IRmadillo™

KEIT spectrometers

Model augmentation as an alternative to calibration transfer - a practical approach for industrial installations

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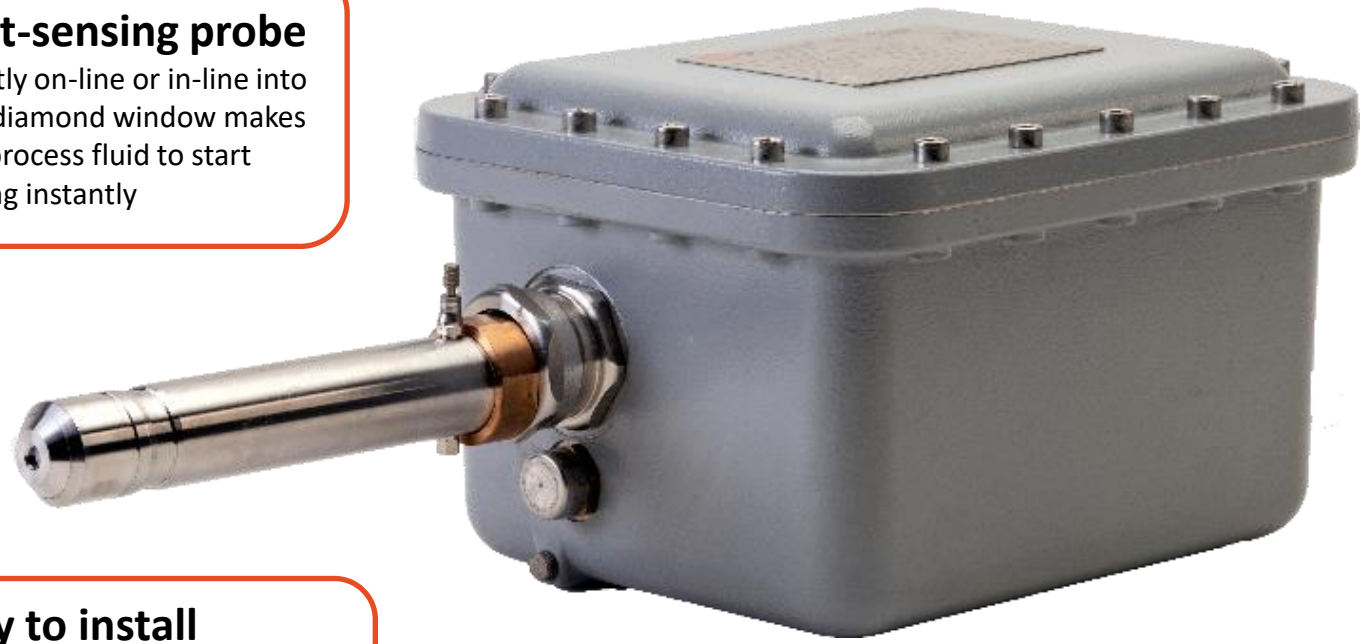
What is the IRmadillo?

Simple, contact-sensing probe
Install the probe directly on-line or in-line into your process and the diamond window makes contact with the process fluid to start measuring instantly



Robust, rugged and reliable
Using a 'fixed-mirror' design, the IRmadillo was built to perform in harsh plant conditions and explosive atmospheres.

Mid-infrared based technology
MIR has significantly more information than NIR – this gives much better performance on most applications

