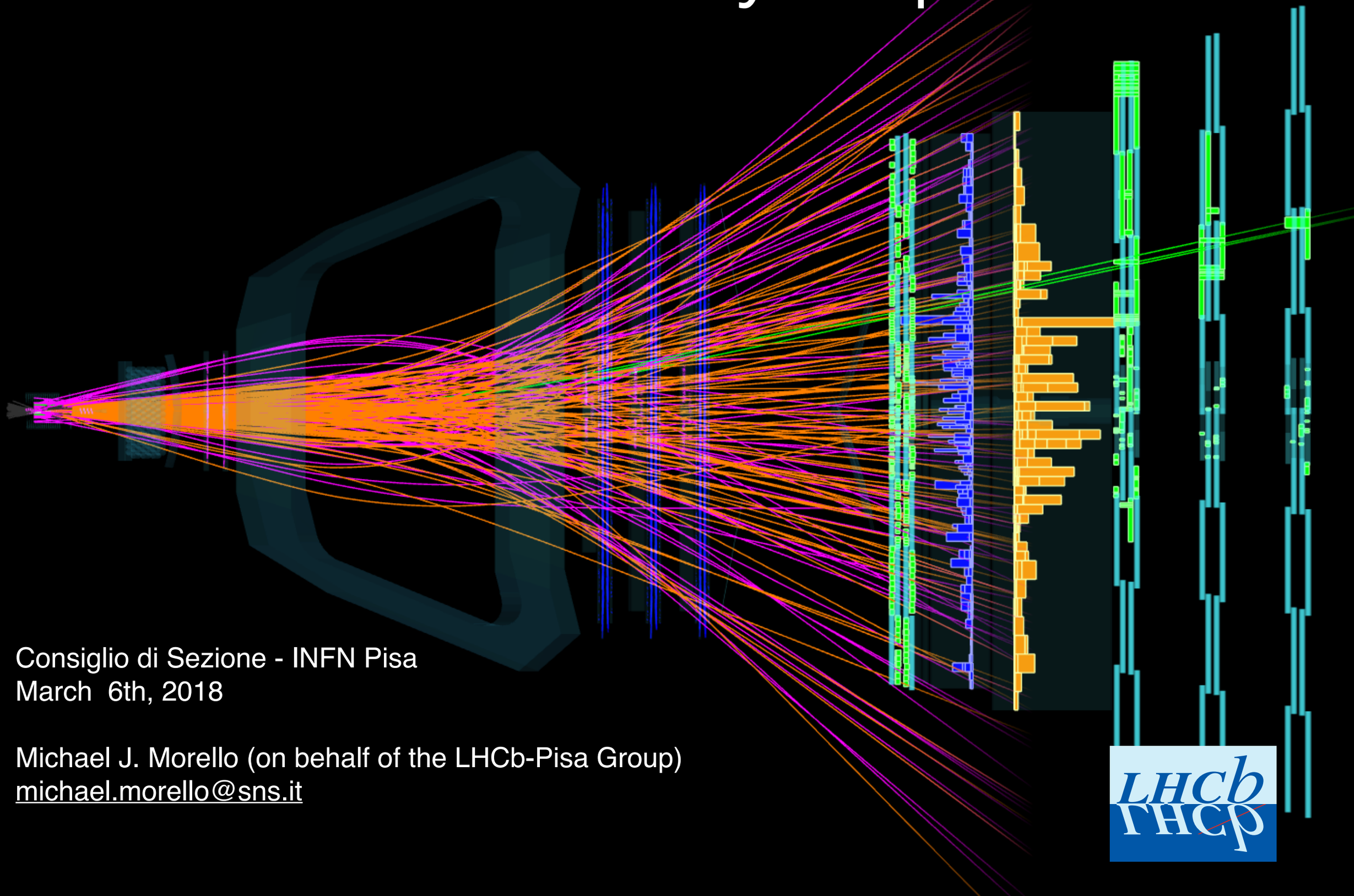
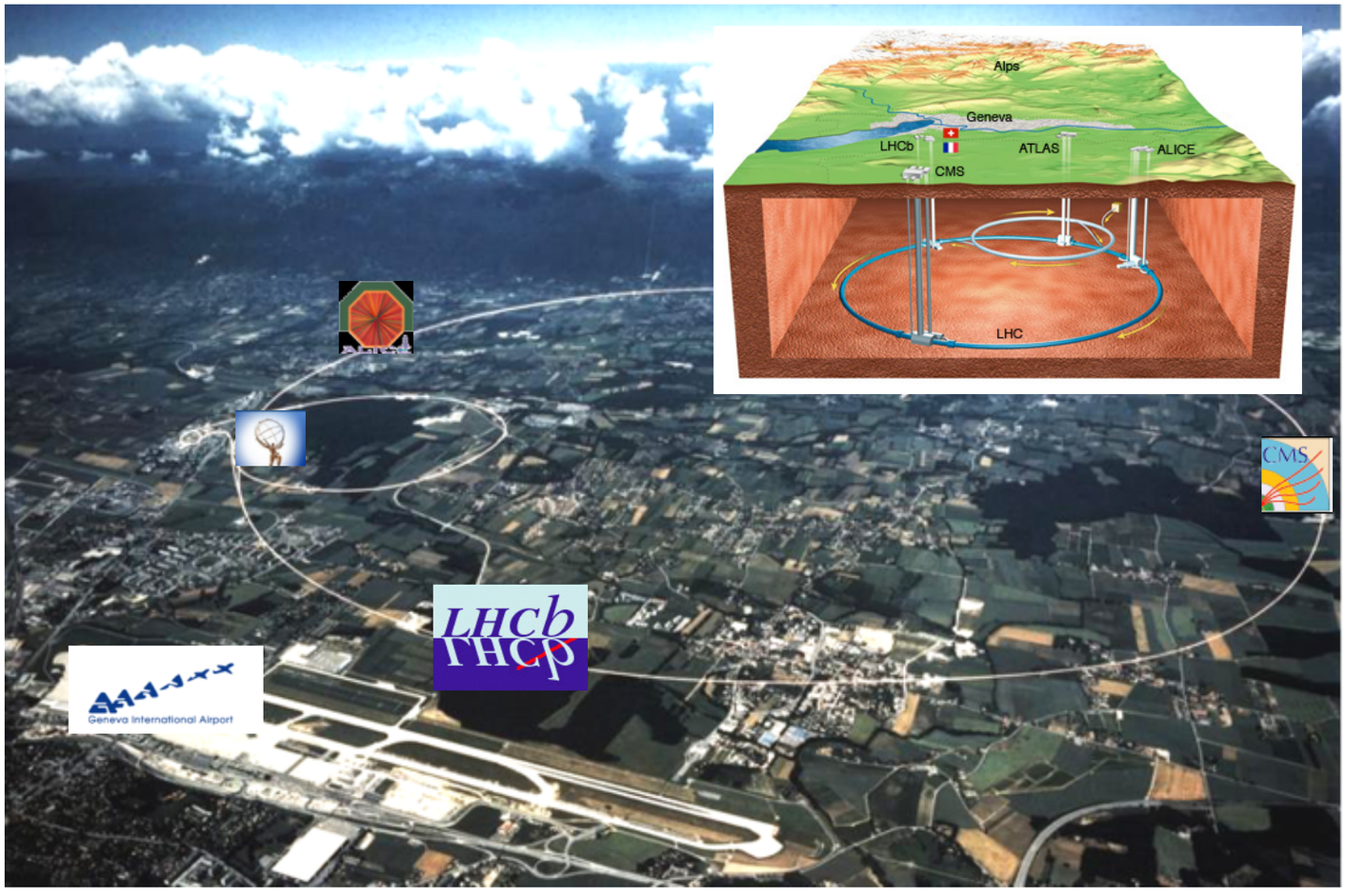
LHCb: the beauty experiment

