Attività di analisi a Cagliari

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13 October 2015, LHCb Italia collaboration meeting

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Reaserch activities

- Sectors
  - Data analysis: Charm e RD WG
  - Muon System: muID, upgrade and electronics

- Responsabilities
  - Alessandro Cardini
    LHCb national responsible (6/2015 –) and Muon System project leader (2013 – 2016)
  - Andrea Contu
    stripping coordinator (6/2014 – 6/2016), Charm sub-convener (2013 – 2015)
  - Marianna Fontana
    muID coordinator (7/2015 – 7/2018)
  - Claudia Vacca
    Charm PID liaison (9/2014 – 9/2016)

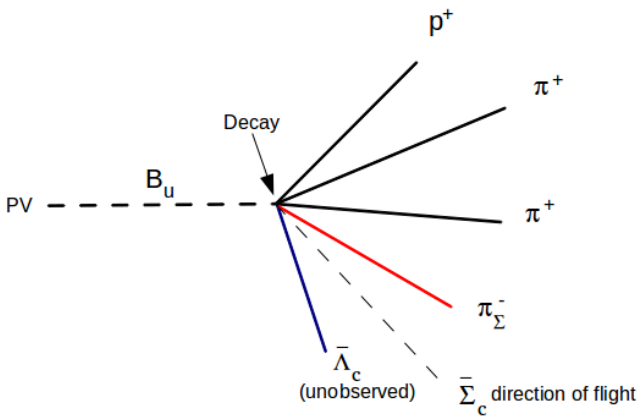
Absolute BF of $\Lambda_c \to Kp\pi$ (A. Contu, B. Saitta, C. Vacca)

Proposal of a new, model-independent method,
applicable in a hadron collider environment

Eur.Phys.J. C, **74** (2014) 3194, arXiv:1408.6802

$$B_u(5279)^+ \to \bar{\Sigma}_c(2455)^{--}\, p\, \pi^+\, \pi^+ \qquad (B_u^- \to \Sigma_c^{++}\, \bar{p}\, \pi^-\, \pi^-) \quad BF \simeq 2.8 \cdot 10^{-4}$$

$$\bar{\Sigma}_c(2455)^{--} \to \bar{\Lambda}_c(2286)^- \pi^- \qquad (\Sigma_c^{++} \to \Lambda_c^+ \pi^+) \quad BF \simeq 100\%$$



- Vertices VX4 ($p\pi^+\pi^+\pi^-_\Sigma$) of total charge ± 2
- π from Σ (π_Σ) has sign of charge opposite to that of the other particles from the B
- assuming above decay chain, the Λ_c four-momentum can be determined without the actual observation of its decay $\to$ **unbiased sample**

Absolute BF of $\Lambda_c \to Kp\pi$ (A. Contu, B. Saitta, C. Vacca)

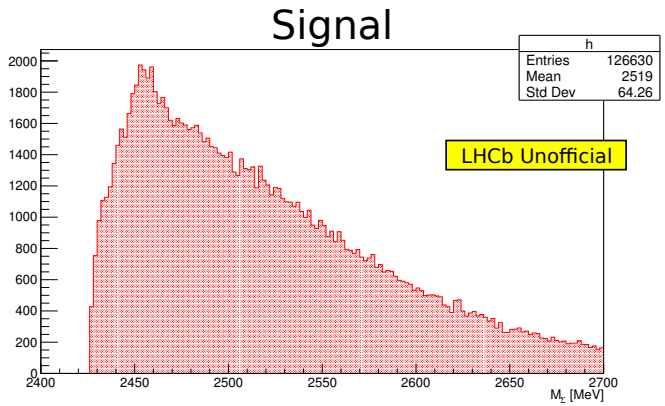
Preliminary result [to be updated]:

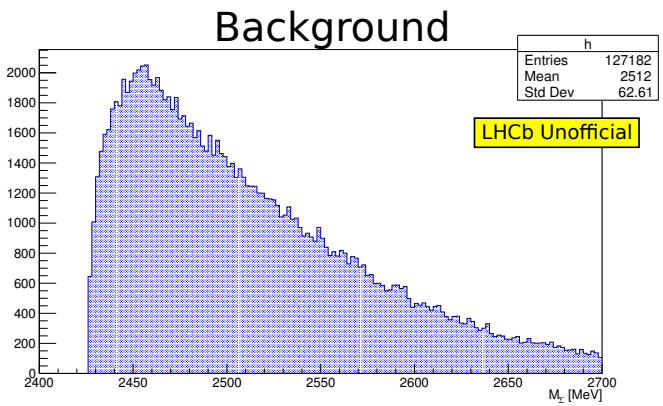
$$\mathrm{BF} = \frac{N_{\Lambda \to Kp\pi}}{N_{\Lambda}} \cdot \frac{1}{\epsilon_{rec}} \simeq 6.2\%$$

