Status of the IFR optimization

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IFR detector optimization

- Parameters to optimize
  - Amount of absorber
  - Width of the scintillator bars
  - Evaluate the worst allowed time resolution

- Quantities to evaluate: muon ID, pion rejection.

- What is needed: superB full simulation (for hadron showers) + reconstruction code.

- The plan is to generate single particle events (muons, pions and then also Kl) and events + background with the Full Sim and write some reconstruction and what's needed to optimize the detector.

To do list (in Perugia)

- Write more GDML description of the IFR: 2 configurations already done (CDR like and BaBar like).

- Write digitization and clusterization

- Write a track fitter and extract relevant information.

- Write a cut-based muon selector similar to the first one used in BaBar.

- Test different configurations (BaBar like, CDR like, some hybrid).

- Make a proposal

What has been done

- Write more GDML description of the IFR: 2 configurations already done (CDR like and BaBar like). DONE

- Write digitization and clusterization DONE

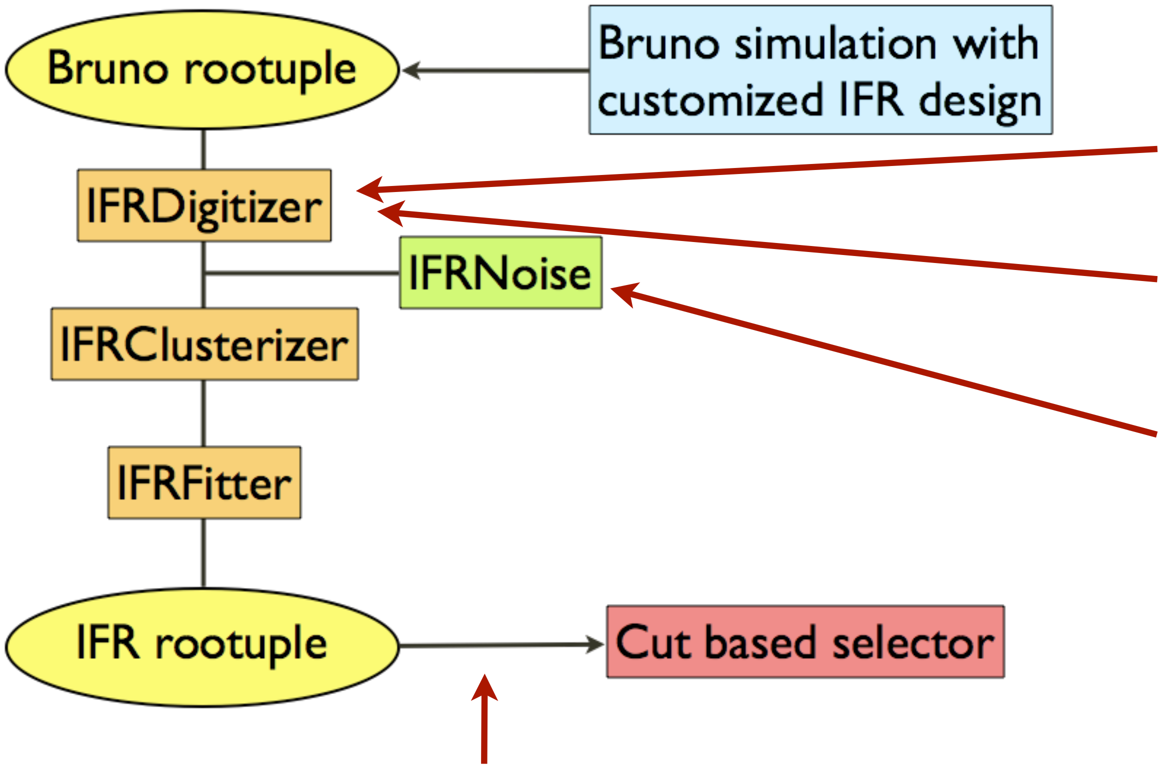
- Write a track fitter and extract relevant information. DONE

- Write a cut-based muon selector similar to the first one used in BaBar. preliminary results

- Test different configurations (BaBar like, CDR like, some hybrid) and different conditions (noise, resolutions). in progress - preliminary results

- Make a proposal

Code structure and improvements



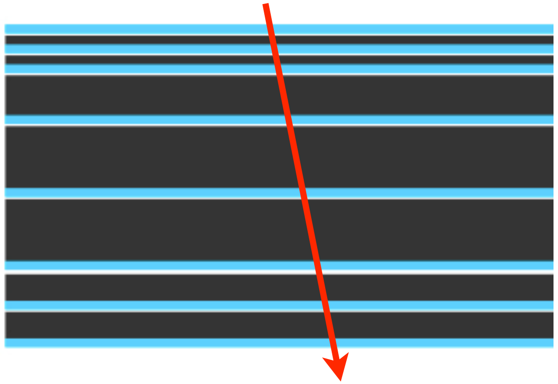
rude optimization, more on that later

From R&D

- Use the proper time resolution.
- Simulate the detection efficiency.
- Add electronics noise to the single particle events.

More details about code in Mauro Munerato's talk

Iron configurations



CDR like configuration

Number of gap	Material	thickness
1	scintillator air iron	2cm 0.5cm 2 cm
2	scintillator air iron	2cm 0.5cm 2cm
3	scintillator air iron	2cm 0.5cm 16cm
4	scintillator air iron	2cm 0.5cm 26cm
5	scintillator air iron	2cm 0.5cm 26cm
6	scintillator air iron	2cm 0.5cm 10cm
7	scintillator air iron	2cm 0.5cm 10cm
8	scintillator	2cm

iron: 920 mm

~5.4 int. len.

CDR like - 10 cm of iron

Number of gap	Material	thickness
1	scintillator air iron	2cm 0.5cm 2 cm
2	scintillator air iron	2cm 0.5cm 2cm
3	scintillator air iron	2cm 0.5cm 14cm
4	scintillator air iron	2cm 0.5cm 22cm
5	scintillator air iron	2cm 0.5cm 22cm
6	scintillator air iron	2cm 0.5cm 10cm
7	scintillator air iron	2cm 0.5cm 10cm
8	scintillator	2cm

iron: 820 mm

~4.8 int. len.

CDR like + 10 cm of iron

Number of gap	Material	thickness
1	scintillator air iron	2cm 0.5cm 2 cm
2	scintillator air iron	2cm 0.5cm 2cm
3	scintillator air iron	2cm 0.5cm 18cm
4	scintillator air iron	2cm 0.5cm 30cm
5	scintillator air iron	2cm 0.5cm 30cm
6	scintillator air iron	2cm 0.5cm 10cm
7	scintillator air iron	2cm 0.5cm 10cm
8	scintillator	2cm

iron: 1020 mm

~6.0 int. len.

Data sample

- We simulated with Bruno (with no magnetic field but with inner detectors):
  - 10000 muons and 10000 pions for each configuration in the range 0.5MeV/c<p_{lab}<4GeV/c
- We processed each collection of events with our code
  - adding random noise
  - changing resolutions and other parameters

A first look at the data

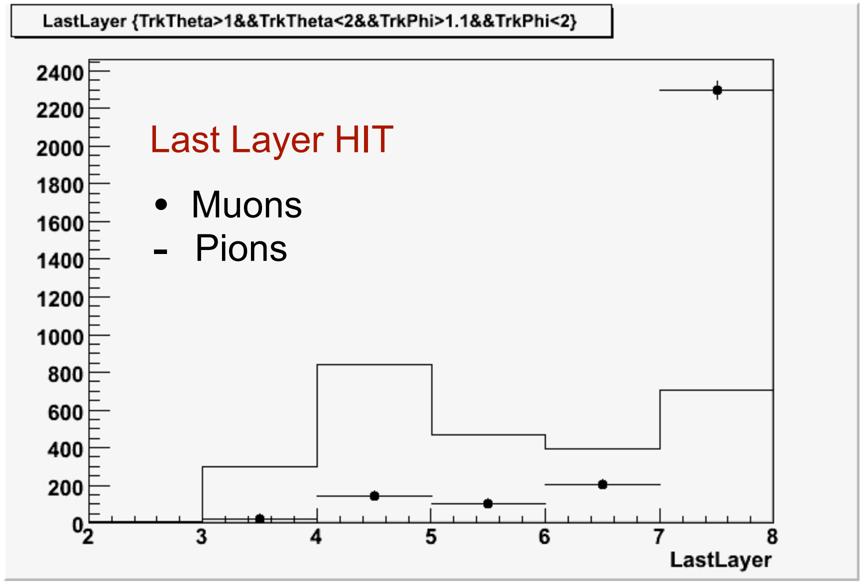
We simulated with Bruno 10000 muons and 10000 pions with momentum 0.5GeV < p < 4GeV.

