International Linear Collider at Stanford Linear Accelerator Center

R&D Plans for Electron Cloud in the Future Linear Colliders

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17 Aug, 2005

ILC R&D Ecloud program

- **R&D at KEK**. SEY laboratory measurements of electron conditioning and coatings studies. Installation of dedicated chamber with electron and energy spectrum detectors diagnostic in the KEKb e^+ ring (ATF?!).
  - XPS measurements confirm carbon layer increase during e- conditioning [H. Kato, KEKb Review, Feb 2005]

- **R&D at CERN**. A large number of electron detectors have been installed in quadrupoles, dipoles and field free regions of the <u>SPS ring</u>, the LHC pre-injector. Laboratory system to measuring SEY of technical materials.
  - Electron cloud current and energy spectrum measurements in SPS
  - Dendritic surface reduces SEY<1 increasing roughness [Hilleret et al. EPAC 2000]
  - Electron conditioning in the SPS … photon, ion conditioning, more.

R&D is focused on reducing the electron cloud in the LHC.

ILC R&D Ecloud program

- **R&D at LANL.** Measurement of the electron trapping mechanism in quadrupole field developing novel electron diagnostics. SLAC collab.
- **R&D at Frascati.** Possibility of important measurements to localize the suspected formation of electrons in Daϕne e^+ ring, in particular, in wiggler and dipole regions.
- **R&D at SNS/BNL.** Measurement of the thin film coatings, development of new techniques to reduce trailing edge multipacting
  - Correlation between SEY and Ar pressure during TiN thin film coatings [H. Hseuh ECLOUD04]
  - Special groove surface design to collect stripped 500keV e^- at injections

  R&D focused to reducing the SNS multipacting.
- **R&D at SLAC.** Laboratory measurements of SEY on bare metals, TiN and NEG coatings before and after processing. Development of grooved surface profile and novel TiCN alloy. Construction of vacuum chambers for installation in PEP-II to verify laboratory measurements.

The ECE program SLAC

Benchmark sim.

- e^- trapping mechanism in Quad
- e^- detector meas. in PEPII
- beam dynamics

Simulations

- e^- cloud generation & equilibrium
- single and multi-bunch instability
- self-consistent 3D simulations

Requirements

Lab measurements

- SEY meas. coatings + treatments
- Coating durability under vacuum
- Grooved surface design

Path

- TiN
- TiZrV
- radius
- groove
- other ?

Demonstration I

Grooved chamber: 6m long section to be installed in PEP-II

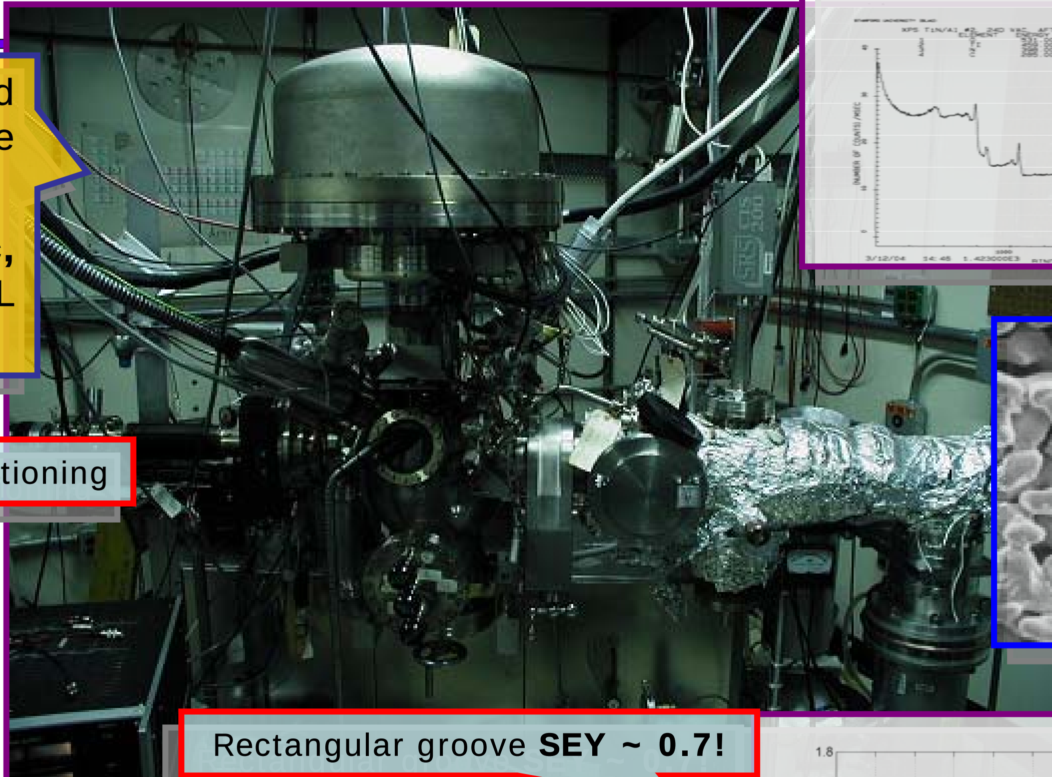
Demonstration II

Installation chamber with coatings in PEPII. Meas. SEY *ex situ*

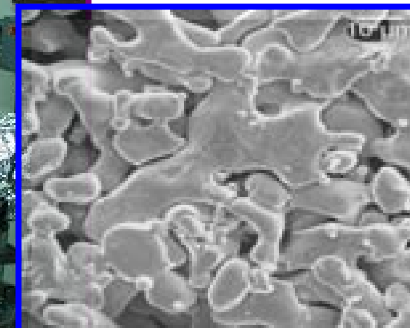
Secondary Electron Yield Measurements and Surface Analysis at SLAC and LBNL

Secondary Electron Yield (SEY) and Surface characterization

R.Kirby,F.Le Pimpec, M.P. SLAC, LBNL, BNL coatings.

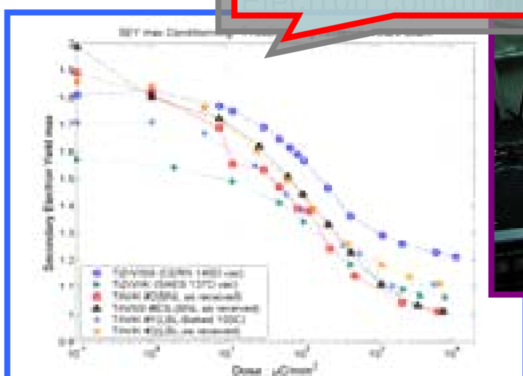


XPS TiN/Al

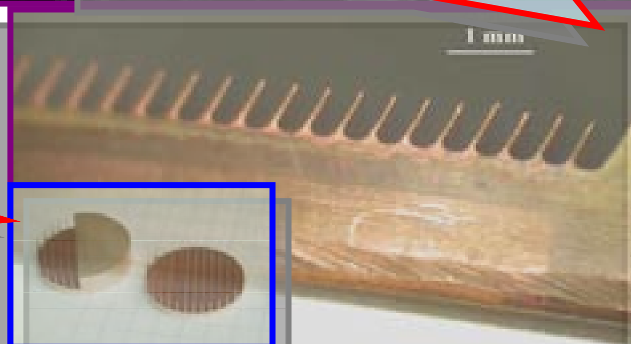


TiZrV NEG sample (LBNL)

