



ILC R&D plan WP 2.2.3: Electron cloud

M. Pivi -SLAC

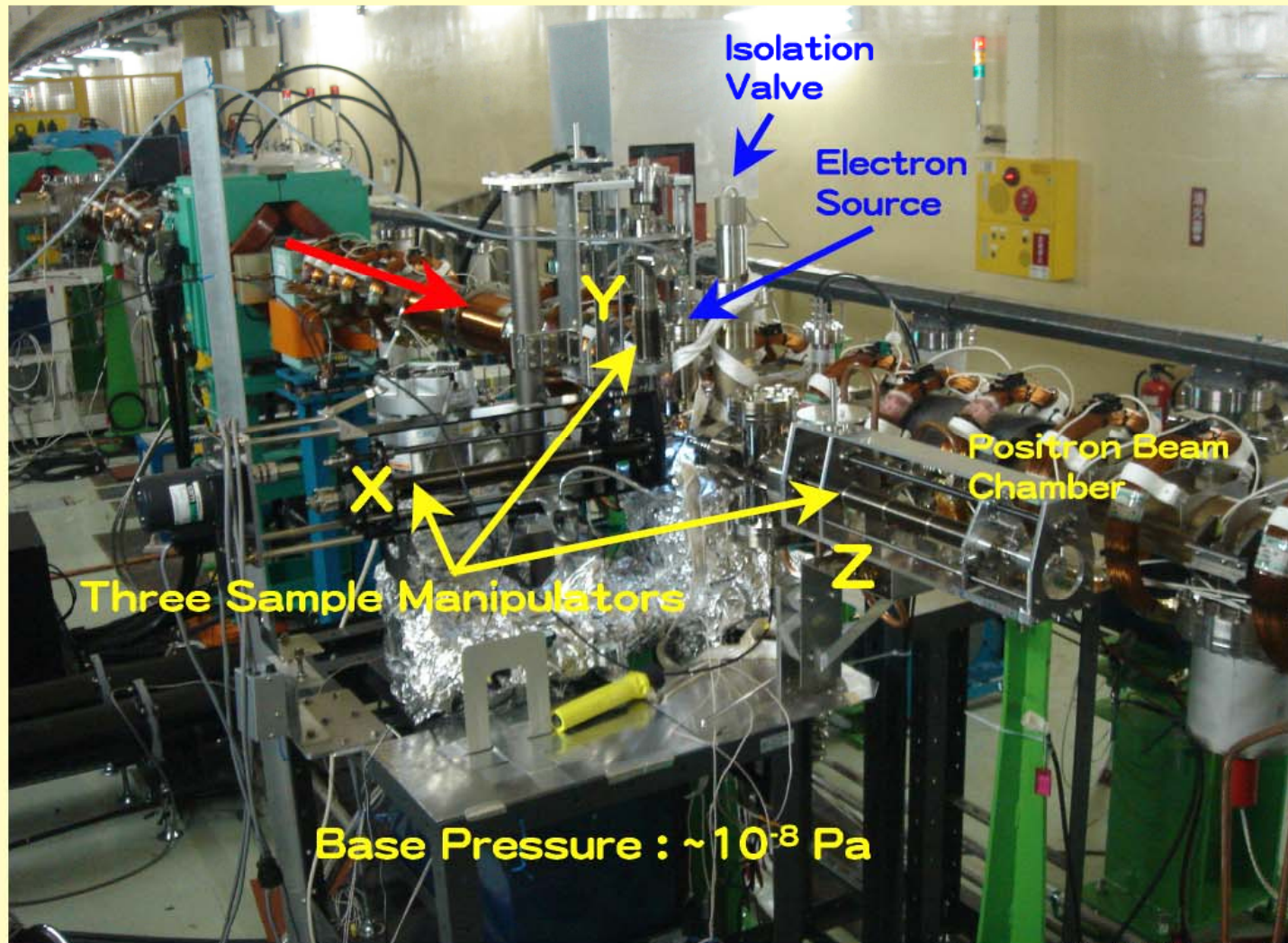
ILC 2007

Hamburg, Germany

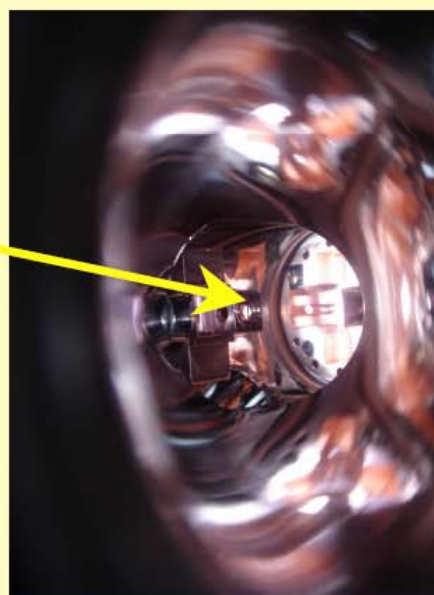
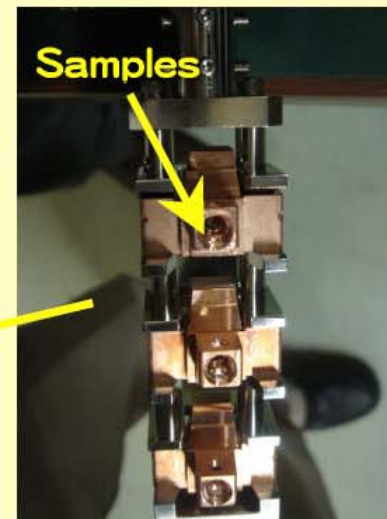
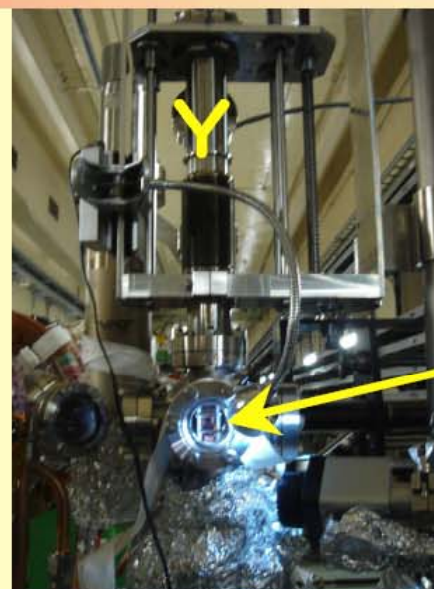
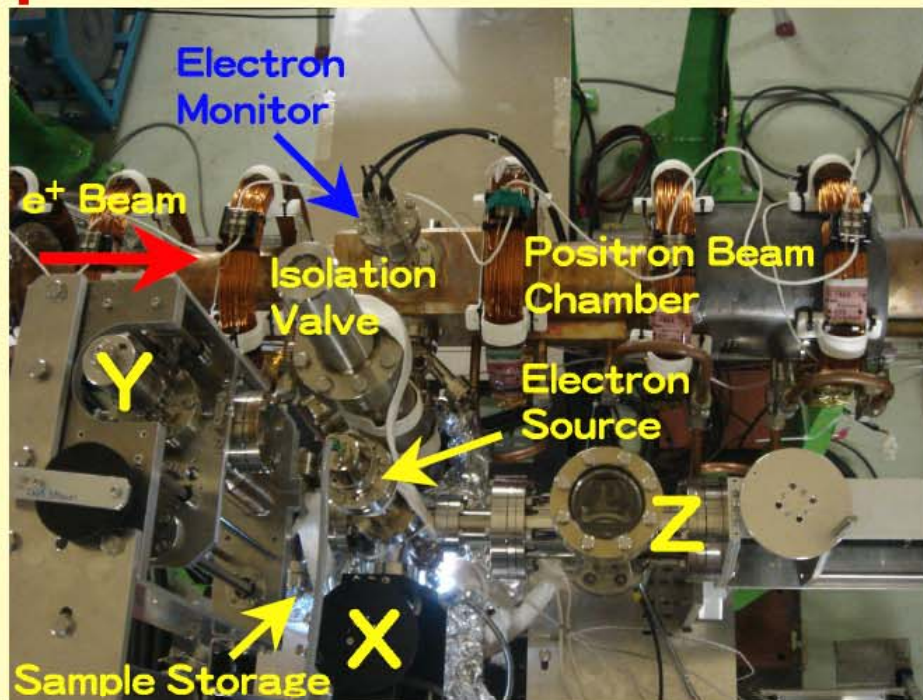


