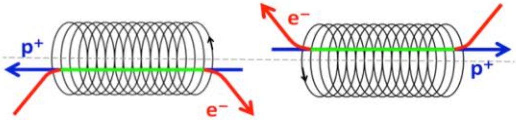
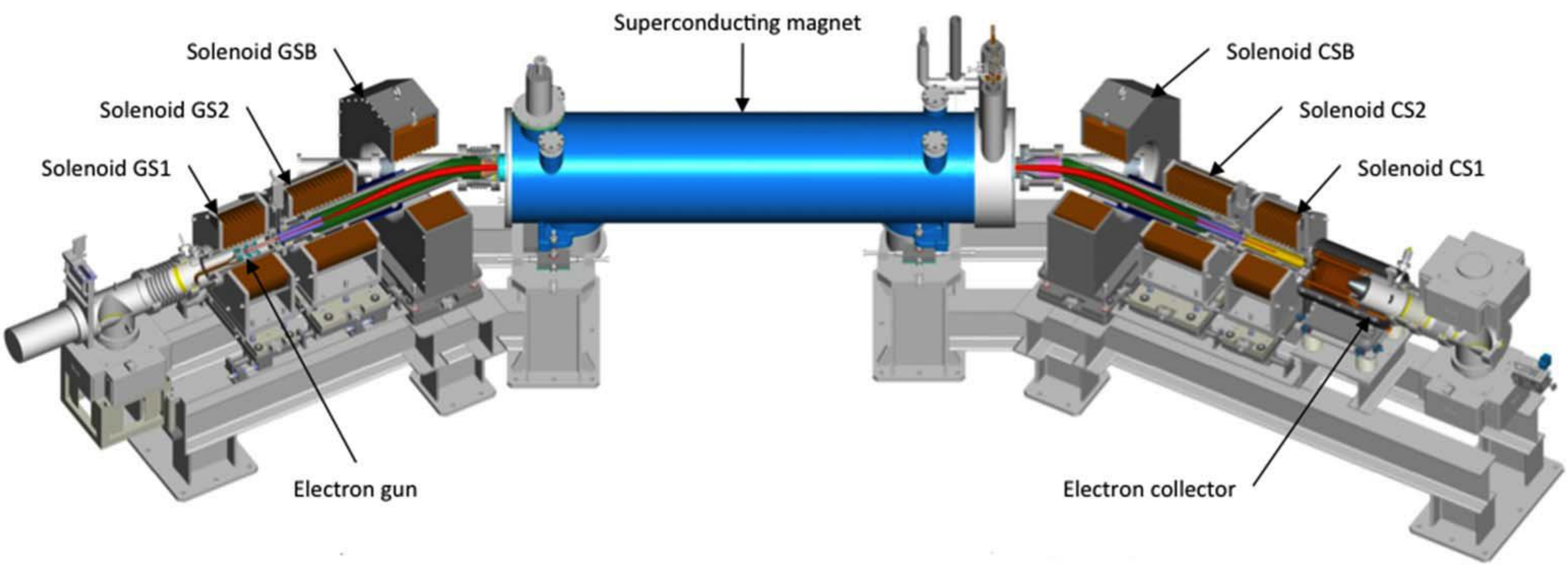


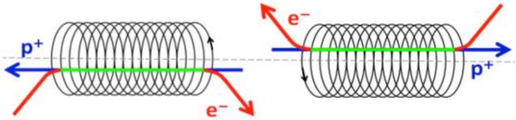

# ELECTRON-LENS TEST STAND INSTRUMENTATION PROGRESS

T. A. Miller†, J. Aronson, D. M. Gassner , X. Gu, A. Pikin, P. Thieberger,
C-AD, BNL, Upton, NY, 11973, U.S.A.

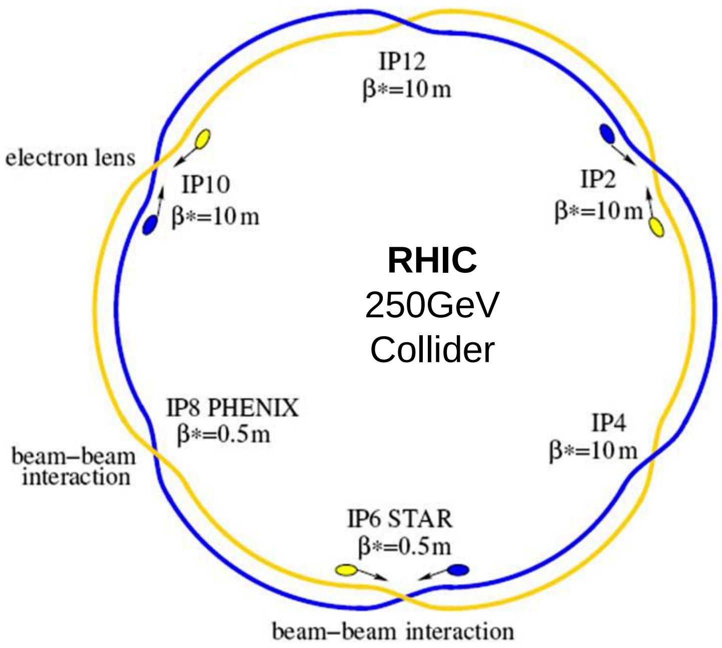



†tmiller@bnl.gov

# Electron Lens Overview




Partial head-on beam-beam compensation with one E-Lens per ring.




Basic idea:

- 2 beam-beam collisions with positively charged beam
- Add collision with a negatively charged beam – with matched intensity and same amplitude dependence

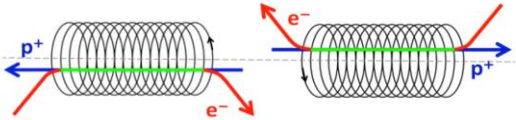
Resulting effects:

- Increased beam lifetime
- Increased luminosity

Built on experience with:

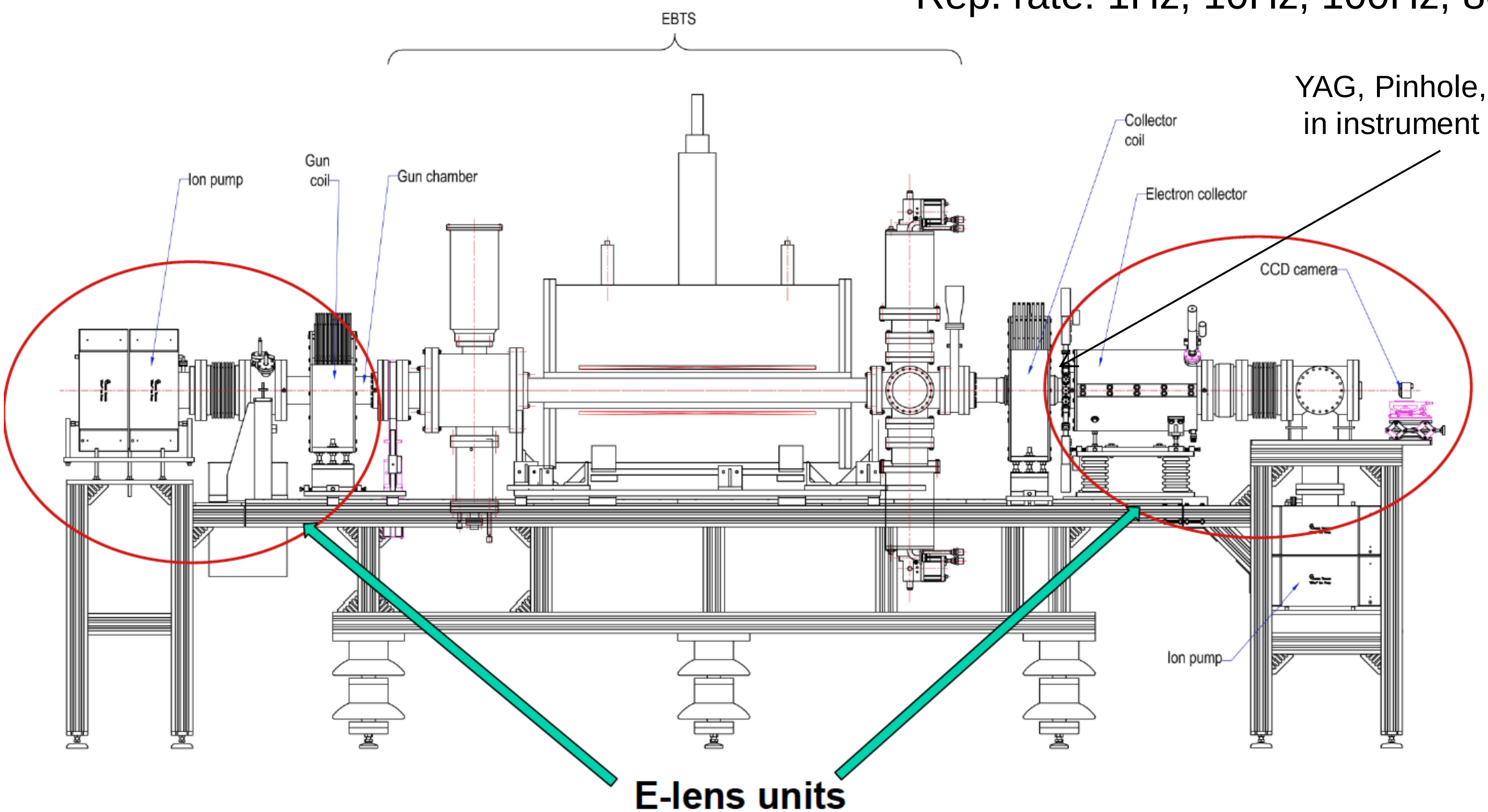
**Tevatron electron lens**
A. Burov, V. Kamerdzhiev, V. Shiltsev,
G. Stancari, A. Valishev, X.-L. Zhang…