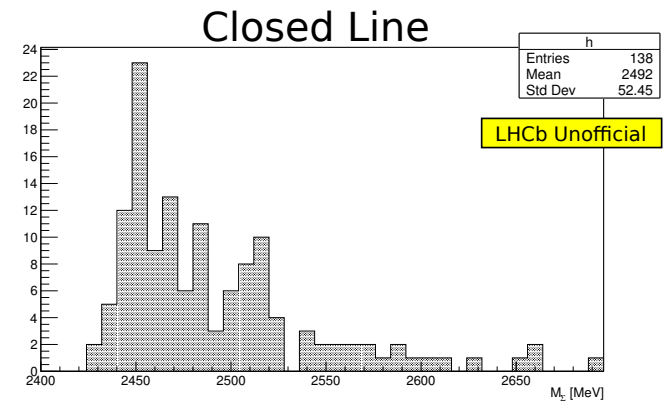
- Most of work done on the optimisation of the selection:
  - new BDT
  - reduced PID cuts
- New MC for Λ reconstruction efficiency:
  VX4 in acceptance, no requirements on Λ_c products
- Studies on trigger:
  - L0: 4*part_L0HadronDecision_TOS*
  - HLT1: 4*part_Hlt1TrackAllL0Decision_TOS*
  - HLT2: 4*part_Hlt2Topo2BodyBBDTDecision_TOS* || 4*part_Hlt2Topo3BodyBBDTDecision_TOS* && (!4*part_Hlt2Topo4BodyBBDTDecision_TOS*)
  - 4*part_Hlt2Topo4BodyBBDTDecision_TOS* enhanced bkg at high masses due to a change on this line configuration in June 2012 $\to$ excluded
  - since π_Σ is slow, this does not affect significantly the signal

Absolute BF of $\Lambda_c \to Kp\pi$: update (A. Contu, B. Saitta, C. Vacca)

- New background line:
  - VX4 with total charge ± 2, but p with opposite sign wrt the other particles (in signal line is the π_Σ)
  - reduces contamination due to events where 3 over the 4 detected particles come from a signal event [autogenerated bkg, 1:1.2, loss of π_Σ]
- Studies on background shape (very tricky...)





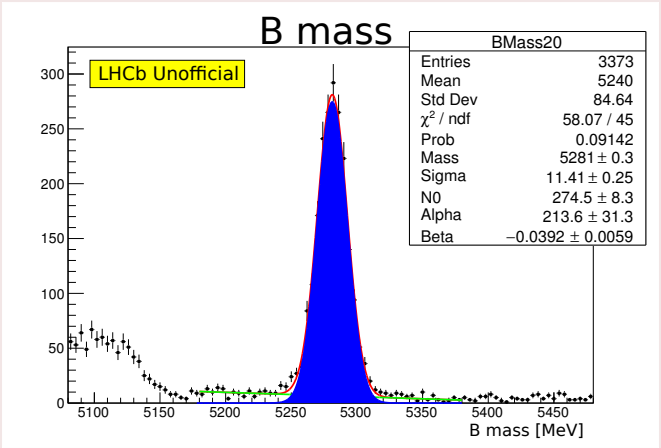


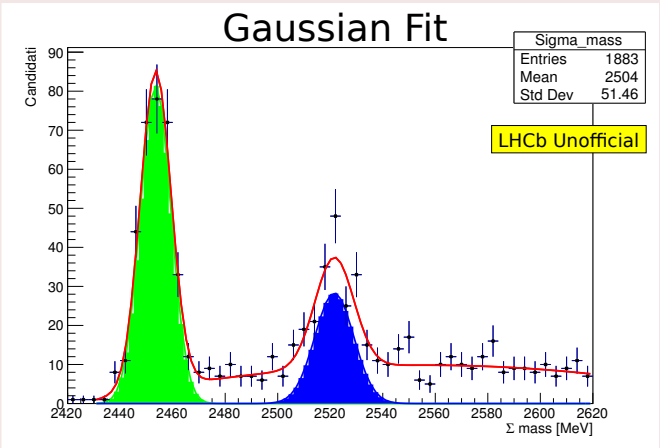
- statistical error $\sim 10 - 12\%$ [~ 90 signal events in the Closed Line]
- systematics

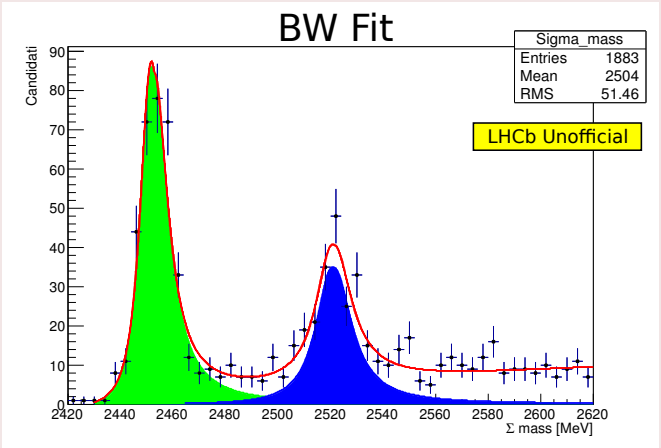
1st observation of $B^+ \to p\pi^+\pi^+\bar{\Sigma}_c(2520)^{--}$

