Summary B: More Observations at Existing Accelerators and Concerns for Future Machines

High energy short pulse proton rings:

B1: J.M. Jiménez, “EC and vacuum effects in the SPS”

B8: T. Kroyer, “Unexpected results on microwave waveguide mode transmission measurements in the SPS beam-pipe”

Medium/high energy long pulse proton rings:

B5: R. Macek, “Experimental studies of EC effects at the Los Alamos PSR: a status report”

B6: T. Toyama, “EC effects in the J-PARC rings and related topics”

Summary B: More Observations at Existing Accelerators and Concerns for Future Machines (cont)

Heavy ion rings and linacs:

B3: W. Fischer, "ECs and vacuum pressure rise in RHIC"

B7: A. Drees, "Correlation of pressure rise and experimental backgrounds at RHIC in Run04"

B4: A. Molvik, "Experimental studies of electron and gas sources in a heavy-ion beam"

High energy positron/electron rings:

B2: A. Novokhatski, "Experimental and simulation studies of EC and multipacting in the presence of small solenoidal fields"

B9: A. Temnykh, Comments on preliminary results at CESR

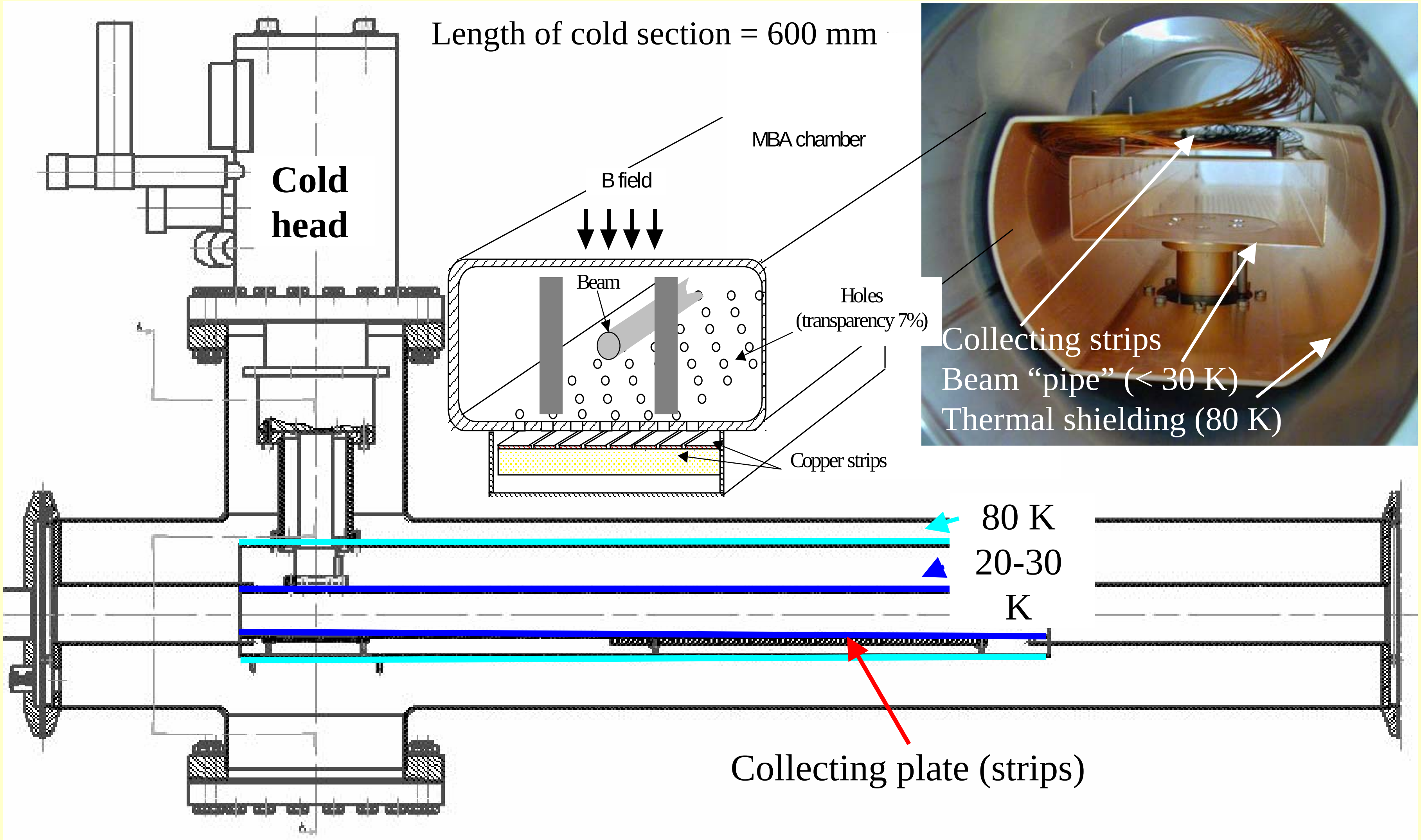
High energy proton rings (SPS)

- New EC diagnostics in SPS
- Results: LHC beams in SPS (25 ns bunch spacing, 10^{11} ppb)
  - EC survival (550 ns gap)
  - Bunch length, energy dependence
  - Chamber height dependence
- Surface conditioning: warm vs. cold, dipole vs. field-free
- 75 ns bunch spacing

- Microwave TE mode transmission diagnostic

Experimental Set-ups

Cold Strip Detector (30 K)



Length of cold section = 600 mm

Cold head

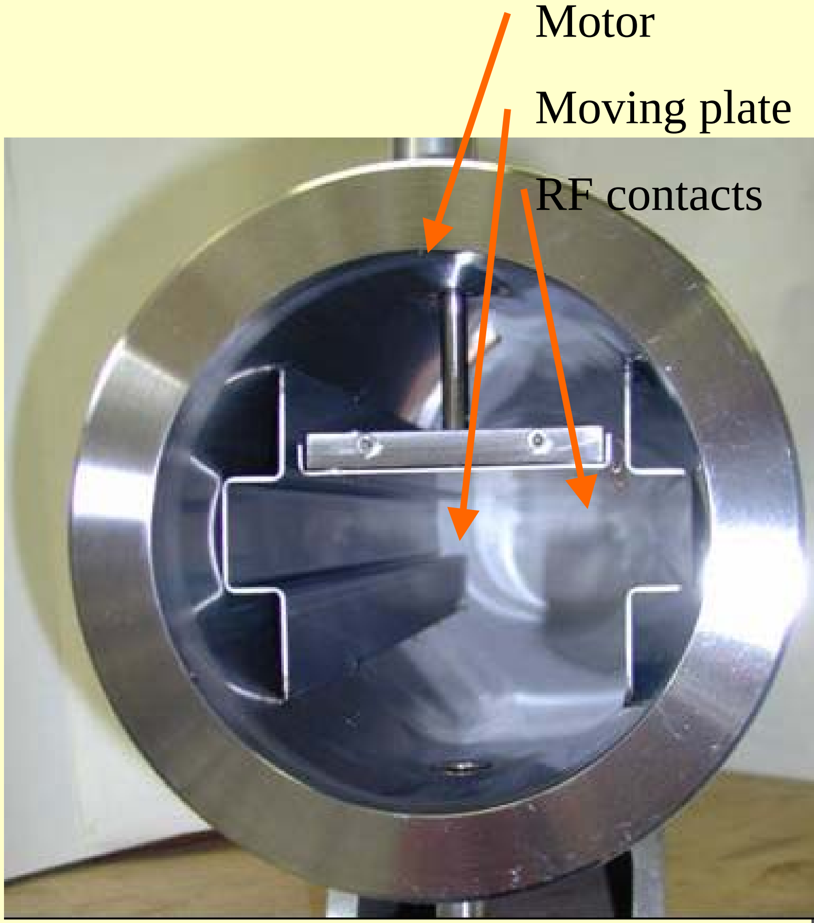
Collecting strips
Beam “pipe” (< 30 K)
Thermal shielding (80 K)

80 K
20-30 K

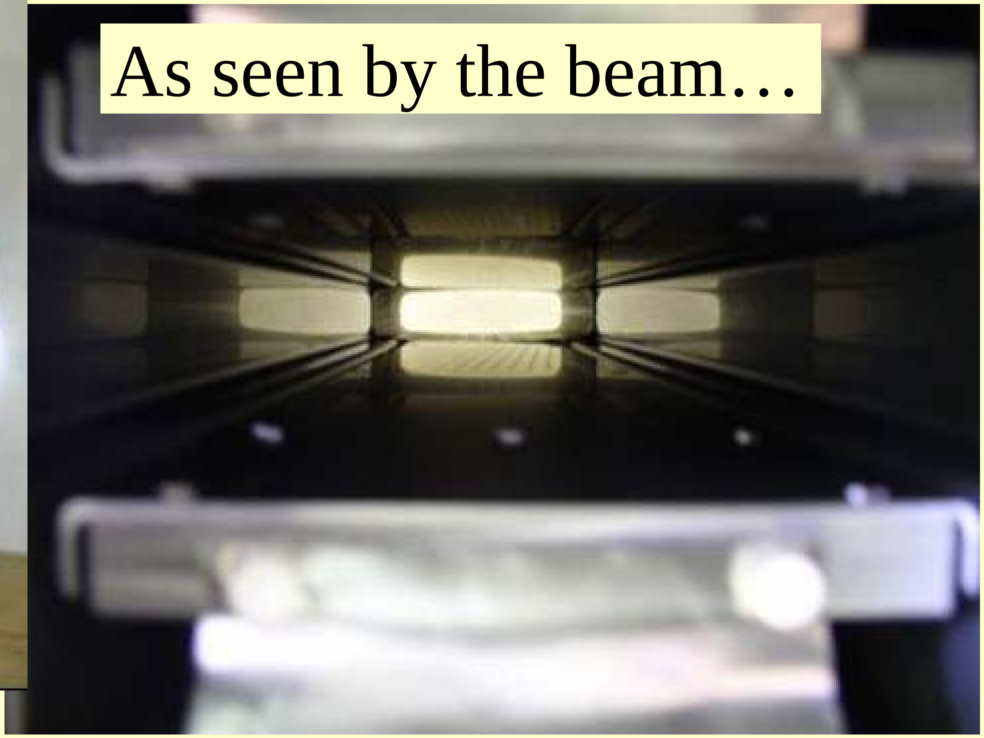
Collecting plate (strips)

Experimental Set-ups

Variable Aperture Strip Detector



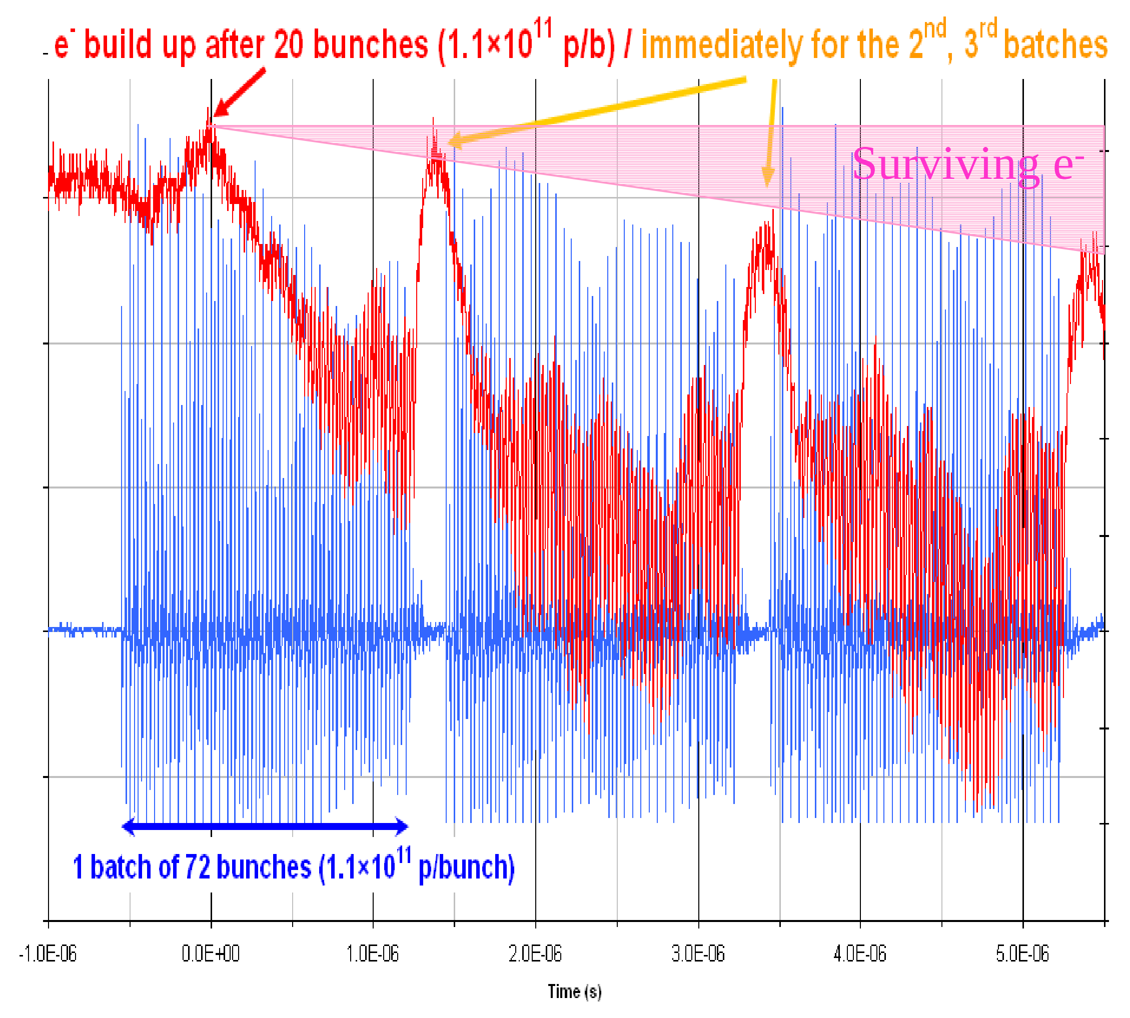
From 35 to 80 mm in height

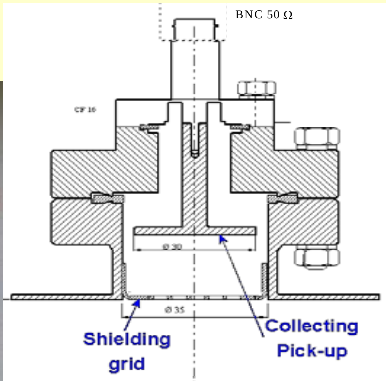


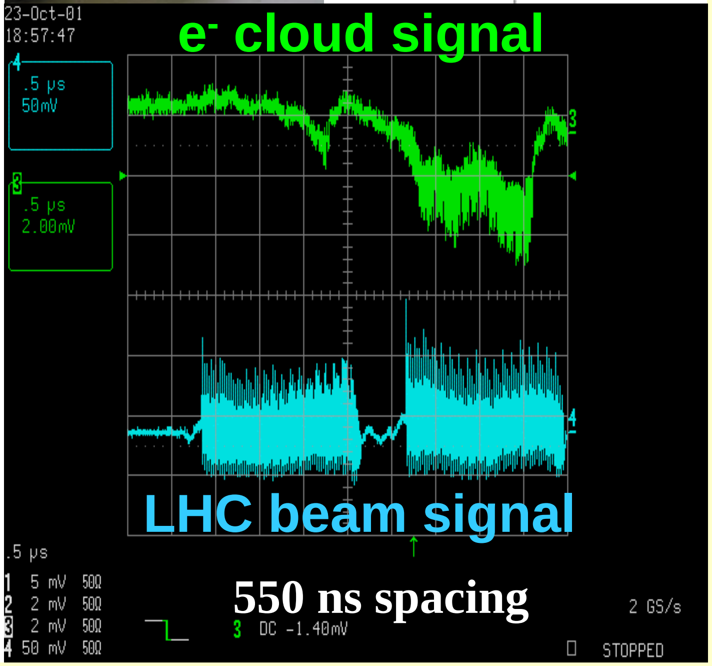
As seen by the beam…

Main Results at 25 ns Bunch Spacing

Build-up measured using a shielded pick-up





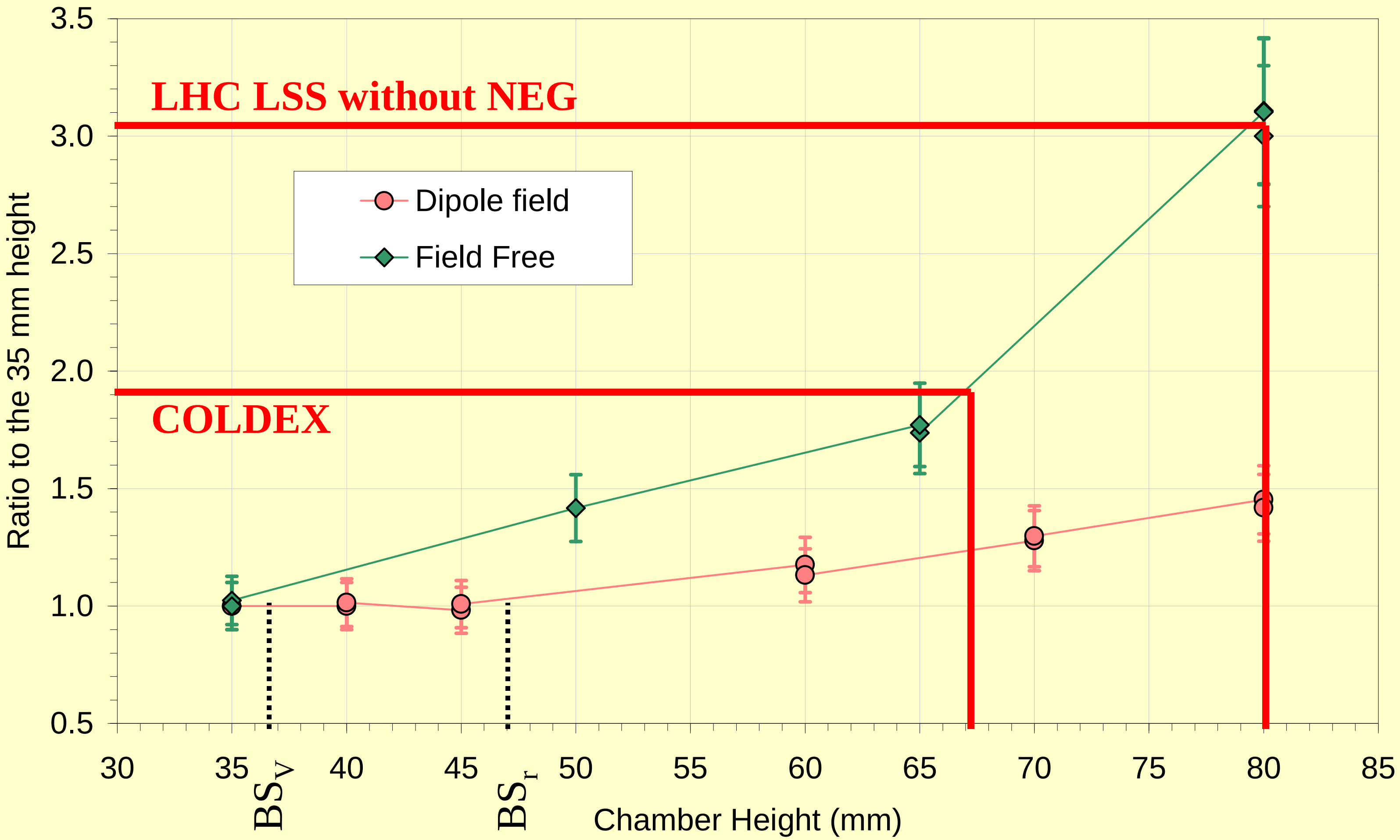


Threshold EC signals: 3 e 10 ppb dipole field (DF)
6.5 e 10 ppb field-free (FF)

Prepared by M. Jimenez
AT Dept / Vacuum Group, ECloud'04

Main Results at 25 ns Bunch Spacing

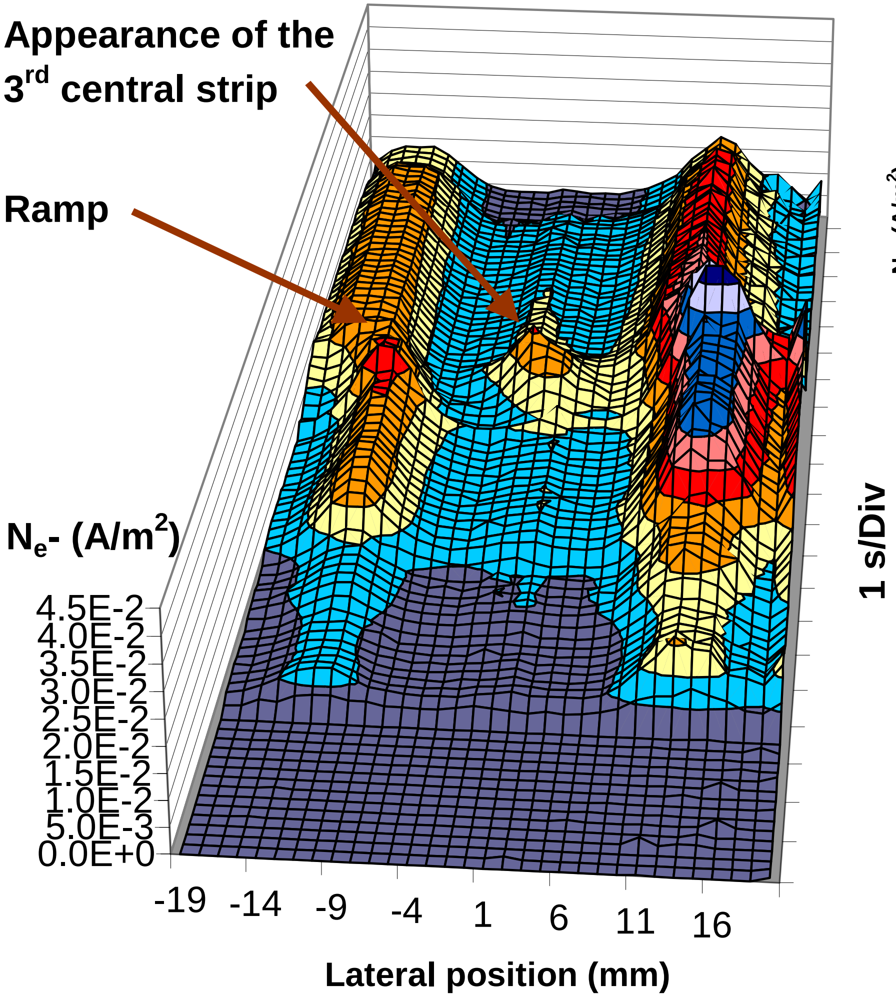
Effect of vacuum chamber height in DF/FF



