PS/HP/Note 97-18
AD Note 6

13/6/97

Minutes of APAL meeting no.5 **Topic : AD instrumentation**

Minutes by T.Eriksson

Present : J.Bosser, M.Brouet, C.Carter, V.Chohan, T.Eriksson, G.Gelato, M.Giovannozzi, J.-Y. Hemery, H.Koziol, M.LeGras, R.Maccaferri, O.Marqversen, S.Maury, G.Molinari, H.Mulder, D.Mohl, F.Pedersen, U.Raich, E.Roux, C.Serre, L.Soby, G.Tranquille, D.Williams,

The goal of the meeting was to get an actual view of the present status of the diagnostics and monitors. Part of the needs have been defined in PS/BD/Note 96-10 by V.Chohan.

1. **Brief recall of main parameters, planning** S.Maury

- Instrumentation issues are under discussion since 1996.
- AD will start up in September -98 with tests in conjunction with the controls group followed by proton setting-up and then, in April -99, with proton/antiproton setting-up followed by pbar physics..
- Proton beam intensity will be 2E10 from PS, but only a few E9 will be decelerated.
- Pbar beam intensity will be up to 5E7.
- RF harmonic changes will be done at lower energies.
- Bunch length will be in the order of 200-500 ns at 100 MeV/c.
- Some of the initial instrumentation requirements will be : DC-transformer with beta-correction, transverse emittance measurements, beam profiles, extracted beam intensities etc.

2. **Diagnostics (Q measurement, deceleration, closed orbit...)** F.Pedersen

- Orbit measurements are important for deceleration, the orbit is distorted due to saturation asymmetry at higher energies and due to remanence asymmetry at lower energies.
- Intensities of bunched beams with a resolution down to 1E6 charges can be measured using the resistive gap pickup used in the h=1 RF-system followed by synchronous detection. Beta-correction has to be applied. The output will be connected to a scanning ADC with memory that will be accessed by the control system.
- During the AD-studies in -96, the longitudinal Schottky power was used to measure beam intensity, but this does only work with debunched beams.
- Q-measurements are critical for the AD-project and a functional FFT-based system is needed as from the start-up of the AD:
    - The low-frequency Schottky pickup, which uses the long transverse damper kickers in section 16 needs further development. **Action**: D.Williams.
    - Measurements down to 1E7 are difficult. Assuming a pickup Q of 500 , calculations are underway to determine the lowest possible beam intensity for correct measurements. **Action**: F.Pedersen.
    - Fast Q-measurements have to be done during deceleration. This is required to avoid transverse blow-up associated with intermediate flat tops, and permits to measure and correct for eddy-current effects.
    - A sampling device with variable clockrate (revolution frequency) is required.
    - Eddy current effects could also be studied with on-the-fly measurements.
    - An option would be to excite the beam, this would provide a big gain in sensitivity. But there is no kicker available. A possible scenario would be to build a new resonant pickup (a 2.2 meter straight section would be needed for this) to be able to use the damper kicker as kicker.
    - A fast FFT-based signal processing system has to be developed. It will be used both for Q measurement and longitudinal Schottky scans (debunched pbar intensity and momentum distribution). Efforts have already been put into this field by the BD-group, but we need to define responsibilities and specifications for the AD as soon as possible. **Action** : BD.

Transparencies presented at the meeting :

AD Schottky Tune Measurements

MD's 1996 and AD Requirements

By Flemming PEDERSEN

50 MHz Resonant Schottky PU

A 50 MHz Resonant Schottky PU was used during normal AAC operation and setting up

It works fine both with bunched and debunched beams of few 10^9 to few 10^{10} at 3.5 GeV/c

It was used successfully with bunched AD proton test beams of $5*10^9$ AND fixed resonance down to about 16% momentum (if no E_L blow-up); limit: betatron line width due to $\Delta f/f$

Measure and analyse at intermediate flat tops with spectrum analyser (slow)

From 16% down to 12%, debunching was required to reduce $\Delta f/f$

FFT Analysis of Bunched Beam Schottky Signals, parameters (Ex.)

p [GeV/c]	f_{rev} **) [MHz]	T_{rev} [µsec]	N_{samp}	ΔQ per bin [E-3]	N_{ave}
3.57	1.5895	0.629	2048	.5	128
0.10	0.1742	5.740	1024	1.0	64

*) Number of averages required depends on Schottky to thermal power spectral density ratios (to be determined by detailed calculations, note to be published)

**) FFT real time bandwidth requirements could be reduced by under-sampling at high revolution frequencies

Requirements for AC FFT Schottky Tune Measurements

Variable frequency tuneable low frequency Schottky PU required.

