# Status of PILGRIM

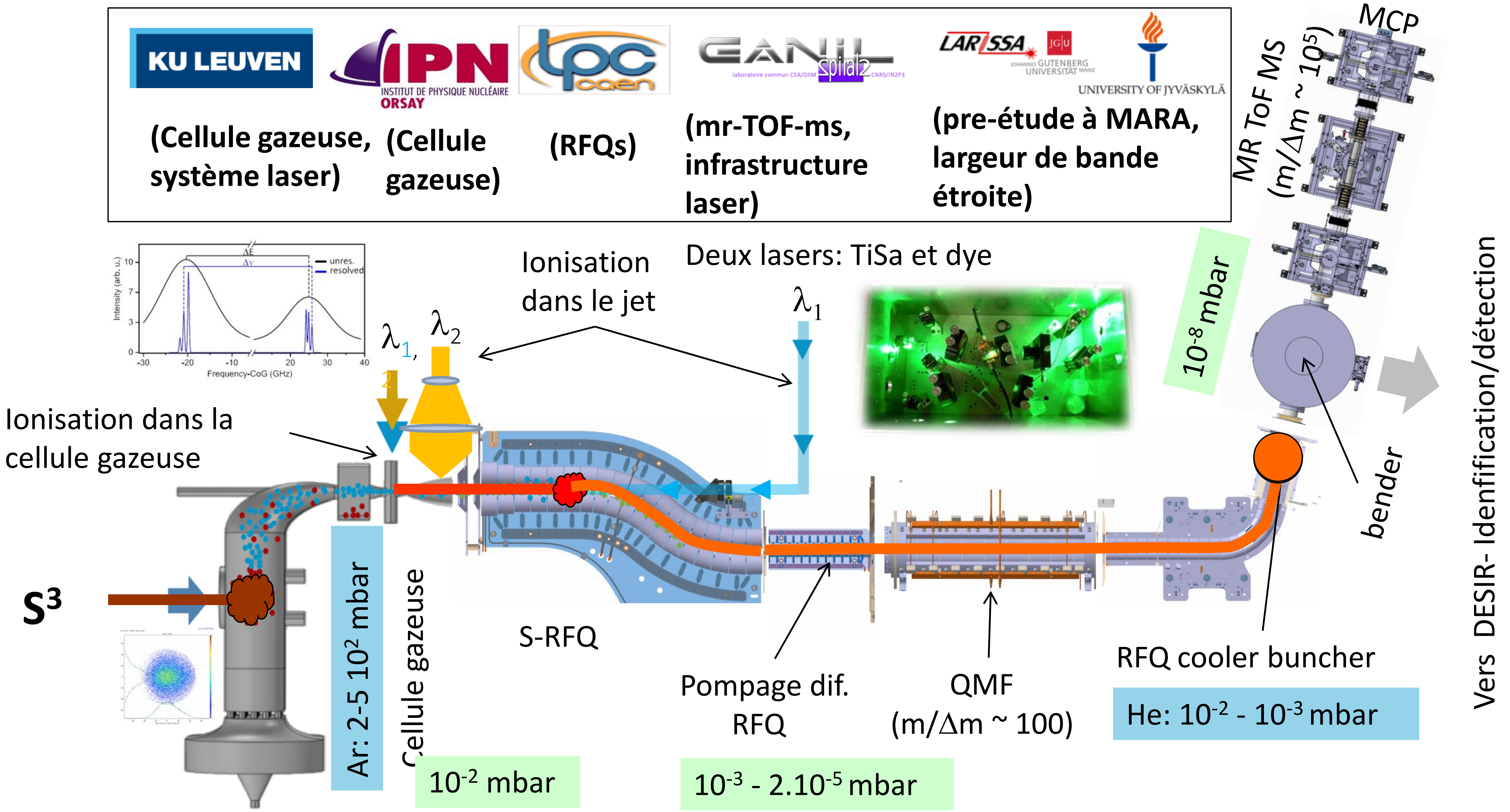
## A Multi-Reflexion ToF Mass Spectrometer (MR-ToF-MS) for S3

