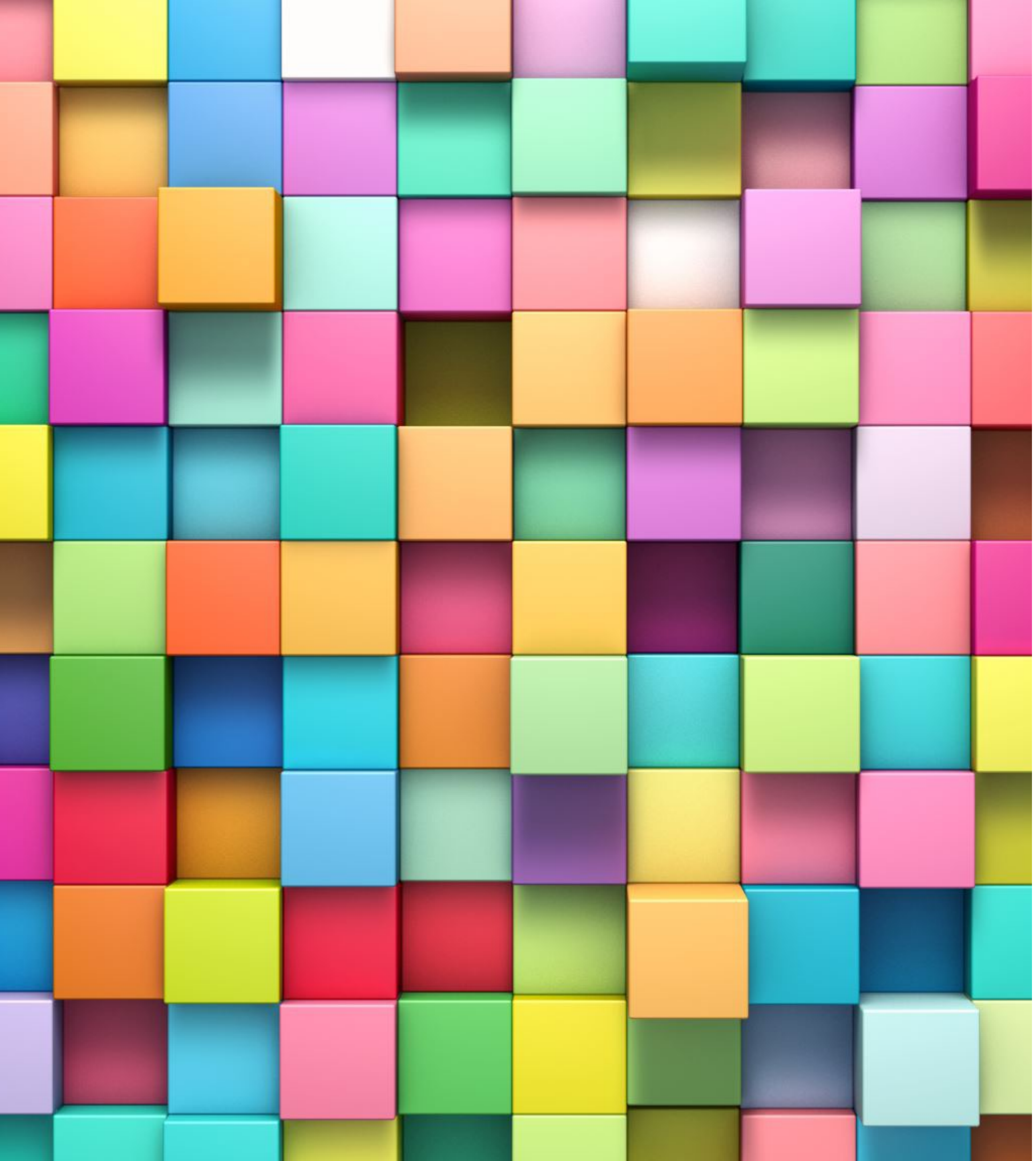
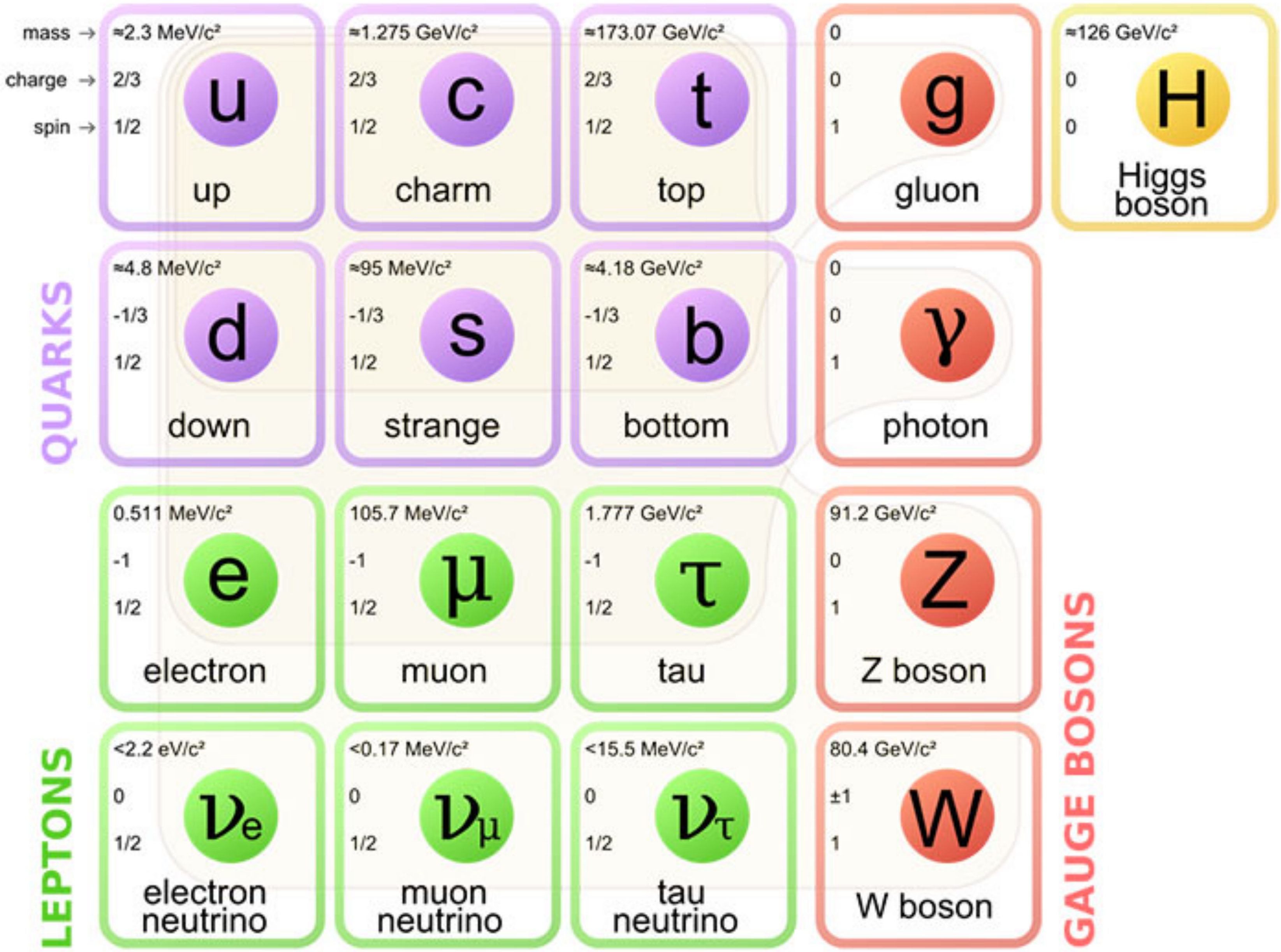


