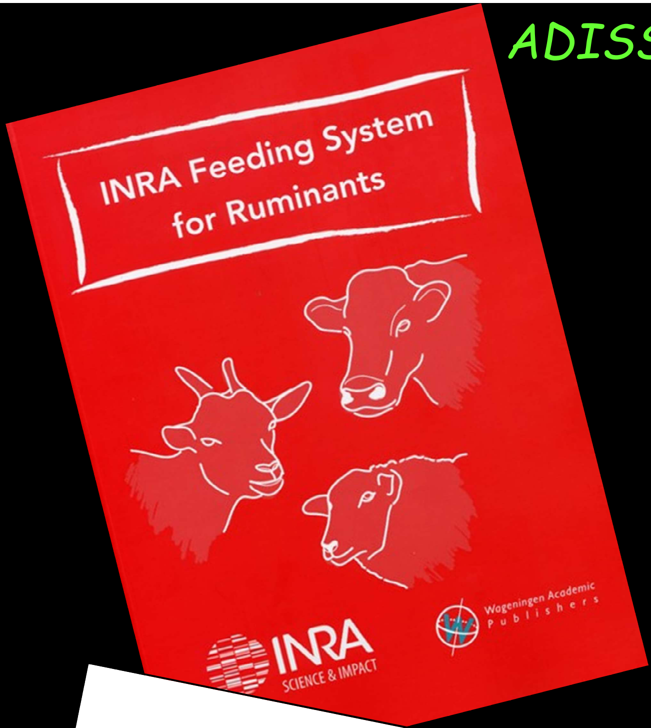
ADISSEO Ruminant Meeting Nov. 14th 2019



INRA 2018 Feeding System for Ruminants: *Major Novelties*

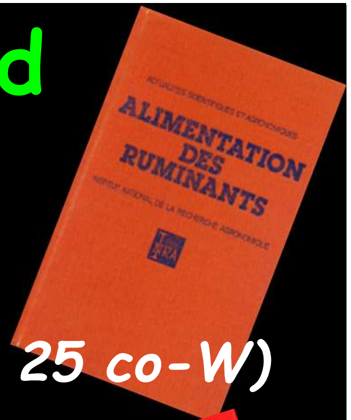
D.Sauvant & P.Nozière

INRA –AgroParisTech

(Chapters 2,3, 4, 6, 7, 13, 14 et 15)

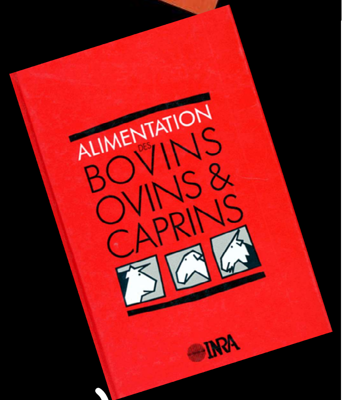
Collaboration with: R.Baumont, V.Berthelot, L.Delaby, G.Cantalapiedra-Hijar, P.Chapoutot, P.Faverdin, S.Lemosquet, I.Ortigues-Marty, JL.Peyraud, P.Schmidely

Modern story of Ruminant Feed Unit Systems in France:



1978: « Alimentation des Ruminants » *(R.Jarrige & 25 co-W)*

= new systems for Energy, MP (PDI) and Fill



1988: Updating with an english version

= LysDi and MetDi

2002: Multispecies tables (French, English, Spanish, Chineese)

2007: last updating before 2018

= responses, dynamic aspects, INRATION…

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Ultimate targets of "systali" ?

- More precise prediction of supplies of major units *(Net Energy=UFL & UFV, Metab.Proteins=PDI, AADI, Ca, P)*

- Prediction of the flows of absorbable nutrients *(VFA + Gaz + Glucose + Fatty acids + AA…)*

- More precise prediction of requirements and multiple responses to UFL, PDI and other nutrients

- Enlarge the fields of applications *(warm countries, intensive diets…)*

The Systali team at work…

→17 major novelties of the INRA 2018 feeding system

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Novelty n°1: Data creation and statistical treatments

1. Building of almost 20 experimental databases

2. Specific encoding of experiments and factors

3. Statistical treatments by Meta-analyses to split intra- and inter-experiments variances

→ More than 500 intra-exp. regressions

Novelty n°2: modelling of transit of particles and liquids

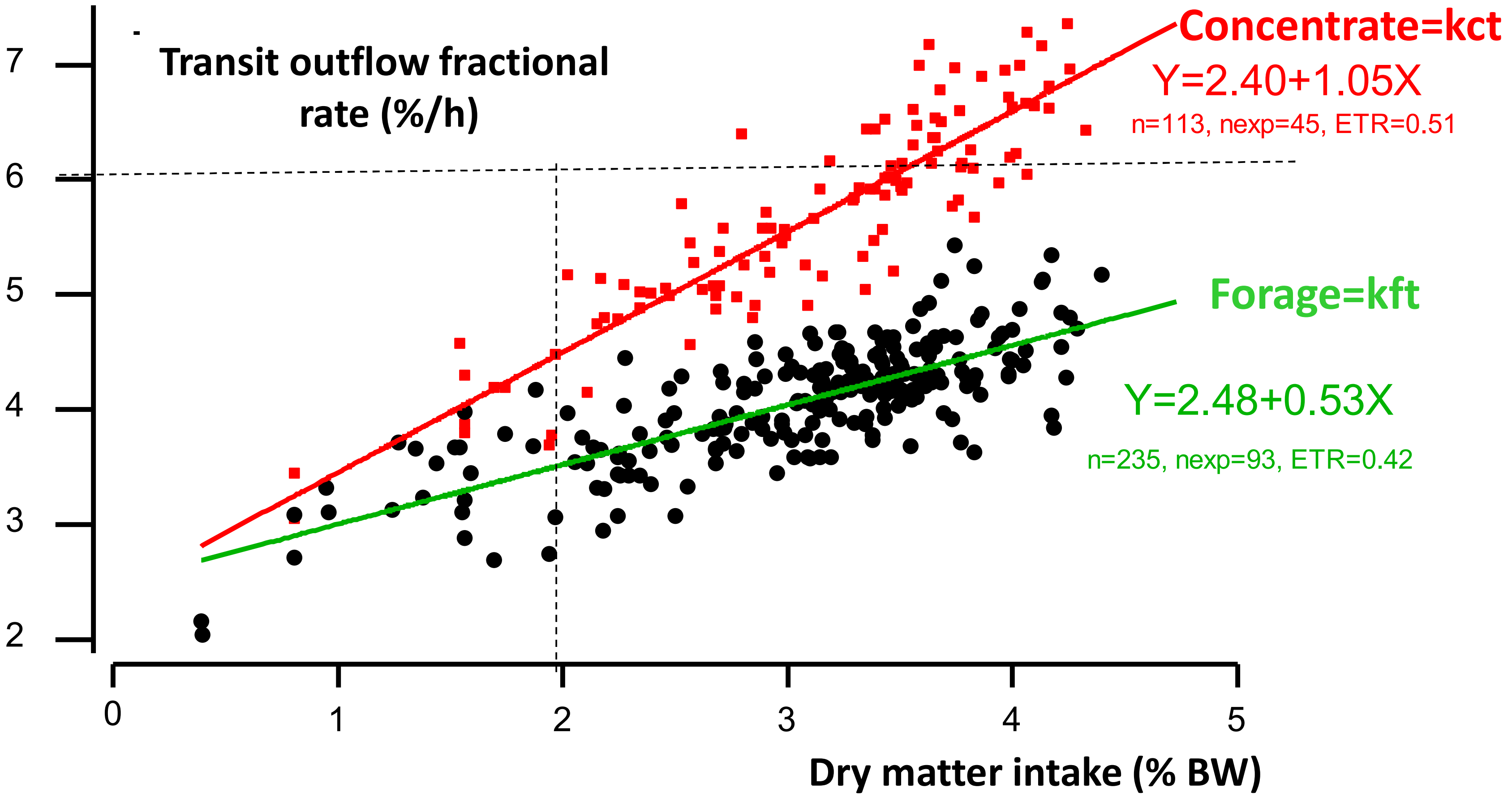
INRA 2007 = constant = kp = 6%/h

No liquid

INRA 2018 → Variable according to:

- **Constituent:** *forage, concentrate, liquid*
- **Factors:** *DMI%BW and PCO*

Influences of intake and type of feed particle on transit



And…negative influence of PCO on kct, kft & klt

→Feed nutritive values of tables are from now indicative
(no more constant)

Novelty n°3: Effective degradation of subtrates in the rumen from in sacco kinetic and transit

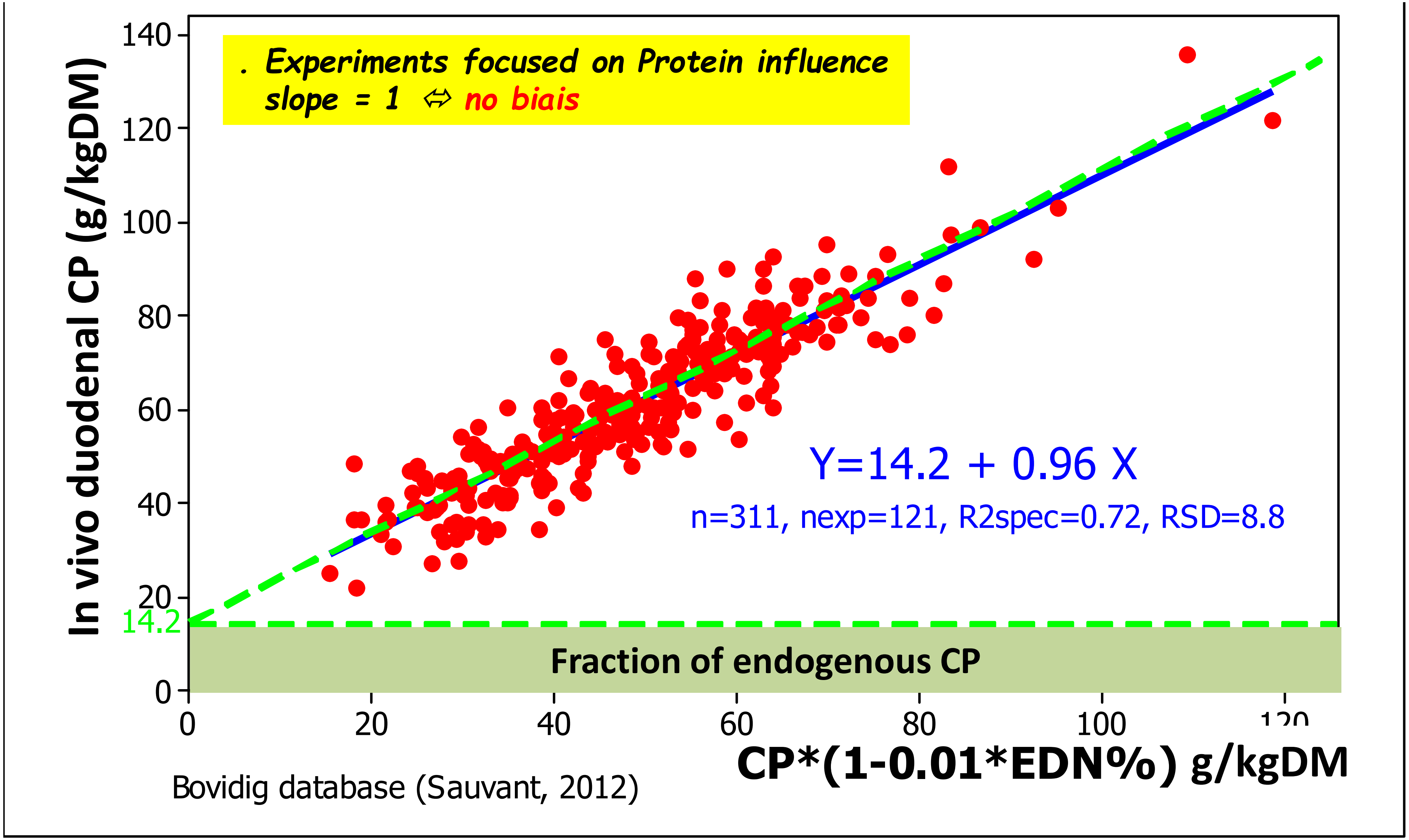
ED = DT = a (100/(100+klt)) + b (kd/(kd+kpt))

a, b, kd ⇔ in situ kinetics (in tables)

klt, kft, kct, kpt = f(DMI%BW, PCO)

→Prediction of duodenal flows from in situ data ? *(Proteins, starch)*

Intra-experiment prediction of duodenal CP flow from in sacco data



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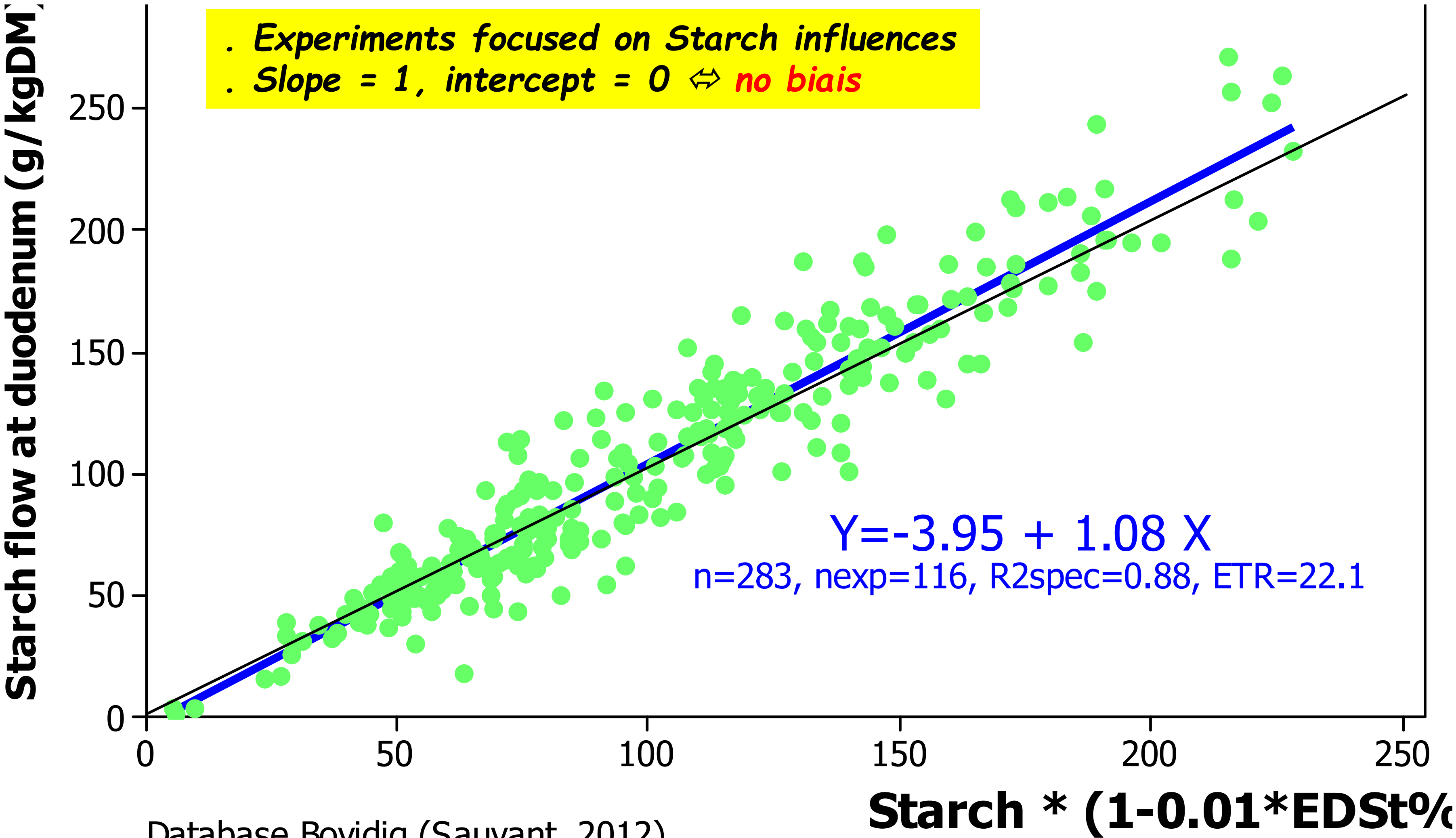
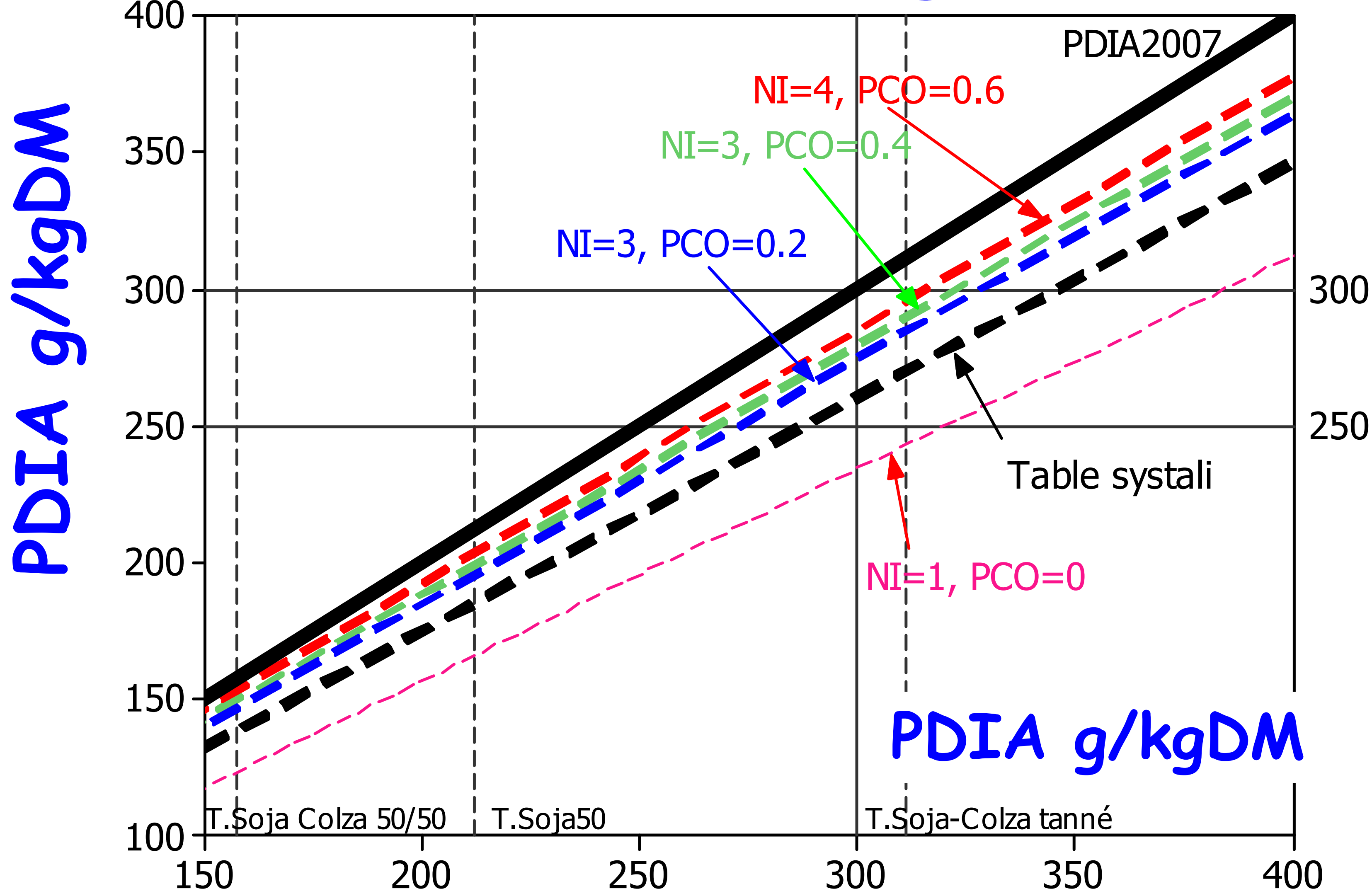
Intra-experiment prediction of duodenal starch flow from in sacco data



Database Bovidig (Sauvant, 2012)

