Working toward XHV

Characterization and Improvements
of the
Vacuum System
for a
GaAs Photoemission Electron Source

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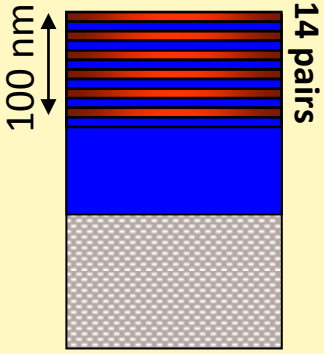
Thomas Jefferson National Accelerator Facility

Thomas Jefferson National Accelerator Facility

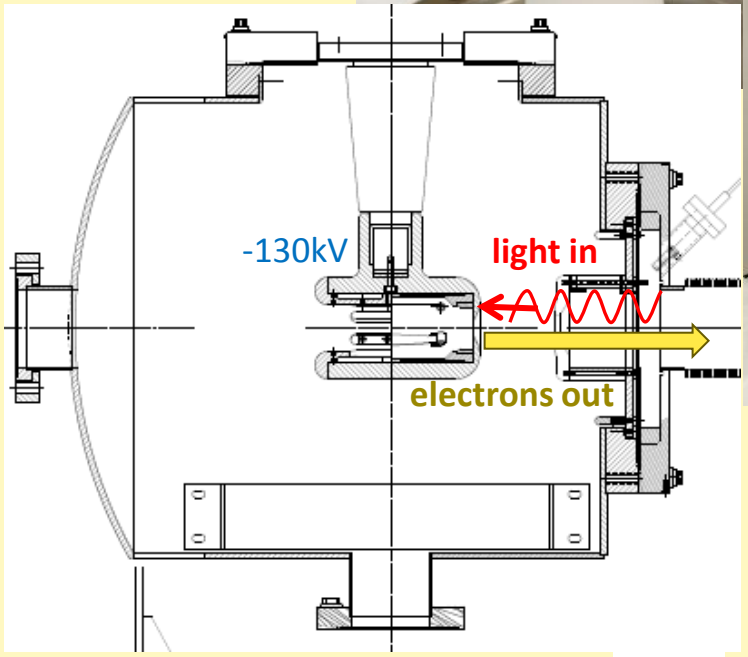
- 6 (12) GeV Electron accelerator for Nuclear Physics
- 85% polarization, up to ~200 μA beam to three experimental halls
- DC photoemission electron source
- Lifetime depends largely on vacuum
- Future accelerators (CLIC, EIC, ILC)
  higher current required

Polarized Electron Source

- DC photoemission source
- Polished electrodes
- 100-130 kV
- Strained superlattice GaAs/GaAsP photocathode



Strained superlattice
GaAs/GaAsP
Bandwidth semiconductor
QE ~ 1%, Pol ~ 85%



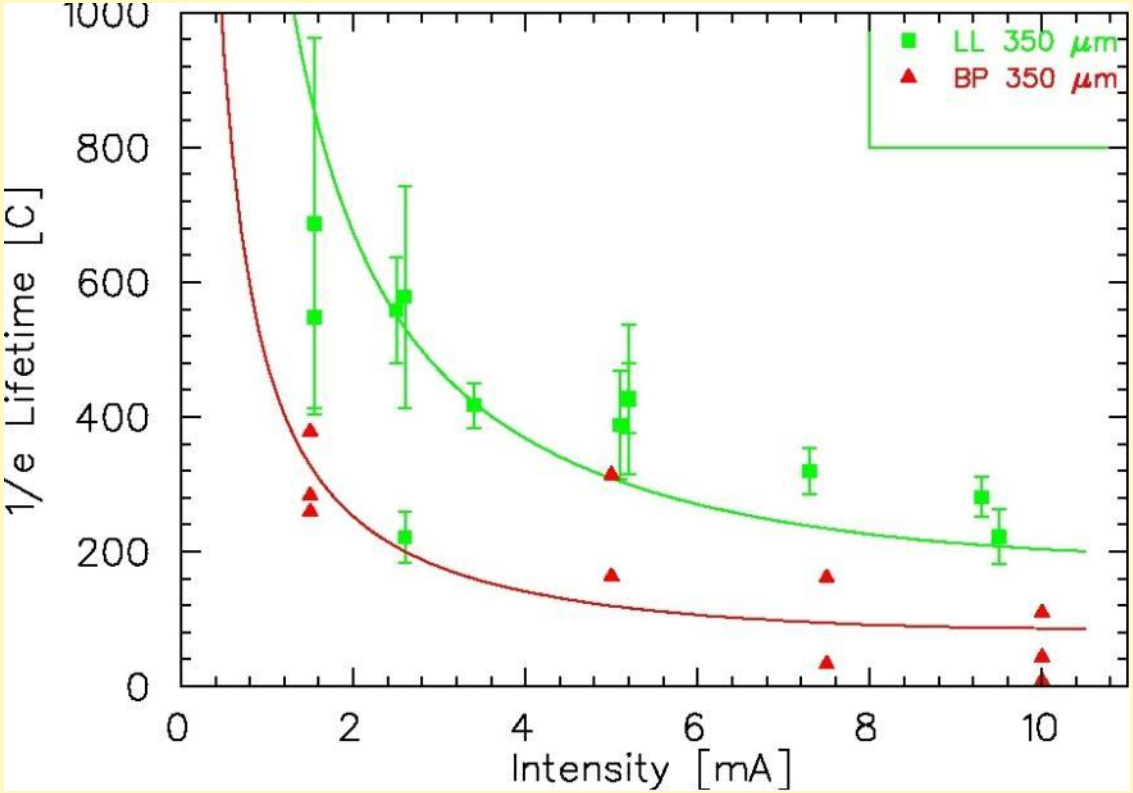
Vacuum affects cathode lifetime

Poor Vacuum, lower photocathode lifetime (red)

