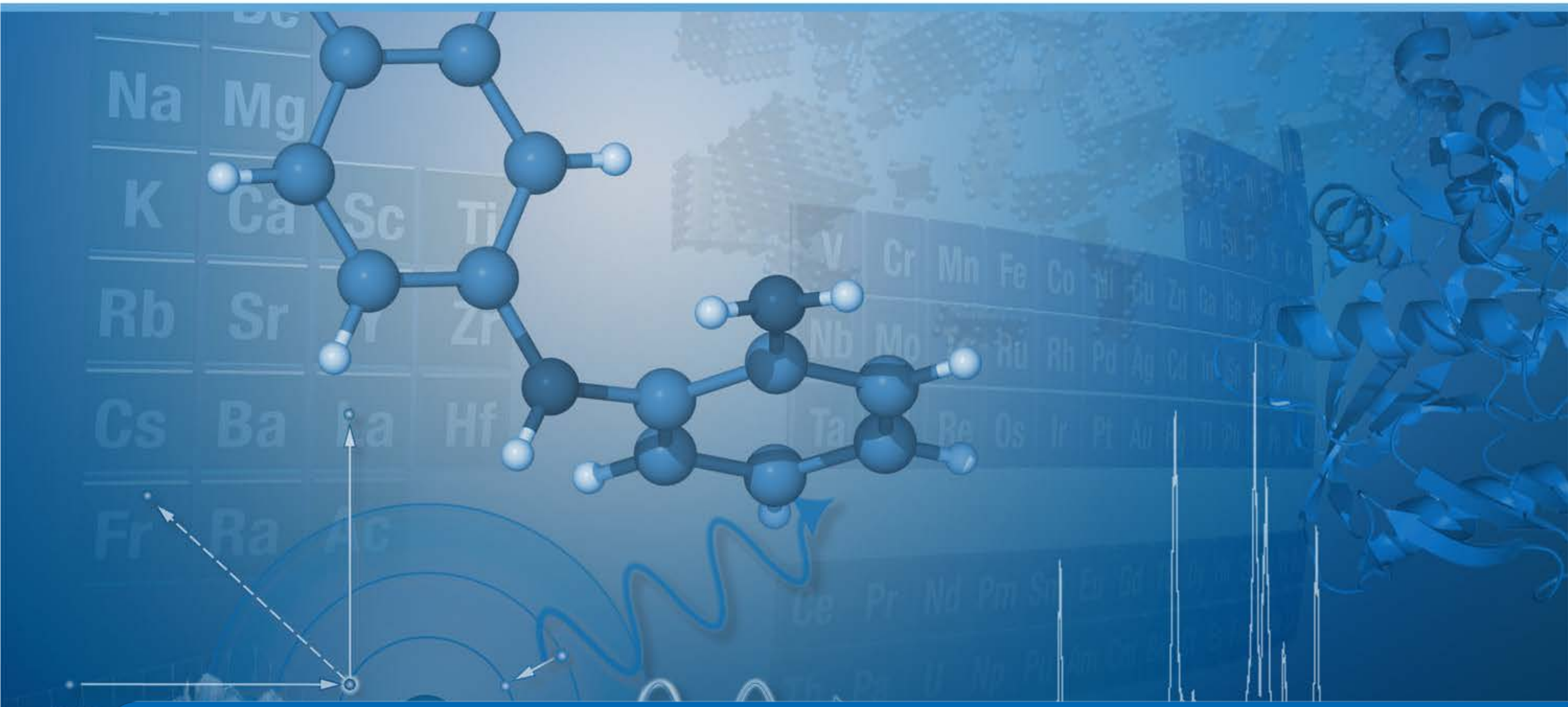
Creating Value in Mining: How XRF Delivers Accuracy and Precision in Daily Routine

Presented by: Kai Behrens & Arkady Buman

Bruker AXS



Webinar: Creating Value in Mining
Today's Speakers

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Creating Value in Mining: How XRF Delivers Accuracy and Precision in Daily Routine

Today's Topics:

EDXRF

- The role of EDXRF in mining
- Performance and benefits of benchtop EDXRF instruments
- The latest EDXRF technology in the S2 RANGER

WDXRF

- WDXRF in mining applications
- Control of iron ore mining with the WDXRF spectrometer S8 TIGER
- Maximum analytical speed with simultaneous WDXRF S8 DRAGON
- Practical example with iron ore

Summary

Why “elements” matter
XRF Applications

Wide range of XRF applications for

- Geological surveys
- Mining: exploration and exploitation
- Industrial minerals
- Raw materials for
  - Cement
  - Ceramics, refractories, glass
  - Catalysts, chemicals, ...
  - Metals

Analysis of major and minor elements as oxides

- for grade control and product quality (purity) based on fused beads

Analysis of traces

- for purity control, geological and environmental mapping based on pressed pellets

Mining Application for EDXRF: Gypsum and Carbonate Rocks

Gypsum

- Sedimentary rock, mostly used as building material and fertilizer

Carbonate rocks

- A class of sedimentary rocks
- Limestone: widely used as building material and raw material in cement and glass industry
- Dolomite: ornamental stone, concrete aggregate and Mg product

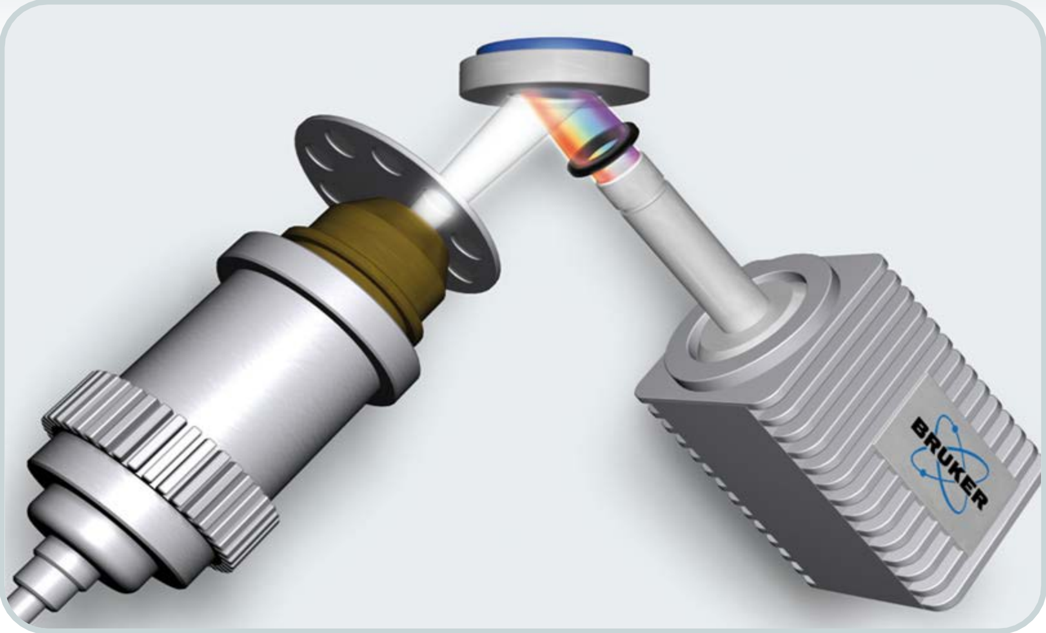
Control of mining operations

- Directions
- Material separation (valuable grades, waste rocks)

Determination of final product grade

- Control of impurities
- Commercial value

Energy Dispersive XRF
New Technology for Geological Applications



EDXRF S2 RANGER with direct excitation

Use of EDXRF for geological monitoring of light elements was limited due to

- low resolution
- high Lower Limits of Detection (LLD) for fused beads

Now the enhanced analytical performance allows using the fusion method for sample preparation for this type of applications

- Analysis of gypsum and carbonate rocks samples as fused beads

Benchtop EDXRF
S2 RANGER

XFlash EDXRF Detector
Advantages of New SDD Technology

- **XFlash**® LE Silicon Drift Detector (LE = light elements – Na, Mg, Al...)
- High transmission window
- Excellent light element performance
- 5^{th} generation Silicon Drift Detector
- 10 mm^2 active area, Peltier cooled
- High energy resolution
- 129 eV FWHM for Mn Kα, 100000 cps without resolution degradation

Excellent performance for Na and Mg

EDXRF Enhancement
50 W Power for Direct Excitation

- End window Pd X-ray tube
- Voltage 10-50 kV
- Max. current 2000 µA
- 9-position filter changer for primary beam filters
- 50 W high power for fast and precise measurements
- Thin, high transmission window for enhanced light element excitation

Sample Preparation and Measurement Conditions

- Samples: 8 certified reference materials
  - Gypsum: GYP-C, GYP-D
  - Carbonate rocks: GBW 07127, 07128, 07130, 07134
  - Limestone: IPT 44, GBW 7120
- Fused beads gypsum:
  0.8 g sample + 8.0 g Li borate mix
- Fused beads carbonate rocks/ limestone:
  0.8 g sample + 8.0 g Li tetraborate
- Tube voltages:
  - 10 kV without filter
  - 40 kV with 500 µm Al filter
  - Measurement time: 300 s each

Accuracy Test of Limestone/Gypsum CRMs

	Limestone				Gypsum			
	GBW 07120		**IPT 44**		**GYP-C**		**GYP-D**	
	Cert.	Meas.	Cert.	Meas.	Cert.	Meas.	Cert.	Meas.
Na_2O	0.03	0.07	0.002	0.06	0.02	0.00	0.07	0.00
MgO	0.71	0.71	2.93	2.92	5.35	5.11	1.73	1.60
Al_2O_3	0.68	0.66	0.33	0.37	0.79	0.84	2.03	2.04
SiO2	6.65	6.60	2.69	2.67	3.50	3.69	8.70	8.93
P_2O_5	0.012	0.13	0.013	0.21	0.02	< LLD	0.03	0.00
SO_3	0.009	0.03	n.d.	0.20	32.97	32.82	36.72	36.53
K_2O	0.15	0.14	n.d.	0.10	0.36	0.32	0.54	0.51
CaO	51.1	51.20	50.5	50.66	30.38	30.51	28.21	28.61
TiO_2	0.038	0.03	0.019	0.01	Trace	0.04	Trace	0.08
Mn_2O_3	0.004	0.01	0.015	0.02	Trace	0.01	Trace	0.02
Fe_2O_3	0.21	0.20	0.3	0.29	0.40	0.40	1.08	1.06