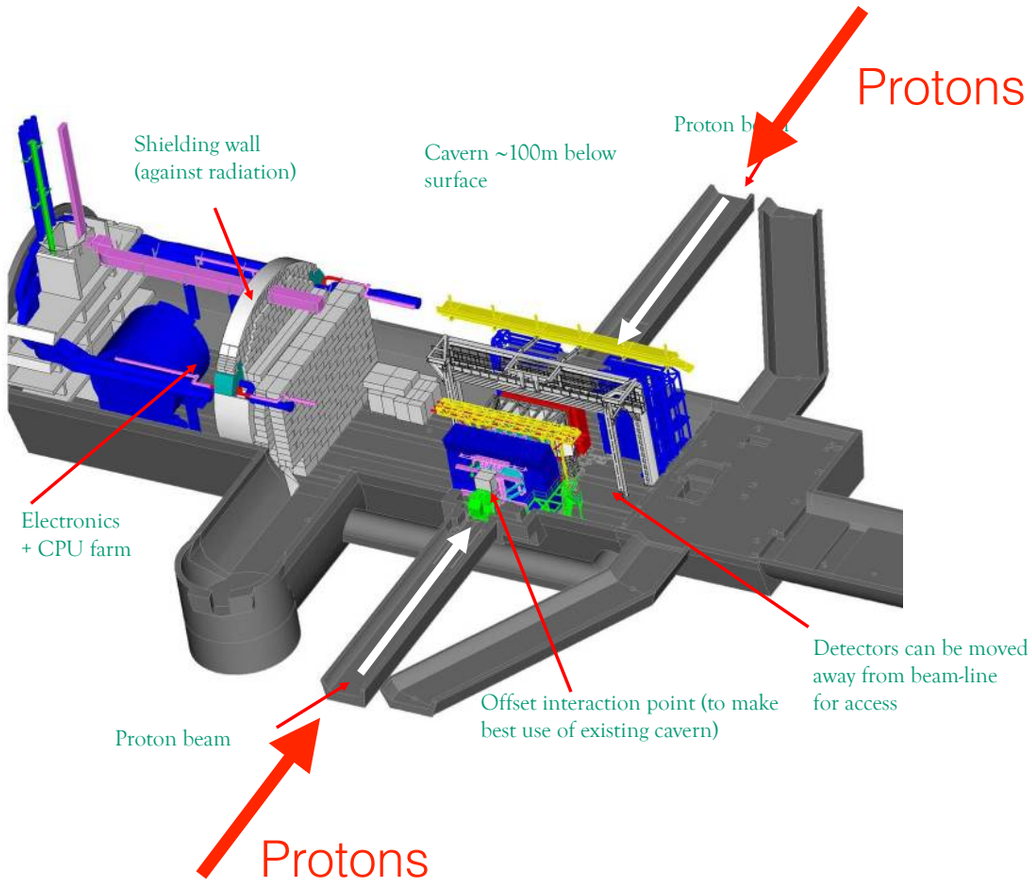


Consiglio di Sezione - INFN Pisa
March 6th, 2018

Michael J. Morello (on behalf of the LHCb-Pisa Group)
michael.morello@sns.it

LHCb at Point 8



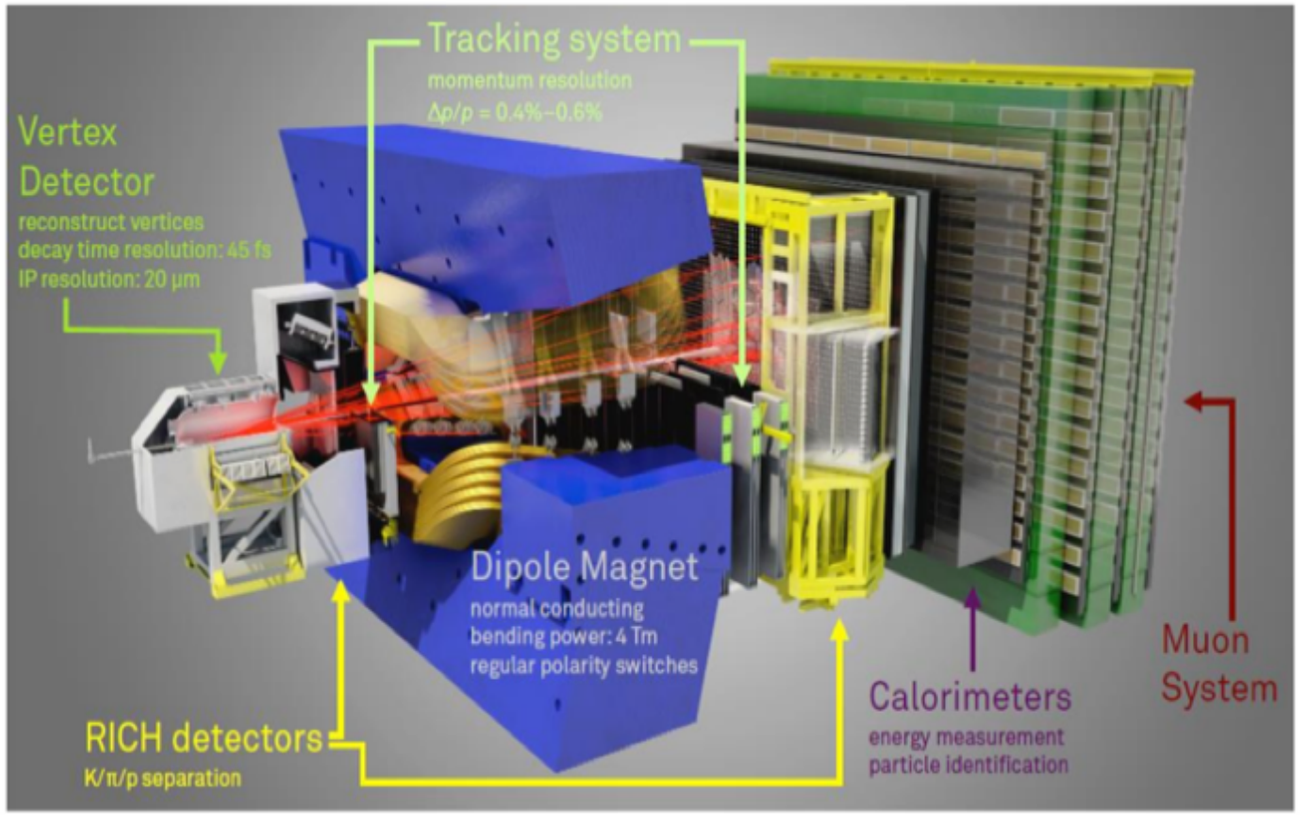


LHCb is a specialized detector covering a broad program of high precision measurements in heavy flavors physics (beauty and charm).

LHCb Detector

- LHCb is a single forward spectrometer, with a warm dipole magnet
  - Acceptance lies in [10 ,300] mrad in the horizontal plane and in [10,250] mrad in the vertical plane.
  - Max intensity of B is about 1T, while the integral is about 4 Tm.

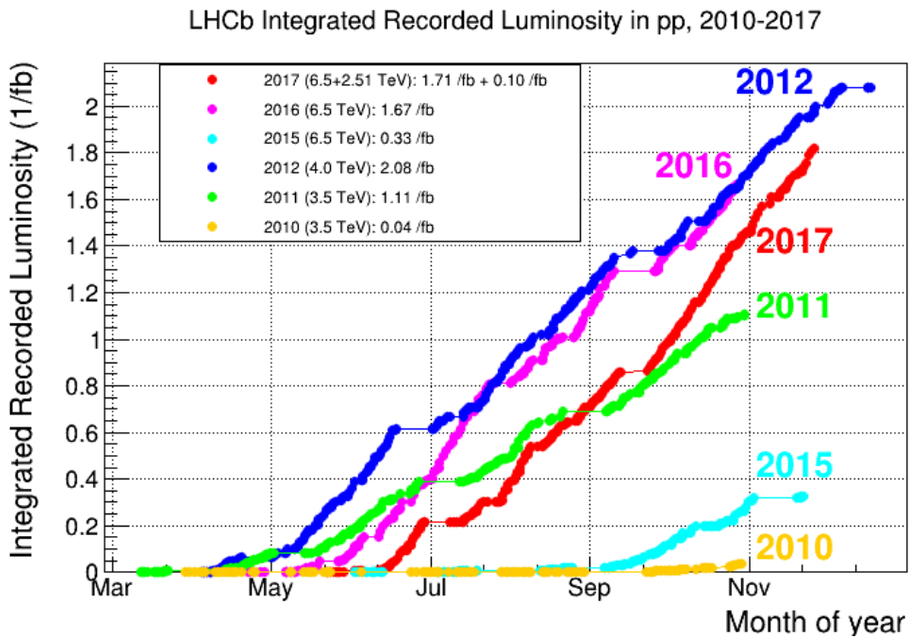
- Excellent tracking
  - VELO + T-stations
- Excellent PID
  - RICH detectors
- Calorimeters and muon sub-detectors.

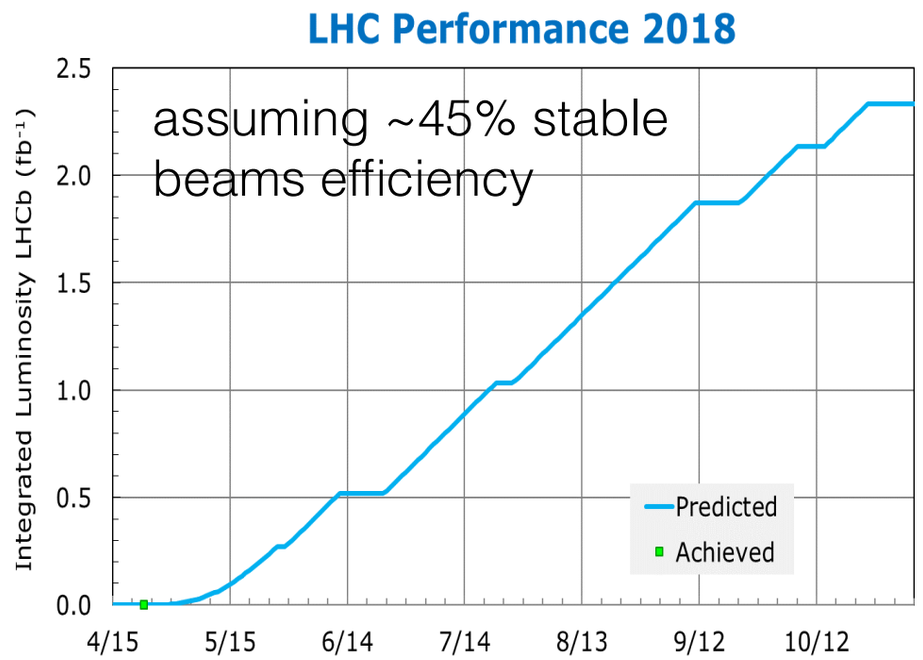


LHCb integrated luminosity

- LHCb able to level instantaneous luminosity
  - L_{inst} ~ [1-4] x 10^{32} $cm^{-2}s^{-1}$ up to now.
- Run 1 at 7-8 TeV (2011-2012).
- Run 2 at 13 TeV (2015-2018) ongoing.
- 40 MHz collision rate (25ns bunch spacing).
- Today ~7 fb^{-1} of "good" data collected.
- Estimated to collect additional ~2.3 fb^{-1} in 2018.

At the end this year LHCb will have a sample of about a factor of 3 wrt Run 1. It could make a "significant" difference for some crucial measurements (Run 2 yields/fb^{-1} > Run 1 yields/fb^{-1}.).





A reach physics program

New Journal of Physics
The open access journal at the forefront of physics
Deutsche Physikalische Gesellschaft DPG IOP Institute of Physics

PAPER

Precision measurement of the B^0_s–$\overline{B}^0_s$ oscillation frequency with the decay $B^0_s \to D^-_s \pi^+$

To cite this article: R Aaij *et al* 2013 *New J. Phys.* **15** 053021

View the article online for updates and enhancements.

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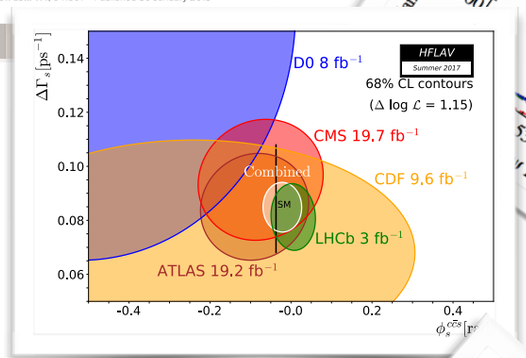
Precision Measurement of CP Violation in $B^0_S \to J/\Psi K^+K^-$ Decays

R. Aaij *et al.* (LHCb Collaboration)
Phys. Rev. Lett. **114**, 041801 – Published 30 January 2015

Article



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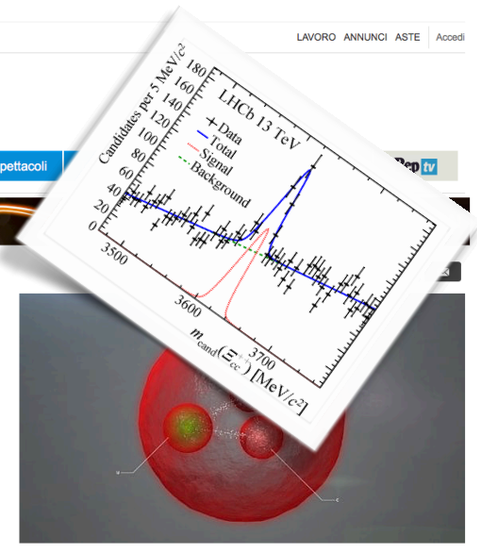
energItalia

Cern, scoperta la particella Xi: "Inseguita da anni, ci aiuterà a capire cosa tiene insieme la materia"



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Archive Volume 522 Issue 7554 Letters Article

NATURE | LETTER OPEN

日本語要約

Observation of the rare $B_s^0 \to \mu^+\mu^-$ decay from the combined analysis of CMS and LHCb data

CMS Collaboration & LHCb Collaboration

Editor's

العربية

PHYSICAL REVIEW LETTERS

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Editors' Suggestion Open Access

Measurement of the $B^0_s \to \mu^+\mu^-$ Branc
Lifetime and Search for $B^0 \to \mu^+\mu^-$ Deca

R. Aaij *et al.* (LHCb Collaboration)
Phys. Rev. Lett. **118**, 191801 – Published 11 May 2017

Article References Citing Articles (5) PDF HTML Export Citation

PHYSICAL REVIEW D

covering particles, fields, gravitation, and cosmology

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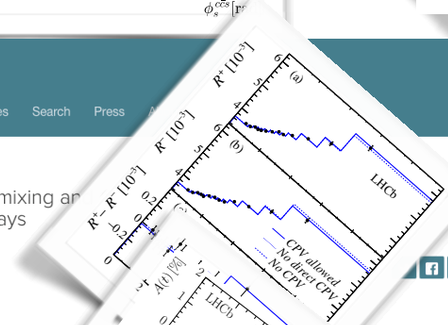
Rapid Communication Open Access

