LHCb experiment at LHC

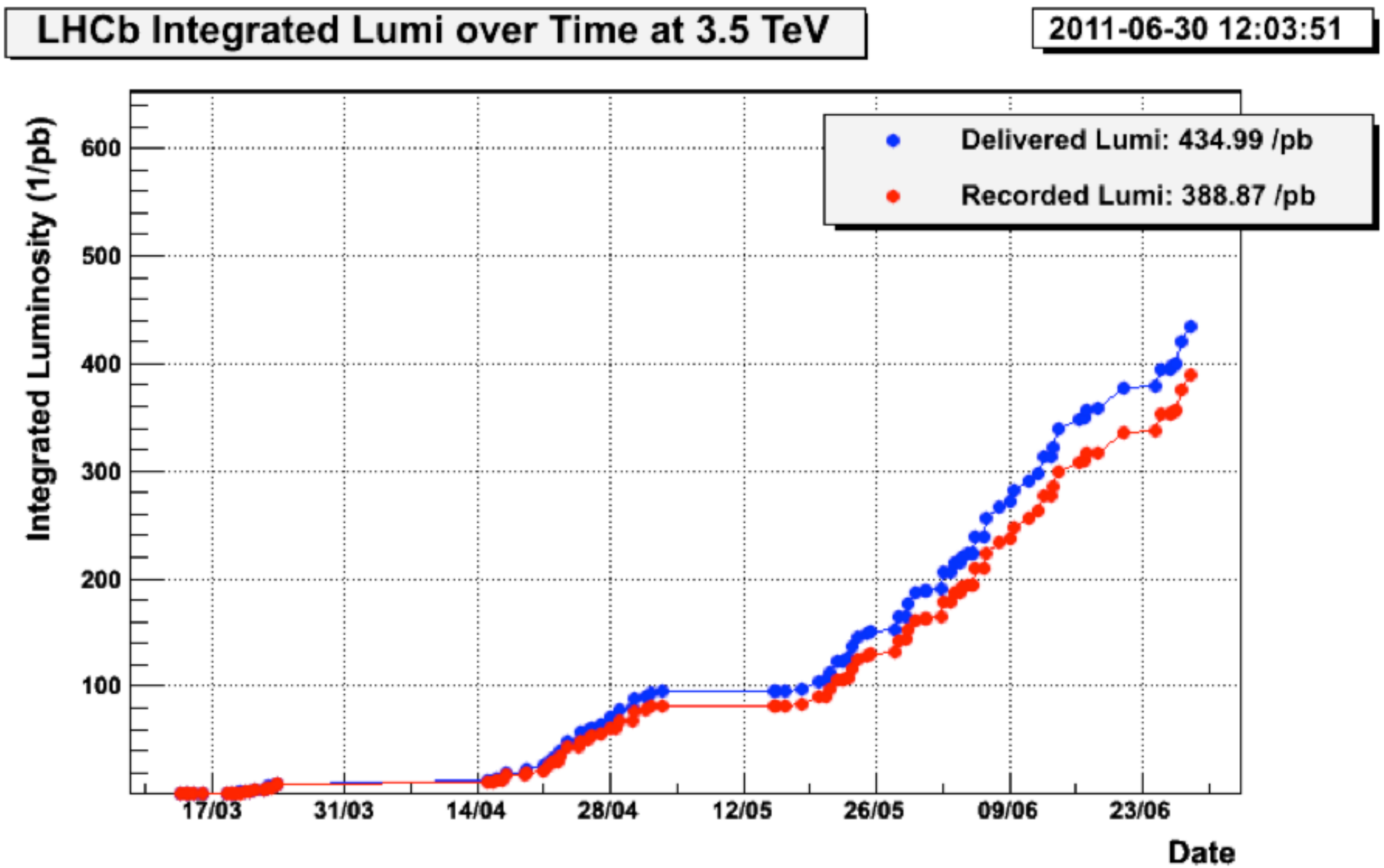
(LNF group activities)

Matteo Palutan
for the Frascati LHCb group

- news from LHCb
- data analysis at LNF
- LHCb upgrade and future activities

LNF meeting, July 6th 2011, Frascati

LHCb data taking 2011



end of June
~390 pb^{-1}
recorded

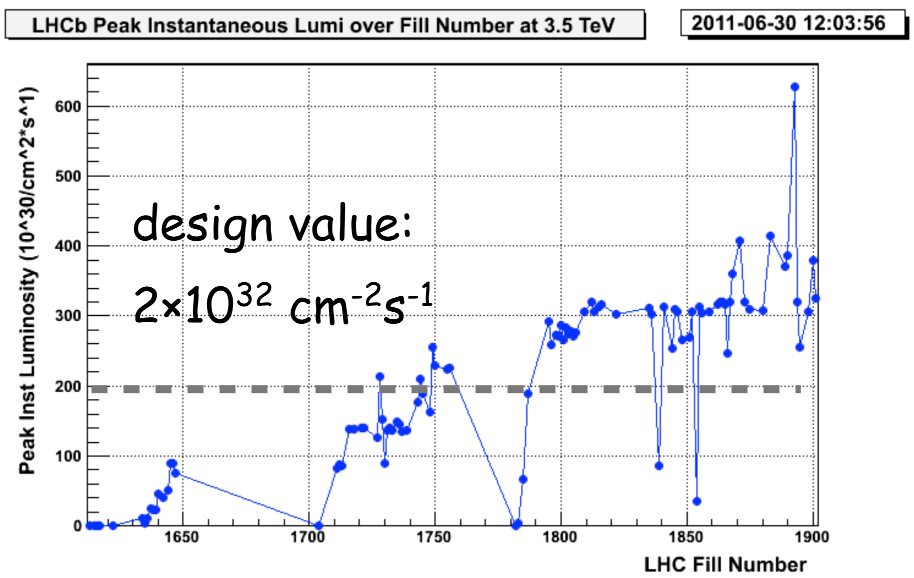
~90% data taking efficiency (data quality retains 99%)

We expect to integrate up to $2fb^{-1}$ within 2012

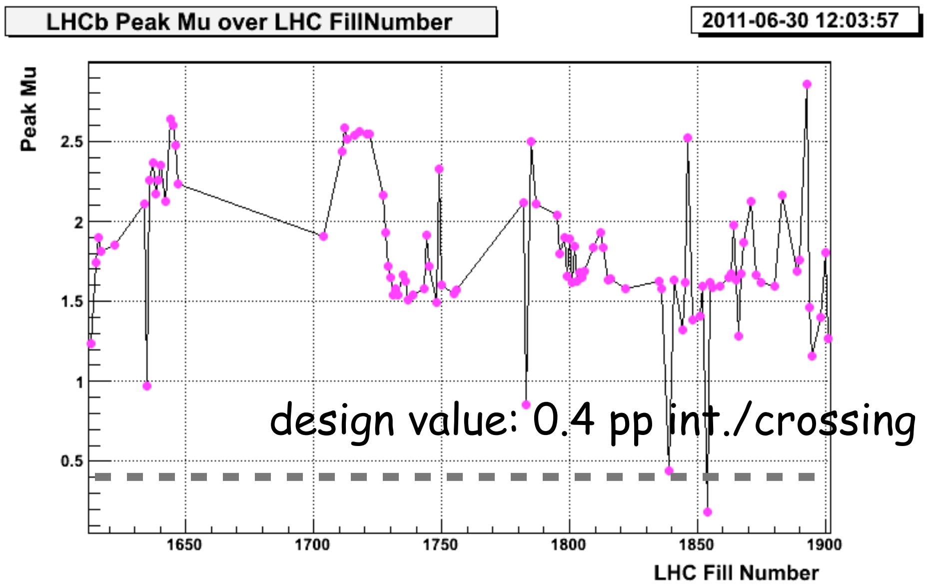
LHCb data taking 2011

LHCb is taking data well above its design specifications!!

max luminosity

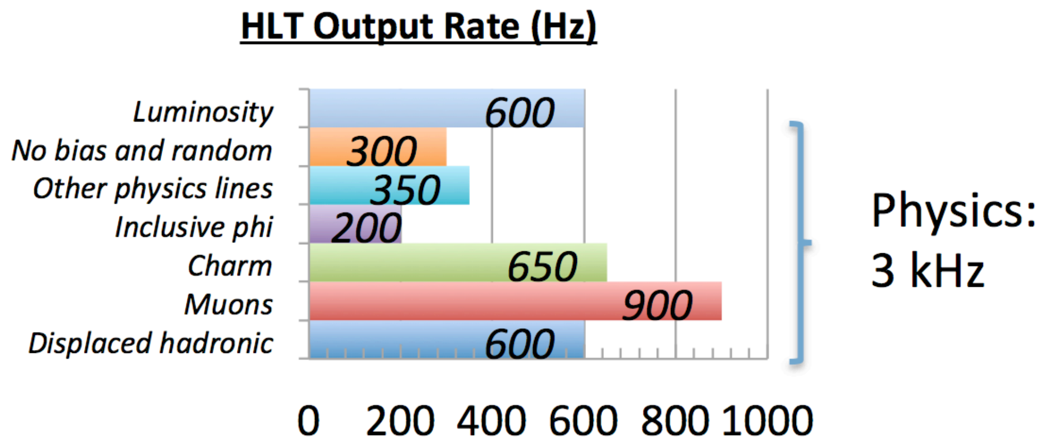


Mu = pp interaction/bunch crossing



Luminosity and trigger strategy:

