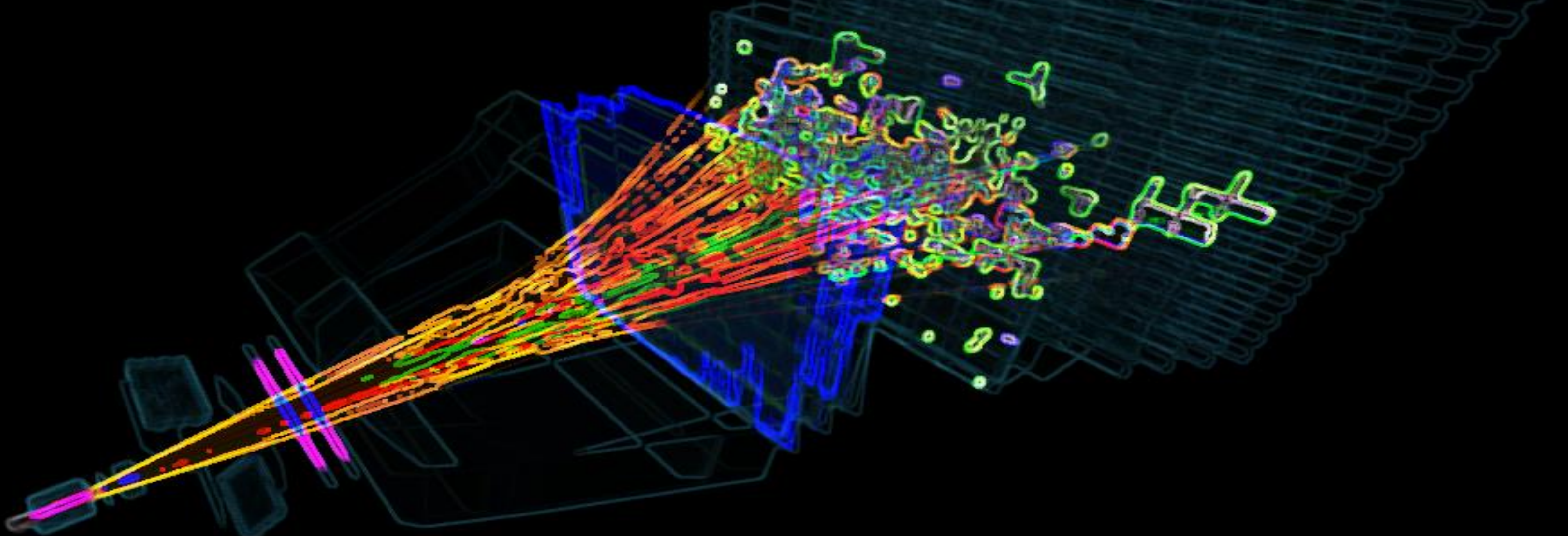
IMPROVING THE RECONSTRUCTION OF LONG-LIVED PARTICLES IN LHCb



ALEXANDRE BREA RODRÍGUEZ

Benás (06/09/2018)

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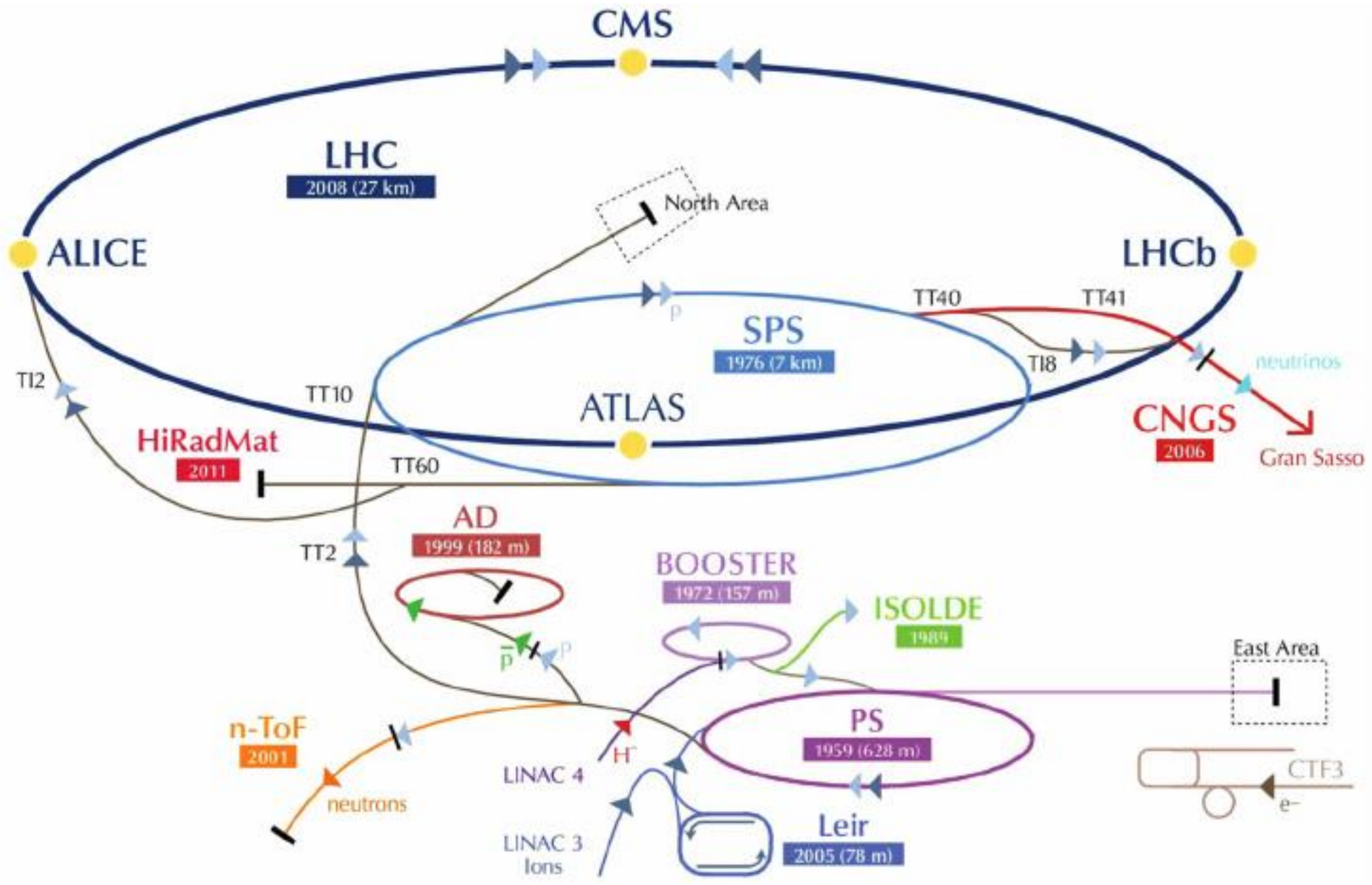
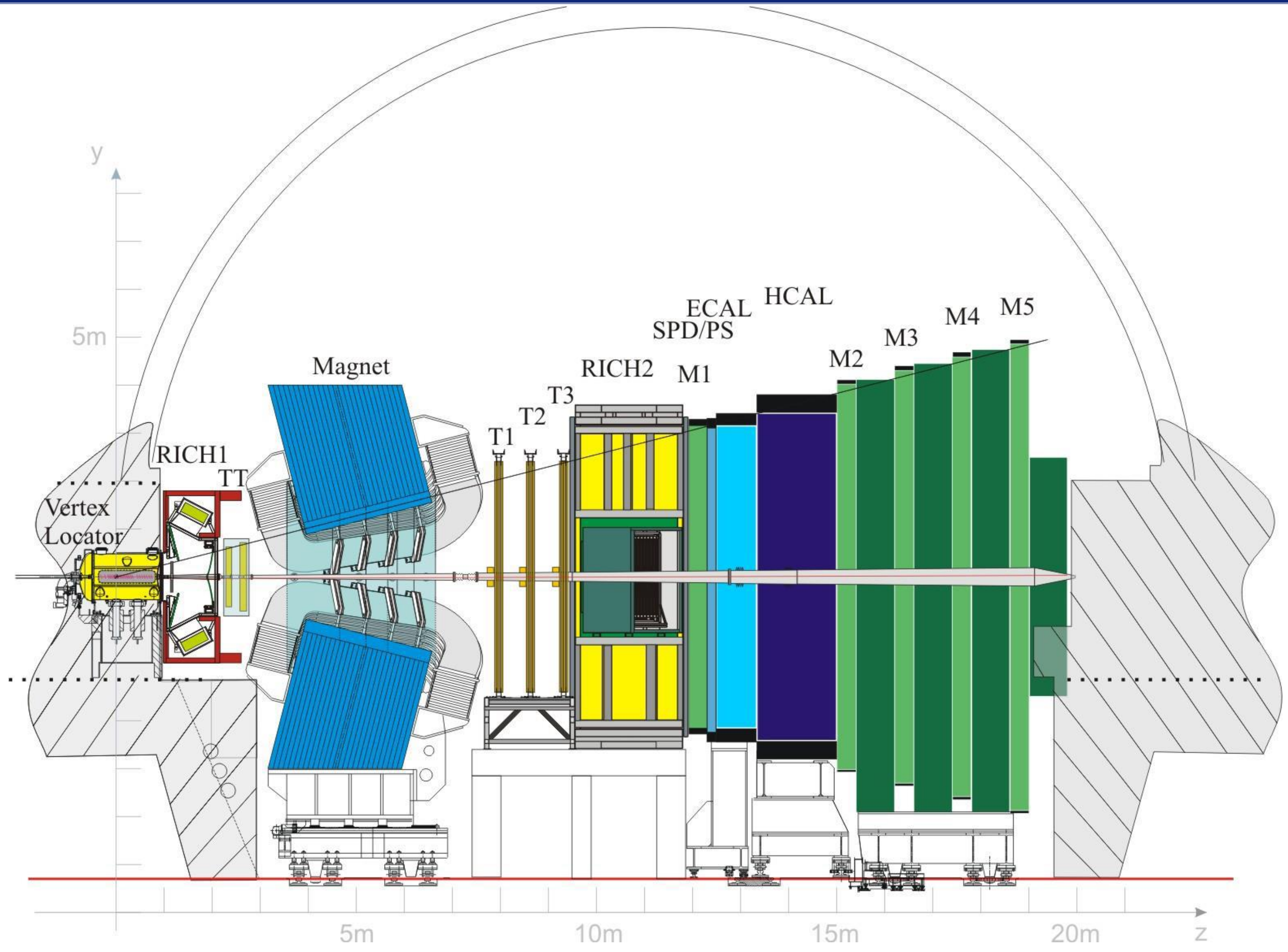
1. INTRODUCTION

USC UNIVERSIDADE DE SANTIAGO DE COMPOSTELA

LHC (Large Hadron Collider) is the world's largest and most powerful particle accelerator.



