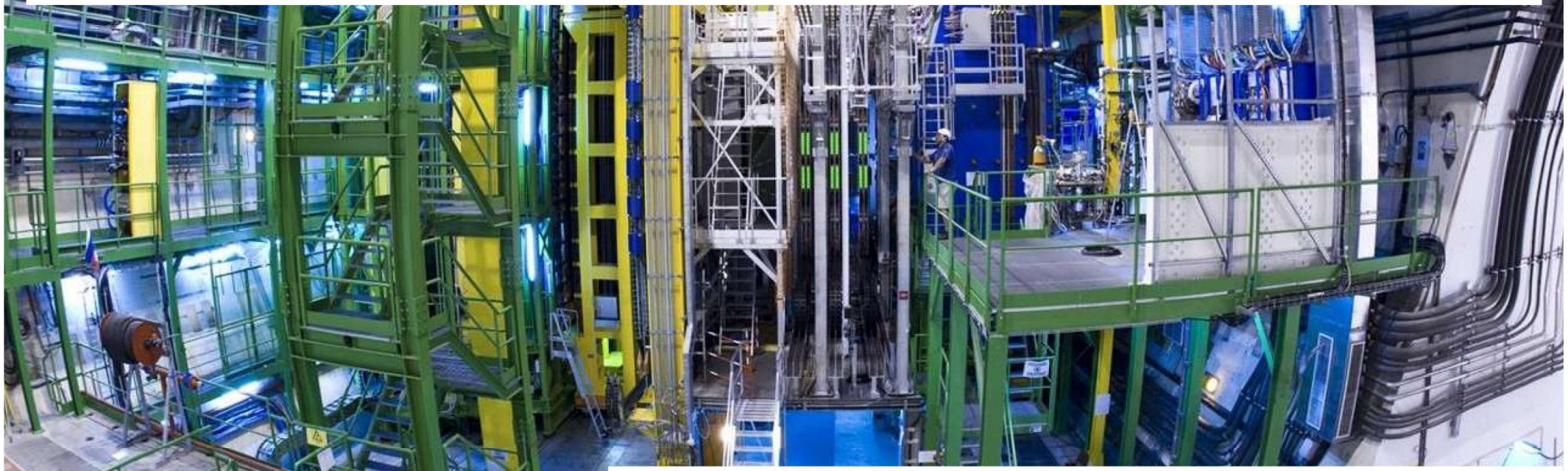
LHCb Flavour physics, QCD processes, research and development at LHCb or DRD4, and LS3 Enhancement of the RICH subdetector electronics



Dr. rer. nat. Florin MACIUC on behalf of the LHCb-Romania Group,

Horia Hulubei National Institute of Physics and Nuclear Engineering (IFIN-HH) and University "Stefan cel Mare" of Suceava (USV)

28.11.2025

LHCb in 3rd RUN

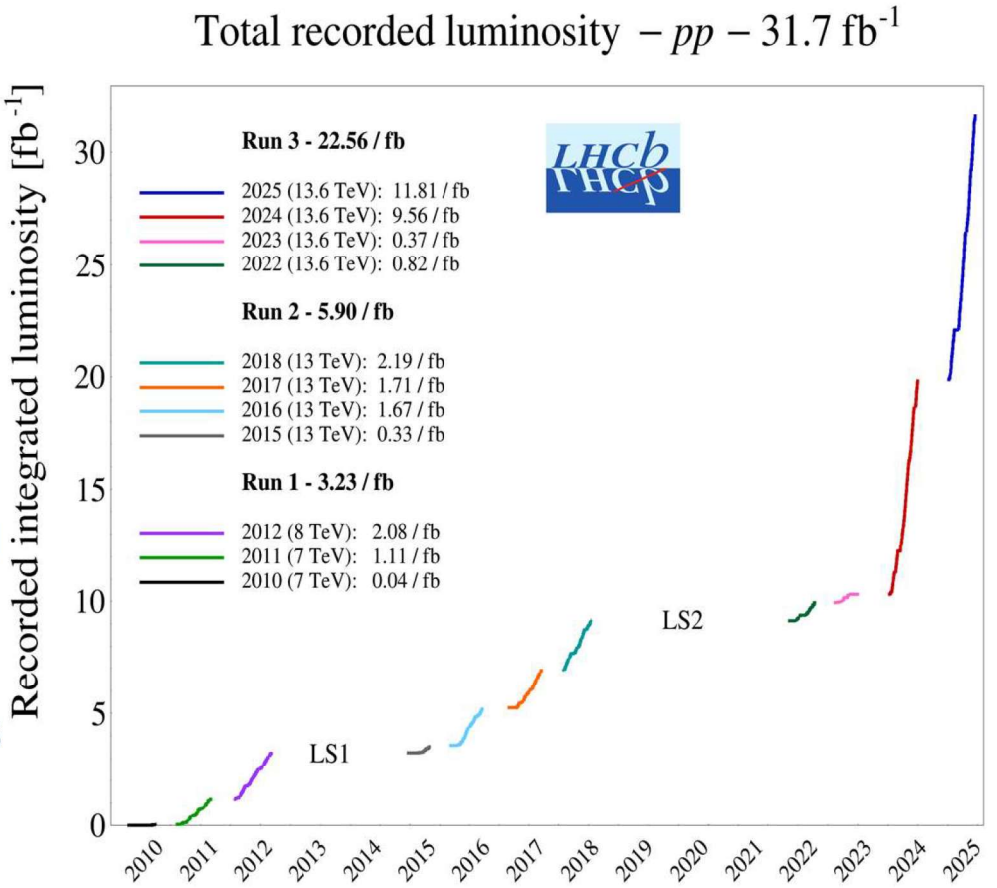
An upgrade of detector in 2nd LS;

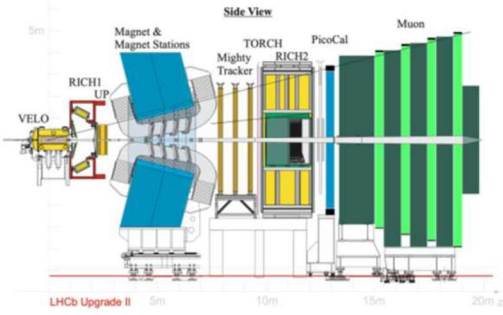
2025 - proton-proton at $\sqrt{s}$=13.6 TeV

Average (highest) luminosity in:
2(2.13) x10^{33} pp/cm^2/s , 5 times 2nd RUN
Av. pile-up as high as 5.3;

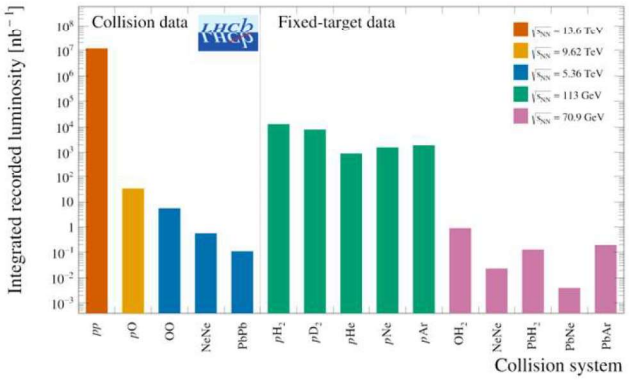
Besides proton-proton collisions, various
Proton-ion, ion-ion, fix target (SMOG);

