cea irfm

A modern Infrastructure to manage shared diagnostic and very high amount of data

Presented by Julian COLNEL on behalf the WEST team

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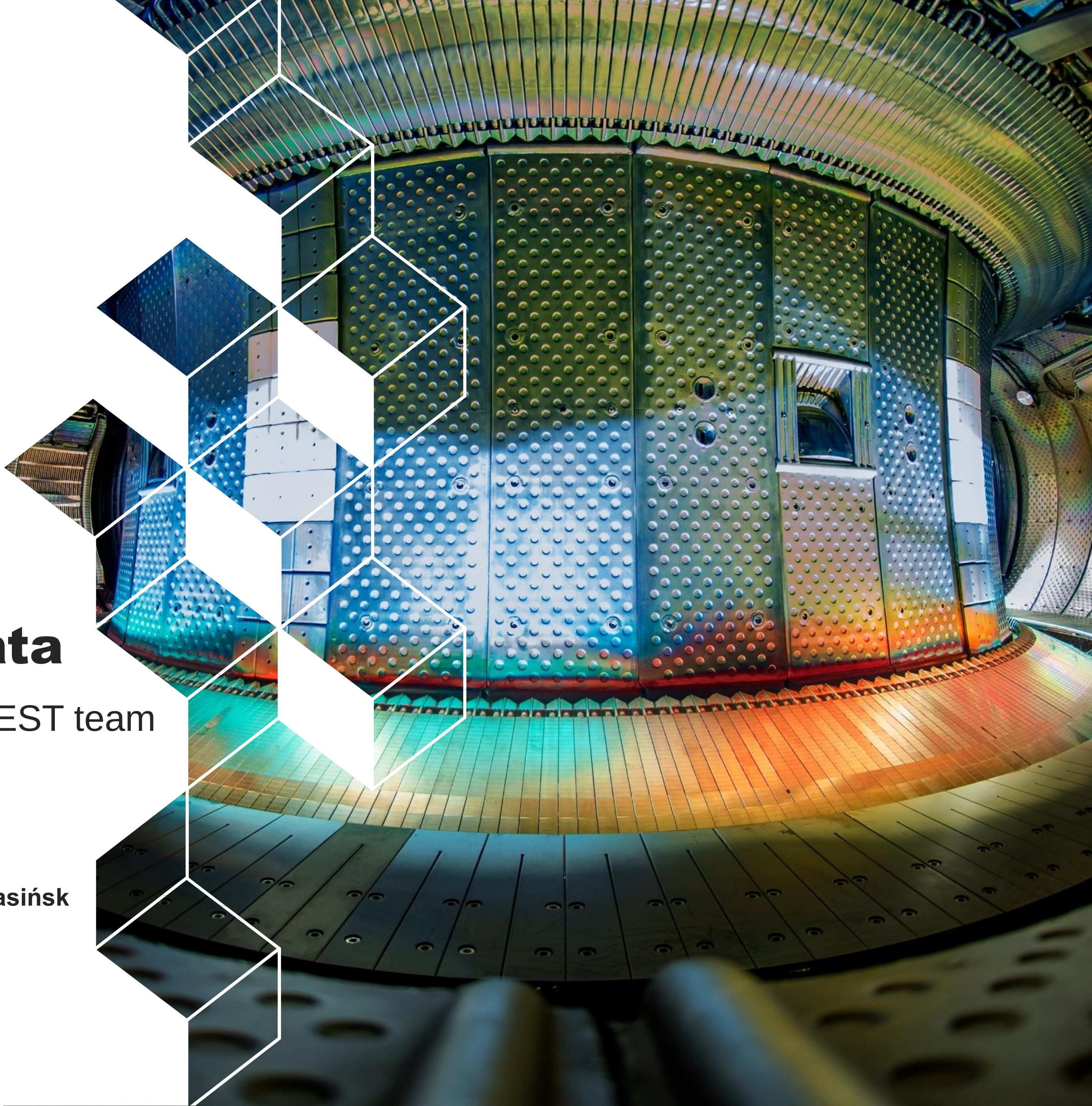
IFPiLM



About me

Julian COLNEL

CODAC & Software engineer at CEA / IRFM

Involved in the Plasma Control System Architecture (Real Time programming)

Designer and developer of the Pulse Sequence Expert system, the real-time communication library, the acquisition quality chain tools.

Responsible of the GEM Westbox integration

Designer and developer of the new IRFM Pinboard

Data Acquisition & Process Duty Officer

Summary

1. **The WEST Tokamak**

   Quite a big data producer

2. **The Tungsten density measurement**

   Just a little bit of physics

3. **The WEST acquisition infrastructure**

   An effective one

4. **The modern acquisition method**

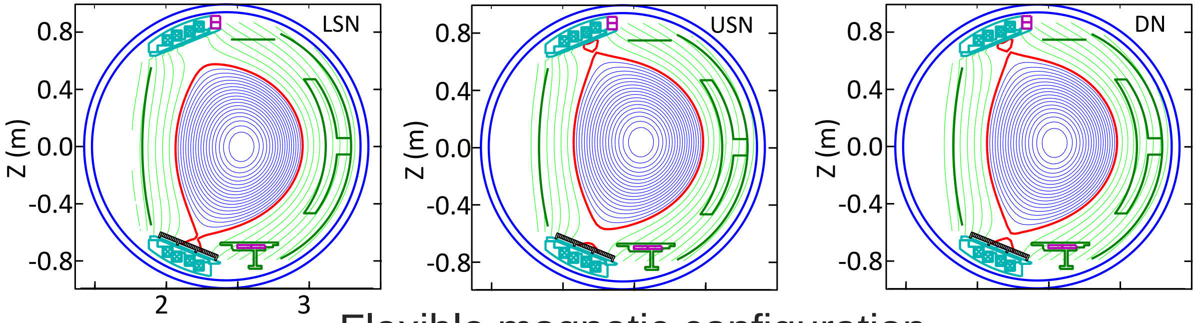
   How to take into account the new needs

1. The WEST Tokamak

Quite a big data producer

A superconducting MA class full W tokamak

B	I_p	R	A	V_p	κ / δ	P_{RF}	Magnetic conf.
3.7 T	1 MA	2.5 m	5-6	15 m^3	1.4 / 0.5	16 MW	LSN, USN, DN



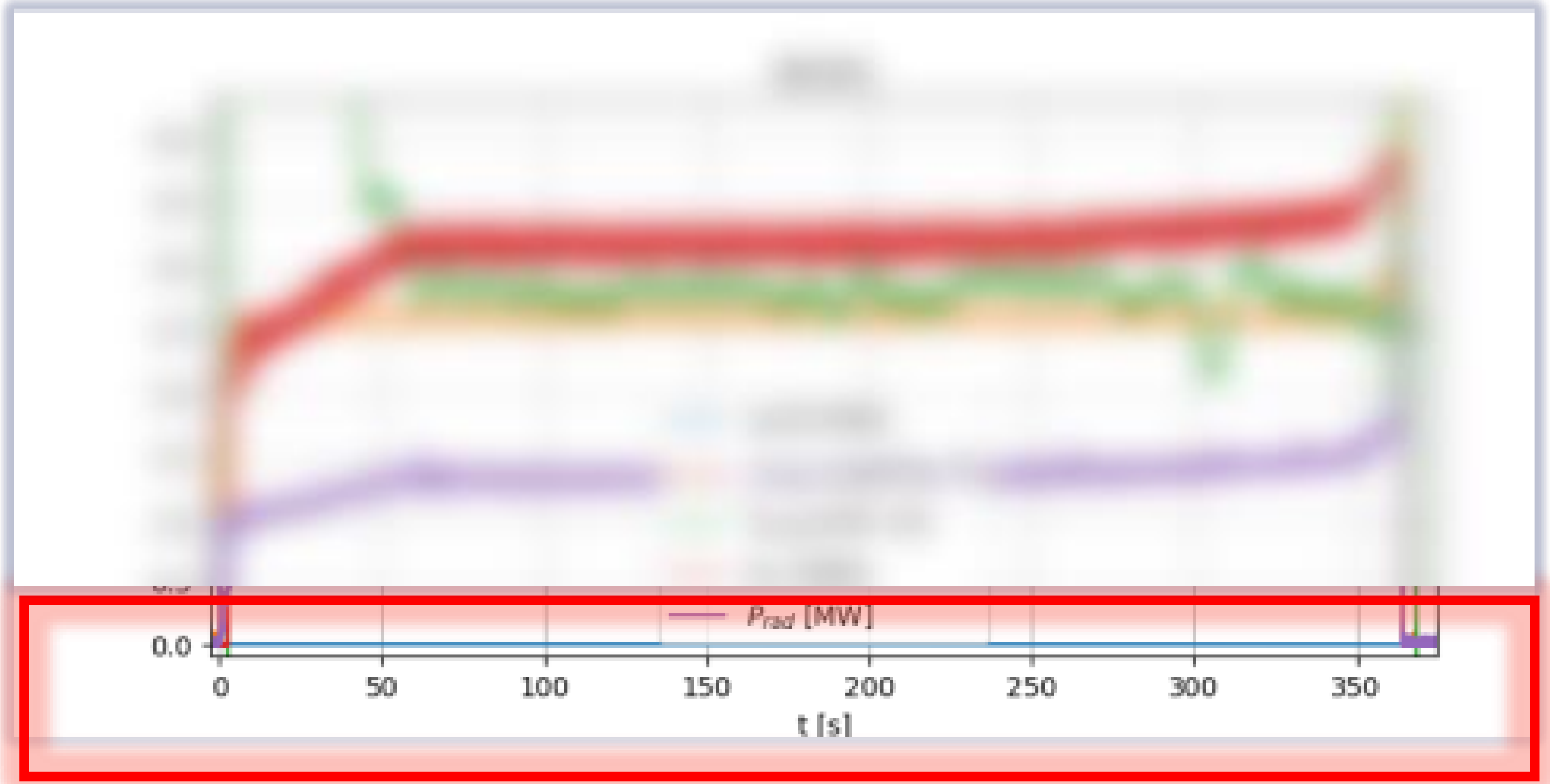
Flexible magnetic configuration

- Superconducting tokamak
- Actively cooled Plasma Facing Components

Long pulse operation (1000 s)
Means a lot of data

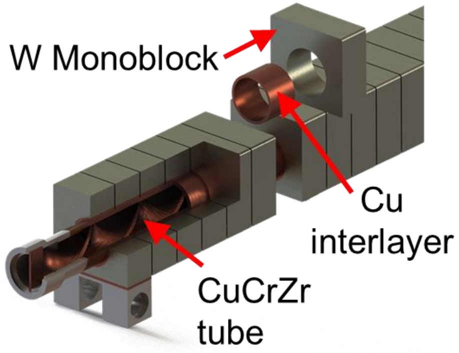
WEST – the recent record 2024/03/08

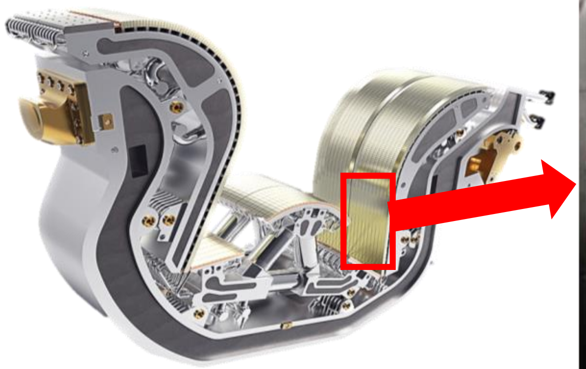
364s (6min) and 1,15GJ of Lower Hybrid Heating