Variations of by-pass MP (PDIA) of feed rich in Protein according to the diet



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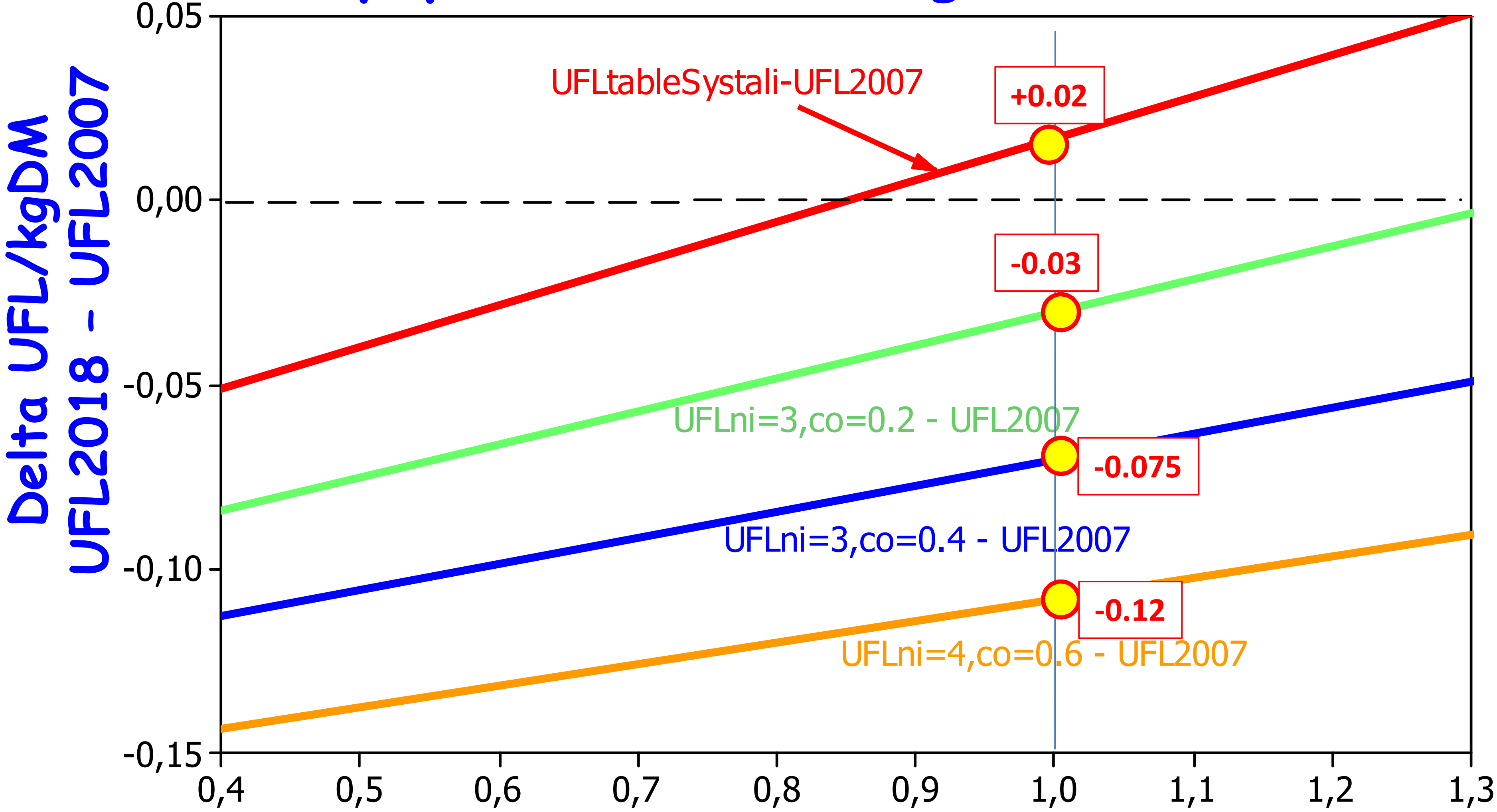
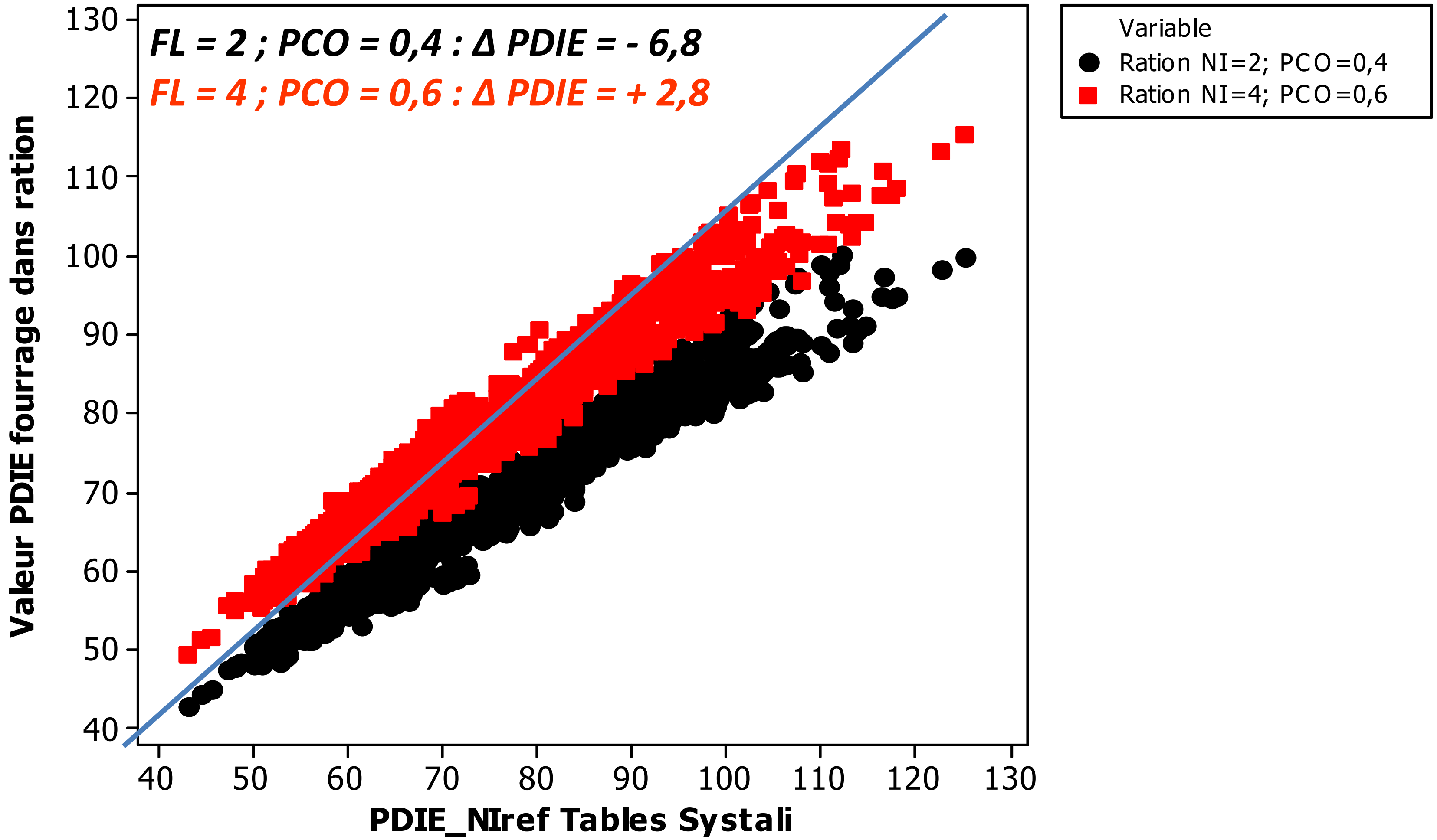
Variations of energy values (UFL/DM) of concentrate and by-products according to the diet.



1 UFL = 1.76 Mcal Milk Net Energy

PDI values of forage in rations

For FL=2 PCO=0,4 and FL=4 PCO=0,6



R.Baumont & al., 2013

*Novelty n°4: nutrition of microbes & protein-energy balance in the rumen

"Rumen Protein balance" (RPB)

= CP intake – CP at duodenum

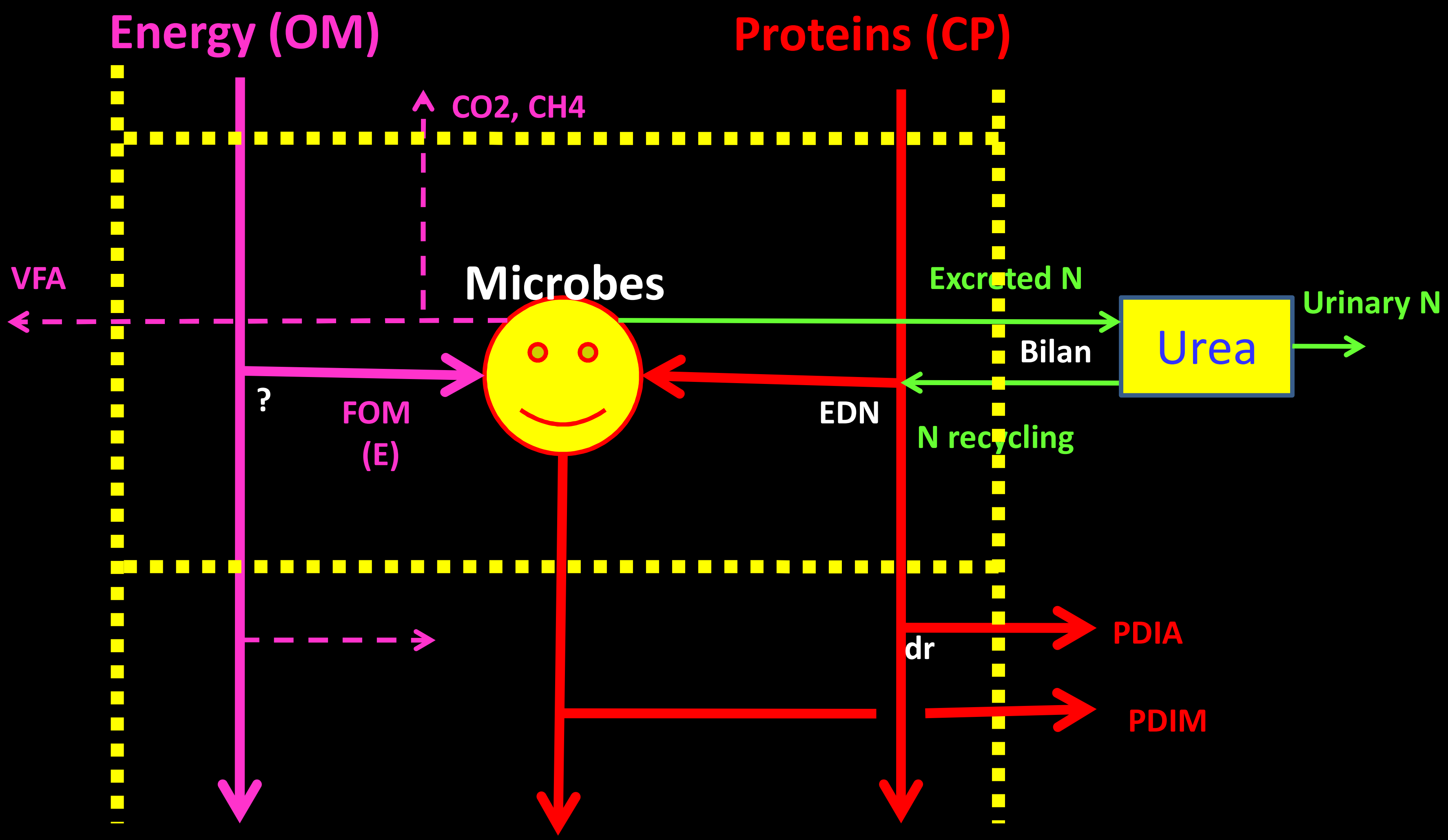
(Additive and frequently measured)

⇔Balance of NH_3⇔urea transferts

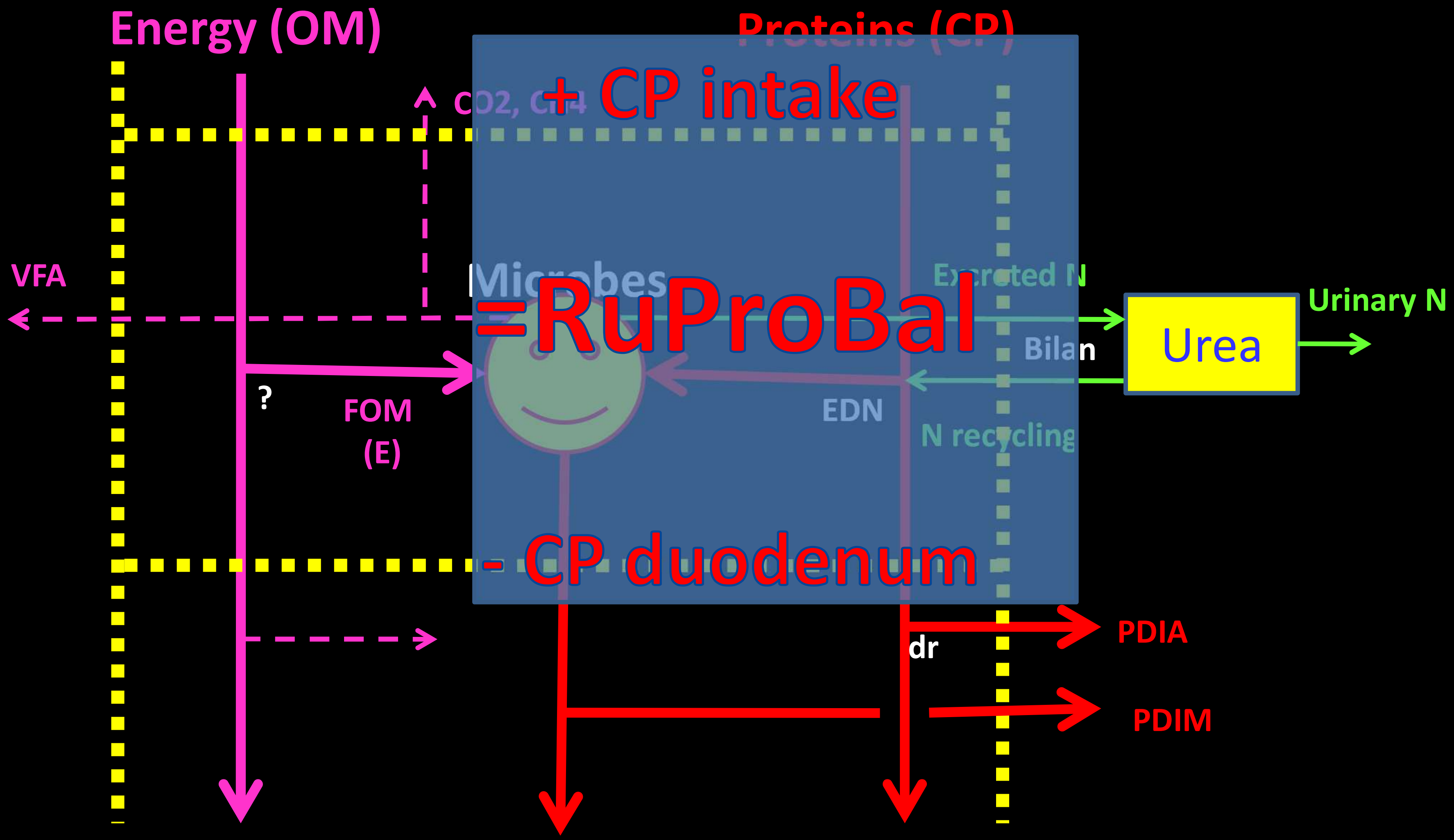
Models of impacts of RPB on:

- *Digestive protein efficiency*
- *Urinary N excretion → global N efficiency*
- *Digestive interactions*
- *Microbial synthesis*

Summary of digestion in the rumen



Rumen Protein balance (RPB)



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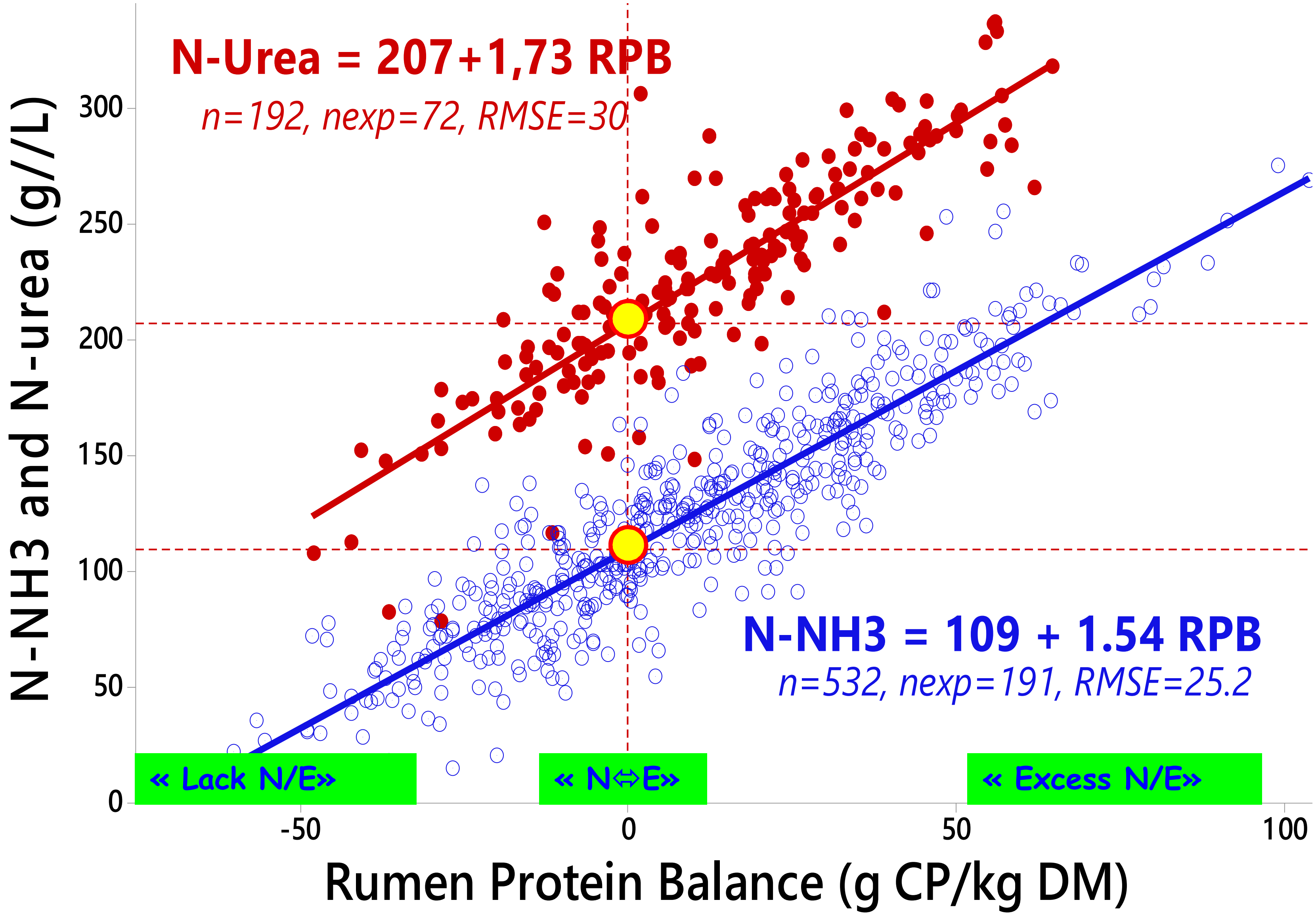
Impacts of RPB on rumen NH_3 & urea of body fluids



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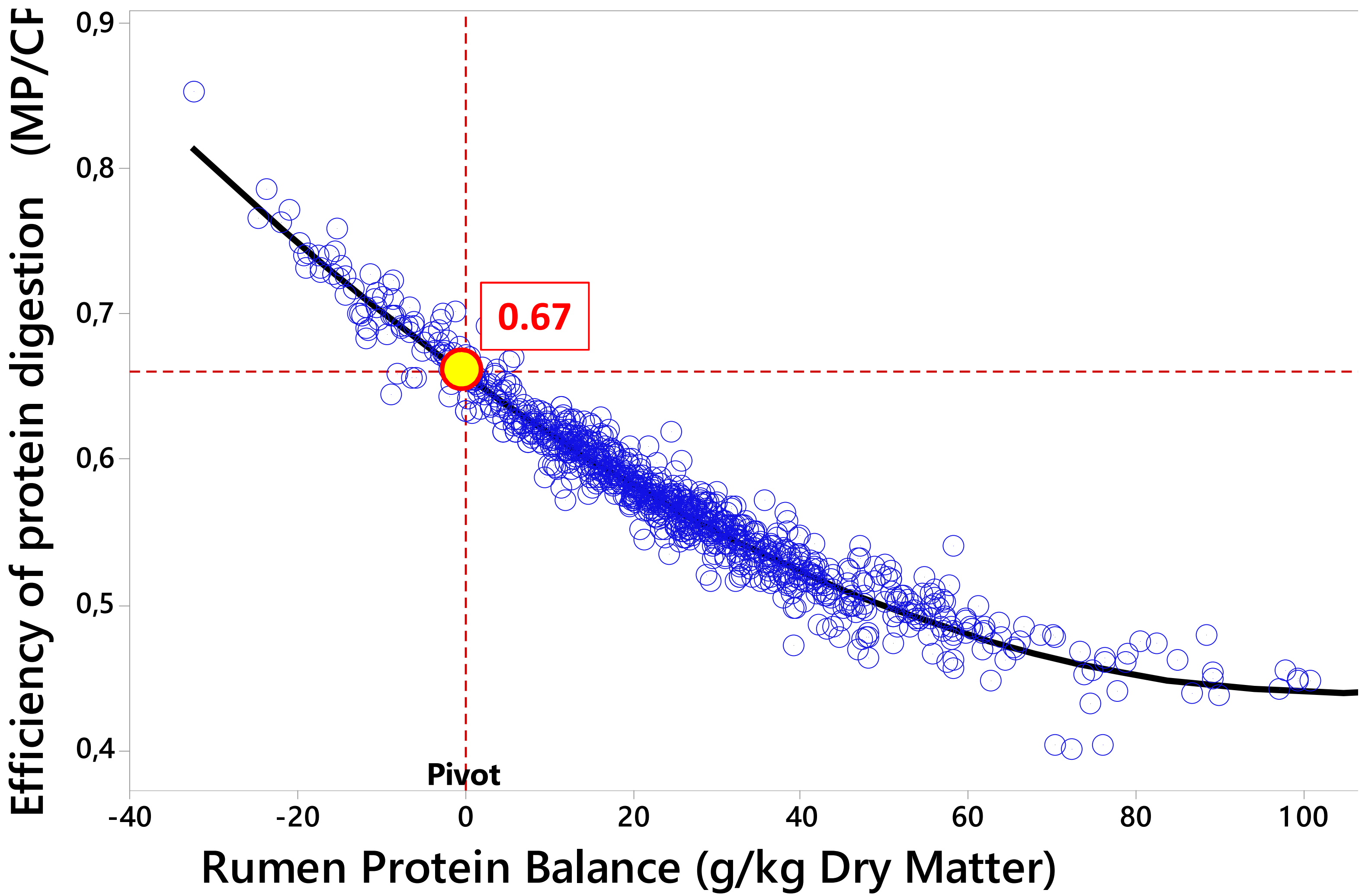
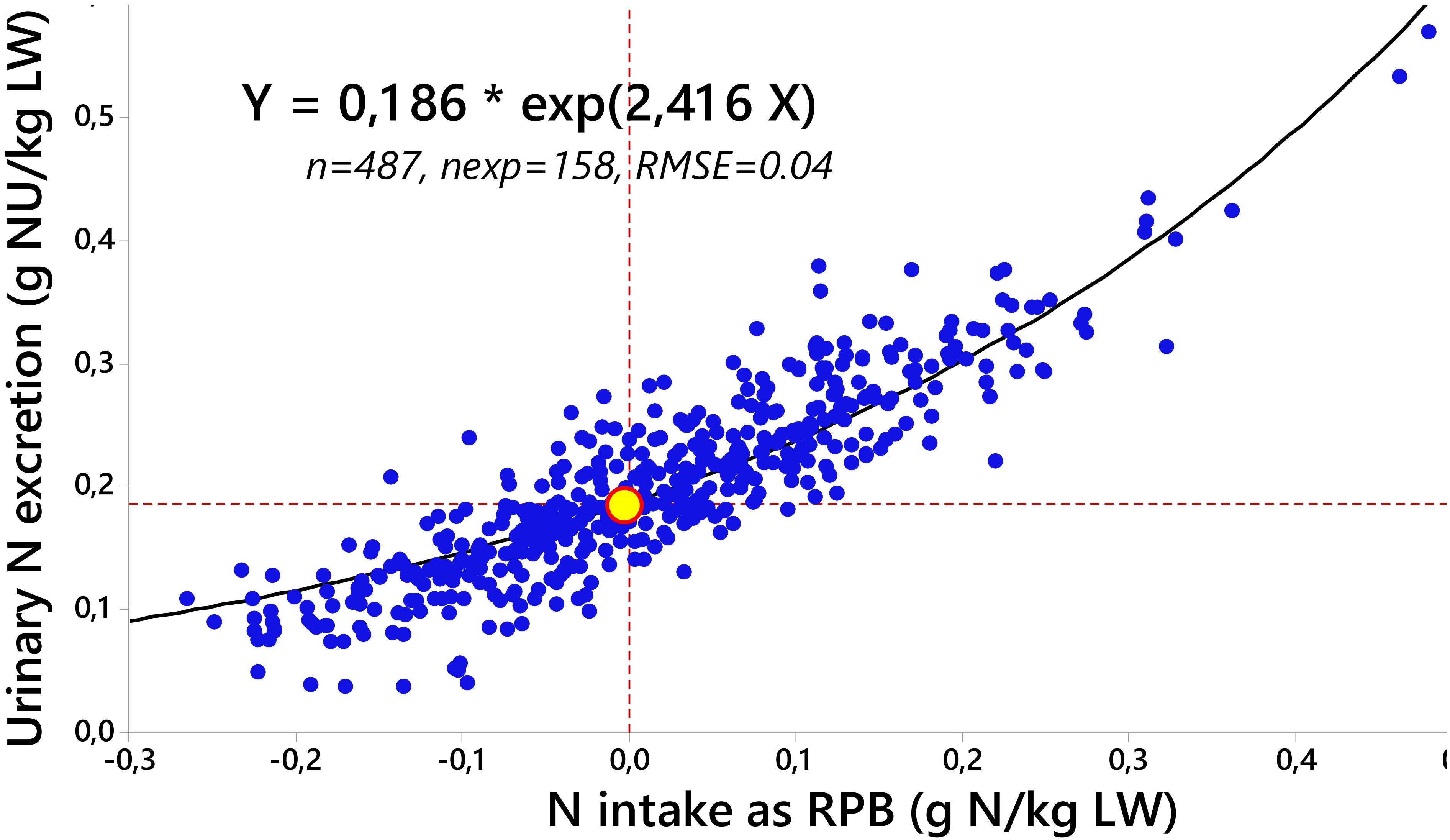
Response of efficiency of Protein digestion (MP/CP) to RPB



= Consequence of the loss of N at the rumen level

Intra-experiment impact of RPB on urinary N excretion.



