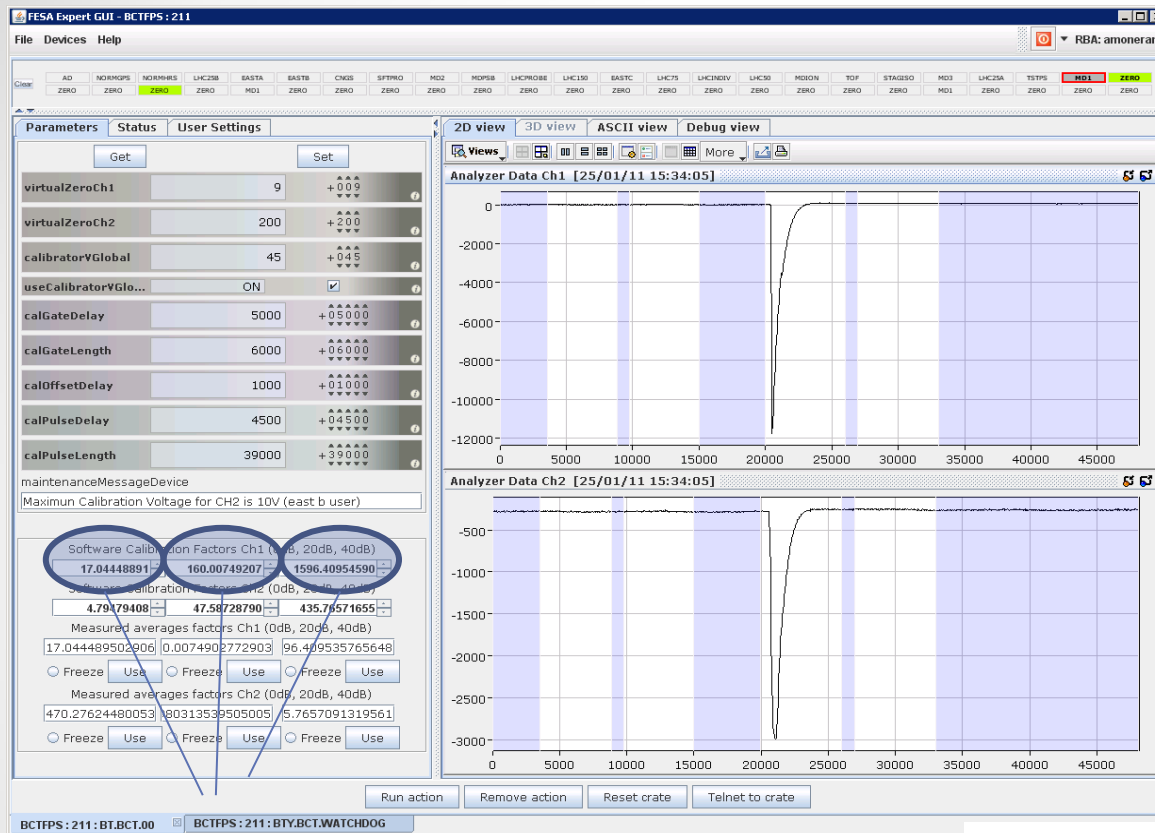
TRIC: Expert GUI Software, Parallel integrator



TRIC: Expert GUI Software



TRIC: Calibration pulses



Cal factors for 0dB, 14dB and 28dB attenuation

Calibration factors can be averaged and frozen, which improves by ~a factor 10 the shot to shot precision.

● MSWG: Upgrade of PS complex BCTs

In laboratory very good stability

	Charge	Current
Accuracy	~1-2%	~1%
Stdev	0.15%	0.02%

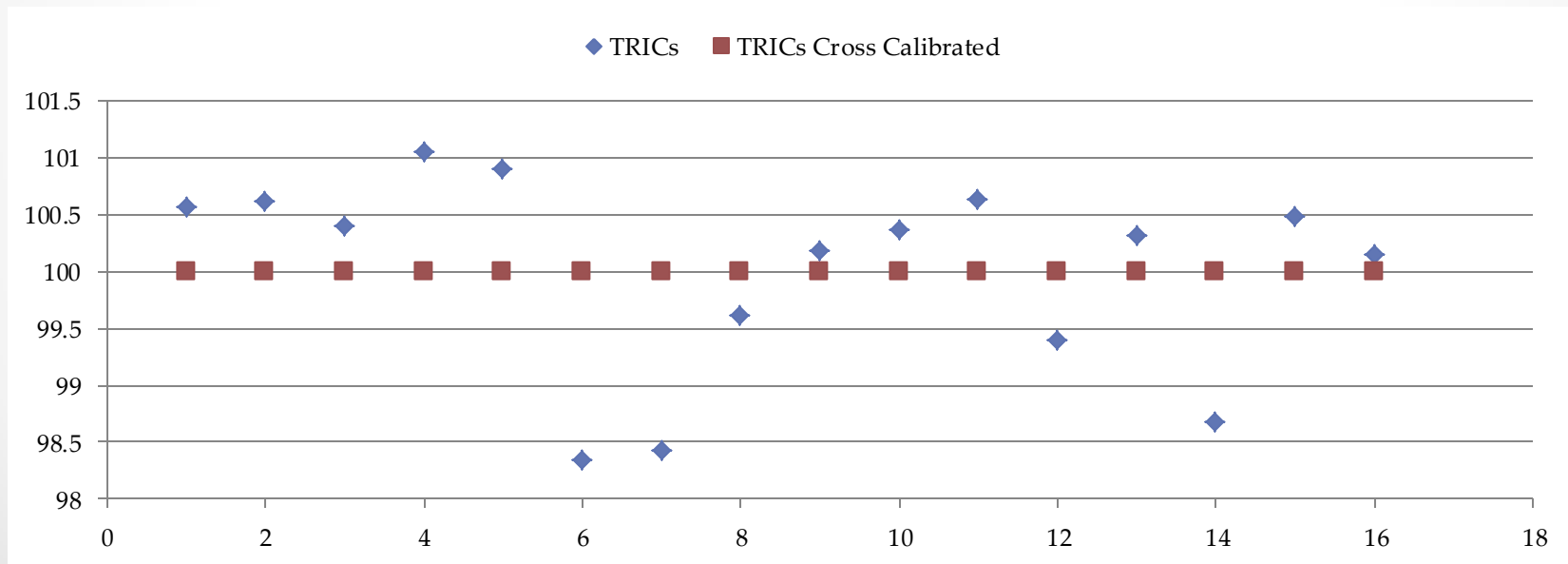
Mainly due to induced noise on calibration pulse