R&D for Upgrade IIb (4th LS) and
Enhancement (3rd LS)





New RICH electronics in 3rd LS;
New alternative for IIb Upgrade,
- Scoping document



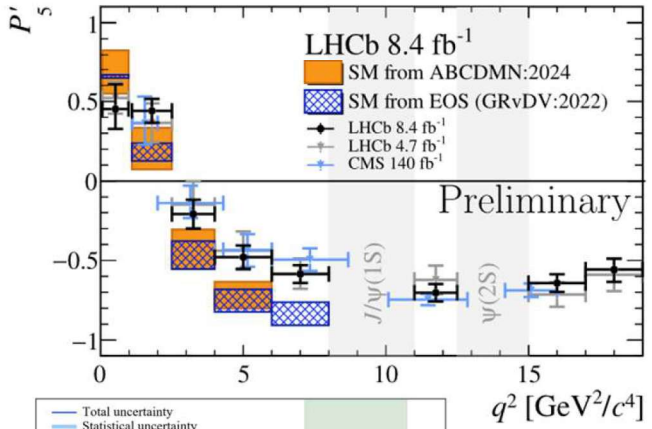
3D spectrometer to 4D spectrometer, time and space resolve the individual collisions in events with ≈30 average visible interactions;

LHCb Physics Highlights in 3rd LHC RUN

- FCNC transitions in decays like $B^0 \rightarrow K^* \mu^+ \mu^-$;

Angular analysis of $B^0 \rightarrow K^* \mu^+ \mu^-$

P'_5 observable, a SM-tension/deviation at level close to 4σ (global fit), LHCb-PAPER-2025-041

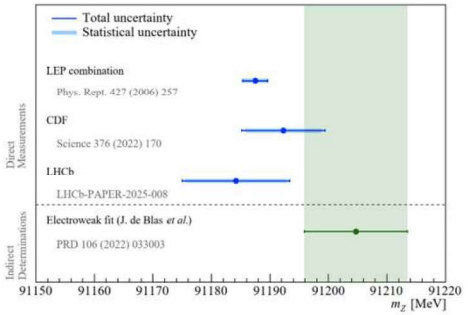


- First dedicated Z0 mass measurement at LHC;

LHCb collaboration, R. Aaij et al., "Measurement of the Z-boson mass", arXiv:2505.15582;

- CKM matrix, $\gamma = 52.6^{+8.5}_{-6.4}$ degrees, one of the best;

LHCb collaboration, R. Aaij et al., "A model-independent measurement of the CKM angle γ in the decays $B^\pm \rightarrow [K^+K^-\pi^+\pi^-]_D h^\pm$ and $B^\pm \rightarrow [\pi^+\pi^-\pi^+\pi^-]_D h^\pm$ (h =K, π)", arXiv:2509.15139;



- First observation of CPV in beauty baryons;

LHCb collaboration, R. Aaij et al., "Observation of charge–parity symmetry breaking in baryon decays", Nature volume 643, pages 1223–1228 (2025)

- New 13.6 TeV pp data measurements, besides pPb or another ion-ion in 3rd RUN:

LHCb collaboration, R. Aaij et al., Measurements of charmed meson and antimeson production asymmetries at √s = 13.6 TeV , arXiv:2505.14494, submitted to JHEP

- Many other analyses, spectroscopy of b-hadrons, etc. About expected 62 new publications in 2025 (published, submitted, and in review), 803 LHCb publications.

LHCb-Romania program: science and tech

- QCD, with EW/Drell-Yan, heavy flavor, and baryon studies,
  - Strangeness hadron productions in soft-QCD and hard-QCD cases (inclusive);
  - Drell-Yan, quarkonia, and soft-QCD (Underlying event) studies;
  - Charm production studies in generators and charmed baryon Λ_c Ξ_c production/decay;
  - Extrapolation to 5th LHC RUN with large pileup of collisions.
- LHCb-RICH Enhancement and IIb Upgrade, R&D, hardware quality, and reconstruction,
  - Enhancement of RICH subdetectors in 3rd LS;
    - FastRICH chip tests in radiation and in laboratory, bPOL DC/DC converters
    - R&D for front-end electronics
  - LHCb IIb Upgrade – sensors characterization and feasibility studies;
  - Students and R&D projects and tasks.
- Models in accelerator collision generators, HEPData, tuning,
  - Comparative studies of particle production for PYTHIA, HERWIG, SHERPA, EPOS, SIBYLL, QGSJET-II, DPMJET-III;
  - Service for LHCb to create entries to HEPData, and RIVET plugins.
- Other tasks including Statistical Methods and Analysis;
  - Reviews, Simulation software tasks, shifts/piquets, HEP Masterclasses and other Outreach events, academic tasks, Patents, prototypes, Documentation, Unfolding Methods and Deep-Learning machine in Unfolding

soft-QCD and hard-QCD in strange hadrons

The new LHCb results were covered as these are not published/public yet

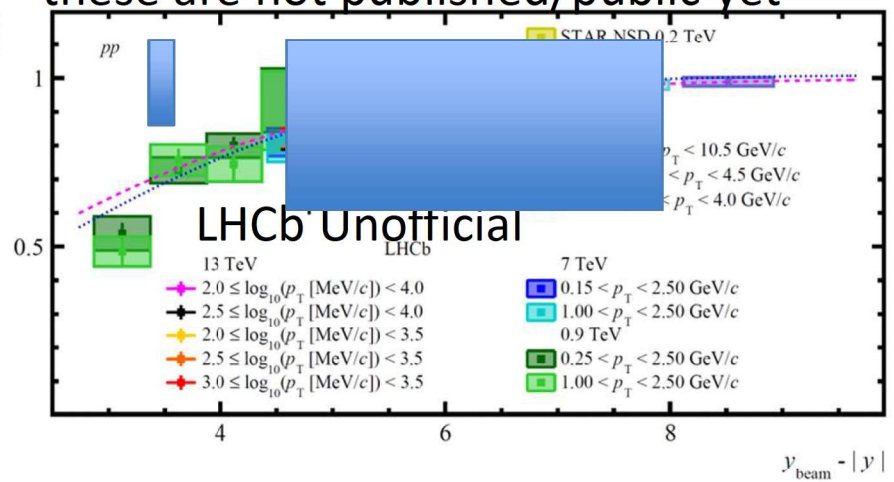
36+22+21 differential cross-section elements: K^0_S,Λ, $\overline{\Lambda}$;

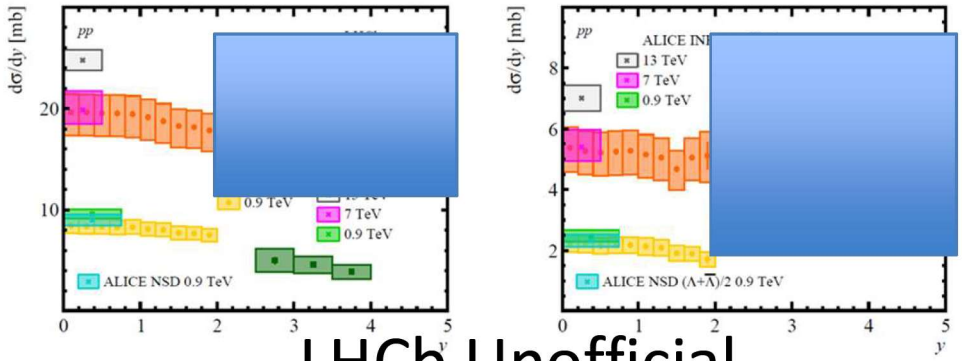
Ratios of baryon to meson, and anti-baryon to baryon