Updated determination of D^0–$\bar{D}^0$ mixing and parameters with $D^0 \to K^+\pi^-$ decays

R. Aaij *et al.* (LHCb Collaboration)
Phys. Rev. D **97**, 031101(R) – Published 22 February 2018



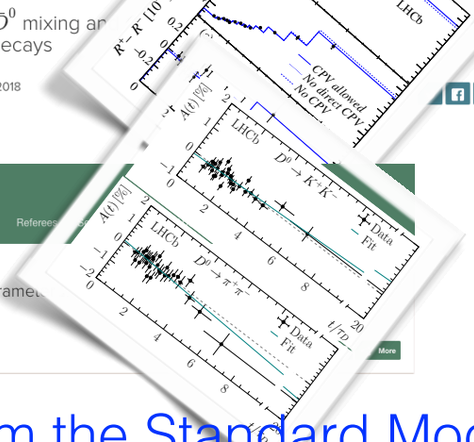
PHYSICAL REVIEW LETTERS

Highlights Recent Accepted Collections Authors Referees

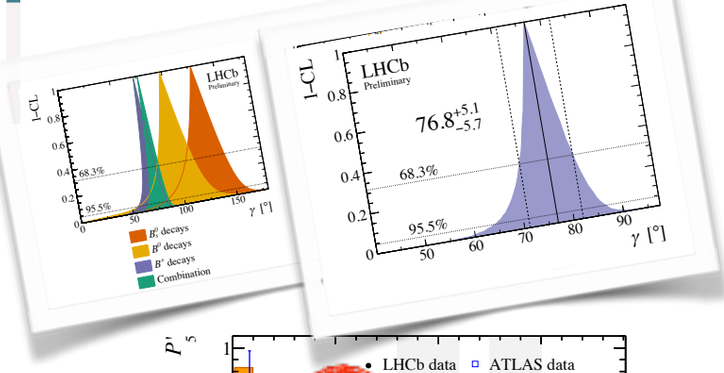
Open Access

Measurement of the CP Violation Parameter and $D^0 \to \pi^+\pi^-$ Decays

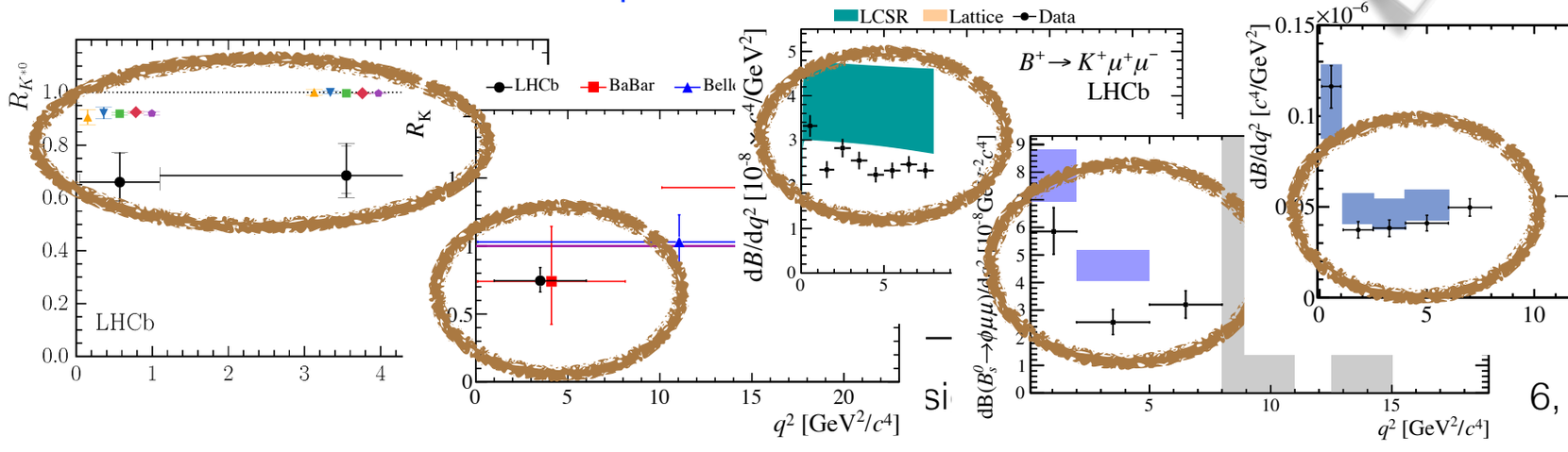
R. Aaij *et al.* (LHCb Collaboration)
Phys. Rev. Lett. **118**, 261803 – Published 28 June 2017

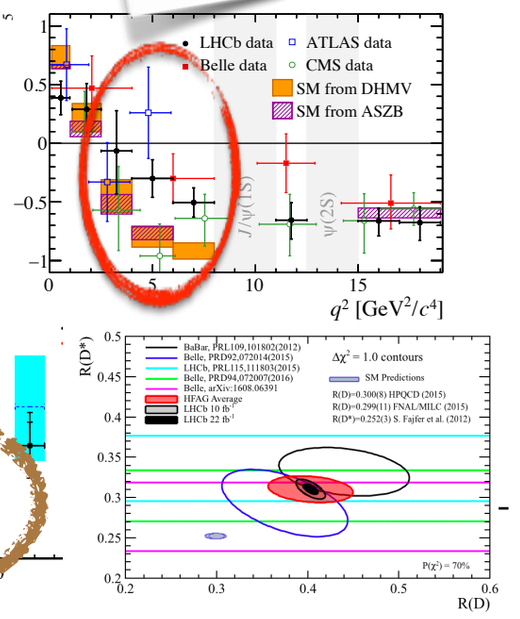


Update of the LHCb combination of the CKM angle γ using $B \to DK$ decays



LHCb finds hints of possible deviations from the Standard Model.





Latest from LHCC meeting

Riccardo Cenci's talk
https://indico.cern.ch/event/692482/

Paper Status

- **Submitted since last LHCC meeting**
  - 2017-033 Amplitude analysis of the decay $B^0 \to K_s^0\pi\pi$ and first observation of $B^0 \to K^*\pi$
  - 2017-039 Search for the rare decay $\Lambda^+_c \to p\mu^+\mu^-$
  - 2017-040 Studies of the resonance structure in $D^0 \to K\pi\pi\pi$ decays
  - 2017-042 Search for excited B_c^+ states
  - 2017-043 A search for weakly decaying b-flavored pentaquarks
  - 2017-044 Search for direct CPV in $\Lambda^+_c \to pKK$ and $\Lambda^+_c \to p\pi\pi$ decays using semileptonic Λ^0_b decays
  - 2017-045 Search for B^+_c decays to two charm mesons
  - 2017-046 Update of D^0-$\overline{D}^0$ mixing parameters and CP violation in $D^0 \to K^+\pi^-$ decays
  - 2017-047 CP asymmetry in $B^0s \to D^{\mp}_sK^{\pm}$ decays
  - 2017-048 CP-violating phase ϕ_s^{dd} in quasi-two-body $B^0 \to (K\pi)(K\pi)$ decays
  - 2017-049 Evidence for the rare decay $\Sigma^+ \to p\mu\mu$
- **Preliminary**
  - 2017-050 Forward top pair production in the dilepton channel in pp collisions at 13 TeV
  - 2018-002 Upsilon production cross-section in pp collisions at √s=13 TeV
  - 2018-003 Inelastic pp cross-section at a centre-of-mass energy of 13 TeV
  - 2018-00X Ultra-peripheral Charmonium Production in Pb-Pb

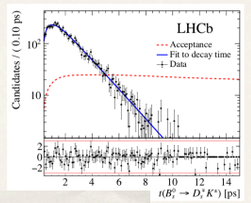
The following slides will focus on the papers in red

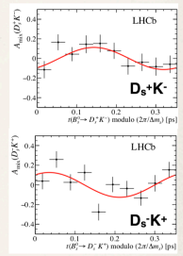
Riccardo Cenci 11 *LHCC Meeting, Feb 28, 2018*

CP Asymmetry in $B^0_s \to D^{\mp}_sK^{\pm}$ Decays

arXiv:1712.07428 LHCB-PAPER-2017-047

- Update of previous results on 1 fb^{-1} [JHEP 11 (2014) 060]
- Fit to B_s and D_s invariant mass, extract signal weights using sPlot technique
- Flavour tagging, ε = 5.7%
- Fit to weighted decay-time distribution to extract CP





Run1 Data

$\gamma = (128\,^{+17}_{-22})^\circ$
$\delta = (358\,^{+13}_{-14})^\circ$
$r_{D_sK} = 0.37\,^{+0.10}_{-0.09}$

se determination of gamma from Bs0

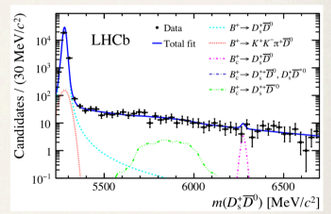
LHCC Meeting, Feb 28, 2018

Search for B^+_c Decays to Two Charm Mesons

- $B_c^+ \to D_{(s)}^{(*)+} D^{(*)}$
- Useful for getting γ measurement, but rate is very small (small BFs and low ε)
- Normalization mode $B^+ \to D^+_{(s)} D$
- No significant signal was observed
- Largest systematic contribution from bkg model

arXiv:1712.04702 LHCB-PAPER-2017-045

Refs.
PLB 286 (1992) 160
PRD 62 (2000) 057503
PRD 65 (2002) 034016
PRD 75 (2007) 097304



Run1 Data

$\frac{f_c}{f_u}\frac{\mathcal{B}(B_c^+ \to D_s^+\overline{D}^0)}{\mathcal{B}(B^+ \to D_s^+\overline{D}^0)} = (\ 3.0 \pm 3.7) \times 10^{-4}\ [< 0.9\,(1.1) \times 10^{-3}]$

$\frac{f_c}{f_u}\frac{\mathcal{B}(B_c^+ \to D_s^{*+}\overline{D}^0) + \mathcal{B}(B_c^+ \to D_s^+\overline{D}^{*0})}{\mathcal{B}(B^+ \to D_s^+\overline{D}^0)} = (-0.1 \pm 1.5) \times 10^{-3}\ [< 2.8\,(3.4) \times 10^{-3}]$

$\frac{f_c}{f_u}\frac{\mathcal{B}(B_c^+ \to D_s^{*+}\overline{D}^{*0})}{\mathcal{B}(B^+$ ... $[<$ ...

