Analysis activities at LNF

Marco Santimaria
on behalf of the LHCb LNF group
Frascati, 14 October 2015

LHCb Italia, 13-14 October 2015

OUTLINE

1. muonID optimization
2. B_s->MuMu and B_d->MuMu

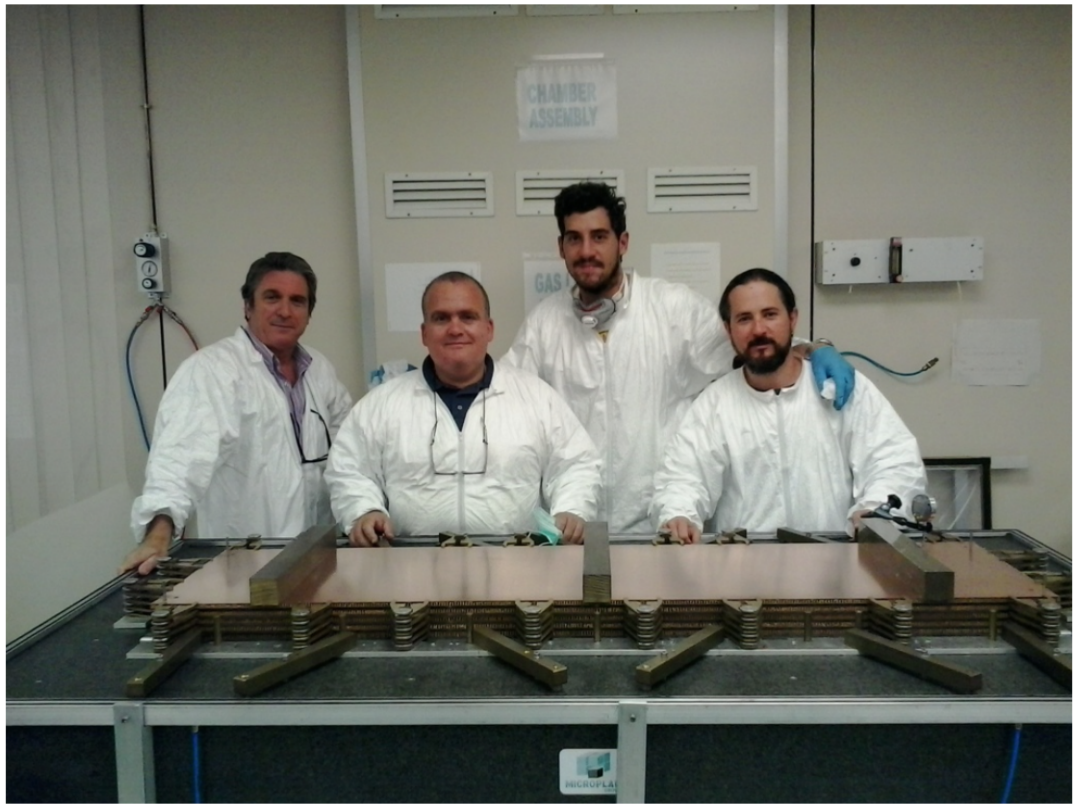
Duties and Responsibilities:

- **Barbara Sciascia** PID convener, ECGD officer
- **Ricardo Vazquez Gomez** Stripping coordinator
- **Matteo Palutan** MuonID convener

Upgrade activities (muon detector): MWPC spare chamber production, new off detector electronics (nODE boards)

muonID optimization

Spare MWPC production



Mario Anelli Luigi Pasquali Andrea Zossi Emiliano Paoletti

Frascati technicians optimizing muon identification!

30 MWPCs to be built

Many months of hard work to prepare all of the needed tools and resume all the different/delicate steps (after 10 years from the last time)

After wiring, the 4 gaps are glued together →

panels planarity < 50 microns!

5 chambers have been built, production is planned to terminate next year

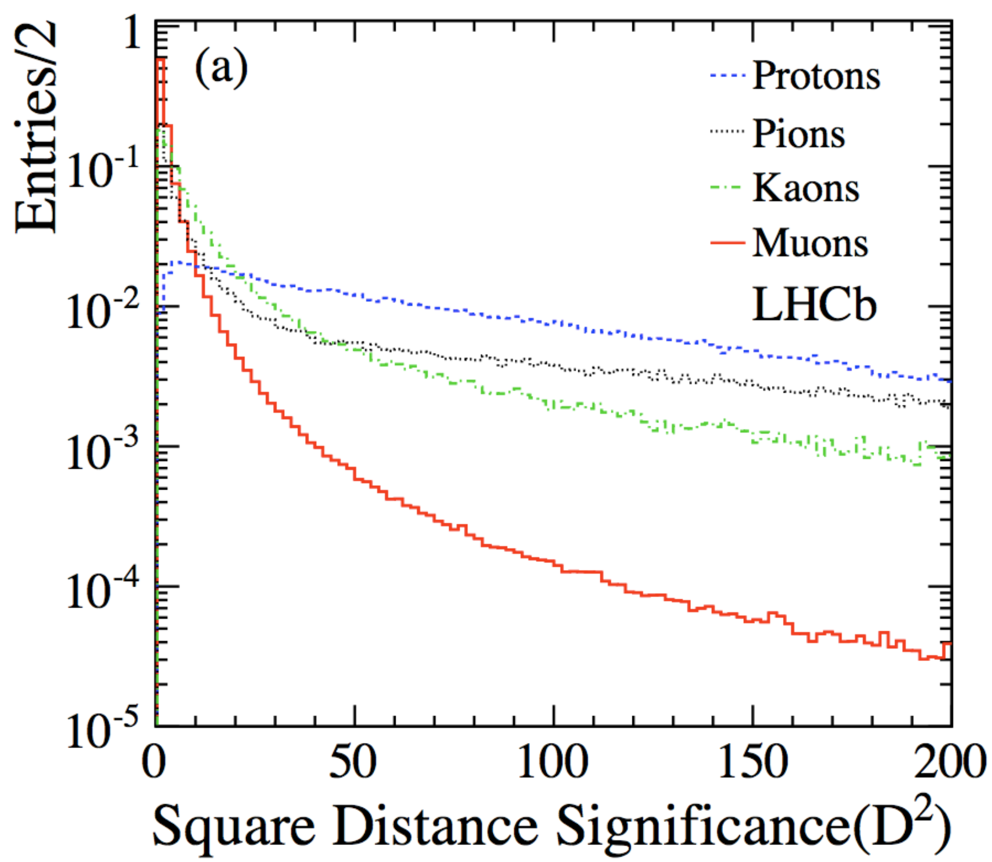
The muon identification

1) isMuon: Hits in FOI around track extrapolation are searched on each station. A coincidence of stations is required as a function of momentum

Momentum range	Muon stations
$3\ \mathrm{GeV}/c < p < 6\ \mathrm{GeV}/c$	M2 and M3
$6\ \mathrm{GeV}/c < p < 10\ \mathrm{GeV}/c$	M2 and M3 and (M4 or M5)
$p > 10\ \mathrm{GeV}/c$	M2 and M3 and M4 and M5

2) Muon likelihood (muDLL): based on average squared distance (D^2) of muon hits to the track extrapolation points

$$D^2 = \frac{1}{N}\sum_i \left\{ \left(\frac{x^i_{closest} - x^i_{track}}{pad^i_x} \right)^2 + \left(\frac{y^i_{closest} - y^i_{track}}{pad^i_y} \right)^2 \right\}$$



-> Combined likelihood (combDLL): the info is combined in a likelihood with RICH and CALO (combDLL).

