

Product Description

SALSA® MLPA® Probemix P419-B1 CDKN2A/2B-CDK4

To be used with the MLPA General Protocol.

Version B1

For complete product history see page 10.

Catalogue numbers:

- **P419-025R:** SALSA MLPA Probemix P419 CDKN2A/2B-CDK4, 25 reactions.
- **P419-050R:** SALSA MLPA Probemix P419 CDKN2A/2B-CDK4, 50 reactions.
- **P419-100R:** SALSA MLPA Probemix P419 CDKN2A/2B-CDK4, 100 reactions.

To be used in combination with a SALSA MLPA reagent kit and Coffalyser.Net data analysis software. MLPA reagent kits are either provided with FAM or Cy5.0 dye-labelled PCR primer, suitable for Applied Biosystems and Beckman/SCIEX capillary sequencers, respectively (see www.mrcholland.com).

Certificate of Analysis

Information regarding storage conditions, quality tests, and a sample electropherogram from the current sales lot is available at www.mrcholland.com.

Precautions and warnings

For professional use only. Always consult the most recent product description AND the MLPA General Protocol before use: www.mrcholland.com. It is the responsibility of the user to be aware of the latest scientific knowledge of the application before drawing any conclusions from findings generated with this product.

General information

The SALSA MLPA Probemix P419 CDKN2A/2B-CDK4 is a **research use only (RUO)** assay for the detection of deletions or duplications in the *CDKN2A*, *CDKN2B* and *CDK4* genes, which are associated with familial cutaneous melanoma, neural system tumour- and pancreatic cancer syndromes. This probemix can also be used to detect the presence of a *MITF* p.E318K (c.952G>A) point mutation and the status of codon 24 of the *CDK4* gene with a WT probe.

Malignant melanoma is estimated to be hereditary in 5-10% of the cases. Familial cutaneous melanoma arises in an autosomal-dominant pattern within the affected families, and germline alterations in the *CDKN2A* gene (9p21.3) are detected in up to 40% of cases (Goldstein et al. 2007). The *CDKN2A* gene encodes for two proteins read in alternative reading frames, namely p16^{INK4A} and p14^{ARF}. The majority of *CDKN2A* mutations detected in familial melanoma patients affect exons 1 and 2, which code for p16^{INK4A}. However, exon 1 mutations specific for p14^{ARF} have also been reported (Hewitt et al. 2002), as well as larger genomic deletions of *CDKN2A* (Randerson-Moor et al. 2001; Knappskog et al. 2006; Lesueur et al. 2008). Moreover, both heterozygous and homozygous deletions harbouring both *CDKN2A* and *CDKN2B* are frequently detected in somatic melanoma samples (Flores et al. 1996).

Another high-penetrance, but low-frequency, melanoma susceptibility gene is *CDK4* (12q14.1), which is mutated in 2% of the melanoma families (Goldstein et al. 2007). Two point mutations (p.R24H and p.R24K) of *CDK4* have been detected in familial melanoma cases (Zuo et al. 1996). In addition, a germline mutation p.E318K (c.952G>A) in the *MITF* gene has been suggested to associate with predisposition to familial melanoma (Yokoyama et al. 2011; Bertolotto et al. 2011).

This SALSA MLPA probemix is not CE/FDA registered for use in diagnostic procedures. Purchase of this product includes a limited license for research purposes.

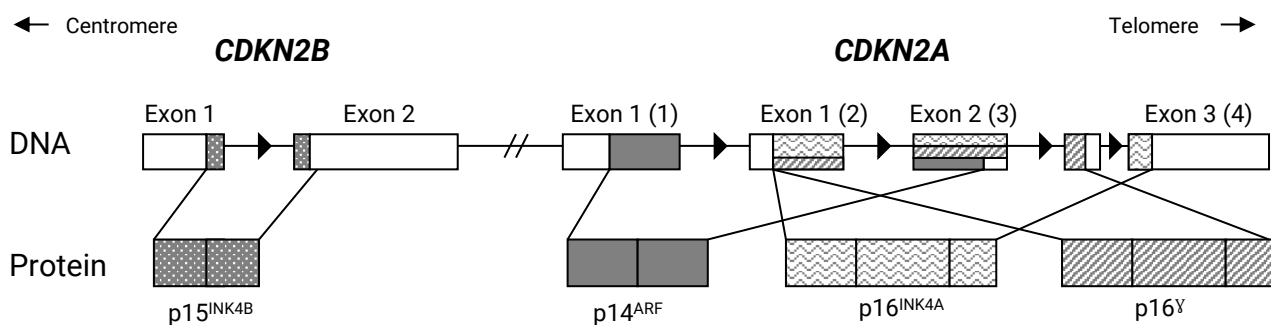
Gene structure and transcript variants:

Entrez Gene shows transcript variants of each gene: <http://www.ncbi.nlm.nih.gov/sites/entrez?db=gene>
Matched Annotation from NCBI and EMBL-EBI (MANE): <https://www.ncbi.nlm.nih.gov/refseq/MANE/> and <http://tark.ensembl.org/>