Excellent agreement between measured and certified values

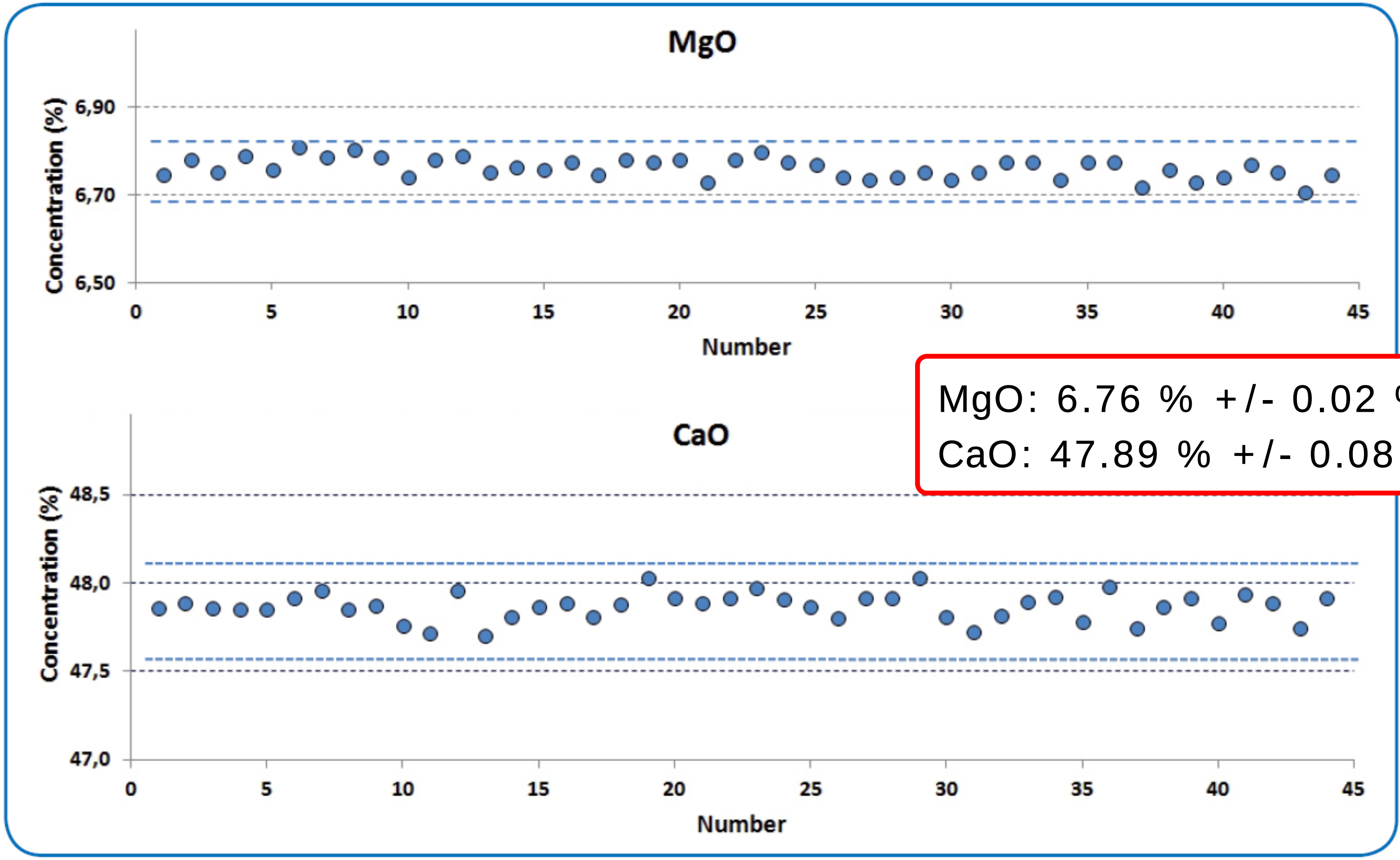
Ready-To-Analyze Solution GEO-QUANT M

- For the analysis of major and minor elements as oxides
- Covers 11 important elements: Na, Mg, Al, Si, P, S, K, Ca, Ti, Mn, Fe
- Based on 20 CRMs
- For grade control and product quality (purity) based on fused beads
- Recommended procedure for preparation of fused beads is included

GEO-QUANT M
Concentration Range of Oxides

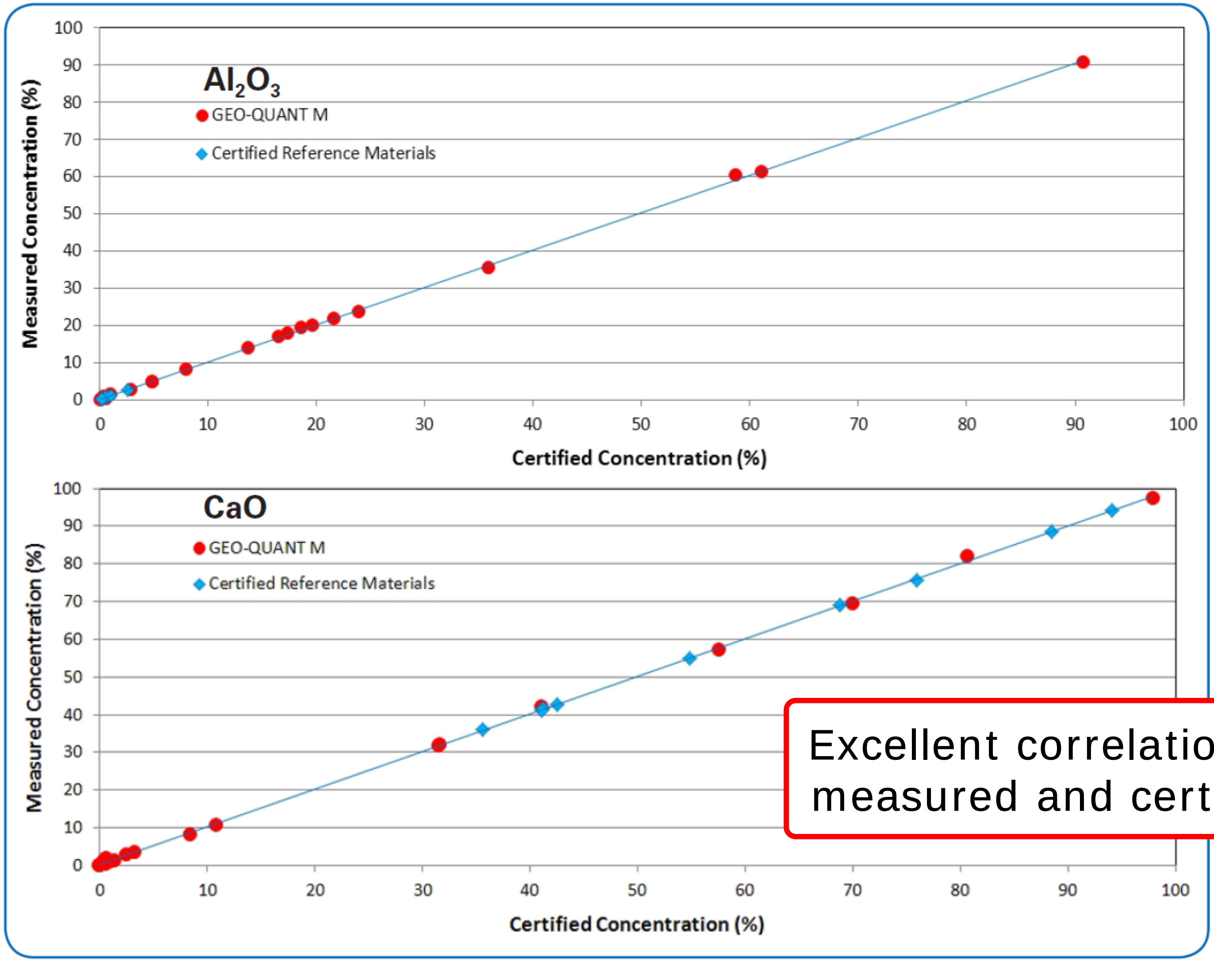
Oxide	Min. Conc. (%)	Max. Conc. (%)
Na_2O	0.02	11.0
MgO	0.02	100.0
Al_2O_3	0.04	90.0
SiO_2	0.40	100.0
P_2O_5	0.01	20.0
SO_3	0.05	55.0
K_2O	0.05	15.0
CaO	0.02	100.0
TiO_2	0.01	8.0
Mn_2O_3	0.01	0.8
Fe_2O_3	0.01	40.0

Stability Test of MgO and CaO Carbonate Rock (GBW07127)



MgO: 6.76 % +/- 0.02 %
CaO: 47.89 % +/- 0.08 %

Correlation of Measured vs. Certified Concentrations for GEO-QUANT M Standards and CRMs



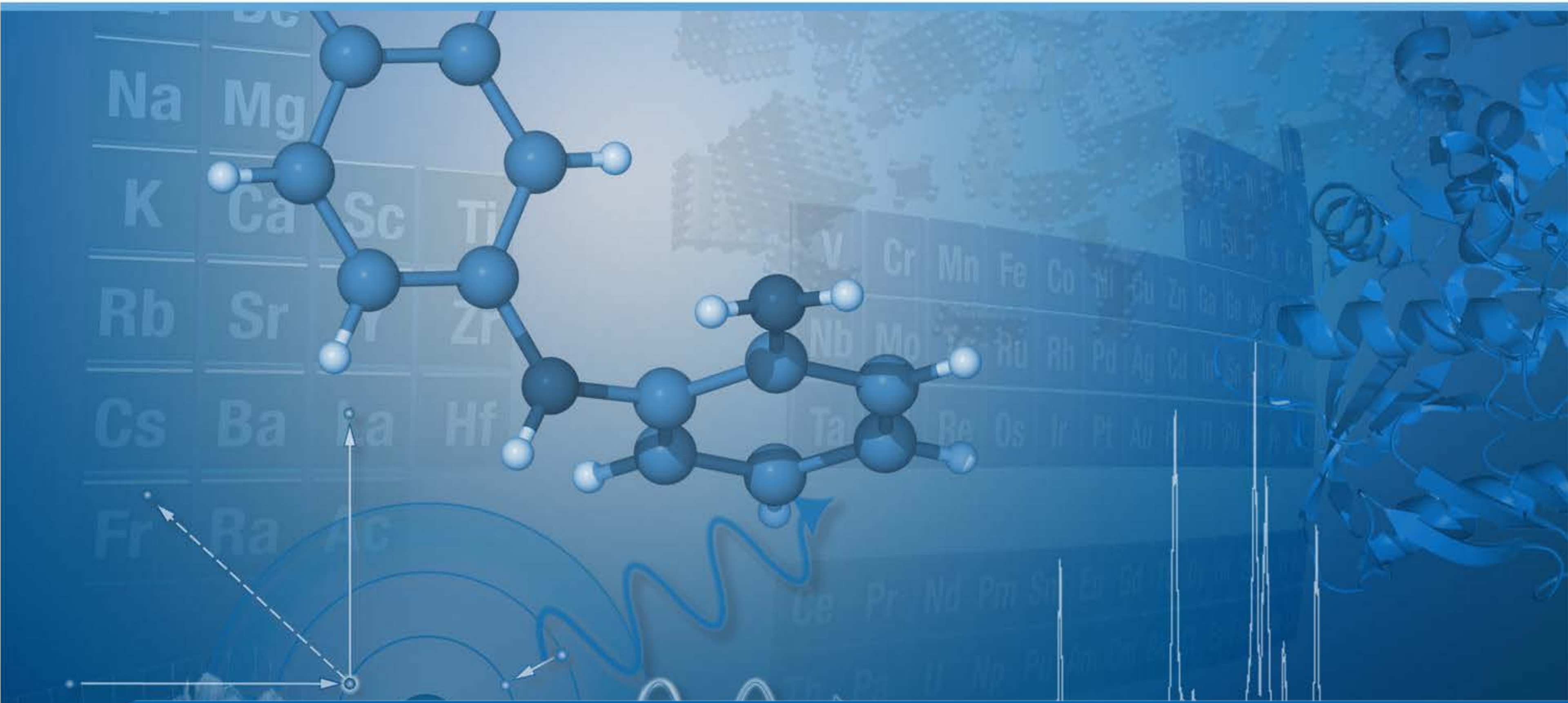
Excellent correlation between measured and certified values

Advantages of EDXRF
S2 RANGER

- Very compact instrument, low cost of ownership
  - Consumables, green-power requirements
- Advanced analytical performance of the modern EDXRF S2 RANGER
  - Energy resolution, count rates
- Ease of use with TouchControl
  - Quick instrument, good counting statistics
- Low maintenance
  - Peltier cooled detector
- Practical and fast method
  - due to simple sample preparation

Iron Ore Analysis

WDXRF



Applications of X-ray Technologies
Iron Ore

- Ore producer / mine site / beneficiation plant
  - Total iron grade control - XRF
  - Beneficiation of low grade ore (milling, washing, gravity separation) - XRD
  - Sinter pellets - XRF & XRD
- Shipping
  - Service / governmental labs
  - Fast grade control, impurities - XRF (ISO 9516)
  - Ore vs. Mill scales: same chemistry, different mineralogy - XRD
- Metals production
  - Oxidation state Fe2+/Fe3+ ratio: amount of reducing agent (coal), CO_2 emission, ...
  - Slag - XRD (BFS = cement) / XRF
  - Steel / Alloys - XRF, OES

Iron Ore
Production 2010 (in Millions of Tons)

Country	Production Millions of tons
China	900
Australia	420
Brazil	370
India	260
Russia	100
Ukraine	72
South Africa	55
United States	49
Canada	35
Iran	33
Sweden	25
Kazakhstan	22
Venezuela	16
Mexico	12
Other countries	31
Total world	**2400**

Source: US Geological Survey, Annual Report

The Leading Sequential WDXRF Spectrometer
S8 TIGER

S8 TIGER
WDXRF Spectrometer Series

The S8 TIGER(((WDXRF spectrometers are the latest models on the market with most modern technology!

