## Future $e^+e^-$ and muon colliders

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## Why do we care about these colliders?

### Why do we care about these colliders? As the next to the last talk, hopefully you already know all the answers, but maybe you've been distracted...



## Any new collider project attempts some sort of optimization

## **Colliders** we can build

Physics we'd like to study

## **Colliders we could** build in X years





## Any new collider project attempts some sort of optimization The have have physics we'd like +-

## **Colliders** we can build

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## Any new collider project attempts some sort of optimization

## Physics we'd like to study

## **Colliders** we can build

## Colliders we could build in X years

MAL MAL





### This dance has played out over many decades following a bifurcation based on particle type



(V. Shiltsev, 2012)

Since then (1990s), the paths of different colliders have diverged: hadron colliders continued the quest for record high energies in particle reactions and the LHC was built at CERN, while in parallel highly productive e+e- colliders called particle factories focused on precise exploration of rare phenomena at *much lower energies*.

(V. Shiltsev, F. Zimmermann 2021 Reviews of Modern Physics)



## **Most basic difference:**

- synchrotron radiation and beamstrahlung from small mass

 Electron colliders collide *fundamental particles -* that exploit the full energy and don't have large QCD backgrounds - BUT they suffer from

 Proton colliders collide composite particles - that generate large QCD backgrounds and you use a fraction of the energy of beam for physics -BUT they have a much larger mass and avoid synchrotron radiation

### If you have a physics target, you can see by eye that electrons are easier!



#### ATLAS VBF $h \rightarrow \tau^+ \tau^-$ candidate event

ILC - ILD 250 GeV  $e^+e^- \rightarrow Zh \rightarrow \mu^+\mu^-h$ 

### This doesn't reflect that the size of backgrounds are also orders of magnitude smaller as well for leptons



## Therefore hopefully it will continue with CEPC/SPPC or FCC-ee/hh



(V. Shiltsev, F. Zimmermann 2021 Reviews of Modern Physics)

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## The accelerator landscape is more nuanced

## The physics capabilities are more varied

The physics needs have evolved with more data driving new efforts! (Both theoretical and experimental data)

BUT, since this talk is about  $e^+e^-$  and  $\mu^+\mu^$ colliders, it turns out there are other possibilities as well:

## What's a Higgs Factory?



(V. Shiltsev, F. Zimmermann 2021 Reviews of Modern Physics)

## An $e^+e^-$ collider dominated by ZH production

#### 12





## These are also the only machines we know how to build "tomorganization for nuclear research

#### **THE INTERNATIONAL LINEAR COLLIDER**









#### + other concepts that are close

#### A MULTI-TEV LINEAR COLLIDER BASED ON CLIC TECHNOLOGY

CLIC CONCEPTUAL DESIGN REPORT

CEPC Technical Design Report

Accelerator

## Do they all do the job?



## I have a strong dislike of showing tables of EFT operators or coupling modifiers

### The difference between an uncertainty on $g_{hXX}$ of 1.2% vs 1.1% makes no real *qualitative* difference probing the scale of new physics

 $\delta g_{hXX}$ 

$$\sim \frac{v^2}{M_{NP}^2}$$

## Indeed they all fit the bill and improve on LHC Energy Frontier Higgs Factory First Stages







An offshore Higgs factory, realized in collaboration with international partners, in order to reveal the secrets of the Higgs boson. The current designs of FCC-ee and ILC meet our scientific requirements. The US should actively engage in feasibility



## Are all Higgs factories created equal? NO!

## Circular

## Beam gets reused for higher lumi

Beam goes in a circle, so synchrotron radiation limits energy reach



### 1 pass only -Lower lumi

Avoids synchrotron radiation - *can* go to higher Energy



## Linear







#### **Snowmass Accelerator Implementation Task Force**

## Z factories - the type of "Higgs" Factory matters!

- Flavor physics TeraZ allows one to go an order of magnitude beyond Belle II
- Light BSM physics TeraZ allows to probe rare Z decays better (e.g. HNL)
- EW precision TeraZ is an enormous jump (although polarization helps a LC)

## Aside: Why can we do so well with Z factories now? LEP1 had $\mathcal{O}(10^7)$ Z bosons FCC-ee proposes $\mathcal{O}(10^{12})$ Z bosons!

Cross section is the same so we need a factor of  $10^5$  on Luminosity!

## **Modern Z-factories** Is CERN planning to consume 5 orders of magnitude more power in a few decades??? NO!



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$$P_{sync}^{loss} \sim \left(\frac{E}{m}\right)^4 \frac{1}{R}$$

## 

Synchrotron power loss is only about a factor of 3 better  $\neq 10^{\circ}$ 





## **Modern Z-factories** Enabled by accelerator physicists! $NC \rightarrow SRF!$ LEP1 beam current ~mA FCC-ee beam current ~ A RF power efficiency ~ $10^3$

## Crab Cavity + Final Focus $\sim 10^2$

You could in principle do TeraZ up to 240 GeV in a LEP length tunnel (of course no detailed implementation study exists)

Does <u>not</u> mean you can do entire FCC-ee program in LEP tunnel, eventually you run out of room for RF and other tricks!









#### ling



### I know of no models where it is relevant yet, but still super cool to get close to the 1st generation, should be a target for theory and experiment!

## ar $e^+e^-$ colliders also have another **otential trick - electron Yukawa**

## If a circular $e^+e^-$ collider can do so much beyond a "Higgs factory", are linear $e^+e^-$ colliders uninteresting? No!!!



## New processes at higher energies



## New processes means new measurement possibilities

# $\kappa_{\lambda} = \frac{\kappa_{\lambda}}{\frac{\text{LL-LHC}}{1}} \begin{bmatrix} 78 \\ 1 \\ 1 \\ 1 \\ 250 \\$

Snowmass Higgs report 2209.07510

	Indirect-h	hh	combined
8]	100-200%	50%	50%
51, 52]	49%		49%
51, 52]	38%	20%	20%
1]	50%		50%
1]	49%	36%	29%
1]	49%	9%	9%
	33%		33%

## Linear colliders and Higgs physics

Energy Frontier Benchmarks Integrated Staging

EF	benchmarks	<i>y</i> <sub>u</sub>	y <sub>d</sub>	y <sub>s</sub>	y <sub>c</sub>	y <sub>b</sub>	y <sub>t</sub>	y <sub>e</sub>	Y <sub>µ</sub>	$y_{ au}$	Tree	Loop	Higgs Width	$\lambda_3$	$\lambda_4$
	LHC/HL-LHC				٠	٠								•	
LHC	ILC/C^3								٠		$\star$				
⊒ ح"~	CLIC			?	٠										
Higgs Factor	FCC-ee/CEPC			?	٠			٠	٠		$\star$				

## Is that all?

### One general theme we've heard this week, how do you think of precision? Coupling modifiers, SMEFT/HEFT, Toy Model, Full Model?

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## There is no such thing as a model independent interpretation!

## One general theme we've heard this we you think of precisior Coupling modifiers, SMEFT/HF Jdel, Full Mod ch thing as a model ndent interpretation!

There is SNE

## Our modern understanding of QFT is based on Wilsonian Renormalization

 $N \times N$  Ising Model



Why it works <u>systematically</u> is that all higher dimension operators contribute as  $\sim \left(\frac{-1}{\Lambda}\right)$ 

**Coarse Grain** 



### Wilsonian renormalization says EVERYTHING is an EFT at low energy!



## This is why regardless of BSM physics

#### UV BSM theory + SM

### Matching scale, like a new particle mass

SM + higher dimension interactions



## This led to a modern renaissance for the LHC and EFTs trying to reverse the logic

UV BSM theory + SM

## However the RGE flow is irreversible!

## $---\bullet \quad \bigwedge = ?$

#### SMEFT, HEFT



## EFTs are not model independent



For example, integrating out the W,Z doesn't give you a sizable new gluon gluon scattering operator!




#### From bottom up measurements you know this too!

#### UV BSM theory + SM

#### SMEFT, HEFT

### You must make model dependent assumptions to use it, otherwise you are guaranteed to see nothing at the LHC or future colliders!



#### From bottom up measurements you know this

UV BSM theory + SM

make model dependent assumptions to use it, otherwise you are guaranteed to see nothing at the LHC or future colliders!







### Therefore if I want to talk about *implications* of precision I need to know the types of UV physics that can map to certain types of operators or observables!

### Let's look at a particular example to see how this works, and why a Linear Collider can have other advantages in Higgs Physics

#### Higgs physics isn't just EFT/couplings: Cute example is the strange Yukawa

1.2

1.0

#### This was done for ILC, but <sup>0.8</sup> should be applicable to FCC-ee/CEPC (ECFA/ ESPPU)

0.2

0.0



#### Higgs physics isn't just EFT/couplings: Cute example is the strange Yukawa

 $\frac{1}{\Lambda^2}(sh\bar{s})h^2$ 

We've heard about MFV, U(2) etc from very nice SMEFT talks this week, so do we ever care about this precision?



### symmetry/dynamics to avoid Flavor bounds

# To generate such O or effect, you need BSM physics that couples to strange quarks and couples to the Higgs



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### symmetry/dynamics to avoid Flavor bounds



## **Spontaneous Flavor Violation (SFV)**

New physics *can* couple in a strongly flavor dependent way if it is aligned in the down-type quark or up-type quark sectors <u>with</u> a *sufficient symmetry* to protect it: SFV provides this *beyond* Aligned Flavor Violation

For example: I could have a new BSM state at the <u>EW scale</u> that just couples to RH strange quarks and nothing else at tree level - perfectly consistent *despite* EFT flavor bounds on Kaon mixing naively setting a scale of 10000 TeV

# This is symmetry protected, and there are simple UV completions!

D. Egana-Ugrinovic, S. Homiller, PM 1811.00017,1908.11376,2101.04119

# SFV is general but let's apply this to the Higgs with a 2HDM



If this was all there was, then an amusing signal generator for strange jet resonances

#### SFV is general but let's apply this to the Higgs with a 2HDM



 $\overline{S}$ 

#### Simple parameter space: mass, coupling to strange, mixing with Higgs

 $-\frac{(sh\bar{s})h^2}{\sqrt{2}}$ 







#### "Higgs Factories" Circular Linear EW program **Flavor Physics Higgs Program** Rare Z decays (BSM search) **Di-Higgs/Higgs Potential** EW program **Testing BSM EW physics directly Higgs Program** Potential new big tunnel! Both options are great and complementary:

# If CEPC then ILC or CLIC immediately?

# What about muons? Where do they fit in?

# Let's go back to our collider plot





# Let's go back to our collider plot



#### What technologies can fill the gap? Avoid synchrotron **Avoid infinitely long** radiation of circular $e^+e^$ linear $e^+e^-$ colliders colliders

### Muon Collider High Energy + High

Lumi in small ring

Once muons are cooled, much more like "conventional" collider

Pheno and full sim studies done

Many synergies with neutrino physics and dovetails well with Fermilab

### WFA High energy in short package

**Understanding Lumi and Power** consumption w/staging still open question

Don't have enough info to do real pheno/exp studies yet



#### What technologies can fill the gap? **Avoid synchr** nitely long colliders Precision colliders OR Energy / EA short package High Energy + H Lumi and Power staging still open

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- Muon Co
- Once muons are cc more like "convention

#### Pheno and full si done

Many synergies with ne and dovetails well w

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#### Precision stion AND Energy gh info to do real studies yet



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High E

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### Particle Physicists Agree on a Road Map for the Next Decade

A "muon shot" aims to study the basic forces of the cosmos. But meager federal hudgets could limit its ambitions

Once muon: more like "cc

Pheno and

Although we do not know if a muon collider is ultimately feasible, the road toward it imi and Power leads from current Fermilab strengths and capabilities to a series of proton beam improvements and neutrino beam facilities, each producing world-class science while performing critical R&D towards a muon collider. At the end of the path is an unparalleled global aging still open facility on US soil. This is our Muon Shot. on

Many synergie: and dovetail



Decipher the Quantum Realm





#### The New York Times

Explore New Paradigms in Physics 56



Illuminate the Hidden Universe

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10 TeV Muon Collider Schematic

p-Collider

u-Acceleration

### Fermilab Batavia, IL

#### PIP-II Upgrade



### Why is it so important to fill this gap?

- data and theory so we better make sure we can!
- but should we put all our eggs in one basket?
- What is the ultimate limit of protons?
  - Have to keep going bigger sustainability and political issues
  - energy of our colliders, is this feasible?
  - consumption spirals eventually?

