DIRAC Note 2004-4

Summary on Λ decay analysis for Ni 2001 to 2003

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1. Introduction

With this note we present the current status of the Λ decay analysis for the Ni 2001 to 2003 data. The aim of this analysis is to study both the Λ mass and the sigma of Λ mass stability during the main years of DIRAC data taking for Ni target. Moreover the ratio $\frac{Effective \quad mass - \Lambda_{mass}}{error}$ was studied as a function of the momentum of the pion. This ratio gives a measurement of the estimation of errors. Finally, results of a Monte Carlo simulation are also presented.

2. Ni data analysis

For our analysis we used data taken with Λ trigger. The Ni 2001 to 2003 data were splitted in ten sub-periods according to running conditions. Table 1 shows these ten sub-periods together with the statistics of Λ triggers analyzed.

Table 1

Data Sub-Periods	Number of lambda trigger analyzed (Mevents)
3540 to 3700 (Ni 2001)	8.23
3700 to 3836 (Ni 2001)	7.15
3843 to 4072 (Ni 2001)	9.31
4073 to 4301 (Ni 2001)	7.43
4302 to 4999 (Ni 2002 20 GeV)	16.16
5000 to 5404 (Ni 2002 24 GeV)	7.19
5405 to 5814(Ni 2002 24 GeV Single Target)	5.88
5405 to 5814(Ni 2002 24 GeV Multi Target)	5.99
5815 to 6448(Ni 2003 20 GeV Single Target)	5.21
5815 to 6448(Ni 2003 20 GeV Multi Target)	4.26

In our analysis program we required events with two tracks downstream. Furthermore we selected events with the time of flight difference between the positive arm track and the negative arm track to be from 0 ns to 1.3 ns (interval we expect the Λ decay products).

Figure 1 shows the Effective Mass of the two tracks, with the Λ hypothesis, for Ni 2002 20 GeV data (Runs 4302-4999). On the figure we note the difference of the invariant mass of the pπ pair with the mass of Λ taken from PDG. This value (-28 KeV) shows the distance of the Λ mass, we reconstruct, from the PDG value. On the same figure we also note the width of Λ. Both values are very important for our analysis. Figure 2 shows the ratio $\frac{Effective\ \ mass - \Lambda_{mass}}{error}$ for the same sub period.

In Table 2 we present the values for the $p\pi_{mass} - \Lambda_{PDGmass}$ difference, the width $\sigma(\Lambda_{mass})$ and the ratio $\frac{Effective\ \ mass - \Lambda_{mass}}{error}$ for all sub-periods for Ni. From this table we observe the following:

- The $p\pi_{mass} - \Lambda_{PDGmass}$ difference is of the order of -20 to -30 KeV. This value is very small in comparison with the Λ mass and shows a very good response of our apparatus. We also observe a very good stability in the Λ mass reconstruction over the three years of data taking.
- The width $\sigma(\Lambda_{mass})$ of Λ is also very stable over the three years. The difference between the years 2001 to 2002 comes from the additional third plane of SciFi we add in the experiment.
- The ratio $\frac{Effective\ \ mass - \Lambda_{mass}}{error}$ shows that errors are underestimated by about 2%-3% for all sub-periods.

Table 2

Data Sub-Periods	$p\pi_{mass} - \Lambda_{PDGmass}$ (MeV)	$\sigma(\Lambda_{mass})$ (MeV)	$\frac{Effmass - \Lambda_{mass}}{error}$
3540 to 3700 (Ni 2001)	-0.022±0.003	0.536±0.003	1.022±0.006
3700 to 3836 (Ni 2001)	-0.019±0.004	0.541±0.004	1.026±0.007
3843 to 4072 (Ni 2001)	-0.026±0.003	0.538±0.003	1.021±0.006
4073 to 4301 (Ni 2001)	-0.027±0.004	0.547±0.004	1.034±0.007
4302 to 4999 (Ni 2002 20 GeV)	-0.028±0.003	0.664±0.003	1.035±0.004
5000 to 5404 (Ni 2002 24 GeV)	-0.025±0.005	0.661±0.004	1.028±0.007
5405 to 5814(Ni 2002 24 GeV Single Target)	-0.023±0.006	0.673±0.005	1.039±0.009
5405 to 5814(Ni 2002 24 GeV Multi Target)	-0.017±0.005	0.667±0.005	1.031±0.008
5815 to 6448(Ni 2003 20 GeV Single Target)	-0.033±0.005	0.660±0.005	1.026±0.008
5815 to 6448(Ni 2003 20 GeV Multi Target)	-0.037±0.006	0.663±0.005	1.028±0.008

