Physics Analyses & Reconstruction

i.e. non-hardware activities

Meeting with ALICE, 2025 05 28

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Areas in Which We are Involved

non strictly-speaking hardware

- areas in which we have been involved in the last ~10 years in *Belle II*:
  - tracking & silicon vertex detector (SVD) *reconstruction*
  - charm, dark matter & tau *physics*
  - physics performance studies related to possible detector upgrades
- not only involved, in most cases we have (had) coordination roles
  - except for the tau physics & upgrade performance
- *our reconstruction expertise is built on and profits from our hardware expertise; physics connected to reconstruction expertise with charm and tau analyses in which high precision tracking is crucial; physics performance for upgrades closes the circle. In the last years we have expanded our physics interests into the promising sector of the dark matter searches.*

Reconstruction Software

mainly on the strip detector & tracking

➡ main contributions for **SVD**

- rewritten almost the whole reconstruction including several improvements in terms of reconstruction performance
- exploitation of cluster time as powerful tool against beam background, improvement of data-MC agreement (resolutions), …

➡ main contributions to **tracking**

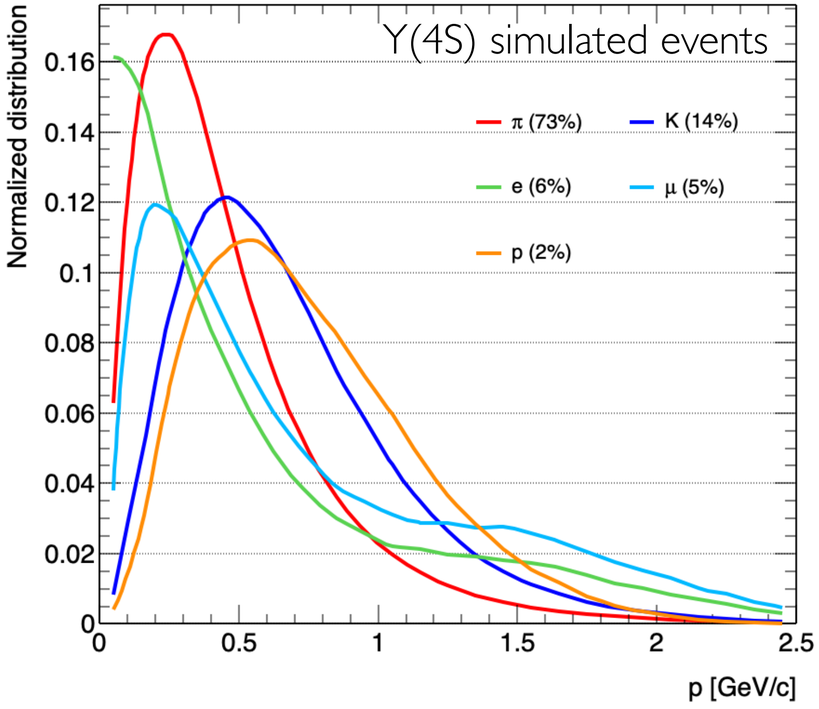
- SVD-standalone pattern recognition; definition of the pixel detector regions of interest on the HLT to reduce PXD data during acquisition (largest software contributions)
- coordination: new software features, validation, online, performance, corrections and systematics

A Typical Y(4S) Event

➡ average multiplicities
- 11 charged tracks
- 5 π^0 & 1 neutral kaon

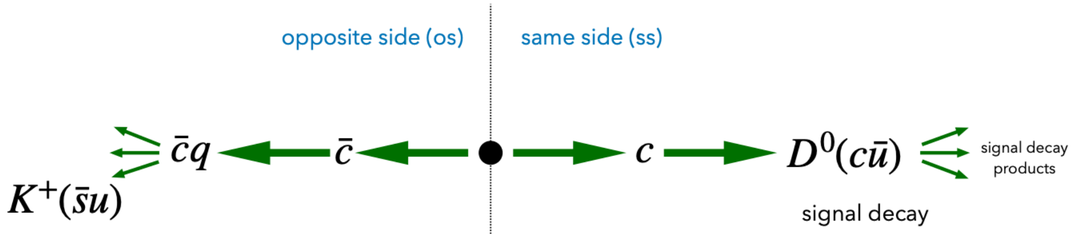
➡ current SVD occupancy in L3 ~0.8%
- ~10.5k channels/side in L3

