

# **NUCLEIC ACID CONSTRUCT FOR INCREASING ADENO-ASSOCIATED VIRUS YIELD, AND CONSTRUCTION METHOD THEREFOR**

## **TECHNICAL FIELD**

5 The present invention relates to the field of gene transfer vector technology, in particular to a nucleic acid construct for increasing adeno-associated virus (AAV) yield and construction method therefor.

## **TECHNICAL BACKGROUND**

10 Recombinant adeno-associated virus (rAAV) is a type of gene transfer vector widely used in basic research and clinical gene therapy. Because of its clinical safety, broad host range, low immunogenicity, and long-lasting expression of exogenous genes *in vivo*, rAAV has been considered one of the most promising gene transfer vectors and widely used in gene therapy and vaccine research around the world. In recent years, more and more investigators start using rAAV for preclinical studies in large animals and clinical trials. AAV genome comprises three key elements: ITR sequences, coding genes for nonstructural  
15 protein Rep, and coding genes for structural protein Cap.

Baculovirus/insect cell system is often used for production of recombinant proteins. Compared with the production using the standard triple-transfection method in HEK293 cells, insect cells can be cultured at high density, serum-free suspension culture, and can be easily scaled up. And, the production method using baculovirus-infected cells is more stable batch to batch. Since 2002, investigators have begun to use  
20 baculovirus/insect cell system for the production of rAAVs. However, due to various reasons associated with the production in insect cells, e.g., the ratio of Cap, Rep, and AAV vector genomic DNAs is not easy to reach the ideal ratio, the packaging efficiency of AAV is not high. And, the rAAV vectors that are packaged by traditional methods have a higher empty capsid rate (11 %-34%) (Benskey et al., 2016). Empty AAV capsid is an impurity that must be removed in the preparation of clinical-grade AAV vectors.  
25 Because the physical and chemical properties of empty AAV and AAV carrying target gene are very similar, purification is very difficult.

## **DESCRIPTION OF THE INVENTION**

In view of the above-mentioned shortcomings of the prior art, the purpose of the present invention is to  
30 provide a nucleic acid construct and its construction method for improving the yield and quality of the rAAVs, so as to solve the problems in the prior art.

In order to achieve the above purpose and other related purposes, the nucleic acid construct provided by the first aspect of the present invention includes: AAV elements, polynucleotides encoding IE protein, and polynucleotides encoding recombination homologous region of baculovirus, and the AAV elements include a polynucleotide encoding Cap proteins, a polynucleotide encoding Rep proteins, and an AAV cis-acting element.

In some embodiments, the IE protein is encoded by one or more genes of Acie0, Acie01, Acie02, and/or, the recombination homologous region of baculovirus is selected from one or more of hr1, hr2, hr3, hr4, and hr5.

In some embodiments, the nucleic acid construct further includes a promoter of the IE protein gene. In some embodiments, the promoter of the IE protein gene is selected from one or more of Gp64, pH, p6.9, or p10.

In some embodiments, the nucleic acid construct further includes a baculovirus promoter. In some embodiments, the baculovirus promoter is linked to a recombination homologous region of baculovirus. In some embodiments, the baculovirus promoter is preferably one or more of pH, Gp64, p6.9, or p10.

In some embodiments, the AAV cis-acting element is selected from ITR sequences.

In some embodiments, the nucleic acid construct further includes an exogenous gene of interest. In some embodiments, the exogenous gene of interest is embedded in between AAV elements.

In some embodiments, the structure of the nucleic acid construct includes: IE gene expression cassette-Cap gene expression cassette-hr1-ITR-exogenous target gene expression cassette-ITR-Rep gene expression cassette. In some embodiments, the structure of the nucleic acid construct includes: IE gene expression cassette-Cap gene expression cassette-ITR-exogenous target gene expression cassette-ITR-Rep gene expression cassette.

In some embodiments, the nucleotide sequence of the nucleic acid construct comprises SEQ ID NO.1, or comprises nucleotide sequences that share at least 75%, 80%, 85%, 90%, 95%, 96 %, 97%, 98%, or 99% homology with SEQ ID NO.1. In some embodiments, the nucleotide sequence of the nucleic acid construct is shown in SEQ ID NO.1.

In some embodiments, the nucleic acid construct is an AAV vector or a recombinant baculovirus vector. In some embodiments, the nucleic acid construct is an AAV vector. In some embodiments, the nucleic acid construct is a recombinant baculovirus vector. In some embodiments, the ecombinant baculovirus vector is preferably a recombinant baculovirus shuttle vector.

The second aspect of the present invention provides a recombinant baculovirus, and the recombinant baculovirus is obtained by constructing any one of the nucleic acid constructs through the baculovirus system, or is obtained by constructing nucleic acid constructs by including any element of the nucleic acid constructs through the baculovirus system.

- 5 The third aspect of the present invention provides an adeno-associated virus, and said AAV is obtained after infection of cells with any one of the recombinant baculoviruses and packaging.

The fourth aspect of the present invention provides a cell line, which is a cell line infected by any one of the recombinant baculoviruses.

- 10 The fifth aspect of the present invention provides an AAV vector system, which includes a baculovirus system and the nucleic acid construct.

The sixth aspect of the present invention provides the construction method of the nucleic acid construct, and the construction method includes integrating the AAV elements carrying the exogenous gene of interest, the polynucleotide encoding the IE protein, and the polynucleotide encoding the recombination homologous region of baculovirus into the backbone of the baculovirus vector.

- 15 The construction method includes one or more (e.g., two or three) of the following features:

- 1) The AAV elements include the polynucleotide encoding Cap proteins, the polynucleotide encoding Rep proteins, and AAV cis-acting elements, e.g., the AAV cis-acting elements are preferably ITR sequences;
- 2) The polynucleotide encoding the IE protein is selected from one or more of Acie0, Acie01, or Acie02;
- 20 3) The backbone of the baculovirus vector is selected from one of pFastBacdual, pFastBac1, pFastBacHTA, pFastBacHTB, or pFastBacHTC; or
- 4) The recombination homologous region of the baculovirus is selected from one or more of hr1, hr2, hr3, hr4, or hr5.

- 25 The seventh aspect of the present invention provides a production method for increasing the yield of AAV, and the production method comprises the following steps: infecting insect cell lines with the recombinant baculovirus.

As mentioned above, the nucleic acid construct and its construction method of the present invention for improving the yield of AAV have at least the following beneficial effects:

- 30 1) The present invention significantly reduces the expression of the target gene inserted in the baculovirus vector in insect cells, reduces the impact of target gene expression on insect cells; improving the growth index of production cells makes it more conducive to the packaging and production of rAAV.

2) Compared with the production using traditional adherent 293 and 293T cells, as well as conventional production methods using baculovirus, this optimized vector construction method significantly improves rAAV production of single cells and unit volume cultures, and reduces production costs, and the production using this method can be scaled up.

- 5     3) A wide range of applications, including the production of AAV gene therapy vectors of various scales and types.

### **Description of Drawings and Figures**

10     Figure 1 is a schematic diagram showing the structure of the pFBd-Cap-ITR-Rep vector of the present invention.

Figure 2 is a schematic diagram showing the map of the pFBd-Cap-ITR-Rep vector of the present invention.

Figure 3 is a schematic diagram showing the structure of the pFBd-IE-hr1Cap-ITR-Rep vector of the present invention.

15     Figure 4 is a schematic diagram showing the map of the pFBd-IE-hr1Cap-ITR-Rep vector of the present invention.

Figure 5 shows the comparison of EGFP expression levels in Sf9 cells 2-4 days after infection with BV-Cap-ITR-Rep and BV-IE-hr1Cap-ITR-Rep of the present invention.

20     Figure 6 shows Western blotting detection of lysates of cells infected with two baculoviruses of the present invention using AAV Cap monoclonal antibody.

Figure 7 shows the electron microscopy examination of rAAV2 of the present invention (titer  $2.0 \times 10^{13}$  VG/mL).

25     Figure 8 shows the fluorescence observation of 293T cells 2 days after transduction with rAAV2 packaged with BV-Cap-ITR-Rep and BV-IE-hr1Cap-ITR-Rep of the present invention.

### **Detailed Description**

30     The present invention is based, at least in part, on the discovery that a nucleic acid construct comprising AAV elements, a polynucleotide encoding an IE protein, and a polynucleotide encoding a recombination homologous region of baculovirus can significantly control the expression of a gene of interest inserted in the baculovirus in its host insect cells, improve the state of cells and the packaging efficiency of AAV, thereby greatly increasing the yield of AAV. The present invention can unexpectedly reduce the empty

capsid rate of rAAV (for example, even if the expression level of Cap is increased, it will not lead to an increase in empty capsid), produce rAAV with better infectivity, and significantly improve the yield of rAAV of single cells and unit volume cultures, therefore is suitable for large-scale production of various AAV gene therapy vectors.

- 5 Unless otherwise defined below, all technical and scientific terms mentioned herein have the meanings commonly understood by those skilled in the art to which this invention belongs.

The term "nucleic acid construct" refers to an artificially constructed nucleic acid segment that can be introduced into target cells or tissues, and the nucleic acid construct can be a lentiviral vector or an AAV vector, which includes a vector backbone, i.e., the empty vector and expression framework.

- 10 The term "vector" refers to a nucleic acid fragment or polynucleotide fragment used to introduce or transfer one or more nucleic acids or one or more polynucleotides into target cells or tissues. Typically, vectors are used to introduce foreign DNA into another cell or tissue. The vector may contain a bacterial resistance gene for growth in bacteria and a promoter for expressing a protein of interest in an organism. DNA can be produced *in vitro* by PCR or any other suitable technique or techniques known to those skilled in the art.

The first aspect of the present invention provides a nucleic acid construct, said nucleic acid construct comprising: AAV elements and a polynucleotide encoding an IE protein, and the AAV elements comprising a polynucleotide encoding Cap proteins, a polynucleotide encoding Rep proteins, and AAV cis-acting elements.

- 20 In one embodiment, the nucleic acid construct further includes a polynucleotide encoding a recombination homologous region of baculovirus.

In some embodiments, the nucleotide sequence of the nucleic acid construct comprises SEQ ID NO.1, or comprises nucleotide sequences that share at least 75%, 80%, 85%, 90%, 95%, 96 %, 97%, 98%, or 99% homology to SEQ ID NO.1. In some embodiments, the nucleotide sequence of the nucleic acid construct is shown in SEQ ID NO.1.

