U–Pb TIMS geochronology using ATONA amplifiers

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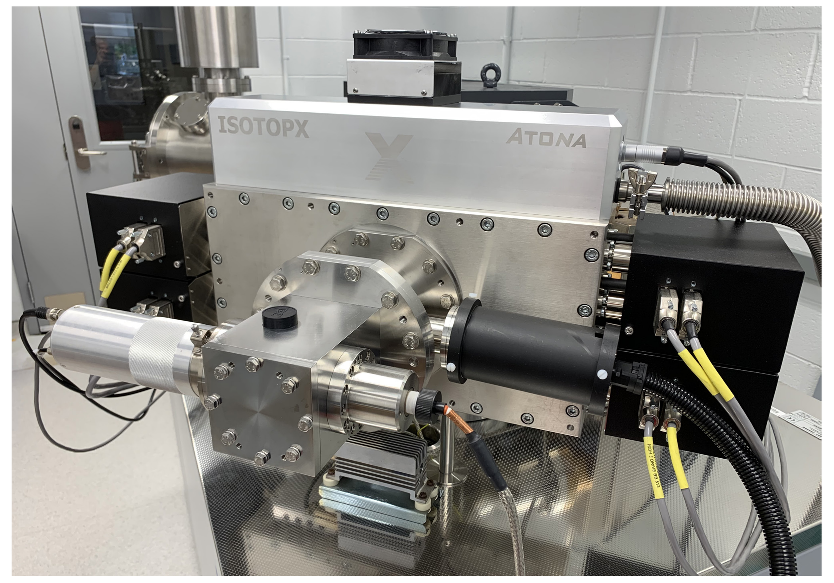
Key points

- **ATONA** [**aA** (10^{-18} A) **to nA** (10^{-9} A)] is a new Faraday cup signal amplifying technology for Isotopx Phoenix thermal ionisation mass spectrometers (TIMS)
- Main advantages for TIMS U–Pb geochronology (compared to conventional ion counting with peak-hopping):
  - » **better precision and accuracy for all but the smallest/youngest samples**
  - » **shorter analysis time**
- We present the results of our tests of the new ATONA system at Princeton University, the conditions in which it is advantageous to use it, and optimised Pb and U analysis methods.