# Electron Lens Test Bench Overview

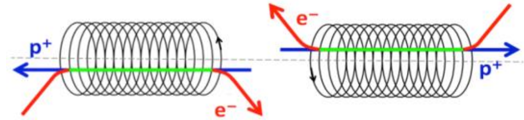



- Purpose
  - Test Electron Gun, Water cooled Collector, modulator, and instrumentation for the E-Lens Project

- System Specs:
  - Beam Energy: 5keV
  - Beam current: 0.6A nominal (1.0A test)
  - Modulated electron gun: 0.5us – DC
  - Rep. rate: 1Hz, 10Hz, 100Hz, 80kHz

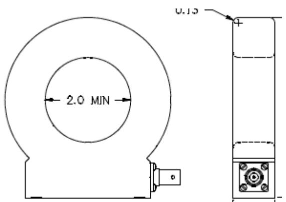


# Current Measurement System




## Current Transformers

- CTs at Gun and Collector: (1 - 5μs / 100μs – DC)
  - DCCT: Bergoz IPCT, 1 - 2000mA (1μA res.), DC – 100μs
  - Pulse CT: Pearson 6585, 1V/A, 50Ω, 0.3%/μs droop

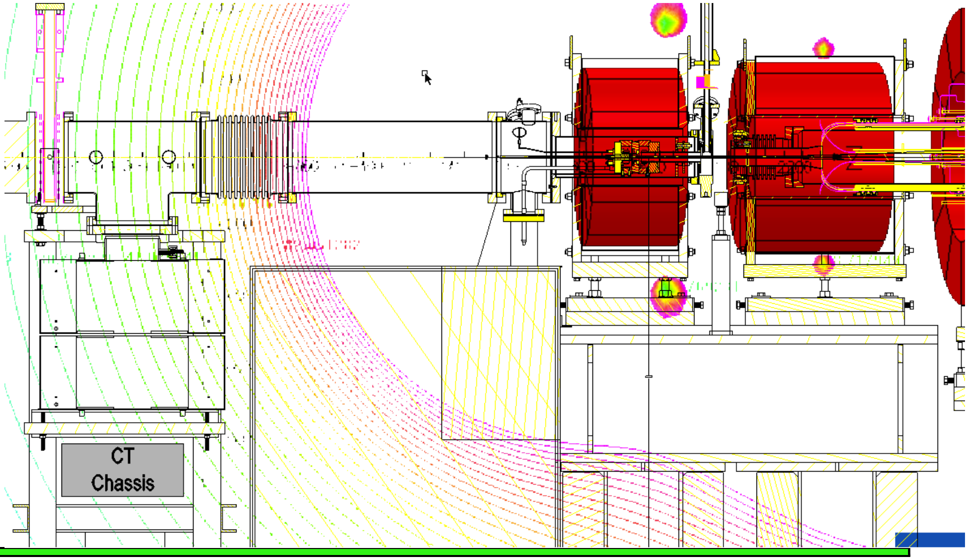



- Calibrator: 0-0.5A @ DC/0.1-1000μs

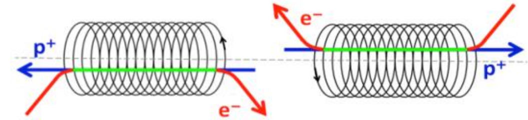

- CT at CPS Ground
  - Pearson 6585

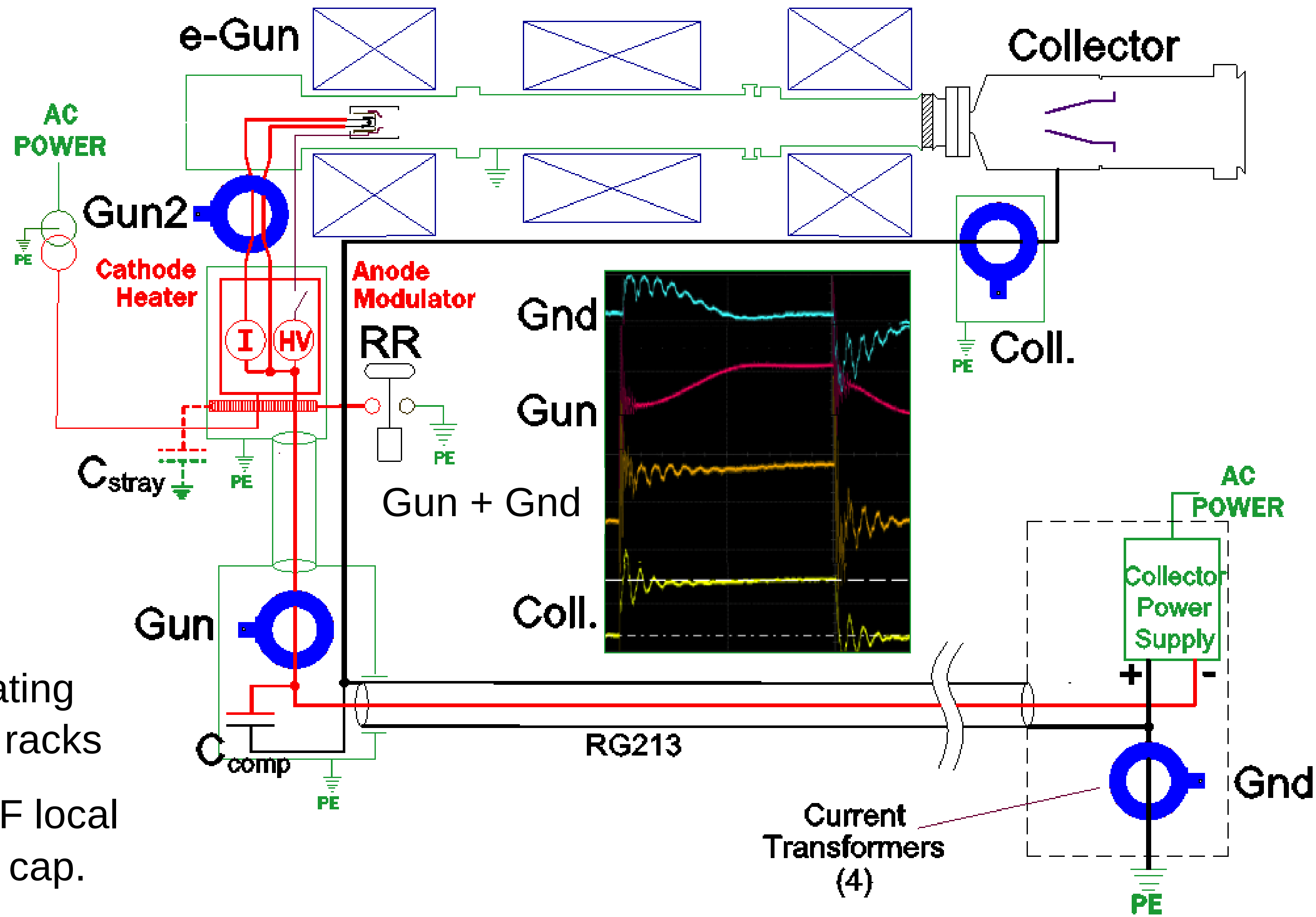
## Static Magnetic Fields

- Gun Solenoid
- Central Super Cond. Solenoid
- Collector Solenoid
- 100 Gauss line (pink) : E-Lens



