Continued Work toward XHV for the Jefferson Lab Polarized Electron Source

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Thomas Jefferson National Accelerator Facility

- 6 (12) GeV Electron accelerator for Nuclear Physics
- 85-90% polarization, up to ~250μA beam (CW) to 3 (4) experimental halls
- DC photoemission electron source
- Strained superlattice GaAs/GaAsP photocathode
- NEG and Ion pumps
- Residual gasses are ionized, back-accelerated and degrade the photocathode
- Future accelerators (CLIC, EIC, ILC) require higher currents

Cryopumped gun project

- Investigate adding bakable cryopump into system
  - Leybold Coolvac 2000 BL, special order
  - Cryosorber panel can be chilled with LN_2 during bakeout
  - Isolation valve for regeneration
  - Chamber: currently in heat treatment
- Can we measure improvement in vacuum due to cryopump?

➢Characterize UHV/XHV gauges

Ionization gauge current contributions

$$I_{measured} = I_{real} + I_{x-ray} + I_{heating} + I_{ESD} + \left(I_{inv.x-ray} + I_{ESDneut.}\right)$$

I_{real}: pressure dependent gas phase ions – species sensitive

$I_{x\text{-}ray}$: x-ray induced electron desorption from collector

- reduce by geometry

I_{ESD}: ions arriving at collector from electron stimulated desorption (ESD) of molecules on the grid

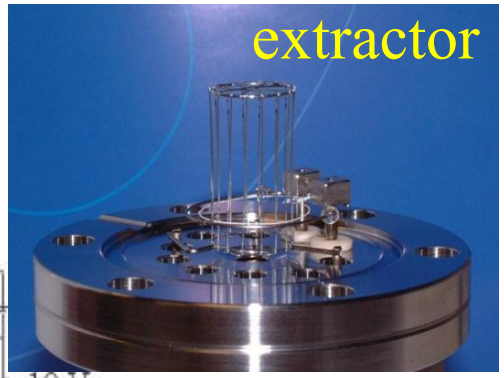
- reduce by degassing grid

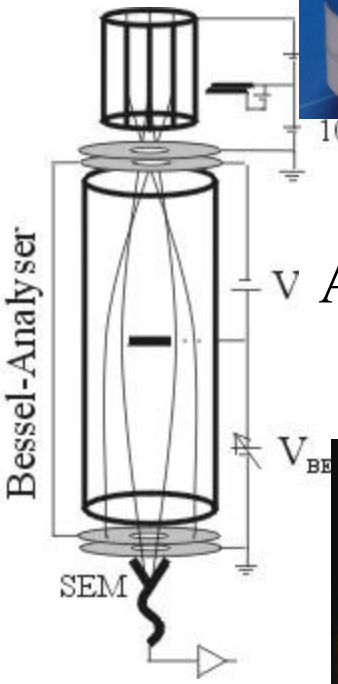
$I_{heating}$: pressure rise due to filament heating – species sensitive

- reduce by material selection, geometry, long duration

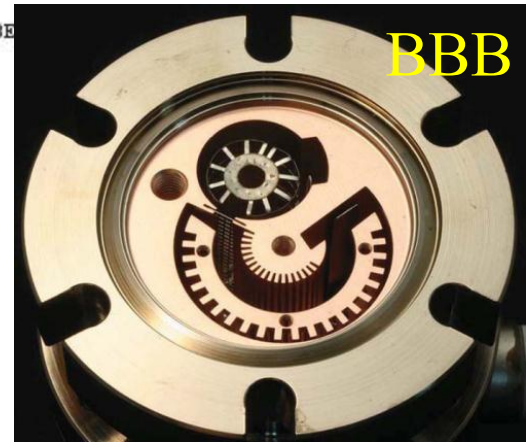
Deep UHV/XHV gauges

- Extractor gauge
  - available for decades
  - x-ray limit reduced through geometry
  - x-ray limit quote: 7.5×10^{-13} Torr
- Axtran gauge
  - Bessel box energy discrimination
  - electron multiplier to assist in low current measurements
  - Purchased, not yet installed
  - Measurement limit quote: <7.5e-15 Torr
- Watanabe BBB (Bent Belt Beam) gauge
  - Newly designed (JVSTA **28** (2010) p. 486)
  - Operates with Leybold IE540 controller
  - 230° degree deflector (similar to Helmer)
  - BeCu housing to reduce $I_{heating}$
  - Manufacturer's lower limit: 4×10^{-14} Torr





