LHCb

Alessandro Cardini / INFN Cagliari
Responsabile Nazionale LHCb

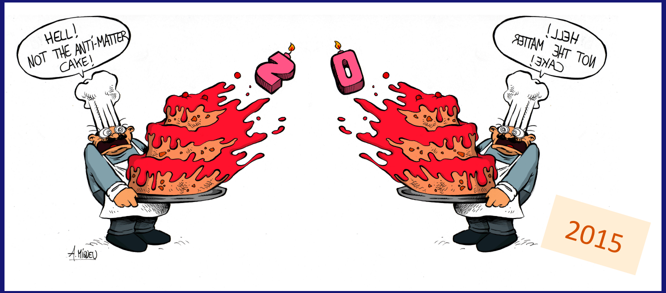
22 anni di LHCb!

- Era ben noto che la sezione d'urto di produzione di B a LHC sarebbe stata grande. Al Workshop di Evian del 1992 vengono presentate 3 proposte di esperimento dedicate alla fisica del B a LHC: due per esperimenti a fixed-target (LHB e GAJET) e una che proponeva di utilizzare uno spettrometro in avanti operante in collider-mode (COBEX)

- LHCC suggerisce ai proponenti di presentare una proposta comune per un esperimento operante in collider-mode per sfruttare la grande sezione d'urto di produzione di b e dotato di una convincente strategia di trigger

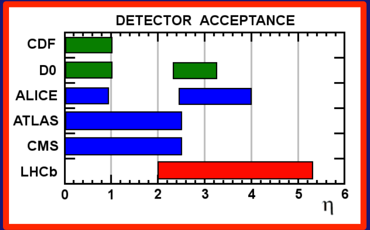
- La lettera di intenti di LHCb viene sottomessa a LHCC nel 1995, "*to build a forward collider detector dedicated to the study of CP violation and other rare phenomena in the decays of Beauty particles*"

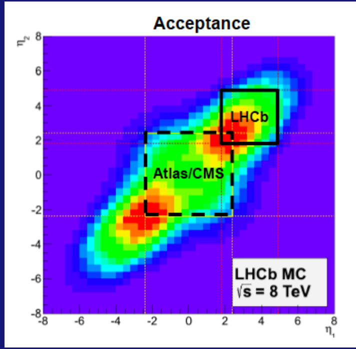
- L'esperimento viene finalmente approvato nel 1998 e il design dell'apparato viene finalizzato nel 2003. Dopo frenetici anni di costruzione e commissioning LHCb comincia a prendere dati il 23 novembre 2009

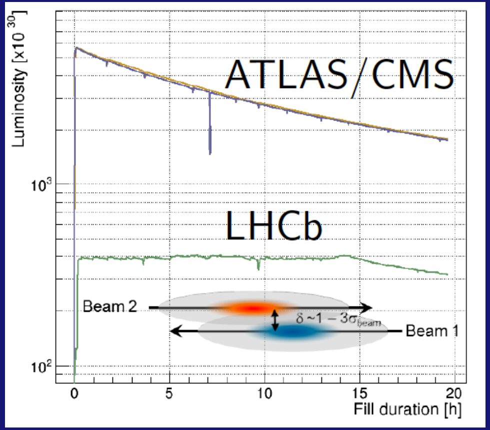


LHCb: Caratteristiche

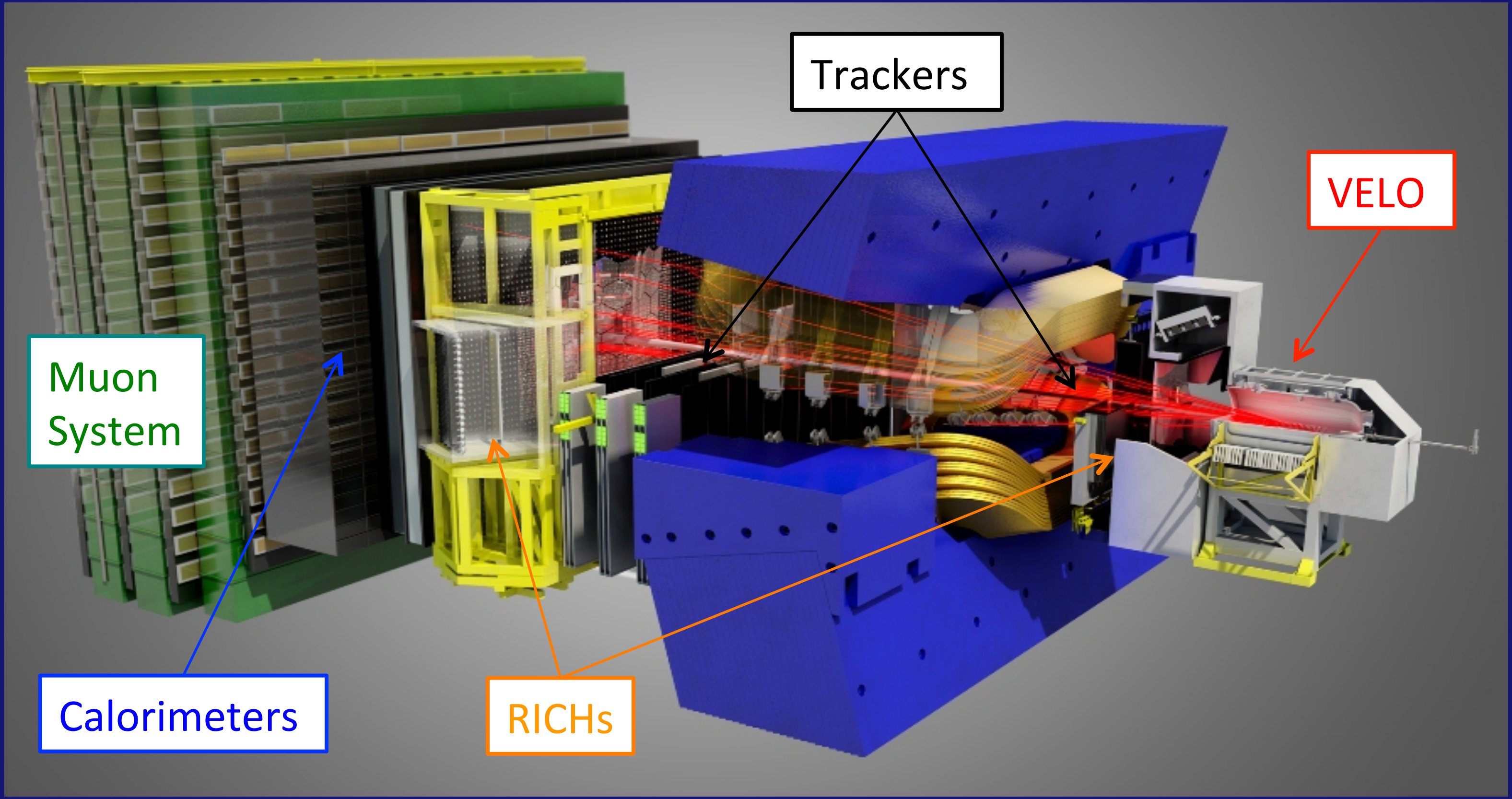
- LHCb è un F-GPD (Forward General-Purpose Detector)
- Spettrometro in avanti, accettanza 2<η<5, 4% dell'angolo solido
- Riesce a sfruttare il 40% della sezione d'urto di produzione di quark pesanti
- Capacità di fare misure di precisione nel settore della beauty e del charm:
  - $\Delta p/p$ = 0.35% @ 5 GeV/c ÷ 0.55% @ 100 GeV/c
  - 20 μm di risoluzione del parametro di impatto per tracce ad alto p_t
  - Risoluzione sul decay time di 45 fs ($B_s \rightarrow D_s \pi$)
  - Opera a luminosità istantanea costante di 4E+32 $cm^{-2}s^{-1}$
  - Trigger multi-livello ad altissima efficienza, ottimizzato per stati finali adronici e leptonici

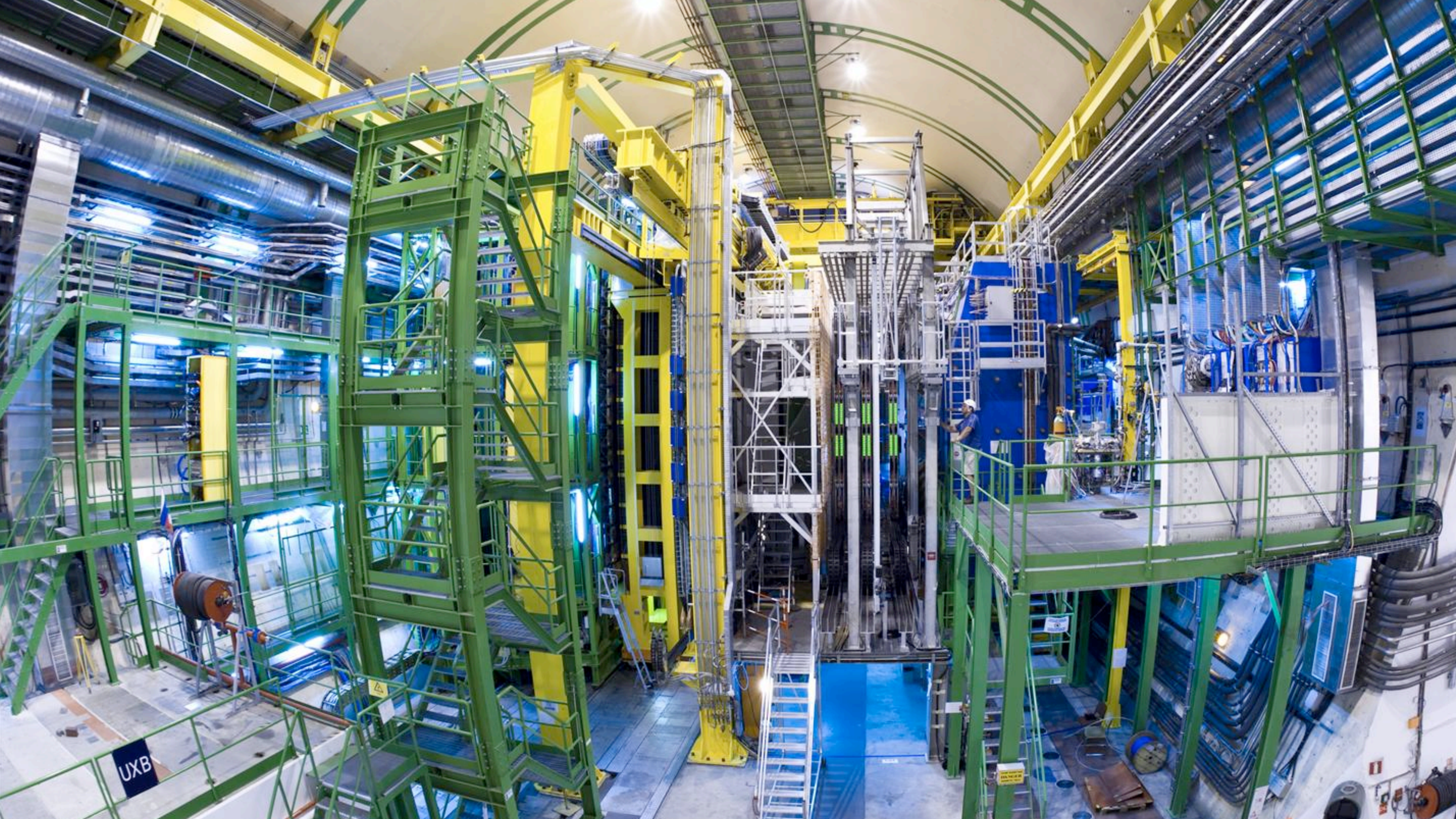






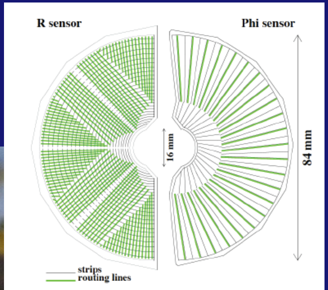
L'apparato sperimentale

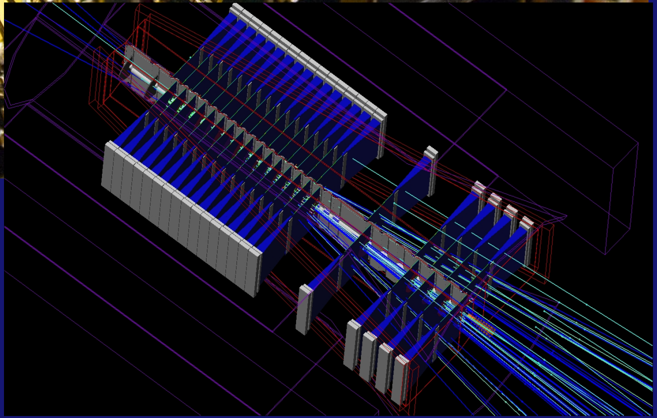


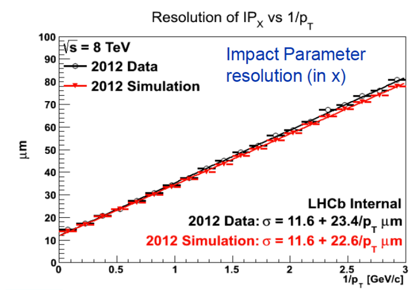

UXB

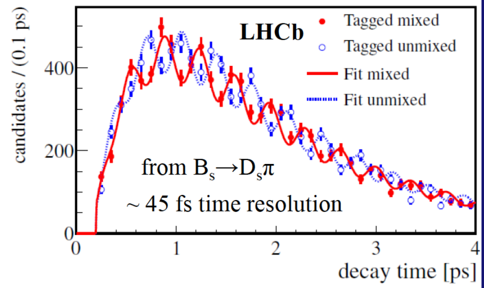
VELO

- 88 silicon sensors, 300 μm thick, n-on-n technology
- Sensors close around beam during data taking, down to 8.1 mm from it
- Working in secondary vacuum, separated by accelerator vacuum by RF foils
- Evaporative CO_2 cooling





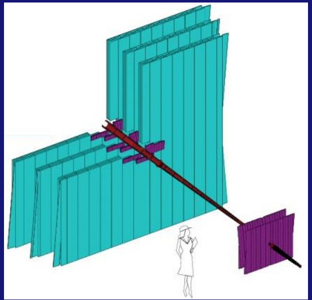


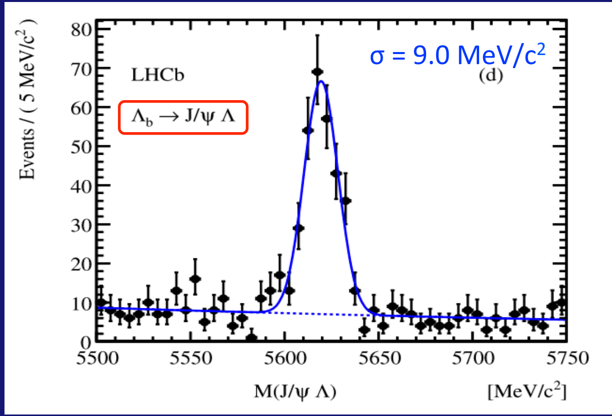


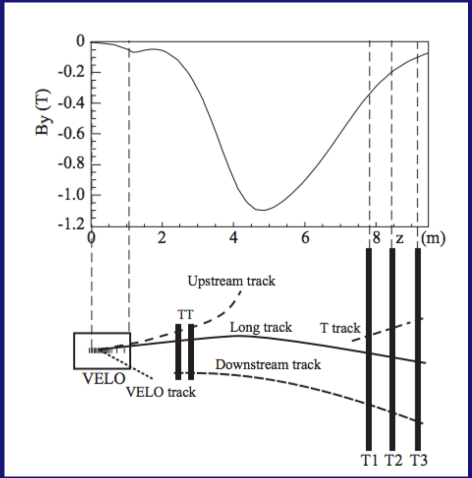
Tracking system

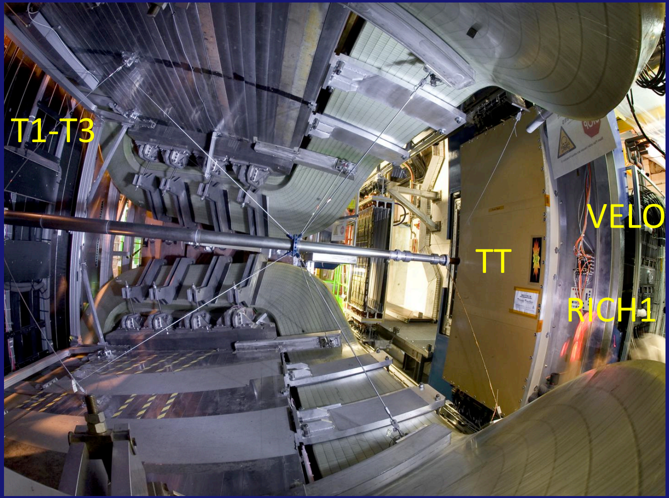
Various tracking stations (Si microstrips, straw tubes) and dipolar magnetic field of 4 Tm provide:

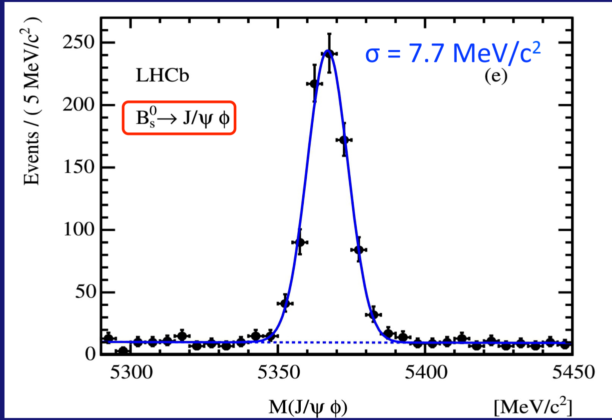
- Excellent mass resolution
- World's best mass measurements









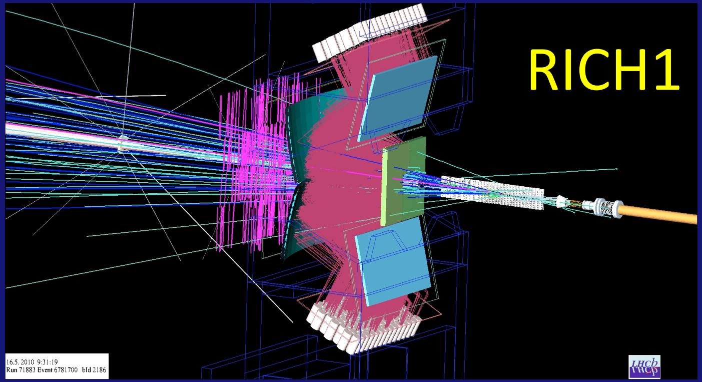


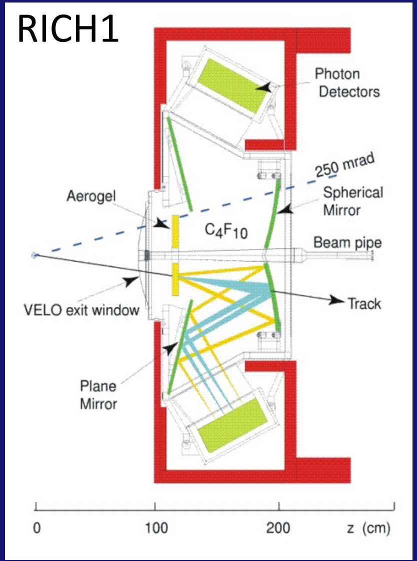
RICH

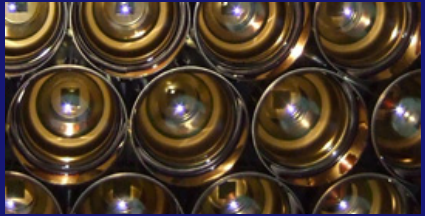
2 RICH detectors in LHCb

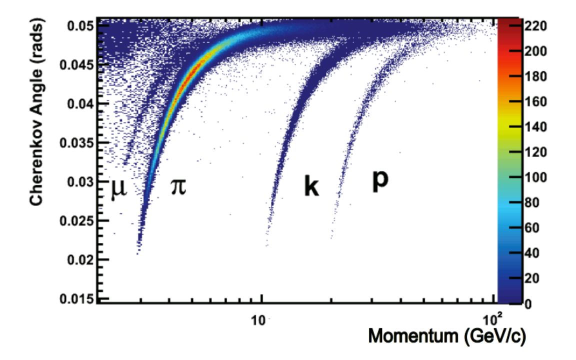
Cherenkov light readout by photon detectors located outside geometrical acceptance

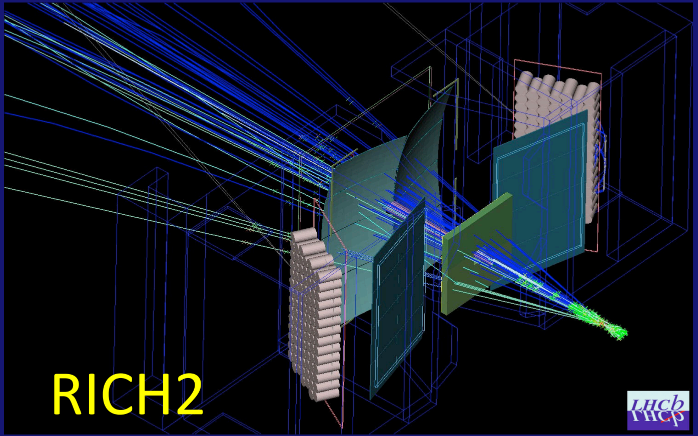
Hybrid Photon Detectors (HPDs) readout with embedded 1 MHz R/O ASIC