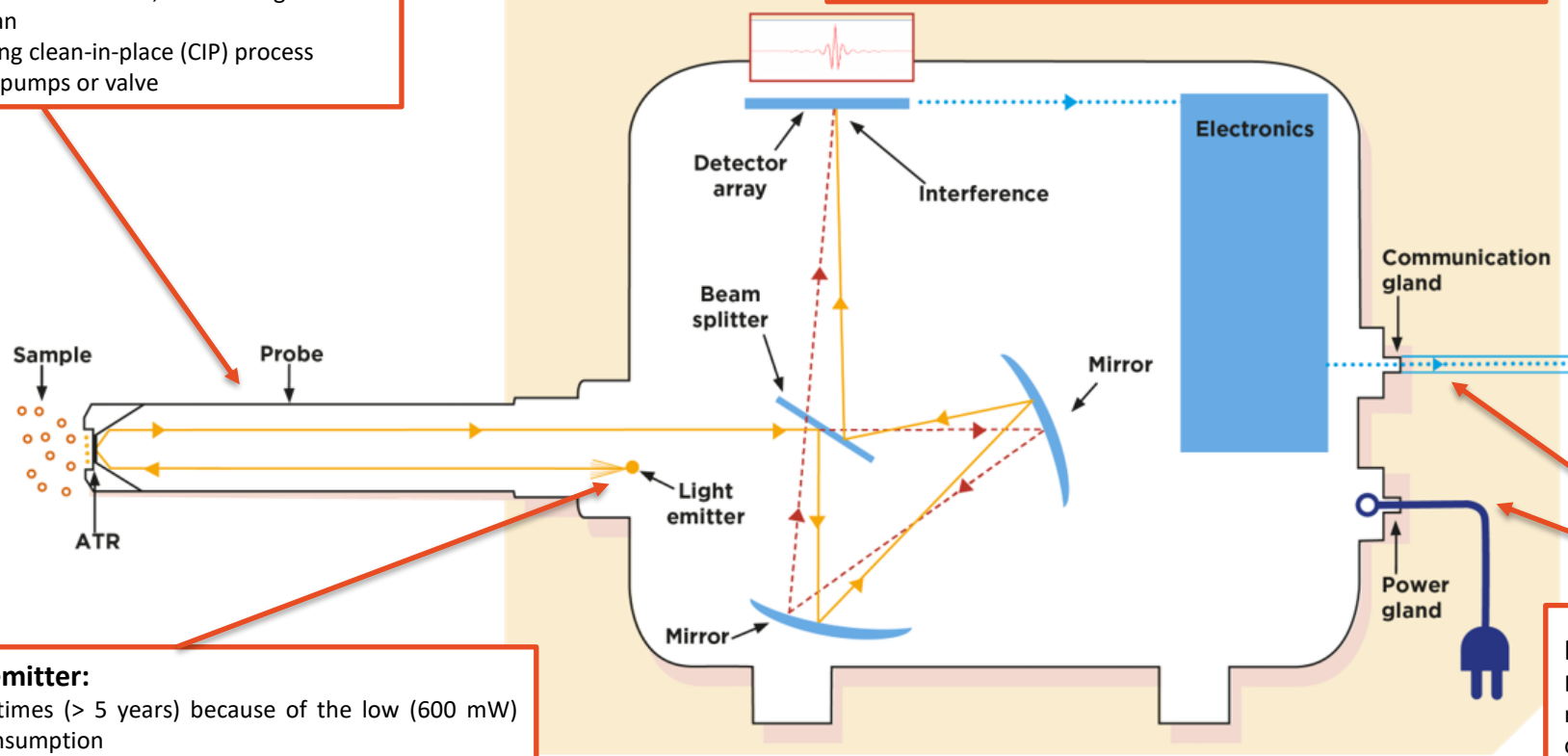
Easy to install
The probe can be installed directly into the process – either with a welded flange, compression seal, Ingold port or optional flow cells

Communicates directly with your DCS
The external controller can use either Modbus or OPC-UA to input measurements directly into the DCS, SCADA or PLC

Design decisions on the IRmadillo

In situ probe:
- Allows installation directly where measurement is needed
- Can remove the need for flow cells, which clog and can become difficult to clean
- Allows the use of existing clean-in-place (CIP) process
- No need for additional pumps or valve

Small but rugged box:
- Install where it's needed, and bring analysis to the process
- Robust, can take a beating, and inherently water resistant (IP65)

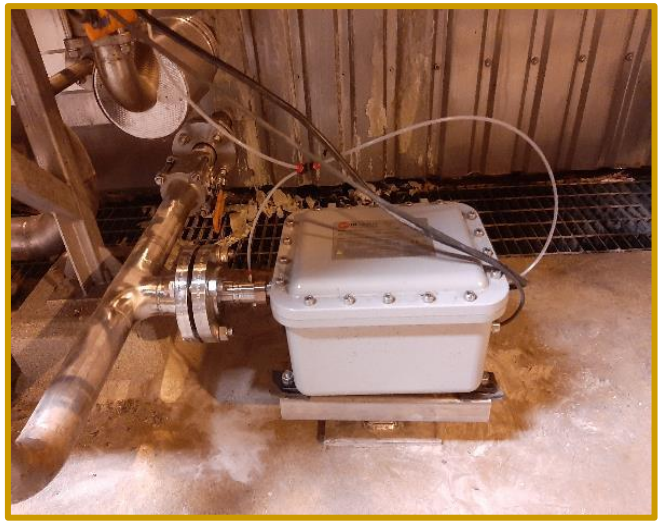


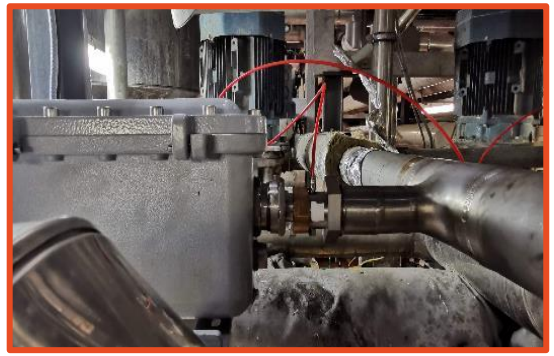
Local data processing:
No need for internet or cloud access: all analysis can be done locally to the machine in a secure way

