

**Experiment 949**  
**Technical Note No. K-066**

**Muon background estimation for PNN2 box region.**

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**Abstract**

Results of an muon background level estimation using current set of PNN2 cuts are presented. The procedure used the results of technotes K034 [1] and K051 [2] as control ones. It was shown that it is possible to reproduce in general the TDCUTS rejection factors of PNN1 analyses and come up with similar number of events. The differences could be explained by cut optimization for the purpose of the PNN2 analyses.

It appears that the muon background level in PNN2 box normalized to 3/3 of data equals to

$$\frac{3}{421.1250} \sim 3 \times 0.0024 = 0.0072 \quad (1)$$

at the moment.

## 1 Introduction

The problems of muon background estimation is well enough described in technote K-034 [1] and in T. Sekeguchi thesis [3] in case of  $\pi^+\nu\bar{\nu}1$  kinematic region.

## 2 Experimental data

The PNN2\_SKIM data from the 2002 data taking run has been used in this analysis..

## 3 Description of the method

The method used for the muon background estimation is described in detail elsewhere [3](see, for instance figure E.10 at this paper). The main idea is to define the rejection factor of TD cuts using events after applying SETUP cuts and  $\overline{RNGMOM}$ . This rejection factor is applied to events left in so called Normalization branch ignoring the possible dependence of this rejection factor from kinematic region. It was shown that the muon background level defined by this method is in good agreement with level defined by so called Shape Line analyses.

## 4 Discussion of the results.

The result on rejection factors from PNN1 analyses have been used as control result. In table 1 the result on TD rejection factors from technote [1], [2] and the rejection factors with new SETUP and TD cuts are presented. The rejection factor for TD cuts and even corresponding number of

Cut name	Events(Rejection)			
	Range tail		Band	
	All	ER box	All	ER box
PNN1 Trigger 1/3 sample of PNN2_SKIM. PRRF not applied.				
SETUP	32085(———)	10460(———)	14362(———)	5291(———)
EV5	14797( 2.17)	4593( 2.28)	6986( 2.06)	2680( 1.97)
ELVETO	8757( 1.69)	2696( 1.70)	3957( 1.77)	1520( 1.76)
TDFOOL	8715( 1.00)	2688( 1.00)	3927( 1.01)	1510( 1.01)
TDVARNN	72( 121 ± 14)	27( 99 ± 19)	37( 106 ± 17)	15( 100 ± 26)
TDCUTS	445 ± 52	387 ± 74	388 ± 63	352 ± 91
PNN1 Trigger from Technote K054 - 2/3 sample				
SETUP	65712(-)	20292(-)	40383(-)	17976(-)
EV5	31432(2.09)	9453(2.15)	19926(2.03)	9081(1.98)
ELVETO	18603(1.69)	5510(1.72)	11335(1.76)	5115(1.78)
TDFOOL	18508(1.01)	5478(1.01)	11283(1.00)	5096(1.00)
TDVAR	137(135±11)	51(107±15)	75(150±17)	34(150±26)
Rej.	480±41	398±56	539±62	529±91

Table 1: Rejection branch of the modern and the 2002 TD cuts for PNN1 events using 1/3 sample from PNN2\_SKIM

events reproduced and are in enough good agreement with that obtained in PNN1 analyses. Some additional work to understand the muon background level better is needed.

## Acknowledgments

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## Appendix A : Cuts used in analyses.

