# Intermediate Report of Summer Projects at CERN

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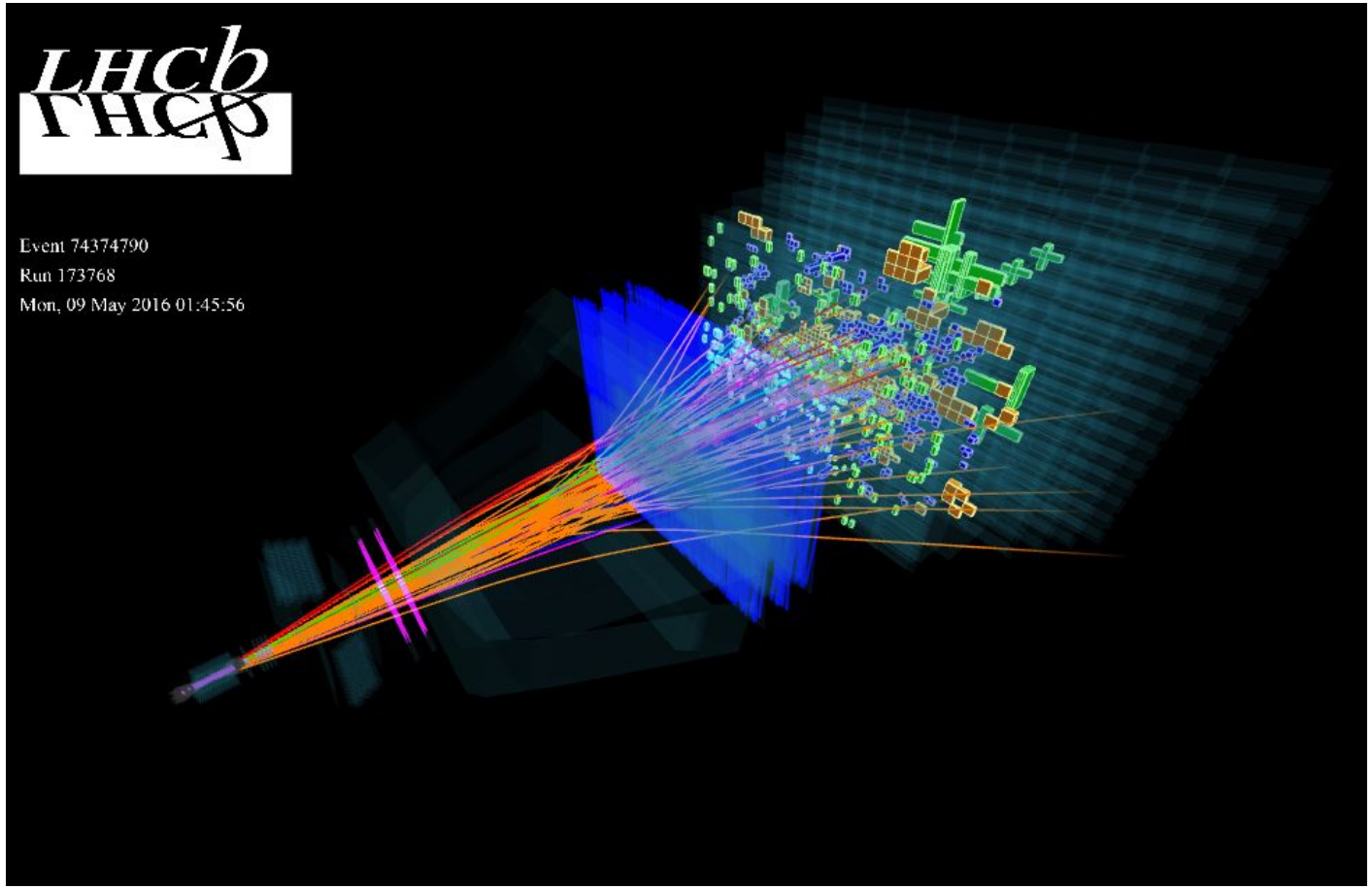
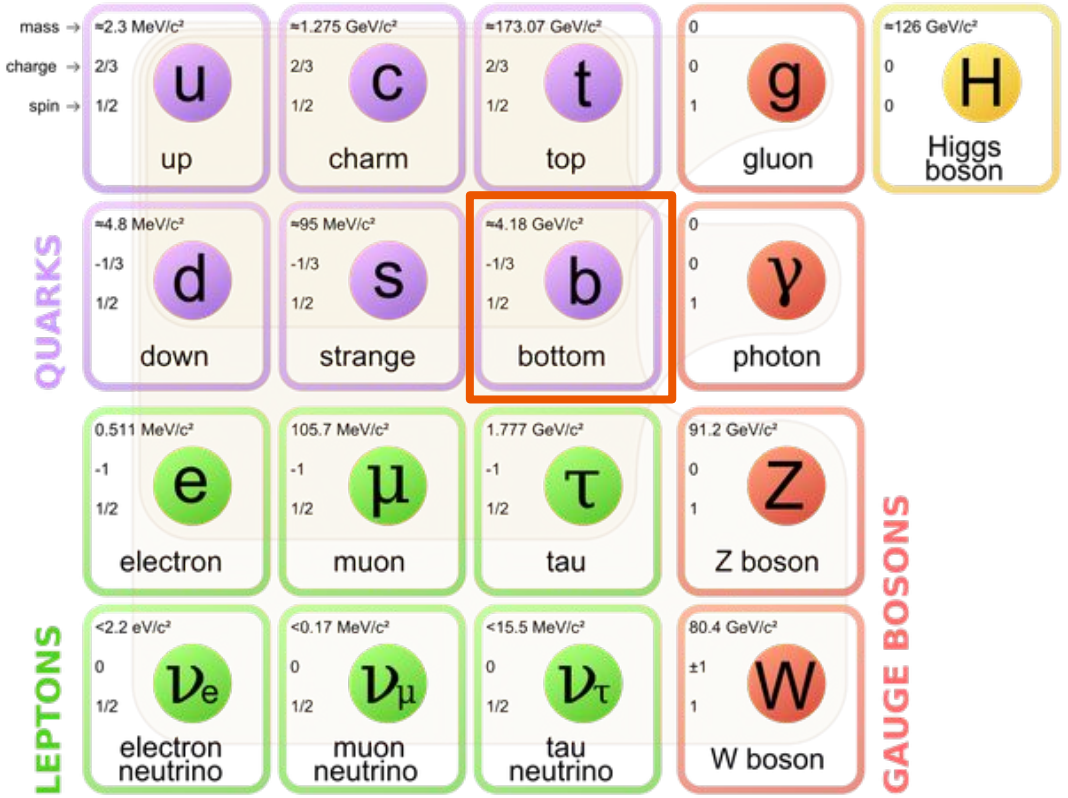
# Big Picture