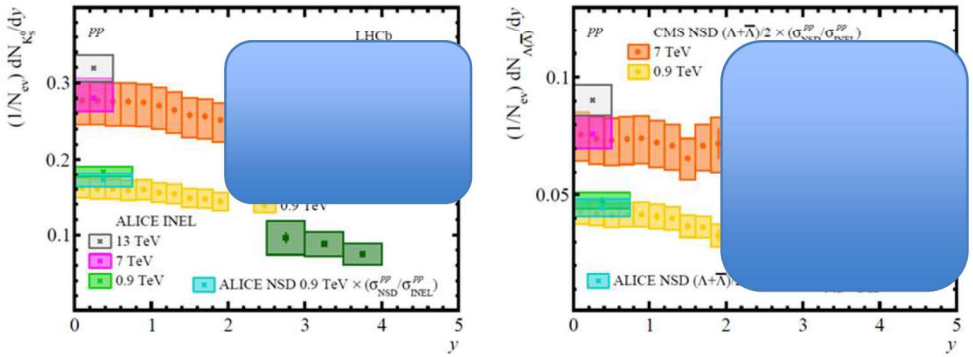
Comparison with old LHCb measurements, ALICE, CMS, STAR;

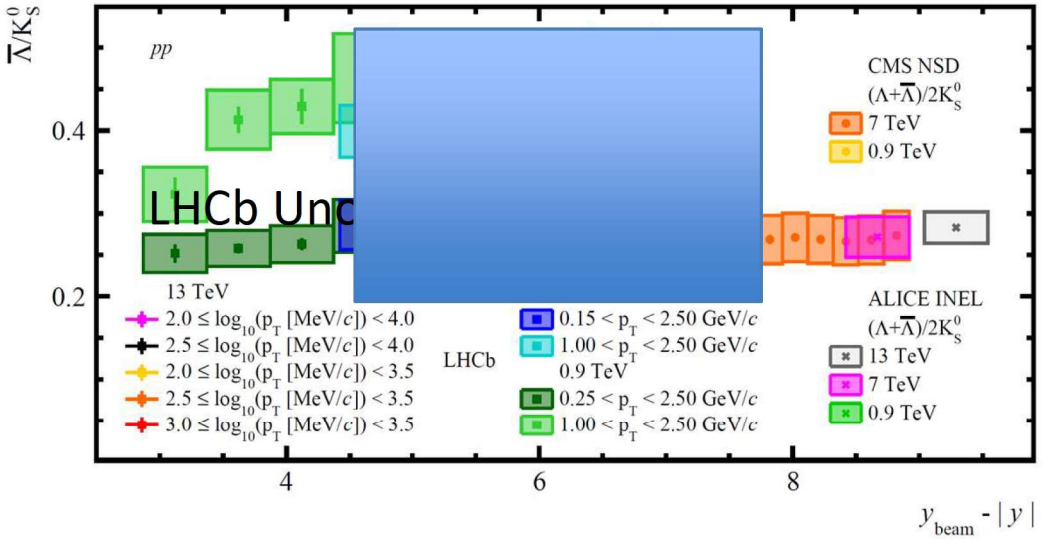
Some systematic revaluated:

- ❑ Non-prompt contamination from charm-hadrons;
- ❑ Kinematic corrections at the edge of LHCb acc.









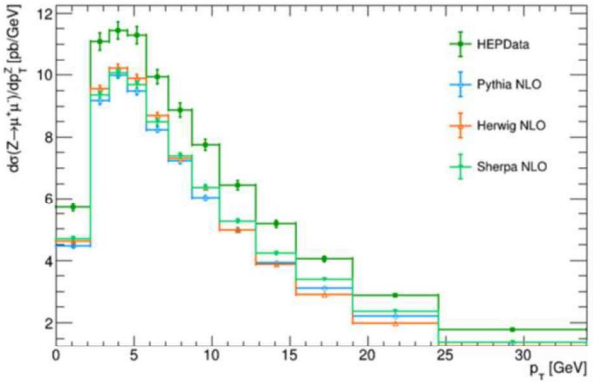
Comparison: p_T-Integrated dσ/dy and rations;

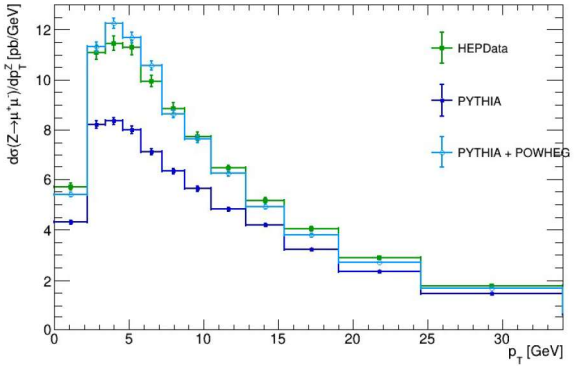
LHCb: 13 TeV; RUN1 LHCb: 7, 0.9 TeV; ALICE: 13,7,0.9 TeV; CMS: 7,0.9 TeV, STAR 0.2 TeV.

Soft-QCD and hard-QCD, EW Z0 boson Quarkonia, and Underlying event

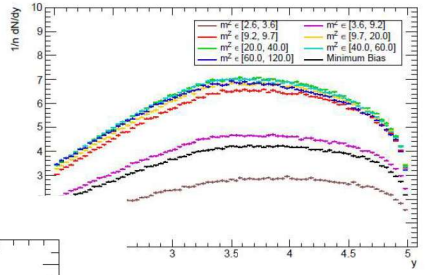
- PhD study of Underlying event and the hard-QCD measurements,
  - Underlying event as function of the hard-QCD parton-parton collision scale;

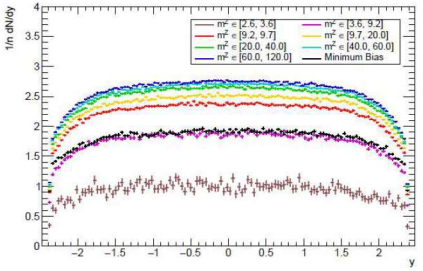
  vs.
  - Measurement of Drell-Yan boson (quarkonia) production with leading-particles (jet) at the hard-QCD scale;
- 1st PhD-year study is a preliminary generator study including comparisons (paper),
  - Various configuration and tuning, PYTHIA 8.3, HERWIG 7.2, SHERPA v3;
  - QCD LO vs NLO(or POWHEG for PYTHIA and HERWIG), Various Tunes for PYTHIA;
  - HEPData comparison.
- Next, LHCb data processing and analysis.