Higher Schottky harmonic required for larger sensitivity (n ~ 2.5 to 10.5)

Fast FFT processing with adequate frequency resolution and averaging required to permit fast measurements at low momentum (due to vacuum limits)

Revolution frequency normalisation (by f_{rev} sampling) required to permit averaging while decelerating (speed) and to identify and correct magnet eddy current effects on tune present at high *dB/dt*.

For reasonable PU closed orbits and electrical asymmetries, the ADC dynamic range requirements is in the order of 60 - 70 dB => 1.6 MHz (0.8 MHz with /2 under-sampling) and 14 bit ADC (~84 dB) is required.

800 kHz Low Frequency Schottky PU's

Resonant Schottky PU's at lower frequency required to cope with larger $\Delta f/f$ at low momentum

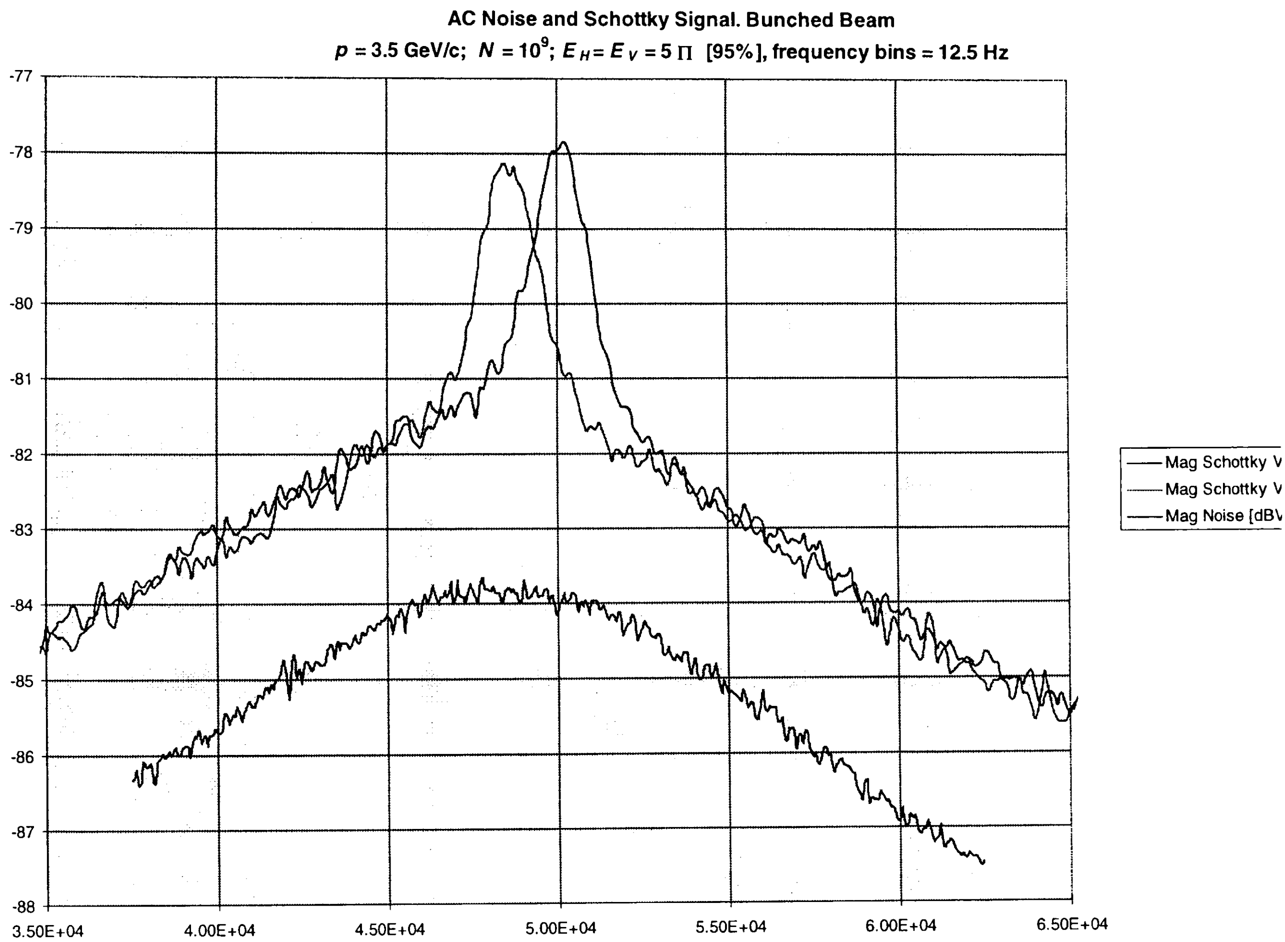
Existing PU's primarily designed to measure injection oscillations of injected muons (dominating charge before filamentation)

