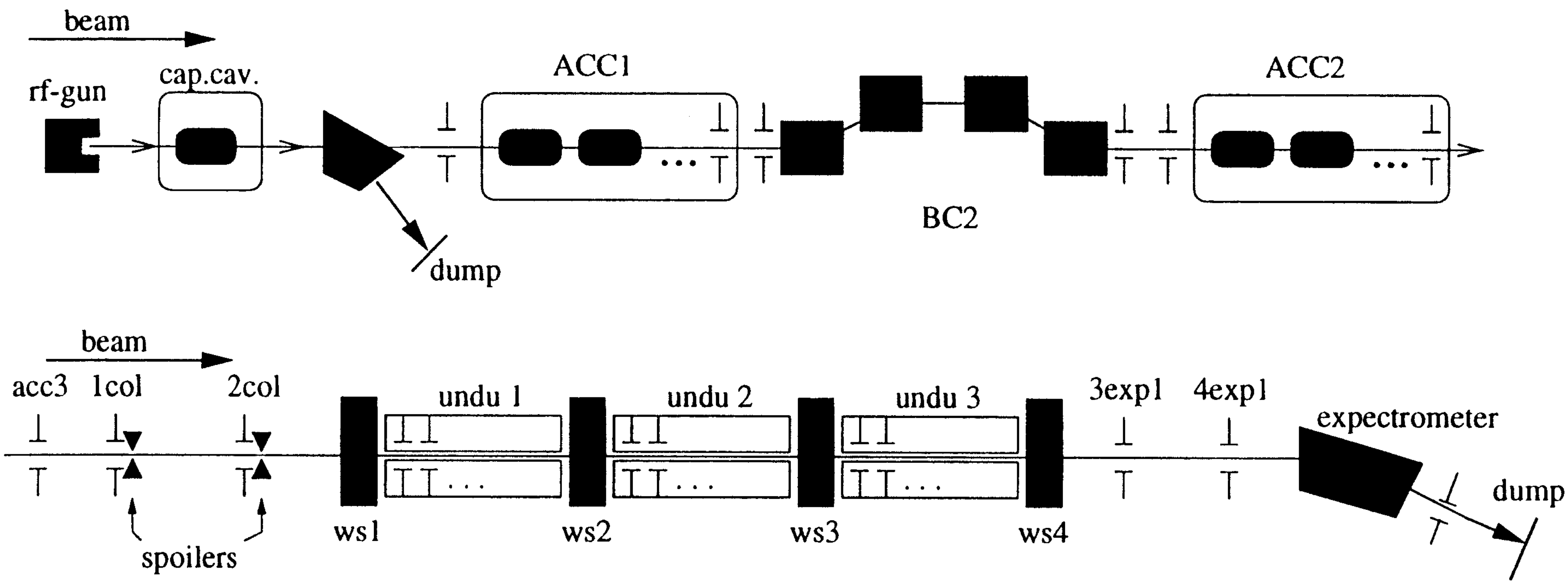
Overview of TTF operation Aug.-Sept.

Main goal: **SASE-FEL proof of principle**

The program was:

1. Injector preparation, stability, measurements
2. Comissioning of new module for ACC1
3. Comissioning of collimator system (as protection for the undulator) + beam loss monitors (photmultipliers)
4. Comissioning of new diagnostics:
   - Wirescanners
   - Stripline BPMs: *new electronics*
     Balakin BPMs: *fully new*
     Reentrant BPMs: *new place, one new electronics*
     Cavity BPMs: *partially new electronics*
     Undulator BPMs: *provisional electronics*
   - Toroids: new electronics for 1 MHz
   - Hasylab instrumentation



THO 6 SOLAR03, NOV06/21:22

"Boundary" conditions for TTF operation

1. Energy gain: ~14 MeV/m, limited by couplers
   cavity #3 of module 1 detuned
   → maximum beam energy 230 MeV

2. Fast protection system not installed yet
   → train with maximum 10 bunches

3. RF gun flat top of 100 μs, to get stable gradient
   → 100 μs of dark current

... and some precautions

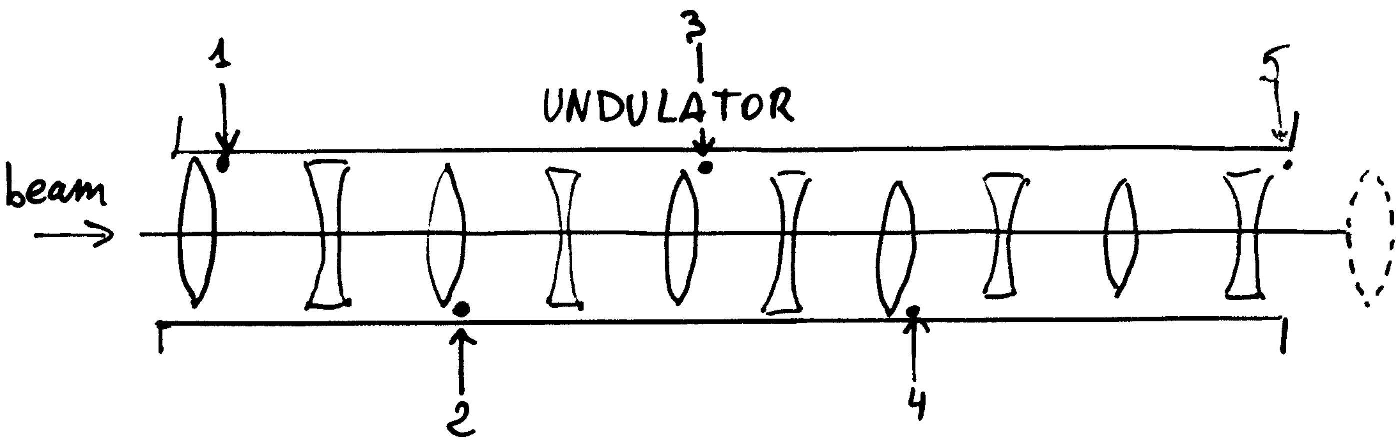
1. **Radiation** of undulator magnet
   (if accumul. dosis 0.5 MGy ⇒ 10% field degradation)
   → careful steerering through collimator
   → minimize beam loss in photomultipliers

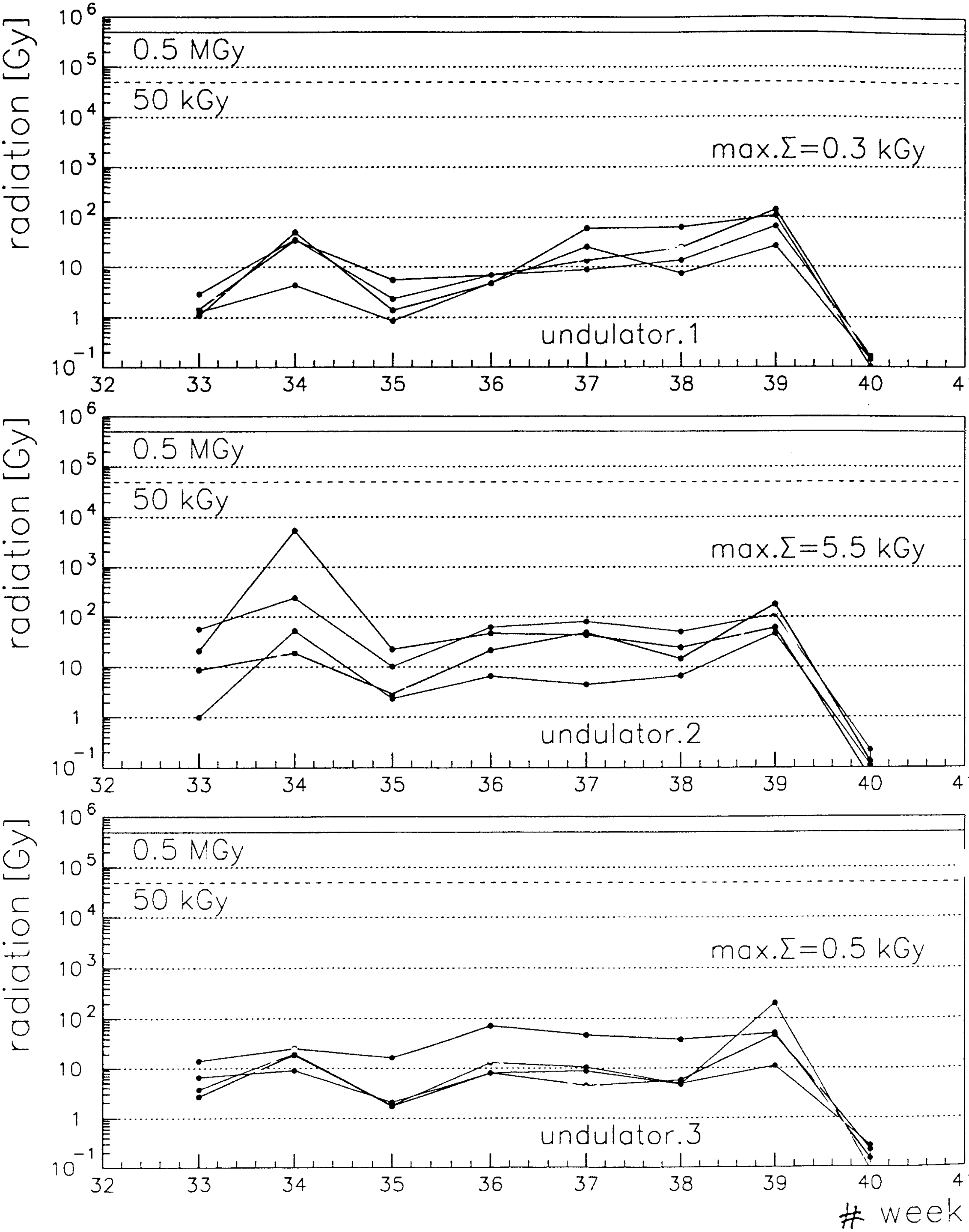
2. **Leak** of He at 2 K to isolating vacuum in ACC1
   → careful operation of RF power

Main problems in operation

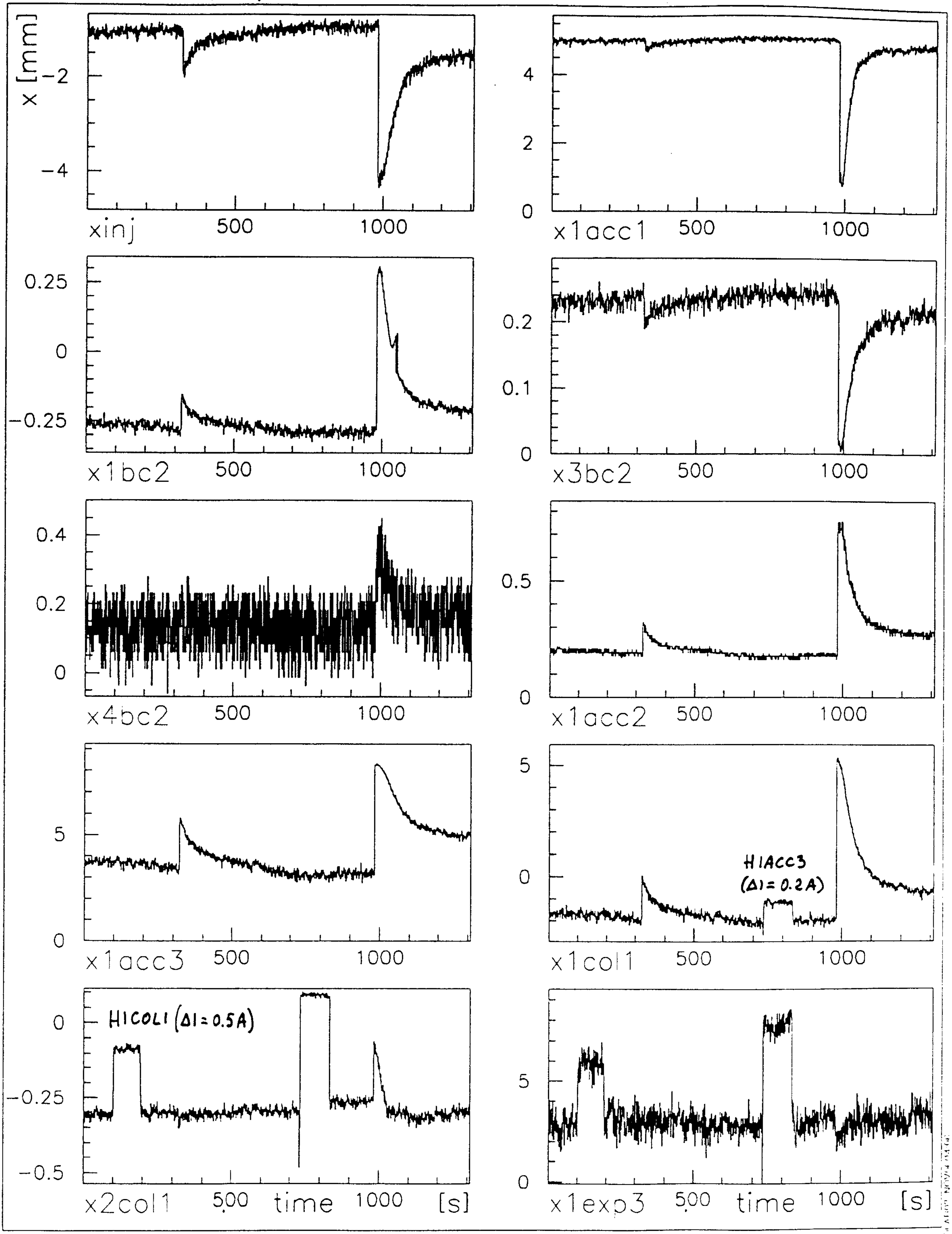
- Several days lost (previous to the FEL Conference) due to problems in the cryogenic compressor system
- Large **radiation** measured at undulator in week 34: 5 kGy
  normal dosis $\leq$ 0.1 kGy (5 kGy $\sim$ 1% of total allowed)
  cause: enough care with beam loss signals taken?
- **Dark current** of 1.2 mA at gun over 100 μs
  $\sim$ same energy as the beam
  cause: vacuum in the gun
  problem: produces large radiation to undulator, large background at screens
  $\rightarrow$ Action: cathode changed, vacuum improved
  now: 0.16 mA
- Large x orbit **jumps** (with BC II on) every 20-40 min.
  also happened when RF gun is switched off and on
  cause: possibly due to changes in the RF gun regulation
  problem: jumps perturb operation and measurements