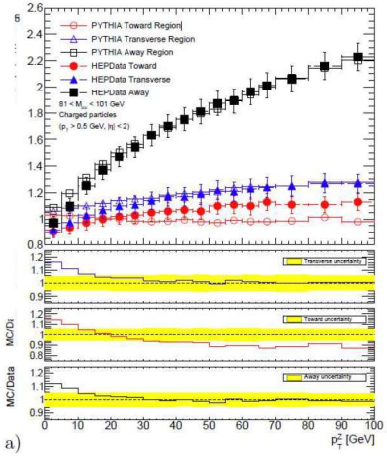


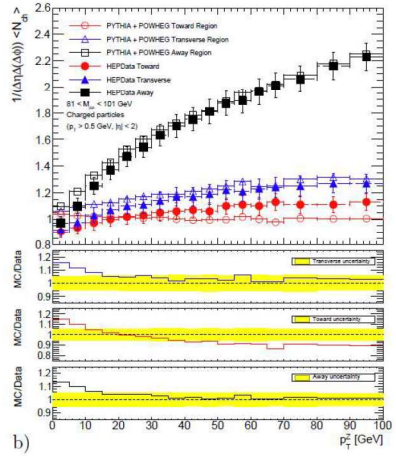


Double-muon (DY) spectra for LHCb acceptance and CMS acceptance in NLO configuration









HEPData and MC statistic in LHCb software

HEPData - 5 finalised submissions in 2025, one update:

1. Measurement of the W → μν cross-sections as a function of the muon transverse momentum in pp collisions at 5.02 TeV;

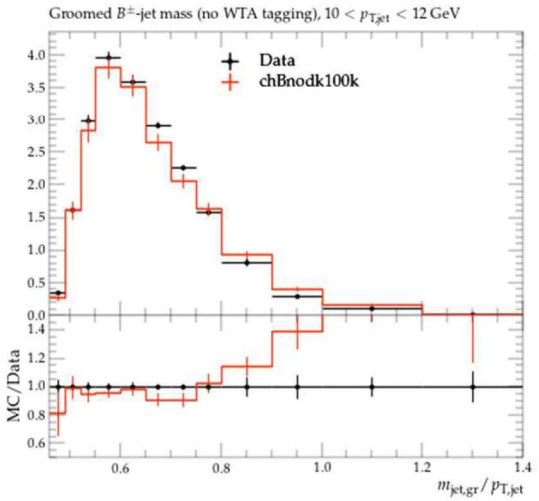
2. Comprehensive analysis of local and nonlocal amplitudes in the $B^0 \to K^{*0} \mu^+\mu^-$ decay;

3. Three-pion Bose-Einstein correlations measured in proton-proton collisions;

4. First measurement of b-jet mass with and without grooming;
RIVET routine to be released by the end of the year (final validation of code is on-going).

5. Measurement of the prompt D^0 nuclear modification factor in pPb collisions at $\sqrt{s_{NN}}$ = 8.16 TeV;

One update for "Precise determination of the B0s-B0sbar oscillation frequency";



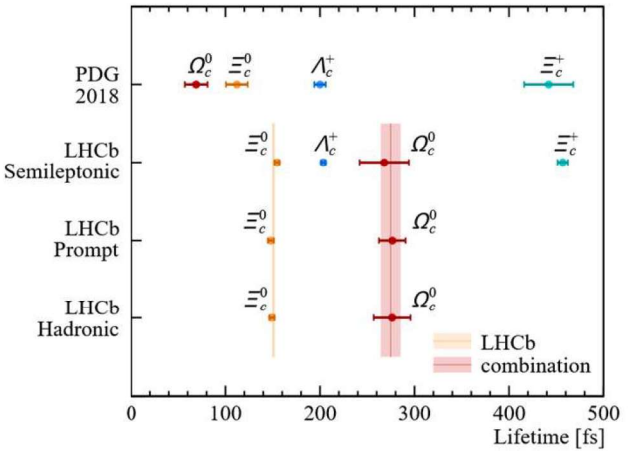
Distribution from validation of code in latest RIVET 4.1.2 obtained using PYTHIA 8.3 stand-alone with special generator hook to enhance B event generation.

47 generator statistics table merge requests successfully done and published until Nov. 2025;

(~ 1 request/week) – number estimated from number of JIRA tasks closed or awaiting validation since Jan. 2025

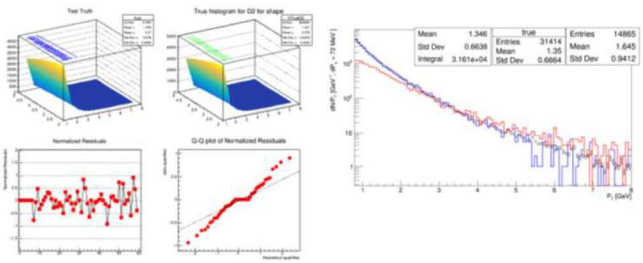
review (chair) "Measurement of the Ω_c^0 and Ξ_c^0 baryon lifetimes using hadronic *b*-baryon decays", JHEP 09 (2025) 157;

Time for a new whole LHCb tune: even in V0 analysis we see problems in baryon production or need of a better color-reconnection parameter set, and more.

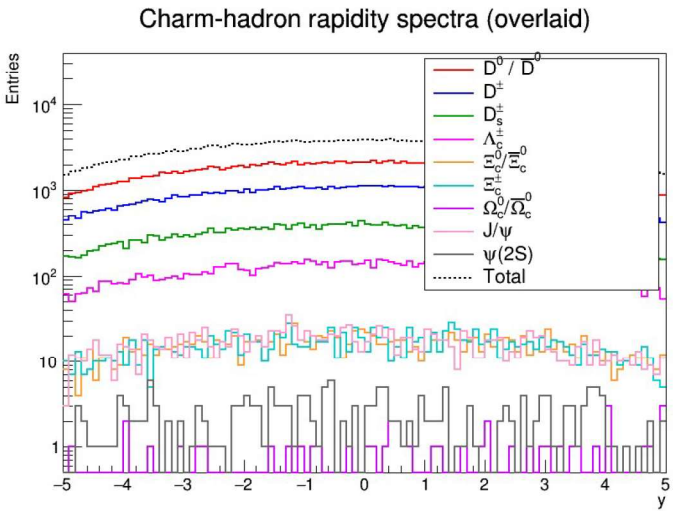


Summary of the lifetimes for charm baryons
Comparison with PDG old data, public results.
Taken from LHCb paper web page (published values):
https://lbfence.cern.ch/alcm/public/analysis/full-details/3875

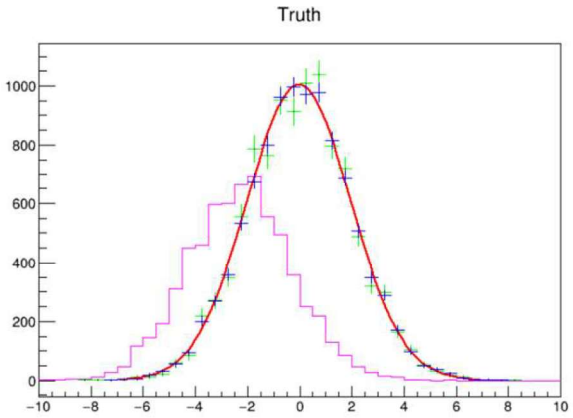
Synergy with other projects of the team:
charm-hadron generator studies, and Unfolding