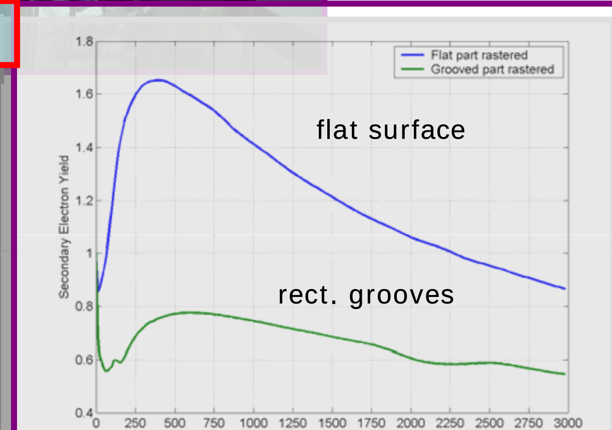
Electron conditioning



Rectangular groove **SEY ~ 0.7!**

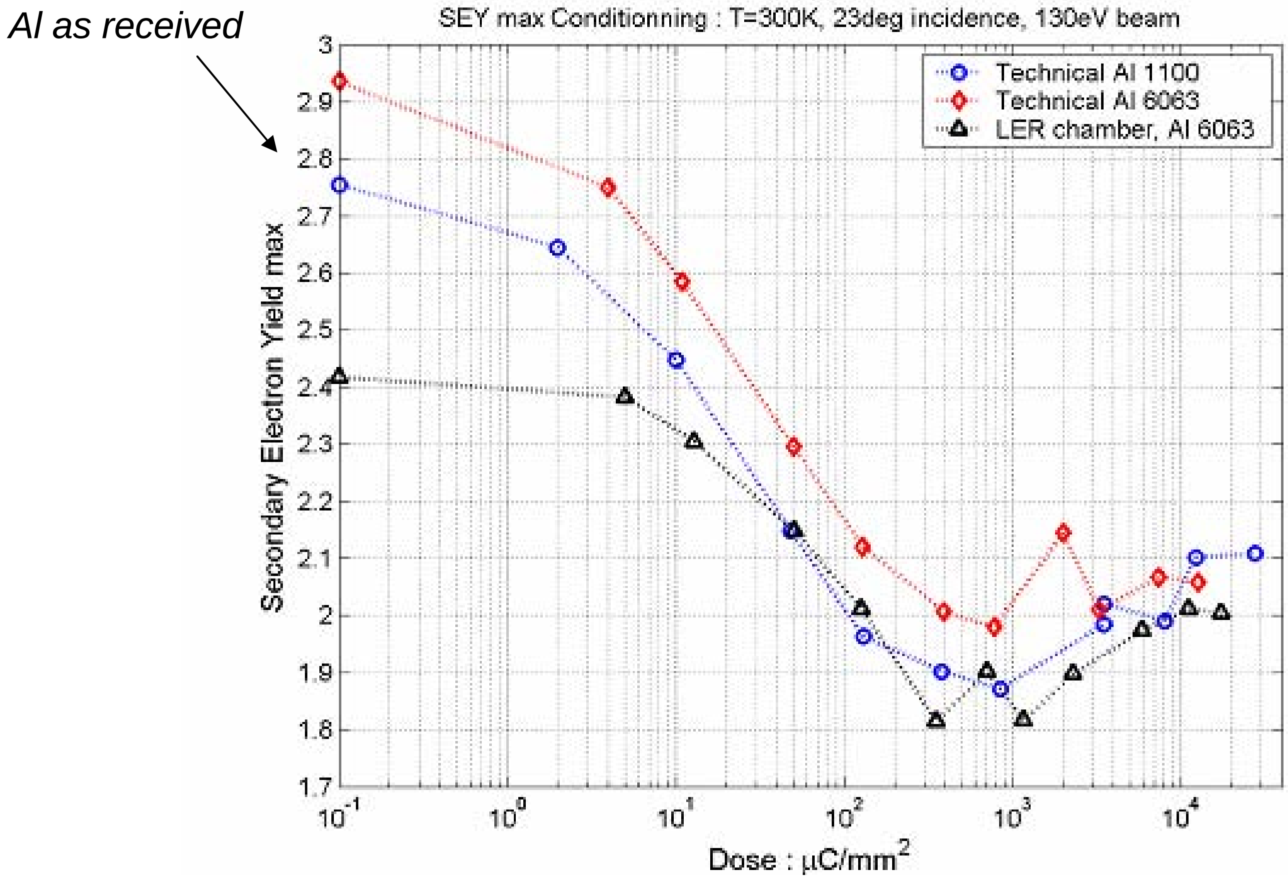


Rectangular and triangular grooves concept



Preparing to install test chambers with grooves in PEP-II, to be used next upgrade

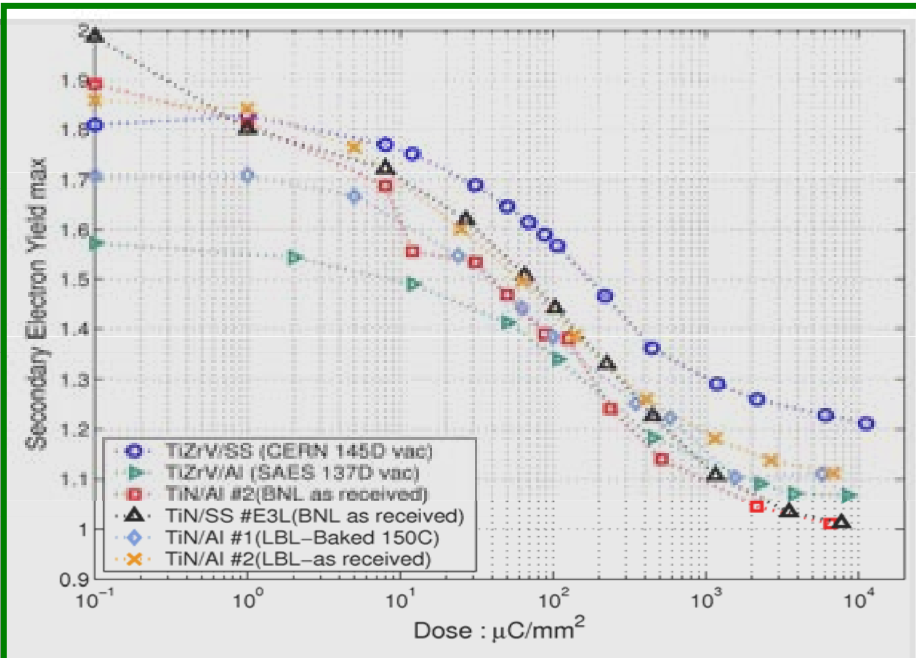
Why not an aluminum chamber?