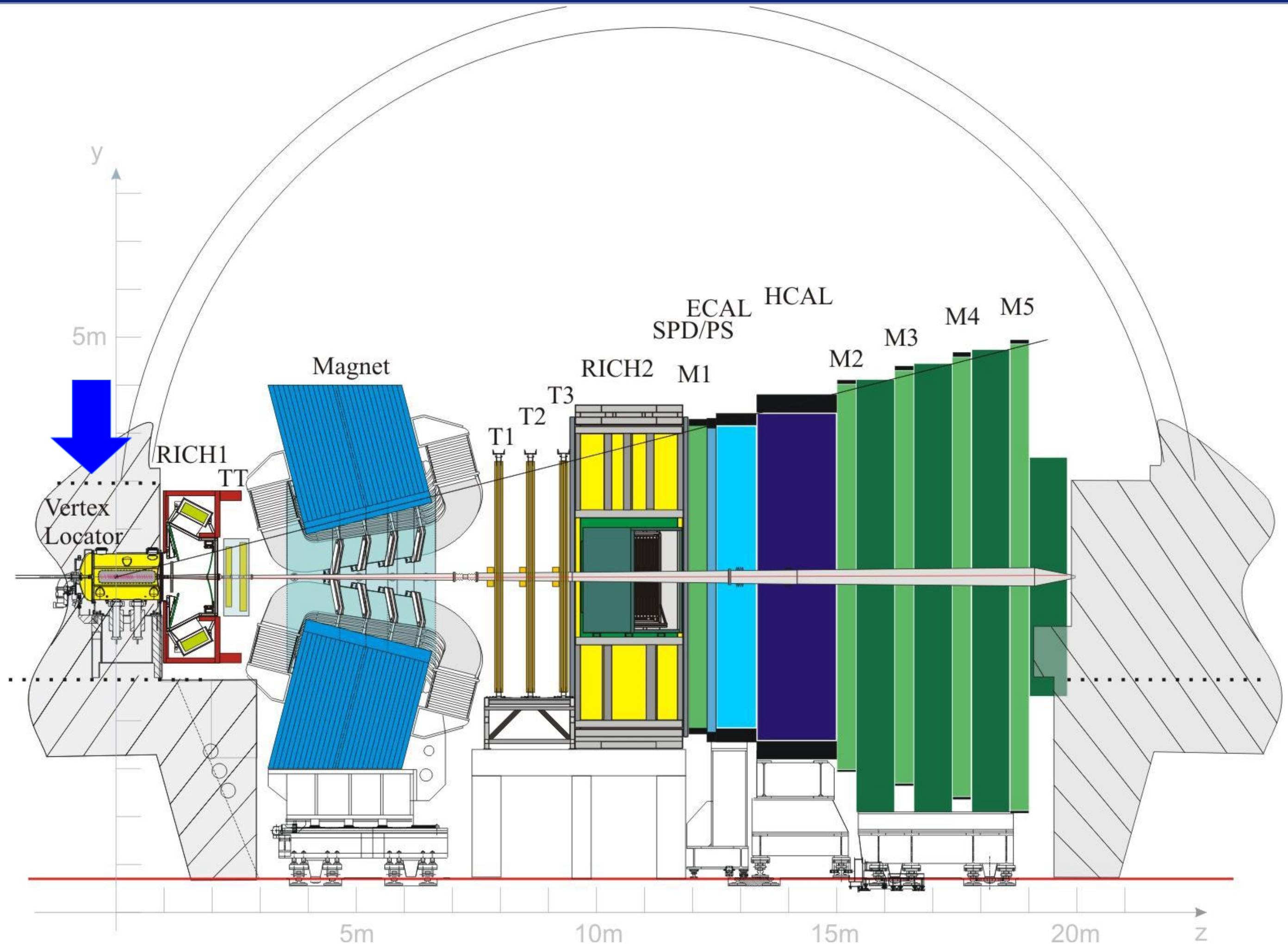


Side view of LHCb detector

LHCb (Large Hadron Collider beauty) is one of the four main experiments located at LHC.

It is focused on the study of the decay of light particles, for example those containing b quarks.

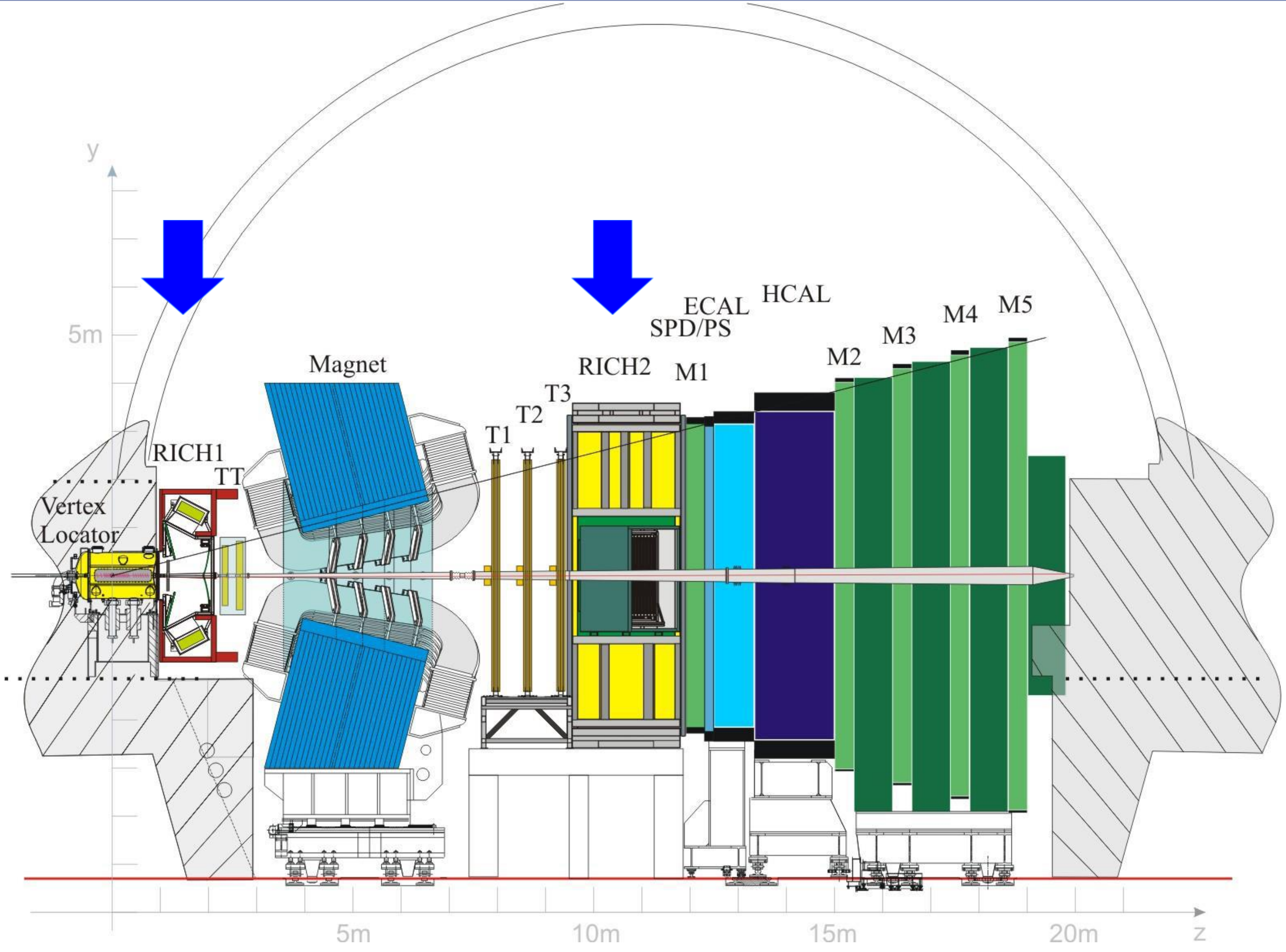
Most of them decay in the forward direction → forward design.



Side view of LHCb detector

Subdetectors:

- **VELO**
- RICHs
- Trackers
- ECAL
- HCAL
- Muon Chambers



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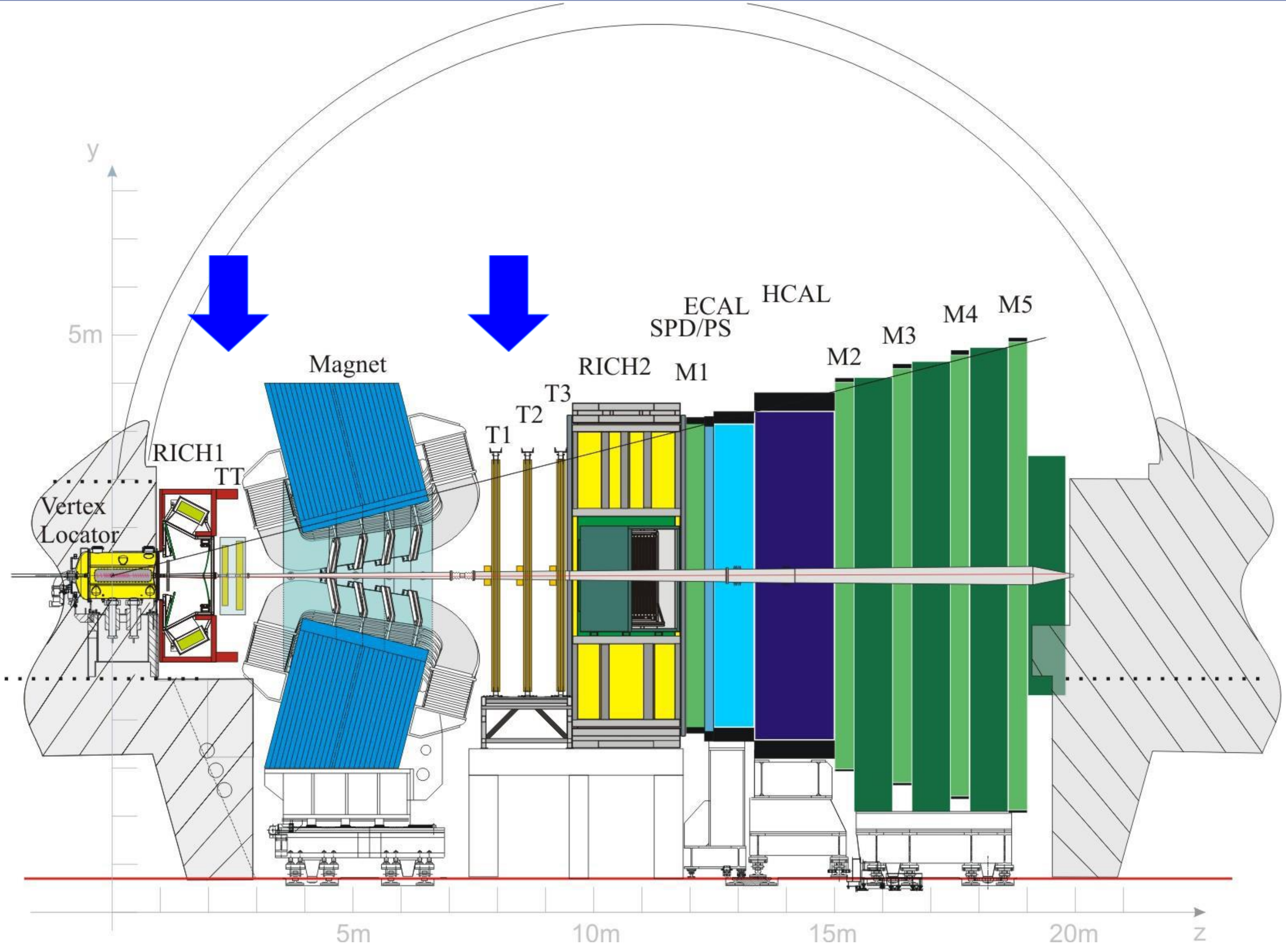

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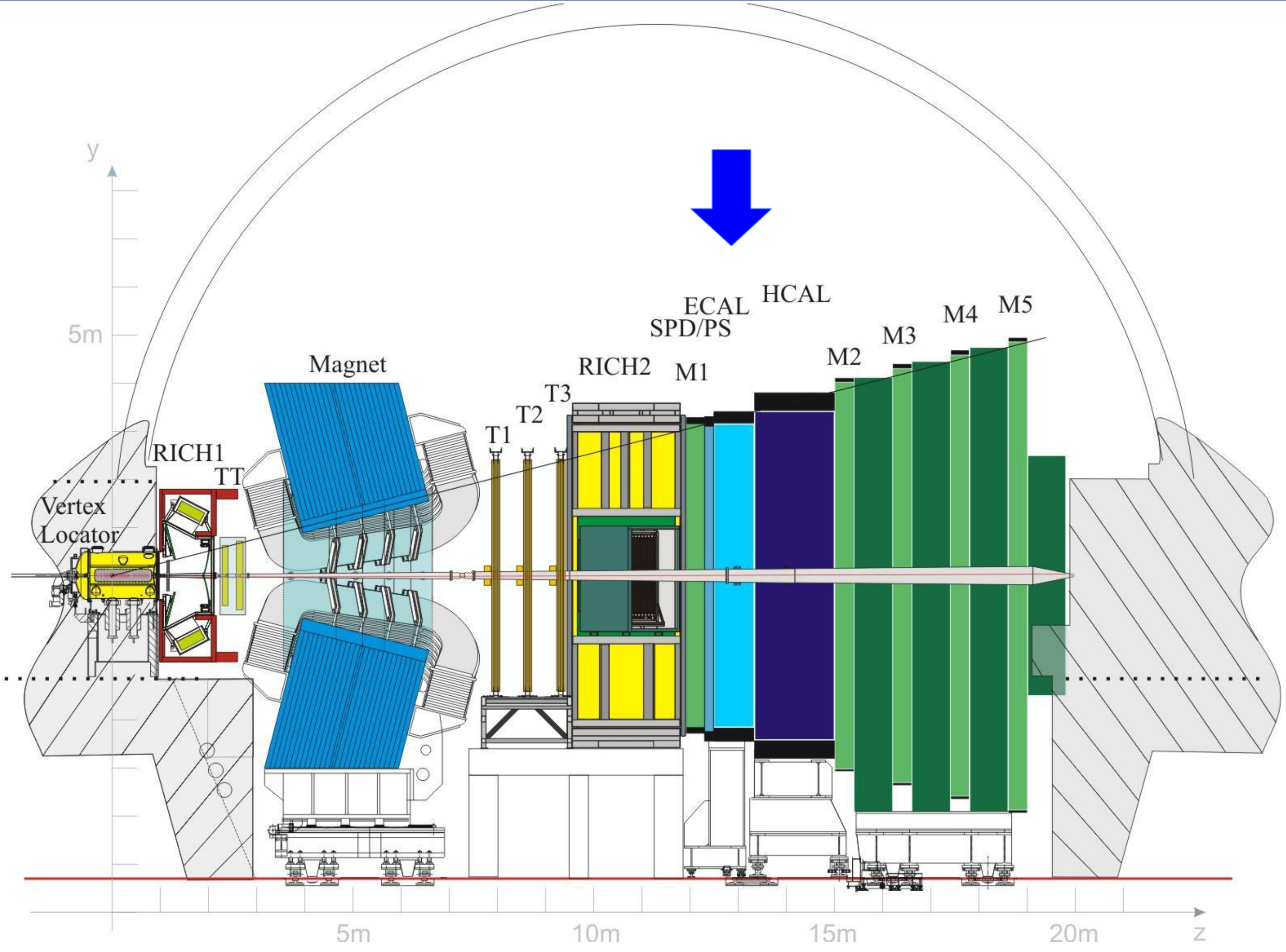