Available in three basic configurations:

- S8 TIGER 1K
- S8 TIGER 3K
- S8 TIGER 4K

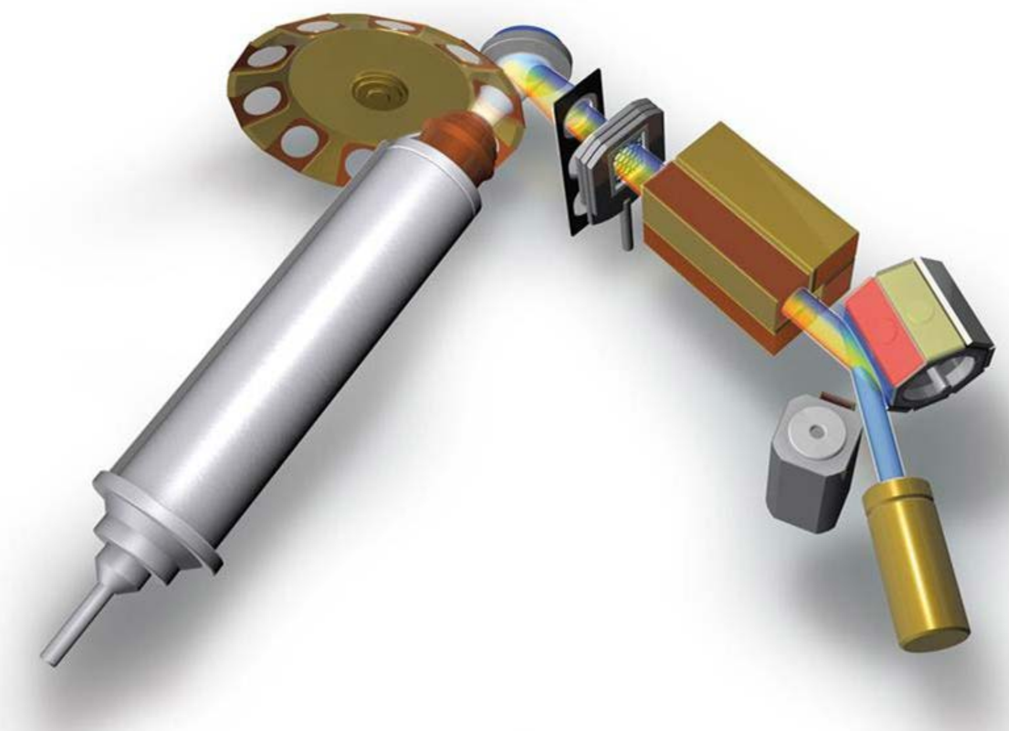
WDXRF Spectrometer Series:
S8 TIGER 4K

High sample throughput, best detection limits, shortest time-to-result and maximum instrument uptime requires:

Superior analytical performance with clear benefits by design:

- Best in the market
- max. 170mA - 4 kW for best light element analysis
- No compressed air
- Dust sealed spectrometer cabinet
- Smallest footprint (~0.8 m^2)
- Reduced cooling water consumption, independent of short fluctuations

S8 TIGER
Sequential WDXRF



Analytical flexibility:

- 4 kW excitation
  20 – 60 kV
- 5 – 170 mA
- 10 beam filters
- 4 collimators
- 8 crystals
- 2 detectors

Precision of WDXRF
Influence Factors

One of the most demanding markets is the analysis of iron ores in service labs:

- Time is money
- Results are always late
- Sample throughput is very high

ISO 9516-1:2003 describes a test each WDXRF spectrometer has to meet before the spectrometer is applicable in this application field.

Each parameter adjustment is checked for the coefficient of variation COV and it must stay below limit values.

WDXRF
Performance Test

Test	C.O.V. (actual)	Max. C.O.V. allowed	Alternate State		
				C.O.V. (actual)	Max. C.O.V. allowed
Stability	0.0307	0.0405			
Mounting & Loading	0.0245	0.0468			
Angular	0.0207	0.0468			
Collimator coarse	0.0360	0.0468	Collimator fine	0.0387	0.0476
Detector Scinti	0.0411	0.0468	Detector Flow	0.0277	0.0472
Crystal	0.0405	0.0468			
Beam Filter	0.0432	0.0468			
Mask	0.0378	0.0468	28mm	0.0303	0.0470
KV/mA	0.0357	0.0468	30 KV 135mA	0.0282	0.0457

High analytical precision:

- Sample mounting and loading through direct positioning
- High precision positioning with mechanical geared goniometer
- Quick and precise change and adjustment of X-ray excitation parameters

Situation
Iron Ore Analysis

Iron Ore Analysis:

- Done to evaluate the commercial value – mainly determined by the total iron concentration
- Done to control the mining process and the refining process

Target:

- Highest accuracy and precision in combination with high sample throughput is required for the total iron analysis

Difficulties for XRF:

- Iron in different oxidation states: no constant stoichiometry for the calculation of oxygen
- Varying mineralogy: Matrix correction is needed, grain size problems for pressed pellets
- Loss on Ignition is time consuming

Solutions for Iron Ore Analysis

Sample preparation by fusion:
+ overcome grain size effects and mineralogy
+ removal of light elements (LOI)
+ better precision and accuracy for majors and minors
+ higher dilution assists the accurate determination of iron
- higher dilution is major drawback for traces
  (more important due to environmental impacts)
- time and money consuming (Pt ware)

Calibration:
- standards not simply available for all sample compositions
+ synthetic standards for fusion method possible

Matrix corrections:
+ fundamental parameters
- determination of the total sample composition is needed
- specific treatment to correct unknown LOI

ISO 9516-1
Iron Ore Analysis with XRF

Elements – 20 total:

- Fe, Si, Ca, Mn, Al, Ti, Mg, P, S, K ,
  Sn, V, Cr, Co, Ni, Cu, Zn, As, Pb, Ba

Sample Preparation:

Fusion:

- Flux $LiBO_2$ 61.465, $Li_2B_4O_7$ 33.535 + 5% $NaNO_3$
- $Na_2B_4O_7$
- $Li_2B_4O_7$

Weights:

- Sample: ~ 0.66 g
- Flux: ~ 7.2 g

Iron Ore
"Theoretical Alphas" and LOI

SPECTRA*plus* calculates alphas for elements

- Advantage: more flexibility
- The chemistry rules can be changed without changing the calibration, i.e. elements and oxides can be evaluated with the same calibration
- Different binders and fluxes can be handled in one calibration

- A compound like CO_2 or H_2O is lost during preparation as a fused bead (LOI, loss on ignition)
- Since the LOI compound is no longer present in the fused bead, it has no influence on absorption of X-rays, i.e. on the alphas
- But: the LOI changes the dilution, because there is less sample material in the fused bead than in a sample without LOI

Iron Ore Analysis
Alternative Procedures

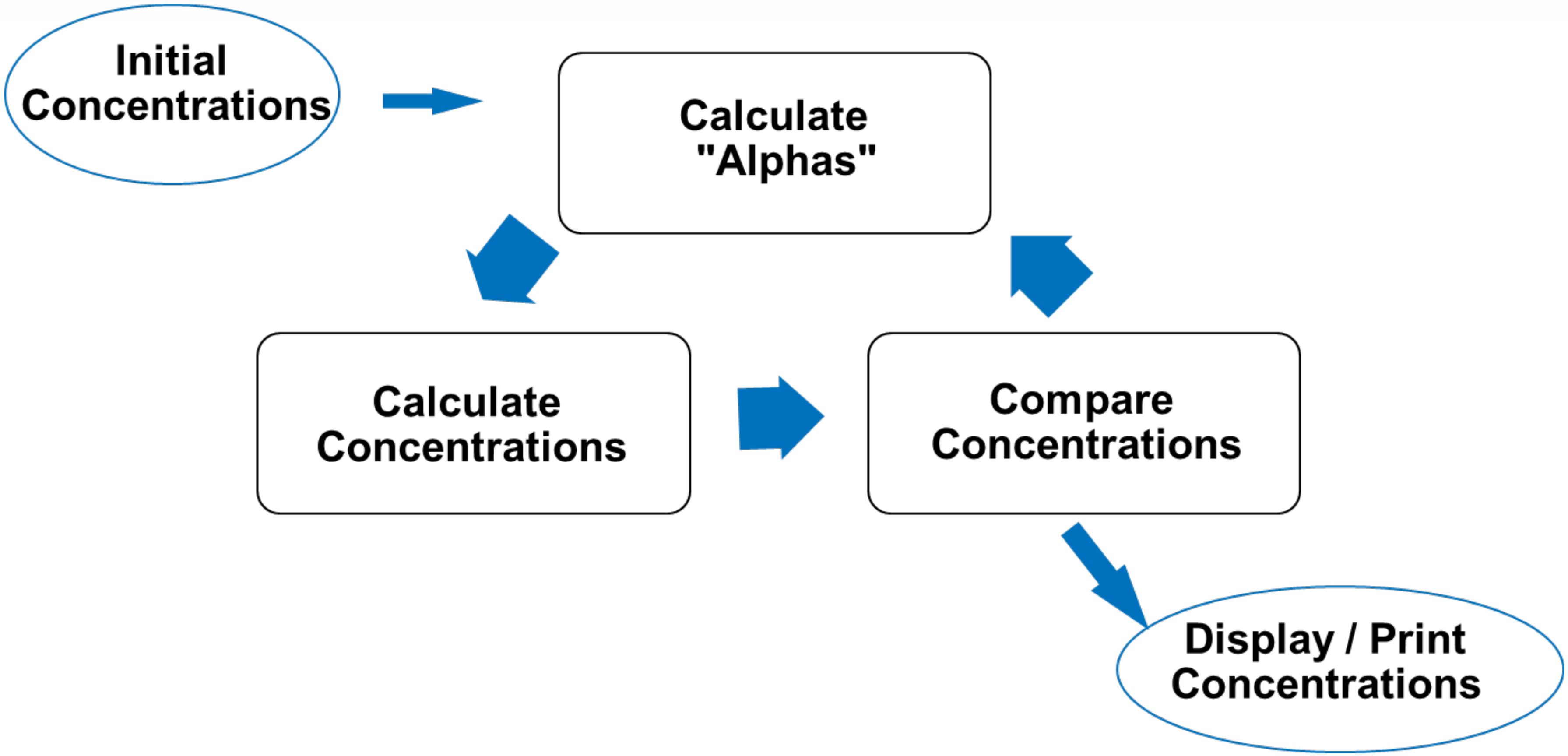
Variable Alpha Method:

- Majors (Fe_2O_3), minors and traces are evaluated using the variable alpha matrix correction method based on fusion method, access LOI from external measurement – cover a broader material range

Combo method:

- Majors (Fe_2O_3) and high minors are analyzed by fusion method, using variable alphas matrix correction, to determine the commercial value
- Low minors and traces (heavy metals and chlorine) are analyzed with pressed pellets to access the environmental impact if needed
- With a database link the results from the fusion method are automatically used for matrix correction during the trace evaluation

Individually Calculated ("Variable") Alphas



Performance Check by XRF
Comparison: CRM Dampier Lump

Element	Certified Conc. [%]	Variable Alphas [%]	Combo Method [%]	Pressed Powders [%]
Mg (%)	0.015	0.015	0.015	0.015
Al (%)	0.173	0.170	0.172	0.169
Si (%)	2.25	2.23	2.24	*2.21*
P (%)	0.0045	0.0057	0.0047	0.0043
S (%)	0.0054	0.0015	0.0049	0.0057
K (%)	0.065	0.061	0,063	0.0063
Ca (%)	0.014	0.013	0.013	0.015
Ti (%)	0.031	0.028	0.029	0.030
Mn (%)	<0.005	<0.005	0.0018	0.0019
Fe (%)	**66.19**	**66.16**	**66.16**	***65.94***

Conclusions
Iron Ore ISO 9516 - 1

- Accuracy and precision are excellent, the test data show that all results follow the certified values
- The Fe concentrations are reported within the CRM Std dev of less than 0.1%
- The test shows that the results are consistent with other very good laboratories:

  * major elements excellent

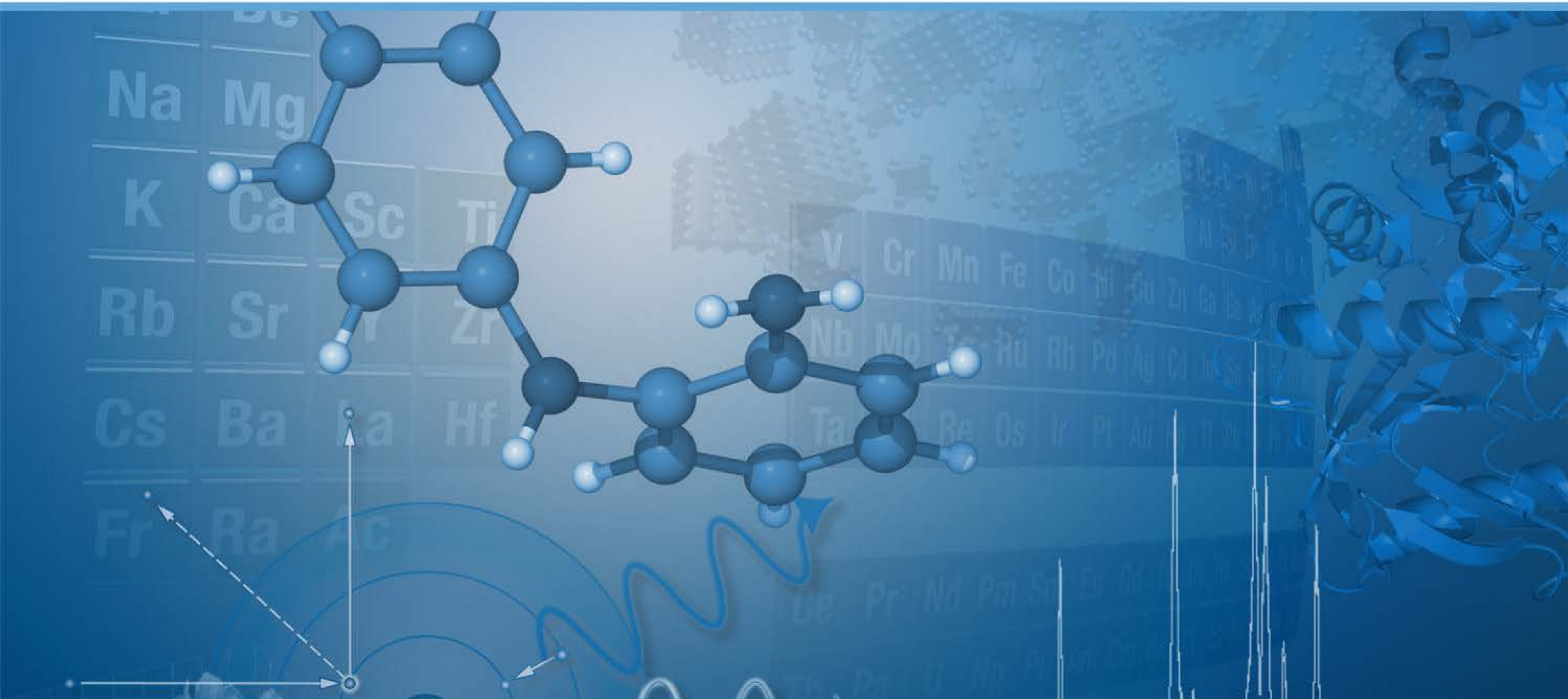
  * traces show higher variability due to counting statistics

  * traces improved by pressed pellet method

  * significantly better for arsenic and chlorine by pressed pellets

  * Variable alpha approach more suitable to broader material range (huge concentration variations)

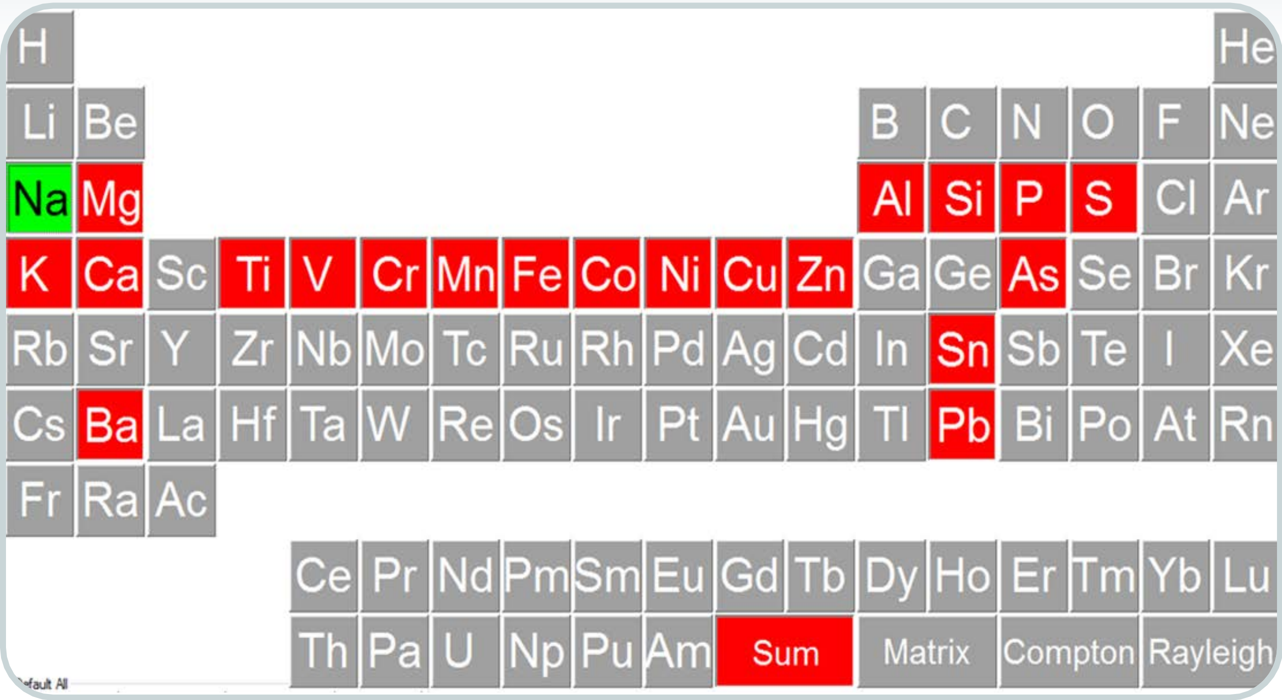
GEO-QUANT F



GEO-QUANT F
Norm Compliant Analysis of Iron Ore

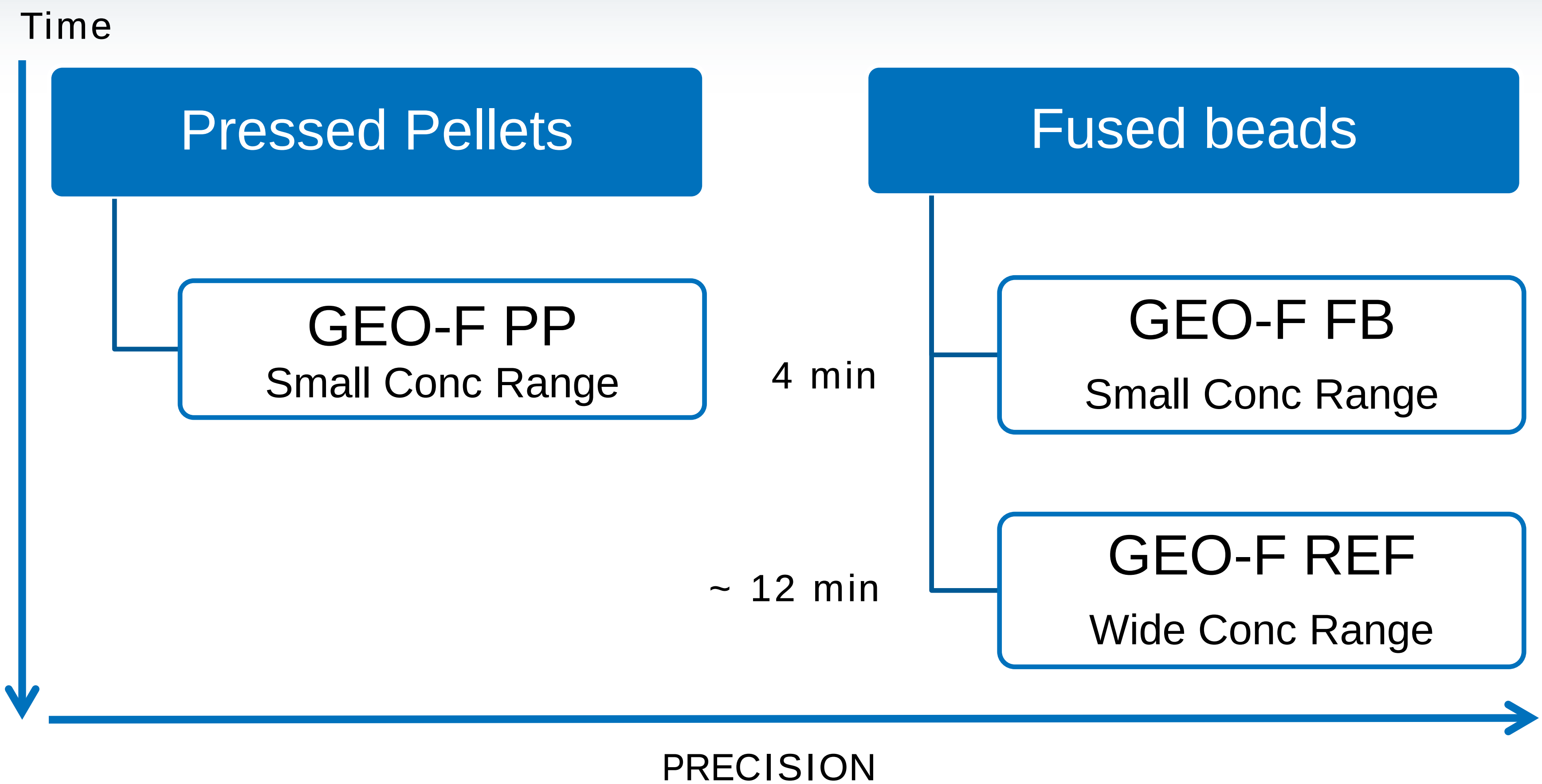
- The solution package for iron ore analysis (grade and process control
- Including methods for pressed pellets in process control applications
- Including methods for fused beads for grade control
- Recipes for all common fusion equipment vendors
- Norm compliant to ISO 9516
- Based on
  - Variable alphas
  - Loss eliminated alphas (alternatively according to ISO 9516)

