



ICAR FEED AND GAS WG WEBINAR

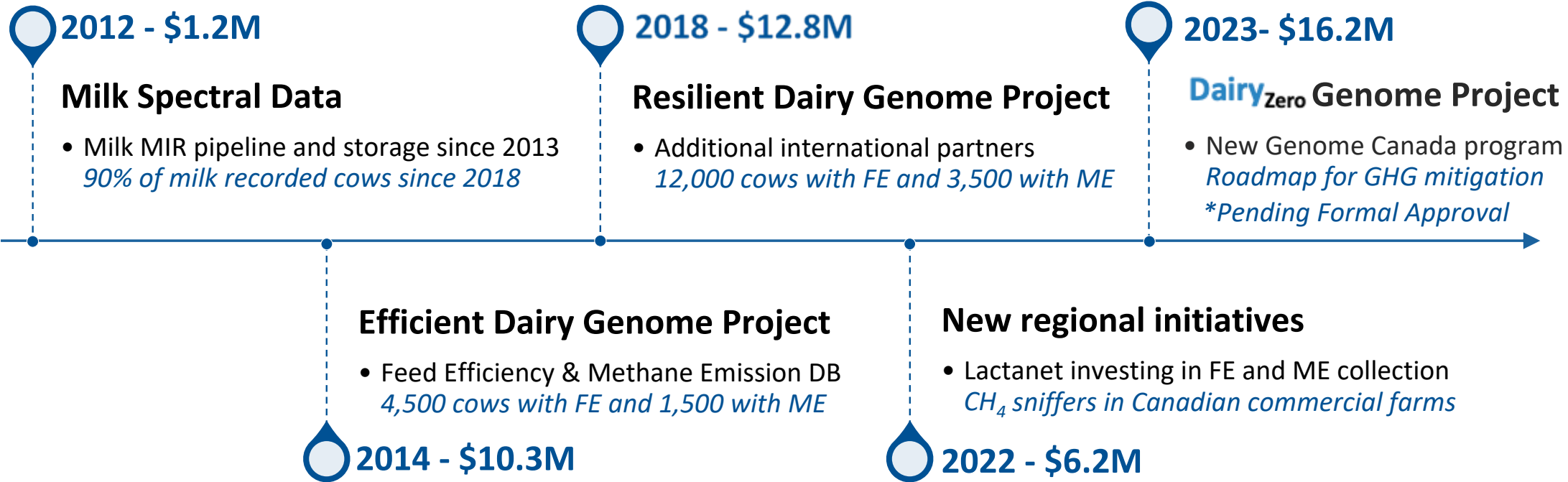
“USING MIR TO PREDICT METHANE EMISSIONS”

Genomic evaluation of MIR predicted methane and next steps

Filippo Miglior
Lactanet Canada & University of Guelph
Guelph, Ontario, Canada



Building Environmental Traits Capacity Over Time



Since 2013, multiple projects (\$4.2M) to genotype cows with medium-high density chips -> over 45,000 cows

MIR data research and pipeline

```
graph TD; A[MIR data research and pipeline] --> B['Gold standard' novel phenotype]; B --> C[Milk MIR prediction of phenotypes]; C --> D[Apply prediction to MIR population]; D --> E[From research to service mode];
```

'Gold standard' novel phenotype

Milk MIR prediction of phenotypes

Apply prediction to MIR population

From research to service mode

Milk MIR Data – R&D and Pipeline

- NSERC & Dairy Cluster projects (2012-2018)
 - **Milk Fat Globule Size** (Fleming et al 2017a JDS)
 - **Milk Fatty Acids** (Fleming et al 2017b JDS)
 - **Lactoferrin & Casein Micelle Size** (Fleming et al 2019 CJAS)
 - MIR standardization (Bonfatti et al 2017a JDS)
 - Prediction calculation comparison (Bonfatti et al 2017b JDS)
 - Pipeline (Miglior et al 2016 ICAR)
- EDGP & RDGP projects and collaborations (2015-2024)
 - **DMI** (Shadpour et al 2022a JDS)
 - **CH₄** (Shadpour et al 2022b JDS; Liu et al 2022 Animal; Van Doormaal et al 2023 ITB Bulletin; Oliveira et al 2024 JDS Comm)
 - **BCS Change** (Frizzarin et al 2023 and 2024; JDS)

Gold standard phenotypes

- **Milk Fat Globule Size:** integrated light scattering
- **Milk Fatty Acids:** gas-chromatography
- **Casein Micelle Size:** dynamic light scattering
- **Lactoferrin:** ELISA
- **DMI:** individual daily feed intake across three farms
 - First 150 DIM at Guelph
 - Full lactation at Sunalta and Edmonton
- **BCS change:** multiple BCS records per lactation in over 1,000 QC herds
- **CH₄:** 3-4 times daily for 1-2 weeks with GreenFeed

Collected Methane

- Collected from the University of Guelph and of Alberta under two international projects:



- Varying collection protocols with the GreenFeed system (C-Lock Inc., Rapid City, SD)



Collection Protocols

	Parity	DIM	Times/day	Duration
U of Guelph	1 st lactation	120-150 DIM	3 or 4	5 consecutive days
U of Alberta	1 st and multiparous	30-250 DIM	2 → 3 →	12 consecutive days 5 consecutive days

Average daily g/d CH₄ production calculated for each animal (weekly average)

CH₄ Analysis at UofG

A Pivotal Result

- Research led by Flavio Schenkel, Saeed Shadpour and Christine Baes
- Close involvement of Lactanet
- **A cow's milk MIR data can be used as a good predictor of its methane production**



J. Dairy Sci. 105:8272–8285
<https://doi.org/10.3168/jds.2021-21176>

© 2022, The Authors. Published by Elsevier Inc. and Fass Inc. on behalf of the American Dairy Science Association®.
This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

Predicting methane emission in Canadian Holstein dairy cattle using milk mid-infrared reflectance spectroscopy and other commonly available predictors via artificial neural networks

Saeed Shadpour,¹ Tatiane C. S. Chud,¹ Dagnachew Hailemariam,² Graham Plastow,² Hinayah R. Oliveira,¹ Paul Stothard,² Jan Lassen,³ Filippo Miglior,^{1,4} Christine F. Baes,¹ Dan Tulpan,¹ and Flavio S. Schenkel^{1*}

¹Centre for Genetic Improvement of Livestock, Department of Animal Biosciences, University of Guelph, Guelph, Ontario, N1G 2W1, Canada

²Department of Agricultural, Food and Nutritional Science, University of Alberta, Edmonton, Alberta, T6G 2P5, Canada

³Center for Quantitative Genetics and Genomics, Aarhus University, Tjele, 8830, Denmark

⁴Lactanet Canada, Guelph, Ontario, N1K 1E5, Canada

Lactanet's Milk MIR Investment

- Based on research results, Lactanet built its internal system for MIR processing to predict CH₄
- Great potential and availability – over **19M** records since 2018
- Milk MIR data on **90% of milk recorded cows** since 2018



MIR Data Processing



Individual milk samples processed by FOSS Milkoscan FTIR spectrophotometers



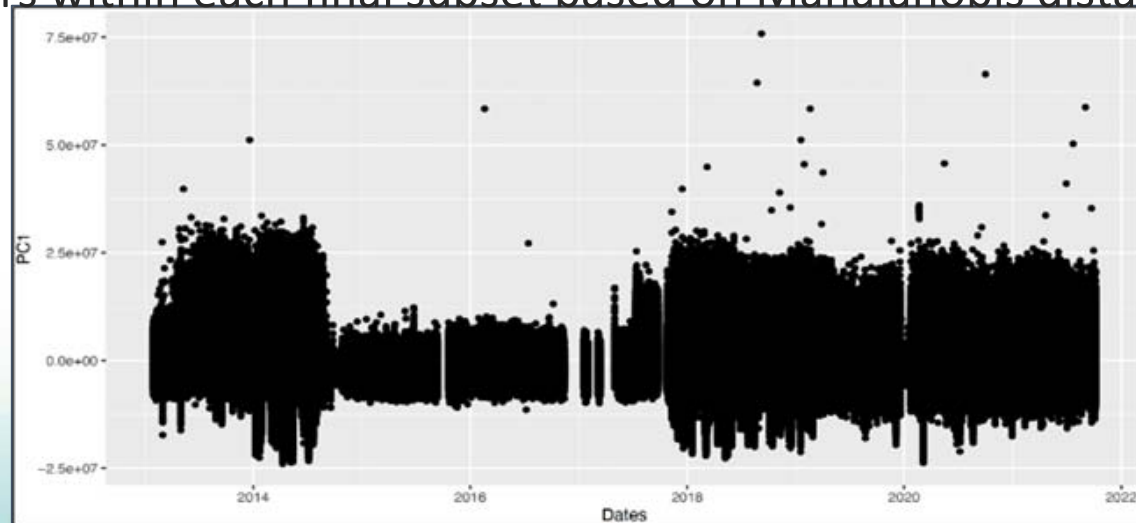


Identification of Subsets

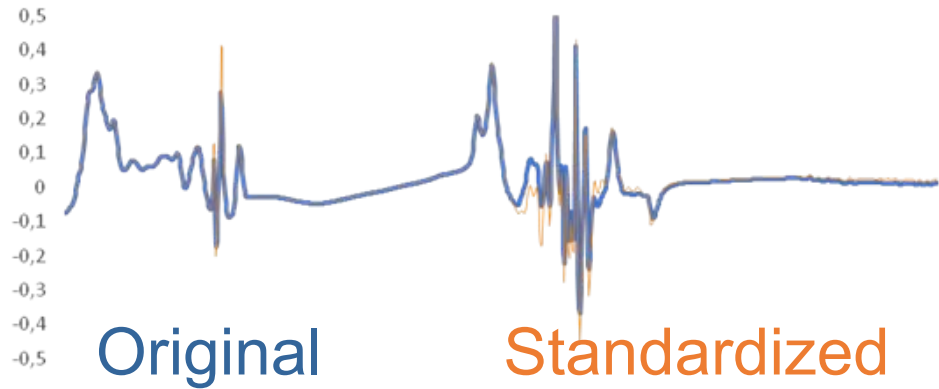
- MIR records split into subsets according to lab
 - From 4 labs, serving 5 provinces
- Keeping only Holstein data