**P. Delahaye,**

**B. M. Retailleau, P. Chauveau and the S3-LEB team**

# S$^3$ Low Energy Branch

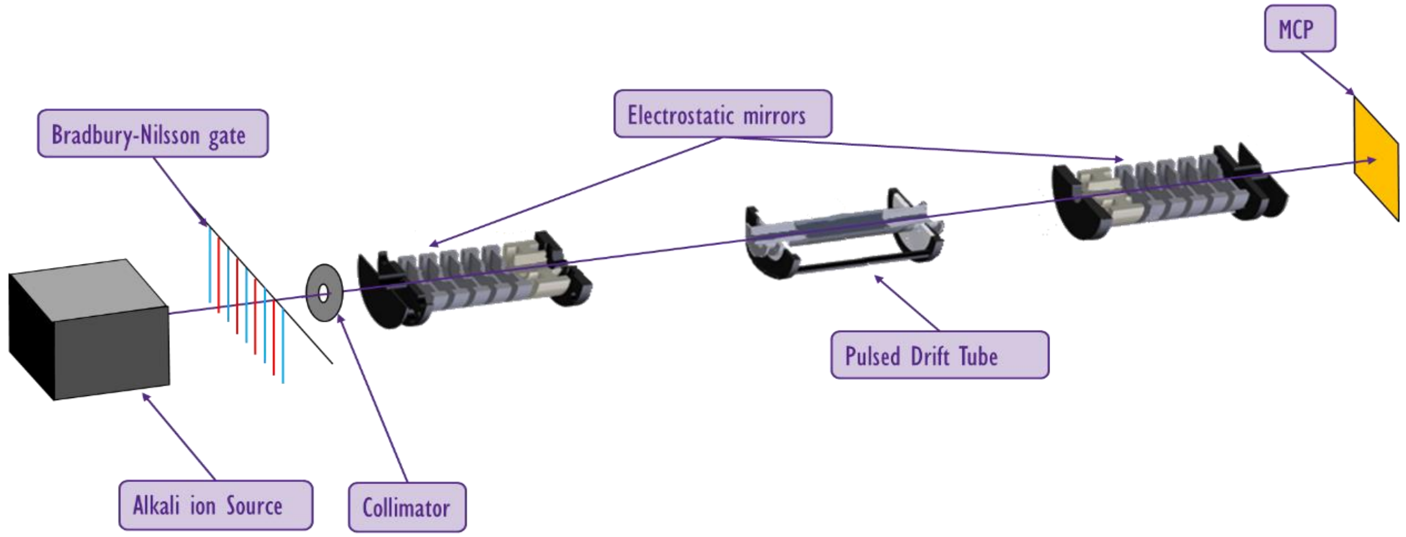
See J. Romans, next session



# PILGRIM off-line commissioning at LPC Caen

**P**iège à **I**ons **L**inéaire du **G**ANIL pour la **R**ésolution des **I**sotopes en **M**asse

**Multi Reflexion Time-of-Flight Mass Spectrometer**




Time-of-flight $t \sim d \cdot \sqrt{\frac{m}{2E}}$

$$R = \frac{m}{\Delta m} \sim \frac{1}{2} \cdot \frac{t}{\Delta t}$$

Where $\Delta t$ is the **time spread** of the ion bunch after N turns in the trap