Detector parameters

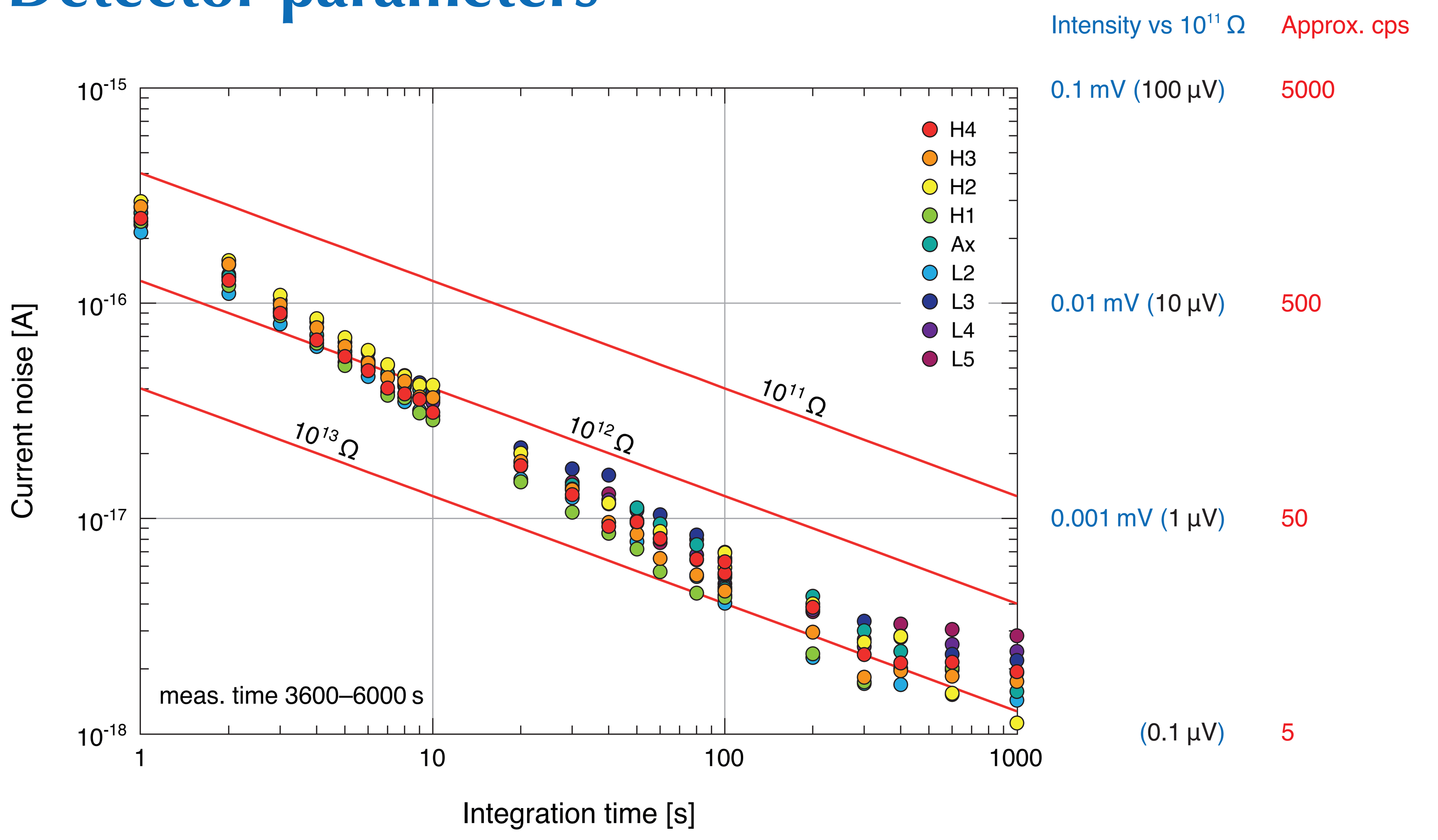


Figure 1. Low amplifier noise is key to measuring small beams precisely. The noise of the ATONA system improves with longer integration times, performing close to the theoretical (Johnson–Nyquist) noise of a 10^{12} Ω resistor at integration periods <10 s and approaching the theoretical limit of a 10^{13} Ω resistor for integrations of >100 s. This implies that for e.g. a 1000 s integration period, one should be able to quantify a beam of 50–100 cps with a signal-to-noise ratio of ~5.

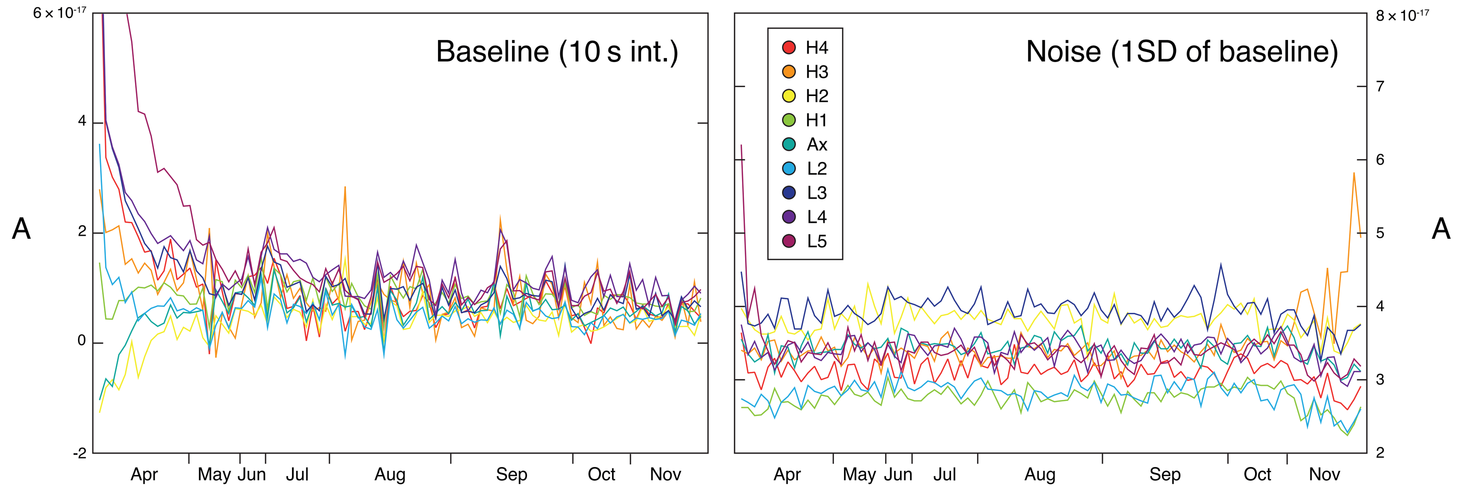


Figure 2. Evolution of baseline parameters over time since installation (measured for 1 h at 10 s integration period).

