Search For Dark Matter at the CMS Experiment

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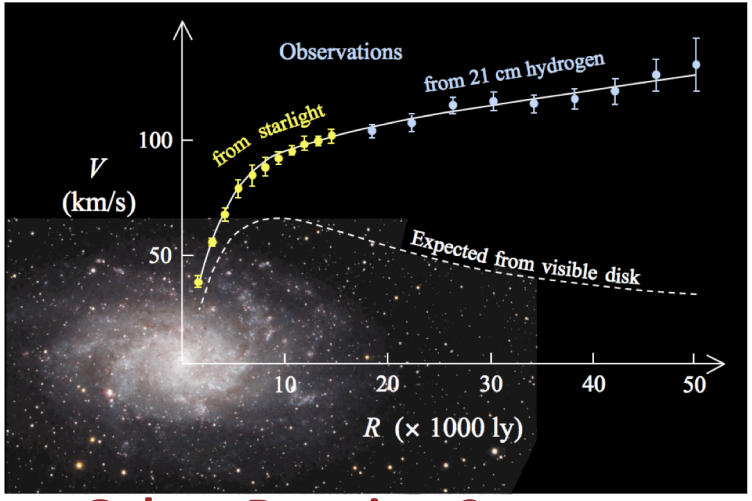
SPRACE

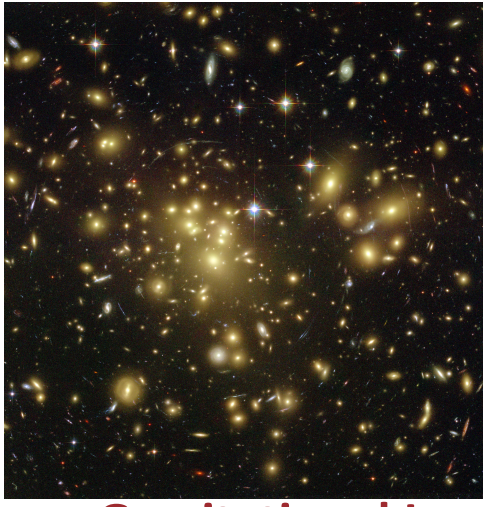
“We propose to build a general purpose detector designed to run at the highest luminosity at the LHC. The CMS (Compact Muon Solenoid) detector has been optimized for the search of the SM Higgs boson over a mass range from 90 GeV to 1 TeV, but it also allows detection of a wide range of possible signatures from alternative electro-weak symmetry breaking mechanisms.”

Abstract of the CMS Letter of Intent, submitted to the LHC Experiments Committee (LHCC) on 1 October 1992