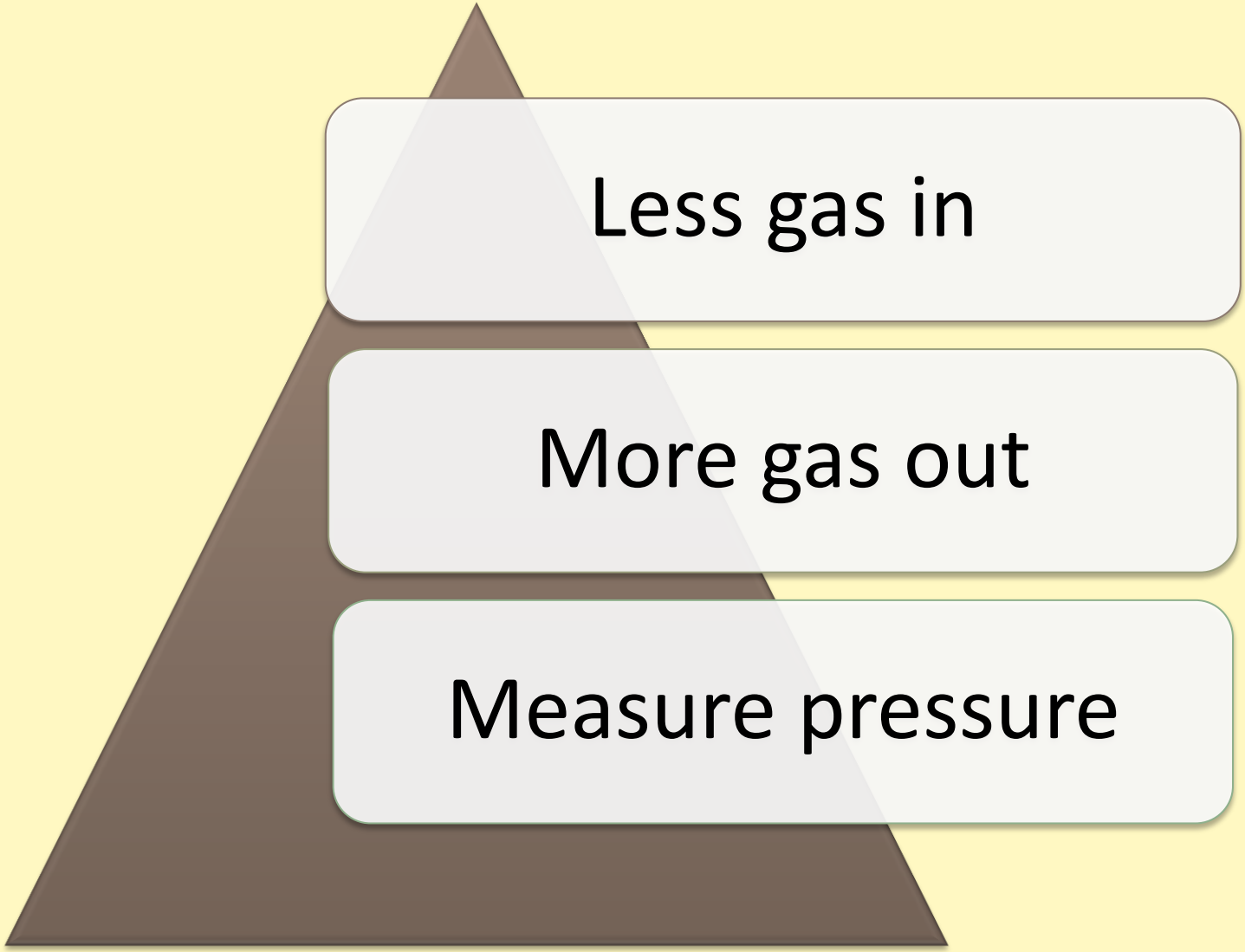
Better vacuum, higher lifetimes

Other lifetime factors

- photocathode properties
- field emission
- beam handling



How to reach XHV ≡ P < 0.76×10^{-12} Torr?



Less gas in: reduce outgassing

- Primary source in stainless system: hydrogen outgassing
- To reduce outgassing
  - reduce thick flange area
  - heat treatment

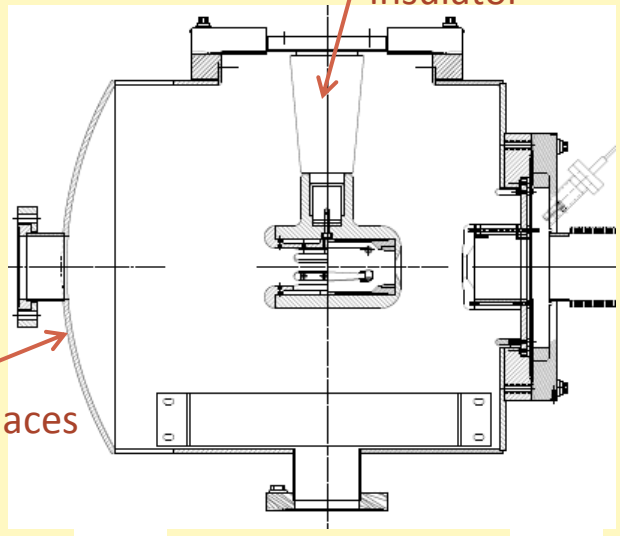
    400°C semi-vacuum bake

    10+ days

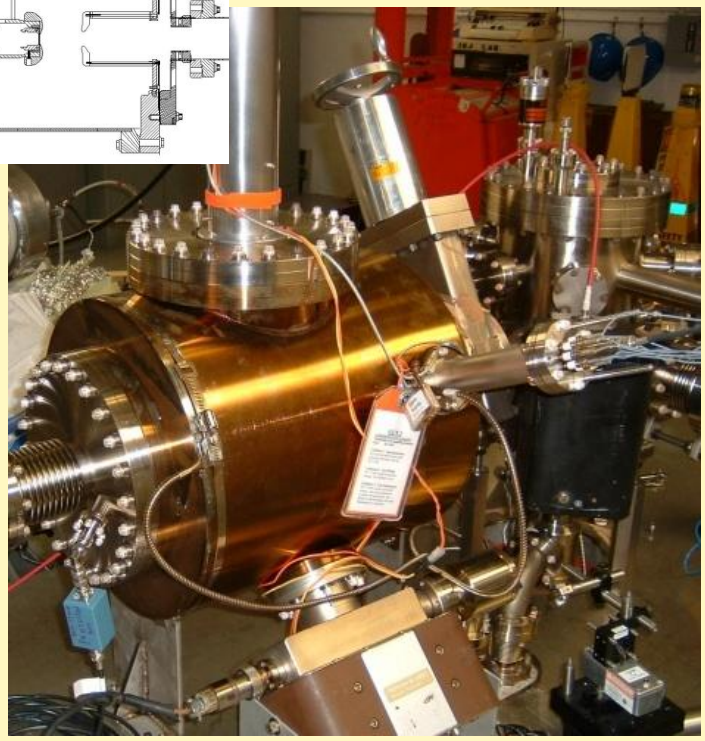
Old design
thick flanges
custom insulator
high field points