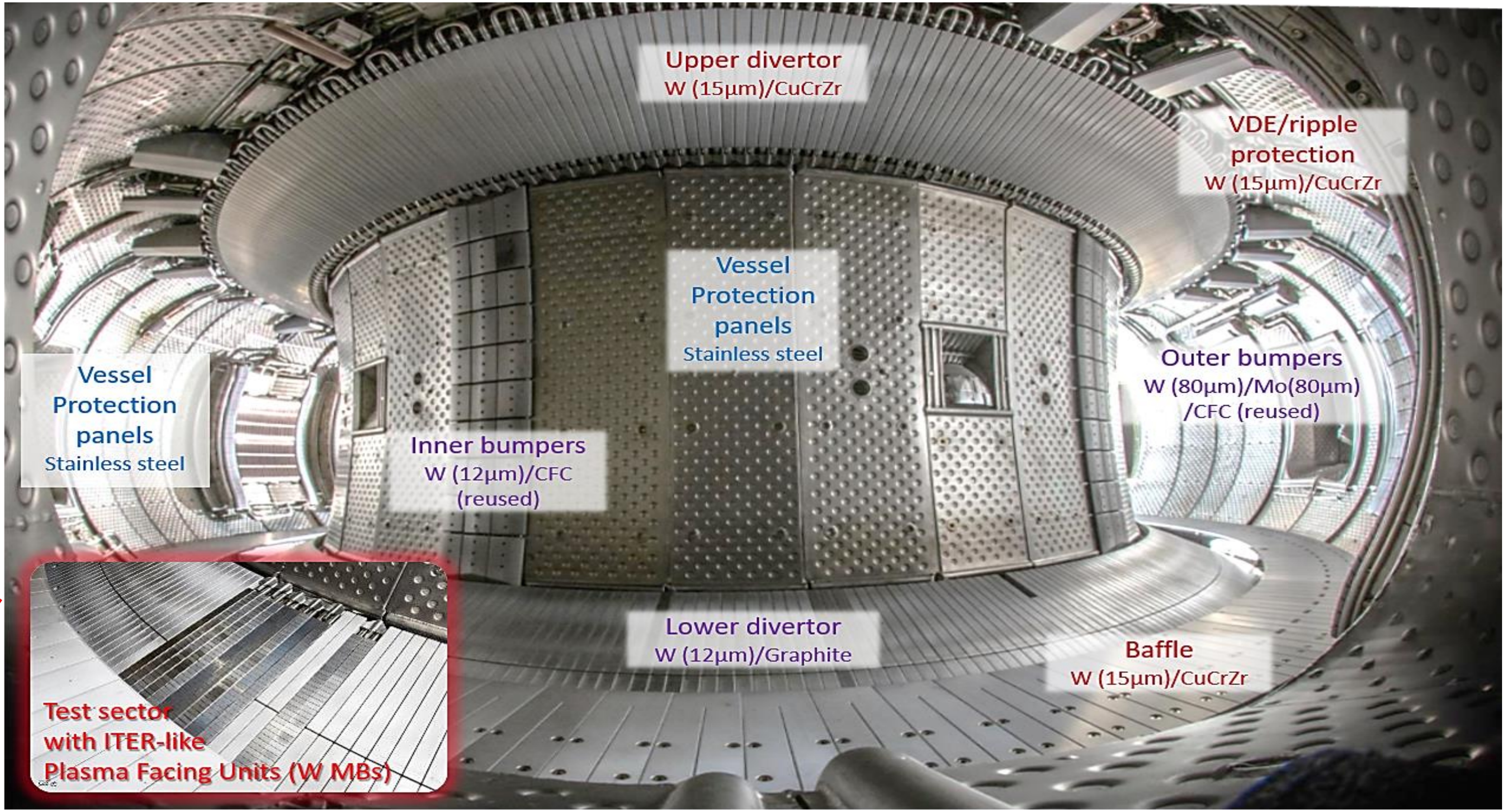


Inside WEST : a full W environment

ITER divertor







(W coatings on CuCrZr/CFC, W bulk)

The Tungsten's benefits & drawbacks

Highest melting point of any metal and maintains strength at high temps

Do not **retain Tritium** > no activation !

Gradually (but slightly) **eroded** by the plasma

→ Damage induced

→ Impacts plasma performance even with a small amount of W (Cw 0,01%)

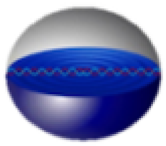
>> the Tungsten density is an important measurement to achieve

2. The Tungsten ratio measurement

Just a little bit of physics

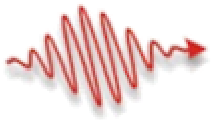
A little bit of physics

particle



$E=mc^2$

photon

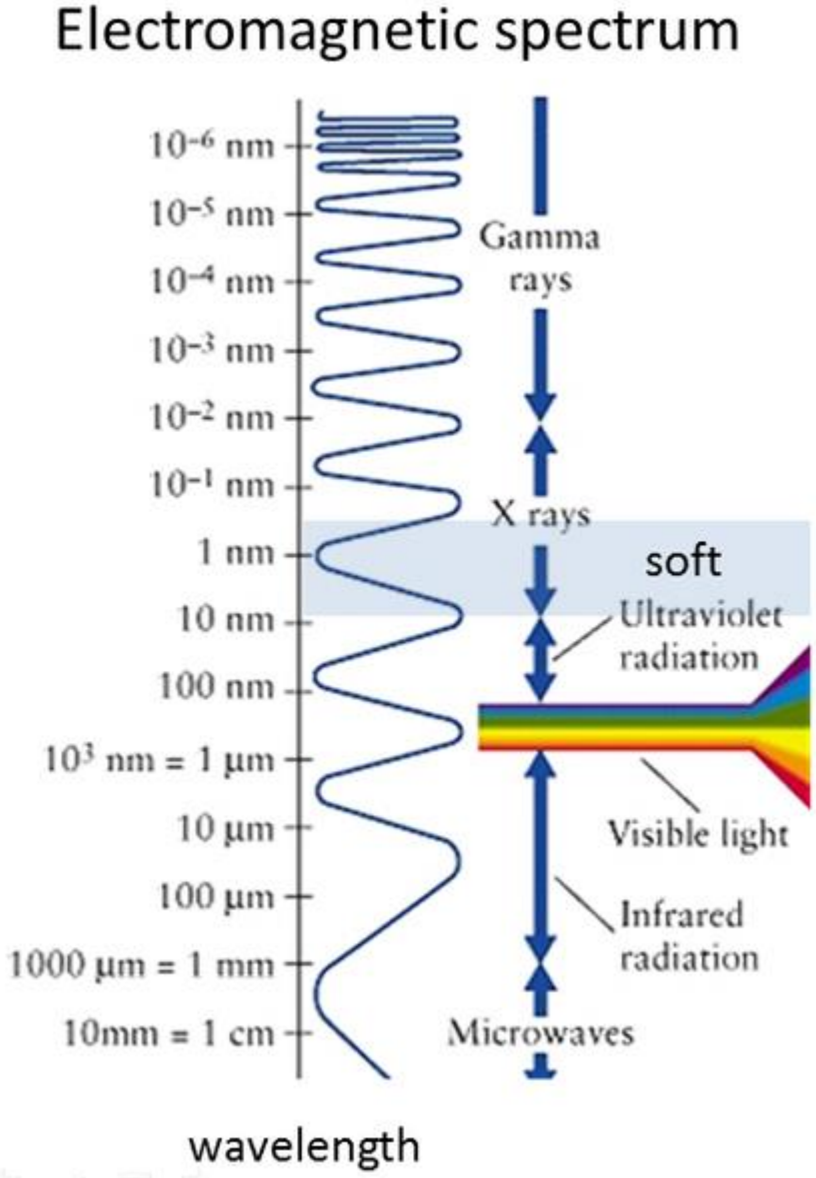


$E=hf$

Tungsten dust into the plasma emits an electromagnetic radiation made up of photons : a “X ray” radiation.

Each radiation has a **specific wavelength** (and **energy** which is inversely proportional).

For tungsten some interesting radiation have a wavelength in between 100ev to 15kev >> **SOFT X RAY**



A little bit of physic : the general case

Tungsten emissivity general equation is :

Fractional abundance

Free-free emissivity (Bremsstrahlung)

Free-bound emissivity (recombination)

Bound-bound emissivity (line emission)

$$\varepsilon_W(h\nu, T_e, n_e, \vec{\Gamma}_{W,q}) = n_e n_W \sum_{i=0}^{Z_W} f_{W,q}(T_e, n_e, \vec{\Gamma}_{W,q}).\left[\epsilon_{S,i}^{f-f}(T_e, n_e, h\nu) + \epsilon_{S,i}^{f-b}(T_e, n_e, h\nu) + \epsilon_{S,i}^{b-b}(T_e, n_e, h\nu)\right]$$

Cooling factor

$$L_W(h\nu, T_e, n_e, \vec{\Gamma}_{W,q})$$

A little bit of physic (just a few last)

$$\varepsilon_W(h\nu, T_e, n_e, \vec{\Gamma}_{W,q}) = n_e n_W L_W(h\nu, T_e, n_e, \vec{\Gamma}_{W,q})$$