- 25 SEQ ID NO: 1 :  
TTCTCTGTCACAGAATGAAAATTTTCTGTCATCTCTTCGTTATTAATGTTTGTAATTGACTGAA  
TATCAACGCTTATTTGCAGCCTGAATGGCGAATGGGACGCGCCCTGTAGCGGCGCATTAAGCG  
CGGCGGGTGTGGTGGTTACGCGCAGCGTGACCGCTACACTTGCCAGCGCCCTAGCGCCCGCT  
30 CCTTTCGCTTTCTTCCCTTCCTTTCTCGCCACGTTGCGCGGCTTTCCCCGTCAAGCTCTAAATC  
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AGTCCACGTTCTTTAATAGTGGACTCTTGTTCCAACTGGAACAACACTCAACCCTATCTCGG  
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 GGGGAAATGTGCGCGGAACCCCTATTTGTTTATTTTTCTAAATACATTCAAATATGTATCCGCTC  
 5 ATGAGACAATAACCCTGATAAATGCTTCAATAATATTGAAAAAGGAAGAGTATGAGTATTCAAC  
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 GGATCTCAACAGCGGTAAGATCCTTGAGAGTTTTCGCCCCGAAGAACGTTTTCCAATGATGAG  
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 TACGCCCCCTATTGACGTCAATGACGGTAAATGGCCCGCCTGGCATTATGCCAGTACATGACC  
 TTATGGGACTTTCCTACTTGGCAGTACATCTACGTATTAGTCATCGCTATTACCATGGTGATGCG  
 30 GTTTTGGCAGTACATCAATGGGCGTGGATAGCGGTTTGACTCACGGGGATTTCCAAGTCTCCA  
 CCCCATTGACGTCAATGGGAGTTTGTGTTTTGGCACCAAAATCAACGGGACTTTCCAAAATGTGCG  
 TAACAACTCCGCCCCATTGACGCAAATGGGCGGTAGGCGTGTACGGTGGGAGGTCTATATAAG  
 CAGAGCTGGTTTAGTGAACCGTCAGATCCGCTAGCGCTACCGGTGCCACCGTCGACGTTTAT  
 TTGTGAAATTTGTGATGCTATTGCTTTATTTGTAACCATCTAGCTTTATTTGTGAAATTTGTGATG

CTATTGCTTTATTTGTAACCATTATAAGCTGCAATAAACAAGTTAACAACAACAATTGCATTTCAT  
 TTTATGTTTCAGGTTTACGGGGGAGATGTGGGAGGTTTTTTTAAAGTTTAAACAGGAACCCCTAG  
 TGATGGAGTTGGCCACTCCCTCTCTGCGCGCTCGCTCGCTCACTGAGGCCGGGCGACCAAAG  
 GTCGCCCCGACGCCCGGGCGGCCTCAGTGAGCGAGCGAGCGCGCAGCTGCCTGCAGGACATG  
 5 TGAGCAAAAGGCCAGCAAAAGGCCAGGAACCGTAAAAAGGCCGCGTTGCTGGCGTTTTTCC  
 ATAGGCTCCGCCCCCTGACGAGCATCACAAAAATCGACGCTCGCGGCCGCTCTAGAGATCAT  
 GGAGATAATTAAATGATAACCATCTCGCAAATAAATAAGTATTTTACTGTTTTTCGTAACAGTTT  
 TGTAATAAAAAAACCTATAAATATTCCGGATTATTCATACCGTCCCACCATCGGGCGCGGATCC  
 GCCGCCCTGGCGGGGTTTTACGAGATTGTGATTAAGGTCCCCAGCGACCTTGACGAGCATCTG  
 10 CCCGGCATTCTGACAGCTTTGTGAACTGGGTGGCCGAGAAGGAGTGGGAGTTGCCGCCAGA  
 TTCTGACTTGATCTGAATCTGATTGAGCAGGCACCCCTGACCGTGGCCGAGAAGCTGCAGC  
 GCGACTTTCTGACGGAGTGGCGCCGTGTGAGTAAGGCCCGGAGGCCCTTTTCTTTGTGCAAT  
 TTGAGAAGGGAGAGAGCTACTTCCACTTACACGTGCTCGTGGAAACCACCGGGGTGAAATCC  
 TTAGTTTTGGGACGTTTCTGAGTCAGATTCGCGAAAACTGATTCAGAGAATTTACCGCGGG  
 15 ATCGAGCCGACTTTGCCAACTGGTTCGCGGTACAAAGACCAGAAACGGCGCCGGAGGCG  
 GGAACAAGGTGGTGGACGAGTGCTACATCCCAATTACTTGCTCCCCAAAACCCAGCCTGAG  
 CTCCAGTGGGCGTGGACTAATTTAGAACAGTATTTAAGCGCCTGTTTGAATCTCACGGAGCGT  
 AAACGGTTGGTGGCGCAGCATCTGACGCACGTGTCGCAGACGCAGGAGCAGAACAAAGAGA  
 ATCAGAATCCCAATTCTGACGCGCCGGTGATCAGATCAAAAACCTTCAGCCAGGTACATGGAGC  
 20 TGGTCGGGTGGCTCGTGGACAAGGGGATTACCTCGGAGAAGCAGTGGATACAGGAGGACCA  
 GGCCTCATACATCTCCTTCAATGCGGCCTCCAACCTCGCGGTCCCAAATCAAGGCTGCCTTGGA  
 CAATGCGGGAAAGATTATGAGCCTGACTAAAACCGCCCCCGACTACCTGGTGGGCCAGCAGC  
 CCGTGGAGGACATTTCCAGCAATCGGATTTATAAAATTTTGGAATAAACGGGTACGATCCCC  
 AATATGCGGCTTCCGTCTTTCTGGGATGGGCCACGAAAAAGTTTCGGCAAGAGGAACACCATC  
 25 TGGCTGTTTGGGCCTGCAACTACCGGGAAGACCAACATCGCGGAGGCCATAGCCCACACTGT  
 GCCCTTCTACGGGTGCGTAAACTGGACCAATGAGAACTTTCCCTTCAACGACTGTGTGGACA  
 AGATGGTGATCTGGTGGGAGGAGGGGAAGATGACCGCCAAGGTCGTGGAGTCGGCCAAAGC  
 CATTCTCGGAGGAAGCAAGGTGCGCGTGGACCAGAAATGCAAGTCCTCGGCCCAGATAGACC  
 CGACTCCCGTGATCGTCACCTCCAACACCAACATGTGCGCCGTGATTGACGGGAACCTCAACG  
 30 ACCTTCGAACACCAGCAGCCGTTGCAAGACCGGATGTTCAAATTTGAACTACCCGCGGTCT  
 GGATCATGACTTTGGGAAGGTCACCAAGCAGGAAGTCAAAGACTTTTTCCGGTGGGCAAAGG  
 ATCACGTGGTTGAGGTGGAGCATGAATTCTACGTCAAAAAGGGTGGAGCCAAGAAAAGACCC  
 GCCCCAGTGACGCAGATATAAGTGAGCCCAAACGGGTGCGCGAGTCAGTTGCGCAGCCATC  
 GACGTCAGACGCGGAAGCATCGATCAACTACGCAGACAGGTACCAAAAACAAATGTTCTCGTC

ACGTGGGCATGAATCTGATGCTGTTTCCCTGCAGACAATGCGAGAGAATGAATCAGAATTCAA  
 ATATCTGCTTCACTCACGGACAGAAAGACTGTTTAGAGTGCTTCCCGTGTCAGAATCTCAAC  
 CCGTTTCTGTCGTCAAAAAGGCGTATCAGAACTGTGCTACATTCATCATATCATGGGAAAGG  
 TGCCAGACGCTTGCACTGCCTGCGATCTGGTCAATGTGGATTTGGATGACTGCATCTTTGAAC  
 5 AATAATCTAGAGCCTGCAGTCTCGACAAGCTTGTGCGAGAAGTACTAGAGGATCATAATCAGCC  
 ATACCACATTTGTAGAGGTTTTACTTGCTTTAAAAAACCTCCCACACCTCCCCCTGAACCTGA  
 AACATAAAATGAATGCAATTGTTGTTGTTAACTTGTTTATTGCAGCTTATAATGGTTACAAATAA  
 AGCAATAGCATCACAAATTCACAAATAAAGCATTTTTTTTCACTGCATTCTAGTTGTGGTTTGT  
 CCAAACCTCATCAATGTATCTTATCATGTCTGGATCTGATCACTGCTTGAGCCTAGGAGATCCGA  
 10 ACCAGATAAGTGAAATCTAGTTCCAACTATTTTGTCAATTTTAAATTTTCGTATTAGCTTACGAC  
 GCTACACCCAGTTCCCATCTATTTTGTCACTCTTCCCTAAATAATCCTTAAAAACTCCATTTCCA  
 CCCCTCCCAGTTCCCAACTATTTTGTCCGCCACAGCGGGGCATTTTCTTCCTGTTATGTTTTT  
 AATCAAACATCCTGCCAACTCCATGTGACAAACCGTCATCTTCGGCTACTTT

In some embodiments, the AAV elements are derived from AAV of different serotypes, such as AAV1,  
 15 AAV2, AAV3, AAV4, AAV5, AAV6, AAV7, AAV8, AAV9, AAV DJ, AAV DJ/8, AAV rh10, AAV  
 Retro , AAV PHP.eB, AAV PHP.B, or AAV PHP.S. The capsid proteins of different serotypes of AAV  
 recognize different receptors on the cell surface, so the infection efficiency to different tissue cells may  
 vary greatly, showing certain organ-targeting specificity. The appropriate serotype of AAV can be  
 selected according to the specific experimental purpose, so as to achieve specific high-efficiency  
 20 transduction of a specific serotype of AAV to a specific type of cell and tissue.

In some embodiments, the AAV elements are derived from AAV1. In some embodiments, the AAV  
 elements are derived from AAV2. In some embodiments, the AAV elements are derived from AAV3. In  
 some embodiments, the AAV elements are derived from AAV4. In some embodiments, the AAV  
 elements are derived from AAV5. In some embodiments, the AAV elements are derived from AAV6. In  
 25 some embodiments, the AAV elements are derived from AAV7. In some embodiments, the AAV  
 elements are derived from AAV8. In some embodiments, the AAV elements are derived from AAV9. In  
 some embodiments, the AAV elements are derived from AAV DJ. In some embodiments, the AAV  
 elements are derived from AAV DJ/8. In some embodiments, the AAV elements are derived from AAV  
 rh10. In some embodiments, the AAV elements are derived from AAV Retro. In some embodiments, the  
 30 AAV elements are derived from AAV PHP.eB/PHP.B/PHP.S.

The Cap proteins are structural proteins, usually including VP1, VP2, and VP3 structural proteins. It is  
 believed that in some embodiments, three structural proteins can be assembled into the capsid protein of  
 AAV.

The Rep proteins are non-structural proteins, usually including Rep78 and 52 proteins. It is believed that in some embodiments, Rep proteins regulate the replication and packaging of DNA.

In one embodiment, the AAV cis-acting elements are selected from inverted terminal repeat sequences (ITR sequences). It is believed that in some embodiments, the ITR sequences fold into a hairpin structure and are the only known cis-acting elements required for replication initiation of AAV DNA and packaging of recombinant AAV virions.

In some embodiments, the nucleic acid construct further includes an exogenous gene of interest. In some embodiments, the exogenous target gene is carried by AAV elements, that is, the exogenous target gene is embedded in between the AAV elements.

Specifically, in some embodiments, the exogenous target gene is embedded between two ITR sequences.

Preferably, in some embodiments, the size of the exogenous target gene is  $\leq 3.5$  kb. It is believed that in some embodiments, due to the size limitation between the two ITR sequences, the size of the exogenous target gene should generally not be too large, otherwise it may lead to poor packaging effect.

The type of the exogenous gene varies according to the purpose of the experiment. The exogenous gene can be a gene related to the treatment of various diseases, such as AADC, FVIII, FIX, and can also be a tool gene commonly used in laboratories, such as EGFP, mCherry gene, and the like.

It is believed that in some embodiments, the nucleic acid construct also includes a promoter for the IE protein-coding gene. It is believed that in some embodiments, the promoter of the IE protein-coding gene is selected from one or more of Gp64, pH, p6.9, and p10. In some embodiments, the promoter of the IE protein-coding gene includes Gp64. In some embodiments, the promoter of the IE protein-coding gene comprises pH. In some embodiments, the promoter of the IE protein-coding gene includes p6.9. In some embodiments, the promoter of the IE protein-coding gene includes p10.

Preferably, in some embodiments, the promoter of the IE protein-coding gene is selected from strong pH promoters. It is believed that in some embodiments, incorporation of an additional copy of ie gene into the nucleic acid construct and expressed under the control of a strong promoter pH above the endogenous IE levels of the virus increases the survival of cells at late stage following baculovirus infection .