Riccardo Cenci 15

Search for Weakly Decaying b-flavored Pentaquarks

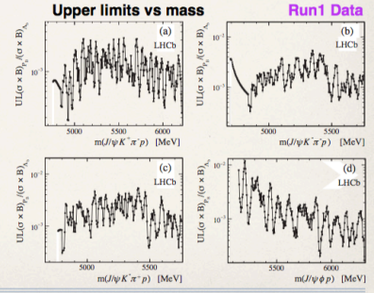
- Additional charmonium pentaquark states, not observed yet
- Scan for peak, step size 4 MeV
- No significant signal was observed
- Normalization channel $\Lambda_b^0 \to J/\psi K^- p$
- Largest systematics from different selection of signal and normalization channels

arXiv:1712.08086 LHCB-PAPER-2017-043

Mode	Quark content	Decay mode	Search window
I	$\bar{b}duud$	$P^+_{B^0p} \to J/\psi K^+\pi^- p$	4668–6220 MeV
II	$\bar{b}uudd$	$P^-_{\Lambda_b^0\pi^-} \to J/\psi K^-\pi^- p$	4668–5760 MeV
III	$\bar{b}duud$	$P^+_{\Lambda_b^0\pi^+} \to J/\psi K^-\pi^+ p$	4668–5760 MeV
IV	$\bar{b}suud$	$P^-_{B_s^0 p} \to J/\psi\phi p$	5055–6305 MeV

Upper limits vs mass

Run1 Data

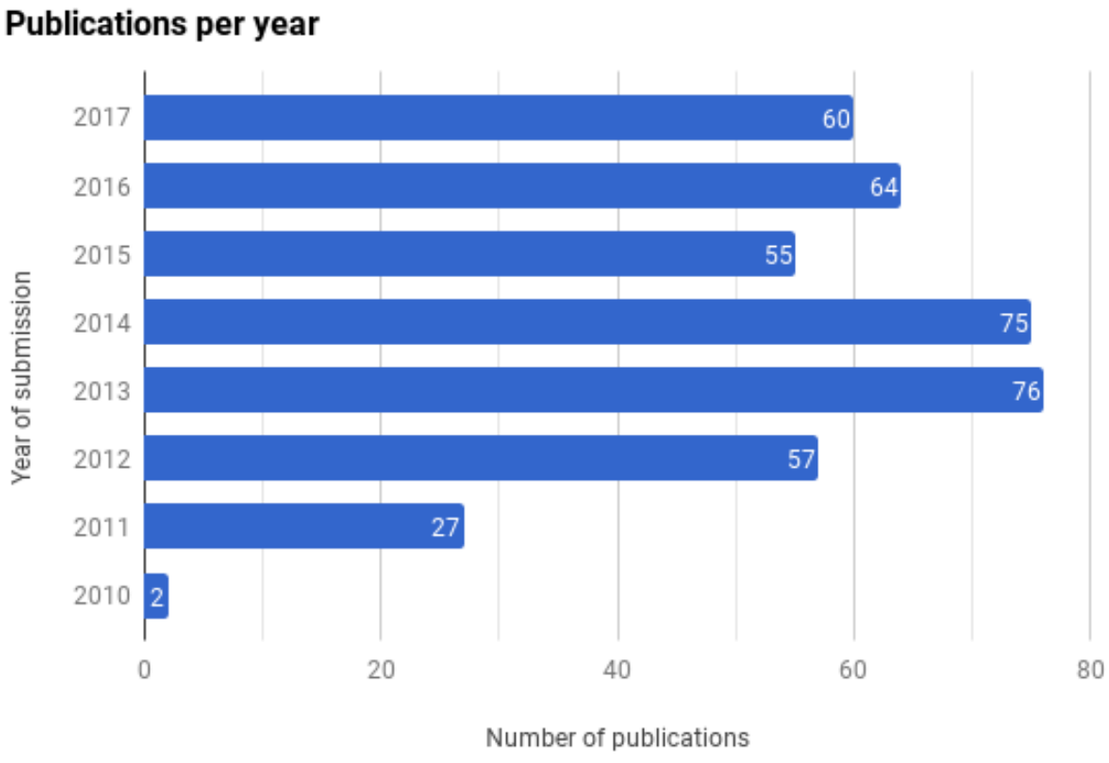


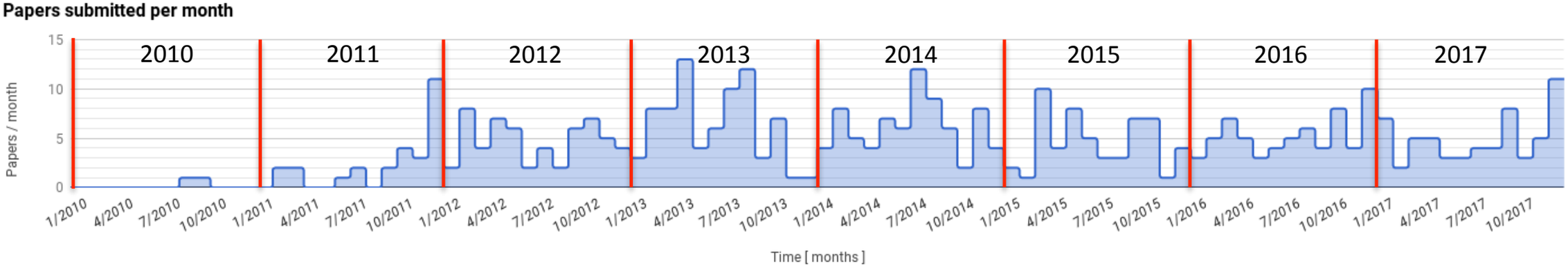
Riccardo Cenci 14 *LHCC Meeting, Feb 28, 2018*

LHCb covers a wide range of topics significantly impacting the field.

LHCb physics output

- Submitted papers: 416.
- Additional 12 to be released for the winter conferences.
- Highest papers/author ratio at LHC.
- Still more Run-I analyses in the pipeline.





LHCb Upgrade I (Run 3, 2021-2023)

VErtex LOcator

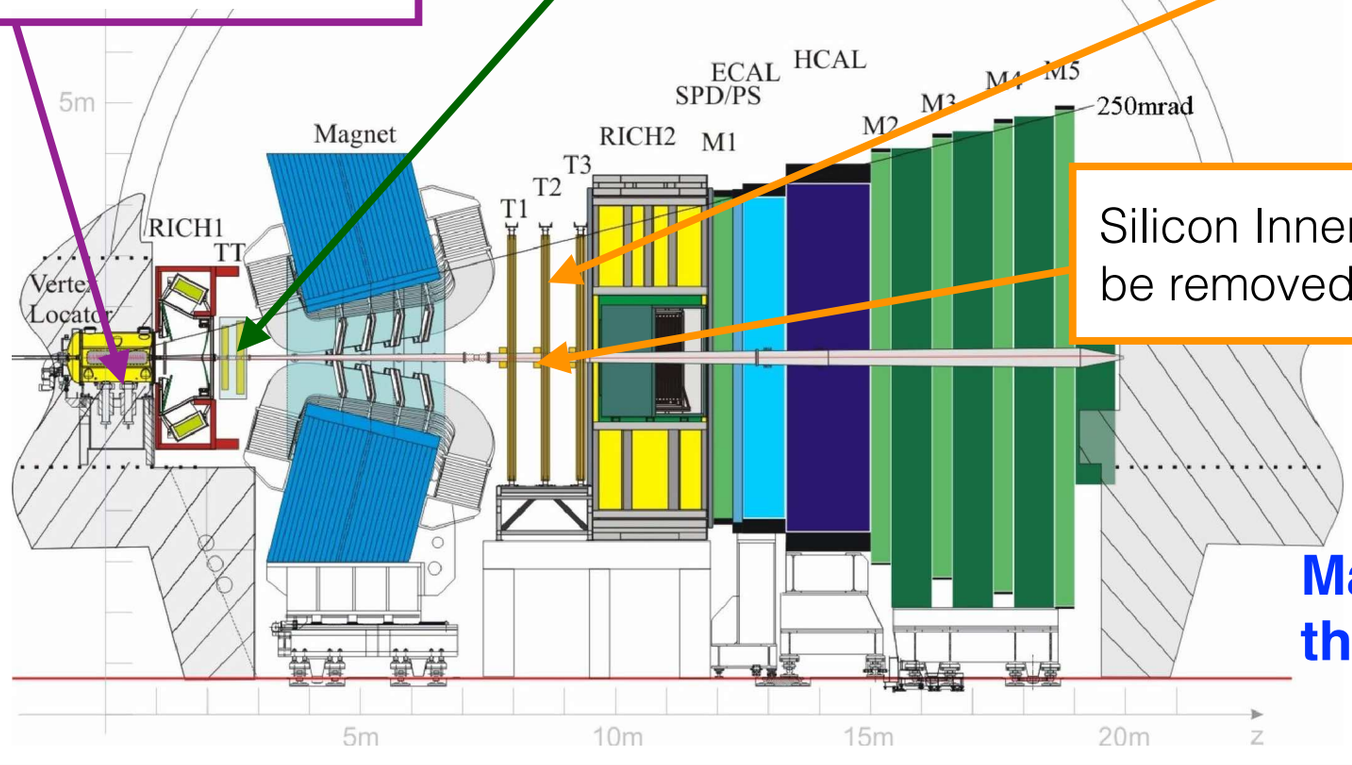
- From strip sensors to hybrid pixel detectors
- Closer to the beam (from 8.2 mm to 5.1 mm)
- CO_2 cooling in micro-channel substrate
- New RF box
- Fluence in the innermost region 8x10^{15} MeV n_{eq} cm^{-2}

Upstream Tracker

- 4 planes (x-u-v-x) of Si strips sensors
- Staves staggered: overlap in x
- Closer to the beam pipe
- Finer granularity
- Bi-phase CO2 cooling in stave support

SCIntillating FIbres

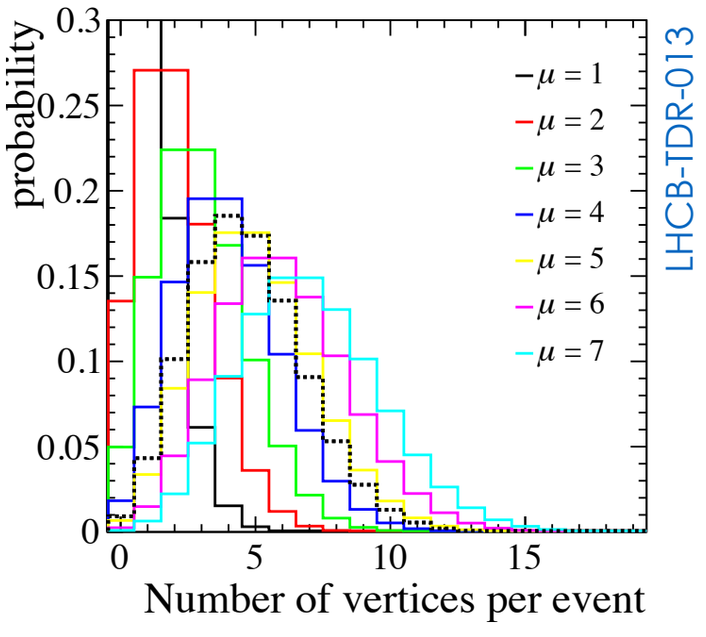
- Scintillating fibres as active detector elements
- 3 stations with 4 detection layers (x-u-v-x)
- 2 x 2.5 m long modules with mirror in the middle
- Readout with SiPMs at the outer edge



Silicon Inner Tracker will be removed.

Upgrade (current) Conditions

- visible interactions=5.5 (1.1)
- $\sqrt{s}$=14 TeV (13 TeV)
- lumi: 2 x 10^{33} cm^{-2} s^{-1} (4 x 10^{32} cm^{-2} s^{-1})
- expected integrated lumi: 50 fb^{-1} (8 fb^{-1})



Major upgrade of the electronics to allow the read-out of all sub-detectors at 40MHz.