➔ **RPB used as a major predictor of urinary N with PDI efficiency**

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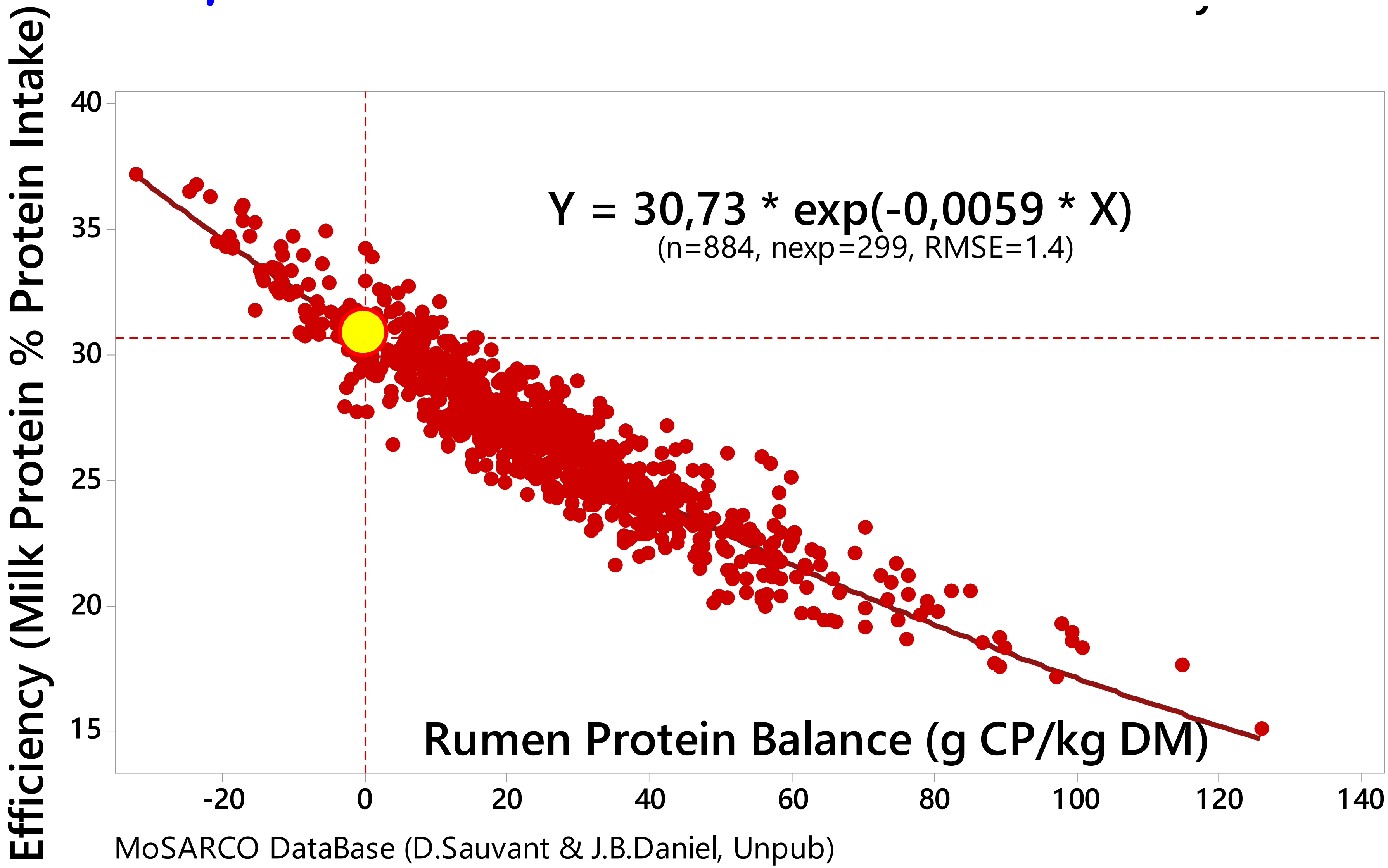
Intra-experiment response of protein efficiency of dairy cows to variations of Rumen Protein Balance



MoSARCO DataBase (D.Sauvant & J.B.Daniel, Unpub)

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*Novelty n°5: Digestive interactions (I)

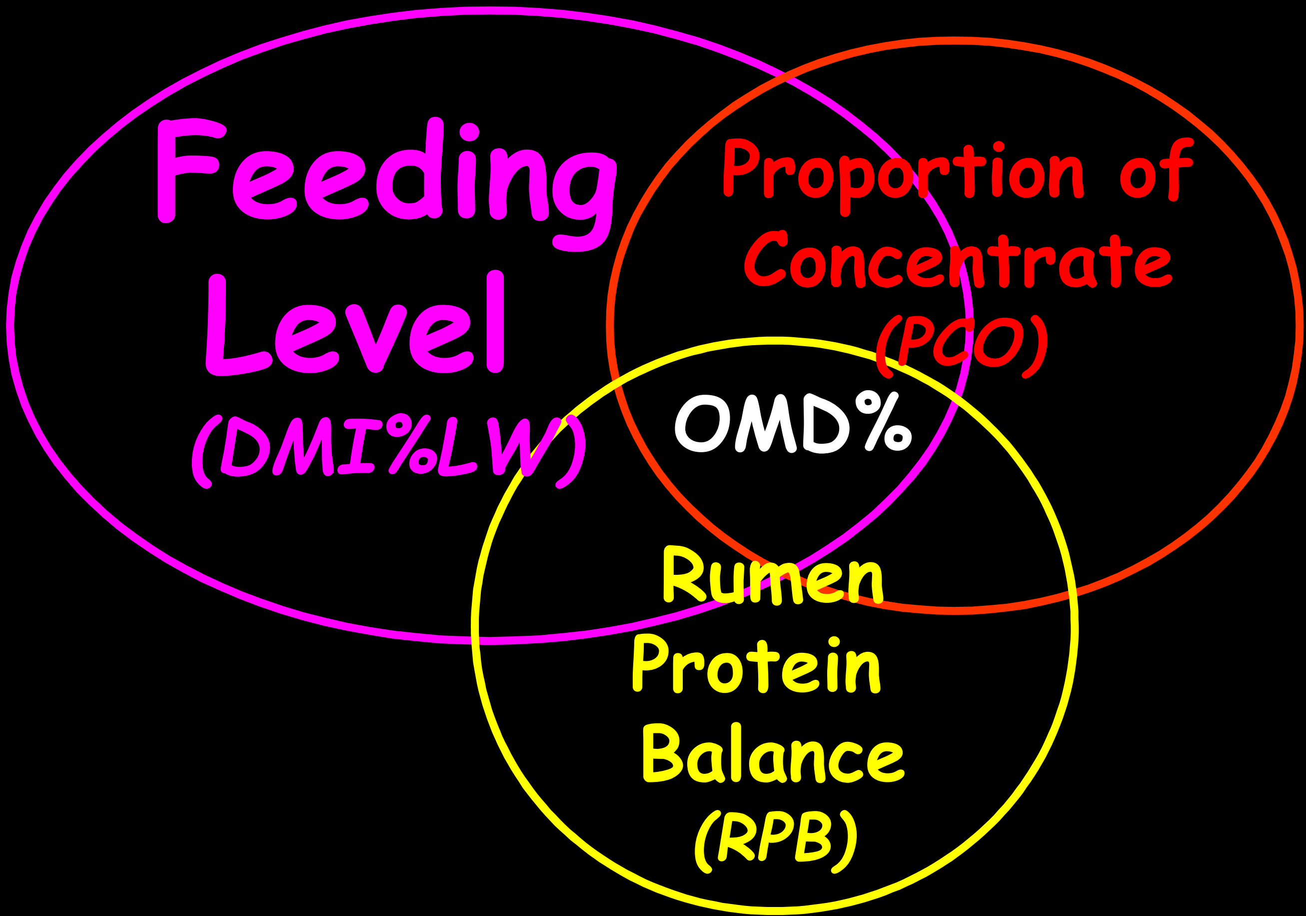
$$VALUEdiet = \Sigma_i\ p_i\ TABLE\_VALUEfeed_i \pm I$$

Modelling I ?

-Impacted item = OMD%

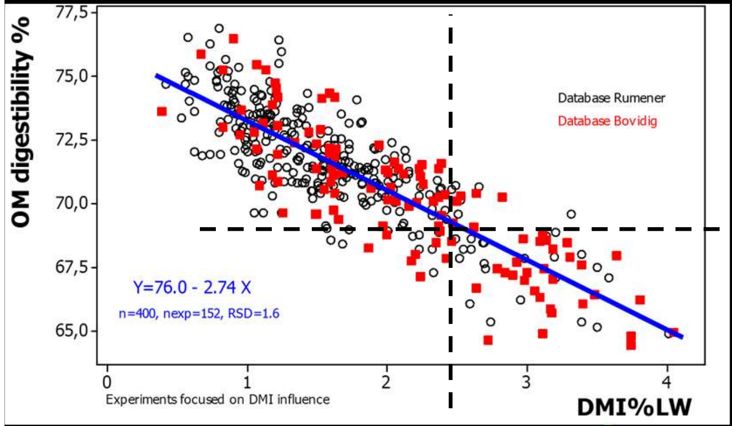
-Causes → Predictors ?

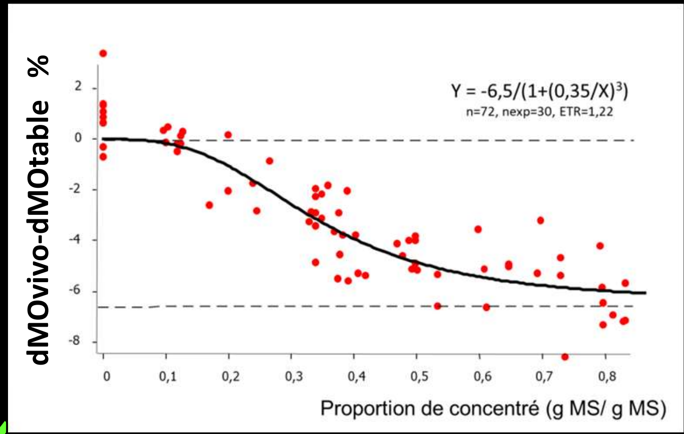
Major causes of digestive interactions altering OM Digestibility ?



➔ 3 different data bases focused on these 3 factors
➔ Check of the additivity of the effects

Modelling digestive interactions

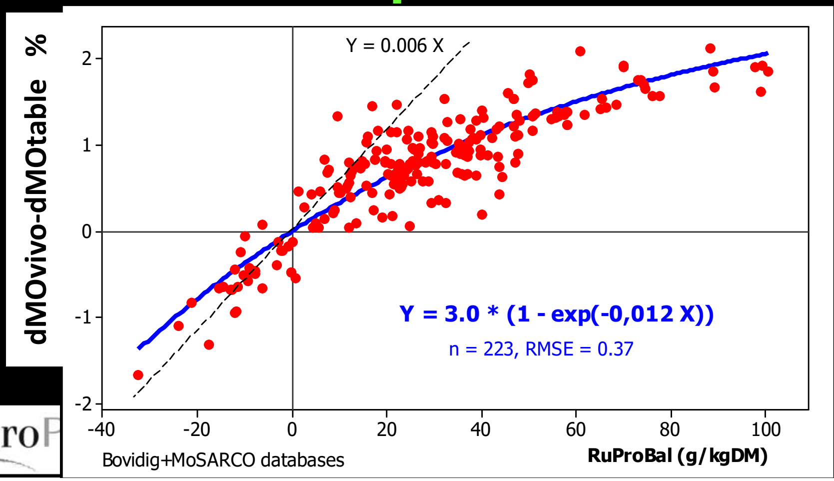




Feeding level (DMI%BW)

Proportion of concentrate (PCO)

OMd « table » vs OMd measured



Rumen Protein Balance (RPB)

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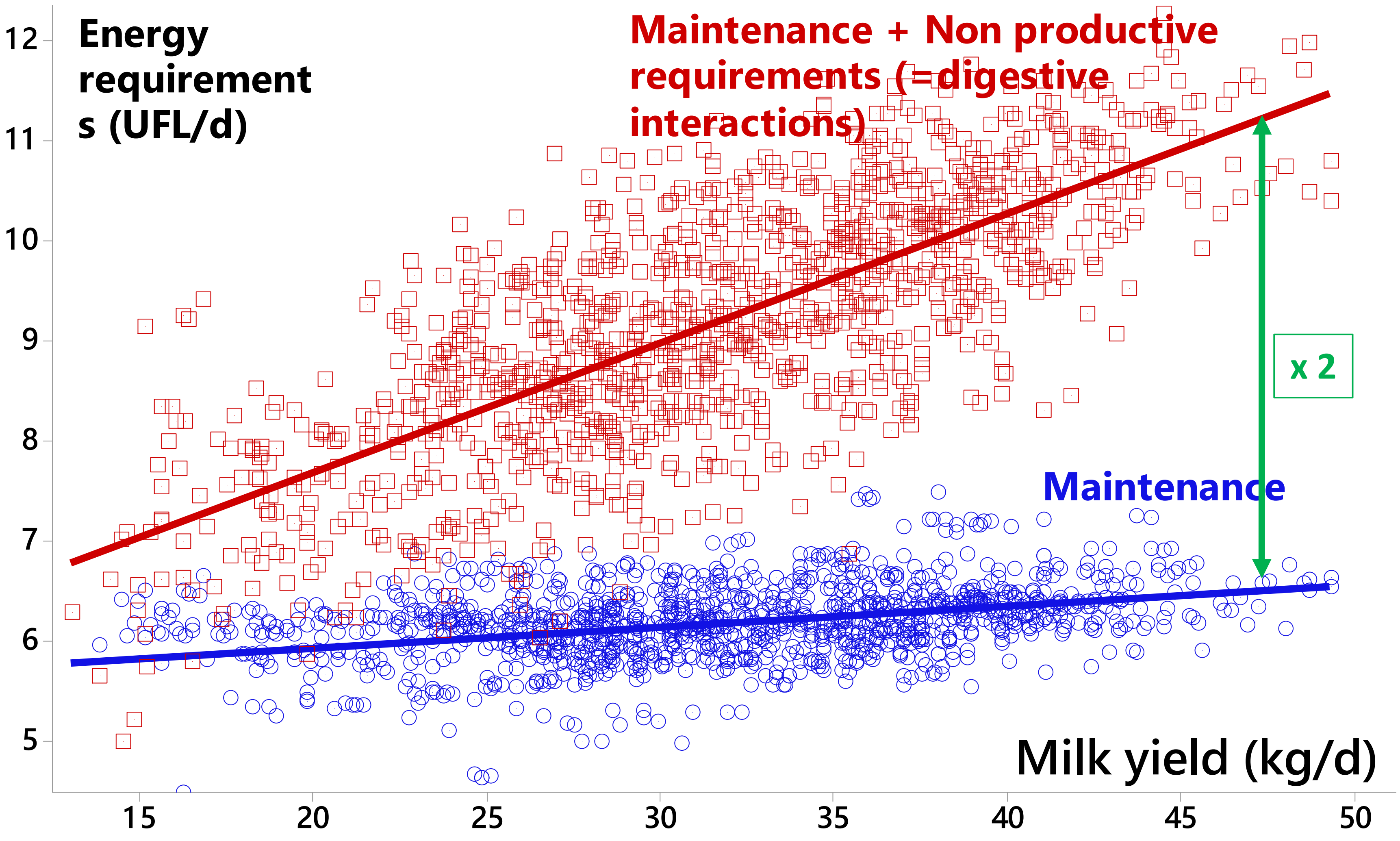
Digestive interactions et non productive requirements of energy:
example of dairy cows



MoSARCO DataBase (D.Sauvant & J.B.Daniel, unpub)

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Novelty n°6: Energy of CH4 and Urine used to calculate ME fron DE

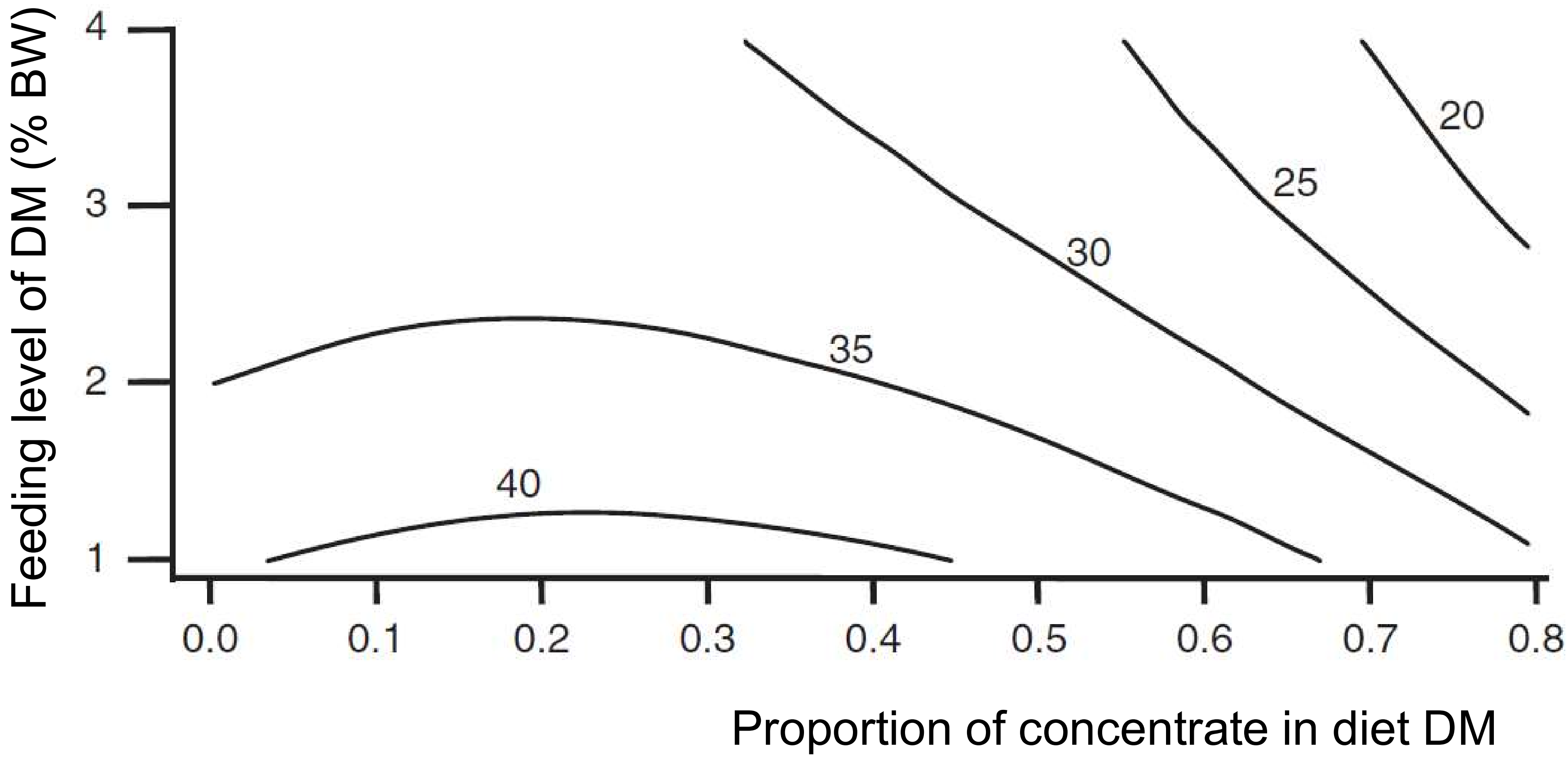
$ME = DE - ECH4 - UE$

$ECH4/DOM = 45.42 - 6.66\ FL + 0.75\ FL^2 + 19.65\ PCO - 35\ PCO^2 - 2.69\ FL*PCO$

$ECH4 = 12.5 * DOM * CH4/DOM$

$UE = 2.9 + 0.017\ CP - 0.47\ FL - 1.64\ PCO$

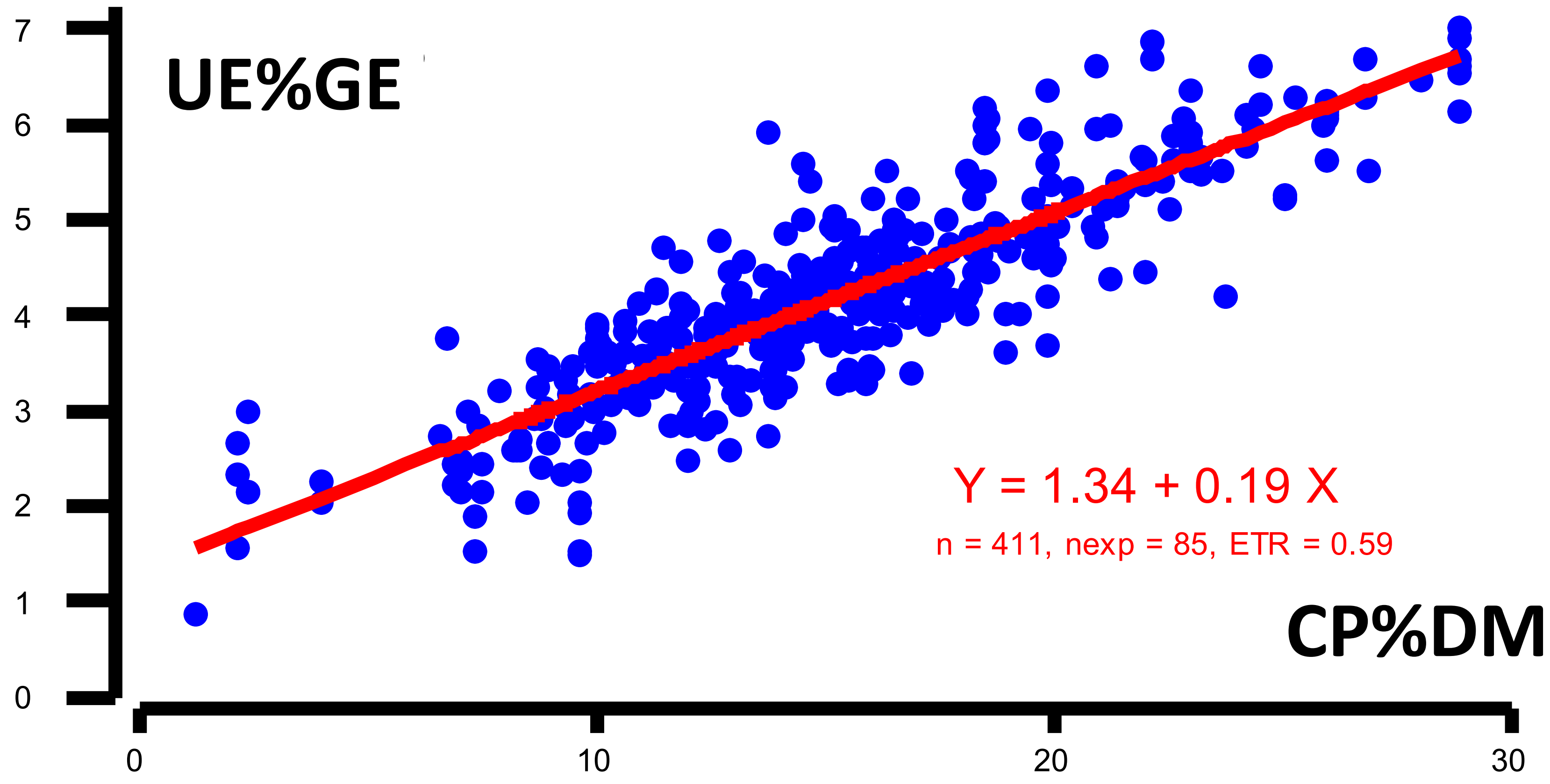
Response of the ratio CH4/DOM to feeding level and proportion of concentrate