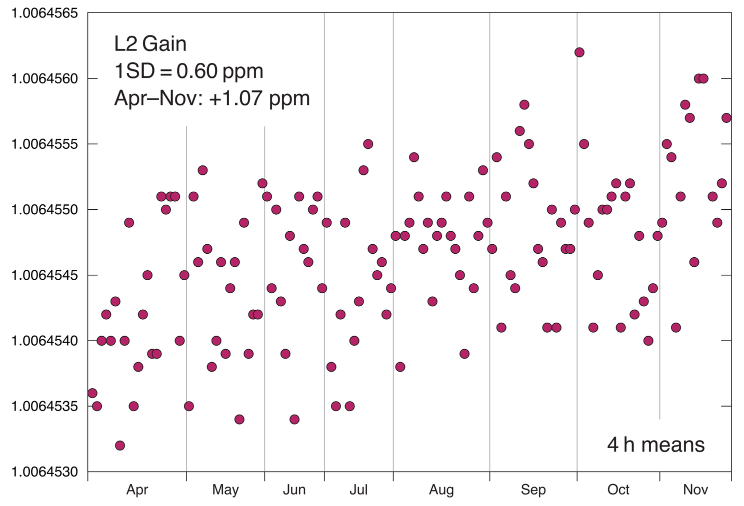


Figure 3. Gain calibration results since installation. The gain values of all channels are highly reproducible over hours to days (default calibration time is 4 h). We observed a slight drift of gain values since installation on the order of 1 ppm across all channels.

U–Pb methods and first results

Measurement setup

Cup configuration

L5	L4	L3	L2	(Ax) PM	H1	H2	H3	H4	
			202Pb	204Pb	205Pb	206Pb	207Pb	208Pb	30 s
				205Pb	206Pb	207Pb	208Pb		10 s
265(UO_2)	267(UO_2)	269(UO_2)	270(UO_2)	(272.7)					30 s

$^{18}O/^{16}O$ (from 265, 267 and 269 (UO_2))

Pb: 2-cycle FaraDaly routine with ^{204}Pb (30 s) alternated with ^{205}Pb (10 s) in the axial Daly photomultiplier (PM) to correct for Faraday–Daly gain

UO_2: static Faraday routine allowing for simultaneous measurement of $^{18}O/^{16}O$ and UO_2 interference corrections using mass 269

Baseline: single at start, 300 s at each half-mass

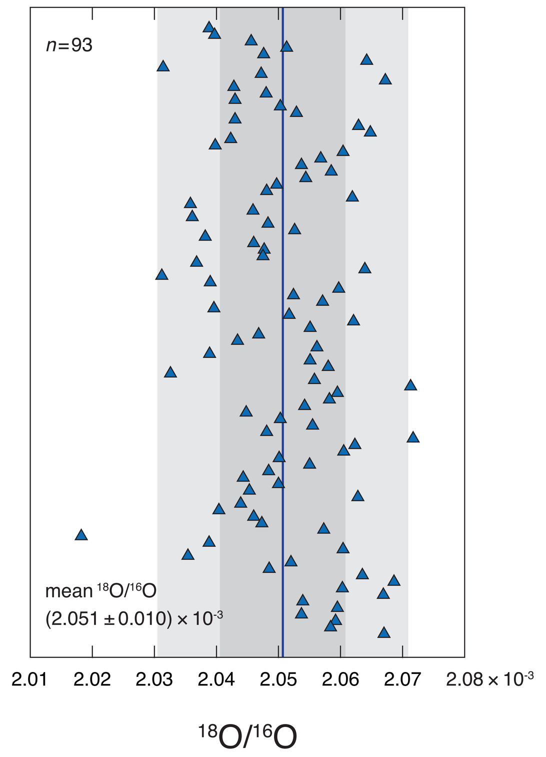


Figure 5. $^{18}O/^{16}O$ measured during our UO_2 runs of zircon is consistent with the IUPAC recommended value of 0.002055.