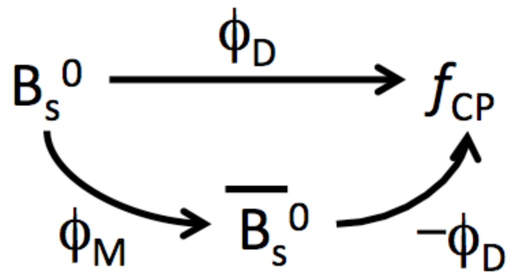
- keep Mu<2.5
- luminosity leveling at $\sim3\times10^{32}$ cm^{-2}s^{-1}



Physics results on 2010 data (36 pb^{-1})

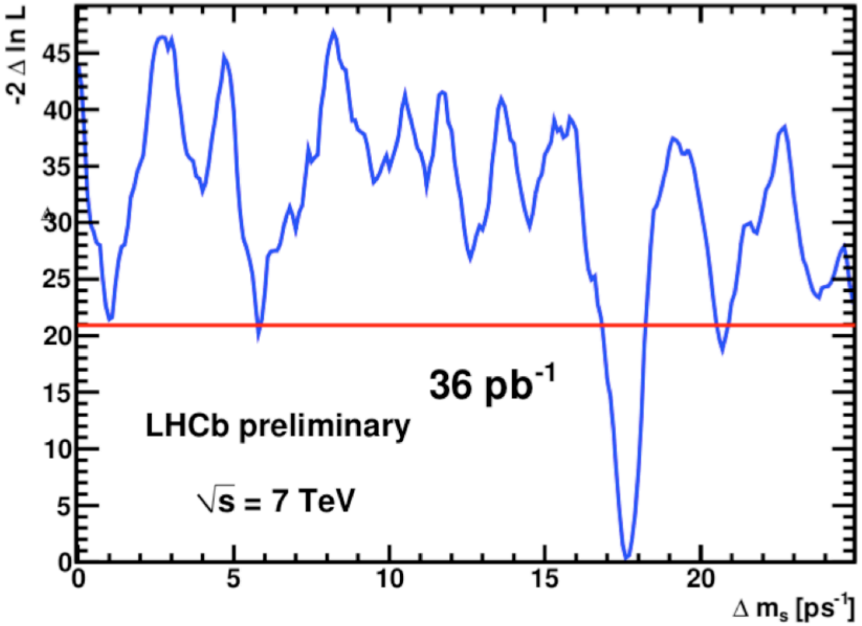
CP violation in B_s decays: φ_s

$$\varphi_s = \varphi_M - 2\varphi_D = -0.0363 \pm 0.0017 \text{ in SM}$$

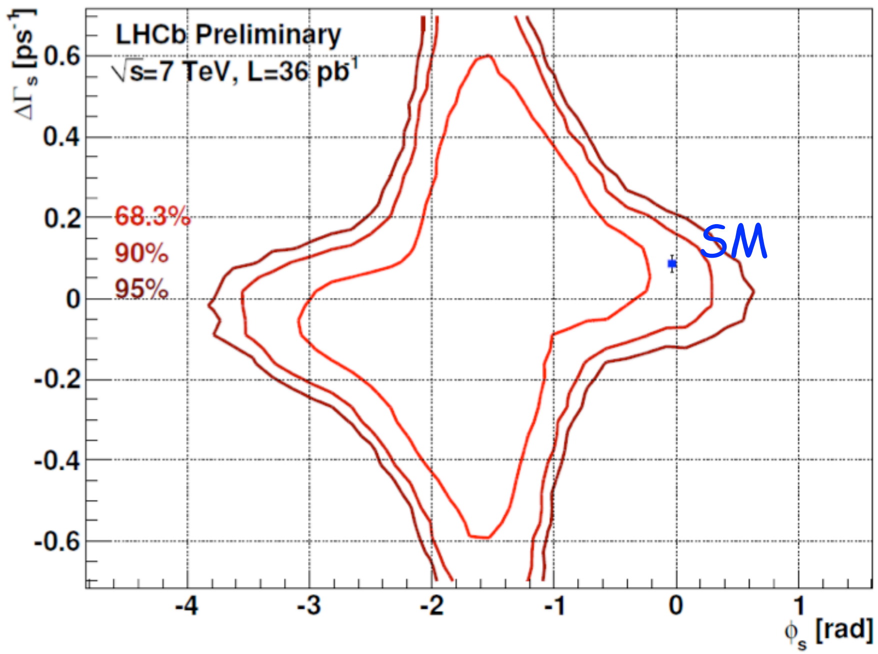


New physics can modify mixing phase, and enhance φ_s

LHCb-CONF-2011-005



$$\Delta m_s = 17.63 \pm 0.11 \pm 0.04\,\mathrm{ps}^{-1}$$



LHCb-CONF-2011-006

$\phi_s \in$ [-2.7, -0.5] rad at 68% CL
$\phi_s \in$ [-3.5, 0.2] rad at 95% CL

Physics results on 2010 data: $B_s \to \mu^+\mu^-$

Physics Letters B 699 (2011) 330–340

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www.elsevier.com/locate/physletb

Search for the rare decays $B_s^0 \to \mu^+\mu^-$ and $B^0 \to \mu^+\mu^-$ ☆

LHCb Collaboration

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ABSTRACT

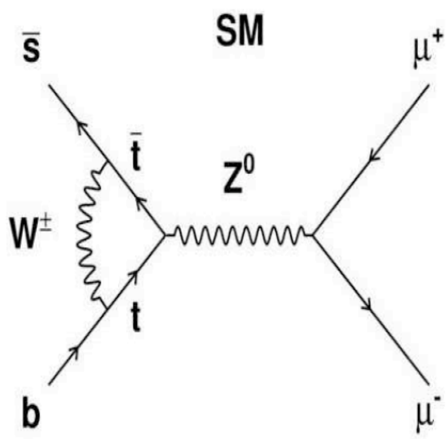
A search for the decays $B_s^0 \to \mu^+\mu^-$ and $B^0 \to \mu^+\mu^-$ is performed with about 37 pb^{-1} of *pp* collisions at $\sqrt{s} = 7$ TeV collected by the LHCb experiment at the Large Hadron Collider at CERN. The observed numbers of events are consistent with the background expectations. The resulting upper limits on the branching ratios are $\mathcal{B}(B_s^0 \to \mu^+\mu^-) < 5.6 \times 10^{-8}$ and $\mathcal{B}(B^0 \to \mu^+\mu^-) < 1.5 \times 10^{-8}$ at 95% confidence level.

Main interest of the LNF group!

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

- Highly suppressed decay in the SM: BR=(3.2±0.2)×10^{-9}

A.J.Buras, arXiv:1012.1447,
E.Gamiz et al. Phys.Rev.D 80 (2009) 014503



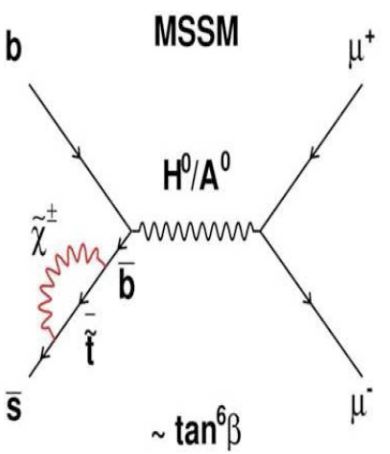
- Current best limit from CDF (3.7 fb^{-1}):

BR<3.6×10^{-8} at 90% CL

[CDF note 9892]

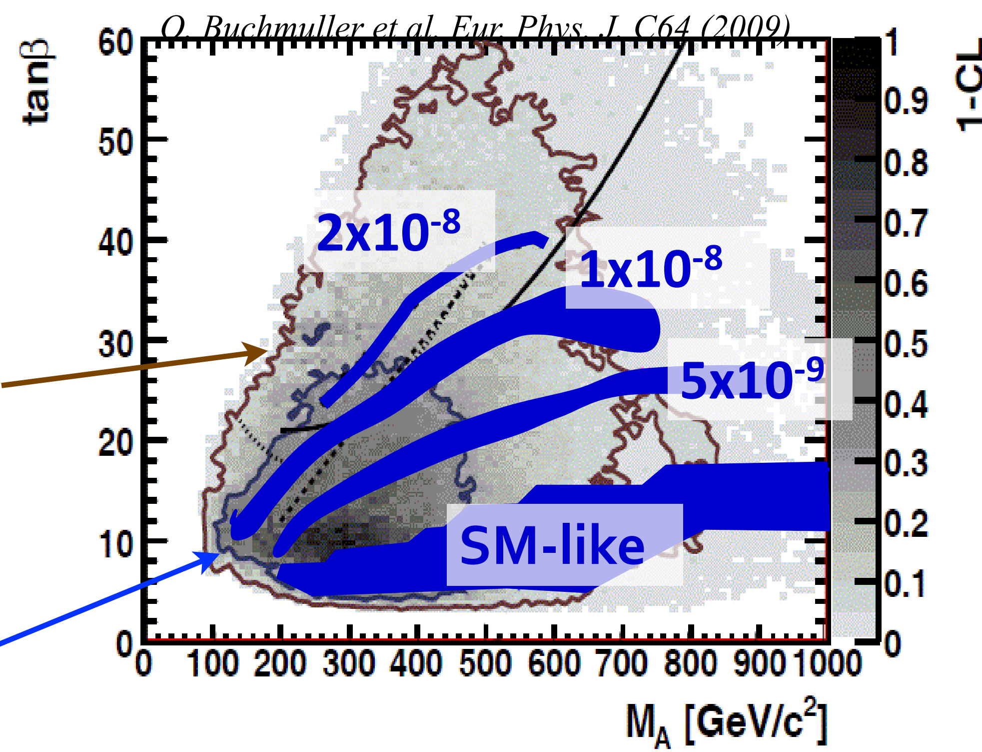
- Sensitive probe to New Physics:

e.g. branching ratio in MSSM enhanced by sixth power of tanβ



Best fit contours in tanβ vs M_A plane in the NUHM1 model

Regions compatible with different values of BR($B_s \to \mu\mu$)