For NM_ mRNA reference sequences: <http://www.ncbi.nlm.nih.gov/sites/entrez?db=nucleotide>
Locus Reference Genomic (LRG) database: <http://www.lrg-sequence.org/>

Exon numbering

From product description version B1-03 onwards, the exon numbering from the MANE transcripts is used for *CDKN2A*, *CDKN2B* and *CDK4*. Consequently, for *CDKN2A*, the exon numbering has been changed: NM_000077.5 (MANE Select) encoding p16INK4A and NM_058195.4 (MANE Plus Clinical) encoding p14ARF are used. Both NM_000077.5 and NM_058195.4 have distinct first exons (both numbered as exon 1) which contain the translation start codon, and share a common second exon, which is translated in different reading frames (see schematic presentation below). The exon numbering used in previous versions of this product description can be found in between brackets in the schematic presentation below. **Please be aware that the MANE and LRG exon numbering do not always correspond, and MANE exon numbering used here may differ from literature.** As changes to the databases can occur after release of this product description, the NM_ sequence and exon numbering may not be up-to-date.



Schematic presentation 1. *CDKN2A* and *CDKN2B* gene structures and proteins encoded. Exon 1 of NM_058195.4 codes the first exon of p14ARF protein and exon 1 of NM_000077.5 codes the first exon of p16INK4A protein. An alternative exon (330 nt before exon 3) for *CDKN2A* is present in NM_001195132.2 transcript variant 5. In this P419 probemix two probes for this alternative exon are included: probe 17807-L22411 at 157 nt and probe 17811-L21945 at 184 nt. The clinical significance of this transcript variant, also known as p16^γ (Lin et al. 2007) is not yet known. Transcript variant 5 includes an additional exon that causes a frameshift in the 3' coding region when compared to variant 1 (encoding p16INK4A). The resulting isoform p16^γ has a distinct C-terminus, which is longer than p16INK4A. However, this transcript is a candidate for nonsense-mediated mRNA decay and it is not known if endogenous protein p16^γ is expressed *in vivo*.

Probemix content

The SALSA MLPA Probemix P419-B1 *CDKN2A/2B-CDK4* contains 57 MLPA probes with amplification products between 121 and 504 nucleotides (nt). This includes 14 probes for the *CDKN2A* gene, nine probes for the *CDKN2B* gene, nine probes for the *CDK4* gene and 10 flanking probes in total for the *CDKN2A* and *CDKN2B* genes. Furthermore, this probemix contains one probe specific for the *MITF* p.E318K (c.952G>A) point mutation, which will only generate a signal when the mutation is present, and one wildtype probe for *CDK4* codon 24, which will have a drop in signal in case of a *CDK4* codon 24 mutation. In addition, 13 reference probes are included that detect relatively copy number stable regions in various cancer types, including cutaneous melanoma. Complete probe sequences and the identity of the genes detected by the reference probes are available in Table 3 and online (www.mrcholland.com).

This probemix contains nine quality control fragments generating amplification products between 64 and 105 nt: four DNA Quantity fragments (Q-fragments), two DNA Denaturation fragments (D-fragments), one Benchmark fragment, one chromosome X and one chromosome Y-specific fragment (see table below). More information on how to interpret observations on these control fragments can be found in the MLPA General Protocol and online at www.mrcholland.com.

Length (nt)	Name
64-70-76-82	Q-fragments (only visible with <100 ng sample DNA)
88-96	D-fragments (low signal indicates incomplete denaturation)
92	Benchmark fragment
100	X-fragment (X chromosome specific)
105	Y-fragment (Y chromosome specific)

MLPA technique

The principles of the MLPA technique (Schouten et al. 2002) are described in the MLPA General Protocol (www.mrcholland.com). More information on the use of MLPA in tumour applications can be found in Hömig-Hölzel and Savola (2012).

MLPA technique validation

Internal validation of the MLPA technique using 16 DNA samples from healthy individuals is required, in particular when using MLPA for the first time, or when changing the sample handling procedure, DNA extraction method or instruments used. This validation experiment should result in a standard deviation ≤ 0.10 for all probes over the experiment.

Required specimens

Extracted DNA, which includes DNA derived from paraffin-embedded tissues, free from impurities known to affect MLPA reactions. For more information please refer to the section on DNA sample treatment found in the MLPA General Protocol. More information on the use of FFPE tissue samples for MLPA can be found in Atanesyan et al. (2017).

Reference samples

A sufficient number (≥ 3) of reference samples should be included in each MLPA experiment for data normalisation. All samples tested, including reference DNA samples, should be derived from the same tissue type, handled using the same procedure, and prepared using the same DNA extraction method when possible. For germline testing, reference samples should be derived from different unrelated individuals who are from families without a history of familial cutaneous melanoma, neural system tumour, pancreatic cancer syndromes or other conditions related to the *CDKN2A/2B* or *CDK4* genes, while for somatic testing, reference samples should be derived from healthy individuals without a history of cancer. More information regarding the selection and use of reference samples can be found in the MLPA General Protocol (www.mrcholland.com).

