LHCb experiment at LHC

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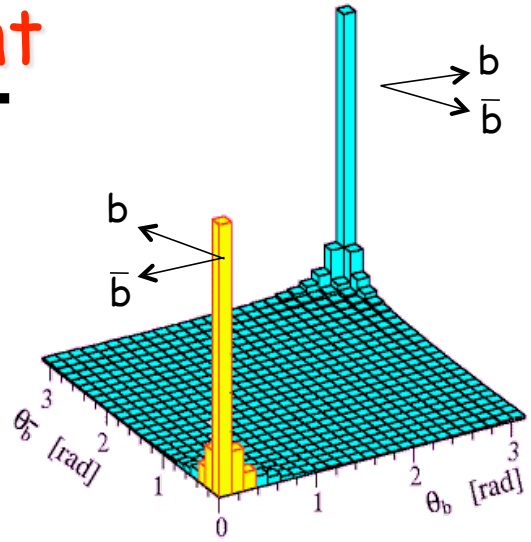
for the Frascati LHCb group

- Introduction
- Data analysis at LNF

40th LNFSC meeting, June 24th 2010, Frascati

The LHCb experiment



Advantages of beauty physics at hadron colliders:

- High value of bb cross sectionat LHC: σ_{bb} ~ 300-500 μb at 10-14 TeV
- Access to all quasi-stable b-flavoured hadrons

The challenge:

- Multiplicity of tracks (~30 tracks per rapidity unit)
- Rate of background events: σ_{bb} ~ 60 mb at $\sqrt{s}$=7 TeV

LHCb running conditions (nominal):

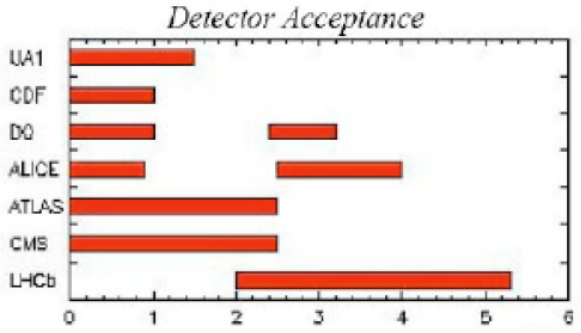
- defocused beams (w.r.t. ATLAS and CMS)→ max luminosity~ 2×10^{32} $cm^{-2}s^{-1}$
- reduced pile-up: on average, 0.4 pp interaction/bunch crossing
- $O(10^{11})$ bb pair produced per fb^{-1}

Search for New Physics in CP violation and Rare Decays:

- CPV: Φ_s, γ in trees and loops, CPV asymmetries in charm decays
- Rare decays: helicity structure in B→ $K^*\mu\mu$ and B_s → $\phi\gamma$, ϕee
  FCNC in loops ($B_s\to\mu\mu$, $D\to\mu\mu$) and trees

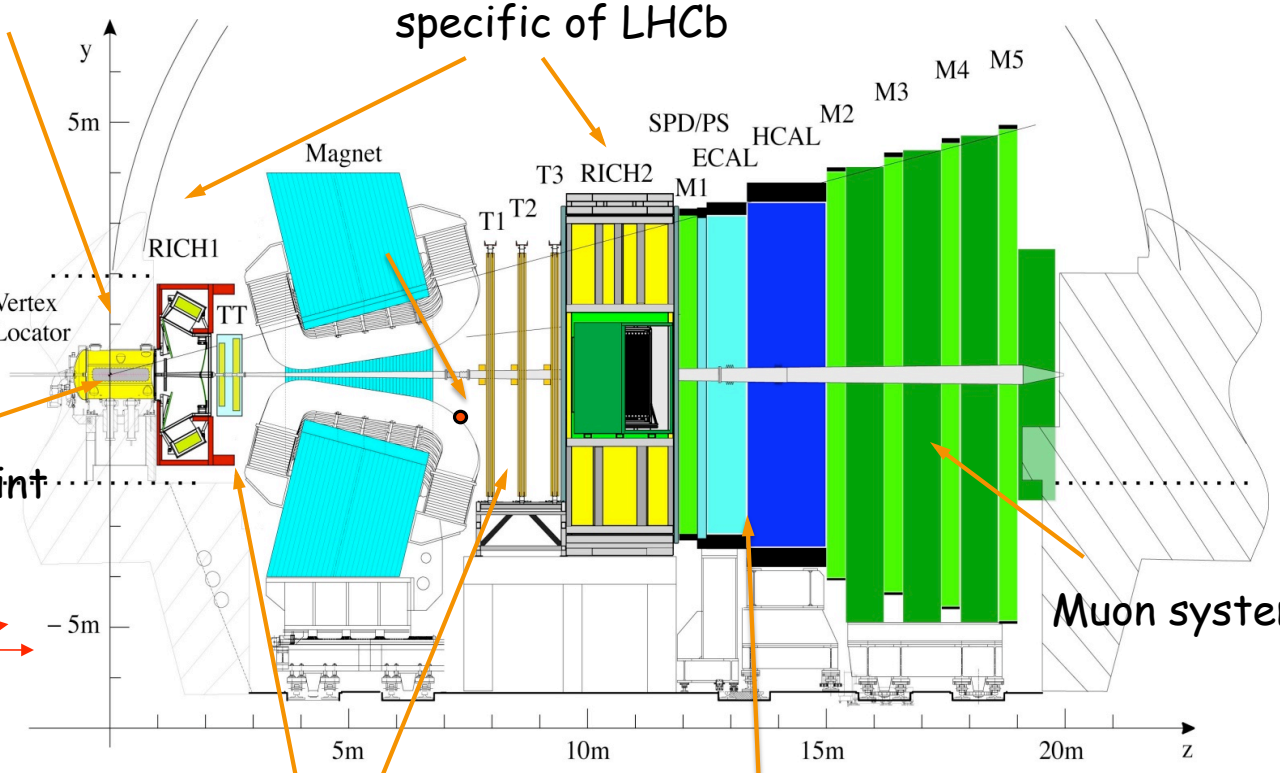
The LHCb detector

"a forward spectrometer"

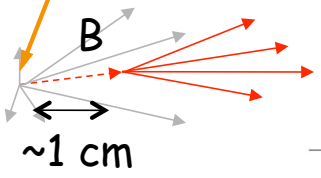


Vertex locator
movable device
35mm from beam out of physics/7mm from beam in physics

RICH detectors specific of LHCb



pp collision point



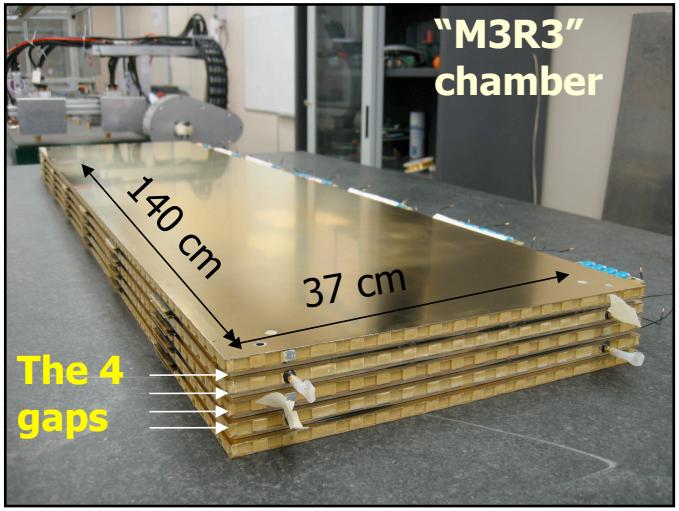
Muon system

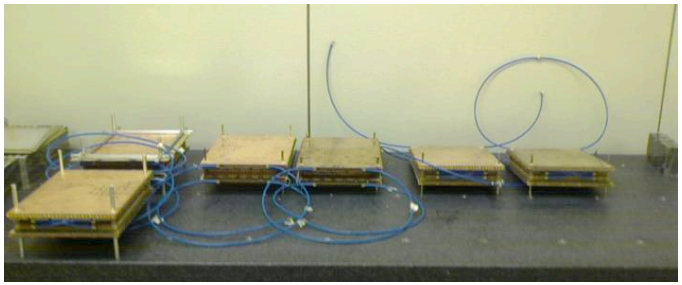
Tracking system

Calorimeters

Muon detector

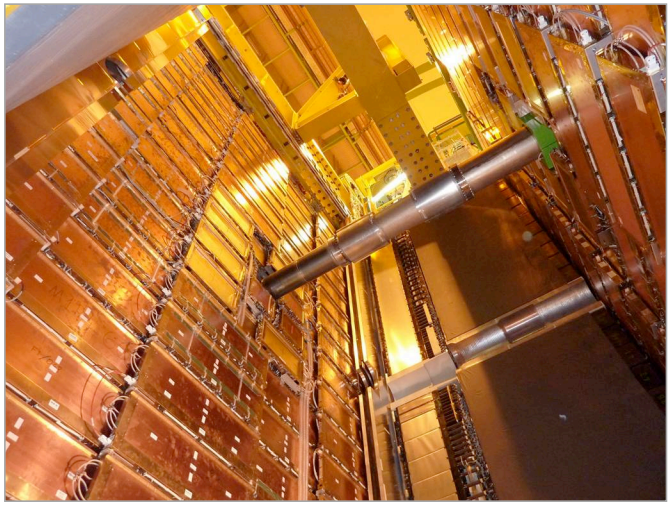
2003: muon chamber (MWPC, GEM) production starts at LNF → ~30% of the whole detector has been built here