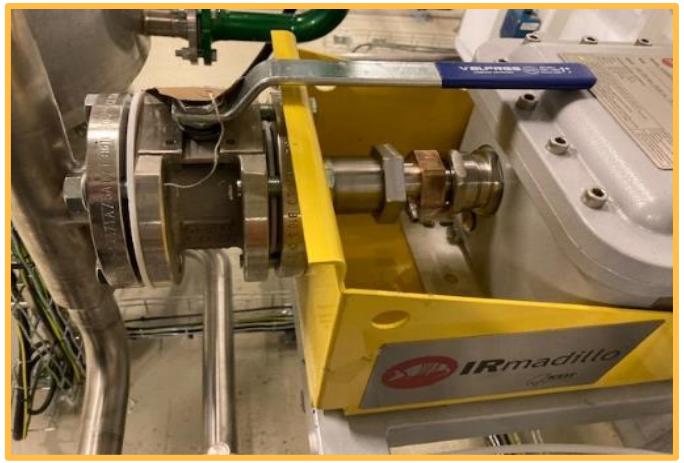
Low power emitter:
- Long life times (> 5 years) because of the low (600 mW) power consumption
- Protects optics from damage cause by localised heating
- No need for alternating power drive as is common with doped SiC emitters – much simpler and cheaper to run

Flying leads:
Easy to install whilst maintaining IP65 rating and ability to survive and operating during cleaning down/water spray

Field installation options







Calibration Transfer

What is Calibration Transfer?

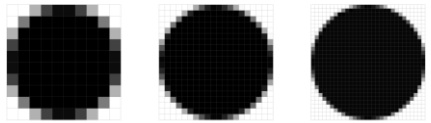
- "A series of analytical approaches or chemometric techniques used to attempt to apply a single spectral database, and the calibration model developed using that database, for two or more instruments, with statistically retained accuracy and precision"

Workman JJ Jr. A Review of Calibration Transfer Practices and Instrument Differences in Spectroscopy. Appl Spectrosc. 2018

Calibration Transfer

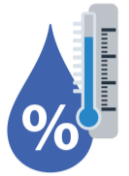
Transfer models between different spectrometers

- Wavelength registration
- Resolution
- Different components



Adapting models to new conditions

- Feedstock
- Process conditions



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How is it currently performed?

- Direct standardization (DS), piecewise direct standardization (PDS), spectral space transformation (SST)…

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How is it currently performed?

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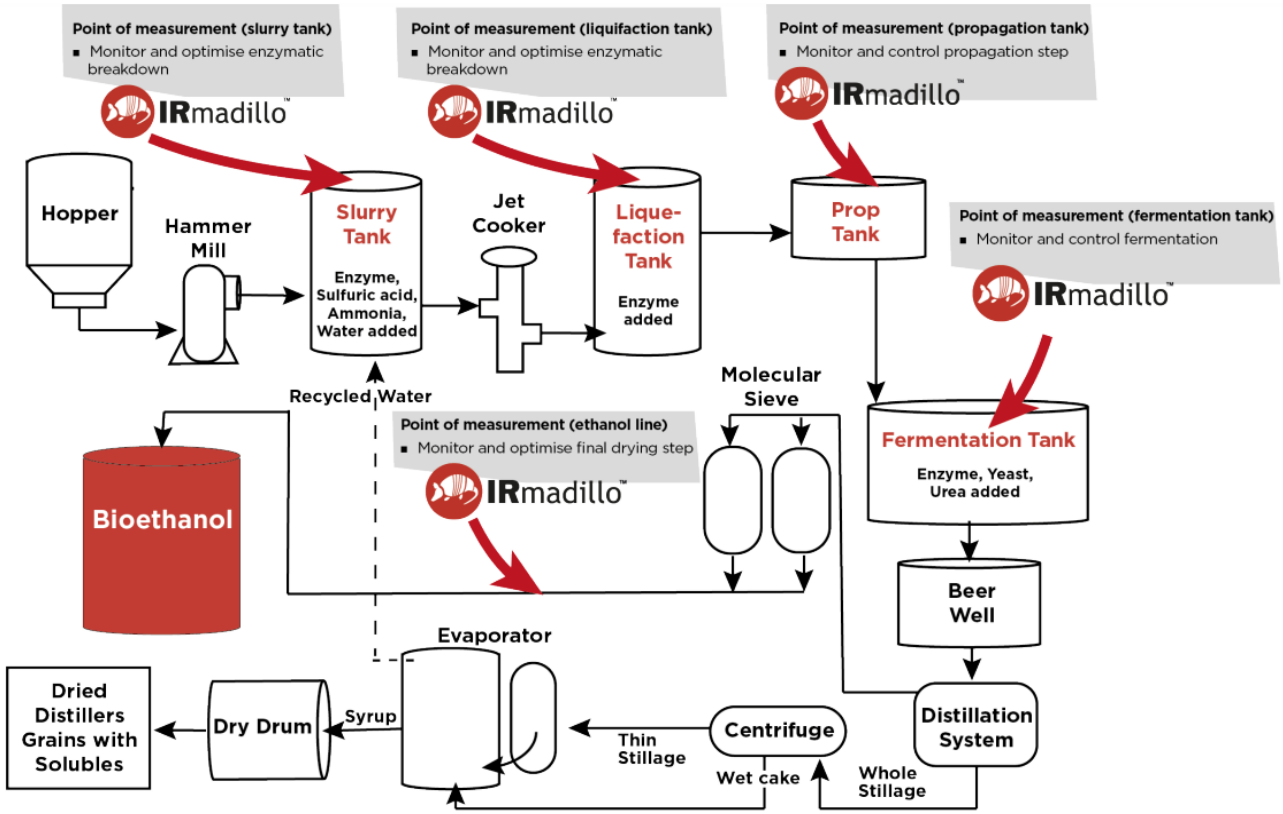
Main Problem

