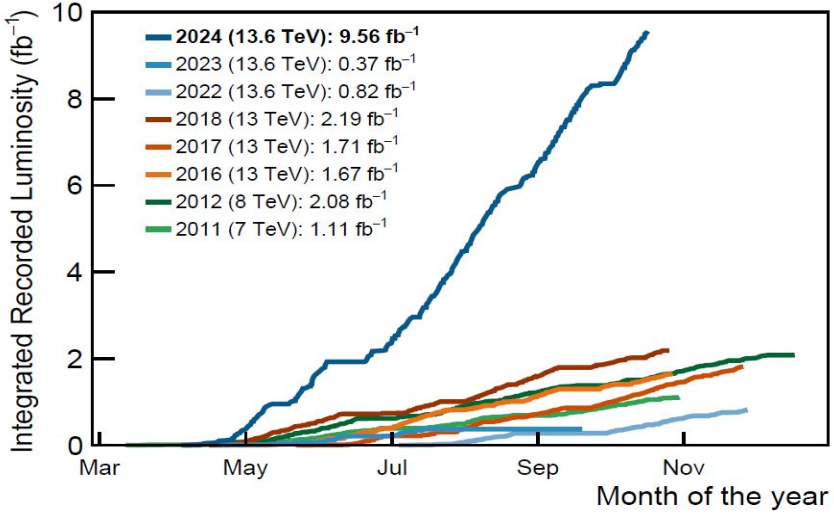
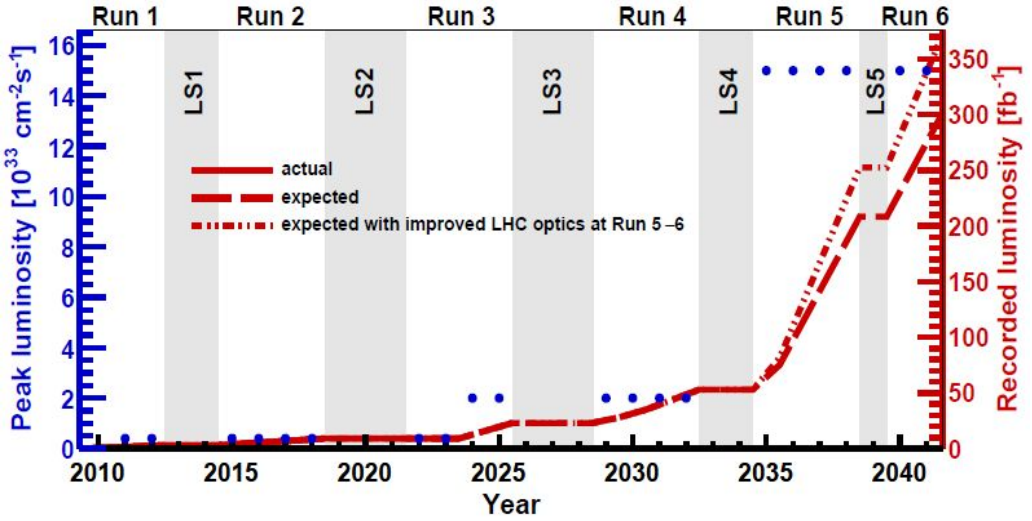
LHCb plans after Run 4 and contributions from Padova

Padova, 25/10/2024

A. Bertolin on behalf of the LHCb Padova group

What integrated luminosity LHCb reached so far and what are the prospects





2011 - 2018: 9 /fb (3 /fb Run 1 + 6 /fb Run 2)

2024: 9 /fb !!! efficiency for hadronic B decays x 2 - 3 wrt Run 2

2025 mid 2026: mostly pp running

enhancements + Upgrade II are funded

what's next ? 300 - 350 /fb !