➔ **Investigate the substructures of b jets**



# Heavy Flavor Tagging

- b jets
  - Initiated by b quark
  - heavy flavored
- Interleaved Flavor Neutralization(IFN flav) is a new flavor tagging jet reco algorithm useful for QCD
  - Conventional Anti $k_t$ algorithm fails to be **Infrared-Collinear(IRC) safe**
    - **IRC safe** = theoretically calculable
  - IFN flav is **IRC safe**
  - It is a part of the new JetFlav package
  - IFN flav iteratively neutralizes flavors of jets and particle as much as possible.



# Initial Motivations

➔ **Goal:**

- Implement JetFlav(which includes IFN flav) package into DaVinci
  - DaVinci is the analysis software developed for LHCb for jet analysis

➔ **What has been accomplished:**

- Learned to change some parameter in DaVinci and run using an option file
- Dug through the source code of DaVinci to investigate the possibility of implementing a different algorithm other than Anti $k_t$
  - FastJet, which DaVinci uses as jet reconstruction interface, comes with several jet reco algorithm. One can specify it using options file.
- Investigated the custom plugin functionality of FastJet

Good reads ;)

Anti $k_t$ paper

IFN flav paper

LHCb hardware paper

# Some Obstacles

- ➔ JetFlav requires nightly builds of DaVinci compatible with latest FastJet
  - ◆ Nightly build of DaVinci and ROOT suffered from a fatal bug on memory level

