



# Summary of Recent Results from SLAC

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**ILC08**

Chicago, University of Illinois

15-20 November 2008



## R&D work at SLAC on mitigation techniques

- Installed 3 experiments with test chambers in PEP-II:
  - “ECLLOUD1” to monitor the reduction *in-situ* of the Secondary Electron Yield (SEY) due to “conditioning”
  - “ECLLOUD2” to test Groove mitigation
  - “ECLLOUD3” chicane to test e-cloud in magnetic field:
    - Aluminum and TiN coated chambers

# Electron cloud chambers installed in PEP-II

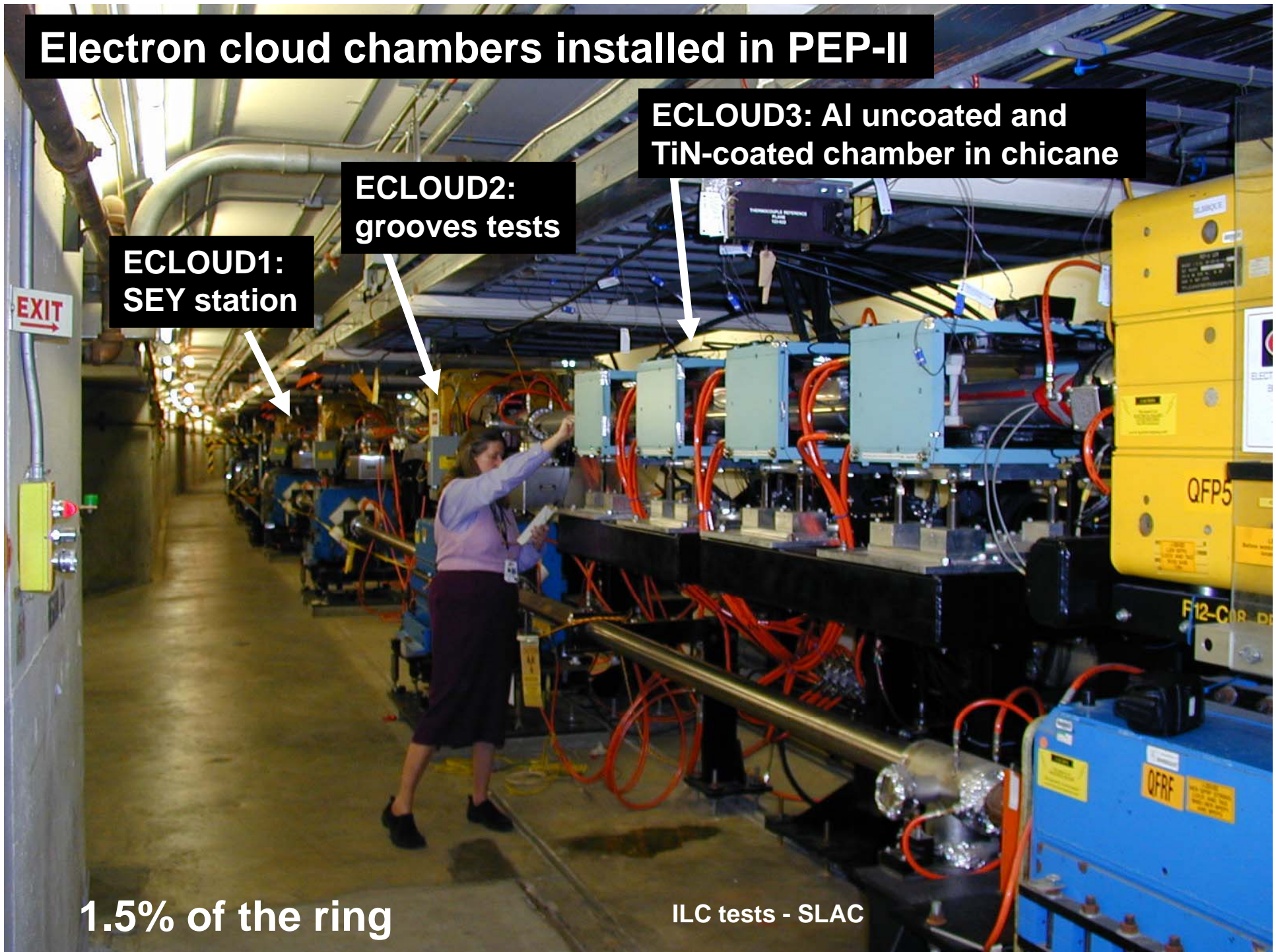
ECLOUD1:  
SEY station

ECLOUD2:  
grooves tests

ECLOUD3: Al uncoated and  