$B_s \rightarrow \mu\mu$ at LHCb

- ❒ Huge cross section: **$\sigma(pp \rightarrow bbX)$ @ 7 TeV ~ 300 μb**

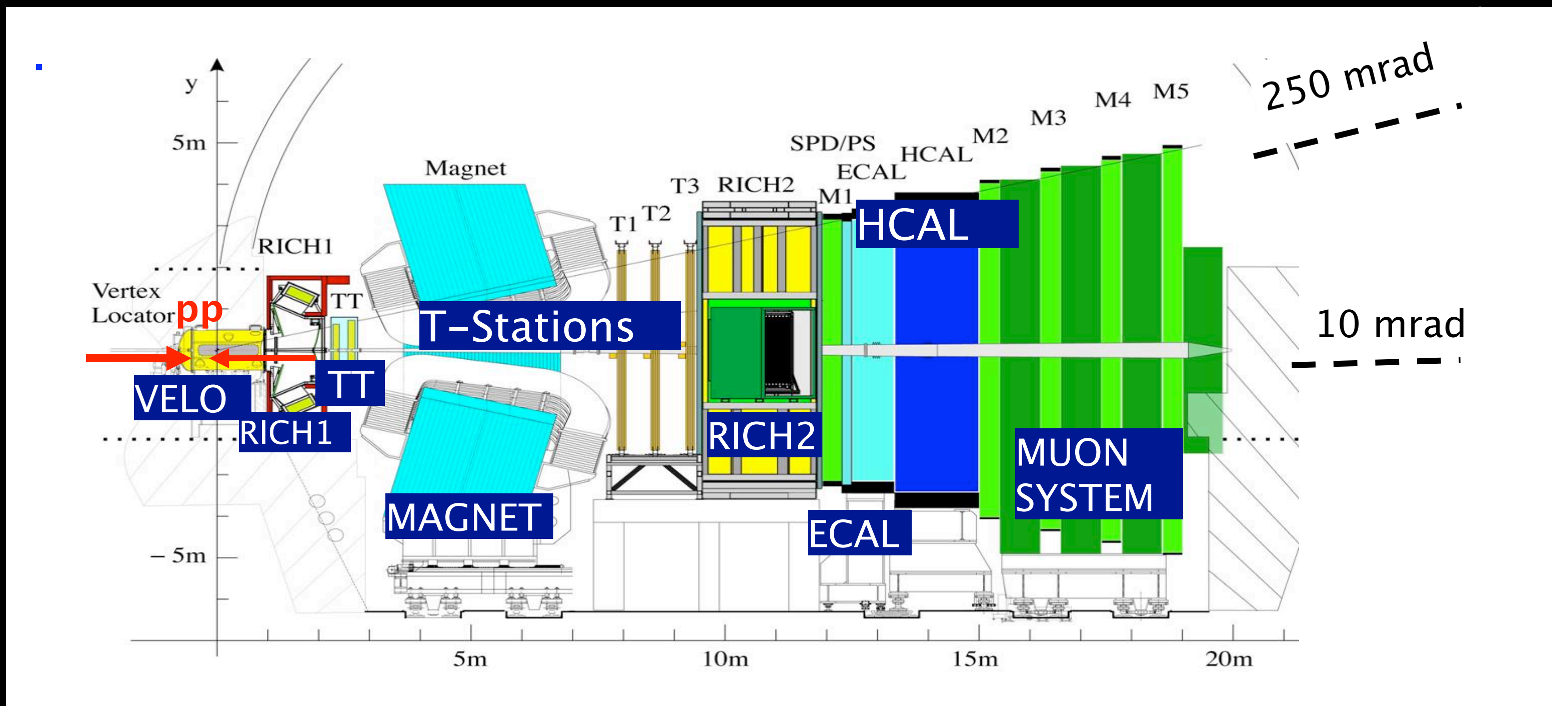
  LHCb, PLB 694 (2010)

  Large acceptance (bb are produced forward/backward): **$1.9<\eta<4.9$**

  → ε(acceptance×reco) for $B_s \rightarrow \mu\mu$~ 10% *SM: 0.7 $B_s \rightarrow \mu\mu$ events*

- ❒ Large boost: **→ average flight distance of B mesons ~ 1 cm**

  → 12k $B^+ \rightarrow J/\psi(\mu\mu)K^+$ with 0.037 fb^{-1} *CDF ~20k with 3.7 fb^{-1}*



Key ingredients for $B_s \rightarrow \mu\mu$

1) Efficient trigger:

- to identify leptonic final states: efficiency ~90% (low p_T thresholds)

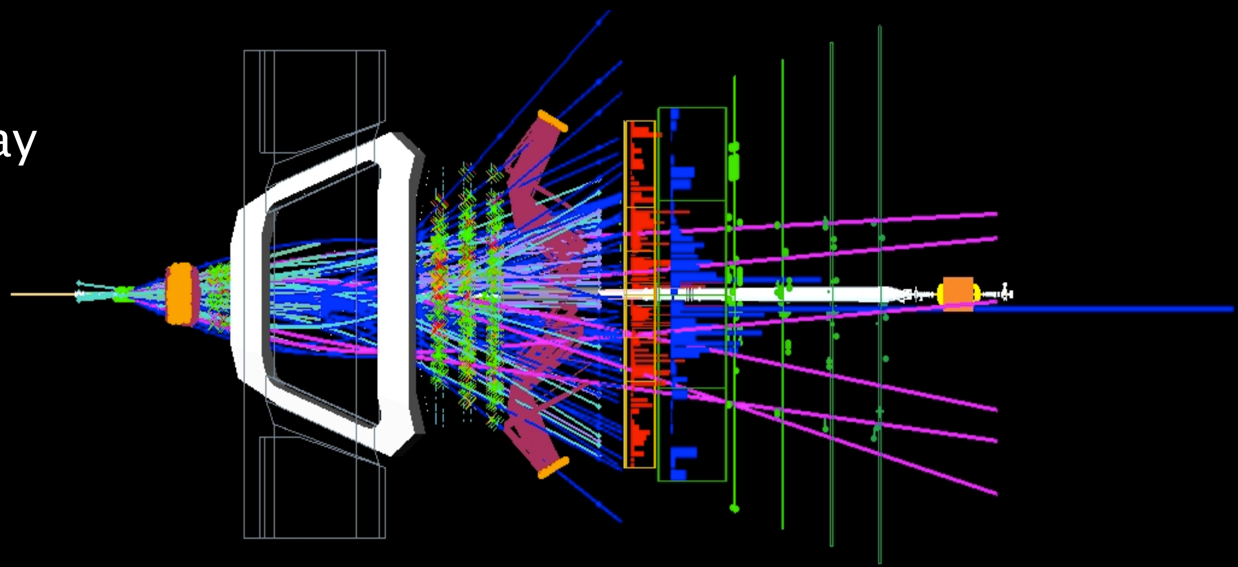
2) Background reduction:

- Very good mass resolution : dp/p~ 0.35% → 0.55% for p=(5-100) GeV/c
- Particle identification: $\varepsilon(\mu \rightarrow \mu)$ ~ 98% for $\varepsilon(h \rightarrow \mu) < 1\%$ for p>10 GeV/c

3) Excellent vertex & IP resolution:

- to separate signals from background : σ(IP)~ 25 μm @ p_T=2 GeV/c

LHCb event display



~2.5 pp interactions per Xing

Background rejection

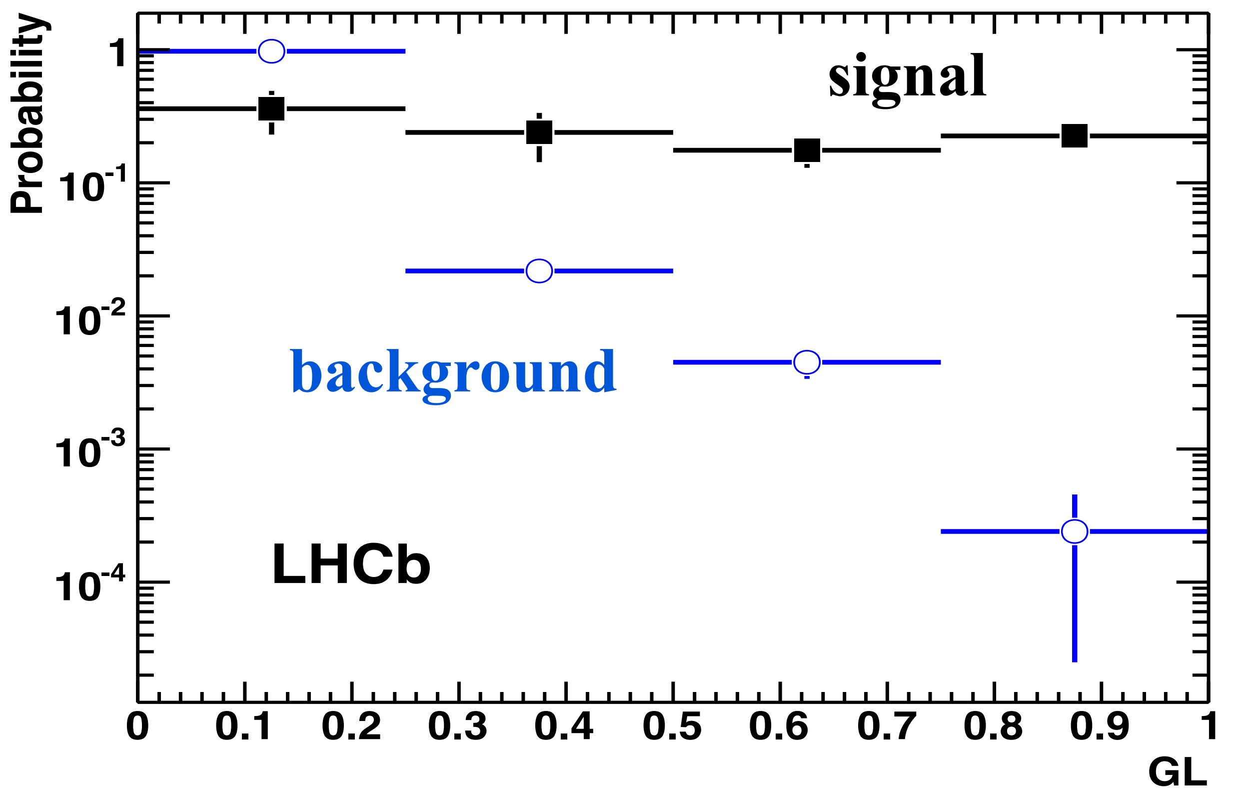
Our main background is combinatorial from two real muons

