Electrons Sources + Polarimetry

Parallel: Technology

Location: Clark Learning Center

08:30 **The Cornell High Brightness Injector** *20'*

Speaker: Dr. Colwyn Gulliford (Cornell University)

Material: **Slides**

08:50 **Photocathodes for High Current Electron Guns** *20'*

Speaker: Dr. Luca Cultrera (Cornell University)

Material: **Slides**

09:10 **High Current SRF Guns** *20'*

Speaker: Dr. E. Wang (Brookhaven National Lab)

Material: **Slides**

09:30 **High Current Spin Polarized Electron Sources** *20'*

Speaker: Dr. Joe Grames (Jefferson National Lab)

Material: **Slides**

09:50 **Magnetic Resonance Polarimetry for Frozen Spin Storage Rings** *20'*

Speaker: Prof. Richard Talman (Cornell University)

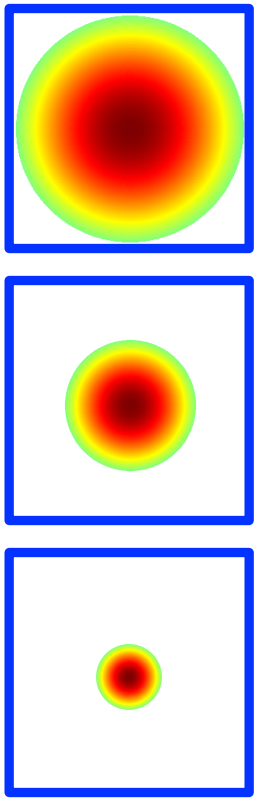
Material: **Slides**

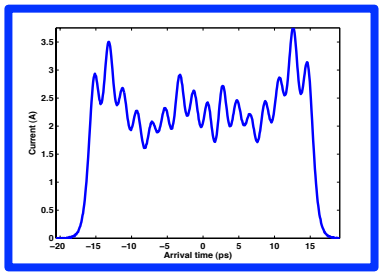
The Cornell High Brightness Injector

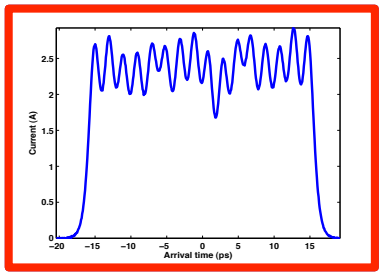
Adam Bartnik & Colwyn Gulliford
Cornell University

