Electron Cloud Induced Pressure rises in the SPS

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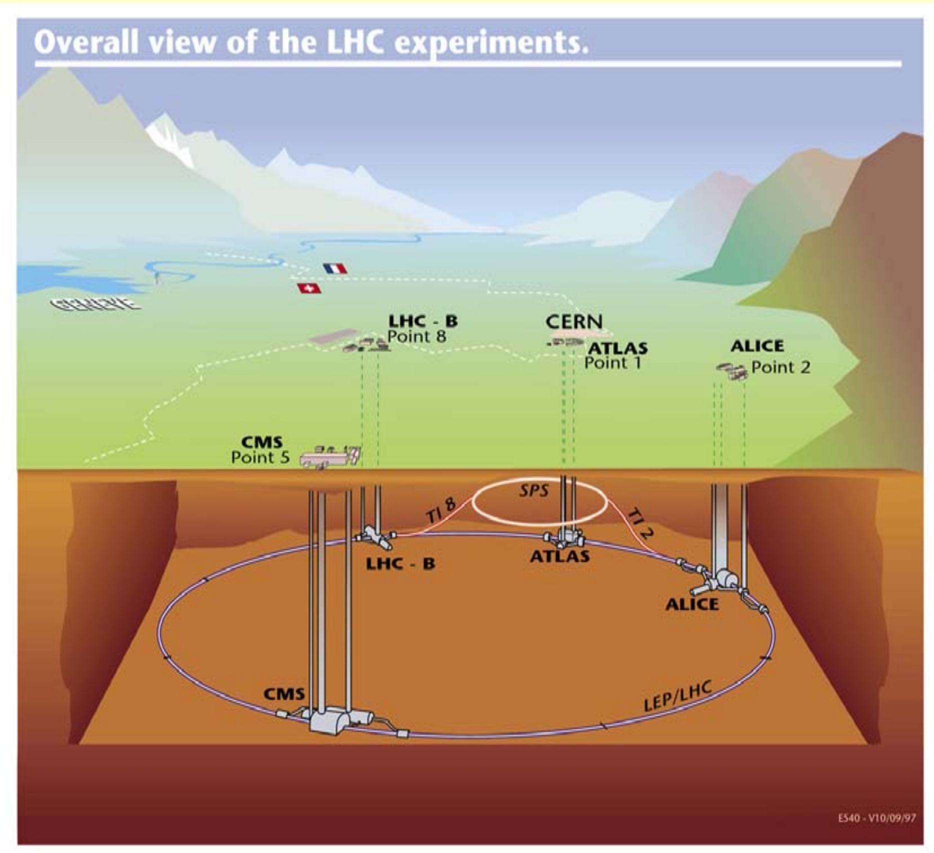
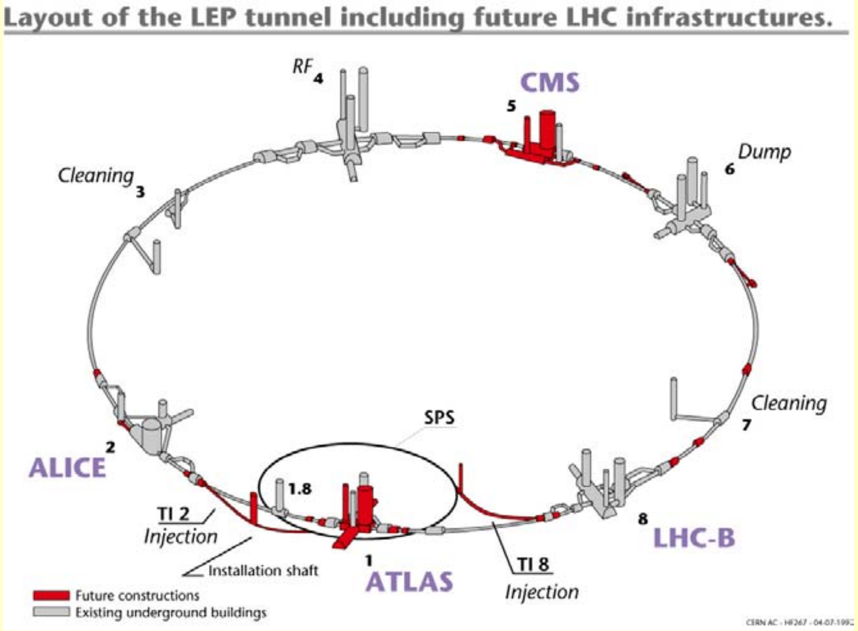
Main topics

- **Introduction – Definitions and SPS Running with LHC-type beams**
- **Strip detectors description (cold and variable aperture)**
- **Main results at 25 ns bunch spacing**
  - Electron cloud build up and thresholds
  - Energy and spatial distributions of the electrons in the cloud
  - Effect of the vacuum chamber height in DF and FF conditions
  - Effect of the ramp to 450 GeV / orbit displacement
  - Beam conditioning at 30 K / RT
- **Preliminary results at 75 ns bunch spacing**
- **NEG coatings: A remedy to the e^- cloud in the RT parts?**
  - Behaviour of an activated NEG, activated + saturated NEG and effect of a continuous injection of electrons.
- **Conclusions**

Introduction
SPS machine





Introduction
Definitions

During the "scrubbing" runs, two mechanisms could take place simultaneously :

Vacuum cleaning/scrubbing,

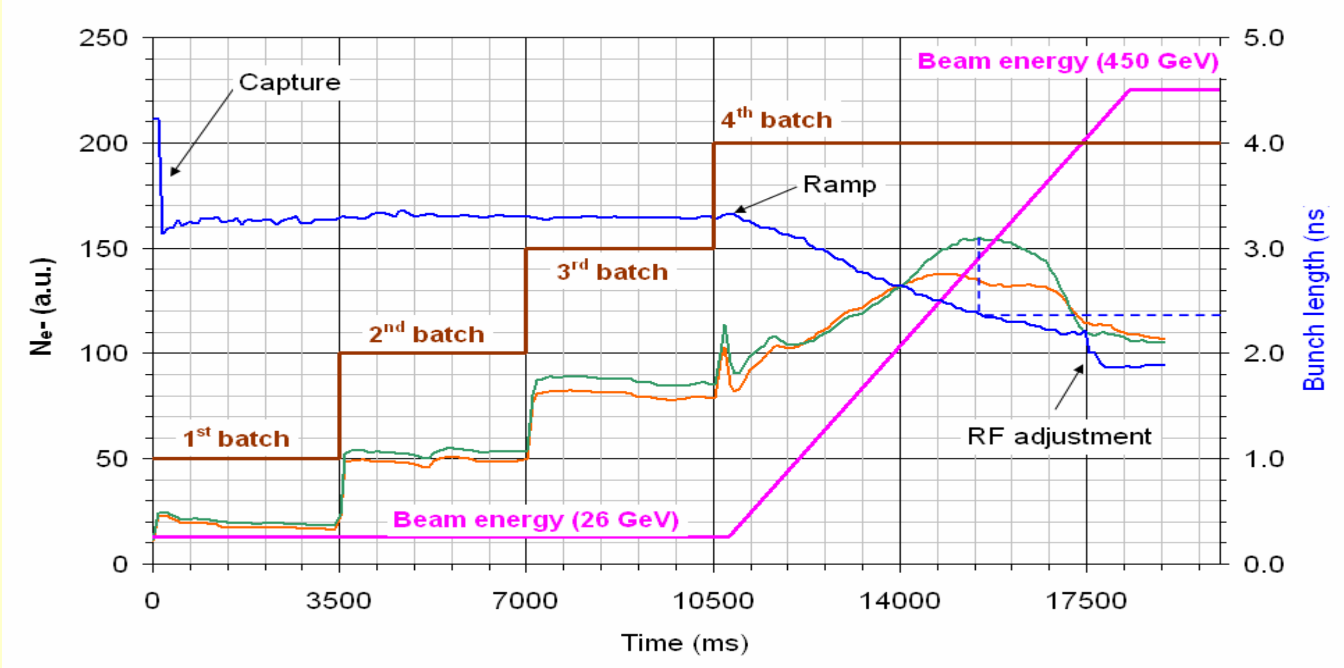
- ⇨ Characterised by a decrease of pressure with the beam time due to the bombardment of the surface by the electrons, photons and ions.

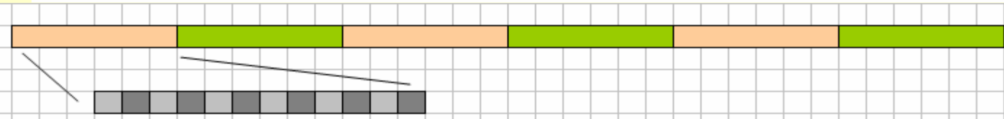
Beam conditioning

- ⇨ Characterised by an improvement of the performances of the device during its first hours of operation. Example of RF cavities called RF conditioning or for a metallic surface where the conditioning by the electrons bombardment is characterised by a decrease of the SEY.

Introduction

SPS Running with LHC-type beams

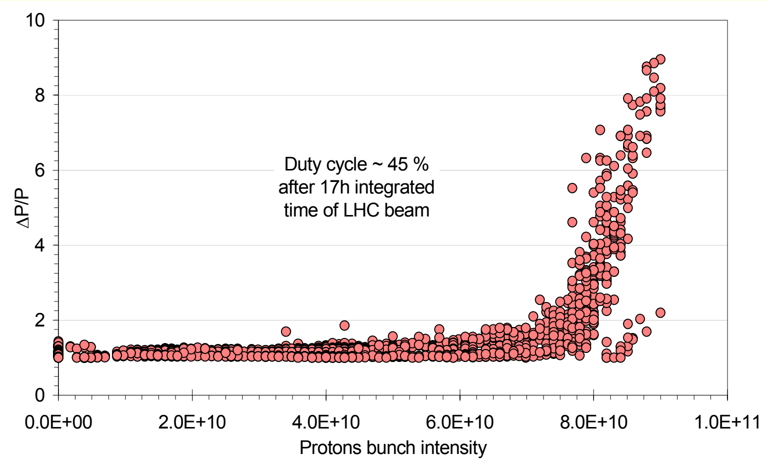


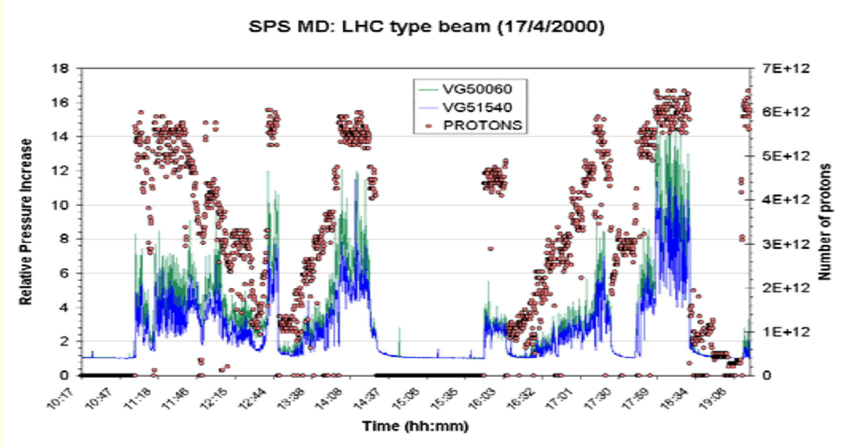


3 or 4 batches injected in the SPS	0 Injection of 1st batch at 26 GeV
Batch injection every 3.5 s	3500 Injection of 2nd batch
225 ns batch spacing	7000 Injection of 3rd batch
72 bunches per batch	10500 Injection of 4th batch
25 ns bunch spacing	10800 Staring ramp to 450 GeV
10^{11} protons per bunch	18300 Flat top at 450 GeV during ~ 2 s
4ns bunch length at injection	

Introduction

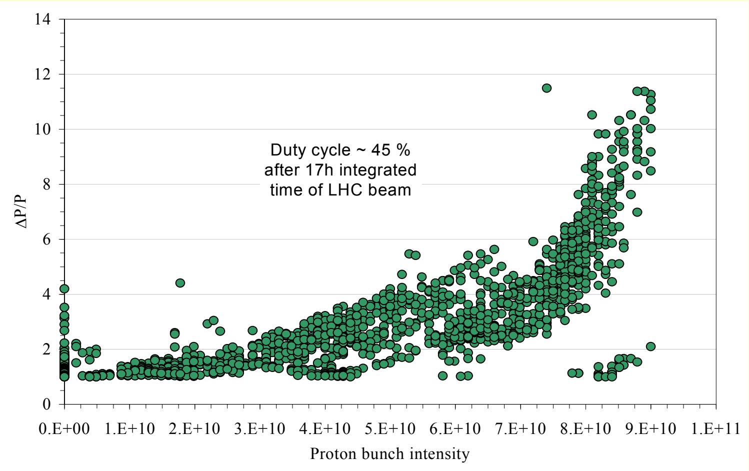
Specific diagnostic detectors absolutely required

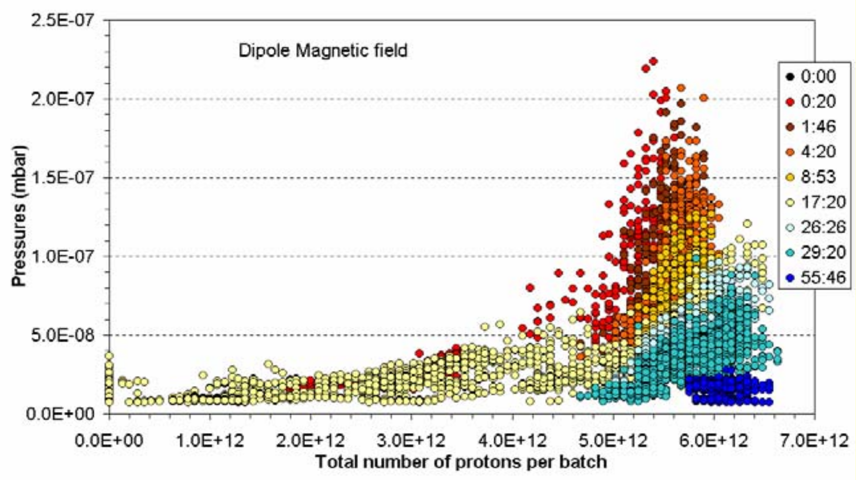




Different behavior between DF and FF

Beam conditioning and bunch dependence observed but results easily understandable

