Report from the Ecloud'12 workshop.

1. Fifth electron-cloud workshop, ECLOUD'12, June 5 to 8 , 2012 La Biodola (Isola d'Elba), Italy
2. Perspectives for positron operation at PETRA III

Rainer Wanzenberg
DESY
Hamburg, Sep. 11, 2012

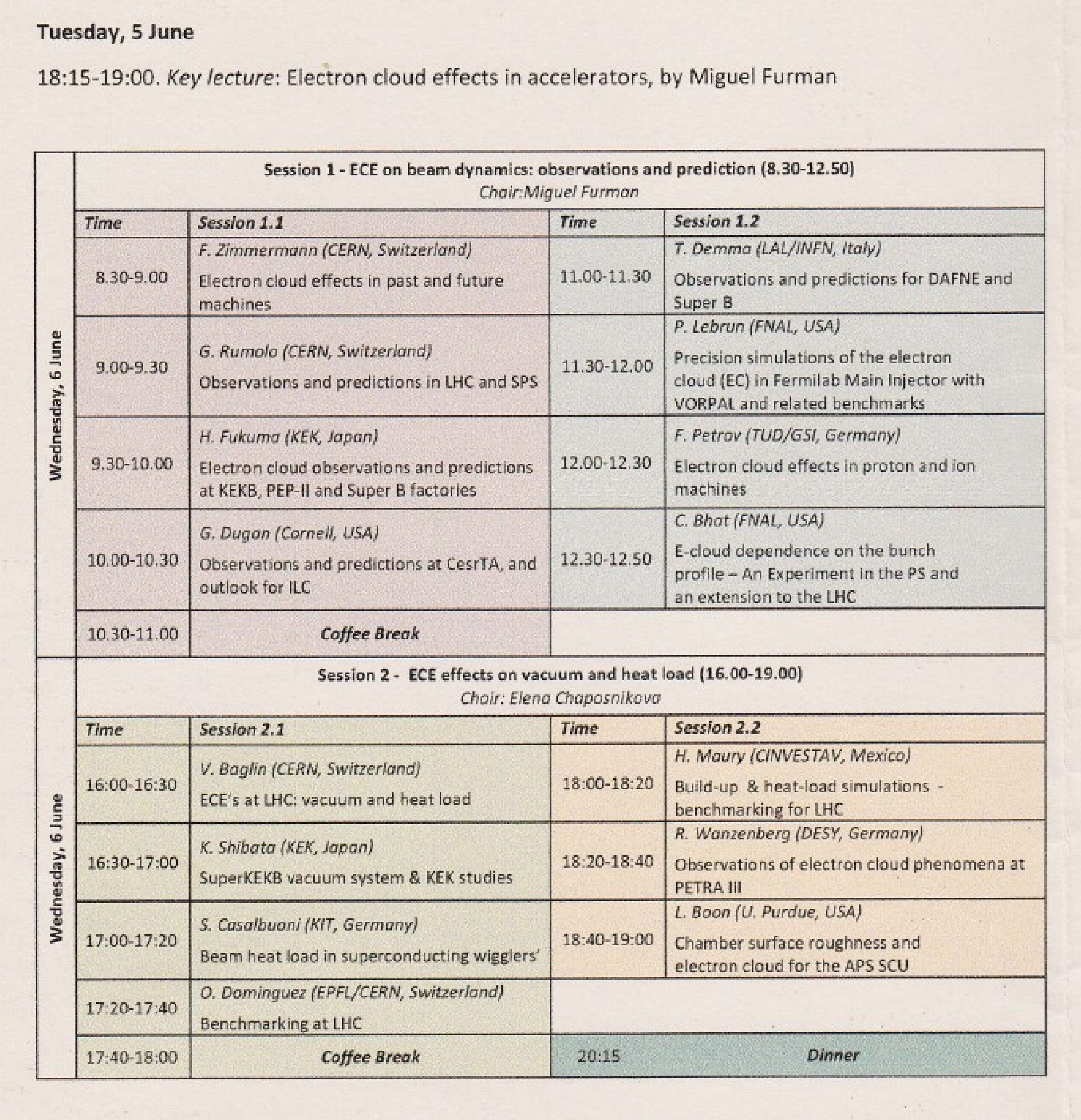
ECLOUD'12

62 participants

United States: 15, Switzerland: 15, Italy: 10, Germany: 7, Japan: 4, Spain: 3, United Kingdom: 3, France: 2, Mexico: 1, Portugal: 1, Russia: 1

Roberto Cimino, INFN - LNF (Chair Organizing Committee)
Frank Zimmermann, CERN (Chair International Advisory Committee)

Program



Tuesday, 5 June

18:15-19:00. *Key lecture*: Electron cloud effects in accelerators, by Miguel Furman

Wednesday, 6 June

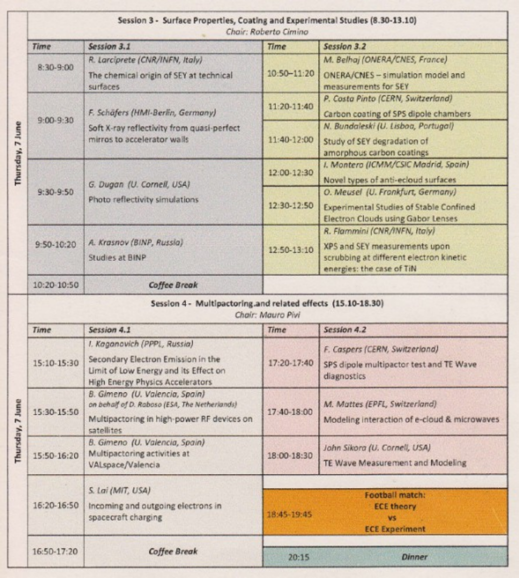
Session 1 - ECE on beam dynamics: observations and prediction (8.30-12.50)
Chair:Miguel Furman

Time	*Session 1.1*	*Time*	*Session 1.2*
8.30-9.00	*F. Zimmermann (CERN, Switzerland)* Electron cloud effects in past and future machines	11.00-11.30	*T. Demma (LAL/INFN, Italy)* Observations and predictions for DAFNE and Super B
9.00-9.30	*G. Rumolo (CERN, Switzerland)* Observations and predictions in LHC and SPS	11.30-12.00	*P. Lebrun (FNAL, USA)* Precision simulations of the electron cloud (EC) in Fermilab Main Injector with VORPAL and related benchmarks
9.30-10.00	*H. Fukuma (KEK, Japan)* Electron cloud observations and predictions at KEKB, PEP-II and Super B factories	12.00-12.30	*F. Petrov (TUD/GSI, Germany)* Electron cloud effects in proton and ion machines
10.00-10.30	*G. Dugan (Cornell, USA)* Observations and predictions at CesrTA, and outlook for ILC	12.30-12.50	*C. Bhat (FNAL, USA)* E-cloud dependence on the bunch profile – An Experiment in the PS and an extension to the LHC
10.30-11.00	***Coffee Break***		

Wednesday, 6 June

Session 2 - ECE effects on vacuum and heat load (16.00-19.00)
Chair: Elena Chaposnikova

Time	*Session 2.1*	*Time*	*Session 2.2*
16:00-16:30	*V. Baglin (CERN, Switzerland)* ECE's at LHC: vacuum and heat load	18:00-18:20	*H. Maury (CINVESTAV, Mexico)* Build-up & heat-load simulations - benchmarking for LHC
16:30-17:00	*K. Shibata (KEK, Japan)* SuperKEKB vacuum system & KEK studies	18:20-18:40	*R. Wanzenberg (DESY, Germany)* Observations of electron cloud phenomena at PETRA III
17:00-17:20	*S. Casalbuoni (KIT, Germany)* Beam heat load in superconducting wigglers'	18:40-19:00	*L. Boon (U. Purdue, USA)* Chamber surface roughness and electron cloud for the APS SCU
17:20-17:40	*O. Dominguez (EPFL/CERN, Switzerland)* Benchmarking at LHC		
17:40-18:00	***Coffee Break***	20:15	***Dinner***



Thursday, 7 June

Session 3 - Surface Properties, Coating and Experimental Studies (8.30-13.10)
Chair: Roberto Cimino

Time	*Session 3.1*
8:30-9:00	*R. Larciprete (CNR/INFN, Italy)* The chemical origin of SEY at technical surfaces
9:00-9:30	*F. Schäfers (HMI-Berlin, Germany)* Soft X-ray reflectivity from quasi-perfect mirros to accelerator walls
9:30-9:50	*G. Dugan (U. Cornell, USA)* Photo reflectivity simulations
9:50-10:20	*A. Krasnov (BINP, Russia)* Studies at BINP
10:20-10:50	***Coffee Break***

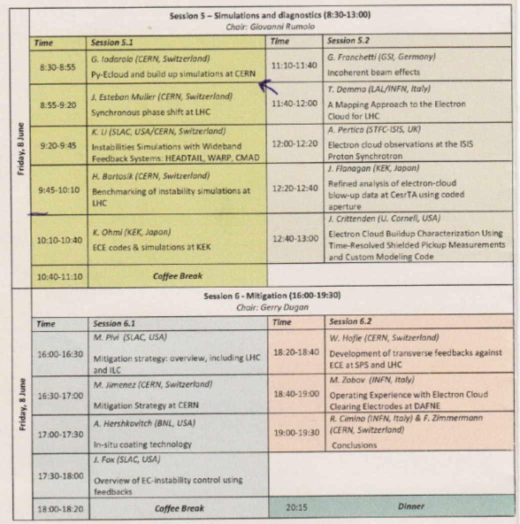
Time	*Session 3.2*
10:50–11:20	*M. Belhaj (ONERA/CNES, France)* ONERA/CNES – simulation model and measurements for SEY
11:20-11:40	*P. Costa Pinto (CERN, Switzerland)* Carbon coating of SPS dipole chambers
11:40-12:00	*N. Bundaleski (U. Lisboa, Portugal)* Study of SEY degradation of amorphous carbon coatings
12:00-12:30	*I. Montero (ICMM/CSIC Madrid, Spain)* Novel types of anti-ecloud surfaces
12:30-12:50	*O. Meusel (U. Frankfurt, Germany)* Experimental Studies of Stable Confined Electron Clouds using Gabor Lenses
12:50-13:10	*R. Flammini (CNR/INFN, Italy)* XPS and SEY measurements upon scrubbing at different electron kinetic energies: the case of TiN

Thursday, 7 June

Session 4 - Multipactoring.and related effects (15.10-18.30)
Chair: Mauro Pivi

Time	*Session 4.1*
15:10-15:30	*I. Kaganovich (PPPL, Russia)* Secondary Electron Emission in the Limit of Low Energy and its Effect on High Energy Physics Accelerators
15:30-15:50	*B. Gimeno (U. Valencia, Spain)* *on behalf of D. Raboso (ESA, The Netherlands)* Multipactoring in high-power RF devices on satellites
15:50-16:20	*B. Gimeno (U. Valencia, Spain)* Multipactoring activities at VALspace/Valencia
16:20-16:50	*S. Lai (MIT, USA)* Incoming and outgoing electrons in spacecraft charging
16:50-17:20	***Coffee Break***

Time	*Session 4.2*
17:20-17:40	*F. Caspers (CERN, Switzerland)* SPS dipole multipactor test and TE Wave diagnostics
17:40-18:00	*M. Mattes (EPFL, Switzerland)* Modeling interaction of e-cloud & microwaves
18:00-18:30	*John Sikora (U. Cornell, USA)* TE Wave Measurement and Modeling
18:45-19:45	**Football match:** **ECE theory** **vs** **ECE Experiment**
20:15	***Dinner***



Friday, 8 June

Session 5 – Simulations and diagnostics (8:30-13:00)
Chair: Giovanni Rumolo

Time	*Session 5.1*
8:30-8:55	*G. Iadarola (CERN, Switzerland)* Py-Ecloud and build up simulations at CERN
8:55-9:20	*J. Esteban Muller (CERN, Switzerland)* Synchronous phase shift at LHC
9:20-9:45	*K. Li (SLAC, USA/CERN, Switzerland)* Instabilities Simulations with Wideband Feedback Systems: HEADTAIL, WARP, CMAD
9:45-10:10	*H. Bartosik (CERN, Switzerland)* Benchmarking of instability simulations at LHC
10:10-10:40	*K. Ohmi (KEK, Japan)* ECE codes & simulations at KEK
10:40-11:10	***Coffee Break***

Time	*Session 5.2*
11:10-11:40	*G. Franchetti (GSI, Germany)* Incoherent beam effects
11:40-12:00	*T. Demma (LAL/INFN, Italy)* A Mapping Approach to the Electron Cloud for LHC
12:00-12:20	*A. Pertica (STFC-ISIS, UK)* Electron cloud observations at the ISIS Proton Synchrotron
12:20-12:40	*J. Flanagan (KEK, Japan)* Refined analysis of electron-cloud blow-up data at CesrTA using coded aperture
12:40-13:00	*J. Crittenden (U. Cornell, USA)* Electron Cloud Buildup Characterization Using Time-Resolved Shielded Pickup Measurements and Custom Modeling Code

Friday, 8 June

Session 6 - Mitigation (16:00-19:30)
Chair: Gerry Dugan

Time	*Session 6.1*
16:00-16:30	*M. Pivi (SLAC, USA)* Mitigation strategy: overview, including LHC and ILC
16:30-17:00	*M. Jimenez (CERN, Switzerland)* Mitigation Strategy at CERN
17:00-17:30	*A. Hershkovitch (BNL, USA)* In-situ coating technology
17:30-18:00	*J. Fox (SLAC, USA)* Overview of EC-instability control using feedbacks
18:00-18:20	***Coffee Break***

Time	*Session 6.2*
18:20-18:40	*W. Hofle (CERN, Switzerland)* Development of transverse feedbacks against ECE at SPS and LHC
18:40-19:00	*M. Zobov (INFN, Italy)* Operating Experience with Electron Cloud Clearing Electrodes at DAFNE
19:00-19:30	*R. Cimino (INFN, Italy) & F. Zimmermann (CERN, Switzerland)* Conclusions
20:15	***Dinner***