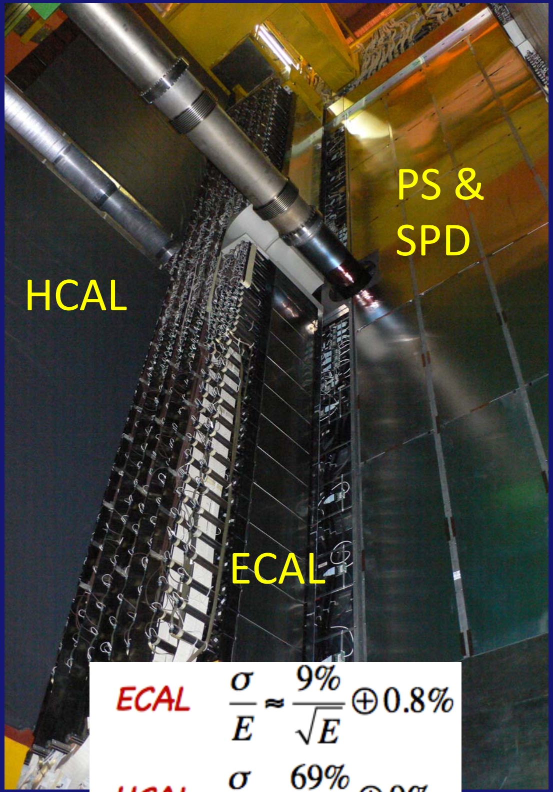








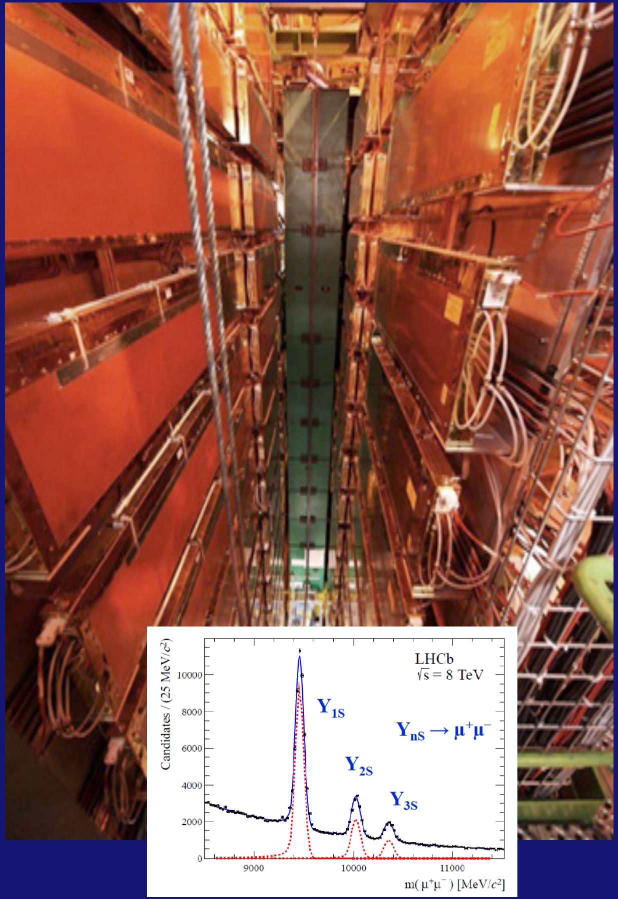
Calorimeter and Muon System



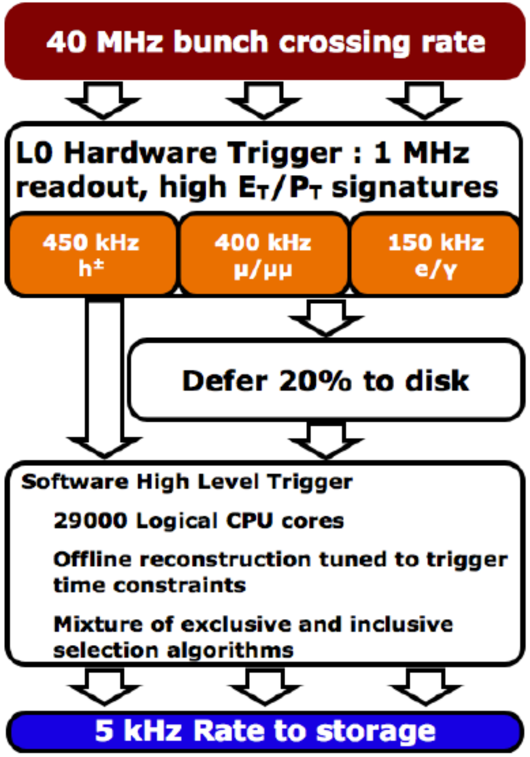
ECAL $\frac{\sigma}{E} \approx \frac{9\%}{\sqrt{E}} \oplus 0.8\%$

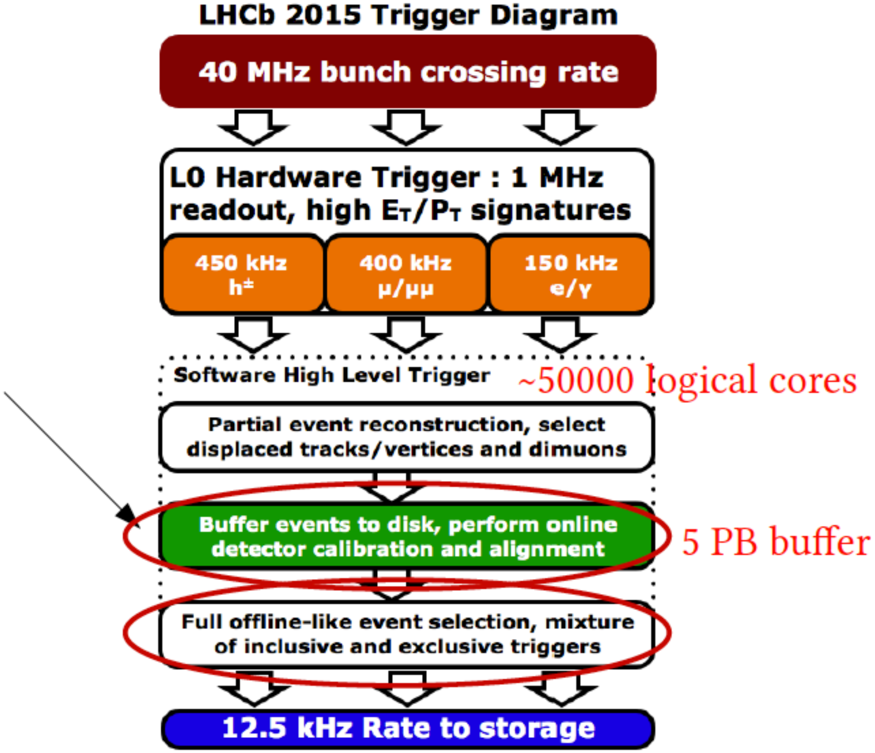
HCAL $\frac{\sigma}{E} \approx \frac{69\%}{\sqrt{E}} \oplus 9\%$

- Calorimeter
  - 4 subsystems (PS, SPD, ECAL, HCAL)
  - Scintillating tiles + lead (SPD, PS, ECAL) or iron (HCAL)
  - Light collection via WLS fibers
  - Provide input to high E_t low level trigger
- Muon Stations
  - 5 muon stations separated by $20\lambda_i$-thick iron filters
  - Projective geometry
  - MWPC & Triple-GEM
  - CF_4-based gas mixture
  - Provide input to high p_t low level muon trigger



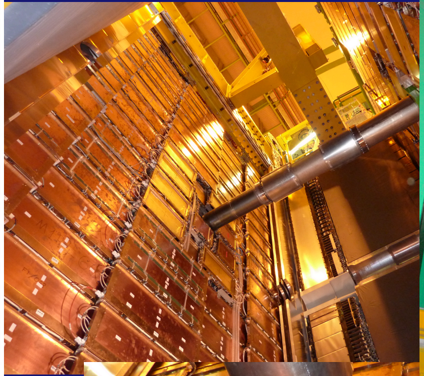
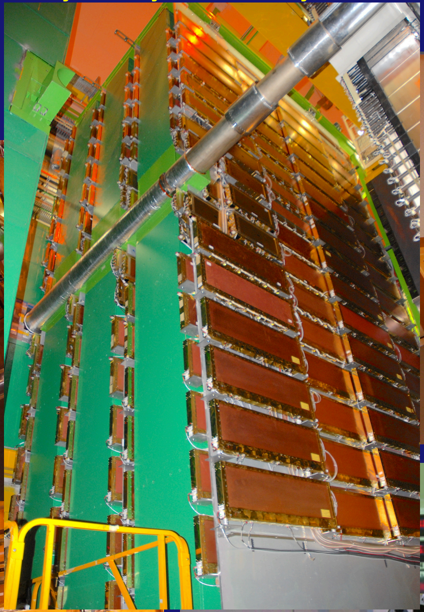
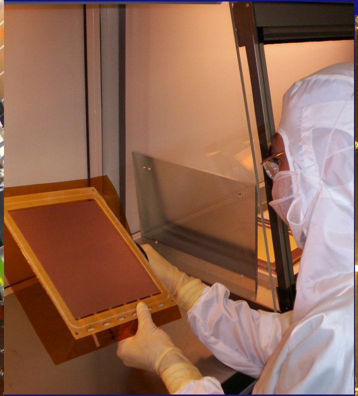
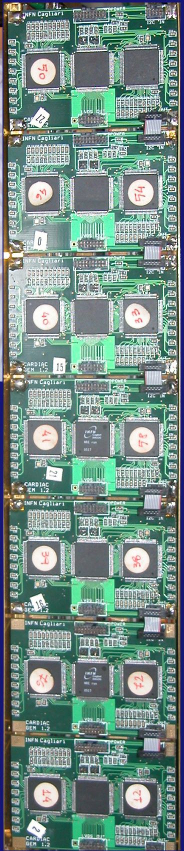
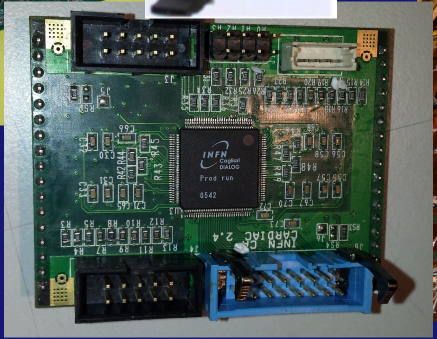
L0-trigger & HLT

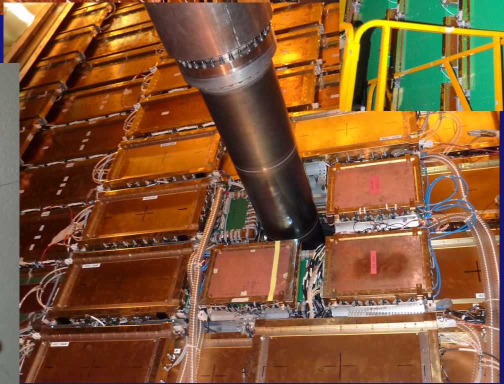


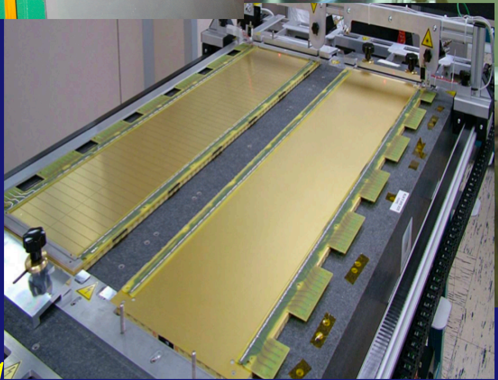


Includes 2.5 kHz Turbo stream

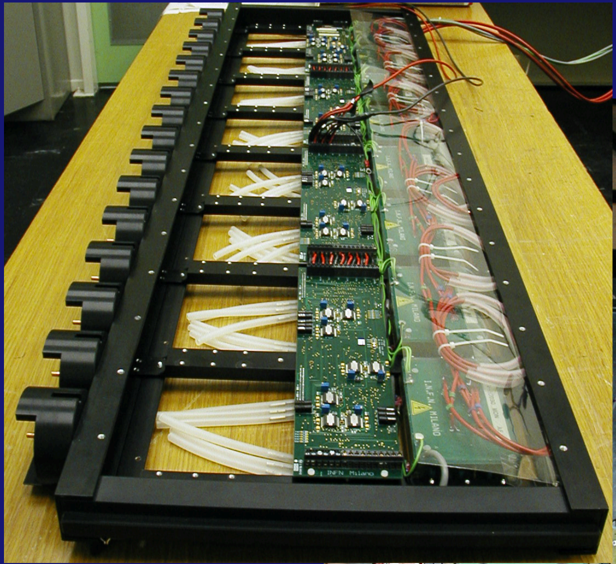
Muon System: CA, FE, FI, LNF, RM1, RM2

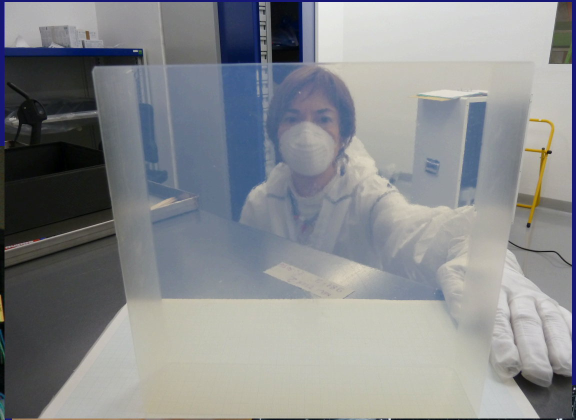






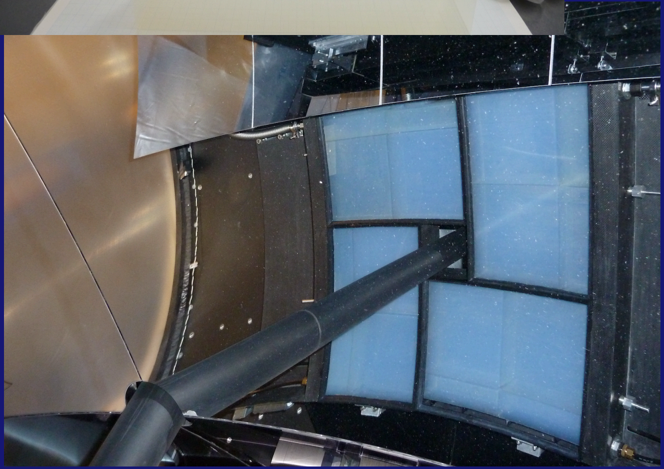




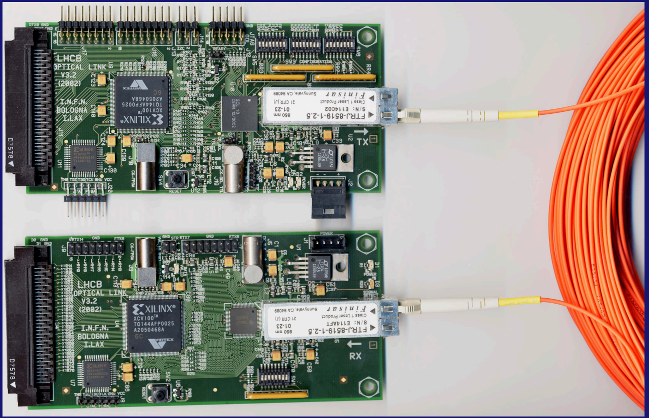
RICH: GE, MIB

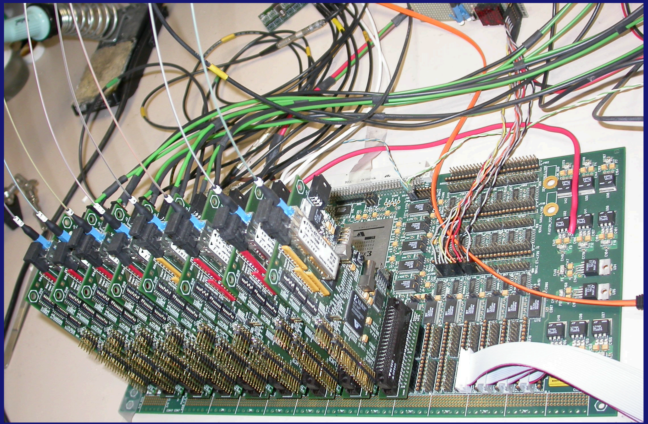


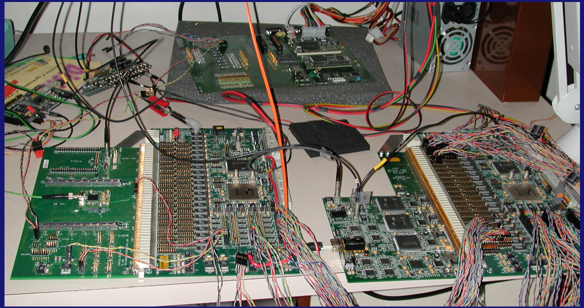


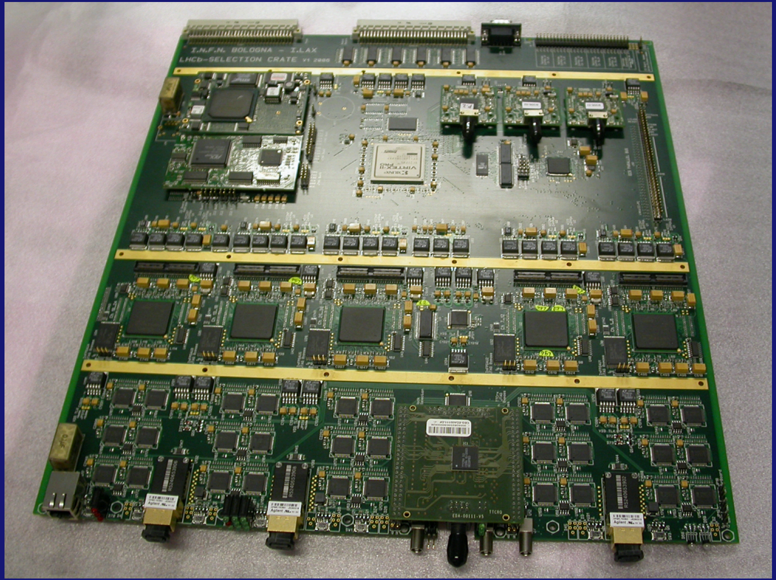


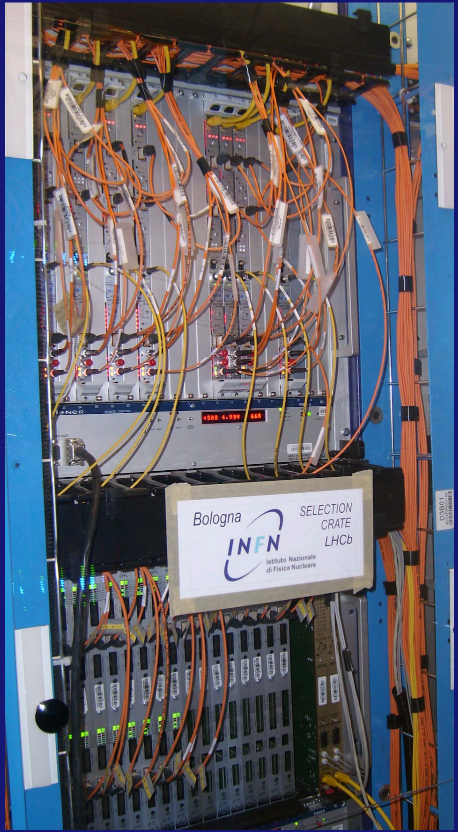
DAQ: BO





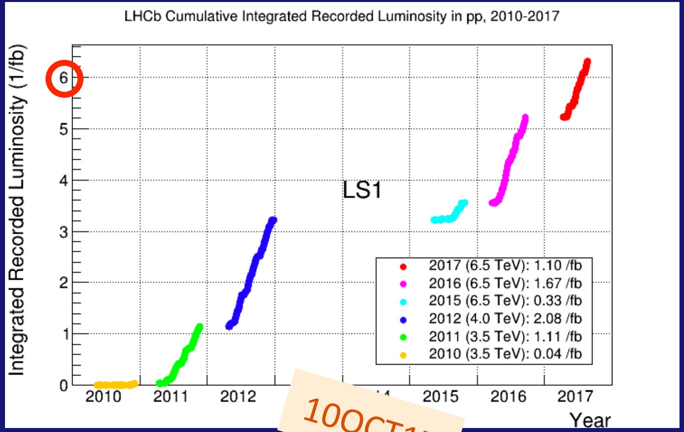


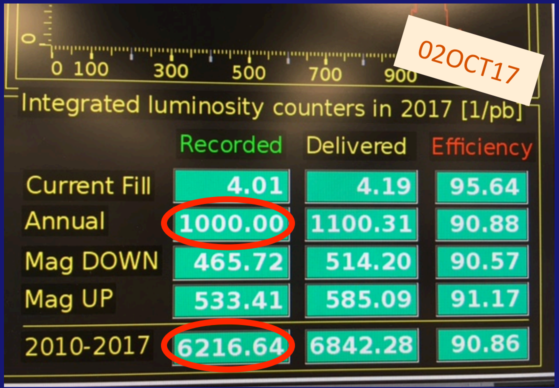


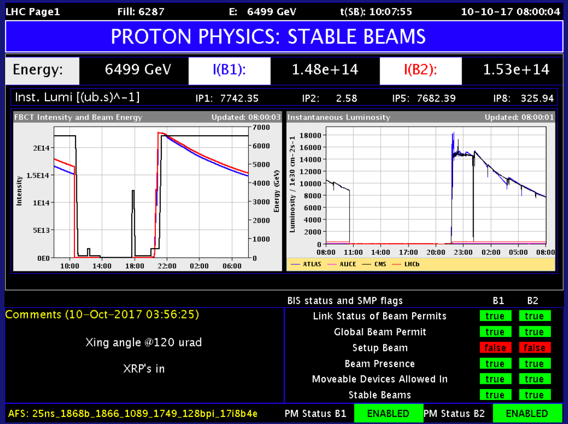

Bologna
INFN
Istituto Nazionale di Fisica Nucleare
SELECTION CRATE LHCb

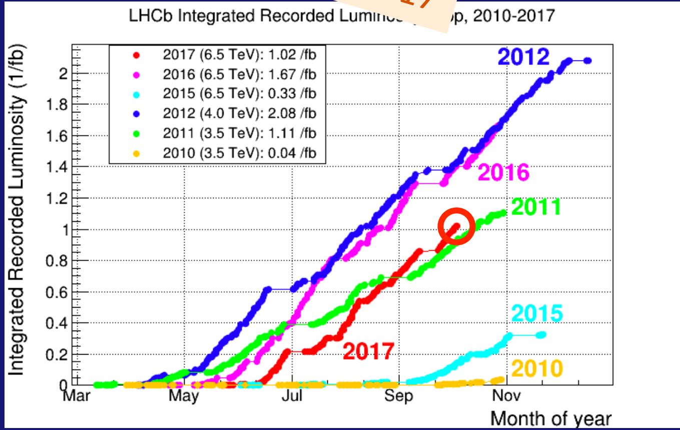
La presa dati 2017

- Running at μ = 1.1 (like in 2015 & 2016), and L_{inst} = 4.4 x $10^{32} cm^{-2} s^{-1}$
- Since August running at slightly lower luminosity (problem in LHC @16L2)
- All subsystem performing like a Swiss watch!
- LHCb global efficiency slightly above 90% - as in the past
- On 07SEP17 09:39, crossed the threshold of $6 fb^{-1}$ recorded by LHCb, and on 02OCT17 23:33, $1 fb^{-1}$ recorded by LHCb in 2017