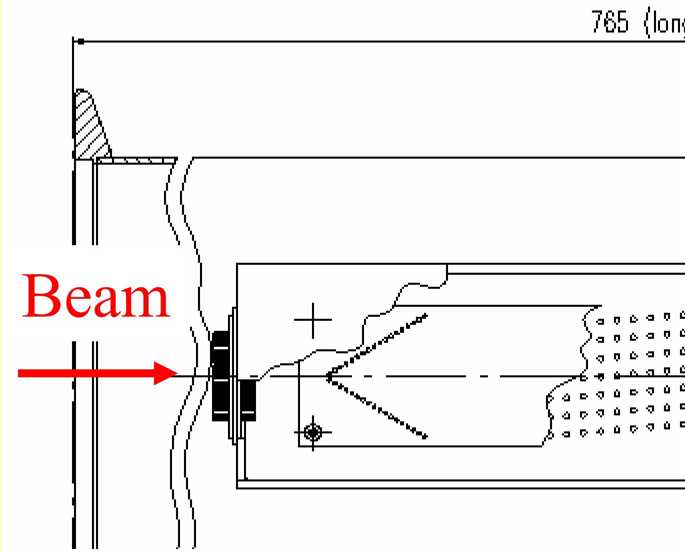


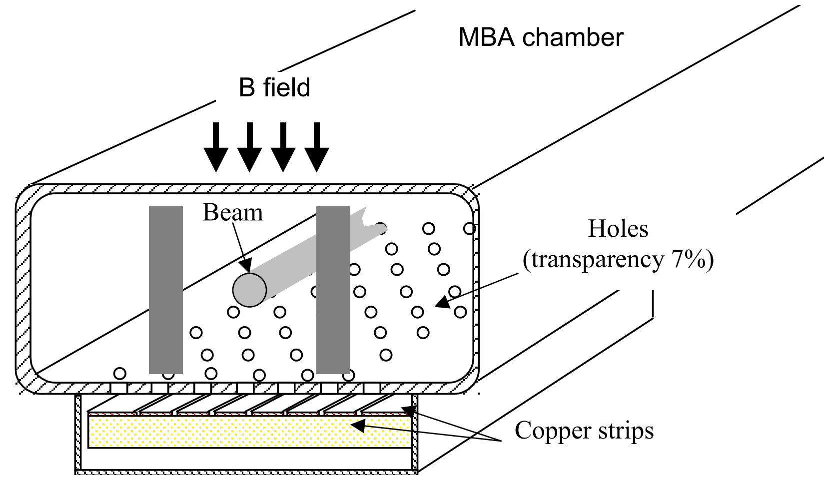


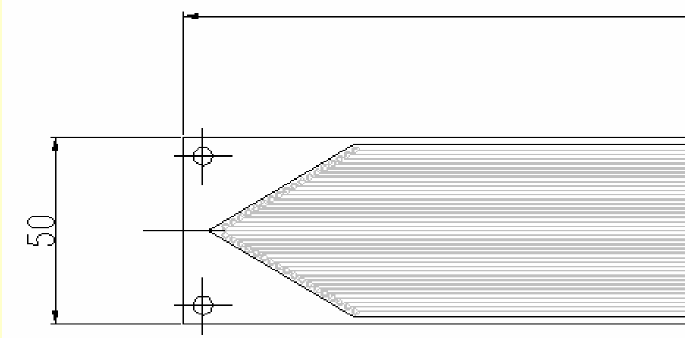
Set up description

…48 channels Strip detectors…

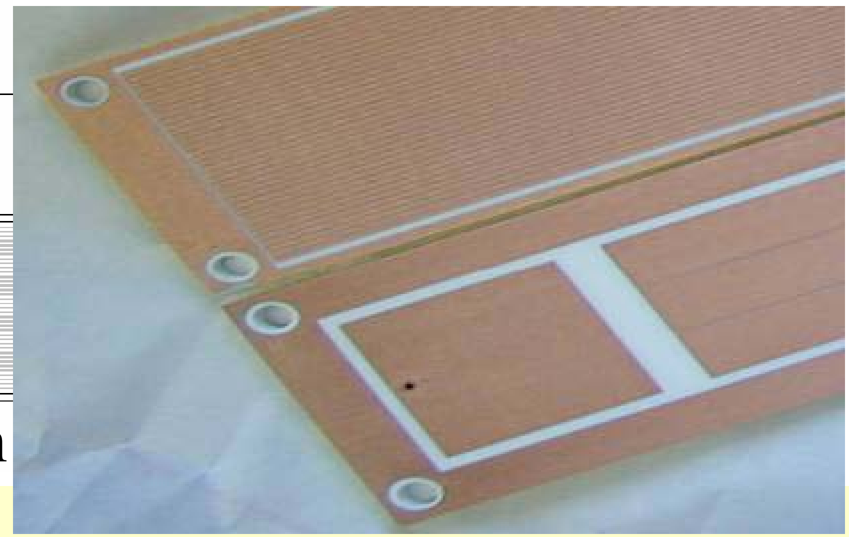
Available in a dipole field region



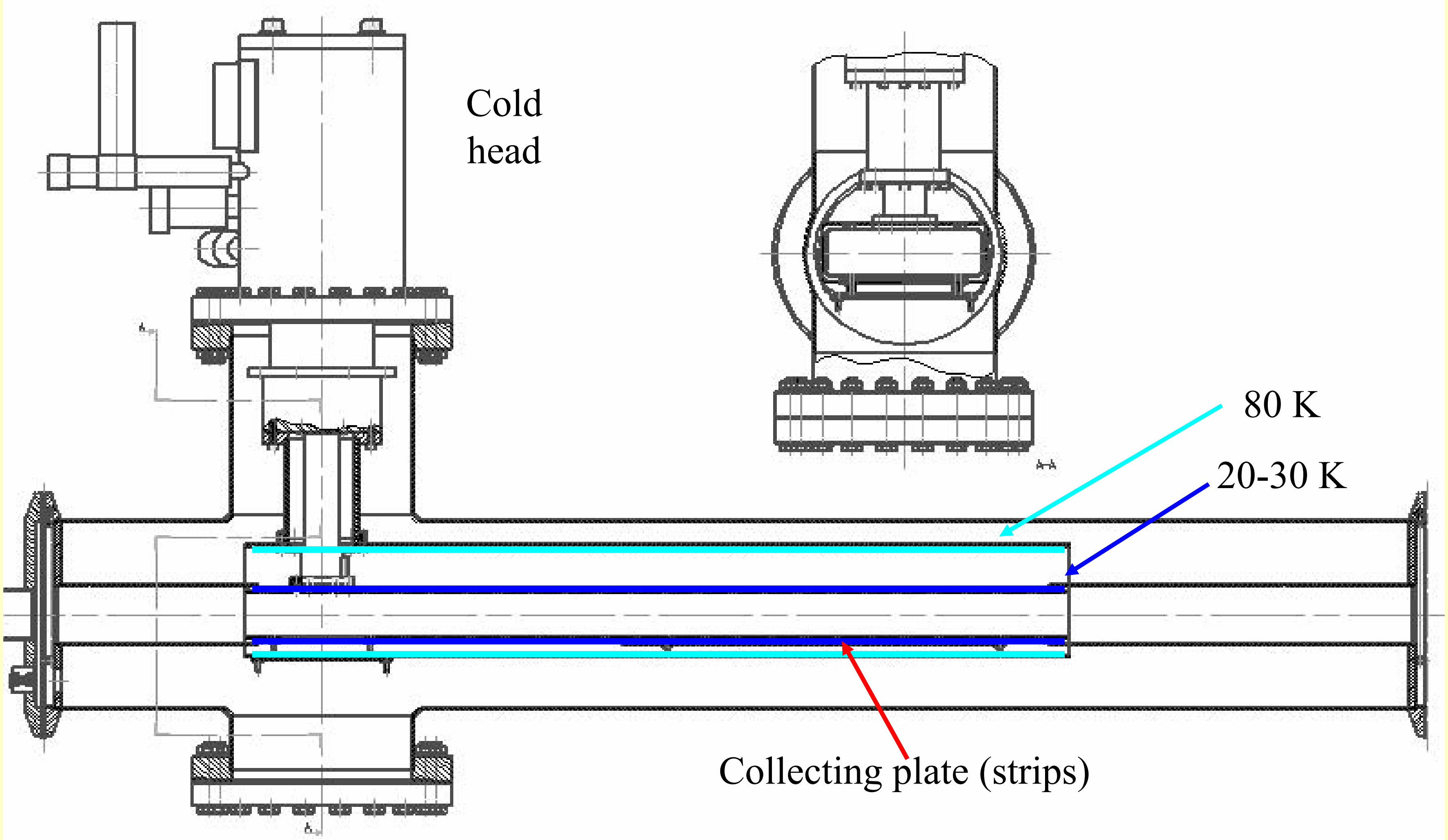




Spatial resolution: 1.25 mm

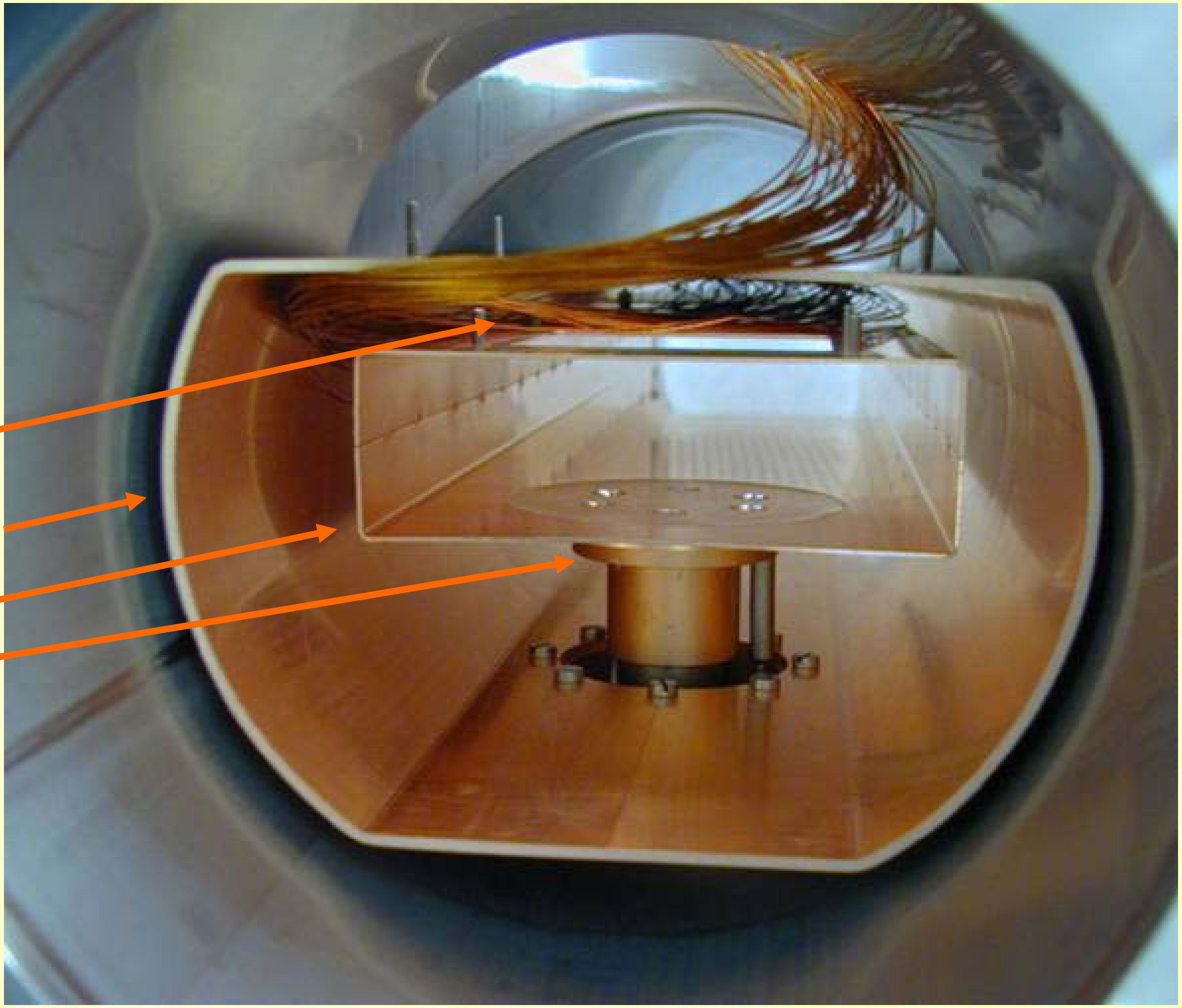


Set up description
…Cold Strip Detector…



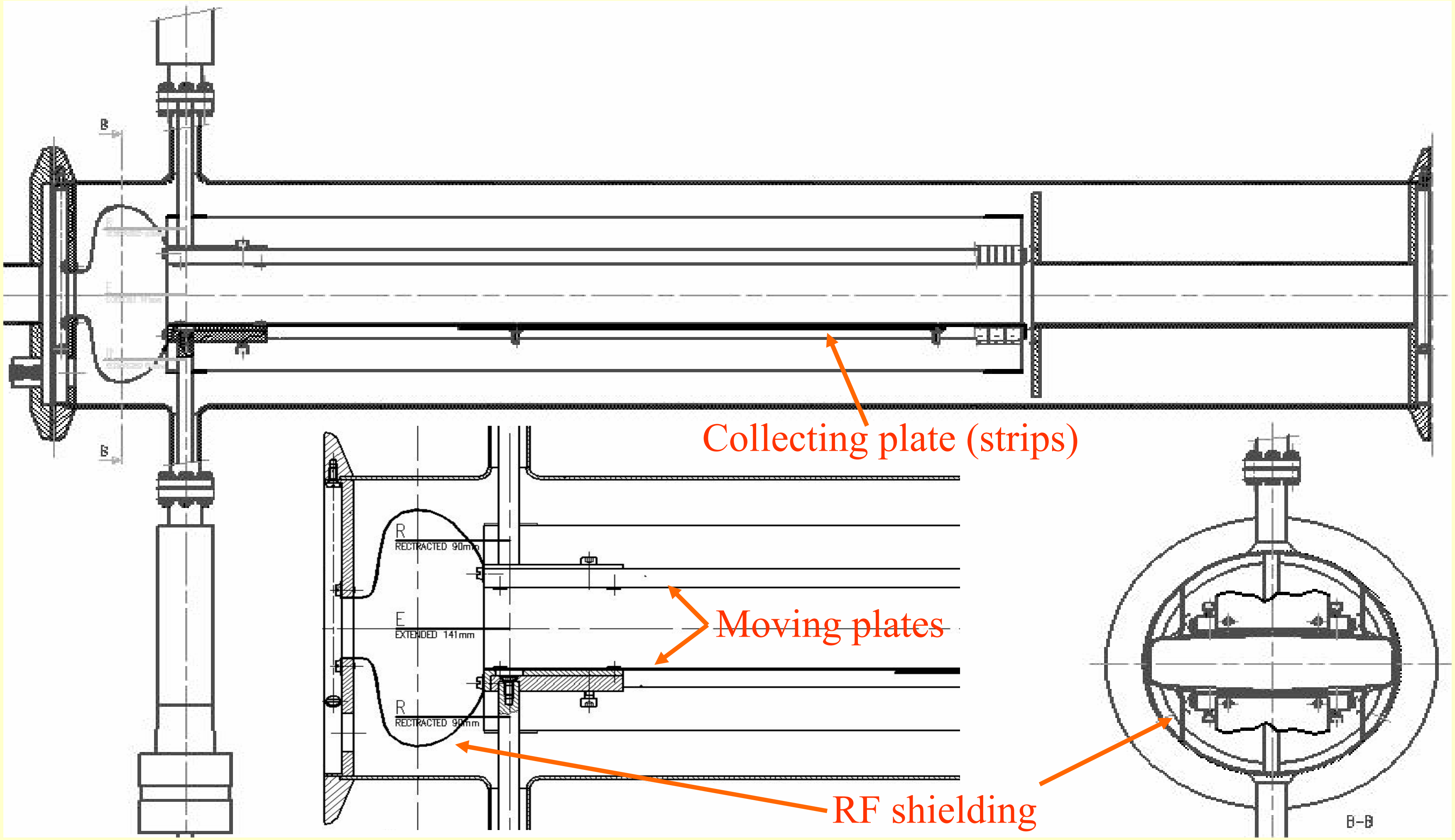
Set up description
…Cold Strip Detector…