Axtran



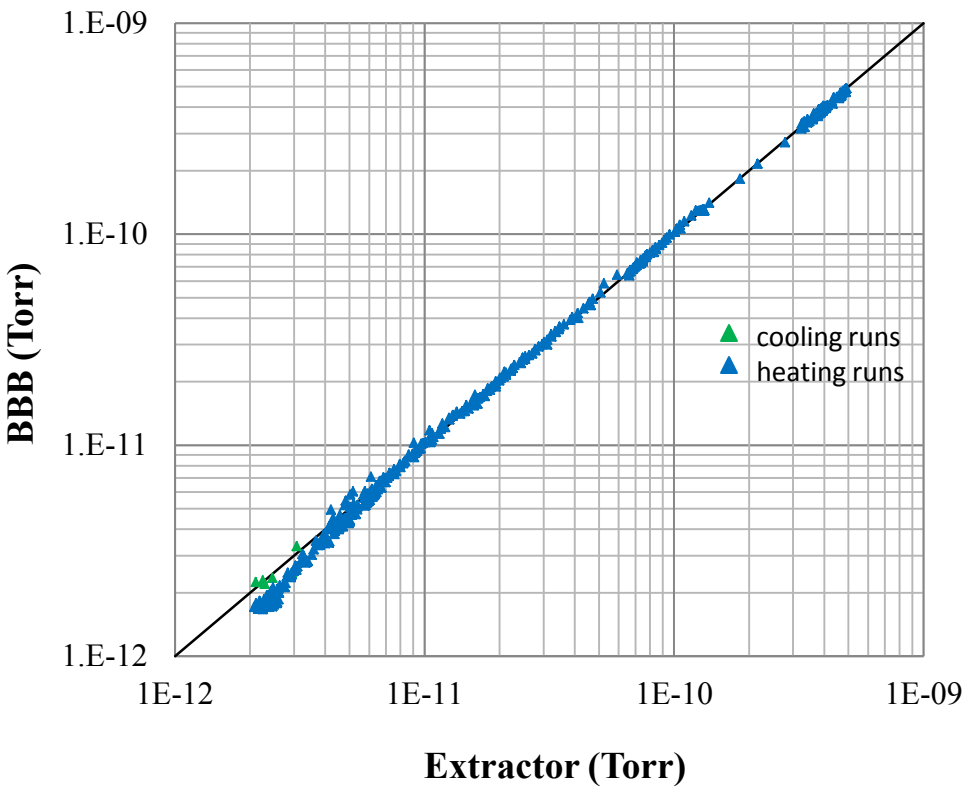
Gauge characterization chamber

- Heat treated twice
  - 400°C 10 days
- Outgassing (Q)
  - $3x10^{-14}$ Torr·L/s·cm^2
- Q following 250°C bake
  - $6.3x10^{-14}$ Torr·L/s·cm^2
- 3800 cm^2, 12L
- Pumping
  - 4 WP1250 NEGs, 60% 1300 L/s
  - 40 L/s ion pump (behind right angle valve)

Predicted pressure
$2x10^{-13}$ Torr

- Extractor Gauge
- BBB Gauge
- 2 Leybold IE540 controllers
- 2 Keithley electrometers
- UHV ion pump power supply
- Diagnostic cross with RGA and ion pump
- NEG activation flange

Linearity between gauges



- BBB and Extractor compared vs. pressure
  - Leybold IE 540 control
  - Keithley Electrometer
- Pressure varied in chamber by heating NEGs or chilling
- Conversion to Torr using manufacturer calibration factor / sensitivity
  - Depends on species
  - Ionization energy
  - Ionization current
  - Geometry

Gauge responses linear response over decades, possible deviation at lowest pressures