Figure 3 shows the ratio $\frac{Effective\ \ mass - \Lambda_{mass}}{error}$ for Ni 2002 20 GeV data (Runs 4302-4999), where (a), (b), (c) and (d) stand for pion momentum intervals 1.2 to 1.4 MeV/c, 1.4 to 1.6 MeV/c, 1.6 to 1.8 MeV/c and 1.8 to 2.0 MeV/c respectively. In Table 3 we present the ratio $\frac{Effective\ \ mass - \Lambda_{mass}}{error}$ as function of pion momentum for all sub-periods for Ni. From the values of table 3 we do not observe any dependence of this ratio as a function of pion momentum.

Table 3

Data Sub-Periods	$\frac{Effmass - \Lambda_{mass}}{error}$ **1.2 to 1.4 GeV**	$\frac{Effmass - \Lambda_{mass}}{error}$ **1.4 to 1.6 GeV**	$\frac{Effmass - \Lambda_{mass}}{error}$ **1.6 to 1.8 GeV**	$\frac{Effmass - \Lambda_{mass}}{error}$ **1.8 to 2.0 GeV**
3540 to 3700 (Ni 2001)	1.060±0.018	1.033±0.011	1.008±0.011	1.021±0.016
3700 to 3836 (Ni 2001)	1.081±0.023	1.021±0.013	1.029±0.012	1.004±0.019
3843 to 4072 (Ni 2001)	1.055±0.016	1.030±0.010	1.022±0.009	0.982±0.013
4073 to 4301 (Ni 2001)	1.116±0.020	1.039±0.012	1.023±0.011	1.010±0.016
4302 to 4999 (Ni 2002 20 GeV)	1.041±0.013	1.044±0.008	1.041±0.007	1.017±0.010
5000 to 5404 (Ni 2002 24 GeV)	1.037±0.020	1.041±0.012	1.032±0.011	1.009±0.016
5405 to 5814 (Ni 2002 24 GeV Single Target)	1.059±0.023	1.049±0.015	1.051±0.015	1.033±0.021
5405 to 5814 (Ni 2002 24 GeV Multi Target)	1.100±0.026	1.043±0.014	1.040±0.013	0.987±0.018
5815 to 6448 (Ni 2003 20 GeV Single Target)	1.067±0.021	1.019±0.013	1.048±0.014	0.995±0.018
5815 to 6448 (Ni 2003 20 GeV Multi Target)	1.118±0.027	1.003±0.014	1.049±0.014	1.022±0.019

3. Monte Carlo simulation for Ni target analysis.

Using the Dirac MC (version 2.63.07) we generated Λ events for Ni target. We analyzed these events in the same way as we did with data. Figure 4 shows the Lambda Momentum, the Lambda Decay Vertex, the Proton Momentum and the Pion Momentum for events generated with Fritiof (Ni 24 GeV) and entering the Dirac apparatus. In fig. 5 we see the Lambda Momentum, the Proton Momentum and the Pion Momentum for Monte Carlo (Ni 2001 24 GeV) events reconstructed with Ariane. Finally in fig. 6 we see the $p\pi - \Lambda_{PDG}$ mass for Monte Carlo data and for the periods Ni 2001 24 GeV, Ni 2002 20 GeV, Ni 2002 24 GeV and Ni 2003 20 GeV.

In Table 4 we present the values for the $p\pi_{mass} - \Lambda_{PDGmass}$ difference, the width $\sigma(\Lambda_{mass})$ and the ratio $\frac{Effective\ \ mass - \Lambda_{mass}}{error}$ for all periods we can simulate for Ni. Practically it is the same table for MC as table 2 for data. From this table we observe the following:

- The $p\pi_{mass} - \Lambda_{PDGmass}$ difference is -117 KeV for the year 2001 and about -430 KeV for 2002 and 2003. This shift of the Λ mass is quite big (5 to 10 times bigger) if we compare it with the shift (Table 2) we observe for the data! Also there is a difference between 2001 and 2002-2003.