Prepared by M. Jimenez
AT Dept / Vacuum Group, ECloud'04

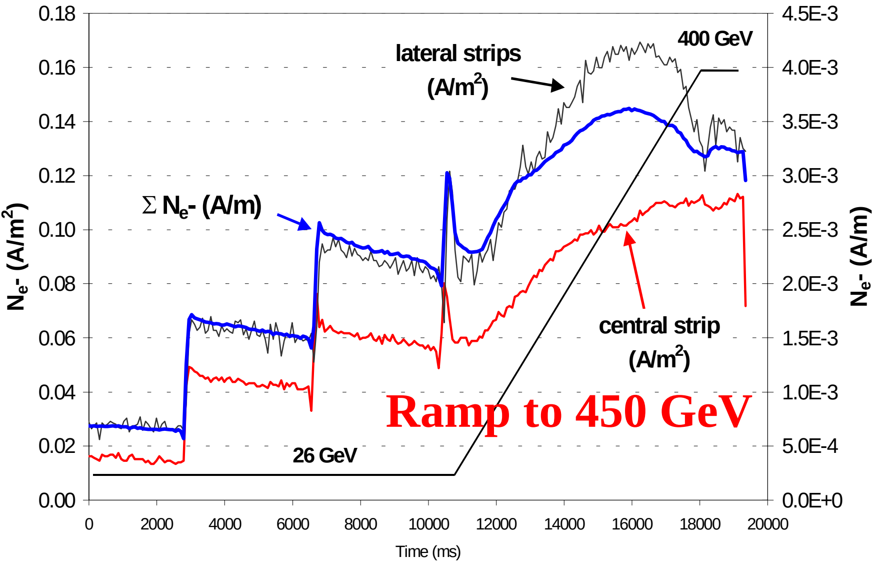
Main Results at 25 ns Bunch Spacing

Detrimental effect of the ramp in Energy

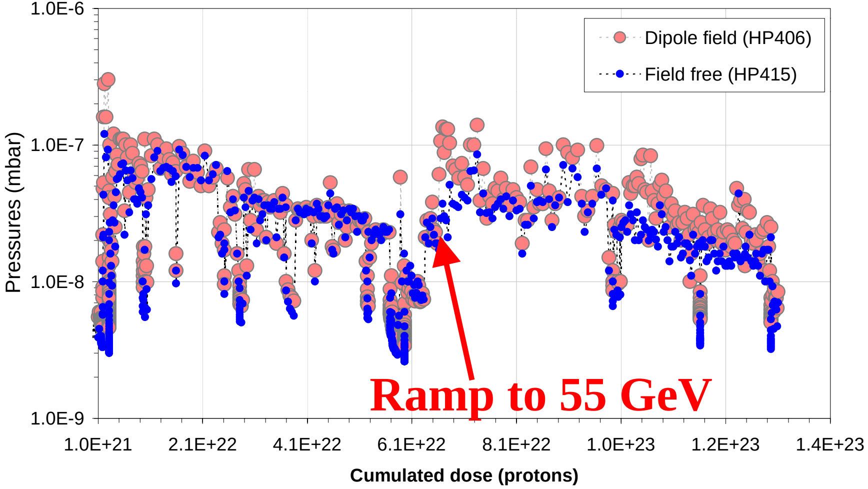


Appearance of the 3rd central strip

Ramp



Ramp to 450 GeV

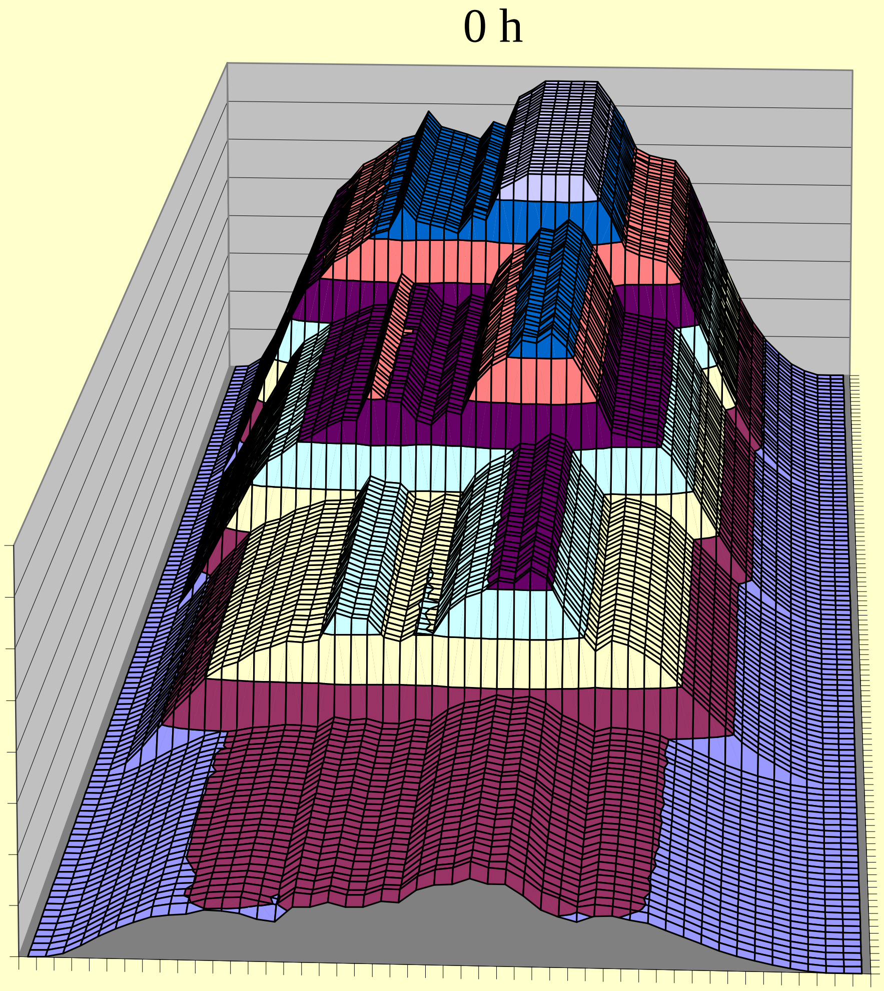


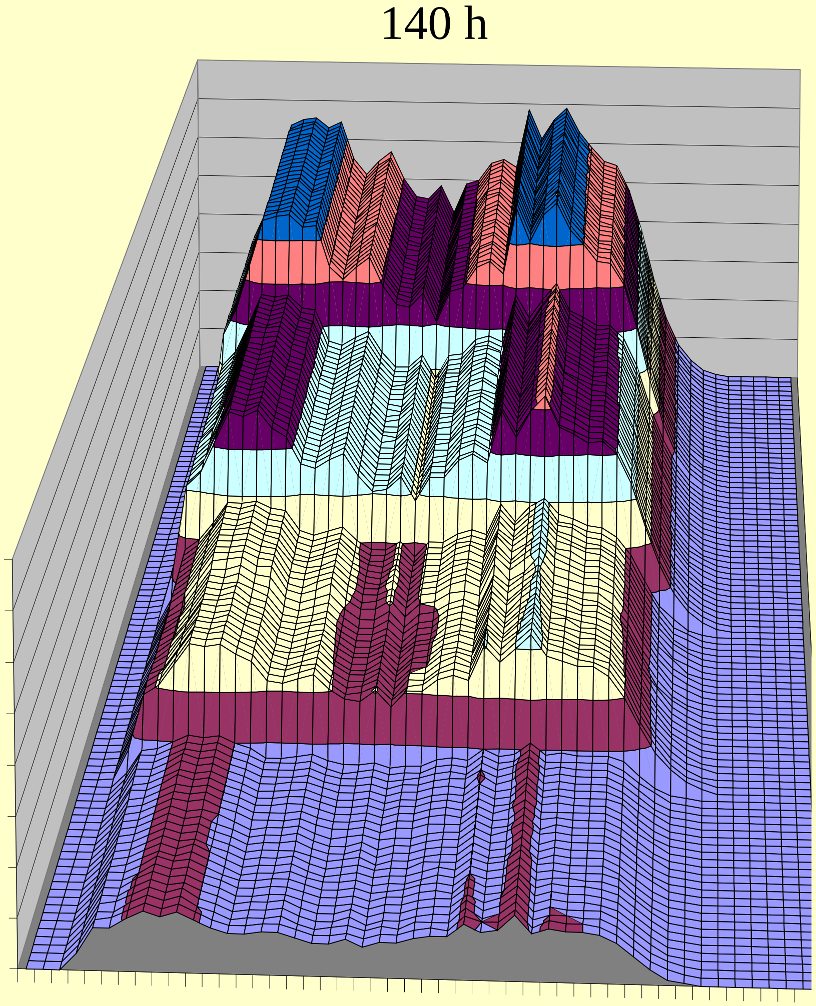
Ramp to 55 GeV

Prepared by M. Jimenez
AT Dept / Vacuum Group, ECloud'04

Main Results at 25 ns Bunch Spacing

Evolution of the Spatial Distribution during the Beam Conditioning 30 K/DF





Prepared by M. Jimenez
AT Dept / Vacuum Group, ECloud'04

Conclusions (2)

LHC and the Electron Cloud

- **Vacuum scrubbing (P decrease with beam time) is observed at RT in both DF and FF**
- **Beam conditioning is observed at RT and at 30 K in both DF and FF**
  - Initial electron activity comparable at room and cryogenic temperatures
  - Electron activity decreases faster at RT than at cryogenic temperatures in FF regions, the difference is marginal in DF
  - 75 ns bunch spacing results in a significantly lower activity (<1/10), but it is still present
  - Beam conditioning is limited by available cooling power / EC induced Instabilities
- **Detrimental effect of the ramp in energy**
  ⇨ bunch length shortening and beam orbit displacement

Preliminary results at 75 ns bunch spacing

Comparison with the 25 ns Bunch Spacing

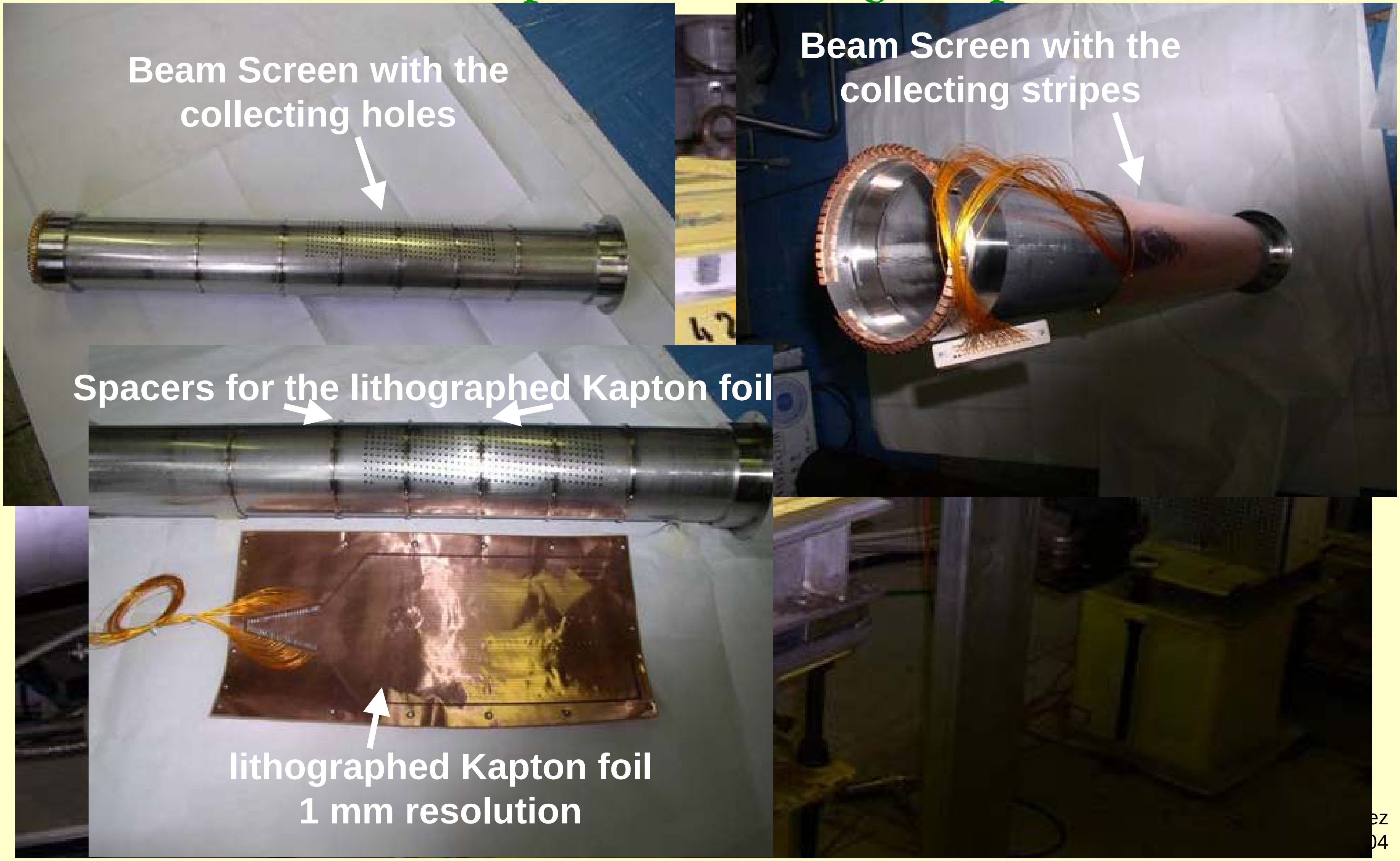
- In the SPS, the electron cloud-induced pressure rises are observed in the dipole field regions, arcs of the SPS
  - ⇨ e^- build up also seen with 50 ns bunch spacing in 2001 (using pressure gauges)
  - ⇨ No signal in Field Free at RT (LSS) but there were already well conditioned
- Comparison between 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	

Experimental program for 2004

New Detectors

Strip Detector in a Quadrupole



Beam Screen with the collecting holes

Beam Screen with the collecting stripes

Spacers for the lithographed Kapton foil

lithographed Kapton foil
1 mm resolution

High energy proton rings (SPS) (cont)

- Microwave TE mode transmission diagnostic
  - Preliminary results measured over 30 m section with dipoles
  - Strong amplitude modulation (unexpected) observed in additional to phase modulation (expected)
  - Signal attenuation greater than expected for EC
  - Memory effect observed, explanation not clear

Motivation (1)

- Initial idea: Measure electron cloud induced modulation of first TE waveguide modes in the SPS beam pipe.
- The results should be directly related to the averaged electron cloud density.

- The maximum density for a classical electron cloud is assumed to be in the order of 10^6 per cm^3 (10^{12} per m^3).
- This density should lead to a small phase shift of roughly 20 degrees over 1km for frequencies between 2 and 3 GHz.

- A similar effect can be observed in the ionosphere, too. It's one of the major factors limiting the accuracy of GPS.

Expected Phase Shift

The phase shift for an angular frequency ω is given by

$$\Delta\phi = -\frac{1}{2}\frac{\omega_p^2}{\omega c}L$$

with the plasma frequency $\omega_p = \sqrt{4\pi\rho_e r_e c^2}$

$\rho_e = 10^{12}/\mathrm{m}^3$ designating the electron volume density,

r_e the classical electron radius and c the speed of light

For the SPS @ f=2 to 3GHz over 1km this would give a phase shift of roughly –25 to -17º.

Summary of the Time Domain Observations

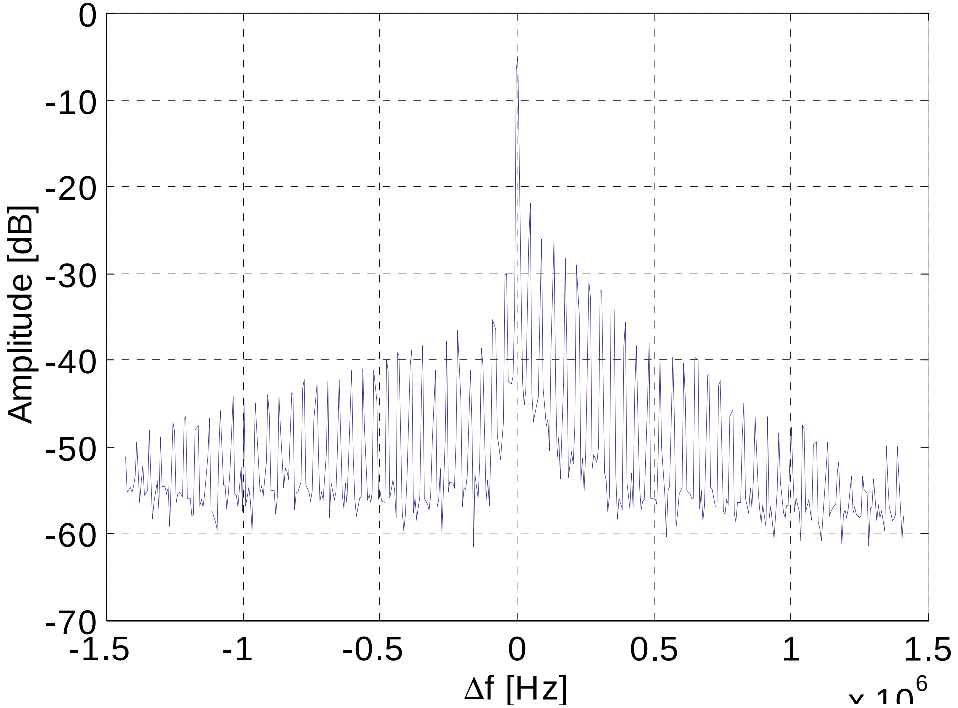
- We have observed
  - a very high microwave signal attenuation during the passage of the beam
  - a reproducible build-up time for small beams
  - erratic tails
- The tails were found
  - for many different microwave carrier frequencies
  - during the entire machine cyle
  - for different beam intensities
  - for single bunch beams
- The “life-time” and “build-up time” of these memory effect is in the range of a few μs.
- There seems to be no threshold unlike for (classical) electron-cloud formation.
- A variation of vacuum pressure (by a factor of 4) did not show any visible change.

Measured over 30 m:
If real, implies plasma density of 1 e 16 /m^2

Caused possibly by dust:
under investigation

Electron Cyclotron Resonance

- Cyclotron resonance of electrons occurs at 28 GHz/T, thus at more than 3.25 GHz with B = 0.117 T in the magnets at injection.
- Close to this frequency a very asymmetric spectrum was found, pointing at an additional phase modulation (AM+PM).
- But: No asymmetric spectrum was observed during the ramping of the magnets at other frequencies.



Medium/high energy proton rings

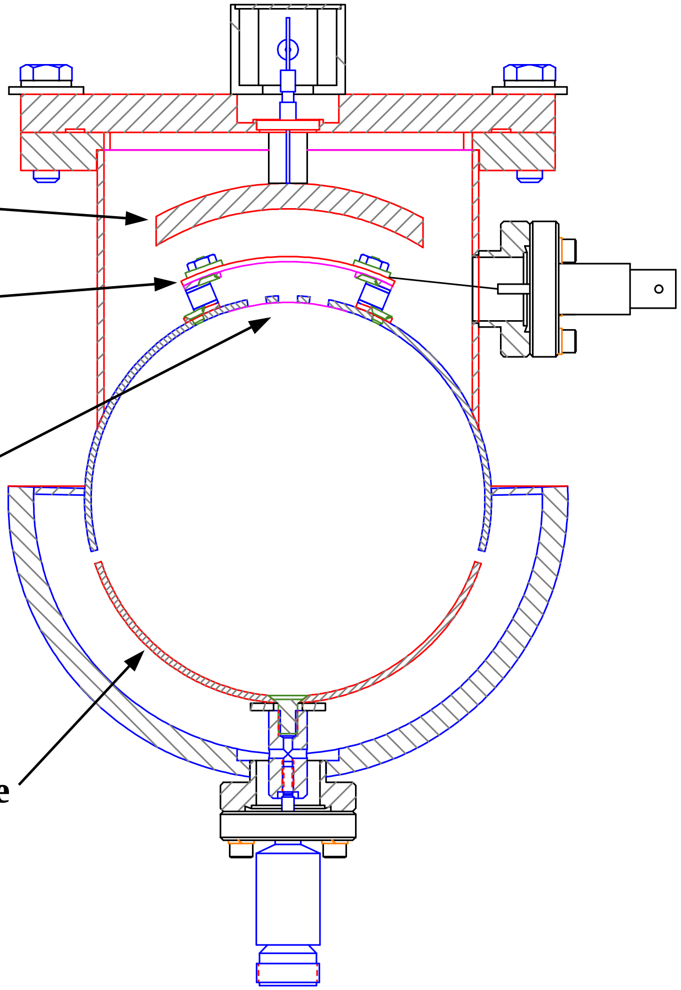
- PSR (800 MeV SR)
  - Introduced electron sweeper diagnostic
  - Many parametric studies over years
  - Reasonable comparisons with EC modeling, but need better data for seed electrons from beam loss
  - e-p instability modeling ongoing

- J-PARC (3 GeV RCS, 50 GeV MR)
- KEK-PS (12 GeV MR)

Outline

- **Introduction: Short summary of well established electron cloud effects (ECE) at PSR**
  - **Data on trailing edge multipactor & electrons surviving the gap**
  - **e-p instability characteristics are discussed elsewhere**
  - **For more information, see a recent comprehensive set of talks (3/15-18, e-p feedback collaboration meeting) on the MAP website: http://physics.indiana.edu/~shylee/ap/mwapc/ and PRSTAB special edition – Two-stream SC**
- **Ongoing issues and results of recent studies on e-cloud buildup**
  - **Parametric studies of e-cloud signals**
  - **Studies of the source strength of the important source(s) of "seed" electrons,**
  - **Electron suppression by TiN**
  - **Some unresolved issues under study**
    - Electron "burst" phenomenon
    - Recovery of "prompt" electron signal (multipactor) following sweeping the gap
    - 1st pulse instability
  - **Beam response to weak kick**

Cross-section of electron-sweeping detector



Collector

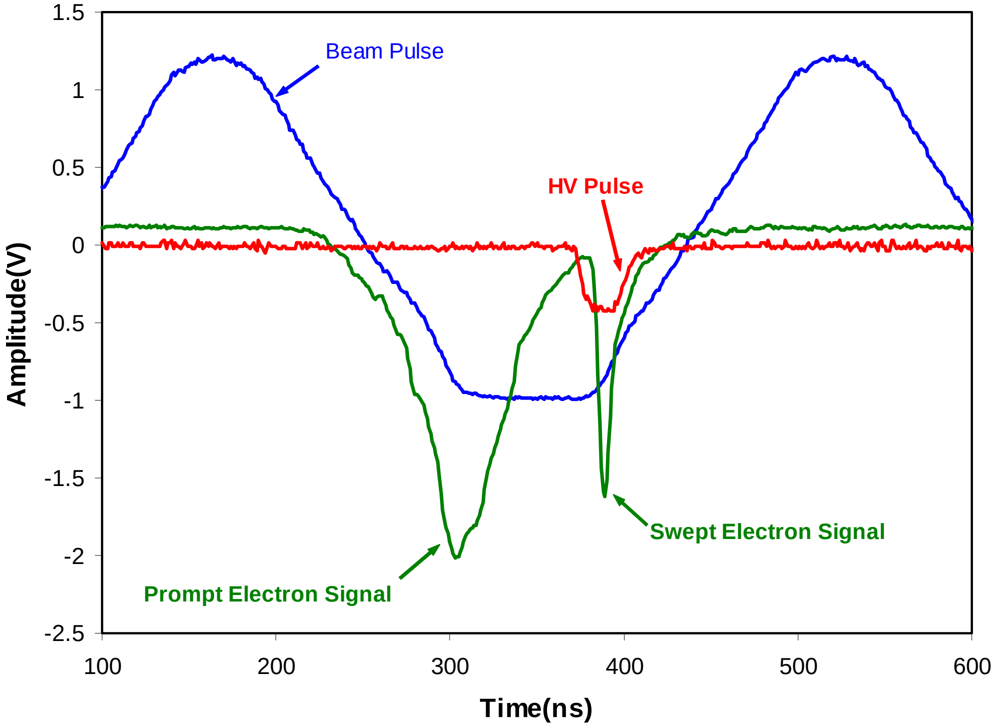
Repeller Grid

Slots & Screen

Pulsed Electrode

Sample Electron Data from Electron Sweeper

- **Signals have been timed correctly to the beam pulse**
- **Device basically acts a large area RFA until HV pulse applied**
- **“Prompt” electrons strike the wall and peak at the end of the beam pulse. Contributions from:**
  - **Trailing edge multipactor**
  - **Captured electrons released at end of beam pulse**
- **“Swept” electron signal is a narrow (~10 ns) pulse collected from ~30% of the cross-sectional area of the pipe**



7.7 μC/pulse, bunch length = 280 ns, 30 ns injection notch, signals averaged for 32 macropulses, repeller = - 25V, HV pulse = 500V

Electron cloud survival (dissipation) curves

(Swept electrons in pipe vs time after end of beam pulse)

- **Early results from electron sweeper for 5µC/pulse beam looking just after extraction**

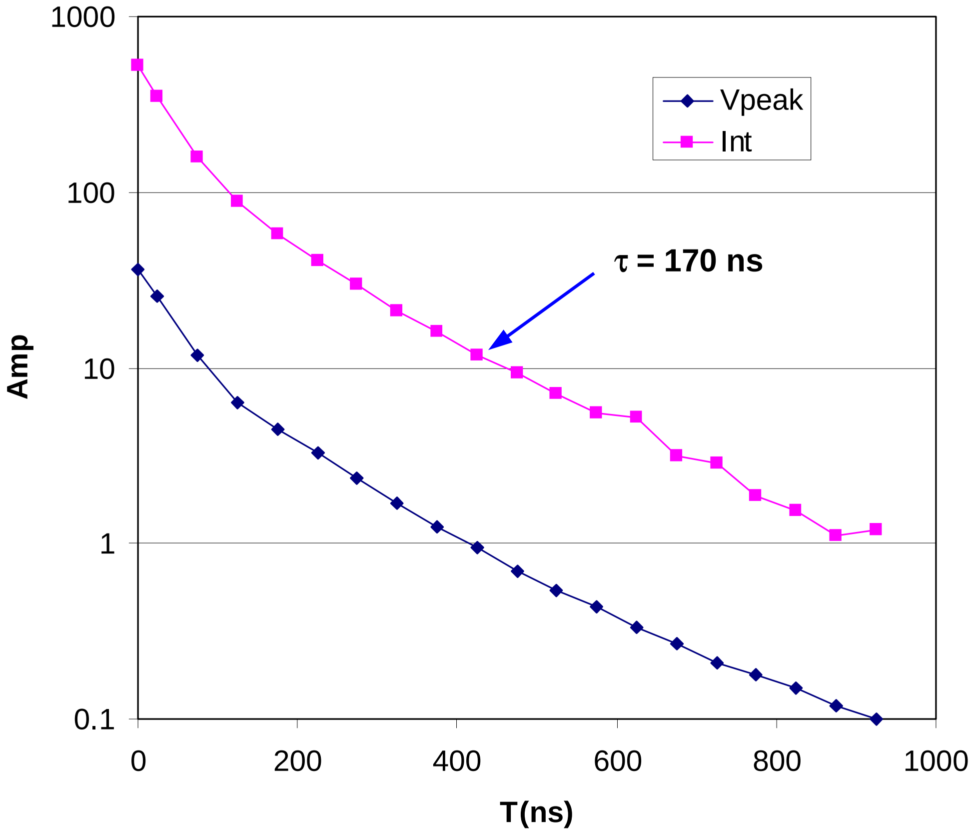
- **Long, approximately exponential tail seen with ~170 ns decay time**

- **Implies a high secondary yield (reflectivity) for low energy electrons (2-5 eV) expected in a beam free region**

$$\delta_{\mathbf{eff}} = \exp\left[-\frac{\mathbf{d}}{\mathbf{c}\cdot\tau}\cdot\sqrt{\frac{\mathbf{m_e}\cdot\mathbf{c}^2}{2\mathbf{E}}}\right] \approx 0.5$$

- **Obtain a neutralization lower limit of ~1% based on swept electron signal at the end of the ~100ns gap**

- **Parametric studies of decay time show it is insensitive to beam intensity, TiN, beam scrubbing, and location**