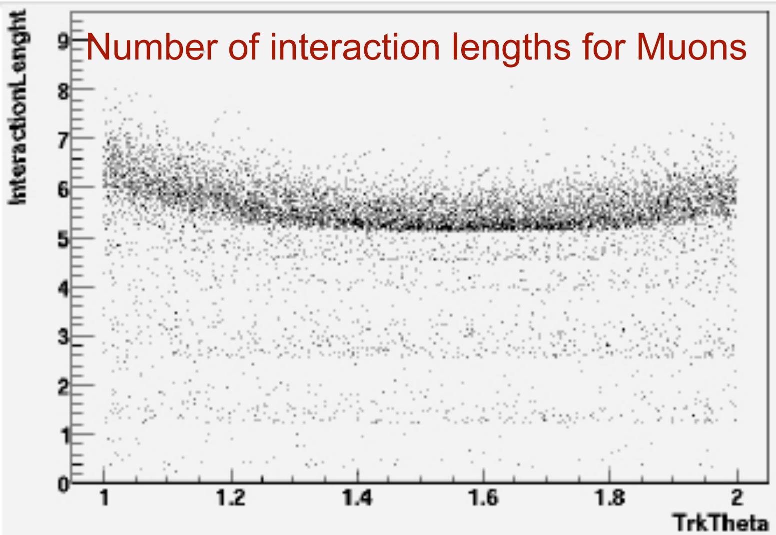
First we use the CDR like configuration of the IFR

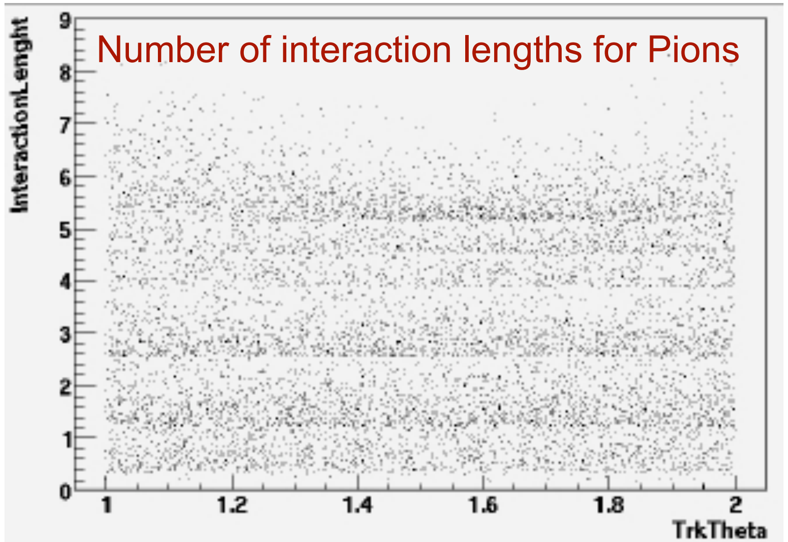
Magnetic field switched OFF - no inner detector (for debug purpose)

Only one sextant of the barrel.

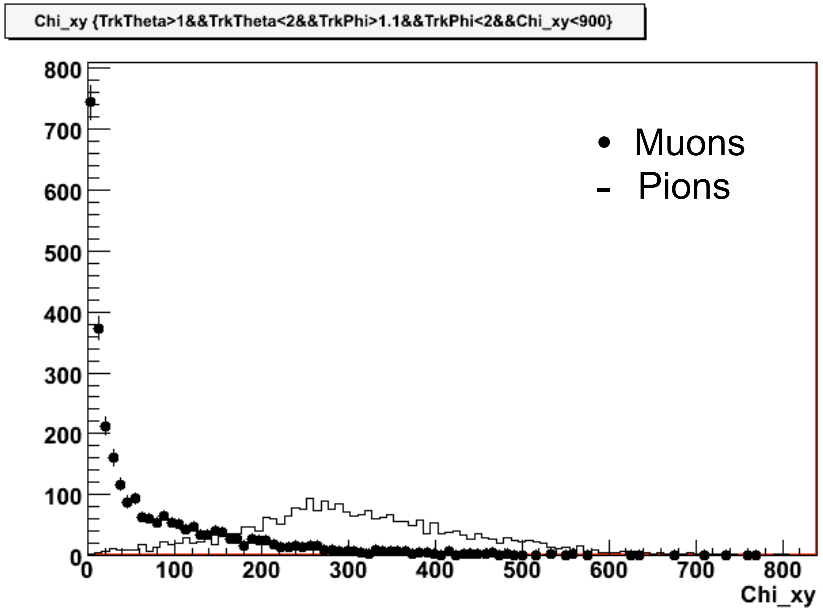
Added random noise corresponding to 1.5% occupancy







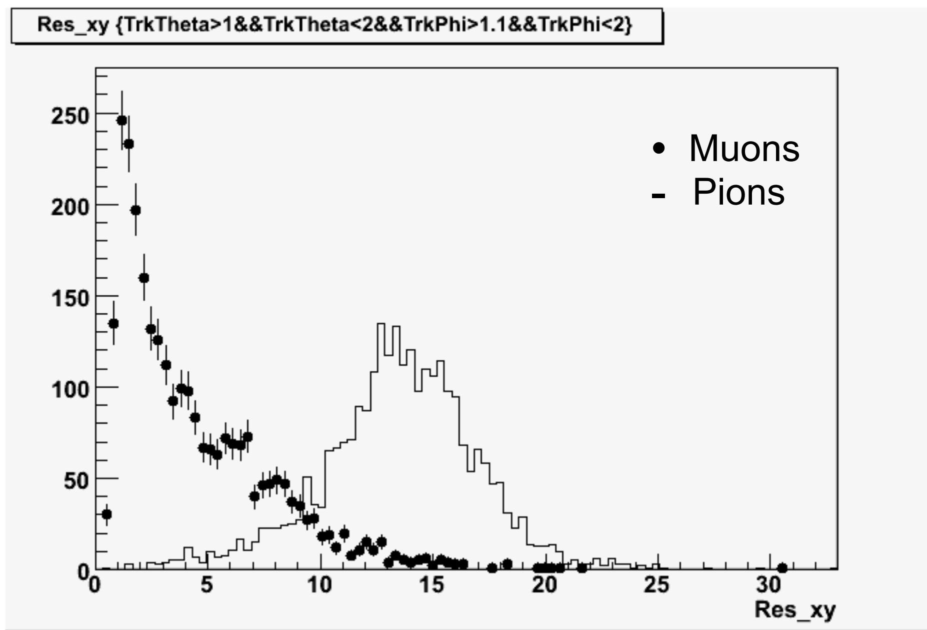
Track reconstruction



We do a linear fit to the track and evaluate the χ^2 and the residual distribution of the hits

In order to fully reconstruct the track we performed 2 fits, one in the xy plane the other in the zy plane.