Physics with LHCb Upgrade II

- Number of b hadrons recorded by LHCb will be O(10^14)
- Matched by **ATLAS and CMS** only for final states with muons
- **Belle II** competitive only for final states with gamma, pi0 or nu
- Comparable with FCC-ee
- **SOME** of the physics that can be done **ONLY** with LHCb Upgrade II
  - 10^-5 precision on charm CPV [deltaACP]
  - SM extensions with RH currents [b->sgamma]
  - spectroscopy [tetraquarks, pentaquarks]
  - rare decays and LFU
  - fixed target collisions with SMOG
- **Many results are expected to remain unsurpassed in precision for a considerable time**
- **More details on the Padova interests in the next few slides**

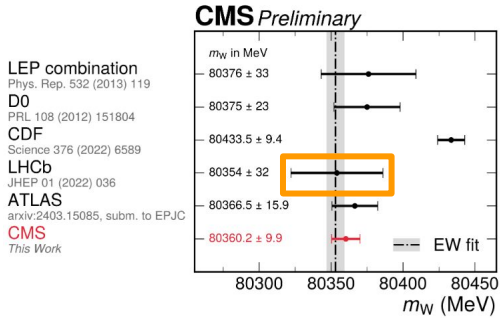
Physics contribution: EW, QCD, Higgs and Exotica

- Important results in QCD and EW sector
- **Measurements statistically limited!!**

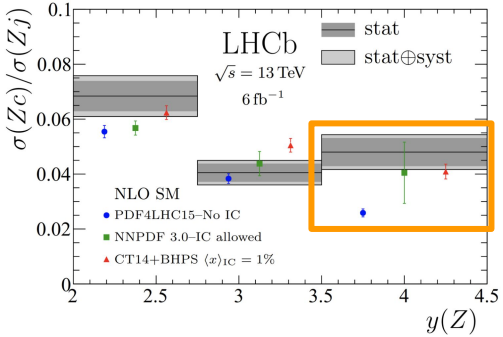
- **LHCb has a very interesting physics case for Run 5!**

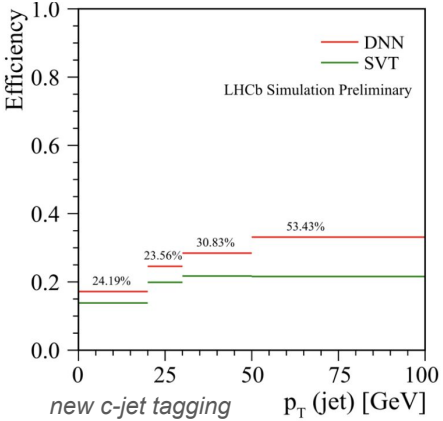
- Possibility to study **Higgs decay to charm**
- High precision on **jets substructure**
- Possibility to investigate double **boson scattering** in forward region
- Searches for **ALPs** and other **DM candidates**

results of W mass fit

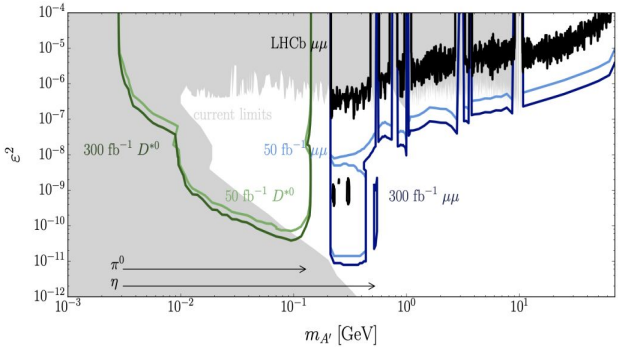


results on intrinsic charm using Z+jet events





new c-jet tagging performance using DNN



expected limits for searches for A'→μμ

https://cds.cern.ch/record/2905625/files/LHCb-CONF-2024-004.pdf

Physics contributions: CKM gamma

the LHCb gamma combination is obtained from at least 16 independent measurements of tree level decays

