# QCD Instantons

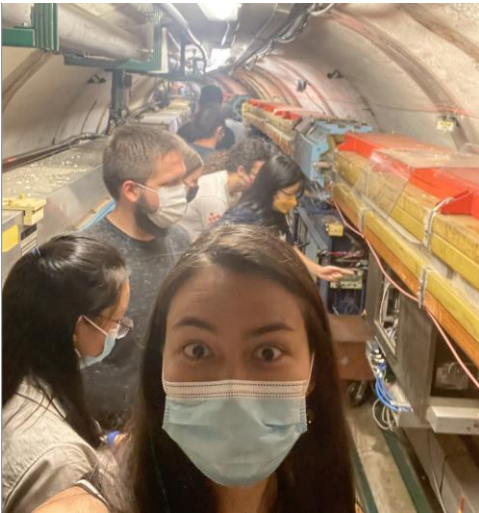US State Department CERN Program

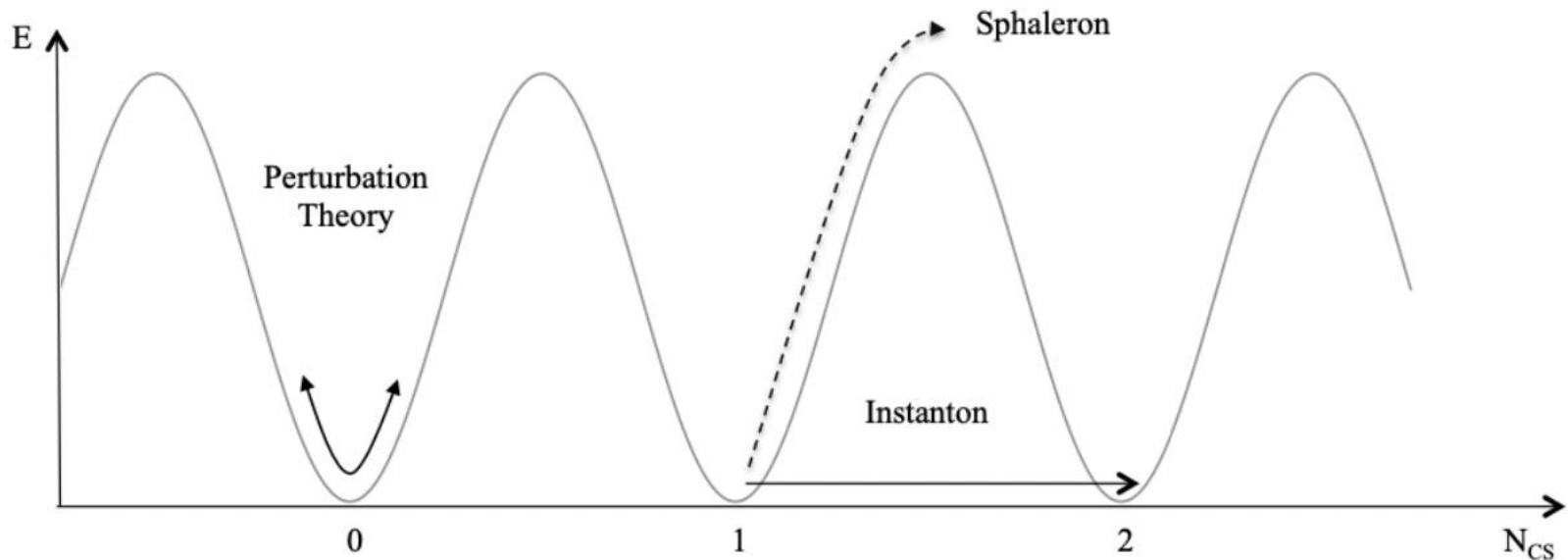Maria Bressan
Tancredi Carli

October 5, 2022

# About me

- Senior undergraduate at Penn State: Physics major, Astrophysics dropout
- Personality:
  - Musician
  - Enfp-t
  - Sun in Virgo
  - Chinese zodiac: year of the snake
  - According to S'Cool lab, I am a Muon Neutrino
- Research interests: exoplanets, quantum cosmology, particle searches
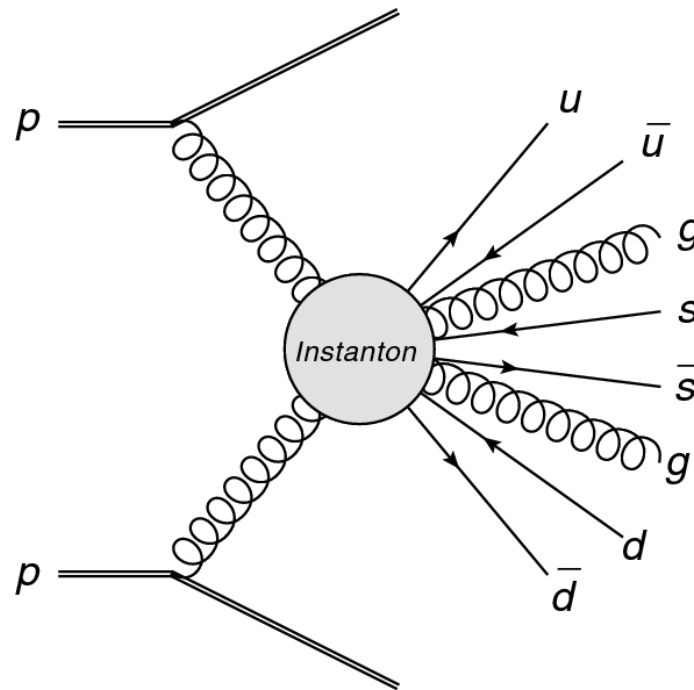
# The QCD Instanton



**A non-perturbative process describing a tunnelling process in which quantum numbers are broken.**

- Instanton processes cannot be described with the usual perturbative approach