Tests done at 3.5 GeV/c using h = 0.5, down-mixing to 50 kHz, analysis with fast FFT, sensitivity is marginal

Pick-up modified for low noise figure in both planes, tuning range extended to 300 kHz to 900 kHz in two ranges

No lower frequency Schottky measurements done in December 96 due to high failure rate of AAC

LF Resonant PU Schottky Spectrum



Low Frequency PU Requirements

Goal: measure bunched beam Schottky tunes by FFT.

Minimise dynamic range (low int.), maximise S/N ratio (high int.)

For an electrostatic PU with short particle transit time:

- ✓ The Schottky current power per line per particle is proportional to frequency squared and PU length squared
- ✓ The betatron line width is proportional frequency
- ✓ => The Schottky current power spectral density [A^2/Hz] is proportional to frequency and intensity and emittance
- ✓ For a resonant PU in .5 to 10 MHz range, transistors exist with negligible noise contribution => source circuit thermal noise dominates
- ✓ Thermal noise current power spectral density [A^2/Hz] is proportional to $1/R_{sh} = \omega C/Q$, so proportional to frequency for fixed Q and C
- ✓ For fixed Q & C the S/N ratio is independent of frequency => Choose frequency to maximise Q (~500 can be obtained in the 1 - 5 MHz range)
- ✓ It helps to have a longer PU. Economy suggest to try to use existing transverse damper kickers [1 m long] in resonant mode.