① We ignore the transport term $\vec{\Gamma}_{W,q}$ in the case of high temperature and high atomic number Z=74

$$\varepsilon_W(h\nu, T_e) = n_e n_W L_W(h\nu, T_e)$$

② We assume plasma is emitting only W impurities (even H is ignored to simplify here)

$$\varepsilon_{SXR} = n_e n_W L_W(h\nu, T_e)$$

Electronic Density n_e is measured by interferopolarymetry

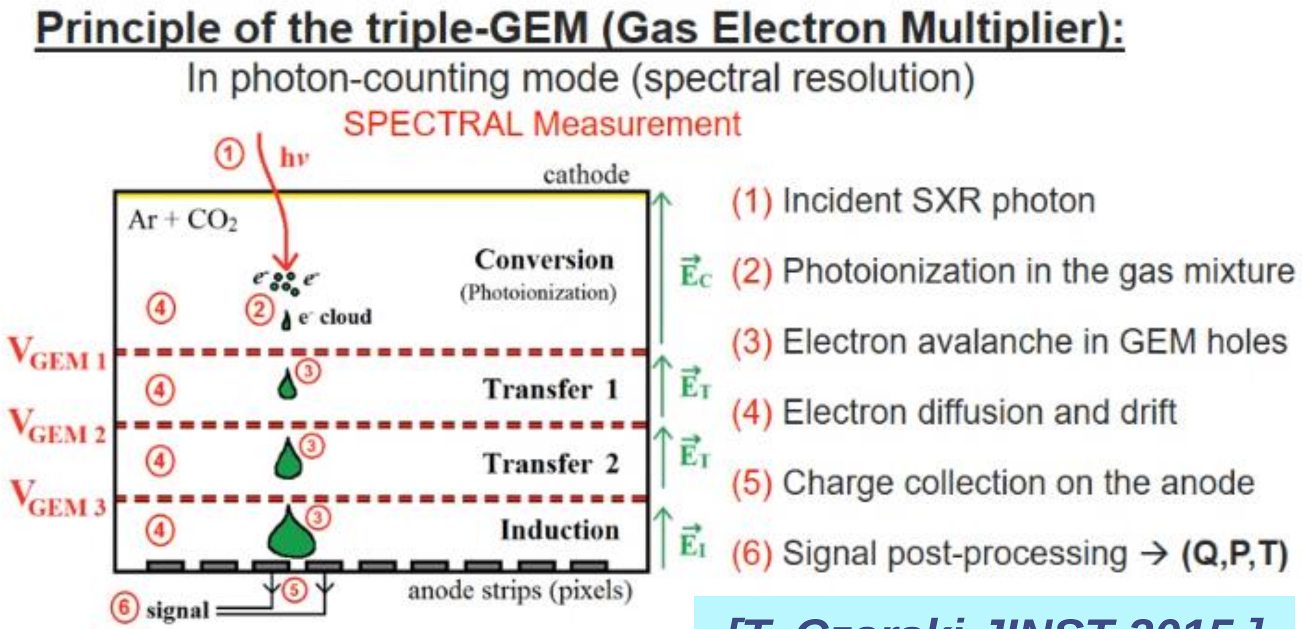
Cooling factor $L_W(h\nu, Te)$ is tabulated

→ **Emissivity has to be measured**

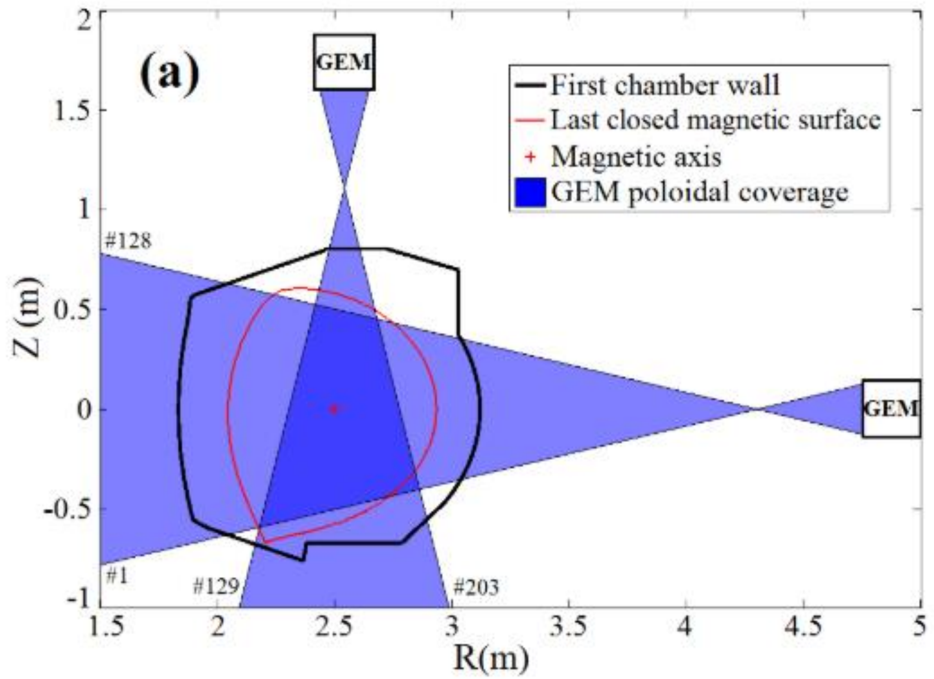
Tungsten density:

$$n_W \simeq \frac{\varepsilon_{SXR}}{n_e . L_W(h\nu, Te)}$$

Detection principles



[T. Czarski JINST 2015]



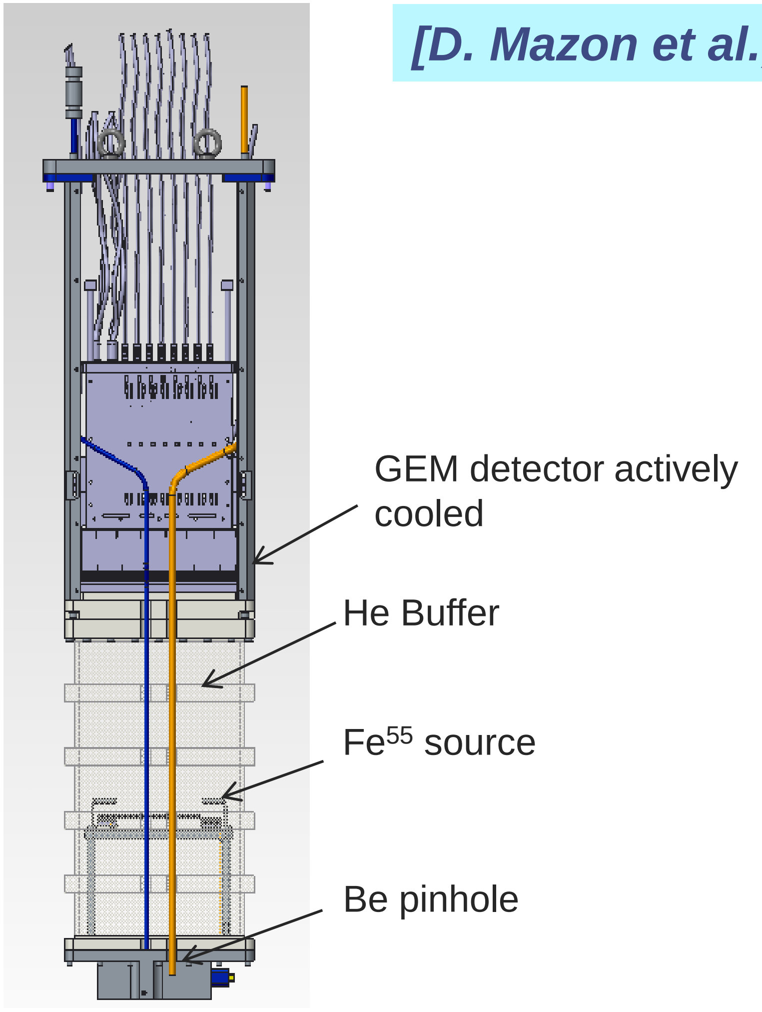
An **electric charge** is **measured** and **photon energy** is deduced by **computation**

This gave an integrated measurement on a line of sight

Thanks to tomographic inversion we deduce **emissivity radially**

The real instrument

Vertical Camera



[D. Mazon et al., JINST 2017]

The instrument contents :

- the **detector** which has so stay at a certain distance of the high temperature
- An **helium buffer** : that helps photon to reach the detector
- An inner **Fe55 source** : a known source to calibrate
- A **Be pinhole** : to limit the amount of photon

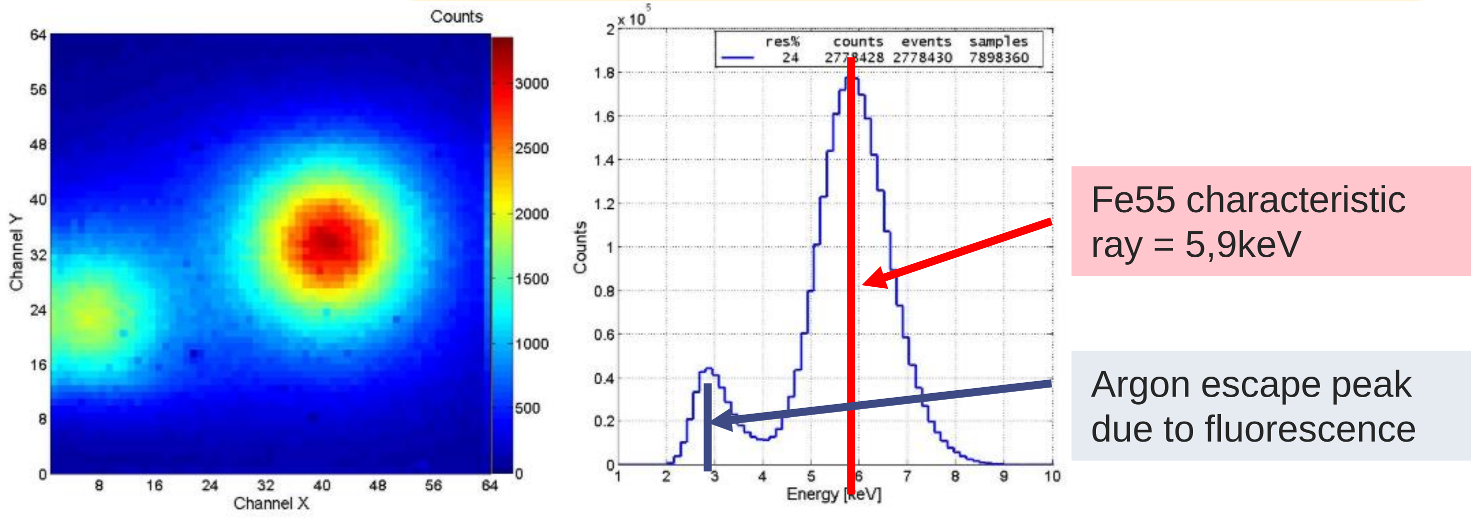


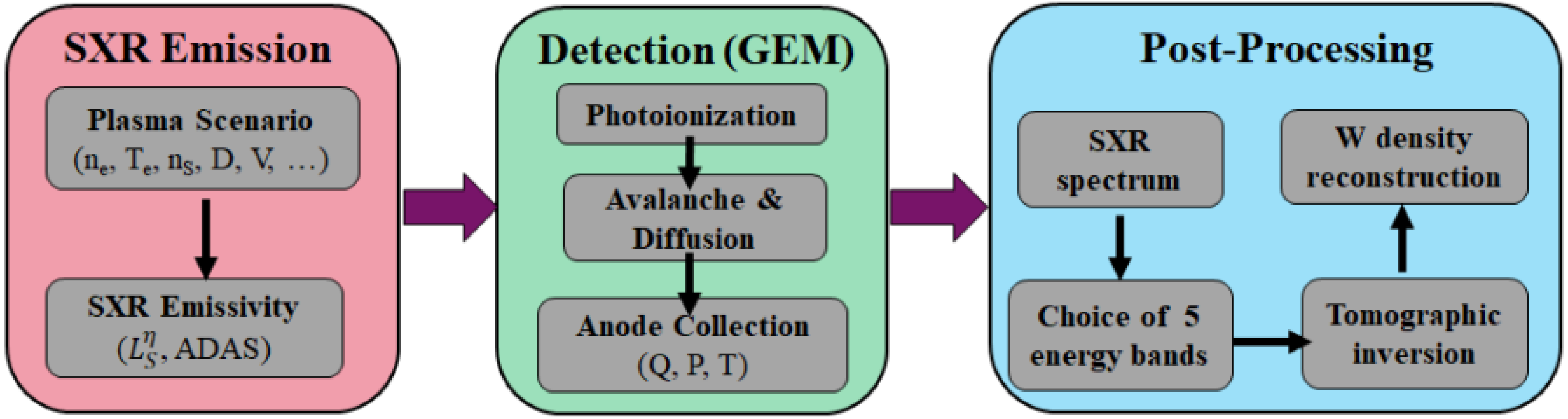
Figure 9. The GEM detector characteristics for two ^{55}Fe reference sources with different intensity for *XY* array structure: planar distribution (left), energy spectra (right).