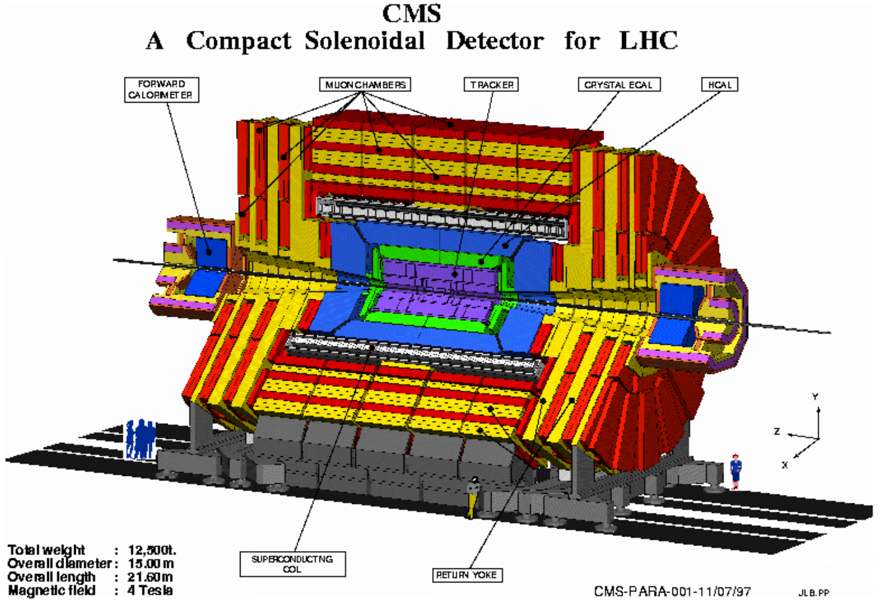
2022년 중점연구소 여름학교 및 성과발표회 워크숍

고에너지 입자 충돌 데이터 연구

Particles

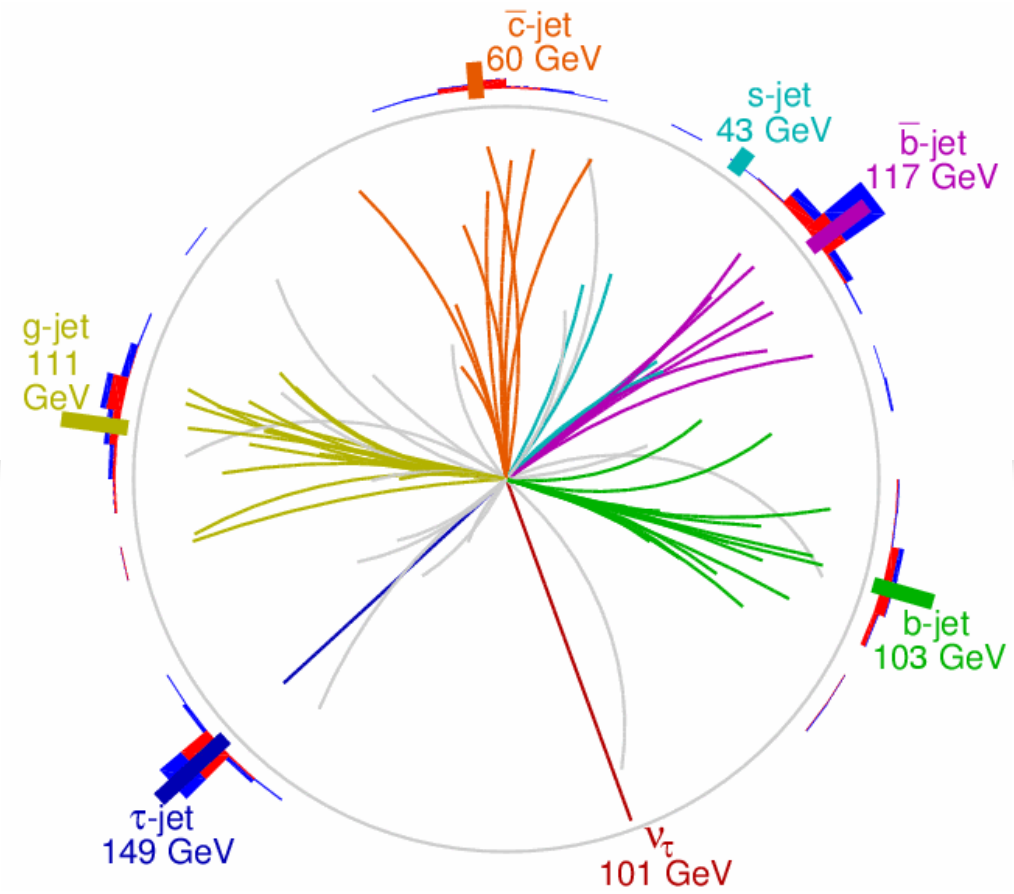

mass →
charge →
spin →
≈2.3 MeV/c²
2/3
1/2
u
up
≈1.275 GeV/c²
2/3
1/2
c
charm
≈173.07 GeV/c²
2/3
1/2
t
top
0
0
1
g
gluon
≈126 GeV/c²
0
0
H
Higgs boson
≈4.8 MeV/c²
-1/3
1/2
d
down
≈95 MeV/c²
-1/3
1/2
s
strange
≈4.18 GeV/c²
-1/3
1/2
b
bottom
0
0
1
γ
photon
0.511 MeV/c²
-1
1/2
e
electron
105.7 MeV/c²
-1
1/2
μ
muon
1.777 GeV/c²
-1
1/2
τ
tau
91.2 GeV/c²
0
1
Z
Z boson
<2.2 eV/c²
0
1/2
νe
electron neutrino
<0.17 MeV/c²
0
1/2
νμ
muon neutrino
<15.5 MeV/c²
0
1/2
ντ
tau neutrino
80.4 GeV/c²
±1
1
W
W boson
QUARKS
LEPTONS
GAUGE BOSONS

LHC-CMS



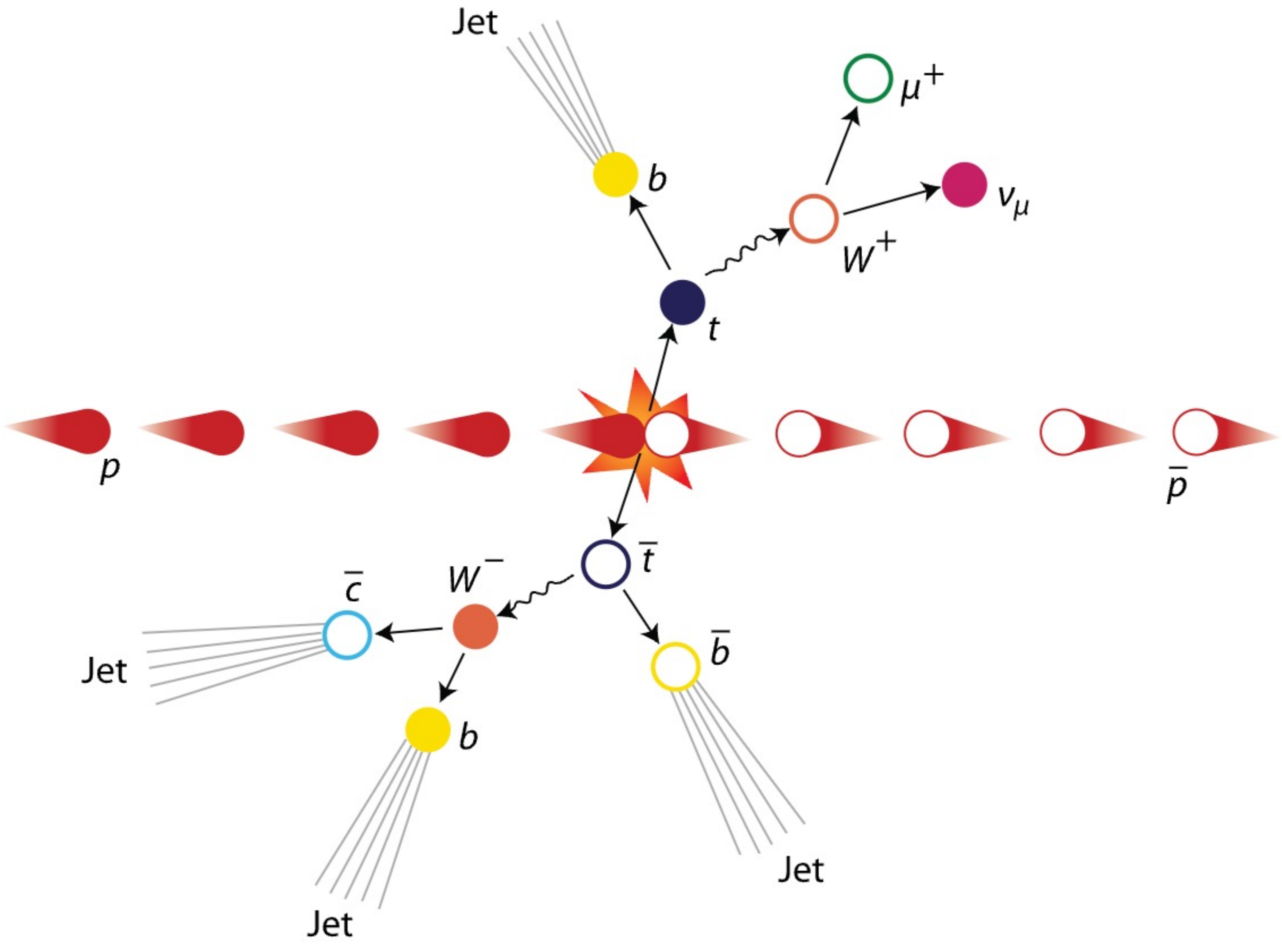
- Proton-proton collision data taken at the LHC at center-of-mass energy of 13 TeV.
- Run II data (2016, 2017, 2018) collected by the CMS detector

