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Assays at the speed of light

Chrysos™ PhotonAssay Technology

Dirk Treasure | Chief Executive Officer | Chrysos Corporation

Chrysos PhotonAssay

Commercialising a best in class gold assay method:

- Fast analysis
- High accuracy and precision
- Low to zero sample preparation
- Large sample size
- Insensitive to sample matrix
- Chemical free
- Non-destructive analysis
- Application to different elements
- Improved OH&S and reduced environmental impact

Conventional assay techniques

- Fire-assay has been the standard method for many centuries
- Existing alternatives:
  - Aqua regia digest & titration
  - Cyanidation
  - Neutron activation analysis

Turn-around time
Usually > 24 hours

Small sample mass (10-50 g)

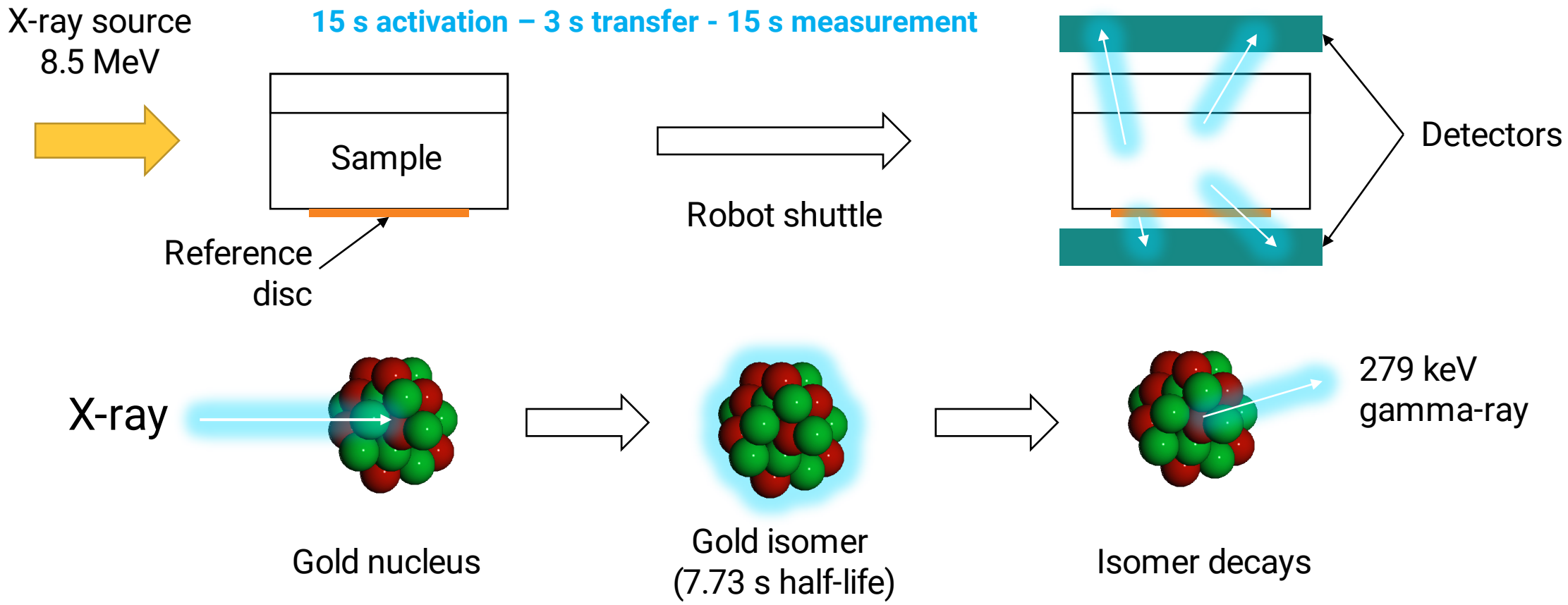
Extensive sample prep

Skilled labour requirements

Hazardous process

Technology

Photoactivation analysis + automatic reference compensation = PhotonAssay



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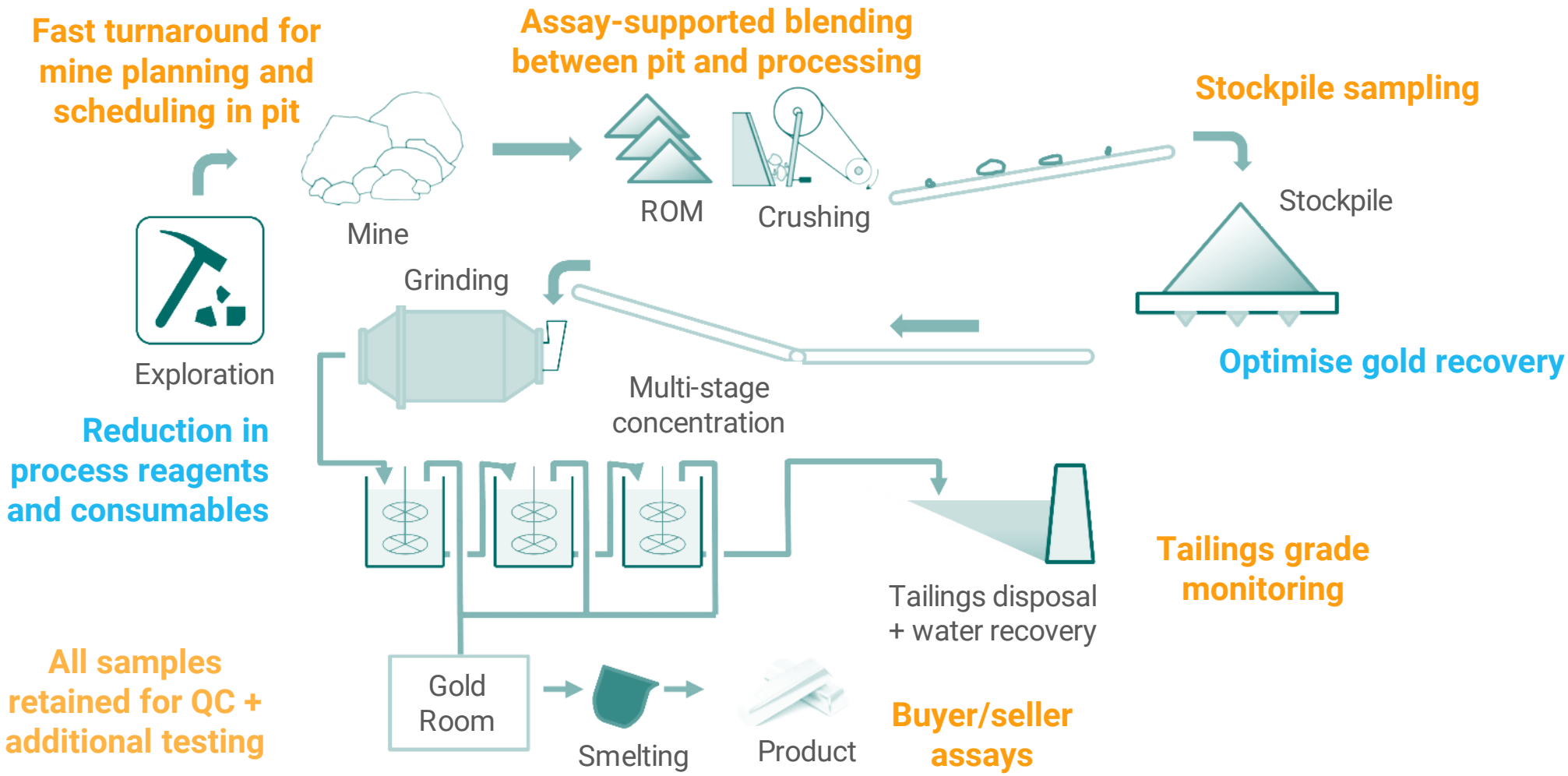
Intrinsic performance benefits