Program

Tuesday 05 June 2012

- **Electron Cloud Effects (ECE) in Accelerators**

Wednesday 06 June 2012

- **ECE on Beam Dynamics: observations and prediction**
- **ECE Effects on Vacuum and Heat Load**

Thursday 07 June 2012

- **Surface Properties, Coating and Experimental Studies**
- **Multipactoring and Related Effects**

Friday 08 June 2012

- **Simulations and Diagnostics**
- **Mitigation**

http://agenda.infn.it/conferenceOtherViews.py?view=standard&confId=4303

Tuesday 05 June 2012

Electron Cloud Effects (ECE) in Accelerators

Opening talk by:

Miguel Furman (*LBNL (Lawrence Berkeley Natl. Lab.)*)

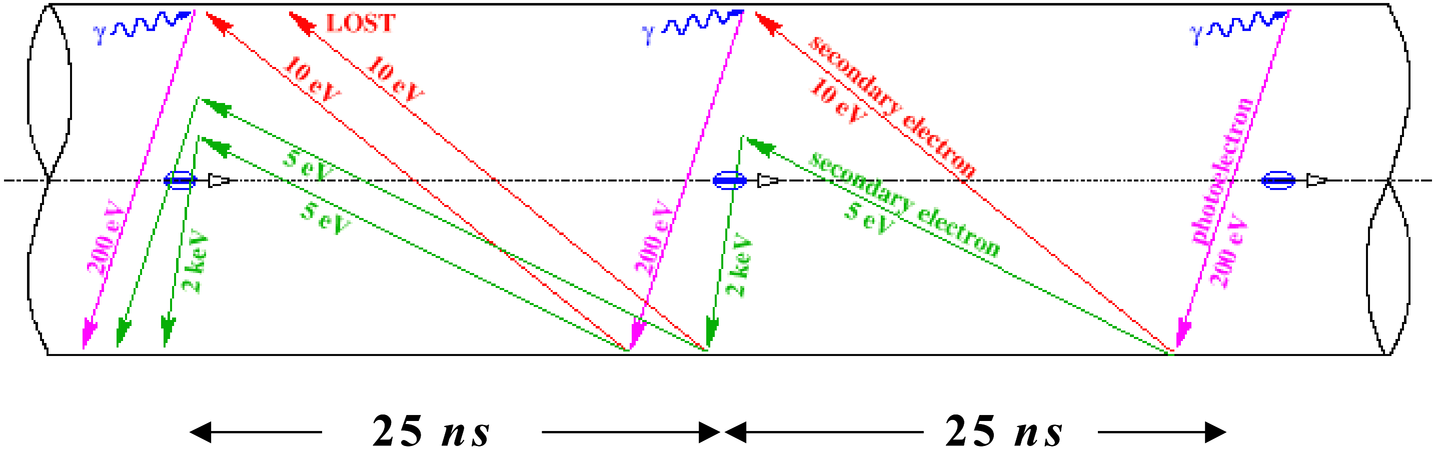
The workshop was dedicated to the memory of Francesco Ruggiero (1957 – 2007).

Francesco's 1997 "crash programme" was meant to address the potential problems at the LHC.

The knowledge that has come out of this programme, plus the recent experience at the LHC and SPS have already greatly benefitted the field as a whole, and will continue to benefit the design and reliability of accelerators worldwide for a long time to come.

What is the ECE

(illustrated with the LHC cartoon by F. Ruggiero)



- **Beam emits synchrotron radiation:**
  - **provides source of photo-electrons**
  - **other sources: beam-gas ionization, stray protons striking the wall**
- **Photo-electrons get rattled around the chamber from multibunch passages**
  - **—especially for intense positively-charged beams (e^+, protons, heavy ions)**
- **Photoelectrons yield secondary electrons**
  - **yield is determined by the secondary emission yield (SEY) function ™(E):**
  - **characterized by peak value δ_{max} at $E=E_{max}$**
  - **e^- reflectivity $\delta(0)$: determines survival time of e^-**
  - **Typically, δ_{max}~1–3, and E_{max}~200-400 eV**

•Typical e^- densities: $n_e=10^{10}–10^{12}\ m^{-3}$ (~a few nC/m)

•Typical e^- energies: <~ 200 eV's (with significant fluctuations)

Consequences

- Possible consequences:
  - single-bunch instability
  - multibunch instability
  - emittance growth
  - gas desorption from chamber walls
  - excessive energy deposition on the chamber walls (important for superconducting machines, eg. LHC)
  - particle losses, interference with diagnostics,…
- In summary: the ECE is a consequence of the interplay between the beam and the vacuum chamber ⇒ “rich physics”
  - many possible ingredients: bunch intensity, bunch shape, beam loss rate, fill pattern, photoelectric yield, photon reflectivity, SEY, vacuum pressure, vacuum chamber size and geometry, …
- The ECE is closely related to the mechanism of photo-amplifiers

* **IT IS ALWAYS UNDESIRABLE IN PARTICLE ACCELERATORS**

* **IT IS A USUALLY A PERFORMANCE-LIMITING PROBLEM**

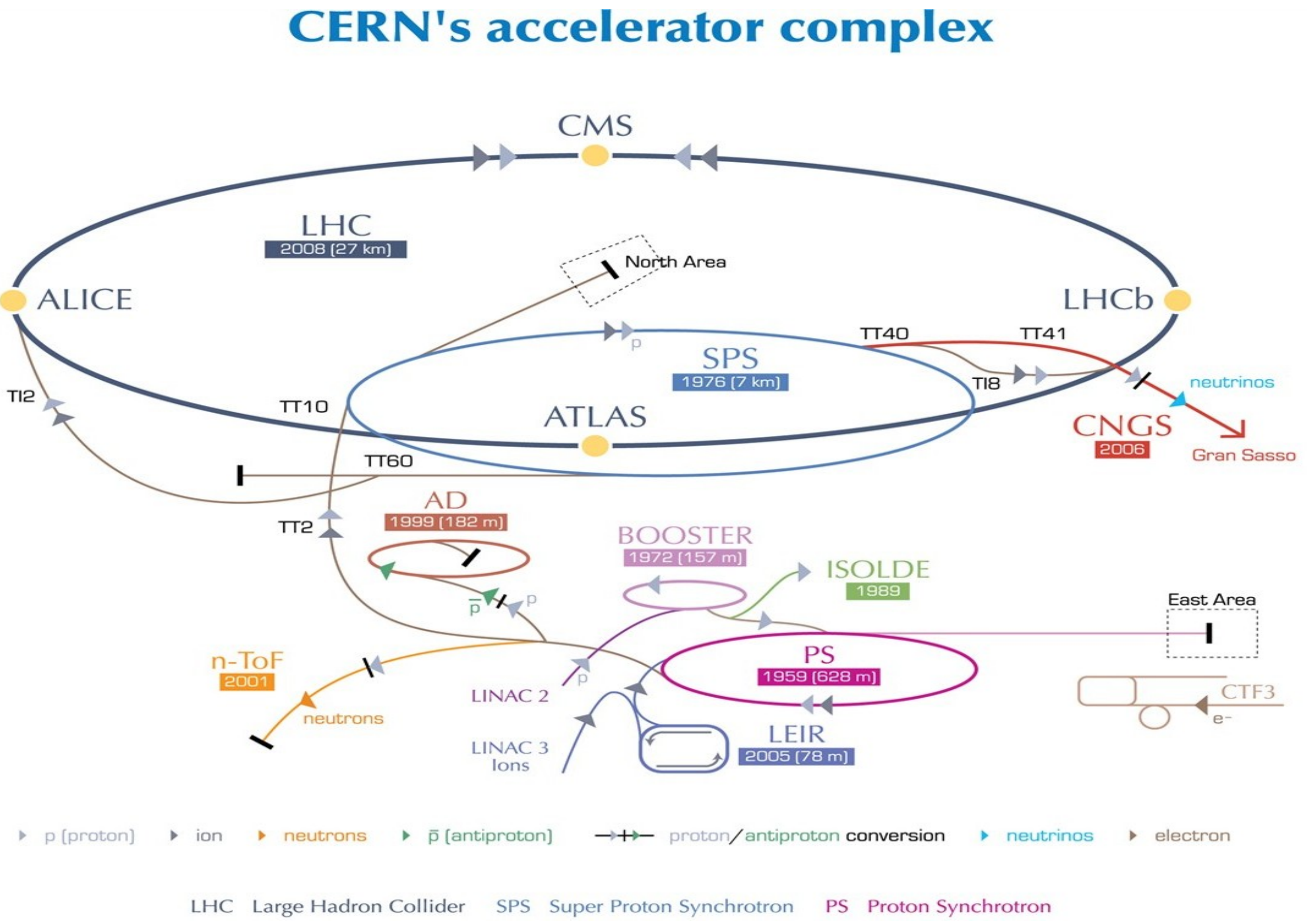
* **IT IS CHALLENGING TO PROPERLY QUANTIFY, PREDICT AND EXTRAPOLATE**

Wednesday 06 June 2012

- ECE on Beam Dynamics: observations and prediction
  - 8 contributions
- ECE Effects on Vacuum and Heat Load
  - 7 contributions

ECE on Beam Dynamics: observations and prediction

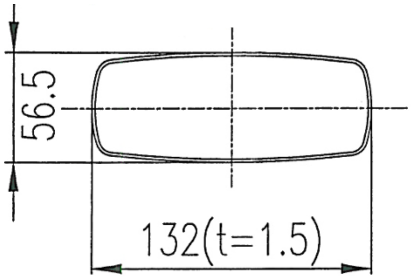
Giovanni Rumolo (*CERN*):
Observations and Predictions in LHC and SPS

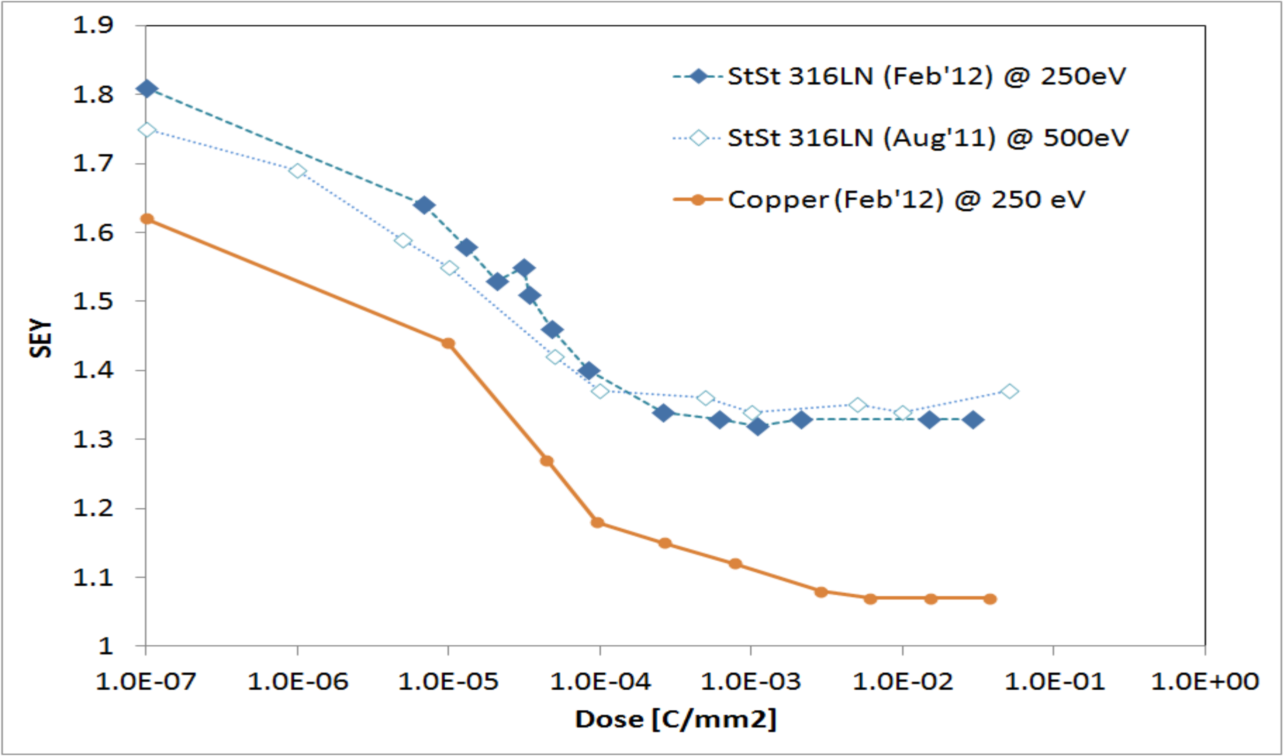


Electron cloud in the SPS

- → SEY threshold values below 1.3 – 1.4 (MBB; Drift B for high beam currents)
- → Beam induced scrubbing cannot be used as the only mitigation technique
  - ☑ Chambers/StSt samples extracted from the SPS never exhibited SEY below 1.5 & e-cloud never suppressed in MBB chambers with 25ns beams
  - ☑ Laboratory scrubbing shows saturation above 1.3 for StSt!
- → a-C coating of at least ~45% of the machine remains the baseline for the SPS upgrade