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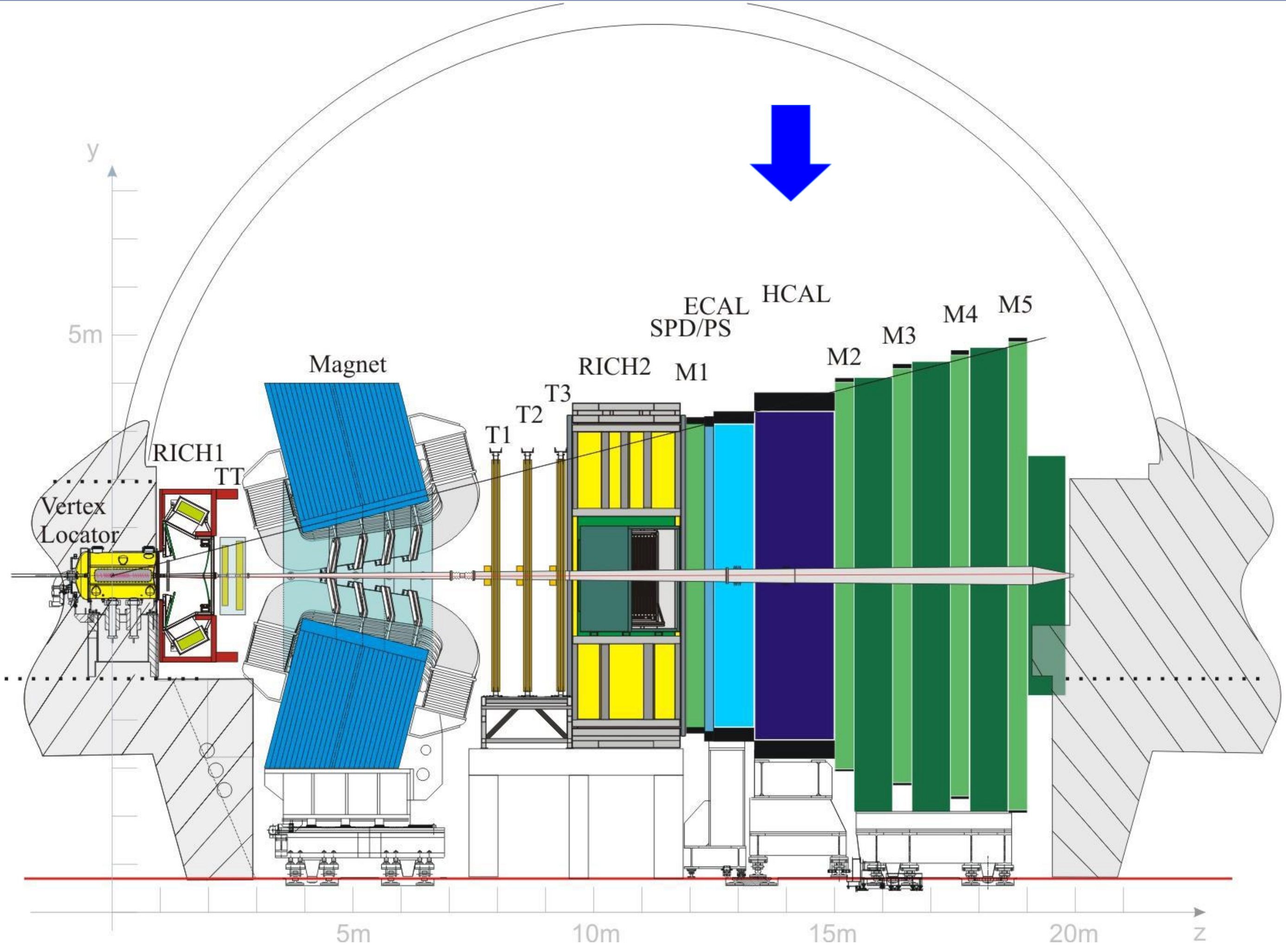

Side view of LHCb detector

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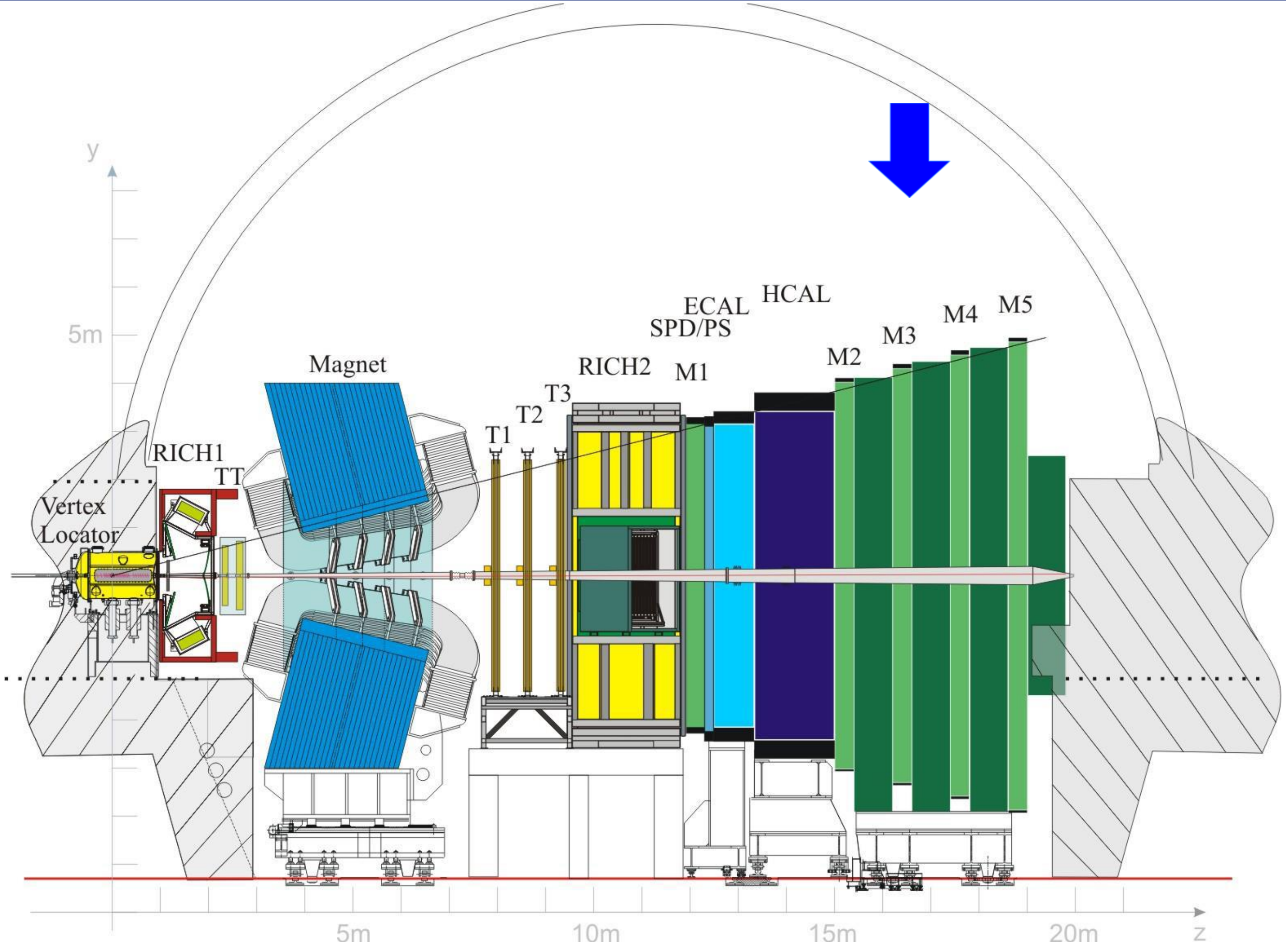