Resolving power: up to $\boldsymbol{R \sim 120.000}$

Precision: $\boldsymbol{\frac{1}{R\sqrt{N}} \sim 7 \cdot 10^{-8}}$ **achieved**

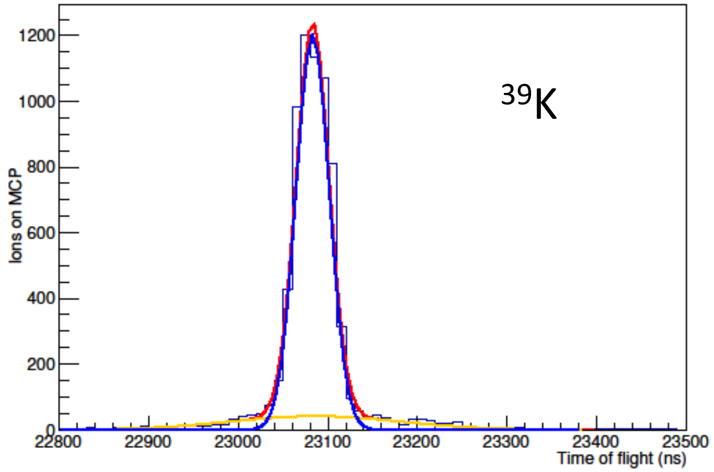
For typical **cycle times of 20 ms**

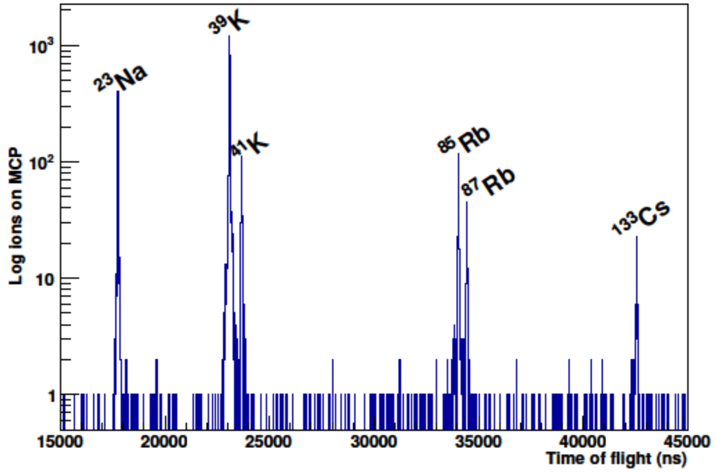
Attained objectives:

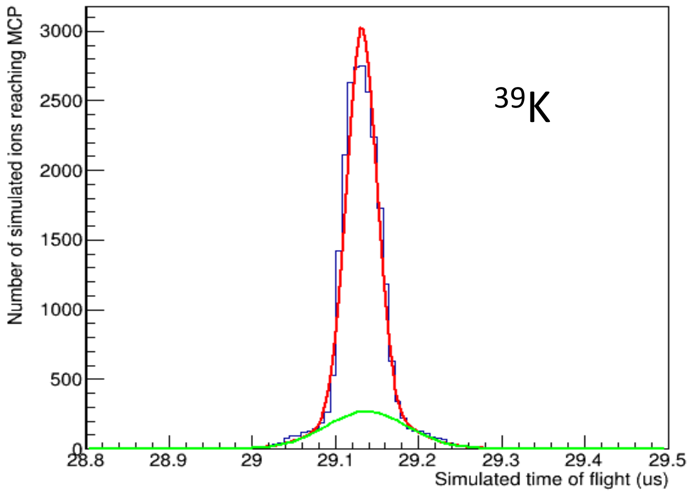
- ✓ testing mass models with mass measurements with better than 100 keV precision (~$5 \cdot 10^{-7}$ for A~200)
- ✓ Separating isolbars with $10^5$ mass resolving power

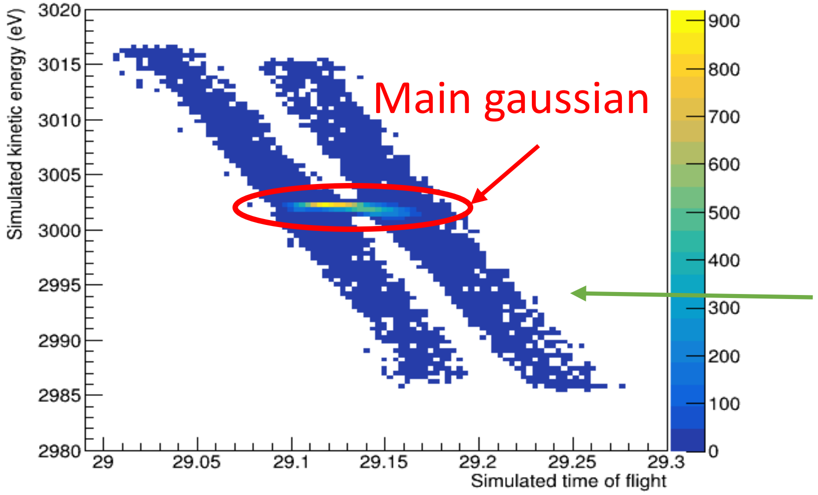
Mass measurement tests performed during the **PhD thesis of Blaise Maël Retailleau**

