Update on Work Package Electron Cloud R&D at SLAC for the ILC Damping Ring

M. Pivi, D. Arnett, G. Collet, F. Cooper, D. Kharakh, F. King, R. Kirby,B. Kuekan, M. Munro, J. Ng, J. Olszewski, B. Smith, C. Spencer, T. Raubenheimer, L. Wang, W. Wittmer, (SLAC) C. Celata, M. Furman (LBNL)

ILC Damping Ring - ILCDR08

Cornell University

8 to 11 July 2008

Indications from the ILC Reference Design Report RDR work

- Simulations indicate that a secondary electron yield of ~1.2 results in a cloud density close to the instability threshold.

- The aim of experimental studies is to obtain a surface secondary electron yield of 1.1.

- Simulations indicate that techniques as grooves in the chamber walls or clearing electrodes, besides coating, will be effective at suppressing the development of an electron cloud.

Electron Cloud and SEY R&D Program

- R&D Goals:
  - Reduce the SEY below instability threshold. SEY ≤ 1.1.

- Surface Approach:
  - Coatings
  - Conditioning
  - Grooved surfaces
  - Clearing electrodes (KEK)

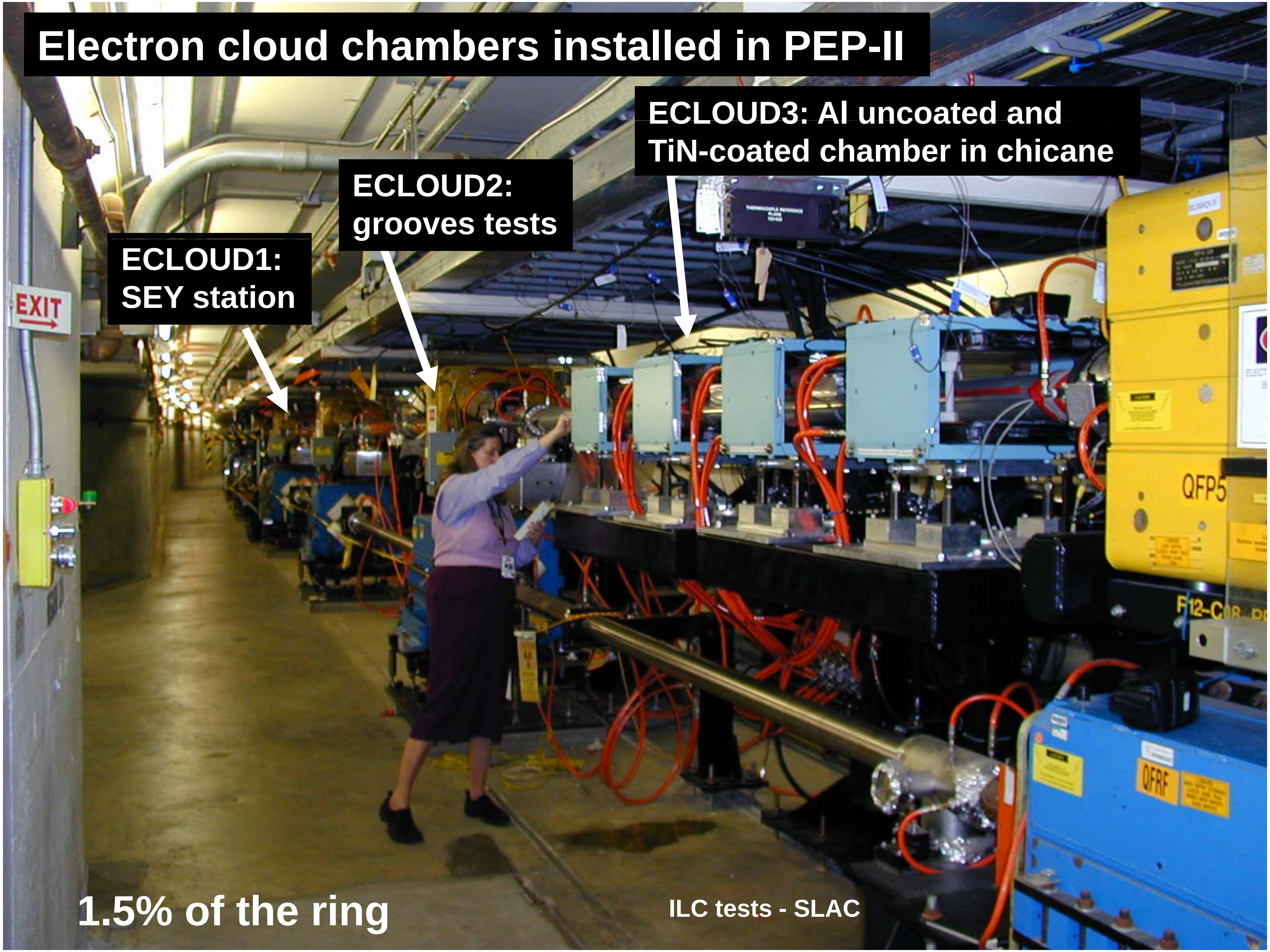
- Experiments in PEP-II:
  - Conditioning
  - Grooved chambers
  - Conditioning and grooved chambers in magnetic field regions

R&D work at SLAC on mitigation techniques

- 3 projects with 6 test chambers in PEP-II straight:
  - **“ECLOUD1”: to monitor the reduction *in-situ* of the SEY due to conditioning**
  - **“ECLOUD2”: to test Groove chambers**
  - **“ECLOUD3”: new Chicane to test in magnetic field chambers:**
    - Aluminum
    - TiN coating
    - Groove chamber (not installed)
    - Non-evaporable getter NEG coating chamber (not installed)

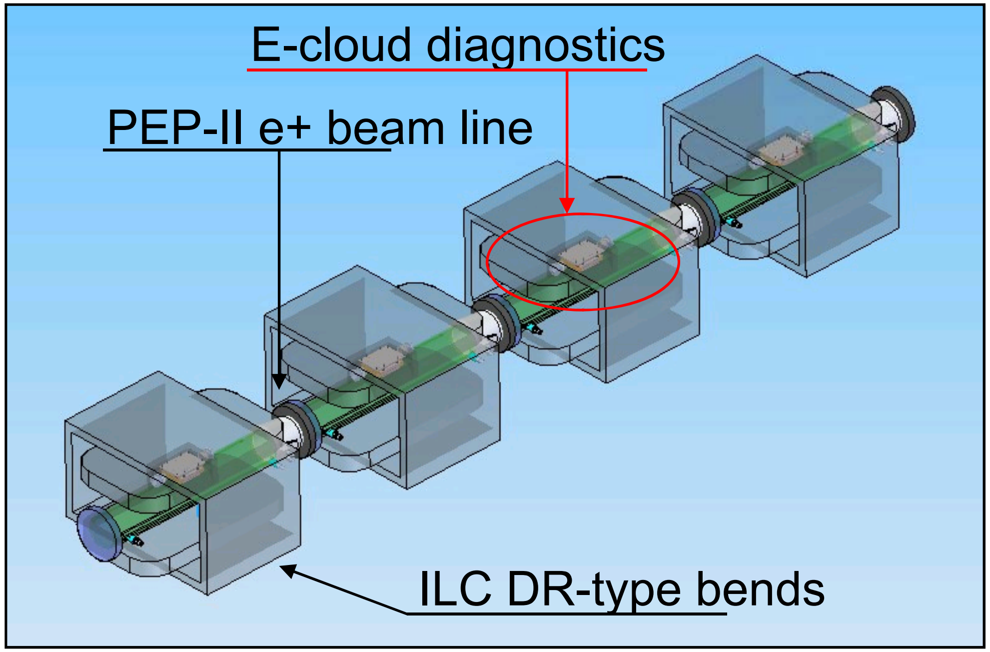
stopped due to FY08 budget

Electron cloud chambers installed in PEP-II

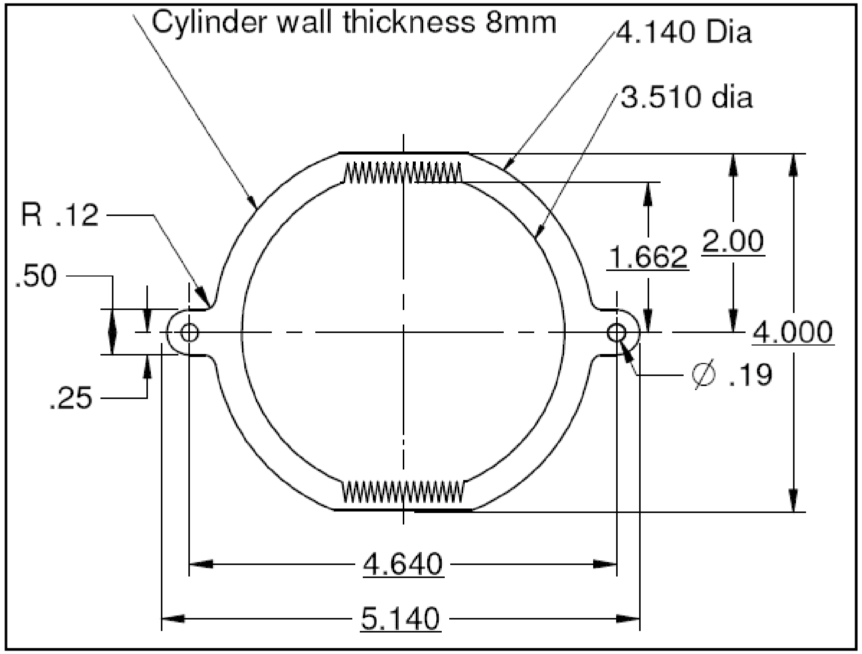


Mitigations Tests SLAC: New ILC Chicane Installation

- Verify efficiency of mitigation techniques in dipoles.
- Installation of a new chicane in PEP-II with ILC DR-type bends, to test chambers with coatings (and chambers with grooves)



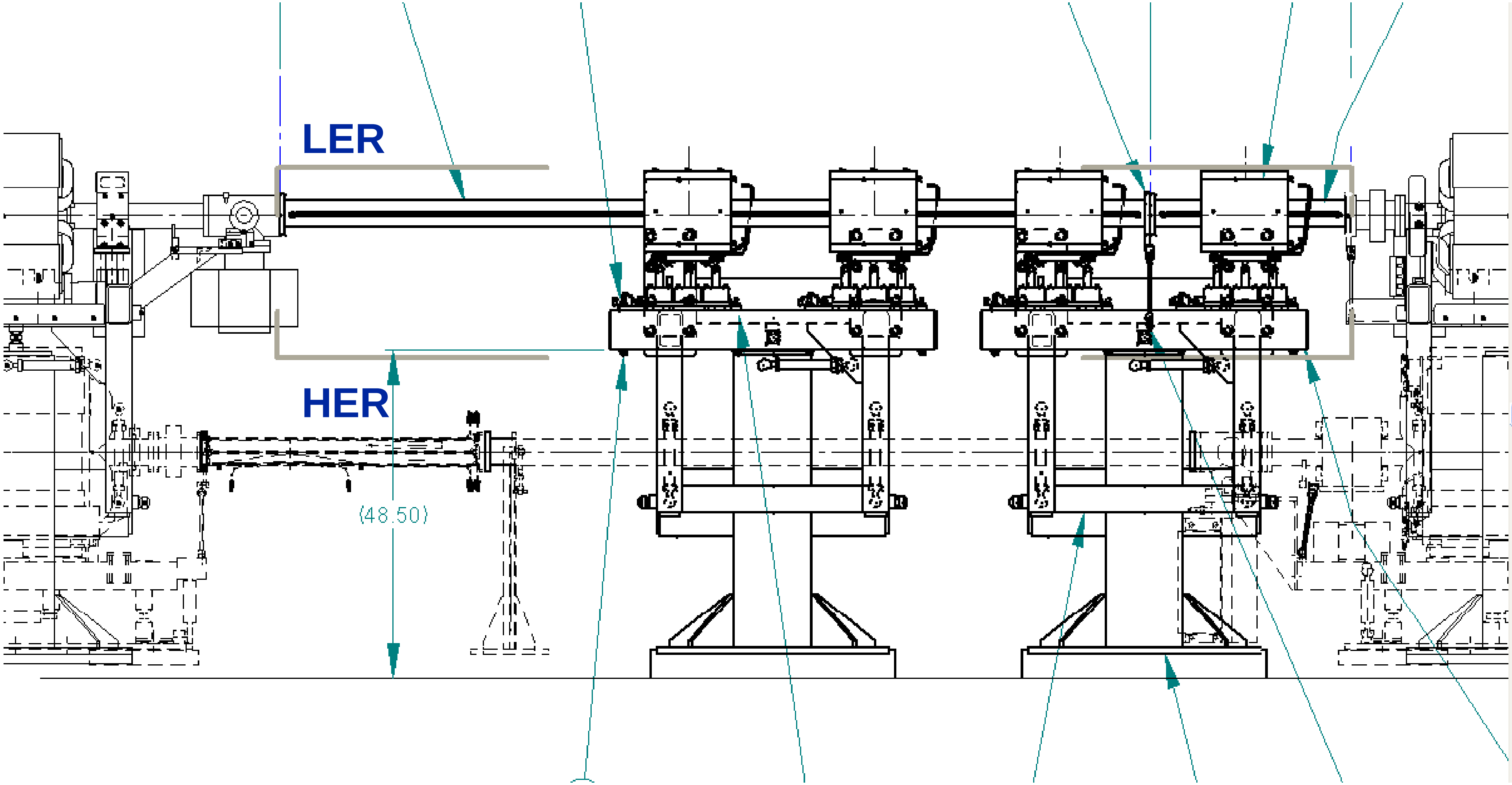
Layout new chicane installation in PEP-II LER



