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LHCb activities in Uppsala

Brief background – introduction

Two recent results

Particle physics in Uppsala NP division

Some preliminary plans

Brief background

- Ph. D. Uppsala – ATLAS
- Fellowship CERN – LHCb
- University of Glasgow
  - LHCb, ATLAS (upgrade), Hyper-K
  - Detector development
- Flavour physics, silicon detectors & electronics
- Uppsala Nuclear Physics Division (since Sept. 2020)
  - Nuclear structure
  - Hadron physics
    - Current/past: BESIII, KLOE, WASA
    - Future: PANDA, LHCb (?), …

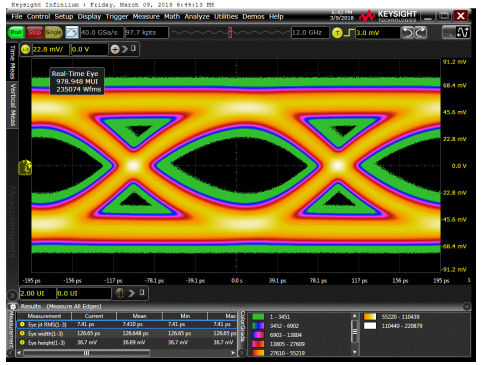
LHCb VELO pre-installation

Heavy flavour studies in Scotland

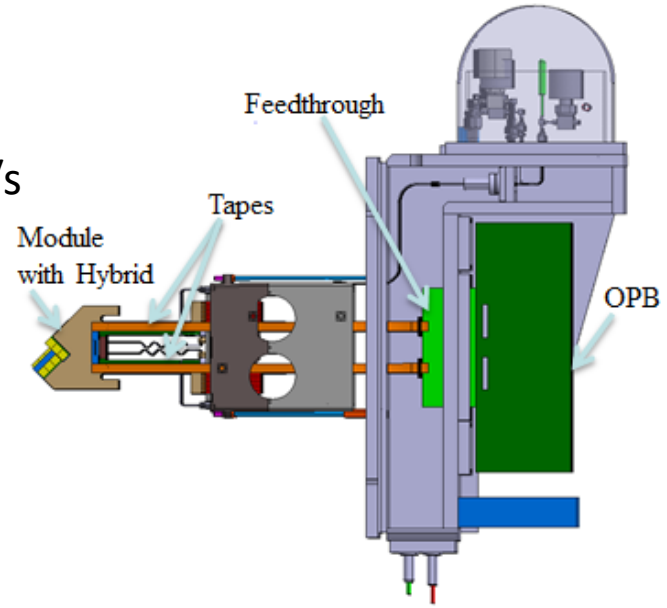
(my past) LHCb programme

- LHCb is a new activity in Uppsala
  - Starting funds from UU
  - Aim to joint LHCb with Uppsala
- Physics analysis
  - Two examples in this talk
- LHCb VELO
  - Original, upgrade I and upgrade II
  - Silicon sensors, systems design, electronics, detector performance

