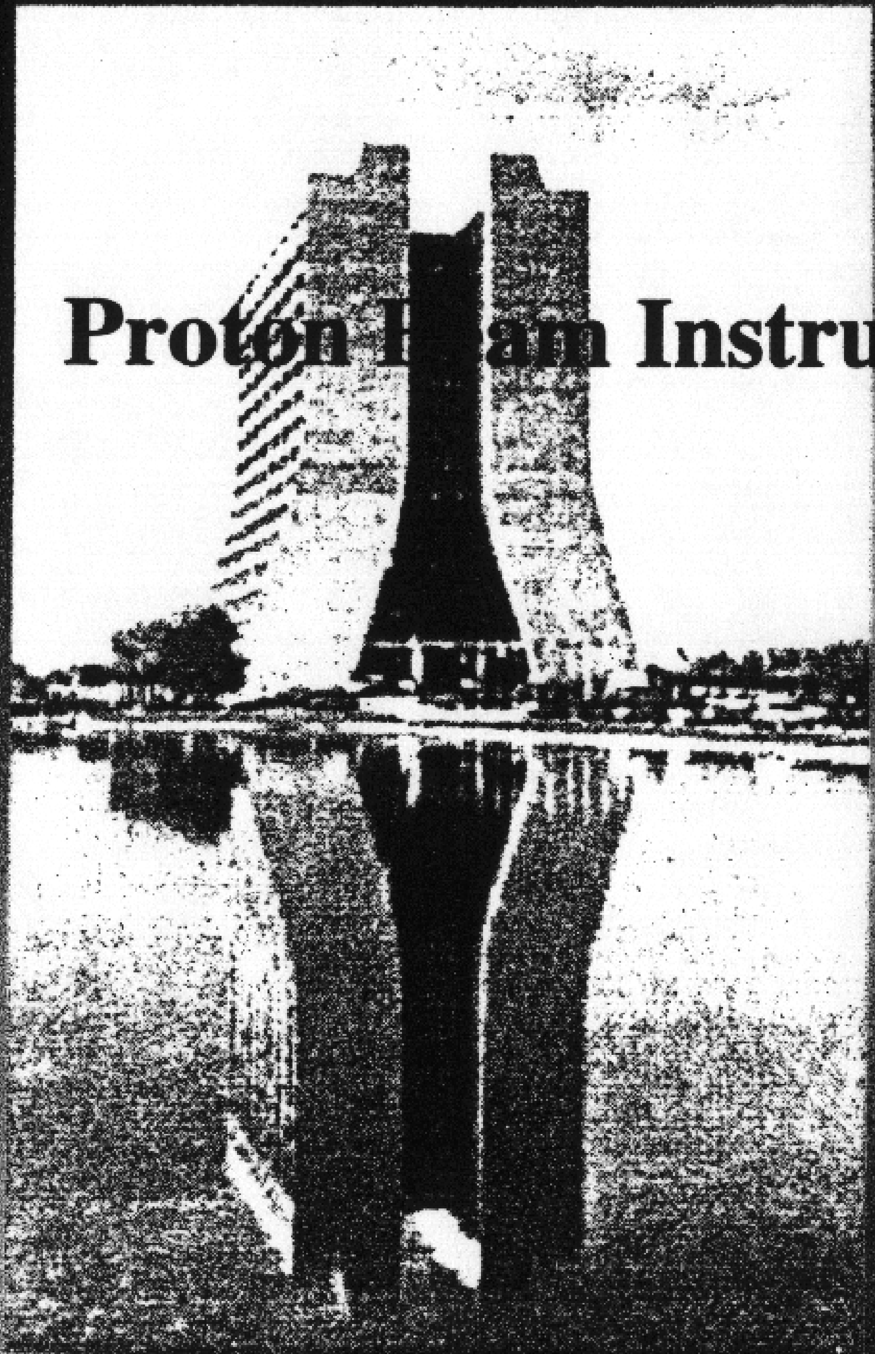
Proton Beam Instrumentation for CNGS



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FNAL [illegible]

Outline (1/2)

- **Beam Position Monitors (BPMs)**
  - requirements
  - choice of pickups
  - the 40 MHz system for LHC beams
  - the 200 MHz system for CNGS beams
  - experience from LEP spectrometer

Outline (2/2)

- **Beam Current Transformers**
- **Profile Monitors**
- **Beam Loss Monitors**

BPM requirements

- 18 BPMs in TT40 and TT41 (H or V, 3 BPMs H+V)
- aperture: r=30 mm
- 3 BPMs have to measure LHC and CNGS beam (TT40)
- requested precision:
  - 1% absolute precision
  - 0.1% resolution

  very tough, seems to be justified for the last 2 BPMs!
- dynamic range:
  - LHC beam: 5*10^9 p/bunch --> 2*10^11 p/bunch (:40)
  - CNGS beam: 2*10^12/10 µs batch --> 4*10^13 p/10 µs batch (:20)

  (to be covered without gain-changes)

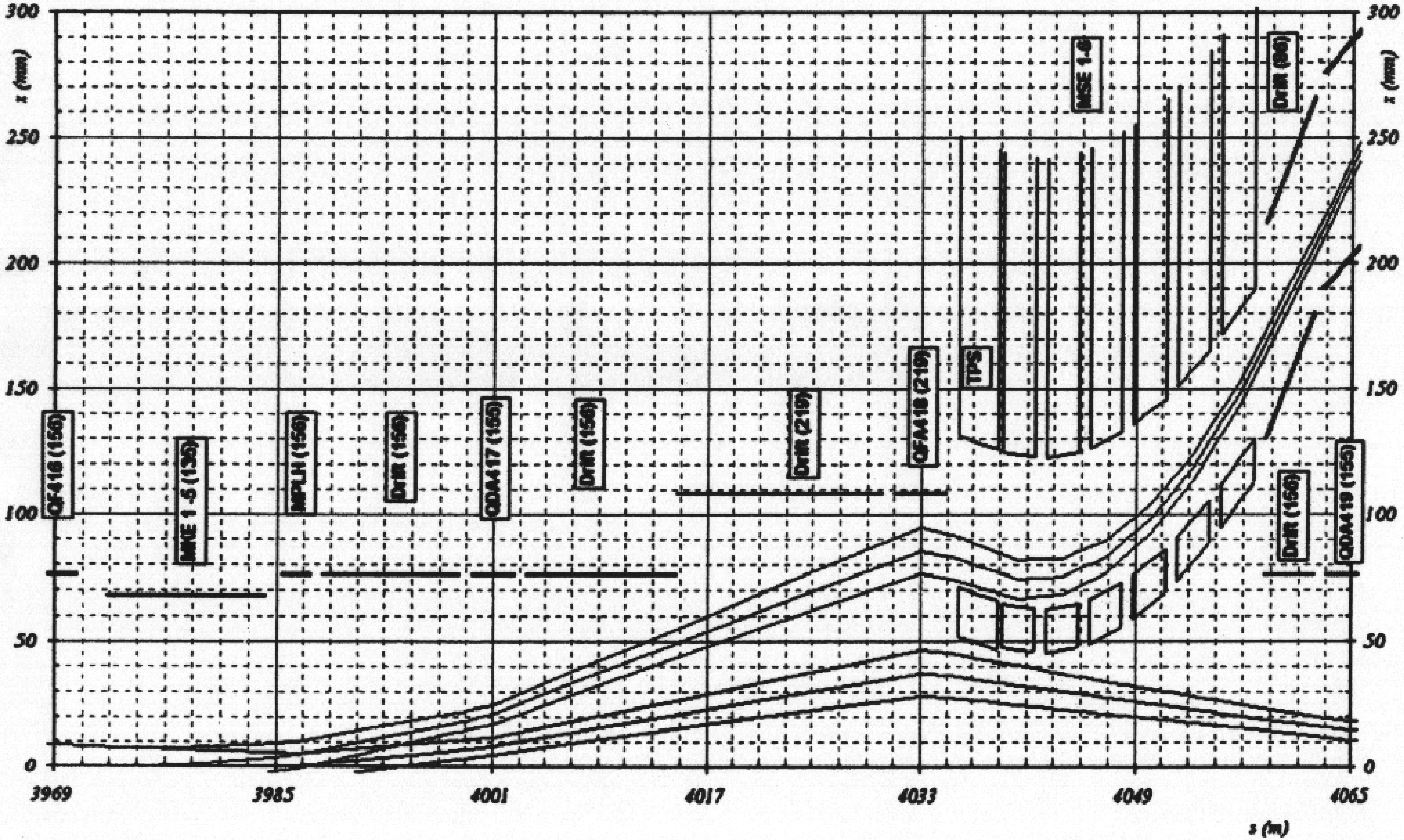
A special BPM

- In the extraction area of the beams from the SPS (LSS4) a BPM in front of the septum magnet is needed with:

  - aperture radius: 100 ... 110 mm

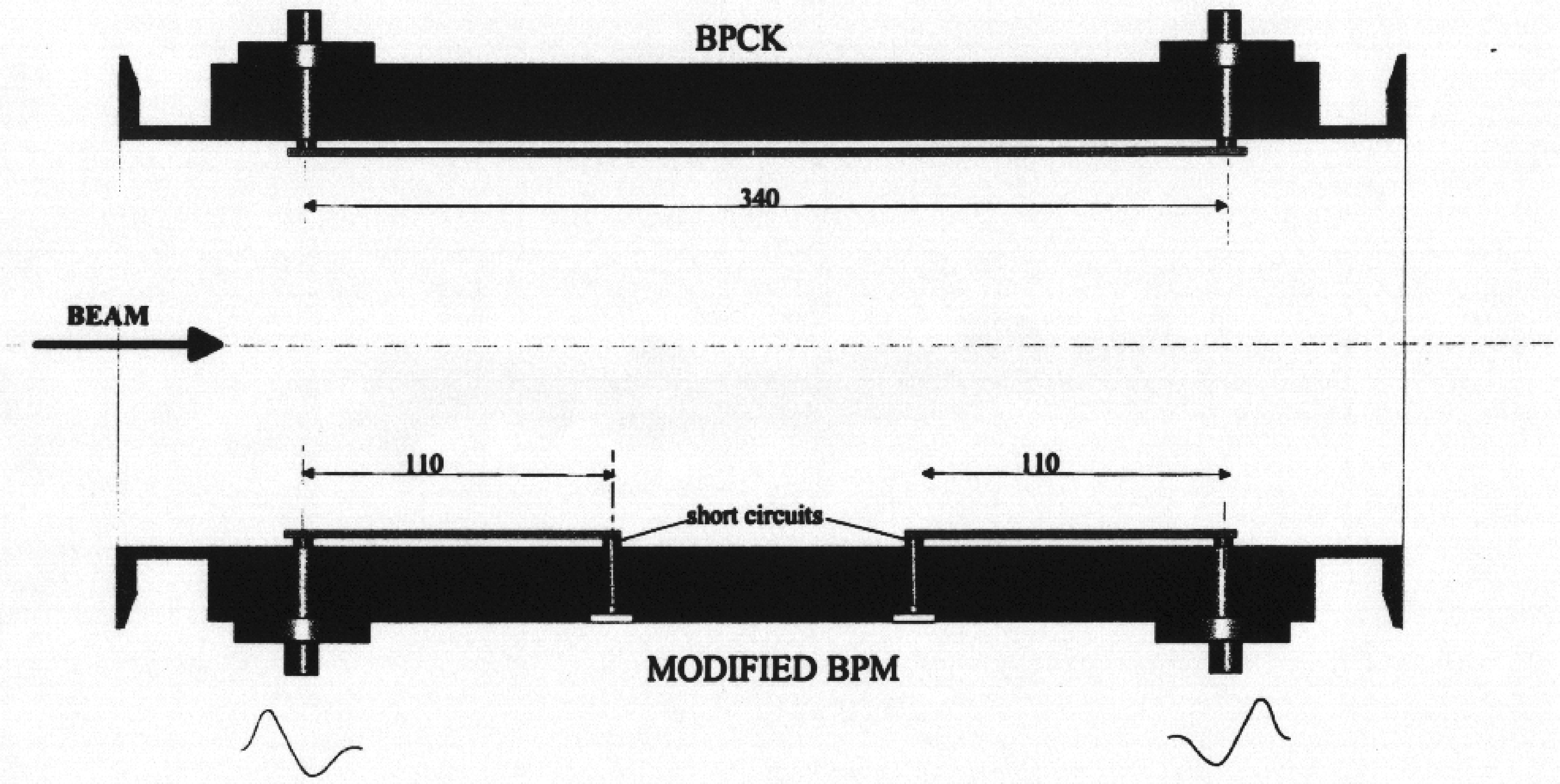
  - required precison and linearity 100 ...200 µm over 50% of the aperture, I.e 0.1 ..0.2%, about a factor 20 away from that what we can do presently.

Chamber


300
250
200
150
100
50
0
z (mm)
QF416 (156)
MKE 1 -5 (136)
MPLH (156)
Drift (156)
QDA417 (156)
Drift (156)
Drift (219)
QFA418 (219)
TPS
MSE 1-6
Drift (86)
Drift (156)
QDA419 (156)
3969
3985
4001
4017
4033
4049
4065
s (m)

Choice of Pickups

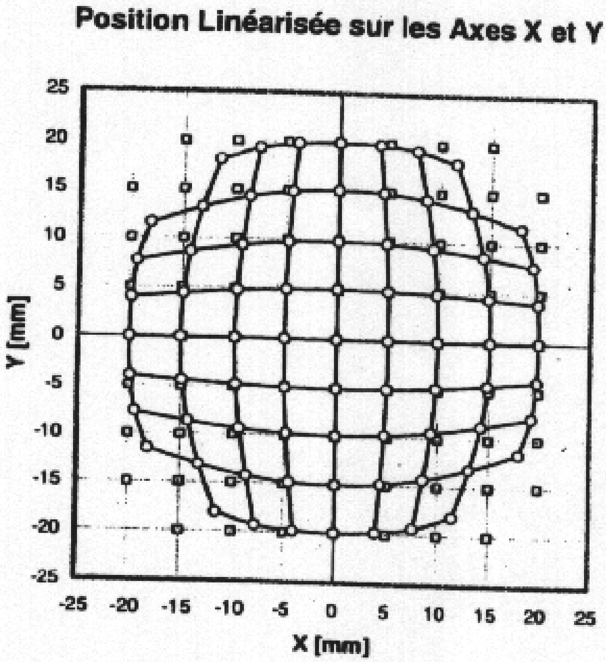
- **For common part (TT40)**
  - recuperation of short directional couplers (2 output ports) from another transfer line (TT60). With short-circuit in the middle part we will construct two independent signal sources.
- **For TT41:**
  Study underway to use button monitors (recuperated from LEP, d=34 mm) in a circular vacuum chamber.
- **Geometric corrections known for button monitors**

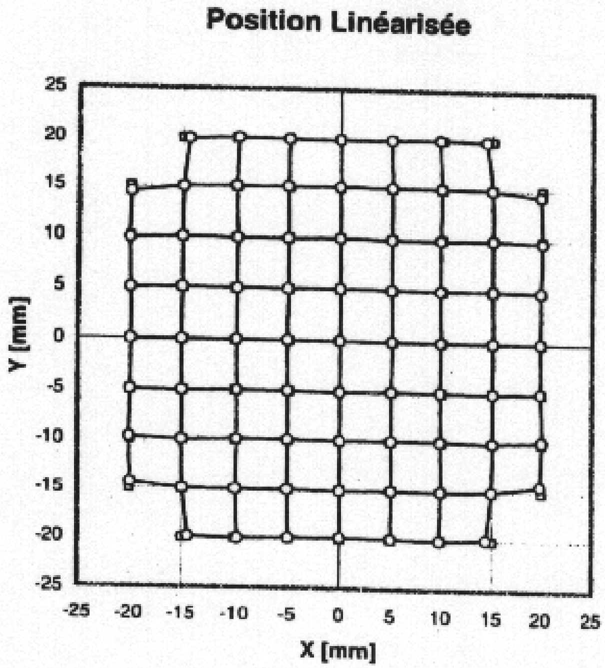

BPCK
340
BEAM
110
110
short circuits
MODIFIED BPM

Linéarisation sur les deux axes

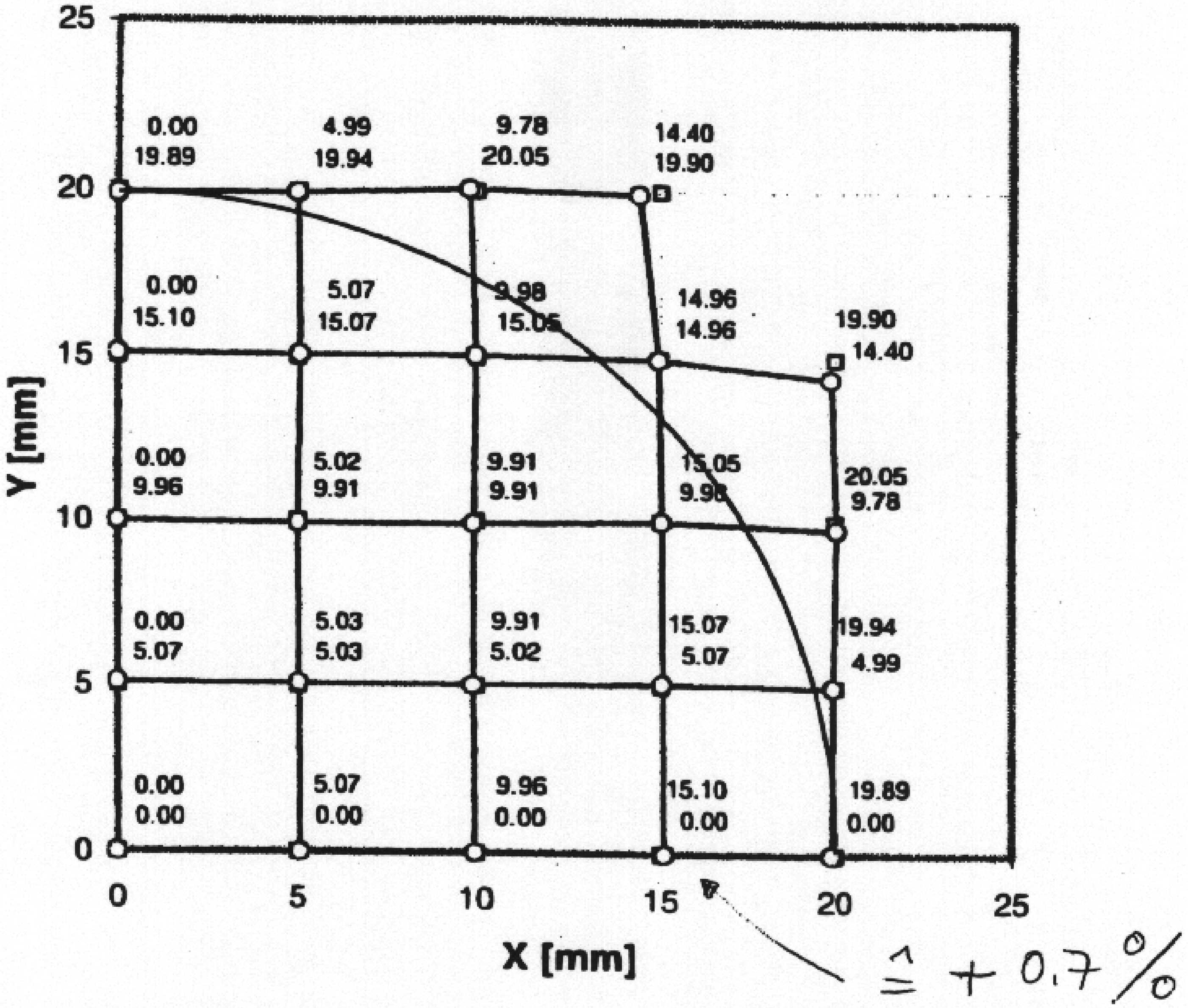
Si les deux axes sont mesurés, cette même correction peut être appliquée simultanément sur les axes X et Y (Fig. 10).

