Search for $K_s^0 \to 2(l^+l^-)$ decays at LHCb

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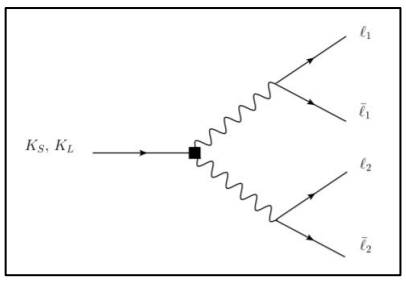


NEW INTEREST! Kaon multilepton decays

- Never been looked for on any experiment
- Test for physics beyond the SM
- Possible link to **Dark Matter!**

Dark Sectors Models [1]

$$K_s^0 \to XX \to 2(l^+l^-)$$

HOW? Trigger HLT2 Implementation for muons

Step 1: Select muons w/ long tracks

Variable	Requirement
Track Ghost Prob	< 0.4
μ IP	> 0.4 mm
μ IP χ^2	> 20
IsMuon	True

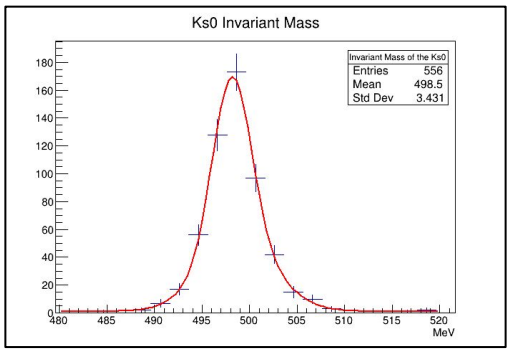
Step 2: Combine them!

Variable	Requirement
$\mu^+\mu^-\mu^+\mu^-$ distance of closest approach	< 0.4mm
K_s^0 Vertex $\chi^2/ndof$	< 20
K_s^0 decay length significance	> 4
K_s^0 invariant mass	$\in [397, 597]$ MeV
K_s^0 IP	< 0.2
K_s^0 cos of direction angle	> 0.995

Step 3: Test on MinBias and Signal Monte Carlo samples

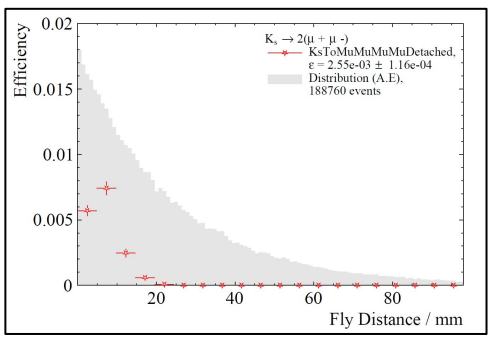
Rate	Efficiency (TOS)	Signal Purity
< 100 Hz	2.55E-03	87%

Mass Reconstruction

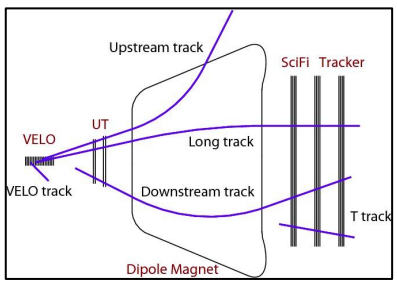


- **Expected BR by the SM** is in the order of [2] $O(10^{-14})$
- **Low rate** ensures a minimal amount of non-interesting events will trigger.
- **High efficiency** while maintaining high signal purity and low rate.
- **87% of all candidates are signal**, not background!

How can we improve?



- **The kaon flies a lot**!
- Working with downstream muons alongside long muons will allow to trigger on more signal!



Trigger HLT2 Implementation for electrons

Variables considered in electron line

Variable	Requirement
pT electrons	>100MeV
Track Ghost Prob	<0.5
Eletcron identification	>1.0
e IP	>0.2mm
e^-/e Max DOCA	< 1.0mm
K_s^0 Vertex $\chi^2/ndof$	<25.0
K_s^0 vertex decay length significance	>2.0
K_s^0 invariant mass	$\in [397, 597]$ MeV

Line efficiency = 1.92 x 10^-2

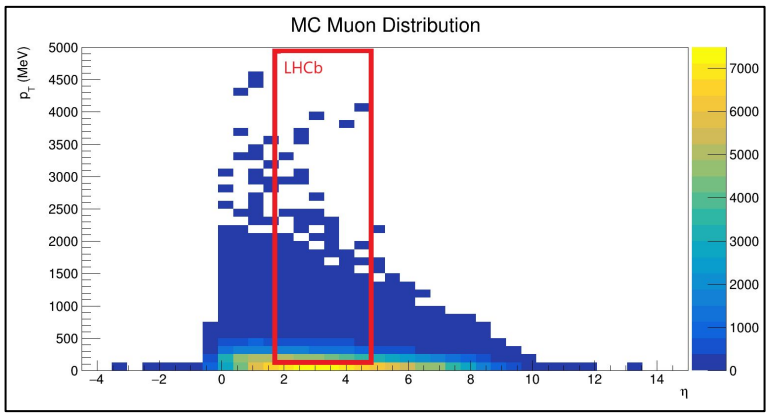
Signal simulation not reconstructable → low pT electron difficult to reconstruction

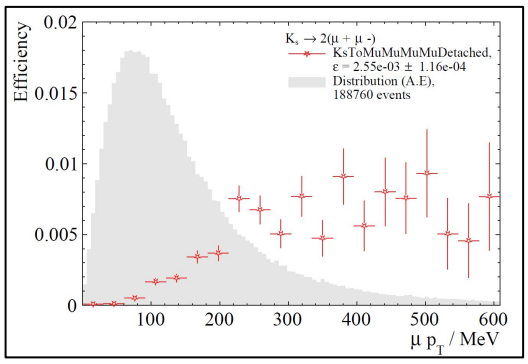
There is ongoing work with truth matching information

Challenges

- Electron track reconstructions at low pT
- Development of supplementary lines involving pions and Ks → $e^+e^-\mu^+\mu^-$

Why LHCb?





- **LHCb pT vs eta coverage** is optimal.
- On Run 3 LHCb will **only use software-based triggers** [3], allowing the study of soft (low pT) decays.
- The low pT threshold is crucial for its kaon physics programme [4].

References: **[1]** M. Hostert and M. Pospelov, "Novel multi-lepton signatures of dark sectors in light meson decays", arXiv:2012.02142 [hep-ph], Dec. 2020. **[2]** G. D'Ambrosio, D. Greynat and G. Vulvert, "Standard model and new physics contributions to K_L and K_S into four leptons", *The European Physical Journal C*, vol. 73, no. 12, 2013. Available: 10.1140/epjc/s10052-013-2678-1 [Accessed 25 August 2021]. **[3]** J. Albrecht, C. Fitzpatrick, V. Gligorov and G. Raven, "The upgrade of the LHCb trigger system", *Journal of Instrumentation*, vol. 9, no. 10, pp. C10026-C10026, 2014. Available: 10.1088/1748-0221/9/10/c10026 [Accessed 25 August 2021]. **[4]** I. Belyaev, G. Carboni, N. Harnew, C. Matteuzzi and F. Teubert, "The history of LHCb", *The European Physical Journal H*, vol. 46, no. 1, 2021. Available: 10.1140/epjh/s13129-021-00002-z [Accessed 14 November 2021].