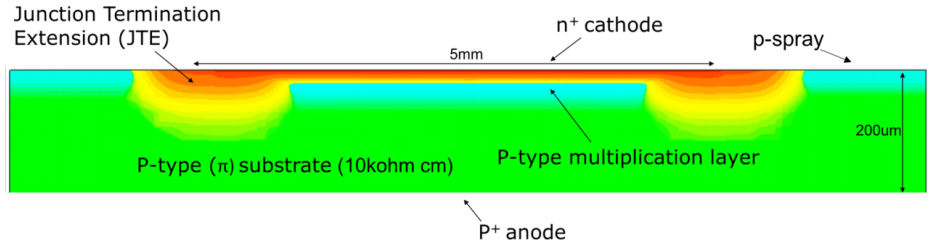
High speed data links 5.12 Gbit/s



VELO detector half

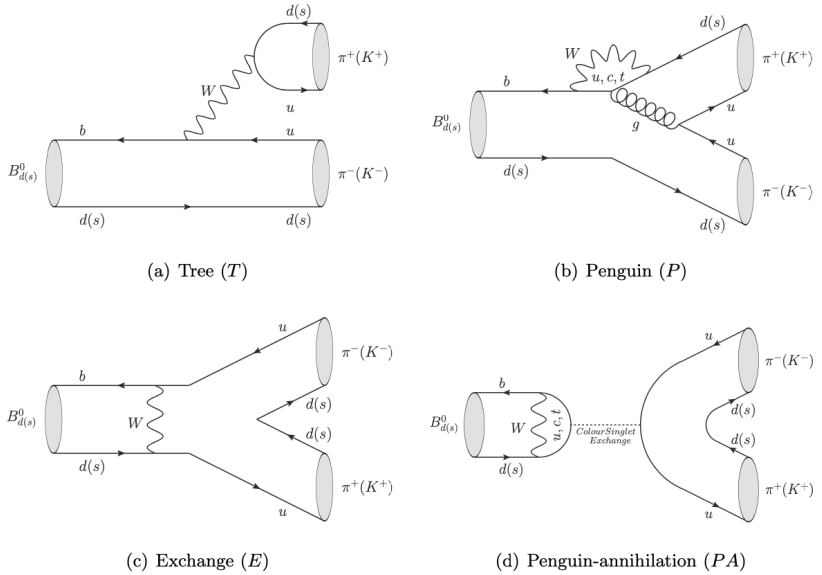


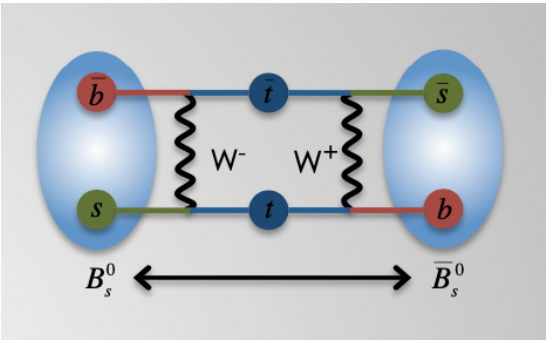
Low gain avalanche photo diode doping profile

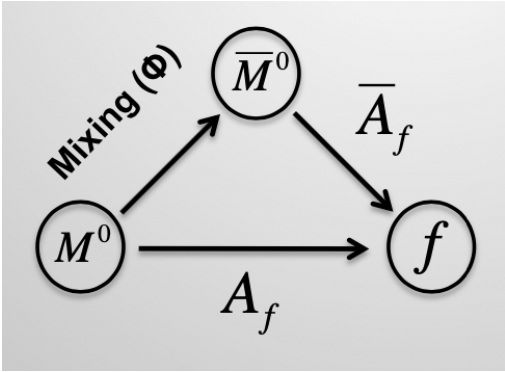


CP violation in $B_s^0 \to K^+K^-$ and $B^0 \to \pi^+\pi^-$

- Why: abundance of matter in the Universe
- How: interference of amplitudes
- $B_s^0 \to h^+h^{(\prime)-}$ – charmless!
  - $|V_{ub}|$ small – large CPV and BSM sensitivity
- B_s^0 mixing
  - Time dependent CPV
- CKM angles γ, β_s & α





