

Physics Working Group Summary

Convenors: Ayres Freitas and Tao Han

Muon Colliders Physics Workshop
(FNAL, Nov. 10–12, 2009)

WG1 Goals:

- Physics motivation after the LHC

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Muon Collider versus CLIC

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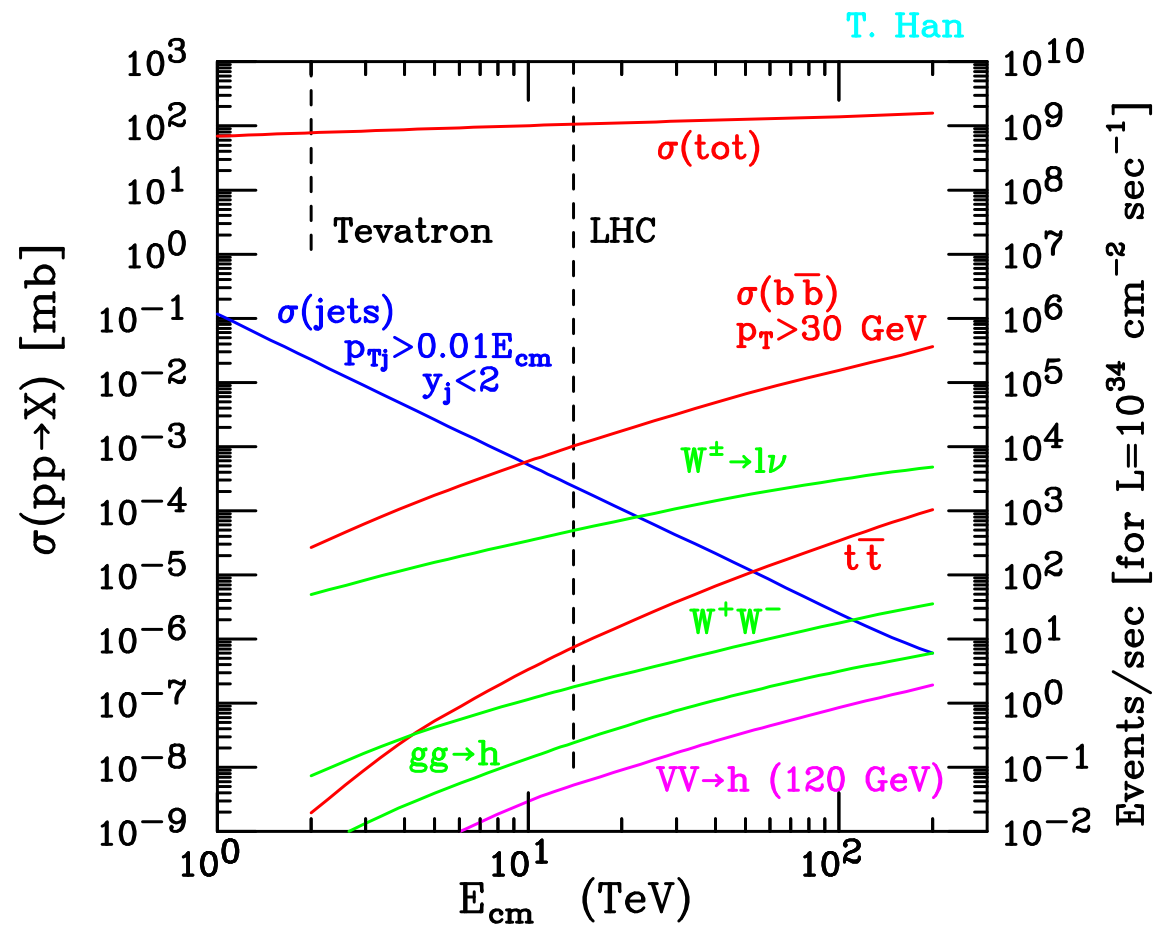
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Muon Collider versus CLIC