Positive control DNA samples

See the section "Positive samples" on the P419 product page on our website.

SALSA Binning DNA SD008

The SD008 Binning DNA provided with this probemix can be used for binning of all probes including the *MITF* mutation-specific probe (probe 17808-L23191 at 162 nt). SD008 Binning DNA is a mixture of genomic DNA from healthy individuals and plasmid DNA that contains the target sequence detected by the above mentioned probe. Inclusion of one reaction with 5 μ l SD008 Binning DNA in initial MLPA experiments is essential as it can be used to aid in data binning of the peak pattern using Coffalyser.Net software. Furthermore, Binning DNA should be included in the experiment whenever changes have been applied to the set-up of the capillary electrophoresis device (e.g. when capillaries have been renewed). Binning DNA should never be used as a reference sample in the MLPA data analysis, neither should it be used for quantification of mutation signals. It is strongly advised that all samples tested are extracted with the same method and derived from the same source of tissue. For further details, please consult the SD008 Binning DNA product description, available online: www.mrcholland.com. **This product is for research use only (RUO).**

Data analysis

Coffalyser.Net software should be used for data analysis in combination with the appropriate lot-specific MLPA Coffalyser sheet. For both, the latest version should be used. Coffalyser.Net software is freely downloadable at www.mrcholland.com. Use of other non-proprietary software may lead to inconclusive or

false results. For more details on MLPA quality control and data analysis, including normalisation, see the Coffalyser.Net Reference Manual.

Interpretation of results

The standard deviation of each individual probe over all the reference samples should be ≤ 0.10 and the final ratio (FR) of each individual reference probe in the patient samples should be between 0.80 and 1.20 for germline testing. When these criteria are fulfilled, the following cut-off values for the FR of the probes can be used to interpret MLPA results for autosomal chromosomes or pseudo-autosomal regions:

Copy number status	Final ratio (FR)
Normal	$0.80 < FR < 1.20$
Homozygous deletion	$FR = 0$
Heterozygous deletion	$0.40 < FR < 0.65$
Heterozygous duplication	$1.30 < FR < 1.65$
Heterozygous triplication/homozygous duplication	$1.75 < FR < 2.15$
Ambiguous copy number	All other values

Note: The term “dosage quotient”, used in older product description versions, has been replaced by “final ratio” to become consistent with the terminology of the Coffalyser.Net software. (Calculations, cut-offs and interpretation remain unchanged.) Please note that the Coffalyser.Net software also shows arbitrary borders as part of the statistical analysis of results obtained in an experiment. As such, arbitrary borders are different from the final ratio cut-off values shown here above.

Please note that these above mentioned final ratios are only valid for germline testing. Final ratios are affected both by percentage of tumour cells and by possible subclonality.

- Arranging probes according to chromosomal location facilitates interpretation of the results and may reveal more subtle changes such as those observed in mosaic or subclonal cases. Analysis of parental samples may be necessary for correct interpretation of complex results of hereditary cases.
- False positive results: Please note that abnormalities detected by a single probe (or multiple consecutive probes) still have a considerable chance of being a false positive result. Sequence changes (e.g. SNVs, point mutations) in the target sequence detected by a probe can be one cause. Incomplete DNA denaturation (e.g. due to salt contamination) can also lead to a decreased probe signal, in particular for probes located in or near a GC-rich region or in or near the *CDK4* gene. The use of an additional purification step or an alternative DNA extraction method may resolve such cases. Additionally, contamination of DNA samples with cDNA or PCR amplicons of individual exons can lead to an increased probe signal (Varga et al. 2012). Analysis of an independently collected secondary DNA sample can exclude these kinds of contamination artefacts.
- Normal copy number variation in healthy individuals is described in the database of genomic variants: <http://dgv.tcag.ca/dgv/app/home>. Users should always consult the latest update of the database and scientific literature when interpreting their findings.
- Not all abnormalities detected by MLPA are pathogenic. In some genes, intragenic deletions are known that result in very mild or no disease (as described for *DMD* by Schwartz et al. 2007). For many genes, more than one transcript variant exists. Copy number changes of exons that are not present in all transcript variants may not have clinical significance. Duplications that include the first or last exon of a gene (e.g. exons 1-3) might not result in inactivation of that gene copy.
- Copy number changes detected by reference probes or flanking probes are unlikely to have any relation to the condition tested for.
- False results can be obtained if one or more peaks are off-scale. For example, a duplication of one or more exons can be obscured when peaks are off-scale, resulting in a false negative result. The risk on off-scale peaks is higher when probemixes are used that contain a relatively low number of probes. Coffalyser.Net software warns for off-scale peaks while other software does not. If one or more peaks are off-scale, rerun the PCR products using either: a lower injection voltage or a shorter injection time, or a reduced amount of sample by diluting PCR products.