→ **reduce it by combining in a likelihood variables related to the geometry and kinematic of the event**

The likelihood variable (GL) is calibrated from data, to avoid bias from MC

a) for signal use $B^0_{(s)} \to h^+h^-$
same topology
LNF

b) for background use the mass sidebands
peaking background negligible

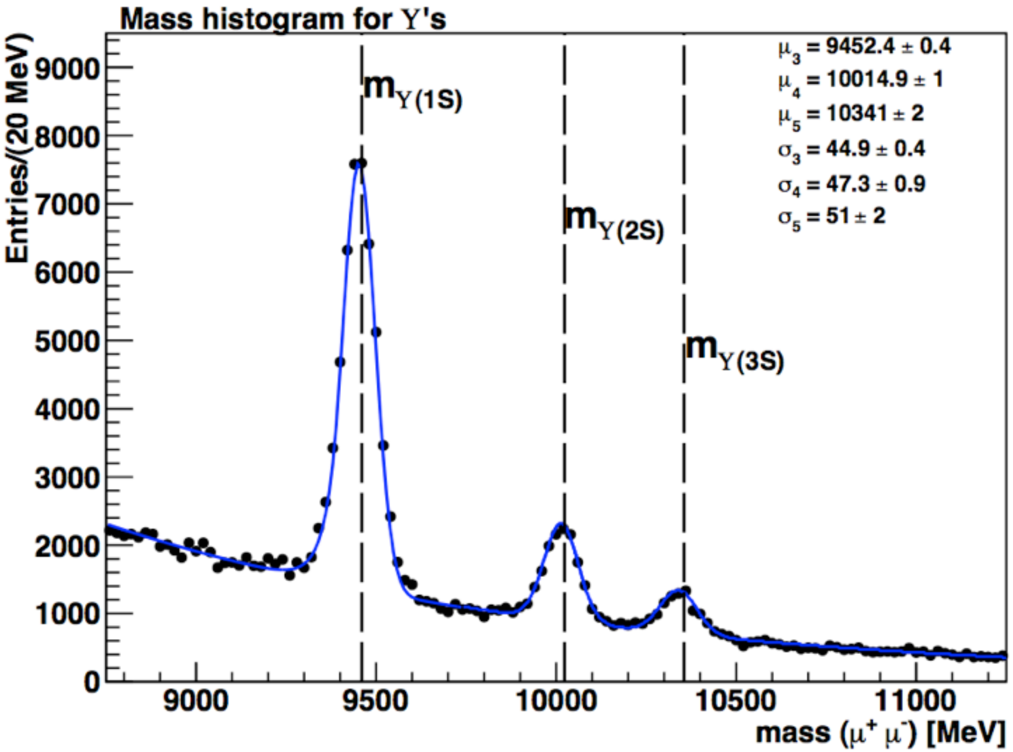


analysis is performed in 4 likelihood bins

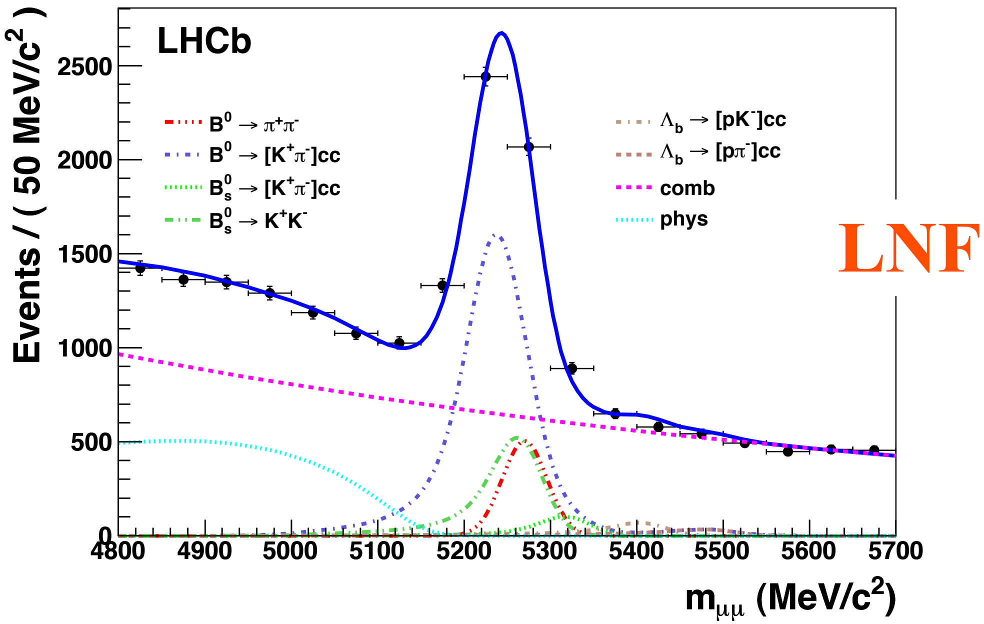
Signal Invariant Mass calibration

The mass averages values are obtained from $B^0 \to K^+\pi^-$ and $B^0_s \to K^+K^-$ (with PID)
The mass resolution is obtained from data via two methods:

1) Interpolate dimuon resonances (J/ψ, $\psi(2s)$, Υ's)



2) Fit to B→hh' inclusive sample (no PID)



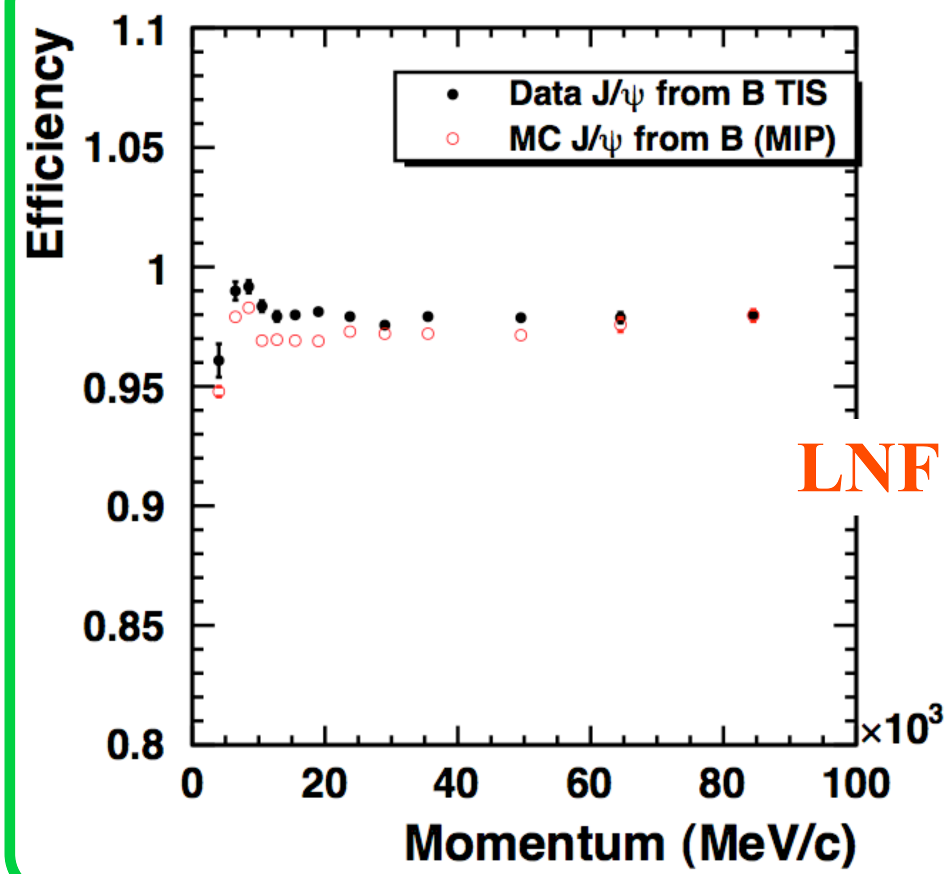
Both methods agree and are combined:

$\sigma = 26.7 \pm 0.9_{stat+syst}$ MeV/c^2

Normalization and efficiencies

The signal PDF can be translated into a number of expected signal events by normalizing to a channel with known BR; three independent channels used (with different systematics)

$B^0 \to K^+\pi^-$	**$B^+ \to J/\psi(\mu^+\mu^-)\ K^+$**	**$B_s \to J/\psi(\mu^+\mu^-)\ \varphi(K^+K^-)$**
2-body	*3-body*	*4-body*