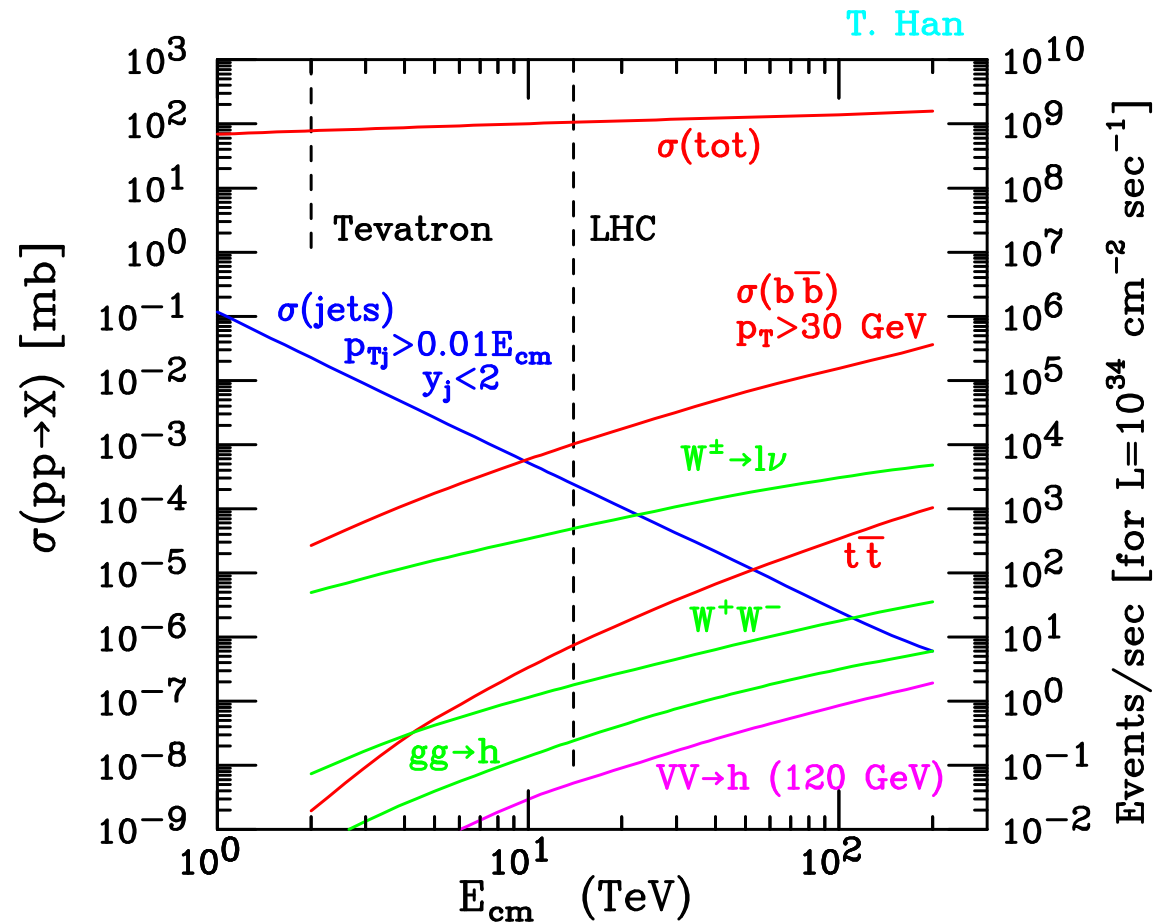
- Machine/Detector/Physics Interface

Feasibility/backgrounds/physics requirement.

SM at the LHC:



SM at the LHC:



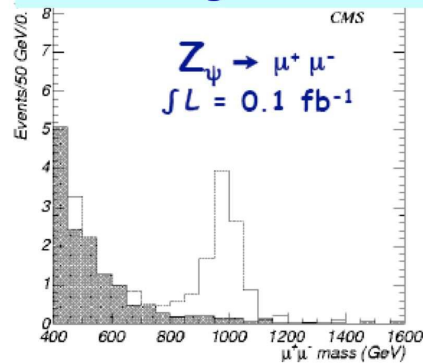
Signal rates high;

Hadronic backgrounds severe! (seen from the curves.)

