

M4CAST

an emerging national collaborative effort for IA applications to accelerators physics and technologies

by Adnan GHRIBI *on behalf of the M4CAST collaboration* (GANIL)
on date de la pres

» **Layout**

Background

Structure

Resources

Short term plans

Ongoing work

Conclusion

Background

Structure

Resources

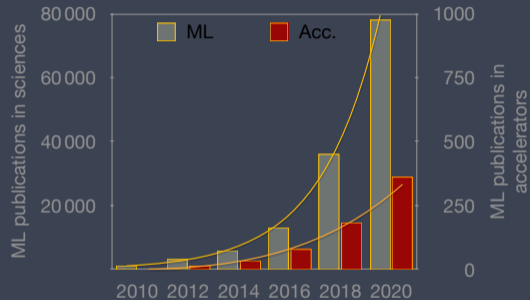
Short term plans

Ongoing work

Conclusion

» Background

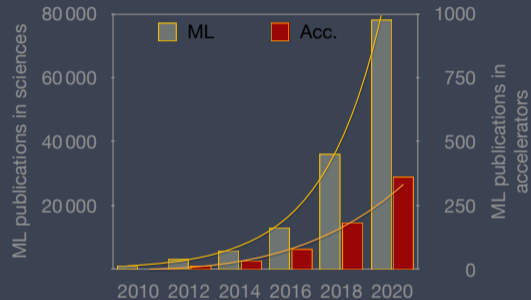
- * Artificial Intelligence has penetrated almost all scientific disciplines ;
- * For accelerator physics, an important dynamic has risen in the US ;
Opportunities in Machine Learning for Particle Accelerators, A. Edelen et al.
- * Others are slowly merging in France and in Europe ;
- * Data and calculation infrastructures also follow a fast development pace.



Number of published ML articles in sciences and for accelerators - ArXiv + Google Scholar.

» Background

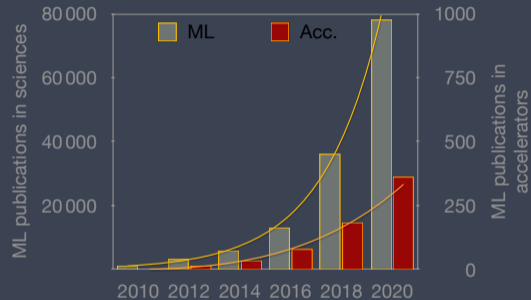
- * Artificial Intelligence has penetrated almost all scientific disciplines ;
- * For accelerator physics, an important dynamic has risen in the US ;
Opportunities in Machine Learning for Particle Accelerators, A. Edelen et al.
- * Others are slowly merging in France and in Europe ;
- * Data and calculation infrastructures also follow a fast development pace.



Number of published ML articles in sciences and for accelerators - ArXiv + Google Scholar.

» Background

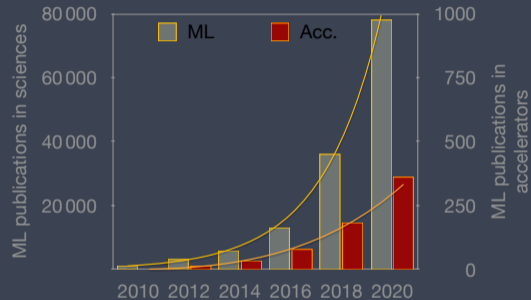
- * Artificial Intelligence has penetrated almost all scientific disciplines ;
- * For accelerator physics, an important dynamic has risen in the US ;
Opportunities in Machine Learning for Particle Accelerators, A. Edelen et al.
- * **Others are slowly merging in France and in Europe ;**
- * Data and calculation infrastructures also follow a fast development pace.



Number of published ML articles in sciences and for accelerators - ArXiv + Google Scholar.

» Background

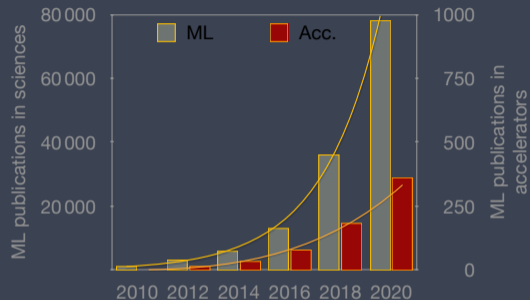
- * Artificial Intelligence has penetrated almost all scientific disciplines ;
- * For accelerator physics, an important dynamic has risen in the US ;
Opportunities in Machine Learning for Particle Accelerators, A. Edelen et al.
- * Others are slowly merging in France and in Europe ;
- * **Data and calculation infrastructures also follow a fast development pace.**



Number of published ML articles in sciences and for accelerators - ArXiv + Google Scholar.