In some embodiments, the IE protein is selected from proteins encoded by one or more (e.g., two or three) genes of Acie0, Acie01, and Acie02. In some embodiments, the IE protein is selected from a protein encoded by Acie0, i.e., IE0. The nucleotide sequence of Acie0 is shown in SEQ ID NO.10, and the amino acid sequence of the IE0 protein is shown in SEQ ID NO.11. In some embodiments, the said IE protein is selected from the protein encoded by Acie01, i.e., IE1. The nucleotide sequence of Acie01 is shown in

SEQ ID NO.12, and the amino acid sequence of IE1 protein is shown in SEQ ID NO.13. In some embodiments, the IE protein is selected from the protein encoded by Acie02, namely IE2 protein. The nucleotide sequence of Acie02 is shown in SEQ ID NO.14, and the amino acid sequence of IE2 protein is shown in SEQ ID NO.15.

5 The sequences of SEQ ID NO.10-15 are as follows:

SEQ ID NO.10:

ATGATAAGAACCAGCAGTCACGTGCTGAACGTCCAGGAAAATATAATGACGTCAAACCTGTGC  
GTCATCGCCATATTCGTGCGAGGCAACGTCCGCTTGCGCAGAAGCTCAGCAGGTAATGATCGA  
TAACTTTGTTTTCTTTCACATGTACAACGCCGACATACAAATTGACGCAAAGCTGCAATGCGG  
10 CGTGCGCTCGGCCGCGTTTGCAATGATCGACGATAAACATTTGGAAATGTACAAGCATAGAAT  
AGAGAATAAATTTTTTTTATTACTATGATCAATGTGCCGACATTGCCAAACCCGACCGTCTGCCC  
GATGACGACGGCGCGTGCTGTCACCATTTTTATTTTTGATGCCCAACGTATTATTCAATGTATTAA  
AGAGATTGAAAGCGCGTACGGCGTGCGTGATCGCGGCAATGTAATAGTGTTTTATCCGTACTT  
GAAACAGTTGCGAGACGCGTTGAAGCTAATTAAAACTCTTTTGCGTGTTGTTTTAAATTTAT  
15 AAATTCTATGCAAATGTACGTGAACGAGTTAATATCAAATTGCCTGTTGTTTATTGAAAAGCTG  
GAAACTATTAATAAAACTGTAAAGTTATGAATTTGTTTGTAGACAATTTGGTTTTGTACGAAT  
GCAATGTTTGTAAAGAAATATCTACGGATGAAAGATTTTTAAAGCCAAAAGAATGTTGCGAAT  
ACGCTATATGCAACGCGTGCTGCGTTAACATGTGGAAGACGGCCACCACGCACGCAAAATGT  
CCAGCGTGACAGGACATCGTATAAATAA

20

SEQ ID NO.11:

MIRTSSHVLNVQENIMTSNCASSPYSCEATSACAEAQQVMIDNFVFFHMYNADIQIDAKLQCGVR  
SAAFAMIDDKHLEMYKHRIENKFFYYDQCADIAPDRLPDDDGACCHHFIFDAQRIIQCIKEIES  
AYGVRDRGNVIVFYPYLKQLRDALKLIKNSFACCFKIINSMQMYVNELISNCLLFIEKLETINKTV  
25 KVMNLFVDNLVLYECNVCKEISTDERFLKPKECCEYAICNACCVNMWKTATTHAKCPACRTSYK

SEQ ID NO.12:

ATGATCCGTACATCCAGCCACGTCTGAACGTCCAAGAAAACATCATGACTTCCAACCTGTGCT  
TCCAGCCCCCTACTCCTGTGAGGCCACTTCAGCCTGCGCTGAGGCCAGCAACTGCAGGTGGA  
30 CACAGGTGGCGATAAGATCGTGAACAACCAGGTCACCATGACTCAAATCAACTTCAACGCTT  
CCTACACCTCTGCCAGCACTCCCTCTCGTGCTAGCTTCGACAACTCATACTCGGAGTTCTGCG  
ACAAGCAACCTAACGATTACTTGTCTTACTACAACCACCCAACCCCGGACGGAGCTGATACTG  
TCATCTCCGACTCTGAAACCGCTGCCGCTAGCAACTTCCTCGCCTCAGTTAACTCGCTCACTG

ACAACGATTTGGTGGAGTGTCTGCTCAAGACCACTGACAACCTGGAGGAAGCTGTGTCCTCT  
 GCCTACTACAGCGAGTCACTCGAACAGCCAGTGGTCGAACAACCCTCTCCTAGCTCAGCTTA  
 CCACGCCGAGTCCTTCGAACACTCTGCTGGTGTCAACCAGCCGTCGGCCACAGGCACCAAGA  
 GGAAGTTGGACGAGTACCTGGATAACTCCCAGGGAGTTGTGGGTCAATTCAACAAGATCAAG  
 5 TTGAGACCTAAGTACAAGAAGAGCACCATCCAGTCATGCGCTACACTGGAACAAACCATCAA  
 CCACAACACTAACATCTGTACAGTGGCTTCCACCCAGGAGATCACTCACTACTTCACAAACGA  
 CTTGCCCCCTACCTGATGAGGTTGACGATAACGACTACAACCTCGAACAGATTCTCCGATCA  
 CATGTCTGAAACCGGTTACTACATGTTGTCGTAAAGAAGTCCGAGGTGAAGCCTTTCGAAAT  
 CATCTTCGCCAAGTACGTCTCTAACGTGGTCTACGAGTACACAAACAACCTACTACATGGTTGA  
 10 CAACCGTGTGTTGTTGTGACCTTCGATAAGATCCGCTTCATGATCAGCTACAACCTGGTTAAG  
 GAGACTGGCATCGAAATCCCACACTCACAGGACGTCTGCAACGATGAGACCGCCGCTCAAAA  
 CTGCAAGAAGTGTCACTTCGTGGACGTCCACCACACATTCAAGGCCGCTCTGACCTCCTACTT  
 CAACCTCGATATGTACTACGCTCAGACAACCTTCGTGACCTTGCTGCAATCACTCGGCGAGCG  
 TAAGTGTGGATTCTCTTGTGCGAAGTTGTACGAGATGTACCAGGACAAGAACCTCTTCACTTT  
 15 GCCCATCATGCTGAGCCGCAAGGAATCAAACGAGATCGAAACCGCCTCTAACAACCTTCTTCGT  
 CTCGCCATACGTTTTCCAGATCCTCAAGTACTCGGAGTCCGTCCAATTCCCGGACAACCCTCC  
 CAACAAGTACGTCGTTGATAACCTGAACCTCATCGTGAACAAGAAGAGCACTCTGACATACA  
 AGTACTCGTCCGTCGCTAACCTGCTCTTCAACAACCTACAAGTACCACGACAACATCGCTTCTA  
 ACAACAACGCCGAGAACCTCAAGAAGGTCAAGAAGGAAGACGGAAGCATGCACATCGTTGA  
 20 GCAGTACTTGACTCAAAACGTCGATAACGTTAAGGGTCACAACTTCATCGTGTTGTCCTTCAA  
 GAACGAGGAAAGGCTGACCATCGCTAAGAAGAACAAGGAGTTCTACTGGATCTCTGGCGAAA  
 TCAAGGACGTTGATGTGAGCCAGGTCATCCAAAAGTACAACAGATTCAAGCACCACATGTTC  
 GTGATCGGCAAGGTCAACCGTCGCGAGTCAACTACACTGCACAACAACCTTGCTGAAGCTCTT  
 GGCCTTGATCCTGCAGGGACTGGTGCCACTCTCCGACGCCATCACATTCGCCGAGCAAAAGC  
 25 TCAACTGCAAGTACAAGAAGTTCGAGTTCAACTAA

SEQ ID NO.13:

MIRTSSHVLNVQENIMTSNCASSPYSCEATSACAEAAQLQVDTGGDKIVNNQVTMTQINFNASYT  
 SASTPSRASFDNSYSEFCDKQPNDYLSYYNHPTPDGADTVISDSETAAASNFLASVNSLTDNDLVE  
 30 CLLKTTDNLEEAVSSAYYSESLEQPVVEQSPSSAYHAESFEHSAGVNQPSATGTRKRLDEYLDNS  
 QGVVGQFNKIKLRPKYKKSTIQSCATLEQTINHNTNICTVASTQEITHYFTNDFAPYLMRFDNDY  
 NSNRFSDHMSETGYVMFVVKKSEVKPFEIIFAKYVSNVVYEYTNYYMVDNRVVFVTFDKIRFM  
 ISYNLVKETGIEIPHSQDVCNDETAQAQNCCKCHFVDVHHTFKAALTSYFNLDMYAQTTFVTLLQ  
 SLGERKCGFLLSKLYEMYQDKNLFTLPIMLSRKESNEIETASNNFFVSPYVSQILKYSESQFPDNP

PNKYVVDNLNLIVNKKSTLTYKYSSVANLLFNKYHDNIASNNNAENLKKVKKEDGSMHIVE  
QYLTQNVNDNVKGHNFIVLSFKNEERLTIKKNEFYWISGEIKDVDVSQVIQKYNRFKHHMFVIG  
KVNRRRESTTLHNNLLKLLALILQGLVPLSDAITFAEQKLNCKYKKFEFN

5 SEQ ID NO.14:

ATGAGTCGCCAAATCAACGCCGCGCCACTCCCAGCAGCAGCCGCGCCACAGGCTGTCTCTCAG  
CCGTCGCCGCATCAACTTTACAACATCTCCCGAAGCCCAGCCGTCTTCAAGCAGTCGCAGCCA  
GCCGTCTTCAAGCAGTCGCAGCCATCGCCGTCAGGAGCGGCGTCAGGAGCAGCGTGTCAGC  
GAAGAAAACGTGCAGATTATCGGGAACGTCAACGAGCCGTTGACGCGCACCTACCATCGTCA  
10 GGGTGTCACGTATTACGTGCACGGTCAGGTTAACATTAGCAATGACGATCCGCTATTAAGTCA  
AGAGGATGACGTCATACTAATTAATAGTGAAAATGTGGATCGTGAACGGTTTCCCGACATCAC  
TGCCCAGCAGTACCAGGATAACATTGCGTCGGAGACAGCTGCGCAGAGGGCTCTGCAACGAG  
GTTTAGATCTTGAGGCTCAGCTGATGAATGAGATTGCCCCAAGGTCTCCCACTTATAGTCCATC  
TTATTCGCCGAATTACGTAATACCACAGTCGCCAGATTGTTTGCCTCGCCGCAGTCTCCGCAG  
15 CCGCAGCAGCAGCAGCAGCAGCAATCAGAACCCGAAGAAGAAGTAGAGGTTTCGTGTAATAT  
TTGTTTTACTACTTTTAAAGACACTAAAAACGTAAATTCCTCGTTTGTGACTTCGATTCAATGTA  
ACCATGCTGTGTGTTTCAAGTGTTATGTCAAGATAATTATGGACAATTCTGTGTACAAATGTTTT  
TGCAGCGCTACTTCATCAGATTGTGCGGTGTACAATAAGCACGGGTATGTAGAATTTATGCCCA  
TTAACGTCACTCGTAACCAGGATTCCATCAAACAGCATTGGCGCGAGCTTTTAGAAAATAACA  
20 CGGTCAACAATCACACCACGGACTTGAACATGTGGAGCAATTGCAAAAAGAACTGTCCGAG  
CTGCGAGCCAAGACCAGCCAAGTTGAACATAAAATGACCATGTAAACAGCGACTACATTATG  
CTTAAACACAAGCATGCTGTGCGCCGAATTAGATTTACAAAAGGCAAACTATGACTTGCAAGAA  
TCTACCAAGAAATCAGAAGAGTTGCAATCGACTGTGAATAATCTGCAAGAACAATTGCGTAAG  
CAGGTGGCCGAGTCTCAAGCCAAATTTTCAGAGTTTGAGCGCAGTAACTCTGATTAGTTTCT  
25 AAGTTACAAACTGTTATGTCTAGACGTAA

SEQ ID NO.15:

MSRQINAATPSSSRHRHLSLSRRRINFTTSPAQPSSSSRSQPSSSSRSHRRQERRQEQRVSEENVQI  
IGNVNEPLTRTYHRQGVITYYVHGQVNISNDDPLLSQEDDVILINSENVDRERFPDITAQQYQDNI  
30 ASETAAQRALQRGLDLEAQLMNEIAPRSPTYSPSYSPNYVIPQSPDLFASPQSPQPQQQQQQQSEP  
EEVEVSCNICFTTFKDTKNVNSSFVTSIHCNHAVCFKCYVKIIMDNSVYKCFCSATSSDCRVYN  
KHGYVEFMPINVTRNQDSIKQHWRELLENNTVNNHTTDLNYVEQLQKELSELRAKTSQVEHKM  
TMLNSDYIMLKHKHAVAELDLQKANYDLQESTKKSEELQSTVNNLQEQLRKQVAESQAKFSEF  
ERSNSDLVSKLQTVMSRR

It is believed that in some embodiments, the IE1 protein is a product of the immediate early gene 1 (ie1) of baculovirus, and the IE protein may also be referred to as a transcriptional regulator protein of baculovirus. It is a multifunctional protein with the ability to activate early and late viral genes and participate in viral genome replication, and participates in the regulation of the viral cycle.