Relevant efficiencies are cross-checked on data control samples

MuonID efficiency from *Jpsi tag-and-probe* is measured as a function of p,p_T; a data/MC correction is applied;

Muon misID is measured on data for pions, kaons and protons

Upper limit on BR($B_s \to \mu^+\mu^-$)

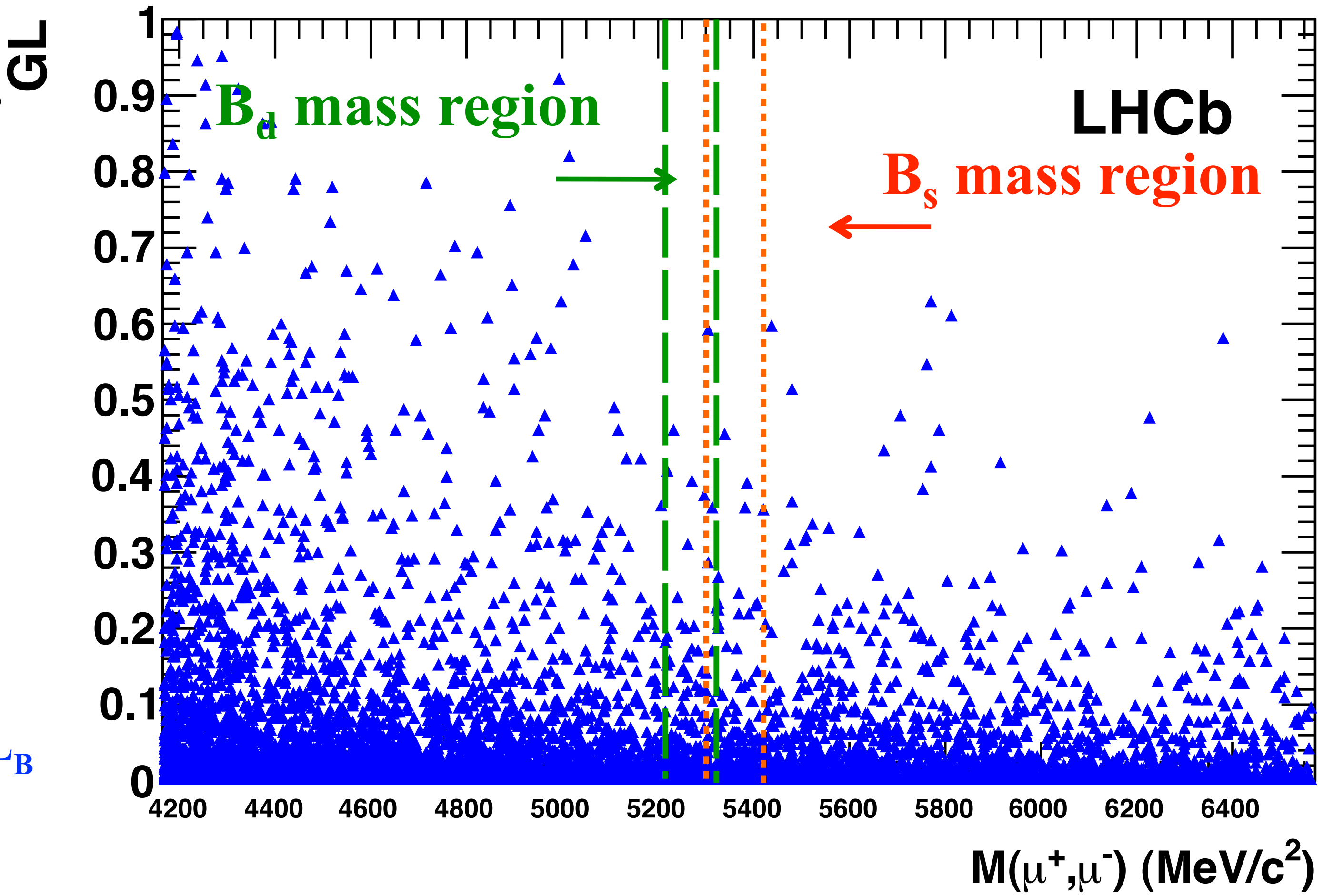
1) Count the events in 4 likelihood bins × 6 mass bins

2) For each bin compute the expected signal and background yields

3) Evaluate compatibility between observed and expected with

- **S+B hypothesis : CL_{S+B}**
- **B only hypothesis: CL_B**
- **exclusion from $CL_S = CL_{S+B}/CL_B$**

Geometrical Likelihood vs Mass



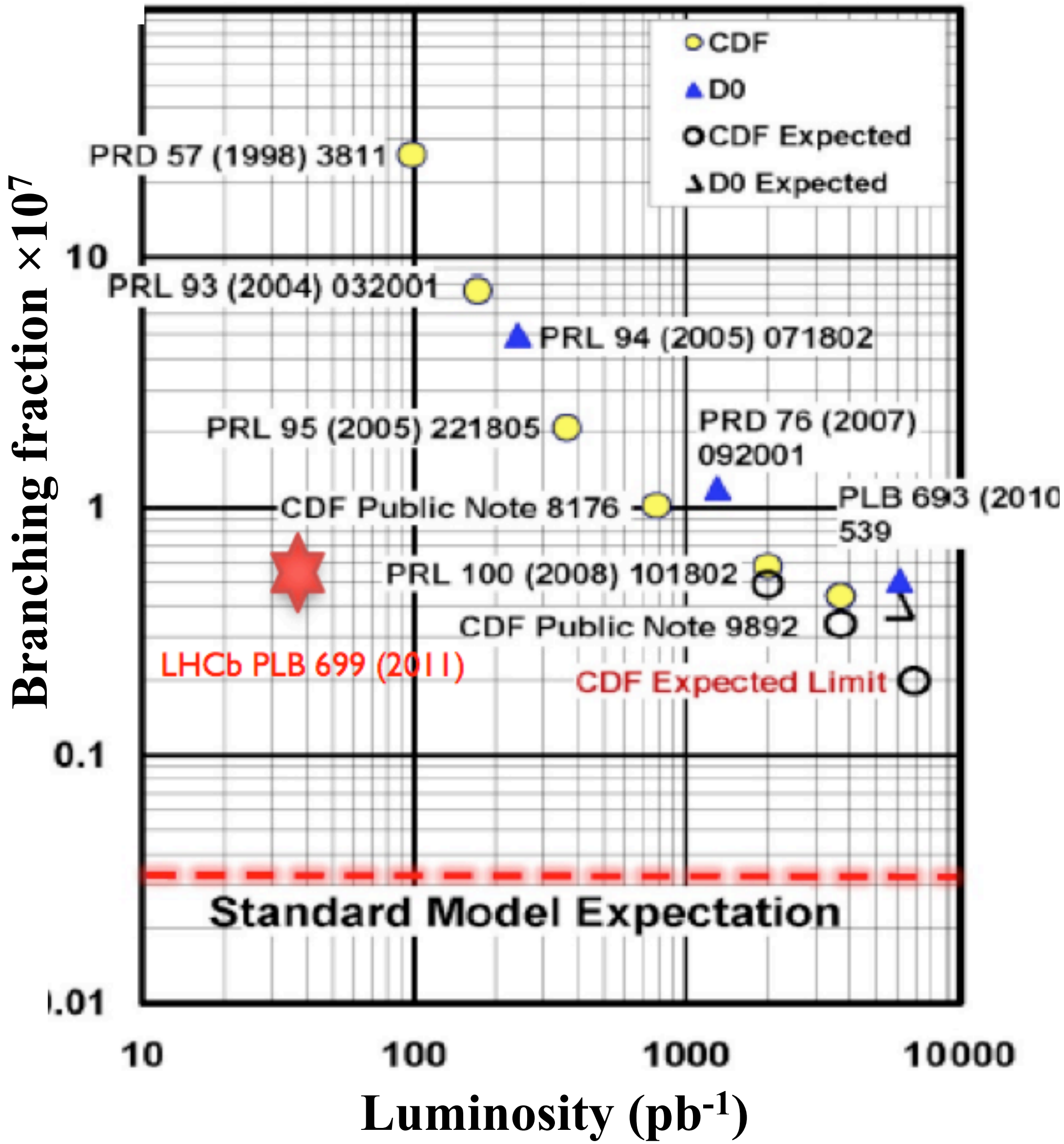
BR($B_s \to \mu\mu$) < 5.6×10^{-8} at 95% CL, with 37 pb^{-1} *Phys. Lett. B 699 (2011)*

CDF BR($B_s \to \mu\mu$) < 4.3×10^{-8} at 95% CL, with 3.7 fb^{-1} *Public note 9892 (2009)*