LHCb-Pisa Group

- Founded in 2013 (end of Run 1).
- Team Leader: G.Punzi.
- Started with only 2.1 FTE (Bedeschi, Morello, Punzi).
- Today well established (9.2 FTE), growing in size, plus several students.

https://web.infn.it/LHCb-PI/

LHCb Pisa		
Bedeschi Franco	DR	60%
Cenci Riccardo	Post-doc	100%
Fantechi Riccardo	PR	10%
Lusiani Alberto	Ric-SNS	70%
Morello Michael J.	Ric-SNS	100%
Pajero Tommaso	PhD	100%
Punzi Giovanni (TL)	PA	100%
Rama Matteo	Ric-INFN	100%
Stracka Simone	Ric-INFN	80%
Walsh John J.	PR	100%
Tuci Giulia	PhD	100%
Di Luca Andrea	laureando	
Lazzari Federico	borsista	
Vitali Giacomo	laureando	

https://web.infn.it/LHCb-PI/index.php/students/thesis

Theses

Ph.D THESES

- 2020 - Tommaso Pajero. In progress.
- 2020 - Giulia Tuci. In progress.
- 2017 - Pietro Marino, Measurement of the CP violation parameter AΓ in D0 → K+K- and D0 → π+π- decays. CERN-THESIS-2017-007.
  - Advisor: M.J. Morello

1 tesi di PhD
+ 2 in coso

MASTER THESES (Laurea Magistrale)

- 2018 - Giacomo Vitali. In progress.
- 2018 - Andrea Di Luca. In progress.
- 2017 - Federico Lazzari, Development of a real-time tracking device for the LHCb Upgrade 1b.
  - Advisors: G. Punzi, R. Cenci.
- 2017 - Giulia Tuci, Measurement of time integrated CP asymmetries in D0→KS0 KS0 decays.
  - Advisors: G. Punzi, S. Stracka, J. Walsh.
- 2017 - Tommaso Pajero, Measurement of the CP violation parameter AΓ in D0 → K+K- and D0 → π+π- decays with LHCb Run 2 data.
  - Advisors: M.J. Morello.
- 2015 - Paola Mocci, Measurement of CP asymmetries of charm hadron decays to eta mesons.
  - Advisors: G. Punzi, S. Stracka.
- 2014 - Daniele Ninci, Ricostruzione di traccia in tempo reale su FPGA ad LHC.
  - Advisors: G. Punzi, F. Spinella, R.Cenci.
- 2014 - Alessio Piucci, Reconstruction of tracks in real-time at high luminosity environment at LHC.
  - Advisors: G. Punzi, M.J.Morello.
- 2013 - Federica Lionetto, Selection of hadronic decays of heavy flavors at LHCb.
  - Advisors: G.Punzi, D.Tonelli.

7 tesi di laurea magistrale
+ 2 in coso

Main activities

- The group has a great deal of expertise in the field of flavor physics, accumulated by its members in many years of activity in previous experiments (BaBar and CDF).

- Actively pursuing some of the most important physics analyses. Full responsibility with contact authors from Pisa.

- Tuning and optimization of the software that simulates the detector (official commitment of the Group).

- Proposal of an innovative real-time tracker to be installed in Run-4, as a natural product of the CSN5 R&D (“RETINA”).

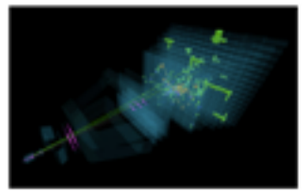
Physics analysis

M.Rama

$B^0_s \to \mu^+\mu^-$ and $B^0 \to \mu^+\mu^-$

- Measurement from LHCb using Run-1+Run-2 data has led to the first observation of the $B_s \to \mu\mu$ decay from a single experiment:

$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = \left(3.0 \pm 0.6\,^{+0.3}_{-0.2}\right) \times 10^{-9}$$
$$\mathcal{B}(B^0 \to \mu^+\mu^-) < 3.4 \times 10^{-10} \text{ @95\%CL}$$



EDITORS' SUGGESTION

Measurement of the $B_s^0 \to \mu^+\mu^-$ Branching Fraction and Effective Lifetime and Search for $B^0 \to \mu^+\mu^-$ Decays

The LHCb Collaboration reports the first observation of the $B_s^0 \to \mu^+\mu^-$ decay from a single experiment. The result is the the most precise measurement of its branching fraction to date.

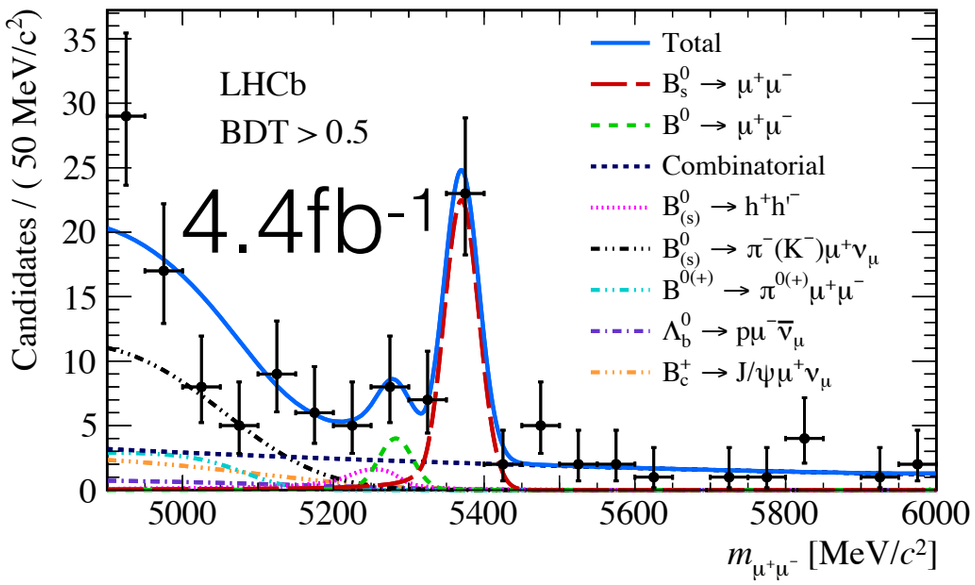
R. Aaij *et al.* (LHCb Collaboration)
Phys. Rev. Lett. **118**, 191801 (2017)

- Also first measurement of the effective lifetime, that will be useful for discriminating between NP models.

- With 300 fb^{-1} in Run 5, LHCb has the potential to reach a relative uncertainty on the the ratio of B^0 to B_s branching fractions at level of 10%. SM prediction $BR(B^0) = (1.0 \pm 0.1) \times 10^{-10}$.

Pisa coordinated the effort to achieve this very important result, also significantly contributed to the analysis.

Phys. Rev. Lett. 118, 191801 (2017)



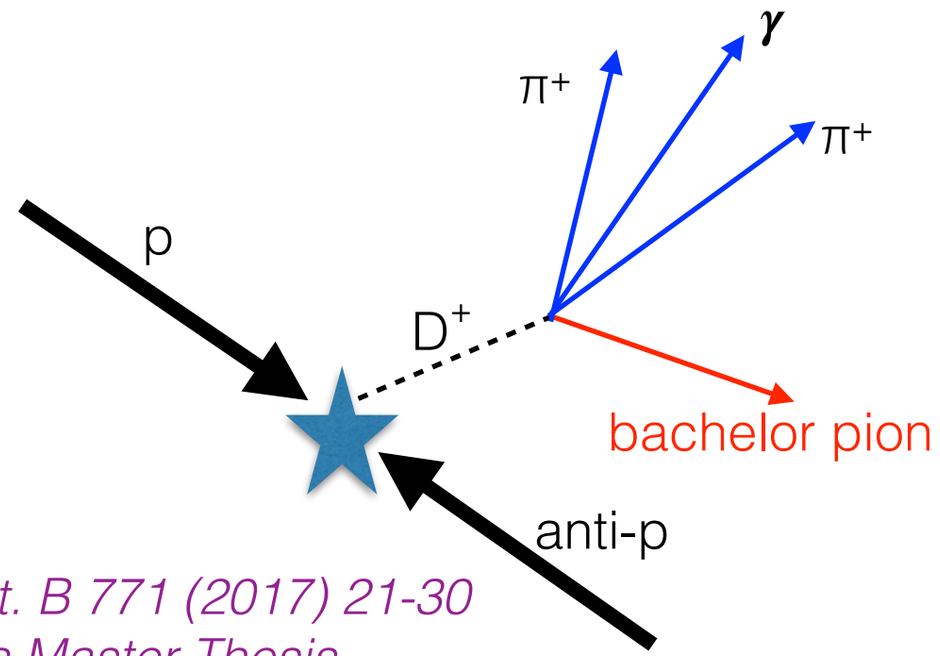
Mocci,Punzi,Stracka

A_{CP} with neutrals: $D^+_{(s)} \to \eta' \pi^+$

First time measurement of CPV in charm with neutrals at LHCb.

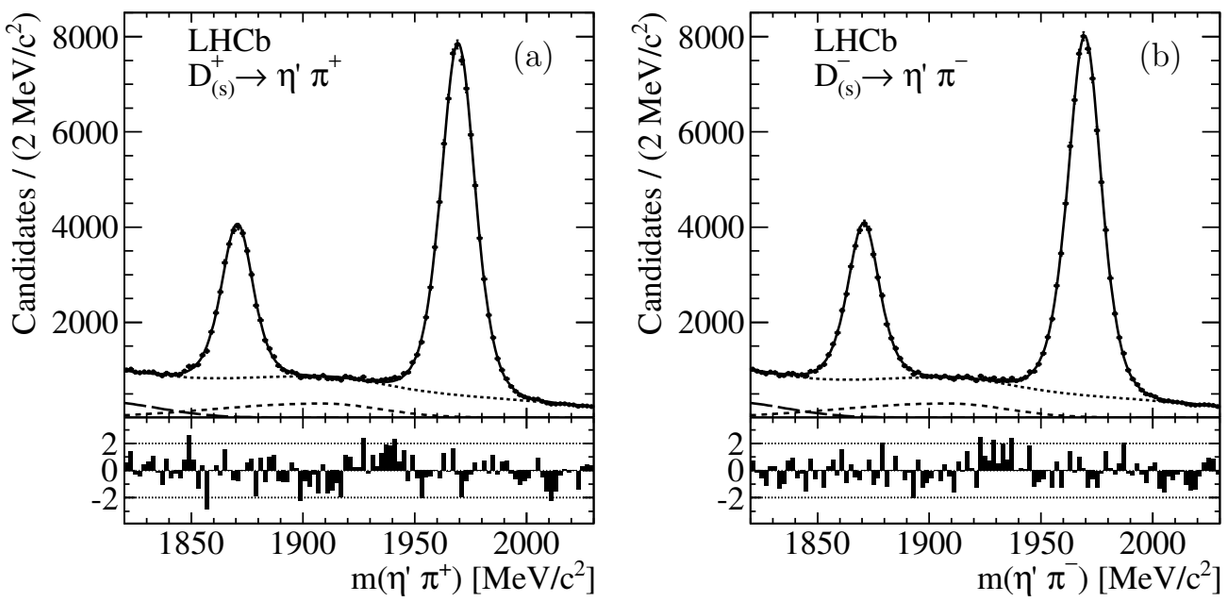
$$\mathcal{A}_{CP}(D^\pm \to \eta'\pi^\pm) = (-0.61 \pm 0.72 \pm 0.55 \pm 0.12)\%,$$
$$\mathcal{A}_{CP}(D_s^\pm \to \eta'\pi^\pm) = (-0.82 \pm 0.36 \pm 0.24 \pm 0.27)\%,$$

Most precise measurement of CP asymmetries in $D^+_{(s)} \to \eta'\pi^+$ decays to date.