$$X_2 = 1.172 \cdot 10^{-5} X_1^{\,5} - 1.399 \cdot 10^{-4} X_1^{\,3} + 1.033 X_1$$
$$Y_2 = 1.172 \cdot 10^{-5} Y_1^{\,5} - 1.399 \cdot 10^{-4} Y_1^{\,3} + 1.033 Y_1$$





Position Linéarisée
Valeurs X - Y



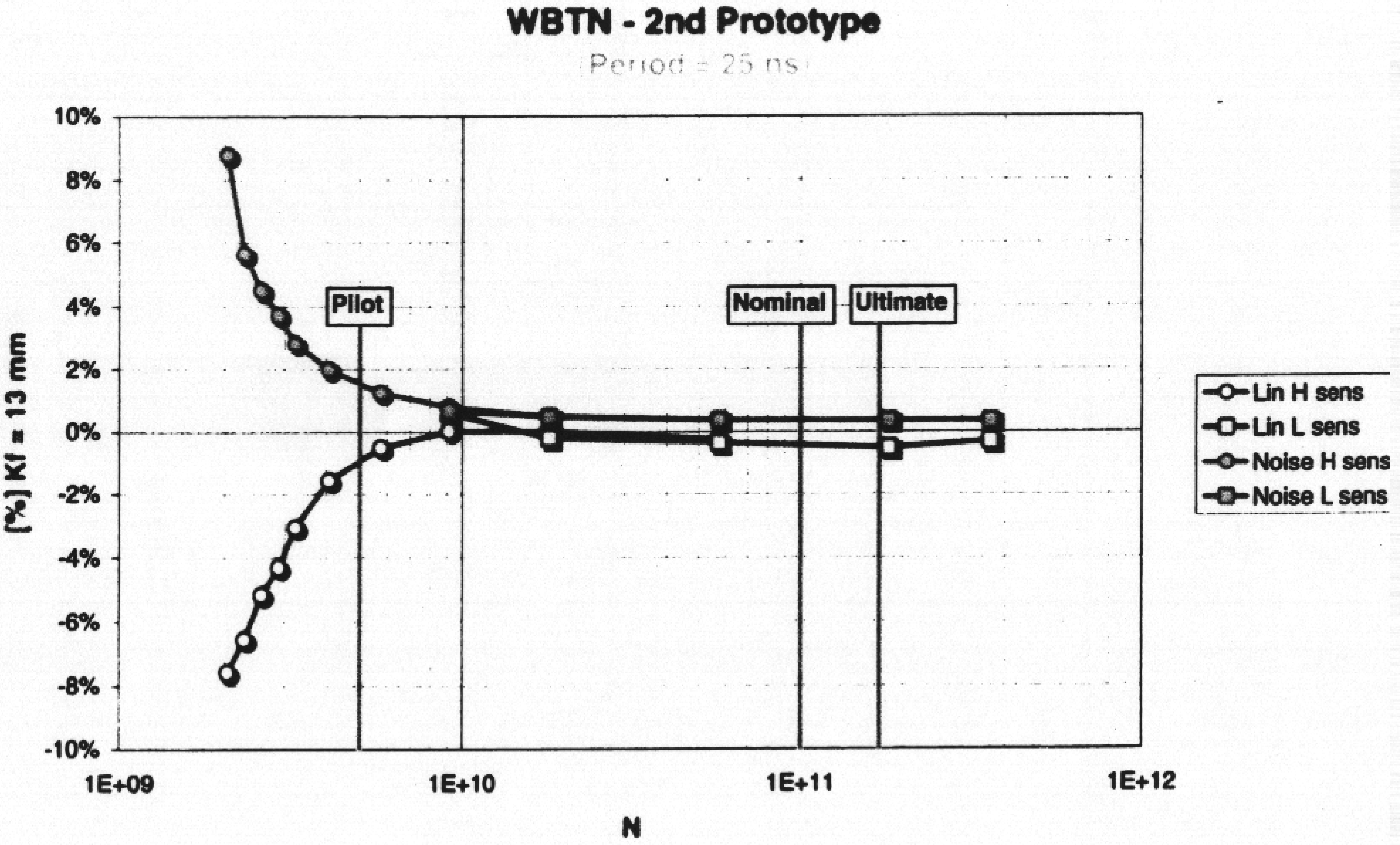
The 40 MHz LHC system

- **Based on the so called "wide band time normaliser" resulting in 40 MHz bandwidth**

- **linearity over intensity range: +/-1%**

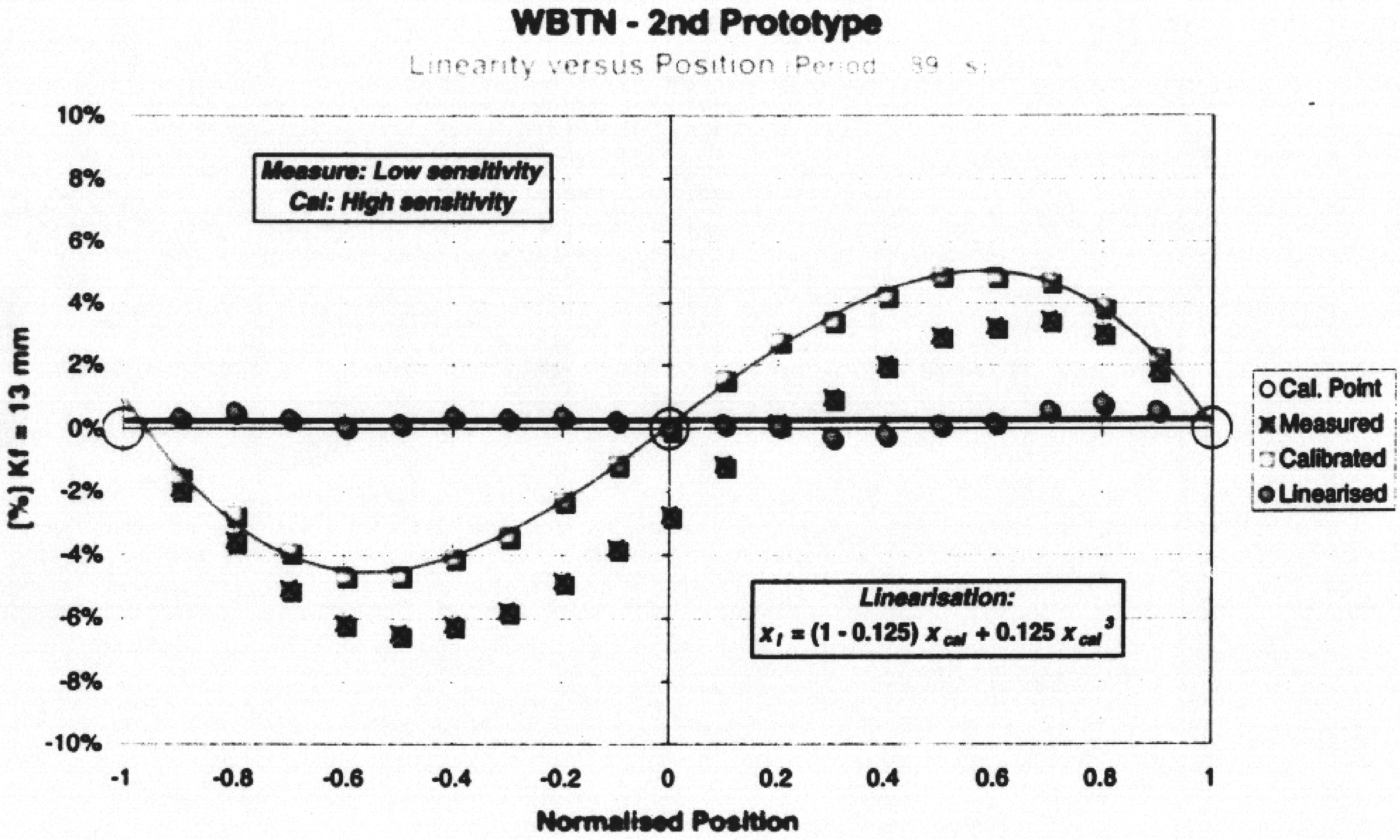
- **linearity over 50% of aperture: +/-1%**