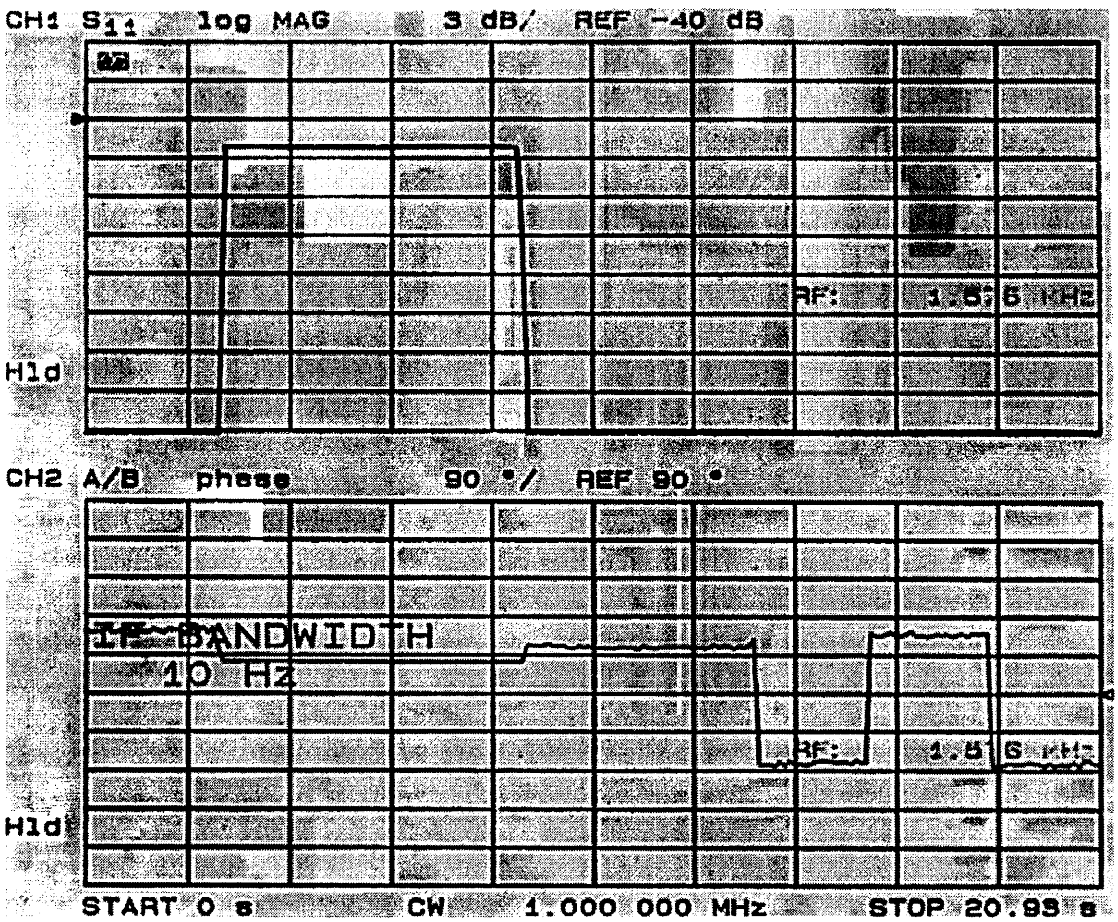
Low Frequency PU Requirements

- ✓ Based on and idea by Dr. Ian Green, UK (source Fritz Caspers), we can de-Q the apparent Q-value to the needed bandwith without deteriorating the S/N ratio (until frequencies where amplifier voltage noise becomes significant)
- ✓ Some further development of the existing resonant PU head amplifiers is required to make it useable for bunched beam Schottky measurements (action L. Søby, D. Williams).

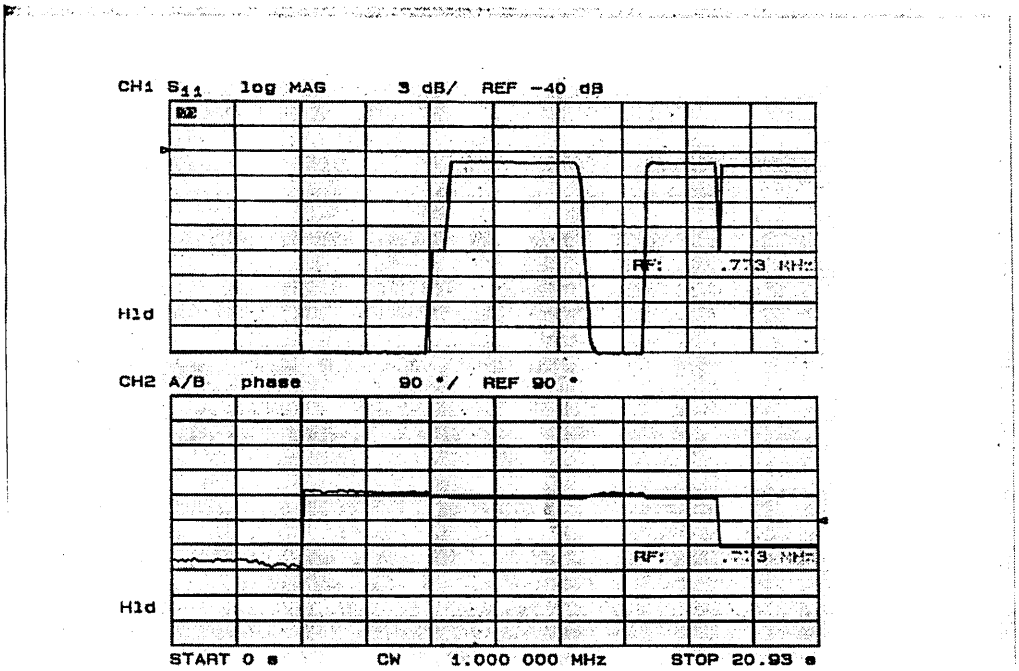
3. **Position pickups** D.Williams

- The system will use an HP network analyzer to do a delta/sigma of the pickup signals.
- A test module has been constructed to simulate pickup signals and noise:
  - Existing head amplifiers followed by 100* booster amplifiers were used.
  - Measurements using 10Hz IF filter done with signals corresponding to a 5E6 beam. Response time measurements need more detailed evaluation.
  - A scan of 60 pu positions takes approx. 2 seconds.
- Beam intensity range has to be defined. At present a range of 100 is possible ,but since the nominal pbar intensity is 1E7 (min) and the usual p test beam intensity is 2E10, a switching system could be considered.
- The 2 pickups inside the electron cooler can be considered part of the pickup system , or treated apart. A decision is to be taken when the ecooler is better defined.
- Subsequent measurements indicate that the head amplifiers have to be replaced or improved.