Side view of LHCb detector

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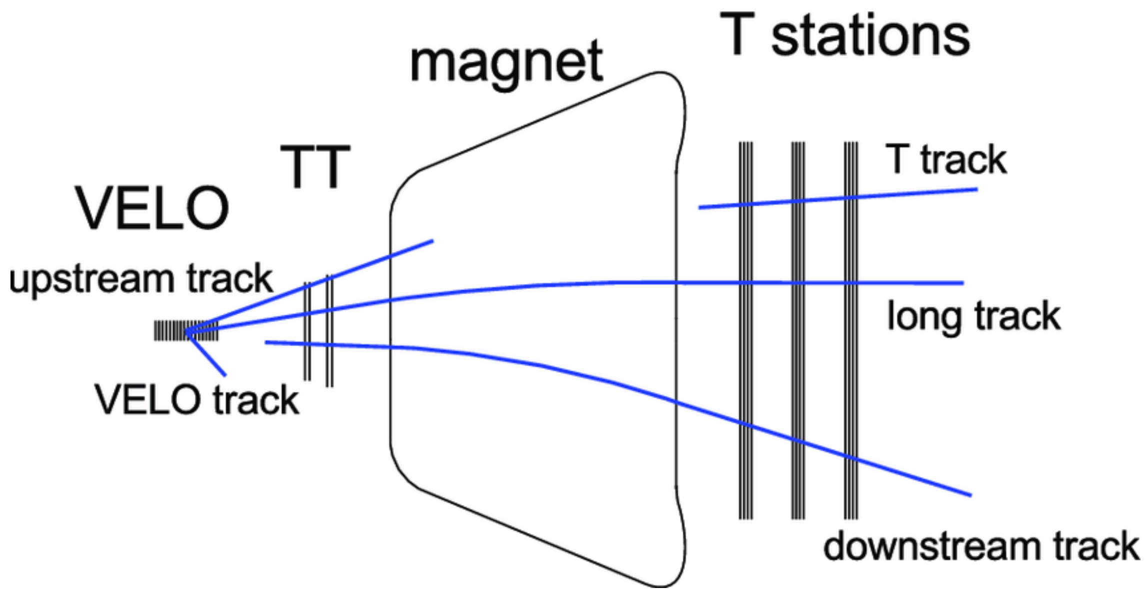
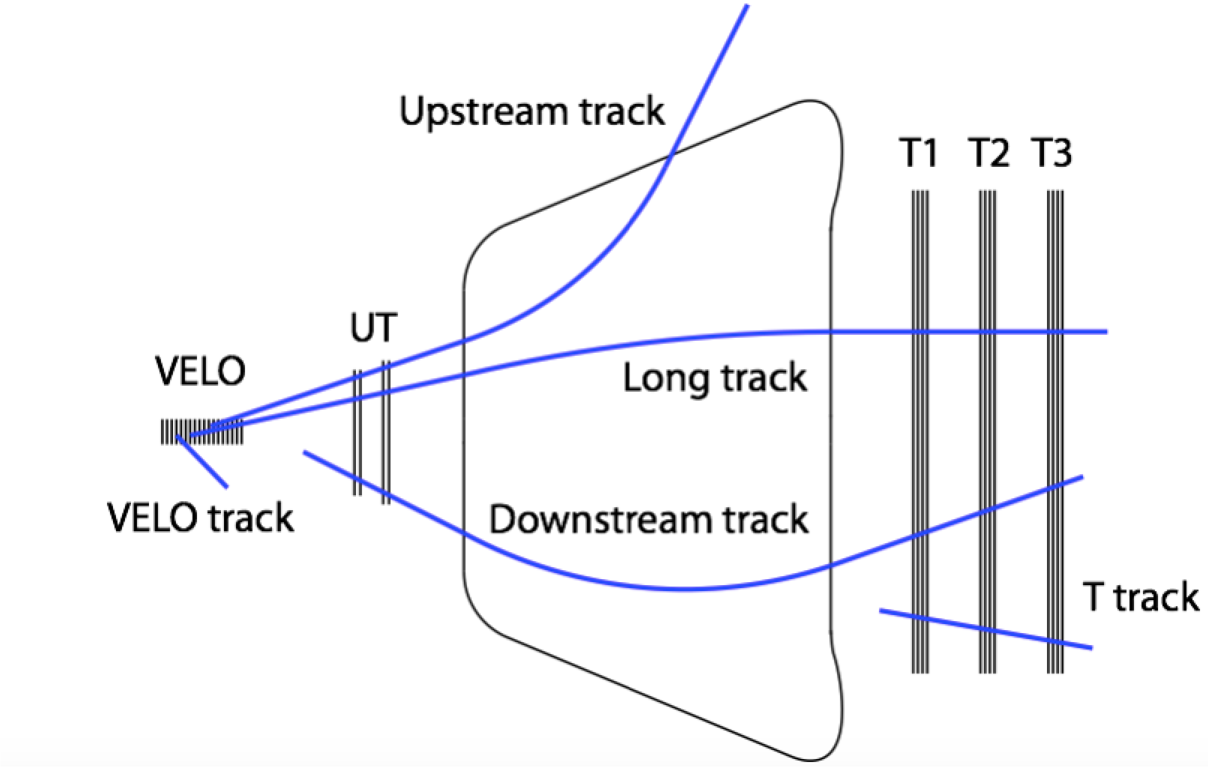
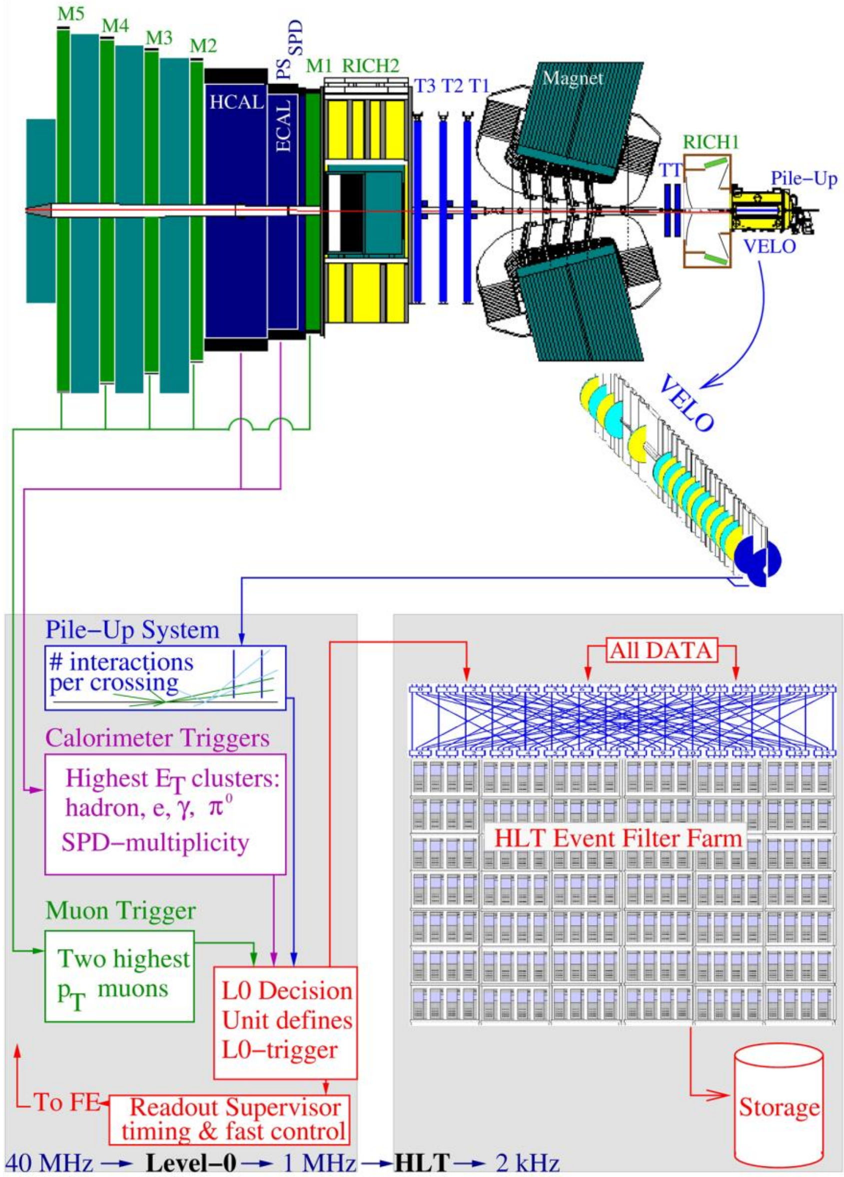
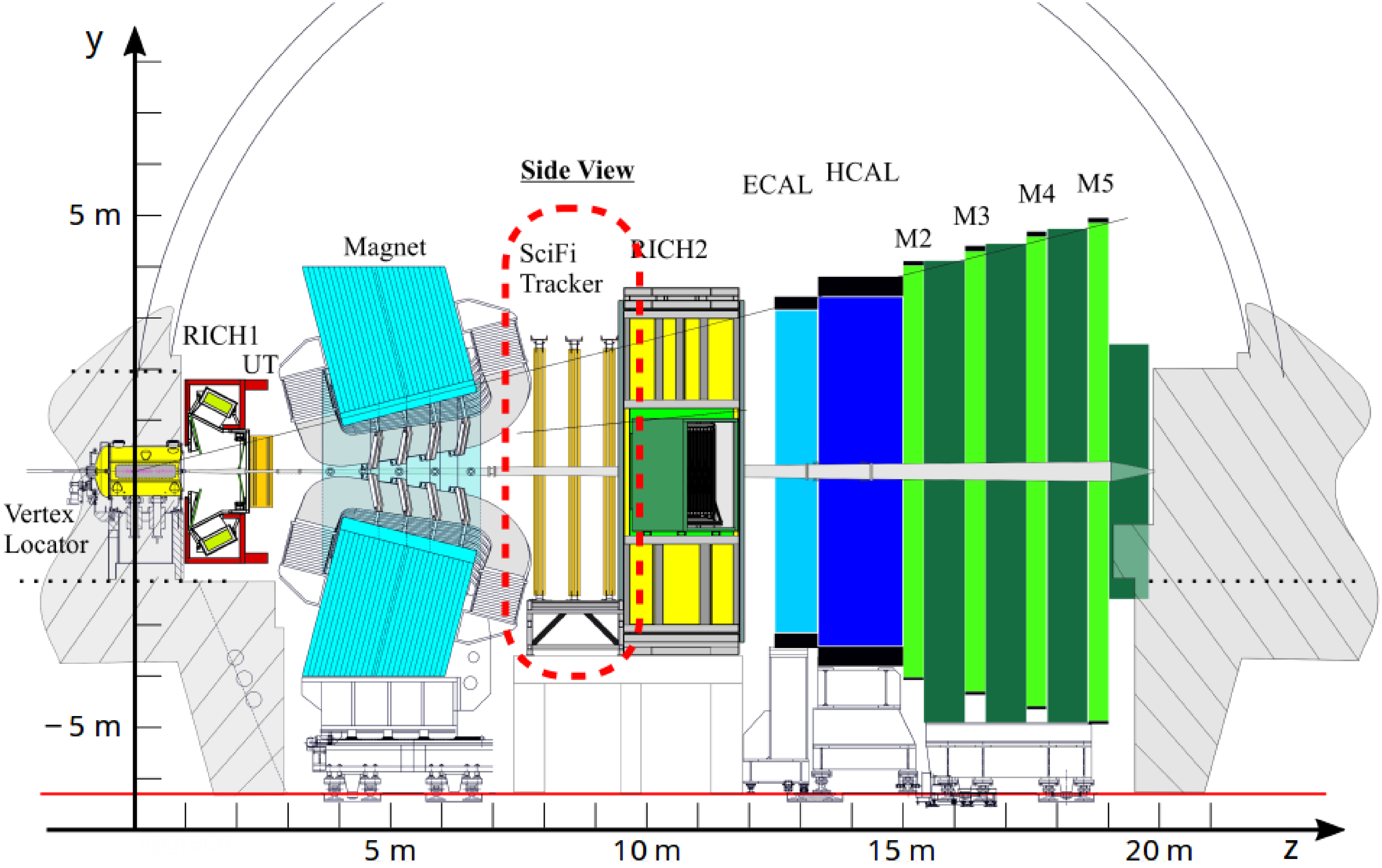

T stations
magnet
TT
VELO
T track
upstream track
long track
VELO track
downstream track


Upstream track
T1 T2 T3
UT
VELO
Long track
VELO track
Downstream track
T track

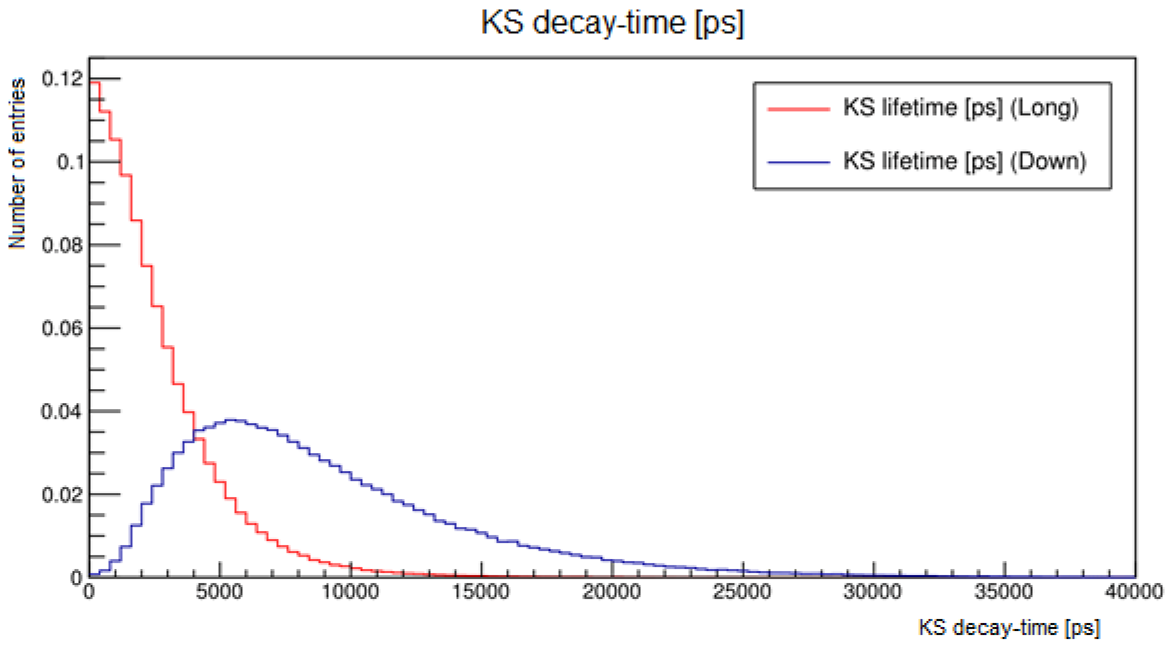

M5
M4
M3
M2
SPD
PS
M1 RICH2
HCAL
ECAL
T3 T2 T1
Magnet
RICH1
TT
Pile−Up
VELO
VELO
Pile−Up System
interactions per crossing
Calorimeter Triggers
Highest E_T clusters: hadron, e, γ, π^0
SPD−multiplicity
Muon Trigger
Two highest p_T muons
L0 Decision Unit defines L0−trigger
To FE
Readout Supervisor timing & fast control
All DATA
HLT Event Filter Farm
Storage
40 MHz → Level−0 → 1 MHz → HLT → 2 kHz


y
5 m
−5 m
Side View
ECAL
HCAL
M2
M3
M4
M5
Magnet
SciFi
Tracker
RICH2
RICH1
UT
Vertex
Locator
5 m
10 m
15 m
20 m
z

Most of LHCb analysis use only long tracks.

But long-lived particles can decay after VELO.

Use Downstream tracks could mean gain a lot of statistics (176 %).



$$K_S^0 \to \mu^+\mu^-$$

A Downstream muon Trigger is needed.