Electron cloud R&D

- Recent ELOUD07 Workshop in Daegu, S. Korea (~50 participants)
 - **Highlights:**
 - Measurements of the surface Secondary Electron Yield (SEY) of samples inserted in accelerators beam lines at KEK and SLAC
 - Low $SEY \leq 1$ measured on samples installed in KEKB and PEP-II
 - Progress with single-bunch instability codes (WARP/POSINST, PETHS benchmarking)
 - Measurements of electron cloud in existing machines: KEKB, PSR quadrupoles, SNS, Tevatron Main Injector, BEPC, CESR , PEP-II..
 - Estimates/measurements of the cloud central density in vacuum chamber
 - Advancement studies on possible mitigation techniques: clearing electrodes, grooves, slots



SEMS at LER (cntrn'd)

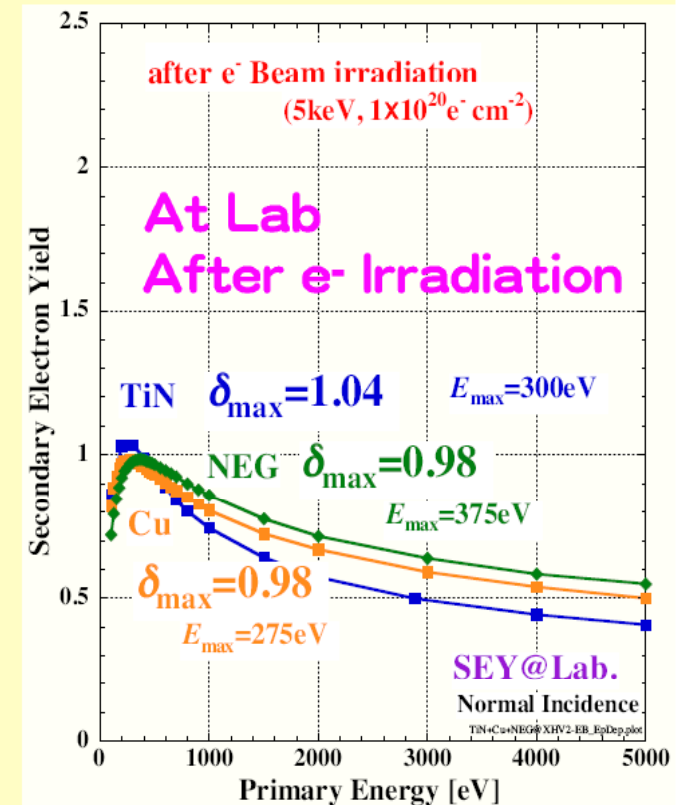
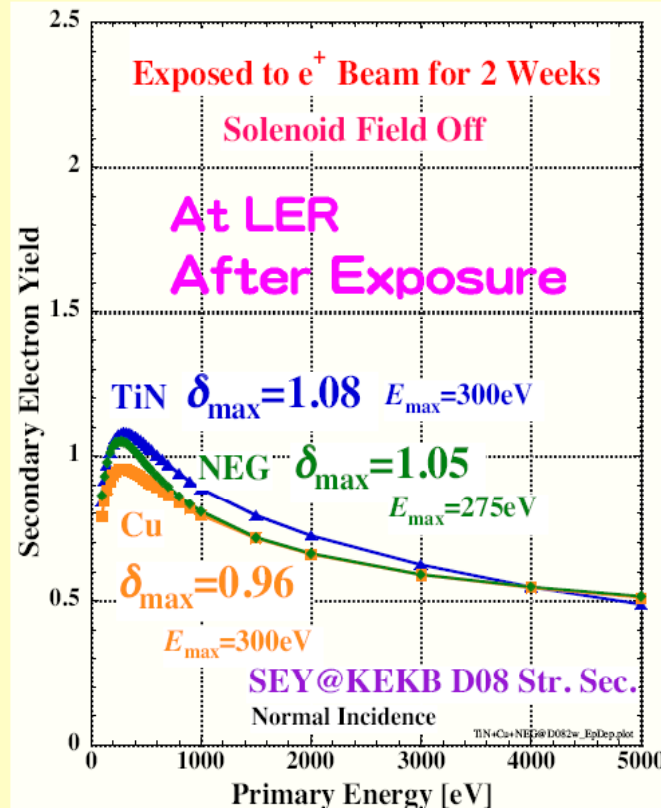
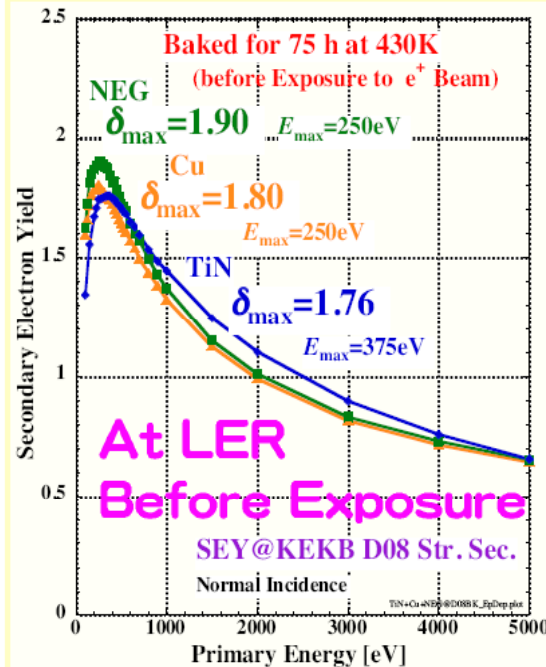