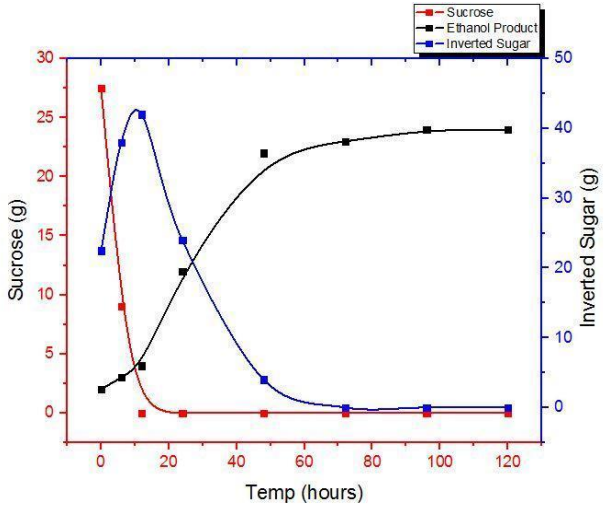
- Requires standard sample measurements on both instruments
- Not always possible due to geographical location of installs and sample degradation

1. Bioethanol Fermentations

Bioethanol Fermentations



- Typically measure in the fermentation tank
- Chemicals of interest during fermentation:
  - Ethanol (desired product)
  - Sugars (DP1, DP2, DP3, DP4)
  - Impurities (lactic/acetic acid, glycerol)



How can we efficiently calibrate for multiple installs with the same application?