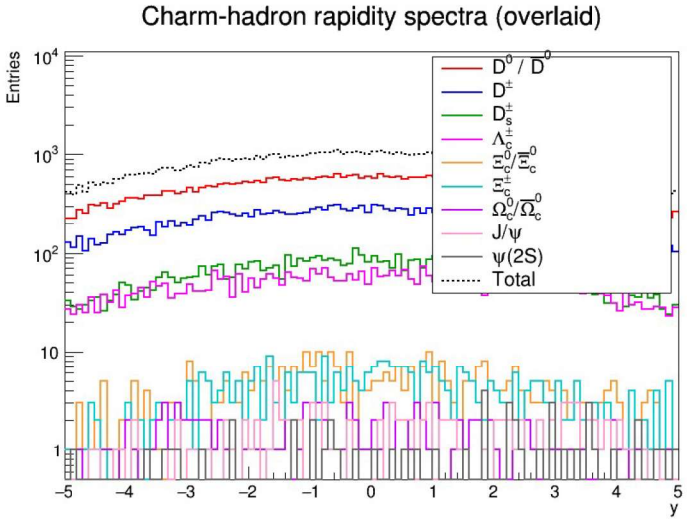
- Charm production, Generators models and older perturbative estimates (FONLL)



Charm-hadron rapidity spectra in MB events generated with PYTHIA, default tune for MB, 8.307 older version. 1M evt



D'Agostini's iterative Bayesian method to unfold toy spectra or DELPES simple Simulations for CMS, LHCb, etc



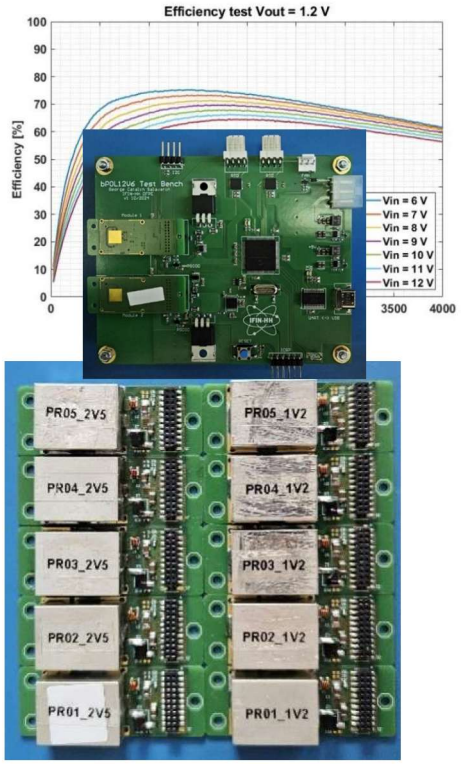
Charm-hadron rapidity spectra in MB events generated with HERWIG, default tune for MB, 0.5 M evt.

- Unfolding in HEP: iterative Bayes (D'Agostini or R-L), SVD, Dynamically stabilized, TUnfold (ROOT, a Tikonov regularization), bin-by-bin, Gaussian
  - Tested the limits and solution stability if imperfect or very poor-quality Monte Carlo description;
  - Multi-dimensional unfolding, various background and signal shapes, regularization scheme strengths vs pitfalls;
  - To do: check OMNIFOLD results and estimate the advantages of the unbinned Machine-Learning approach, establish the criteria for solution quality determination in real data.

R&D for LS3 Enhancement and IIb Upgrade

ASICs – FastRICH, bPOLs in Lab and in X-ray

bPOL in lab



Both FastRICH chip and bPOL converter tested In lab to check the performance and suitability;

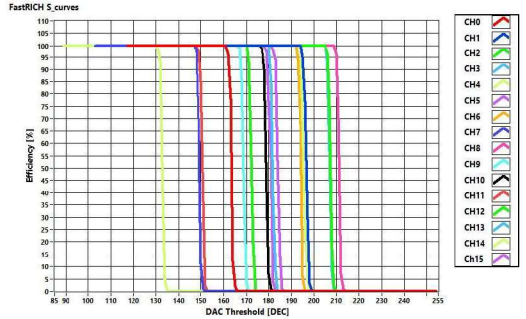
FastRICH performance is so far within the accepted limits and in concordance with simulation;

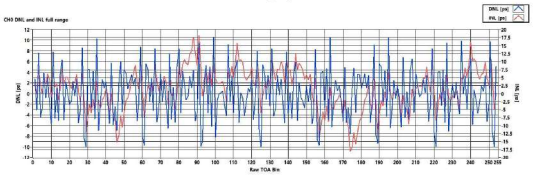
bPOL converter is also fulfilling its expectations;

- We investigate and are in contact with CERN team to see if we could be affected by the radiation-hardness failure
- Carrier board designed for FastRICH, bPOL, and lpGBT.

FastRICH chip was subjected to a TID >> 6 Mrads (6 Mrads (Si), for Cu ~30 Mrads), without any apparent effect.

FastRICH, in lab



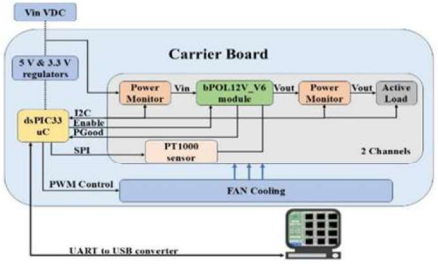


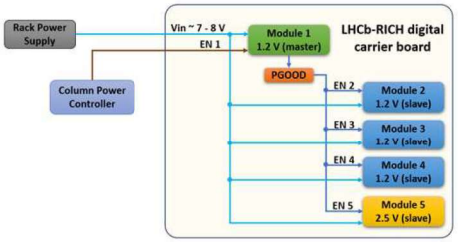
differential non-linearity of the TDC bins ~ 5 ps RMS

Typical jitters 5 or 15 ps

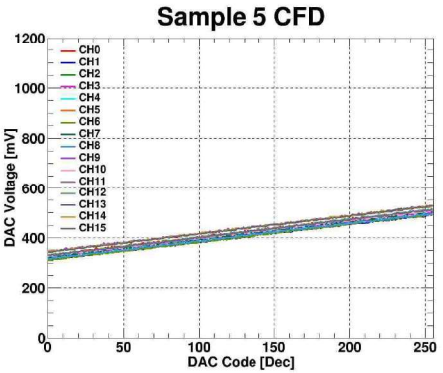
Time bin size of about ~25 ps

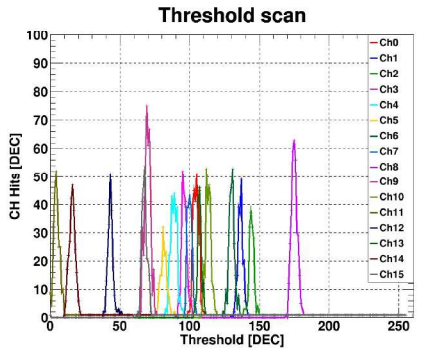
We have to test the simulation RMS values per channel at for 1..N ph-el.