Jet



- Jet is originated from high energy particles (such as quark, gluon..) in collision experiment (such as LHC).
- Jet can be distinguished as b-jet, g-jet, s-jet,⋯

Top quark decay



연구내용

- LHC-CMS 고에너지 입자 충돌 사건 데이터를 기반으로 제트를 분석 이해하고, 탑 입자와 같은 고에너지 기본 입자 성질 변수 측정

- 충돌 에너지가 높은 입자 충돌 사건이나 낮은 확률로 생성되는 물리 이벤트 분석의 경우, 기본 입자를 재구성하고 충돌 사건의 물리적 특성을 기반으로 데이터를 분류하는 기존의 분석 방식 한계 극복

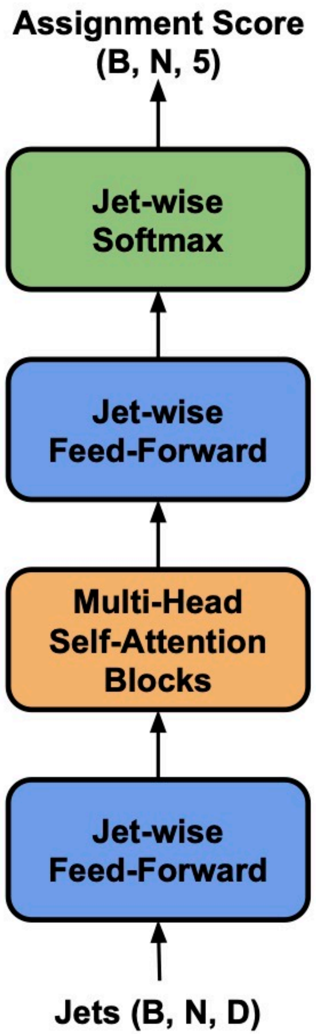
- 과거 축적된 데이터 분석 방식을 적극 고에너지 입자 분석에 활용하는 동시에, 머신 러닝 알고리즘 연구 기법을 추가하여, 표준 모형 및 새로운 물리 현상 연구 기법 다각화

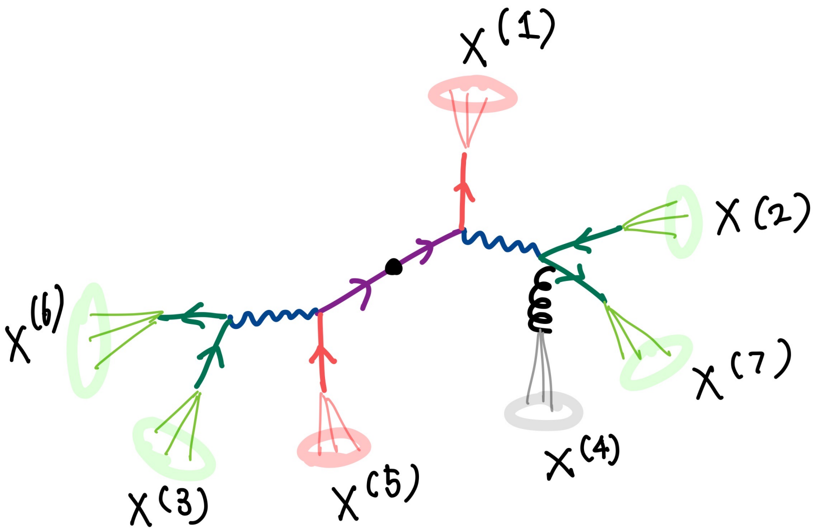
- 머신 러닝, 딥러닝 연구 기법으로 새로운 충돌 실험의 검출기 개발

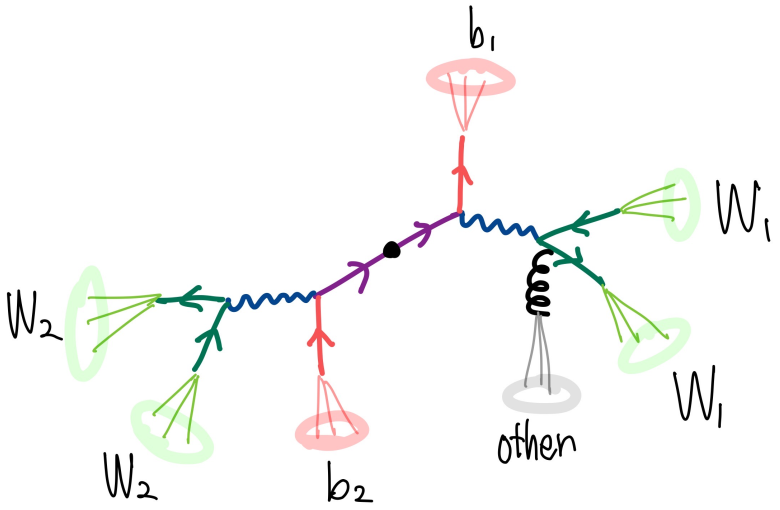
세부 연구 주제 및 연구자

- 양승진 (박사과정): 고에너지 충돌 사건의 멀티 제트 이해 및 탑 쿼크 생성 연구
- **고병학 (박사과정): 고에너지 충돌 싱글 탑에서의 CP Violation 연구**
- 장우진 (참여연구원): 고에너지 충돌 탑 쿼크 사건 분석하여 Vts 측정
- 김정우 (석사과정): 고에너지 충돌 실험에서 s-jet tagging 연구
- 강다영 (박사과정): Z’ 보존 탐색을 통한 새로운 물리 현상 연구
- 김슬기 (박사과정): 암흑 물질 연구의 기반이 되는 모노 탑 생성 연구
- 손영완 (석사과정): 탑 쿼크 성질 이해를 위한 스핀 연구
- 이윤재 (참여연구원): 딥러닝을 활용한 검출기 연구

멀티 제트 이해 및 탑 쿼크 생성 연구







멀티 제트 이해 및 탑 쿼크 생성 연구

Journal of the Korean Physical Society, Vol. 74, No. 3, February 2019, pp. 219∼223

Quark-Gluon Jet Discrimination Using Convolutional Neural Networks

Jason Sang Hun LEE,* Inkyu PARK, Ian James WATSON† and Seungjin YANG‡
Department of Physics, University of Seoul, Seoul 02504, Korea

(Received 20 June 2018, in final form 5 September 2018)

Currently, newly developed artificial intelligence techniques, in particular convolutional neural networks, are being investigated for use in data-processing and classification of particle physics collider data. One such challenging task is to distinguish quark-initiated jets from gluon-initiated jets. Following previous work, we treat the jet as an image by pixelizing track information and calorimeter deposits as reconstructed by the detector. We test the deep learning paradigm by training several recently developed, state-of-the-art convolutional neural networks on the quark-gluon discrimination task. We compare the results obtained using various network architectures trained for quark-gluon discrimination and also a boosted decision tree (BDT) trained on summary variables.