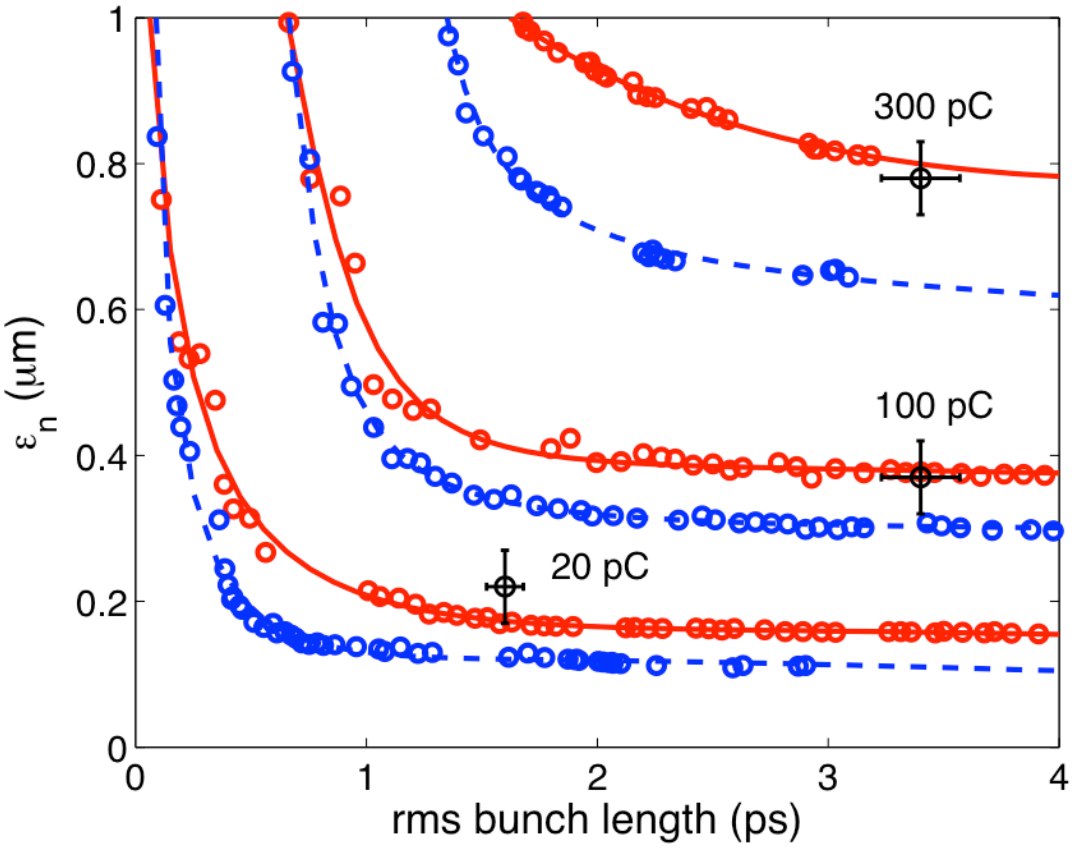
Effects of the Laser Shape

Ideal Shape

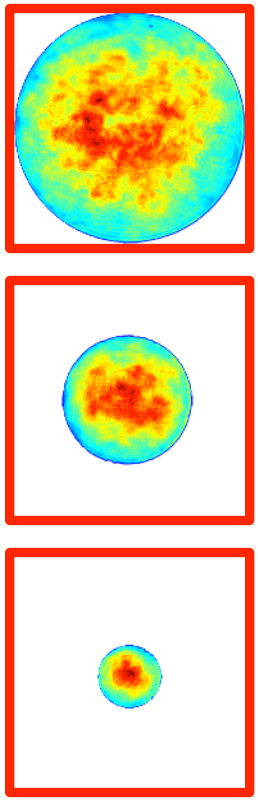








Measured Shape



Summary

- The CU injector meets all LCLS – II requirements
  - Emittance growth well compensated up to 300 pC
  - (at 300 pC) ε_{th} = 0.41 μm, final at 9.5 MeV: ε_n = 0.6 μm
  - Emittance scales roughly as $\sqrt{Q}$
- At higher charge, compensation is worse
  - 1nC: ε_{th} = 0.6 μm, ε_n = 1.6 μm
  - Emittance scales roughly as Q
- Full (50 MHz) duty factor demonstrated up to 375 pC (20 mA)
  - Likely need a larger (off-center) cathode to go further

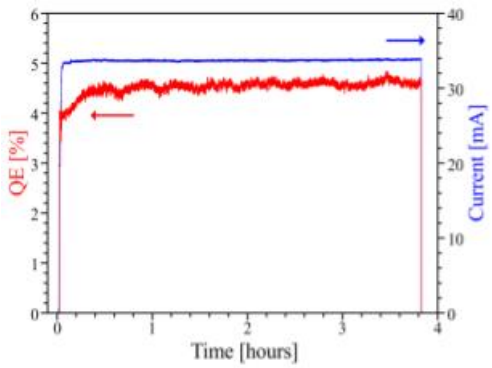
SLAC

DOE Nuclear Physics awards
DE-SC0012493, DE-AC02-76SF00515

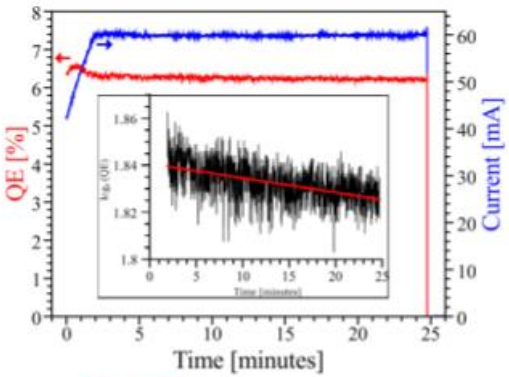
Photocathodes for High Current Electron Guns

