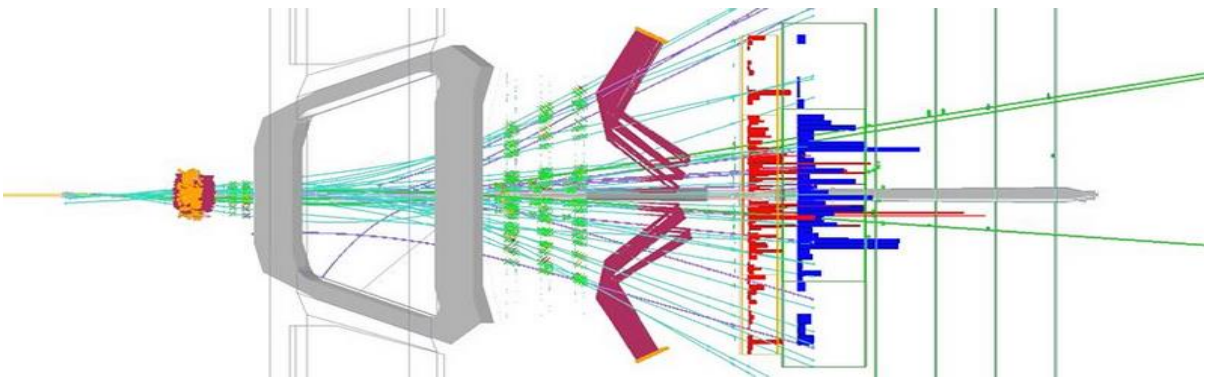
The search for rare and forbidden decays at the LHCb



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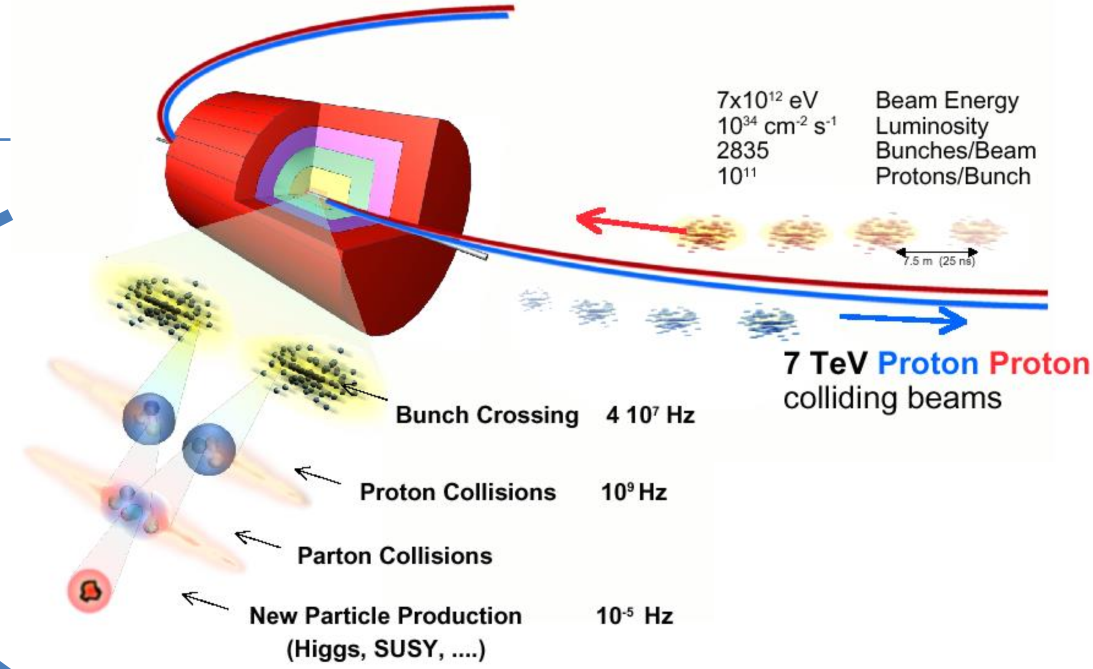
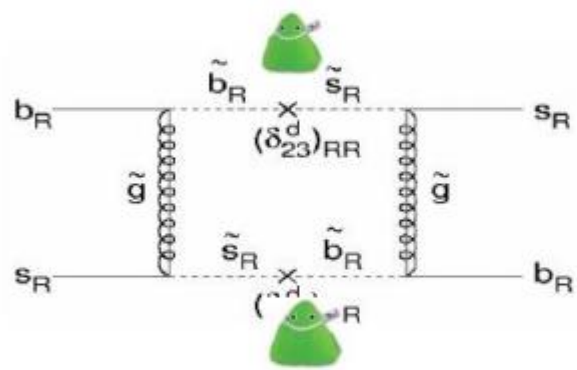
Probing of particles