- Incident X-rays and emitted gamma-rays are very penetrating
  - True bulk analysis of large samples (typically 400-600 g)
- Insensitive to chemical form of gold and largely insensitive to physical form
- Largely insensitive to sample matrix
  - RMS matrix error < 0.2% relative for any material with atomic number Z ≤ 30 eg water, carbon, silicate ore, sulphide ore, Cu concentrate …
  - Straightforward correction for other materials eg Pb concentrate
- Fully automated analysis
- Negligible residual radioactivity

Applications of rapid turn-around assay



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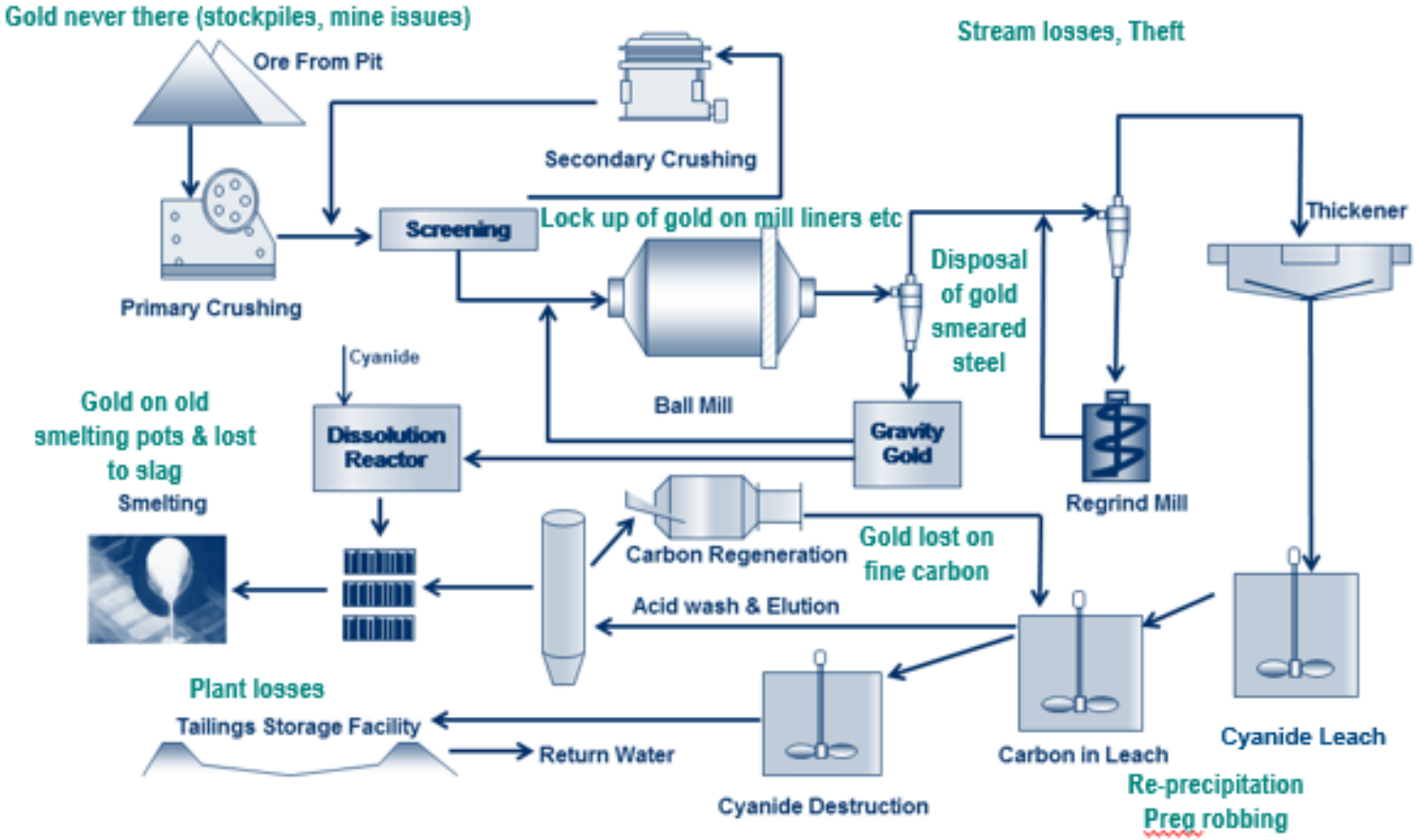
Optimise Gold Recovery

