ELECTRON CLOUD OSERVATIONS IN THE SPS

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[1]SL/OP, [2]SL/BI, [3]LHC/VAC, [4]SL/AP

CERN GENEVA SWITZERLAND

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Main topics

- Introduction
- Review of the main results obtained in 2001
  - Electron cloud in dipole field regions / field free
  - Beam scrubbing: evolution of the secondary electron yield coefficient (δ), $\Delta P/P$
  - Effect of multibatch injections, missing bunches, 50 ns bunch spacing…
- Objectives for 2002
  - Description of the new detectors and their capabilities

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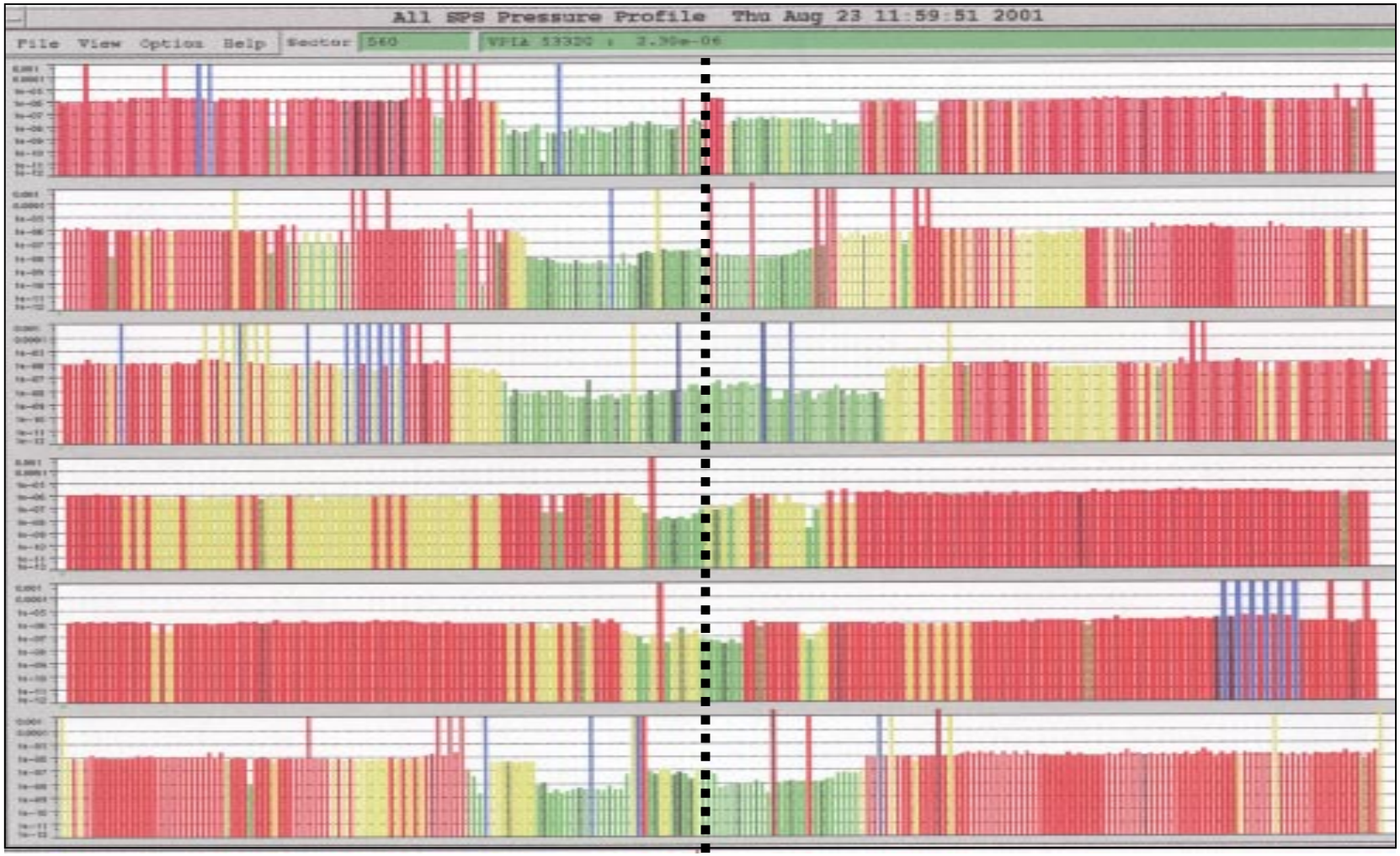
Introduction: Dynamic pressures in the SPS

Pressures in the SPS with 3 batches @ 4.0x10^{10} p/b



Red = P >10^{-4} Pa, Green = P < 10^{-4} Pa

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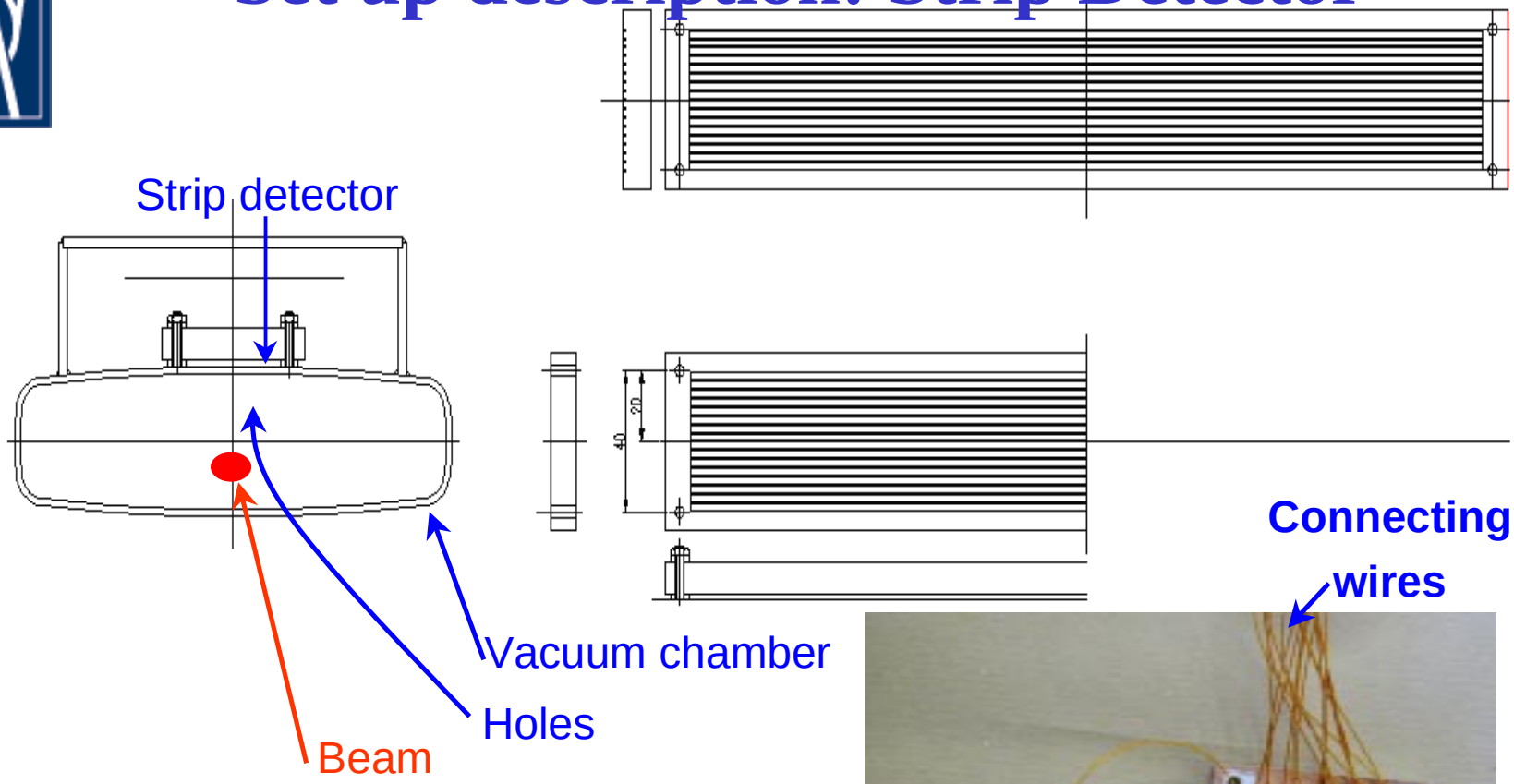
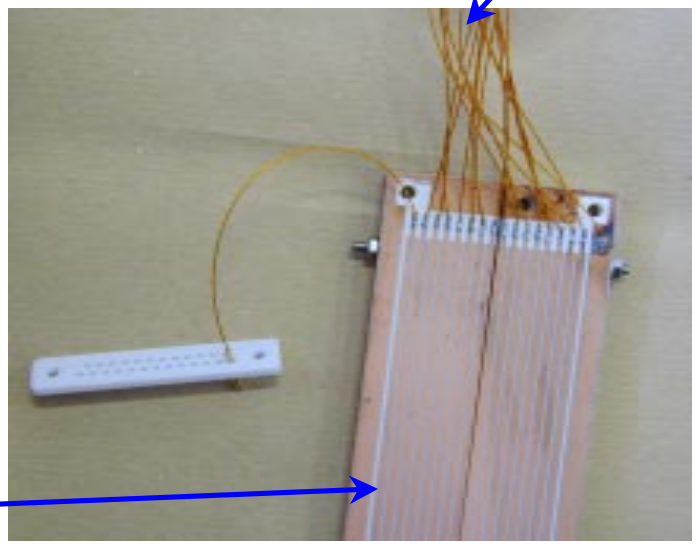
Set up description: Strip Detector





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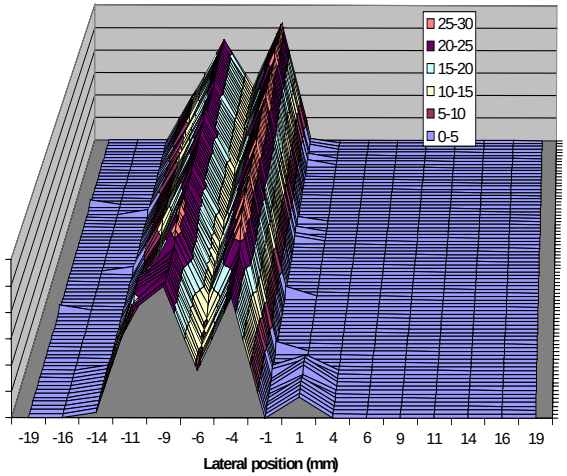
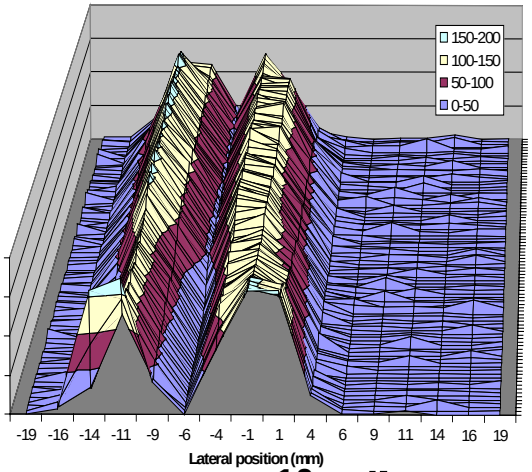
Beam Effects: Bunch Intensity

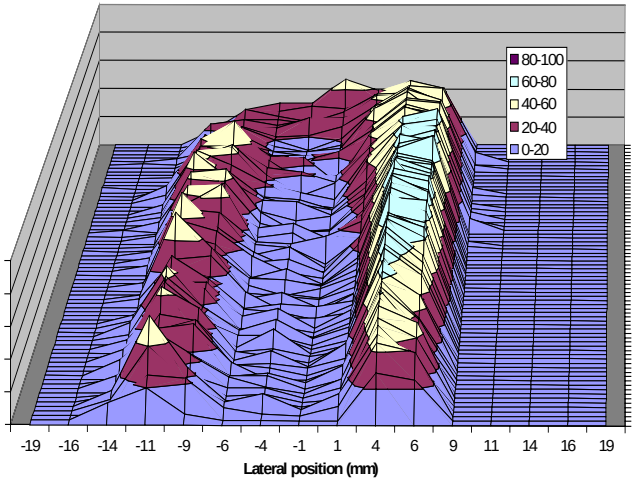
Effect of a dipole field: 2 strips @ high intensities