Hole (1.5mm ϕ) of Electron Monitor



KEKB SEYs after Exposure to e-Cloud w/o Solenoid Field

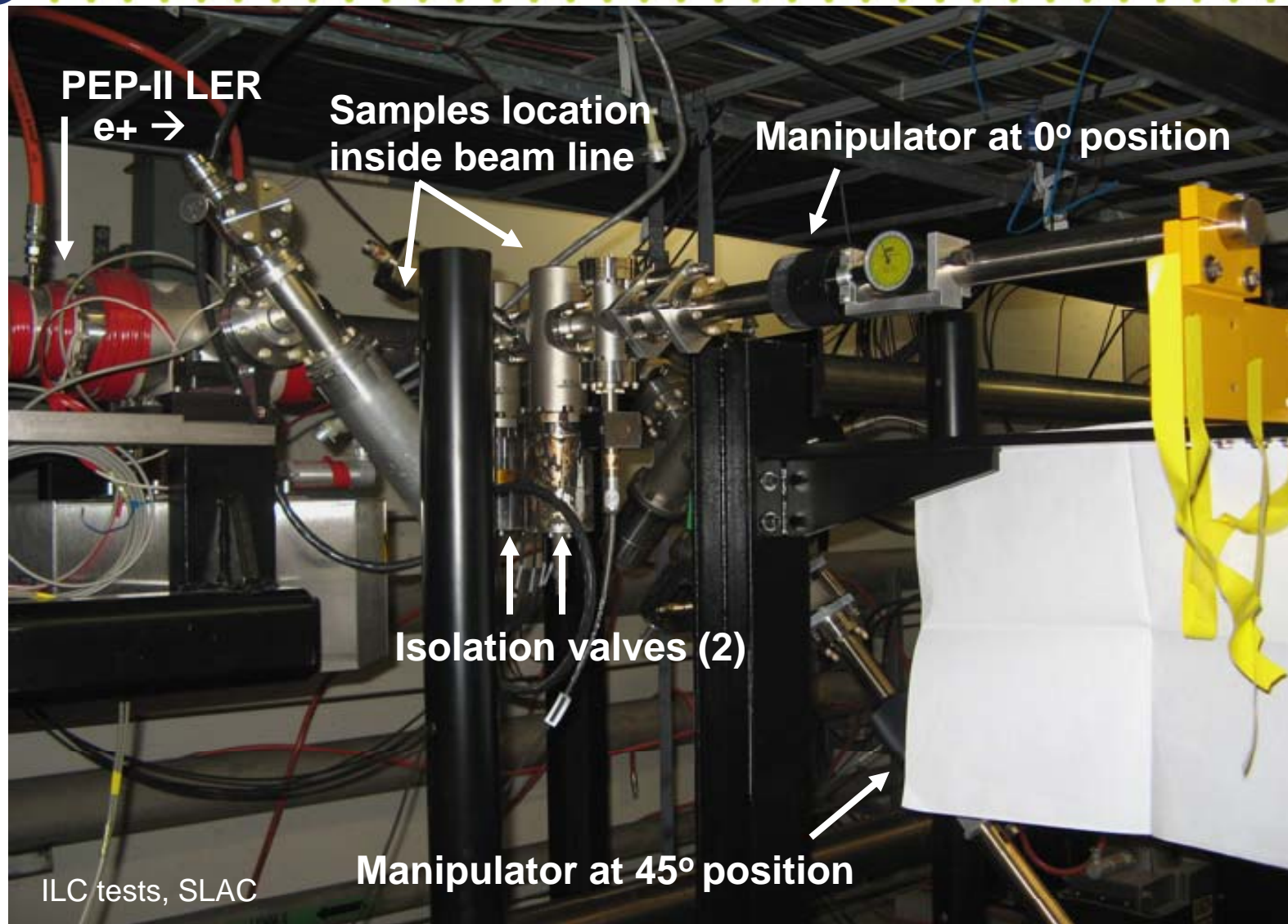
Primary Electron Energy Dependence of SEYs for Copper, TiN and NEG



- All as-received Samples : High δ_{\max} (NEG : Highest δ_{\max})
- After Exposure to e-Cloud : Drastic Decrease of δ_{\max} for All (Copper : Lowest δ_{\max})
- Results obtained at LER are almost consistent with those results obtained at Lab.
- Surface Analyses : e^- beam induced graphitization was found for copper surface exposed to e-Cloud as found in lab experiment. (In lab, the same graphite formation at TiN surface + graphite and carbide formation at NEG surface were found.)

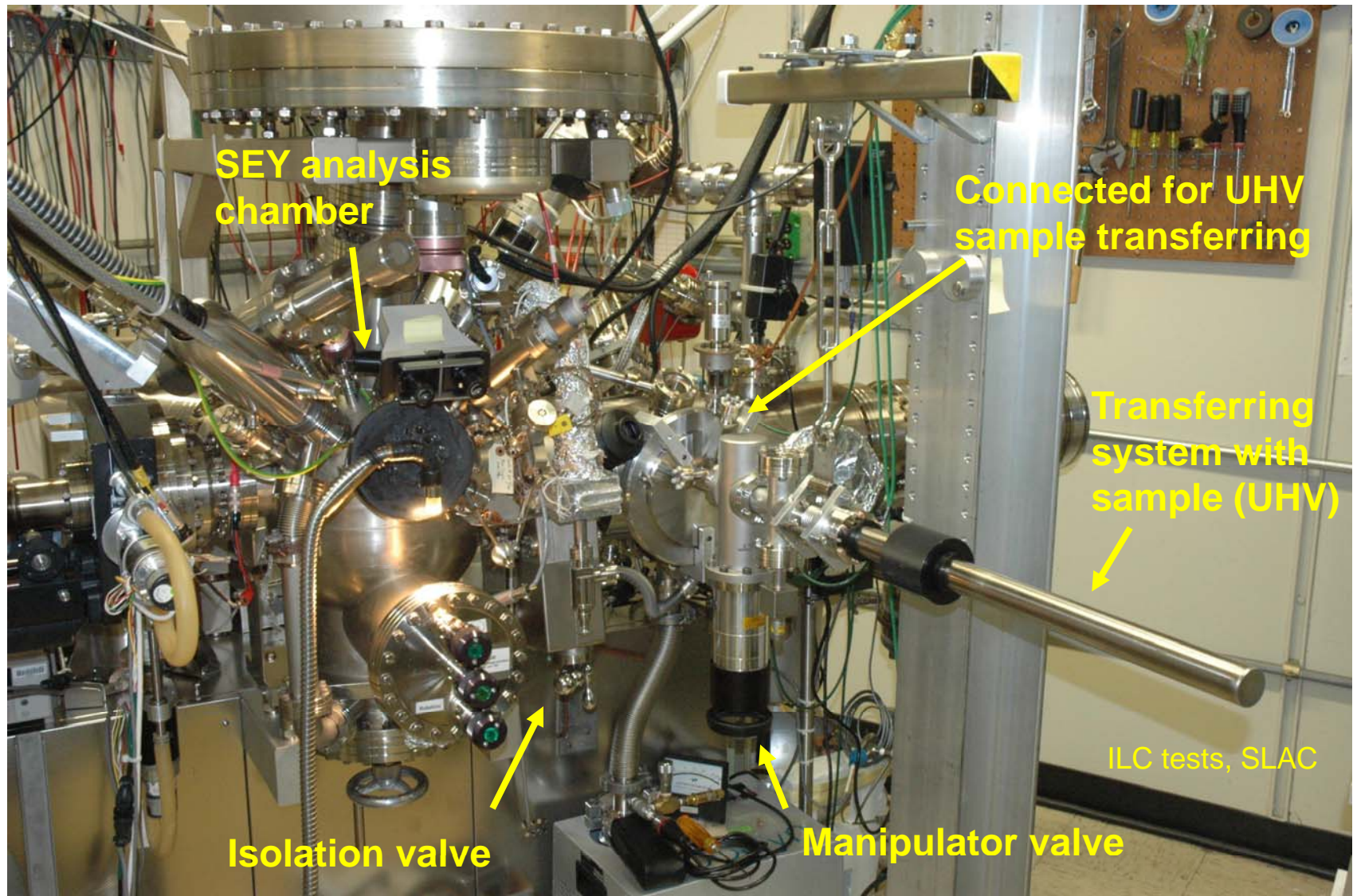


SEY test station in PEP-II LER (SLAC)