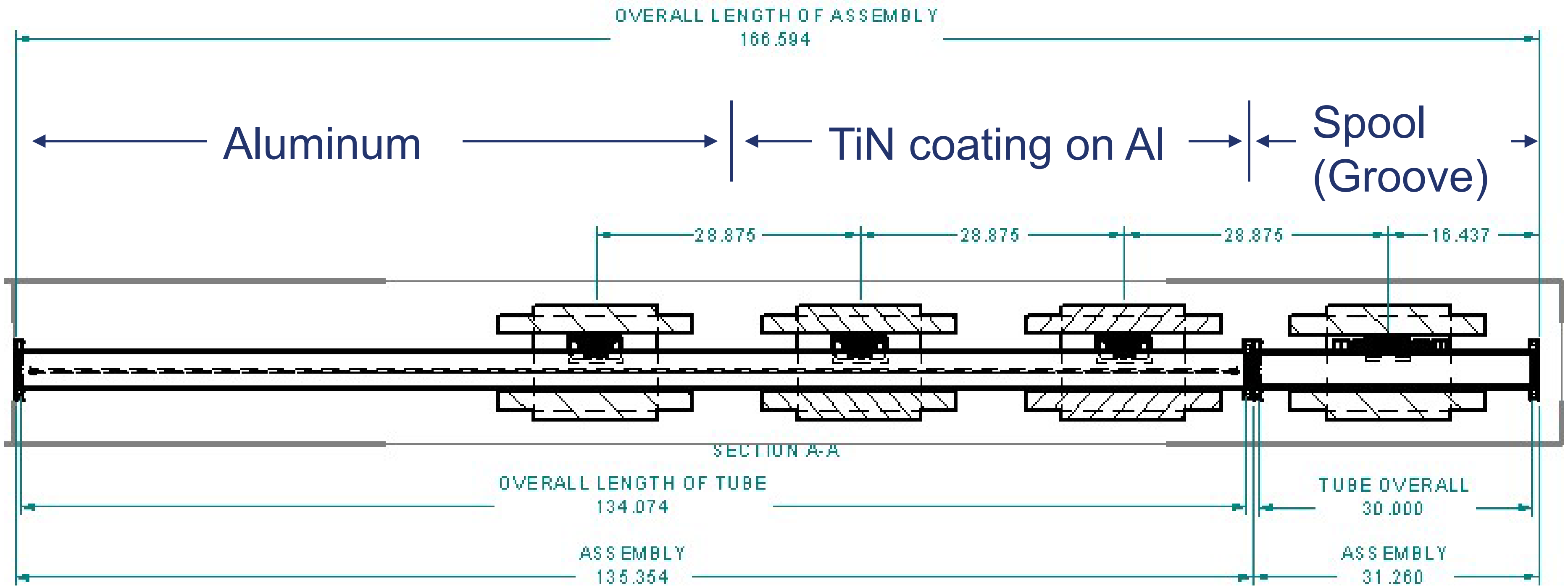
PEP-II chamber with triangular grooves

Chicane Assembly Layout

PEP-II

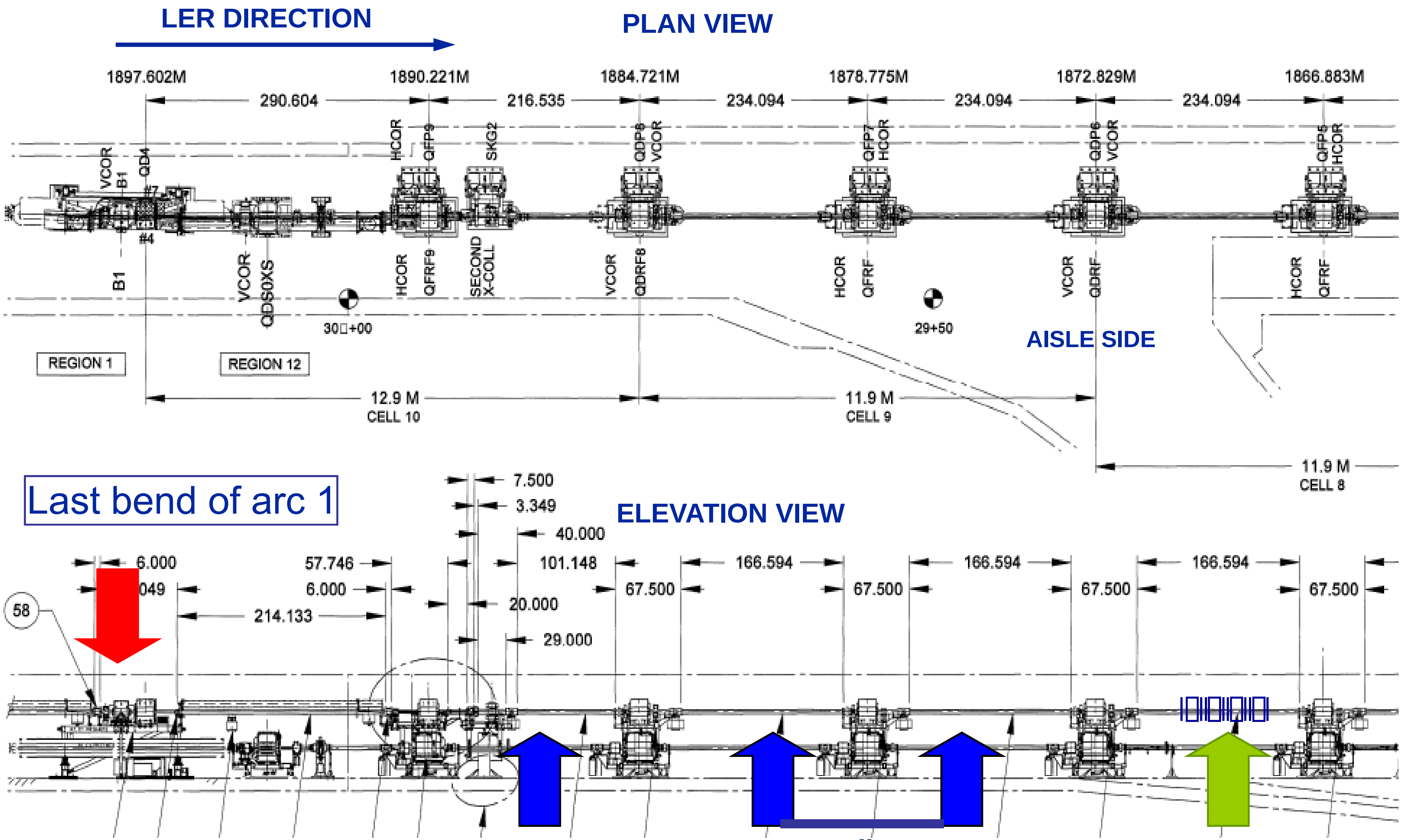


"ECLOUD3" Chicane: Vacuum Chambers Layout



- 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

Layout of electron cloud tests in PEP-II

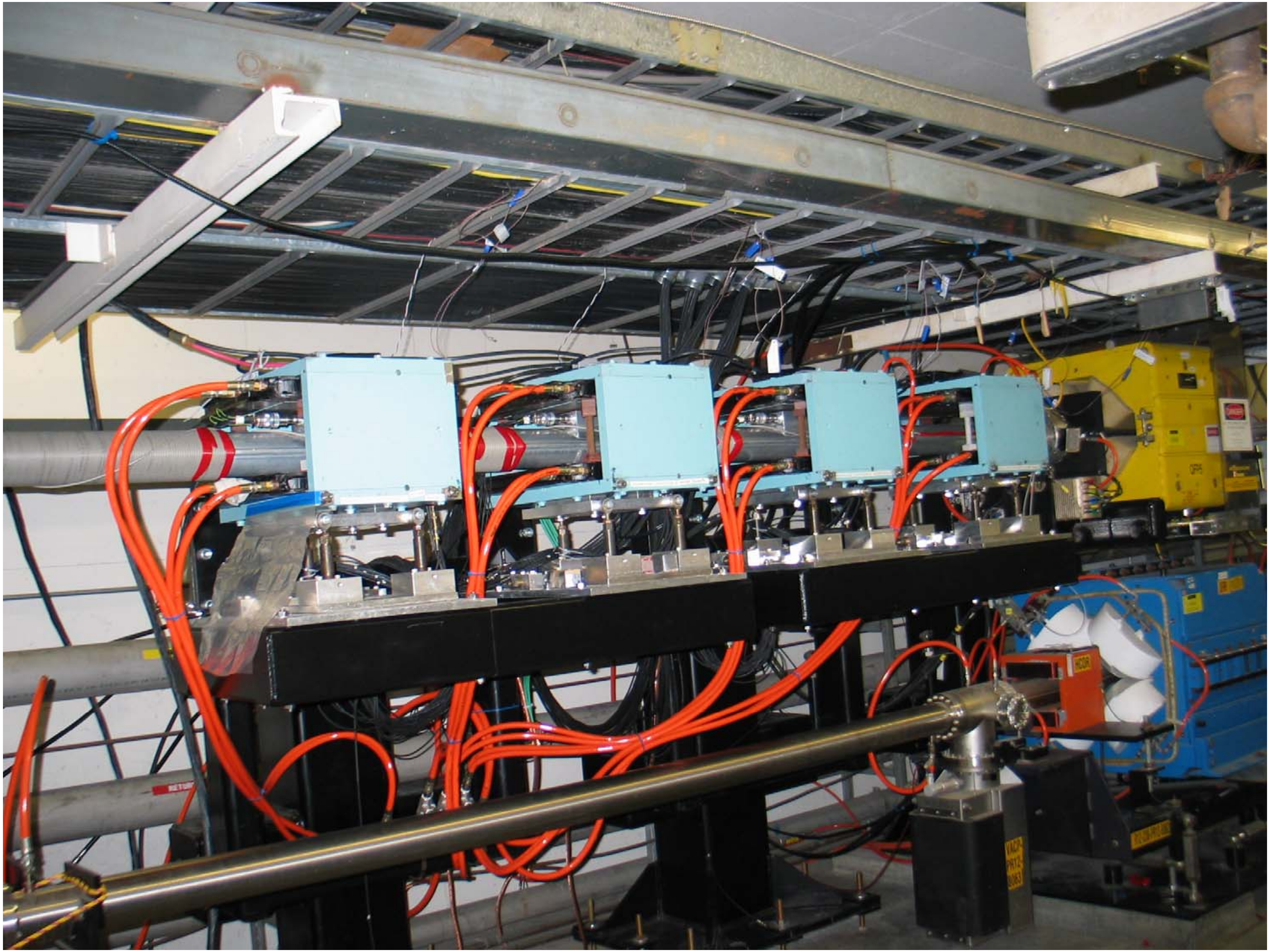


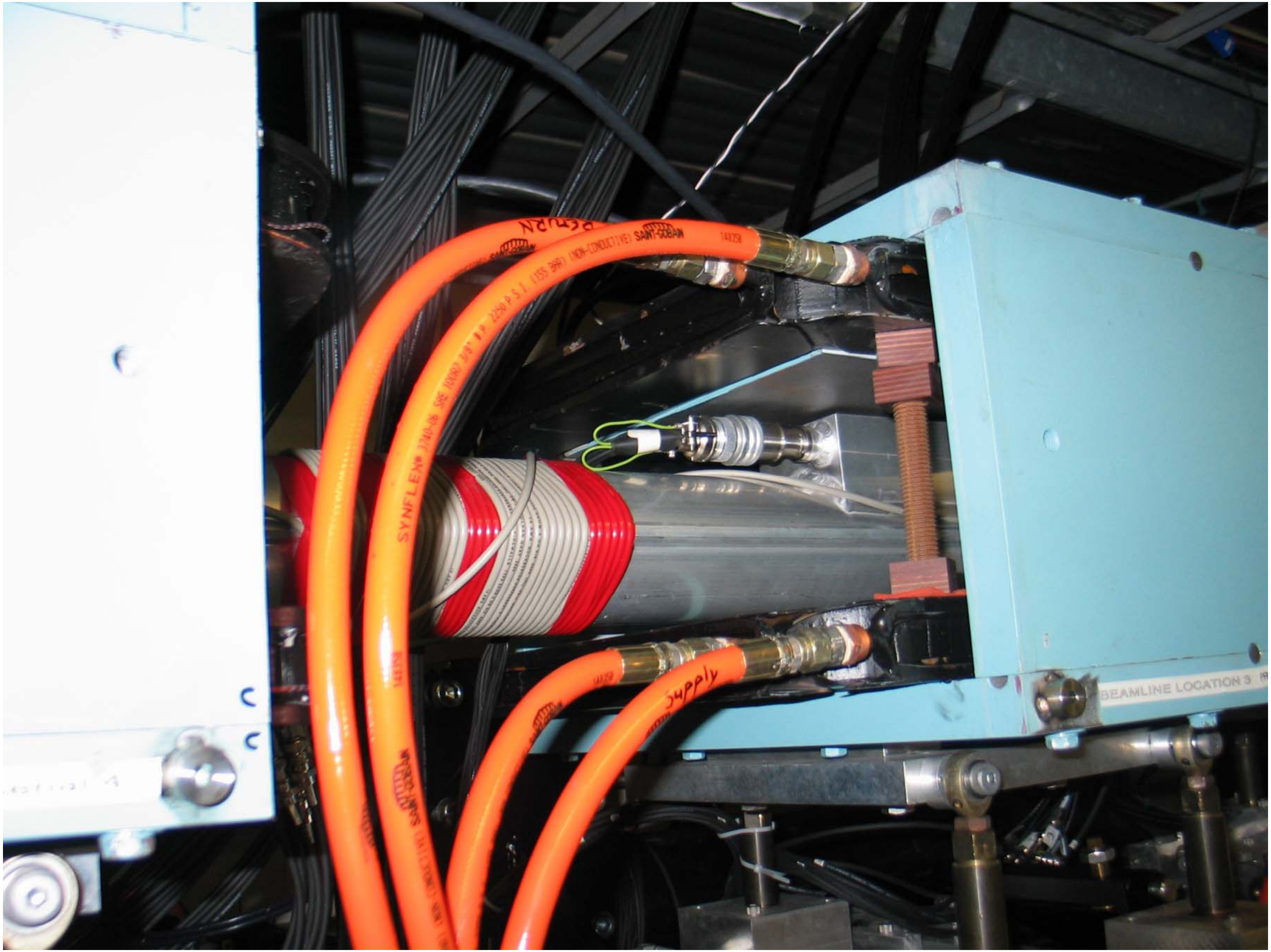
SEY station

Grooves/Smooth

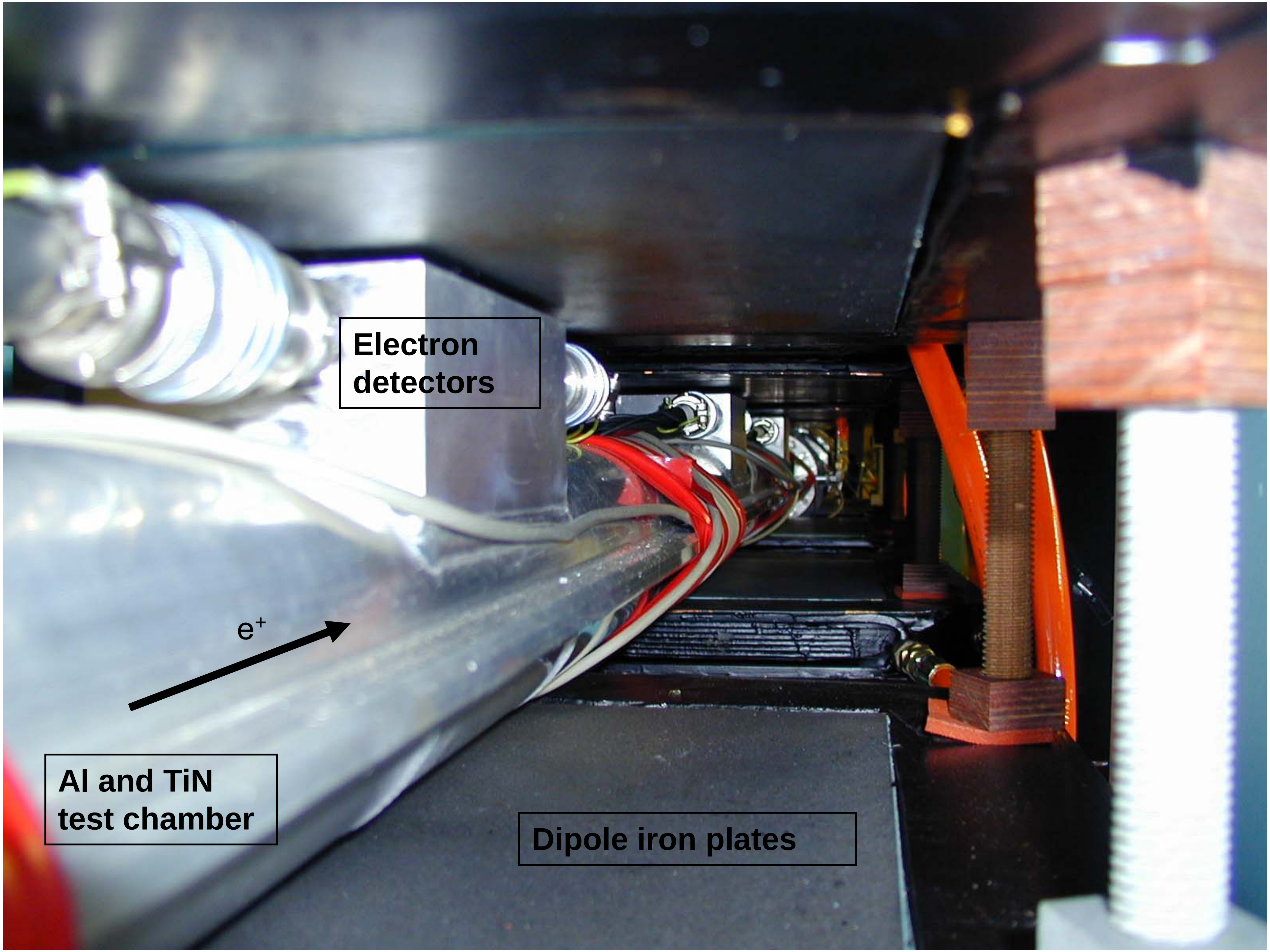
New chicane


Dec 3, 2007
HCOR





SAINT-GOBAIN
Supply
BEAMLINE LOCATION 3


Electron detectors
e+
Al and TiN test chamber
Dipole iron plates

Impact of e-cloud experiment on PEP-II operations

