SUSY Search activities at IHEP

Huajie Cheng, Shan Jin, Yang Liu, Feng Lu, Mhamad Kassem Ayoub, Xin Wang, <u>Da Xu</u>, Chenzheng Zhu, Xuai Zhuang (IHEP, CAS)





中国科学院高能物理研究所

Institute of High Energy Physics Chinese Academy of Sciences

SUSY Intro



A theory to describe physics beyond standard model, with additional symmetry introduced: fermions ~ bosons

symmetry introduced: fermions ~ bosons

If weak-scale SUSY existed, it could... Moderate the hierarchy problem Realize grand unification of gauge couplings Provide a suitable dark matter candidate



SUSY searches @ LHC



SUSY search strategy is driven by cross-section and luminosity: Early analyses are dominated by inclusive searches for gluinos/squarks. Increasing luminosity gives access to rare production channels.

IHEP SUSY Family



INTRO: List of SUSY search activities @ IHEP

The searches are categorized into different final states.

- ElectroWeak SUSY search with two hadronic taus(Leading topic)
 - Direct stau pair production
 - Chargino/Neutralino pair decay via stau
 - Chargino/Neutralino pair decay via Wh
- Strong/ElectroWeak SUSY search with one lepton(Leading topic)
 - Gluino/Squark pair decay via WW
 - Chargino/Neutralino pair decay via Wh
 - Chargino pair decay via WW
- Strong/EW SUSY search with Same-sign two leptons or three leptons
 - Gluino/stop/sbottom (long) decay chain
 - Chargino/Neutralino pair decay via Wh

This talk is to highlight the published results. More recent activities could be found in the following SUSY talks.

EWK-tau



- Signal: Direct gaugino pair decay via stau/Wh; direct stau decay.
- Targeting at least two hadronic taus final state.
- Signal optimization: cut-and-count; MVA R&D in dstau channel.
- Fake background (dominant!) estimation Key Strategy
 - QCD(2 fake taus): ABCD method/ Fake-factor method
 - W+jets (1 fake tau): tau-promotion method/simultaneous fit in dedicated defined control region
- Latest public result in Run2@36fb-1.
- 140fb-1 result is expected Spring 2019.

EWK-tau

Direct stau pair production

- Particular interesting light stau channel
- Challenge due to low cross-section

Run1@20.1fb-1 — published

- Focus on tauhad-tauhad channel.
- Exclude one mass point with combined cutand-count & machine learning —>

· Run2@140fb-1 — ongoing

- Pros. Increased energy & luminosity
- Cons. High pile-up/ increased tau trigger threshold/ poor MC stats:
 - playing with combined triggers to extend the kinematic region;
 - · looking into tauhad-taulep channel;
 - explore background estimation strategies
- Ongoing analysis already shows a very promising expectation:-) Don't miss us @ Moriond 2019.



EWK-tau



 $m_{\tilde{\chi}^{\pm}}, m_{\tilde{\chi}^{0}}$ [GeV]

Chargino/Neutralino pair decay via Wh

- Advantage of good H-> tautau BR.
- Higgs mass constrain.
- Serve as a nice complimentary channel for the Wh searches, especially could gain in the compressed mass region.

Strong/EWK 1-lepton

Inclusive

Strong 1L

Targeting two scenarios already studied in the previous iteration of the analysis using $36.1 \, \text{fb}^{-1}$ of data.

- Gluino/squark pair production decaying into W bosons and neutralinos through intermediate charginos together with multiple jets.
- Final state with 1 lepton, multiple jets and $E_{\rm T}^{\rm miss}$.



Electroweak

Wh 1Lbb:

Studying *Wh* signal model already targeted in the previous analysis iteration with partial Run-2 data.

- $\tilde{\chi}_1^{\pm}$ - $\tilde{\chi}_2^0$ production with subsequent decay into W and h bosons together with two $\tilde{\chi}_1^0$.
- Considering explicitly only the decay $h \rightarrow b\bar{b}$.
- > Final state with 1 lepton, $E_{\rm T}^{\rm miss}$ and two *b*-tagged jets.

Three types of signal scenarios

- Ranging from inclusive strong production — benefit from large cross-section
- To dedicated electroweak searches — Wh/WW

Electroweak

WW 1L:

Targeting electroweak model never studied before in the 1-lepton channel.