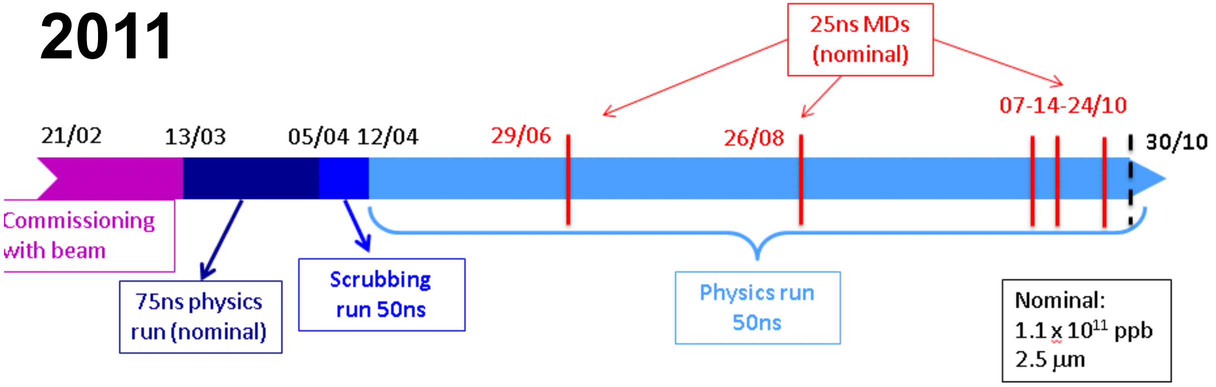
MBB Chamber:





Electron cloud in the LHC

2011



25ns MDs (nominal)

21/02

13/03

05/04 12/04

29/06

26/08

07-14-24/10

30/10

Commissioning with beam

75ns physics run (nominal)

Scrubbing run 50ns

Physics run 50ns

Nominal:
1.1×10^{11} ppb
2.5 µm

- **75ns operation → No electron cloud observations in 2011**
- 50ns operation
  - → **Electron cloud signatures during scrubbing**
  - → **Physics operation with only residual electron cloud** 25ns MDs → **Always electron cloud**, it allowed monitoring the evolution of δ_{max} in the arcs

⇒ The **scrubbing run** took place in the week 5–12 April 2011

⇒ **Nominal 50ns spaced beams with up to 1020 bunches per beam injected into the LHC and stored at 450 GeV/c**

⇒ **Very efficient machine cleaning**

⇒ **After scrubbing, physics with 50ns** and stable beams with **1380** bunche**s per beam** on 28 June 2011

Electron cloud in the LHC: Concluding remarks

	δ_{max} (estimated)	Threshold δ_{max} (50ns, 450 GeV)	Threshold δ_{max} (50ns, 3.5 TeV)	Threshold δ_{max} (25ns, 450 GeV)	Threshold δ_{max} (25ns, 3.5 TeV)
Beam screen (arcs)	**1.52**	**2.2**	**2.1**	**1.45**	**1.37**

⇒ **After the 25ns MDs, the LHC beam chambers have been cleaned to δ_{max} values well below the build up threshold for nominal 50ns beams**

⇒ **Since** the present level of machine conditioning was preserved, **'ecloud-less' operation of LHC with 50ns beams up to high intensities is currently taking place in 2012, even in absence of a new scrubbing run**

⇒ **50ns physics operation has been serving the purpose to clean parts of the LHC open to air to the needed extent**

⇒ **25ns beams** are still affected by e-cloud, but scrubbing should be possible could with **~2 weeks machine time** (including also test ramps) or alternative filling schemes (micro-batches) could be used

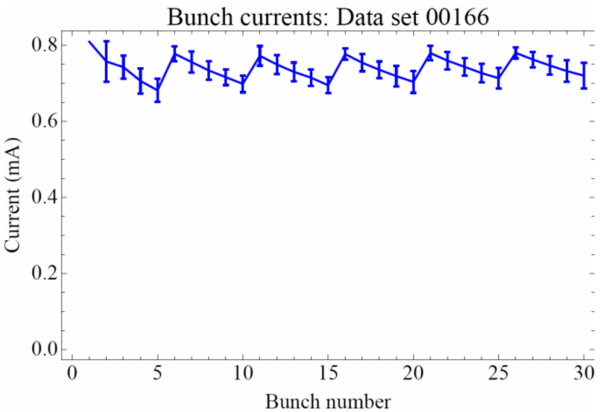
ECE on Beam Dynamics: observations and prediction

Gerald Dugan (*Cornell University*) :
Observations and Predictions at CesrTA,
and outlook for ILC

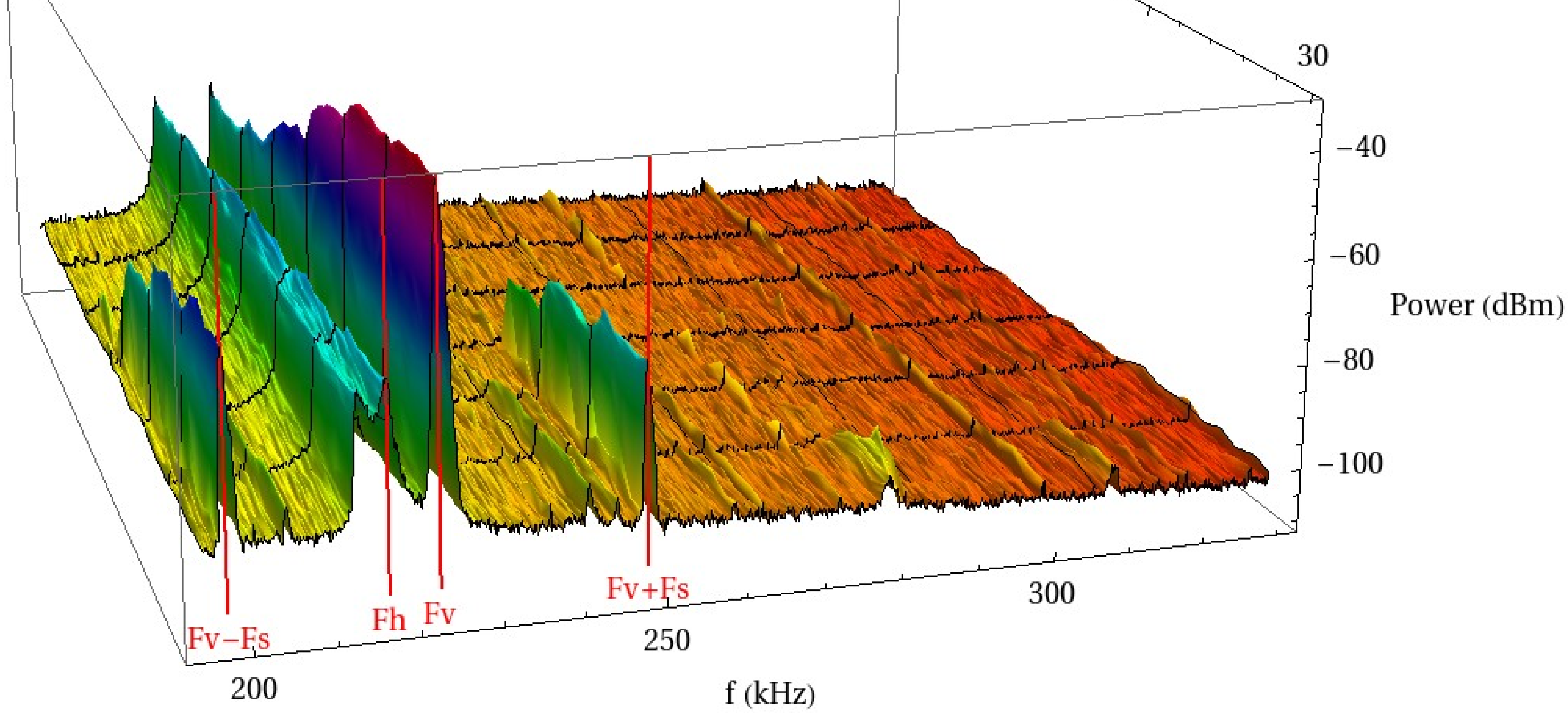
- **Studies of the impact of electron clouds on the dynamics of bunch trains in Cesr have been a major focus of the Cesr Test Accelerator (CesrTA) program.**
- **In this presentation, we report measurements along bunch trains of**
  - **coherent tune shifts,**
  - **coherent instability signals,**
  - **(coherent damping rates), and**
  - **emittance growth.**
- **The measurements were made for a variety of bunch currents, train configurations, beam energies and transverse emittances, similar to the design values for the ILC damping rings.**
- **The measurements will be compared with simulations which model the effects of electron clouds on beam dynamics, to extract simulation model parameters and to quantify the validity of the simulation codes.**

30 bunch train: bunch by bunch spectra

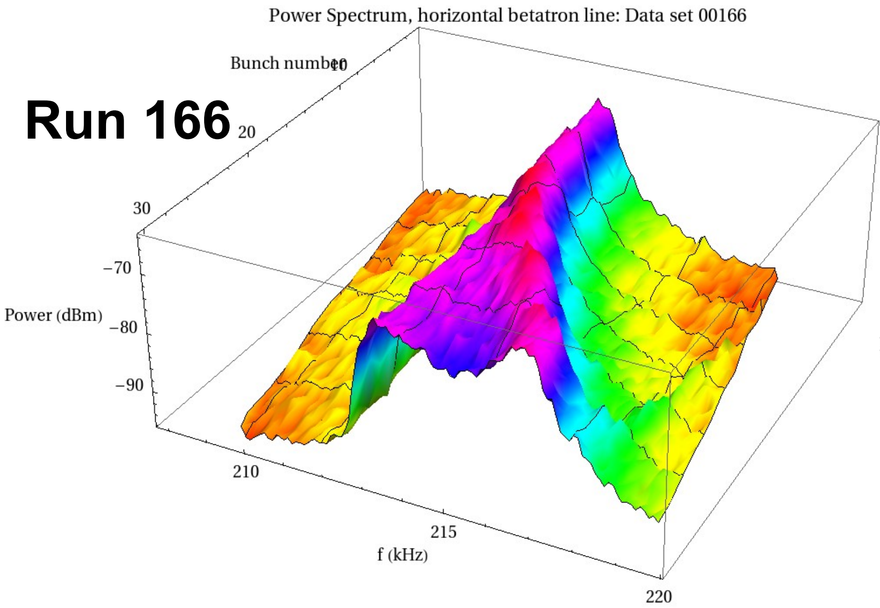
Beam parameters:
- 2.1 GeV;
- H (V) emittance: 2.6 nm (20 pm);
- bunch length 10.8 mm;
- tunes (H, V, S): (14.57,9.6, 0.065)
- momentum compaction 6.8x10^{-3}
- (H,V) chrom = (1.33,1.155)
- Avg current/bunch = 0.74 mA.
- L-FBK off; H-, V-FBK at 20%



Power Spectrum: Data set 00166

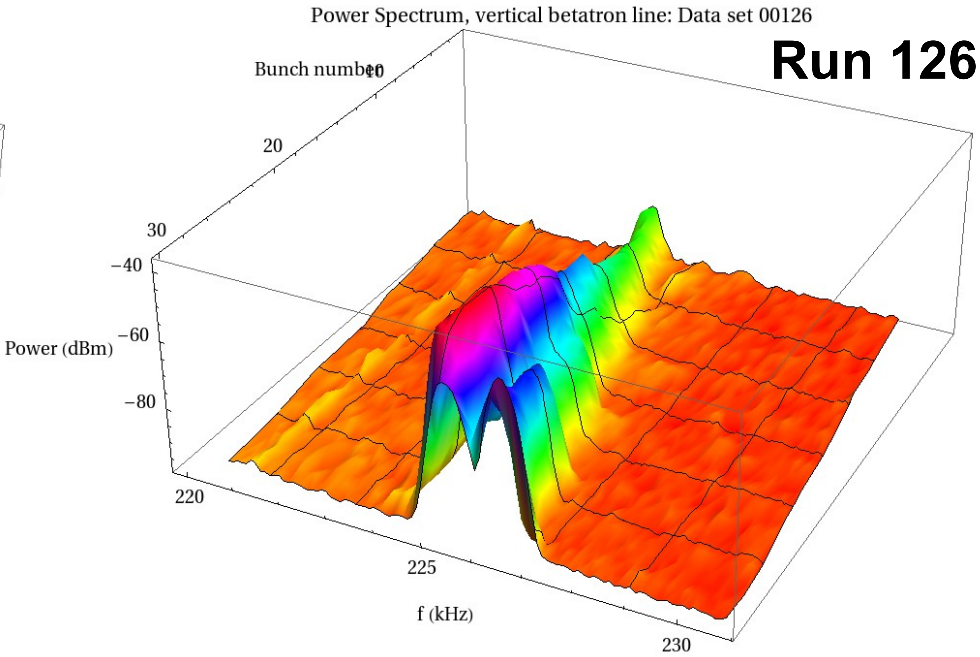


Detailed features of horizontal and vertical lines



Power Spectrum, horizontal betatron line: Data set 00166

Run 166



Power Spectrum, vertical betatron line: Data set 00126

Run 126

A lower frequency (~3 kHz) shoulder in the horizontal tune spectrum is attributable to the known dependence of horizontal tune on the multibunch mode.

In many cases, there is bifurcation of the vertical tune spectrum, which starts to develop at the same bunch number as the head-tail lines, and is not well understood.

ECE Effects on Vacuum and Heat Load

Kyo Shibata
(*High Energy Accelerator Research Organization (KEK)*):
SuperKEKB Vacuum System & KEK Studies

KEKB was shut down on Jun 30th 2010, and upgrade of KEKB has started.