- Collecting strips
- Thermal shielding (80 K)
- Beam "pipe" (< 30 K)
- Cold head



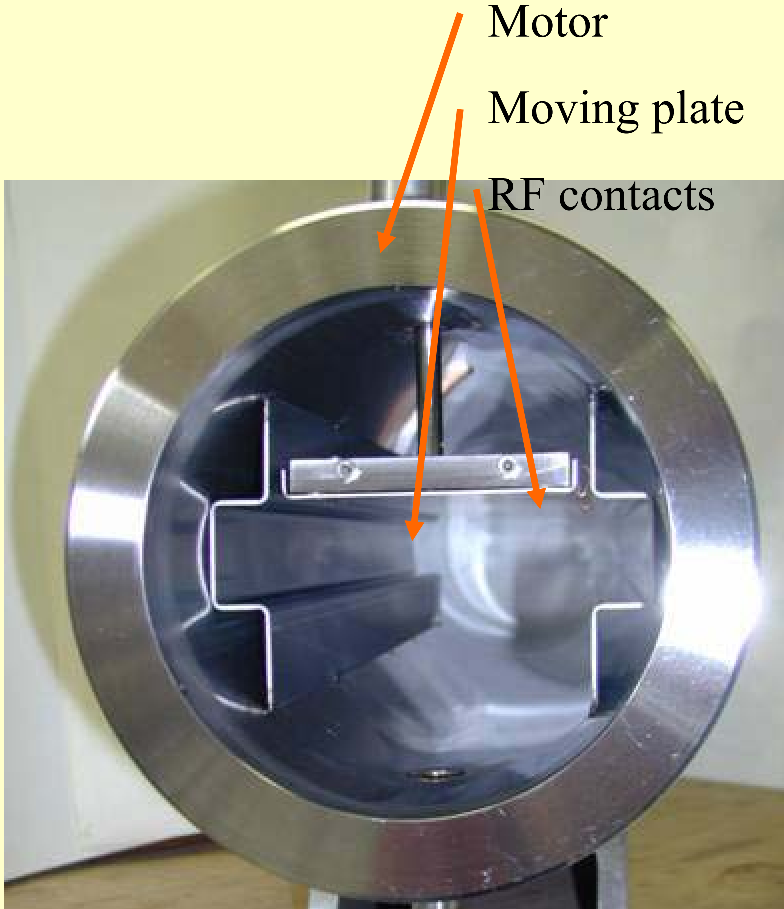
Set up description

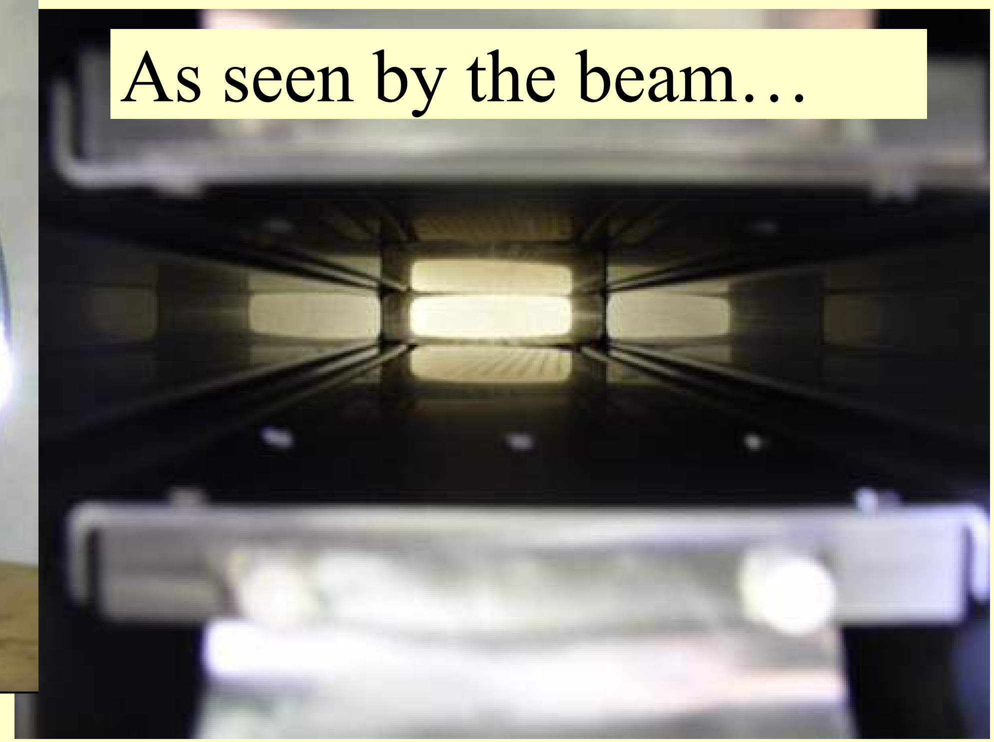
…Variable Aperture Strip Detector…



Set up description

…Variable Aperture Strip Detector…



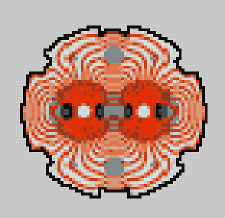


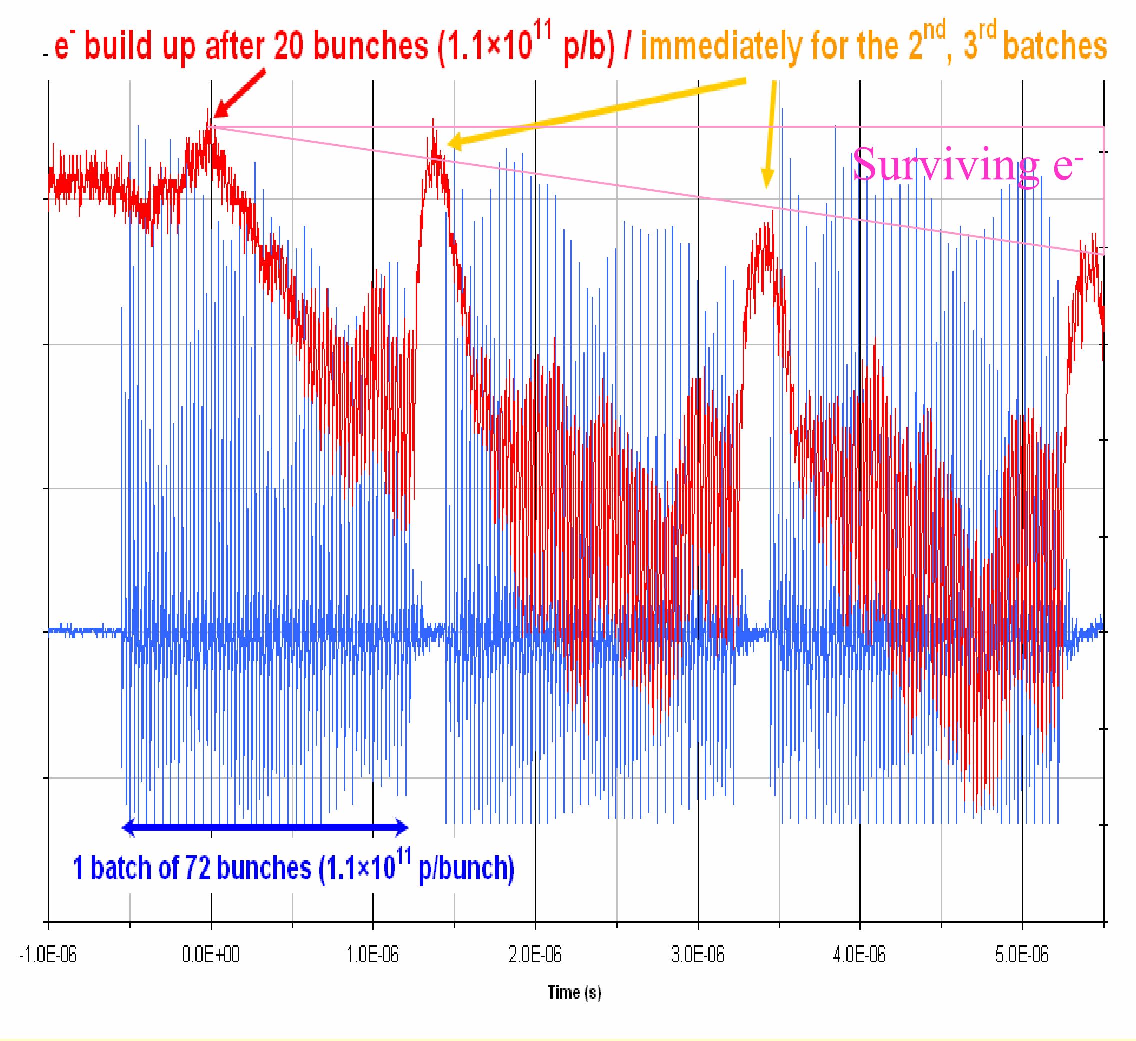
e^- cloud build up @ 25 ns bunch spacing
Thresholds and filling pattern

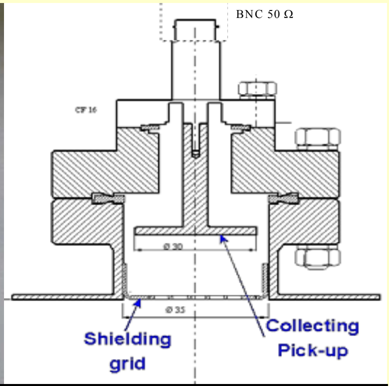
- **Electron cloud build up and thresholds**
  - Bunch intensity thresholds: 3.0×10^{10} p/b in DF instead of 5.0×10^{10} p/b in FF
  - At 1.1×10^{11} p/b:
    ⇨ **build up start after only 20 bunches**
    ⇨ **“Surviving” electrons observed between batches**
- **Filling pattern**
  - Bunch intensity ⇨ Linear dependence; in DF: $N_{e^-}(1.1\times10^{11})$= **5** × $N_{e^-}(5.0\times10^{10}$ p/b)
  - Number of batches (filling factor) ⇨ Linear dependence
  - Bunch spacing (meas. in 2001) ⇨ Electron cloud visible with 50 ns bunch spacing
  - Batch spacing ⇨ > 550 ns required to decouple the effect of successive batches
  - Missing 12 bunches reduced but did not suppressed e^- cloud (factor 8)
  - Bunch length (4ns) ⇨ N_{e^-} × **2** when the bunch length is decreased by 30%

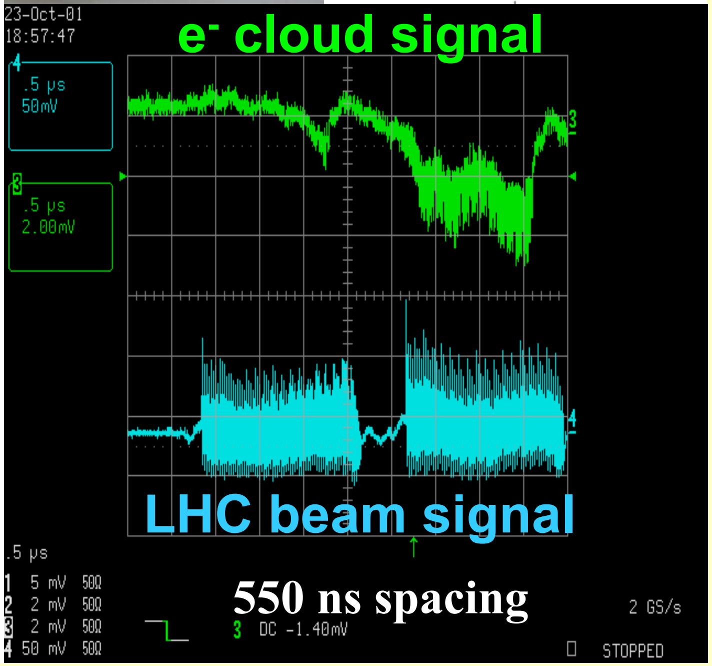
e^- cloud build up @ 25 ns bunch spacing