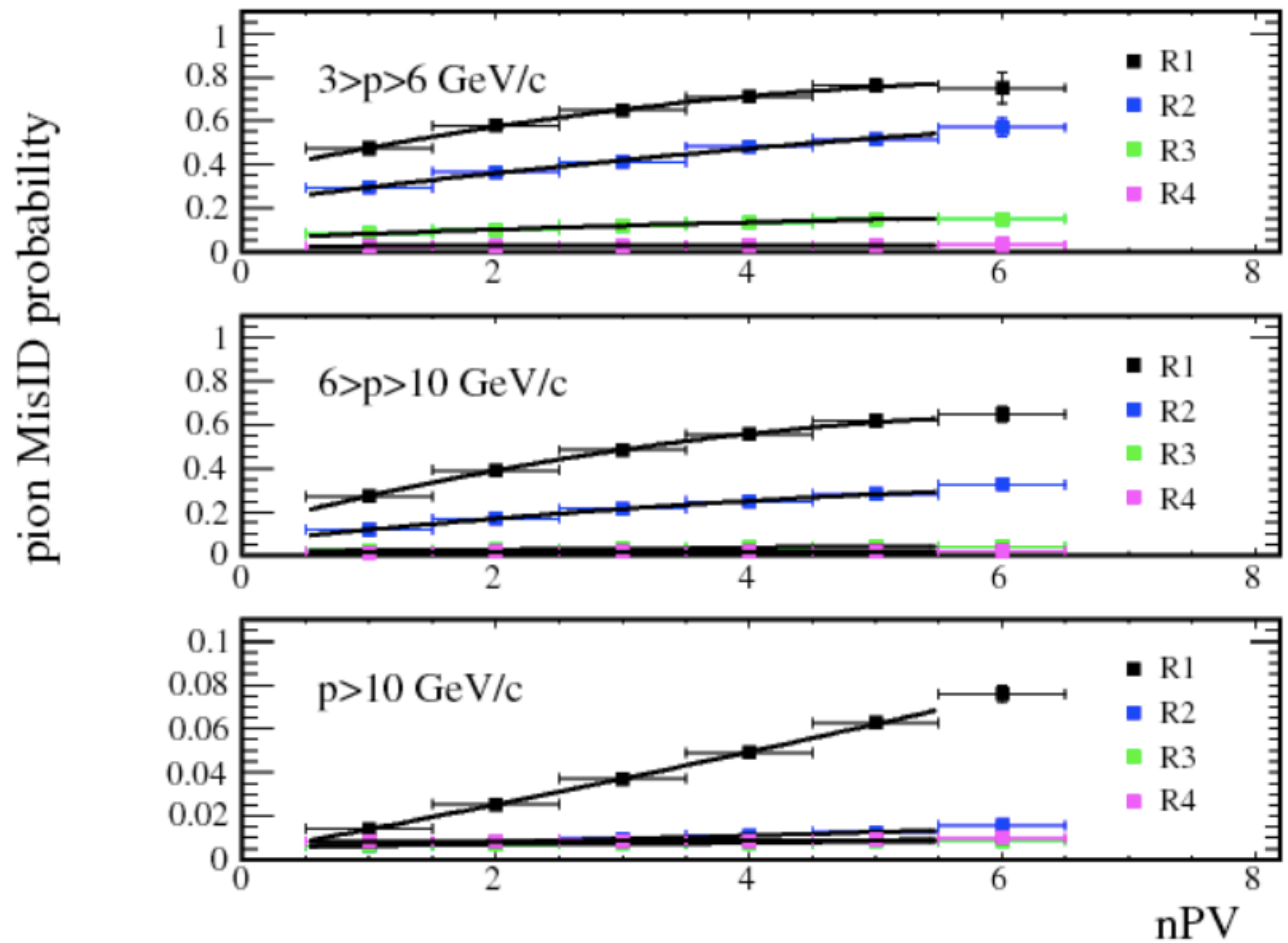
Improving muID: redefine muon classifier after isMuon to exploit full detector information: space residuals, multiple scattering, times, isolation, multiplicity.

-> **Account for correlations**

isMuon at high luminosity

- Pion misID (isMuon selection) vs nPVs for different regions and momentum ranges, as measured on 2012 calibration data

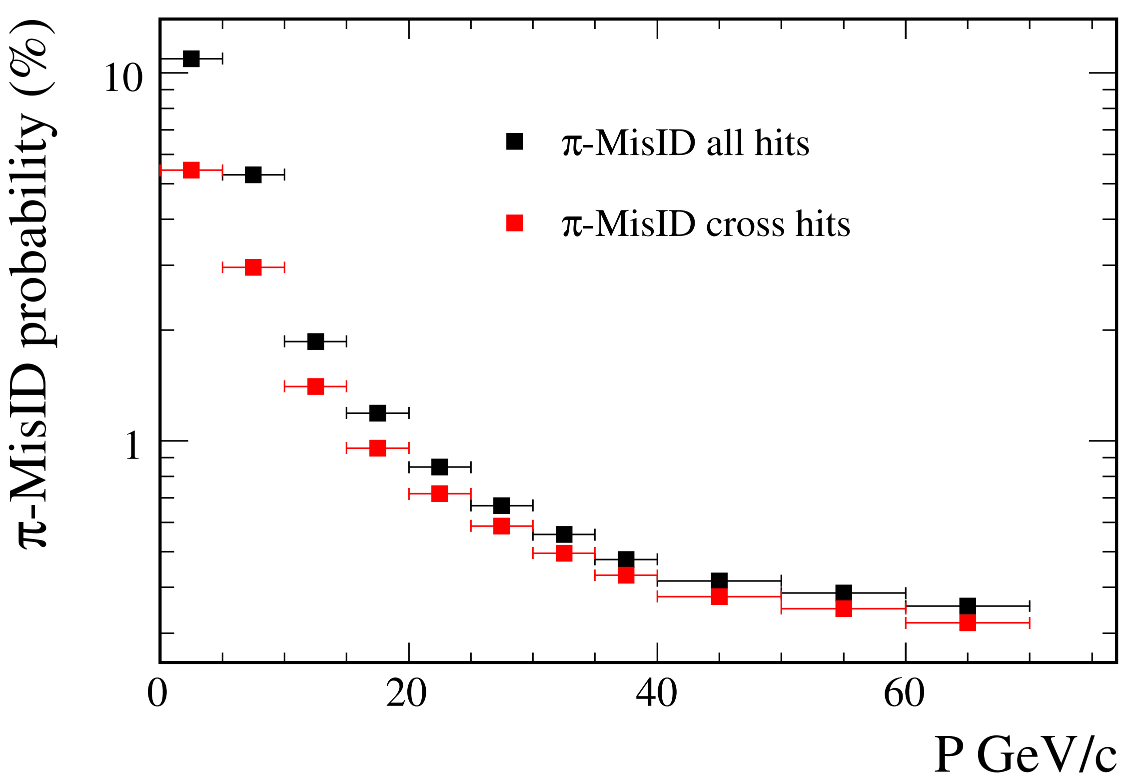
- The observed behavior is used to extrapolate misID at 2x10^{33} luminosity, at which <nPVs>~7.4