- Turning ON the solenoid around aluminum beam pipe, 2m long section, generated 4% luminosity increase
- Turning ON the chicane generated 1-2% luminosity increase

… making difficult to request dedicated time from PEP-II for testing

Plan for ECLOUD3 experiment in PEP-II

Measurements plan:

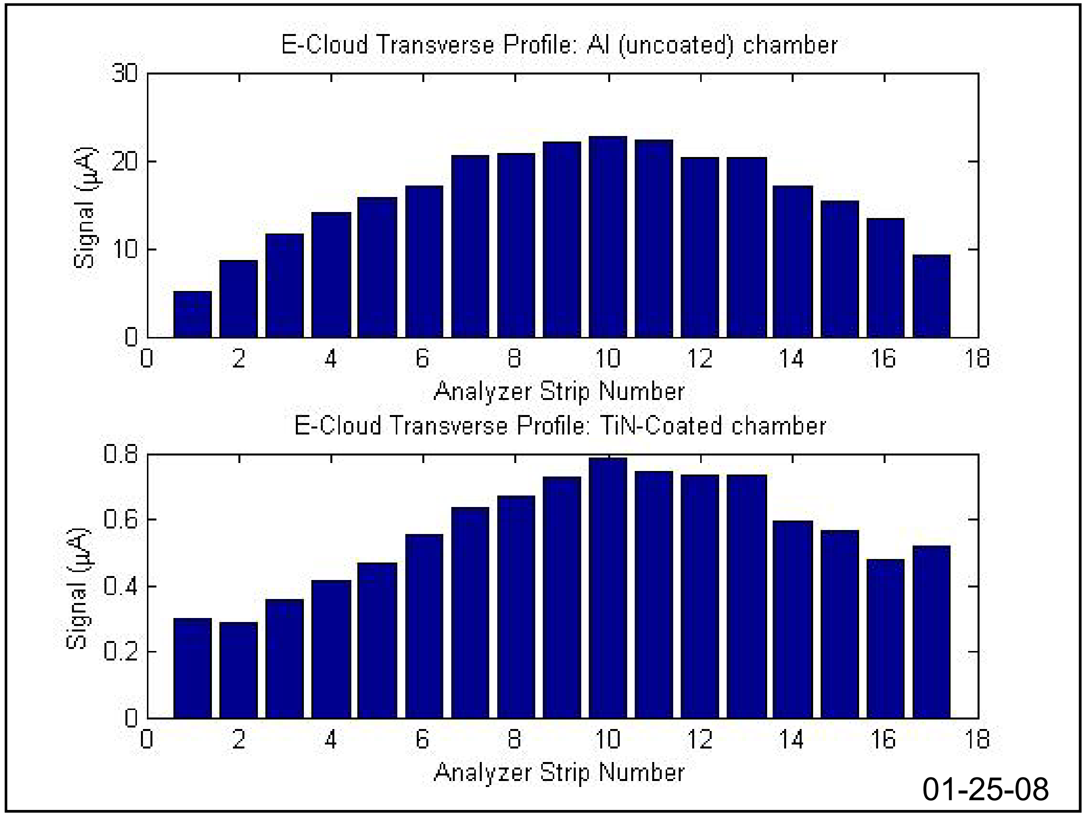
- Electron cloud current as a function of beam current
- Electron energy spectrum
- Verify existence of resonances in electron cloud density as suggested by C. Celata LBNL

for Aluminum and TiN coating chamber

Electron cloud detectors, SLAC

Electron **detectors** to measure e- horizontal distribution and energy

M. Pivi, R. Kirby, SLAC

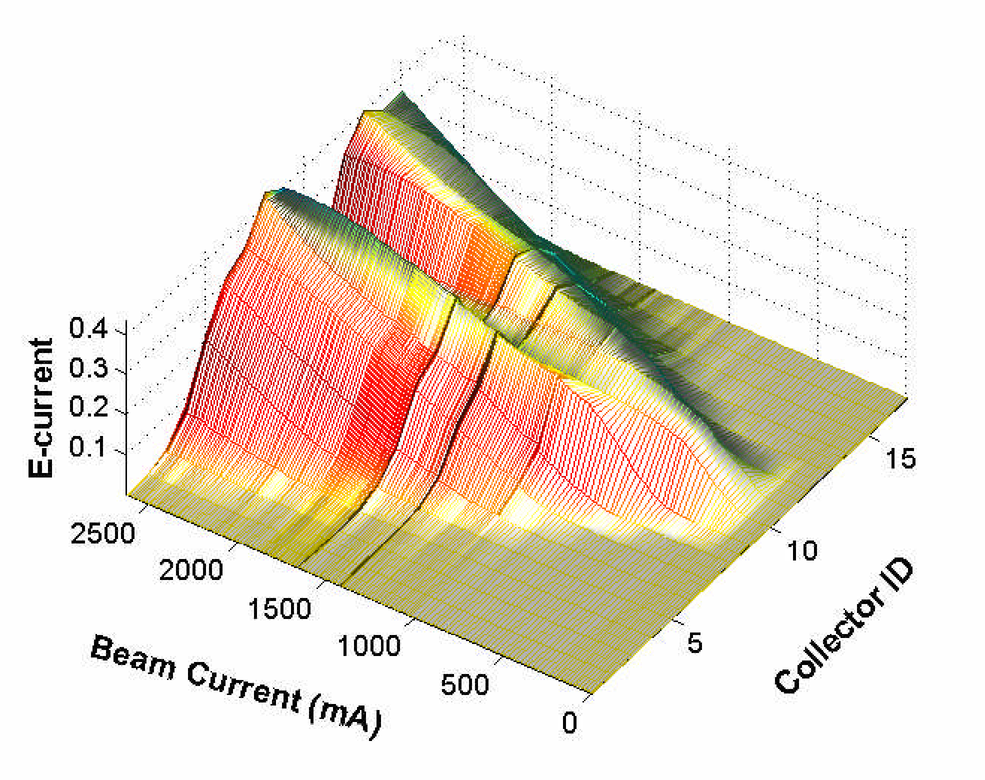


Chicane OFF.