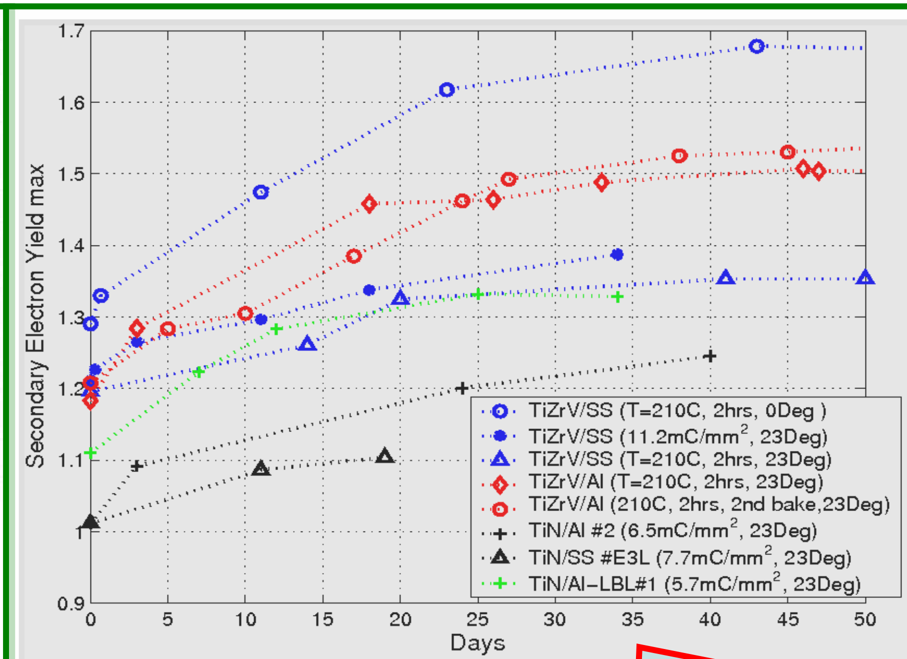


Electron conditioning (bombardment) effect on the SEY for aluminum. Laboratory measurements at SLAC and CERN agree very well. The electron conditioning is not completely effective to lowering the aluminum SEY as needed [SLAC-PUB-10894].

Most of the Daϕne ring is made of aluminum chambers.

Electron conditioning (scrubbing or processing) of thin films TiN, TiZrV. Laboratory measurements, SLAC.





Residual gas recontamination under vacuum

- Based on **laboratory measurements**, the required conditioning dose in ILC DR would be achievable in hours of beam operation during commissioning.
- Concerns about **effective e⁻ conditioning time** and **coatings durability** in an accelerator environment …

Electron conditioning: issues

- Electron conditioning "Asymptotic" behavior:

  - In an accelerator environment, the electron cloud itself is providing the conditioning of the vacuum chamber walls (in laboratory: conditioning is constant by fixed beam)

  - When the SEY decreases, the efficiency of the electron conditioning will decrease as well

- Recontamination:

  - Competing effect: residual gas recontamination → e^- cloud reappears

- PICTURE at the SEY threshold:

  Two effects competing against each other

e^- (asymptotic) Conditioning

↓

SEY threshold

↑

recontamination

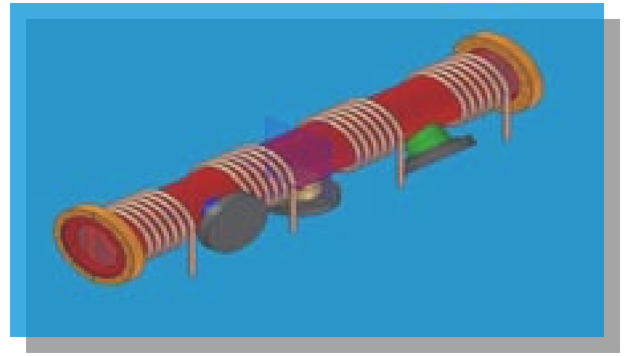
(1) solution (LHC): running at higher current for a period of time

(2) key: combined photon/ions conditioning may keep SEY below threshold (?!)

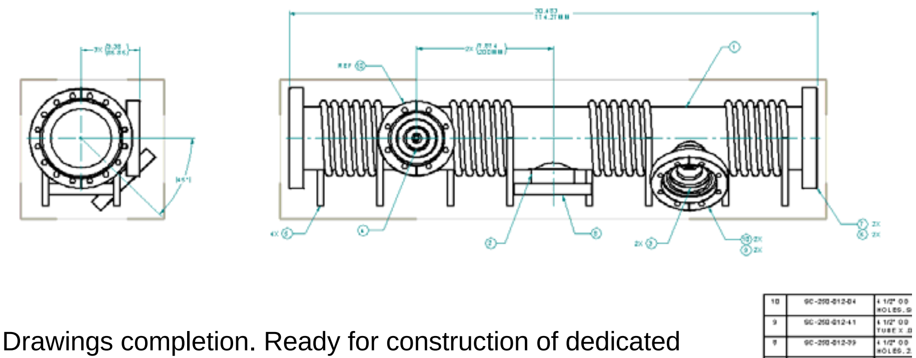
R&D plans at SLAC: installation of test chambers

Installation of dedicated chamber with coated samples in the PEP-II Low Energy Ring (LER) to:

- Test the efficiency of *in situ* of electron conditioning
- Test the combined photon conditioning effect
- Test thin film coatings durability in accelerator environment



Project 1



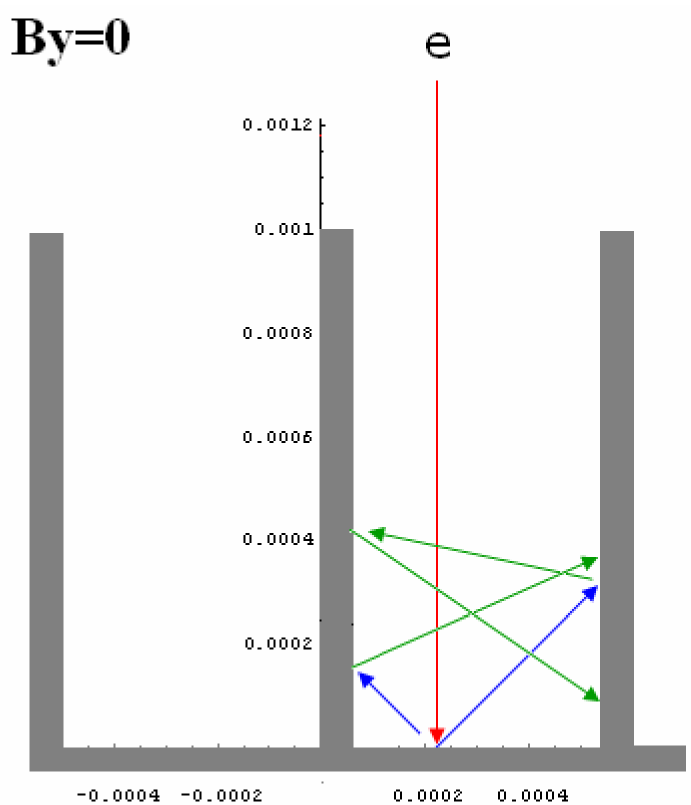
Drawings completion. Ready for construction of dedicated chamber with coated samples

(Left) intended installation PEP-II LER PR12 downstream VAC-PR12-3101
(Right) sample transferring system