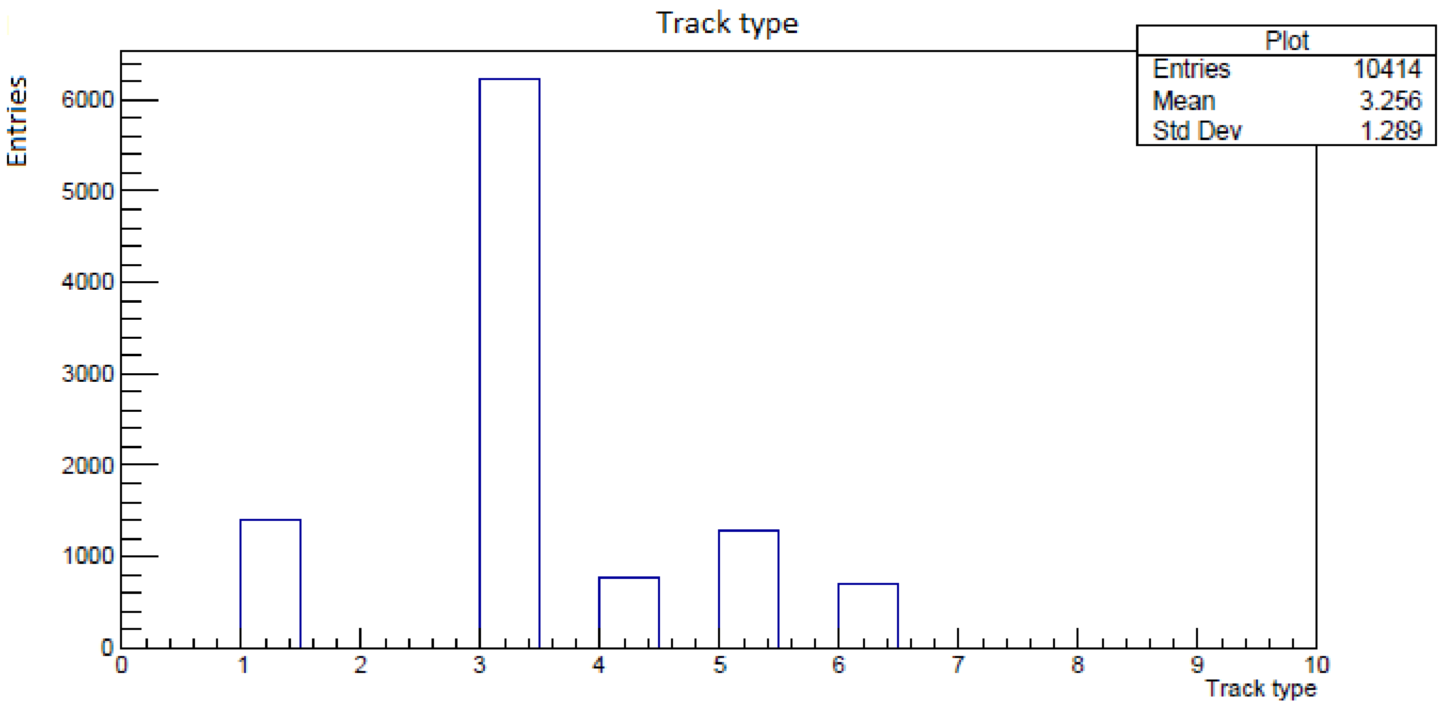
2. DOWNSTREAM TRACKS STUDY

Particle	Average(%)	Particle	Average(%)
e^-	4.74926	e^+	3.80531
μ^-	1.03245	μ^+	1.32743
π^+	34.63126	π^-	32.77286
K^+	3.33333	K^-	2.92035
p^+	9.70501	p^-	5.25074

Table 1: Main daughters asociated to Downstream tracks

Particle	Average(%)	Particle	Average(%)
γ	8.55457	ρ^0	3.62832
ρ^+	1.56342	ρ^-	1.32743
No particle	6.28319	π^0	0.16699
π^+	12.24190	π^-	12.12389
K_L^0	2.15339	K_S^0	22.15339
K^+	2.77286	K^-	2.33030
n	0.97345	$\bar{n}$	1.71091
p^+	1.82891	p^-	1.68042
η	0.97345	Λ	4.74926

Table 2: Main mothers asociated to Downstream tracks

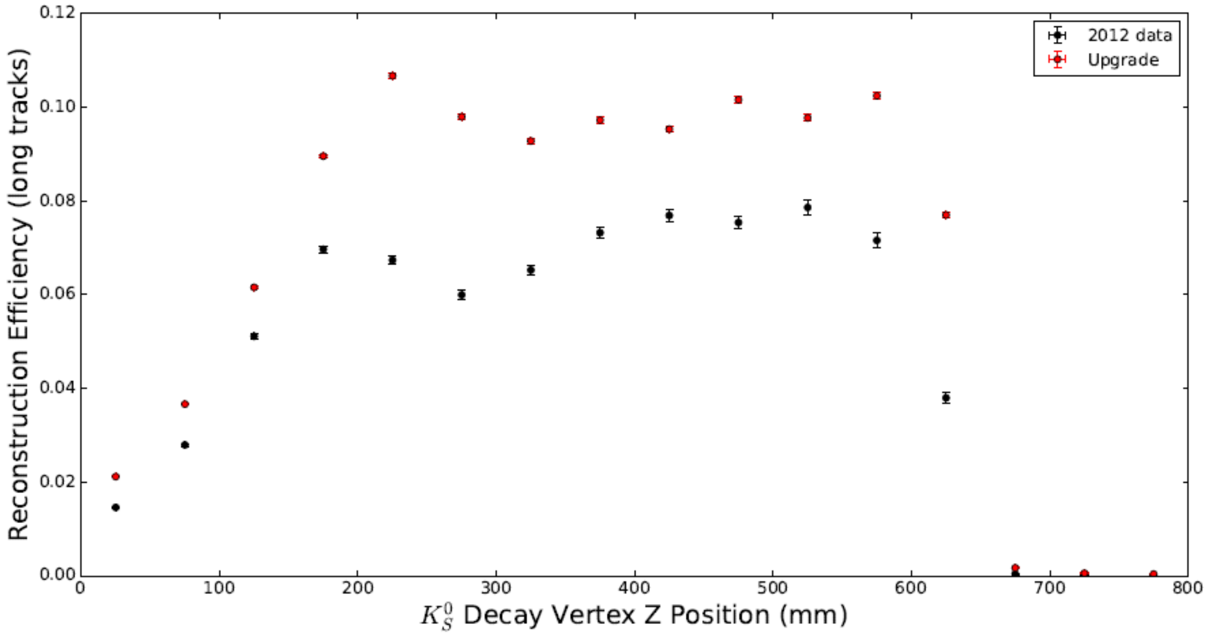


	Velo	VeloR	Long	Upstream	Downstream	Ttrack	Muon
Code	1	2	3	4	5	6	7

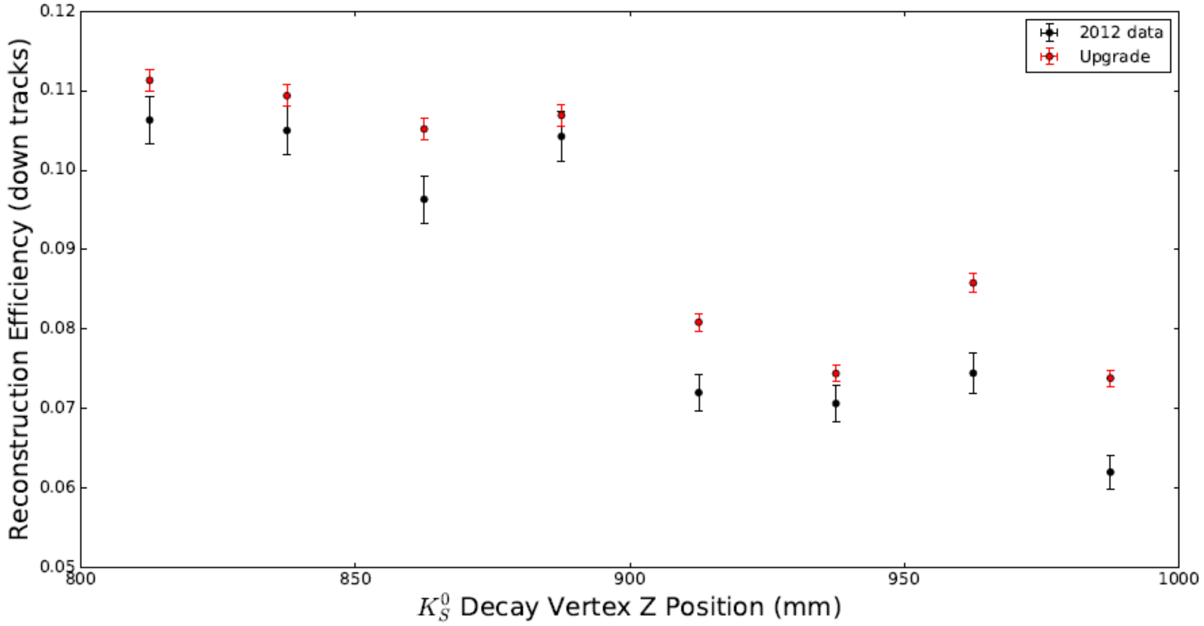
Benchmark

$$K_S^0 \to \pi^+\pi^-$$

LONG

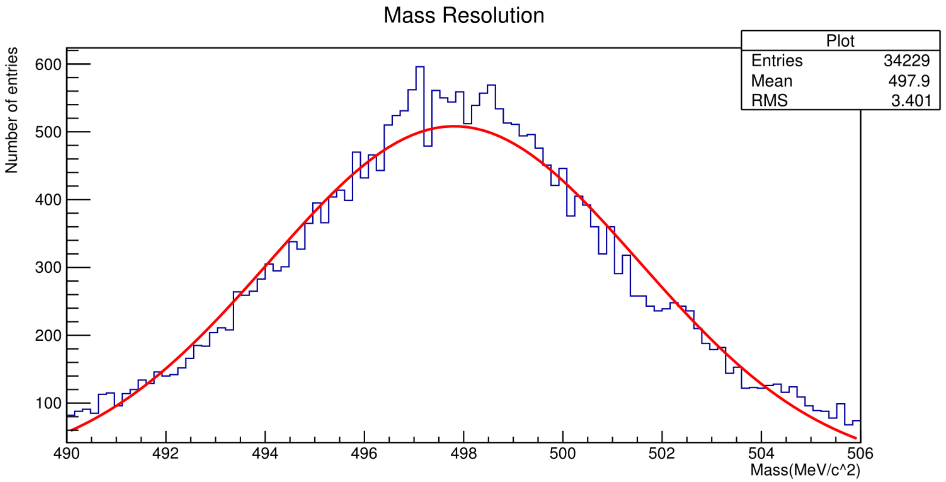


DOWN

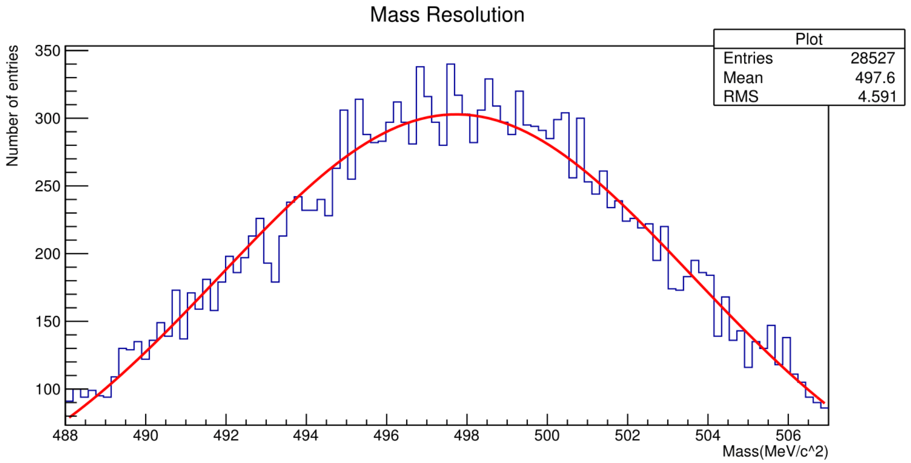


- Shape related to VELO stations.
- Higher efficiency in the Upgrade.