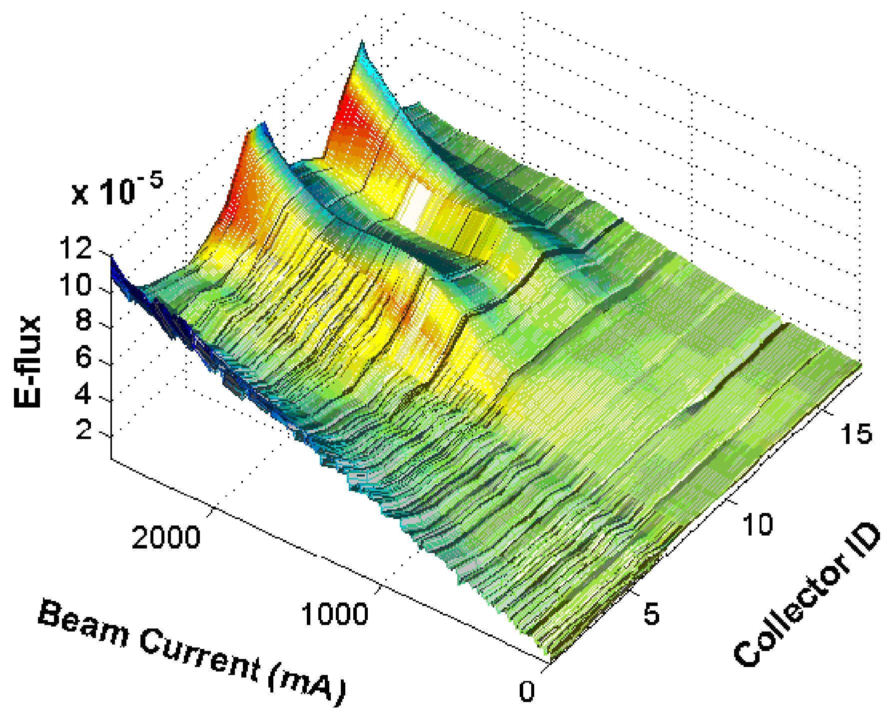
Collectors signal. Aluminum (above) and TiN coating (below) show a reduction of ~30.

ECLOUD3: Electron cloud in a dipole

Uncoated aluminum chamber



TiN-coated aluminum chamber

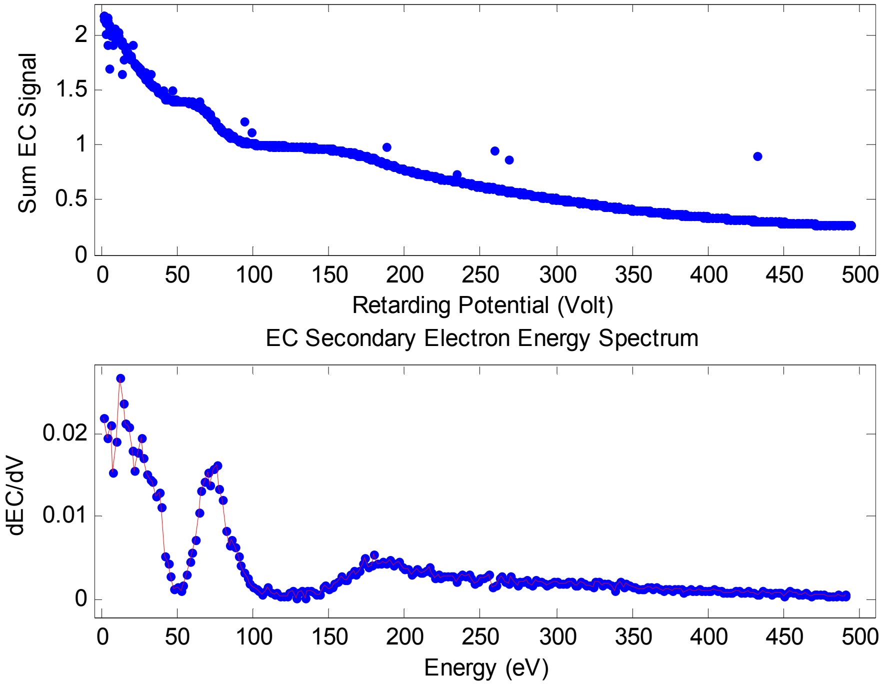


Lateral distribution consistent with simulation.

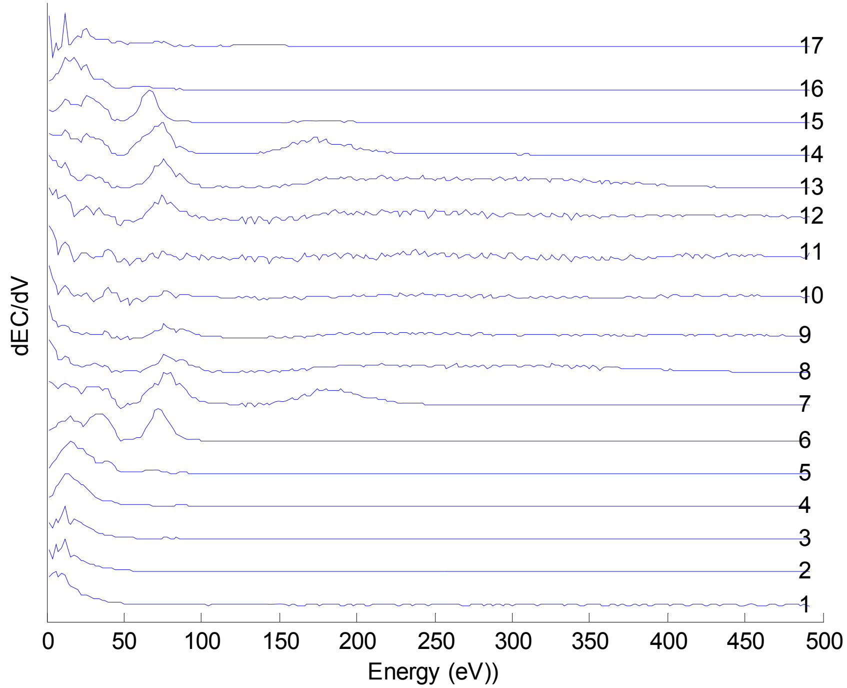
L. Wang et al, SLAC

ECLOUD3: Electron energy spectrum

Integrated and differential spectra: sum of all channels.

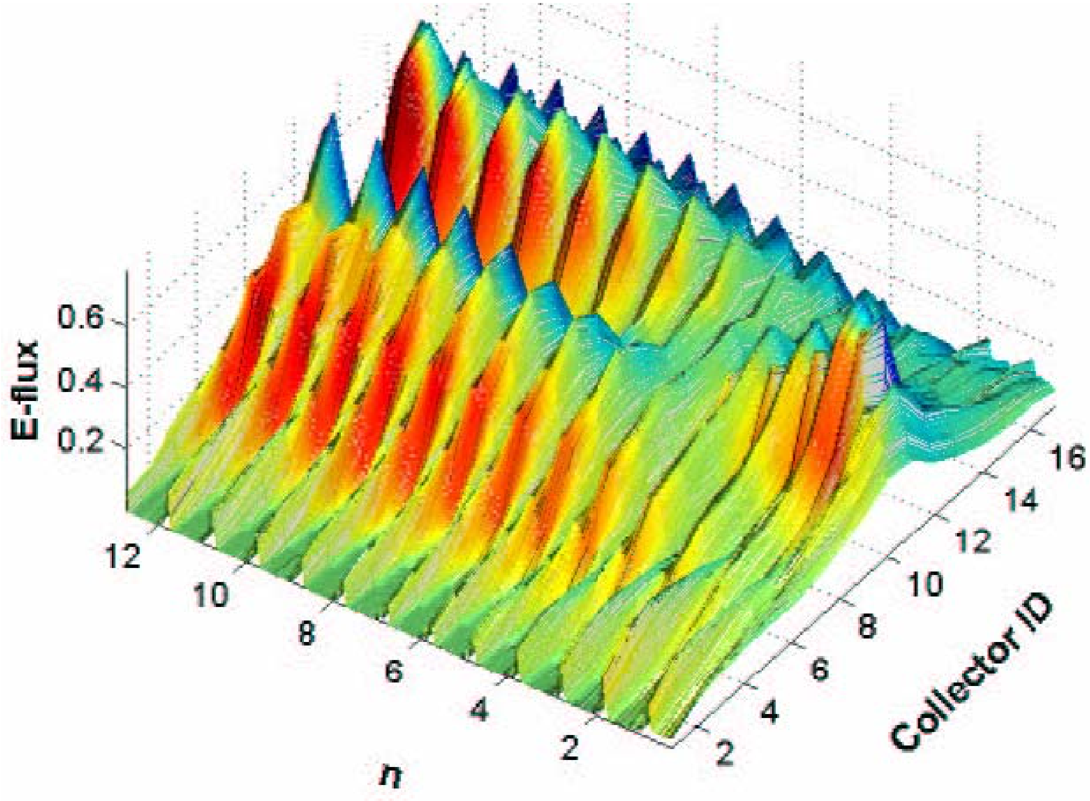


Differential energy spectra for each RFA channel.



- Features in energy spectrum characteristic of chamber geometry, bunch charge and bunch spacing
- Consistent with previous simulations. [L. Wang, ECLOUD04, SLAC-PUB-10751]

ECLOUD3: Magnetic field strength



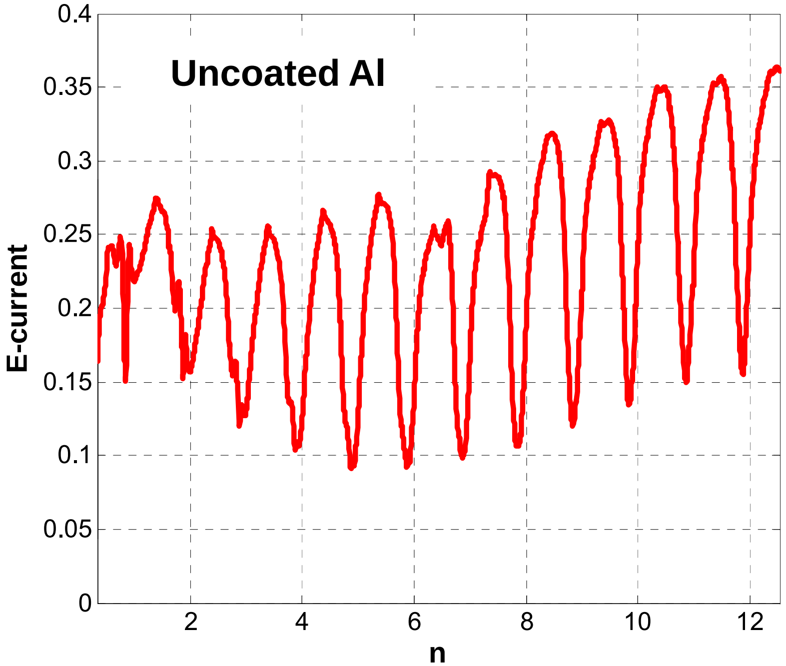
Electron flux peaks (and valleys) separated by integer values of n.