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

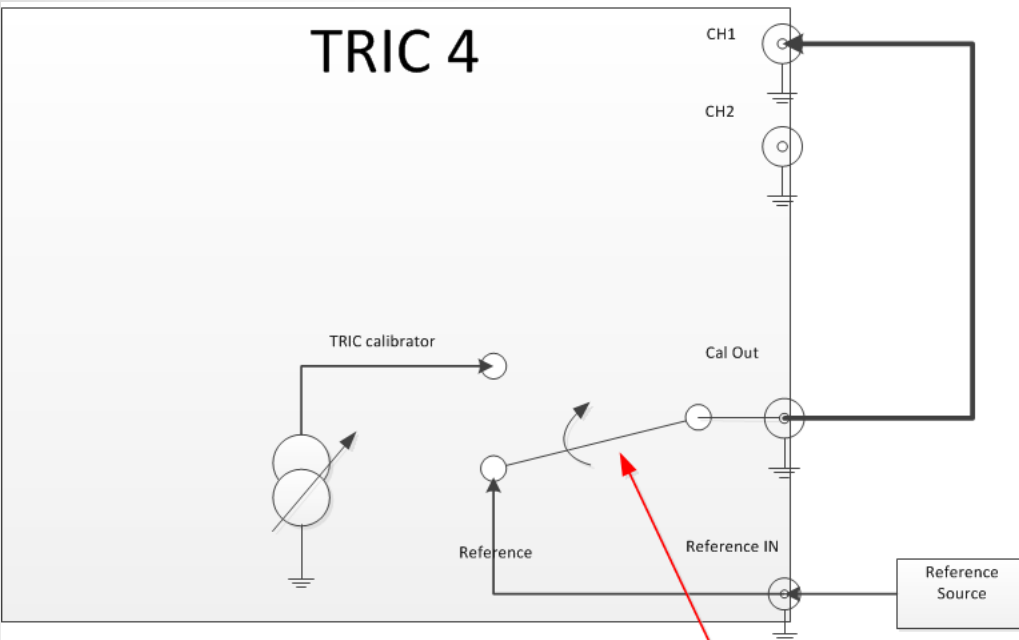
Measurement System	$C_{FBCT1,DCCT}$	$C_{FBCT2,DCCT}$
TRIC	0.65 %	1.16 %
Online Calibration		
TRIC	0.074 %	0.189 %
Offline Calibration		

TRIC: Cross calibration

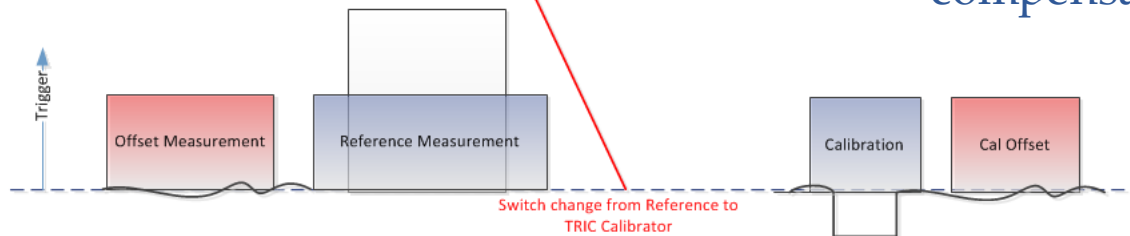
- In order to improve the relative accuracy between DCCTs and FBCTs we have cross calibrated the TRICs, to one reference TRIC, reducing the relative error between them from $\pm 1.5\%$ to $\pm 0.2\%$.
- A new method, using a commercial current reference, should improve this even further and will be applied in LS1 to all TRIC



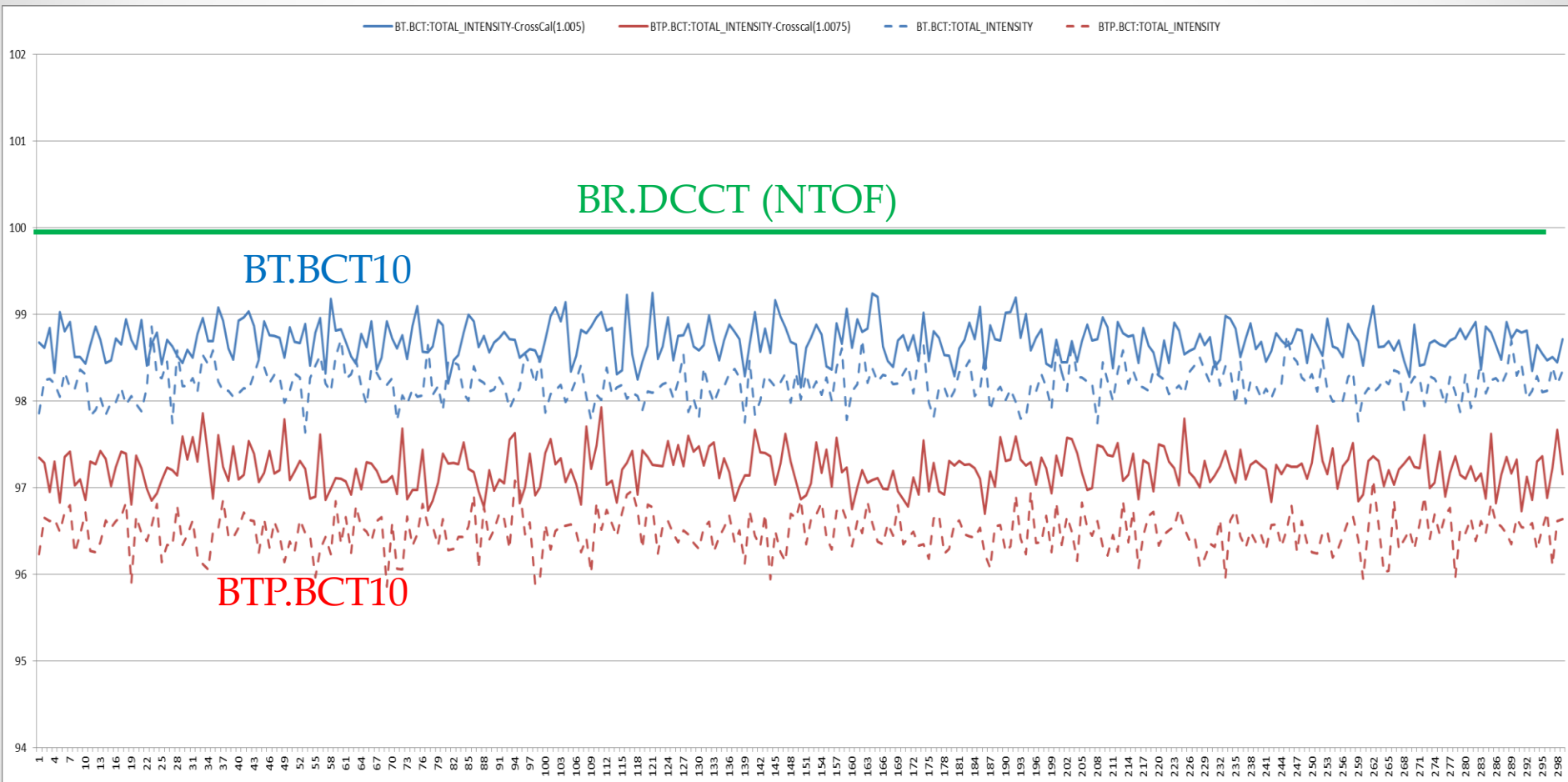
Cross calibration



1. All TRIC's will in LS1 be re-calibrated with a current reference (commercial). And the relative difference will be corrected for.
2. By injecting a well known and precise current to the input, and using the onboard calibrator, relative gain and amplitude errors can be compensated for.