Sensitivity

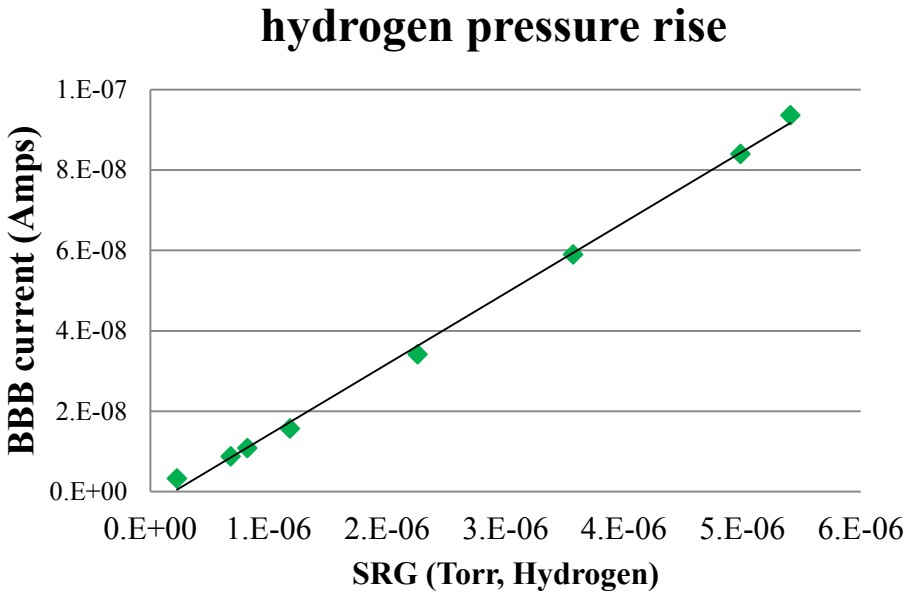
$$S = \frac{I_i}{P \times I_e}$$

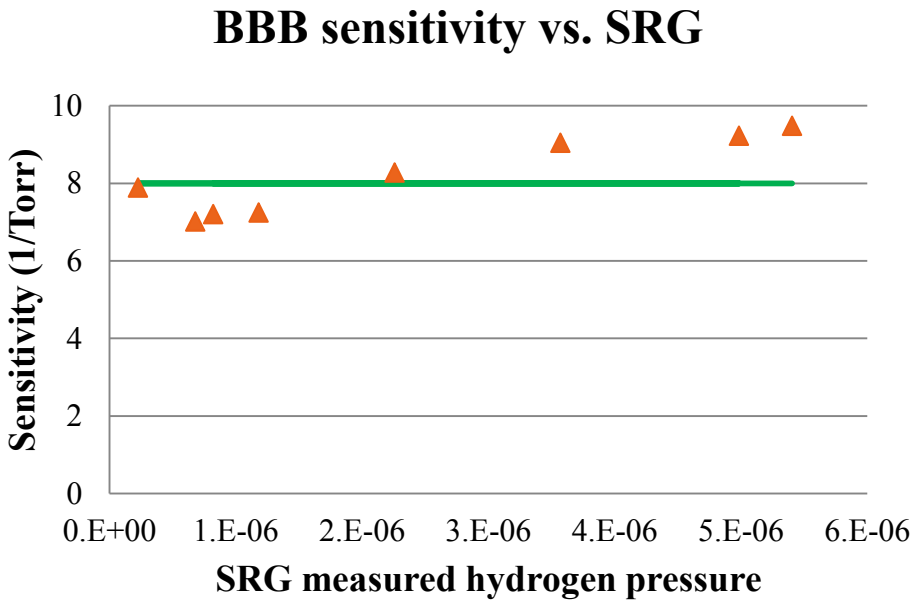
I_i ← Ion current

I_e ← Emission current

BBB and Extractor

- 120V electron energy
- 1.6 mA emission current
- geometry, collection efficiency vary