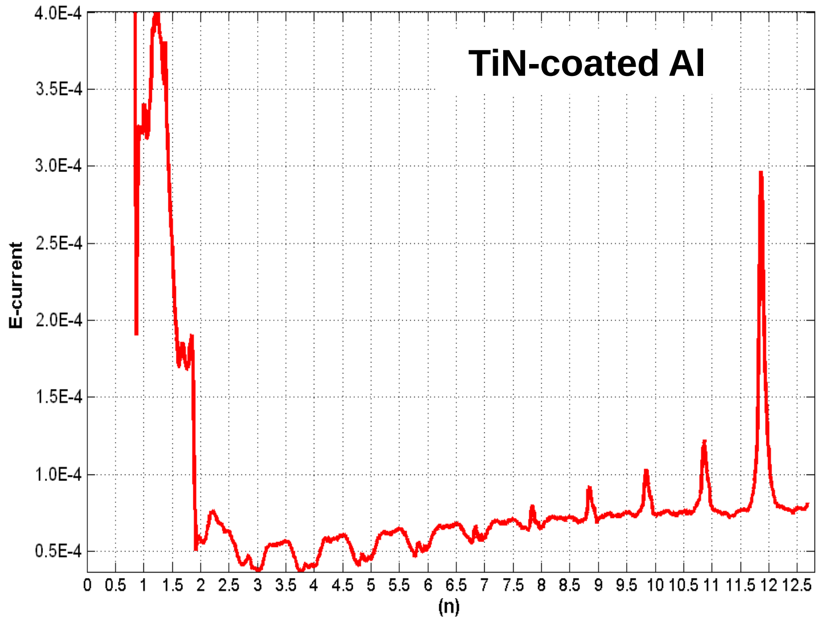
Phase of cyclotron motion with respect to bunch crossing affects energy gain, possibly leading to the observed modulation in electron flux at the chamber wall.

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

ECLOUD3: New resonance effect in a dipole

ECLOUD signal vs. B-field, summed over all strips





- TiN-coated chamber shows orders of magnitude lower signal
- Resonances expected from simulation (C. Celata *et al.*, LBNL)
- Data analysis continuing, with simulation efforts.

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 ⇒

Resonance

Important:

Cyclotron period is function only of B for v<<c.

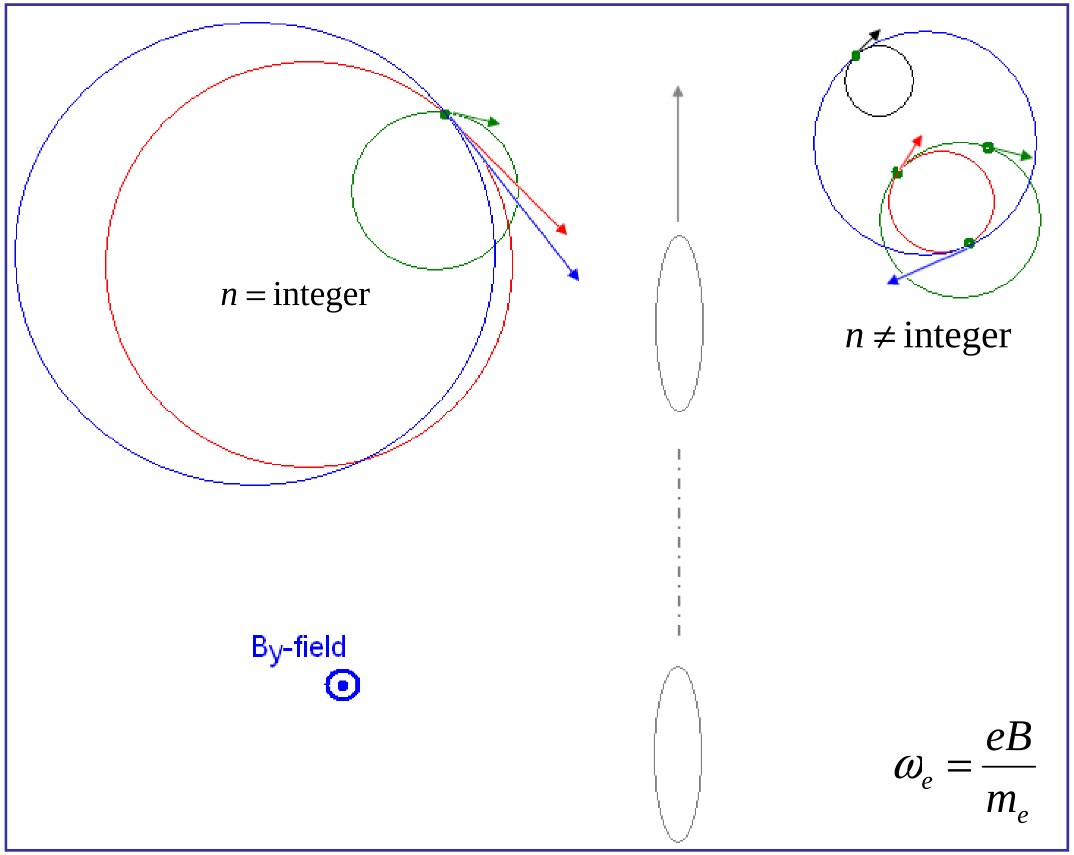
$$\tau_c = \frac{2\pi m_0 \gamma}{qB}$$

γ = relativistic factor

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

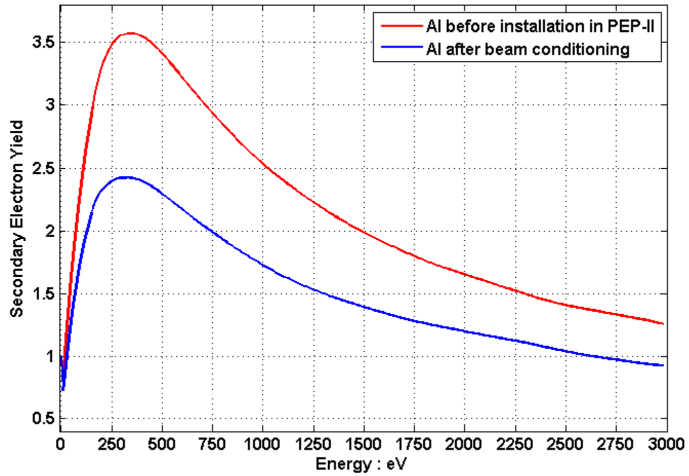
Celata, Feb. 14, 2008 16

Observed in simulations by C. Celata LBNL



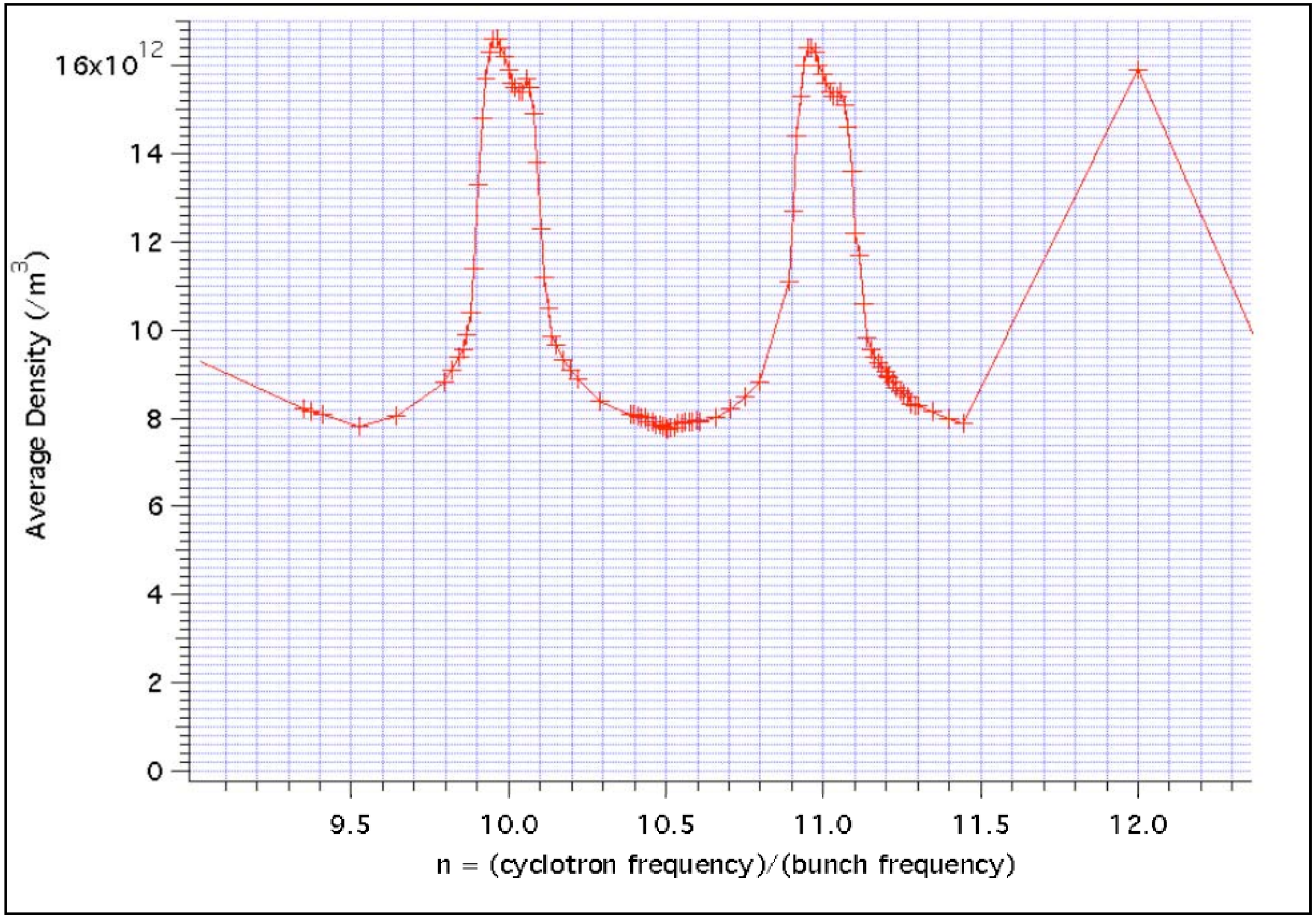
$$n = \frac{bunch\ spacing}{cyclotron\ period} = \text{integer} \rightarrow \text{larger energy gain}$$

$$n = \frac{bunch\ spacing}{cyclotron\ period} = \text{Half integer} \rightarrow \text{smaller energy gain}$$