Build up measured using a shielded pick-up





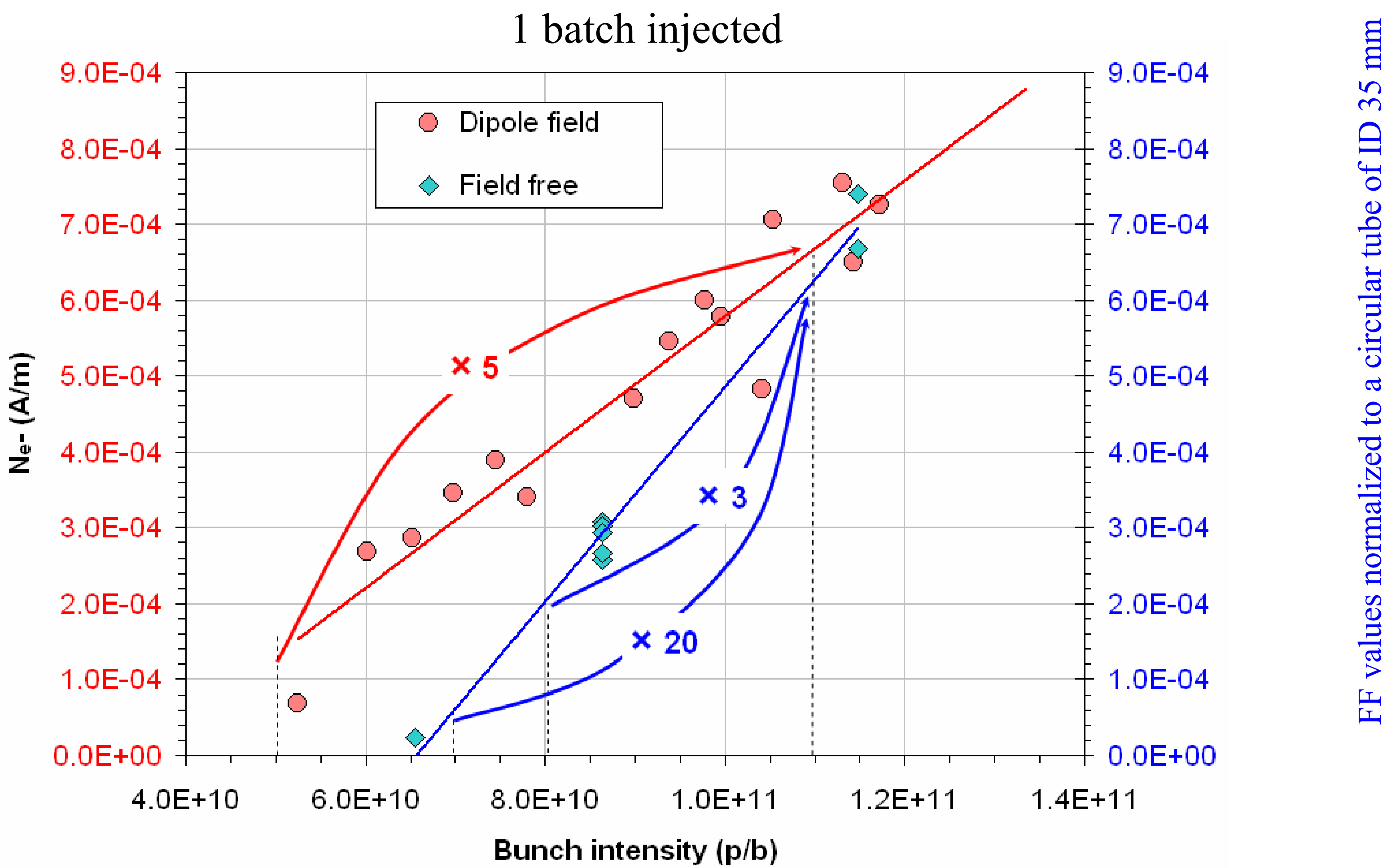




e^- cloud build up @ 25 ns bunch spacing

Build up measured using a strip detector

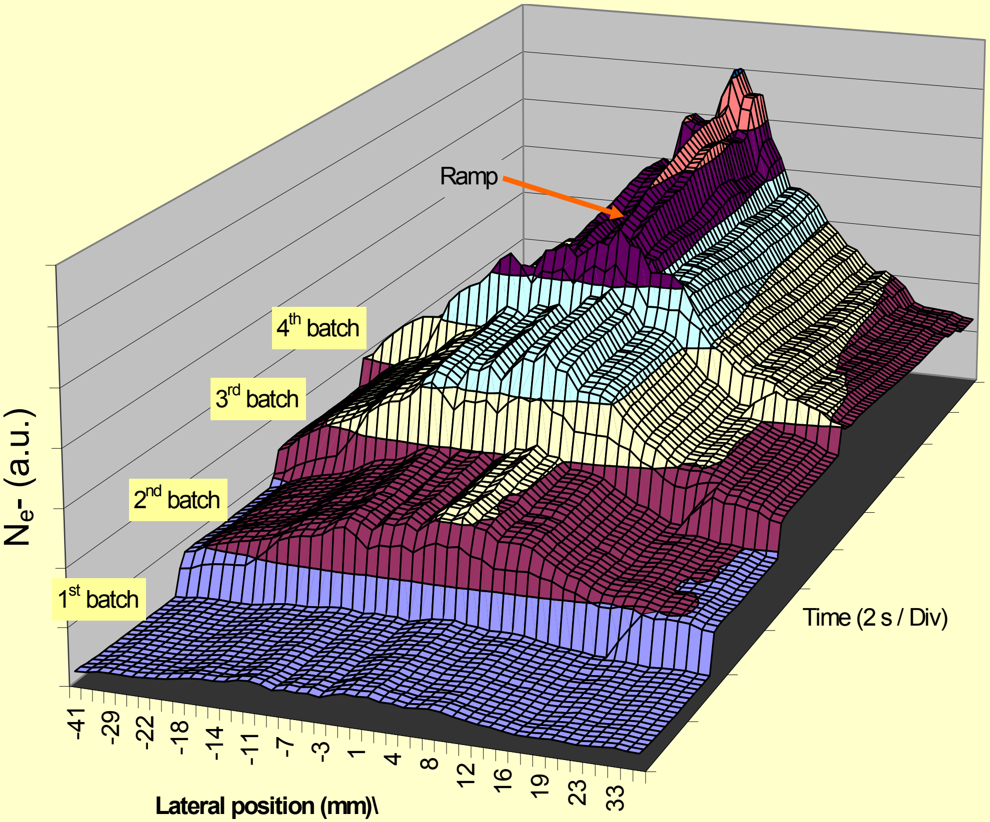
Effect of the bunch intensity



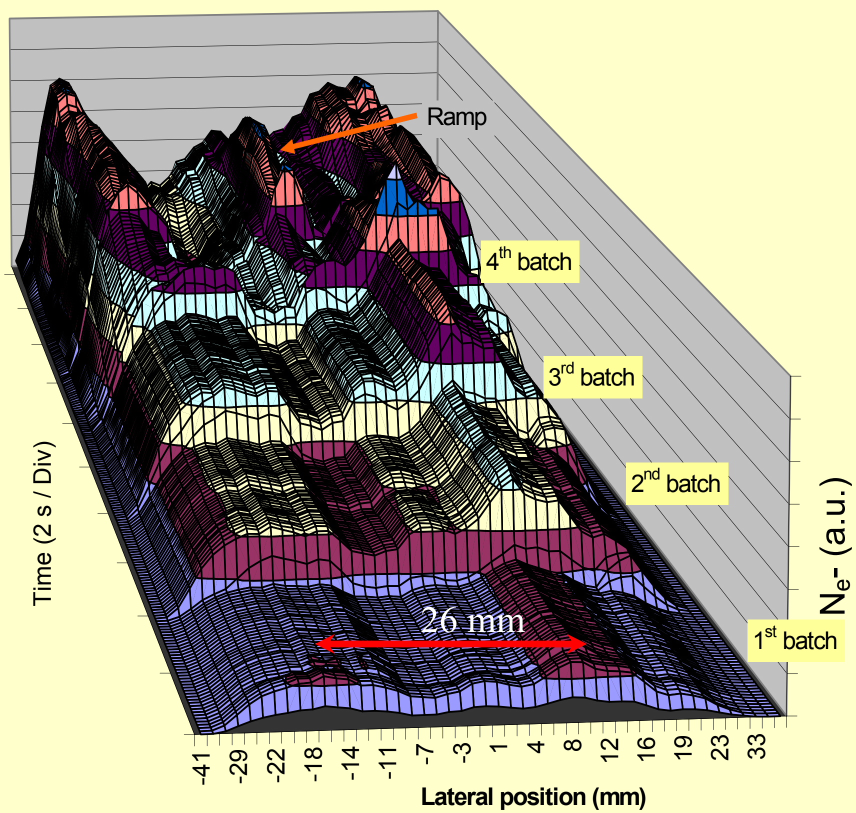
e^- cloud build up @ 25 ns bunch spacing