- **calibration system for Norm.Ap. -1, 0, +1**



WBTN - 2nd Prototype
(Period = 25 ns)
10%
8%
6%
4%
2%
0%
-2%
-4%
-6%
-8%
-10%
[%] Kf = 13 mm
1E+09
1E+10
1E+11
1E+12
N
Pilot
Nominal
Ultimate
Lin H sens
Lin L sens
Noise H sens
Noise L sens

14.07.20


WBTN - 2nd Prototype
Linearity versus Position
Measure: Low sensitivity
Cal: High sensitivity
10%
8%
6%
4%
2%
0%
-2%
-4%
-6%
-8%
-10%
[%] Kf = 13 mm
Linearisation:
x_l = (1 - 0.125) x_cal + 0.125 x_cal^3
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
Normalised Position
Cal. Point
Measured
Calibrated
Linearised

14.07.2000

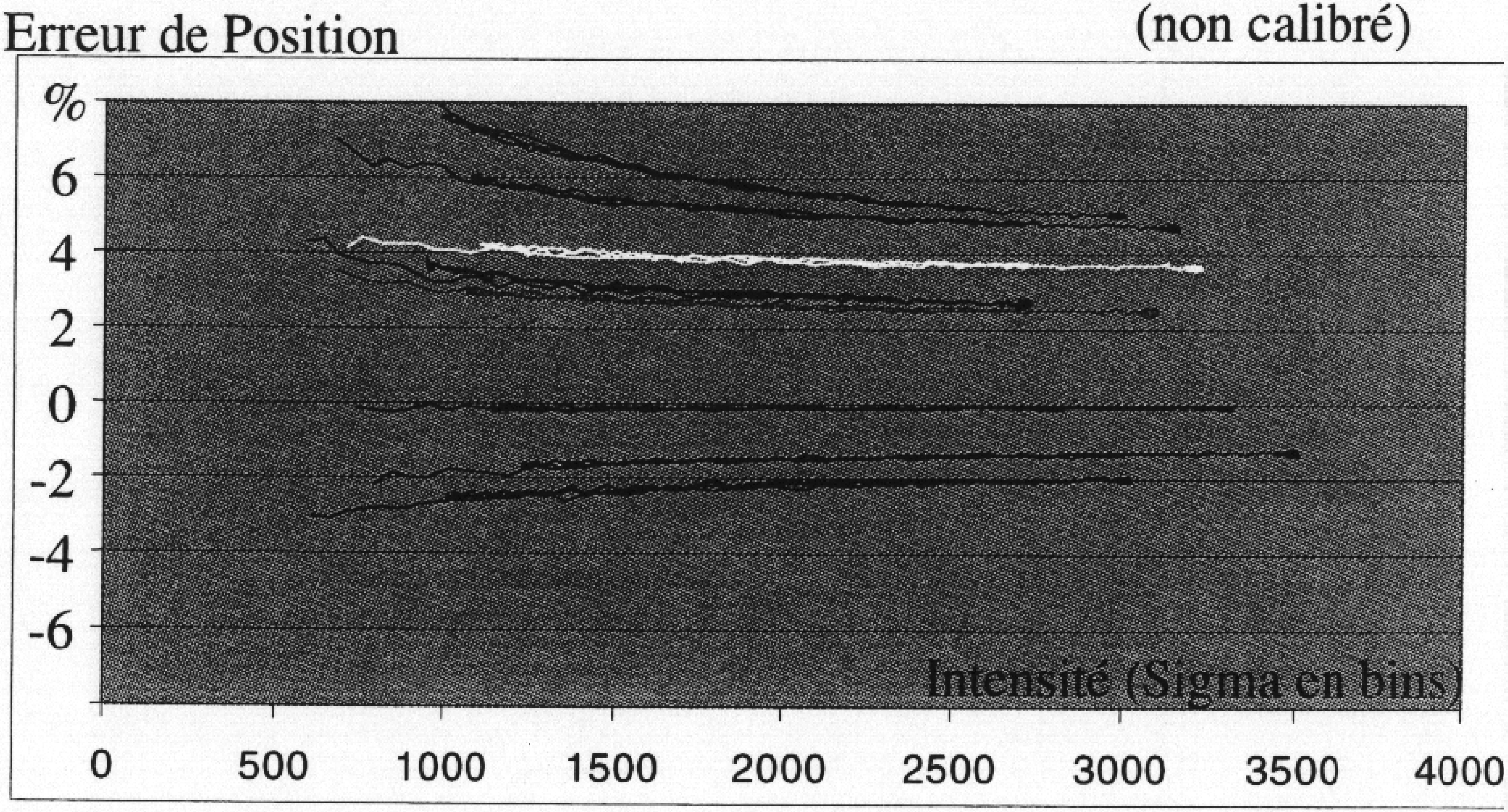
The 200 MHz system

- Based on homodyne receivers
  used in the SPS since 1976
- linearity over intensity range: not well known;
  improved recently [illegible] calibration
- linearity over aperture: not known
- calibration system:
  uses beam as calibrator signal with switch in input module, questionable for transfer line!

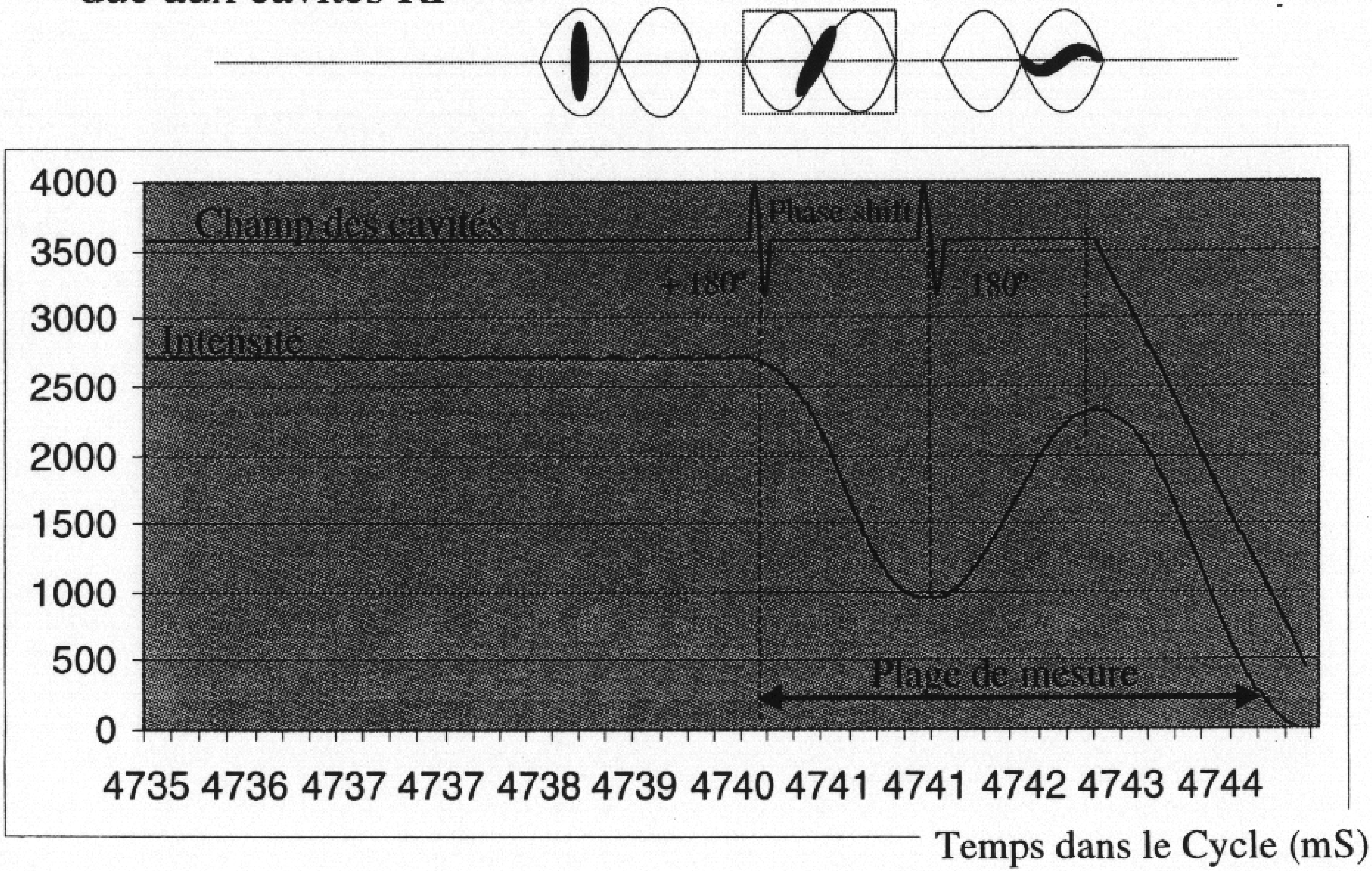
La Linéarité de la chaîne ?