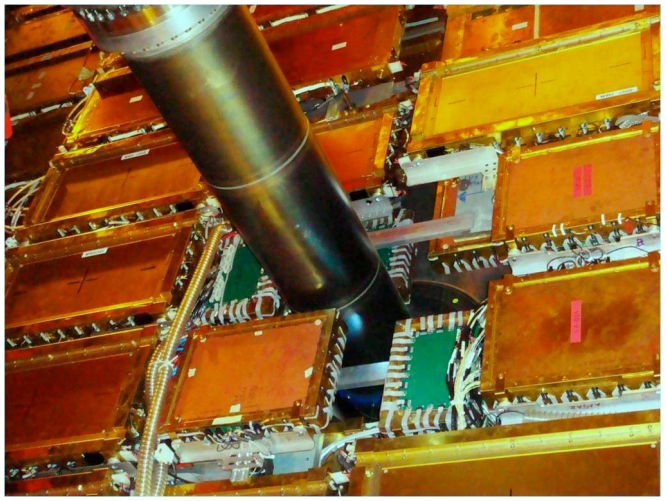




after 5 years and 1380 chambers...

2009: Muon system is ready for data taking



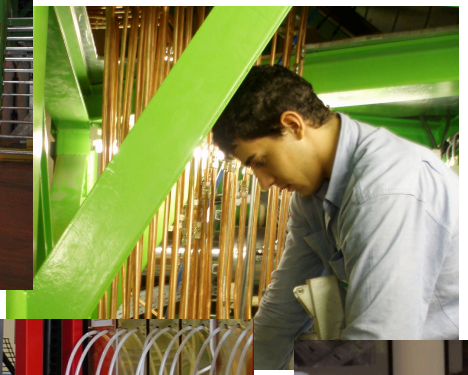


Many thanks to ...

Chamber production

Chamber test

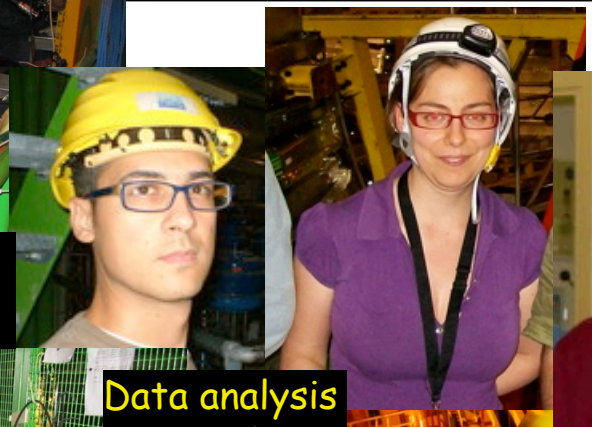
Detector installation: chambers, services



Front end electronics

... and to....