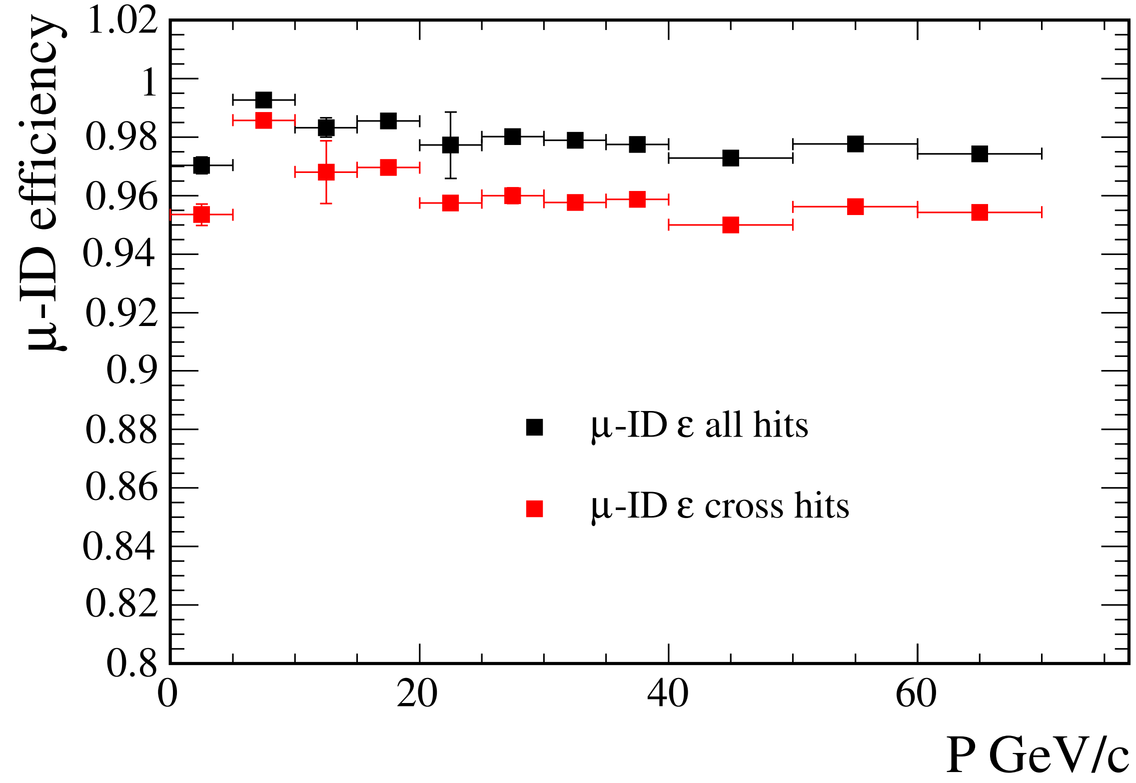


misID increases as a function of luminosity, especially in the inner regions, where it is dominated by accidental hits

With the present algorithms **we expect in upgrade conditions (2x10^{33}) a factor of 2 more background** at high momenta
-> Big effort to improve, as described in the following slides

isMuon with crossed hits: isMuonTight





By requiring **crossed hits only** (i.e. both x and y readout channels fired), the pion misID decreases, at the cost of ~ 2% muon efficiency loss

measured at ⟨nPV⟩~2.3	3 < p < 6 GeV	6 < p < 10 GeV	p > 10 GeV
isMuon	0.1093±0.0006	0.0529±0.0002	0.00954±0.0002
isMuonTight	0.0544±0.0004	0.0296±0.0001	0.0077±0.0001

extrapolated at ⟨nPV⟩~7.4	3 < p < 6 GeV	6 < p < 10 GeV	p > 10 GeV
isMuon	0.16±0.01 (1.46)	0.088±0.003 (1.66)	0.0184±0.0005 (1.93)
isMuonTight	0.097±0.008 (0.89)	0.056±0.002 (1.06)	0.0132±0.0004 (1.38)

With isMuonTight at high luminosity we get close to isMuon performance at low luminosity