TRIC: Cross calibration



	BT.BCT:TOTAL_INTENSITY-CrossCal(1.005)	BTP.BCT:TOTAL_INTENSITY-Crosscal(1.0075)	BT.BCT:TOTAL_INTENSITY	BTP.BCT:TOTAL_INTENSITY
sdev	0.209316747	0.228945269	0.203293706	0.227041391
Mean	98.6951285	97.2092564	98.19382824	96.47856397

TRIC: Measured uncertainties

Empty cycles

Uncertainty error measured in BT.BCT (2σ)

Cycle Name	I_{Meas} [1e10]	$2\sigma_{\text{E.C.}}$ [1e10]	%N.S.R
CNGS _{20dB}	2286.9	0.530	0.024
EASTA _{20dB}	335.3	1.421	0.421
LHC_SU_B _{20db}	187.2	0.552	0.295
LHCPROBE _{0dB}	1.042	0.072	6.912
LHCINDIV _{0dB}	45.31	0.188	0.416

Uncertainty error measured in PS DCCT (2σ)

R1: 0.8E10

FS: 5E13

R2: 0.14E10

FS: 2.5E12

R3: 0.03E10

FS: 1E11

Uncertainty error measured at F16.BCT126 (2σ)

Cycle Name	I_{Meas} [1e10]	$2\sigma_{\text{E.C.}}$ [1e10]	%N.S.R
CNGS _{0dB}	2058.76	3.116	0.151
EASTA _{0dB}	265.52	0.277	0.104
TOF _{0dB}	92.59	0.322	0.349
TOF _{20dB}	483.19	1.024	0.207
AD _{20dB}	1411.06	1.237	0.088
LHC_ION _{0dB}	1.226	0.238	19.638

Uncertainty can in some cases be dominated by DCCT

DCCT R1 limited by ADC. In LS1 this will be upgraded from 12 to 16 bits.

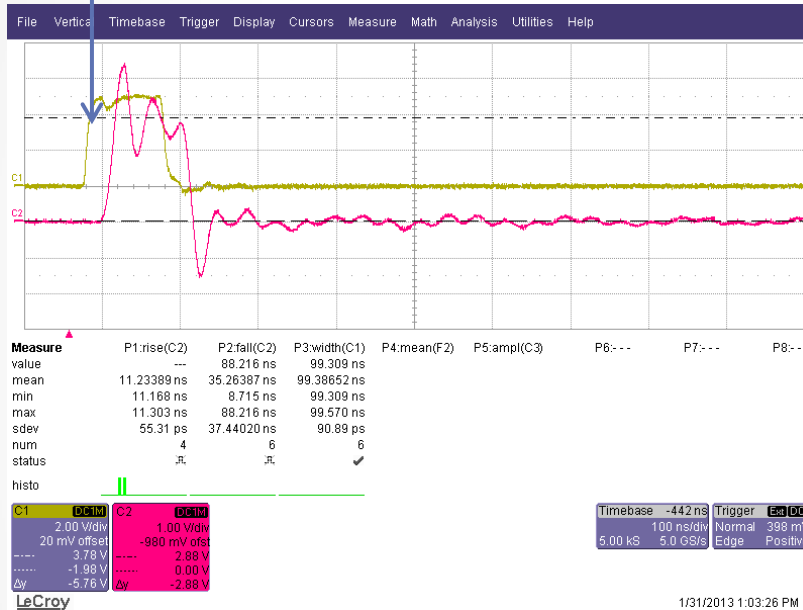
Error analysis for TRIC based acquisitions in the CERN PS and PSB ejection lines, M. Andersen et al.

Linac and Booster injection upgrades

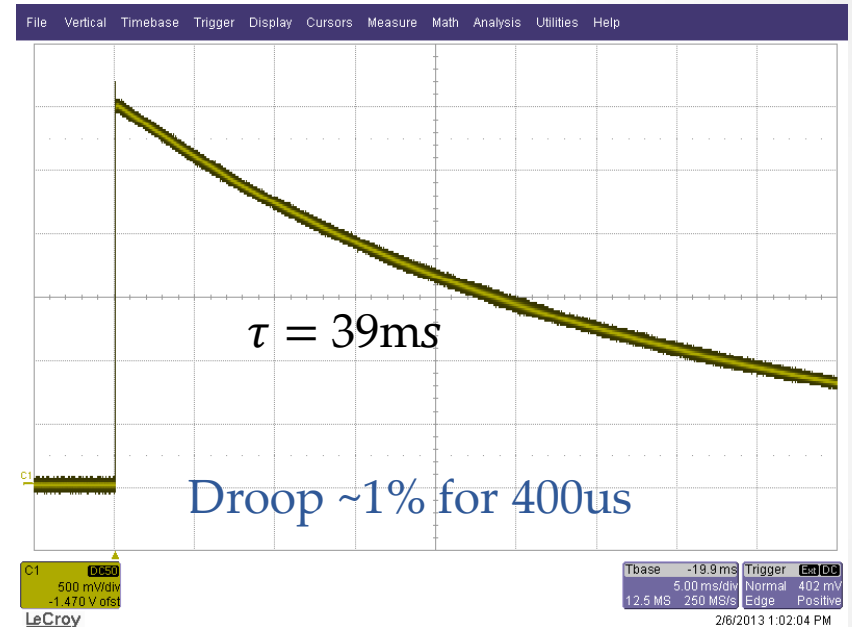
1. L2 and BI acquisition system to TRIC. As from LT.TRA30 acquisitions will be moved to BOR.
2. BI.BCT 10 and 20 modified for L4, **not in plan.**
3. L3 BCTs acquisition system to TRIC
4. L3 ITF.MTR25 HF frequency noise reduction.
ITH.MTR41 new BCT with improved shielding,
not in plan
5. L4 will be equipped with TRIC.

