# AAP Review - Electron Source

Axel Brachmann
SLAC

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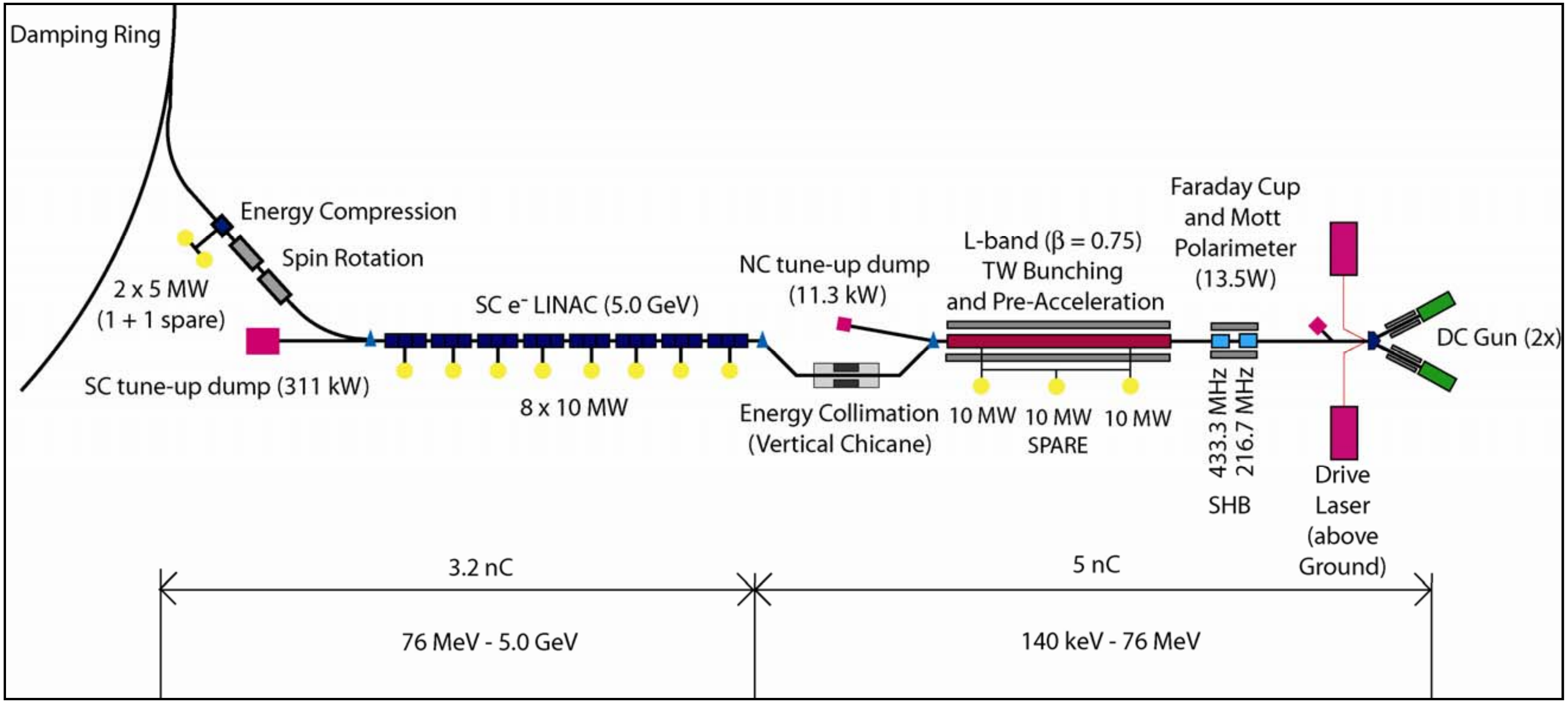
# The Baseline Source

Electron source provides polarized electron beam and consists of all systems from source laser to 5 GeV injection to damping rings.