➡ soft charged tracks momentum spectrum

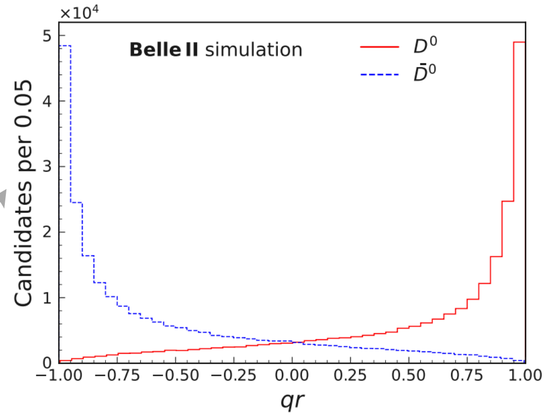


Charm Physics

high-precision measurements

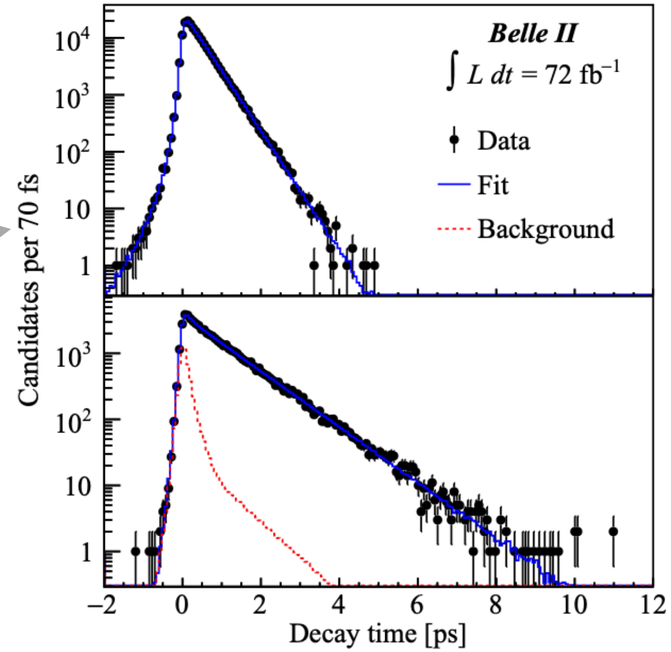


Phys. Rev. D 107, 112010 (2023)



- the *original* expertise is on D^0 **mixing ad CP violation** measurements
  - time-dependent (x,y, y_{CP}, ΔY) and time integrated (A_{CP}) analyses
  - $D^0 \rightarrow K\pi$, K^+K^-, $\pi^+\pi^-$, $K_S\pi^+\pi^-$, $\pi^+\pi^-\pi^0$
- with a master student (now software deputy coordinator) we have started the **charm flavour tagger**, evolved in an HBDT-based tool that allows to infer the flavour of the D^0 from the rest of the ccbar event increasing the statistics for CPV measurements
- with the D^0 **lifetime** measurement (started with master student, now convener of a physics WG) we have triggered the measurement of (world-best) D_s, Λ_c, D^+, and Ω_c lifetimes at Belle II

Phys. Rev. Lett. 127, 211801 (2021)