LINAC3 and PSB injection transformers

100 mA – 100ns



With 100 turns



With 20 turns

Output signals with head amplifier

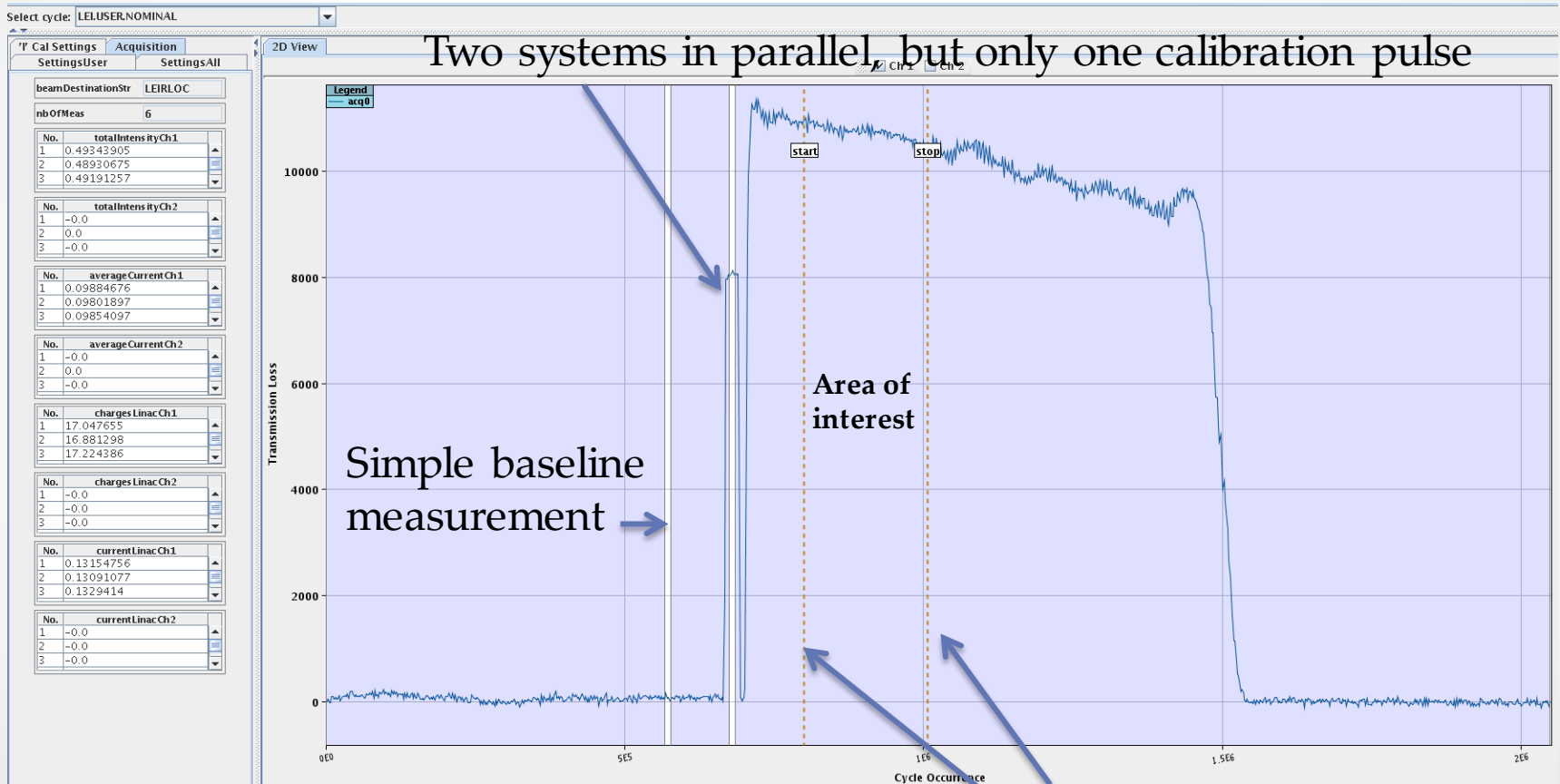
PSB injection transformers and L3...

Improved shielding for ITH.MTR41. Rest of L3 BCTs of this type.