Identification of Subsets and Quality Control

- Remove uninformative and water associated regions
 - Using 241 spectral datapoints
- Within each lab subsets, change in patterns over time using PCA (Bonfatti et al., 2017) and Bayesian Changepoint Detection used to form additional subsets with homogenous signals
 - Only using MIR records since 2018 due to limited prior samples and increased variability
- Removed outliers within each final subset based on Mahalanobis distance



Standardization and Pretreatment



- **Standardize** the spectra of the secondary spectrometer to match the spectra from the master machine (Bonfatti et al. 2017)
 - Valacta Lab, Ste-Anne-de-Bellevue, QC
- Smoothing **pretreatment** using a third order **Savitzky–Golay** filter yielded the best results and applied to all spectra
- All spectral datapoints included in standardization and pretreatment steps and then reduced back again to 241

Predicting Methane

- MultiLayer Perceptron Artificial Neural Network based on Bayesian regularization model
- 241 MIR spectral datapoints used as input predictors
- Collected average daily methane from 496 cows from two herds between 5-305 DIM

Prediction accuracy of 0.70

Genetic Correlation 0.92 (0.22)



**JDS
Communications®**
TBC; TBC

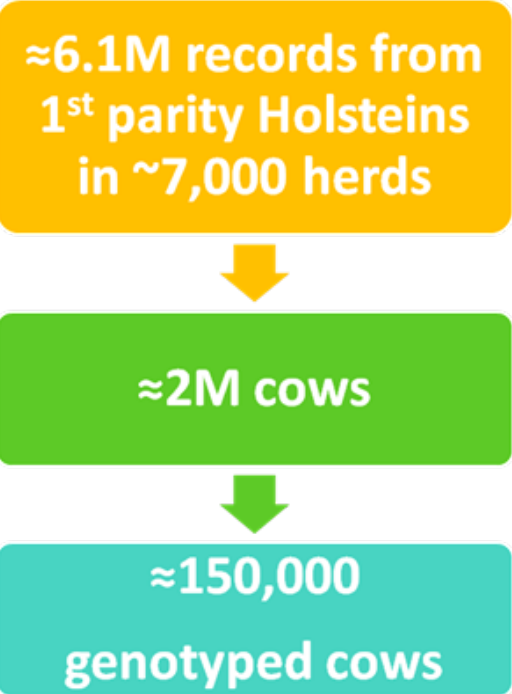
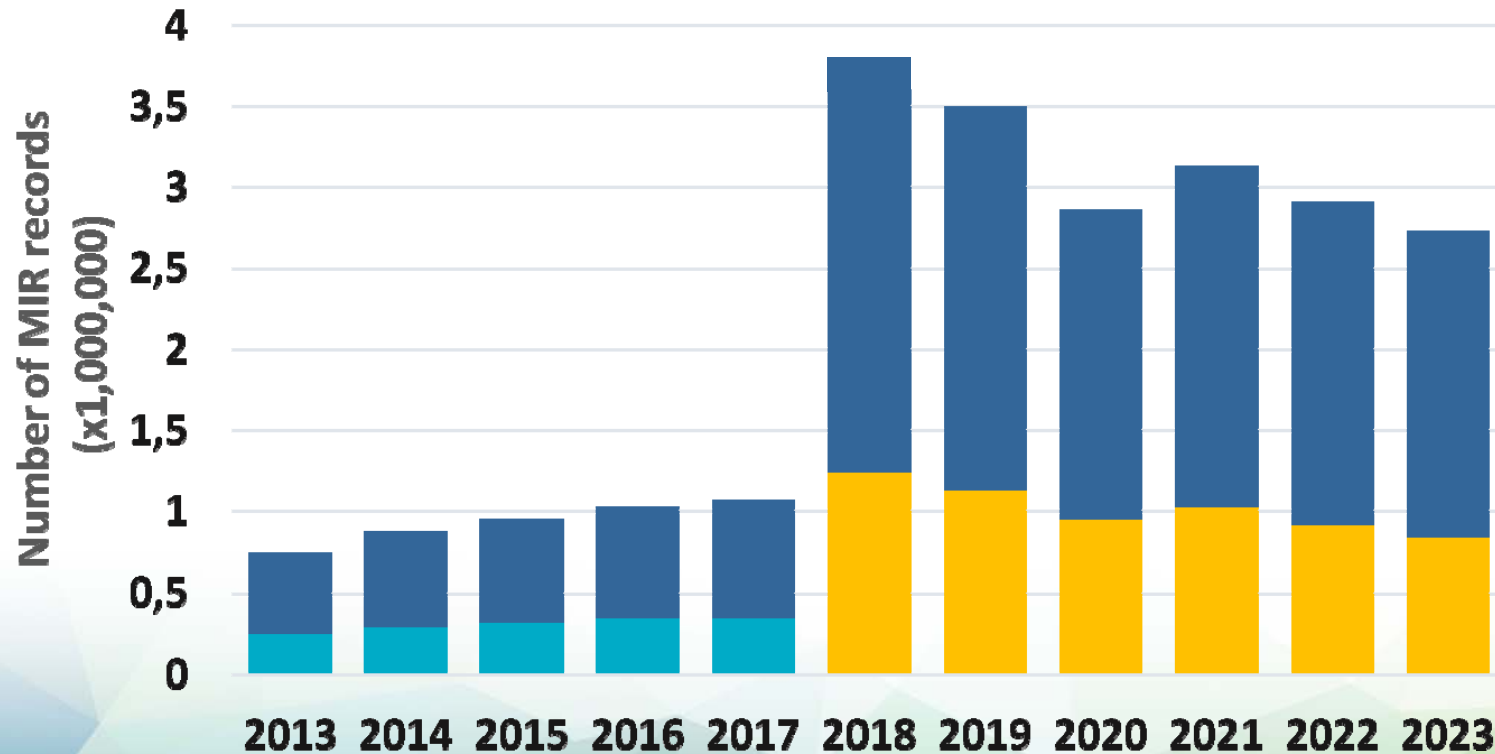
<https://doi.org/10.3168/jdsc.2023-0431>
Symposium Review
Genetics