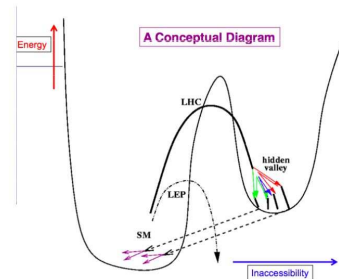
Searches at the LHC:

BSM Physics at the LHC

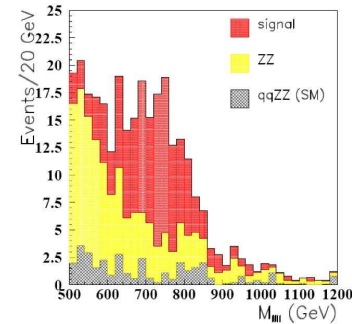
New Gauge Bosons?



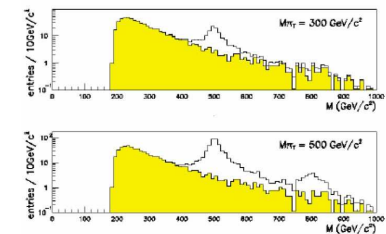
Hidden Valleys?



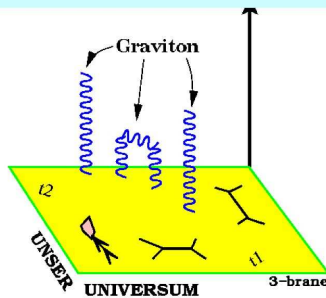
ZZ/WW resonances?



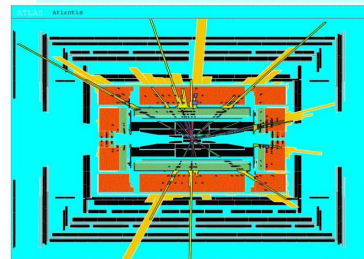
Technicolor?



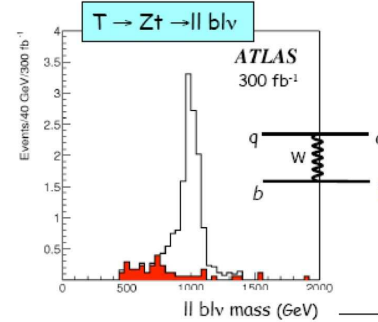
Extra Dimensions?



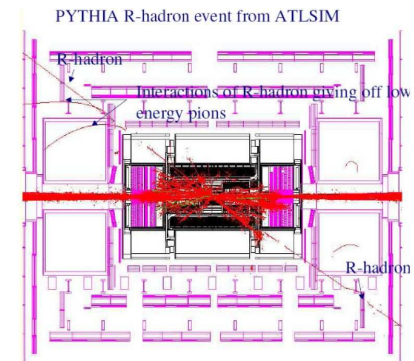
Black Holes???



Little Higgs?