PACS numbers: 13.90.+i, 13.87.−a, 12.38.Qk, 13.87.Fh
Keywords: Machine learning, Jet tagging, QCD, Jet, Fragmentation
DOI: 10.3938/jkps.74.219

I. INTRODUCTION

In recent years, new techniques have been developed for image analysis and classification. This arose from the finding that neural networks composed of successive layers of convolutional filters operating on the previous layer can be successfully and efficiently trained with networks dozens of layers deep. This is to be compared to traditional densely connected neural networks, where adding multiple layers makes training unstable and slow and generally does not improve performance. This new paradigm of a neural network goes under the moniker of Deep Learning and was most famously adapted for use in the creation of AlphaGo, a Go AI which achieved the unprecedented feat of defeating a Go world champion [1].

Recently, these techniques have been applied to jet physics by interpreting the energy depositions forming a two-dimensional image in (η, ϕ) space [2,3]. The space is pixelized, and the pixel luminosity is proportional to the amount of energy carried by particles of the jet travelling in the direction of the pixel. Convolutional neural network techniques were applied to these jet-images [2]. This has been extended by treating the different types of particles as being different color channels producing a color image representation of the jets [4]. In this paper, we train various recently-developed, start-of-the-art convolutional neural network types to discriminate quark-initiated jets and gluon-initiated jets and compare the results from the different networks. In particular, we discuss the expected performance from 13 TeV LHC data with the CMS detector [5]. Other approaches being investigated for jet physics include geometric deep learning for processing non-Euclidean data, such as graphs and manifolds [6]. The authors of these studies argue that this approach can reduce the loss of information that occurs with pixelization so that classification performance can be improved [7,8].

II. MONTE CARLO MODELS

We use MadGraph5_aMCatNLO v2.6.0 to generate the hard process for dijet and Z+jet events at leading order [9]. We separately generate events for quarks and gluons and label the jets "quark" or "gluon" based on the hard process being generated. We do this to avoid ambiguities in the matching process. As outlined in the event selection below, we also require dijets to be balanced to reduce further ambiguities due to hard radiation producing further gluon-like jets. We interface the generated hard-process events to PYTHIA 8.2 with the default PYTHIA tune for parton showering and underlying event generation [10]. We use the fast detector simulator DELPHES to approximate CMS reconstruction particle-flow algorithms [11]. DELPHES uses the FASTJET package for anti-k_T algorithm with a jet radius of $R = 0.5$ [12]. The default settings of the packages have been used to generate events.

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PoS PROCEEDINGS OF SCIENCE

Volume 390 - 40th International Conference on High Ene
(ICHEP2020) - Parallel: Top Quark and Electroweak Phys

Top quark pair reconstruction using an attention-based

J. Lee, I. Park, I. Watson and S. Yang*

Full text: pdf

Pre-published on: February 26, 2021
Published on: April 15, 2021

Abstract

For many top quark measurements, it is essential to reconstruct the top quark
For example, the top quark pair production process in the all-jets final state ha
daughter partons and additional jets from initial or final state radiation. Due to
permutations, it is very hard to assign jets to partons. We use a deep neural n
based architecture together with a new objective function for the jet-parton ass
novel deep learning model and the physics-inspired objective function enable
using jet-wise input variables while the attention mechanism bypasses the co
usually leads to intractable computational requirements. The model can also b
reject the overwhelming QCD background, showing increased performance o
methods.

DOI: https://doi.org/10.22323/1.390.0348

SciPost Physics Submission

Zero-Permutation Jet-Parton Assignment using a Self-Attention Network

Jason S. H. Lee[1], Inkyu Park[1], Ian J. Watson[1*] and Seungjin Yang[1]

1 Department of Physics, University of Seoul, Seoul 02504, Republic of Korea
* ijwatson@physics.uos.ac.kr

April 29, 2022

Abstract

In high-energy particle physics events, it can be advantageous to find the jets associated with the decays of intermediate states, for example, the three jets produced by the hadronic decay of the top quark. Typically, a goodness-of-association measure, such as a χ^2 related to the mass of the associated jets, is constructed, and the best jet combination is found by optimizing this measure. As this process suffers from a combinatorial explosion with the number of jets, the number of permutations is limited by using only the n highest p_T jets. The self-attention block is a neural network unit used for the neural machine translation problem, which can highlight relationships between any number of inputs in a single iteration without permutations. In this paper, we introduce the Self-Attention for Jet Assignment (SaJa) network. SaJa can take any number of jets for input and outputs probabilities of jet-parton assignment for all jets in a single step. We apply SaJa to find jet-parton assignments of fully-hadronic $t\bar{t}$ events to evaluate the performance. We show that SaJa achieves better performance than a likelihood-based approach.

Contents

Vts measurement

Top quark property measurement:

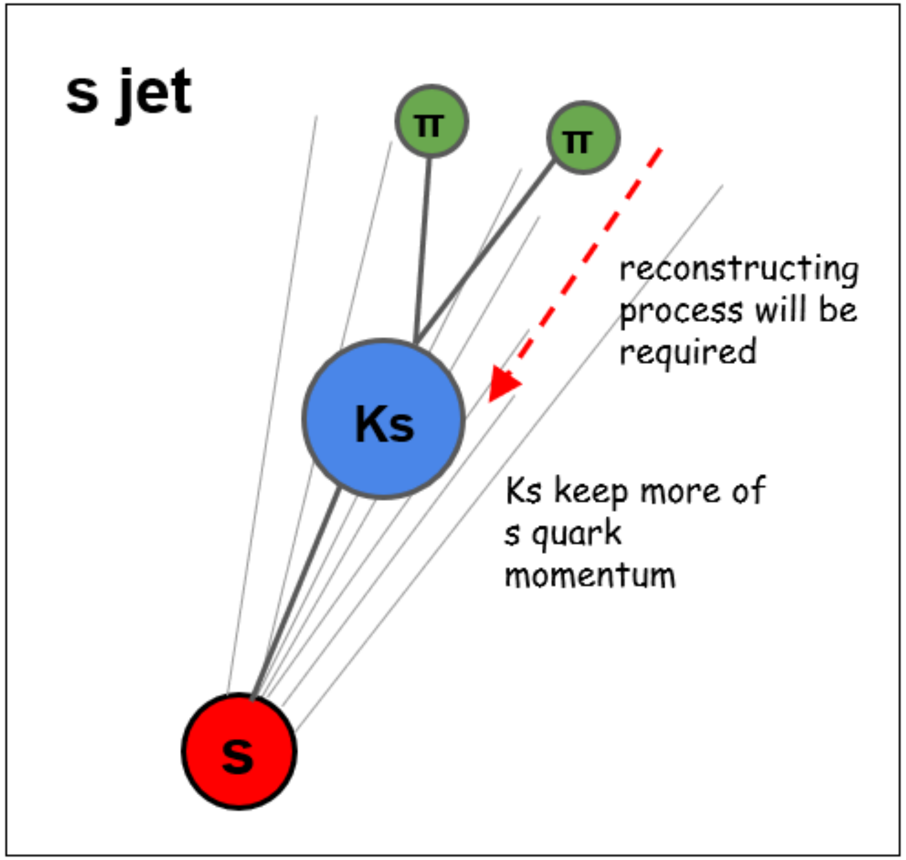
$|V_{ts}|$ is a one of elements of CKM matrix that is a 3x3 unitary in Standard Model (SM) complex matrix and describes information on charged weak interaction