Transferring system connected to lab set-up (SLAC)



30 May – 2 June, 2007

ILC 2007 DESY, Germany

Conditioned sample in position for XPS surface analysis and SEY measurements in laboratory set-up (SLAC)

R. Kirby, ILC tests, SLAC

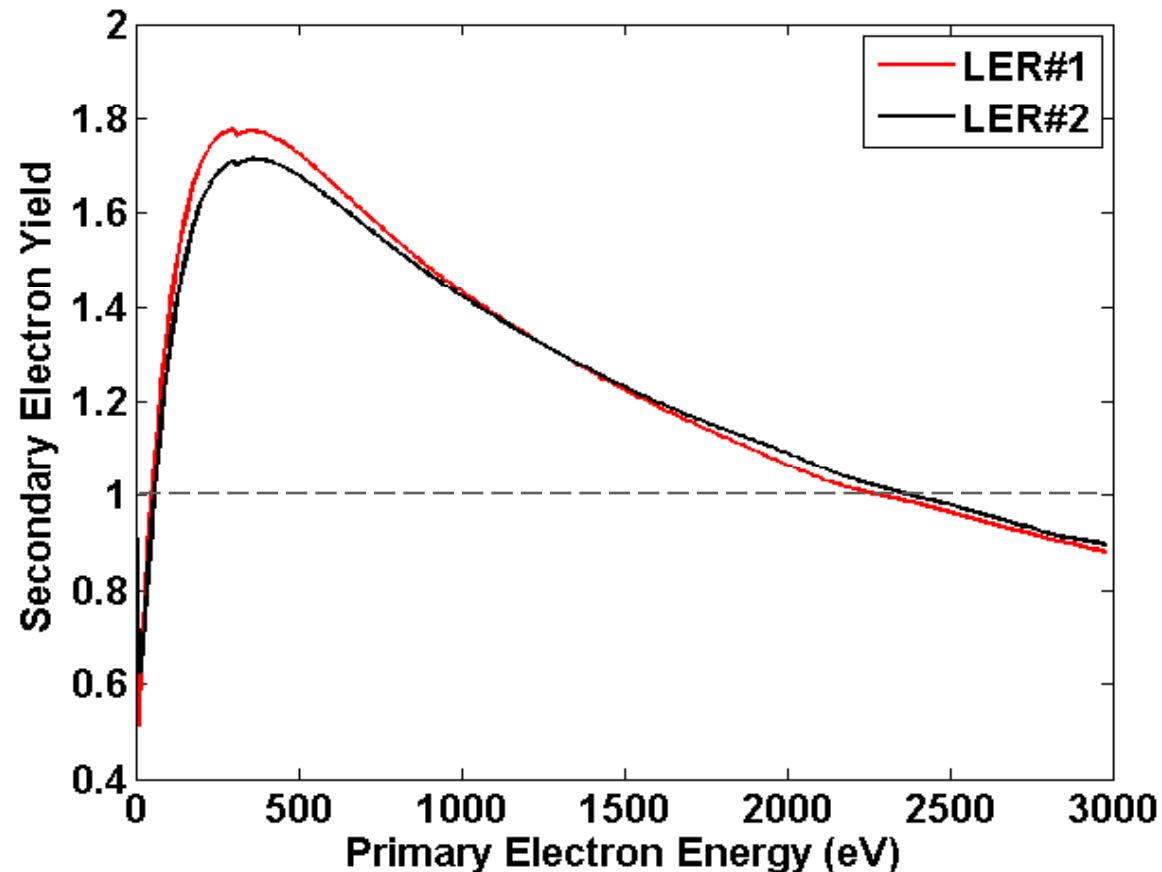
30 May – 2 June, 2007

ILC 2007 DESY, Germany

M. Pivi – SLAC



SEY test chamber samples: SEY before installation in PEP-II

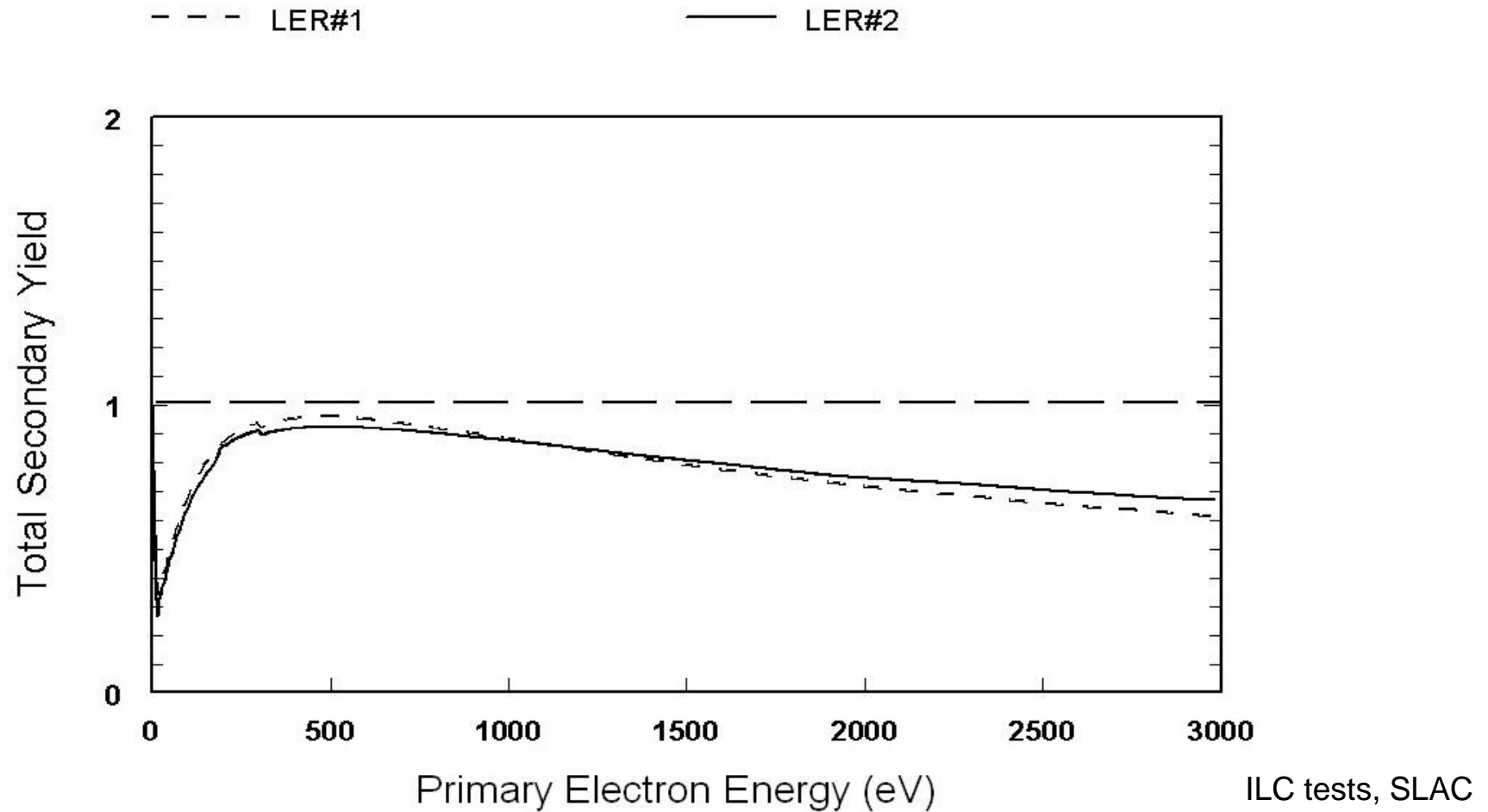