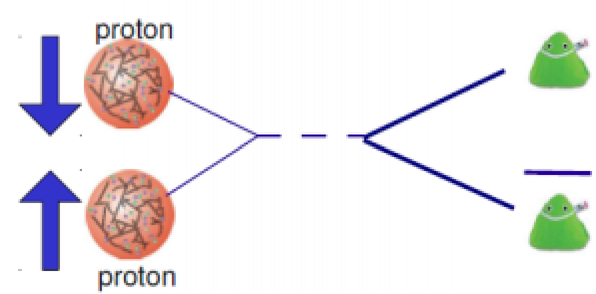


The ways to find new particles

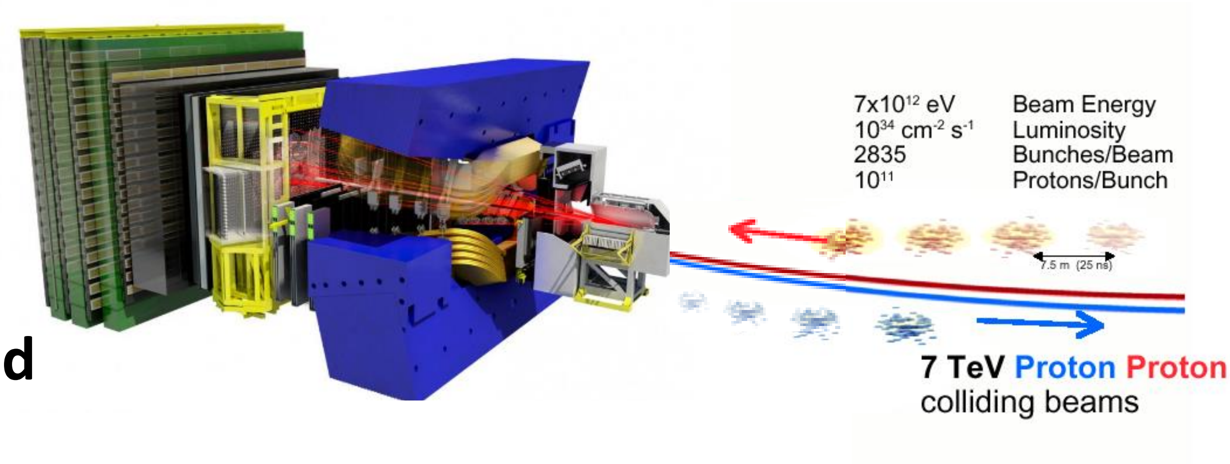
Indirect searches
New particles appearing as virtual particles in quantum loops



Direct searches
Produce new particles as real particles in pp collisions



The LHCb experiment



The ways to find new particles

Indirect searches
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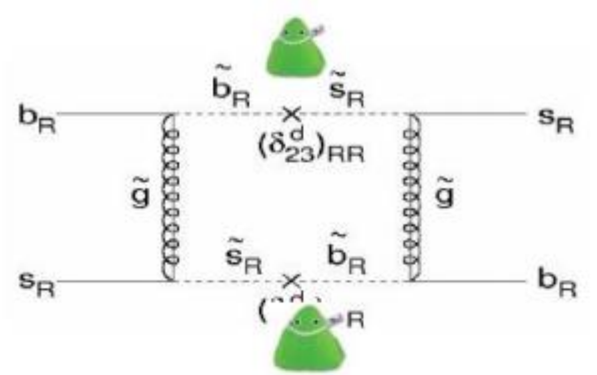
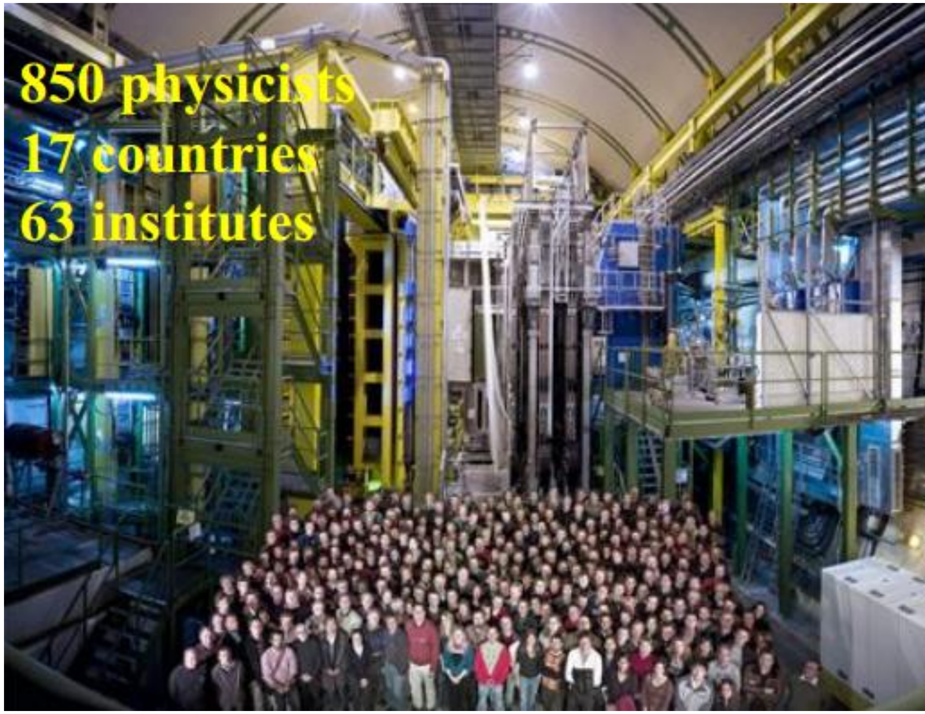


