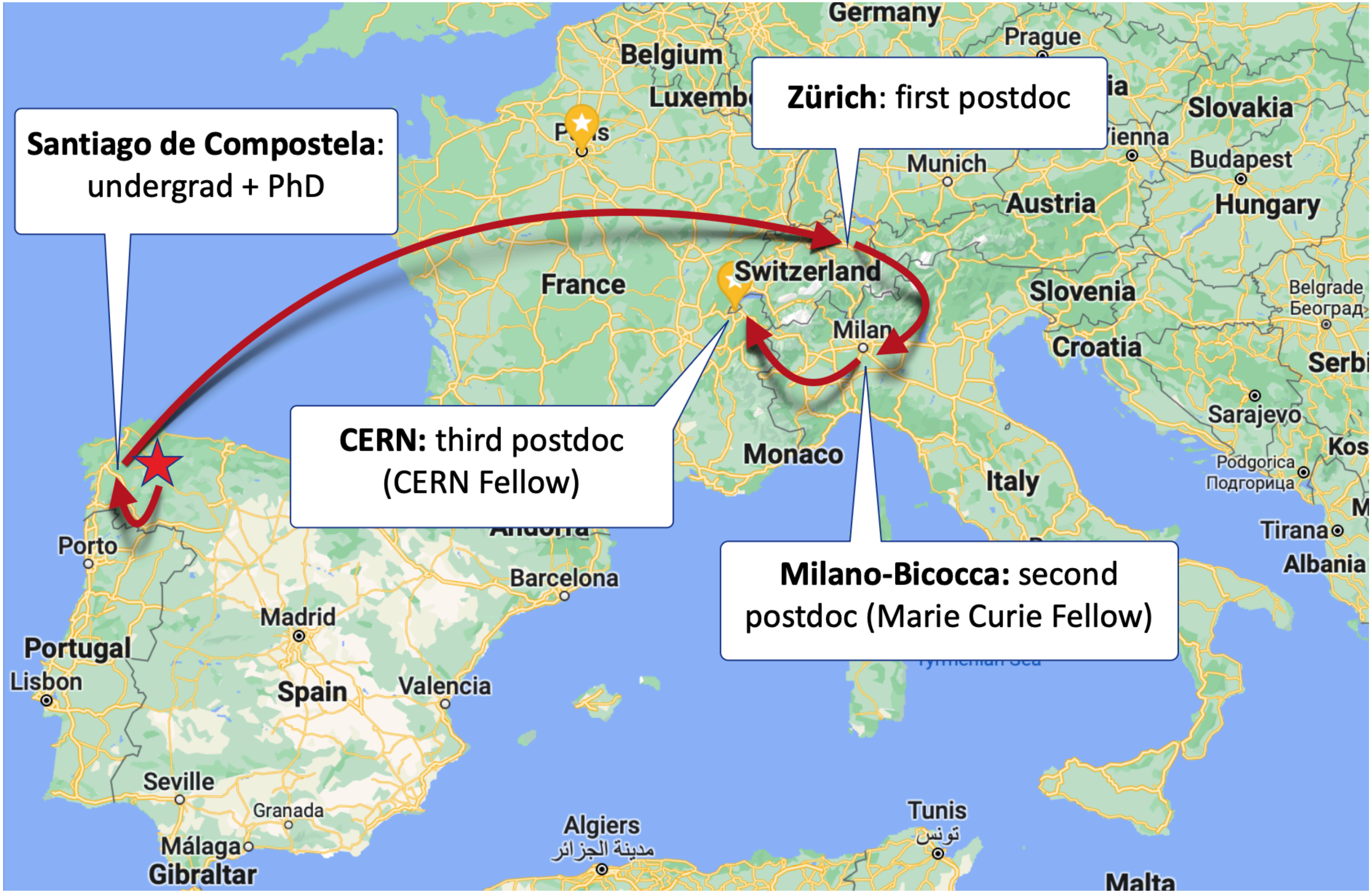
Julián García Pardiñas

My past journey



Santiago de Compostela: undergrad + PhD

Zürich: first postdoc

Milano-Bicocca: second postdoc (Marie Curie Fellow)

CERN: third postdoc (CERN Fellow)

Previous and current activities

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TD CPV and spectroscopy in B_s^0->$(K^+\pi^-)(K^-\pi^+)$ + Software acceleration with GPUs

Measurement the LFU ratios R(D^+) and R(D^{*+})

SW dev. and ML for trigger and event filtering in HL

SW dev. and ML to automate Data Quality Monitoring (DQM)

ML developments for FPGAs

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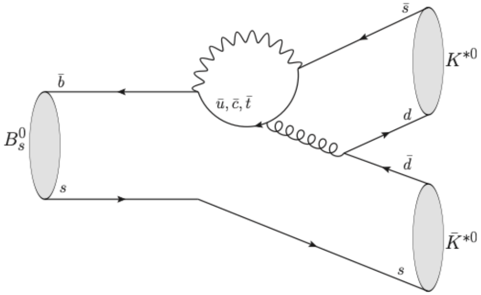
TD CPV and amplitude analysis in $B_s^0 \to (K^+\pi^-)(K^-\pi^+)$

$\phi_s^{s\bar{q}q}$ phases

- The $b \to s\bar{q}q$ transitions occur at **loop-level** in the SM. $\Longrightarrow$ **Potential New Physics** entering the decay.
- The phase $b \to s\bar{s}s$ was measured by LHCb using $B_s^0 \to \phi\phi$ decays [Phys. Rev. D 90, 052011 (2014)]. → Compatible with the SM expectation.

First LHCb Run 1 measurement of $\phi_s^{s\bar{d}d}$

The $B_s^0 \to K^{*0}(K^+\pi^-)\overline{K}^{*0}(K^-\pi^+)$ decay proceeds via a gluonic penguin diagram in the SM.



It is sensible to the phase $\phi_s^{s\bar{d}d}$, expected to be ~ 0 in the SM [JHEP 1503 (2015) 145].

To **increase the statistics**: study $B_s^0 \to (K^+\pi^-)(K^-\pi^+)$ decays with $M(K^\pm\pi^\mp) \in [750, 1600]$ MeV$/c^2$.

Dominant $K\pi$ structures:

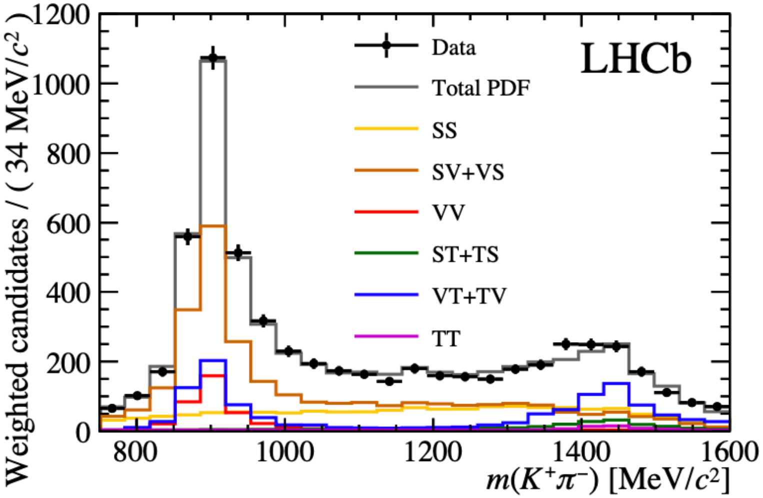
- Scalar ($j = 0$): $K_0^*(800)^0$, $K_0^*(1400)^0$, non-resonant
- Vector ($j = 1$): $K^*(892)^0$
- Tensor ($j = 2$): $K_2^*(1400)^0$

This leads to $3 \times 3 = 9$ channels and 19 polarisation amplitudes in total.

→ Same phase $\phi_s^{s\bar{d}d}$ used for all the amplitudes.