ECH4/DOM = 45.42 – 6.66 FL + 0.75 FL² + 19.65 PCO – 35 PCO² - 2.69 FL*PCO

→ECH4 = 12.5 * DOM * CH4/DOM

Response of UE%GE to dietary CP and to factors of digestive interaction



UE%GE = 2.9 + 0.17 CP%MS – 0.47 FL – 1.64 PCO

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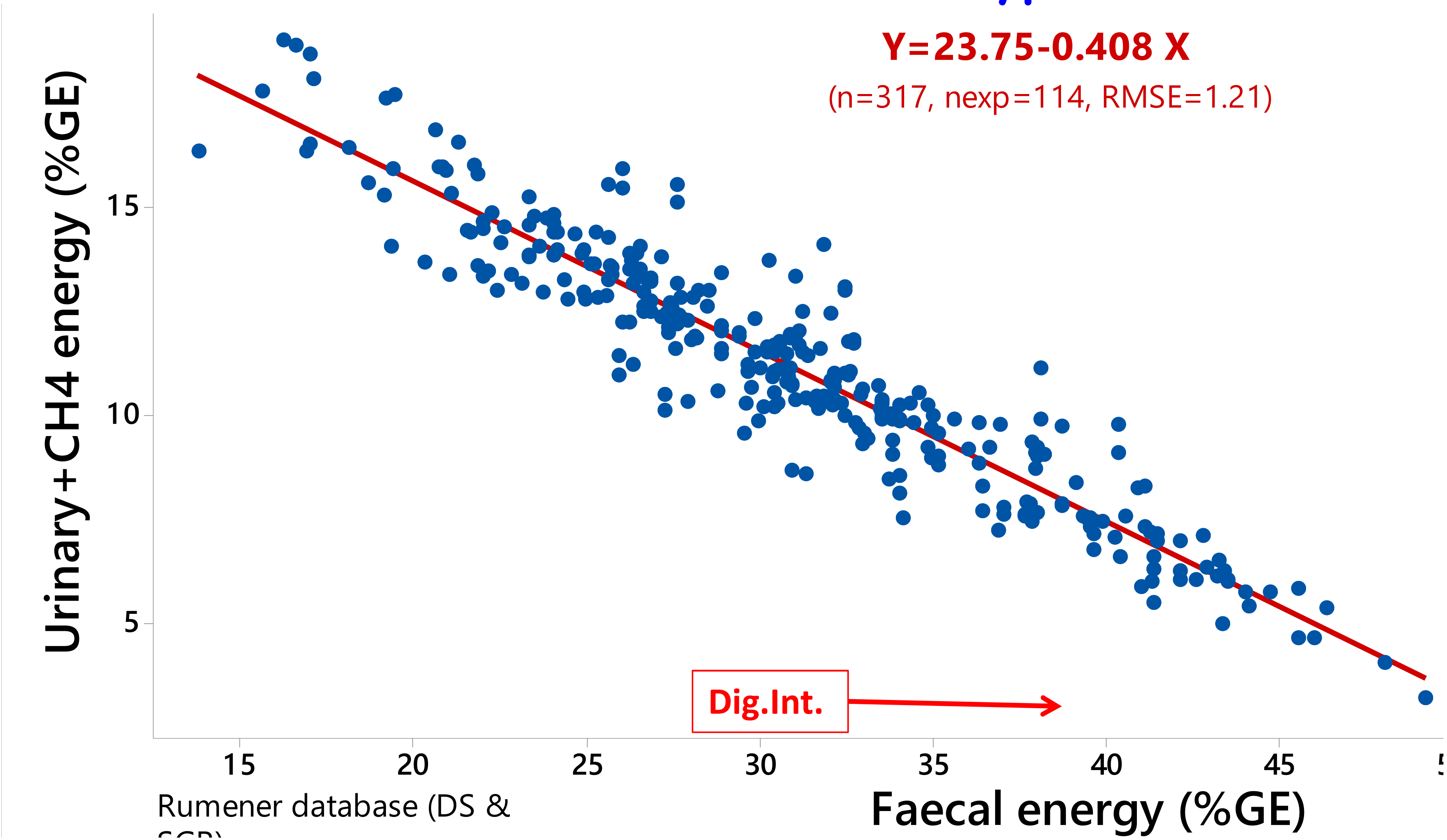
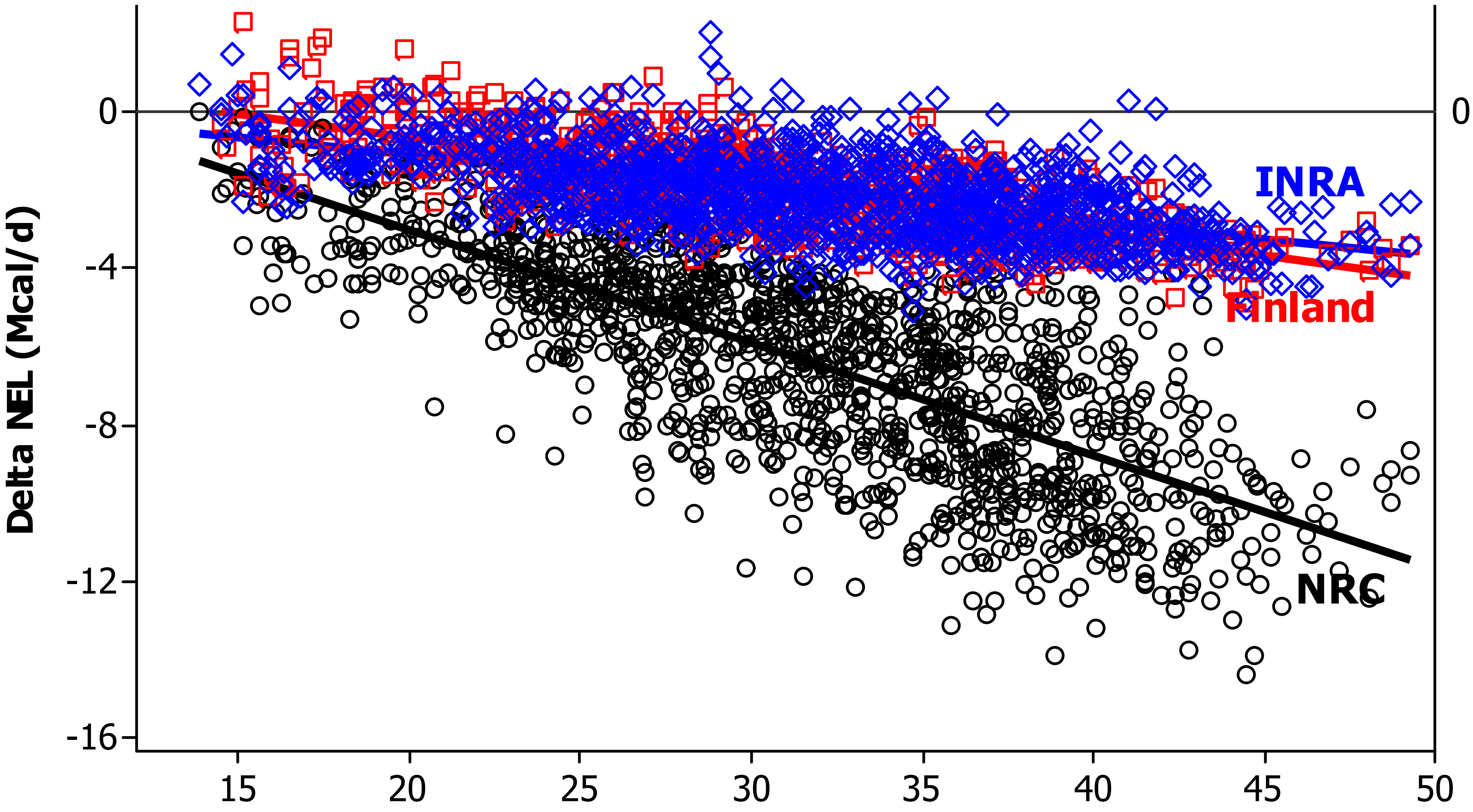
Compensation between Fecal and CH4+Urine energy losses under influence of Feeding Level in calorimetric studies with various types of ruminants



Increase 10 pts of FE ➔ decrease of 4 pts of UE+ECH4

➔ Necessity to account this relationship to avoid to overestimate NP energy losses

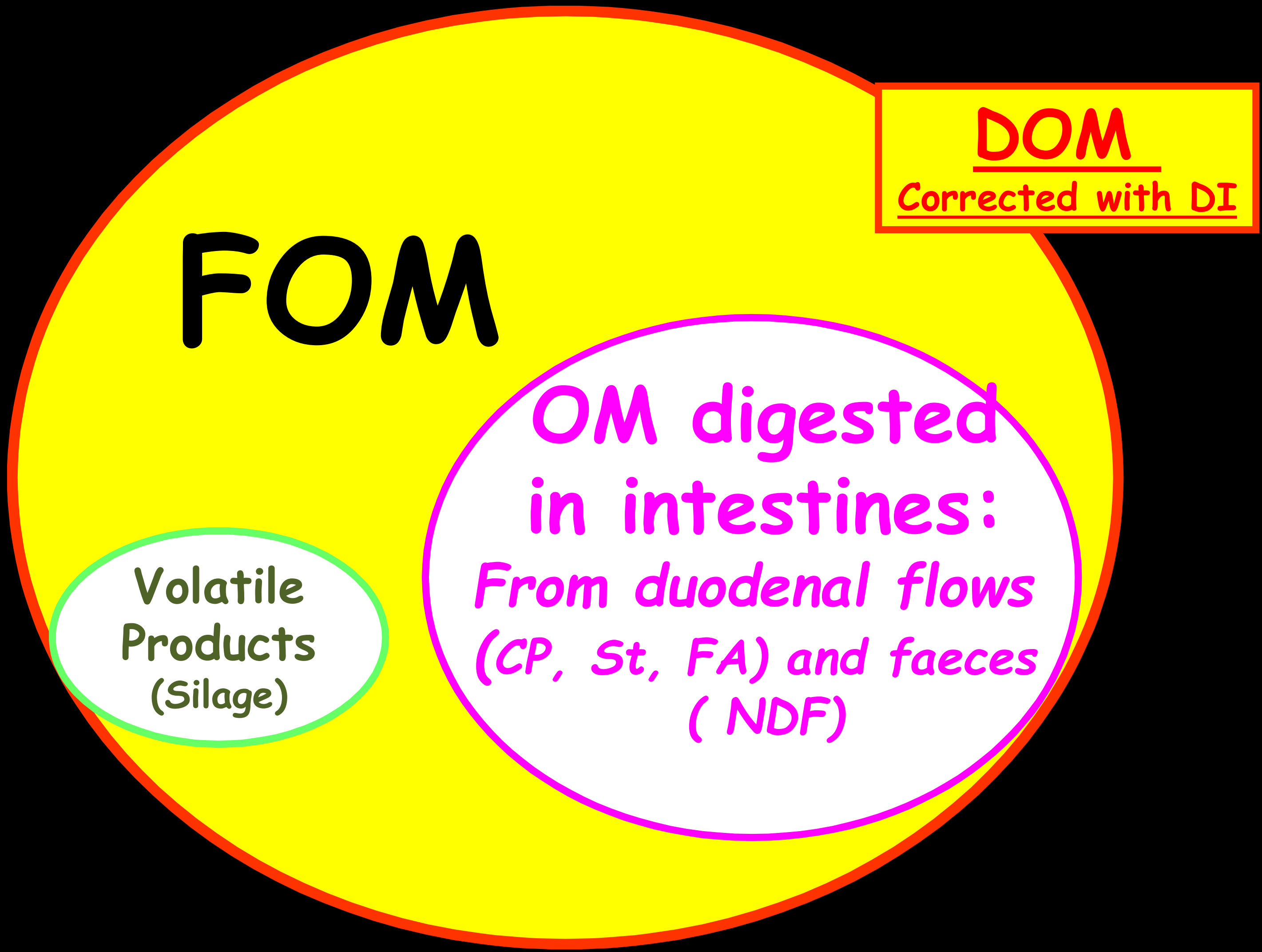
Comparison of NEL corrections (Mcal/d) in function of MY for 3 feed Unit Systems (NRC, INRA, Finland)



Calculations from MoSARCO Database

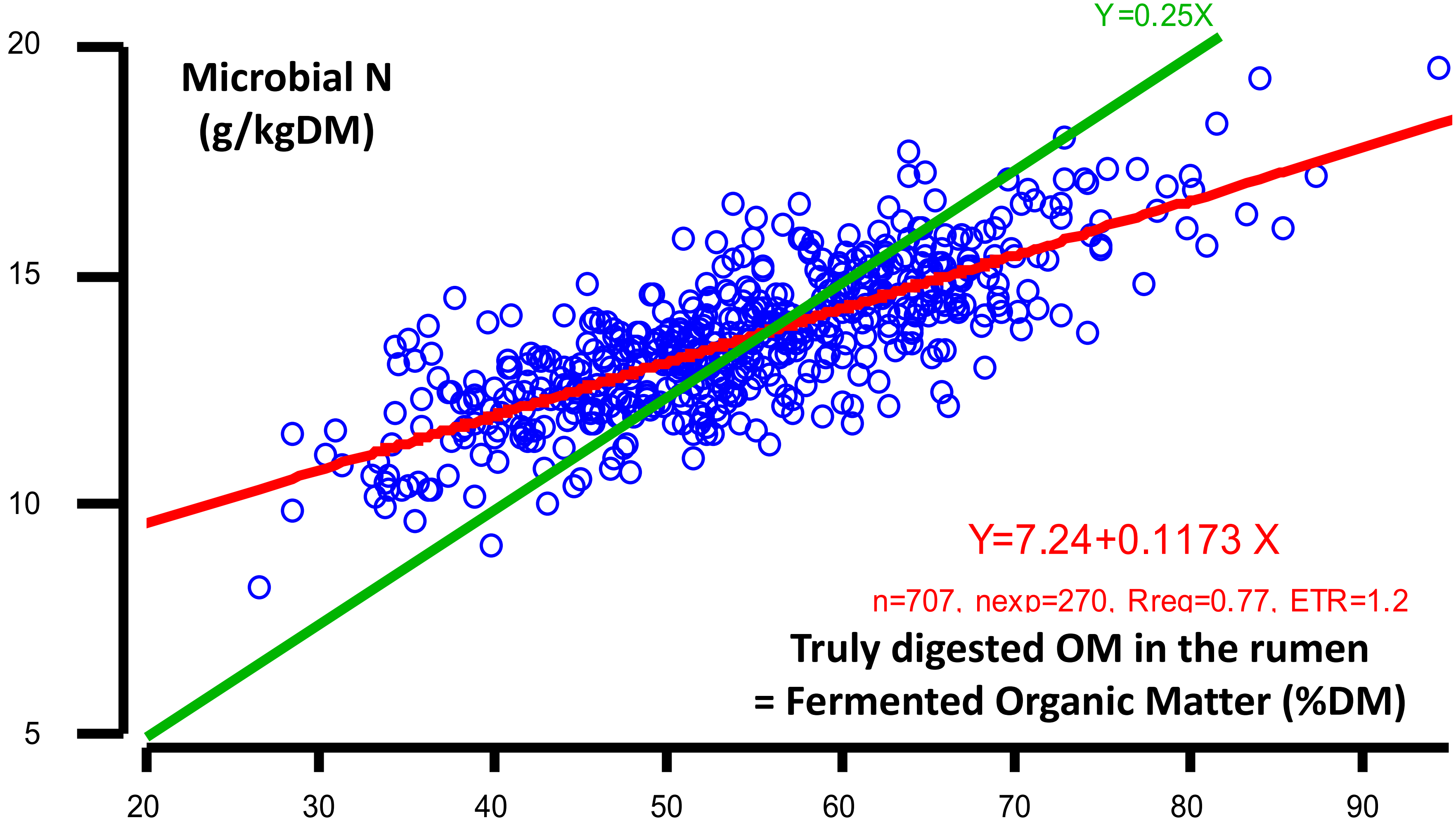
-Only INRA and Finish systems take into account compensation of Digestive Interactions
-Fixed ratio between NE/TDNc for NRC

Novelty n°7: Fermented organic matter



➔ *prediction of Microbes and VFA from FOM*

*Novelty n°8: Prediction of microbial N synthesis from FOM



« Bovidig » database (D.Sauvant, 2012)