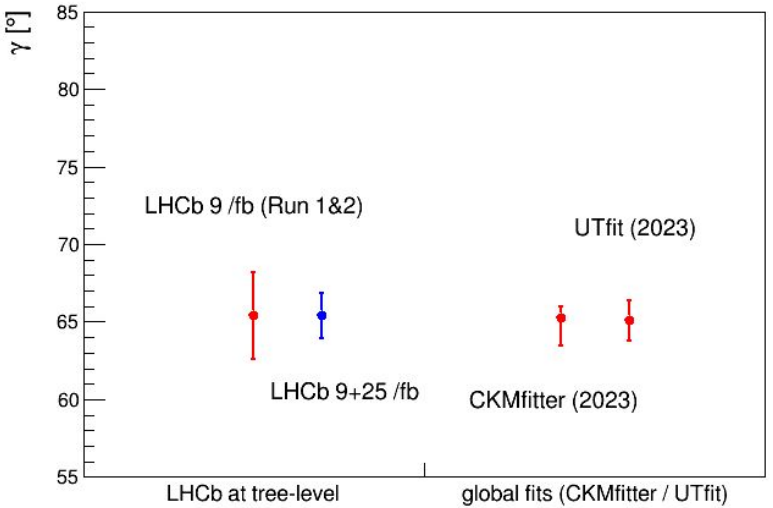
at present updated up to the Run 2 data, uncertainty, dominated by statistic, is 4.3 %

not yet the accuracy needed to compare with CKMfitter and UTfit

deviations between these two determination would be a clear indication of physics BSM (due, for example, to new loop contributions)

boosting the statistic to 300 /fb is mandatory to reach a sub-degree accuracy

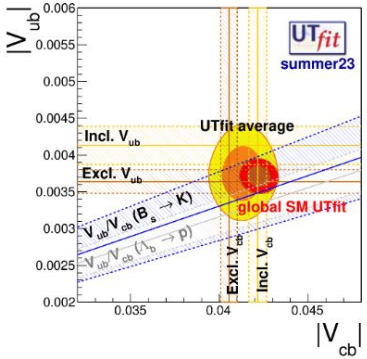
already a nice step forward in Run 3 with the new calorimeter-less hadronic trigger (x 2 - 3 efficiency boost already reported)

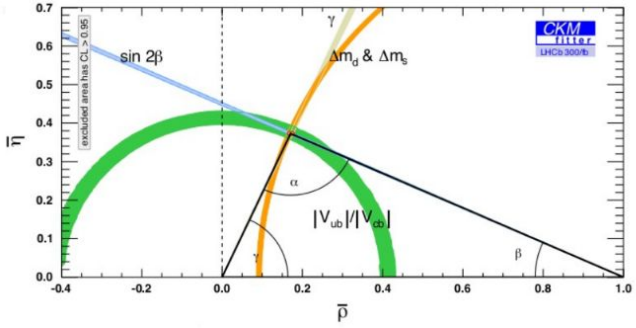


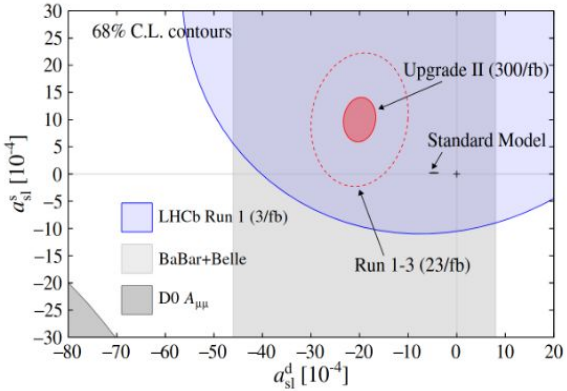
https://doi.org/10.48550/arXiv.1808.08865

Physic contribution: Measurements of unitarity triangle sides and semileptonic decays

