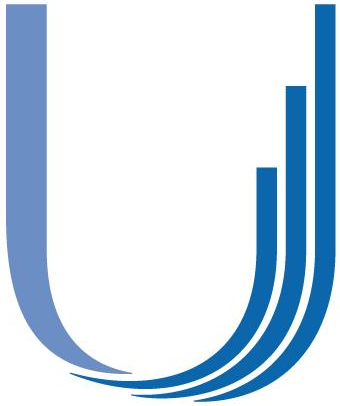


LHC Injectors Upgrade

PSB Orbit and PS/PSB fast BCT projects

L. Søby

Outline

- Relevant Beam parameters
- PS Complex Fast BCTs
  - Proposed technical solutions
  - Specific points about calibration
- PSB Trajectory and Orbit
  - Solution after LS1
  - Final solution when all cables are available
- PSB Extraction BPMs
  - New trajectory pickups and electronics
  - Wide-band pickup in BTP
- Conclusions

Relevant Beam parameters

Parameter	LEIR	PSB (per Ring)	PS	SPS
Particle Types	Pb54+	p	p	p
Revolution Frequency [kHz]	360 - 1422	599 – 1750 – 1810 (1)	436647.3424-476824.1330	43.4
Main RF Frequency(ies) [MHz]	0.36 – 2.84	C02: 0.6 - 2; C04: 1.2 - 3.9; C16: 5 - 16	3.0565 - 10.0133, 13, 20,40 80, 200	
Momentum Range [GeV/c/charge]	0.341 – 1.44	0.31 - 2.12 - 2.78 (1)	2.12- 2.78 (1) - 26	14 - 450
Kinetic Energy Range [GeV/u]	0.0042 - 0.072	0.05 - 1.4 - 2 (1)	1.4 - 2 (1) – 25.07	214 - 450
Gamma	1.005 – 1.08	1.053 - 2.4791 - 3.1315 (1)	2.479 - 3.131 (1) - 28.14	16 - 480
Cycle Length [s]	2.4 – 600 (typ 3.6)	1.2	1.2, 2.4, 3.6	3.6 to 100
Harmonic Number	1, 2	1 - 2	7 - 420	4620
Number of Bunches	1, 2	1 - 2	1 - 420	1, 576(2), 4200 (3)
Total Beam Intensity Range [e10 charges]	0.5, 10	0.5 - 900 – 1400 (2500)	0.2 - 4000	0.2 - 7200
Bunch Intensity Range [e10 charges]	0.2, 5	0.5 - 900 – 1400 (2500)	0.2 - 1000	0.2 - 50
Bunch Length [ns] at 4 sigmas	250 - 2000	75 - 250	3.5 - 280	1 – 5
Bunch Spacing [ns]	350 - 1350	286, 327, ~580, 16000 (4)	0, 25, 50, 75, 100, 150, (6)	5, 25, 50, n*25, … 23000
Normalised Emittances [um -1 σ rms]	0.5	H 0.3 - 15 V 0.2 - 8	H 0.3 - 20 V 0.2 - 15	H 0.4 - 11.0 V 0.4 - 8.0

For the Injectors Rings

(1) After PSB upgrade to 2 GeV.
(2) 2 batches of 25ns LHC beam for scrubbing.
(3) 5 ns bunch spacing beams.
(4) After extraction
(5) The bunch spacing is variable as the revolution period changes during acceleration. It varies from a maximum spacing of 2300 for single bunch at low energy to 5 for the 200 MHz recaptured CT/MTE beams.
Please refer to the detailed tables for the full range (https://edms.cern.ch/document/1157752).

LHC Injectors Upgrade

PS Complex Fast BCTs

CERN

Transfer Line Intensity Specifications

Derived Parameter: Beam Intensity in Transfer Lines: Total Charges

Expected interface:

Should publish after the last injection/extraction an array of total number of charges crossing the monitors during each transfer (injection/extraction) and on a given cycle

Expected Performance:

Parameter	PSB
Absolute Accuracy (RMS)	2% + 5e8 charges
Resolution = detectable differences between transfers or consecutive shots (RMS)	2e8 charges

0.1% or 2.5E10

Derived Parameter: Beam Intensity in Transfer Lines 3/3: Bunch by Bunch

Expected interface:

Should publish an array containing the intensity per bunch

Expected Performance:

Parameter	PSB
Absolute Accuracy (RMS)	2% + 5e8 charges
Resolution = detectable drop between consecutive measurement windows (RMS)	2e8 charges

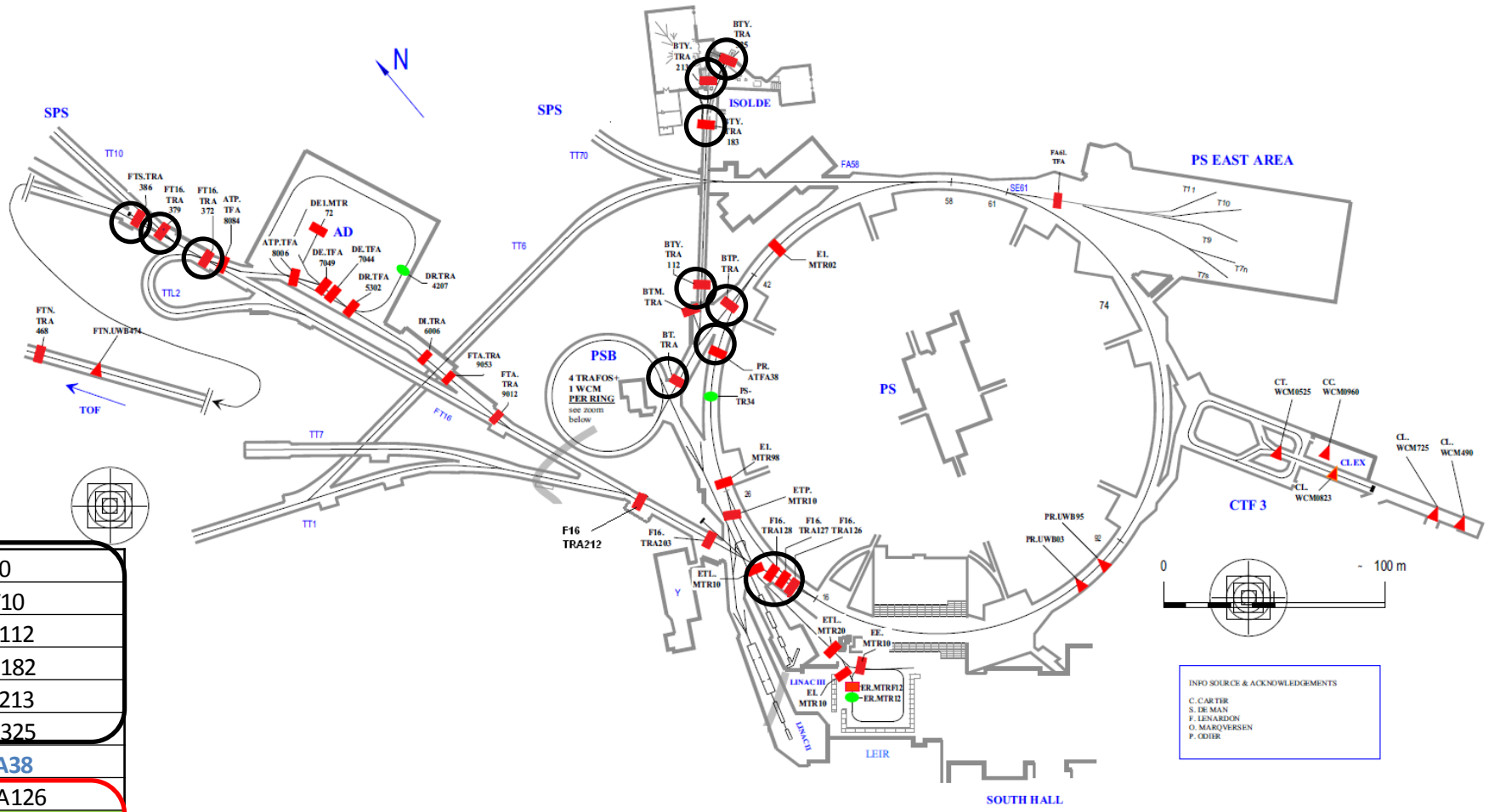
Remark: It is presently not possible to provide calibrated intensity values for bunches spaced by less than 25nsec with 2% accuracy.