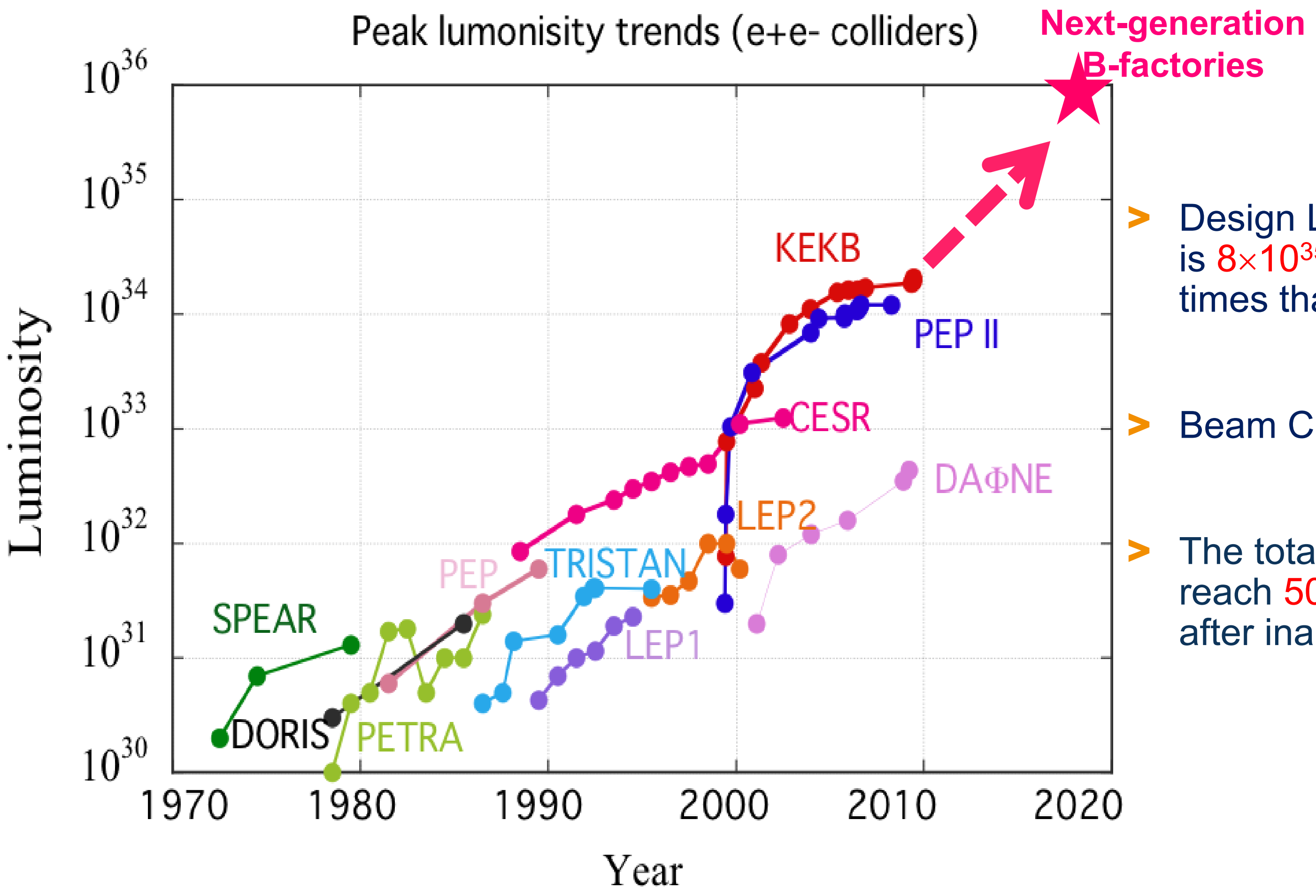
KEKB B-factory :

- **Electron-positron collider with asymmetric energies of 8 GeV (e-) and 3.5 GeV (e+).**
- **Made a great contribution to confirmation of CP violation in the neutral B meson system.**
- **Operation period : 1998 to 2010**
- **Peak luminosity : 2.1×10^{34} $cm^{-2}s^{-1}$**
- **Total integrated luminosity : 1040 /fb**

To pursue research on flavor physics, much more luminosity is required and the SuperKEKB project was begun in 2010.

- **Commissioning of SuperKEKB will start in the second half of FY2014.**

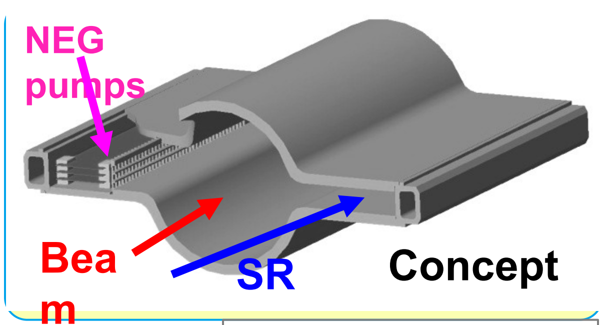
Mission of SuperKEKB



- Design Luminosity of SuperKEKB is 8×10^{35} /cm²/s, which is about 40 times than the KEKB's record.
- Beam Current: 3.6/2.6 A (e+/e)
- The total integrated luminosity will reach 50 /ab just over ten years after inauguration.

New Beam Pipes for SuperKEKB

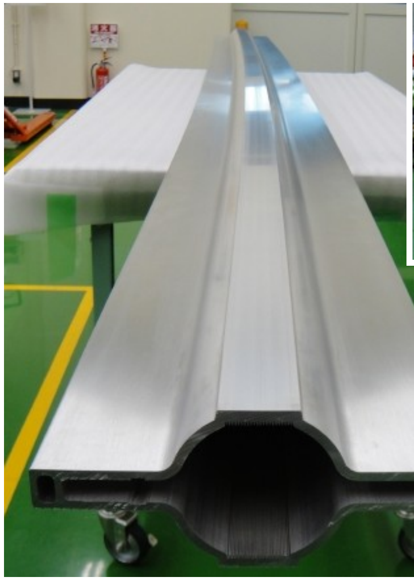
- To cope with the electron cloud issues and heating problems, antechamber type beam pipes are adopted with a combination of TiN coatings, grooved shape surfaces and clearing electrodes.



by courtesy of Y. Suetsugu

- **LER arc section:**
  - ✓Beam pipes are replaced with new aluminum-alloy pipes with antechambers. (~2000 m)
- **HER arc section:**
  - ✓Present copper beam pipes are reused.
  - ✓Since the HER energy is reduced from 8.0 to 7.0 GeV, SR power at normal arc section is more or less the same as KEKB.
- **Wiggler section (both ring):**
  - ✓Copper beam pipes with antechambers are used.

Wiggler section (copper)



Arc section (aluminum)

Countermeasures against Electron Cloud Effect

- Electron cloud instability can be a serious problem for LER (e+)
  - The threshold of electron density to excite the head-tail instability is $\sim 1.6\times10^{11}$ e^-/m^3.
  - By using these countermeasures, the average electron density on the order of 10^{10} e^-/m^3 will be obtained.
  - Various mitigation techniques were evaluated at KEKB LER.

by courtesy of Y. Suetsugu

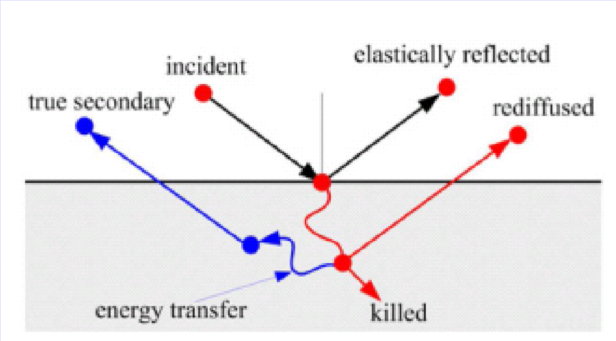
Sections	L [m]	L [%]	Countermeasure	Material
Total	3016	100		
Drift space (arc)	1629 m	54	TiN coating + Solenoid	Al (arc)
Steering mag.	316 m	10	TiN coating + Solenoid	Al
Bending mag.	519 m	17	TiN coating + Grooved surface	Al
Wiggler mag.	154 m	5	Clearing Electrode	Cu
Q & SX mag.	254 m	9	TiN coating	Al (arc)
RF section	124 m	4	(TiN coating +) Solenoid	Cu
IR section	20 m	0.7	(TiN coating +) Solenoid	Cu or ?

Thursday 07 June 2012

- Surface Properties, Coating and Experimental Studies
  - 10 contributions
- Multipactoring and related effects
  - 7 contributions

Rosanna Larciprete (CNR-Istituto dei Sistemi Complessi, Roma, and INFN-LFN, Frascati , Italy) :

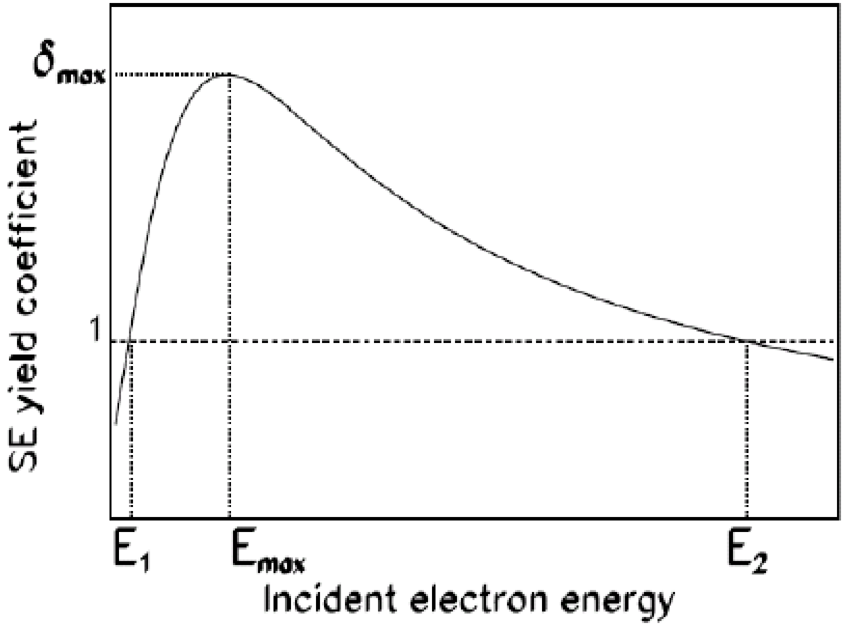
The chemical origin of SEY at technical surfaces



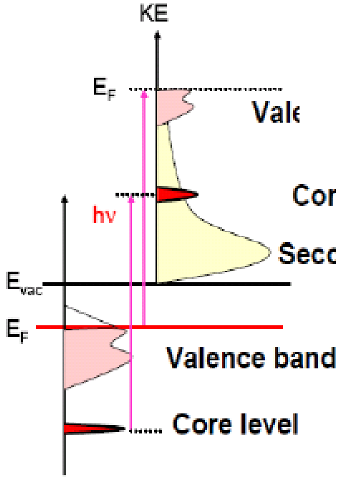
secondary electron emission

three-step process:

- production of SEs at a depth *z*
- transport of the SE toward the surface
- emission of SE across the surface barrie



X-ray photoelectron spectroscopy (XPS)