Phys. Lett. B 771 (2017) 21-30
P.Mocci 's Master Thesis

Full Run 1 data sample, N($D^\pm$)=63k and N($D_s^\pm$)=152k.



Contents lists available at ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Measurement of *CP* asymmetries in $D^\pm \to \eta'\pi^\pm$ and $D_s^\pm \to \eta'\pi^\pm$ decays

LHCb Collaboration

ARTICLE INFO

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Editor: L. Rolandi

ABSTRACT

A search for *CP* violation in $D^\pm \to \eta'\pi^\pm$ and $D_s^\pm \to \eta'\pi^\pm$ decays is performed using proton–proton collision data, corresponding to an integrated luminosity of 3 fb^{-1}, recorded by the LHCb experiment at centre-of-mass energies of 7 and 8 TeV. The measured *CP*-violating charge asymmetries are $\mathcal{A}_{CP}(D^\pm \to \eta'\pi^\pm) = (-0.61 \pm 0.72 \pm 0.53 \pm 0.12)\%$ and $\mathcal{A}_{CP}(D_s^\pm \to \eta'\pi^\pm) = (-0.82 \pm 0.36 \pm 0.22 \pm 0.27)\%$, where the first uncertainties are statistical, the second systematic, and the third are the uncertainties on the $\mathcal{A}_{CP}(D^\pm \to K^0_S\pi^\pm)$ and $\mathcal{A}_{CP}(D_s^\pm \to \phi\pi^\pm)$ measurements used for calibration. The results represent the most precise measurements of these asymmetries to date.

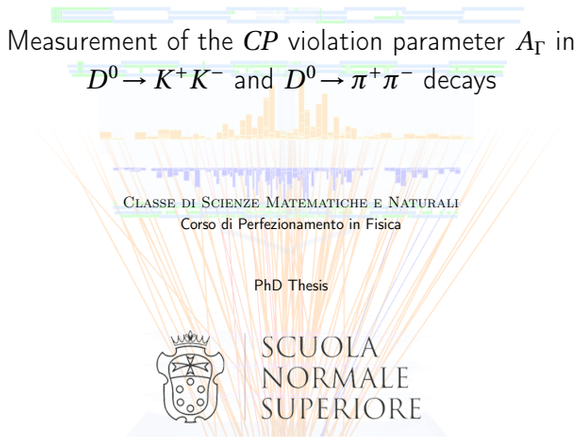
Marino, Morello, Pajero, Punzi

Time-dependent CPV in $D^0 \to h^+h^-$

Most precise measurement of CPV in the charm sector. Most precise asymmetry measurement in LHCb.

$$A_\Gamma(K^+K^-) = (-0.30 \pm 0.32 \pm 0.10) \times 10^{-3}$$
$$A_\Gamma(\pi^+\pi^-) = (0.46 \pm 0.58 \pm 0.12) \times 10^{-3}$$

It approaches the level of 10^{-4}. Not yet evidence for CP violation, but very close to the SM predictions.



P. Marino's PhD thesis
CERN-THESIS-2017-007

T. Pajero (new PhD student) is updating the measurement to the full Run1+Run2 statistics.

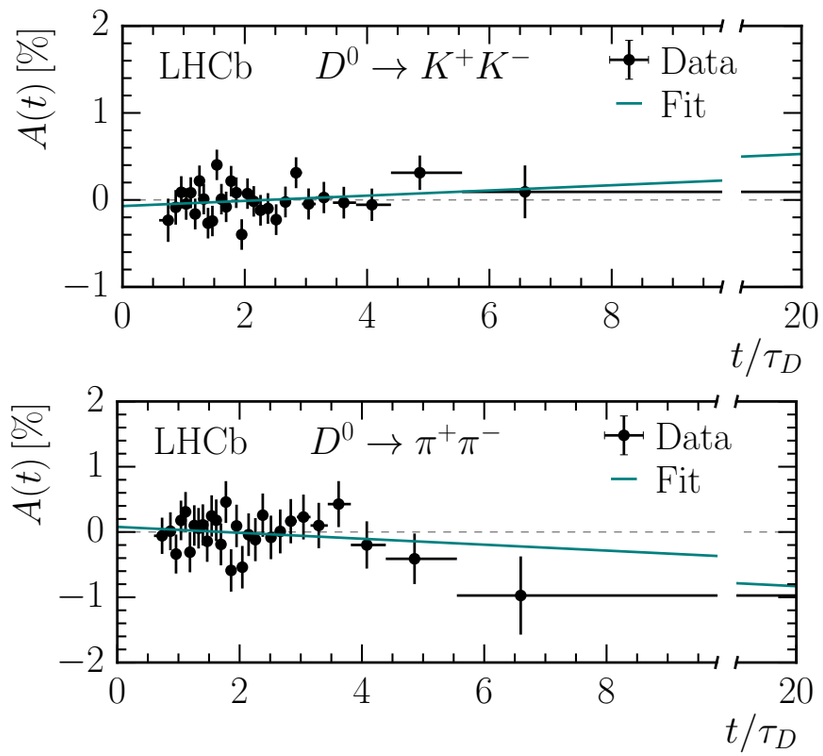
PRL **118,** 261803 (2017) PHYSICAL REVIEW LETTERS week ending 30 JUNE 2017

Measurement of the *CP* Violation Parameter A_Γ in $D^0 \to K^+K^-$ and $D^0 \to \pi^+\pi^-$ Decays

R. Aaij *et al.**
(LHCb Collaboration)
(Received 22 February 2017; published 28 June 2017)

Asymmetries in the time-dependent rates of $D^0 \to K^+K^-$ and $D^0 \to \pi^+\pi^-$ decays are measured in a pp collision data sample collected with the LHCb detector during LHC Run 1, corresponding to an integrated luminosity of 3 fb^{-1}. The asymmetries in effective decay widths between D^0 and $\overline{D}^0$ decays, sensitive to indirect *CP* violation, are measured to be $A_\Gamma(K^+K^-) = (-0.30 \pm 0.32 \pm 0.10) \times 10^{-3}$ and $A_\Gamma(\pi^+\pi^-) = (0.46 \pm 0.58 \pm 0.12) \times 10^{-3}$, where the first uncertainty is statistical and the second systematic. These measurements show no evidence for *CP* violation and improve on the precision of the previous best measurements by nearly a factor of two.

DOI: 10.1103/PhysRevLett.118.261803



Phys. Rev. Lett. 118, 261803 (2017).

Punzi, Stracka, Walsh, Tuci

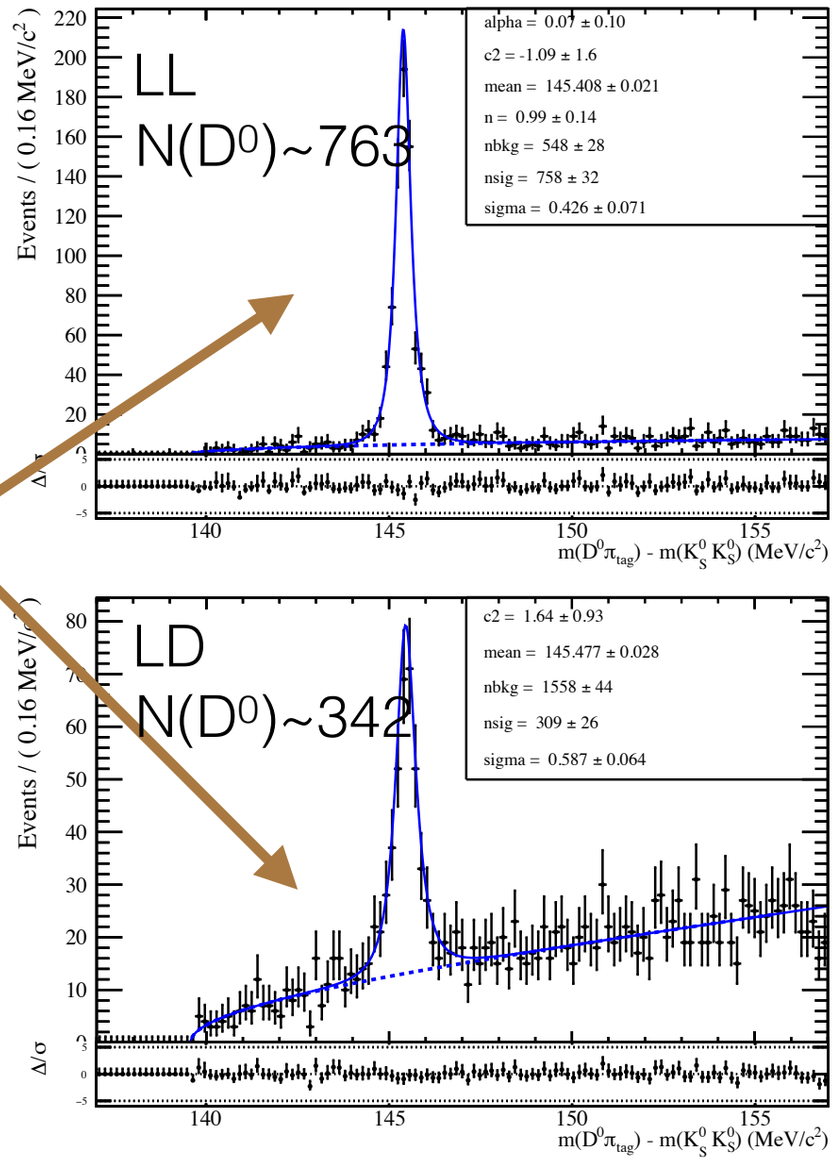
Time integrated $A_{CP}(D^0 \to K_S K_S)$

- Very promising for searching direct CPV in charm.
- Challenging in LHCb because K_{short} is a neutral long-lived particle. Need an efficient reconstruction of "downstream" tracks.

- Analysis in advanced state, currently under internal review. Publication of results on Run 2 (2015-2016) data expected for Beauty18 on May.

- Master thesis of G. Tuci. Extension to full Run1 + Run2 will attain a precision of ~1%, the same of current world average.
- Important motivation and benchmark for the Pisa proposal of the "Downstream Tracker" for future LHCb-Upgrades (see next).

Run 2 (2015-2016) data



G. Tuci's Master Thesis

LHCb simulation

- Pisa officially contributes to the tuning and the optimization of the software that simulates the detector.
  - R. Cenci is Co-convener of the Simulation Working Group (Jun 2015 - Mar 2018).
- Pisa also committed for the LHCb-Upgrade I (Run-3) to coordinate and significantly contribute to the effort for developing the Fast Simulator.
  - M. Rama is the Coordinator of the Fast Simulation subgroup (Sep 2016 - now).