Expert GUI Software, Linac integrator

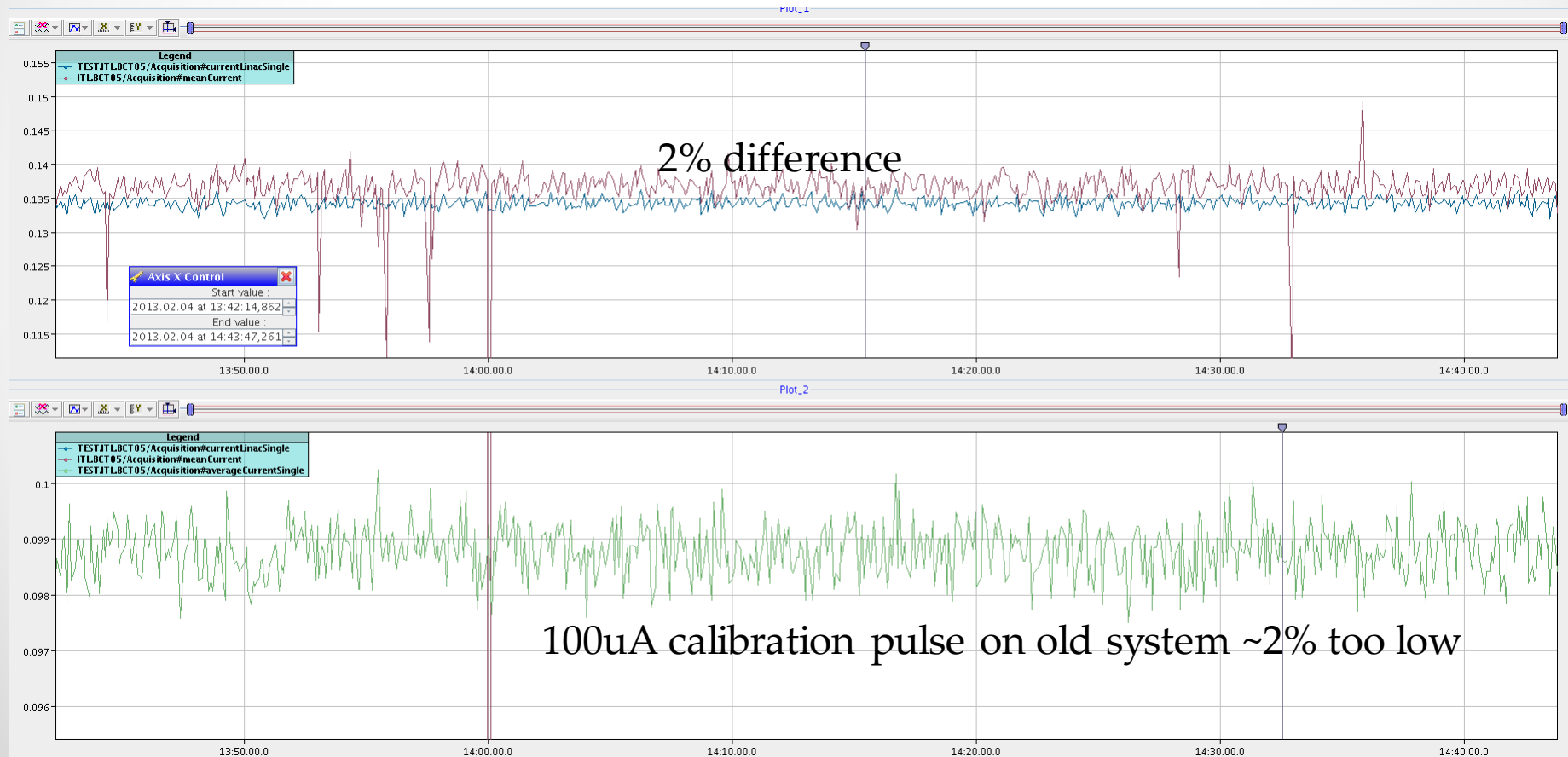
- ITL.BCT05



External timings
Start RF / Stop RF

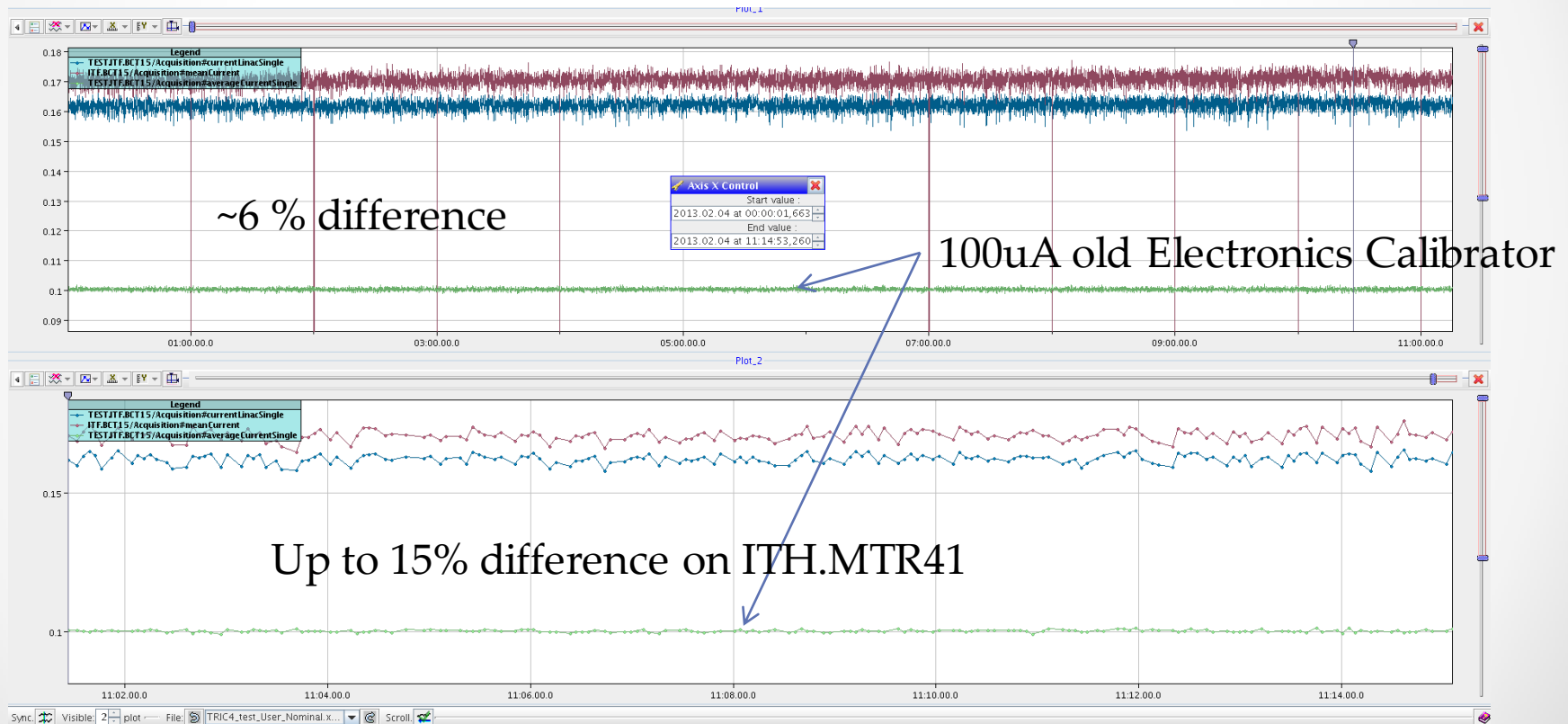
L3 Measurements TRIC versus old system

- ITL.BCT05



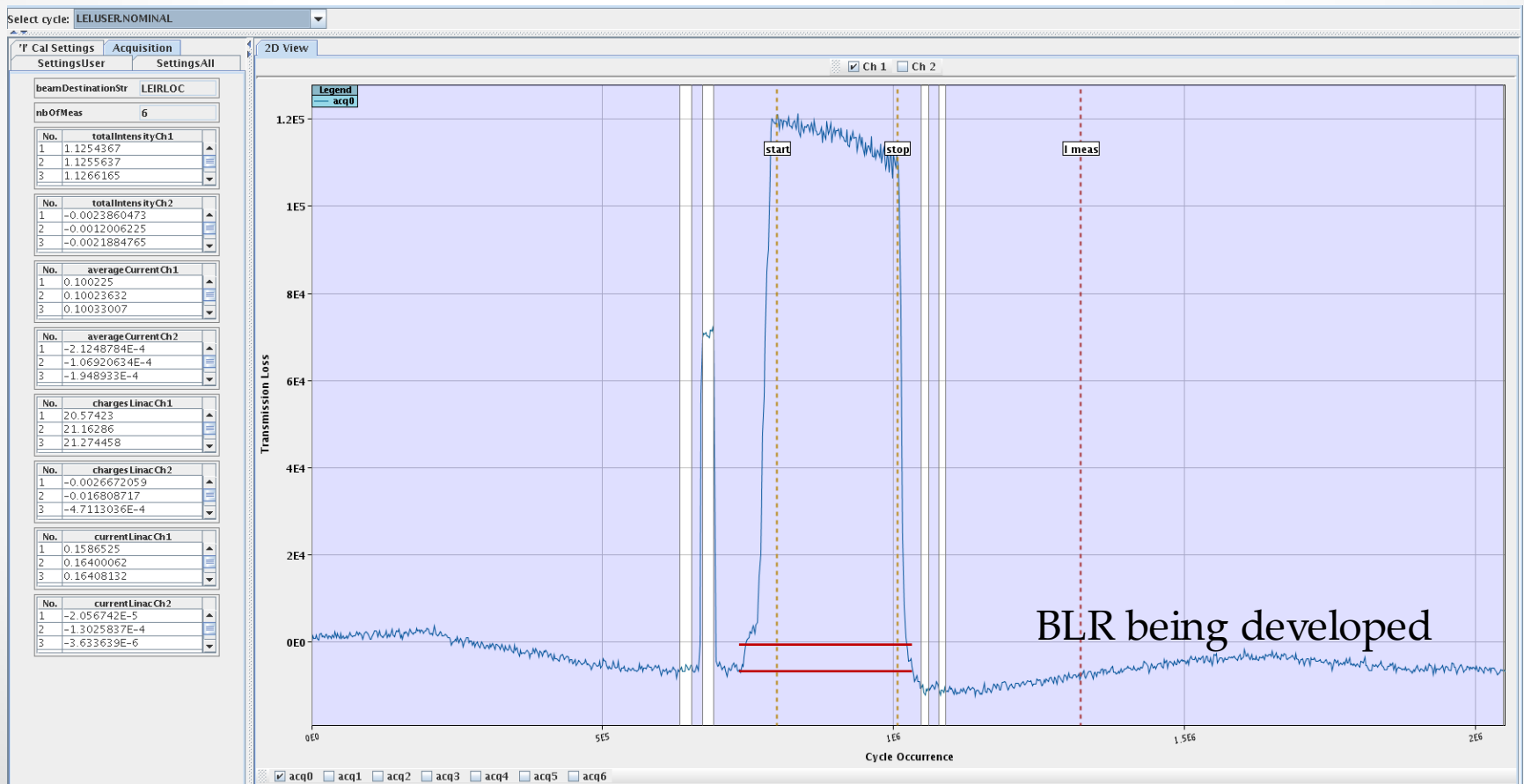
L3 Measurements TRIC versus old system

- ITF.BCT15



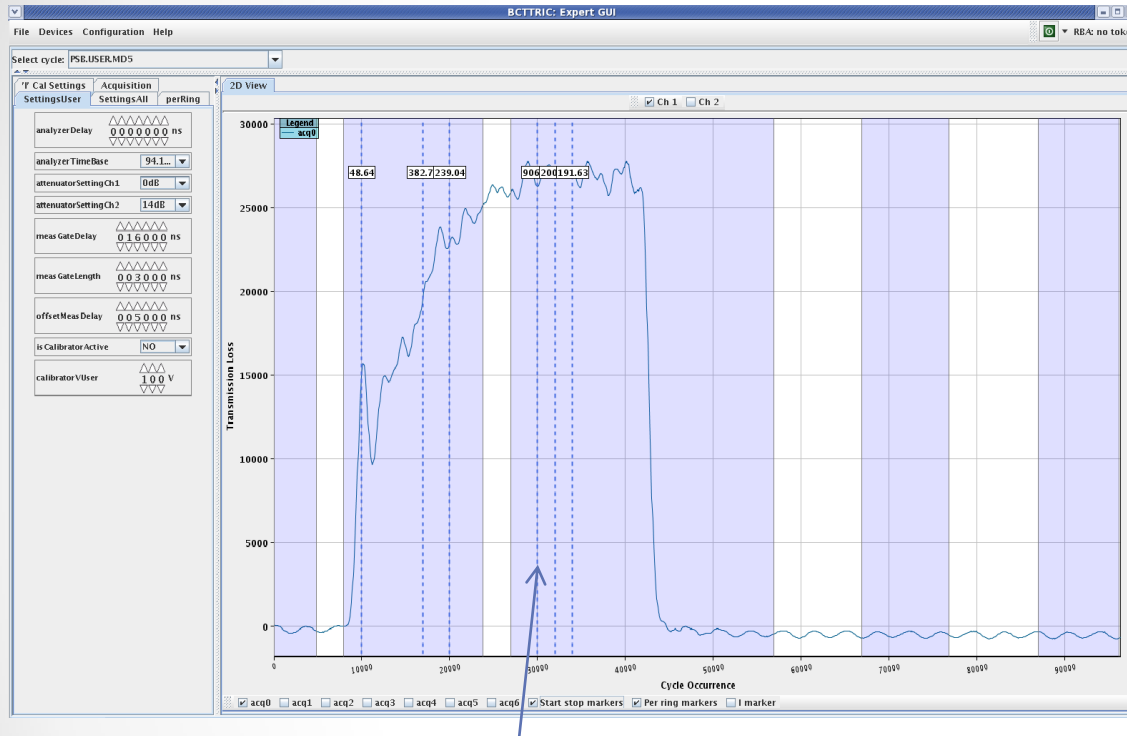
L3 Measurements TRIC versus old system

- ITF.BCT15



- MSWG: Upgrade of PS complex BCTs

L2 first measurements



Ring intensity acquisition:
Development ongoing

No intensity per ring required except for BI.BCT10.