ILC tests, SLAC

LER #1 and #2 samples are then inserted in the PEP-II stainless steel chamber respectively in the plane of the synchrotron radiation fan (0° position) and out of this plane (45° position)



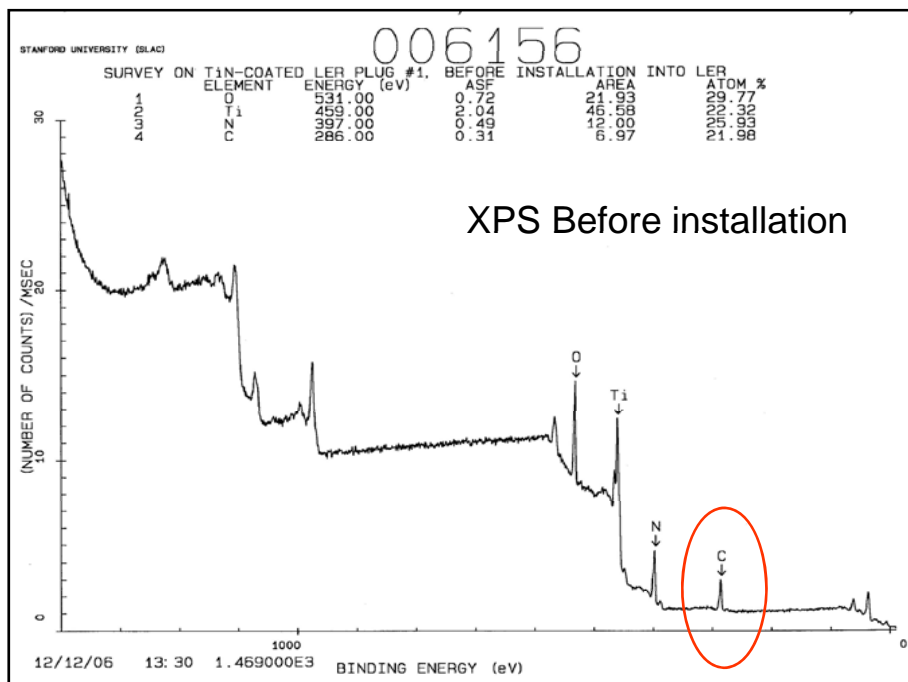
Secondary Yields after two months in PEP-II LER



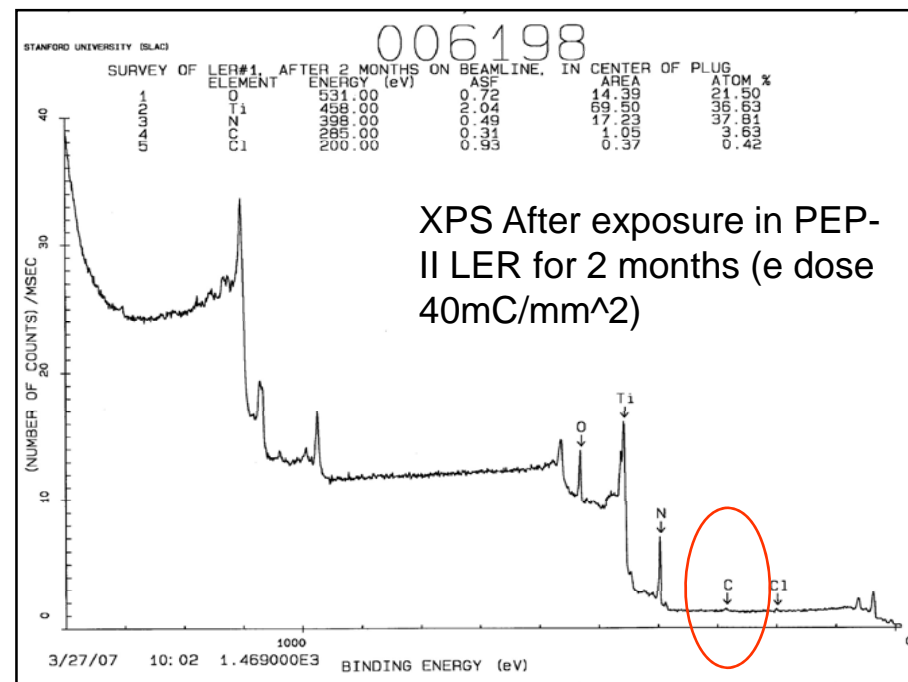


Surface analysis: Carbon content decrease

X-ray photon spectroscopy.