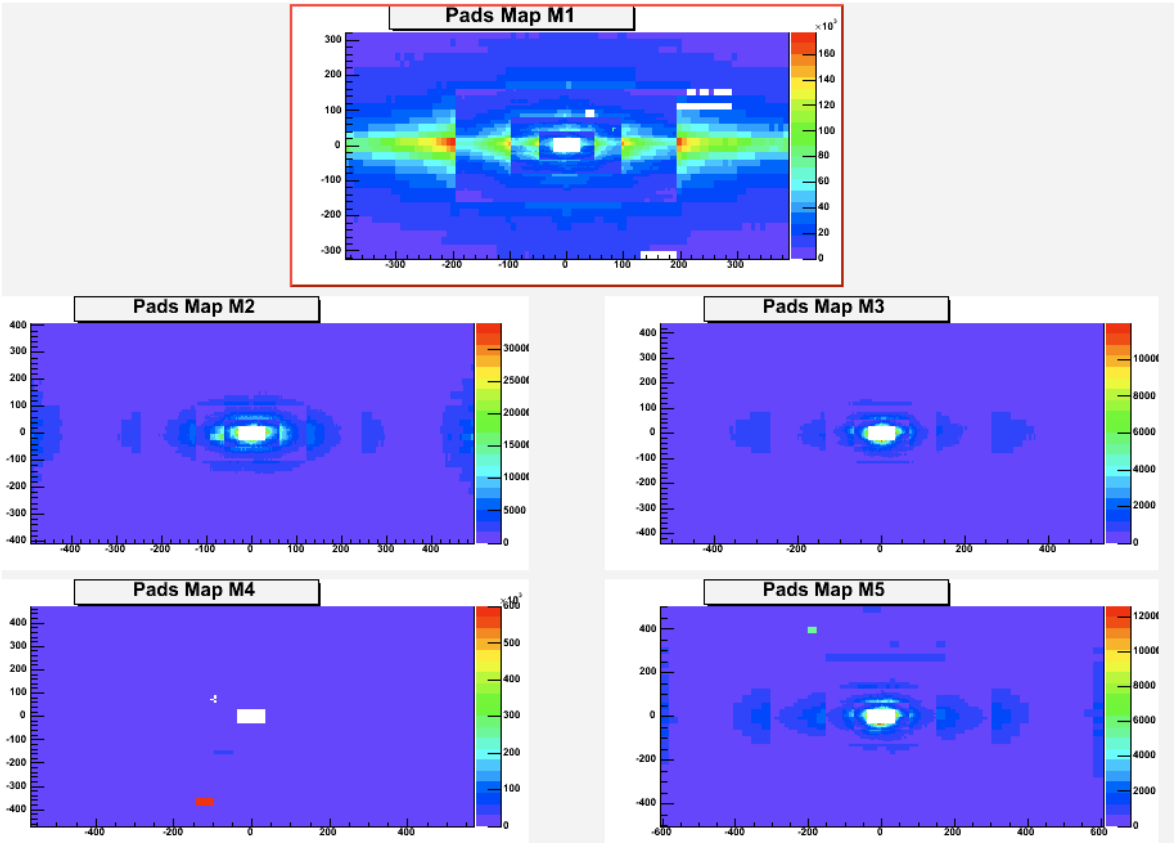

Front end electronics
Detector commissioning


Data analysis
μ - ID


Detector control system

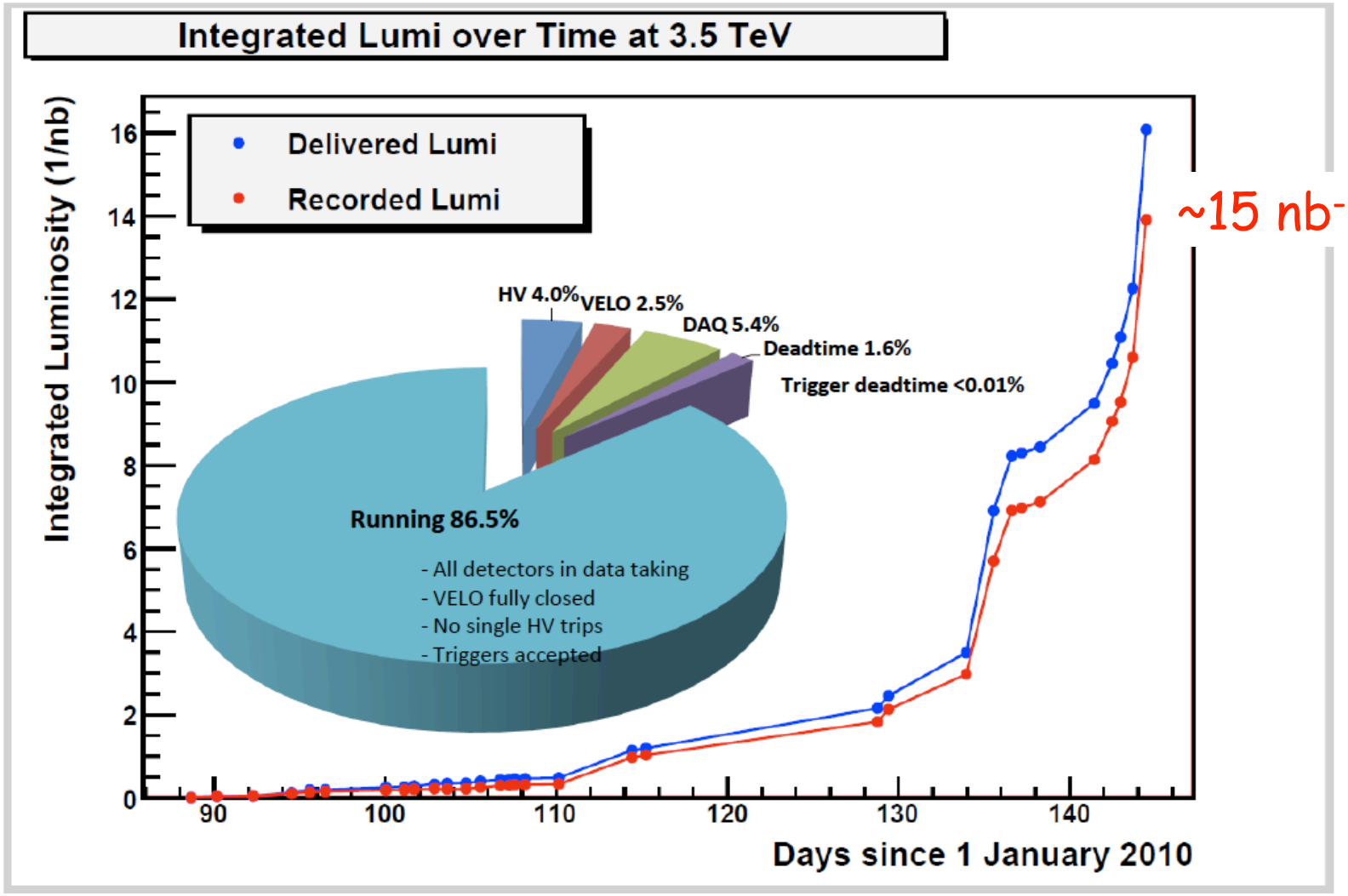

Nobel Museum
..ready for the Nobel prize!

2010: muon detector smooth operation



- only 2 gaps/5000 disconnected, 0.01% dead channels
- measured perfomances: ε>99% within 25ns, σ_t<=4ns, cluster size <1.2, aligned to <=1mm

LHCb data taking



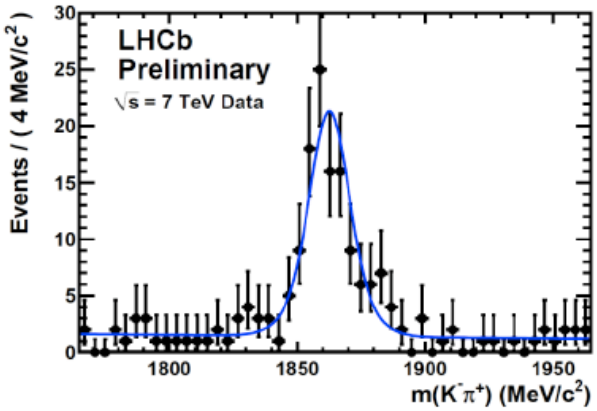
B mesons observed: $B \to D^0 \mu \nu X$, $D^0 \to K^- \pi^+$

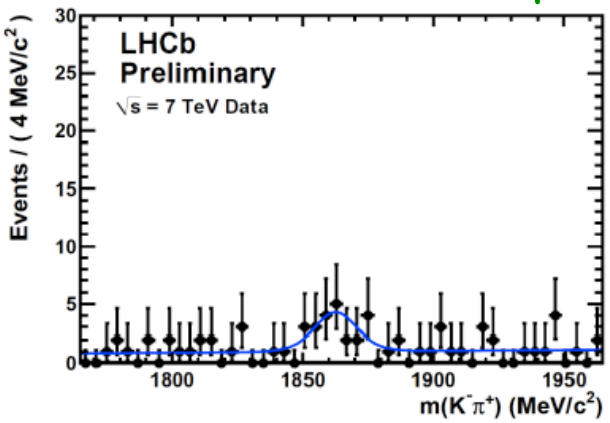
Correlate D^0 with the muon of the right (wrong) sign

Right sign $D^0\mu^-$

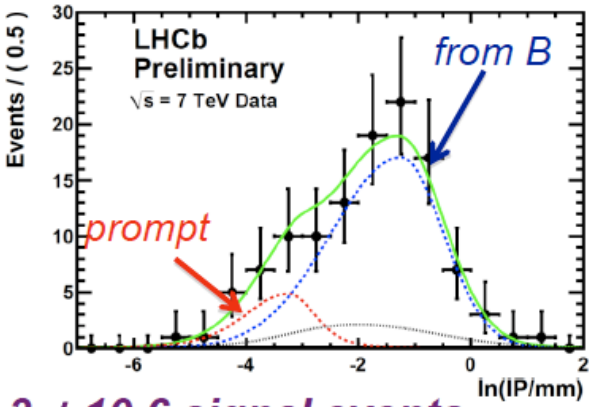
Wrong sign $D^0\mu^+$

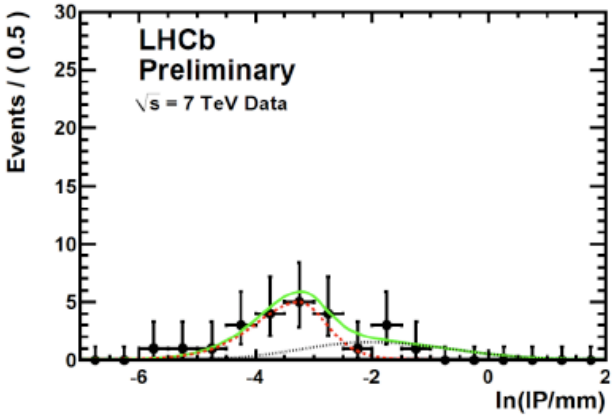
$m(K^-\pi^+)$





D^0 IP

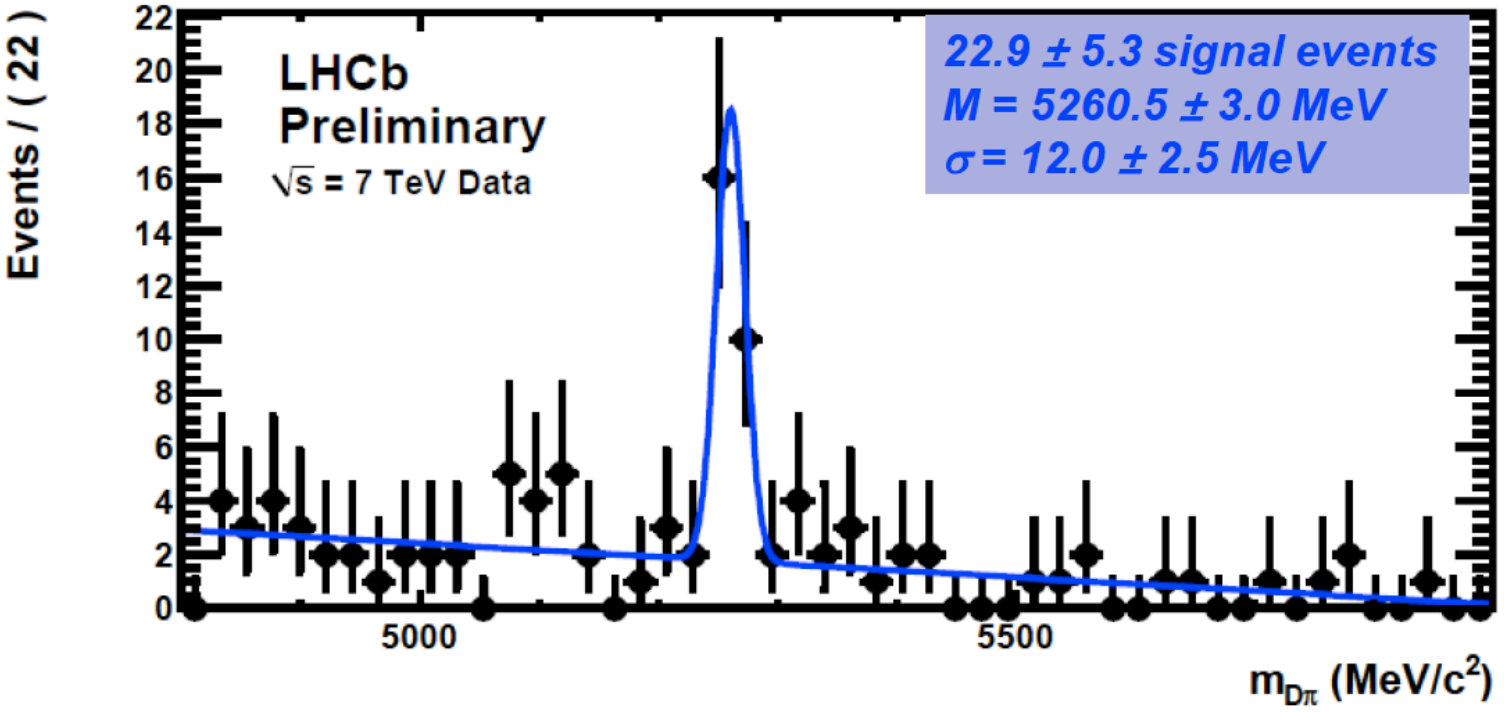




85.3 ± 10.6 signal events with D from B

First fully reconstructed B mesons

$$\overline{B^0} \rightarrow D^+\pi^- \;+\; B^+ \rightarrow \overline{D^0}\pi^+$$