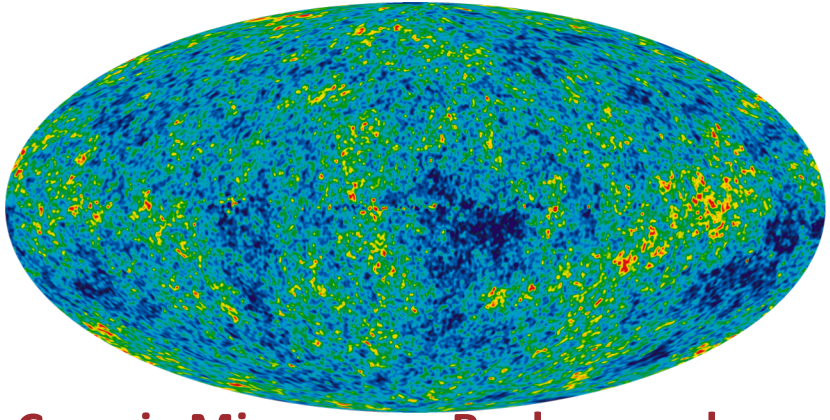
Dark Matter



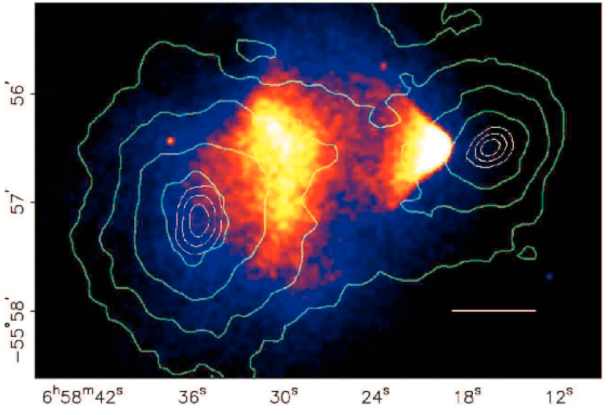
Galaxy Rotation Curves



Strong Gravitational Lensing

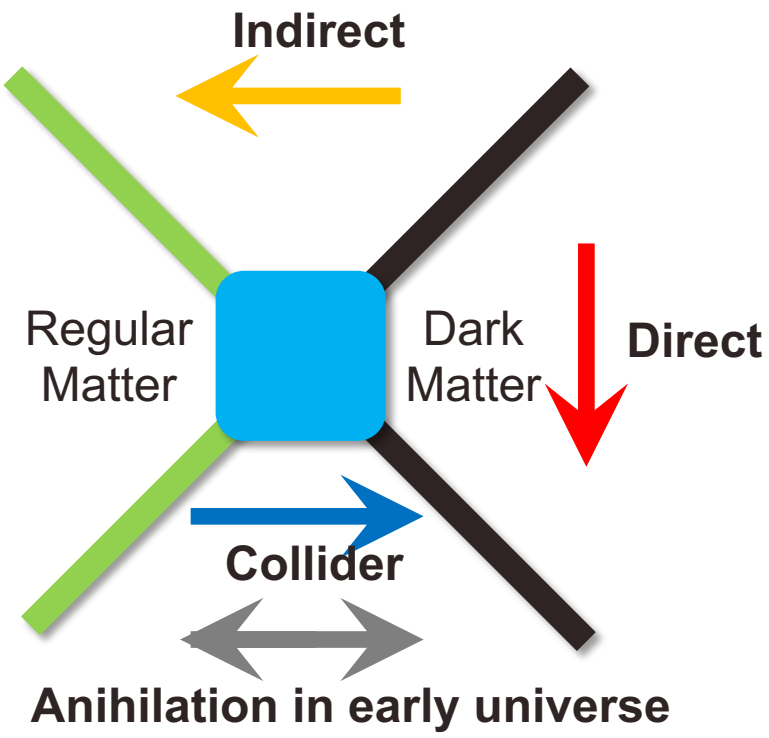


Cosmic Microwave Background



Bullet Cluster

Strategies to Search for Dark Matter



Direct detection

- ❑ DM-nucleus scattering

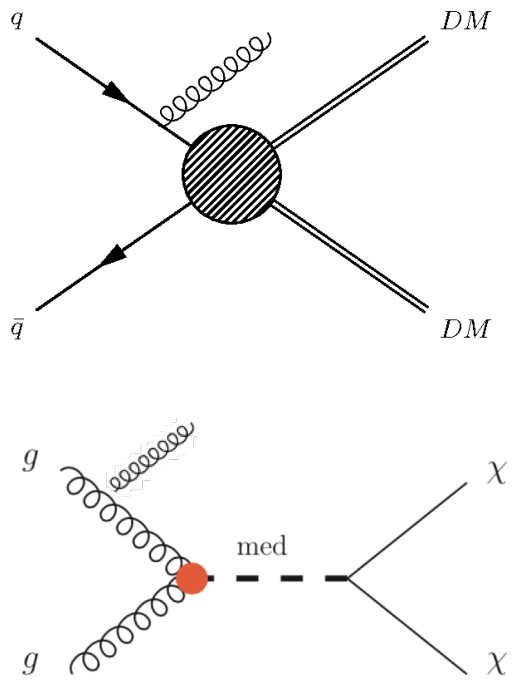
Indirect detection

- ❑ DM Annihilation products

Collider production

- ❑ Production of DM at the lab (e.g. LHC)
  - Clear strategy for WIMP
  - Sensitive to a large DM mass range

Modeling Dark Matter Production at the LHC



Model-independent search

- Contact Interaction
  - Limited at LHC energies
- Simplified Models
  - DM: pair-produced Dirac fermion
  - Mediator: (vector or scalar), NWA
  - Minimal flavor violation
  - Parameters:
    - Coupling structure, M_{med}, M_{DM}, g_{sm}, g_{DM}