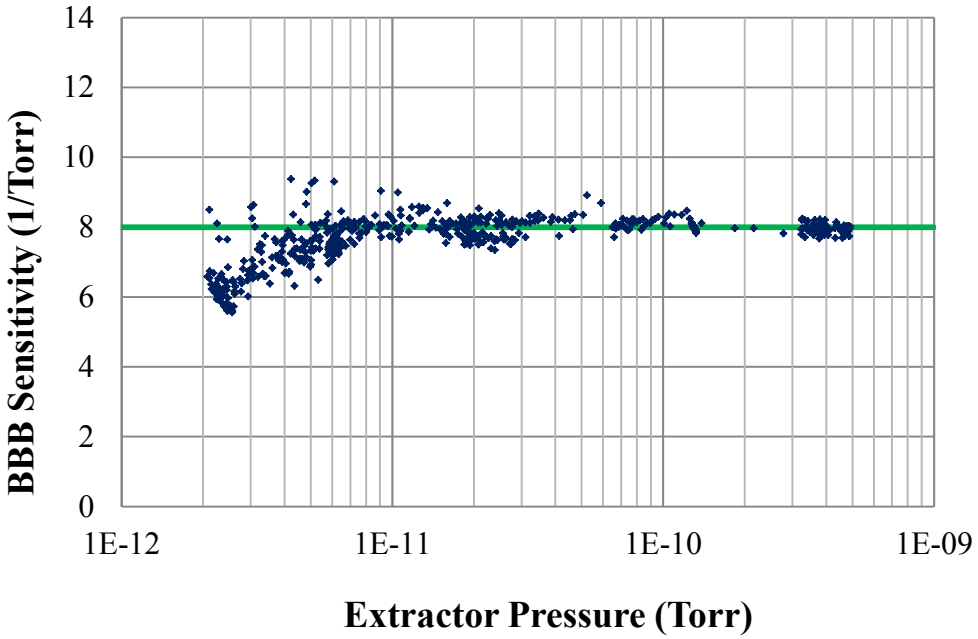




BBB vs. SRG data from previous setup

BBB sensitivity calculated using extractor

SRG Data: pressure 10^5 higher than our area of concern
Calculate BBB sensitivity from Extractor gauge pressure?



Calculated Extractor pressure relies on sensitivity of extractor gauge.

