status report

Edwige Tournefier (LAPP, Annecy)
on behalf on the LHCb collaboration

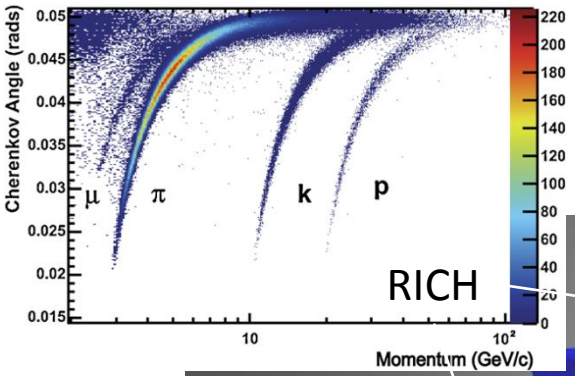
LHCC open session

March, 5th 2014

Outline

- LS1 activities
- Run 2 preparation
- LHCb physics output
- LHCb upgrade
- Conclusion

The LHCb detector



MUON

Magnet

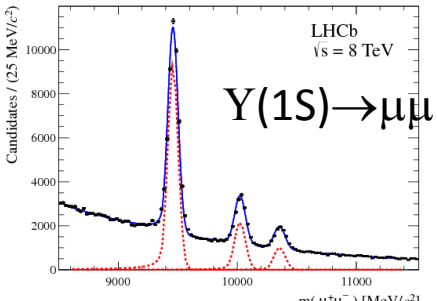
Calorimeters

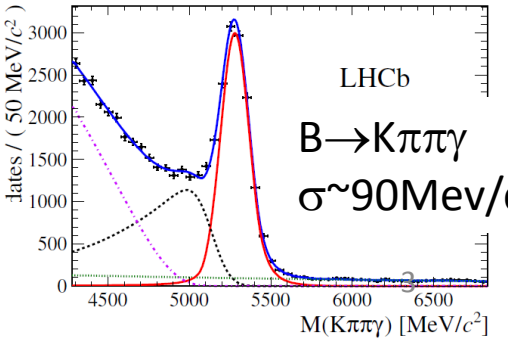
VELO

IP resolution: 20μm
⇒ 45ps on 2-body decay

Tracking

Δp/p~0.5% (5-100 GeV/c)

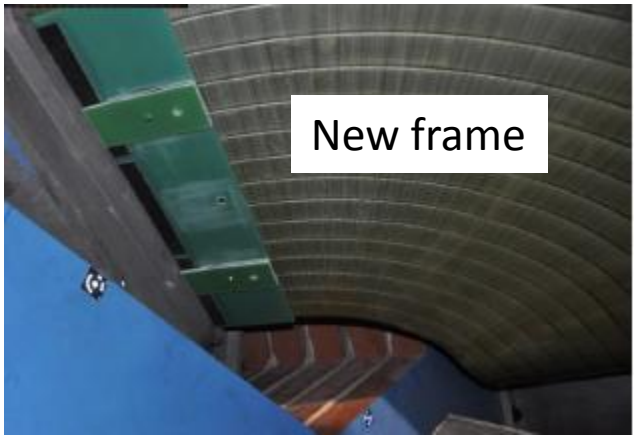




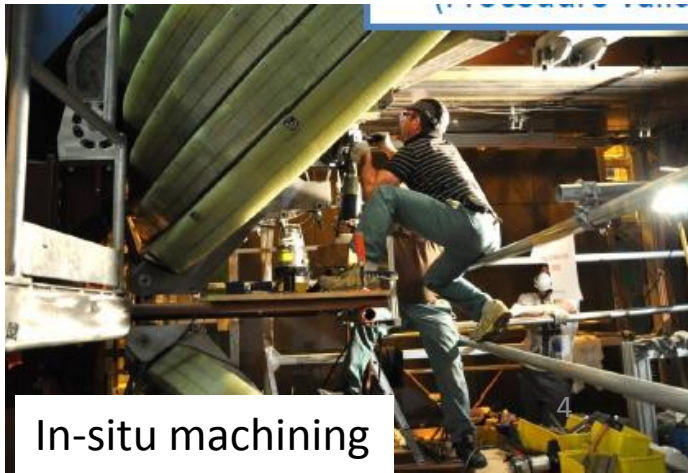
LS1 activities

- Consolidation of dipole magnet:
  - Rubber protections moved due to the Up/Down cycles
  - Old protections removed and replaced with an improved version

Done!

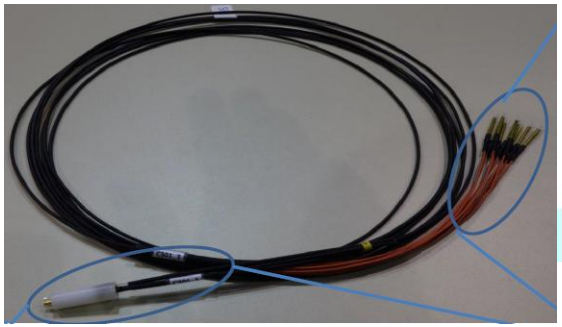


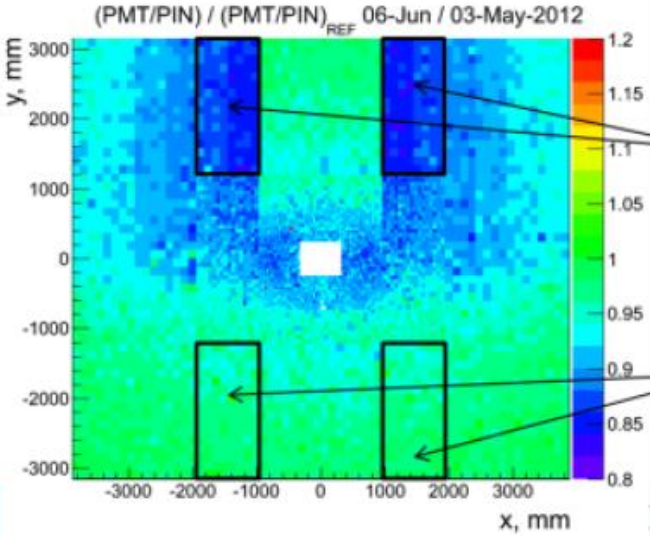
Removing the old rubber protections



LS1 activities

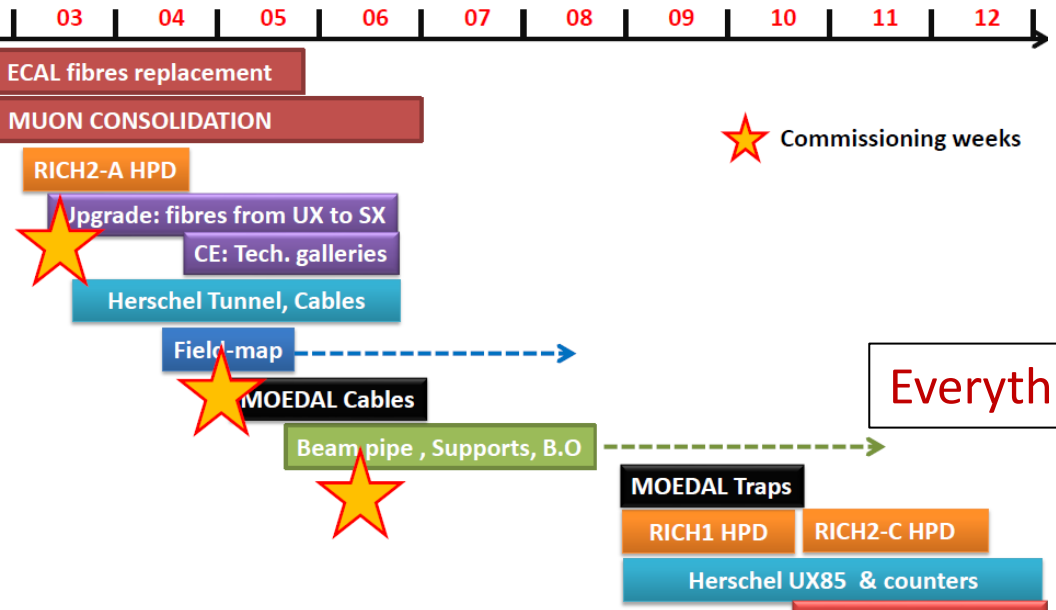
- Ongoing maintenance + improvements to subdetector (hardware and software)
  - HCAL: replacement of ~15% PMs
  - RICH: improved version of the spare HPDs (improved vacuum)
  - ECAL: replacement of the fibers+LED system used for calibration
    - Degradation of fibers due to radiation
    - Plastic fibers replaced with quartz rad hard one

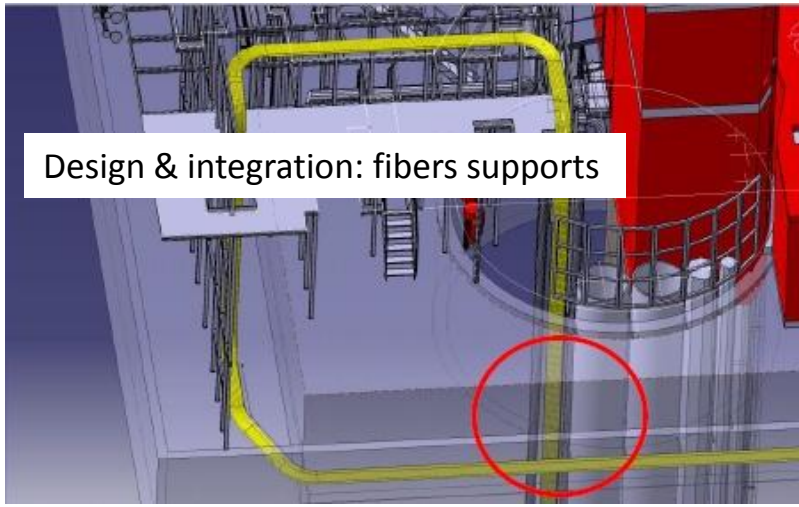




LS1 activities

- Computing: preparing the full re-stripping of Run1 data with final calibrations (legacy dataset) → planned for end of summer
- Preparing the LHCb upgrade during LS1!
  - Installation of the supports for the optical fibers in preparation
- Preparing the restart for Run2:
  - Regular commissioning weeks



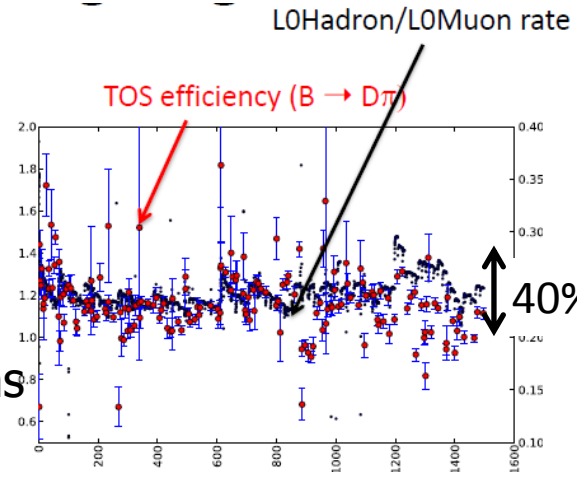


Everything going on smoothly and on time !

Run2 preparation

- LHCb Run2:
  - Stay at L= $4x10^{32}$ $cm^{-2}s^{-1}$, 50ns → 25ns ⇒ less pile-up
  - 8 → 13 TeV ⇒ bbbar and ccbar cross-sections x~1.6

⇒ The trigger needs to be improved for the new conditions



L0 (hardware trigger limited to 1MHz) :

an example of efficiency and stability increase:

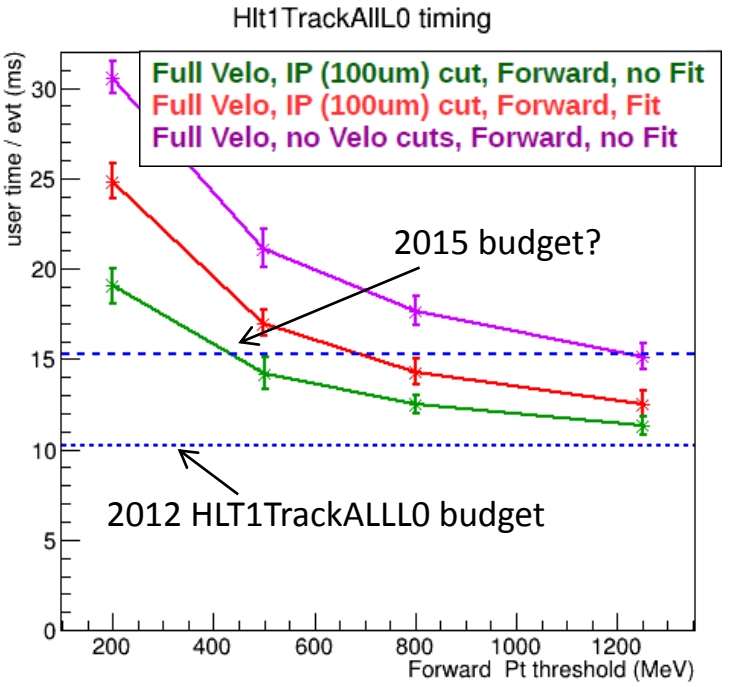
- Ageing correction of HCAL and ECAL (fill by fill):
  - monitor using minbias events
  - Adjust HV on fill by fill basis to correct gain

HLT: CPU increase by a factor 2

⇒ can perform more complex selections in HLT

- Optimize tracking algorithm (⇒p_T threshold)