- more accurate determination of |Vub|/|Vcb|, 1 % accuracy
- |Vub| measurement using Bc decays
- |Vcb| measurement using baryonic decays
- semileptonic asymmetries
- differential decay rate measurements → new physics





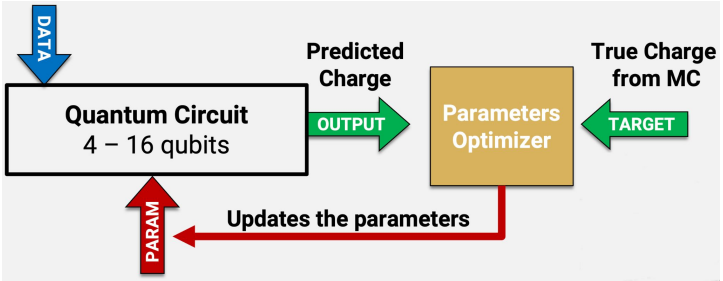


Sample ($\mathcal{L}$)	$\delta a^s_{\rm sl}[10^{-4}]$	$\delta a^d_{\rm sl}[10^{-4}]$
Run 1 (3 fb^{-1}) [210, 211]	33	36
Run 1-3 (23 fb^{-1})	10	8
Run 1-3 (50 fb^{-1})	7	5
Run 1-5 (300 fb^{-1})	3	2
Current theory [34, 200]	0.03	0.6

Software contributions: new software technologies

- LHCb Padova group is contributing to the usage of new software and analysis technologies to search for new effects or properties in data

- Two main areas:
  - **Quantum Computing**
    - Established first exercise of b-jet tagging using Quantum Machine Learning
    - Now searching for particle correlations to enhance differences due to fragmentation



  - **Analysis facilities & GPUs for analysis**
    - Innovative analysis software by using advanced ML methods already used for b- to c-jets discrimination will be used to study jet sub-structure
    - exploit PID to investigate strange-tagging

Software contributions: trigger

at present the backbone of the LHCb first level trigger (Hlt1) consist of:

- `Hlt1TrackMVADecision`
- `Hlt1TwoTrackMVADecision`

strongly suspect this will be inadequate for Run 5, investigate the application of some of the new technologies mentioned previously ie advanced ML methods exploiting the full event / information available

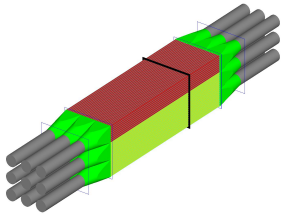
at present the LHCb second level trigger (Hlt2) is using mostly exclusive trigger lines reconstructing the beauty meson / baryons decays of interest

rates are kept under control using rather conventional NN algorithms trained on background taken from data

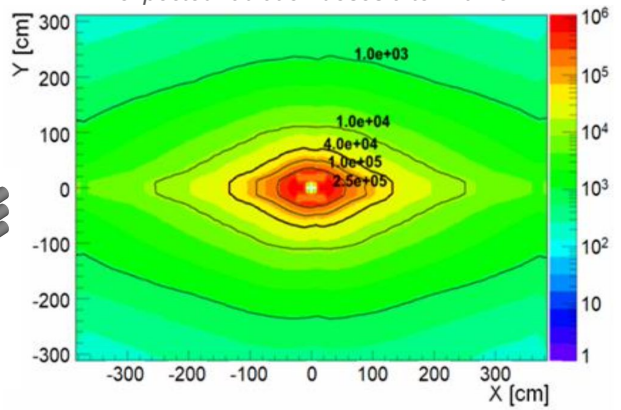
strongly suspect these will be inadequate for Run 5, investigate the application of advanced ML methods