- 5 In some embodiments, the recombination homologous region of baculovirus (hr) is selected from one or more (e.g., two, three, four or five) of hr1 (its nucleotide sequence shown in SEQ ID NO.16), hr2 (its nucleotide sequence shown in SEQ ID NO.17), hr3 (its nucleotide sequence is shown in SEQ ID NO.18), hr4 (the nucleotide sequence of hr4 left is shown in SEQ ID NO.19, and the nucleotide sequence of hr4 right is shown in SEQ ID NO.20), and hr5 (its nucleotide sequence is shown in SEQ ID NO.21).
- 10 The sequences of SEQ ID NO.16-21 are as follows:

SEQ ID NO.16:

ATCGATGTTGACCCCAACAAAAGATTATAATTAATCATAATCACGAACAACAAGTCAATG  
AAACAAATAAACAAAGTTGTGCGATAAACATTCATAAATGACACAGCAACATAAATTCTTGCA  
TAATAAAAATTTAAATGACATCATATTTGAGAATAACAAATGACATTATCCCTCGATTGTGTTTT  
15 ACAAGTAGAATTCTACCCGTAAAGCGAGTTTAGTTTTGAAAAACAAATGACATCATTTGTATAA  
TGACATCATCCCCTGATTGTGTTTTACAAGTAGAATTCTATCCGTAAAGCGAGTTCAGTTTTGA  
AAACAAATGAGTCATACCTAAACACGTTAATAATCTTCTGATATCAGCTTATGACTCAAGTTAT  
GAGCCGTGTGCAAAACATGAGATAAGTTTATGACATCATCCACTGATCGTGCGTTACAAGTAG  
AATTCTACTCGTAAAGCCAGTTCGGTTATGAGCCGTGTGCAAAACATGACATCAGCTTATGAC  
20 TCATACTTGATTGTGTTTTACGCGTAGAATTCTACTCGTAAAGCGAGTTCGGTTATGAGCCGTG  
TGCAAAACATGACATCAGCTTATGAGTCATAATTAATCGTGCGTTACAAGTAGAATTCTACTCG  
TAAAGCGAGTTGAAGGATCATATTTAGTTGCGTTTATGAGATAAGATTGAAAGCACGTGTA  
ATGTTTCCCGCGCGTTGGCACAACTATTTACAATGCGGCCAAGTTATAAAGATTCTAATCTGA  
TATGTTTTAAACACCTTTGCGGCCCGAGTTGTTTTCGTACGTGACTAGCGAAGAAGATGTGT  
25 GGACCGCAGAACAGATAGTAAACAAAACCTAGTATTGGAGCAATAATCGAT

SEQ ID NO.17:

TGAGCAAAACACAACCGGCAAATTCTCGGCGGCCGTTTGGAATGCGGAATAATTGCCATATG  
TAAATGATGTCATCGGTTCTAACTCGCTTTACGAGTAGAATTCTACGTGTAACATAATCAAG  
30 AGATGATGTCATTTGTTTTTCAAACTGAACTCAAGAAATGATGTCATTTGTTTTTCAAACTG  
AACTGGCTTTACGAGTAGAATTCTACTTGTAACACAATCGAGAGATGATGTCATATTTTGCA  
CACGGCTCTAATTAACTCGCTTTACGAGTAAATTTCTACTTGTAACGCATGATCAAGGGATGA  
TGTCATTGGATGAGTCATTTGTTTTTCAAACTAACTCGCTTTACGAGTAGAATTCTACTTGT

AAAACACAATCAAGGGATGATGTCATTATACAAATGATGTCATTTGTTTTTCAAACCTAAACTC  
 GCTTTACGGGTAGAATTCTACTTGTAACACAGCAACTCGAGGGATGATGTCATCCTTTACTCGA  
 TGATTATAAACGTGTTTATGTATGACTCATTTGTTTTTCAAACCTAAACTCGCTTTACGAGTAGA  
 ATTCTACTTGTAACGCACGATCAAGGGATGATGTCATTTATTTGTGCAAAGCTCGATGTCATCT  
 5 TTTGCACACGATTATAAACACAATCCAAATAATGACTCATTTGTTTTTCAAACCTGAACTCGCTT  
 TACGAGTAGAATTCTACTTGTAACACACAATCAAGGGATGATGTCATTTTCAAATGATGTCAT  
 TTGTTTTTCAAACCTAAACTCGCTTTACGAGTAGAATTCTACTTGTAACACACAATCAAGGGAT  
 GATGTCATTTTAAAAATGATCATTTGTTTTTCAAACCTAAACTCGCTTTACGAGTAGAATTCTAC  
 GTGTAACACACAATCAAGGGATGATGTCATTTACTAAATAAAATAATTATTTAAATAAAACTGT  
 10 TTTTATTGTCAAATACACATTGATTCAC

SEQ ID NO.18:

ACGCGTAGAATTCTACTTGTAAGCAAGTTAAATAAGCCGTGTGCAAAAATGACATCAGACA  
 AATGACATCATCTACCTATCATGATCATGTTAATAATCATGTTTTTAAATGACATCAGCTTATGAC  
 15 TAATAATTGATCGTGCGTTACAAGTAGAATTCTACTCGTAAAGCGAGTTTAGTTTTGAAAACAA  
 ATGAGTCATCATTAACATGTTAATAATCGTGTATAAAGGATGACATCATCCACTAATCGTGCGT  
 TACAAGTAGAATTCTACTCGTAAAGCGAGTTCGGTTTTGAAAACAAATGACATCATTTCTTG  
 ATTGTGTTTTACACGTAGAATTCTACTCGTAAAGTATGTTTCAGTTTAAAAACAAATGACATCA  
 TTTTACAGATGACATCATTTCTTGATTATGTTTTACAAGTAGAATTCTACTCGTAAAGCGAGTTT  
 20 AGTTTTTAAAAACAAATGACATCATCTCTTGATTATGTTTTACAAGTAGAATTCTACTCGTAA  
 GCGAGTTTAGTTTTGAAAACAAATGACATCATCTCTTGATTATGTTTTACAAGTAGAATTCTA  
 CTCGTAAAGCGAGTTTAGTTTTGAAAACAAATGACATCATCCCTTGATCATGCGTTACAAGT  
 AGAATTCTACTCGTAAAGCGAGTTGAATTTTGATTACAATATT

25 SEQ ID NO.19:

ATGCATATAATTGTGTACAAAATATGACTCATTAATCGATCGTGCGTTACAAGTAGAATTCTACT  
 GGTAAGCAAGTTCGGTTGTGAGCCGTGTGCAAAACATGACATCATACTAATCATGTTTATAA  
 TCATGTGCAAAATATGACATCATCCGACGATTGTGTTTTACAAGTAGAATTCTACTCGTAAAGC  
 GAGTTTAAAAATTTTGTGACGTCAATGAAACAACGTGTAATATTTTTTACAATATTTAAGTGAA  
 30 ACATTATGACTTCCAATAATTTTGTGGATGTGGATACGTTTGCAAGACAATTGATTACAGATAAA  
 TGTAGTGCTCTAATCGAAAGATGCGGATCTGTTGCCGGCAAACATTTTAGAGATTAGTAGAGA  
 AAGGCCAGAGACAAGTATTTGAGGTGCCAACTCAAAAAAACTATGAATACATTAAAAAATTA  
 TTTTACGAACAAAATATATGGACGATTCGATAGATTATAAAGATTTTAACAGACGCATCCTATT  
 GATAGTTTTTAAATTTCGCTTTAAACAAGAGCACCAACTACTTCCATCGTACTAAAGAGATCAT

CGAGGTGGCCATTAAACGTTTAAACAAAATTAACCCCGATTAAAGAGTTCTCCGCGCAATGC  
TTCAGCATTACAAATGAATGTTTGGAAAATCTAGA

SEQ ID NO.20:

5 AACTGGCTTTACGAGTAGAATTCTACTTGTAACACAATCAAGAAATGATGTCATTTTTGTAC  
GTGATTATAAACATGTTTAAACATGGTACATTGAACTTAATTTTTGCAAGTTGATAAACTAGATT  
AATGTATGACTCATTTGTTTGTGCAAGTTGATAAACGTGATTAATATGACTCATATGTTTGTG  
CAAAAATGGTGTATCGTACAACTCGCTTTACGAGTAGAATTCTACTTGTAACACAATCG  
AGGGATGATGTCATTTGTAGAATGATGTCATTTGTTTTTCAAACCGAACTCGCTTTACGAGT  
10 AGAATTCTACTTGTAACACAATCGAGGGATGATGTCATTTGTAGAATGATGTCATCGTACAA  
ACTCGCTTTACGAGTAGAATTCTAGTAAACAC

SEQ ID NO.21:

TTGAAAATTTATTGCCTAATATTATTTTTGTCAGTTCGTTGTCATTTATTAATTTGGATGATGT  
15 CCATTTGTTTTTAAAATTGAACTGGCTTTACGAGTAGAATTCTACGCGTAAAACACAATCAA  
GTATGAGTCATAAGCTGATGTCATGTTTTGCACACGGCTCATAACCGAACTGGCTTTACGAG  
TAGAATTCTACTTGTAACGCACGATCGAGTGGATGATGGTCATTTGTTTTCAAATCGAGAT  
GATGTCATGTTTTGCACACGGGCTCATAAACTGCTTTACGAGTAGAATTCTACGTGTAACGC  
ACGATCGATTGATGAGTCATTTGTTTTGCAATATGATATCATACAATATGACTCATTTGTTTT  
20 TCAAACCGAACTTGATTTACGGGTAGAATTCTACTCGTAAAGCACAATCAAAAAGATGATG  
TCATTTGTTTTTCAAACCTGAACTCTCGGCTTTACGAGTAGAATTCTACGTGTAACACAAT  
CAAGAAATGATGTCATTTGTTATAAAAAATAAAAGCTGATGTCATGTTTTGCACATGGCTCAT  
AACTAACTCGCTTTACGGGTAGAATTCTACGCGTAAACATGATTGATAATTAAATAATTC  
ATTTGCAAAGCTATACGTAAATCAAACGGACGTTATGGAATTGTATAATATTAAATATGCA  
25 ATTGATCCAACAAATAAAATTATAATAGAGCAAGTCGAC

Preferably, in some embodiments, the recombination homologous region of baculovirus is selected from hr1. It is believed that in some embodiments, hr1 is a repetitive sequence scattered throughout the baculovirus genome, and that hr1 is an origin of replication of baculovirus and also functions as an enhancer. Although the enhancement effect was not obvious in the early stage of infection, it became  
30 more significant in the late stage of infection. In some embodiments, the recombination homologous region of baculovirus (hr) includes hr2. In some embodiments, the recombination homologous region of baculovirus (hr) includes hr3. In some embodiments, the recombination homologous region of

baculovirus (hr) includes hr4. In some embodiments, the recombination homologous region of baculovirus (hr) includes hr5.

