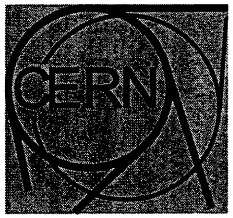


EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
ORGANISATION EUROPEENNE POUR LA RECHERCHE NUCLEAIRE

CERN - PS DIVISION

PS/BD/Note 2001-014 (Tech.)

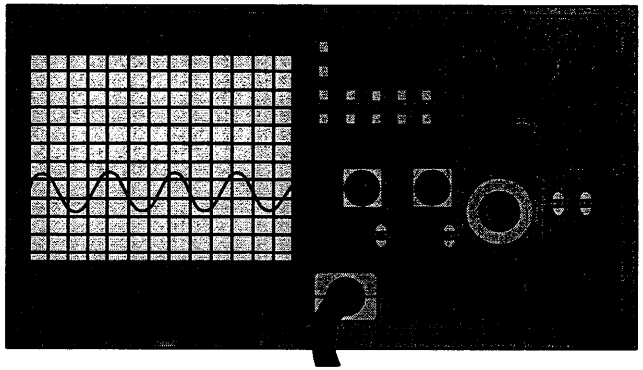
BEAM INTENSITY MEASUREMENTS IN THE LHC

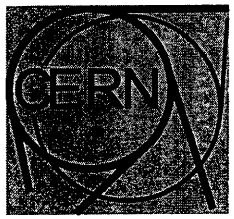
V. Chohan

Copies of Transparencies presented
at the LHC Beam Instrumentation Review,
19-20 November 2001.

Beam Intensity Measurements

- Requirements
- What we Intend to do
- DC-BCT
  - Type, Limits, Improvements
  - General layout
  - Status
- Fast BCT
  - The TT2/TT10, SPS, TI2/TI8 Fast Current Transformer
  - Fast Beam Current Transformer Acquisition System
  - Fast BCTs for the LHC
- A.O.B.
  - Work Teams & References

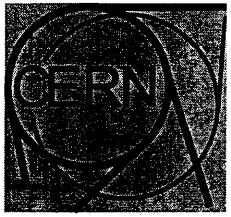




Beam Intensity Measurements
Requirements:

Circulating Proton Beams	*charges*	
Nominal	1.1E11/bunch	560 mAmps
Ultimate	1.67E11/bunch	~ 850 mAmps
Commissioning	0.17E11/bunch	~ 82 mAmps
Single Pilot	5E9/bunch	~ 9 μAmps

Lead Ions [208 pb 82+]	5.58E9 /bunch { 6.8E7 ions/bunch }	~ 5 mAmps



Beam Intensity Measurements
What we Intend to do:

For the circulating nominal beams – DC-BCT

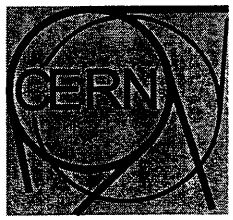
- *Zero-flux device ('Unser' type)*
- *2 independent DC-BCT systems (for redundancy) installed per LHC ring in IP 4*

The Device Characteristics:

- **Temperature Dependence ~ 7 μA/'C**
- **Resolution 1.8 μA** *[Res. defined as Std Dev of a series of m'ments]*
- **Dynamic Range 100 dB [9 μA to 850 mA]**

Hence Acceptable for nominal or commissioning beams

Note :For the single Pilot beam – DC-BCT resolution poses a problem (> 10 % error) and alternative means need to be found – { see later fast-BCT }

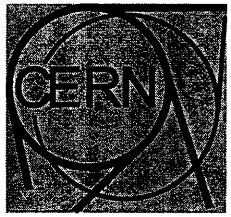


Development of DC-BCT at CERN

We have a certain 'history' and past experience with such devices in various Accelerators & Storage Rings

{ post-ISR era >>> G.Gelato , P.Odier et al - PS Division }

- **AD:** protons: 100 μA to 6 mA (ex- AC Ring)
  antiprotons: 0.3 μA to 9 μA (not measured by a DC-BCT)
- **PSB:** protons: 7 mA to 3 A [in each of 4 Rings]
  ions (pb): 40 μA to 2 mA
- **CPS:** protons: 1 mA to 3 A
  ions (pb): 5 μA to 2 mA
  antiprotons: 70 μA to 700 μA
- **EPA:** leptons: 200μA to 300 mA
- **LEAR:** antiprotons: 70 μA to 4 mA
  ions (pb): 10 to 30 μA