» Background

- * Artificial Intelligence has penetrated almost all scientific disciplines ;
- * For accelerator physics, an important dynamic has risen in the US ;
Opportunities in Machine Learning for Particle Accelerators, A. Edelen et al.
- * Others are slowly merging in France and in Europe ;
- * Data and calculation infrastructures also follow a fast development pace.



Number of published ML articles in sciences and for accelerators - ArXiv + Google Scholar.

⇒ However, we lack synergy and organisation to foster these new developments.

Background

Structure

Resources

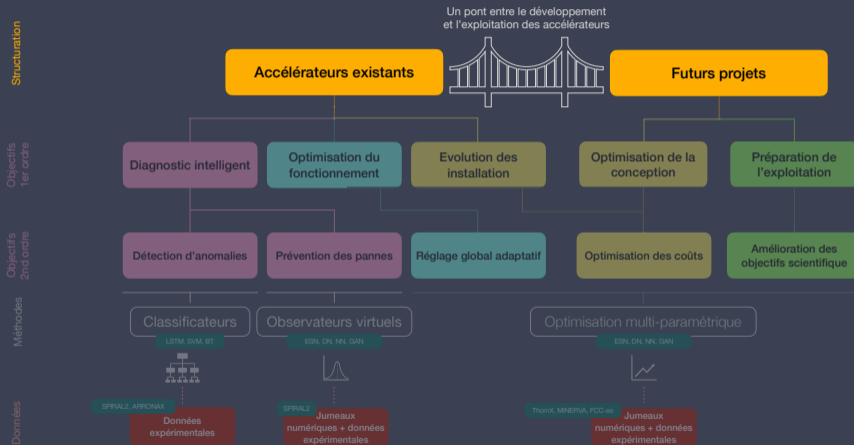
Short term plans

Ongoing work

Conclusion

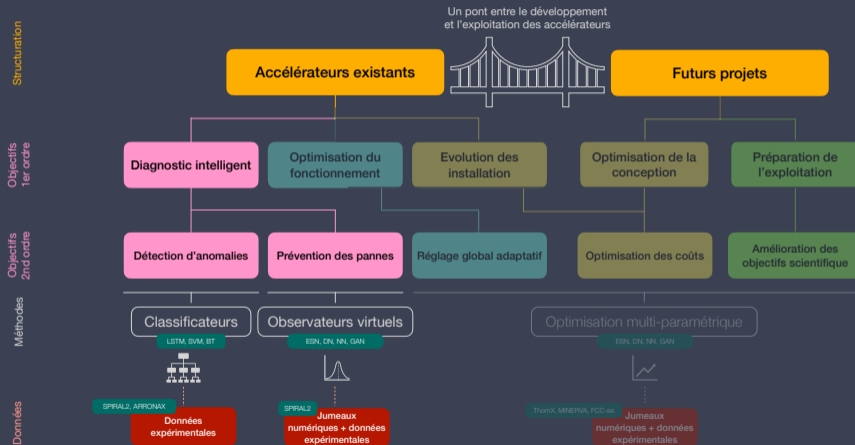
» Structure

Working groups



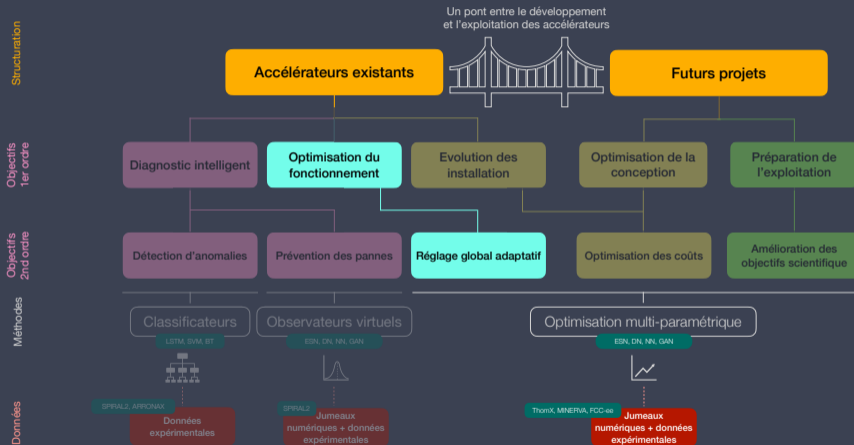
» Structure

Working groups



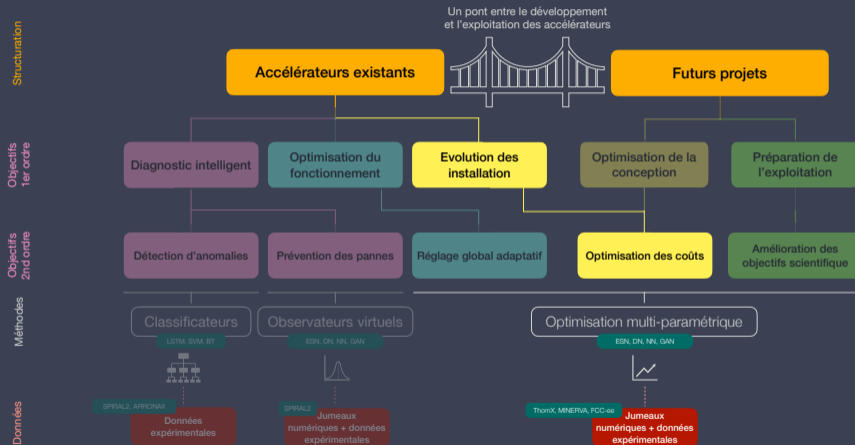
» Structure

Working groups



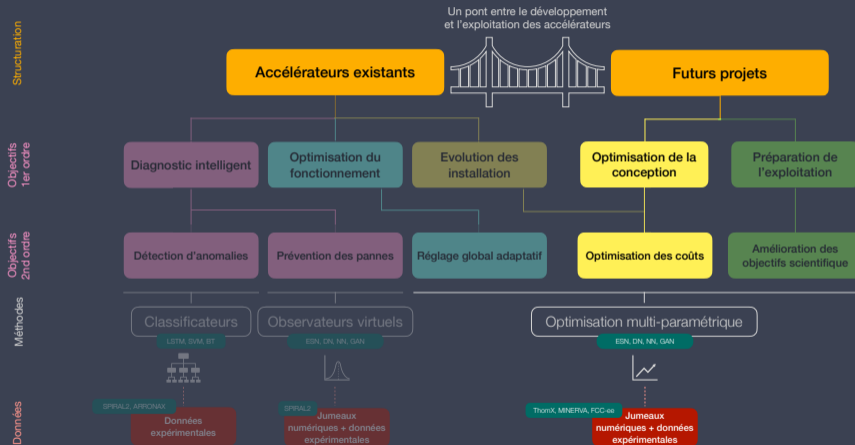
» Structure

Working groups



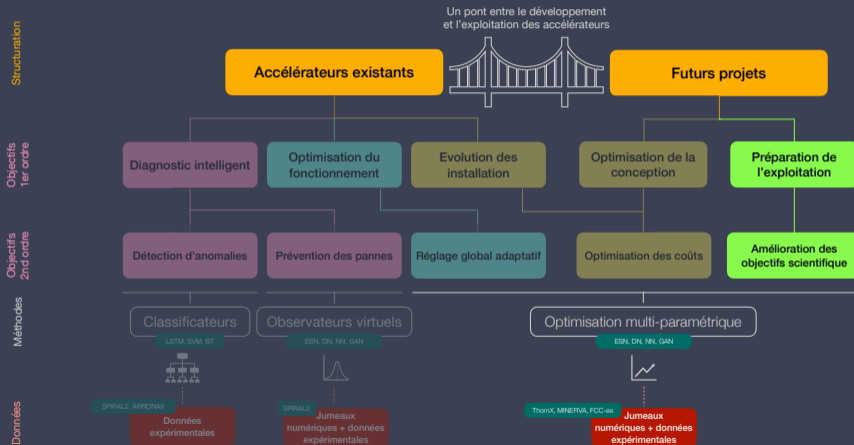
» Structure

Working groups



» Structure

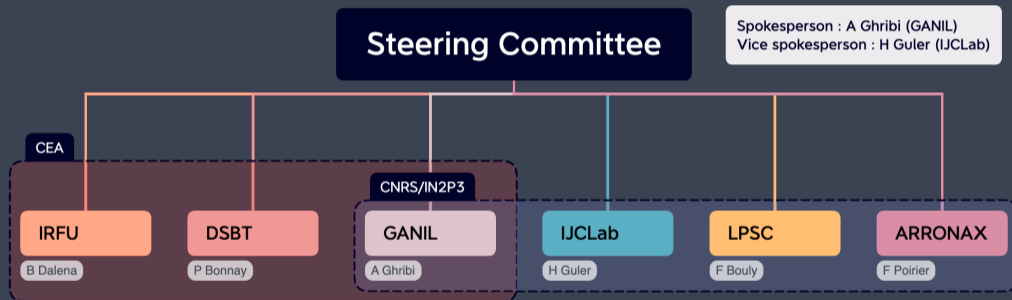
Working groups



» Structure