TiN-coated chamber in chicane

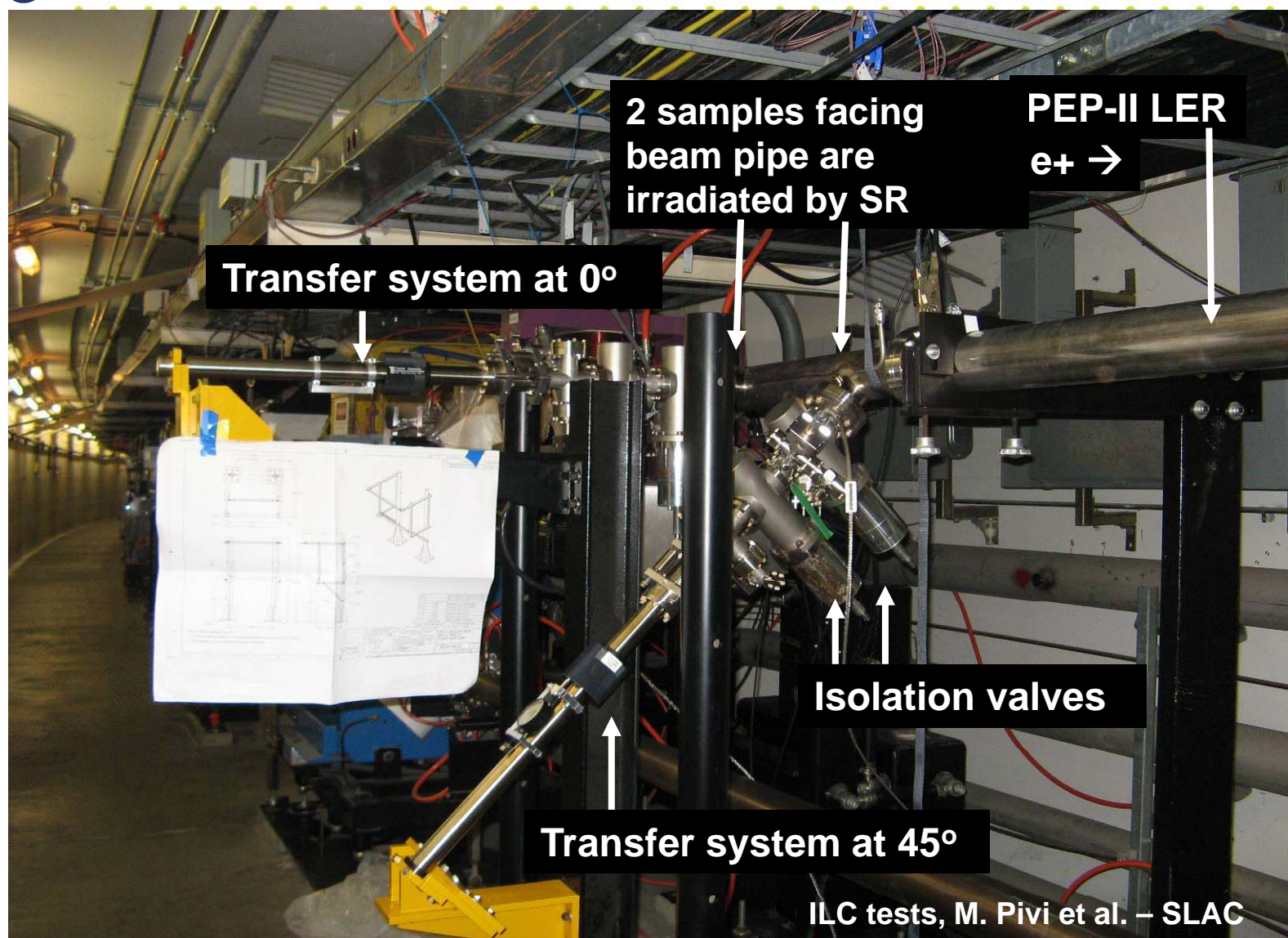
1.5% of the ring

ILC tests - SLAC



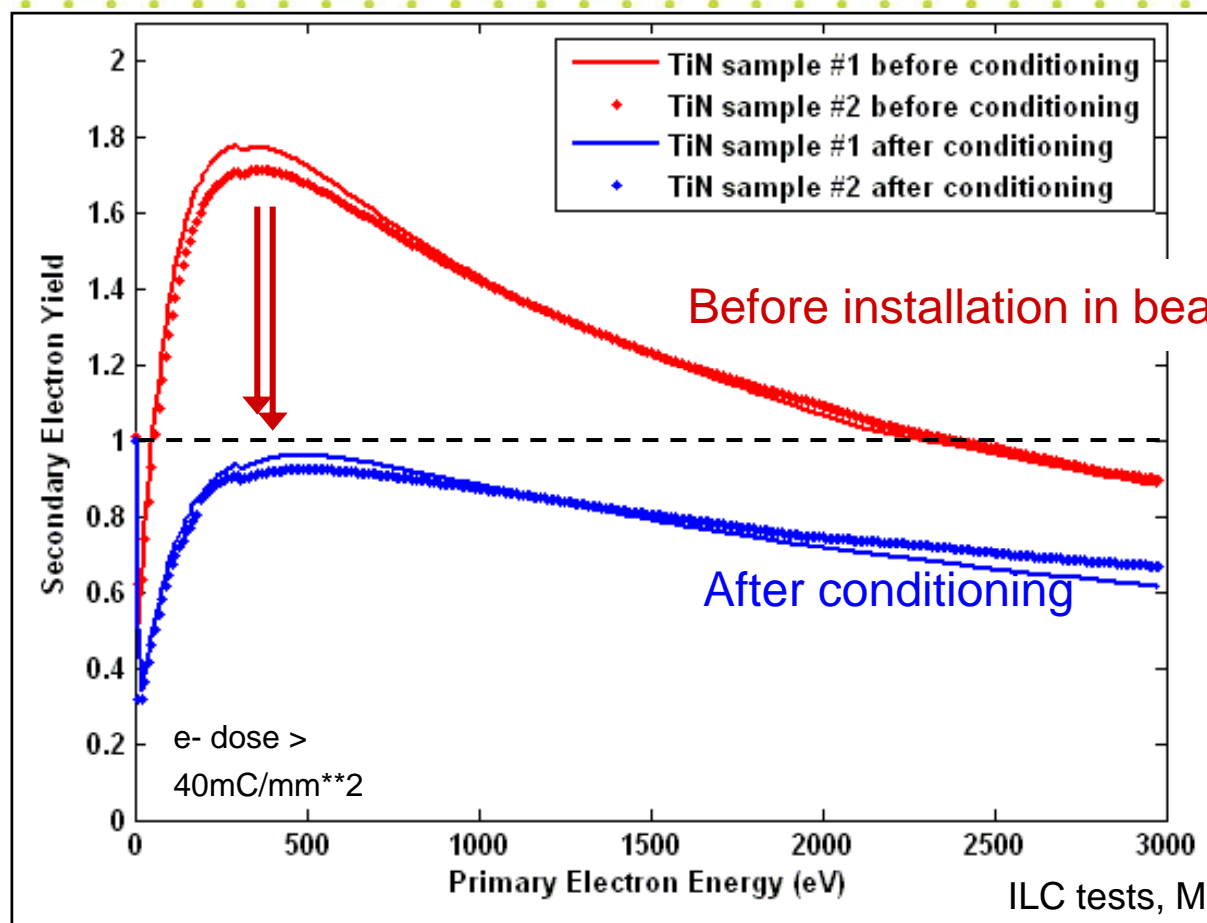


## “ECLLOUD1” SEY test station in PEP-II





## Results of Conditioning in PEP-II LER beam line

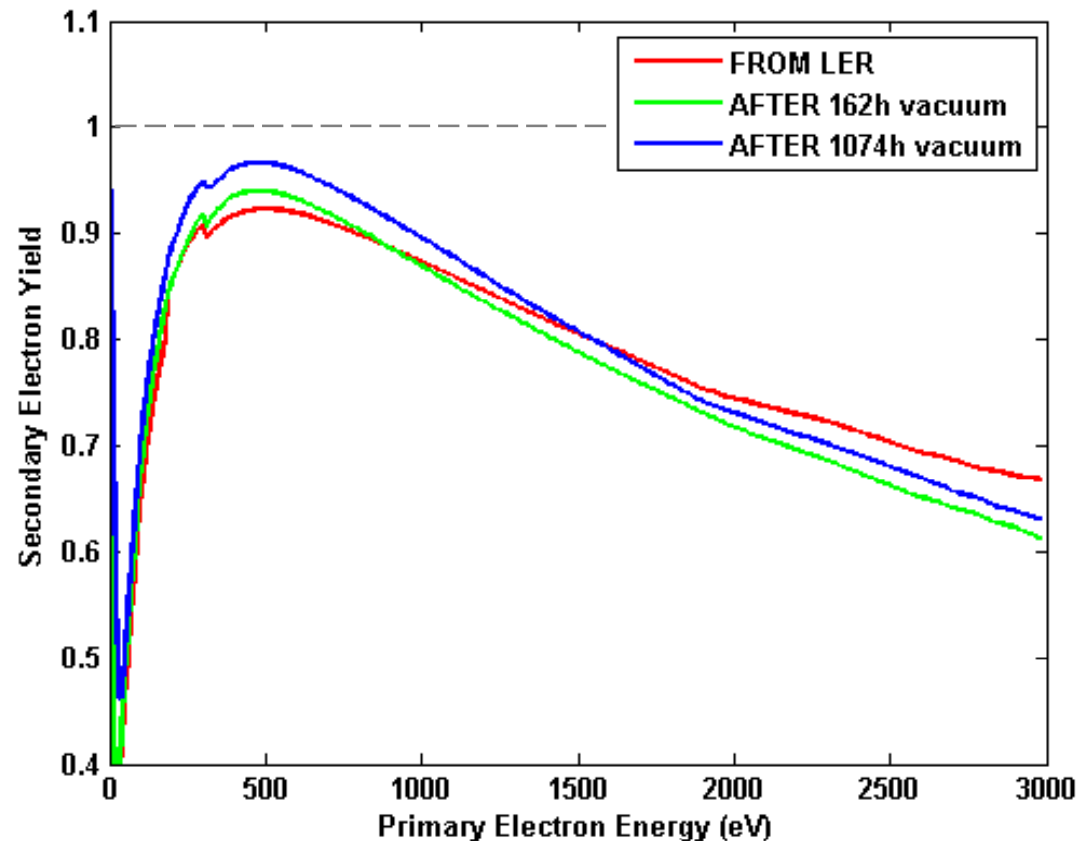


TiN samples measured before and after 2-months conditioning in the beam line. Samples inserted respectively in the plane of the synchrotron radiation fan (0° position) and out (45°).

Similar SEY measured *in situ* at KEKB by S. Kato et al.



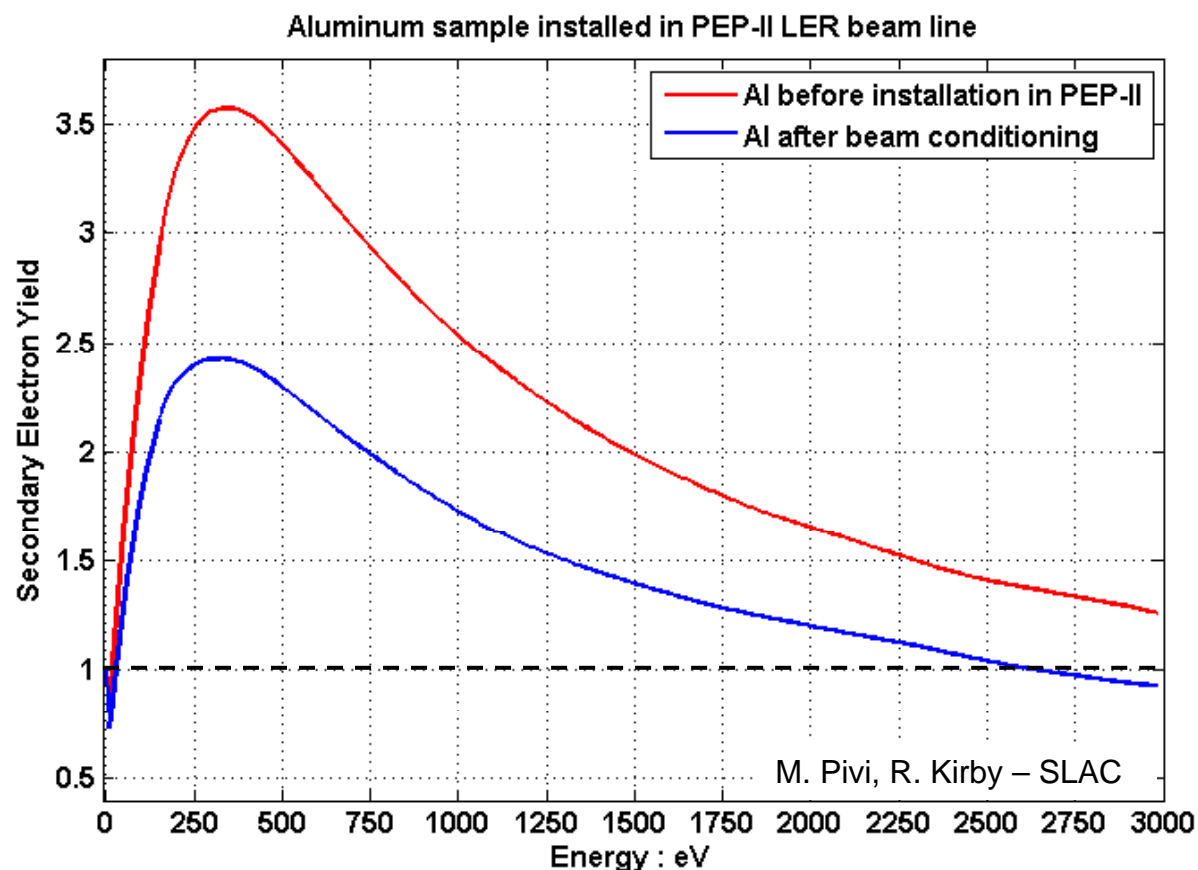
# Secondary Electron Yield recontamination after long term exposure in vacuum environment



