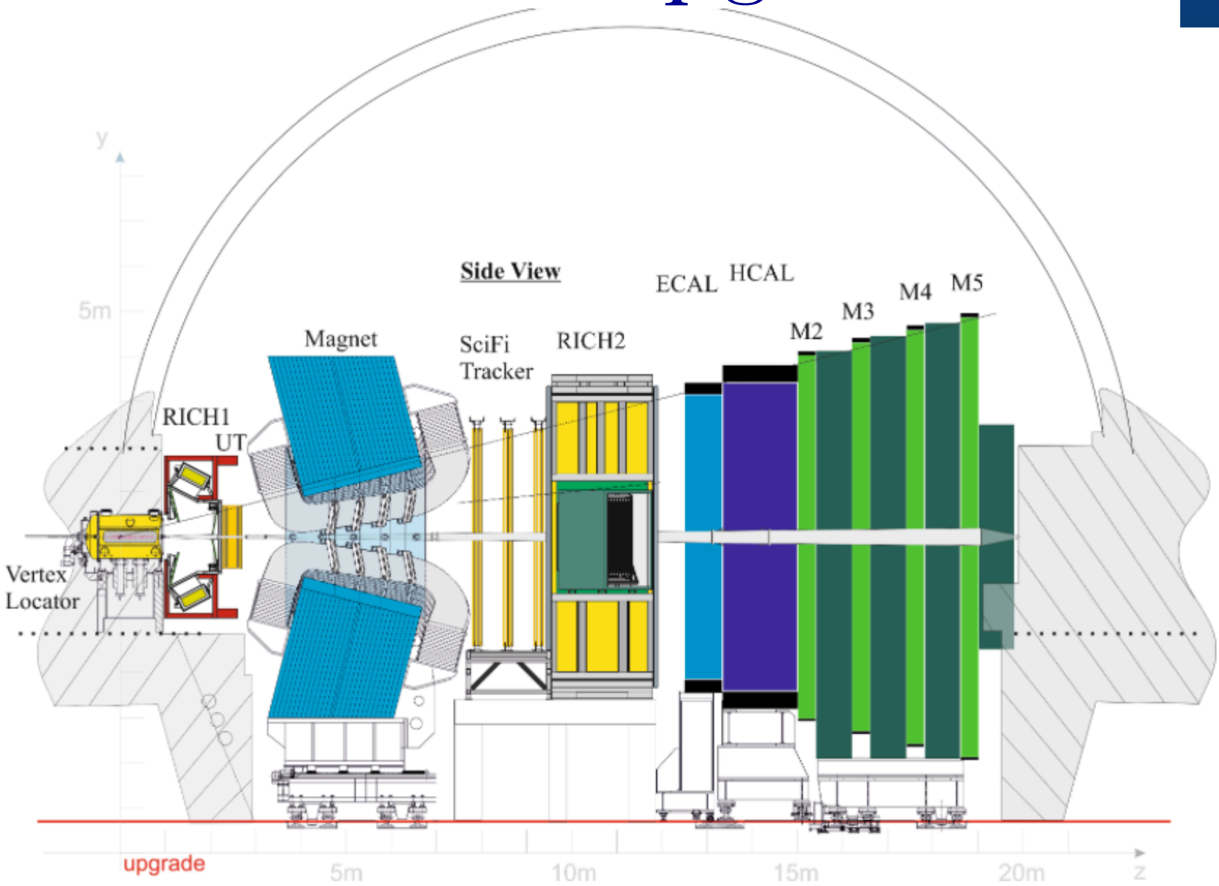
LHCb upgrade



P. de Simone on behalf of the LNF LHCb group

50th Meeting of the LNF scientific committee – November 23-24, 2015

outline

1) introduction

Run 1 & few highlights of the LHCb results
Run 2 & few physics opportunities
LHCb upgrade

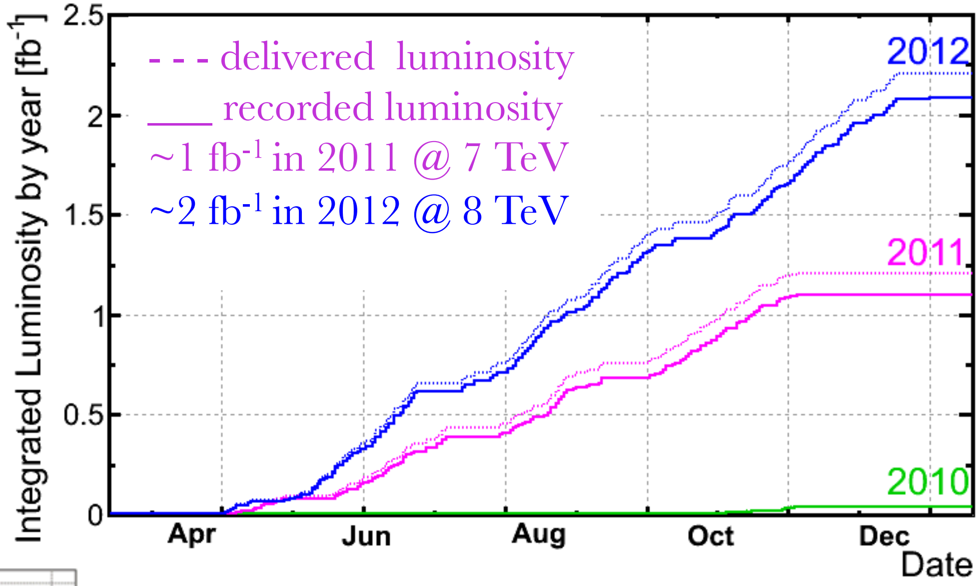
2) upgrade of the LHCb-Muon detector @ LNF

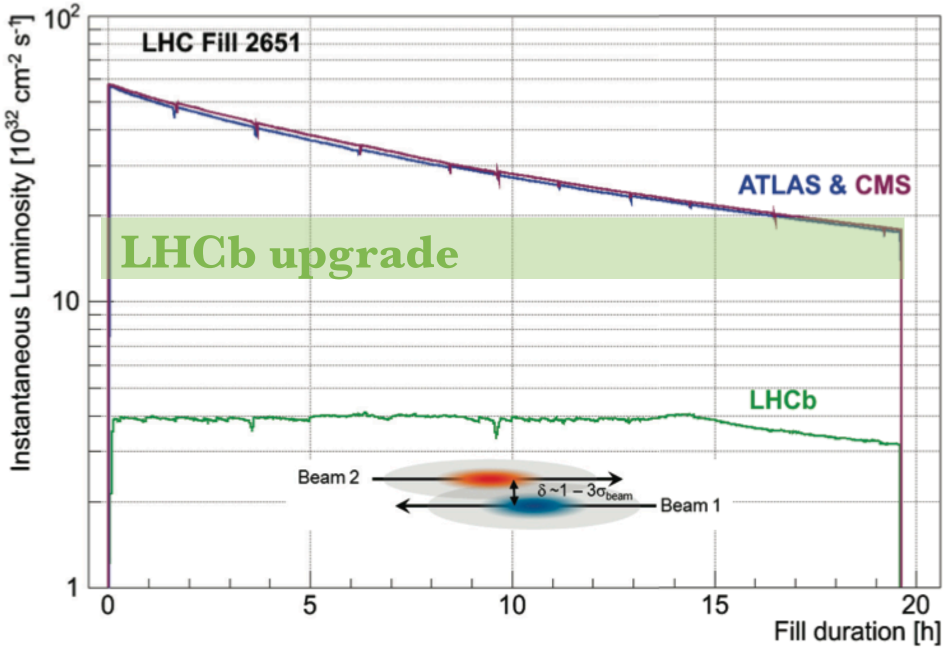
MWPCs spare production
new readout
Muon detector performances at upgrade

3) conclusion

Run 1

the results from LHCb have definitively proved the concept of a flavour physics experiment in the forward region at a hadron collider





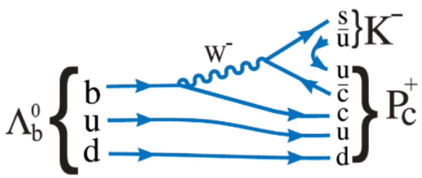
LHCb 2012 running conditions :

- ✓ running at levelled luminosity of $\sim 3\text{-}4\times10^{32}\ \mathrm{cm^{-2}s^{-1}}$ and pile-up ~ 2.3
- ✓ 50 ns bunch spacing
- ✓ 1 MHz readout
- ✓ data record at ~3-5 kHz

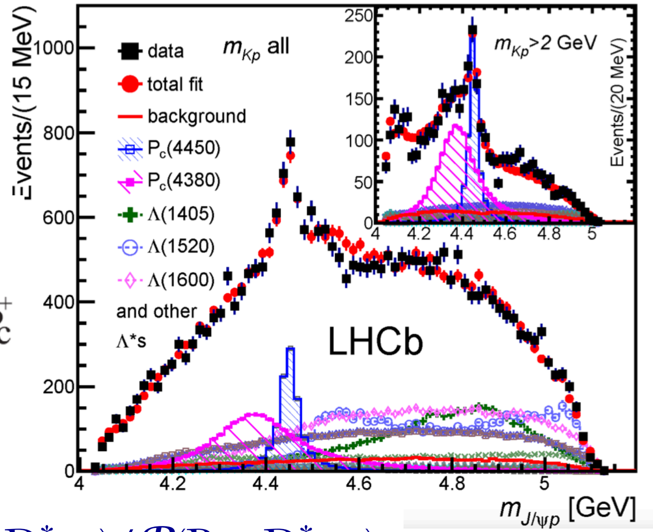
few highlights of LHCb results

285 papers integrating over published, accepted and submitted

observation of two pentaquarks in $\Lambda^0_b \to J/\psi p K^-$

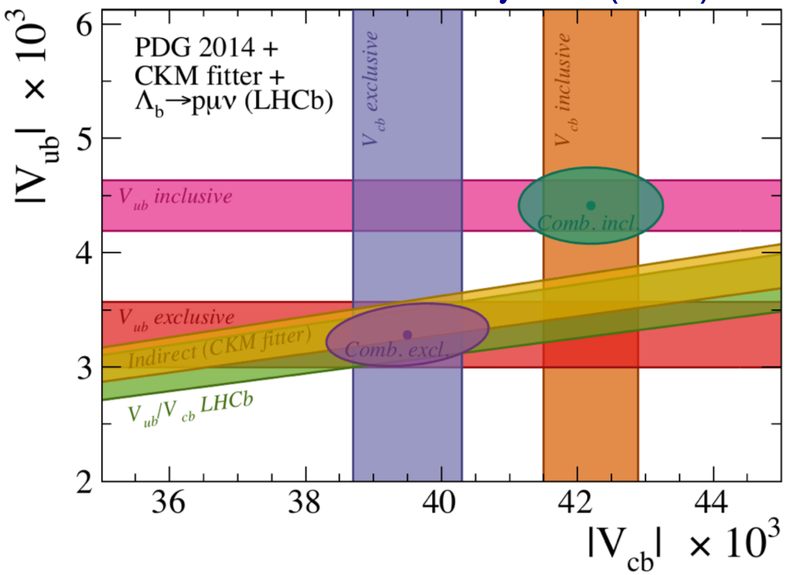


PRL 115 (2015) 07201



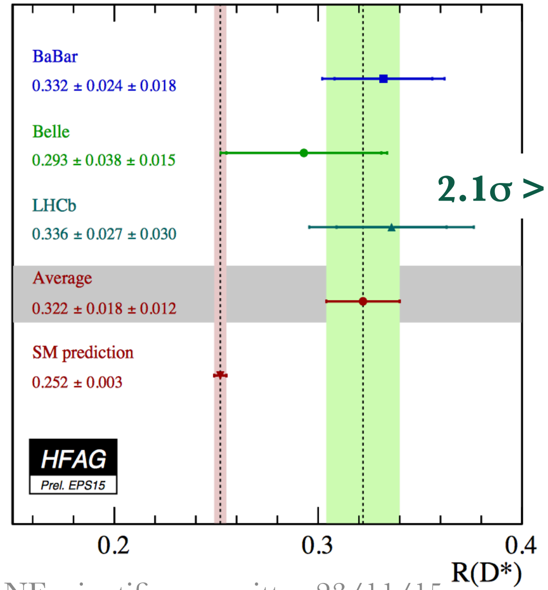
$|V_{ub}/V_{cb}|$ from $\Lambda_b \to p\mu\nu / \Lambda_b \to \Lambda_c\mu\nu$

Nature Phys. 11 (2015) 743



$R(D^*) = \mathcal{B}(B \to D^*\tau\nu) / \mathcal{B}(B \to D^*\mu\nu)$

PRL 115 (2015) 112001



2.1σ > SM value

and

- ✓ full angular analysis of $B^0 \to K^{*0}\mu^+\mu^-$ **LHCb-CONF-2015-002**
- ✓ ϕ_s measurements in $B_s \to J/\psi K^+K^-$ **PRL 114 (2015) 041801**

…

few highlights of LHCb results: $B_s \to \mu^+\mu^-$

combination of CMS and LHCb data

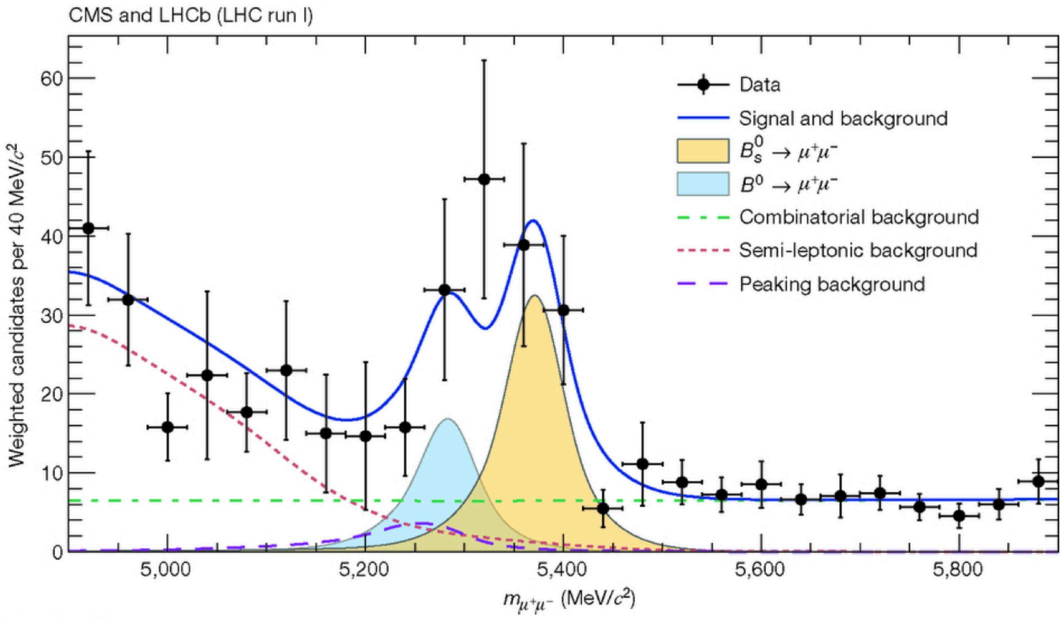
first observation of $B_s \to \mu^+\mu^-$ with 6.2 σ