Contributors and representatives

Multiphysics Modelling, Machine learning and Model-based Control in Accelerator Sciences and Technologies



Background

Structure

Resources

Short term plans

Ongoing work

Conclusion

» Resources

» Resources

Experimental * LINAC SPIRAL2 + Cyclotrons (GANIL)

» Resources

Experimental

- * LINAC SPIRAL2 + Cyclotrons (GANIL)
- * ARRONAX

» Resources

Experimental

- * LINAC SPIRAL2 + Cyclotrons (GANIL)
- * ARRONAX
- * ThomX (IJCLab)

» Resources

Experimental

- * LINAC SPIRAL2 + Cyclotrons (GANIL)
- * ARRONAX
- * ThomX (IJCLab)
- * Cryogenic test bench (DSBT/CEA)

» Resources

Experimental

- * LINAC SPIRAL2 + Cyclotrons (GANIL)
- * ARRONAX
- * ThomX (IJCLab)
- * Cryogenic test bench (DSBT/CEA)
- * Minerva test bench (IJClab)

» Resources

Experimental

- * LINAC SPIRAL2 + Cyclotrons (GANIL)
- * ARRONAX
- * ThomX (IJCLab)
- * Cryogenic test bench (DSBT/CEA)
- * Minerva test bench (IJClab)

Calculation

- * 5000h allocated on Jean-Zay (IDRIS) - WVB project

» Resources

Experimental

- * LINAC SPIRAL2 + Cyclotrons (GANIL)
- * ARRONAX
- * ThomX (IJCLab)
- * Cryogenic test bench (DSBT/CEA)