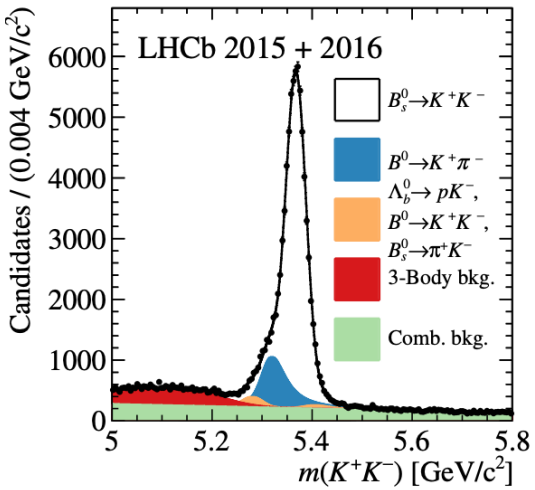


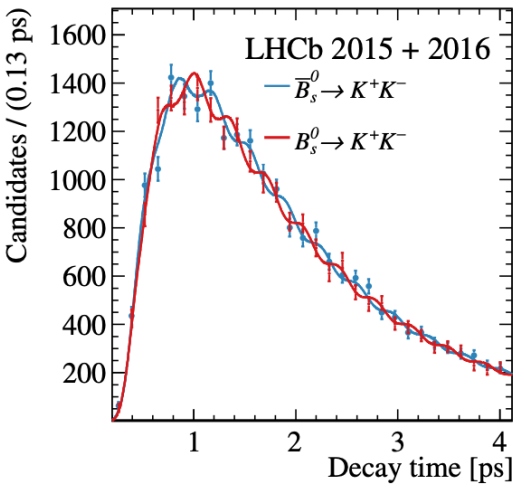
CP violation in $B_s^0 \to K^+K^-$ and $B^0 \to \pi^+\pi^-$

- Time dependent asymmetry
  - $C_{\pi\pi}$, $S_{\pi\pi}$, C_{KK}, S_{KK} & $A_{\Delta\Gamma}$
  - World-best measurement
- $(C_{KK}, S_{KK}, A_{\Delta\Gamma}) = (0, 0, -1)$ excluded at $6.5\boldsymbol{\sigma}$
  - First observation of time dependent CPV in B_s^0 decays!
- Time integrated asymmetries in $B^0 \to K^+\pi^-$ and $B_s^0 \to \pi^+K^-$
  - SM sum rule check:

$$A_{CP}(t) = \frac{\Gamma_{\bar{B}^0_{(s)}\to f}(t) - \Gamma_{B^0_{(s)}\to f}(t)}{\Gamma_{\bar{B}^0_{(s)}\to f}(t) + \Gamma_{B^0_{(s)}\to f}(t)} = \frac{-C_f \cos(\Delta m_{d(s)} t) + S_f \sin(\Delta m_{d(s)} t)}{\cosh\left(\frac{\Delta\Gamma_{d(s)}}{2} t\right) + A_f^{\Delta\Gamma} \sinh\left(\frac{\Delta\Gamma_{d(s)}}{2} t\right)},$$