Benchmark model search

- SUSY
- Inert Two-Higgs Doublets Model

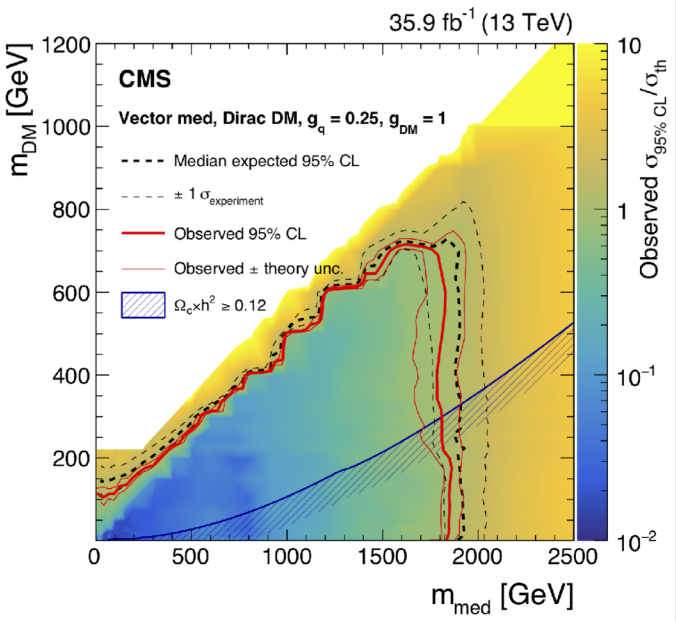
Monojet Channel

Search in monojet channel

- Most direct channel.
- Collaboration with Texas Tech

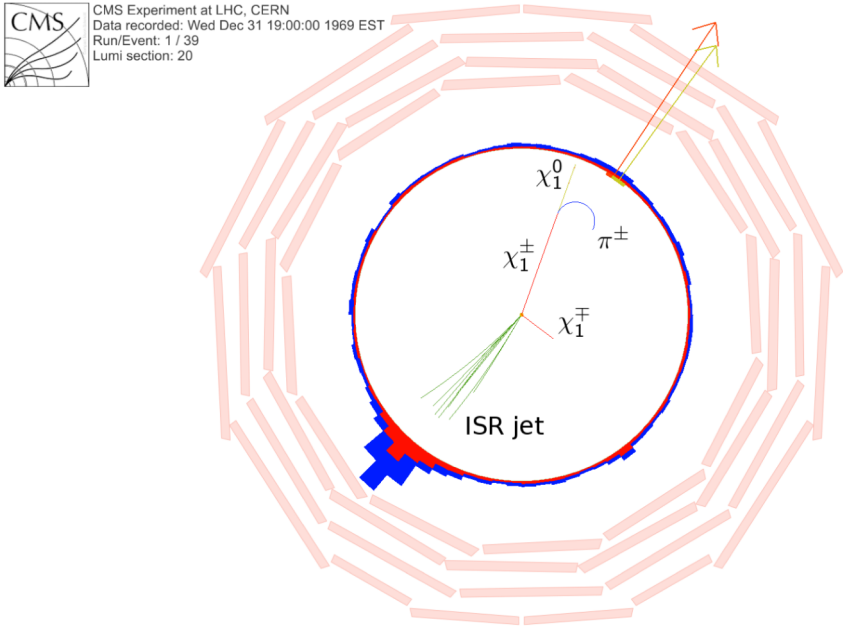
Run II Data

- Monojet Analysis
  - Journal of High Energy Physics 07, 014 (2017)
  - Phys. Rev. D 97, 092005 (2018)



Alternative Signals

- Models with long-lived mediators
  - Disappearing Tracks signal
  - Reconstruction of a short track
- Models
  - SUSY with AMSB
  - Feebly Interacting Massive Particles (FIMPs)
- Collaboration with Ohio State University
  - SPRACE Team:
    - Phd Student: Breno Ozari
    - Master Student: Felipe Aguiar and João Boger
    - Professors: PM, Thiago Tomei, Andre Lessa (Theory)