# Ground Coupling Problem

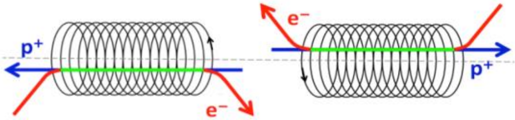



$C_{stray}$: floating
Control racks

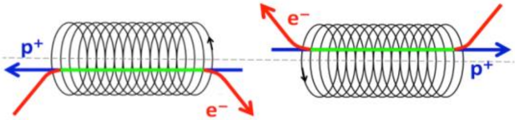
$C_{comp}$: 5uF local
storage cap.

# Ringing in pulsed current meas.




– CTs installed on beam power supply conductors
  - Mismatched power transmission line
  - No space for in-vacuum beam current CT
– Main HV power transport: parallel conductors in separate conduit
  - Changed to RG213 coax ➔ **Same Ringing**
– RC installed on ends of 50Ω power cable ➔ **no change**
– Capacitor added across ceramic break ➔ $\Delta f_C$ only; **same amplitude**
– Pearson 6585 installed close to gun [Heater + HVcom] ➘ (blue trace)

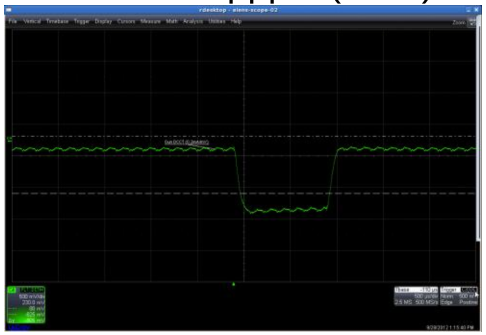
# Static Magnetic Field Interference on DCCT




- Static Field measured = ~15 Gauss (collector)
  - ~36 Gauss expected in E-Lens
  - Field varies ± with Oper’g param’s
- DC offset
  - 150mV offset with ~15 Gauss field
  - 0.030” MuMetal Shield -> 1 Gauss
  - Iron + MuMetal design underway

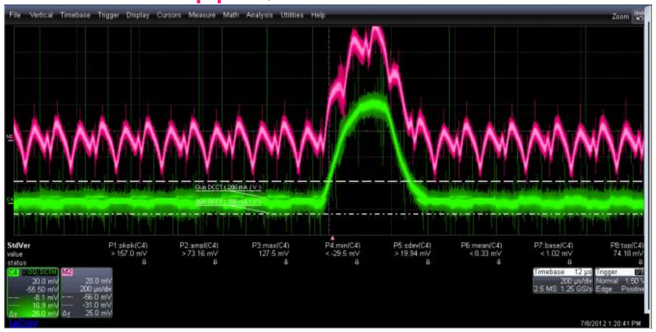

- AC oscillation
  - 7kHz internal excitation seen on output when in field (pink)
  - Within spec (25mV) with shield (*accuracy preserved*)

~100mV rippple (15 G)



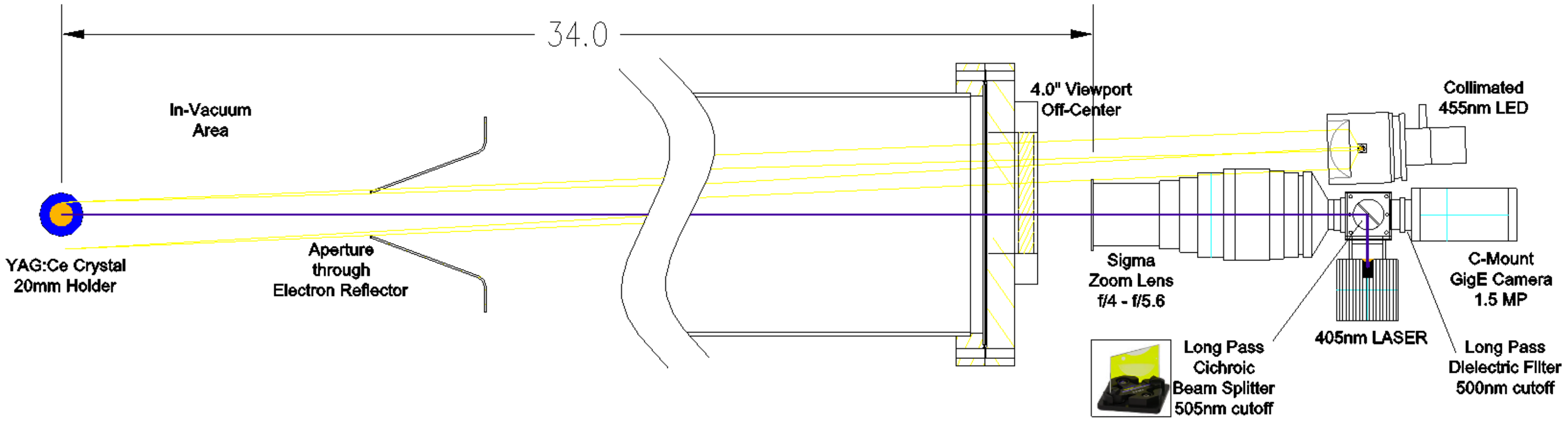
~20mV ripple (1 G)

7kHz ripple, 15G / **with shield**



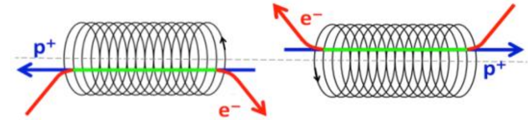
# YAG Beam Profile Monitor

## System Overview




- Camera: Manta G145B, GigE, 2/3" CCD 1.5MP 12-bit
- Zoom Lens: manual
- Target: YAG:Ce single crystal (20mm active area X 0.1mm thick) distance = 1.3m from lens
  - Crystals coated with either 100nm Al or C coatings applied at BNL for bleeding off charge
- Illumination:
  - Adjacent mounted White projection LED
  - Adjacent mounted 455nm (blue) projection LED
  - On Axis 405nm (violet) Laser via dichroic beam splitter

# Lens Comparison




## Performance Details

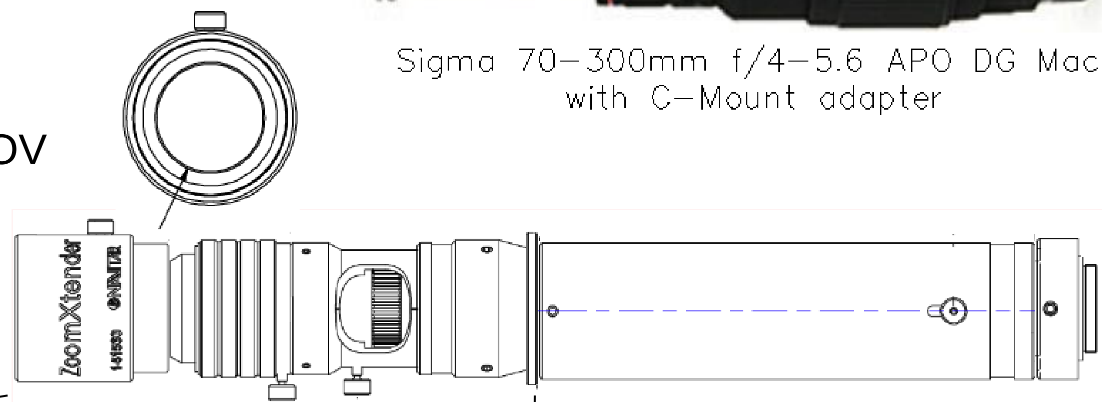
Sigma Corp. : (Final Choice based on aperture)