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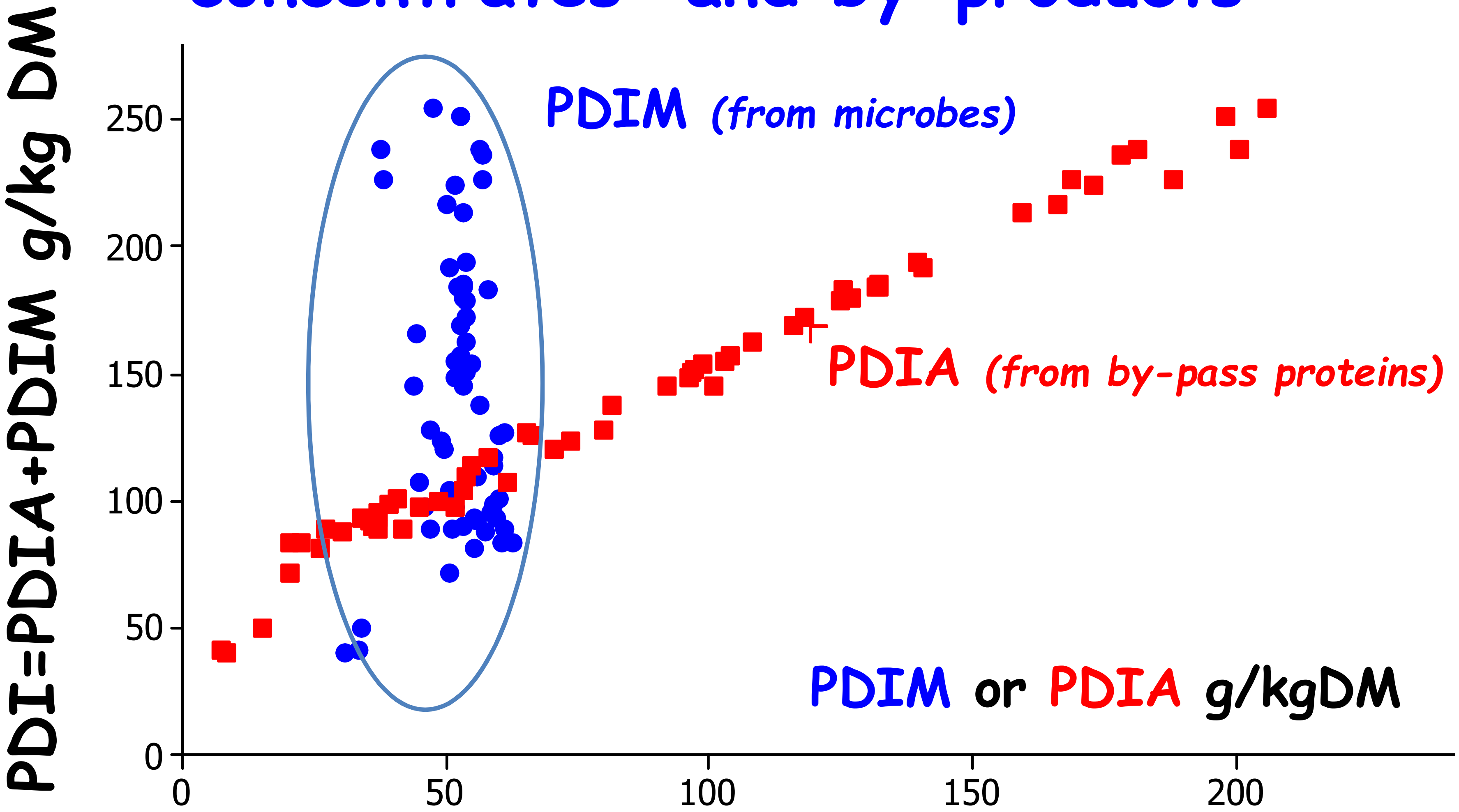
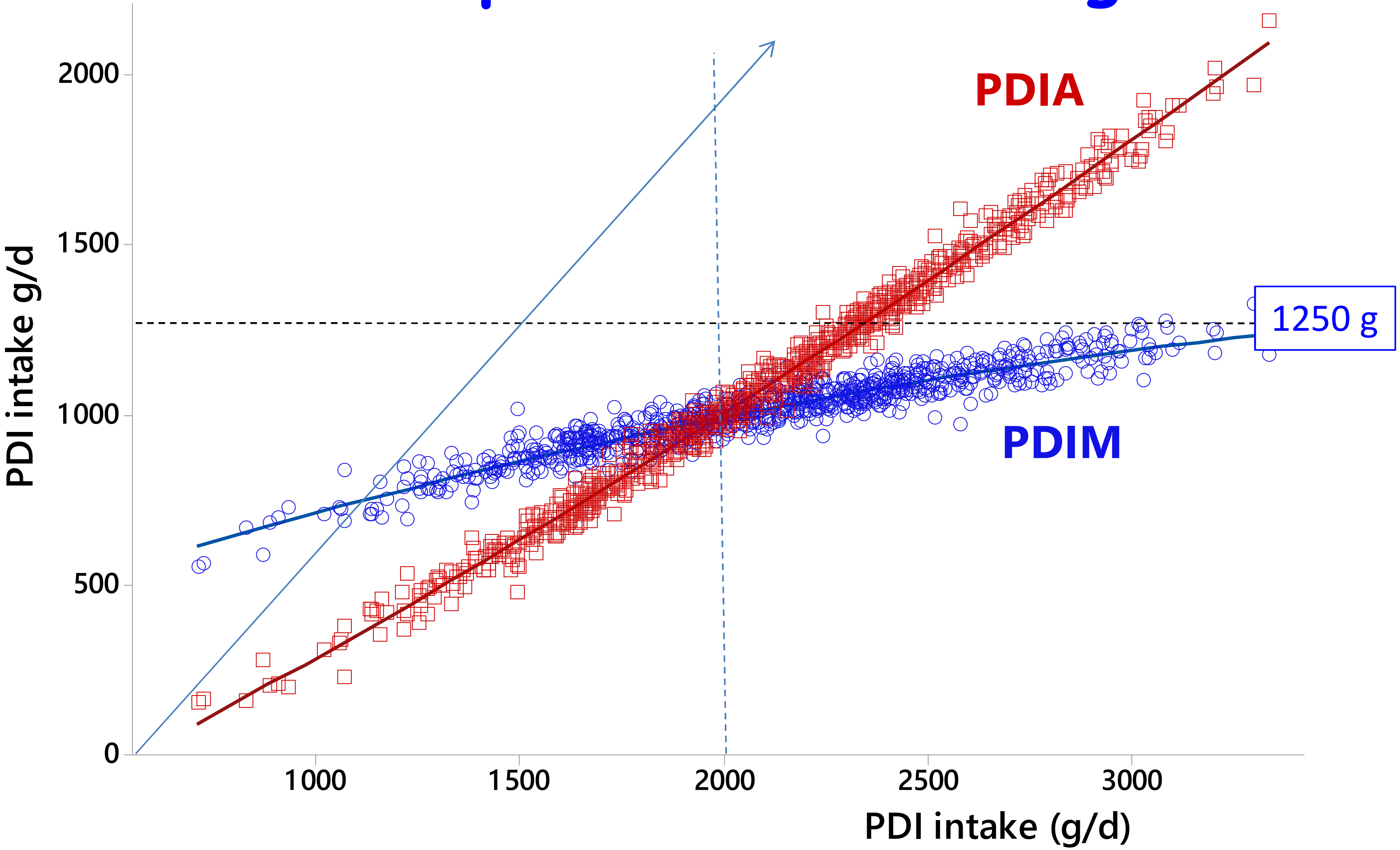
PDIA and PDIM components of PDI values of concentrates and by-products



PDI values depend essentialy from PDIA values
➔ Challenge of precision on PDIA and EDN

Trace of the limit of capacity of production of microbial protein in lactating cows



PDIA ⇔ more efficient to actually increase PDI supply

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*Novelty n°9 : Prediction of flows of absorbable nutrients

PDI

VFA = 8.3 mol/kg FOM *(Nozière et al., 2010)*

Glucose = f(Starch digested in small intestine; *Offner & Sauvant, 2004*)

Fatty acids= f(FA at duodenum x digFA; *Glasser, Schmidely…*)

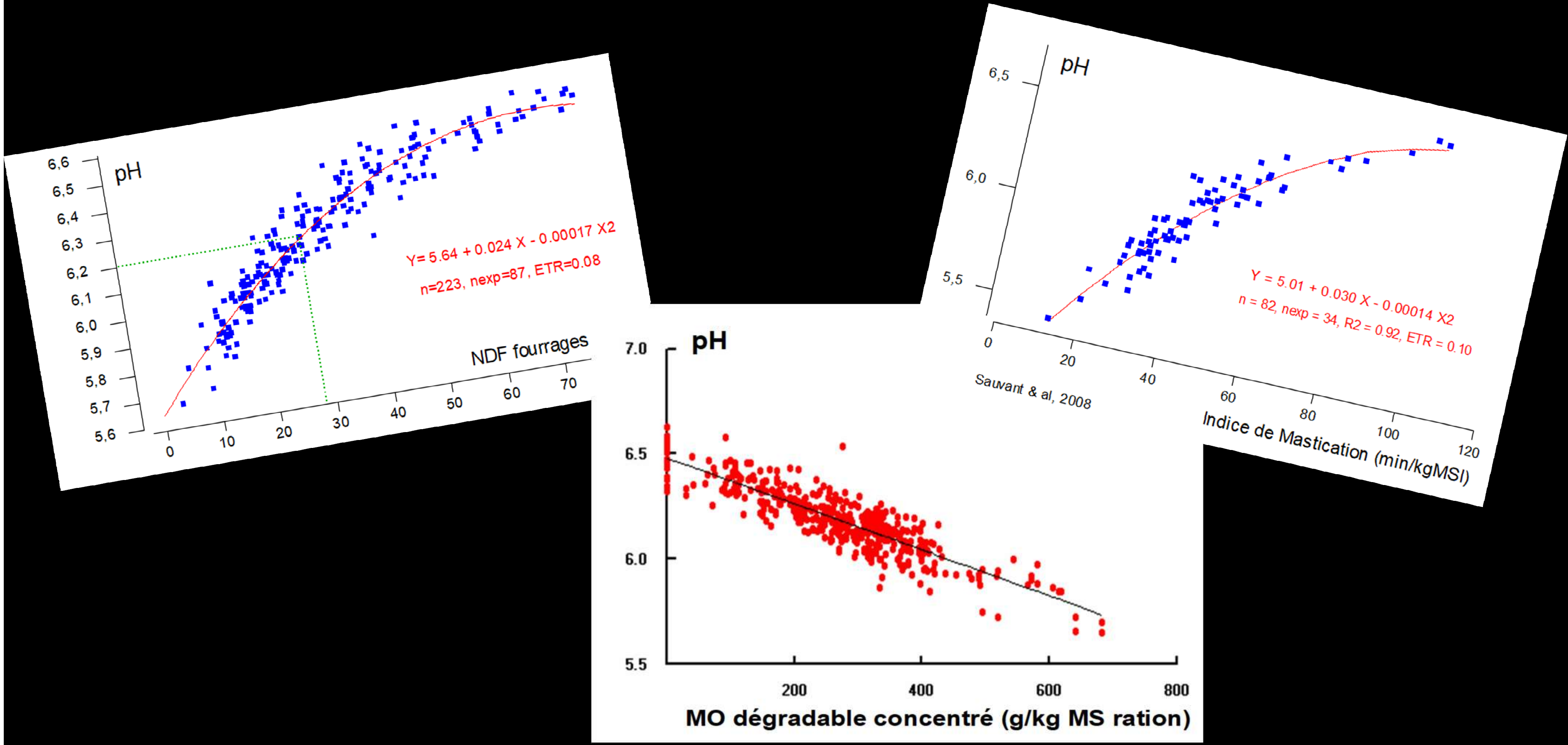
Profiles of absorbable nutrients

AADI (cf Chapter 4)

Profiles of VFA (Ac, Prop, Bu; Chapter 3)

Profiles of FA (cf chapter 3, cf Hydrog+Isom)

Novelty n°10: evaluation of the risk of rumen acidosis



Responses of rumen pH to 8 criteria of prediction

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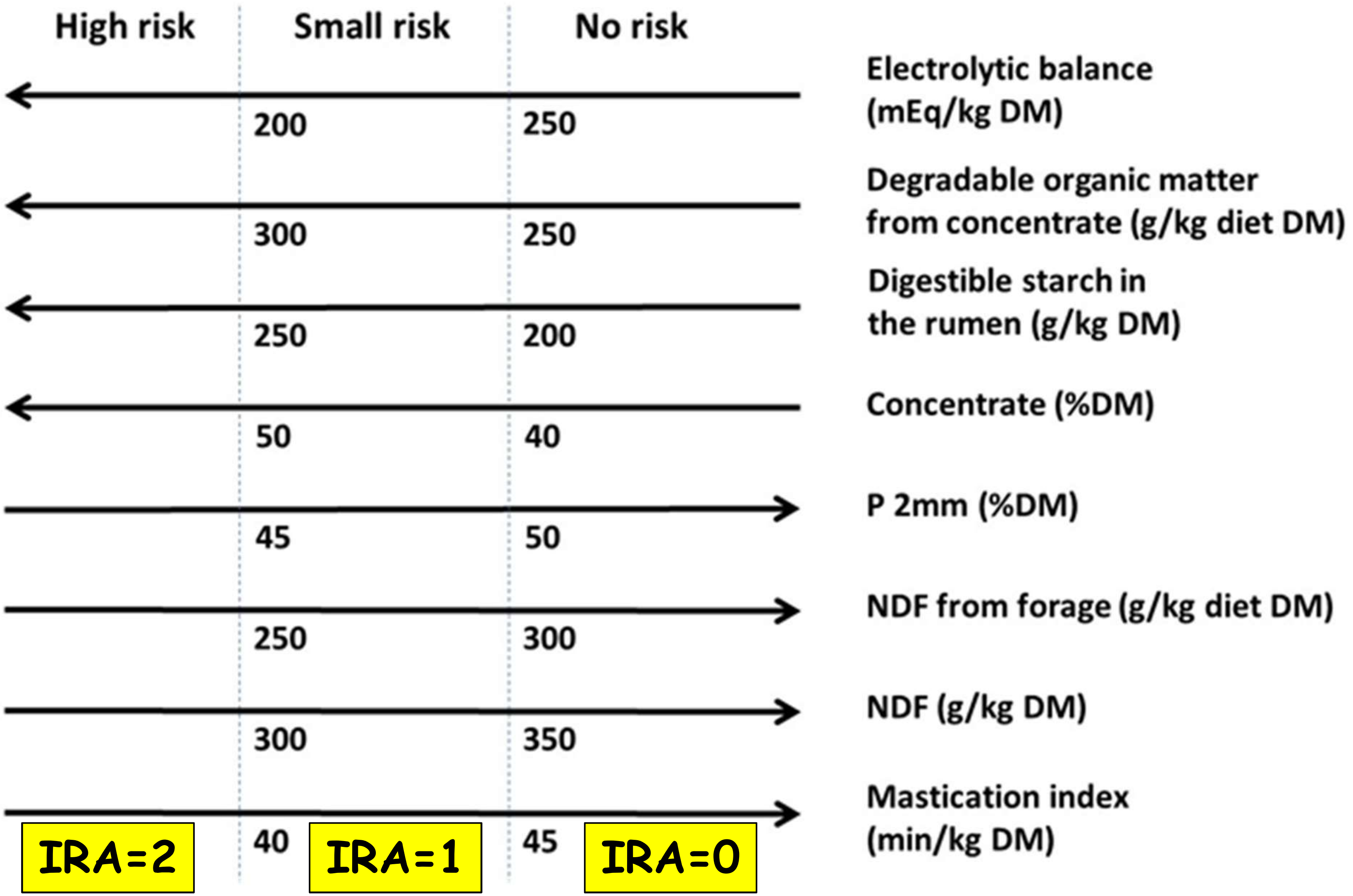
Summary of the limit values of 8 indexes of risk of acidosis (IRA) in cattle



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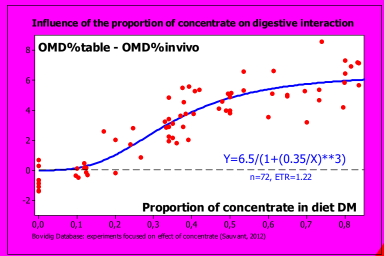
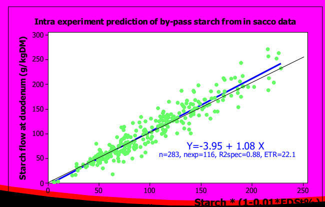
*Novelty n°11: integration of all the digestive equations



Equations to calculate UFL, PDI… (≈50)

Other equations
(Mastication, pH, Encombrement, Flux nutrients…)
(≈50)



*Novelty n°11: integration of all the digestive equations

Equations to calculate UFL, PDI… (≈50)

Other equations (Mastication, pH, Encombrement, Flux nutriments…) (≈50)

Integration into a Mechanistic model of rumen and gut

(D.Sauvant & al)

Diagram of calculations of UF and PDI supplies

(50 equations)

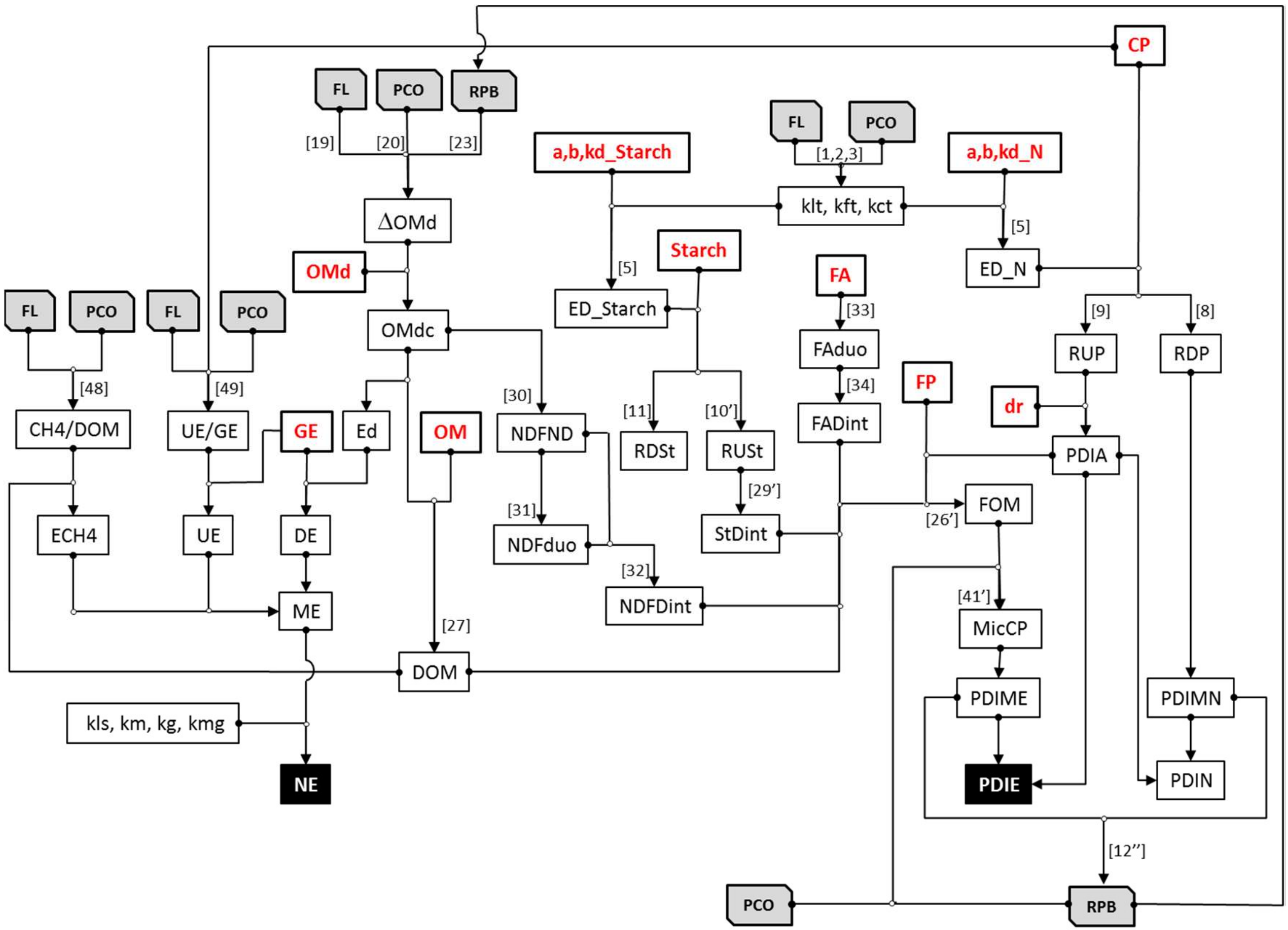


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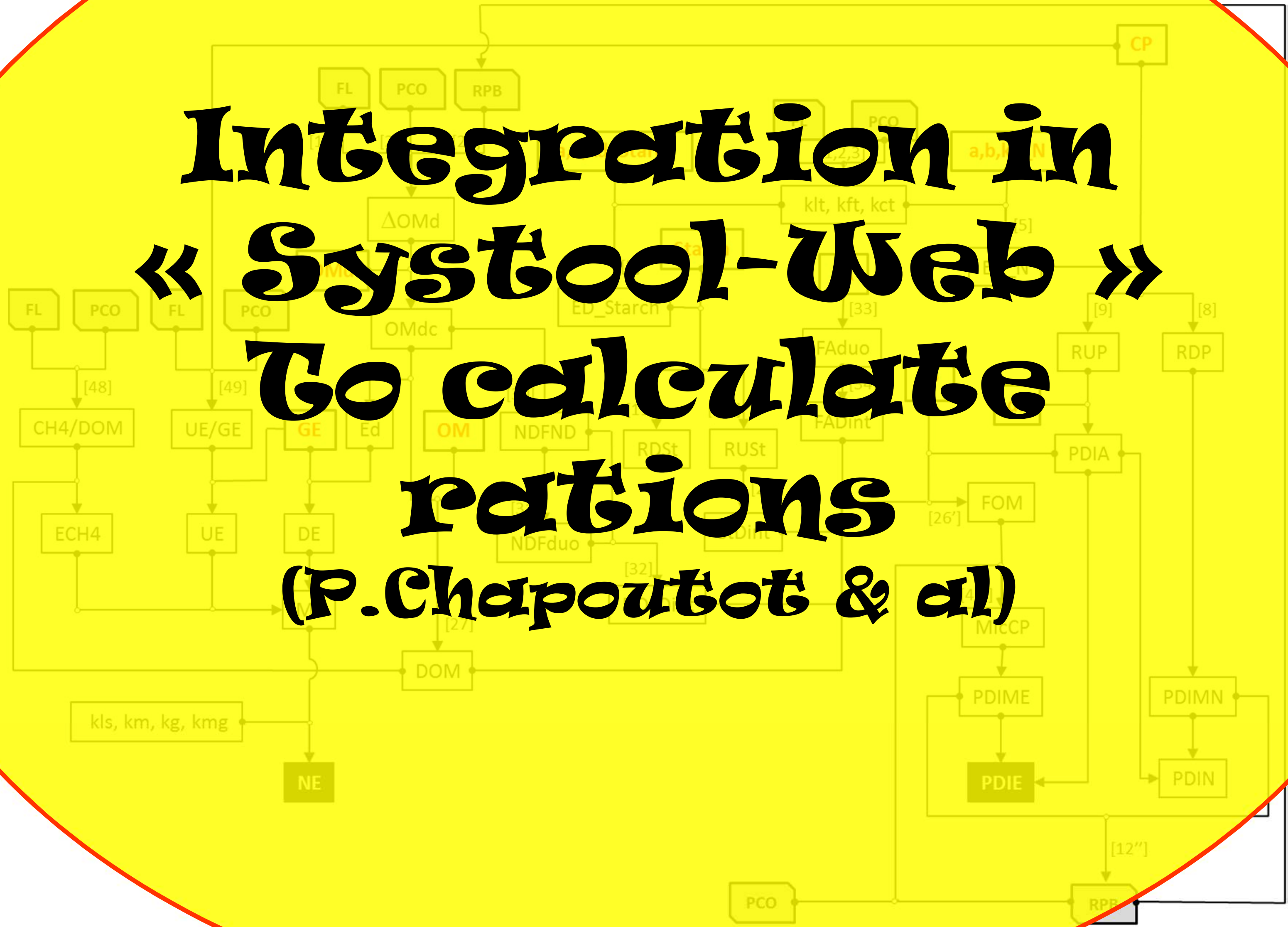
Diagram of calculations of UF and PDI supplies



Integration in « Systool-Web »
To calculate rations
(P.Chapoutot & al)

Further Integration with requirements and responses (Sirar and INRATION)

(P.Faverdin et al.)

Available end 2019-begin 2020

*Novelty n°12: calculation of maintenance and non productive protein requirements: 3 factors (End.Faecal, Maint., Scurf)

$$PDI\_req = PDI_{MFP} + PDI_{EUN} + PDI_{SCURF}$$

DMIkg * [0.5 * (5.7 + 0.74 * NDOM%)] /0.67 (⇔End.Faec.)