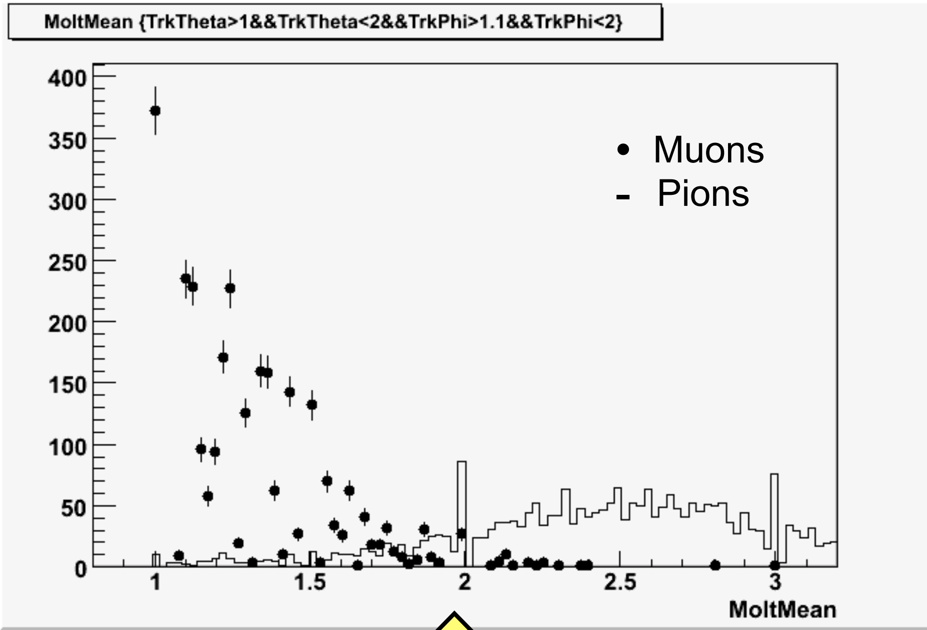
We also calculated the χ^2 of the hits with respect to the generated track using the MC truth information.



χ^2 distribution of the hits with respect to the fitted track for muons and pions

residual distribution for muons and pions

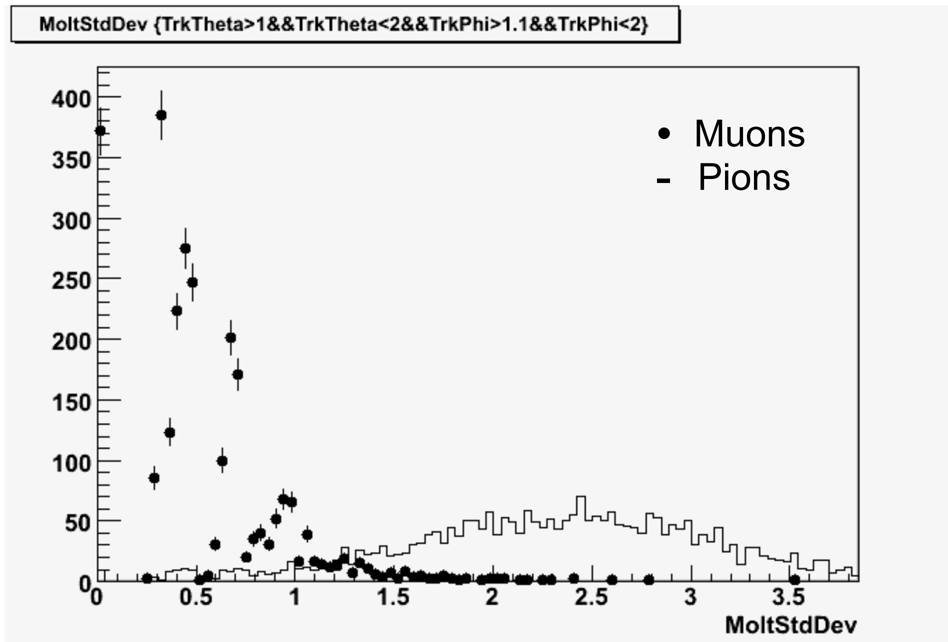
Shower size



To have an idea of the transverse development of the shower we evaluate the average multiplicity.

Average multiplicity of hit strips per cluster for muons and pions

... and its standard deviation



Muon ID in BaBar

1. The energy released in the Electromagnetic Calorimeter (E_{cal}). not used in our selection
2. The number of IFR hit layers in a cluster (N_L).
3. A boolean variable true when the cluster has a hit in the Inner RPC (*hasInner*). we don't have inner IFR (at least for now)
4. The first IFR hit layer in the cluster (F_h). It is a positive integer for planar layers, and is equal to -1 for the Inner RPC[2]. There is no layer numbered as 0.
5. The last IFR hit layer in the cluster (L_h). It is a positive integer for planar layers, and is equal to -1 for the Inner RPC. There is no layer numbered as 0.
6. The number of interaction lenghts traversed by the track in the BaBar detector (λ). It is estimated with the use of the track extrapolation into the IFR until the last hit layer.
7. The number of interaction lenghts which the track is expected to traverse in the BaBar detector in the muon hypothesis (λ_{exp}). It is estimated with the use of the track extrapolation into the IFR until the last active layer.

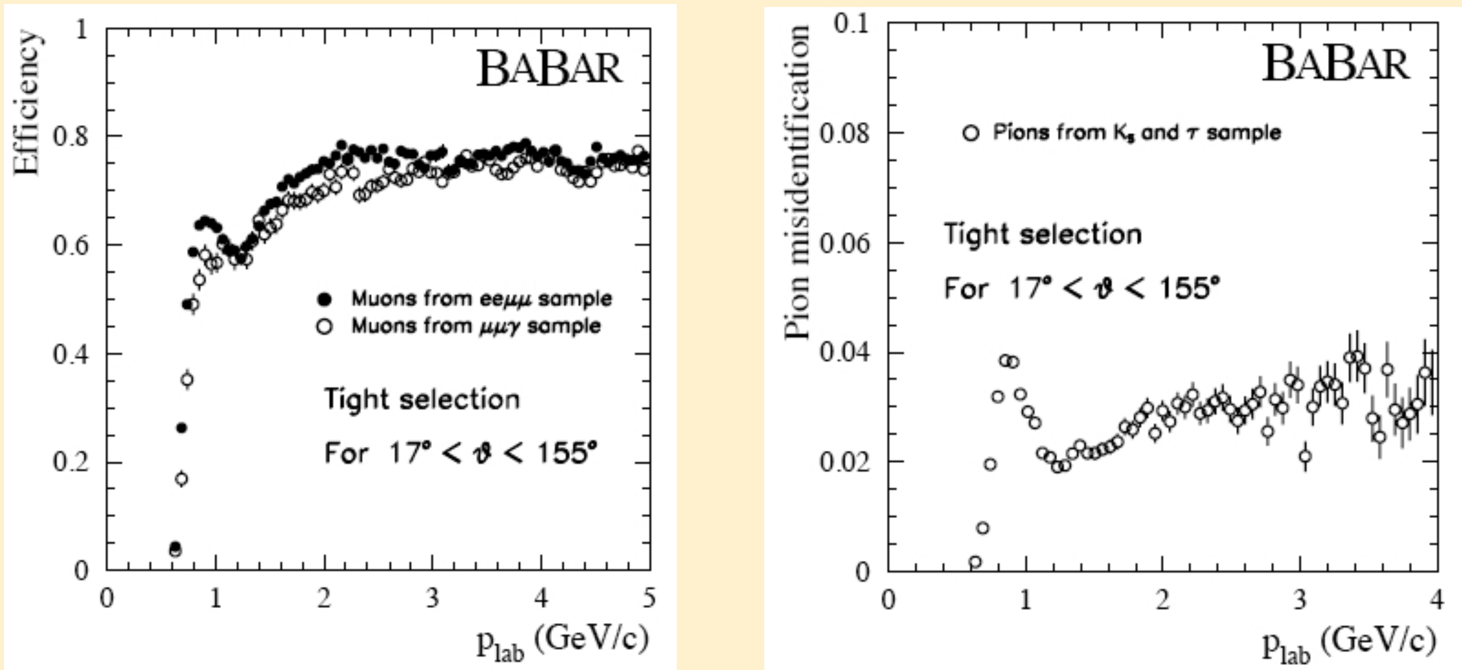
for track extrapolation MC truth has been used

8. The χ^2/d.o.f of the IFR hit strips in the cluster with respect to the track extrapolation (χ^2_{trk}).
9. The χ^2/d.o.f. of the IFR hit strips with respect to a 3-rd order polynomial fit of the cluster (χ^2_{fit}).
10. The total number of IFR hit strips in the $i -$ th layer ($N_s(i)$).
11. The total number of IFR hit strips in the cluster (N_s).