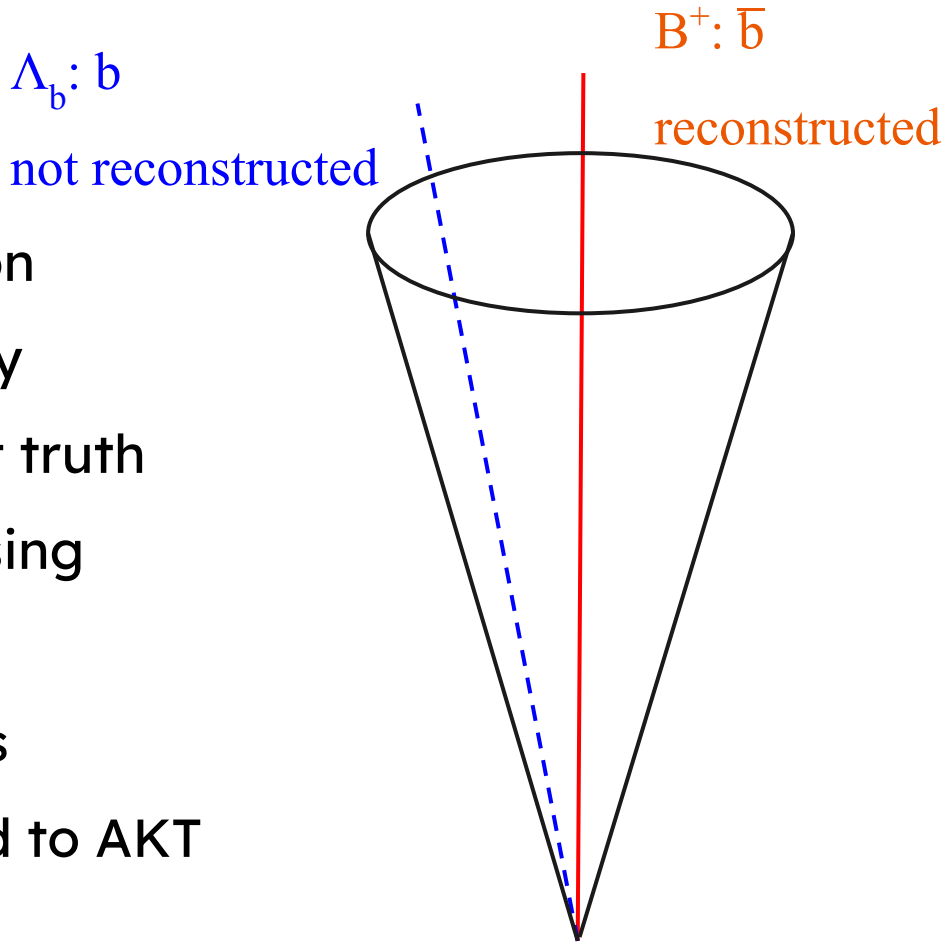
- ➔ DaVinci does not like dumping all event information
  - ◆ But we need all hadronization and preferably all particle info
  - ◆ Using DaVinci to output all original b hadrons at reco level jets for analysis may be difficult

# New Approach

- ➔ While the implementation of JetFlav is still essential, I decided to take another approach to look into some properties of IFN flav
  - Use Pythia to generate MC events
  - Use truth level data to test the efficiency of IFN flav compared to Anti $k_t$

# Experimental Difficulties

- ➔ JetFlav assumes that all hadrons are truthfully reconstructed
- ➔ But the fact is that we **only** reconstruct B+ meson through a single J/Psi K+ channel experimentally
- ➔ In other words, there maybe less flavored jets at truth level compared to reco level because of the missing flavored hadrons
- ➔ We want to check purity on the reco level and its efficiency on both reco and truth level compared to AKT




At truth level, should be flavor neutral

At reco level, we see a $\bar{b}$ flavored jet

# Future Prospect

- ➔ We will need to analyze the reco level purity as well using DaVinci
  - ◆ Up to now, the nightly build of DaVinci has been fixed and a new dev patch is in the process of being released
  - ◆ Hopefully it will work and we can implement IFN flav as a jet reco plugin into FastJet
  - ◆ The implementation will facilitate our understanding of IFN flav
  - ◆ It will also help us understand the effects of experimental restrictions(i.e cannot reconstruct the HF hadrons in every event) and how to make useful measurements to test QCD at higher precision with the theorists.