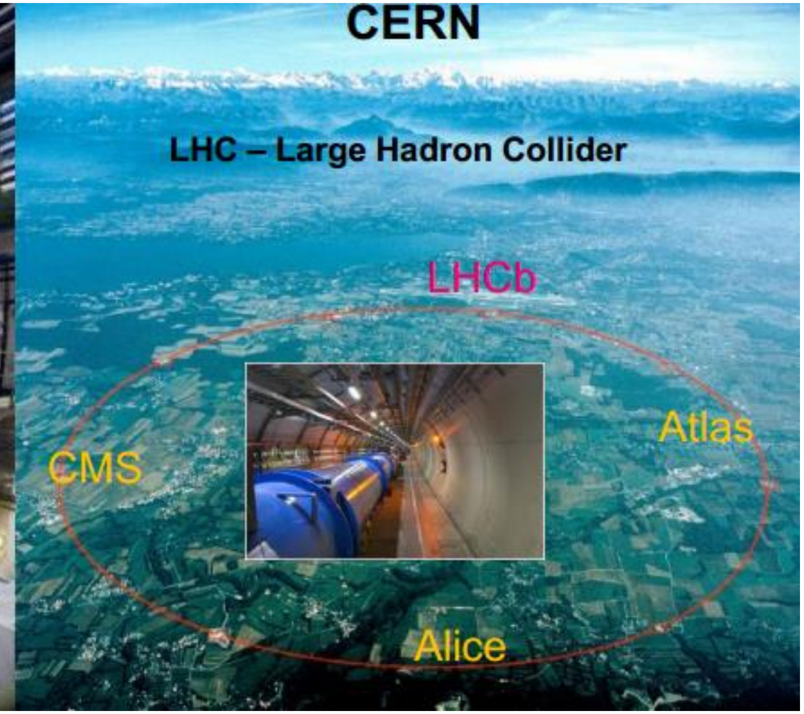
- New particles are hiding: need to look for **small deviations** – need precise and clean measurements,
- **Precise measurements** of low energy phenomena tells us about unknown physics at higher energies, even larger than in direct searches!

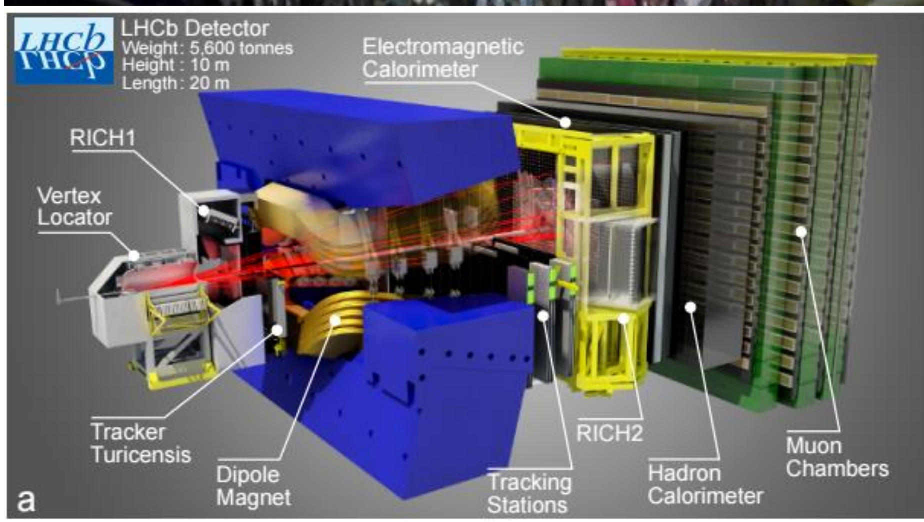
Two esperimental approches:

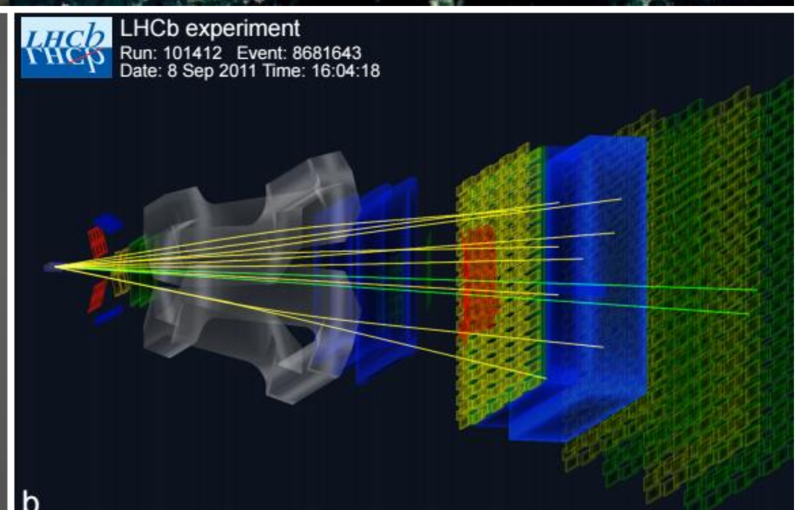
- ❑ **CP violation:** probe differences between matter and antimatter
- ❑ **Rare dacays:** search for decays that are (almost) imposible in the Standard Model