P419-specific note

- In samples from tumour tissues, reference probes are more prone to have deviating copy number results as compared to blood derived germline samples. When regions targeted by reference probes are affected by copy number alterations, it can help to turn the slope correction off in Coffalyser.Net analysis to get the correct copy number interpretation on the target region.

Limitations of the procedure

- In most populations, the major cause of genetic germline defects in the *CDKN2A*, *CDKN2B* and *CDK4* are small (point) mutations, most of which will not be detected by using SALSA MLPA Probemix P419 CDKN2A/2B-CDK4. Likewise, most genetic alterations observed in somatic samples are small (point) mutations. If present, these type of mutations in the *CDKN2A*, *CDKN2B* and *CDK4* genes will not be detected by using SALSA MLPA Probemix P419.
- MLPA cannot detect any changes that lie outside the target sequence of the probes and will not detect copy number neutral inversions or translocations. Even when MLPA did not detect any aberrations, the possibility remains that biological changes in that gene or chromosomal region *do* exist but remain undetected.
- Sequence changes (e.g. SNVs, point mutations) in the target sequence detected by a probe can cause false positive results. Mutations/SNVs (even when >20 nt from the probe ligation site) can reduce the probe signal by preventing ligation of the probe oligonucleotides or by destabilising the binding of a probe oligonucleotide to the sample DNA.
- MLPA analysis on tumour samples provides information on the *average* situation in the cells from which the DNA sample was purified. Gains or losses of genomic regions or genes may not be detected if the percentage of tumour cells is low. In addition, subclonality of the aberration affects the final ratio of the corresponding probe. Furthermore, there is always a possibility that one or more reference probes *do* show a copy number alteration in a patient sample, especially in solid tumours with more chaotic karyotypes.

Confirmation of results

Copy number changes detected by only a single probe always require confirmation by another method. An apparent deletion detected by a single probe can be due to e.g. a mutation/polymorphism that prevents ligation or destabilises the binding of probe oligonucleotides to the DNA sample. Sequence analysis can establish whether mutations or polymorphisms are present in the probe target sequence. The finding of a heterozygous mutation or polymorphism indicates that two different alleles of the sequence are present in the sample DNA and that a false positive MLPA result was obtained.

Copy number changes detected by more than one consecutive probe should be confirmed by another independent technique such as long range PCR, qPCR, array CGH or Southern blotting, whenever possible. Deletions/duplications of more than 50 kb in length can often be confirmed by FISH.

LOVD and COSMIC mutation databases

CDKN2A database (LOVD) - <https://databases.lovd.nl/shared/genes/CDKN2A>

CDKN2B database (LOVD) - <https://databases.lovd.nl/shared/genes/CDKN2B>

CDK4 database (LOVD) - <https://databases.lovd.nl/shared/genes/CDK4>

COSMIC database for somatic mutations in cancer - <https://cancer.sanger.ac.uk/cosmic>

We strongly encourage users to deposit positive results in the LOVD and COSMIC. Recommendations for the nomenclature to describe deletions/duplications of one or more exons can be found on <http://varnomen.hgvs.org/>.

Please report false positive results due to SNVs and unusual results (e.g. a deletion of *CDKN2A* exons 1 and 3 but not exon 2) to MRC Holland: info@mrcholland.com.