- Studies indicate ~35% of gold lost to tailings is avoidable
  - Industry feedback is an expectation of 1-3% improvement in recovery



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Reduction in Consumables

- Overuse of reagents
  - Overdosing to ensure maximum recovery
  - Overgrinding to ensure liberation
  - Operating the process plant retrospectively on old data
- Industry feedback is 3-5% reduction
  - Reagent costs are ~A$3/t of ore (S&P Global Database)
  - Equivalent to A$1.5m for a project with:
    - 250 kozpa
    - 1g/t gold grade
    - 75% gold recovery

Reagent costs are around $3/t of ore processed

Reagents	Usage	Input cost	Unit operating cost
	g/t	$/t reagent	$/t ore
Cyanide	750	2,450	1.84
Lime	1,500	150	0.23
Hydrochloric Acid	300	1,000	0.30
Carbon	200	3,000	0.60
Caustic	75	1,500	0.11
Other (eg O_2)			0.21
Total			**3.28**
Weighted average as per S&P Global mining model database			**3.02**

Commercial unit – PA1408X

- Improve precision more than two-fold at low grade
- Containerised system, designed for deployment in a commercial assay laboratory environment
- Radiation safety and licensing
- Fully automated sample handling
- Automatic calibration, data analysis and reporting
- 24/7 operation with high availability
  - target >95% outside scheduled maintenance
- Automated QA/QC

PA1408X – Perth Installation

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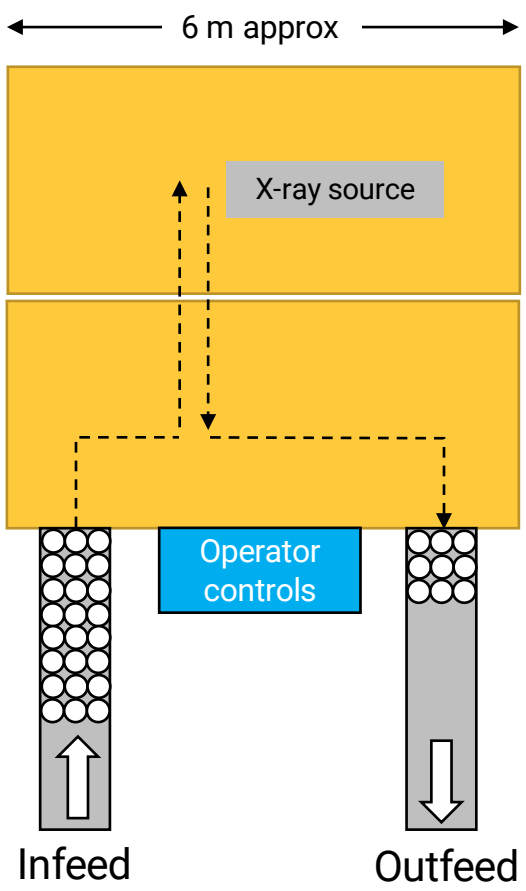
PA1408X – sample prep and loading