Dosimeters location

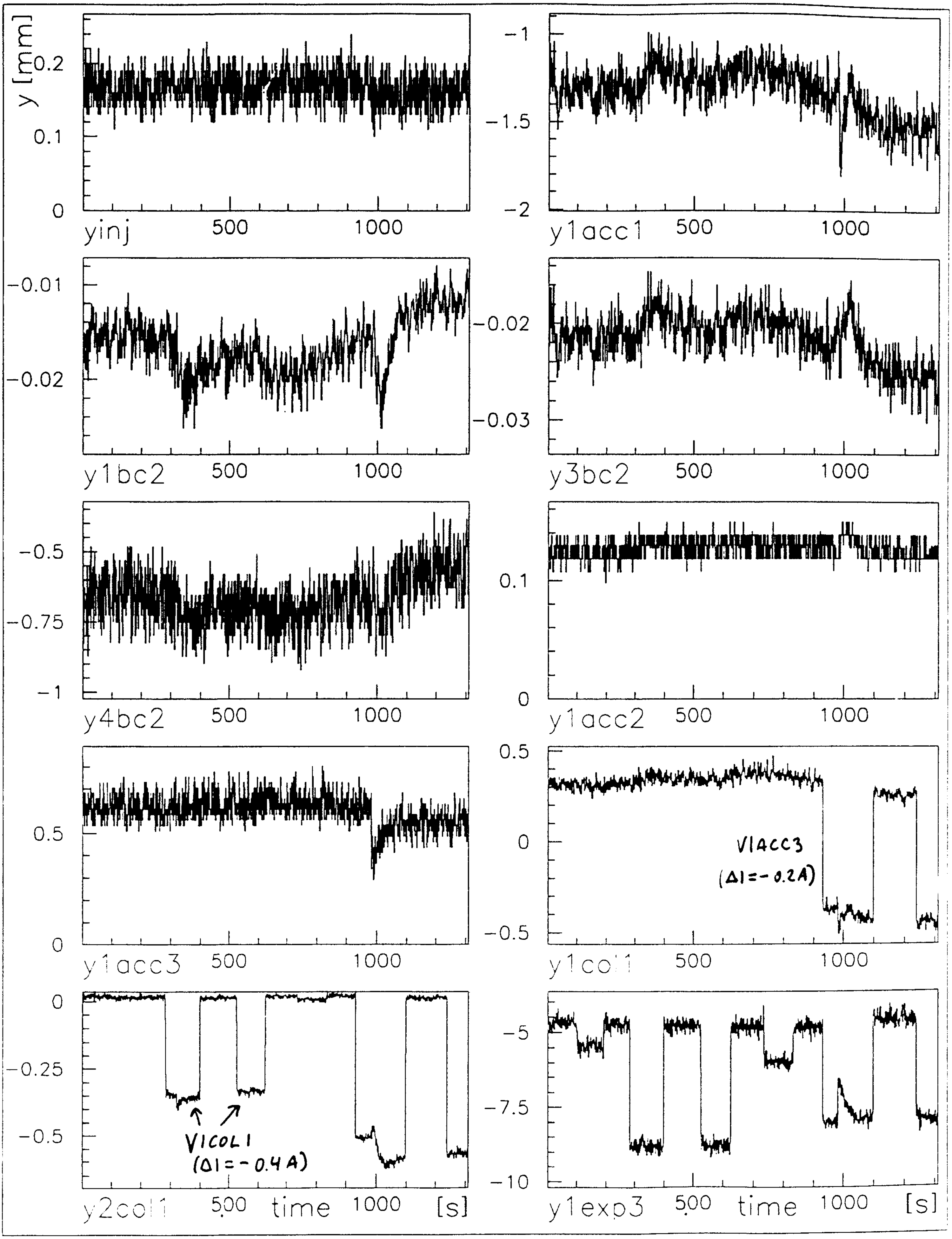


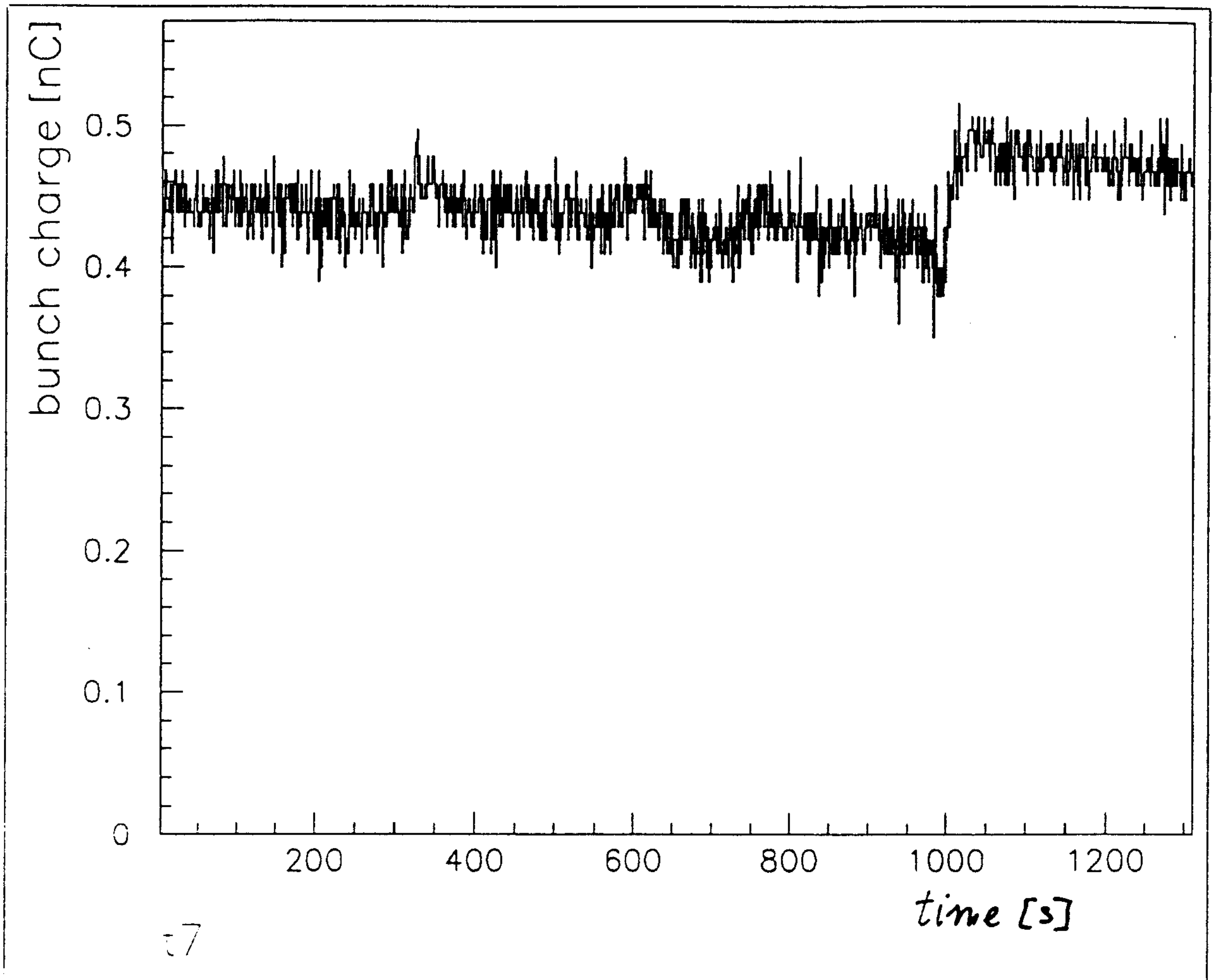

radiation [Gy]
0.5 MGy
50 kGy
max.Σ=0.3 kGy
undulator.1
radiation [Gy]
0.5 MGy
50 kGy
max.Σ=5.5 kGy
undulator.2
radiation [Gy]
0.5 MGy
50 kGy
max.Σ=0.5 kGy
undulator.3
week

BPM horizontal meas.



BPM vertical meas.





bunch charge [nC]
0.5
0.4
0.3
0.2
0.1
0
200
400
600
800
1000
1200
time [s]
t7

Main achievements

- **Start up** linac with 1 nC dumped in/before collimator
  no radiation damage in the undulator
- Stable and reproducible magnet settings (quads+steerers)
- Operation test with **8 nC** and 10 bunches:
  8 nC (gun) $\rightarrow$ 4 nC (collimator) $\rightarrow$ 4 nC (dump)
  relative rf-phase adjustment for compression and maximum energy
  no extra radiation dosis to the undulator observed
- Operation with bunch compressor **BC II**:
  bunch compressed to $\sigma_z = (0.5 - 0.6) \pm 0.1$ mm
  (preliminary results from L. Catani et al./INFN)
- **Beam measurements** (next)

Beam measurements

Beam loss monitors reported by G. Schmidt

Beam emittance reported by G. Schmidt
with wirescanners and quadrupole tomography

Bunch length with BC II (L. Catani et al./INFN)
using interferometry of diffraction radiation

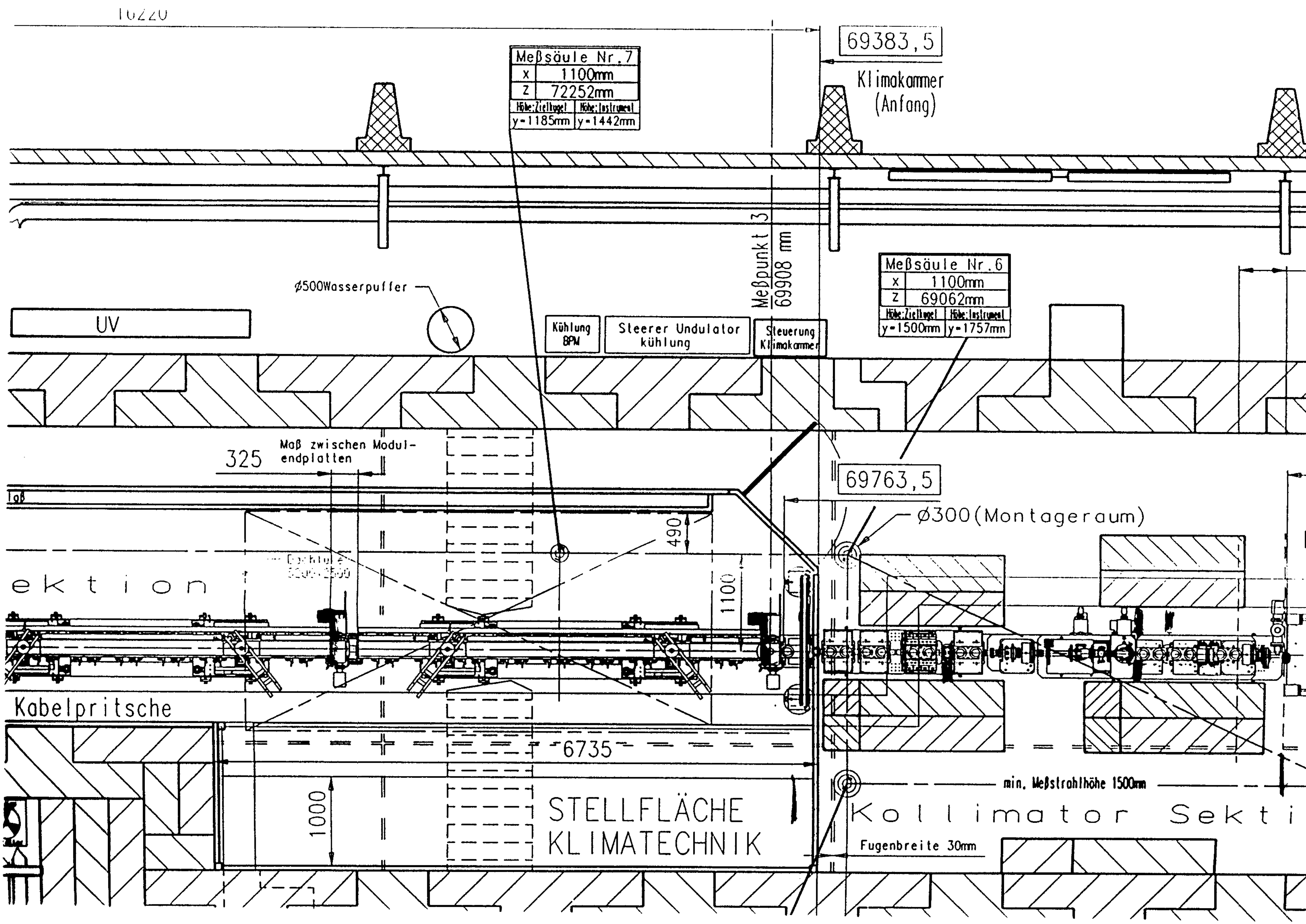
Spectrum meas. of undulator radiation (Hasylab)
Large background (gammas) at Hasylab detectors
cause: gammas from dump and from dispersive area
problem: no spectrum signal, damage of camera
→ Action: heavy shielding placed, quadrupole in dispersive area set to 12 A (when needed)
further test needed in next run