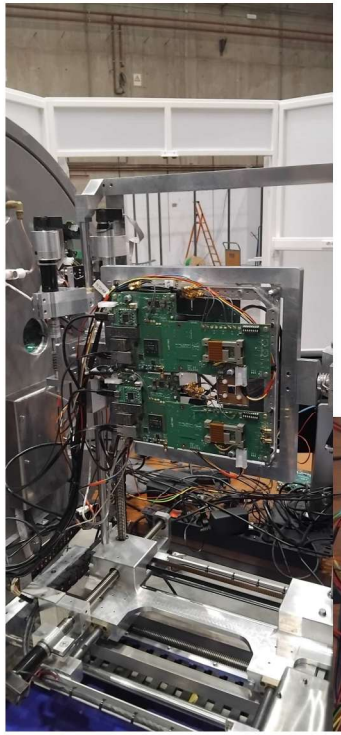
Future digital carrier board used in test-bench for mass testing of bPOLs;





Single Event Effects in FastRICH – ion beams

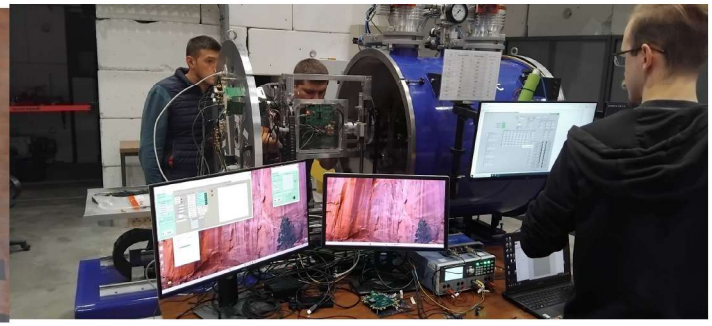
- FastRICH chip was tested with ion beams in eff. LET range [3, 125] MeV cm^2/mg;



Tests done at Heavy Ion Facility of CRC from UC Louvain;

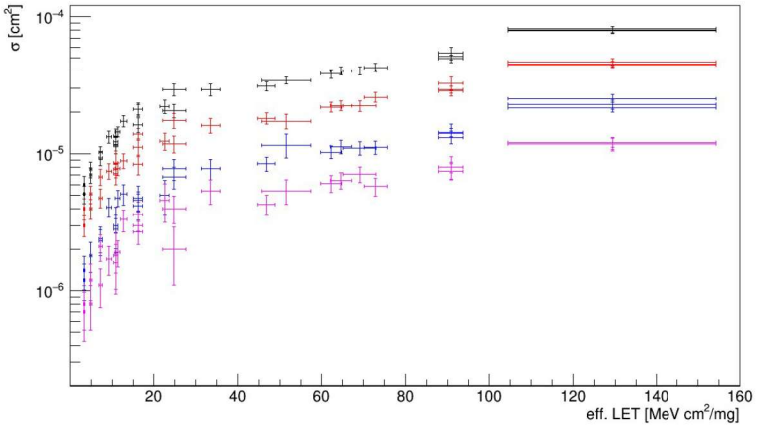
Results:

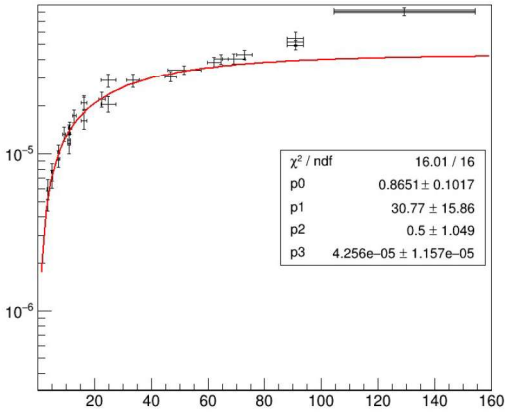
- ELT protection prevented any SEL or Burnout up to the highest effective LET;
- No critical problems seen (delivered >10^8 ions/cm^2 above 70 MeV cm^2/mg);
- Observed SET and SEU with low threshold for CMOS 65 nm tech node;
  - Most is not all these SEE are inconsequential, as the CERN/Barcelona design mitigated the effects within 150 ns per SEE.

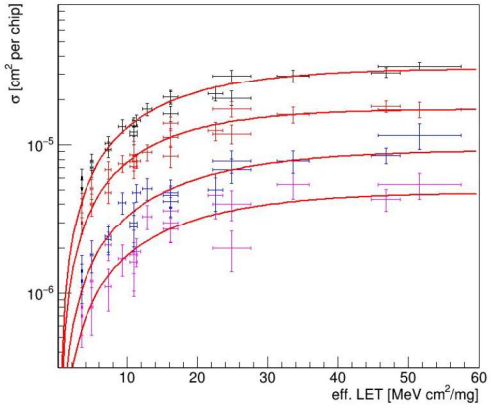


Analysis in progress but very optimistic; Need more data to make absolutely certain that the SET and SEU do not affect the ~40k chip operation in 5th LHC run;

Cross-sections of Single event Upsets (in cm^2) for three blocks: Digital, Analog, Phase Locked Loop, with errros in LET and stat. errors



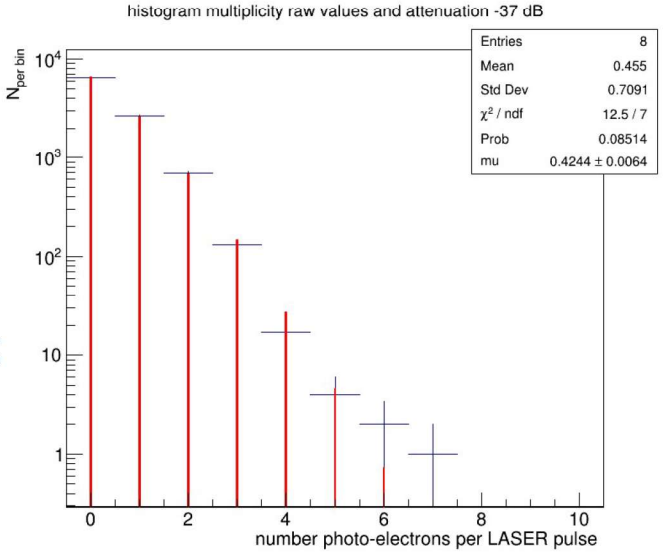




The threshold Is quite low, at about 0.1 MeV cm^2 /mg, but the design prevents errors to last for more than 6 clock ticks, ~150 ns

Sensors in LHCb IIb Upgrade and DRD4

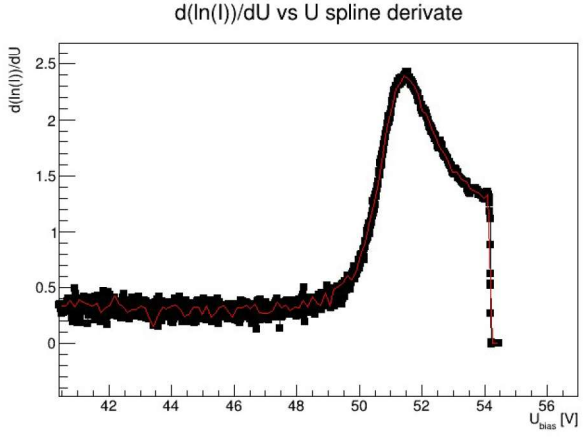
Geometrical Poisson distribution



Campaign to Characterize SiPM operation

- New measurements at -30 deg. Also scheduled an irradiation of several SiPM sensors at 9 MV IFIN's TANDEM (10 MeV protons)
- Expanded the list of SiPMs to test;
- To access a new facility for cryogenic temperature tests (2026);
- Potential measurements at about -200 deg C.