Parametric studies on e-cloud signals

- Parametric studies of multipacting signal (prompt signal)

Variable	Effect on Prompt signal	Other notes
Beam Intensity	Strong effect ~ I^n	n = 2 – 10, depending on location and conditioning
Bunch long. shape	Significant effect	Changed bunch shape in several ways
Transverse shape	Strong effect	e's largest in direction of major axis
Beam Scrubbing	Significant effect	Factor ~5 reduction over several months of ops (2002)
Beam losses & ring vacuum	Linear in both	(See graphs later in talk)
Location in ring	significant	Related to losses, beam transverse shape, vacuum and seed electrons from foil
TiN	Mixed results	
Weak solenoid field	Strong reduction	Factor of ~ 50 reduction at ~20 G
Added beam in gap	Increases signal	Also increase electrons surviving gap

- Cumulative energy spectra from RFA have been measured as a function of intensity, location in the ring, beam scrubbing, and TiN coatings
- Also some observations in presence of sub-threshold coherent motion as well as some for unstable beams

Experiments on effect of beam losses and vacuum

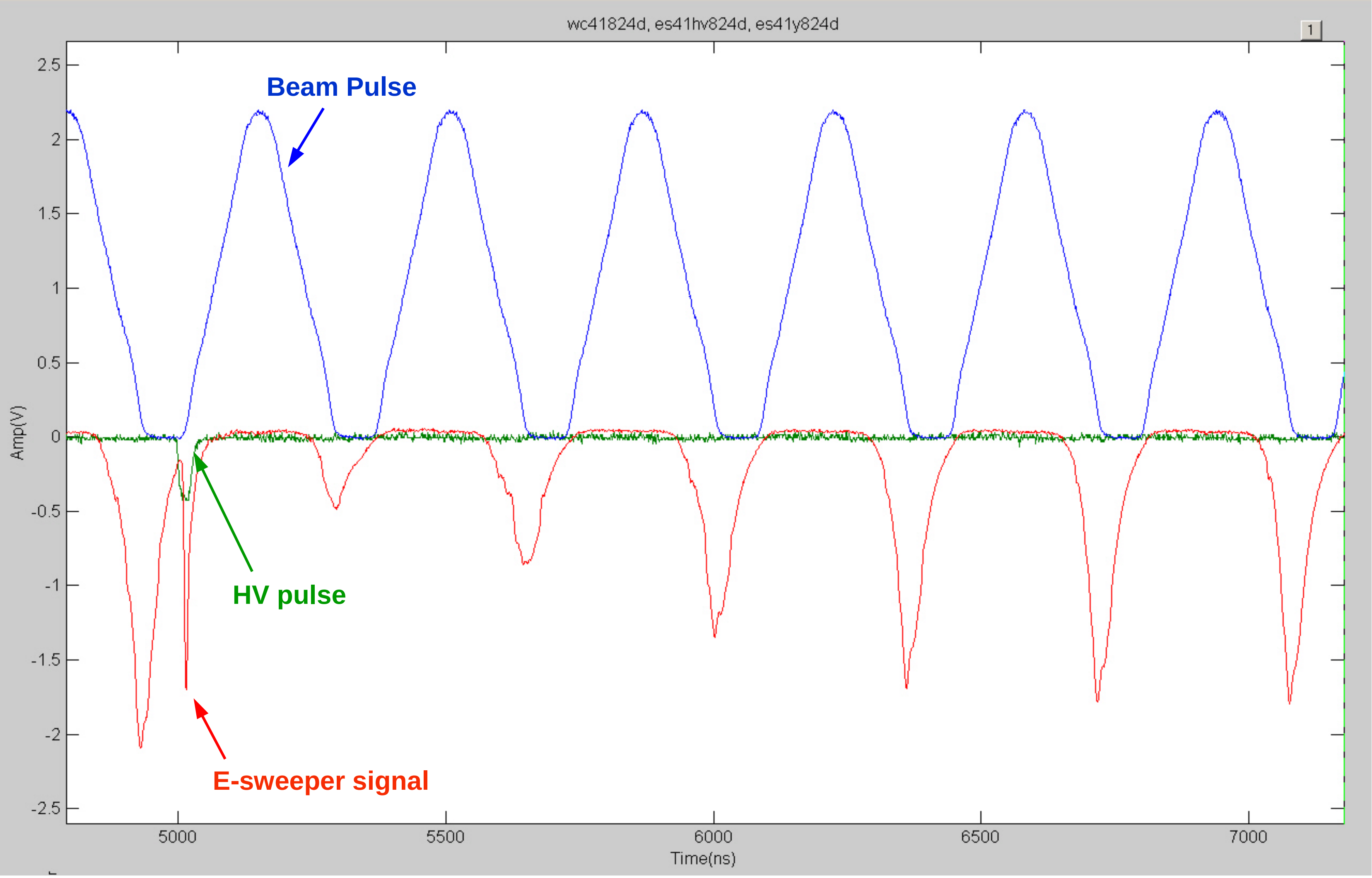
- **Changed beam losses two ways**
  - **Move stripper foil into the beam**
    - Changes amount of foil scattering but all other beam parameters fixed
    - Monitor foil current
  - **Introduce local closed orbit bumps, measure losses with local loss monitor (scintillator with ~ 10 ns resolution, if desired)**
  - **Find that prompt electron signal in RFA is linear in relative losses over considerable range**

- **Changed vacuum in several sections by turning off ion pumps**
  - **Find that prompt electron signal in RFA is linear over range of 10-1000 nTorr**
  - **Electrons surviving the gap unchanged at intensities studied**

Studies of suppressing e-cloud buildup

- **TiN coatings gave mixed results**
  - **suppressed “prompt” electrons by a factor of 100 or more in tests in section 5 of PSR in 1999,**
  - **perhaps a factor of 40 in section 9 but**
  - **no improvement in section 4 in 2002 tests**
- **Weak solenoid magnetic field suppressed prompt electrons by factor of ~ 50 in a 0.5 m section in PSR**
  - **Solenoids over ~12% of circumference had no effect on instability**
- **Beam conditioning over time reduced prompt electron signals and improved the instability threshold curves**

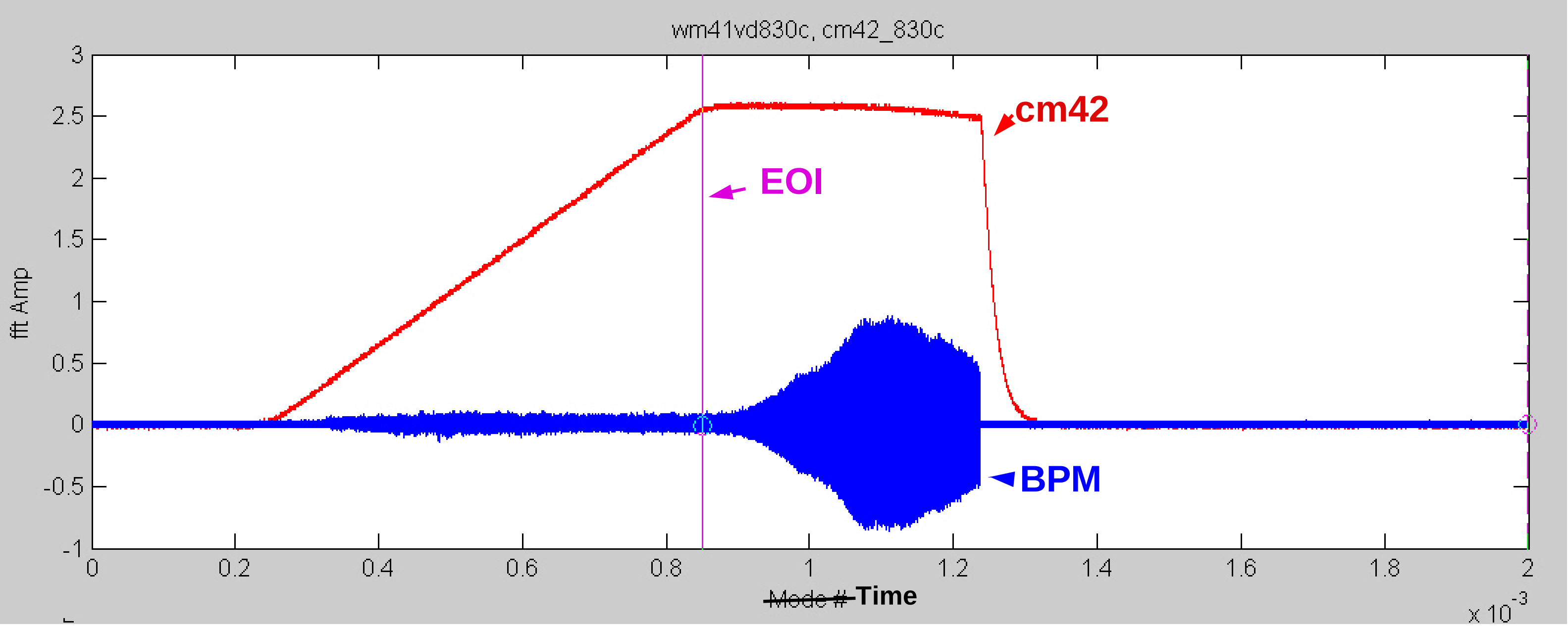
Recovery after “Clearing Gap” of electrons



Bk 98, p 50-51

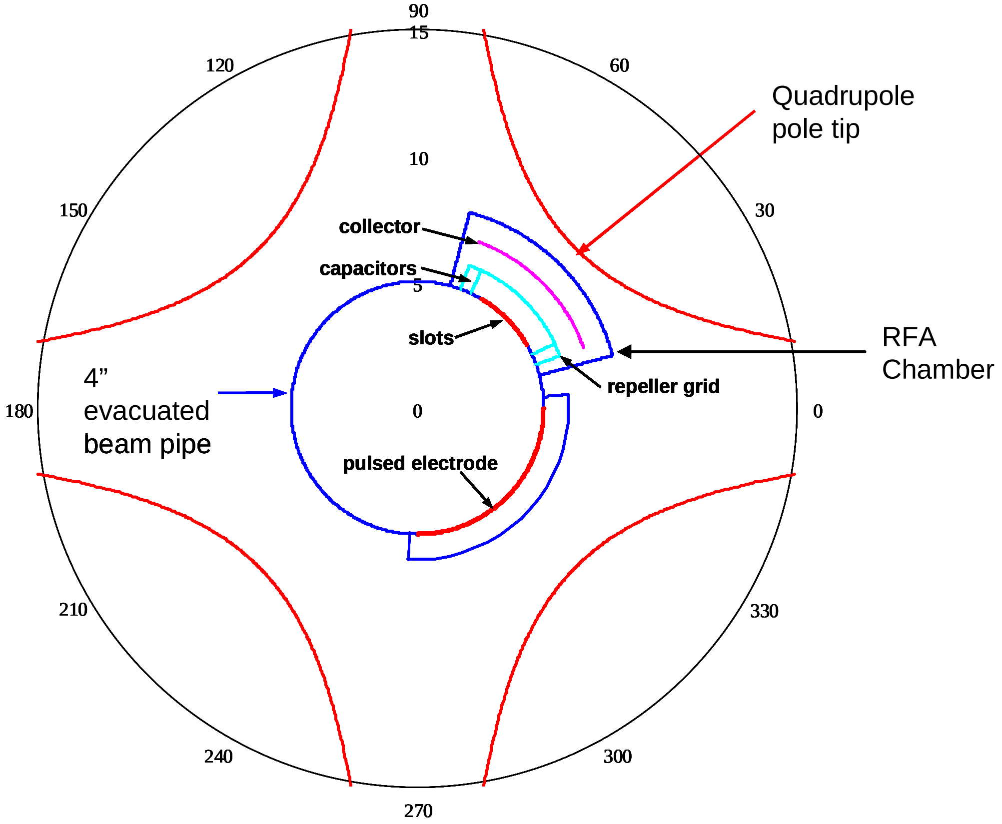
Beam response to weak kick

- Motivated by possibility of obtaining wake functions/impedance
- 5 μC/pulse beam stored for 400 μs
- Buncher at 11 kV, about twice as much as at instability threshold for this intensity
- ±1 kV kick on pinger at EOI for 1 turn
- Large beam losses near end of response



Proposal for future work

- Electrons in quadrupoles are an unresolved issue for PSR
  - Simulations of Pivi indicate significant multipacting plus trapping in mirror fields of quad
  - Source terms for seed electrons from grazing proton losses should be largest in quads
  - Results from biased BPM plates striplines suggest many electrons in PSR quad
- Concept for detector in PSR quad



Medium/high energy proton rings (cont)

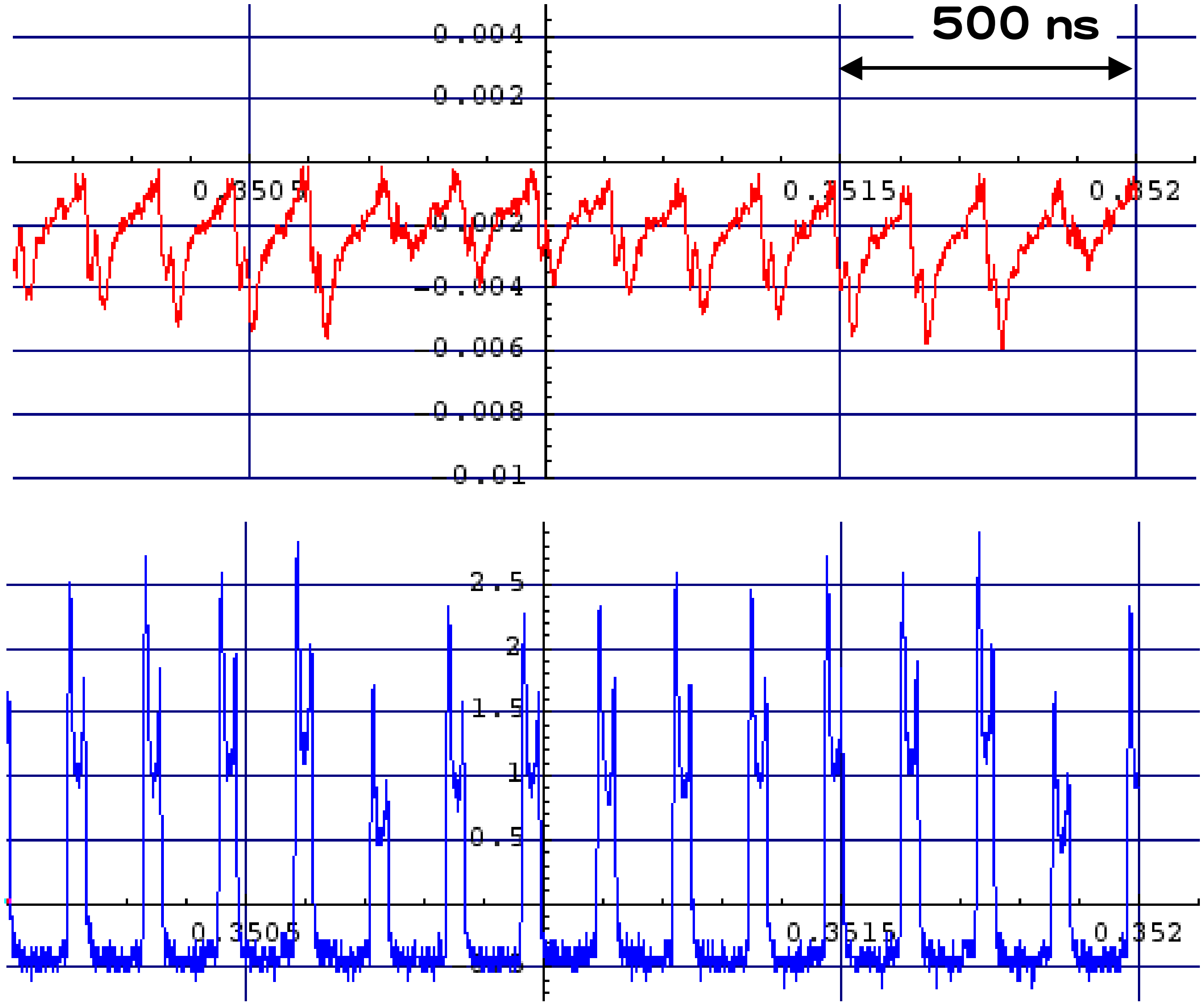
- PSR

- J-PARC, Japan Proton Accelerator Research Complex (3 GeV RCS and 50 GeV MR)
  - Simulated EC buildup and ECI for bunched and coasting beams
  - Analyzed electron yield (seed electrons) from many sources
  - ECI not expected for present parameters, assuming cures
    - TiN coating
    - solenoids

- KEK PS (12 GeV PS MR)
  - Measured EC with electron sweeper for bunched and coasting beams

Electron build-up due to bunched beam @ KEK-PS MR

- **Electron sweeping detector / 9 bunches**

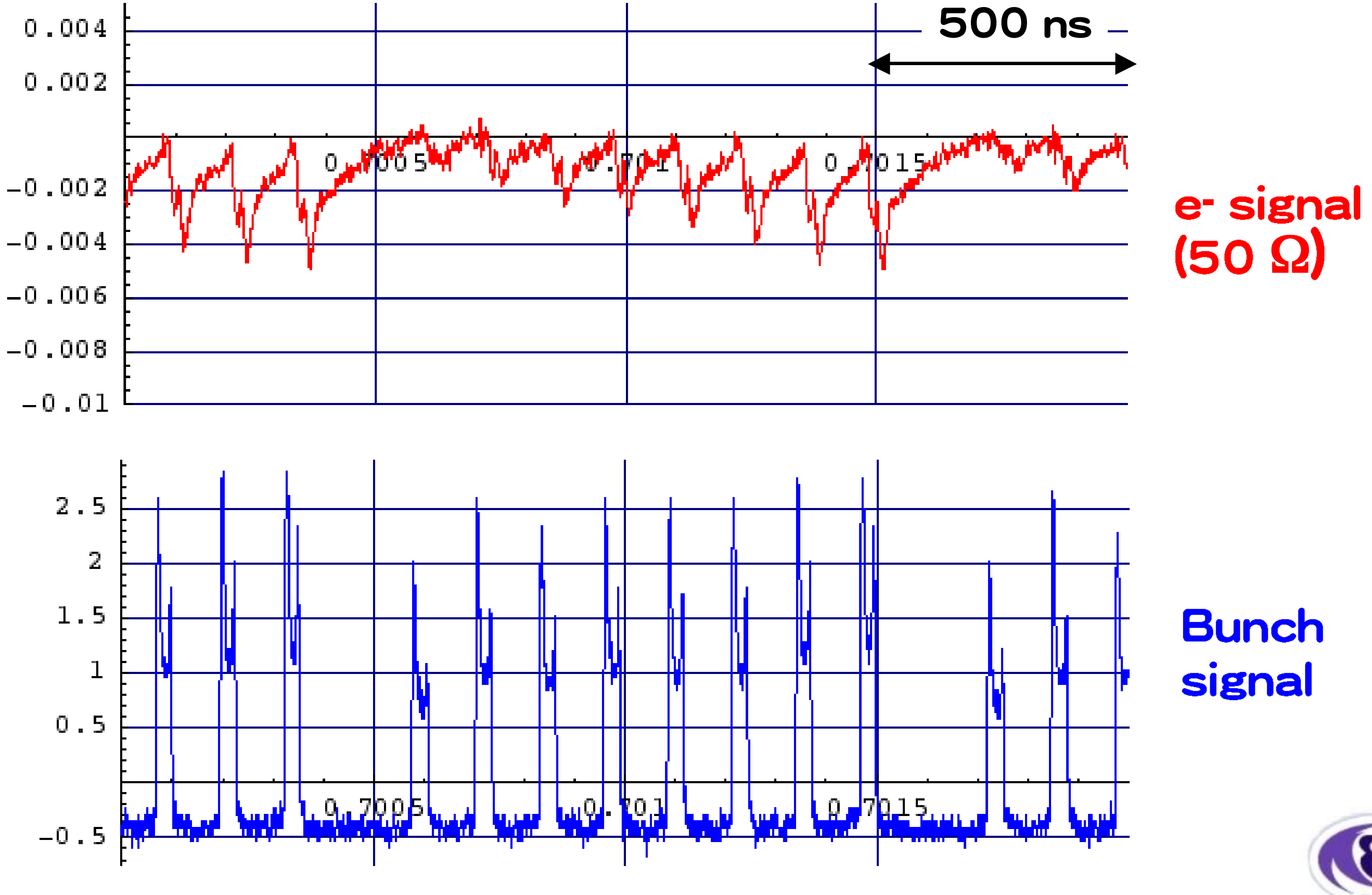


e- signal (50 Ω)

Bunch signal

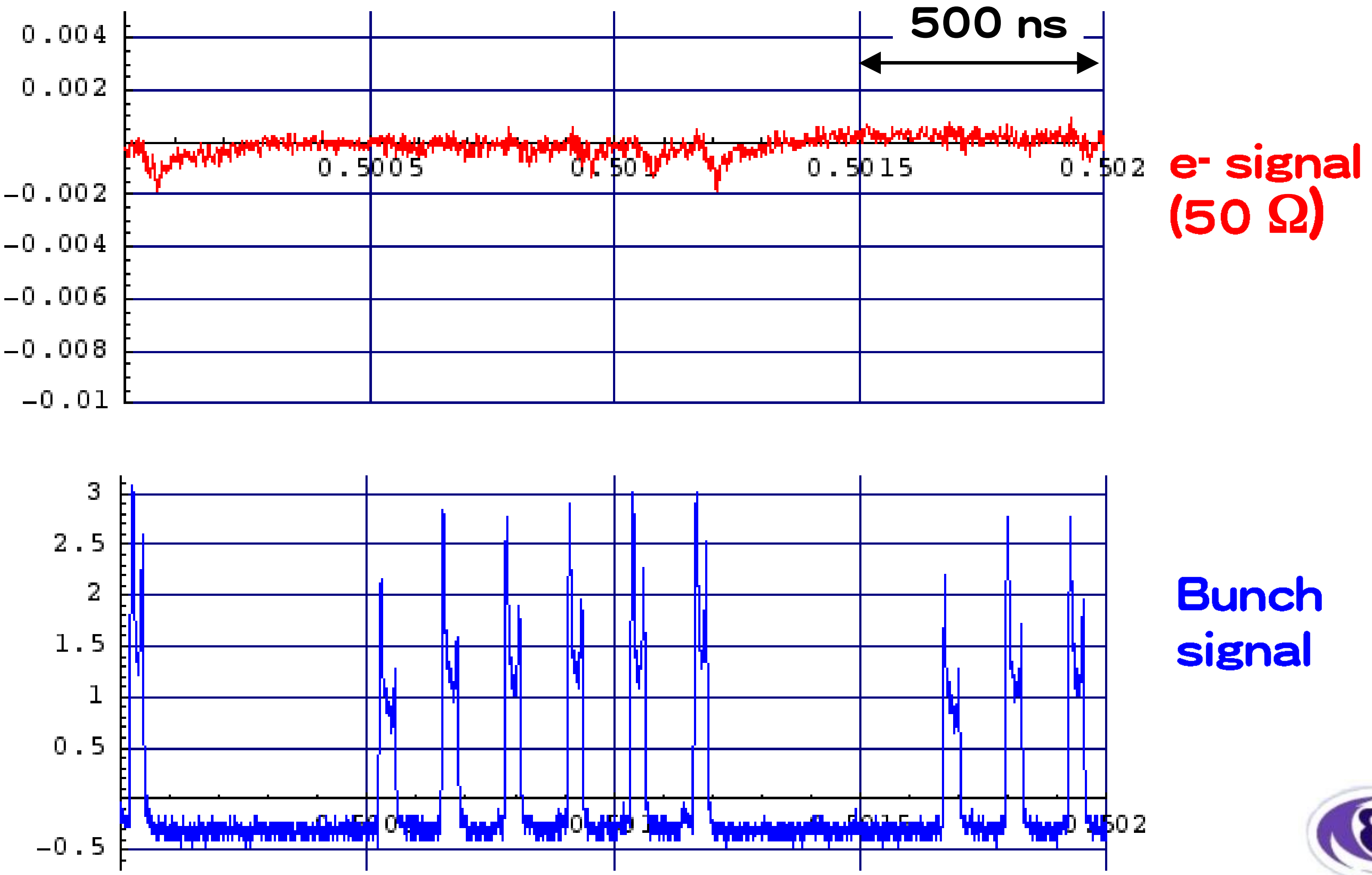
J-PARC Electron build-up due to bunched beam @ KEK-PS MR