# Understanding the bunch formation




Second gaussian

**Double gaussian shape very well reproduced by SIMION simulations**

- BNG yields 2 distributions in energy
- The main one, peaked in energy (±1.5 eV) is used for measuring masses and determining the resolving power of PILGRIM after trapping
- The second one corresponds to ions passing through the gate while it is opening/closing, exhibiting a much larger energy spread (±15 eV)

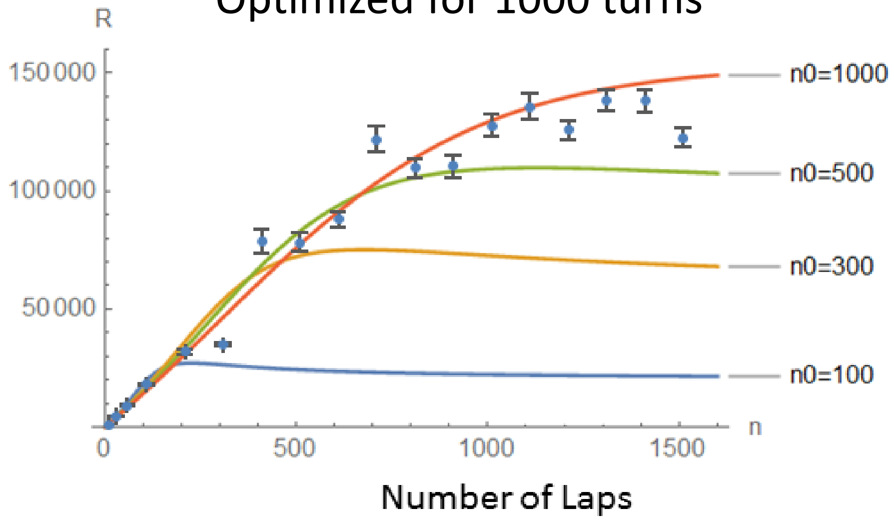
**Characteristics of the bunch are similar to the one simulated from the S3-LEB RFQ cooler buncher**

# Understanding the resolving power evolution

$$R \approx \frac{n \cdot T}{\sqrt{\Delta t_0^2 + n^2 \cdot \Delta T_{foc}^2 + \left[\frac{\partial t_d}{\partial E} \cdot \Delta E \cdot \left(1 - \frac{n}{n_0}\right)\right]^2}}$$

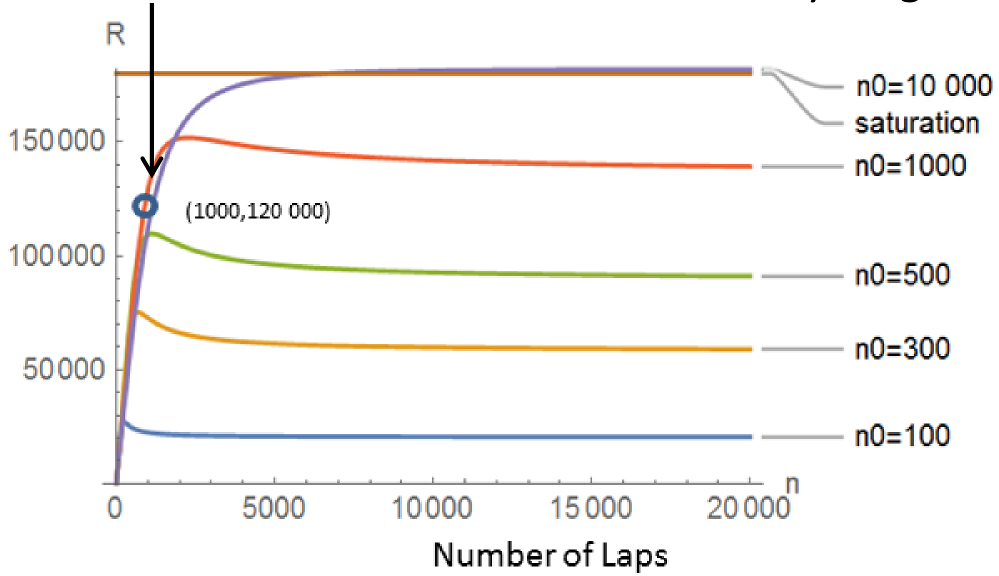
Similar expression derived in eg.
W. Plaß et al. IJMS 349–350 (2013)