Data produced

The GEM instrument is a **photon counter** .. It produces 100Gb for a 300s pulse

50 data acquisition unit @WEST >> 5T per pulse ..

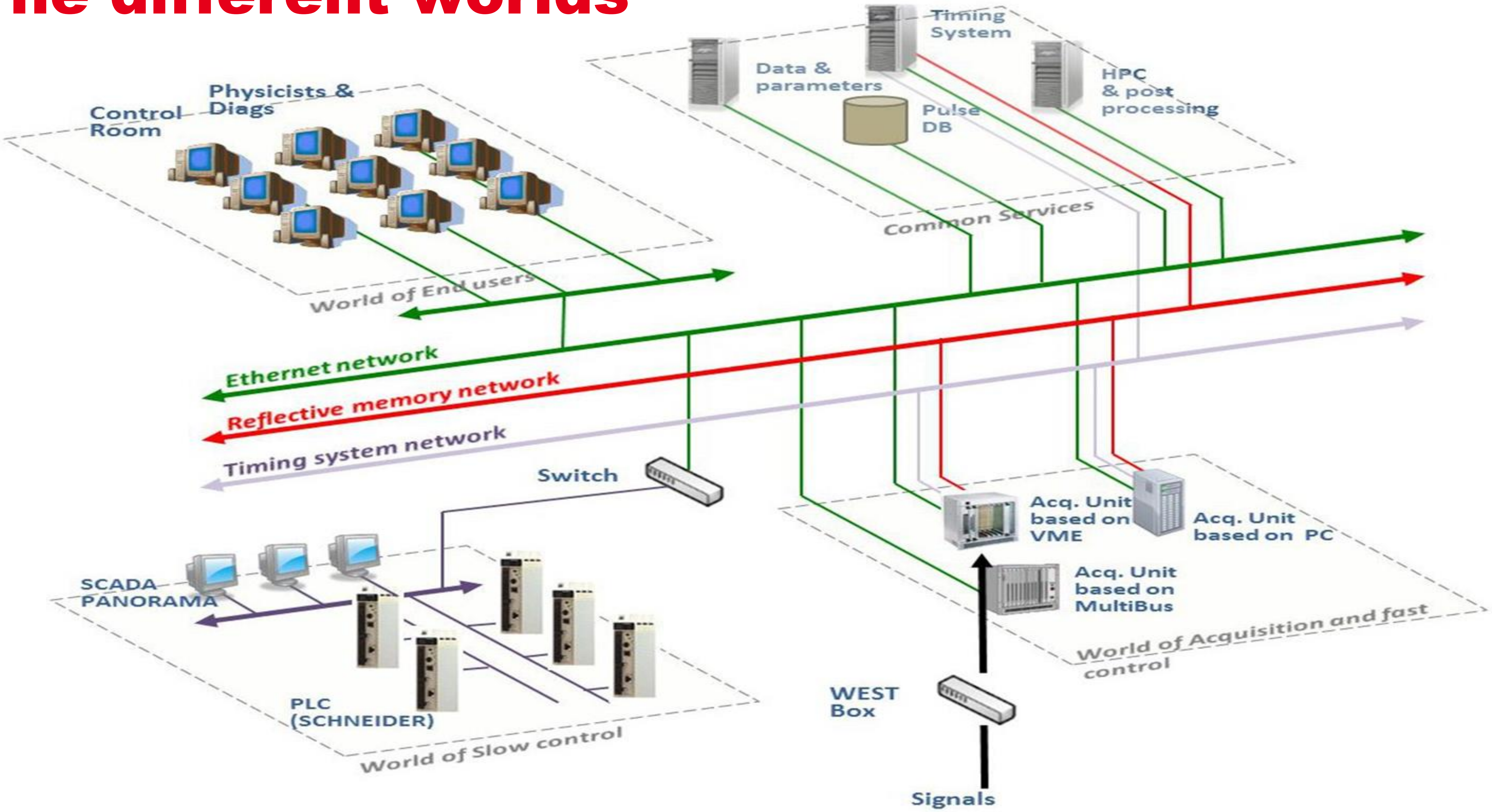
But the needed value is actually “only” the Tungsten density, which is obtain by **post-processing**.