The LHCb experiment





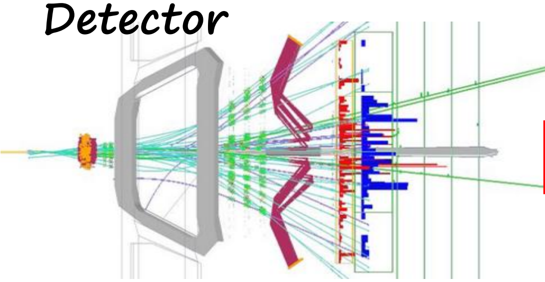




The LHCb data

40 MHz

Detector



35 GB/s
1 MHz

L0 Trigger

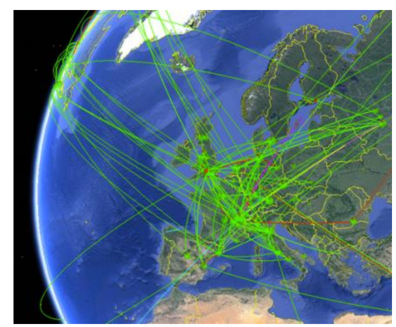
hardware

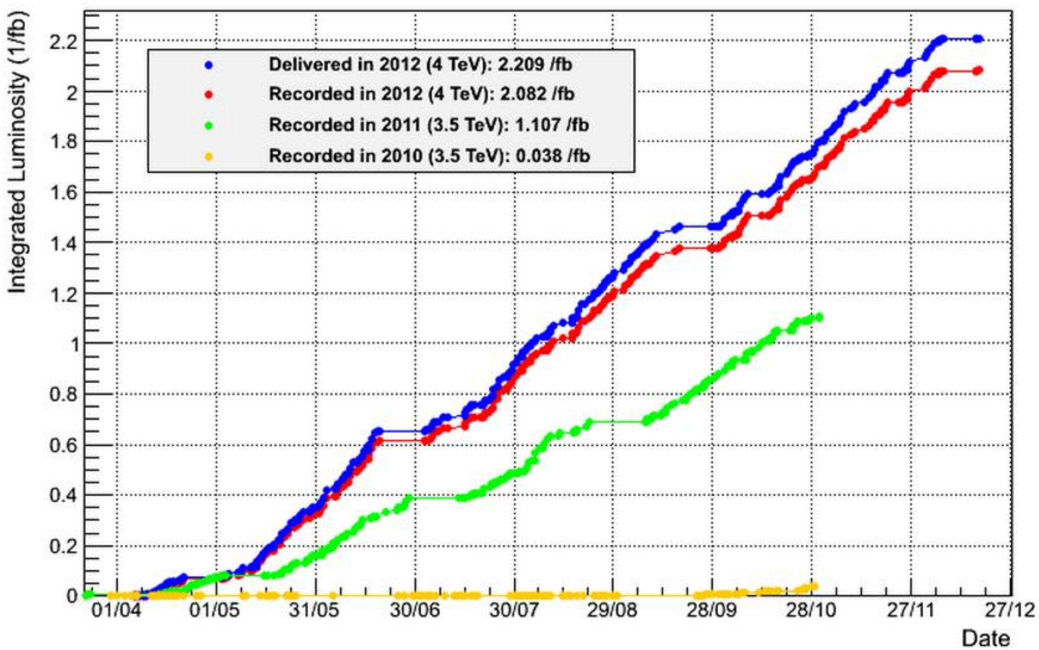
3 kHz

$2 \cdot 10^{10}$ events/year

Hight Level Trigger

Grid Computing





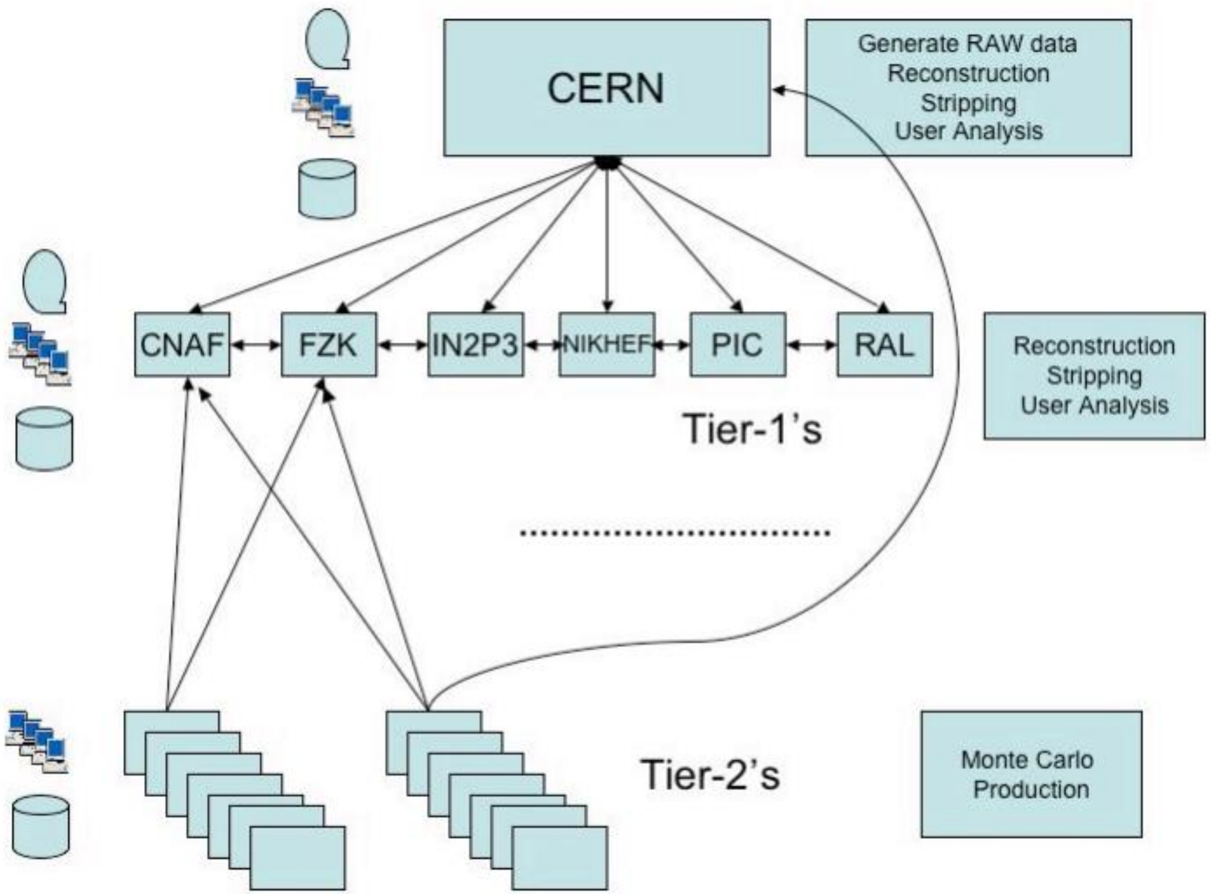
20 PB of data on permamnent storage !

In the case of rare decays the reduction factor of data have to be extremely high to select signal from overwhelming background

Two main aproaches of data processing at LHCb

1. <u>The central data processing</u>

- common for all users,
- large scale data reconstruction and data preselection is being performed at CERN and Tier-1,



Two main aproaches of data processing at LHCb

1. <u>The central data processing</u>

2. <u>The analysis of centrally preselected samples</u>

- Performed by physics groups or individual researchers
- Centrally preselected samples are processed to obtain data in a reduced format (ROOT ntiples),
- Iterative processing. Physics analyses need multiple processing of data (improved software, better calibration etc.).