Preliminary test results :
(Magnitude trace corresponds to beam position and also indicates response time, phase trace corresponds to whether the beam is at left or right side)

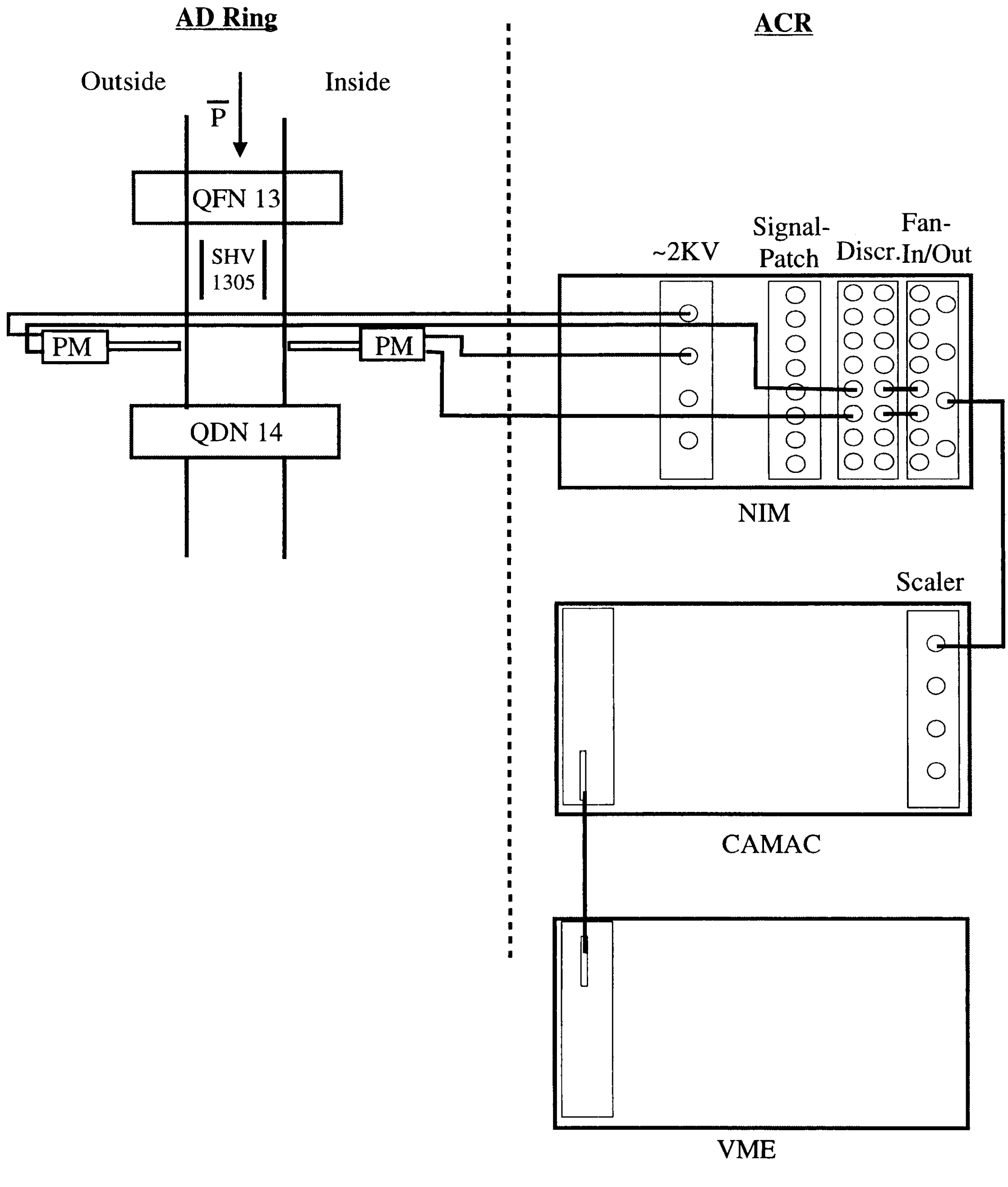


Test results with 100 Hz IF bandwidth:



4. **Beam profile with scrapers** L.Soby

- The existing AC-system will be kept as is. (Beam scraped step by step in section 13, electrons detected with scintillators outside the vacuum chamber and beam profile plotted)
- System has been used down to 2 GeV/c during the md-sessions. Lower beam energies have to be checked.
- The existing Camac-based scaler can be replaced by a VME module to simplify integration into the new control system.
- The old electron coherent oscillation detector has not been used since the installation of the resonant pickup and can be taken out of the machine.



Schematics of AC beam profile measurement system.