TD CPV and amplitude analysis in $B_s^0 \to (K^+\pi^-)(K^-\pi^+)$

- Flavour-tagged, time-dependent, angular and $K\pi$ invariant mass analysis.
- Model with **19 polarisation amplitudes**.
- Fit to **background-subtracted** data performed using **GPUs**. → **2000x faster** than 1 CPU.



[JHEP 03 (2018) 140]

Results

- CP-violating parameters: $\phi_s^{s\bar{d}d} = -0.10 \pm 0.13 \pm 0.14$ rad, $|\lambda| = 1.035 \pm 0.034 \pm 0.089$. → **Compatible with the SM expectations.**

\+ First/best measurement of all the CP-averaged amplitude parameters.

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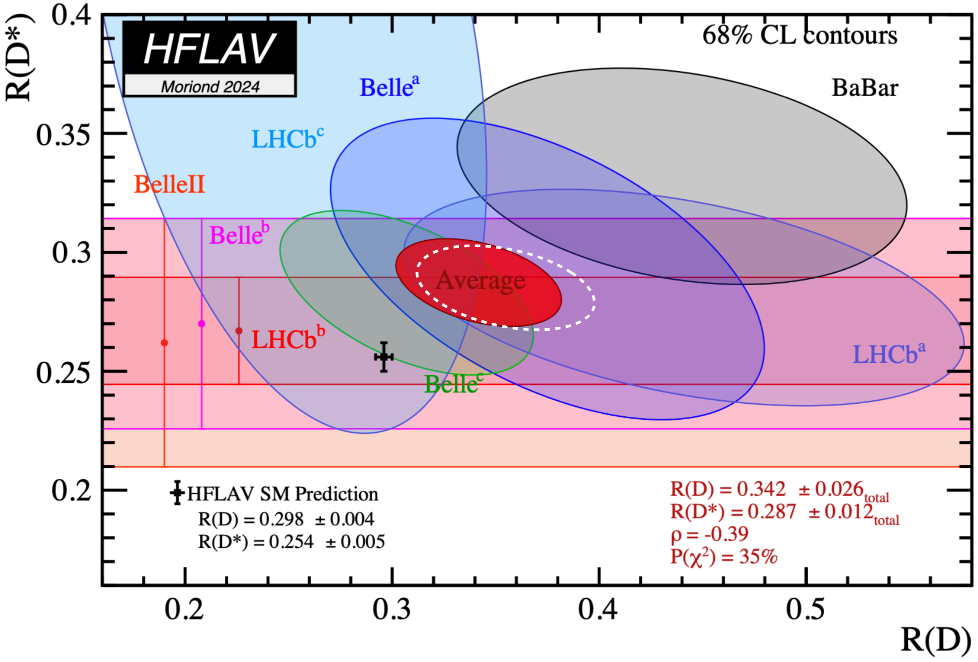
First LHCb measurement of R(D⁺) and R(D*⁺)

$$R(D^{(*)}) = \frac{\mathcal{B}(B\to D^{(*)}\tau^{+}\nu_{\tau})}{\mathcal{B}(B\to D^{(*)}\mu^{+}\nu_{\mu})} = \frac{\epsilon_{\mu}^{D^{(*)+}}}{\epsilon_{\tau}^{D^{(*)+}}}\frac{N_{\tau}^{D^{(*)+}}}{N_{\mu}^{D^{(*)+}}}\frac{1}{\mathscr{B}(\tau^{-}\to\mu^{-}\overline{\nu}_{\mu}\nu_{\tau})}$$

[Phys. Rev. Lett. 134, 061801]



100+ data samples

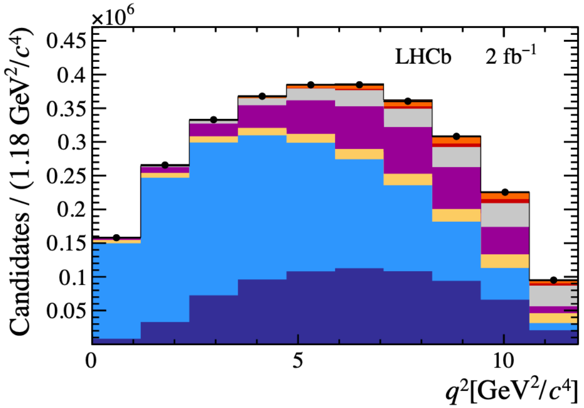
22 types of bkg.

4 regions in fit

68 fit parameters

14 checks

22 syst. uncert.



🟧 $\overline{B}\to D^{+}\tau^{-}\nu$

🟥 $\overline{B}\to D^{*+}\tau^{-}\nu$

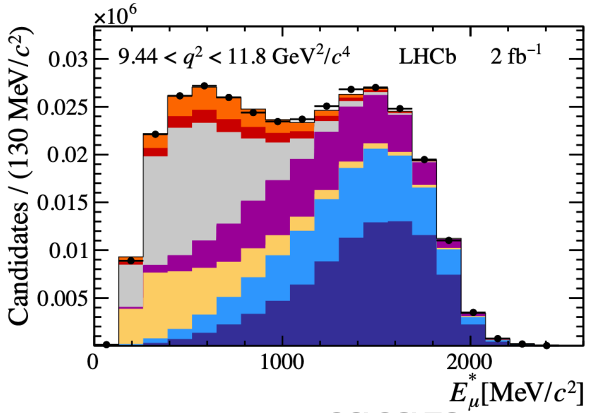
🟦 $\overline{B}\to D^{+}\mu^{-}\nu$

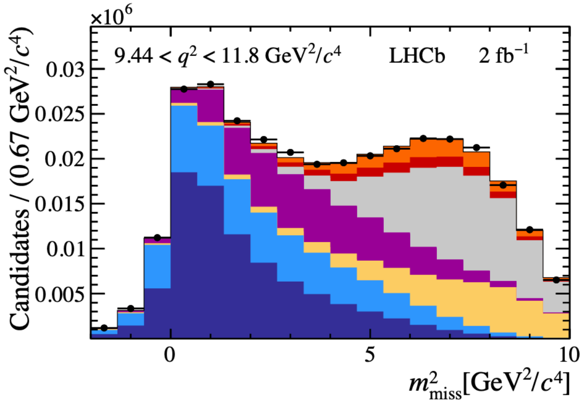
🟦 $\overline{B}\to D^{*+}\mu^{-}\nu$

⬜ $\overline{B}\to D^{+}X_{c}X$

🟪 $\overline{B}\to D^{**}\mu^{-}/\tau^{-}\nu$

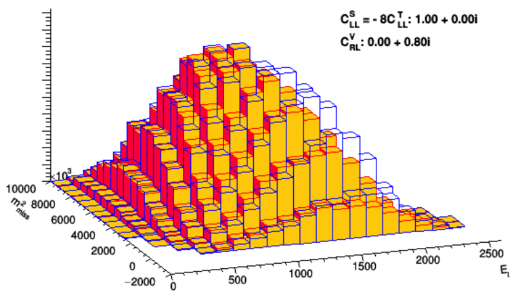
🟨 Comb + misID





Side products of the analysis

HistFactory/RooFit-HAMMER



Usage of **C++11** when interfacing with HAMMER.


TECHNICAL REPORT • OPEN ACCESS

RooHammerModel: interfacing the HAMMER software tool with HistFactory and RooFit

J. García Pardiñas[1], S. Meloni[1], L. Grillo[2], P. Owen[3], M. Calvi[1] and N. Serra[3]

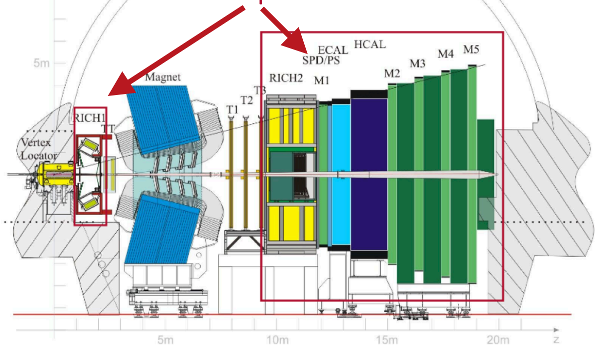
Published 19 April 2022 • © 2022 The Author(s)

Journal of Instrumentation, Volume 17, April 2022

Citation J. García Pardiñas *et al* 2022 *JINST* **17** T04006

DOI 10.1088/1748-0221/17/04/T04006

Tracker-only simulation



Sub-detector response turned off

Package of emulations for:

- L0Hadron TOS, L0Global TIS.
- PID.
- Neutral isolation.