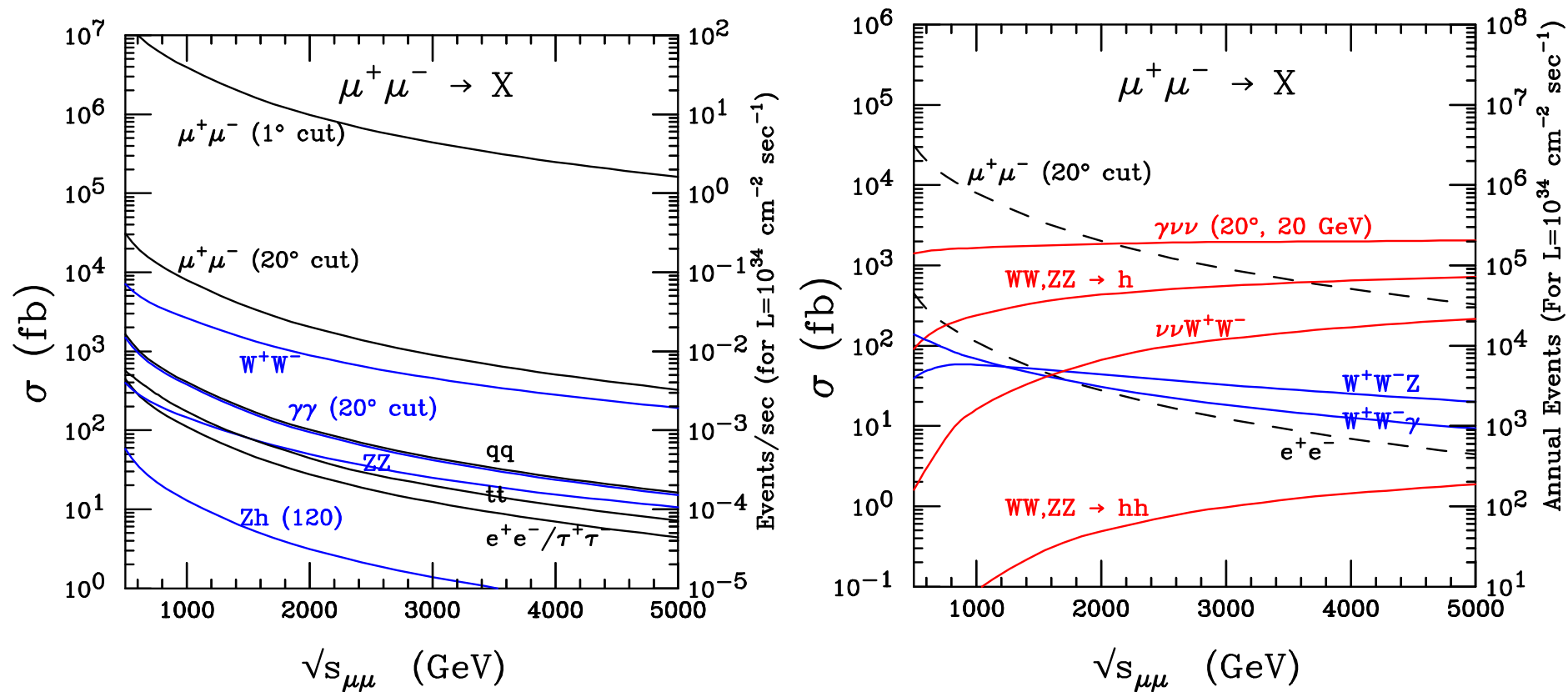


Split Susy?