- 50mm front aperture,
  ➔ **Good** light gathering;
- **Poor** light rejection outside FOV
- $200 *off the shelf*

Sigma 70−300mm f/4−5.6 APO DG Macro with C−Mount adapter

Navitar:

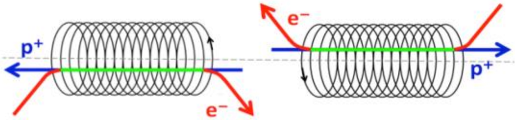
- 25mm front aperture,
  ➔ **poor** light gathering ability;
- **good** light rejection outside FOV
- $2,100 *custom assembly*



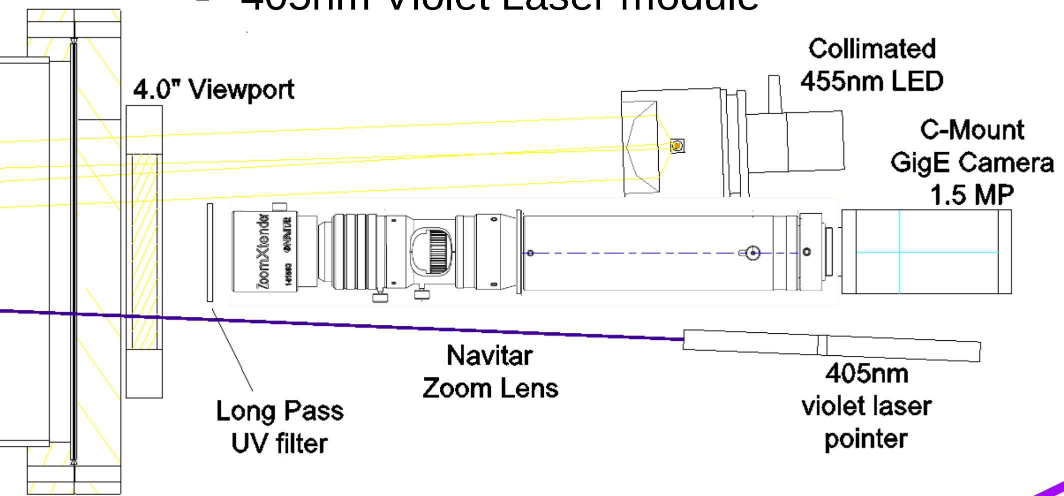

Zoom lens camera adapter tube, 2X magnification 1−6030

C−Mount Coupler 1−6010

# Adjacent mounted Illumination

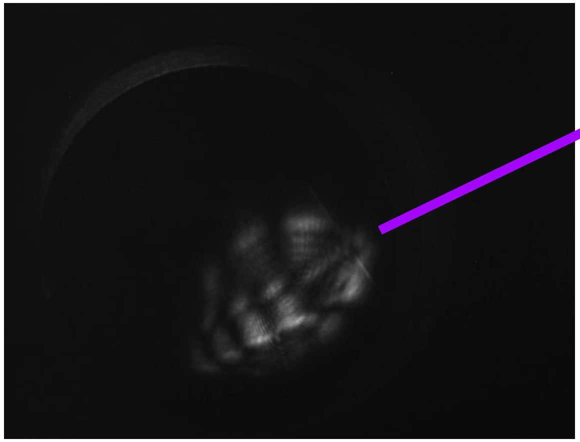



– Stimulate YAG:Ce to fluoresce
  - 455nm Royal Blue collimated LED
  - 405nm Violet Laser module

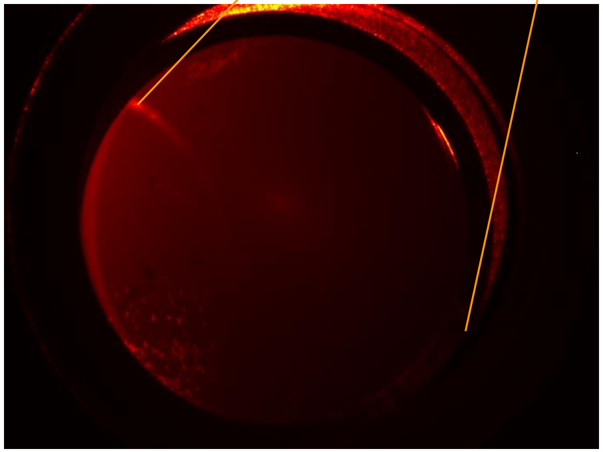



Beam of Light Technologies, OR, USA

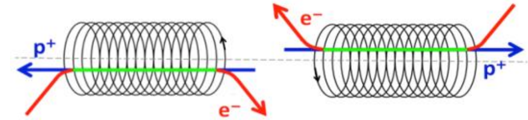
ThorLabs, USA



Colored Red to improve contrast



# UV Filter Selection




Use UV filter to block unwanted UV from affecting camera



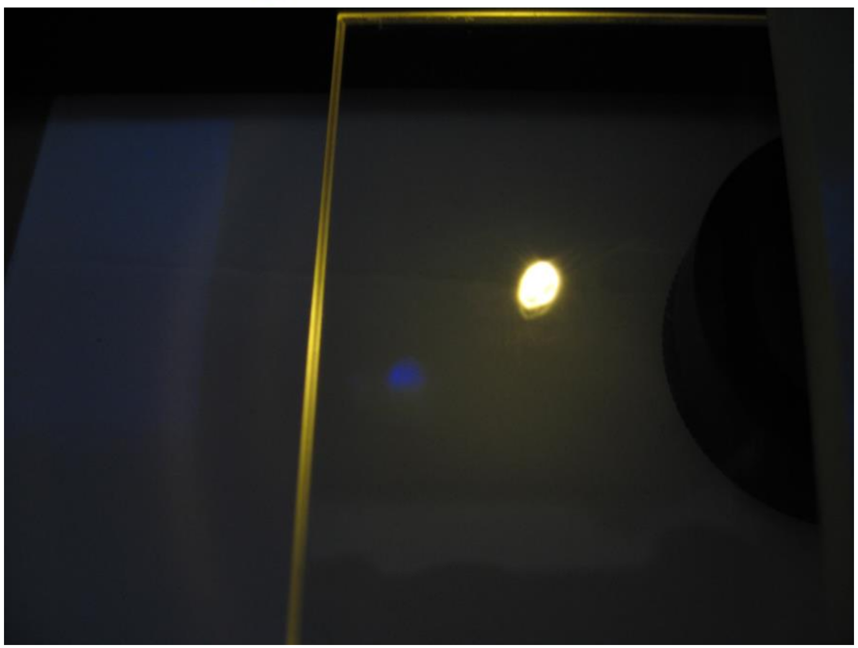
Energy Absorbed
in the filter !
➔Local emission

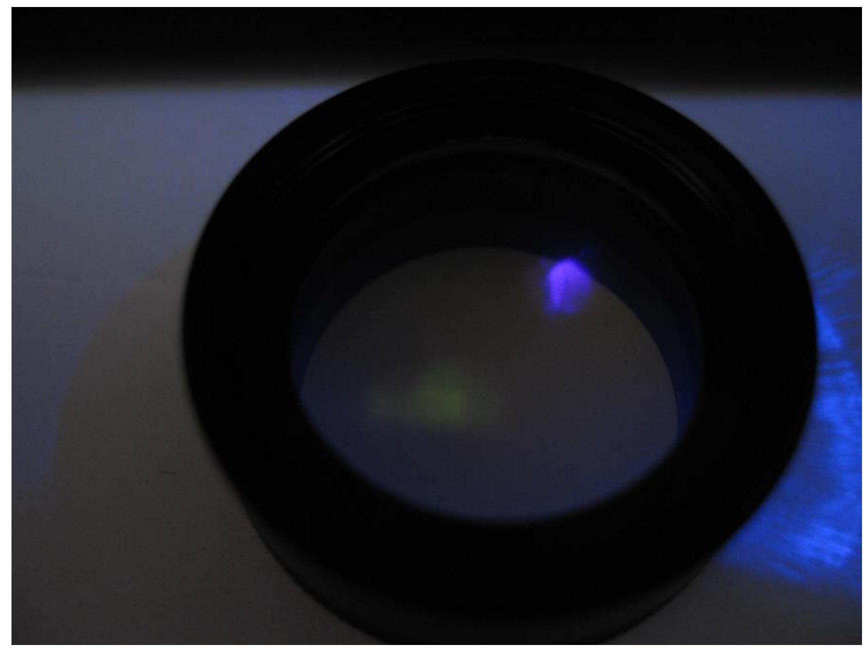
Longpass colored glass filter, Thorlabs FGL435S

“Wrong choice!”