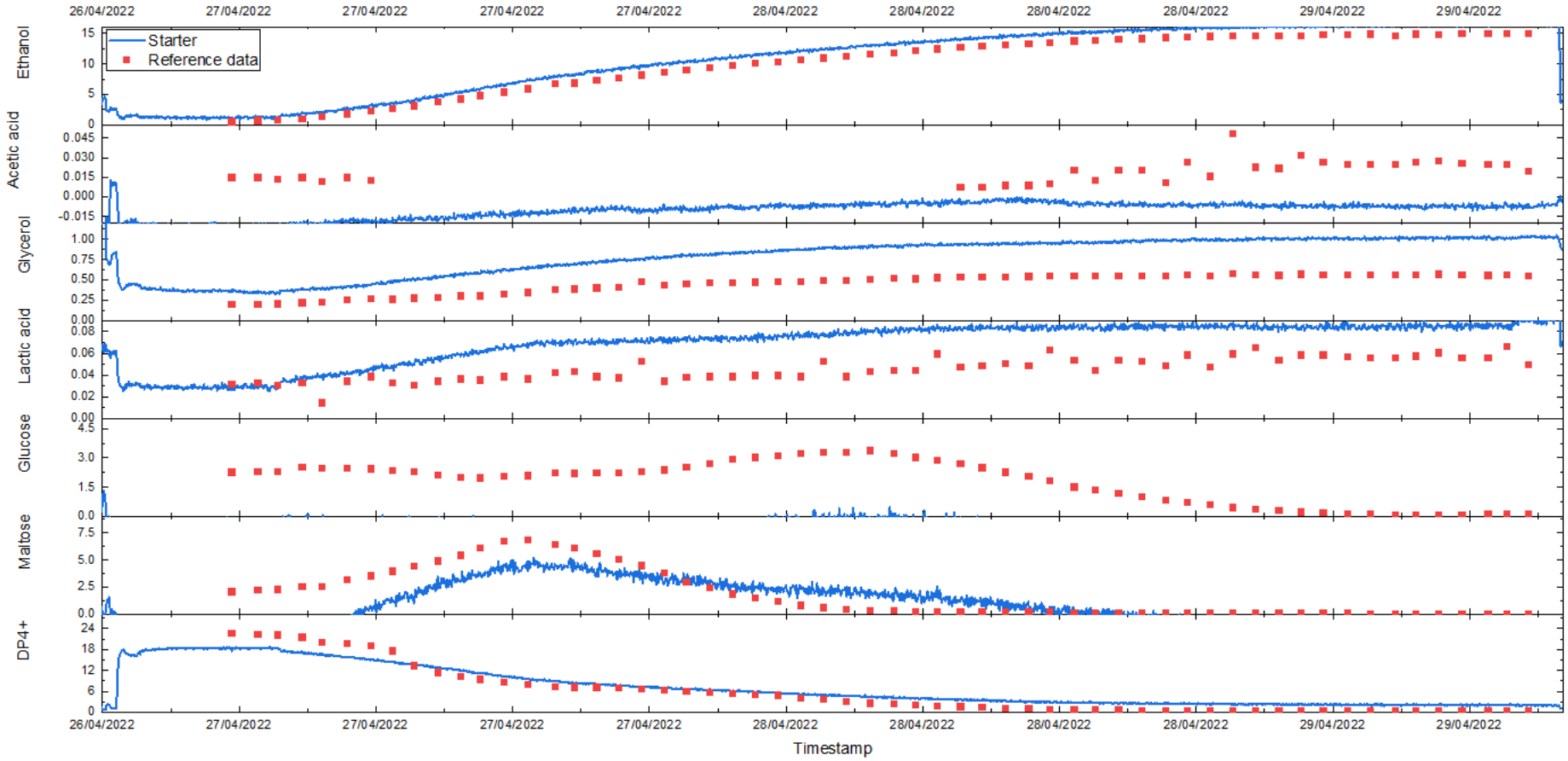
Starter Calibrations

Models built for a certain application using one or more IRmadillos developed using lab and/or process data

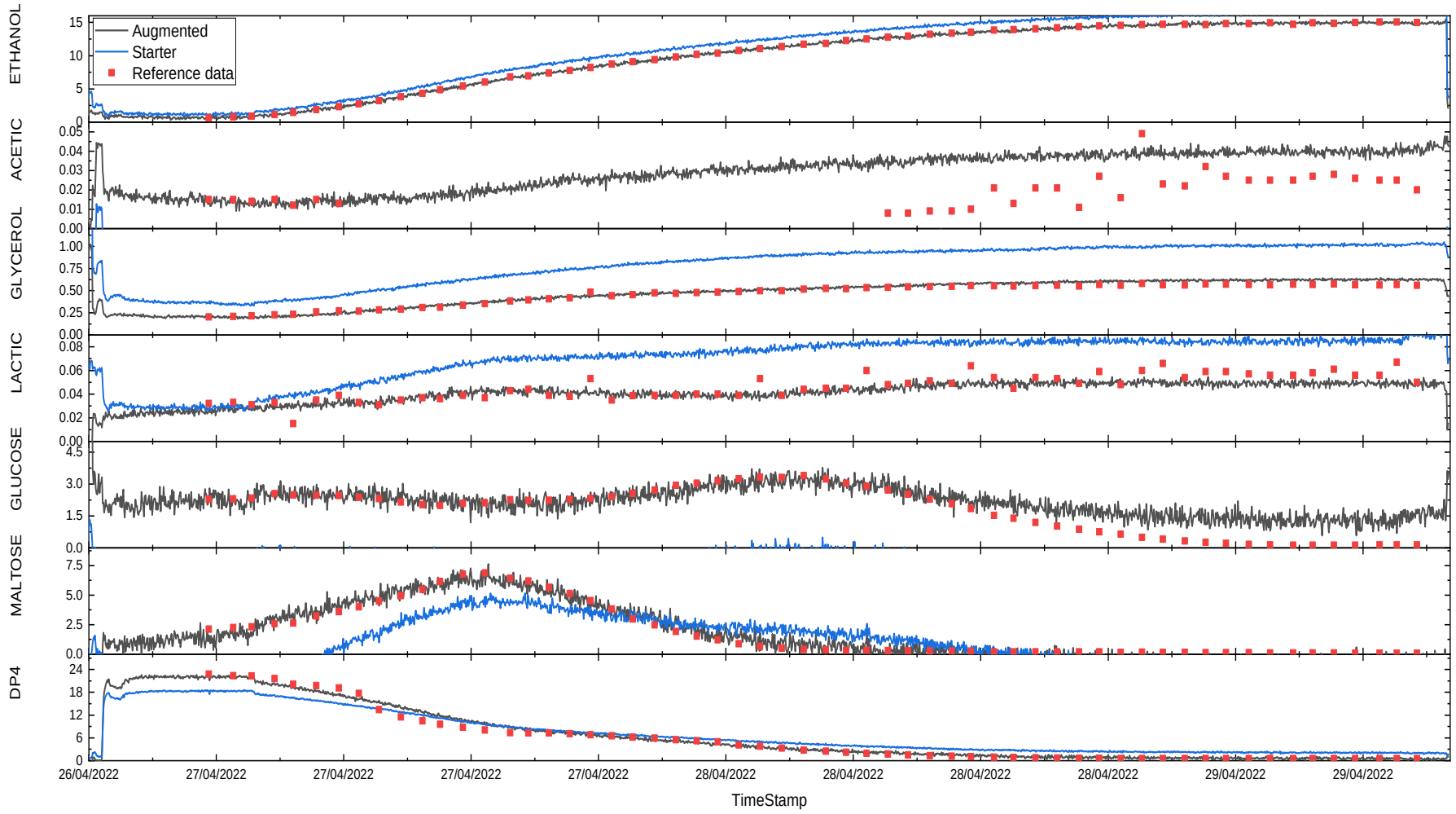
Ship out IRmadillos with pre-loaded starter calibrations