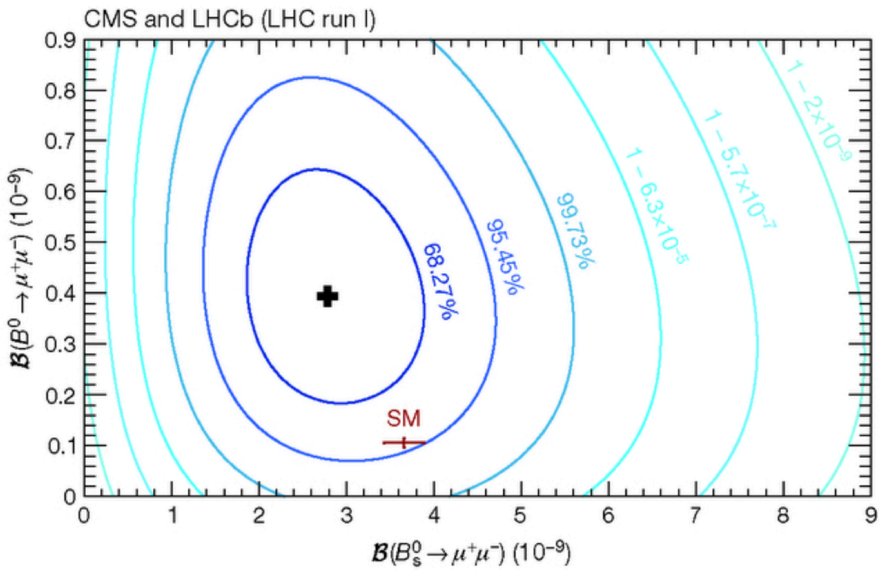
$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = 2.8^{+0.7}_{-0.6} \cdot 10^{-9}$

first evidence for $B^0 \to \mu^+\mu^-$ with 3.0 σ

$\mathcal{B}(B^0 \to \mu^+\mu^-) = 3.9^{+1.6}_{-1.4} \cdot 10^{-10}$

Nature 522 (2015) 68





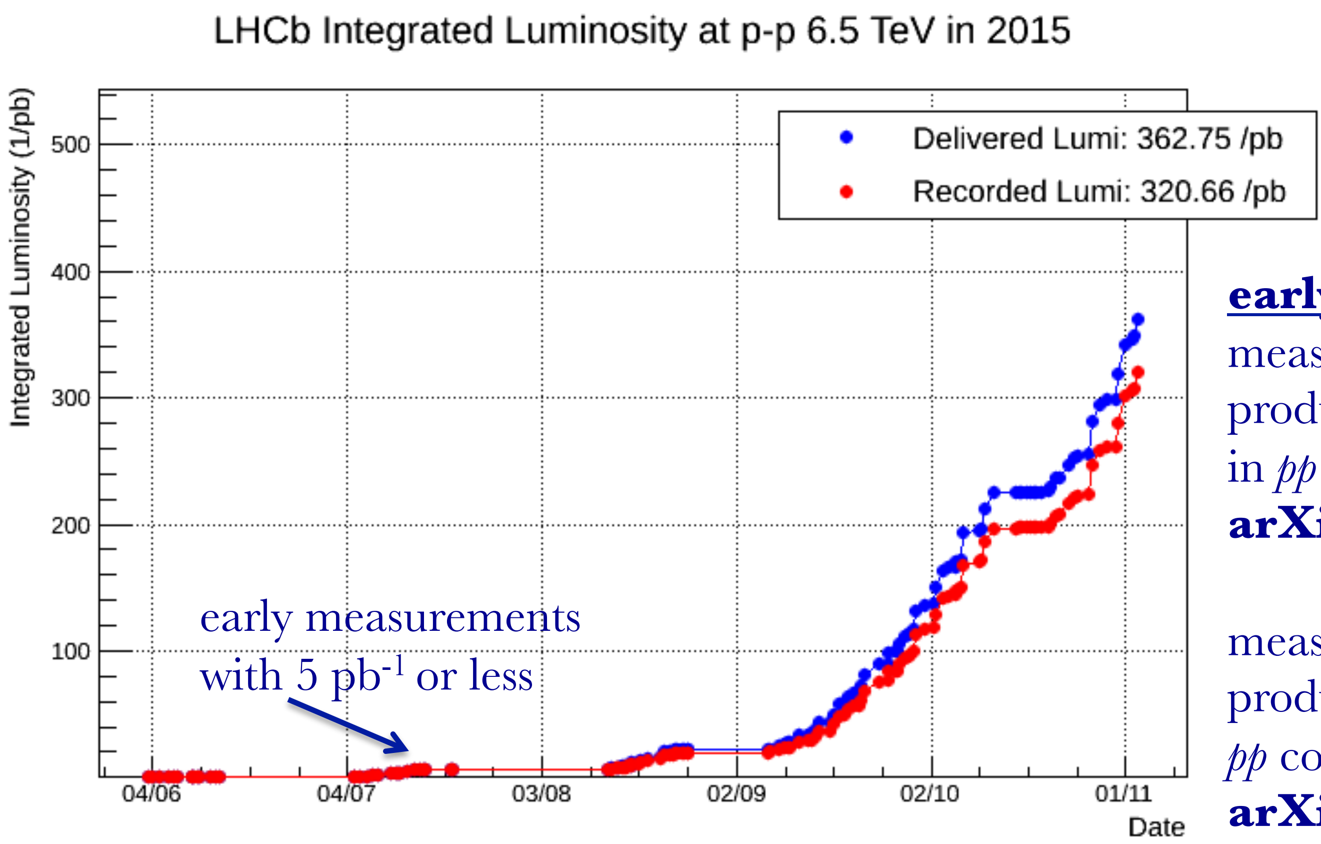
results consistent with SM at 2σ level

set strong constraints on BSM theories (possible scalar and pseudo-scalar couplings)

LHCb analysis coordinated by the LNF group

Run 2 data taking

✓at 13 TeV, LHCb gains from higher √s and 25 ns bunch spacing
✓during LS1 some sub-detector consolidation
✓changes of data flow in trigger: rate to storage from 5kHz to 12.5 kHz



early measurements:

measurements of prompt charm production cross-sections in *pp* collisions at √s=13TeV
arXiv:1510.01707

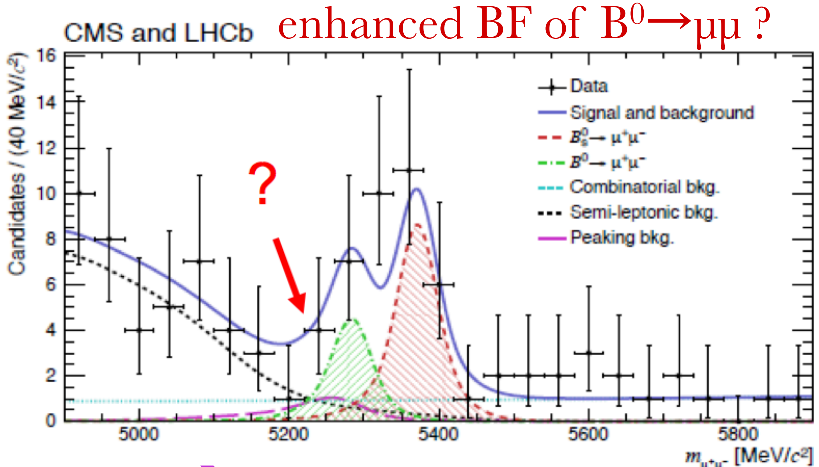
measurement of forward J/ψ production cross-sections in *pp* collisions at √s=13TeV
arXiv:1509.00771

Run 2 up to 2019 ➔ 8 fb^{-1}

Run 2 will offer a significant increase in sample sizes (~ x6 in b-yields), which will allow for ever more precision: these are some anomalies highlighted by LHCb spokeperson (Guy Wilkinson)

enhanced BF of $B^0 \to \mu\mu$?

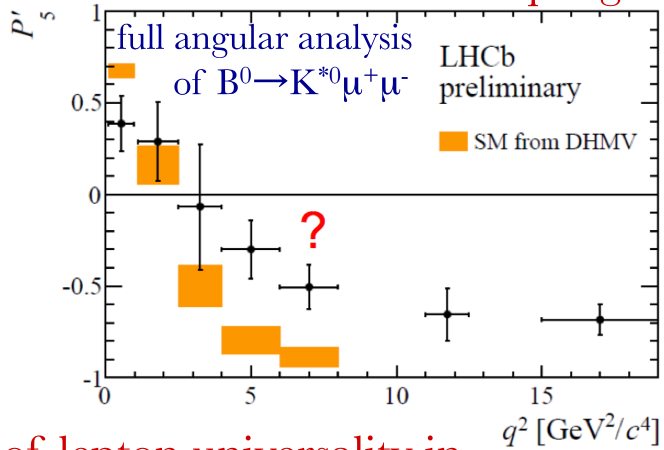
Nature 522 (2015) 68



LNF group ➔ bkg studies in the last year, a good reduction seems possible

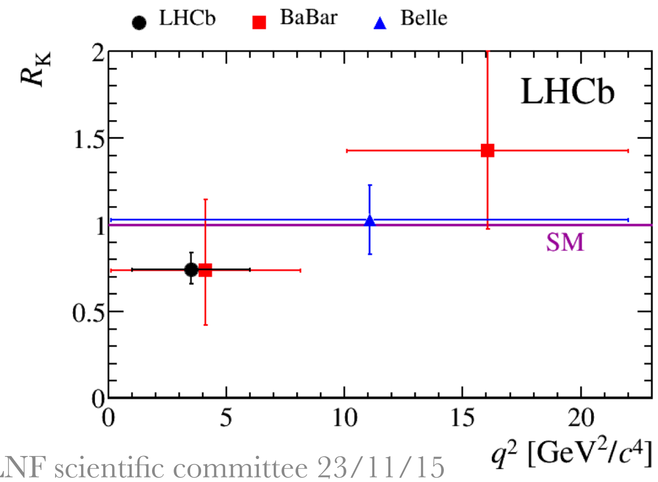
odd behaviour in EW penguins

LHCb-CONF-2015-002



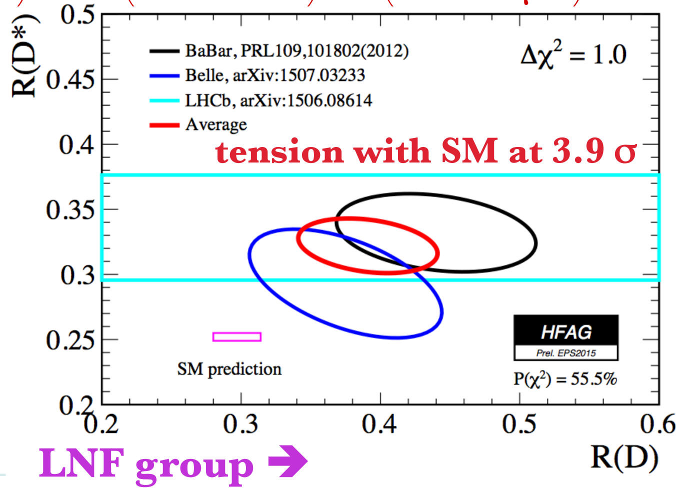
violation of lepton universality in $B \to K l^+ l^-$?

PRL 113 (2014) 151601



violation of lepton universality in $R(D^*) = \mathcal{B}(B \to D^*\tau\nu) / \mathcal{B}(B \to D^*\mu\nu)$?

PRL 115 (2015) 112001



LNF group ➔ starting analysis on $R(D_s)$

the LHCb upgrade

there is an excellent physics case to push for improved precision

aim at experimental sensitivities comparable to theoretical uncertainties

fully exploit LHC physics in the forward region

however, beyond LHC Run II, the increase of statistics is limited by the 1 MHz readout and associated hardware trigger L0

upgrade will be performed during LS2, now expected to be 2019-20

upgrade all sub-detector electronics to 40 MHz readout (Muon ➔ LNF)

make all trigger decision in software

some new detectors: tracking detectors and RICH

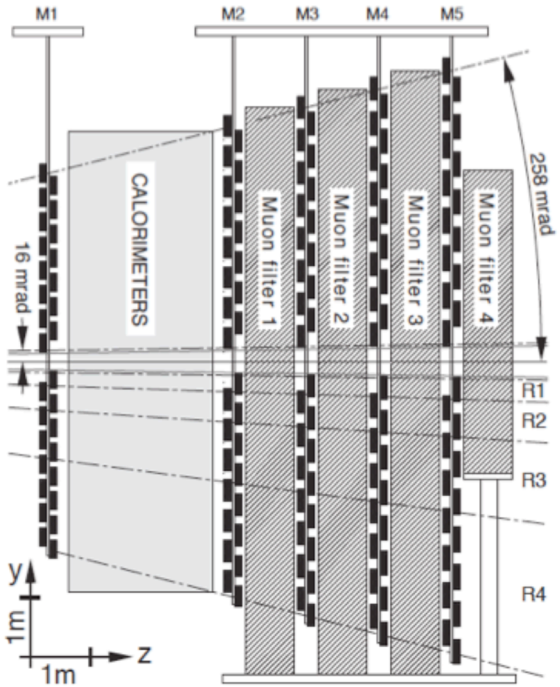
restart data taking in 2021 at $\mathcal{L}$ up to 2×10^{33} cm^{-2}s^{-1}, pile-up≃7.4

upgrade detector qualified to accumulate 50 fb^{-1}

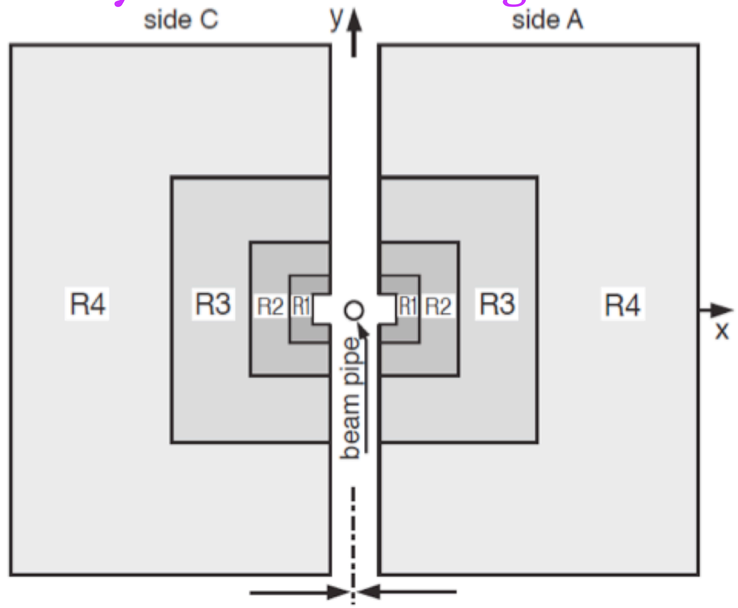
upgrade of the Muon detector @ LNF

detector layout at upgrade

muon detector side view



station layout with the 4 regions indicated



MWPCs X-Y strip readout OR-ed by the FE, apart M4R1 and M5R1 pad readout

- **M1 station will be removed**
- profiting of the new HCAL layout, additional shielding (30 cm tungsten) **will be installed** in front of M2R1 to mitigate the higher rates of the innermost regions ➔ from MC we expect a rate reduction of ~ 25%
- additional shielding (Pb) **already installed** behind M5 to reduce back-scattered particles from LHC magnets

MWPCs @ high luminosity

MWPC ageing studies (**LHCb-2004-029**) show that $Q_{tot} \simeq 0.45$ C/cm accumulated by the detectors does not imply a degradation in performances. However Q_{tot} is about 70% of the maximum integrated charge expected in the inner region of M2 over the 50fb^{-1} of integrated luminosity foreseen

➔ detector ageing is a concern after LS3

- adequate supply of spare MWPCs ➔ the number of detectors required has been estimated from the current replacement rate

33% MWPC spares for the R1 and R2 regions
20% MWPC spares for the R3 regions
10% MWPC spares for the R4 regions