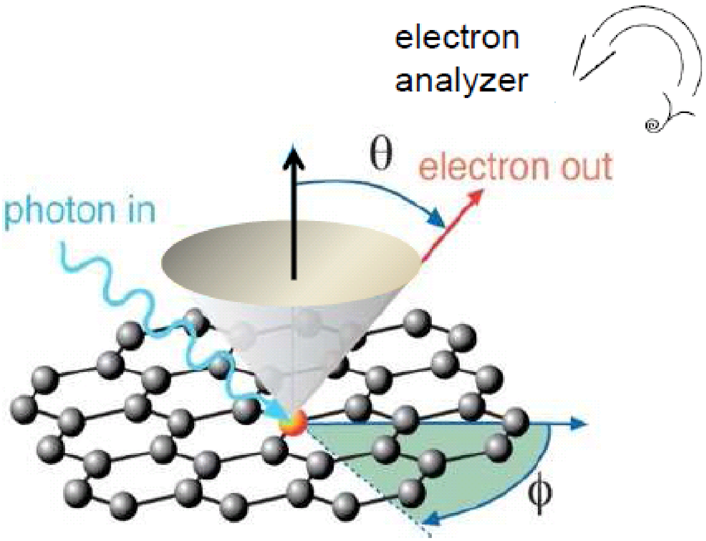


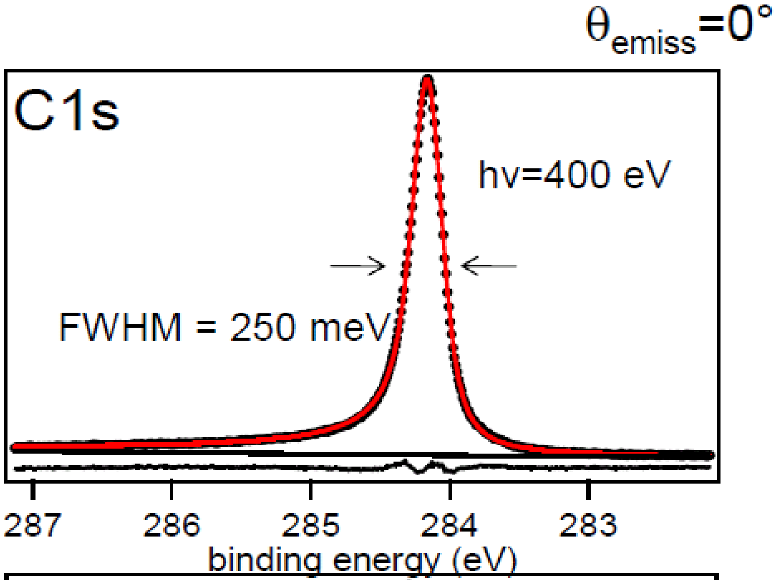
$$KE=h\nu-BE-\varphi$$

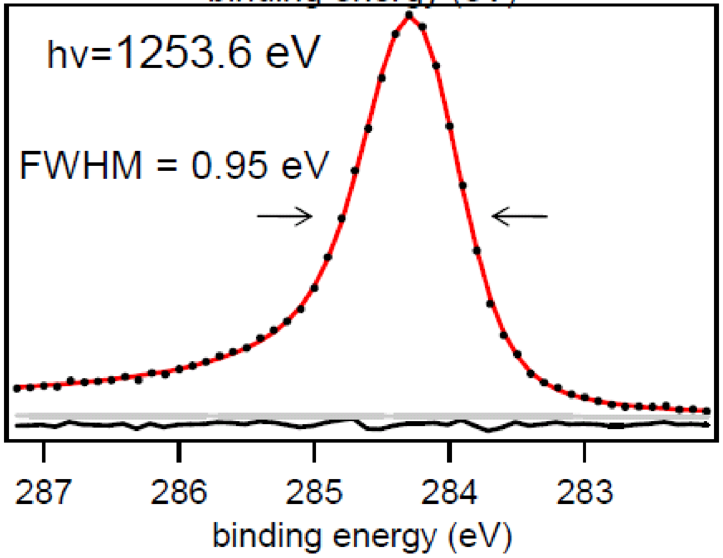
KE: kinetic energy

φ: work function

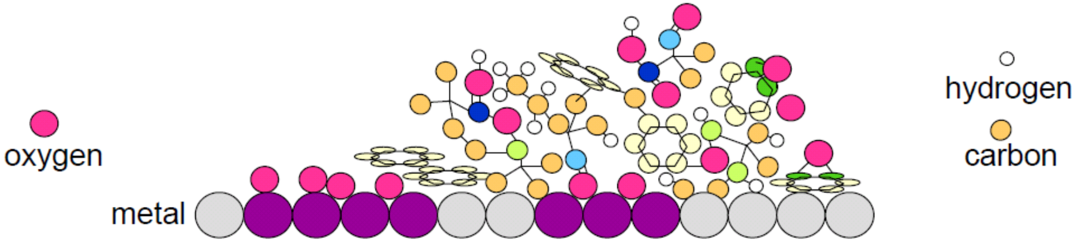
BE: binding energy

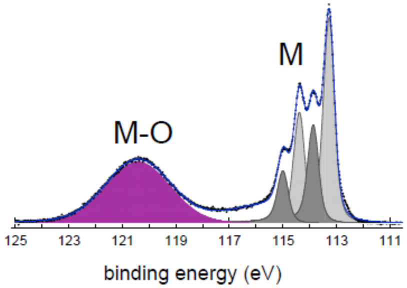


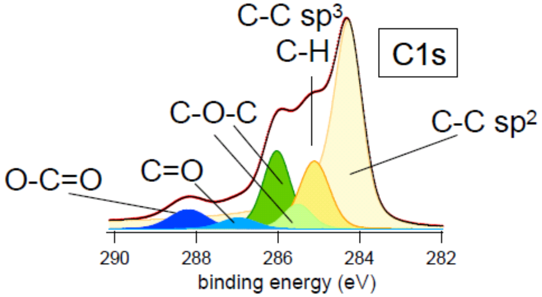




XPS of technical surfaces / C film on Cu







Cu-O dissociation → O_2

CO → reaction → CO_2

oxide reduction

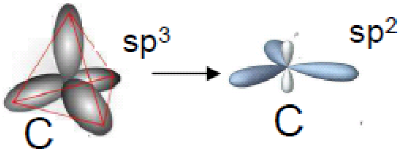
C-H dissociation → H_2

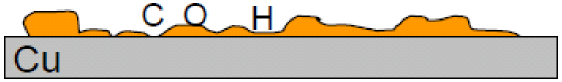
$sp^3 \rightarrow sp^2$ conversion

CO → C-O dissociation → O_2

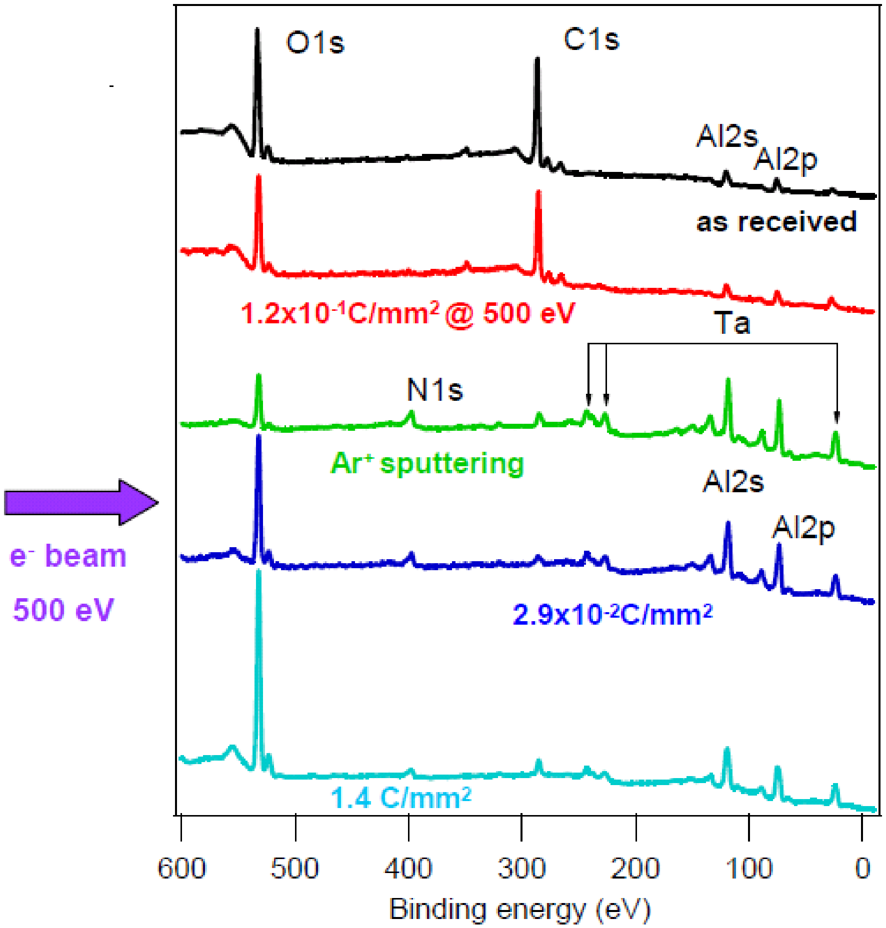
C film growth

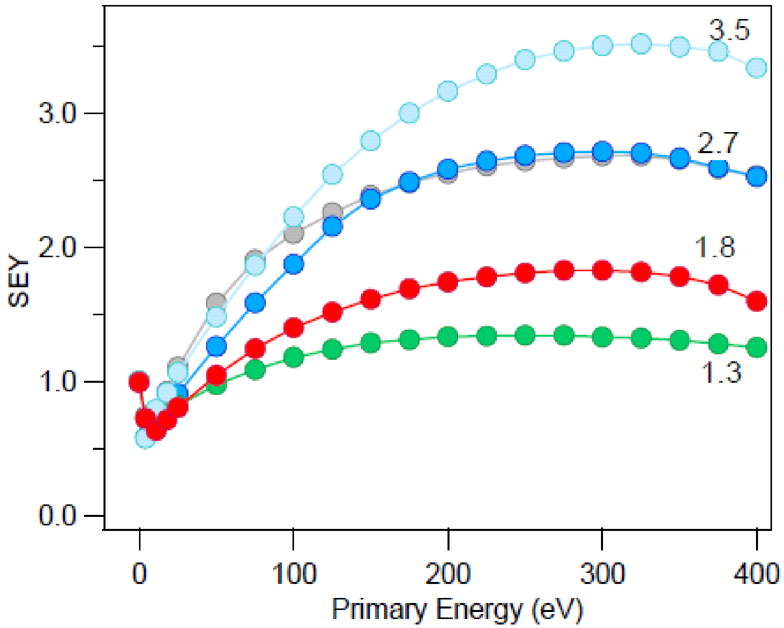
C film on Cu,
SEY reduction !
2.2 → 1.1





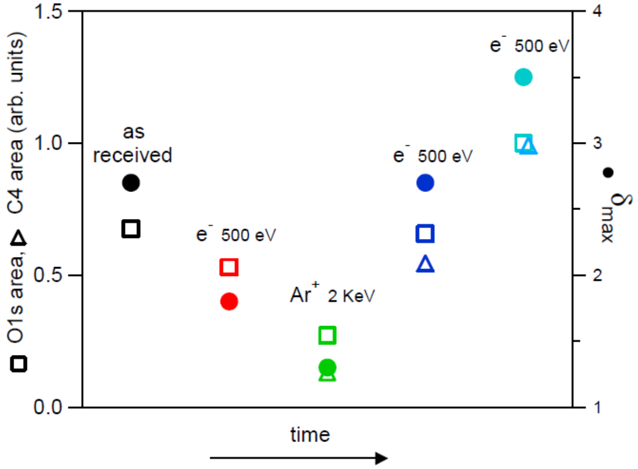
Al samples from PETRA III



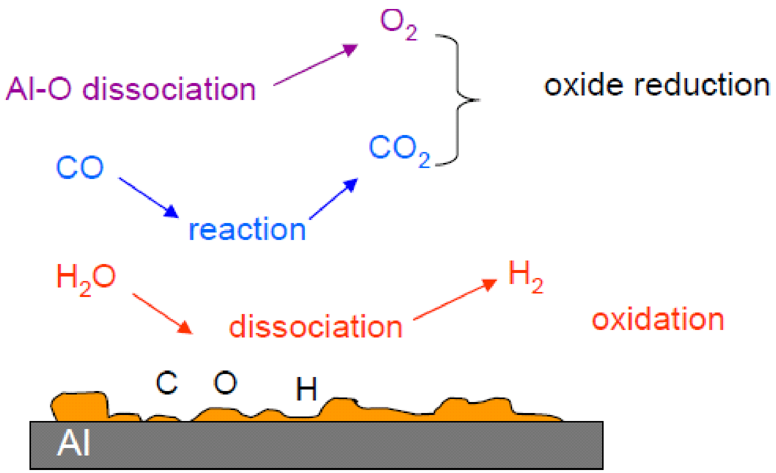


dissociation of residual gas molecules as H_2O and CO induced at the metal surface by the e^- beam determines a rapid oxidation of the irradiated area, as well as, although to a lesser extent, of the surrounding region

Al samples from PETRA III



the SEY variation follows the oxygen content of the Al surface



Al-O dissociation → O_2

CO → reaction → CO_2

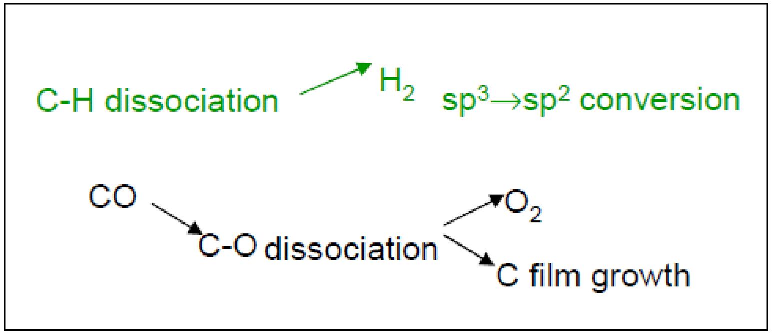
oxide reduction

H_2O → dissociation → H_2

oxidation

SEY is determined by the rates of Al oxidation and reduction

reactions involving C play a minor role



C-H dissociation → H_2 $sp^3 \rightarrow sp^2$ conversion

CO → C-O dissociation → O_2, → C film growth

Thursday 07 June 2012

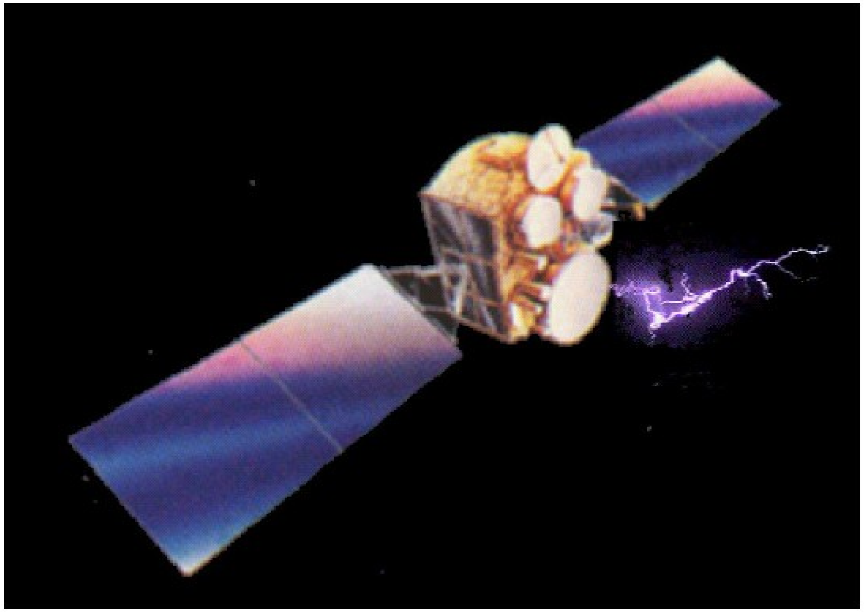
- Surface Properties, Coating and Experimental Studies
  - 10 contributions
- **Multipactoring and related effects**
  - 7 contributions

Multipactoring and related effects

Shu T. Lai (MIT, USA)

SPACECRAFT CHARGING: INCOMING AND OUTGOUNG ELECTRONS

Spacecraft Charging is Harmful to the Health of Onboard Electronics



Charging affects

- Scientific measurements
- Telemetry signals
- Electronic communications

Discharges degrade

- Solar cells
- Controls
- Navigation

Why do Spacecraft Charge?

- Consider a plasma in thermal equilibrium

$$\frac{1}{2}m_e \mathrm{v}_e^{\,2} = \frac{1}{2}M_i V_i^2$$

- The electrons are much lighter and faster than the ions

$$\mathrm{v}_e >> V_i$$

- Therefore, the flux of electrons is much higher than that of ions

$$n_e q_e \mathrm{v}_e >> n_i q_i V_i$$

- This is why spacecraft often charge to negative potentials in a plasma
- This is true not only in space but also in the laboratory.