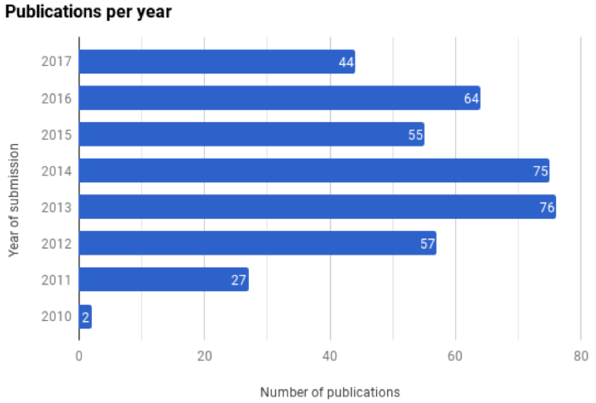




Highlights di fisica

Paper statistics

@ 11OCT17



- 400 papers submitted
  - 2016/17: record of publications in a data taking period (and upgrade construction) for LHCb

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH (CERN)

CERN-EP-2017-254
LHCb-PAPER-2017-037
October 12, 2017
version-7.1

Measurement of the $B^\pm$ production cross-section in pp collisions at $\sqrt{s} = 7$ and $13\,\text{TeV}$

LHCb collaboration†

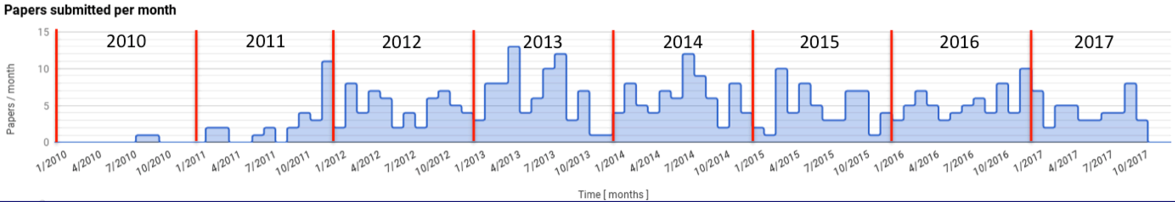
Abstract

The production of $B^\pm$ mesons is studied in pp collisions at centre-of-mass energies of 7 and 13 TeV, using $B^\pm \to J/\psi K^\pm$ decays and data samples corresponding to $1.0\,\text{fb}^{-1}$ and $0.3\,\text{fb}^{-1}$, respectively. The production cross-sections summed over both charges and integrated over the transverse momentum range $0 < p_T < 40\,\text{GeV}/c$ and the rapidity range $2.0 < y < 4.5$ are measured to be

$$\sigma(pp \to B^\pm X, \sqrt{s} = 7\,\text{TeV}) = 43.0 \pm 0.2 \pm 2.5 \pm 1.7\,\mu\text{b},$$
$$\sigma(pp \to B^\pm X, \sqrt{s} = 13\,\text{TeV}) = 86.6 \pm 0.5 \pm 5.4 \pm 3.4\,\mu\text{b},$$

where the first uncertainties are statistical, the second are systematic, and the third are due to the limited knowledge of the $B^\pm \to J/\psi K^\pm$ branching fraction. The ratio of the cross-section at 13 TeV to that at 7 TeV is determined to be $2.02 \pm 0.02\,(\text{stat}) \pm 0.12\,(\text{syst})$. Differential cross-sections are also reported as functions of p_T and y. All results are in agreement with theoretical calculations based on the state-of-art fixed next-to-leading order quantum chromodynamics.

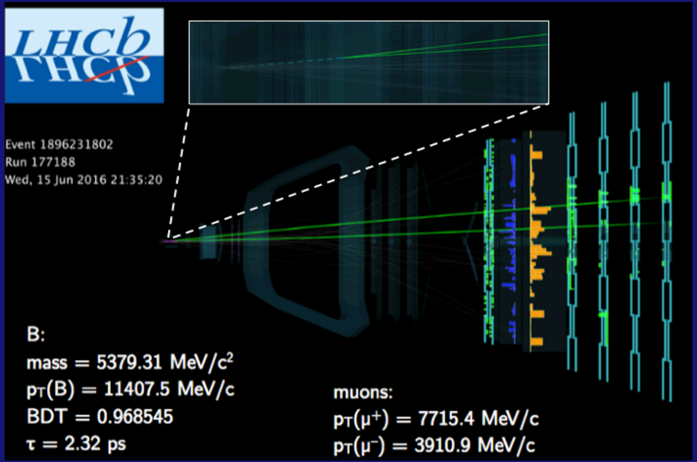
Submitted to JHEP

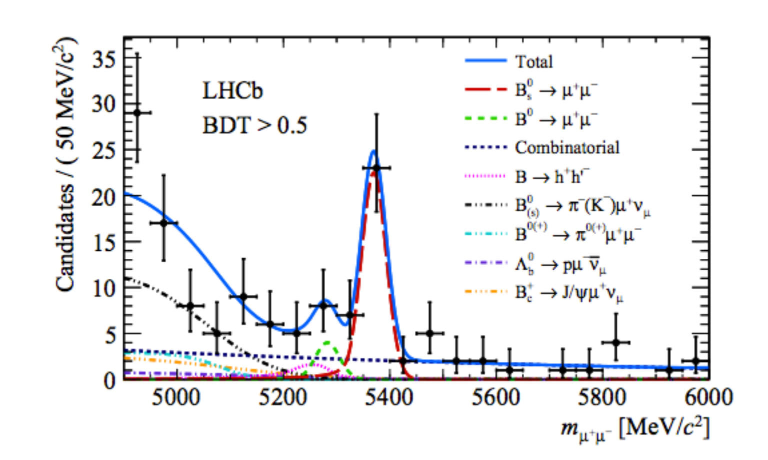


	Papers
Total number of papers:	400
Total number of citations:	19,944
Average citations per paper:	50.0
Breakdown of papers by citations:	
Renowned papers (500+)	1
Famous papers (250-499)	13
Very well-known papers (100-249)	31
Well-known papers (50-99)	81
Known papers (10-49)	191
Less known papers (0-9)	83

$B_s \to \mu\mu$ with Run2 data

- Analysis performed with using the full Run1 dataset + 1.4 fb^{-1} of Run2
- First observation of $B_s \to \mu\mu$ from a single experiment
- Also first measurement of effective $B_s \to \mu\mu$ lifetime, with still quite large uncertainty, but important proof of concept opening the avenue of precision measurements





First single experiment observation of $B_s^0 \to \mu^+\mu^-$ decay:

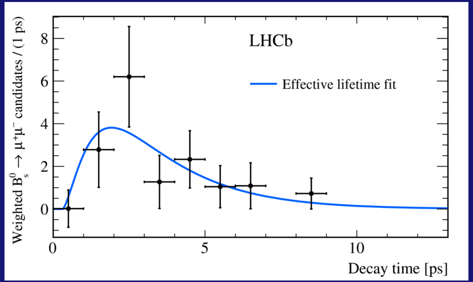
$$\mathcal{B}(B_s^0 \to \mu^+\mu^-) = (3.0^{+0.7}_{-0.6}) \times 10^{-9} \ (S = 7.8\sigma)$$

No evidence for $B^0 \to \mu^+\mu^-$, stringent limit set:

$$\mathcal{B}(B^0 \to \mu^+\mu^-) < 3.4 \times 10^{-10} \text{ at 95\% CL}$$

First measurement of effective lifetime

$$\tau(B_s^0 \to \mu^+\mu^-) = 2.04 \pm 0.44 \pm 0.05 \text{ ps}$$

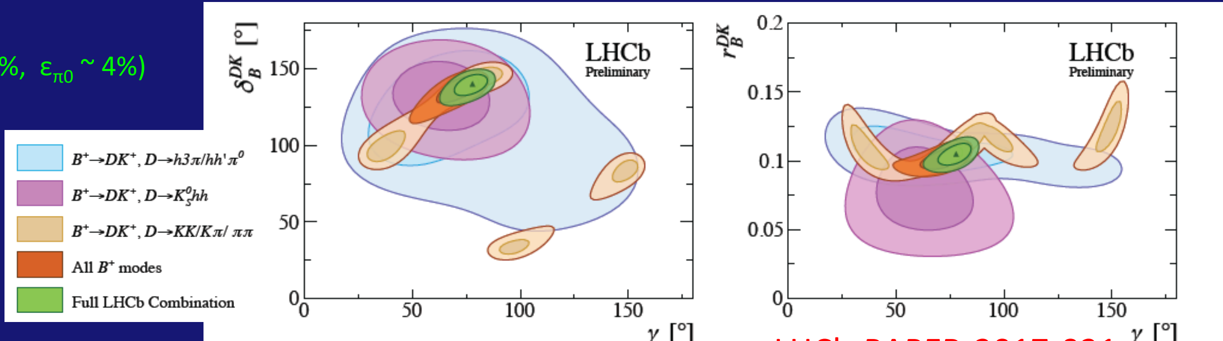


Phys. Rev. Lett. 118 (2017) 191801

γ from $B^\pm \rightarrow (D^{*0} \rightarrow D^0\, \pi^0/\gamma) K^\pm$

- Data set: Run 1 (3 fb^{-1}) + Run 2 (2 fb^{-1})
- Challenging because of low efficiencies (ε_γ ~ 20%, $\varepsilon_{\pi 0}$ ~ 4%)
- Use only a partial reconstruction of D*!

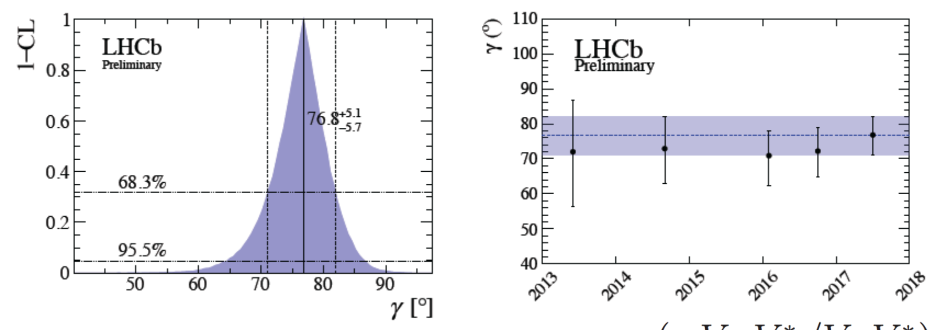
- In combination with:
  - $B^\pm \to D^0 K^{*\pm}$ [LHCb-CONF-2016-014]
  - $B^\pm \to D^{*0} K^{*\pm}$ [LHCb-PAPER-2017-021]
  - $B^0_s \to D_s^\mp K^\pm$ [LHCb-CONF-2016-015]
  - $B^\pm \to D^0 K^\pm$ [LHCb-PAPER-2017-021]



LHCb-PAPER-2017-021

➔ Most precise measurement of γ to date!

$$\gamma = (76.8^{+5.1}_{-5.7})^\circ$$

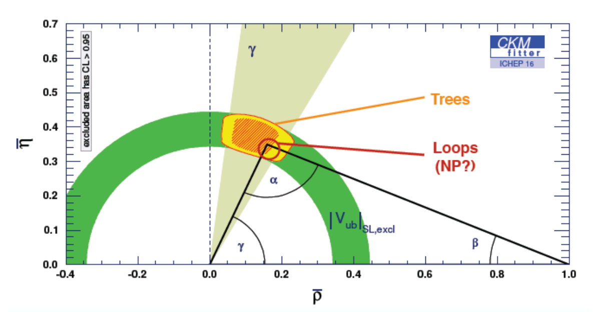


$$\gamma \equiv \arg(-V_{ud}V^*_{ub}/V_{cd}V^*_{cb})$$

LHCb-CONF-2017-004

- Compare γ measured in tree-level diagram with the value inferred from indirect global fits (loops)

- Does the unitarity triangle close?



CPV in $B^0 \rightarrow (cc)K_s^0$

- Decay-time-dependent CP violation in $B^0 \rightarrow J/\Psi\ (e^+e^-)\ K_s^0$ and $B^0 \rightarrow \Psi(2s)\ (\mu^+\mu^-)\ K_s^0$

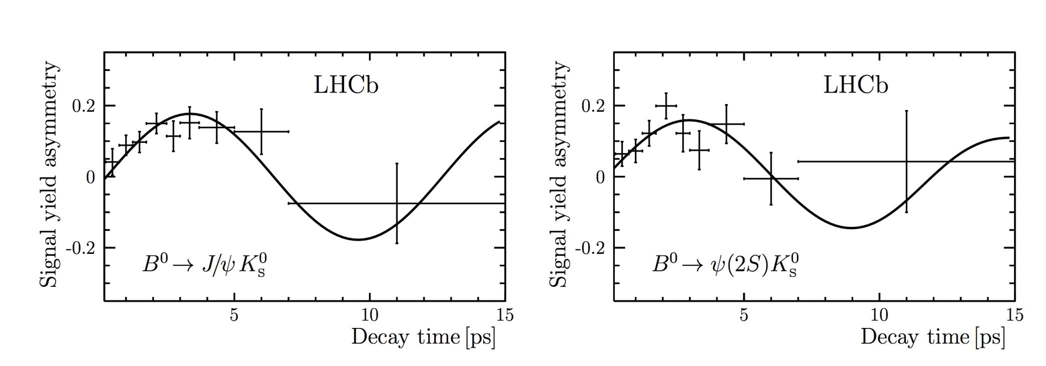
- Data sample: 1.0 fb^{-1} (7 TeV) + 2.0 fb^{-1} (8 TeV)

$$A_{CP}(t) = \frac{S\sin(\Delta m t) - C\cos(\Delta m t)}{\cosh(\Delta\Gamma t/2) + A_{\Delta\Gamma}\sinh(\Delta\Gamma t/2)}$$

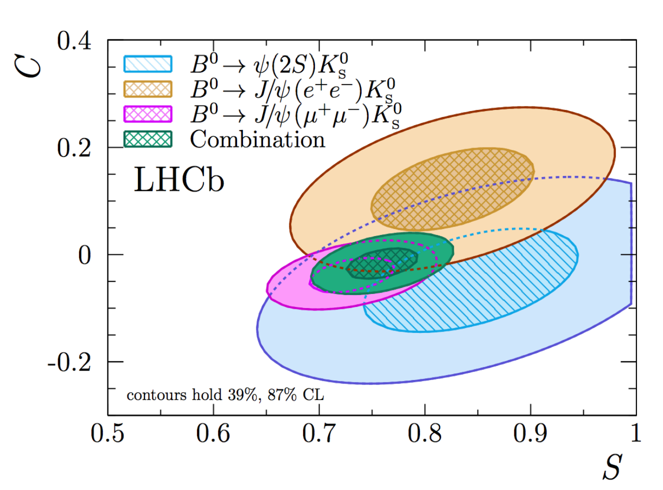
$$\overset{\Delta\Gamma=0}{\approx} S\sin(\Delta m t) - C\cos(\Delta m t)$$

$$S_{J/\psi K^0_S} \approx \sin 2\beta$$

- Working to include Run2 dataset in the analysis



LHCb-PAPER-2017-029



LHCb average

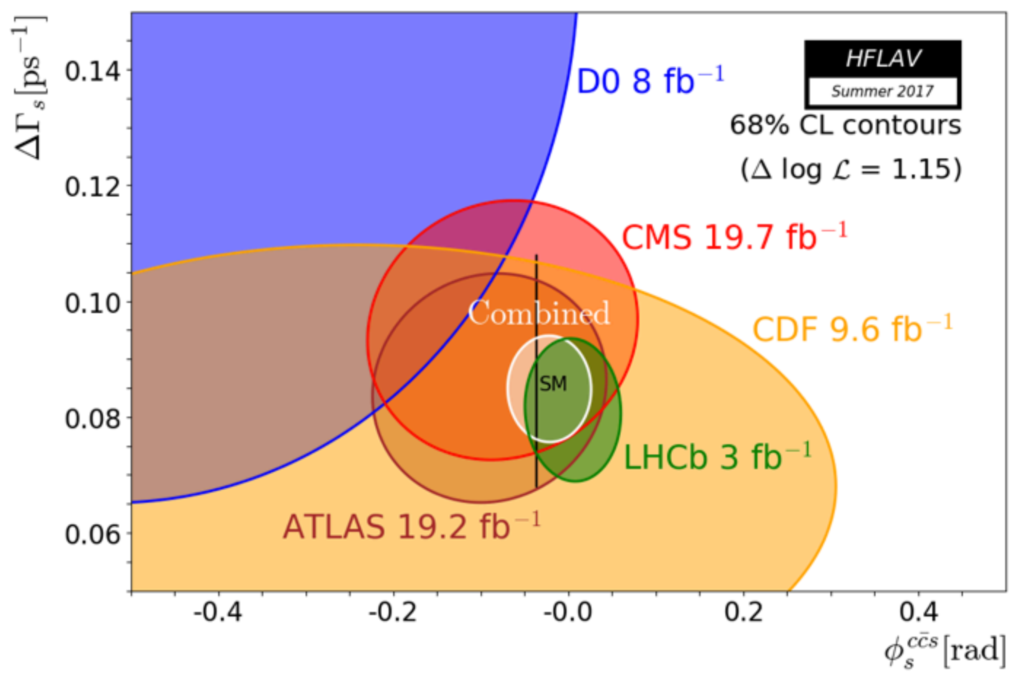
of all charmonium modes $J/\psi(ee,\mu\mu)$, $\psi(2S)(\mu\mu)$

$$C(B^0 \to [c\bar{c}]K^0_S) = -0.017 \pm 0.029$$
$$S(B^0 \to [c\bar{c}]K^0_S) = 0.760 \pm 0.034$$

- $\sin 2\beta$ improved by 20%
- Expected to improve the precision of the world average
- Consistent with CKM prediction of $\sin 2\beta = 0.740^{+0.020}_{-0.025}$

Legacy ϕ_s result from Run1

- LHCb measured ϕ_s from Run1 with $B_s \to J/\psi KK$ (and $B_s \to J/\psi \pi\pi$) already some time ago, but the measurement only included the *KK* system around the $\phi(1020)$ mass
- There is non negligible statistics for $m_{KK} > 1.05$ GeV/c^2
- Quite challenging to include it, as a decay- time dependent amplitude analysis is involved
- Using all available Run1 analysis
- Now working on the update with Run2 data



$$\phi_s = 1 \pm 37\,\text{mrad and } |\lambda| = 0.973 \pm 0.013$$

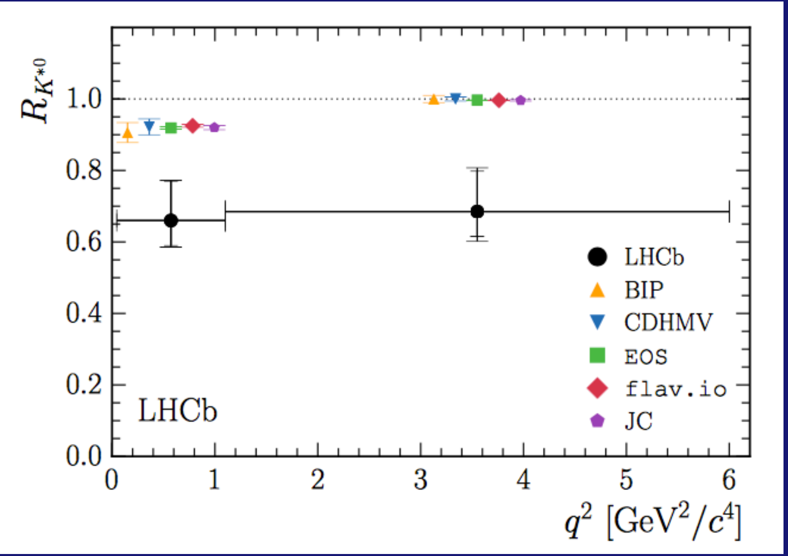
JHEP 08 (2017) 037

Lepton Flavor Universality: R(K*)

- New measurement with $B^0 \rightarrow K^{*0} l^+ l^-$ in two bins of q^2
- Performed using a double ratio to minimize systematic uncertainties

$$R_{K^{*0}} = \frac{\mathcal{B}(B^0 \to K^{*0}\mu^+\mu^-)}{\mathcal{B}(B^0 \to K^{*0} J/\psi(\to \mu^+\mu^-))} \Bigg/ \frac{\mathcal{B}(B^0 \to K^{*0} e^+ e^-)}{\mathcal{B}(B^0 \to K^{*0} J/\psi(\to e^+ e^-))}$$

- Working to include Run2 data – expected to reduce uncertainties by a factor 2



2.1 – 2.3 standard deviations from the Standard Model

$$R_{K^{*0}} = \begin{cases} 0.66 \,^{+\,0.11}_{-\,0.07}\,(\text{stat}) \pm 0.03\,(\text{syst}) & \text{for } 0.045 < q^2 < 1.1 \ \text{GeV}^2/c^4 \\ 0.69 \,^{+\,0.11}_{-\,0.07}\,(\text{stat}) \pm 0.05\,(\text{syst}) & \text{for } 1.1 \quad < q^2 < 6.0 \ \text{GeV}^2/c^4 \end{cases}$$

2.4 – 2.5 standard deviations from the Standard Model

JHEP 08 (2017) 055

Lepton Flavor Universality: R(D*)

- In SM amplitudes for processes involving e, μ and τ must be identical up to effects depending on the lepton masses
- Dataset: 3 fb^{-1} (Run1)

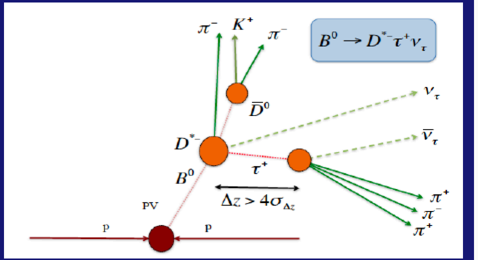
$$\mathcal{R}(D^{*-}) \equiv \mathcal{B}(B^0 \to D^{*-}\tau^+\nu_\tau)/\mathcal{B}(B^0 \to D^{*-}\mu^+\nu_\mu)$$