Luca Cultrera
Cornell University

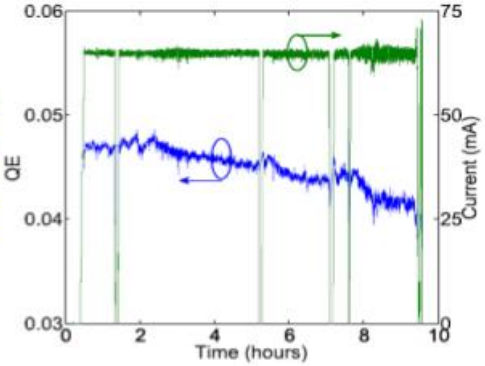
Alkali antimonides



Cs_3Sb
QE @ 520 nm 4%
Max AVG current 33 mA
Lifetime >> 500 C
NO QE DECAY

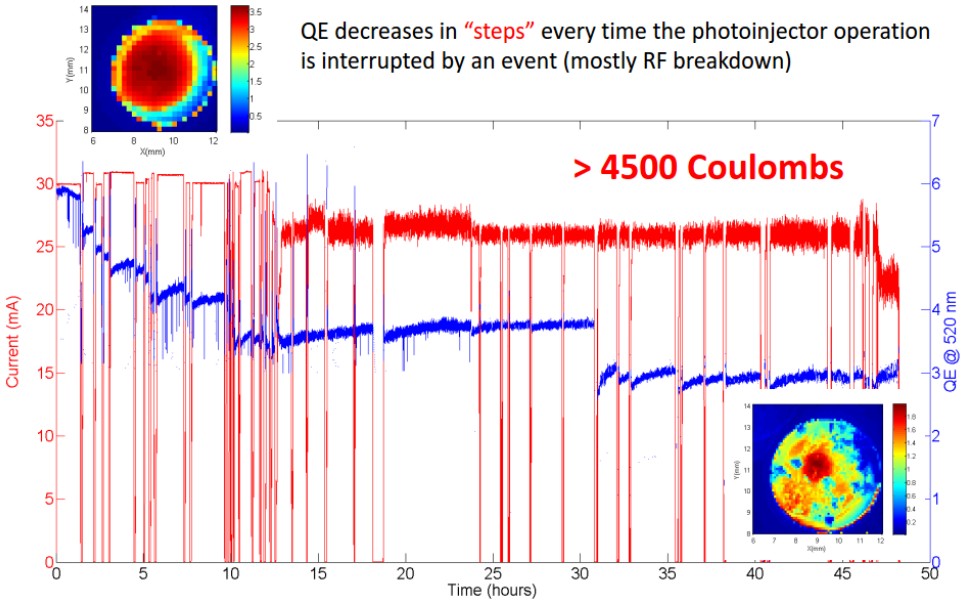


Cs_2KSb
QE @ 520 nm 6.5%
Max AVG current 60 mA
Lifetime >> 2000 C
1/e QE 30 hr



Na_2KSb
QE @ 520 nm 4.5%
Max AVG current 65 mA
Lifetime >> 2000 C
1/e QE 66 hr

QE decreases in "steps" every time the photoinjector operation is interrupted by an event (mostly RF breakdown)



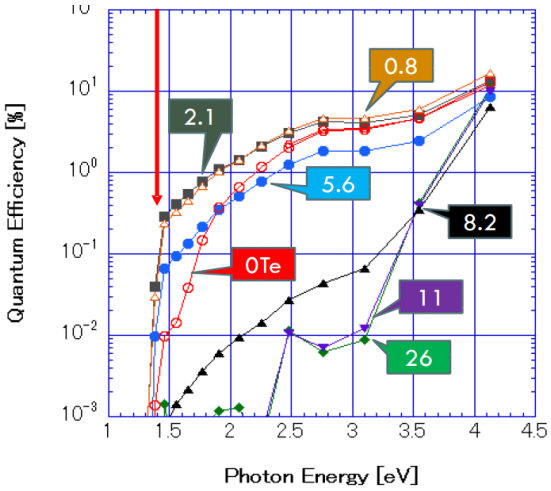
Lifetime is ok
Laser power is enough
Pushing to demonstrate 100 mA

Where are the limits??

R&D in new materials

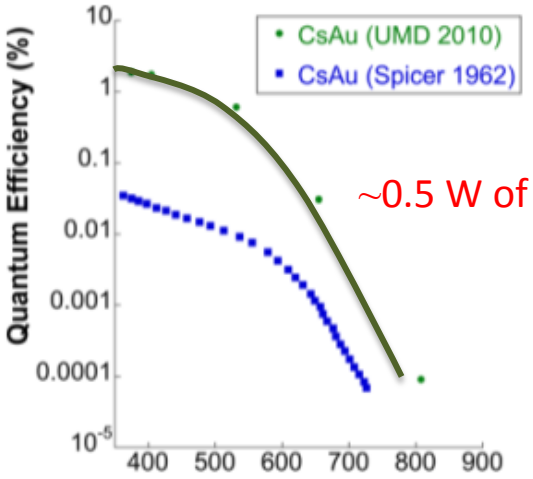
- CsTe over GaAs

Vacuum requirements / Lifetime ?
Intrinisic emittance ?
Will it work with superlattices preserving polarization?



- Cesium auride

Vacuum requirements / Lifetime ?
Response time ?
Intrinisic emittance ?

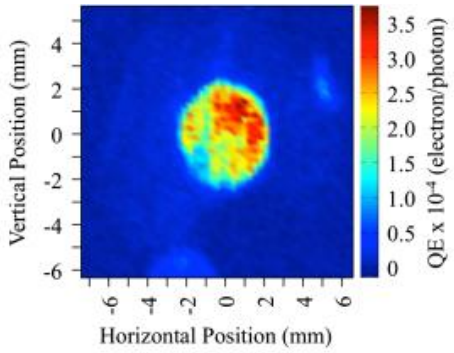


~0.5 W of VIS laser / mA average current !!!

- Coated metals

Vacuum requirements / Lifetime ?
Intrinisic emittance ?

~0.5 W of UV laser / mA average current !!!



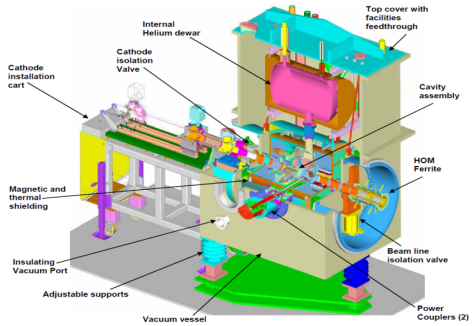
With CsBr coating intrinsic emittance is 3x worse than bare Cu