- **Electron sweeping detector / 8 bunches**



J-PARC Electron build-up due to bunched beam @ KEK-PS MR

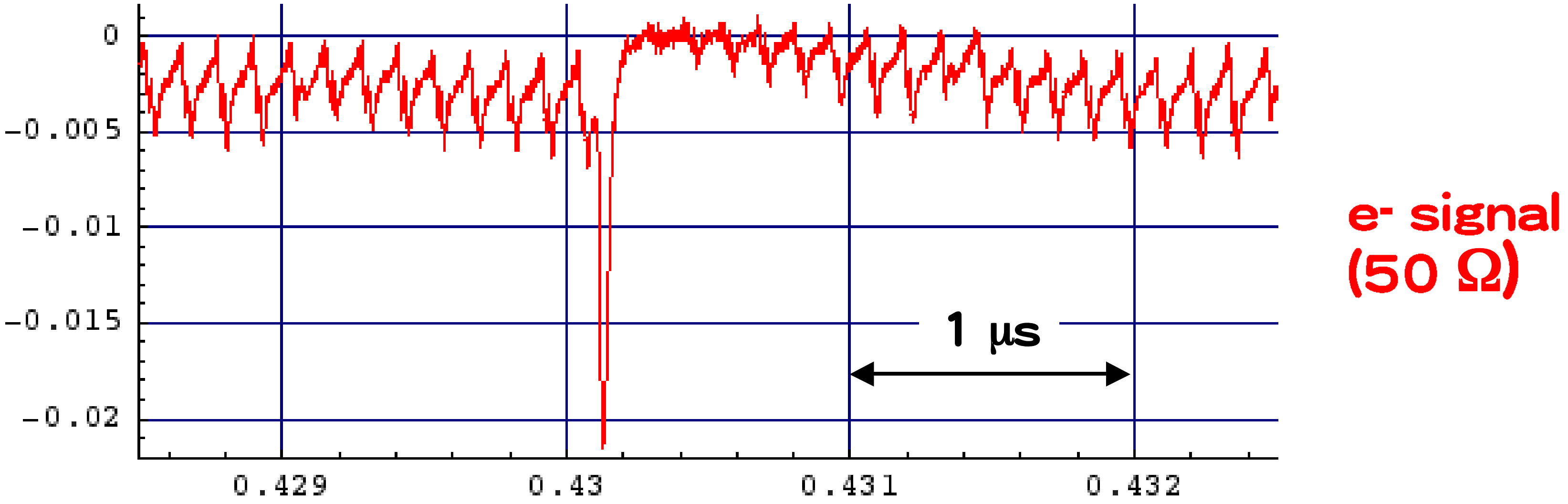
- Electron sweeping detector / 6 bunches
  No electron signal for < 5 bunches



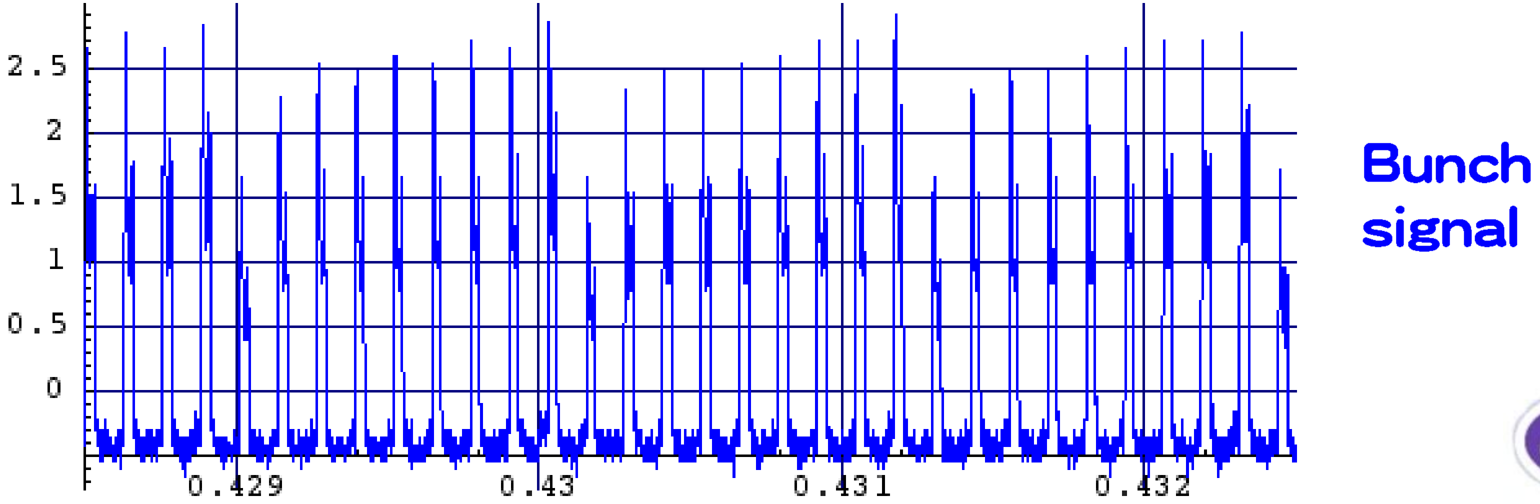
Electron build-up due to bunched beam @ KEK-PS MR

- Electron sweeping detector / 9 bunches

electron cloud is saturated within a few bunches



e- signal (50 Ω)

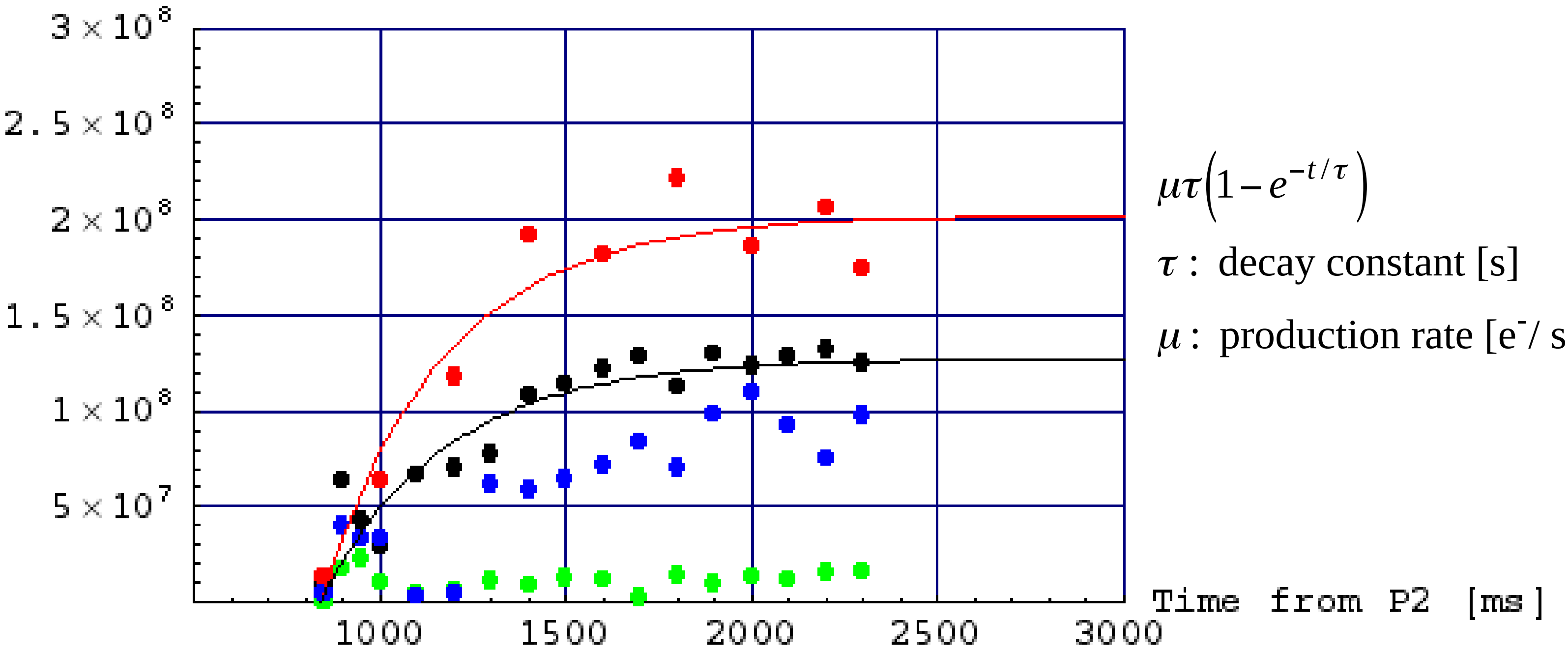


Bunch signal

Electron build-up due to coasting beam @ KEK-PS MR

Swept electrons @ IV-5D

Black: NB~3.6 10^{12} ppp, no bump
Blue: NB~3.0 10^{12} ppp, no bump
Green: NB~1.9 10^{12} ppp, no bump
Red: NB~3.6 10^{12} ppp, vert. bump->beam loss



$$\mu\tau\left(1-e^{-t/\tau}\right)$$

τ : decay constant [s]

μ : production rate [e^-/ s]

Electron build-up due to coasting beam @ KEK-PS MR

variables	KEK-PS MR
Energy [GeV]	12
N_B [protons]	3.6×10^{12}
f_{rev} [kHz]	882
P [Pa]	$2 - 6 \times 10^{-6}$
production rate [e^-/m.p]	3×10^{-9} ($6 - 17 \times 10^{-8}$ cal.)
production rate [e^-/m]	1×10^{4}
λ_e [/m]	3×10^{9}
λ_p [/m]	0.97×10^{10}
Neutralization @ saturation	0.3
Time constant [s]	0.3

⇧

Experiment

No visible instability

Heavy ion rings and linacs

- RHIC
  - Pressure rise observed in warm chambers with Au^{79+}, d^+, p
  - Consistent with EC-stimulated gas desorption
  - EC matters only insofar as it creates pressure rise
  - Studies with NEG and solenoids
  - ECEs measured in cold chambers of interest to LHC
  - Calcs to correlate backgrounds with pressure at collisions

- Heavy ion induction linac for HIF
  - "Extreme" beam
  - Large fill factor required
  - Beam (ion) loss on walls main concern (at quads – cf. PSR) when desorbed gas is ionized by beam
  - Experimental techniques developed; data analysis removing diagnostic systematics
  - Close partnership with theory

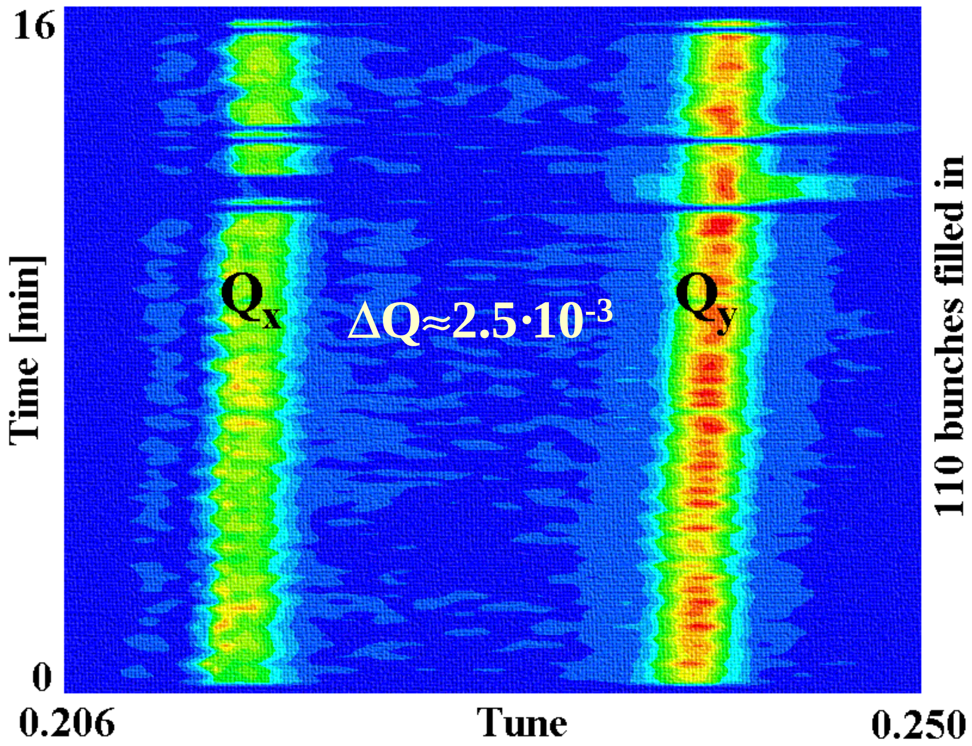
Pressure rise mechanisms considered so far

- Electron cloud → **confirmed**
  - Coherent tune shift in bunch train
  - Electron detectors
- Ion desorption → **small**
  - Rest gas ionization, acceleration through beam
  - Ion energies ~10eV
  - Effect too small to explain pressure rise at injection
- Beam loss induced desorption → **under investigation**
  - No reliable desorption coefficients
  - Need to have beam losses in all locations with pressure rise

[W. Fischer et al., "Vacuum pressure rise with intense ion beams in RHIC", EPAC'02]

Indirect observation – coherent tune shift along bunch train

$33 \cdot 10^{11}$ p^+ total, $0.3 \cdot 10^{11}$ p^+/bunch, 110 bunches, 108 ns spacing (2002)



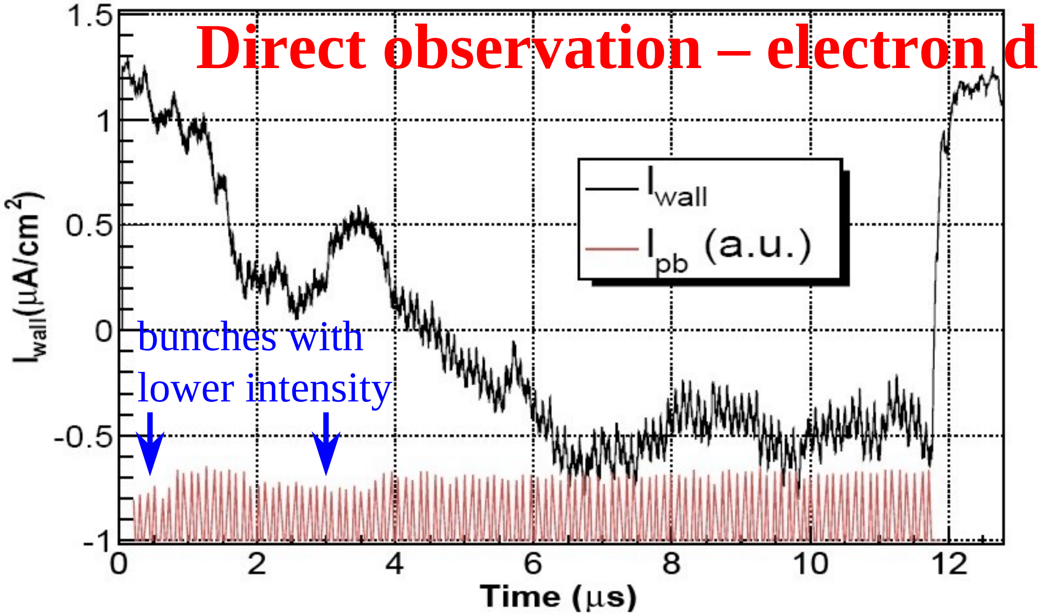
(1) From measured tune shift, the e-cloud density is estimated to be 0.2 – 2.0 $nC \cdot m^{-1}$

(2) E-cloud density can be reproduced in simulation with slightly higher charge and 110 bunches (CSEC by M. Blaskiewicz)

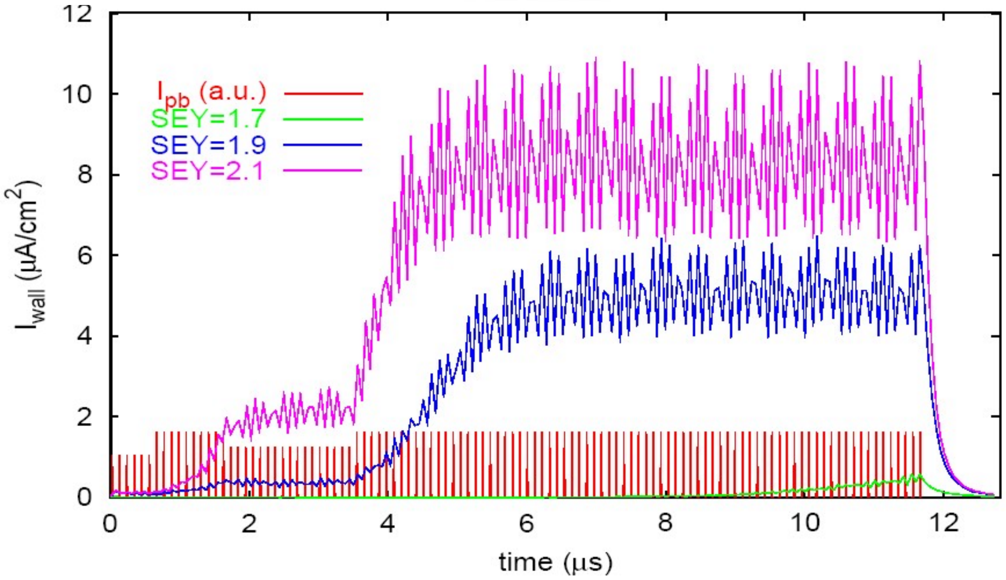
[W. Fischer, J.M. Brennan, M. Blaskiewicz, and T. Satogata, “Electron cloud measurements and observations for the Brookhaven Relativistic Heavy Ion Collider”, PRSTAB 124401 (2002).]

Direct observation – electron detectors

U. Iriso-Ariz



bunches with lower intensity



Observation:

$88\cdot10^{11}$ p^+ total

$0.8\cdot10^{11}$ p^+/bunch

110 bunches

108 ns spacing

Simulation:

Variation of SEY_{max}: 1.7 to 2.1

Keep R=0.6

(reflectivity for zero energy)

Good fit for

SEY_{max} = 1.8 and R=0.6

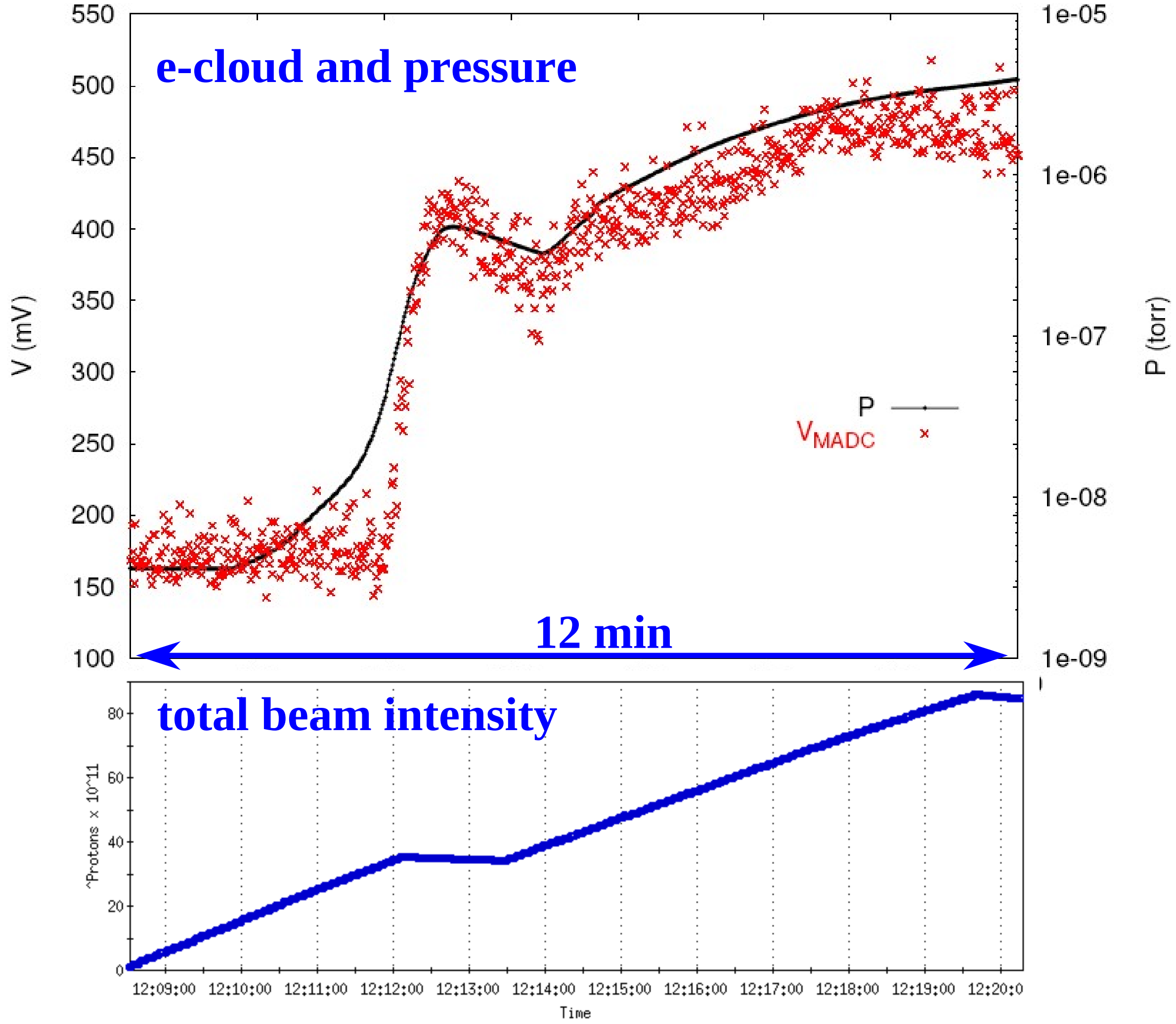
Code: CSEC by M. Blaskiewicz

[U. Iriso-Ariz et al. “Electron cloud and pressure rise simulations for RHIC”, PAC’03.]

Electron cloud and pressure rise

$86\cdot10^{11}$ p^+ total, $0.78\cdot10^{11}$ p^+/bunch, 110 bunches, 108 ns spacing

U. Iriso-Ariz



Clear connection between e-cloud and pressure at injection

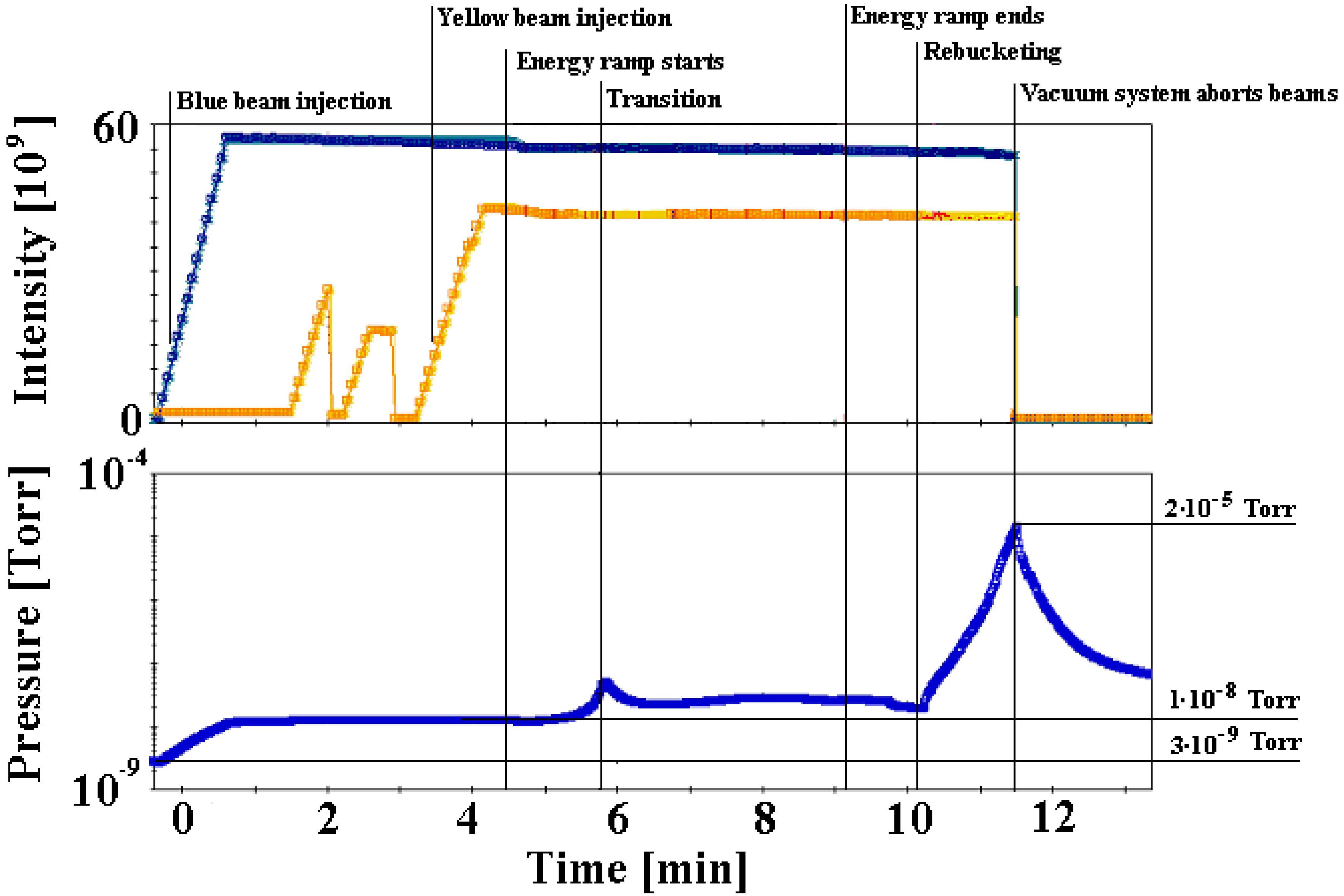
Estimate for η_e assuming pressure caused by e-cloud:

0.001-0.02

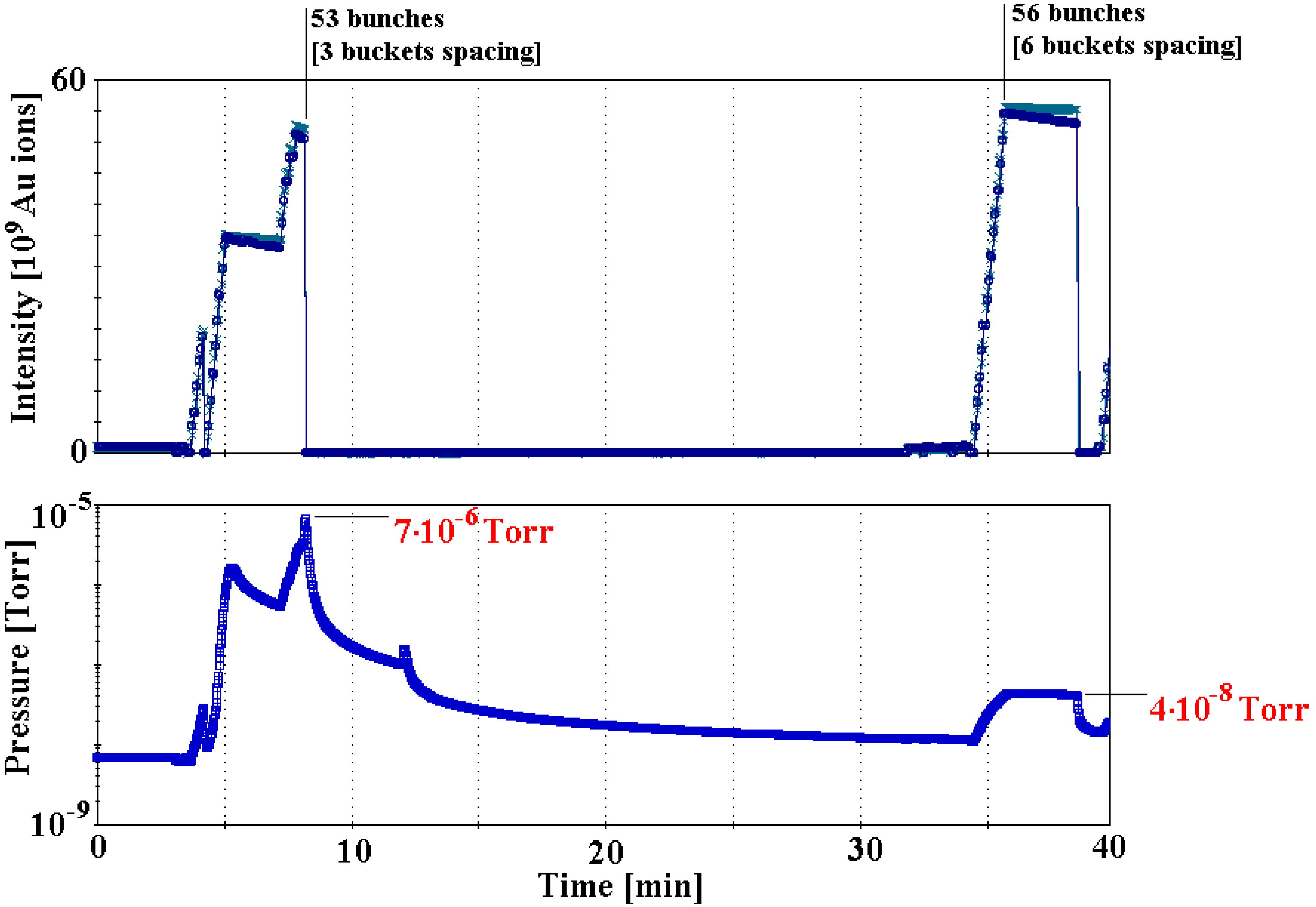
(large error from multiple sources)

[U. Iriso-Ariz et al. “Electron cloud observations at RHIC during FY2003”, in preparation.]