In some embodiments, the nucleic acid construct further includes a baculovirus promoter. In some embodiments, the baculovirus promoter is selected from one or more (e.g., two, three, or four) of polyhedron promoter (pH), Gp64, p6.9, and p10. It is believed that in some embodiments, hr is connected in *cis* to the baculovirus promoter to promote IE-mediated transactivation, and at the same time, IE will bind to hr1 in a dimer form to increase the expression of downstream proteins.

In some embodiments, the structure of the nucleic acid construct includes: IE gene expression cassette-Cap gene expression cassette-hr1-ITR-exogenous target gene expression cassette-ITR-Rep gene expression cassette. In some embodiments, the structure of the nucleic acid construct is: IE gene expression cassette-Cap gene expression cassette-ITR-exogenous target gene expression cassette-ITR-Rep gene expression cassette.

The gene expression cassette includes a gene and its promoter.

In a preferred embodiment, the structure of the nucleic acid construct includes: pA-IE1-pH-pA-Cap-p6.9p10-hr1-ITR-exogenous target gene and its promoter-pA-ITR-pH-Rep-pA. In a preferred embodiment, the structure of the nucleic acid construct is: pA-IE1-pH-pA-Cap-p6.9p10-hr1-ITR-exogenous target gene and its promoter-pA-ITR-pH-Rep-pA.

Specifically, in some embodiments, the nucleic acid construct is an AAV vector or a recombinant baculovirus vector. In some embodiments, the nucleic acid construct is an AAV vector. In some embodiments, the nucleic acid construct is a recombinant baculovirus vector. In some embodiments, the recombinant baculovirus vector is a recombinant baculovirus shuttle vector.

In some embodiments, the AAV vector or recombinant baculovirus vector further includes a vector backbone.

In some embodiments, the vector backbone can be selected from suitable vector backbones sold in the market, such as pFastBacdual, pFastBac1, pFastBacHTA, pFastBacHTB, pFastBacHTC, or the like.

In one embodiment, the vector backbone is pFastBacdual.

In some embodiments, the rAAV titer obtained by packaging the nucleic acid construct is at least  $1 \times 10^{12}$  VG/mL (for example, at least  $1.5 \times 10^{12}$ ,  $2 \times 10^{12}$ ,  $2.5 \times 10^{12}$ ,  $3 \times 10^{12}$ ,  $3.5 \times 10^{12}$ ,  $4 \times 10^{12}$ ,  $4.5 \times 10^{12}$ ,  $5 \times 10^{12}$ ,  $5.5 \times 10^{12}$ ,  $6 \times 10^{12}$ ,  $7 \times 10^{12}$ ,  $7.5 \times 10^{12}$ ,  $8 \times 10^{12}$ ,  $8.5 \times 10^{12}$ ,  $9 \times 10^{12}$ ,  $9.5 \times 10^{12}$ ,  $1 \times 10^{13}$ ,  $5 \times 10^{13}$ , or  $1 \times 10^{14}$  VG/mL), that is, the copy number of AAV genome contained in each mL of virus culture medium is at

least  $1 \times 10^{12}$  (for example, at least  $1.5 \times 10^{12}$ ,  $2 \times 10^{12}$ ,  $2.5 \times 10^{12}$ ,  $3 \times 10^{12}$ ,  $3.5 \times 10^{12}$ ,  $4 \times 10^{12}$ ,  $4.5 \times 10^{12}$ ,  $5 \times 10^{12}$ ,  $5.5 \times 10^{12}$ ,  $6 \times 10^{12}$ ,  $7 \times 10^{12}$ ,  $7.5 \times 10^{12}$ ,  $8 \times 10^{12}$ ,  $8.5 \times 10^{12}$ ,  $9 \times 10^{12}$ ,  $9.5 \times 10^{12}$ ,  $1 \times 10^{13}$ ,  $5 \times 10^{13}$ , or  $1 \times 10^{14}$ ).

In some embodiments, the rAAV titer obtained by packaging the nucleic acid construct is at least  $2.60 \times 10^{12}$  VG/mL, that is, the copy number of the AAV genome contained in each mL of virus culture medium is at least  $2.60 \times 10^{12}$ .

The yield of the rAAV is determined by qPCR method, and the detection steps are as follows:

The standard used in quantitative PCR is pAAV-MCS plasmid linearized by single restriction enzyme digestion with PvuI-HF (NEB).

The primer sequences used in quantitative PCR are:

10 ITR Forward primer 5'-GGAACCCCTAGTGATGGAGTT-3' (SEQ ID NO: 2)

ITR Reverse primer 5'-CGGCCTCAGTGAGCGA-3' (SEQ ID NO: 3)

The running program of the quantitative PCR was:  $95^{\circ}\text{C}$  for 60 s, ( $95^{\circ}\text{C}$  for 15 s,  $60^{\circ}\text{C}$  for 30 s, 40 cycles). After plotting the standard curve according to the CT value obtained by quantitative PCR and the concentration of the standard, the titer of the sample was calculated.

15 The second aspect of the present invention provides a recombinant baculovirus, which is obtained by constructing any one of the nucleic acid constructs through the baculovirus system, or is obtained by constructing nucleic acid constructs by including any element of the said nucleic acid constructs through the baculovirus system.

The nucleic acid constructs comprising any element from any of said nucleic acid constructs mainly refer to: nucleic acid constructs comprising AAV elements, nucleic acid constructs comprising a polynucleotide encoding an IE protein, nucleic acid constructs comprising polynucleotides encoding recombination homologous region of baculovirus. The nucleic acid constructs comprising AAV elements can also be selected from nucleic acid constructs comprising a polynucleotide encoding Cap proteins, nucleic acid constructs comprising a polynucleotide encoding Rep proteins, and nucleic acid constructs comprising AAV cis-acting elements. The recombinant baculovirus can be constructed from the above nucleic acid constructs together through a baculovirus system.

The baculovirus system is selected from Bac-to-Bac system (derived from ThermoFisher/Invitrogen), flashBac/BacMagic system (derived from Mirus/EMD/OET/Nextgen), BaculoDirect system (derived from ThermoFisher/Invitrogen), and BacPAK6/Baculogold system (derived from BD Biosciences/Clontech).

Specifically, the recombinant baculovirus is obtained by transforming competent cells with the nucleic acid construct, extracting bacmid, and transfecting Sf9 insect cells.

The competent cells can be selected from any applicable competent cells in the art, as long as the purpose of the present invention is not limited. For example, the competent cells can be DH10Bac.

The third aspect of the present invention provides an adeno-associated virus (AAV), which is obtained by packaging any one of the recombinant baculoviruses. The adeno-associated virus can be used to treat  
5 various diseases, such as hemophilia, spinal muscular atrophy, Duchenne muscular dystrophy, Parkinson's disease, age-related macular degeneration, and the like.

The fourth aspect of the present invention provides a cell line, which is a cell line infected by any one of the recombinant baculoviruses.

In some embodiments, the cell line is an insect cell line, such as Sf9 cells, Sf21 cells, High5 cells.

10 The fifth aspect of the present invention provides an AAV vector system, which includes a baculovirus system and the nucleic acid construct.

The sixth aspect of the present invention provides the construction method of the nucleic acid construct, the construction method comprising integrating the AAV elements carrying the exogenous gene of interest and the polynucleotide encoding the IE protein into the backbone of the baculovirus vector.

15 The construction method also includes integrating the polynucleotide encoding the recombination homologous region of baculovirus into the backbone of the baculovirus vector.

In some embodiments, the AAV elements include a polynucleotide encoding Cap proteins, a polynucleotide encoding Rep proteins, and AAV cis-acting elements.

In some embodiments, the AAV cis-acting elements are selected from inverted terminal repeat sequences  
20 (ITR sequences).

Specifically, in some embodiments, the polynucleotide encoding the IE protein is linked to a strong promoter pH.

In some embodiments, the polynucleotide encoding the recombination homologous region of baculovirus is linked in *cis* to a baculovirus promoter. In some embodiments, the baculovirus promoter is p6.9 or p10.

25 In some embodiments, the backbone of the baculovirus vector is selected from pFastBacdual, pFastBac1, pFastBacHTA, pFastBacHTB, pFastBacHTC, and etc.

In some embodiments, the recombination homologous region of baculovirus is selected from one or more (e.g., two, three, four, or five) of hr1, hr2, hr3, hr4, and hr5.

The seventh aspect of the present invention provides an AAV production method, the production method  
30 comprising the following steps: infecting insect cell lines with the recombinant baculovirus.

The production method can improve the yield of the AAV.

In some embodiments, the cell line is selected from an insect cell line. In one embodiment, the insect cell line is selected from Sf9 cells.

5 The eighth aspect of the present invention provides a method of treating diseases, said method comprising administering an effective amount of any one of the AAVs to patients.

In some embodiments, the diseases include, for example, hemophilia, spinal muscular atrophy, Duchenne muscular dystrophy, Parkinson's disease, age-related macular degeneration, and the like.

The invention also includes any of the following numbered paragraphs:

- 10 1. A nucleic acid construct, characterized in that, the nucleic acid construct comprises: AAV elements, the polynucleotide encoding IE protein, and the AAV elements comprise the polynucleotide encoding Cap proteins, the polynucleotide encoding Rep proteins, and AAV cis-acting elements.
2. The nucleic acid construct according to paragraph 1, wherein the nucleic acid construct further comprises a polynucleotide encoding a recombination homologous region of baculovirus.
- 15 3. The nucleic acid construct according to paragraph 2, wherein the IE protein is selected from one or more encoded proteins of Acie0, Acie01, and Acie02, and/or, the recombination homologous region of baculovirus is selected from one or more of hr1, hr2, hr3, hr4, and hr5.
4. Any one of the nucleic acid constructs described in paragraphs 1-3, characterized in that the nucleic acid construct also includes the promoter of the IE protein-coding gene, and the promoter of the IE protein-coding gene is selected from one or more of Gp64, pH, p6.9, and p10.
- 20 5. Any one of the nucleic acid constructs described in paragraphs 1-4, wherein the nucleic acid construct further comprises a baculovirus promoter connected to a recombination homologous region of baculovirus, and the baculovirus promoter is preferably one or more of pH, Gp64, p6.9, and p10.
6. Any one of the nucleic acid constructs described in paragraphs 1-5, wherein the AAV cis-acting elements are selected from ITR sequences.
- 25 7. Any one of the nucleic acid constructs described in paragraphs 1-6, wherein the nucleic acid construct further comprises an exogenous gene of interest embedded in between AAV elements.
8. Any one of the nucleic acid constructs described in paragraphs 1-7, wherein the structure of the nucleic acid construct is: IE gene expression cassette-Cap gene expression cassette-ITR-exogenous target gene expression cassette-ITR- Rep gene expression cassette.
- 30 9. Any one of the nucleic acid constructs described in paragraphs 1-8, wherein the nucleotide sequence of the nucleic acid construct is as SEQ ID NO.1.