Build up measured using a strip detector

In field free conditions

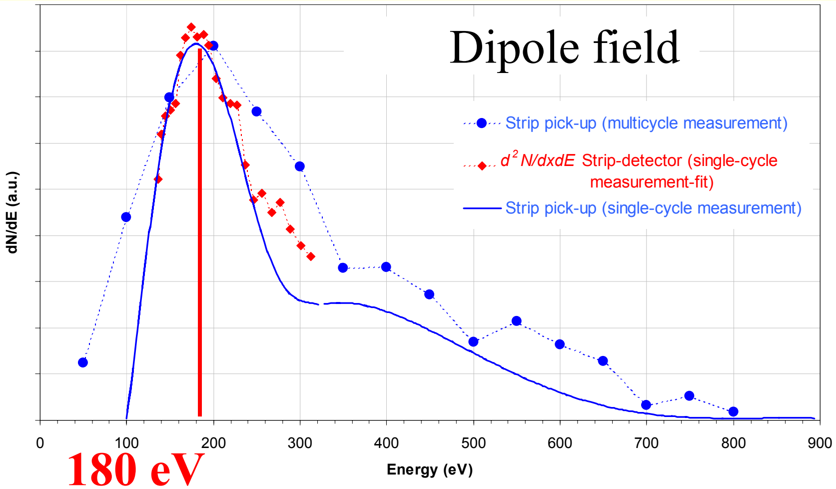


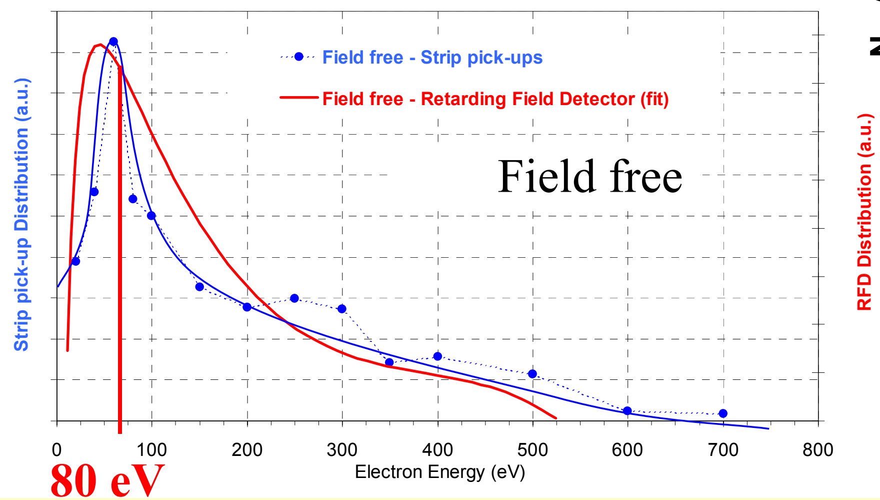
In dipole field conditions

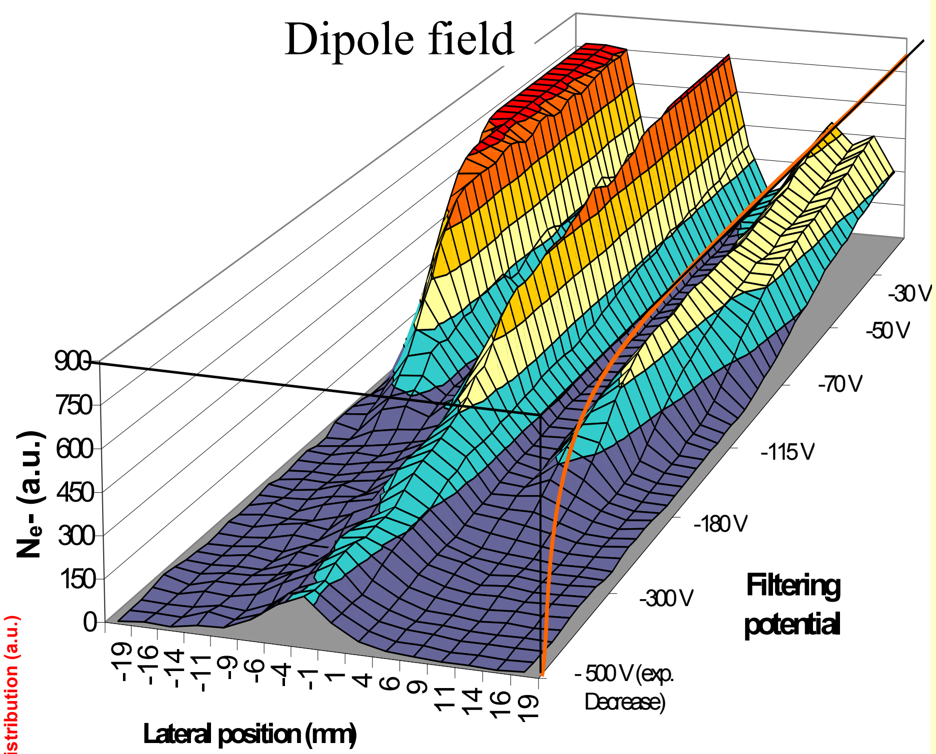


e^- cloud build up @ 25 ns bunch spacing

Energy distributions in FF and DF conditions







Heat load efficiency = HLE

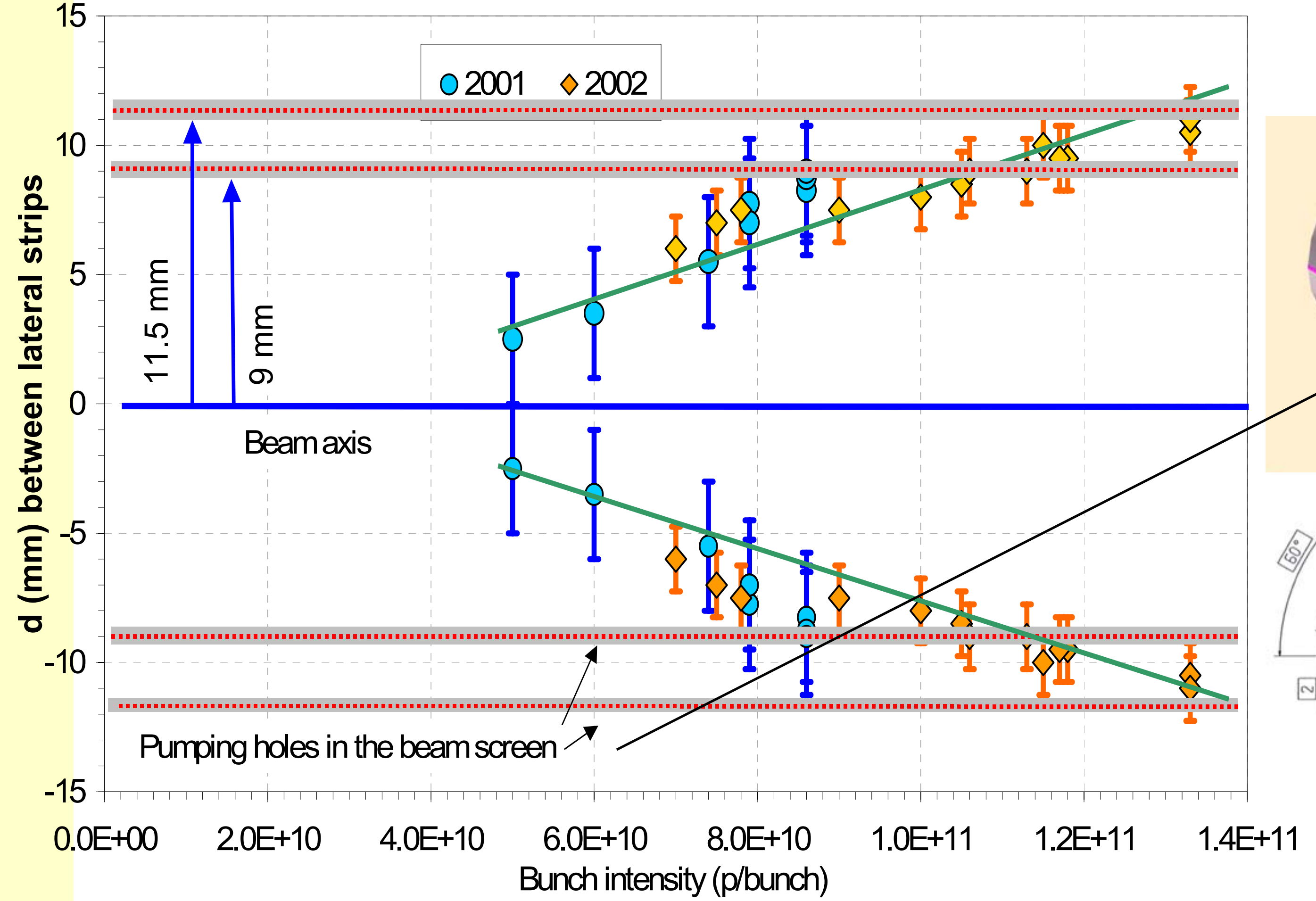
$e^-_{HLE}(DF)$= 1.7 × $e^-_{HLE}(FF)$

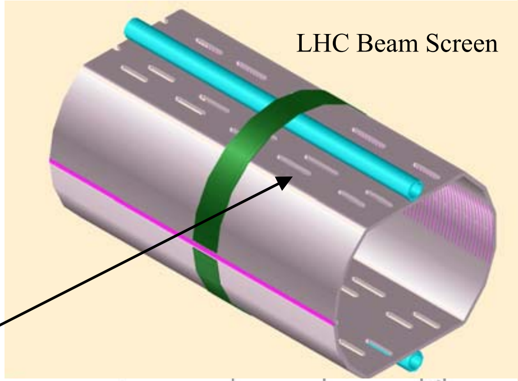
E_e->180 eV located in the centre

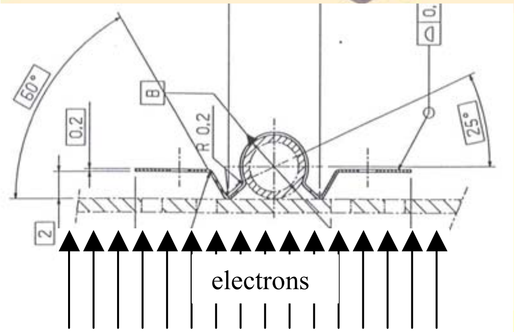
⇨ faster beam conditioning observed

e^- cloud build up @ 25 ns bunch spacing

Spatial distribution / baffles to intercept electrons





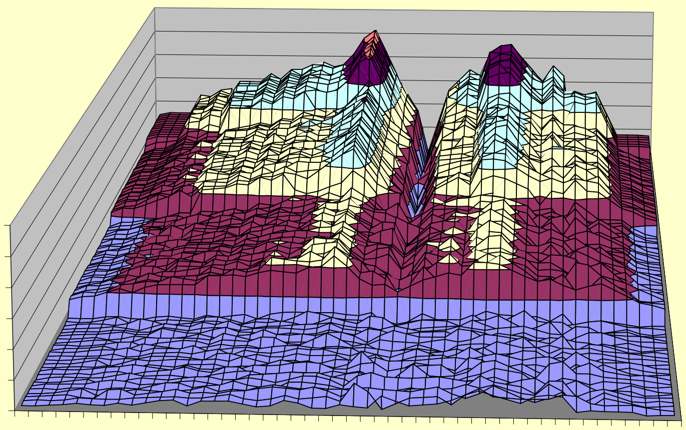


e^- cloud build up @ 25 ns bunch spacing

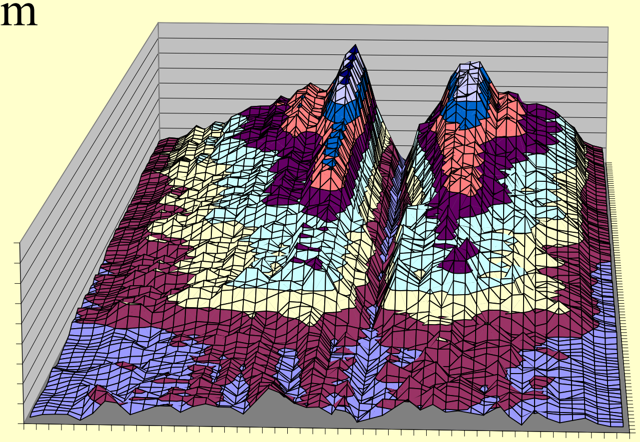
Spatial Distribution at RT /FF

Dependence on Vacuum chamber height

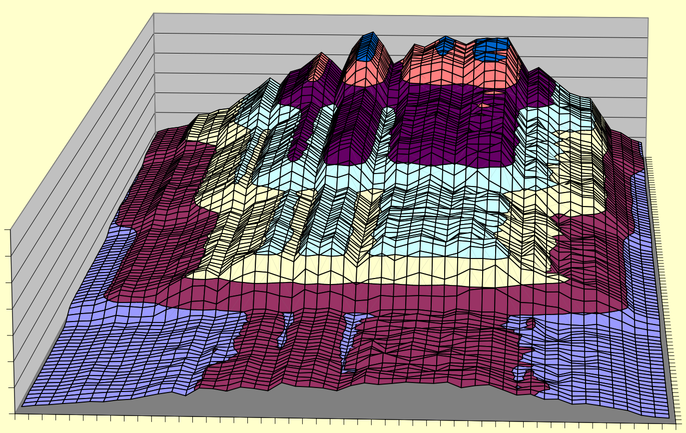
35mm



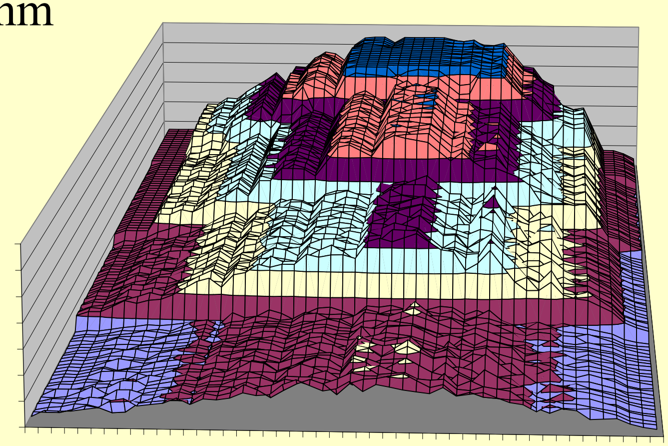
50mm



65mm



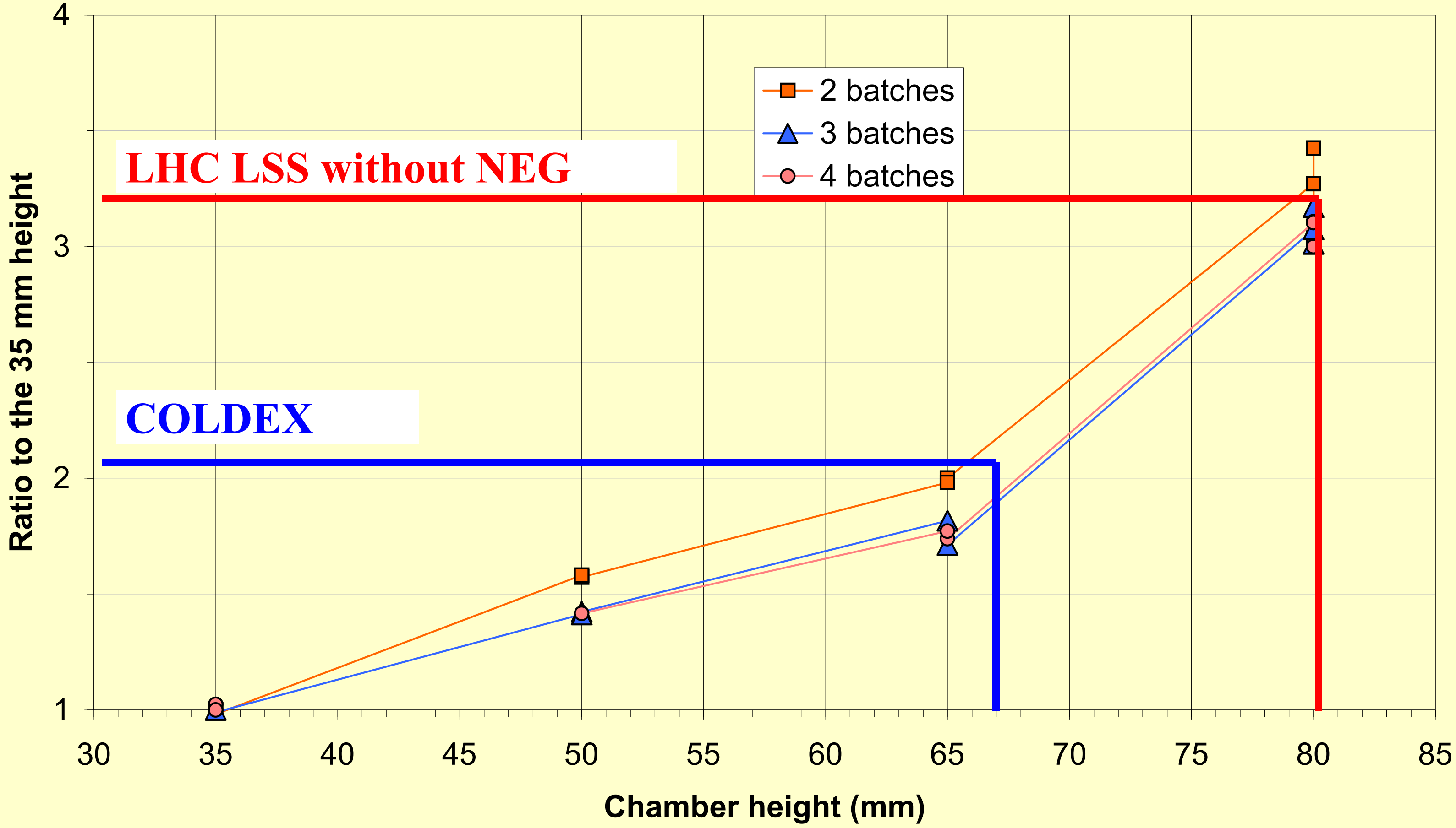
80mm



e^- cloud build up @ 25 ns bunch spacing

Spatial Distribution at RT /FF

Dependence on Vacuum chamber height