The following cuts have been used in the muon background study analyses (divided for convenience in some arbitrary groups, cuts in green color wasn't applied, cuts in magenta color has different meaning for PNN1 and PNN2 samples ):

0 **The general purpose** 2 cuts

The general purpose cut: **BAD\_RUN** , **FIX\_ALL**

**The SETUP cuts:**

1 **PCUTS** comprises 10 cuts

**B4DEDX**, **BWTRS**, **B4TRS**, **B4ETCON**, **B4CCD**, **CKTRS**, **CKTAIL**, **CPITRS**, **CPITAIL**, **TIMCON**

2 **TGCUTS** comprises 35 cuts

Cut name	Events(Rejection)			
	Range tail		Band	
	All	ER box	All	ER box
PNN2 Trigger 1/3 sample of PNN2_SKIM. All PNN2 cuts were applied.				
SETUP	1052( 1.0000)	10( 1.0000)	2317( 1.0000)	158( 1.0000)
EV5	526( 2.0000)	4( 2.5000)	1182( 1.9602)	80( 1.9750)
ELVETO	311( 1.6913)	1( 4.0000)	677( 1.7459)	43( 1.8605)
TDFOOL	310( 1.0032)	1( 1.0000)	676( 1.0015)	43( 1.0000)
TDVARNN	1( 310 ± 310)	0(10)	7( 96 ± 36)	1( 43 ± 43)
TDCUTS	1052±1052	10 ± 10	331 ± 125	158 ± 158
TDCUTS	0(1033)	0(103)	323 ± 122	338 ± 239
PNN2 Trigger 1/3 sample of PNN2_SKIM. All PNN1 cuts were applied.				
SETUP	6782(———)	3176(———)	6814(———)	3449(———)
EV5	2643( 2.5660)	1271( 2.4988)	3456( 1.9716)	1758( 1.9619)
ELVETO	1548( 1.7074)	741( 1.7152)	1996( 1.7315)	995( 1.7668)
TDFOOL	1545( 1.0019)	741( 1.0000)	1983( 1.0066)	987( 1.0081)
TDVARNN	16( 96 ± 24)	9( 82 ± 27)	18( 110 ± 26)	8( 123 ± 43)
TDCUTS	423 ± 106	352 ± 117	378 ± 89	431 ± 152

Table 2: Rejection branch of modern TD cuts for PNN2 events using 1/3 sample from PNN2\_SKIM

TGQUALT, TGTCON, B4TIM, B4EKZ, B4EKZ\_IC, TGZFOOL, EPITG, EPIMAXK, TARGET, TGER, DTGTPP, RTDIF, DRP, TGKTIM, EIC, TIC, TGEDGE, TGENR, PIGAP, TGLIKE, TGB4, PHIVTX, OPSVETO, TGPVCUT, TIMKF, CCDPUL, RVUPV, DELC, NPITG, VERRNG, ANGLI, ALLKFIT, TPICS, KIC, EPIONK

3 *RNGMOM*

4 COS3D

5 ZFRF

6 ZUTOUT

7 RSDEX

8 UTCQUAL

9 PRRF

10 LAY14

11 IPIFLG

12 TGCEO

13 TGDEX

14 PVCUTNEW

15 TDCUT comprises 4 cuts

EV5, ELVETO, TDFOOL, TDVARNN

## Appendix B : Rejection and Normalization branch.

The PNN2\_SKIM set of 2002 data taking run has been used in this analysis. The total statistics in this set is 30.995.248 events. For muon background study **all events** were considered as **the PNN2 trigger** events.

Cut Name	Events of PNN2_SKIM data	
	PNN 2 Rejection	PNN2 Normalization
COUNTER	30987169( 1.0000)	30985632( 1.0000)
BAD_RUN	30401803( 1.0192)	30400266( 1.0193)
FIX_ALL	30401803( 1.0000)	30400266( 1.0000)
RTOTGT42	30401803( 1.0000)	30400266( 1.0000)
RTOTLT33	30401803( 1.0000)	30400266( 1.0000)
BOX2	30401803( 1.0000)	
BOX2		4649482( 6.5384)

Table 3: The PNN2 general run rejection branch cuts.