Development of DC-BCT at CERN

Ongoing Work looks promising to bring down the resolution of the device down to the order of 0.5 μA to 1 μA

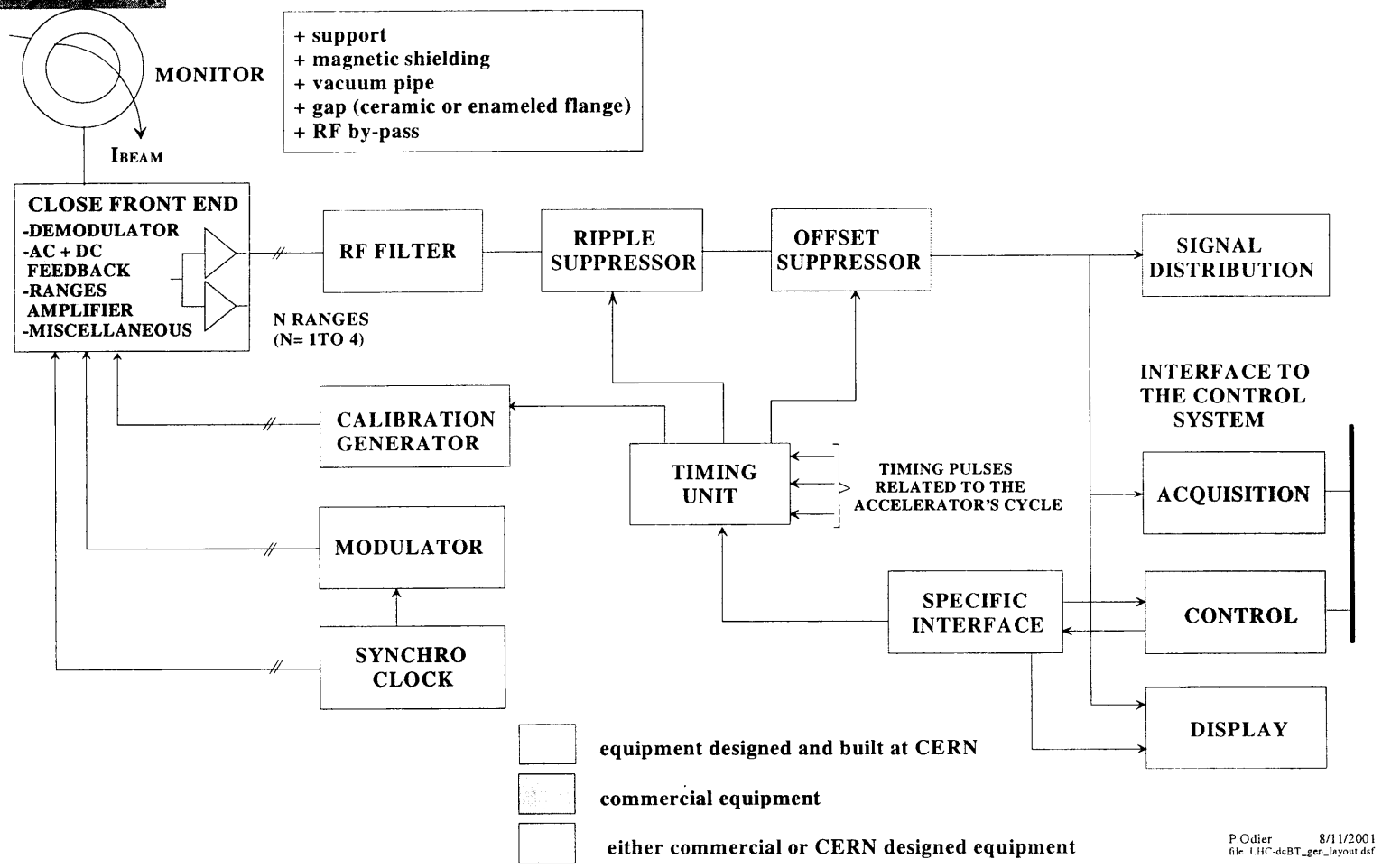
How?

