Full simulation and detector optimization

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Outline

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   - Status @ SLAC
   - Code status
   - Geometries tested
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2. Code developments and improvements
   - Three configurations studied: 620mm, 820mm and 920mm
   - Detector optimization
3. Background
   - Background studies
4. Looking forward

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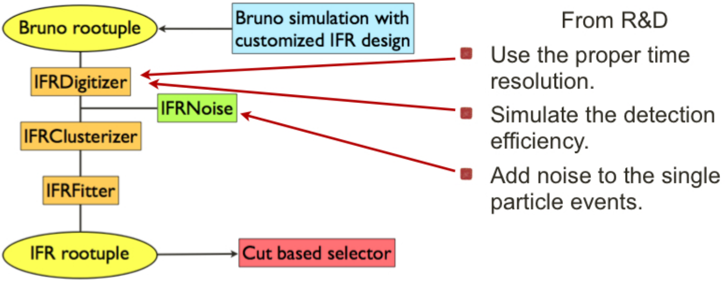
Looking backward

- We arrived at the SLAC workshop with preliminary results about detector optimization using our own reconstruction code running on Bruno-generated rootuples.
- Preliminary results showed good muon identification vs pion rejection except for low momentum tracks.
- We also tested three different iron configurations (820mm, 920mm, 1020mm) having not very different results.



Analysis of different configurations

With IfrRootCode we can analyze:

- some important physics pamameter;
- different configurations of IFR stratigraphy;
- optimize cuts for improve the muon efficiency and the pion rejection;
- change some parameters, like noise, and see the effect on efficiency;

Geometries tested

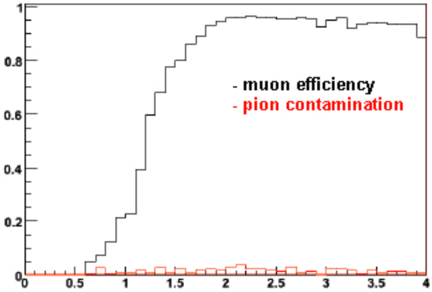
Starting from CDR geometry configuration(called C2), we had another two configurations: one with 10cm of iron added(C6=C2+10cm) and one with 10cm removed(C5=C2-10cm).

Number of gap	Material	thickness C5	thickness C2	thickness C6
1	scintillator air iron	2cm 0.5cm 2 cm	2cm 0.5cm 2 cm	2cm 0.5cm 2 cm
2	scintillator air iron	2cm 0.5cm 2cm	2 cm 0.5cm 2 cm	2 cm 0.5cm 2 cm
3	scintillator air iron	2cm 0.5cm 14cm	2cm 0.5cm 16cm	2cm 0.5cm 18cm
4	scintillator air iron	2cm 0.5cm 22cm	2cm 0.5cm 26cm	2cm 0.5cm 30cm
5	scintillator air iron	2cm 0.5cm 22cm	2cm 0.5cm 26cm	2cm 0.5cm 30cm
6	scintillator air iron	2cm 0.5cm 10cm	2cm 0.5cm 10cm	2cm 0.5cm 10cm
7	scintillator air iron	2cm 0.5cm 10cm	2cm 0.5cm 10cm	2cm 0.5cm 10cm
8	scintillator	2cm	2cm	2cm

Results @ SLAC

Starting from three previous presented configurations, @ SLAC we had:

- C2(CDR): $\epsilon_{mu} \approx 78.1\%$; $r_\pi \approx 1.6\%$;
- C5(CDR - 10cm): $\epsilon_{mu} \approx 79.2\%$; $r_\pi \approx 1.7\%$;
- C6(CDR + 10cm): $\epsilon_{mu} \approx 79.2\%$; $r_\pi \approx 1.5\%$;
  - Was difficult to see differences between these three configurations
- very low efficiency at low momentums.



Code developments and improvements

1. We spent the last couple of months improving the reliability of our code and adding features to it.
2. The results are not much different but we have a better understanding of what we have in our hands and how to finalize the work.