Symposium Review: Development of genomic evaluation for methane efficiency in Canadian Holsteins

Hinayah R. Oliveira,¹² Hannah Sweett,¹ Saranya Narayana,¹ Allison Fleming,¹ Saeed Shadpour,³ Francesca Malchiodi,³⁴ Janusz Jamrozik,¹³ Gerrit Kistemaker,¹ Peter Sullivan,¹ Flavio Schenkel,³ Dagnachew Hailemariam,⁵ Paul Stothard,⁵ Graham Plastow,⁵ Brian Van Doormaal,¹ Michael Lohuis,⁴ Jay Shannon,⁴ Christine Baes,³⁶ and Filippo Miglior¹³

Apply prediction to MIR population

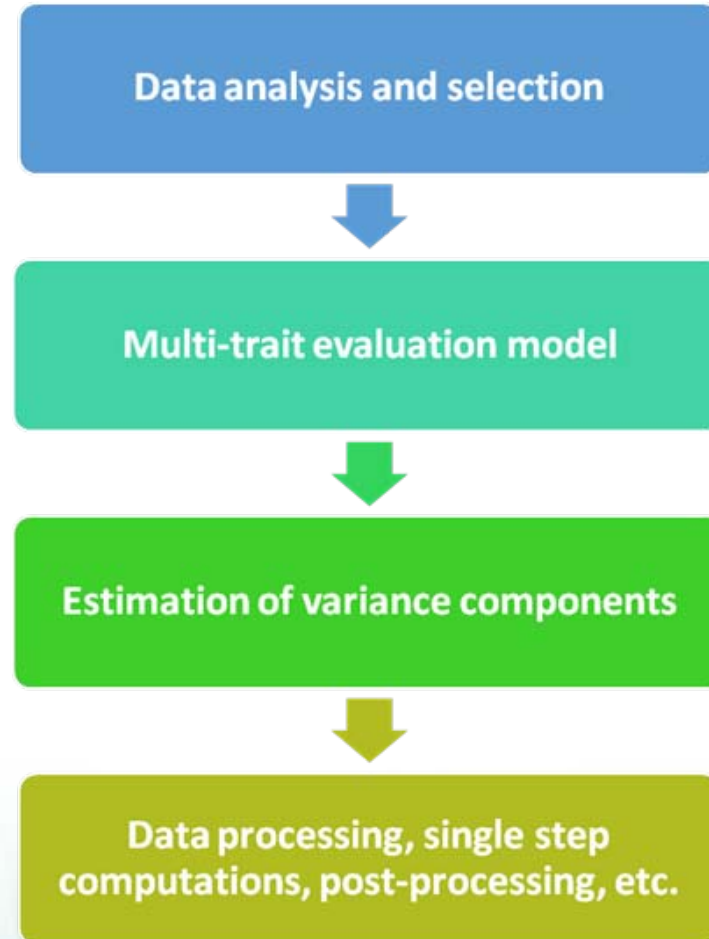
- Great potential and availability – over **19M** records since 2018
- Milk MIR data on **90% of milk recorded cows** since 2018