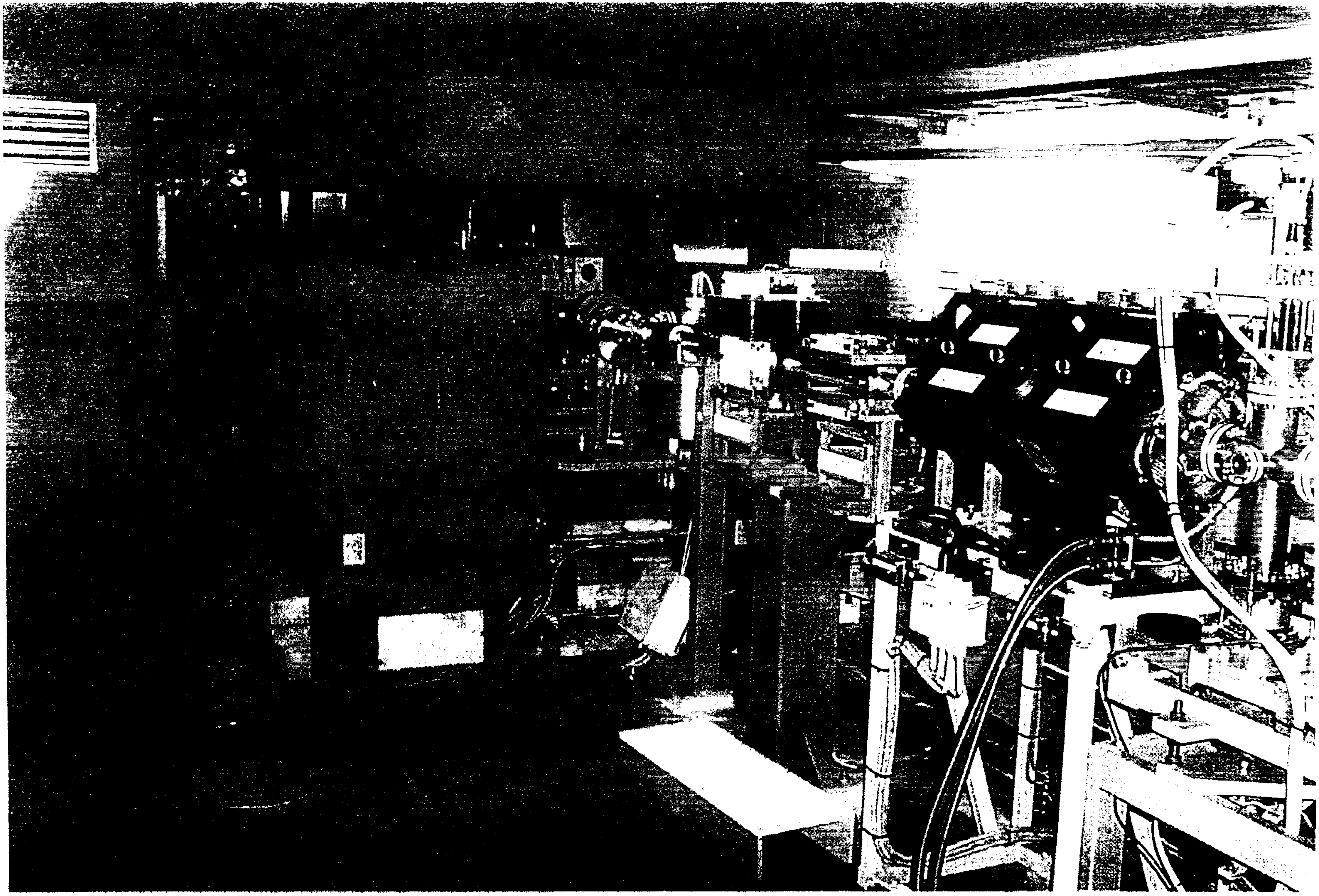
Beam position meas. in undulator
with wirescanners and antenna BPMs in undu. 1 & 2

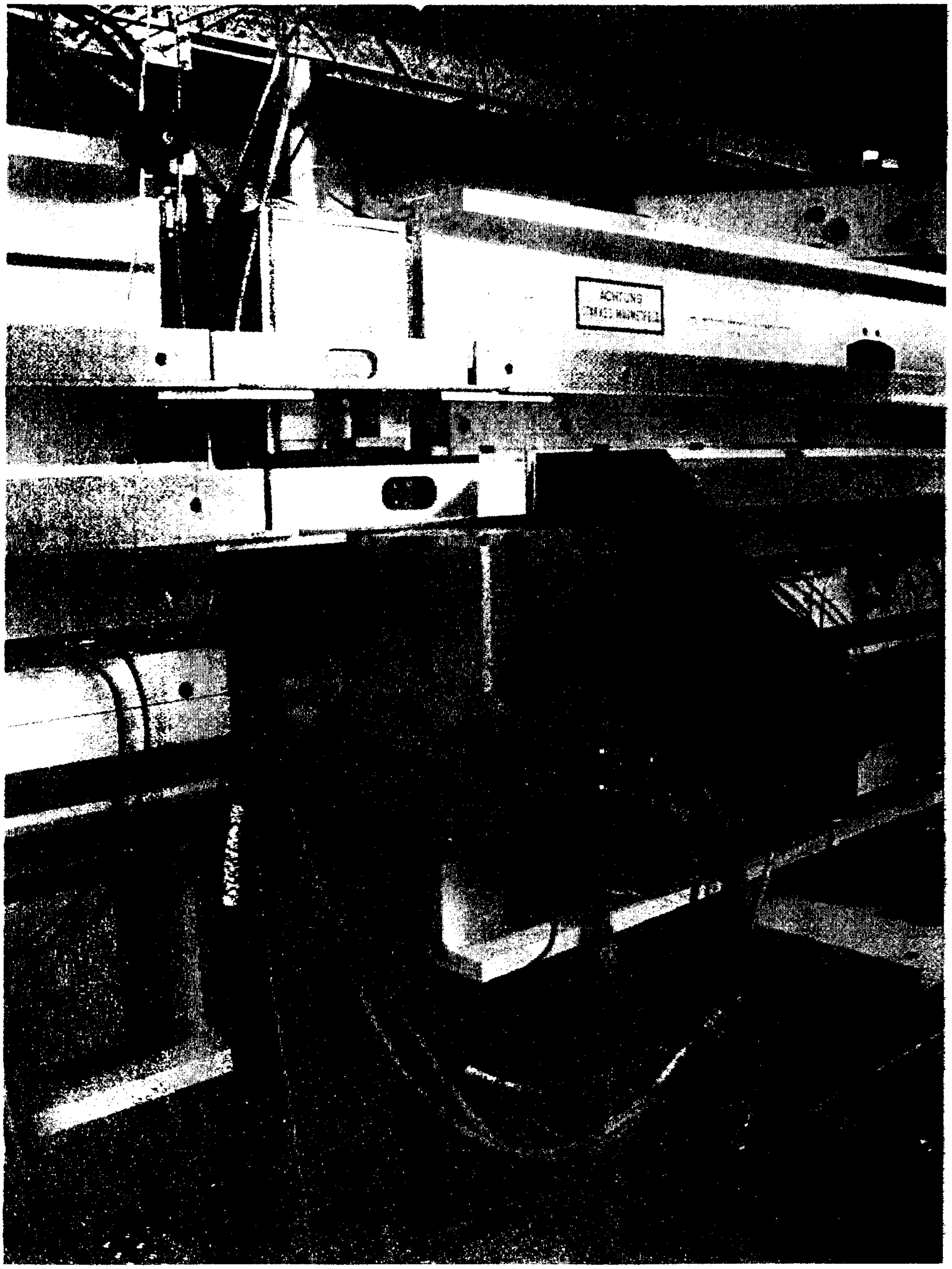
Beam dispersion at the undulator

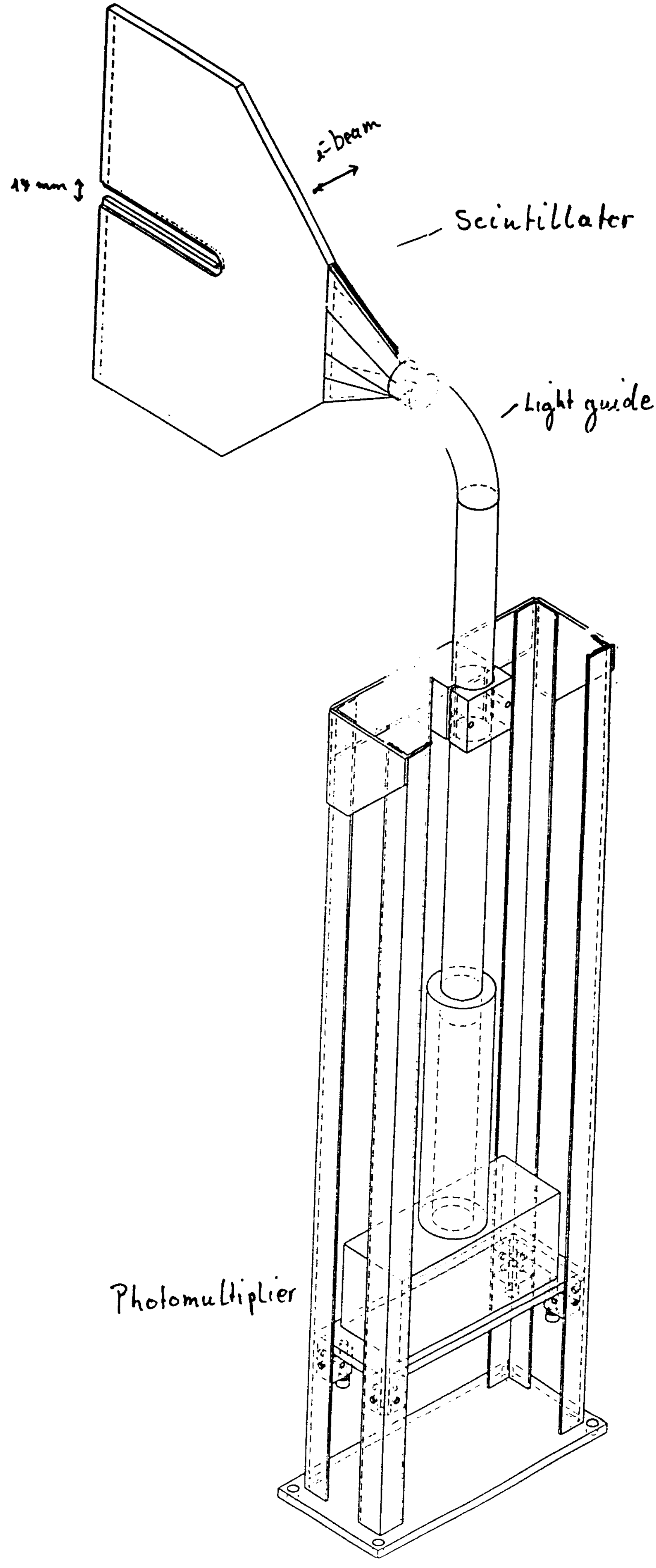
- ΔE by decreasing klystron voltage of ACC1 and ACC2
- ΔE by detuning cavity 8 of module ACC2