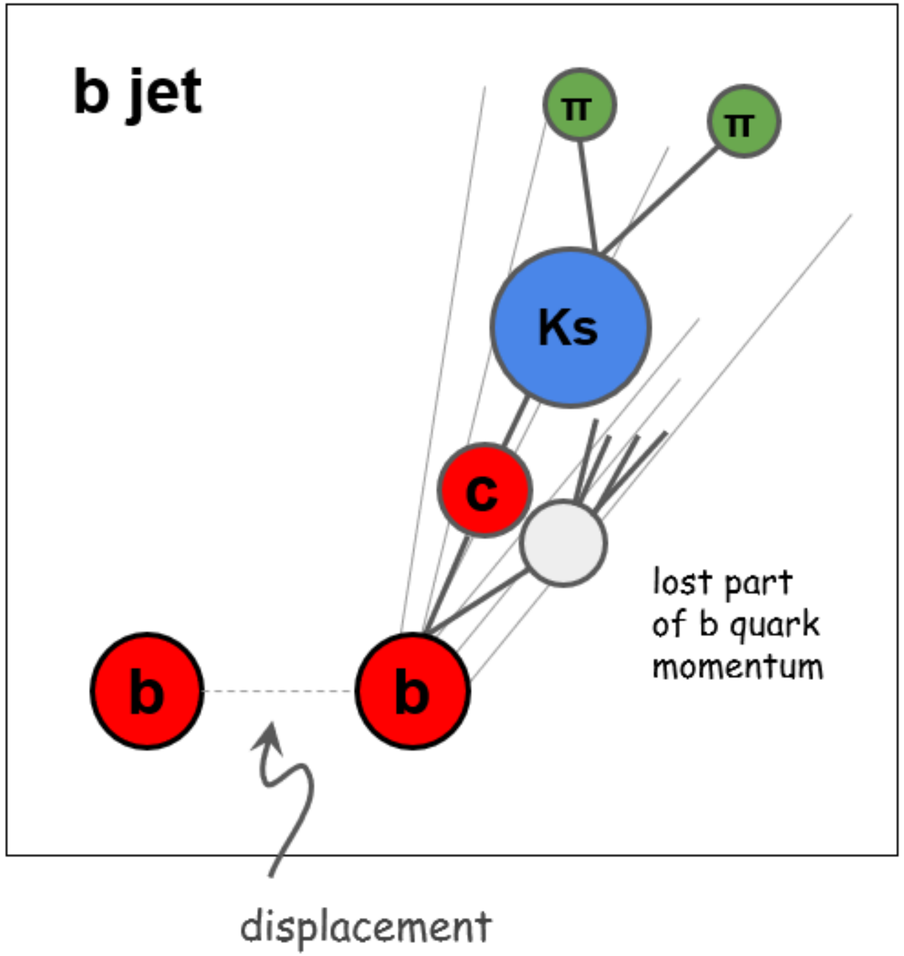
$$V_{\mathrm{CKM}} = \begin{pmatrix} V_{\mathrm{ud}} & V_{\mathrm{us}} & V_{\mathrm{ub}} \\ V_{\mathrm{cd}} & V_{\mathrm{cs}} & V_{\mathrm{cb}} \\ V_{\mathrm{td}} & V_{\mathrm{ts}} & V_{\mathrm{tb}} \end{pmatrix}$$

$$|V_{ts}|^2 = \frac{BR(t\to sW)}{BR(t\to qW)}$$

- There is a difference of magnitude of about three orders between ratio of decay of top-quark into s-quark and of top-quark into b-quark
- The analysis strategy will be doing ‘s-tagging’ and it is important to improve the jet discriminating performance
- Now we’re using Boosted Decision Tree (BDT) algorithms as the jet discriminator and testing performance from other methods is also in our plan

S-jet tagging for Vts measurement





Vts measurement

Oral Sessions

2022 KPS Spring Meeting

Wednesday-Friday, April 20-22, 2022; Virtual Conference

Session D1-pa: Accelerator-based Particle Physics Experiments IV
9:00 AM-10:48 AM, Thursday, April 21, 2022
Room: 01

Chair: 김현수, 세종대학교

Abstract: D1.04* : Measurement of |Vts| using jet discrimination on ttbar dilepton final state events in pp collision at 13 TeV

Presenter:
JANG Woojin
(Department of Physics, University of Seoul)

Author:
LEE Jason Sang Hun*1, JANG Woojin 1, WATSON Ian James*1, ROH Youn Jung*1, PARK Inkyu 1
(1Department of Physics, University of Seoul)

In the Standard Model (SM), the flavour-changing weak interaction between quarks is described by the CKM matrix which is unitary in the SM. However, this unitarity may be broken in several of the Beyond Standard Model scenarios. Therefore, it is important to measure the elements in the matrix with various and precise methods to precisely probe nature at a fundamental level. This study proposes to measure |Vts|, one of the matrix elements which has not yet been fully studied, directly using the dilepton final state of top pair production in pp collision at 13 TeV with a jet discrimination method based on a machine learning algorithm.

Keyword:
vts, ckm, jet discriminatio

Measuring $|V_{ts}|$ directly using strange-quark tagging at the LHC

Woojin Jang,* Jason Sang Hun Lee,† Inkyu Park,‡ and Ian James Watson§
University of Seoul,
163, Seoulsiripdae-ro, Dongdaemun-gu,
Seoul, Republic of Korea

Abstract

The Cabibbo-Kobayashi-Maskawa (CKM) element V_{ts}, representing the coupling between the top and strange quarks, is currently best determined through fits based on the unitarity of the CKM matrix, and measured indirectly through box-diagram oscillations, and loop-mediated rare decays of the B or K mesons. It has been previously proposed to use the tree level decay of the t quark to the s quark to determine $|V_{ts}|$ at the LHC, which has become a top factory. In this paper, we extend the proposal by performing a detailed analysis of measuring $t \to sW$ in dileptonic $t\bar{t}$ events.

In particular, we perform detector response simulation, including the reconstruction of K^0_S, which are used for tagging jets produced by s quarks against the dominant $t \to bW$ decay. We show that it should be possible to exclude $|V_{ts}| = 0$ at 5.5σ with the expected High Luminosity LHC luminosity of 3000 fb^{-1}, considering only the statistical uncertainties, and not the systematic uncertainties which will play a role in setting the final analysis limits.

PACS numbers: 14.40.Df, 14.65.Ha, 12.15.Hh, 12.38.Qk, 13.87.-a

Keywords: CKM matrix, s-jet tagging, top quark

Accepted for paper in JKPS

Z' 보존 탐색을 통한 새로운 물리 현상 연구

2021 KPS Spring Meeting

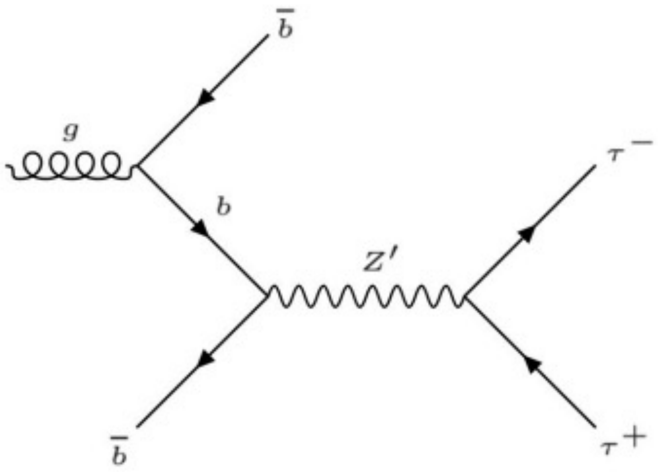
2021-04-21 ~ 2021-04-23 H1.008*

Search for Z' bosons decaying into tau pairs in bottom fermion fusion process

PARK Inkyu *1, LEE Jason Sang Hun[1], ROH Youn Jung [1], WATSON Ian James[1], KANG Dayoung [1]
[1]University of Seoul
icpark@uos.ac.kr

Abstract :

Anomalies in the B-meson decays reported by the b physics experiments could be explained by a heavy neutral gauge boson, Z', with flavor changing bs coupling and a nonuniversal coupling to leptons. In this study, we investigate the Z' decaying to tau tau in association with at least one b-jet. The analysis is performed in the tau mu channel in pp collisions at center-of-mass energy of 13 TeV using data corresponding to an integrated luminosity of 35.9/fb collected by CMS detector.