From research to service mode



Lactanet and Semex collaborated on the development of the prediction and a new, single step genomic evaluation system



Data Used for Genetic Evaluation

- First parity Holsteins from 6,128 herds
- Between 120 and 185 DIM

Records	905,662	Genotyped Animals	252,383
Cows	621,687	Genotyped Cows	82,770
Sires	11,491	Genotyped Sires	8,932

*Numbers for February 2024 evaluations

Genomic Evaluation for Methane Efficiency

- **Single-step four-trait Animal Model (using MiX99)**
 - Predicted Methane (CH_4 , g/d), Milk (kg/d), Fat (kg/d), Protein (kg/d)
 - Fixed: Age at calving, DIM, Year-Season of calving
 - Random: Herd-Test-Date, Permanent Environment, Animal
- **Methane Efficiency (ME):**
 - Predicted CH_4 production genetically independent of Milk, Fat and Protein yields via linear regression
(recursive re-parameterization, Jamrozik et al., 2017 JDS)

Methane Efficiency helps to reduce the methane production of the herd without impacting production levels

Genetic Parameters

	Predicted CH ₄	Milk Yield	Fat Yield	Protein Yield
Predicted CH ₄	0.23	-0.13	0.38	-0.11
Milk Yield	-0.06	0.38	0.48	0.83
Fat Yield	-0.18	0.66	0.27	0.71
Protein Yield	0.01	0.90	0.74	0.28

Heritabilities on diagonal, Genetic correlations above diagonal, Phenotypic correlations below diagonal

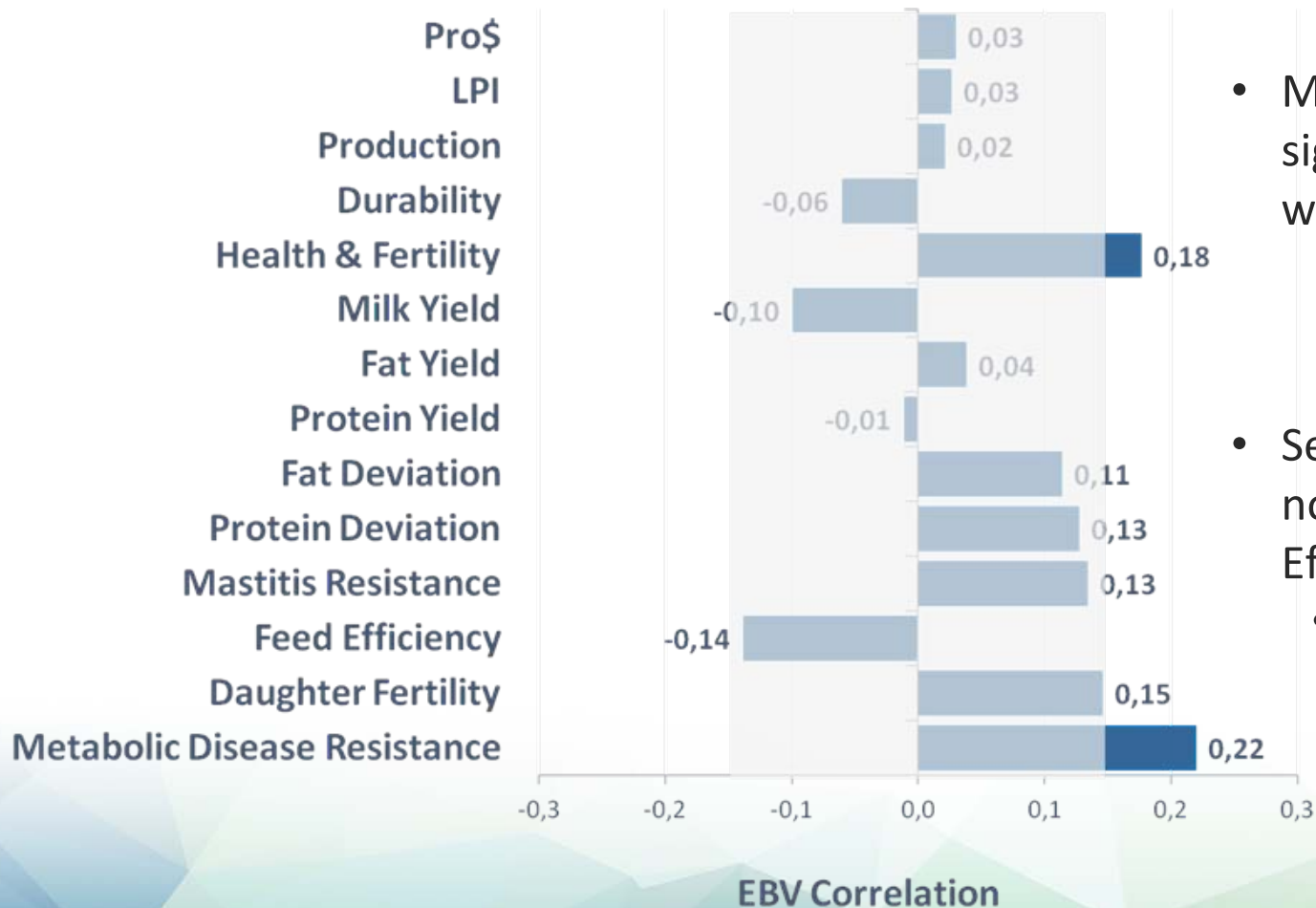
*all approximated SE are <0.033

Methane Efficiency vs Methane Production

- 75% genetic correlation between Methane Efficiency and Methane Production
- Methane Efficiency is not genetically correlated with any production traits