TiN surface standing-by in vacuum: SEY < 1 even after 1000 hours.  
Recontamination effects are small for TiN after conditioning in PEP-II.



## ECLOUD1: Uncoated Aluminum in PEP-II



- After long conditioning in PEP-II beam line: sample SEY maximum remains > 2
- Well supported by previous SLAC and CERN set-up measurements
- CesrTA / Daphne have aluminum vacuum chambers: expect large e-cloud effects



# Summary “ECLLOUD1” experiment

Summary of samples conditioned in the accelerator beam line

	SEY before installation	SEY after conditioning
TiN/Al	1.7	0.95
TiZrV	1.33	1.05
Cu	1.8	1.22
StSt	1.85	1.26
Al	3.5	2.4

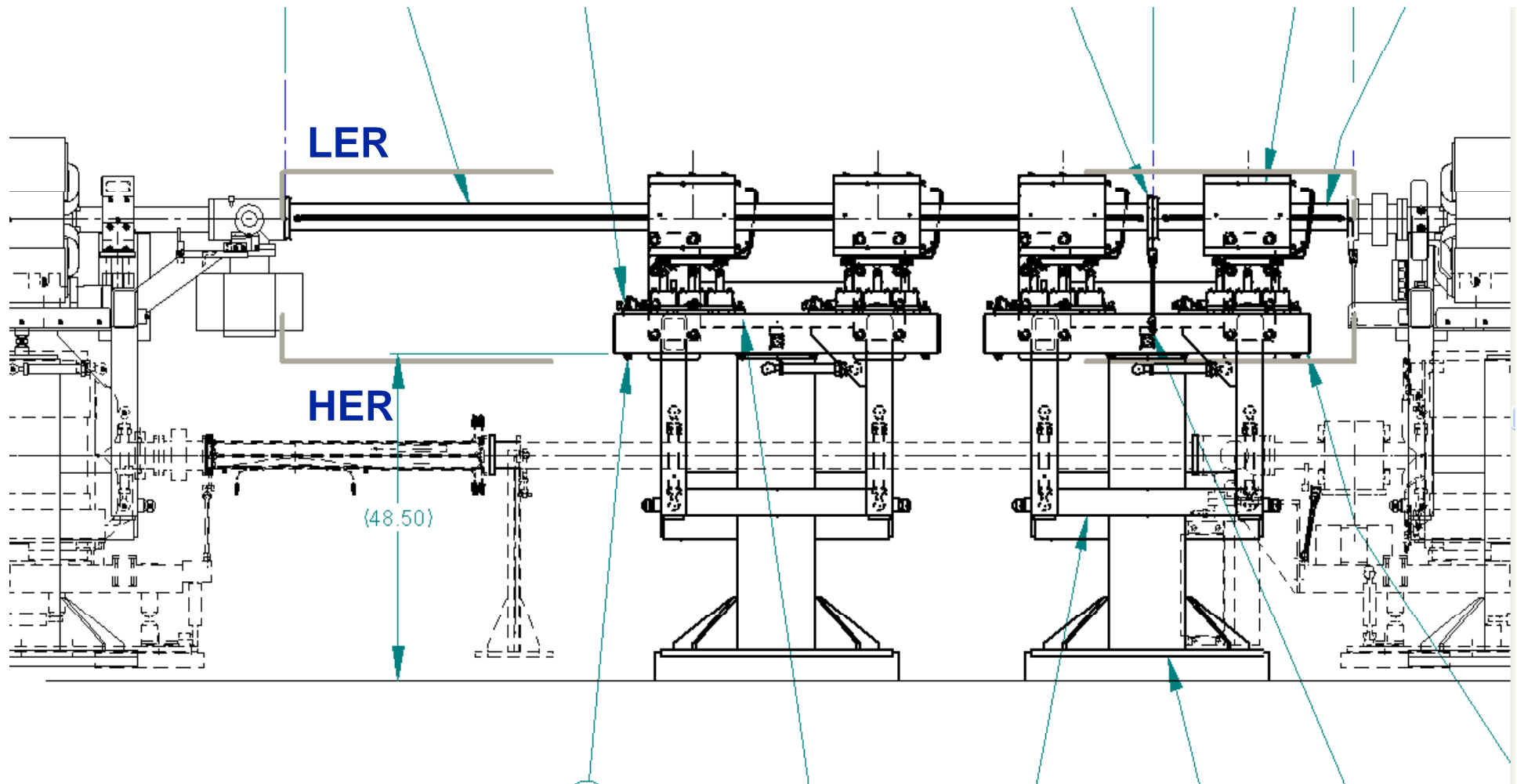
- References:

- papers in preparation for submission to Physical Review ST AB and Phys. Rev. Lett.
- M. Pivi *et al.* MOPP064 EPAC 2008;
- F. Le Pimpec *et al.* Nucl. Inst. and Meth., A564 (2006) 44;
- F. Le Pimpec *et al.* Nucl. Inst. and Meth., A551 (2005) 187;