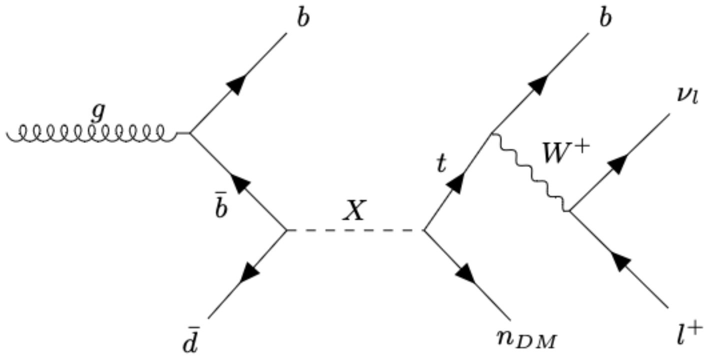
암흑 물질 연구의 기반이 되는 모노 탑 생성 연구

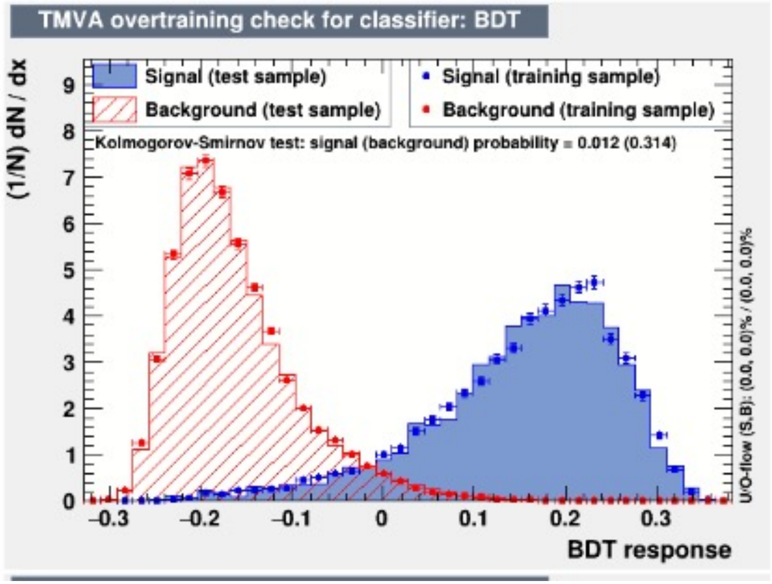
Monotop and Monojet Signatures of Baryon Number Violation

Amandeep Kaur Kalsi,[1] Teruki Kamon,[2] Seulgi Kim,[3] Shuichi Kunori,[4] Jason S.H. Lee,[3] Shivali Malhotra,[4] Tielige Mengke,[4] Denis Rathjens,[2] Youn Jung Roh,[3] Adrian Thompson,[2] and Ian James Watson[3]

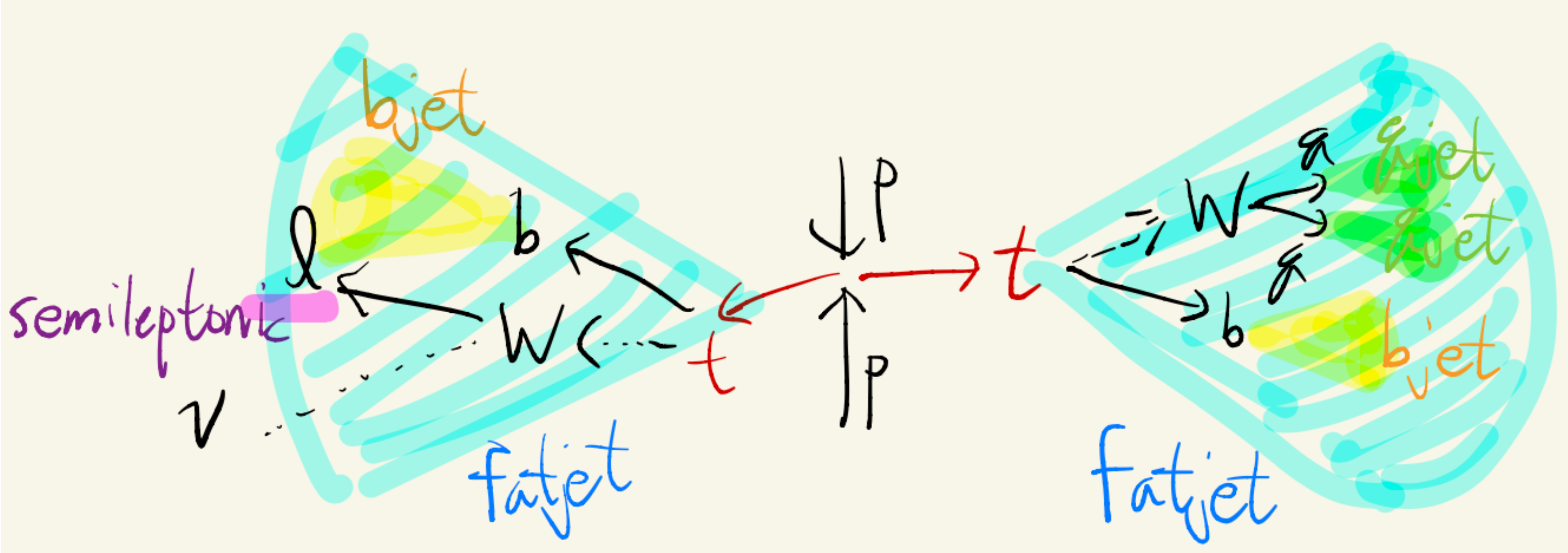
[1] *Punjab Agricultural University, Ludhiana, India*
[2] *Mitchell Institute for Fundamental Physics and Astronomy, Department of Physics and Astronomy, Texas A&M University, College Station, TX 77845, USA*
[3] *Department of Physics, University of Seoul, Seoul 02504, Republic of Korea*
[4] *

A minimal non-thermal dark matter model is studied which can explain both the existence of dark matter and the baryon asymmetry in the universe. Two color-triplet, iso-singlet scalars with $\mathcal{O}$(TeV) masses and a singlet Majorana fermion are required in this study. A new fermion with mass of $\mathcal{O}$(GeV) becomes stable and can play the role of the dark matter candidate when it is approximately the same mass as the proton. In the model we consider, the fermion interacts with top quarks via the exchange of colored scalar fields. This interaction opens up the possibility to search for such dark matter candidates in events at the LHC that contain a single jet or a single top quark.





Top polarization



딥러닝을 활용한 검출기 연구

Journal of the Korean Physical Society, Vol. 75, No. 9, November 2019, pp. 652~659

Quark Gluon Jet Discrimination with Weakly Supervised Learning

Jason Sang Hun LEE,* Sang Man LEE, Yunjae LEE,† Inkyu PARK, Ian James WATSON‡ and Seungjin YANG
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(Received 18 June 2019; revised 26 July 2019; accepted 26 August 2019)

Deep learning techniques are currently being investigated for high energy physics experiments, to tackle a wide range of problems, with quark and gluon discrimination becoming a benchmark for new algorithms. One weakness is the traditional reliance on Monte Carlo simulations, which may not be well modelled at the detail required by deep learning algorithms. The weakly supervised learning paradigm gives an alternate route to classification, by using samples with different quark–gluon proportions instead of fully labeled samples. This paradigm has, therefore, huge potential for particle physics classification problems as these weakly supervised learning methods can be applied directly to collision data. In this study, we show that realistically simulated samples of dijet and Z+jet events can be used to discriminate between quark and gluon jets by using weakly supervised learning. We implement and compare the performance of weakly supervised learning for quark–gluon jet classification using three different machine learning methods: the jet image-based convolutional neural network, the particle-based recurrent neural network and and the feature-based boosted decision tree.