Optimized for 1000 turns




**R=120.000** while **180.000** is theoretically feasible, but for way longer times

Operation of PILGRIM

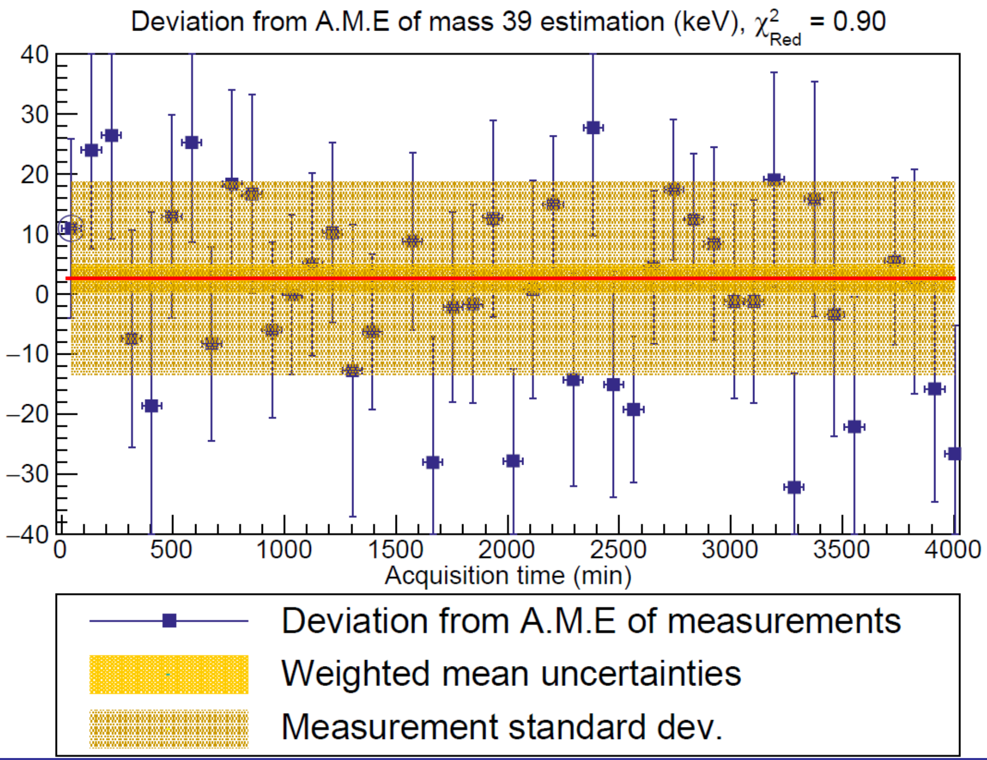



Eventual limitation comes from accumulation of **2nd order geometrical aberrations** $\Delta T_{foc}^2$

# Attaining a mass accuracy better than $10^{-7}$

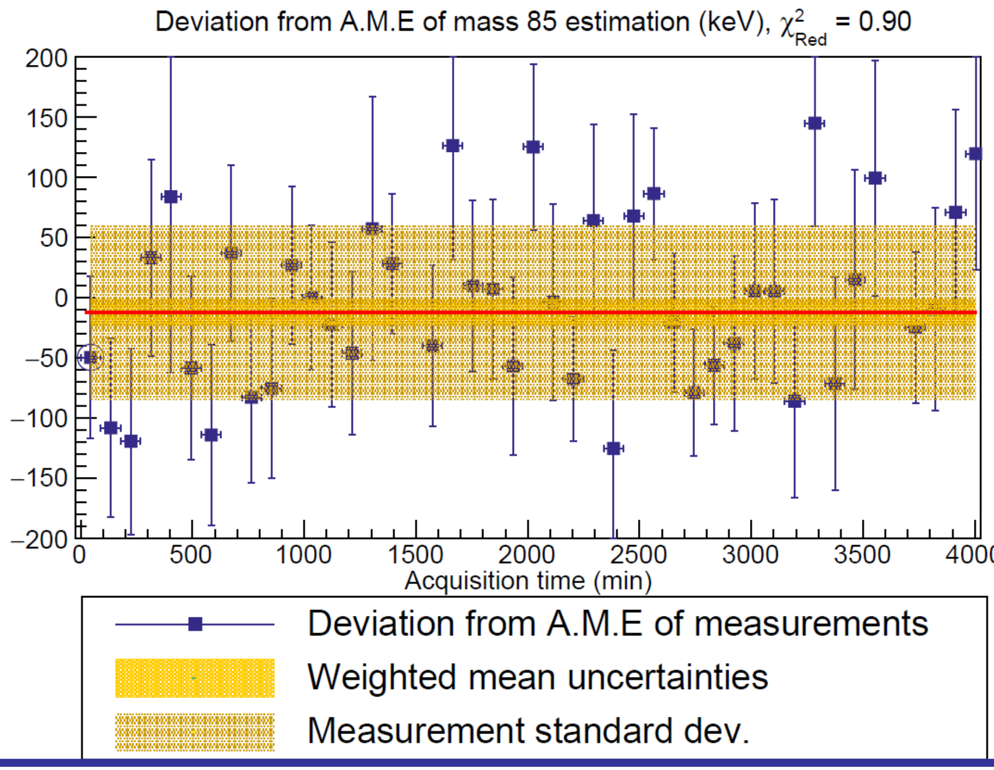
$mc^2 = (a \times t + b)^2$ **-3/2T** Correction due to relativity!