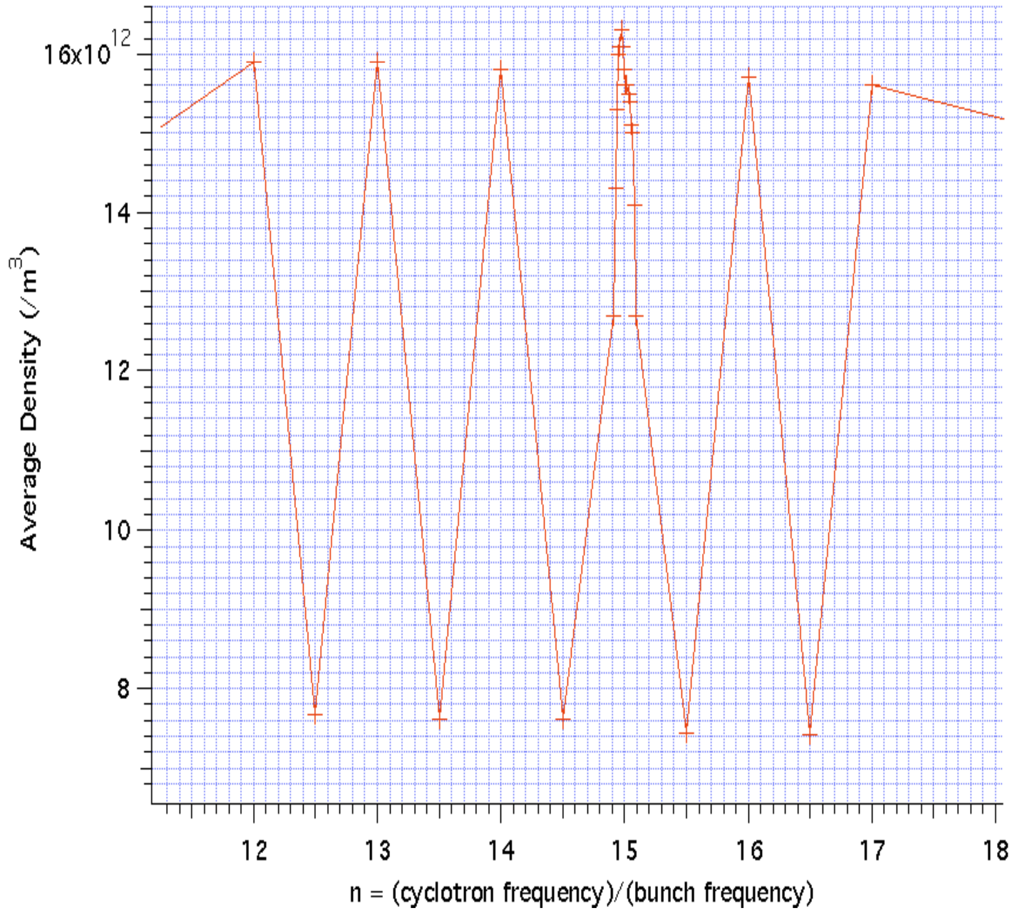
$n = \text{integer}$ →

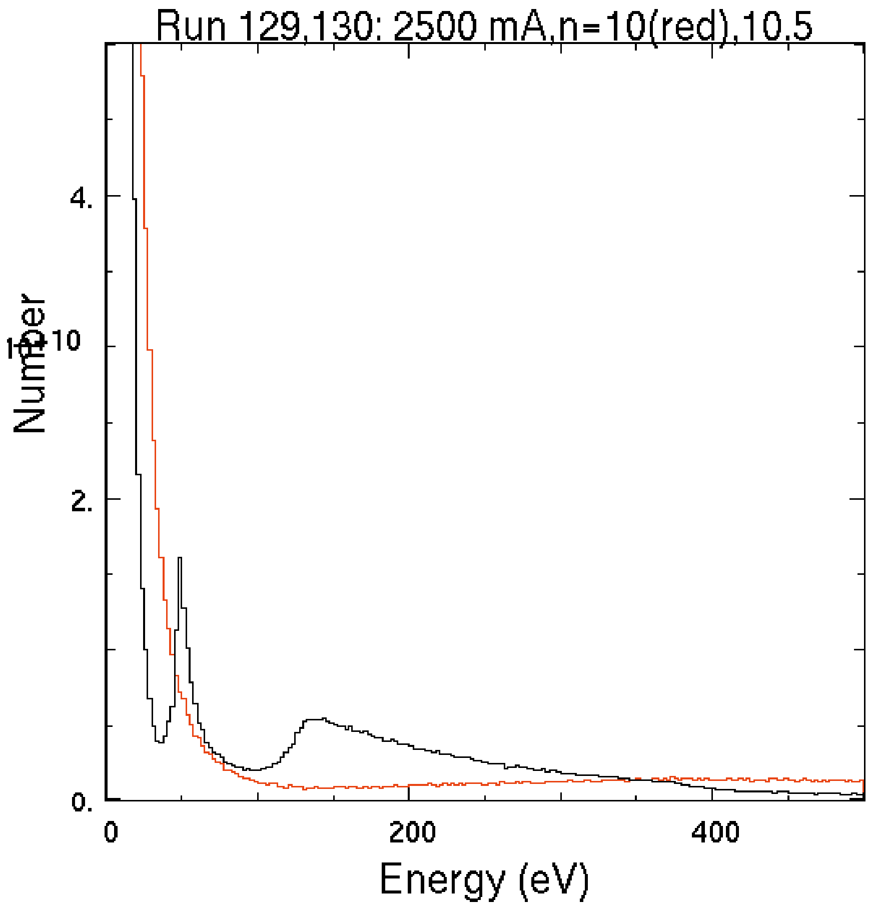
Simulations results with POSINST from C. Celata LBNL



Uniform magnetic field used in POSINST PEP-II simulations.

Simulations results from C. Celata LBNL





ECLOUD3 simulations and benchmarking Status

- SLAC / LBNL simulation effort ongoing

More detailed magnets measurements:

- Recently, we measured some By variation and fringe field at the edge of the magnet

- Precise magnetic measurements have started, to feed 3D electron cloud simulations

Electron cloud chicane Installation in PEP-II: ECLOUD3

- **Project management and coordination –** M. Pivi, J. Ng
- **Magnets –** C. Spencer
- **Power Supplies –** P. Bellomo
- **Magnets Stand Supports –** D. Kharakh
- **Vacuum chamber drawings –** F. Cooper
- **Vacuum chamber diagnostics & assembly –** R. Kirby
- **Cabling –** F. King
- **Electronics** A. Kacharovsky

D. Arnett, B. Smith, B. Kuekan, M. Munro, W. Wittmer, L. Wang, J. Olszewski, Wallace, T. Raubenheimer (SLAC)

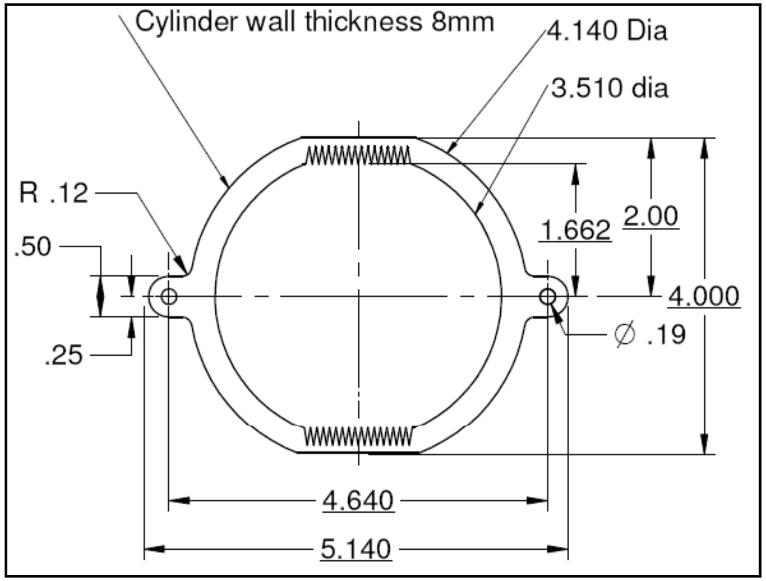
Thanks to PEP-II colleagues: M. Sullivan, J. Seeman, K. Burrows, S. De Barger, U. Wienands

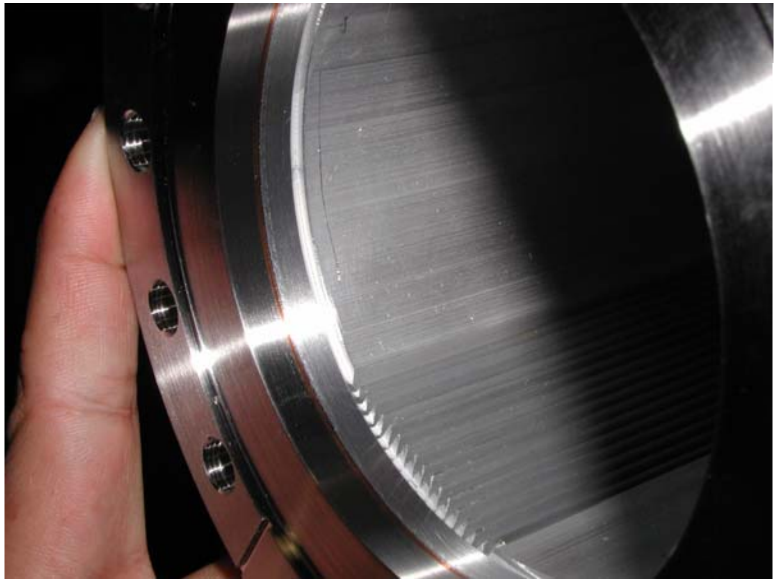
ECLOUD3: Summary

- Goal: mitigation of electron clouds in a dipole magnetic field region
- Preliminary results:
  - **Demonstrated TiN-coating is 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:
  - **M. Pivi, J. Ng et al., EPAC 2008;**
  - **paper being prepared for submission to Phys. Rev. Lett.**

ECLOUD3 Grooved chamber for Cesr-TA

- Grooved chamber for dipole:





Morrison, Pivi, Wang, SLAC

Chamber fabricated, but needs final assembly and TiN coating
(originally built for ELCOUD3, but was not installed due to budget cuts.)

Experimental plans SLAC

- Remaining issues:
  - **TiN durability: PEP-II TiN chamber samples**
  - **Measure SEY in a dipole**

- Moving to CesrTA:
  - **All PEP-II experiments: ECLOUD1, ECLOUD2, ECLOUD3**

- Moving to Fermilab:
  - **ECLOUD1, after CesrTA**

- Tests at KEKB and SPS at CERN, groove insertions

Milestones to ILC Technical Design Phase

The goal is to complete the following tasks by early 2011 as input for the Technical Design Phase:

- Select coatings in different regions of damping ring: TiN with respect to TiZrV non-evaporable getter NEG
- Characterize thin-film coating durability
- Need to experimentally characterize Photoemission in ILC DR parameters range to estimate initial electron density
- Characterize the electron cloud build-up and instability by simulations and measurements in existing accelerators

Milestones to ILC Technical Design Phase

- o Model build-up in wigglers and quadrupoles
- o Characterize the electron cloud instability in existing facilities and CesrTA
- o Model the ILC DR electron cloud instability

Evaluate need for additional mitigation techniques (besides coating):

- o Tested clearing electrodes in magnetic field at KEKB and CESR and SPS
- o Test triangular groove in magnetic field
- o Characterize the impedance and HOMs of mitigation techniques
- o Evaluate need of antechamber
- o Specify mitigation requirements in DR

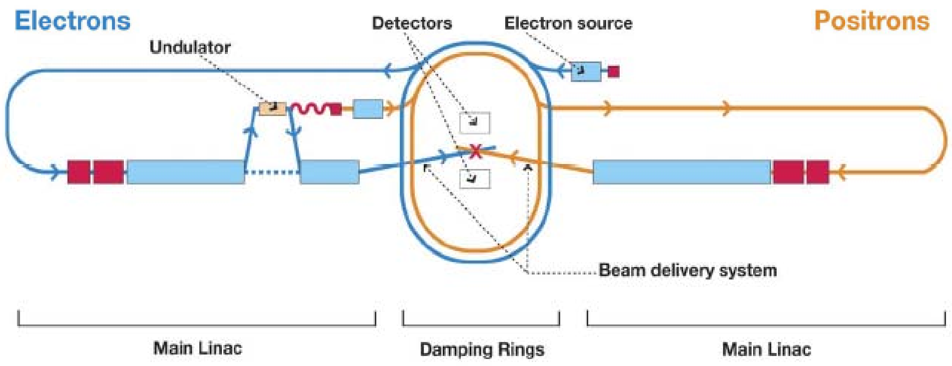
Recommendation of mitigation techniques as input for the TDP

Include trinagular groove mitigation tests at KEKB, SPS and at CesrTA

1. TiN durability

2. Measurements of SEY in dipole

e-cloud expectations in the positron DR



Simulated cloud density and single-bunch density threshold.