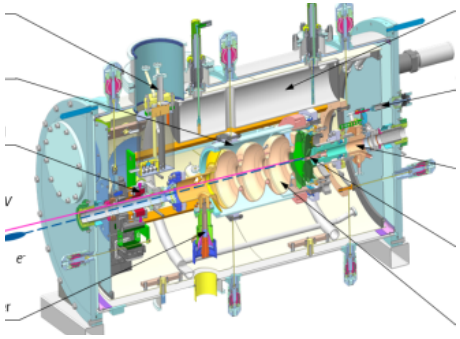
2.63 mm mrad / mm

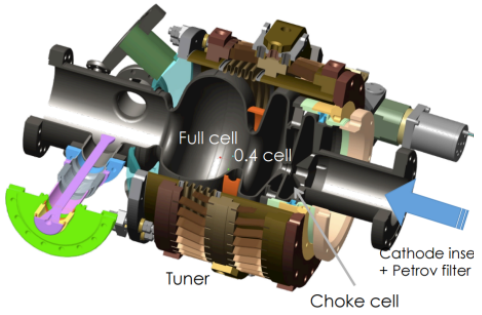
High Current SRF Guns

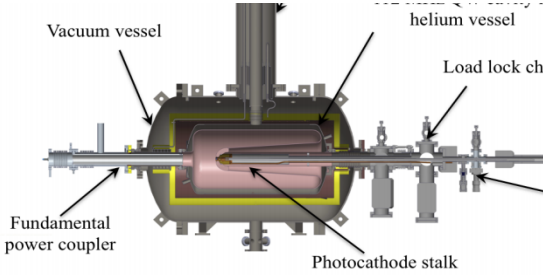
Erdong Wang
Brookhaven National Lab

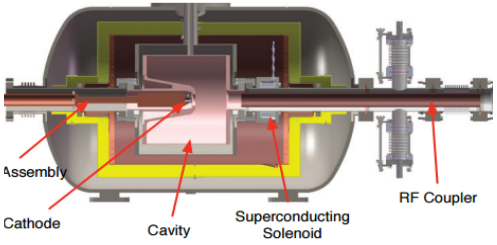
High current SRF photoinjectors in the world

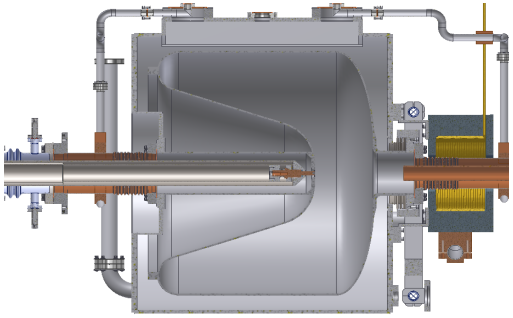


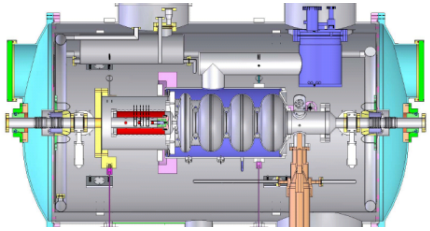






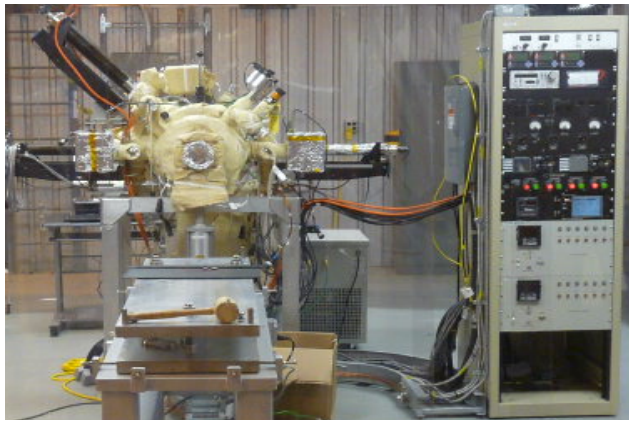


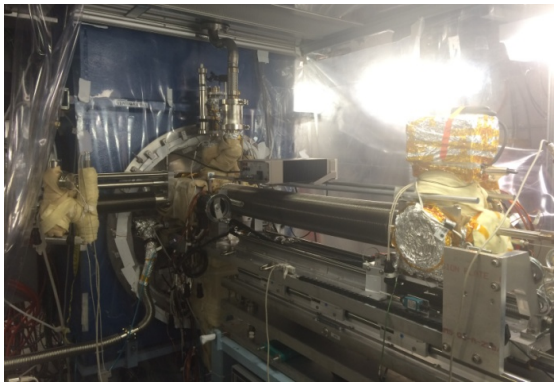




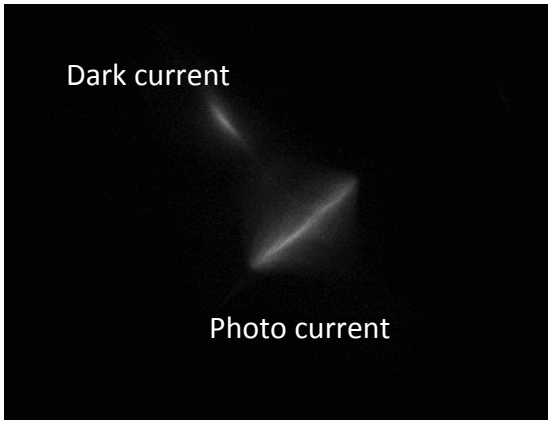
- several SRF photoinjectors baesd upon NCRF (20 MV/m), SCRD (20-35 MV/m)
- promising to provide high bunch charge (nC), high average current and small emittance beam.
- continued progress ... some are being conditioned, others commissioning, a few making beam ~ 1mA