- **Reduce Noise in the Demodulator Electronics**
- **Improvements in the feedback electronics**

Other issues under constant follow-up:

- ***Technical /construction : 'bakeout' [~ 150-200 'C] in relevant section***
- ***Performance: temperature stability gets relevant during Beam Studies if/when multiple pilots (n x 5E9) are stored, 'noisy' machine environment, magnetic elements proximity etc....***

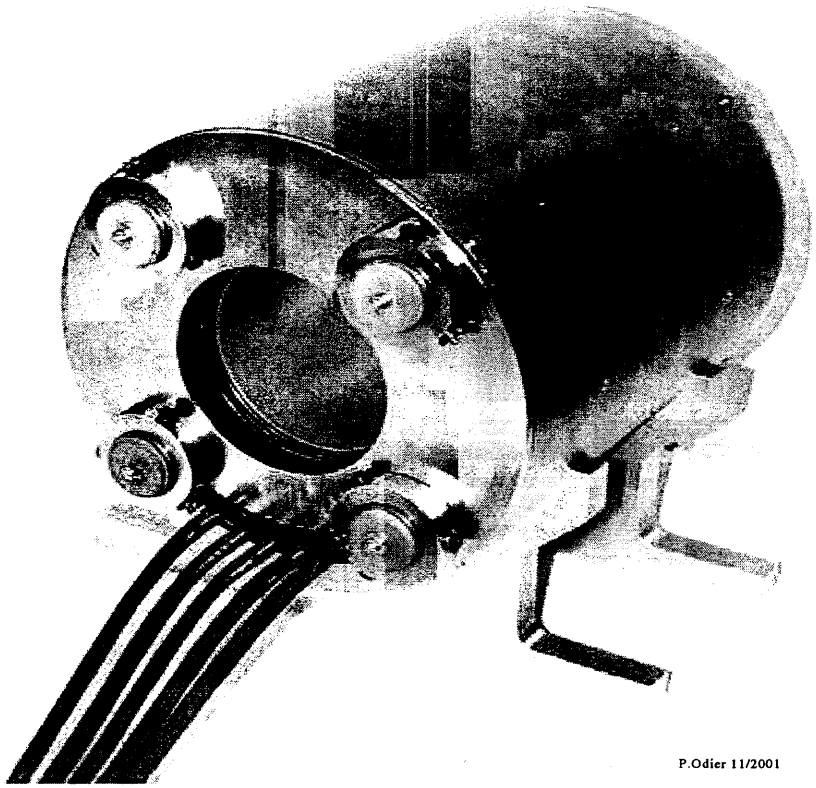
DC-BCT Typical Layout



Prototype Device in Lab

LHC dc BEAM TRANSFORMER

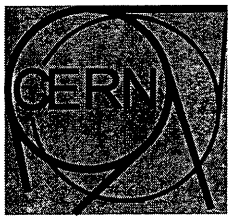
external diameter: 270 mm
internal diametre: 114 mm
lenght: 345 mm



P.Odier 11/2001 lhc3b.jpg

STATUS:

- **1 Monitor & magnetic shielding built**
- **Design of the 2 new front-end electronics cards is under way , i.e., DEMODULATOR and FEED BACK cards. The noise and ripple in the electronic modules is expected to be reduced , hence permitting resolution of 0.5 to 1 μA**



Fast Beam Current Transformers in the LHC

Intention is to Install Devices permitting individual bunch-to-bunch measurement in the transfer lines and each LHC ring.