We already have good reason to think we need to get to higher energy - both from

 FCC-hh and SPPC follow the LEP/LHC paradigm - but we don't know for sure if we can build detectors to get the physics out - 2070 makes it easy to not focus on it for now,

• QM tells us we need to increase lumi roughly quadratically if we want to increase

• pp total cross section increases with  $\sqrt{s}$ , do our beams burn off too fast and power

#### Even if we had the resources, it's not clear how far we can go without supporting broad R&D



#### We can dream big like Fermi, but whether we can do it even if we had the resources is a different story



# Why do we need higher energy?

- LHC dataset so far: Lack of BSM evidence
- Preparing for Higgs Factory Results
- Completing the Standard Model
- Higgs Mass + SUSY
- Minimal Dark Matter
- Electroweak Phase Transition

### Lessons learned from the LHC so far

	Model	<i>ℓ</i> ,γ	Jets	s† E <sub>T</sub>	<sup>iss</sup> ∫£ dt[fl	b <sup>-1</sup> ]	Limit					Reference
SUO AD	DD $G_{KK} + g/q$ DD non-resonant $\gamma\gamma$	0 e, μ, τ, γ 2 γ	/ 1-4	4 j Ye	s 139 36.7	M <sub>D</sub> M <sub>S</sub>			11.2 TeV 8.6 TeV	n = 2 n = 3 HLZ NLO		2102.10874 1707.04147
AD AD	DD QBH DD BH multijet		2 j ≥3	j – j –	37.0 3.6	M <sub>th</sub> M <sub>th</sub>			8.9 TeV 9.55 TeV	n = 6 $n = 6, M_D = 3$	TeV, rot BH	1703.09127 1512.02586
	S1 $G_{KK} \rightarrow \gamma \gamma$ Jlk RS $G_{KK} \rightarrow WW/ZZ$	2γ multi-chann	nel	-	139 36.1	G <sub>KK</sub> mass G <sub>KK</sub> mass		4.5 Te	eV	$\frac{k/M_{Pl}}{k/\overline{M}_{Pl}} = 0.1$		2102.13405 1808.02380
Bul Bul 2U	JIK RS $G_{KK} \rightarrow WV \rightarrow \ell \nu q q$ JIK RS $g_{KK} \rightarrow tt$ JED / RPP	1 e, μ 1 e, μ 1 e, μ	2 j / ≥1 b, ≥ ≥2 b, 3	1J Ye ⊵1J/2j Ye ≥3j Ye	es 139 es 36.1 es 36.1	G <sub>KK</sub> mass g <sub>KK</sub> mass KK mass		2.0 TeV 3.8 TeV		$k/M_{Pl} = 1.0$ $\Gamma/m = 15\%$ Tier (1,1), $\mathcal{B}(A^{(1)})$	$(1) \rightarrow tt) = 1$	2004.14636 1804.10823 1803.09678
SS SS	SM $Z' \rightarrow \ell \ell$ SM $Z' \rightarrow \tau \tau$	2 e, μ 2 τ	-	-	139 36.1	Z' mass Z' mass		5.1 2.42 TeV	TeV			1903.06248 1709.07242
Ler Ler	eptophobic $Z'  o bb$ eptophobic $Z'  o tt$	0 e,μ	2 b ≥1 b, ≩	o – ≥2JYe	· 36.1 s 139	Z' mass Z' mass		2.1 TeV 4.1 TeV		$\Gamma/m = 1.2\%$		1805.09299 2005.05138
ss de po	SM $W' \to \ell v$ SM $W' \to \tau v$	1 e, μ 1 τ	-	Ye Ye	es 139 es 139	W' mass W' mass		5.0	6.0 TeV TeV			1906.05609 ATLAS-CONF-2021-02
$\begin{array}{ccc} SSM & W \rightarrow tB \\ HVT & W' \rightarrow W \\ HVT & W' \rightarrow W \end{array}$	$VT W' \to UZ \to \ell v qq \text{ model}$ $VT W' \to WZ \to \ell v \ell' \ell' \text{ model}$	- Β 1 <i>e</i> ,μ	≥10, 2 j / 2 i (VI	≥ij – 1J Ye BE) Ve	es 139	W' mass W' mass	340 GeV	4.4 Te	V	$g_V = 3$ $g_V c_V = 1$ $g_C = 1$	0	2004.14636
HV	$VT W' \rightarrow WH \text{ model B}$ RSM $W_R \rightarrow \mu N_R$	0 e, μ 2 μ	≥1 b, 2 1 J	≥2 J J –	139 80	W' mass W <sub>R</sub> mass		3.2 TeV 5.0	TeV	$g_V = 3$ $m(N_R) = 0.5$ Te	eV, $g_L = g_R$	2007.05293 1904.12679
	qqqq llqq	_ 2 e,μ	2 j _	j – –	37.0 139	Λ Λ		1	_	21.8 TeV 35	η <sub>LL</sub> 5.8 TeV η <sub>LL</sub>	1703.09127 2006.12946
	eebs μμbs ++++	2 e 2 µ ≥1 e.u	1 b 1 b >1 b :	o – o – >1i Ve	· 139 · 139			2.0 TeV		$g_* = 1$ $g_* = 1$ $ C_{11}  = 4\pi$		2105.13847 2105.13847 1811.02305
Axi	kial-vector med. (Dirac DM)	0 e, μ, τ, γ	$\gamma \qquad 1-4$	4j Ye	s 139	m <sub>med</sub>		2.1 TeV	_	$g_q=0.25, g_{\chi}=1, r$	$m(\chi)=1 \text{ GeV}$	2102.10874
	seudo-scalar med. (Dirac DM) ector med. Z'-2HDM (Dirac DM) seudo-scalar med. 2HDM+a	0 e, μ, τ, γ VI) 0 e, μ multi-chann	γ 1-4 2b	4 j Ye D Ye	es 139 es 139 139	m <sub>med</sub> m <sub>med</sub>	376 GeV 560 GeV	3.1 TeV		$g_q=1, g_{\chi}=1, m(\chi \tan \beta = 1, g_Z=0.8, \tan \beta = 1, g_V=1, n)$	∠)=1 GeV , m(χ)=100 GeV n(χ)=10 GeV	2102.10874 2108.13391 ATLAS-CONF-2021-03
Sca	calar LQ 1 <sup>st</sup> gen	2 e 2 //	≥2 >2	j Ye	es 139	LQ mass		6.8 TeV		$\beta = 1$ $\beta = 1$		2006.05872
O Scala Scala	calar LQ 3 <sup>rd</sup> gen calar LQ 3 <sup>rd</sup> gen calar LQ 3 <sup>rd</sup> gen	1 τ 0 e, μ	2b ≥2j,≧	oj Ye ≥2b Ye	es 139 es 139	LQ <sup>u</sup> mass LQ <sup>u</sup> mass	1.2 1.24			$\mathcal{B}(LQ_3^u \rightarrow b\tau) =$ $\mathcal{B}(LQ_3^u \rightarrow t\nu) =$	1	2108.07665 2004.14060
Sca	calar LQ 3 <sup>rd</sup> gen calar LQ 3 <sup>rd</sup> gen	≥2 <i>e</i> , μ, ≥1 0 <i>e</i> , μ, ≥1	τ≥1 j, ≥ τ0 − 2 j	≥1b – ,2b Ye	139 s 139	LQ <sup>a</sup> mass LQ <sup>a</sup> mass	1. 1.26			$\mathcal{B}(LQ_3^d \rightarrow t\tau) =$ $\mathcal{B}(LQ_3^d \rightarrow b\nu) =$	1 1	2101.11582 2101.12527
Vec	ector LQ 3 <sup>rd</sup> gen $Q TT \rightarrow Zt + X$	1 τ 2e/2u/>3e	2 b ,µ >1 b	o Ye ≥1i –	es 139	LQ <sup>v</sup> mass		7 TeV		$\mathcal{B}(LQ_3^V \rightarrow b\tau) =$ SU(2) doublet	= 0.5, Y-M coupl.	2108.07665
arks	$ \begin{array}{c} Q BB \rightarrow Wt/Zb + X \\ Q T_{5/3}T_{5/3} T_{5/3} \rightarrow Wt + X \end{array} $	multi-chann 2(SS)/≥3 e	nel $\mu \ge 1$ b,	≥1j Ye	36.1 s 36.1	B mass T <sub>5/3</sub> mass	1.3	a TeV		SU(2) doublet $\mathcal{B}(T_{5/3} \rightarrow Wt)=$	$1, c(T_{5/3}Wt) = 1$	1808.02343 1807.11883
	$\begin{array}{c} Q \ T \to Ht/Zt \\ Q \ Y \to Wb \\ Q \ P \to Wb \end{array}$	1 e, μ 1 e, μ	≥1 b, ≥1 b,	≥3j Ye ≥1j Ye	es 139 es 36.1	T mass Y mass		1.8 TeV 1.85 TeV		SU(2) singlet, $\kappa_T$ $\mathcal{B}(Y \to Wb) = 1$	$c_{R}(Wb) = 1$	ATLAS-CONF-2021-0- 1812.07343
	$rac p \to rp$ (cited quark $q^* \to qg$	- υ e,μ	, ≥1 2 j	j, ∠iJ – į –	139	q* mass		2.0 100	6.7 TeV	only u* and d*, /	$\Lambda = m(q^*)$	1910.08447
Excite Excite	xcited quark $q^* \rightarrow q\gamma$ xcited quark $b^* \rightarrow bg$	1γ 	1 j 1 b,	j – 1j –	36.7 36.1	q* mass b* mass		5.3 2.6 TeV	3 TeV	only u* and d*, /	$\Lambda = m(q^*)$	1709.10440 1805.09299
	cited lepton $v^*$	3 e, μ, τ	-	-	20.3	$v^*$ mass		3.0 TeV		$\Lambda = 3.0 \text{ TeV}$ $\Lambda = 1.6 \text{ TeV}$		1411.2921
	rpe III Seesaw RSM Majorana v	2,3,4 e, µ 2 µ	ι ≥2 2j SS) νατία	j Ye j -	es 139 · 36.1	N <sup>0</sup> mass N <sub>R</sub> mass	910 GeV	3.2 TeV		$m(W_R) = 4.1$ Te	eV, $g_L = g_R$	2202.02039 1809.11105 2101.11061
LR	age triplet $H^{\pm\pm} \rightarrow M^{\pm}M^{\pm}$	$2,0,+c,\mu$ (0	SS) –		139	H <sup>±±</sup> mass	1.08 Te	A 2		DY production	$B(H^{\pm\pm} \rightarrow \ell \tau) = 1$	ATLAS-CONF-2022-0
LR Hig Hig Hid	ggs triplet $H^{\pm\pm} \rightarrow W^{\pm}W^{\pm}$ ggs triplet $H^{\pm\pm} \rightarrow \ell\ell$ aas triplet $H^{\pm\pm} \rightarrow \ell\tau$	2,3,4 e, μ (3 3 e, μ, τ		-	· 20.3	H <sup>±±</sup> mass	400 GeV			DY production, 2	$(n_i) \rightarrow (i) = 1$	141.636
Other Hig Ma Wa	ggs triplet $H^{\pm\pm} \rightarrow W^{\pm}W^{\pm}$ ggs triplet $H^{\pm\pm} \rightarrow \ell\ell$ ggs triplet $H^{\pm\pm} \rightarrow \ell\tau$ ulti-charged particles agnetic monopoles	2,3,4 e, μ (3 3 e, μ, τ – –	-	-	20.3 36.1 34.4	H <sup>±±</sup> mass multi-charged pa monopole mass	400 GeV article mass 1.22	2.37 TeV		DY production, 2 DY production, 4 DY production, 4	q =5e $g =1g_D$ , spin 1/2	1812.03673 1905.10130
*Only a	ggs triplet $H^{\pm\pm} \rightarrow W^{\pm}W^{\pm}$ ggs triplet $H^{\pm\pm} \rightarrow \ell\ell$ ggs triplet $H^{\pm\pm} \rightarrow \ell$ r ulti-charged particles agnetic monopoles $\sqrt{s} = 8 \text{ TeV}$ selection of the available SY Searches*	$3 e, \mu, \tau$ - - - - - - - -	- - fu nite on i	= 13 Te\ III data	20.3 36.1 34.4	H <sup>±±</sup> mass multi-charged pa monopole mass 10 <sup>-</sup> nomena is sh mits	400 GeV article mass 1.22 -1 -1	2.37 TeV	<u> 1</u> 0	DY production, 2 DY production, 1 DY production, 1 Mass s	$ \begin{array}{c} \text{Scale [TeV]} \\ \text{Scale [TeV]} $	Prelimina
*Only a *Only a <b>ASSUS</b> h 2022 Model	ggs triplet $H^{\pm\pm} \rightarrow W^{\pm}W^{\pm}$ ggs triplet $H^{\pm\pm} \rightarrow \ell \ell$ ggs triplet $H^{\pm\pm} \rightarrow \ell r$ ulli-charged particles agnetic monopoles $\sqrt{s} = 8 \text{ TeV}$ calentian of the available SY Searches*	2,0,4 ε,μ,τ 3 ε,μ,τ - - - - - - - - - - - - - - - - - - -	- - - fu fu 6 CL e ∫∠	= 13 Te\ II data	20.3 36.1 34.4	H** mass multi-charged pr monopole mass 10 <sup>-</sup>	400 GeV article mass 1.22 -1 -1 Mass limit	2.37 TeV	<u> 1</u>	Mass :	scale [TeV] ATLAS	<b>Prelimin</b> $\sqrt{s} = 13$
*Only a <b>ASSUS</b> th 2022 <b>Model</b> $\bar{q} \rightarrow q \bar{x}_{1}^{0}$	ggs triplet $H^{\pm\pm} \rightarrow W^{\pm}W^{\pm}$ ggs triplet $H^{\pm\pm} \rightarrow \ell\ell$ ggs triplet $H^{\pm\pm} \rightarrow \ell$ util-charged particles agnetic monopoles $\sqrt{s} = 8 \text{ TeV}$ selection of the available SY Searches* S $0 e, \mu$ monopole	2.3,4 e, µ, 7 3 e , µ, 7 5 = 13 TeV artial data 2 mace lim - 95% 5 ignature 2-6 jets 1.3 iste	$\int_{-\frac{1}{2}}^{-\frac{1}{2}} \int_{-\frac{1}{2}}^{-\frac{1}{2}} \int_{-$		20.3 36.1 34.4 <b>ver Li</b>	H** mass multi-charged pr monopole mass 10 <sup>-</sup> normana is sh mits	400 GeV article mass 1.22 -1 -1 Mass limit	2.37 TeV	· · · · · · · · · · · · · · · · · · ·	Mass s (ζ <sup>0</sup> <sub>1</sub> )≤400 GeV (ζ <sup>0</sup> <sub>1</sub> )≤400 GeV	scale [TeV] ATLAS	<b>Prelimina</b> $\sqrt{s} = 13$
*Only a *Only a <b>LAS SUS</b> ch 2022 <b>Model</b> $i, \bar{q} \rightarrow q \tilde{\chi}_{1}^{0}$	ggs triplet $H^{\pm\pm} \rightarrow W^{\pm}W^{\pm}$ ggs triplet $H^{\pm\pm} \rightarrow \ell \ell$ ggs triplet $H^{\pm\pm} \rightarrow \ell \ell$ ulti-charged particles agnetic monopoles $\sqrt{s} = 8 \text{ TeV}$ selection of the available <b>SY Searches*</b> S $0 e, \mu$ mono-jet $0 e, \mu$	2.9, 4 c, µ (3 3 c, µ, r - - - - - - - - - - - - - - - - - - -	$\frac{-}{\sqrt{s}}$ $\frac{\sqrt{s}}{tu}$ $\frac{-}{tu}$ $\frac{-}{tu}$ $\frac{-}{tu}$ $\frac{-}{tu}$	= 13 Te\ III data now eta . Lov C dt [fb <sup>-</sup> 139 139 139	20.3 36.1 36.1 34.4 <b>ver Li</b> $\frac{1}{\hat{q}}$ [1×, 8× $E$ $\frac{\hat{q}}{\hat{q}}$ [8× Dege $\frac{\hat{g}}{\hat{a}}$	H** mass multi-charged pr monopole mass 10 <sup>-</sup> normana is ch mits	400 GeV article mass 1.22 -1 -1 Mass limit -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1	2.37 TeV		DY production, [ DY production, [ DY production, [ Mass :	scale [TeV] ATLAS	<b>Prelimina</b> $\sqrt{s} = 13$