GEO-QUANT F
Norm Compliant Analysis of Iron Ore



21 elements, including Na
(not required for ISO 9516)

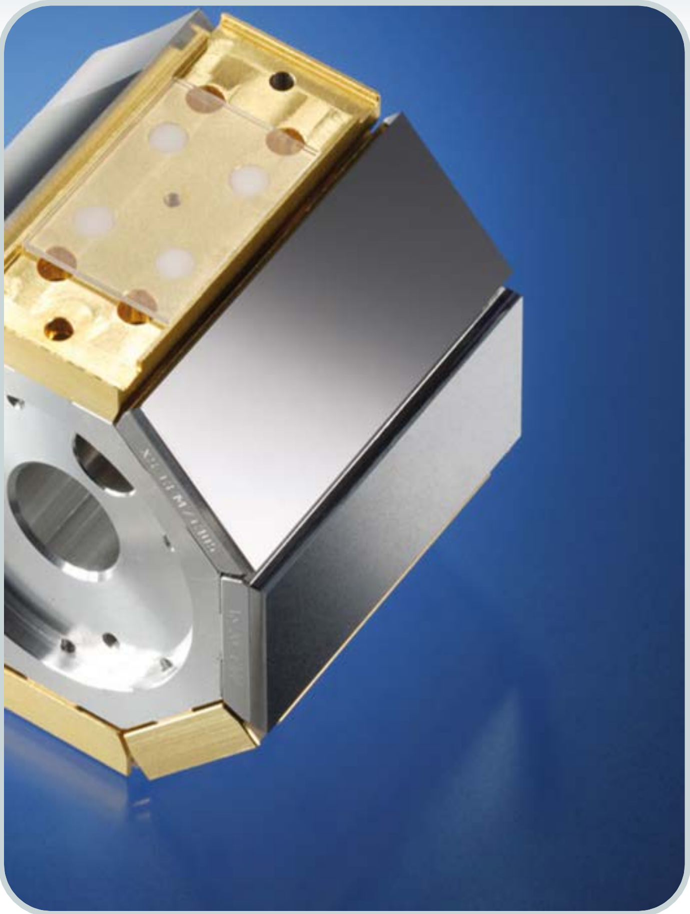
GEO-QUANT F
Measurement Strategy



GEO-QUANT F
Hardware

- GEO-QUANT F contains
  - 16 certified reference materials (no synthetic standards)
  - Evaluation samples
  - User manual
  - Preparation manual
- GEO-QUANT F requires
  - LIF 220 crystals
  - XS-100 crystal

GEO-QUANT F
XS-100



The XS-100 is a synthetic multilayer:

- Covers the elemental range from F to Cl
- Increased sensitivity compared to the XS-CEM
- Enhanced long term stability compared to the PET
- Stable, independent from temperature changes

- Advantages:
  - Time optimzed measurement from F to Cl in one run without crystal change
  - Sample throughput and analyzing speed
  - Shared background positions, fewer background measurements

GEO-QUANT F
Application Range

	GEO-QUANT F		ISO 9516	
	Min	Max	Min	Max
Fe_2O_3	18.9	97.0	54.3	100.0
SiO_2	0.6	36.3	0.42	13.9
CaO	0.01	15.8	0.03	17.8
Mn_3O_4	0.021	2.0	0.03	1.1
Al_2O_3	0.1	11.5	0.19	6.6
TiO_2	0.005	10.7	0.03	7.8
MgO	0.02	8.32	0.33	3.3
P_2O_5	0.009	2.7	0.01	1.4
SO_3	0.007	2.3	0.1	1.5
K_2O	0.003	2.6	0.01	0.5
V_2O_5	0.002	0.8	0.003	0.5
SnO_2	0.0001	0.2	0.001	0.02
Cr_2O_3	0.001	0.2	0.001	0.04
Co_3O_4	0.002	0.2	0.001	0.03
NiO	0.001	0.2	0.014	0.017
CuO	0.008	0.2	0.015	0.08
ZnO	0.002	0.4	0.006	0,21
As_2O_3	0.112	0.1	0.01	0.08
PbO	0.004	0.56	0.02	0.34
BaO	0.0012	0.2	0.04	0.45

- Covers the ISO 9516 application range
- Includes low grade materials

GEO-QUANT F Accuracy

Element	Certified [%]	ISO 9516 [%]	GEO-QUANT F [%]
Fe2O3	66.85	66.64	66.58
SiO2	3.71	3.80	3.89
CaO	0.20	0.20	0.20
MnO	0.23	0.23	0.23
Al2O3	0.18	0.15	0.15
TiO2	0.022	0.030	0.023
MgO	0.18	0,18	0.179
S	0.007	0.029	0.012
K2O	0.003	0.026	0.014

- Accuracy test with CRM NIST 690
- Excellent performance
- Passing ISO 9516

Iron Ore
Rapid Grade Control

- Rapid control of element concentration
- Quality check
  - at the mining site
  - at shipping stations

Narrow concentration range and similar matrix allows pressed pellet preparation

- Quickest sample preparation:
- Crushing, milling, pressing with cellulose as binder (15 g sample + 2 g binder)

- Maximum 60 s measurement time

- Simple automation path, high sample throughput, easy operation, fast feedback

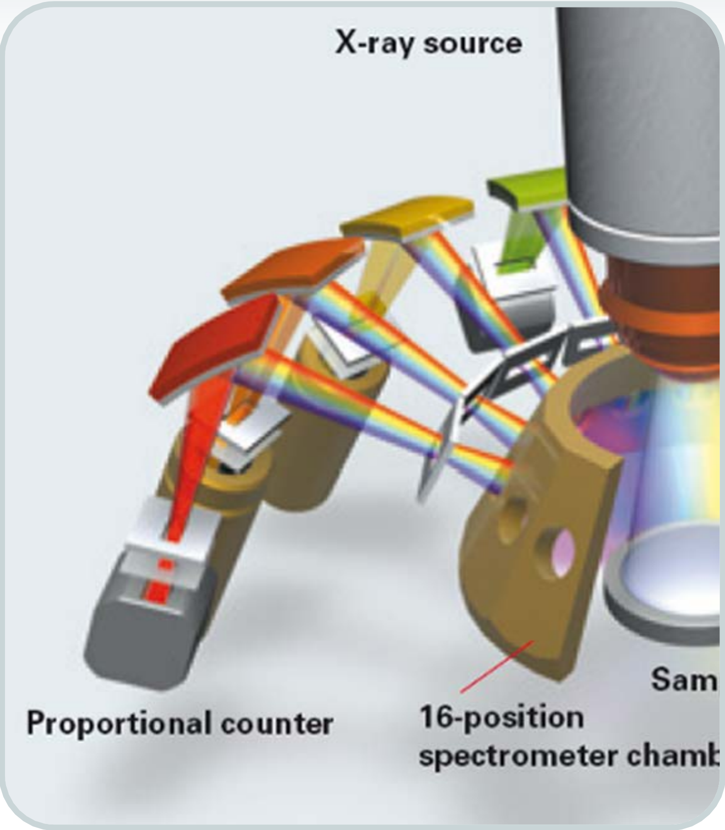
S8 DRAGON

Truly Simultaneous X-ray Fluorescence (XRF)
for Precise, High-Speed Elemental Analysis in Mining

New Truly Simultaneous XRF
S8 DRAGON

- Truly simultaneous XRF spectrometer combining single element channels with the new Multielement Channel™
- Covers almost the whole periodic table from C upwards in one run in less than 40 seconds
- 4 kW high excitation power
- Unmatched precision for all relevant elements in mining production and exploration
- Footprint more than 25% smaller compared to previous instruments

S8 DRAGON
The Optimal Solution - Less Is More



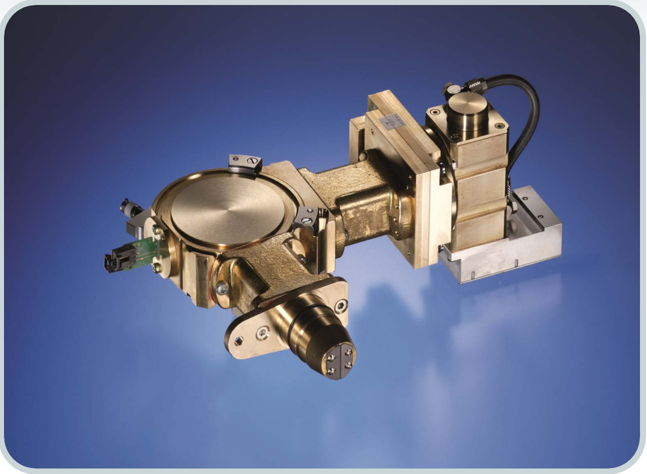
- Best analytical performance with max 15 channels plus Multielement Channel:
- Highest intensity due to most compact beam path (close coupling of tube-sample-detector)
- Stable vacuum due to small volume of sample and spectrometer chamber with pre-evacuation step
- Fewer channels offer more performance

S8 DRAGON
Single Element Channels

Up to 15 Single Element Channels plus Multielement Channel:

Crystals

- Optimized bent crystals for each element with high resolution and sensitivity
- Individually temperature controlled



Attenuators (up to 6)

- Automated absorbers
- for high dynamic ranges

Detectors

- Proportional and Scintillation counters for optimum detection

S8 DRAGON
Multielement Channel

XFlash technology of Bruker

- 5th generation Silicon Drift Detector (SDD)