PACS numbers: 13.90.+i, 13.87.−a, 12.38.Qk, 13.87.Fh
Keywords: QCD, Jet, Fragmentation, Weakly supervised learning, Machine learning
DOI: 10.3938/jkps.75.652

I. INTRODUCTION

The use of machine learning techniques in high energy physics has been of major interest in recent years due to its potential to improve the analysis of particle collision data. One specific area in which machine learning is used for improvement is the discrimination between quark-initiated and gluon-initiated jets [1,2]. Though these machine learning techniques show excellent performance, they heavily rely on Monte Carlo (MC) simulations for input, as they are trained on the microscopic details of the simulation, which may not be well-modelled due to the non-perturbative nature of Quantum Chromodynamics (QCD) at low energies. Thus, the performance of these methods can be sub-optimal when applied to real data, and care is needed.

In contrast, weakly supervised paradigms, such as Classification Without Labels (CWoLa) [3] and Learning from Label Proportions (LLP) [4,5], can alleviate these issues as they can be used as data-driven classifiers. This is done as they allow training using samples that are mixtures of quark and gluon events of different proportions rather than requiring pure, labeled quark and gluon samples. In the CWoLa method, you train a classifier to distinguish between quark-enriched and gluon-enriched samples. Under the condition that the only difference between the two samples are the quark–gluon proportions (and not the features of the quark or gluon in each sample), training a classifier to distinguish the two samples is equivalent to training a classifier to distinguish a quark and from a gluon. The CWoLa technique is beginning to be used in LHC analyses; for example in the CMS $t\bar{t}b\bar{b}$ analysis, it has been used to distinguish the multijet background, which is difficult to model because of the high number of jets [6].

The CWoLa method is simple to apply to any machine learning algorithm as it allows training without any truth information, such as quark–gluon labels or the class proportions of the mixed samples, but uses the same techniques as for standard machine learning with labels. This allows for direct use with dijet and Z+jet samples for quark–gluon jets as they have different quark and gluon fractions [7,8]. A classifier that is trained to distinguish between two mixed samples, which could be made directly from collision data even though we use simulations for this study, is also able to optimally discriminate between the quark jet and the gluon jet processes, in the limit where the only difference between the samples is the quark-gluon jet fraction [3,9].

Three machine learning methods, Convolutional Neural Network (CNN), Recurrent Neural Network (RNN) and Boosted Decision Tree (BDT) are used for weakly supervised learning. The CNN, which is used as an image analysis and classification technique, is able to operate

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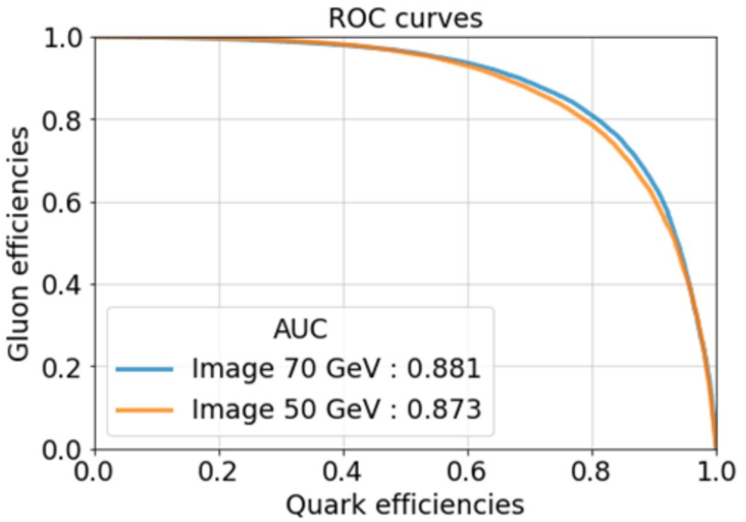
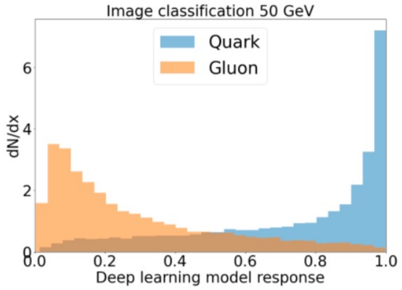
‡E-mail: ian.james.watson@cern.ch

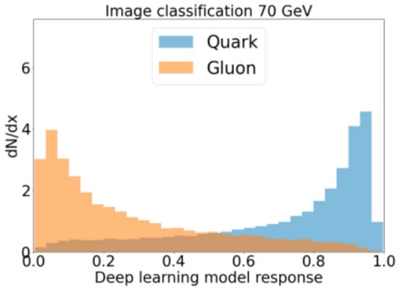
DREAM FOR FUTURE

Quark and Gluon Jet Identification

- Image based model(Image) used for classification between quark(u,d) and gluon jets at 50 GeV and 70 GeV.
- Distributions of model responses show separated quark side and gluon side.
- Quark efficiency and gluon efficiency can be achieved about 79% at 50 GeV, 80% at 70 GeV.



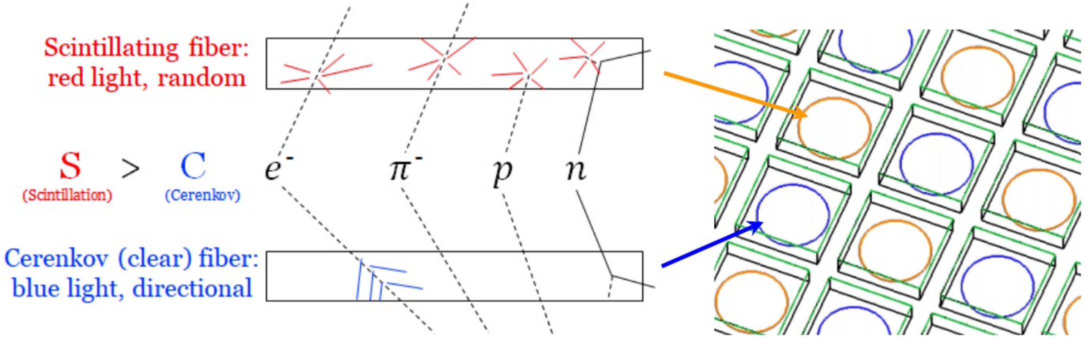




딥러닝을 활용한 검출기 연구

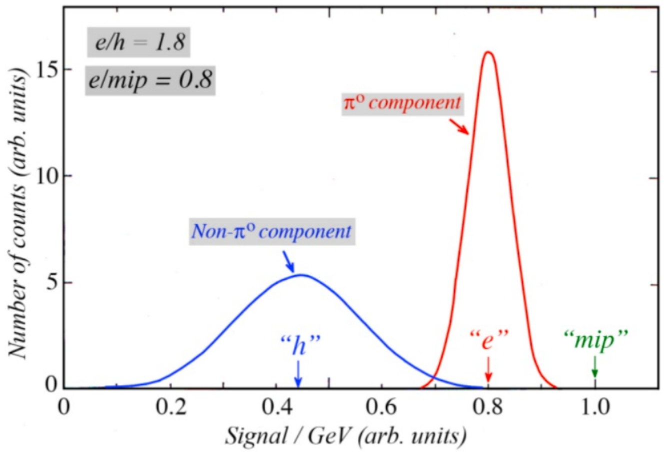
Dual-Readout Calorimeter

- Dual-readout calorimeter is considered of detector for FCC-ee and CEPC due to its great hadronic energy resolution.
- Dual-readout calorimeter has two different, Scintillation and Cerenkov fibers components.
  - Scintillation fibers react to both EM and hadronic particle, Cerenkov fiber reacts to EM particle only.
- Ratio of hadronic component and EM component h/e is differed by Scintillation part $(h/e)_S$ and Cerenkov part $(h/e)_C$.