Provide customers with a visual representation of how their process is trending

Bioethanol Fermentation – Starter Calibration



Bioethanol Fermentation - Augmented Calibrations



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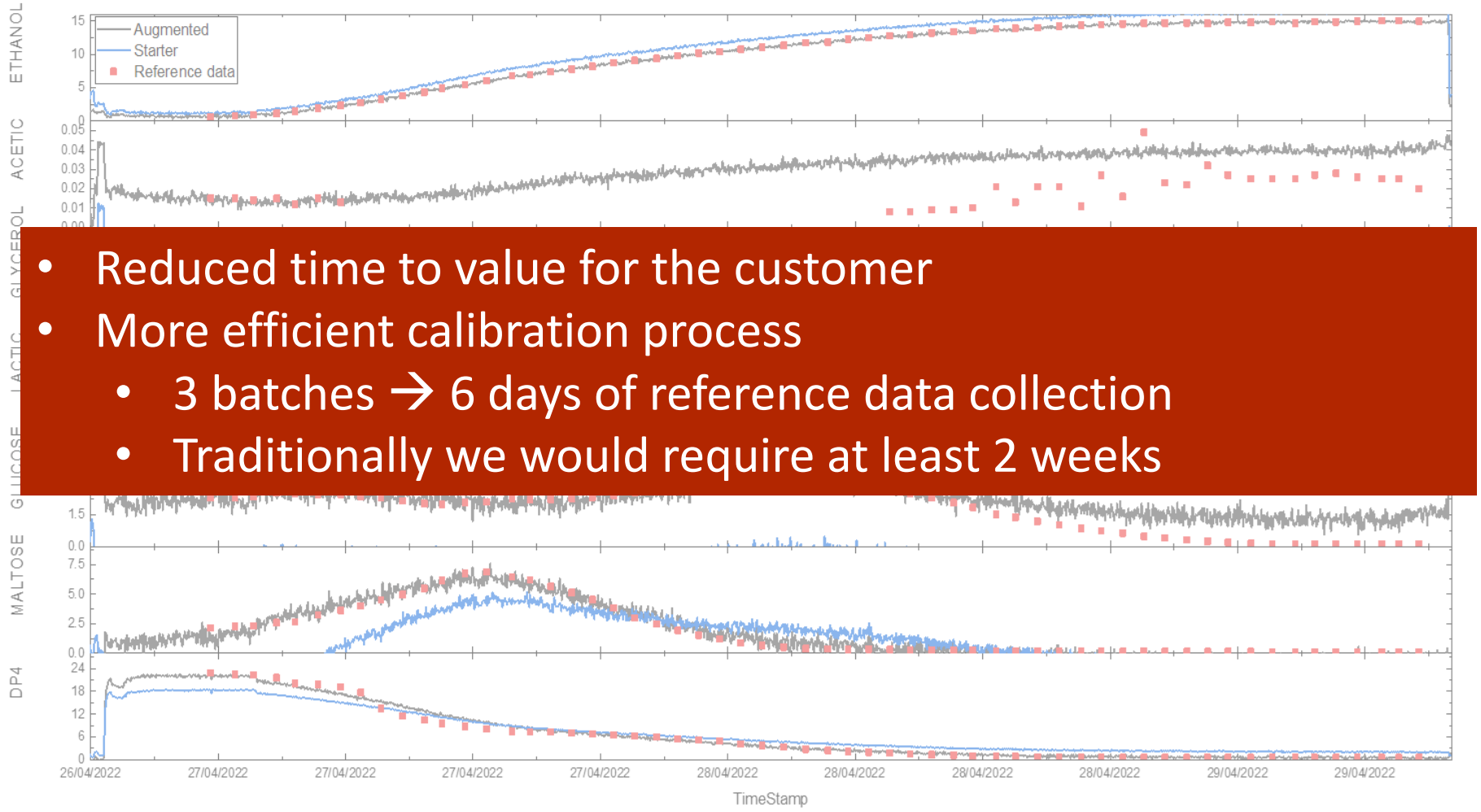

- Reduced time to value for the customer
- More efficient calibration process
  - 3 batches → 6 days of reference data collection
  - Traditionally we would require at least 2 weeks

2. Bioethanol to Vodka

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Ethanol fermentations for different industries are essentially the same from a process perspective – the difference is in the feedstock.

Corn → Bioethanol

Wheat → Vodka

Can we use the same calibrations across industries using the augmentation approach?