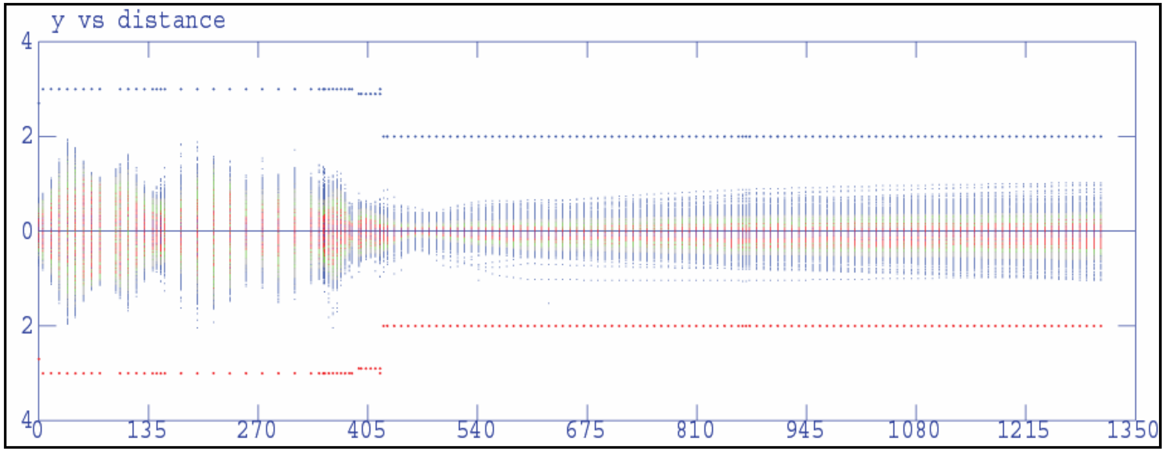
# Source Parameters

| Parameter | Symbol | Value | Unit |
|---|---|---|---|
| **Electrons per bunch (at gun exit)** | $n_e$ | $3 \times 10^{10}$ | **Number** |
| **Electrons per bunch (at DR injection)** | $n_e$ | $2 \times 10^{10}$ | **Number** |
| **Number of bunches** | $N_e$ | ~ 3000 | **Number** |
| **Bunch repetition rate** | $F_{\mu b}$ | 3 | **MHz** |
| **Bunch train repetition rate** | $F_{mb}$ | 5 | **Hz** |
| **Bunch length at source** | $\Delta t$ | ~ 1 | **ns** |
| **Current in bunch at source** | $I_{avg}$ | 3.2 | **A** |
| **Energy stability** | S | < 5 | **% rms** |
| **Polarization** | $P_e$ | 80 (min) | **%** |
| **Photocathode quantum efficiency** | QE | 0.5 | **%** |
| **Drive laser wavelength** | $\lambda$ | $790 \pm 20$ | **nm** |
| **Single bunch laser energy** | E | 5 | **μJ** |

# Beam Line Optics

- Complete set of optics from Gun to DR is available
- Low Energy simulations : include space charge

**Example: Beam envelope along the NC injector**




➢ 95% of electrons produce by the DC gun are captured within 6-D damping ring acceptance:

$\gamma(Ax+Ay) \leq 0.09\text{m}$ and $\Delta E \times \Delta z \leq (\pm 25 \text{ MeV}) \times (\pm 3.46 \text{ cm})$

# Critical Issues

- Source Laser System
  - **This is primarily an engineering task**
  - **Challenge is to integrate various state of the art laser technology aspects into one system that is matched to Photocathode and Gun**
- DC Gun
  - **High Voltage/High Gradient to counteract space charge forces**
  - **UHV technology ($10^{-12}$ Torr)**
- Photocathodes
  - **Main issue is the surface charge limit**
  - **QE/Polarization**