*Only a *Only a <b>LAS SUS</b> Sch 2022 <b>Model</b> $, \bar{q} \rightarrow q \bar{\chi}_{1}^{0}$ $, \bar{s} \rightarrow q \bar{q} W \bar{\chi}_{1}^{0}$	ggs triplet $H^{\pm\pm} \rightarrow W^{\pm}W^{\pm}$ ggs triplet $H^{\pm\pm} \rightarrow \ell\ell$ ggs triplet $H^{\pm\pm} \rightarrow \ell$ ulli-charged particles agnetic monopoles <b>v s</b> = 8 TeV <b>s</b> <b>s</b> <b>s</b> <b>s</b> <b>s</b> <b>s</b> <b>s</b> <b>s</b>	2-6 jets 2-6 jets 2-6 jets	$\frac{-}{\sqrt{s}}$ fu hits on the constant of the	- 	20.3 36.1 34.4 Ver Lii <sup>1</sup> ] <sup>2</sup> <sup>2</sup> <sup>3</sup> <sup>4</sup> <sup>1</sup> ]×.8×.0 <sup>2</sup> <sup>3</sup> <sup>2</sup> <sup>3</sup> <sup>2</sup> <sup>3</sup>	H** mass multi-charged pr monopole mass 10 <sup>-</sup> nomene is sh mits Degen.]	400 GeV article mass 1.22 -1 Mass limit -0.9 Forbidde	2.37 TeV 1.85 1.15-1.95 2.3 2.2		DY production, $ _{L}$ DY production, $ _{L}$ DY production, $ _{L}$ Mass : $(\tilde{\chi}_{1}^{0}) \leq 400 \text{ GeV}$ $m(\tilde{\chi}_{1}^{0}) \leq 60 \text{ GeV}$ $m(\tilde{\chi}_{1}^{0}) = 0 \text{ GeV}$ $\tilde{\chi}_{1}^{0} = 100 \text{ GeV}$ $(\tilde{\chi}_{1}^{0}) \leq 600 \text{ GeV}$	af = 5e gf = 1g <sub>D</sub> , spin 1/2 <b>ATLAS</b>	<b>Prelimina</b> $\sqrt{s} = 13$ <b>Prelimina</b> $\sqrt{s} = 13$ <b>Prelimina</b> $\sqrt{s} = 13$ <b>Prelimina</b> $\sqrt{1000}$
$\frac{i \phi_{i} \phi_{i} \phi_{i}}{i \phi_{i} \phi_{$	ggs triplet $H^{\pm\pm} \rightarrow W^{\pm}W^{\pm}$ ggs triplet $H^{\pm\pm} \rightarrow \ell\ell$ ggs triplet $H^{\pm\pm} \rightarrow \ell\ell$ ggs triplet $H^{\pm\pm} \rightarrow \ellr$ ulti-charged particles agnetic monopoles $\sqrt{s} = 8 \text{ TeV}$ SY Searches* SS $0 e, \mu$ $0 e, \mu$ $1 e, \mu$ $e, \mu\mu$ $0 e, \mu$	2-6 jets 2-6 jets 2-6 jets 2-6 jets 2-6 jets 2-6 jets 2-7 jets 2-6 jets 2-7 je	$\sqrt{s}$ = fu $\sqrt{s}$ = fu c CL $e$ $\int \mathcal{L}$ $E_T^{miss}$ $E_T^{miss}$ $E_T^{miss}$		20.3 36.1 34.4 ver Lii	H** mass multi-charged pr monopole mass 10 <sup>-</sup> normana is ch <b>mits</b>	400 GeV article mass 1.22 -1 Mass limit 0.9 Forbidder	2.37 TeV 1.85 1.15-1.95 2.3 1.15-1.95 2.2 2.2 1.97		DY production, $ _{L}$ DY production, $ _{L}$ <b>Masss</b> $(\tilde{k}_{1}^{0}) < 400 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 6 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 0 \text{ GeV}$ $\tilde{k}_{1}^{0}) = 100 \text{ GeV}$ $(\tilde{k}_{1}^{0}) = 600 \text{ GeV}$ $(\tilde{k}_{1}^{0}) = 600 \text{ GeV}$ $\tilde{k}_{1}^{0} = 700 \text{ GeV}$ $\tilde{k}_{1}^{0} = 700 \text{ GeV}$	gi = 5e gi = 1g <sub>D</sub> , spin 1/2 ATLAS Re	$\frac{1911203673}{1905.10130}$ <b>Prelimina</b> $\sqrt{s} = 13$ <b>Second Second Sec</b>
*Only a *Only a <b>CAS SUS</b> th 2022 <b>Model</b> $, \bar{q} \rightarrow q \bar{\chi}_{1}^{0}$ $, \bar{g} \rightarrow q \bar{q} (\ell) \tilde{\chi}_{1}^{0}$ $, \bar{g} \rightarrow q \bar{q} (\ell) \tilde{\chi}_{1}^{0}$ $, \bar{g} \rightarrow q \bar{q} (\ell) \tilde{\chi}_{1}^{0}$	ggs triplet $H^{\pm\pm} \rightarrow W^{\pm}W^{\pm}$ ggs triplet $H^{\pm\pm} \rightarrow \ell\ell$ ggs triplet $H^{\pm\pm} \rightarrow \ell$ ulti-charged particles agnetic monopoles <b>v s</b> = 8 TeV <b>s</b> <b>s</b> <b>s</b> <b>s</b> <b>s</b> <b>s</b> <b>s</b> <b>s</b>	2.5; e ( µ, c 3 e, µ, c 5 = 13 TeV artial data a mass lim - 95% Signature 2-6 jets 2-6 jets 2-6 jets 2-6 jets 2 jets 7-11 jets 6 jets 3 b	$E_T^{miss}$		20.3 36.1 34.4 / tes or obe ver Lii <sup>1</sup> ] <sup>4</sup> [1x, 8x E <sup>7</sup> [8x Dege <sup>7</sup> <sup>8</sup> <sup>8</sup> <sup>8</sup> <sup>8</sup> <sup>8</sup> <sup>8</sup> <sup>8</sup> <sup>8</sup>	H** mass multi-charged pr monopole mass 10 <sup>-</sup> normana is sh mits	400 GeV article mass 1.22 -1 Mass limit 	2.37 TeV 1.85 1.15-1.95 2.2 2.2 1.97 2.25	ـــــــــــــــــــــــــــــــــــــ	DY production, $ _{L}$ DY production, $ _{L}$ <b>Masss</b> : $(\tilde{t}_{1}^{0}) < 400 \text{ GeV}$ $-m(\tilde{t}_{1}^{0}) = 5 \text{ GeV}$ $m(\tilde{t}_{1}^{0}) = 0 \text{ GeV}$ $m(\tilde{t}_{1}^{0}) = 100 \text{ GeV}$ $(\tilde{t}_{1}^{0}) < 500 \text{ GeV}$ $(\tilde{t}_{1}^{0}) < 200 \text{ GeV}$	artLAS	$\frac{1917.393}{1905.10130}$
$\frac{i}{2} \frac{i}{2} \frac{i}$	ggs triplet $H^{\pm\pm} \rightarrow W^{\pm}W^{\pm}$ ggs triplet $H^{\pm\pm} \rightarrow \ell\ell$ ggs triplet $H^{\pm\pm} \rightarrow \ell$ ulti-charged particles agnetic monopoles <b>v</b> = 8 TeV <b>y</b> calantion of the available <b>SY Searchess</b> * <b>S</b> <b>S</b> $0 e, \mu$ mono-jet $0 e, \mu$ $1 e, \mu$ $ee, \mu\mu$ $0 e, \mu$ $SS e, \mu$ $0.1 e, \mu$ $SS e, \mu$ $0.1 e, \mu$	2-6 jets 3 c, µ, τ 5 = 13 TeV a mace line - 95% 6 ignature 2-6 jets 2 jets 7-11 jets 3 jets 3 jets 2 jets	$E_T^{miss}$ $E_T^{miss}$ $E_T^{miss}$ $E_T^{miss}$ $E_T^{miss}$ $E_T^{miss}$ $E_T^{miss}$		20.3 36.1 34.4 2 2 2 2 3 4 2 2 2 2 2 2 2 2 2 2 2 2 2	H** mass multi-charged pr monopole mass 10 <sup>-</sup> normana is ch <b>mits</b>	400 GeV article mass 1.22 -1 Mass limit 0.9 Forbidde	2.37 TeV 2.37 TeV 1.85 2.3 1.15-1.95 2.2 2.2 1.97 2.25 4 2.25		DY production, $ _{L}$ DY production, $ _{L}$ DY production, $ _{L}$ <b>Masss</b> s $(\tilde{k}_{1}^{0}) < 400 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 6 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 0 \text{ GeV}$ $(\tilde{k}_{1}^{0}) = 100 \text{ GeV}$ $(\tilde{k}_{1}^{0}) < 600 \text{ GeV}$ $(\tilde{k}_{1}^{0}) < 600 \text{ GeV}$ $(\tilde{k}_{1}^{0}) < 200 \text{ GeV}$ $(\tilde{k}_{1}^{0}) = 200 \text{ GeV}$ $(\tilde{k}_{1}^{0}) = 200 \text{ GeV}$ $(\tilde{k}_{1}^{0}) = 200 \text{ GeV}$ $(\tilde{k}_{1}^{0}) = 200 \text{ GeV}$	atLA	$\frac{1911293}{1922.03673}$ $\frac{1912.03673}{1905.10130}$ <b>Prelimina</b> $\sqrt{s} = 13$ <b>Seference</b> 2010.14293 2102.10874 2010.14293 2101.01629 RNEP-2022.014 2008.06032 1909.08457 S-CONF-2018-041 1909.08457 2101.1627
$\frac{i}{2} = \frac{i}{2} = \frac{i}$	ggs triplet $H^{\pm\pm} \rightarrow W^{\pm}W^{\pm}$ ggs triplet $H^{\pm\pm} \rightarrow \ell\ell$ ggs triplet $H^{\pm\pm} \rightarrow \ell\ell$ ggs triplet $H^{\pm\pm} \rightarrow \ellr$ ulli-charged particles agnetic monopoles <b>SY Searches*</b> <b>SY Searches*</b> <b>S</b> $0 e, \mu$ $0 e, \mu$	2.6 jets 2.6 je	$\frac{1}{\sqrt{s}}$ fu fu fu fu fu fu fu fu fu fu	= 13 TeV III data new eta . LOV C dt [fb <sup>−</sup> 139 139 139 139 139 139 139 139 139 139	20.3 36.1 34.4 ver Lii	Hit mass multi-charged pr monopole mass 10 <sup>-</sup> normana is ch mits	400 GeV article mass 1.22 -1 -1 Mass limit 0.9 Forbiddet	2.37 TeV 1.85 1.15-1.95 2.2 2.2 1.97 2.25 255 255	m m(i) m(i) m(i) m(i) m m(i) m m(i) m m(i) m m(i) m m(i) m m(i) m	DY production, $ _{L}$ DY production, $ _{L}$ DY production, $ _{L}$ <b>Masss</b> : $(\tilde{t}_{1}^{0}) < 400 \text{ GeV}$ $-m(\tilde{t}_{1}^{0}) = 5 \text{ GeV}$ $m(\tilde{t}_{1}^{0}) = 0 \text{ GeV}$ $m(\tilde{t}_{1}^{0}) = 0 \text{ GeV}$ $(\tilde{t}_{1}^{0}) = 0 \text{ GeV}$ $(\tilde{t}_{1}^{0}) = 200 \text{ GeV}$ $(\tilde{t}_{1}^{0}) < 200 \text{ GeV}$ $(\tilde{t}_{1}^{0}) < 200 \text{ GeV}$ $(\tilde{t}_{1}^{0}) = 200 \text{ GeV}$ $(\tilde{t}_{1}^{0}) < 200 \text{ GeV}$	scale [TeV] ATLAS	$\frac{111232}{119203673}$ $\frac{111232}{1905.10130}$ <b>Prelimina</b> $\sqrt{s} = 13$ <b>Sterence</b> 2010.14293 2102.10874 2010.14293 2101.014297 2101.01429 2100.0147 2101.0147 210.0147 2101.01
*Only a *Only a <b>ASS SUS</b> h 2022 <b>Model</b> $\bar{q} \rightarrow q \bar{x}_{1}^{0}$ $\bar{s} \rightarrow q \bar{q} (\ell) \chi_{1}^{0}$ $\bar{s} \rightarrow q \bar{q} (\ell) \chi_{1}^{0}$	$ggs triplet H^{\pm \pm} \rightarrow W^{\pm}W^{\pm}$ $ggs triplet H^{\pm \pm} \rightarrow \ell\ell$ $ggs triplet H^{\pm \pm} \rightarrow \ell\ell$ $ggs triplet H^{\pm \pm} \rightarrow \ell$ $ys$ $from a ggs triplet H^{\pm \pm} \rightarrow \ellr$ $ys$ $ggs triplet H^{\pm \pm} \rightarrow \ellr$ $ggs triplet H^{\pm} \oplus \ellr$ $ggs triplet H^{\pm} \rightarrow \ellr$ $ggs trip$	2.6 jets 2.6 je	$E_T^{miss}$ $E_T^{miss}$ $E_T^{miss}$ $E_T^{miss}$ $E_T^{miss}$ $E_T^{miss}$ $E_T^{miss}$		20.3 36.1 34.4 2 2 2 2 3 3 4 2 2 2 2 2 2 3 4 2 2 2 2 2 2 2 2 2 2 2 2 2	H** mass multi-charged pr monopole mass 10- 10- momana is ch mits Degen.] n.]	400 GeV article mass 1.22 -1 Mass limit 0.9 Forbidde 0.68	2.37 TeV 2.37 TeV 1.85 2.3 1.15-1.95 2.2 2.2 1.97 2.25 2.55 1.35 Δ		DY production, $ _{L}$ DY production, $ _{L}$ DY production, $ _{L}$ <b>Masss</b> s $(\tilde{k}_{1}^{0}) < 400 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 6 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 0 \text{ GeV}$ $(\tilde{k}_{1}^{0}) = 100 \text{ GeV}$ $(\tilde{k}_{1}^{0}) < 600 \text{ GeV}$ $(\tilde{k}_{1}^{0}) < 600 \text{ GeV}$ $(\tilde{k}_{1}^{0}) = 200 \text{ GeV}$ $(\tilde{k}_{1}^{0}) = 100 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 0 \text{ GeV}$	artLAS	$\int \frac{1}{192,00673} \frac{1}{1905,10130}$
$i \rightarrow q \bar{q} \tilde{\chi}_{1}^{0}$ $i \rightarrow q \bar{\chi}_{1}^{0}$	$ggs triplet H^{\pm\pm} \rightarrow W^{\pm}W^{\pm} ggs triplet H^{\pm\pm} \rightarrow \ell\ell ggs triplet H^{\pm\pm} \rightarrow \ell\ell ggs triplet H^{\pm\pm} \rightarrow \ellr ulti-charged particles agnetic monopoles sy searches sy searches$	2.6; e, $\mu$ (C) 3 e, $\mu$ , $\tau$ = 13 TeV ritial data a mass lim - 95% ignature 2-6 jets 1-3 jets 2-6 jets 2-7 jets 3-7 jets	$k_T^{miss}$ $k_T^{miss}$ $k_T^{miss}$ $k_T^{miss}$ $k_T^{miss}$ $k_T^{miss}$ $k_T^{miss}$ $k_T^{miss}$ $k_T^{miss}$ $k_T^{miss}$ $k_T^{miss}$ $k_T^{miss}$ $k_T^{miss}$ $k_T^{miss}$ $k_T^{miss}$ $k_T^{miss}$ $k_T^{miss}$ $k_T^{miss}$		20.3 36.1 34.4 2 2 2 2 3 3 4 2 2 2 2 2 2 2 2 2 2 2 2 2	Hit mass mult-charged pr monopole mass 10 <sup>-</sup> promana is ch mits Degen.] n.]	400 GeV article mass 1.22 -1 -1 Mass limit 0.9 Forbidden 0.68 0.13-0.85 Forbidden 0.65	2.37 TeV 1.85 1.15-1.95 2.3 1.15-1.95 2.2 2.2 1.97 2.25 255 255 255 255 255 255 25		DY production, $ _{L}$ DY production, $ _{L}$ DY production, $ _{L}$ <b>Masss</b> : $(\tilde{\xi}_{1}^{0}) \leq 400 \text{ GeV}$ $m(\tilde{\xi}_{1}^{0}) = 5 \text{ GeV}$ $m(\tilde{\xi}_{1}^{0}) = 5 \text{ GeV}$ $m(\tilde{\xi}_{1}^{0}) = 0 \text{ GeV}$ $m(\tilde{\xi}_{1}^{0}) = 0 \text{ GeV}$ $(\tilde{\xi}_{1}^{0}) = 200 \text{ GeV}$ $(\tilde{\xi}_{1}^{0}) < 200 \text{ GeV}$ $(\tilde{\xi}_{1}^{0}) < 200 \text{ GeV}$ $(\tilde{\xi}_{1}^{0}) = 300 \text{ GeV}$ $(\tilde{\xi}_{1}^{0}) \geq 200 \text{ GeV}$ $(\tilde{\xi}_{1}^{0}) \geq 200 \text{ GeV}$ $(\tilde{\xi}_{1}^{0}) \geq 200 \text{ GeV}$ $(\tilde{\xi}_{1}^{0}) = 10 \text{ GeV}$ $m(\tilde{\xi}_{1}^{0}) = 10 \text{ GeV}$ $(\tilde{\xi}_{1}^{0}) = 500 \text{ GeV}$	ce atLAS 2004.	$\frac{111232}{118220673}$ $\frac{111232}{1905.10130}$