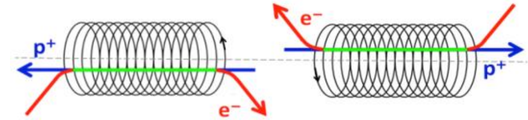
All Energy Reflected
➔NO emission!

Longpass dielectric coated filter, Thorlabs FEL0500
“Edgepass”

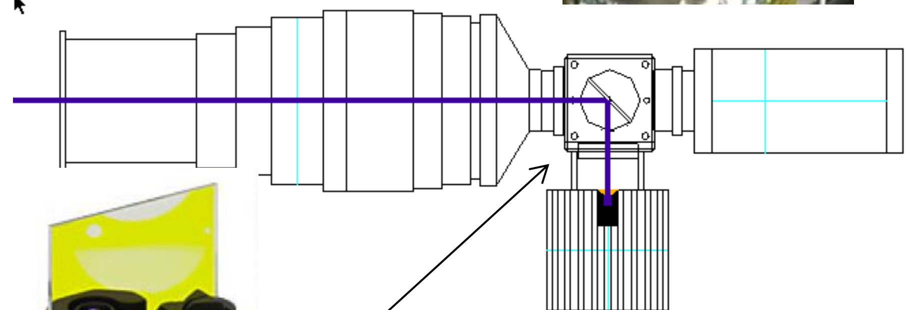





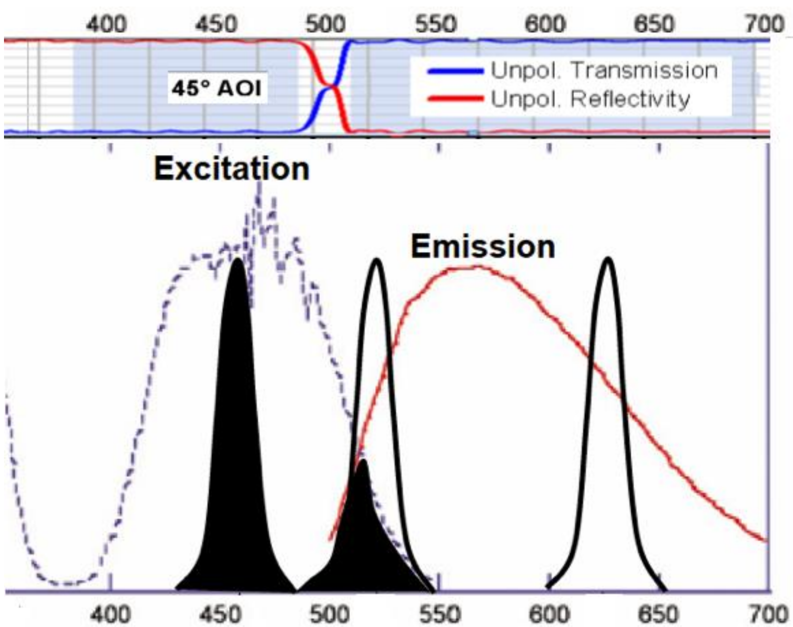
# On Axis Laser Illumination




- Propagate 405nm laser through camera lens
  - On axis– easier to close gap around lens on viewport
  - Magnified laser spot
- Use dichroic Beam Splitter (BS)
  - Reflect Blue & Violet
  - Pass YAG emission



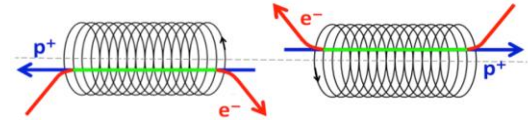
500nm Dichroic Beam Splitter Edmund Optics NT47-421




Y. Zhu, et al, …Optical Properties of YAG:Ce…"

- BS thickness vs. Image Resolution:
  - 3mm thick optic: grossly out of focus
  - 1.1mm thick optic: 34μm resolution

# YAG Beam Profile Measurements

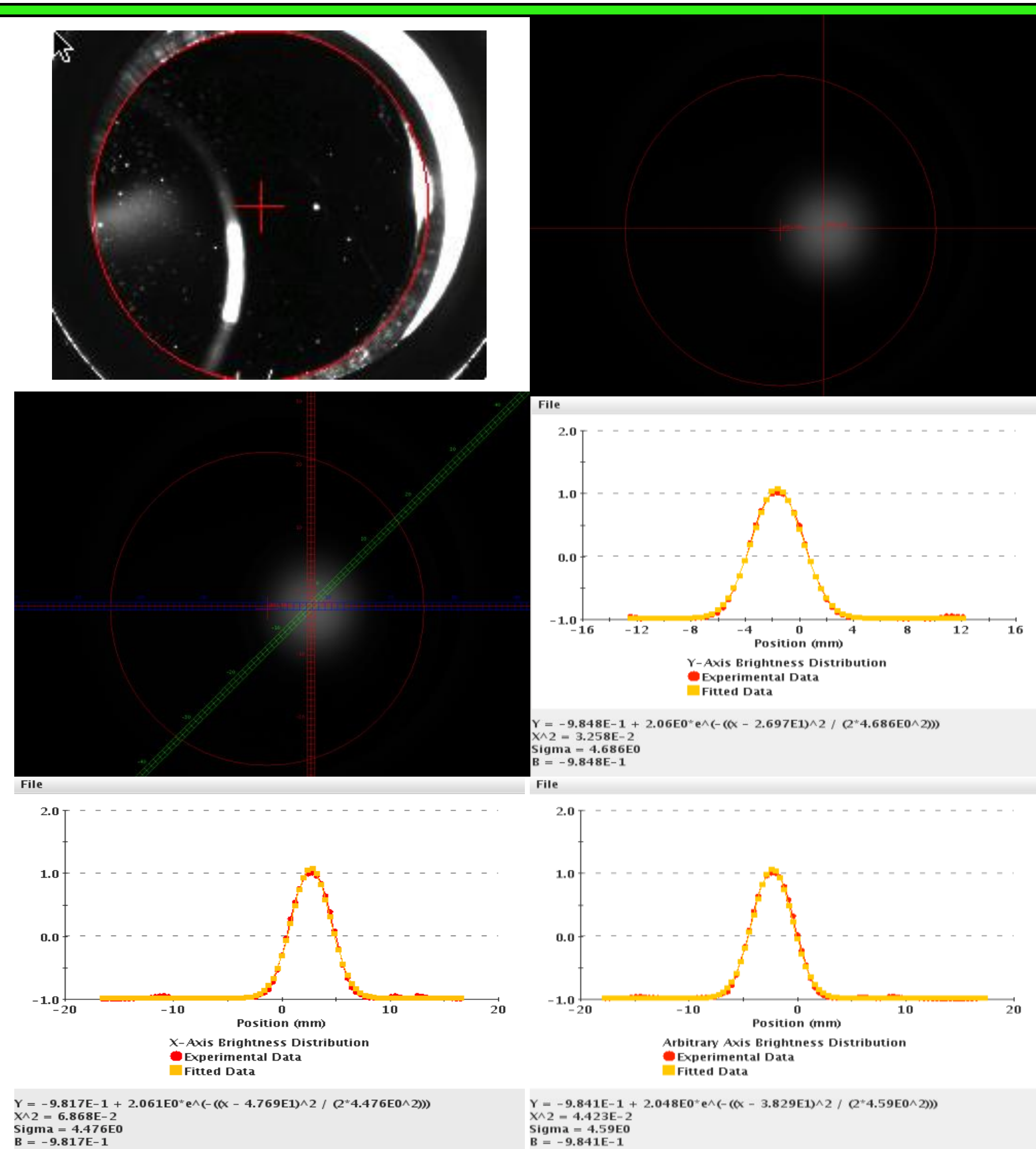



- Image analysis tools
  - Define 20mm Ref. Circle

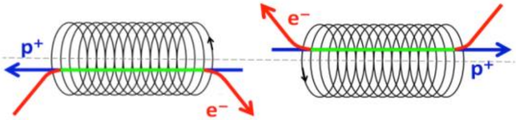
    using white light illumination

    allowing calibration of beam size
  - Find Center of Gravity

    allows calibration of beam size
  - Define Arbitrary 3rd Axis
    - 45° in example shown
  - Generate profiles along axes.
  - Calculate parameters:
    - Sigma
    - Gaussian fit ($\chi^2$)
    - Beam size (based on x% threshold; where x is user defined)