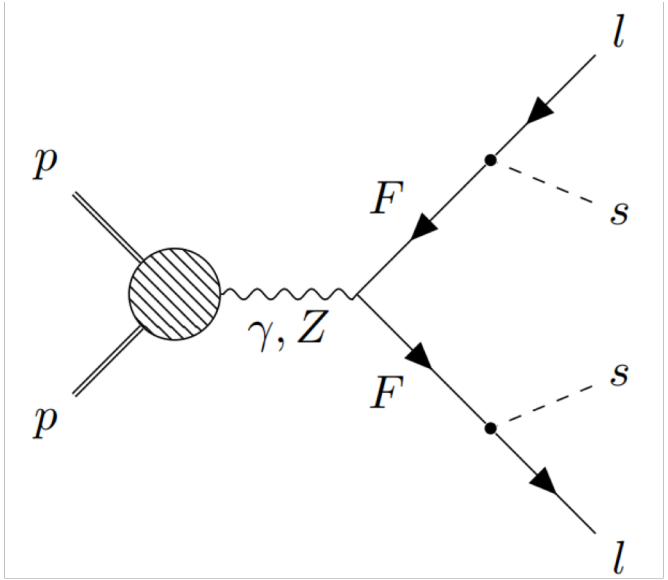
Disappearing Tracks Signal

Signal Selection

- Missing E_T
- Hard Jet
  - Need to model well the hard jet emission

Short track

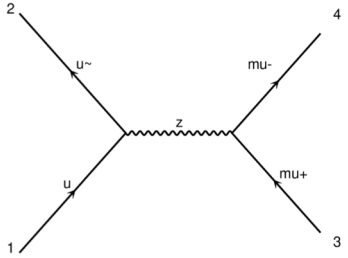
- Need to reconstruct the short track
- Need to estimate the background (mainly instrumental)

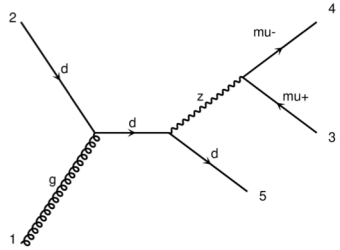


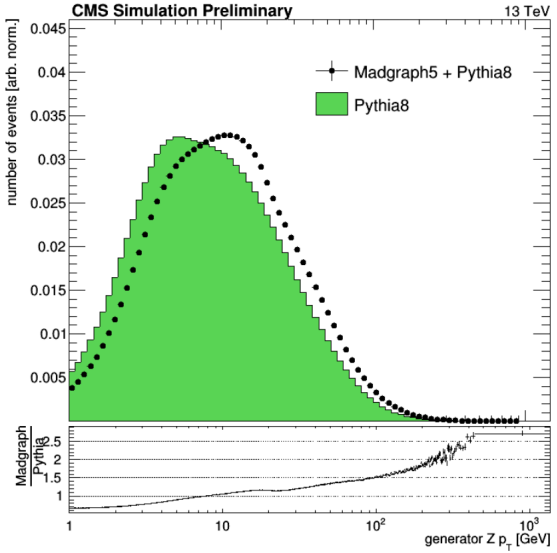
Ongoing work

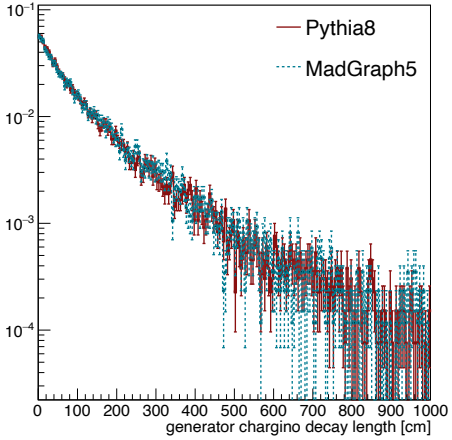
Signal Simulation

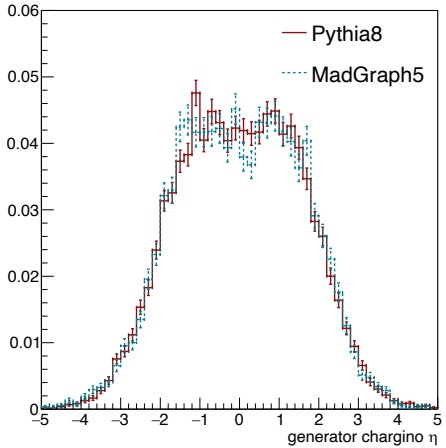
- Triggering Issues
  - Missing E_T
  - Hard Jets
- Correct Missing E_T profile:
  - Using Madgraph + Pythia
  - Extra Jet in the hard process
  - Merging scheme