High transmission window

- Unique energy resolution
- 129 eV FWHM @ Mn Kα, 100,000 cps

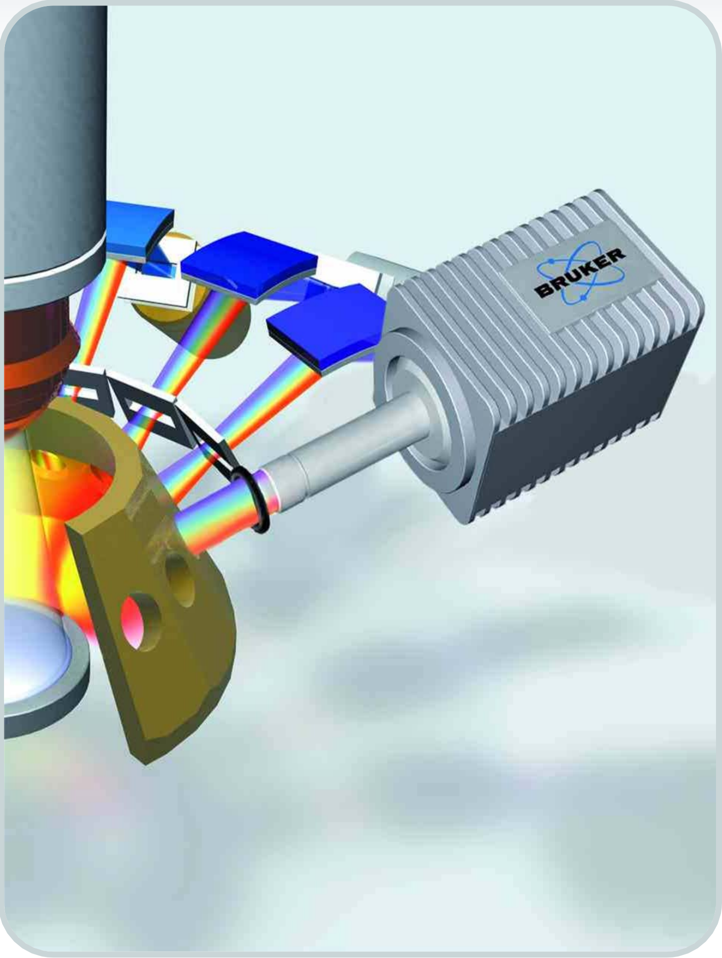
Unmatched count rates

- up to 300,000 cps input count rate
- up to 100,000 cps output count rate
- without resolution degradation

Peltier cooled

- Maintenance free

S8 DRAGON
Multielement Channel



- Essential benefits of the unique Multielement Channel ™

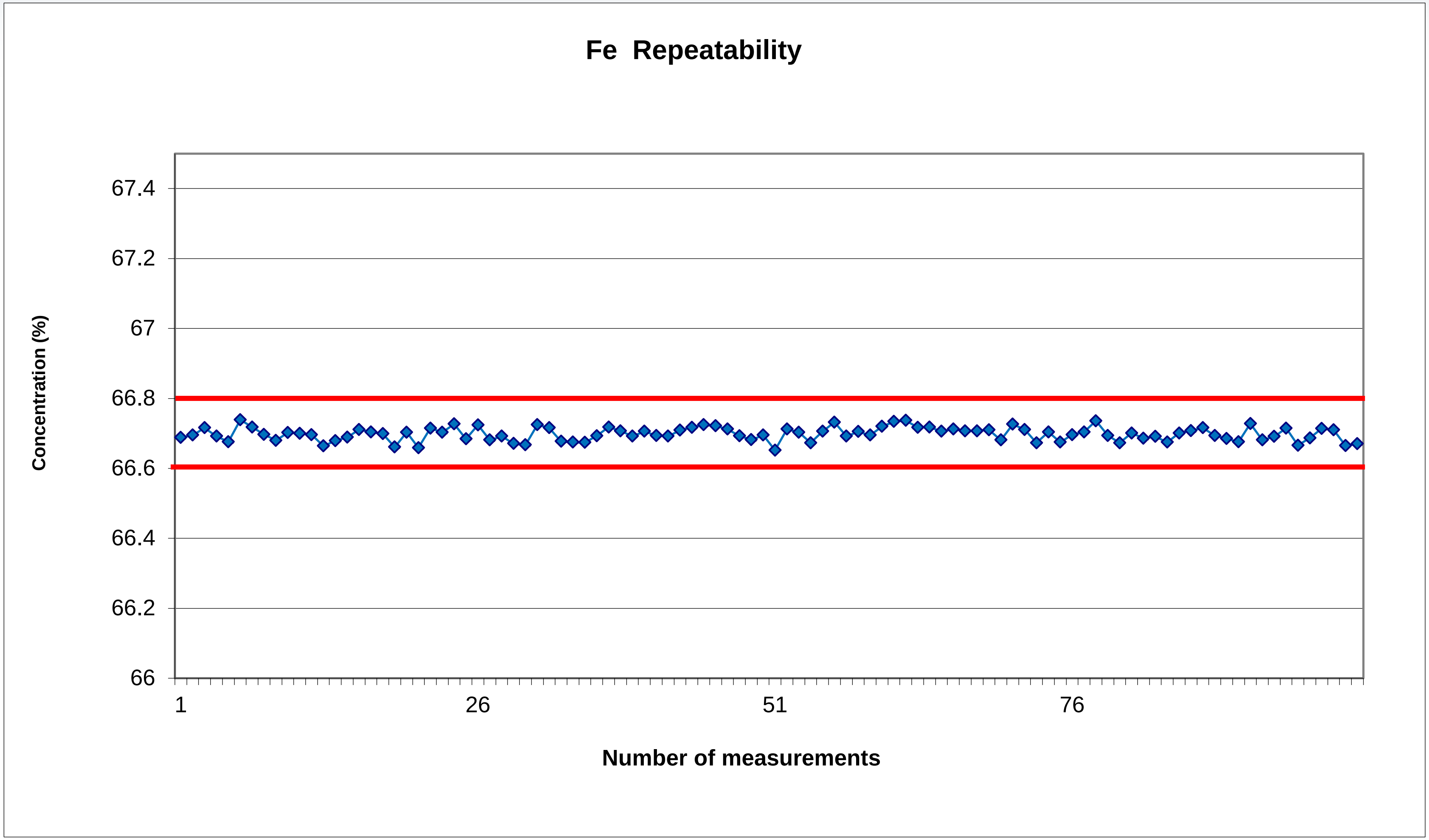
- Elemental fingerprinting
  - Identification and analysis of all elements from Na upwards
- Analytical flexibility
  - Contaminations can be traced
  - Analysis of non-routine samples
  - Upgrading of analytical methods with additional elements in minutes - no further installation of new hardware
- Dual-mode data acquisition
  - Internal backup for data safety with a second internal source

Iron Ore
Pressed Pellet

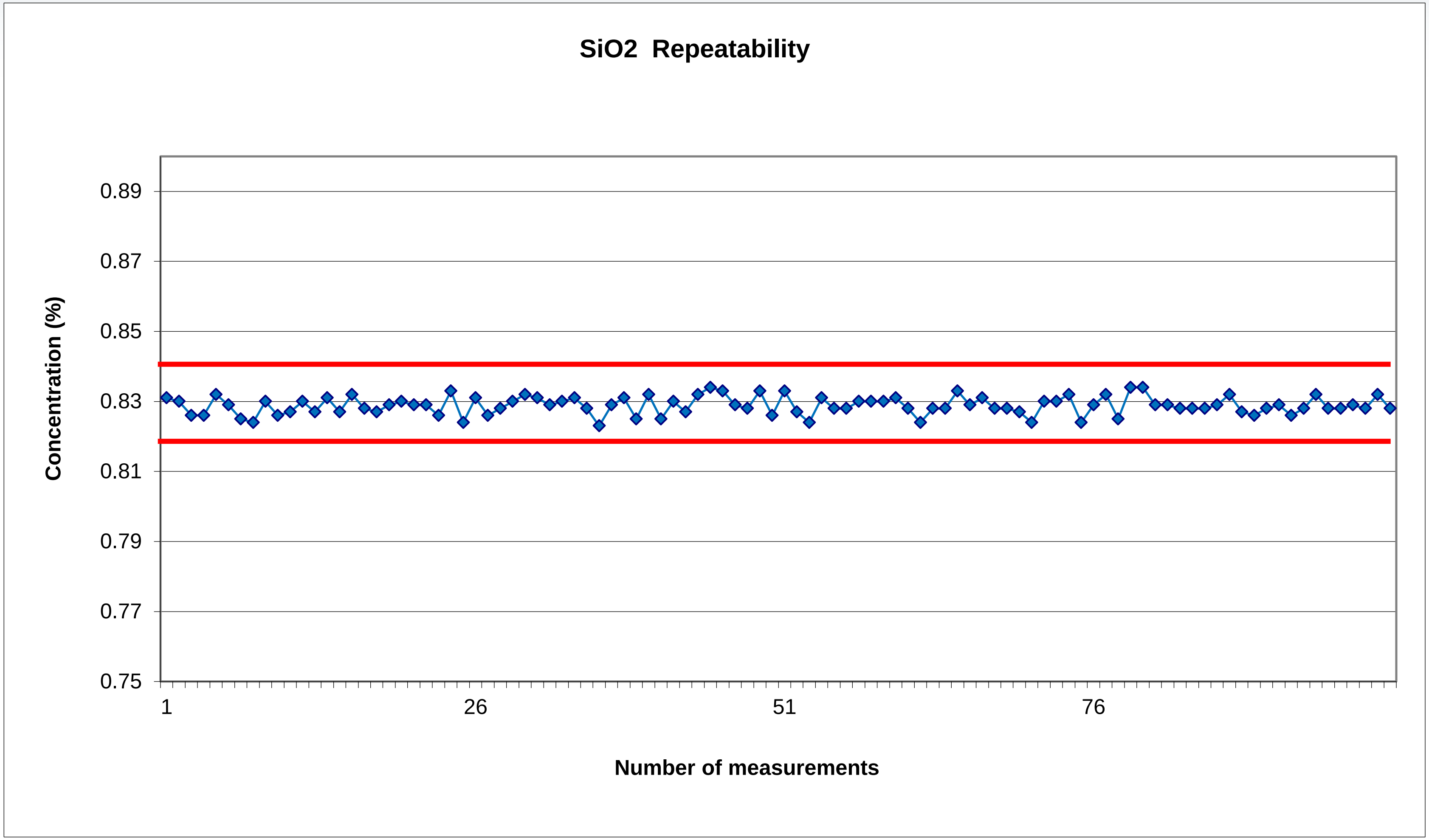
Quick grade control at mining labs:

- Simple and fast sample preparation for narrow element ranges
- Maximum measurement time:
  - 60 s
- Typical measurement time:
  - 40 s
- Analytical precision:
  - Fe: **66.698 +/- 0.020%**
    Rel. Std. Dev. 0.029
- Detection limit for traces:
  Si at 9 ppm
  P at 0.3 ppm

Precision Test on Fe in One Week
200 Measurements: 66.698 +/- 0.020%



Precision Test on SiO2 in One Week
200 Measurements: 0.829 +/- 0.002%



Performance Test
200 Measurements - Summary

Sample	Average (%)	Abs. Std. Dev. (%)	Rel. Std. Dev. (%)
Fe (%)	66.698	0.020	0.029
SiO2 (%)	0.829	0.003	0.312
P (%)	0.040	0.000	0.368
Al2O3 (%)	0.902	0.004	0.422
Mn (%)	0.673	0.014	2.026
CaO (%)	0.013	0.001	4.003
MgO (%)	0.032	0.000	1.351
TiO2 (%)	0.053	0.001	2.319
K2O (%)	0.017	0.000	0.833

Iron Ore
Shipping Control

- Iron Ore grade control in accredited commercial service labs / customs / central labs

- Wide concentration ranges with huge variety of different matrices

- Matrix correction according to ISO 9516
  - Loss corrected alphas
  - Variable alpha model
- Fused bead preparation
  - Handling of grain size effects
  - Mineralogical effects
  - Sample dilution
  - Best accuracy