# YAG Damage Incident

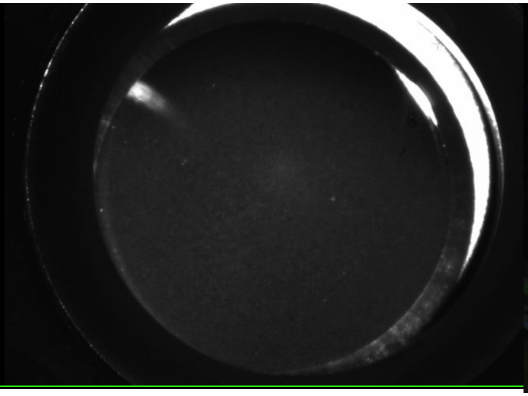



- 3 shots of 80μs pulse of 400~500mA beam, 5keV
  - *Based on pre-commissioned diagnostics & data loggers*
- Result :
  - ➔ Thermal damage to the crystal
  - Partially still fluorescent during bench inspection
  - Color photo of UV illumination shows blue reflecting area and yellow fluorescent area
  - aluminum holder shielded 5mm ring around crystal

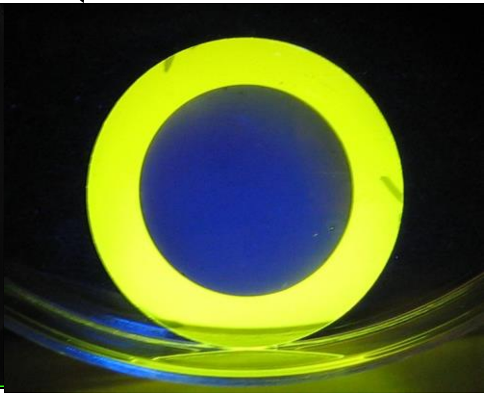
Damaged YAG removed from aluminum holder

Part of YAG still sensitive to beam – dead lower center


Photo of damaged YAG in vacuum – white illumination

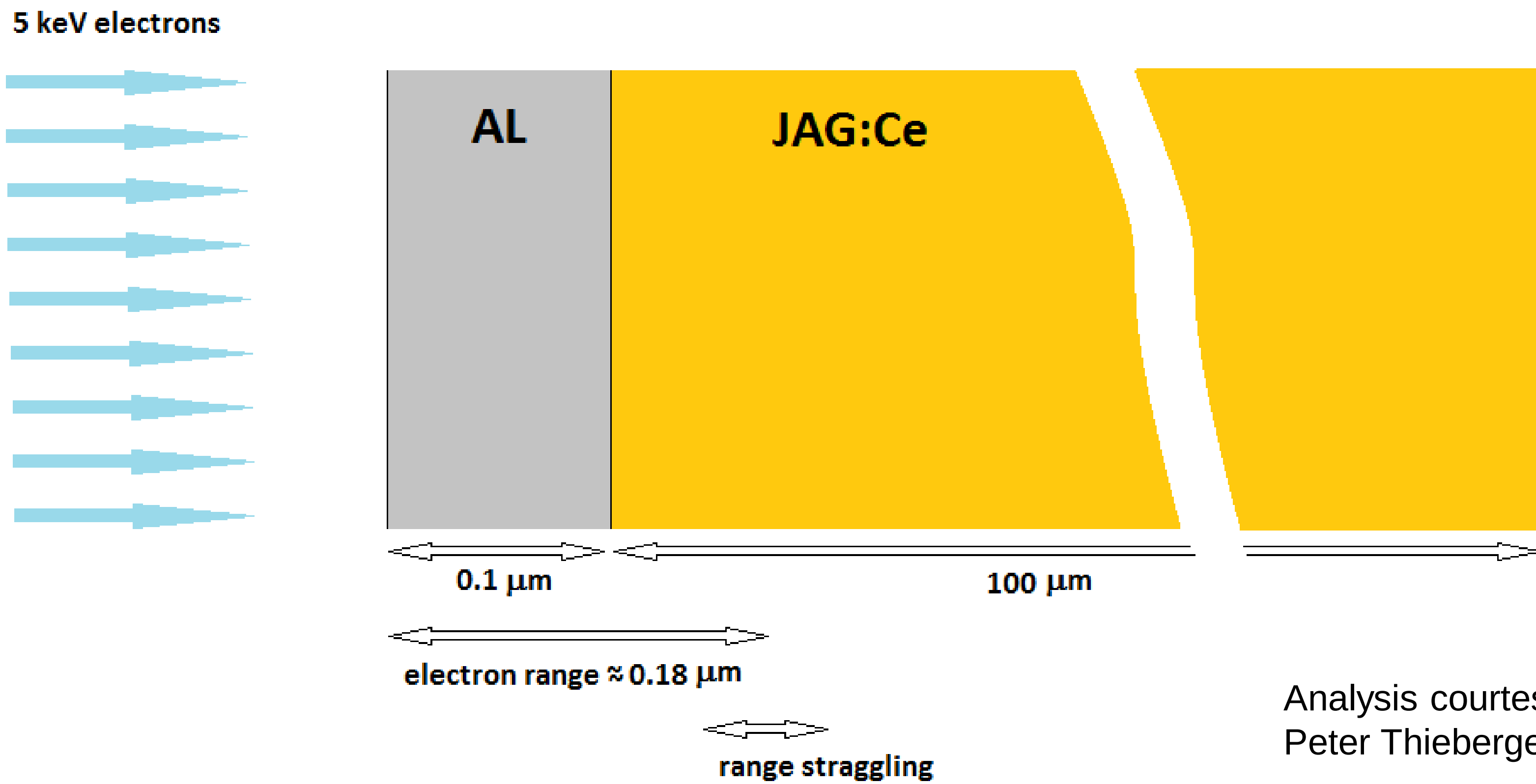


455nm illuminated YAG after removal



# YAG Heating Model

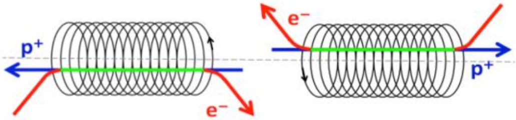
**Approximate penetration thicknesses for a 5 keV electron beam incident on a YAG screen covered with a 100 nm thick aluminum layer**



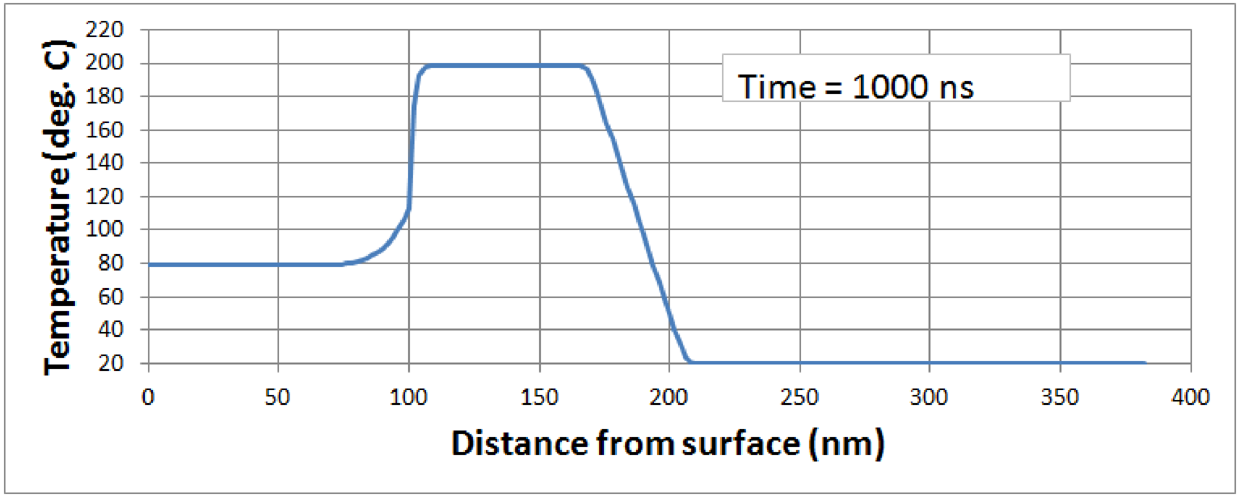

Analysis courtesy of
Peter Thieberger, BNL

The entire energy is deposited in a surface layer only about 0.2 microns thick leading to potential thermal shock damage due to sheer stresses that develop due to differential expansion of adjacent layers that are at different temperatures. Ranges are rough estimates based on the so called corrected Gruen formula.