# “ECLOUD3”: Layout of PEP-II dedicated Chicane

PEP-II

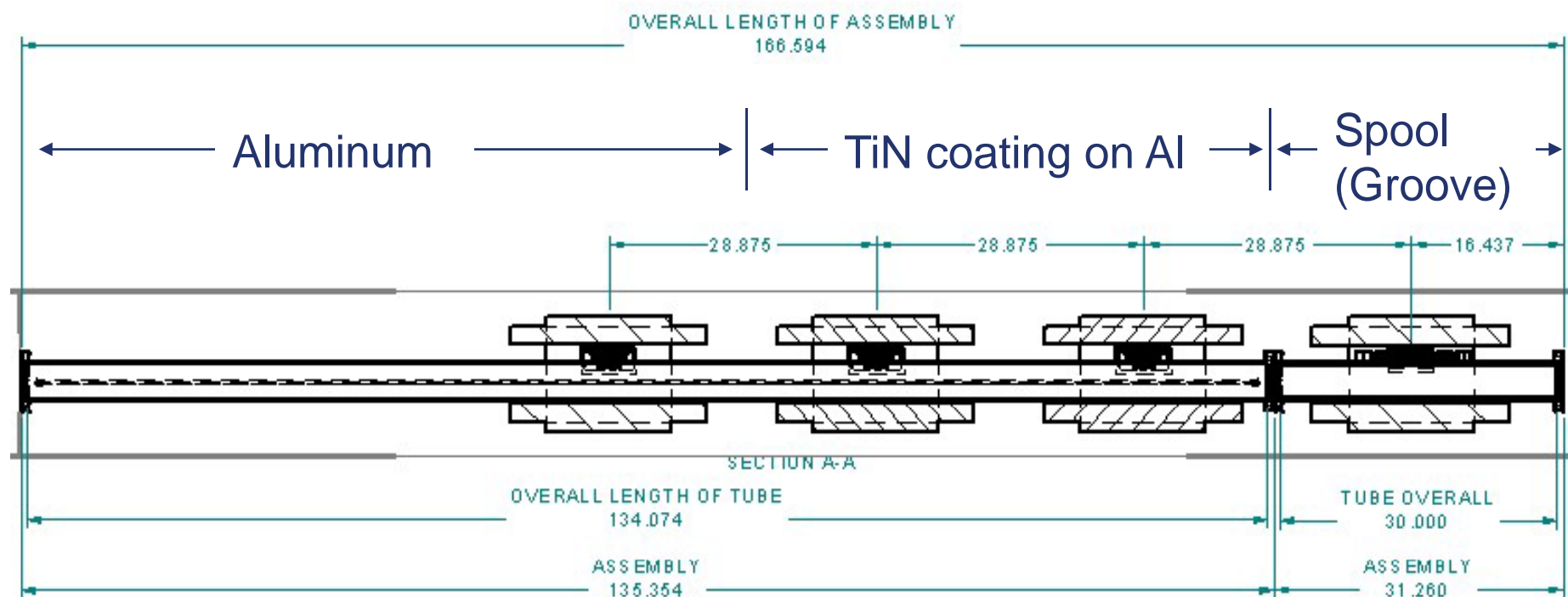


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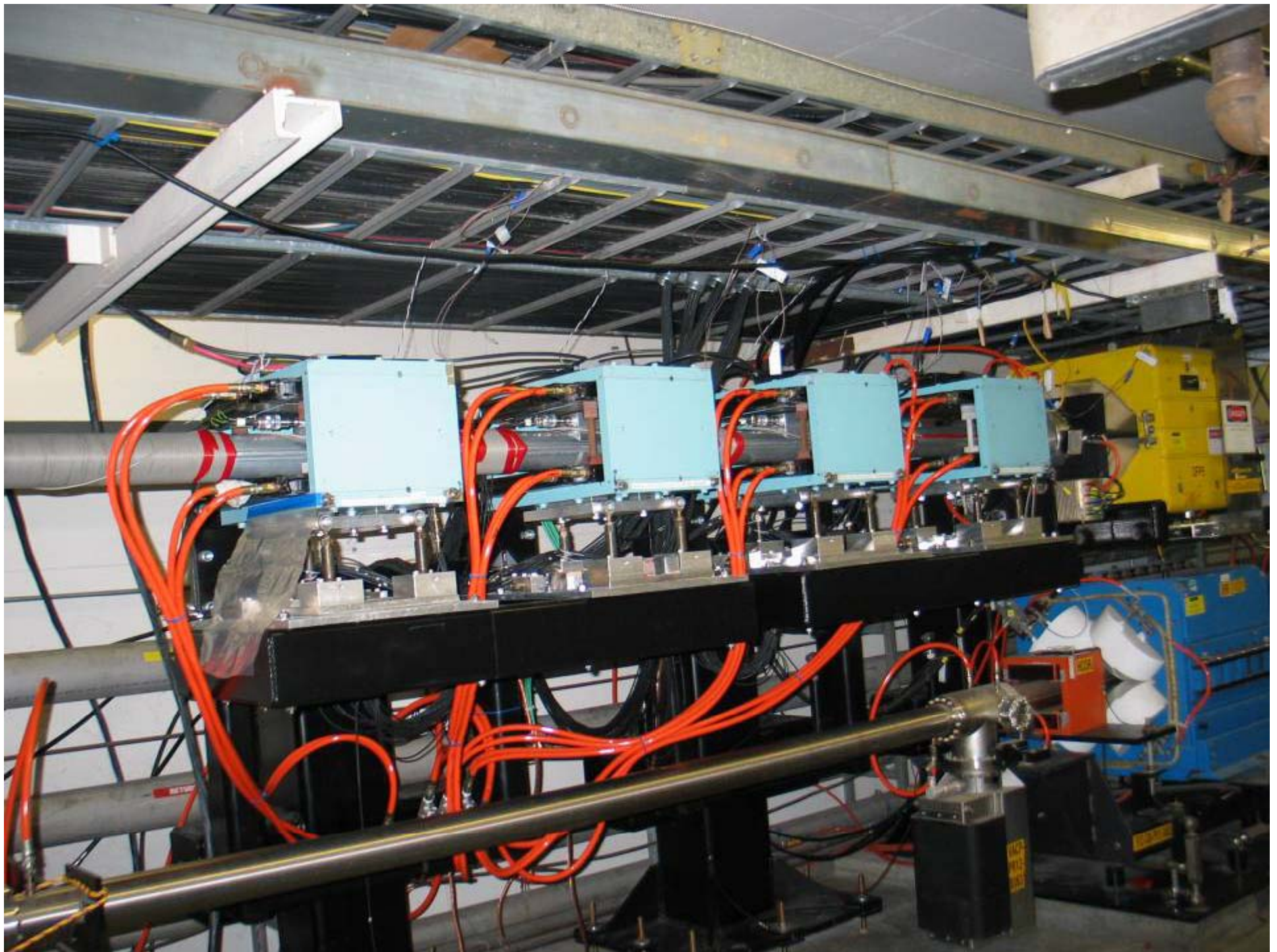
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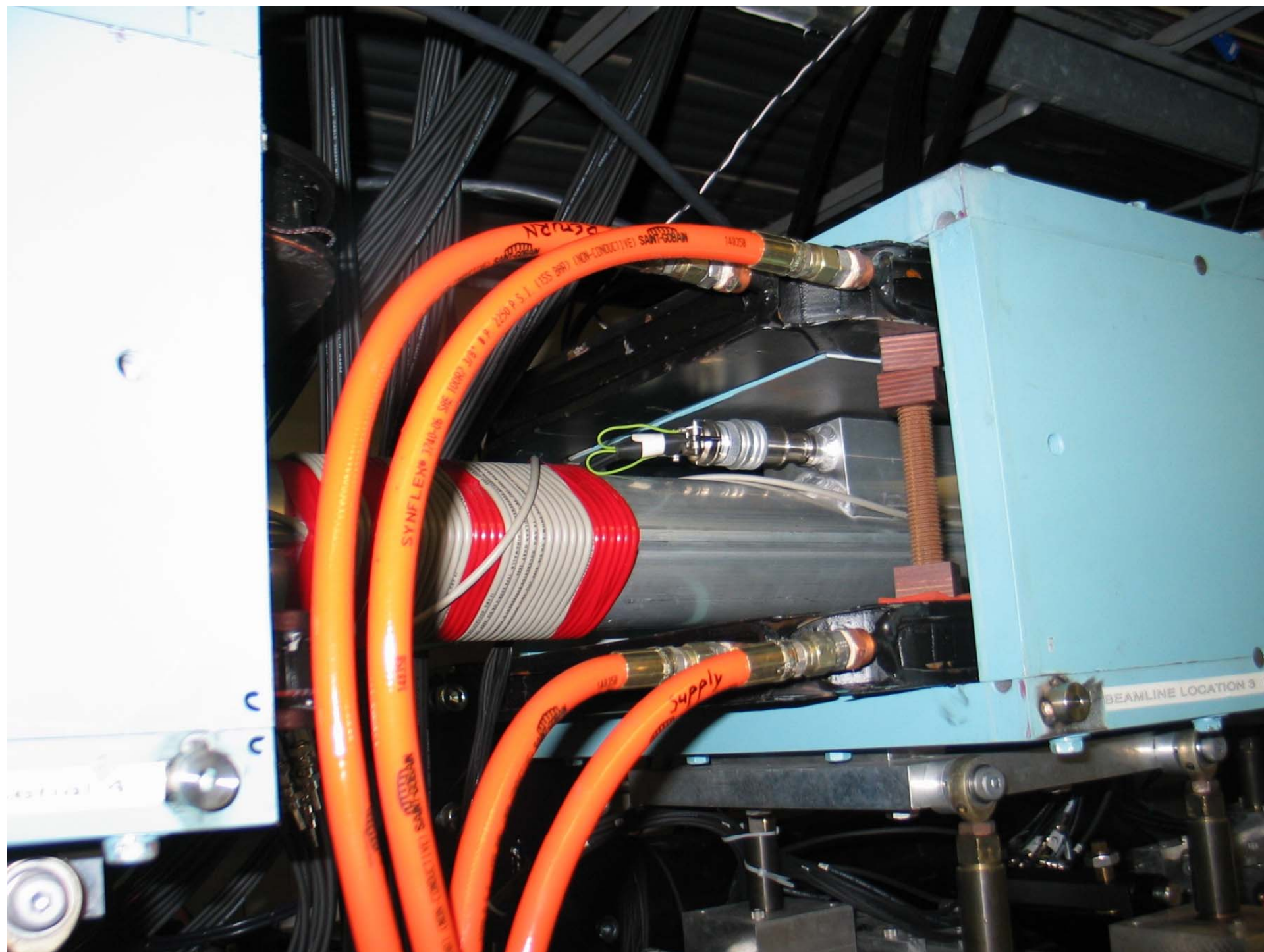