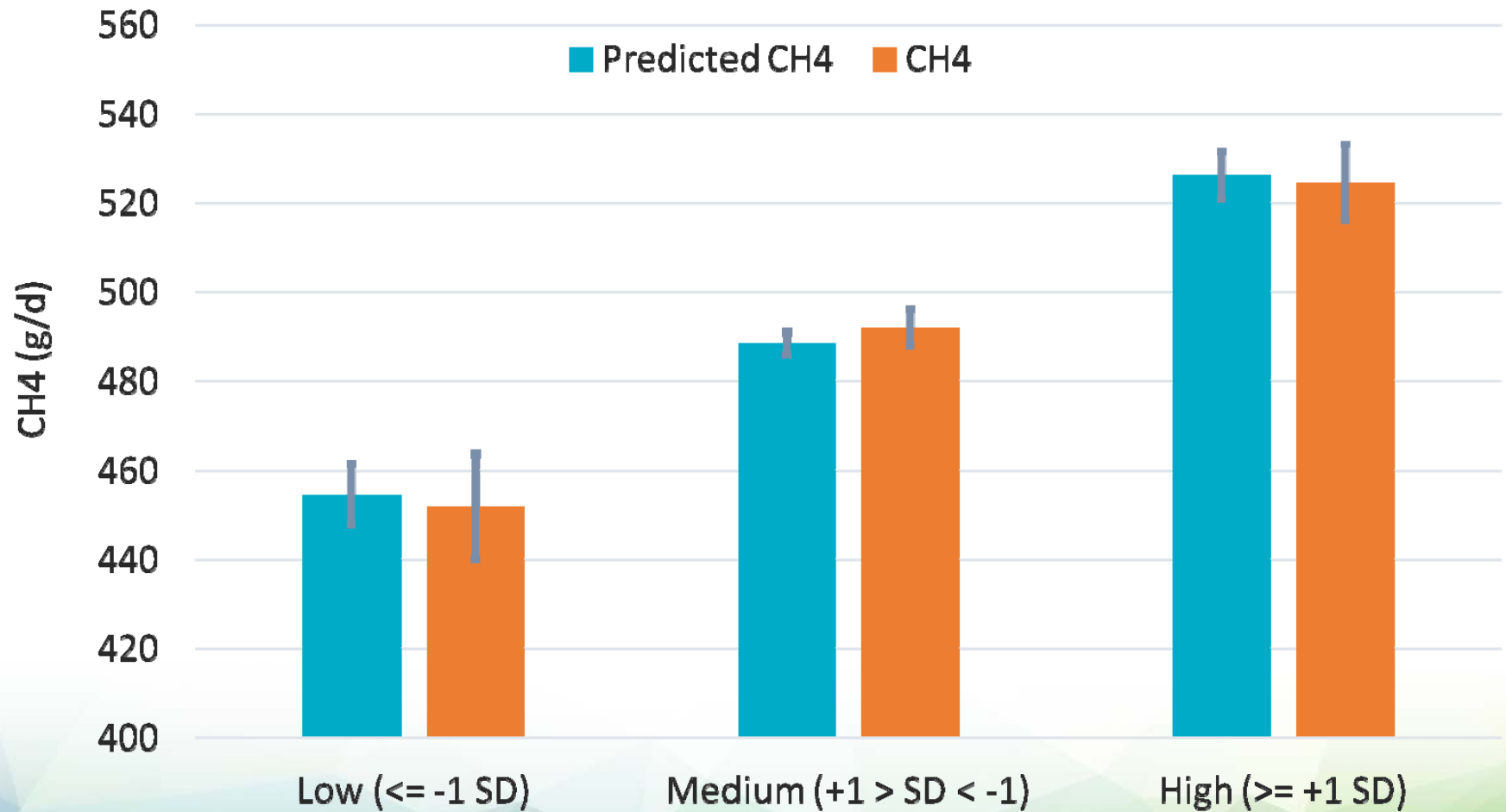
	Milk	Fat	Protein
Methane Production	-0.13	0.38	-0.11
Methane Efficiency	0.00	0.00	0.00

Methane Efficiency is a New Trait



- Methane Efficiency does not have a significant unfavorable correlation with any other evaluated trait
- Selection for Feed Efficiency does not also improve Methane Efficiency
 - Both traits are independent of production yields