Cut Name	Events of PNN2_SKIM data	
	PNN 2 Rejection	PNN2 Normalization
B4DEDX	24719468( 1.2299)	3748763( 1.2403)
BWTRS	15092075( 1.6379)	2149918( 1.7437)
B4TRS	13023628( 1.1588)	1806949( 1.1898)
B4ETCON	12865529( 1.0123)	1777362( 1.0167)
B4CCD	12731345( 1.0105)	1761787( 1.0088)
CKTRS	8524167( 1.4936)	921554( 1.9118)
CKTAIL	8074704( 1.0557)	852511( 1.0810)
CPITRS	7407420( 1.0901)	685571( 1.2435)
CPITAIL	7404185( 1.0004)	685195( 1.0006)
TIMCON	5971094( 1.2400)	550771( 1.2441)
PCUTS	5971094( 5.0915)	550771( 8.4418)

Table 4: The PNN2 PCUTS rejection and Normalization branch cuts.

**RNGMOM have been used in k051 (Left Tail and Band events):**

**( ptot.lt.229.0.and.rngmom\_new3(0.).lt.2.2 )**

In Tables 4,5,6,7 are listed the cut names in Normalization and Rejection branch for PNN2\_SKIM data.

Cut Name	Events of PNN2.SKIM data	
	PNN 2 Rejection	PNN2 Normalization
TGQUALTO	5549437( 1.0760)	484650( 1.1364)
TGTCON	5425914( 1.0228)	434143( 1.1163)
B4TIM	5425914( 1.0000)	434143( 1.0000)
B4EKZ	4326842( 1.2540)	249512( 1.7400)
B4EKZ_IC	4326842( 1.0000)	249512( 1.0000)
TGZFOOL	4326842( 1.0000)	244585( 1.0201)
EPITG	4262328( 1.0151)	175427( 1.3942)
EPIMAXK	4101808( 1.0391)	175427( 1.0000)
TARGF	4082302( 1.0048)	174265( 1.0067)
TGER	3843358( 1.0622)	154572( 1.1274)
DTGTTP	3842974( 1.0001)	154493( 1.0005)
RTDIF	3803049( 1.0105)	153057( 1.0094)
DRP	3780485( 1.0060)	149976( 1.0205)
TGKTIM	3618826( 1.0447)	138833( 1.0803)
EIC	3435253( 1.0534)	129940( 1.0684)
TIC	3433476( 1.0005)	129858( 1.0006)
TGEDGE	3359896( 1.0219)	124723( 1.0412)
TGENR	3238188( 1.0376)	122006( 1.0223)
PIGAP	3202902( 1.0110)	120264( 1.0145)
TGLIKE	3037935( 1.0543)	110780( 1.0856)
TGB4	2876052( 1.0563)	103487( 1.0705)
PHIVTX	2717500( 1.0583)	88545( 1.1687)
OPSVETO	2501375( 1.0864)	74431( 1.1896)
TGPVCUT	2405918( 1.0397)	66306( 1.1225)
TIMKF	1813857( 1.3264)	57480( 1.1536)
CCDPUL	805243( 2.2526)	19826( 2.8992)
RVUPV	791650( 1.0172)	19458( 1.0189)
DELC	776389( 1.0197)	18979( 1.0252)
NPITG	776389( 1.0000)	18979( 1.0000)
VERRNG	709661( 1.0940)	17145( 1.1070)
ANGLI	709276( 1.0005)	17119( 1.0015)
ALLKFIT	657843( 1.0782)	15682( 1.0916)
TPICS	657701( 1.0002)	15678( 1.0003)
KIC	653178( 1.0069)	15635( 1.0028)
EPIONK	652242( 1.0014)	15622( 1.0008)
TGCUTS	652242( 9.1547)	15622( 35.2561)

Table 5: The PNN2 TGCUTS rejection and Normalization branch cuts.