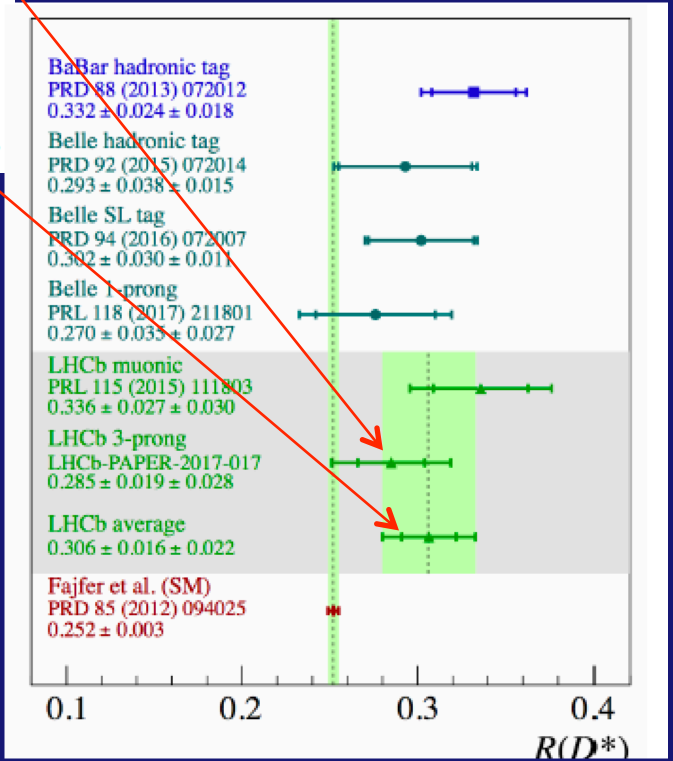
- Possible to reconstruct taus decaying to 3 pions in the LHCb environment
- Started exploring the generalization of the R(D*) to the B_c sector, R(J/Ψ)
- Preliminary result available, 2σ from SM

$$\mathcal{R}(J/\psi) = \frac{\mathcal{B}(B_c^+ \to J/\psi\,\tau^+\bar{\nu}_\tau)}{\mathcal{B}(B_c^+ \to J/\psi\,\mu^+\bar{\nu}_\mu)} = 0.71 \pm 0.17\,(\text{stat}) \pm 0.18\,(\text{syst})$$

- Excellent future perspective using Run2 data

- **LHCb hadronic**
  $R(D^*) = 0.285 \pm 0.019 \pm 0.025 \pm 0.013$
- LHCb muonic
  $R(D^*) = 0.336 \pm 0.027 \pm 0.030$
- Preliminary LHCb average
  $R(D^*) = 0.306 \pm 0.027$
- New world average
  $R(D^*) = 0.304 \pm 0.015$ (3.4 σ above SM)

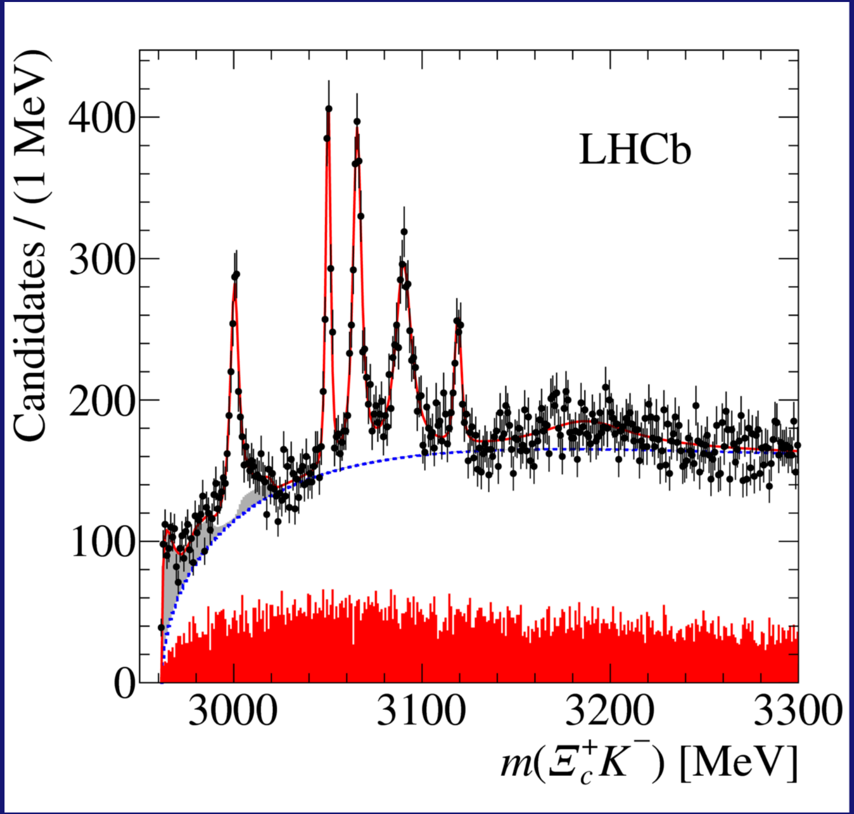




LHCb-PAPER-2017-017

Observation of 5 new Ω_c excited states

- Only $\boldsymbol{\Omega_c}$ ground states (J_P = 1/2⁺ and 3/2⁺) were known till now
- Ξ_c ($\rightarrow pK^-\pi^+$) combined with opposite sign kaons looking at the invariant mass
- 5 new narrow states observed in one shot!
- (Most likely a record for the number of narrow states found in a single analysis)
- Resonances quantum numbers measurement underway



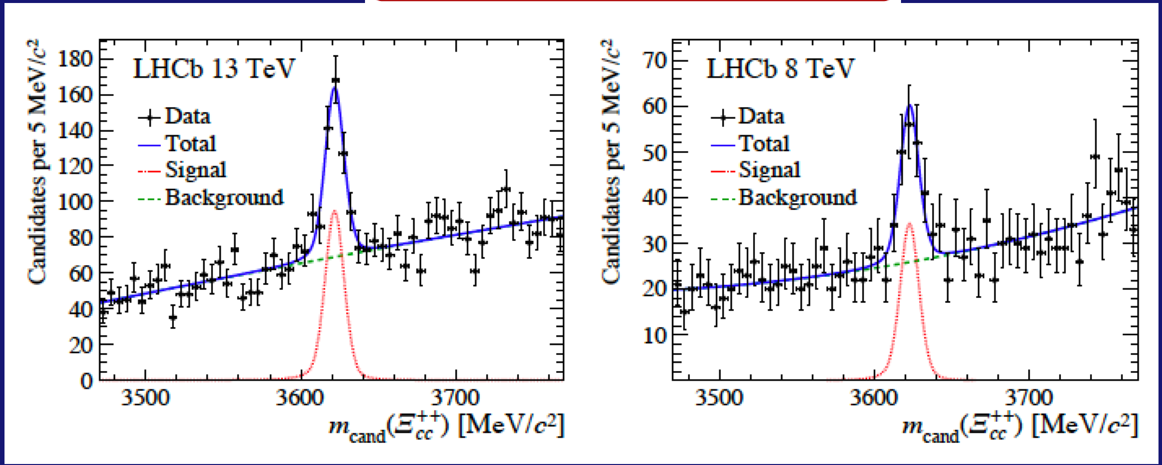
Phys. Rev. Lett. 118 (2017) 182001

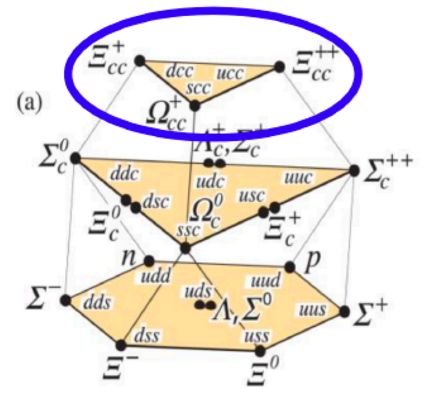
First observation of the Ξ_{cc}^{++}

- Doubly-charmed baryons predicted by quark model
- Observation of Ξ_{cc}^{+} claimed by SELEX but not seen by BaBar, FOCUS, Belle and LHCb
- Search for $\Xi_{cc}^{++} \rightarrow \Lambda_c^{+} K^{-} \pi^{+} \pi^{-}$
- Data sample: $2fb^{-1}$ (8 TeV) and $2fb^{-1}$ (13 TeV)

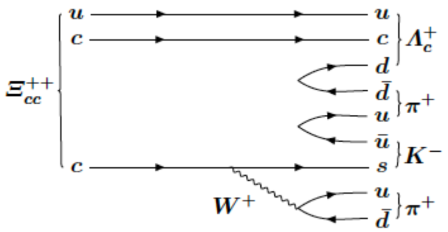
$m(\Xi_{cc}^{++}) = 3621 \pm 0.72\ \text{(stat)} \pm 0.31\ \text{(syst)}\ \text{MeV}/c^2$

LHCb-PAPER-2017-018





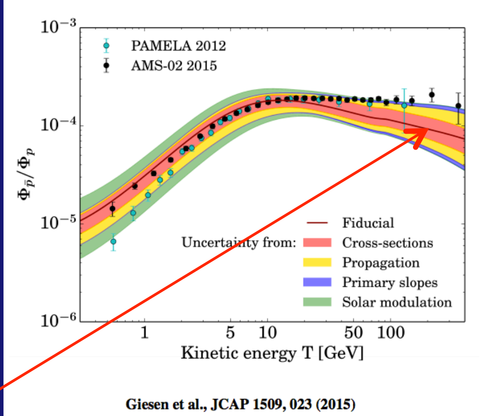
Lattice QCD calculations
$m(\Xi_{cc}^{++}) = 3606 \pm 11 \pm 8\ \text{MeV}/c^2$
[arXiv: 1704.02647]

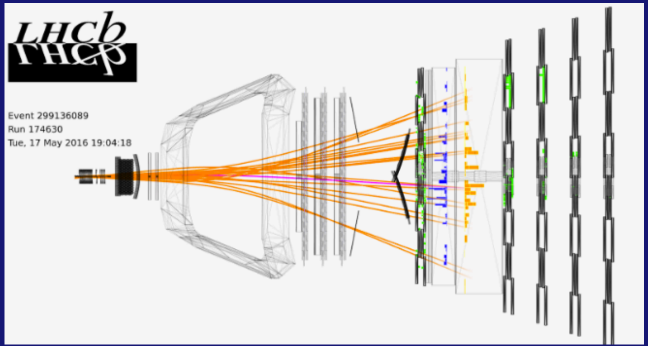


- Large signals found: 7.6σ (2012) and 12.9σ (2016)
- Lifetime measurement in progress

Anti-p production in pHe

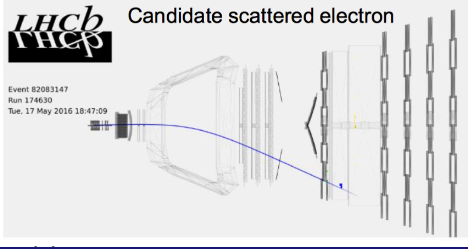
- Measurement motivated by the need to understand energy dependence of *p* component from cosmic rays in space
- Theoretical uncertainties are limited by precise knowledge of cross section for basic processes in the interstellar medium, like those arising from *p*He collisions (orange band)
- LHCb can effectively exploit the SMOG system for relevant measurements in this sector
- Absolute cross-section difficult to measure because it is <u>difficult to know precisely the luminosity →</u> exploit well known pe^- elastic scattering

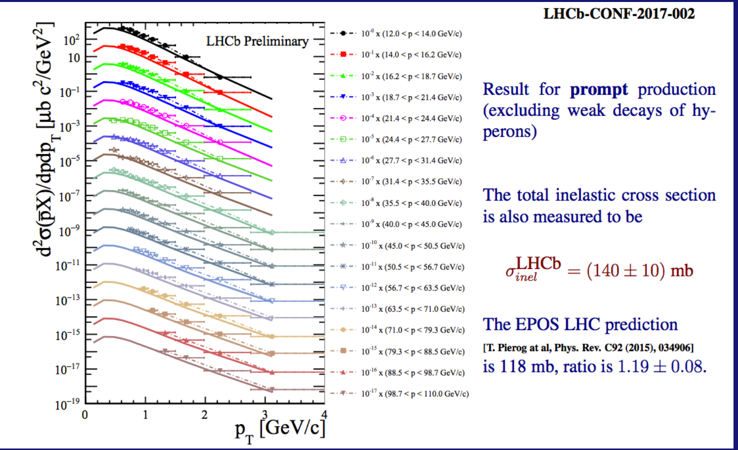




LHCb-CONF-2017-002

Paper in preparazione



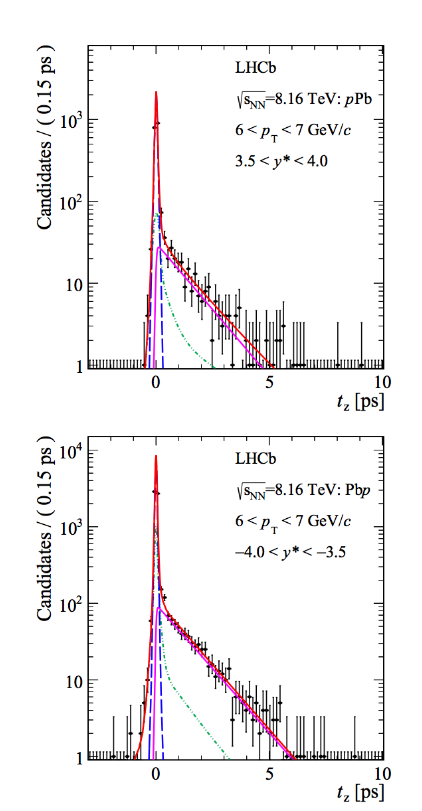


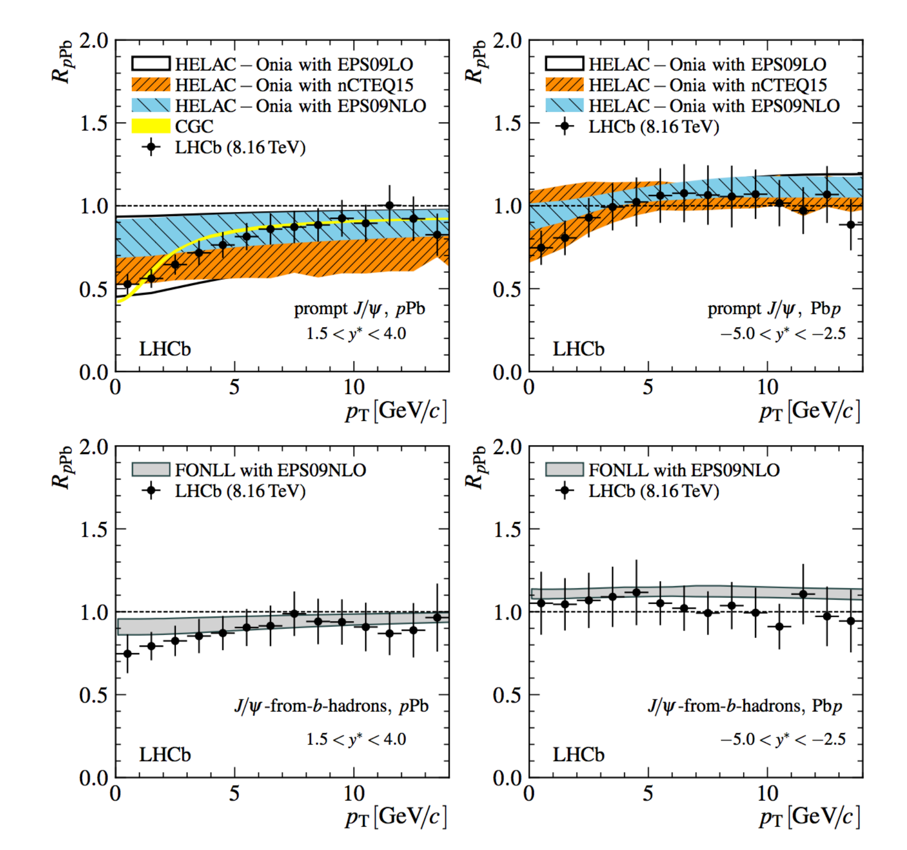
J/Ψ production in pPb collisions

- 8.16 TeV center of mass energy per nucleon pair
- 2016 data
  - pPb collisions: 13.6 nb^{-1}
  - Pbp collisions: 20.8 nb^{-1}
- Difference acceptance in pPb and Pbp collisions

- J/Ψ prompt and from b-hadrons cross sections: production relative to pp collisions, scaled by the Pb mass number (nuclear modific. factor)

- First beauty-hadron production measurement down to p_T = 0 in pPb and Pbp collisions at LHC in 2016





LHCb Upgrade!

Perché l'Upgrade?

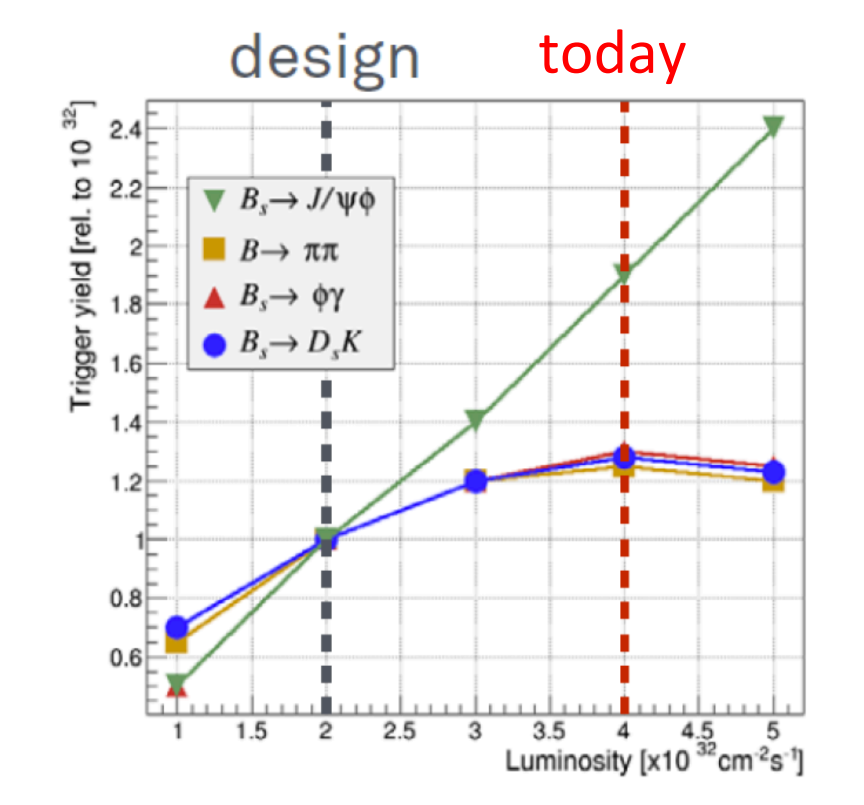
CERN-LHCC-2011-001
CERN-LHCC-2012-007

- No (yet) evidence for New Physics
  - ➔ Look for tiny deviation from SM predictions
  - ➔ More (x10) data required

- The current 1 MHz level-0 trigger output is a severe limitation!

- If luminosity increases
  - – trigger yield of hadronic events saturates
  - – need harder cuts on P_t and E_t due to the 1 MHz bandwidth limit
    - ➔ no gain in statistics
    - ➔ limited to ~5 fb^{-1} in Run2

- Note that our upgrade luminosity does not depend LHC upgrade, we only use a fraction of the available luminosity (i.e. what is used by ATLAS and CMS)



Upgrade HOWTO

CERN-LHCC-2011-001
CERN-LHCC-2012-007

- Remove the level-0 hardware trigger
- Readout an event at every bunch crossing (40 MHz)
- New front-end electronics (with on-chip zero suppression)
- New DAQ system
- Use an efficient fully software trigger accessing complete event information, running at the bunch crossing rate, performing a full online event reconstruction
- Redesign several detectors to cope with increased occupancies

LHC era → HL-LHC era

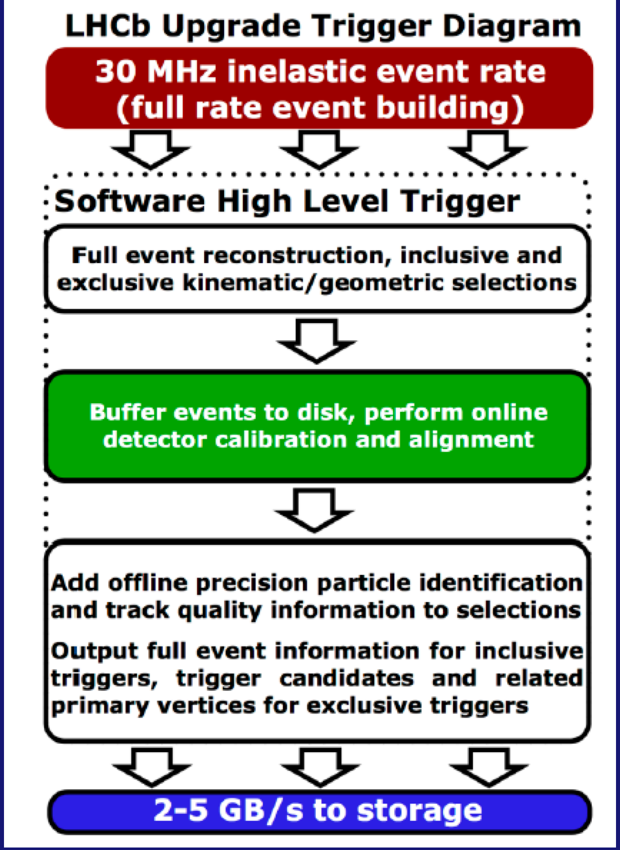
Run (years)	Run 1 (2010-2012)	Run 2 (2015-2018)	Run 3 (2021-2023)	Run 4 (2027-2029)
Integrated luminosity	3 fb^{-1}	8 fb^{-1}	25 fb^{-1}	50 fb^{-1}
Instantaneous luminosity	4×10^{32} $cm^{-2}s^{-1}$		2×10^{33} $cm^{-2}s^{-1}$	