Decay chain completely reconstructed (7-body decay!), 3 fb^{-1}

$$B_u(5279)^+ \to \bar{\Sigma}_c(2520)^{--}\, p\, \pi^+\, \pi^+$$
$$\bar{\Sigma}_c(2520)^{--} \to \bar{\Lambda}_c(2286)^-\pi^-$$
$$\bar{\Lambda}_c(2286)^- \to K^+\bar{p}\pi^-$$



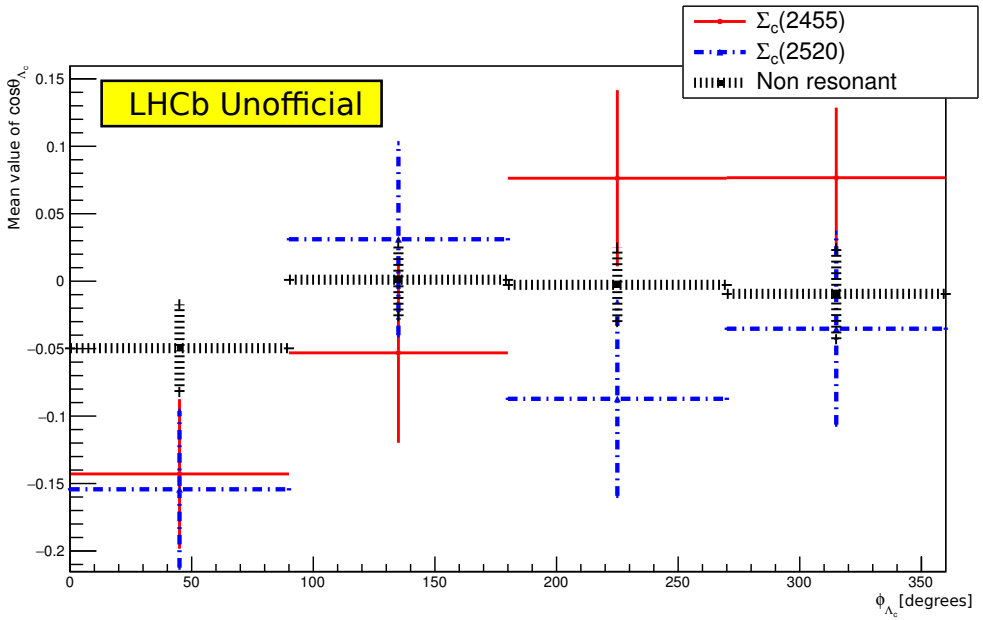




	Σ_c(2455)		Σ_c(2520)		
	M[MeV]	FWHM[MeV]	M[MeV]	FWHM[MeV]	N(2520)/N(2455)
Gauss	2453.5±0.4	13.8±0.7	2522±1	18±2	0.44±0.05
BW	2452.9±0.5	13±1	2521.4±0.8	16±3	0.45±0.05

Angular analysis $\Sigma_c \to \Lambda_c\pi$ (A. Contu, M. Fontana, M. Pili, B. Saitta, C. Vacca)

- $\Sigma_c(2455)$: $J^P=\frac{1}{2}^+$ (measured), $\Sigma_c(2520)$: $J^P=\frac{3}{2}^+$ (quark model)
- $\Sigma_c(2455)$ having $J = \frac{1}{2} \Longrightarrow$ isotropic angular distribution of the decay products, independent from its polarisation
- $\Sigma_c(2520)$ having $J = \frac{3}{2} \Longrightarrow$ angular anisotropy is produced IF it is polarised
- similar efficiencies for the Σ decay products (p and η distributions are consistent)
- asymmetries in $\Sigma_c(2455)$ decay products angular distributions are assigned to instrumental effects $\to$ correction factors to $\Sigma_c(2520)$



Further asymmetry in $\Sigma_c(2520)$ angular distribution might allow measurement of its spin

$D^0 \to \mu^+\mu^-$ (D. Brundu, A. Cardini, A. Contu, F. Dettori, M.Fontana)

- Very rare FCNC decay: receives two contributions within the SM
  - SM short distance contribution: $\mathcal{B}(D^0 \to \mu^+\mu^-) \sim 10^{-18}$
  - SM long distance contribution: $\mathcal{B}(D^0 \to \mu^+\mu^-) \sim 10^{-11}$
- Interesting to look for New Physics: BF larger up to several orders of magnitude
- Current upper limit measured by LHCb with 1 fb^{-1} (2011) [Phys. Lett. B (2013) 725]

$$\mathcal{B}(D^0 \to \mu^+\mu^-) < 6.2\ (7.6) \times 10^{-9} \text{ @ } 90\%(95\%) \text{ CL}$$

Update with the FULL Run 1 dataset

- D^* – tagged samples: $D^{*0} \to D^0(\mu^+\mu^-)\pi_s$
- Dedicated stripping line
- Blind analysis: data removed in the D^0 range [1835-1895]MeV$/c^2$
- Branching fraction wrt to the $D^0 \to \pi^+\pi^-$ decay

$$\mathcal{B}(D^0 \to \mu^+\mu^-) = \frac{N_{D^0\to\mu^+\mu^-}}{N_{D^0\to\pi^+\pi^-}} \cdot \frac{\epsilon_{D^0\to\mu^+\mu^-}}{\epsilon_{D^0\to\pi^+\pi^-}} \cdot \mathcal{B}(D^0 \to \pi^+\pi^-)$$