(data under analysis)

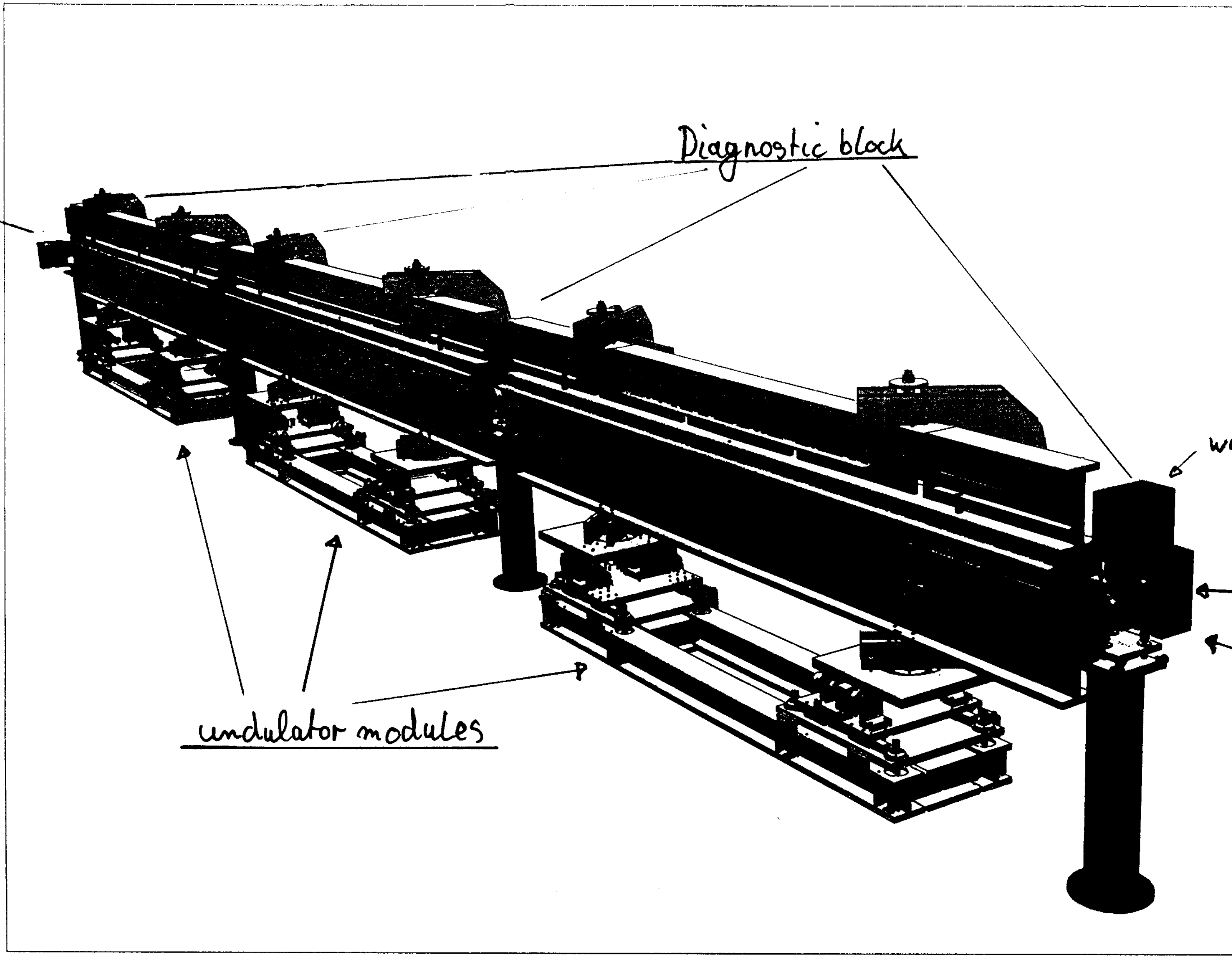

69383,5
Meßsäule Nr.7
x 1100mm
z 72252mm
Höhe:Zielkugel y=1185mm
Höhe:Instrument y=1442mm
Klimakammer
(Anfang)
Meßpunkt 3
69908 mm
Meßsäule Nr.6
x 1100mm
z 69062mm
Höhe:Zielkugel y=1500mm
Höhe:Instrument y=1757mm
ø500Wasserpuffer
UV
Kühlung
BPM
Steerer Undulator
kühlung
Steuerung
Klimakammer
325
Maß zwischen Modulendplatten
69763,5
ø300(Montageraum)
490
1100
ektion
Kabelpritsche
6735
1000
STELLFLÄCHE
KLIMATECHNIK
min. Meßstrahlhöhe 1500mm
Kollimator Sekti
Fugenbreite 30mm