5. **Intensity measurements** G.Gelato

Measuring AD beam intensity.

<u>Circulating beam:</u>

N = $5 \cdot 10^7$ antiprotons.

Momentum	Current
100 MeV/c	1.4 μA
200 MeV/c	2.75 μA
3.5 GeV/c	12.7 μA

Currently available resolution ~ 2 μA , possibly improvable to 1 μA.

To obtain a 1% resolution, one has to work with at least $5 \cdot 10^8$ proton charges at 3.5 GeV/c.

The best strategy appears to be using a proton beam of 10^9 protons or more at high momentum to calibrate a Schottky noise monitor, then use the monitor to measure beams of low intensity.

Measuring AD beam intensity.

<u>Ejected beam:</u>

N = Between 10^7 and $5 \cdot 10^7$ antiprotons in about 200 ns.

Currently available resolution ~ $6 \cdot 10^6$ charges, possibly improvable to $2 \cdot 10^6$.

This resolution is no better than 20% in the N = 10^7 case.

Questions:

a) Is such a resolution of any use?

b) What do we know about the noise environment in the ejection area?

Measuring AD beam intensity.

<u>After the RF quadrupole:</u>

N ~ $2 \cdot 10^6$ antiprotons.

Pulse repetition rate about 1 pulse every 15 minutes (order of magnitude).

With proven techniques, the resolution would be so low that optimising the transmission of the beam through the quadrupole would be next to impossible.

Novel techniques have been suggested by W. Pirkl, who intends to explore them.

They require a rather time consuming development and the results cannot be guaranteed.

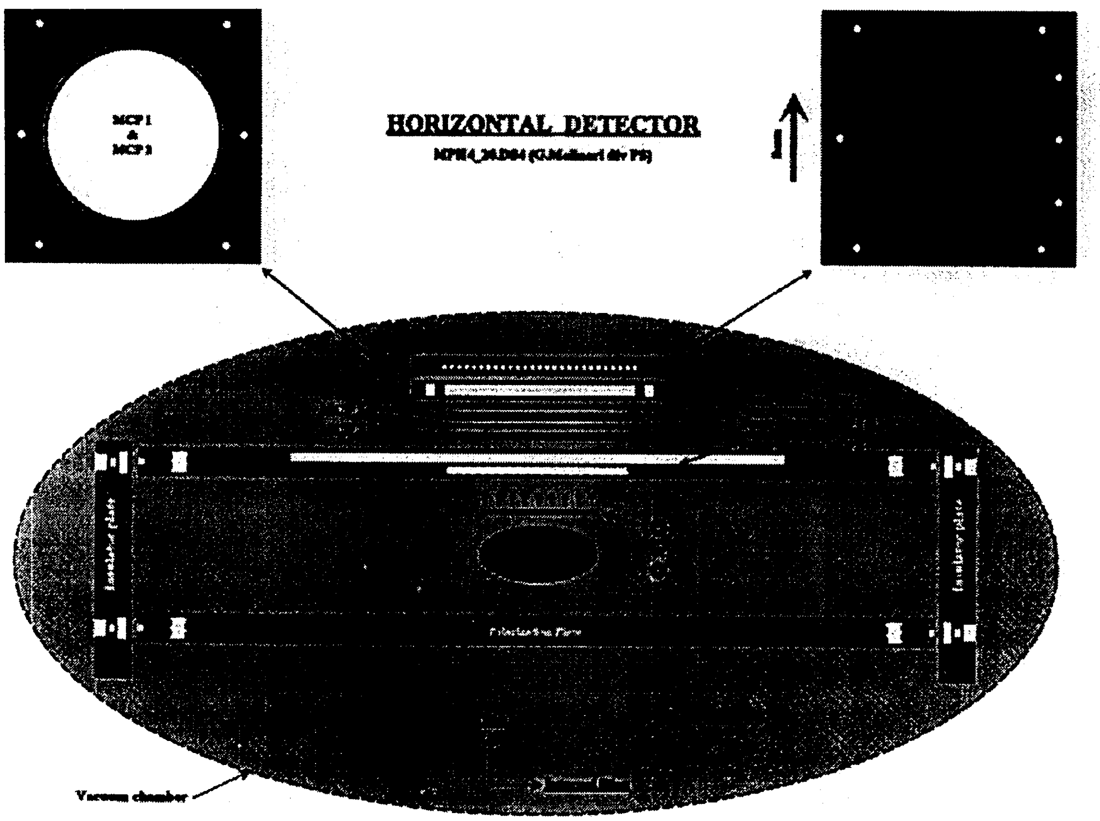
The noise environment is not well known, but high disturbing RF fields are likely to be present.