## Appendix C : Some picture for Rejection and Normalization branch.

( Fig. 1 All PNN2.SKIM data  
 Fig. 2 PNN2 Rejection branch: EPION and  $\overline{RNGMOM}$   
 Fig. 3 PNN2 Normalization branch:  $\overline{TDVARNN}$  and  $\overline{RNGMOM}$  )

Cut Name	PNN2 events (Rejection)
<b>Rejection branch</b>	
<i>RNGMOM</i>	485160( 1.3444)
COS3D	421792( 1.1502)
ZFRF	339948( 1.2408)
ZUTOOUT	339207( 1.0022)
RSDEDX	110603( 3.0669)
UTCQUAL	96584( 1.1451)
PRRF	50763( 1.9026)
LAYV4	50763( 1.0000)
IPIFLG	28176( 1.8016)
TGCEO	25149( 1.1204)
TGDEDX	24294( 1.0352)
PVCUTNEW	3368( 7.2132)
<b>Cuts7-70</b>	<b>3368( 9026.6600)</b>
<b>Normalization branch</b>	
<i>SETUP<sub>NORM</sub></i>	15622( 35.2561)
<i>EV5</i>	8831( 1.7690)
<i>ELVETO</i>	7774( 1.1360)
<i>TDFOOL</i>	4005( 1.9411)
<i>TDVARNN</i>	2941( 1.3618)
<i>TDCUT</i>	2941( 5.3118)
RNGMOM	42( 70.0238)
COS3D	40( 1.0500)
ZFRF	40( 1.0000)
ZUTOOUT	40( 1.0000)
RSDEDX	19( 2.1053)
UTCQUAL	8( 2.3750)
PRRF	7( 1.1429)
LAYV4	0(——)
IPIFLG	0(——)
TGCEO	0(——)
TGDEDX	0(——)
<b>Cuts7-70</b>	<b>0(——)</b>

Table 6: The PNN2 SETUP rejection and Normalization branch cuts.

Cut Name	PNN2 events (Rejection)
<b>Rejection branch</b>	
<i>SETUP<sub>RJCT</sub></i>	3368( 7.2132)
EV5	1707( 1.9730)
ELVETO	988( 1.7277)
TDFOOL	986( 1.0020)
<b>Variation TDVARNN cut limit. Standart is 0.76</b>	
TDVARNN-0.76;0.5	8( 123.2500)
TDVARNN-0.25	29( 116.1380)
<b>TDCUT-0.76;0.5</b>	8( 421.0000)
<b>TDCUT-0.25</b>	29( 116.1379)
<b>ALL_CUTS</b>	8(3873396.0000)
<b>ALL_CUTS</b>	8( 30987168)
<b>Normalization branch</b>	
PVCUTNEW	0(———)
<b>TDCUT</b>	0(———)
<b>ALL_CUTS</b>	0(———)
<b>ALL_CUTS</b>	0( 30985632)
<b>Estimated background is <math>\frac{3}{421.1250} \sim 3 \times 0.0024 = 0.0072</math></b>	

Table 7: The PNN2 TDCUT rejection and Normalization branch cuts.