*Only a *Only a <b>ASS SUS</b> h 2022 <b>Model</b> $\bar{g} \rightarrow q \bar{\chi}_{1}^{0}$ $\bar{g} \rightarrow q \bar{\chi}_{1}^{0}$	$\begin{array}{c} \operatorname{ggs} \operatorname{triplet} H^{\pm} \to W^{\pm} W^{\pm} \\ \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell \ell \\ \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell \ell \\ \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell r \\ \operatorname{ulli-charged particles} \\ \operatorname{agnetic monopoles} \\ \hline \mathbf{V}^{S} = 8 \ TeV \\ \end{array} \begin{array}{c} \mathbf{V}^{S} \\ \mathbf{S}^{S} \\ \operatorname{striplet} \\ \mathbf{S}^{S} \\ \operatorname{striplet} \\ \mathbf{S}^{S} \\ \operatorname{striplet} \\ \mathbf{S}^{S} \\ \operatorname{striplet} \\ \end{array} \begin{array}{c} 0 \\ e, \mu \\ \end{array} \\ \begin{array}{c} 0 \\ e, \mu \\ 0 \\ e, \mu \\ \operatorname{striplet} $	$\begin{array}{c} 2.5, \epsilon \in \mu \text{ G}\\ 3 \in \mu, \tau\\ \hline 3 \in \mu, \tau\\ \hline \end{array}$	$E_T^{miss}$		20.3 36.1 34.4 2 2 2 2 3 3 4 2 2 2 2 2 2 2 2 2 2 2 2 2	H** mass multi-charged pr monopole mass 10 <sup>-</sup> normana is ch mits Degen.] n.]	400 GeV article mass 1.22 -1 -1 Mass limit 0.68 0.13-0.85 Forbidden 0.65 Forbidden 0.85	2.37 TeV 1.85 1.15-1.95 2.3 1.15-1.95 2.3 2.2 2.2 1.97 2.25 2.5 2.5 2.5 2.5 2.5 2.5 2.		DV production, $ _{L}$ DV production, $ _{L}$ DV production, $ _{L}$ <b>Masss</b> : $(\tilde{k}_{1}^{0}) < 400 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 5 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 5 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 600 \text{ GeV}$ $(\tilde{k}_{1}^{0}) < 200 \text{ GeV}$ $(\tilde{k}_{1}^{0}) < 200 \text{ GeV}$ $(\tilde{k}_{1}^{0}) = 200 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 100 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 100 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 160 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 100 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 100 \text{ GeV}$	artLAS	$\frac{111232}{118220673}$ $\frac{111232}{1905.10130}$ <b>Prelimina</b> $\sqrt{s} = 13$ <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Con</b>
$i \rightarrow q \bar{\chi}^{0}$	$\begin{array}{c} \text{ggs triplet } H^{\pm} \rightarrow W^{\pm} W^{\pm} \\ \text{ggs triplet } H^{\pm} \rightarrow \ell \ell \\ \text{ggs triplet } H^{\pm} \rightarrow \ell \ell \\ \text{ggs triplet H^{\pm} \rightarrow \ell r \\ \text{ulli-charged particles } \\ \text{agnetic monoples} \end{array}$	2.6; e, $\mu$ C 3 e, $\mu$ T = 13 TeV intrial data a mass lim = 95% iggnature 2-6 jets 1-3 jets 2-6 jets 2-1 jets 3 b 2 b 2 b 2 b 2 b 2 c 1 jets 3 jets/1 b 2 jet	$E_T^{miss}$ $E_T^{miss}$		20.3 36.1 34.4 2 2 2 2 3 3 4 2 2 2 2 2 2 3 4 4 2 2 2 2 2 2 2 2 2 2 2 2 2	Hit mass multi-charged pr monopole mass 10- normana is ch mits Degen.] n.]	400 GeV article mass 1.22 -1 -1 Mass limit 	2.37 TeV 1.85 1.15-1.95 2.3 1.15-1.95 2.2 2.2 1.97 2.25 2.55		DY production, $ _{L}$ DY production, $ _{L}$ DY production, $ _{L}$ <b>Masss</b> : $(\tilde{k}_{1}^{0}) < 400 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 6 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 6 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 0 \text{ GeV}$ $(\tilde{k}_{1}^{0}) < 600 \text{ GeV}$ $(\tilde{k}_{1}^{0}) < 600 \text{ GeV}$ $(\tilde{k}_{1}^{0}) < 600 \text{ GeV}$ $(\tilde{k}_{1}^{0}) = 200 \text{ GeV}$ $(\tilde{k}_{1}^{0}) = 300 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 500 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 500 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 500 \text{ GeV}$	Grand Strand Str	$\begin{array}{c} 1817.232\\ 1812.03673\\ 1905.10130\\ \hline \\ \hline$
*Only a *Only a <b>ASS SUS</b> h 2022 <b>Model</b> $\bar{q} \rightarrow q \bar{x}_{1}^{0}$ $\bar{g} \rightarrow q \bar{q} \bar{x}_{1}^$	$\begin{array}{c} \text{ggs triplet } H^{\pm \pm} \rightarrow W^{\pm}W^{\pm}\\ \text{ggs triplet } H^{\pm \pm} \rightarrow \ell\ell\\ \text{ggs triplet } H^{\pm \pm} \rightarrow \ell\ell\\ \text{ggs triplet } H^{\pm \pm} \rightarrow \ellr\\ \text{ulli-charged particles}\\ \text{agnetic monopoles}\\ \hline \textbf{Vs} = \textbf{8 TeV} \qquad \textbf{y}_{\text{ggs}}\\ \hline \textbf{SY Searches}^{\star}\\ \textbf{SY Searches}^{\star}\\ \textbf{SS e.}\\ \textbf{SS e.}\\ \textbf{Multi-e.}\\ \textbf{SS e.}\\ \textbf{0} e.\mu\\ \textbf{SS e.}\\ \textbf{0} e.\mu\\ \textbf{0} e.\mu\\ \textbf{SS e.}\\ \textbf{0} e.\mu\\ \textbf{0} e.\mu\\ \textbf{SS e.}\\ \textbf{0} e.\mu\\ \textbf$	2.6 jets 3. $e, \mu, \tau$ 5 = 13 TeV artial data a mass limit 2.6 jets 1.3 jets 2.6 jets 2.6 jets 3.b 6 jets 3.b 6 jets 3.b 6 jets 2.6 jets 2.6 jets 3.b 6 jets 2.6 jets 3.b 6 jets 3.b 6 jets 2.6 jets 3.b 6 jets 3.b 7.11 jets 2.6 jets 3.b 6 jets 3.b 6 jets 3.b 7.11 jets 3.b 6 jets 3.b 7.11 jets 3.b 7.11 jets 3.b 7.15 jets 3.b 7.5 jets 3.5 jets	$E_T^{miss}$		20.3 36.1 34.4 7 tes or obe ver Lin $\frac{1}{7}$	H** mass multi-charged pr monopole mass 10 <sup>-</sup> normana is ch mits Degen.] n.]	400 GeV article mass 1.22 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1	2.37 TeV 1.85 1.15-1.95 2.3 2.2 2.2 1.97 2.2 2.2 1.97 2.25 2.5 2.5 2.5 1.35 Δ 1.4 1.4	$\begin{array}{c} & & & & & \\$	DV production, $ _{L}$ DV production, $ _{L}$ DV production, $ _{L}$ <b>Masss</b> : $(\tilde{k}_{1}^{0}) < 400 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 5 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 6 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 0 \text{ GeV}$ $\tilde{k}_{1}^{0} > 600 \text{ GeV}$ $\tilde{k}_{1}^{0} > 600 \text{ GeV}$ $\tilde{k}_{1}^{0} > 600 \text{ GeV}$ $\tilde{k}_{1}^{0} > 600 \text{ GeV}$ $\tilde{k}_{1}^{0} > 200 \text{ GeV}$ $\tilde{k}_{1}^{0} > 200 \text{ GeV}$ $\tilde{k}_{1}^{0} = 200 \text{ GeV}$ 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<b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b>Control</b> <b></b>
$i \rightarrow i \rightarrow$	$\begin{array}{c} \text{ggs triplet } H^{\pm \pm} \rightarrow W^{\pm} W^{\pm} \\ \text{ggs triplet } H^{\pm \pm} \rightarrow \ell \ell \\ \text{ggs triplet } H^{\pm \pm} \rightarrow \ell \ell \\ \text{ggs triplet } H^{\pm \pm} \rightarrow \ell r \\ \text{ulli-charged particles} \\ \text{agnetic monoples} \\ \hline \textbf{SY Searches}^{\star} \\ \hline \textbf{SY Searches}^{\star} \\ \hline \textbf{SY Searches}^{\star} \\ \hline \textbf{SS e.} \\ \hline \textbf{SS e.} \\ \mu \\ 0 e.\mu \\ 0 $	2.6; e, $\mu$ C 3 e, $\mu$ T <b>5</b> = 13 TeV <b>initial data</b> <b>a</b> macciliant <b>biggnature</b> <b>2</b> -6 jets 1-3 jets 2-6 jets 2-6 jets 2-6 jets 2-6 jets 3 b 6 jets 3 b 6 jets 3 b 6 jets 2 b 2 b 2 b 2 b 2 b 2 b 2 b 2 b	$E_T^{miss}$		20.3 36.1 34.4 i = 34.4 i = 34.4	Hit mass multi-charged pr monopole mass 10- normana is ch mits Degen.] n.]	400 GeV article mass 1.22 -1 -1 Mass limit Mass limit 0.9 Forbidden 0.68 0.13-0.85 Forbidden 0.68 0.13-0.85 0.68 0.13-0.85 0.05 0.05 0.05 0.06 0.85 0.06 0.96	2.37 TeV 1.85 1.15-1.95 2.3 1.15-1.95 2.2 2.2 1.97 2.25 2.55 2.55 2.55 2.55 2.55 2.55 2.55 1.35 Δ 2.5 1.4 8 	$\begin{array}{c} & & & & & & & \\ & & & & & & \\ & & & & $	DY production, $ _{L}$ DY production, $ _{L}$ DY production, $ _{L}$ <b>Masss</b> : $(\tilde{\chi}_{1}^{0}) < 400 \text{ GeV}$ $m(\tilde{\chi}_{1}^{0}) = 6 \text{ GeV}$ $m(\tilde{\chi}_{1}^{0}) = 6 \text{ GeV}$ $m(\tilde{\chi}_{1}^{0}) = 0 \text{ GeV}$ $(\tilde{\chi}_{1}^{0}) = 0 \text{ GeV}$ $(\tilde{\chi}_{1}^{0}) < 600 \text{ GeV}$ $(\tilde{\chi}_{1}^{0}) < 600 \text{ GeV}$ $(\tilde{\chi}_{1}^{0}) = 200 \text{ GeV}$ $(\tilde{\chi}_{1}^{0}) = 300 \text{ GeV}$ $(\tilde{\chi}_{1}^{0}) = 300 \text{ GeV}$ $m(\tilde{\chi}_{1}^{0}) = 0 \text{ GeV}$	2106.	$\frac{1111232}{119203673}$ $\frac{111232}{1905.10130}$ <b>Prelimin</b> $\sqrt{s} = 13^{-2}$ <b>eference</b> $\frac{2010.14293}{2102.10874}$ $\frac{2010.14293}{2101.01629}$ $\frac{2010.14293}{2100.10874}$ $\frac{2010.14293}{2100.10874}$ $\frac{2010.14293}{2100.10874}$ $\frac{2010.1293}{2100.08457}$ $\frac{2101.12527}{2101.12527}$ $\frac{1101.12527}{2101.12527}$ $\frac{100.08457}{2100.1203799}$ $\frac{2100.07665}{1805.01649}$ $\frac{2102.03799}{2102.03799}$ $\frac{2102.03799}{2102.03799}$ $\frac{2102.03799}{2102.03799}$ $\frac{2102.03799}{2102.03799}$ $\frac{2102.10874}{2006.05880}$ $\frac{2006.05880}{2006.05880}$ $\frac{206.07586}{1911.12606}$ $\frac{1909.08215}{1900.08215}$