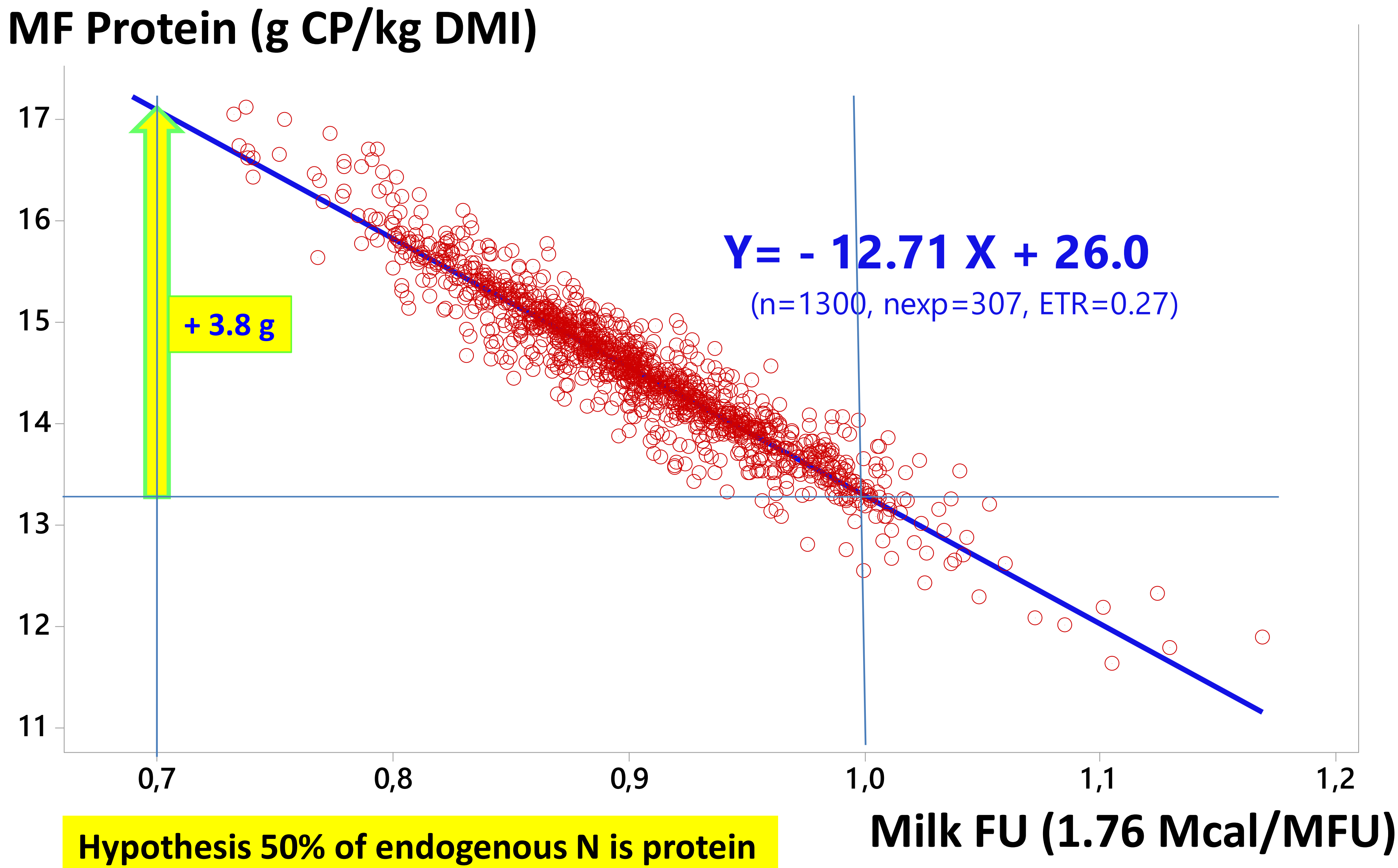
+ 0.312*BWkg (⇔ Maintenance ⇔ T.O.)

+ (0.2*BW**0.6) /0.67 (⇔Scurf)

0.67 = mean metabolic efficiency of PDI

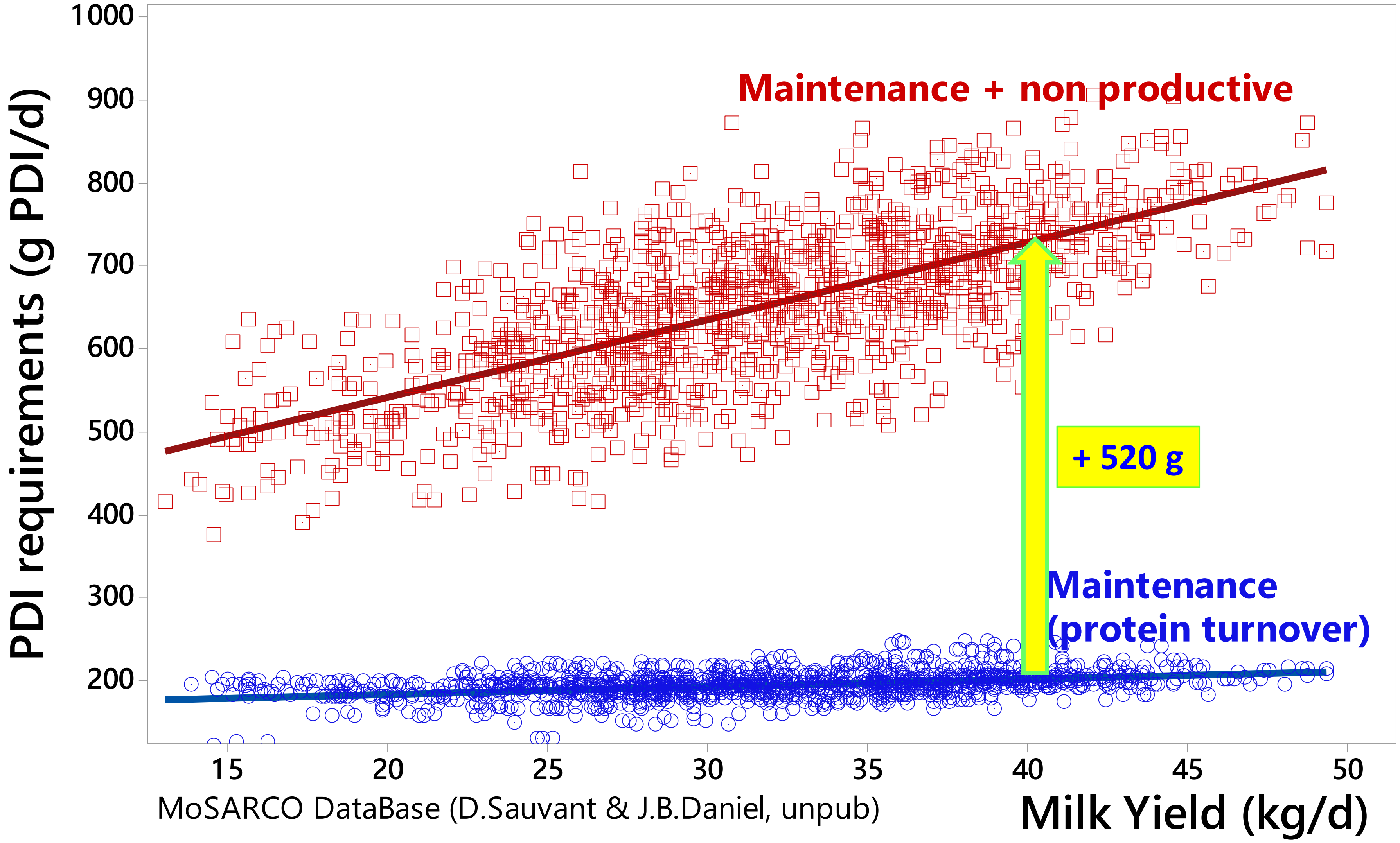
⇔ Requirements are now dependant from BW, feed supplies and quality

Calculated influence of dietary energy concentration on losses of MF protein



Hypothesis 50% of endogenous N is protein

Maintenance and non productive PDI requirements in lactating cows



MoSARCO DataBase (D.Sauvant & J.B.Daniel, unpub)

Hypothesis: PDIeff=0.67

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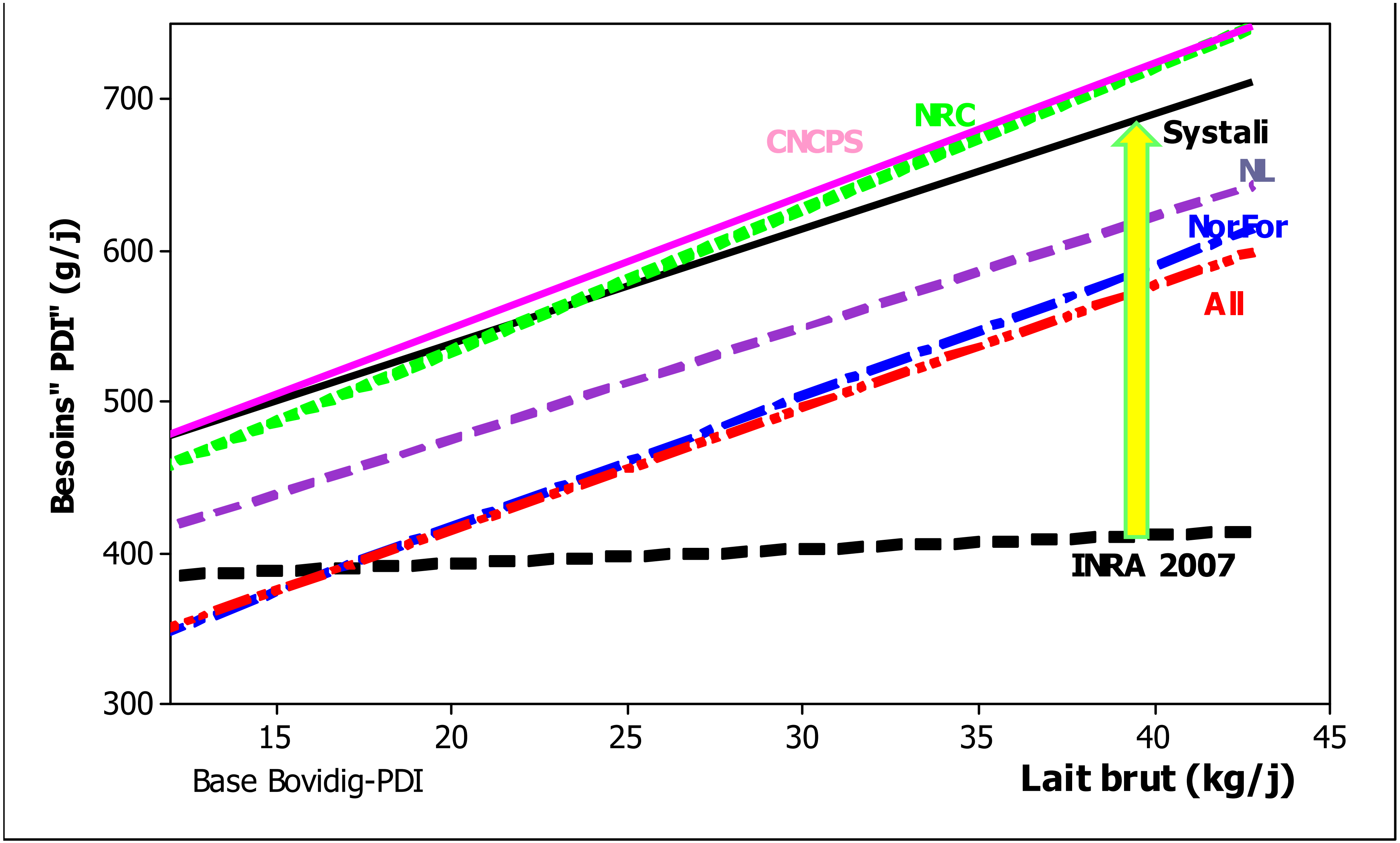
Besoins protéiques non productifs des vaches laitières



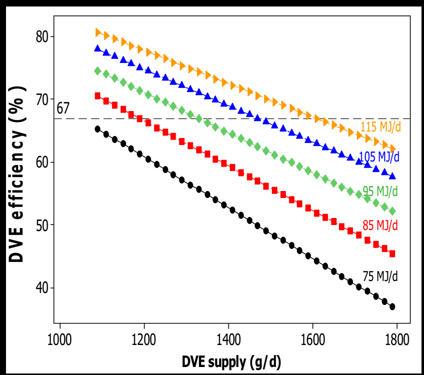
*Novelty n°13. Efficiency of PDI ?

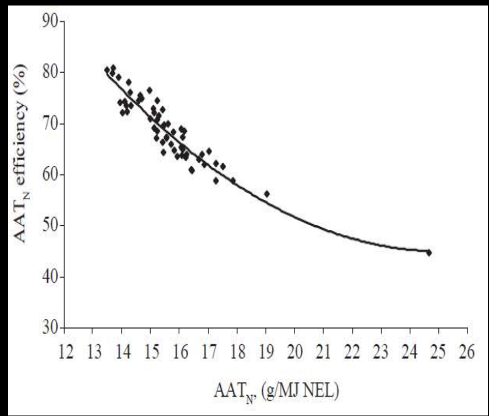
1. Constant ? *64%, 67% (INRA2007,NRC ...)*

2. Variable for milk protein

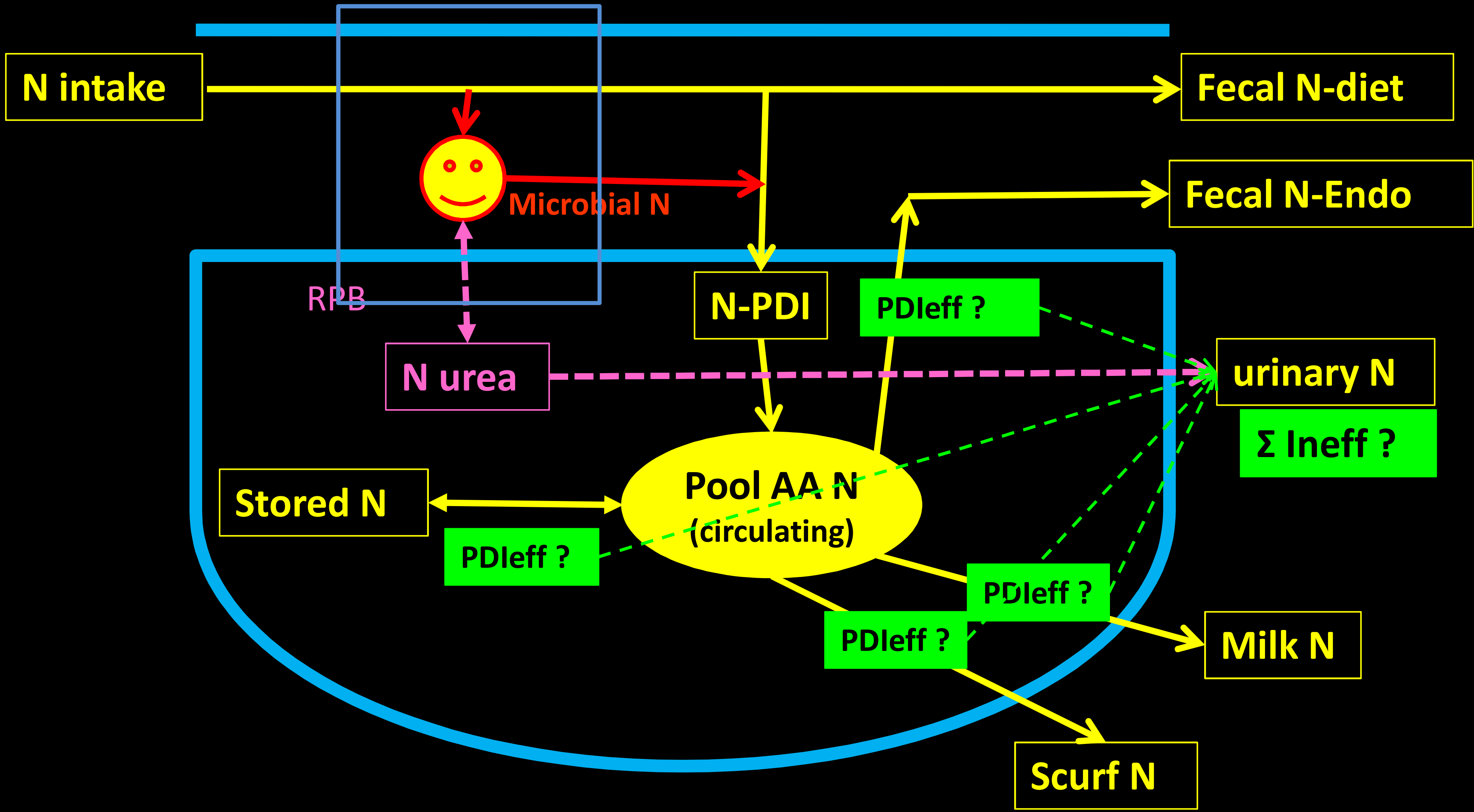
NorFor (2011): PDIeff → PMP = f(PDI/NE)

OEB/DVE (2011): PDIeff → PMP = f(MY)





Major N flows involved in PDI efficiency



➔ Common value of PDIeff

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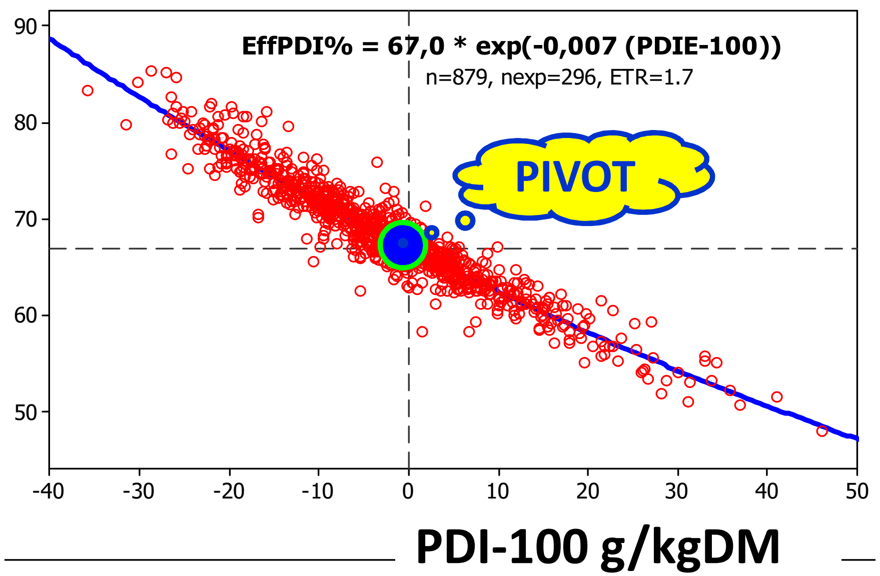
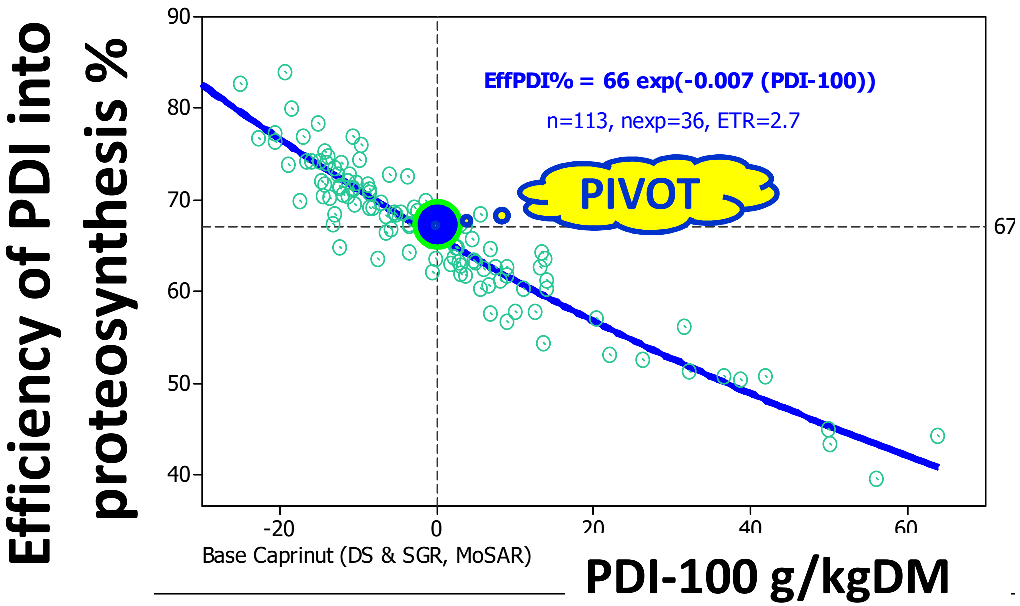
PDI efficiency in cows and goats in function of dietary PDI

COWS



GOATS



100 g PDI/kg DM ⇔ PDIeff=67%
For growing ruminants pivot at PDIeff=50%

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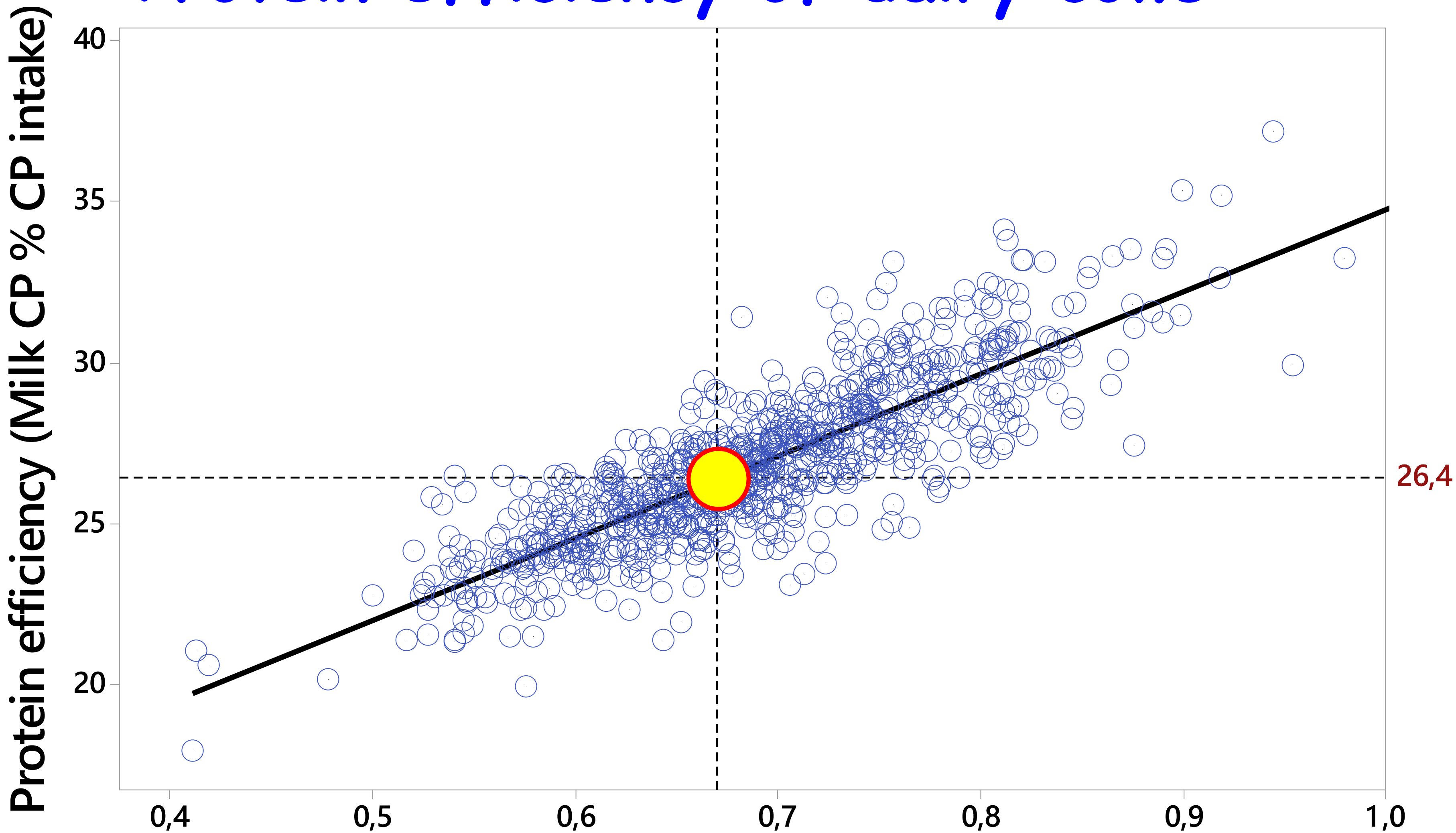
Impact of PDI efficiency on the global Protein efficiency of dairy cows