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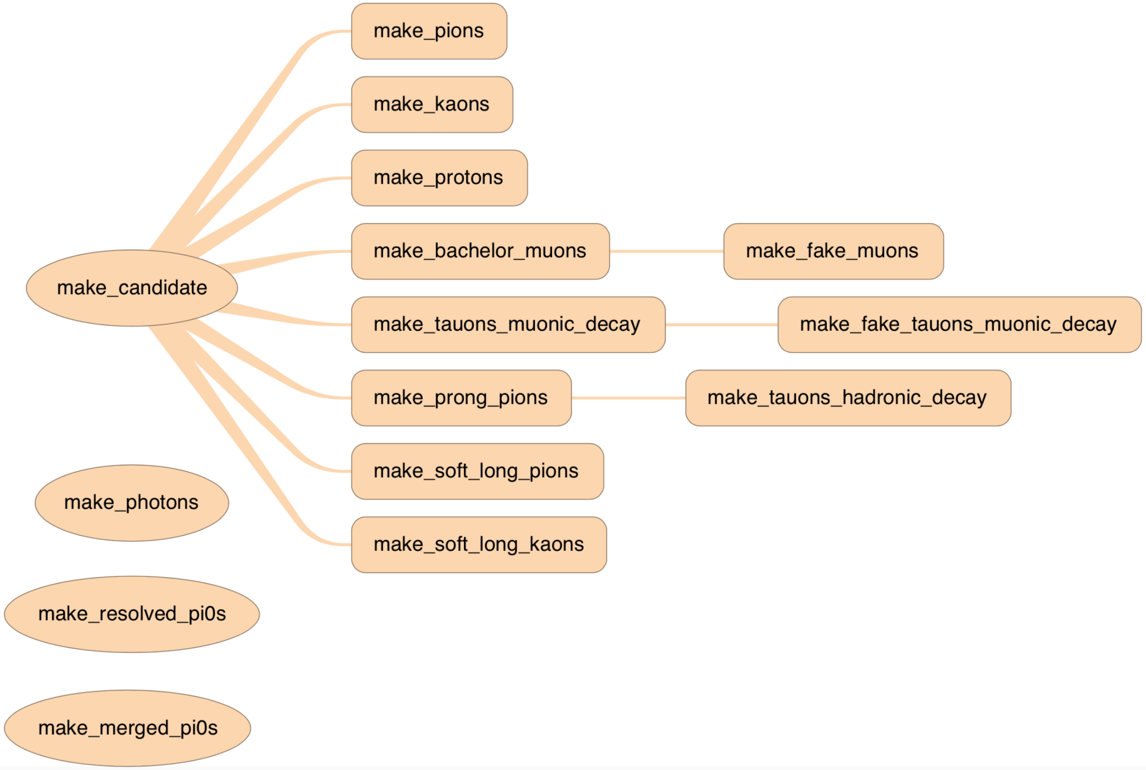
SW development for RTA HLT2 in Run 3

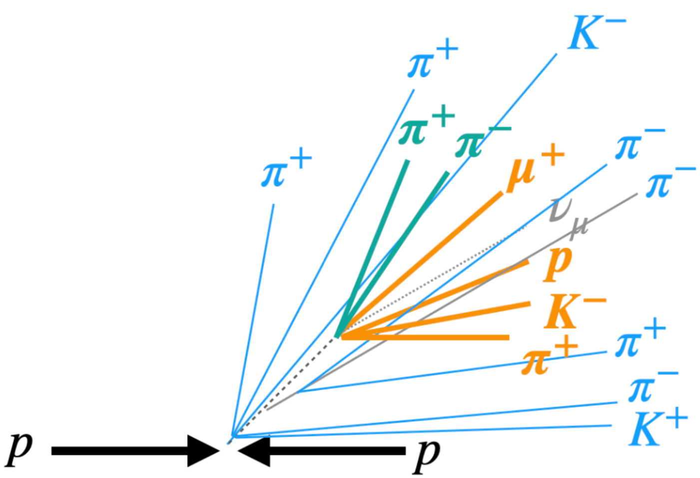
- Co-coordinated the migration of **~100 HLT2 SL lines** to the Run 3 trigger software (Moore). ~15 developers.
- **Modularised and streamlined the selections** with composite builders.

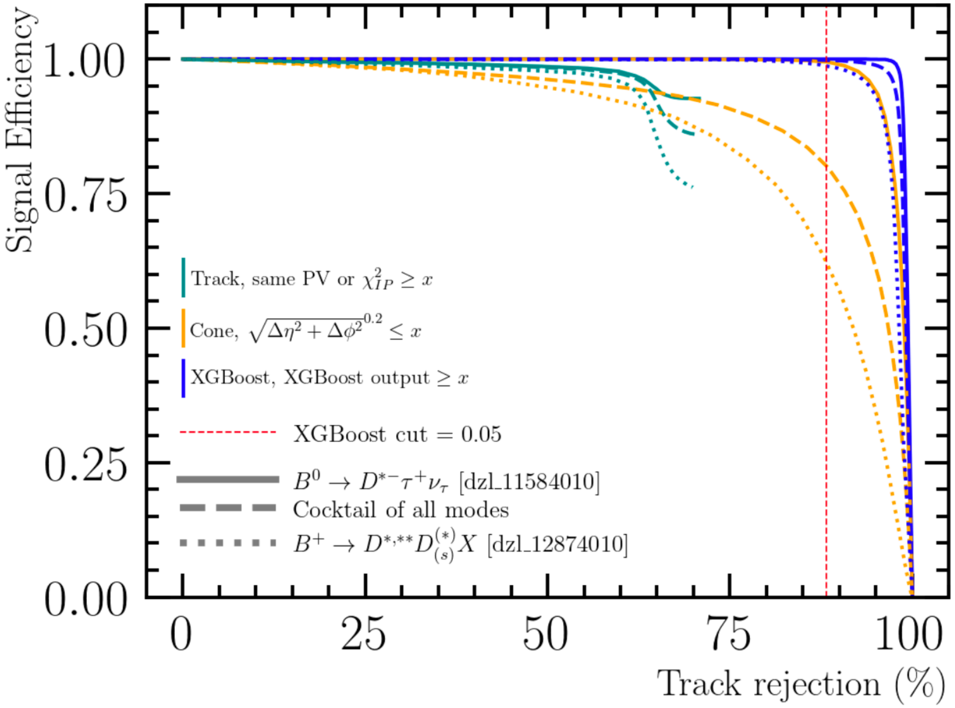


SW development for DPA in Run 3

From Run 3 onwards, the SL WG needs to select which part of the event needs to be stored.
→ Crucial for bkg and spectroscopy studies.