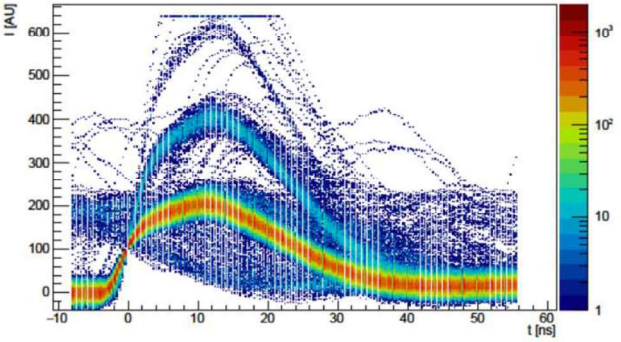
One method to determine the Breakdown point



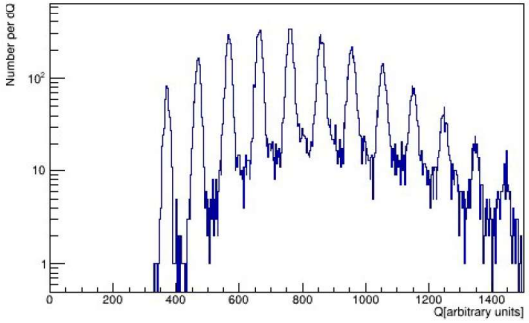
Laboratory and tool changes:

Added new capabilities which use the existing hardware;
List of quality tests and full characterization set implemented;
Improved the automatization, and added new light sources;
New Software for data analysis and for hardware interface.

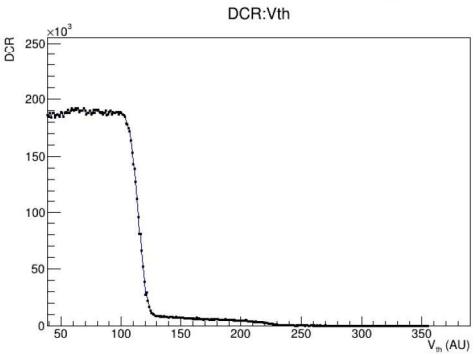
1, 2, and 3 photo-electrons

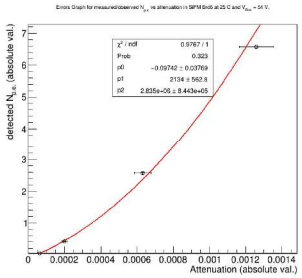


Number of photo electrons, q-spectrum



~180k Dark count rate (Hz) for
~2 V overvoltage, 25 deg. C

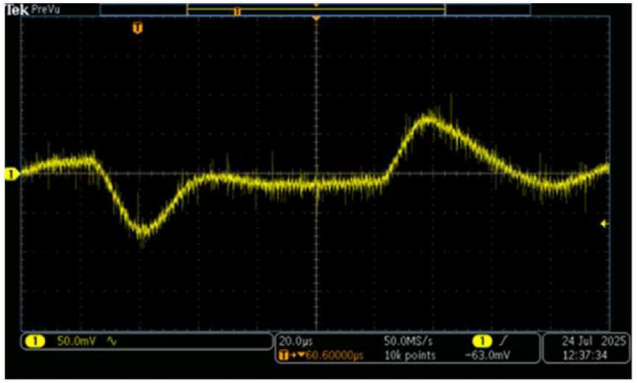




Projects of LHCb-Romania M. Sc. students

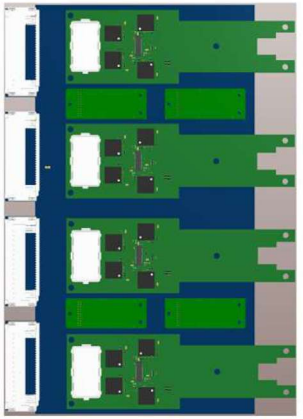
1st project includes of a MSc student includes:

- ✓ bPOLs efficiency and transient response;
- ✓ design of carrier board for LS3 Enhancement;
- ✓ Mass testing bench for bPOL (~3500 DC/DC);
- ✓ Help with FastRICH testing.



The bPOL12V transient response, for V_{out} = 1.2 V

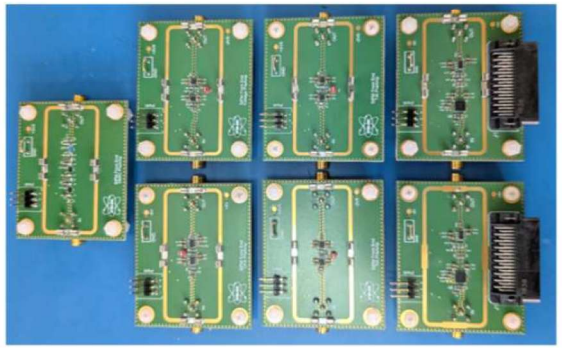
Carrier board



2nd project of an MSc student:

- ✓ Design of Preamplifier and amplifier boards, with BW > 1 GHz;
- ✓ Design and calibration of a photo-diode beam-profiler systems for accelerator irradiation;
- ✓ SiPM test-PCBs design and optimization.

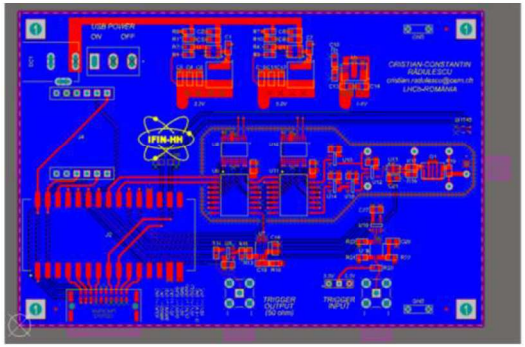
Pre-Amplifier and PCBs for SiPM

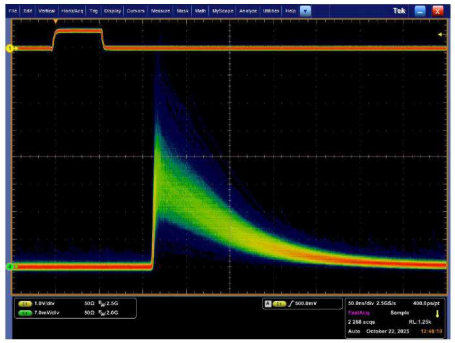


3rd project for an MSc student:

- ✓ Light emitting diode (LED) system with fast Control and narrow leading edge, prec. ~ns;
- ✓ Study of MaPMT response and characterization;
- ✓ Help with SiPM testing;

Light source PCB and signal





Hope the students will pursue a PhD at LHCb-Ro.