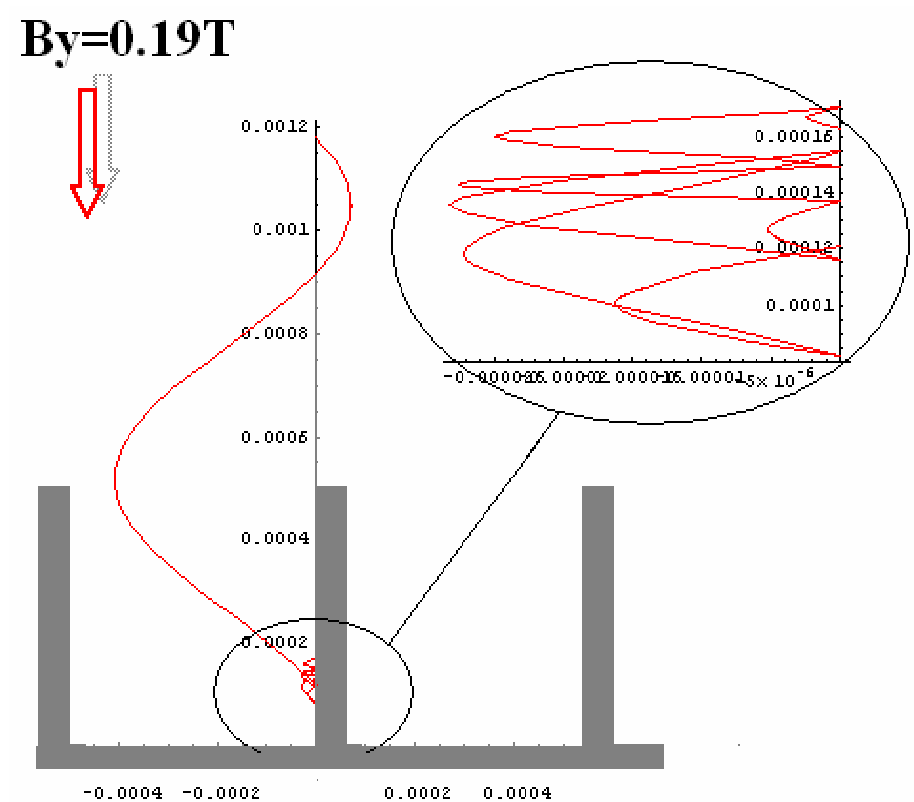
Rectangular Grooves to Reduce SEY

Rectangular grooves can reduce the SEY without generating geometric wakefields. The resistive wall impedance is roughly increased by the ratio to tip to floor.

Schematic of rectangular grooves
Without B field



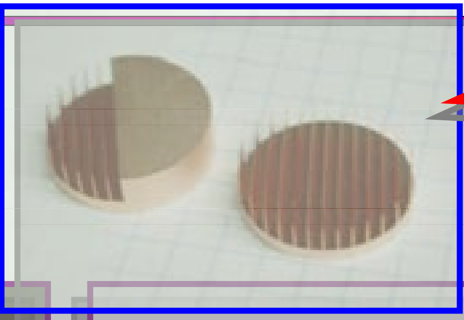
Schematic of rectangular grooves
With B field



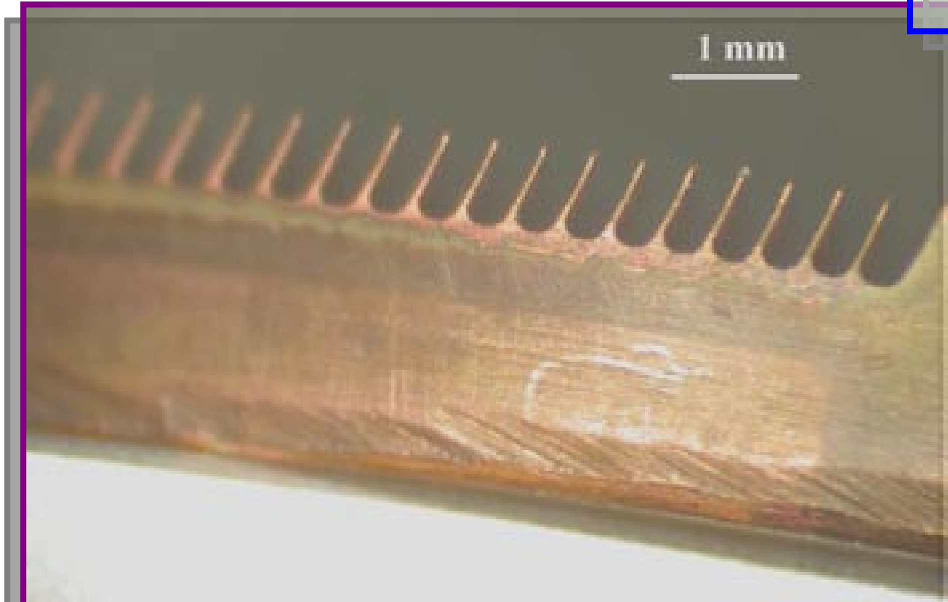
Rectangular (!) groove design: Laboratory tests, SLAC

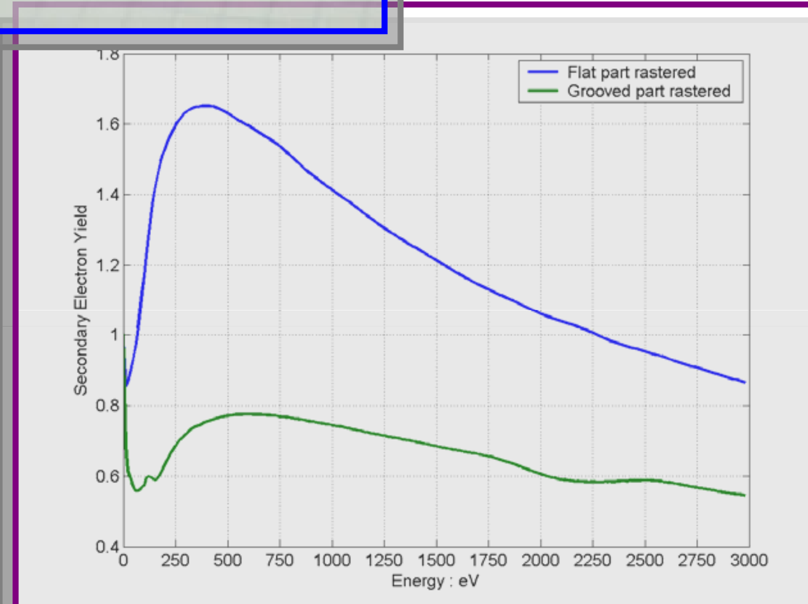
M.P. and G. Stupakov, SLAC

Artificially increasing surface roughness.