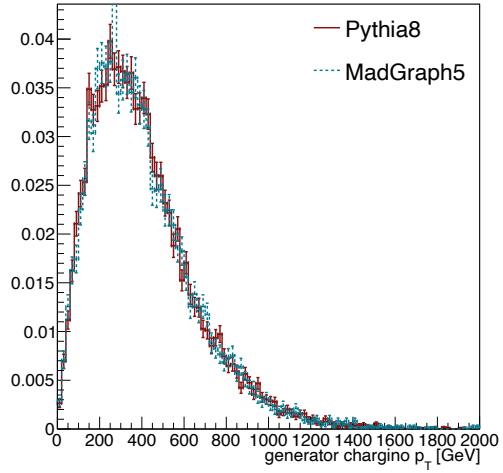


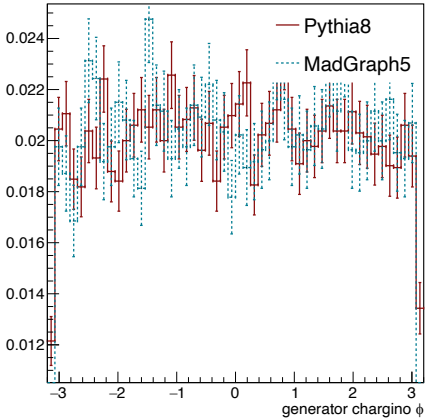


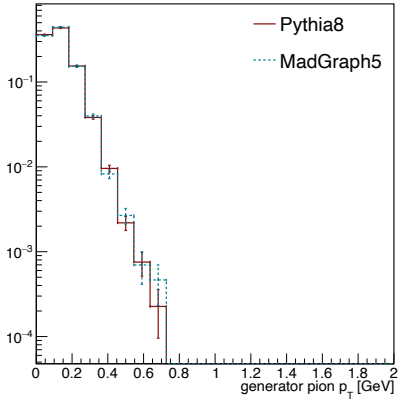


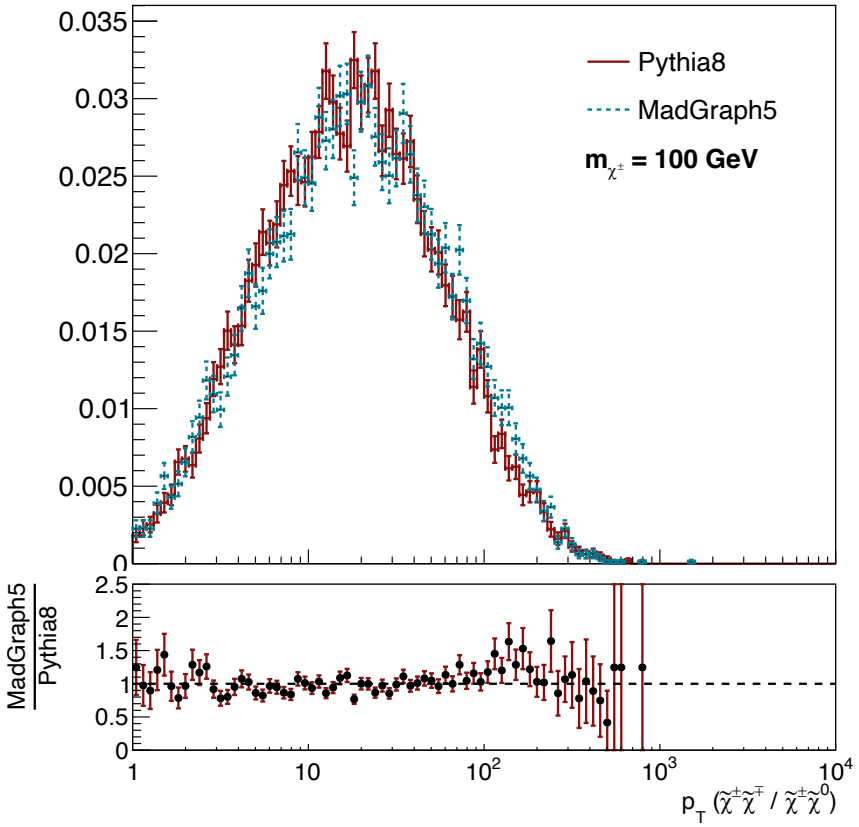

Pythia8
MadGraph5
generator chargino decay length [cm]