*Only a Higher Higher	$\begin{array}{c} \text{ggs triplet } H^{\pm\pm} \rightarrow W^{\pm}W^{\pm}\\ \text{ggs triplet } H^{\pm\pm} \rightarrow \ell\ell\\ \text{ggs triplet } H^{\pm\pm} \rightarrow \ell\ell\\ \text{ggs triplet } H^{\pm\pm} \rightarrow \ellr\\ \text{ulli-charged particles}\\ \text{agnetic monoples}\\ \hline \hline V & \text{SEC} \\ \hline V &$	2.6; e, $\mu$ or 3. e, $\mu$ , $\tau$ = <b>5</b> = 13 TeV artial data a mass limit <b>a</b> mass limit <b>a</b> mass limit <b>b</b> mass limit <b>a</b> mass limit <b>a</b> mass limit <b>b</b> mass limit <b>a</b> mass limit <b>b</b> mass limit	$E_T^{miss}$		20.3 36.1 34.4 $i_{1}$ $\frac{1}{q}$ [1x, 8x E $\frac{1}{q}$ [8x Dege $\frac{1}{q}$ [8x Deg	Hit mass mult-charged pr monopole mass 10- momona is ch mits Degen.] nn.]	400 GeV article mass 1.22 -1 -1 00WD Mass limit 0.9 Forbidden 0.63 Forbidden 0.65 Forbidden 0.65 0.13-0.85 0.68 0.13-0.85 0.68 0.13-0.85 0.68 0.13-0.85 0.68 0.13-0.85 0.68 0.13-0.85 0.68 0.13-0.85 0.68 0.13-0.85 0.68 0.68 0.13-0.85 0.68 0.13-0.85 0.68 0.13-0.85 0.68 0.13-0.85 0.68 0.13-0.85 0.68 0.65 0.68 0.65 0.68 0.65 0.68 0.66 0.65 0.65 0.66 0.65 0.65 0.66 0.65 0.68 0.65 0.66 0.65 0.66 0.65 0.66 0.65 0.66 0.65 0.66 0.65 0.66 0.65 0.66 0.65 0.66 0.66 0.65 0.66 0.66 0.65 0.65 0.66 0.65 0.65 0.66 0.65 0.65 0.66 0.65 0.66 0.66 0.65 0.66 0.65 0.66 0.65 0.66 0.66 0.65 0.66 0.66 0.65 0.66 0.66 0.65 0.66 0.65 0.66 0.66 0.66 0.66 0.66 0.66 0.65 0.66 0.	2.37 TeV 1.85 1.15-1.95 2.3 1.15-1.95 2.3 2.2 2.2 1.97 2.2 2.2 1.97 2.2 2.2 1.97 1.97 1	$m_{(\vec{k}_{2}^{0}, \vec{k}_{1}^{0})=360 \text{ GeV}, m(\vec{k}_{1}^{0})=m(\vec{k}_{1}^{0})=m(\vec{k}_{1}^{0})=m(\vec{k}_{1}^{0})=m(\vec{k}_{2}^{0}, \vec{k}_{1}^{0})=m(\vec{k}_{1}^{0})=m$	DV production, $ _{L}$ DV production, $ _{L}$ DV production, $ _{L}$ <b>Masss</b> s $(\tilde{t}_{1}^{0}) < 400 \text{ GeV}$ $-m(\tilde{t}_{1}^{0}) = 5 \text{ GeV}$ $m(\tilde{t}_{1}^{0}) = 5 \text{ GeV}$ $m(\tilde{t}_{1}^{0}) = 0 \text{ GeV}$ $\tilde{t}_{1}^{0}) = 600 \text{ GeV}$ $\tilde{t}_{1}^{0} > 600 \text{ GeV}$ $\tilde{t}_{1}^{0} = 100 \text{ GeV}$ $m(\tilde{t}_{1}^{0}) = 100 \text{ GeV}$ $m(\tilde{t}_{1}^{0}) = 10 \text{ GeV}$ $m(\tilde{t}_{1}^{0}) = 10 \text{ GeV}$ $m(\tilde{t}_{1}^{0}) = 60 \text{ GeV}$ $m(\tilde{t}_{1}^{0}) = 60 \text{ GeV}$ $m(\tilde{t}_{1}^{0}) = 60 \text{ GeV}$ $m(\tilde{t}_{1}^{0}) = 10 \text{ GeV}$ $m(\tilde{t}_{1}^{0}) = 10 \text{ GeV}$ $m(\tilde{t}_{1}^{0}) = 10 \text{ GeV}$ $m(\tilde{t}_{1}^{0}) = 00 \text{ GeV}$ $m(\tilde{t}_{1}^{0}) = 0 \text{ GeV}$ $m(\tilde{t}_{1}^{0}) = 0 \text{ GeV}$	2106. 2004.	$\frac{111232}{112203673}$ $\frac{1112303673}{1905.10130}$ <b>Prelimin</b> $\sqrt{s} = 13^{-2}$ <b>Eference</b> $\frac{2010.14293}{2102.10874}$ $\frac{2010.14293}{2101.01629}$ RN-EP-2022-014 $\frac{2000.04293}{2101.01629}$ RN-EP-2022-014 $\frac{2000.04857}{2101.12527}$ $\frac{2101.12527}{1090.08457}$ <b>S-CONF-2018-041</b> $\frac{1909.08457}{2102.10874}$ $\frac{2101.12527}{2103.08189}$ $\frac{14060.20122}{2103.08189}$ $\frac{14060.20122}{2103.08189}$ $\frac{14060.20122}{2103.08189}$ $\frac{14060.20122}{2103.08189}$ $\frac{14060.20122}{2103.08189}$ $\frac{14060.20122}{2103.08189}$ $\frac{14060.20120}{2006.05880}$ $\frac{01676, 2108.07586}{1911.12606}$ $\frac{1908.08215}{1908.08215}$
* Only 2 Higher Higher Highe	$\begin{array}{c} \operatorname{ggs} \operatorname{triplet} H^{\pm} \to W^{\pm} W^{\pm} \\ \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell \ell \\ \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell r \\ \operatorname{ggs} \operatorname{ggs} \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell r \\ \operatorname{ggs} \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell r \\ \operatorname{ggs} \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell r \\ \operatorname{ggs} \operatorname{ggs} \operatorname{ggs} \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell r \\ \operatorname{ggs} gg$	$\sum_{i=1}^{2} \sum_{j=1}^{2} \sum_{2$	$E_T^{miss}$		20.3 36.1 34.4 $i_{1}^{1}$ $i_{2}^{1}$ $i_{3}^{1}$	Hi* mass multi-charged pr monopole mass 10- normana is ch mits Degen.] n.] Degen.] n.] Degen.] n.] Degen.] n.]	400 GeV article mass 1.22 -1 -1 0.0WD Mass limit 0.9 Forbidden 0.68 0.13-0.85 Forbidden 0.68 0.13-0.85 0.067 Forbidden 0.85 0.067 0.96 0.42 11 0.90 0.42 11 12 0.90 0.9	2.37 TeV 1.85 1.15-1.95 2.2 2.2 1.97 2.25 255 255 255 255 255 255 25	$\begin{array}{c} & & & & \\ & & & & \\ & & & & \\ & & & & $	DY production,   DY production,   DY production,   DY production,   DY production,   ( $k^0_1$ ) <400 GeV $m(k^0_1) = 6$ GeV $m(k^0_1) = 6$ GeV $m(k^0_1) = 6$ GeV $m(k^0_1) = 6$ GeV $m(k^0_1) = 0$ GeV $(k^0_1) <500$ GeV $(k^0_1) <500$ GeV $(k^0_1) <500$ GeV $(k^0_1) = 100$ GeV $(k^0_1) = 100$ GeV $(k^0_1) = 100$ GeV $m(k^0_1) = 10$ GeV $m(k^0_1) = 0$ GeV $(k^0_1) = 0$ GeV $(k^$	2106. 2004.	$\frac{111122}{11812.03673}$ $\frac{11212.03673}{1905.10130}$ <b>Prelimina</b> $\sqrt{s} = 13$ <b>Eference</b> $\frac{2010.14293}{2102.10874}$ $\frac{2010.14293}{2101.14293}$ $\frac{2010.14293}{2101.14293}$ $\frac{2010.14293}{2101.1629}$ <b>RN-EP-2022-014</b> $\frac{2008.06032}{1909.08457}$ $\frac{2101.12527}{2101.12527}$ $\frac{1908.03122}{2100.1649}$ $\frac{2101.12527}{2101.12527}$ $\frac{1908.03122}{2100.203799}$ $\frac{2108.07665}{1805.01649}$ $\frac{2102.10874}{2006.05860}$ $\frac{2006.05880}{2006.05860}$ $\frac{1908.08215}{1990.08215}$ $\frac{1908.08215}{1990.08215}$
* Only a Higher Higher Highe	$\begin{array}{c} \operatorname{ggs} \operatorname{triplet} H^{\pm} \to W^{\pm} W^{\pm} \\ \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell \ell \\ \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell \ell \\ \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell r \\ \operatorname{ulli-charged particles} \\ \operatorname{agnetic monoples} \\ \hline \mathbf{V} = 8 \ \mathrm{TeV}  \begin{array}{c} \mathcal{V}_{\mathbf{p}} \\ \mathbf{p}_{\mathbf{p}} \\ \end{array} \\ \begin{array}{c} \operatorname{calaction of the available} \\ \end{array} \\ \hline \mathbf{SY Searches}^{*} \\ \hline \\ \mathbf{SY Searches}^{*} \\ \hline \\ \mathbf{SY Searches}^{*} \\ \hline \\ \mathbf{SS e}_{\mu} \\ \end{array} \\ \begin{array}{c} 0 \ e, \mu \\ 0 \ e, \mu \\ 0 \ e, \mu \\ \end{array} \\ \begin{array}{c} 0 \ e, \mu \\ 0 \ e, \mu \\ \end{array} \\ \hline \\ \hline \\ \begin{array}{c} 0 \ e, \mu \\ 0 \ e, \mu \\ \end{array} \\ \hline \\ \hline$	$\begin{array}{r} 2.6; e, \mu, \sigma\\ 3, e, \mu, \tau\\ 3, e, \mu, \tau\\ 3, e, \mu, \tau\\ \hline 3, e, \mu, \tau\\ \hline 3, e, \mu, \tau\\ \hline 1, 0, 0\\ \hline 1, 0\\ \hline$	$E_T^{miss}$		20.3 36.1 34.4 $i_{1}$ $i_{2}$ $i_{3}$ $i_{4}$ $i_{5}$ $i_{1}$ $i_{1}$ $i_{1}$ $i_{1}$ $i_{1}$ $i_{1}$ $i_{1}$ $i_{2}$ $i_{1}$ i	Hit mass mult-charged pr monopole mass 10 <sup>-</sup> normana is ch mits Degen.]	400 GeV article mass 1.22 -1 -1 0.000 Mass limit 0.68 0.13-0.85 Forbidden 0.65 Forbidden 0.65 Forbidden 0.85 0.05 0.05 0.05 0.05 0.85 0.06 1.22 0.9 0.9 0.9 0.9 0.9 0.9 0.9 0.9	2.37 TeV         1.85         1.15-1.95         2.2         2.2         2.2         2.2         2.2         2.2         2.2         2.2         2.2         2.2         2.5         1.35         1.4	$m_{(\vec{q})} = m_{(\vec{q})} = m_{$	DV production, $ _{L}$ DV production, $ _{L}$ DV production, $ _{L}$ <b>Masss</b> : $(\tilde{k}_{1}^{0} _{2} < 400 \text{ GeV} - m(\tilde{k}_{1}^{0})_{1} = 5 \text{ GeV} m(\tilde{k}_{1}^{0})_{1} = 0 \text{ GeV}$ $m(\tilde{k}_{1}^{0})_{1} = 1 \text{ GeV}$ $m(\tilde{k}_{1}^{0})_{1} = 1 \text{ GeV}$ $m(\tilde{k}_{1}^{0})_{1} = 1 \text{ GeV}$ $m(\tilde{k}_{1}^{0})_{1} = 0 \text{ GeV}$ $m(\tilde{k}_{1}^{0})_{1} = 1 \text{ GeV}$ $m(\tilde{k}_{1}^{0})_{1} = 1 \text{ GeV}$ $m(\tilde{k}_{1}^{0})_{1} = 1 \text{ GeV}$ $m(\tilde{k}_{1}^{0})_{1} = 0 \text{ GeV}$ $m(\tilde{k}_{1}^{0})_{1} = 1 \text{ GeV}$ $m(\tilde{k}_{1}^{0})_{1} = 1 \text{ GeV}$ $m(\tilde{k}_{1}^{0})_{1} = 1 \text{ GeV}$ $m(\tilde{k}_{1}^{0})_{1} = 0 \text{ GeV}$	2106. 2004.	$\frac{11122}{1912.03673}$ $\frac{1905.10130}{1905.10130}$
* Only a Higher Higher Highe	$\begin{array}{c} \operatorname{ggs} \operatorname{triplet} H^{\pm} \to W^{\pm} W^{\pm} \\ \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell \ell \\ \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell \ell \\ \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell r \\ \operatorname{ulli-charged particles} \\ \operatorname{agnetic monopoles} \end{array} \qquad $	$\begin{array}{c} 2.5; \in \mu, 0\\ 3 \in \mu, \tau\\ \hline 3 \in \mu, \tau\\ \hline 3 \in \mu, \tau\\ \hline \end{array}$	$E_T^{miss}$		20.3 36.1 34.4 7 7 7 7 7 7 7 7	Hit mass multi-harged pr monopole mass 10- normana is ch mits Degen.] n.] Degen.] n.] Degen.] n.] Degen.] n.] Degen.] n.]	400 GeV article mass 1.22 -1 -1 0.0WD Mass limit 0.9 Forbidden 0.68 0.13-0.85 Forbidden 0.68 0.13-0.85 0.68 0.13-0.85 0.68 0.13-0.85 0.68 0.13-0.85 0.55 0.68 0.13-0.85 0.68 0.13-0.85 0.55 0.06 0.06 0.06 0.06 0.05 0.05 0.06 0.05 0.06 0.05 0.05 0.06 0.05 0.06 0.05 0.06 0.05 0.06 0.05 0.05 0.06 0.06 0.05 0.06 0.05 0.06 0.05 0.06 0.05 0.06 0.06 0.06 0.06 0.05 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.06 0.05 0.06 0.05 0.0	2.37 TeV 1.85 2.3 1.15-1.95 2.2 2.2 1.97 2.25 2.5 2.5 2.5 2.5 2.5 1.35 Δ 2.5 1.4 3 m	$\begin{array}{c} & & & & & \\ & & & & & & \\ & & & & & \\ & & & & & \\ & & & & & & \\ & & & & & & \\ & & &$	DY production, $ _{L}$ DY production, $ _{L}$ DY production, $ _{L}$ Masss : $(\hat{x}_{1}^{0}) < 400 \text{ GeV} - m(\hat{x}_{1}^{0}) = 5 \text{ GeV} - m(\hat{x}_{1}^{0}) = 5 \text{ GeV} - m(\hat{x}_{1}^{0}) = 5 \text{ GeV} - m(\hat{x}_{1}^{0}) = 1000 \text{ GeV} - (\hat{x}_{1}^{0}) = 1000 \text{ GeV} - (\hat{x}_{1}^{0}) = 0 \text{ GeV} - (\hat{x}_{1}^{0}) = 200 \text{ GeV} - m(\hat{x}_{1}^{0}) = 200 \text{ GeV} - m(\hat{x}_{1}^{0}) = 0 \text{ GeV} - m(\hat{x}_{1}^{0}) = 5 \text{ GeV} - m(\hat{x}_{1}^{0}) = 0 \text{ GeV} - m($	2106. 2004.	$\begin{array}{c} 111.232\\ 1812.03673\\ 1905.10130\\ \hline \\ \hline$
$\frac{i}{q} \rightarrow q\bar{\chi}_{1}^{0}$ $\frac{i}{\bar{q}} \rightarrow q\bar{\chi}_{1}^{0}$ $\frac{\bar{q}}{\bar{q}} \rightarrow \bar{q} \rightarrow q\bar{q} \rightarrow q\bar{\chi}_{1}^{0}$ $\frac{\bar{q}}{\bar{q}} \rightarrow \bar{q} \rightarrow q\bar{q} $	$\begin{array}{c} \operatorname{ggs} \operatorname{triplet} H^{\pm} \to W^{\pm} W^{\pm} \\ \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell \ell \\ \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell \ell \\ \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell r \\ \operatorname{ulli-charged particles} \\ \operatorname{agnetic monopoles} \\ \hline & \checkmark S = 8 \ \mathrm{TeV} \\ \end{array} \begin{array}{c} \sqrt{s} = 8 \ \mathrm{TeV} \\ \end{array} \begin{array}{c} \sqrt{s} \\ \mathrm{sec} \\ \mathrm{sec}$	2.6; e, $\mu$ of $3 = e, \mu$ of $2 = 13$ TeV initial data of models line in $-95\%$ 5: Signature in $-95\%$ 5: Signature in $2-6$ jets in $-1.3$ jets in $2-6$	$E_T^{miss}$		20.3 36.1 34.4 $i_{1}$ $i_{2}$ $i_{3}$ $i_{4}$ $i_{4}$ $i_{1}$ $i_{1}$ $i_{1}$ $i_{1}$ $i_{2}$ $i_{8}$ i	Hit mass mult-charged pr monopole mass 10- pormana is ch mits Degen.] 	400 GeV article mass 1.22 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1	2.37 TeV         1.85         1.15-1.95         2.2         2.2         2.2         2.2         2.2         2.2         2.2         2.2         2.5         2.5         2.5         1.35         Δ         25         1.4	$m_{(\vec{q})} = m_{(\vec{q})} = m_{$	DV production, $ _{L}$ DV production, $ _{L}$ DV production, $ _{L}$ <b>Masss</b> : $(\tilde{k}_{1}^{0} _{<400} \text{ GeV} - (\tilde{k}_{1}^{0} _{<15} \text{ GeV} - (\tilde{k}^{0} _{<15} \text{ GeV} - (k$	2106.	$\frac{1811.203673}{1905.10130}$ $\frac{1812.03673}{1905.10130}$ $\frac{1812.03673}{1905.10130}$ $\frac{1812.03673}{1905.10130}$ $\frac{1812.03673}{1905.10130}$ $\frac{1812.03673}{1905.10130}$ $\frac{1812}{1905.0474}$ $\frac{2010.14293}{2101.01629}$ $\frac{2010.14293}{2101.01629}$ $\frac{2010.14293}{2101.01629}$ $\frac{2010.14293}{2101.01629}$ $\frac{2010.14293}{2101.01629}$ $\frac{2010.14293}{2101.01629}$ $\frac{2010.14293}{2101.01629}$ $\frac{2101.12527}{1908.03122}$ $\frac{2101.12527}{1908.03122}$ $\frac{2101.12527}{1908.03122}$ $\frac{2101.12527}{1908.03122}$ $\frac{2101.12527}{1908.03122}$ $\frac{2100.207399}{2102.03799}$ $\frac{2102.0799}{2102.03799}$ $\frac{2102.0799}{2102.03799}$ $\frac{2102.0799}{2102.07986}$ $\frac{1908.08215}{1901.08215}$ $\frac{1908.08215}{1911.12606}$ $1908.0$