5mm depth (PEP-II)
Same SEY results



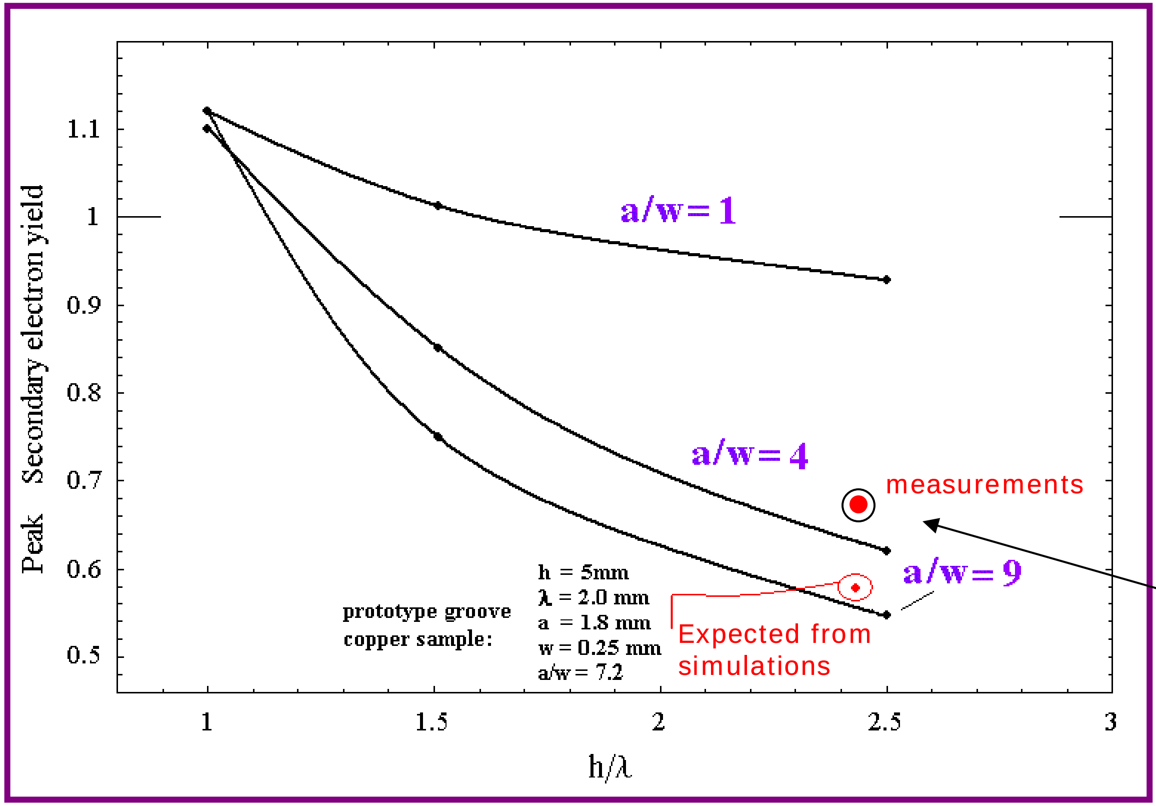


Special surface profile design, Cu OFHC.
EDM wire cutting. Groove: 0.8mm depth, 0.35mm step, 0.05mm thickness.

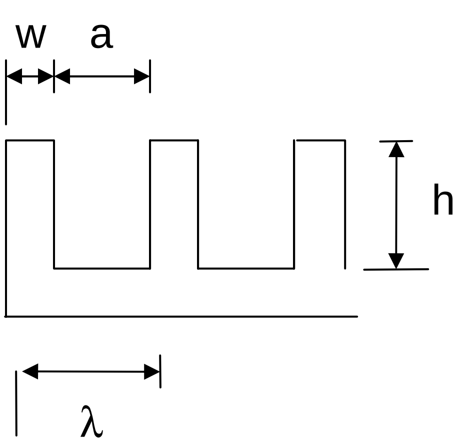
Measured SEY reduction < 0.8.
More reduction depending geometry.

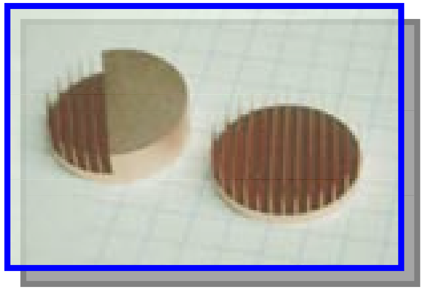
Triangular groove concept A. Krasnov LHC-Proj-Rep-617

Simulation rectangular grooves



grooves parameters





Prototype groove copper sample

Simulations rectangular groove profile.
Reference SEY on a flat copper surface is ~1.7.

Also shown measured compared with expected SEY.

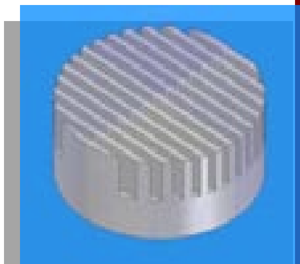
R&D plans at SLAC: rectangular groove chambers

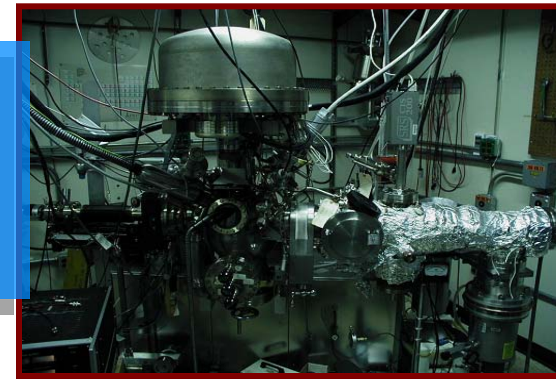
Installation of dedicated chambers 6 m long sections in the PEP-II LER to:

• Test the efficiency of the rectangular groove concept in field free region

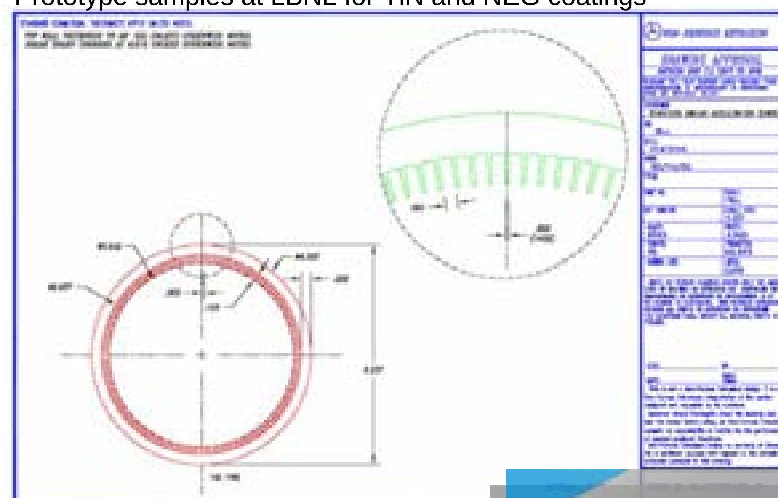
PEP-II and ILC collaboration project

Does groove concept work in dipole or wigglers where we needed most ?