LER#1



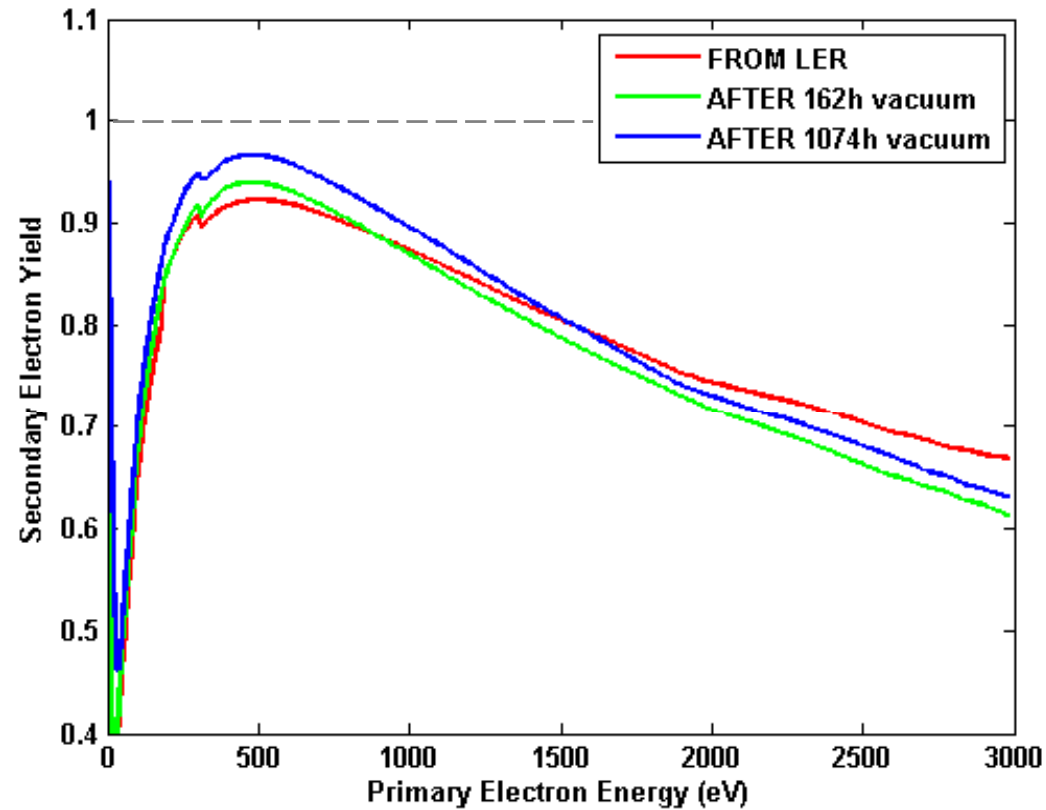
ILC tests, SLAC

Carbon content is strongly reduced after exposition to PEP-II LER → synchrotron radiation + electron + ion conditioning. This is a different result if compared to electron (only) conditioning in laboratory set-up where carbon crystals growth has been observed by many laboratories.



SEY recontamination

SEY recontamination

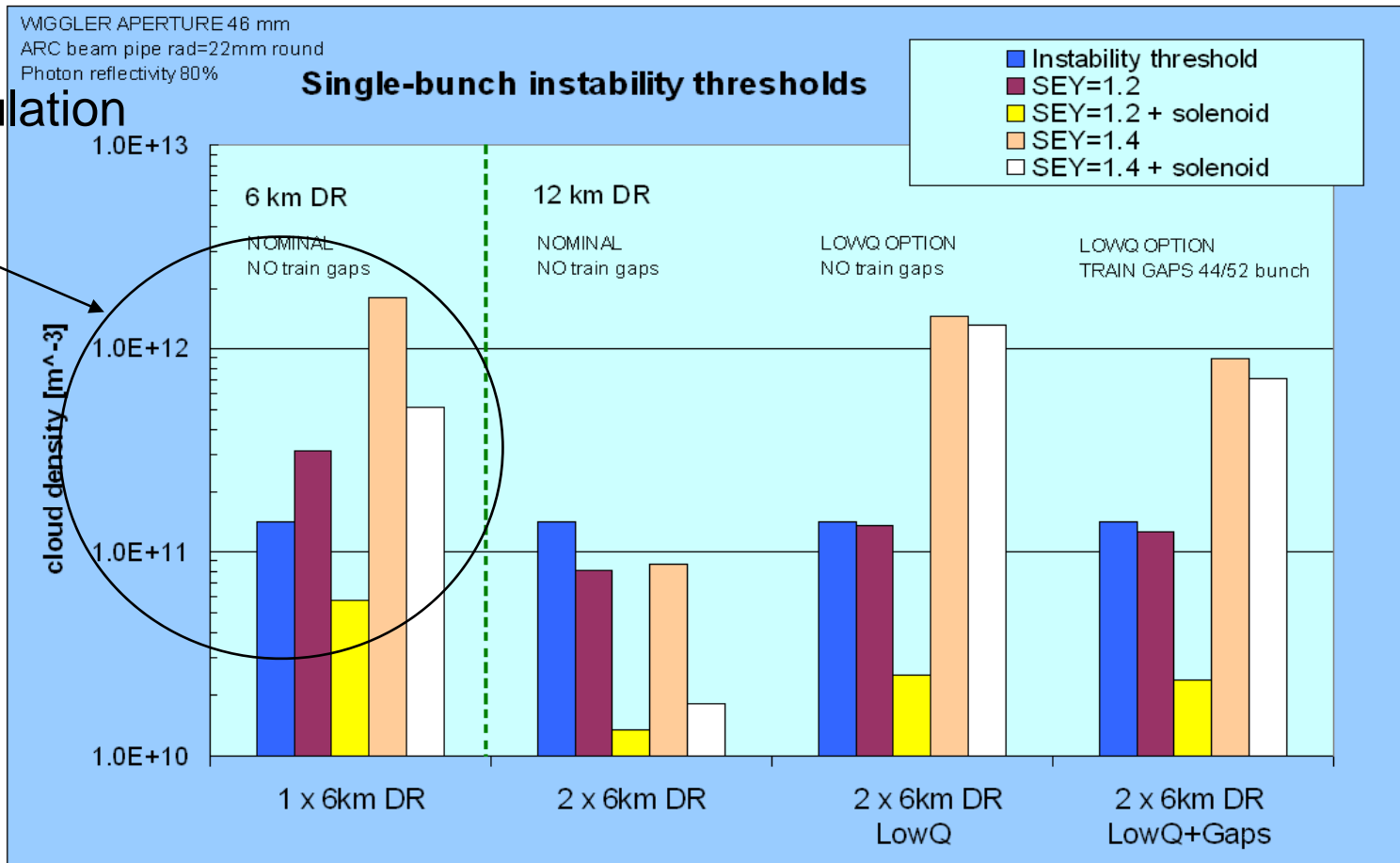


SEY increases slightly if sample is left under vacuum following conditioning in PEP-II LER. Measured SEY after 162h and 1074 hours sitting in SLAC laboratory setup. Average pressure 1.0×10^{-9} torr, 10:1 H₂:CO.



Simulations

2006 simulation campaign



Ring average cloud density. Cloud density (e/m^{-3}) near beam ($r=1mm$) and before bunch passage. Solenoids decrease the cloud density in DRIFT regions, where they are only effective. Compare options 6/12km. All cases wiggler aperture 46mm.

Simulation campaign: 1) need detailed build-up simulations with SEY~1, and 2) more accurate photoelectric yield input parameters from experiment (see Cimino & Malyshev)

For ILC-DR one need to circulate Samples, to put resources (also for SR) and manpower to study:

- 1) 0-1keV Electron induced el. emission yield (SEY)
- 2) and its angular dependence
- 3) Photoemission Yield and Photoemission induced el. energy distribution (also Angle resolved!)
- 4) Photon - reflectivity
- 5) Electron induced energy distribution curves
- 6) Heat load
- 7) Photon and electron induced desorption
- 8) Surface properties changes during conditioning.
- 9) Chemical modifications vs. conditioning.
- 10) Relation between photon and electron conditioning.

... and this on all vacuum high tech. materials...

Input parameters in e-cloud models

- Photon distribution, diffused and forward scattered reflection
- Photon induced electron production
 - *there are no data directly related to the ILC DR (i.e. measured at 3 and 30 keV),*
 - *there are no data for NEG coated and TiN coated surfaces,*
 - *the access to SR beamline and volunteers to perform a study are required*
- Secondary electron production
 - The uncertainties here are almost the same as with photons:
 - Secondary electron yields dependence on the potential gradient near the surface
 - Secondary electron yields dependence on the magnetic field near the surface
 - Choice of material: NEG coated surfaces was not well studied yet, it is still not clear what is better (i.e. lower SEY) NEG TiZrV coating or TiN coating.