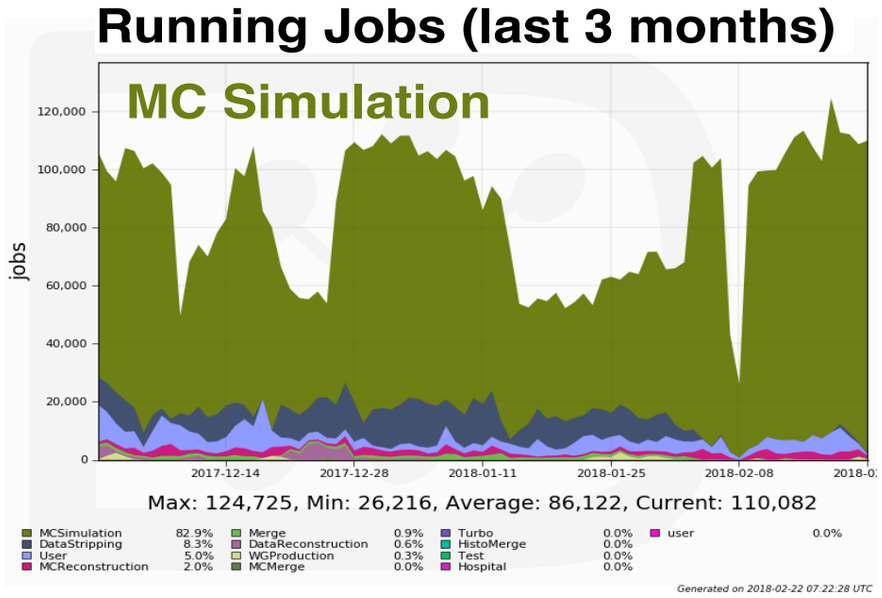
Cenci, Pajero, Stracka

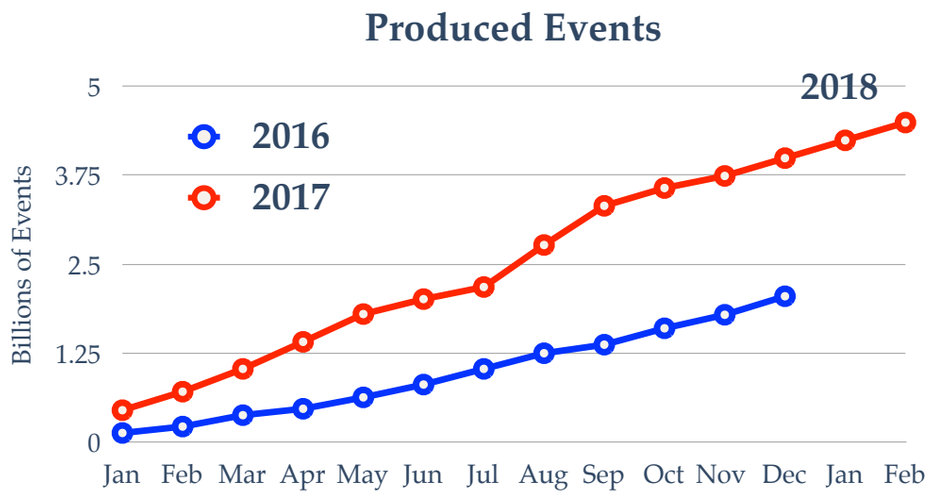
MC Production

- Efficient MC Production is fundamental, because takes most of the LHCb computing resources (80%).

- Multiple tasks, from submission of MC sample requests to coordination and maintenance of the software.

- Number of produced events has doubled in 2017 wrt 2016.



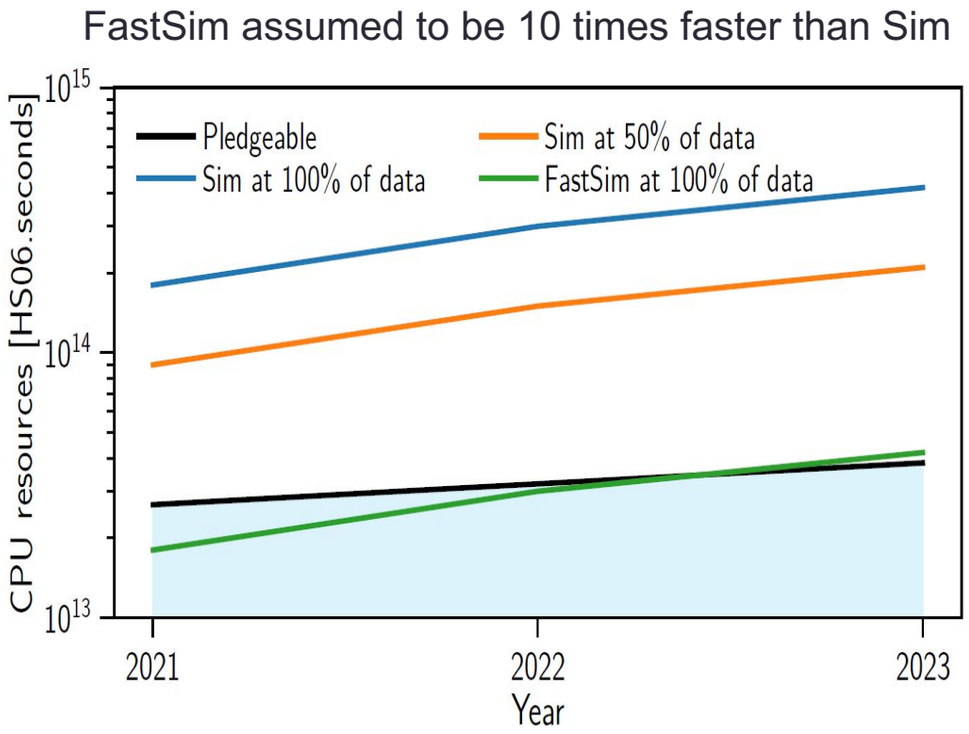


Rama, Vitali

A faster detector simulation

- Many analyses already limited by the Monte Carlo sample size. Started a coordinated effort for improving the simulation performance.

- Fundamental in Run-3, where the increase in computing power will not compensate the higher data rate .



- Pisa is developing a flexible framework which allows to select full/fast sim modes for different particle types and sub-detectors, depending on user's needs.

- Pisa is also committed in developing a fast simulation based on hits library for the calorimeter. (G. Vitali, Master Thesis)

Towards Future Upgrades

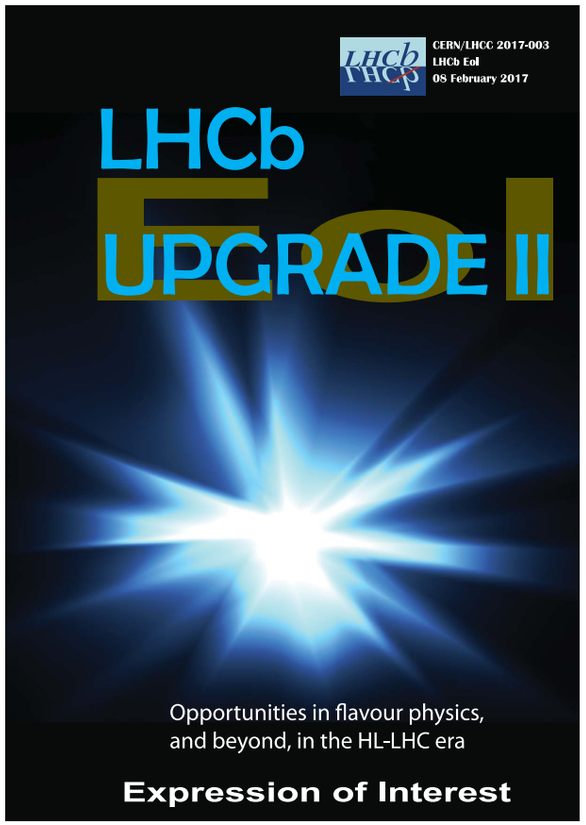
Already funded and in construction

- LHCb Upgrade I in Run-3 (2021-2023)
  - L_{inst}= 2 x 10^{33} cm^{-2} s^{-1}, integrate 22 fb^{-1} by the end of Run 3.

- LHCb Upgrade Ib in Run-4 (2026-2029)
  - Profit from LS3 for a “consolidation” of Upgrade I in Run 4 (1b).
  - integrate 50 fb^{-1} by the end of Run 4. Same inst. luminosity of Run-3.
- LHCb Upgrade II in Run 5 (2031-2033) and beyond.
  - New experiment to be installed in LS4.
  - L_{inst} = 2 x 10^{34} cm^{-2} s^{-1}, integrate > 300 fb^{-1}.
  - May be the only general heavy flavour experiment on this timescale.

Proposal for Future LHCb Upgrades.

CERN-LHCC-2017-003



“It is proposed to upgrade the LHCb experiment in order to take full advantage of the flavour-physics opportunities at the High Luminosity LHC (HL-LHC).

.....

This project will extend the HL-LHC's capabilities to search for physics beyond the Standard Model, and implements the highest-priority recommendation of the European Strategy for Particle Physics (Update 2013), which is to exploit the full potential of the LHC for a variety of physics goals, including flavour.”

LHCb timeline in the next decades

The LHCb Upgrade I will enable to integrate about 22 fb^{-1} by end of Run 3 and 50 fb^{-1} by end of Run 4.

LS3 consolidation

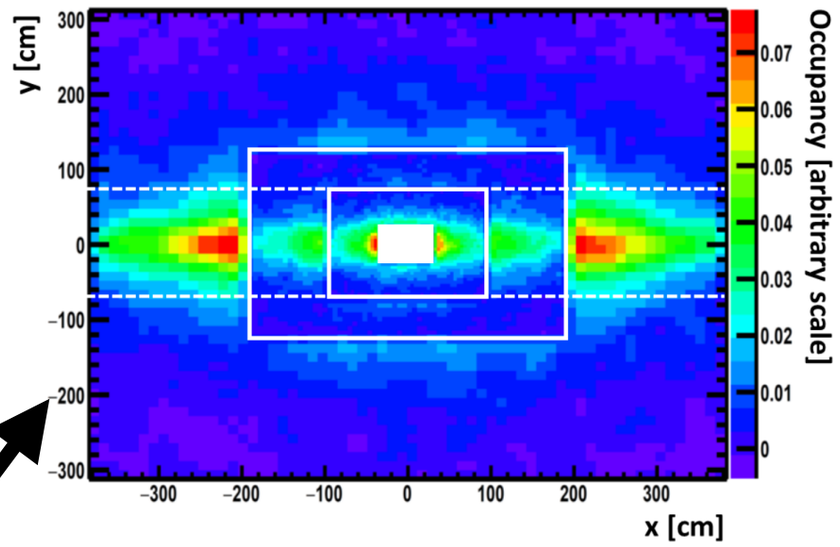
- Profit from LS3 to implement some consolidations of the upgraded LHCb in Run 4 (2027-2030).