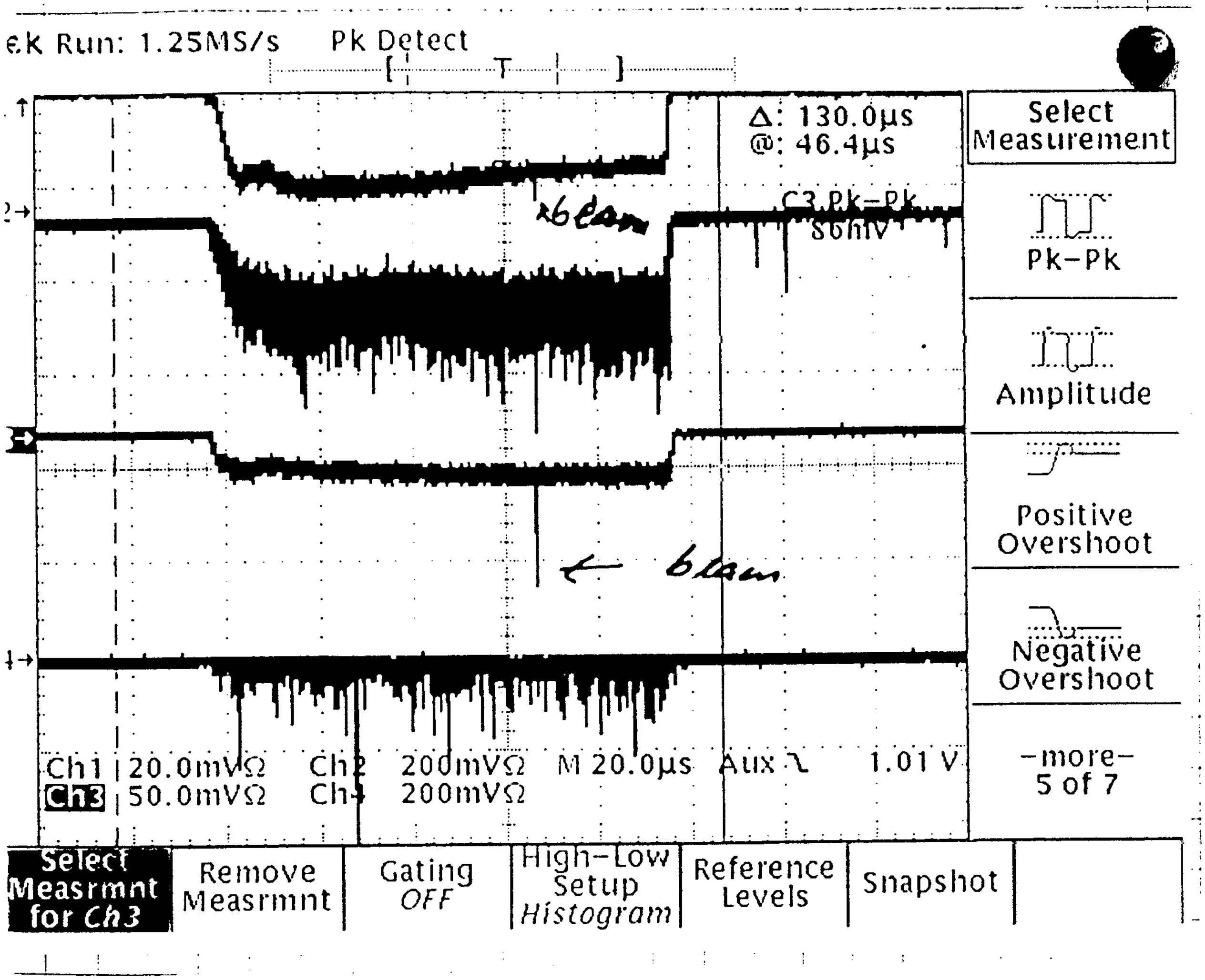

ACHTUNG

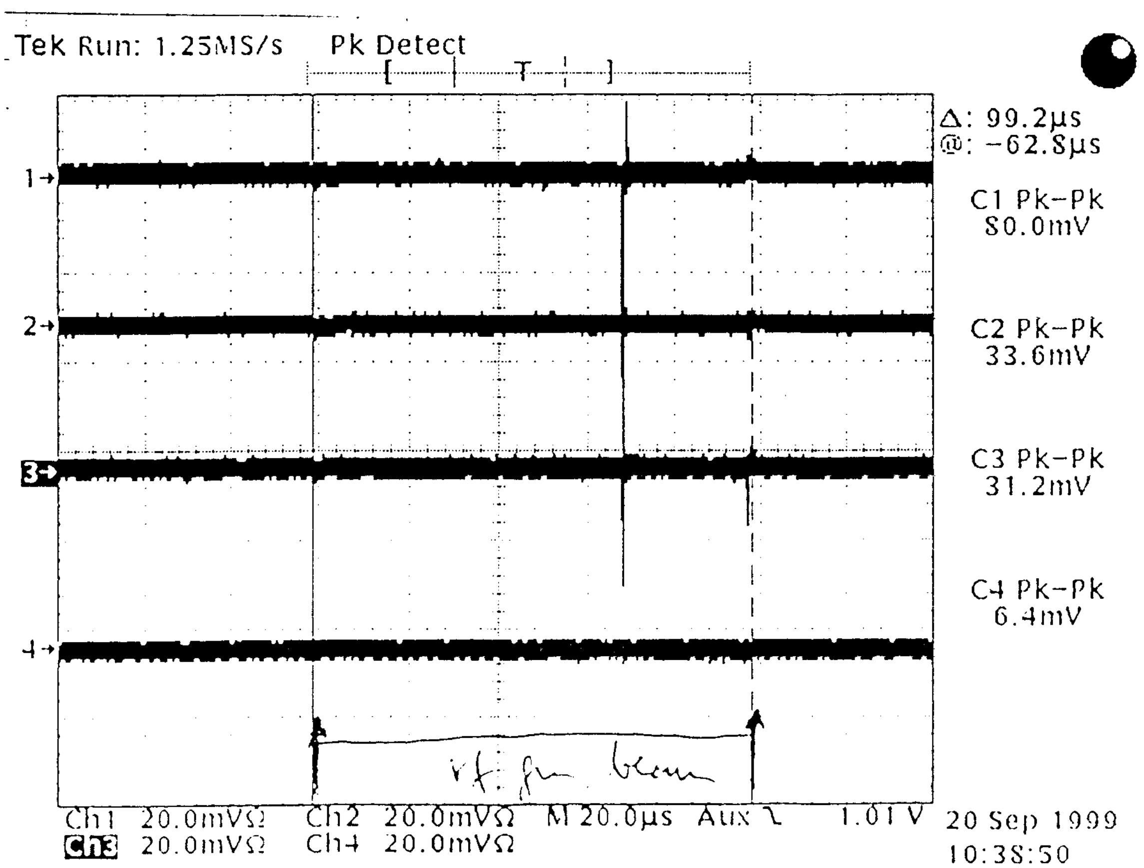

14 mm
e-beam
Scintillater
Light guide
Photomultiplier

TTF-FEL Phase 1

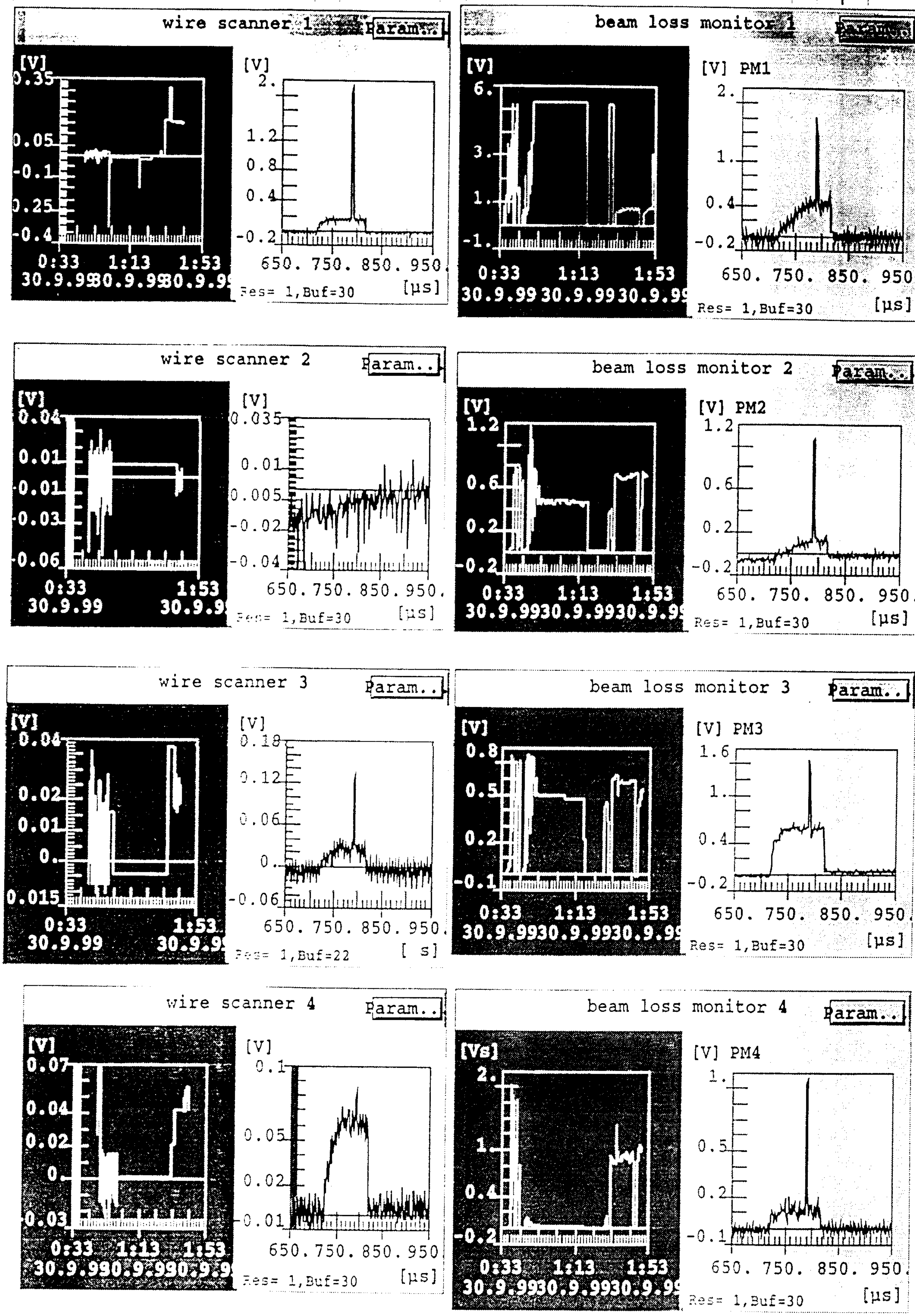


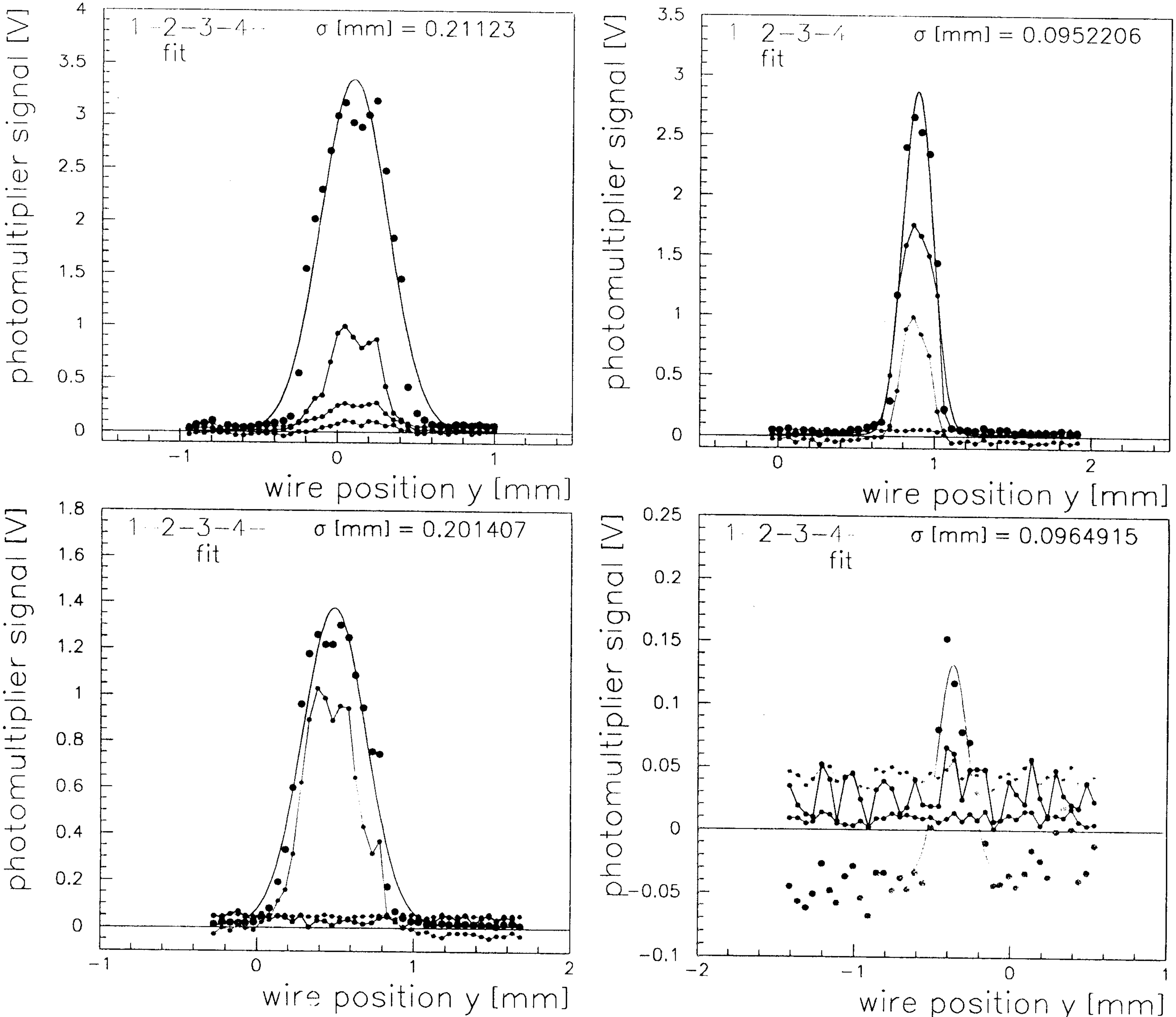
rotation of Diagnostic Block is not in !


ek Run: 1.25MS/s Pk Detect
Δ: 130.0µs
@: 46.4µs
C3 Pk-Pk
beam
← beam
Ch1 20.0mVΩ Ch2 200mVΩ M 20.0µs Aux ⌐ 1.01 V
Ch3 50.0mVΩ Ch4 200mVΩ
Select Measurement
Pk-Pk
Amplitude
Positive Overshoot
Negative Overshoot
-more- 5 of 7
Select Measrmnt for Ch3
Remove Measrmnt
Gating OFF
High-Low Setup Histogram
Reference Levels
Snapshot


Tek Run: 1.25MS/s Pk Detect
Δ: 99.2µs
@: -62.8µs
C1 Pk-Pk
80.0mV
C2 Pk-Pk
33.6mV
C3 Pk-Pk
31.2mV
C4 Pk-Pk
6.4mV
Ch1 20.0mVΩ Ch2 20.0mVΩ M 20.0µs Aux ⌐ 1.01 V
Ch3 20.0mVΩ Ch4 20.0mVΩ
20 Sep 1999
10:38:50

Signals and history for photomultiplier adjusted:





PCASTRO@SOLAR03, NOV06/23:08

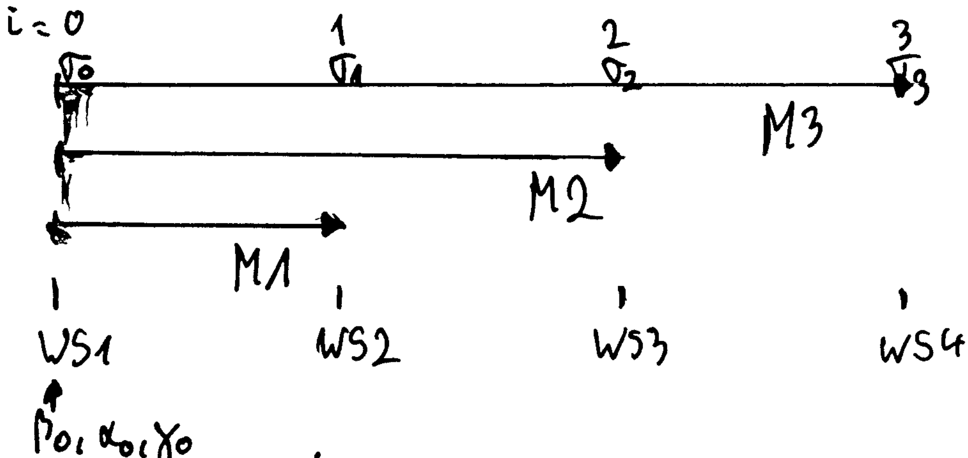
R. Schmidt, [illegible].11.99

Emittance calculation from the 4 Wire Scanner

→ 4 points of measurement

→ We need the transfermatrix

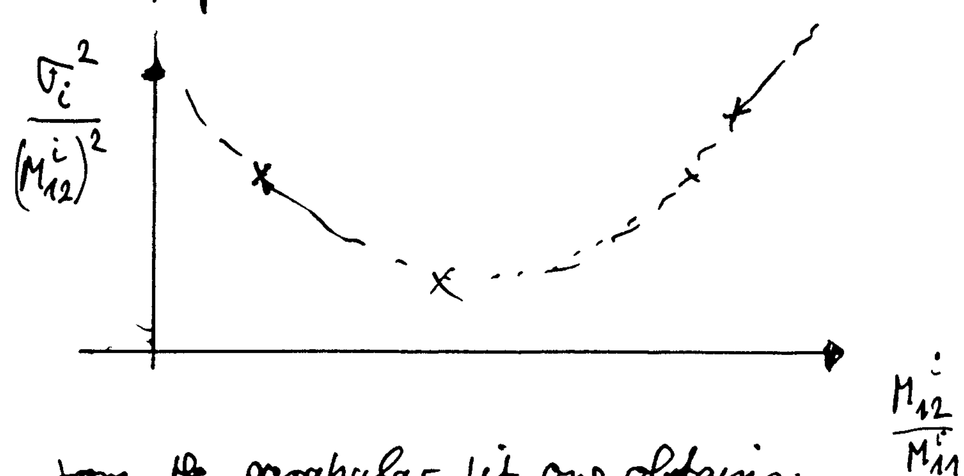
→ We have three free parameters β, β' and ε



$$\varepsilon\beta_i = M_{11}^{i}\,(\beta_0\varepsilon) - 2\,M_{12}^{i}\,M_{11}^{i}\,(\varepsilon\alpha_0) + M_{12}^{i\,2}\,(\varepsilon\gamma_0)$$

$$\frac{\varepsilon\beta_i}{M_{11}^{i\,2}} = \varepsilon\beta_0 - 2\left(\frac{M_{12}^{i}}{M_{11}^{i}}\right)(\varepsilon\alpha_0) + \left(\frac{M_{12}^{i}}{M_{11}^{i}}\right)^2(\varepsilon\gamma_0)$$

with $\sqrt{\varepsilon\beta_i} = \sigma_i$



from the parabolar fit one obtains:

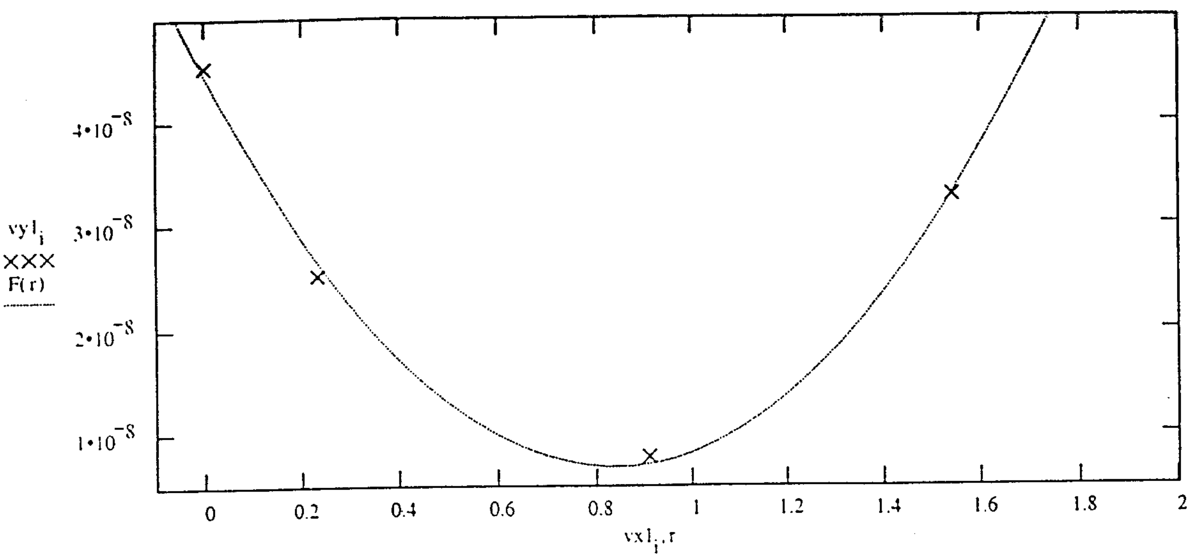
$$\boxed{\begin{array}{l}\varepsilon \\ \beta_0\,,\,\alpha_0\end{array}}$$

G. Schmidt, -MPY-, 4.11.99

Emittance Measurement with the Wire Scanners

Measure 4 beam profiles
Knowing the transfer matrix one can calculate the emittance

First preliminary results: vertical 2.10.99



$$\text{NormEmittance} := \text{Emittance} \cdot \frac{E0}{0.511} \qquad \text{NormEmittance} = 8.5884 \cdot 10^{-6}$$

Problems:

Beam Jitter from Macropuls to Macropuls
Beta-mismatch changes if focusing is changed (rf focusing etc.)
Stability of the algorithm against these effects must be investigated.