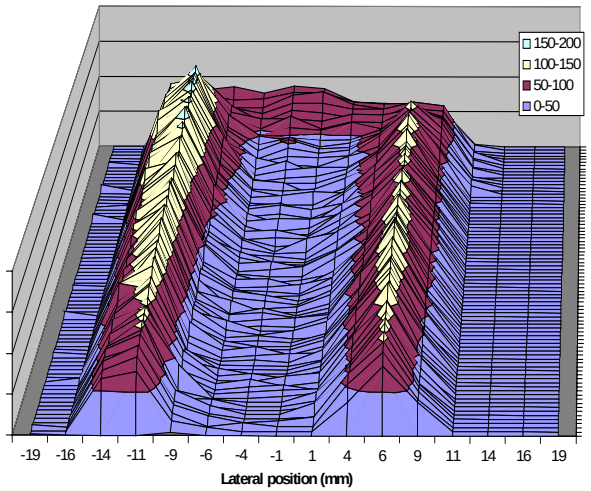
5.0x10^{10} p/b



6.0x10^{10} p/b



7.9x10^{10} p/b



8.6x10^{10} p/b

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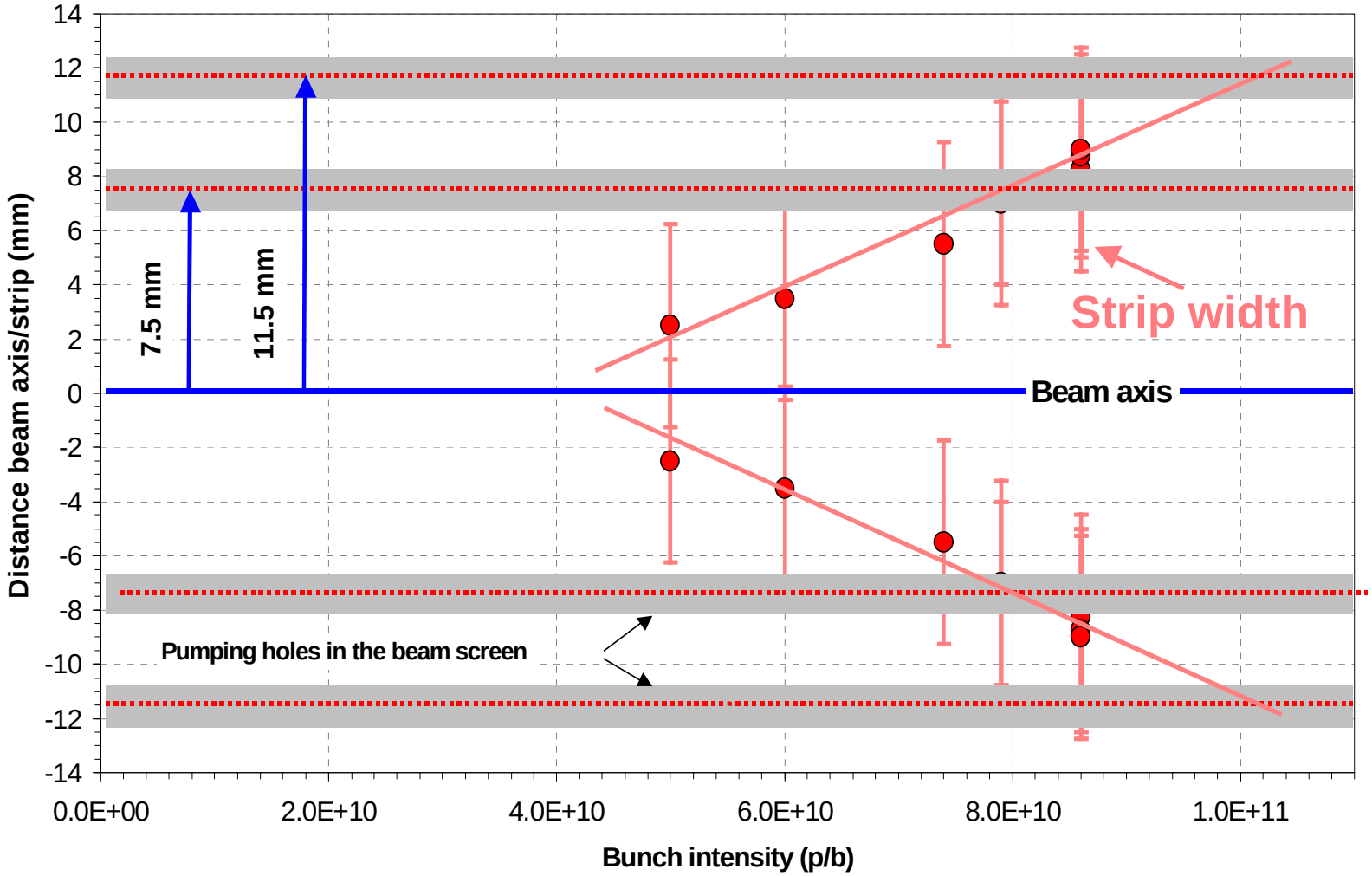
Beam Effects: Bunch Intensity

Effect of a dipole field: 2 strips @ high intensities



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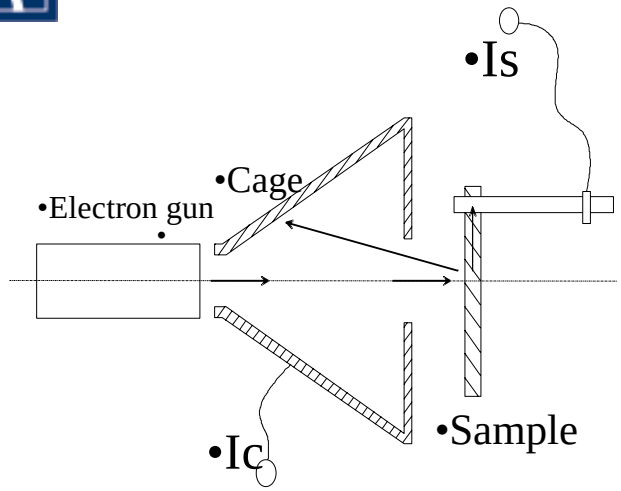
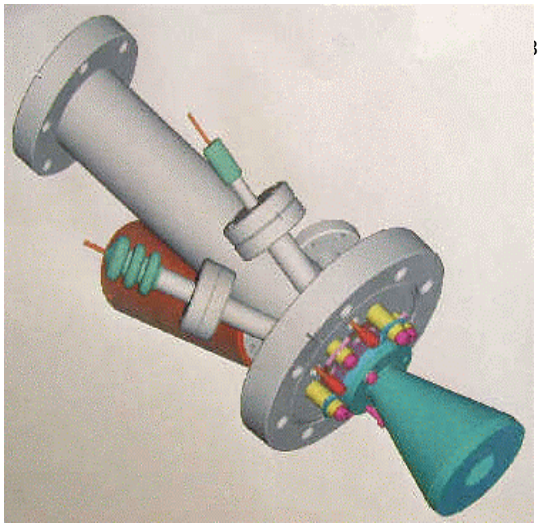
SEY Measurements

In situ measurement in the SPS

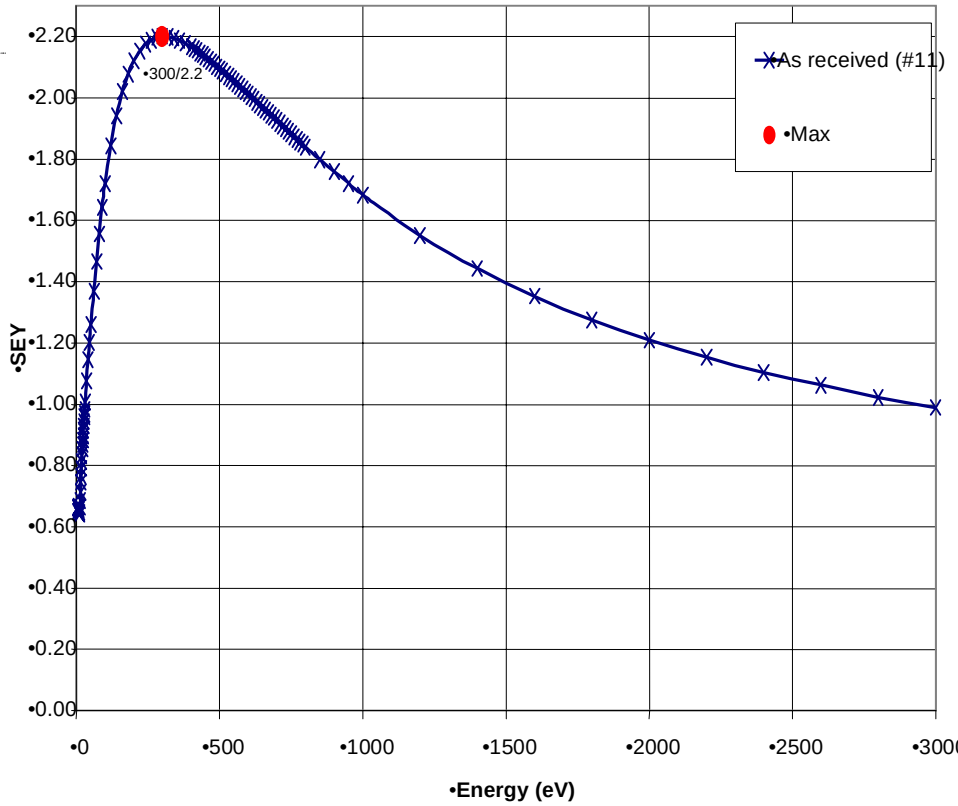


$$SEY \equiv \delta = \frac{I_{Emitted}}{I_{Incident}} = \frac{I_{Collector}}{I_{Collector} + I_{Sample}}$$



•Typical Copper SEY

•CERN LHC/VAC B.HENRIST 8/2001



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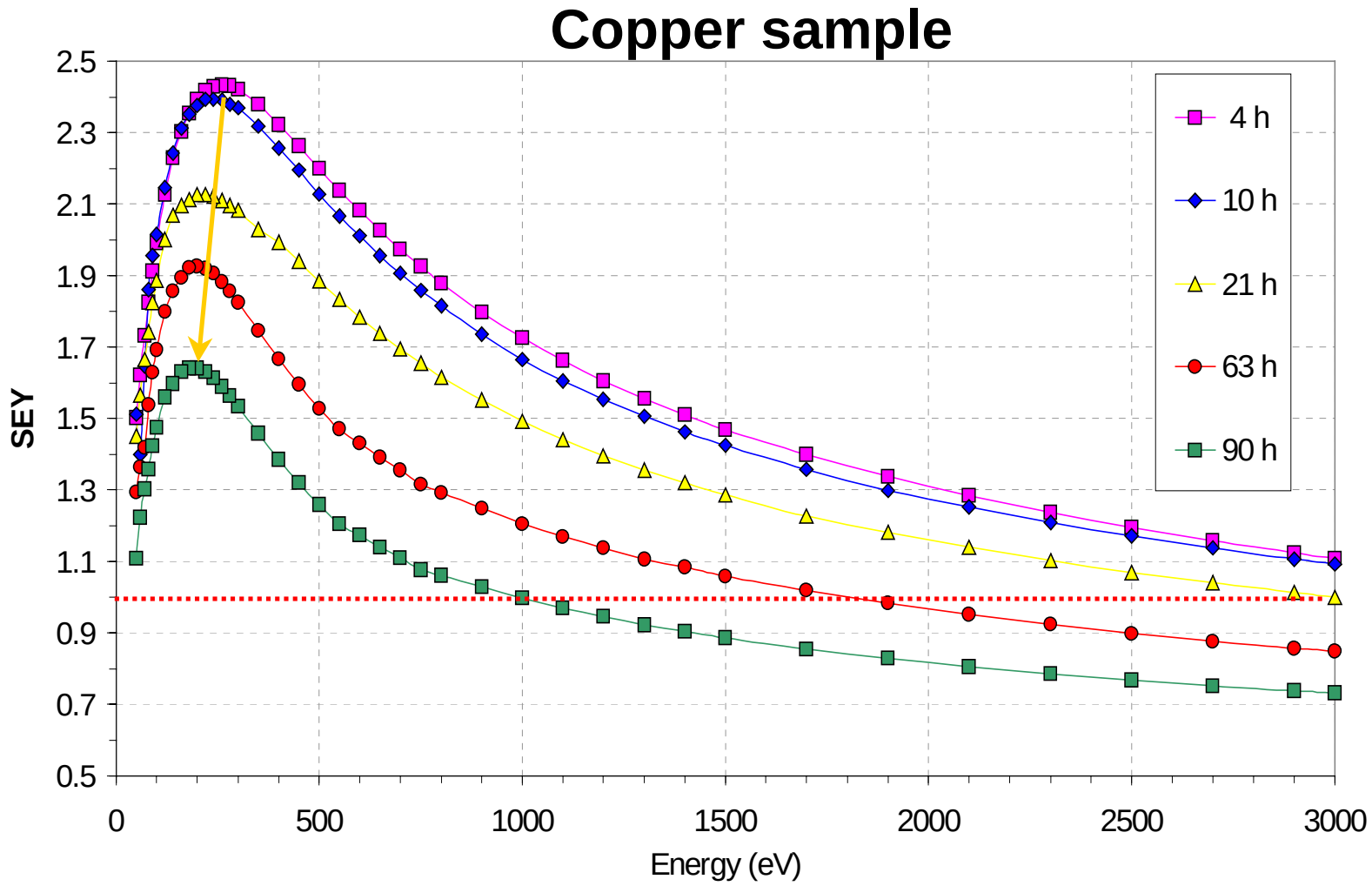
Beam scrubbing: SEY Measurements