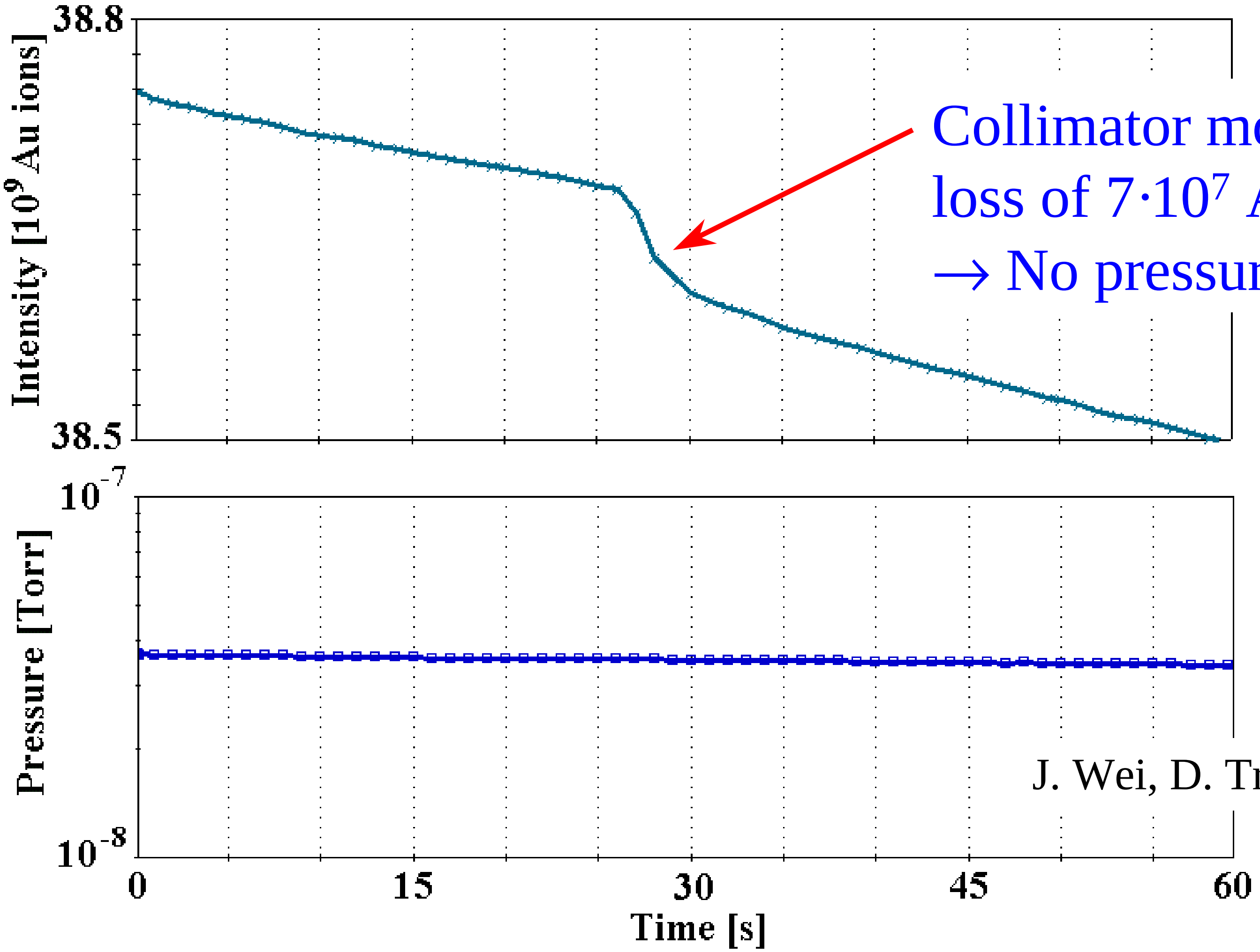
Blue pressure rise sector 8



Injection with different bunch spacing



Additional losses at pressure rise location



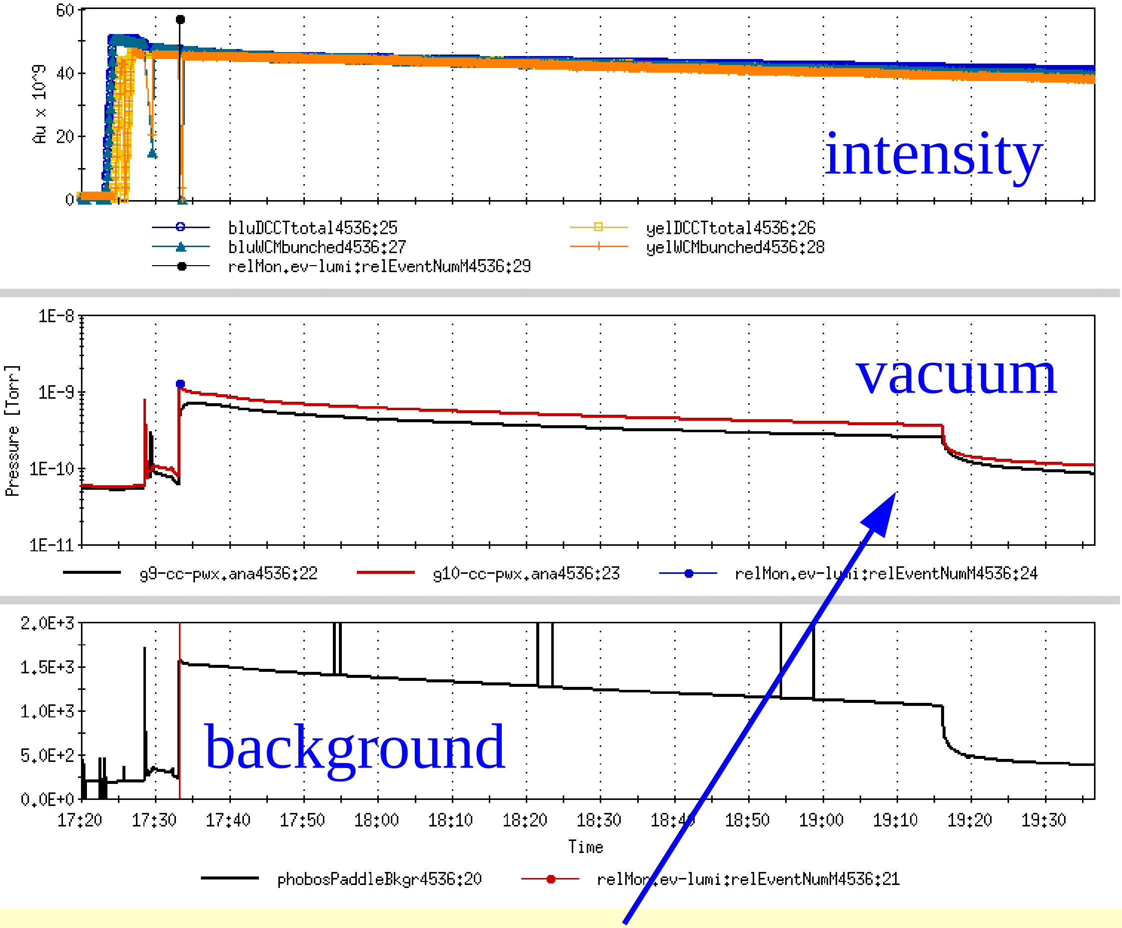
Collimator movement lead to loss of $7 \cdot 10^7$ Au ions in 5sec
→ No pressure rise observed

J. Wei, D. Trbojevic, W. Fischer

PHOBOS background increase after rebucketing, drops after minutes to 2 hours

(most severe luminosity limit in Run-4)

Rebucketing, bunch length reduced to 50%



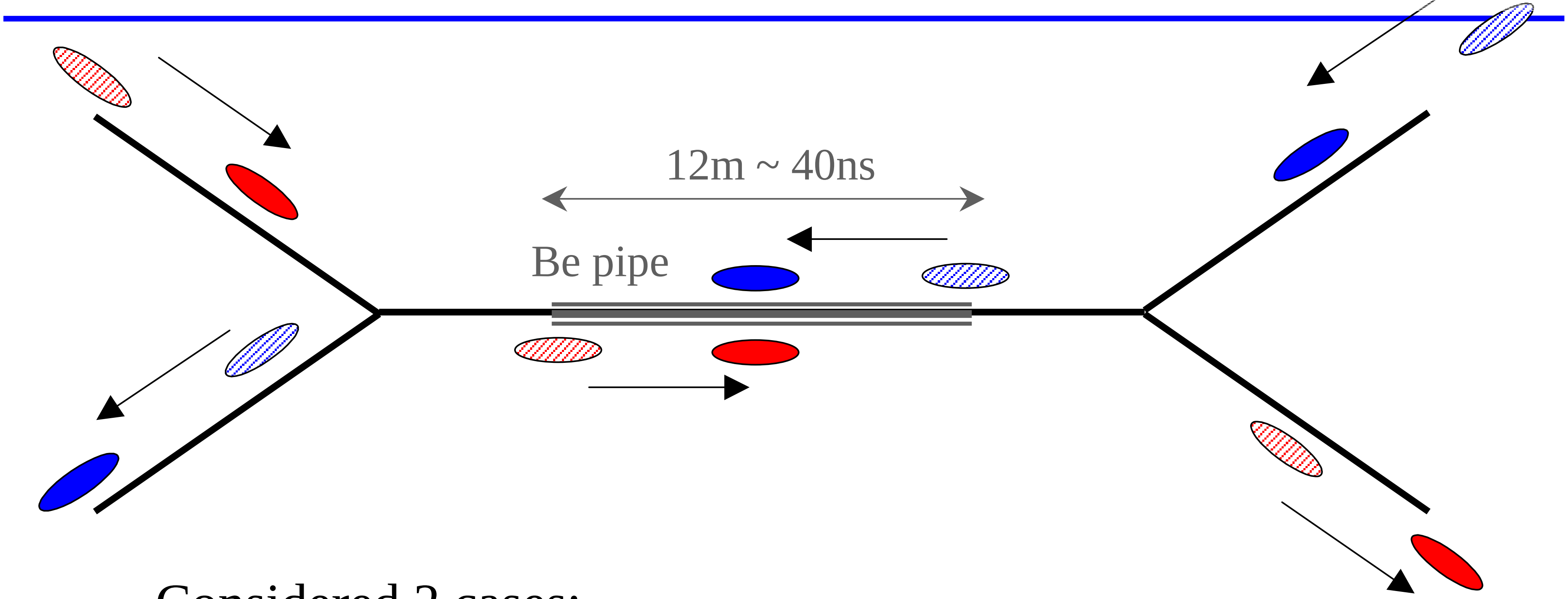
intensity

vacuum

background

[Some thoughts on switch-off: U. Iriso and S. Peggs, “Electron cloud phase transitions”, BNL C-A/AP/147 (2004). **Can e-cloud codes create 1st order phase transitions?**]

IR10 pressure rise simulations (1) **G. Rumolo, GSI**



Considered 2 cases:

At IP:

nominal bunch spacing (~216ns) and double intensity

At end of the beryllium pipe:

normal intensity, spacing of 40ns then 176ns

[G. Rumolo and W. Fischer, “Observation on background in PHOBOS and related electron cloud simulations”, BNL C-A/AP/146 (2004).]

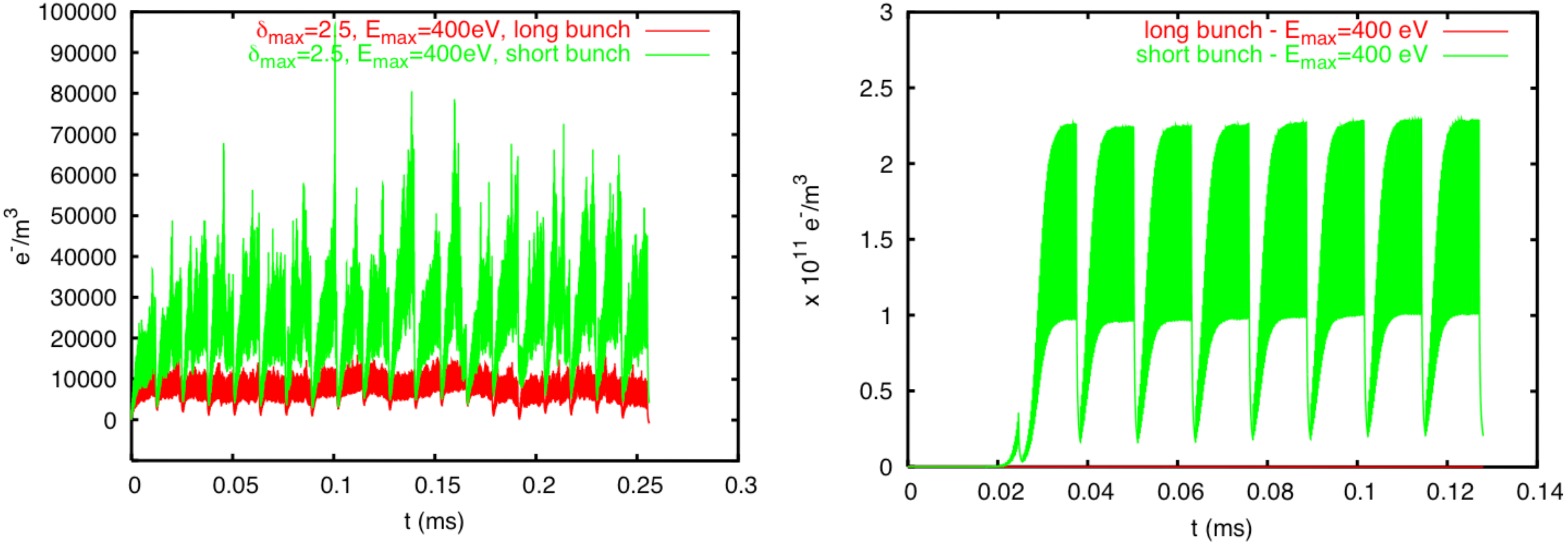
IR10 pressure rise simulations (2) **G. Rumolo, GSI**

Important result:

After surface parameter calibration find e-clouds at end of 12m Be pipe, but not in center

→ May be sufficient to suppress e-cloud at ends

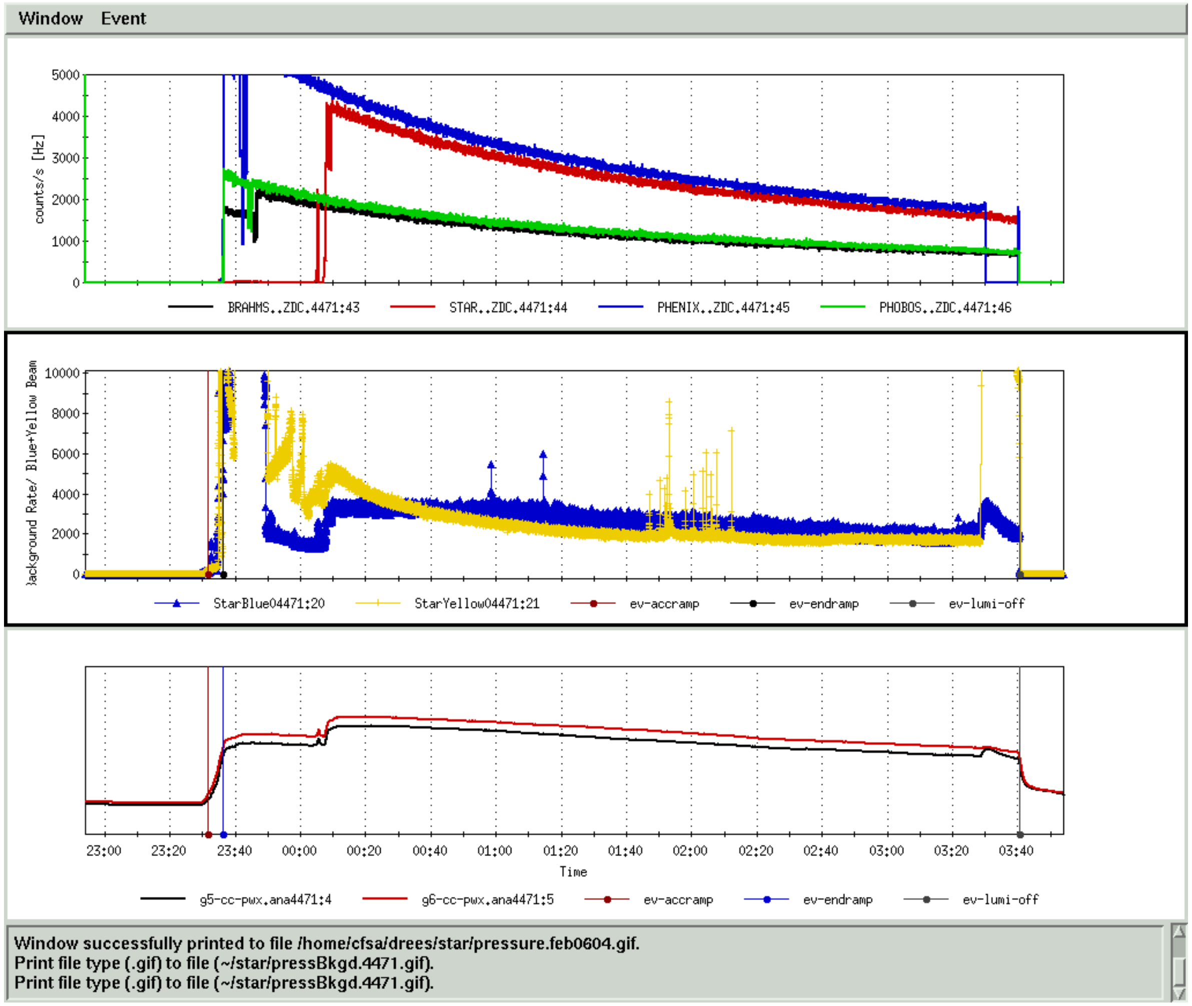
E_{max}=400 eV and δ_{max}=2.5



Center of Be pipe

End of Be pipe

Fill 4471 ZDC coincidence, pressure and backgrounds



```
Window successfully printed to file /home/cfsa/drees/star/pressure.feb0604.gif.
Print file type (.gif) to file (~/star/pressBkgd.4471.gif).
Print file type (.gif) to file (~/star/pressBkgd.4471.gif).
```

No excess rate
at STAR

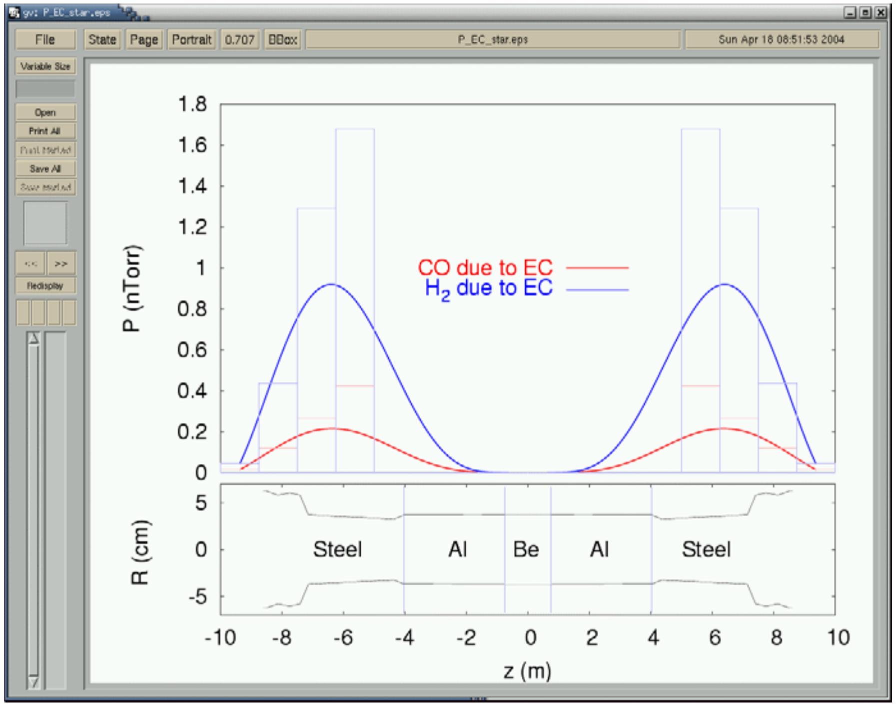
Decent background

Small pressure rise

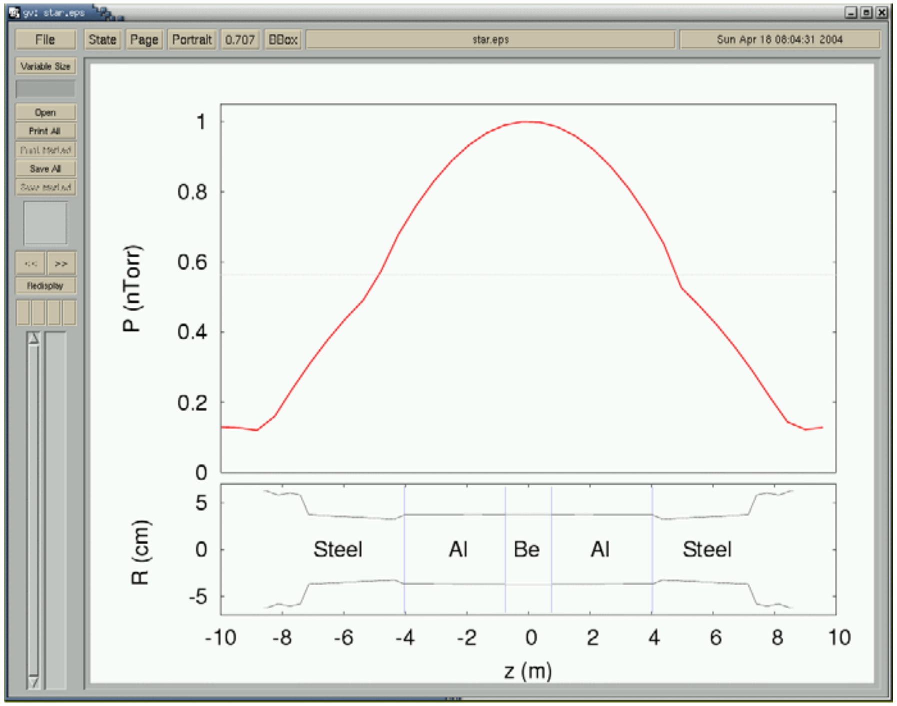
Accidental collision rate consistent with beam-gas; can be used to benchmark EC codes