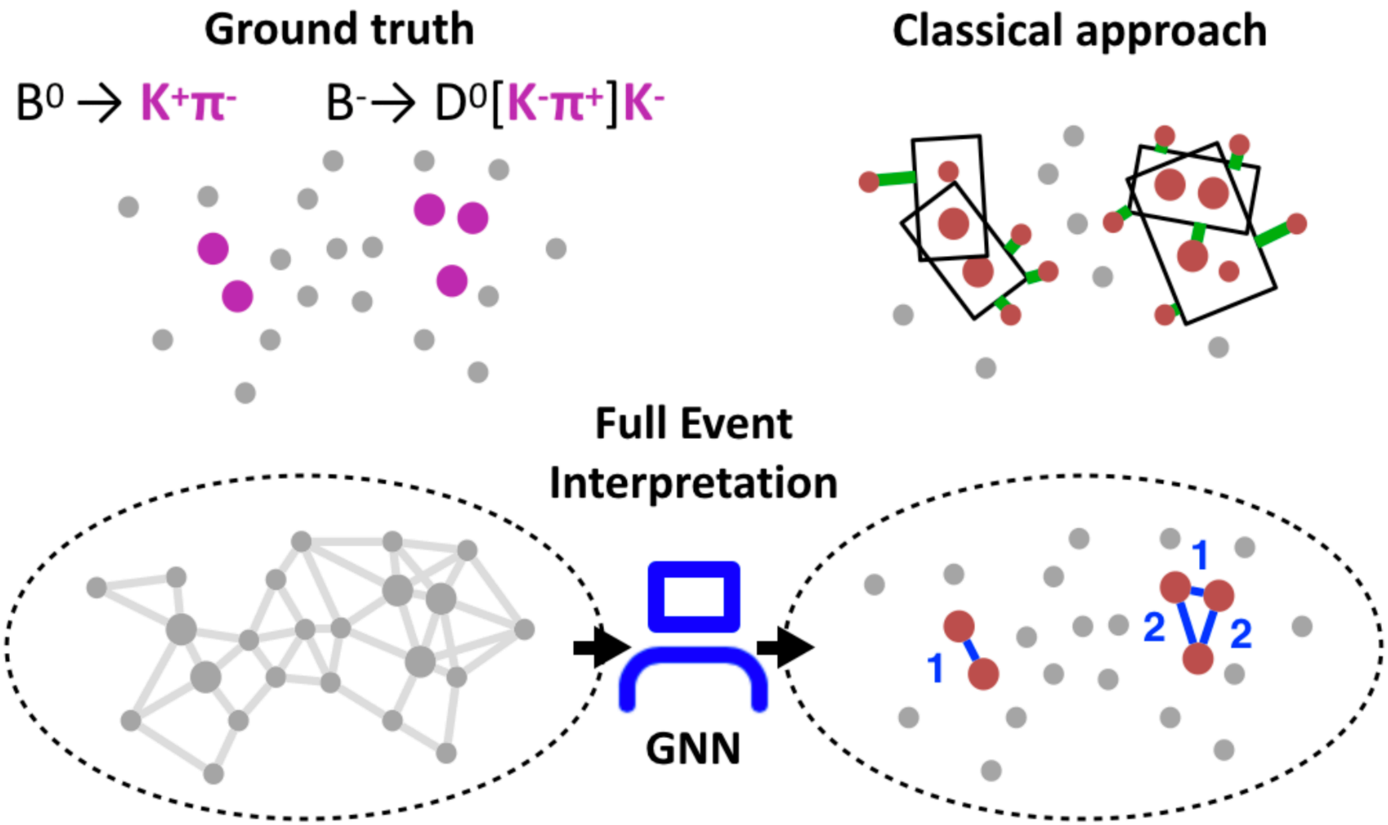
I have co-coordinated the creation of the first (MVA-based) tool for event-size reduction in SL lines [CERN summer student's project]. ~8 developers.





~10x event-size reduction. Commissioned for SL Sprucing lines.

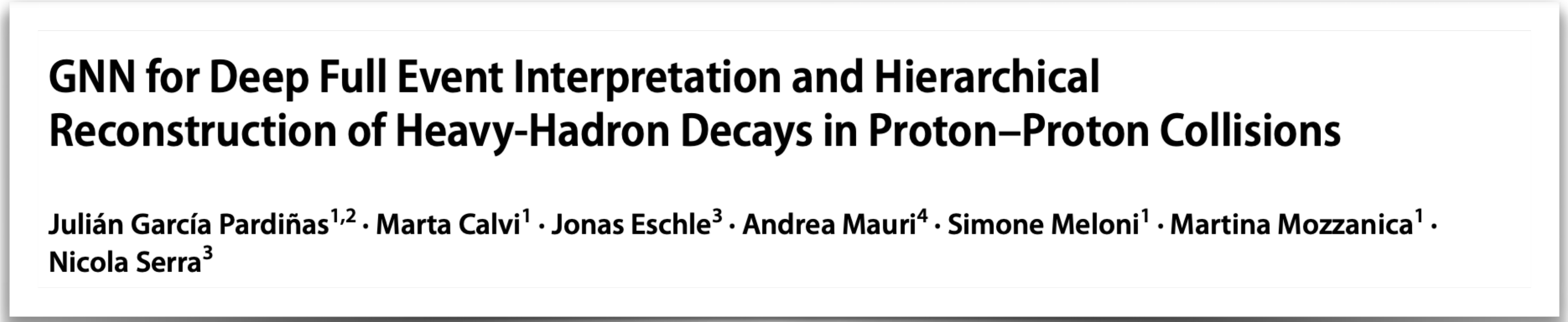
Deep-learning based Full Event Interpretation (DFEI)



One-go inclusive **multi-signal reconstruction + pileup suppression**, **for optimal event filtering in high-luminosity conditions**.

➥ Target implementation in Sprucing for Run 3, HLT2 for Upgrade II.

First version of the algorithm

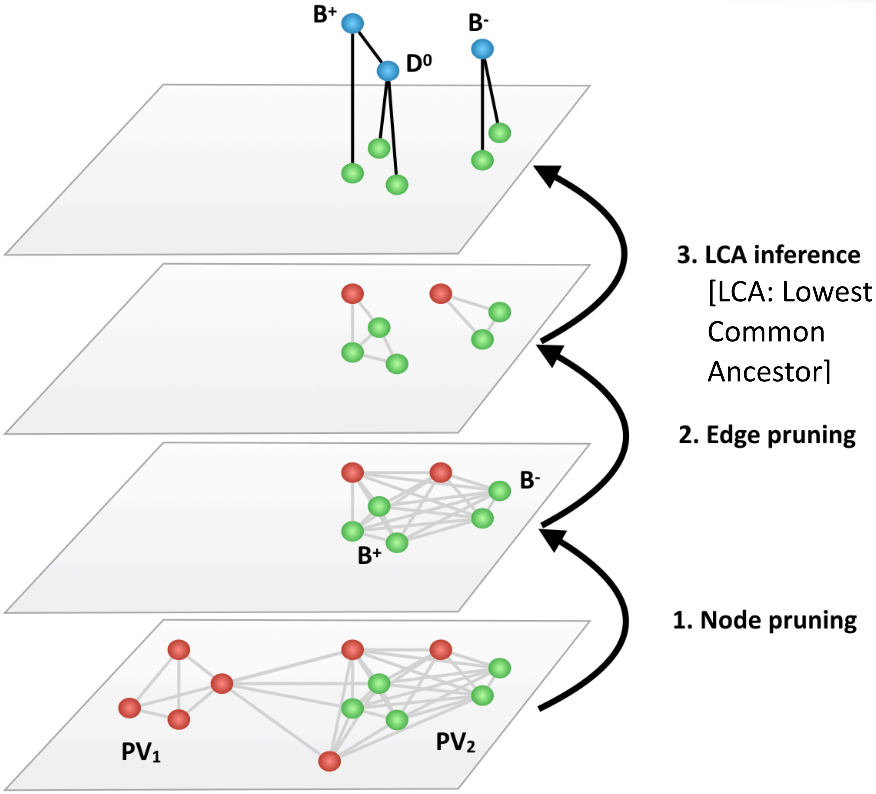


GNN for Deep Full Event Interpretation and Hierarchical Reconstruction of Heavy-Hadron Decays in Proton–Proton Collisions