Evolution of the SEY with LHC beam time



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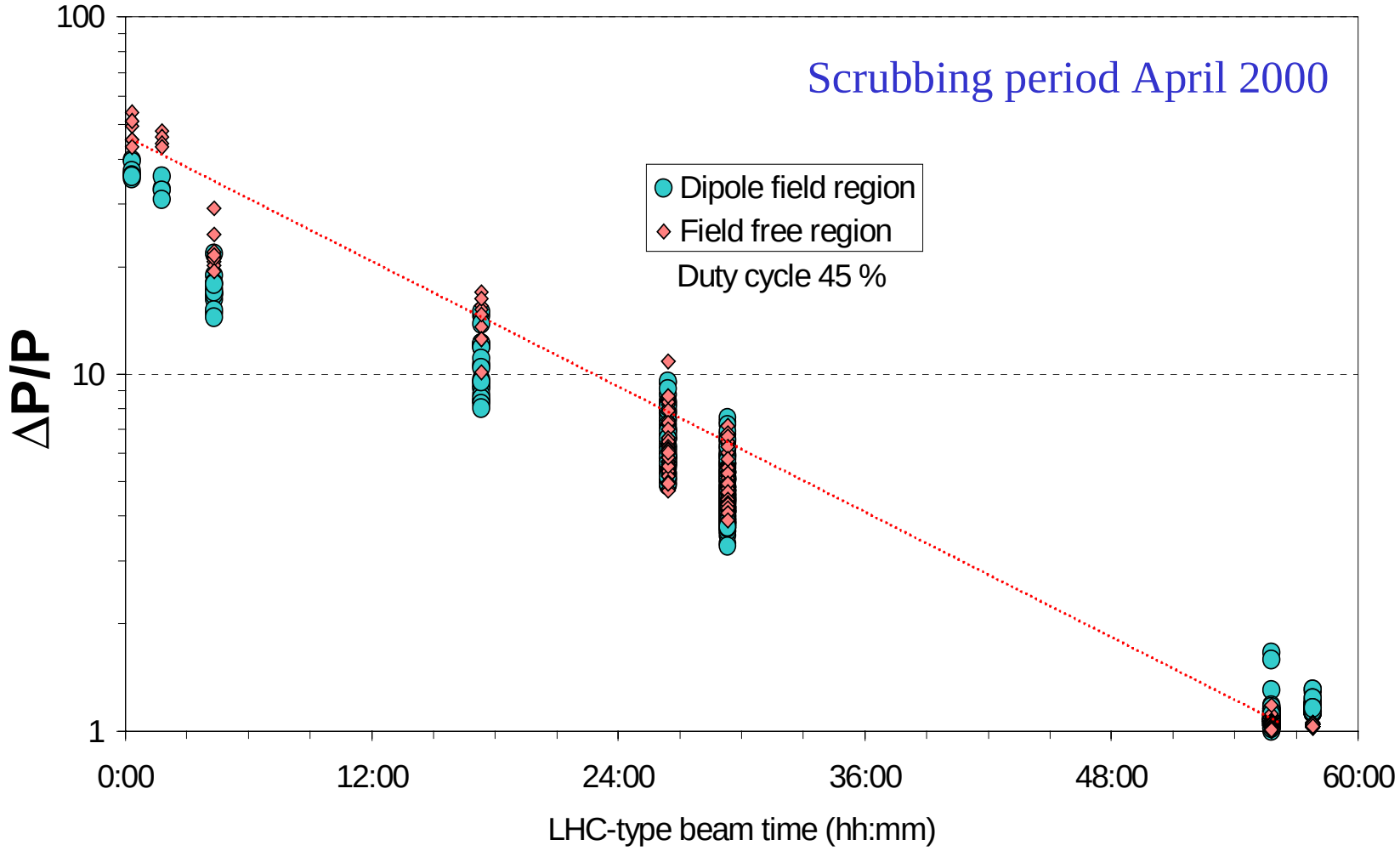
Beam scrubbing

Pressure rise as a function of the LHC integrated beam time



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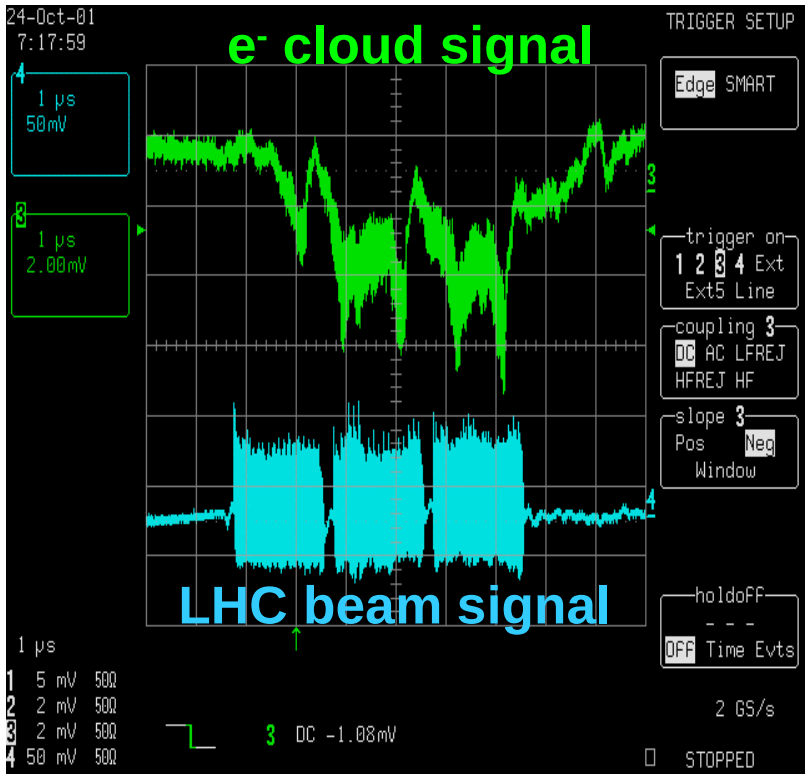
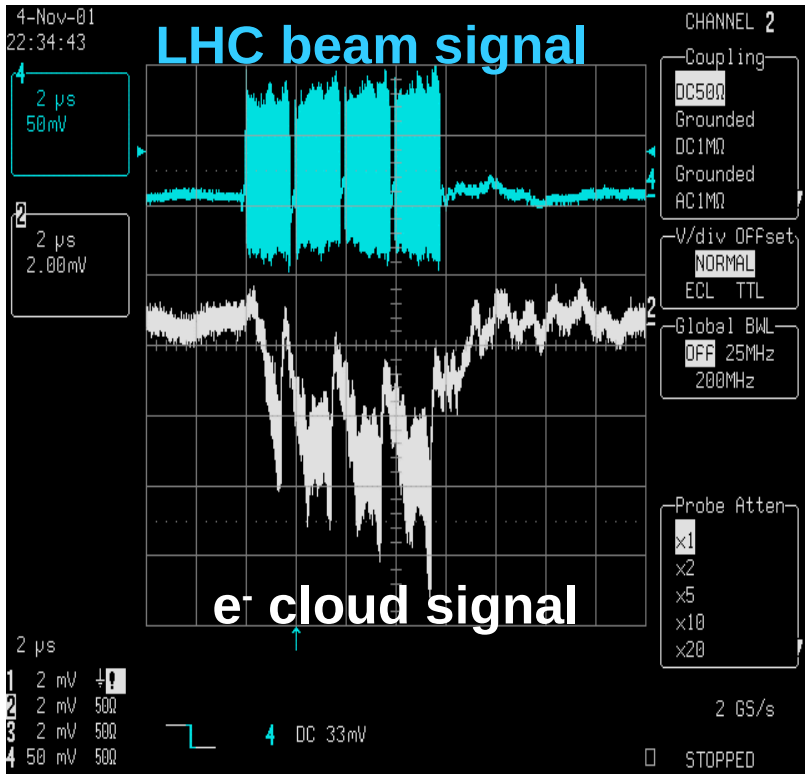
Beam Effects: Filling Pattern

Multi-batch injection: 3 and 4 batches





by 3 batches **by 4 batches**

Signal (-) generated by 3 and 4 batches

225 ns batch spacing (nominal)

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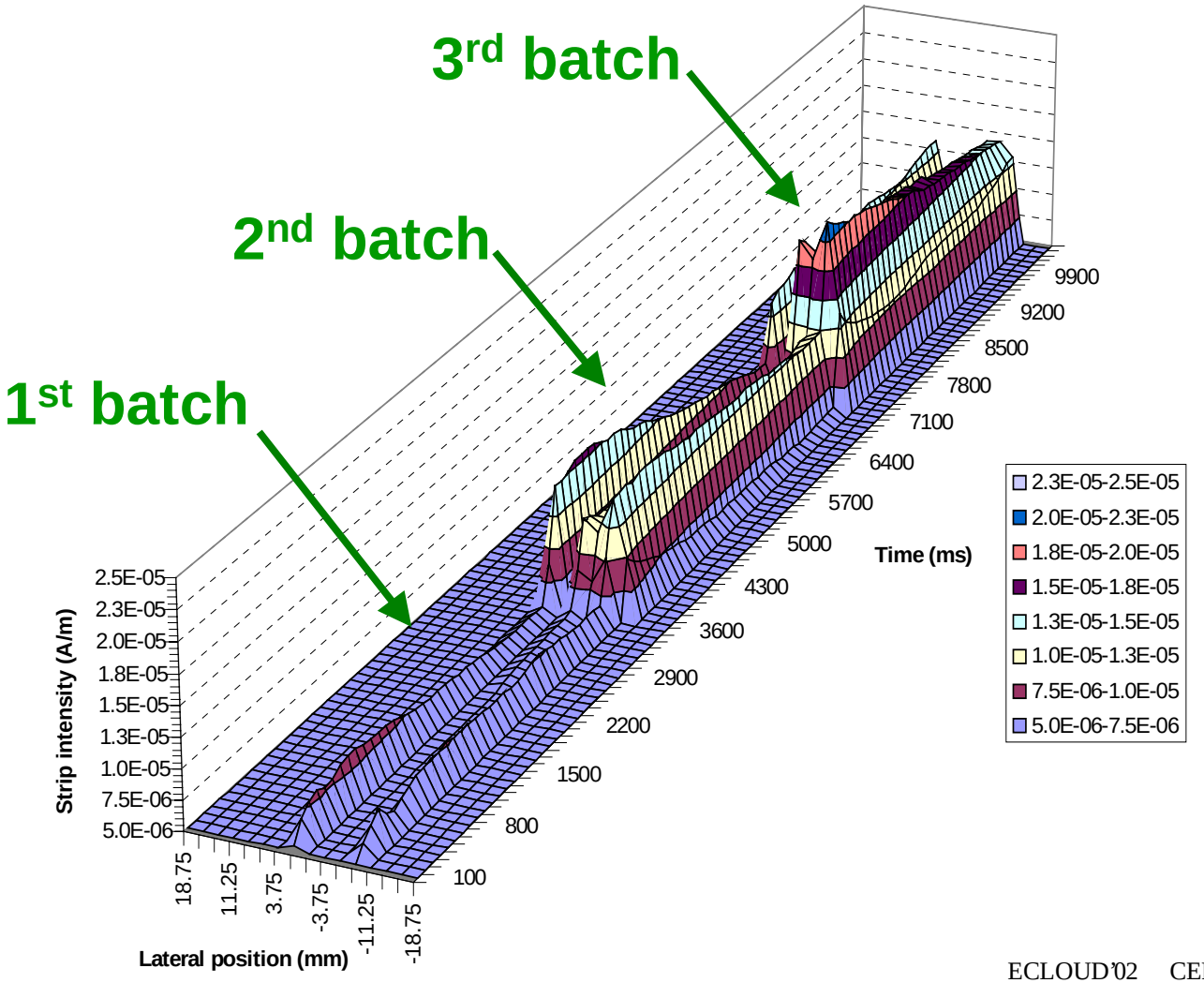
Beam Effects: Filling Pattern