BaBar Cut based selector

- $0.05 < E_{cal} < 0.4$ (applied on tracks in the angular region covered by EMC $\theta(\text{rad}) < 2.45$)
- $N_L \geq 2$
- $\Delta\lambda < 1$
- $\lambda > 2.2$
- $\chi^2_{trk} < 5$
- $\chi^2_{fit} < 3$
- $T_c > 0.3$ (applied only on tracks in the polar angle interval $0.3 < \theta(\text{rad}) < 1$)
- $\overline{m} < 8$
- $\sigma_m < 4$

→ Tight Selector



SUPER B MUON SELECTOR

Building a muon selector in one week it's a hard task, we end up with this preliminary selection made looking for a pion misidentification of the order of some % (equivalent to a BaBar Tight cut based selector).

Chi2 zy<350

Chi2 xy<350

First Layer Hit <3

Number of Interaction Lenghts >2

abs(MuonInteractionLenght-InteractionLenght)<1.5

Average Multiplicity < 2

Standard Deviation of the multiplicity <1.5

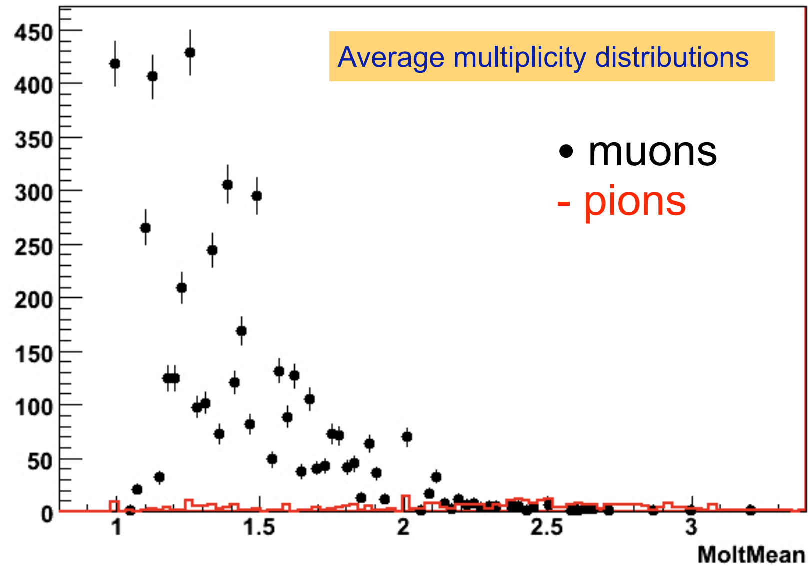
Ratio Layer >0.6

Trk Chi2 zy <5000

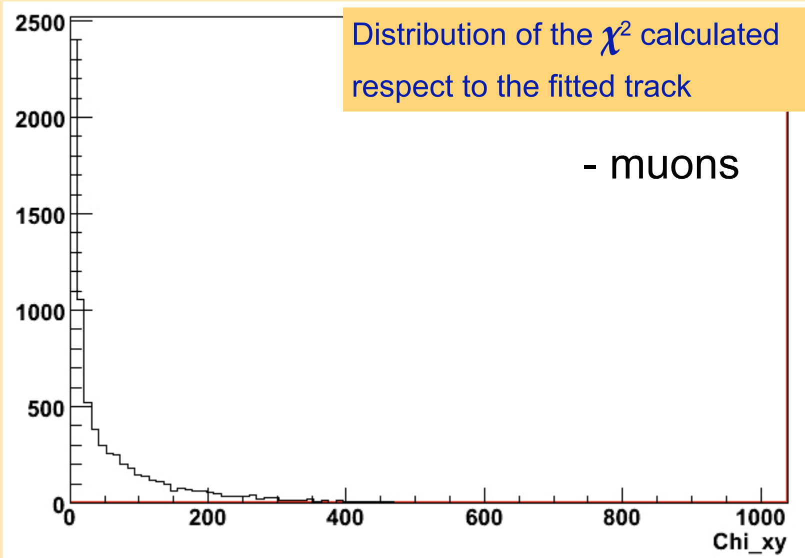
Trk Chi2 xy <100000

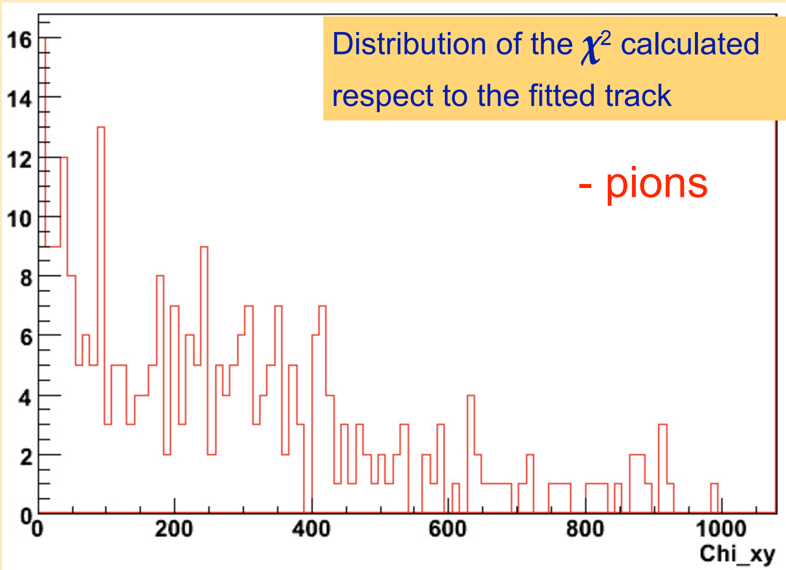
Cut's optimization has been done just looking at the distributions for pions and muons separately applying all the cuts except the one we were studying.

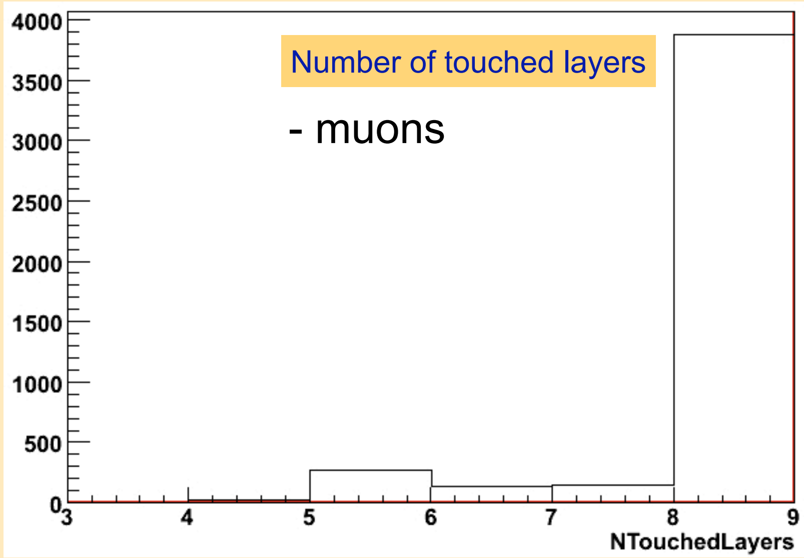
The optimization process has been complicated by the low statistics for the pions