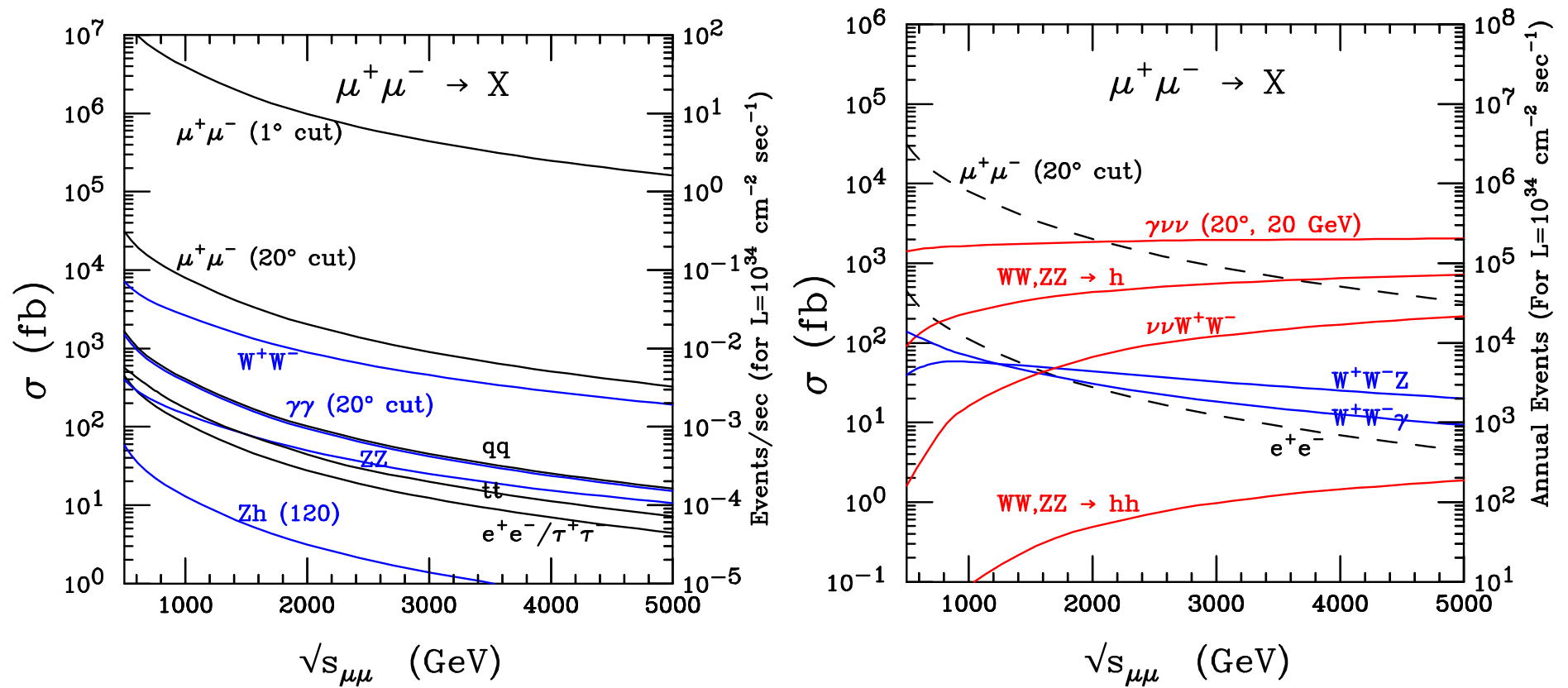


We do not know what is out there for us...

SM at a muon collider:



SM at a muon collider:



Signal rates low;
Machine/instrumental backgrounds severe!
(but not seen in the plots.)

Physics WG Activities:

Session 1: Simulation Tools and Backgrounds (Joint with MDI/Detector)

Stephen Mrenna: Tools for Calculations and Simulations

Session 2: Higgs and extensions (chairs: Shufang Su, Tao Liu)

Dave Cline: (A/H) Higgs Factory, Possible CP Violation and 6D Cooling

Bogdan Dobrescu: Tests of the uplifted Higgs region

Manuel Toharia: Tree-level Higgs FCNC's in RS models

Brooks Thomas: Leptophilic Higgs phenomenology at both hadron and muon colliders

Marc Sher: $\tau - \mu$ flavor transition

Discussion

Session 3: SUSY (chair: Marcela Carena)

James Gainer: SUSY at ILC

Olaf Kittel: Resonant Higgs boson interference in chargino production

Federico von der Pahlen: Probing CP-violating MSSM Higgs mixing at a μ -Collider

Stephen Martin: Expectations for Supersymmetry after the LHC

Discussion

Session 4: Strong dynamics and exotics

(chairs: Hooman Davoudiasl, Adam Martin)

Gustavo Burdman: 4th family revisited

GuiYu Huang: Heavy leptons and Z'/W' in Randall-Sundrum

Seth Quackenbush: Z' physics

Amarjit Soni: FCNC, CP violation and more at the muon collider

Discussion

Session 5: Astro/cosmo connection

(chairs: Dan Hooper, Gabe Shaughnessey)