hfjetpy > hfjetpy > pythia_quark_gluon_ezra.py > PythiaQuarkGluon > calculate_events

```
107  class PythiaQuarkGluon(process_base.ProcessBase):
585      def calculate_events(self, pythia):
586
587          iev = 0  # Event loop count
588
589          self.parton_counter = 0
590
591          while iev < self.nev:
592              if not pythia.next():
593                  continue
594
595              self.event = pythia.event
596
597              # Check if the event contains desired parton, else continue
598              '''
599              rdc
600              # In our case we would only want b quark right?
601              # Leave it to be both for now
602
603              # just keep bottom
604              '''
605              desired_pid = [5] # charm, bottom quark
606              desired_parton_found = False
607              for parton in pythia.event:
608                  if parton.id() in desired_pid:
609                      if (self.min_eta_hadron - 1) <= abs(parton.eta()) <= (self.max_et
610                          desired_parton_found = True
611                          #print("\nfound b quark!!!\n")
612                          break
613              if not desired_parton_found:
614                  self.parton_counter += 1
```

```
[ruide@lxplus916 r
uide]$ /bin/python3.11
Python 3.11.7 (main, Jan 22 2024, 00:00:00) [GCC 11.4.1 2
0231218 (Red Hat 11.4.1-3)] on linux
Type "help", "copyright", "credits" or "license" for more
 information.
>>> quit
Use quit() or Ctrl-D (i.e. EOF) to exit
>>>
/bin/python3.11^Cruide]$
[ruide@lxplus916 ruide]$ ./hfjetpy/hfjetpy/slurm_pythia_h
f_gen.sh
Number of pT-hat bins: 1
Number of events per job: 90
Number of cores per pT-hat bin: 110
Calculating bin 1 (pThat_min=70) with core number 0
Loading myheppyy
  Loading requirement: fastjet/3.4.2
    LHAPDF6/6.5.4 pythia8/8310 root/6.28.12
    HepMC2/2.06.11 yasp/current heppyy/current
python is /afs/cern.ch/work/r/ruide/yasp/venvyasp/bin/pyt
hon
python /afs/cern.ch/work/r/ruide/hfjetpy/hfjetpy/pythia_q
uark_gluon_ezra.py -o /afs/cern.ch/work/r/ruide/lib -c /a
fs/cern.ch/work/r/ruide/hfjetpy/hfjetpy/config/mass_zg_th
etag.yaml --user-seed 1021 --py-pthatmin      70 --py-ecm
 5020 --nev 90 --replaceKP 1 --chinitscat 4   --pythiaopt
s HardQCD:all=off
```