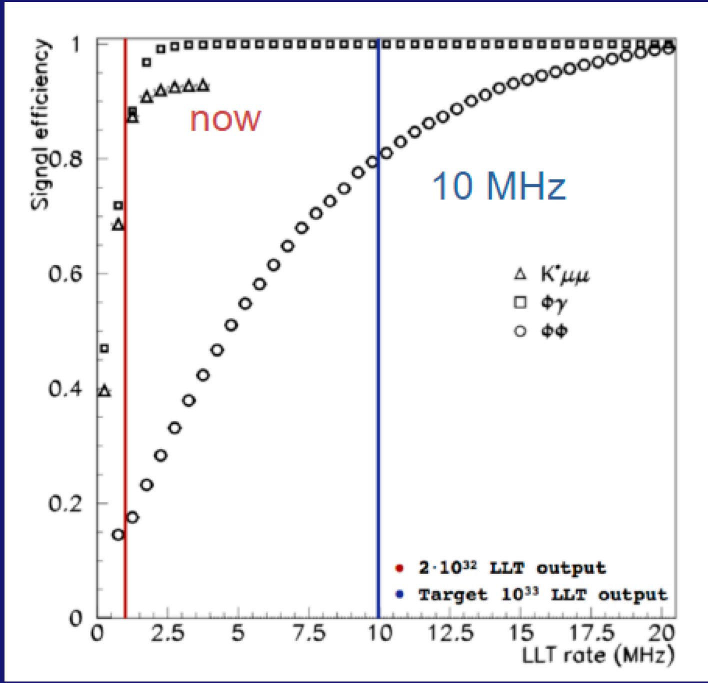
Current LHCb → | Upgraded LHCb →

LS2
LHCb Upgrade

- Data taking conditions
  - Leveled L = $2 \cdot 10^{33}/cm^2/s$
  - 30 MHz collisions
  - 20-100 kHz to disk
  - ~5 fb^{-1} per year
- Challenges
  - High pile-up
  - Large occupancies - difficult event reconstruction and PID
  - Huge Data Rate
  - Radiation damage

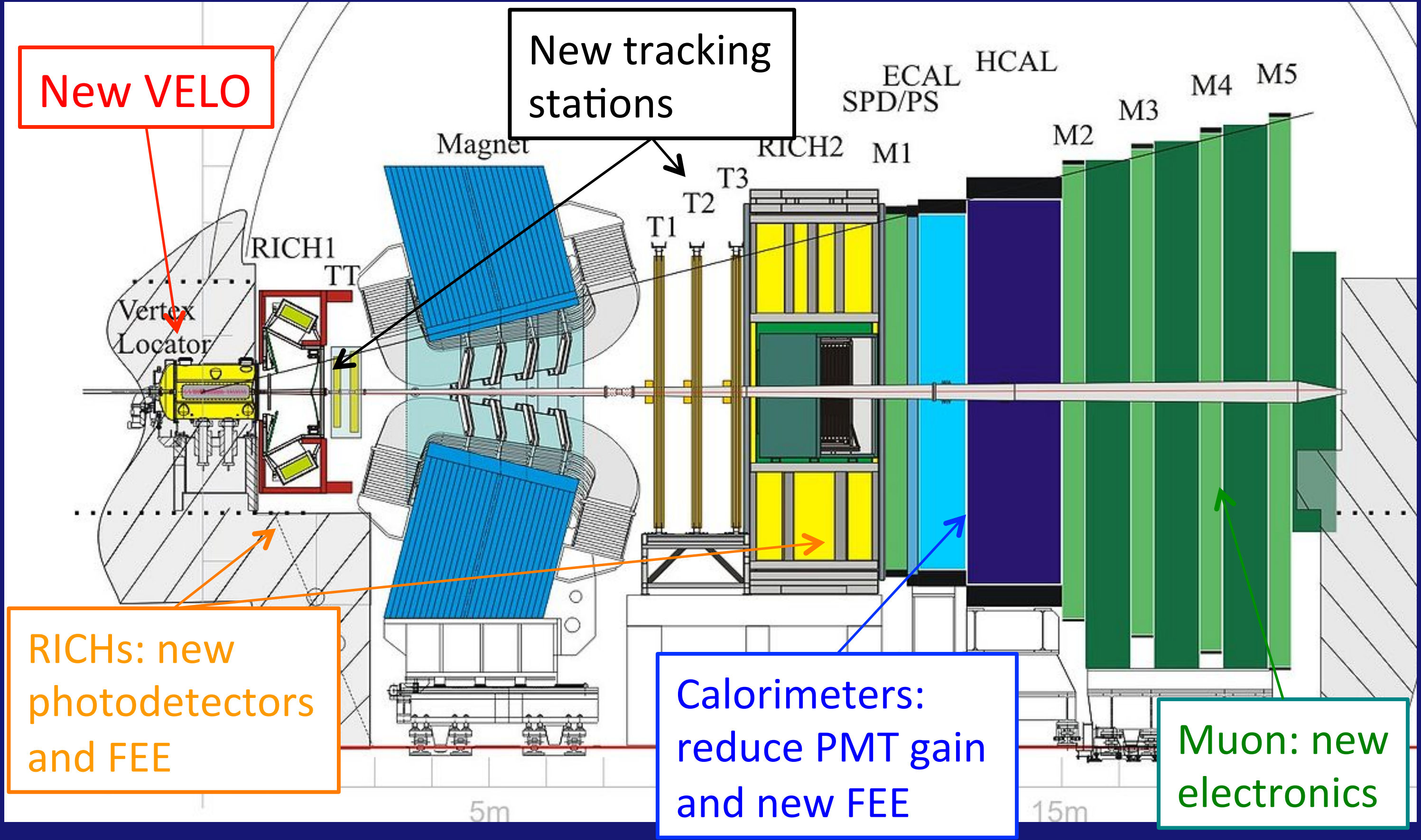
Software Trigger

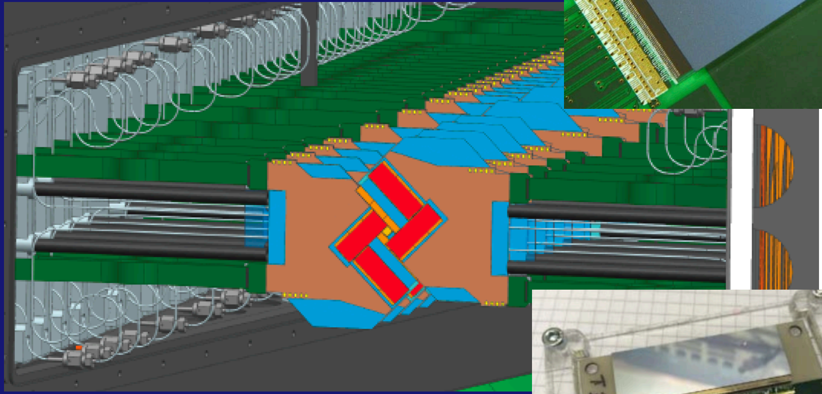


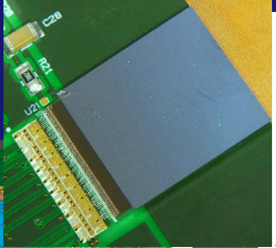


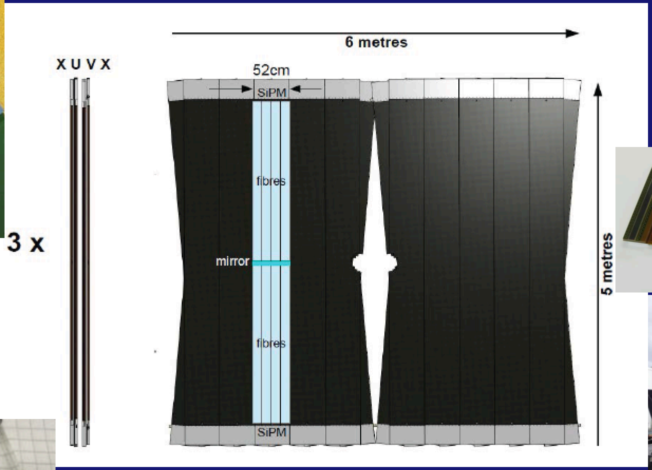
- Trigger farm: 50k logical CPU cores
- Offline-like reconstruction tuned to available time constraints
- Mixture of exclusive and inclusive selection algorithms

Detector Upgrade

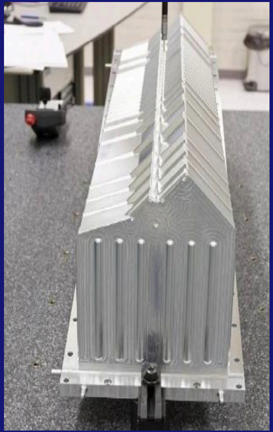


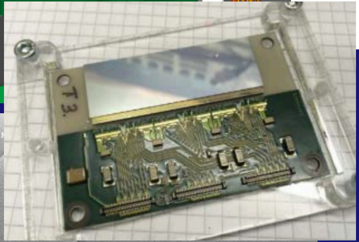


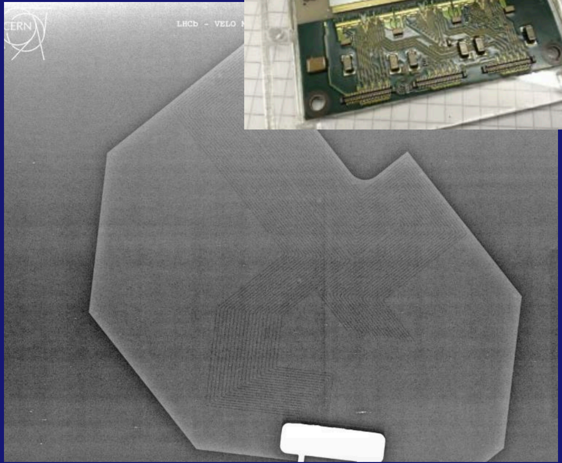

C28
R21
U21

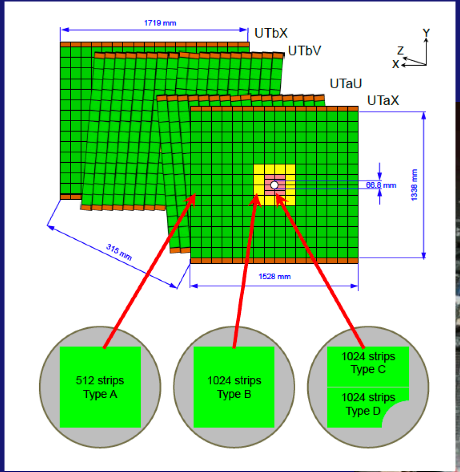

6 metres
X U V X
52cm
SiPM
fibres
3 x
mirror
fibres
SiPM
5 metres

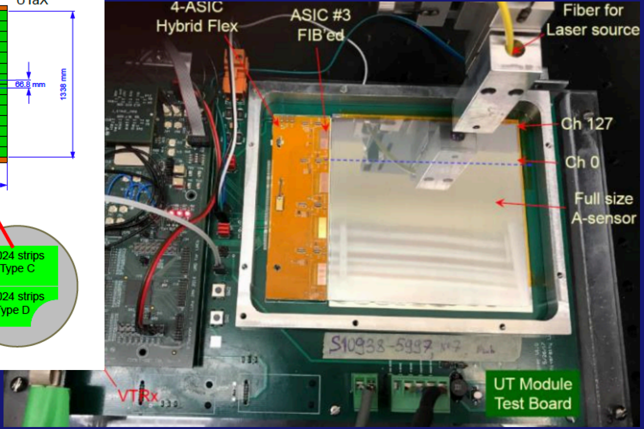

Each of the four boxes houses five detector modules. 128 modules will make up the new scintillating fibre (SciFi) tracker, part of the major upgrade of the LHCb detector (Image: Christian Joram/ CERN)





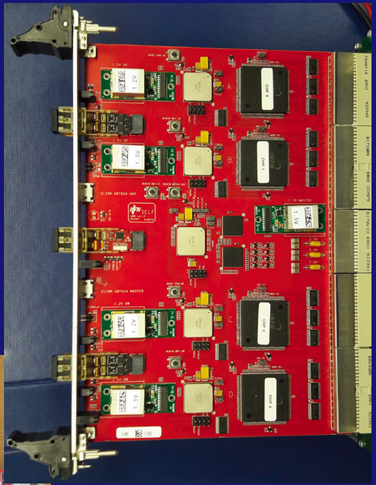

LHCb - VELO

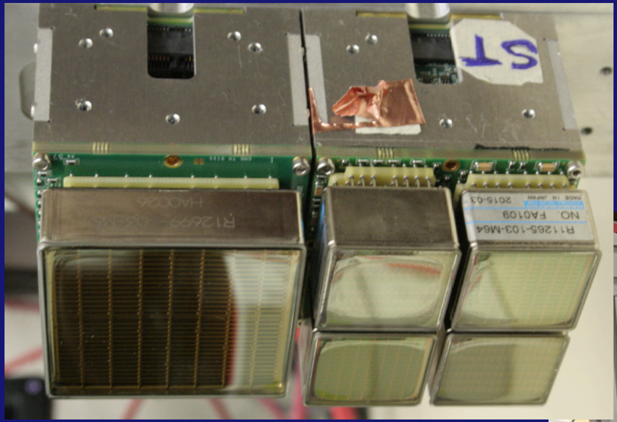

1719 mm
UTbX
UTbV
UTaU
UTaX
Y
Z
X
66.8 mm
1338 mm
315 mm
1528 mm
512 strips
Type A
1024 strips
Type B
1024 strips
Type C
1024 strips
Type D

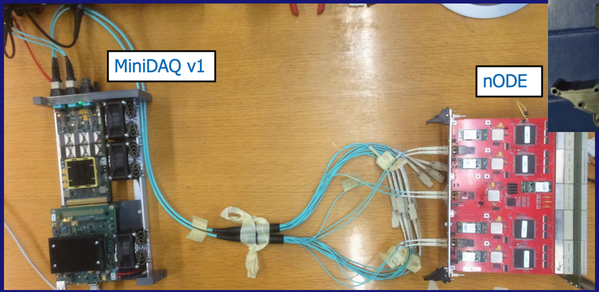

4-ASIC
Hybrid Flex
ASIC #3
FIB'ed
Fiber for
Laser source
Ch 127
Ch 0
Full size
A-sensor
VTRx
UT Module
Test Board

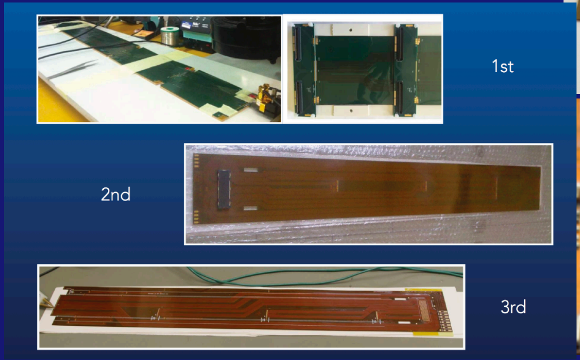
Contributi Italiani all'Upgrade

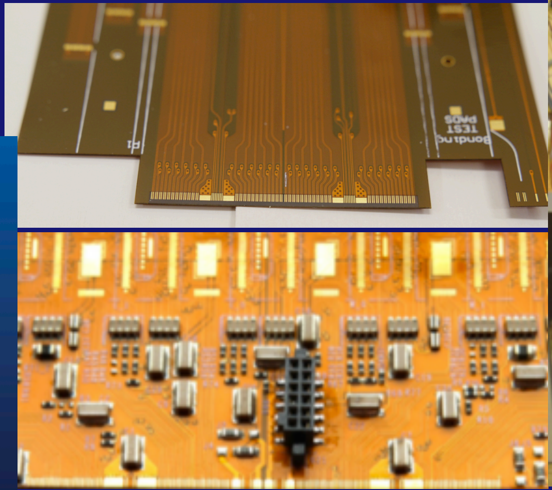
- All'INFN l'Upgrade di LHCb è stato valutato positivamente dal CTS nel 2013, e successivamente approvato dalla CSN1
- Nel 2014 sono stati preparati i due MoU sull'Upgrade, approvati successivamente dall'INFN
- Upgrade LHCb
  - RICH: MaPMT, CLARO, EC, Photo-Detector Module, HV, mechanics (FE, MIB, PD)
  - Trigger & DAQ: PCIe Gen3 readout boards, event builder, HLT on many-cores architectures and GPU (BO, PI, PD)
  - UT: sensor support mechanics, the cooling system, the hybrid circuits and low mass fan-out cables (MI)
  - Muon: spare MWPC, nSYNC, nODE, remove some IBs, nSB and nPDM (CA, FE, FI, LNF, RM1, RM2)

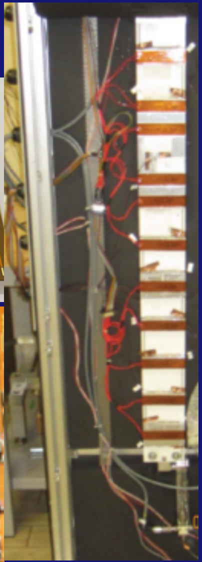





MiniDAQ v1
nODE


1st
2nd
3rd





Verso il futuro!

- LHCb ha cominciato a studiare la possibilità di operare a luminosità fino a 1-2E+34 $cm^{-2}s^{-1}$

LS2: Major changes, Upgrade I Installation

- Run 3 (2021-2023)
  - LHCb Upgrade I
  - $L=2\times10^{33}$ cm^{-2} s^{-1}, ~5 fb^{-1}/yr

Upgrade I, ongoing

LS3: "Consolidation", Upgrade 1b Installation

- Run 4 (2026-2029)
  - LHCb Upgrade Ib
  - $L=2\times10^{33}$ cm^{-2} s^{-1}, ~5 fb^{-1}/yr Total Int. L ~ 50fb^{-1}

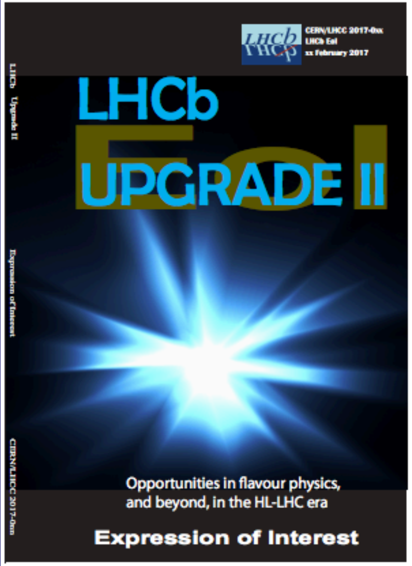
Consolidamento

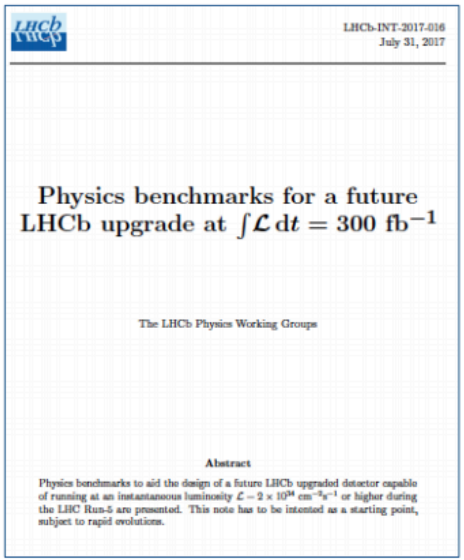
LS4: Major Changes, Upgrade II Installation

- Run 5/6 (2031-)
  - LHCb Upgrade II
  - $L=1\text{-}2\times10^{34}$ cm^{-2} s^{-1}, ~50 fb^{-1}/yr

Upgrade II

Total Int L ~ 300fb^{-1}



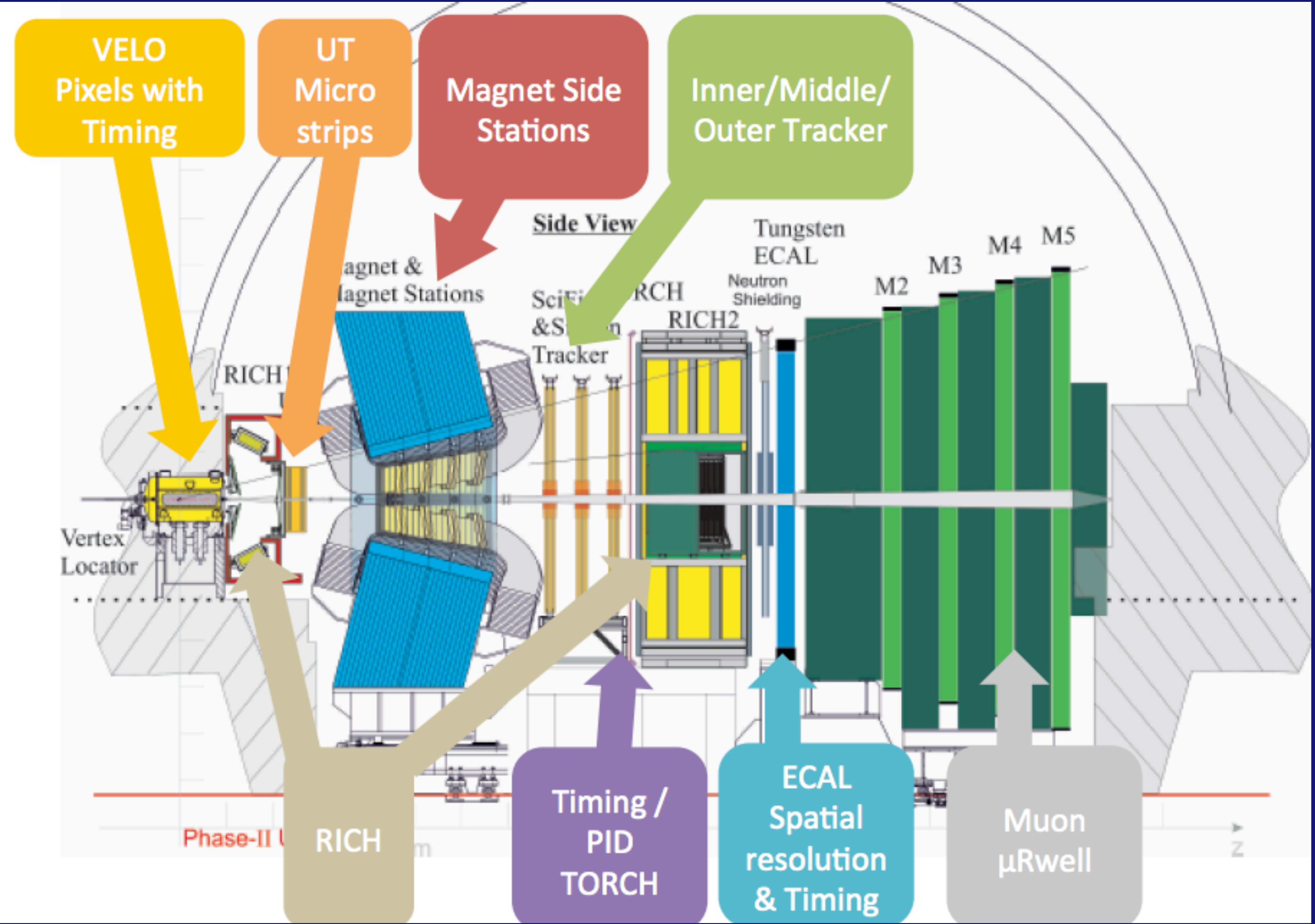

LHCb-INT-2017-016
July 31, 2017

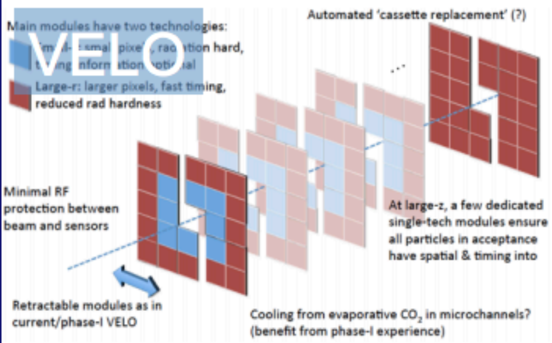
Physics benchmarks for a future LHCb upgrade at $\int \mathcal{L}\,dt = 300\ fb^{-1}$

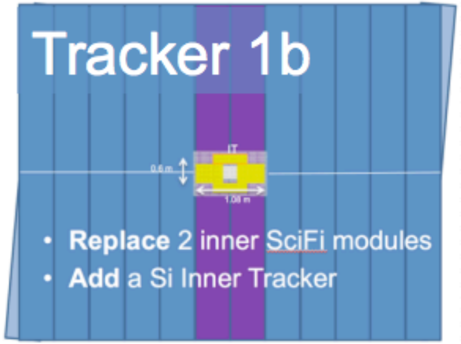
The LHCb Physics Working Groups

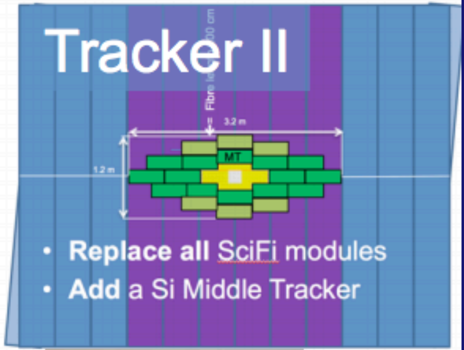
Abstract

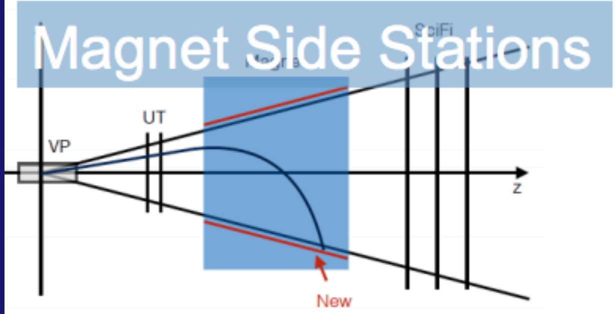
Physics benchmarks to aid the design of a future LHCb upgraded detector capable of running at an instantaneous luminosity $\mathcal{L} = 2\times10^{34}\ cm^{-2}s^{-1}$ or higher during the LHC Run-5 are presented. This note has to be intented as a starting point, subject to rapid evolutions.