Table 1. SALSA MLPA Probemix P419-B1 CDKN2A/2B-CDK4

Length (nt)	SALSA MLPA probe	Chromosomal position (hg18) ^a				
		Reference	CDKN2A	CDKN2B	CDK4	Other
64-105	Control fragments – see table in probemix content section for more information					
121	Reference probe 19616-L27455	4p13				
128	Reference probe 21566-L30677	18q21				
132	CDKN2B probe 22023-L30944			Exon 2		
140	CDKN2B probe 11867-L23435			Exon 1		
145	Reference probe 14199-L22409	2q13				
151	CDK4 probe 03173-L22410				Exon 3	
157 Ø	CDKN2A probe 17807-L22411		Intron 2			
162 §	MITF probe 17808-L23191					p.E318K (c.952G>A)
166	CDK4 probe 17809-L21943				Exon 2	
172	Reference probe 12741-L21983	21q22				
178	CDK4 probe 17810-L21944				Exon 1	
184 Ø	CDKN2A probe 17811-L21945		Intron 2			
190 «	CDK4 probe 17812-L23573				Exon 6	
196	Reference probe 05268-L30942	2p22				
202 ~	MLLT3 probe 01287-L23185					9p21.3
208	CDKN2B probe 16066-L23293			Exon 1		
216 ∞ Ж	CDK4 probe 17813-SP0552-L22575				WT codon 24	
222	CDKN2B probe 11871-L22416			Exon 1		
229	CDKN2B probe 16059-L18233			Exon 2		
236	CDKN2A probe 21912-L19021		Exon 3			
242	CDKN2A probe 01289-L31535		Exon 1			
250	Reference probe 18056-L31125	16q23				
256	CDKN2A probe 16060-L31124		Upstream			
263	CDKN2A probe 15674-L31123		Exon 2			
269	CDKN2A probe 15675-L31122		Downstream			
275 «	CDK4 probe 17735-L31121				Exon 8	
283	CDKN2A probe 01291-L22469		Exon 3			
288	Reference probe 08834-L30725	2p13				
294 ~	DMRTA1 probe 18242-L23192					9p21.3
301 ~	MTAP probe 15677-L21991					9p21.3
307 ~	TMC1 probe 08987-L23572					9q21.13
314	Reference probe 17876-L23179	19q13				
319 ~	MTAP probe 01293-L22907					9p21.3
328 ~	MTAP probe 01294-L13278					9p21.3
335	Reference probe 09776-L23522	15q15				
341	CDKN2A probe 14004-L31117		Upstream			
349 ~	DMRTA1 probe 18243-L23511					9p21.3
357	CDK4 probe 17815-L23512				Exon 4	
364	CDKN2A probe 21951-L30767		Exon 2			
373	CDKN2B probe 15992-L23660			Upstream		
379	Reference probe 05288-L23294	14q22				
385	CDKN2A probe 17817-L23295		Exon 2			
394	CDKN2A probe 08659-L30724		Exon 1			
400 «	CDK4 probe 21952-L30768				Exon 7	
409	CDKN2B probe 03814-L03851			Exon 1		
418 «	CDK4 probe 21950-L30943				Exon 8	
425	CDKN2A probe 15680-L30801		Upstream			
432 ~	PTENP1 probe 17311-L23180					9p13.3
440 ~	MTAP probe 17819-L23181					9p21.3
448	CDKN2B probe 17820-L23182			Exon 2		

Length (nt)	SALSA MLPA probe	Chromosomal position (hg18) ^a				
		Reference	CDKN2A	CDKN2B	CDK4	Other
454	Reference probe 09107-L21996	4q25				
463	CDKN2B probe 17821-L21955			Exon 2		
470 ~	MIR31 probe 13665-L22879					9p21.3
477	Reference probe 14956-L31118	6q22				
483 «	CDK4 probe 21953-L30769				Exon 5	
490	CDKN2A probe 12475-L30941		Upstream			
504	Reference probe 21229-L30802	10p11				

^a See section Exon numbering on page 2 for more information.

§ Mutation-specific probe. This probe will only generate a signal when the *MITF* p.E318K (c.952G>A) mutation is present.

∞ Wild type sequence detected. A lowered probe signal can be due to a mutation in codon 24 of *CDK4*. Other variants near the ligation site can also cause a lowered signal. A positive result must be confirmed by another method.

« Probe located in or near a GC-rich region. A low signal can be caused by salt contamination in the DNA sample leading to incomplete DNA denaturation, especially of GC-rich regions.

Ж This probe consists of three parts and has two ligation sites. A low signal of this probe can be due to depurination of the sample DNA, e.g. due to insufficient buffering capacity or a prolonged denaturation time. When this occurs in reference samples, it can look like an increased signal in the test samples.

~ Flanking probe. Included to help determine the extent of a deletion/duplication. Copy number alterations of only the flanking or reference probes are unlikely to be related to the condition tested.

Ø This probe targets an alternative exon present in NM_001195132.2 transcript variant 5, also known as p16^γ. Clinical and/or diagnostic significance of copy number alterations in this alternative exon is not yet known, please see Schematic representation 1 and the note below this figure on page 2 for further information.

SNVs located in the target sequence of a probe can influence probe hybridization and/or probe ligation. Single probe aberration(s) must be confirmed by another method.

Table 2a. *CDKN2A* and *CDKN2B* probes arranged according to chromosomal location