green values are the ratios wrt isMuon at <nPVs>~2.3

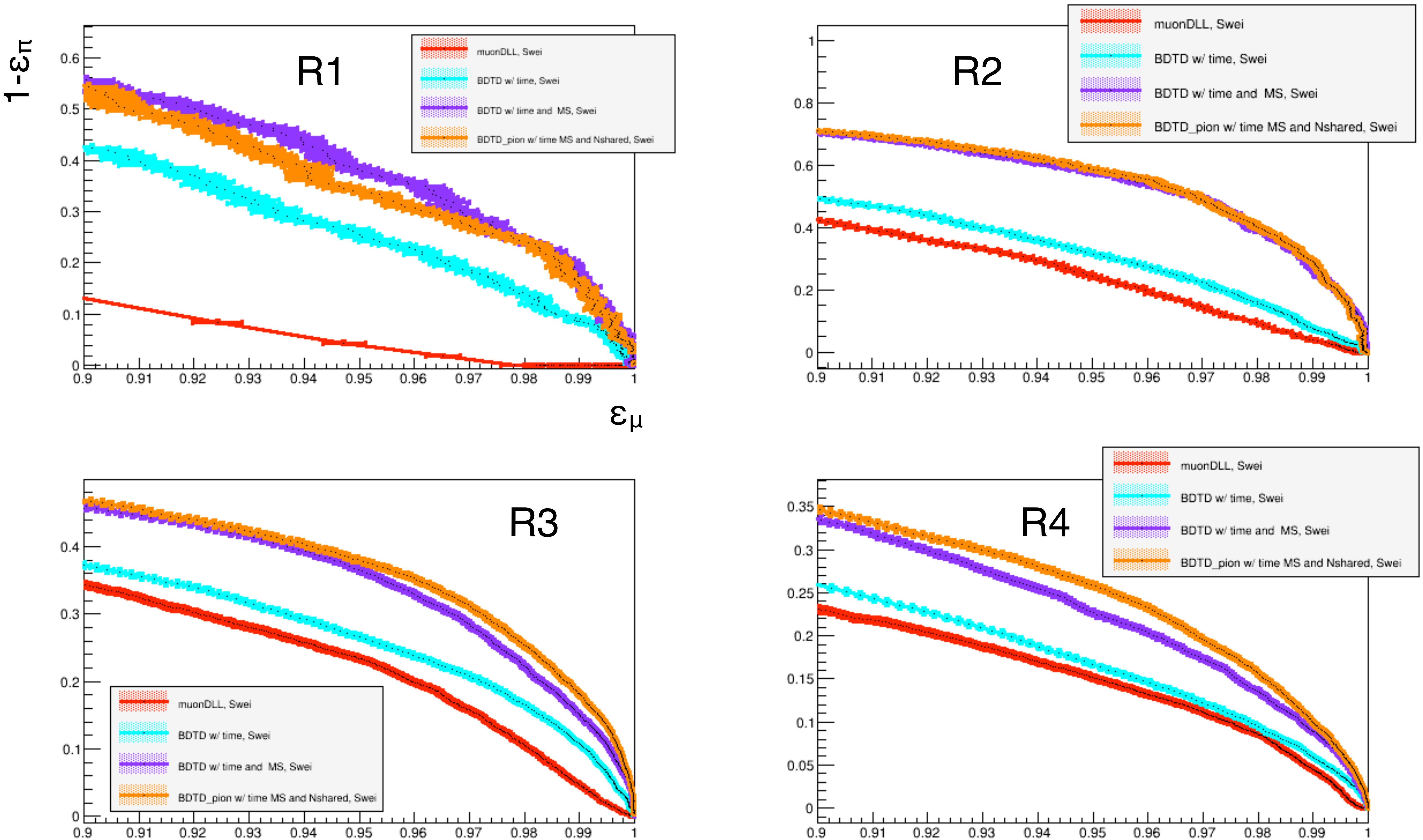
The Boosted Decision Tree

LNF group + Flavio Archilli (CERN)

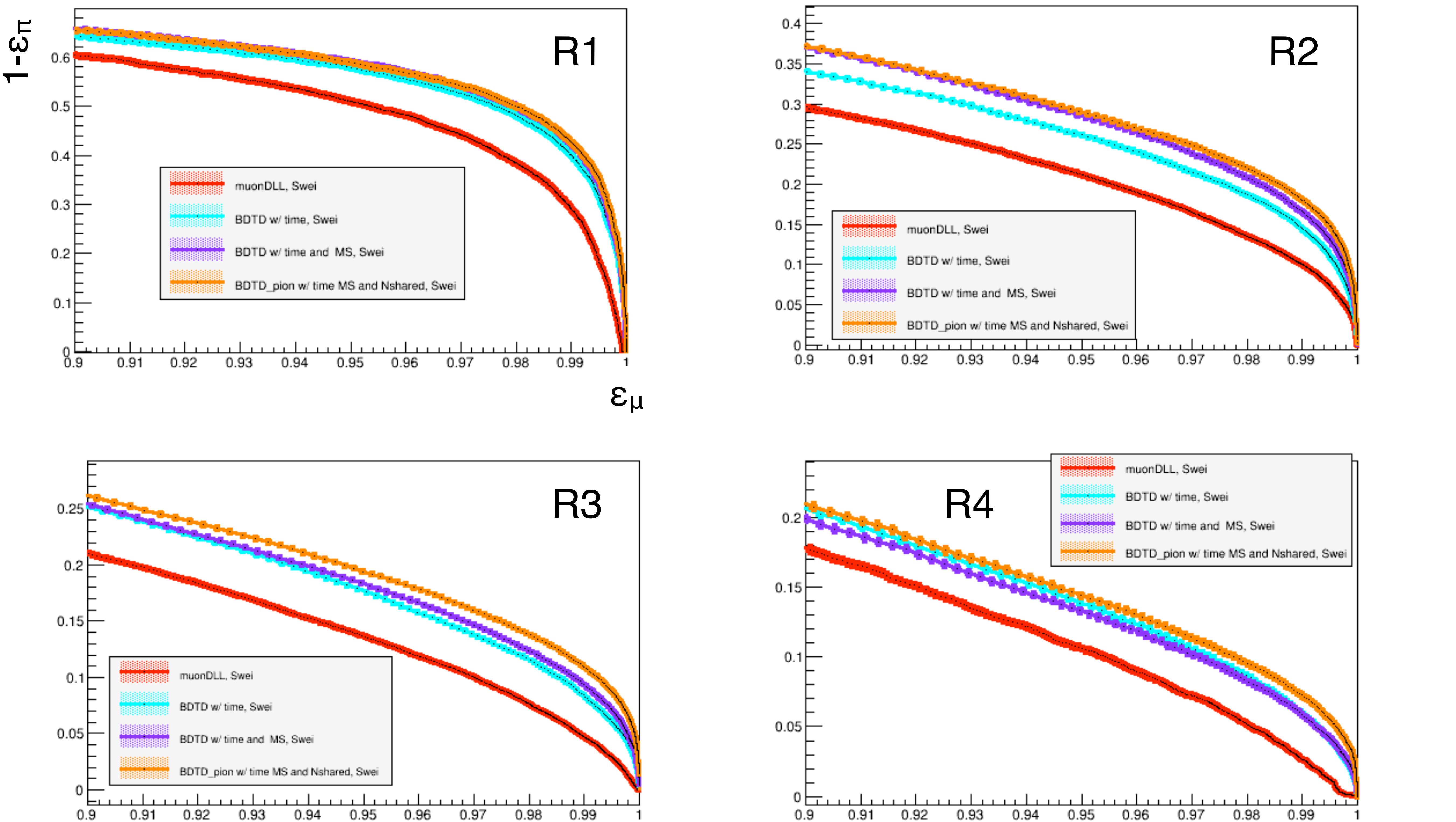
- Several BDTs have been trained using data control samples of muon as signal and pion (or proton) as background.
- The training samples are defined by tight selection cuts (including mass cuts). **isMuonTight is always required**.
- When computing ROCs, residual background is subtracted via sPlot technique