G. Schmidt, -MPY-, 4.11.99

Difference to Phase space tomography

PST takes the average of several consecutive bunches inside the macropuls.
Limitations by optical system.

WS are taking average of several macropulses but always the same bucket inside the macropuls.
Maybe problems with lineartiy of photo multiplier

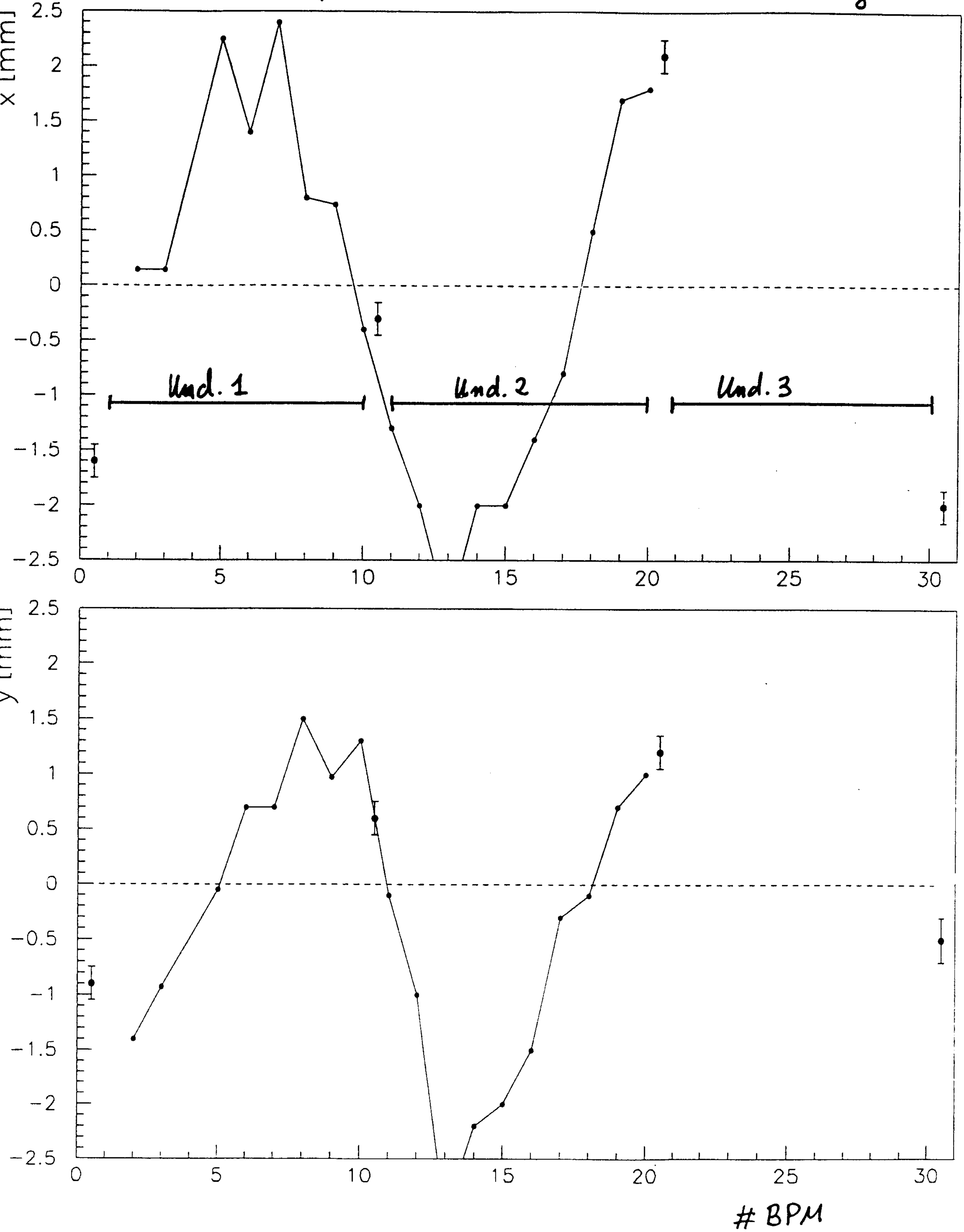
Results during this run

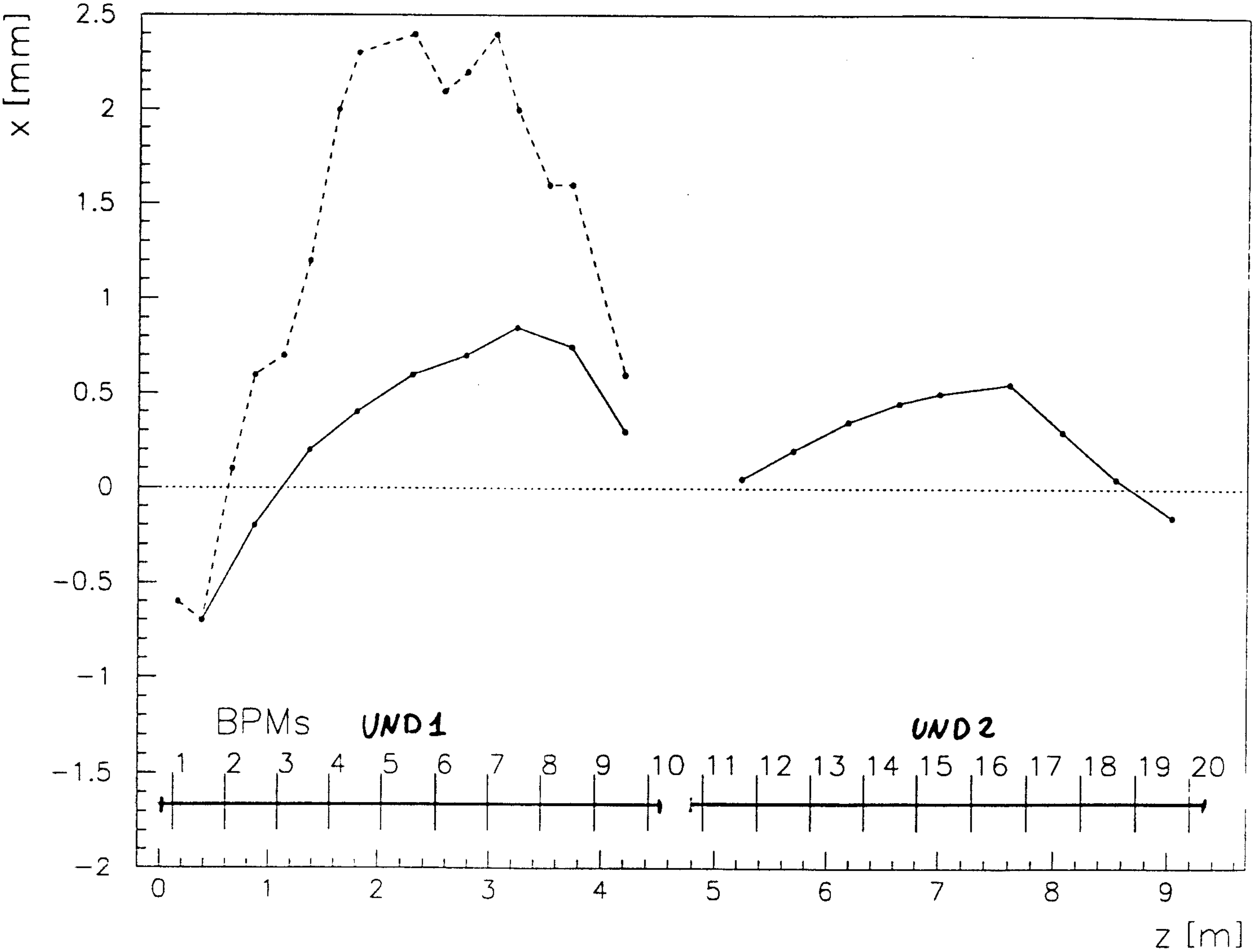
PST in BC2: **$\varepsilon \approx$ 50 mm mrad**

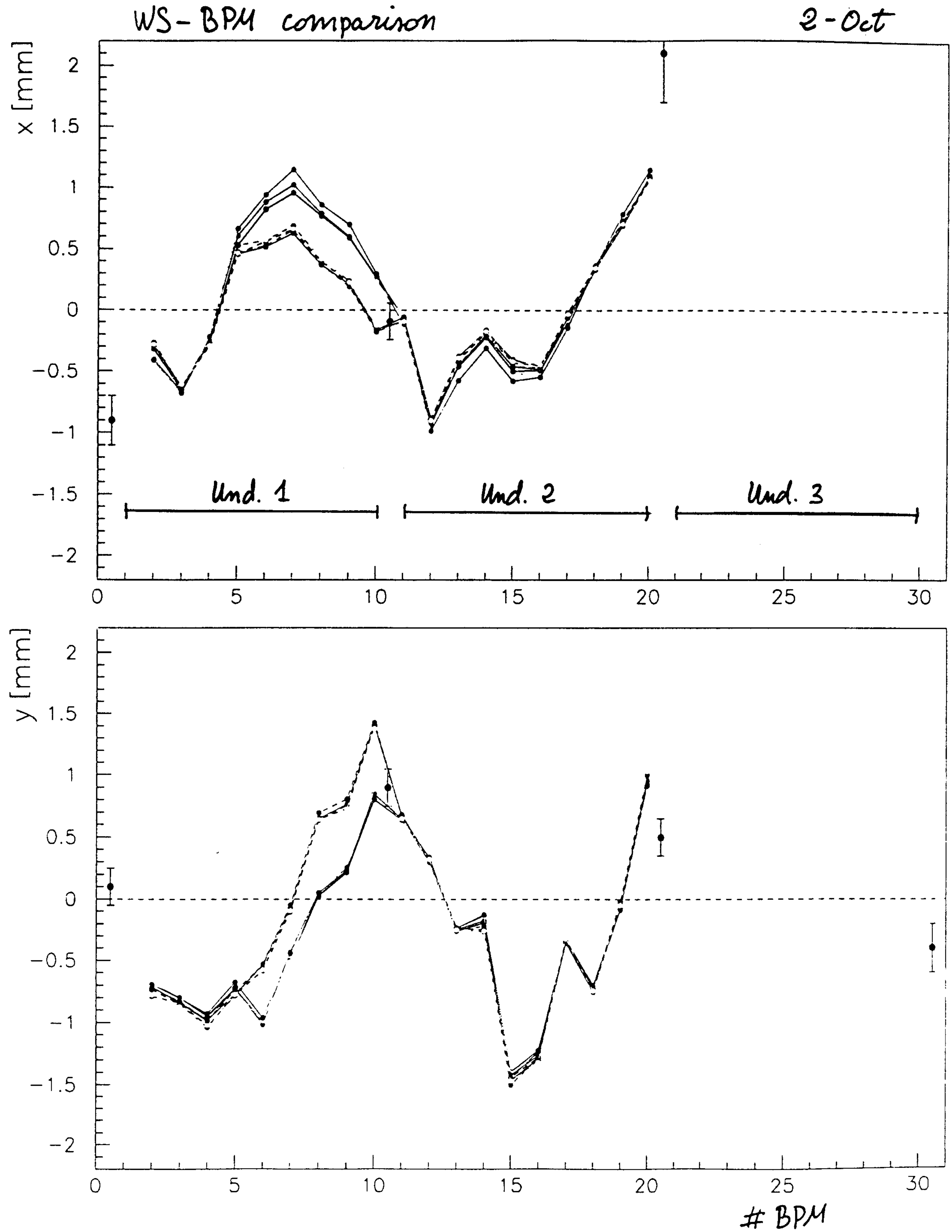
WS: **$\varepsilon \approx$ 7,4 to 20 mm mrad**