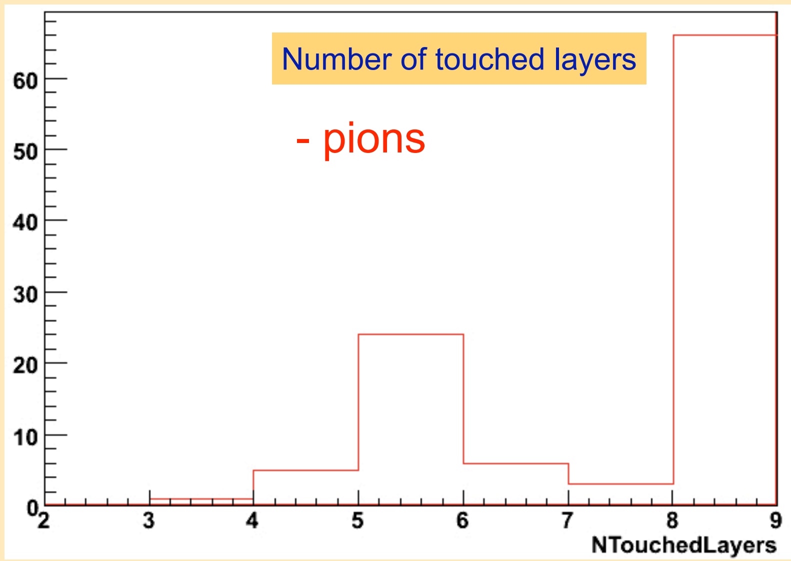


Cuts optimization





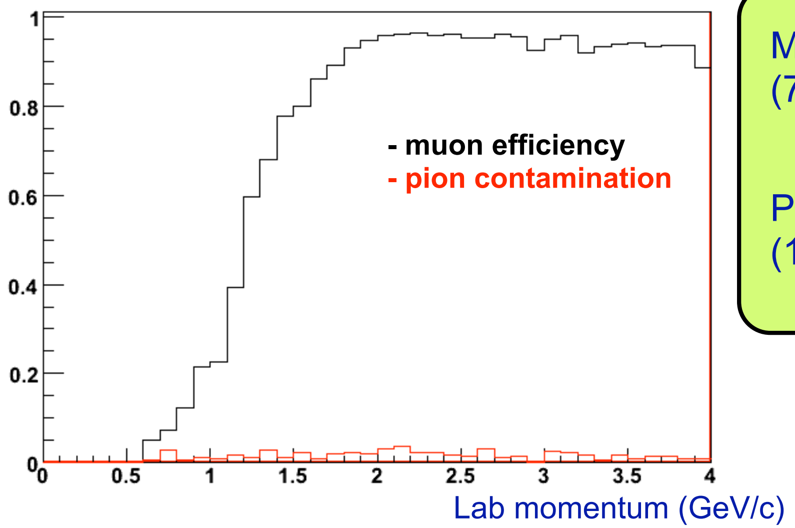




Performances on CDR configuration

CDR configuration has 92 cm of iron - ~5.4 interaction length

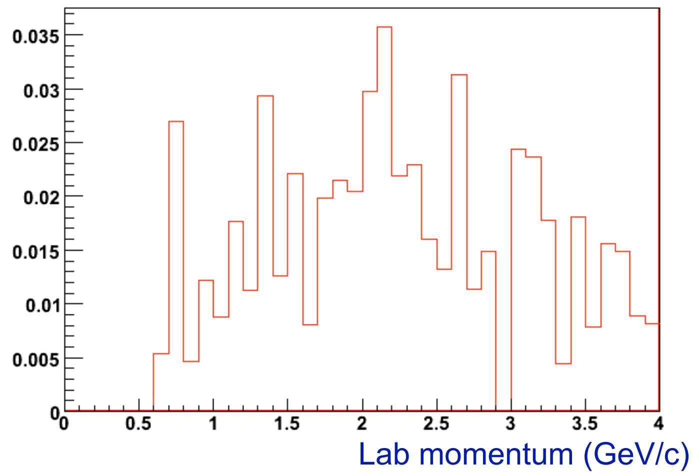
Muon efficiency as function of the momentum