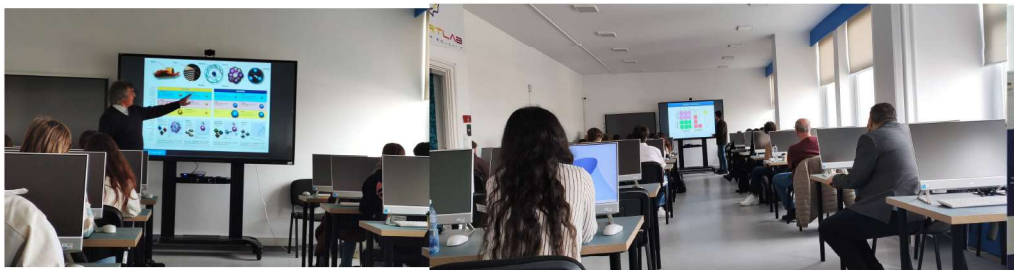
Outreach and academic popularization of HEP topics

- Two Masterclasses in 2025 at USV (Suceava) and IFIN/IFA (Bucharest);
- Several other events dedicated for high-school professors and students, including two at CERN for Suceava's teachers and professors;
- Support for a Summer school, Researchers night, Museums night, Astronomy and astrophysics Olympiads, University of Bucharest events.
- Three IFIN members are teaching at UB and UPB/UNSTPB:










LHCb-Romania – 2025 group summary of main publications, conference output, and deliverables

- ❑ Papers - published, submitted, and in review

- G.C. Salavarin and V.M. Placinta, Performance Assessment of bPOL12V Power Modules for the Next LHCb-RICH Front-end Electronics, TWEPP 2025 Topical Workshop on Electronics for Particle Physics, 6 – 10 October 2025, Rethymno, Crete, Greece, paper submitted to JINST;
- V. M. Placinta (on behalf of LHCb-RICH), "The LS3 Enhancement of the RICH detectors", XII International Workshop on Ring Imaging Cherenkov Detectors - RICH2025, 15 -19 September 2025, Mainz, Germany, to be published in NIM A (to be submitted in December, under review in LHCb-RICH);
- Roxana-Maria MOCANU, et al., "QCD interactions and processes from sub-GeV scale to about 1 TeV scale in proton-proton collisions at $\sqrt{s}$=13 TeV", to be submitted in December to Chinese Physics C;
- LHCb collaboration, "Measurement of prompt K^0_S and Λ production cross-sections and ratios in proton-proton collisions at $\sqrt{s}$ =13 TeV", (paper in internal review, earliest publication date in February);
- M. Bartolini, et al, "LHCb RICH Fast-timing photon detection at the SPS charged particle beam", JINST, 20, P03034, 2025;
- Other 2 papers pending for early next year, one LHCb analysis contribution, one RICH-LHCb analysis, DRD4 talks, etc;

- ❑ Two conference participations (posters – see up), plus one early next year;
- ❑ Two patents approved (submitted during previous LHCb project and approved in 2025);

C.C. Rădulescu, L.N. Cojocariu "Multi-sensor platform for long term monitoring in real time of indoor environment and natural radiation background";
V. Lupusoru et. al. "System with photodiode for real time monitoring of accelerated particles beams parameters"

- ❑ Already mentioned: HEPData submissions of 5 + 1 LHCb measurements, tens of LHCb talks in LHCb WG and two in Collaboration meetings;
- ❑ About 7 outreach events plus 2 Masterclasses for LHCb/CERN;
- ❑ >5 prototypes – either new or recently calibrated, including light source (~1ns Leading Edge), profiler, carrier board, mass-test bench for DC/DC converters, PCBs for FastRICH tests, etc.

LHCb-Romania – group

IFIN-HH (research institute) and USV (public university) groups;

10 researchers (all physicists and 5 have also engineer degree),
2 R&D engineers
5 students (3 Engineer degrees)
One staff, one engineer, 2 assistants;

5.2 Full time equivalent, plus synergy with IFIN-HH Nucleus

Hope to provide for 4 PhD students in 2026;

Table 1: IFIN-HH and USV subgroups, IDTs are Development and Research engineers with a PhD or equivalent, many physicists in our group have also an engineering license, the PI included

IFIN-HH	
1. Florin MACIUC, physicist	2. Alexandru Tudor GRECU physicist
3 Elena GIUBEGA physicist	4. Mihai STRATICIUC physicist
5. Lucian-Nicolae COJOCARIU IDT2	6 Vlad PLACINTA IDT2
7. Ovidiu Emanuel HUTANU eng.	8. Vlad LUPUSORU research assistant/student
9 Alexandru Cătălin ENE physicist	10. George SALAVIRIN research assistant (MSc)
11 Alina MOTORGA financial and acquisition staff	12. Cristian Radulescu research assistant (MSc)
13. Mocanu Roxana research assistant (PhD student)	14 Vlad ION assistant (Programmer) (leave of absence)
15. Mircea LECHINTAN research assistant (leave of absence)	16. Andrei-Theodor Hotnog research assistant (MSc)
USV	
17. Mihai DIMIAN professor	18. Cristian PÎRGHIE physicist
19. Camelia PÎRGHIE physicist	20. Daniel PRELIPCEAN physicist
21. Robert-Mihai Amarinei physicist	

An extended list of former LHCb-Romania students shows, the majority continued in group and even got permanent positions, some joined private firms or got high-school teaching positions:

- the list includes 12 PhDs, 2 IT PhDs, 3 MSc, 5 bachelors
- 5 PhDs had LHCb topics, and 2 PhDs LHCb-related topics.

Consider replacement for 3 members, and looking to increase the workforce FTE, plus salary budget from different sources, directly or indirectly; 87% coverage in 2025.

No	Name	former position	present position	Institute
1.	Lucian COJOCARIU	PhD student	IDT3	IFIN
2.	Elena Giubega	PhD student	researcher	IFIN
3	Adrian BONDARESCU	PhD student	staff	teaching
4.	Bogdan Paul POPOVICI	PhD student	researcher	IFIN
5.	Ion BURDUCEA	PhD student	researcher	IFIN
6.	Eliza TEODORESCU	PhD student	researcher	ISS
7	Mihai STRATICIUC	PhD student	researcher	LHCb-Ro
8.	Marius ORLANDEA	PhD student	researcher	IFIN-HH
9.	Ana-Elena Dimitriu	M.Sc. student	researcher	IFIN-HH
10.	Laurentiu DUMITRU	IT admin (PhD)	IT and technology	industry
11.	Teodor IVANOAICA	IT GRID admin (PhD)	IT specialist	industry
12	Doru PACESILA	PhD student	researcher	IFIN
13.	Vlad PLACINTA	PhD student	engineer	IFIN
14.	Alexandru ENE	PhD student	researcher	IFIN
15.	Simona DIRLECI	MSc student	professor	teaching
16.	Nicole DOLOT	programmer graduate	MSc student	Uni. Amsterdam
17	Andrei TOPALA	undergraduate	graduate	-
18	Radu JOMIRU	undergraduate	undergraduate	UPB
19	Cristian RADULESCU	bachelor	MSc student	UPB and IFIN
20	George Salavarin	bachelor	MSc student	UPB and IFIN
21	Vlad Lupusoru	bachelor	MSc student	UPB and IFIN
22	Roxana MOCANU	MSc student	Doctoral student	UB and IFIN

LHCb-Romania: 2026 planning and long term

- New analyses in LHCb: Underlying event, hard-QCD measurements in high-mass muon pair events, hope to cover charm baryons (production and decay studies);
- Generator tuning, generator studies (including pQCD estimate and data comparison)
- Support LHCb in Simulation software and HEPData;
- Continue R&D for: LHCb-RICH LS3 Enhancement, LHCb IIb Upgrade, DRD4 talks and popularization, support for DRD4 deliverables (Front-end electronics and sensors);
- Enhance the RICH detectors during 3rd Long Shutdown and before LS3, TDRs for LHCb-RICH;
  - Implement 500 carrier boards; Mass testing of FastRICH, detector modules, carrier boards and plugins, etc.
  - Make LHCb detector a 4D spectrometer by 2035, and implement 100% synergy between LHCb and DRD4 tasks/goals/projects;
- Continue the outreach program, academic activities, and support for the students;
- Provide the mandatory services to LHCb: shifts/piquets, reviews of analyses and paper drafts, provide support for LHCb-RICH group, conferences, and other LHCb tasks.