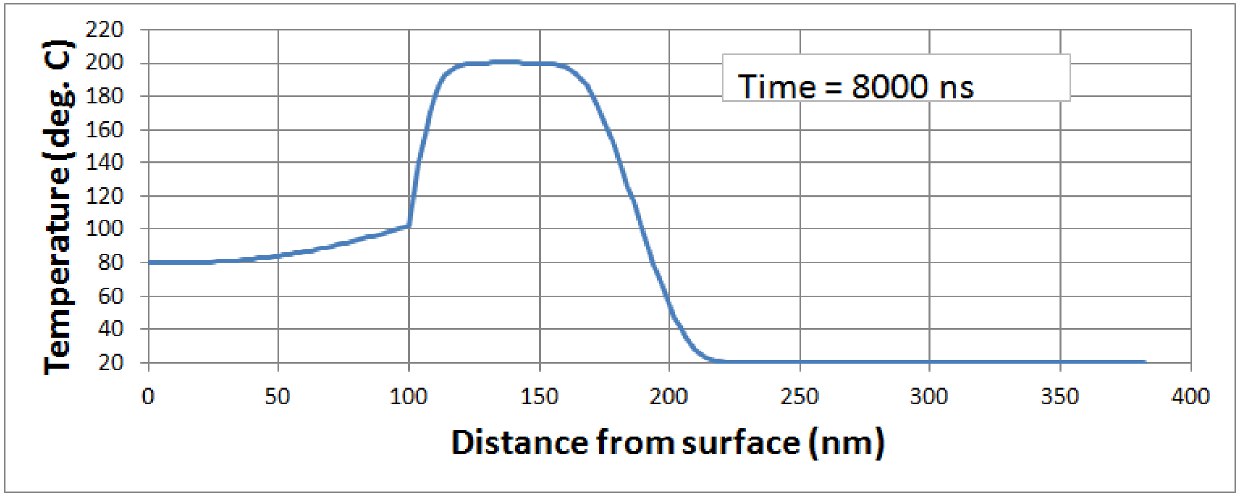
# YAG Heating Model




**Temperatures at the center of a 1cm diameter (6σ), 200 mA, 5 keV, 1 μs long electron beam on a YAG screen with 0.1 μm thick aluminum**



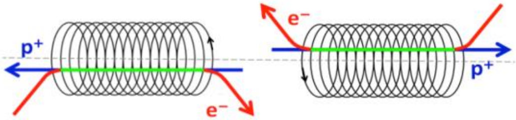

Temperatures at the end of the 1 μs pulse




Temperatures 7 μs later

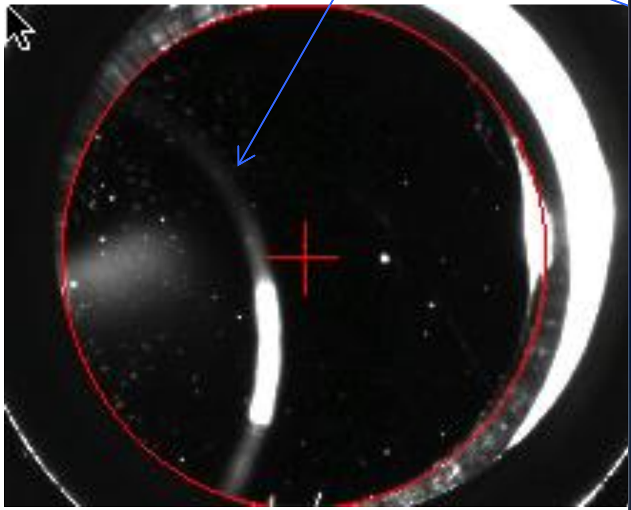
Analysis courtesy of Peter Thieberger, BNL

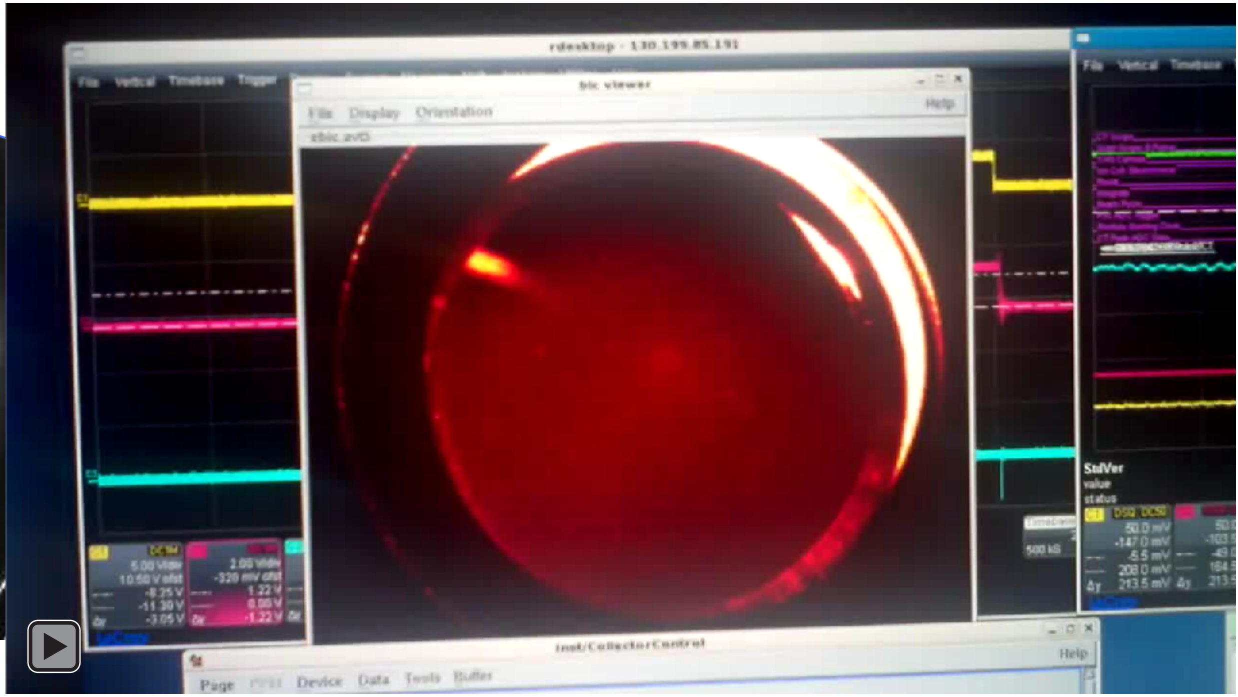
# Destructive YAG Test




– Before replacing YAG, the damaging beam pulses were repeated & documented
  - 660mA pulses, 80μs long, 1Hz repetition rate
  - YAG heated so much that deflection was visible after each shot
  - Couldn't reproduce the same level of damage with the expected parameters… WHY?