Julián García Pardiñas[1,2] · Marta Calvi[1] · Jonas Eschle[3] · Andrea Mauri[4] · Simone Meloni[1] · Martina Mozzanica[1] · Nicola Serra[3]

[Comput Softw Big Sci 7, 12 (2023)]

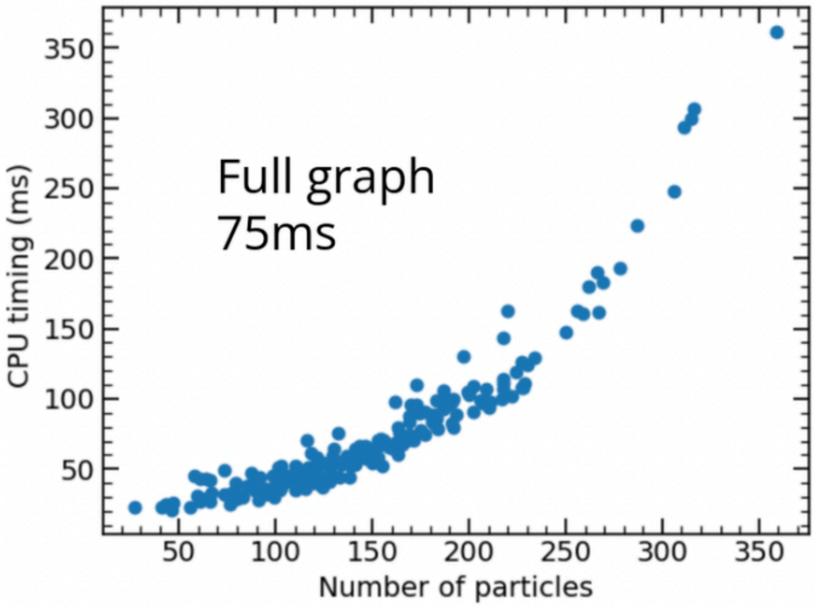
Good performance, but inference time of $\mathcal{O}(1\text{s})$

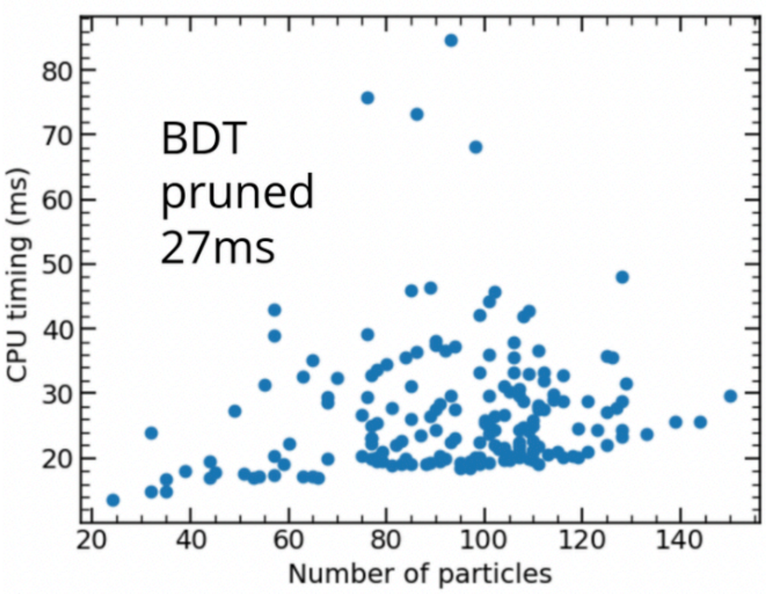


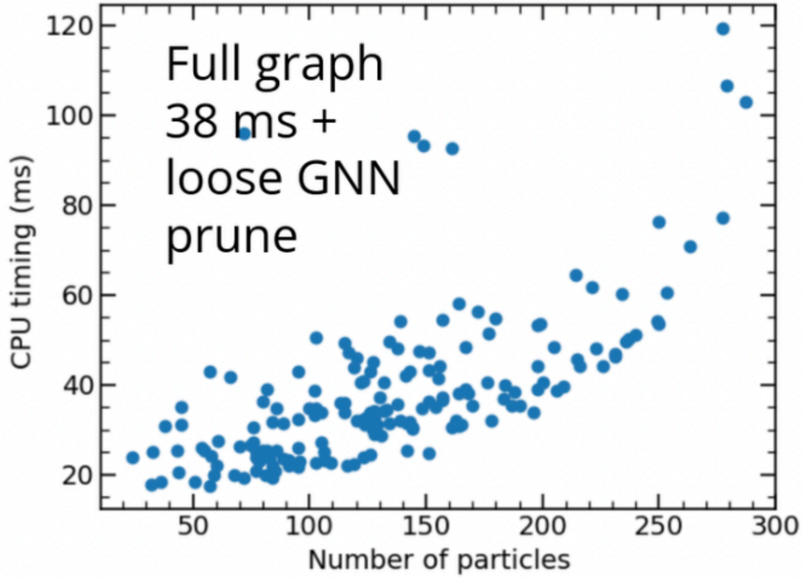
Blue: reconstructed ancestors.
Green: particles from a b-hadron
Red: particles from the rest of the event

Work on CPU-based inference speedup

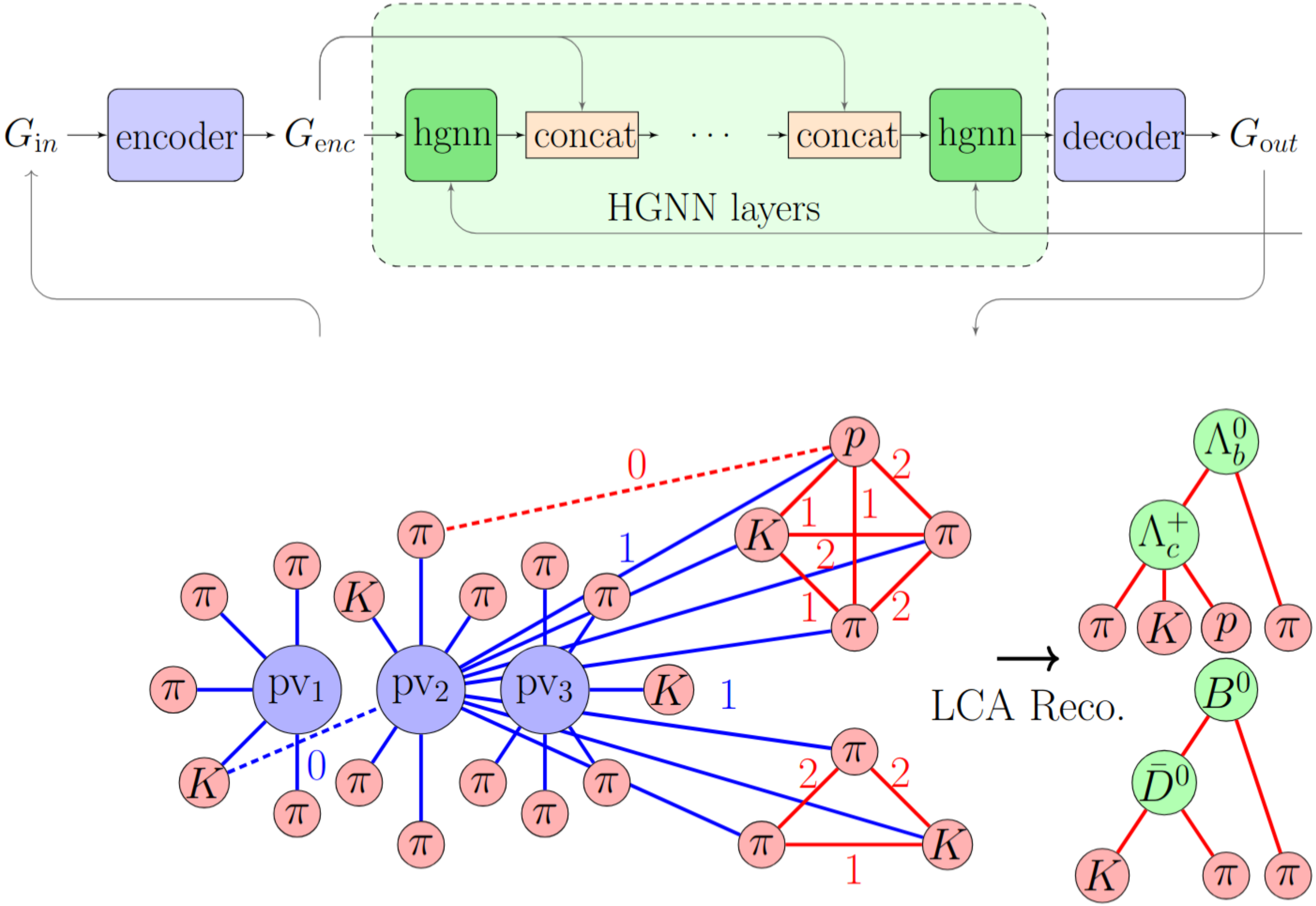
1. Work on alternative (faster) pre-filtering algorithms.
2. Work on dynamic weight pruning in the GNN.
3. Work on a C++ based inference pipeline thanks to a collaboration with the TMVA SOFIE team.