New design

inverted commercial insulator

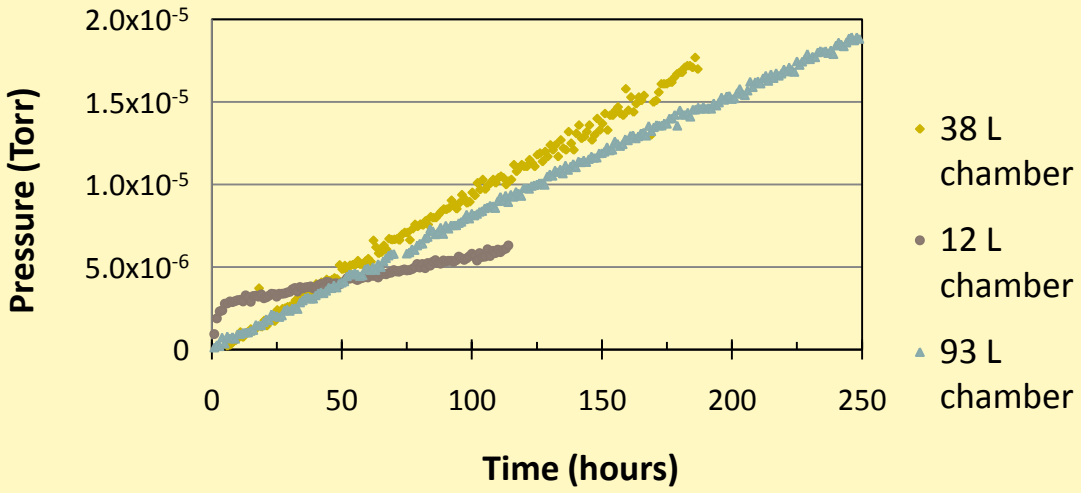


thin dome replaces thick flanges



Less gas in: reduce outgassing

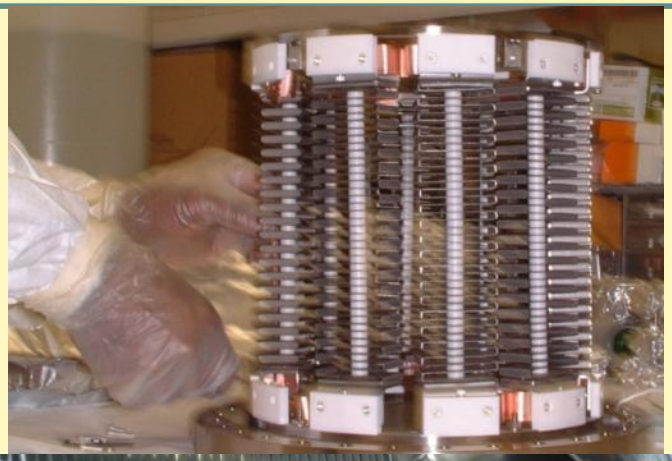
- Outgassing measured by Spinning Rotor Gauge rate of rise
- Semi-vacuum bake
  - Hot air outside
  - Vacuum inside

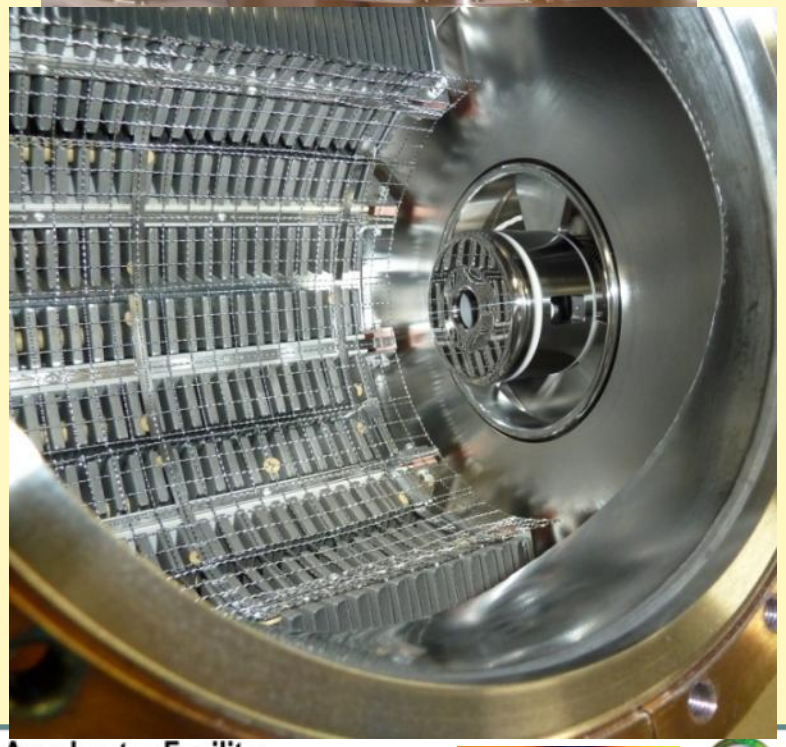


chamber	treatment	Q (Torr·L/s·cm^2)
304	900ºC 2 hours before welding	9 x 10 $^{-13}$
93 liter, 316LN EP	400ºC, ~10 days	1.5x10^{-13}
38 liter, 316, thin wall, EP	400ºC, ~10days	1.13x10^{-13}
12 liter, 304	400ºC, ~10 days	3.5x10^{-14} ?