Red flags





Very High Priority R&D Objectives

- WP 2.1.1 {
 - 2.1.1.1 Lattice design for baseline positron ring
 - 2.1.1.2 Lattice design for baseline electron ring
- WP 2.1.4 2.1.4.3 Demonstrate < 2 pm vertical emittance
- WP 2.2.1 2.2.1.2 Characterize single bunch impedance-driven instabilities
- WP 2.2.3 {
 - 2.2.3.1 Characterize electron cloud build-up
 - 2.2.3.2 Develop electron cloud suppression techniques
 - 2.2.3.3 Develop modelling tools for electron cloud instabilities
 - 2.2.3.4 Determine electron cloud instability thresholds
- WP 2.2.4 {
 - 2.2.4.1 Characterize ion effects
 - 2.2.4.2 Specify techniques for suppressing ion effects
- WP 3.5.1 3.5.1.1 Develop a fast high-power pulser

The 11 objectives identified as "Very High" priority divide into 6 Work Packages, with each Work Package encompassing those objectives grouped at the third level of the WBS.



The Process

- Presently, the R&D plan is inclusive.
 - **For example, WP 2.2.3 (Electron Cloud) lists 45 potential investigators. Not all these investigators are likely to get funding for their activities.**
- Coordination and elimination of duplication should happen by communication and agreement.
 - **The specific tasks identified in the R&D plan should form a focus for the discussions that need to take place.**
- The Work Package Coordinator should play a role in ensuring that the necessary discussion happen, and happen constructively.
 - **Difficult decisions may be needed, but holding collaborations together is essential. We need to work positively with each other to achieve the R&D goals.**



Working Package (WP) 2.2.3 (e-cloud)

Potential Investigators

CERN

Warner Bruns
Fritz Caspers
Daniel Schulte
Frank Zimmermann
Cockcroft Institute
Oleg Malyshev
Ron Reid
Andy Wolski

Cornell

Jim Crittenden
Mark Palmer

DESY

Rainer Wanzenberg

FNAL

Panagiotis Spentzouris

INFN-LNF

David Alesini
Roberto Cimino
Alberto Clozza
Pantaleo Raimondi

KEK

John Flanagan
Hitoshi Fukuma
Ken-ichi Kanazawa
Kazuhito Ohmi
Kyo Shibata
Yusuke Suetsugu
Shigiri Kato

LANL

Bob Macek

LBL

John Byrd
Christine Celata
Stefano de Santis
Art Molvik
Gregg Penn

Marco Venturini

Miguel Furman

Kiran Sonnad

Mike Zisman

PAL

Eun-San Kim

Rostock University

Aleksander Markovik

Gisela Poplau

SLAC

Karl Bane

Bob Kirby

Alexander Krasnykh

Mauro Pivi

Tor Raubenheimer

Tom Markiewicz

John Seeman

Lanfa Wang



FY07-FY10, WP 2.2.3 (e-cloud)

S3 WBS	Objective	Priority
2.2.3.1	Characterize electron-cloud build-up	Very High
2.2.3.2	Develop electron-cloud suppression techniques	Very High
2.2.3.3	Develop modelling tools for electron-cloud instabilities	Very High
2.2.3.4	Determine electron-cloud instability thresholds	Very High

Staff effort (FTE)

S3 WBS	2007	2008	2009	2010
2.2.3.1	2.0	2.0		
2.2.3.2	3.0	3.0		
2.2.3.3	2.0	2.0		
2.2.3.4	1.5	1.5		

Travel, at US\$10k/FTE (US\$k)

S3 WBS	2007	2008	2009	2010
2.2.3.1	20	20		
2.2.3.2	30	30		
2.2.3.3	20	20		
2.2.3.4	15	15		

M&S (US\$k)

S3 WBS	2007	2008	2009	2010
2.2.3.1	0	0		
2.2.3.2	730	920		
2.2.3.3	0	0		
2.2.3.4	0	0		



WP 2.2.3 (e-cloud)

Objective 2.2.3.2: Develop electron-cloud suppression techniques

Very High Priority

Actions to suppress the electron cloud are required for the positron damping ring. The B-factories have implemented external solenoid fields to mitigate electron cloud in field-free regions, which constitute a large fraction of the PEP-II and KEKB positron rings [1, 2]. Notably, the electron cloud effect in KEKB remains a major obstacle to shorter bunch spacing and higher luminosity, even with solenoid windings [3]. In the ILC damping rings, beam instability can occur even if electron cloud is present only in the wigglers and dipoles, where external solenoid fields are not effective in preventing build-up of the cloud. Therefore, R&D is required into techniques that can be applied in regions of strong magnetic fields to prevent build-up of electron cloud.

Preliminary studies (mostly based on simulations, but supported by some laboratory measurements) suggest that techniques such as grooves in the wall of the vacuum chamber, or the use of clearing electrodes, could be effective at suppressing the electron cloud in regions of strong wiggler or dipole fields [4, 5]. On the basis of these studies, a single 6 km positron damping ring has now been adopted in the baseline configuration for the ILC. However, a demonstration of the effectiveness of possible suppression techniques is required to validate this choice; an (expensive) alternative is to use two positron damping rings to reduce the beam current. Any technique used to mitigate build-up of electron cloud must be consistent with stringent requirements for large aperture and low impedance in the damping rings.



WP 2.2.3 (e-cloud)

Achieving the objective of developing suppression techniques for the electron cloud will involve the following tasks:

1. **Study coating techniques, test the conditioning of coated surfaces and characterize their performance *in situ* in CEsrTA, PEP-II and KEKB.**
2. **Test clearing electrode concepts by installing chambers with clearing electrodes in existing machines and in magnetic field regions in CEsrTA, PEP-II, KEKB, LHC and HCX (LBNL). Characterize the impedance seen by the beam, the generation of higher order modes (HOMs), and the power deposited in the electrodes.**
3. **Test “groove” concepts by installing chambers with grooved or finned surfaces in existing machines, including bend and wiggler sections in CEsrTA and PEP-II. Characterize the impedance and HOMs.**



Example: WP 2.2.3 (e-cloud)

Potential Investigators on these tasks will be:

David Alesini
Fritz Caspers
Alexander Krasnykh
Bob Macek
Art Molvik
Cho Ng
Mark Palmer
Mauro Pivi
Yusuke Suetsugu
Lanfa Wang

A total effort of 3 FTE per year for two years will be required. Work includes mainly experimental studies with support of simulations.

An M&S budget of \$730k in 2007, and \$920k in 2008 is required.

Work on these tasks should start now. The goal is to complete all three tasks by the end of 2008 as input for the Engineering Design Report (EDR).



Example: WP 2.2.3 (e-cloud)

The required input includes:

- **Experimental data from machines including CesrTA, PEP-II, KEKB, LHC. Data should include detailed comparison of electron cloud density with beam in sections with mitigation techniques implemented (coated surfaces, clearing electrodes, grooved and/or slots etc.) compared with the electron cloud density in sections without mitigating techniques.**

The deliverables will include:

- **Technical specifications for techniques to be used to suppress build-up of electron cloud in the positron damping ring, consistent with aperture and impedance requirements.**
- **Guidance for the design of the vacuum chamber material and geometry (Objective 3.1.1.1), and for the technical designs for principal vacuum chamber components (Objective 3.1.1.2).**



WP 2.2.3 (e-cloud)

If the electron cloud density is not reduced below the threshold level for beam instabilities, then the positron damping ring will be unable to provide a beam meeting the specifications for beam quality, stability and intensity; this will have a potentially significant impact on the luminosity of the ILC.