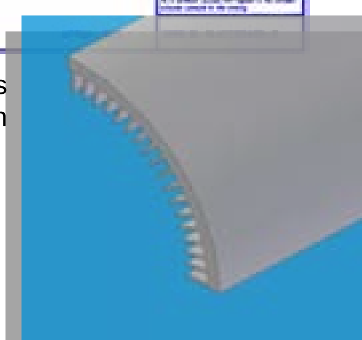




Prototype samples at LBNL for TiN and NEG coatings



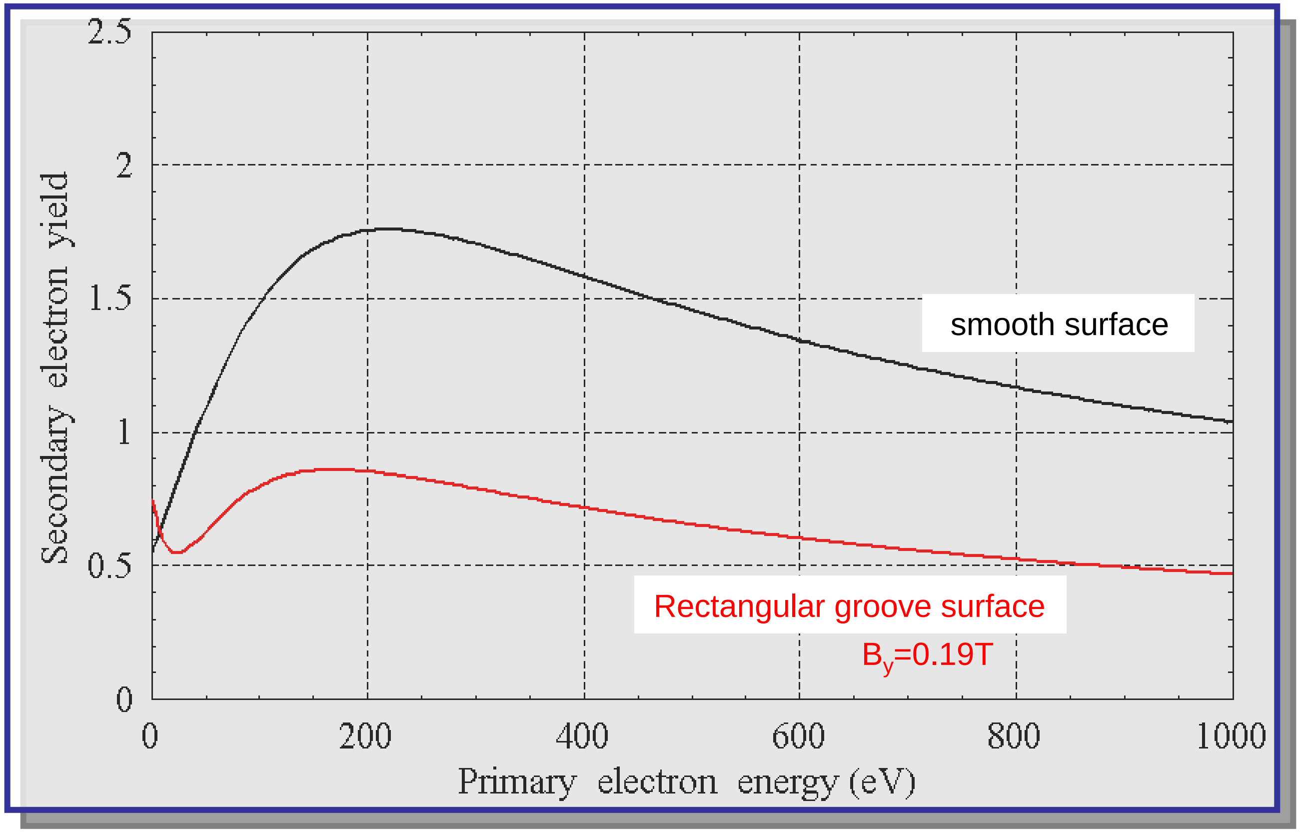
TiN/aluminum prototype chambers extruded grooved surface installation in PEP-II LER



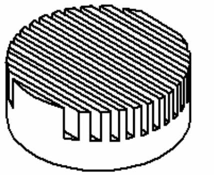
Project 2

Wakefields modeling with MAFIA

Rectangular grooves in dipole: SEY



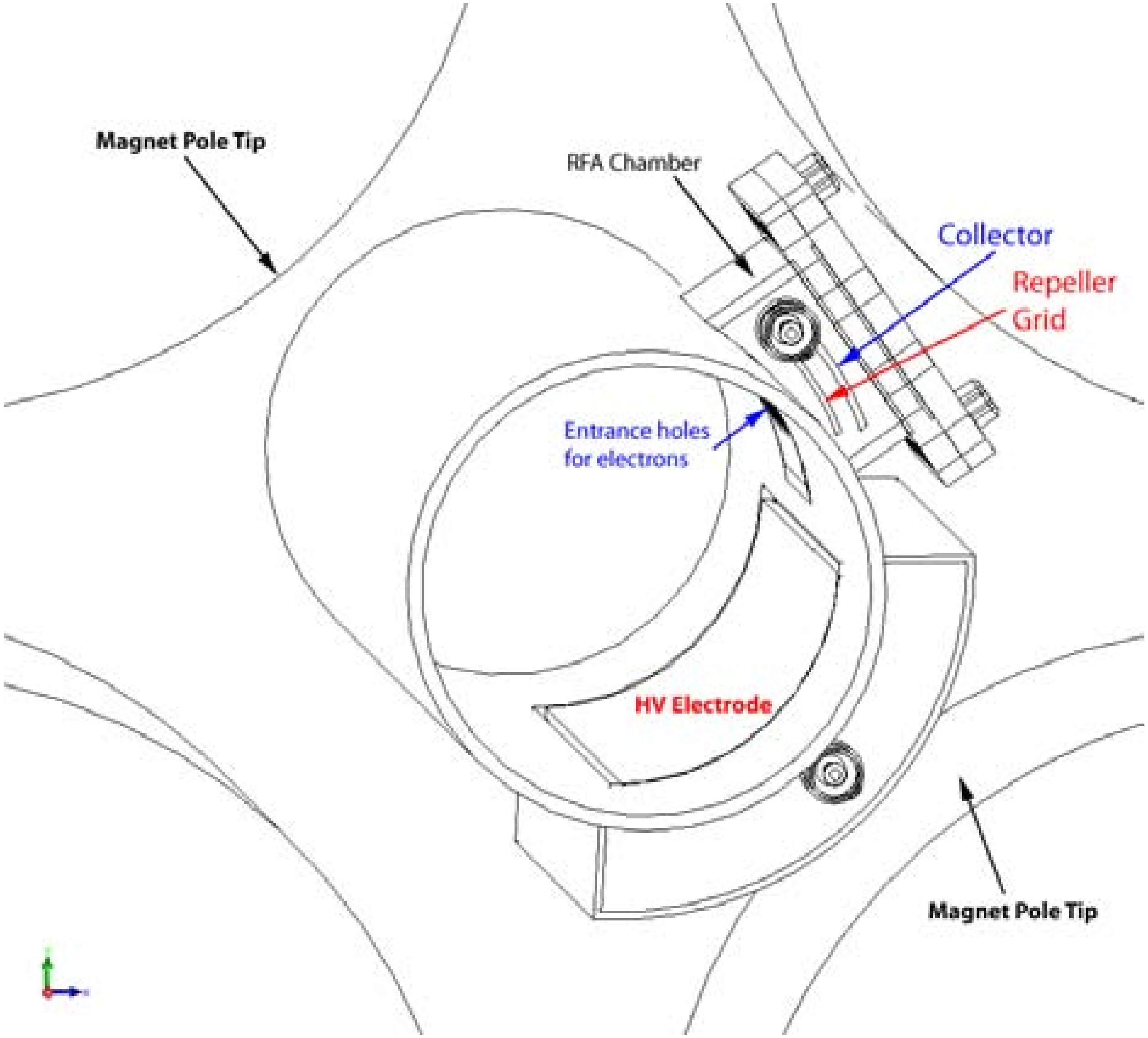
Sim. parameters
rectangular groove:
period = 0.25 mm
depth = 0.25 mm
width = 0.025 mm



Simulated secondary yield of a rectangular grooved surface in a dipole field compared with a smooth surface (field free reference).