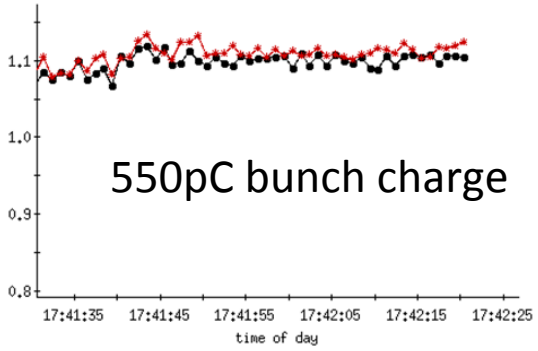
BNL 704MHz SRF gun got the high bunch charge beam this year





- The QE of CsK_2Sb was 4.1% at initial prepared and 3.8% before inserting into the gun.
- The gun was then conditioned and sent beam to a Faraday cup. Pulsed operations yielded bunches with up to 0.55nC per-bunch.
- The gun was operated in pulsed mode at 0.85MV kinetic energy. The ICT and Faraday cup measurements confirmed QE=1% at low current.
- After running for a couple of days including condition and high bunch charge test, there was no observed degradation of the QE.

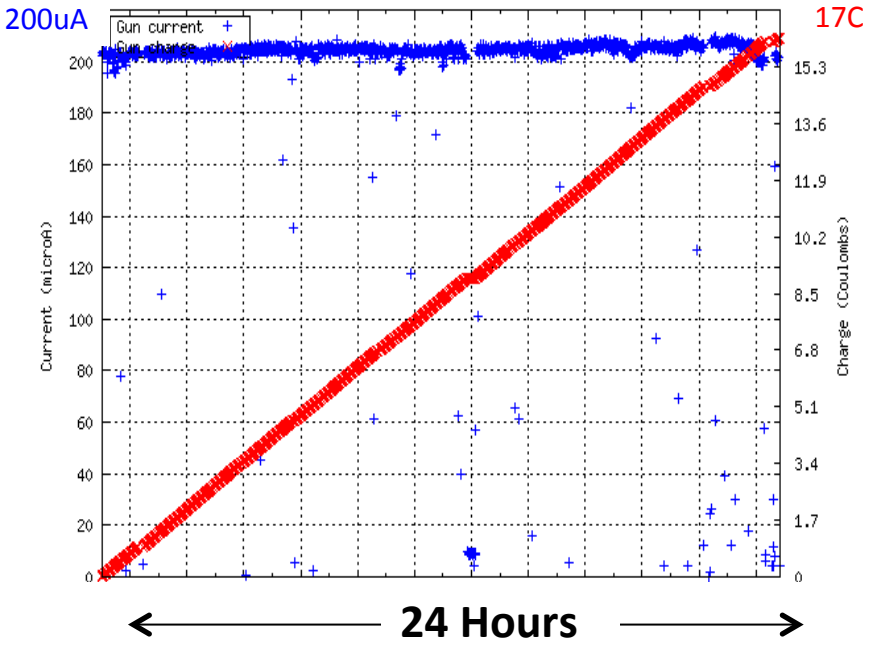


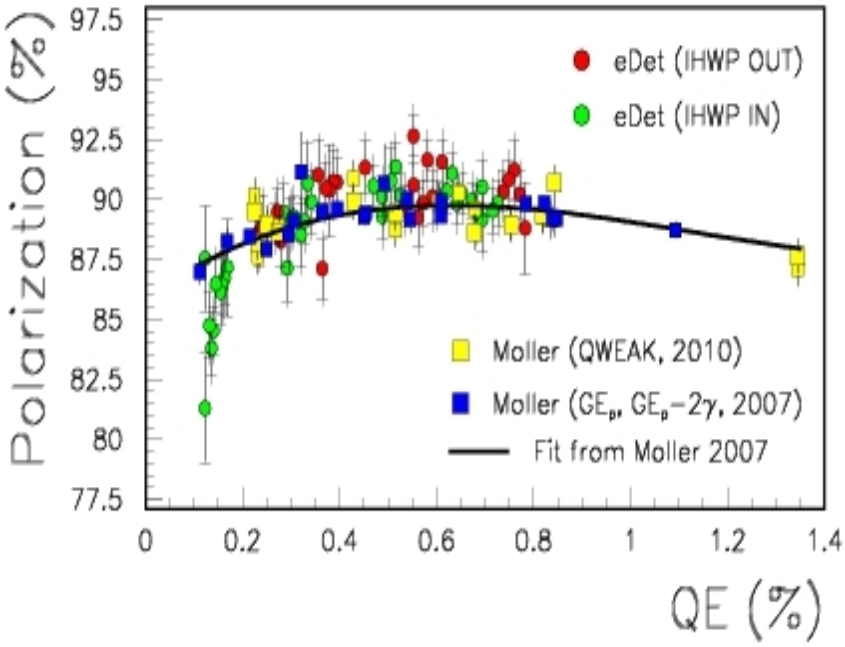


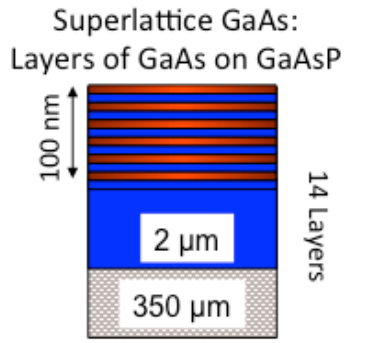
High Current Spin Polarized Electron Sources

Joseph Grames
Jefferson Lab

Daily Operation of CEBAF Photogun







- Delivering polarized beam to 3 Users simultaneously means **providing average current > 200 μA**
- Delivering 20C/day for weeks without invasive interruption means **achieving 1/e charge lifetimes that are > 200 C**
- Parity violation experiments benefit from a **polarized source that remains constant over long periods of time**.