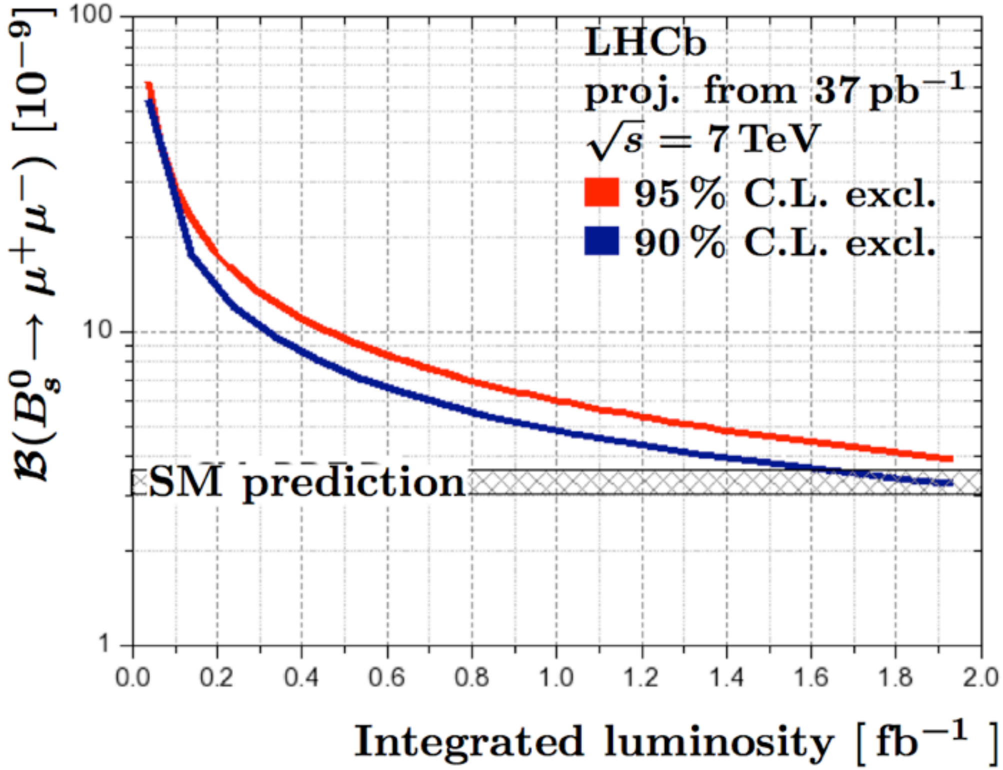
D0 BR($B_s \to \mu\mu$) < 5.1×10^{-8} at 95% CL, with 6.1 fb^{-1} *Phys. Lett. B 693 (2010)*

Present results and future prospects

Present status



LHCb expects to integrate up to 2 fb^{-1} within 2012. The projected sensitivity on $B_s \rightarrow \mu\mu$ exclusion is shown



We're working to update this summer with 300 pb^{-1}...waiting for ATLAS/CMS

LNF analysis group 2011/2012

People: P. De Simone*, G. Lanfranchi*, M. Palutan, A. Sarti
+ new: B. Sciascia, F. Archilli (postdoc) and F. Soomro (postdoc)
*(Patrizia as Muon Detector Operation Coord.; Gaia as Bsmumu convener)

2011 results (direct involvement):

1) Jpsi production cross section
"Measurement of J/psi production in pp collisions at sqrt(s)=7 TeV",
Eur.Phys.J.C71 (2011) 1645 (CERN-LHCb-ANA-2010-004/012)

2) $B_s \to \mu^+\mu^-$ with 37pb^{-1}
"Search for the rare decays B^0_s -> \mu^+\mu^- and B^0 -> \mu^+\mu^-",
Physics Letters B 699 (2011) 330-340. (CERN-LHCb-ANA-2011-007)

Present and future activities:

1) $B_s \to \mu^+\mu^-$ update with 300 pb^{-1} (this summer?), than pass to the 1 fb^{-1} sample
2) add new channels: interesting prospects for LFV study in $\tau \to \mu\mu\mu$ with 2011/12 data
3) Muon chamber effi monitoring, MuonID effi/bkg performances

Prospects for LHCb data taking and future upgrade

2011-2012 : 2 fb^{-1} at 7 TeV (σ_{bb} = 300 μb)
2015-**2017** : 3 fb^{-1} at 14 TeV (σ_{bb} = 600 μb)

LHCb upgrade for year 2019-2021 run (and beyond...)

Letter of Intent submitted to the LHCC in march:

- L > 10^{33} $cm^{-2}s^{-1}$ → > 5 fb^{-1}/year (today x 5)
- Doubling hadron trigger efficiency → > 10 fb^{-1}/year (today x 10)

Sub-detectors are readout at 40 MHz (now is 1 MHz) and software trigger (PC farm),
+ new VELO (pixel) + new Inner Tracking (fibers)

2011-2013	R&D and TDR preparation
2014	Get approval for TDR and financial budget
2015-2018	Detector upgrade
2019	Start data taking

<u>NB: super-LHC is not needed for the upgrade</u>

LHCC feedback (March-June meetings)

Physics Case:

The Committee congratulates LHCb for the excellent work done on the physics case for the upgrade. It finds the arguments for flavour physics with 50 fb^{-1} very compelling. This amount of data allows measurements at the level of the theoretically achievable precision for many quantities sensitive to new physics. With 5 fb^{-1} of collected data, most searches for deviations from the Standard Model (SM) predictions will be turned into precision measurements of the SM value with the LHCb upgrade. The level of accuracy achievable is comparable, in case of overlap, with that foreseen at future SuperB factories with 50 ab^{-1}; this makes the upgraded LHCb experiment a well-matched competitor and a very important complement.

After the LHCb upgrade feasibility committee review:

LHCC referees find the result of the review very supportive of the upgrade strategy chosen and encourage the LHCb collaboration to proceed in the drafting of an upgrade TDR. The recommendations received point out very clearly all the areas which need special attention. The LHCC referees endorse them and expect appropriate answers in the upcoming TDR

Upgrade / consolidation activities in the Muon System

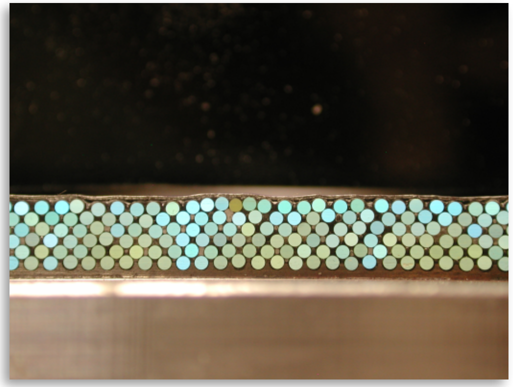
1) Electronics

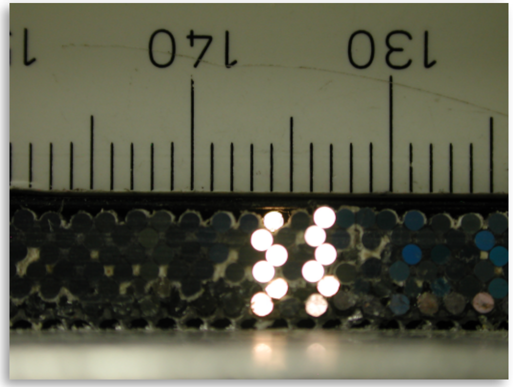
Define the architecture for 40 MHz readout, start testing FPGA, check in detail the feasibility of the proposed scheme

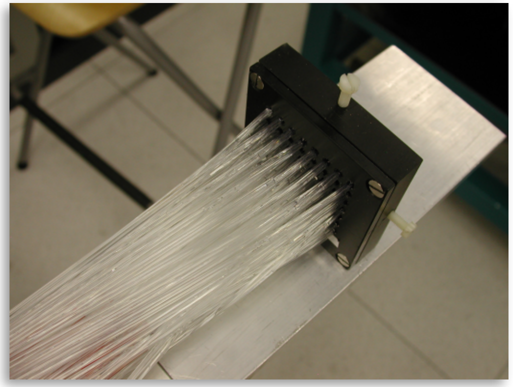
2) Chambers

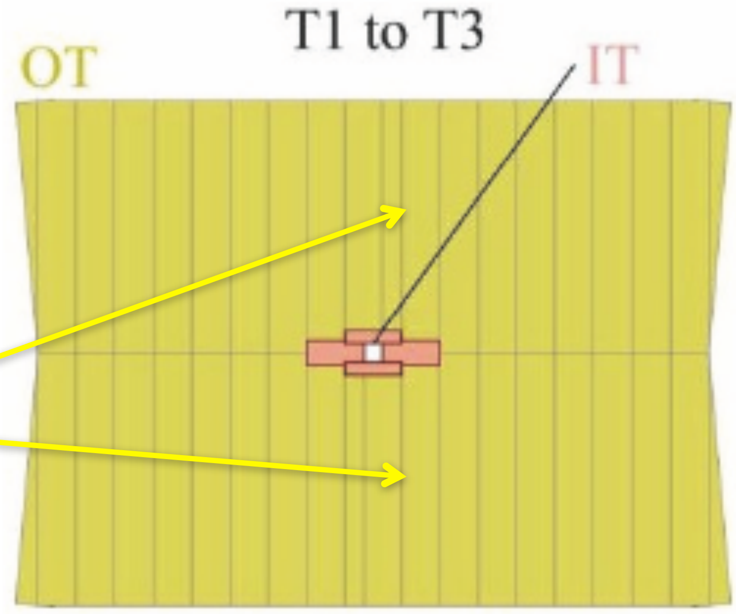
- The long term resistance of Muon Chambers has to be yet understood (up to now no significant ageing, but high currents in some chambers which are cured by conditioning)
- Rate effects must be verified for inner regions (in principle no problems below 10^{33} $cm^{-2} s^{-1}$)
- M1 will be removed (p_T given by track finding in the farm)
- Chamber and electronics spare pools to be increased for the long term running (→ some areas, lack of chamber spares) most probably using the long shutdown 2013-14
- Better shield for backsplashes in M5 (to be studied)

R&D on thick scintillating fibers (LNF)



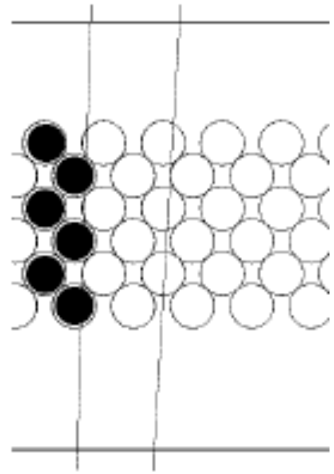






A possible replacement of central OT modules exposed to radiation and high hits densities