LNF and PNPI task

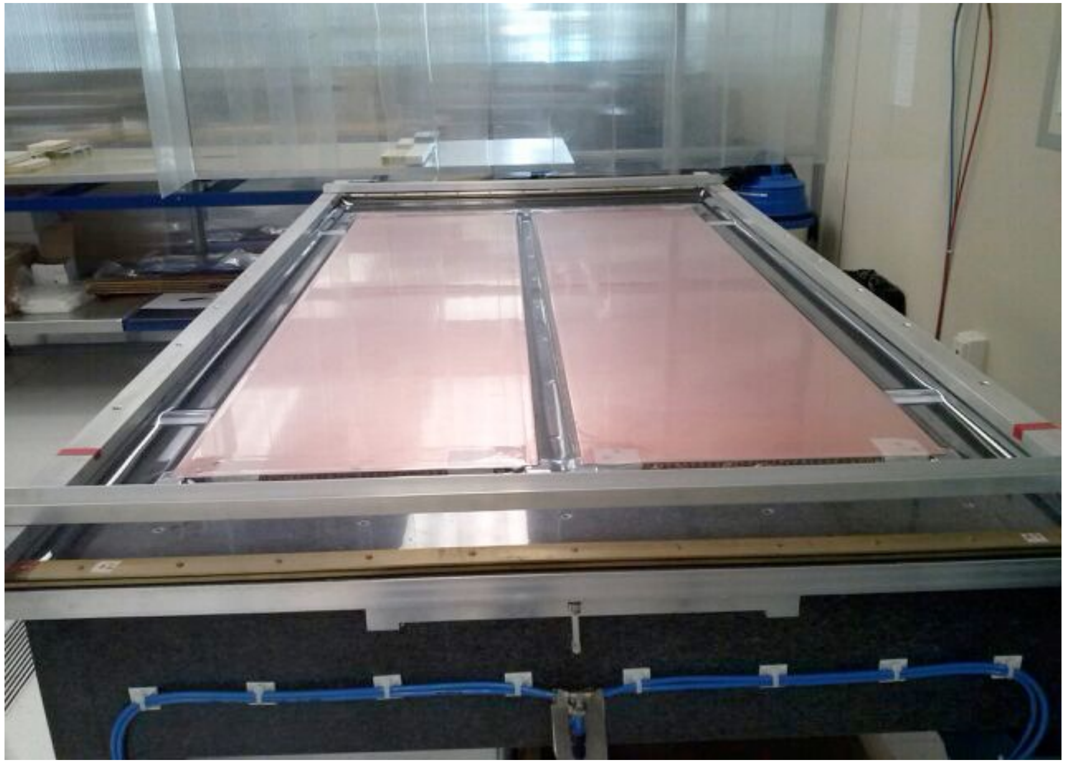
we postpone the construction of inner chambers (R1 and R2) of the stations M2 and M3, since for these stations/regions readout modifications are being studied

chambers production @ LNF (I)

10 years after the massive production of LHCb MWPCs, LNF was the only INFN site where such a production could be restarted again

the goal is to produce 30 MWPCs of large dimensions 1.6×0.4 m^2

many months of work to prepare all of the needed tools and resume all the different steps



first step is panel assembly (PCB+honeycomb+PCB) in the clean room, 3 panels glued at a time: all 135 panels needed for the LNF chambers (both M5R4 and M5R2) have been produced, with the required planarity ≤50 μm

second step HV bars are glued on special tables

third step chamber wiring,
2 panels at a time
after the panels are tested with HV

fourth step lateral bars are glued, and the 4 gaps are finally assembled

chambers production @ LNF (II)

the first M5R4 chamber has been closed on May 26th

a huge thanks to the LNF-LHCb technical staff for the great work !

Manpower: 2.5 FTE from LNF (till dec. 2015, then 2.0)

after chamber assembly ➔ **test gas tightness and leakage currents + scan with radioactive source** will start in the next weeks in a dedicated test facility

- ✓ to build 30 chambers at LNF
- ✓ 8 chambers already closed
- ✓ with 2.5 FTE we are closing ~2 chambers/month
- ✓ to conclude the chamber production within 2016
- ✓ next February will start the production of 5 spare GEM chambers for RUN 2

Muon readout @ 40 MHz

the existing front-end electronics is already readout at the rate of 40 MHz intended for the upgraded experiment, **on the other hand**

1) the off-detector readout electronics provides to the DAQ system the full hit information (position and time) only at a rate of 1 MHz
2) and is not compliant with the new fast communication protocol based on the GBT chipset

- ✓ **design a new board** (**nODE**) back compatible with the current ODE
- ✓ use new GBTx and versatile link components to implement DAQ, TFC and ECS interfaces
- ✓ use a new custom ASIC (nSYNC) to integrate all the required functionalities
  - clock synchronization and BX alignment
  - time measurements and histogram capability
  - zero suppression algorithm, data truncation and buffering
- ✓ guarantee enough flexibility to increase granularity and reduce channel occupancy
  - possible IB boards replacement in the high occupancy zone
  - possible chambers replacement in low granularity zone

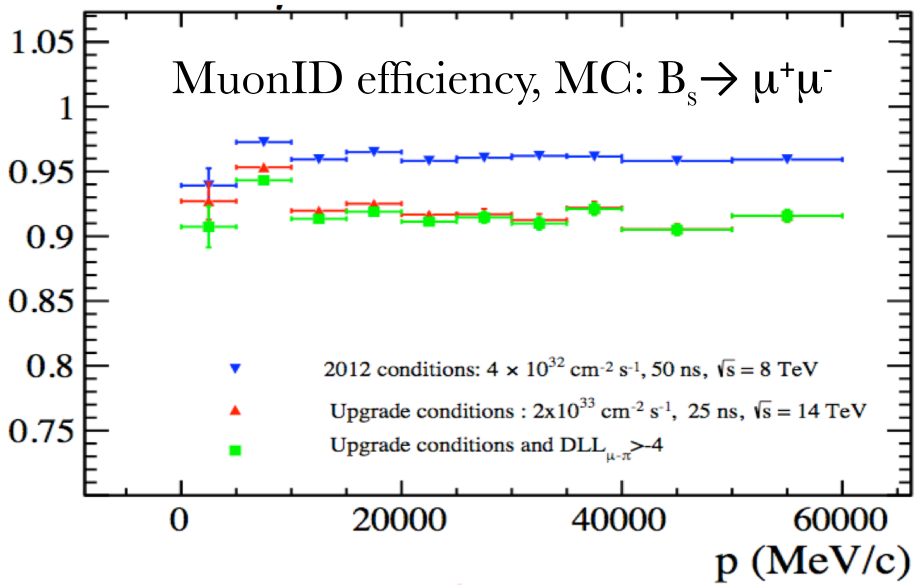
foreseen 180 nODEs, included spares (**chip** Cagliari, **board** LNF)

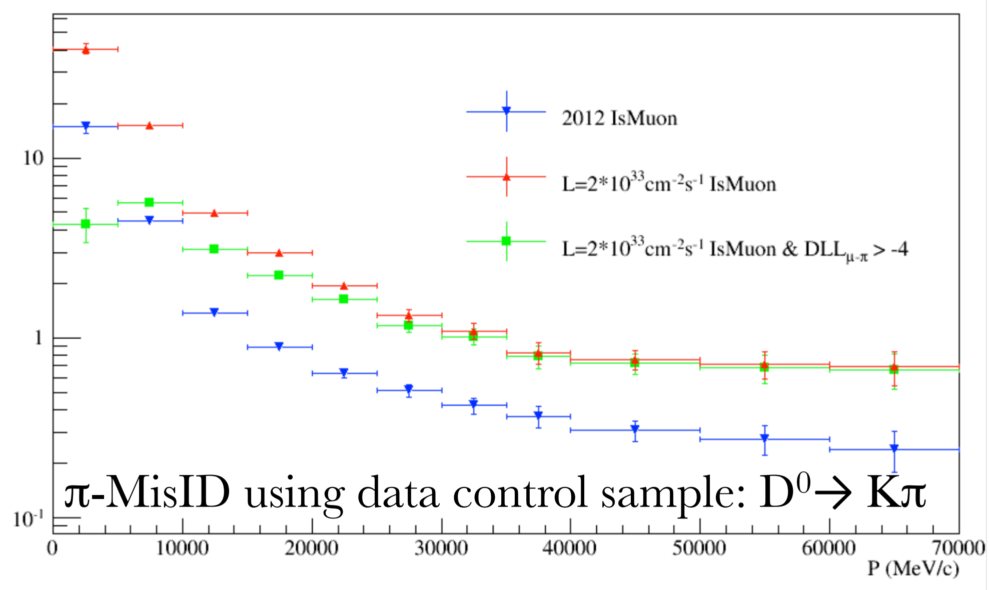
23-24/11/2015 LHCb electronic review

Acknowledge: servizio elettronica LNF (A. Balla, M. Gatta)

Upgrade PID TDR

- for the TDR, a considerable effort has been spent in projecting the detector performances to the Run III upgrade scenario $\mathcal{L} = 2 \times 10^{33}\ cm^{-2}s^{-1}$, pile-up ≃ 7.4, $\sqrt{s}$ = 14 TeV





- results are shown as a function of p at high luminosity in red compared with the 2012 in blue

➔ ε-MuonID: 5% loss for muons; π-MisID: a factor of 2 background increase is observed

- the observed π-MisID increase would seriously affect our S/B ratio at high luminosity, which is clearly not acceptable mainly for the physics program on rare decays

we concentrated then on studying possible improvements to the muon identification at upgrade, as shown in the next slides

Muon IDentification **is a two-step procedure**

step 1 ➔ IsMuon

on each station hits around the track extrapolation points are collected within search windows (FOI) that are parameterized depending on μ momentum and crossed detector region

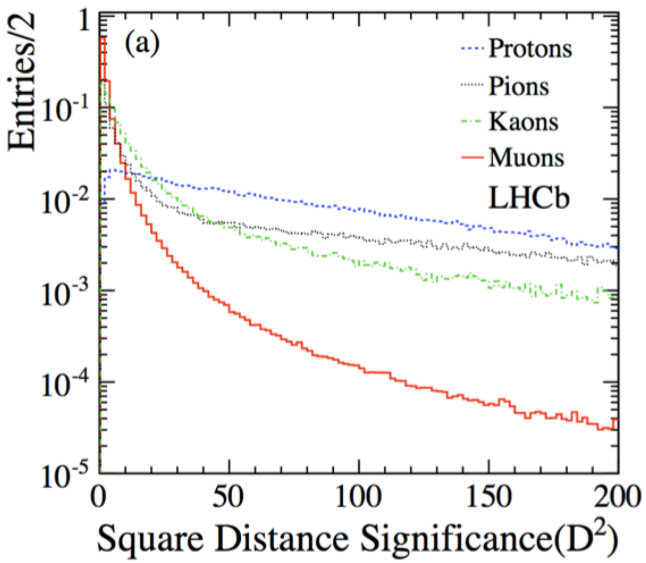
a coincidence of stations is required as a function of momentum ➔

Momentum range	Muon stations
$3\ \mathrm{GeV}/c < p < 6\ \mathrm{GeV}/c$	M2 and M3
$6\ \mathrm{GeV}/c < p < 10\ \mathrm{GeV}/c$	M2 and M3 and (M4 or M5)
$p > 10\ \mathrm{GeV}/c$	M2 and M3 and M4 and M5

step 2 ➔ Muon Likelihood (muDLL)

based on the average squared distance D^2 of the closest μ hit in FOI to the track extrapolation points on each station

$$D^2 = \frac{1}{N}\sum_i \left\{ \left(\frac{x^i_{closest} - x^i_{track}}{pad^i_x} \right)^2 + \left(\frac{y^i_{closest} - y^i_{track}}{pad^i_y} \right)^2 \right\}$$



muDLL is then combined in a likelihood with RICH and CALO (**combDLL**)

improving Muon IDentification

step 1 ➔ IsMuon

IsMuon collecting all hits in FOI, also from unpaired strips
IsMuonTight collecting only crossed hits in FOI
(crossed hits: both X and Y readout channels fired)

we studied the performances of the isMuonTight to understand if an improvement of the background rejection is possible at high luminosity with a reasonable signal loss

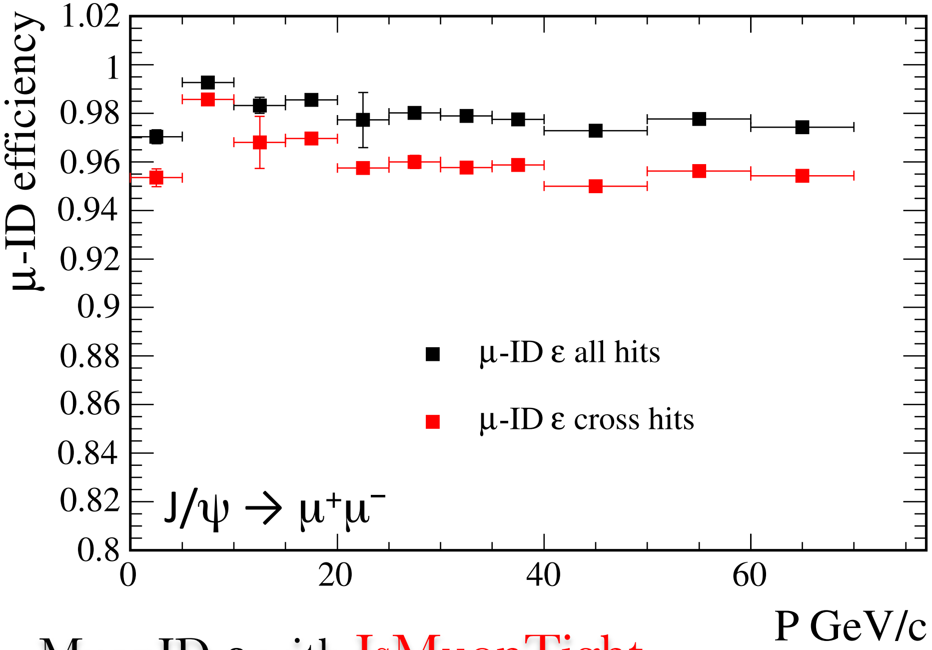
step 2 ➔ redefine the muon classifier

to exploit the full detector informations (space residuals & multiple scattering errors, hit times, number of shared hits) and to account for correlations, we introduced multi variate discriminants **BDTs**