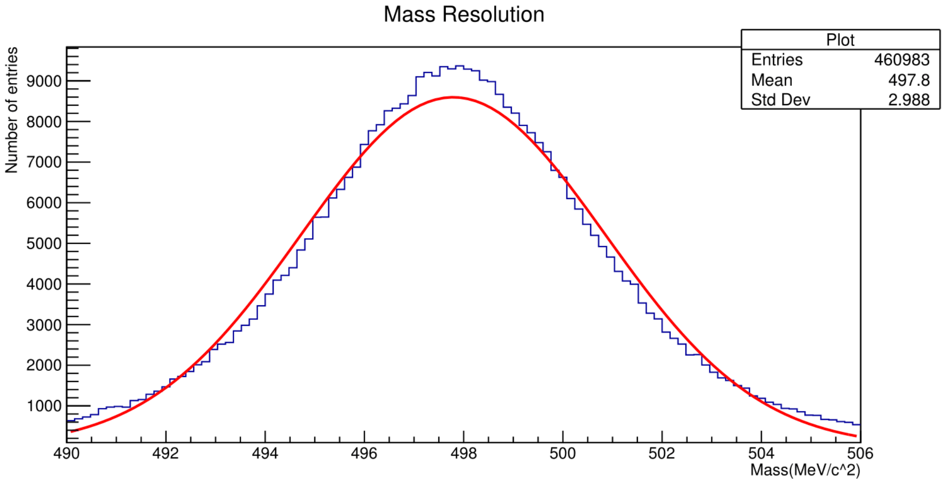
LONG (2012 MC)



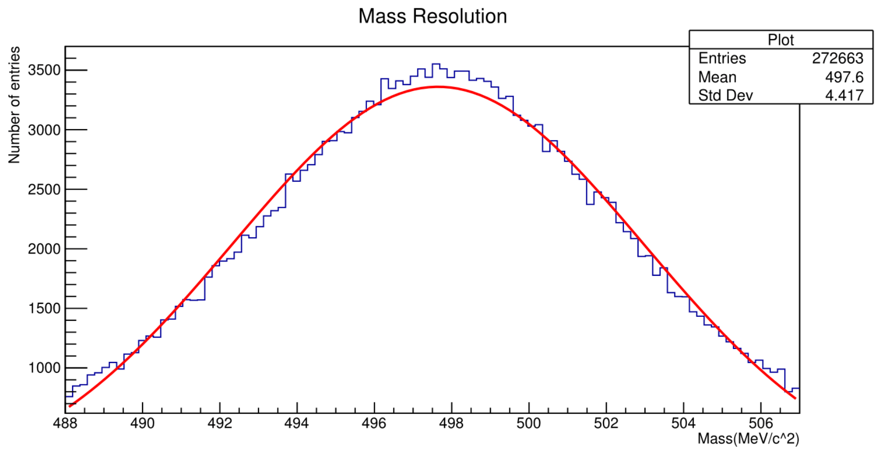
DOWN (2012 MC)



LONG (Upgrade MC)



DOWN (Upgrade MC)

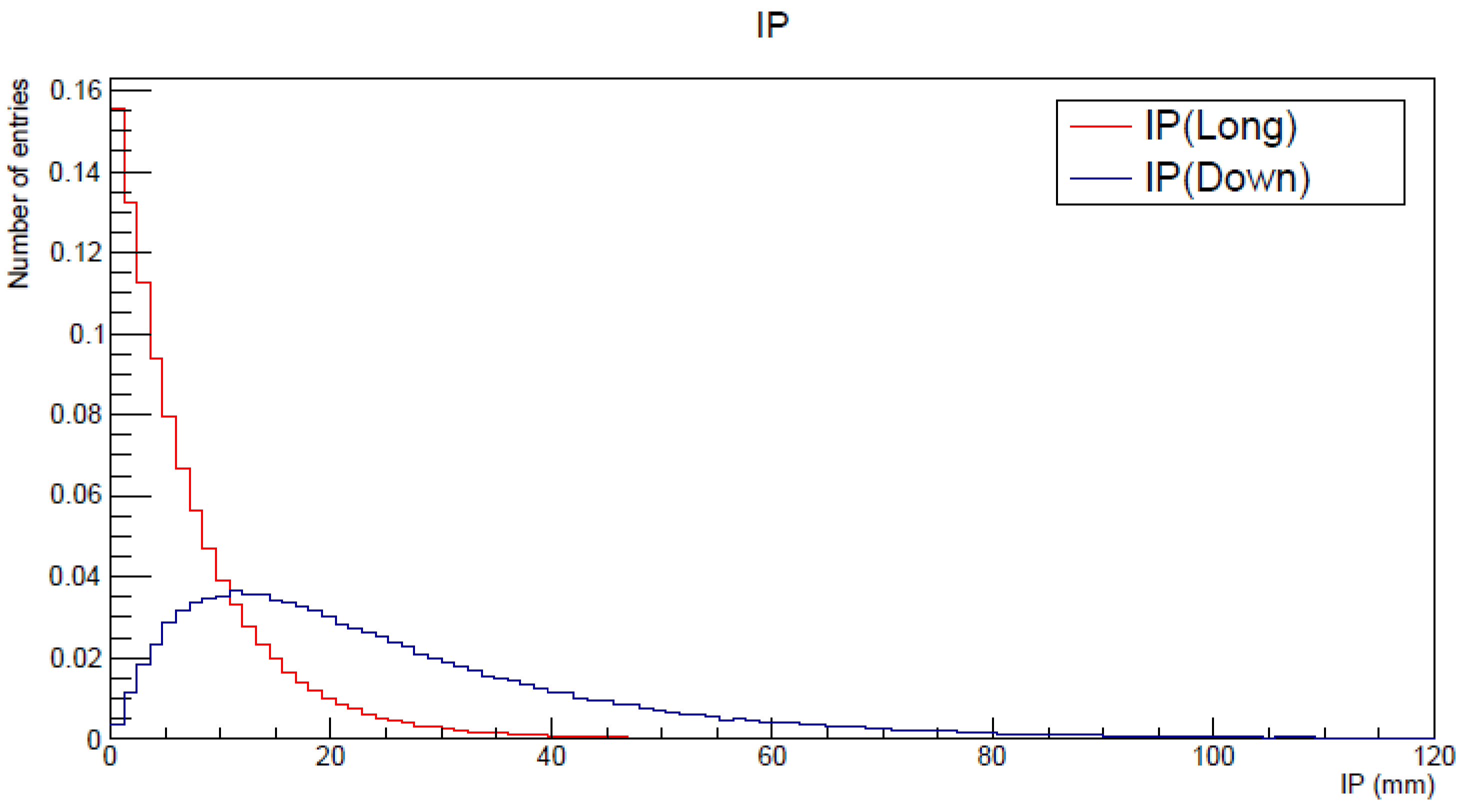


$\sigma_{Down}(2012)$	$\sigma_{Down}(Upgrade)$	$\sigma_{Long}\ (2012)$	$\sigma_{Long}(Upgrade)$
5.87	5.33	3.73	3.18

Table 3: Mass resolution in the different cases in MeV/c^2.

Better Mass Resolution in the Long case (Factor 0.6)

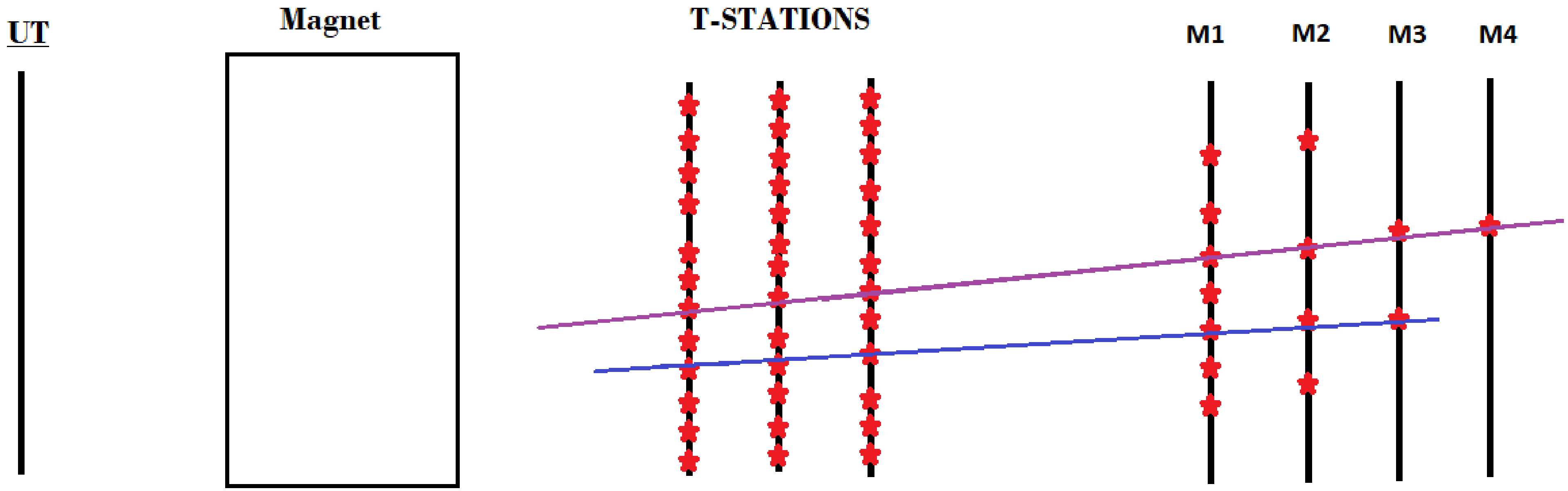
Better Mass Resolution in the Upgrade in both (Factor 0.9)

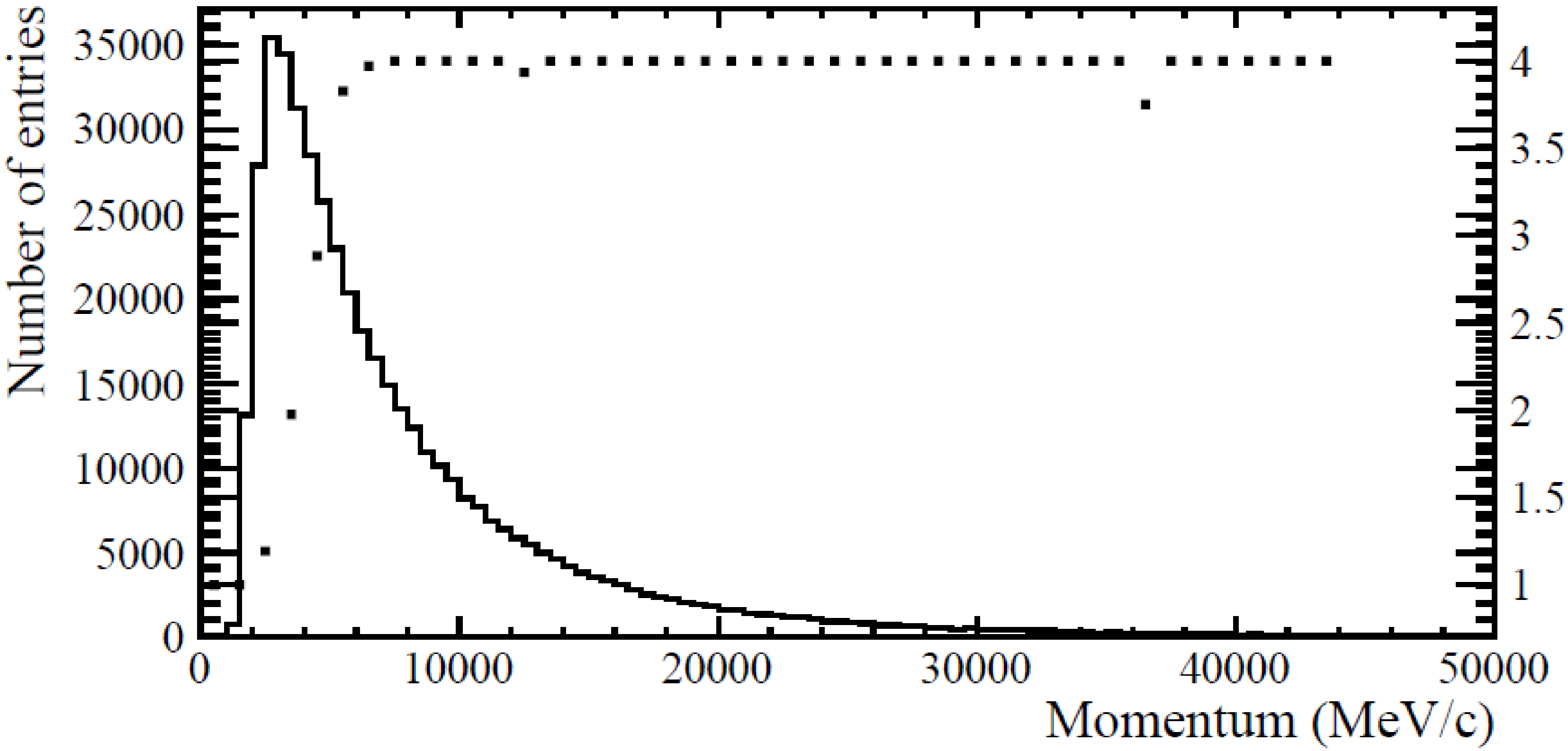


Worse vertex resolution in Downstream case.