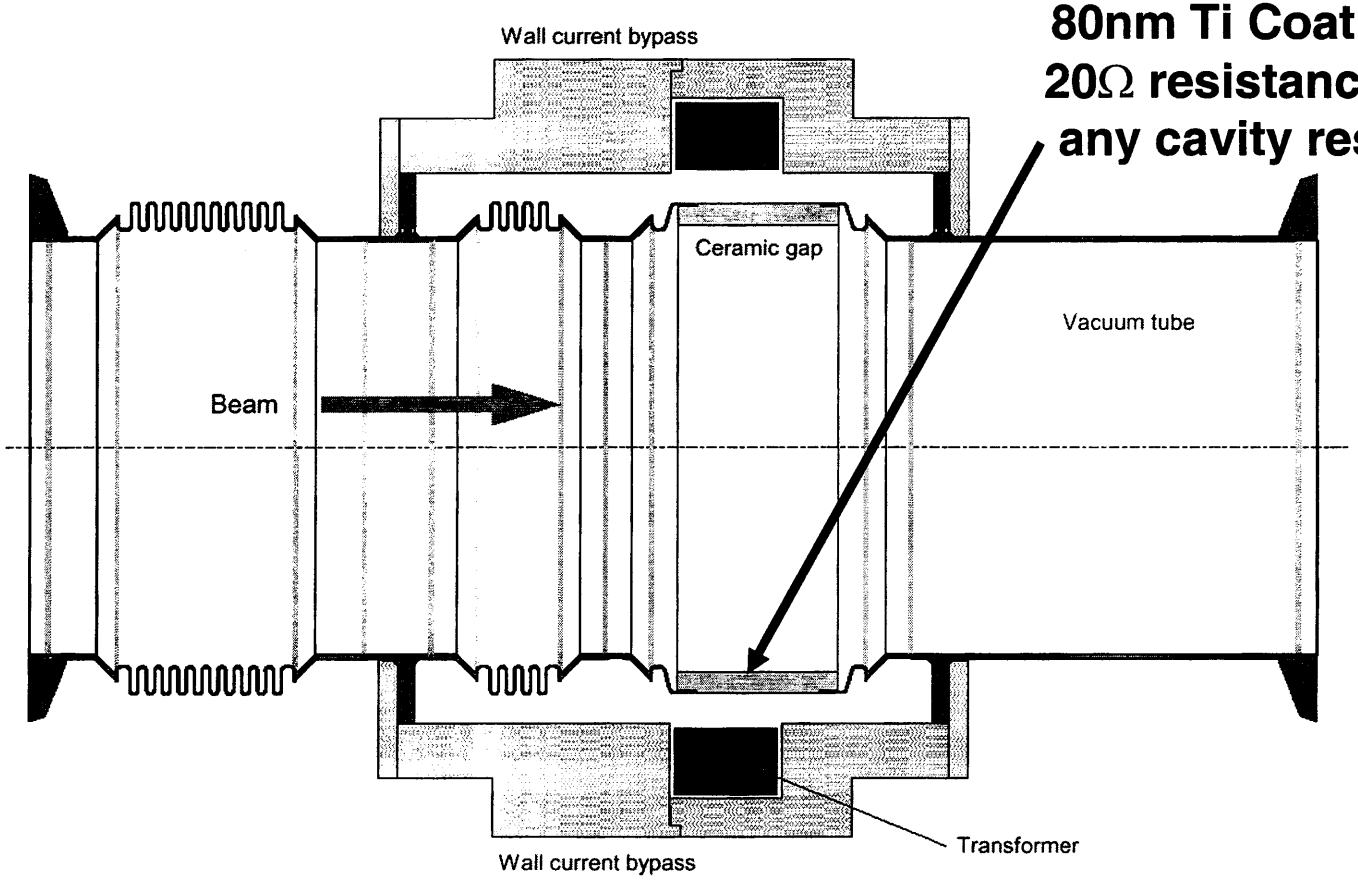
A. Guerrero, H. Jakob, R. Jones, J-J Savioz, H. Schmickler

Characteristics:

- **High Bandwidth, Low droop Transformer**
- **40 MHz bunch-to-bunch acquisition rate**
- **Accuracy of 1-2 % for 5E9 protons**
- **30 dB Dynamic Range** ***(single pilot to ultimate per bunch)***