VSC
VAL SPACE
CONSORTIUM

esa

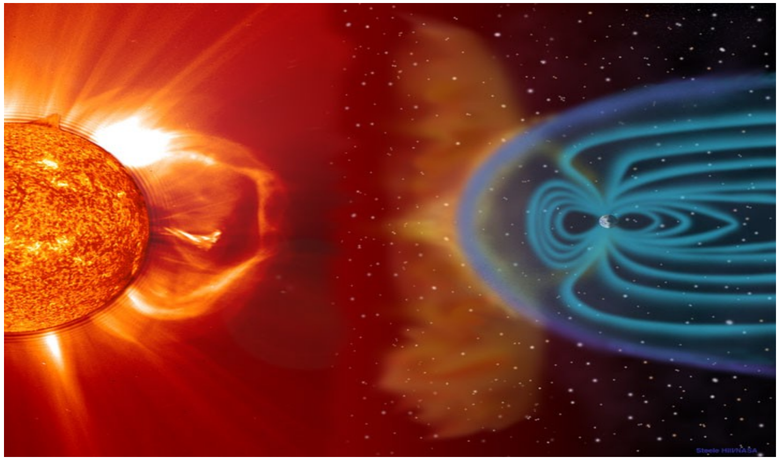
Activities of the Val Space Consortium and the European Space Agency in the Study of RF Breakdown Phenomena in Microwave Passive Components for Space Applications

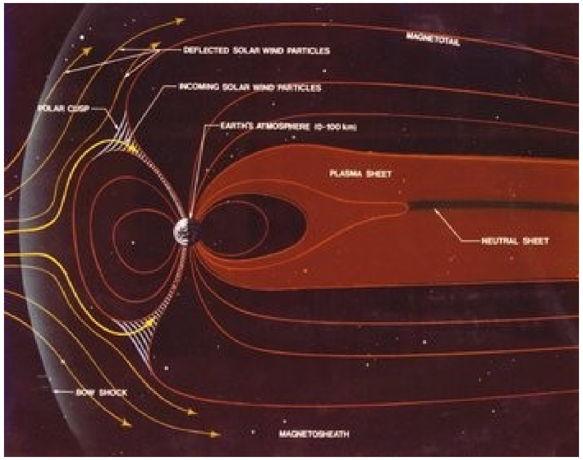
Benito Gimeno(1,3), Vicente E. Boria(2,3), David Argilés(3), David Raboso(4)
(1) University of Valencia, Spain
(2) Technical University of Valencia, Spain
(3) VAL SPACE CONSORTIUM, Valencia, Spain
(4) European Space Agency, ESA/ESTEC, The Netherlands

ECLOUD'12

ECLOUD'12
5-9 June 2012, La Biodola, Isola d'Elba, Italy

- Space weather is a very hostile environment
- Solar activity causes a continuous flux of high energy elemental particles towards the spaceships





European High Power RF Space Laboratory:

Up to date the Laboratory can carry out these tests:

- **Multipactor effect: Single-carrier and Multicarrier**
- **Corona effect**
- **Power Handling**
- **Passive Intermodulation (PIM): guided and radiated**

Friday 08 June 2012

- Simulations and diagnostics
  - 10 contributions
- Mitigation
  - 7 contributions

Giovanni Iadarola (CERN)

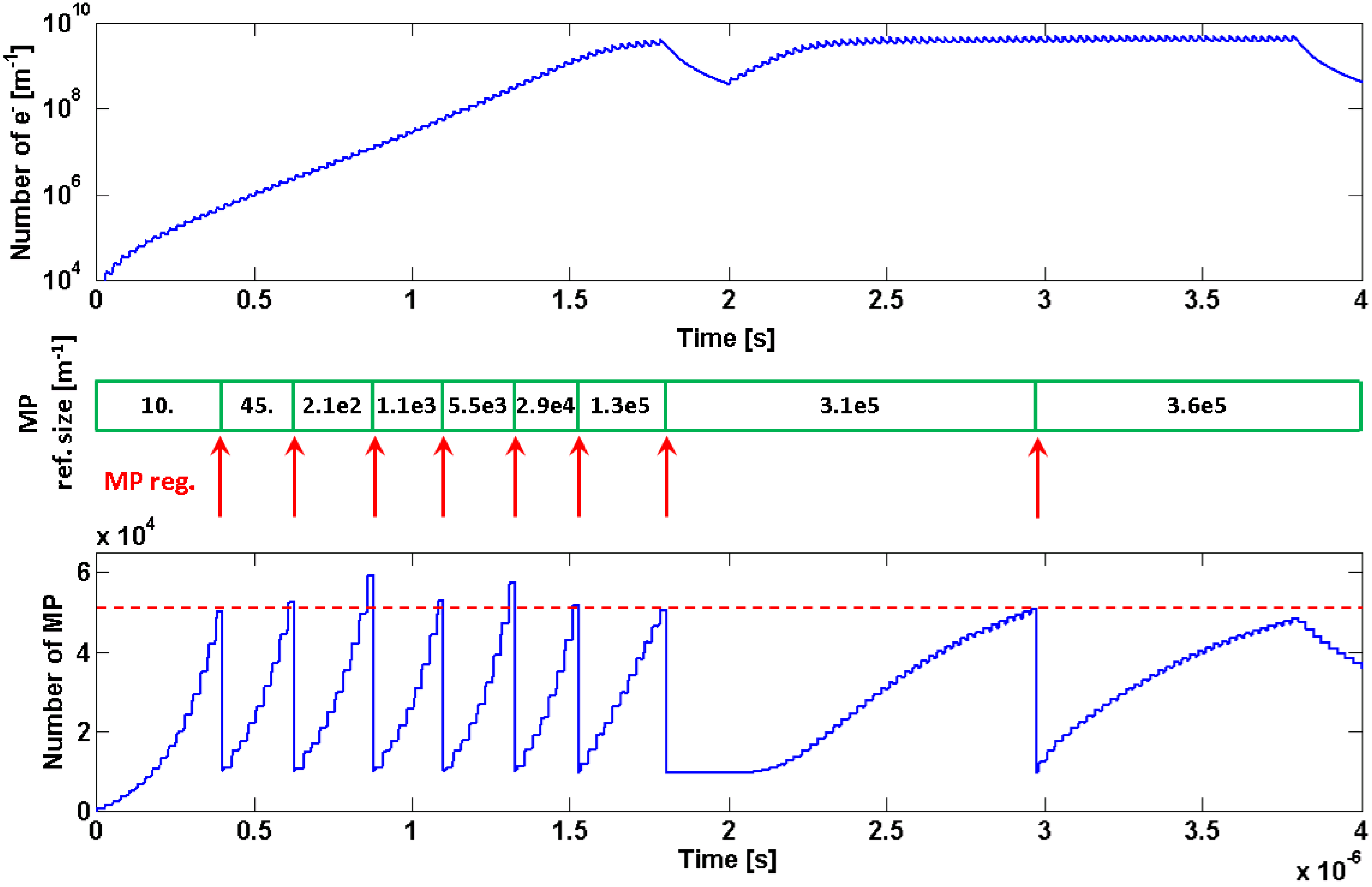
Py-Ecloud and Build Up Simulations at CERN

ECLOUD	PyECLOUD
• Developed at CERN since **1997** (mainly by F. Zimmermann, G. Bellodi, O. Bruning, G. Rumolo, D. Schulte)	• Development started in **2011**
• Pioneering work which defined a **physical model for the EC build-up**	• Inherits the **physical model of ECLOUD**
• **FORTRAN 77** code	• **Python** code
• **Scarcely modular** (difficult to maintain, develop and debug)	• **Strongly modular** (much easier to develop and maintain)
	• **Several improvements** introduced with better performances in terms of **reliability, accuracy, efficiency, and flexibility**

Simulations and diagnostics: Py-Ecloud

Macroparticle size management

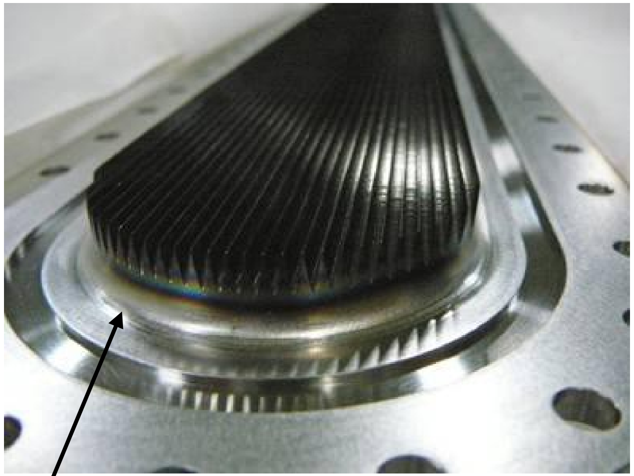
The **reference MP size N_{ref}** is adaptively changed during the simulation:

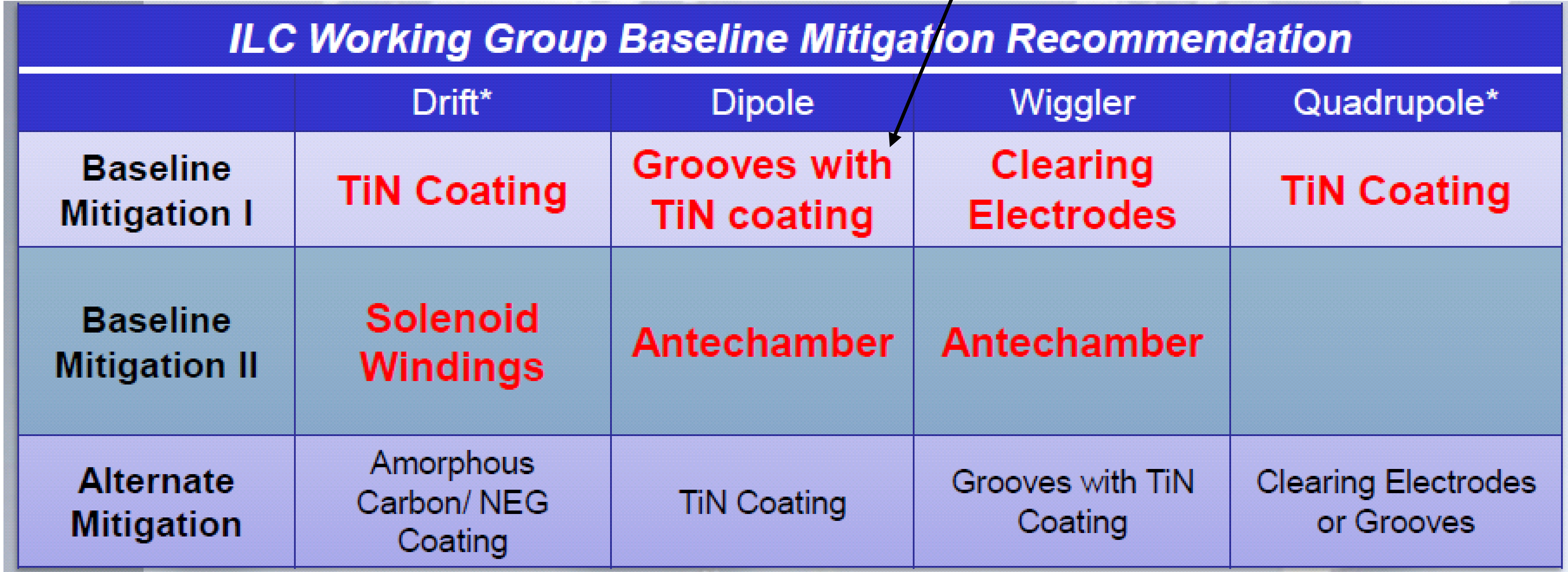


Mitigation

Mauro Pivi (SLAC)

Mitigation Strategy: Overview, including LHC and ILC





ILC Working Group Baseline Mitigation Recommendation				
	Drift*	Dipole	Wiggler	Quadrupole*
Baseline Mitigation I	TiN Coating	Grooves with TiN coating	Clearing Electrodes	TiN Coating
Baseline Mitigation II	Solenoid Windings	Antechamber	Antechamber	
Alternate Mitigation	Amorphous Carbon/ NEG Coating	TiN Coating	Grooves with TiN Coating	Clearing Electrodes or Grooves

- Amorphous carbon not sufficiently tested in lepton machines under high radiation, yet

Mitigation

José Miguel JIMENEZ (CERN)

SPS: Mitigation Strategy at CERN

- SPS has to be prepared to digest:
  - High bunch intensity: up to 2.5 10^{11} ppb @ 25 ns ; 3.5 10^{11} ppb @ 50 ns

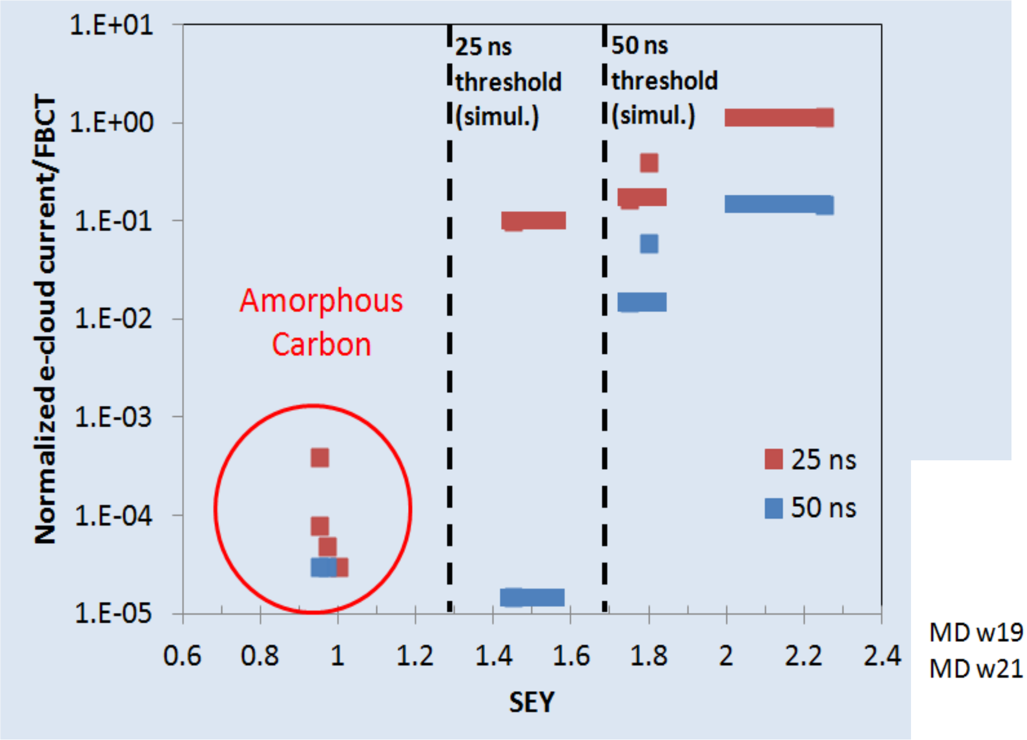
  and

  - Small emittances (LHC requirements)