*Only a *Only a <b>LAS SUS</b> Mu <b>Model</b> $\bar{q} \rightarrow q\bar{\chi}_{1}^{0}$ $\bar{g} \rightarrow q\bar{\chi}_{1}^{0}$ $\bar{g} \rightarrow q\bar{\chi}_{1}^{0}$ $\bar{g} \rightarrow q\bar{q}\bar{\chi}_{1}^{0}$ $\bar{g} \rightarrow q\bar{q}\bar{\chi}_{1}^{0}$ $\bar{g} \rightarrow q\bar{q}W\bar{\chi}_{1}^{0}$ $\bar{g} \rightarrow q\bar{q}W\bar{\chi}_{1}^{0}$ $\bar{g} \rightarrow q\bar{q}W\bar{\chi}_{1}^{0}$ $\bar{g} \rightarrow q\bar{q}W\bar{\chi}_{1}^{0}$ $\bar{g} \rightarrow q\bar{q}W\bar{\chi}_{1}^{0}$ $\bar{g} \rightarrow t\bar{t}\chi_{1}^{0}$ $\bar{t}_{1} \bar{t} \rightarrow t\bar{t}\chi_{1}^{0}$ $\bar{t}_{1} \bar{t} \bar{t}\chi_{1}^{0}$ $\bar{t}_{1} \bar{t} \bar{t}\chi_{1}^{0}$ $\bar{t} \bar{t}\chi_{1}^{0}$ $\bar{t}\chi_{1$	ggs triplet $H^{\pm\pm} \rightarrow W^{\pm}W^{\pm}$ ggs triplet $H^{\pm\pm} \rightarrow \ell\ell$ ggs triplet $H^{\pm\pm} \rightarrow \ell\ell$ ggs triplet $H^{\pm\pm} \rightarrow \ell$ ulti-charged particles agnetic monopoles $\sqrt{s} = 8 \text{ TeV}$ SY Searches* SY Searches* SS e.µ 0 e.µ 1 e.µ $ee.µ\mu$ 0 e.µ 0 e.µ $0 e.\mu$ $SS e.\mu$ 0 e.µ $0 e.\mu$ $SS e.\mu$ $0 e.\mu$ $2\tau$ $0 e.\mu$ $1 e.\mu$ $1 e.\mu$ $1 e.\mu$ $2 e.\mu$ $2 e.\mu$ Multiple $\ell/jet$ $2 e.\mu$ $ee.\mu\mu$ $0 e.\mu$ $0 e.\mu$ $0 e.\mu$ $1 e.e.\mu$ $0 e.\mu$ $0 e.\mu$ 0 e.	$2b + e + \mu + G$ $3e + \mu + T$ $3e + \mu + T$ $3e + \mu + T$ $2a + 2a +$	$E_T^{miss}$		20.3 36.1 34.4 $i_{1}$ $\frac{1}{q}$ [1x, 8x E g [8x Dege $\frac{1}{g}$ [8x Dege $\frac{1}{g}$ [8x Dege $\frac{1}{g}$ $\frac{1}{g}$ [8x Dege $\frac{1}{g}$ $\frac{1}{g}$ [8x Dege $\frac{1}{g}$ $\frac{1}{g}$ $$	Hit mass mult-charged pr monopole mass in 10- momona is ch mits Degen] nn] Degen] nn] 0.205 cbidden 0.205 cbidden 0.256 0.13-0.23	400 GeV article mass 1.22 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1	2.37 TeV 1.85 1.15-1.95 2.2 2.2 1.97 2.25 2.5 2.5 1.35 A 1.4 m	$\begin{array}{c} & & & & & \\ & & & & & & \\ & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & & \\ & &$	DV production, $ _{L}$ DV production, $ _{L}$ DV production, $ _{L}$ Masss s $(\tilde{k}_{1}^{0}) < 400 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 5 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 5 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 0 \text{ GeV}$ $\tilde{k}_{1}^{0} > 600 \text{ GeV}$ $\tilde{k}_{1}^{0} > 600 \text{ GeV}$ $\tilde{k}_{1}^{0} > 600 \text{ GeV}$ $\tilde{k}_{1}^{0} > 600 \text{ GeV}$ $\tilde{k}_{1}^{0} > 200 \text{ GeV}$ $\tilde{k}_{1}^{0} > 200 \text{ GeV}$ $\tilde{k}_{1}^{0} > 200 \text{ GeV}$ $\tilde{k}_{1}^{0} > 200 \text{ GeV}$ $\tilde{k}_{1}^{0} = 100 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 100 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 10 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 10 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 10 \text{ GeV}$ $m(\tilde{k}_{1}^{0}) = 0 \text{ GeV}$ $m(\tilde{k}_{1}^{0$	CE	$\frac{111123}{11220673}$ $\frac{111230673}{1905.10130}$ <b>Prelimina</b> $\sqrt{s} = 13 \ \]$ <b>eference</b> 2010.14293 2102.10874 2010.14293 2101.01629 RN-EP-2022-014 2008.06032 1309.08457 2101.12527 2109.08457 2101.12527 2109.08457 2101.12527 2109.08457 2101.12527 2109.08457 2101.12527 2109.08457 2101.12527 2109.08457 2010.12527 11090.08457 2010.12527 11090.08457 2010.27586 1805.01649 2102.10874 2006.05880 2016.7586 1911.12606 1909.08215 1911.12606 1909.08215 1911.12606 1909.08215 1911.12606 1909.08215 1911.12606 1806.04030 2103.11684 2100.07586 2201.02472 2201.02472 2201.02472 201
$ \frac{i}{\overline{q}} = $	$\begin{array}{c} \operatorname{ggs} \operatorname{triplet} H^{\pm} \to W^{\pm} W^{\pm} \\ \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell \ell \\ \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell \ell \\ \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell r \\ \operatorname{ulli-charged particles} \\ \operatorname{agnetic monoples} \end{array} \qquad $	2.5; e (µ G 3 e, µ, τ = 13 TeV initial data a mass limit = 95% bignature 2-6 jets 1-3 jets 2-6 jets 2-1 jet 3 jets/1 b 2 jets/2 jets 2 jets 2 jets 2 jets 2 jets 2 jets/2 jets 2 jets/2 jets/	$\begin{array}{c} -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ $		20.3 36.1 34.4 i = 34.4 i = 34.4	Hit mass mult-charged pr monopole mass 10- pormana ie ch mits Degen.] n.] Degen.] Dege	400 GeV article mass 1.22 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1	2.37 TeV 1.85 1.15-1.95 2.2 2.2 1.97 225 255 255 1.35 A 7 725 1.4 1.4 1.5 .22 2.2 1.97 2.25 .225 .25 .25 .25 .25 .25	$\begin{array}{c} & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & & & & \\ & & & & & & & \\ & & & & & & & \\ & & & & & & \\ & & & & & & \\ & &$	DY production,   DY production,   DY production,   DY production,   DY production,   ( $\tilde{k}_{1}^{0}$ ) < 400 GeV $m(\tilde{k}_{1}^{0}$ ) = 5 GeV $m(\tilde{k}_{1}^{0}) = 5$ GeV $m(\tilde{k}_{1}^{0}) = 0$ GeV $m(\tilde{k}_{1}^{0}) = 0$ GeV $\tilde{k}_{1}^{0}$ < 600 GeV $\tilde{k}_{1}^{0}$ < 600 GeV $\tilde{k}_{1}^{0}$ < 600 GeV $\tilde{k}_{1}^{0}$ < 600 GeV $\tilde{k}_{1}^{0}$ > 200 GeV $\tilde{k}_{1}^{0}$ > 200 GeV $\tilde{k}_{1}^{0}$ > 600 GeV $\tilde{k}_{1}^{0}$ > 10 GeV $\tilde{k}_{1}^{0}$ > 0 CeJ = 1 $\tilde{k}_{1}^{0}$ > $ZG$ = 1 Pure Wino Pure higgsino $\tilde{k}_{1}^{0}$ > 100 GeV $\tau(\tilde{\ell})$ = 0.1 ns	CE CE CE CE CE CE CE CE	$\frac{11}{122.03673}$ $\frac{11}{122.03673}$ $\frac{11}{122.03673}$ $\frac{11}{1905.10130}$ <b>Prelimina</b> $\sqrt{s} = 13$ <b>Eference</b> $\frac{2010.14293}{2102.10874}$ $\frac{2010.14293}{2101.01629}$ $\frac{2010.14293}{2100.10629}$ $\frac{2010.14293}{2100.10629}$ $\frac{2010.14293}{2100.10629}$ $\frac{2010.14293}{2100.06032}$ $\frac{1909.08457}{2101.12527}$ $\frac{2101.12527}{2101.12527}$ $\frac{2101.12527}{2101.12527}$ $\frac{1908.03122}{2103.08189}$ $\frac{1006.0212.03799}{2108.07665}$ $\frac{1201.12527}{1202.10874}$ $\frac{2006.05880}{2006.05880}$ $\frac{2016.7586}{1911.12606}$ $\frac{1908.08215}{1911.06660}$ $\frac{1908.08215}{1911.12606}$ $\frac{1908.0820}{1910.1762}$ $\frac{1908.0820}{1910.1762}$
*Only a *Only a <b>ASS SUS</b> h 2022 <b>Model</b> $\bar{q} \rightarrow q\bar{\chi}_{1}^{0}$ $\bar{g} \rightarrow q\bar{\chi}_{1}^{0}$ $\bar{g} \rightarrow q\bar{\chi}_{1}^{0}$ $\bar{g} \rightarrow q\bar{q}\chi_{1}^{0}$ $\bar{g} \rightarrow q\bar{q}\chi_{1}^{0}$ $\bar{g} \rightarrow q\bar{q}\chi_{1}^{0}$ $\bar{g} \rightarrow q\bar{q}\chi_{1}^{0}$ $\bar{g} \rightarrow q\bar{\chi}_{1}^{0}$ $\bar{g} \rightarrow t\bar{\chi}_{1}^{0}$ $\bar{g} \rightarrow t\bar{\chi}_{1}^{0}$ 	$\begin{array}{c} \operatorname{ggs} \operatorname{triplet} H^{\pm} \to W^{\pm} W^{\pm} \\ \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell \ell \\ \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell \ell \\ \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell r \\ \operatorname{ggs} \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell r \\ \operatorname{ggs} \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell r \\ \operatorname{ggs} \operatorname{ggss} \operatorname{ggss} \operatorname{ggss} \operatorname{ggsss} \operatorname{ggssss} \operatorname{ggsss} \operatorname{ggssss} \operatorname{ggssss} \operatorname{ggsssss} \operatorname{ggssssss} ggsssssssssssssssssssssssssssssssssss$	$2 = 13 \text{ E} + \mu \text{ G}$ $3 = e, \mu \text{ G}$ $3 = e, \mu \text{ G}$ $3 = 13 \text{ TeV}$ $1 = 13 \text{ TeV}$ $- 95\%$ $2  for a started of the started of t$	$\begin{array}{c} -\\ \hline \\ $		20.3 36.1 34.4 2 2 2 2 2 2 2 2 2 2 2 2 2	Hit mass mult-charged pr monopole mass monopole monopole mass monopole monopole mass monopole mass monopole mass monopole mass monopole mass monopole monopole mass monopole monopole monopole monopole monopole monopole monopole monopole monopole monopole monopole monopole monopole monopole monopole monopole monopole monopole mo	400 GeV article mass 1.22 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1	2.37 TeV 1.85 1.15-1.95 2.2 2.2 1.97 2.2 2.2 1.97 2.2 1.35 1.4 m	$\begin{array}{c} & & & & & \\ & & & & & & \\ & & & & & & \\ & & & & & \\ & & & & & & \\ & & & & & \\ & & &$	DV production,  _{L} DV production,  _{L} DV production,  _{L} DV production,  _{L} Masss : $\frac{(k_{1}^{0}) < 400 \text{ GeV}}{(k_{1}^{0}) = 5 \text{ GeV}}$ $\frac{m(k_{1}^{0}) = 5 \text{ GeV}}{(k_{1}^{0}) = 0 \text{ GeV}}$ $\frac{m(k_{1}^{0}) = 0 \text{ GeV}}{(k_{1}^{0}) = 200 \text{ GeV}}$ $\frac{k_{1}^{0} < 600 \text{ GeV}}{(k_{1}^{0}) = 200 \text{ GeV}}$ $\frac{k_{1}^{0} < 600 \text{ GeV}}{(k_{1}^{0}) = 200 \text{ GeV}}$ $\frac{m(k_{1}^{0}) = 200 \text{ GeV}}{(k_{1}^{0}) = 200 \text{ GeV}}$ $\frac{m(k_{1}^{0}) = 200 \text{ GeV}}{(k_{1}^{0}) = 200 \text{ GeV}}$ $\frac{m(k_{1}^{0}) = 400 \text{ GeV}}{m(k_{1}^{0}) = 10 \text{ GeV}}$ $\frac{m(k_{1}^{0}) = 10 \text{ GeV}}{m(k_{1}^{0}) = 10 \text{ GeV}}$ $\frac{m(k_{1}^{0}) = 10 \text{ GeV}}{m(k_{1}^{0}) = 10 \text{ GeV}}$ $\frac{m(k_{1}^{0}) = 10 \text{ GeV}}{m(k_{1}^{0}) = 10 \text{ GeV}}$ $\frac{m(k_{1}^{0}) = 10 \text{ GeV}}{m(k_{1}^{0}) = 10 \text{ GeV}}$ $\frac{m(k_{1}^{0}) = 10 \text{ GeV}}{m(k_{1}^{0}) = 10 \text{ GeV}}$ $\frac{m(k_{1}^{0}) = 10 \text{ GeV}}{m(k_{1}^{0}) = 10 \text{ GeV}}$ $\frac{m(k_{1}^{0}) = 10 \text{ GeV}}{m(k_{1}^{0}) = 10 \text{ GeV}}$ $\frac{m(k_{1}^{0}) = 10 \text{ GeV}}{m(k_{1}^{0}) = 10 \text{ GeV}}$	CE CE CE CE CE CE CE	$\begin{array}{c} 111.2321\\ 1812.03673\\ 1905.10130\\ \hline \\ \hline$