Circumference	6.7 km
Simulated ρ_e with δ_{max}=1.2 and solenoids [10^{11} m^{-3}]	0.7
SB: ρ_e threshold [10^{11} m^{-3}]	1.4
Sim. ρ_e / SB threshold	**0.5**

DR 6.7 km	ECLOUD	SEY THRESHOLD
arcs dipole	expected	~1.2
wigglers sections	expected	~1.2
Long straight sections	preventable	1.3

- In DR arcs and wiggler sections: aiming at SEY < 1.1
- In DR straight sections: preventable by large chamber apertures, coating, solenoid and/or grooves.

Aluminum chamber

Electron energy spectrum

J. Ng, SLAC

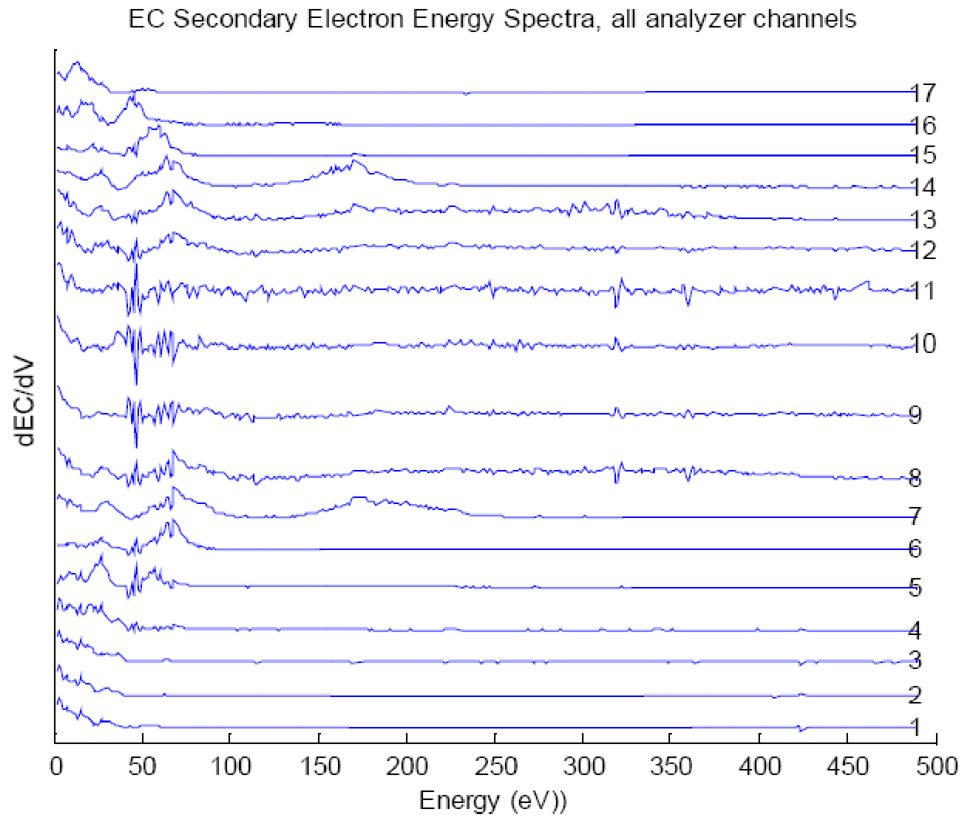
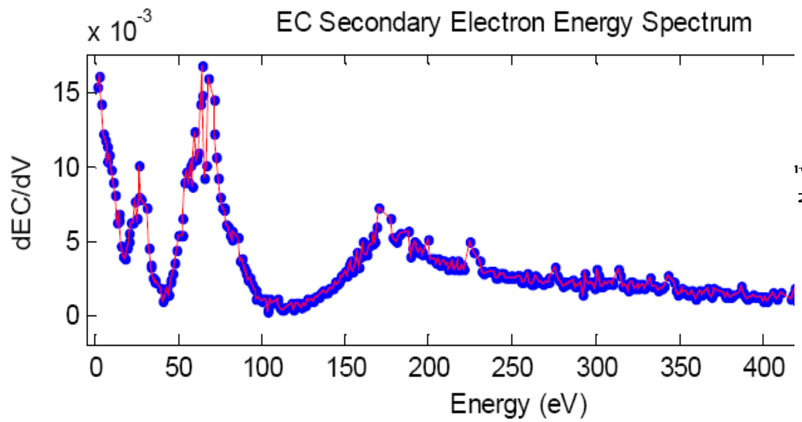


Figure 18. Energy spectra for all analyzer strips. Solenoid Off. n=10.5.



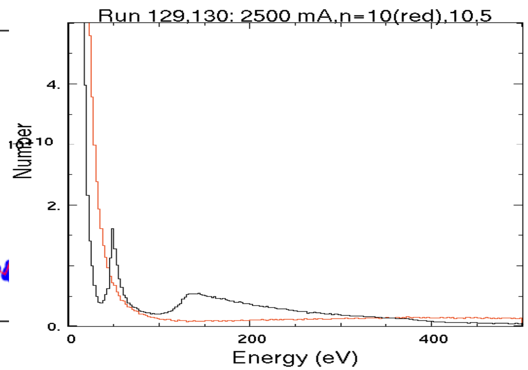
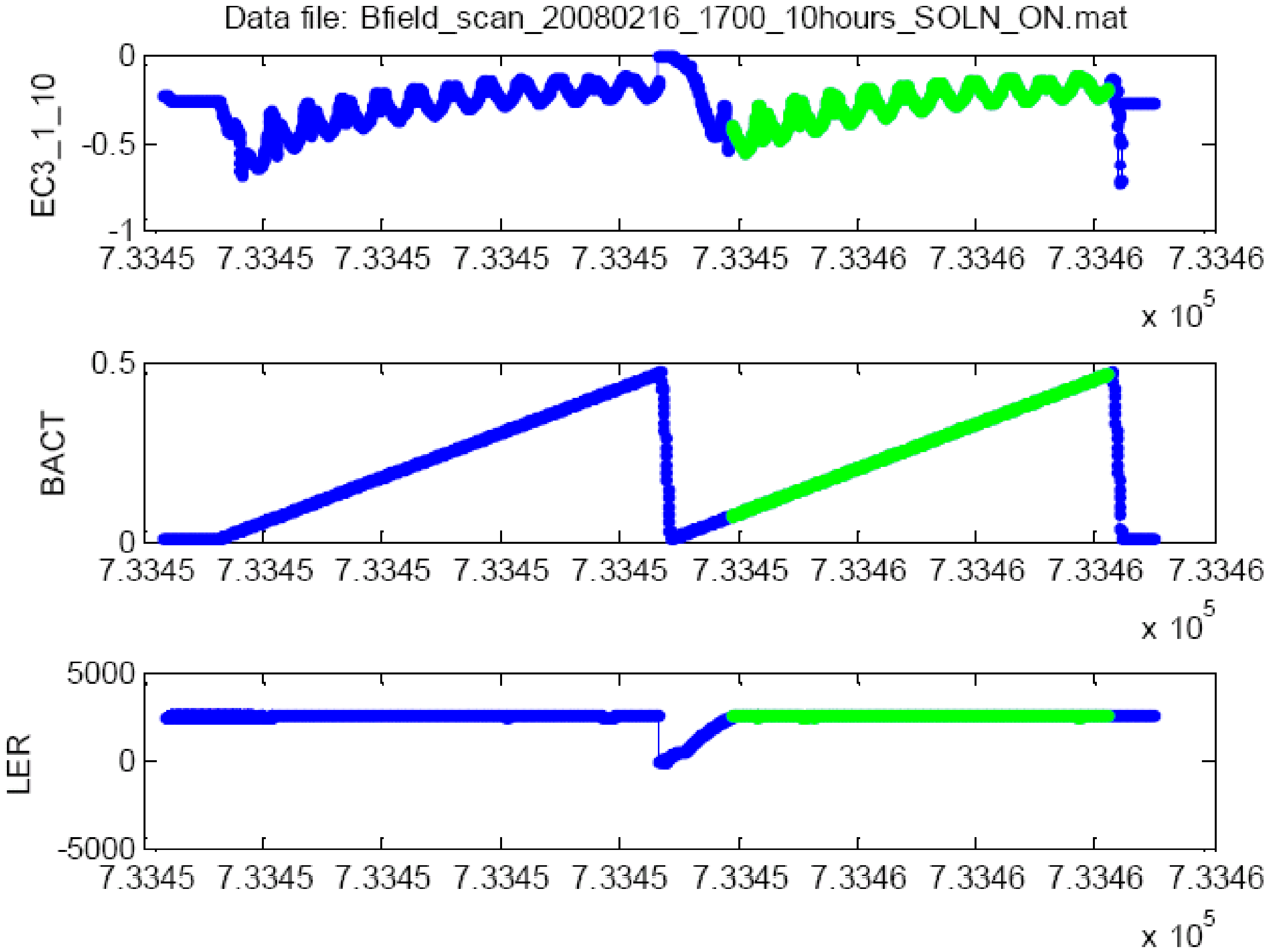


Figure 17. Energy spectrum, summed over all analyzer strips. Solenoid OFF. n=10.5.

From previous slide.
Simulated energy spectrum

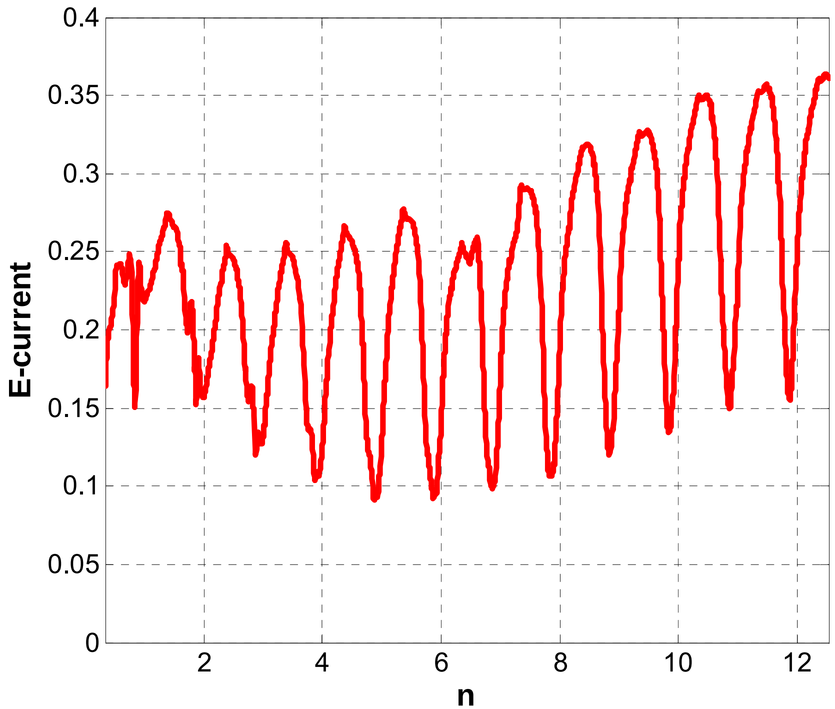


Collector signal (top) and Chicane B-field (middle) scans. Two scans. Beam current about 2500mA (bottom). External solenoid on.