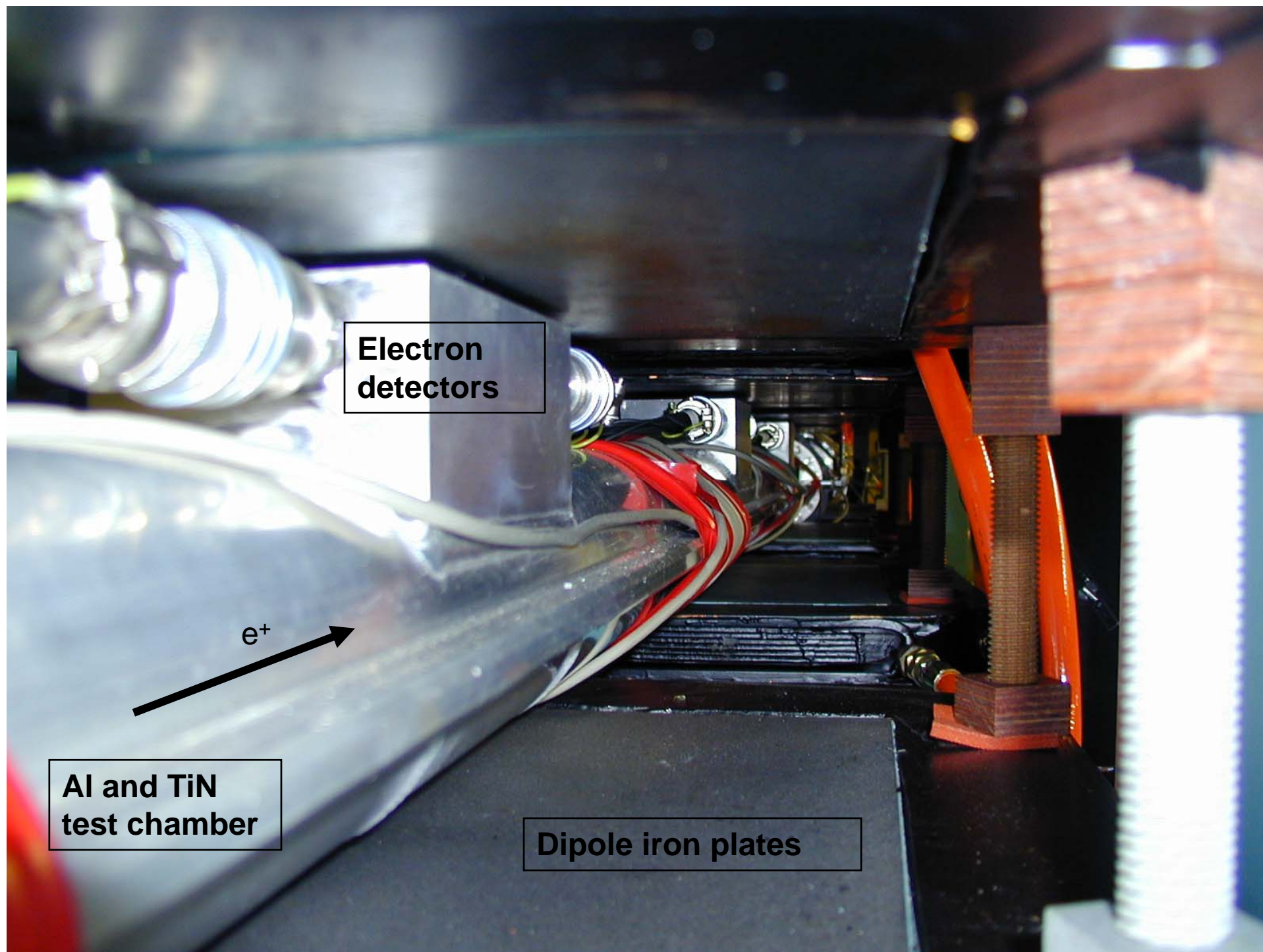
# “ECLOUD3” Chicane: Vacuum Chambers Layout



- 2 chambers: 135.3” and 31.2”.
- 4 analyzer electron cloud detectors, one at each magnet location
- The Al chamber is partially coated with TiN







Electron  
detectors

$e^+$

Al and TiN  
test chamber

Dipole iron plates



## Plan of ECLOUD3 experiments in PEP-II

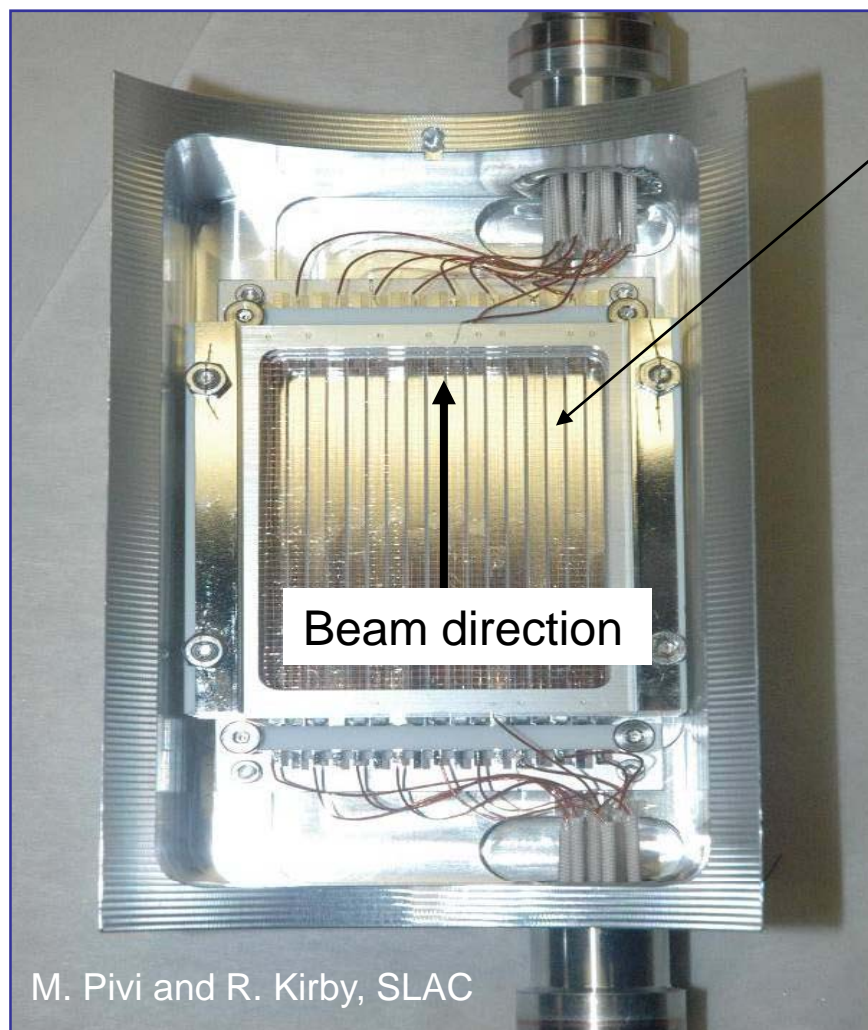
### Measurements plan:

- Electron cloud current as a function of beam current
- Electron energy spectrum
- Verify existence of resonances in electron cloud density as suggested by C. Celata LBNL