Base MoSARCO (D.Sauvant & JB.Daniel, unp)

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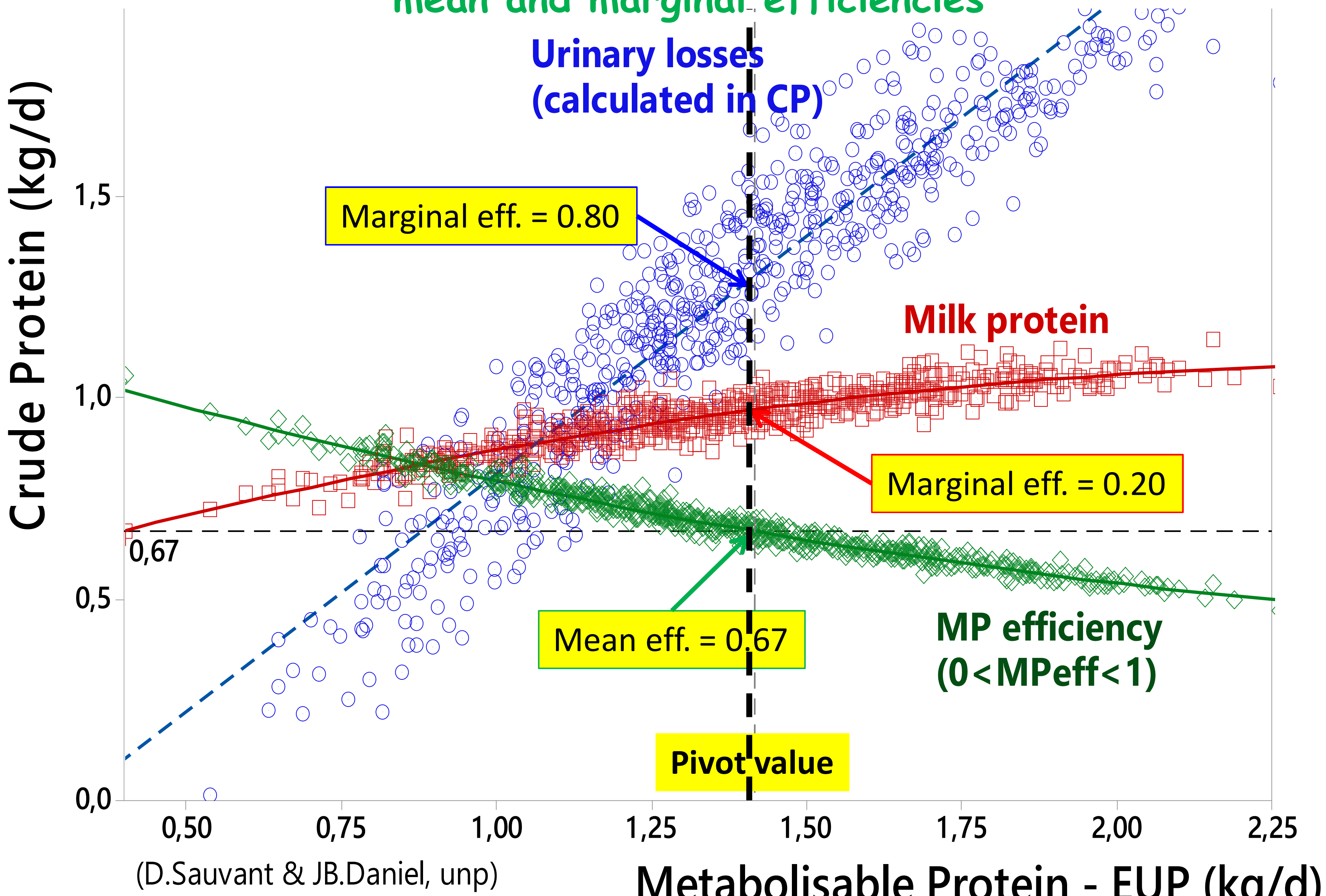
Response of PDIeff is a part of the multiple responses to PDI in cows: mean and marginal efficiencies



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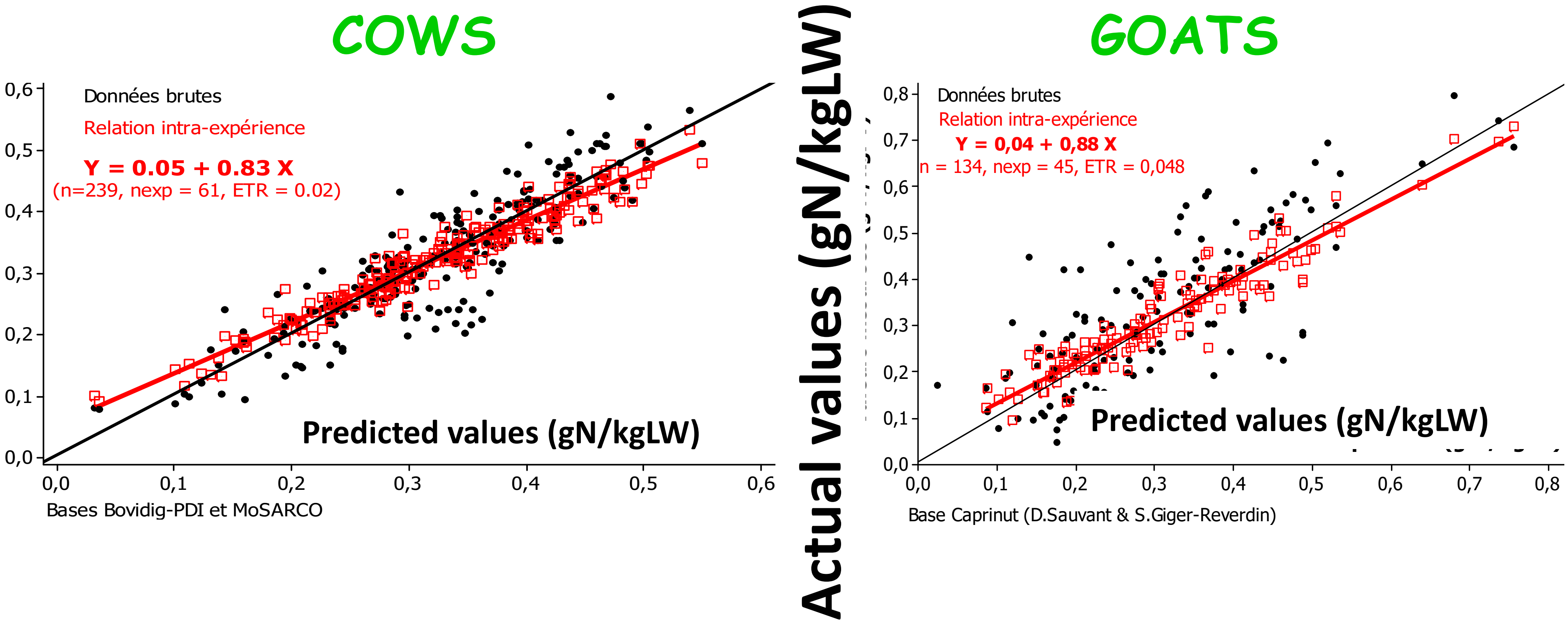
Novelty n°14: Factorial prediction of urinary N excretion: 5 factors (2 major)

1. ≈ 0.75 * N_RPB
2. N_PDI * (100 – PDIeff)/100

3. N_EndUr = maintenance
4. N_Puric = f(N_Microbes)
5. 0.47 * N_Balance

Factorial prediction of urinary-N losses



Predicted values = f(RPB, IneffPDI, LW…)

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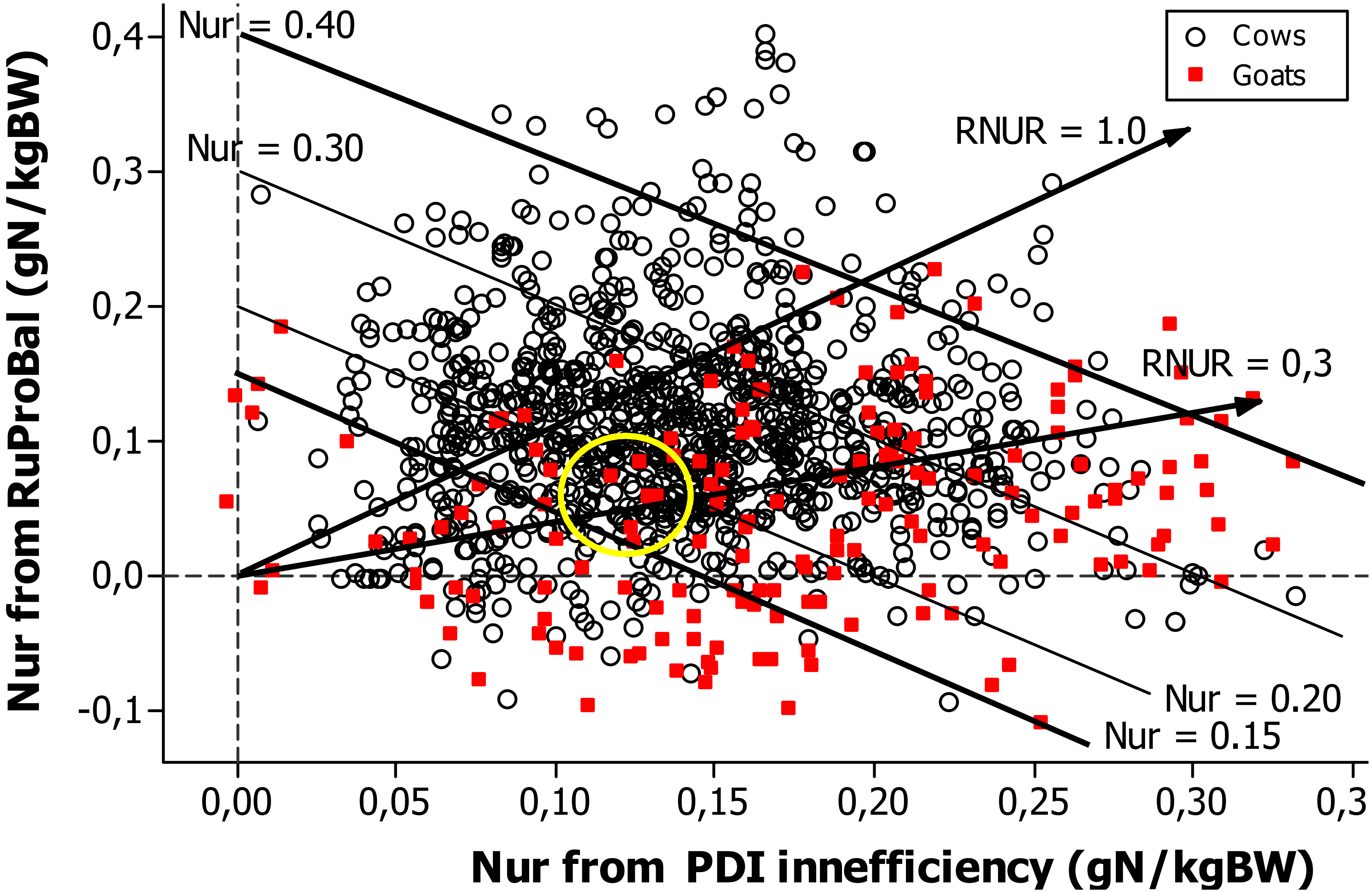
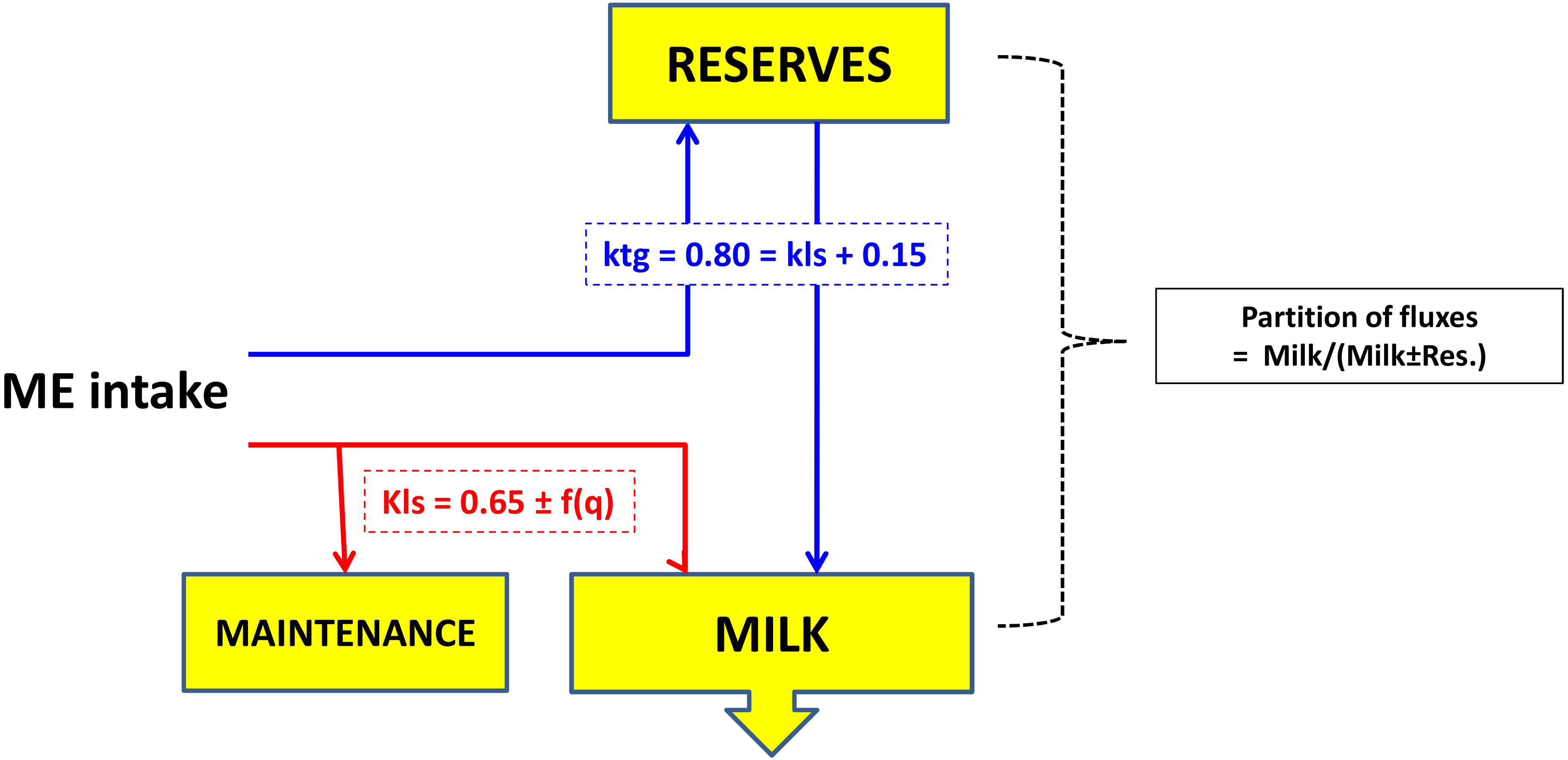
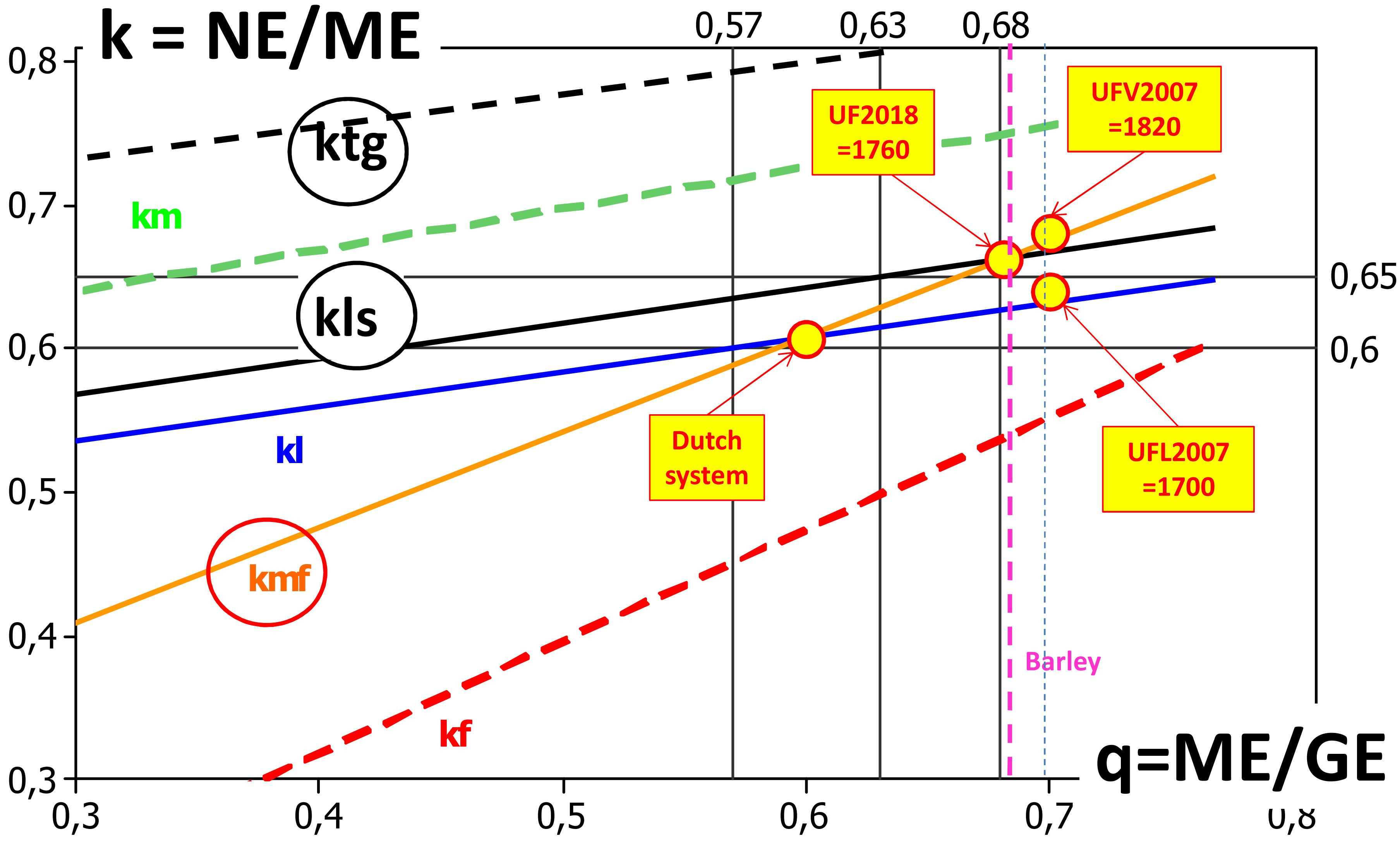
Diagnosis of N nutrition (cows and goats)



Novelty n°15: Efficiency of ME in lactating females *(former kl no more used)*



New bases of choice of UFL and UFV ?