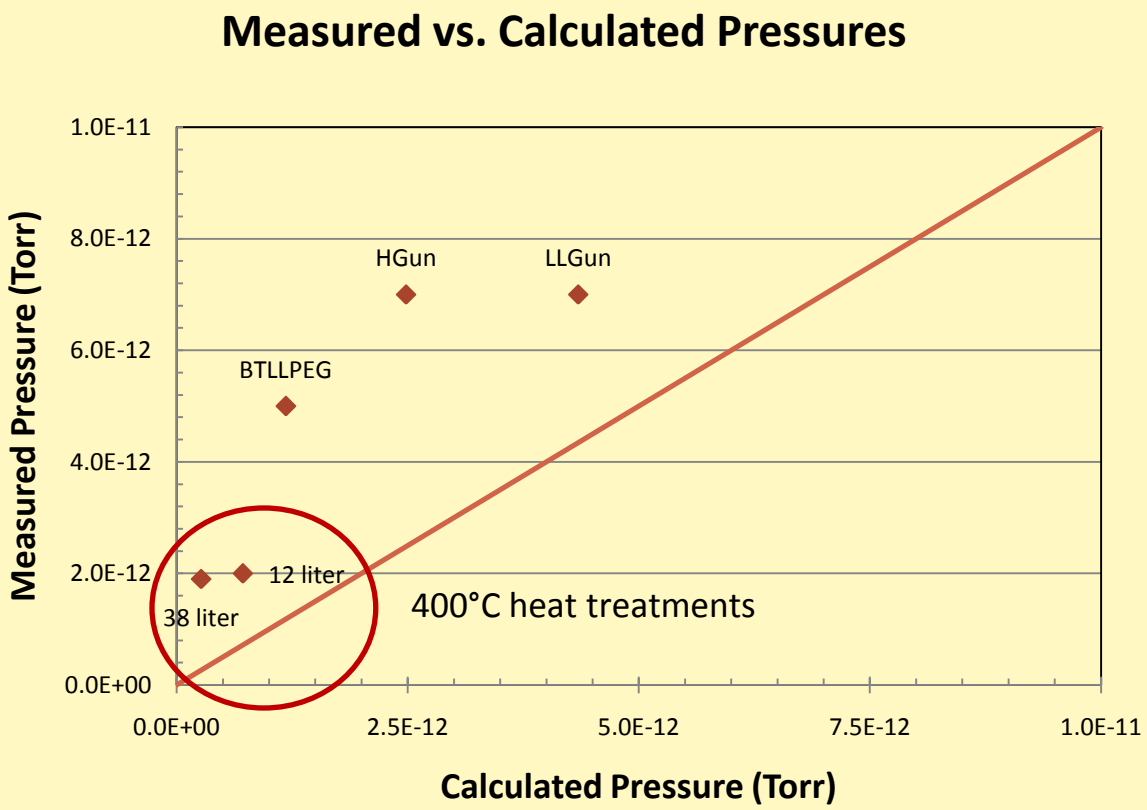
More gas out: improve pumping

- Pump system combines
  - non-evaporable getters (NEG)
  - ion pumps
- Rotate NEG modules to eliminate line of sight from walls to cathode/anode gap
- Add ~400ºC activation during 250ºC bake





Pumping



- P_{calc}=QA/S
- Approaching calculated pressures
- Heat treated chambers: closer to expected pressure
- All pressures nitrogen equivalent

Pressure still not as low as predicted

Do ion pumps limit a chamber's ultimate pressure?

System 1: 40 L/s ion pump (diode)

Flapper Valve	HV Chamber IP	Extractor Gauge
Open	0.1 nA	8.8×10^{-12} Torr
Closed	3.5 nA	8.2×10^{-12} Torr

Hurts!

Flapper valve between ion pump and NEG pumped chamber with extractor gauge

System 2: old custom diode PE ion pump

Flapper Valve	HV Chamber IP	Extractor Gauge
Open	0.5 nA	7.0×10^{-12} Torr
Closed	1.8 nA	7.8×10^{-12} Torr
Open	0.3 nA	7.6×10^{-12} Torr
Closed	1.1 nA	8.8×10^{-12} Torr

Helps!

need more data

trying XHV option on Gamma ion pumps, no clear results yet

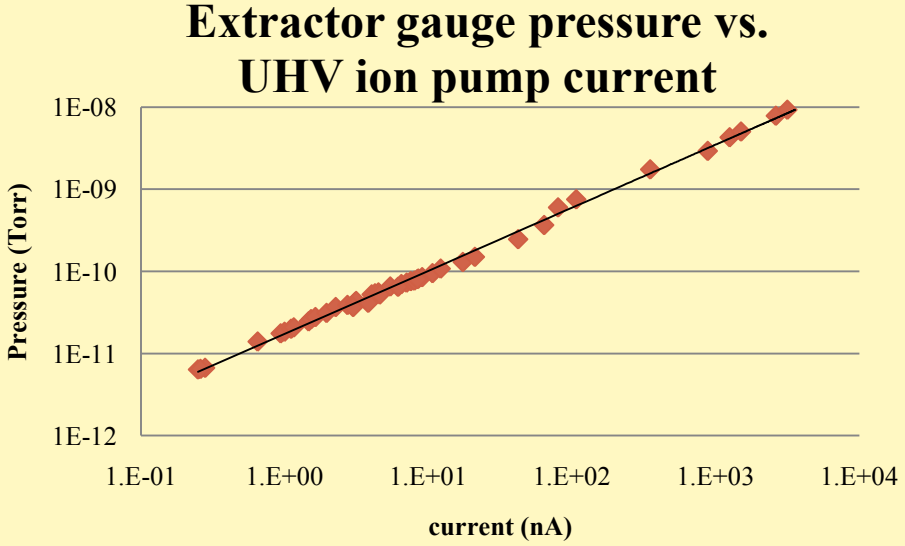
Reduce SIP size?

UHV ion pump supplies

- UHV ion pump power supplies

  - power ion pumps once turned on
  - monitor current down to <1 nA
  - sensitive relative pressure monitor
    - diagnose vacuum activity due to field emission without glowing filament

- Work in progress to extend lower measurement limit
- Now can read 10 picoA, see vacuum activity at that level

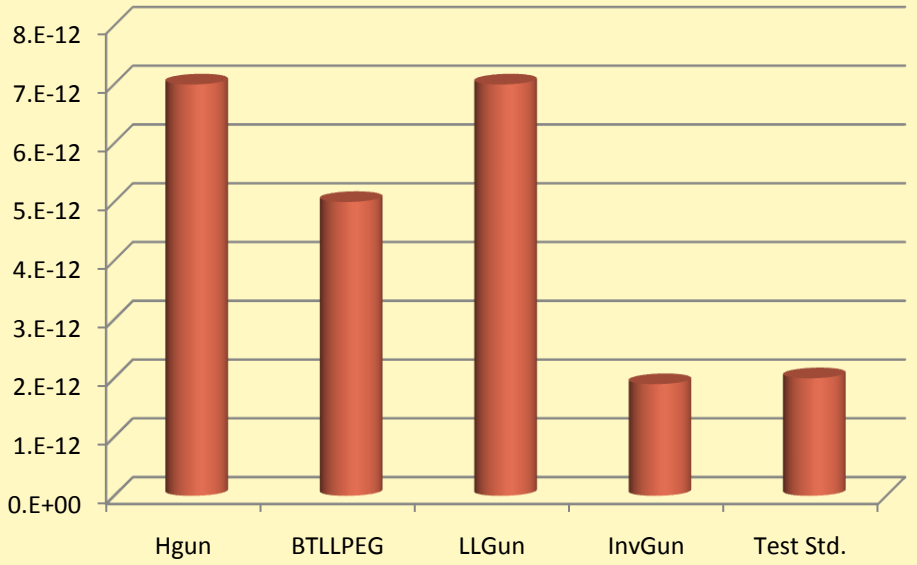


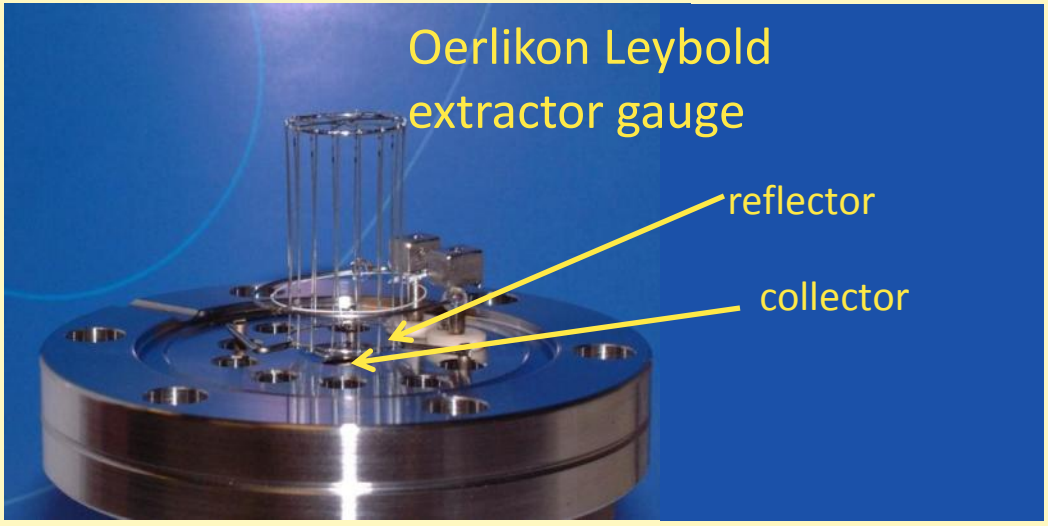
Measure pressure

- $2x10^{-12}$ Torr limit
  - Real pressure?
  - Gauge limitation?