Coarse or pulverised material in samples jars

Sample jars loaded onto automatic conveyor

Safety and operator requirements



- Fully automated sample handling. Operator loads and unloads samples from outside unit
- Electronic X-ray source: no power, no radiation
- Equipment packaged as ‘black box’. No operator access during routine use
- Radiation levels, interlocks etc in compliance with state and national regulations
- Samples can be safely handled, stored or disposed of after analysis
- Minimal opportunities for human error

Performance on CRMs

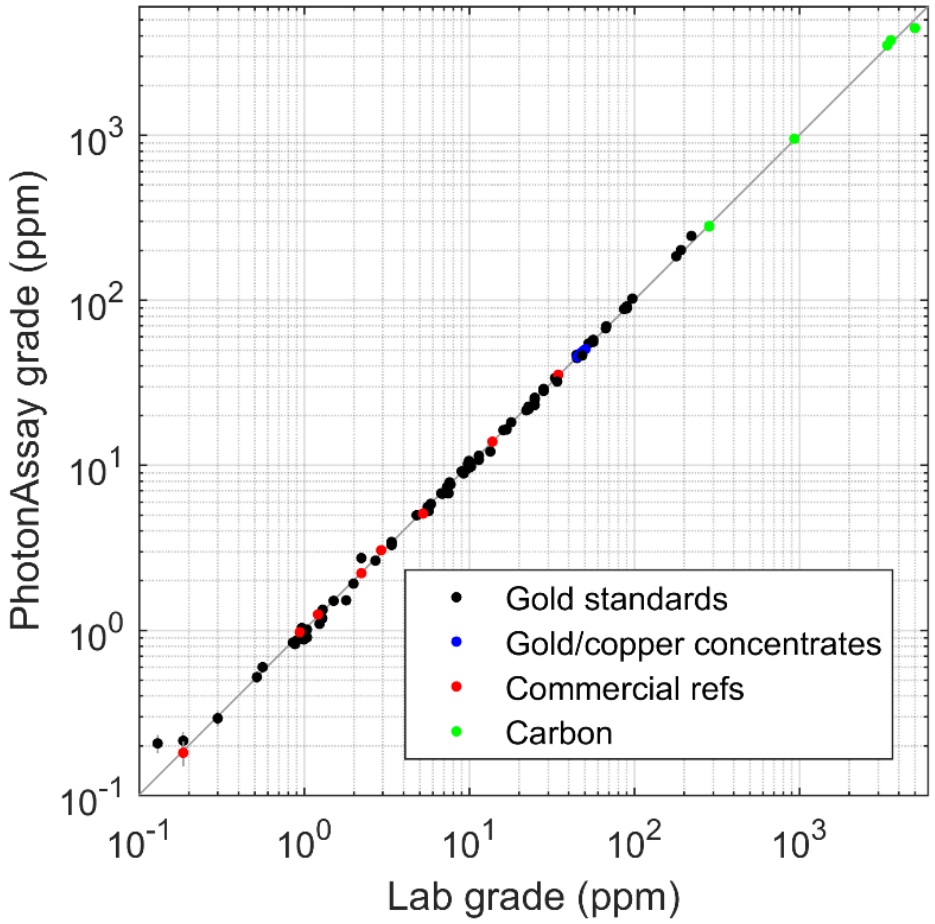
Parameter	PhotonAssay	Fire assay†	Aqua regia†
Throughput	72 samples/h*		
Det. limit (3σ)	30 ppb*	1 ppb (ICP finish) 10 ppb (AAS finish) 3 ppm (gravimetric)	1-20 ppb, depending on finish
Accuracy @ 0.1 ppm	20% (0.02 ppm)	10-12%	15%
Accuracy @ 1 ppm	3-4%	3-4%	4-6%
Accuracy @ >10 ppm	<1.5%	2.5-3.5%	4-6%