Need ~30ns-35 bunch spacing.

Presently bunch by bunch measurements are NOT requested.

https://edms.cern.ch/nav/P:CERN-0000077383:V0/P:CERN-0000094107:V0/TAB3

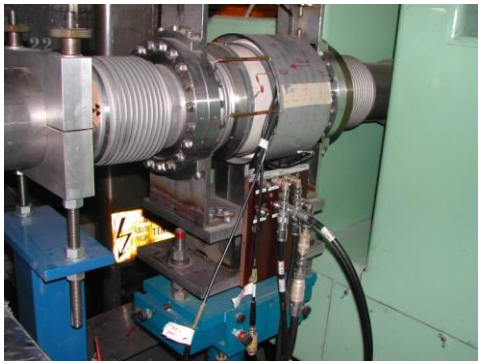
Fast BCT locations (PS complex)

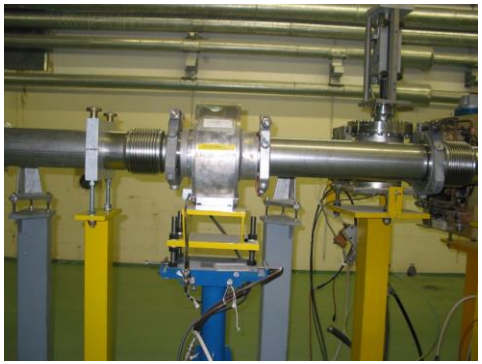


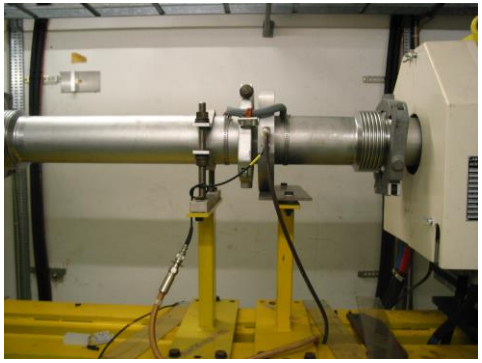
- BT.BCT10
- BTP.BCT10
- BTY.BCT112
- BTY.TRA182
- BTY.BCT213
- BTY.TRA325
- PR. ATFA38
- FT16.TRA126
- FT16.TRA203
- FT16.TRA372
- FT16.TRA379
- FT16.TRA386
- FTN16.486

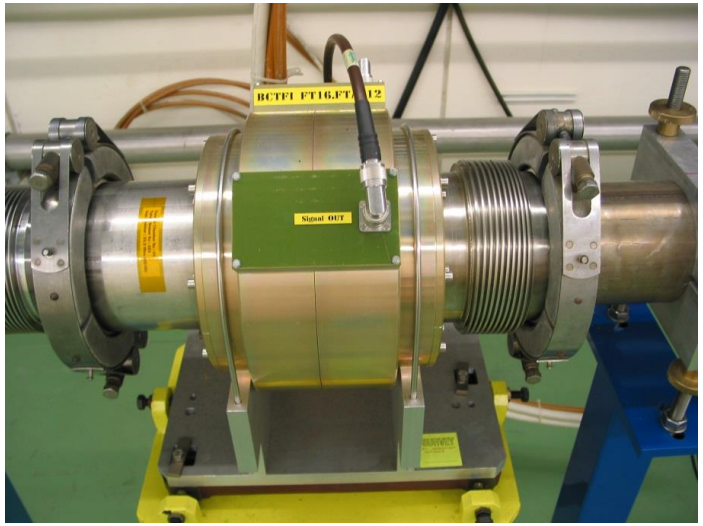
Proposed Technology: BCT Upgrades

Very old and different BCTs









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

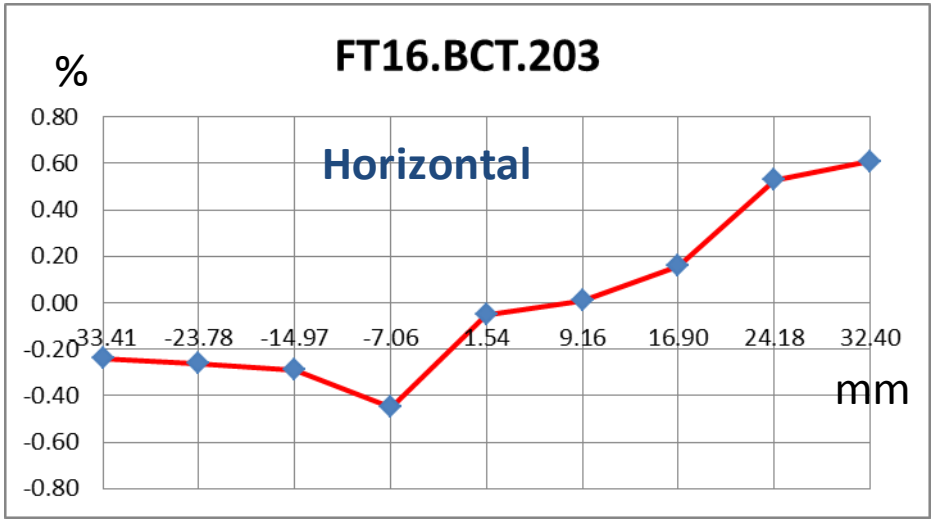
By installing same type BCTs everywhere we will:

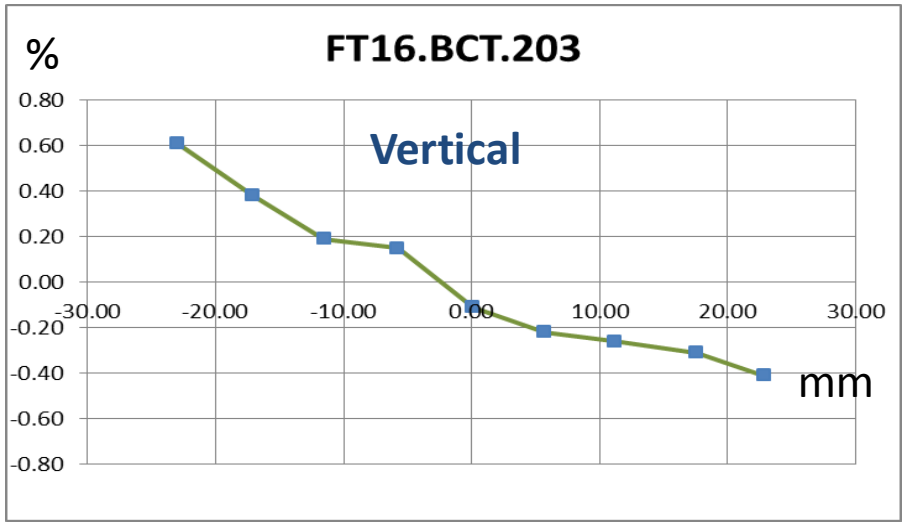
- **Have same amplitude and phase response over a larger frequency range, i.e. same bunch length response (see later)**
- **The new design also has reduced beam position dependency (see later)**

New Fast BCT toroids from Bergoz

Performance of the prototype (measured)	
Bunch length dependency (0.2 ns – 0.4 ns RMS)	not yet measured*
Beam position dependency (± 5 mm) (40 MHz)	< 0.14% / 5 mm
Beam position dependency (± 5 mm) (Integral)	< 0.2% / 5 mm
Intensity to amplitude linearity	below noise
Transfer impedance (40 MHz)	1.29 V / A
Transfer impedance (Integral)	1.63 V / A
Bandwidth	392 Hz – 61.6 MHz
Output pulse width FWHM	~3.1 ns
Ringing after 20 ns (amplitude)	~1% **

Beam position dependency

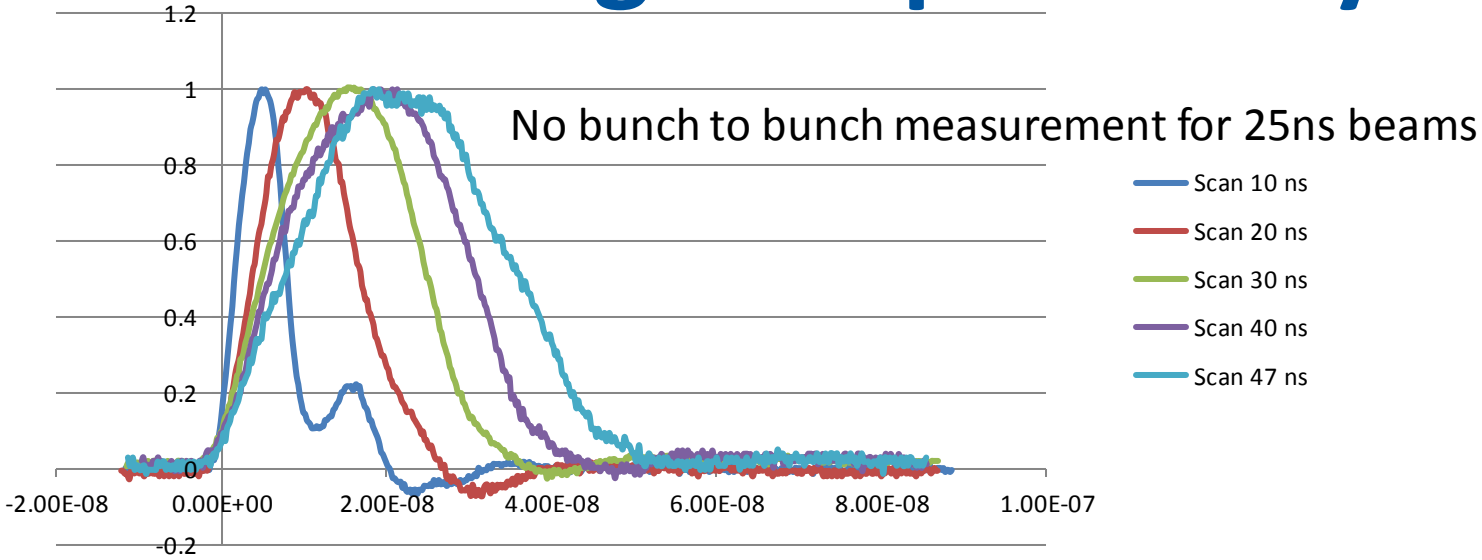




In LHC type BCT, which is same as FT16.BCT212 and FTN.BCT486 (TOF) ~1% per mm.