Test Facilities: CEsrTA

- CEsr-c is a wiggler-dominated electron-positron collider.
- The proposed development of CESR into CEsrTA would allow a unique opportunity for electron cloud studies at a dedicated test facility, operating in a parameter regime directly relevant for the ILC damping rings.
 - **Requires relocation of wigglers to allow tuning for low natural emittance; upgrade of instrumentation for tuning for low vertical emittance; installation of instrumented test chambers in wigglers.**
- A range of other important studies will also be possible (e.g. low-emittance tuning, development of instrumentation for fast beam-size measurements of ultra-low emittance beams).
- Presently, there are serious funding uncertainties...



Test Facilities: KEKB

- Electron cloud effects have already been studied extensively at KEKB, but not in the same low-emittance parameter regime in which the damping rings will operate.
- Solenoid fields in the straight sections have been effective at suppressing electron cloud effects in the B factories; but recent interest in a SuperB factory motivates further research.
- Tests of grooved and coated chamber surfaces for suppressing e-cloud are already underway at PEP-II, but studies of suppression techniques in wigglers with low emittance beams will require other facilities. Clearing electrode tests are planned at KEKB.
- KEKB LER could be tuned for ~ 1 nm emittance by reducing the energy from 3.5 GeV to 2.3 GeV.
- For the next two years, the priority for KEKB will be to continue to provide luminosity for BELLE. However, there may be some limited opportunity for electron cloud studies for ILC in that time, if the operational (power) costs of the machine are provided.



Test Facilities: HERA-DR

- More than just a test facility: the proposed development of HERA into HERA-DR would actually provide one of the damping rings for the ILC.
- Staged program over several years:
 - 2007 – 2009: installation of new injection line, replacement of NC RF, re-commissioning as test facility;**
 - 2009 – X: test facility programme, including demonstration of operational performance in key areas;**
 - X – (X+7): ILC project start, procurement and installation of new DR components, further DR tests, de-installation and transport to ILC site, re-installation and commissioning.**
- Initial studies show this plan to be an interesting possibility.



Other Test Facilities

- DAΦNE
 - **electron cloud**
 - **fast injection/extraction kickers**
- FNAL-A0
 - **fast injection/extraction kickers**
- Third-generation synchrotron light sources, e.g. LBNL-ALS, ANL-APS
 - **low emittance tuning**
 - **fast ion effects**
- LHC
 - **electron cloud**



Test Facility Funding

- The S3 Task Force has collected information on CEsrTA and on the use of KEKB for ecloud studies. Briefly, we find that:
 - CEsrTA is a realistic project only if funding at the level of \$0.5M is found to support the program in FY08, \$7M in FY09 and \$12M in FY10 and FY11.
 - The program would directly address (in time for the EDR) several critical R&D areas for the ILC damping rings, including electron cloud, low-emittance tuning, ion effects, and beam instrumentation.
 - Without the understanding that would be gained by tests at CEsrTA (or equivalent tests elsewhere) and demonstration of effective suppression techniques, electron cloud must be considered a serious risk to damping rings performance given the present baseline configuration.
 - KEKB could offer some opportunities for electron cloud tests as an alternative to CEsrTA, but the program has not been developed to the same level of detail, some additional funding would be needed, and the studies would have to defer to BELLE operation. \$1.5-2M mainly electricity costs per month from end of FY08.
 - Without tests at CEsrTA, serious consideration would have to be given to the acceptability of the risk in the present baseline configuration.



Milestones to EDR

The goal is to complete the following tasks by early 2009 as input for the Engineering Design Report (EDR)

- o Test coating techniques and determine conditioning effectiveness in PEP-II, KEKB, SPS, DAΦNE, CESR
- o Characterize the conditioning effect of thin-film coatings, stainless steel, Al, Cu installed in accelerator beam line and exposed either to high or low synchrotron radiation.
- o Further characterize TiZrV NEG vs TiN coatings to select DR candidate.
- o Characterize the surface recontamination rate.
- o Characterize the durability of thin-film coatings after long term exposure in an operating accelerator beam line. Study PEP-II TiN-chambers after 10 years operation.
- o Characterize the electron cloud build-up by simulations and measurements in existing accelerators, KEKB, CESR, HCX (LBNL)
- o Characterize the electron cloud in wigglers and quadrupoles



Milestones to EDR

The goal is to complete the following tasks by early 2009 as input for the Engineering Design Report (EDR)

- o Test coating techniques and determine conditioning effectiveness in PEP-II, KEKB, LHC, DAΦNE, CESR
- o Characterize the conditioning effect of thin-film coatings, stainless steel, Al, Cu installed in accelerator beam line and exposed either to high or low synchrotron radiation. Evaluate the efficiency of conditioning on NEG coating with respect to TiN.
- o Characterize the surface recontamination rate.
- o Characterize the durability of thin-film coatings after long term exposure in an operating accelerator beam line. Study PEP-II TiN-chambers after 10 years operation.
- o Characterize the electron cloud build-up by simulations and measurements in existing accelerators, KEKB, CESR, HCX (LBNL)
- o Characterize the electron cloud in wigglers and quadrupoles



Milestones to EDR

- o Characterize the electron cloud instability by measurements in existing facilities possibly including CEsrTA or KEKB operating with ultra-low emittances.
- o Characterize the electron cloud instability in ILC DR by simulations
- o Evaluate the need for mitigation techniques such as antechambers, clearing electrodes, grooves and slots in addition to coatings for the ILC DR baseline configuration and for alternate configurations.

Additional mitigation techniques:

- o Test clearing electrodes in magnetic field regions including wigglers at KEKB and CESR and dipoles at PEP-II
- o Test triangular groove or slots in magnetic field regions including wigglers and dipoles
- o Characterize the impedance and HOMs of mitigation techniques

Recommendation of mitigation techniques to prevent the electron cloud in the ILC damping ring as input for the Engineering Design Report (EDR) by 2009



Thanks!

To contributors and collaborators:

R. Kirby, L. Wang, T. Raubenheimer, S. Kato,

D. Arnett, G. Collet, R. Kirby, N. Kurita, T. Markiewicz, B. Mckee, M. Morrison, G. Stupakov, N. Phinney, J. Seeman (SLAC), M. Palmer, D. Rubin, D. Rice, L. Schachter, J. Codner, E. Tanke, J. Crittenden (Cornell), J. Gao (HIPEP), A. Markovic et al. (Rostock Univ.), M. Zisman, S. De Santis, C. Celata, M. Furman, J.L. Vay, S. De Santis (LBNL), K. Oide, K. Ohmi, Y. Suetsugu (KEK), F. Willeke, R. Wanzenberg (DESY), J.M. Laurent, A. Rossi, E. Benedetto, F. Zimmermann, G. Rumolo, J.M. Jimenez, J-P. Delahaye (CERN), A. Wolski (Cockcroft Univ.), B. Macek (LANL), C. Vaccarezza, S. Guiducci, R. Cimino, P. Raimondi (Frascati), O. Malyshev et many other colleagues...