Multi-batch injection: 3 batches

Dipole field region



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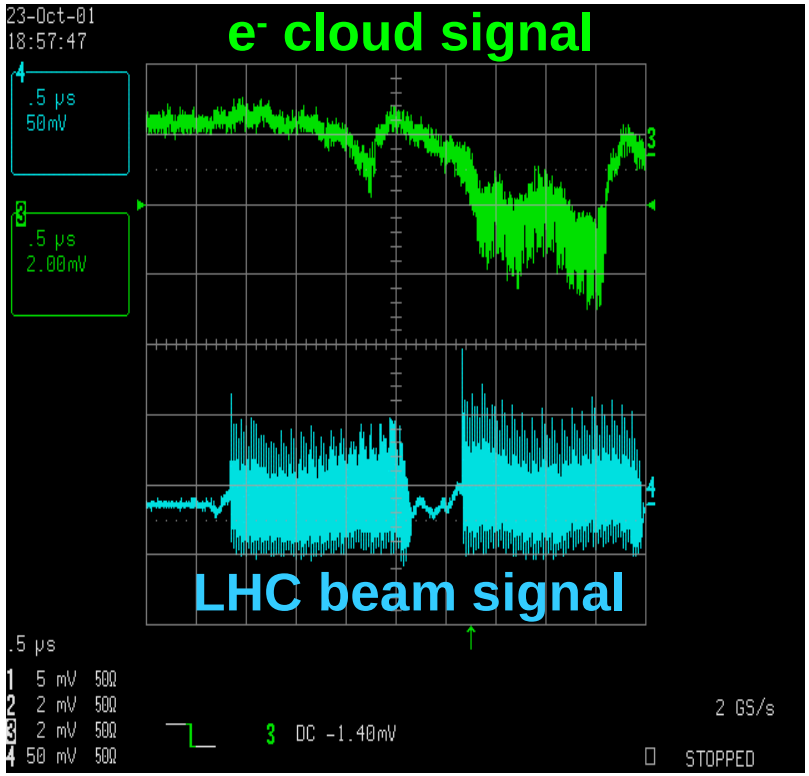
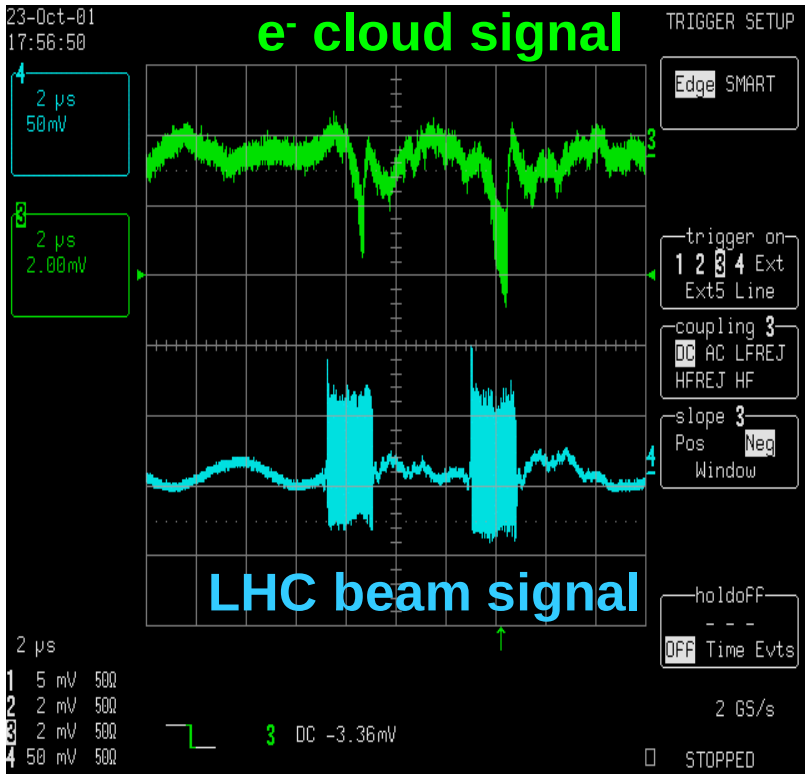
Beam Effects: Filling Pattern

Multi-batch injection: Batch spacing





550 ns spacing **~5.25 µs spacing**

Signal (-) generated by 2 batches

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Beam Effects: Filling Pattern

- @ 8.0×10^{10} p/b, only 20 bunches are need for the e^- cloud build up (25 ns spacing)
- 12 Missing bunches in the centre of the batch do not suppress the e^- cloud but decrease the intensity by a factor of 8
- 10^{11} p/bunch achieved using the 50 ns bunch spacing ☞ e^- cloud activity 10 time below the level expected for an "equivalent" total intensity ($5_x 10^{10}$ p/b).
- Multi-batch injection: only a long batch spacing > 500 ns will reduce the e^- cloud activity.

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Conclusions (1)

- Beam Effect: Bunch intensity
  - X **e^- cloud threshold bigger (x2.5) in field free than in dipoles**
    - **Dipole field regions: 2.0 10^{10} p/b**
    - **Field free regions: 5.0 10^{10} p/b**
  - X **2 strips @ high intensities as predicted by simulations**

    The position of the two strips at high intensities is close to the position of the pumping holes in the beam screen in the present design.
- Filling pattern: e^- cloud build up (25 ns spacing)
  - X **20 bunches needed @ 8.0x10^{10} p/b to build up the e^- cloud.**
- Filling pattern: Missing bunches in the batch
  - X **Do not suppress the e^- cloud, 12 missing bunches decreased pressure rises by 8.**
- Filling pattern: **Bunch spacing (50 ns)**
  - X **10^{11} p/b achieved α e^- cloud activity 10 time below the level expected for an "equivalent" total intensity.**

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Conclusions (2)

- Filling pattern: Batch spacing
  - X **Batch spacing < 500 ns do not reduce the e^- cloud activity**
- Beam scrubbing: Field free and dipole regions
  - X **Scrubbing visible in both the field free and the dipole regions**

    α **recontamination by the non-bombarded surface could explain a lower efficiency in dipole regions.**
- Beam scrubbing: Effect of venting
  - X **Worse situation in the SPS due to the venting of the whole machine during last shutdown for the installation of the pumping port shielding (PPS)**

    α **decrease of the threshold of the e^- cloud**
- Beam scrubbing: SEY measurements
  - X **SEY coefficient (δ) of a copper sample decreased from 2.4 down to 1.6 after about 90 hours of integrated LHC beam.**

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e^- Cloud studies in the SPS

Parameters being investigated

		Field free region	Dipole field region
Electron cloud phenomena			
	e^- cloud activity (intensity)	Electrons energy analyser, strip pick-ups, strip detectors	
	e^- cloud build-up	Pick-ups, Strip pick-ups	Strip pick-ups
	Energy distribution of the electrons	Electrons energy analysers	
		Electrostatic energy analyser	-
		Retarding field detector	-
	Spatial distribution of the electrons	Strip detectors (32 and 16 channels)	
	Secondary electron yield measurements (δ)	New Secondary Electron Yield (δ) set-up	
	Surface treatment to cure e^- cloud	Pressure, pick-ups	-
Beam effects			
	Bunch intensity	Pressures, strip detectors, strip pick-ups	
	Filling pattern Batch length Missing bunches Bunch spacing Bunch length Batch spacing Filling factor	Pressures, strip detectors, strip pick-ups	
	Scrubbing	New Secondary Electron Yield (δ) set-up	
LHC related issues			
	Power deposited by the electron cloud (heat load)	WAMPAC 1&2	WAMPAC 2
		Pick-up calorimeters	
	"Cold" Measurements (COLDEX)	COLDEX	-
	NEG coating tests	Test bench for NEG coating	-
Other checkings			
	HOM measurements	HOM antenna	-
	Ions	Ion detector	-
	Partial pressures = f (e^- bombardement)	Residual gas analyser (RGA)	-

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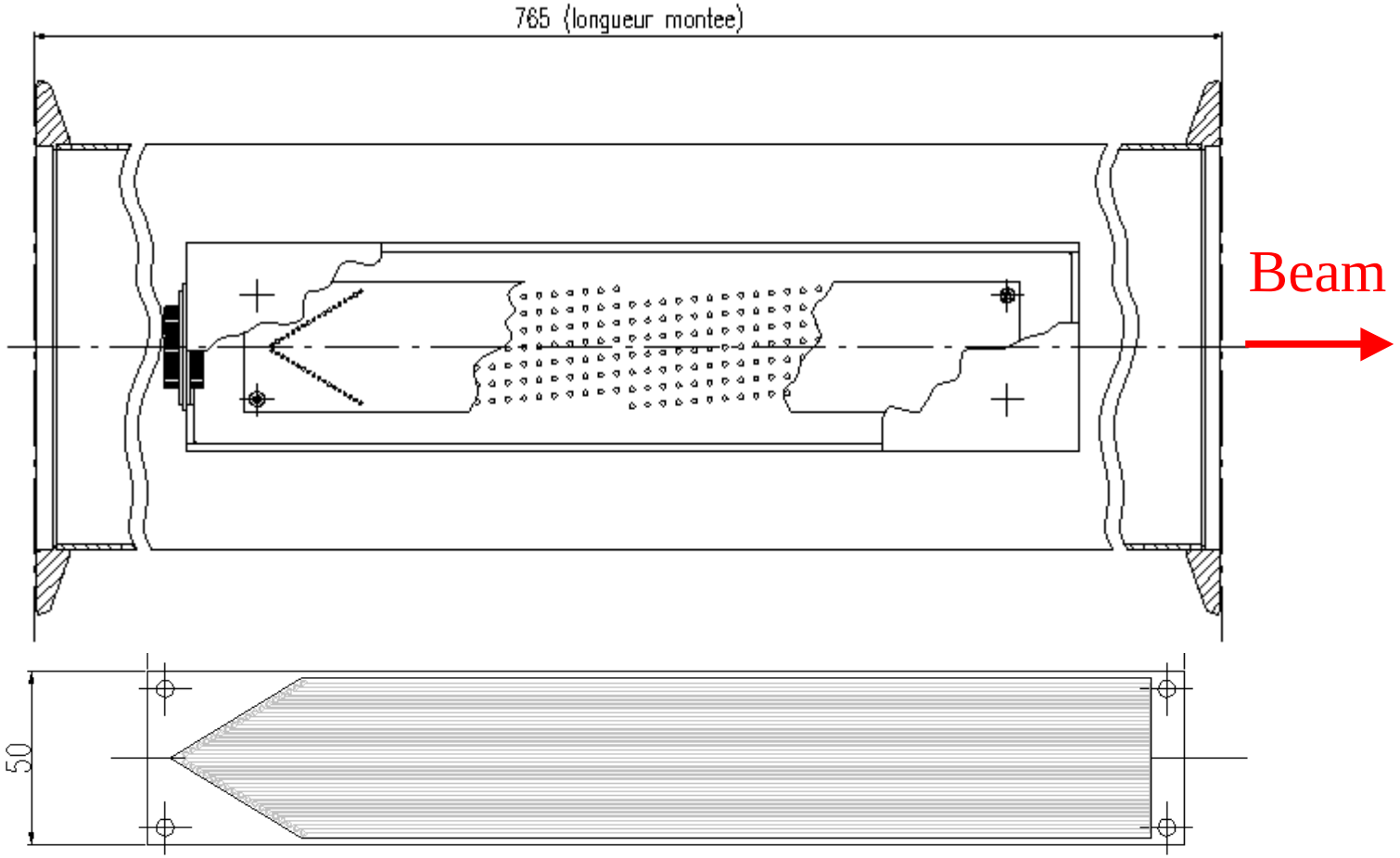
e^- Cloud studies in the SPS