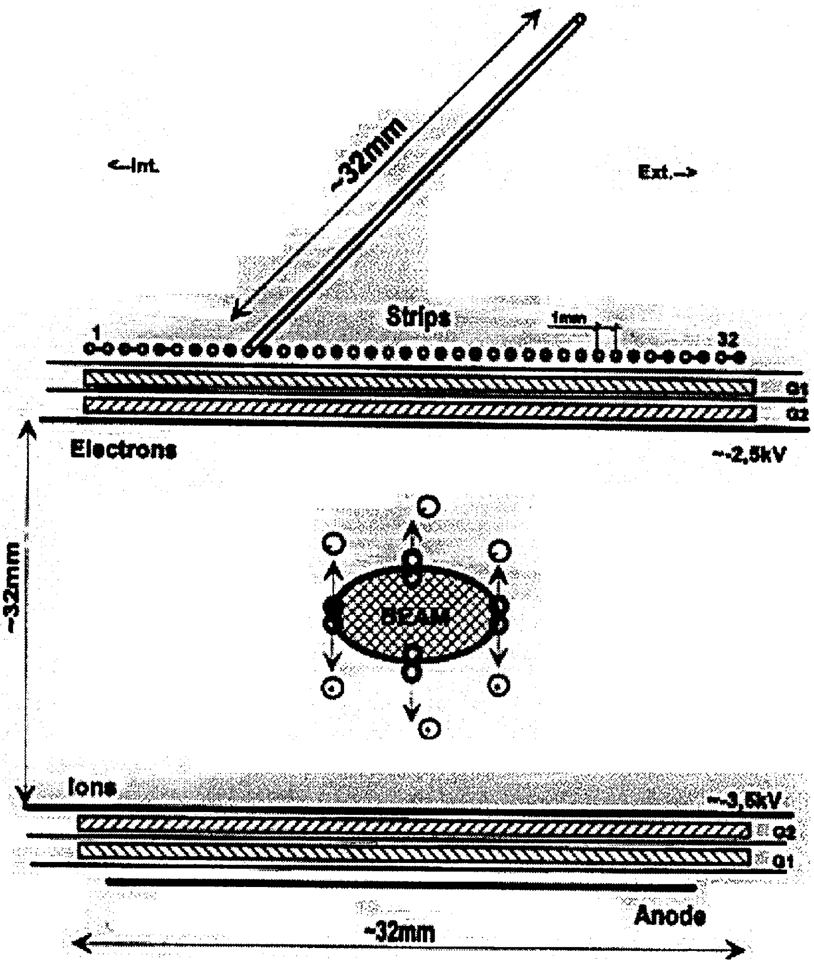
Comments :

- Normal ejected beam intensity is 0.5 - 1E7 pbars, in stacking mode up to 1E8
- After RFQ decelerator: N=<2E6 pbars at low energy (100keV) mixed with 1E7 at higher energy.
- Highest possible resolution (2E6) is necessary in lab conditions (ej. trafos)
- RF signal can also be used for intensity measurements. (see point 2)
- MWPC:s could possibly be used for intensity measurements, but with a limited resolution. (J.Y. Hemery)

6. **Ionisation profile monitors** G.Molinari

- System have been used in LEAR for real-time monitoring of the ecooling process.
- Propose to use same type in AD. 1 ms update interval possible.
- Non-destructive measurement useful at variable beam energies although not tested at high energy.
- The LEAR monitor has a 32 by 32 mm aperture, this can be increased.
- Vacuum issues with new elements inside the tube have to be considered.
- Placement in AD to be defined. A zero dispersion region is preferable to allow for emittance measurements.
- Use in transfer lines is not possible.

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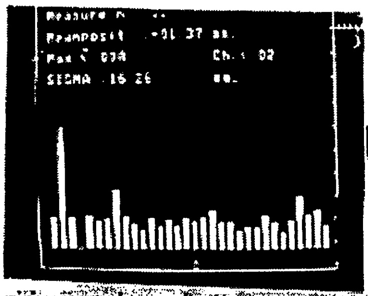

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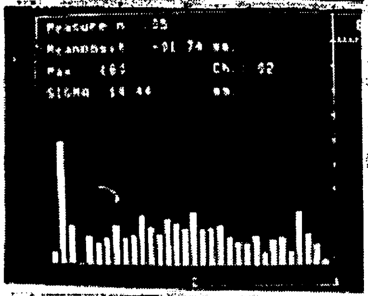