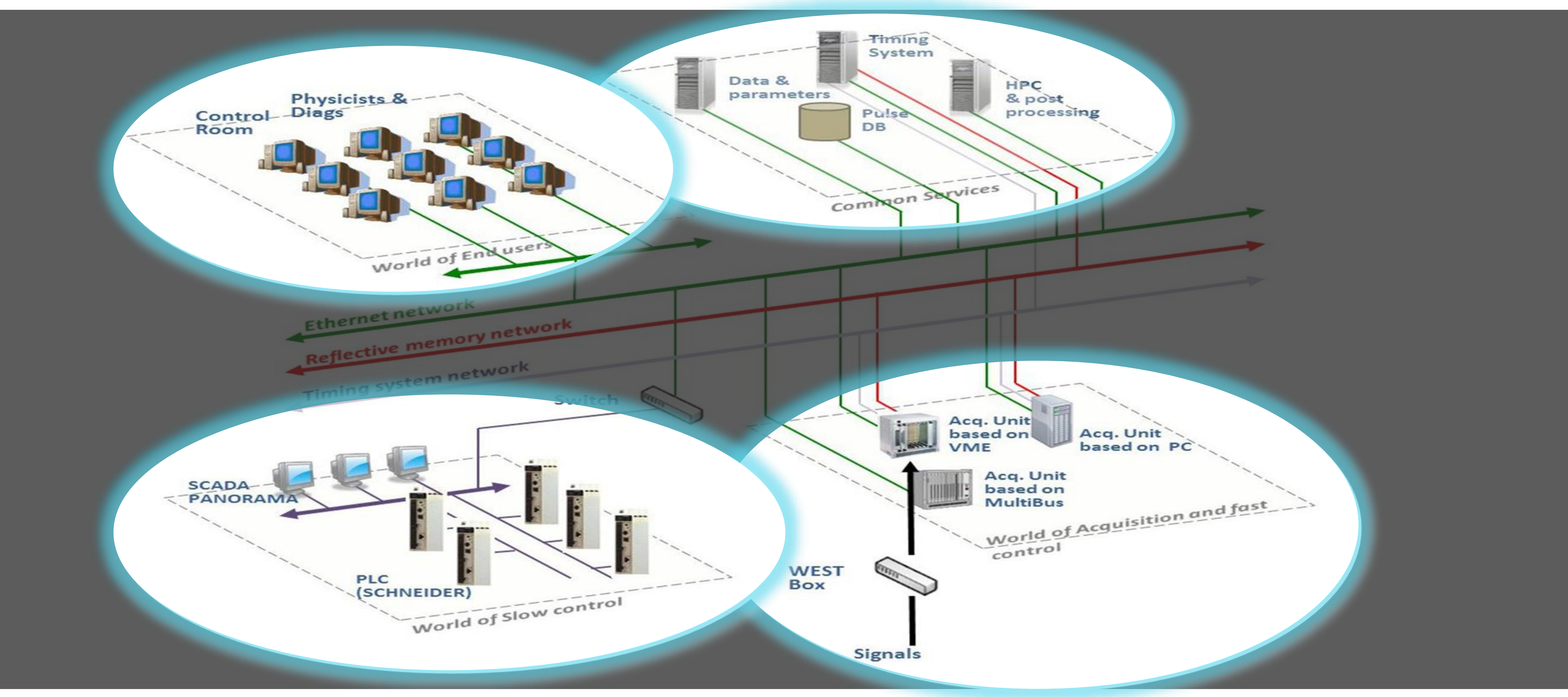
3. The WEST Acquisition infrastructure

An effective one

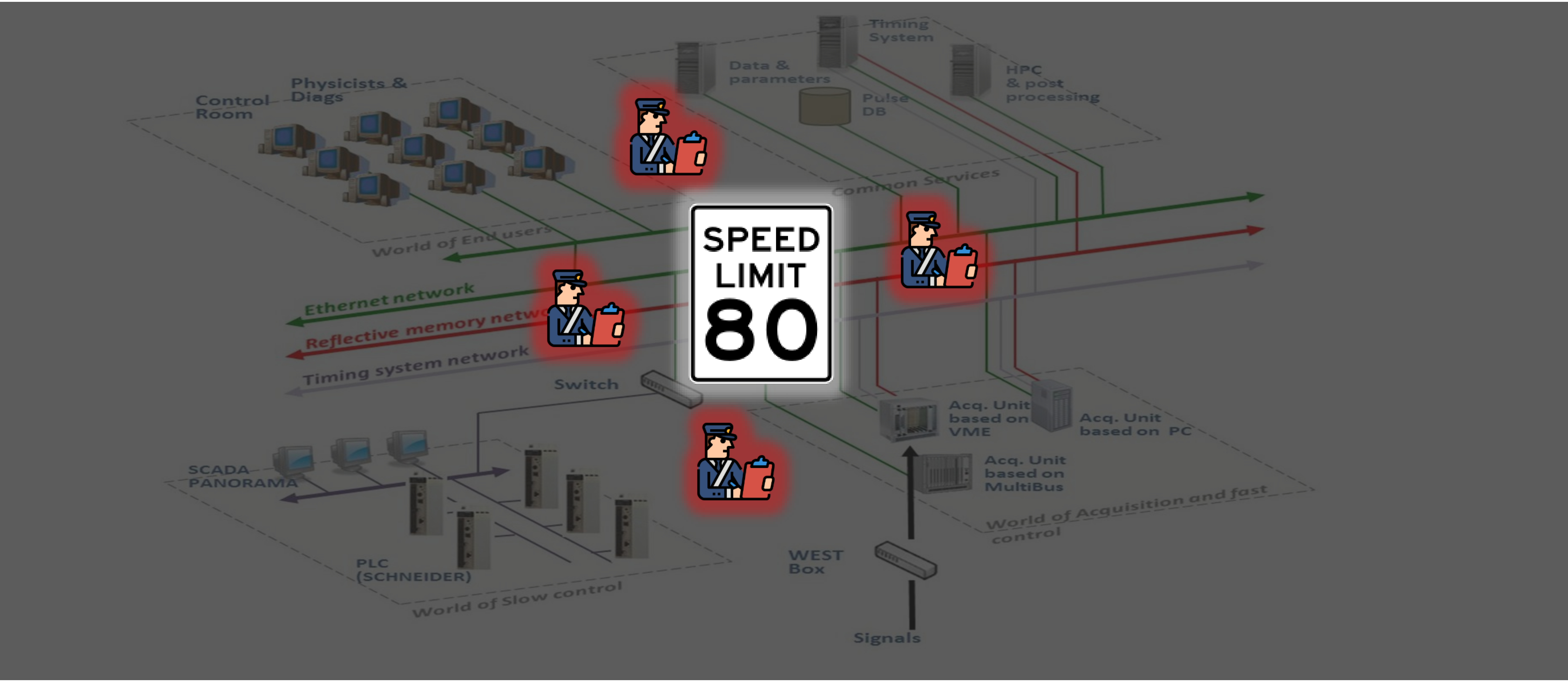
The different worlds



The Acquisition World

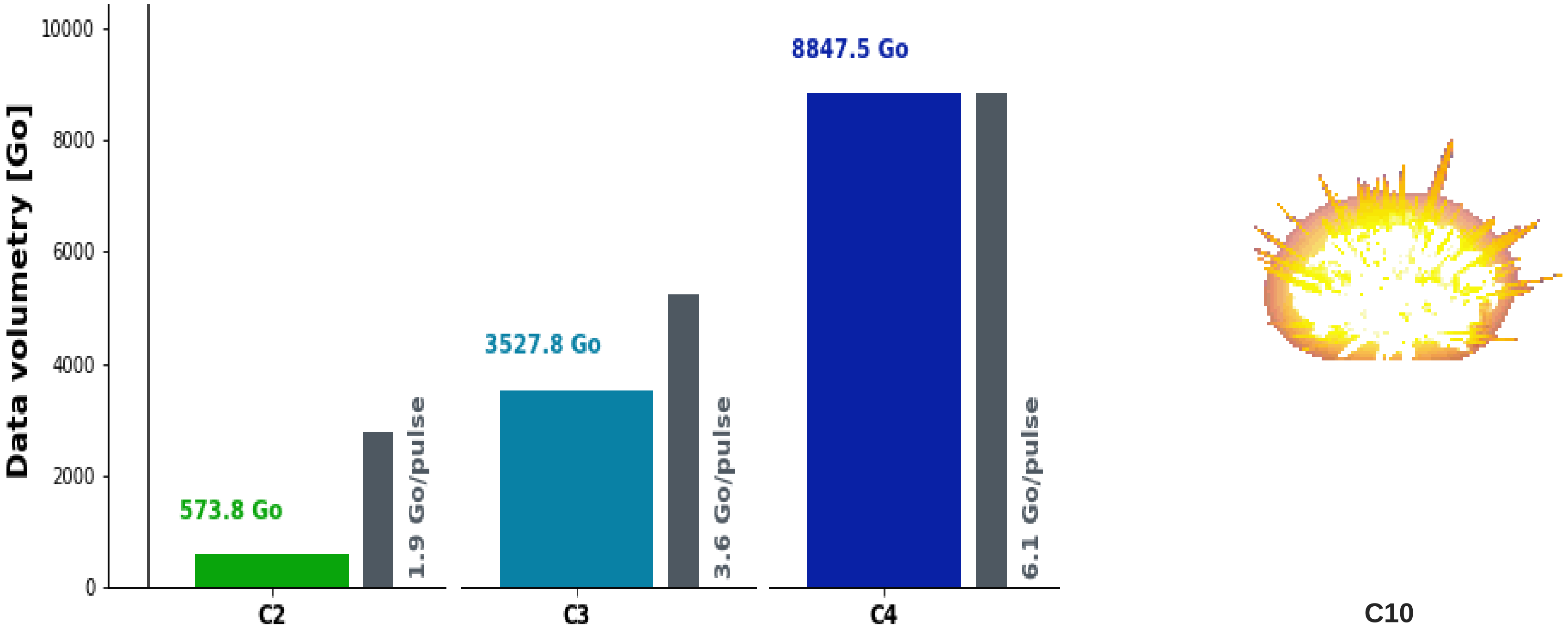


The world of .. security



What is the problem ?

Data are growing ~~(much too)~~ fast .. Faster than the network



The problem

Network link are not easy to change :

- evolutions are **limited**
- it’s highly **expensive**

Acquisition network remains a IPV4 network .. That means .. Only 255 devices possibles

4. The modern acquisition method

How to take into account the new needs

The requirements

01

IMPORTANT AMOUNT OF LOCAL DISK

SSD support high magnetic fields .. Allow to avoid useless and time consuming data transfert

02

A PRIVATE NETWORK

To allow multiple actors sharing data without impacting the others acquisition units.

03

USE & SHARE STANDARD

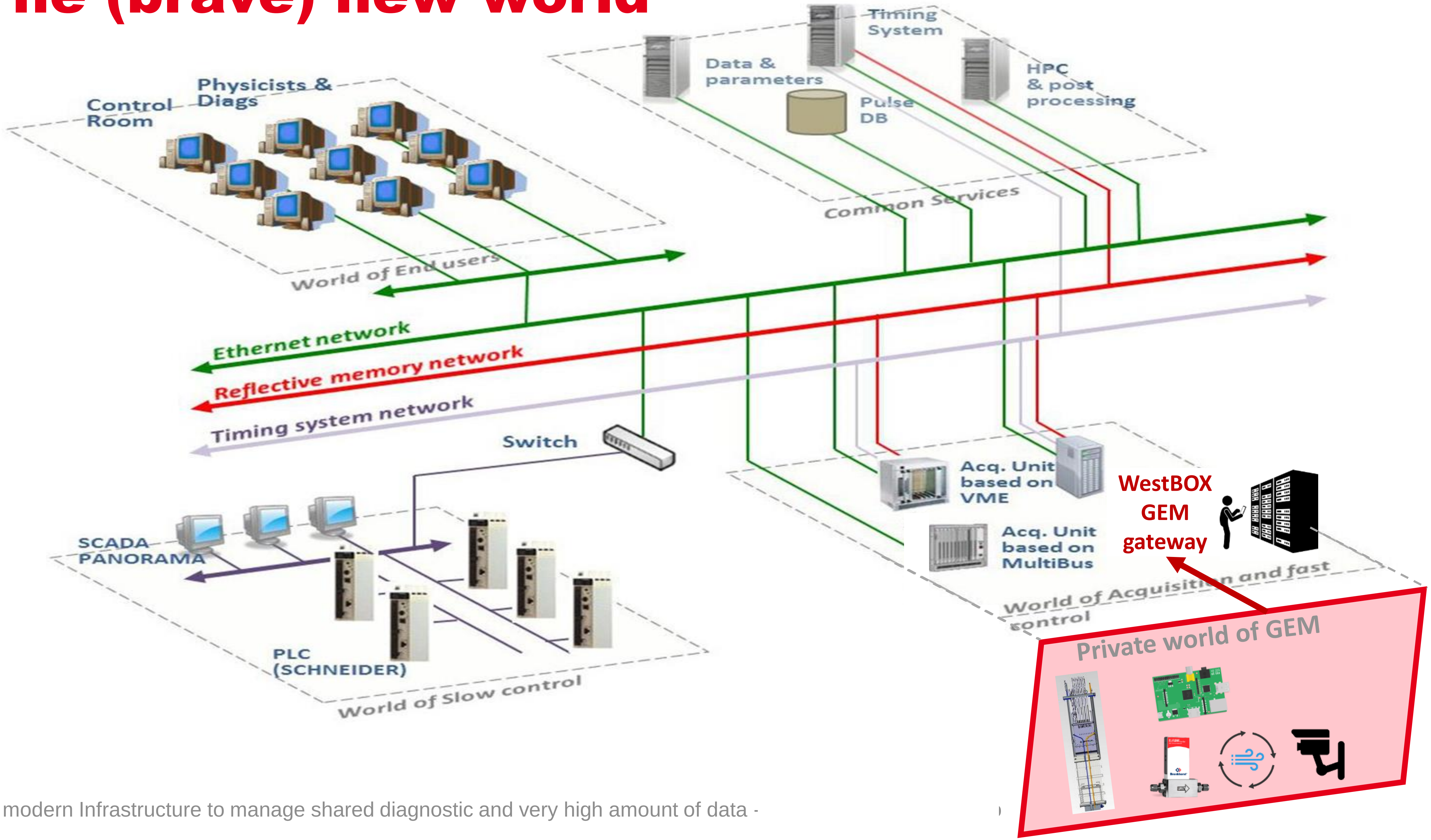
A lot of requirements are common : pulse sequence synchronization, parameter readings, datafile saving..

04

NO NEED LICENCES

Also a need of cost effectivness but mainly for long terme maintenance purpose..