Good results on firsts tests with BI.BCT10. On total intensity / average current.

As for L3 two external timings to define area of interest.

All BCT acquisitions will be moved to TRIC in LS.

Acquisition of all BCTs after LT.TRA30 moved from L2 to BOR

PSB and PS extraction lines upgrades

1. New FBCTs for PSB:

- BT.BCT10, BTP.BCT10, BTM.BCT10, BTY.BCT112, **BTY.BCT183**,
BTY.BCT213, BTY.BCT325

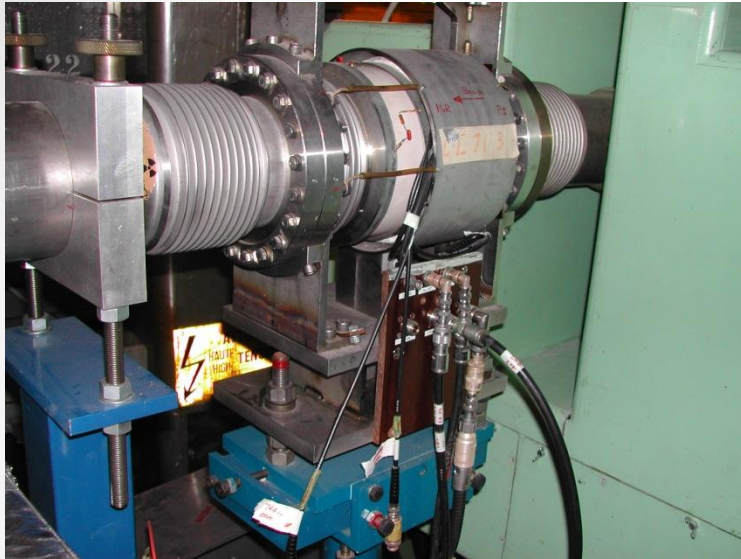
2. New FBCTs for PS:

- PR.ATFA38, FT16.BCT126, FT16.BCT372, FT16.BCT379, FTD.BCT386

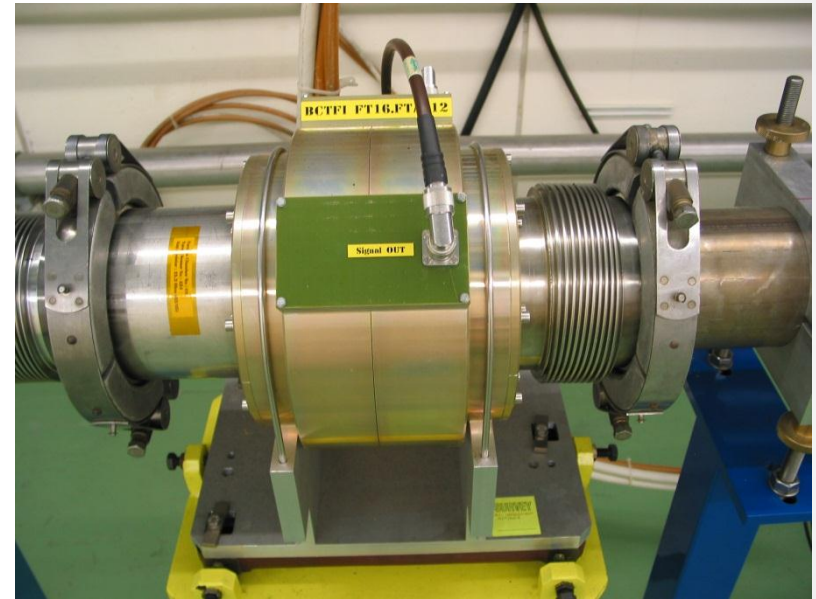
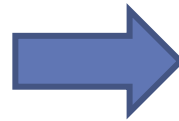
3. TRIC to ADE