Work in progress

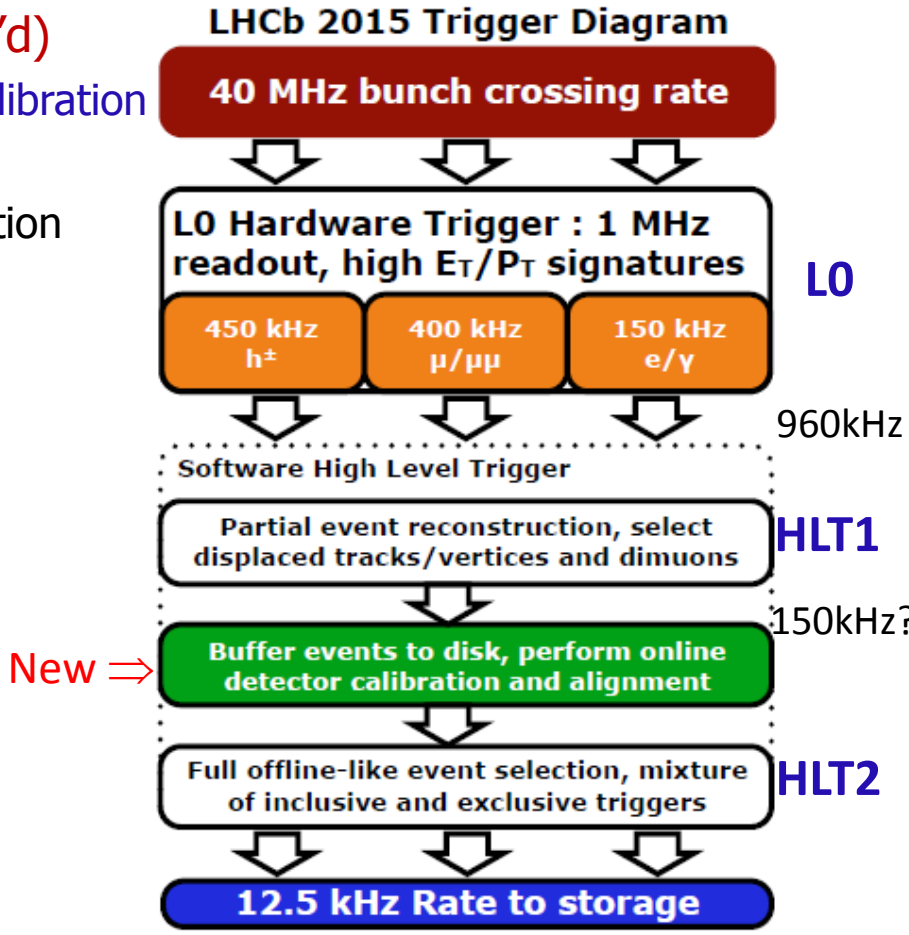


Run2 preparation

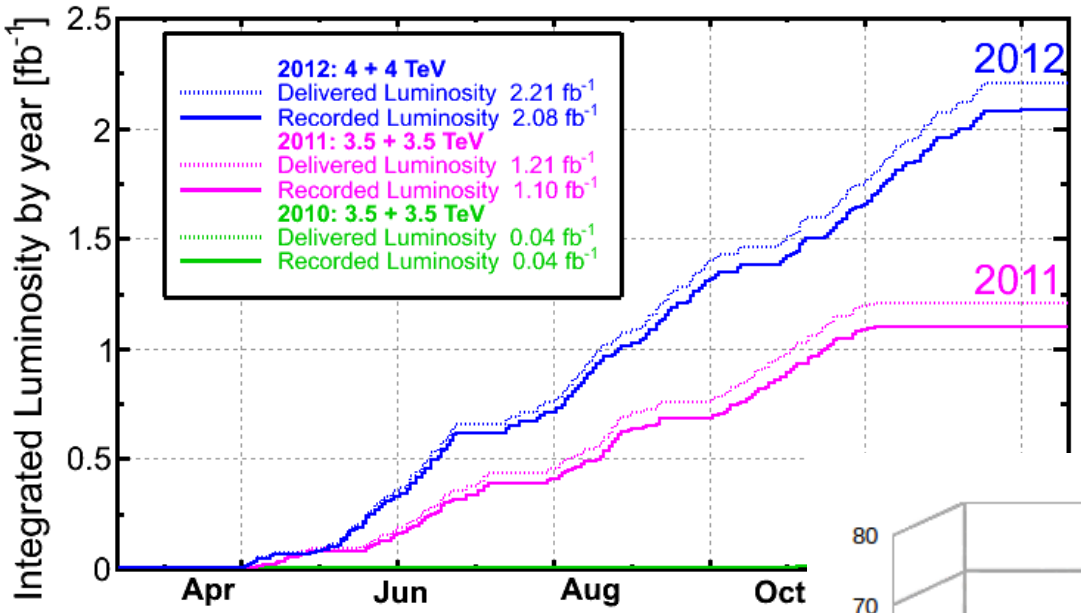
⇒ HLT improvements and optimizations (cont'd)

- Online alignment of tracking system + RICH calibration using minbias events fill by fill
- HLT2 fully deferred: uses tracking/RICH calibration
  ⇒ improved efficiency + less reprocessing
- Split HLT1 and HLT2 processes
- Re-use HLT1 reconstruction in HLT2

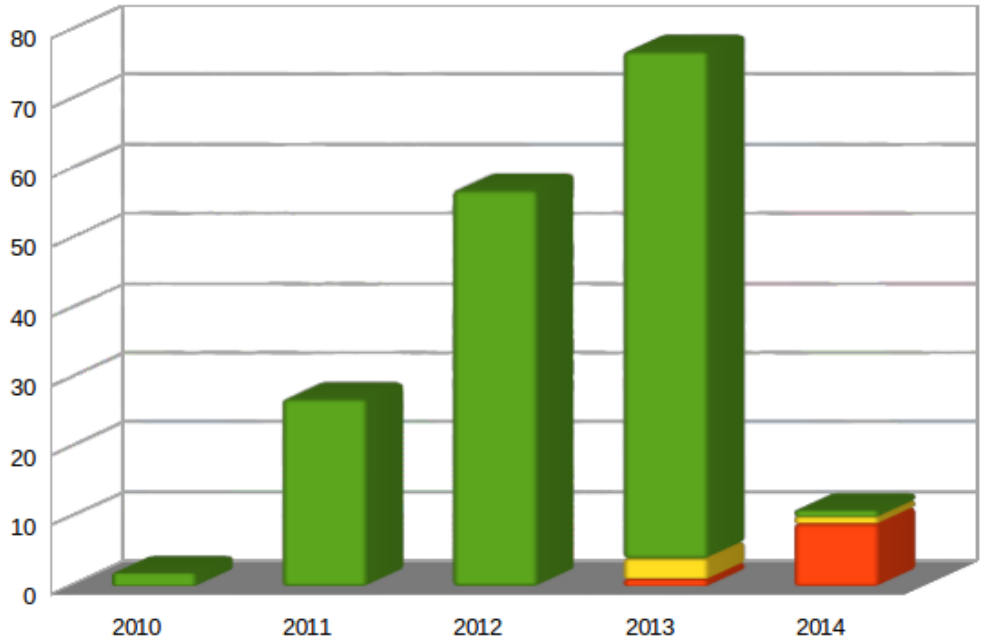
Work in progress



LHCb physics output



Published papers
Accepted
Submitted



Papers submitted since last LHCC

B-hadron lifetimes

Measurement of the $B^0_s \to D_s^- D_s^+$ and $B^0_s \to D^- D_s^+$ effective lifetimes arXiv:1312.1217

Measurement of the B_c^+ meson lifetime using $B_c^+ \to J/\psi \mu^+ \nu_\mu X$ decays arXiv:1401.6932

Measurements of the B^+, B^0, B_s^0 meson and Λ_b^0 baryon lifetimes arXiv:1402.2554

Precision measurement of the Λ^0_b / B^0 lifetime ratio arXiv:1402.6242

Production, cross-sections

Observation of associated production of a Z boson with a D meson in the forward region arXiv:1401.3245

Updated measurements of exclusive J/ψ and $\psi(2S)$ production cross-sections in pp collisions at $\sqrt{s}$=7 TeV J. Phys. G: Nucl. Part. Phys. 41 (2014) 055002 arXiv:1401.3288

Measurement of Upsilon production in pp collisions at sqrt{s}=2.76 TeV arXiv:1402.2539

Measurement of charged particle multiplicities and densities in pp collisions at $\sqrt{s}$=7TeV in the forward region arXiv:1402.4430

B-hadron decay

Searches for Λ^0_b and Ξ^0_b decays to $K^0_S p\pi^-$ and $K^0_S pK^-$ final states with first observation of the $\Lambda_b^0 \to K^0_S p\pi^-$ decay arXiv:1402.0770

CP violation

A study of CP violation in $B^\pm \to DK^\pm$ and $B^\pm \to D\pi^\pm$ decays with $D \to K^0_S K^\pm \pi^\mp$ final states arXiv:1402.2982

Measurement of resonant and CP components in $B^0_s \to J/\psi \pi^+ \pi^-$ decays arxiv:1402.6248

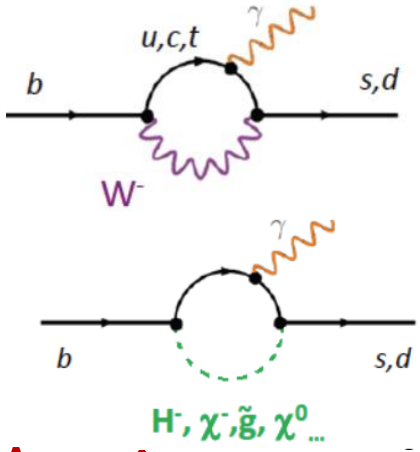
Search for new physics with rare decays

Search for Majorana neutrinos in $B^- \to \pi^+ \mu^- \mu^-$ decays arXiv:1401.5361

Observation of photon polarization in the $b \to s\gamma$ transition arXiv:1402.6852

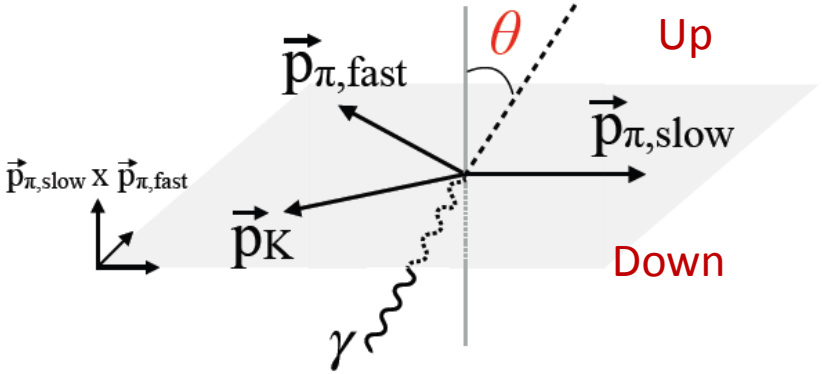
arXiv:1402.6852

Photon polarization in b→sγ



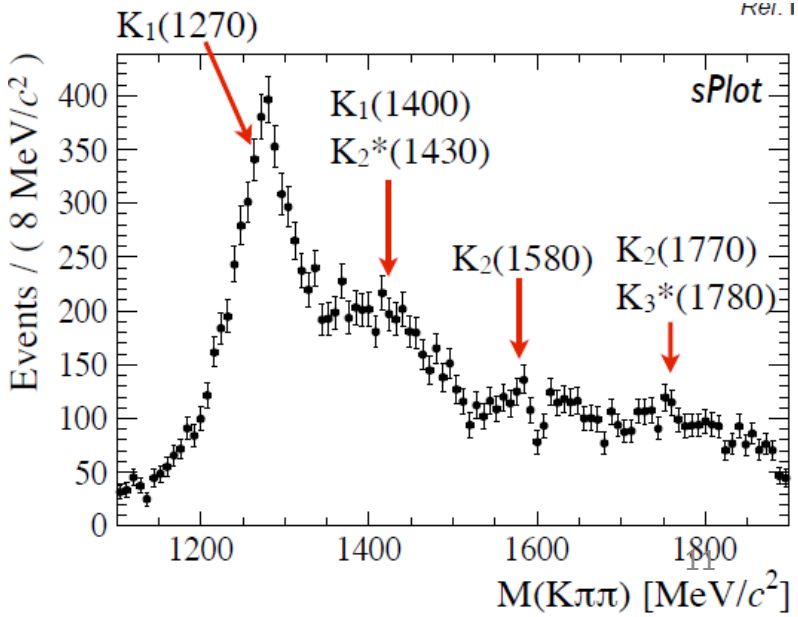
- Standard Model: photon almost fully left-handed in b→sγ
  NP can introduce a significant right-handed component

- Measurement of up/down asymmetry in $B^+ \to K^+ \pi^- \pi^+ \gamma$ decay: $A_{UD} \propto \lambda_\gamma$



$$\mathcal{A}_{UD} = \frac{\int_0^{\pi/2} \frac{d\Gamma}{d\cos\theta} d\cos\theta - \int_{\pi/2}^{\pi} \frac{d\Gamma}{d\cos\theta} d\cos\theta}{\int_0^{\pi} \frac{d\Gamma}{d\cos\theta} d\cos\theta}$$

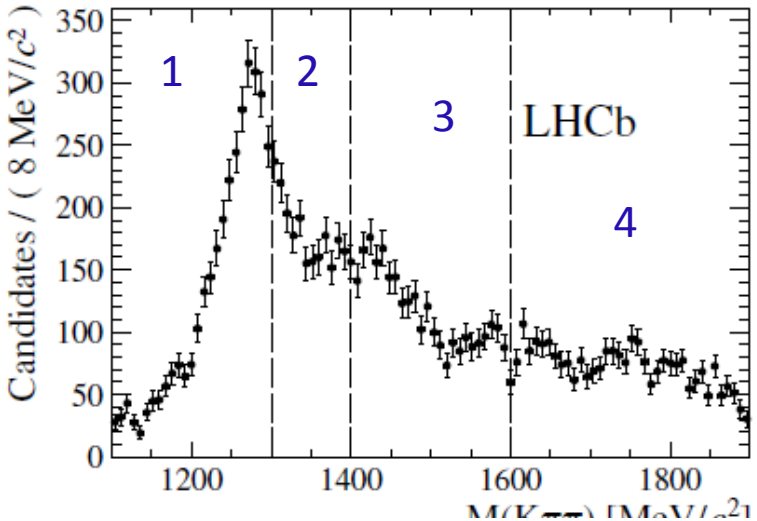
- Proportional factor between A_{UD} and λ_γ depends on the $K^{res} \to K^+ \pi^- \pi^+$ resonances and their interference : not well known



Photon polarization in b→sγ

- Up-Down asymmetry measured in 4 bins of the $K^+ \pi^- \pi^+$ invariant mass

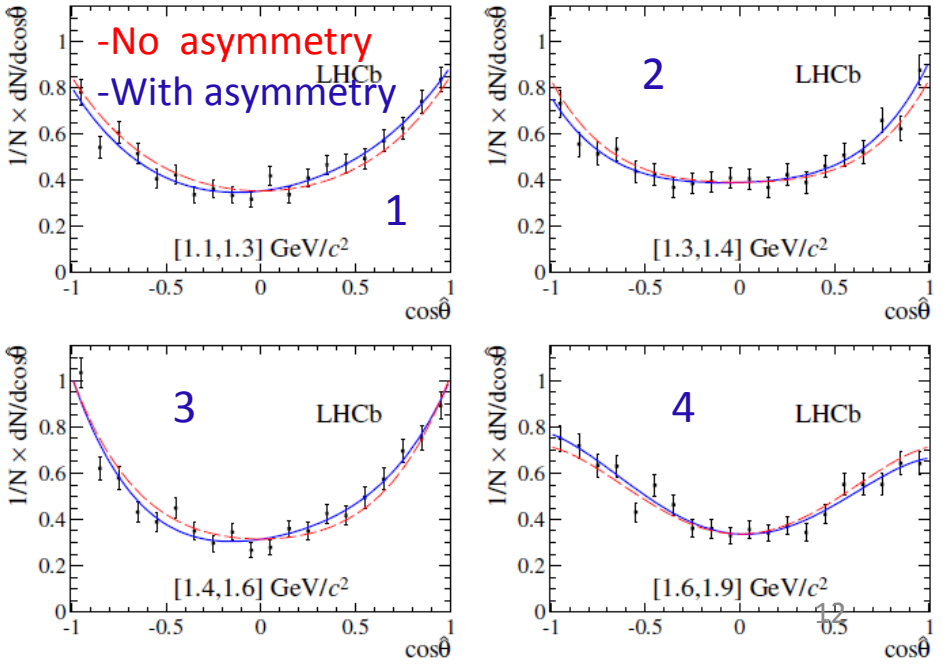
M(Kππ)	[1.1, 1.3]	[1.3, 1.4]	[1.4, 1.6]	[1.6, 1.9]
$\mathcal{A}_{ud}$	6.9±1.7	4.9±2.0	5.6±1.8	−4.5±1.9



⇒ The photon is polarized at 5.2σ

⇒ First direct observation of photon polarization!