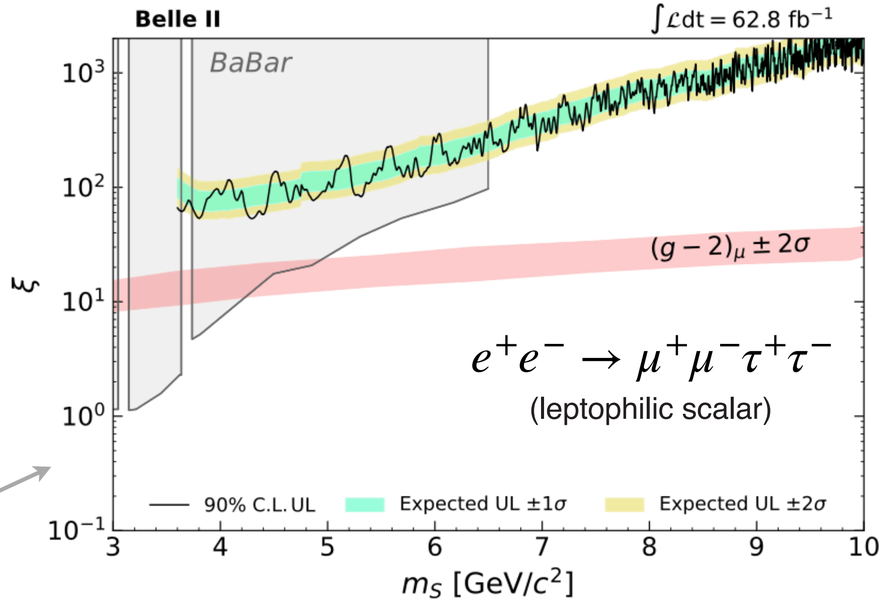
Dark Matter Physics & Tau

searches

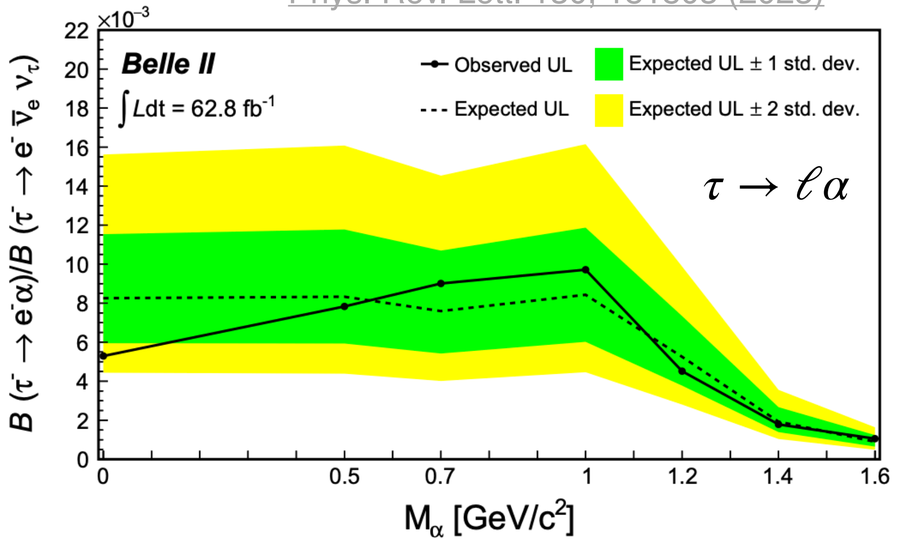
- the main goal is to **test new physics models** predicting new particles that interact with SM particles via different portals
  - vector (dark photon, Z'), scalar (dark higgs), pseudo-scalar (axions, ALPs), neutrino (heavy neutrinos)
  - one analysis, different interpretations possible
  - tested **mass in the MeV-GeV range**

- some examples:
  - $e^+e^- \to \mu^+\mu^- X\ (X \to \tau^+\tau^-)$ X = non-SM resonance
  - LFV $\tau \to \ell\alpha\ (\alpha \text{ invisible})$
  - $e^+e^- \to \mu^+\mu^- Z'\ (Z' \text{ invisible})$ PRL124, 141801 (2020) first Belle II publication
  - $e^+e^- \to A'(\to \mu^+\mu^-)h'(\to h^+h^-/\mu^+\mu^-)$ PhD ongoing displaced vertex