10. Any one of the nucleic acid constructs described in paragraphs 1-9, wherein the nucleic acid construct is an AAV vector or a recombinant baculovirus vector, and the recombinant baculovirus vector is preferably a recombinant baculovirus shuttle vector.
11. A recombinant baculovirus, characterized in that, the recombinant baculovirus is obtained by  
5 constructing the nucleic acid construct described in any one of paragraphs 1-10 through a baculovirus system, or by jointly constructing any of the nucleic acid constructs containing any element of the nucleic acid constructs described in paragraphs 1-10 through the baculovirus system.
12. An adeno-associated virus, characterized in that the adeno-associated virus is obtained after infection of cells with the recombinant baculovirus described in paragraph 11 and packaging.
- 10 13. A cell line, characterized in that the cell line is a cell line infected with the recombinant baculovirus described in paragraph 11.
14. An AAV vector system, characterized in that the AAV vector system comprises a baculovirus system and any one of the nucleic acid constructs described in paragraphs 1-10.
15. A method for constructing any one of the nucleic acid constructs described in paragraphs 1-10,  
15 characterized in that the construction method comprises integrating AAV elements carrying an exogenous gene of interest and the polynucleotide encoding an IE protein into the backbone of a baculovirus vector.
16. The construction method according to paragraph 15, wherein the construction method includes one or more of the following features:
- 1) The AAV elements include a polynucleotide encoding Cap proteins, a polynucleotide encoding Rep  
20 proteins, and AAV cis-acting elements, and the AAV cis-acting elements are preferably ITR sequences;
- 2) The IE protein is encoded by one or more of Acie0, Acie01, and Acie02 genes;
- 3) The backbone of the baculovirus vector is selected from one of pFastBacdual, pFastBac1,  
pFastBacHTA, pFastBacHTB, and pFastBacHTC;
- 4) The recombination homologous region of baculovirus is selected from one or more of hr1, hr2, hr3, hr4,  
25 and hr5;
- 5) Integrating the polynucleotide encoding the recombination homologous region of baculovirus into the backbone of the baculovirus vector.
17. A production method of adeno-associated virus, characterized in that the production method  
comprises the following steps: infecting insect cell lines with the recombinant baculovirus described in  
30 paragraph 11.

Embodiments of the present invention are described below through specific examples, and those skilled in the art can easily understand other advantages and effects of the present invention from the content disclosed in this specification. The present invention can also be implemented or applied through other different specific implementation modes, and various modifications or changes can be made to the details in this specification based on different viewpoints and applications without departing from the spirit of the present invention.

Before further describing the specific embodiments of the present invention, it should be understood that the protection scope of the present invention is not limited to the following specific embodiments; it should also be understood that the terms used in the examples of the present invention are to describe specific embodiments, not intended to limit the protection scope of the present invention; in the description and claims of the present invention, unless the context clearly indicates otherwise, the singular forms "a", "an" and "the" include plural forms.

When the examples give numerical ranges, it should be understood that, unless otherwise stated in the present invention, the two endpoints of each numerical range and any value between the two endpoints can be selected. Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art. In addition to the specific methods, equipment, and materials used in the embodiments, according to those skilled in the art's grasp of the prior art and the description of the present invention, any methods, equipment, and materials of the prior art similar or equivalent to the practice of the present invention can also be used.

The following examples take EGFP as an exogenous target gene as an example.

#### **Example 1. Construction of recombinant baculovirus shuttle vector and acquisition of recombinant baculovirus**

Identify related genes: Both Cap and Rep protein-coding genes are derived from the AAV2 genome (GenBank: AF043303.1), according to the ribosome leak scanning mechanism reference (Smith RH, Levy JR, Kotin RM: A simplified baculovirus-AAV expression vector system coupled with one-step affinity purification yields high-titer rAAV stocks from insect cells. Mol Ther 2009, 17(11):1888-1896) point mutations of bases were generated; Acie01 (GenBank: NC\_001623.1), recombination homologous region of baculovirus hr1 (GenBank: M14313.1).

Entrust the gene company to synthesize the corresponding sequences: Cap gene sequence (nucleotide sequence SEQ ID NO: 4), Rep gene sequence (nucleotide sequence SEQ ID NO: 5), hr1 and p6.9, p10 promoter combination (hr1p6.9p10, nucleotide sequence of SEQ ID NO: 6), pH promoter and Acie01 combination (pH-Acie01, nucleotide sequence of SEQ ID NO: 7). The above sequences and the ITR-

CMV-EGFP sequence in the pAAV-EGFP vector (modified by Kanglin Biotech (Hangzhou) Co., Ltd.) were cloned into pFastBac dual (Invitrogen) using the homologous recombination method well known in the art, and two recombinant baculovirus shuttle vectors pFBd-Cap-ITR-Rep (Figure 1 and Figure 2, nucleotide sequence SEQ ID NO: 8) and pFBd-IE-hr1Cap-ITR-Rep (Figure 3 and Figure 4, nucleotide sequence SEQ ID NO: 9 ) were obtained after identification by sequencing.

The sequences of SEQ ID NO.4-9 are as follows:

SEQ ID NO: 4:

```
ACGGCTGCCGACGGTTATCTACCCGATTGGCTCGAGGACACTCTCTCTGAAGGAATAAGACAG
TGGTGGAAGCTCAAACCCGGCCACCACCACCAAAGCCCGCAGAGCGGCATAAGGACGACA
10 GCAGGGGCCTTGTGCTTCCCGGGTACAAGTACCTCGGACCCTTCAACGGACTGGACAAGGGA
GAGCCGGTGAACGAGGCAGACGCCGCTGCCCTCGAGCACGACAAAGCCTACGACCGGCAGC
TCGACAGCGGAGACAACCCTTACCTCAAGTACAACCACGCCGACGCGGAGTTCCAGGAGCG
CCTTAAAGAAGATACGTCTTTTGGGGGCAACCTCGGACGAGCAGTCTTCCAGGCGAAAAAGA
GGGTTCTTGAACCTCTGGGCCTGGTTGAGGAACCTGTTAAGACGGCTCCGGGAAAAAAGAG
15 GCCGGTAGAGCACTCTCCTGTGGAGCCAGACTCCTCCTCGGGAACCGGAAAGGCGGGCCAG
CAGCCTGCAAGAAAAAGATTGAATTTTGGTCAGACTGGAGACGCAGACTCAGTACCTGACCC
CCAGCCTCTCGGACAGCCACCAGCAGCCCCCTCTGGTCTGGGAACTAATACGATGGCTACAG
GCAGTGGCGCACCAATGGCAGACAATAACGAGGGCGCCGACGGAGTGGGTAATTCCTCGGG
AAATTGGCATTGCGATTCCACATGGATGGGCGACAGAGTCATCACCACCAGCACCCGAACCT
20 GGGCCCTGCCCACCTACAACAACCACCTCTACAAACAAATTTCCAGCCAATCAGGAGCCTCG
AACGACAATCACTACTTTGGCTACAGCACCCCTTGGGGGTATTTTGACTTCAACAGATTCCAC
TGCCACTTTTACCACGTGACTGGCAAAGACTCATCAACAACAACCTGGGGATTCCGACCCAA
GAGACTCAACTTCAAGCTCTTTAACATTCAAGTCAAAGAGGTCACGCAGAATGACGGTACGA
CGACGATTGCCAATAACCTTACCAGCACGGTTCAGGTGTTTACTGACTCGGAGTACCAGCTCC
25 CGTACGTCTCGGCTCGGCGCATCAAGGATGCCTCCCGCCGTTCACAGCAGACGTCTTCATGG
TGCCACAGTATGGATACCTCACCTGAACAACGGGAGTCAGGCAGTAGGACGCTCTTCATTTT
ACTGCCTGGAGTACTTTTCTTCTCAGATGCTGCGTACCGGAAACAACCTTTACCTTCAGCTACA
CTTTTGAGGACGTTCTTTCCACAGCAGCTACGCTCACAGCCAGAGTCTGGACCGTCTCATGA
ATCCTCTCATCGACCAGTACCTGTATTACTTGAGCAGAACAAACACTCCAAGTGGAACCACCA
30 CGCAGTCAAGGCTTCAGTTTTCTCAGGCCGGAGCGAGTGACATTCGGGACCAGTCTAGGAAC
TGGCTTCCTGGACCCTGTTACCGCCAGCAGCGAGTATCAAAGACATCTGCGGATAACAACAAC
AGTGAATACTCGTGGACTGGAGCTACCAAGTACCACCTCAATGGCAGAGACTCTCTGGTGAAT
CCGGGCCCCGGCGATGGCAAGCCACAAGGACGATGAAGAAAAGTTTTTCTCAGAGCGGGG
```

TTCTCATCTTTGGGAAGCAAGGCTCAGAGAAAACAAATGTGGACATTGAAAAGGTCATGATT  
 ACAGACGAAGAGGAAATCAGGACAACCAATCCCGTGGCTACGGAGCAGTATGGTTCTGTATC  
 TACCAACCTCCAGAGAGGCAACAGACAAGCAGCTACCGCAGATGTCAACACACAAGGCGTT  
 CTTCCAGGCATGGTCTGGCAGGACAGAGATGTGTACCTTCAGGGGCCCATCTGGGCAAAGAT  
 5 TCCACACACGGACGGACATTTTCACCCCTCTCCCCTCATGGGTGGATTTCGGACTTAAACACCC  
 TCCTCCACAGATTCTCATCAAGAACACCCCGGTACCTGCGAATCCTTCGACCACCTTCAGTGC  
 GGCAAAGTTTGCTTCCTTCATCACACAGTACTCCACGGGACAGGTCAGCGTGGAGATCGAGT  
 GGGAGCTGCAGAAGGAAAACAGCAAACGCTGGAATCCCGAAATTCAGTACACTTCCAACTAC  
 AACAAGTCTGTTAATGTGGACTTTACTGTGGACACTAATGGCGTGTATTTCAGAGCCTCGCCCC  
 10 ATTGGCACCAGATACCTGACTCGTAATCTGTAA

SEQ ID NO: 5:

CTGGCGGGGTTTTACGAGATTGTGATTAAGGTCCCCAGCGACCTTGACGAGCATCTGCCCCGGC  
 ATTTCTGACAGCTTTGTGAACTGGGTGGCCGAGAAGGAGTGGGAGTTGCCGCCAGATTCTGA  
 15 CTTGGATCTGAATCTGATTGAGCAGGCACCCCTGACCGTGGCCGAGAAGCTGCAGCGCGACT  
 TTCTGACGGAGTGGCGCCGTGTGAGTAAGGCCCCGGAGGCCCTTTTCTTTGTGCAATTTGAGA  
 AGGGAGAGAGCTACTTCCACTTACACGTGCTCGTGGAACCACCGGGGTGAAATCCTTAGTT  
 TTGGGACGTTTCCTGAGTCAGATTCGCGAAAACTGATTTCAGAGAATTTACCGCGGGATCGAG  
 CCGACTTTGCCAACTGGTTCGCGGTCACAAAGACCAGAAACGGCGCCGGAGGCGGGAACA  
 20 AGGTGGTGGACGAGTGCTACATCCCCAATTACTTGCTCCCCAAAACCCAGCCTGAGCTCCAGT  
 GGGCGTGGACTAATTTAGAACAGTATTTAAGCGCCTGTTTGAATCTCACGGAGCGTAAACGGT  
 TGGTGGCGCAGCATCTGACGCACGTGTGCGCAGACGCAGGAGCAGAACAAAGAGAATCAGAA  
 TCCCAATTCTGACGCGCCGGTGATCAGATCAAAAACCTTCAGCCAGGTACATGGAGCTGGTCG  
 GGTGGCTCGTGGACAAGGGGATTACCTCGGAGAAGCAGTGGATACAGGAGGACCAGGCCTC  
 25 ATACATCTCCTTCAATGCGGCCTCCAACCTCGCGGTCCCAAATCAAGGCTGCCTTGACAATGC  
 GGGAAAGATTATGAGCCTGACTAAAACCGCCCCCGACTACCTGGTGGGCCAGCAGCCCGTGG  
 AGGACATTTCCAGCAATCGGATTTATAAAATTTTGGAACTAAACGGGTACGATCCCCAATATGC  
 GGCTTCCGTCTTTCTGGGATGGGCCACGAAAAAGTTCGGCAAGAGGAACACCATCTGGCTGT  
 TTGGGCCTGCAACTACCGGGAAGACCAACATCGCGGAGGCCATAGCCCACACTGTGCCCTTC  
 30 TACGGGTGCGTAAACTGGACCAATGAGAACTTTCCCTTCAACGACTGTGTGGACAAGATGGT  
 GATCTGGTGGGAGGAGGGGAAGATGACCGCCAAGGTCGTGGAGTCGGCCAAAGCCATTCTC  
 GGAGGAAGCAAGGTGCGCGTGGACCAGAAATGCAAGTCCTCGGCCCAGATAGACCCGACTC  
 CCGTGATCGTCACCTCCAACACCAACATGTGCGCCGTGATTGACGGGAACTCAACGACCTTC  
 GAACACCAGCAGCCGTTGCAAGACCGGATGTTCAAATTTGAACTCACCCGCCGTCTGGATCA