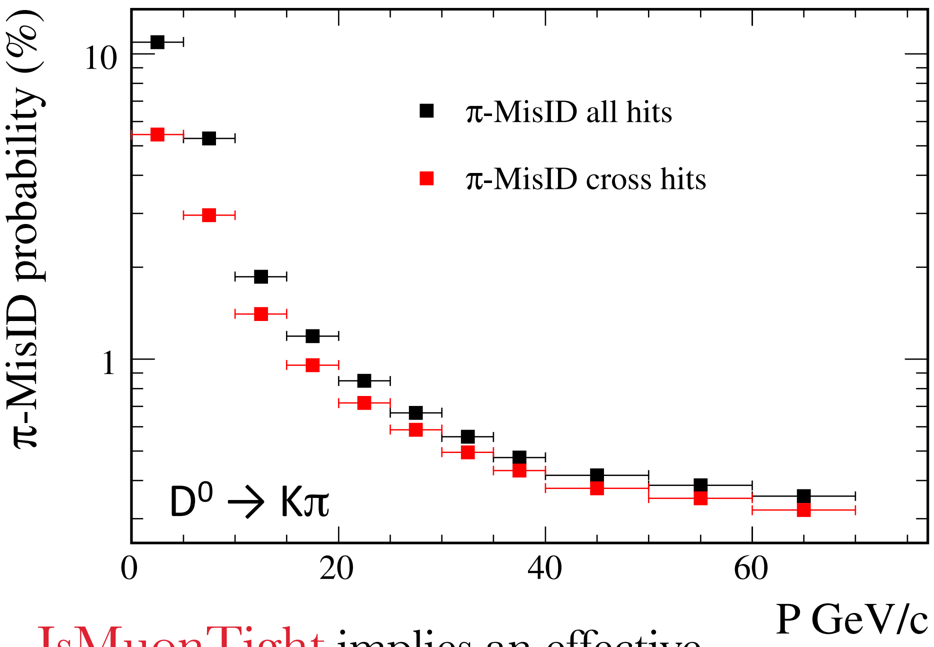
MuonID-ε and π-MisID with IsMuonTight

2012 data samples

✓μs and πs probes are TIS (L0 && HLT1 && HLT2) unbiased



MuonID-ε with IsMuonTight decreases of ≈ 2 % @ p ≳ 30 GeV/c



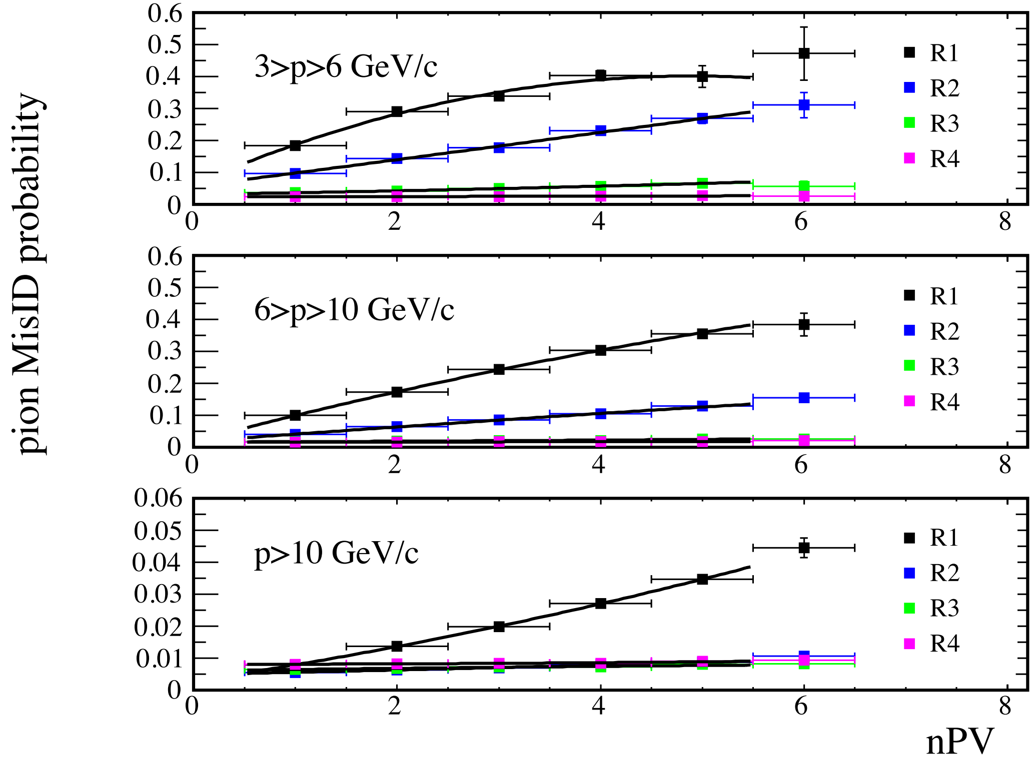
IsMuonTight implies an effective decrease of the π-MisID

π-MisID extrapolated at high luminosity

π-MisID as a function of nPV for different regions and momentum ranges, as measured on 2012 calibration data

the observed behaviour is used to extrapolate π-MisID at $\mathcal{L} = 2 \times 10^{33}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$, <nPV> ≃ 7.4

the π-MisID extrapolation @ high nPV is done fitting with a polynomial of the second order in the nPV range 0.5 - 5.5 ➔ systematic is evaluated moving up and down the nPV upper limit



- the increase of the π-MisID is especially relevant for the inner regions, where it is dominated by accidental hits

π-MisID extrapolated at high luminosity : numbers

measured at pile-up ~ 2.3	3< p< 6 GeV/c	6< p< 10 GeV/c	p> 10 GeV/c
IsMuon	.1093 ± .0006	.0529 ± .0002	.00954 ± .00002
isMuonTight	.0544 ± .0004	.0296 ± .0001	.0077 ± .0001

with isMuonTight at high lumi we get close to the isMuon performance at low lumi

extrapolated at pile-up ~ 7.4	3< p < 6 GeV/c	6 <p< 10 GeV/c	p> 10 GeV/c
IsMuon	.16 ± .01 (1.46)	.088± .003±.001 (1.66)	.018±.001±.001 (1.93)
isMuonTight	.098 ±.008± .002 (0.89)	.056±.002±.002 (1.06)	.013±.0004±.001 (1.38)

numbers btw parentheses are the ratios wrt to IsMuon at nPV~2.3

the crossing request is very effective, since it rejects a sizable fraction of accidentals

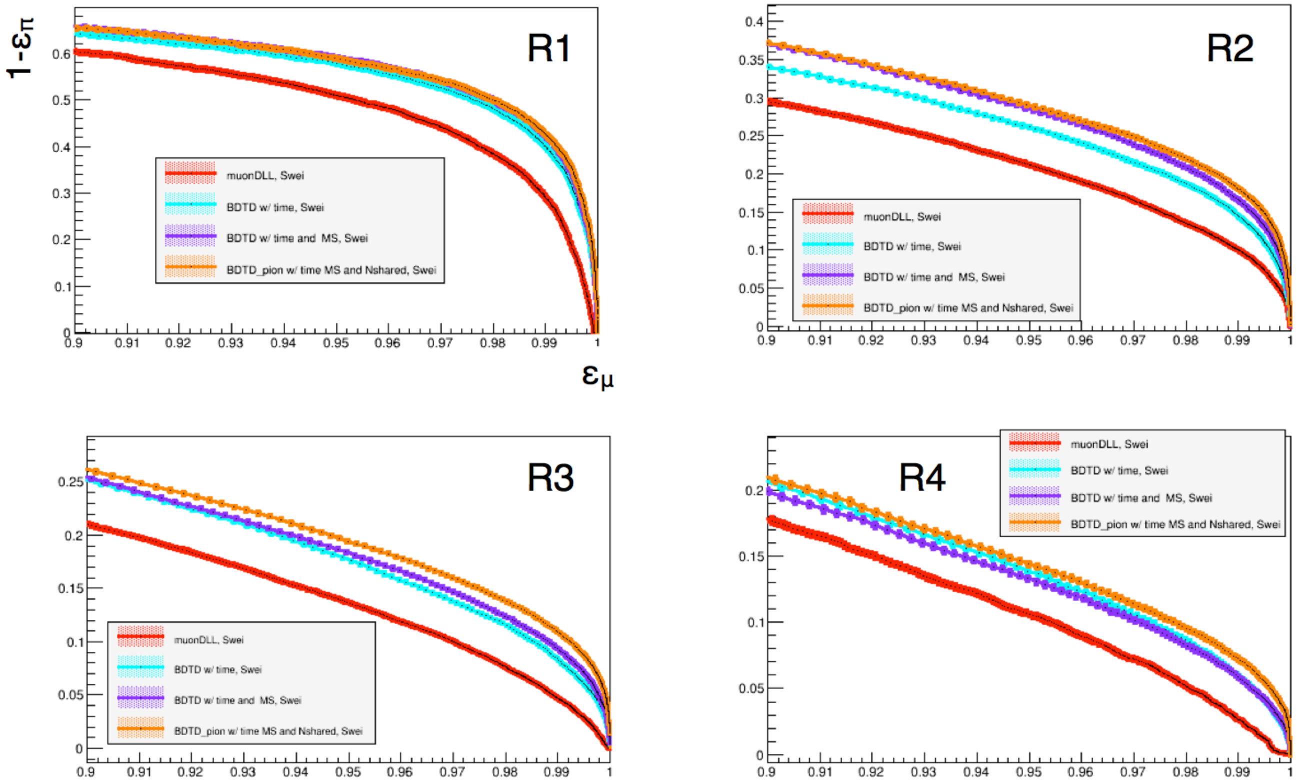
the Boosted Decision Tree LNF group + F. Archilli (CERN)

✓ several BDTs have been trained using <u>data control samples</u> of μs as signal, and πs as background

✓ the full information from the muon detector have been used: space residuals, multiple scattering errors, times, number of shared hits

✓ BDT procedure accounts for correlations between hits positions in muon stations

P > 10 GeV/c



ROCs →
curves for π rejection vs μ efficiency
(relative to isMuonTight) are produced for different regions and momentum ranges

π-MisID performances vs luminosity

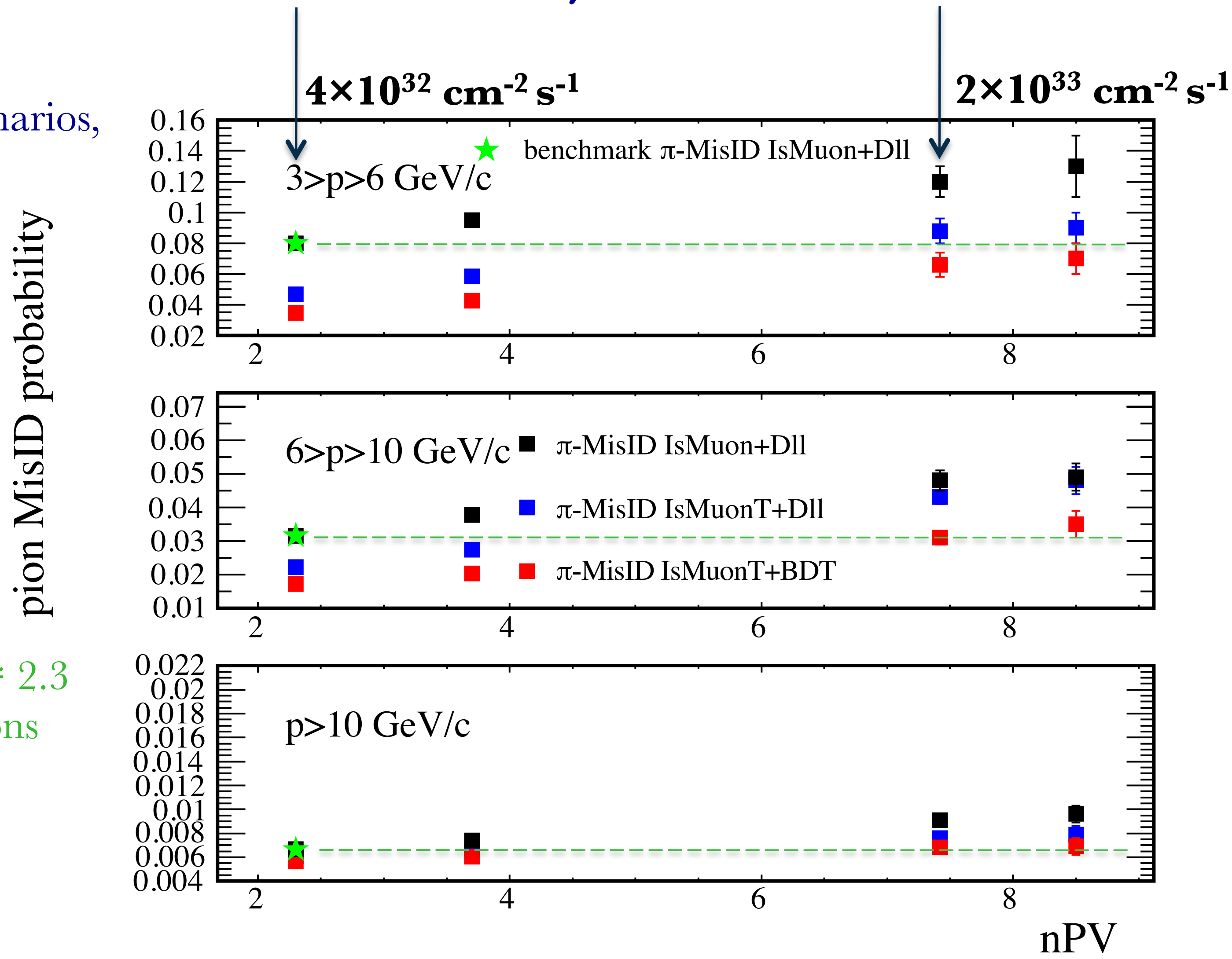
we compare three scenarios, both at low and high luminosities:

IsMuon+Dll

IsMuonTight+Dll

IsMuonTight+BDT

IsMuon+Dll @ nPV ≃ 2.3
2012 running conditions
➔ benchmark value



the proposed improvements (IsMuonTight+BDT) guarantee for the upgrade conditions the same MisID we have now, thus preventing from any sensitivity losses with luminosity increase

workshop on muon identification at LHCb 15-16/10/2015 Frascati

in view of the upgrade we organized this workshop to begin fruitful discussions and collaboration with our LHCb colleagues

Thursday, 15 October 2015

09:30 - 11:00 MuonID from RUN I to upgrade conditions

09:30 **Introduction** *30'*
Speaker: Matteo Palutan (Istituto Nazionale Fisica Nucleare Frascati (IT))
matteo_muidintro...

10:00 **Detector related considerations** *30'*
Speaker: Alessandro Cardini (INFN Cagliari, Italy)
detector-related c... detector-related c...

10:30 **Status of MuonDLL** *30'*
Speaker: Ricardo Vazquez Gomez (Istituto Nazionale Fisica Nucleare (IT))
MuonID_newDLLC...

11:00 - 11:30 Coffee break

11:30 - 13:10 Physics requirements

11:30 **MuonID at high p/pT** *30'*
Speaker: Lorenzo Sestini (Universita e INFN, Padova (IT))
muonID_v2.pdf

12:00 **MuonID at low p/pT** *30'*
Speaker: Paul Seyfert (Universita & INFN, Milano-Bicocca (IT))
pseyfert.pdf

12:30 **Rare decays: B(s)mumu case** *20'*
Speaker: Ricardo Vazquez Gomez (Istituto Nazionale Fisica Nucleare (IT))
muonIDworkshop_...

12:50 **Rare decays: D0mumu case** *20'*
Speaker: Marianna Fontana (Universita e INFN (IT))
talk.pdf

14:30 - 16:30 Improved/Improving muonID algorithms

14:30 **MC studies for high luminosity** *30'*
Speaker: Violetta Cogoni (Universita e INFN (IT))
pres_workshopmul...

15:00 **BDT algorithms for MuonID identification** *30'*
Speaker: Flavio Archilli (CERN)

15:30 **MuonID performances at high luminosity** *30'*
Speaker: Patrizia De Simone (Istituto Nazionale Fisica Nucleare Frascati (IT))
HLMuonID_Wlnf.pdf

16:00 **Clustering in MuonID** *30'*
Speaker: Marco Santimaria (Istituto Nazionale Fisica Nucleare Frascati (IT))
santimaria.pdf

16:30 - 17:00 Coffee break

17:00 - 19:00 Improved/Improving MuonID algorithms

17:00 **MuonID optimization for low p/pT** *30'*
Speaker: Giacomo Graziani (Universita e INFN, Firenze (IT))
muid3.pdf

17:30 **Improving rejection against decays in flight** *30'*
Speaker: Francesco Dettori (CERN)
Dettori-MuIDKink...

18:00 **MuonID via Kalman fit** *30'*
Speaker: Xabier Cid Vidal (CERN)
MuonID_XabierCid...

20:00 - 22:00 Social dinner

Friday, 16 October 2015

09:30 - 11:00 MuID vs trigger: RUN II and Upgrade Scenarios

09:30 **MuonID in Offline/Online at RUN II** *30'*
Speaker: Kevin Dungs (Technische Universitaet Dortmund (DE))
talk.pdf

10:00 **Perspectives for MuonID in the trigger at upgrade** *30'*
Speaker: Johannes Albrecht (Technische Universitaet Dortmund (DE))
albrecht.pdf

10:30 **Trigger selection for strangeness decay muons** *30'*
Speaker: Diego Martinez Santos (Universidade de Santiago de Compostela (ES))
Dimuontriggers_Di... Dimuontriggers_v2... Dimuontriggers_v2...