New 36 channels Strip detector

Available in a dipole field region



Spatial resolution: 1.25 mm

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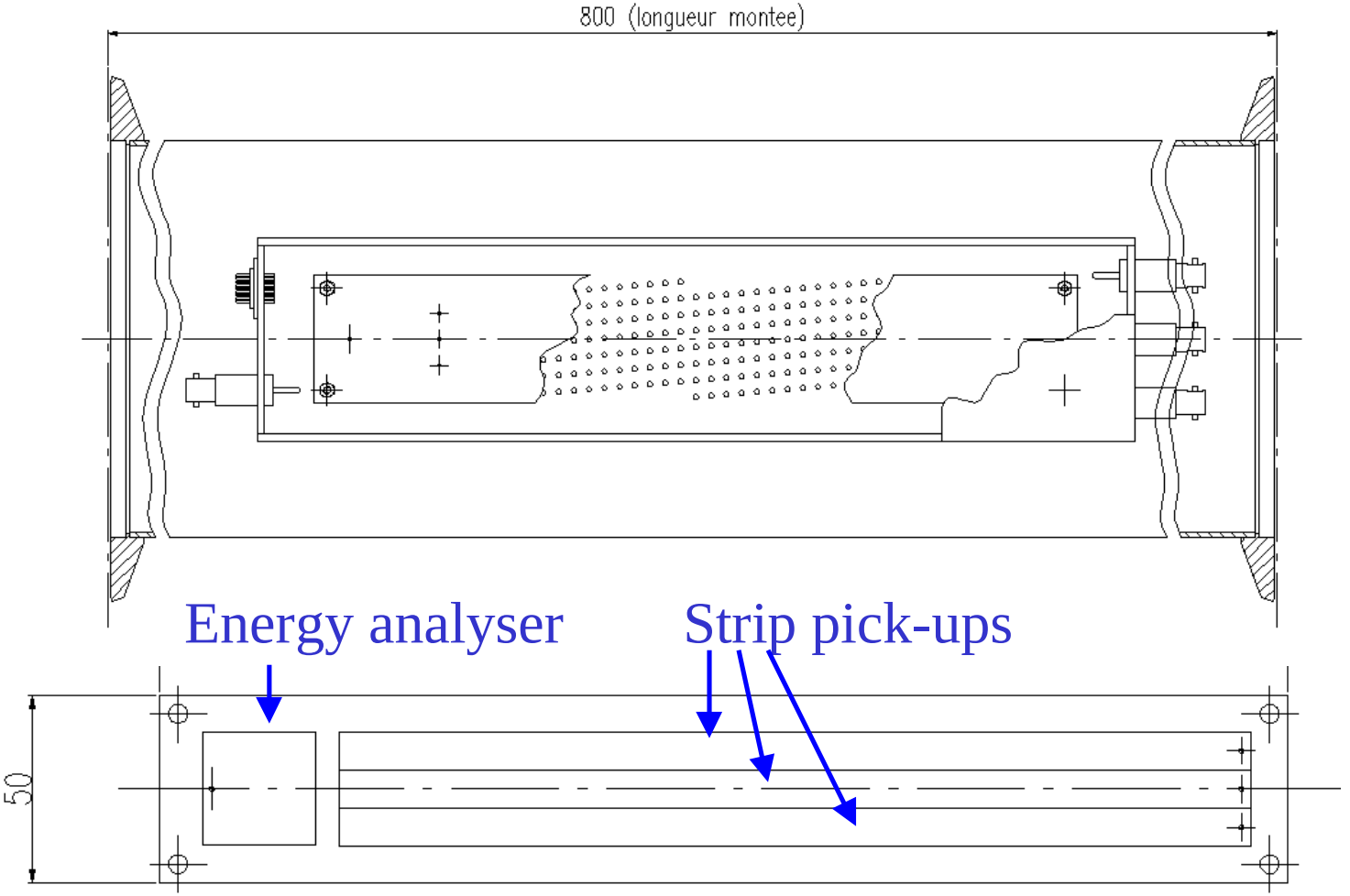
e^- Cloud studies in the SPS

Energy analyser and strip pick-ups (1)

Available in a dipole field region



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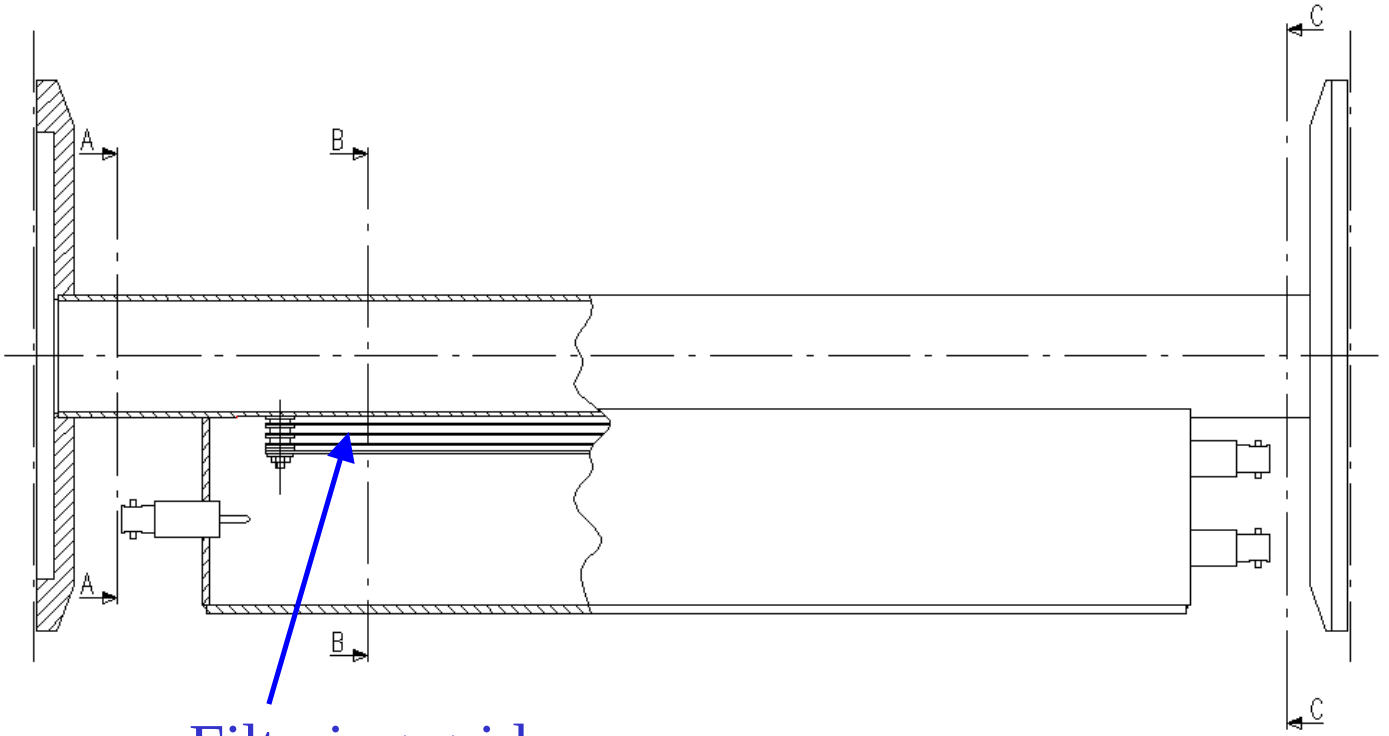
e^- Cloud studies in the SPS

Energy analyser and strip pick-ups (2)

Available in a dipole field region



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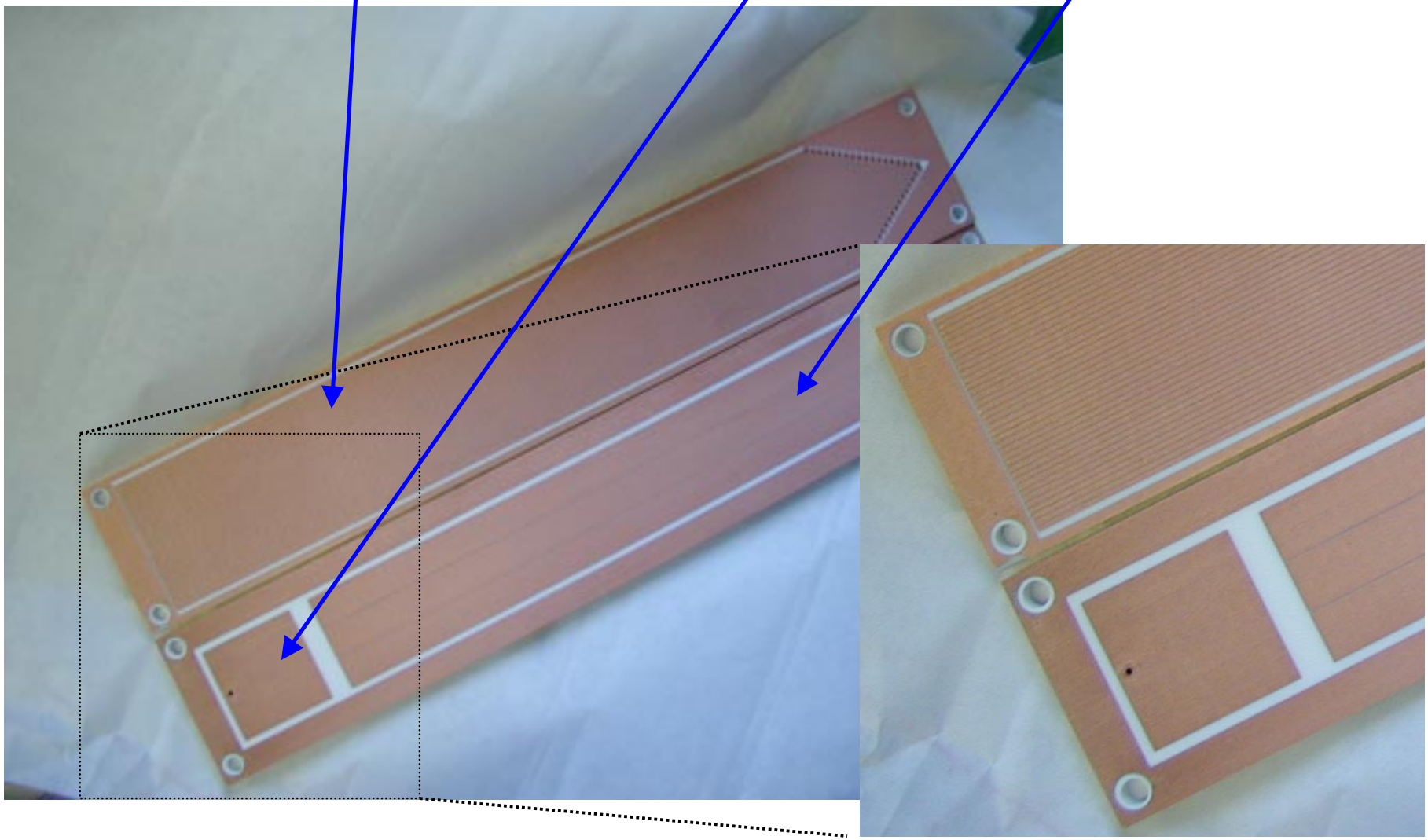
e^- Cloud studies in the SPS