4. Finish TRIC installation in LEIR (2 cards)

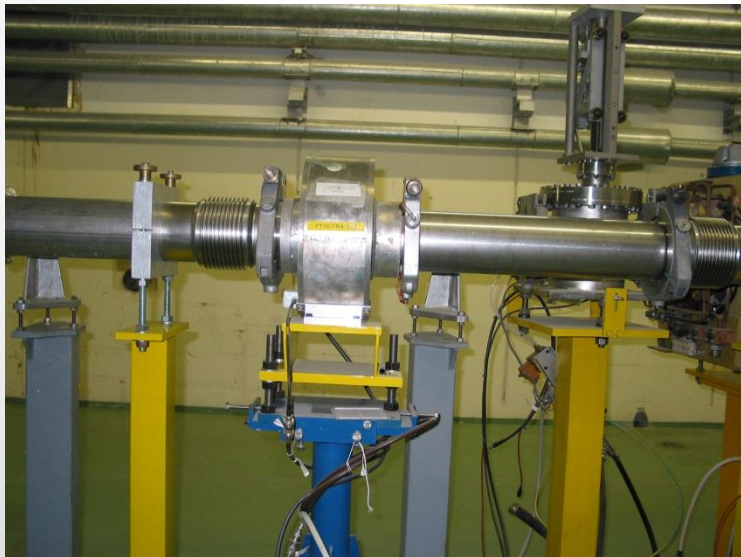
FBCT Upgrades



FT16.BCT126



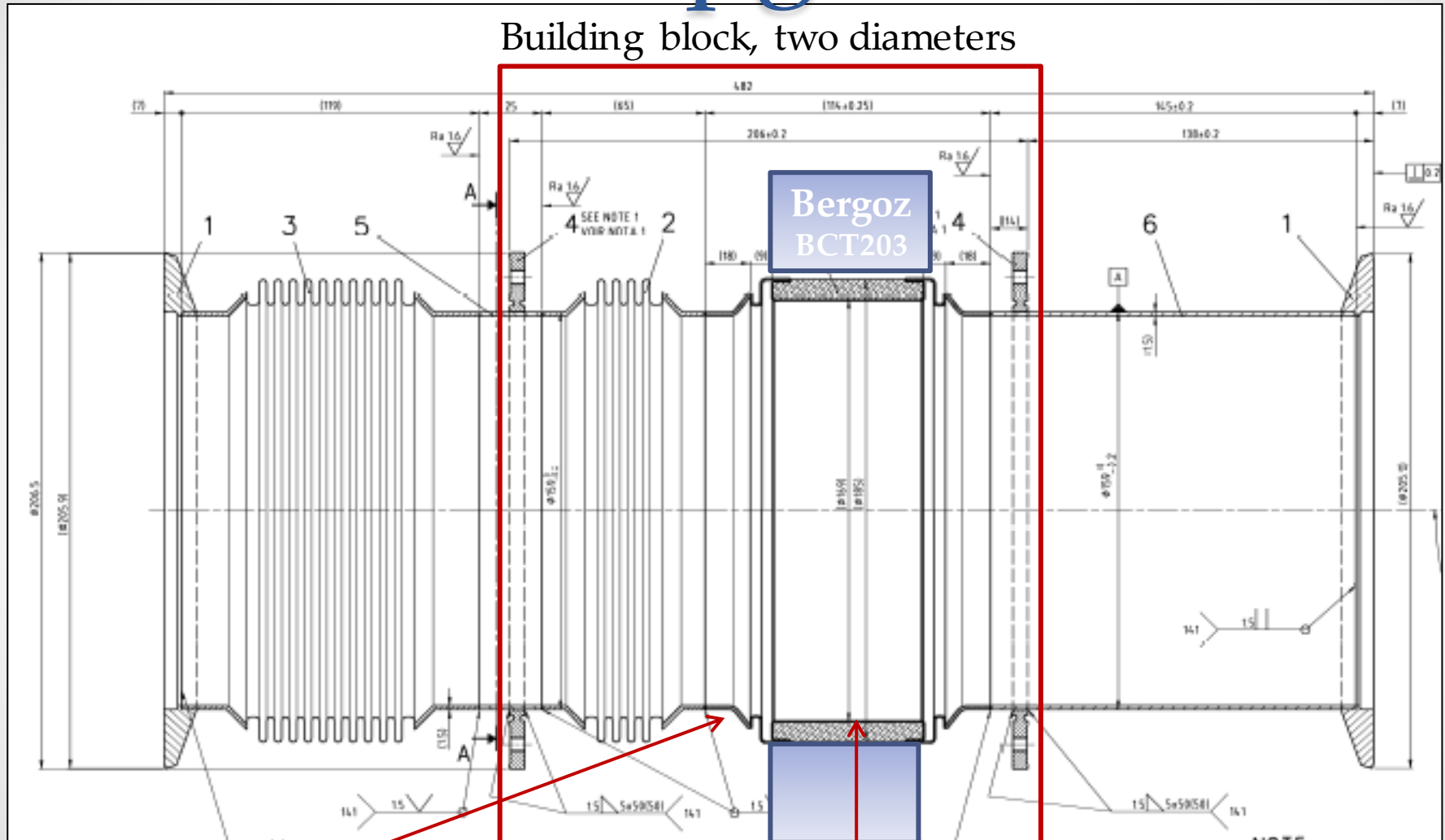
SPS type BCT but with new toroid,
qualified on FT16.BCT203