Phys. Rev. Lett. 131, 121802 (2023)

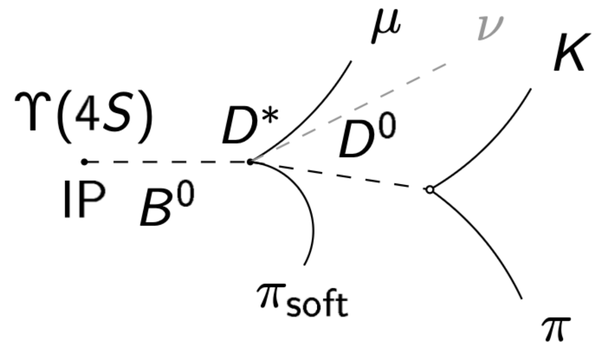


Phys. Rev. Lett. 130, 181803 (2023)

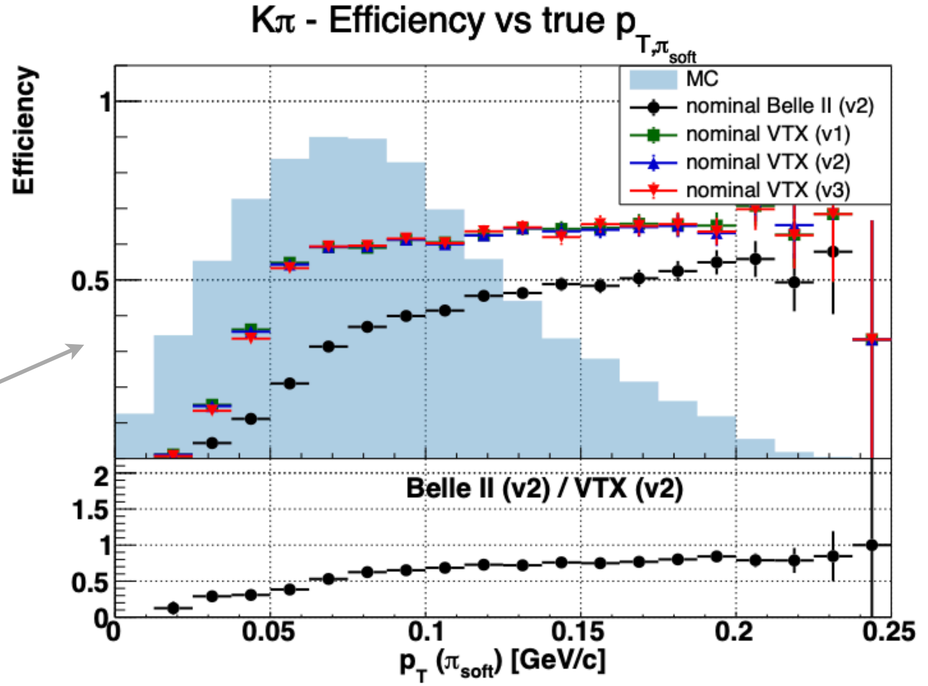


Performance Studies

for possible future upgrades



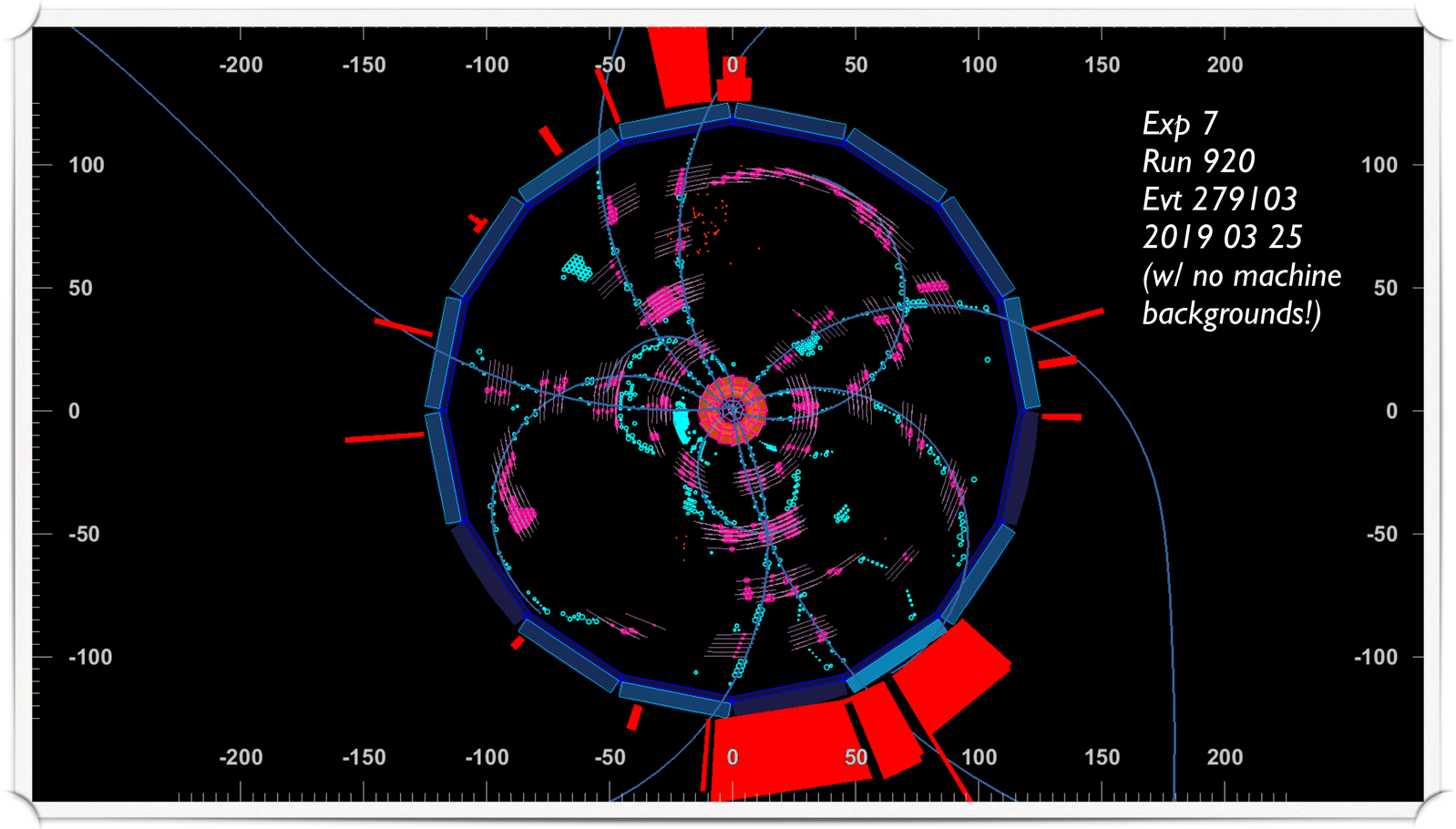
- the main goal is to support the design of the new detector with quantitative analyses performed on benchmark channels, e.g.
  - $B^0 \to D^{*-}(\to \bar{D}^0\pi_s^-)\ \mu^+\nu_\mu$
  - $B^0 \to J/\psi K_S$
- our main interest is the new vertex detector, VTX
  - 5-to-7 layer all-pixel detector based on CMOS-MAPS
  - evaluation of the performance vs different background levels
  - optimisation of the number of layers and their radial position
  - impact of the material budget for different ladder design (including pretty accurate mechanics and cooling simulation)



The Belle II Detector Upgrades Framework Conceptual Design Report

backup slides

A Candidate Hadronic Event at Belle II (2019)



NOTE: the DAQ is not synchronous to the bunch crossing (150÷250 MHz)

→ detectors integrate many collisions (+ beam background)

→ reconstruction is not as easy as it may look here