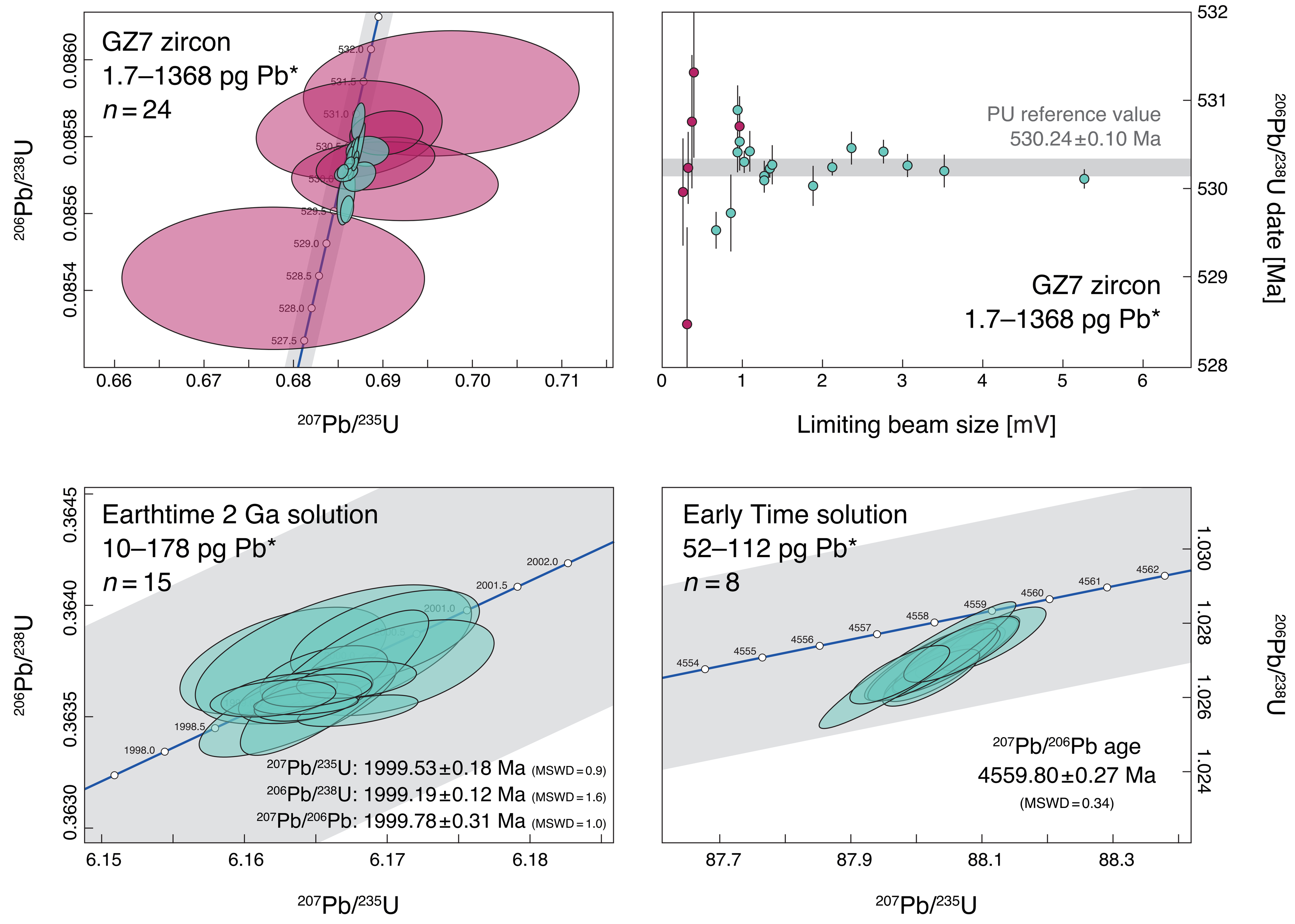


Figure 4. U–Pb FaraDaly dating results for shards of megacrystic zircon GZ7 (Nasdala et al. 2018, GGR), the Earthtime 2 Ga and Early Time 4.5 Ga synthetic solutions. Synthetic solution data on loads >10 pg Pb* show good reproducibility and accuracy. GZ7 aliquots were prepared in a range of sizes down to 1.7 pg Pb*. The accuracy of $^{206}Pb/^{238}U$ date appears to scale with average intensity of the limiting beam (^{205}Pb or ^{206}Pb depending on zircon size and spike weight), with a drop-off below ~1 mV. $^{207}Pb/^{235}U$ dates of the smallest GZ7 aliquots remain accurate despite large uncertainties for ^{207}Pb beams of a few 10s µV. Pb was analysed for 100–200 cycles (1.5–2.5 h) following a single, long (3 × 300 s) baseline.