Expanding to more tasks: heterogeneous GNNs



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Automatic DQM in dynamic regime

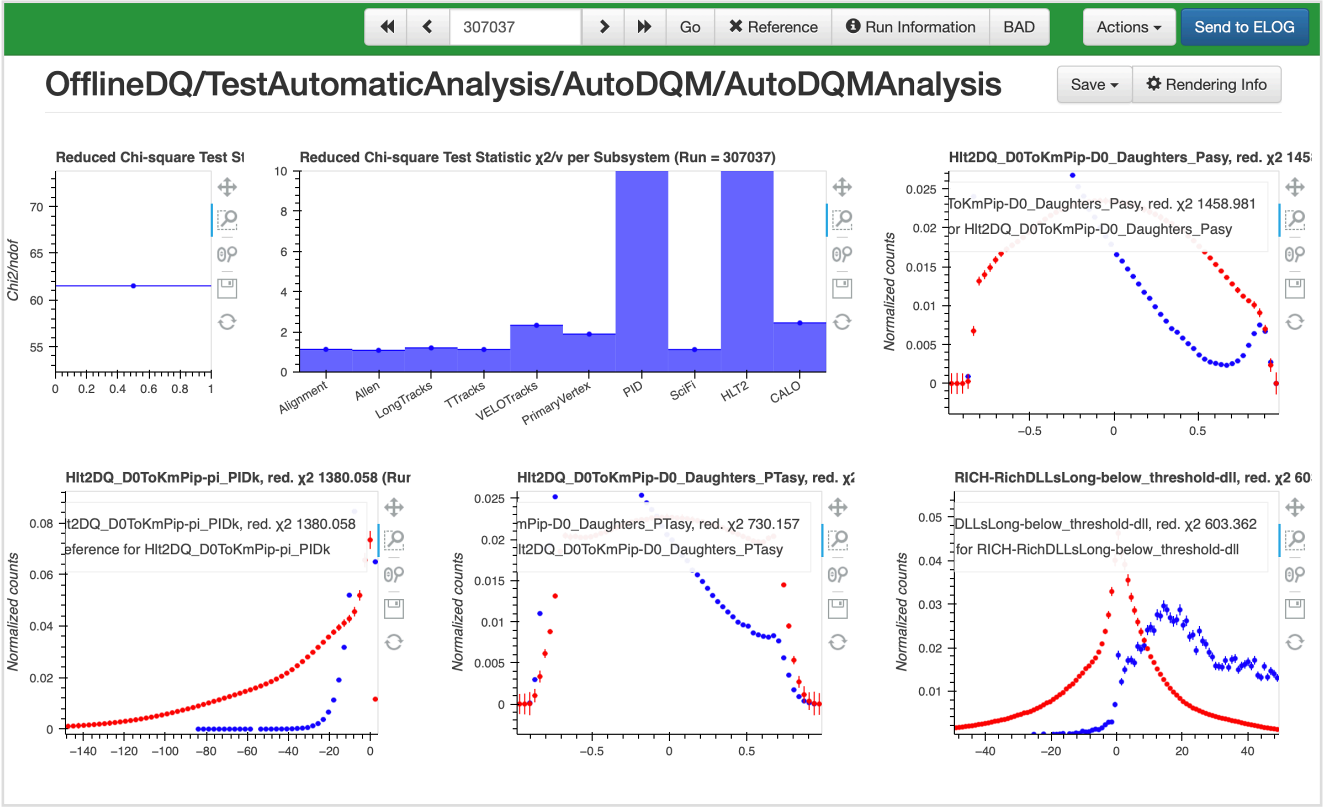
Both Online and Offline DQM are done by shifters, very person-power demanding.

Goals:

- Increase accuracy.
- Reduce person power.
- Adapt to changing conditions.
- Provide a robust and unbiased response.

Novel statistics-based method

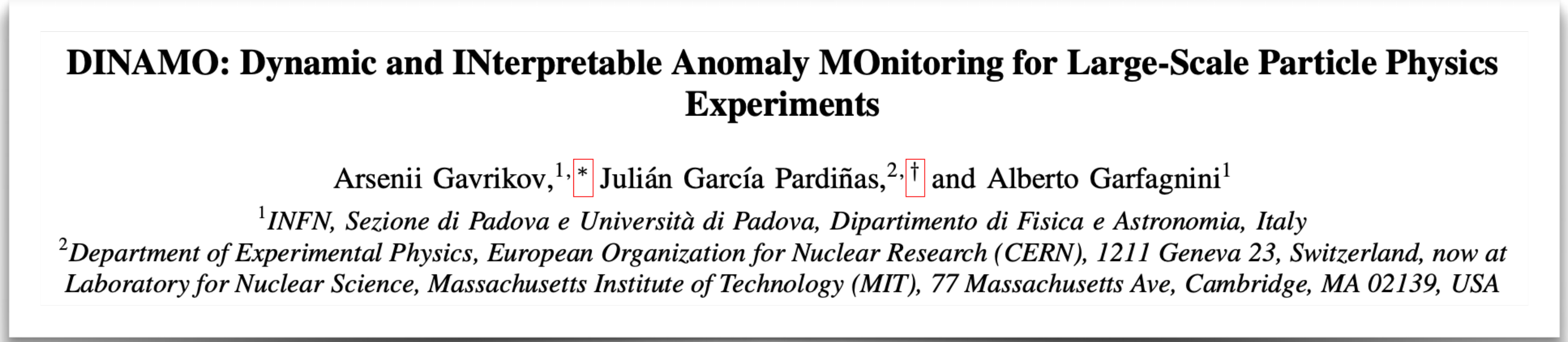
- Automatic data-driven construction of **templates with uncertainties**.
- **Gradual evolution of templates in time**, when triggered by shifters/experts.
- **Statistical comparison** of current run with current set of templates. **Unbiased** wrt. run length via sampling method. Global or per sub-system/histogram.



Commissioned in Offline DQM, expected to reduce person power to 1/3.