- Oerlikon Leybold extractor gauges
  - x-ray limit quoted $<0.76x10^{-12}$ Torr
  - recessed collector
  - vary reflector voltage

x-ray limit measurement

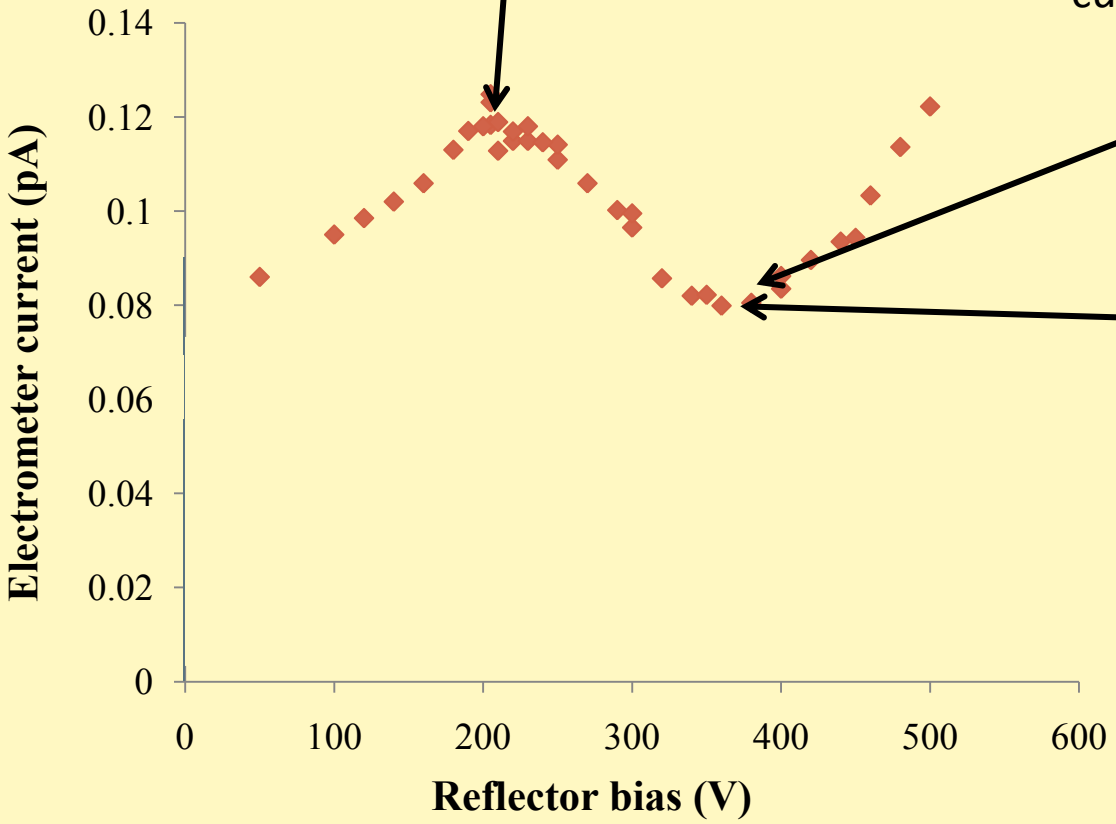




Measure X-ray limit

operating voltage:
gas phase ions detected
0.12 pA=3.55x10^{-12} Torr

reflector voltage increased:
gas phase ions rejected
current from x-ray stimulated
emission from collector



no background subtraction
x-ray limit
2.4x10^{-12} Torr

method published by Fumio Watanabe,
J. Vac. Sci. Technol. A **9**, 2744 (1991)

Measure X-ray limit

operating voltage:
gas phase ions detected
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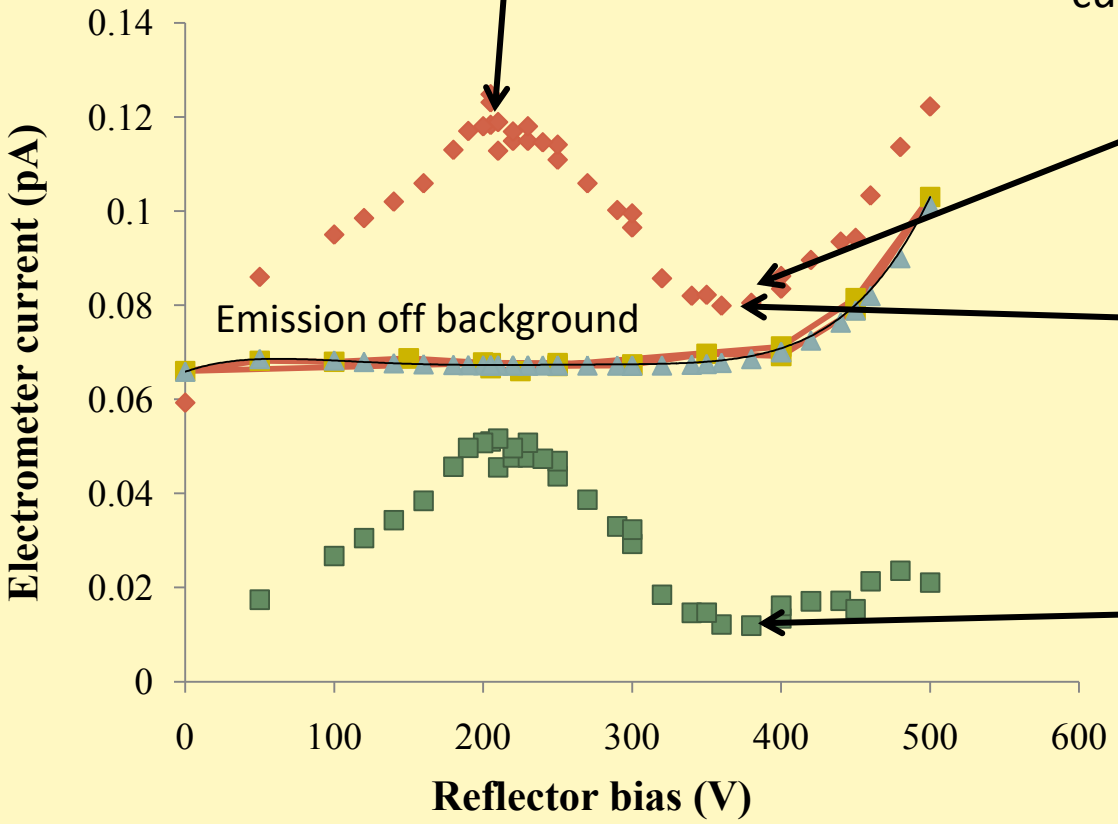