We compare:	input variables
muonDLL	**space residuals normalized to pad size**
BDT w/ time	**same as muonDLL + times**
BDT w/ time and MS	**include multiple scattering in residual computation**
BDT w/time MS and Nsha	**include Nshared**

pion misID vs muon efficiency, p<10 GeV/c



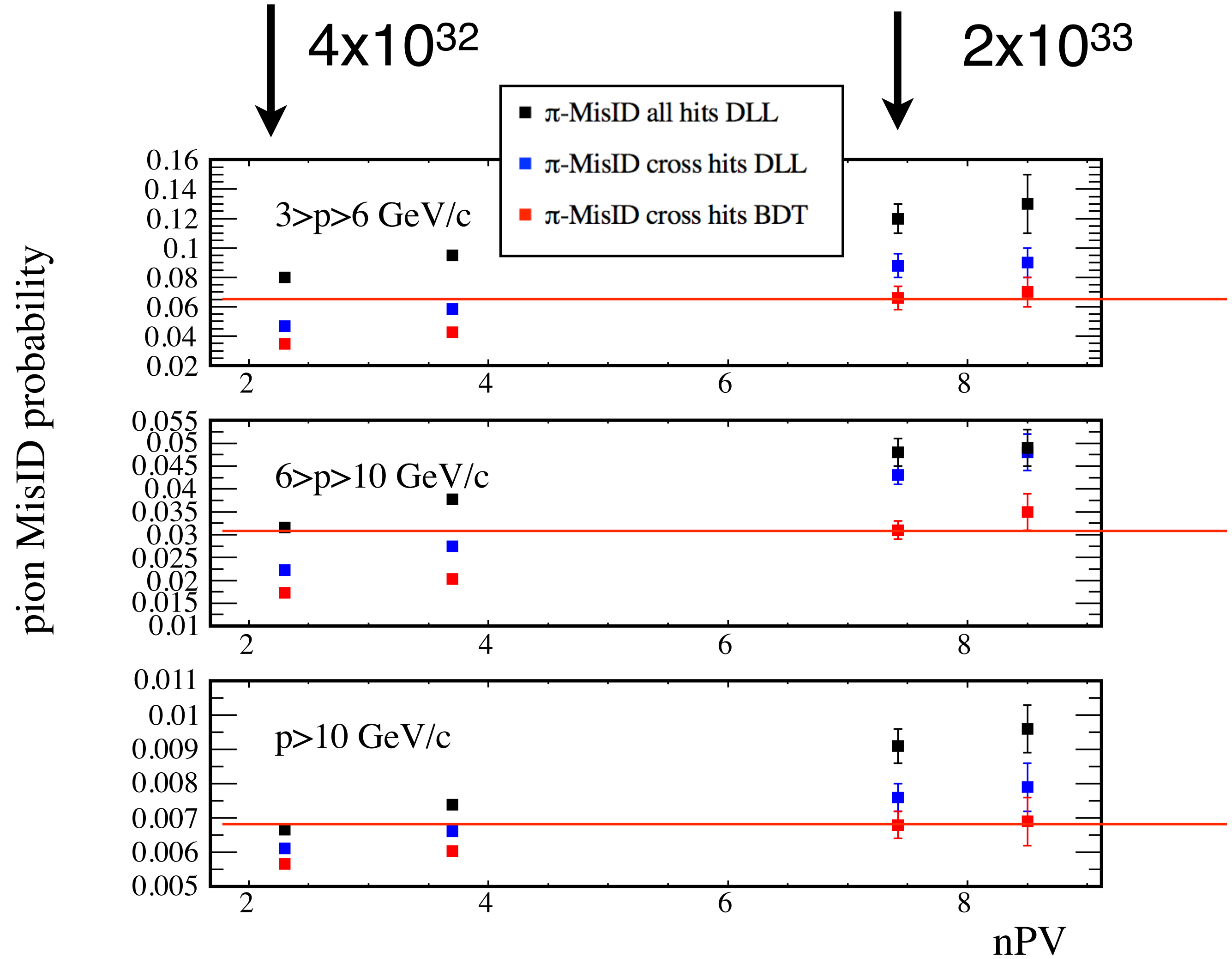
pion misID vs muon efficiency, p>10 GeV/c



BDT performances vs luminosity

We compare 3 different scenarios, both at low and high luminosities:

1. **isMuon+muonDLL** (what we have now)
2. **IsMuonTight+muonDLL**
3. **IsMuonTight+BDT**



measured at ⟨nPV⟩~2.3

	3 < p < 6 GeV	6 < p < 10 GeV	p > 10 GeV
isMuon + muonDLL	0.0799±0.0007	0.0315±0.0002	0.00666±0.00003
isMuonTight + muonDLL	0.0469±0.0005	0.0222±0.0002	0.00611±0.00003
isMuonTight + BDT	0.0348±0.0005	0.0173±0.0002	0.00567±0.00003

extrapolated at ⟨nPV⟩~7.4

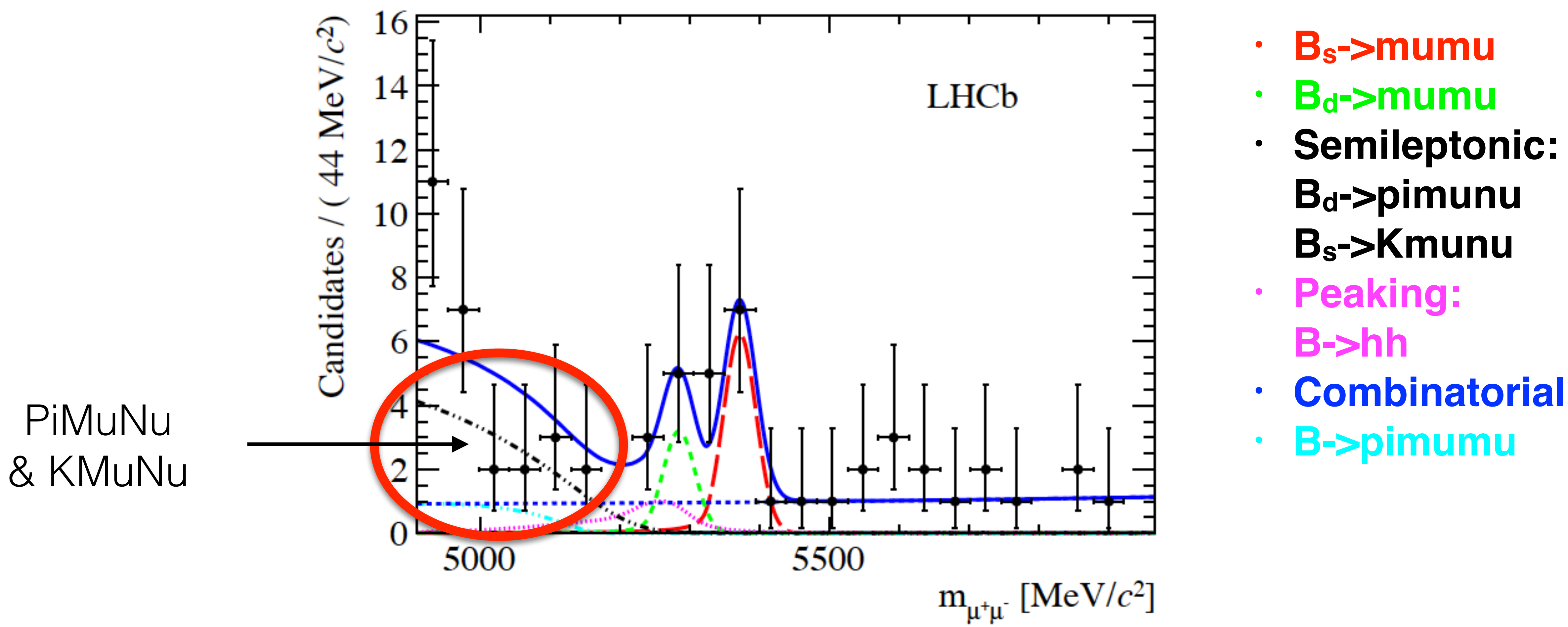
	3 < p < 6 GeV	6 < p < 10 GeV	p > 10 GeV
isMuon + muonDLL	0.12±0.01 (1.50)	0.048±0.003 (1.52)	0.0091±0.0005 (1.37)
isMuonTight + muonDLL	0.088±0.008 (1.10)	0.043±0.002 (1.37)	0.0076±0.0004 (1.14)
isMuonTight + BDT	0.066±0.008 (0.83)	0.031±0.002 (0.98)	0.0068±0.0004 (1.02)