Strip detector/ Energy analyser/strip pick-ups



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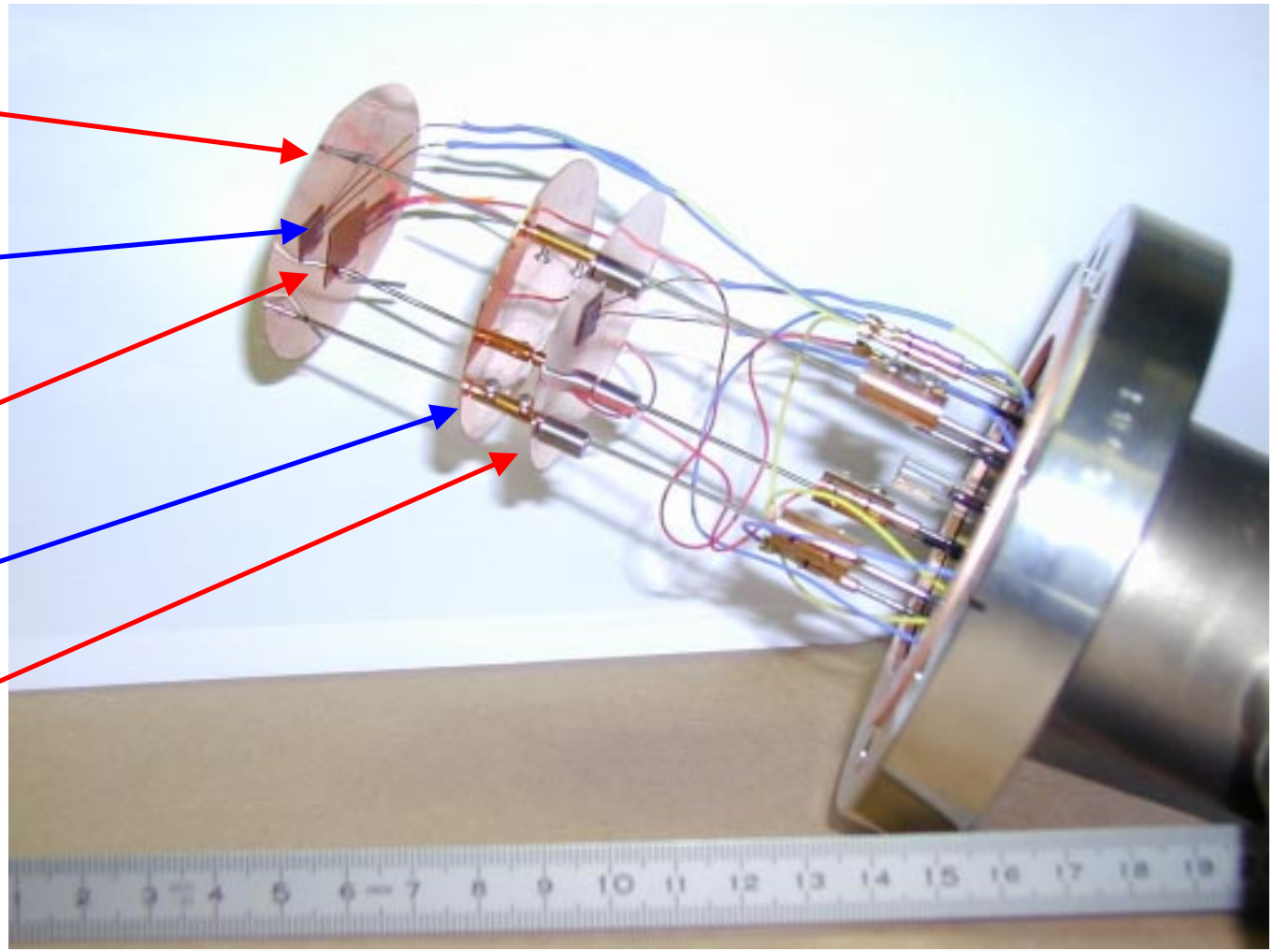
e^- Cloud studies in the SPS

Pick-up calorimeters



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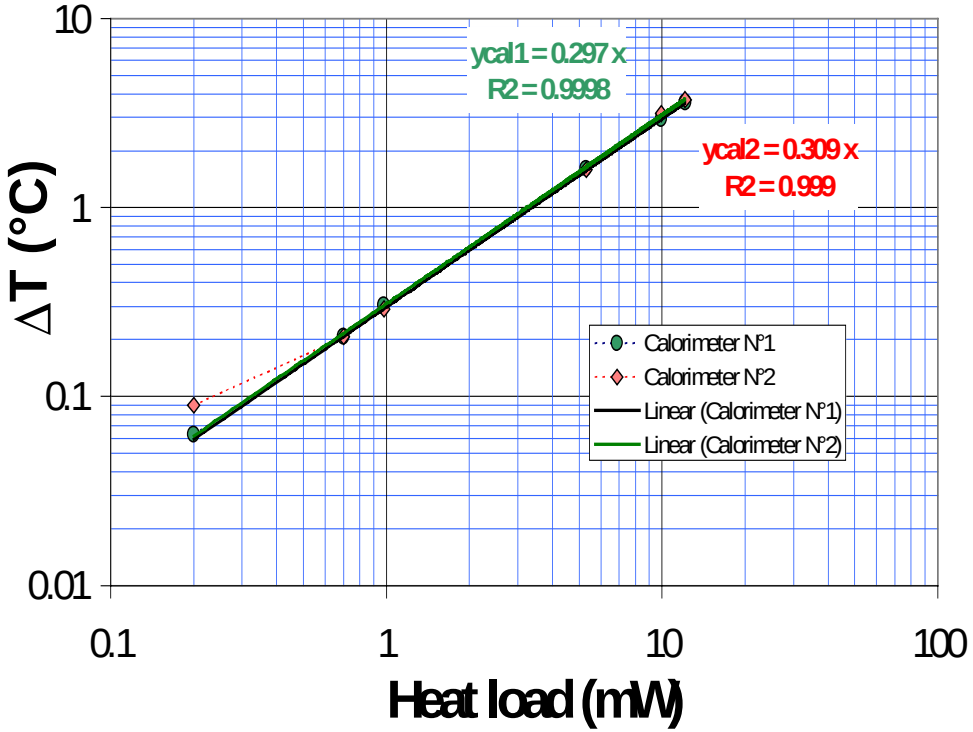
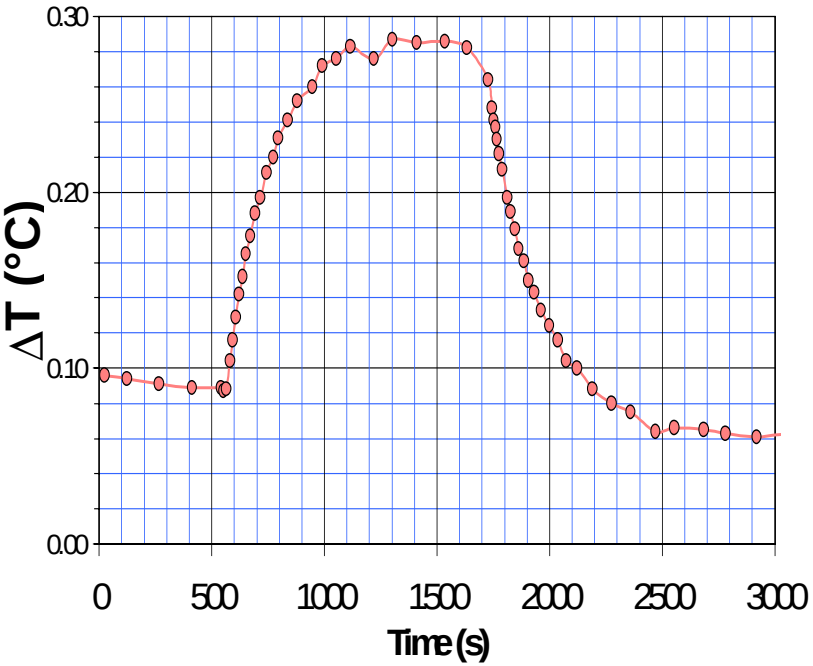
e^- Cloud studies in the SPS

Pick-up calorimeters

ΔT = f (Heat load)



ΔT measured for 0.7 mW



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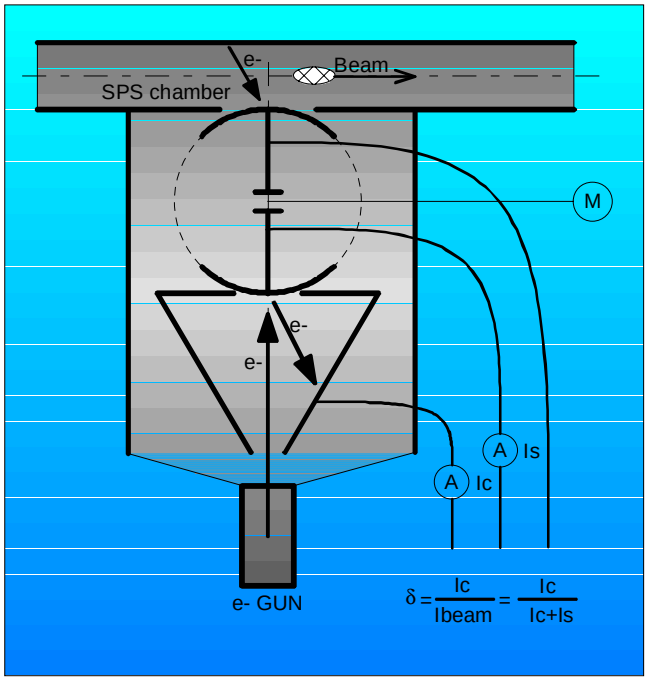
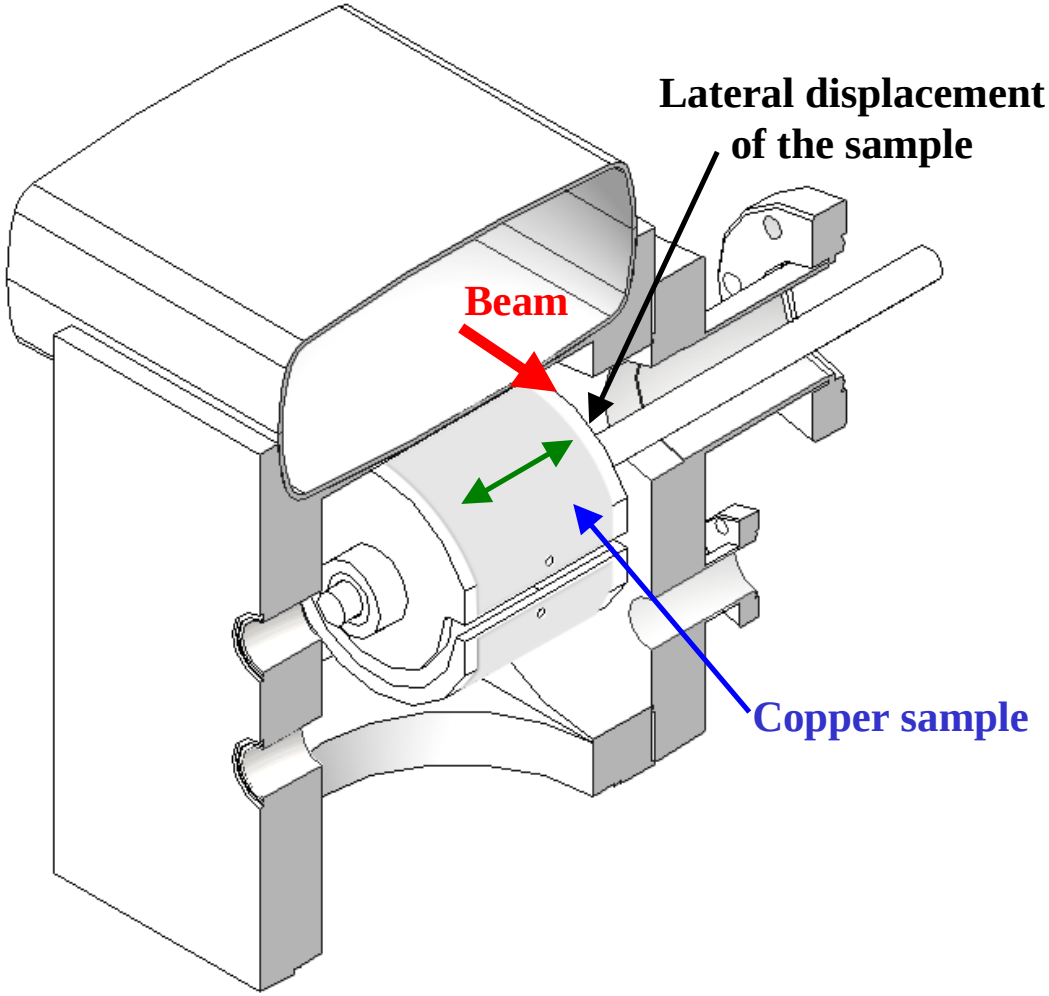
e^- Cloud studies in the SPS