Predicted vacuum distribution

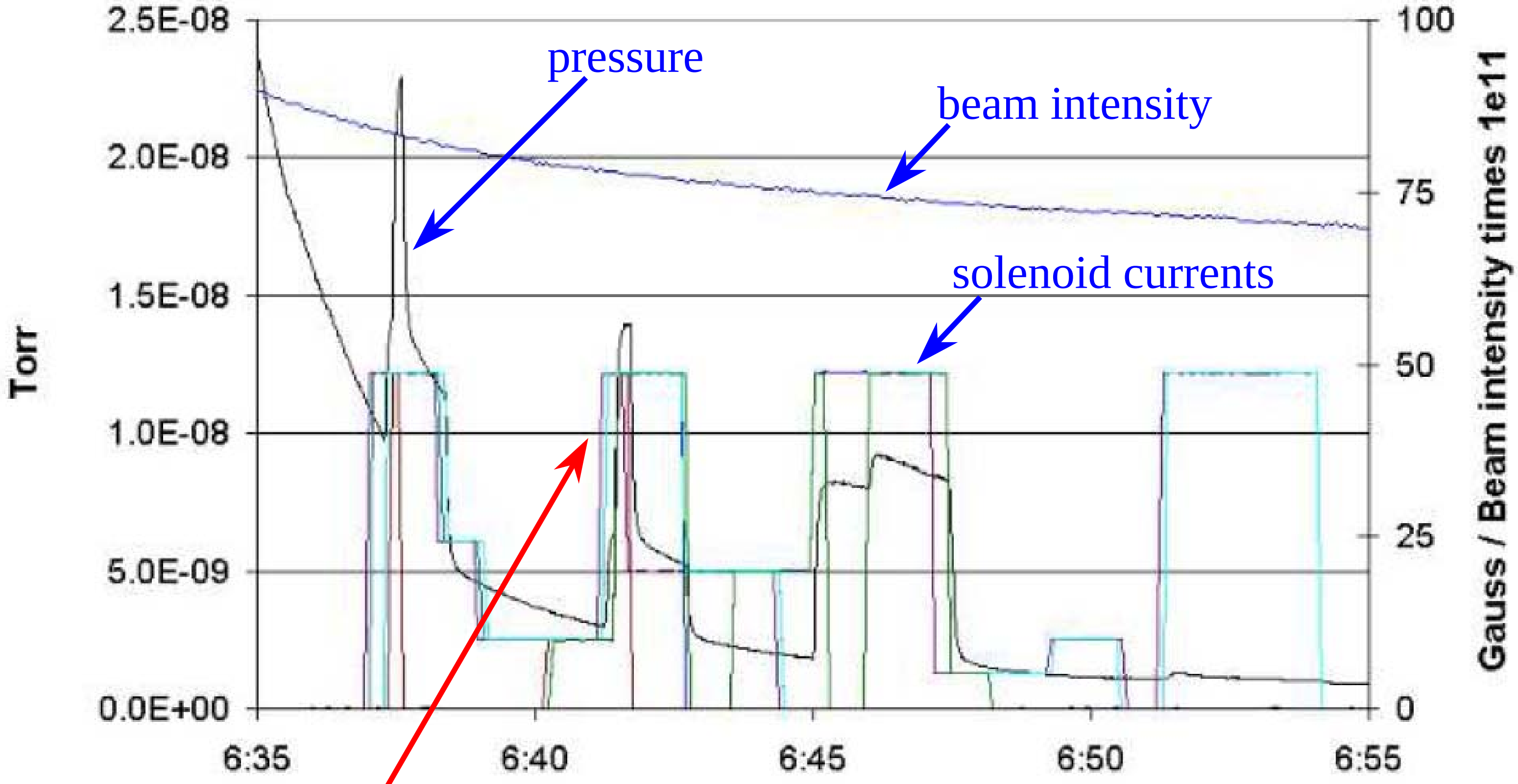
Instantaneous pressure distribution as created by EC



Without beam (VACCALC)*



* Ping He, BNL



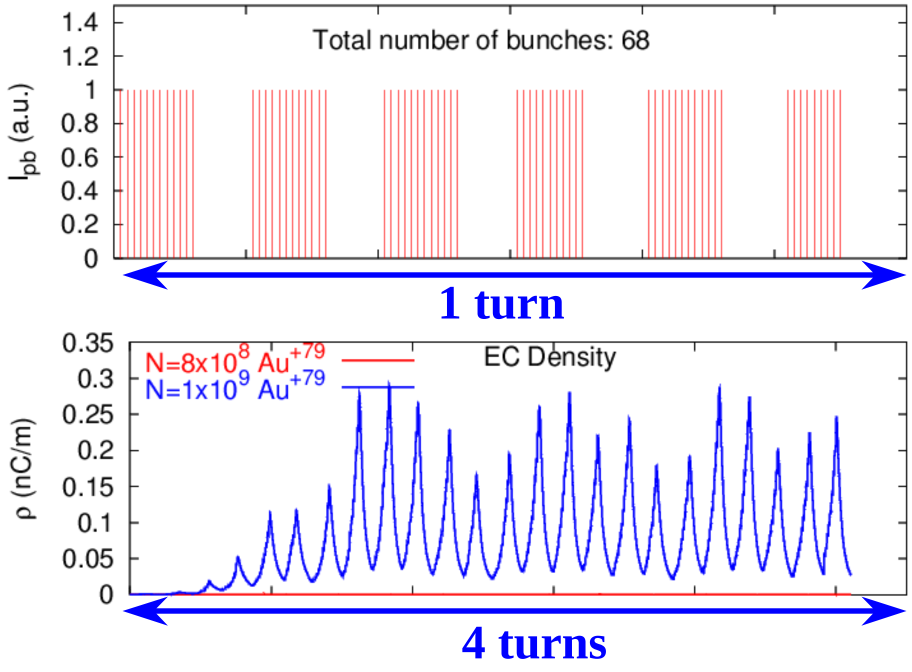
pressure increase with increasing solenoid fields **U. Iriso-Ariz**

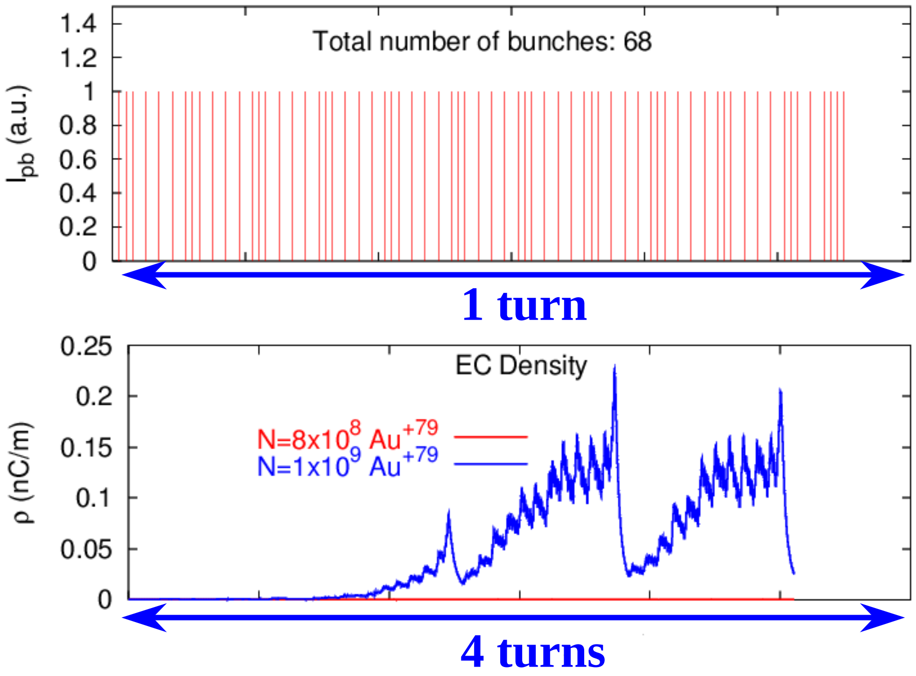
[U. Iriso-Ariz et al., “Electron cloud observations at RHIC during FY2003”, BNL C-A/AP note in preparation (2003)]

Counter measures: bunch pattern (4)

Assuming e-cloud induced pressure rise, test bunch patterns in simulation, and observe e-cloud densities. **U. Iriso-Ariz**

5 cases tested with 68 bunches (20% more than Run-3), all with same parameters close to e-cloud threshold (except pattern)





Code: CSEC by M. Blaskiewicz

- Electron cloud driven pressure rise observed in RHIC (no other e-cloud driven problems so far)
  - With all species (Au^{79+}, d^+, p^+),
  - In warm region only
  - At injection
    - Limits intensity
  - At store
    - Limits intensity (after rebucketing)
    - Causes experimental background
- Counter measures
  - Complete baking of all elements
  - NEG coated pipes → tested successfully, will install ~200m for next Run
  - Bunch patterns → most uniform distributions used
  - Solenoids → work, no wide scale application for now (NEG preferred)
  - Scrubbing → works, but need to remove remaining electronics from tunnel

Heavy ion rings and linacs

- RHIC
  - Pressure rise observed in warm chambers with Au^{79+}, d^+, p
  - Consistent with EC-stimulated gas desorption
  - EC matters only insofar as it creates pressure rise
  - Studies with NEG
  - ECEs measured in cold chambers of interest to LHC
  - Calcs to correlate backgrounds with pressure at collisions

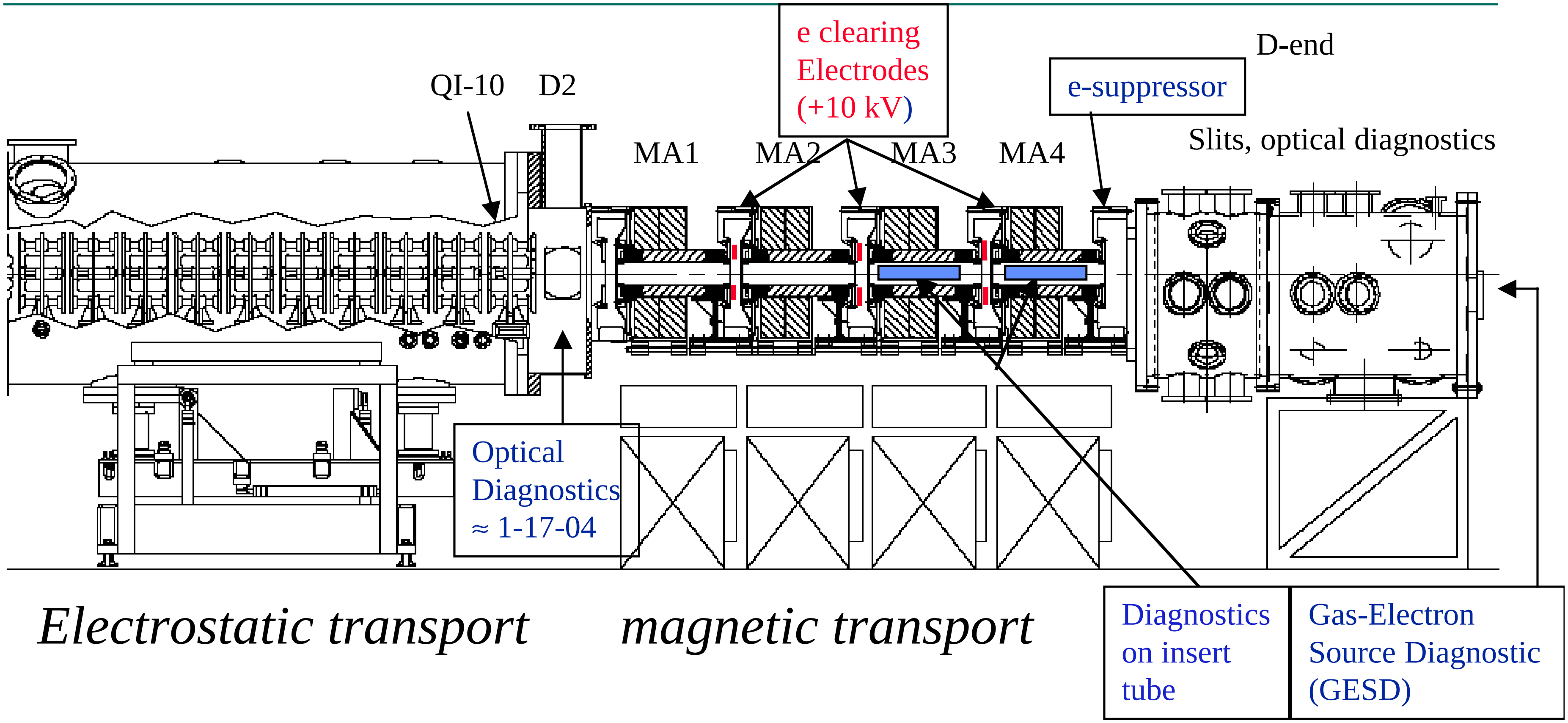
- Heavy ion induction linac for HIF
  - "Extreme" beam
  - Large fill factor required
  - Beam (ion) loss on walls main concern (at quads – cf. PSR) when desorbed gas is ionized by beam
  - Experimental techniques developed; data analysis removing diagnostic systematics
  - Close partnership with theory

HIF-ECE distinguishing features

- Economic mandate to maximally fill beam pipe - ions scrape wall
- Linac with high line charge density (Beam potential ϕ_b > 1 kV)
- Induction accelerator characteristics

  - If beam head scrapes: gas desorbed ($\Gamma_0 \sim 10^3$- 10^4) and secondary e^- (Γ_e ~ 100) trapped by rising ϕ_b. Control of beam head is essential.
  - If beam flattop scrapes: gas desorbed, SEY not necessarily trapped.
  - If desorbed gas reaches beam: e^- from ionized gas are deeply trapped by ϕ_b, cold ions expelled. This is expected to be main e^- source in HIF, especially near injection energies (10-100 keV/amu) where atomic cross sections peak (~10^{-15} cm^2).
  - Electrons are trapped for time to drift through 1 magnet, then expelled.
- Beam-induced multipactor not present
- Trailing-edge multipactor not an issue (≥0.2 s between pulses).

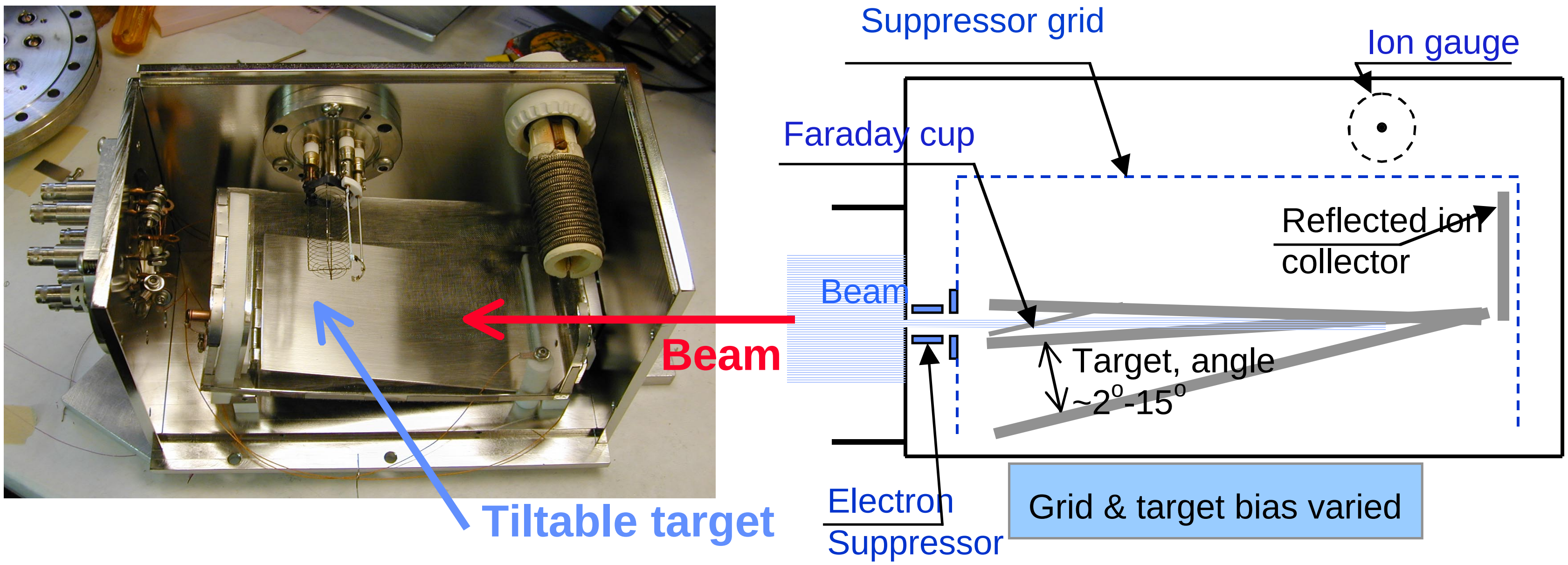
HCX layout for ECE studies in magnetic quads



- ECE experiments began with diagnostics mounted on insert tubes within magnetic quads MA3 & MA4.
- Later experiments removed insert tubes, added electron-suppressor after MA4 and clearing electrodes between magnets.

Measure electron emission Γ_e and gas desorption Γ_0 from 1 MeV K^+ beam impact on target

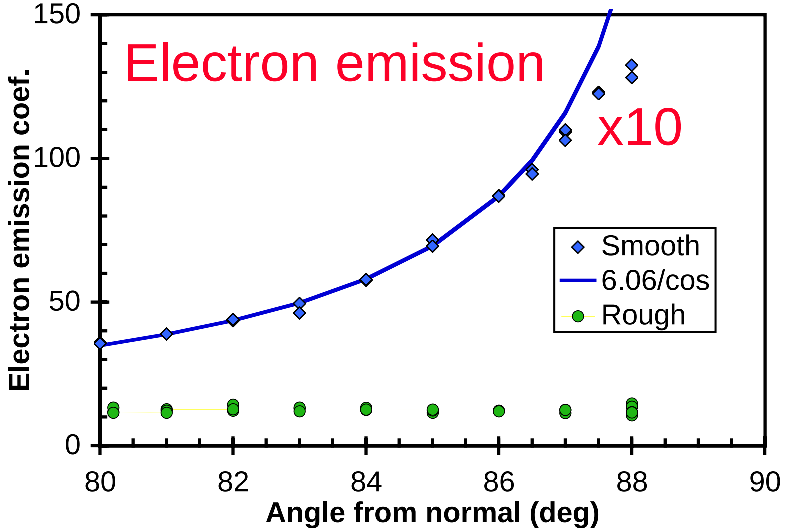
Gas, electron source diagnostic (**GESD**)



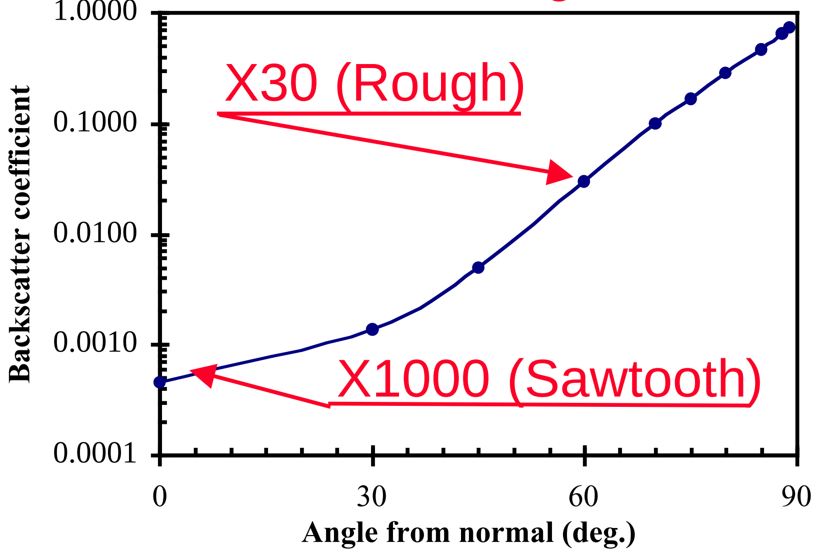
- Measure coefficient of electron Γ_e and gas emission Γ_0 per incident K^+ ion.
- Calibrates beam loss from electron currents to flush wall electrodes.
- Evaluate mitigation techniques: baking, cleaning, surface treatment…
- Measuring scaling of Γ_0 with ion energy – test electronic sputtering model

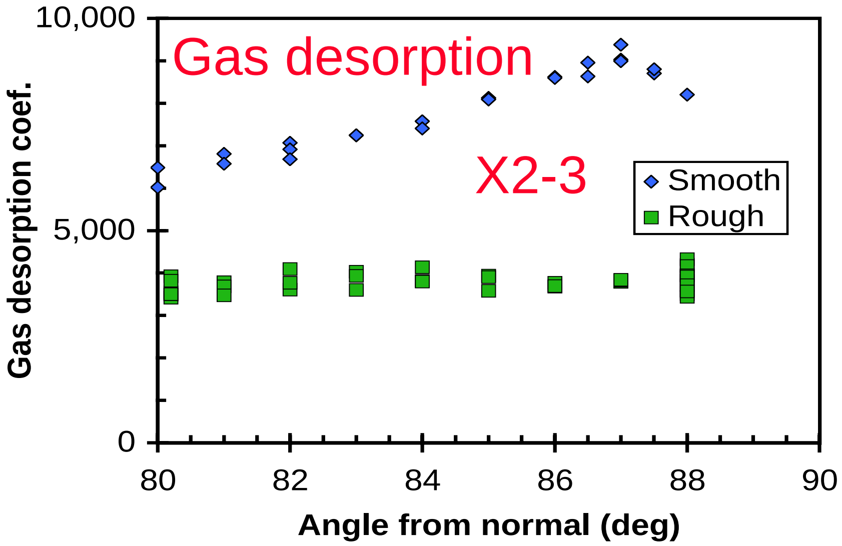
Rough surface mitigates ion-induced electron emission, gas desorption, and ion scattering

- Surface roughened by glass-bead blasting (Inexpensive, but can warp surface)
- Angle of incidence: grazing ⇒ ~60º [from 1/cos emission]
- Sawtooth surface (CERN-SPS) more effective, but more expensive.



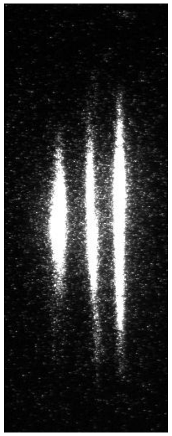
Ion backscattering - SRIM

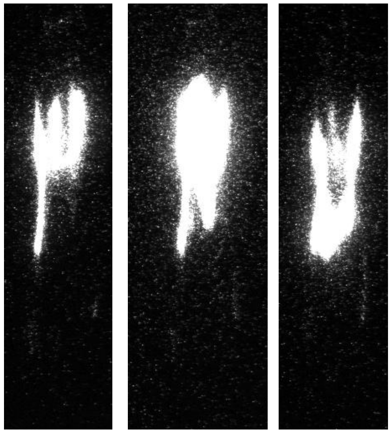




Progress towards high quality beam transport – electron effects only part of picture

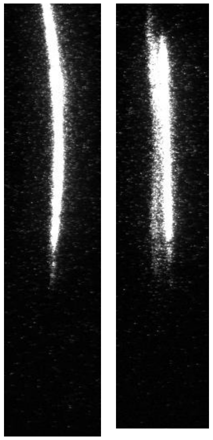
- Beam split into 3, going through a 5.5 cm diam. circular bore (Imaged on scintillator, after beam passes through a slit)





- Slight improvement from opening bore to 6 x 10 cm elliptical bore without suppressor.
- 3-shots shown: still not reproducible.

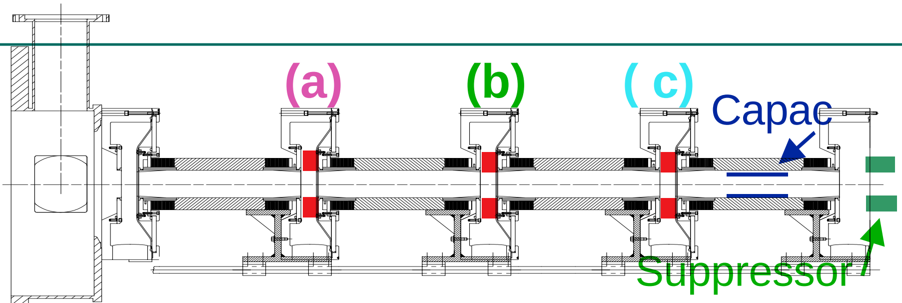
- Electron suppression added between quad. magnets and scintillator – blocks secondary electrons ⇒ trifurcation an ECE
- Scintillator image of beam through a slit is much cleaner
- Quad magnetic field errors: harmonics ≤1%, ≤1mm, ≤1° (?)
- Simulations predict retuning of electrostatic and magnetic quads will eliminate beam loss.