- Selection strategy revised: loose preselection + new BDT + ProbNNmu

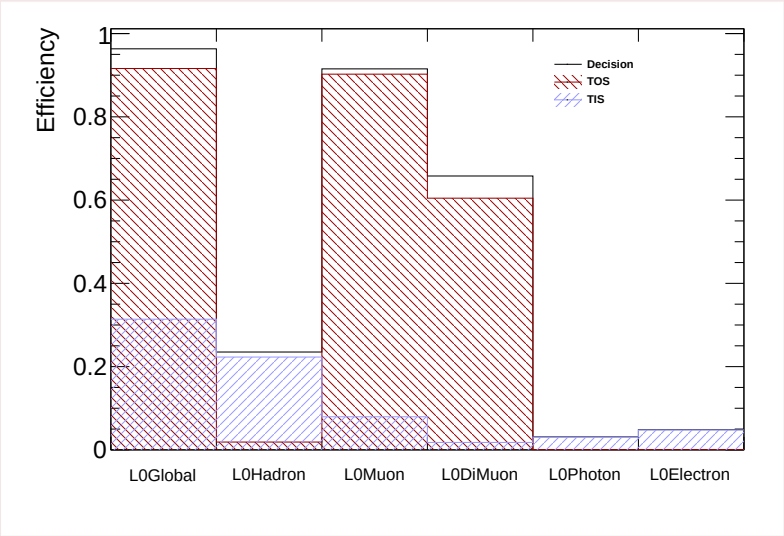
Selection strategy (D. Brundu, A. Cardini, A. Contu, F. Dettori, M.Fontana)

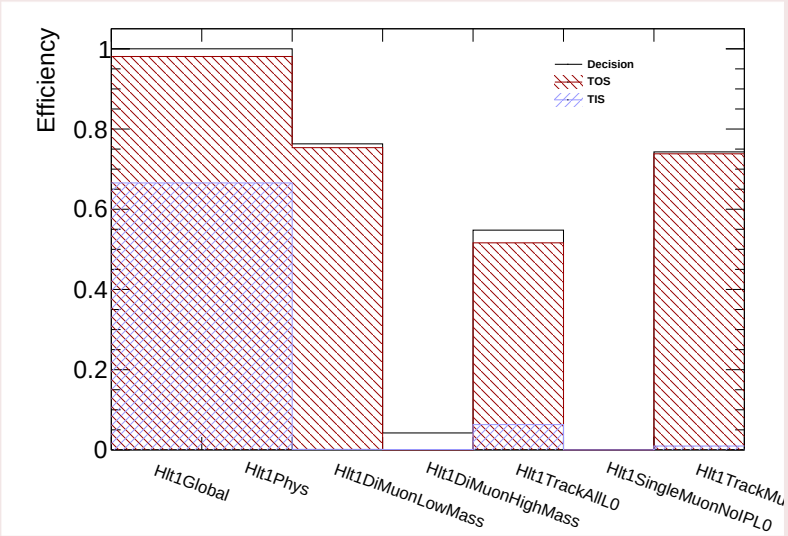
Main backgrounds

- Combinatorial: random combinations of two real muons
- MisID: due to D^0 hadronic two-body decays with hadrons misidentified as muons $D^{*0} \to D^0(\pi^+\pi^-)\pi_s$ and $D^{*0} \to D^0(K^+\pi^-)\pi_s$

Trigger

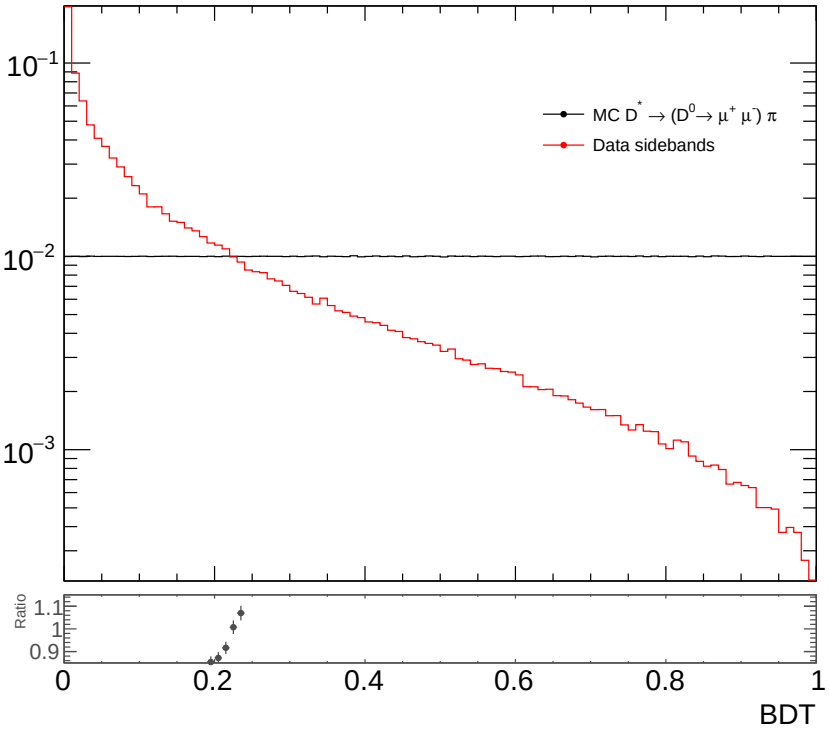
Trigger path	ϵ (Dec)	ϵ (TOS)
L0Muon || L0DiMuon || L0GlobalTIS	0.962083	0.96101
Hlt1DiMuonLowMass || Hlt1TrackMuon || Hlt1PhysTIS	0.965171	0.963791