$$P = \frac{I_i}{S \times I_e}$$

Gauge sensitivity depends on

- Ionization energy
- Gas species

same

- Geometry
- Collection efficiency

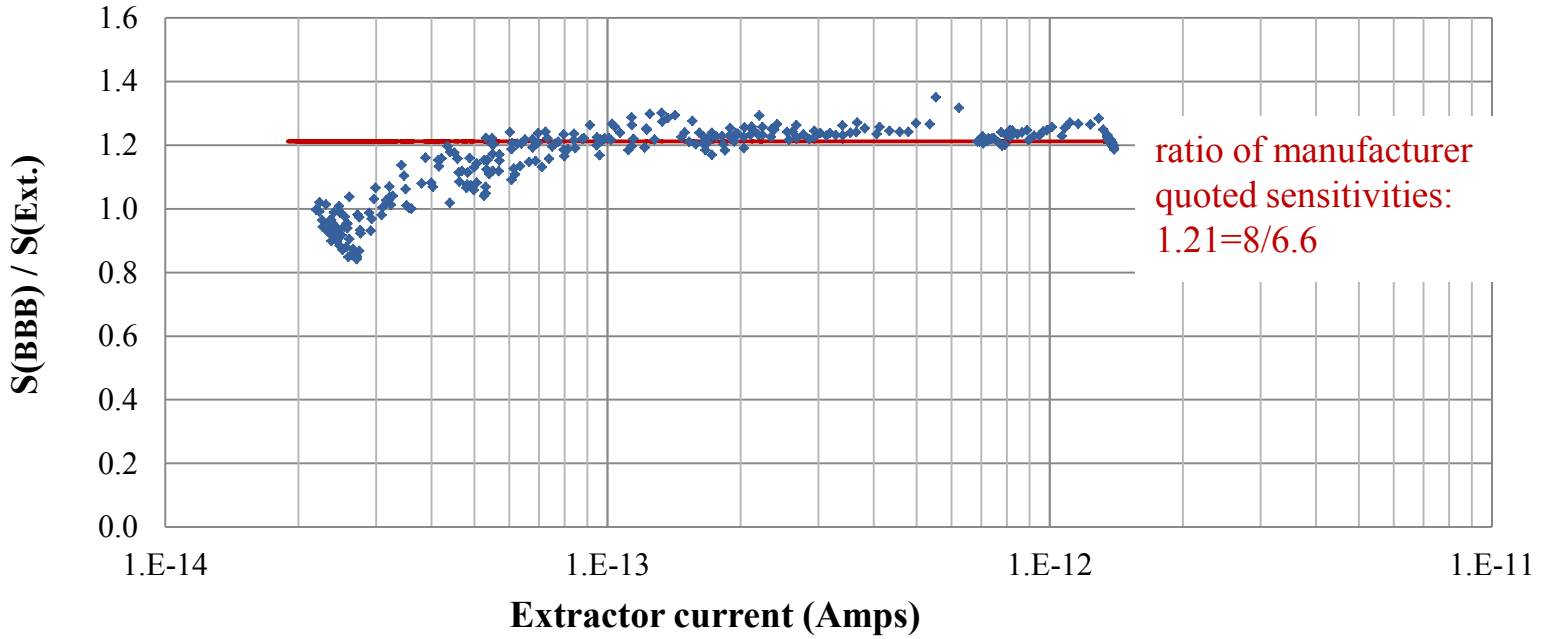
constant

relative sensitivity

Define sensitivity ratio

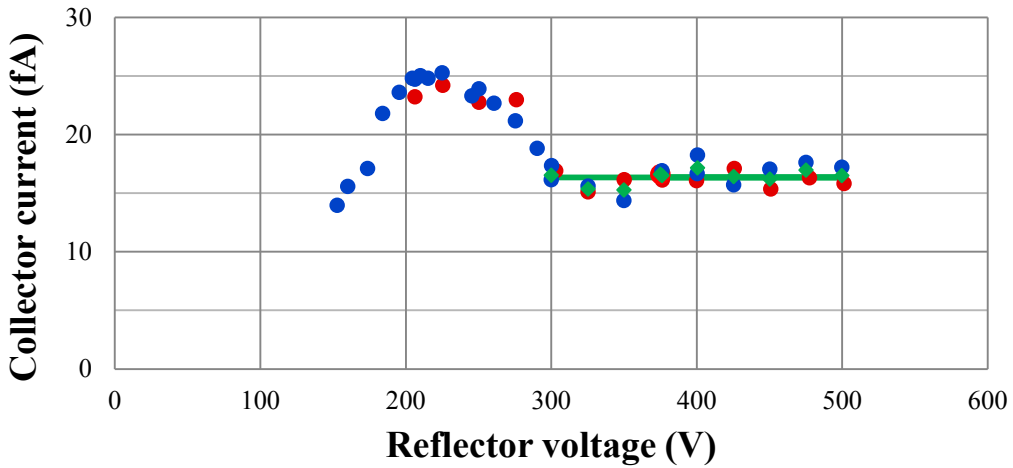
- should be constant

$$\frac{S_{BBB}}{S_{EXT}} = \frac{I_{BBB}}{I_{EXT}}$$

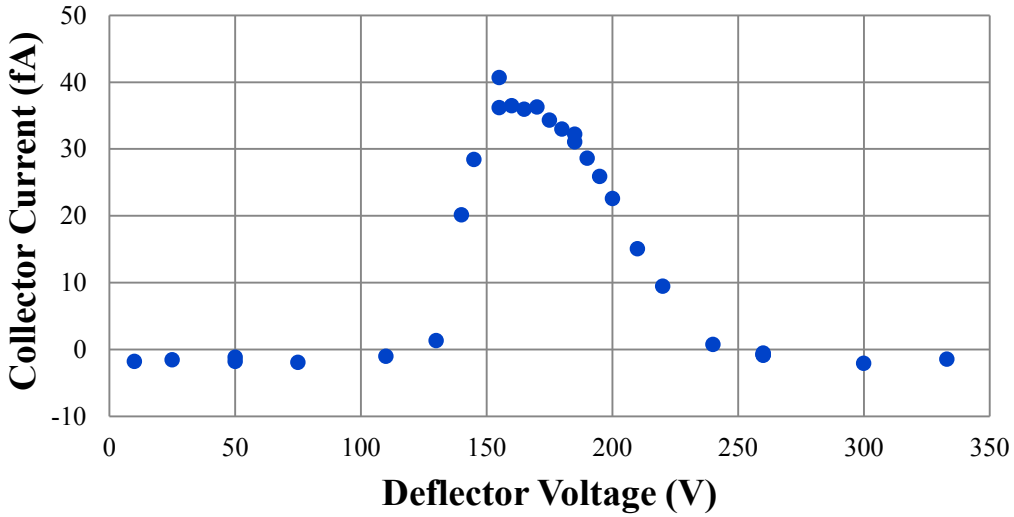


Can the deviation from constant behavior be explained by gauge backgrounds?