with isMuonTight+BDT we restore the present misID

green values are the ratios wrt isMuon at <nPVs>~2.3

B_s->MuMu
B_d->MuMu

$B_{s,d}$ -> MuMu analysis optimization

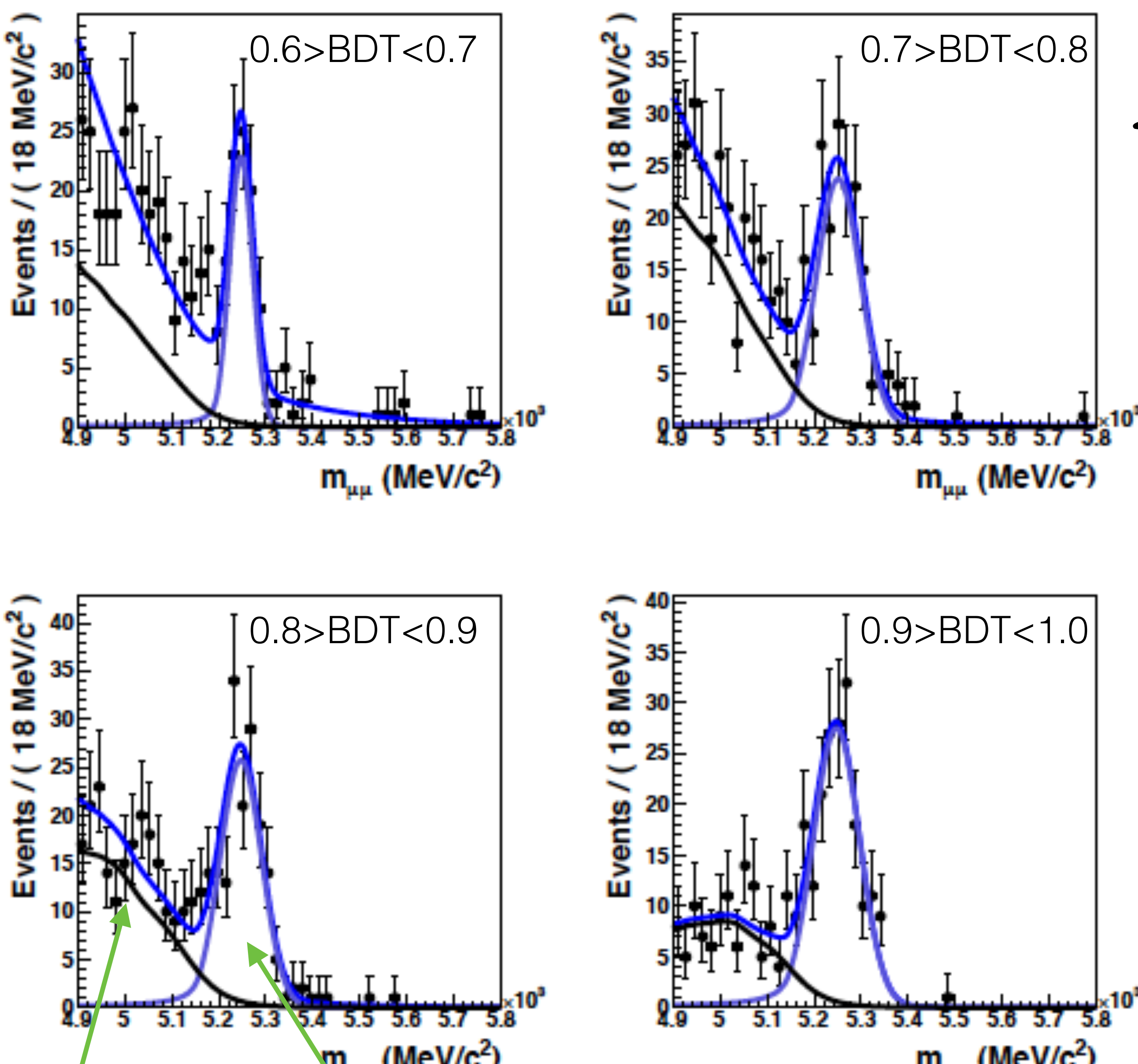


1. **Evaluation of the semileptonic background**: extracted using MC (normalized to B->JpsiK), need to better assess systematics on yield and mass/BDT shapes
2. **Improve PID selection** to reduce peaking B->hh background under B_d
3. **Study the sensitivity to new observables**, e.g. limits on B_s->MuMuGamma ISR, B_s*->MuMu
4. **Reduction of combinatorial background** via optimization of BDT and isolation (M.Rama, Pisa)

Evaluation of semileptonic yields from data

- Select the PiMu and KMu final states from data using hard cuts, fit the semileptonic yields and use them in B_s->MuMu analysis after correcting for the different PID selection