High Current and High Polarization Results

Parameter	Value	Value
Laser Rep Rate	499 MHz	1500 MHz
Laser Pulse Length	30 ps	50 ps
Laser Wavelength	780 nm	780 nm
Laser Spot Size	**0.45 mm**	**0.35 mm**
Photocathode	GaAs/GaAsP	GaAs/GaAsP
Gun Voltage	100 kV	200 kV
Beam Current	**1 mA**	**4 mA**
Run Duration	8.25 hr	1.4 hr
Extracted Charge	30.3 C	20 C
Charge Lifetime	**210 C**	**80 C**
Fluence Lifetime	**132 kC/cm^2**	**83 kC/cm^2**
Bunch Charge	2.0 pC	2.7 pC
Peak Current	67 mA	53 mA
Peak Current Density	42 A/cm^2	55 A/cm^2

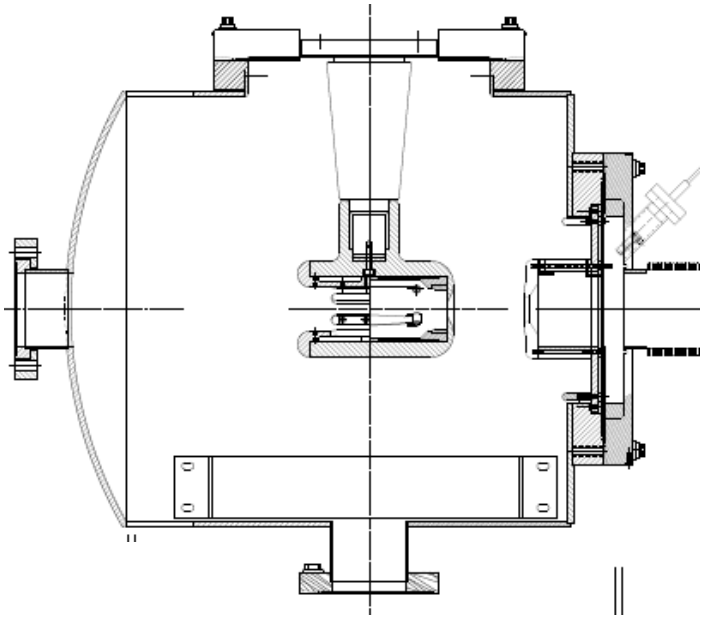
J. Grames *et al.*, PAC07, THPMS064

R. Suleiman *et al.*, PAC11, WEODS3

- kC charge lifetimes required before >mA level polarized beam for months-long physics experiment
- Higher QE > 1%
  - Reduces power req'd
  - Explore Bragg reflector)
  - Thicker active

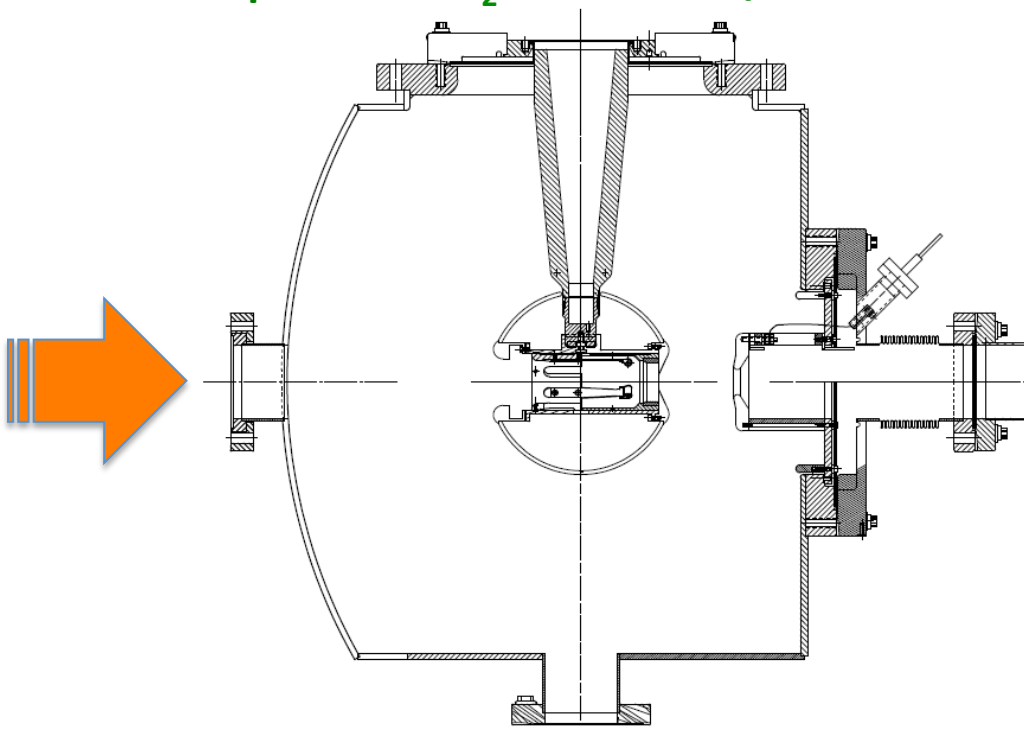
Physics at JLAB Requires a 350 kV Photogun