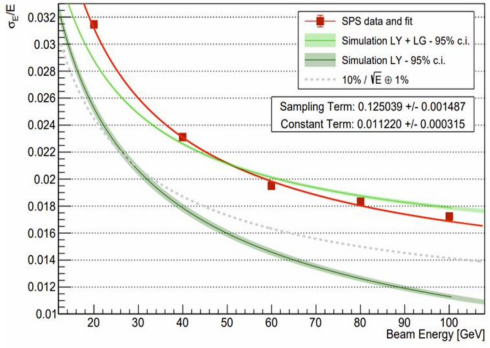
Hardware contribution: ECAL upgrade

- ECAL has to be redesigned to achieve **same performance of Run 2**, facing new challenges:
  - **Higher pile-up**
  - **Higher radiation dose**
- Intense R&D to develop new **Spaghetti Calorimeter** modules for ECAL inner region

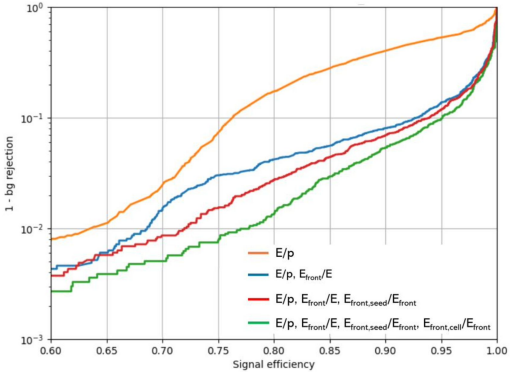


expected radiation doses after Run 5





energy resolution obtained using SPS data during TB campaign

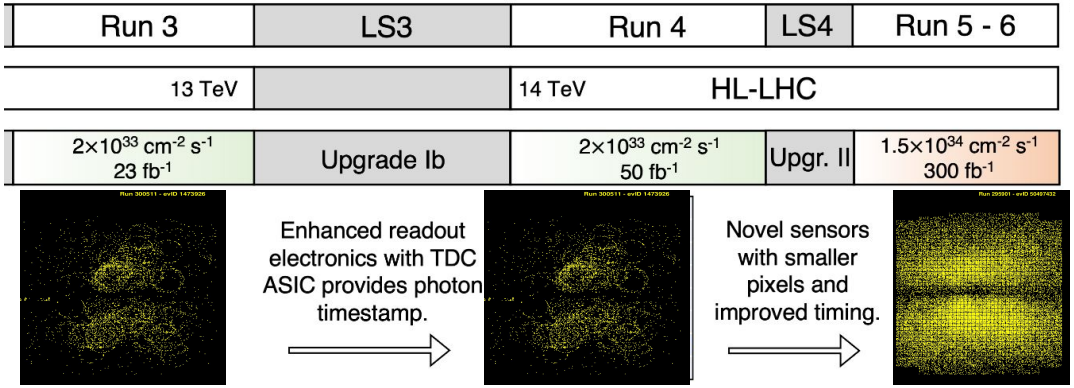


study on electron vs pion discrimination exploiting ECAL longitudinal segmentation

- Padova group interests and contributions:
  - LHCb **detector simulation software development**
  - Analysis of Test-beams data and **characterization of modules**
  - online data processing using FPGAs