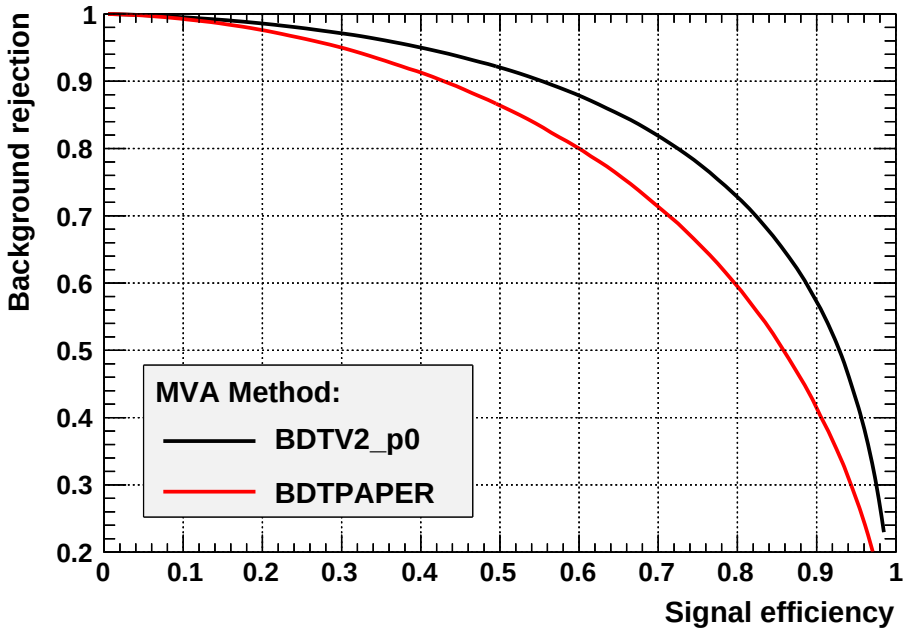




BDT (D. Brundu, A. Cardini, A. Contu, F. Dettori, M.Fontana)

- BDT reoptimised wrt the previous analysis in the variables used and in the training method
- Signal: MC $D^{*0} \to D^0(\mu^+\mu^-)\pi_s$
- Background: data right sideband of the D^0 mass distribution ($m_{\mu\mu} - m_{D^0}^{PDG} > 30$)





List of variables

μ cos(θ) , cos(γ) $= \hat{p}_{D^0} \cdot \hat{r}_{D^0}$, D^0 IPχ^2, min(μ p_{T}) , D^0 vertex χ^2 , D^* DTF χ^2 , D^0 cos(θ) , D^0 $FD\chi^2$, min(μ Iso) , π Iso , π p_{T} , D^0 DTF p_{T}

Selection: optimisation (D. Brundu, A. Cardini, A. Contu, F. Dettori, M.Fontana)

- BDT and ProbNN selection cuts chosen in order to maximise the Punzi fom:

$$P = \frac{\epsilon_{\mu\mu}^{BDT+ProbNNmu}}{a/2 + \sqrt{N_{bkg}}}$$

- $\epsilon_{\mu\mu}^{BDT+ProbNN}$: BDT+ProbNNmu signal efficiencies (from MC)
- $N_{bkg} = w_{comb} N_{comb} + w_{misID} N_{misID}$: number of background events in the signal region
  - N_{comb}: taken from the blind $D^{*0} \to D^0(\mu^+\mu^-)\pi_s$ fit
  - $N_{misID}(\pi\pi \to \mu\mu) = N_{\pi\pi}(TIS) \cdot \frac{\epsilon_{\pi\pi\to\mu\mu}}{\epsilon_{\pi\pi}} = N_{\pi\pi}(TIS) \cdot \mathcal{P}(\pi\pi \to \mu\mu) \cdot \frac{\epsilon_{\mu\mu}(L0Hlt1)}{\epsilon_{TIS}(L0Hlt1)}$
    - $N_{\pi\pi}(TIS)$: number of $D^{*0} \to D^0(\pi^+\pi^-)\pi_s$ events from data (for each BDT cut)
    - $\mathcal{P}(\pi\pi \to \mu\mu)$: probability of misID taken from `PIDCalib` [backup]
    - $\epsilon_{\mu\mu}(L0Hlt1)$: $D^{*0} \to D^0(\mu^+\mu^-)\pi_s$ trigger efficiency from MC
    - $\epsilon_{TIS}(L0Hlt1) = \frac{N_{\pi\pi}(TISandTOS)}{N_{\pi\pi}(TOS)}$: $D^{*0} \to D^0(\pi^+\pi^-)\pi_s$ TIS efficiency from data ($\sim 5\%$)
  - w_{comb} and w_{misID}: weights to take into account the importance of each background $\to$ toy studies
- a parameter chosen to be 3