# R&D Program

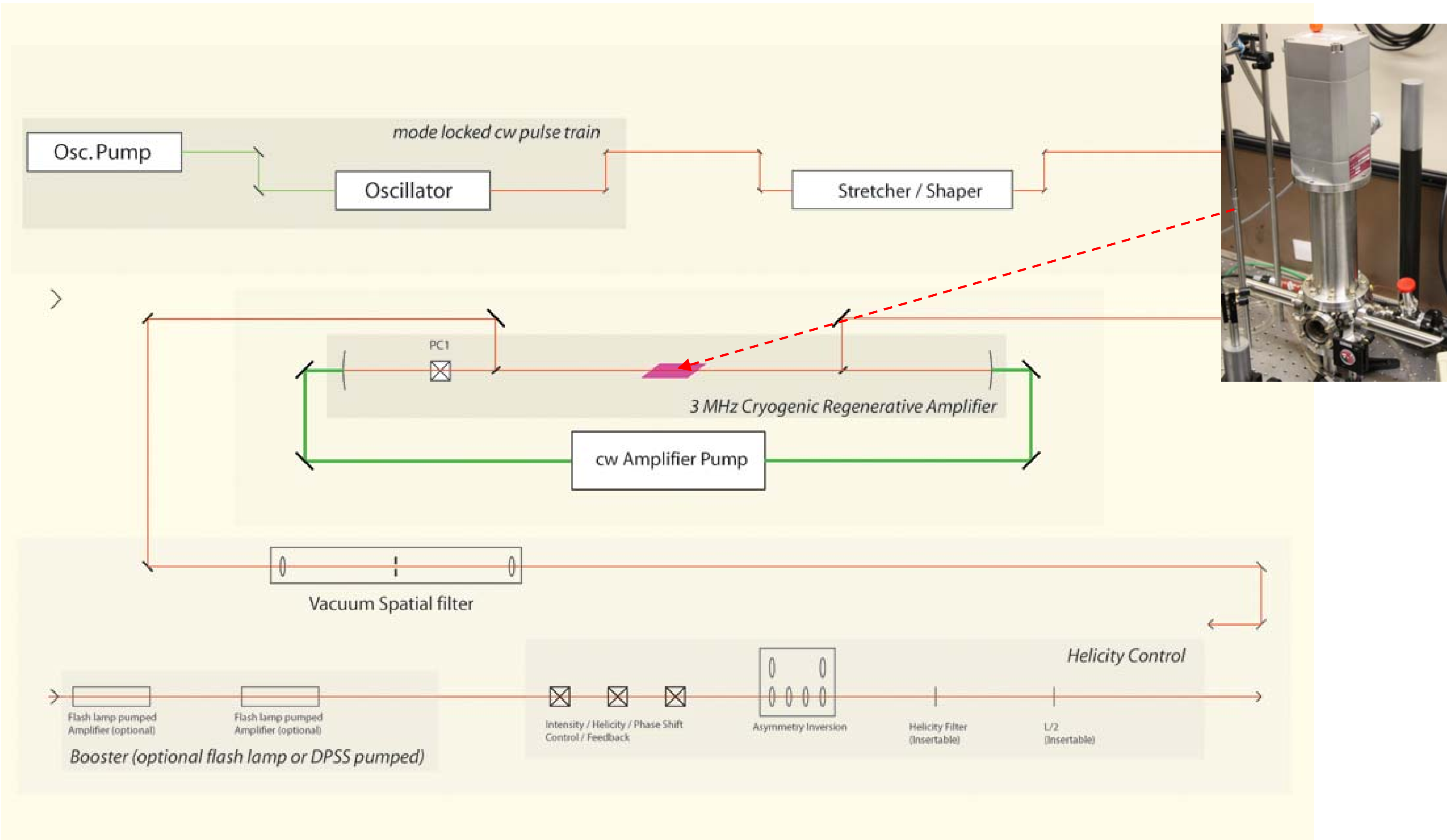
Active R&D focus on 'critical' issues and accelerator physics:

- **SLAC:**
  - Laser system development
  - Photocathode R&D
  - Optics design
- **Jlab**
  - DC Gun development
- **Japan**
  - Anticipate continuation of Univ. of Nagoya Photocathode and DC gun work at KEK
- **SBIR (DOE sponsored Industry collaboration)**
  - Laser and photocathode R&D

# R&D beyond Baseline Design

- RF guns for polarized beams
  - **BNL: SC RF Gun**
  - **FNAL: NC RF Gun Plain Wave Transformer**
- Source development at test facilities
  - **E.g. STF @ KEK (but unpolarized)**
- New method of generating polarized electrons from GaAs without NEA requirement
  - **See talk by H. Tomizawa (Spring 8)**