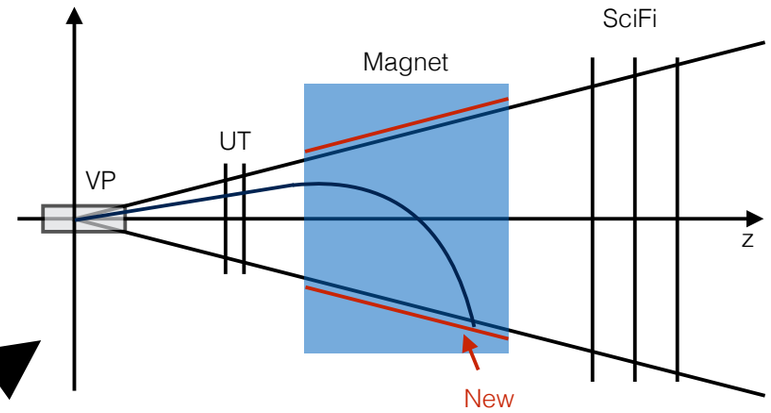
- Some already planned and mandatory e.g. replace innermost part of ECAL due to radiation damage (strong physics interest: π^0, γ, e^-)

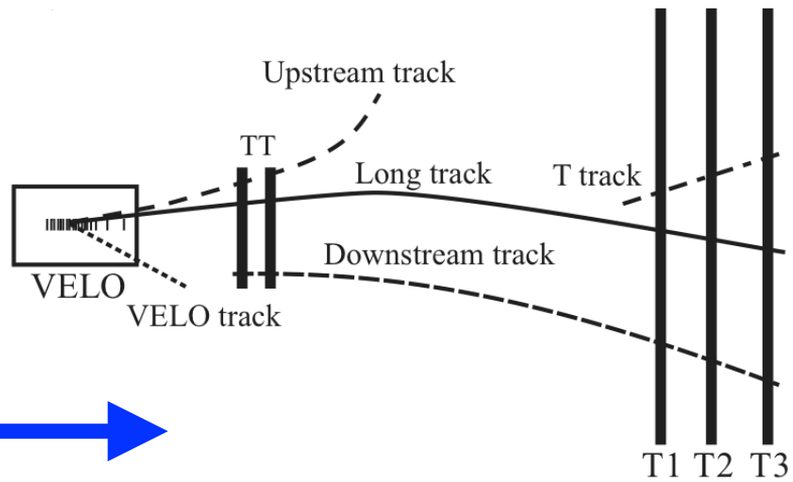
- Other proposals to improve LHCb performance and physics acceptance:

  - tracking stations inside the magnet to improve tracking acceptance for low momentum particles.

  - Build a “downstream tracker unit” (RETINA like) that can be integrated in the DAQ architecture and act as an embedded track-detector to reconstruct downstream tracks in realtime (long-lived particles K_S,Λ).



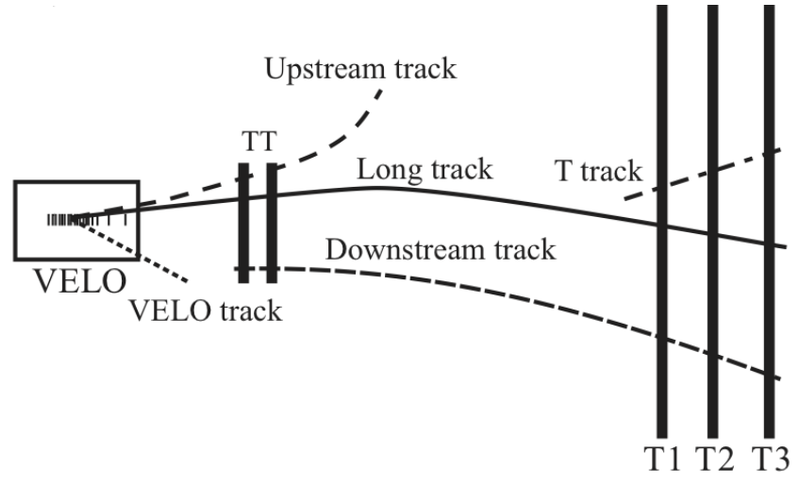




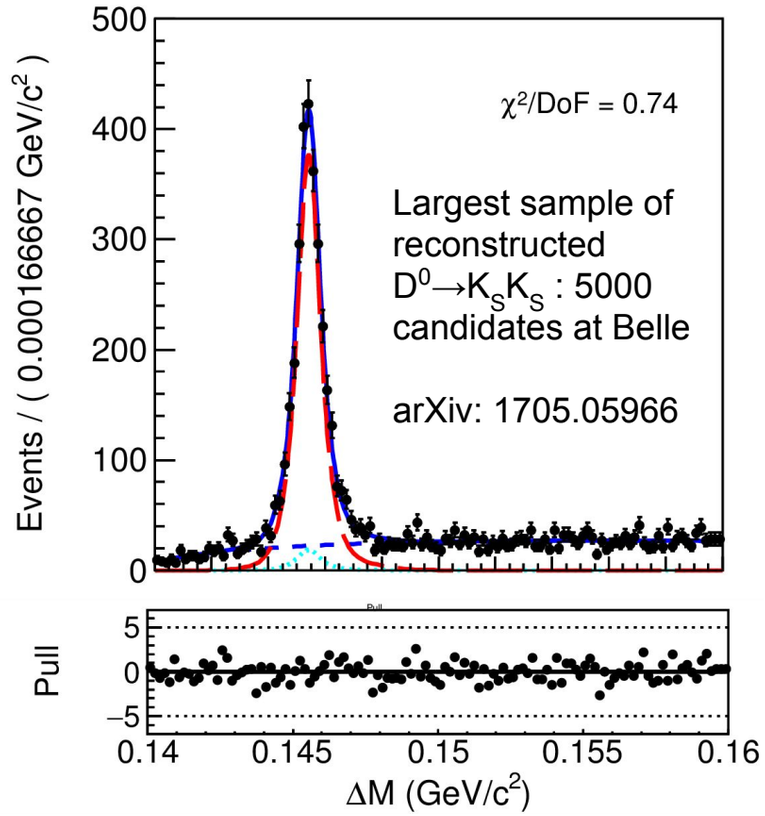
Pisa proposal

Why a Downstream Tracker?

- In the Upgrade era trigger will remain software (huge farm of CPUs processing 30MHz of pp collisions).
  - Physics output will entirely rely on the real-time analysis. No resources for any further offline data processing. Physics not reconstructed in the trigger is lost.



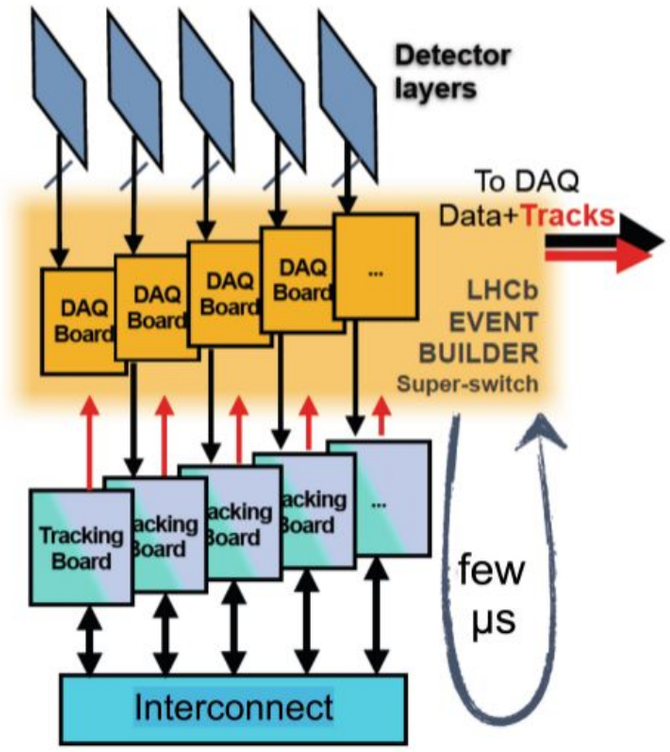
- Finding tracks downstream the magnet at the earliest trigger level is not part of the baseline trigger scheme (significant CPU required).
- This would result in limited (if any) efficiency for decays with downstream tracks (K_S,K_L,Λ,…) that cannot easily be triggered thorough other signatures. Currently LHCb yields < Belle 2 yields.

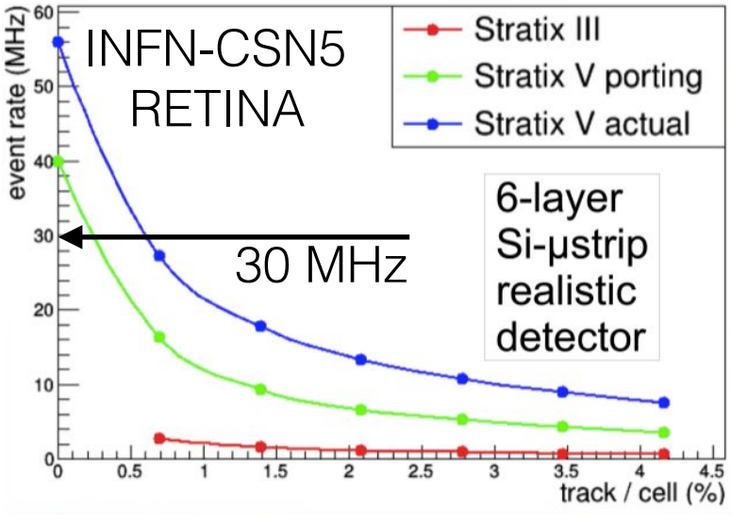


Cenci, Fantechi, Lazzari, Morello, Punzi, Stracka, et al.

Distributed-embedded Retina

- Rely on Artificial Retina algorithm, very suitable for massive pattern recognition.
- A single tracking board performing both hit distribution and template matching.
- Use commercial PCIe FPGA boards, one for each DAQ Board (~250 boards connected high-speed optical network).
- Pisa proposal fully based on results from INFN-CSN5 RETINA project.
- Planned to install a first prototype already in Run-3 to track a “vertical slice”.
  - Currently discussing if the prototype can already accelerate online reconstruction in Run-3.





See S.Stracka talk - Beyond the LHCb Phase-1 Upgrade Workshop Elba
https://agenda.infn.it/conferenceDisplay.py?confId=12253

Outreach

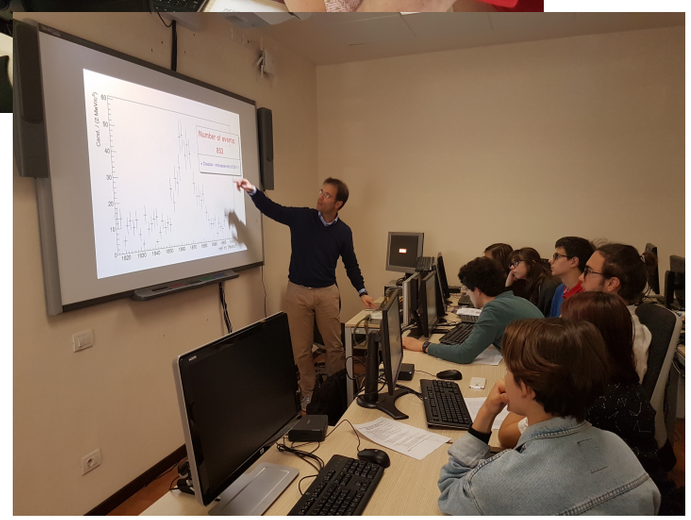
- LHCb-Pisa contributes every year to several outreach events:

- CERN LHCb MasterClass.

- Bright Toscana: la notte dei ricercatori.

- Digital Lab Science VIS-SNS.

- Un giorno da ricercatore VIS-SNS.



Conclusions

- LHCb smoothly taking data during Run 2 - collecting huge samples of heavy flavored decays.

- Wide physics output that significantly impacts the field.

- LHCb-Upgrade Phase I behind of the corner. Proposal of Future Upgrades Phase II to run at higher luminosity submitted to LHCC and under discussion within the community.

- LHCb-Pisa Group doing an excellent job contributing to physics analysis, to current and future LHCb simulation software, and paving the way to flavor physics at extreme intensity.

Backup