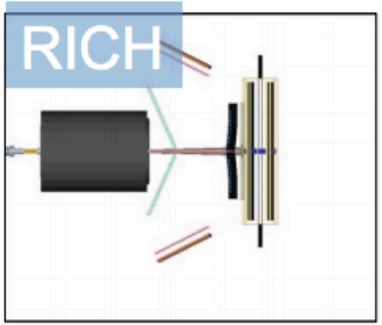

VELO
Pixels with
Timing
UT
Micro
strips
Magnet Side
Stations
Inner/Middle/
Outer Tracker
Side View
Tungsten
ECAL
Neutron
Shielding
M2
M3
M4
M5
RICH2
Tracker
Vertex
Locator
RICH
Timing /
PID
TORCH
ECAL
Spatial
resolution
& Timing
Muon
µRwell
z

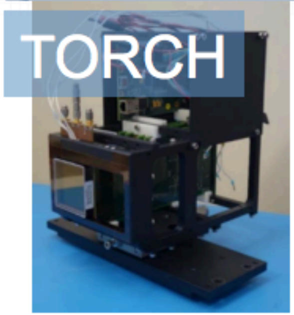

VELO
Main modules have two technologies:
Large-r: larger pixels, fast timing, reduced rad hardness
Automated 'cassette replacement' (?)
Minimal RF protection between beam and sensors
At large-z, a few dedicated single-tech modules ensure all particles in acceptance have spatial & timing info
Retractable modules as in current/phase-I VELO
Cooling from evaporative CO_2 in microchannels? (benefit from phase-I experience)

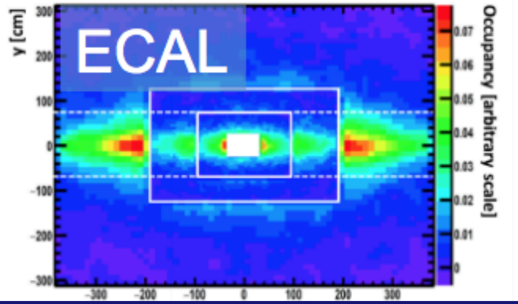

Tracker 1b
IT
• Replace 2 inner SciFi modules
• Add a Si Inner Tracker


Tracker II
MT
• Replace all SciFi modules
• Add a Si Middle Tracker

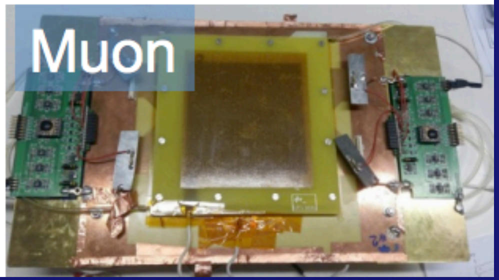

Magnet Side Stations
SciFi
UT
VP
z
New


RICH


TORCH


ECAL
y [cm]
Occupancy [arbitrary scale]


FPGA
Tracking

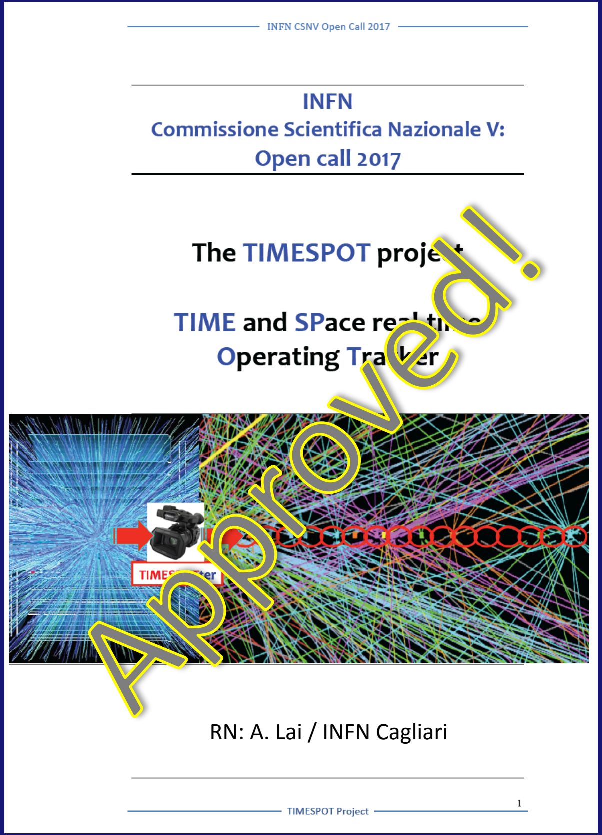

Muon

Alcuni interessi italiani

- 4D pixels (3D pixel with timing info) in a Super VELO
  - possibile @LS4
- uRwell detectors for the Muon Stations
  - possibile @LS3 o LS4
  - Tecnica sviluppata a LNF
  - In studio per CMS/SHiP
  - Particolare R&D richiesto per LHCb per l'alta rate
- Online Downstream Reconstruction
  - Possibile @LS3
  - FPGA-based real-time track reconstruction at 40MHz with low-latency
  - Attività in sinergia con CSN5 Retina fino a fine 2017

4D pixel → TIMESPOT: CALL Gr5

- Questa idea vede la luce nell'ambito di LHCb Italia a fine del 2015; in occasione del bando del PRIN viene preparata una proposta da alcuni dei gruppi italiani di LHCb
- Realizzare un dimostratore di un tracciatore 4D utilizzando pixel Si/diamante e con ottime risoluzioni spaziali/temporali e real-time tracking
- Nel 2017 si decide di scrivere la proposta per una CALL di CSN5
- La proposta riscuote moltissimo interesse non solo all'interno di LHCb, ma attira l'attenzione di tante persone coinvolte in attività di CSN1 e CSN5, e non solo
- Personale vicino ai 20 FTE, di cui 1/3 di LHCb, un grande successo per la nostra comunità
- La proposta viene approvata alla CSN5 di settembre, si parte nel 2018!
- <u>Ottima opportunità per un R&D estremamente competitivo nel panorama internazionale per futuri esperimenti ad altissima luminosità</u>


INFN CSNV Open Call 2017

INFN
Commissione Scientifica Nazionale V:
Open call 2017

The TIMESPOT proje

TIME and SPace re
Operating Tra ker

RN: A. Lai / INFN Cagliari

TIMESPOT Project 1

La Collaborazione Italiana

Personale 2018 / 2017 / 2016 / 2015

- Persone 136 / 132 / 127 / 123
- Ricercatori 118 / 114 / 109 / 101
- Autori 113 / 107 / 97 / 97
- FTE 100.4 / 95.8 / 90.4 / 86
- MOF-A 85 / 78 / 72 / 83
- Post-Doc 19 / 18 / 14 / n.d.
- PhD 19 / 20 / 22 / 14

Sempre importante presenza italiana nel management

- Spokesperson: G. Passaleva da 01JUL17
- Physics Coordinator: V. Vagnoni

- Operations
  - Deputy Operation Coordinator: B. Sciascia
  - DQ & Monitoring co-coordinator: W. Baldini
  - Lumi & ion Runs co-coordinator: . G. Manca
  - PID Coordinator: M. Fontana
  - Simulation co-coordinator: R. Cenci
  - Muon PL: M. Palutan
  - Muon Deputy PL: W. Baldini
  - UT Deputy PL: N. Neri

- Physics WG
  - B Decays to Charmonia: F. Dordei
  - Charmless B-decays: S. Perazzini
  - B hadrons & Quarkonia: L. Anderlini
  - Charm Physics: A. Contu
  - Ion & Fixed Target: G. Graziani
  - Statistics: D. Tonelli

- Performance
  - Tracking & alignment: L. Grillo
  - PID & Calo objects: M. Fontana
  - Simulation: R. Cenci

- Editorial board: R. Santacesaria, F. Bedeschi

- Membership Committee: M. Calvi

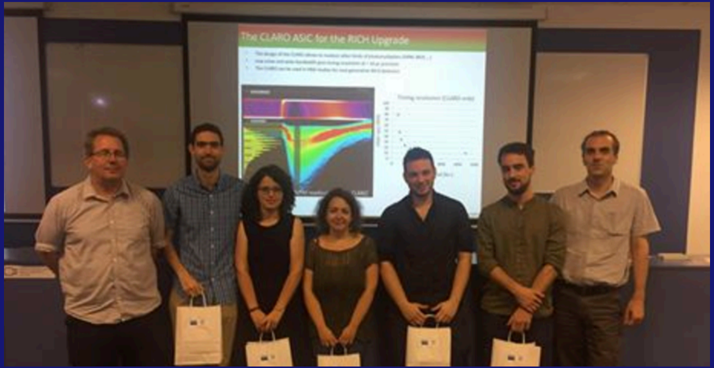
Nuovi Assunti @INFN 2017

- Vincitori “Concorsone” per LHCb
  - Lucio Anderlini (FI)
  - Andrea Contu (CA)
  - Francesca Dordei (CA)
  - Mirco Dorigo (TS)
  - Paolo Gandini (MI)
  - Alessandra Pastore (BA)
  - Stefano Perazzini (BO)
  - Simone Stracka (PI)

Early Career Scientist awards

The second set of prizes for outstanding contributions of early career scientists were awarded on June 16th 2017. Twenty-nine nominations were submitted and considered by the committee formed by Patrick Robbe (chair), Rolf Lindner (technical coordinator), Monica Pepe-Altarelli (deputy spokesperson), Stefan Roiser (computing coordinator), Silvia Borghi (operations coordinator) and Vincenzo Vagnoni (physics coordinator).

- Lucia Grillo (INFN, MIB): online tracking & alignment
- Giulio Dujany (LPNHE/CNRS): real-time vertexing & tracking
- Elena Dall'Occo (NIKHEF): Si-sensor evaluation for VELO Upgrade
- Renato Quagliani (LAL): a new seeding algorithm for tracking
- Claudio Gotti (INFN, MIB): CLARO development



Tutti italiani!!!

Conclusioni

- LHCb continua a produrre importanti risultati di fisica
- La presa dati nel 2017 prosegue con un apparato in perfette condizioni
- Upgrade
  - Lavoro procede sostanzialmente come previsto
  - Alcune produzioni già partite, altre in partenza a breve
  - Lieve ritardo nella schedule ma non ci sono criticità
- Il personale aumenta, grazie anche alle nuove assunzioni INFN
- Si comincia a guardare ad un futuro upgrade per sfruttare al meglio LHC
- Il futuro della fisica del sapore ad altissima statistica è estremamente challenging; con l'esperienza accumulata finora e le nuove opportunità di R&D che stanno cominciando, <u>LHCb ha tutte le carte in regola per continuare a giocare un ruolo da leader in questo campo</u>

Spare slides - Fisica

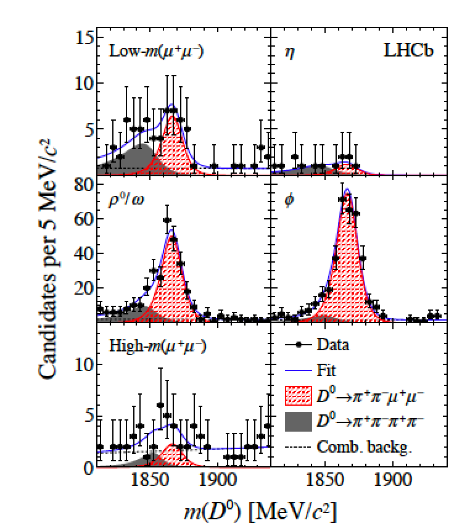
First observation of $D^0 \to h^+h^-\mu^+\mu^-$

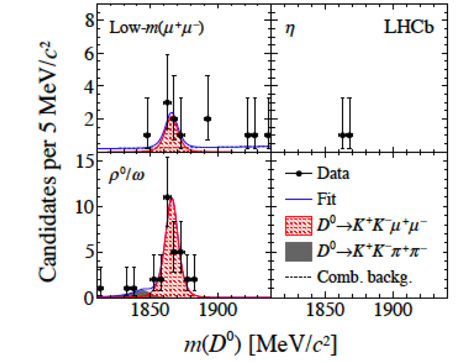
- First observation of D^0 mesons decaying into $\pi^+\pi^-\mu^+\mu^-$ and $K^+K^-\mu^+\mu^-$
- Data set: 2 fb^{-1} at 8 TeV
- Normalisation decay $D^0 \to K^-\pi^+[\mu^+\mu^-]_{\rho 0/\omega}$
- Signal in almost every $q^2 = m^2(\mu\mu)$ bin
- Total BF (Long-Distance dominated) in agreement with SM
- Expected to tighten constraints on possible short distance contributions

$$\mathcal{B}(D^0 \to \pi^-\pi^+\mu^+\mu^-) = (9.64 \pm 0.48 \pm 0.51 \pm 0.97) \times 10^{-7}$$
$$\mathcal{B}(D^0 \to K^-K^+\mu^+\mu^-) = (1.54 \pm 0.27 \pm 0.09 \pm 0.16) \times 10^{-7}$$

Rarest charm decays measured to date

LHCb-PAPER-2017-019

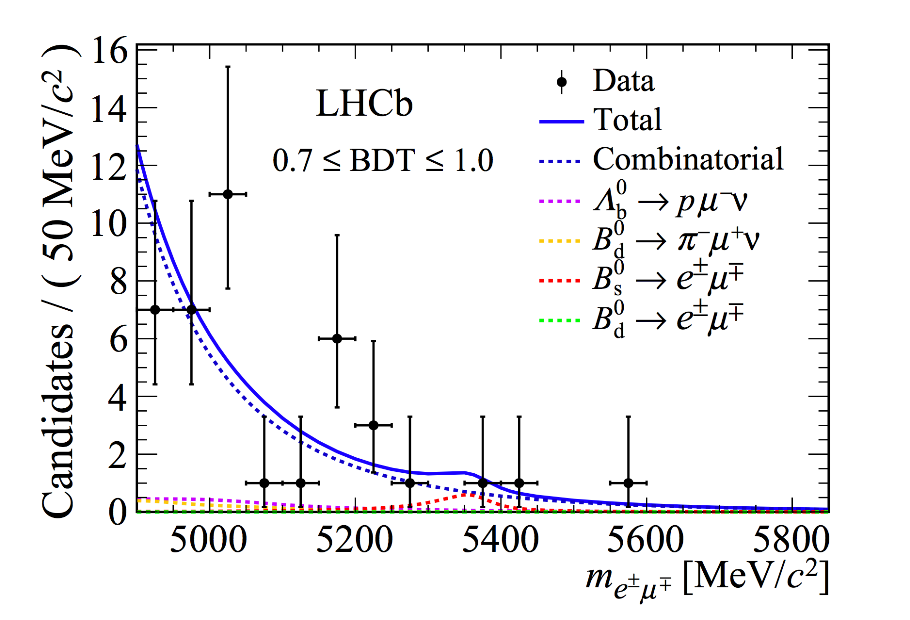




Search for the decays $B^0_{(s)} \to e^+\mu^-$

- Lepton-flavor violating decays
- Data sample: 1.0 fb^{-1} (7 TeV) + 2.0 fb^{-1} (8 TeV)
- No excess of signal observed with respect to background
- Put a limit to the BF
- Best upper limit to date, 2÷3 better than the previous result from LHCb

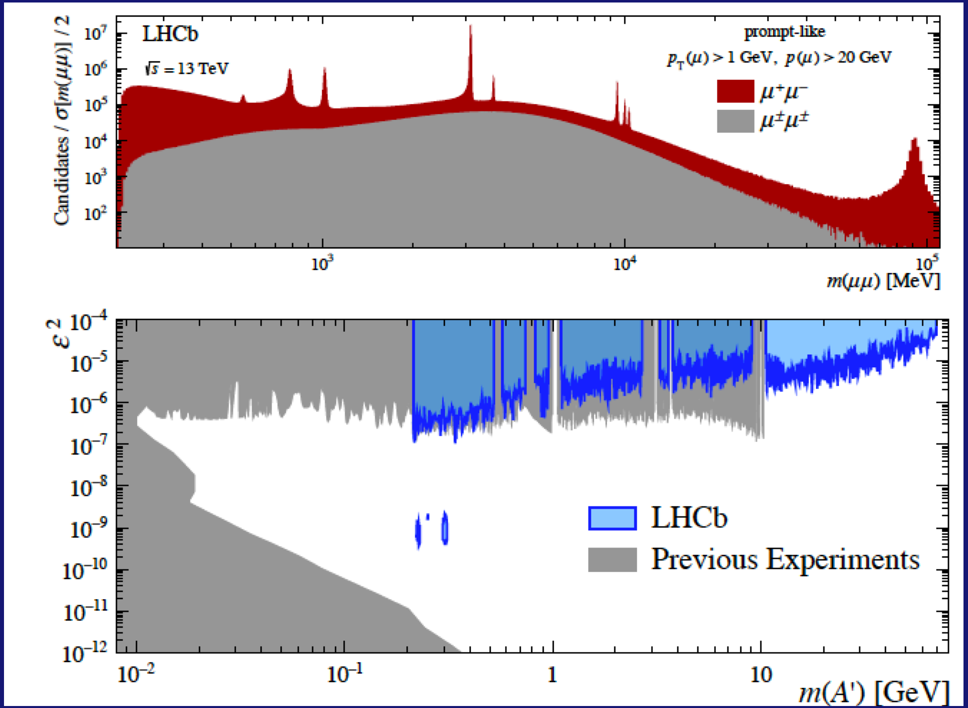
$$\mathcal{B}(B^0_s \to e^\pm \mu^\mp) < 5.4\ (6.3) \times 10^{-9}$$
$$\mathcal{B}(B^0 \to e^\pm \mu^\mp) < 1.0\ (1.3) \times 10^{-9}$$
at 90 (95)% CL



LHCb-PAPER-2017-031

Search for Dark Photons in 13 TeV pp collisions

- Search for A' → $\mu^+\mu^-$ decay in 2016 data, 1.5 fb^{-1}
- Output of Turbo stream
- Prompt-like search: μμ threshold up to 70 GeV
- Long-lived search: 214 < m(A') < 350 MeV
- Prospects
  - **2017**: big improvements in the software-trigger efficiency for low-mass dark photons
  - **Run 3**: removal of the hardware trigger, giving access to O(100÷1000) times more decays than 2016



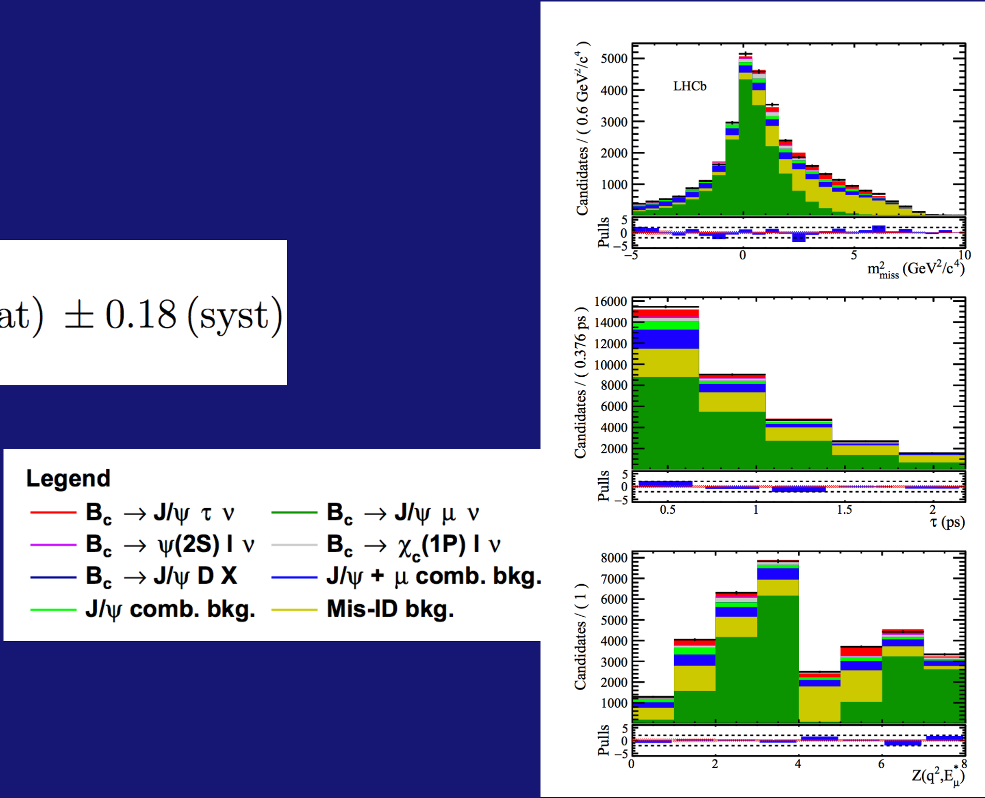
LHCb-PAPER-2017-038

Lepton Flavor Universality: R(J/Ψ)