R&D to improve the performance

[arXiv:2501.19237]

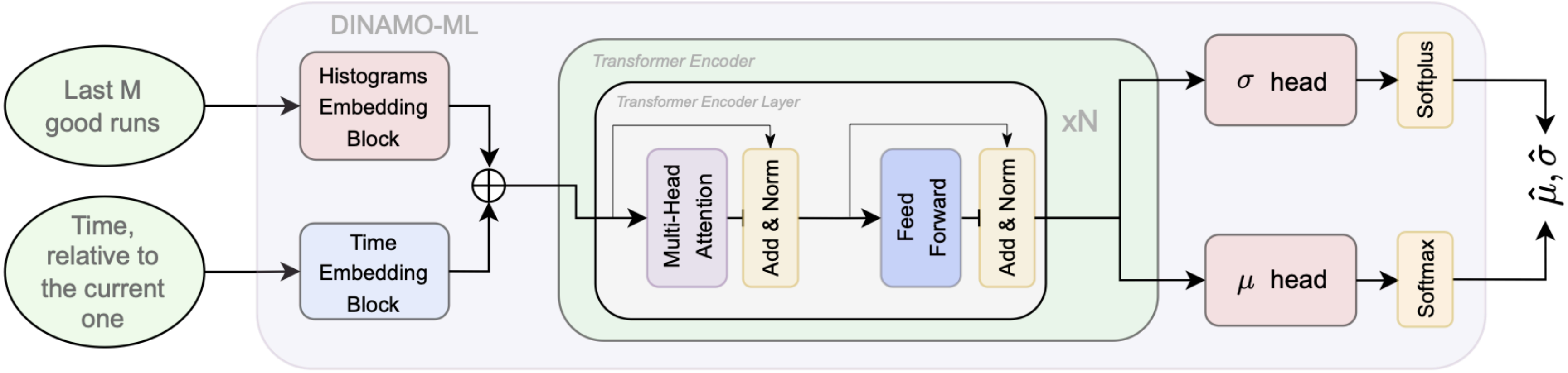


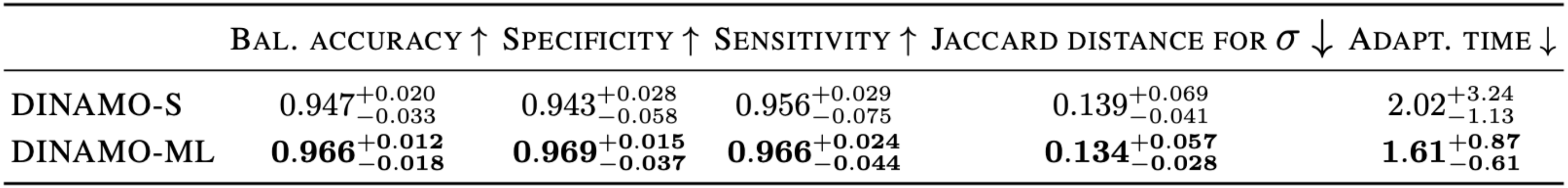
DINAMO: Dynamic and INterpretable Anomaly MOnitoring for Large-Scale Particle Physics Experiments

Arsenii Gavrikov,[1,*] Julián García Pardiñas,[2,†] and Alberto Garfagnini[1]

[1]*INFN, Sezione di Padova e Università di Padova, Dipartimento di Fisica e Astronomia, Italy*
[2]*Department of Experimental Physics, European Organization for Nuclear Research (CERN), 1211 Geneva 23, Switzerland, now at Laboratory for Nuclear Science, Massachusetts Institute of Technology (MIT), 77 Massachusetts Ave, Cambridge, MA 02139, USA*

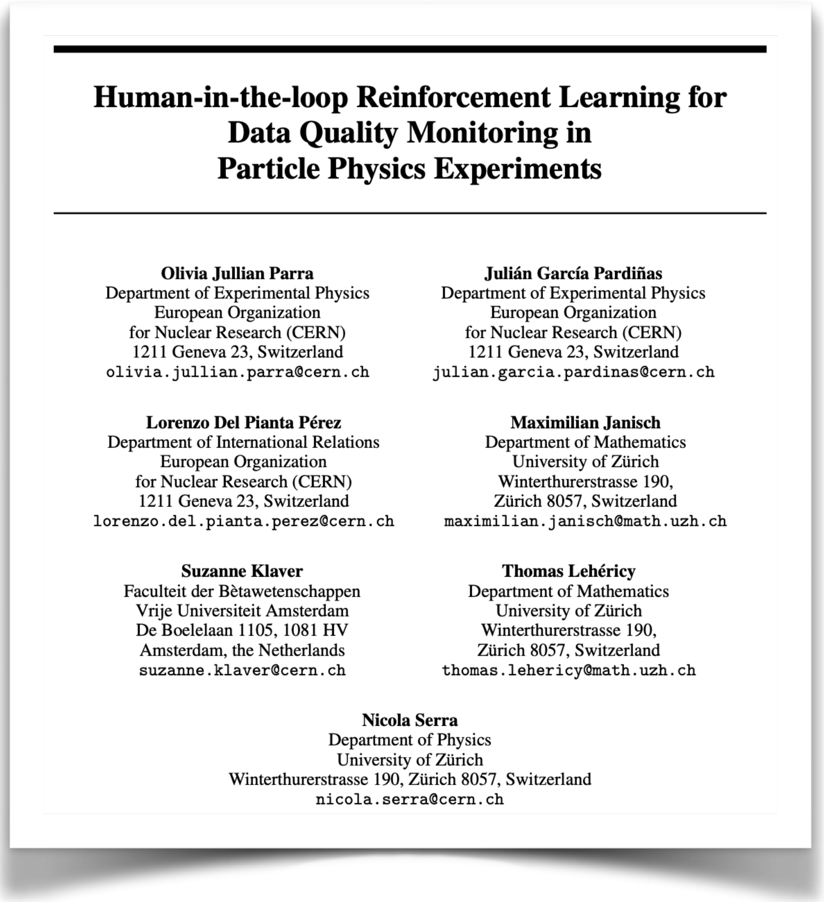
Predict the evolving templates with uncertainties using a transformer model and incremental learning.





	Bal. accuracy ↑	Specificity ↑	Sensitivity ↑	Jaccard distance for σ ↓	Adapt. time ↓
DINAMO-S	$0.947^{+0.020}_{-0.033}$	$0.943^{+0.028}_{-0.058}$	$0.956^{+0.029}_{-0.075}$	$0.139^{+0.069}_{-0.041}$	$2.02^{+3.24}_{-1.13}$
DINAMO-ML	$\mathbf{0.966^{+0.012}_{-0.018}}$	$\mathbf{0.969^{+0.015}_{-0.037}}$	$\mathbf{0.966^{+0.024}_{-0.044}}$	$\mathbf{0.134^{+0.057}_{-0.028}}$	$\mathbf{1.61^{+0.87}_{-0.61}}$

R&D to increase the level of automation



Human-in-the-loop Reinforcement Learning for Data Quality Monitoring in Particle Physics Experiments

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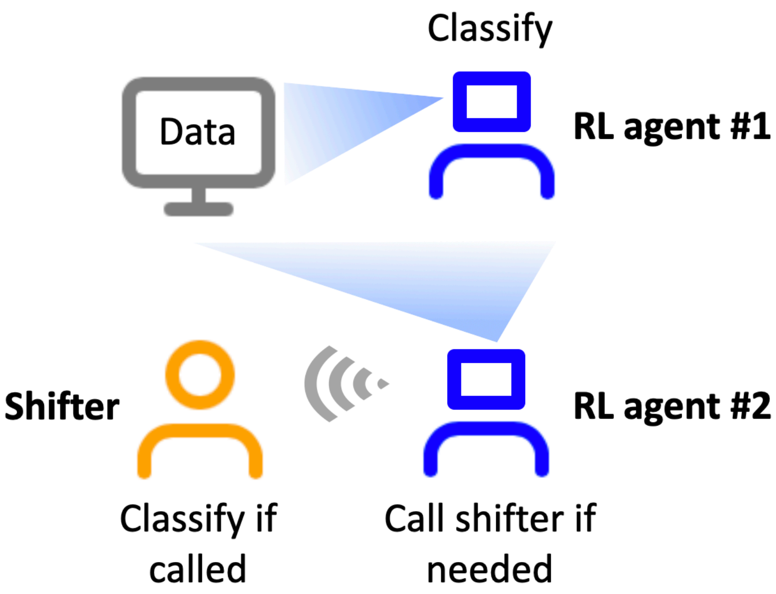
[arXiv:2405.15508]