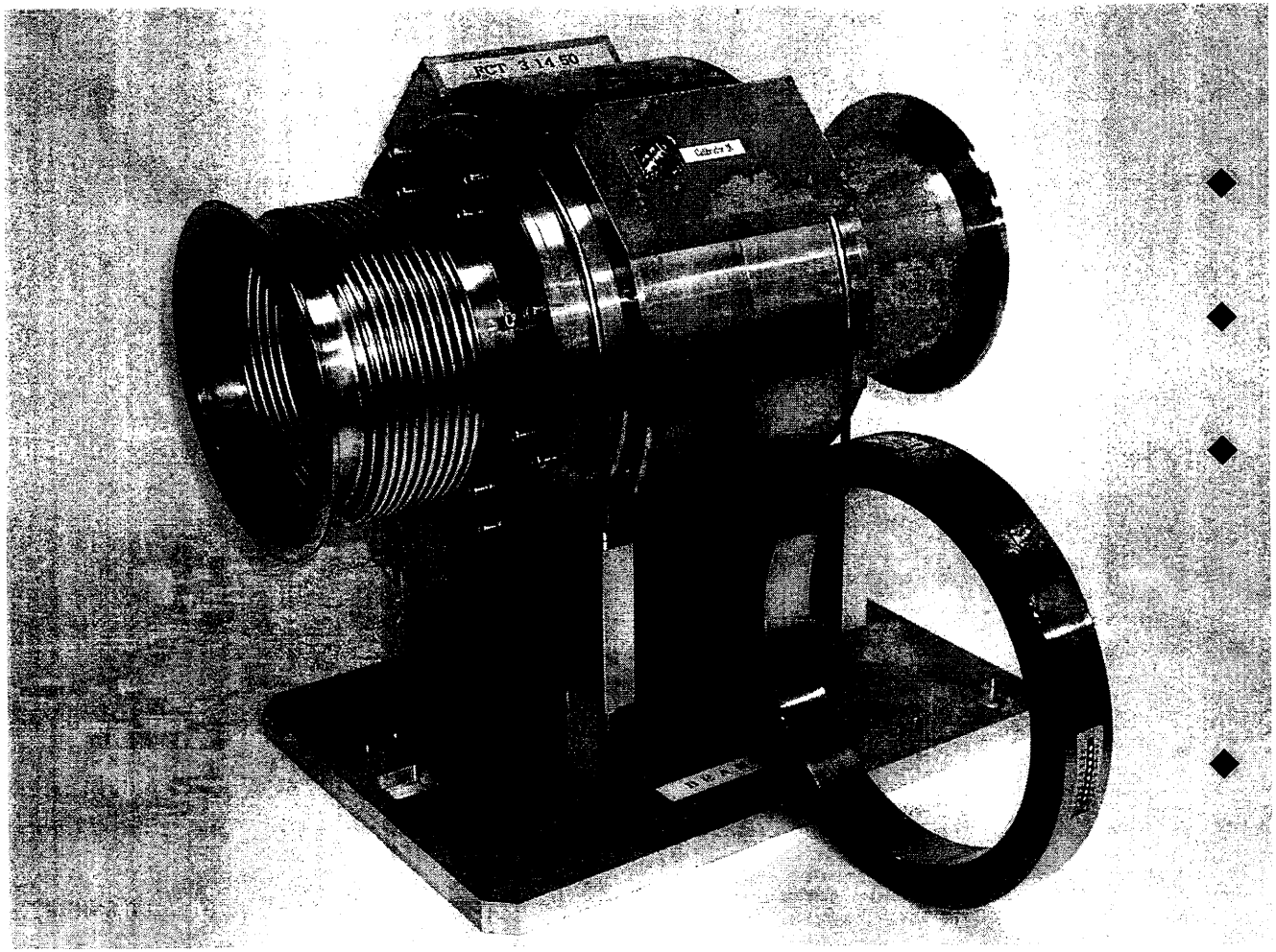
The TT2/TT10, SPS, TI2/TI8 Fast Current Transformer