Array of fibers

Distributions of signal for shower components[1)]



Normalized to the response for minimum ionizing particles ("mip")
The average values of hadronic response(h) is smaller than EM response(e)

1) Lee, S., Livan, M. and Wigmans, R. (2018) Nucl. Instr. and Meth. A882, 148

딥러닝을 활용한 검출기 연구

DREAM FOR FUTURE

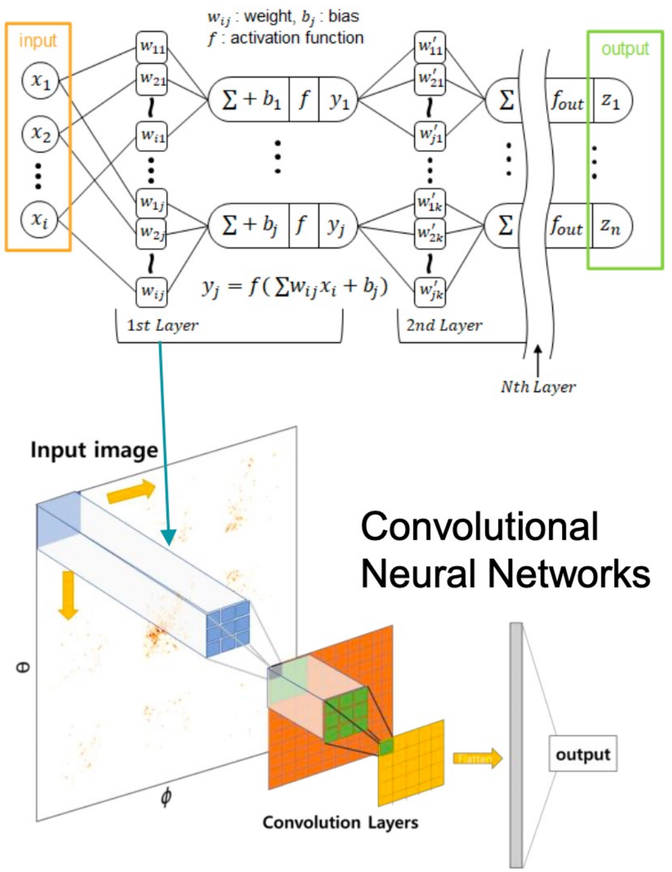
Deep Learning Methods

- Convolutional neural networks(CNN) have weight matrix of certain size.
  - Weight matrix convolute certain window over input image.
  - Output is also array and the weight matrix work as convolution filters finding contour or shape features over image.
- Binary classifications are performed between two particle.
  - Softmax function for output to return between 0(background) to 1(signal).
  - Cross entropy loss as loss function for binary classification between particles.

$$\mathrm{loss}(y,p) = -(y\log p + (1-y)\log(1-p))$$

(y is target value, p is prediction value)

Neural Networks

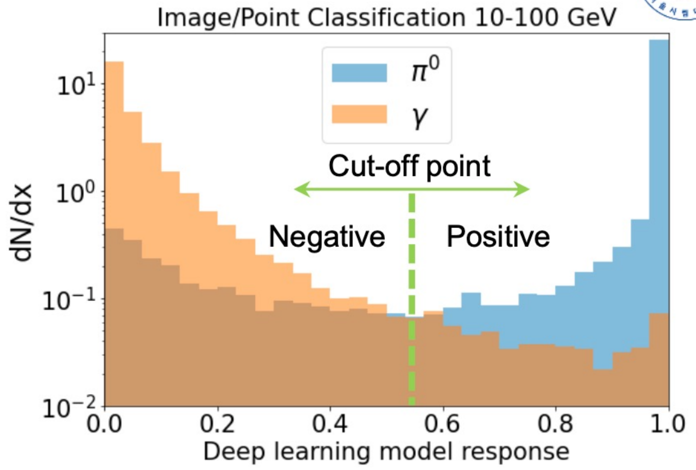


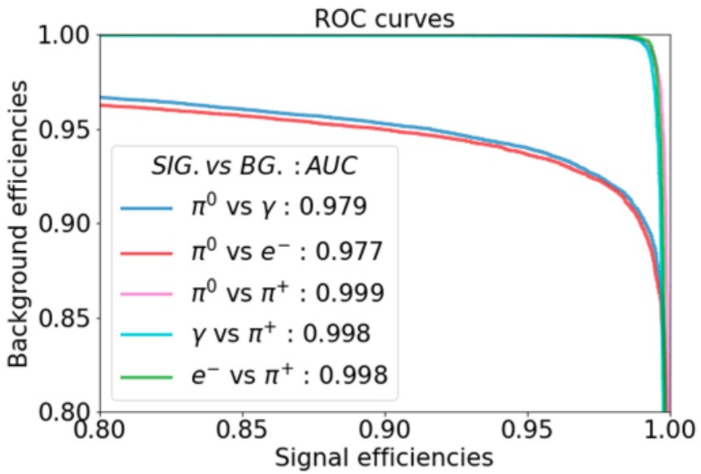
Convolutional Neural Networks

딥러닝을 활용한 검출기 연구

Particle Identification

- After training model, model responds to input data between 1.0(signal) to 0.0(background).
  - As π^0 decays to two gamma, some having very narrow opening angle are misidentified as gamma shower.
- Receiver operating characteristics(ROC) curve drawn with signal and background efficiencies.
  - $\text{signal efficiency} = \frac{\#\ of\ signal}{\#\ of\ positive\ reponse}$,$\text{background efficiency} = \frac{\#\ of\ background}{\#\ of\ negative\ reponse}$
  - Positive and negative responses are decided by certain cut-off point.
- Area under ROC curve(AUC) close to 1.0 implies high signal and background efficiencies, performance of classification are compared by AUC value.
  - AUC 0.97 - 93% efficiencies, AUC 0.99 - 99% efficiencies.





딥러닝을 활용한 검출기 연구

2021 KPS Spring Meeting
2021-04-21 ~ 2021-04-23
C1.05

Machine Learning application on particle identification for dual-readout calorimeter

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Abstract:

The dual-readout calorimeter consists of scintillating and Cerenkov fibe
together. This design allows to measure both electromagnetic and hadr
with high precision in a single component, and neural network based m
learning (deep learning) implementations can maximise the physics pote
future colliders. Since classification using deep learning has been studi
can be applied to identifying incident particles of shower to improve eve
and jet analysis. We present demonstrations of particle discrimination fo
readout calorimeter performed with energy deposit of simulated shower
calorimeter. Image based deep learning model analyzes pixelated energ
with convolutional neural networks. and raw energy deposits can be app
point cloud based deep learning method.

Keywords:

Dual-readout calorimeter, Deep learning, Particle identification

2021 KPS Fall Meeting
2021-10-20 - 2021-10-22

Particle identification for Dual-R

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Abstract:

The dual-readout calorimeter consists of scintillating and Cerenkov fibers read out together to measure hadronic showers with high energy precision. for future colliders. Currently, it is under development and neural network-based machine learning (deep learning) implementations are under investigation to maximize the physics potential. Classification using deep learning is applied to identify particle showers with their incident particles. Image-based deep learning models analyze pixelated energy deposits with convolutional neural networks, while point cloud-based deep learning methods train using lists of energy deposits. We compare the performance of these methods when trained to identify various electromagnetically and hadronically showering particles using the dual-readout calorimeter.

Keywords:

Dual-readout calorimeter, Deep learning, Particle identification

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Deep learning methods are being applied to high-energy physics widely. We are investigating deep learning implementations for the dual-readout calorimeter. The dual-readout calorimeter, proposed for future colliders (FCC and CEPC), consists of scintillating and Cerenkov fibers readout together to measure hadronic showers with high energy resolution. Particle and jet identification has always been a challenging problem, especially when relying only on the calorimeter system. Typically, spatial energy distribution in the calorimeter is used to help identify the different types of particles. However, the dual-readout calorimeter captures both scintillating and Cerenkov radiations, which not only helps improve the hadron energy resolution but provides additional pivotal information for particle identification. We present both particle and jet identification performance using image-based deep learning techniques optimized for the dual-readout calorimeter system.

Plan

- 양승진 (박사과정): 논문 수정/게재 및 박사학위
- 고병학 (박사과정): 논문 작성을 위한 CMS internal review, 학회발표
- 장우진 (참여연구원): CMS internal note 작성, 논문작성
- 김정우 (석사과정): 석사 학위, 학회발표
- 강다영 (박사과정): CMS internal note 작성
- 김슬기 (박사과정): 논문 작성
- 손영완 (석사과정): 석사 학위
- 이윤재 (참여연구원): 학회 발표, 논문 작성