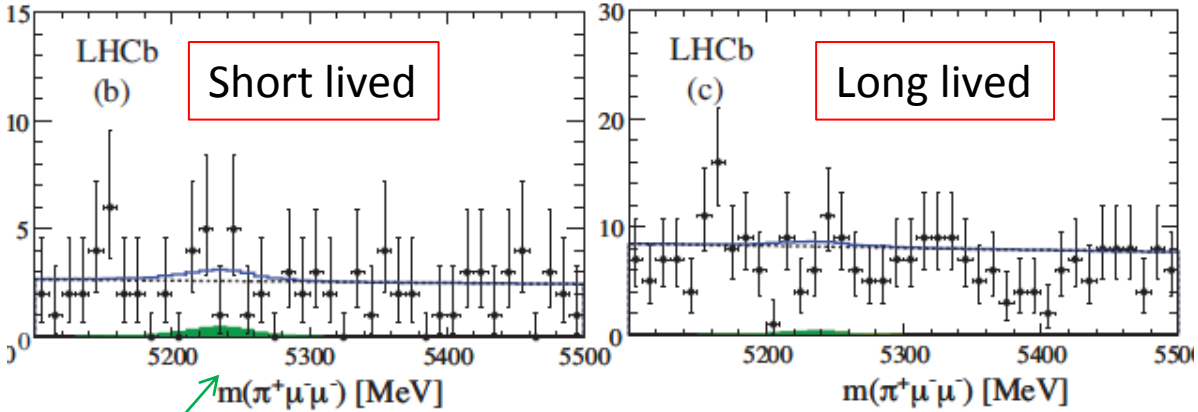
Theory input needed to extract polarisation

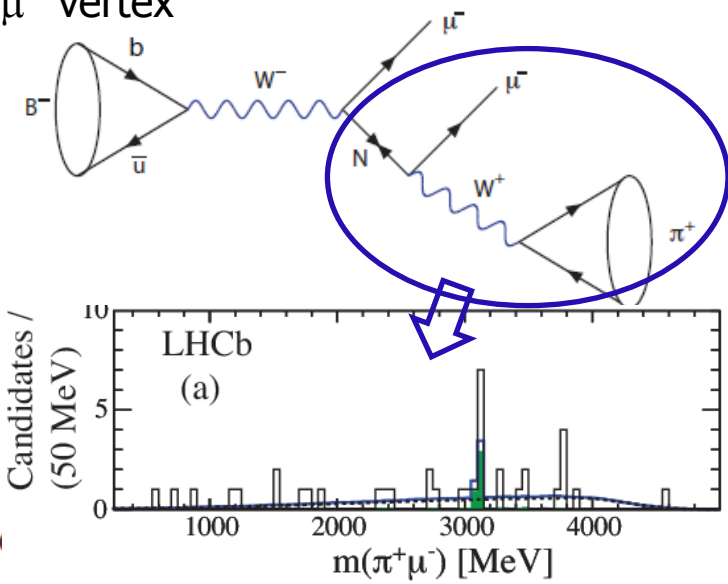


arXiv:1401.5361

Search for Majorana neutrinos

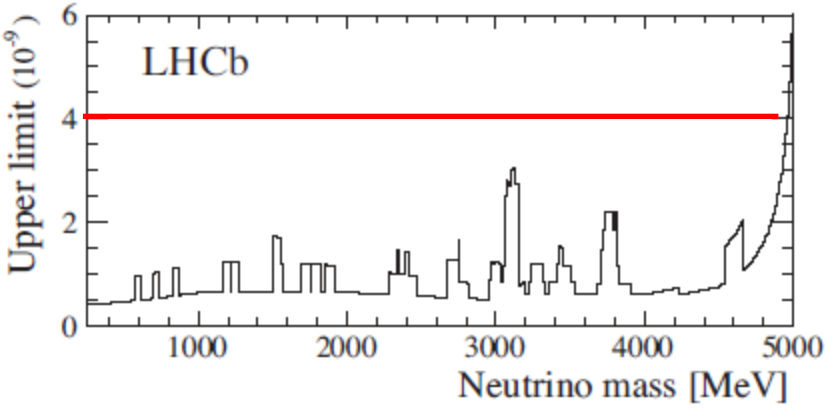
- Search for Majorana neutrino in $B^- \to \pi^+ \mu^- \mu^-$ (forbidden in SM)
  - Search also for long-lived neutrinos: detached $\pi^+ \mu^-$ vertex





Peaking background
from $B \to J/\psi K$(or π)

$\Rightarrow$Upper limit on Br($B^- \to \pi^+ \mu^- \mu^-$)
and on the coupling of N to muons



Lifetime measurements: introduction

Why?

- B-hadron lifetimes prediction: all equal at 0th order + corrections $\propto 1/m_b^2$
  $\Rightarrow$ Test of Heavy Quark Expansion theory

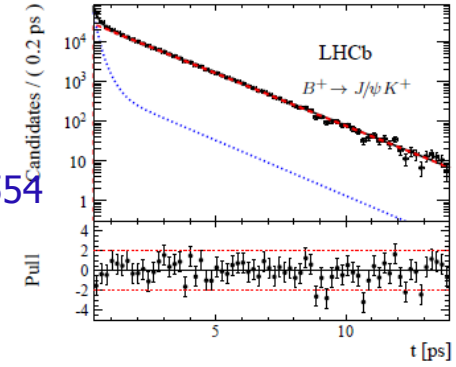
- Width (Γ_L, Γ_H) and width difference ($\Delta\Gamma_{s,d}$) of mass eigenstates ($B_{s,d}$) $\Rightarrow$ SM test

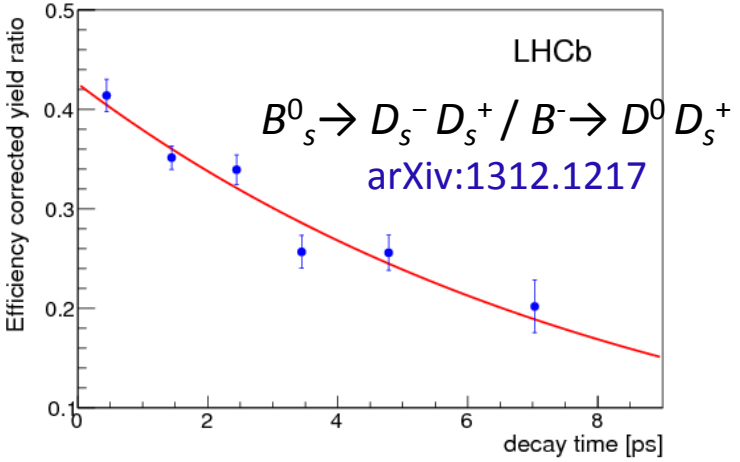
- B_c exception: 2 heavy quarks, difficult predictions (weak and strong force interplay)
  $\Rightarrow$ Test theory models (predictions $\tau(B_c)$ = 300-700 fs)

\+ important inputs to other measurements

How?

- Methods:
  - Absolute lifetime:
    - b-hadrons arXiv:1402.2554
    - B_c arXiv:1401.6932
  - Ratio of lifetimes:
    - Λ^0_b arXiv:1402.6242
    - $B^0_s \to D_s^- D_s^+$ arXiv:1312.1217





$\Rightarrow$Most precise measurement of Γ_L

$\Gamma_L = 0.725 \pm 0.014 \pm 0.009$ ps^{-1}

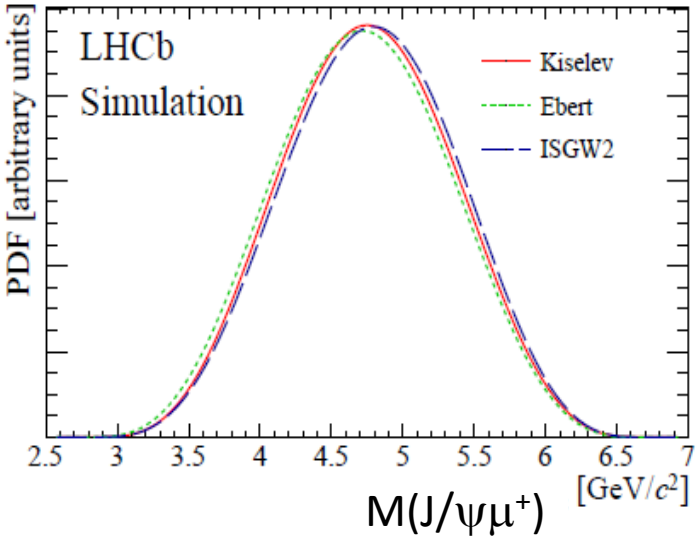
Measurement of B_c^+ lifetime using $B_c^+ \to J/\psi \mu^+ \nu_\mu X$

arXiv:1401.6932

- B_c : only observed open-flavor state formed by 2 heavy quarks
  $\Rightarrow$ its decay dynamics have distinctive features

- Measurement of B_c^+ lifetime provides an essential test of theoretical models
- Predictions: $\tau(B_c)$ = 300-700 fs

- LHCb analysis using partially reconstructed decay $B_c^+ \to J/\psi \mu^+ \nu_\mu (X)$
  - High statistic and clear 3μ signature
  - Partial reconstruction
    $\Rightarrow$ Decay models needed for the dynamics of $B_c^+ \to J/\psi \mu^+ \nu_\mu$



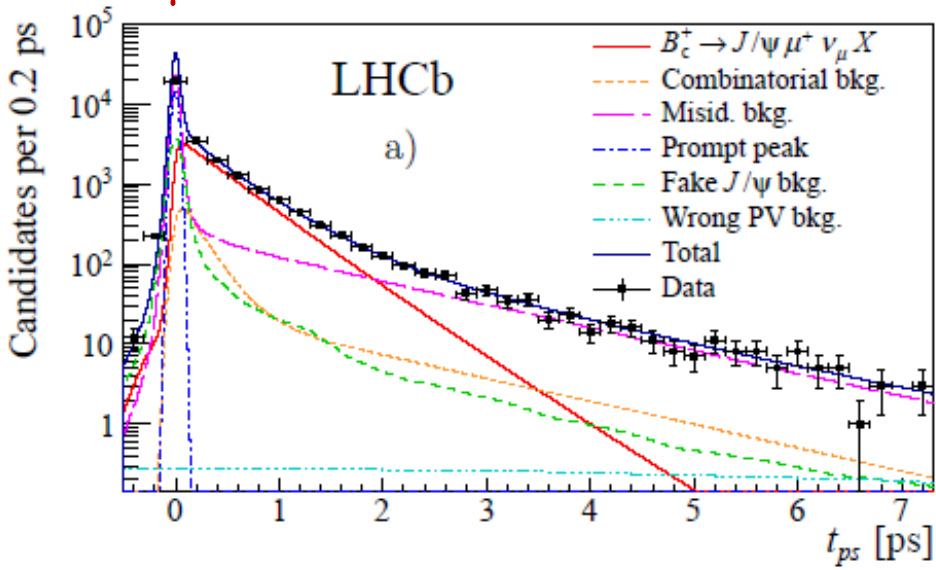
Measurement of B_c^+ lifetime using $B_c^+ \to J/\psi \mu^+ \nu_\mu X$

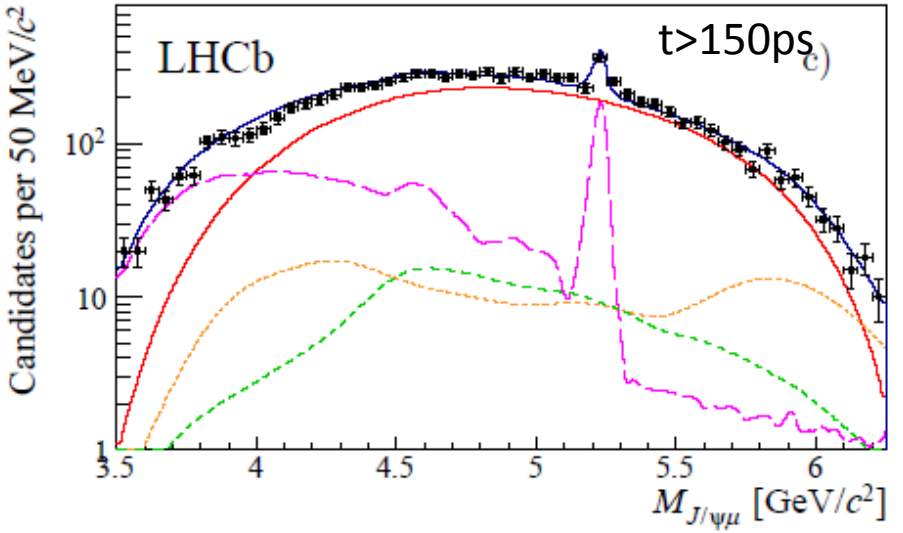
- Important ingredients:
  - Relate the pseudo propertime t_{ps} to the decay time
  - 2D models of M($J/\psi\mu$) and t_{ps} for bkg and signal

- The lifetime is extracted from a 2D fit of t_{ps} and M($J/\psi\mu$)