Variation des positions tour par tour pour quelques BPM:

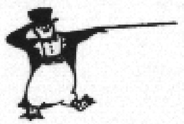
(non calibré)



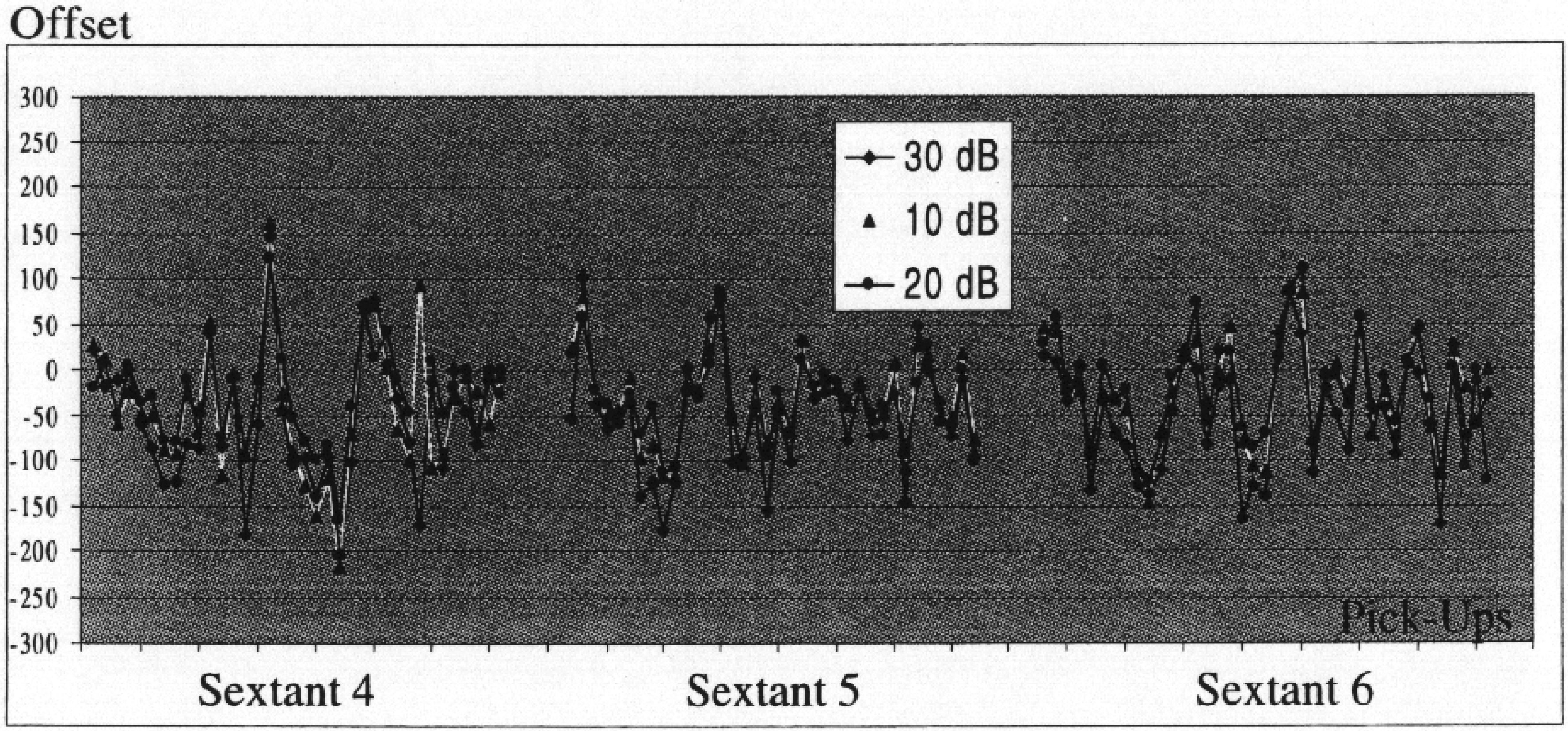
Extraction des protons et variation de la composante 200MHz due aux cavités RF



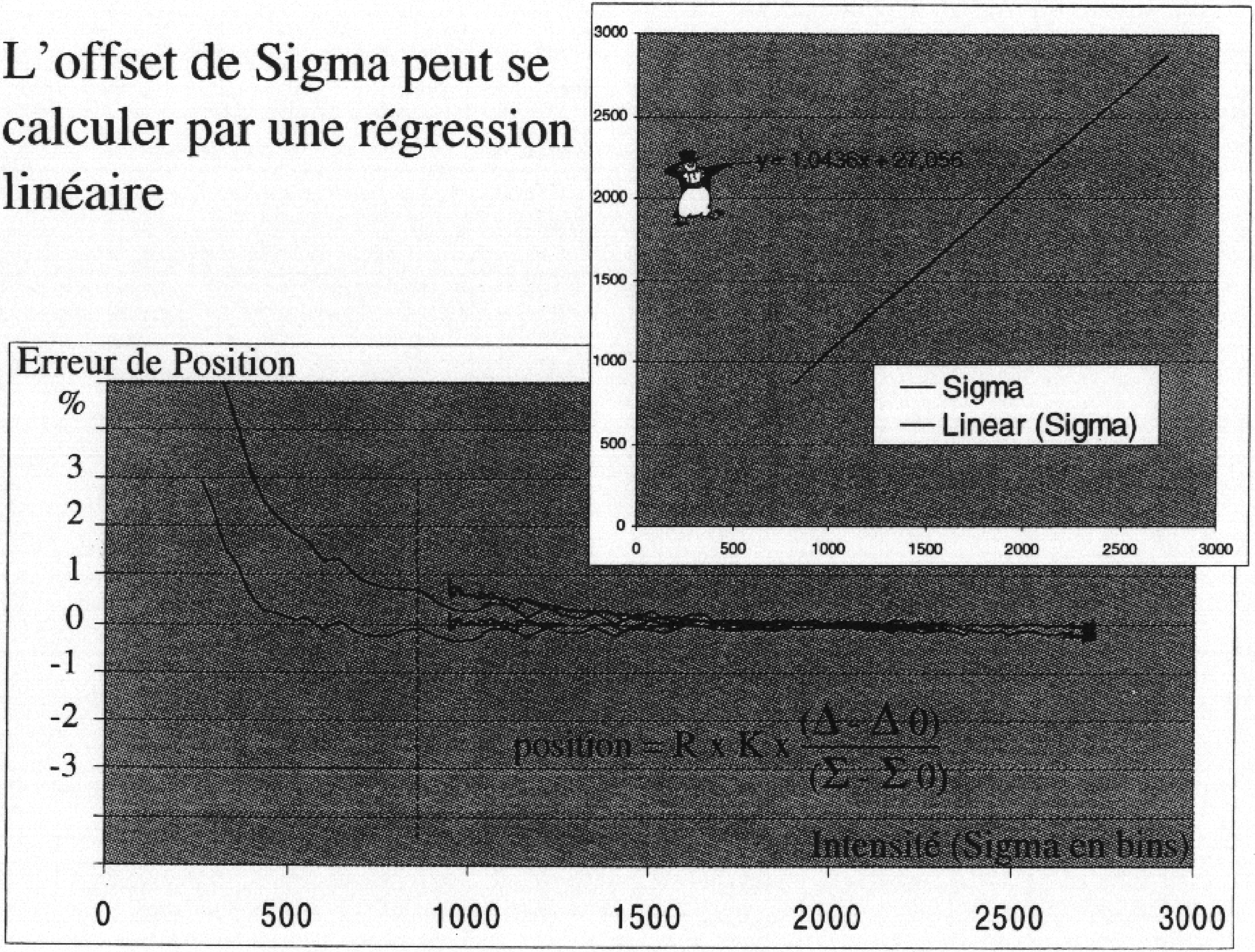
Corrélation des mesures



Bonne corrélation aux gains 10 à 30 dB … valide la méthode



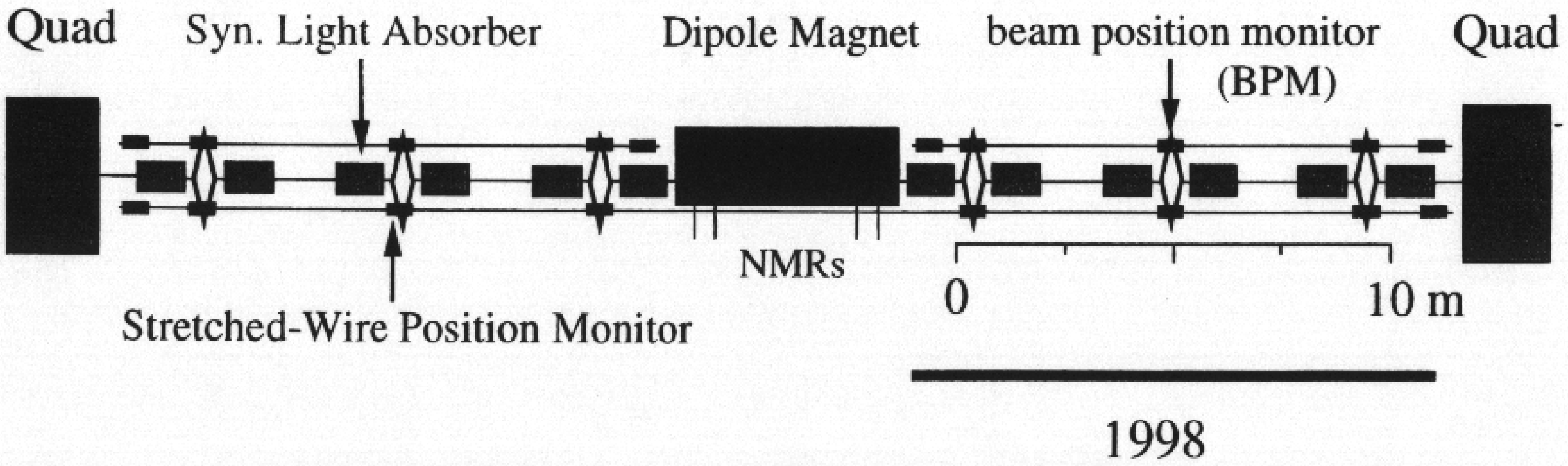
L’offset de Sigma peut se calculer par une régression linéaire