SEY detector





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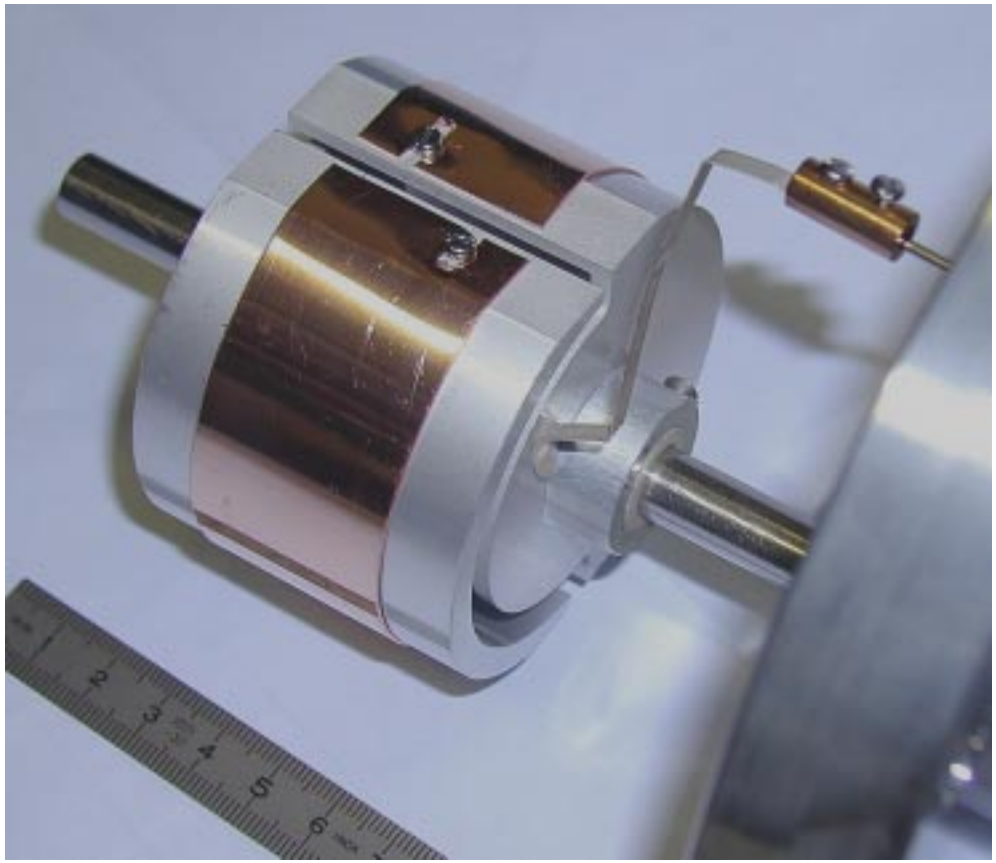
e^- Cloud studies in the SPS

SEY detector

Lateral view

Copper sample



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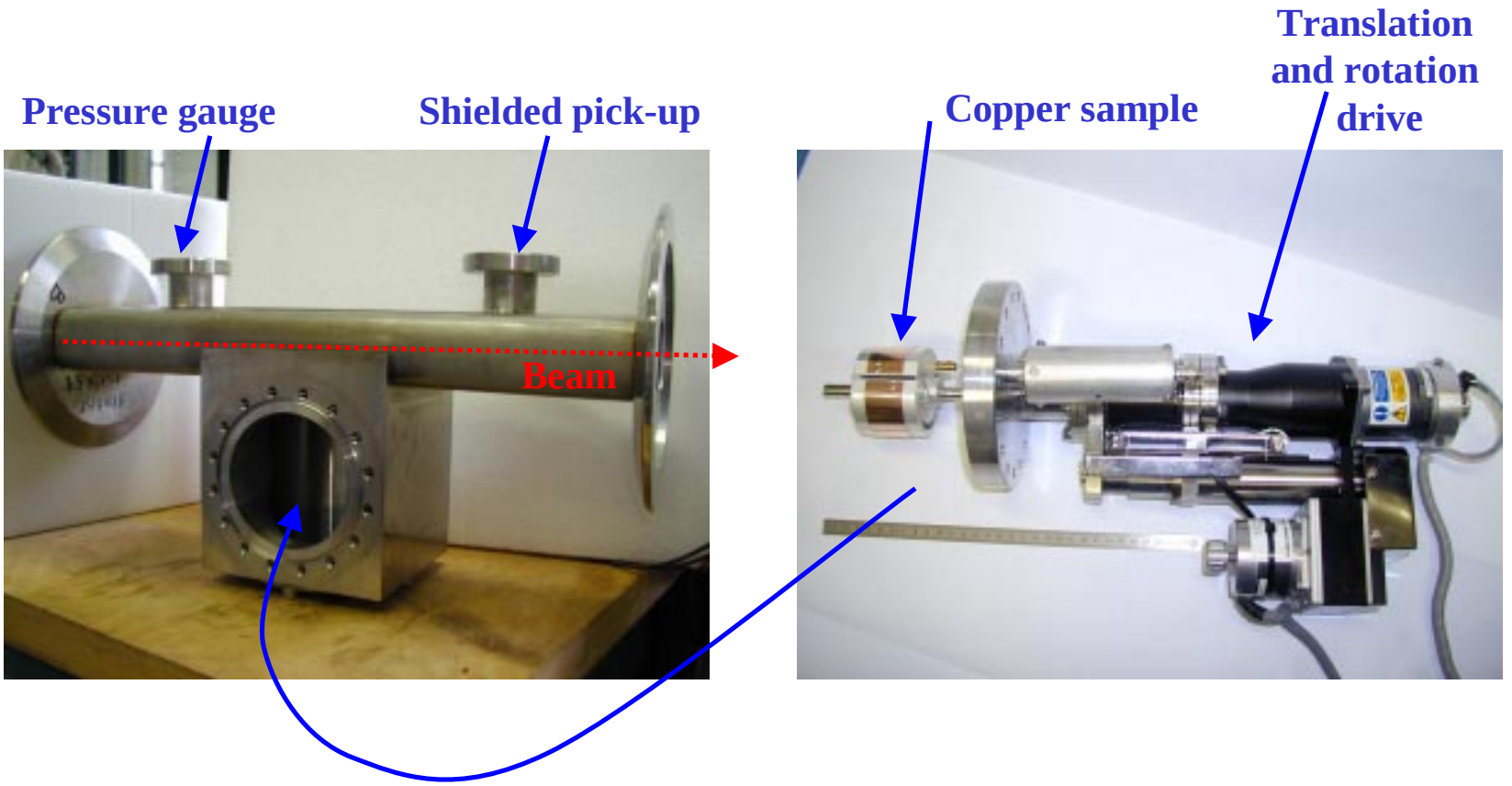
e^- Cloud studies in the SPS

SEY detector



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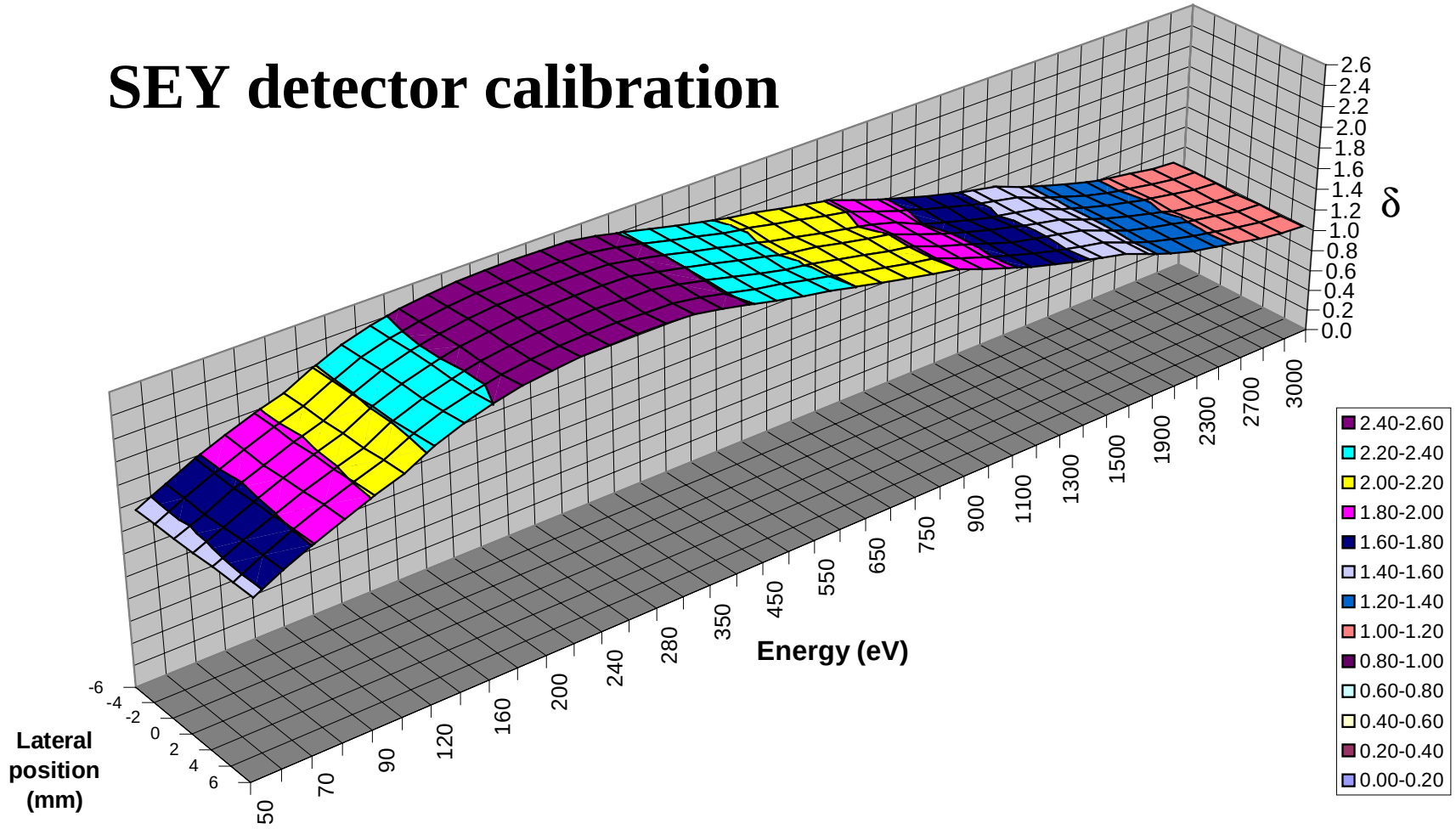
e^- Cloud studies in the SPS

SEY detector

SEY detector calibration



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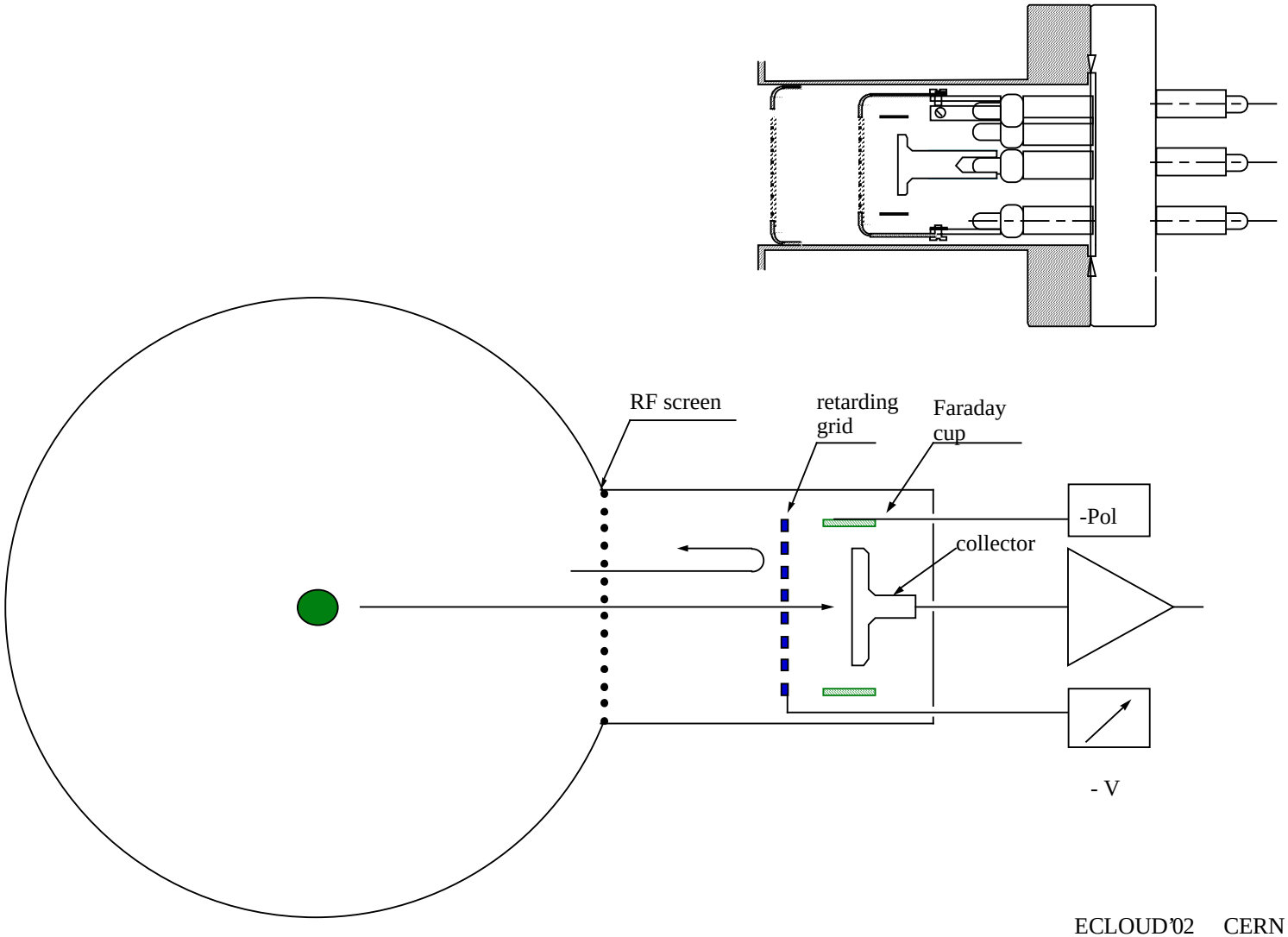
e^- Cloud studies in the SPS