11:00 - 11:30 Coffee break

11:30 - 13:00 Combined performances and calibration

11:30 **Data-driven calibration of simulated PID** *30'*
Speaker: Lucio Anderlini (Universita e INFN, Firenze (IT))
Data-driven calibr...

12:00 **Perspectives on combined PID** *30'*
Speaker: Christopher Rob Jones (University of Cambridge (GB))
ANNPID - Muon PI...

12:30 **Conclusions and outlook** *30'*
Speaker: Barbara Sciascia (INFN (IT))

LHCb-LNF group

Bencivenni Giovanni	staff	40	
Campana Pierluigi	staff	55	
Ciambrone Paolo	staff	30	
de Simone Patrizia	staff	80	
Felici Giulietto	staff	30	
Lanfranchi Gaia	staff	60	
Ogilvy Stephen	post. Doct.	100	
Palutan Matteo	staff	80	LNF-group coordinator and MuonID convener
Santimaria Marco	PHD student	100	
Sarti Alessio	staff	70	
Sciascia Barbara	staff	80	PID convener, ECGD officer
Vazquez Gomez Ricardo	post. Doct.	100	Stripping coordinator

several duties and responsibilities in the LHCb collaboration

conclusions

✓ LHCb surpassed Run 1 performance expectations

➔ **huge physics output**

✓ very good perspectives for RUN II: LNF group is involved in crucial analyses such as $B_d \rightarrow \mu^+\mu^-$ and $R(D_s)$

✓ the LHCb upgrade is fully approved and funded, and it will be ready for installation in 2019 and operational at the end of 2020

LHCb upgrade: LNF hardware activities

- LNF chamber production site resumed and now operative
- 8 MWPC spares already built;
  we plan to complete the production end 2016,
  + 5 GEM chambers for Run 2
- we are responsible to project and to realize the boards of the new Off Detector Electronics; the design is being reviewed today at CERN

LHCb upgrade: LNF software activities

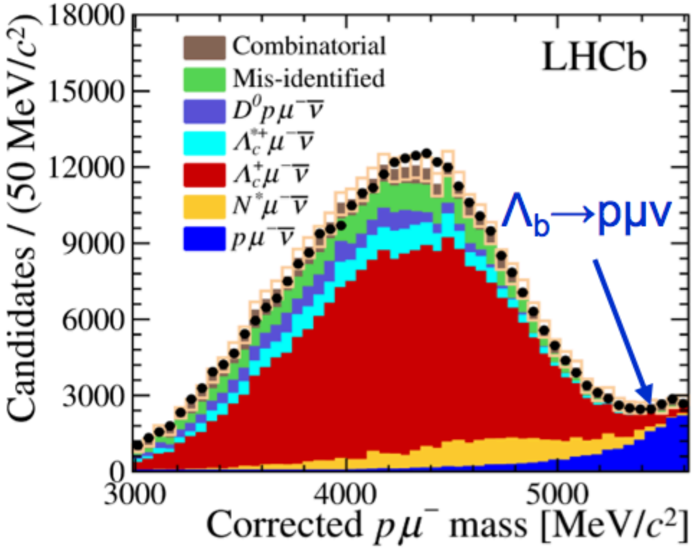
- our studies on Muon Identification at high luminosities have shown that we are able to <u>restore the average π-MisID increase (~ factor of 2) with the pile-up</u>

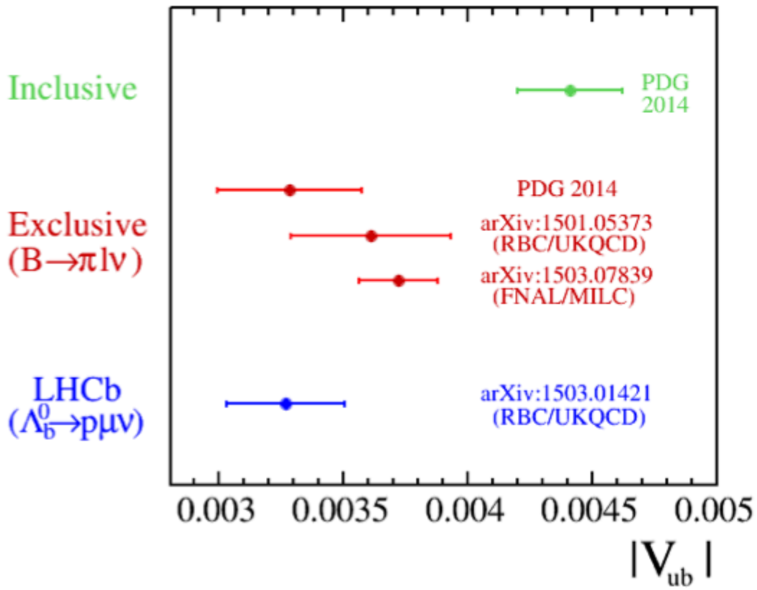
spares

few highlights of LHCb results: $|V_{ub}/V_{cb}|$ from $\Lambda_b \to p\mu\nu$/ $\Lambda_b \to \Lambda_c\mu\nu$

Nature Phys. 11 (2015) 743

$N(\Lambda_b \to p\mu\nu) = 17\,687 \pm 733$





$$|V_{ub}| = (3.27 \pm 0.15 \pm 0.16 \pm 0.06) \times 10^{-3}$$

- ✓ in good agreement with the exclusive average using $B_u \to \pi l\nu$
- ✓ other tree level semileptonic decays decays being explored

few highlights of LHCb results: R(D*) = $\mathcal{B}(B\to D^{*}\tau\nu)/\mathcal{B}(B\to D^{*}\mu\nu)$

$B\to D^{*}\tau\nu$

PRL 115 (2015) 112001

powerful channel to test lepton universality

ratios $R(D^*) = \mathcal{B}(B\to D^*\tau\nu)/\mathcal{B}(B\to D^*\mu\nu)$
could deviate from SM values, e.g. in models with charged Higgs bosons

identify $B\to D^*\tau\nu$, $D^* \to D\pi$, $D\to K\pi$, $\tau\to\mu\nu\nu$

similar kinematic reconstruction to $\Lambda_b\to p\mu\nu$

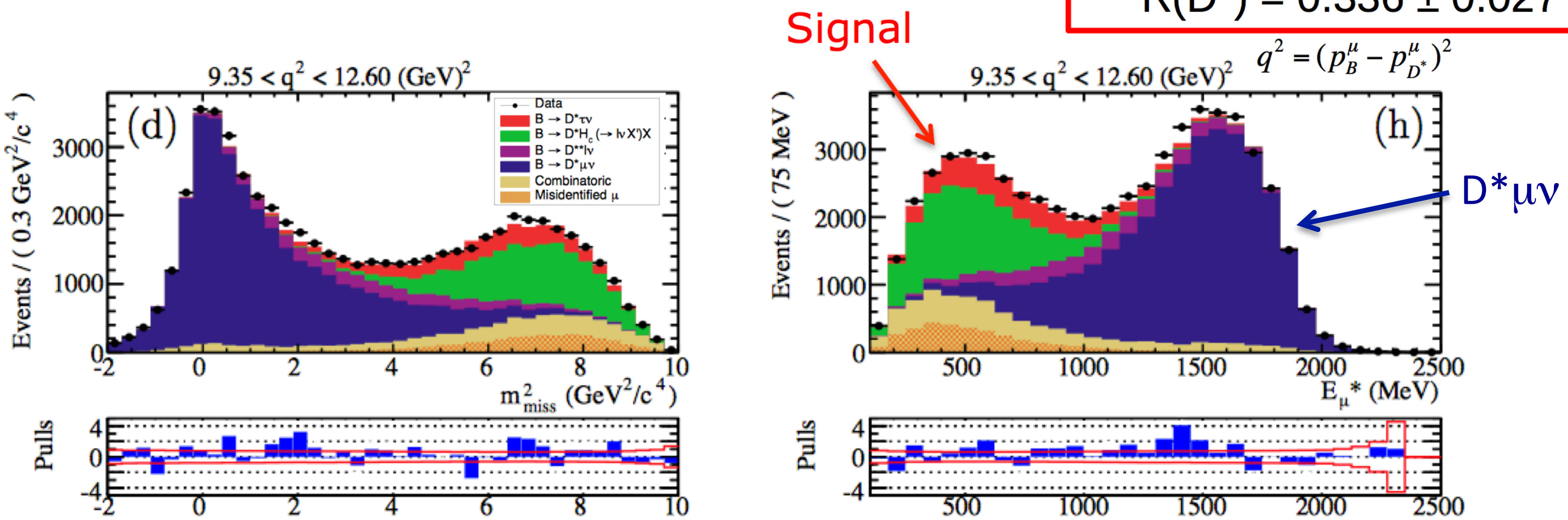
assume $p_{B,z} = (p_{D^*} + p_\mu)_z$ to calculate $m_{miss}^2 = (p_B - p_{D^*} - p_\mu)^2$

require significant B, D, τ flight distances & use isolation MVA

separate signal from background by fitting in m_{miss}^2, q^2 and E_μ

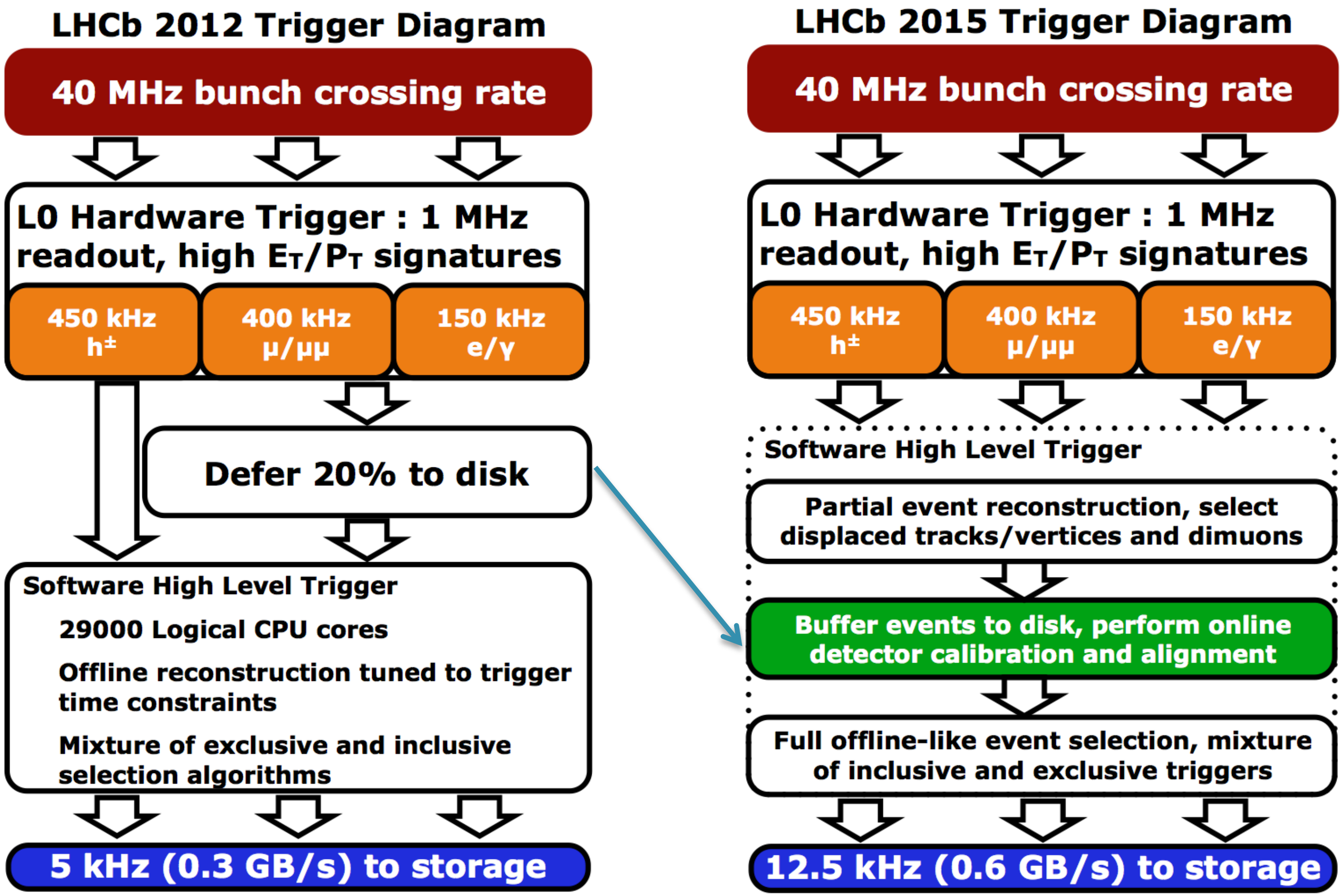
shown below ➔ high q^2 region only (best signal sensitivity)

$$\boxed{R(D^*) = 0.336 \pm 0.027 \pm 0.030}$$

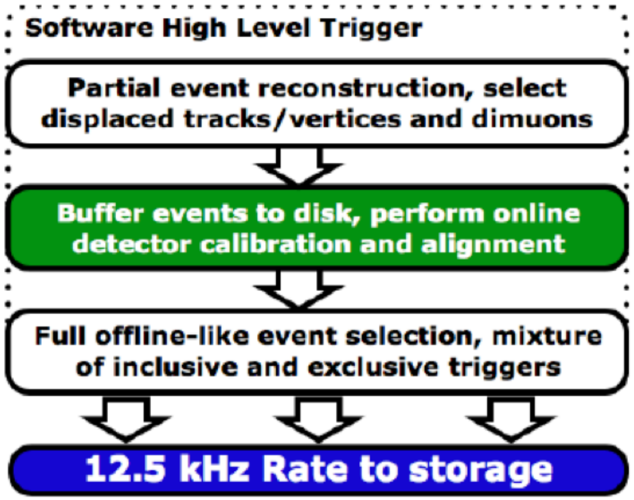


Run 2 data taking

✓at 13 TeV, LHCb gains from higher √s and 25 ns bunch spacing
✓during LS1 some sub-detector consolidation and changes of data flow in trigger



Run 2: improving data quality in trigger

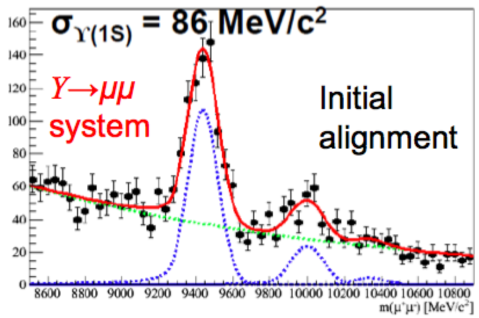


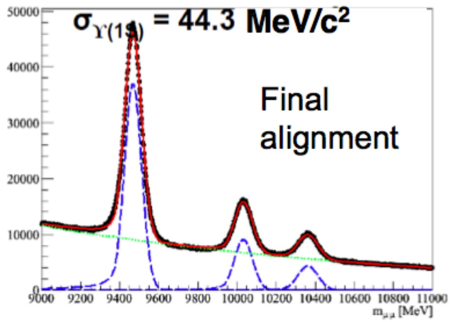
Note this step (new to 2015), between the initial and final HLT selections

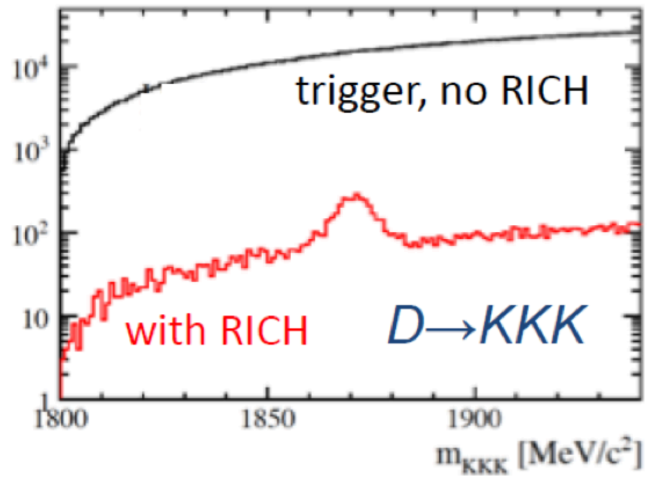
Here the events are written to local disks (~4 PB available) while calibration and alignment is performed.