- Generalization of the R(D*) to the B_c sector
- Dataset: 3 fb^{-1} (Run1)

$$\mathcal{R}(J/\psi) = \frac{\mathcal{B}(B_c^+ \to J/\psi\, \tau^+ \overline{\nu}_\tau)}{\mathcal{B}(B_c^+ \to J/\psi\, \mu^+ \overline{\nu}_\mu)} = 0.71 \pm 0.17\,(\mathrm{stat}) \ \pm 0.18\,(\mathrm{syst})$$

- 2 sigma from SM prediction
- Excellent future prospects:
  - Use RunII data
  - Better MC with finer missing mass bins
  - B_c decay form factor uncertainties reduced by LQCD work

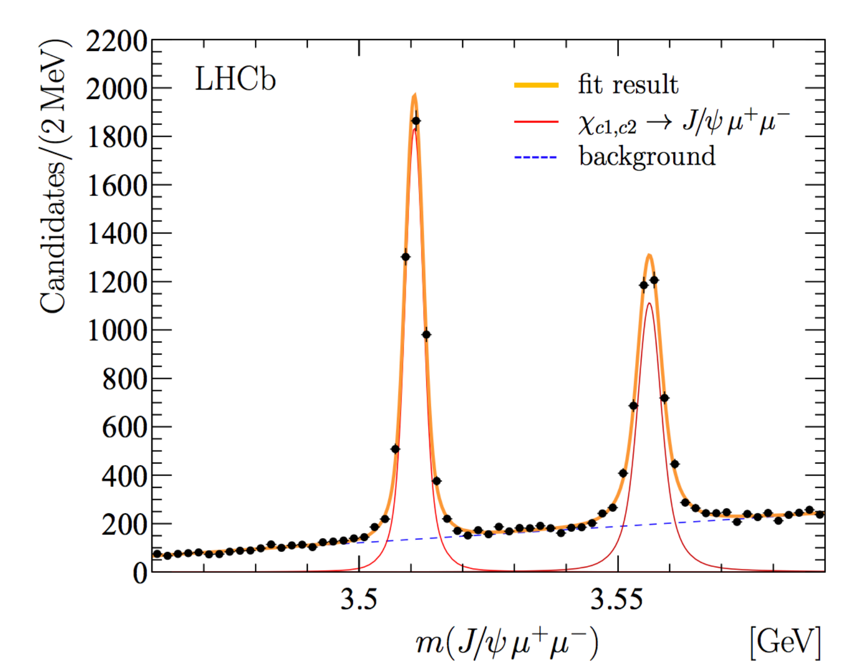


LHCb-PAPER-2017-035

Studies of χ_c Dalitz Decays

- First observation of $\chi_{c1,2} \rightarrow J/\Psi \mu^+ \mu^-$
- Dataset: 3 fb^{-1} (Run1) + 2 fb^{-1} (Run2)
- Relevant breakthrough in the χ_c spectroscopy

$$m(\chi_{c1}) = 3510.71 \pm 0.04 \pm 0.09\,\text{MeV}$$
$$m(\chi_{c2}) = 3556.10 \pm 0.06 \pm 0.11\,\text{MeV}$$
$$m(\chi_{c2}) - m(\chi_{c1}) = 45.39 \pm 0.07 \pm 0.03\,\text{MeV}$$
$$\Gamma(\chi_{c2}) = 2.10 \pm 0.20\,(\text{stat}) \pm 0.02\,(\text{syst})\,\text{MeV}$$



LHCb-PAPER-2017-036

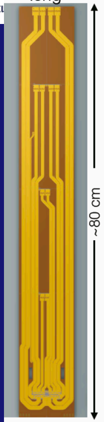
Spare slides - Upgrade

UT: Flex & Testing

Milano

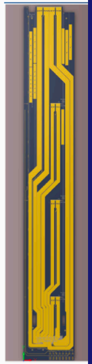
Flex cables

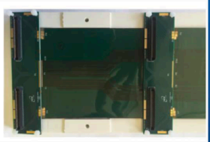
long



- Design validated, 3 generations of prototype tested successfully
- Production of >300 cables planned to start in August 2017, to be completed by end of April 2018. Three different types of cables: long, medium, short
- Cables will be produced in batches (30/month) and tested in Milano starting in September 2017
- Goal test 30 cables/week (2 operators, 10-12 weeks)
- Test: visual inspection, electrical continuity, impedance, metrology, via coupon validation

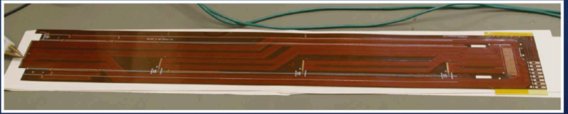
medium





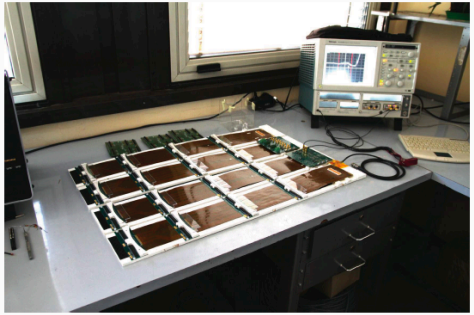
1st

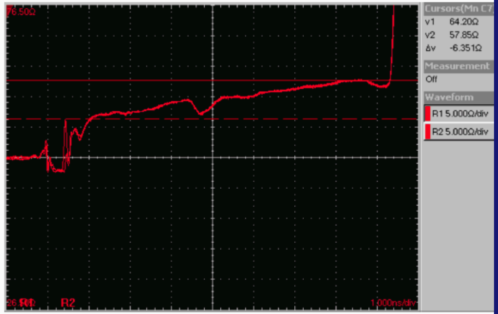
2nd

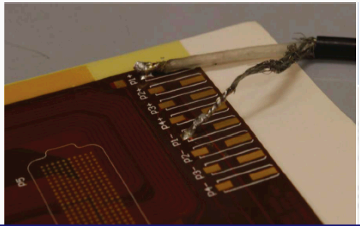


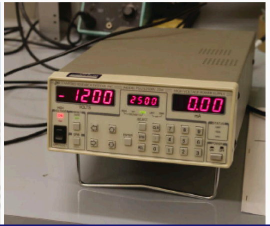
3rd

Time domain reflectometry









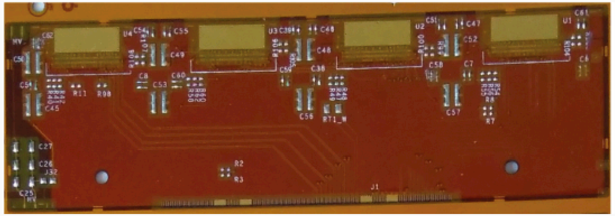
HV test up to 1200 V
Specs require 500 V

UT: hybrids

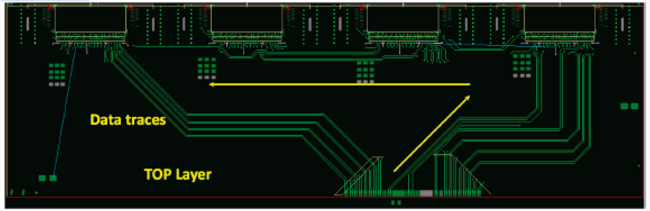
Milano

- Design of 4 ASIC hybrid validated and prototype tested
- Production of 1200 hybrids to start in January 2018 and concluded in 3 months (Italian vendor)
- Gluing and bonding of ASIC to hybrid (500k bonds)
- Test and QA of fully populated hybrid ~6-8 months
- Activity: visual inspection, bonding, initial test, burn-in, final test, preparation for shipping
- Support from mechanic workshop e.g. jigs, test panel design

Kapton hybrid prototype



4 layer stack-up



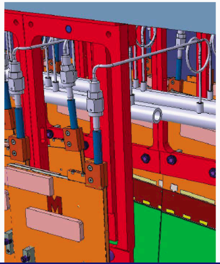
Milano

UT: cooling

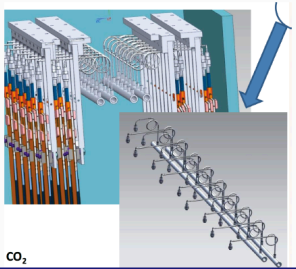
Mechanics and cooling

- Design and construction of CO_2 distribution system for the cooling of the sensors and FEE
- Thermal simulation and test of the cooling system based on TRACI and stave prototypes

Detail of cooling pipes



Cooling system distribution



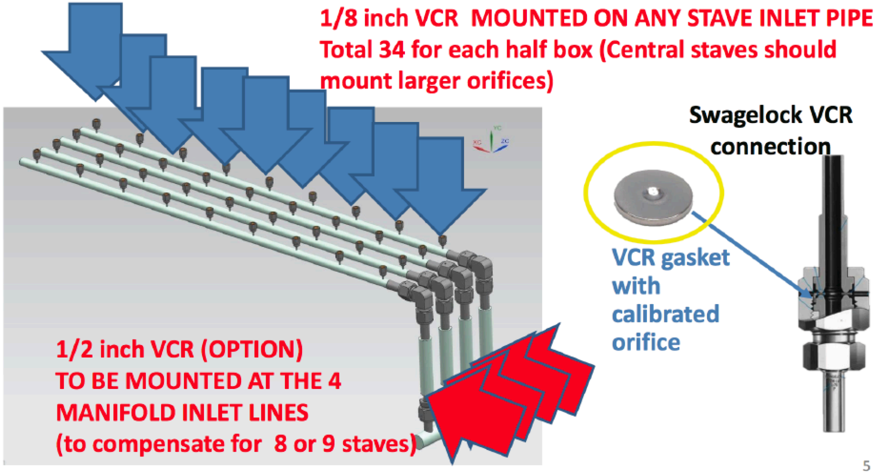
TRACI v3 for CO_2 cooling in Milano

Design and construction of CO_2 manifold

VCR GASKET WITH CALIBRATED ORIFICE COMPACT OPTION

For a correct CO_2 flow distribution for each stave => Inlet fluid concentrated pressure drop: flow restrictors = VCR GASKET WITH CALIBRATED ORIFICE to be mounted on EVERY stave inlet coolant supply pipe

- COMPACT OPTION: the gasket is «hidden» in the manifold system
- SUCCESFULLY TESTED IN ATLAS



5

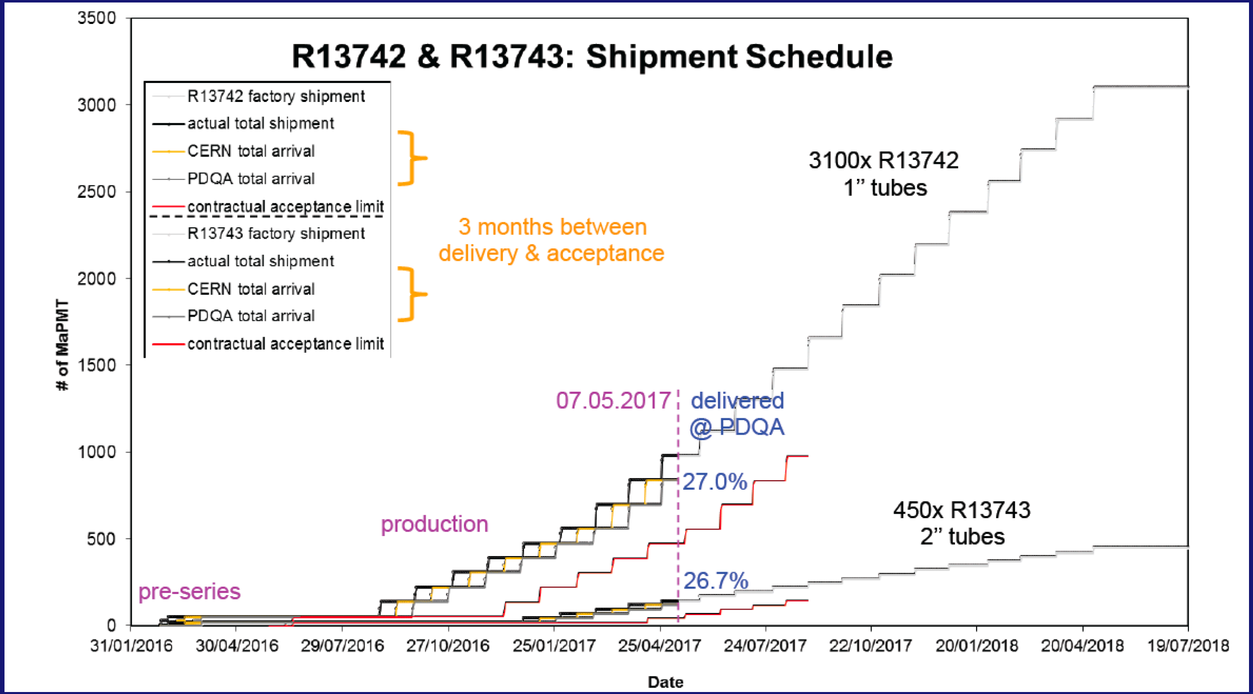
RICH upgrade activities

FE, GE, MIB, PD

- MaPMT QA
- CLARO design and test
- Elementary Cell
  - Baseboard
  - Backboard
  - FEB
- RICH2 Cooling mechanics
- MaPMT new HV system

MaPMT QA

MIB, PD



MaPMT QA ongoing in Padova and in Edinburgh

CLARO production status

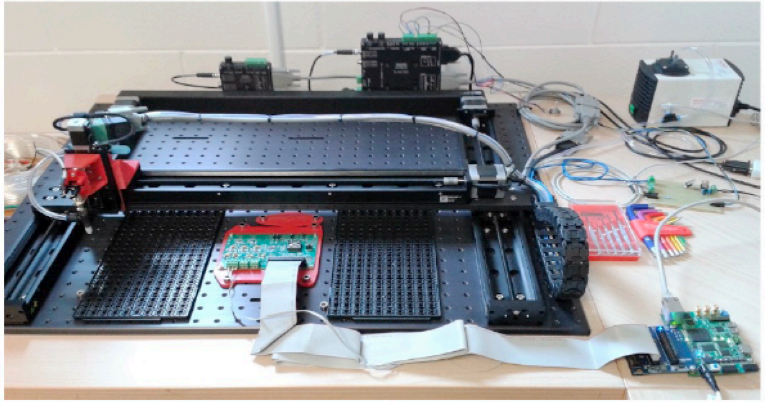
MIB

- CLARO production schedule:
  - **April 2017**: received **400 CLARO chips** (pre-production run)
    - All received CLAROs have been tested with the automatic pick-and-place test setup and results analyzed
  - Maskset + engineering run (9 wafers) produced at AMS
  - ~30k chips ready for packaging at ASE
  - First 200 packaged chips (validation) to be shipped from ASE to CERN on **June 9**
  - The rest will be packaged and shipped before **September 2017**
  - **July 2018**: receive packaged chips from the production run

CLARO QA setup (1)

FE, MIB

- System for automated functional testing of the CLARO has been developed in Ferrara (see "movie" demo file on INDICO)
  - Commissioning ongoing (more details in M. Bolognesi presentation, Meeting on CLARO and EC electronics QA, May 22nd)
- Test station for (manual) single chip measurement is built and being commissioned

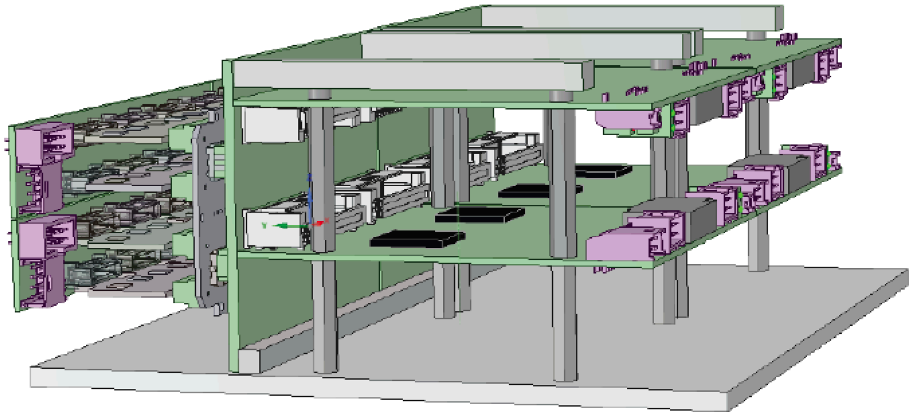


40k chips!

4

FEB/BkB QA test setup (1)

- A test setup for automated tests of FEB and Back-Boards is being built in Ferrara
  - More details in I. Neri presentation (Meeting on CLARO and EC electronics QA, May 22nd)

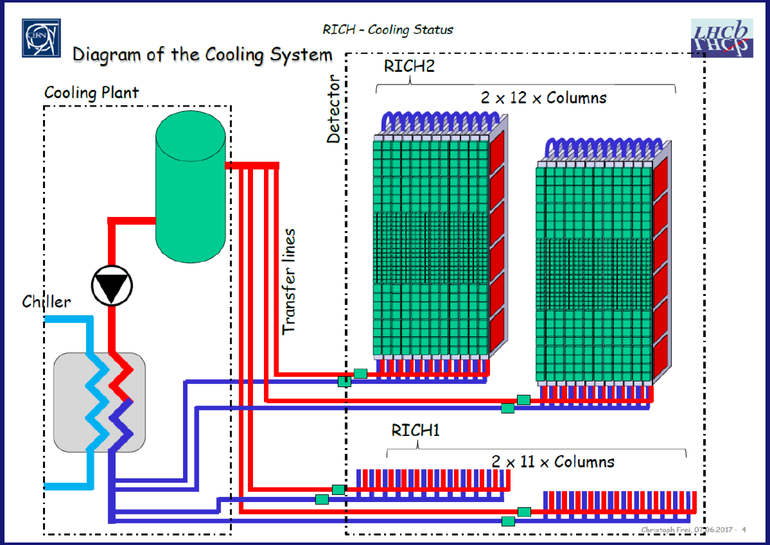


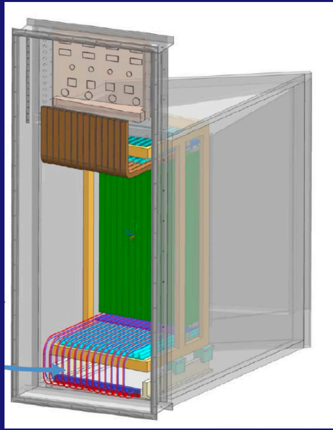
Automatic test setup under preparation, using the FEB + System Controller developed in Ferrara for FEB and Back-Boards QA to test 4 ECs, using the dark-box + LED illuminator concept developed in Edinburgh for Ma-PMT QA (with cooling system)

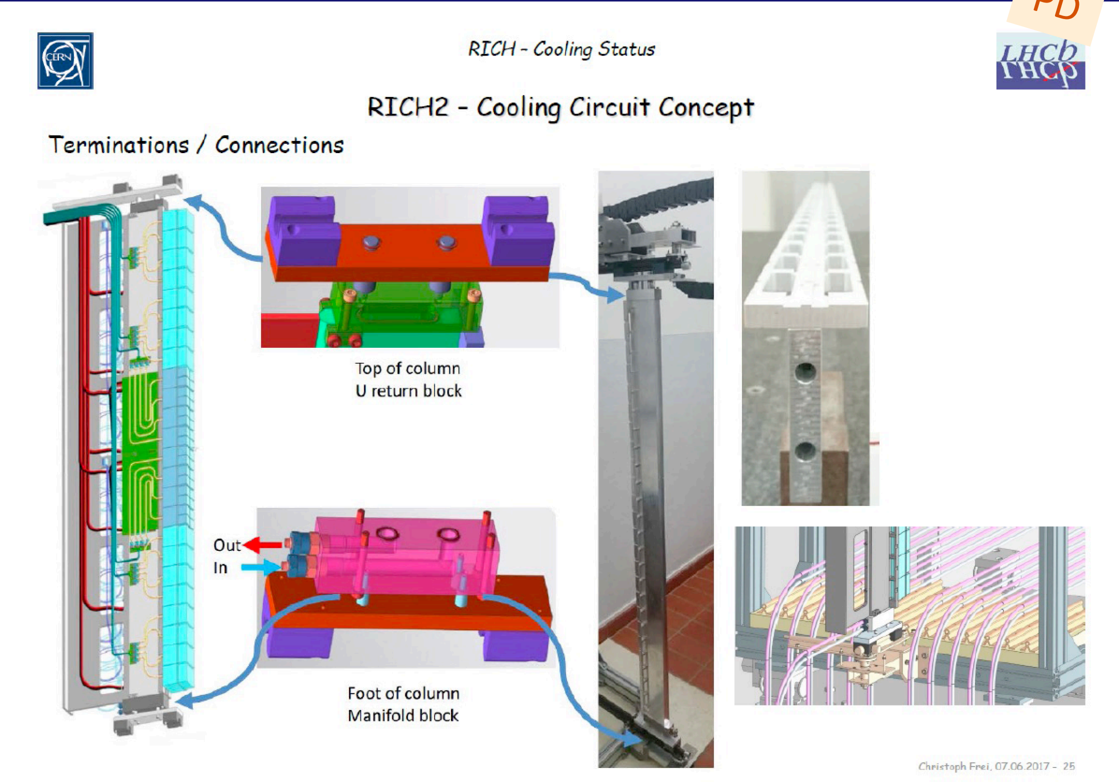
QA baseboards

GE

RICH2 cooling





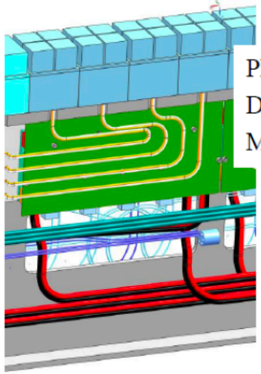


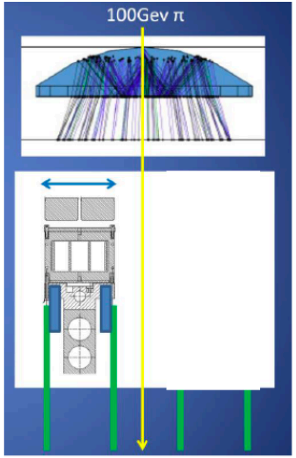
PD

RICH: Test Beam Activities

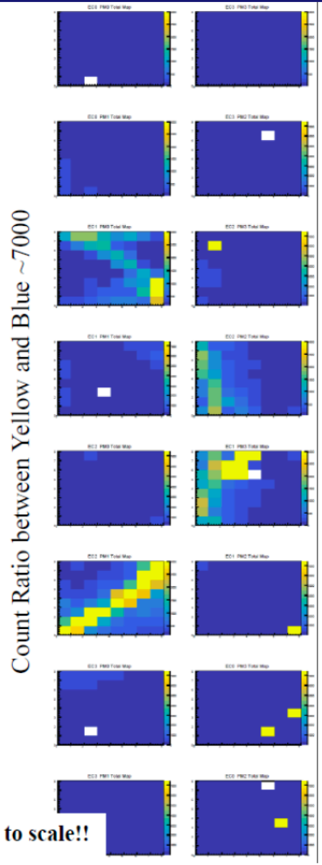
First Ring from a complete Photon Detector Module, Mini-DAQ1 and Online Presenter in a Test Beam.