FT16.BCT372

FBCT upgrades

Building block, two diameters

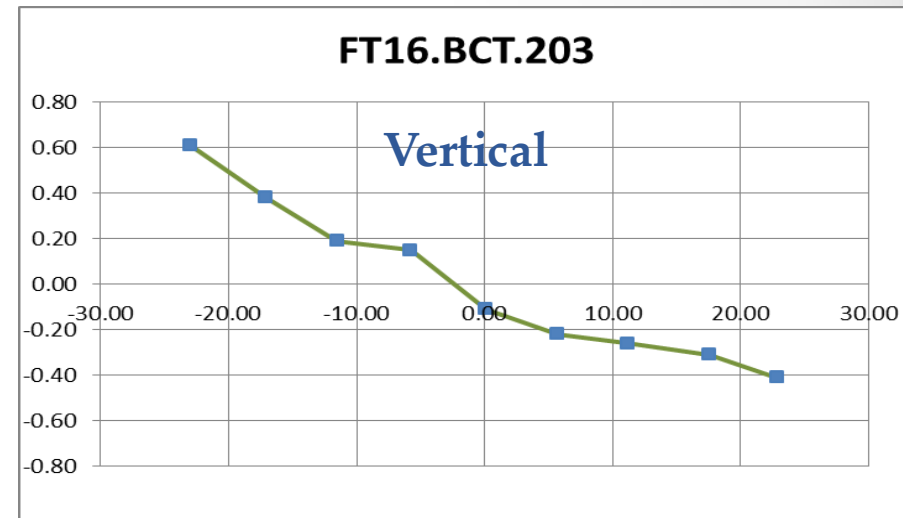
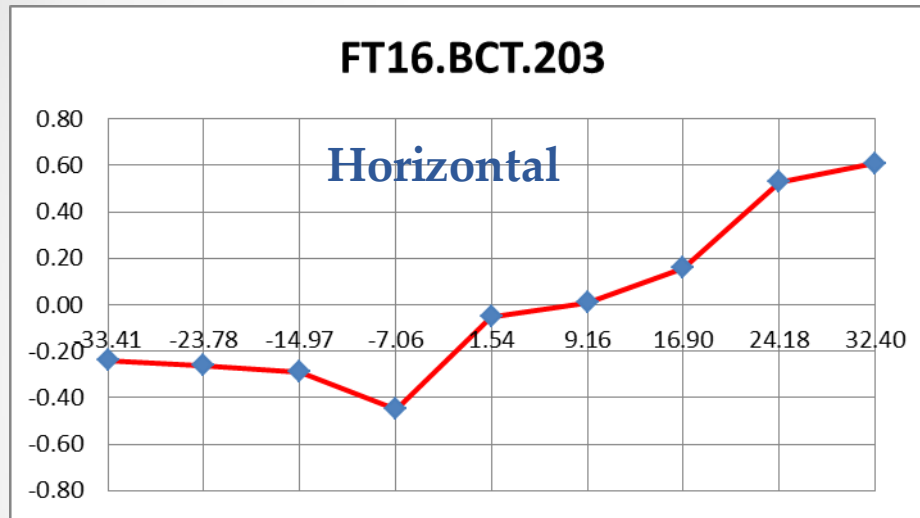


SPS +TOF:
ID=156mm

PSB-PS and TT2:
ID=130mm

Ceramic ID=169mm

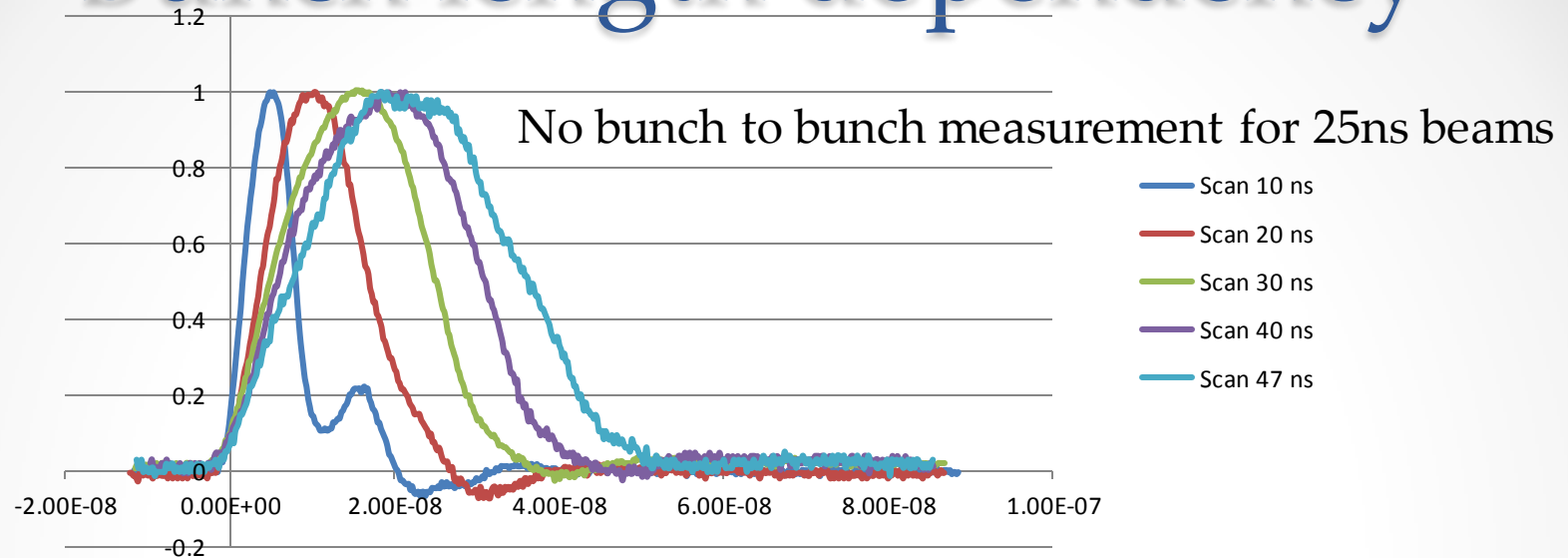
Beam position dependency



In LHC type BCT, which is same as FT16.BCT212 and FTN.BCT486 (TOF) ~1% per mm.

For FT16.BCT203 we find 1% for ± 30 mm beam displacement for 4ns bunches ☺. For longer bunches this dependency is smaller.

Bunch length dependency



Bunch length	PS DCCT [E10]	FT16.BCT.203 [E10]	FT16.BCT.212 [E10]	FT16.BCT.372 [E10]	(PS Ring-FT16.BCT.203) / PS DCCT	(PS Ring-FT16.BCT.212) / PS DCCT	(PS Ring-FT16.BCT.372) / PS DCCT
4 ns	11.27	11.27	11.67	10.92	-0.03%	-3.61%	3.10%
Sigma	0.97	0.97	1.2	1.04	1.50%	6.67%	3.50%
8 ns	10.5	10.5	10.89	10.14	-0.42%	-4.13%	3.00%
Sigma	0.69	0.91	1.15	0.97	1.55%	7.57%	3.95%
12 ns	10.81	10.86	11.31	10.46	-0.47%	-4.62%	3.28%
Sigma	0.81	0.8	1.18	0.81	1.54%	7.48%	2.44%

LEIR, PSB, PS DCCTs

- Upgrade analogue electronics to LHC standards, Front-end as well as back-end
- **Upgrade to L4 beam currents**
- New ADCs: From MPV908 to VD80,
- **New CPU (MEN A20)**
- Improved FESA class with more flexible baseline restoration. First specifications written.

Summery

- The new Linac integrator has been (almost 100%) qualified, but we need to include BLR and ring intensity.
- **All Linac's will be equipped with TRIC at startup after LS1. Two BCTs in L3 will be modified.**
- **BI.BCT10 and BI.BCT20 to be modified LS1/LS2?. OK from OP needed.**
- All transfer line will be equipped with TRIC as well. Only ADE and LEIR missing.
- **New cross calibration of all TRIC will be done in LS1.**
- **A new FBCT (FT16.BCT203) has been commissioned during 2012, and shows very good beam position dependency as well as bunch length dependency.**
- 11 FBCT in the PSB and PS extraction lines will be replaced during LS1.
- **Significant renovation of PS complex DCCTs in LS1**