New: Beauty Conference, September 2020

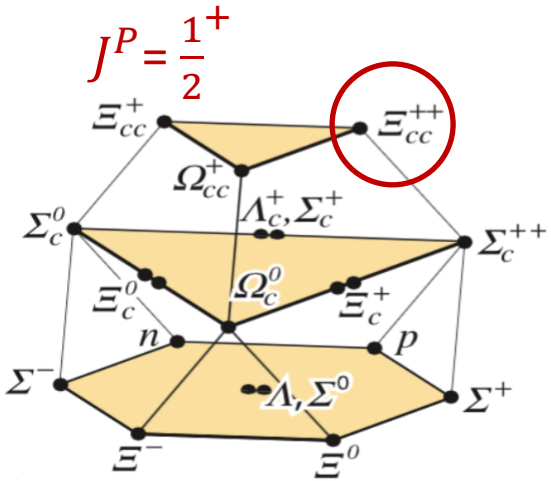


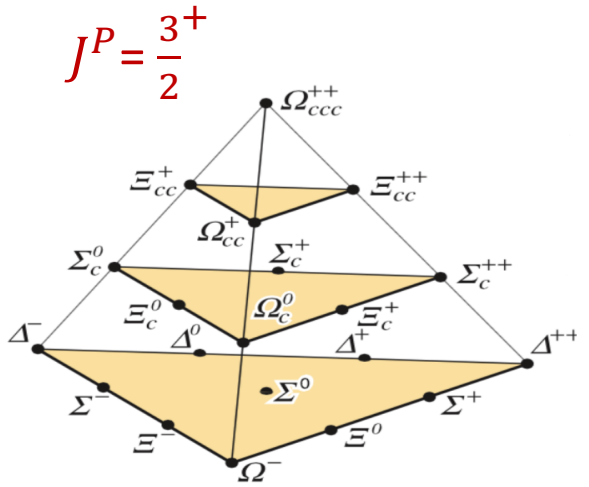


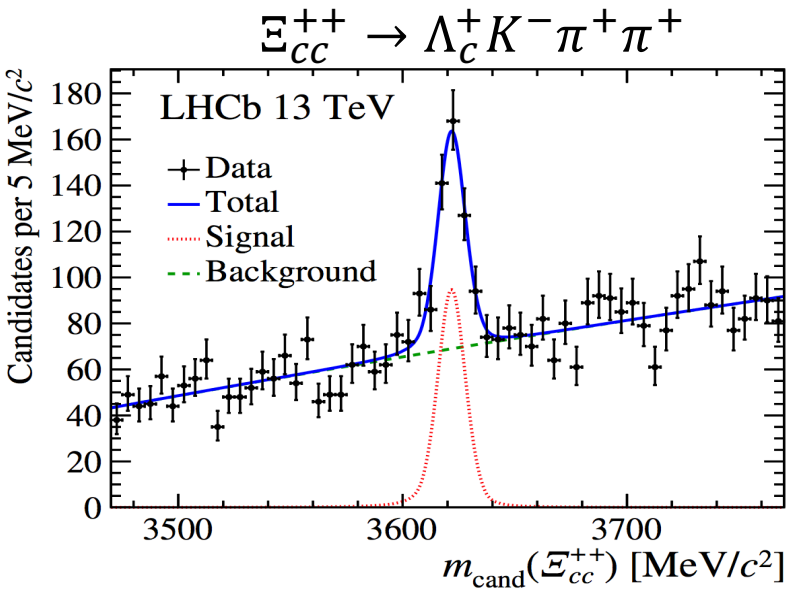
$$\Delta \equiv \frac{A_{CP}^{B^0}}{A_{CP}^{B_s^0}} + \frac{\mathcal{B}(B_s^0 \to K^-\pi^+)}{\mathcal{B}(B^0 \to K^+\pi^-)} \frac{\Gamma_s}{\Gamma_d} = 0$$ OK!

Spectroscopy: doubly-charmed baryons

- Baryons with (u, d, s, c) ∈ SU(4) flavour
  - All combinations should exist!
- LHCb 2017: discovery of Ξ_{cc}^{++} (link)
  - 49 new hadronic states discovered at the LHC
    - This is the only weakly decaying state
- Further results
  - Confirmation mode: $\Xi_{cc}^{++} \to \Xi_c^+ \pi^+$ (link)
  - Lifetime: 256 ± 28 fs (link)
  - Mass: 3621.55 ± 0.38 MeV/c² (link)
  - Production cross section (link)
  - Limit on BR($\Xi_{cc}^{++} \to D^+ p K^- \pi^+$) (link)