Length (nt)	SALSA MLPA probe	Gene (exon) ^a	Chromosomal band (hg18) / Ligation site	Partial sequence ^b (24 nt adjacent to ligation site)	Distance to next probe
202 ~	01287-L23185	<i>MLLT3</i>	9p21.3	GGTCCGGAGCAC-AGTAACATACAG	891.4 kb
470 ~	13665-L22879	<i>MIR31</i>	9p21.3	GTCCTTCGTGTA-TTGCTGTGTATG	290.7 kb
328 ~	01294-L13278	<i>MTAP</i> , ex 1	NM_002451.4; 123-122 reverse	GGTGGTGGTGCC-AGAGGCCATGTC	35.2 kb
440 ~ #	17819-L23181	<i>MTAP</i> , ex 5	NM_002451.4; 502-503	TGGAAGTCATTC-TTGTGCCAGAGG	16.8 kb
319 ~	01293-L22907	<i>MTAP</i> , ex 6	NM_002451.4; 725-726	GAGGTGGTTCTT-GCTAAGGAGGCT	4.5 kb
301 ~ #	15677-L21991	<i>MTAP</i> , ex 7	NM_002451.4; 825-826	ACCGGGTCTTAA-AGACCCTGAAAG	108.2 kb
269	15675-L31122	CDKN2A , down	NM_000077.5 & NM_058195.4; 182 nt after ex 3	TGAAATGCGGTT-AAAATGATGAAT	0.5 kb
236	21912-L19021	CDKN2A , ex 3	NM_000077.5; 656-657 NM_058195.4; 730-731	CCTTTTAACGTA-GATATATGCCTT	0.1 kb
283	01291-L22469	CDKN2A , ex 3	NM_000077.5; 510-511 NM_058195.4; 584-585	TGAAAGAACCAG-AGAGGCTCTGAG	0.4 kb
		stop codon	499-501 (ex 3) of NM_000077.5		
157 Ø	17807-L22411	CDKN2A , int 2	NM_000077.5 & M_058195.4; 358 nt before ex 3; NM_001195132.2; 658-659	GGGAAAGGCCAC-ATCTTCACGCCT	0.1 kb
184 Ø	17811-L21945	CDKN2A , int 2	NM_000077.5 & M_058195.4; 446 nt before ex 3; NM_001195132.2; 570-571	AGCGCCAGAGCC-TGAGGCGCCCTT	2.3 kb
385	17817-L23295	CDKN2A , ex 2	NM_000077.5; 430-431 NM_058195.4; 504-505	TGCGCGCGGCTG-CGGGGGGCACCA	0.2 kb
		stop codon	458-460 (ex 2) of NM_058195.4		
364 #	21951-L30767	CDKN2A , ex 2	NM_000077.5; 273-272 reverse NM_058195.4; 347-346 reverse	GCGTCGTGCACG-GGTCGGGTGAGA	0.1 kb
263	15674-L31123	CDKN2A , ex 2	NM_000077.5 & NM_058195.4; 45 nt before ex 2	TCCTTTCCGTCA-TGCCGGCCCCCA	3.5 kb
242	01289-L31535	CDKN2A , ex 1	NM_000077.5; 158-157 reverse NM_058195.4; 3.5 kb before ex 2	TCCGACCGTAAC-TATTCGGTGCGT	0.2 kb

Length (nt)	SALSA MLPA probe	Gene (exon) ^a	Chromosomal band (hg18) / Ligation site	Partial sequence ^b (24 nt adjacent to ligation site)	Distance to next probe
		start codon	31-33 (ex 1) of NM_000077.5		
394	08659-L30724	CDKN2A , ex 1	NM_000077.5; 71 nt before ex 1 NM_058195.4; 3.7 kb before ex 2	GCACCGGAGGAA-GAAAGAGGAGGG	0.1 kb
256	16060-L31124	CDKN2A , up (int 1)	NM_000077.5; 138 nt before ex 1 NM_058195.4; 3.8 kb before ex 2	GCCTGGAAAGAT-ACCGCGGTCCCT	19.3 kb
341	14004-L31117	CDKN2A , up (ex 1)	NM_000077.5; 19.4 kb before ex 1 NM_058195.4; 92-93	TGACCCTCCGGA-TTCGGCGCGCGT	0.1 kb
		start codon	62-64 (ex 1) of NM_058195.4		
425	15680-L30801	CDKN2A , up (ex 1)	NM_000077.5; 19.6 kb before ex 1 NM_058195.4; 23 nt before ex 1	AGTCTGCAGTTA-AGGGGGCAGGAG	0.2 kb
490	12475-L30941	CDKN2A , up	NM_000077.5; 19.7 kb before ex 1 NM_058195.4; 175 nt before ex 1	CGCAGGGCTCAG-AGCCGTTCCGAG	8.4 kb
448	17820-L23182	CDKN2B , ex 2	NM_004936.4; 3776-3777	GACATTACCAAG-GTTTGTACAAAT	1.9 kb
463	17821-L21955	CDKN2B , ex 2	NM_004936.4; 1923-1924	TCAGGGTGCAGA-GGTCAGACTAAG	1.0 kb
229	16059-L18233	CDKN2B , ex 2	NM_004936.4; 899-900	GCCTGTCTGAGA-CTCACAGGAAGG	0.2 kb
		stop codon	767-769 (ex 2)		
132 #	22023-L30944	CDKN2B , ex 2	NM_004936.4; 691-690 reverse	ACGGGCAGACGA-CCCCAGGCATCG	2.8 kb
409	03814-L03851	CDKN2B , ex 1	NM_004936.4; 462-463	CCTGGAAGCCGG-CGCGGATCCCAA	0.1 kb
		start codon	353-355 (ex 1)		
140	11867-L23435	CDKN2B , ex 1	NM_004936.4; 319-320	CCAACGGTGGAT-TATCCGGGCCGC	0.1 kb
222	11871-L22416	CDKN2B , ex 1	NM_004936.4; 252-253	TCCTAGGAAGGA-GAGAGTGCGCCG	0.3 kb
208	16066-L23293	CDKN2B , ex 1	NM_004936.4; 91 nt before ex 1	CCTCCCGCGGAT-CACAGCGGACAG	0.1 kb
373	15992-L23660	CDKN2B , up	NM_004936.4; 163 nt before ex 1	GTCTCTGGCGCA-TGCGTCTAGCA	437.6 kb
294 ~	18242-L23192	DMRTA1 , ex 1	9p21.3	GCGGTCAGCGCA-CTTCCACTTGG	4.4 kb
349 ~	18243-L23511	DMRTA1 , ex 2	9p21.3	GGCTAGAAGGCA-TTCTACGGTTCT	11.2 Mb
432 ~	17311-L23180	PTENP1	9p13.3	CAAACTAATTA-CAGAGTTGCGCA	40.9 Mb
307 ~	08987-L23572	TMC1	9q21.13	ATTCTGAGGTT-TCTGGCTAACTT	-