80nm Ti Coating giving 20Ω resistance to damp any cavity resonances



FCT basic construction
Fast Beam Current Transformer

The TT2/TT10, SPS, TI2/TI8 Fast Current Transformer



SPS Housing + Bergoz FBCT

Bandwidth

- **500MHz**

Droop

- **0.16% per μs**

Dynamic Range

- **~65dB**

for LHC ~ 30 dB

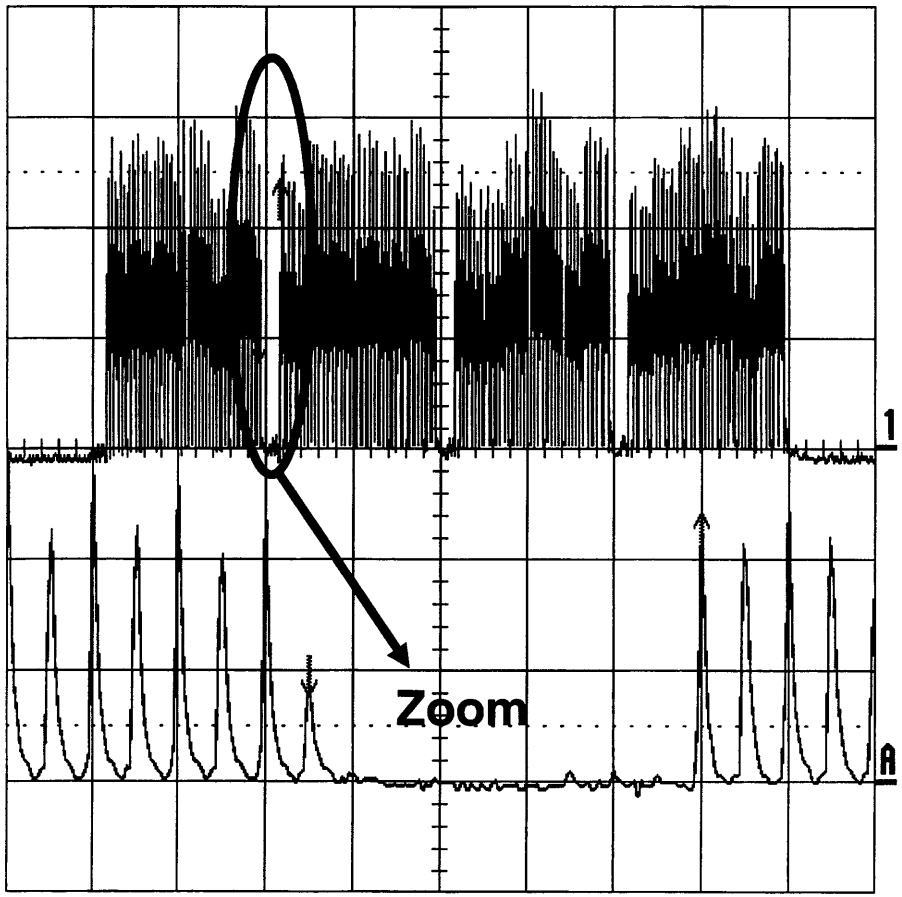
Pilot = 180mVp

Ultimate = 6.7Vp }

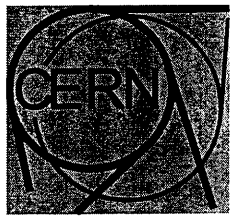
System Noise

- **< 2mV peak-peak**

The TT2/TT10, SPS, TI2/TI8 Fast Current Transformer

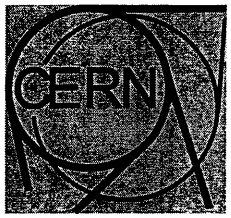


- 4 Batch Measurements in the SPS during 2001
- Bunch-to-bunch intensity variations clearly visible
- No influence of preceding bunch on signal even after 250m of cable