Azar Mustafayev: Lepton Flavor Violation and SUSY Dark Matter

Hock Seng Goh: Leptonic Higgs Portal of Dark Matter

Yu Gao: Indications of dark matter from astrophysical observations

Michael Ramsey-Musolf: EW Baryogenesis, Dark Matter, and a Muon Collider

Discussion

Comparative Remarks:

Physics reach:

	Higgs(es)	SUSY	Strong Dynamics	Exotics	Astro/Cosmo
(s)LHC $E_{qq} \approx 1.5 - 3 \text{ TeV}$	✓	✓	✓× non-resonance?	✓✓ ΔL	✓× missing mass? CP-V ?
CLIC	✓✓ H potential	✓	✓	✓	✓ CP-V
μ -Collider	✓✓✓ H resonances CP-V	✓	✓	✓	✓ CP-V

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Experimentation:

	Higgs(es)	SUSY	Strong Dynamics	Exotics	Astro/Cosmo
(s)LHC	ECal, p_μ $\eta \sim 5$, b/τ tag	HCal, E_T^{miss} b/τ tag	high p_T e, μ high p_T $W's, t's$	...	... E_T^{miss}
CLIC	$b/c/\tau$ tag $\theta \sim 12^\circ$	threshold scan 80% pol.	...	$A_{FB,LR}$ pol.	scan
μ -Collider	$R_E \sim 0.1\%$ $\theta \sim 20^\circ$, pol _T ?	scan? pol. _L ?	...	A_{FB} pol. ?	scan?

Benchmark Scenarios:

– Bread & butter channels:

$$\mu^+\mu^- \rightarrow e^+e^-, \mu^+\mu^-, \tau^+\tau^-, q\bar{q}, b\bar{b}, t\bar{t}, W^+W^-...$$

$E \approx E_{cm}/2 \Rightarrow$ should have no machine backgrounds!

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– Post-LHC Physics (CLIC comparison*)

*CLIC report: [hep-ph/0412251](https://arxiv.org/abs/hep-ph/0412251).

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– Post-LHC Physics (CLIC comparison*)

(1) Higgs physics: Resonant production $H, A...$ [†]

Consider $\mu^+\mu^- \rightarrow H/A \rightarrow b\bar{b}, t\bar{t}, tc, \tau^+\tau^-, \mu\tau$ or $W^+W^-, \tilde{\chi}^+\tilde{\chi}^-$
with $M_{H/A} \sim \text{TeV}$, $\Gamma \sim 1 - 10 \text{ GeV}$.

CP-violation for $H - A$ interference

$\Rightarrow$ Mass, width, couplings, CP ...

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(2) SUSY:

a. CLIC report choice: an MSUGRA point (for comparison)

b. EW states (that could decouple at the LHC):[‡]

$$\mu^+\mu^- \rightarrow \tilde{H}^+\tilde{H}^-, \tilde{H}^0\tilde{H}^0, \tilde{\ell}\tilde{\ell}.$$

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[‡]Olaf Kittel and Federico von der Pahlen; Dave Cline; Soni

[‡]Steve Martin

(3) Strong dynamics: $W_L W_L$ scattering

Consider $\mu^+ \mu^- \rightarrow \nu \nu W^+ W^-, \nu \nu Z Z, \nu \nu t \bar{t}$ via H, ρ_{TC} or non-resonance.

$$\sigma(W_L^+ W_L^-) / \sigma(Z_L Z_L) \rightarrow 2, \text{ large, or } < 1.$$

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(4) Exotics:

- a. $Z' Z' Z'$ [§]: precision on mass/width; A_{FB} probes chiral couplings.
- b. $\mu^+ \mu^- \rightarrow \gamma, Z, Z' \rightarrow D \bar{D}, N \bar{N}, E \bar{E}$.*

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(5) Astro/Cosmo connection:

- a. TeV dark matter: $\mu^+ \mu^- \rightarrow \gamma + E^{miss}$ [¶]
- b. Leptophilic “dark force” (more strongly coupled to leptons).

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A lot of rich physics. The fun has just begun.

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