TGACTTTGGGAAGGTCACCAAGCAGGAAGTCAAAGACTTTTTCCGGTGGGCAAAGGATCAC  
GTGGTTGAGGTGGAGCATGAATTCTACGTCAAAAAGGGTGGAGCCAAGAAAAGACCCGCCC  
CCAGTGACGCAGATATAAGTGAGCCCAAACGGGTGCGCGAGTCAGTTGCGCAGCCATCGACG  
TCAGACGCGGAAGCATCGATCAACTACGCAGACAGGTACCAAAACAAATGTTCTCGTCACGT  
5 GGGCATGAATCTGATGCTGTTTCCCTGCAGACAATGCGAGAGAATGAATCAGAATTCAAATAT  
CTGCTTCACTCACGGACAGAAAGACTGTTTAGAGTGCTTTCCCGTGTCAGAATCTCAACCCGT  
TTCTGTCGTCAAAAAGGCGTATCAGAACTGTGCTACATTCATCATATCATGGGAAAGGTGCC  
AGACGCTTGCCTGCGATCTGGTCAATGTGGATTTGGATGACTGCATCTTTGAACAATA  
A

10

SEQ ID NO: 6:

ATCGATGTTGACCCCAACAAAAGATTTATAATTAATCATAATCACGAACAACAACAAGTCAATG  
AAACAAATAAACAAGTTGTGCGATAAAACATTCATAAATGACACAGCAACATACAATTCTTGCA  
TAATAAAAATTTAAATGACATCATATTTGAGAATAACAAATGACATTATCCCTCGATTGTGTTTT  
15 ACAAGTAGAATTCTACCCGTAAAGCGAGTTTAGTTTTGAAAAACAAATGACATCATTTGTATAA  
TGACATCATCCCCTGATTGTGTTTTACAAGTAGAATTCTATCCGTAAAGCGAGTTCAGTTTTGA  
AAACAAATGAGTCATACCTAAACACGTTAATAATCTTCTGATATCAGCTTATGACTCAAGTTAT  
GAGCCGTGTGCAAAACATGAGATAAGTTTATGACATCATCCACTGATCGTGCGTTACAAGTAG  
AATTCTACTCGTAAAGCCAGTTCGGTTATGAGCCGTGTGCAAAACATGACATCAGCTTATGAC  
20 TCATACTTGATTGTGTTTTACGCGTAGAATTCTACTCGTAAAGCGAGTTCGGTTATGAGCCGTG  
TGCAAAACATGACATCAGCTTATGAGTCATAATTAATCGTGCGTTACAAGTAGAATTCTACTCG  
TAAAGCGAGTTGAAGGATCATATTTAGTTGCGTTTATGAGATAAGATTGAAAGCACGTGTAAA  
ATGTTTCCCGCGCGTTGGCACAACATTTACAATGCGGCCAAGTTATAAAAGATTCTAATCTGA  
TATGTTTTAAAACACCTTTGCGGCCCCGAGTTGTTTGCGTACGTGACTAGCGAAGAAGATGTGT  
25 GGACCGCAGAACAGATAGTAAAACAAAACCCTAGTATTGGAGCAATAATCGATGACGTCGCT  
GACGTAGCGCTTTGAATTCCGCGCGCTTCGGACCGGGATCGTGACCAAATTCGGTTTTGCGAC  
GATGCAGAGTTTTTGAACAGGCTGCTCAAACACATAGATCCGTACCCGCTCAGTCGGATGTAT  
TACAATGCAGCCAATACCATGTTTTACACGACTATGGAAAATATGCCGTGTCCAATTGCAAGT  
TCAACATTGAGGATTACAATAACATATTTAAGGTGATGGAAAATATTAGGAAACACAGCAACA  
30 AAAATTCAAACGACCAAGACGAGTTAAACATATATTTGGGAGTTCAGTCGTGCAATGCAAAGC  
GTAAAAAATATTAATAAGGTAAAAATTACAGCTACATAAATTACACAATTTAACTGCAGTCTG  
GAGATACGGACCTTTAATTCAACCCAACACAATATATTATAGTTAAATAAGAATTATTATCAAT  
CATTTGTATATTAATTAATAACTATACTGTAAATTACATTTTATTTACAATC

SEQ ID NO: 7:

AAC TTG TTT ATT GCAG CTT ATA ATG GTT ACA AATAA AGCA ATAG CAT CACA AATTT CACA AATA  
AAG CATTTTT TTT CACT GCATT CTAG TTG TGG TTT GTCC AAAC TCA TCA ATGT ATCTT ATCAT GTC  
TGG ATCTG ATCACT GCTT GAG CCTAG GAG ATCC GATCAT GGAG ATAATT AAAATG ATAACCATC  
5 TCGCAAATAAATAAGTATTTTACTGTTTTTCGTAACAGTTTTGTAAATAAAAAAACCTATAAATATT  
CCGGATTATTCATACCGTCCCACCATCGGGCGCATGATCCGTACATCCAGCCACGTCTGAACG  
TCCAAGAAAACATCATGACTTCCAAC TGTGCTTCCAGCCCCTACTCCTGTGAGGCCACTTCAG  
CCTGCGCTGAGGCCCAGCAACTGCAGGTGGACACAGGTGGCGATAAGATCGTGAACAACCA  
GGTCACCATGACTCAAATCAACTTCAACGCTTCCTACACCTCTGCCAGCACTCCCTCTCGTGC  
10 TAGCTTCGACAAC TCACTCGGAGTTCTGCGACAAGCAACCTAACGATTACTTGTCTTACTAC  
AACCACCCAACCCCGGACGGAGCTGATACTGTCATCTCCGACTCTGAAACCGCTGCCGCTAG  
CAACTTCCTCGCCTCAGTTAACTCGCTCACTGACAACGATTTGGTGGAGTGTCTGCTCAAGAC  
CACTGACAACCTGGAGGAAGCTGTGTCTCTGCCTACTACAGCGAGTCACTCGAACAGCCAG  
TGGTCGAACAACCCTCTCCTAGCTCAGCTTACCACGCCGAGTCCTTCGAACACTCTGCTGGTG  
15 TCAACCAGCCGTCGGCCACAGGCACCAAGAGGAAGTTGGACGAGTACCTGGATAACTCCCA  
GGGAGTTGTGGGTCAATTCAACAAGATCAAGTTGAGACCTAAGTACAAGAAGAGACCATCC  
AGTCATGCGCTACACTGGAACAAACCATCAACCACAACACTAACATCTGTACAGTGGCTTCCA  
CCCAGGAGATCACTCACTACTTCACAAACGACTTCGCCCCCTACCTGATGAGGTTGACGATA  
ACGACTACAAC TCGAACAGATTCTCCGATCACATGTCTGAAACCGGTTACTACATGTTTCGTCTG  
20 TTAAGAAGTCCGAGGTGAAGCCTTTTCGAAATCATCTTCGCCAAGTACGTCTCTAACGTGGTCT  
ACGAGTACACAAACA ACTACTACATGGTTGACAACCGTGTGTTTCGTTGTGACCTTCGATAAGA  
TCCGCTTCATGATCAGCTACAACCTGGTTAAGGAGACTGGCATCGAAATCCCACACTCACAGG  
ACGTCTGCAACGATGAGACCGCCGCTCAAACTGCAAGAAGTGTCACTTCGTGGACGTCCAC  
CACACATTCAAGGCCGCTCTGACCTCCTACTTCAACCTCGATATGTACTACGCTCAGACAACC  
25 TTCGTGACCTTGCTGCAATCACTCGGCGAGCGTAAGTGTGGATTCTCTTGTGCAAGTTGTAC  
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5 SEQ ID NO: 8:

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SEQ ID NO: 9:

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 GGTCCCAATGGGGTCTCGGTGGGGTATCGACAGAGTGCCAGCCCTGGGACCGAACCCCGCGT  
 15 TTATGAACAAACGACCCAACACCCGTGCGTTTTATTCTGTCTTTTTATTGCCGTCATAGCGCGG  
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 20 TTTTGGATGACCTGGCTCACATCAACGTCCTTGATTTCGCCAGAGATCCAGTAGAACTCCTTGT  
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 20 CAAGGGGATTACCTCGGAGAAGCAGTGGATACAGGAGGACCAGGCCTCATACATCTCCTTCA  
 ATGCGGCCTCCAACTCGCGGTCCCAAATCAAGGCTGCCTTGGACAATGCGGGAAAGATTATG  
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 25 TACCGGGAAGACCAACATCGCGGAGGCCATAGCCCACACTGTGCCCTTCTACGGGTGCGTAA  
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 GAGGGGAAGATGACCGCCAAGGTCGTGGAGTCGGCCAAAGCCATTCTCGGAGGAAGCAAGG  
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 30 GTTGCAAGACCGGATGTTCAAATTTGAACTCACCCGCCGTCTGGATCATGACTTTGGGAAGGT  
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 CATGAATTCTACGTCAAAAAGGGTGGAGCCAAGAAAAGACCCGCCCCCAGTGACGCAGATAT  
 AAGTGAGCCCAAACGGGTGCGCGAGTCAGTTGCGCAGCCATCGACGTCAGACGCGGAAGCA  
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CTGTTTCCCTGCAGACAATGCGAGAGAATGAATCAGAATTCAAATATCTGCTTCACTCACGGA  
 CAGAAAGACTGTTTAGAGTGCTTTCCCGTGTCAGAATCTCAACCCGTTTCTGTCGTCAAAAAG  
 GCGTATCAGAAACTGTGCTACATTCATCATATCATGGGAAAGGTGCCAGACGCTTGCACTGCC  
 TGCGATCTGGTCAATGTGGATTTGGATGACTGCATCTTTGAACAATAATCTAGAGCCTGCAGTC  
 5 TCGACAAGCTTGTGCGAGAAGTACTAGAGGATCATAATCAGCCATAACCACATTTGTAGAGGTTTT  
 ACTTGCTTTAAAAAACCTCCCACACCTCCCCCTGAACCTGAAACATAAAATGAATGCAATTGT  
 TGTGTAACTTGTTTATTGCAGCTTATAATGGTTACAAATAAAGCAATAGCATCACAAATTTCA  
 CAAATAAAGCATTTTTTTTCACTGCATTCTAGTTGTGGTTTGTCCAACTCATCAATGTATCTTAT  
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 10 CCAAATATTTTGTCAATTTTAAATTTTCGTATTAGCTTACGACGCTACACCCAGTTCCCATCTATT  
 TTGTCACTCTTCCCTAAATAATCCTTAAAAACTCCATTTCACCCCTCCCAGTTCCCAACTATTT  
 TGTCCGCCCACAGCGGGGCATTTTTCTTCCTGTTATGTTTTTAATCAAACATCCTGCCAACTCC  
 ATGTGACAAACCGTCATCTTCGGCTACTTT

The two recombinant vectors were transformed into DH10Bac competent cells (Invitrogen) for blue-white  
 15 screening, respectively. The white positive clones were picked and cultured, and the bacmids were  
 extracted using PureLink™ HiPure Plasmid DNA Purification Kits (Invitrogen). The two types of  
 bacmids were transfected into adherent Sf9 cells (Gibco), and the primary recombinant baculoviruses  
 were harvested 3 days later and amplified to the P2 generation. Finally, the recombinant baculoviruses of  
 P2 generation were named BV-Cap-ITR-Rep and BV-IE-hr1Cap-ITR-Rep, respectively, and the virus  
 20 titers were determined by TCID50 method. For details of this part, refer to the Bac-to-Bac Expression  
 System Operation Manual (Invitrogen).