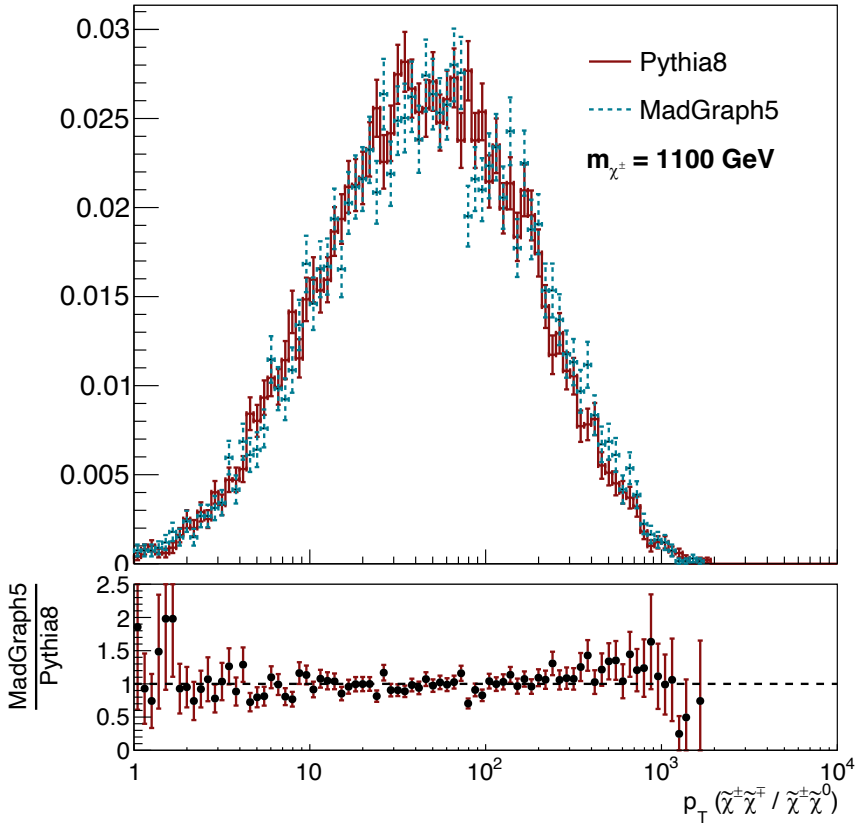

Pythia8
MadGraph5
generator chargino η

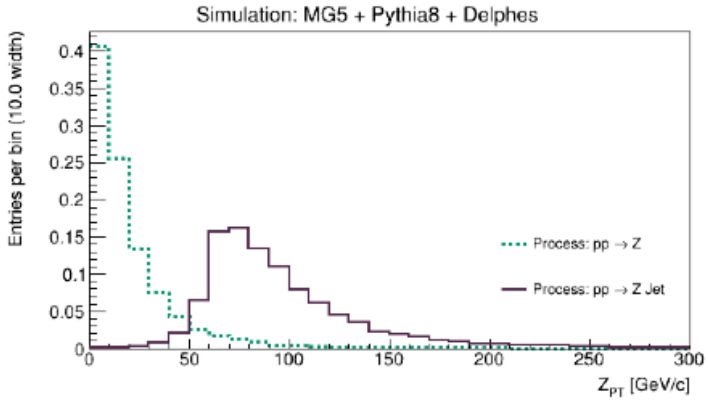

Pythia8
MadGraph5
generator chargino p_T [GeV]