- * Minerva test bench (IJClab)

Calculation

- * 5000h allocated on Jean-Zay (IDRIS) - WVB project

Storage

- * CC IN2P3

» Resources

Experimental

- * LINAC SPIRAL2 + Cyclotrons (GANIL)
- * ARRONAX
- * ThomX (IJCLab)
- * Cryogenic test bench (DSBT/CEA)
- * Minerva test bench (IJClab)

Calculation

- * 5000h allocated on Jean-Zay (IDRIS) - WVB project

Storage

- * CC IN2P3

HR

- * Internships 2022/2023 GANIL/IRFU/DSBT

» Resources

Experimental

- * LINAC SPIRAL2 + Cyclotrons (GANIL)
- * ARRONAX
- * ThomX (IJCLab)
- * Cryogenic test bench (DSBT/CEA)
- * Minerva test bench (IJCLab)

Calculation

- * 5000h allocated on Jean-Zay (IDRIS) - WVB project

Storage

- * CC IN2P3

HR

- * Internships 2022/2023 GANIL/IRFU/DSBT
- * Ongoing PhD thesis at IJCLab

» Resources

Experimental

- * LINAC SPIRAL2 + Cyclotrons (GANIL)
- * ARRONAX
- * ThomX (IJCLab)
- * Cryogenic test bench (DSBT/CEA)
- * Minerva test bench (IJCLab)

Calculation

- * 5000h allocated on Jean-Zay (IDRIS) - WVB project

Storage

- * CC IN2P3

HR

- * Internships 2022/2023 GANIL/IRFU/DSBT
- * Ongoing PhD thesis at IJCLab
- * Ongoing postdoc at LPSC