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

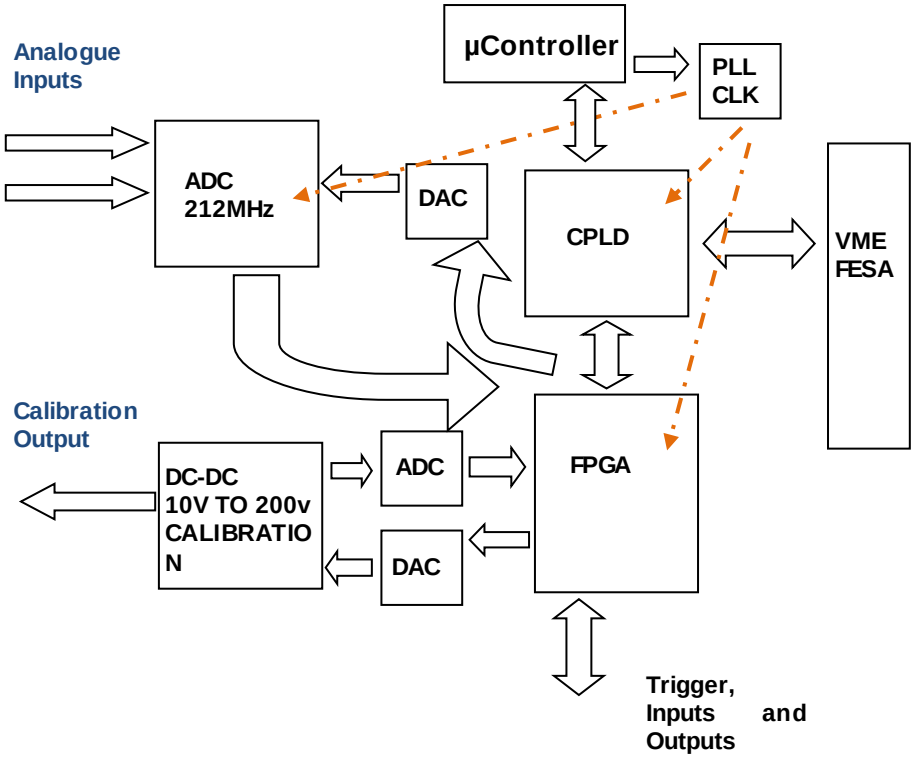
Bunch length dependency

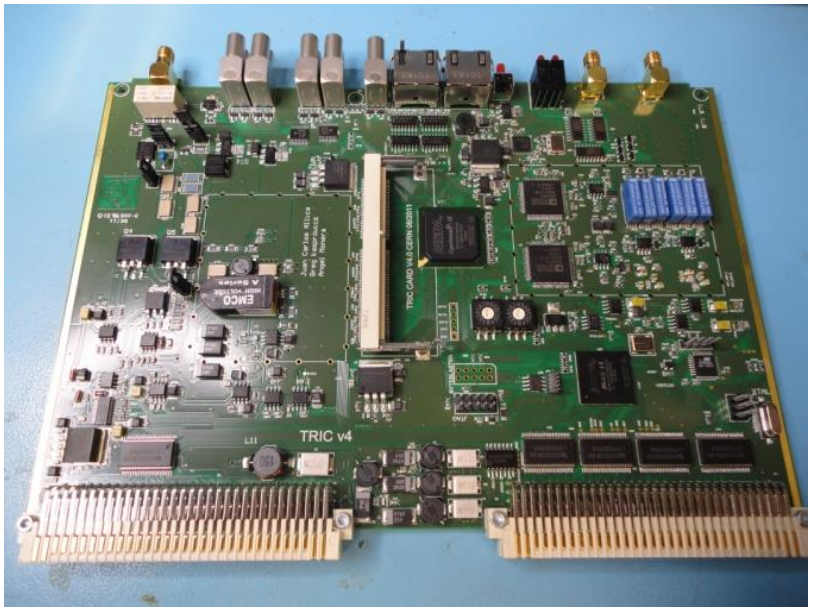


Bunch length	PS DCCT [E10]	FT16.BCT.203 [E10]	FT16.BCT.212 [E10]	FT16.BCT.372 [E10]	(PS Ring-FT16.BCT.203) / PS DCCT	(PS Ring-FT16.BCT.212) / PS DCCT	(PS Ring-FT16.BCT.372) / PS DCCT
4 ns	11.27	11.27	11.67	10.92	-0.03%	-3.61%	3.10%
Sigma	0.97	0.97	1.2	1.04	1.50%	6.67%	3.50%
8 ns	10.5	10.5	10.89	10.14	-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%

TRIC acquisition system

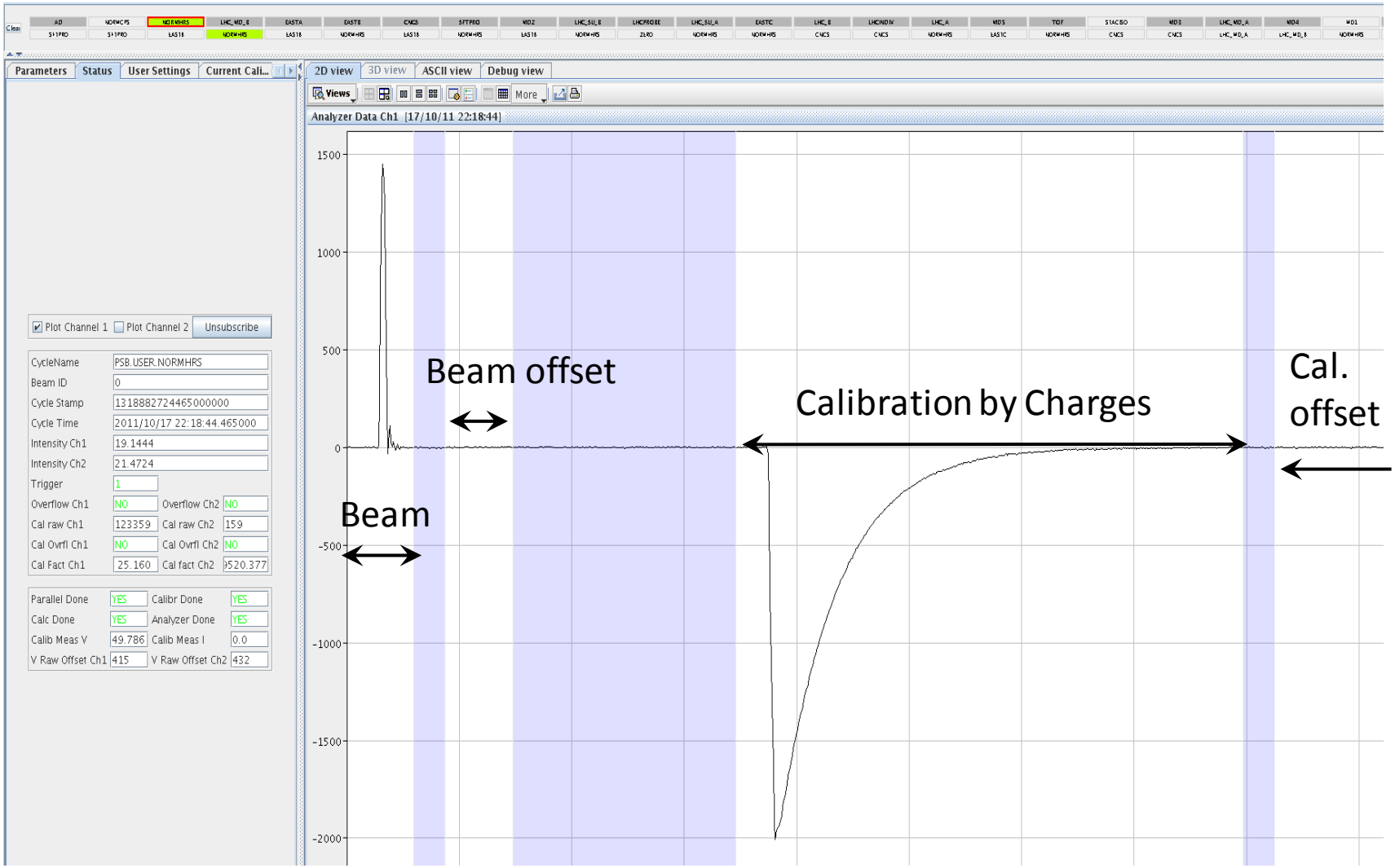
- TRIC is a VME64x 6U standard Card used to measure Beam intensity using signals coming from the BCT in the PS complex
- **Integrates in digital domain signals using its on board calibrator as a reference.**
- Calibration can be either on-line (charges, **current**) or off-line.
- **Different Integration modes (Parallel, Linac) both with offset suppression.**
- Installed on all PS complex BCTs after the PSB. After LS1 also on LN2/LN3/LN4 BCTs