Average Predicted and Collected CH4 by GEBV class



Interpretation

Reduce CH₄ production by selecting for higher Methane Efficiency without impacting production traits

5-point ↑ in a sire's RBV for ME, daughters are expected to produce 3kg less CH₄ per year

1.5% decrease in CH₄ emissions per cow per year

Herd owners selecting for ME can achieve 20-30% reduction in CH₄ emissions from their herd by 2050

The screenshot shows the Interbull Bulletin website interface. At the top, there is a navigation bar with 'Home', 'Archives', and 'About'. The main content area displays the title 'Implementation of Methane Efficiency Evaluations for Canadian Holsteins' and a list of authors: Brian Van Doormaal, Hinayah Rojas de Oliveira, Saranya Narayana, Allison Fleming, Hannah Stewart, Francesca Malchiodi, Janusz Jamrozik, Gerrit Kistemaker, Peter Sullivan, and Filippo Miglior. A 'PDF' button is visible next to the article title. The page also includes publication information: 'Published 2023-12-13' and 'Issue No. 59 (2023), Proceedings of the 2023 Interbull Meeting'.

Future Strategy

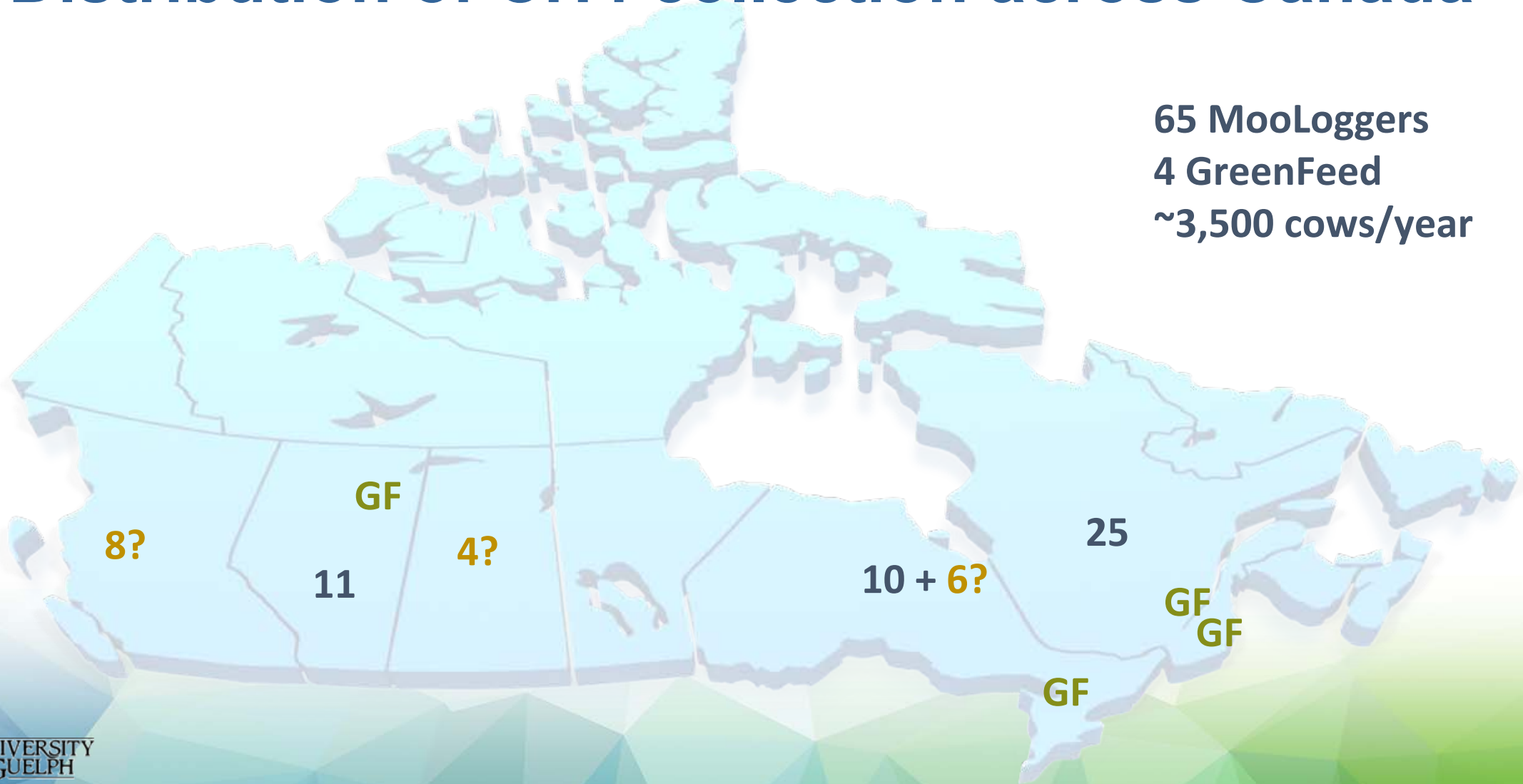
The current MIR prediction is for 1st parity Holsteins, 120-185 DIM