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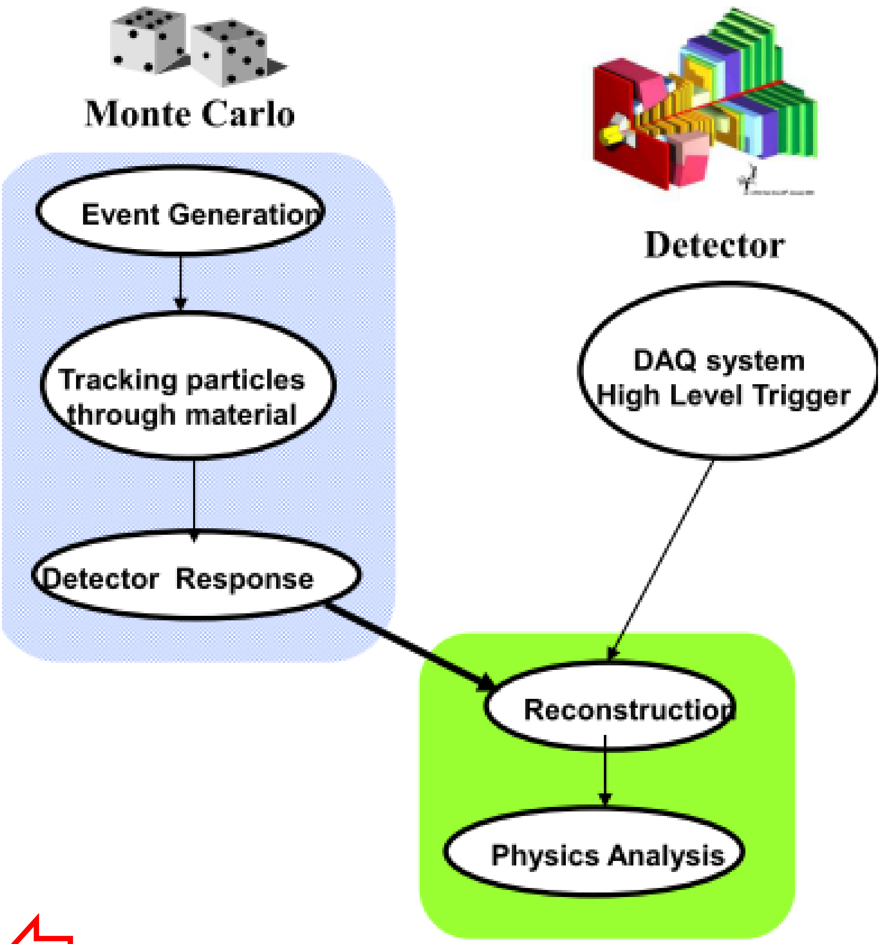
❖ **PLGrid Plus** contribution - infrastructure and developed services:

- **CVMFS** - automatic distribution of experiments' software
- **Proof on Demand** - intensive paraller data analisys (parrallel ROOT processing of large data samples)
- **XRootD** - service for direct access to files in ROOT format
- **GooFit** – implementation of the RooFit package on GPGPU for advanced statistical analysis.

The role of Monte Carlo simulations



- **The Monte Carlo (MC) simulation** role is to mimic what happens in the spectrometer to understand experimental effects and correct measured quantities
  - MC events are **processed as real data** (reconstruction and physics analysis) but in the case of MC we know the *truth*.
  - Comparing the simulation to what is measured we can interpret the results.

General features:

- The size of samples is **milions of events** (in particular for rare daycays),
- Production rate in average is **1000 events per 24 hours** per single core,
- **Central production** is prioritized. Long delay in production of particular samples (or refusal if too many events is requested)
- **Local production** has to be performed.

⇦ Performed at Tier-2 and then data are uploaded to the associated Tier-1

⇦ Run at user accesible resources.

Selected activities

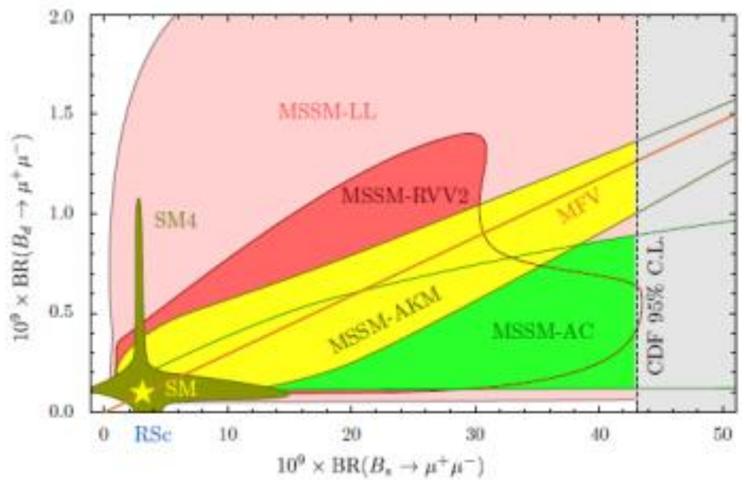
- Baryon and Lepton number violeting decay
  $\Lambda_b^0 \to K^- \mu^+$ ⇦ B. Rachwał PhD thesis — **ongoing**
- Lepton flavour violeting decay
  $\tau^- \to \mu^- \mu^+ \mu^-$ ⇦ M. Chrząszcz PhD thesis, arxiv: 1409.8548 — **Submitted to JHEP**
- *General* measurement
  $\sigma(b\bar{b})$ with inclusive final states ⇦ dr hab. M. Kucharczyk LHCb-CONF-2013-002 — **Collaboration review**
- The important one from LHCb
  $B_s^0 \to \mu^+ \mu^-$ ⇦ Combined of LHCb and CMS data arxiv: 1411.4413v1 — **Submitted to Nature**