# Cultural Experience

## Lyon

# Cultural Experience

## Lyon

# Cultural Experience

## Lyon

# Cultural Experience

## Mont Jura and Geneva

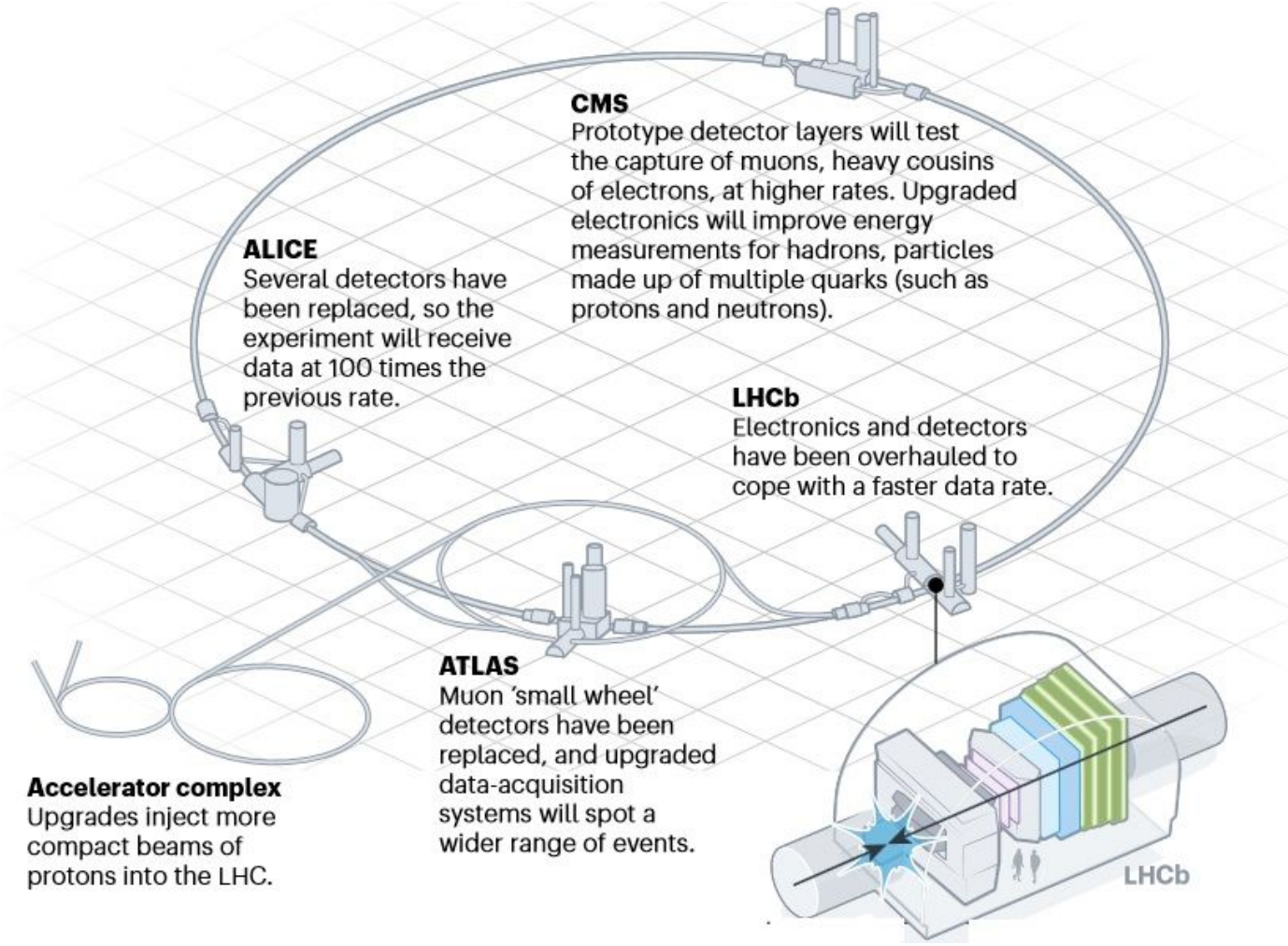
UNIVERSITY OF MICHIGAN

# Thank you!!

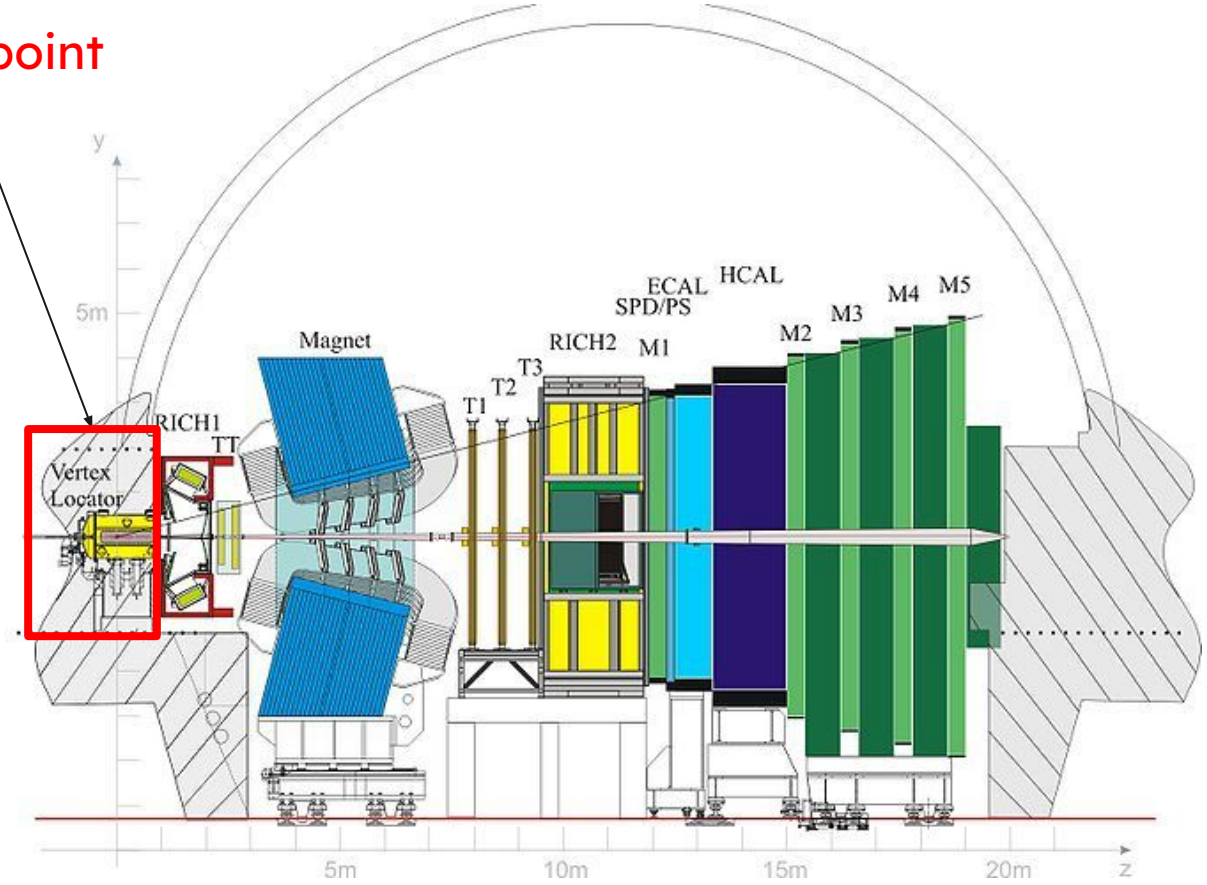
# Large Hadron Collider beauty (LHCb)