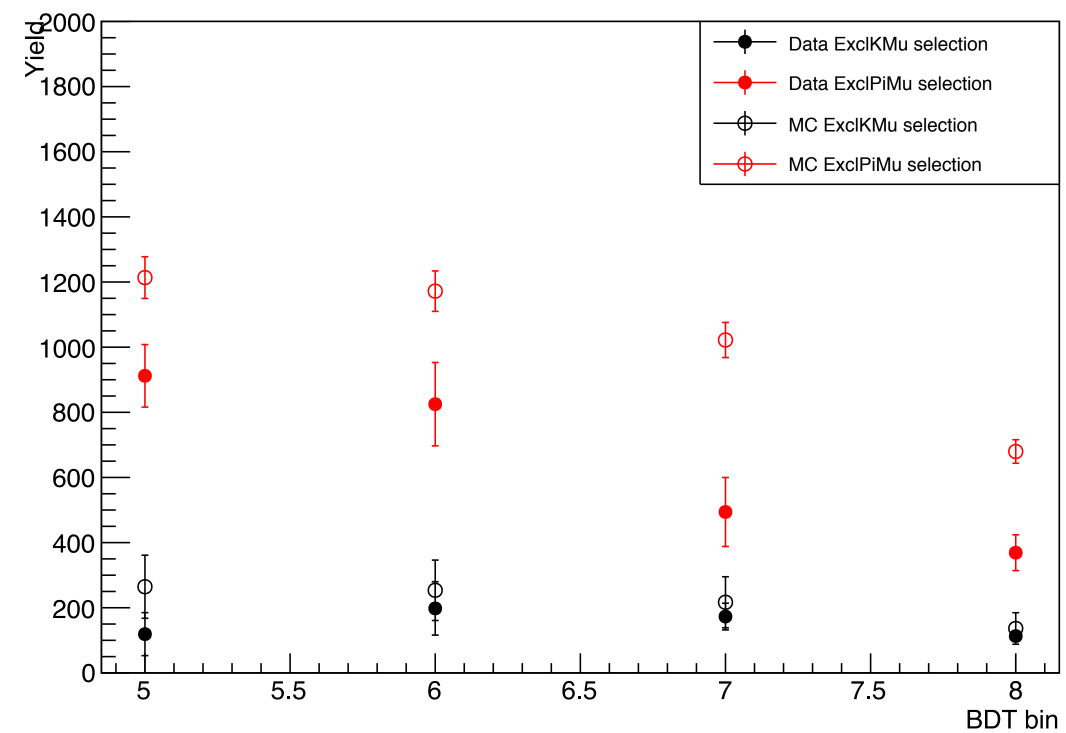
KMu selection on data



Semileptonic

B->hh single misID

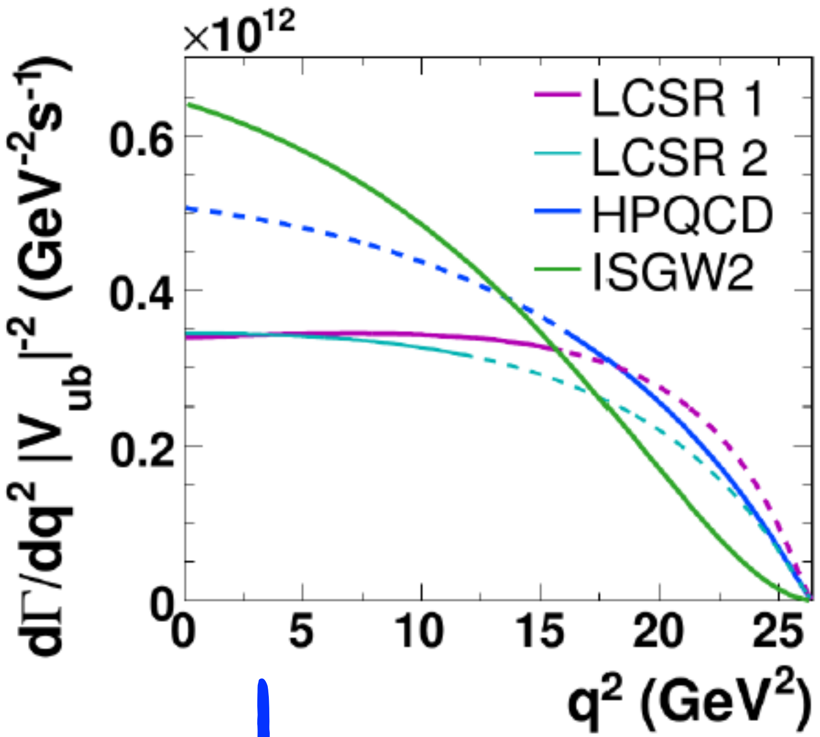
Extract the yield of PiMuNu and KMuNu, taking into account trigger, BDT and misID efficiencies

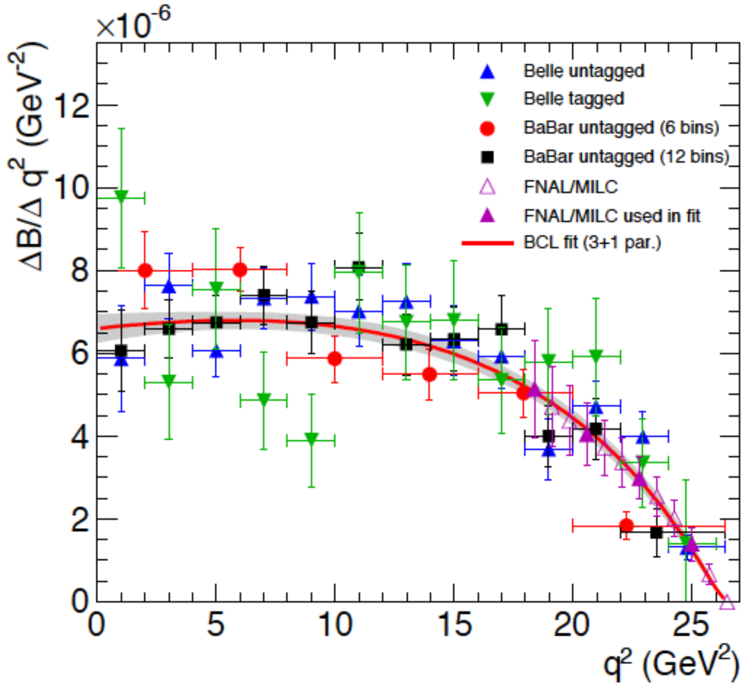


The MC expected yield is always higher than the data

The semileptonic form factors

- In the MC the KMuNu and PiMuNu samples are generated with the **Isgur-Wise form-factors (ISGW2)** settings for the form factors (from http://arxiv.org/abs/hep-ph/9503486)