Fast Beam Current Transformer Acquisition System

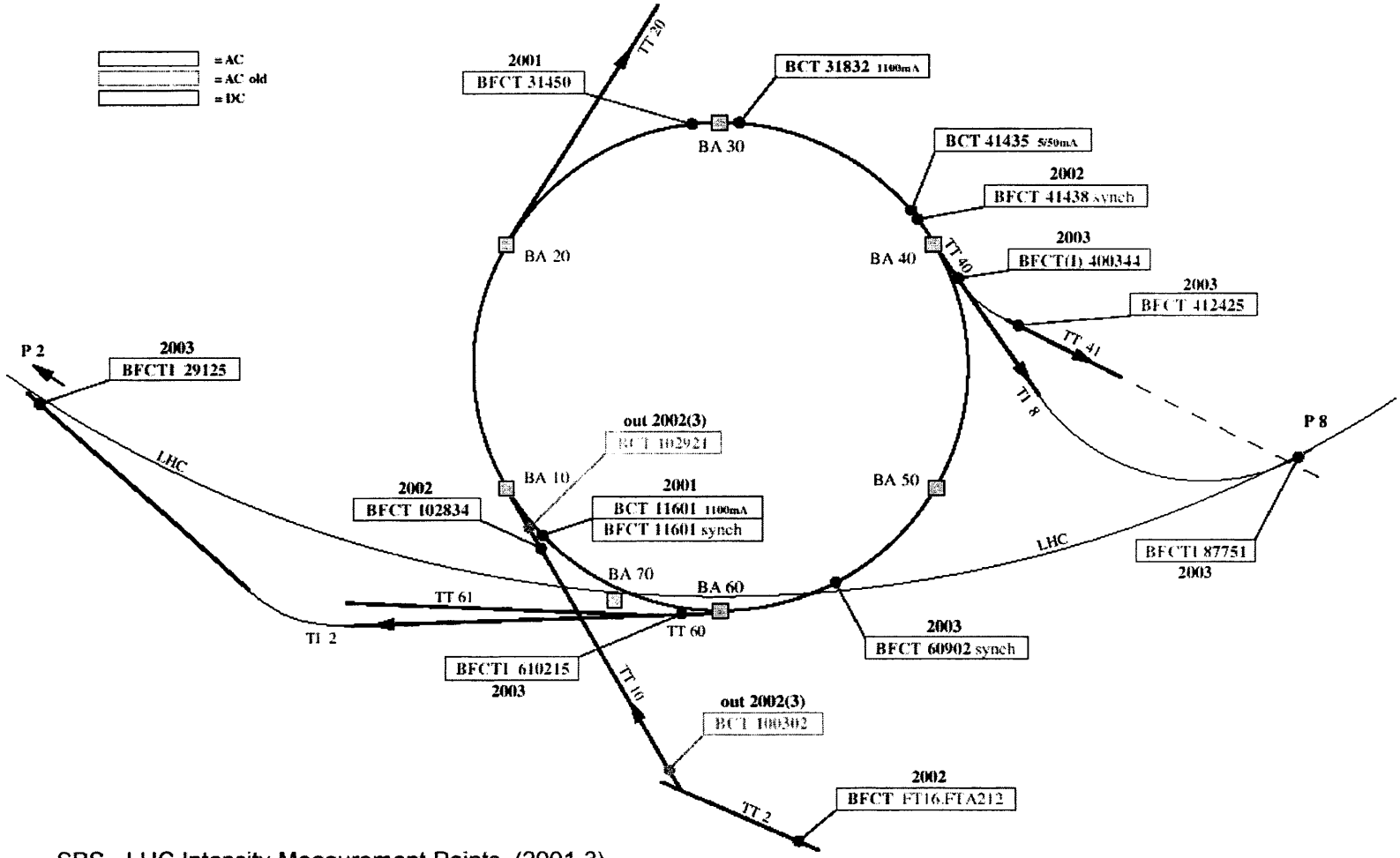
- ***Analogue Acquisition based on a fast integrator chip***
  - **Designed by the Laboratoire de Physique Corpusculaire, Clermont-Ferrand for use in the LHCb Preshower Detector.**
  - **Uses interleaved, 20MHz integrators and sample & hold circuitry to give 40MHz data.**
- ***Digital Acquisition***
  - **A mezzanine card will be produced, containing this chip and a 12bit, 40MHz ADC, for use with the same Data Acquisition Board (TRIUMF, Canada) *developed for the LHC Beam Position System.***
  - **Bunch synchronous timing provided by the *TTCbi module*, part of the Timing,Trigger & Control system developed for the LHC experiments [CERN-RD12 Project Development]**



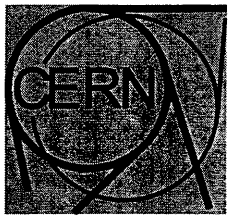
Fast BCTs for the LHC

- *2 independent FBCT systems (for redundancy) installed per LHC ring on either side of IP4*
- *LHC system will be based on current design for SPS*
- *Acquisition system identical to that foreseen for the SPS and its transfer lines.*
- *Uses foreseen for the LHC system:*
  - *Measurement of Pilot bunch intensities*
  - *Determination of bunch-to-bunch intensity variations*
  - *Possible input to beam dump system for finding the dump kicker synchronisation gap*
  - *Electron Cloud & Instability studies*

Fast-BCTs in TT2, TT10, SPS, TI 2, TI 8



SPS - LHC Intensity Measurement Points (2001-3)



Acknowldgements & References

Work reported here is a joint effort of 2 CERN teams :

- Meyrin site *[P.Odier, J. Longo, V. Chohan]*
- Prevessin site *[A. Guerrero, H. Jakob, R. Jones, J-J Savioz, H. Schmickler]*

Some References:

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6. J.Bosser,C.Bovet etal: LHC Beam Instrumentation Conceptual Design Report, LHC Proj.Report 370, Feb 2000