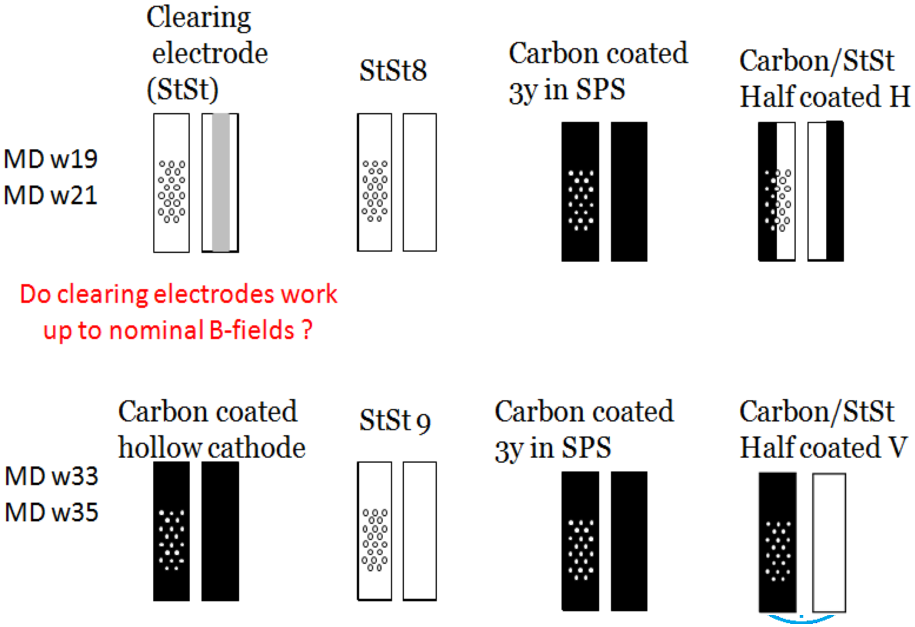
  cannot be guaranteed since electron cloud limitations have been identified:
  - Beam instabilities: transverse emittance blow-up and single bunch vertical instability
  - Pressure rise: beam gas scattering, dose rates to tunnel and components
- Improvements considered against Electron Cloud:
  - Suppression of the build-up: Clearing electrodes and very low SEY (<1.1) coatings
  - Mitigation of the build-up: Scrubbing Runs
  - Cure of the induced effects (single bunch vertical instability): High bandwidth feedback systems

Status Report

EC Suppression – Very low SEY a-C Coatings



- ☞ In dipole magnets, coating the top and bottom surfaces is required
- ☞ In field free regions, coating the entire inner surface is required

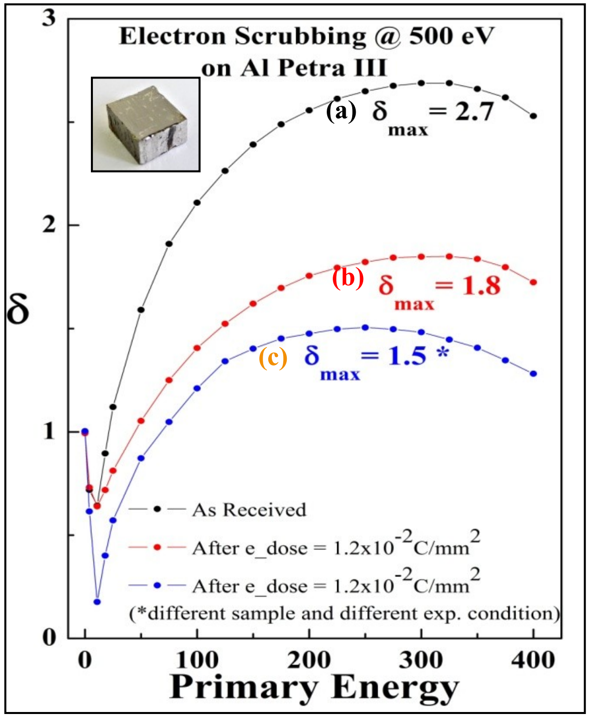


Do clearing electrodes work up to nominal B-fields ?

Perspectives for positron operation at PETRA III

PETRA III Vacuum chamber

IPAC 2011
Secondary Electron Yield of Al Samples from the Dipole chamber of PETRA III
D.R. Grosso, M. Commisso,
and R. Cimino,
LNF-INFN, Frascati Italy
R. Flammini, CNR-IMIP,
Monterotondo, Italy
R. Larciprete, CNR-ISC, Rome, Italy
R. W., DESY, Hamburg, Germany



Arc: Al, 80 mm x 40 mm

Instability threshold – coasting beam model

Broad band resonator model + coasting beam model *)

$$Z(\omega) = \frac{cR_S}{\omega}\frac{1}{1+iQ\left(\frac{\omega_e}{\omega}-\frac{\omega}{\omega_e}\right)} \tag{10}$$

$$= K\frac{\lambda_e}{\lambda_+}\frac{L}{\sigma_y(\sigma_x+\sigma_y)}\frac{\omega_e}{\omega}\frac{Z_0}{4\pi}\frac{Q}{1+iQ\left(\frac{\omega_e}{\omega}-\frac{\omega}{\omega_e}\right)},$$

where K is an enhancement factor due to cloud size, pinching etc. [11], and Z_0 is the impedance of vacuum (377Ω). The figure 4 shows $K = 1.5$. In the case of KEKB, the enhancement factor was $K = 2 \sim 4$ for the vertical wake field.

$$U \equiv \frac{\sqrt{3}\lambda_+ r_e\beta\omega_0}{\gamma\omega_e\eta\sigma_\delta}\frac{|Z_\perp(\omega_e)|}{Z_0} = \frac{\sqrt{3}\lambda_+ r_e\beta}{\gamma\nu_s\omega_e\sigma_z/c}\frac{|Z_\perp(\omega_e)|}{Z_0}$$

< 1

threshold density:

$$\rho_{e,th} = \frac{2\gamma\nu_s\omega_e\sigma_z/c}{KQ\sqrt{3}r_e\beta L}$$

$$K \sim \omega_e\sigma_z/c.$$

(L = circumference of the ring)

Q ~ 5 < K

$$\omega_{e,y} = \sqrt{\frac{\lambda_+ r_e c^2}{\sigma_y(\sigma_x+\sigma_y)}}$$

λ_+ = beam line density in the e+ bunch

	$K \sim \omega_e\sigma_z/c.$
PETRA III:	**~ 1.4 x 10^{12} m^{-3}**

(PETRA III, 960 bunches, 100 mA)

***) K. Ohmi: Electron Cloud Effect in Damping Rings of Linear Colliders**
31st ICFA Advanced Beam Dynamics Workshop on Electron-Cloud Effects "ECLOUD'04"

PETRA III – Commissioning and User Runs

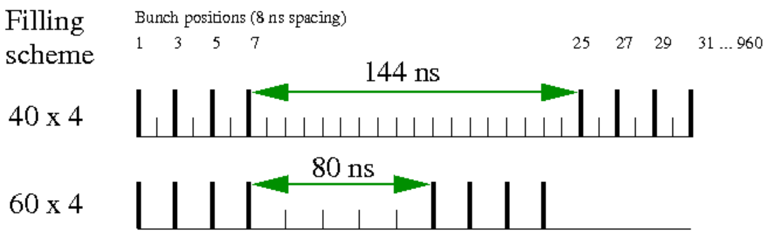
2009

- Commissioning:
  - First stored beam (April 13)
  - Operation with <u>all</u> (2 x 10) wigglers from

    Aug 12, 2009

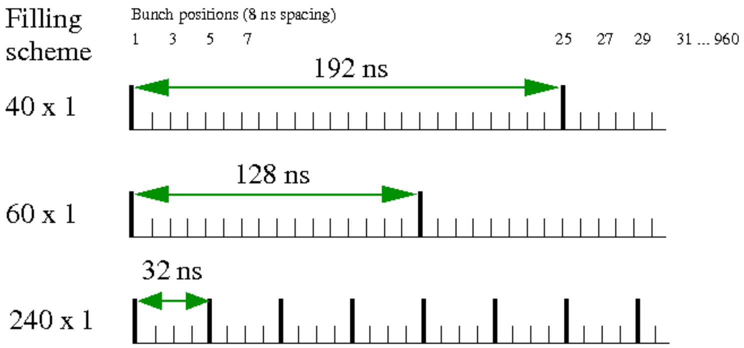
2010

- First user runs (friendly user) (Feb, 2010)
- Ecloud studies May/June 2010
- Aug 2 – Aug 7, 2010
  - Machine studies <u>without</u> wigglers
- User runs (Aug 2010)



2011

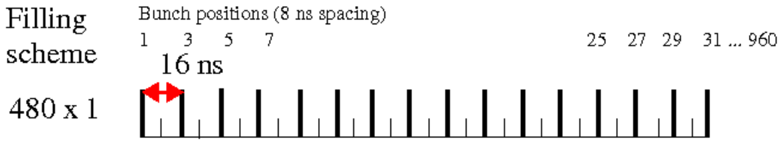
- About 9 month of user runs
  - 3 bunch patterns



- Ecloud Studies Oct, Nov.

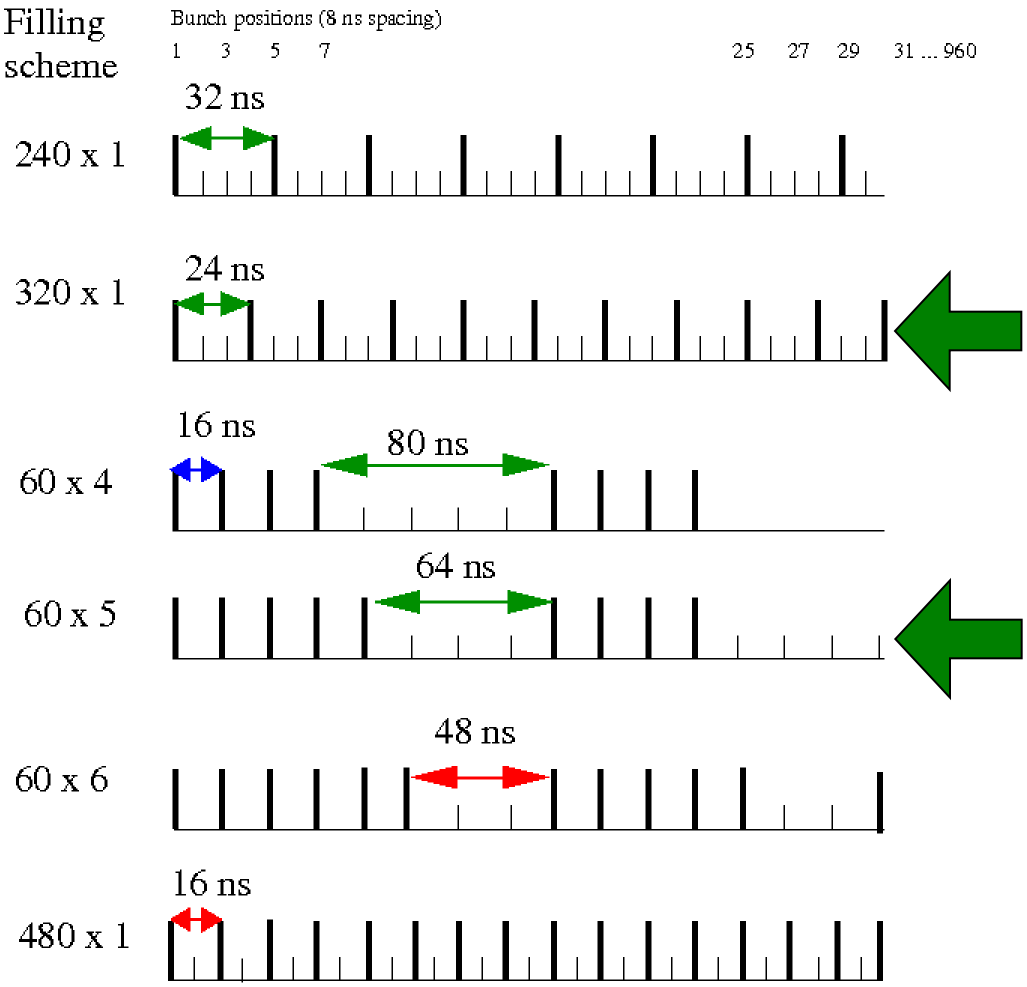
2012

- Scrubbing Run (March)



- User runs, bunch pattern as 2011 + recently 320 bunches

Conditioning + Scrubbing: Benefits



100 mA in 320 bunches
Without any significant
emittance increase !

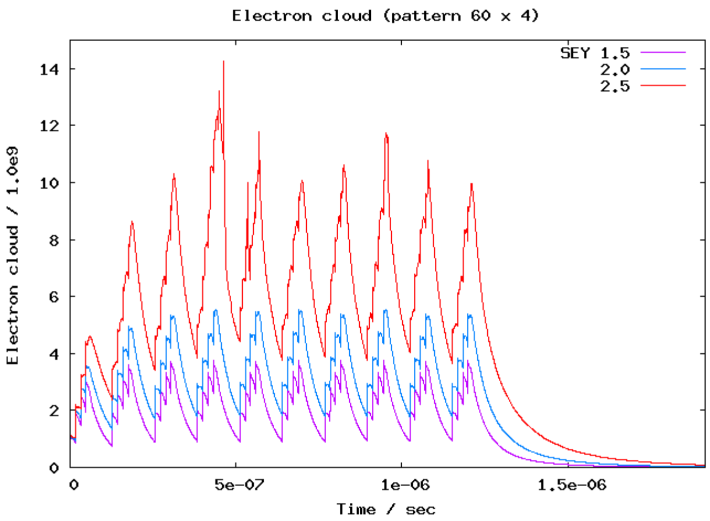
100 mA in 60 x 5 bunches
Without any significant
emittance increase!