ATONA vs (Daly) ion counting

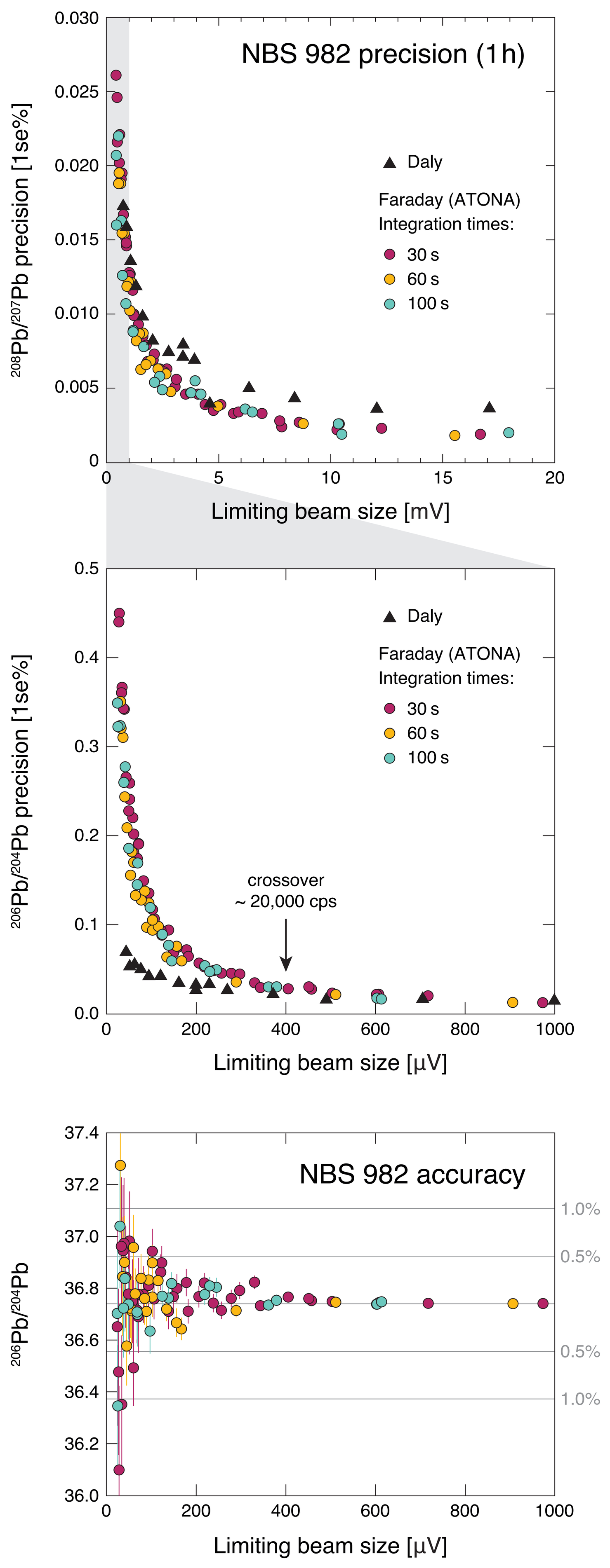


Figure 6. Results of automated 1 h-long runs of NBS 982 with the Daly/photomultiplier system and ATONA amplifiers at three different integration times and a range of intensities. Faraday runs reach higher precisions at average intensities >2 mV ($^{208}Pb/^{207}Pb$ data); Daly performs better at lowest intensities <400 µV (~20,000 cps; $^{206}Pb/^{204}Pb$ data). Extended integration times of 60–100 s have little effect on either precision or accuracy; the marginal gains are in the intensity range where Daly outperforms Faradays.