$\Rightarrow \tau(B_c^+) = 509 \pm 8\ (stat) \pm 12(syst)\ fs$

PDG 2013: $\tau(B_c^+) = 452 \pm 33$ fs





arXiv:1402.2554

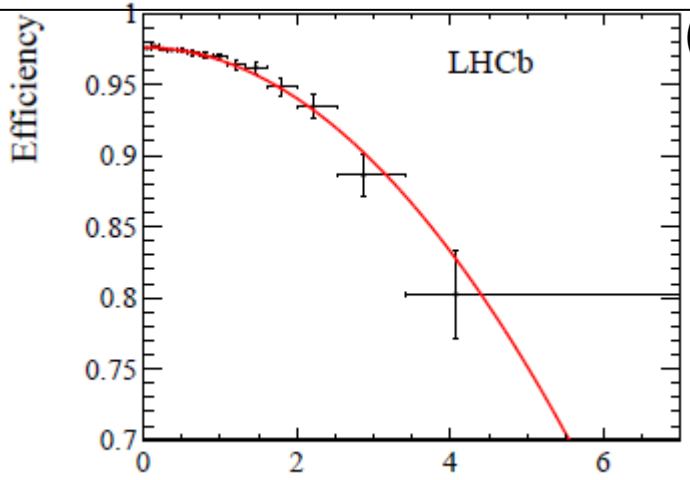
Measurement of b-hadron lifetimes

- Heavy quark expansion theory predicts b hadron lifetimes:
  $\Rightarrow$ all b-hadrons lifetimes equal at 0th order + corrections $\propto 1/m_b^2$

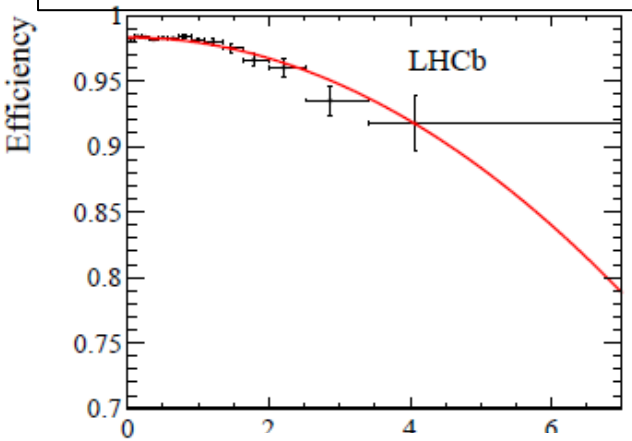
- Measurement of absolute b-hadron lifetimes using J/ψ X final states:
  - Detached J/ψ vertex
  $\Rightarrow$ Need to understand the efficiency as a function of the propertime
  $\Rightarrow$ Data-driven technique based on $B^+ \to J/\psi K^+$ unbiased sample

$B^+ \to J/\psi K^+$
$B^0 \to J/\psi K^{*0}$
$B^0 \to J/\psi K_s^0$
$B_s^0 \to J/\psi \phi$
$\Lambda_b^0 \to J/\psi \Lambda$

Online VELO-track reconstruction efficiency (for J/ψ)

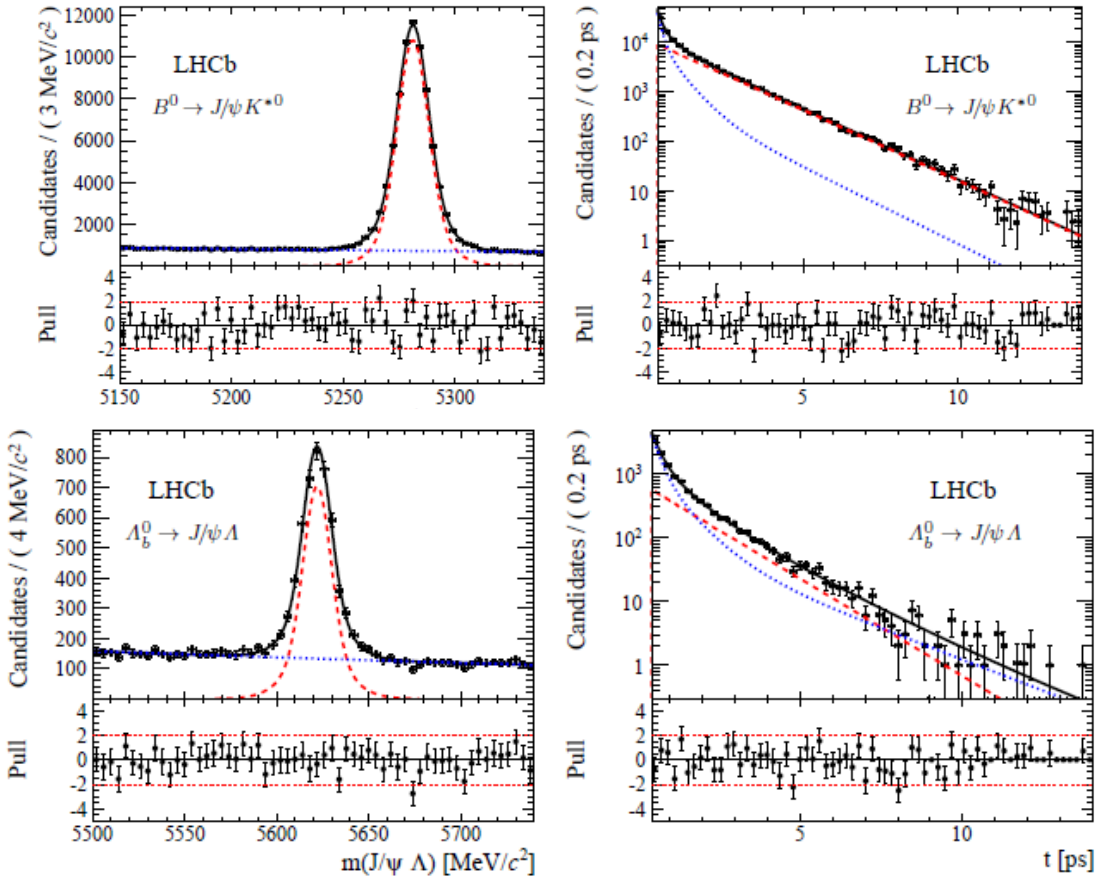


Offline VELO-track reconstruction efficiency (for K,π)



Measurement of b-hadron lifetimes

⇒ Most precise single measurements of b hadron lifetimes! (except Λ^0_b)



Lifetime	Value [ps]
$\tau_{B^+ \to J/\psi K^+}$	$1.637 \pm 0.004 \pm 0.003$
$\tau_{B^0 \to J/\psi K^{*0}}$	$1.524 \pm 0.006 \pm 0.004$
$\tau_{B^0 \to J/\psi K^0_S}$	$1.499 \pm 0.013 \pm 0.005$
$\tau_{\Lambda_b^0 \to J/\psi \Lambda}$	$1.415 \pm 0.027 \pm 0.006$
$\tau_{B_s^0 \to J/\psi \phi}$	$1.480 \pm 0.011 \pm 0.005$

⇒ Lifetime ratios in agreement with SM prediction and CPT invariance

Ratio	Value
$\tau_{B^+}/\tau_{B^0 \to J/\psi K^{*0}}$	$1.074 \pm 0.005 \pm 0.003$
$\tau_{B_s^0}/\tau_{B^0 \to J/\psi K^{*0}}$	$0.971 \pm 0.009 \pm 0.004$
$\tau_{\Lambda_b^0}/\tau_{B^0 \to J/\psi K^{*0}}$	$0.929 \pm 0.018 \pm 0.004$
τ_{B^+}/τ_{B^-}	$1.002 \pm 0.004 \pm 0.002$
$\tau_{\Lambda_b^0}/\tau_{\overline{\Lambda}_b^0}$	$0.940 \pm 0.035 \pm 0.006$
$\tau_{B^0 \to J/\psi K^{*0}}/\tau_{\overline{B}^0 \to J/\psi \overline{K}^{*0}}$	$1.000 \pm 0.008 \pm 0.009$

Measurement of the Λ^0_b / B^0 lifetime ratio

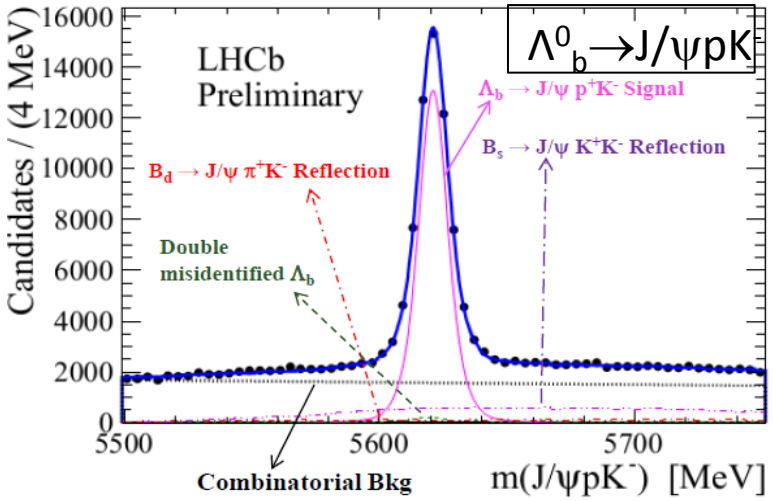
arXiv:1402.6242

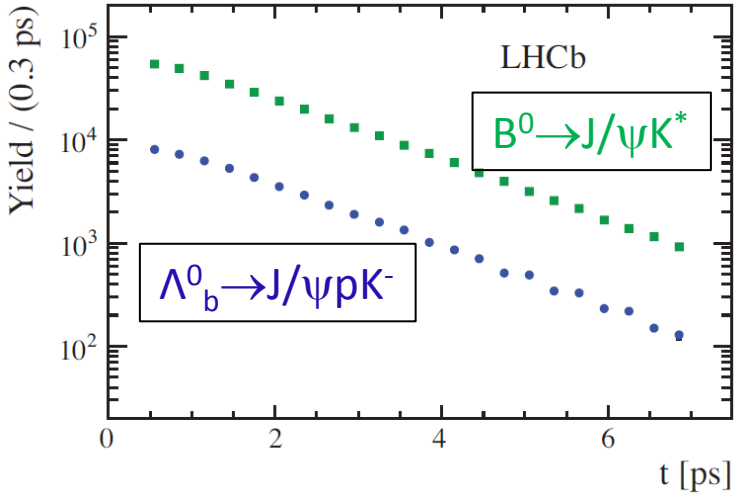
- HQE theory predicts that Λ^0_b and B^0 lifetimes differ only by few %
- 2013 PDG value: $\tau(\Lambda^0_b)/\ \tau(B^0)=0.798\pm0.052$!

- LHCb measurement uses the ratio of yields:
  - $\Lambda^0_b \to J/\psi p K^-$
  - $B^0 \to J/\psi K^{*0}(\to \pi^+ K^-)$

  Same 4 track topology $\Rightarrow$ cancelation of systematics

  Decay time distributions obtained by performing mass fits in bins of decay time





$\Rightarrow \tau(\Lambda^0_b)/\ \tau(B^0)= 0.974 \pm 0.006 \pm 0.004$
in agreement with theory expectation !

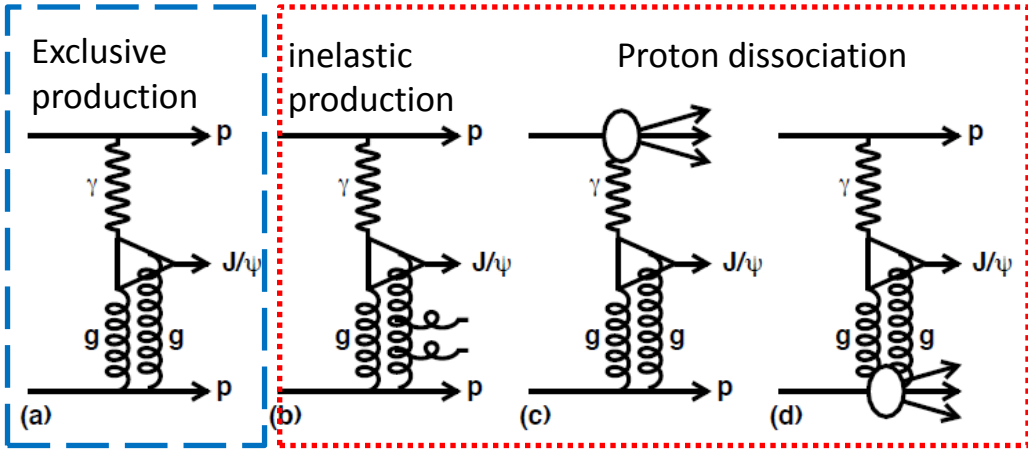
$\Rightarrow \tau(\Lambda^0_b) = 1.468 \pm 0.009 \pm 0.008$ ps
(when combined with LHCb result arXiv:1402.2554)

J. Phys. G: Nucl. Part. Phys. 41 (2014) 055002
arXiv:1401.3288

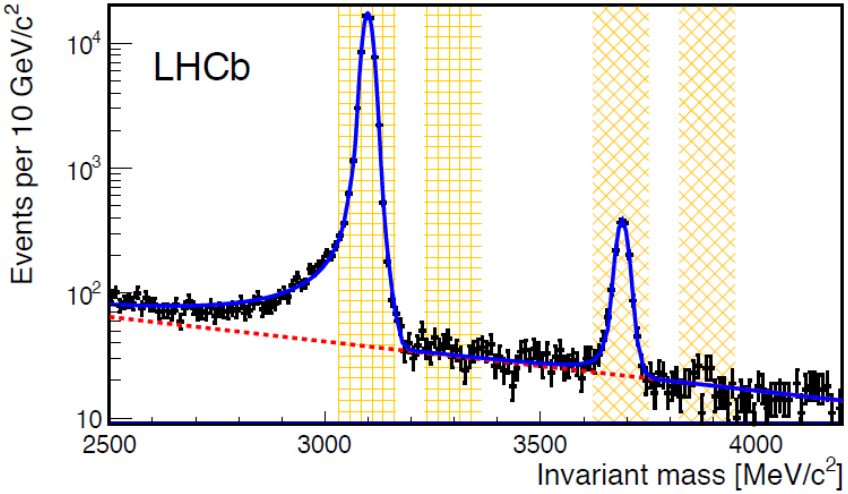
Exclusive J/ψ and ψ(2S) production

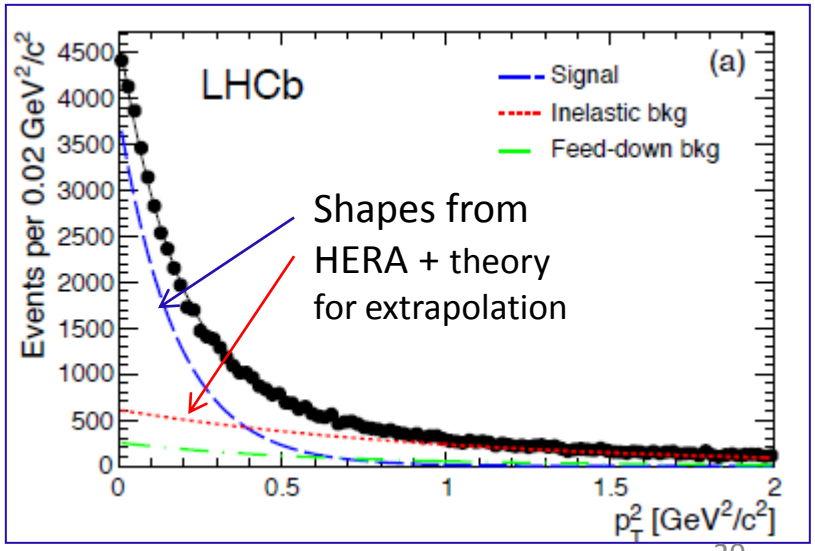
- Exclusive J/ψ and ψ(2S) production: test of QCD and pomeron theory + constraint on gluon PDF