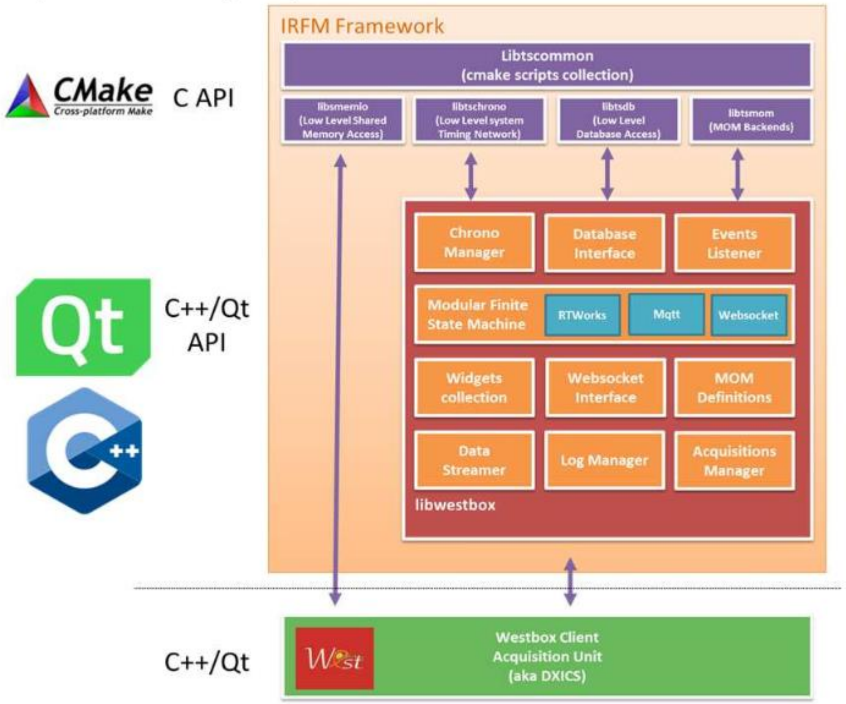
The (brave) new world



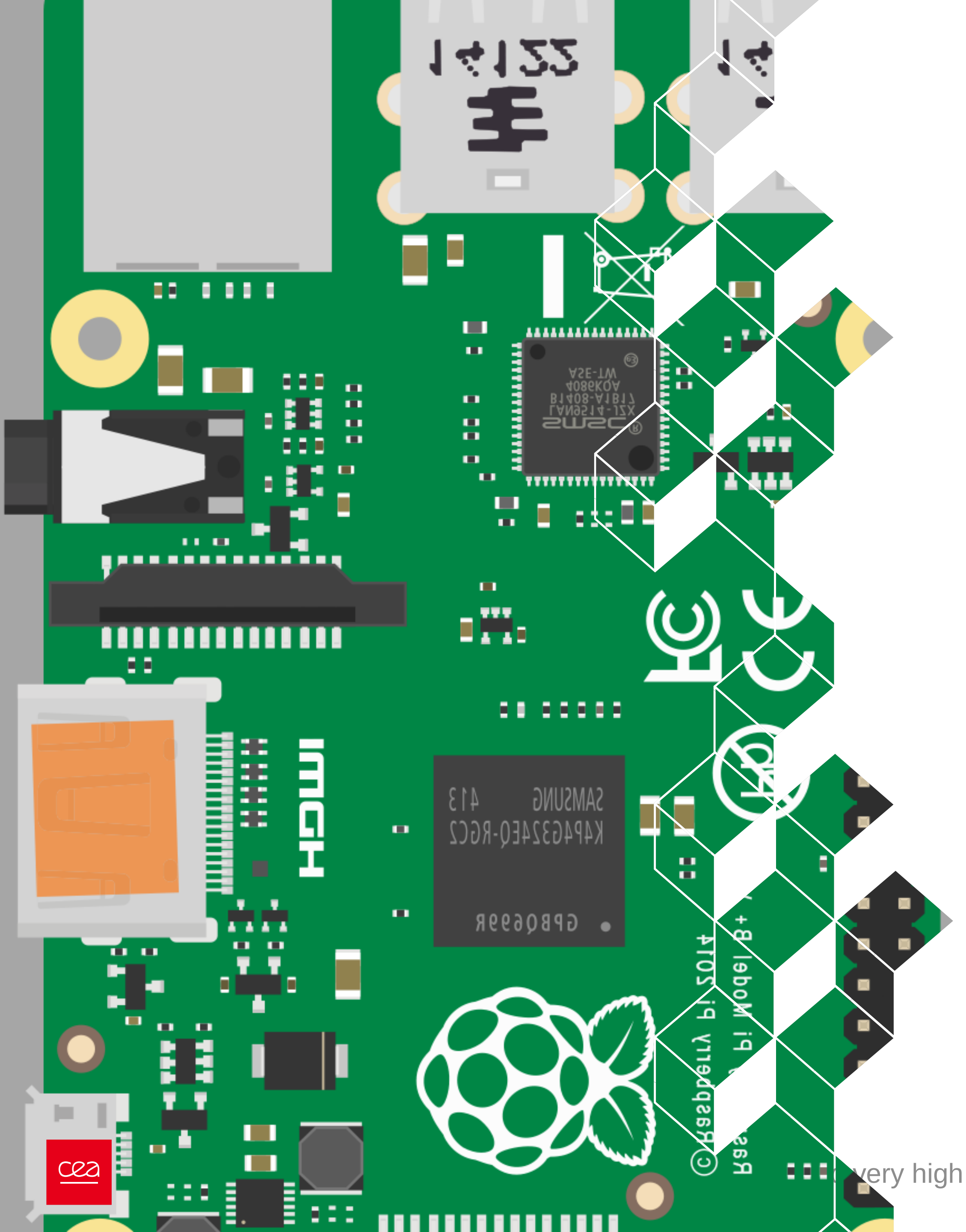
The WESTBOX gateway

A specialized **advanced** computer called « Westbox » acts as **gateway** between GEM network and acquisition network with **65Tb** of SSD available (650Pulses → ~6 weeks)

WESTBOXES are synchronized with Pulse experiments by an expert system called « supervisor »



Overview of the Qt based Westbox infrastructure



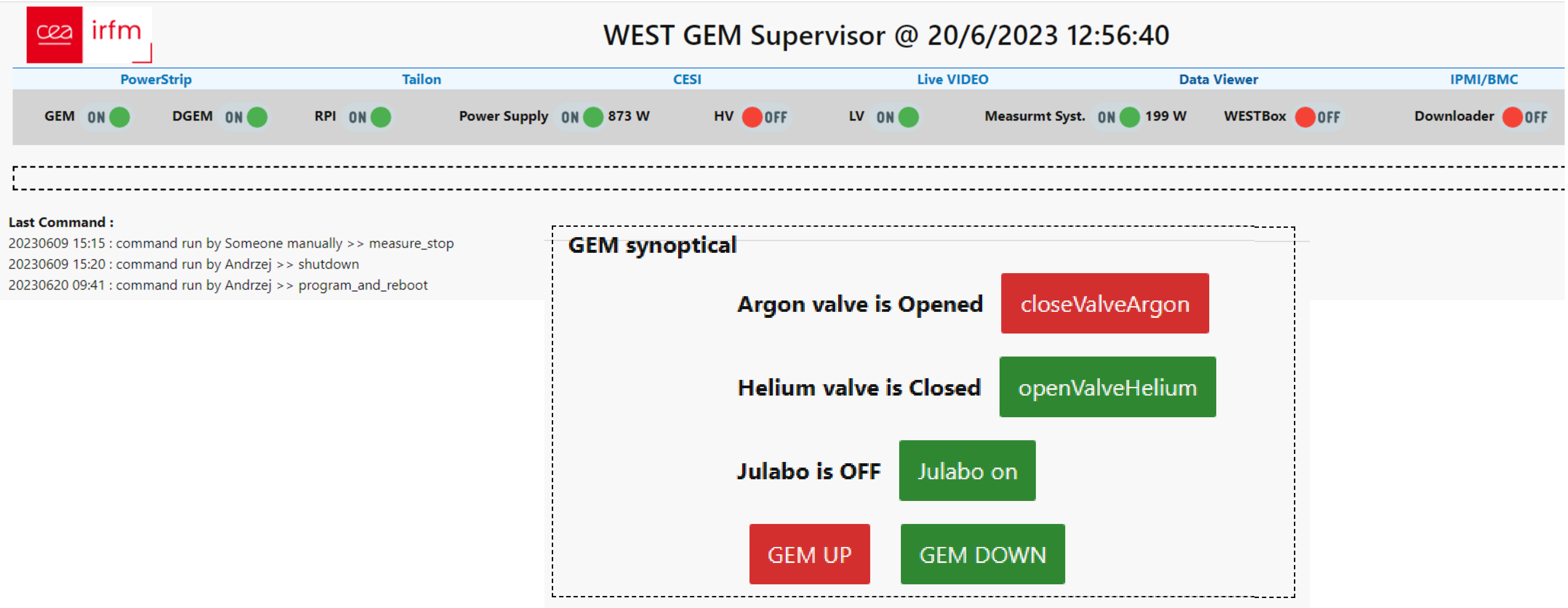
The manager

A raspberry Pi has been chosen to manage the different device

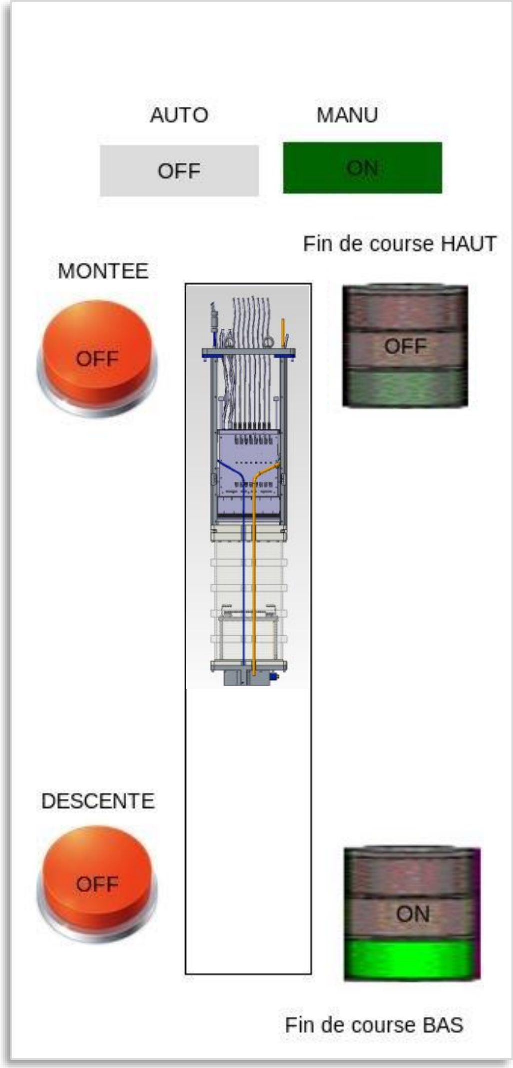
- **Backup** is easy
- Robust
- Lite and simple to program : bash/Php
- Cost effective

Autonomous & dedicated remote powerstrip

First function of the manager, turning on/off the different units thanks to a **dedicated HTML interface**.



Autonomous & dedicated slow controller



A **basic schema**: lift up or down by actuating a motor

As there is no **side effect** on other system, we are able to manage locally.

Motor are managed

with a ABB driver

Autonomous & dedicated Cooling system

basic Schema : turn on or off the cooler for electronic boards.

No side effect if GEM detector is in trouble.