Experience from LEP spectrometer

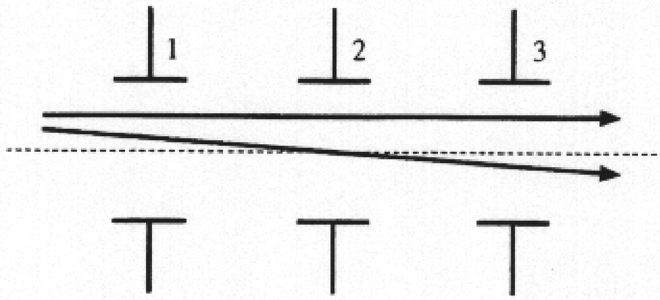
- LEP spectrometer:
  installation to measure beam energy to 100 ppm precision using the beam deflection in a dipole magnet.
- Requires BPMs with sufficient resolution and stability within an electrical aperture of +/- 1mm.
- Solution:
  - Construction of BPM triplets on each side of dipole
  - Calibration of gain with beam bumps
  - Consistency checks on data with "Triple residual"
- A similar installation should be designed for the two last BPMs in front of the target.

Spectrometer Method (III)

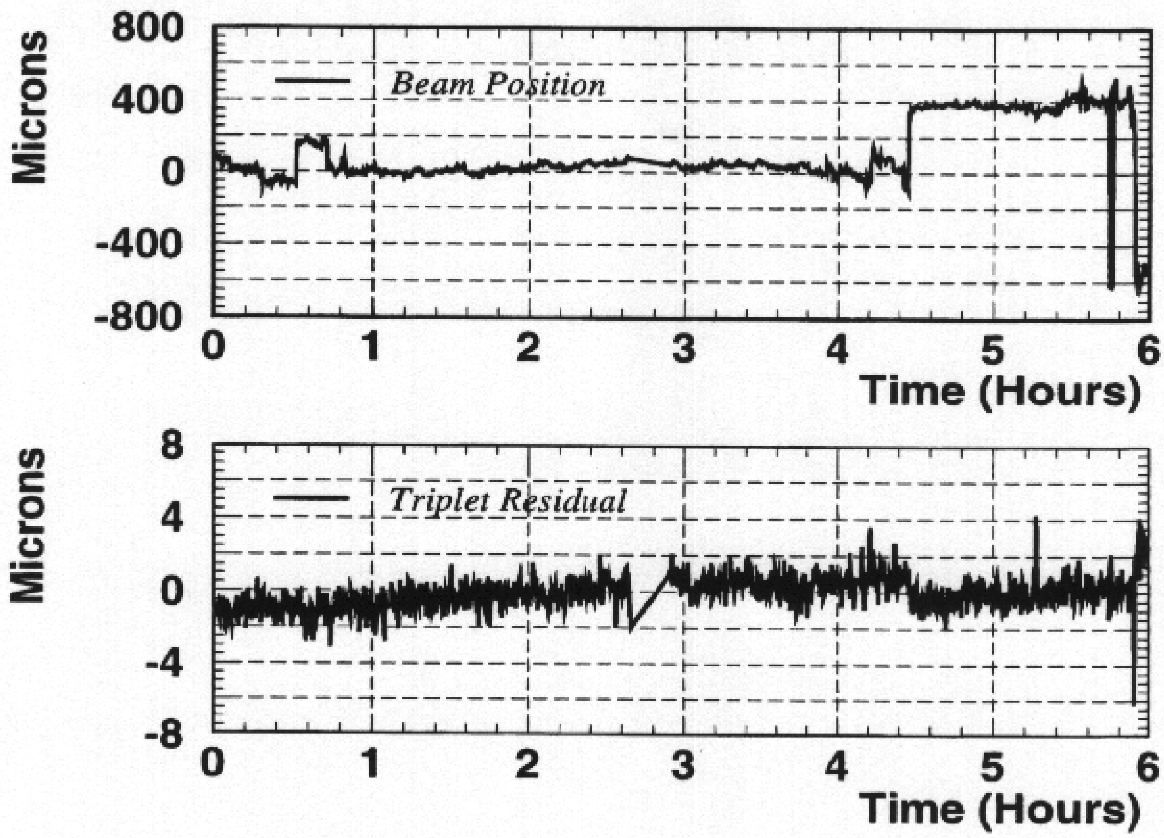


- BPM button shielded by synchrotron light absorber
- BPM support temperature stabilised and position monitored
- Mild iron magnet (10 times lower variations with temperature)
- Last year: prototype, this year: full setup (including new magnet)