  Measurement $BR \sim 10^{-9}$

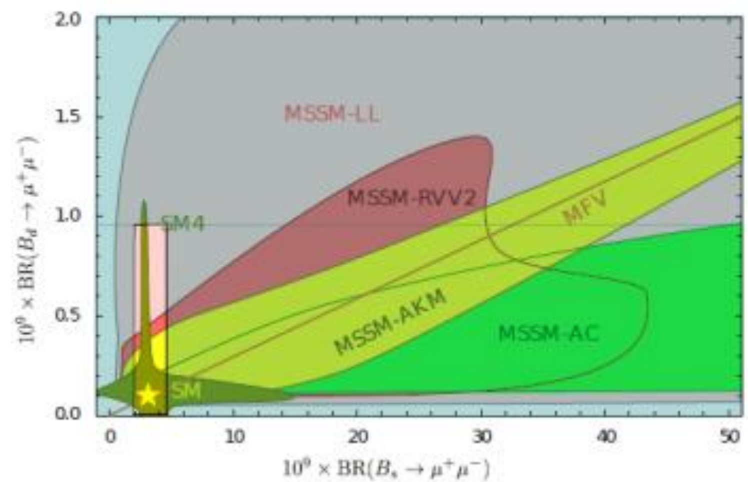
All of these activities (as well as many others within LHCb collaboration) can bring as toward important milestone on the path of understanding the fundamental principle of Standard Model and New Physics extensions!
Cyfronet resources play important role in these searches by contributing in the WLCG and allowing the local MC production and final physics analysis.

$B_s^0 \to \mu^+\mu^-$ *milestone*

Before Run 1



After Run 1



… the branching ratio turns out to be consistent with Standard Model prediction. This result is extremely important, as it rules out many New Physics models.

Summary

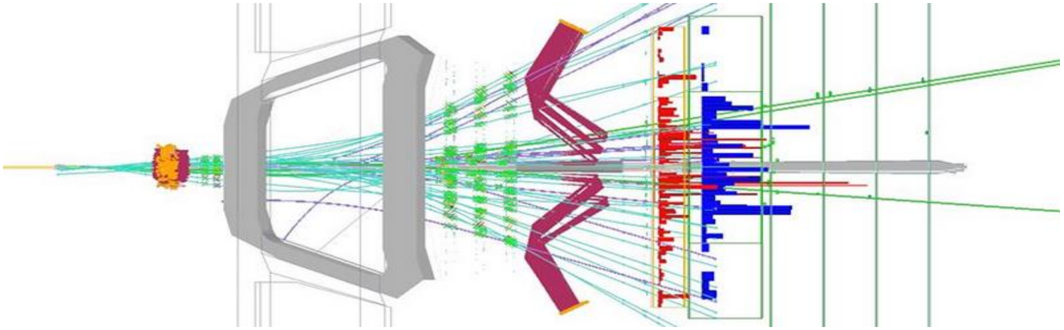
The search for rare and forbidden decays at the LHCb

- ✓ Many interesting, **world-best results** from LHC Run 1
  - Most of them consistent with Standard Model.
  - New Physics is not yet discovered. We need more data.

- ✓ Expect many **exciting results** from Run 2 (2015-2017) when we will collect another 5 fb^{-1} at 13-14 TeV.

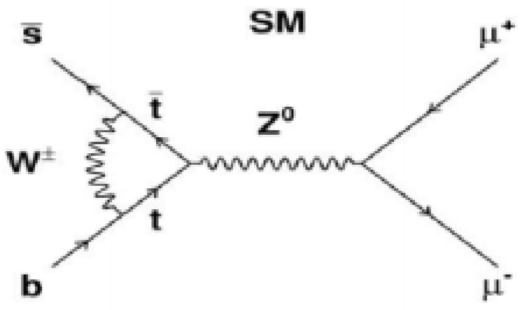
- ✓ **Polish Grid** resources extensively used.