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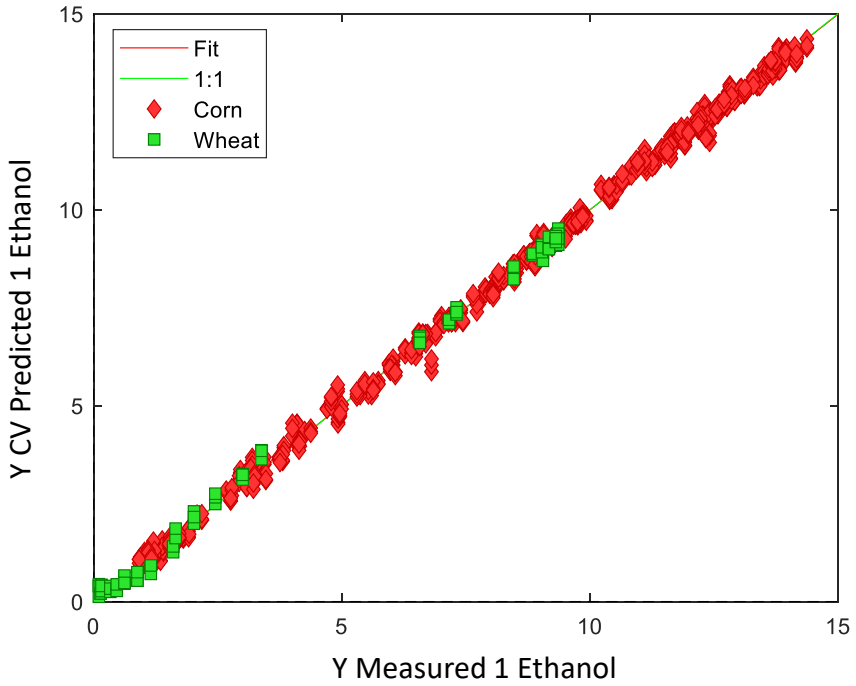
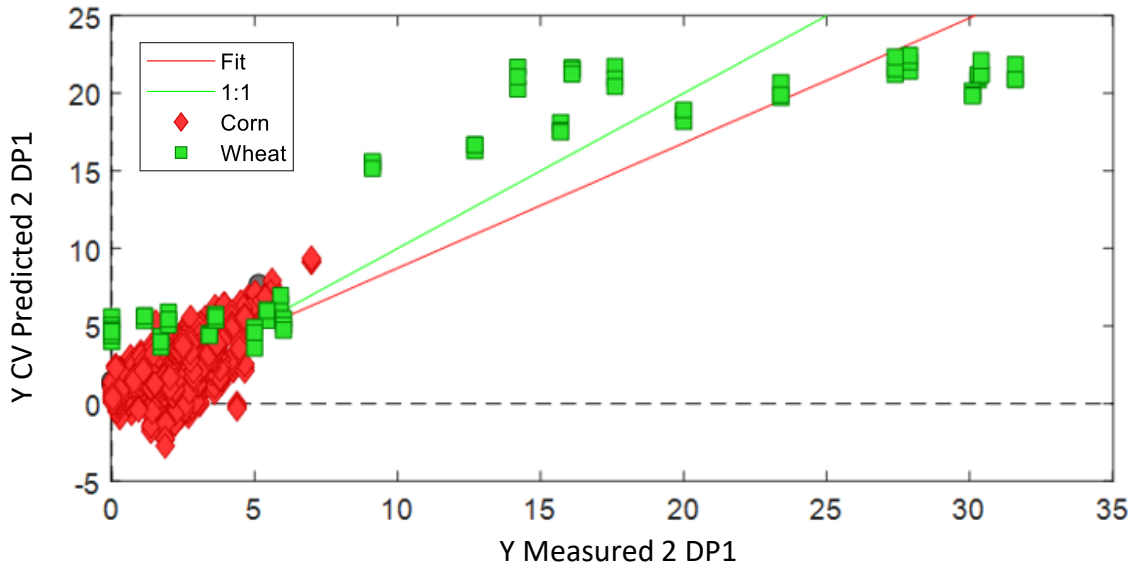
Ethanol



DP1



3. Brewing Mash

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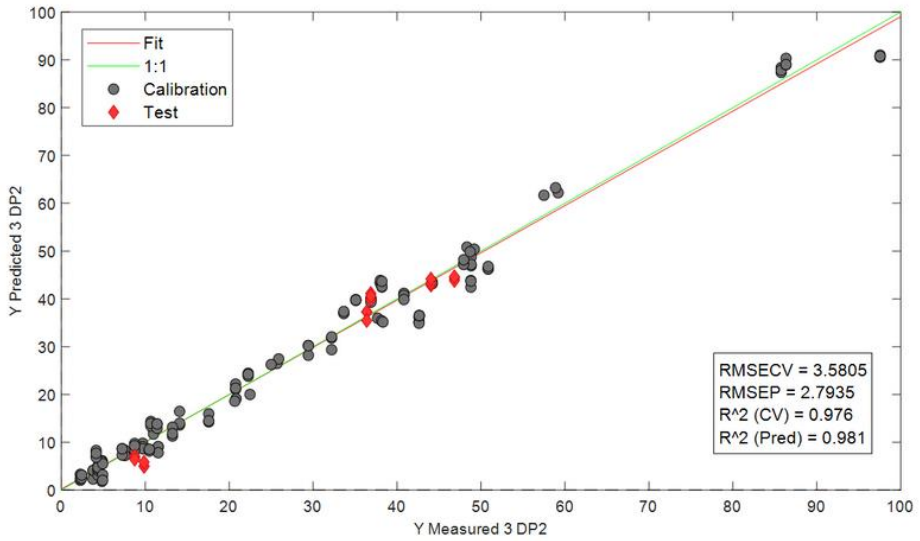
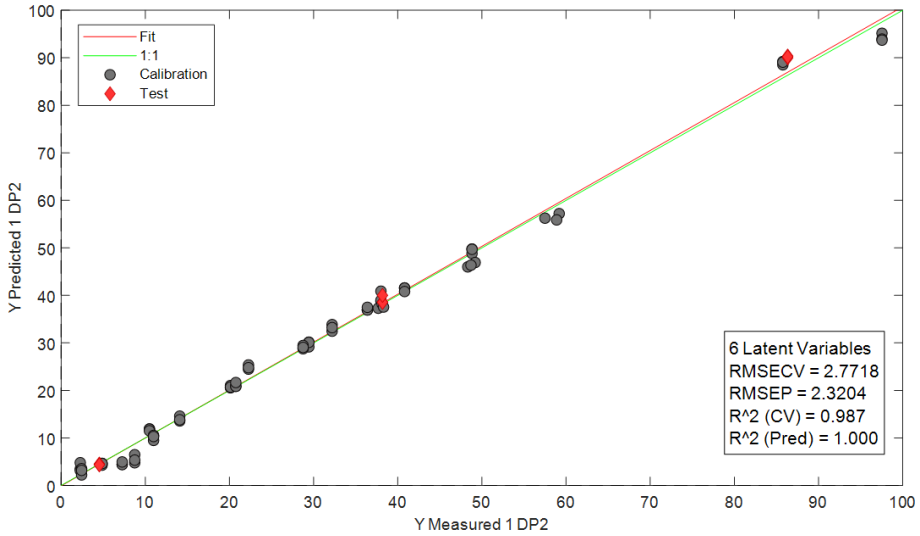
Beer can be produced from a variety of different grains including malt, sorghum and wheat where the choice of grains used typically depends on geography.