for Aluminum and TiN coating chamber

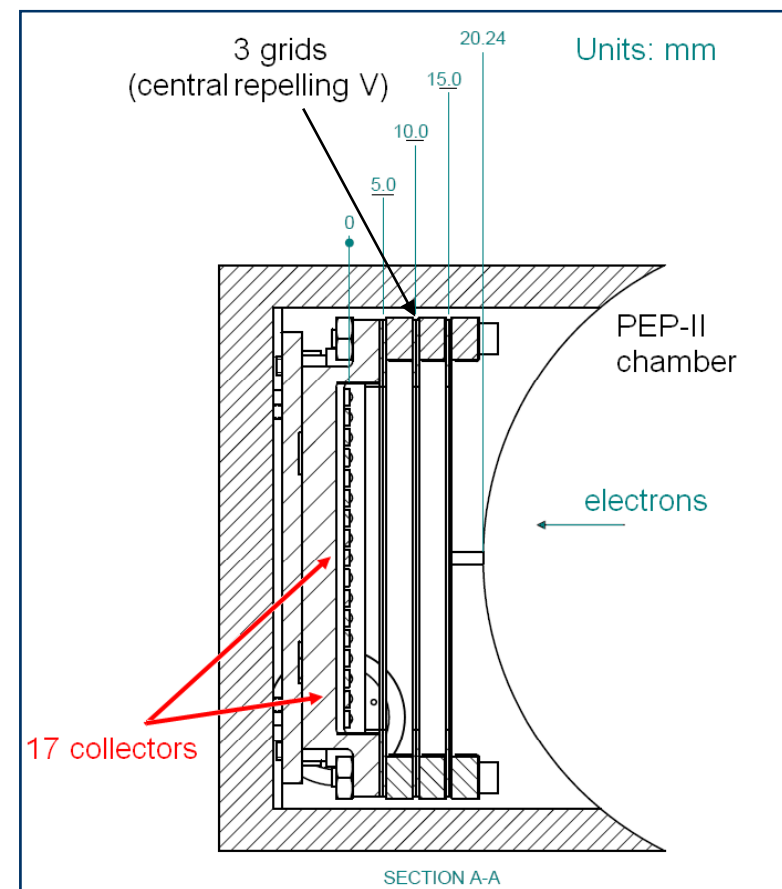


# Electron cloud detectors in magnets, SLAC



M. Pivi and R. Kirby, SLAC

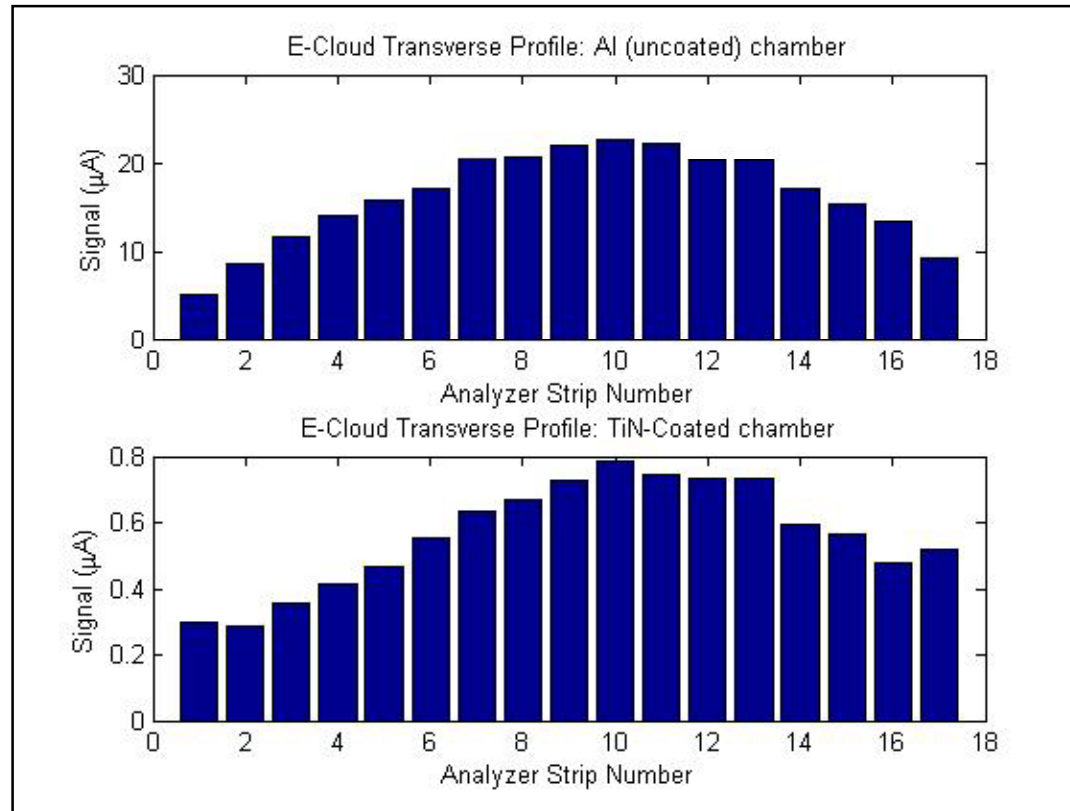
17 collectors to measure horizontal e- distribution and 3 grids to measure e- energy spectrum



Electron **detectors**, Retarding Field Analyzer (RFA) type [R. Rosenberg, K. Harkay]



# Electron cloud with no field: Chicane OFF



Electron collectors signal in the two sections with no magnetic field.

TiN coating (below) shows a reduction of a factor  $\sim 30$  with respect to Aluminum (above).

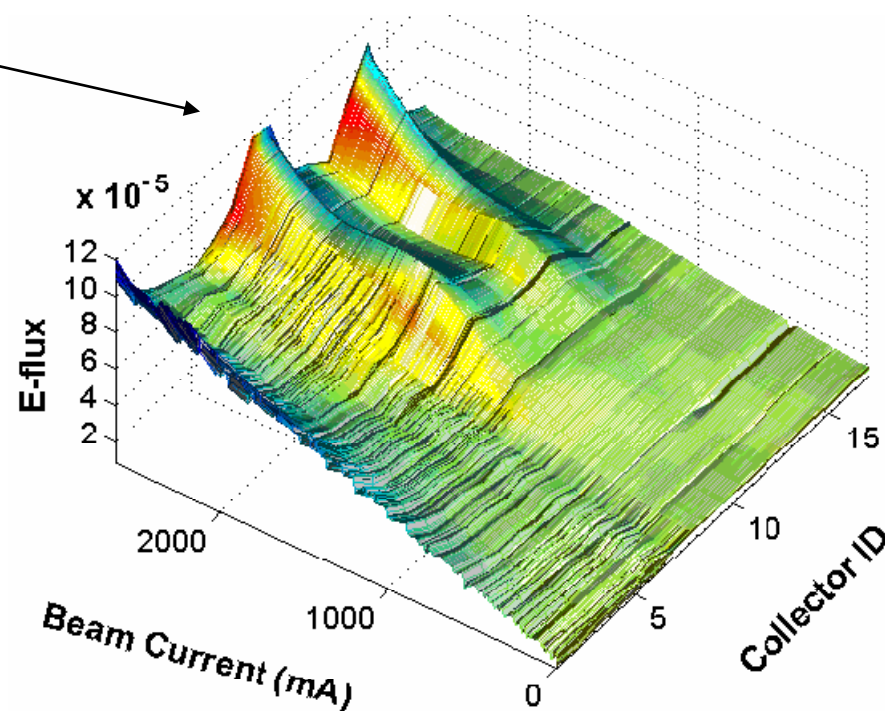
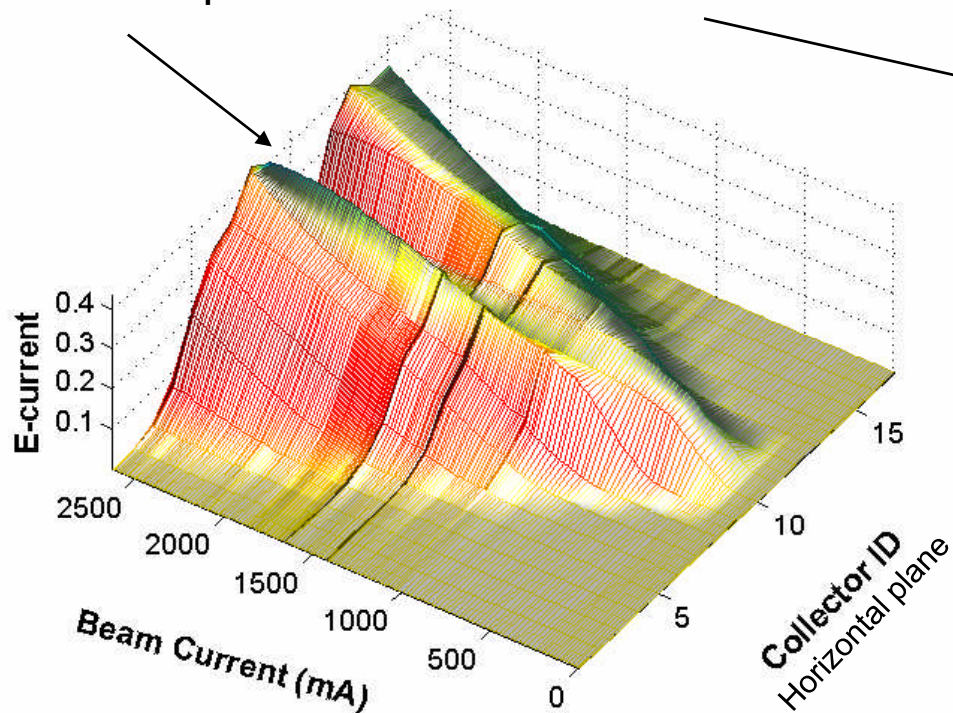


# Electron cloud in a dipole field: Chicane ON

Uncoated Aluminum section

TiN-coated section

“Two-stripe” electron distribution in the horizontal plane



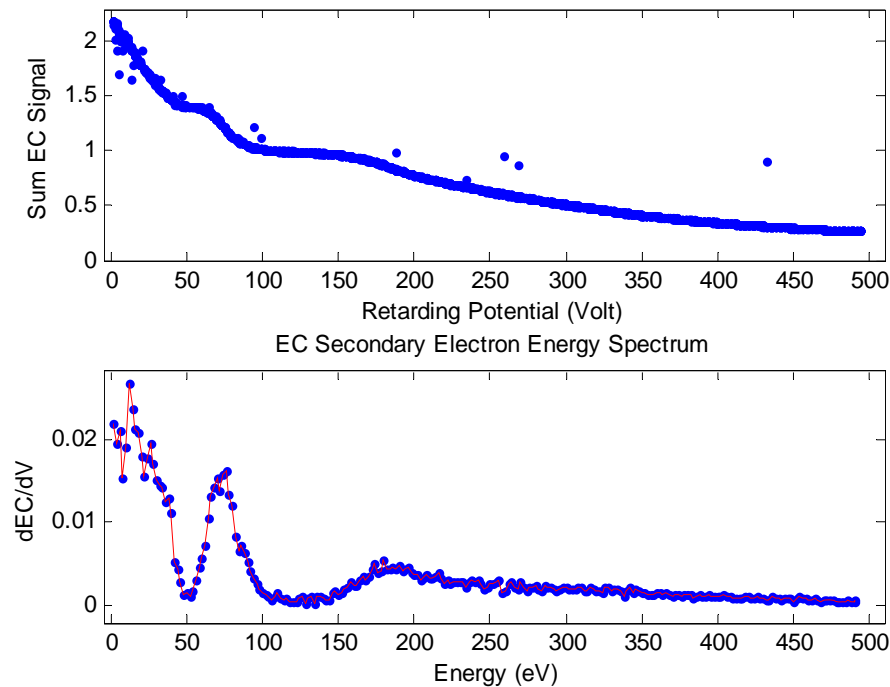
L. Wang et al, SLAC

Note the magnitude of reduction in TiN section. Distributions consistent with simulation.