Background current measurements



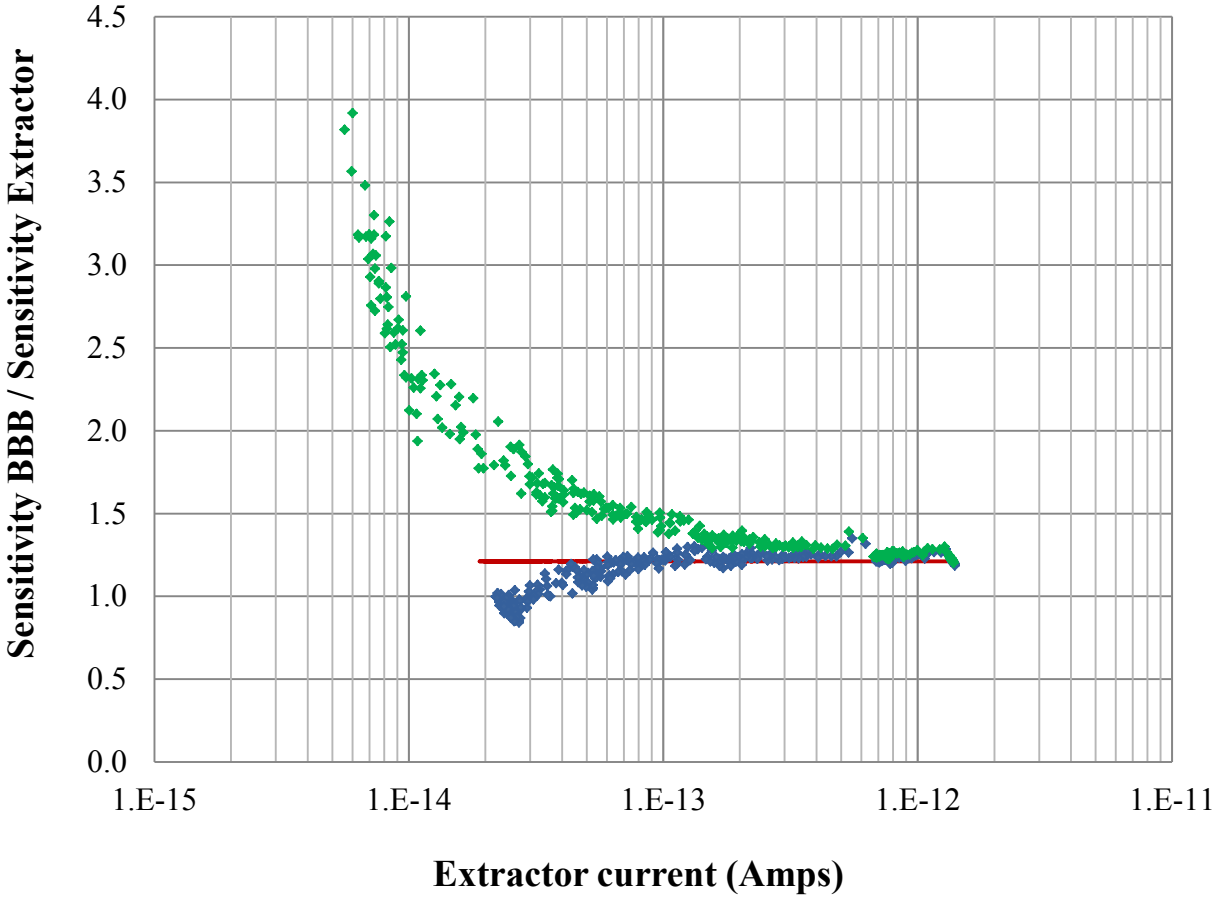
Extractor x-ray current accounts for 3/5 of total measured signal



BBB signal of 35 fA with background of -1 fA

Gauge backgrounds measured at different times, different pressures

Sensitivity ratio: x-ray limit correction

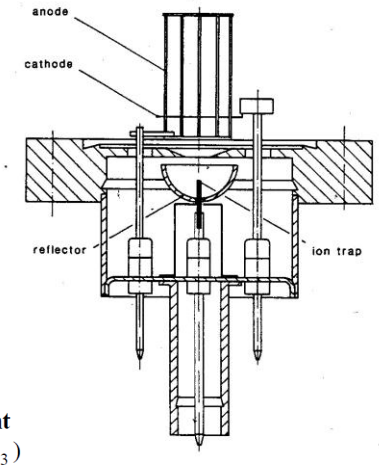


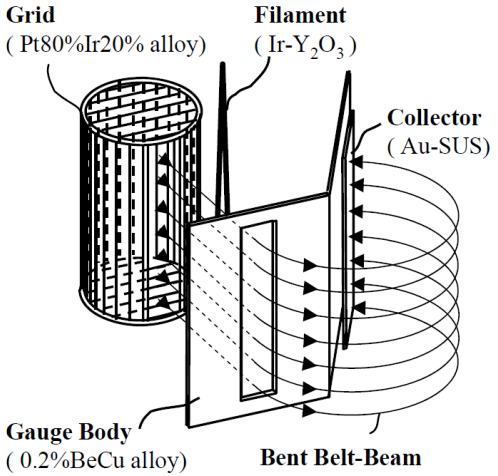
- Subtraction of x-ray background for extractor gauge overcorrects
- What else?
  - ESD limits
  - Load due to gauges
  - Small current measurement errors
  - nonlinearity in gauge response?