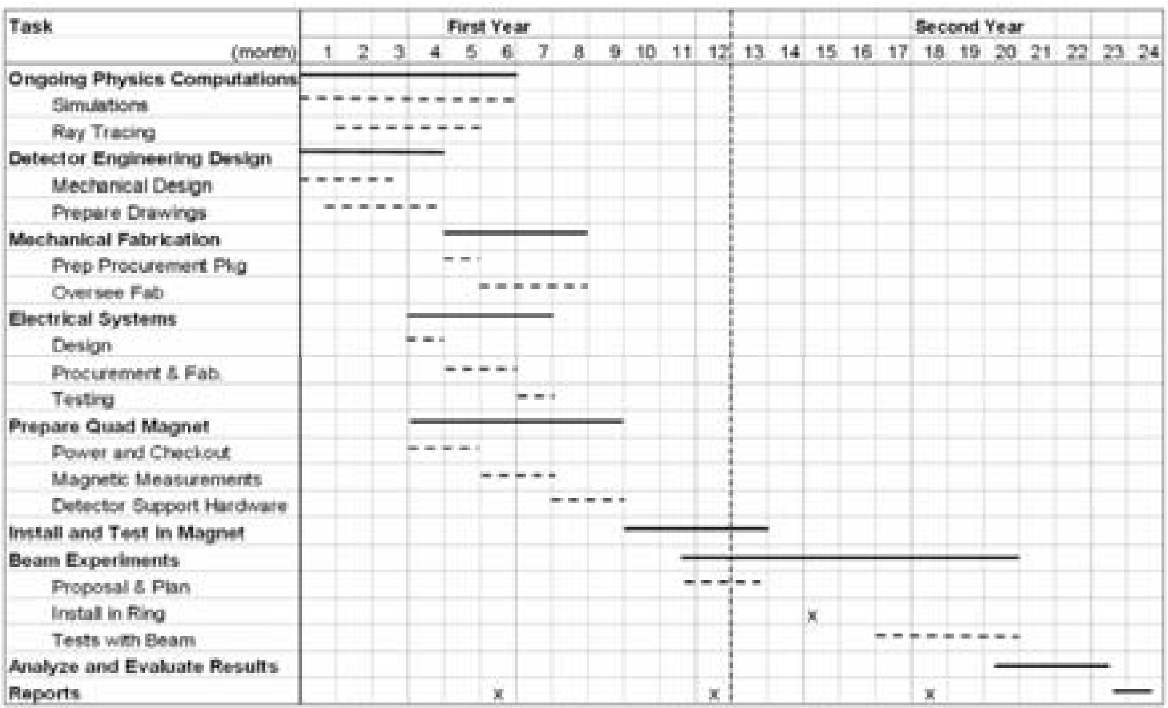
- Possible solution: need laboratory and accelerator tests in dipole field

Electrons are trapped in quadrupole field: Layout of proposed electron sweeping detector for PSR (LANL) quads (courtesy R. Macek)



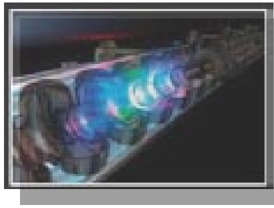
Status of e-sweeper for PSR quad (courtesy R. Macek)

- **Phase I SBIR complete (Physics Design)**
- **Phase II (2 year grant) has awarded to TechSource**
  - ◆ **CRADA being developed with LANSCE**
- **Plan:**
  - ◆ **Engineering design and fabrication and installation in a spare PSR quad over the next 12-13 months**
  - ◆ **Installation of quad with detector and run beam tests in the following 6-7 months**



Los Alamos Neutron Science Center

Future Directions



- Electron cloud R&D program to select possible remedy
  - o Laboratory measurements of the secondary electron yield of thin film coatings and testing the effectiveness of electron or ion conditioning
  - o Fabrication of specially grooved chamber surfaces
  - o Increase few mm chamber aperture beneficial
- Demonstration chambers will be installed in PEP-II
- Electron trapping in quadrupole field: PSR ring, LANL
- Active world wide collaboration on simulation code development and e-cloud suppression R&D

Web site:
http://www-project.slac.stanford.edu/ilc/testfac/ecloud/elec_cloud.html

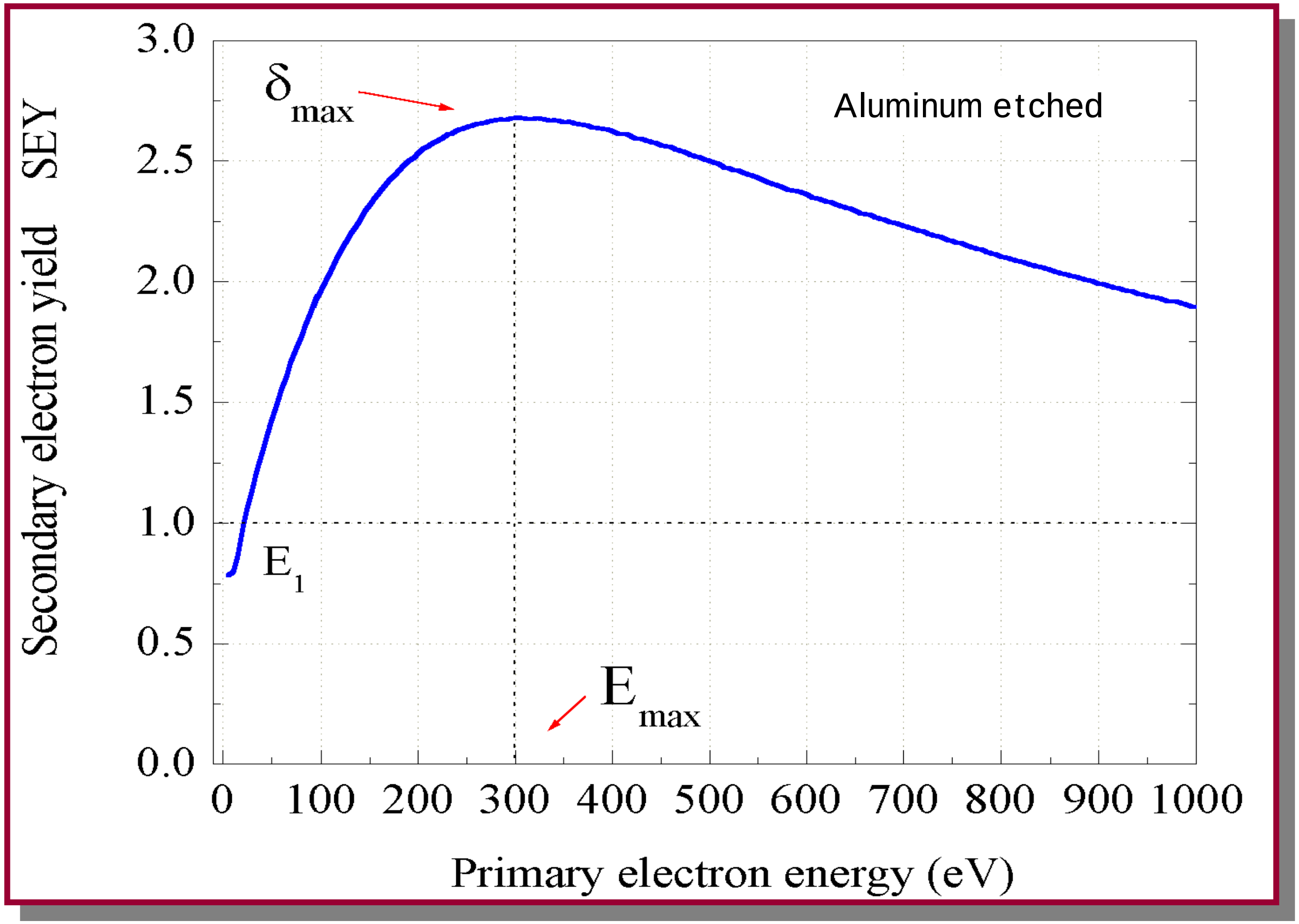
O. Grobner, M. Furman, J. Seeman, A. Novokhatski, N. Kurita, G. Stupakov, A. Chao, K. Harkay, B. McKee, G. Collet, K. Jobe, M. Ross, G. Rumolo, A. Seryi, A. Variola, P. Bambade, F. Zimmermann,

Y. Cai, R. Cimino, A. Feiz, S. Heifets, U. Irizo, K. Ohmi, G. Rumolo, G. Vorlaufer, C. Vaccarezza, A. Wolski, D. Lee, R. Macek,

J.M. Laurent, N. Hilleret, M. Jimenez, A. Rossi, V. Baglin, and many other colleagues ..