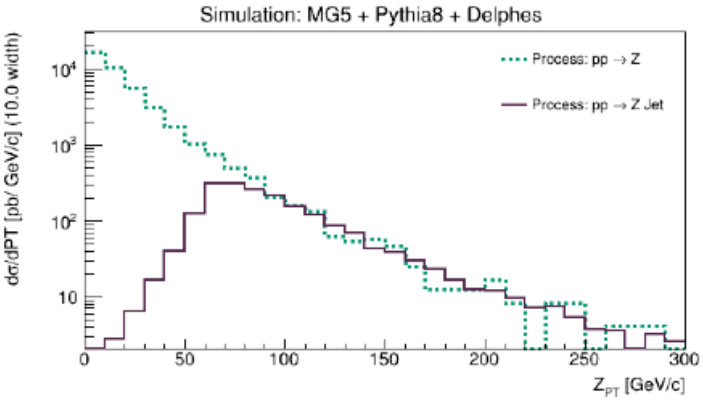

Pythia8
MadGraph5
generator chargino ϕ

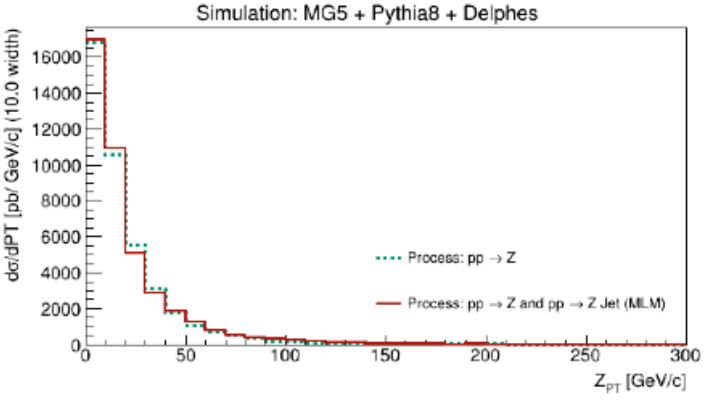

Pythia8
MadGraph5
generator pion p_T [GeV]

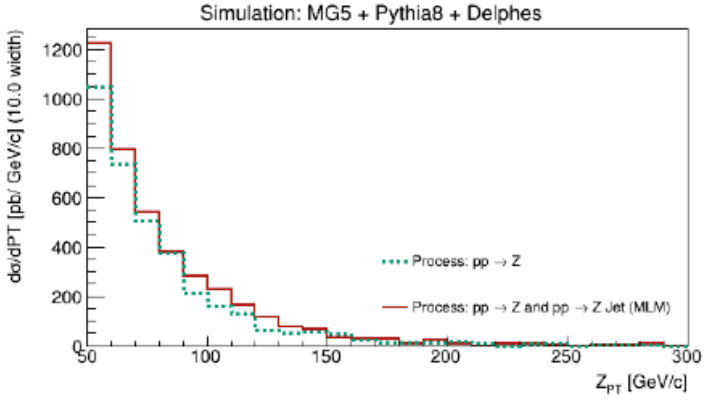

Pythia8
MadGraph5
$m_{\chi^{\pm}}$ = 100 GeV
MadGraph5 / Pythia8
p_T ($\tilde{\chi}^{\pm}\tilde{\chi}^{\mp}$ / $\tilde{\chi}^{\pm}\tilde{\chi}^{0}$)


Pythia8
MadGraph5
$m_{\chi^{\pm}}$ = 1100 GeV
MadGraph5 / Pythia8
p_T ($\tilde{\chi}^{\pm}\tilde{\chi}^{\mp}$ / $\tilde{\chi}^{\pm}\tilde{\chi}^{0}$)


Simulation: MG5 + Pythia8 + Delphes
Entries per bin (10.0 width)
Process: pp → Z
Process: pp → Z Jet
Z_{PT} [GeV/c]