- Select events with
  - Exclusively 2 tracks identified as μ
  - No photons
  - Low pT



J/ψ ψ(2S)

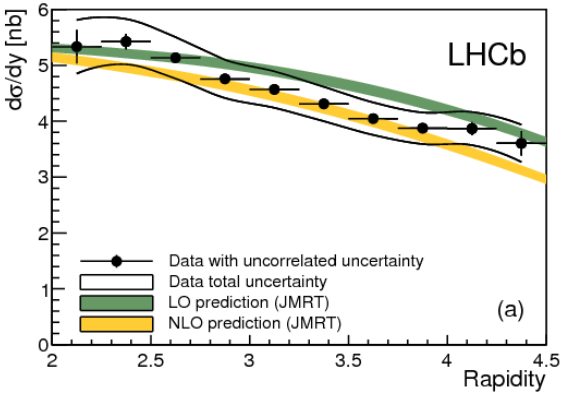


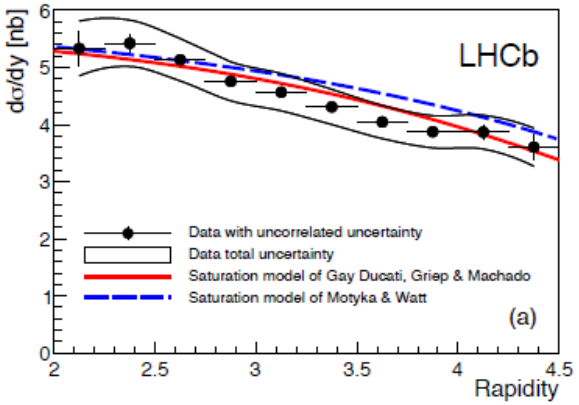


Exclusive J/ψ and ψ(2S) production

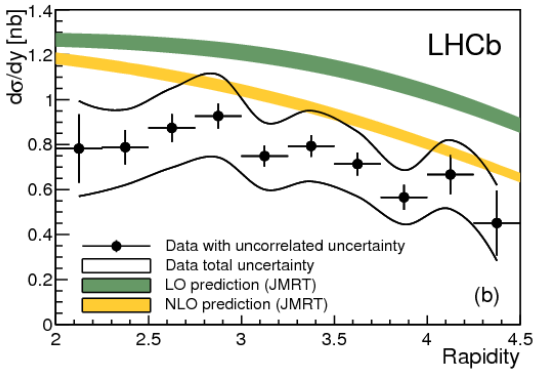
- First measurement of differential cross-section for ψ(2S) !
- Comparions with theory predictions (LO, NLO and saturation effects)
  - ⇒ need NLO
  - ⇒ results agree with saturation models

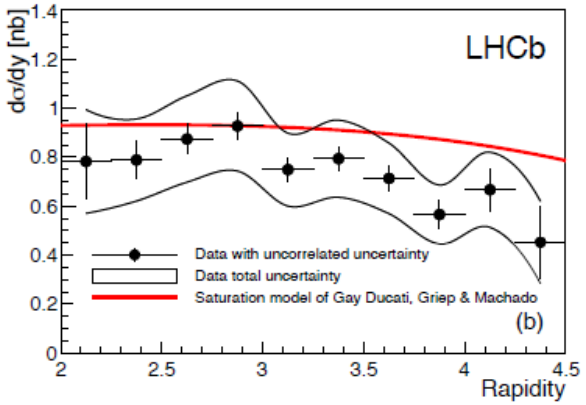
J/ψ





ψ(2S)





LO
NLO

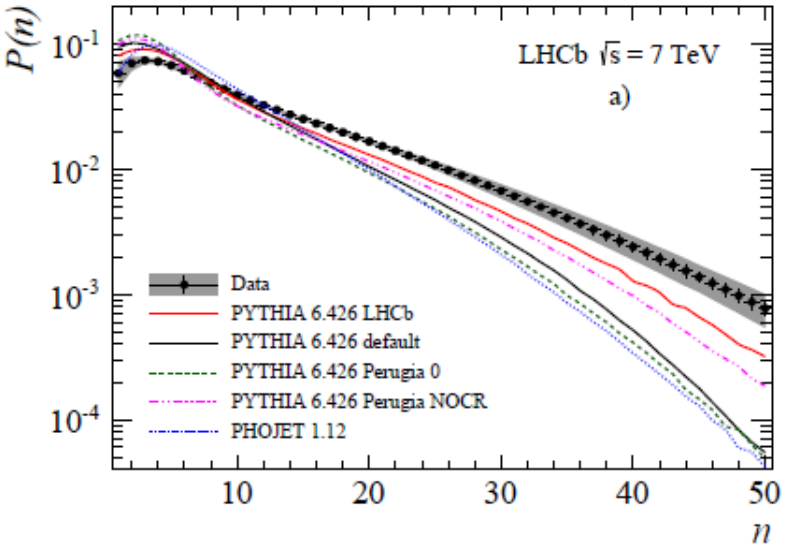
Saturation model 1
Saturation model 1

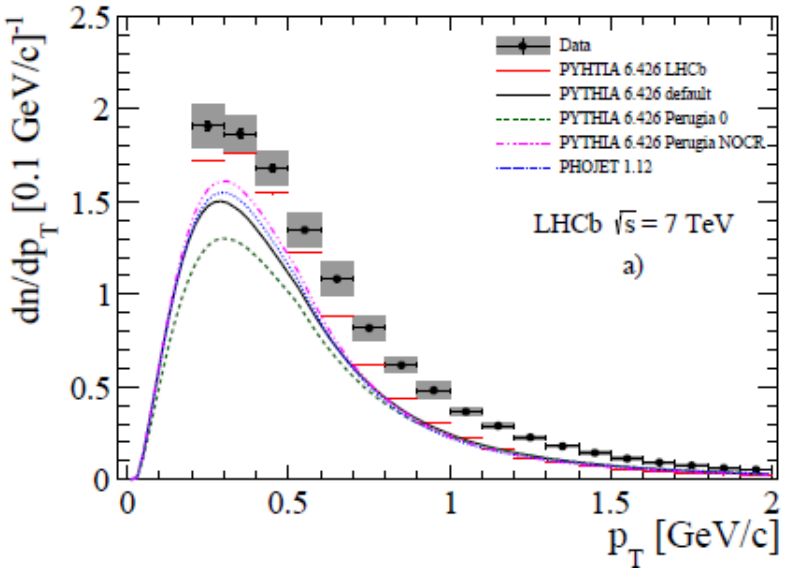
arXiv:1402.4430

Measurement of charged particles multiplicities in pp collisions

- Soft QCD measurements used for tuning of parameters in MC
  ⇒ vital for understanding background in NP search or precision measurements
- Prompt charged particle multiplicity measurement at 7 TeV

  ⇒ clear disagreement with PYTHIA6





Measurement of charged particles multiplicities in pp collisions

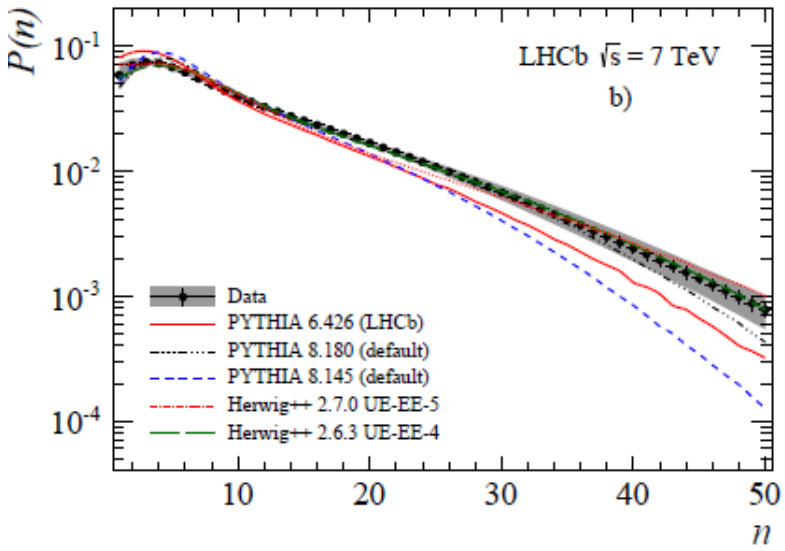
- Soft QCD measurements used for tuning of parameters in MC

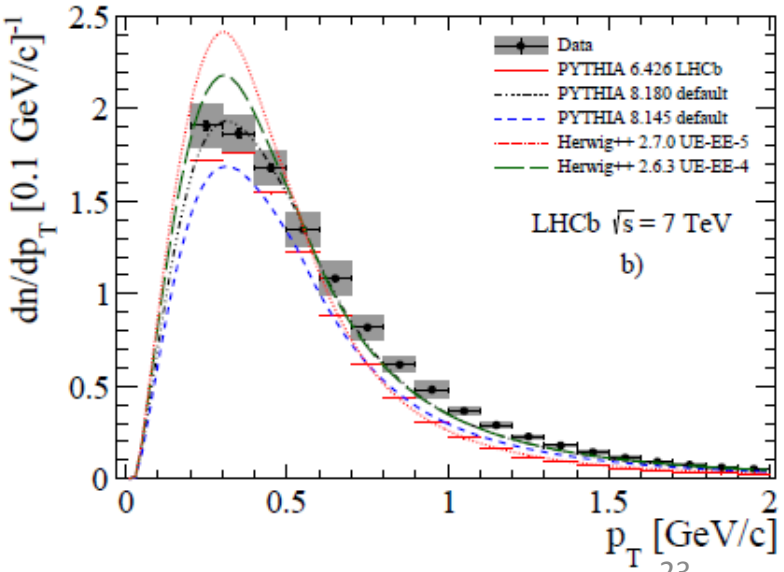
  ⇒ vital for understanding background in NP search or precision measurements