- $^{39}K$ using $^{23}Na$ and $^{85}Rb$ as references




$\sigma_m$=2.4 keV, $\sigma_m$/m=6.7 $10^{-8}$

- $^{85}Rb$ using $^{39}K$ and $^{23}Na$ as references



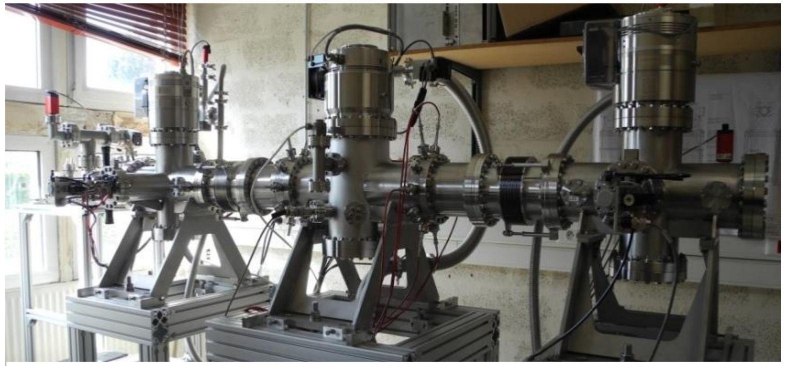

$\sigma_m$=10.7 keV, $\sigma_m$/m=14 $10^{-8}$

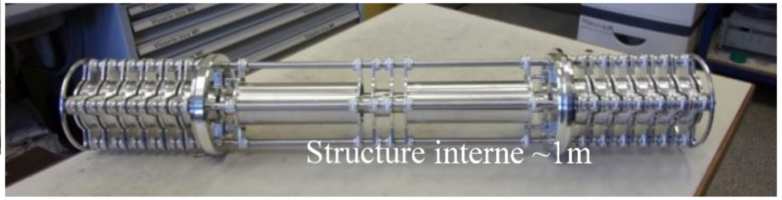
**Deviation ~1$\sigma_m$ reduced by 15% thanks to the correction!**

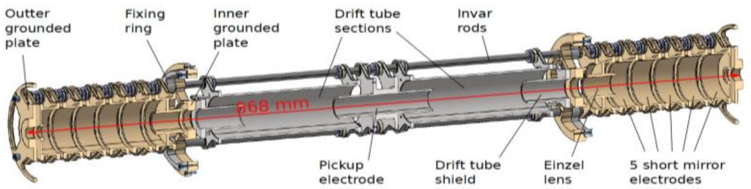
# PILGRIM

**P**iège à **I**ons **L**inéaire du **G**ANIL pour la **R**ésolution des **I**sotopes en **M**asse

Mass separation, identification and mesurement
for N=Z and very heavy nuclei produced at S3






P. Chauveau, P. Delahaye, et al., «PILGRIM, a Multi-Reflection Time-of-Flight Mass Spectrometer for Spiral2-S3 at GANIL,» *Nuclear Instruments and Methods in Physics Research B* , vol. 376, p. 211, 2016.