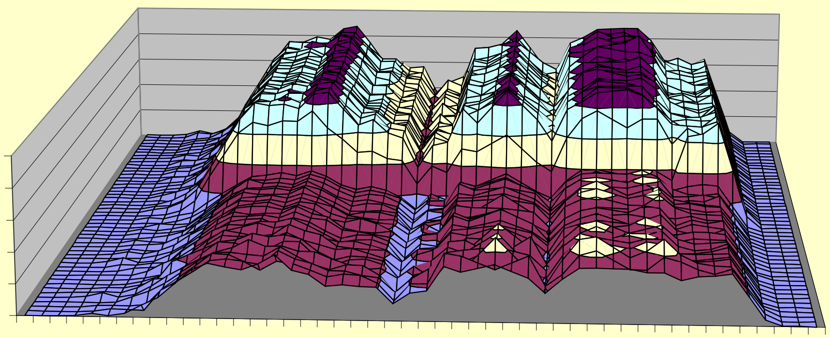


e^- cloud build up @ 25 ns bunch spacing

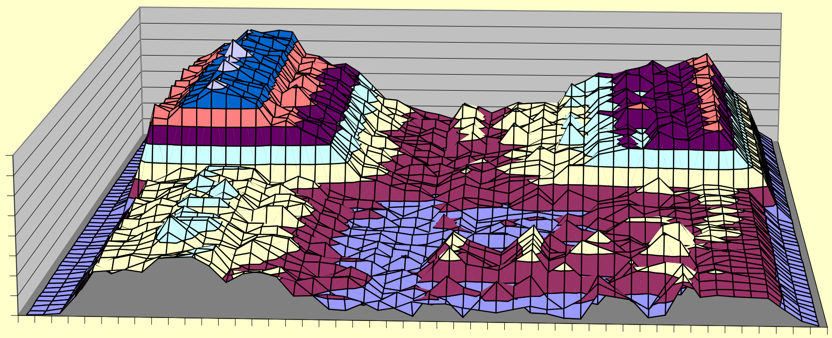
Spatial Distribution at RT /DF

Dependence on Vacuum chamber height

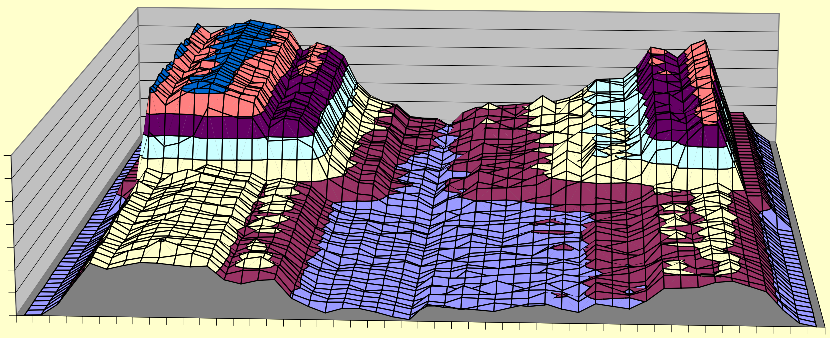
40mm



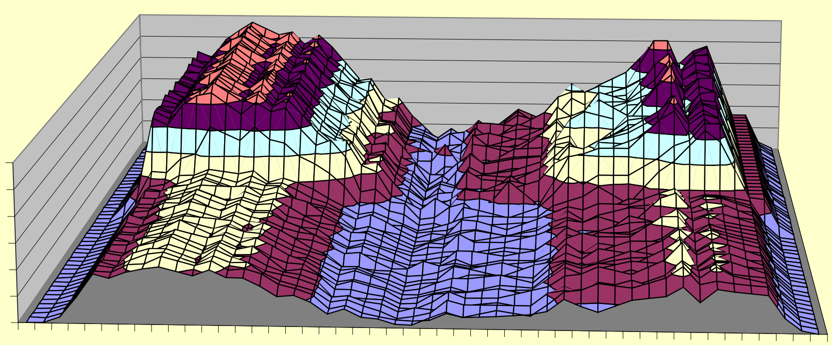
60mm



70mm



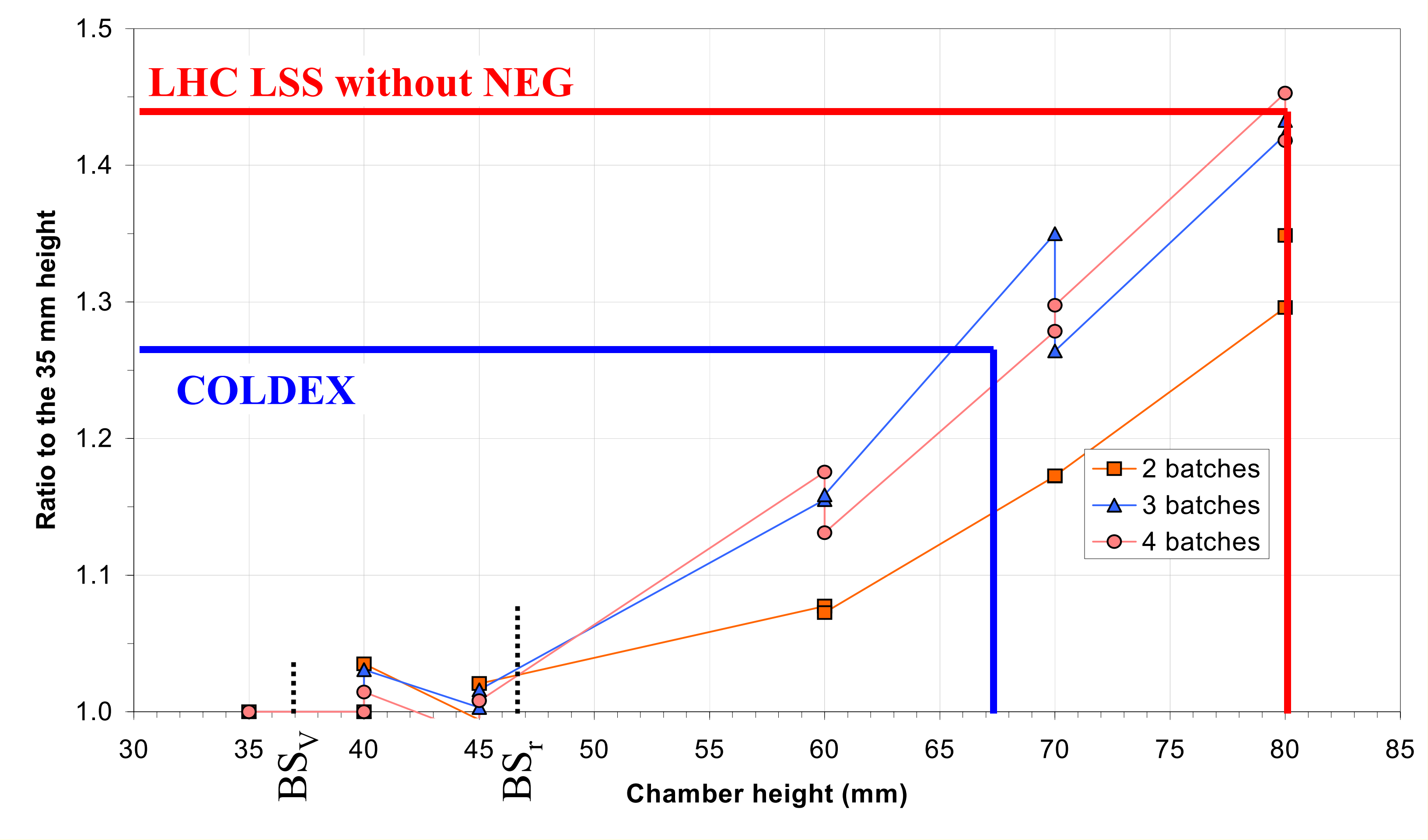
80mm



e^- cloud build up @ 25 ns bunch spacing

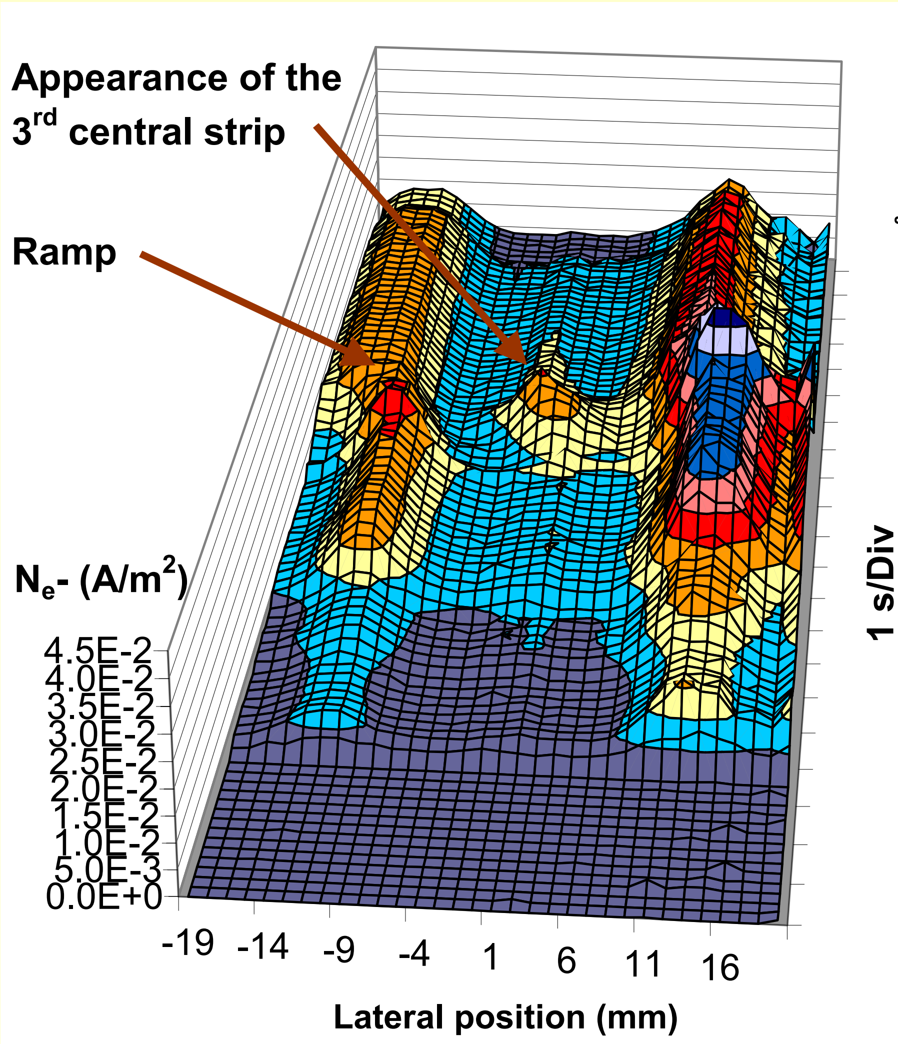
Spatial Distribution at RT /DF

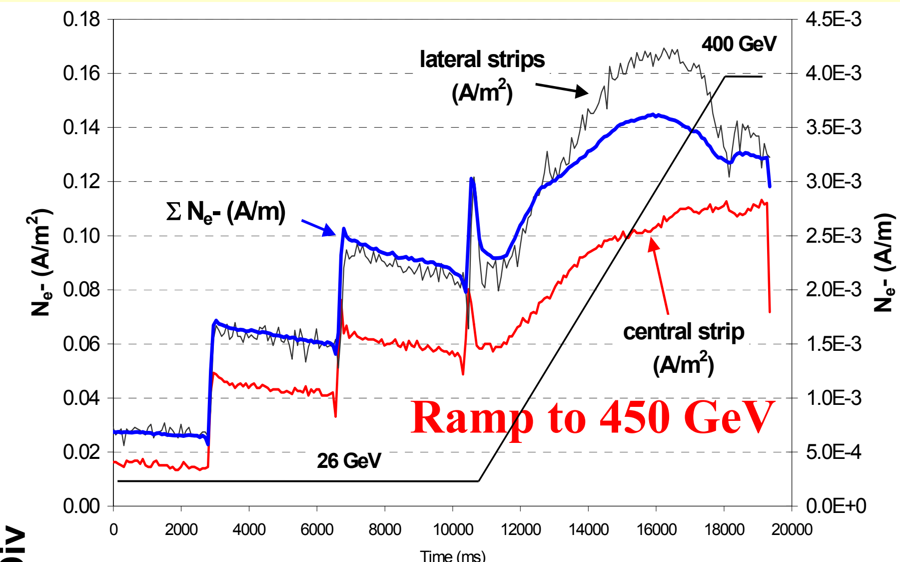
Dependence on Vacuum chamber height

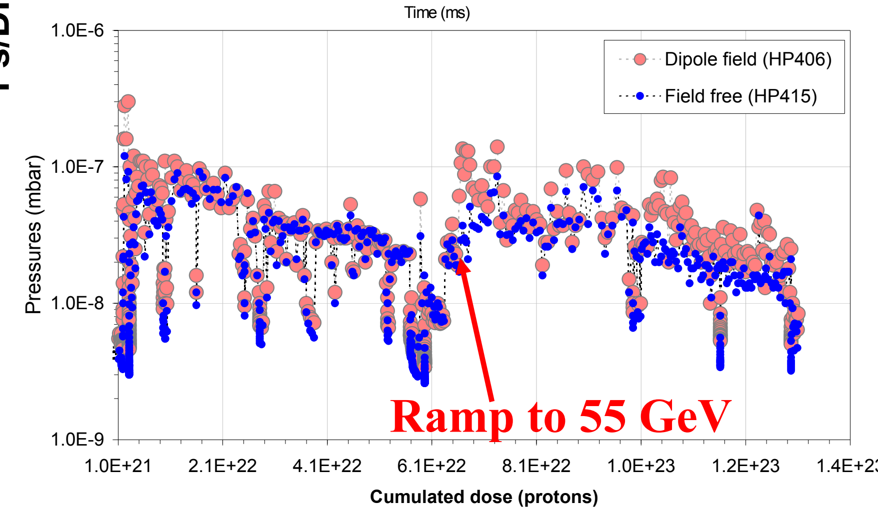


e^- cloud build up @ 25 ns bunch spacing

Detrimental effect of the ramp in energy



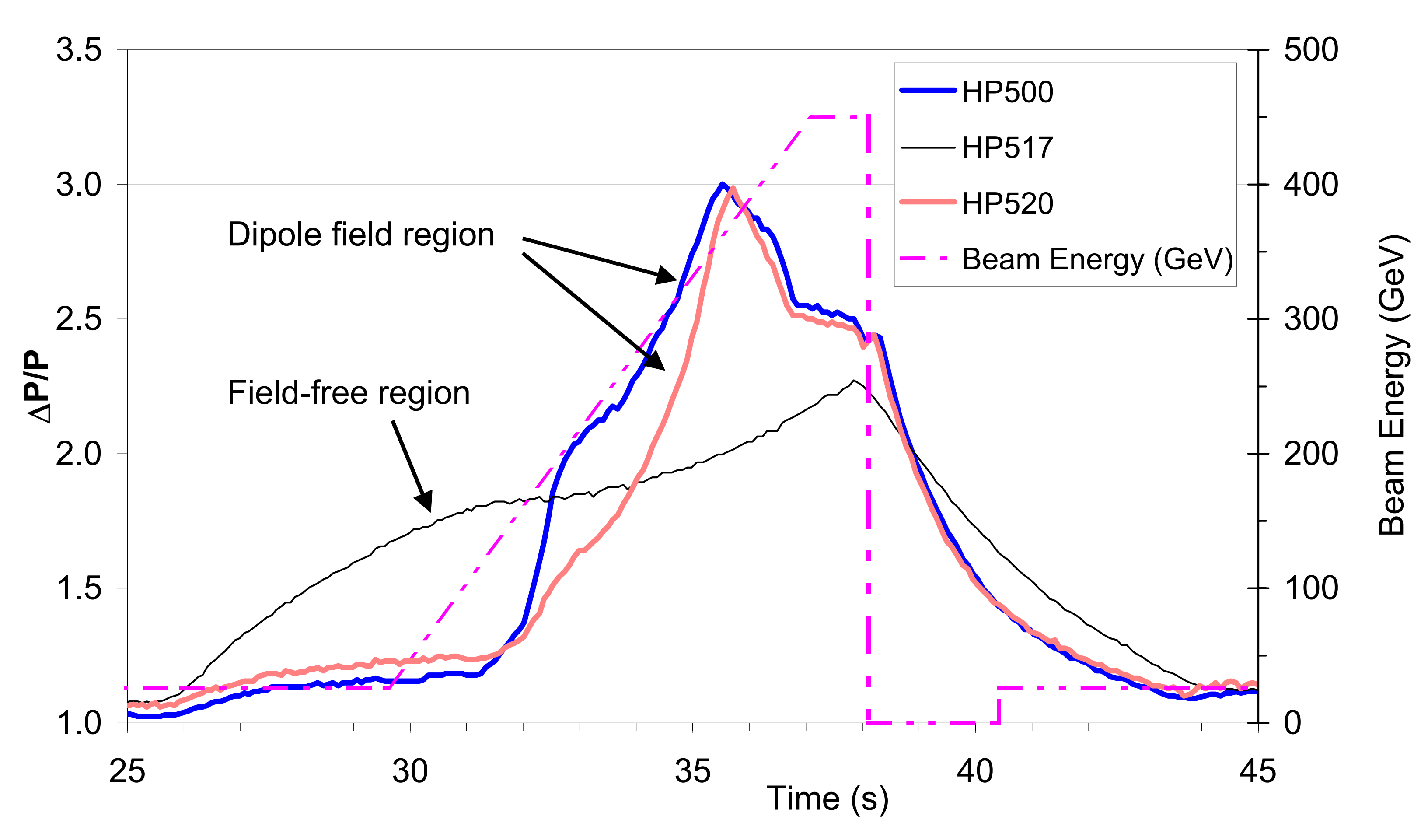




e^- cloud build up @ 25 ns bunch spacing

Detrimental effect of the ramp in energy

Variation of the pressures



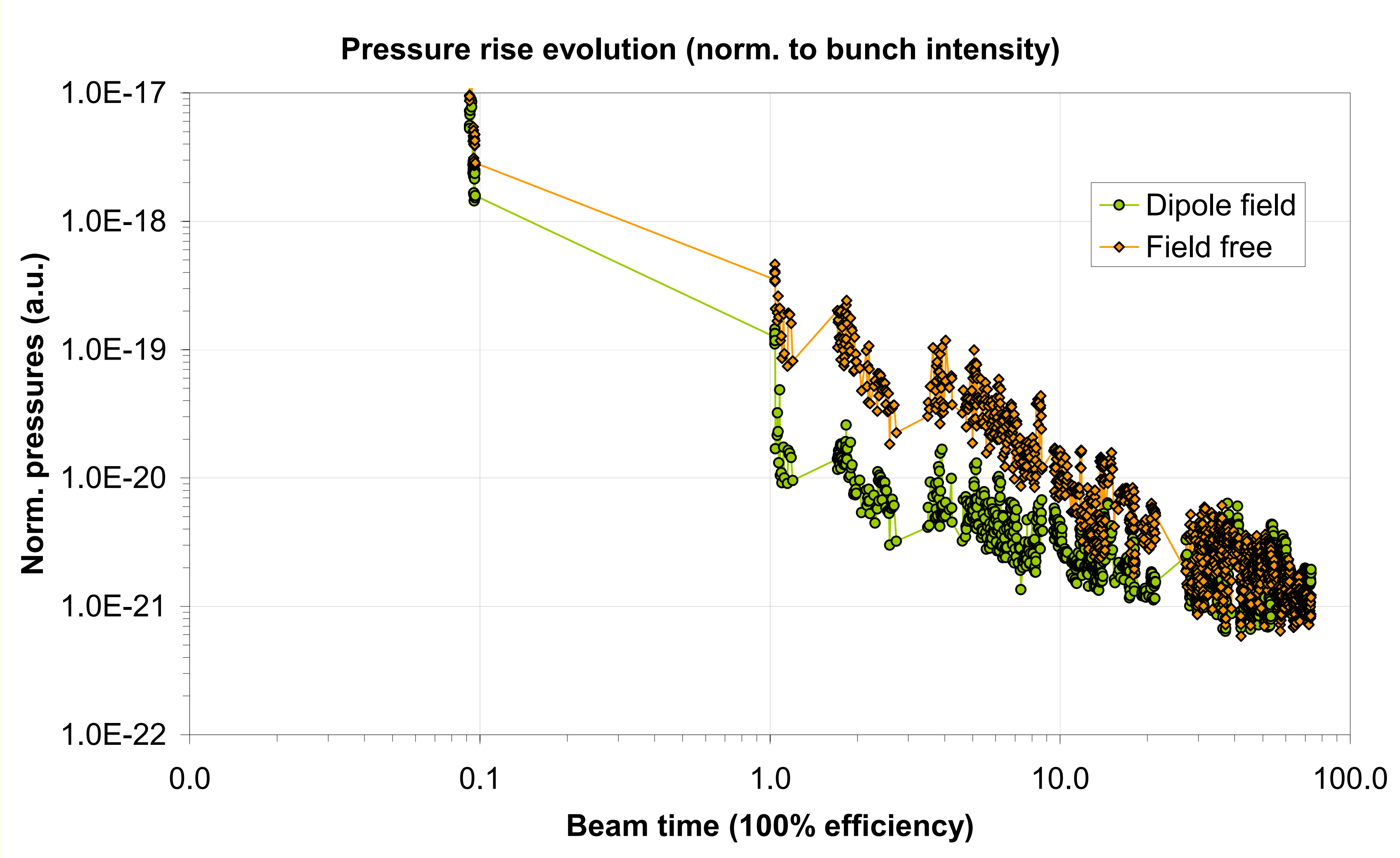
Beam conditioning

Electron cloud build up @ 25 ns bunch spacing

- **At RT in both DF and FF**
  - P=f(I_{bunch}), threshold increased with beam time
    - In DF: 3.0×10^{10}p/b ⇨ 8.0×10^{10}p/b
    - In FF: 5.0×10^{10}p/b ⇨ > 1.3×10^{11}p/b