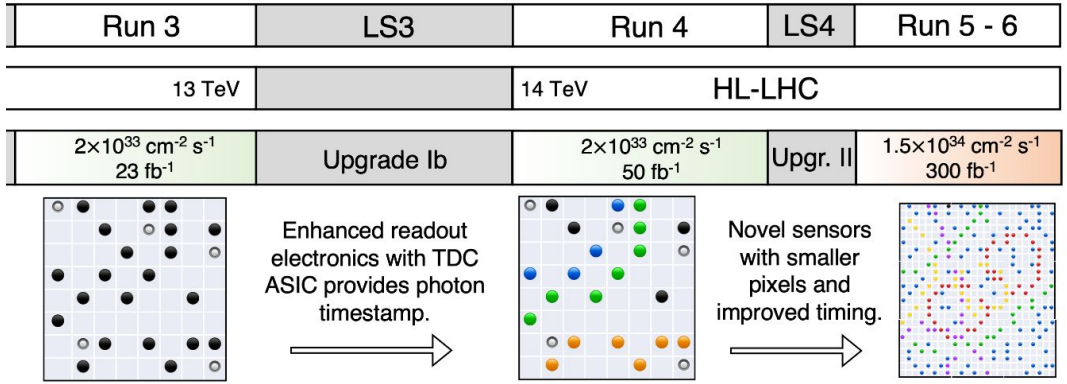
Hardware contribution: RICH upgrade

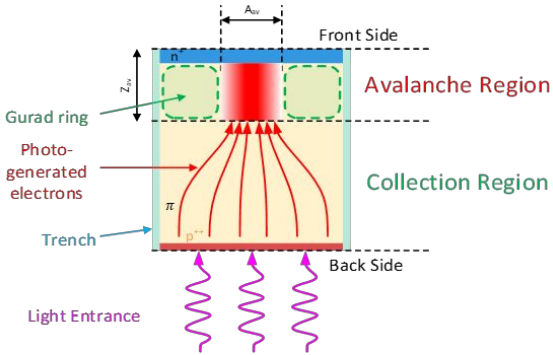
- Hadron particle identification is key to unique LHCb physics capabilities

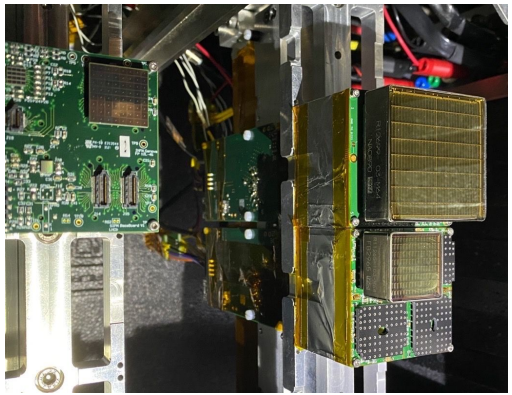


Hardware contribution: RICH upgrade

- Hadron particle identification is key to unique LHCb physics capabilities
- Timestamping each photon with a few tens of ps resolution to maintain the PID performance with mu~40
- Padova interested in the R&D of the time resolved RICH
  - test beams of the time resolving electronics
  - R&D on new fast radiation hard SiPM
  - R&D on cryogenic or local cooling for SiPM







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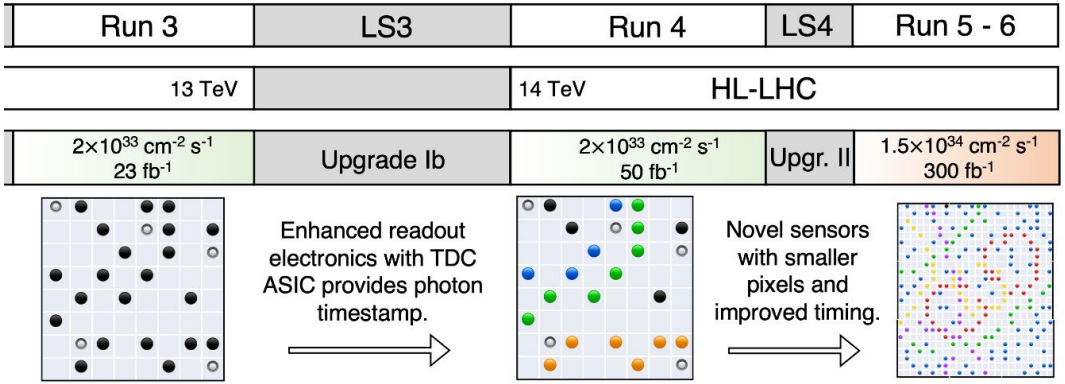

https://lbfence.cern.ch/alcm/figure/details/3573
https://lbfence.cern.ch/alcm/figure/details/3837