Is it better to have a single global model or multiple individual grain models?



DP2 Global Model



DP2 Malt Model

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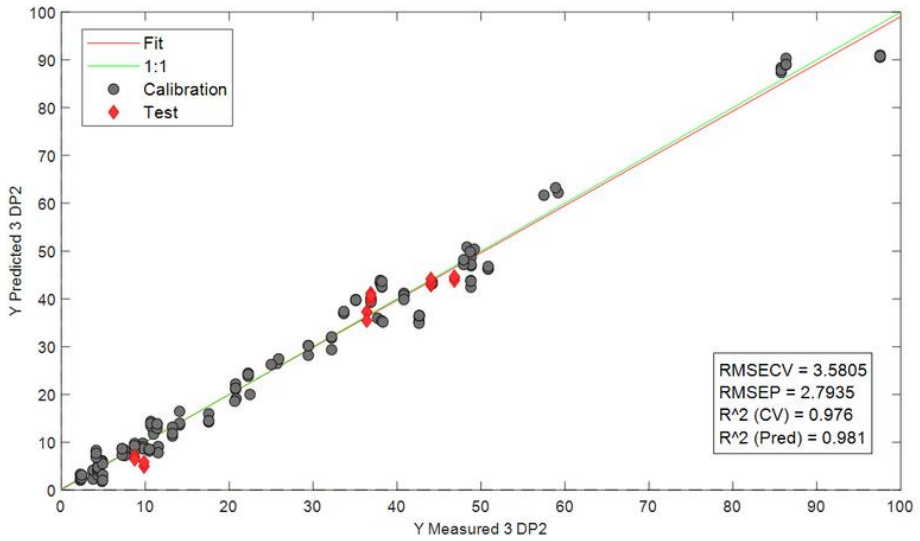
Depends on the application!



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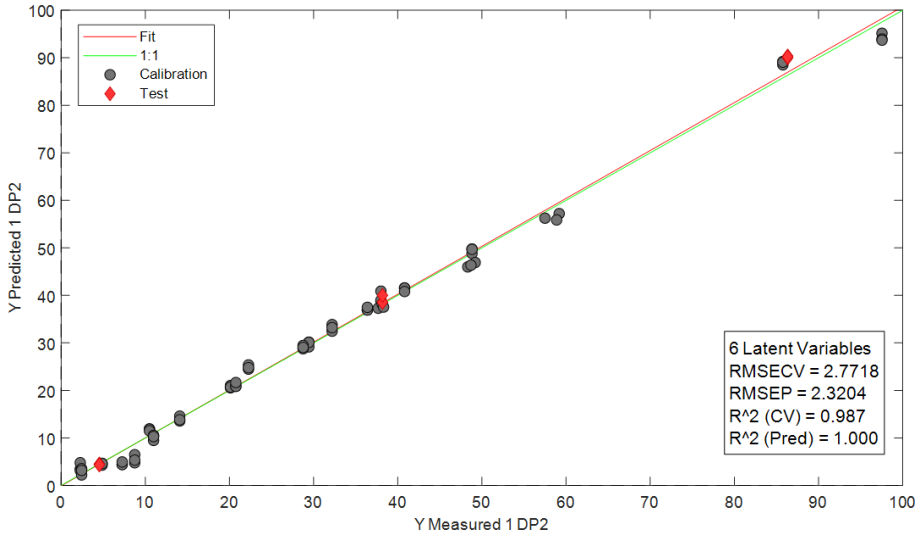

DP2 Malt Model

To be continued…