» Resources

Experimental

- * LINAC SPIRAL2 + Cyclotrons (GANIL)
- * ARRONAX
- * ThomX (IJCLab)
- * Cryogenic test bench (DSBT/CEA)
- * Minerva test bench (IJCLab)

Calculation

- * 5000h allocated on Jean-Zay (IDRIS) - WVB project

Storage

- * CC IN2P3

HR

- * Internships 2022/2023 GANIL/IRFU/DSBT
- * Ongoing PhD thesis at IJCLab
- * Ongoing postdoc at LPSC
- * PhD thesis beginning at GANIL

» Resources

Experimental

- * LINAC SPIRAL2 + Cyclotrons (GANIL)
- * ARRONAX
- * ThomX (IJCLab)
- * Cryogenic test bench (DSBT/CEA)
- * Minerva test bench (IJCLab)

Calculation

- * 5000h allocated on Jean-Zay (IDRIS) - WVB project

Storage

- * CC IN2P3

HR

- * Internships 2022/2023 GANIL/IRFU/DSBT
- * Ongoing PhD thesis at IJCLab
- * Ongoing postdoc at LPSC
- * PhD thesis beginning at GANIL
- * FCC-ee fellowship beginning at IRFU

Background

Structure

Resources

Short term plans

Ongoing work

Conclusion

» Short term plans

Mai 2022 PEPR NumPex Exascale contribution
Advanced multi-physics modelling

» Short term plans

Mai 2022 PEPR NumPex Exascale contribution
Advanced multi-physics modelling

Oct. 2022 ANR MRSEI
Preparing Horizon Infratec01 2024 (this fall)

» Short term plans

Mai 2022 PEPR NumPex Exascale contribution
Advanced multi-physics modelling

Oct. 2022 ANR MRSEI
Preparing Horizon Infratec01 2024 (this fall)

Nov. 2022 IN2P3 transverse project
This fall

» Short term plans

Mai 2022 PEPR NumPex Exascale contribution
Advanced multi-physics modelling

Oct. 2022 ANR MRSEI
Preparing Horizon Infratec01 2024 (this fall)

Nov. 2022 IN2P3 transverse project
This fall

2023-2024 Contribution to a national roadmap for ML applied to accelerators physics and technologies
Includes academy-industry think tank

» Short term plans

Mai 2022 PEPR NumPex Exascale contribution
Advanced multi-physics modelling

Oct. 2022 ANR MRSEI
Preparing Horizon Infratec01 2024 (this fall)

Nov. 2022 IN2P3 transverse project
This fall

2023-2024 Contribution to a national roadmap for ML applied to accelerators physics and technologies
Includes academy-industry think tank

Others **Connections with other European projects**

Ex. Eurolabs, LHC-HL, FCC-ee, FCC-hh, MYRRHA (faults compensation), CLARA, ESS, XFEL, SLAC (RF breakdown detection and prediction)...

Background

Structure

Resources

Short term plans

Ongoing work

Conclusion

» Ongoing work

Anomaly detection and state observers

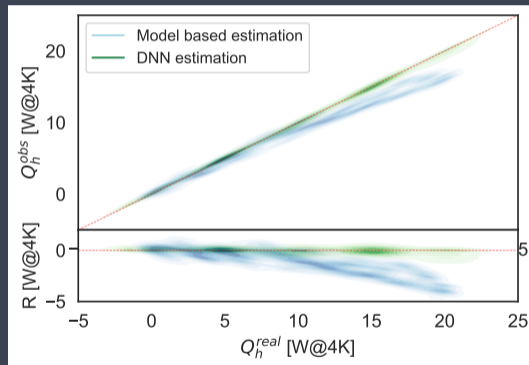
GANIL

Metrics	SVM	LSTM
Accuracy	0.98	0.93
Precision	0.97	0.88
Recall	0.99	0.98
F_1 score	0.98	0.93

Performance index comparison between SVM¹ and LSTM² for valves anomaly detection with models generated data [Vassal et al. Frontiers (2022)].