Only when this is satisfactory is second stage of HLT executed.

This step important, as better alignment provides better signal discrimination. Also means we can trust information we would not use otherwise in HLT (*i.e.* from RICH).

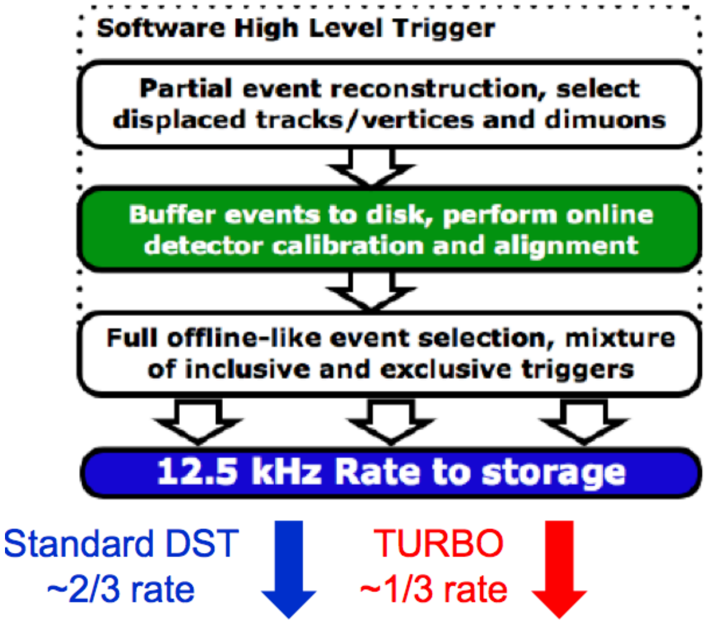






Goal is to improve background rejection, & to do online much of what was traditionally done offline!

Run 2: turbo stream



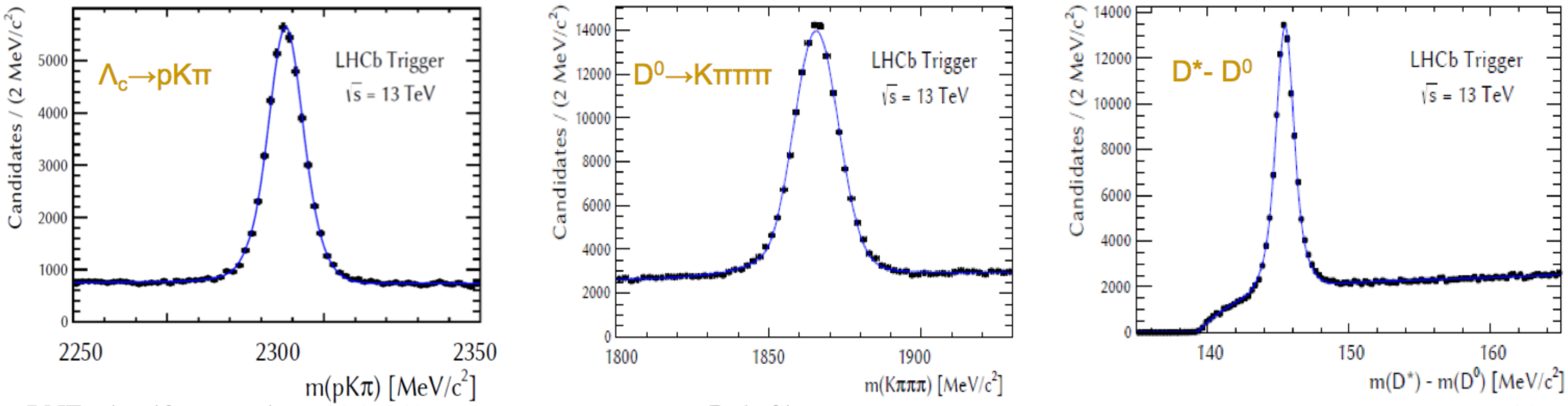
Corollary of new procedure is that recorded data are already suitable for physics analysis.

Cautiously start to exploit this feature for high yield studies – establish the 'TURBO' stream

- Store candidates as found by the HLT
- Discard most of raw data
- Hence reduce storage by ~90%
- No need for offline processing
- Data immediately ready for analysis !

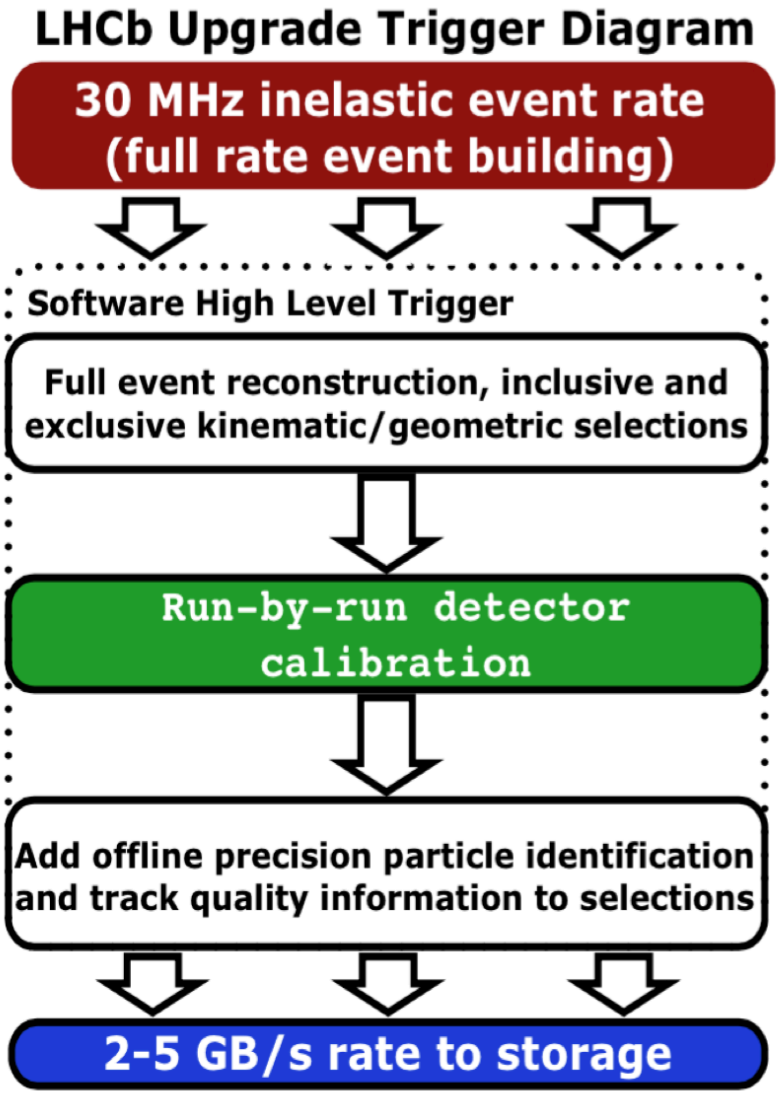
TURBO used for first run-2 physics results.

Charm signals coming through TURBO stream

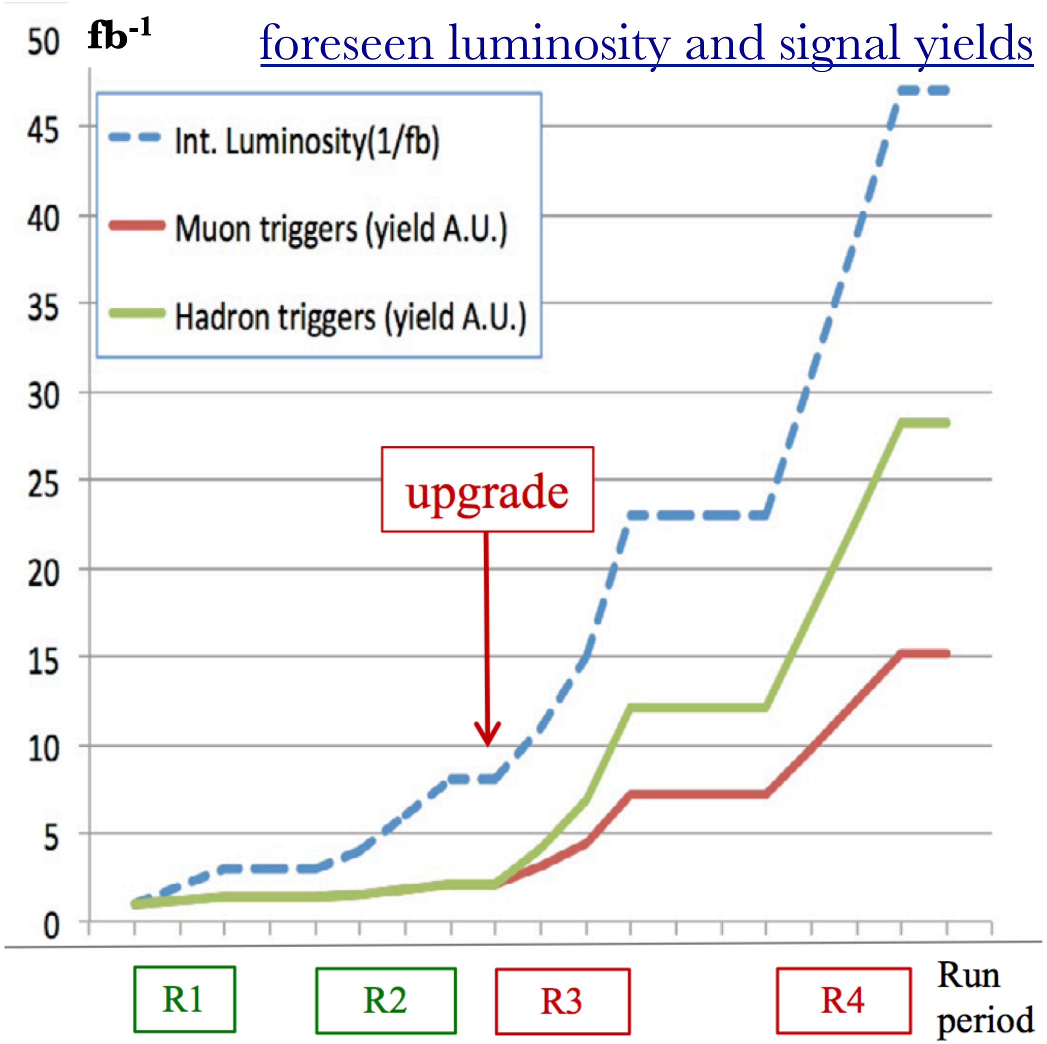


the LHCb upgrade: trigger

efficient and selective software trigger with access to the full detector information at every 25 ns bunch crossing



foreseen luminosity and signal yields



the LHCb upgrade: detector

$\mathcal{L} = 2{\times}10^{33}\ \mathrm{cm}^{-2}\,\mathrm{s}^{-1}$ requires some new detectors and 40 MHz readout clock new electronics

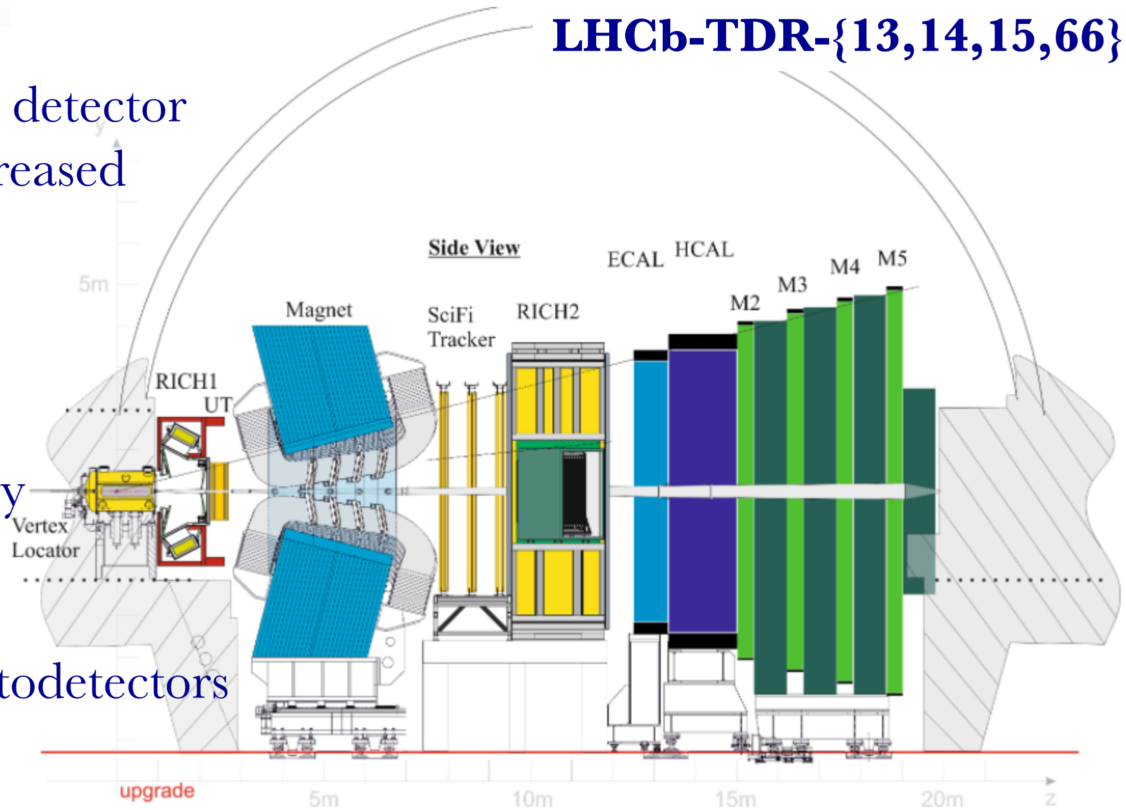
VELO from microstrip sensors (R,ϕ) to 55×55 μm² pixel sensors
closer to the beam, from 5.5 mm to 3.5 mm

LHCb-TDR-{13,14,15,66}

Upstream Tracker silicon strip detector
adapt segmentation to increased occupancy

SciFi Tracker 3 stations
of X-U-V-X scintillating
fibre planes single technology
to operate

PID RICH1 redesigned; new photodetectors
for RICH1 and RICH2



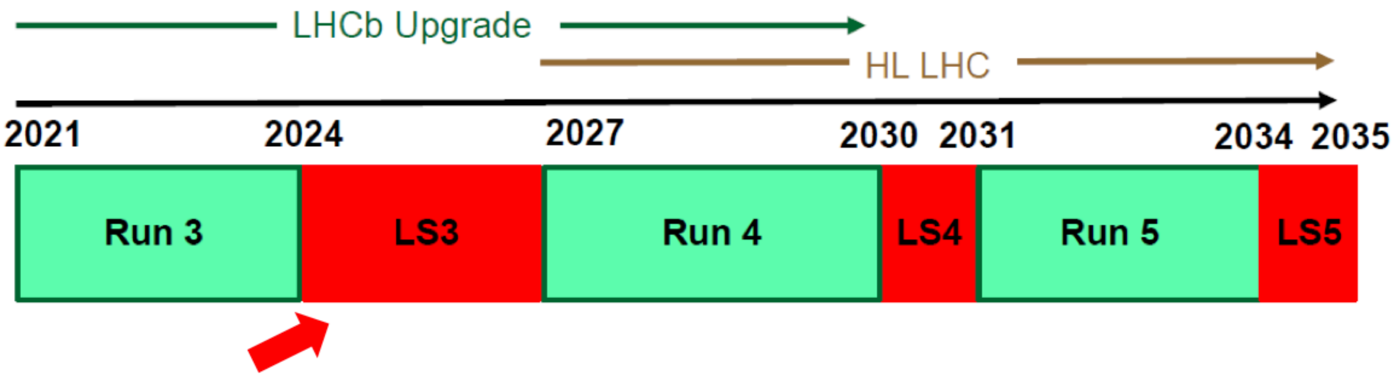
LHCb & upgrade sensitivities

this table, from **LHCB-TDR-012**, summarises some of the goals that can be achieved in flavour-physics with 50 fb^{-1} and the upgrade detector