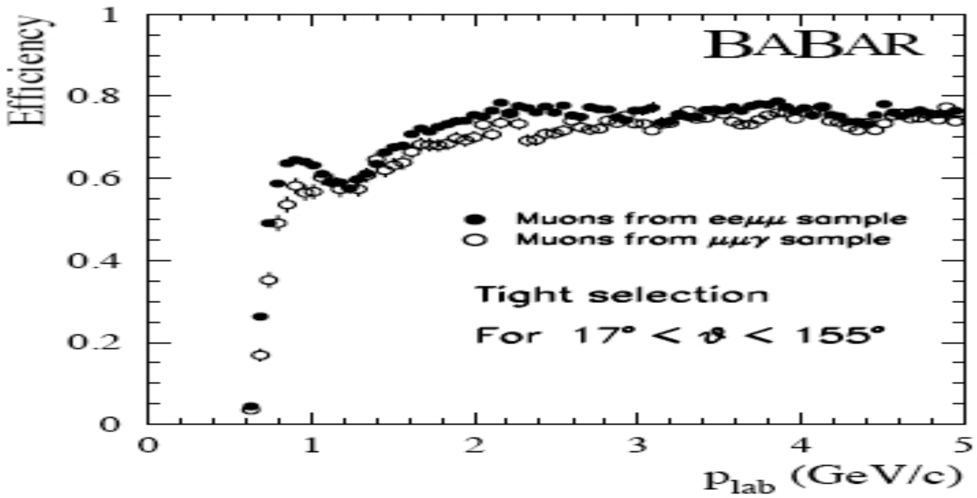


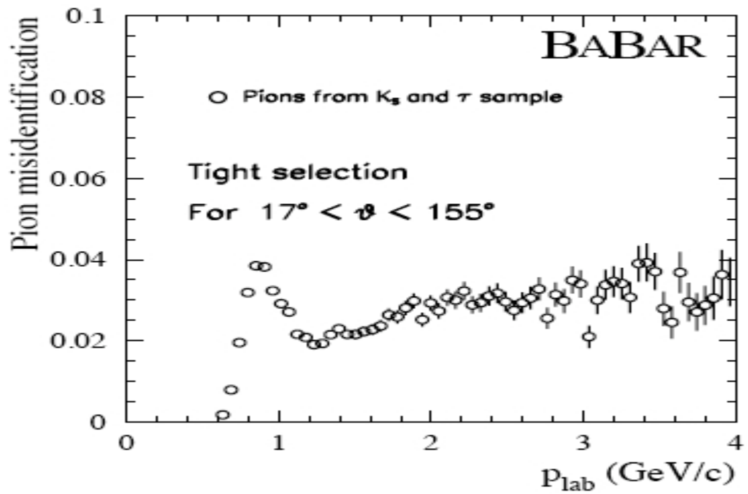
Muon efficiency (78.1 +- 0.5) %

Pion contamination (1.6 +- 0.2) %

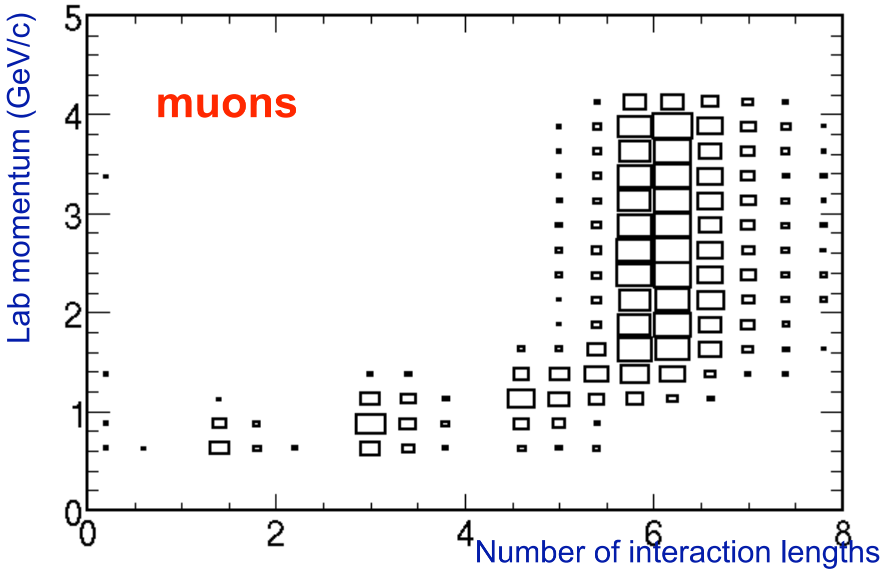
Enlargement of the pion contamination

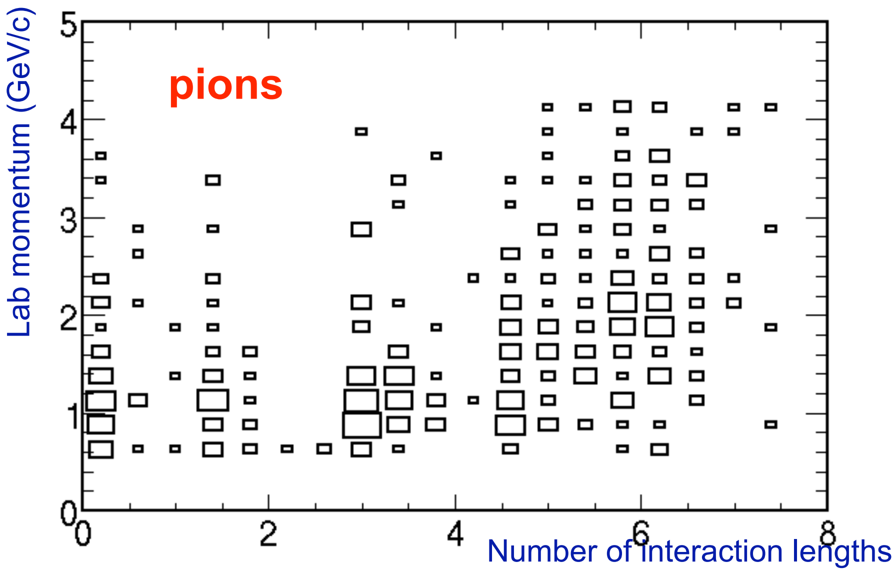






The low momentum region





Most of the low momentum muons end up in the IFR after traveling from 1 to 5 interaction length.

The cuts responsible for the efficiency loss at low momentum are the one on the number of interaction lengths.
A cut dependent on the momentum can help and need to be studied.

Energy deposition and shape of the shower in the calorimeter may help to improve the separation in this region.

About the 30% of the remaining pions decays into the active volume of the IFR.

It's probably irreducible contamination

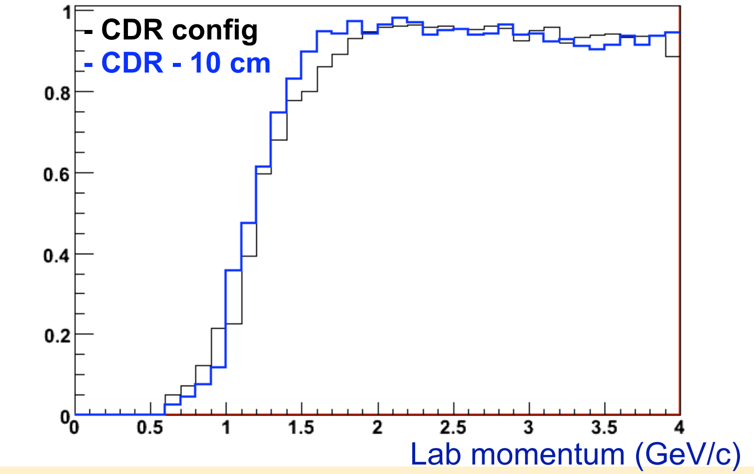
A better spatial resolution may help

Testing different configurations

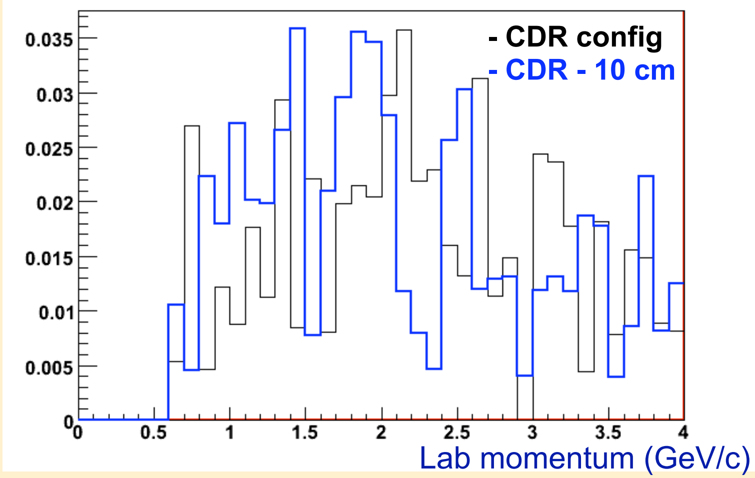
CDR layout
Muon efficiency
(78.1 +- 0.5) %
Pion contamination
(1.6 +- 0.2) %