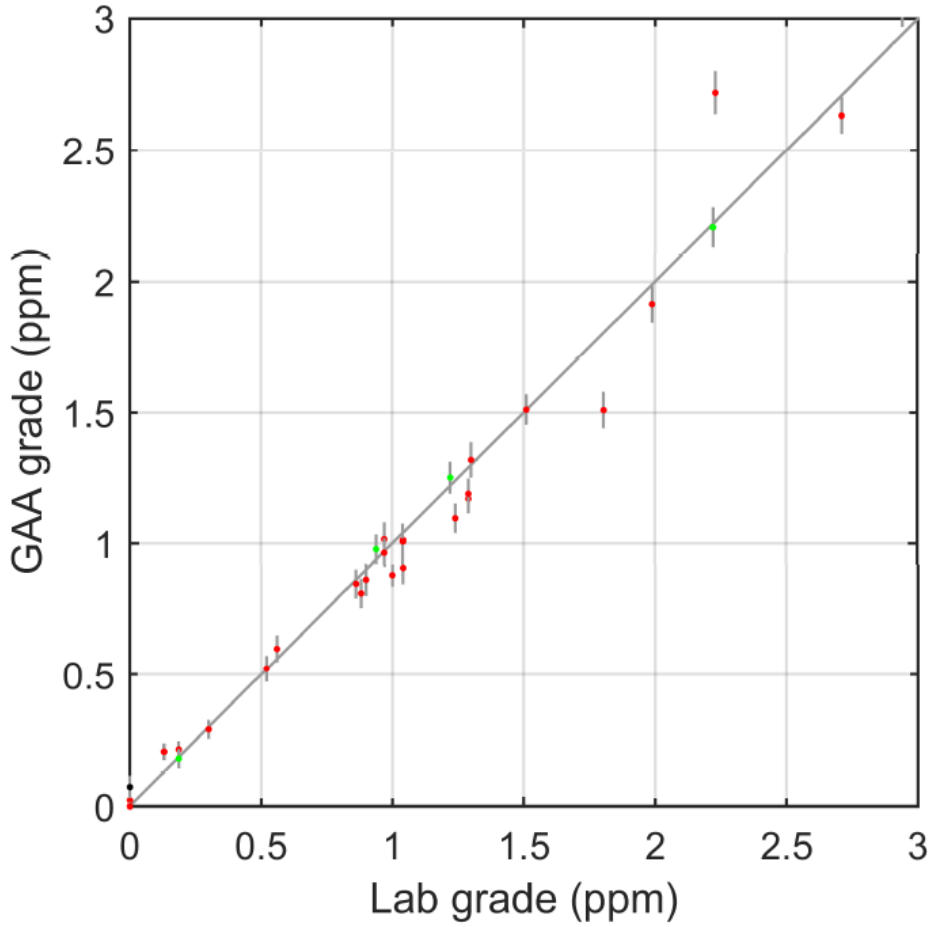
* Throughput/sensitivity can be traded

† Ideal performance, homogenous materials, outliers excluded

Fire assay comparison

- High correlation for samples run in test work at full scale <0.9% discrepancy





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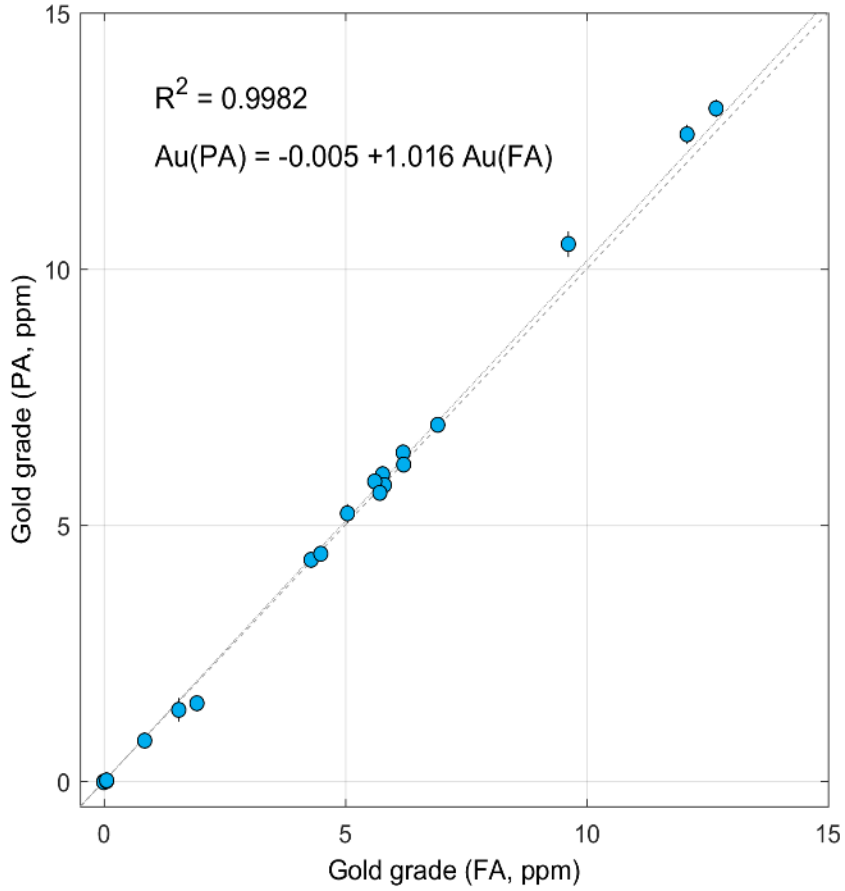
PA1408X – factory testing

- Samples received from multiple operations and companies in:
  - North America
  - Central America
  - Africa
  - Australia
- Diverse ore and material types
  - Gold, Copper/gold, polymetallic, ore, process pulps, carbon, resin
- Certified reference materials provided or purchased from:
  - OREAS, Rocklabs, Gannet Holdings, AMIS and RRM
- Approximately 1600 sample splits in total

Performance on client materials

- Example: 22 samples received from Peruvian gold operation
- 1-3 kg of each sample received; sampled to exhaustion into PA jars
- Samples provided blind; client subsequently provided FA data (4 repeats)



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QA/QC and operation protocols

- Plan to mimic conventional fire-assay QA/QC protocol
  - ~10% of processed samples will comprise
    - Certified reference materials and blanks
    - Repeat samples
    - Client-supplied CRMs and repeats (supplied blind)
- Reference disc directly ties each assay back to CRM suite
- As method is non-destructive, QA/QC samples can be reused
  - Automated charting and report generation
- System operation is fully automated (loading/unloading samples and pressing ‘start’ button)
  - Low-skill operators overseen by qualified personnel

Validation program (started mid-April)

Instrument performance

- Detection limits
- Linearity
- Automatic calibration process
- Repeatability
- Total measurement uncertainty
- Approx 10,000 samples