Exon numbering used in previous versions of this product description can be found in between brackets.

~ Flanking probe. Included to help determine the extent of a deletion/duplication. Copy number alterations of only the flanking or reference probes are unlikely to be related to the condition tested.

Ø This probe targets an alternative exon present in NM_001195132.2 transcript variant 5, also known as p16γ. Clinical and/or diagnostic significance of copy number alterations in this alternative exon is not yet known, please see Schematic representation 1 and the note below this figure on page 2 for further information.

This probe's specificity relies on a single nucleotide difference compared to a related gene or pseudogene. As a result, an apparent duplication of only this probe can be the result of a non-significant single nucleotide sequence change in the related gene or pseudogene.

Table 2b. CDK4 probes arranged according to chromosomal location

Length (nt)	SALSA MLPA probe	Gene (exon) ^a	Chromosomal band (hg18) / Ligation site	Partial sequence ^b (24 nt adjacent to ligation site)	Distance to next probe
275 «	17735-L31121	CDK4 , ex 8	NM_000075.4; 1157-1158	TCTCTGAGGCTA-TGGAGGGTCCTC	0.2 kb
		stop codon	1065-1067 (ex 8)		
418 «	21950-L30943	CDK4 , ex 8	NM_000075.4; 976-977	CTCCCTCAGGA-AATGCTGACTTT	0.6 kb
400 «	21952-L30768	CDK4 , ex 7	NM_000075.4; 959-960	GAGGAGTCGGGA-GCAGAGCTGCTG	0.3 kb
190 «	17812-L23573	CDK4 , ex 6	NM_000075.4; 827-828	GACCAGTTGGGC-AAAATCTTTGAG	1.3 kb
483 «	21953-L30769	CDK4 , ex 5	NM_000075.4; 689-690	GTTGTTACACTC-TGGTACCGAGCT	0.2 kb
357	17815-L23512	CDK4 , ex 4	NM_000075.4; 644-645	GGCCTGGCCAGA-ATCTACAGCTAC	0.3 kb
151	03173-L22410	CDK4 , ex 3	NM_000075.4; 433-434	AACCCTGGTGTT-TGAGCATGTAGA	0.3 kb
166	17809-L21943	CDK4 , ex 2	NM_000075.4; 303-304	GAGGAGGCCTTC-CCATCAGCACAG	0.1 kb
216 ∞ Ж	17813-SP0552-L22575	CDK4 , ex 2	WT for codon 24 NM_000075.4; 225-224 and 197-196 reverse	GTGGGGATCACG-28nt spanning oligo-ACACCAATTTCA	0.7 kb
		start codon	156-158 (ex 2)		
178	17810-L21944	CDK4 , ex 1	NM_000075.4; 74 nt before ex 1	TCCGGCGTTCGC-CCCGCCCTCCCA	-

∞ Wild type sequence detected. The presence of the **CDK4** codon 24 mutation will result in a decreased probe signal. Other variants near the ligation site can also cause a lowered signal. A positive result must be confirmed by another method.

⚠ This probe consists of three parts and has two ligation sites. A low signal of this probe can be due to depurination of the sample DNA, e.g. due to insufficient buffering capacity or a prolonged denaturation time.

« Probe located in or near a GC-rich region. A low signal can be caused by salt contamination in the DNA sample leading to incomplete DNA denaturation, especially of GC-rich regions.

Table 2c. *MITF* probe

Length (nt)	SALSA MLPA probe	MITF point mutation	Ligation site	Partial sequence ^b (24 nt adjacent to ligation site)	Distance to next probe
162 §	17808-L23191	p.E318K (c.952G>A)	NM_000248.4; 1083-1084	TCATCAAGCAAA-AACCCGTTCTTG	-

§ Mutation-specific probe. This probe will only generate a signal when the *MITF* p.E318K (c.952G>A) mutation is present. It has been tested on artificial DNA and on positive cell line samples listed on page 3.