Electron stimulated desorption

$$I_{measured} = I_{real} + I_{x-ray} + I_{heating} + I_{ESD} + \ldots$$

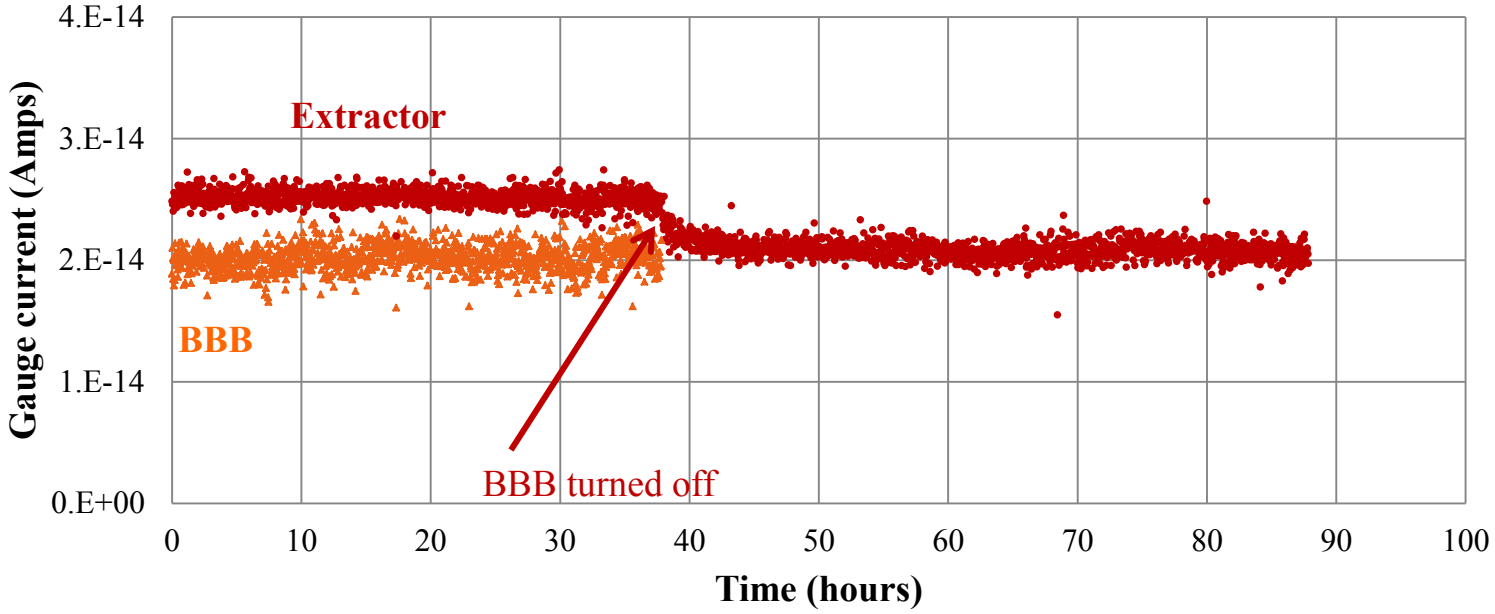
- Electrons can liberate elements adsorbed on the grid
- If grid - filament potential equal to electron energy, ESD difficult to separate
- Methods to reduce ESD
  - high energy electron bombardment (degas mode)
  - operate grid at elevated temperature
  - grid material optimization (BBB)
  - stabilize for months
  - Axtran: energy analysis since electron energy ≠ grid-filament potential