  - Position of the 2 lateral strips independent from beam conditioning (expected)
  - Beam conditioning in FF faster than in DF
  - Vacuum cleaning/scrubbing observed: ΔP decrease by ~100 in DF and FF at RT
- **At 30 K in both DF**
  - Beam conditioning (FF/RT) ≈ **12 ×** Beam conditioning (DF/ 30 K)
- **Secondary Electron Yield (δ) measurements at RT in FF**
  - δ decreased down to 1.5 in FF
  - "Venting" to air reset the δ to its initial value (as in the Lab)
  - "Memory" effect on a conditioned surface (faster conditioning as in Lab)
  - δ drift without LHC-type beams ⇨ **less than 4 h to recover the initial value**

Beam conditioning

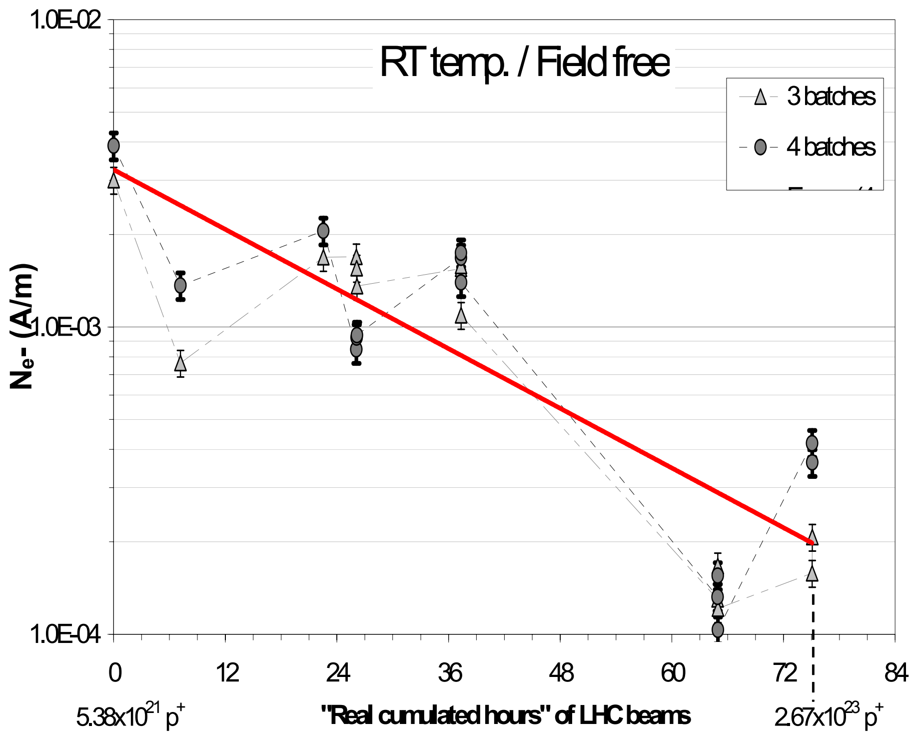
Pressure rise showed a conditioning effect



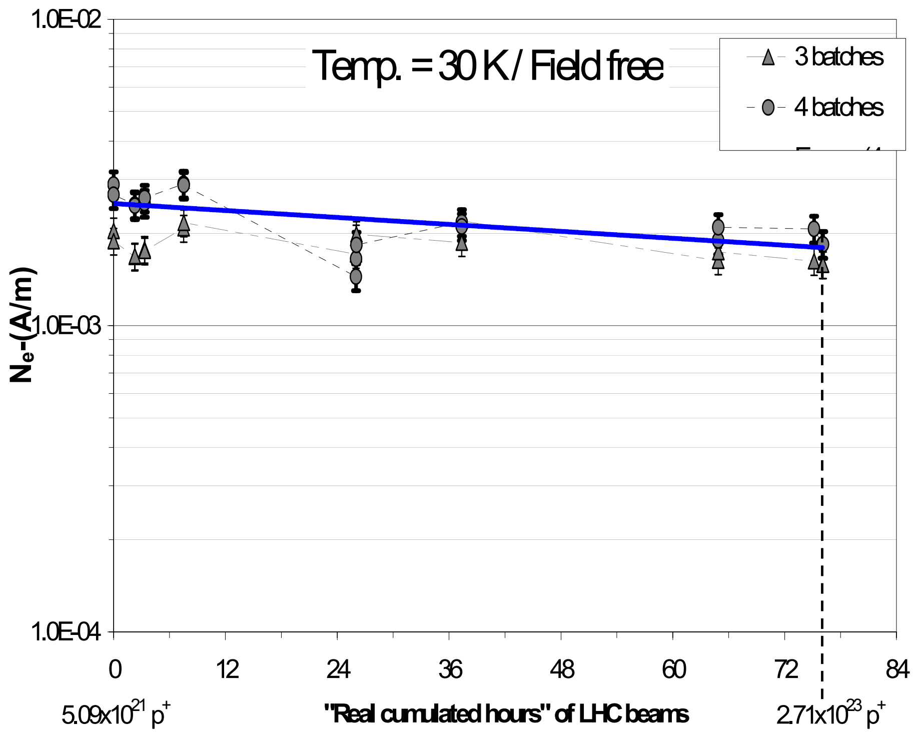
Beam conditioning

Electron cloud activity at 30K or RT in a FF

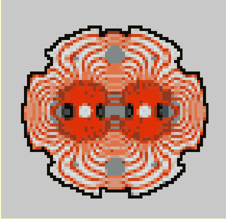
RT (VASD detector)



30 K (CSD detector)



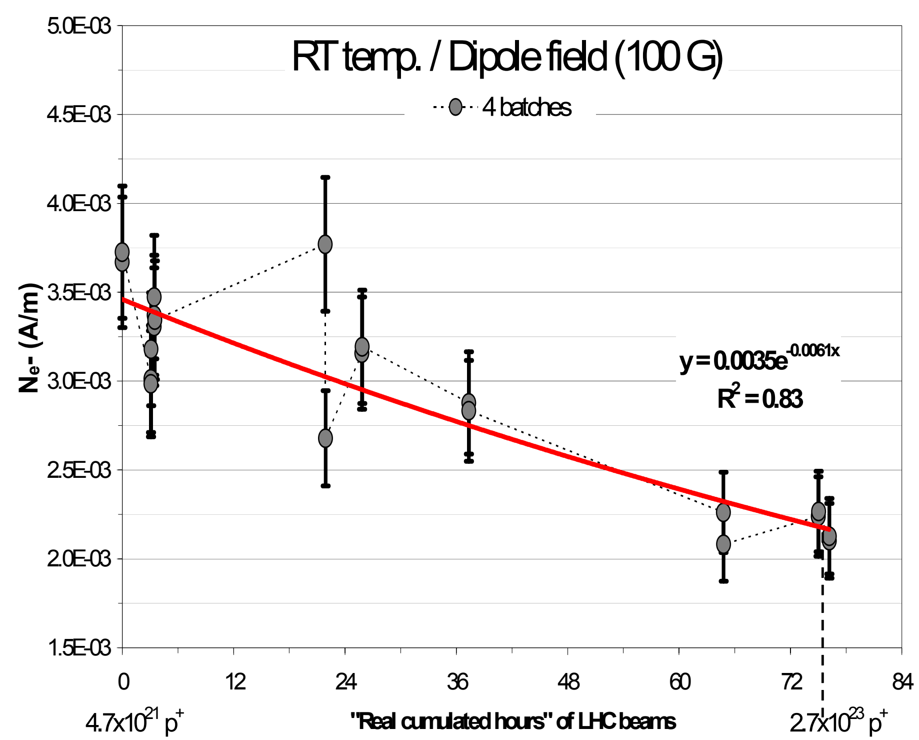
FF values normalized to a circular tube of ID 35 mm



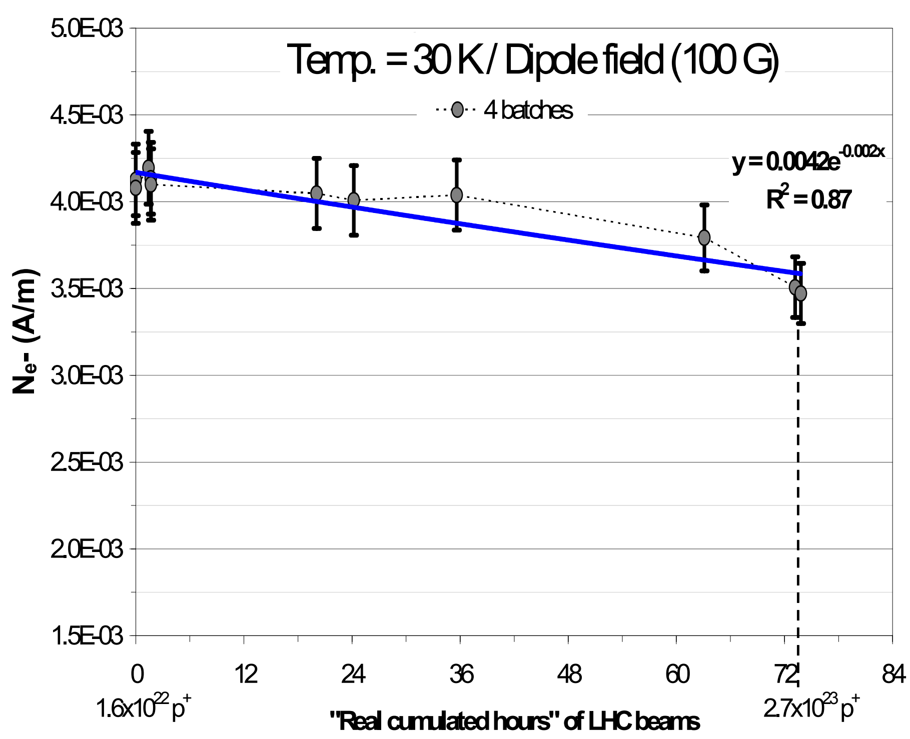
Beam conditioning

Electron cloud activity at 30K or RT in a DF

RT (VASD detector)