$\frac{i}{\sqrt{2}} = \frac{i}{\sqrt{2}} \sum_{k=1}^{N} \sum_{k=1}^{N} \sum_{\substack{i \in \mathcal{I} \\ Highting \\ $	$\begin{array}{c} \operatorname{ggs triplet} H^{\pm} \to W^{\pm} W^{\pm} \\ \operatorname{ggs triplet} H^{\pm} \to \ell \ell \\ \operatorname{ggs triplet} H^{\pm} \to \ell \ell \\ \operatorname{ggs triplet} H^{\pm} \to \ell r \\ \operatorname{ggs triplet} M^{\pm} \to \ell r \\ \operatorname$	2.5; € ; $\mu$ ; $\pi$ <b>5</b> = 13 TeV <b>initial data</b> <b>a</b> mace lim <b>a</b> mace lim <b>bigmature</b> <b>2</b> -6 jets 2 -1 jet 3 jets/1 b 2 jets/1 b 2 jets/1 b 2 c 1 -4 b 1 b 1 -5 jets 2 -1 jet 3 <i>b</i> 0 jets 2 -1 jet -1	$\begin{array}{c} -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ $		20.3 36.1 34.4 7 7 7 7 7 7 7 7 7 7 7 7 7	Hit mass mult-harged pr monopole mass 10- normana is ch mits Degen.]       	400 GeV article mass 1.22 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1	2.37 TeV         1.85         1.15-1.95         2.2         2.2         2.2         2.2         1.97         255         1.35         2.25         1.35         1.4         8         m         2.205         2.205         2.205         2.205	$\begin{array}{c} & & & & \\ & & & & \\ & & & & \\ & & & & $	DV production,   DV production,   DV production,   DV production,   DV production,   Masss : $(k^0) \le 400 \text{ GeV}$ $m(k^0) = 5 \text{ GeV}$ $m(k^0) = 6 \text{ GeV}$ $m(k^0) = 0 \text{ GeV}$ $(k^0) \le 500 \text{ GeV}$ $(k^0) = 200 \text{ GeV}$ $(k^0) = 200 \text{ GeV}$ $(k^0) = 100 \text{ GeV}$ $m(k^0) = 0 \text{ In S}$ $r(\ell) = 0.1 \text{ ns}$ $r(\ell) = 10 \text{ ns}$ $r(\ell) = 10 \text{ ns}$ $r(\ell) = 10 \text{ ns}$	CE CE CE CE CE CE CE	$\frac{11122}{11812.03673}$ $\frac{11905.10130}{11905.10130}$
*Only a <b>LAS</b> SUS Mu <b>ASS</b> SUS <i>A</i> 2022 <b>Model</b> $, \bar{q} \rightarrow q \bar{\chi}_{1}^{0}$ $, \bar{s} \rightarrow q \bar{q} \bar{\chi}_{1}^{0}$ $\bar{b}_{1}$ $\bar{b}_{1}$ , $\bar{b}_{1} \rightarrow b \bar{\chi}_{2}^{0} \rightarrow b h \bar{\chi}_{1}^{0}$ $\bar{b}_{1}$ , $\bar{h}_{1} \rightarrow t \bar{\chi}_{1}^{0}$ $\bar{b}_{1}$ , $\bar{h}_{1} \rightarrow t \bar{\chi}_{1}^{0}$ $\bar{h}_{1}$ , $\bar{h}_{1} \rightarrow t \bar{\chi}_{1}^{0}$ $\bar{h}_{1}$ , $\bar{h}_{1} \rightarrow t \bar{\chi}_{1}^{0}$ $\bar{h}_{1}$ , $\bar{h}_{1} \rightarrow t \bar{\chi}_{1}^{0}$ $\bar{\chi}_{1}^{-} \bar{\chi}_{1} \rightarrow t \bar{\chi}_{1}^{0}$ , $\bar{\chi}_{1} \rightarrow t \bar{\chi}_{1}^{0}$ $\bar{\chi}_{2}^{-} \bar{\chi}_{2} \rightarrow \bar{\chi}_{1} + Z$ $\bar{\chi}_{2}^{0}$ via $WZ$ $\bar{\chi}_{1}^{+}$ via $WW$ $\bar{\chi}_{1}^{0}$ via $\bar{\chi}_{1}/\bar{p}$ , $\bar{\tau} \rightarrow \tau \bar{\chi}_{1}^{0}$ $R \bar{L}_{LR}$ , $\bar{t} \rightarrow t \bar{\chi}_{1}^{0}$ $R \bar{t}_{LR}$ , $\bar{t} \rightarrow t \bar{\chi}_{1}^{0}$ $R \bar{t}_{LR}$ , $\bar{t} \rightarrow t \bar{\chi}_{1}^{0}$ $\bar{t} \rightarrow t \bar{G}$ $\bar{\chi}_{1}^{+} / \bar{\chi}_{1}^{0} \rightarrow \bar{\chi}_{1}^{+} \rightarrow q \bar{\chi}_{1}^{0}$	$\begin{array}{c} \operatorname{ggs} \operatorname{triplet} H^{\pm} \to W^{\pm} W^{\pm} \\ \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell \ell \\ \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell \ell \\ \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell r \\ \operatorname{ggs} \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \ell r \\ \operatorname{ggss} \operatorname{triplet} H^{\pm} \to \ell r \\ \operatorname{ggsss} \operatorname{ggsss} \operatorname{triplet} H^{\pm} \to \ell r \\ \operatorname{ggsss} \operatorname{triplet} H^{\pm} \to \ell r \\ \operatorname{ggsss} \operatorname{triplet} H^{\pm} \to \ell r \\ \operatorname{ggsss} \operatorname{ggsss} \operatorname{ggsss} H^{\pm} \to \ell r \\ \operatorname{ggsssss} H^{\pm} \to \ell r \\ ggsss$	$\begin{array}{c} 2.5; \in \mu \text{ G} \\ 3 \in \mu, \tau \\ \hline 1 \\ 1 \\$	$\begin{array}{c} -\\ \hline \\ $		20.3 36.1 34.4 $i_{1}$ $i_{2}$ $i_{3}$ $i_{4}$ $i_{5}$ $i_{6}$ $i_{1}$ $i_{1}$ $i_{1}$ $i_{1}$ $i_{6}$ $i_{8}$ $i_{1}$ $i_{1}$ $i_{1}$ $i_{1}$ $i_{1}$ $i_{1}$ $i_{7}$ $i_{1}$ $i_{7}$ $i_{1}$ $i_{7}$ $i_{1}$ $i_{7}$ $i_{1}$ $i_{7}$ $i_{1}$ $i_{7}$ $i_{1}$ $i_{7}$ $i_{7}$ $i_{8}$ $i_{1}$ $i_{1}$ $i_{7}$ $i_{1}$ $i_{7}$ $i_{8}$ i	Hit mass mult-harged pr monopole mass 10- normana is eh mits Degen.]  Degen.]  Degen.]  Degen.]   	400 GeV article mass 1.22 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1	2.37 TeV         1.85         1.15-1.95         1.15-1.95         2.2         2.2         2.2         2.2         2.2         2.2         2.2         2.2         2.5         1.35         1.4         8         m         2.55         1.4         8         m         2.205         2.2         2.05         2.2         2.05         2.2         1.3         1.9	$m_{(\vec{q})} = m_{(\vec{q})} = m_{$	$\begin{array}{c} \left\{ \chi_{1}^{(0)} + 400  \mathrm{GeV} \\ & \\ & \\ \mathbf{Masss} \\ \end{array} \right. \\ \left\{ \begin{array}{c} \chi_{1}^{(0)} + 400  \mathrm{GeV} \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ & \\ $	(q = 5e (g = 14p., spin 1/2 (Scale [TeV] (ATLAS Re (CE (ATLA 2004.) (2106.) (2004.) (2106.) (2004.) (2106.) (2004.) (2106.) (2004.) (2106.) (2004.) (2106.) (2004.) (2106.) (2004.) (2106.) (2004.) (2106.) (2004.) (2106.) (2004.) (2106.) (2004.) (2106.) (2	$\begin{array}{c} 1812.03673\\ 1812.03673\\ 1905.10130\\ \hline \\ \hline$
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$ \begin{array}{c} & \bullet \\ \bullet$	$\begin{array}{c} \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \mathcal{W}^{\pm} \mathcal{W}^{\pm} \\ \operatorname{ggs} \operatorname{triplet} H^{\pm} \to \mathcal{U}^{\dagger} \\ \operatorname{ggss} \operatorname{triplet} H^{\pm} \to \mathcal{U}^{\dagger} \\ \operatorname{ggss} \operatorname{triplet} H^{\pm} \\ \operatorname{ggss} \operatorname{ggss} \operatorname{triplet} H^{\pm} \to \mathcal{U}^{\dagger} \\ \operatorname{ggsss} \operatorname{ggss} \operatorname{ggss} \operatorname{triplet} H^{\pm} \to \mathcal{U}^{\dagger} \\ \operatorname{ggsss} \\ \operatorname{ggsss} \operatorname{ggsss} \operatorname{ggss} \operatorname{ggsss} \operatorname{ggsss} \operatorname{ggssss} \operatorname{ggsss} \operatorname{ggssss} \operatorname{ggssss} \operatorname{ggsssss} \operatorname{ggssssss} \operatorname{ggssssss} \\ ggsssssssssssssssssssssssssssssssssss$	$2 = 13 \text{ Fe} + \mu \text{ G}$ $3 = e, \mu \text{ G}$ $3 = e, \mu \text{ G}$ $3 = 13 \text{ TeV}$ $1 = 13 \text{ TeV}$ $3 = 13 \text{ TeV}$ $2 = 13  Te$	$\begin{array}{c} -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ -\\ $		20.3 36.1 34.4 $i_1$ $i_2$ $i_3$ $i_4$ $i_4$ $i_4$ $i_4$ $i_5$ $i_6$ $i_8$	Hi** mass multi-charged pr monopole mass 10 <sup>-</sup> pormana ie ch mits Degen.]  Degen.]       	400 GeV article mass 1.22 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1	2.37 TeV 1.85 1.15-1.95 2.2 2.2 1.97 2.25 2.5 2.5 2.5 2.5 2.5 2.5 2.	$(\vec{x}_{1}^{0})=360 \text{ GeV}, m(\vec{x}_{1}^{0})=300 \text{ GeV}, m(\vec{x}_{1}^{0})=300 \text{ GeV}, m(\vec{x}_{1}^{0})=300 \text{ GeV}, m(\vec{x}_{1}^{0},\vec{x}_{1}^{0})=130 \text{ GeV}, m(\vec{x}_{1}^{0},\vec{x}_{1}^{0})=130 \text{ GeV}, m(\vec{x}_{1}^{0},\vec{x}_{1}^{0})=130 \text{ GeV}, m(\vec{x}_{1}^{0})=360 \text{ m}, m(\vec{x}_{1}^{0})=360 \text{ m}, m(\vec{x}_{1}^{0})=200 $	DV production,   DV production,   DV production,   DV production,   DV production,   Masss : $\frac{(k^0) < 400 \text{ GeV}}{(k^0) - 560 \text{ GeV}}$ $\frac{(k^0) < 560 \text{ GeV}}{(k^0) - 100 \text{ GeV}}$ $\frac{(k^0) < 500 \text{ GeV}}{(k^0) - 100 \text{ GeV}}$ $\frac{(k^0) < 500 \text{ GeV}}{(k^0) - 300 \text{ GeV}}$ $\frac{(k^0) < 500 \text{ GeV}}{(k^0) - 300 \text{ GeV}}$ $\frac{(k^0) < 500 \text{ GeV}}{(k^0) - 300 \text{ GeV}}$ $\frac{(k^0) < 500 \text{ GeV}}{(k^0) - 300 \text{ GeV}}$ $\frac{(k^0) < 500 \text{ GeV}}{(k^0) - 300 \text{ GeV}}$ $\frac{(k^0) - 100 \text{ GeV}}{(k^0) - 300 \text{ GeV}}$ $\frac{(k^0) - 100 \text{ GeV}}{(k^0) - 500 \text{ GeV}}$ $\frac{(k^0) - 100 \text{ GeV}}{(k^0) - 500 \text{ GeV}}$ $\frac{(k^0) - 100 \text{ GeV}}{(k^0) - 500 \text{ GeV}}$ $\frac{(k^0) - 100 \text{ GeV}}{(k^0) - 500 \text{ GeV}}$ $\frac{(k^0) - 100 \text{ GeV}}{(k^0) - 500 \text{ GeV}}$ $\frac{(k^0) - 100 \text{ GeV}}{(k^0) - 00 \text{ GeV}}$ $\frac{(k^0) - 00 \text{ GeV}}{(k^0) - 00 \text{ GeV}}$ $\frac{(k^0) - 00 \text{ GeV}}{(k^0) - 00 \text{ GeV}}$ $\frac{(k^0) - 00 \text{ GeV}}{(k^0) - 00 \text{ GeV}}$ $\frac{(k^0) - 00 \text{ GeV}}{(k^0) - 00 \text{ GeV}}$ $\frac{(k^0) - 00 \text{ GeV}}{(k^0) - 00 \text{ GeV}}$ $\frac{(k^0) - 00 \text{ GeV}}{(k^0) - 00 \text{ GeV}}$ $\frac{(k^0) - 100 \text{ GeV}}{(k^0) - 00 \text{ GeV}}$ $\frac{(k^0) - 100 \text{ GeV}}{(k^0) - 00 \text{ GeV}}$ $\frac{(k^0) - 100 \text{ GeV}}{(k^0) - 00 \text{ GeV}}$ $\frac{(k^0) - 100 \text{ GeV}}{(k^0) - 00 \text{ GeV}}$ $\frac{(k^0) - 00 \text{ GeV}}{(k^0) - 00 \text{ GeV}}$ $\frac{(k^0) - 00 \text{ GeV}}{(k^0) - 00 \text{ GeV}}$ $\frac{(k^0) - 00 \text{ GeV}}{(k^0) - 00 \text{ GeV}}$ $\frac{(k^0) - 00 \text{ GeV}}{(k^0) - 00 \text{ GeV}}$ $\frac{(k^0) - 00 \text{ GeV}}{(k^0) - 00 \text{ GeV}}$ $\frac{(k^0) - 00 \text{ GeV}}{(k^0) - 00 \text{ GeV}}$ $\frac{(k^0) - 00 \text{ GeV}}{(k^0) - 00 \text{ GeV}}$ $\frac{(k^0) - 00 \text{ GeV}}{(k^0) - 00 \text{ GeV}}$ $\frac{(k^0) - 00 \text{ GeV}}{(k^0) - 00 \text{ GeV}}$ $\frac{(k^0) - 00 \text{ GeV}}{(k^0) - 00 \text{ GeV}}$	атьа (1) (1) (1) (1) (1) (1) (1) (1) (1) (1)	$\begin{array}{c} 1812.03673\\ 1812.03673\\ 1905.10130 \end{array}$