no background subtraction
x-ray limit
2.4x10^{-12} Torr

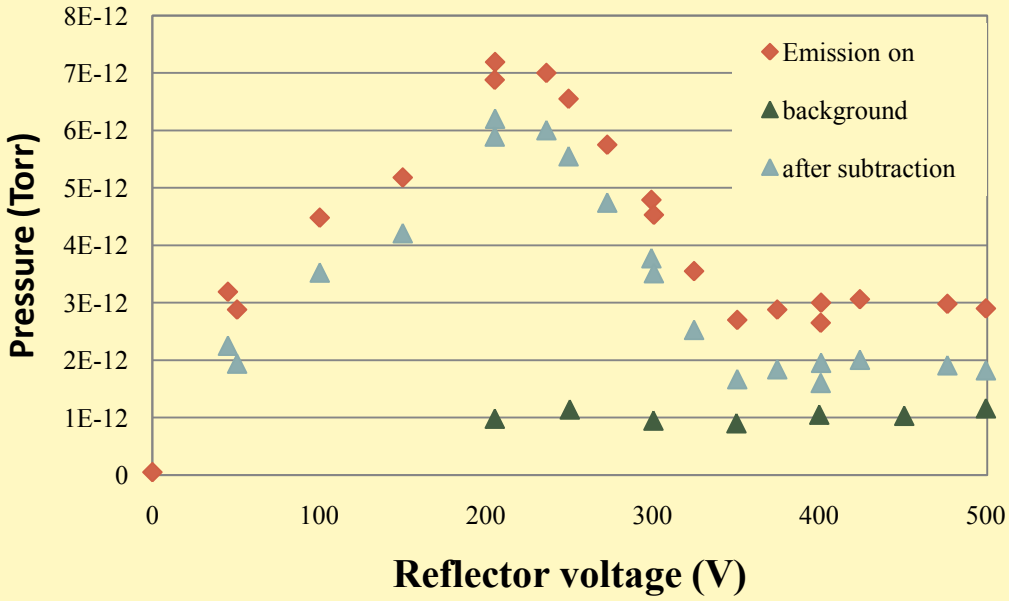
subtract background
x-ray limit
7.1x10^{-13} Torr

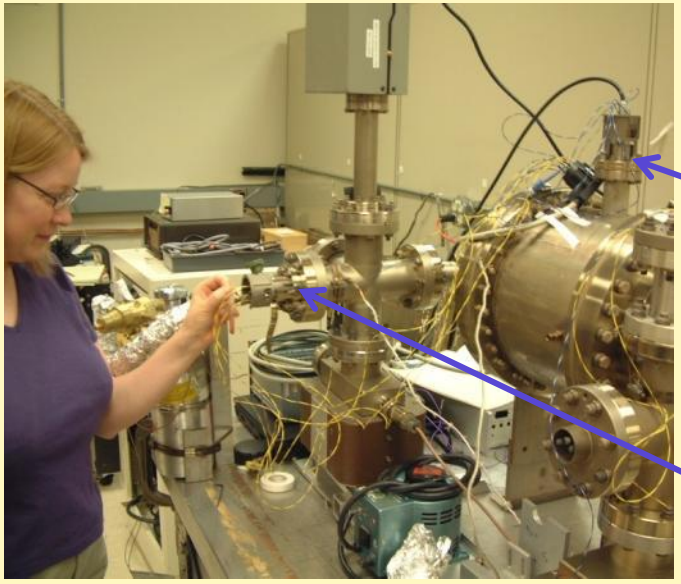
looks promising

method published by Fumio Watanabe,
J. Vac. Sci. Technol. A **9**, 2744 (1991)