BPM Triplet Residual

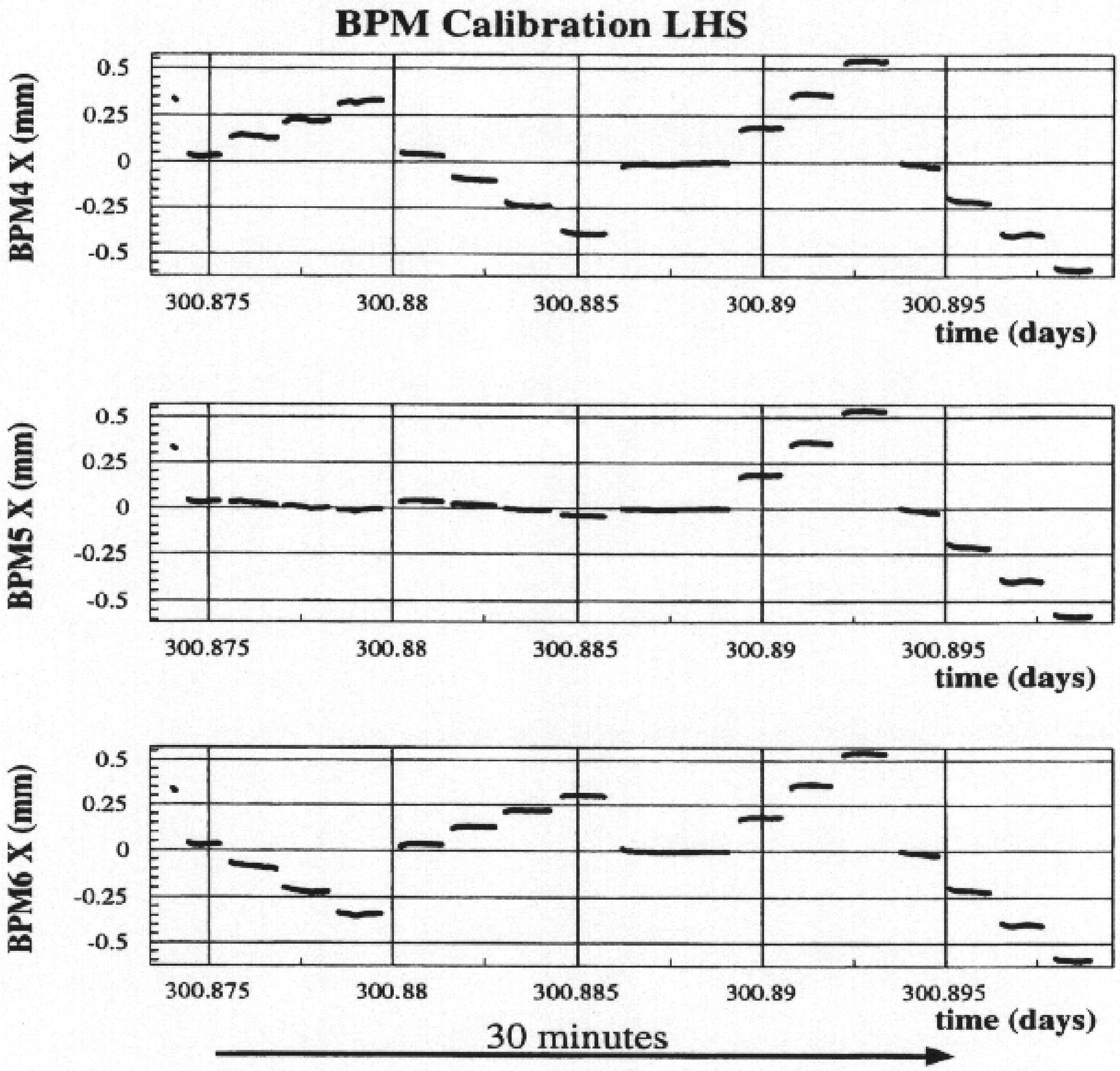


$$T = \frac{X1 + X3}{2} - X2$$



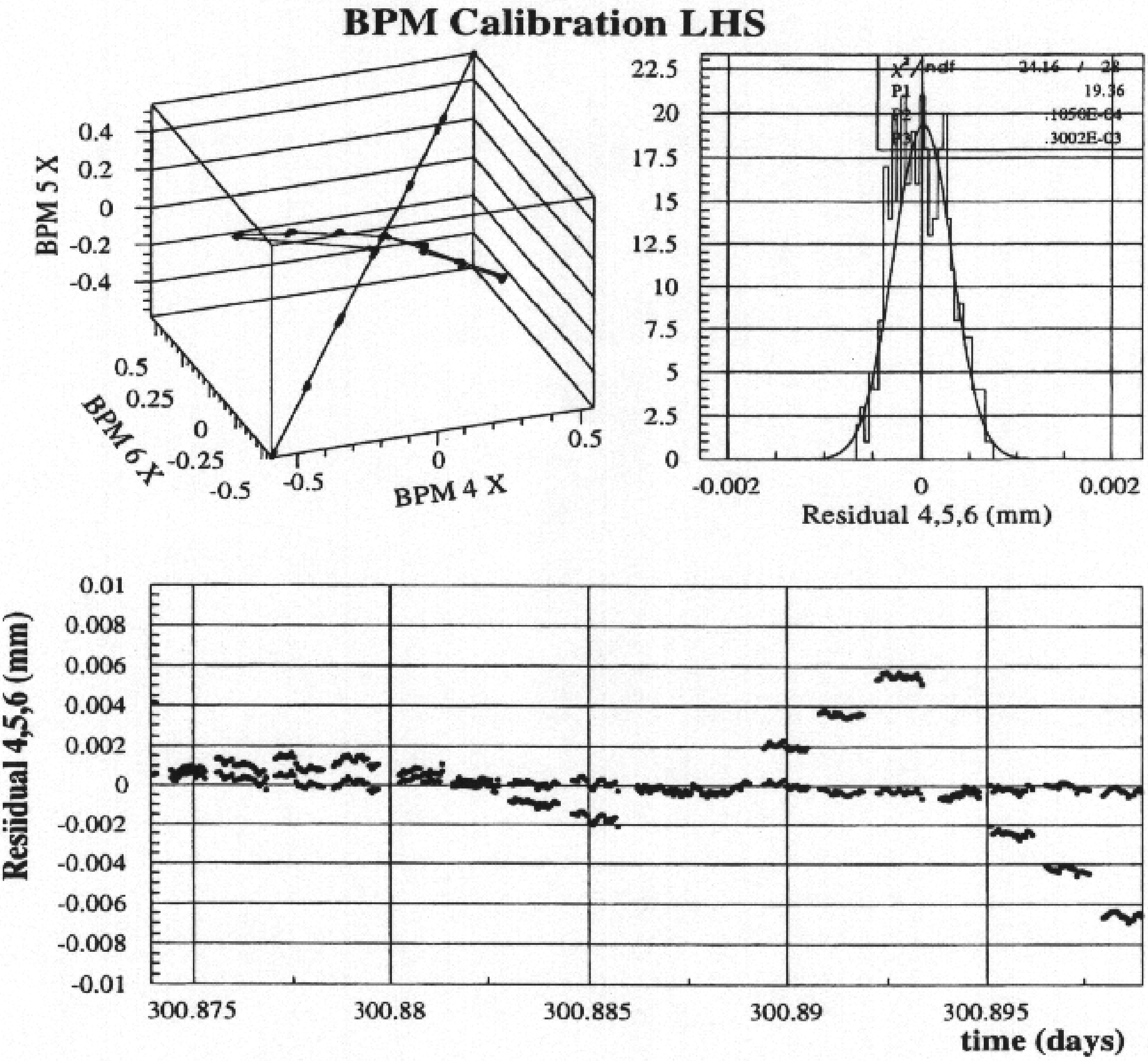
- BPMs in field-free region
- Triplet residual is a measure of BPM resolution
- Should be unaffected by parallel or angle changes

BPM Gain Calibration



- Angle bumps centred on PU5 $X_4 = -X_6$, $X_5 = 0$
- Parallel bumps $X_4 = X_5 = X_6$
- In 3D, defines the plane $X_5 = \frac{X_4}{2} + \frac{X_6}{2}$

BPM Gain Calibration



- Compare measured plane → relative gains
- Correct PU4 and PU6 to PU5
- $\sigma = 0.3\mu m$ for triplet residual after correction
- Reproducibility before/after ramp approaches 1/1000
- Only done for later fills

Summary BPMs

- “shared” directional couplers for TT40
  and LEP button monitors for TT41
  to do: measure geometric non-linearity for couplers
- 40 MHz system for LHC beams, performance meets requirements, has to be checked with beam (year 2001)
- 200 MHz homodyne receivers for CNGS beams, probably OK, but things to do:
  - measure intensity linearity after new calibration method for offsets in the sum channel
  - measure position linearity with bumps
  - design a new calibration system without beam
- spectrometer type installation for last 2 BPMs in TT41

Beam Current transformers

- Basically no major problem, but
  Requested precision of 1% very difficult to achieve
- Reasons:
  1) Intrinsic precision/linearity of integrators: 1..2%
  2) Generation, Transmission and measurement of calibration pulse: 1..2%
  3) Unpredictable capture of parasitic signals:
  - Extreme example: Kicker firing induces signals into BCT cables downstream TT10, pictures shown for small signal amplitudes of heavy ions beam.

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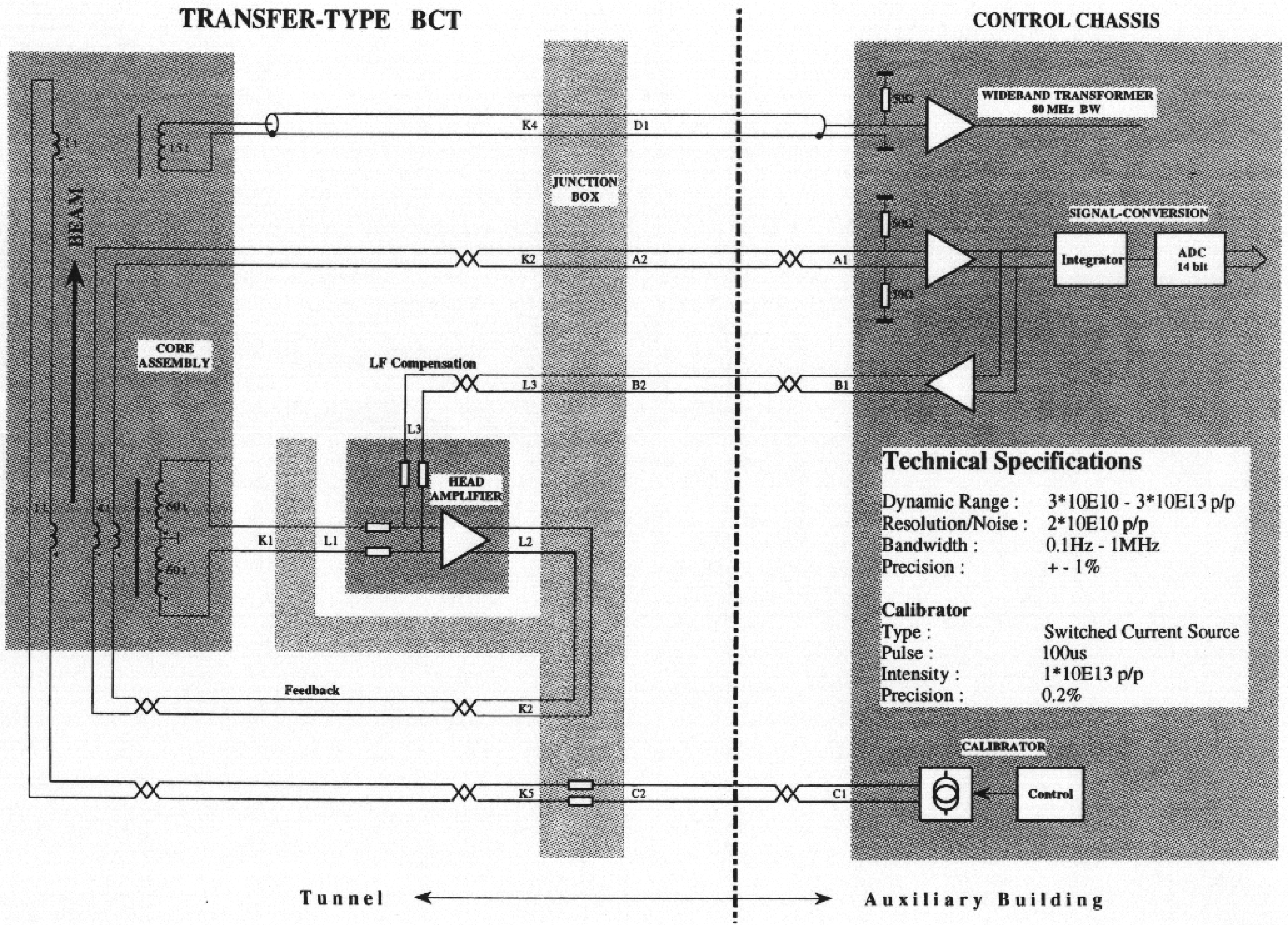
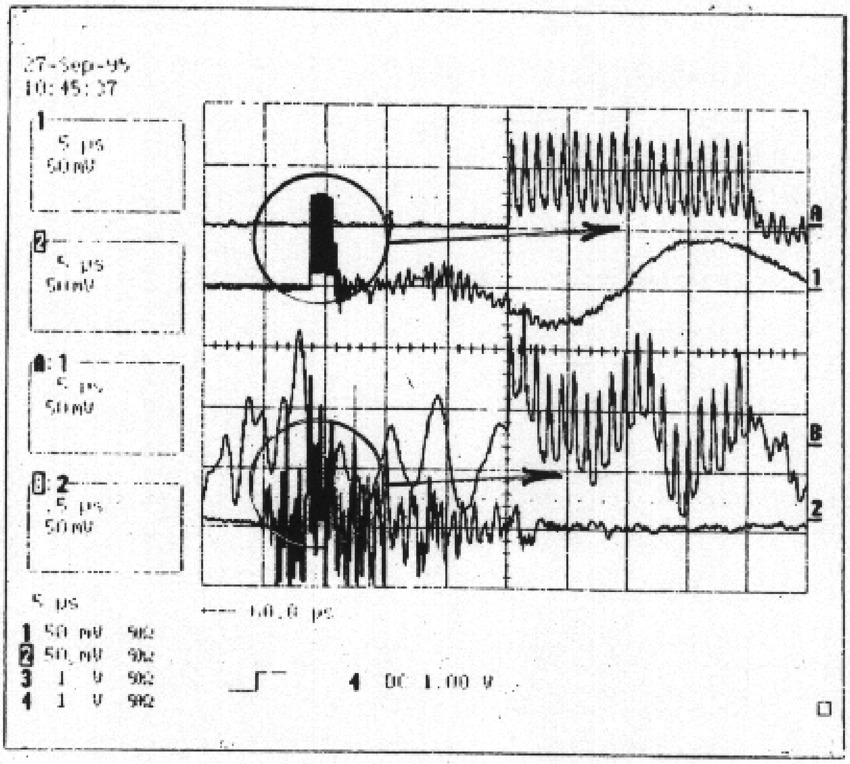