- Prompt charged particle multiplicity measurement at 7 TeV

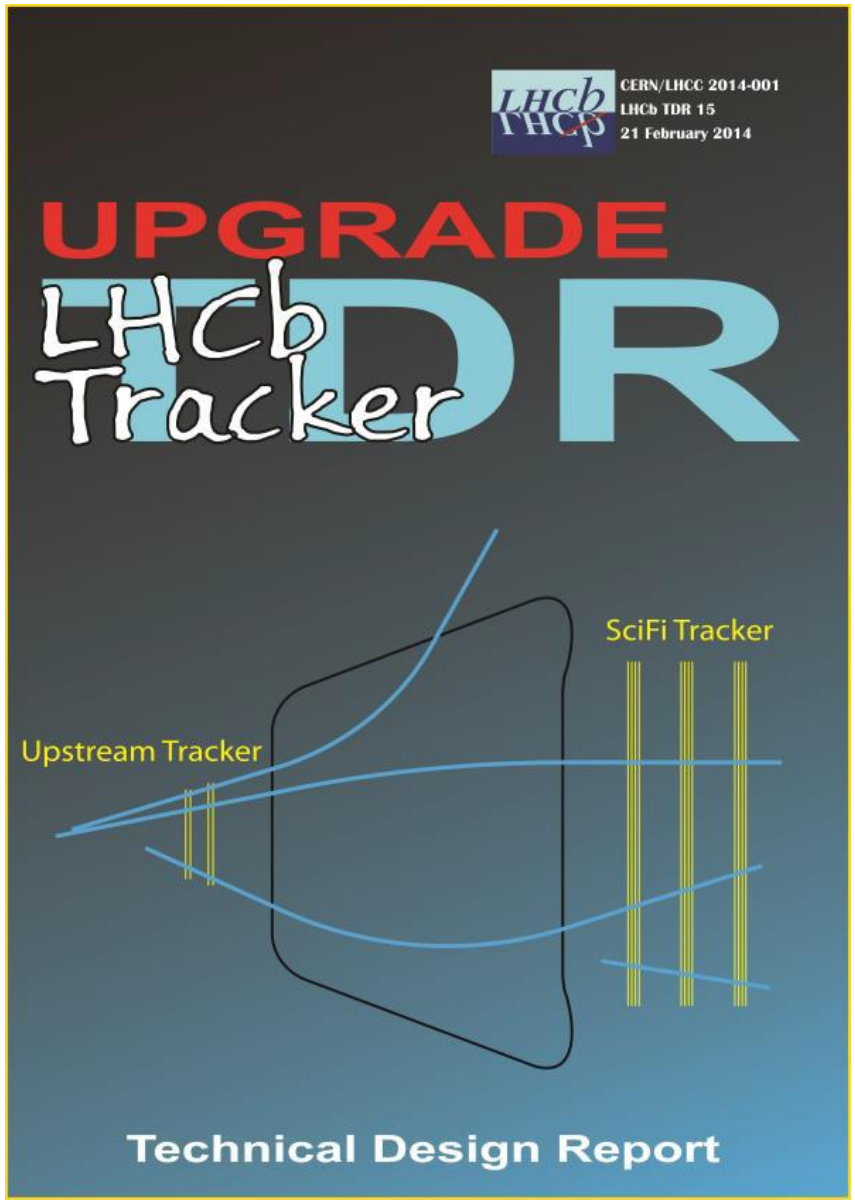
  ⇒ clear disagreement with PYTHIA6

  ⇒ better with PYTHIA 8 (expected) but not perfect





LHCb Upgrade

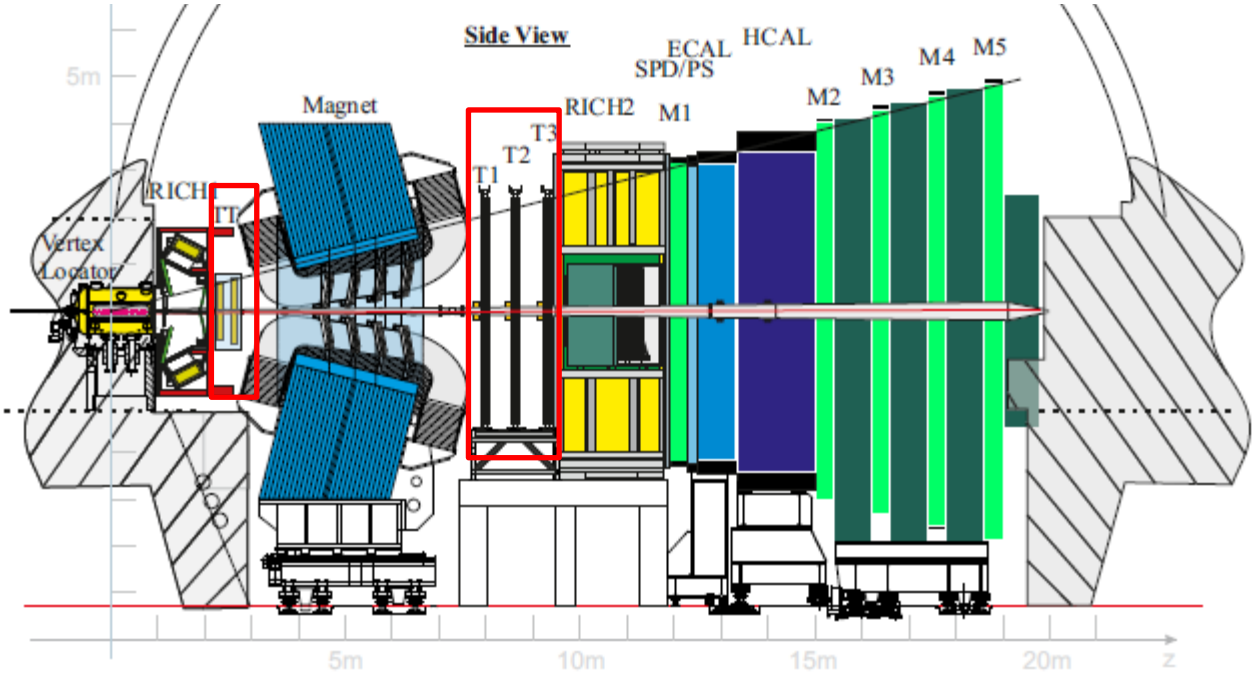


- VELO and PID TDRs submitted to LHCC in December
- LHCb Tracker upgrade delivered to the LHCC on Feb 21st
- Only one more TDR to come: Online, DAQ and Trigger (June)

Tracker upgrade

LHCb upgrade:

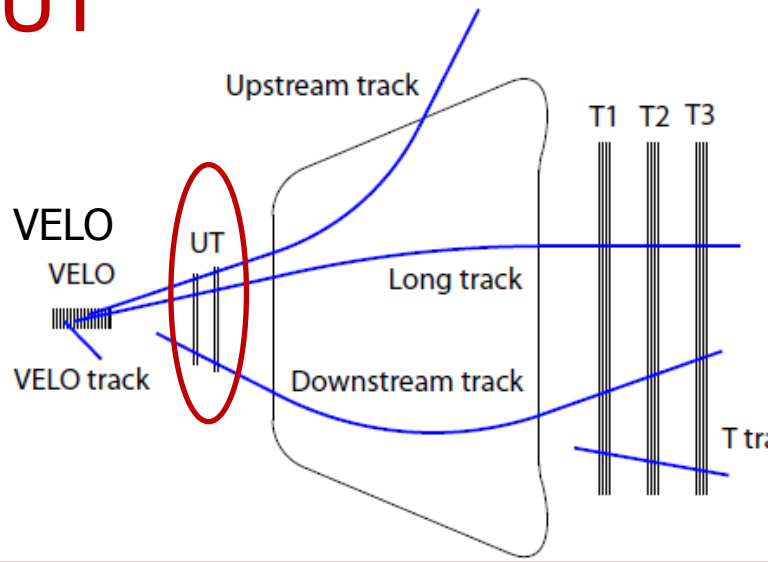
- Detector readout at 40 MHz (1MHz hardware trigger removed)
  ⇒ replacement of front-end electronics and of some sensitive elements
- L = 2×10^{33} $cm^{-2}s^{-1}$, nb of pp int. per bunch crossing (ν)=7.6 ⇒ higher occupancy
  ⇒ Need to increase granularity (TT, OuterT-stations)
- Radiation dose
  ⇒ Some detectors need to be replaced to sustain the radiation during the upgrade



TT upgrade: UT

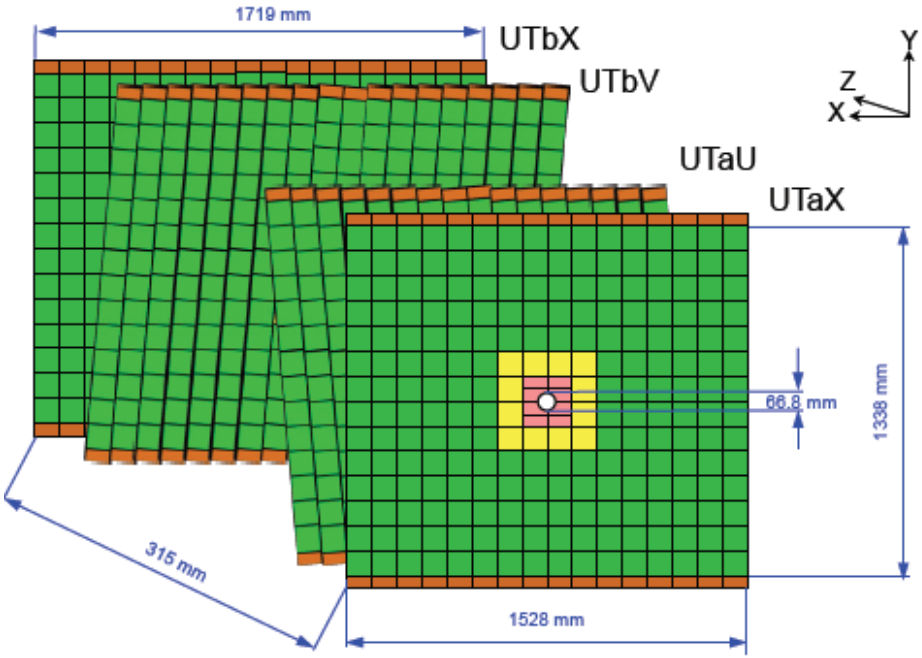
Why a TT? (upgraded version = Upstream Tracker)

- Fast momentum estimate for use in trigger
- Reconstruction of long-lived particles decaying beyond VELO
- Ghost rate reduction by ~ a factor 3
- Improves the momentum resolution (~25%)



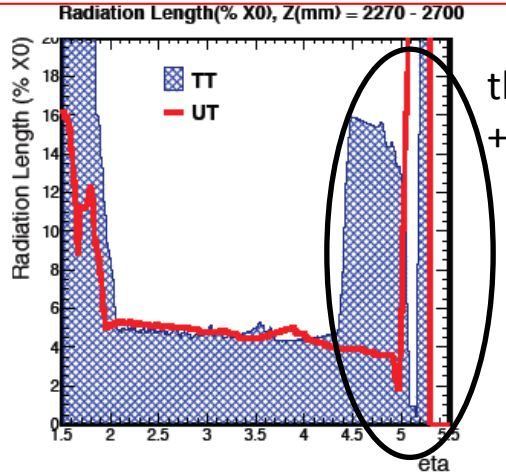
Geometry of UT:

- Silicon sensors (10x10cm^2) - 512 or 1024 strips



Detector optimization:

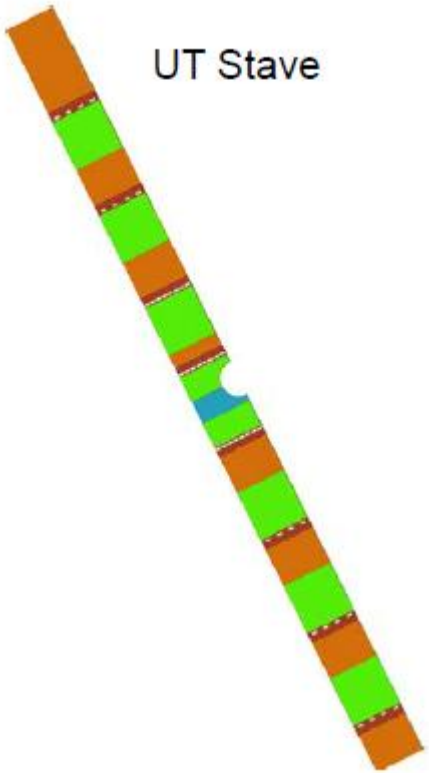
- minimize gaps (sensors overlap)
- maximize acceptance (beam pipe clearance)
- minimize material

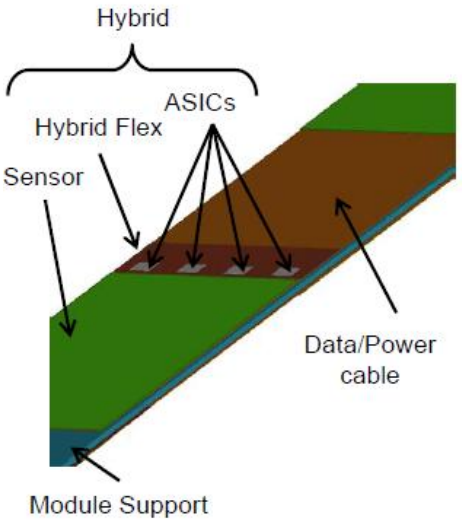


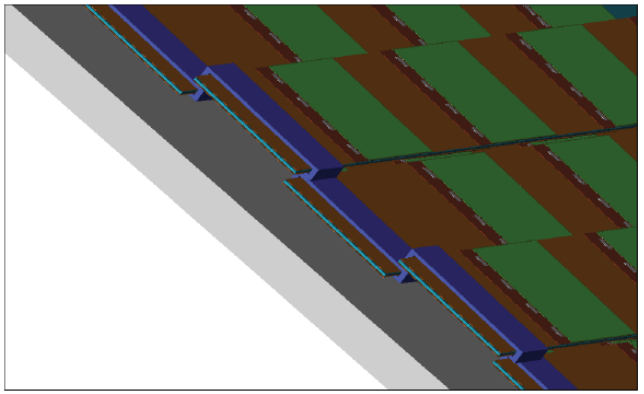
thermal insulation + box

TT upgrade

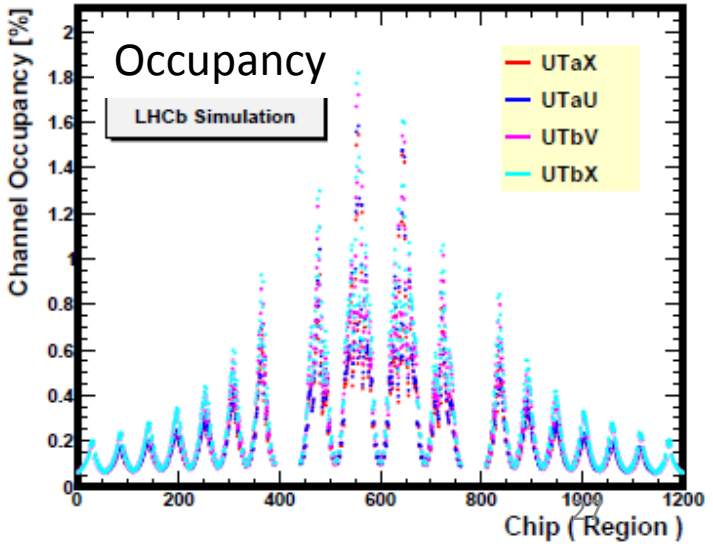
- Silicon sensors placed on staved system inspired by ATLAS upgrade silicon
- Cooling integrated into staves: -5 °C





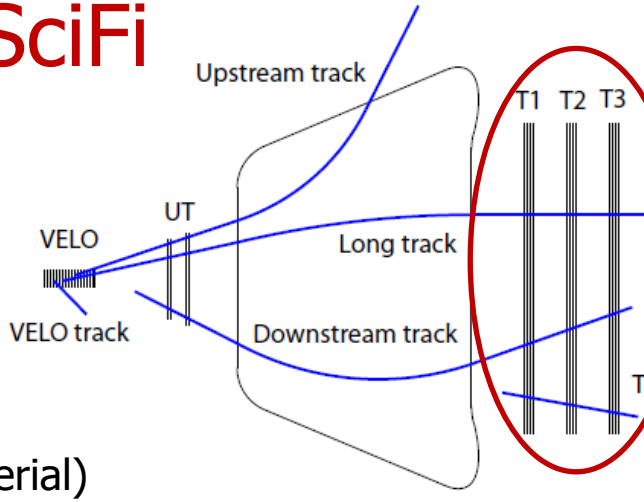


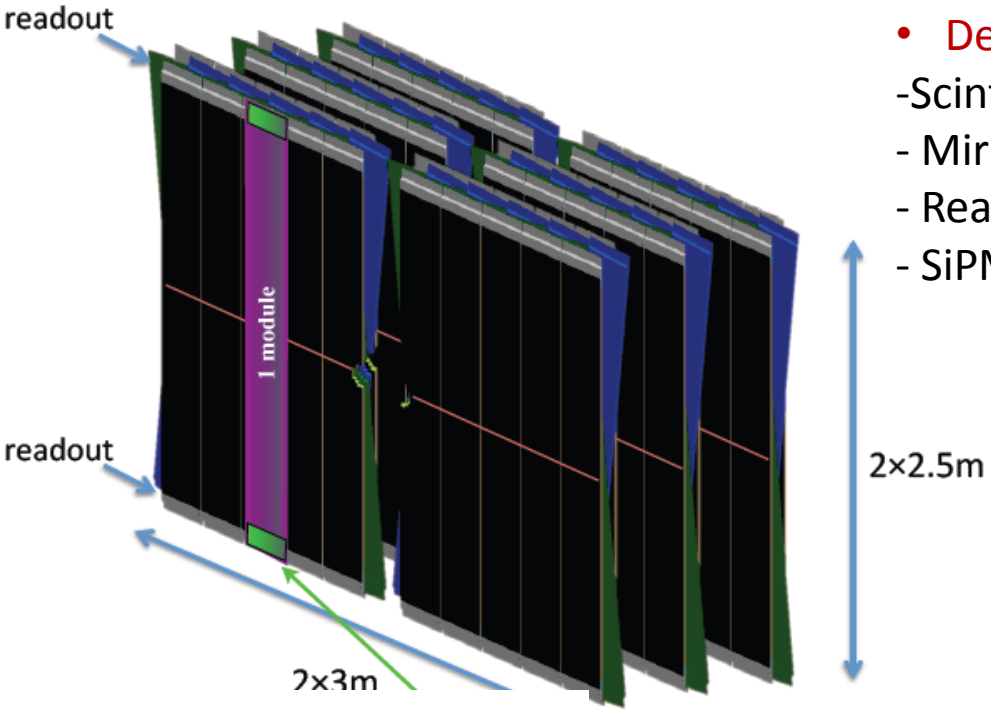
40MHz silicon strip R/O
→ dedicated SALT ASICs chip