➔ **LHCb detector**

- Detect mainly forward particles
- Lower luminosity-> Reduced background
- Faster Data Rate
- Retractable VELO detector



# Large Hadron Collider beauty (LHCb)



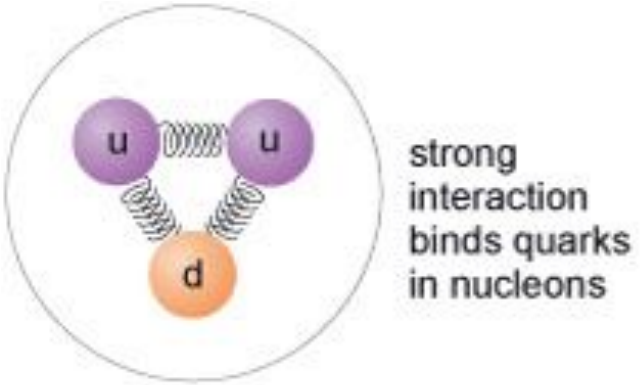

➔ **Goal of the LHCb**

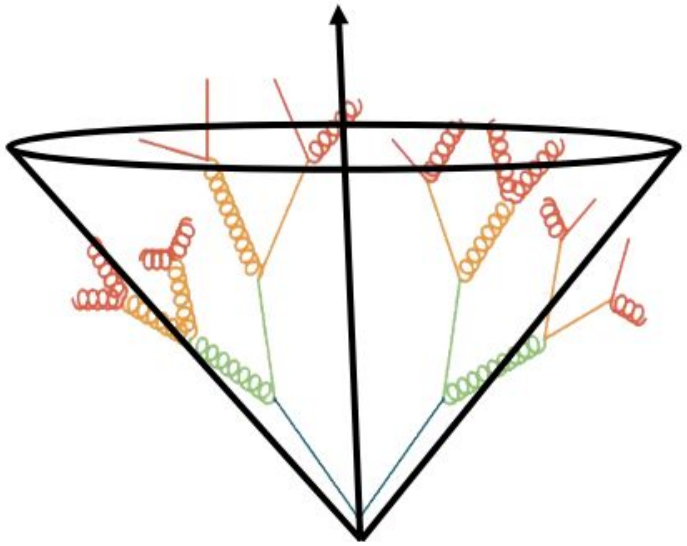
- Measure parameters of the CP violation in the interactions of b hadrons
- Insight to matter-antimatter Asymmetry
- Insight to strong interaction and production