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Comparison of maintenance requirement of a cow of 650 kg between 2007 & Systali

	Vaches 2007	Vaches systali (1)
UFL/PM	0.041	0.054
UFL entravé	5.28	6.56 (2)
UFL stabulation	5.80	6.90
PVkg (PM)	650	650

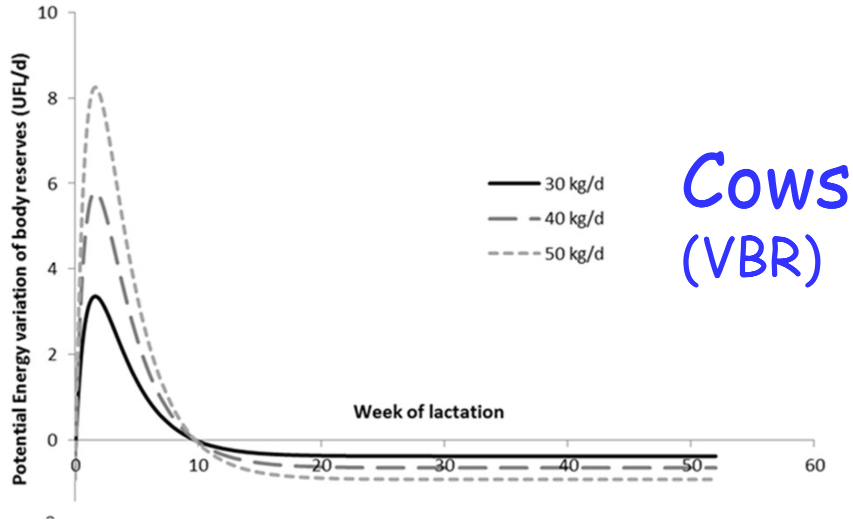
➔(1) 145 kcalEM/kg PM ⇔ 94.2 kcal ENL/kgPM
➔(2) - 5% pour l'animal entravé
➔1 UFL = 1760 kcal

*Novelty n° 16: Modelling mobilisation/accretion of body reserves at potential

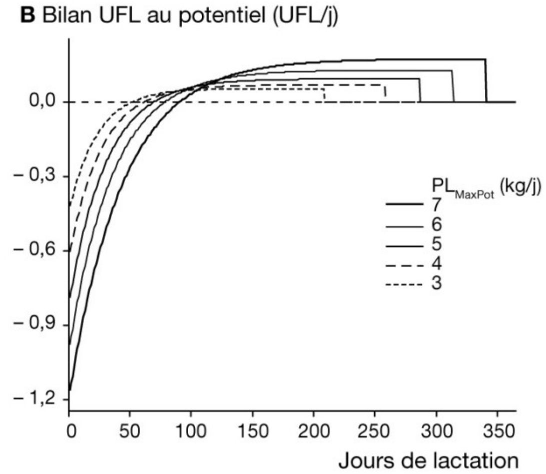
- A model to simulate expected variation of energy body reserves as a function of:
  - Stage of lactation
  - Potential milk yield
  - Body condition score

- The sum of energy mobilised is equal to the sum of energy deposition

➔ Concept of theoritical Energy Balance which takes account of kinetics of reserves in lactation and gestation (goat)



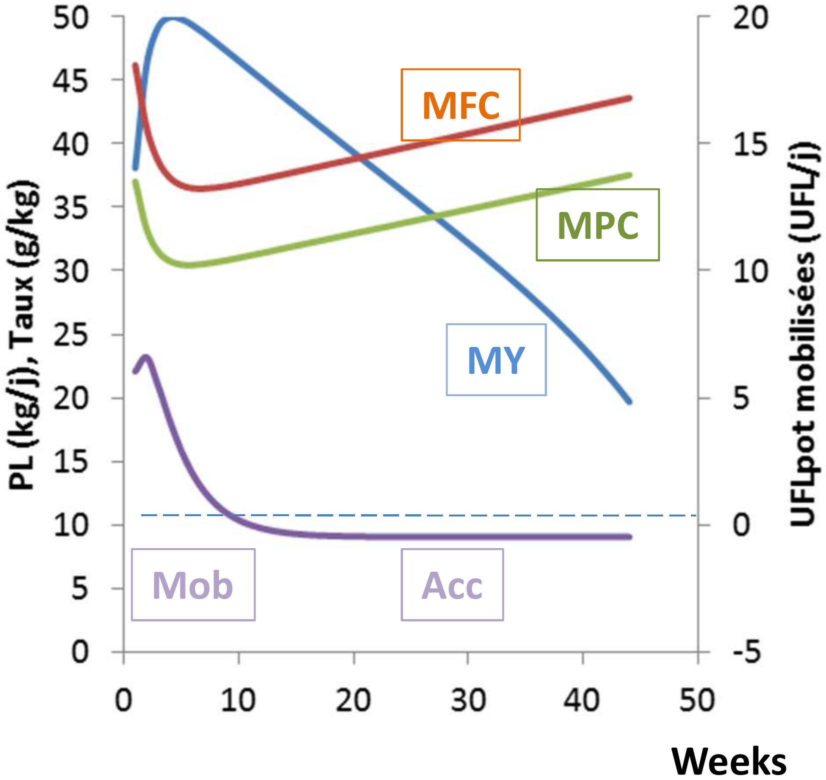
Cows (VBR)



GOATS (EnBal)

Reference Lactation curves (Cows):

⇔ En.Bal = 0 and PDIeff = 0.67 ⇔ Pivot



➔Calculations of requirements at a given stage and potential
➔Formulation of diets in two steps (1) requirements at potential (2) responses around potential

Energy value of a variation of 1 kg eBW
(INRA, 2018)

	Δ Lip (g)	Δ Prot (g)	Δ EN (Mcal)(1)	Δ UFL (1)
Cows	511	129	6.29	2.9
Goats	433	137	4.80	2.2
Ewes *(BCS=2.5)*	270	190	3.58	1.67
Meat Cows *Mult.*	380	130	4.27 (2)	2.6
Meat Cows *Primi.*	210	160	2.85 (2)	1.8

(1) ΔUFL = [ΔEN/0.80)/0.65] /1.76
(2) with kpf

Energy value of a variation of 1 point of BCS

Cows = 206 UFL

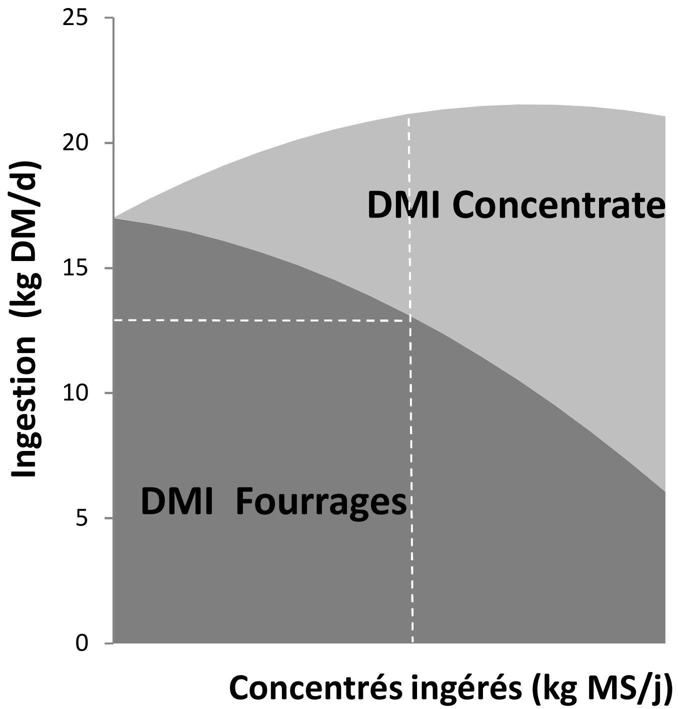
Meat Cows = 200/160 UFL
(NEC+/-)

Ewes = 28 UFL

Goats = 22 UFL

*Novelty n°17: multiple responses to supplies; A.example of concentrate supply

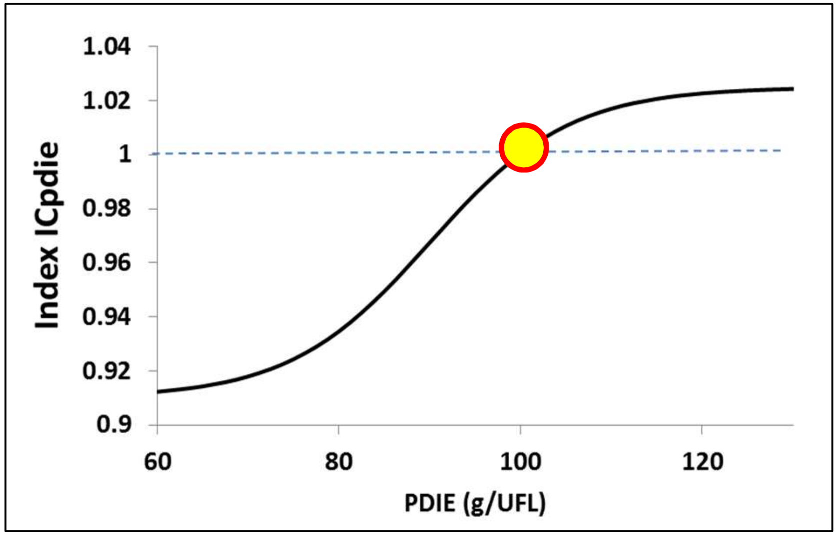
1. Response of intake



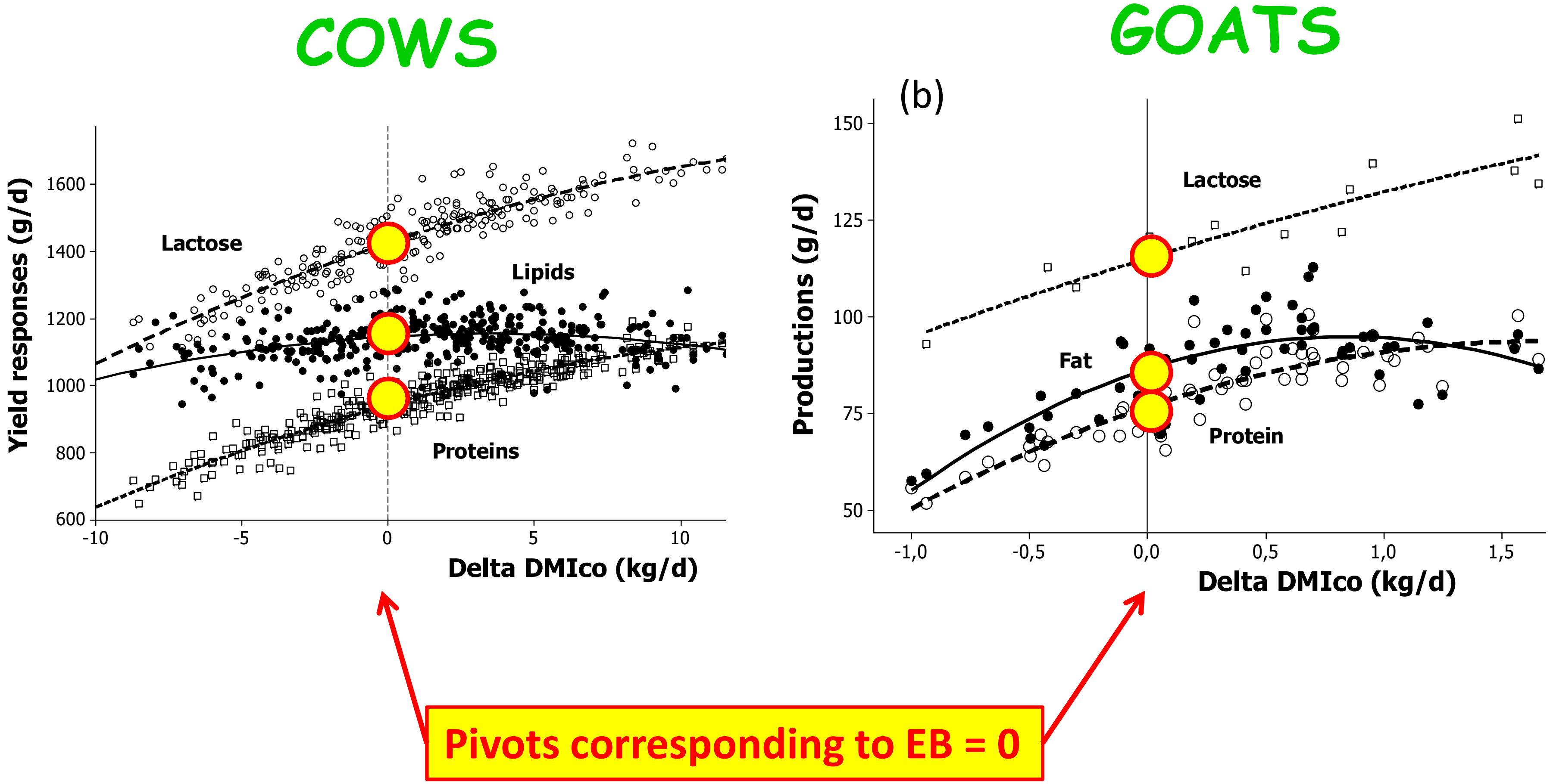
NEW:

1) Integration of the effect of dietary protein on Intake Capacity (IC) and on Fo x Co substitution rate.

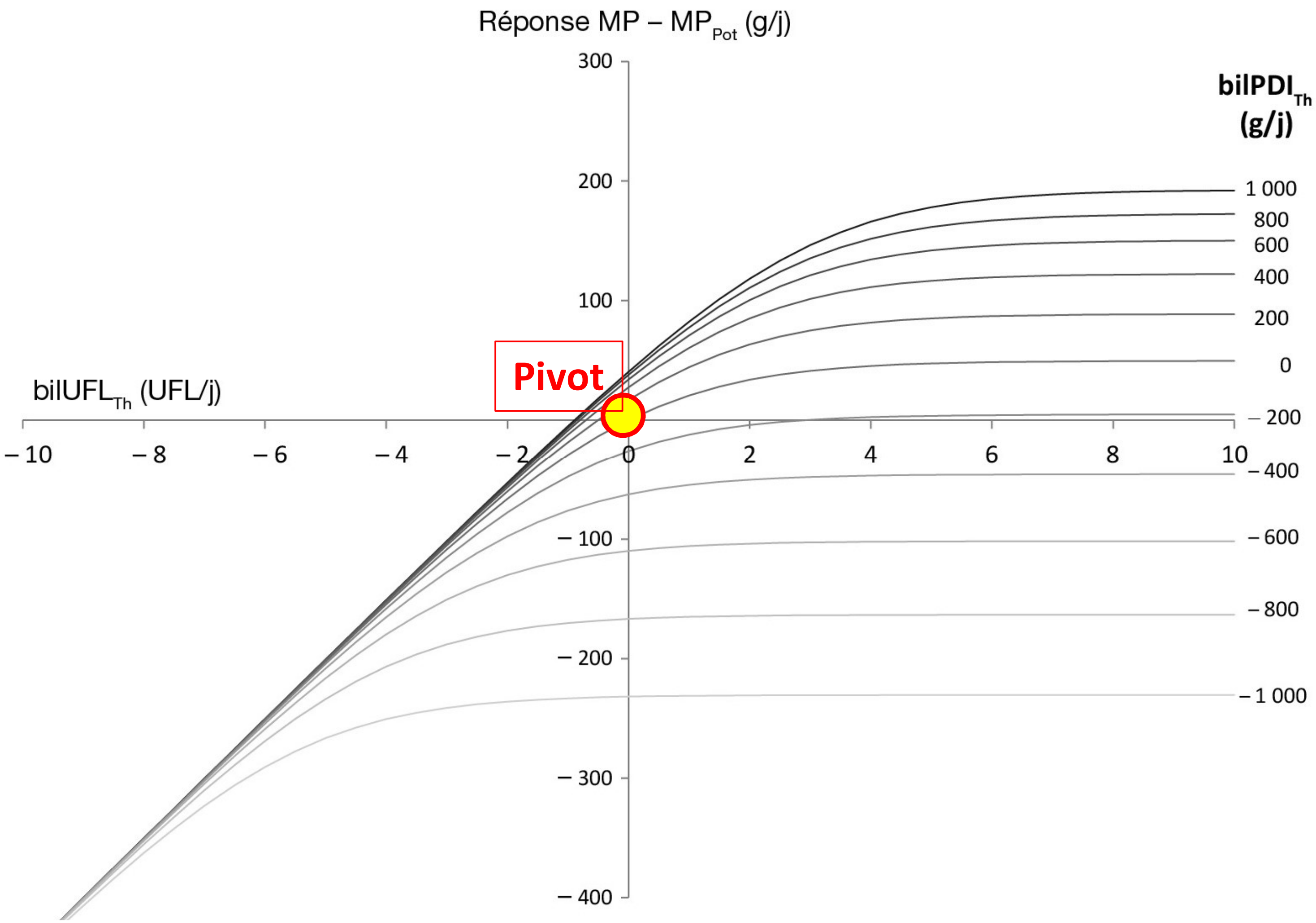
2) Specific Fill Value of concentrate



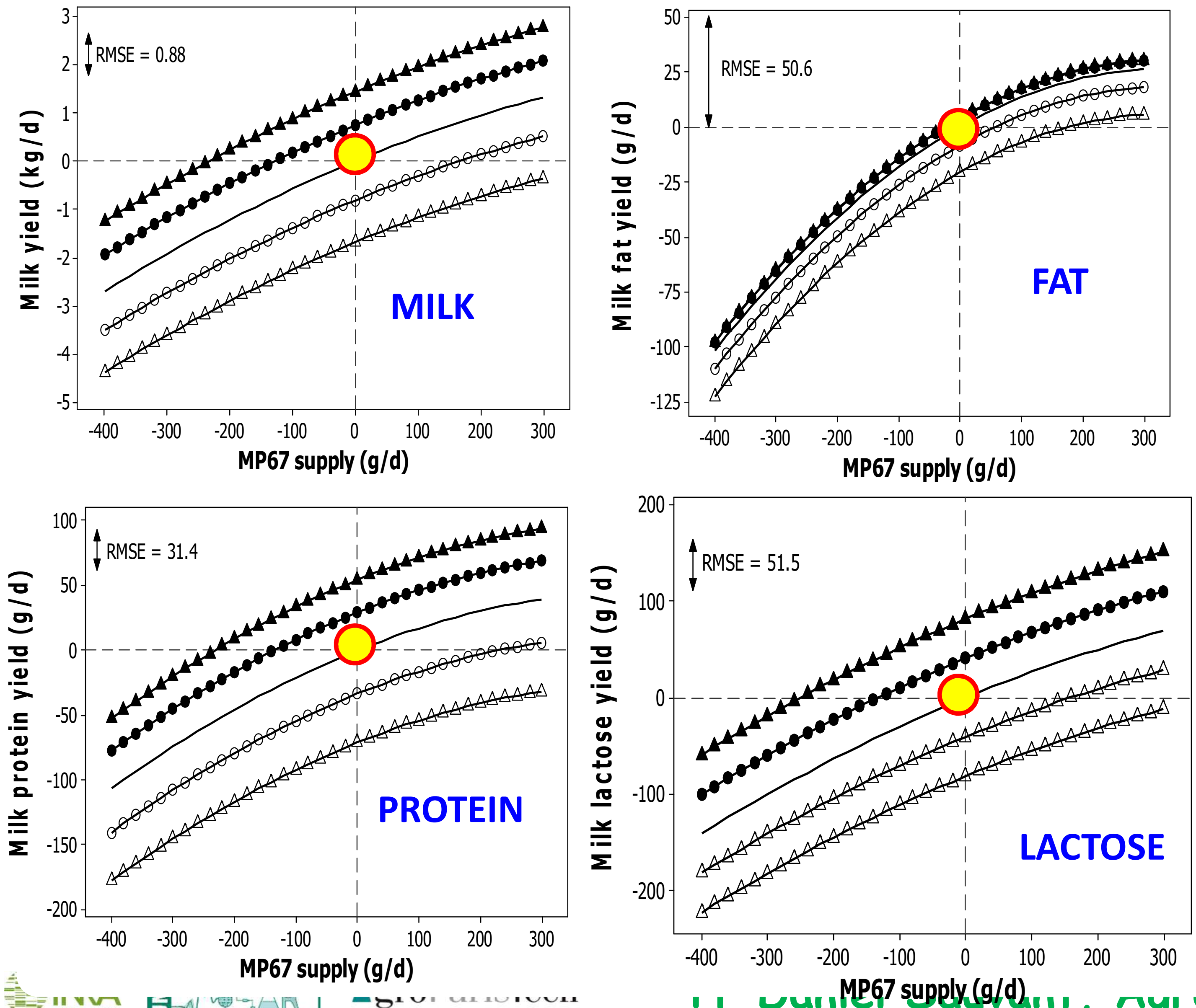
2. Responses of milk constituents productions



3. Simultaneous responses of milk protein production to UFL and PDI supplies *(Faverdin et al., 2018)*



B. Milk yield and milk component yields responses to En and PDI in cows (*JB.Daniel et al., 2016*)

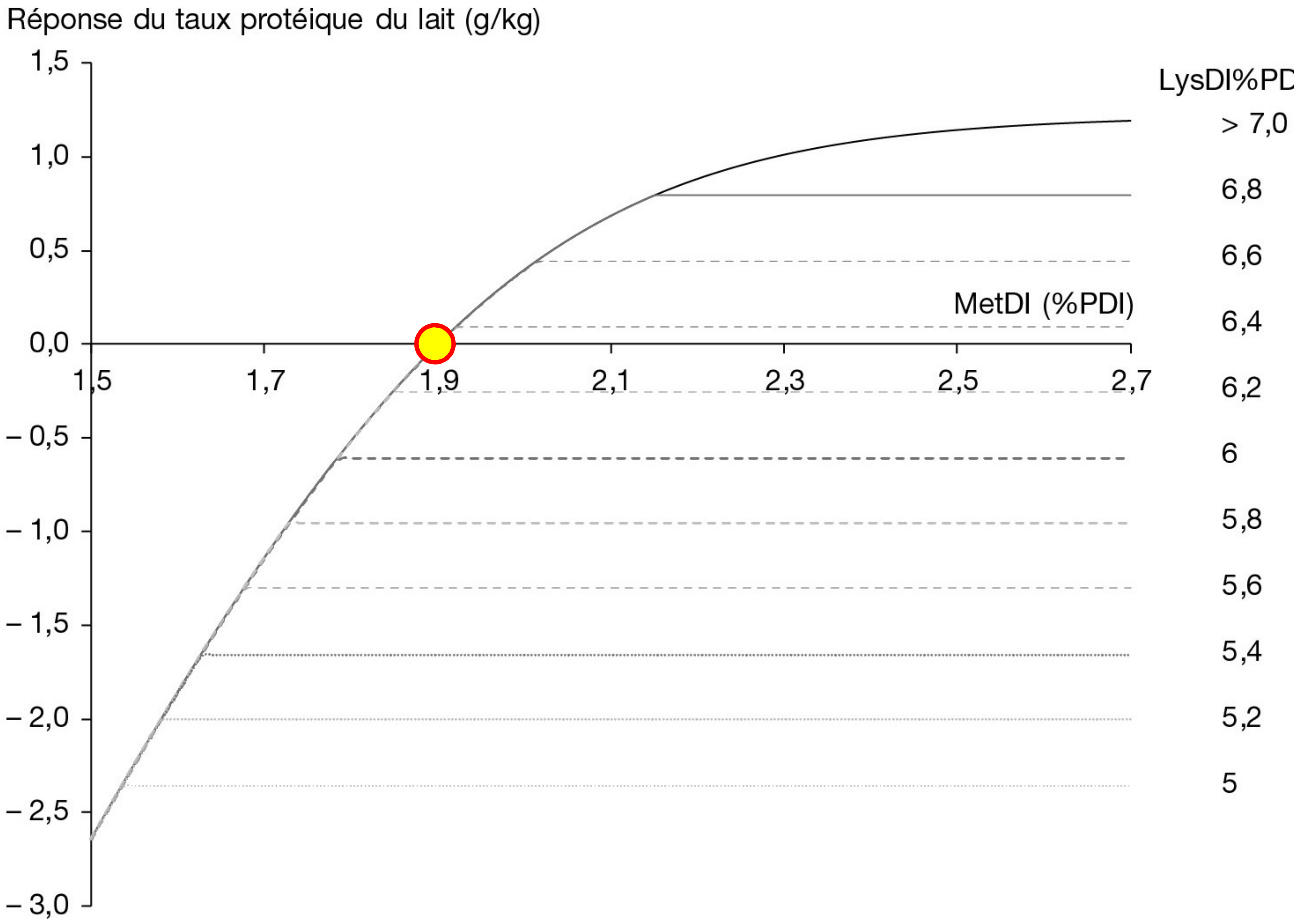


- **No interaction between NE_L and MP**
- **Diminishing return to both protein and energy**
- **Sensitivity to E x N supply**

1. MLY => 490 g/d
2. MPY => 360 g/d
3. MFY => 187 g/d

Responses of milk protein content to LysDi et MetDi

(Lemosquet et al., 2018)



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CONCLUSIONS

A deep updating was necessary to build a new scientifically based system.

- The 17 novelties allow to better account biological phenomenons and to increase the precision of predictions of supplies, requirements and multiple responses to diets.

-Consistency of all the key equations was checked.

-Predictions of flows of absorbable nutrients are proposed.

- The price of a better precision is an increased level of complexity which is compensated thanks to the computer