Sample handling

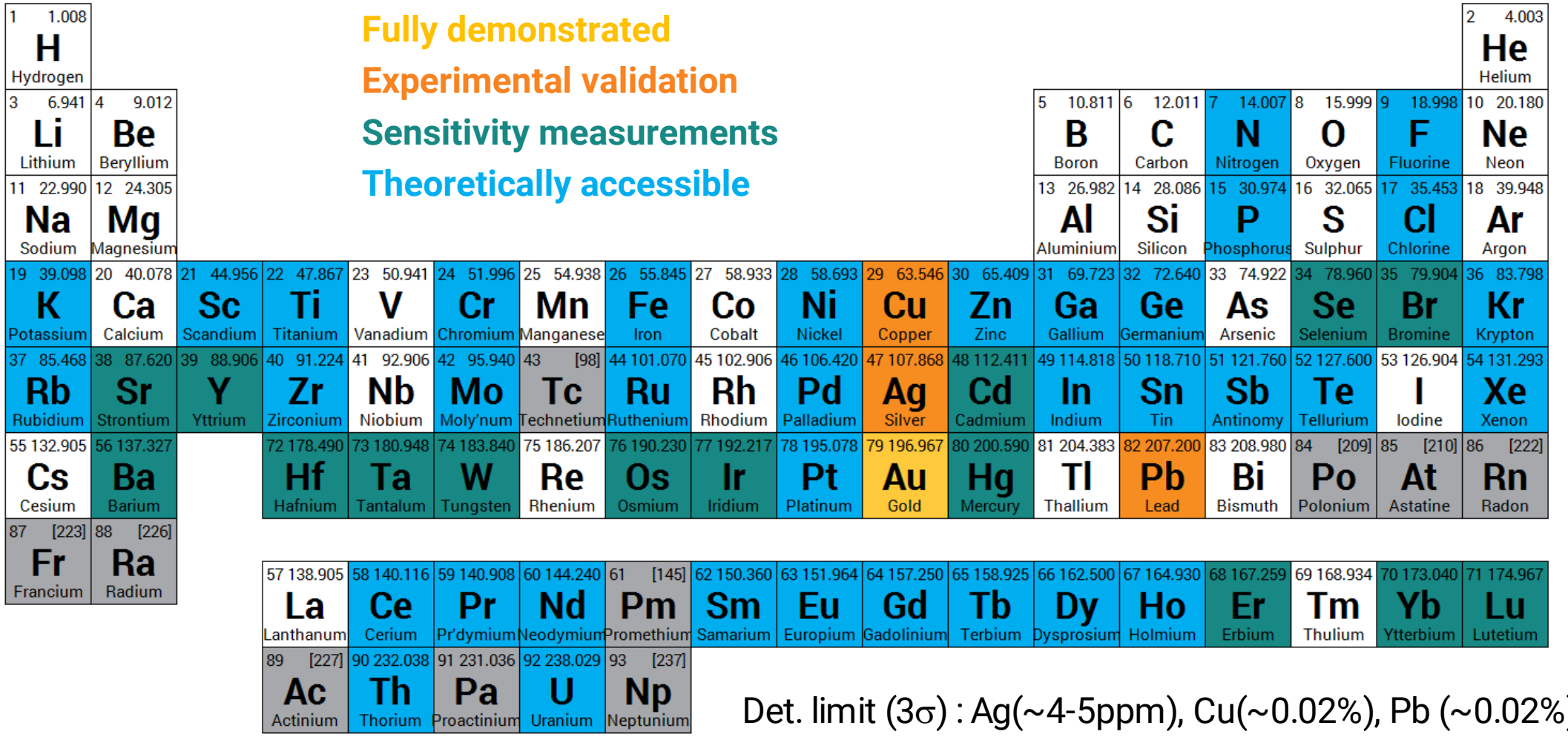
- Sampling methodology
- Sensitivity to crush/grind size
- Establish QA/QC protocols
- Operator protocols
- Comparison back to fire-assay

Validation → NATA (ISO17025) → JORC

Moisture

- PhotonAssay can easily measure wet materials, but by default reports grade in as-received basis
  - Initial measurements performed on dry materials
- Chrysos is currently testing a novel on-line moisture measurement method
- This would allow dry-basis reporting for wet samples, slurries etc without pre-drying

Other elements



Det. limit (3σ) : Ag(~4-5ppm), Cu(~0.02%), Pb (~0.02%)

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Summary

- PhotonAssay provides accurate gold analysis and is insensitive to chemical of physical form of the sample
- Rapid, non-destructive true bulk analysis of large samples
- PA1480X unit designed for convenient deployment and operation in commercial or mine-site laboratories
- Roll out of five additional units planned for 2019
  - Units two & three for Kalgoorlie with Ausdrill (<1m samples pa capacity)
- Release of ruggedized ‘mine-site’ unit planned for 2020
- Fee-per-sample lease model

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Thank you

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