Fit model (D. Brundu, A. Cardini, A. Contu, F. Dettori, M.Fontana)

- Number of background events extracted from a fit to the $D^{*0} \to D^0(\mu^+\mu^-)\pi_s$ and $D^{*0} \to D^0(\pi^+\pi^-)\pi_s$ data
- As a general strategy many parameters have been extracted from the MC and fixed to data

$D^{*0} \to D^0(\mu^+\mu^-)\pi_s$

Component	$m(D^0)$	$m(D^*) - m(D^0)$
Signal tagged	Blind	Blind
Signal untagged	Blind	Blind
misID $\pi\pi$	Blind	Blind
$D^* \to D^0(\pi^-\mu^+\nu_\mu)\pi^+$	to be studied	
$D^* \to D^0(K^-\mu^+\nu_\mu)\pi^+$	to be studied	
Combinatorial	RooChebychev	RooDstD0BG
misID $K\pi$	Exponential	Gaussian

$D^{*0} \to D^0(\pi^+\pi^-)\pi_s$

Component	$m(D^0)$	$m(D^*) - m(D^0)$
Signal tagged	Double CB	Double CB
Signal untagged	CB	RooDstD0BG
Combinatorial	RooChebychev	RooDstD0BG
misID $K\pi$	Exponential	Gaussian

Fit model (D. Brundu, A. Cardini, A. Contu, F. Dettori, M.Fontana)

- Number of background events extracted from a fit to the $D^{*0} \to D^0(\mu^+\mu^-)\pi_s$ and $D^{*0} \to D^0(\pi^+\pi^-)\pi_s$ data
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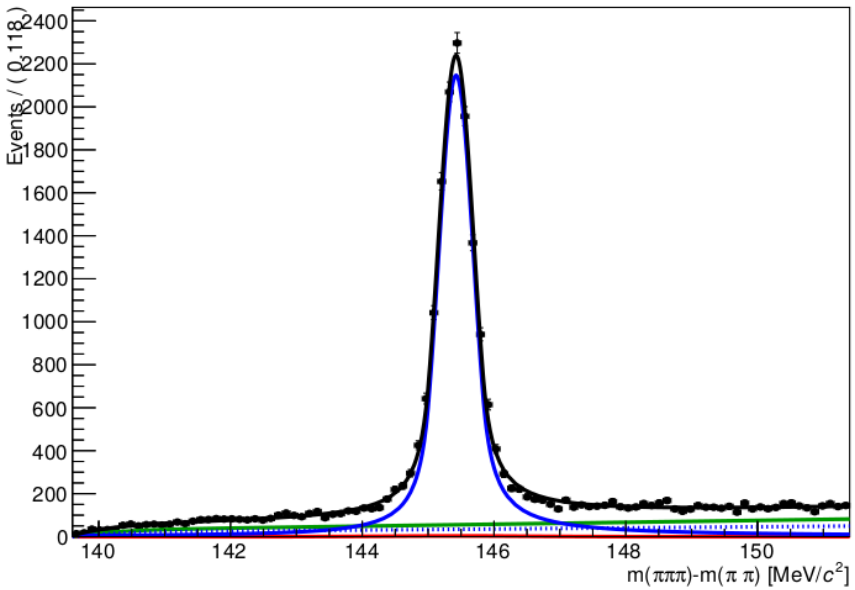
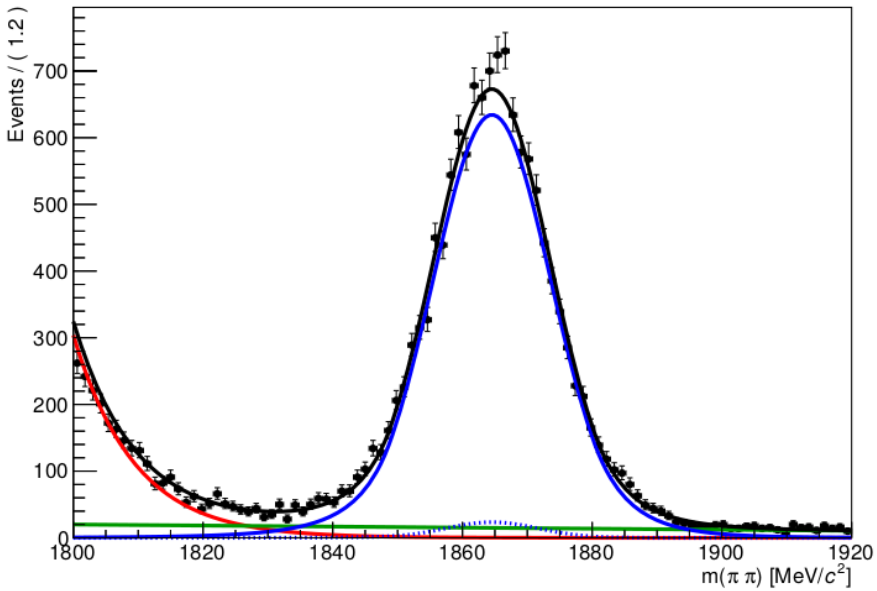
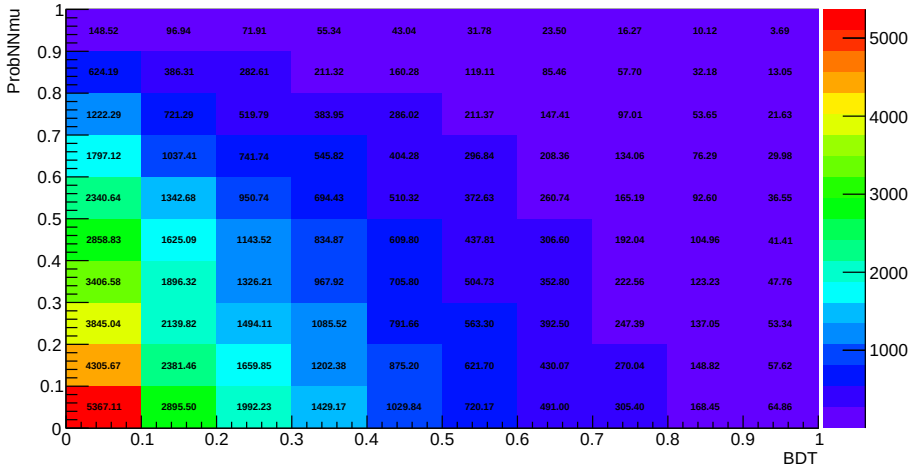