Calibration of the B-field is ongoing

Data analysis at LNF

1) Muon chamber hardware efficiency maps

2) Offline muon identification: algorithm validation, efficiency, background

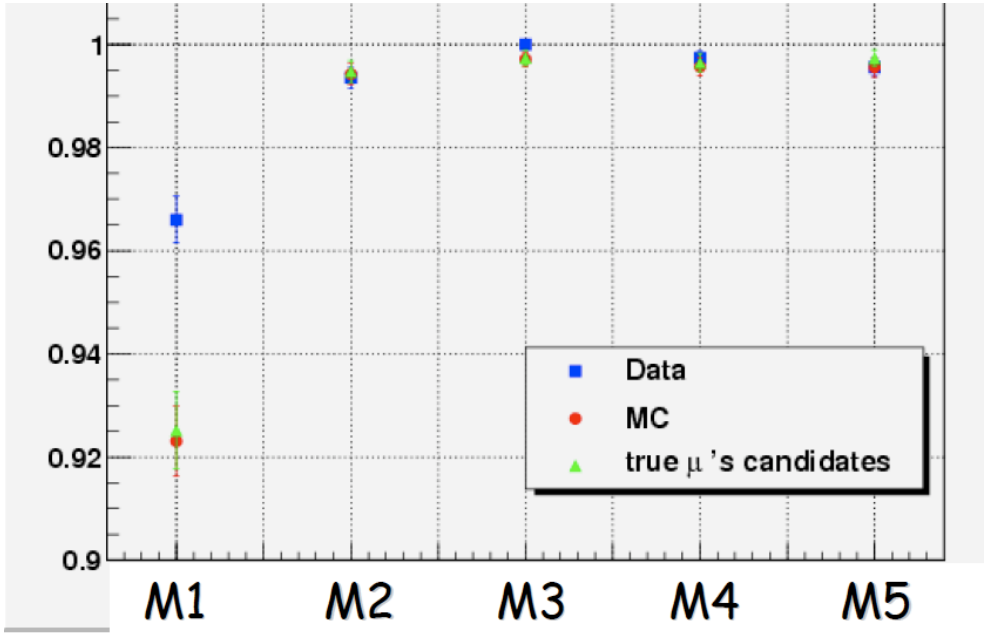
3) J/psi production cross section (->10pb^{-1})

4) $B_s \rightarrow \mu^+\mu^-$ (->200pb^{-1})

- LNF analysis group: P. De Simone, G. Lanfranchi, M. Palutan, A. Sarti
- 1) and 2) are under our responsibility
- 3) and 4) in cooperation with flavor and rare decay WGs (G.L. as convener of $B_s \rightarrow \mu^+\mu^-$ WG)

Muon chamber efficiency

Muon tracks selected from min bias events, with 4 out of 5 stations fired



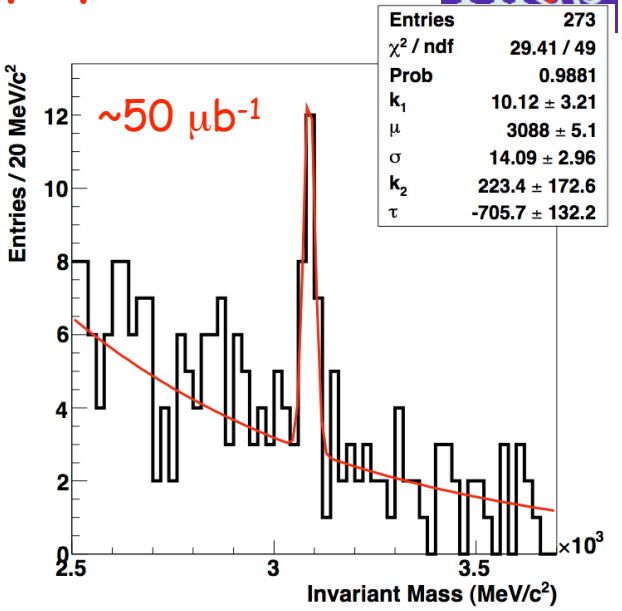
Excellent data-MC agreement for M2-M5 (refining the method on M1 to suppress residual bkg on data)

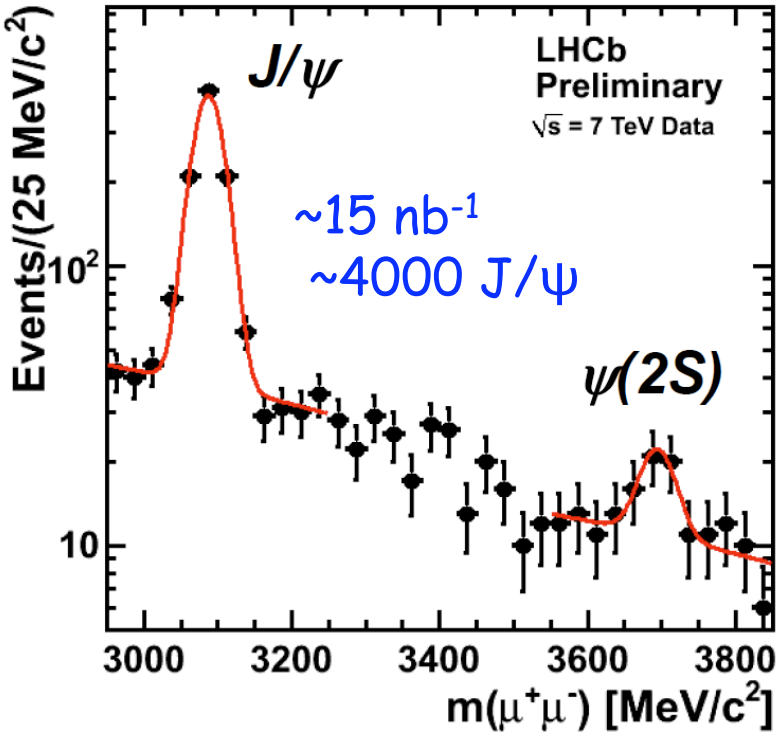
(online monitor already in data-stream)

MuonID validation: J/ψ→μ⁺μ⁻

- Offline muon identification based on matching btw reconstructed tracks and hits in the muon station [LHCb-PUB-2009-013]

- First J/ψ observed on April 7, 2010 (1:30AM)

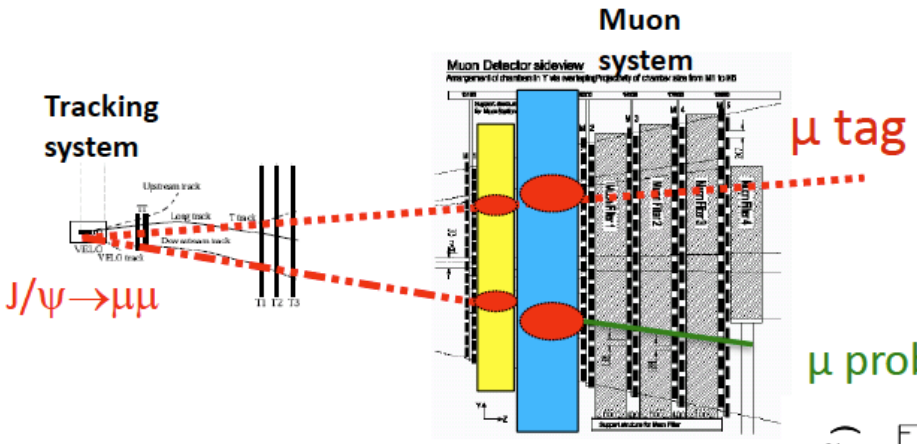




Work in progress:

- measure MuonID efficiency with tag and probe method → LNF group
- measure J/ψ and ψ(2s) production rate and polarization in pp collisions → within the LHCb flavor working group

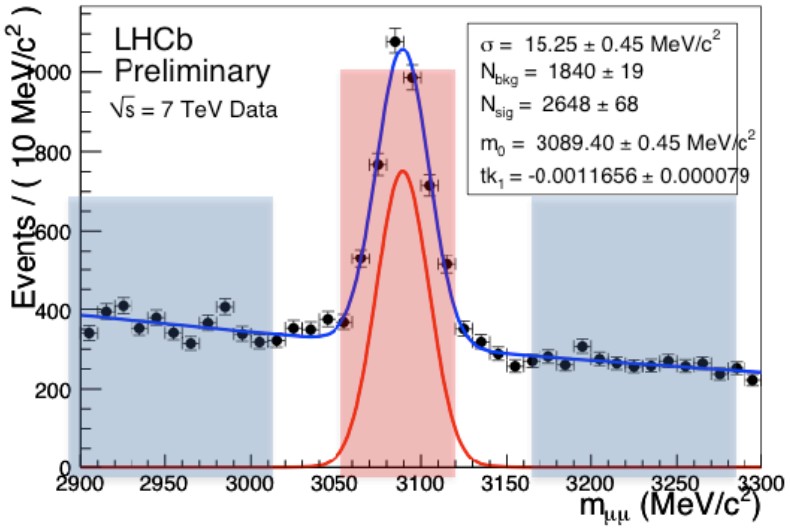
MuonID efficiency



Tag and probe method:

1) 2-track vertex
2) one muon identified by MuonID → tag
3) 2nd track satisfies loose calorimeter selection → probe

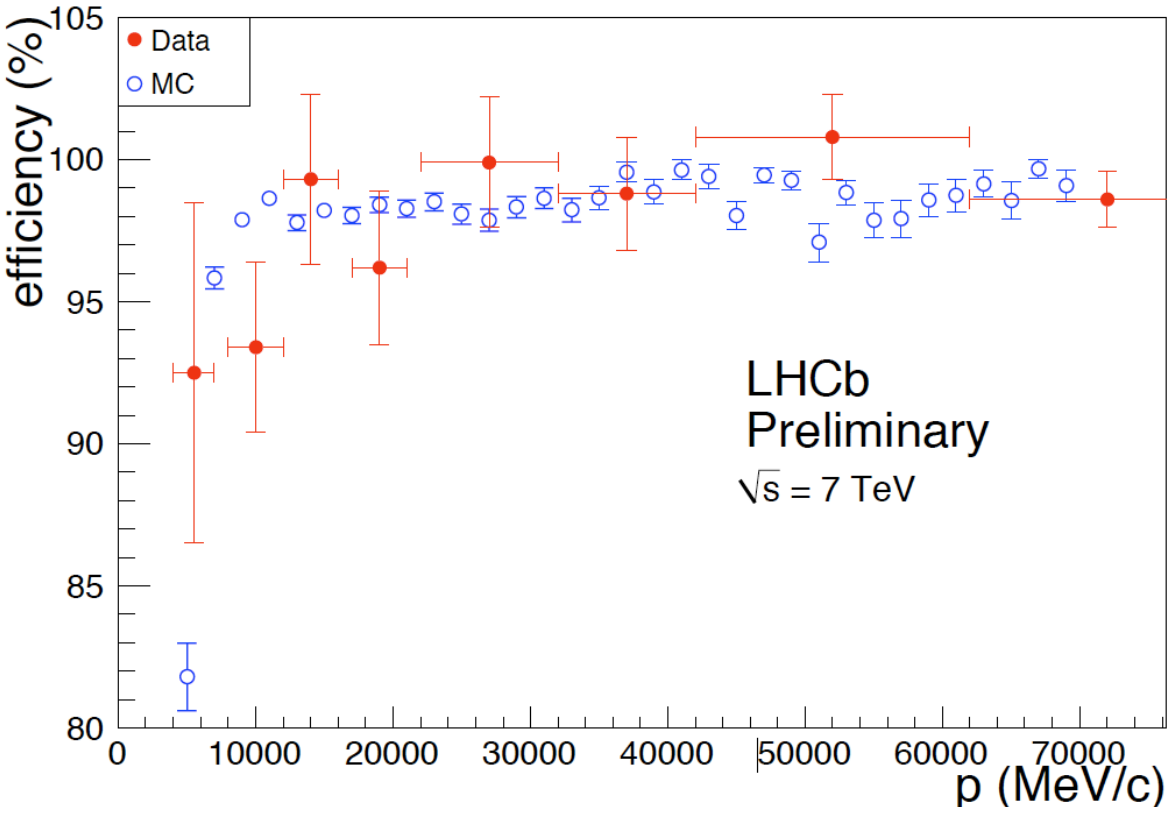
[MC study in LHCb-PUB-2010-002]



Background subtraction using mass sidebands

- → ε(μ) = 97.3 ± 1.2 %

MuonID efficiency vs p

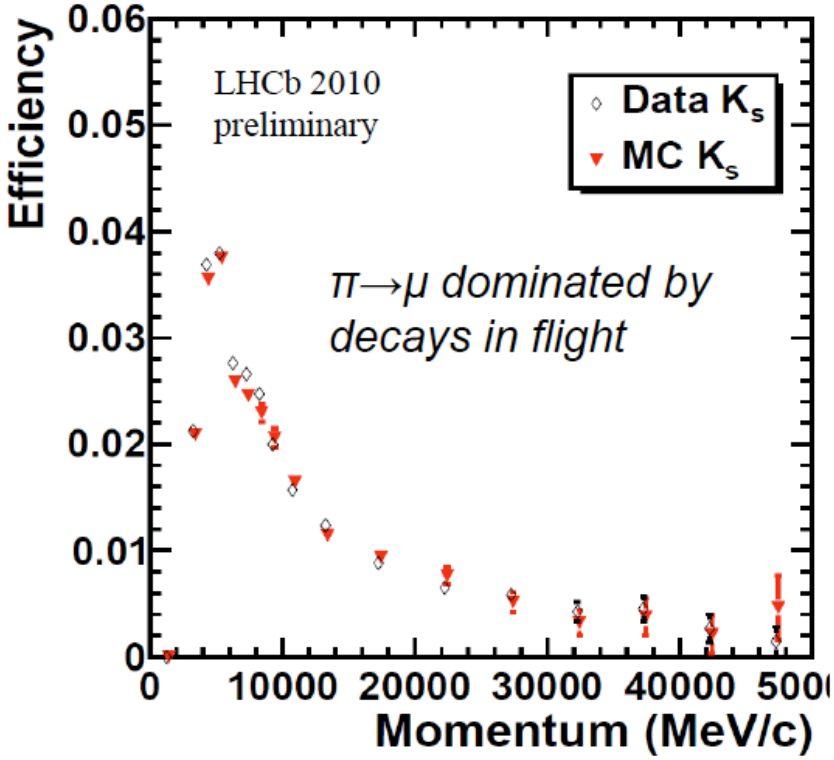


Universal curve → compute efficiency corrections for all analyses involving μ's
With present statistical accuracy, good agreement btw data and MC

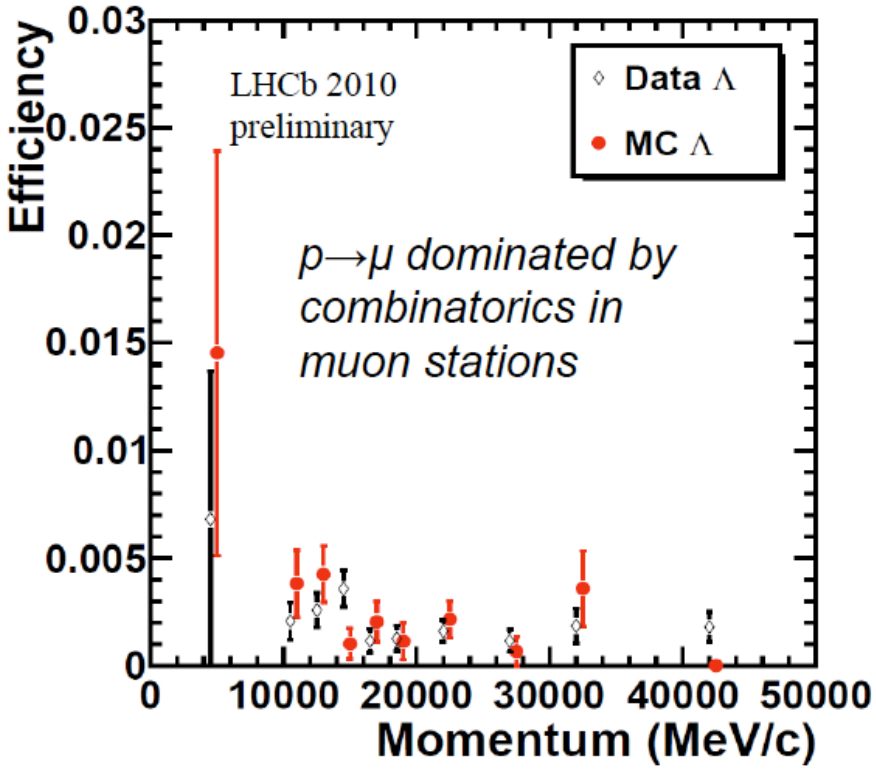
(calibration stream AND online monitor already running)