- In EW theory - baryon number; In QCD - chirality

# **Experimental Signatures**



- **Identifying features used to search for QCD instantons:**
  - **Isotropic decay & many partons produced:** partons (i.e. quarks and gluons) have no preferred direction of decay
  - **Chirality:** all partons from instanton process have same **handedness**
  - **Flavor democracy:** one pair of each kinematically allowed quark flavor produced per instanton event

# Instanton Mass - Theory Prediction



arXiv:1911.09726
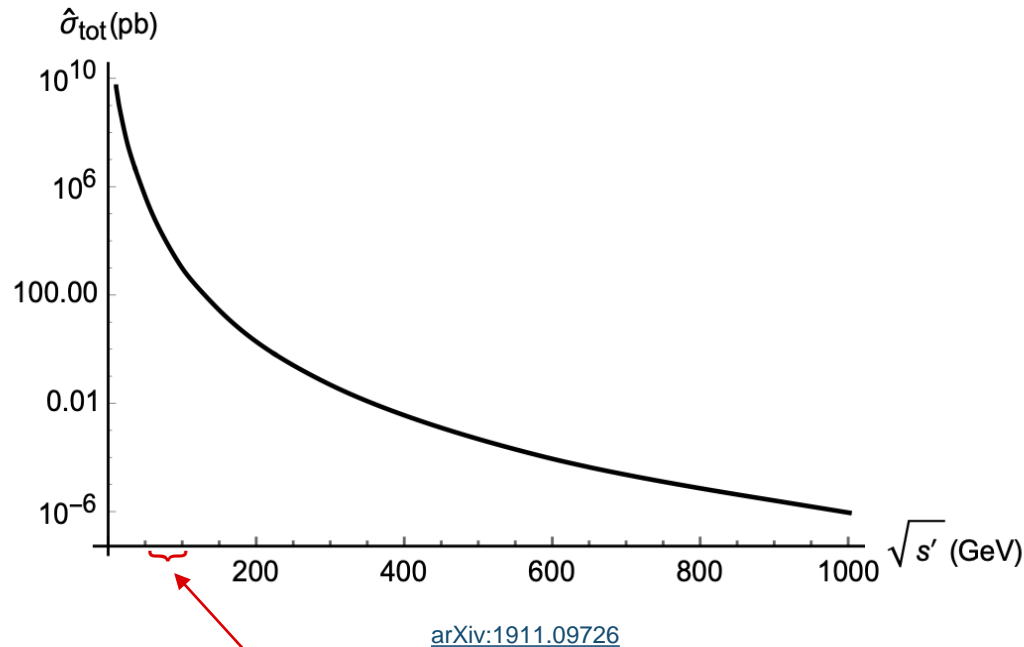
Region of our analysis

- Most likely to have mass ~100 GeV (this is less than the top quark!)
- Theory prediction has large uncertainty → design analysis to be least sensitive to shape of mass distribution