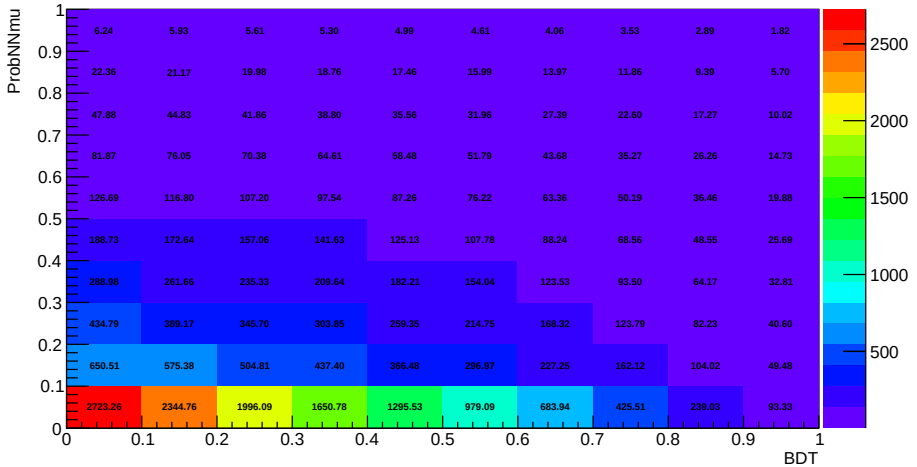
Background studies ..ongoing (D. Brundu, A. Cardini, A. Contu, F. Dettori, M.Fontana)

- Use toys to check the influence of the two backgrounds on the error of the BF
- By comparing the different set of toys it is possible to determine a weight, that is given to the Punzi for the optimisation
- The scan is done only for values of combinatorial and misID backgrounds close to a plausible point of optimisation

Background combinatorial 2011+2012- ProbNN vs BDT



Background $\pi\pi$ misid 2011+2012- ProbNN vs BDT



- For BDT [0.7 - 0.9] and ProbNN [0.6 - 0.9]: N_{comb}: 32 - 134, N_{misID}: 9 - 50

Ongoing

- Efficiencies studies
- Finalisation of the fit model

Other analyses (A. Contu)

- Charm Rare Decays
  - Search for $D^0 \to \pi\pi\mu\mu$. $BF < 5.5 \times 10^{-7}$ at 90% CL (phase space decays), resonant modes observed for the first time in $M(\mu\mu)$ [PLB 728 (2014) 234-243]
  - $\mathcal{B}(D^0 \to K\pi\rho/\omega(\to \mu\mu))$, useful to normalise many 4-body decays
    LHCb-PAPER-2015-048-001 (soon 2nd circulation)
- Charm mixing and CPV in $D^0 \to K_S\pi\pi$
  - Upgrade perfomance studies reported in the UPT document [LHCb-PUB-2014-040]
  - Time-dependent analysis on the Dalitz plane using the D^*-tagged (2012) sample to determine the mixing parameters x and y, using the "bin-flip" method (WG review)
- Strange decays:
  - It is possible to reconstruct K^+ decays, especially with a "downstream" final state [LHCb-PUB-2014-032]
  - Precision measurement of the K^+ mass using $K^+\pi^+\pi^-\pi^+$ (long tracks). Feasibility studies done in a summer student project 2015 https://indico.cern.ch/event/393184/contribution/0/attachments/1147422/1645801/mikkelbjoern_summerstudent_presentation.pdf