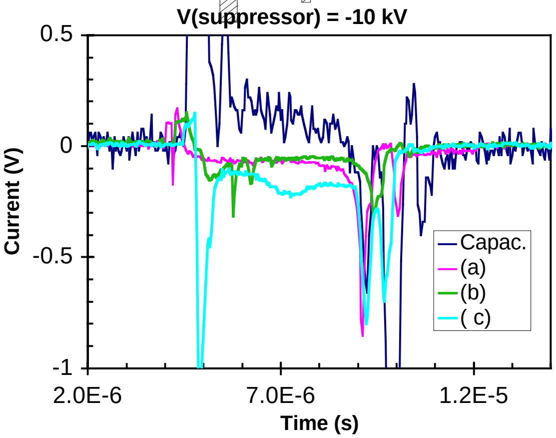


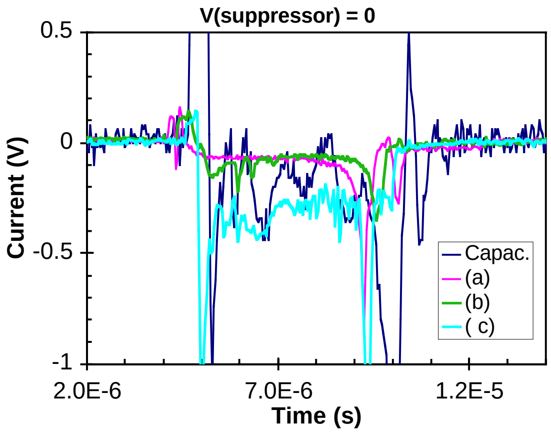
New tools: suppressor ring, clearing electrodes between quads

- Suppressor blocks electrons from quads – improves beam quality
- Clearing electrodes work: upstream indep. of down-stream changes
- Measure drift velocity of e$^-$?

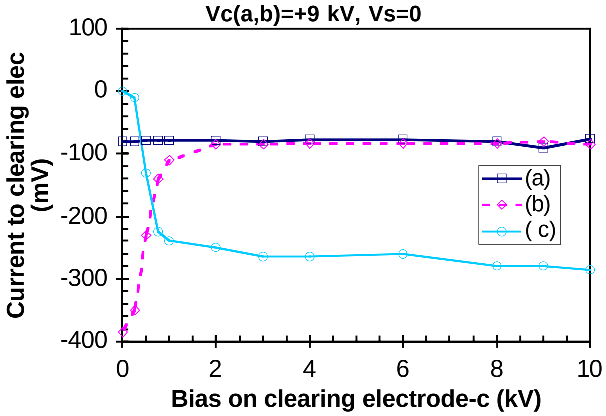
$$\frac{v_e}{v_b} = \frac{2I_e}{I_b} = 0.14$$

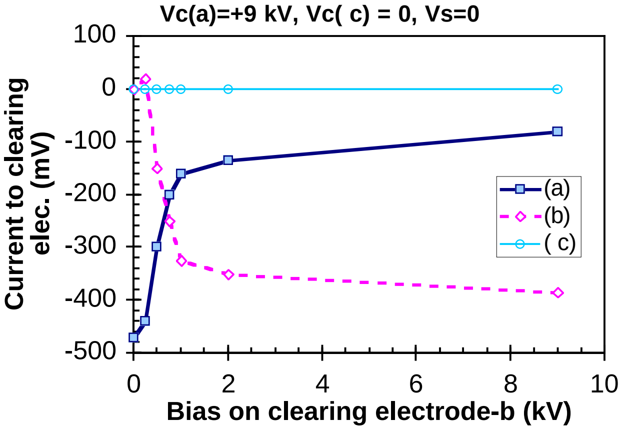






- Capac. electrode: polarity varies with V_s
- Can suppressor reduce e$^-$ to reproducible trickle?

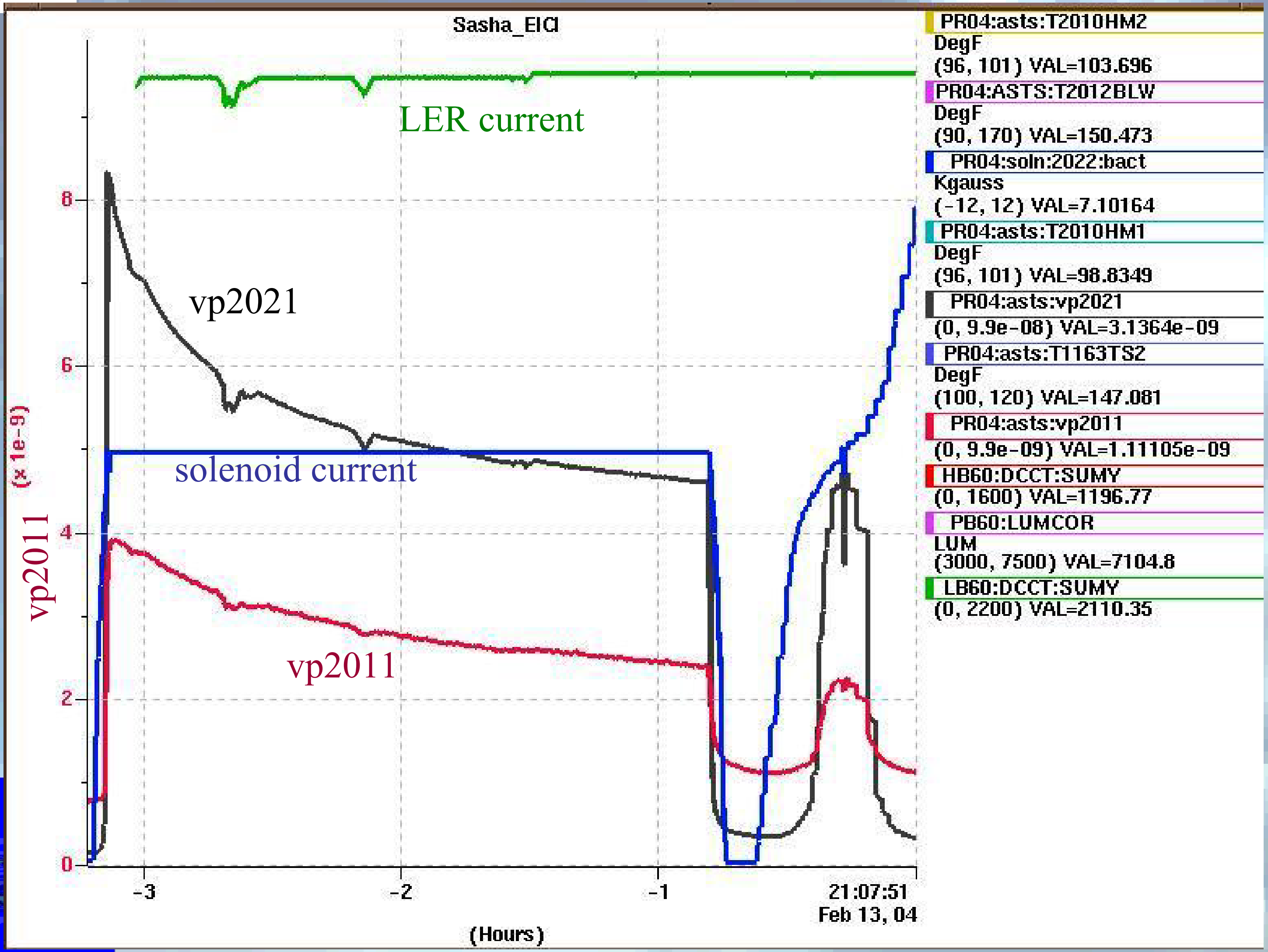




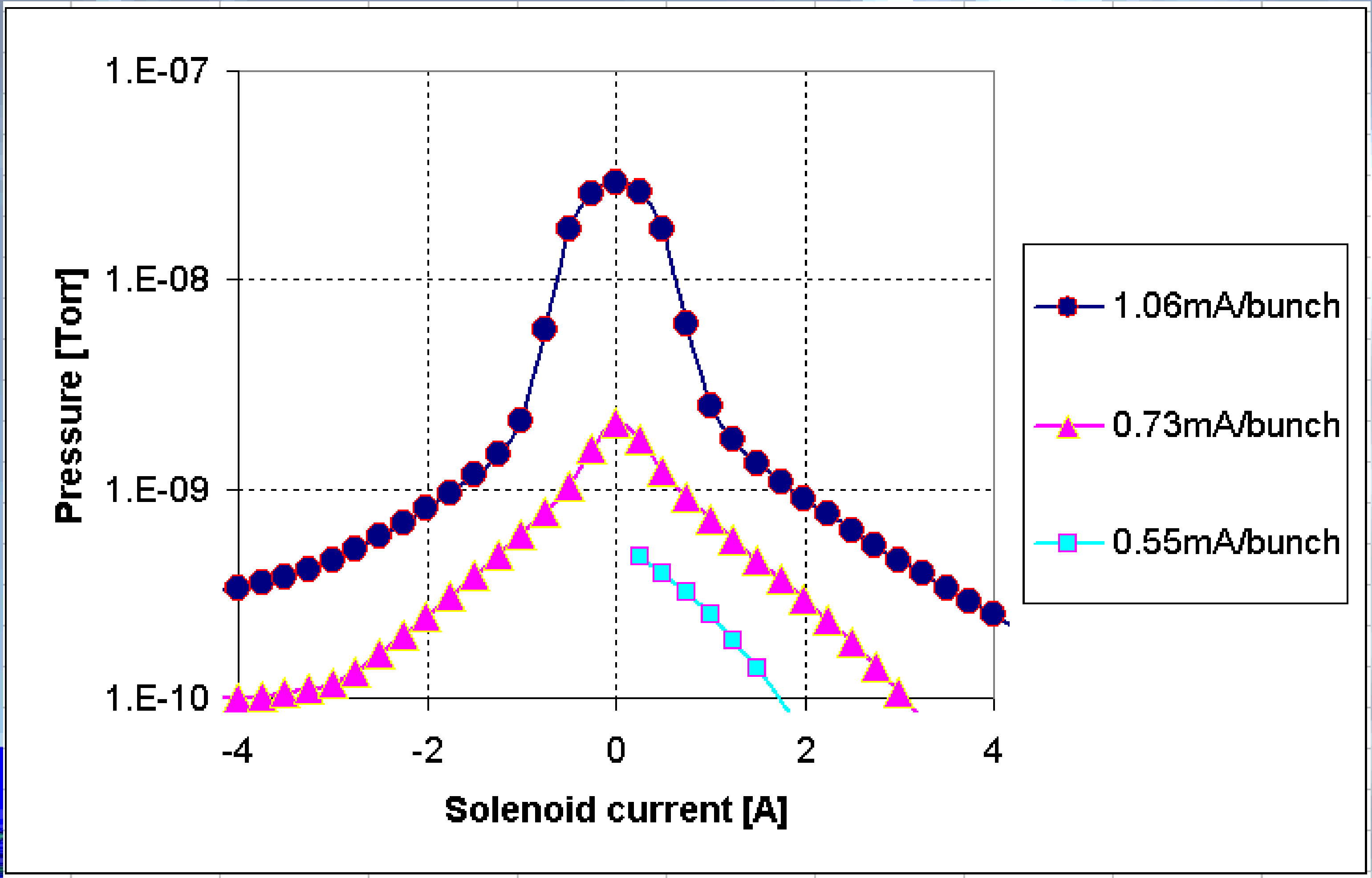
High energy positron/electron rings

- e+e- colliders
  - Solenoidal fields, HOMs, vacuum pressure, and EC
  - New observations at CESR

“Electron Cloud” Vacuum Cleaner



VP 2021 (no magnets)



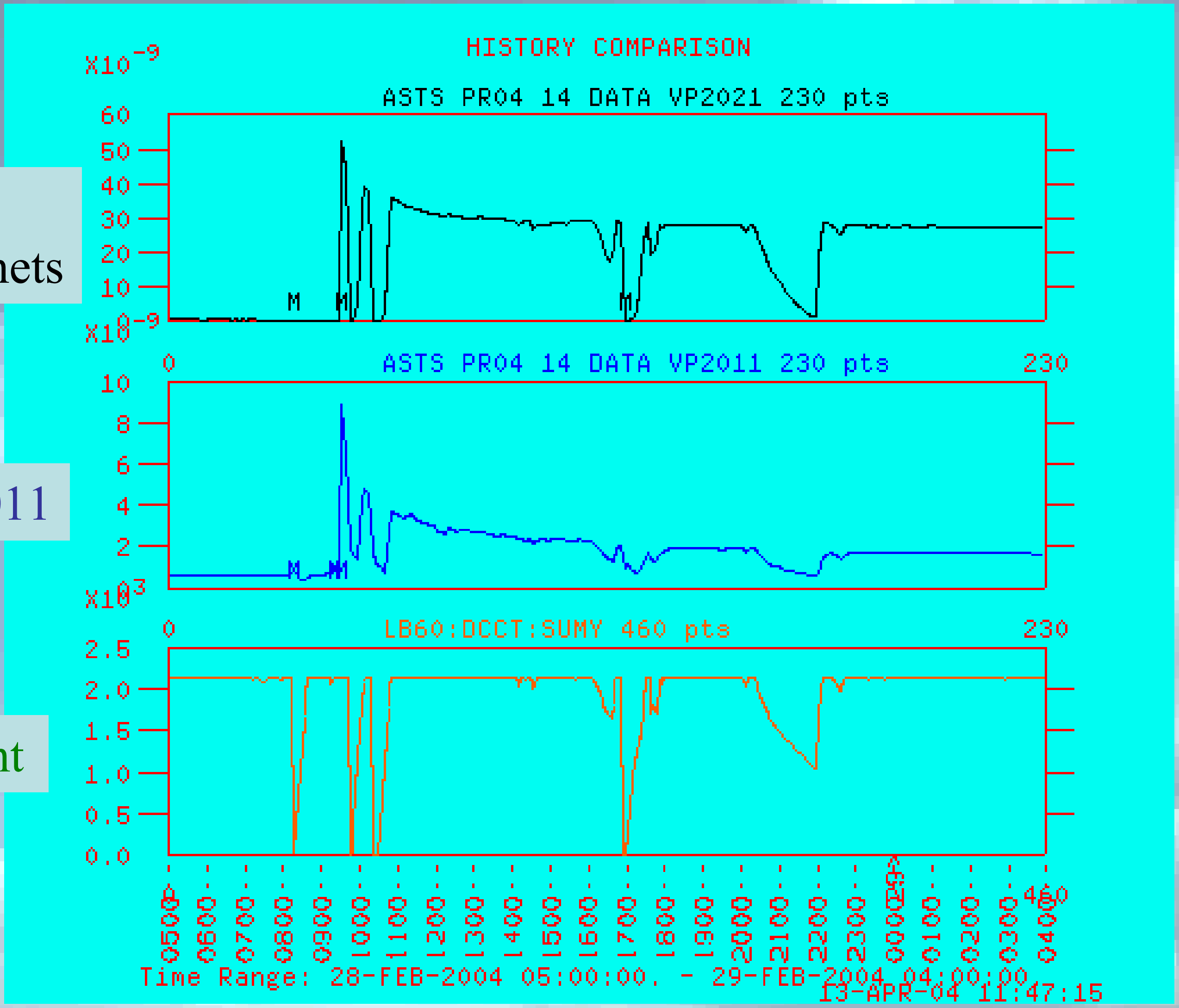
"Multipacting" Cleaner

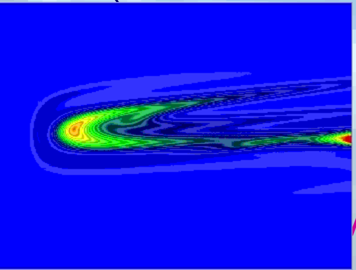
A.Novokhatski *"Electron Cloud Multipacting in the Presence of Small Solenoidal Fields"*

Vp2011
No magnets

vp2011

LER current

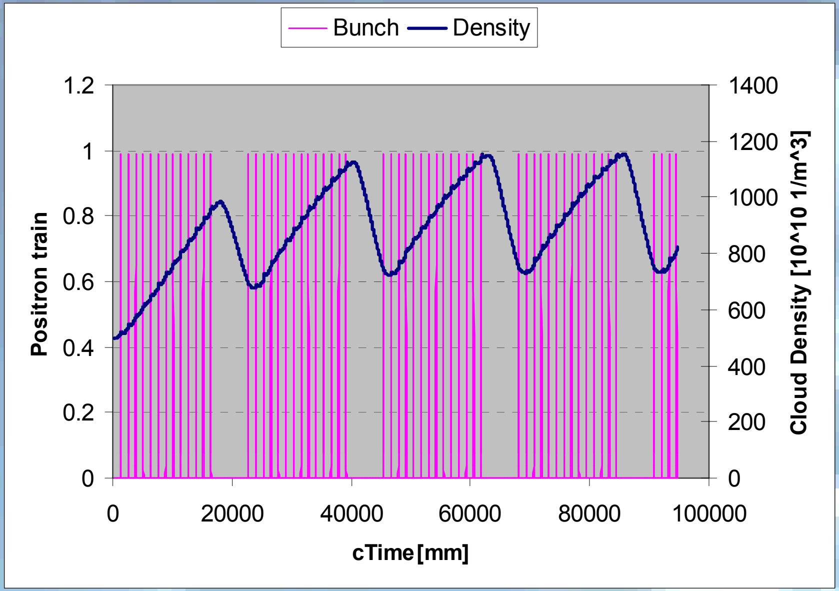




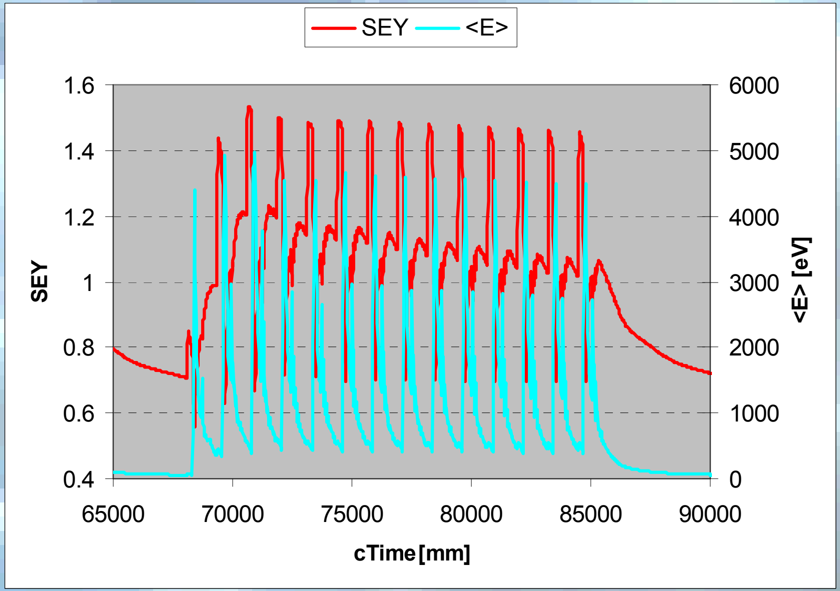
Positron Mini-Trains. Zero Magnetic field. Simulation.

A.Novokhatski *"Electron Cloud Multipacting*
in the Presence of Small Solenoidal Fields"

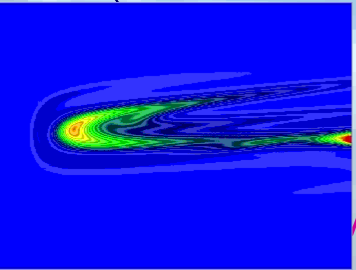
Dynamic equilibrium



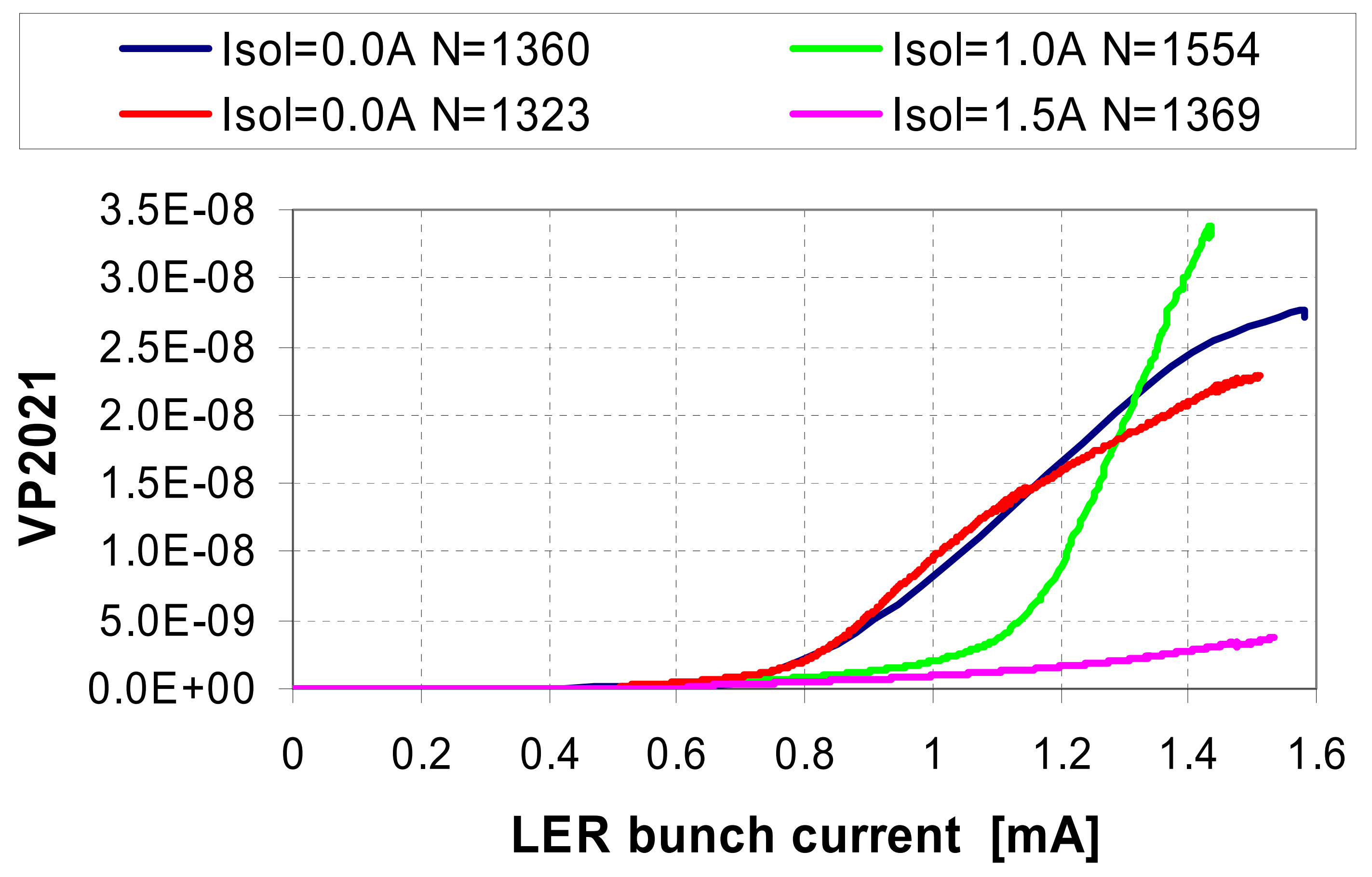
Electron cloud density



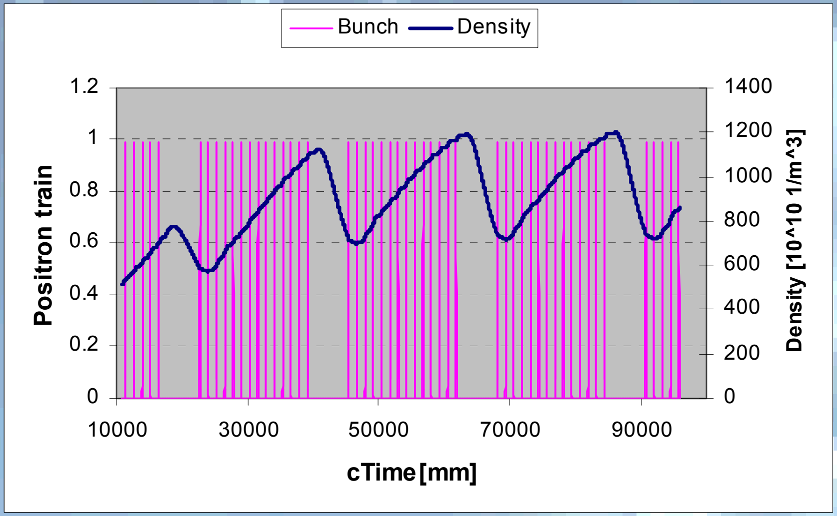
Secondary Emission Yield and
Averaged Energy of Bombarding Electrons



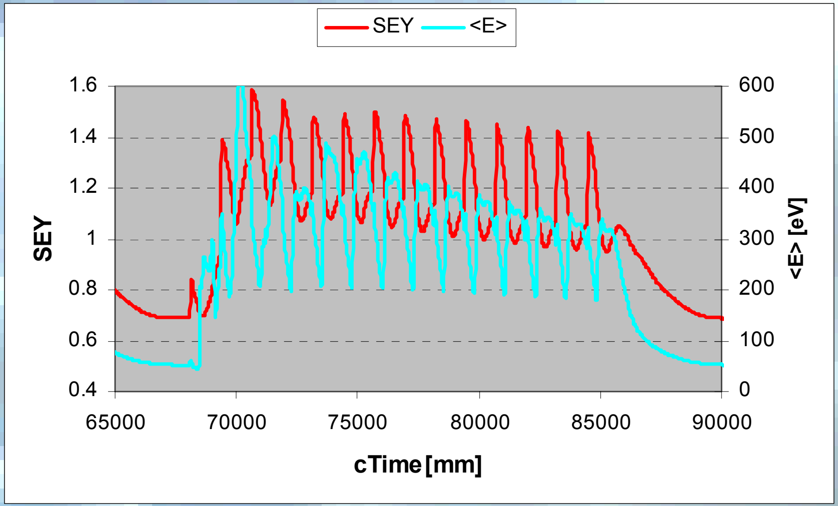
Magnetic field



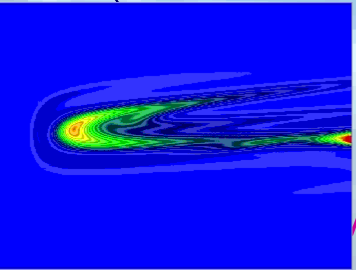
3 Gauss Magnetic field. Simulation.