Removing 10 cm of iron = 82 cm iron tihckness, ~ 4.9 interaction lengths

Muon efficiency as function of the momentum



Pion contamination as function of the momentum

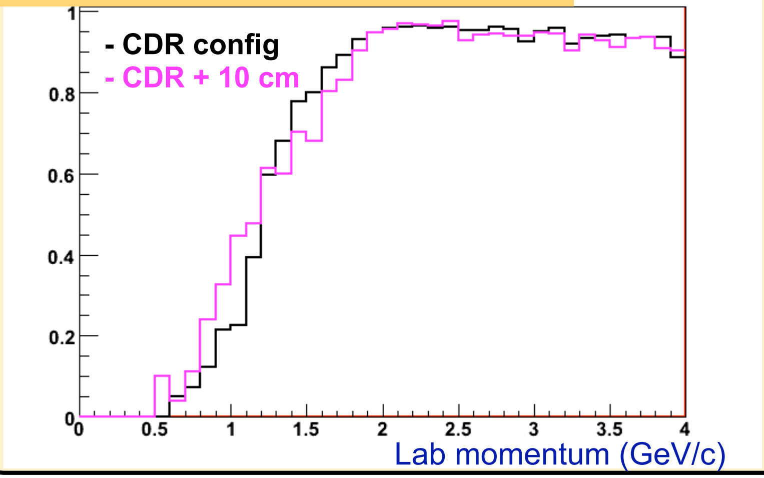


Muon efficiency
(79.2 +- 0.5) %

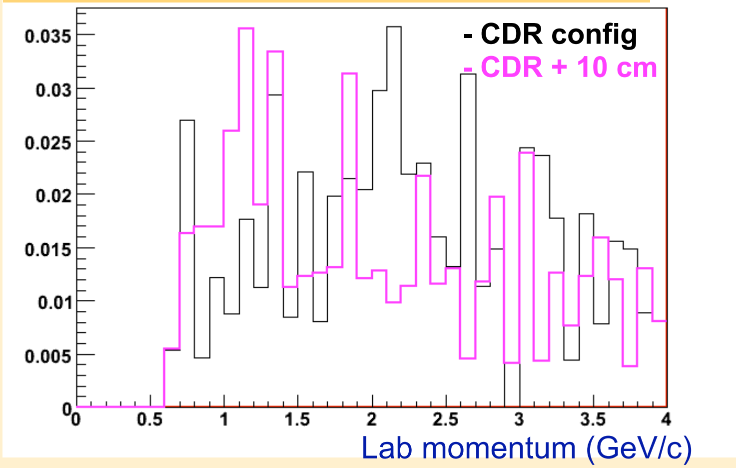
Pion contamination
(1.7 +- 0.2) %

Adding 10 cm of iron = 102 cm iron tihckness, ~ 6.0 interaction lengths

Muon efficiency as function of the momentum



Pion contamination as function of the momentum



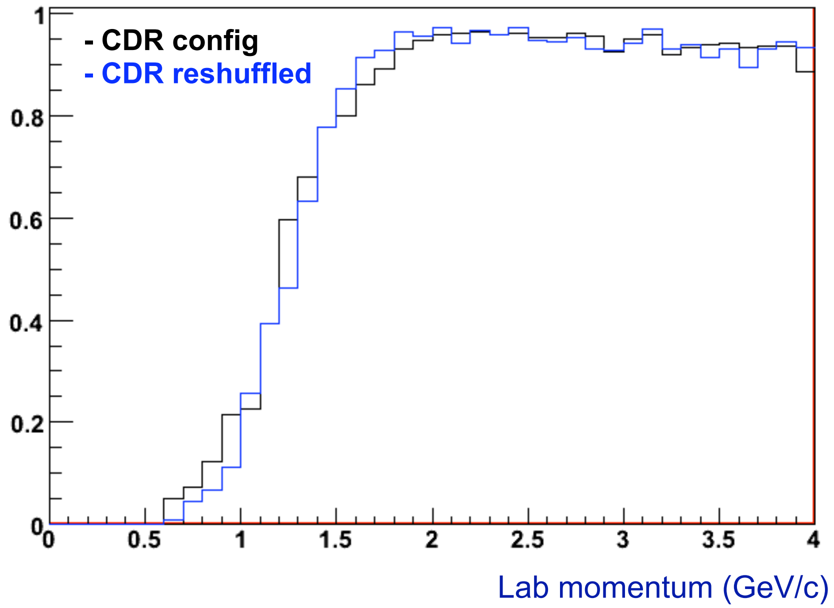
Muon efficiency
(79.2 +- 0.5) %

Pion contamination
(1.5 +- 0.2) %

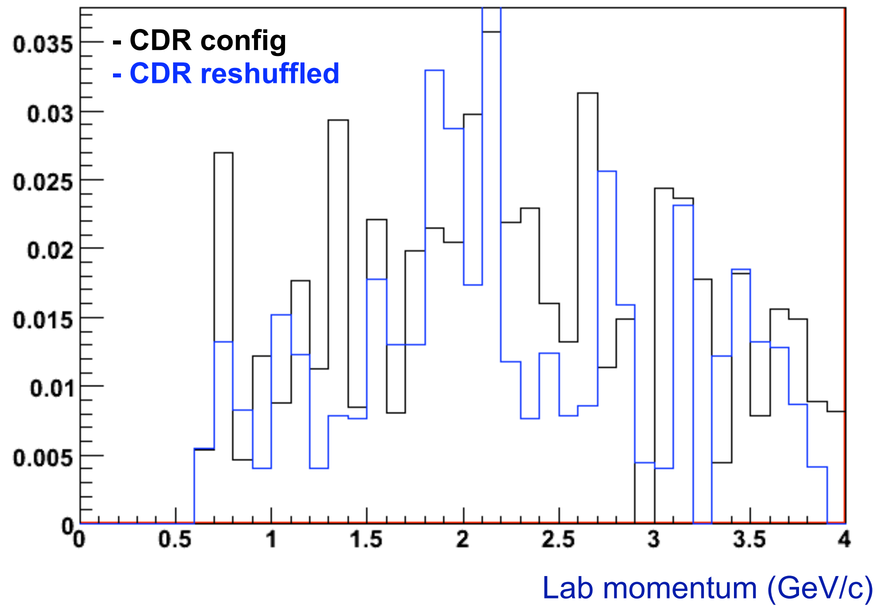
Reshuffling layers

Another way to proceed is to change the position of the active layers leaving the total amount of iron unaffected. In this test we take the CDR configuration and place the layer 4 closer to layer 3.

Muon efficiency as function of the momentum



Pion contamination as function of the momentum



CDR layout

Muon efficiency (78.1 +- 0.5) %

Pion contamination (1.6 +- 0.2) %

CDR reshuffled

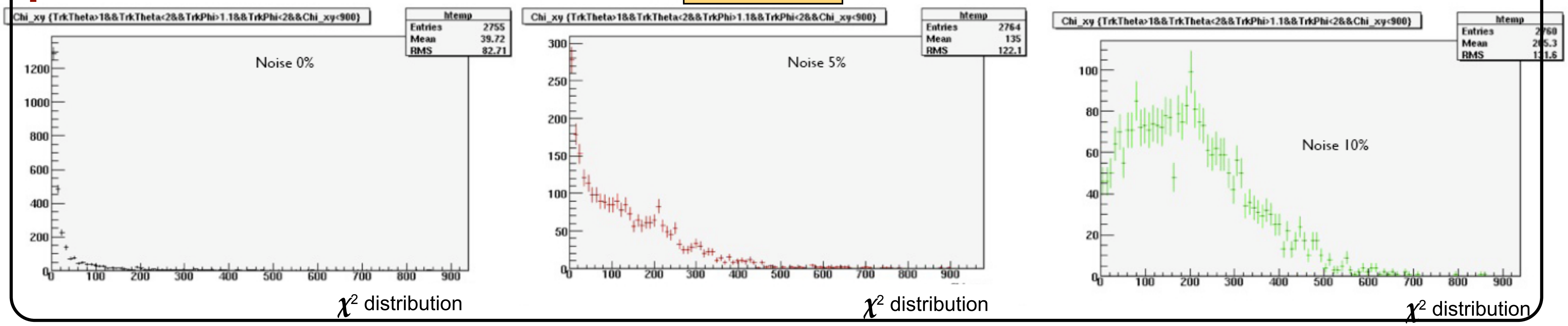
Muon efficiency (76.9 +- 0.5) %

Pion contamination (1.3 +- 0.2) %

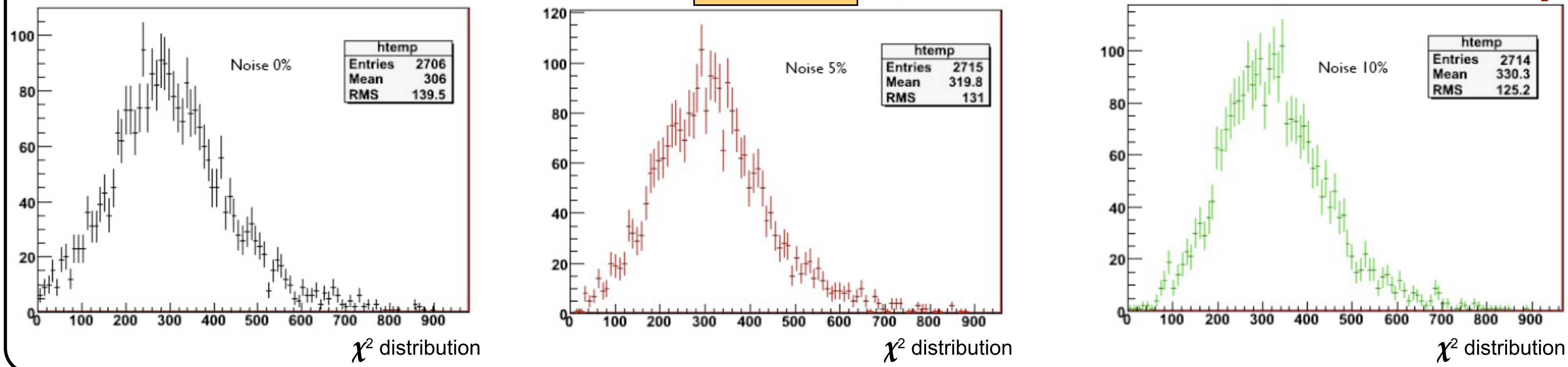
Effect of the noise

Random flat noise has been added to the single particle hits to check the degradation of the performances with the increasing of the background: with an occupancy of 10% muons start looking like pions.