# Laser System Development

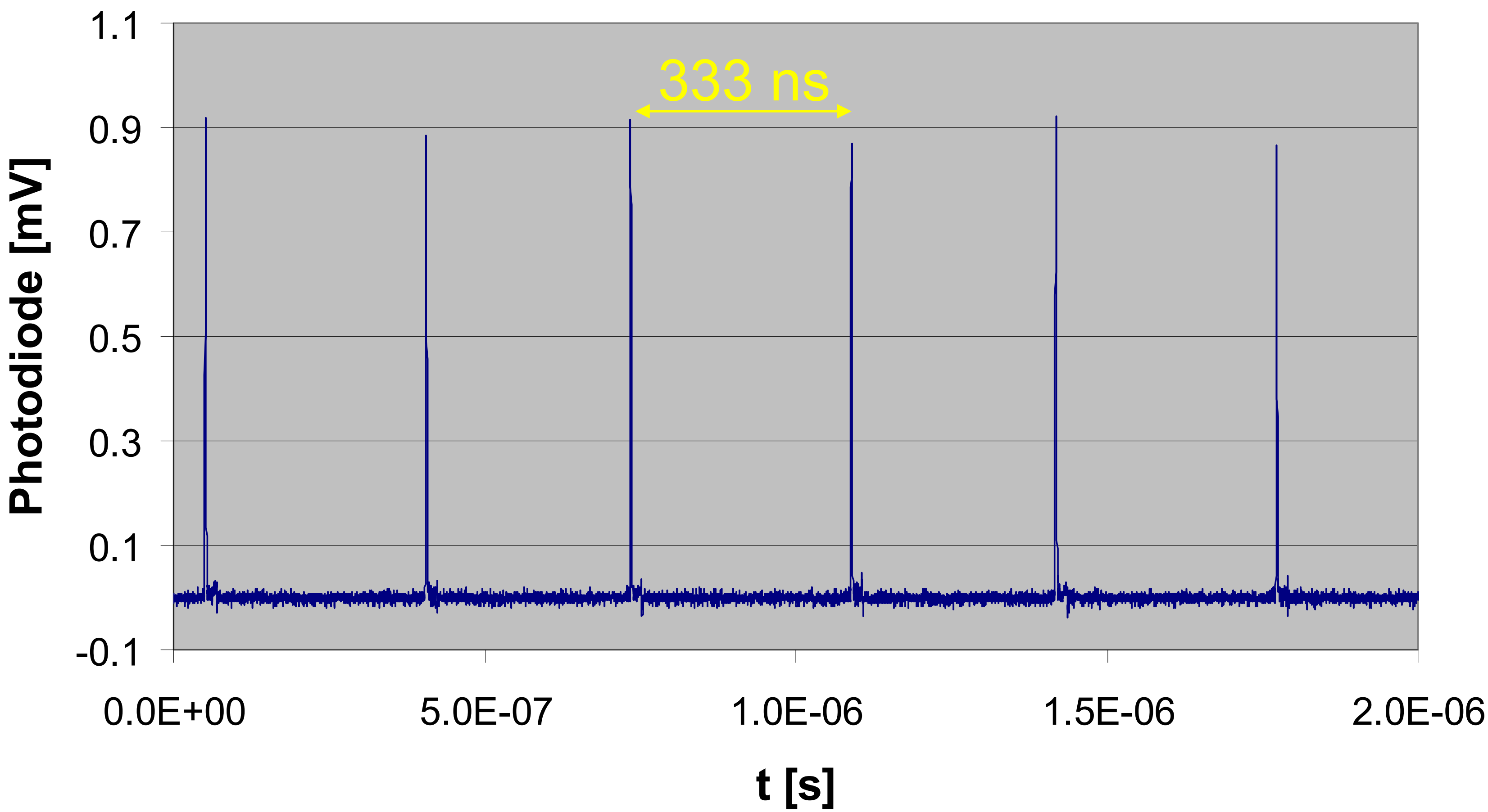


# Laser R&D progress

- Development of amplifier seed √
  - **Modelocked oscillator**
  - **Optical pulse stretching to 600 ps – 1 ns**
- Successful test of pulse switching at 3 MHz √
  - **component of regenerative amplifier**
- Current work now
  - **40 W frequency doubled cw Yb:YAG laser**
  - **Re-engineering of amplifier pump laser**
- For regenerative amplifier a cryogenically cooled Ti:Sapphire crystal will be used next
  - **Suppression of thermal lensing**