Type	Observable	Current precision [in 2012]	LHCb 2018	Upgrade (50 fb^{-1})	Theory uncertainty
B_s^0 mixing	$2\beta_s$ ($B_s^0 \to J/\psi\ \phi$)	0.10 [9]	0.025	0.008	~ 0.003
	$2\beta_s$ ($B_s^0 \to J/\psi\ f_0(980)$)	0.17 [10]	0.045	0.014	~ 0.01
	$A_{\mathrm{fs}}(B_s^0)$	6.4×10^{-3} [18]	0.6×10^{-3}	0.2×10^{-3}	0.03×10^{-3}
Gluonic penguin	$2\beta_s^{\mathrm{eff}}(B_s^0 \to \phi\phi)$	–	0.17	0.03	0.02
	$2\beta_s^{\mathrm{eff}}(B_s^0 \to K^{*0}\bar{K}^{*0})$	–	0.13	0.02	< 0.02
	$2\beta^{\mathrm{eff}}(B^0 \to \phi K_S^0)$	0.17 [18]	0.30	0.05	0.02
Right-handed currents	$2\beta_s^{\mathrm{eff}}(B_s^0 \to \phi\gamma)$	–	0.09	0.02	< 0.01
	$\tau^{\mathrm{eff}}(B_s^0 \to \phi\gamma)/\tau_{B_s^0}$	–	5 %	1 %	0.2 %
Electroweak penguin	$S_3(B^0 \to K^{*0}\mu^+\mu^-; 1 < q^2 < 6\,\mathrm{GeV}^2/c^4)$	0.08 [14]	0.025	0.008	0.02
	$s_0\ A_{\mathrm{FB}}(B^0 \to K^{*0}\mu^+\mu^-)$	25 % [14]	6 %	2 %	7 %
	$A_{\mathrm{I}}(K\mu^+\mu^-; 1 < q^2 < 6\,\mathrm{GeV}^2/c^4)$	0.25 [15]	0.08	0.025	~ 0.02
	$\mathcal{B}(B^+ \to \pi^+\mu^+\mu^-)/\mathcal{B}(B^+ \to K^+\mu^+\mu^-)$	25 % [16]	8 %	2.5 %	~ 10 %
Higgs penguin	$\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	1.5×10^{-9} [2]	0.5×10^{-9}	0.15×10^{-9}	0.3×10^{-9}
	$\mathcal{B}(B^0 \to \mu^+\mu^-)/\mathcal{B}(B_s^0 \to \mu^+\mu^-)$	–	~ 100 %	~ 35 %	~ 5 %
Unitarity triangle angles	γ ($B \to D^{(*)}K^{(*)}$)	~ 10–12° [19, 20]	4°	0.9°	negligible
	γ ($B_s^0 \to D_s K$)	–	11°	2.0°	negligible
	β ($B^0 \to J/\psi\ K_S^0$)	0.8° [18]	0.6°	0.2°	negligible
Charm *CP* violation	A_Γ	2.3×10^{-3} [18]	0.40×10^{-3}	0.07×10^{-3}	–
	ΔA_{CP}	2.1×10^{-3} [5]	0.65×10^{-3}	0.12×10^{-3}	–

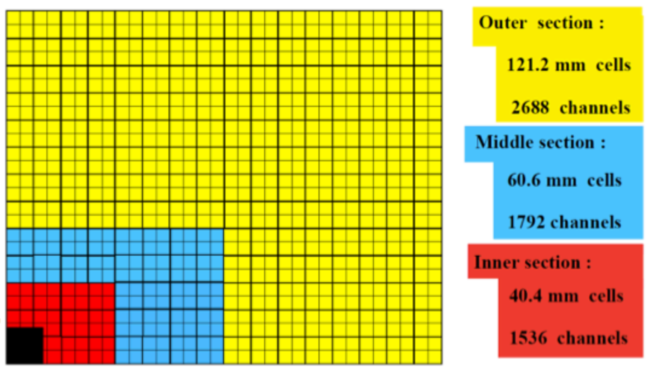
LHCb upgrade : LS3 opportunities

The ~50 fb^{-1} of the Upgrade era will require runs 3 and 4.

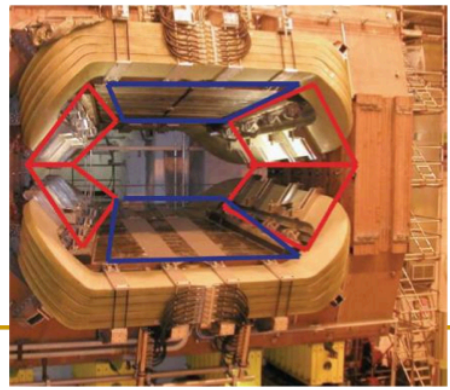


LS3, between runs 3 & 4 is an extended long shutdown, in preparation for HL-LHC.
LHCb in LS3: consolidation + opportunity to enhance capabilities of detector further.

e.g. replace inner region (or more) of ECAL with a more performant technology to improve e/γ/π^0 performance



e.g. instrument sides of dipole with tracking stations – can give a significant improvement in acceptance for high multiplicity decays

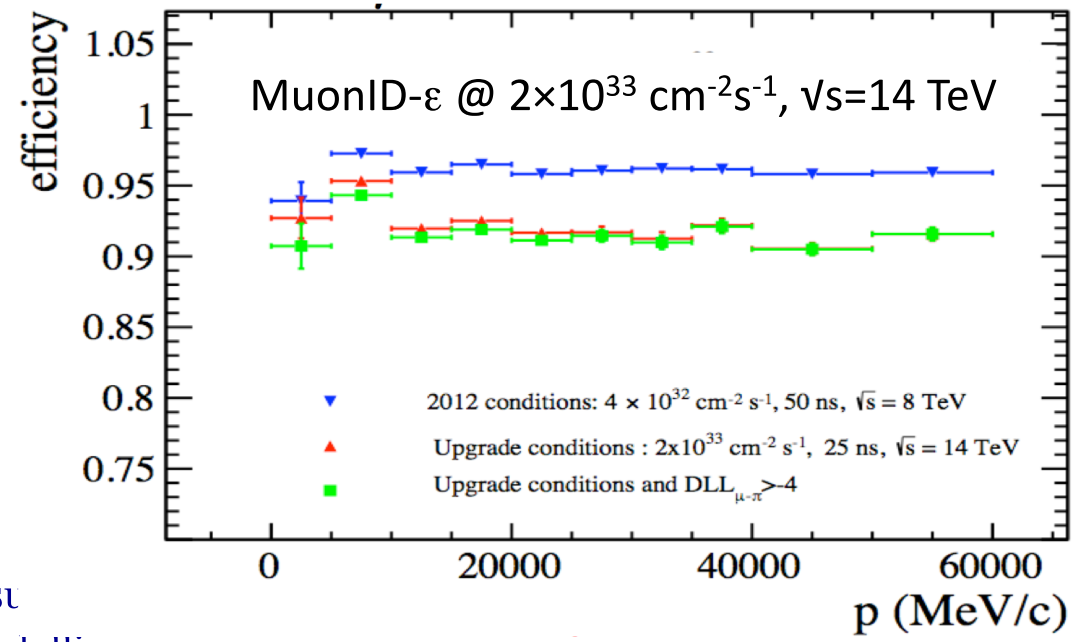


dead time induced inefficiency: TDR

chamber inefficiency at $\mathcal{L} = 2 \times 10^{33}\ \mathrm{cm^{-2}s^{-1}}$

Region	Inefficiency at $2 \times 10^{33}\ \mathrm{cm^{-2}s^{-1}}$
M2R1	7.1 ± 2.8 %
M2R2	4.1 ± 1.1 %
M2R3	2.6 ± 0.4 %
M2R4	1.7 ± 0.3 %
M3R1	3.3 ± 1.1 %
M3R2	1.2 ± 0.3 %
M3R3	0.9 ± 0.1 %
M3R4	0.6 ± 0.1 %
M4R1	1.1 ± 0.3 %
M4R2	1.3 ± 0.2 %
M4R3	0.9 ± 0.2 %
M4R4	0.6 ± 0.1 %
M5R1	1.3 ± 0.5 %
M5R2	1.4 ± 0.3 %
M5R3	1.2 ± 0.2 %
M5R4	2.3 ± 0.3 %

the chamber inefficiency is convoluted with MC ($B_s \rightarrow \mu\mu$ events in this case) to get the MuonID algorithm efficiency at $\mathcal{L} = 2 \times 10^{33}\ \mathrm{cm^{-2}s^{-1}}$

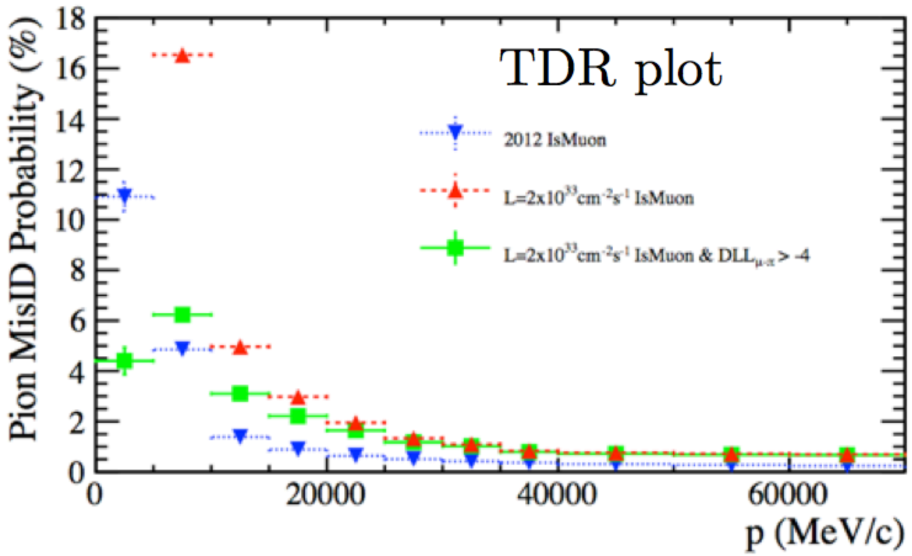


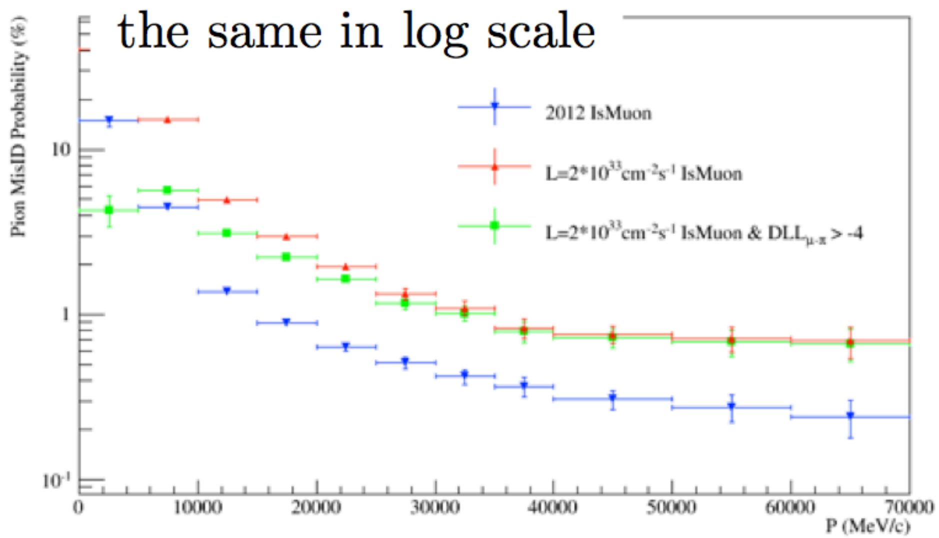
≃ 5% loss per single μ

these projections are based on rates measu on detector in 2012 runs + a detailed modelling of dead time vs luminosity (validated on high luminosity special runs)

Upgrade PID TDR

- for the TDR, a considerable effort has been spent in projecting the detector performances to the Run III upgrade scenario $\mathcal{L} = 2 \times 10^{33}\,\mathrm{cm^{-2}s^{-1}}$, pile-up ≃ 7.4, $\sqrt{s}$ = 14 TeV





- π-MisID probability using data control sample of $D^0 \to K\pi$
- results is shown as a function of momentum at high luminosity in red compared with the 2012 π-MisID in blue: a factor of 2 background increase is observed

today I will report the most recent developments on hadron MisID from the LNF-LHCb group

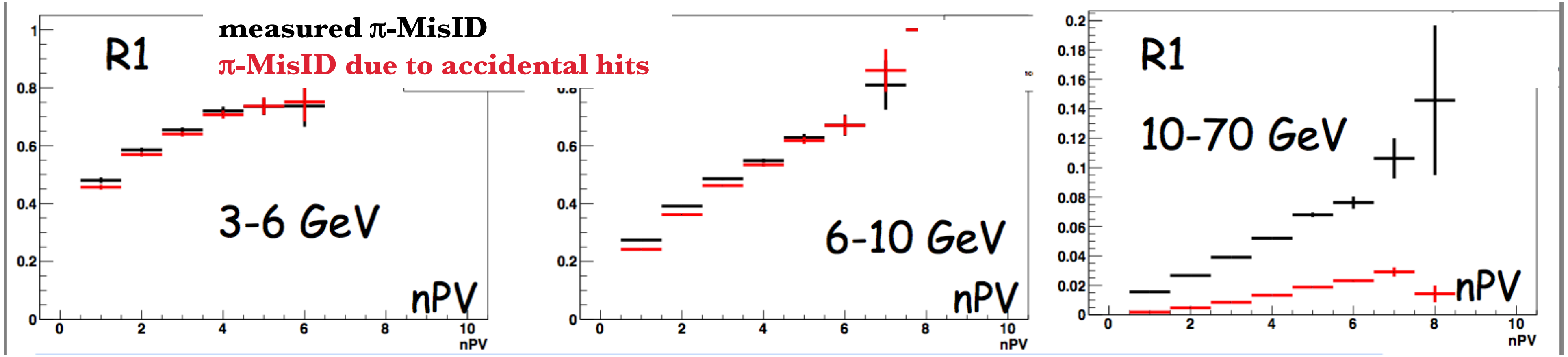
π-MisID vs pile-up in the muon-system inner regions R1

the main sources of background in the muon-system are two:

correlated ➔ muons from decays-in-flight, and punch-through

uncorrelated ➔ accidentals hits

to disentangle the contribution from accidentals, we compute the uncorrelated product of probabilities of having at least one hit in FOI in each station and we compare it to total π-MisID