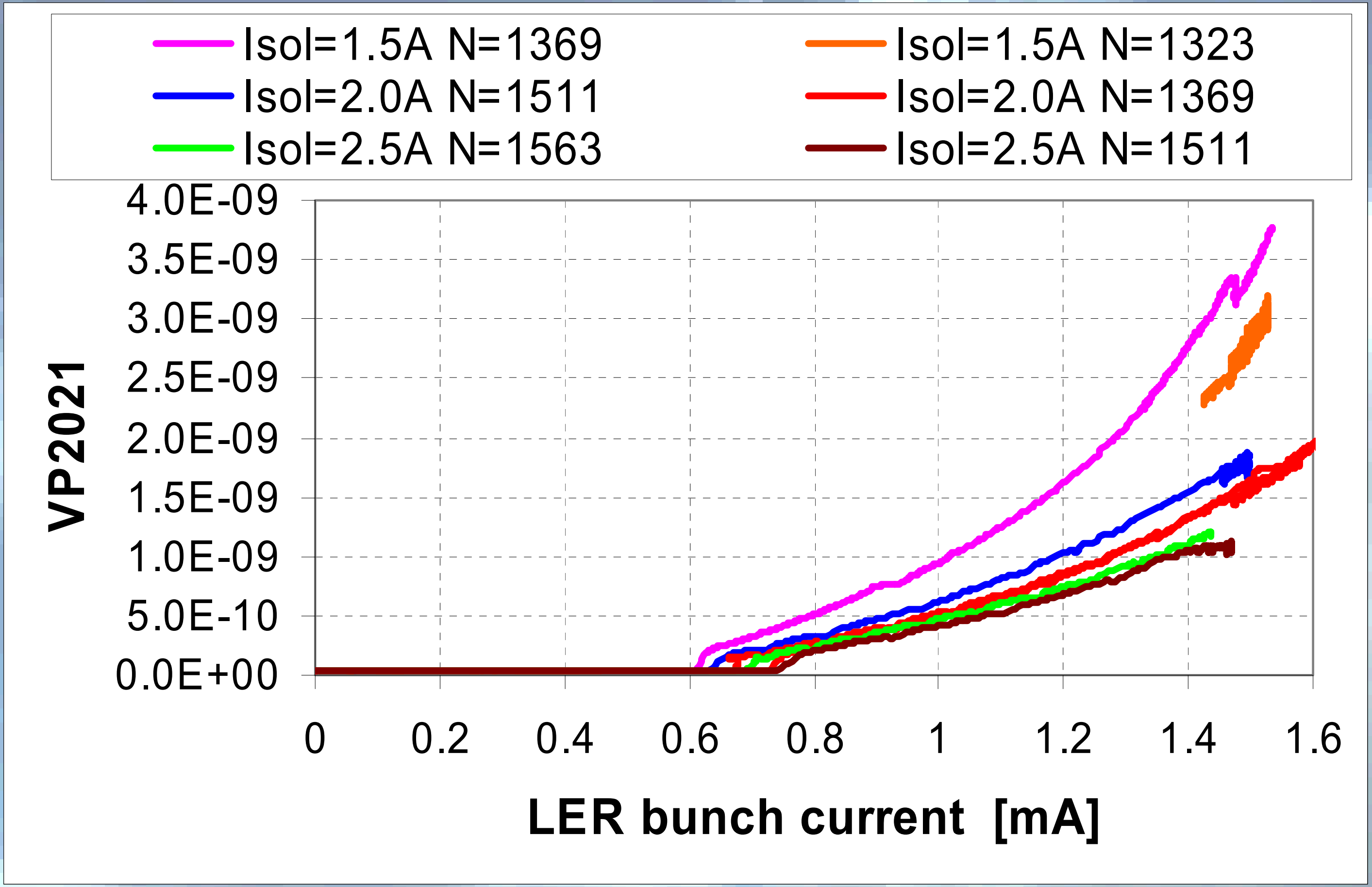
Electron clod density

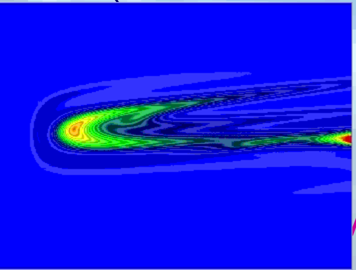


Secondary Emission Yield and Averaged Energy of Bombarding Electrons



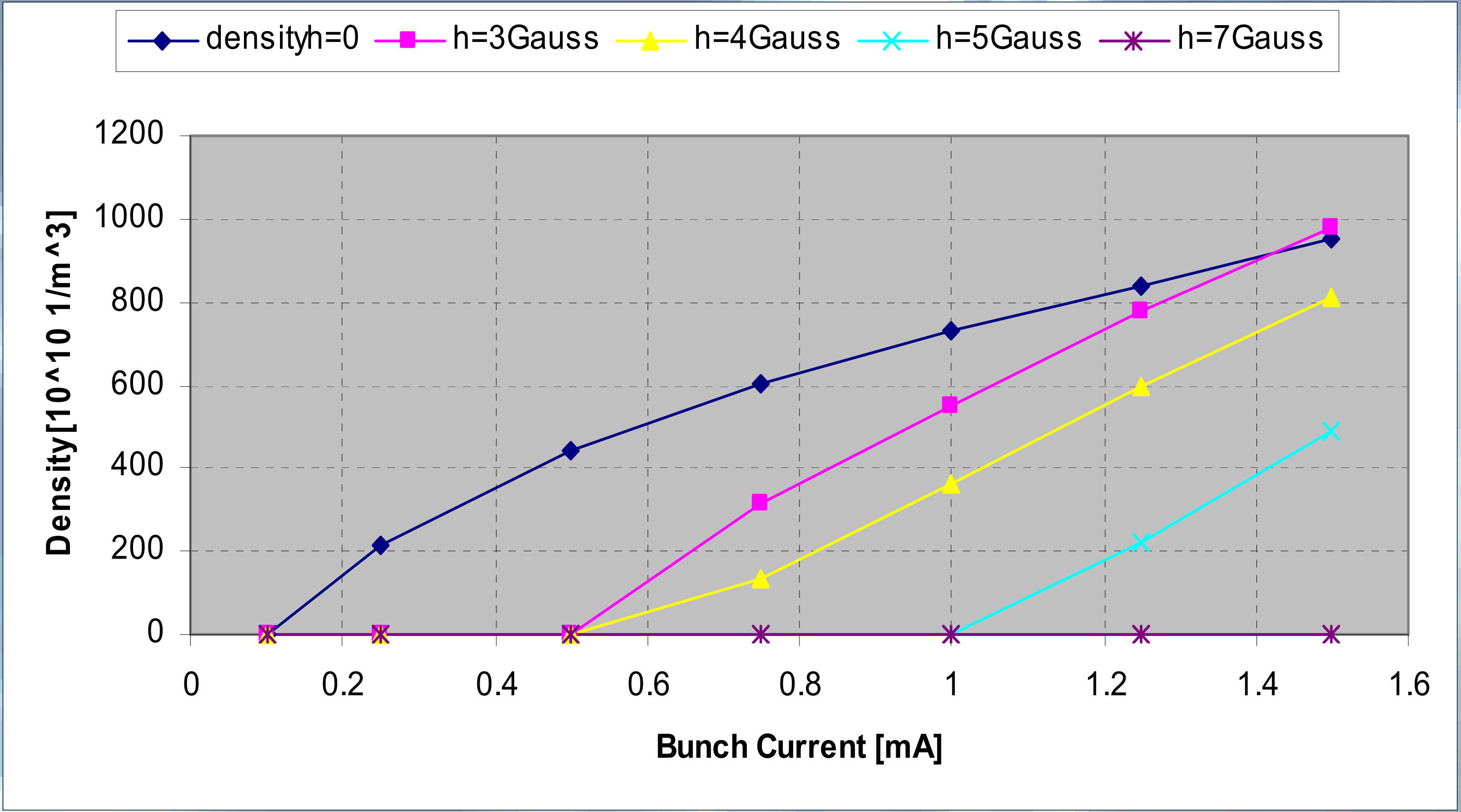
Higher Magnetic Field

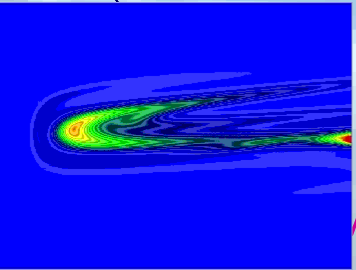




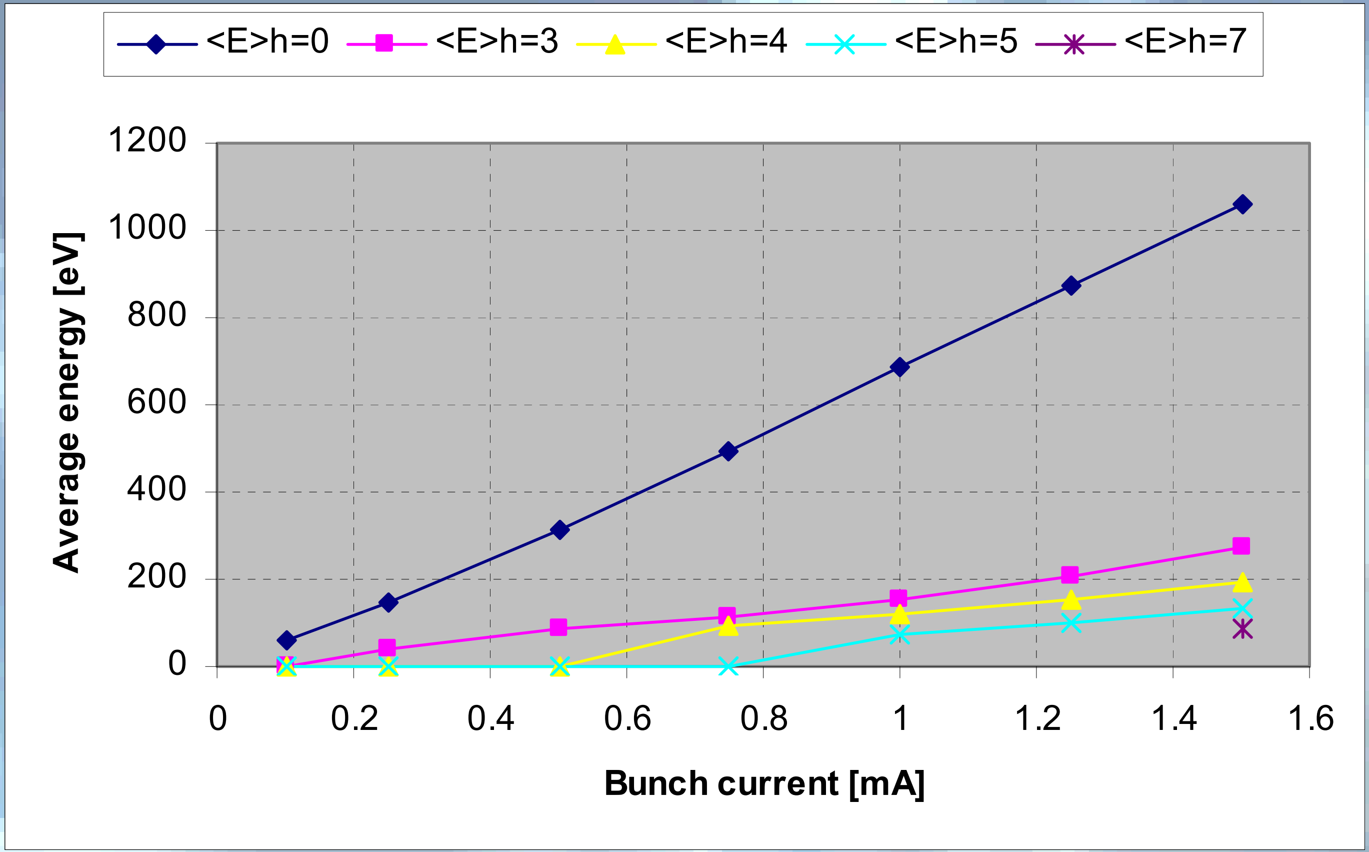
Electron Cloud Density for Different Magnetic Field. Simulation.

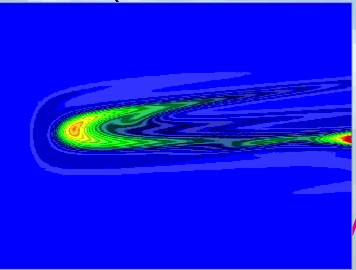
A.Novokhatski "Electron Cloud Multipacting in the Presence of Small Solenoidal Fields"



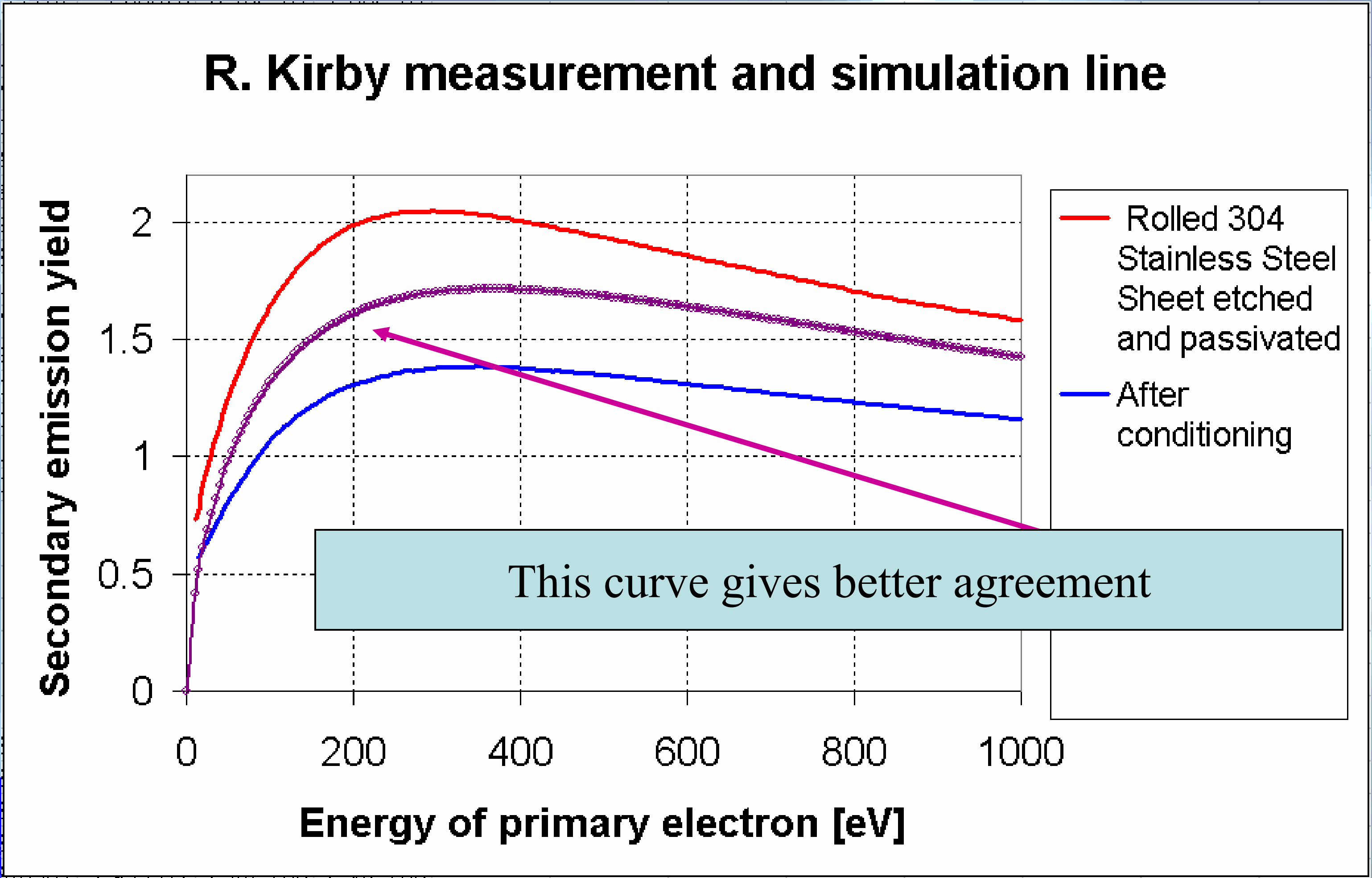


Average Energy of Bombarding Electrons for Different Magnetic Field. Simulation.



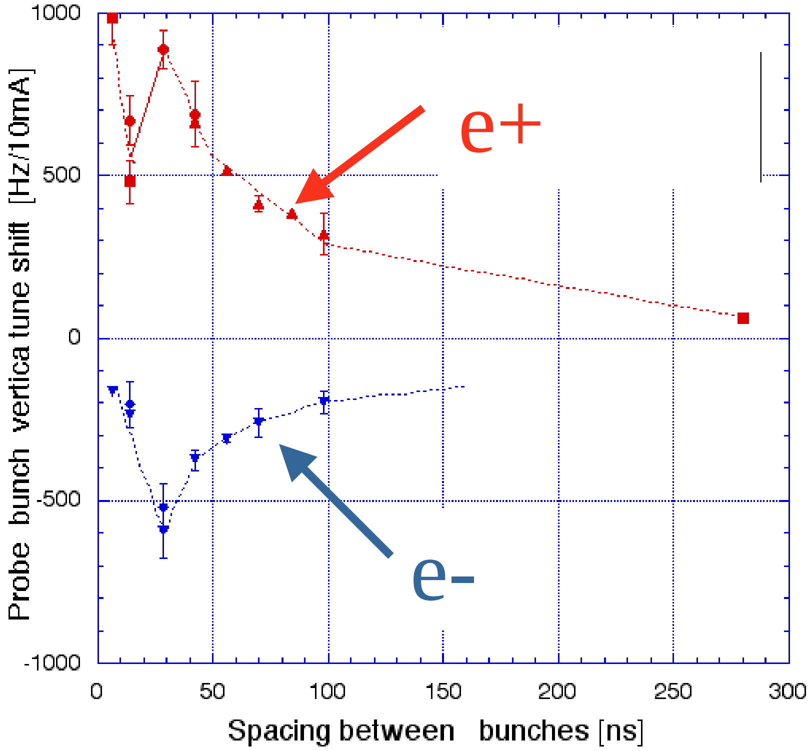


Secondary emission yield curves for simulations. We tried all three

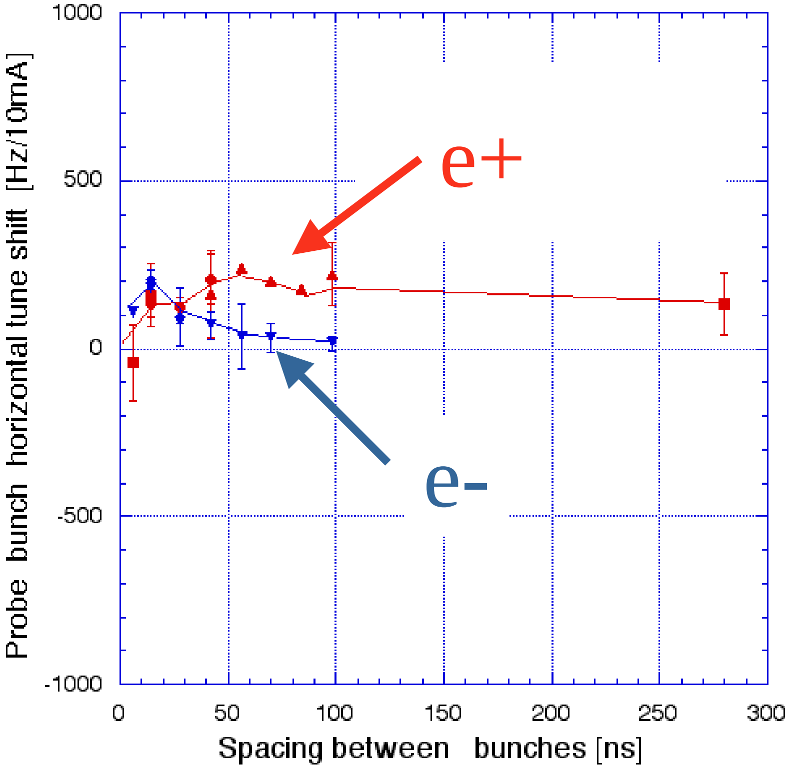


This curve gives better agreement

- Probe bunch tune shift versus bunch spacing normalized to 10mA of leading bunch current.
  - Vertical tune shift



  - Horizontal tune shift

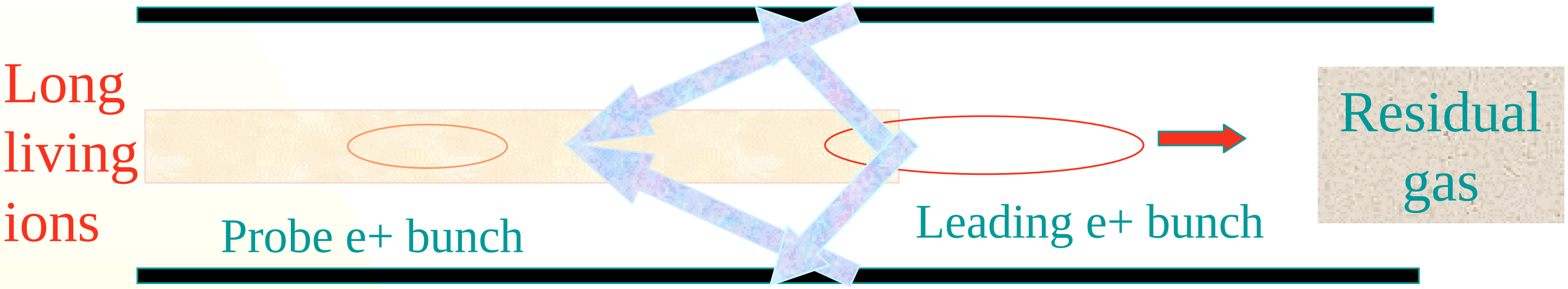


- Negative charge on orbit (electron cloud !). Maximum density at 15ns and decay time ~ 100ns
- Vertical tune bigger than horizontal (elliptical distribution, dipole field effect ?)
- Why we e-cloud (negative charge on orbit) with electron beam ?

Possible Model

(not commonly accepted)

- Positron beam experiment



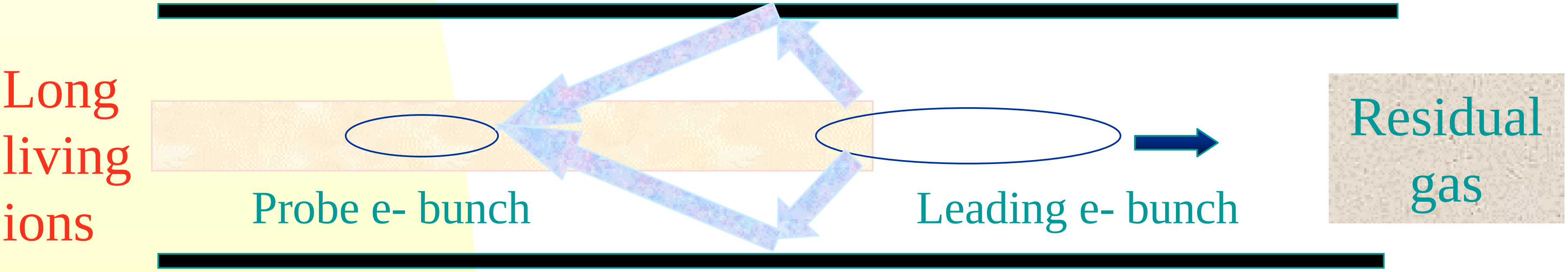
Long living ions

Probe e+ bunch

Leading e+ bunch

Residual gas

- Electron beam experiment



Long living ions

Probe e- bunch

Leading e- bunch

Residual gas

Concluding remarks

- EC suppression
  - Scrubbing (SPS, RHIC)
  - Solenoid (PEPII, KEKB, RHIC, PSR)
  - NEG (RHIC, SPS,…)
  - EC Collectors (HIF, KEK-PS)
- EC vs pressure (RHIC, SPS, KEKB, PEPII)
- Bunch length effect (SPS, RHIC)
- Memory effect and EC lifetime (PSR, KEKB, SPS)
- New EC diagnostics
  - RFA in quads (SPS, PSR (planned))
  - EC sweeper (PSR, KEK-PS)
  - HIF
  - Microwave TE (more work needed)

Concluding remarks

- EC suppression
  - Scrubbing (SPS, RHIC)
  - Solenoid (PEPII, RHIC)
  - EC Collectors (HIF, KEK-PS)
- EC vs vacuum (RHIC)
- Bunch length effect (SPS, RHIC)
- EC distribution (asymmetry) (KEKB)
- Memory effect and EC lifetime (PSR, KEKB, SPS)
- Electron pinch (Bfactories, LHC)
- EC diagnostics
  - RFA in quads (SPS, PSR (planned))
  - EC sweeper (PSR, KEK-PS)
  - HIF
  - Microwave TE (more Qs?)