Muon system Upgrade (A. Cardini, V. Cogoni, M. Fontana)

- The present configuration of the detector could not be the optimal solution for the Upgrade: high flux of particles might decrease the efficiencies and the identification of the muons.
- It is essential to reoptimise the Muon System

Tuned Monte Carlo

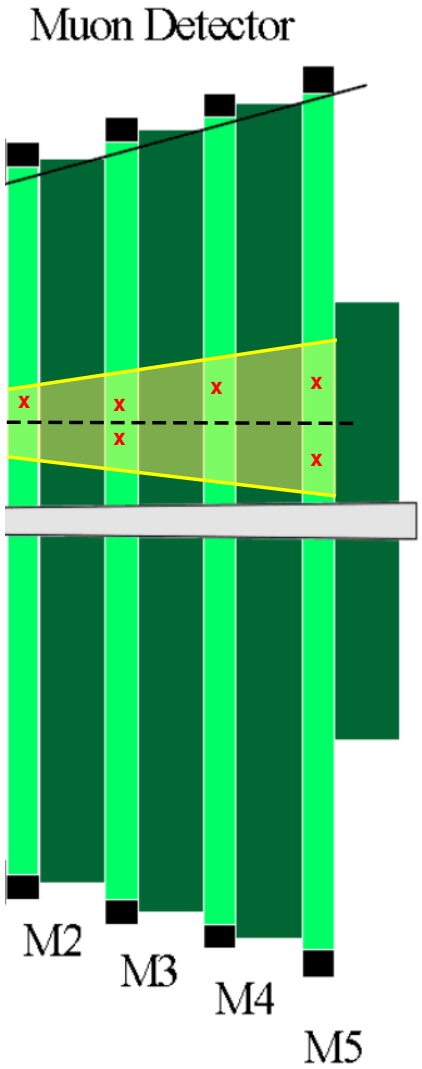
The official MC does not reproduce correctly different effects due to the cavern or the low energy component. An ad hoc MC has been implemented:

- $\mathcal{L} = 2 \cdot 10^{33} \text{cm}^{-2}\text{s}^{-1}$, $\sqrt{s} = 14\text{TeV}$
- Energy threshold in production and tracking decreased
- Description of the cavern included
- New description of the beampipe shielding within M2 included

New tool

- Emulate digitisation
- It allows to study particle fluxes, ghost fluxes, occupancies
- It allows to modify the readout configuration

MuID studies (A. Cardini, V. Cogoni, M. Fontana)



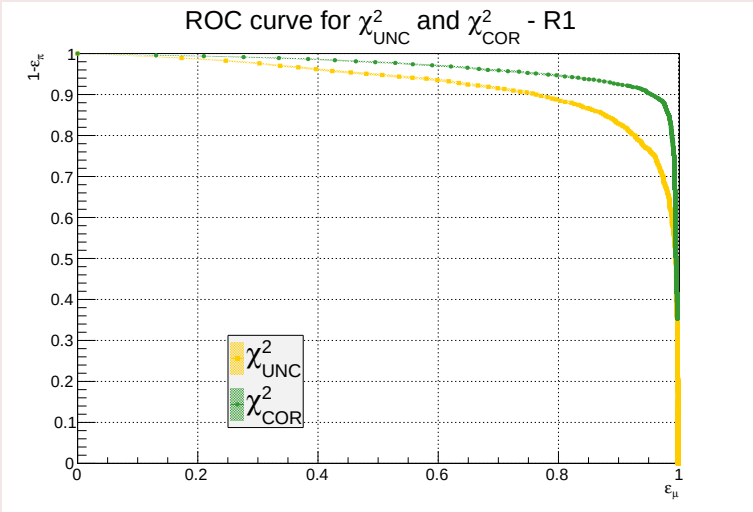
isMuon

momentum range	station
$p \in [3, 6]$ GeV/c	M2 & M3
$p \in [6, 10]$ GeV/c	M2 & M3 & (M4 or M5)
$p > 10$ GeV/c	M2 & M3 & M4 & M5

muID con best χ^2

$$\chi^2 = \delta\vec{x}^T \, Var(z)^{-1} \delta\vec{x}$$

$$\chi^2_{COR} \rightarrow Var(z)_{jk} \forall j, k; \qquad \chi^2_{UNC} \rightarrow Var(z)_{jk}, j = k$$



Conclusions

- Fruitful production of interesting analyses in Cagliari
- Absolute BF of the $\Lambda_c \to Kp\pi$ close to completion: expected by the end of the year
- Update of the $D^0 \to \mu^+\mu^-$ BF ongoing: expected for winter/spring conferences
- Starting collaboration with Zurich for the $B^0 \to K^*\mu\mu / B^0 \to K^*ee$ measurement

- Useful studies for the Muon System upgrade:
  - ongoing studies on the possible removal of M2R1
  - studies at very high luminosities ($5 - 10 \times 10^{33}\ cm^{-2}s^{-1}$)

Thanks for your attention!