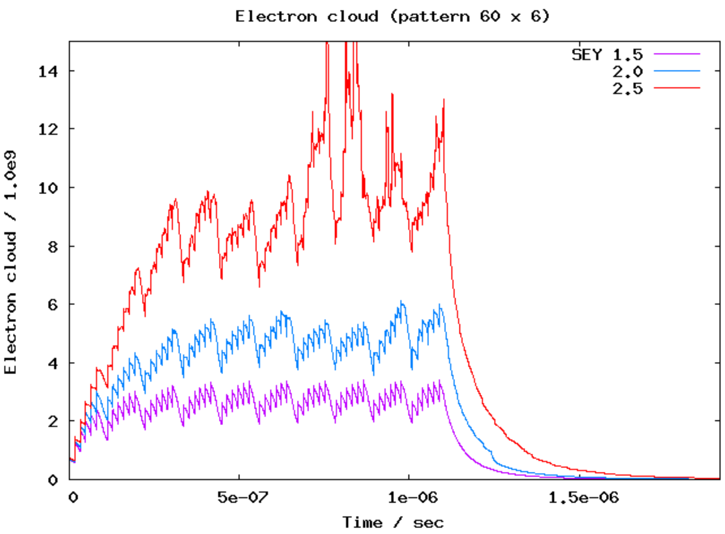
Emittances increase:
60 x 6 bunches

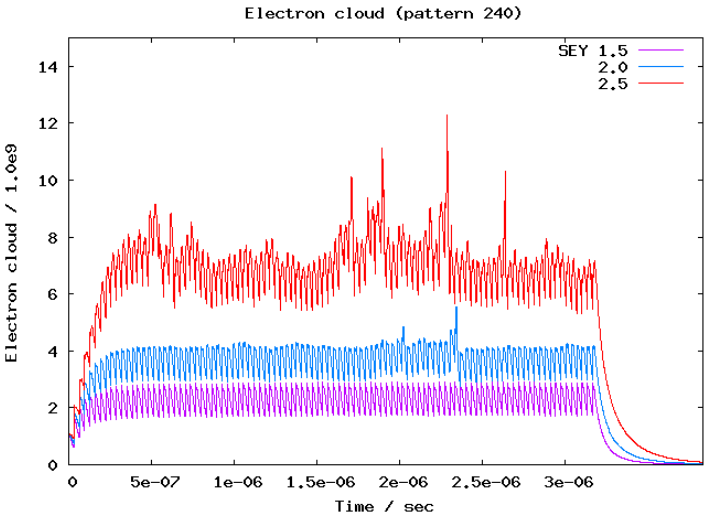
480 bunches (used for scrubbing)

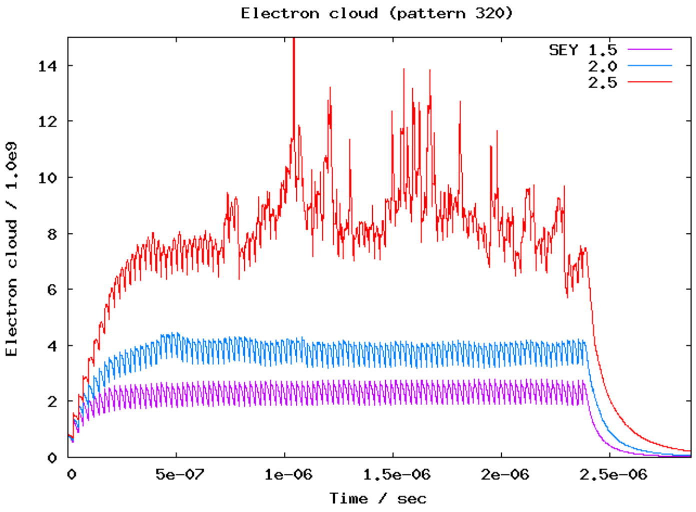
Simulations with ECLOUD 4.0

PETRA III, 100 mA, different filling patterns, SEY: 1.5, 2.0, 2.5


Electron cloud (pattern 60 x 4)

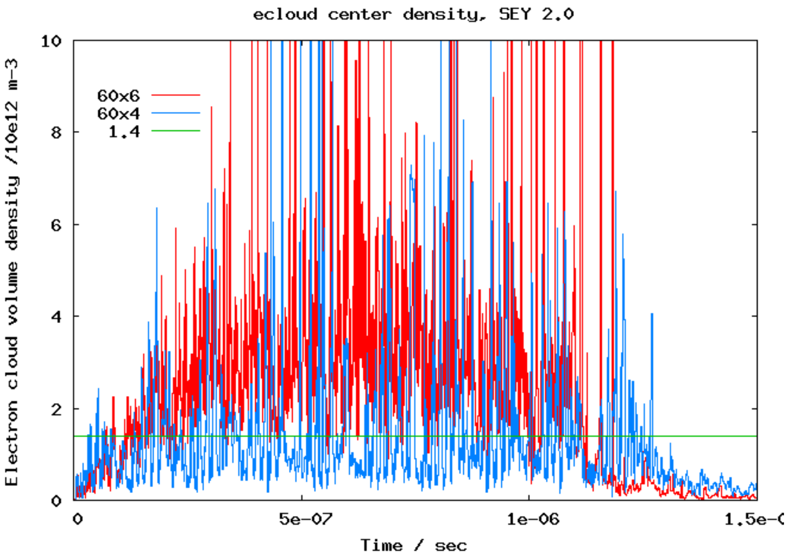

Electron cloud (pattern 60 x 6)


Electron cloud (pattern 240)


Electron cloud (pattern 320)

Simulations with ECLOUD 4.0 (cont.)

PETRA III, 100 mA, different filling patterns, center density



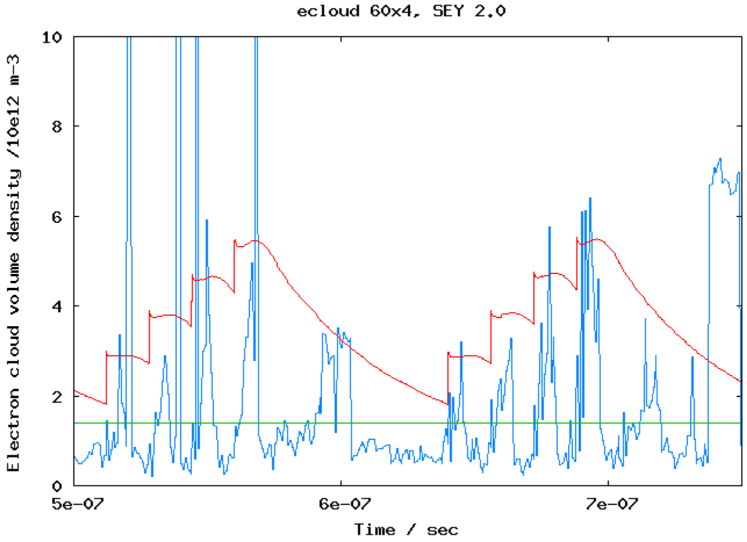
Emittance growth

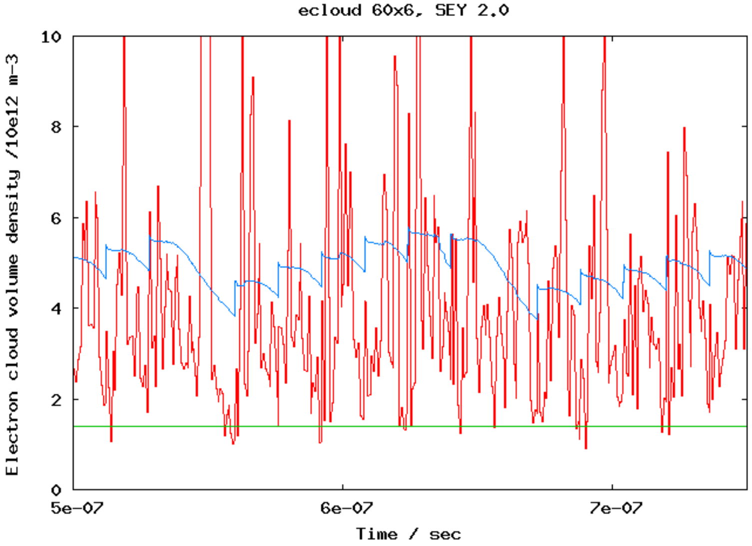
100 mA 60 x 6 not ok

100 mA 60 x 4 ok

(threshold density ~ 1.4e^{12} m^{-3})

Simulation studies indicate an instability for the 60 x 6 pattern if the SEY is about 2.0



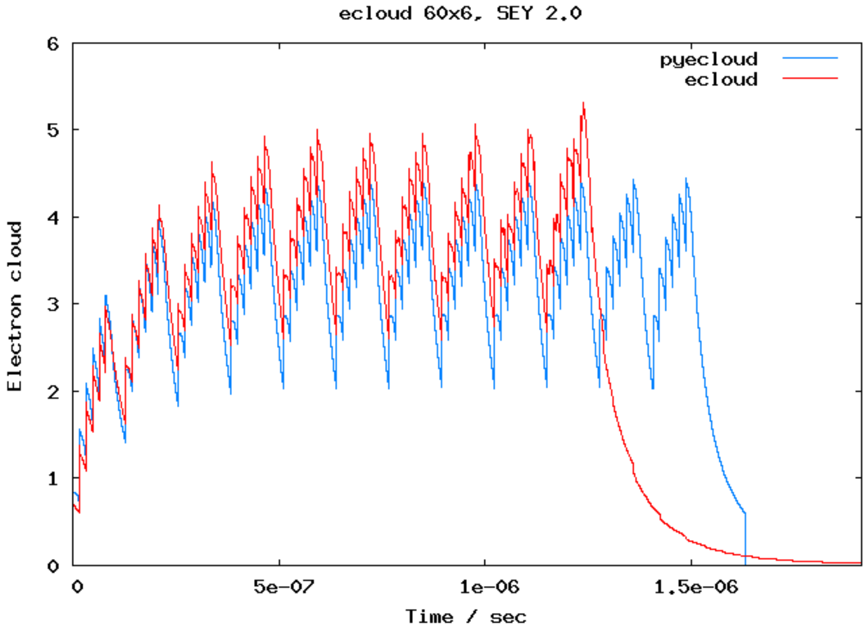


Recent Simulations with PYECLOUD

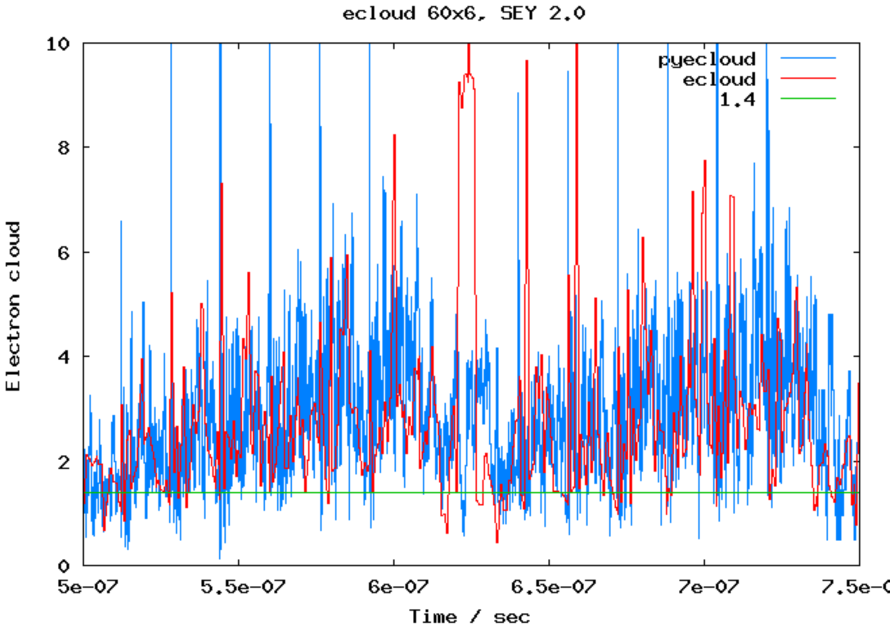
PETRA III, 100 mA, 60x6 bunches, SEY: 2.0

Comparison ECLOUD 4.0 versus PYECLOUD, preliminary results

Total number of electons:
Blue: PYECLOUD, Red: ECLOUD 4.0



Central cloud density



PETRA III Perspectives

- A clear conditioning effect has been observed. For user runs filling patterns with 40 x 4 and 60 x 4 bunches were used in 2010. In 2011 it was possible to fill 240 bunches with a 32 ns bunch spacing.
- In 2012 two dedicated scrubbing runs have improved the situation. It is possible to use 320 bunches with 24 ns bunch spacing and no significant emittance growth (user runs with 320 bunches May 16, 2012).
- This "proves" that the observed emittance growth is really due to electron clouds.
- Simulations for different filling patterns indicate that the SEY is ~ 2.0 after conditioning and scrubbing.
- Measurements of Al samples at INFN, Frascati, have shown NO formation of a carbon layer, which is required to reduces the SEY significantly. The SEY is following the oxygen content of the surface. A SEY of 1.5 was found in the lab only under very good vacuum conditions (10^{-10} mbar).
- In my view: Operation with 480 bunches (16 ns bunch spacing) will require a SEY of about 1.5 which can only be achieved with scrubbing runs AND better vacuum conditions.

Thank you for your attention !