Measurement of muon MisID

$\pi \rightarrow \mu$ misID from $K_S \rightarrow \pi^+\pi^-$



$p \rightarrow \mu$ misID from $\Lambda \rightarrow p\pi$



Excellent data/MC agreement (0.1-0.2%)
This measurement is relevant to control background in rare decays with μ's

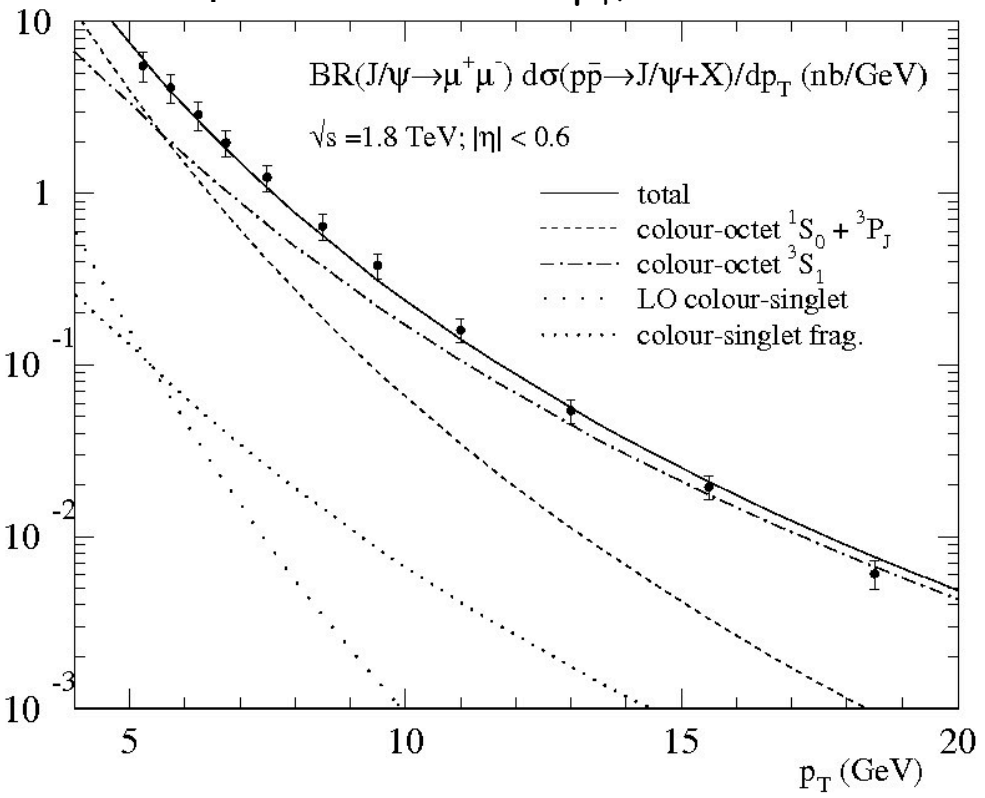
J/psi analysis: motivations

- QCD test by measuring the J/ψ and ψ(2s) production cross section and polarization in bins of p_T and rapidity (y);
- Use proper time to disentangle, for each bin, contributions from prompt J/ψ or J/ψ from B decays;
- Aims at 10% accuracy per bin in $0<p_T<12$ GeV/c and $2<y<4.5$ → 10-20 pb^{-1} needed

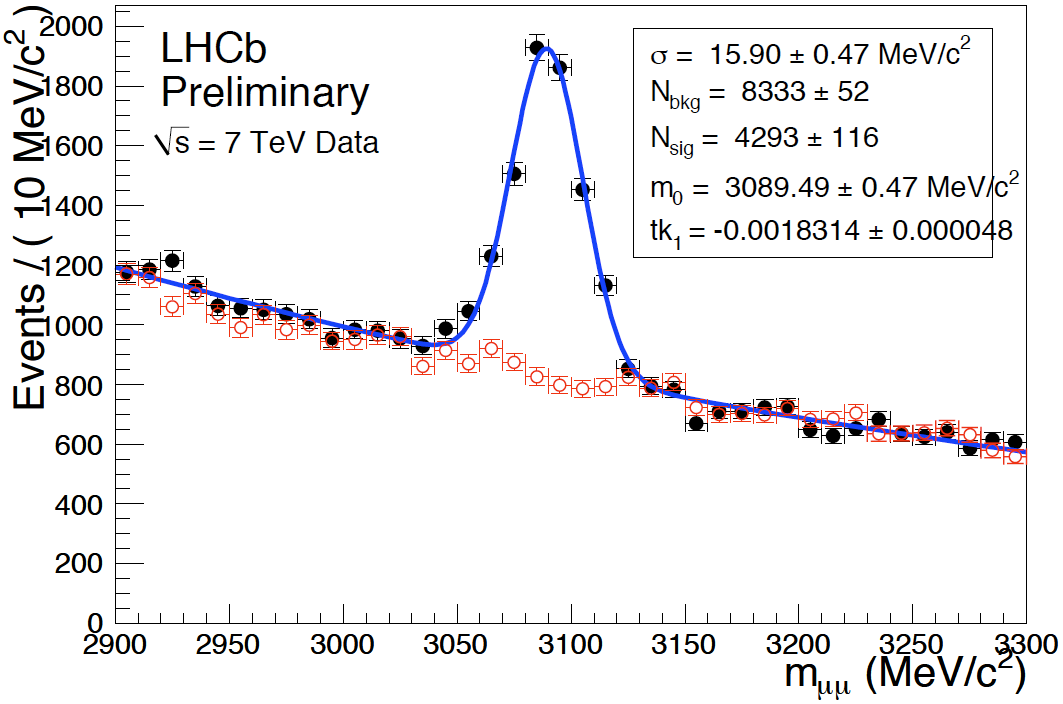
Goals for ICHEP (15-100nb^{-1}):
- $d\sigma/dp_T$ (all J/ψ)
- J/ψ from B vs J/ψ prompt

integrating over p_T, y

J/ψ cross section vs p_T, Tevatron data



J/psi analysis: signal yield



~15 nb^{-1}
4300 evts
σ = 16MeV/c^2

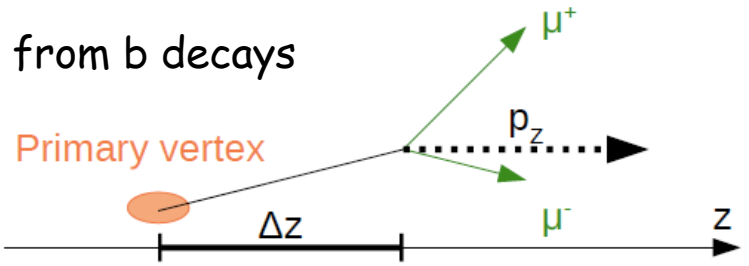
- Signal counts from mass fit in each (p_T,y) bin: from 15 nb-1
- Efficiency: tracking, μID, trigger
- Background studies using sidebands and same-sign dimuon events (LNF group)

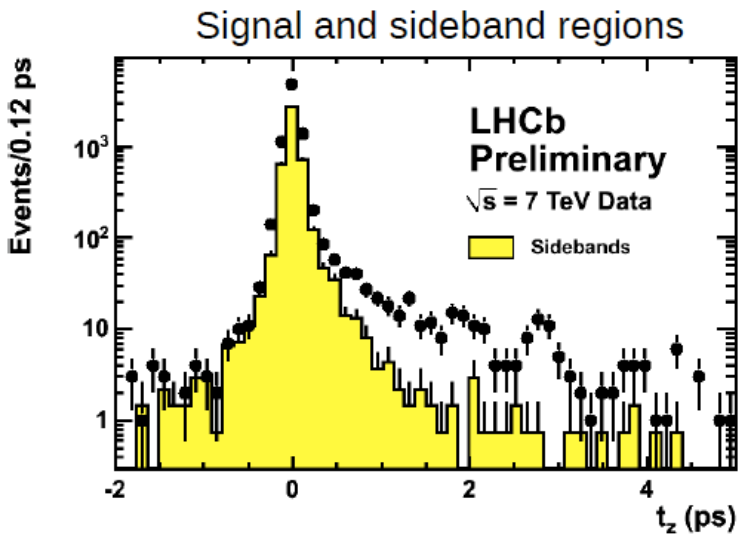
(dimuon stream prepared for the whole WG)