S8 DRAGON
Iron Ore – Fused Beads

Measurement:
- 40 kV, 100 mA – Full 4 kW excitation

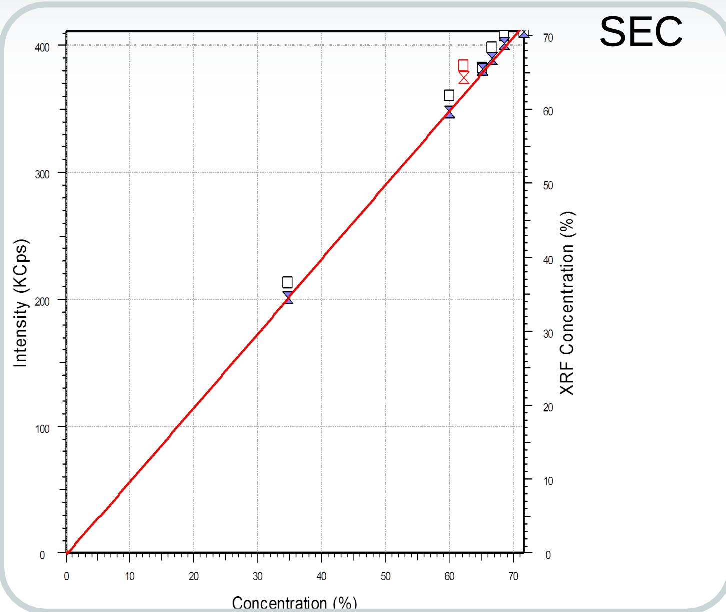
Configuration:
- Single Element Channels plus Multielement Channel

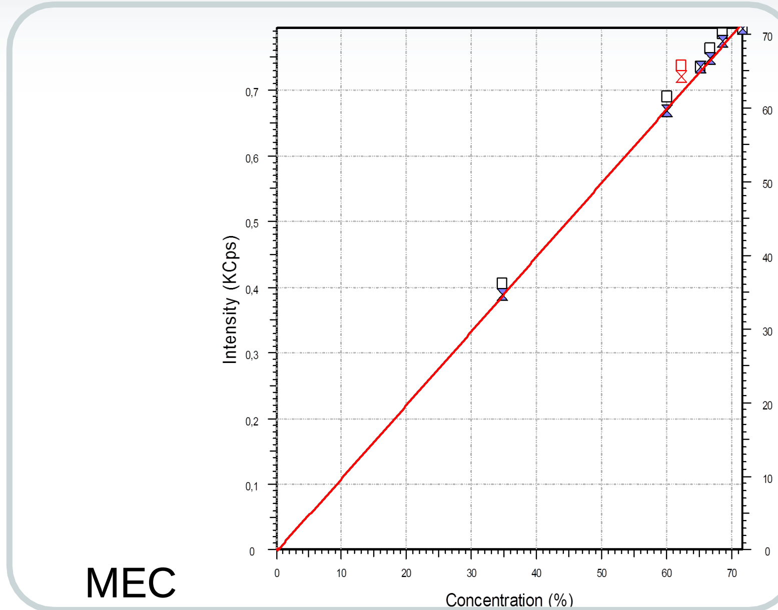
Elements
- Al, As, Ba, Ca, Cr, Co, Cu, Fe, K, Mg, Mn, Mo, Nb, Ni, P, Pb, S, Si, Sn, Ti, V, Zn

Calibration Details:

	Min [%]	Max [%]	Abs. Cal. Std. Dev. [%]	LOD [3 s, ppm]
Fe	34.6700	71.5000	0.563	45
SiO2	0.1610	38.5800	0.036	46
Al2O3	0.2080	3,3000	0.0324	85
P	0.0056	0.0432	0.0007	0.3
Mn	0.0130	4.3200	0.0045	1.6

More Information with the Multielement Channel (MEC)





Calibration details for Fe: Range 34.67 -71.50%

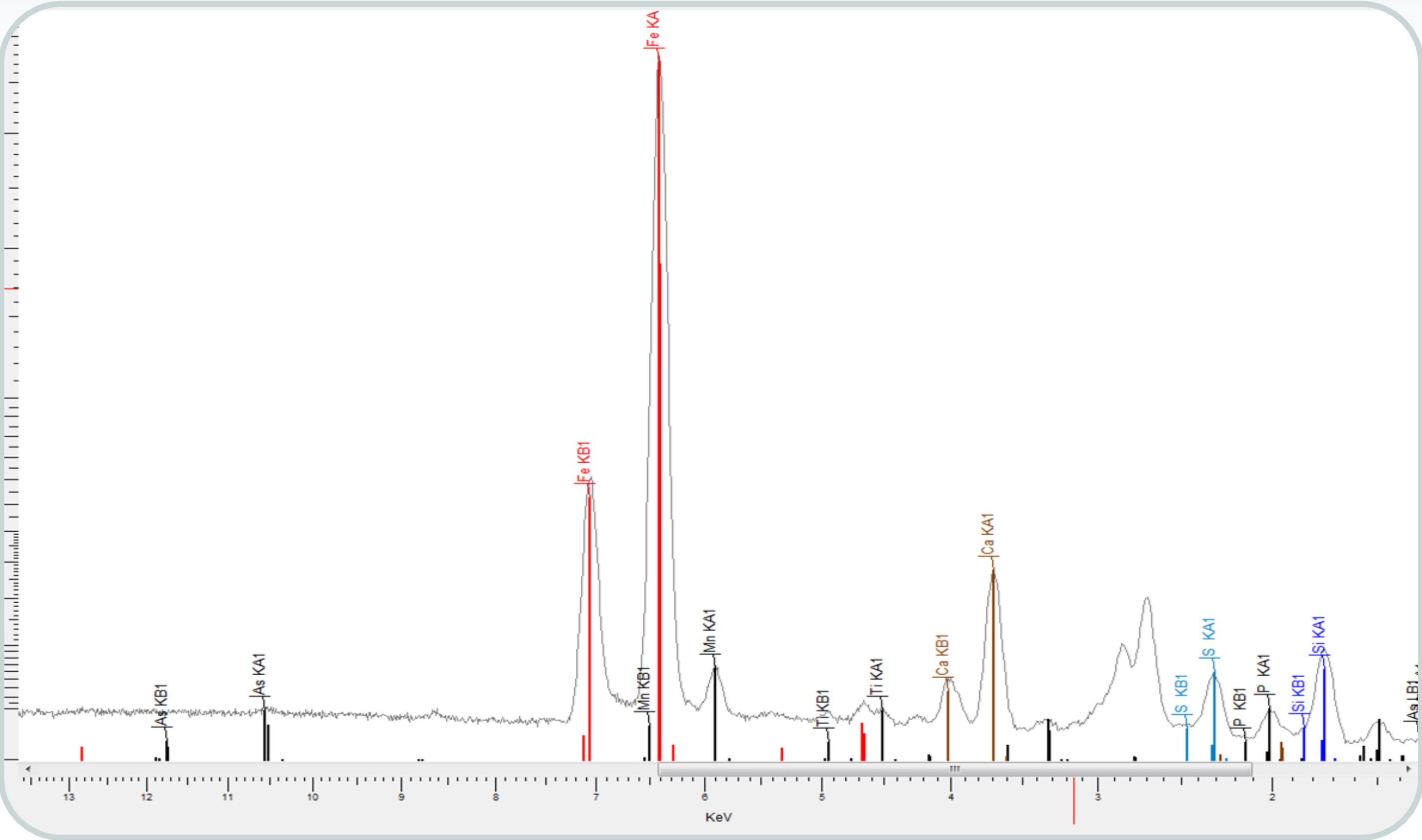
Fe (Single Element Channel) – LiF 200:

Calibration Std. Dev.: 0.563%

Fe (Multielement Channel) – SDD:

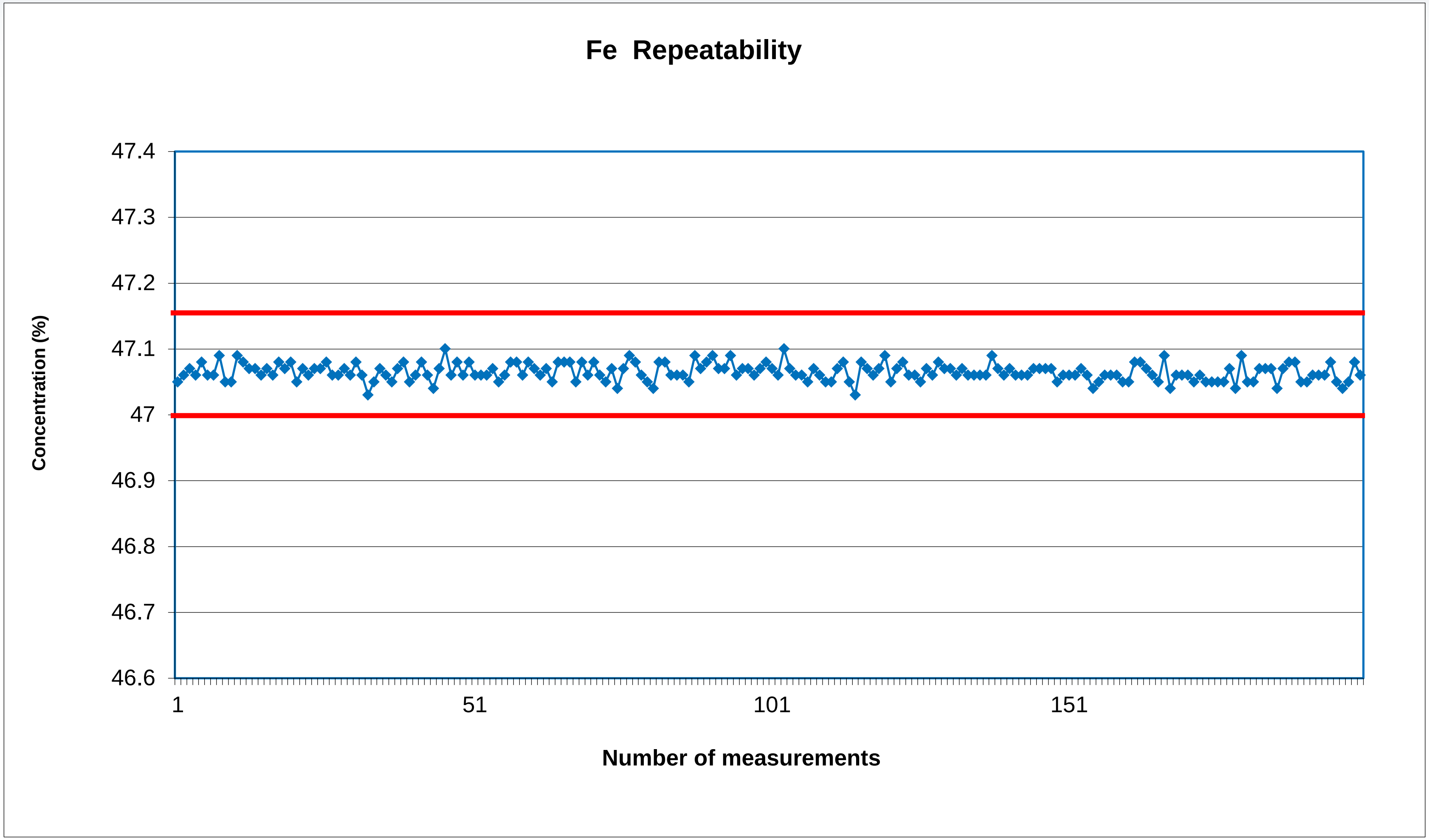
Calibration Std. Dev.: 0.503%

Spectrum Iron Ore
Dual Mode Data Acquisition

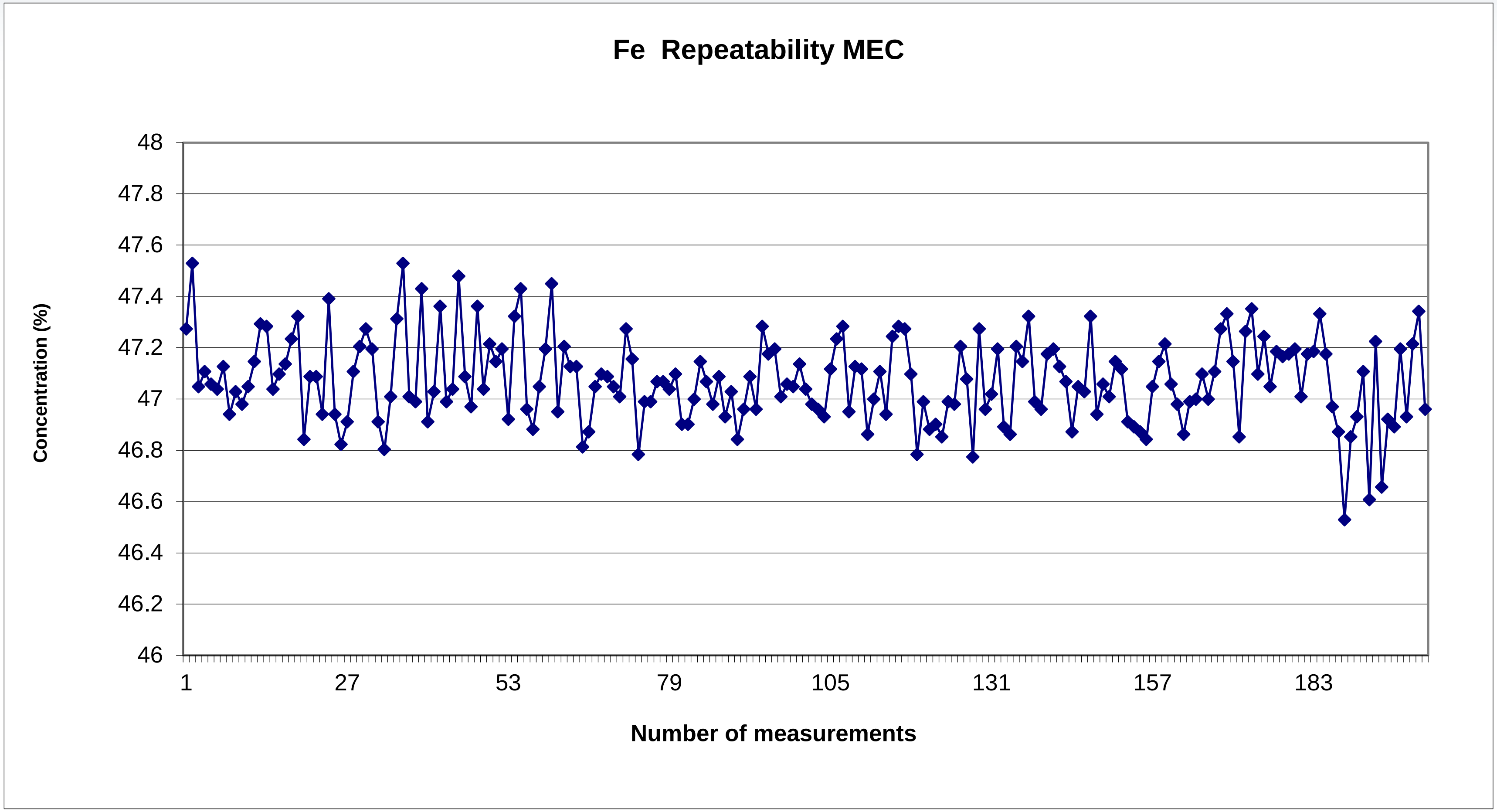


Parallel measurement of SEC (WDX) and Multielement Channel
Identification of trace elements, internal backup (second information source)

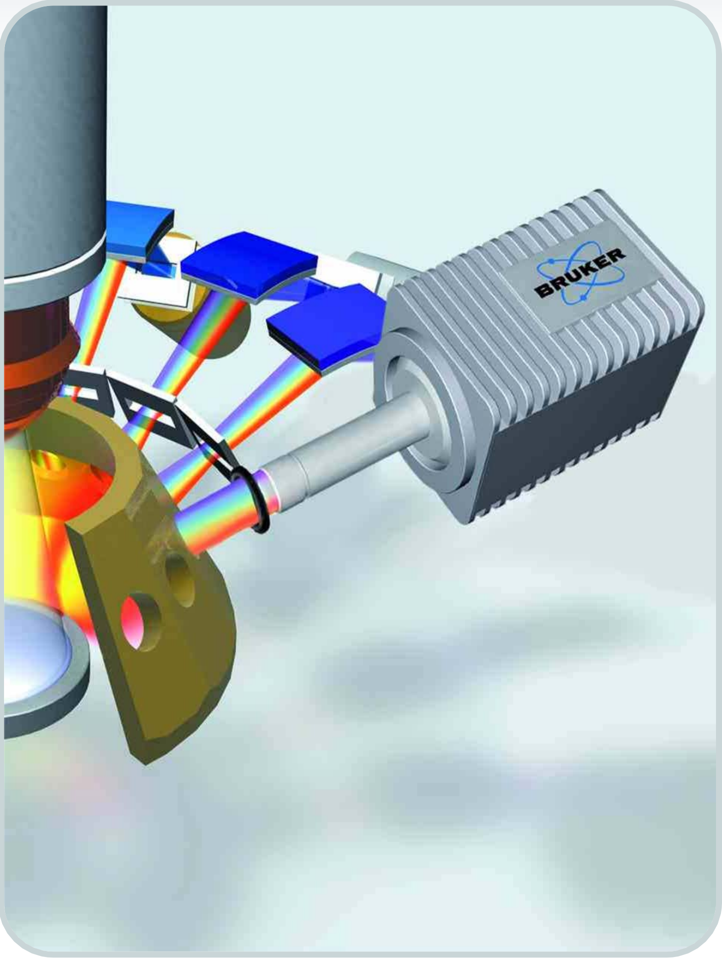
SEC: Precision Test on Fe in One Week
200 Measurements: 47.065 +/- 0.013%



MEC: Precision Test on Fe in One Week
200 Measurements: 47.072 +/- 0.166%



S8 DRAGON
Multielement Channel



Comparison of SEC and MEC

- Accuracy at the same level between SEC and MEC
- Precision better for SEC
- Therefore: Elements for best precision and lowest detection limits to be analyzed with SEC

- Screening and internal backup with MEC
- Every sample has the fingerprint spectra for later evaluation available
- Consistency check between SEC and MEC with every measurement
- New elements are added instantly

Performance Test in One Week
200 Measurements - Summary

BRUKER

Sample	Average (%)	Abs. Std. Dev. (%)	Rel. Std. Dev. (%)
Fe (%)	47.065	0.013	0.028
SiO2 (%)	0.673	0.006	0.869
P (%)	0.031	0.001	0.746
Al2O3 (%)	4.081	0.014	0.334
Mn (%)	15.348	0.016	0.102
CaO (%)	0.032	0.001	1.867
MgO (%)	0.032	0.002	5.401
TiO2 (%)	0.023	0.003	11.705
K2O (%)	0.160	0.001	0.484

S8 DRAGON
Iron Ore Analysis

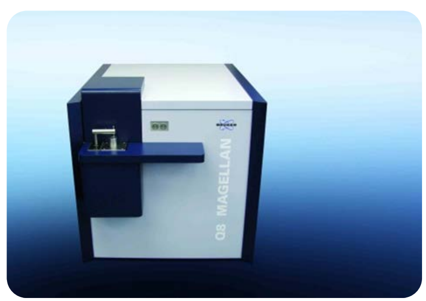
Designed for

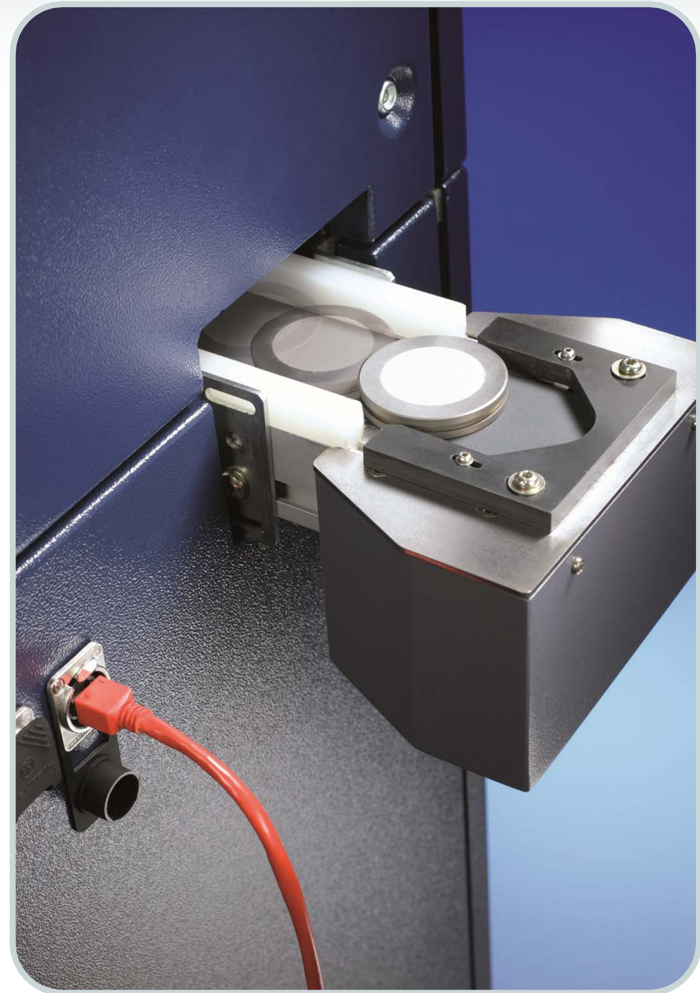
- Best analytical precision for major elements, such as Fe
- Lowest detection limits for hazardous elements, such as Cd and Pb
- High analyzing speed with less than 60 s measurement time
- Fast response for process adjustments
- High sample throughput with more than 1400 samples per day

Unique combination for analytical flexibility and analytical data safety with the Multielement Channel

S8 DRAGON
Automation Ready

- Automated sample transport and pickup at the back of the unit
- Interface for belt connection or robot
- Sample Magazine accessible for non-routine samples from the front
- Easy and simple integration path to automated sample preparation:
  - AXSCOM interface
  - TCP/IP connection
  - Link to Bruker OES





Benefits of XRF for Process and Grade Control in Mining Applications

- WDXRF spectrometer S8 TIGER for grade control, delivering excellent precision and accuracy paired with high analytical flexibility
- EDXRF spectrometer S2 RANGER for smaller process labs and industrial minerals applications
- High sample throughput and maximum analytical speed with simultaneous WDXRF spectrometer S8 DRAGON
- Specialized ready-to-analyze solutions for mining applications
- High degree of automation

Questions and Answers

Any questions?

Please type any questions you may have for our speakers in the Q&A panel and click Send.

How did we do?

When you exit the webinar, please fill out our evaluation survey to let us know. We appreciate your feedback.

Thank you!

BRUKER

Innovation with Integrity