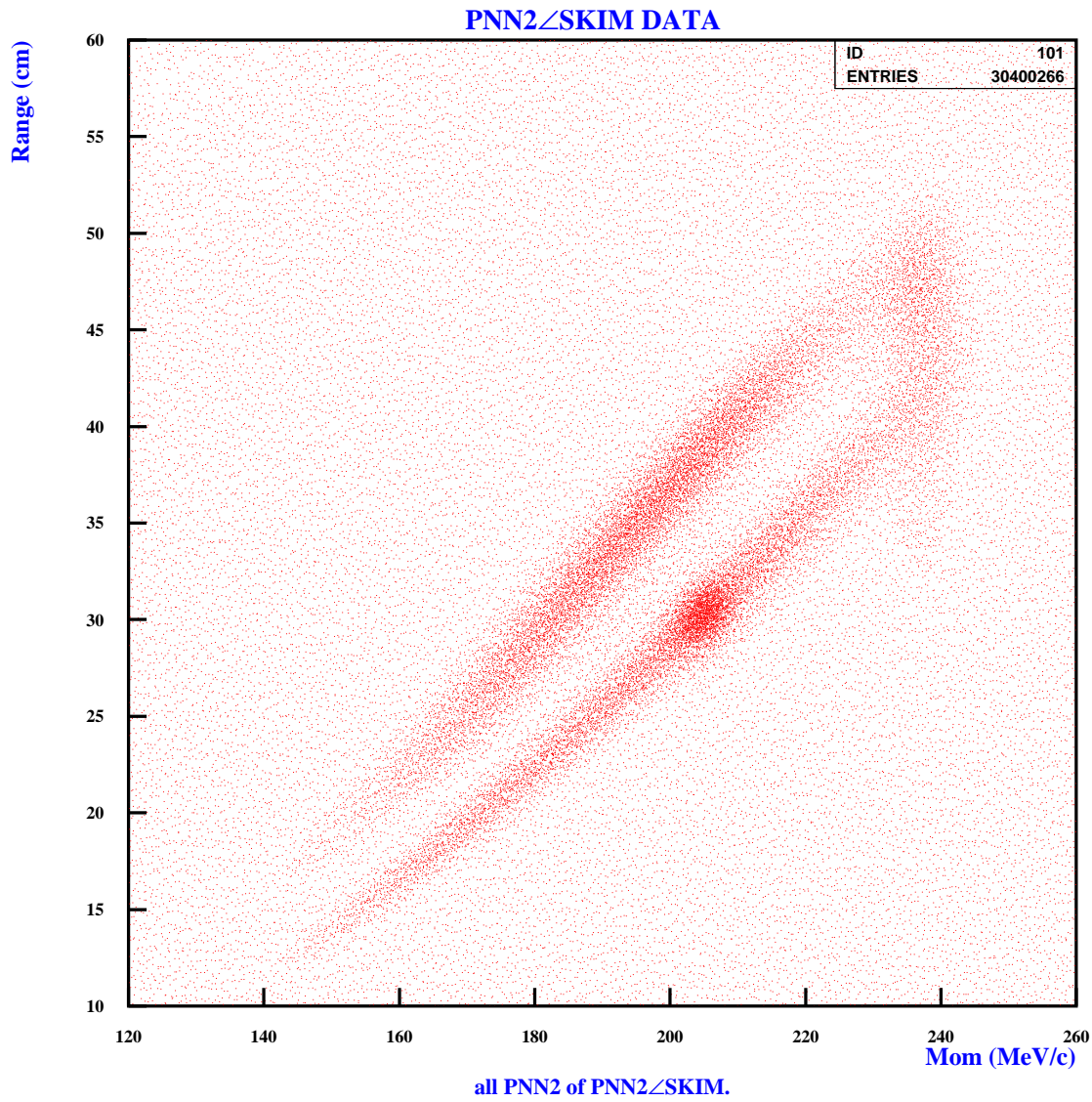


Figure 1: All PNN2\_SKIM data



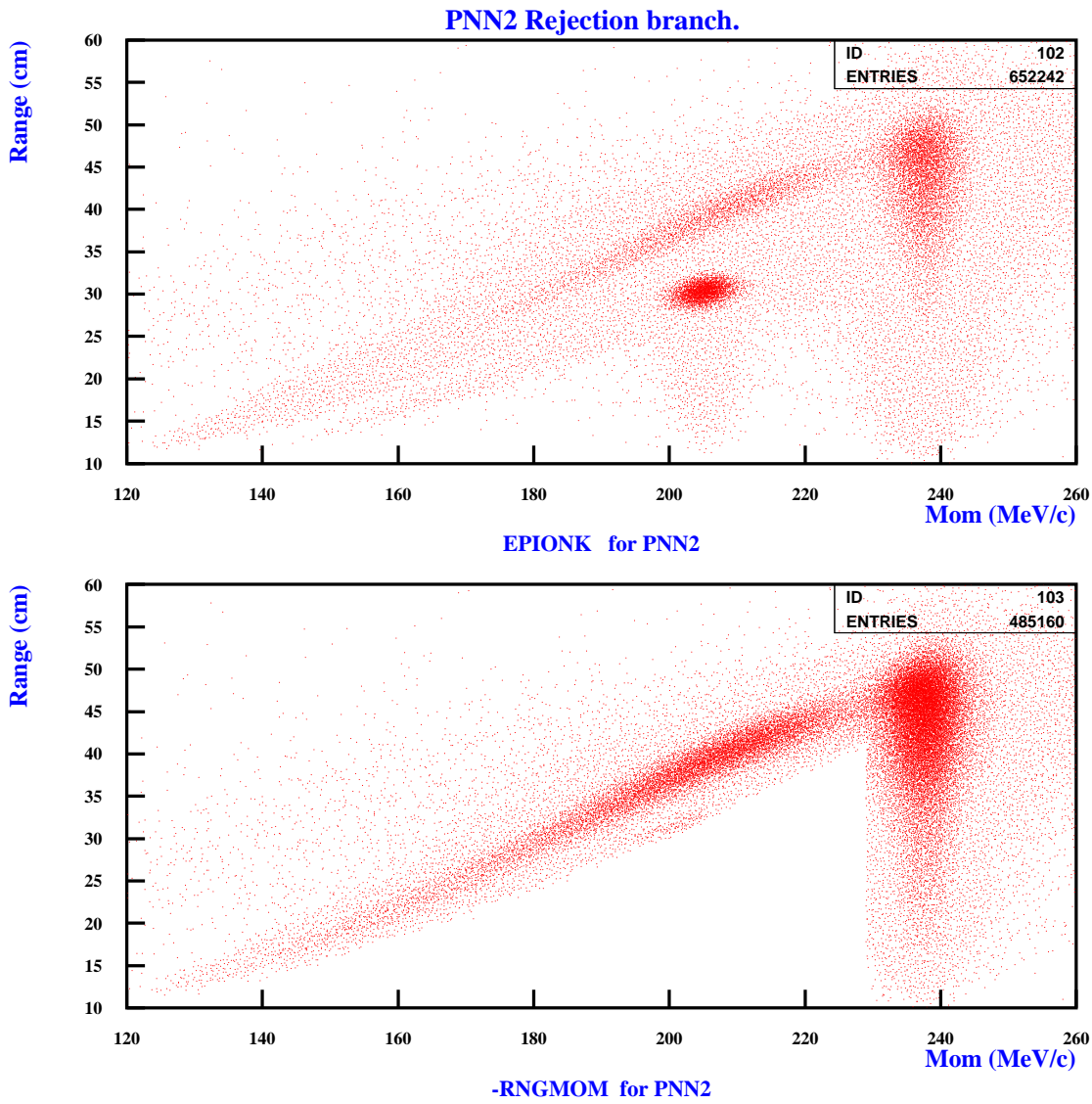


Figure 2: PNN2 Rejection branch: EPION and  $\overline{RNGMOM}$

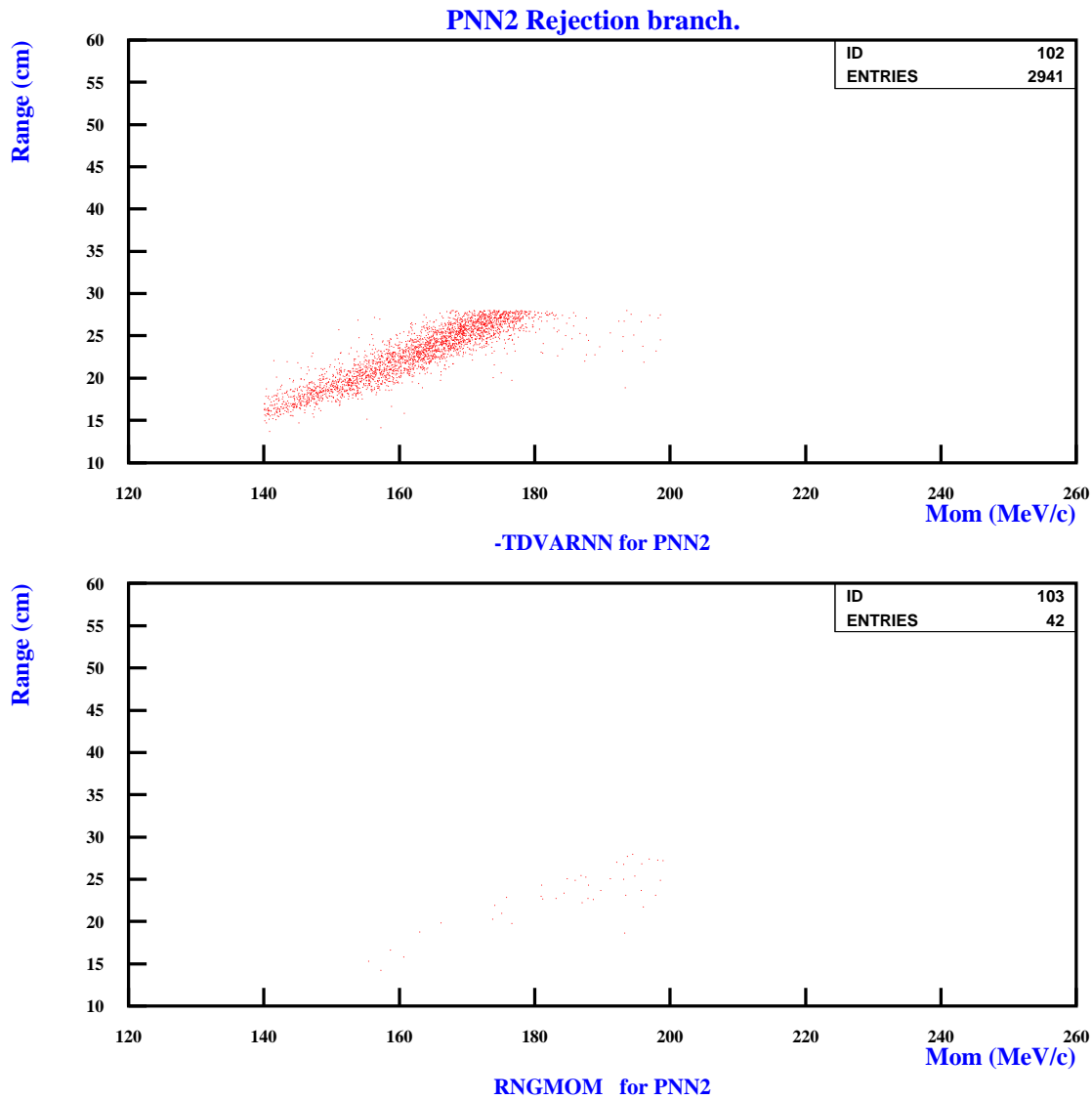


Figure 3: PNN2 Normalization branch:  $\overline{TDVARNN}$  and RNGMOM

## References

- [1] S. Chen, J. Hu, A. Konaka, J. Mildenerger, K. Mizouchi, T. Sekiguchi, D. Vavilov, 2002  $\pi^+\nu\bar{\nu}$  data analyses, E949 K-034.
- [2] A. Artamonov, TD acceptance and rejection for  $\pi^+\nu\bar{\nu}$  analyses, E949 K-051.
- [3] Tetsuro Sekiguchi, Measurement of the  $K^+ \rightarrow \pi^+\nu\bar{\nu}$  Branching Ratio, KEK K-decay Report 2005-3, February 2005, E949J/KEK.