. ¹Support Vector Machines

. ²Long Short Term Memory Networks



Density distribution of predictors and residuals for model based and DNN based observers. [Ghribi et al. (2022)]

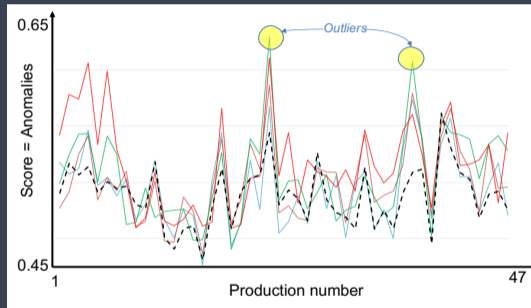
» Ongoing Work

Data mining and anomaly detection/classification

ARRONAX

Detection of outliers for radio-isotope production

- * Regular and stable production over several days;



Isolation Forest anomaly detection for different variables dimension reduction.

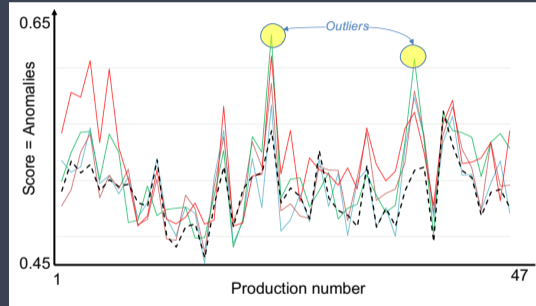
» Ongoing Work

Data mining and anomaly detection/classification

ARRONAX

Detection of outliers for radio-isotope production

- * Regular and stable production over several days;
- * Exploring several approaches for clustering (DBSCAN, Isolation Forest) and detection robustness;
- * identification and classification of outliers.



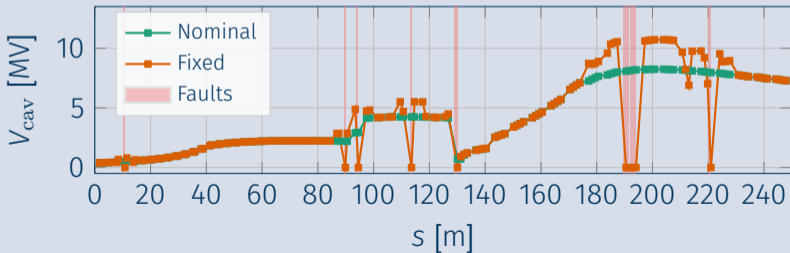
Isolation Forest anomaly detection for different variables dimension reduction.

» Ongoing Work

LPSC

Multi-objective optimisation for fault compensation

- * LightWin : a tool to find compensation settings for rf cavity failures in linacs
- * multi-objective optimisation problem :
 - * at least 8 variables : amplitude and phase of compensating cavities ;
 - * at least 6 objectives : ΔW_{kin} , $\Delta\phi$, beam parameters,
- * currently using least-squares (not adapted, looking into genetic algorithm, PSO and ML techniques ...)

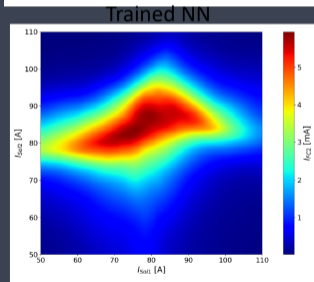
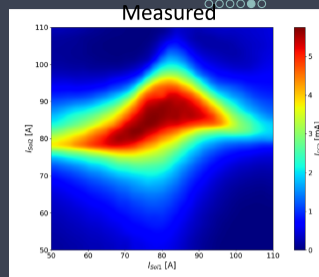


» Ongoing work

PhD - Model of a linac injector with ANN

- * RNN Model LEBT (+RFQ)
 - * 3 hidden layers with 64 neurones
- * Training w. measured ($\sim 10^4$) and simulated (beam dynamic code) data
- * (Predictor not fully terminated)
- * Also studied : on-line tuning of A LEBT : PSO algorithm "plugged" on the control system

LPSC



Transmission Map in the MYRRHA LEBT. [M. De-bongnie, Phd Thesis (2021).]

» Ongoing Work

Other contributions

IRFU / IJCLab

- * Echo State Networks for Dynamic Aperture prediction → IRFU
- * LinacNet : a new architecture for linear accelerator surrogate model → IJCLab

Background

Structure

Resources

Short term plans

Ongoing work

Conclusion

» Conclusion

- * M4CAST : an emerging collaborative effort around IA for accelerators concentrating on data/methods sharing ;
- * MOU under signature this fall ;
- * Integrates within a new European dynamic around IA for accelerators ;
- * Bridges existing and future projects as well as, reliability and optimization, R&D and operation, ...

Questions ?

Thank
you !