Electron cloud resonances: Aluminum chamber

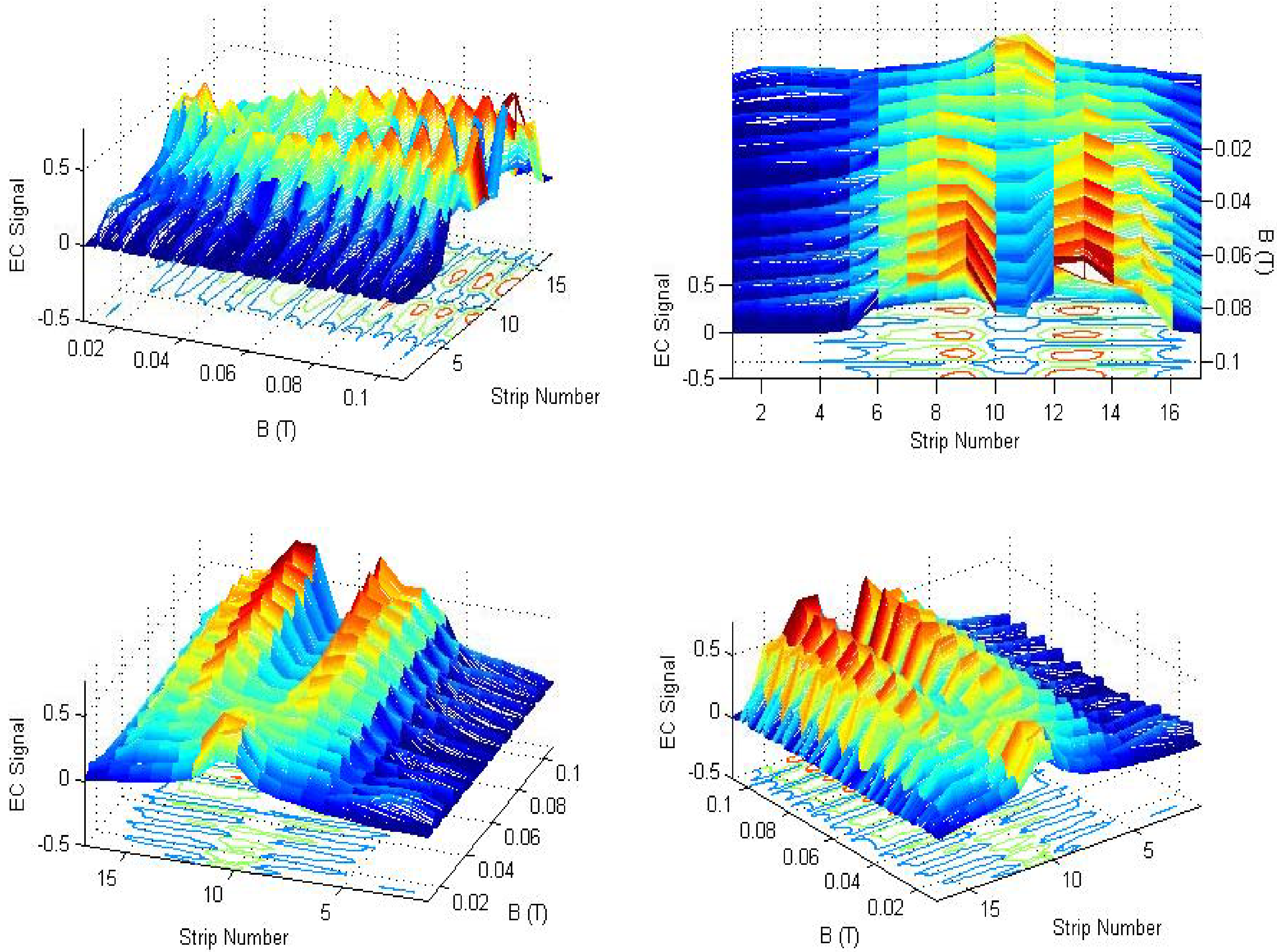
- There is a maximum of electron signal at **n~integer +0.5**
- There is a minimum of electron signal close at **n~integer**
- But expected maximum and minimum with 0.5 integer shift

Beam current, collectors voltage, and Chicane magnetic field



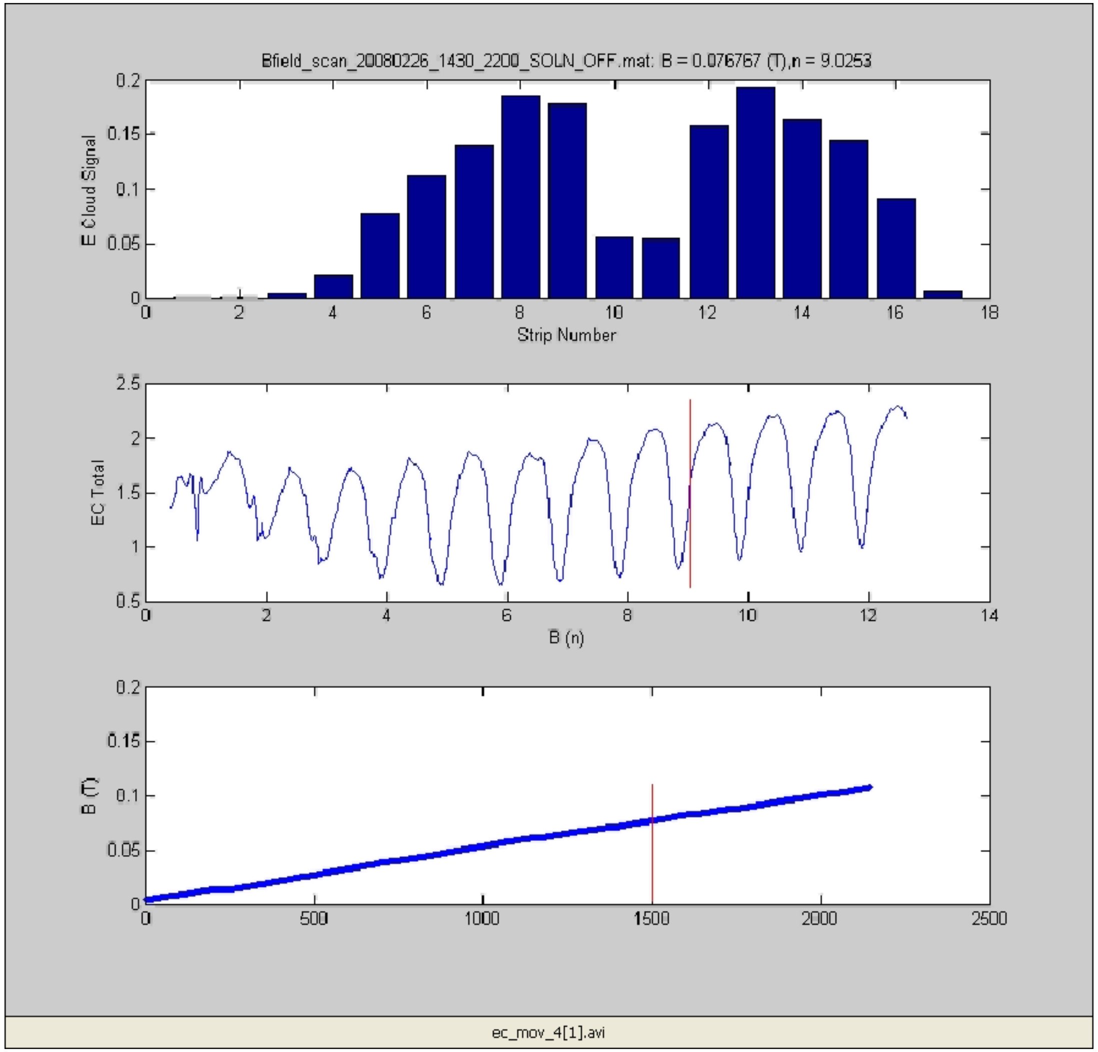
Sum of the 17 collectors signal vs magnetic field (n)

n=bunch spacing / gyration motion period

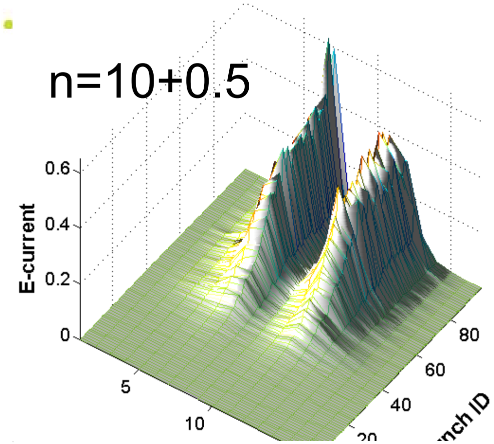


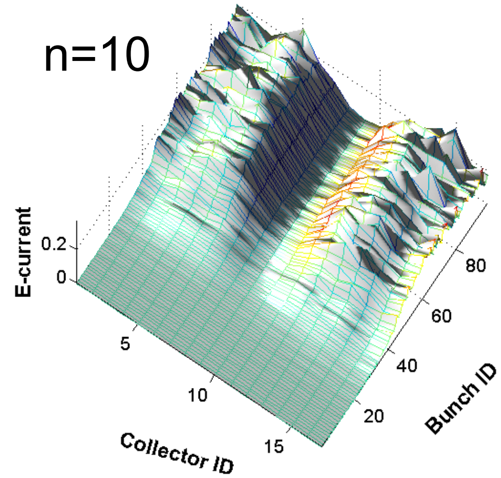
Johnny Ng SLAC

Cloud horizontal distribution in dipole



Experiment



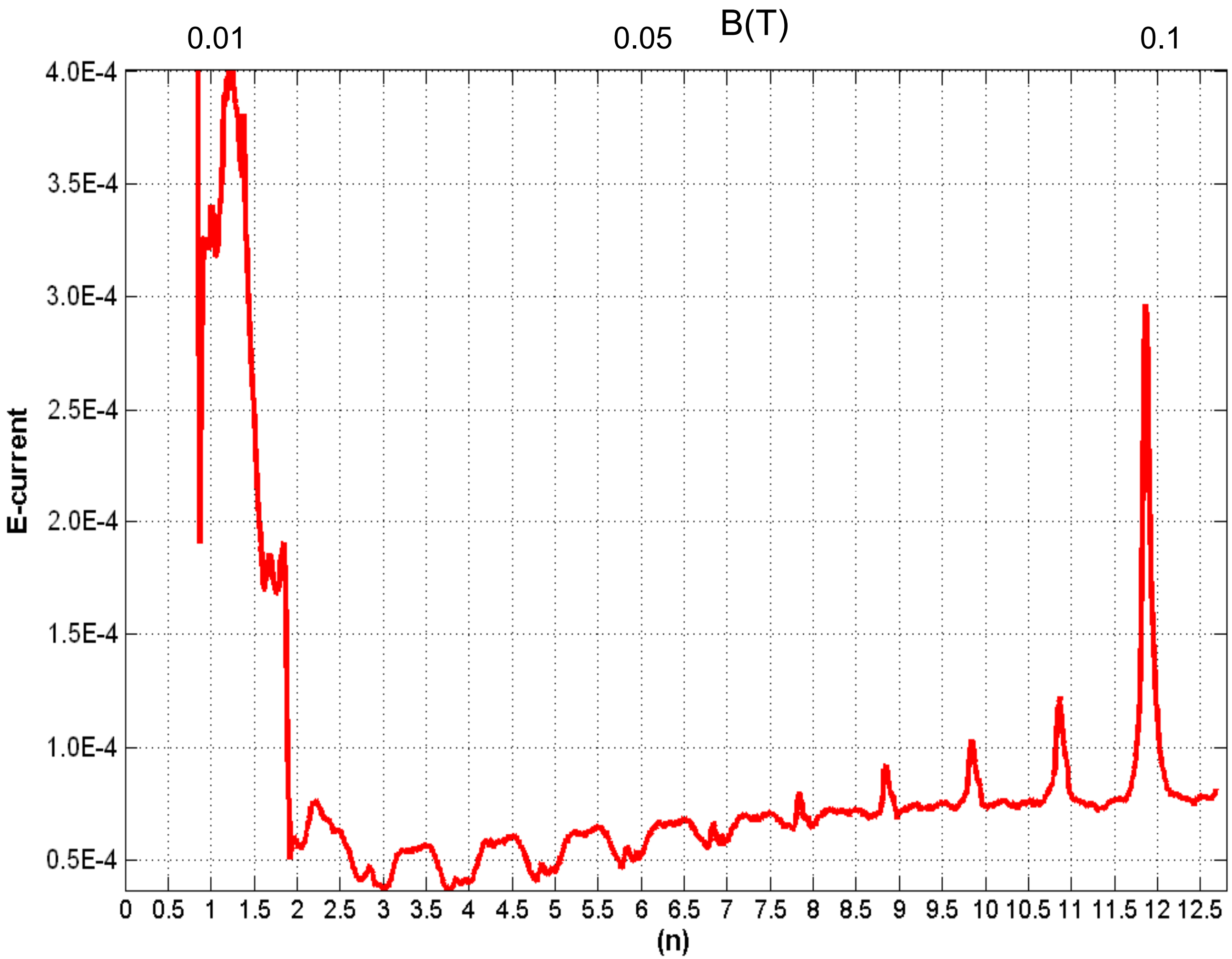


Simulation

Lanfa Wang, SLAC

Animation by J. Ng, SLAC

TiN chamber results



Electron cloud current vs B-field, sum of all stripes. TiN chamber.