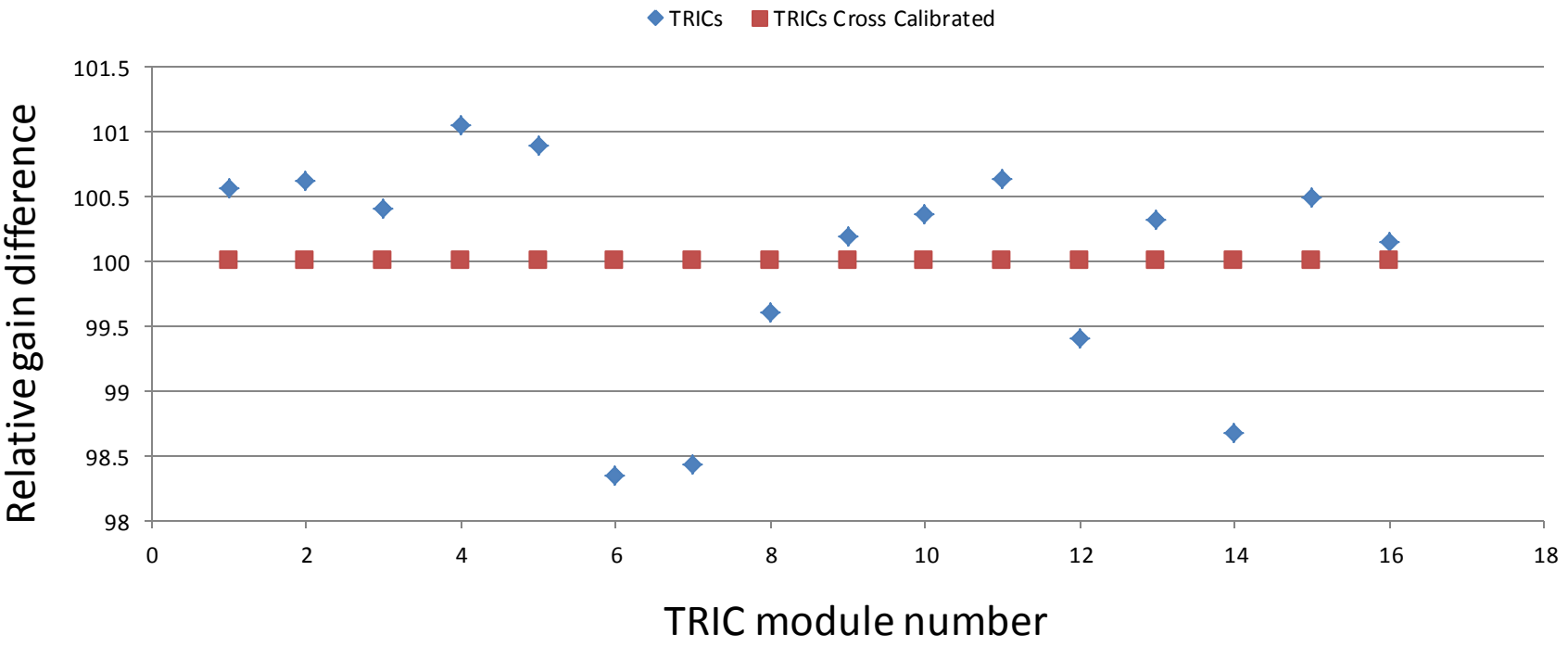
212 MHz ADC, 12bit

TRIC: Expert GUI Software, Parallel integrator



TRIC: Cross calibration

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



Budgetary Requirements and installations

- General cost breakdown (consolidation):

		2013	2014	2015
64275	PS complex Beam transformers & PUs [CHF]	391k	98k	100k
		-70k		

- 2015 budget moved to 2014 to start LN3 BCT upgrade.
- Installations foreseen December 2013 to January 2014. For the moment no showstopper.

LHC Injectors Upgrade

PSB Trajectory and Orbit

CERN

Trajectory specifications

Derived Parameter: Turn by Turn Injection Trajectories in the Ring

Expected Results:

Should publish the H&V positions per monitor at the end of each cycle, for G consecutive gates of length L, during N consecutive turns and acquired from a given time T in the cycle assuming that there is no harmonic change during the selected time window.

Expected Performance:

Parameter	PSB (per ring)
G (number of gates per turn)	1 to 2 bunches
L (gate length)	1 main RF bucket
N (Number of turns)	100
Absolute Accuracy	0.5mm (excl. mech. Offset)
Resolution evolution (RMS) [mm]	0.2mm > 5e10c/bch 0.5mm > 5e9c/bch

Derived Parameter: Trajectory - Capture Acquisition – in the Ring

Expected Results:

Should publish the H&V positions per monitor at the end of each cycle, for G gates of length L and during N consecutive turns and acquired from a given time or turn T in the cycle assuming that there is no harmonic change during the selected time window.

Expected Performance:

Parameter	PSB (per ring)
G (number of gates-Bunches per turn)	1 to 2
L (gate length)	1 main RF bucket
N (Number of turns)	N max = 200000 / G 50000 / G
Absolute Accuracy	0.5mm (excl. mech. Offset)
Resolution (RMS) [mm]	0.2mm > 5e10c/bch 0.5mm > 5e9c/bch

https://edms.cern.ch/nav/P:CERN-0000077383:V0/P:CERN-0000094107:V0/TAB3

Orbit specifications

Derived Parameter: Orbit (+ Gated) over the cycle

Expected Results:

Should publish up to a maximum of N averages of the H&V closed-orbit positions for all monitors at the end of each cycle acquired every X ms over a period with beam that start from MTG event S to another MTG event E.

Expected Performance:

Parameter	PSB (per ring)
N (maximum number of averages)	N = 4000
Absolute Accuracy	0.5mm (excl. mech. Offset)
X (Time between averages) [msec]	1
Resolution (RMS) [mm]	0.2mm > 5e10c/bch 0.5mm for beam > 5e9c/bch

Derived Parameter: MRP over the cycle

Expected Results:

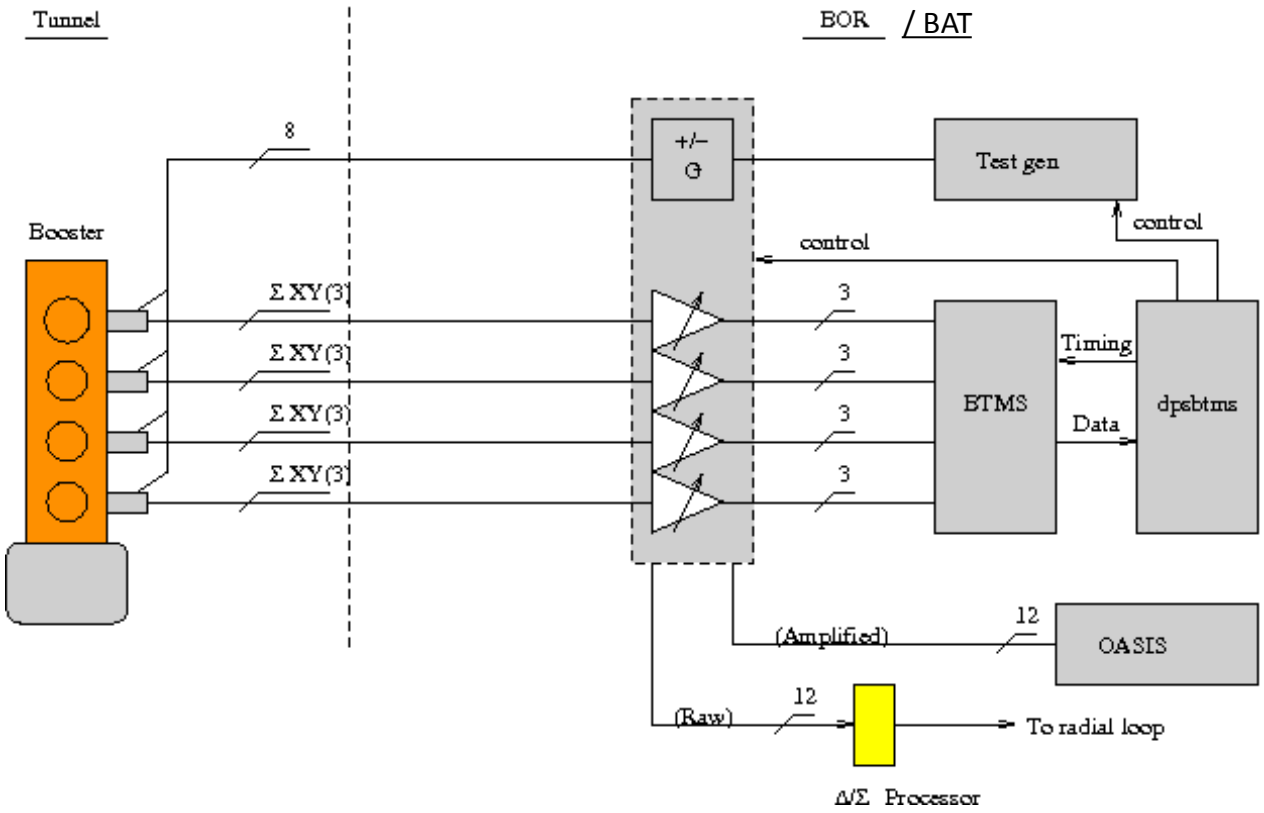
Should calculate and publish N main radial position averages (i.e. averages of the H orbit positions of all monitors) at the end of each cycle and acquired every X ms over a period with beam that start from MTG event S to another MTG event E.

Expected Performance:

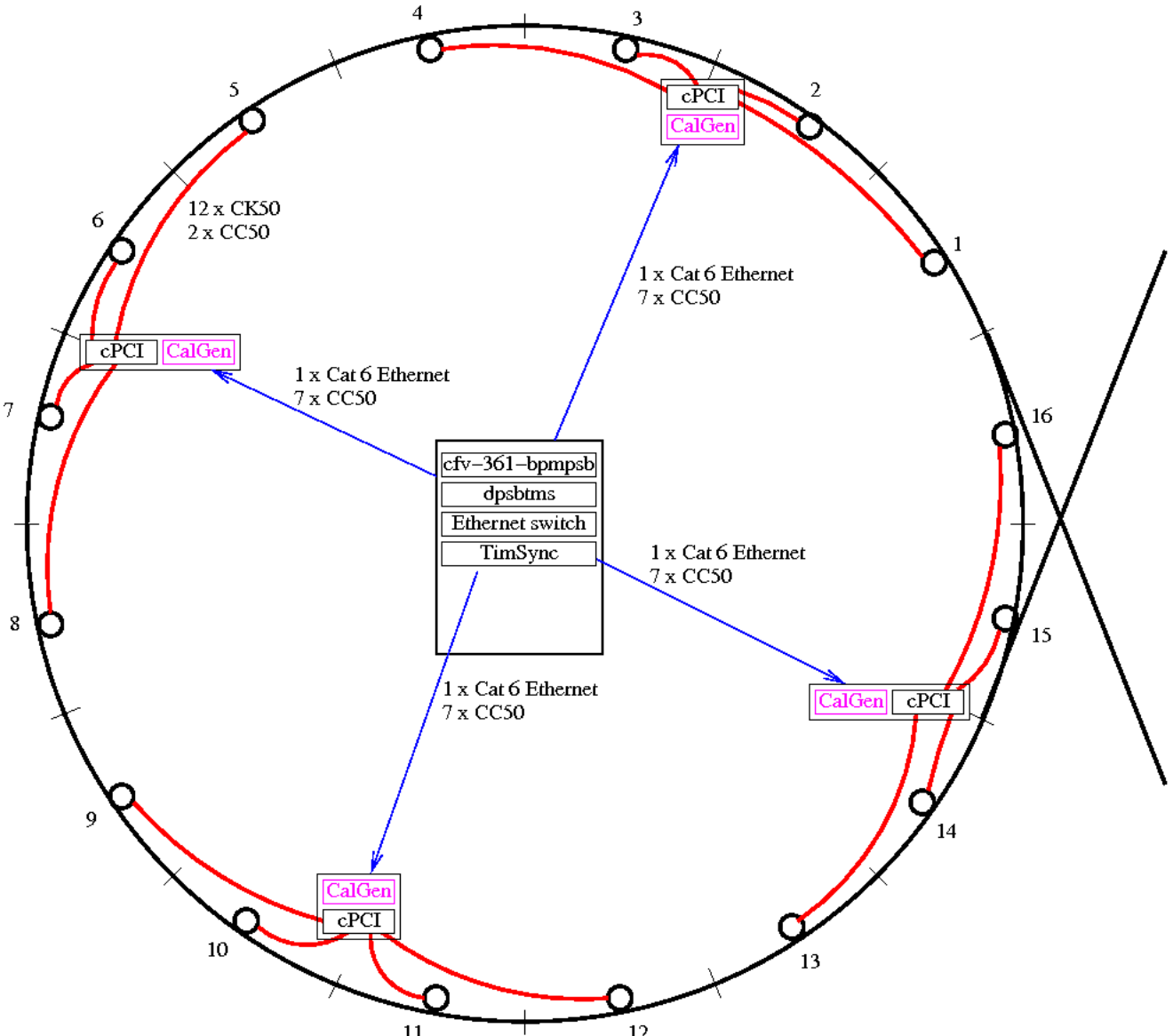
Parameter	PSB (per ring)
N (maximum number of averages)	N = 4000
X (Time between averages) [msec]	1
Absolute accuracy	0.5mm (excl. mech. Offset)
Resolution (RMS) [mm]	0.2mm > 5e10c/bch 0.5mm > 5e9c/bch

Proposed Technology

- Re-use old BPM's, new analogue FE's, new cables
- **Digital: Commercial system from ALPHA DATA, same as PS. 200000 measurement points for the 4 rings.**