3. DOWNSTREAM MUONS TRIGGER

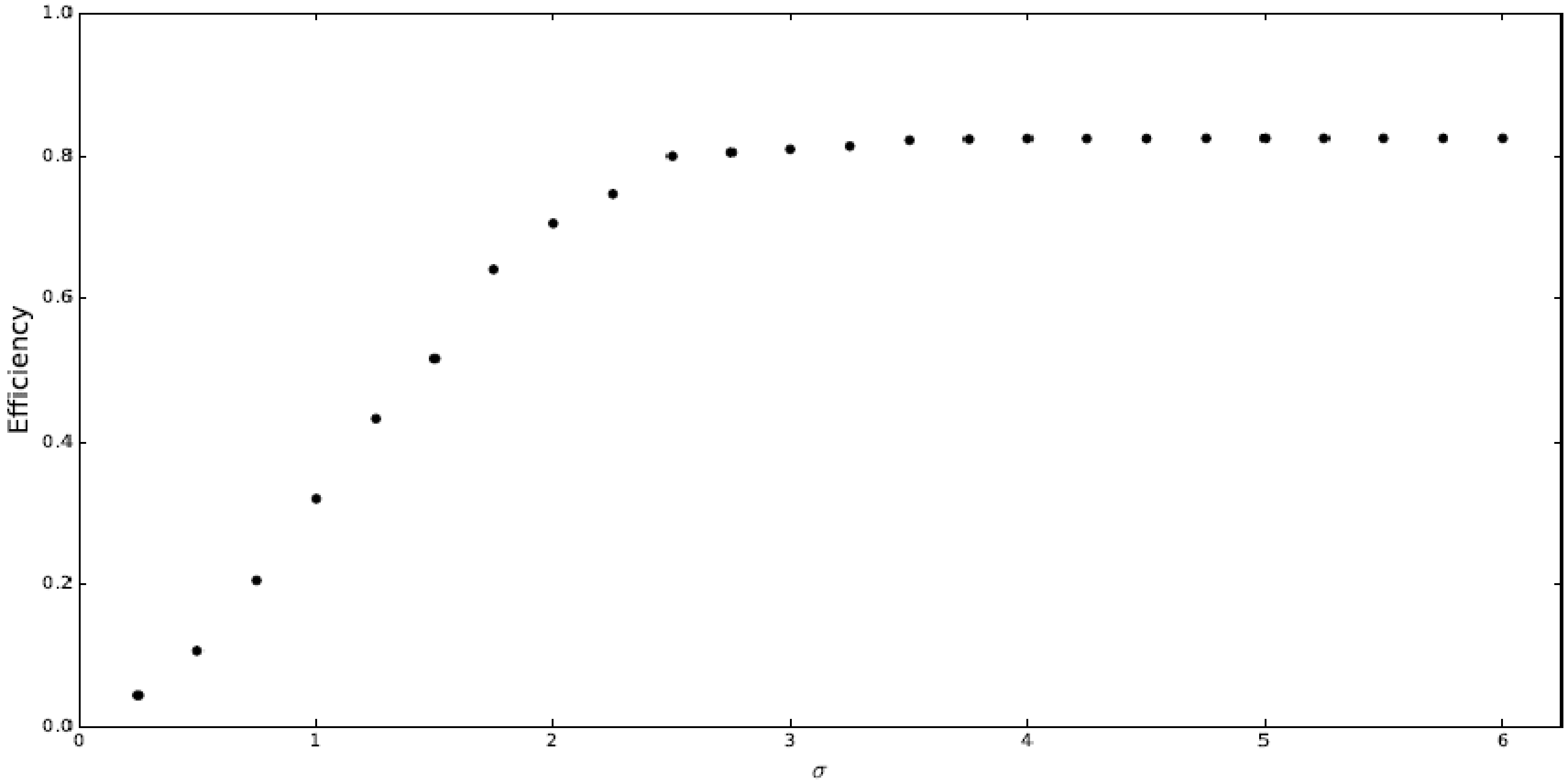
- A lot of interesting final states contain downstream muons.
- Use only T-Stations for the tracking is very time consuming, due the T-Stations high occupancy.
- We will start with a standalone reconstruction of the muons in order to filter the T-stations hits that we want.





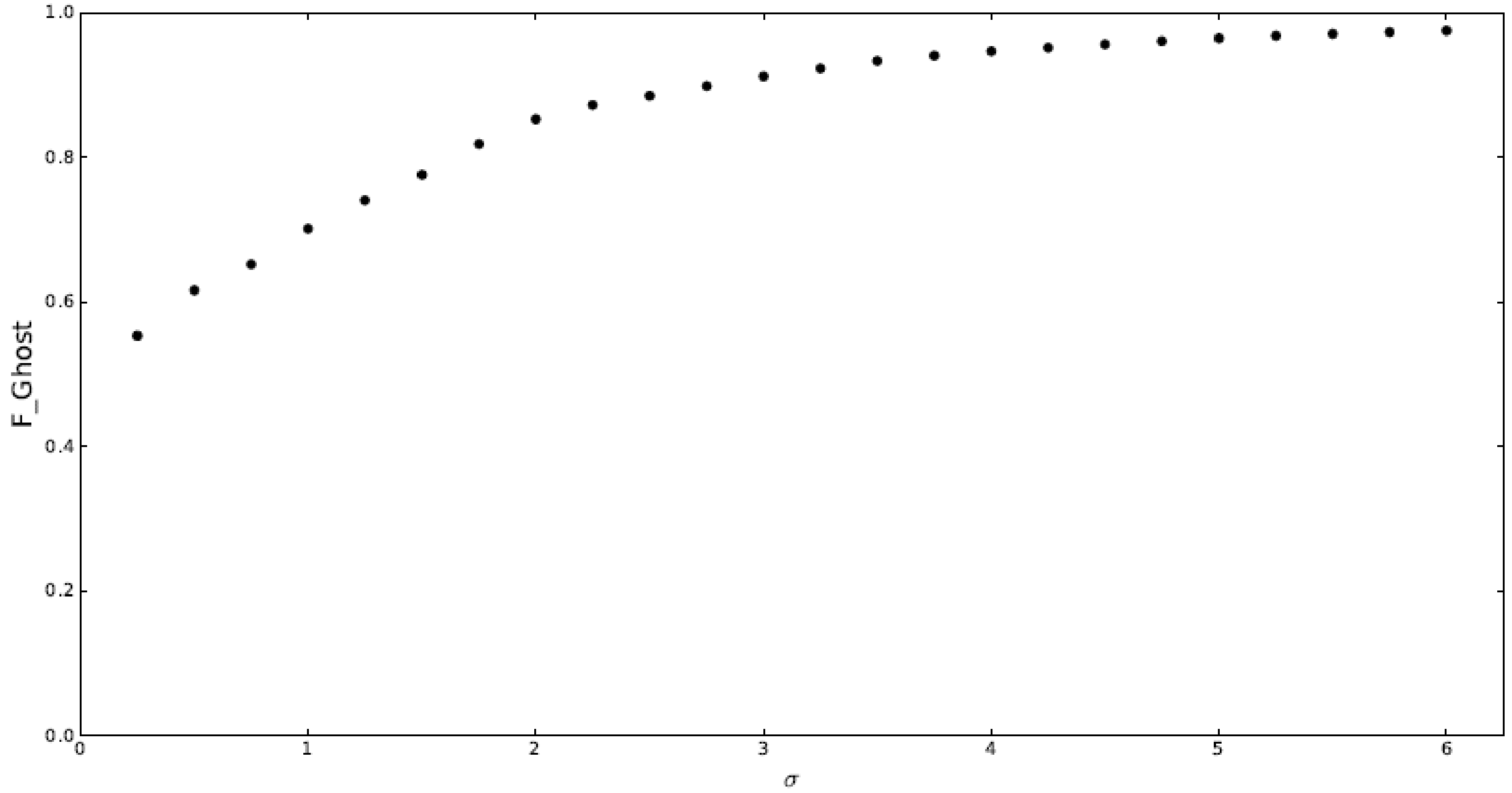
We need to take into account the high number of muons that don’t reached last station (M4).

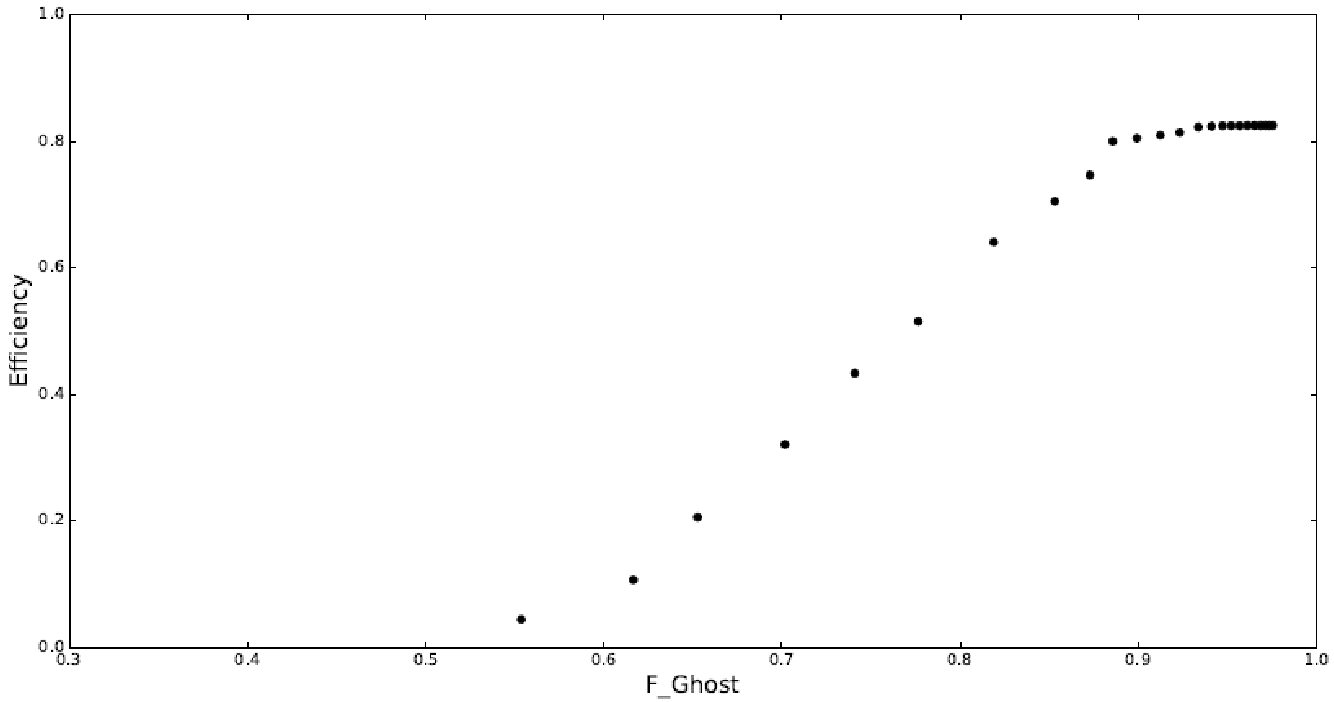
$$\sigma_x = \frac{hit_x - traj_x}{\sqrt{S(hit_x)^2 + S(traj_x)^2}}$$