# How do we search for particles?

- **Proton (p) bunches** collide every 25ns
- **Event** - particles produced by one p-p collision
    modeled as one **parton** from each proton interact
- Quarks and gluons are produced in an event
    - Due to confinement, they **hadronize** (i.e. decay into a **jet** of hadrons)
- **Tracks** - charged hadrons curve in the magnetic field, radius of curvature proportional to momentum
- Reconstruct **vertices** and **jets**



Secondary vertex

Jet direction

Impact parameter

Primary vertex
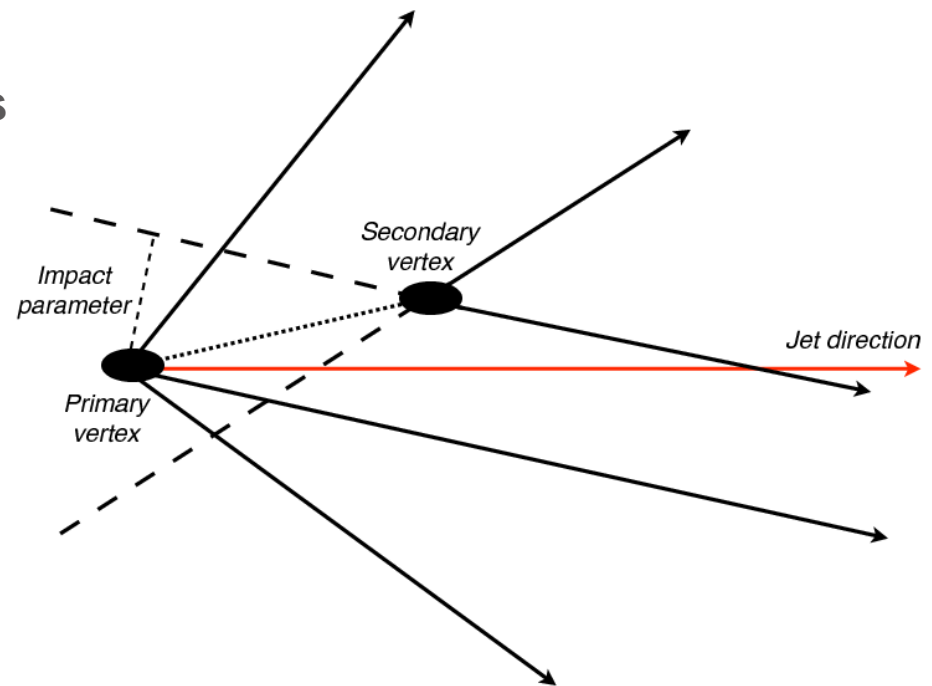
# Flavor democracy: soft b-tagging

- **B-tagging** - algorithms to identify b hadrons
  - Longer lifetime -> secondary vertices
- Existing algorithms are bad for low transverse momentum (pT)
- Newer b-tagging algorithm aims to improve this:
  - "Soft b-hadron tagging for compressed SUSY scenarios"
- We can use Monte-Carlo simulated data to study our algorithm performance.