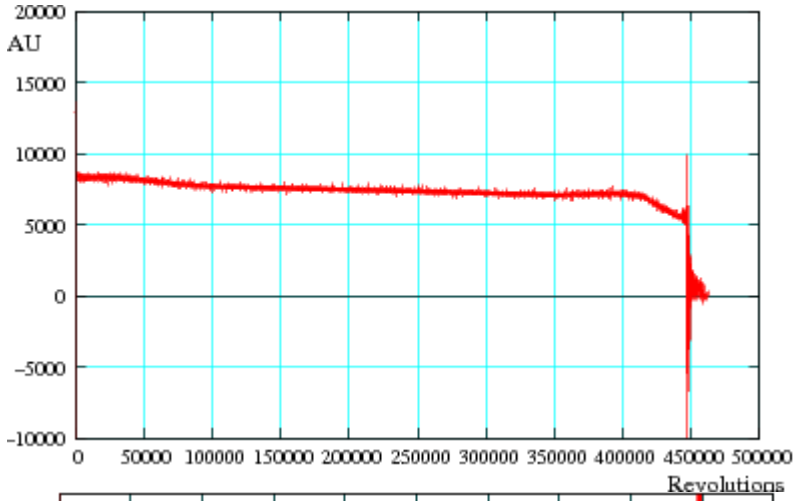
Proposed final layout when new cables available

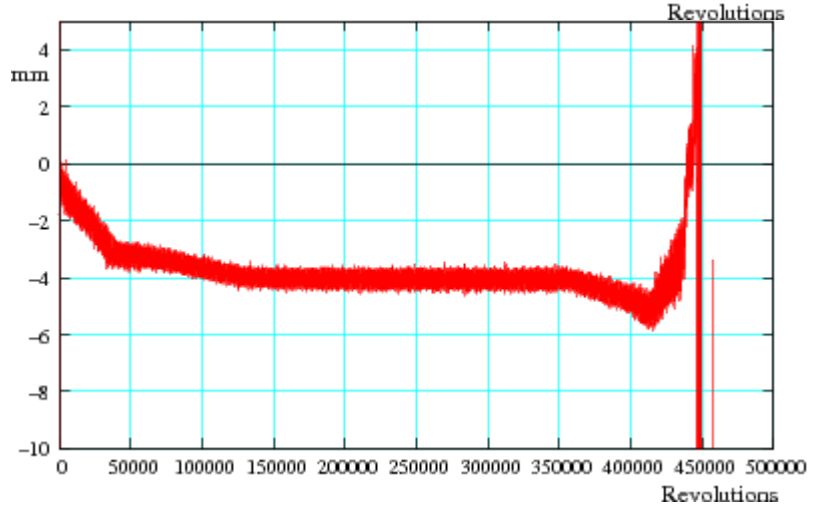


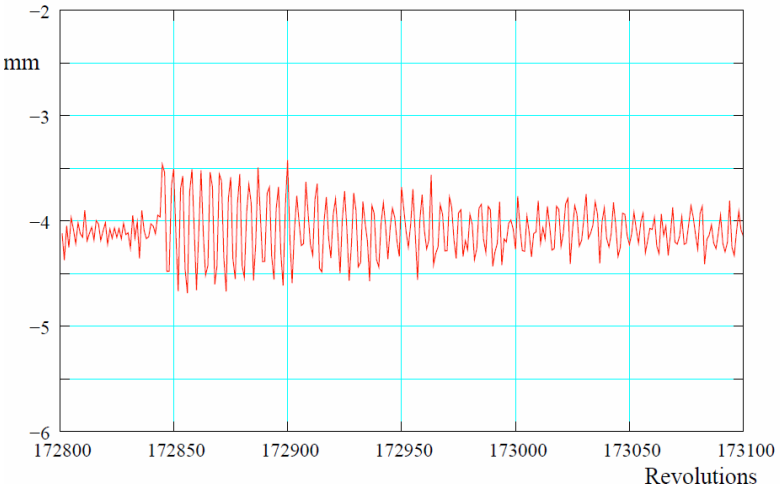
Status of Development:

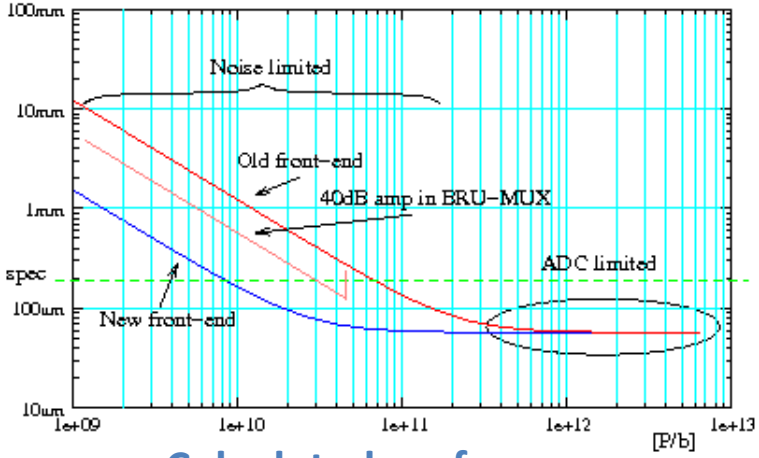
First beams acquired 2013 PU7, PU8 and PU9

Measured resolution estimated to 70um with 7E12. Tune kick oscillations of ±0.5mm





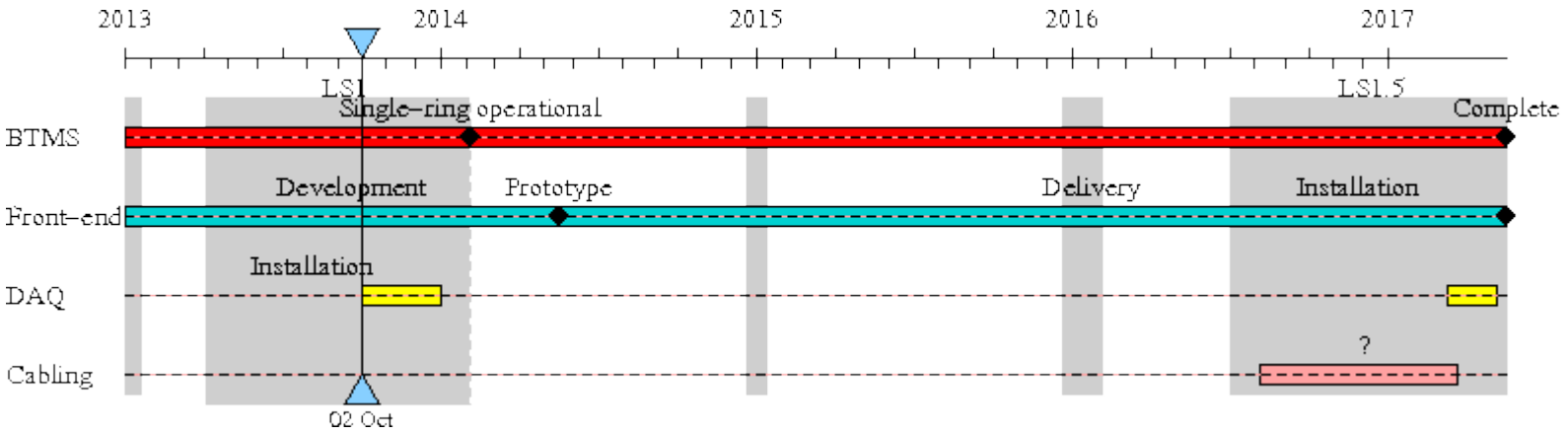




Calculated performance

Installation and Commissioning Plan

- The digital acquisition hardware for 3 rings is delivered, but not yet installed.
- Single-ring acquisitions, will be available after LS1. Beam intensity above 1e11ppb expected to give a resolution of around 200um



Budgetary Requirements

- Updated budget fits spending profile.