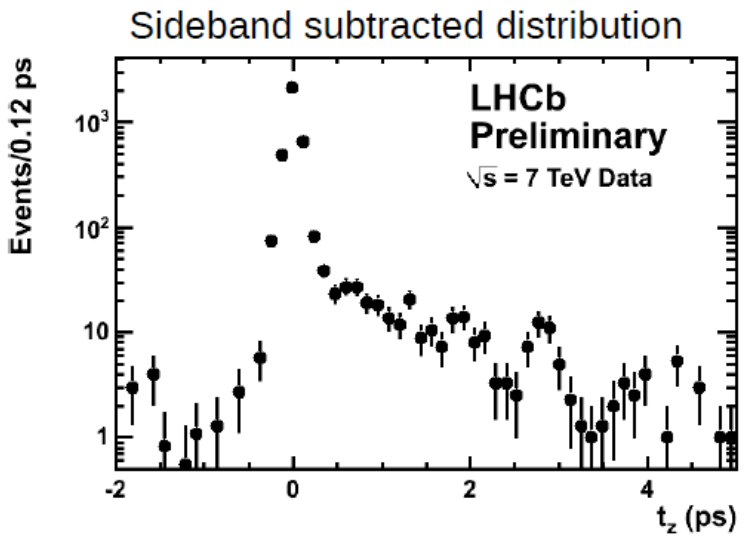
J/psi effective lifetime

Use pseudo-proper time to distinguish prompt from b decays

$$t_z = \Delta z \frac{M_{J/\psi}}{p_{zJ/\psi}}$$

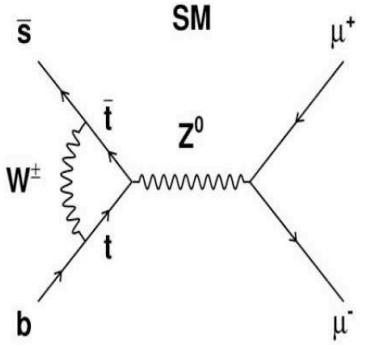






Clear signal from B hadron decays

Search for $B_s \to \mu^+\mu^-$: motivations



- Highly suppressed decay in the SM: BR=(3.6±0.4)×10^{-9}

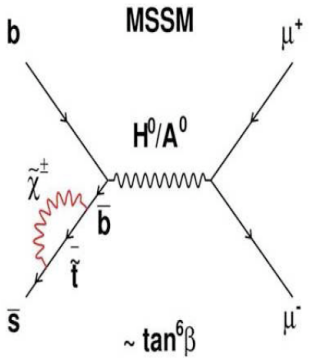
  [Buras, arXiv:0910.1032]

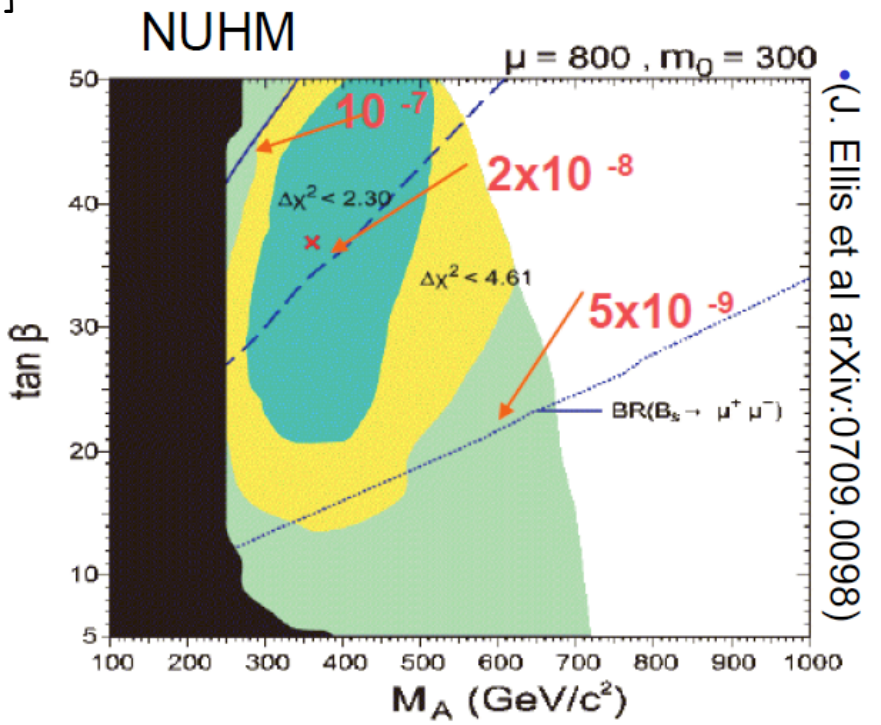
- Current best limit from CDF (3.7 fb^{-1}):

  BR<3.3×10^{-8} at 90% CL

  [CDF note 9892]

- Sensitive probe to New Physics:
  e.g. branching ratio in MSSM enhanced by sixth power of tanβ



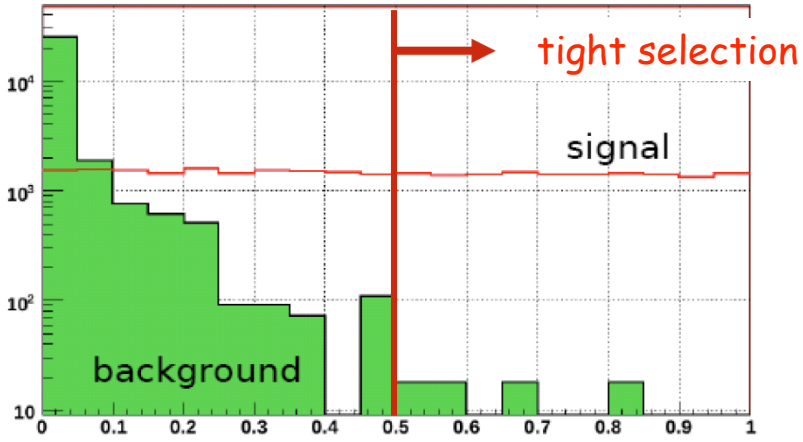


(J. Ellis et al arXiv:0709.0098)

$B_s \to \mu^+\mu^-$: analysis overview

Same philosophy as Tevatron→ loose preselection, then classify events according to a 3D likelihood:

1. $\mu^+\mu^-$ invariant mass
2. geometrical likelihood (GL): muon impact parameter, B lifetime, DOCA, isolation
3. μ identification



Control channels ($B_{(s)} \to hh'$) will be used to calibrate GL and invariant mass

Normalize to known B decay channels ($B_d \to K\pi$, $B^+ \to J/\psi(\mu^+\mu^-)K^+$) to derive BR:

$$BR(B_s) = BR(B^{norm}) \times \frac{N_{Bs}^{GL}}{N_{Bnorm}^{Tight}} \times \frac{\varepsilon_{Bnorm}^{REC}}{\varepsilon_{Bs}^{REC}} \times \frac{\varepsilon_{Bnorm}^{Sel|REC}}{\varepsilon_{Bs}^{Sel/REC}} \times \frac{\varepsilon_{Bnorm}^{Trig|Sel}}{\varepsilon_{Bs}^{Trig|Sel}} \times \frac{f_{Bnorm}}{f_{Bs}}$$

main systematics (~13%) from hadronization rate $f_{u,d}/f_s$

→ extract f_d/f_s by measuring $B_d \to DK/B_s \to D_s\pi$ at LHCb (arXiv:1004.3982)

→ normalize instead to B_s channel (better measurements needed)