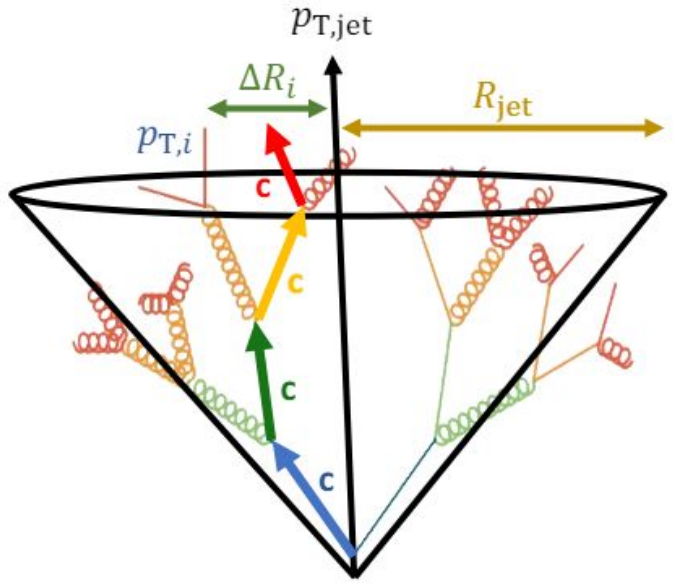
# Jet Background

➔ **What are jets/Why study jets**

- Narrow cones of hadrons and other particles created by hadronization of quarks and gluons under high-p collision
- Hadronization: quarks and gluons turn into hadrons
- Probes of strong interaction(or Quantum Chromodynamics)
  - We know little about strong interactions(hadronization, non-perturbative)



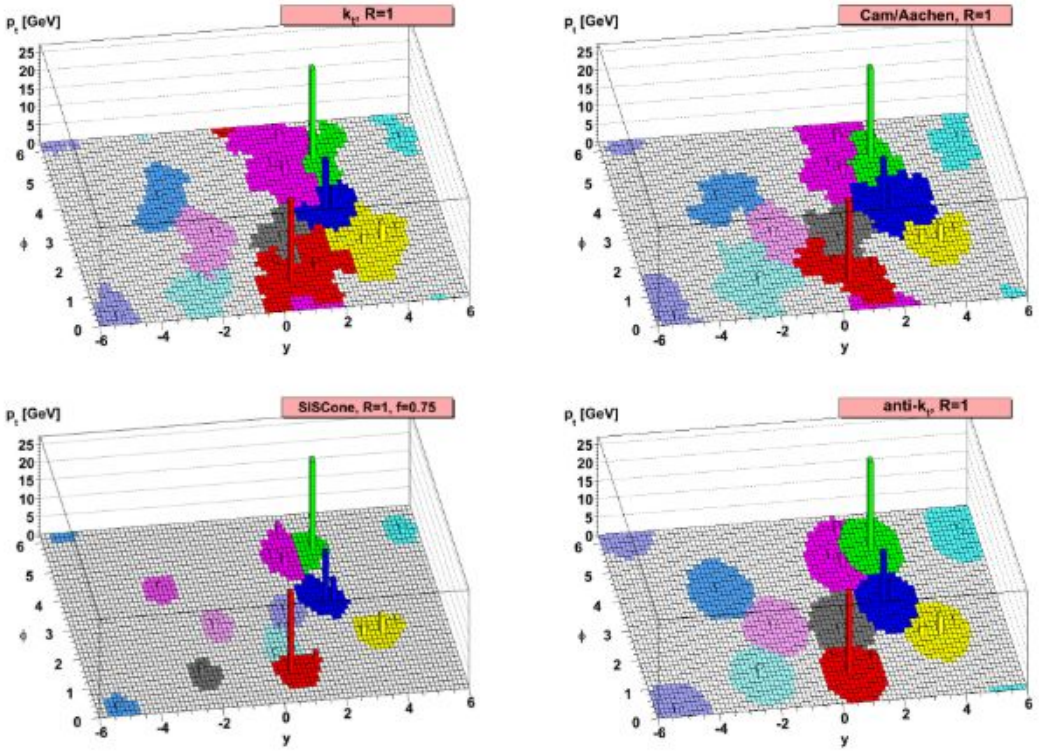






Stolen from Ezra's presentation

# Jet Reconstruction

- **Anti $k_t$ algorithm**
  - resistant to soft radiation(particles with low p)
  - gives circular boundary
  - IRC(Infrared-Collinear) safe
    - Yield result friendly to the theorists
- **Algorithm**
  - Find the hardest particle
  - Group the soft particles around it
  - Find the next hardest particle
  - Group the soft particles
  - Iterate

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