Retarding field detector / Electron Energy



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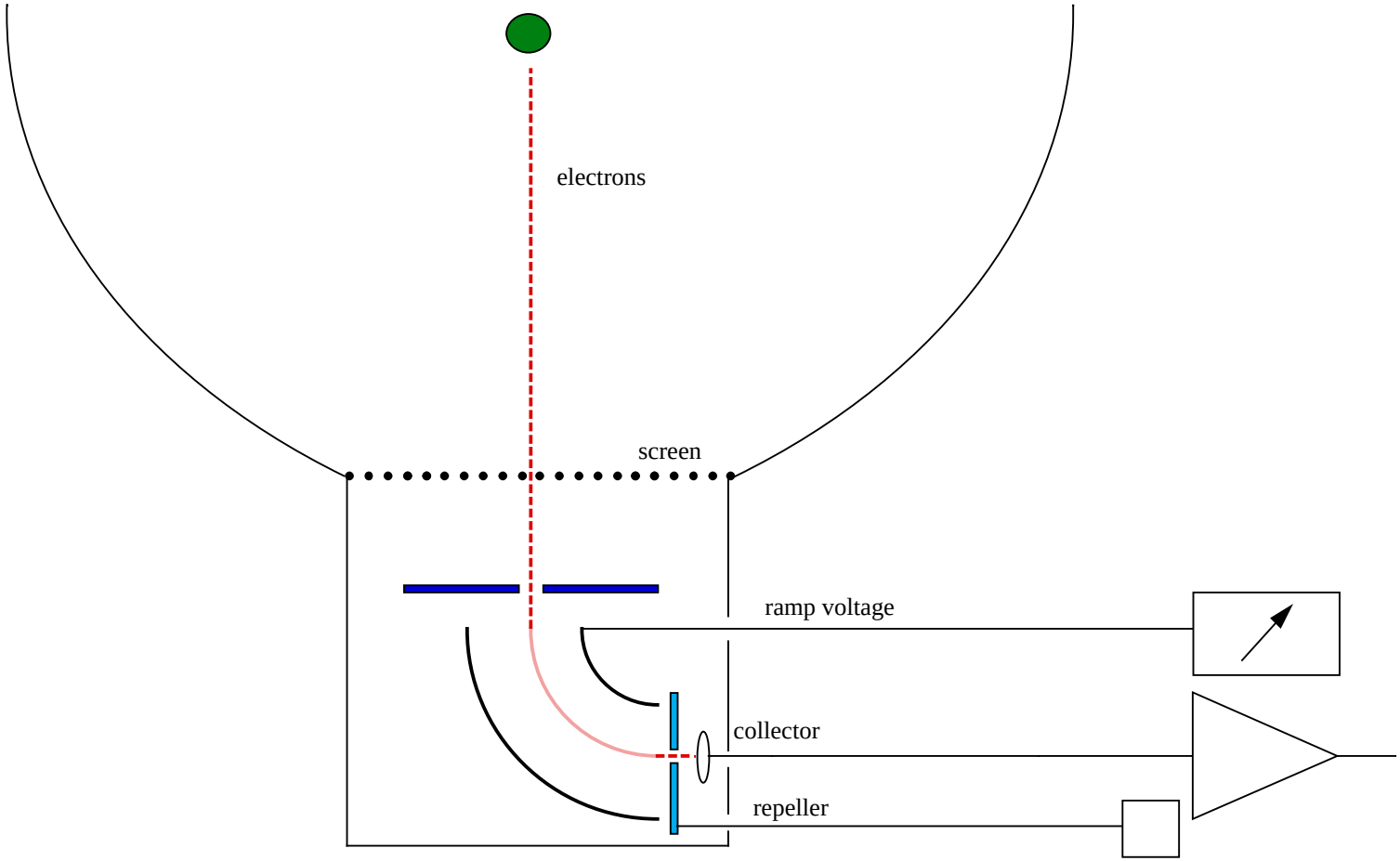
e^- Cloud studies in the SPS

Electrostatic energy analyser / Electron Energy



Electrostatic energy analyser

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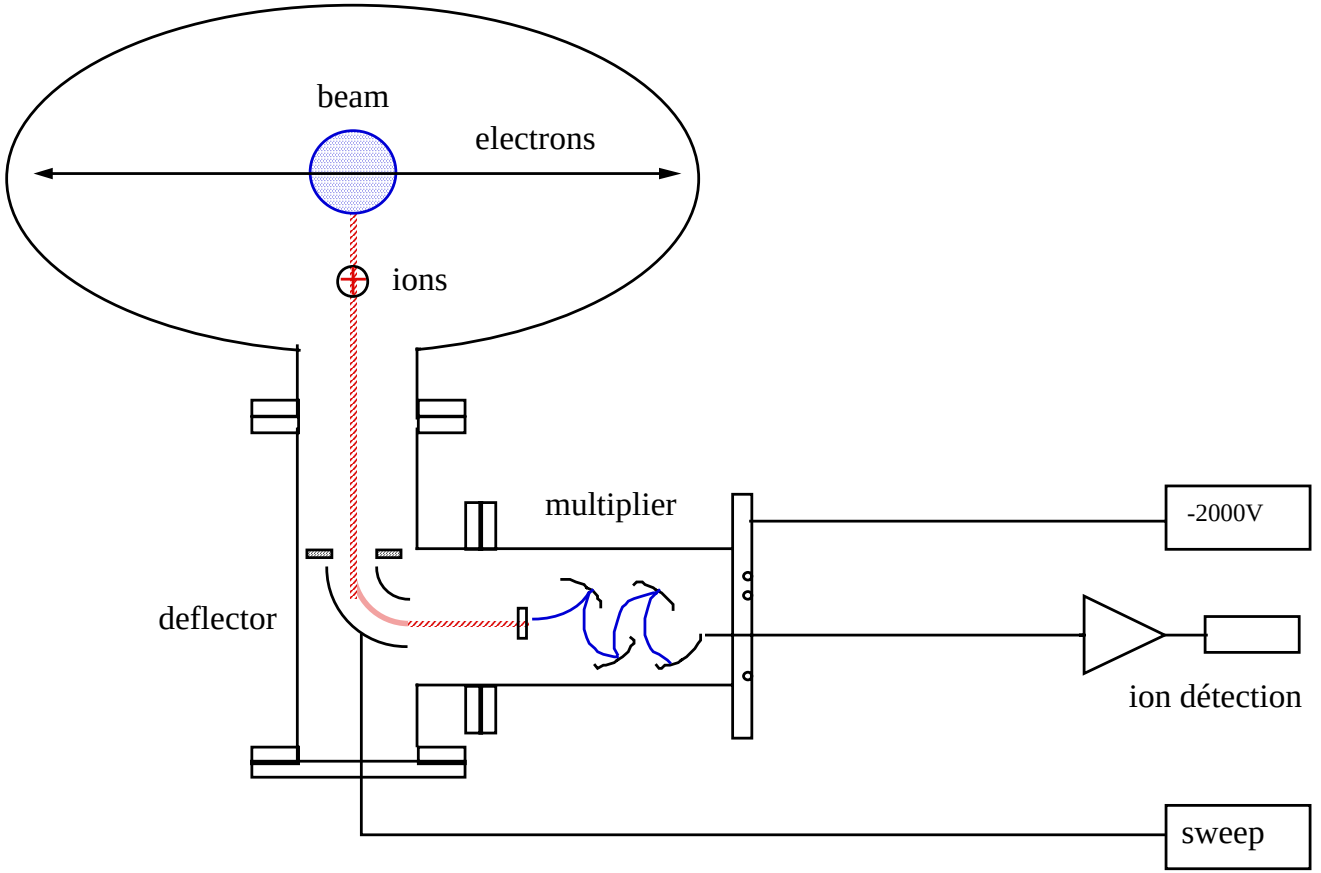
J.M. Jimenez, J.M. Laurent, U. Iriso, K. Weiss, F. Zimmermann

e^- Cloud studies in the SPS

Ions detector



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Conclusions - Objectives

- **Electron cloud phenomena**
  - Improve the results on the spatial distribution ☞ position of the pumping slots in LHC beam screens
  - Measure the energy distribution of the electrons ☞ crosscheck simulations ☞ simulate the scrubbing effect
- **Beam effects**
  - Study the effect of the 50 ns bunch spacing , missing bunches and satellite bunches as a possible way to reduce the electron cloud activity
  - Confirm the scrubbing effect as being a solution to decrease the secondary electron yield coefficient (δ)
- **LHC issues**
  - Measure the heat load due to the electron cloud in the SPS and extrapolate to the LHC beam conditions

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Scrubbing Period
Planning and Priorities (1)

- Definitions / Possible misunderstanding

  $\Delta P/P$ is a direct signature of the e^- bombardment. A decrease could be due to:

  - A cleaning of the surface (gas desorbed pumped by ion pumps)
  - A decrease of the e^- cloud activity X decrease of SEY (δ)

- Objectives of the scrubbing period
  - Measure the scrubbing time required in the SPS, after a shutdown, before being able to inject the LHC
    - Follow the decrease of the $\Delta P/P$
  - Validate the "scrubbing scenario" for the LHC
    - Decrease of SEY (δ) X decrease of the heat load in the cryo circuit

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Scrubbing Period
Planning and Priorities (2)

- Pressure interlocks will come first in the arcs
  - Start the scrubbing with 1 batch [5.0 - 5.5x10^{10} p/bunch]
    - Scrubbing in the arcs X $\Delta P/P$ will decrease (%30 in 3 days in 2001)
    - All detectors equipped with dipole field will be used

      Strip detector, SEY detector, Strip pick-ups, Wampac2, energy detectors…
- After about 2-3 days, increase the intensity to the highest value achievable with 1 batch
  - Reduce the duty cycle or dump earlier to cope with the $\Delta P/P$
    - Scrubbing both in the field free (if > 5.5x10^{10} p/b) and in the arcs
    - All detectors will be used

      Strip detector, SEY detector, Strip pick-ups, Wampac1 & 2, energy detectors, COLDEX, NEG Tests bench…

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Scrubbing Period
Planning and Priorities (3)

- "Set-up points"

  To compare the evolution of the ΔP/P, e^- cloud behaviours (threshold, intensity, build-up…)X Measurements in identical conditions should be made:

  – Before the scrubbing period
  – Before the multi-batch period
  – Before the end of the scrubbing period

Proposal: 1 batch of 48 bunches, variable intensities [up to the nominal]

- Multi-batch and LHC issues

  COLDEX, NEG test bench, Wampac1 will have their optimum resolution with 2 or 3 batches

X 2 periods of 8 h [Wednesday] and [Tuesday-Wednesday]

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