- The width $\sigma(\Lambda_{mass})$ of Λ is smaller than the width we observe in Table 2 for the data. The difference between the years 2001 to 2002 comes from the additional third plane of SciFi we add in the experiment. We observe the same effect with data.
- The ratio $\frac{Effective\ \ mass - \Lambda_{mass}}{error}$ shows that errors are overestimated for most periods. In any case these values are different from those of the data (Table 2).

All above remarks suggest possible problems with the detector alignment and the material description in MC.

Table 4

MC data	$p\pi_{mass} - \Lambda_{PDGmass}$ (MeV)	$\sigma(\Lambda_{mass})$ (MeV)	$\frac{Effmass - \Lambda_{mass}}{error}$
Ni 2001 (24 GeV)	-0.117±0.004	0.449±0.004	0.909±0.007
Ni 2002 (20 GeV)	-0.431±0.005	0.594±0.004	0.977±0.008
Ni 2002 (24 GeV)	-0.421±0.005	0.591±0.004	0.970±0.008
Ni 2003 (20 GeV)	-0.432±0.005	0.604±0.004	1.000±0.009

To investigate the above problems we made a special MC run by setting the Energy Loss to zero. The values, for this run, of the $p\pi_{mass} - \Lambda_{PDGmass}$ difference and the width $\sigma(\Lambda_{mass})$ of Λ appear in Table 5, together with the values of the normal run. From Table 5 we observe that the shift of the Λ mass was reduced by half while the width is the same. This suggests that the Energy Loss effects have to be taking into account for the detector alignment.

Table 5

MC data	$p\pi_{mass} - \Lambda_{PDGmass}$ (MeV)	$\sigma(\Lambda_{mass})$ (MeV)
Ni 2002 (20 GeV)	-0.431±0.005	0.594±0.004
Ni 2002 (20 GeV) Eloss=0	-0.242±0.005	0.577±0.004

Finally we also made several MC runs by increasing multiple scattering in the detector. The results of this investigation appear in Table 6. From the values of this Table we observe that the shift of the Λ mass is unaffected but the width of Λ increases, as expected. An increment as large as 20% in multiple scattering gives values of the Λ width close to those we observe from the data analysis. This suggests possible problems with the material description in MC.

Table 6

MC data	$p\pi_{mass} - \Lambda_{PDGmass}$ (MeV)	$\sigma(\Lambda_{mass})$ (MeV)
Ni 2001 (24 GeV)	-0.117±0.004	0.449±0.004
Ni 2001 (24 GeV) (+ 10% multiple scattering)	-0.108±0.006	0.503±0.006
Ni 2001 (24 GeV) (+ 20% multiple scattering)	-0.125±0.007	0.538±0.006
Ni 2001 (24 GeV) (+ 30% multiple scattering)	-0.121±0.007	0.554±0.007
Ni 2002 (20 GeV)	-0.431±0.005	0.594±0.004
Ni 2002 (20 GeV) (+ 10% multiple scattering)	-0.419±0.007	0.617±0.004
Ni 2002 (20 GeV) (+ 20% multiple scattering)	-0.419±0.008	0.644±0.004
Ni 2002 (20 GeV) (+ 30% multiple scattering)	-0.403±0.008	0.677±0.004

4. General conclusions

Concerning the data analysis from Tables 2 and 3 we observe a good stability on the Λ_{mass} and on the σ (Λ_{mass}) for the various sub-periods of 2001 to 2003. From the ratio $\frac{Effective \;\; mass - \Lambda_{mass}}{error}$ we conclude that errors are underestimated by about 2%-3%. We do not observe any significant dependence as function of pion momentum.

Concerning MC analysis the results from Table 4 show some divergence from data. Further investigation by setting Energy Loss to zero and increasing multiple scattering suggests possible problems with the detector alignment and the material description in MC.