My task: apply this
new algorithm to the
instanton case



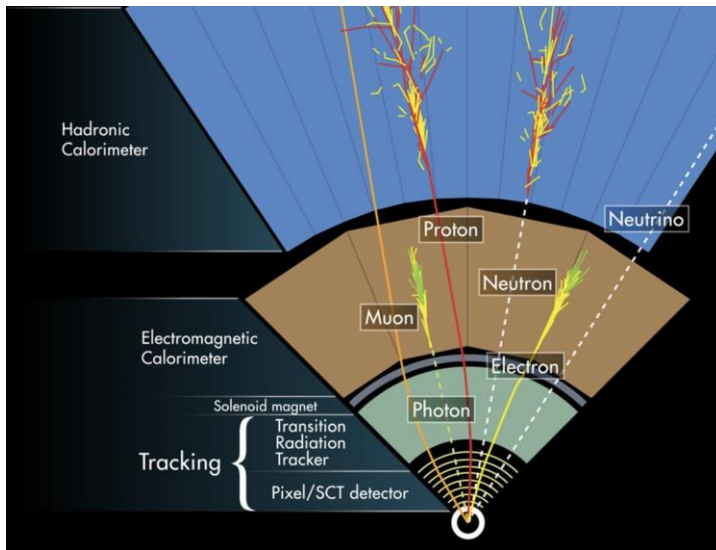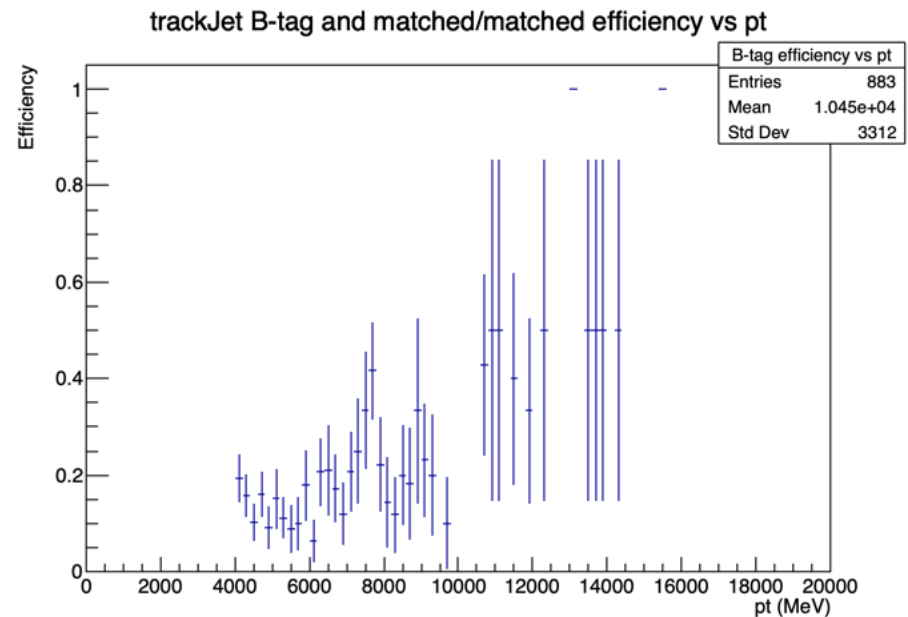https://cds.cern.ch/record/2659377?
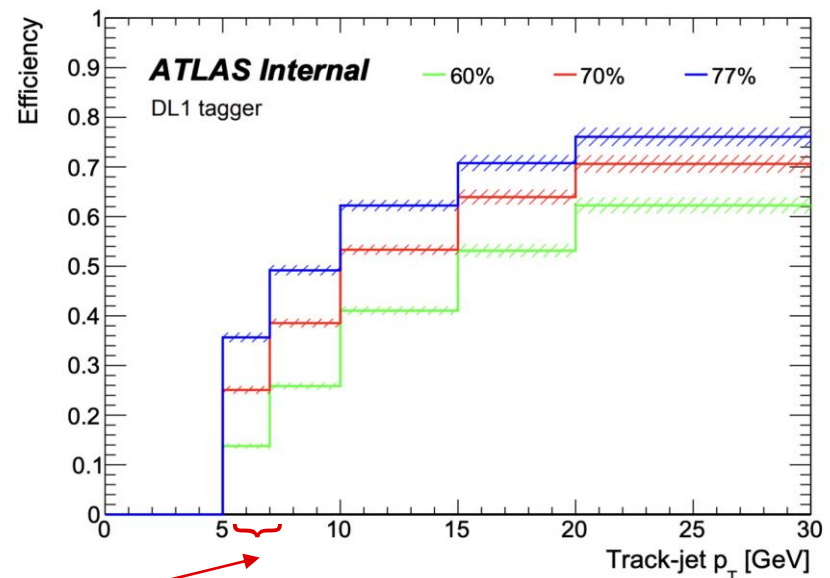
Region of our analysis

# TrackJet Performance

- **trackJets**: precise measurement of curvature and therefore momentum, but this only measures charged hadrons so we lose about ⅓ of the data (roughly ⅓ +, ⅓ -, ⅓ neutral pions)
  - Works better for low $p_T$
- Efficiency = (# b-tagged and matched)/(# matched)



Adapted from https://cds.cern.ch/record/1505342

# What's next?

- See if the newer soft b-tagging algorithms are promising:
  - trackJet Tagging
  - Tracks-based Low-pT Vertex Tagging
  - Track Clusters-based Low-pT Vertex Tagging
- Study identification of hadrons that can be used to tag quark flavor

# Thanks for watching!! Questions?