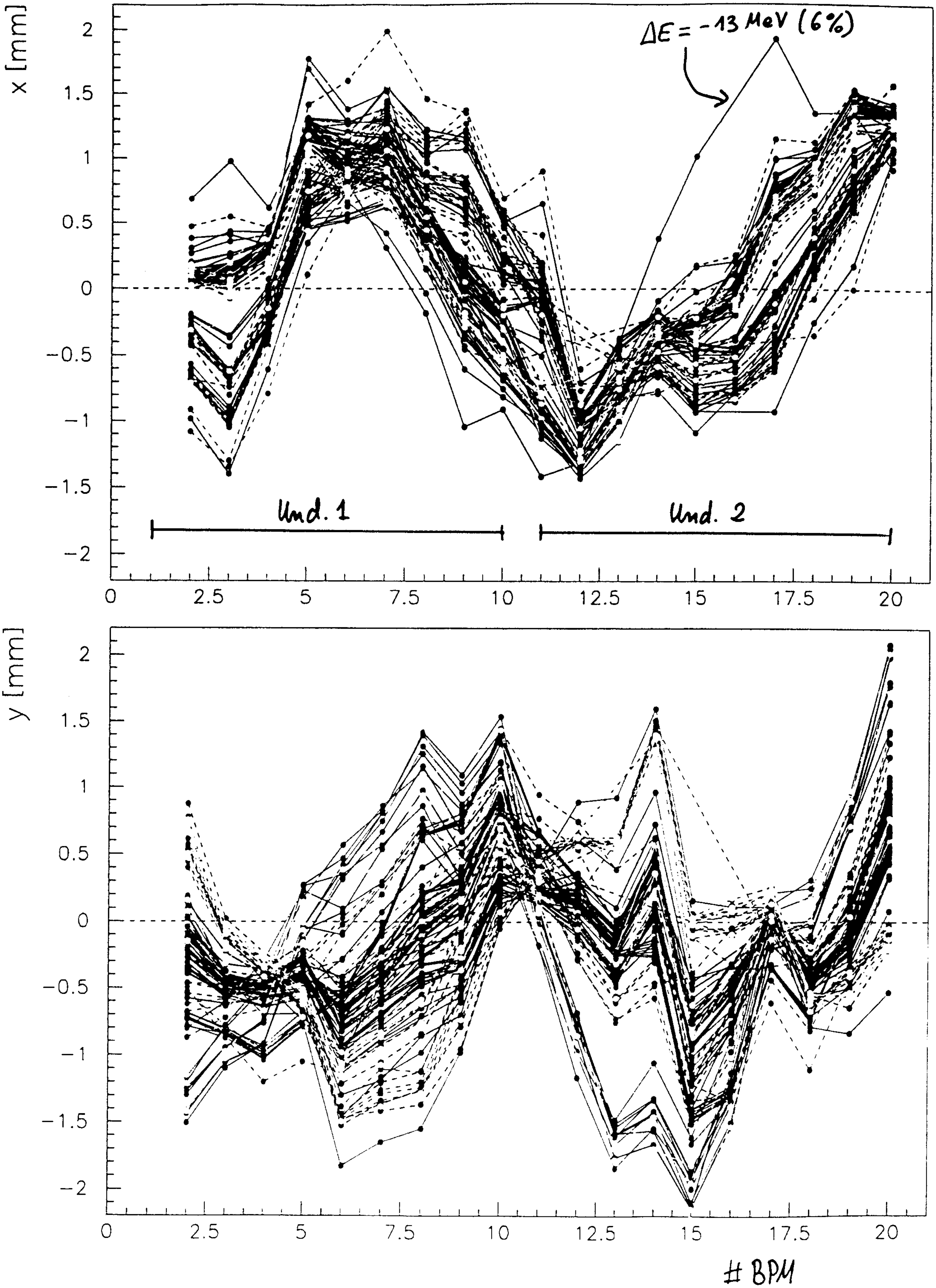
} not measured on the same day

WS - BPM comparison 27-Aug




x [mm]
z [m]
BPMs
UND 1
UND 2

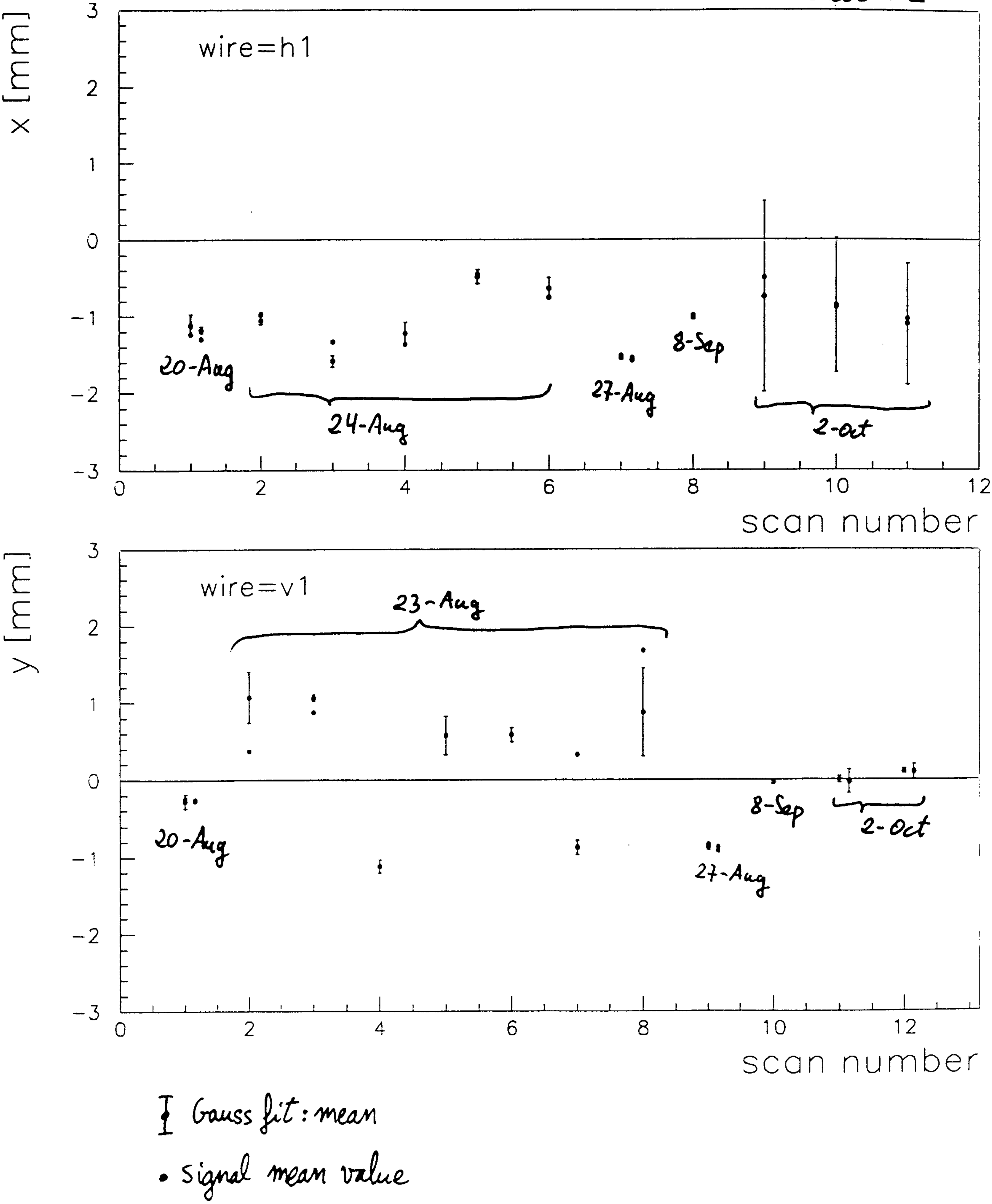

WS-BPM comparison
2-Oct
x [mm]
Und. 1
Und. 2
Und. 3
y [mm]
BPM



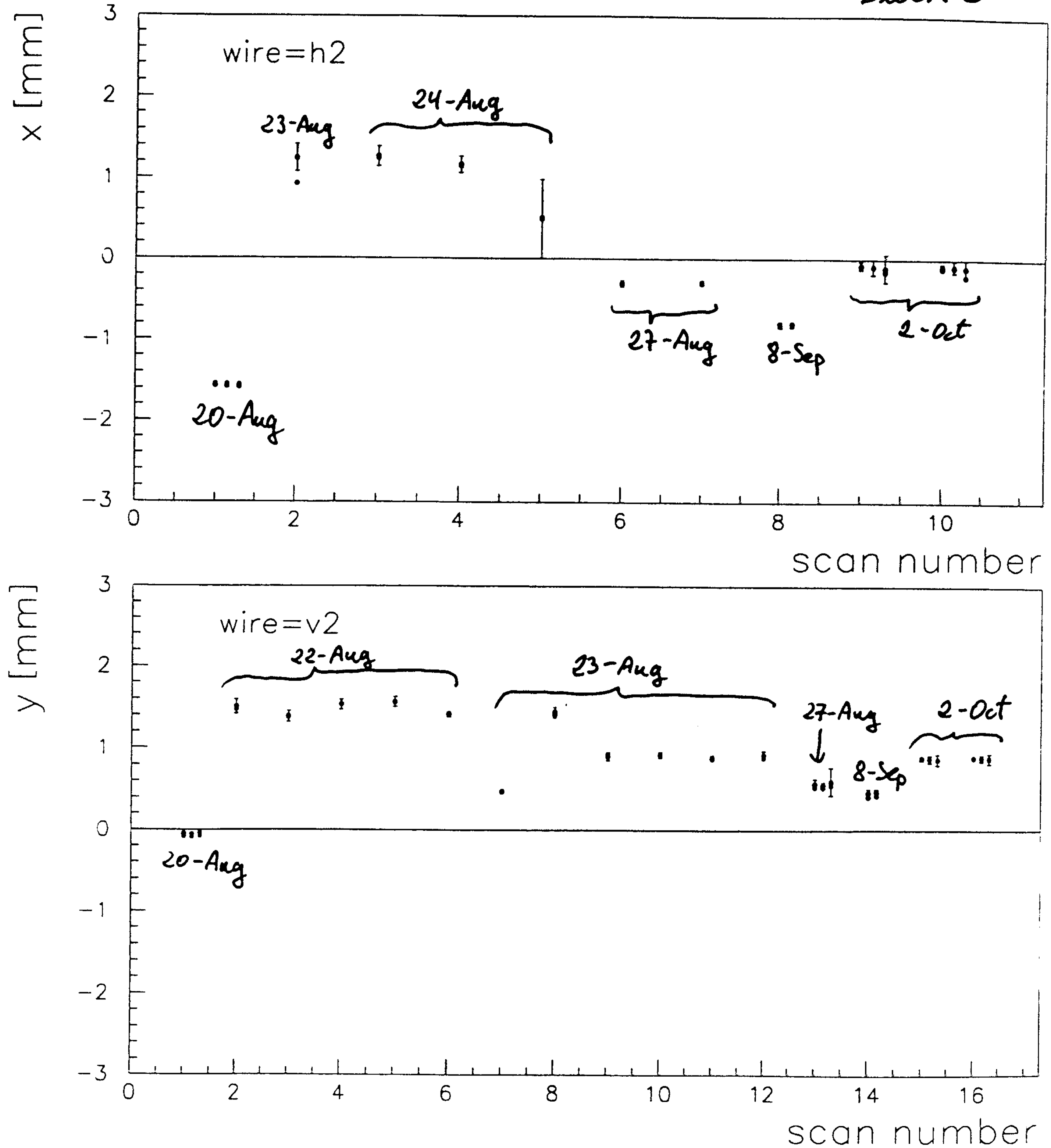
days 1,2,3 Oct.