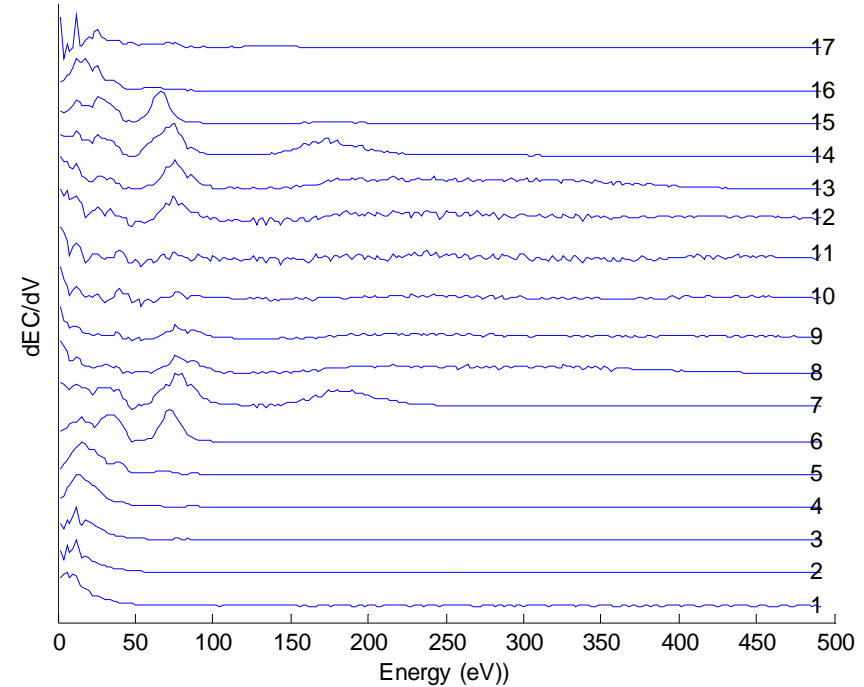


# Electron energy spectrum

Integrated and differential spectra: sum of all channels.



Differential energy spectra for each RFA channel.

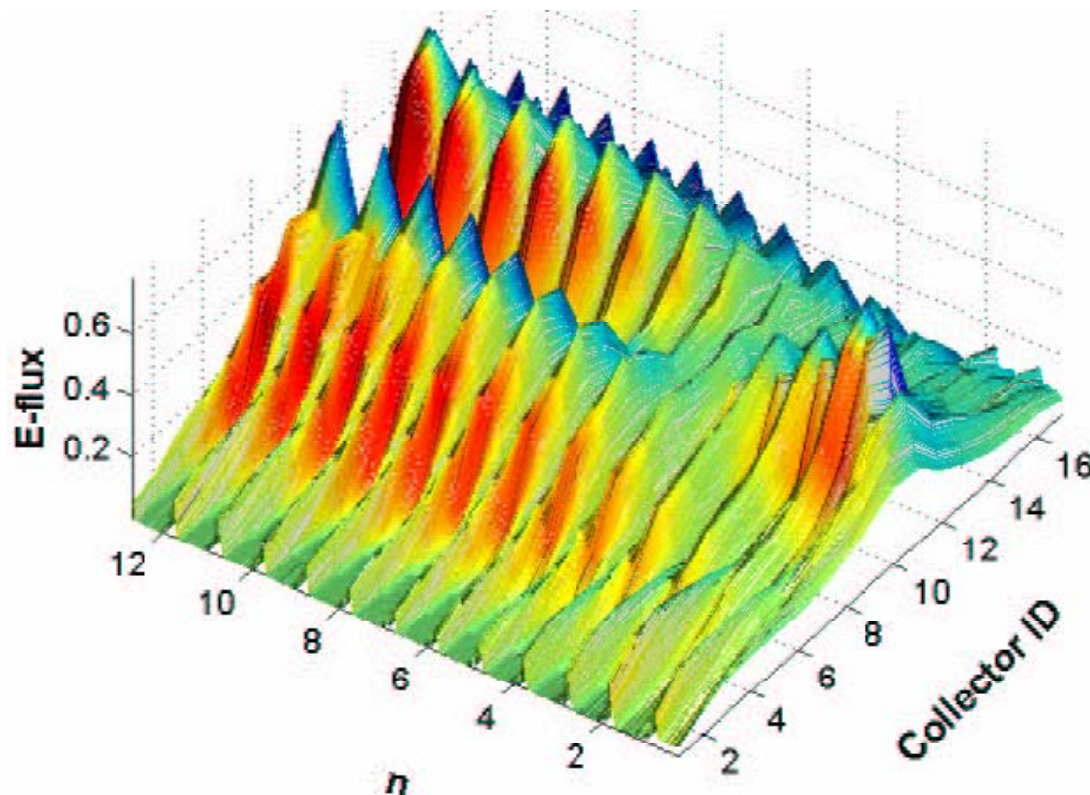


J. Ng et al, SLAC

- Retarding Field Analyzers: Grid used to repel electrons and measure energy spectrum
- Consistent with previous simulations. [L. Wang, ECLOUD04, SLAC-PUB-10751]



## ECLOUD3: Magnetic field Resonances



$$n = \frac{\text{bunch spacing in time}}{\text{electron cyclotron period}} \propto B$$

e- cyclotron period and bunch spacing couple into resonances

$n$  proportional to  $B$  field.

We varied chicane magnetic field.

Electron flux peaks (and valleys) separated by integer values of  $n$ .

Phase of cyclotron motion with respect to bunch crossing affects energy gain, possibly leading to the observed modulation in electron flux at the chamber wall.

M. Pivi, J. Ng et al, SLAC



# Observed in simulations by C. Celata LBNL



## A Hypothesis

If:

The **bunch spacing** is an integral multiple of the **cyclotron period**

Then:

Each time the electron gets a push from the beam field, it is in the same position  $\Rightarrow$

**Resonance**

Important:

Cyclotron period is function only of B for  $v \ll c$ .