CEBAF Inverted 200 kV DC
Load Lock Inverted Photogun



Building **two** 350 kV DC
Load Lock Inverted Photoguns

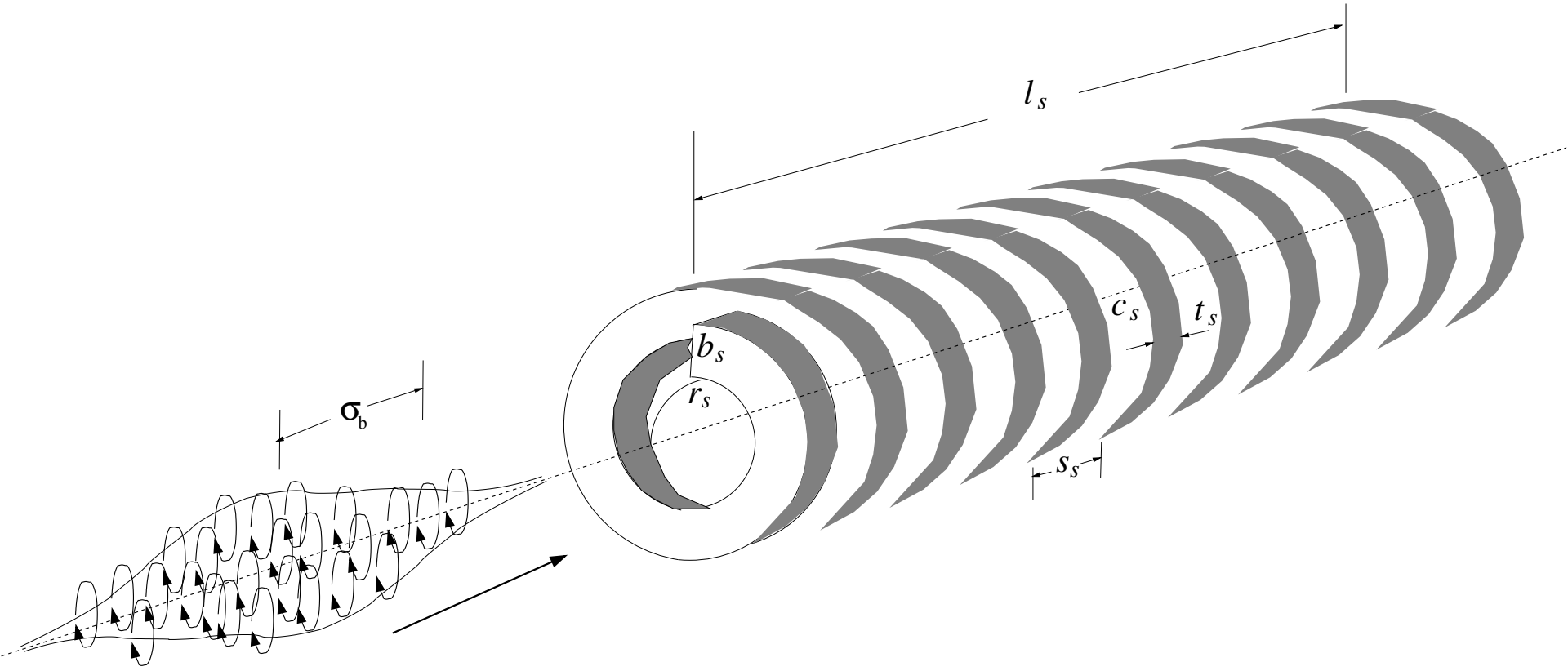
Incorporates CsK_2Sb and GaAs/GaAsP SSL

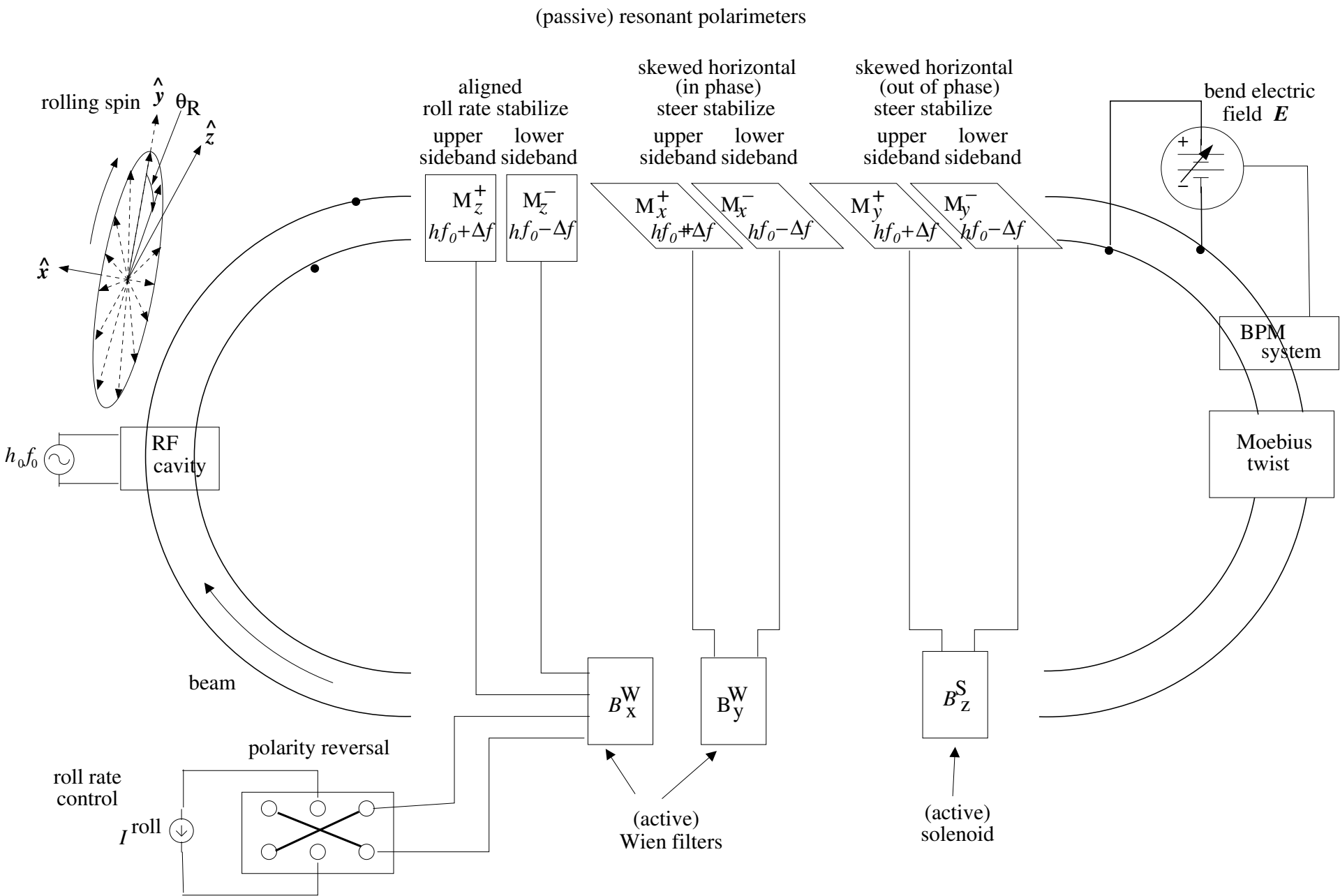


- Longer "R30" insulator
- Spherical electrode
- Thin NEG sheet moves ground further away
  - **Maximum Field strength ~ 10 MV/m**

Magnetic Resonance Polarimetry for Frozen Spin Storage Rings

Richard Talman
Cornell University


l_s
c_s
t_s
b_s
r_s
s_s
σ_b


(passive) resonant polarimeters
rolling spin
$\hat{y}$
θ_R
$\hat{z}$
$\hat{x}$
aligned
roll rate stabilize
upper sideband
lower sideband
M_z^+ $hf_0+\Delta f$
M_z^- $hf_0-\Delta f$
skewed horizontal
(in phase)
steer stabilize
upper sideband
lower sideband
M_x^+ $hf_0+\Delta f$
M_x^- $hf_0-\Delta f$
skewed horizontal
(out of phase)
steer stabilize
upper sideband
lower sideband
M_y^+ $hf_0+\Delta f$
M_y^- $hf_0-\Delta f$
bend electric field $\boldsymbol{E}$
BPM system
Moebius twist
$h_0 f_0$
RF cavity
beam
B_x^W
B_y^W
B_z^S
polarity reversal
roll rate control
I roll
(active) Wien filters
(active) solenoid

Electron Source Status & R&D Opportunities

DC Gun