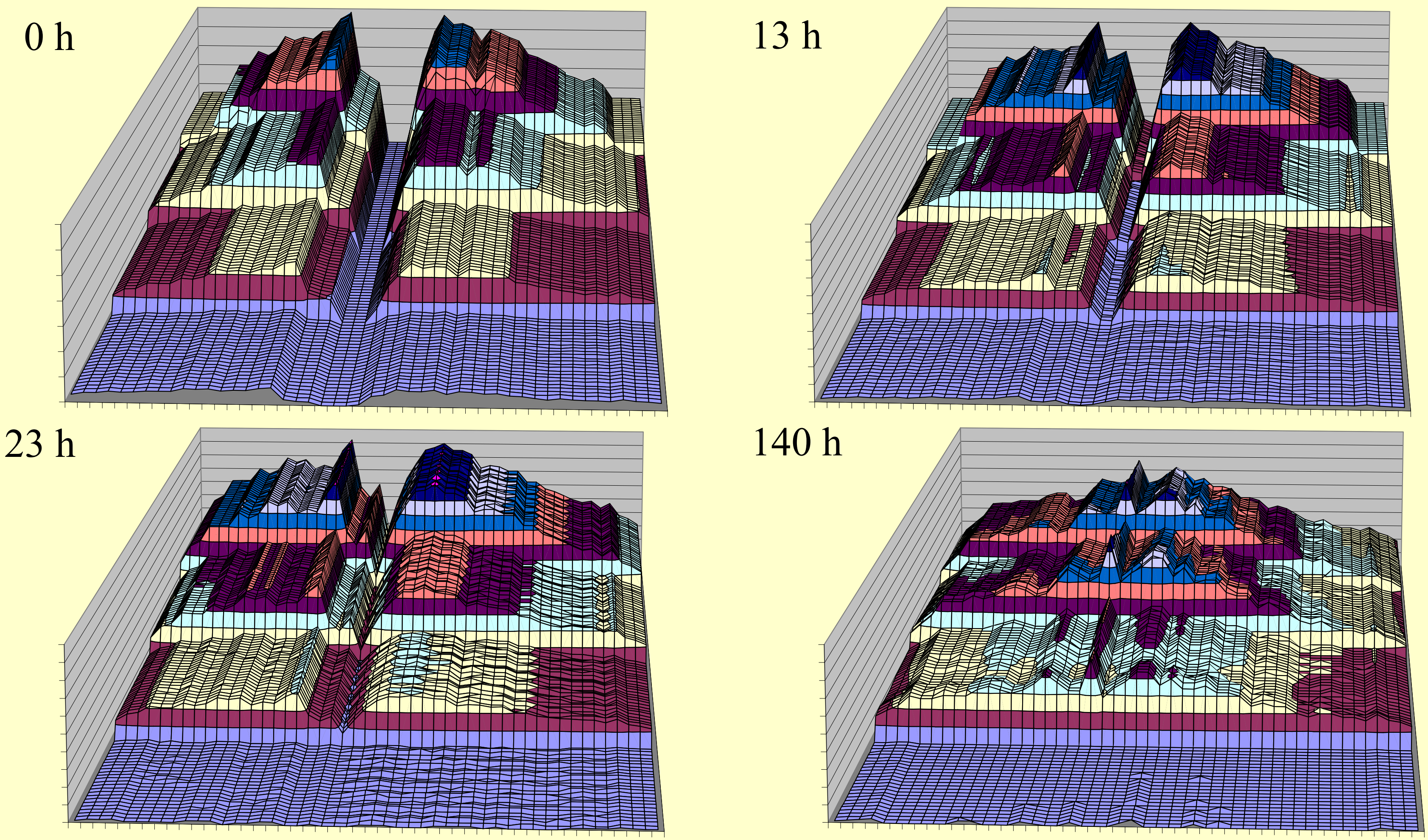


30 K (CSD detector)



Beam conditioning

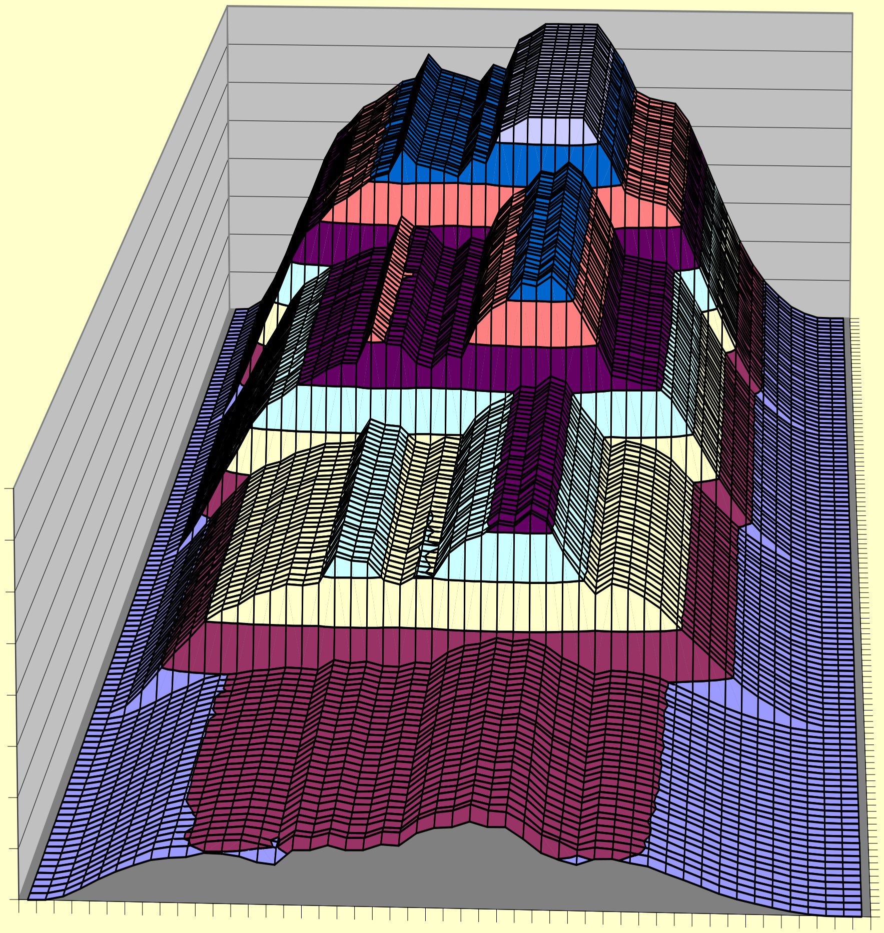
Evolution of the Spatial Distribution @30 K in FF



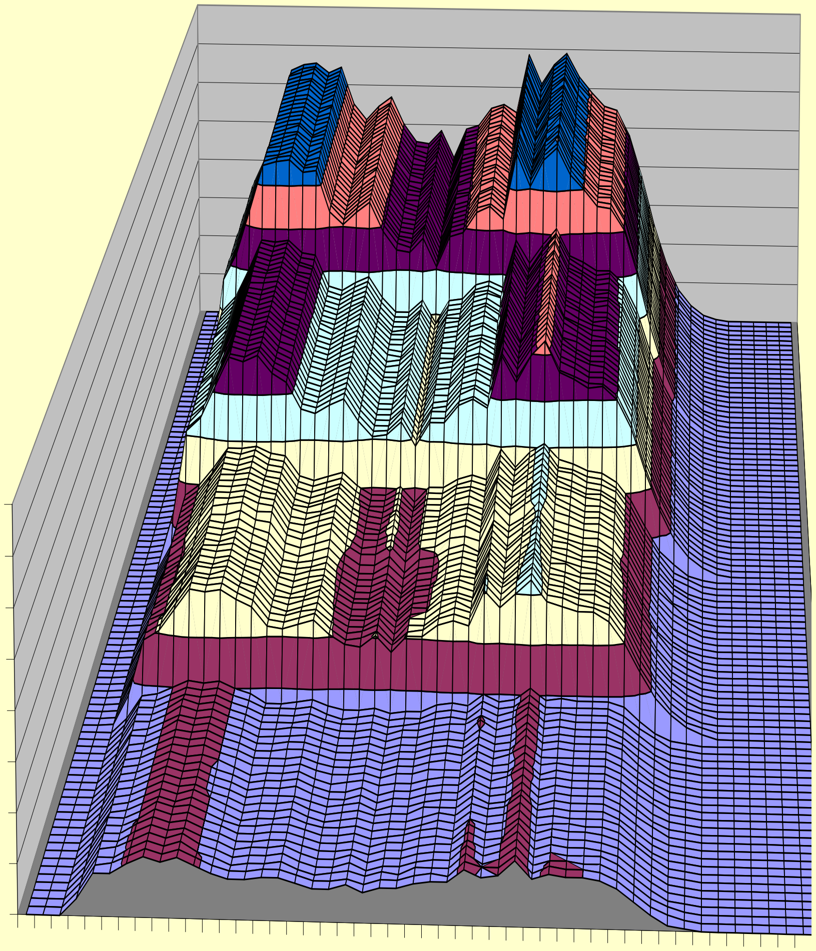
Beam conditioning

Evolution of the Spatial Distribution @30 K in DF

0 h



140 h

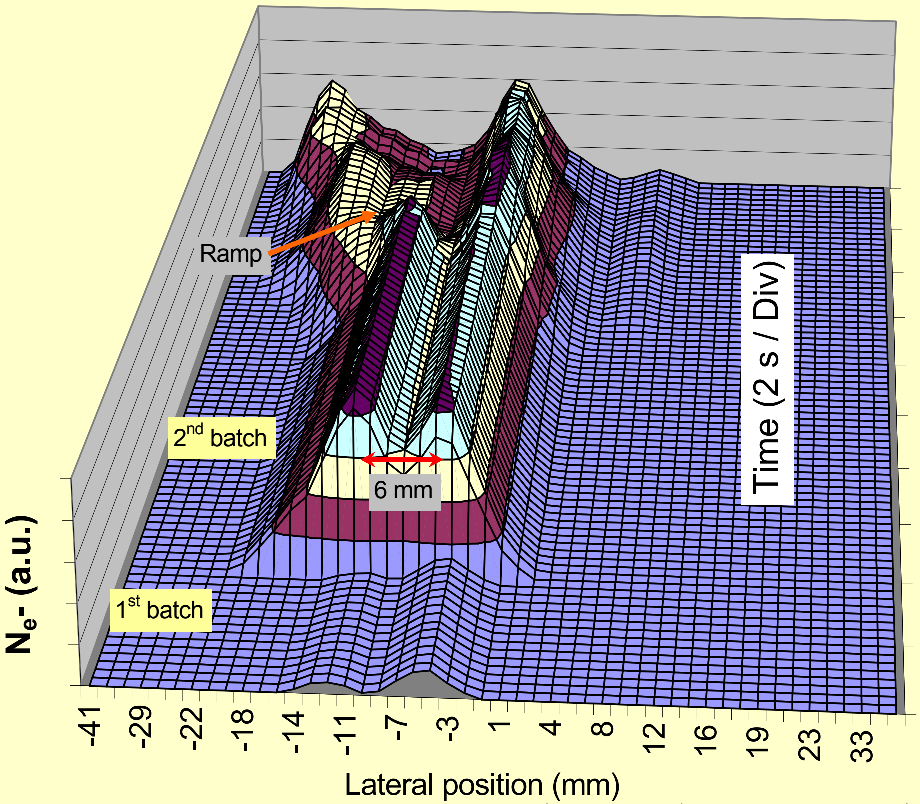


Electron cloud build up at 25 and 75 ns

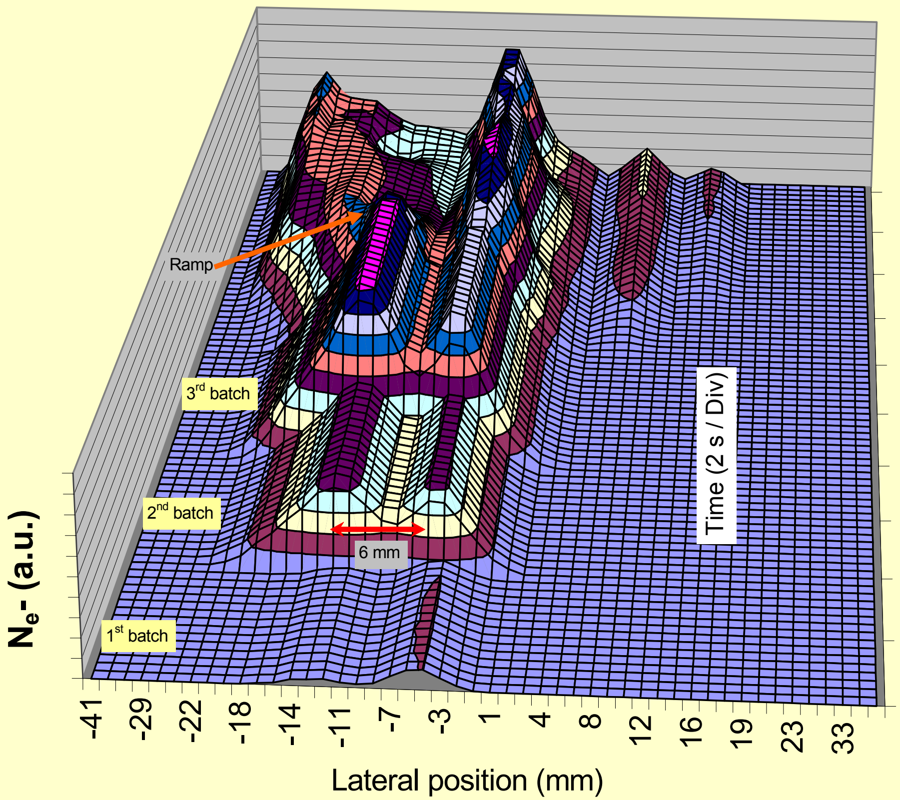
75 ns bunch spacing with a ramp to 450 GeV

In dipole field conditions

2 batches



3 batches



6 mm strip spacing can not be explained by a bunch length increase

Electron cloud build up at 25 and 75 ns
Comparison

- **In the SPS, the electron cloud-induced pressure rises are observed in the dipole field regions, arcs of the SPS**
  - ⇨ e^- build up also seen with 50 ns bunch spacing in 2001 (using pressure gauges)
  - ⇨ No signal in Field free at RT (LSS) but there were already well conditioned
- **Comparison between 25 and 75 ns bunch spacing in dipole field regions:**
  - – Smaller pressure rises ⇨ factor 4
  - – Smaller electron flux to the walls ⇨ factor 20 measured in a DF @ 30 K
  - ☞ **Multipacting is still present with 75ns bunch spacing but at a much lower level.**
  - ☞ **Strip separation is different between the 25 and 75 ns bunch spacing (?)**

	Bunch spacing	
	25 ns	**75 ns**
	by a factor	
Pressure increase	12	3
Electron cloud activity at 30K	**Activity in A/m**	
In field free conditions	2.2×10^{-4}	no signal
In dipole field conditions	7.6×10^{-4}	3.8×10^{-5}
Electron cloud activity (A/m) at RT	**Activity in A/m**	
In field free conditions	7.0×10^{-5}	no signal
In dipole field conditions	1.1×10^{-3}	no signal
	detection limit 10^{-6} A/m	

NEG coatings: A remedy to the electron cloud in the RT parts of the LHC ?

- **Lab measurements:**
  - Activated NEG coating even saturated has a SEY (δ) below 1.4
- **SPS measurements:**
  - Before activation, NEG coating behave as stainless steel (as expected)
  - After activation and saturation with H_2O ⇨ no e^- cloud build up visible
  - 8 cycling (bake out + H_2O saturation) did not decrease performances
  - Seeding electrons (100 eV / 10^{16} e^-/m) did not trigger an e^- build up
  - NEG coating suppress the background in the luminescence monitor
    ☞ e^- cloud suspected to be responsible for the background

    YES, measurements showed that activated NEG coating even saturated with H_2O are a remedy to the electron cloud in the RT chambers

…Conclusions (1)…

- **SPS should be able to inject the LHC after 5 days of beam conditioning (3 or 4 batches at 1.1×10^{11} p/bunch)**
  - No signal in the field-free regions (long straight sections), the electron cloud activity decreased below < 10^{-9} A/m
  - In the arcs (dipole field), electron cloud still "visible" with 4 batches injected
    ⇨ Pressure rises decreased by a factor > 100

  ☞ Similarly to RF and HV devices, beam conditioning efficiency limited to the parameters used during the scrubbing
  ⇨ will not be effective if running conditions become more favourable
- **Ultimate SEY value reached after 4 days in the FF regions in the SPS ☞ $\delta = 1.5$**
  - ☞ Shows the multipacting threshold under these conditions
  - ☞ Is in good agreement with analytical calculations
- **Upward drift of the SEY (δ) observed if the SPS is not operated with LHC-type beams is not an issue**

  ⇨ Measurements confirmed that SEY recovered its initial value after 4 hours of operation with LHC-type beams.

…Conclusions (2)…

- **Detrimental effect of the ramp in energy**
  ⇨ bunch length shortening and beam orbit displacement)
    - ☞ Need to be quantified (factor 2 ?)
- Vacuum cleaning (P ↓with beam time) observed at RT in both DF / FF
- Beam conditioning observed and confirmed at RT
  ⇨ faster in FF than in DF
- Tendency of conditioning at 30 K in both DF and FF (faster in FF)
- Heat loads measured in the SPS at 30K in DF are higher than 1.2 W/m with 4 batch-injections at 1.1×10^{11} p/b, at the start-up.

<u>Priorities for 2004 run</u>

- 75 ns: bunch spacing ⇨ Electron cloud build up?
- 25 ns: Heat loads / beam conditioning of cold surfaces
- Bunch length effects
- Effect of physisorbed gases

☞ Schedule to be adapted to avoid limitations by the SPS kickers (overheating)