IMPROVEMENTS:

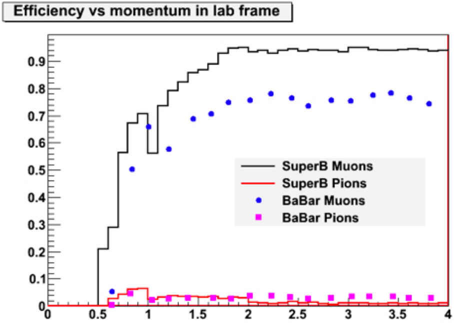
1. recovered muon efficiency at for low momentum tracks
2. calculated the layer multiplicity for the tracks
3. add cuts to the hits with very low energy deposition ($< 100 keV$)
4. fixed few code bugs
5. added the possibility to handle parameterization from a config file
6. added the possibility to handle also background events (in progress)
7. made additional detector configuration based on possible prototype layout
8. added energy deposition in the EMC

Three configurations

For the prototype optimization and code validation wa start testing these three layouts(620mm, 820mm and 920mm) changing the thickness of iron gap.

Number of gap	Material	thickness C1(820mm)	thickness C2(920mm)	thickness C3(620mm)
1	scintillator	2cm	2cm	2cm
	air	0.5cm	0.5cm	0.5cm
	iron	2 cm	2 cm	2 cm
2	scintillator	2cm	2 cm	2 cm
	air	0.5cm	0.5cm	0.5cm
	iron	2cm	2 cm	2 cm
3	scintillator	2cm	2cm	2cm
	air	0.5cm	0.5cm	0.5cm
	iron	16cm	16cm	12cm
4	scintillator	2cm	2cm	2cm
	air	0.5cm	0.5cm	0.5cm
	iron	16cm	24cm	12cm
5	scintillator	2cm	2cm	2cm
	air	0.5cm	0.5cm	0.5cm
	iron	16cm	24cm	12cm
6	scintillator	2cm	2cm	2cm
	air	0.5cm	0.5cm	0.5cm
	iron	16cm	14cm	12cm
7	scintillator	2cm	2cm	2cm
	air	0.5cm	0.5cm	0.5cm
	iron	14cm	10cm	10cm
8	scintillator	2cm	2cm	2cm

Our baseline is still the almost-CDR like design



- 920 mm of iron
- possible to reuse the babar iron.
- not necessary to add iron outside the barrel (but recommended).

Performances from simulation:
muon efficiency: 86.7 ± 0.1 %
pion efficiency: 2.1 ± 0.1%

Comparison with BaBar muon ID from real data

	M.I	V.L.	L.	T.	V.T.
μ	99.05±0.03	92.73±0.09	87.6±0.1	74.3±0.2	70.3±0.2
π	54.0±0.1	16.45±0.09	7.44±0.06	2.76±0.04	2.42±0.04

Miscellanea of test results and considerations I

Table with results for different configuration

mm of iron	muon efficiency	pion contamination
920 (baseline)	91.8 ± 0.1	1.8 ± 0.1
820	91.8 ± 0.1	1.9 ± 0.1
620	90.9 ± 0.1	2.5 ± 0.1

- the 620mm configuration is quite worst wrt the others.
- discriminating between 820 and 920 is at this moment beyond our possibility (more on that later)

Adding noise 1.5% noise occupancy

mm of iron	muon efficiency	pion contamination
920 (baseline)	86.7 ± 0.1	2.1 ± 0.1
620	86.4 ± 0.1	2.7 ± 0.1

Adding random noise to the simulation every configuration get worst as expected. Need to add machine background now.

Effect of the noise on baseline configuration

noise level	muon efficiency	pion contamination
0 noise	91.8 ± 0.1	1.8 ± 0.1
1.5% occupancy	86.7 ± 0.1	2.1 ± 0.1
5% occupancy	76.4 ± 0.1	2.1 ± 0.1

No cut re-optimization has been done when adding noise.
Performances can be very dependent on the optimization

Miscellanea of test results and considerations II

effect of optimization on cut based muon identification

configuration	muon efficiency	pion contamination
920 (m.r. optim)	85.0 ± 0.1	1.7 ± 0.1
920 (g.c. optim)	86.7 ± 0.1	2.1 ± 0.1

configuration	muon efficiency	pion contamination
620 (m.r. optim)	85.0 ± 0.1	2.5 ± 0.1
620 (g.c. optim)	86.4 ± 0.1	2.7 ± 0.1

The results of the two optimizations are quite in agreement,
but very small variations in the cuts lead to discrepancies in the performances that are of the order of the differences between the configurations that we want to measure.