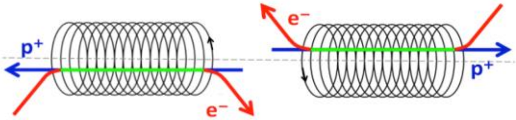
Reflection of in polished surface of YAG



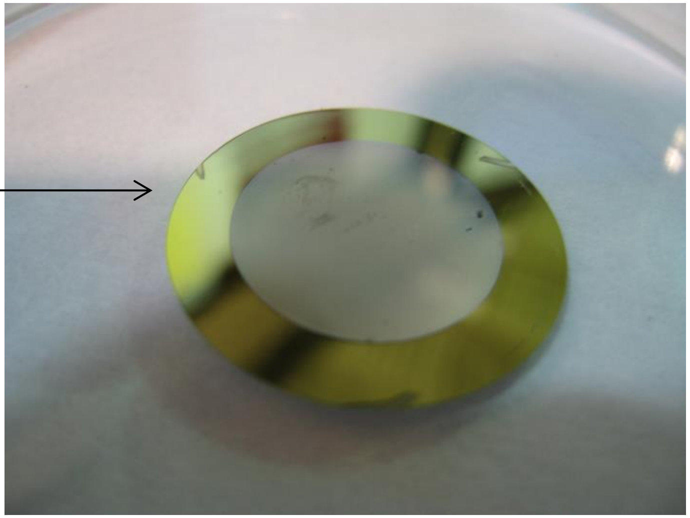


See this video on line at: http://www.youtube.com/watch?v=TOrgEd4AAAI/…

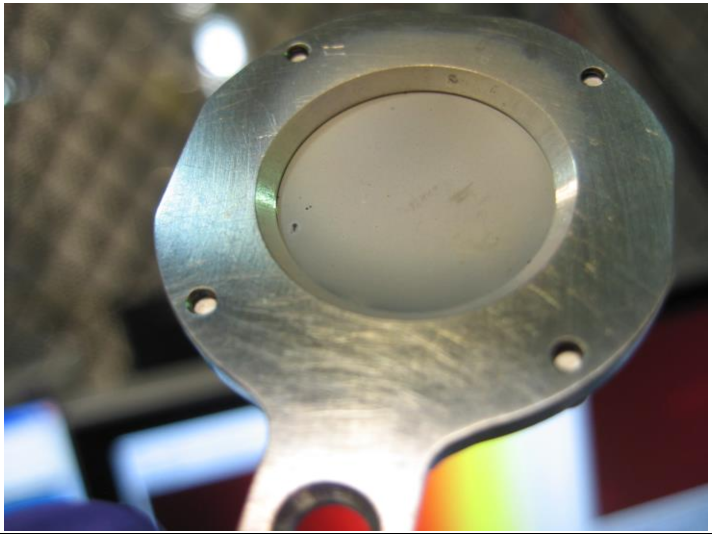
# YAG Damage Analysis

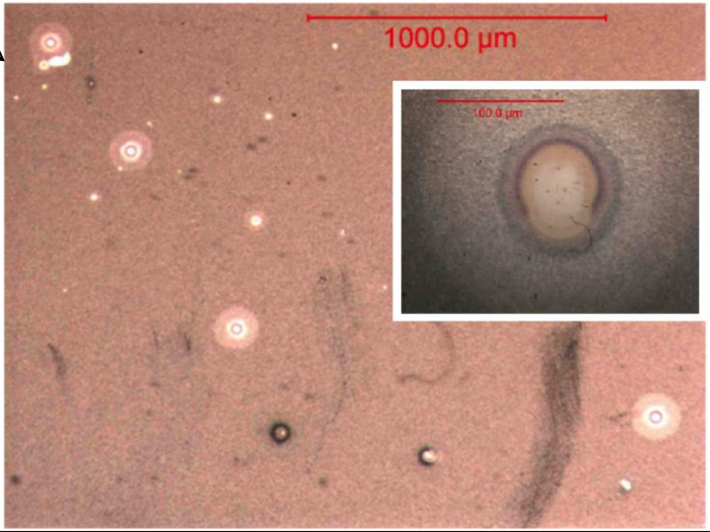



- Color: white opaque
- Surface: still smooth
- Micro damage points seen under microscope

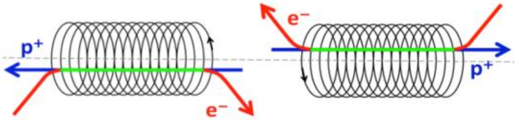


Damaged YAG in aluminum holder (**downstream side**)





# Four Quadrant Halo Monitor



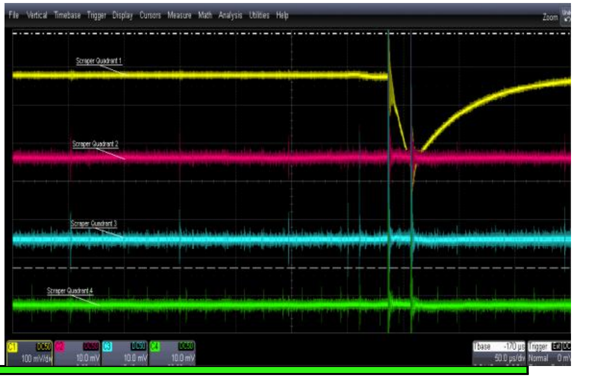

- Located with YAG & Pinhole just before collector
- Unbiased, 33.5mm aperture
- Integrated signals logged from isolated electrodes
- Waveforms:
  1) Pulsed beam image current induced on halo electrodes. Room to scan without loss.
  2) Signature of beam oscillating between gun and collector ➔ $V_{CPS}$ too low.
  3) Direct hit by beam

$V_{CPS}$=Collector Power Supply

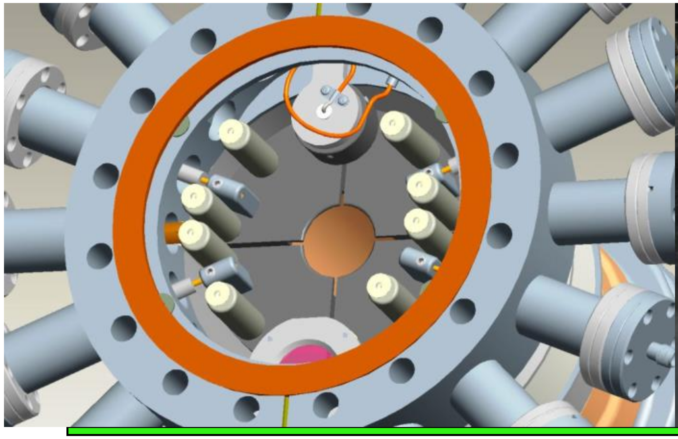
1

2

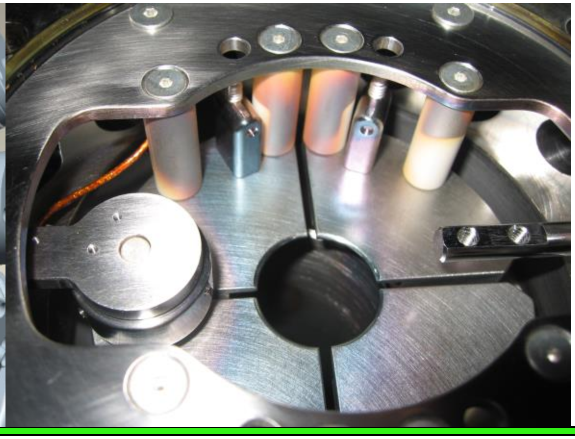
3



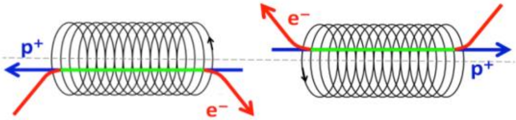
Conceptual Design



Opened during YAG replacement



# Upcoming Tasks

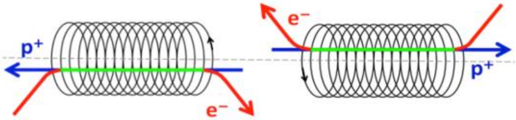



Installation of two E-Lens machines in RHIC planned over the next several months.

Remaining tasks to complete:

1) Complete commissioning of a Pinhole-Scan Profile Monitor
    a) Compare to YAG profiles
2) Solve pulse ringing problem current transformers
3) Perform controlled destructive YAG test
    a) Find operational thermal limit
    b) Find permanent thermal limit
4) Test new BPM design & commission electronics

# Acknowledgements




I would like to thank following colleagues for their support:

- K. Hamdi, J. Hock,, C.Liu, B. Sheehey, M. Stetski and other members of the Collider-Accelerator Department

- B. Schoepfer and members of the EBIS group

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- N. Baer, J. Carlson, T. Curcio, S. Jao, J. Kelly , B. Johnson, K. Mernick, and other members of the Accelerator Instrumentation and Beam Components Group

Thank you for your attention