- Allow the possibility to globally optimise multiple correlated tasks, partially involving human actors.
  - ➥ **Balance classification accuracy vs amount of human interaction.**
  - ➥ Long-term goal: optimise multiple operations in a control room. **Balance data collection efficiency vs operational costs.**

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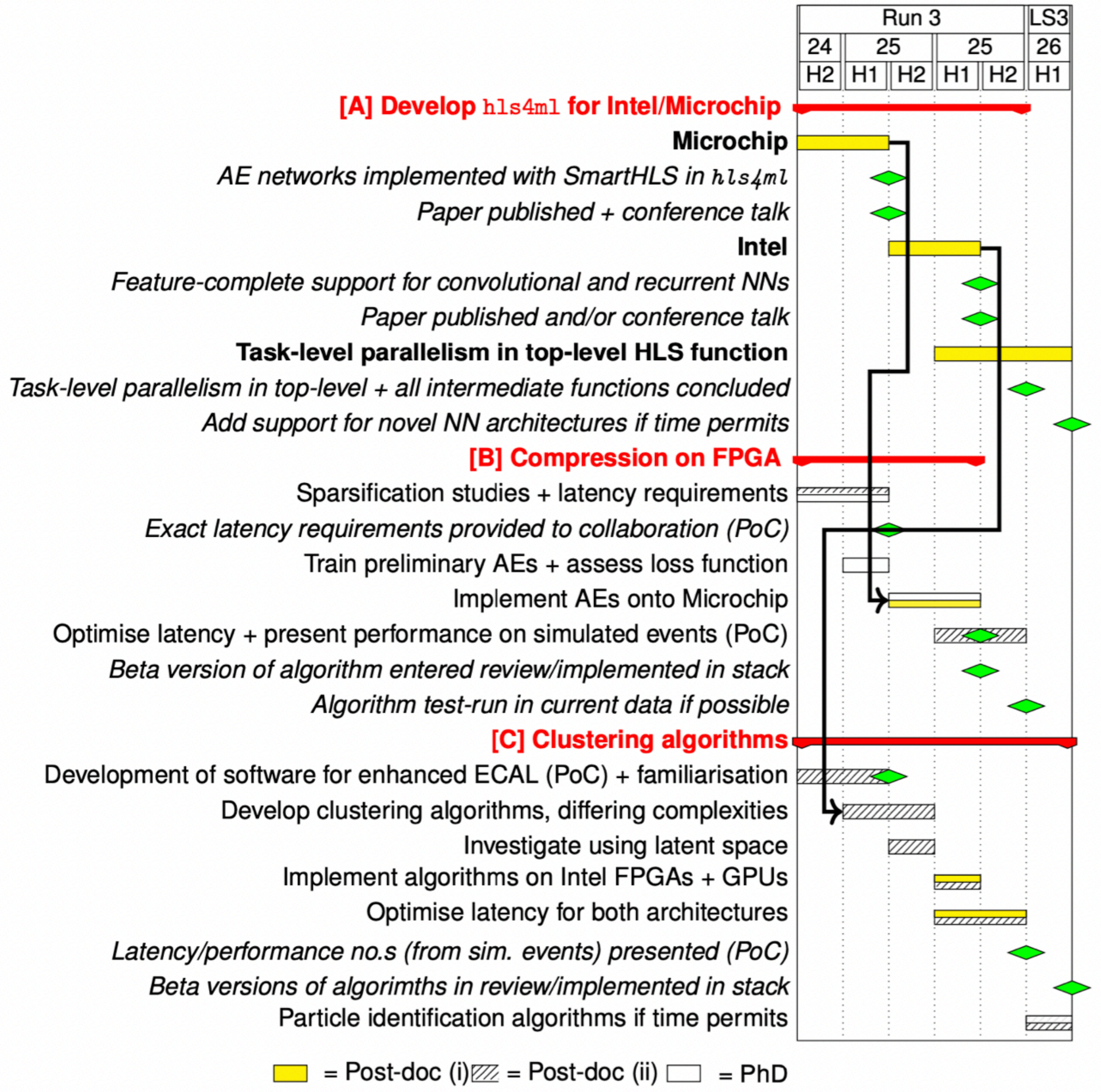
Eluned’s NSF CSSI grant

A) Developing hls4ml to be compatible with SmartHLS and Intel

B) Developing ML-based compression for PicoCal frontend

C) Developing ML-based compression for PicoCal backend



Status of the current developments

1. [✅] Use hls4ml to parse an example keras model targeting a Vivado backend. Understand the structure of the produced C++ code.

2. [✅] Understand how SmartHLS works. Study the project and file structure for a simple example provided in their tutorials.

3. [⚒️] Transform the relevant hls4ml output files to allow SmartHLS to parse them.
   A. [✅] Get a basic version of the C++ code to compile within SmartHLS.
   B. [✅] Check the numerical results after variable quantisation with CSIM.
   C. [✅] Sinthesise and study latency.
   D. [⚒️] Play with pragmas to optimise performance as needed.

4. [ ] Abstract from the learnings and implement an expansion of hls4ml to cover this new backend.

5. [ ] Use the new expansion of hls4ml to convert the LHCb ML models.

Some ML coordination activities

IML

Inter-Experimental LHC Machine Learning Working Group

https://eucaif.org/

EuCAIF

The LHCb ML Forum

I first suggested this initiative one year ago, in a [talk at the Software Framework(s) for LHCB's Future Workshop](). → Now created inside the Software and Computing Board.

- **Scope:**
  - **ML discussion at the production level on aspects which are either cross-project or LHCb-common** (including common ML interfaces and pipelines, developments of ML for FPGA, usage of LLMs for documentation, …).
  - Discussion of external ML opportunities for LHCb (requests of LHCb speakers for project-unspecific ML overview talks, new multi/inter-experiment ML networks, available hardware infrastructure, …).

ML Forum meetings

LHCb ML Forum

Tuesday 4 Feb 2025, 15:30 → 17:00 Europe/Zurich

Julian Garcia Pardinas (Massachusetts Inst. of Technology (US))

Description Zoom link: https://cern.zoom.us/j/66519173550?pwd=WcrbtA8ltaD7sRj2AiGaxCbrP

15:30 → 15:35 **News**

Speaker: Julian Garcia Pardinas (Massachusetts Inst. of Technology (US))

News_040225.pdf

15:35 → 15:55 **Introduction to the ODISSEE project**

Speaker: Vava Gligorov (Centre National de la Recherche Scientifique (FR))

ODISEE_LHCb_ML_... ODISEE_LHCb_ML_...

15:55 → 16:15 **LLM status/studies at IHEP**

Speaker: Mr Xuhao Yuan (Institute of High Energy Physics, Beijing, China)

20250204.pptx

16:15 → 16:35 **Introducing LHCbFinder: Semantic Search and Future Prospects with LLMs**

Speaker: Mohamed Elashri (University of Cincinnati)

lhcbfinder_lhcb_for...

ML Forum Meeting - ML on FPGA

Wednesday 26 Feb 2025, 15:30 → 17:00 Europe/Zurich

2/R-030 (CERN)

Julian Garcia Pardinas (Massachusetts Inst. of Technology (US))

zoom LHCbMLForumMeeting

15:30 → 15:35 **News**

Speaker: Julian Garcia Pardinas (Massachusetts Inst. of Technology (US))

News_26.02.25.pdf

15:35 → 15:45 **Work and plans from France**

Speaker: Christina Agapopoulou (Université Paris-Saclay (FR))

French work & plans...

15:45 → 15:55 **Work and plans from Syracuse**

Speaker: Lauren Mackey (Syracuse University (US))

Syracuse University ...

15:55 → 16:05 **Work and plans from MIT**

Speaker: Eluned Anne Smith (Massachusetts Inst. of Technology (US))

MIT_ML_Plans.pdf