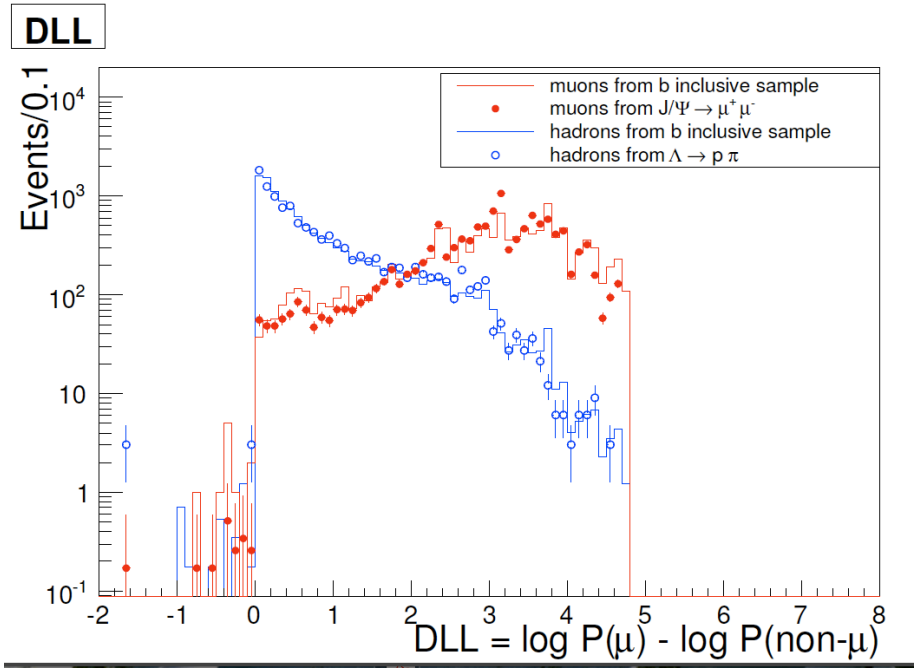
How to improve μID

Standard μID requires 2,3 or 4 hits (depending on track momentum) in M2,…,M5 stations in a large FOI around the extrapolated track.

A good discriminating variable btw muons and bkg (both combinatorics and decays in flight) is the average square distance btw the extrapolated track and the muon hits

$$D = \frac{1}{N}\sum_{i=0}^{N}\left\{\left(\frac{x_{closest,i} - x_{track}}{pad_x}\right)^2 + \left(\frac{y_{closest,i} - y_{track}}{pad_y}\right)^2\right\}$$

This variable is used to build a muon likelihood which improves rejection of $B \to hh'$ bkg to $B_s \to \mu\mu$



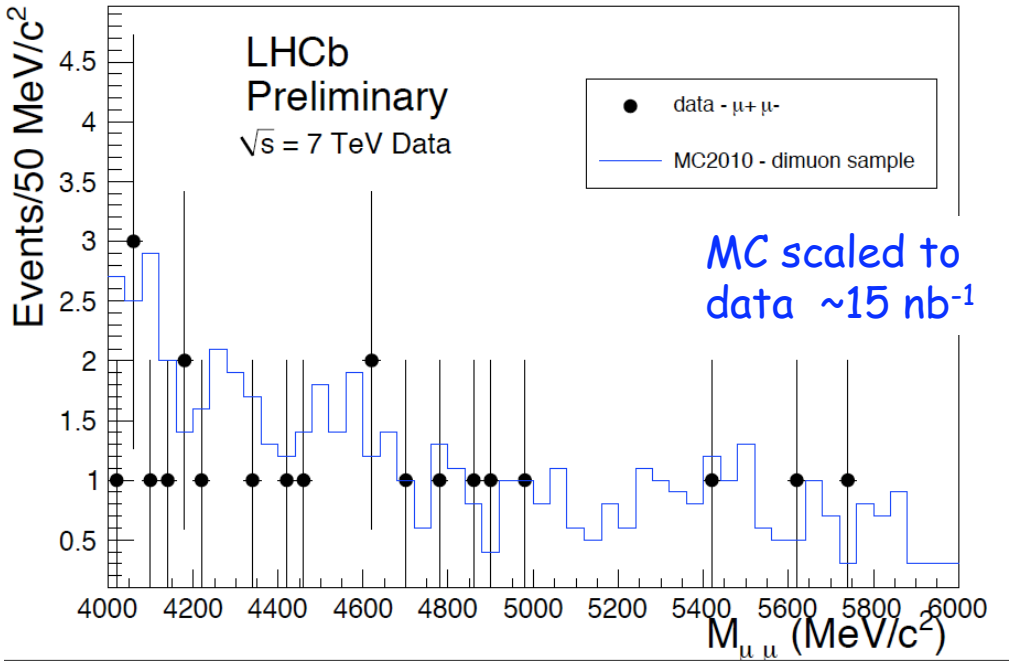
We're presently calibrating the muon likelihood on true muons from J/ψ and $\Lambda \to p\pi$ decays

$B_s \rightarrow \mu^+\mu^-$: a first look at background

Data-MC comparison after loose preselection

[LHCb ArXiv:0912.4179]

Reasonable agreement btw data and MC



- A factor of >10^4 more rejection power expected from geometrical likelihood: with present limited stat., preliminary studies ongoing on $K_S \rightarrow \pi\pi$ and $D \rightarrow K\pi$

- Invariant mass resolution (MeV/c^2):

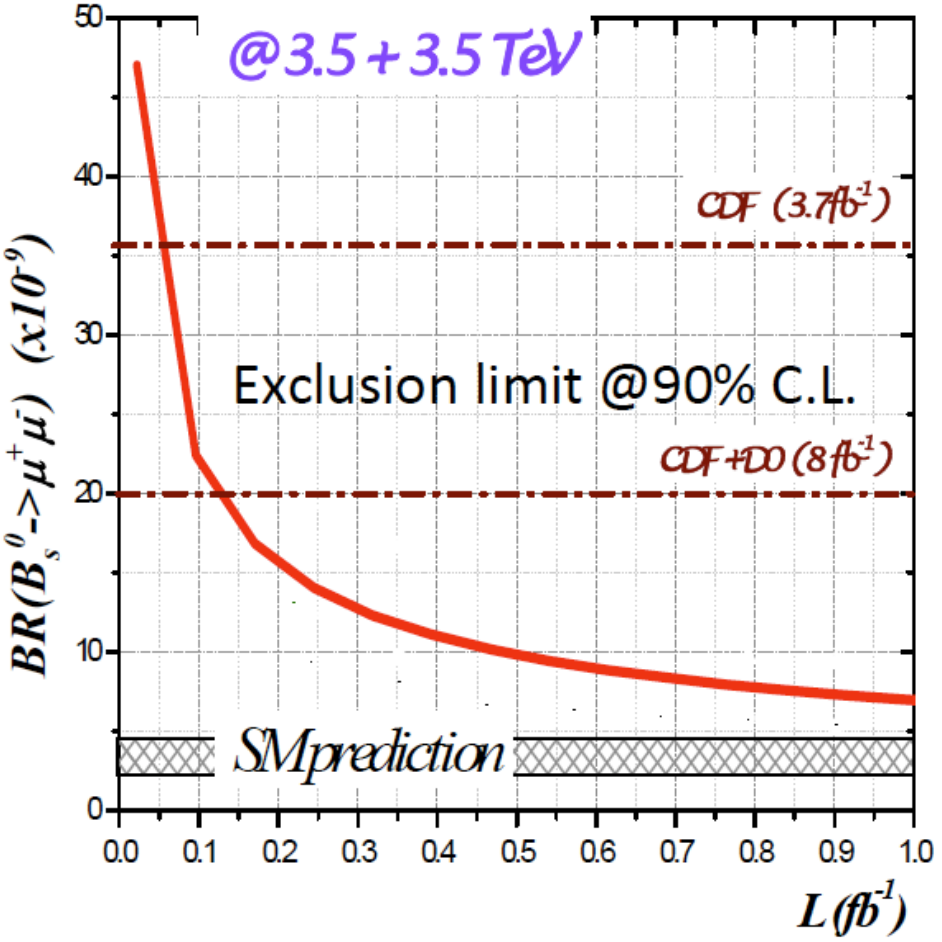
	K_S	J/ψ	B_s
data	3.5	~15	
MC	3.3	~13	~20

LHCb prospects for $B_s \rightarrow \mu^+\mu^-$

Ongoing studies on data (very preliminary!) indicate that MC simulation is reliable

LHCb sensitivity (from MC):

- with 0.1 fb^{-1} we can improve the current best experimental limit
- with 1 fb^{-1} we expect to exclude BR up to 7×10^{-9} at 90% CL



Conclusions

- LNF/LHCb group contributed *substantially* to the construction of the MUON detector: MWPC and GEM chambers (~1/3 of total), off-detector electronics, mechanical infrastructures, services, installation and full apparatus commissioning → huge effort from a very well motivated and highly experienced team of technicians, engineers and physicists
- Very active contribution to data taking and muon detector maintenance: run chief, muon piquet and data quality shifts attended

- Our goal now is giving a *comparable* contribution to data analysis!
- We're responsible for:
  - muon chamber efficiency monitoring
  - offline muon ID validation, calibration and monitoring
- We're deeply involved in:
  - measurement of J/psi production (preliminary results at ICHEP)
  - search for $B_s \rightarrow \mu^+\mu^-$ (LHCb milestone)

…full integration with LHCb analysis WGs