So... being pretty much confident about our code we can use a black box to perform the optimization and the selection (Neural Net or BDT).

Proposal for prototype construction

Therefor for prototype design we recommend the following layout

```
|=|=|========|====|====|====|====|====|====|=======|=====|
|2|2|     16     | 8  |  8 |  8 |  8 |  8 |  8 |    14    |  10  |
```

this allow us to easily test some interesting different configurations

- with more/less iron;
- with more active layers;
- with different spacing between the layers;
- changing the granularity.

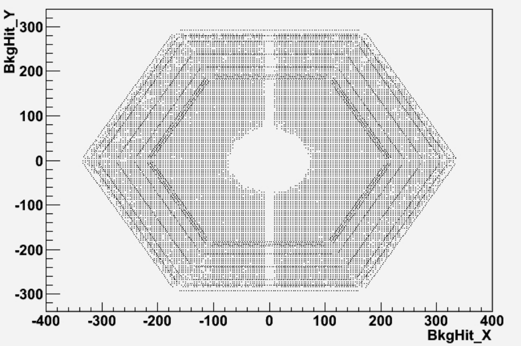
Background digitization

- In the digitization we impose:
  1. hits have are in the same sextant and layer;
  2. hits have same *TrackID* and same Pdg_{code};
- one hit is moved in the middle of square;
- we simulate 5K events of brehmstalung;
- we digitize the background in all sexstants and in endcaps;
- we studied the count hot region for neutrons;
- we want to estimate a neutron background rate.
- we want to estimate the total background in the IFR.

- We can study background coming from different particles.
- Results that will be shown are only background distribution (not rate) because we don't have the right scale factor.

Digitization of endcaps

- Geometry of endcaps are like CDR;
- we improve the digitization in endcaps too, dividing scintillators into squares of $4 \times 4cm^2$;
- we use this digitization for studing background;



Neutron from brehmstralung background I (PRELIMINARY)

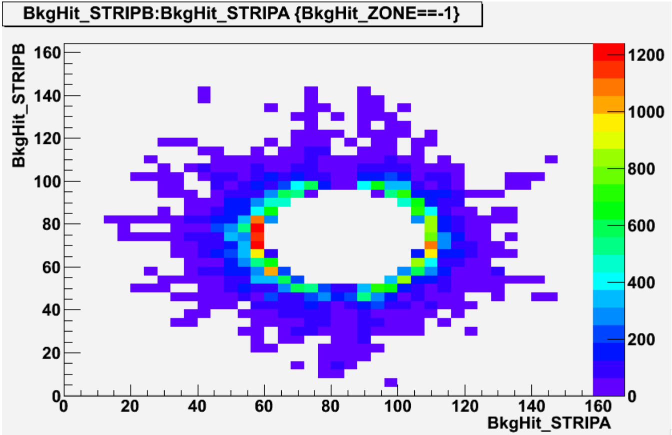


Figure: Neutrons distribution in the backward region.

Neutron from brehmstralung background II (PRELIMINARY)

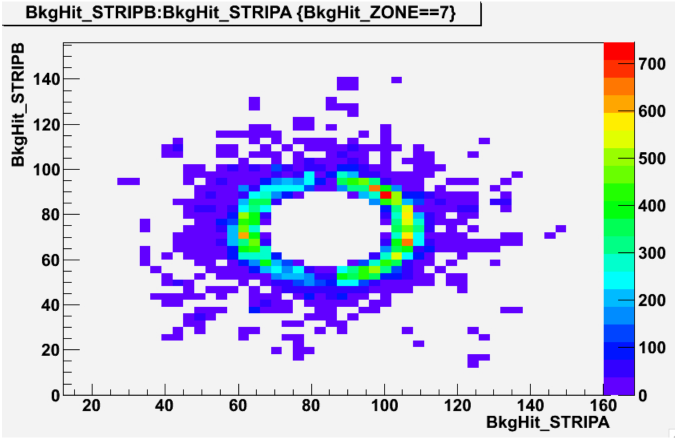


Figure: Neutrons distribution in the forward region.