Test setup:
2.3 m long module made of 6 layers of scintillating fibers (1mm thick) sent to a channel of MAPMT H8500



Signal amplifier + analog readout
(64 channels ~ 64 mm)

External MDT tracker (σ_x ~ 150 μm)

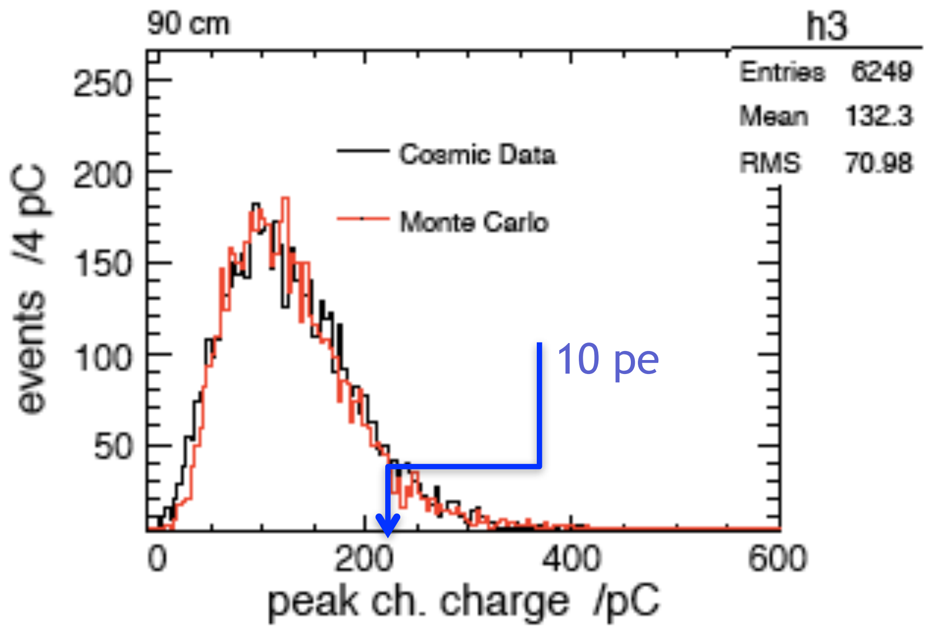
Preliminary results

- Fiber spatial resolution ~290 μm
(→ 200 μm with 0.7 mm fibers)

- P.E. number ~ 7 p.e. @1 m from the PM

- Threshold ~ ¼ p.e. (noise 5%)

- Track efficiency ~ 93% (@ 2.3 m from PM)
~ 98% (@ 0.6 m)



B.D.Leverington, M.Anelli, P.Campana, R.Rosellini
arXiV:1106.5649

Next steps:

- Test MAPMT R7600 (better QE, less cross-talk)
- Fibers with double cladding (to reduce X0)
- Squared fibers

Conclusions

- LNF/LHCb group contributed substantially to the construction of the MUON detector → 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 deeply involved in rare decays studies with muon in the final states

full integration with LHCb analysis WGs

- Italian groups (and LNF, too) are interested to a possible prosecution of LHCb beyond phase 1 (>2017): "italian" subdetector upgrade and maintenance
- Ongoing R&D on specific (and new) subdetectors: open opportunities, to be explored in the next future

detailed schedule (budget/human resources) will be assessed during preparation of TDR

Il gruppo LHCb nel 2012

F.Archilli	100
G.Bencivenni	70
P.Campana	0 LHCb spokesman!
P.DeSimone	70
G.Lanfranchi	100
F.Murtas	40
M.Palutan	100
A.Sarti	80
B.Sciascia	70
A.Sciubba	70
F. Soomro	100

FTE 8,0

P.Ciambrone	20
G.Felici	20

M.Anelli	50
R.Rosellini	70
M.Santoni	20
A.Saputi	30

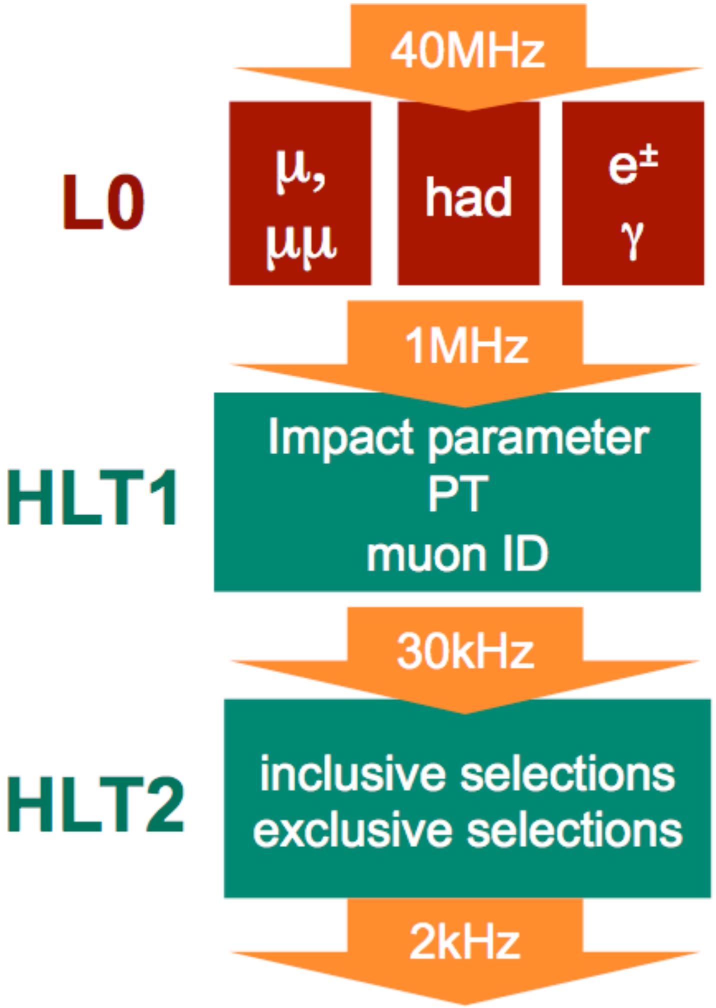
SPCM 4 mesi uomo
SELF 10 mesi uomo

Richieste economiche:

ME	106
MI	16
Consumo	26
Inventariabile	5
Costr.Apparati	85


SPARES

Trigger for $B_{s,d} \to \mu\mu$



	Muon Lines
L0	Single- μ: p_T> 1.4 GeV/c μμ: p_{T1}>0.56 GeV/c p_{T2}>0.48 GeV/c
HLT1	single-μ: p_T>0.8 GeV/c IP>0.11 mm single-μ: p_T>1.8 GeV/c (no IP)
HLT2	Several lines with $M_{\mu\mu}$ cuts and/or displaced vertex

- Half of the bandwidth (~1 kHz) given to the muon lines
- p_T cuts on muon lines kept very low → ε(trigger $B_{sd} \to \mu\mu$) ~ 90%
- Trigger rather stable during the whole period (despite L increased by ~10^5)

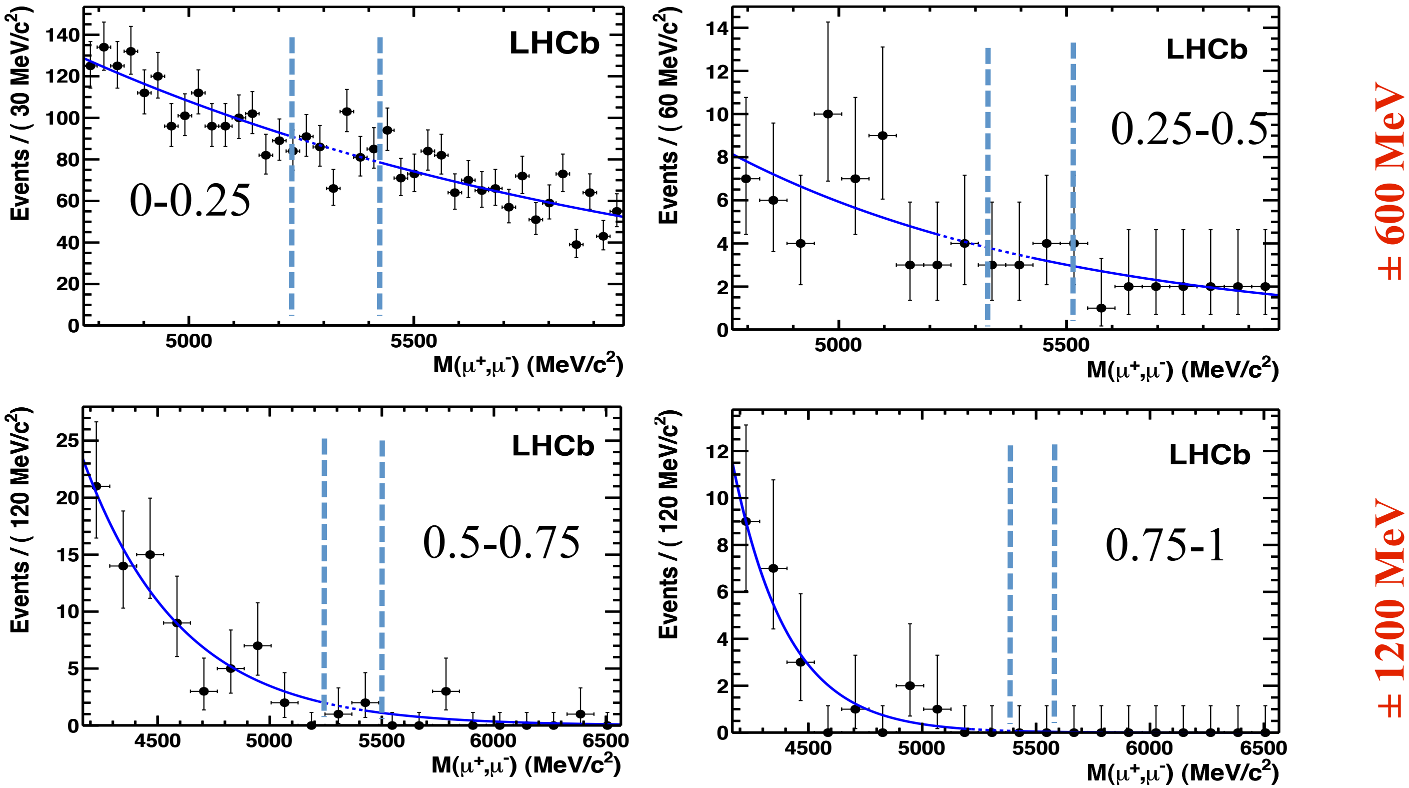
Background expectation

The expected background events in signal regions are extracted from a fit of the mass sidebands divided in likelihood bins