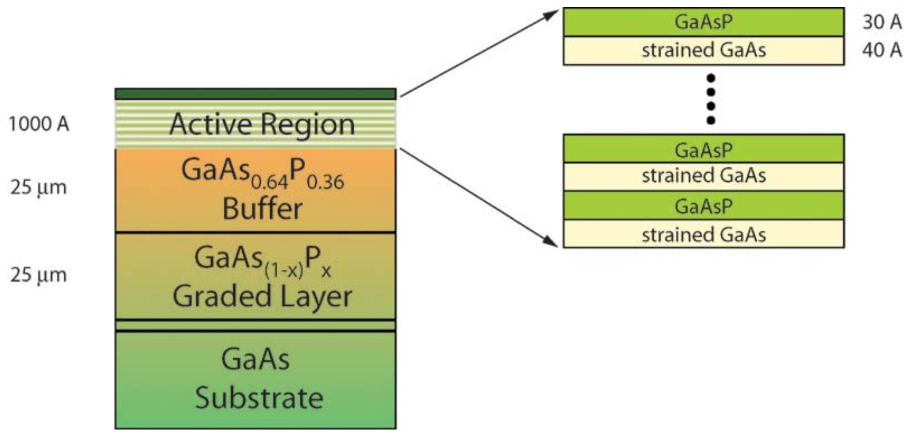
# Generation of 3 MHz seed pulse train

Switching of 79 MHz modelocked seed laser with 3 MHz Pockels cell:



# Photocathode Research

## Baseline Design: GaAs/GaAsP




- Semiconductor engineering to optimize current designs to ILC conditions:
  - **Composition and layer structure**
  - **Doping level**
  - **Activation technique**

  } 

  - **QE**
  - **Polarization**
  - **Lifetime**
  - **Surface charge limit**

# Photocathode R&D Highlights

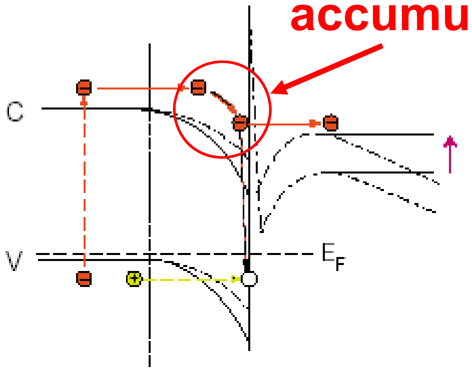
- Use of SLAC's polarized source development facility
- Faraday Rotation System to study depolarization mechanism
- Testing of various alternatives to GaAs/GaAsP → InAlGaAs, AlGaAs
- Co-deposition of alkali elemements enhances cathode lifetime, improves robustness
  - **traditionally Cs only; new techniques e.g. Cs+Li**
    - SBIR/SLAC collaboration (SBIR partner: SAXET Surface Science, Inc)
- Most important question remains:
  - **Surface charge limit**