Muons



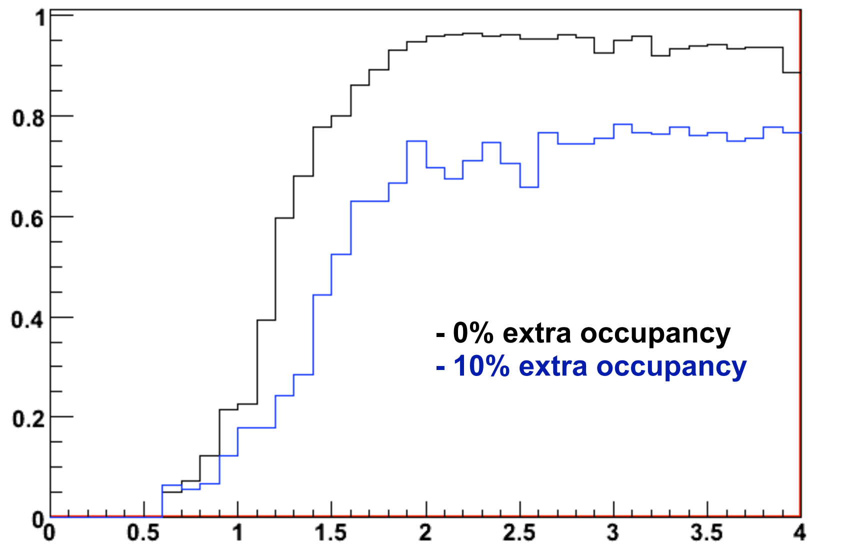
Pions



Effect of the noise

The muon selector performances get worst with the noise (no re-optimization of the cuts has been done)

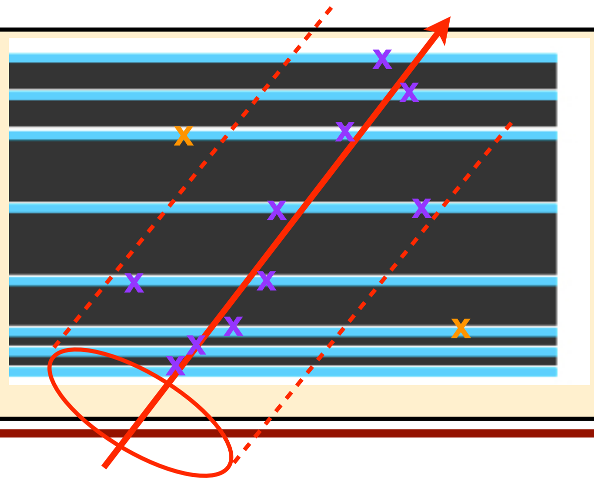
Muon efficiency as function of the momentum



Noise	Muon efficiency	Pion contamination
0%	78.1%	1.6%
1.5%	74.5%	1.7%
5%	69.2%	2.2%
10%	58.3%	2.1%
15%	45.7%	1.8%

Clearly a better, let's say a real track swimmer would help reducing this effect.

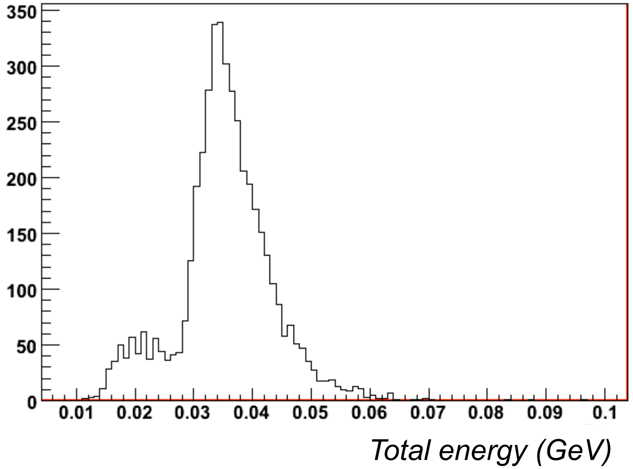
Our track finder is just a cylinder with 50cm of radius centered in the axis of the generated particle; further studies are needed also on that.



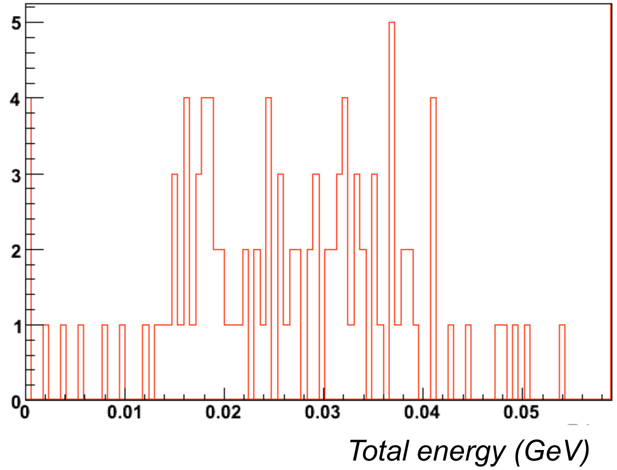
Just for fun

We plan to study also the energy deposition in the scintillator... but we don't really want to add a charge readout.

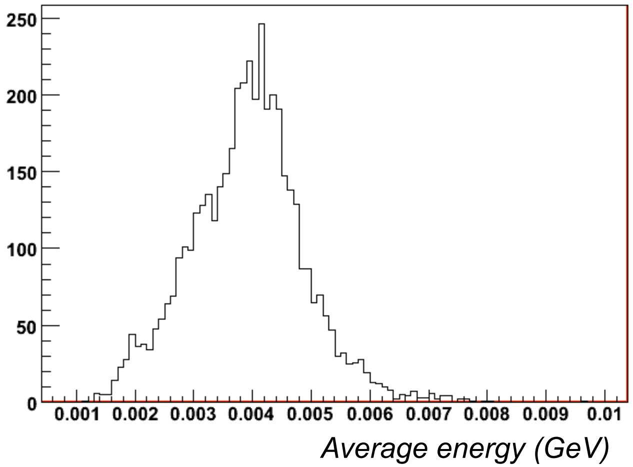
Total energy deposition in the IFR for Muons



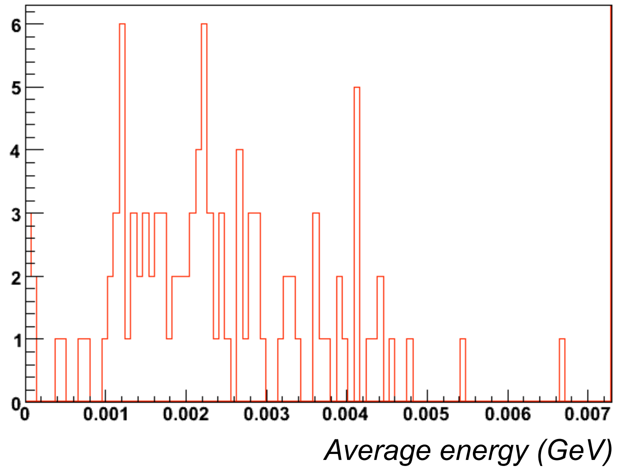
Total energy deposition in the IFR for Pions



Average energy deposition per layer in the IFR for Muons



Average energy deposition per layer in the IFR for Pions



What did we learn?

- At p_{lab}>1.5GeV/c we are in good shape with the CDR layout.
- The efficiency is still low for p_{lab}<1.5GeV/c.
- Noise is bad (what a news!). In the present situation 5% occupancy seems to be already high, but it strongly depends on the swimmer.
- That we still have a lot of work to do

Outcome

- At p_{lab}>1.5GeV/c we are in good shape with the CDR layout. → We probably don't need to add iron to the CDR layout: reuse of BaBar iron is fine
- The efficiency is still low for p_{lab}<1.5GeV/c. → Need to study different cuts and configurations.
- Noise is bad (what a news!). In the present situation 5% occupancy seems to be already high, but it strongly depends on the swimmer. → Improve our code and use the background from Bruno simulation
- That we still have a lot of work to do → Just work