### **Example 2. Packaging and titer determination of rAAV2**

The two types of recombinant baculoviruses of P2-generation were used to infect 25 mL of suspension  
 Sf9 cells (density 3.0E+06 cell/mL) at MOI=0.1, and the cells were harvested after 4 days. 5 mL of TNT  
 25 lysis solution (20 mM Tris-HCl, pH 7.5, 150 mM NaCl, 1% Triton X-100, 10 mmol/L MgCl<sub>2</sub>) was used  
 and incubated at room temperature for 1 h to lyse the cells. Add nuclease at a final concentration of 50  
 U/mL to digest the cell lysate at 37°C for 2 h, take samples and use proteinase K (Tiangen) to digest the  
 capsid at 56°C for 1 h, and determine the titer by qPCR. The detection steps are as follows:

The standard used in the quantitative PCR is the pAAV-EGFP plasmid linearized by single restriction  
 30 enzyme digestion with PvuI-HF (NEB) (the plasmid sequence is shown in SEQ ID NO: 22).

SEQ ID NO.22:

ACATGTGAGCAAAAAGGCCAGCAAAAAGGCCAGGAACCGTAAAAAGGCCGCGTTGCTGGCGTT

TTTCCATAGGCTCCGCCCCCTGACGAGCATCACAAAAATCGACGCTCAAGTCAGAGGTGGC  
 GAAACCCGACAGGACTATAAAGATACCAGGCGTTTCCCCCTGGAAGCTCCCTCGTGCGCTCTC  
 CTGTTCCGACCCTGCCGCTTACCGGATACCTGTCCGCCTTTCTCCCTTCGGGAAGCGTGGCGC  
 TTTCTCATAGCTCACGCTGTAGGTATCTCAGTTCGGTGTAGGTCGTTTCGCTCCAAGCTGGGCTG  
 5 TGTGCACGAACCCCCCGTTCAGCCCCGACCGCTGCGCCTTATCCGGTAACTATCGTCTTGAGTC  
 CAACCCGGTAAGACACGACTTATCGCCACTGGCAGCAGCCACTGGTAACAGGATTAGCAGAG  
 CGAGGTATGTAGGCGGTGCTACAGAGTTCCTGAAGTGGTGGCCTAACTACGGCTACACTAGAA  
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 10 CGCGCAGAAAAAAAGGATCTCAAGAAGATCCTTTGATCTTTTCTACGGGGTCTGACGCTCAGT  
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 TTATTTGTGAAATTTGTGATGCTATTGCTTTATTTGTAACCATCTAGCTTTATTTGTGAAATTTGT  
 GATGCTATTGCTTTATTTGTAACCATTTATAAGCTGCAATAAACAAGTTAACAACAACAATTGCA  
 TTCATTTTATGTTTCAGGTTACGGGGGAGATGTGGGAGGTTTTTTAAAGTTTAAACAGGAACC  
 CCTAGTGATGGAGTTGGCCACTCCCTCTCTGCGCGCTCGCTCGCTCACTGAGGCCGGGCGACC

AAAGGTCGCCCCGACGCCCGGGCGGCCTCAGTGAGCGAGCGAGCGCGCAGCTGCCTGCAGG

The sequences of the primers used in quantitative PCR are:

ITR Forward primer 5'-GGAACCCCTAGTGATGGAGTT-3' (SEQ ID NO: 2)

ITR Reverse primer 5'-CGGCCTCAGTGAGCGA-3' (SEQ ID NO: 3)

- 5 The running program of quantitative PCR was: 95°C for 60 s, (95°C for 15 s, 60°C for 30 s, 40 cycles). After plotting the standard curve according to the Ct value obtained by quantitative PCR and the concentrations of the standard, the titer of the sample was calculated. The yields of rAAVs packaged using BV-Cap-ITR-Rep and BV-IE-hr1 Cap-ITR-Rep were determined to be 2.39E+04 VG/cell (equivalent to 7.18 E+10 VG/mL) and 8.67 E+05 VG/cell (equivalent to 2.60 E+12 VG/mL), respectively.

10 **Example 3. Comparison of the expression of EGFP in the process of cell infection and the expression of Cap proteins in the cell lysates**

After 48 h, 72 h, and 96 h of infection, the cells infected by the two baculoviruses were examined under an inverted fluorescence microscope. The optimized recombinant baculovirus can greatly reduce the expression of the target gene (the target gene in this example is EGFP) (Figure 5). The reduction of the  
15 expression of the target gene (EGFP) seems to weaken the interference to rAAV packaging in cells, making it more conducive to the expression of rAAV packaging-related structural and functional proteins.

The same amount of cell lysates was assayed by Western blotting using Cap protein antibody (Progen) (Figure 6). The results showed that after the optimized recombinant baculovirus infected the cells, the expression levels of Cap proteins in the cells were significantly increased.

20 **Example 4. Electron microscopy examination of purified rAAV2 and infectivity determination**

POROS™ CaptureSelect™ affinity chromatography media (Thermo) was used to purify rAAV2 from the cell lysate, and its titer was determined by fluorescent quantitative PCR (the determination method is the same as in Example 2). The purified rAAV2 was subject to negative staining treatment and examined using transmission electron microscopy (Figure 7). The genome-packaged rAAV2 was solid particles, and  
25 the center of defective rAAV particles without nucleic acid was stained dark. Overall, the morphology of the purified rAAV2 is good, and the empty capsid rate is significantly reduced (~3%) compared with those obtained using traditional method (Benskey et al., 2016), suggesting that the optimized baculovirus vector construct significantly reduces the proportion of empty capsid viruses in the packaging product, which would significantly reduce the burden on downstream steps such as removal of empty capsid  
30 viruses.

The purified rAAV2 was serially diluted and used to infect 293T cells cultured on 48-well plate (5.0 E+04 cells/well) at MOI=10000, 2000, 400, and 80, respectively. Two days after infection, the expression of EGFP was examined by fluorescence microscopy. The experimental results show that the rAAV2 prepared using this system has high *in vitro* infection activity (Figure 8).

- 5 The above examples are intended to illustrate the disclosed embodiments of the present invention, and should not be construed as limiting the present invention. In addition, various modifications set forth herein, as well as changes in the method of the invention, will be obvious to those skilled in the art without departing from the scope and spirit of the invention. Although the invention has been specifically described in connection with various specific preferred embodiments of the invention, it should be
- 10 understood that the invention should not be limited to these specific embodiments. In fact, various modifications as mentioned above which are obvious to those skilled in the art to obtain the invention should be included in the scope of the present invention.

## Claims

1. A nucleic acid construct, wherein the nucleic acid construct comprises: AAV elements and a polynucleotide encoding an IE protein, and the AAV elements comprise a polynucleotide encoding Cap proteins, a polynucleotide encoding Rep proteins, and AAV cis-acting elements.
- 5 2. The nucleic acid construct according to claim 1, wherein the nucleic acid construct further comprises a polynucleotide encoding a recombination homologous region of baculovirus.
3. The nucleic acid construct according to claim 2, wherein the IE protein is encoded by one or more of Acie0, Acie01, and Acie02 genes, and/or, the recombination homologous region of baculovirus is selected from one or more of hr1, hr2, hr3, hr4, and hr5.
- 10 4. The nucleic acid construct according to claim 1, wherein the nucleic acid construct further comprises a promoter of an IE protein-coding gene, and the promoter of the IE protein-coding gene is selected from one or more of Gp64, pH, p6.9, and p10.
5. The nucleic acid construct according to claim 1, wherein the nucleic acid construct further comprises a baculovirus promoter connected to a recombination homologous region of baculovirus, and the  
15 baculovirus promoter is preferably one or more of pH, Gp64, p6.9, and p10.
6. The nucleic acid construct according to claim 1, wherein the AAV cis-acting elements are selected from ITR sequences.
7. The nucleic acid construct according to claim 1, wherein the nucleic acid construct further comprises an exogenous gene of interest embedded in between AAV elements.
- 20 8. The nucleic acid construct according to claim 7, wherein the nucleic acid construct has a structure: IE gene expression cassette-Cap gene expression cassette-ITR-exogenous gene of interest expression cassette-ITR- Rep gene expression cassette.
9. The nucleic acid construct according to claim 1, wherein the nucleotide sequence of the nucleic acid construct is as shown in SEQ ID NO.1.
- 25 10. The nucleic acid construct according to claim 1, wherein the nucleic acid construct is an adeno-associated virus vector or a recombinant baculovirus vector, and the recombinant baculovirus vector is preferably a recombinant baculovirus shuttle vector.
11. A recombinant baculovirus, wherein the recombinant baculovirus is obtained by constructing the nucleic acid construct of any one of claims 1-10 through a baculovirus system, or by jointly constructing  
30 the nucleic acid constructs containing any element in the nucleic acid construct of any one of claims 1-10 through the baculovirus system.

12. An adeno-associated virus, wherein the adeno-associated virus is obtained by infecting cells with the recombinant baculovirus of claim 11 and packaging.
13. A cell line, wherein the cell line is a cell line infected with the recombinant baculovirus of claim 11.
14. An adeno-associated virus vector system, wherein the adeno-associated virus vector system comprises a baculovirus system and the nucleic acid construct of any one of claims 1-10.
15. A method for constructing the nucleic acid construct of any one of claims 1-10, wherein the method comprises integrating AAV elements carrying an exogenous gene of interest, a polynucleotide encoding an IE protein, and a polynucleotide encoding a recombination homologous region of baculovirus into a backbone of a baculovirus vector.
16. The method according to claim 15, wherein the method includes one or more of:
- 1) the AAV elements include a polynucleotide encoding Cap proteins, a polynucleotide encoding Rep proteins, and AAV cis-acting elements, and the AAV cis-acting elements are preferably ITR sequences;
  - 2) The polynucleotide encoding the IE protein is selected from one or more of Acie0, Acie01, and Acie02 genes;
  - 3) The backbone of the baculovirus vector is selected from one of pFastBacdual, pFastBac1, pFastBacHTA, pFastBacHTB, and pFastBacHTC;
  - 4) The recombination homologous region of baculovirus is selected from one or more of hr1, hr2, hr3, hr4, and hr5.
17. A method for producing an adeno-associated virus, wherein the method comprises the step of infecting an insect cell line with the recombinant baculovirus of claim 11.