Manageable through **RS232 communication** (converted in USB on raspberry)

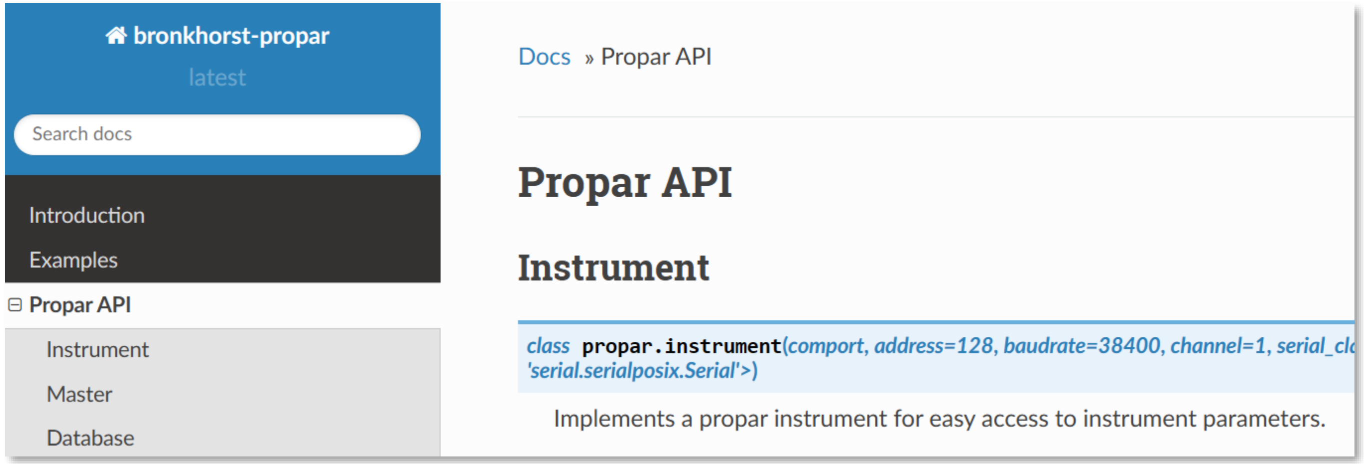
Autonomous & dedicated Gas injection & measurement

The GEM requires a precise gas injection to retrieve and manage :

the **helium pressure** in the buffer Helium is needed for the photon not to be absorbed and to reach the detector

The **argon pressure** in the detector : argon is needed for the photon to generate an electron

→ **Impact on the computation**

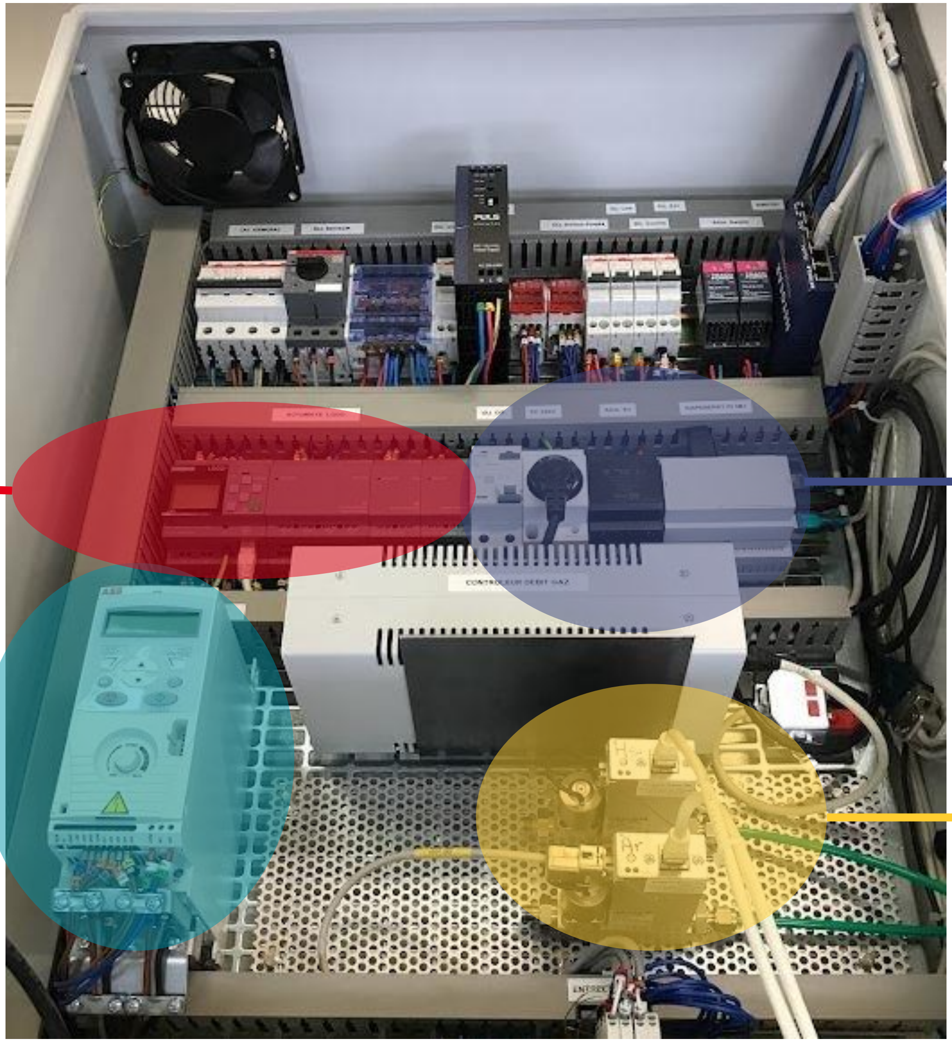


Autonomous & dedicated cabinet

[D. Guibert et al., SOFT 2024]

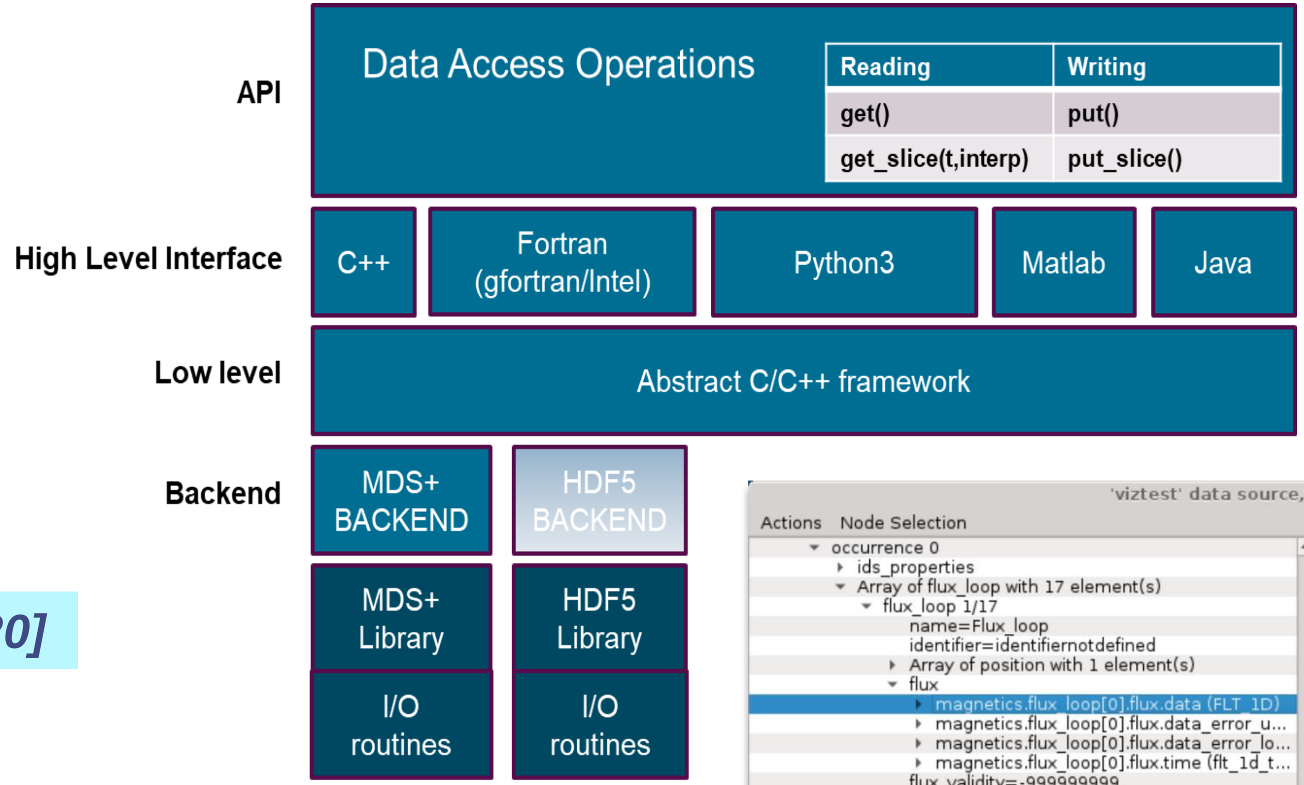
Compact design of the cabinet

Entirely **exportable** for laboratory test

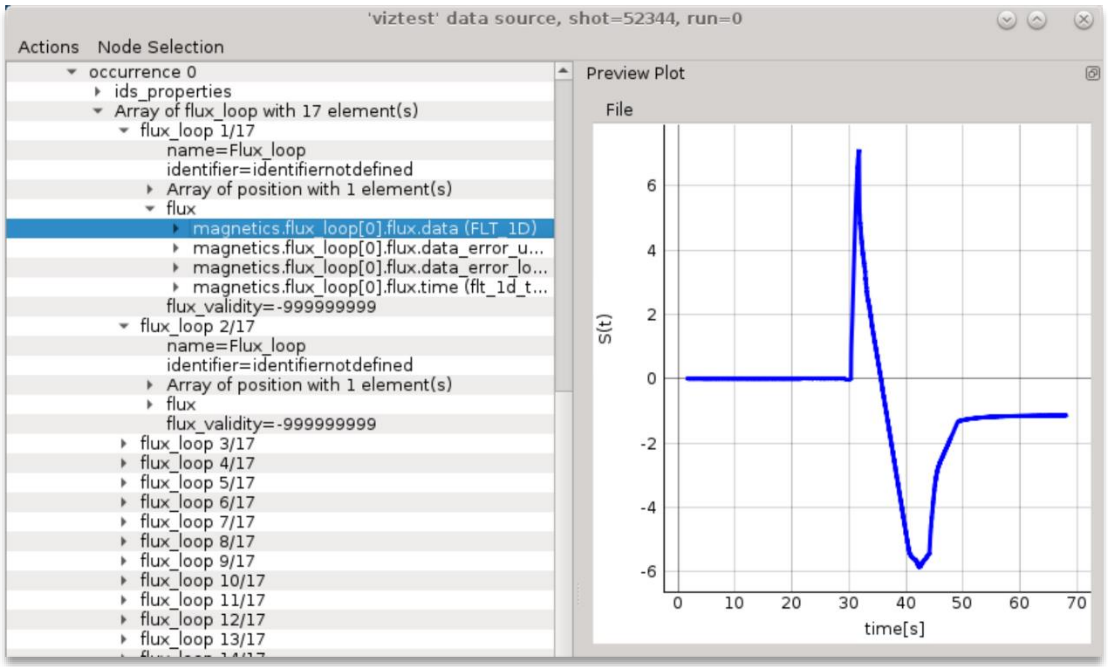


Data automatically produced in IMAS Format

Post treatment are launched as soon as data are available and produce data directly in IMAS format & database.