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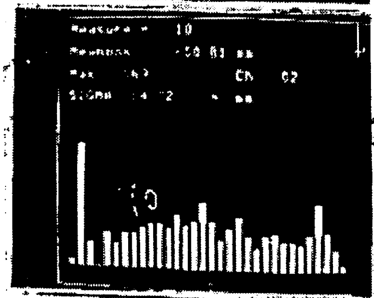

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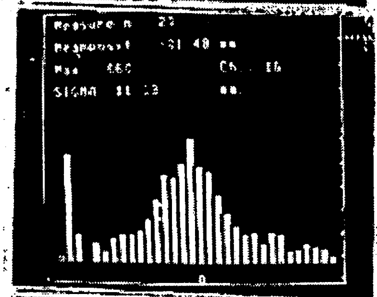

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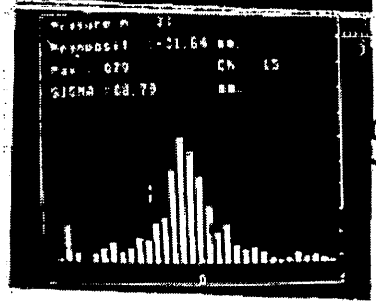

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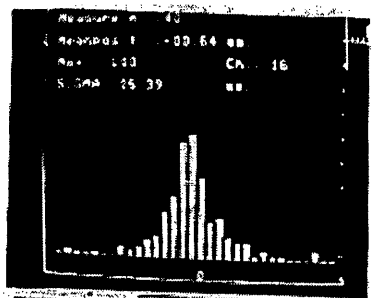

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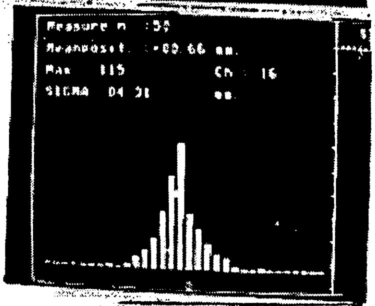

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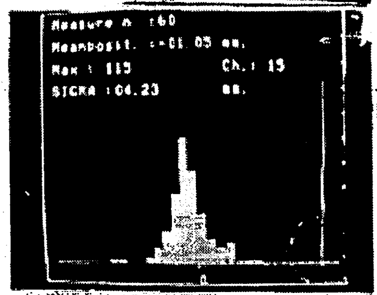

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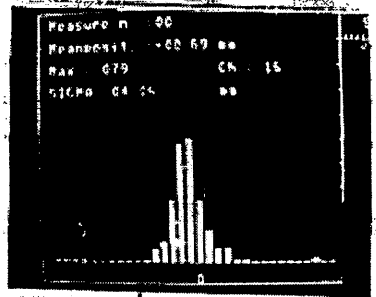
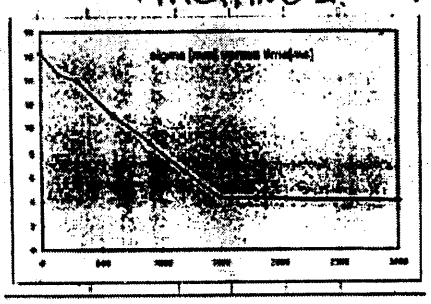


3000

MACHINE 1. 47mA=Ie



7. **Pickup mechanics** R.Maccaferri

This subject will be discussed at the stochastic cooling meetings.

8. **Future meetings** J.Bosser

For the moment, there seems to be no need for a "mini-workshop" on instrumentation. Subsequent APAL meetings on instrumentation will be organised, the next one on extraction and transfer line instrumentation and FFT-based Q-measurements.

Other points :

- Vacuum aspects (M.Brouet) :
  - All new installations have to be vacuum and bakeout compatible.
  - All unused equipment should be taken out of the vacuum chamber.
  - The vacuum group has to approve all modifications.
  - Equipment should withstand at least 150 deg. bakeout.
  - A scheme with all new sublimation pump locations indicated will be distributed shortly. **Action** : M.Brouet.

- Points not covered in this meeting:
  - Transfer line monitors (MWPC).
  - MTV:s
  - Old PSB loss monitors (injection monitoring); are they still in ? The cables are still there.......These monitors are no longer required. **Action** : R.Maccaferri
  - Low frequency digitizers (injection monitoring); to be kept, but this point is not urgent.