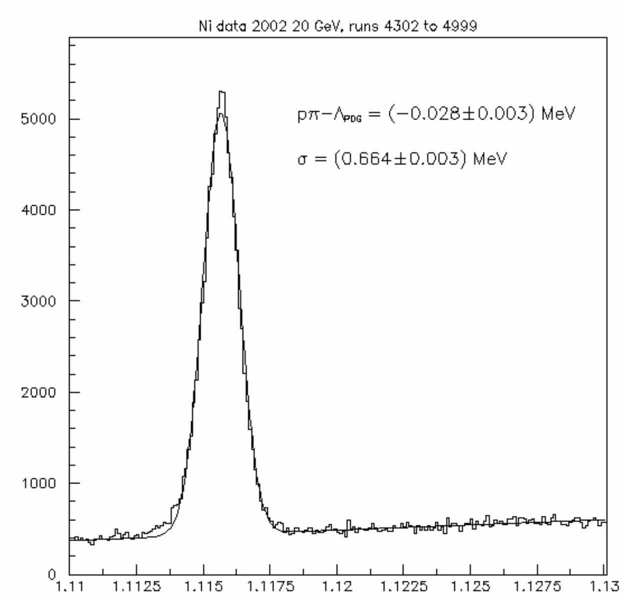

Fig 1: The Effective Mass of the two tracks, with the Λ hypothesis, for Ni 2002 20 GeV data (Runs 4302-4999).

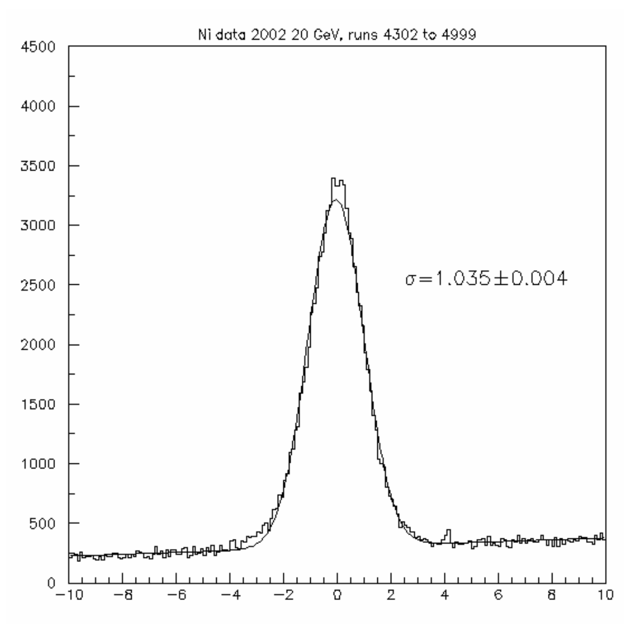

Fig 2: The ratio $\frac{Effective\ \ mass - \Lambda_{mass}}{error}$ for Ni 2002 20 GeV data (Runs 4302-4999).

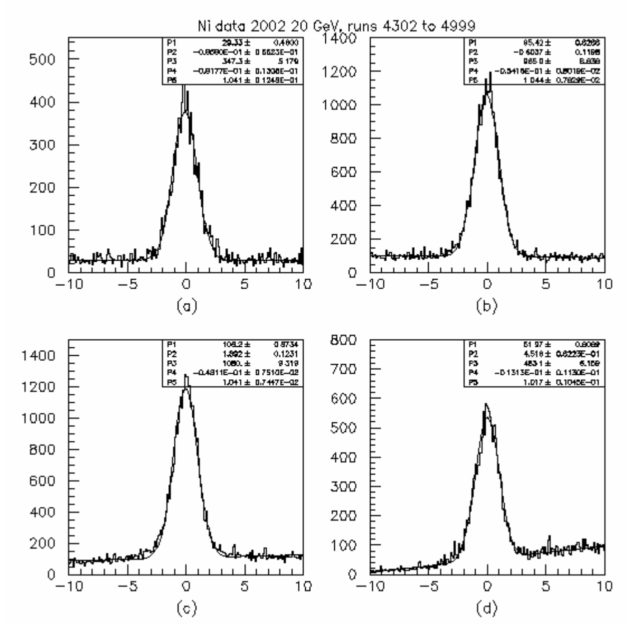

Fig 3: The ratio $\frac{Effective\ \ mass - \Lambda_{mass}}{error}$ for Ni 2002 20 GeV data (Runs 4302-4999). Where (a), (b), (c) and (d) stand for pion momentum intervals 1.2 to 1.4 MeV/c, 1.4 to 1.6 MeV/c, 1.6 to 1.8 MeV/c and 1.8 to 2.0 MeV/c respectively.