T stations upgrade: SciFi

- Current T-stations composed of 2 subdetectors:
  - Outer tracker (straw tubes) + Inner tracker (silicon micro-strip)
- Upgrade: replace all with scintilating fibers
  - Advantage of 1 single technology
  - Pattern recognition fast enough for HLT
  - Resolution <100μm , very low material budget (active material)



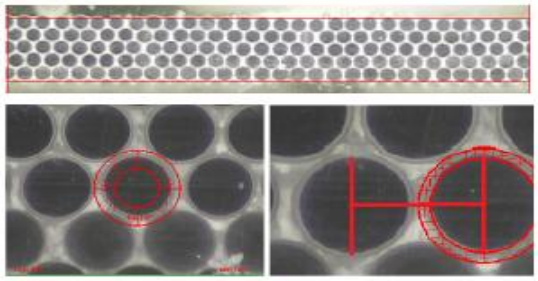


- Detector technology:

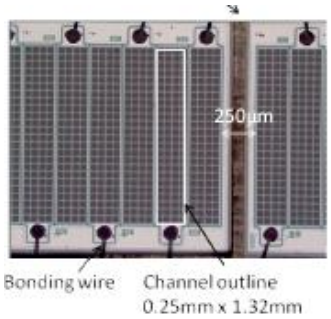
-Scintillating fibers (∅250μm, L=2.5m)
- Mirrors in the center for better light collection
- Readout at 40MHz by SiPM
- SiPMs + FE electronics in readout box

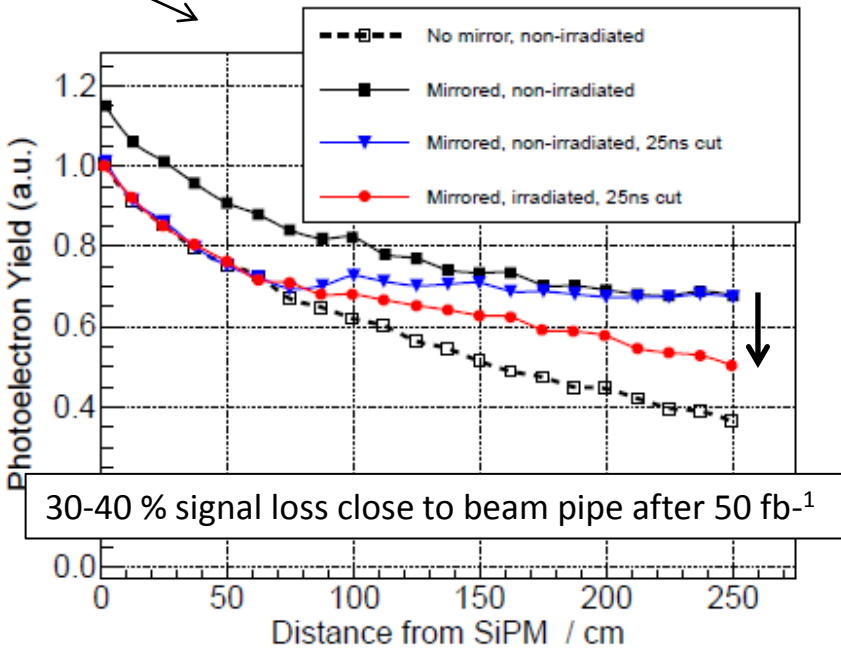
SciFi Tracker

∅250µm fibers mat



- Fibers
  - Radiation studies:
    - Small effect on wavelength
    - Signal loss due to attenuation length acceptable
- SiPM
  - Hamamatsu and KETEK tested: OK
  - Fast signal response and recovery
  - Radiation: to be kept at -40 °C
- Electronics
  - Fast shaper (10ns)
  - 25ns gated integrator
  - Clusterization in FPGA



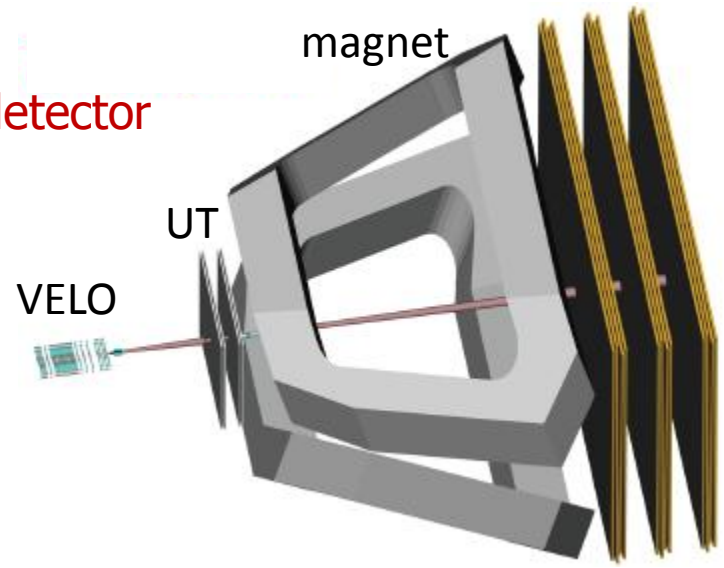


Upgrade Tracking performance

SciFi

- New detector in simulation
- Track reconstruction algorithm rewritten for new detector

  ⇒ Efficiency, ghost rates, resolution



- Long tracks reconstruction efficiency:

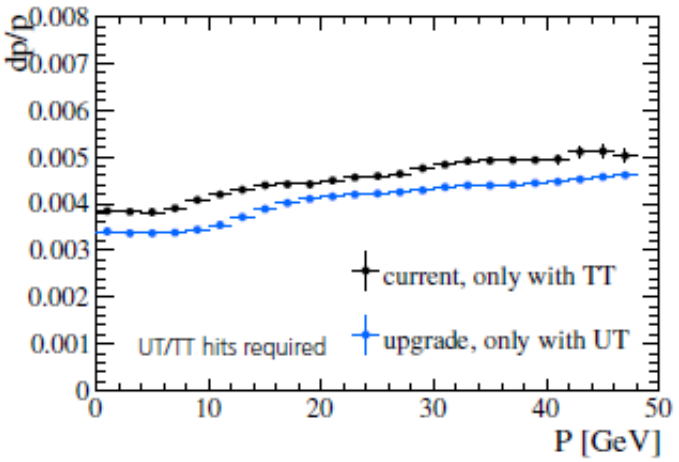
  For b-hadron daughters, p>5GeV/c:

	current LHCb	Upgrade LHCb	
Luminosity ($cm^{-2}s^{-1}$)	$4x10^{32}$	$1x10^{33}$	$2x10^{33}$
efficiency (%)	96.8	95.6	94.7

⇒ Good overall efficiencies

- Algorithm not tuned
- Detector geometry can be tuned as well

- Momentum resolution:
  - Better than current design thanks to less material



Conclusions

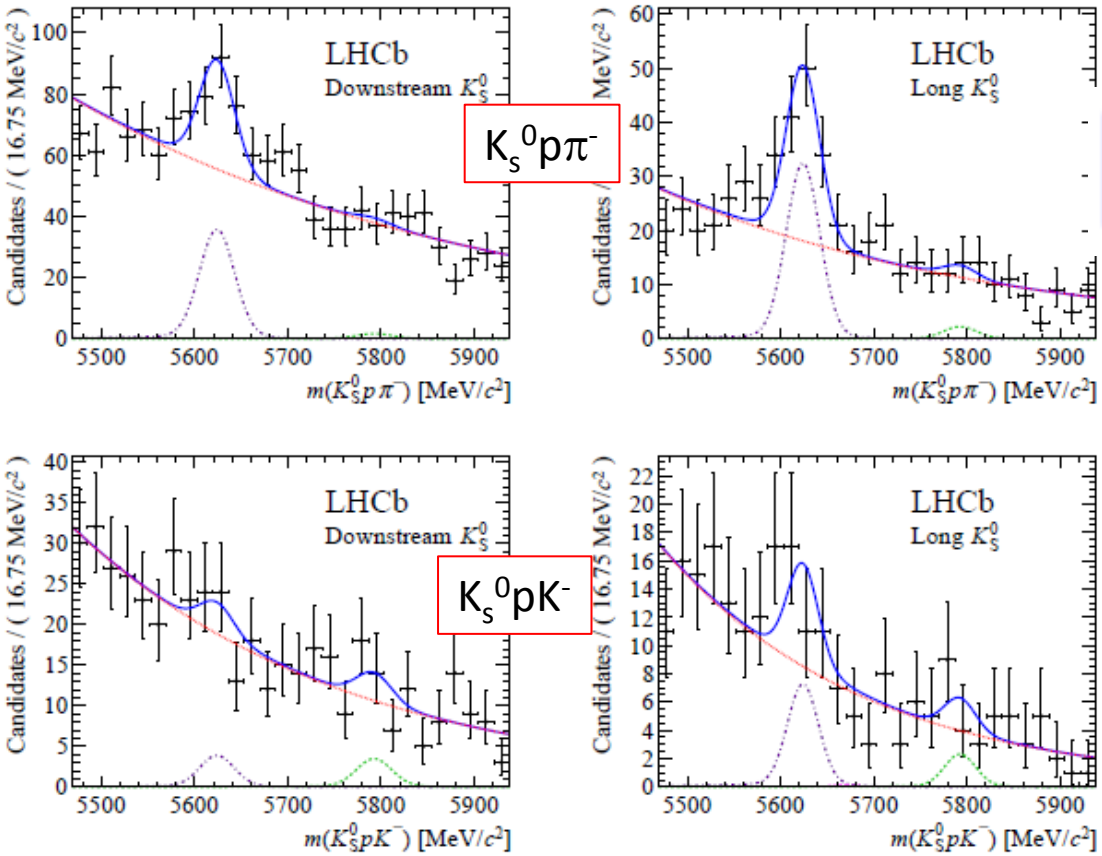
- LHCb is producing lots of high quality data results
  And still more to come with Run1 data!
- Improvements / maintenance on the detector going smoothly during LS1
- Actively preparing Run2 and the restart
- The penultimate TDR has been submitted (Tracker)
  Last TDR to come: Online, DAQ and trigger (June)
- All the upgrade activities are on schedule for LS2

SPARES

Search for b-baryons decays: $\Lambda_b^0 (\Xi_b^0) \to K_s^0 p\pi^-$ and $K_s^0 pK^-$

arXiv:1402.0770

- Study of b-baryons is an almost unexplored field: large program!
- Search for $\Lambda_b^0 (\Xi_b^0) \to K_s^0 p\pi^-$ and $K_s^0 pK^-$ and Br measurement wrt $B_s^0 \to K_s^0 \pi^+ \pi^-$



First observation of $\Lambda_b^0 \to K^0 p\pi^-$

$$\mathcal{B}(\Lambda_b^0 \to \bar{K}^0 p\pi^-) = \\ = (1.57 \pm 0.21 \pm 0.08 \pm 0.42 \pm 0.06) \times 10^{-5}$$

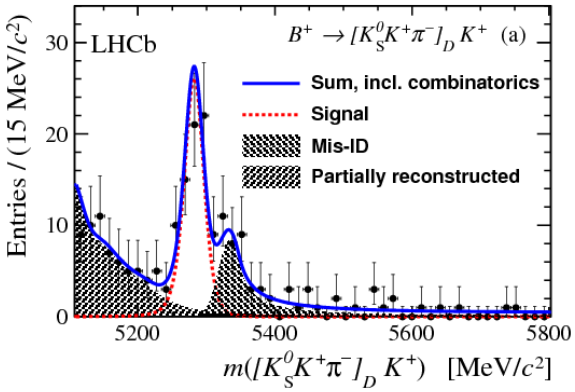
Fisrt measurement of CP asymmetry

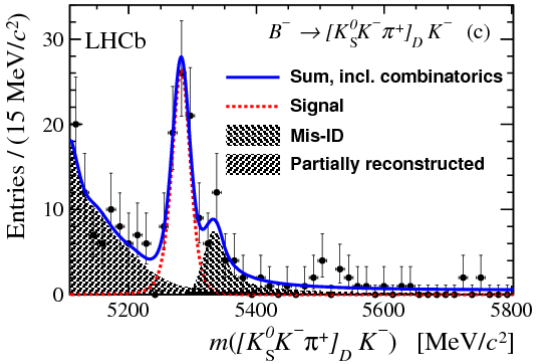
$$\mathcal{A}^{CP}(\Lambda_b^0 \to \bar{K}_s^0 p\pi^-) = \\ (0.22 \pm 0.13 \pm 0.03)$$