Item	kCHF
PU cabling	224
Removal of old cabling	50
Acquisition system	300
Front-end electronics	130
FEC	10
Test generator	15
Timing + distribution	15
Misc	5
Total	**749**

2012	2013	2014	2015	2016	2017	2018	Total
220	21	109	10	20	20	350	750

- Unclear however when cables for the full system can/will be pulled !

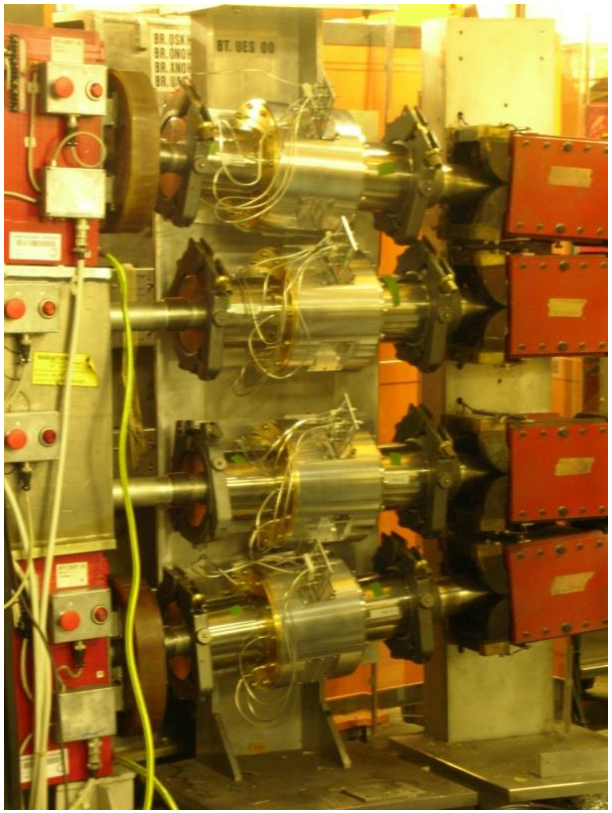
LHC Injectors Upgrade

PSB extraction trajectory

CERN

Beam trajectory in the PSB extraction lines

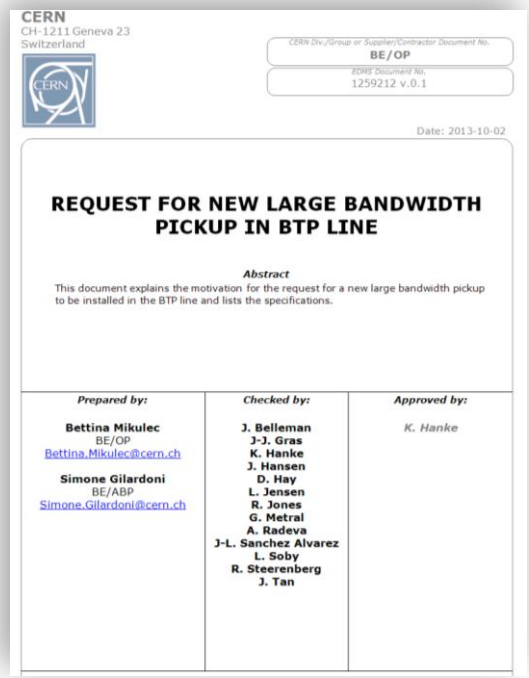
- Motivation
  - Capacitive type are seriously affected by beam losses
  - 50% of the transfer line already equipped with new BPM type (CONS)
  - Upgrade acquisition chain, dynamic range = 1700
  - Standardize BPM types (3 types in the past)
- Status
  - 10 Inductive BPMs + 2 spare produced
  - Electronics: 90% done
- Budget : 64021: RAS
- Planning LS1
  - Nov: Electronics installation
  - Nov. – Jan : BPM installation in the machine
  - Ready for machine start-up
- Concern: Helicoflex seals



Recombination line : BT.U00

New Wide Band Pick-Up in BTP

- Motivation
  - Pin down the reason for the observed instabilities, which are the source of a part of the losses at PS injection
- Specifications (EDMS 1259212)
  - 1-8 bunches
  - Range of bunch length: ~60-300 ns
  - Beam intensity range: from 5E10 ppb to ~1E13 ppb
  - Desired bandwidth range: from 200 kHz to min. 250 MHz
  - Observation of individual bunches should be possible
  - Resolution 0.2mm
- Proposed technology
  - Wide band pickup in the BTP line,
  - similar to the one installed in TT2
- WP responsible: BI-PI, J. Bellemann
- Budget: allocated 75kCHF 2015-2016
- Planning
  - 2015: development
  - End 2016: machine installation



CERN
CH-1211 Geneva 23
Switzerland

CERN Div./Group or Supplier/Contractor Document No.
BE/OP
EDMS Document No.
1259212 v.0.1

Date: 2013-10-02

REQUEST FOR NEW LARGE BANDWIDTH PICKUP IN BTP LINE

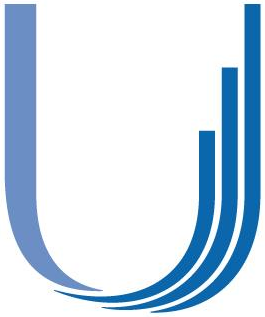
Abstract

This document explains the motivation for the request for a new large bandwidth pickup to be installed in the BTP line and lists the specifications.

Prepared by:	*Checked by:*	*Approved by:*
Bettina Mikulec BE/OP Bettina.Mikulec@cern.ch **Simone Gilardoni** BE/ABP Simone.Gilardoni@cern.ch	**J. Belleman** **J-J. Gras** **K. Hanke** **J. Hansen** **D. Hay** **L. Jensen** **R. Jones** **G. Metral** **A. Radeva** **J-L. Sanchez Alvarez** **L. Soby** **R. Steerenberg** **J. Tan**	*K. Hanke*

Conclusions

- **FBCTs:**
  - 10 FBCTs will be installed in the PSB and PS extraction lines + PR.ATFA38. Upgrades of Linac BCTs foreseen.
  - New cross calibration of all TRIC cards
- **BTMS**
  - First test very positive
  - 1 ring multiplexed system ready for start-up
- **BTU**
  - All 20 BPMs upgraded by end of LS1
  - Idem for acquisition system
- **Wideband PU for BTP line**
  - Development will start in 2015



LHC Injectors Upgrade

THANK YOU FOR YOUR ATTENTION!