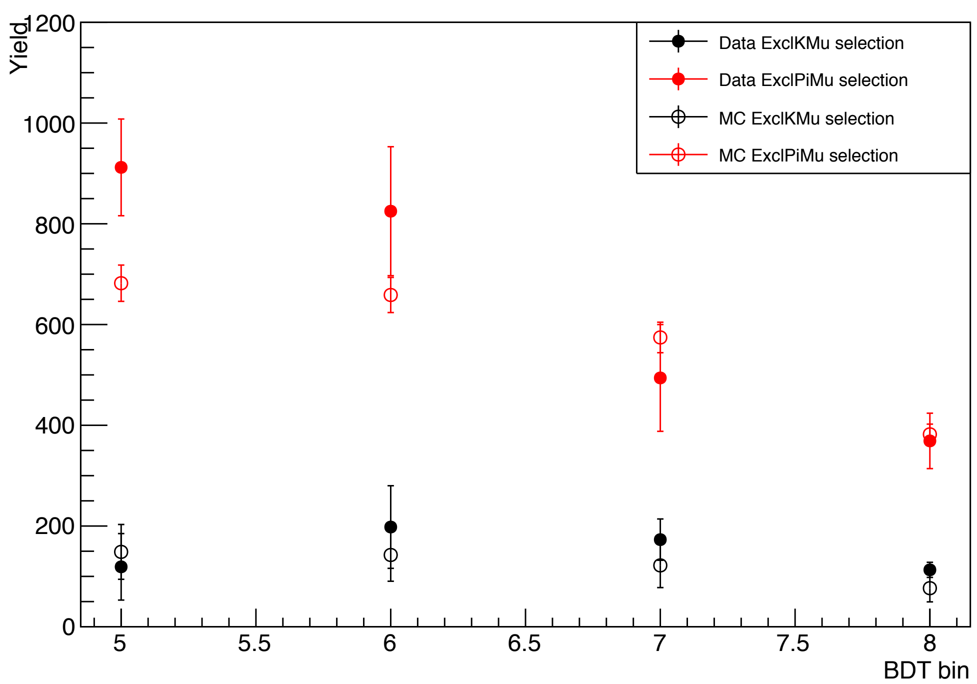




The form-factors used (ISGW2) do not agree well with lattice calculations or with the experimental data

http://pdg.lbl.gov/2014/reviews/rpp2014-rev-vcb-vub.pdf

Reweighting MC events according to LCSR form factor



Using the reweight, the data/MC yields agree within 1 sigma

Bonus track: plan to participate in the B_s->KMuNu analysis for V_{ub} determination, namely in the study of the normalization channel

PID optimization

- The PID cut for published B_s->MuMu analysis is very soft (DLLK<10 && DLLmu>-5)
- Move to ProbNN variables to increase the rejection power over B->hh background:
  1. Linear combinations of ProbNN vars
  2. MVA combination of ProbNN vars

Using the best operator and different cuts we can estimate the total B->hh yield:

	DLL	linear > 0.2	linear > 0.3	linear > 0.4	BDT > -0.15	BDT > -0.10	BDT > -0.05
B->hh yield	19.7	10.5	6.7	4.3	9.0	6.0	3.4
Signal Eff	95.4%	94.3%	90.6%	84.6%	93.1%	89.7%	80.0%

published analysis (DLL) — best rejection (BDT > -0.05)

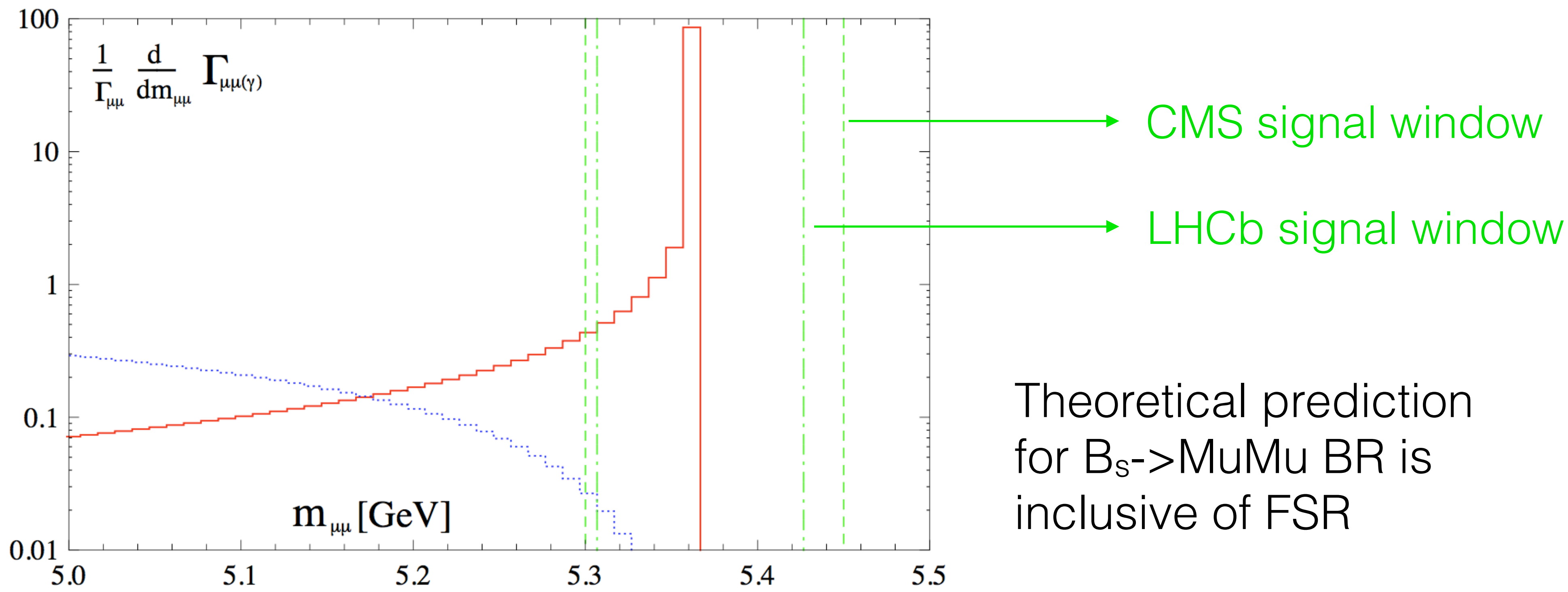
When reducing the signal yield by 15% the B->hh gets reduced by x6

Need to evaluate with **expected sensitivity** which scenario is the optimal -> ongoing

Study on B_s->mumugamma

photon emission from quarks (ISR)

photon emission from muons (FSR)



Theoretical prediction for B_s->MuMu BR is inclusive of FSR

FSR (helicity suppressed) largely dominant for small photon energies, can be summed to all orders in the soft-photon approximation and leads to a multiplicative correction factor with respect to the non-radiative rate. Included in MC via PHOTOS generator (agrees with theory expectation < 2%)

ISR vanishes in the limit of low photon energies and represent a background for the extraction of short-distance information on the B_s->MuMu amplitude -> to be subtracted as a background or demonstrate is negligible. Even more relevant in the B_d mass region

Previous studies, based on ref. arXiv:hep-ph/0410146 demonstrated ISR is negligible for B_s and B_d; **in the context of an improved analysis, with much reduced background and smaller systematics, we would like to set for the first time a limit on its rate**

Conclusions

muonID

- isMuonTight is a valid option for the 1st step of the muonID at high luminosity, allowing to improve the background rejection
- Studies on the BDT performances for the 2nd step of muonID are ongoing:
    1. BDT training still to be finalized
    2. We are studying the correlation of the new algorithms with CALO and RICH response, in order to determine the combined background rejection

B_s->MuMu

- Analysis improvement:
    1. New semileptonic background evaluation
    2. New PID selection to reduce B->hh
    3. Study the sensitivity to new observables