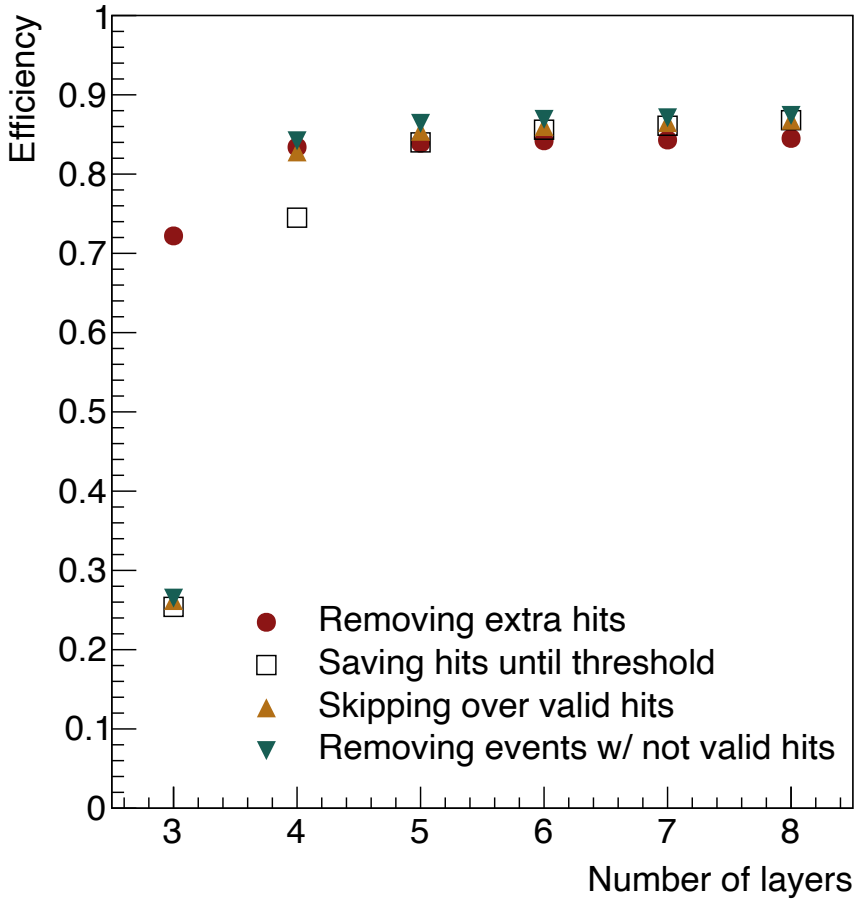

Simulation: MG5 + Pythia8 + Delphes
dσ/dPT [pb/ GeV/c] (10.0 width)
Process: pp → Z
Process: pp → Z Jet
Z_{PT} [GeV/c]


Simulation: MG5 + Pythia8 + Delphes
dσ/dPT [pb/ GeV/c] (10.0 width)
Process: pp → Z
Process: pp → Z and pp → Z Jet (MLM)
Z_{PT} [GeV/c]


Simulation: MG5 + Pythia8 + Delphes
dσ/dPT [pb/ GeV/c] (10.0 width)
Process: pp → Z
Process: pp → Z and pp → Z Jet (MLM)
Z_{PT} [GeV/c]

Short Track Reconstruction

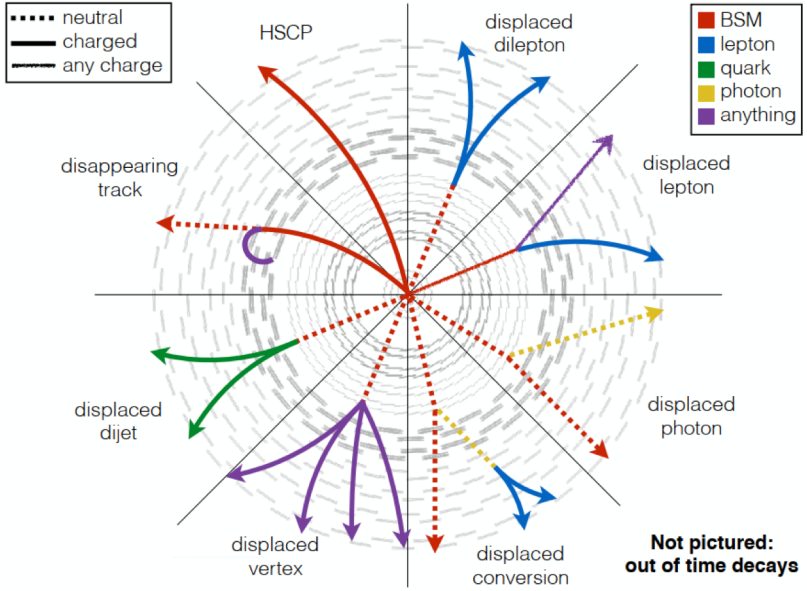
- Identification of short track
  - Missing Hits
  - Track reconstruction efficiency
  - Signal Simulation
- Background estimation
  - Instrumental bg
    - Muons or electrons with no calorimeter deposit
    - Fake tracks



Prospect

Ongoing

- ❑ Signal validation
- ❑ Trigger
  - Missing Et +jets
- ❑ Background estimation via Machine Learning
  - Fake track
  - Charged leptons

New Channels and Students

- ❑ Phd: Julia Leite and Bruno Lopes
- ❑ Master: Cauê Sousa and Stephanie Dardengo