1 TeV

Direct searches for new phenomena beyond the Standard Model roughly tells us that we are already probing up to the  $\gtrsim$  1 TeV scale











 $k \sim \mathcal{O}(\%) \implies M_{NP} \gtrsim \mathcal{O}(1) \text{ TeV}$ 





### Lessons learned from the LHC so far



eV

phénomena is shown. Many of the limits are based on simplified models, c.f. refs. for the assumptions made

64

#### There <u>could</u> still be new physics at LHC/HL-LHC... but we need to invest NOW in R&D

#### **Data suggests** generically there is a gap from **EW** scale to scale of New Physics

We need to be able to probe ≫1 TeV





#### This logic can be applied both ways to Higgs factories as well!



Conservative Scaling for Upper Limit on Mass Scale Probed by Higgs Precision

If we <u>see</u> a deviation, we need to be able to at least reach greater than the few TeV scale

Whether 1% or .1% there are *no* guarantees that this precision is sufficient to break the SM, technology and cost driven

Need to be prepared to reach well beyond Higgs factories rather than assume they will set the scale









# A 10 TeV muon collider would satisfy this!

# Completing the SM

#### The Higgs is the most unique particle we've ever found and connected to so many questions about our universe

**Origin of EWSB?** 

Thermal History of Universe

Naturalness

**Fundamental** or Composite?

Is it unique?

**Higgs Portal** to Hidden Sectors?

**Stability of Universe** 

Higgs **Physics** 

> **CPV** and Baryogenesis

Origin of masses?

Snowmass EF Higgs Topical Report S. Dawson, PM, I. Ojalvo, C. Vernieri et al 2209.07510

**Origin of Flavor?** 



### The SM Higgs is an *unprecedented* particle.

#### LEP was a Z boson factory and produced ~ 17 Million Z bosons

**Z** boson Branching Fractions



All major Branching Fractions are  $\geq O(1\%)$ 

#### The same Higgs Branching Fractions span 8 to 20 ORDERS OF MAGNITUDE If we're ever to fully test the Higgs or Higgs potential we need a lot more than planned so far!

**Higgs Factories produce** ~ 1 Million Higgs bosons

**Higgs boson Branching Fractions** 





Similar concept to LHC/FCC-hh for why a muon collider can produce so many Higgs! (See Dario's talk for more details)







Protons Particle Data Group 2016 valence peaks at x~.2 sea of quarks and gluons below

# Both FCC-hh and µCol have a







2308.02633 M.Forslund, PM
## A 10 TeV muon collider wouldn't complete the SM but it would be a next logical step beyond Higgs factories!

## SUSY and the Higgs

## Naturalness!



I take QFT and spacetime symmetries very seriously! 75

While some people got depressed about a lack of SUSY at LHC, if you *trusted* the theory the Higgs mass told you not to worry!

A natural theory should have implications for the actual Higgs mass, and the MSSM says the scale should be high for  $m_h = 125$  GeV





## Naturalness and Supersymmetry Example

ach

76



### The Higgs at 125 GeV already suggested the SUSY scale was high, e.g. Stops ~ 10 TeV

### FCC-hh is superior to 10 TeV muon collider for Stop Searches, given colored particle nature

### In realistic models - EWinos/ Sleptons tend to be TeV scale which is within reach of a 10 TeV muon collider





### The simplest models of WIMP DM still are untested directly!





## ILC 0.5 TeV









## **n collider** is extremely well suited for this!

X+MET inclusive

Disappearing track

Kinematic limit,  $0.5 \times E_{\rm CM}$ 

## Testing the EWPT

### Next era in SM history is the "Electroweak Phase Transition"



## What is the phase diagram of the Electroweak Symmetry?





## However, we don't know that there was symmetry restoration at temperatures $\gg$ EW scale!



### h

## Even if it is restored we don't know the order of the phase transition experimentally



Probe the Higgs self interactions to at least  $\lambda_3 \sim O(1) \%$ 





## **10 TeV** $\mu$ **Col**



# See other examples in Dario's and Nadia's talks for $\mu$ Col and literature!

A leptonic vision for the future



## Conclusions

- beyond just being "Higgs Factories"
- Getting to higher energy is necessary not optional!
  - energy OR precision paradigm
  - better supported in the past
- sure we have options!

Circular and Linear Higgs Factories offer complementary physics cases and are far

Muon Colliders and WFA provide alternative routes to protons that change the

• We must support R&D along all paths, e.g. instead of a first stage muon collider being potentially 20 years away it could have been 10 if accelerator R&D was

 If the world ended up with an FCC path at CERN and Muon Collider at Fermilab this would be amazing for physics and HEP in general, but let's do the work to make

### Inaugural US Muon Collider Meeting





### If you're in the US come join us as this is (IMCC) and must continue to be an international effort!

## Or there is a nice GGI program next summer if you prefer Firenze...