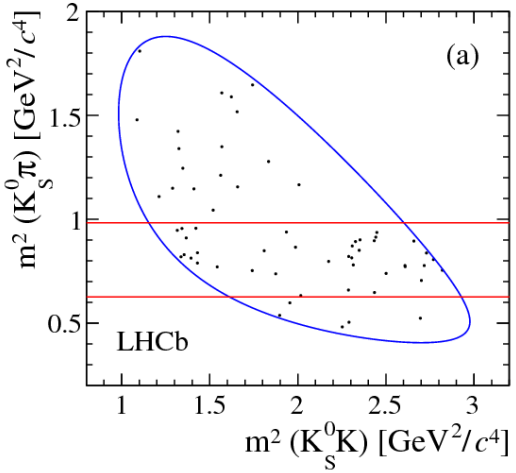
arXiv:1402.2982

Study of CP violation in B->DK(π) decays

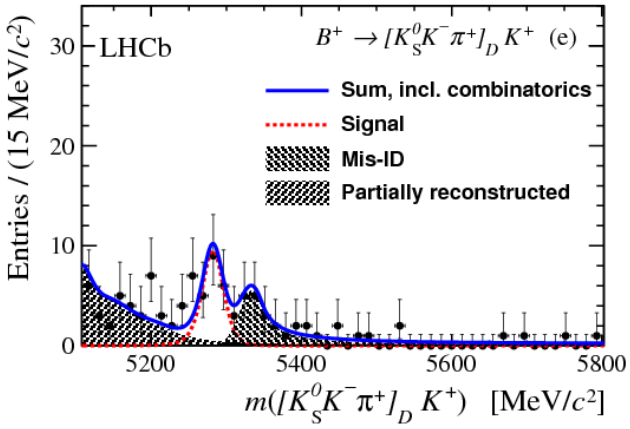
SS

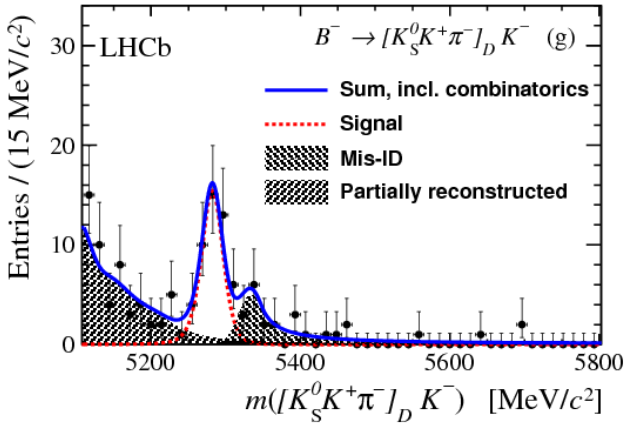


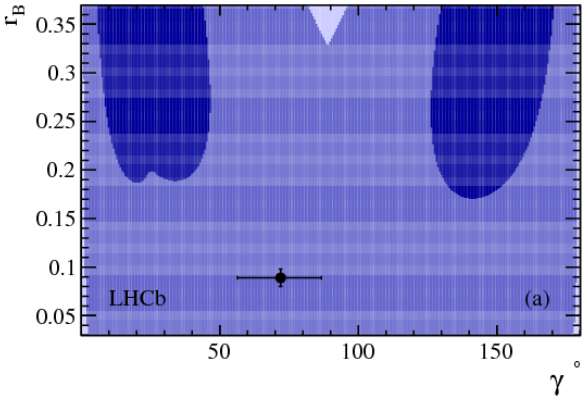




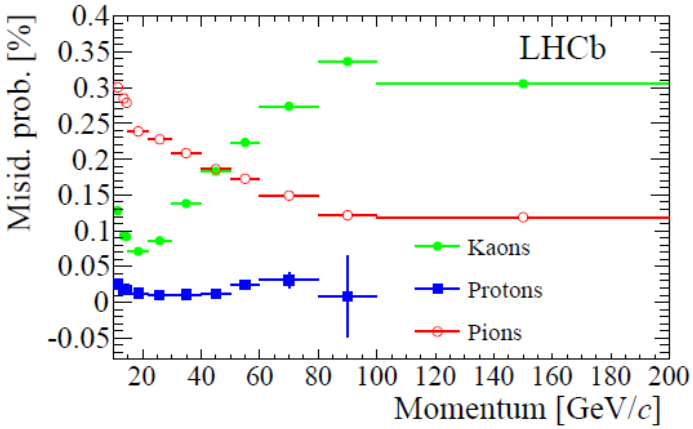
OS

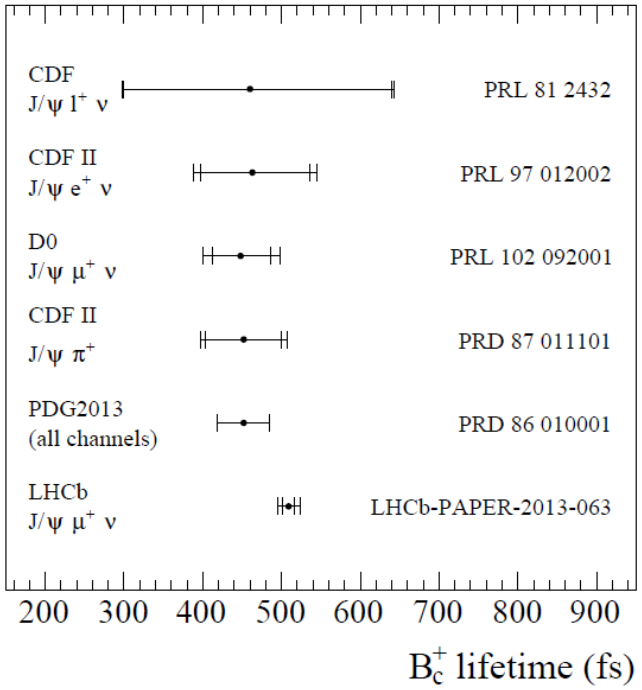






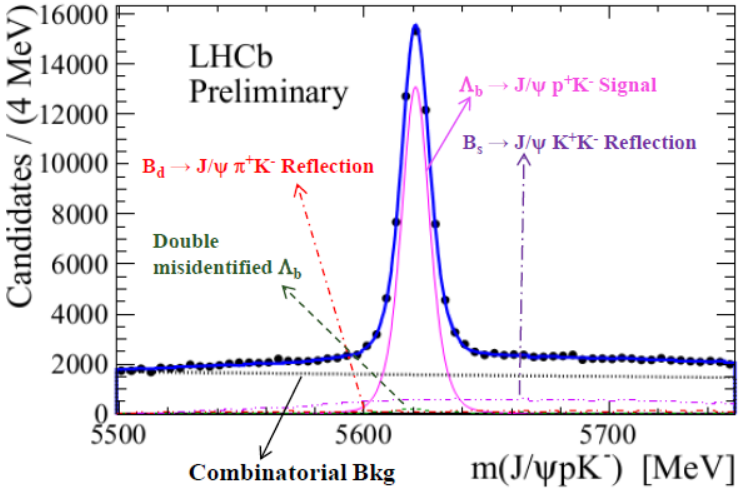
Bc lifetime

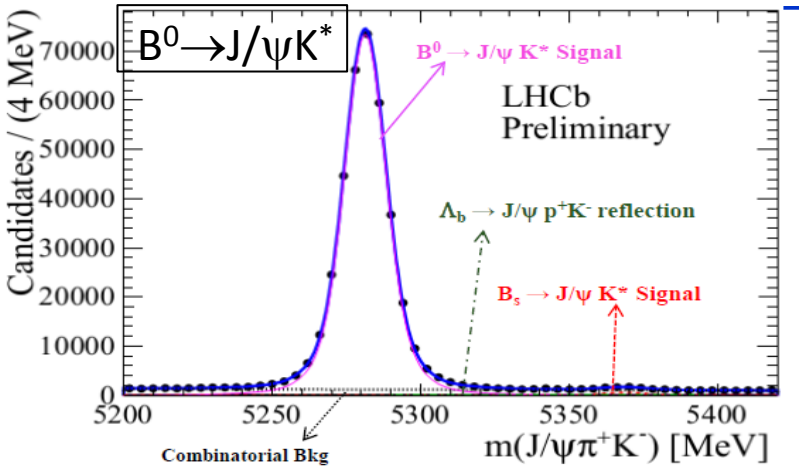

LHCb
Misid. prob. [%]
Momentum [GeV/c]
Kaons
Protons
Pions

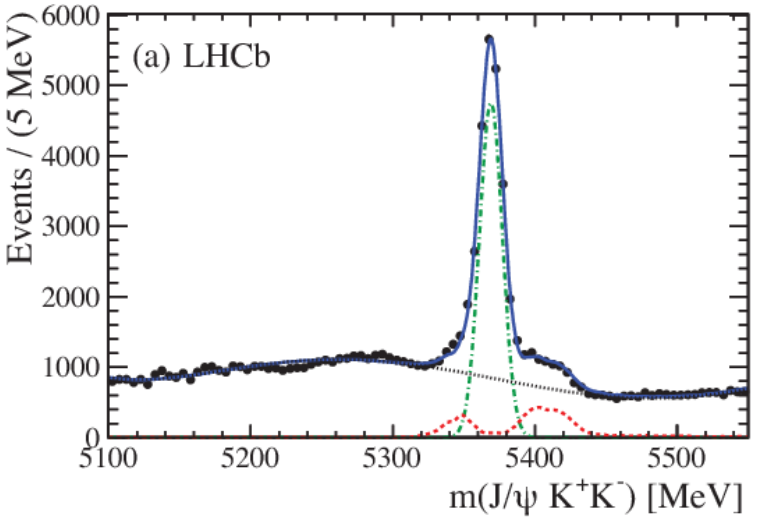

CDF
J/ψ l+ ν
PRL 81 2432
CDF II
J/ψ e+ ν
PRL 97 012002
D0
J/ψ μ+ ν
PRL 102 092001
CDF II
J/ψ π+
PRD 87 011101
PDG2013
(all channels)
PRD 86 010001
LHCb
J/ψ μ+ ν
LHCb-PAPER-2013-063
B+c lifetime (fs)

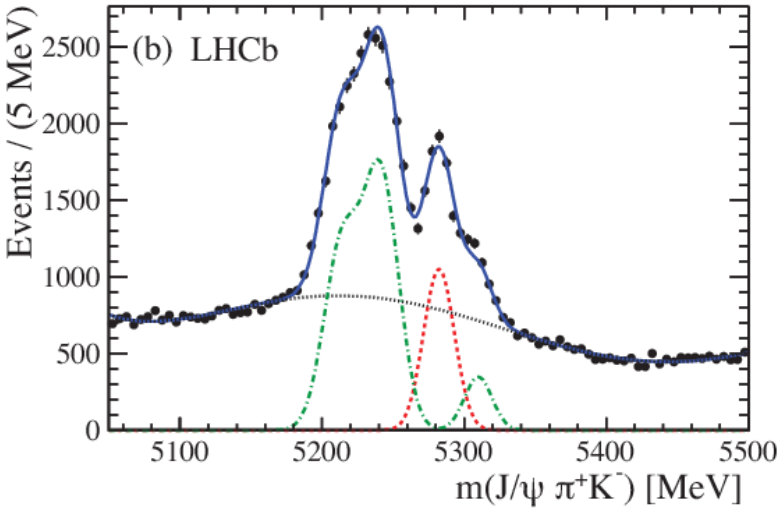
Λ^0_b lifetime

- Background from misid: shapes from MC , yields from data

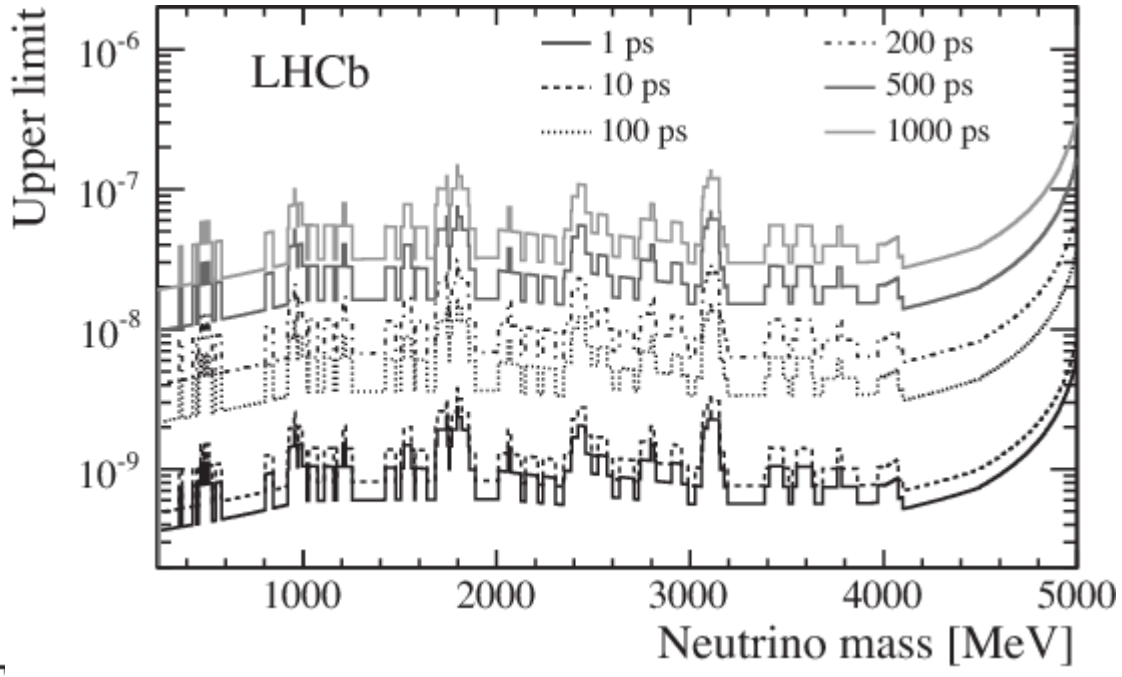


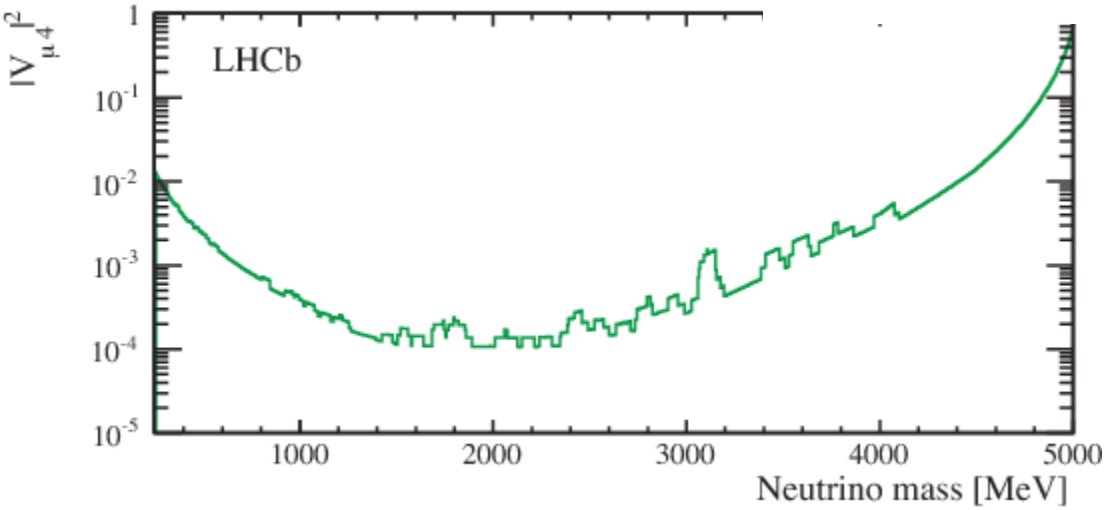






Search for Majorana neutrino: limits





Upgrade Tracking performance

- Adding UT hits to Long tracks:
  - reduction of ghost rates by a factor > 2
  - Drop of efficiency ~1%