[L. Fleury et al., SOFT 2020]



IMAS = **I**TER **I**ntegrated **M**odelling and **A**nalysis **S**uite

5. Conclusion

Still some works to do

Results and plans

The modern acquisition methods implemented has succeeded taking into account different « standard » needs (synchronization, data storage, post-processing)

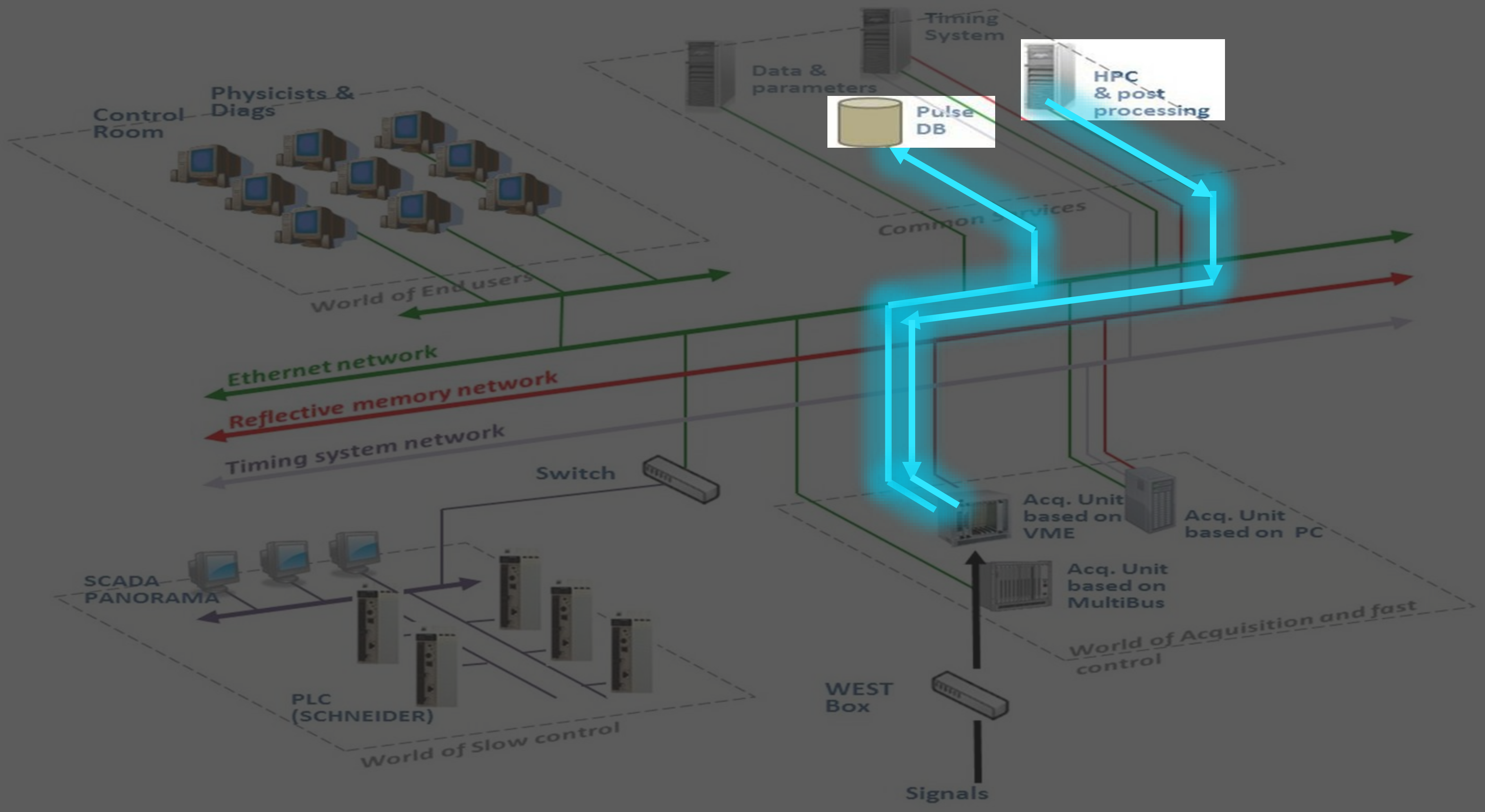
For GEM purpose it has shown his benefits : the acquisition is now **automatized**.

Horizontal camera to install for improve precision

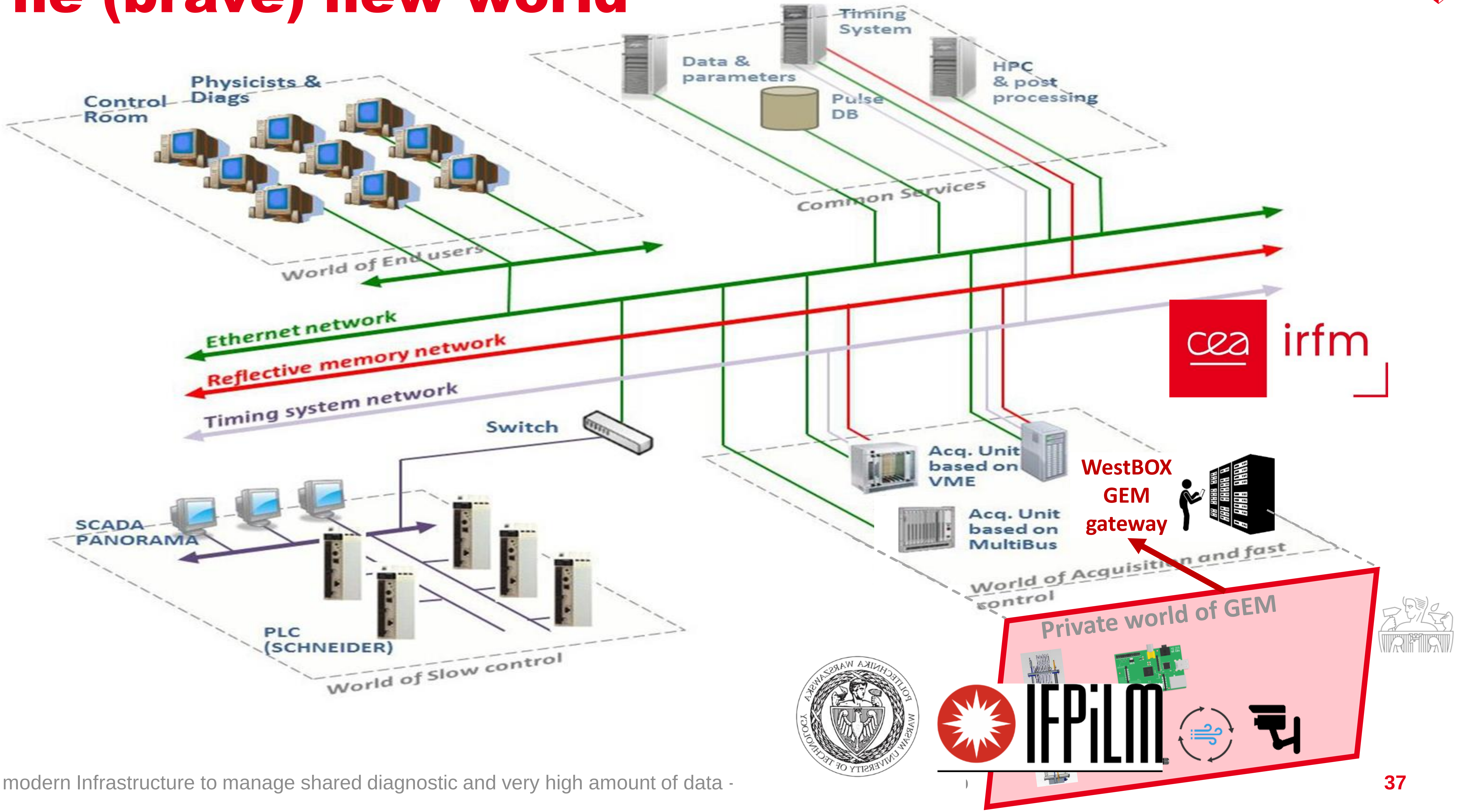
Next step will be to produce data on the **real-time network** (means at least in milliseconds) in order to have the tungsten density live.

Obrigado ! Thank you ! Merci

The problem -

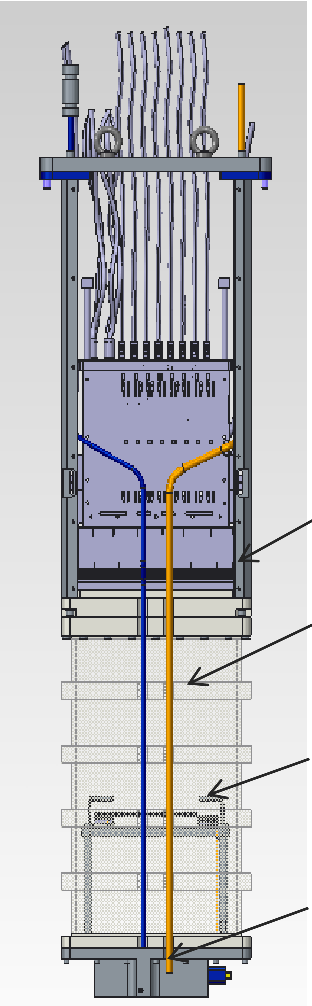

Timing System
Data & parameters
HPC & post processing
Pulse DB
Physicists & Diags
Control Room
Common Services
World of End users
Ethernet network
Reflective memory network
Timing system network
Switch
Acq. Unit based on VME
Acq. Unit based on PC
Acq. Unit based on MultiBus
SCADA PANORAMA
PLC (SCHNEIDER)
World of Slow control
WEST Box
World of Acquisition and fast control
Signals

The (brave) new world



Vertical Camera

[D. Mazon et al., JINST 2017]



GEM detector

He Buffer

Fe^{55} source

Be pinhole

→

A little bit of physic (just a few last)

General equation for emissivity of a given **S source** (which have different ions **Zs**) source is :

Fractional abundance → $f_{S,q}$; Free-free emissivity (Bremsstrahlung); Free-bound emissivity (recombination); Bound-bound emissivity (line emission)

$$\varepsilon_S(h\nu, T_e, n_e, \vec{\Gamma}_{S,q}) = n_e n_S \sum_{i=0}^{Z_S} f_{S,q}(T_e, n_e, \vec{\Gamma}_{S,q}).\left[\epsilon_{S,i}^{f-f}(T_e, n_e, h\nu) + \epsilon_{S,i}^{f-b}(T_e, n_e, h\nu) + \epsilon_{S,i}^{b-b}(T_e, n_e, h\nu)\right]$$

Cooling factor

$L_S(h\nu, T_e, n_e, \vec{\Gamma}_{S,q})$ → $L_W(h\nu, T_e)$ → Lw tabulated

We ignore the transport term in the case of high temperature and high atomic number Z

We assume plasma is emitting only W impurities (we ignore even H)

Tungsten density:

$$n_W \simeq \frac{\varepsilon_{SXR}}{n_e.L_W}$$

Electronic Density Ne is measured by interferopolarymetry

Cooling factor of the tungsten Lw is tabulated

→ Emissivity has to be measured