- ✓ **Increased discovery potential in future!**



Backup

$B_s^0 \to \mu^+\mu^-$

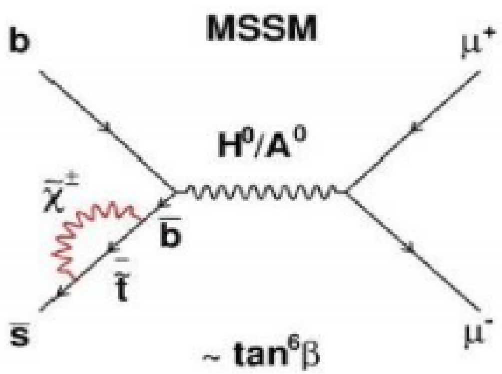


- SM prediction

  BF($B^0 \to \mu\mu$)=(1.07 ± 0.10) · 10^{-10} [A. Buras et al., JHEP 1010 (2010)]

  BF($B^0_s \to \mu\mu$)$_{<t>}$ =(3.54 ± 0.30) · 10^{-9} [arXiv:1204.1735]

  GIM and helicity suppressed in SM

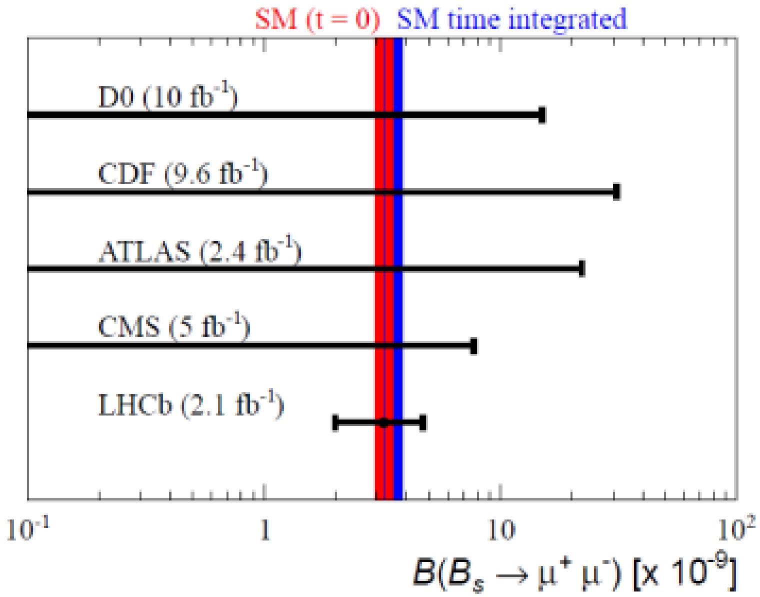


$$\mathrm{Br}_{\mathrm{MSSM}}(B_q \to \ell^+\ell^-) \propto \frac{M_b^2 M_\ell^2 \tan^6\beta}{M_A^4}$$

Very high sensitivity to New Physics, eg. CMSSM and NUHM1:
[O. Buchmuller et al, arXiv:1112.3564v2, May 2012]

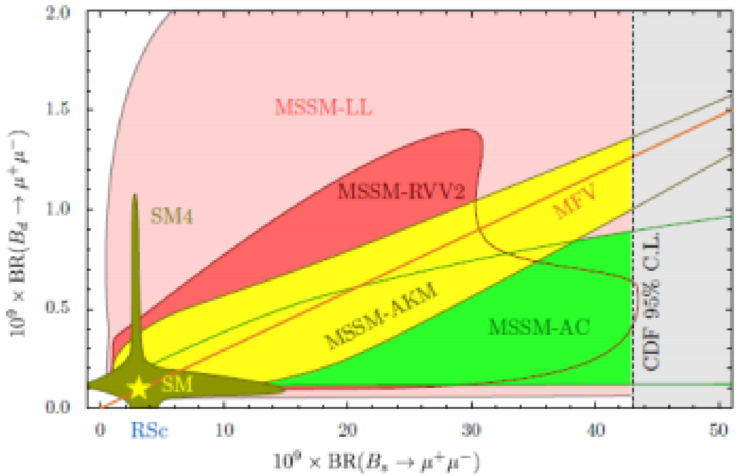
Backup

$B_s^0 \to \mu^+\mu^-$

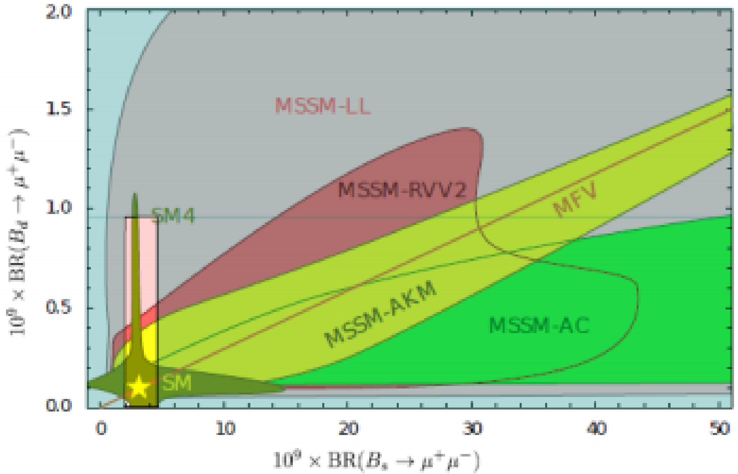


Unoffficial compilation based on arXiv:1107.0266 (D. M. Straub)

Summer 2010:



Autumn 2012:



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