^a See section Exon numbering on page 2 for more information.

^b Only partial probe sequences are shown. Complete probe sequences are available at www.mrcholland.com. Please notify us of any mistakes: info@mrcholland.com.

SNVs located in the target sequence of a probe can influence probe hybridization and/or probe ligation. Single probe aberration(s) must be confirmed by another method.

Table 3. Reference probes arranged according to chromosomal location.

Length (nt)	SALSA MLPA probe	Gene	Chromosomal band (hg18)	Partial sequence (24 nt adjacent to ligation site)	Location (hg18) in kb
196	05268-L30942	<i>SPAST</i>	2p22	GGACGTCTATAA-TGACAGTACTAA	02-032,177
288	08834-L30725	<i>DYSF</i>	2p13	TATTATCTGGAA-TACCAGAGATGT	02-071,750
145	14199-L22409	<i>EDAR</i>	2q13	GAGAGTTCTGTG-GGTGGAGAGAAG	02-108,894
121	19616-L27455	<i>ATP8A1</i>	4p13	CAGATTCTTCTT-CGAGGAGCTCAG	04-042,278
454	09107-L21996	<i>CFI</i>	4q25	ACGATGCATGTA-TCATTAGGTTGG	04-110,887
477	14956-L31118	<i>LAMA2</i>	6q22	GAATGCTGTATG-TTGGTGGGTTAC	06-129,868
504	21229-L30802	<i>CCDC7</i>	10p11	ATCGCCTTAAAC-AGAGGTCTAAAT	10-032,800
379	05288-L23294	<i>ATL1</i>	14q22	AAGCTAACAATT-TAGCAGCCGTGG	14-050,160
335	09776-L23522	<i>SPG11</i>	15q15	TCAGCAGAACAA-ATGGCCCTTCT	15-042,700
250	18056-L31125	<i>PLCG2</i>	16q23	GATCCAGCAGTA-CTTCCCATCCAA	16-080,518
128	21566-L30677	<i>DCC</i>	18q21	GAGTTGTGGCTT-ACAATGAATGGG	18-048,959
314	17876-L23179	<i>SLC7A9</i>	19q13	CCTAAGACCACC-AGTCTCCAAAAG	19-038,051
172	12741-L21983	<i>RIPK4</i>	21q22	AAGCCAAGAAGA-TGGAGATGGCCA	21-042,050

Complete probe sequences are available at www.mrcholland.com.

Related products

For related products, see the [product page](#) on our website.

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P419 product history	
Version	Modification
B1	Two probes for <i>CDK4</i> have been replaced and one has been added, one probe for <i>CDKN2A</i> has been replaced, one probe for <i>CDKN2B</i> has been added, several reference probes have been replaced, and there are several differences in lengths but not in the sequences detected.
A2	Several probes have a small change in length, but no change in sequence detected.
A1	First release.

Implemented changes in the product description
<p>Version B1-05 – 30 June 2025 (04P)</p> <ul style="list-style-type: none"> - Description of the position of the 256 nt, 341 nt and 425 nt probe changed (no change in actual target sites). - Positive control DNA samples section: information moved to product page on website. - Related SALSA MLPA products section replaced with a reference to the product page on website. <p>Version B1-04 – 31 January 2023 (04P)</p> <ul style="list-style-type: none"> - Paragraph about the positive samples updated with more detailed copy number alteration information on cancel cell line samples on page 3.

- *CDKN2A* probe (16060-L31124) at 256 nt location updated in Tables 1 and 2: intron 1, instead of exon 1. Version B1-03– 01 November 2022 (04P)
- Product description rewritten and adapted to a new template.
- Exon numbering of the *CDKN2A* gene has been changed according to MANE.
- Ligation sites of the probes targeting the *CDKN2A*, *CDKN2B* and *MTAP* genes are updated according to new versions of the NM_ reference sequences.
- Small changes of probe lengths in Table 1 and 2 in order to better reflect the true lengths of the amplification products.
- New references added on page 10.

Version B1-02 – 07 June 2019 (01P)

- Correction made to associate the proteins p16^{INK4a} and p14^{ARF}, encoded by the *CDKN2A* gene, to the correct transcripts (NM_000077 and NM_058195, respectively) on page 2 and 8.
- Various minor textual changes.

Version B1-01 – 17 December 2018 (01P)

- Product description adapted to a new product version (version number changed, changes in Table 1 and Table 2).
- Product description adapted to a new template.
- For uniformity, the chromosomal positions and bands in this document are now all based on hg18(NCBI36).

More information: www.mrcholland.com; www.mrcholland.eu

	MRC Holland bv; Willem Schoutenstraat 1 1057 DL, Amsterdam, The Netherlands
E-mail	info@mrcholland.com (information & technical questions) order@mrcholland.com (orders)
Phone	+31 888 657 200