SL/BI-EM hj 08.00
SL/BI-EM hj 09.97

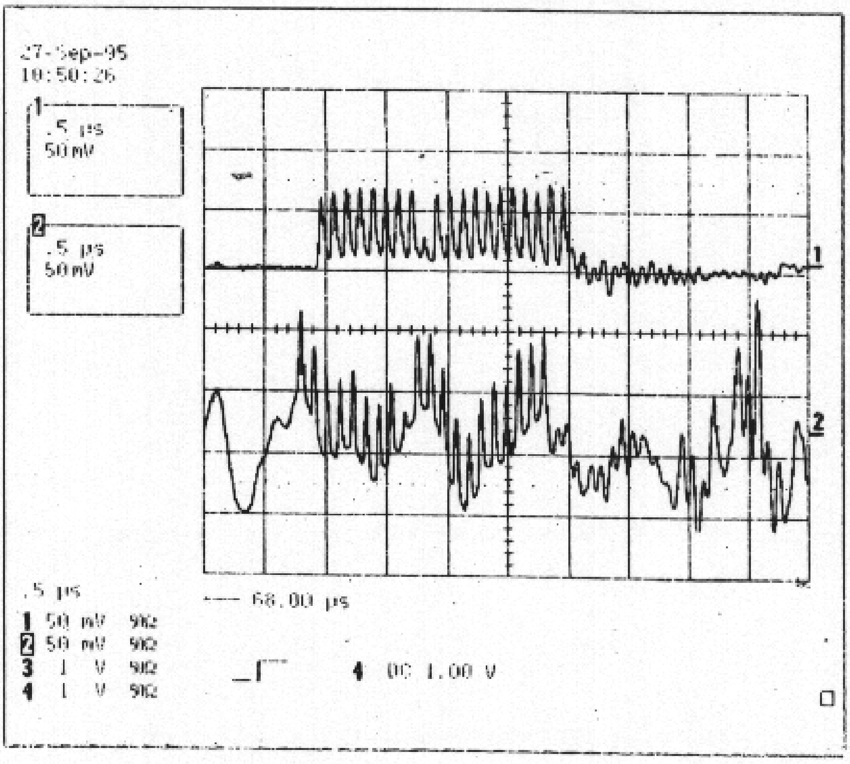
Injection Kicker Noise

seen on low intensity ion beam measurements with transfer BCT's in TT10



BCT 100302
upstream

BCT 102 921
downstream



BCT 100 302
upstream

BCT 102 921
downstream

Profile Measurements

- 8 profile monitors are foreseen in the line
- 1 profile monitor in front of the target
- for the beam line (σ=0.8 to 3.23 mm):= medium brilliance

  screens: OTR for the nominal beam

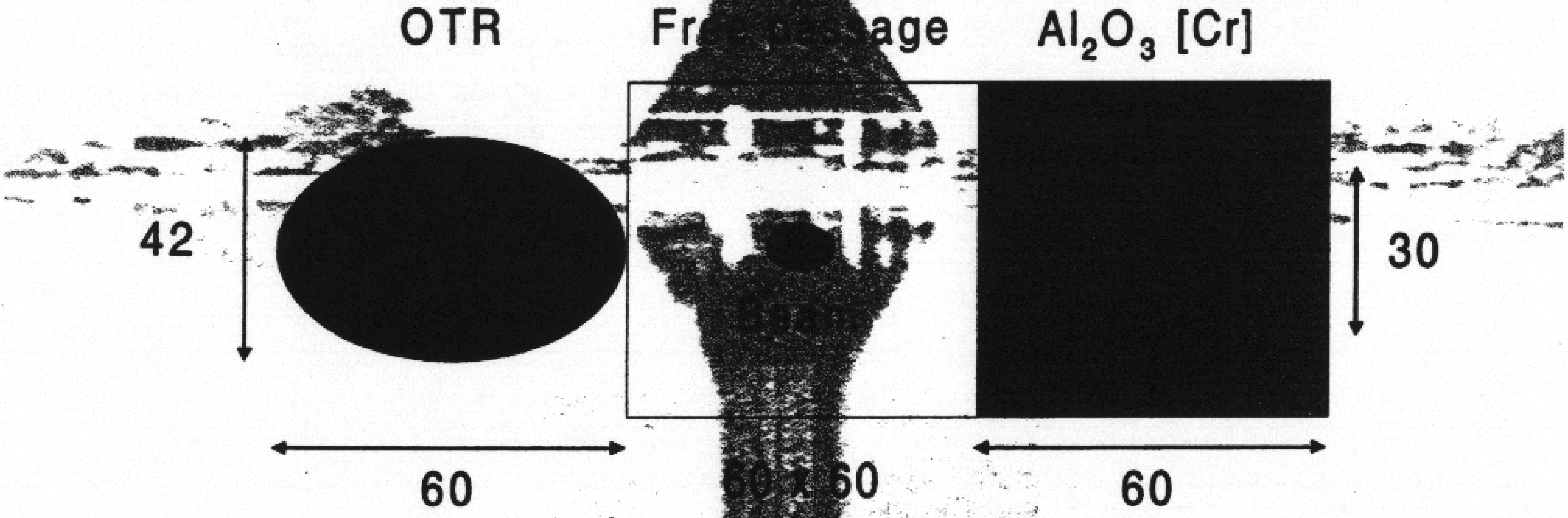
  Al_2O_3 for set-up or bad days
- for the target station TBIU (σ=0.32 mm):= high brilliance

  OTR screen only

  H & V beam scanners as a back-up

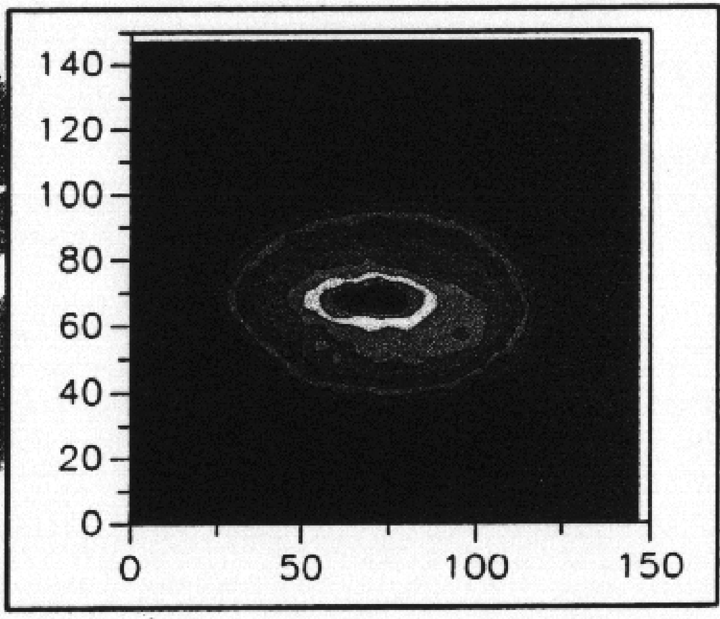
Screen Station:

Screens as seen by the camera



Profile acquisition

- The acquired images can be observed on a TV monitor and are also digitised with a frame grabber for off-line analysis
- The resolution will be 384x288 pixels and the dynamic range is covered with linear attenuators
- CCD and Tube cameras will be used depending on the local radiation level



Beam Loss Monitoring

- The beam losses will be monitored with the standard SPS 1 litre air-filled Ionisation Chambers [IC]
- 8 Chambers are foreseen along the line
- Sensitivity/resolution ~3000 charges
- Data acquisition:

12 bits

2 acquisitions for noise subtraction

scale capacitor adjusted to detect 10^9 to $4\ 10^{12}$ p

Multiplicity

- The Multiplicity is a global check of beam/target matching and will be checked with the help of Titanium SEM foils located in front (TBIU) and behind (TBID) the Target.
- SEM efficiency: 3.5 to 2.8% depending on "ageing" i.e. integral of charge seen, multiplicity ~ 20, makes ageing different, but ageing of Titanium (0.3%) much smaller than Aluminium (50%)
- Acquisition : 12 bits, 2 acquisitions for noise subtraction
- Precision: 5% relative