Our Goals:

- Enhance milk MIR prediction
 - Increase # CH₄ records with GreenFeed
 - Install CH₄ sniffers (MooLogger) in up to 65 robotic farms across Canada
 - ✓ Including Jersey and Ayrshire, in addition to Holstein
 - ✓ Multiple parities
 - ✓ Full lactation
 - ✓ Different feeding and management systems
- Enhanced genomic evaluation
 - Using new milk MIR prediction
 - Using new milk MIR prediction + collected CH₄ from GreenFeed and sniffers

Distribution of CH4 collection across Canada

65 MooLoggers
4 GreenFeed
~3,500 cows/year



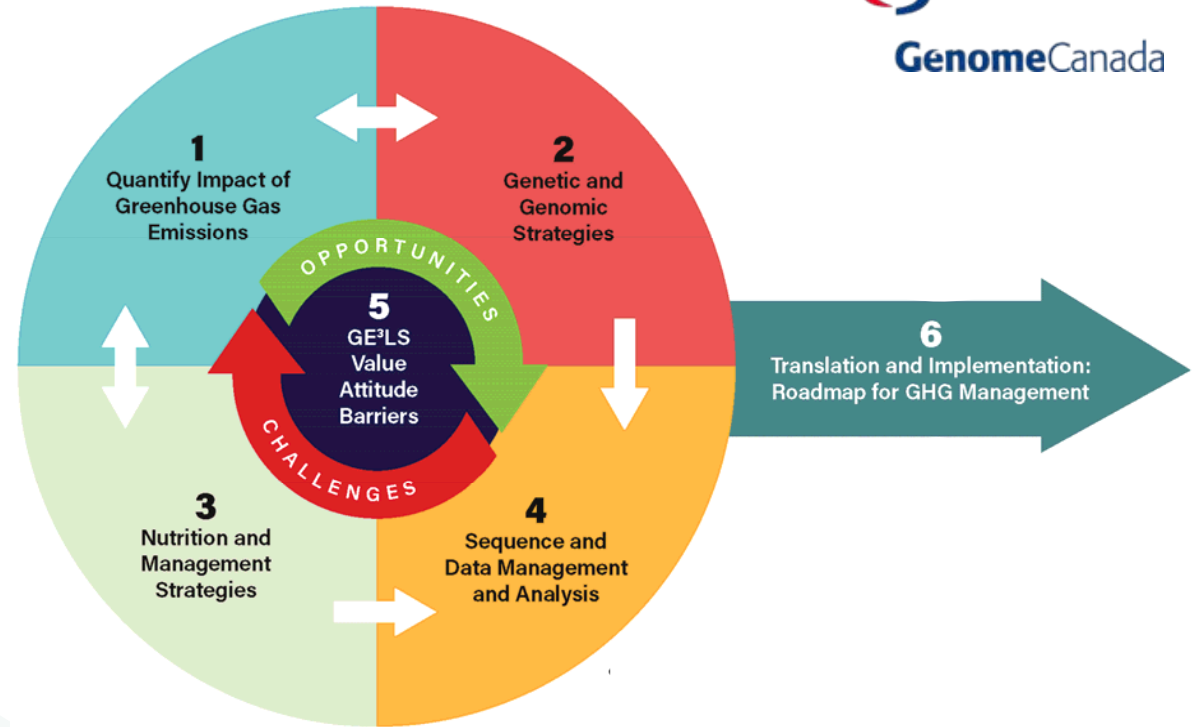
Climate-Smart Agriculture and Food Systems – ICT 2022

Leveraging Genomics to Achieve Dairy Net Zero

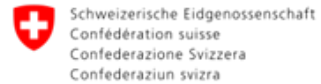


GOALS

- Consolidation of existing methane emissions data (including beef)
- Estimate animal and herd-level emissions
- Quantify potential GHG reductions through genetic and nutrition strategies
- Enhance CH₄ genomic evaluations
- Understand public attitudes/behaviours to emissions reductions
- Develop and implement CH₄ herd monitoring and benchmarking tools
- **Develop a roadmap for CH₄ mitigation**



Acknowledgements



A Team Effort

Allison Fleming
Janusz Jamrozik
Gerrit Kistemaker
Filippo Miglior
Saranya Narayana
Hinayah Oliveira
Hannah Sweett
Brian Van Doormaal



Christine Baes
Flavio Schenkel
Saeed Shadpour

And all grad students and post-docs that every day, three times a day have been collecting CH4 data since 2016



Francesca Malchiodi
Mike Lohuis
Jay Shannon

Dagnachew Hallemariam
Graham Plastow
Paul Stothard



2023 International Dairy Federation Innovation in Climate Action Award awarded to Lactanet and Semex



2023 University of Guelph Innovation of the Year Award awarded to team