- **Cornell** – Reliable operation to **400 kV gun (NaKSb, GaAs, can introduce GaAs/GaAsP)**
  - Operation to ~350 pC under control, increase laser size/length higher charge, run off-axis
- **JLAB** – Building **350 kV inverted gun (K_2CsSb, GaAs/GaAsP)**
  - Scaling 200 kV CEBAF gun for higher voltage, operate 10 mA at ERL
- **BNL – Testing Gatling Gun** to 110kV (GaAs)
  - Commissioning multi-photocathode gun, combine 4 x 2.5mA = 10mA

RF Gun

- **BNL** – Recent progress operating **SRF Gun 704 MHz (K_2CsSb) w/ 1% QE and 0.5 nC**
  - Study gun performance, increase gradient
  - ERL Goals: high bunch charge (nC) or high average current (100's mA)
- Globally - several SRF photoinjectors in development
  - Most are in commissioning, some have begun operation at >1 mA

Unpolarized Photocathode

- **Alkalai Antimonides** – Robust operation with **>2000 C lifetime up to 50-60 mA**
  - Improve understanding of limits e.g. on ion bombardment, charge lifetime
  - Alternatives that can provide ~mA/W e.g. CsAu or coated metal

Polarized

- **GaAs/GaAsP** – Routine operation with **100-200 C lifetime up to 4 mA**
  - Apply CsTe thin film
  - Increase QE e.g. testing DBR photocathode, greater active layer thickness