$$\tau_c = \frac{2\pi m_0 \gamma}{qB}$$

$\gamma$  = relativistic factor

**So electron stays in resonance until detuned by relativistic mass increase or space charge.**

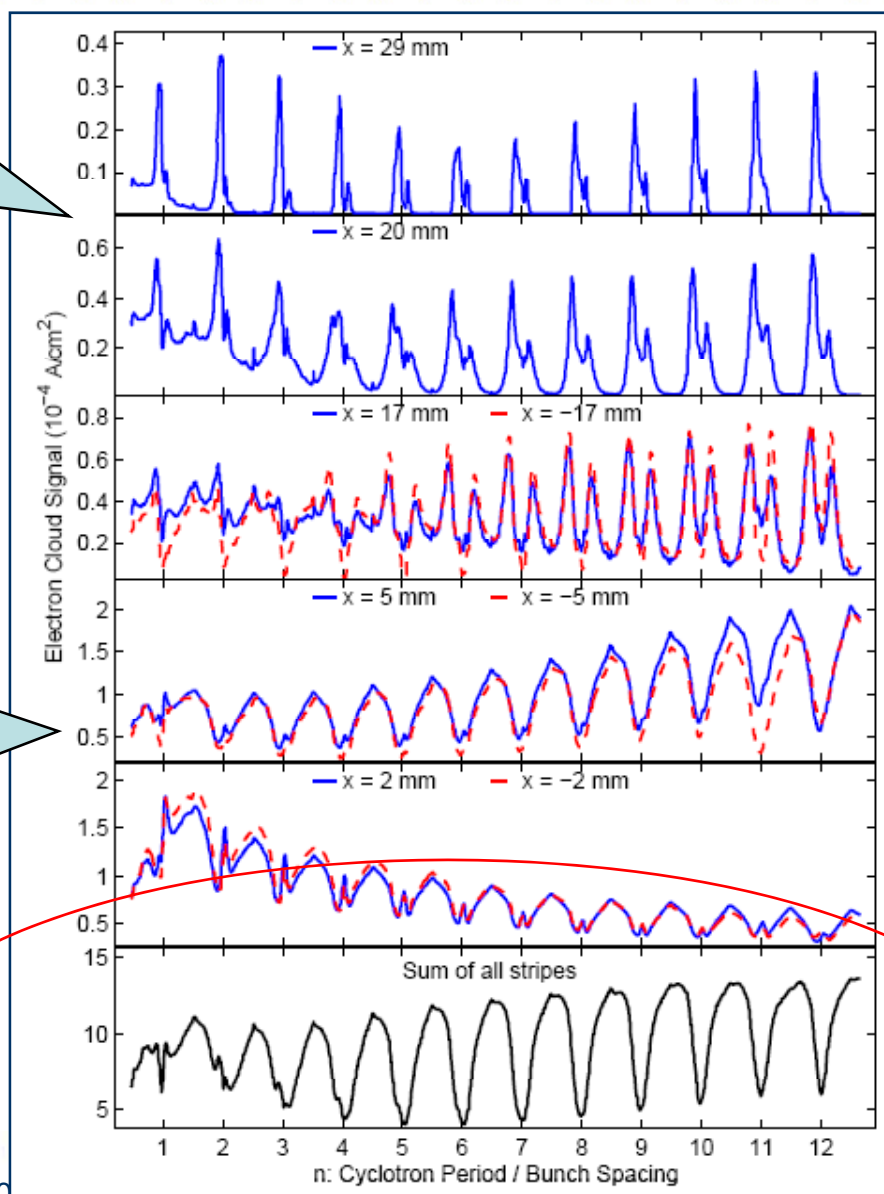
*Celata, Feb. 14, 2008* 16



# Resonance effect in a dipole field: Aluminum section

NOTE: far from center chamber axis (large  $x$ 's), the e- signal peaks at  $n=\text{integer}$

NOTE: close to center axis, a stronger signal peaks at  $n=\text{half integer}$



Uncoated aluminum section. Electron cloud current signal as a function of the ratio  $n$ , cyclotron period to bunch spacing, at 2500 mA PEP-II LER beam current.

The first five plots are data from individual RFA collector stripes.

The bottom plot shows the total signal summed over all collectors peaks at  $n=\text{half integer}$ .

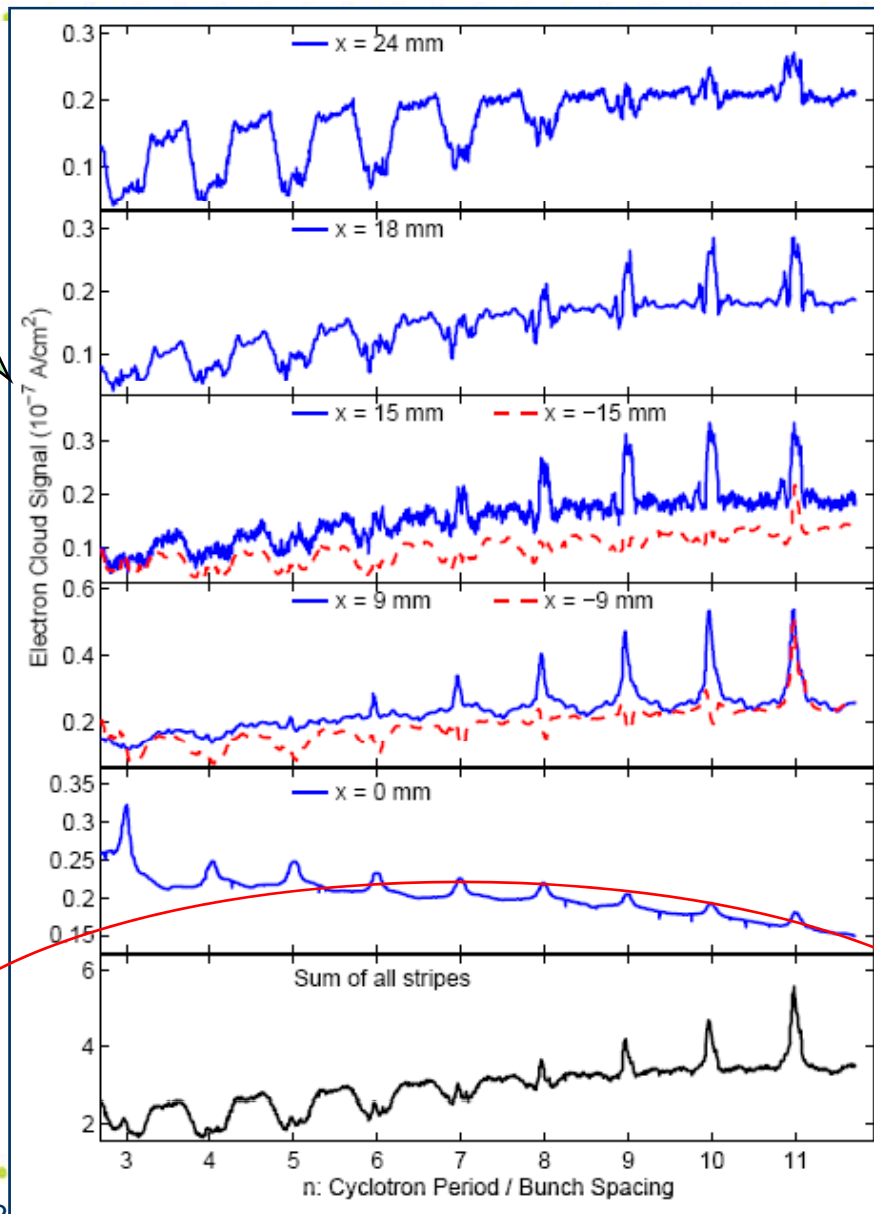
J. Ng et al, SLAC



# Resonance effect in a dipole field: TiN section

NOTE: orders of magnitude lower current than aluminum section.

NOTE: peaks.



Same as previous slide but for TiN coated section

The first five plots are data from individual RFA collector stripes.

The bottom plot shows the total signal summed over all collectors peaks at (large)  $n$ =integer values. J. Ng et al, SLAC



# ECLOUD3: Summary

- Goal: mitigation of electron clouds in a dipole magnetic field region
- Results:
  - Demonstrated TiN-coating is very effective in a dipole
  - Characterized electron cloud in DR dipole field
  - Observed new resonance: modulation in electron flux as magnetic field strength is varied
  - Resonance: reduce electron cloud density in ILC DR by tuning the arc dipole field

## References:

- paper being prepared for submission to Phys. Rev. Lett.
- M. Pivi, J. Ng et al., EPAC 2008;

# Additional Plans

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- \* KEK:
  - Ongoing tests of SLAC groove insertions in wigglers at KEKB (see Suetsugu-san presentations).
- \* CERN: manufacturing small groove insertions for SPS dipole tests.
- \* CesrTA:
  - Removed all PEP-II experiments ECLOUD1,2,3 (plus additional grooved chamber) and redeploying at Cornell.
- \* Project-X:
  - Re-deploy ECLOUD1 (SEY Station) to Fermilab (after CesrTA)



# Milestones to ILC Technical Design Phase

The goal is to complete the following tasks by 2010 as input for the Technical Design Phase:

- Characterize the electron cloud build-up and instability by simulations and measurements in existing accelerators: CesrTA, SPS, Daphne, SuperKEKB
- Model the ILC DR electron cloud instability
- Characterize Photoemission in ILC DR parameters range (experimental)

Evaluate need for additional mitigation techniques (besides coating):

- Clearing electrodes
- Triangular groove
- Antechamber
- Characterize the impedance and HOMs of mitigation techniques

Specify mitigation requirements for DR



# Recommendation for mitigation for ILC

## DR design: Under Discussion

DR element	% ring	Antechamber	Coating	Additional Mitigation	Remarks
DRIFT in STRAIGHT	33	No	NEG	Solenoid	Groove if necessary
DRIFT in ARC	56	Downstream of BEND only	NEG	Solenoid	Groove if necessary
BEND	7	Yes	TiN	Grooves and Electrodes	
WIGG	3	Yes	TiN	Electrodes and Grooves	
QUAD	1	Downstream BEND / WIGG	TiN	Grooves and Electrodes	

Preliminary table to be completed as input for Technical Design Phase. Goal is to turn all Red colors to Green in the next two years.

Other mitigations under development (ex: Carbon coating CERN)

# Summary

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- \* Successful international R&D program on electron cloud mitigations.
- \* TiN coating has been demonstrated to have an SEY below the instability threshold. Work continues to address a few remaining issues.
- \* Yet, requirements at future colliders (2 picometer emittance in the ILC DR, e.g.) are challenging.
- \* Hence, close collaboration between labs to develop complementary mitigation techniques is needed to further suppress the electron cloud effect.