Better background subtraction

Measure
"emission off" background with gauge elements biased



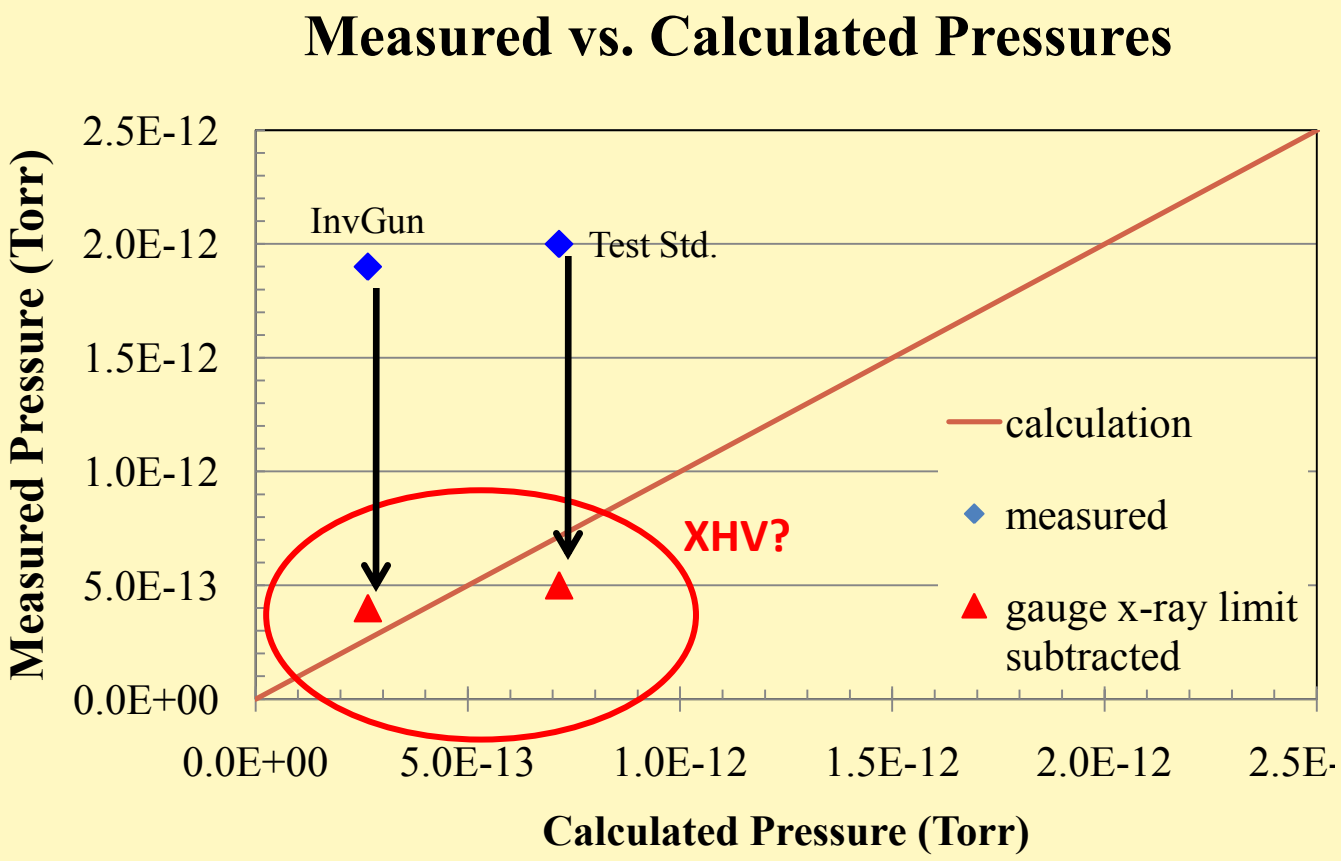


First extractor:
biased, no emission
current/pressure measured

Second extractor:
biased, emission on
no current/pressure measured

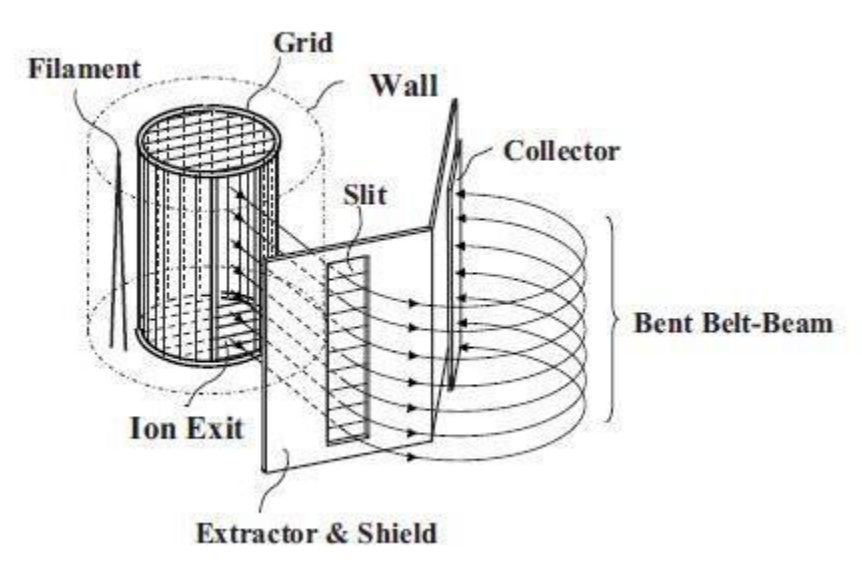
x-ray limit near
2×10^{-12} Torr
as installed?

X-ray limit subtraction



- Subtract x-ray limit of gauge from measured pressure
- Nitrogen equivalent pressure into XHV regime
- Error bars huge subtracting similar numbers

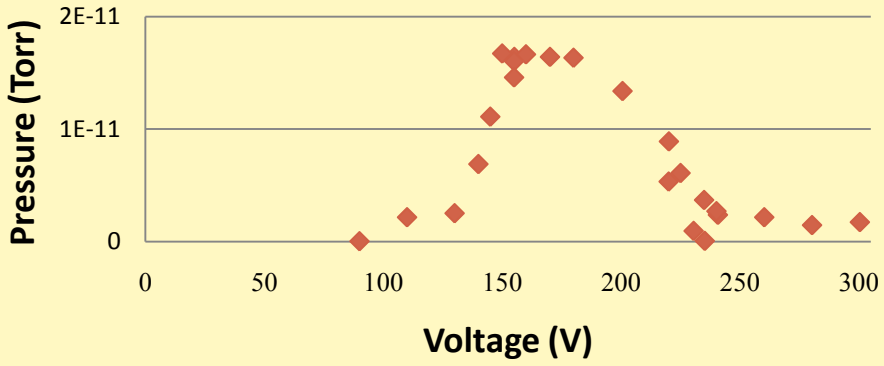
Watanabe BBB Gauge



Fumio Watanabe JVSTA 28(3) p.486 2010

Deflector variation
background below IE540 detection limits
(use electrometer below $1x10^{-13}$ Torr)

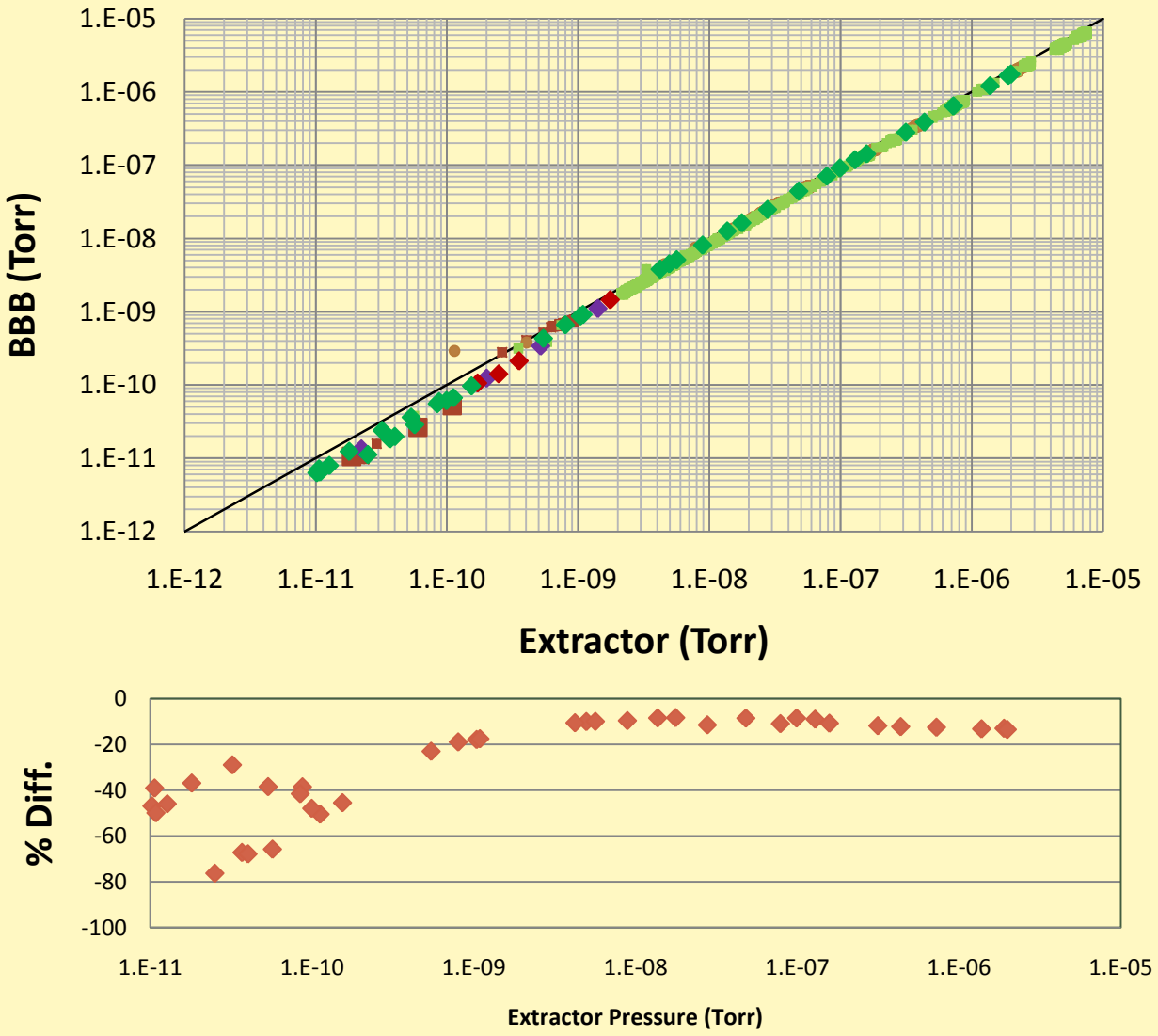
230º deflector, BeCu housing
pressure measurement limit quoted
$4x10^{-14}$ Torr !!!
Leybold IM540 controller + bias