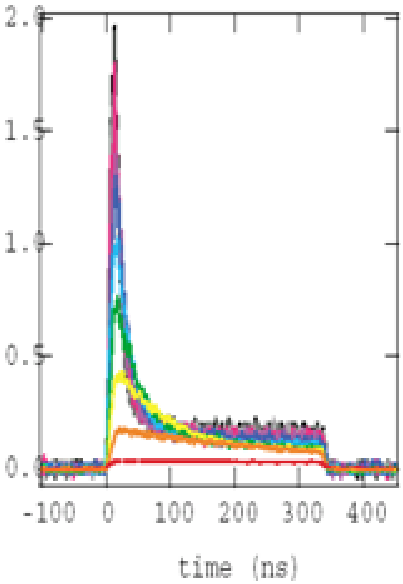
  → **needs ILC laser system**

# Surface charge limit

- Photon absorption excites electrons to conduction band
- Electrons can be trapped near the surface; electron escape prob. < 20%
- Electrostatic potential from trapped electrons raises affinity
- Affinity recovers after electron recombination
- Increasing photon flux counterproductive at extremes

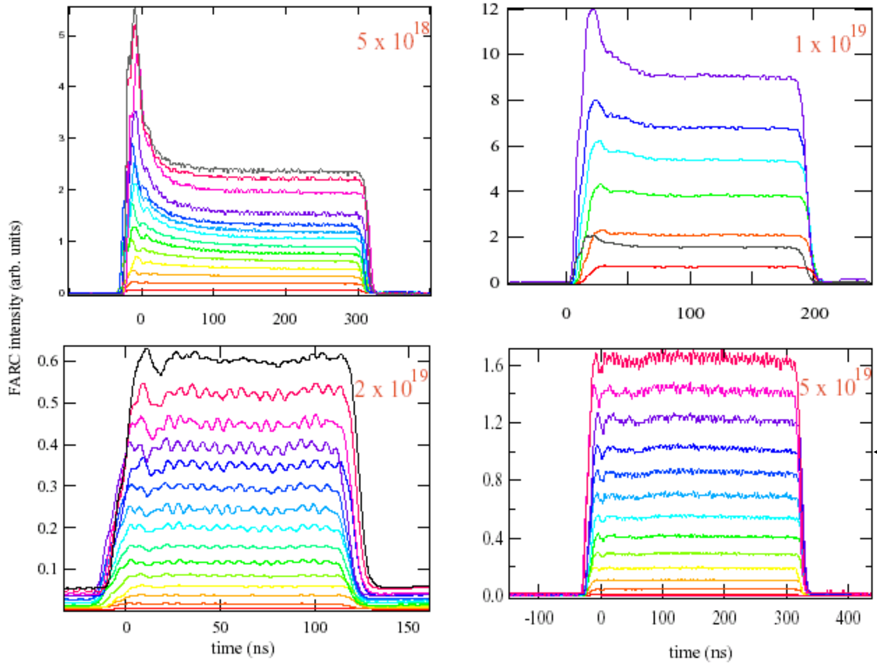
Electron accumulation



# Surface charge limit mitigation

Optimization: Adjustment of doping level
Caveat: Negative effect on Polarization




Four samples with different doping levels:

- $5\times10^{18}$ cm$^{-3}$
- $1\times10^{19}$ cm$^{-3}$
- $2\times10^{19}$ cm$^{-3}$
- $5\times10^{19}$ cm$^{-3}$

~ 2 A (laser limited)

ILC peak current at source: 4 to 5 A

Measurement at ms time scale is required!

# DC Gun Research

- Based on past experience at SLAC and Jlab
- Currently Gun R&D program is carried out at Jlab under Matt Poelkers leadership
- Synergy with CEBAF injector development
  → **Beneficial to ILC**

- R&D program:
  - **UHV technology (vacuum system, materials)**
  - **HV design (power supply, normal vs. inverted)**
  - **Geometry of Pierce electrodes optimization for ILC beam**

# Minimum Machine Impact

- Minimum Machine does not change e- source parameters → fundamental design changes are unlikely
- Single tunnel design is feasible in general
- Questions :
  - Tunnel space sharing (multiple beam lines) needs CAD model and evaluation :

  → International working group for 3D visualization

  - RF distribution :

  → adopt main linac solution for SC part of the source

# Summary

- RDR design remains baseline

- Activities focus on R&D to solve critical source issues:
  - **Source Laser system**
  - **DC Gun for polarized beams**
  - **Photocathodes**

- Goal is to demonstrate nominal ILC beam using optimized photocathodes, laser system and DC Gun

→ integrated injector test lab