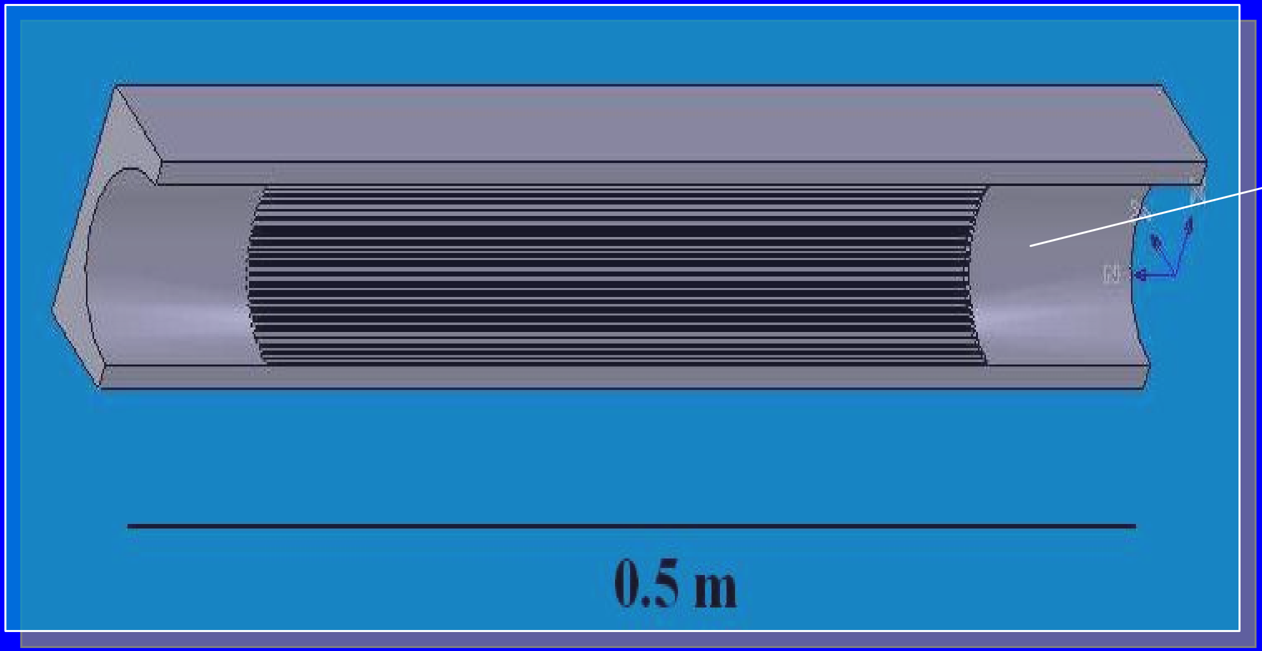
Thanks !

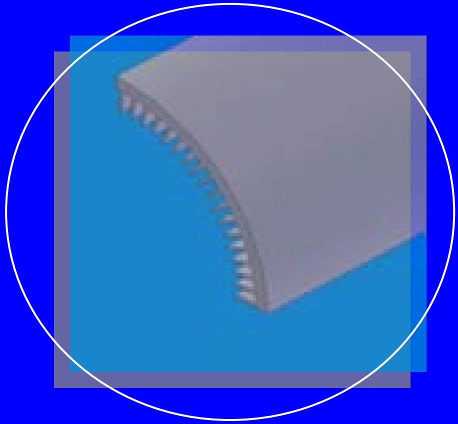
Secondary electron yield (SEY) for aluminum (SLAC)



Typical secondary yield for *as received* aluminum. Peak SEY~3, unacceptable for DR operations. Note: it should be $E_{avg} > E_1$ to have average SEY >1 thus electron multiplication.

Wake field simulations using groove profile chamber





MAFIA simulations (A. Novokhatski) indicate that wake fields are not excited during the beam passage. Very small losses come from the step transition from the smooth surface to the grooved surface and are estimated 1.5E-04 V/pC.

Power losses due to image charge contained (ex. PEP-II, dP/ds=1W/cm).

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$$\omega_{e,y} = \sqrt{\frac{\lambda_+ r_e c^2}{\sigma_y(\sigma_x+\sigma_y)}} \qquad (1) \quad \text{frequency}$$

$\hat{Z}$

$$Z_{th} = 4\pi \frac{\gamma \alpha_p c_\delta \nu_y a_e c_z}{N_0 r_e c^2} \qquad (2) \quad \text{Threshold impedance}$$

$$Z_\perp(\omega) = \frac{cR_s}{\omega} \frac{1}{1+iQ\left(\frac{\omega_e}{\omega} - \frac{\omega}{\omega_e}\right)} \qquad (3) \quad \text{Resontator impedance}$$

$$\hat{Z} \approx \frac{cR_s}{Q} \frac{Q}{2\omega_e} \qquad (4) \quad \text{Resontator Impedance peak value}$$

$$\frac{cR_s}{Q} = \frac{2\pi \rho_e a_e C}{\lambda_+ c} \qquad (5) \quad \text{Estimated amplitude}$$

Table 1: Parameters for possible ILC damping rings.

Circumference	17km	6km	3km
Energy [GeV]	5.0	5.0	5.0
Bunch charge [10^{10}]	2.0	2.0	2.0
Horizontal tune	76.31	56.58	51.28
Vertical tune	41.18	41.62	31.59
Beam sizes $\sigma_{x,y}$ [μm]	103, 7.3	98, 6.8	76, 5.5
Mom. comp. [10^{-4}]	1.22	1.42	2.68
Bunch length [mm]	6.0	6.0	6.0
Energy spread [10^{-3}]	1.3	1.5	1.2
Synchrotron Tune	0.07	0.034	0.026

Table 3: Analytical estimate of single-bunch vertical threshold strong dipole field case.

Circumference	17 km	6 km	3 km
ρ_e [10^{12} m^{-3}]	0.2	1.0	3.0
cR_s/Q Eq. (5) [10^8 m^{-2}]	0.34	0.66	1.2
Q (assumed value)	17	17	17
ω_e Eq. (1) [10^{11} s^{-1}]	7.2	7.7	9.7
Eq. (4) [10^{-4} m^{-2}s]	4.0	7.3	10
Z_{th} Eq. (2) [10^{-4} m^{-2}s]	6.1	9.0	13