(on behalf of the RICH Upgrade Team)





Test Beam Set-up



Photon Detector Module:16 MaPMTs, 1024 ch, 128 CLAROs, 2 Digital Boards, 12 Opt Data Links, 2 Control Optical links, Pre-production mechanics and cooling.

Mini DAQ 1, fully configured @40MHz, TFC, Online Presenter.

We wish to thank the Online team for their support and commitment to get the MiniDAQ working: THANK YOU!

The RICH Team, 6 June 2017

Picture not to scale!!

Muon Upgrade

LNF

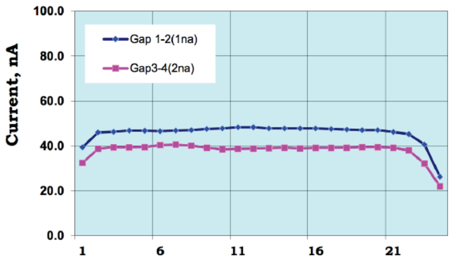
MWPC spare production

M. Anelli
M. Palutan
E. Paoletti
L. Pasquali

	PNPI				Frascati	
	M2R3	M2R4	M3R3	M4R2	M5R2	M5R4
planned	7	6	7	4	5	22
completed	7	6	7	1	6	24

Production completed in Frascati; almost completed at PNPI

Source test (Cs137)



Dressing with FEE and final test at CERN (to be completed during 2018)

Muon Upgrade: Electronics

BA, CA, LNF, RM1, RM2

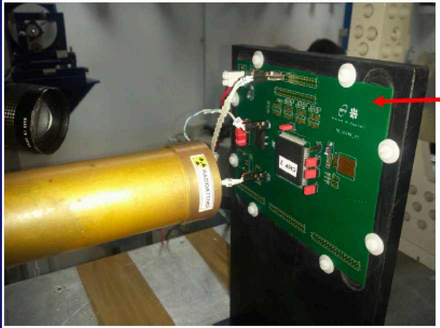
Preparation of the electronics is proceeding at full steam

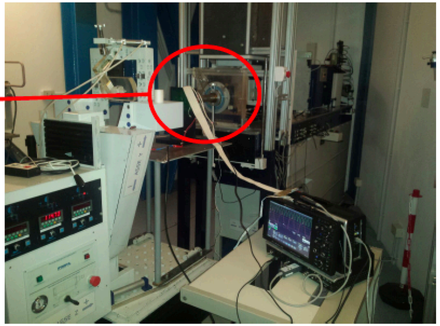
- test on nSYNC v2 ongoing: results on irradiation test awaited during summer
- first nODE prototype with nSYNC v2 under test at LNF
- nSYNC/nODE aiming at PRR beginning october 2017, to launch nSYNC production november 2017
- nSB/nPDM test on prototypes ongoing, aim at PRR dec. 2017
- preparation/test of firmware, full chain test with miniDAQ ongoing in RM2

In all cases we aim at producing the boards during 2018

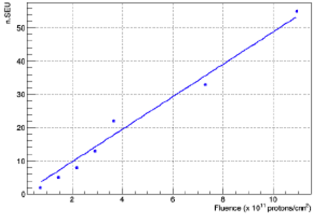
nSYNC irradiation test at Catana

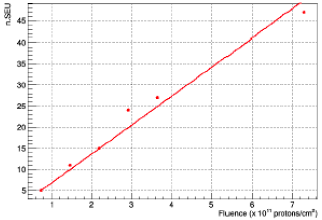
We have developed a complete DAQ system to perform the test (monitor power consumption, TDC status, error counters, PLL period ecc.).

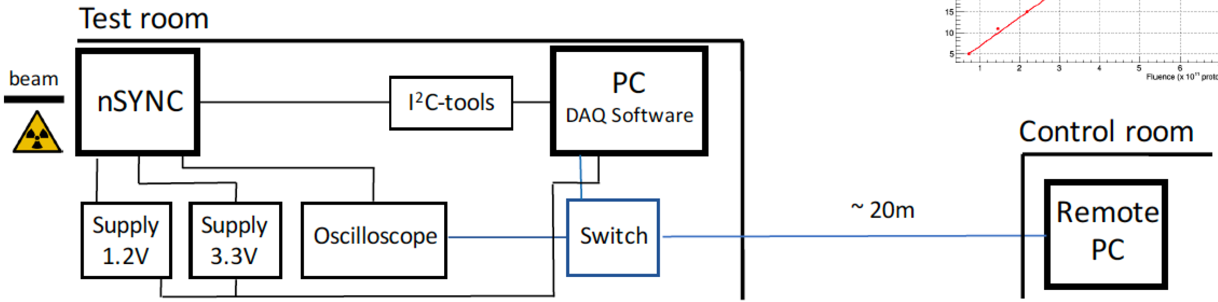




<u>Data analysis ongoing:</u>
preliminary estimate of TDC SEU cross sections ~ $(5\div7)\cdot10^{-11}$ cm^2







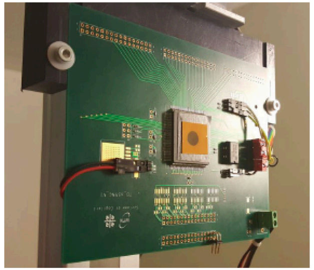
CA

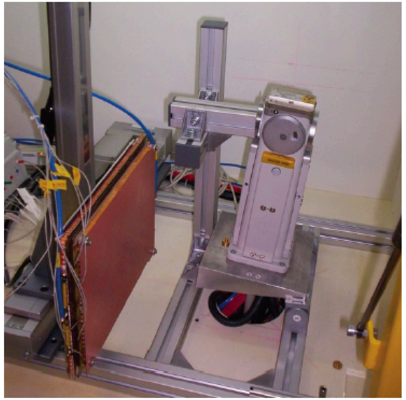
X-ray irradiation test in Cagliari

CA

We are using an X-Ray irradiation system, used in the past to check uniformity on 3GEM detectors, for nSYNC TID studies.

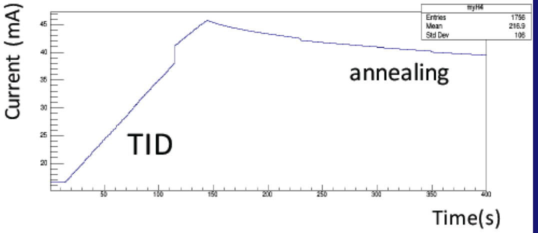
- X-ray tube with Fe anode, 20kV, max. 40mA, water cooled (0.9 kW), 250 μm Be exit window
- Smallest x-ray spot: 7 mm diameter
- XY DUT moving system with 50 μm accuracy available, alignement with radiochromic film
- Need to expose the silicon (bare die)





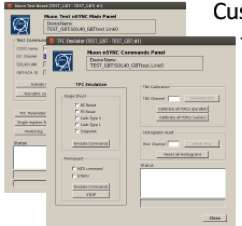
Study ongoing for the dose rate calibration with Si PIN diodes

Analyzing dose-induced damage current increase and annealing

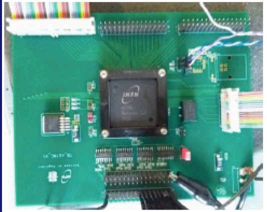


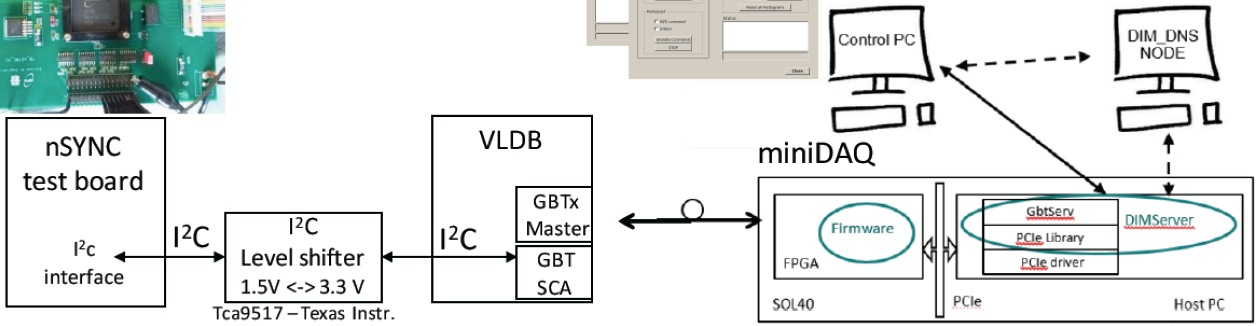
nSYNC test done at Roma Tor Vergata

- Used miniDAQ (a mini complete emulation of the LHCb upgraded readout) and 2 VLDB boards (Versatile Link Demo Board) from Tor Vergata and Frascati.
- Tested successfully the communication between nSYNC and GBT-SCA chip (for the first time) through the ECS dataflow: FPGA [SOL40-SCA_core] -> GBTx -> GBT-SCA -> nSYNC;
  - Tested the read / write operations for some R/W nSYNC registers;
  - Tested the TDC calibration commands;
  - Tested the read operation of the TDC status.



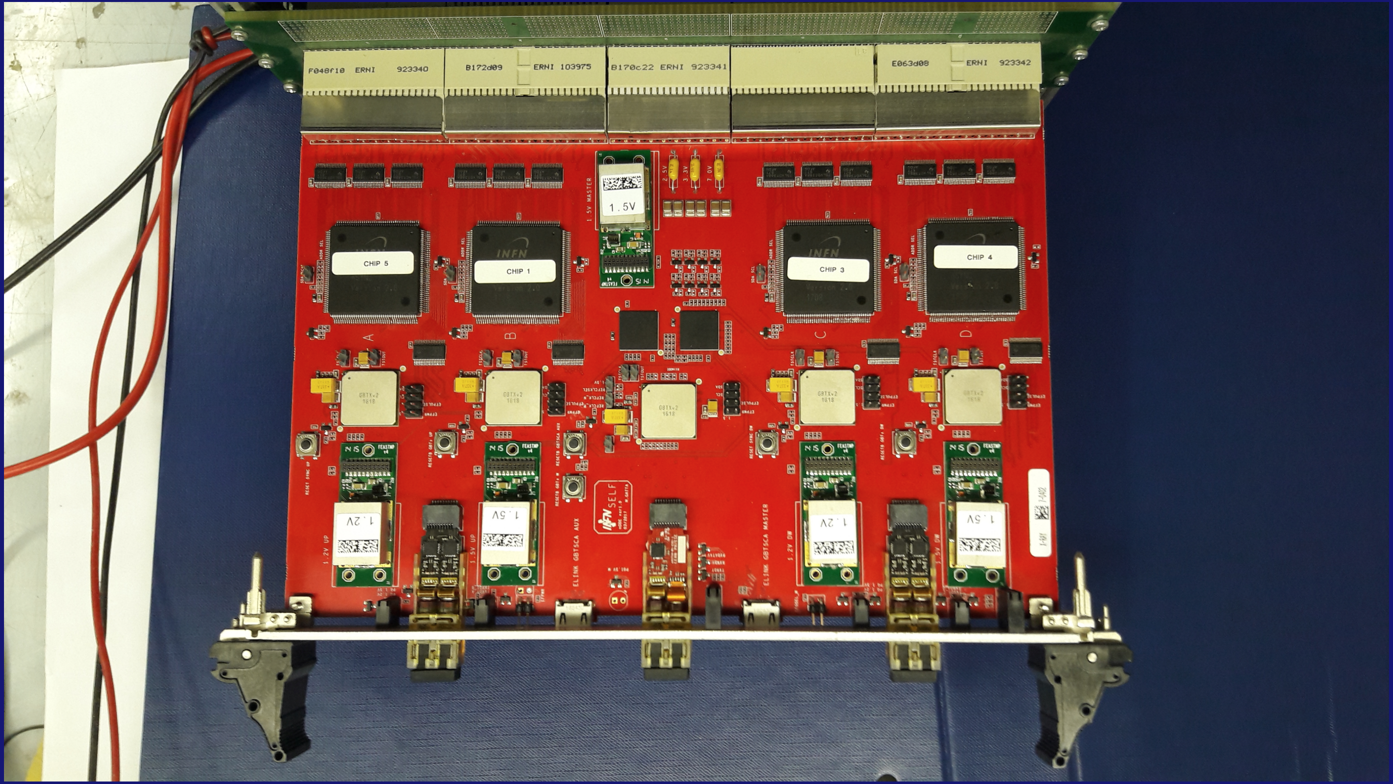
Custom WinCC panels for nSYNC control





First nODE prototype under test

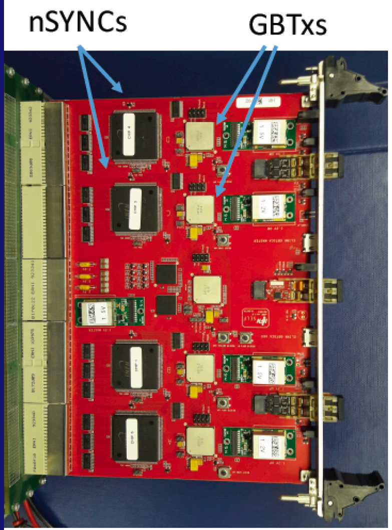
LNF

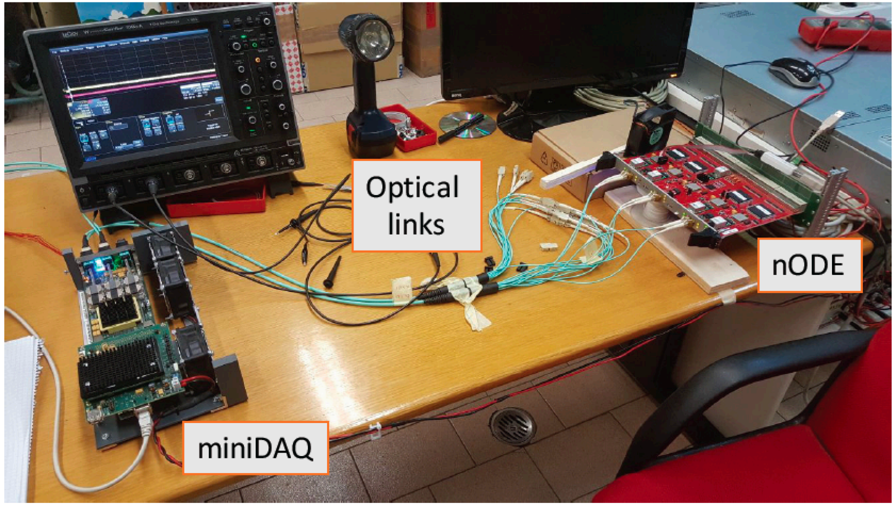


nODE test done at Roma Tor Vergata

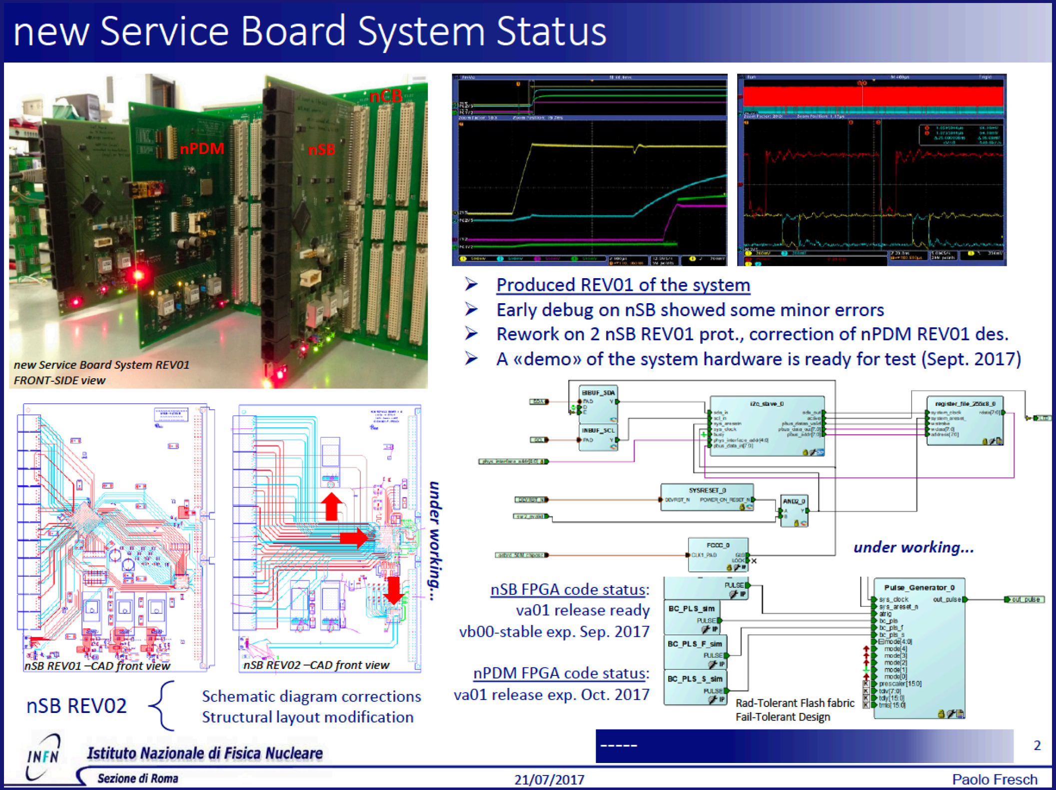
BA, CA, LNF, RM2

- Used the miniDAQ also to make preliminary tests on the nODE board.,
- Improved WinCC panels to control and monitor operations on nODE,
- Configured successfully the GBTx chips (master and slaves),
- Tested successfully the reception by the nSYNCs of the Trigger and Fast Control (TFC) commands, through the optical link (and relative counters and snapshots),
- Test ongoing on the synchronization between the board and the readout system.





nSB / nPDM



RM1

- Settembre
  - System test con MiniDAQ
  - Test funzionali e caratterizzazione ritardi
  - Preparazione gara nSB rev02 e nPDM rev02
- Ottobre
  - Beta stable release del codice FPGA nPDM
  - Finalizzazione progetti schede nSB e nPDM rev02
- Novembre
  - Ordine effettivo schede (campionatura) per validazione
  - (Eventuale secondo giro di test con MiniDAQ (ancora con schede rev01))
  - (Eventuali miglioramenti codici FPGA e test)
- Inizio 2018
  - Quando arrivano i prototipi rev02 → settimana di test (validazione campionature)
  - Partenza produzione (fondi 2018)

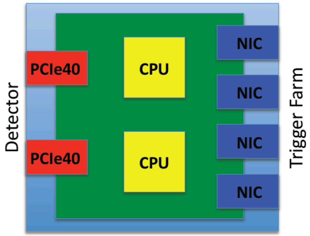
The BEB Project

BO

Aim of the BEB project

- Select/arrange optimal Event Builder servers to host the PCIe40 readout interface boards and to perform the Event Building at 40 MHz.
- Work in collaboration with "E4 Computing (Italy)".

With a single PCIe40 the input data rate to the server RAM is about 100 Gb/s. The overall traffic through it is of about 400 Gb/s.



Parameters

- PCIe40 cards per server
- PCIe lanes on the mother board
- NIC compatibility and performance
- Single vs multi socket server
- Memory bandwidth
- Possibility of PCIe bifurcation: matching of 2 x 8 lanes to 16 lanes
- …

Test Setup

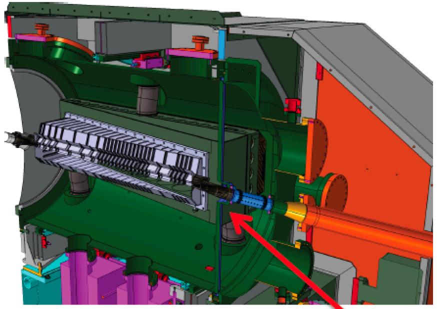
- R&D project is funded by LHCb
- The test setup will be installed in Bologna.
- Up to date high-ended servers are being selected by E4, on the basis of our requirements.
- E4 will perform preliminary functional tests.
- We will check the servers' performance satisfy the benchmarks.
- We need a PCIe40 to generate the traffic to the RAM of the hosting server. New items will be available by the late Autumn at the cost of ~8kCHF/board.

Nuova proposta: SMOG2

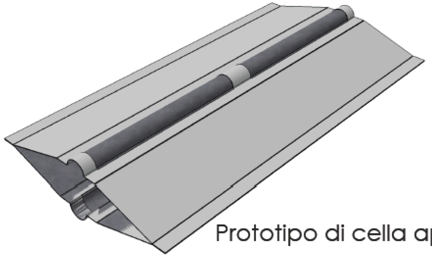
- LNF, FE, CERN, Nikhef
- Manpower: 2-3 FTE italiani nel 2018
- Responsabilità italiana
- Approvazione LHCb prevista per fine 2017/inizio 2018
- Installazione @ LS2

Upgrade di SMOG

FE, LNF



Posizione della nuova cella



Prototipo di cella apribile

Dettagli tecnici

Una cella di accumulazione, il cui materiale è in fase di valutazione e discussione con gli esperti LHC verrà installata di fronte al VELO.

Per motivi simili a quelli del VELO dovrà essere apribile all'iniezione del fascio LHC e quanto più ermetica una volta chiusa dopo lo squeeze del fascio.

L'iniezione del gas avrà una nuova linea attraverso il vessel del VELO che dovrà conseguentemente essere modificato (Nihkef).

La cella sarà collegata attraverso spring fingers appositi e wakefield suppressor.