Beam position measurements using WS

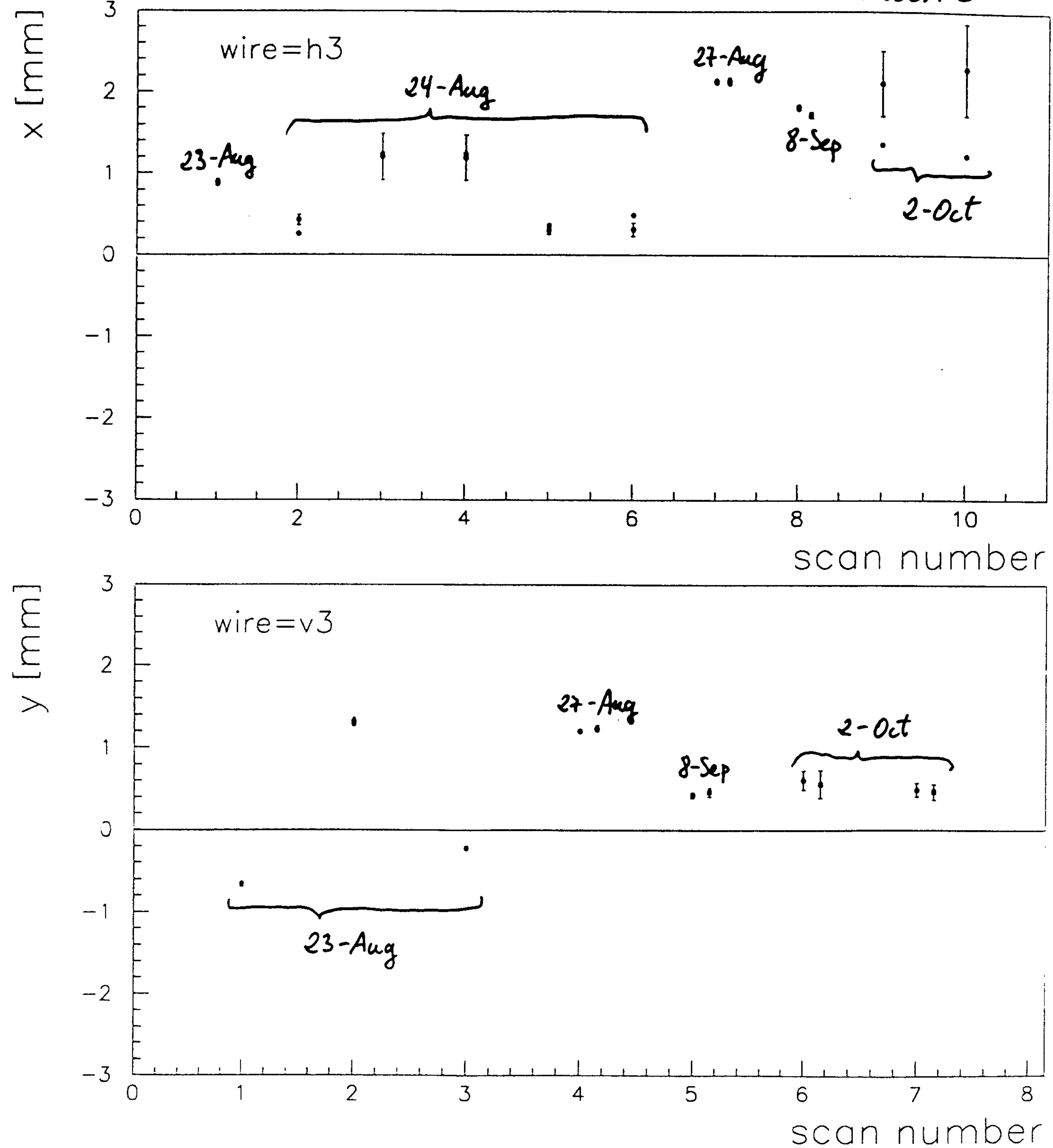
Block 1



Block 2

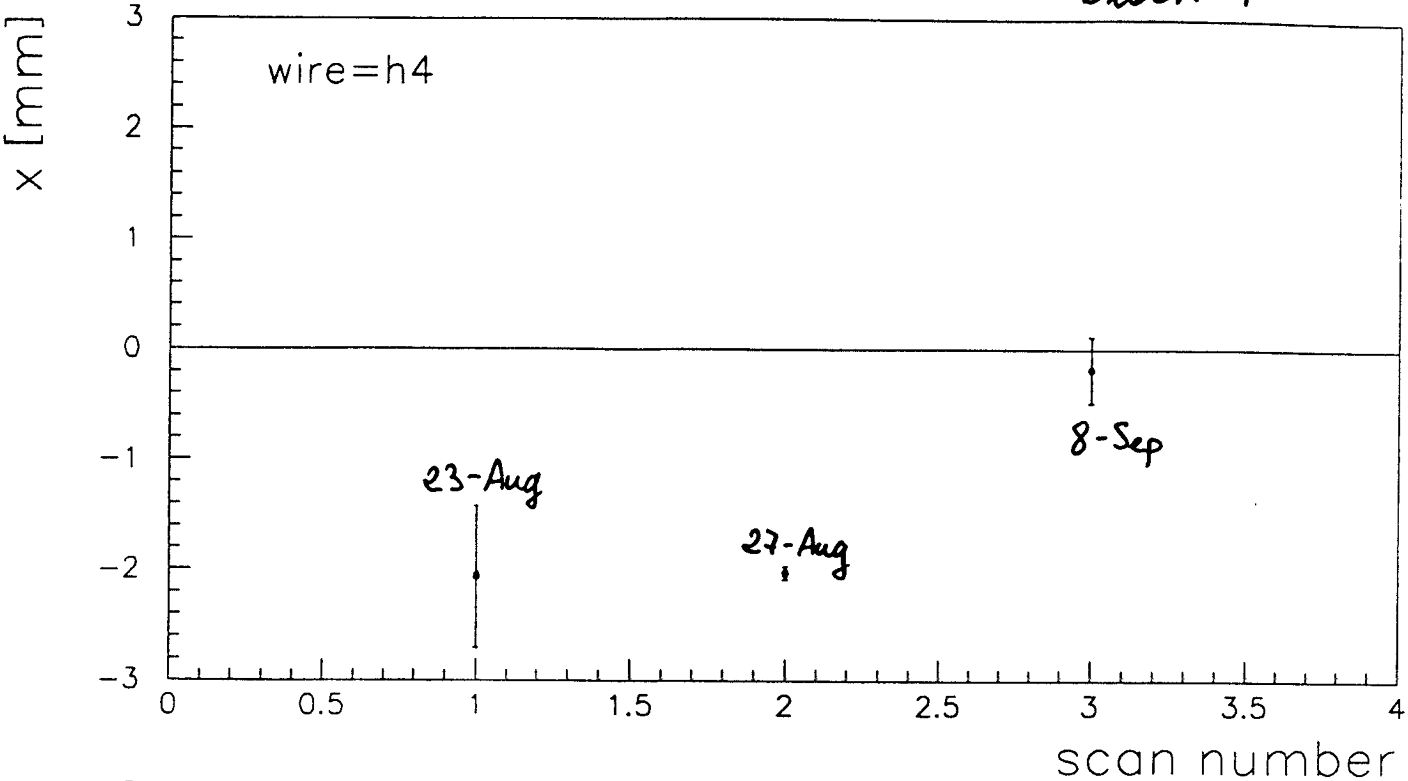

wire=h2
x [mm]
23-Aug
24-Aug
27-Aug
8-Sep
2-Oct
20-Aug
scan number
wire=v2
y [mm]
22-Aug
23-Aug
27-Aug
2-Oct
8-Sep
20-Aug
scan number

Block 3

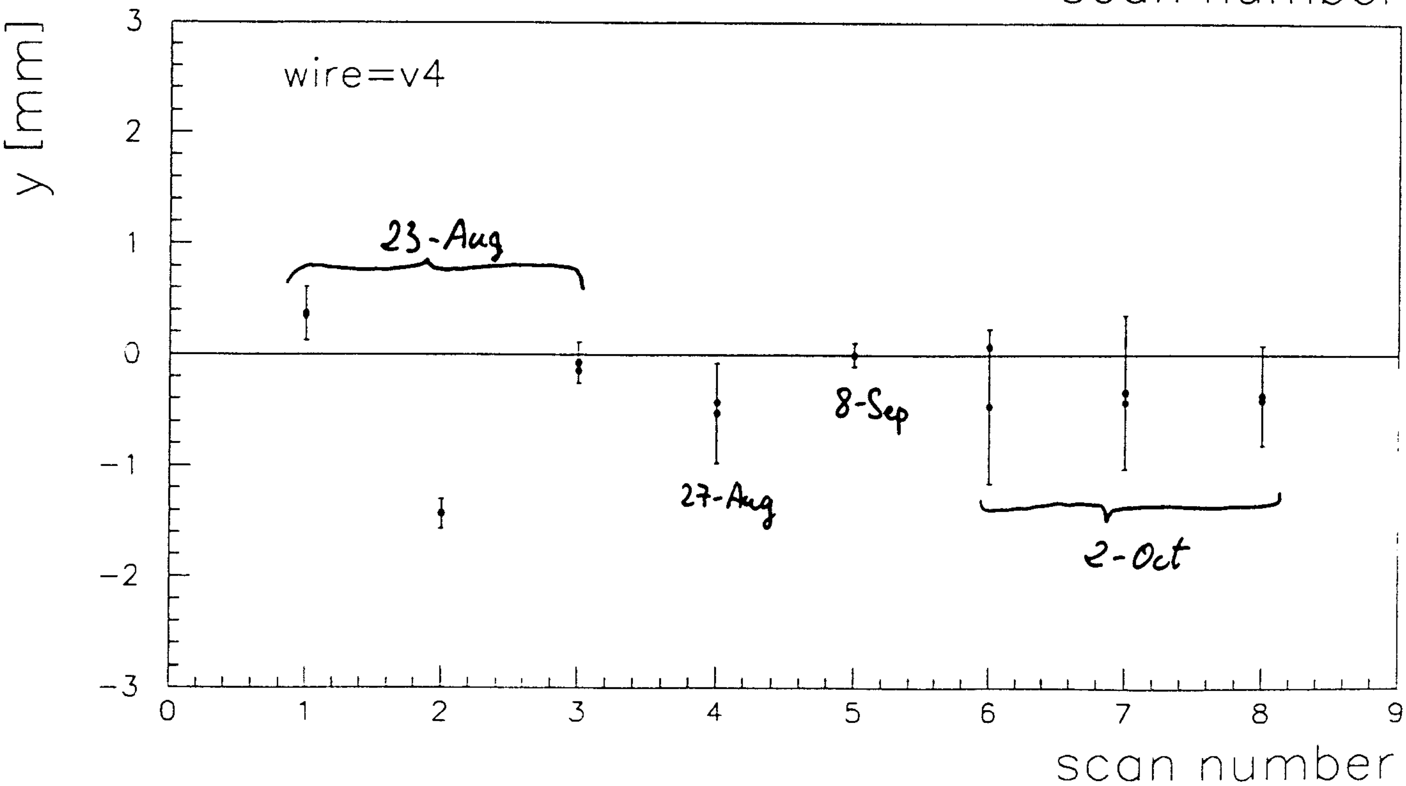


wire=h3
x [mm]
23-Aug
24-Aug
27-Aug
8-Sep
2-Oct
scan number
wire=v3
y [mm]
23-Aug
27-Aug
8-Sep
2-Oct
scan number

Block 4



x [mm]
wire=h4
23-Aug
27-Aug
8-Sep
scan number



y [mm]
wire=v4
23-Aug
27-Aug
8-Sep
2-Oct
scan number

Relevant beam parameters for SASE

1. Beam emittance $\geq 5\pi$ mm mrad
2. Bunch length $\geq$ 1 mm, $\Rightarrow$ 1 nC $\hat{=}$ $I_{\text{peak}} \leq$120 A
   with BC II on: 0.6 mm $\Rightarrow$ 1 nC $\hat{=}$ I_{peak}=200 A
3. Energy spread (measured) FWHM $\leq$ 0.7 MeV

$\Rightarrow$ expected gain $\leq$ 10 (provided orbit rms $\leq$ 10 μm)

Main limiting factor:

Beam orbit rms $\geq$ 0.5 mm in undulator

What we learnt is ...

- Smooth start up of linac with collimator+undulator
- Bunch compression: not a big deal, provided that:
  - phase measured at ACC1 and 2 (with 8 nC)
  - pyroelectric detector signal available
- Orbit in undulator: problem with vacuum chamber alignment
- Best transmission at high bunch charge:
  8 nC (gun) $\rightarrow$ 4 nC (collimator) $\rightarrow$ 4 nC (dump)
  no extra radiation dosis to the undulator
- How to reduce background in Hasylab instruments

Training of new operators: went fast

new operators from TESLA Collaboration are wellcome

What we need to improve ...

- Reduce/dump dark current from gun
  vacuum in gun as good as possible
- Rf-gun regulation
- Find the cause of orbit jumps
- Improve undulator-collimator alignment
  determine beam position at collimator quadrupoles
- BPMs:
  more BPMs in injector: electronics
  calibration measurement with beam
  self-calibration with beam current
- Beam measurements
  acquistion need to be faster
  measure parameters under same conditions (if possible
  same time)