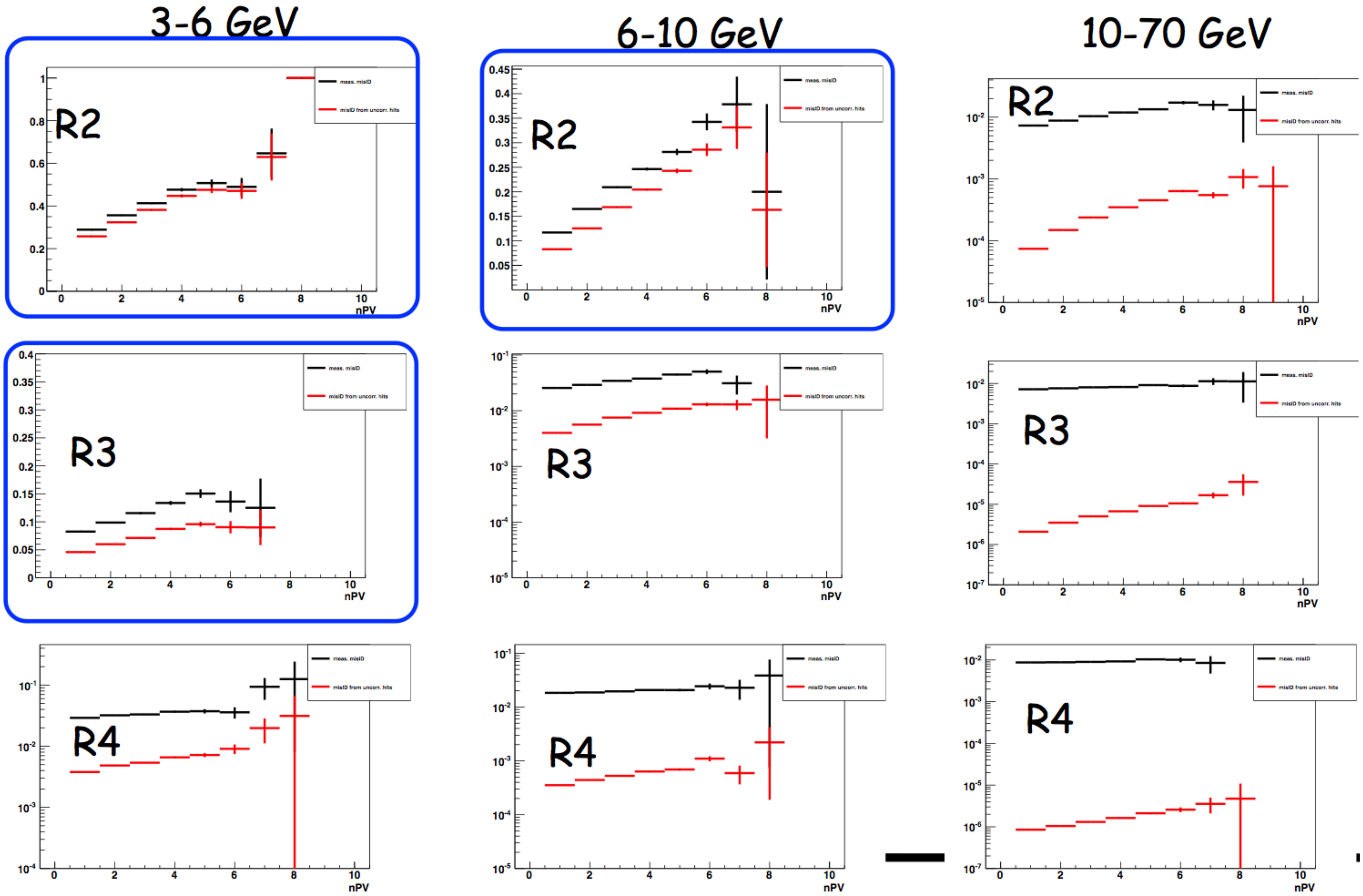


- the 3 momentum bins correspond to a coincidence of 2,3 and 4 stations ➔ IsMuon variable

1) **accidental background is fully dominating the p-MisID below 10 GeV/c**
2) **~1/3 of total above 10 GeV, while the total p-MisID increase with pile-up**

to be noted: results obtained IsMuon variable

π-MisID vs pile-up in the muon-system regions R2, R3, R4



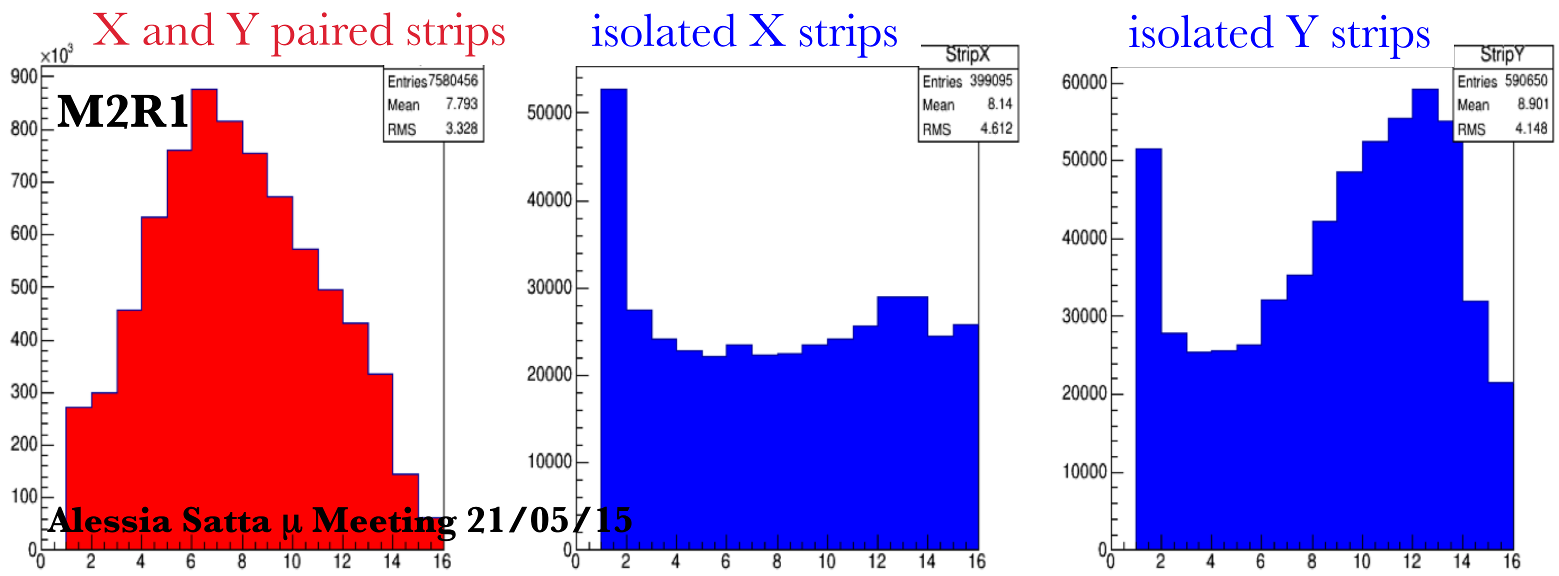
IsMuon and IsMuonTight

IsMuon → collecting all hits in FOI, also from unpaired strips

IsMuonTight → collecting only crossed hits in FOI
(crossed hits: both X and Y readout channels fired)

current MuonId procedures are based on IsMuon variable

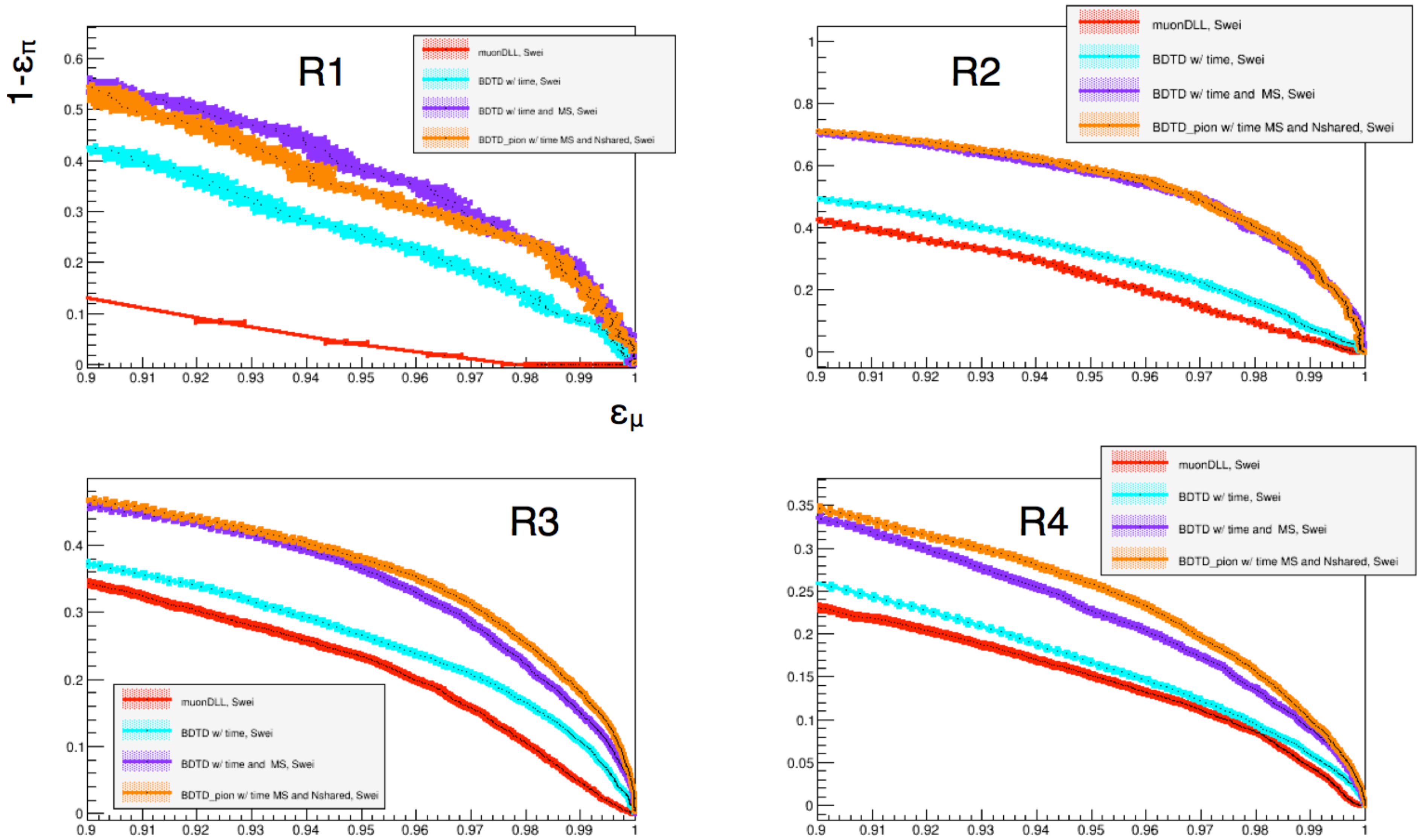
time spectra for :



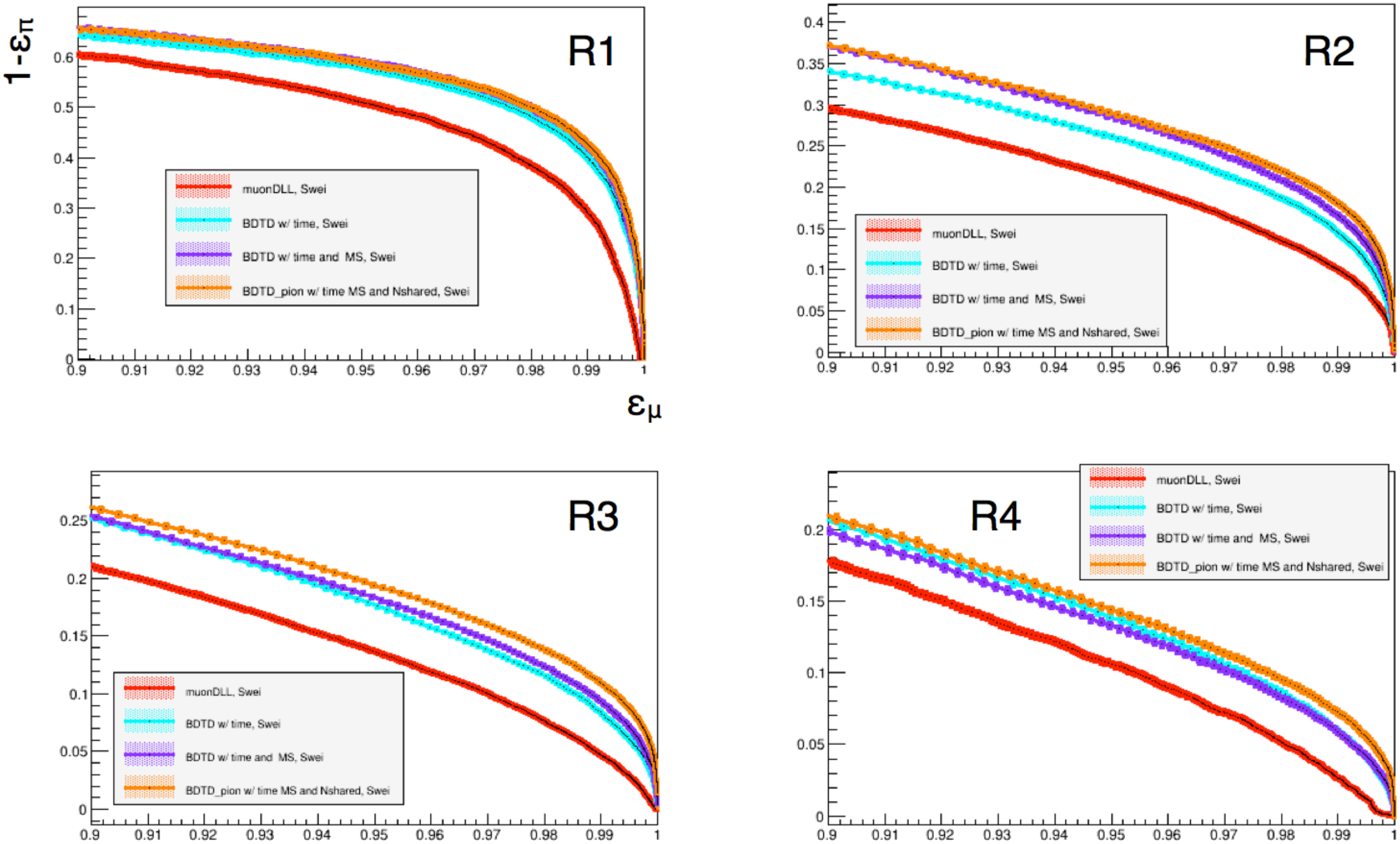
hits from unpaired X or Y strips can be out of time respect to the event bunch crossing

- we (re)studied the performances of the isMuonTight to understand if an improvement of the background rejection is possible at high luminosity with a reasonable signal loss

ROCs for πs versus μs, p < 10GeV/c



ROCs for πs versus μs, p > 10GeV/c



π-MisID performances vs luminosity: numbers

measured at pile-up ∼ 2.3	3< p< 6 GeV/c	6< p< 10 GeV/c	p> 10 GeV/c
IsMuon+muDLL	.0799 ± .0007	.0315 ± .0002	.00666 ± .00003
isMuonTight+muDLL	.0469 ± .0005	.0222 ± .0002	.00611 ± .00003
isMuonTight+BDT	.0348 ± .0005	.0173 ± .0002	.00567 ± .00003

extrapolated at pile-up ∼ 7.4	3< p < 6 GeV/c	6 <p< 10 GeV/c	p> 10 GeV/c
IsMuon+muDLL	.12 ± .01 (1.5)	.048±.003±.001 (1.52)	.0091±.0005±.0011 (1.4)
isMuonTight+muDLL	.088±.008±.008 (1.1)	.043±.002± .002 (1.37)	.0076±.0004±.0011 (1.1)
isMuonTight+BDT	.068±.008±.004 (0.85)	030±.002±.003 (0.95)	.0066±.0004±.0009 (1.0)

numbers btw parentheses are the ratios wrt isMuon+muDLL at pile-up∼ 2.3, **which represent the benchmark values**