$$K_S^0 \to \mu^+\mu^-$$

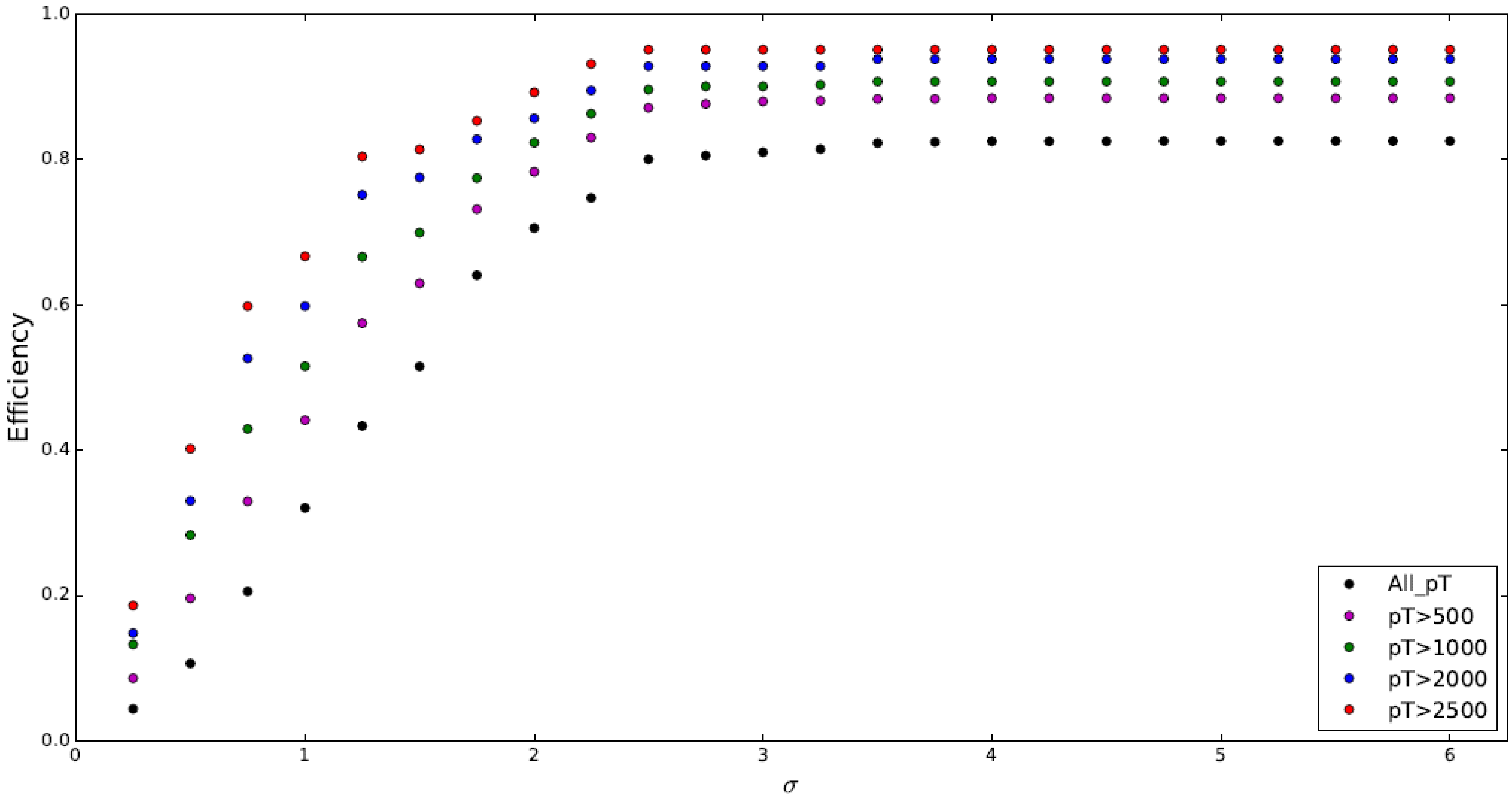
Ghost: We call Ghost those candidates that verify the selection criteria, but are not muons actually.



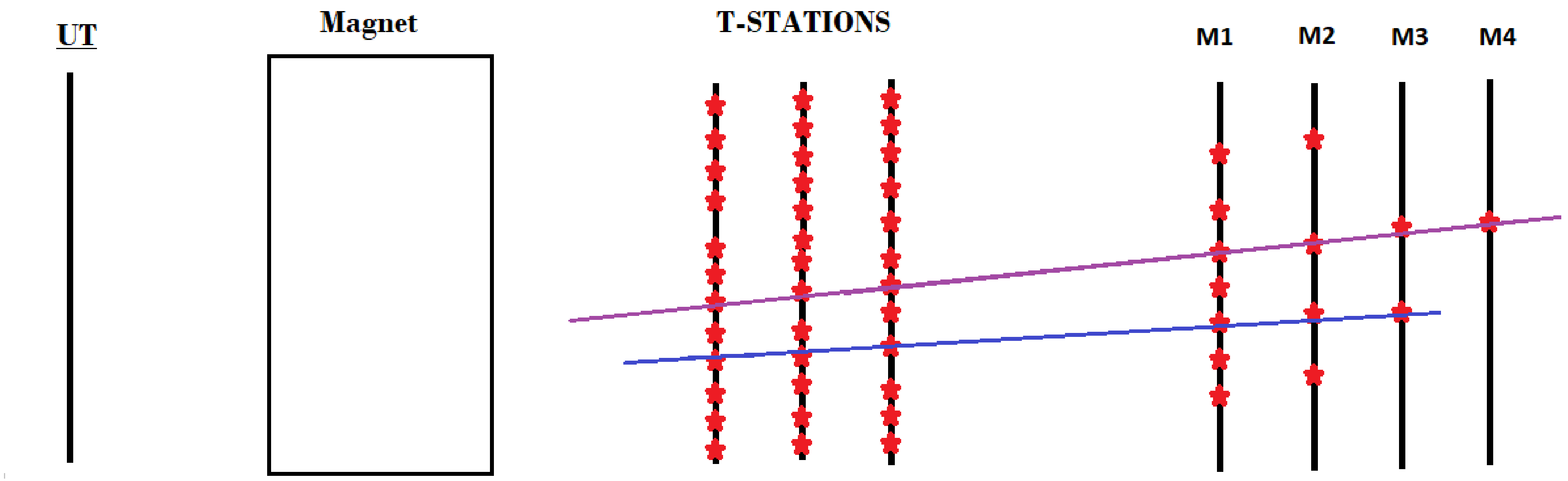


$F_{ghost} = 0.90$	$F_{ghost} = 0.85$	$F_{ghost} = 0.78$
$\epsilon = 0.82$	$\epsilon = 0.70$	$\epsilon = 0.50$

Table 4: Some values for the efficiency and the ghost average.

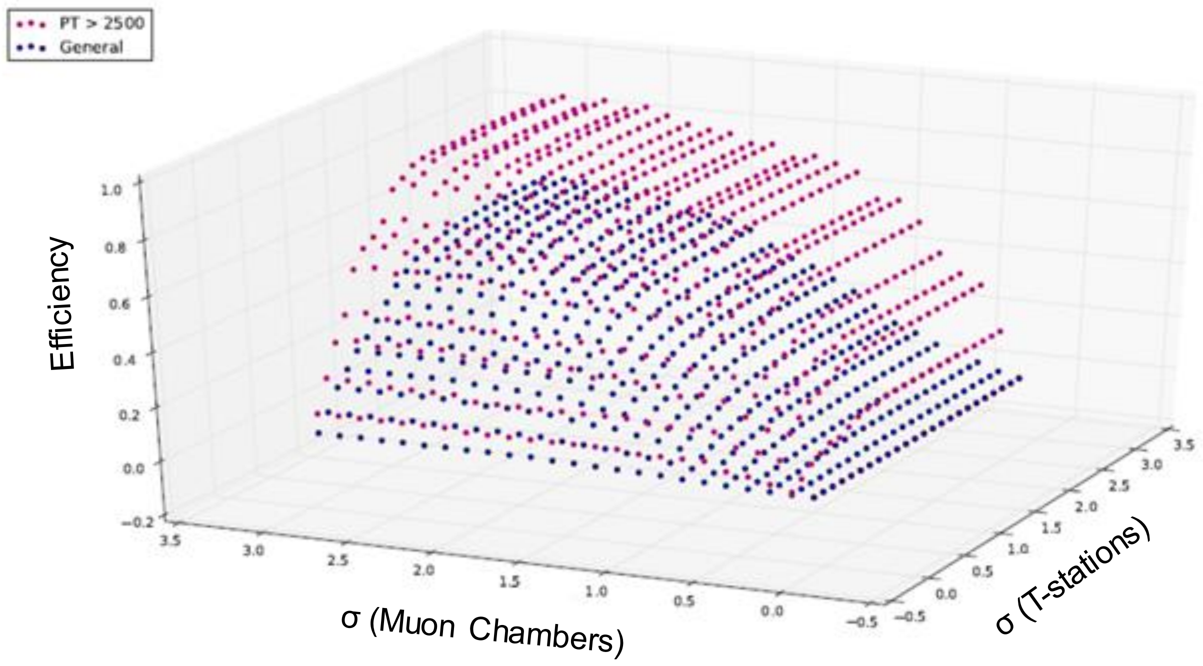

Efficiency
σ
0.0
0.2
0.4
0.6
0.8
1.0
0
1
2
3
4
5
6
All_pT
pT>500
pT>1000
pT>2000
pT>2500

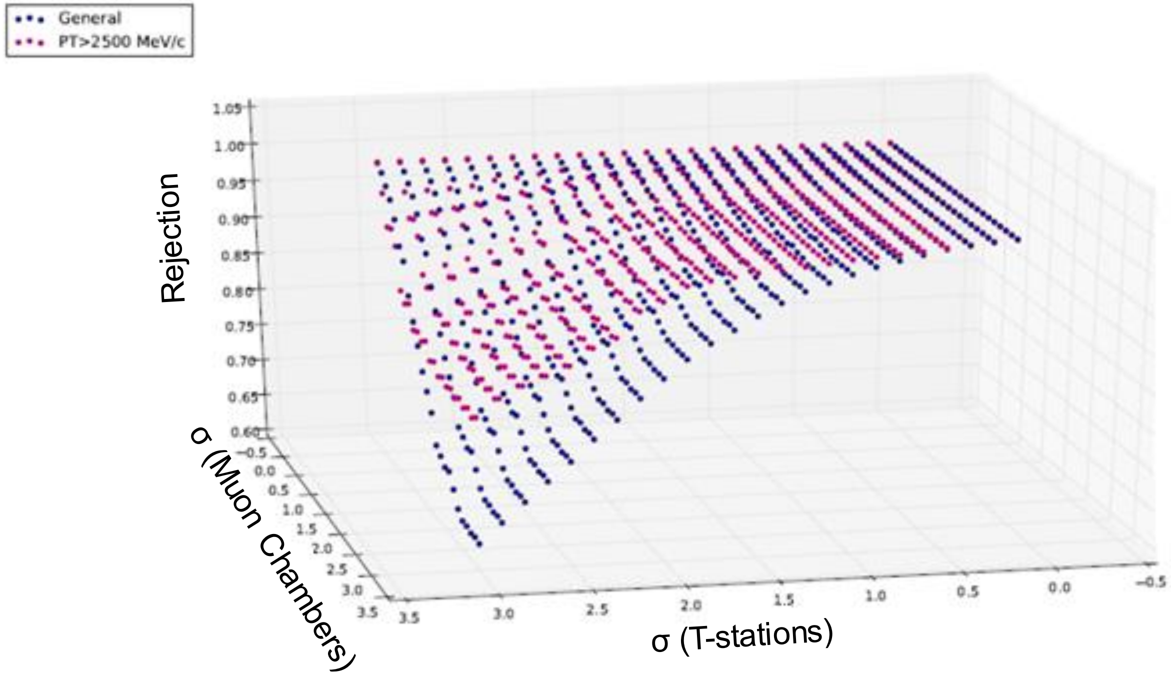
$$\sigma_x = \frac{hit_x - traj_x}{\sqrt{S(hit_x)^2 + S(traj_x)^2}}$$



General Efficiency reach 62.6 %

Efficiency imposing pT > 2500 MeV/c reach 89 %





Rejection is the number of filtered hits on the T-stations.

For low σ values we have high Rejection values, but low efficiency.

4. CONCLUSIONS

- In the Downstream tracks study, we saw thath most common particles related to it are K_S^0 mesons as mothers and pions as daughters.

- Benchmark: $K_S^0 \to \pi^+\pi^-$

- The K_S^0 reconstruction **efficiency** for this channel is **higher than 10%** using downstream tracks for decays in the interval between 800 and 1000 mm on the z direction. This value is even higher in Upgrade conditions.

- The pions IP confirm a worse **vertex resolution** in the Down case. Comparing the width of the K_S^0 reconstructed mass distribution we observe a **worse mass resolution in the Downstream case.**

- The **efficiency** reconstructing K_S^0 using Dowstream tracks with the explained strategy (starting with the 2 last hits) overcome 80 % in the general case and 96 % for transverse momenta > 2500 MeV/c.

$F_{ghost} = 0.90$	$F_{ghost} = 0.85$	$F_{ghost} = 0.78$
$\epsilon = 0.82$	$\epsilon = 0.70$	$\epsilon = 0.50$

- The efficiency finding hits in the T-stations next to the muons trajectory increases with σ until reaching 62.6% in the general case and 89% for pT>2500 MeV/c.

- Taking into accout that the Rejection values for high σs are low, **we should search a intemediate value,** obtaining a high efficiency filtering a high number of hits.

- For transverse momenta > 2500 MeV/c we can obtain a **efficiency of 80 % filtering 93% of the hits** in the T-stations and **solving the biggest challenge to the functionally of the Trigger.**

Thank you for your attention!