Gauge comparison system

- Old gun chamber
- NEG module array
- 25 L/s SEM/XHV ion pump
- 2 extractor gauges
- 1 BBB gauge
- 1 device formerly known as RGA
- Spinning rotor gauge
- Two gas inlet manifold with leak valves
- Outgassing sub-optimal
- Pumps not optimally activated
- No gauges with traceable or up-to-date calibration

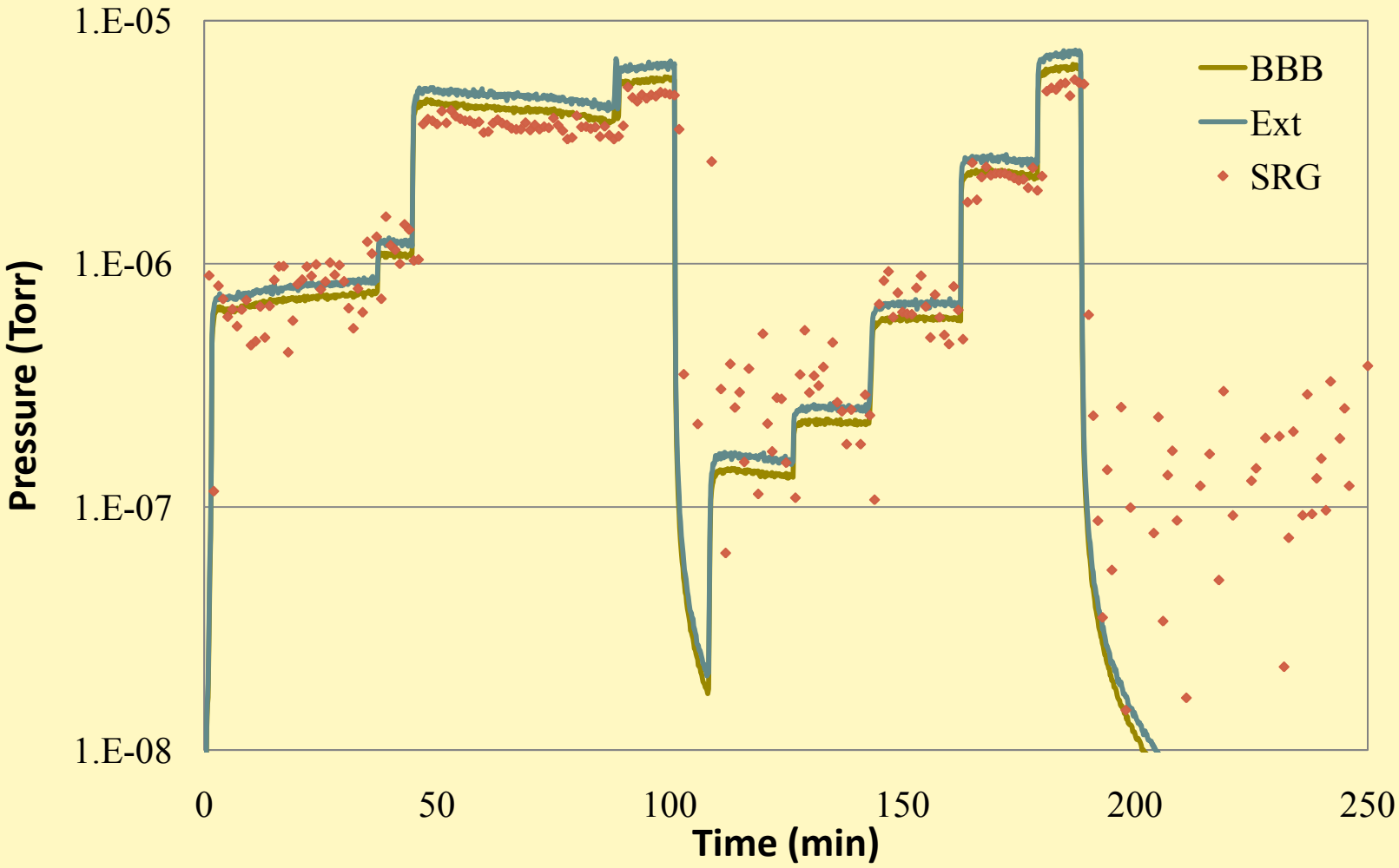
First data: Gauge comparison



- Extractor and BBB recorded with hydrogen gas introduction
- Extractor readings slightly higher
  - calibration issue
- % difference increases at lower pressures

  need more data
- Need data below 5×10^{-12} Torr
  - Better test chamber

Spinning Rotor Gauge Comparison



Threefold work toward XHV

- Outgassing measurably reduced
  - 400ºC long heat treatment
  - Reduced area of thick flanges
- Pumping configuration improved
  - Rotated GP1250 NEG modules
  - Activate during bakeout
  - Still investigating ion pump behavior
- Accurate pressure measurement
  - Extractor gauge “as installed” x-ray limit measurements
  - New Watanabe BBB gauge first data

Thank you for your attention

Installed Load-Locked gun