P. Chauveau, Design, simulations and test of a Time-of-Flight spectrometer for mass measurement of exotic beams from SPIRAL1/SPIRAL2 and gamma-ray spectroscopy of nuclei close to 100Sn. Thèse de l'Université de Caen Normandie., 2016.

B. M. Retailleau, PILGRIM : un spectromètre de masse par temps de vol pour S3 et brisure de la symétrie d'isospin dans le 38K. Thèse de l'Université de Caen Normandie., Février 2021.

**Compact, affordable, precise and fast**

We presently miss 3 turbo pumps!
To continue the commissioning with beams from the S3LEB RFQs

**Thanks a lot for your attention!**

# Backup

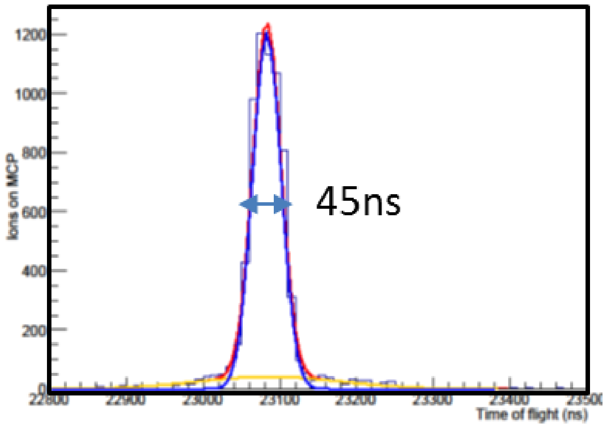
# Understanding the resolving power evolution

$$R \approx \frac{n \cdot T}{\sqrt{\Delta t_0^2 + n^2 \cdot \Delta T_{foc}^2 + \left[\frac{\partial t_d}{\partial E} \cdot \Delta E \cdot \left(1 - \frac{n}{n_0}\right)\right]^2}}$$

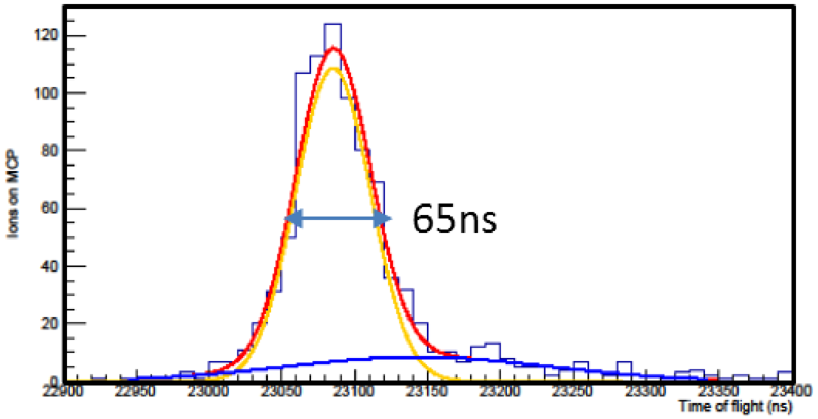
Initial dispersion — Aberrations — Time-flight-focussing for $n_0$ laps

Similar expression derived in eg.
W. Plaß et al. IJMS 349–350 (2013)

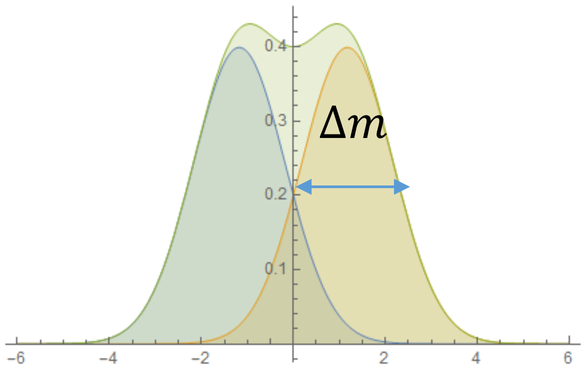
Time of flight distribution of ions shot through PILGRIM




Time of flight distribution after 1000 turns: t-1000T




Normalized gaussians




$$R = \frac{m}{\Delta m} \sim \frac{1}{2} \cdot \frac{t}{\Delta t}$$