Current due to heating by filaments

$$I_{measured} = I_{real} + I_{x-ray} + I_{heating} + I_{ESD} + \ldots$$



Use one gauge to measure the additional current generated by other hot filament

ΔI (BBB) = 4.8 fA

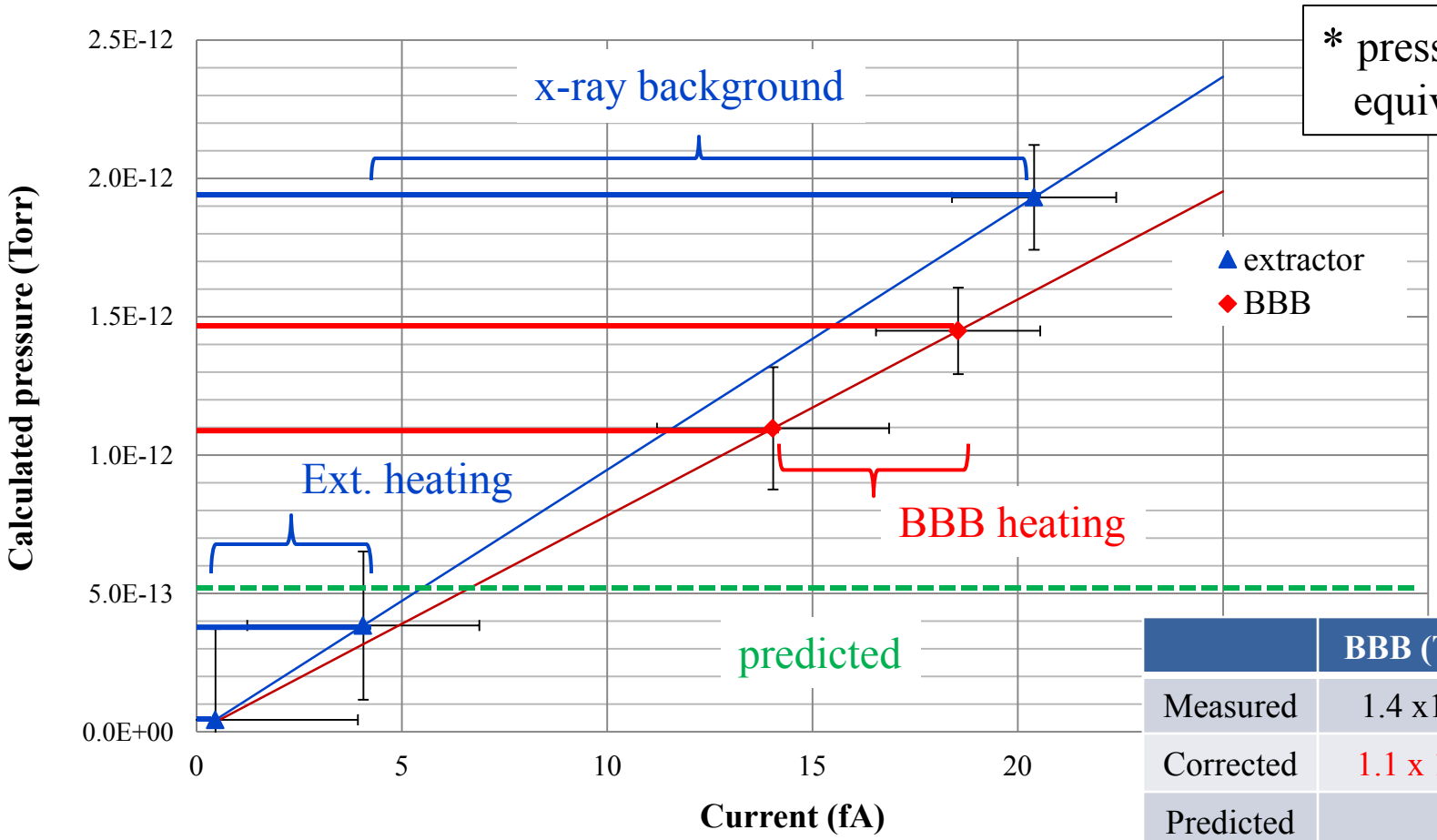
ΔI (Extractor) = 5.6 fA

BeCu BBB housing should reduce effect

Difference minimized after 6 months?

So what is our pressure?

$$I_{measured} = I_{real} + I_{x-ray} + I_{heating} + I_{ESD} + \ldots$$



	BBB (Torr)	Extractor
Measured	1.4×10^{-12}	1.9×10^{-12}
Corrected	1.1×10^{-12}	5×10^{-14}
Predicted	6×10^{-13}	

Conclusions

- Pressure in our systems (nitrogen equivalent) corrected for gauge effects is near $1x10^{-12}$ Torr
- BBB signal to noise good: Noise < 10% signal
- Extractor gauge: measurements at lowest pressures dominated by background
- BBB and extractor agree very well above $1x10^{-11}$ Torr
- The BBB gauge should be able to quantify pressure improvements in the bakable cryopump system.

Future work

- Verify outgassing rate of chamber
  - Is our predicted pressure correct? Does measured pressure agree?
- Add Axtran gauge to the system
  - Compare gauge with electron multiplier to avoid some small signal measurement issues
  - ESD ion discrimination capability
  - Determine which of the BBB and extractor is deviating from linear response
- Gauge calibration to verify / determine sensitivity
  - Repeat comparison with SRG (hydrogen vs. nitrogen)
  - UHV calibration at NIST, PTB…
  - XHV calibration (its own research project!)
- Add cryopump to NEG / ion pumping system
  - Can we use the cryopump alone to achieve better pressures?
  - Can we better activate NEGs?
  - Is NEG / Ion pumping system limiting our pressure?