Neutron from brehmstralung background III (PRELIMINARY)

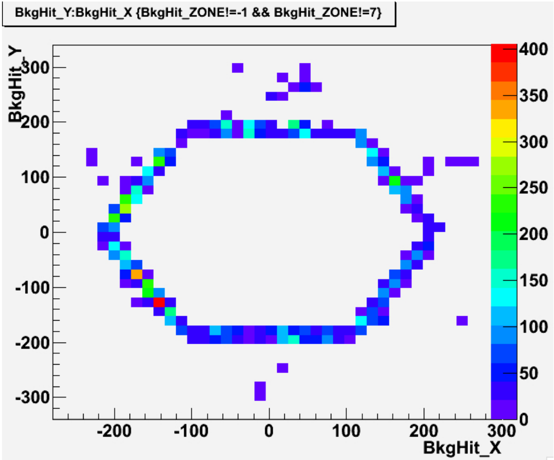


Figure: Neutrons distribution in the barrel.

Neutron from brehmstralung background IV (PRELIMINARY)

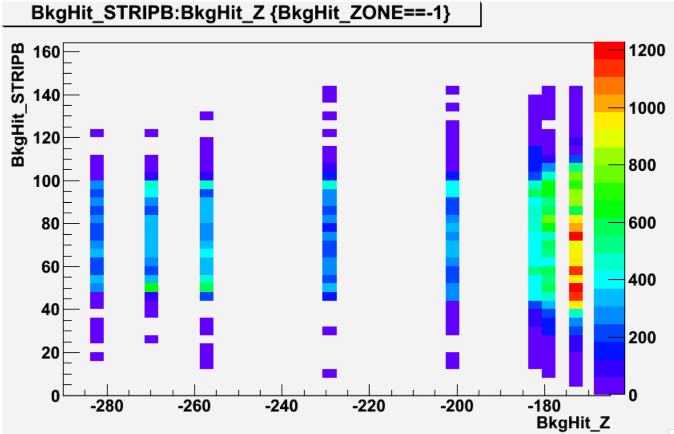


Figure: Neutrons distribution in the backward region - Z view.

Neutron from brehmstralung background V (PRELIMINARY)

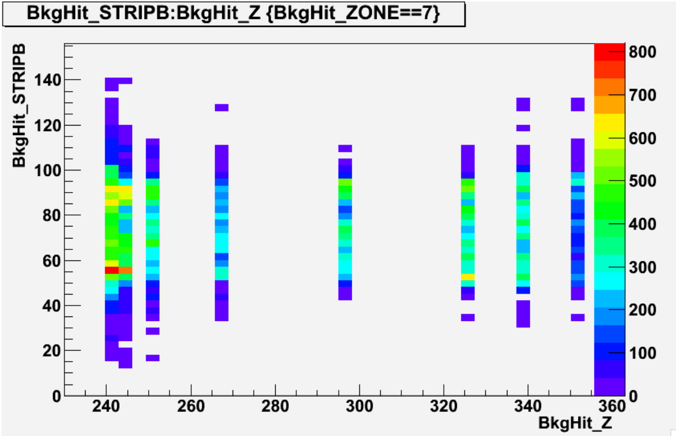


Figure: Neutrons distribution in the forward region - Z view.

Looking forward

The muon ID goodness for different detector layouts are very sensitive to the cuts optimization: now that we have a good understanding and reliability of our code we should leave this duty to some more automatic tool such as a NN or a BDT and care about the results only.

At this point we really need a background production. We just simulate some beamstralung events (1000) to have a preliminary estimate of the rates; the processing time is very high, we will made a formal request to the background group at this meeting

We would also need the simulation of signal events, like:

$$e^+e^- \to \mu^+\mu^-\gamma \qquad e^+e^- \to e^+e^-\mu^+\mu^-$$

$$K_S \to \pi^+\pi^- \qquad e^+e^- \to \tau^+\tau^-$$

generators availability will be checked within the full sim group.