- $\tilde{\chi}_1^{\pm}$ pair-production with subsequent decay into W boson and $\tilde{\chi}_1^0$.
- > Final state with 1 lepton, $E_{\rm T}^{\rm miss}$ and a relatively low number of jets.
- Very similar to SM background, therefore reduced sensitivity compared to Wh model.
 As will be show in later slides, sensitivity can be achieved with a shape fit setup.
- Analysis possibly complementary to 2-lepton analysis.



Strong/EWK 1-lepton



Targeting 1-lepton + 2-6 jets and Etmiss.

- 1L channel provides better suppression on the multi-jet background.
- Compressed regions benefit from soft leptons region.
- Signal regions are binned in Njet, Nbjet, Meff.
- A powerful but complex shape fit in 28 SRs+ 28 CRs was performed: yielding highly competitive exclusion limits for gluinos/squarks



36.1 fb-1 @ PhysRevD.96.112010



Strong/EWK 1-lepton



Targeting 1-lepton + 2 jets and Etmiss.

- 1Lbb channel provides competitive limit comparing to other channels (1Igamgam/SS2L/3L)
- Statistical combination on different signal regions.
- 36 fb-1 paper: coming out SOON.
- 140 fb-1 study: aiming for LHCP2019.





Targeting 1-lepton + 2-3 jets and Etmiss.

- No strong limit so far due to low crosssection.
- Sensitivity has been studied with a few benchmark points selected according to the existing exclusion map.
- · Techniques involve shapefit/RNN.
- 140 fb-1 study: aiming for Summer2019.



Strong SS2L/3L

Targeting a number of various signal scenarios riched with lepton activities:
 i.e. gluino long decay chain. Also plan to look into Wh in summer.



- Independent decay of gluino provides a powerful SM background suppresser: same-sign 2L /3L criteria.
- Low SM bkg allows loose Etmiss requirement: leading to profound sensitive in the compressed mass region.

Strong SS2L/3L

 Backgrounds: Fake leptons(Matrix-method), charge-flipped e, prompt SS/3L processes.

Summary plot @ 36 fb-1 Run2

- profound performance of SS analysis in the compressed region!

- · Latest public result in Run2@36fb-1.
- 140fb-1 result is expected in Moriond 2019.





Summary

A short review on three SUSY topics with IHEP leading/important contributions: a busy 2019 foreseen!

- ElectroWeak SUSY search with two hadronic taus(leading)
 - Direct stau pair production —> Moriond
 - Chargino/Neutralino pair decay via stau —> Summer
 - Chargino/Neutralino pair decay via Wh —> Summer

· Strong/ElectroWeak SUSY search with one lepton(leading)

- Gluino/Squark pair decay via WW —> LHCP
- Chargino/Neutralino pair decay via Wh —> LHCP
- Chargino pair decay via WW —> Summer

Strong/EW SUSY search with Same-sign two leptons or three leptons

- Gluino/stop/sbottom (long) decay chain —> Moriond
- Chargino/Neutralino pair decay via Wh —> Summer

Hope we can chat more in CLHCP2019 🤓

More preliminary ongoing studies in ——

14:00	Beyond Standard Model (until 16:00)
14:00	SUSY Search activities at IHEP - Da Xu (IHEP, Beijing)
14:15	Inclusive and Electroweakino SUSY search with leptons - Yang LIU (IHEP)
14:30	Electroweakino SUSY search with Wh - Huajie Cheng (高能所)
14:45	Search for direct stau production with the ATLAS detector - ChenZheng Zhu (S)

Extra slides

SUSY searches @ LHC

SUSY searches rely on the understanding of the SM backgrounds.

Standard Model

Top, multijets V, VV, VVV, Higgs & combinations of these

Combined fit of all regions and backgrounds and incl. systematic exp. and theor. uncertainties as nuisance parameters

Reducible backgrounds

Determined from data Backgrounds and methods depend on analyses

Irreducible backgrounds

Dominant sources: normalise MC in data control regions Subdominant sources: MC

Validation

Validation regions used to cross check SM predictions with data

Signal regions

blinded

blinded