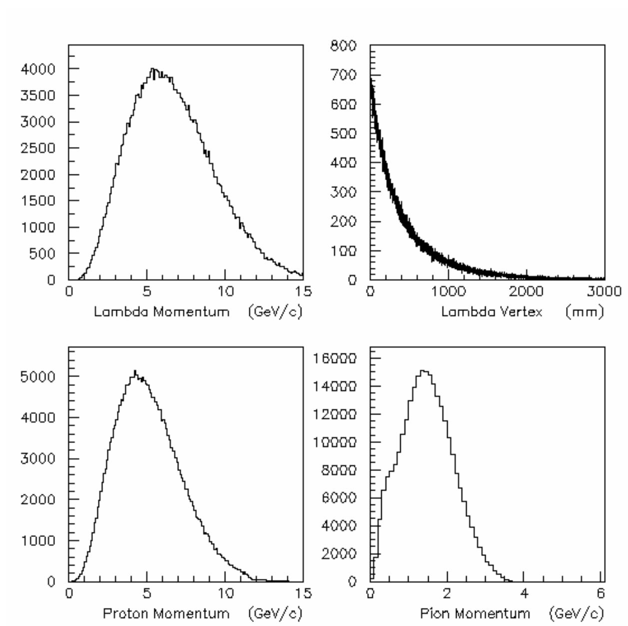

Fig 4: The Lambda Momentum, the Lambda Decay Vertex, the Proton Momentum and the Pion Momentum for events generated with Fritiof (Ni 24 GeV) and entering the Dirac apparatus.

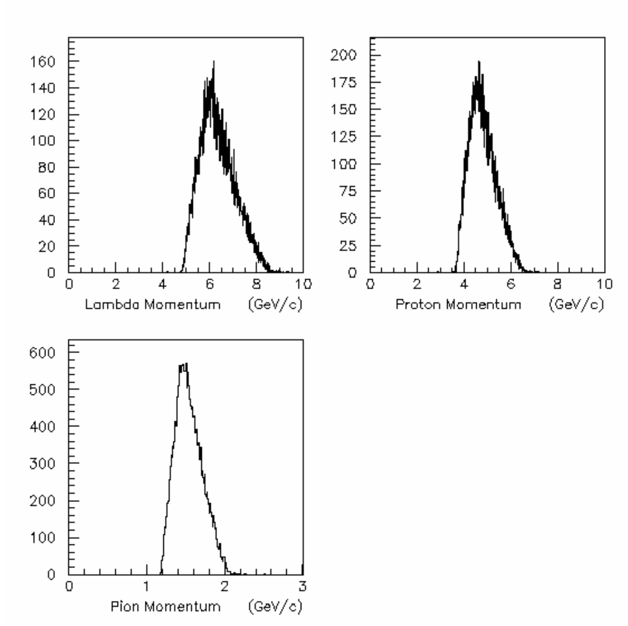

Fig 5: The Lambda Momentum, the Proton Momentum and the Pion Momentum for Monte Carlo (Ni 2001 24 GeV) events reconstructed with Ariane.

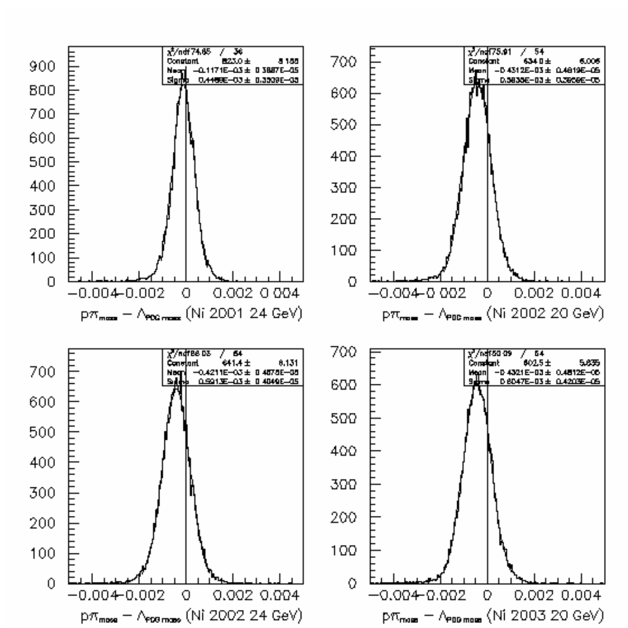

Fig 6: The $p\pi - \Lambda_{PDG}$ mass for Monte Carlo data and for the periods Ni 2001 24 GeV, Ni 2002 20 GeV, Ni 2002 24 GeV and Ni 2003 20 GeV.