Signal mass window: $M(B_s)\pm60$MeV; Sidebands: ±600 (1200) MeV

Expected background events in B_s mass region

GL bin	$B_s\to\mu\mu$
0-0.25	329.1 ± 6.4
0.25-0.5	7.4 ± 1.0
0.5-0.75	$1.51^{+0.41}_{-0.35}$
0.75-1	$0.08^{+0.10}_{-0.05}$



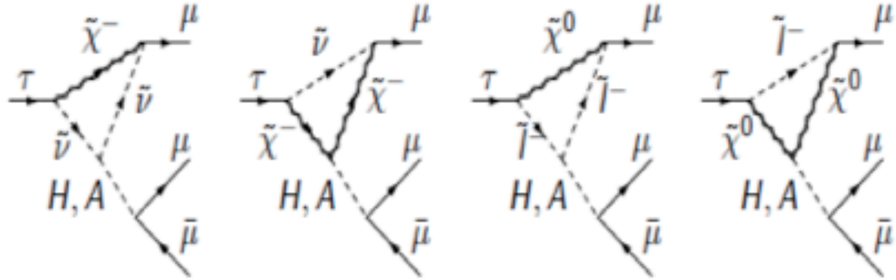
background is very low in the search window for high GL values

Sensitivities to key flavour channels

Type	Observable	Current precision	LHCb (5 fb^{-1})	Upgrade (50 fb^{-1})	Theory uncertainty
Gluonic penguin	$S(B_s \to \phi\phi)$	-	0.08	0.02	0.02
	$S(B_s \to K^{*0}\bar{K}^{*0})$	-	0.07	0.02	< 0.02
	$S(B^0 \to \phi K_S^0)$	0.17	0.15	0.03	0.02
B_s mixing	$2\beta_s\ (B_s \to J/\psi\phi)$	0.35	0.019	0.006	~ 0.003
Right-handed currents	$S(B_s \to \phi\gamma)$	-	0.07	0.02	< 0.01
	$\mathcal{A}^{\Delta\Gamma_s}(B_s \to \phi\gamma)$	-	0.14	0.03	0.02
E/W penguin	$A_T^{(2)}(B^0 \to K^{*0}\mu^+\mu^-)$	-	0.14	0.04	0.05
	$s_0\, A_{\rm FB}(B^0 \to K^{*0}\mu^+\mu^-)$	-	4%	1%	7%
Higgs penguin	$\mathcal{B}(B_s \to \mu^+\mu^-)$	-	30%	8%	$< 10\%$
	$\frac{\mathcal{B}(B^0 \to \mu^+\mu^-)}{\mathcal{B}(B_s \to \mu^+\mu^-)}$	-	-	$\sim 35\%$	$\sim 5\%$
Unitarity triangle angles	$\gamma\ (B \to D^{(*)}K^{(*)})$	$\sim 20°$	$\sim 4°$	0.9°	negligible
	$\gamma\ (B_s \to D_s K)$	-	$\sim 7°$	1.5°	negligible
	$\beta\ (B^0 \to J/\psi\, K^0)$	1°	0.5°	0.2°	negligible
Charm CPV	A_Γ	2.5×10^{-3}	2×10^{-4}	4×10^{-5}	-
	$A_{CP}^{dir}(KK) - A_{CP}^{dir}(\pi\pi)$	4.3×10^{-3}	4×10^{-4}	8×10^{-5}	-

Lepton Flavour Violation: tau decays

$$\mathcal{B}_r(\tau \to \mu\mu\mu) \simeq 1 \times 10^{-7} \left(\frac{\tan\beta}{60}\right)^6 \times \left(\frac{100\,\mathrm{GeV}}{m_A}\right)^4.$$



Taus at LHC are mostly (~60%) produced in prompt charm decays, and prompt charm production has been measured ~2 larger than expected ☺

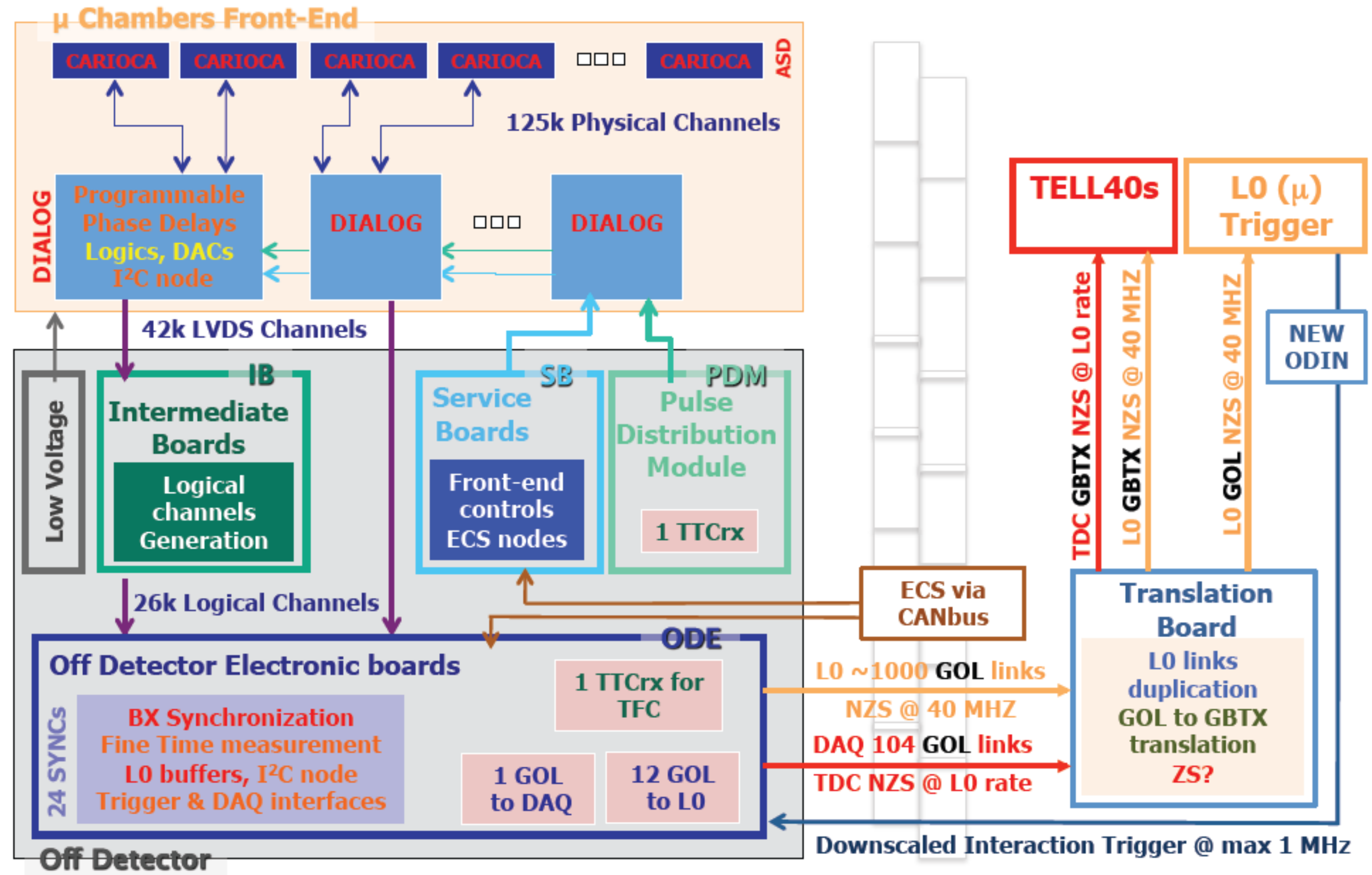
Very simplified MC studies in the past, using only ~40% of the produced taus, show that we can be competitive with Belle (BR<2.1×10^{-8} @90% C.L.) with ~2 fb^{-1} at 14 TeV CoM → 2 fb^{-1} at 7 TeV given the measured cross-sections. MC studies were limited by bkg statistics → Move to real data!

First look at 2010 data looks very promising… selections optimized on MC, see zero events in 37 pb^{-1} → BR<2.6×10^{-7} @90% C.L.

Expect interesting results in $\tau \to \mu\,\mu\,\mu$ *decays with 2011/12 data.*

Other tau decays under study: $\tau \to \mu\,\gamma$, $\tau \to \mu\,\Phi$, $\tau \to p\,\mu\,\mu$, etc…

Minimal Upgrade First Idea



C. DePlano (CA) and the Cagliari-Frascati group