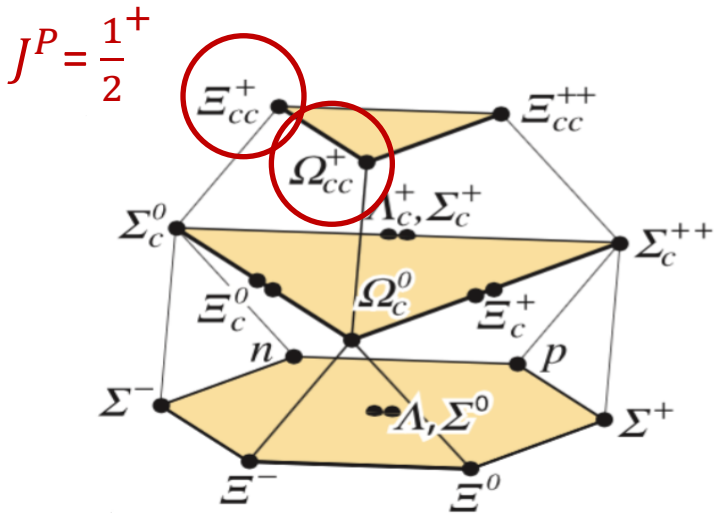


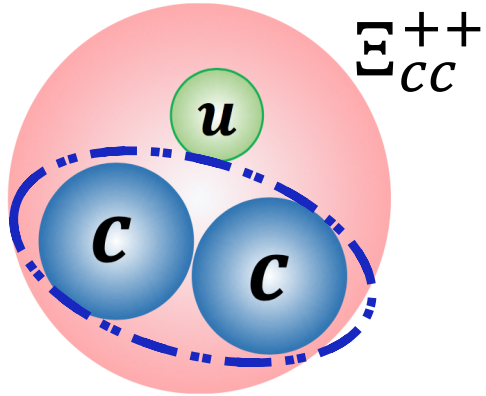




Spectroscopy: doubly-charmed baryons

- Next step: finding the $J^P = \frac{1}{2}^+$ partners
  - Limit on BR($\Xi_{cc}^+ \to \Lambda_c^+ K^- \pi^+$) (link)
  - Ongoing searches: $\Xi_{cc}^+ \to \Xi_c^+ \pi^+ \pi^-$, $\Omega_{cc}^+ \to \Xi_c^+ K^- \pi^+$
    - Several other promising modes identified
- Exploring the properties
  - Lifetime & mass measurements
- Excited states:
  - Spectrum different to singly-heavy baryons
    - Heavy di-charm quarks are quasistatic

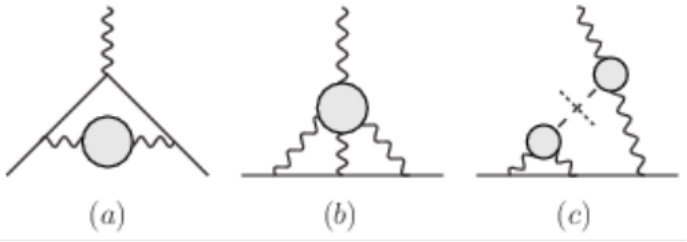




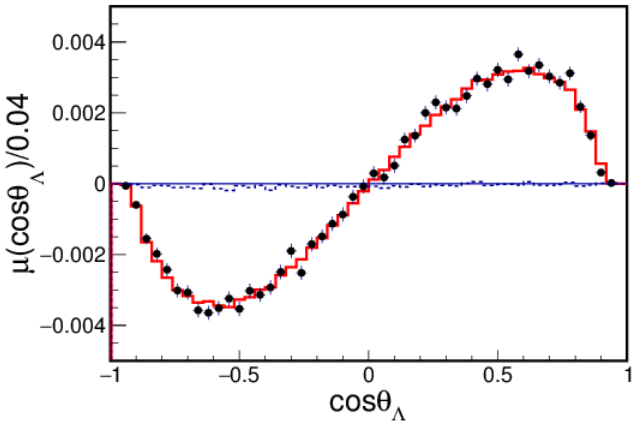
Other particle physics activities in Uppsala NP

- g-2 SM prediction
  - Theoretical calculations
  - KLOE: $e^+e^- \rightarrow$ *hadrons* experimental input
- BESIII: Decay parameters of $\Lambda^0 \rightarrow p\pi^-$
  - Methodology applicable to other decays
- BESIII: charm hadrons
  - Important input to LHCb measurements
- KLOE, WASA, BESIII: $\eta \rightarrow \pi^+\pi^-\pi^0$
  - Measure light quark mass difference $m_d - m_u$

g-2 hadronic contributions



$\Lambda^0 \rightarrow p\pi^-$ polarisation



LHCb Uppsala – preliminary plans

- Membership discussions with LHCb
  - Target: associate membership
- In discussion with the Swedish PP community
  - Would like to join next LHC-k bid for operational and computing resources
  - Is there any interest from other groups?
- Analysis: a wealth of data available on disk!
- Possible instrumentation projects
  - HV-CMOS tracker for LS3
  - VELO with fast timing for LS4