Light Stop at LHC

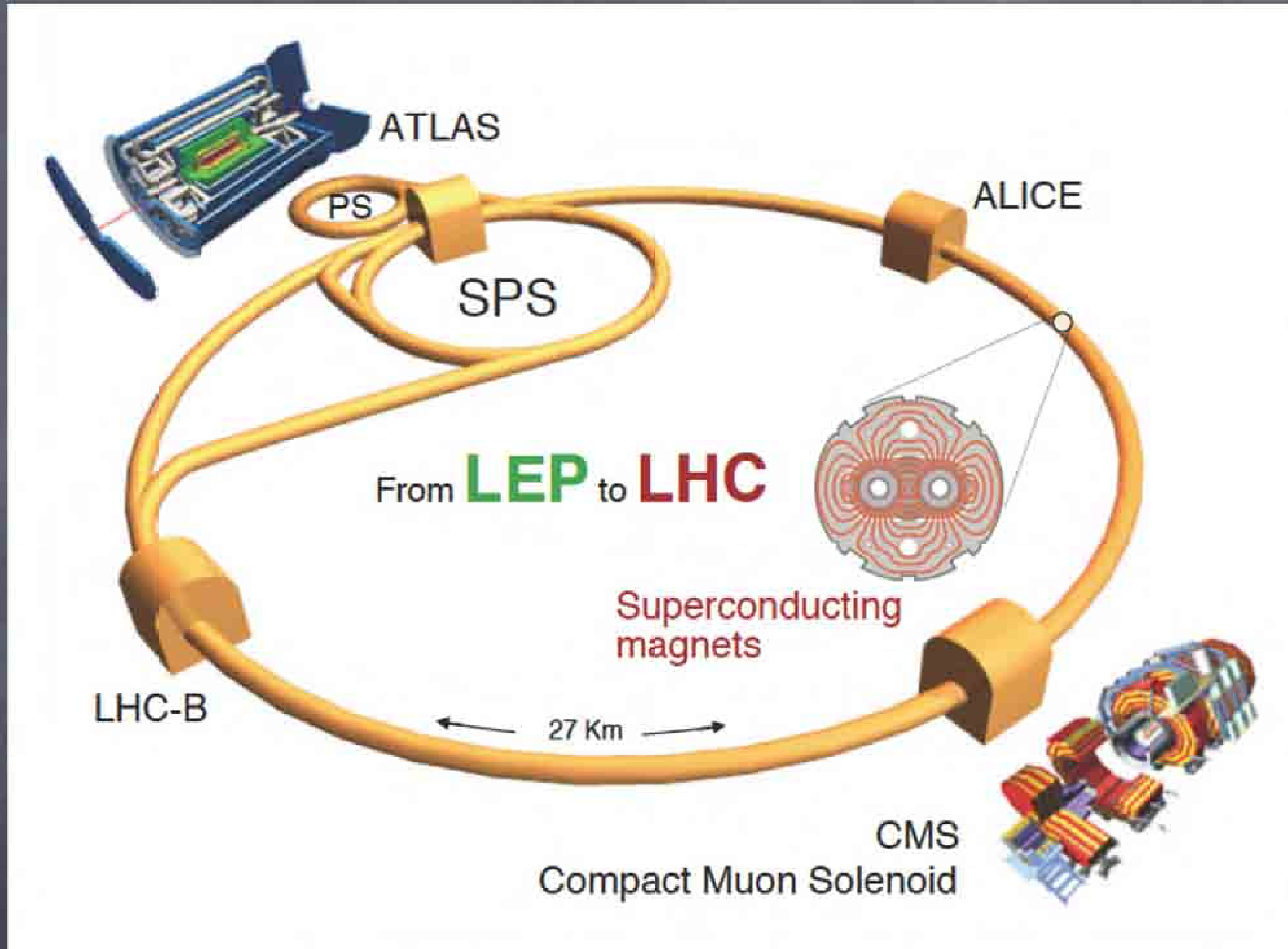
Qi-Shu Yan (GUCAS)
In Collaboration With
Xiao-Jun Bi and Peng-Fei Yin

Available via arXiv: 1111.2250

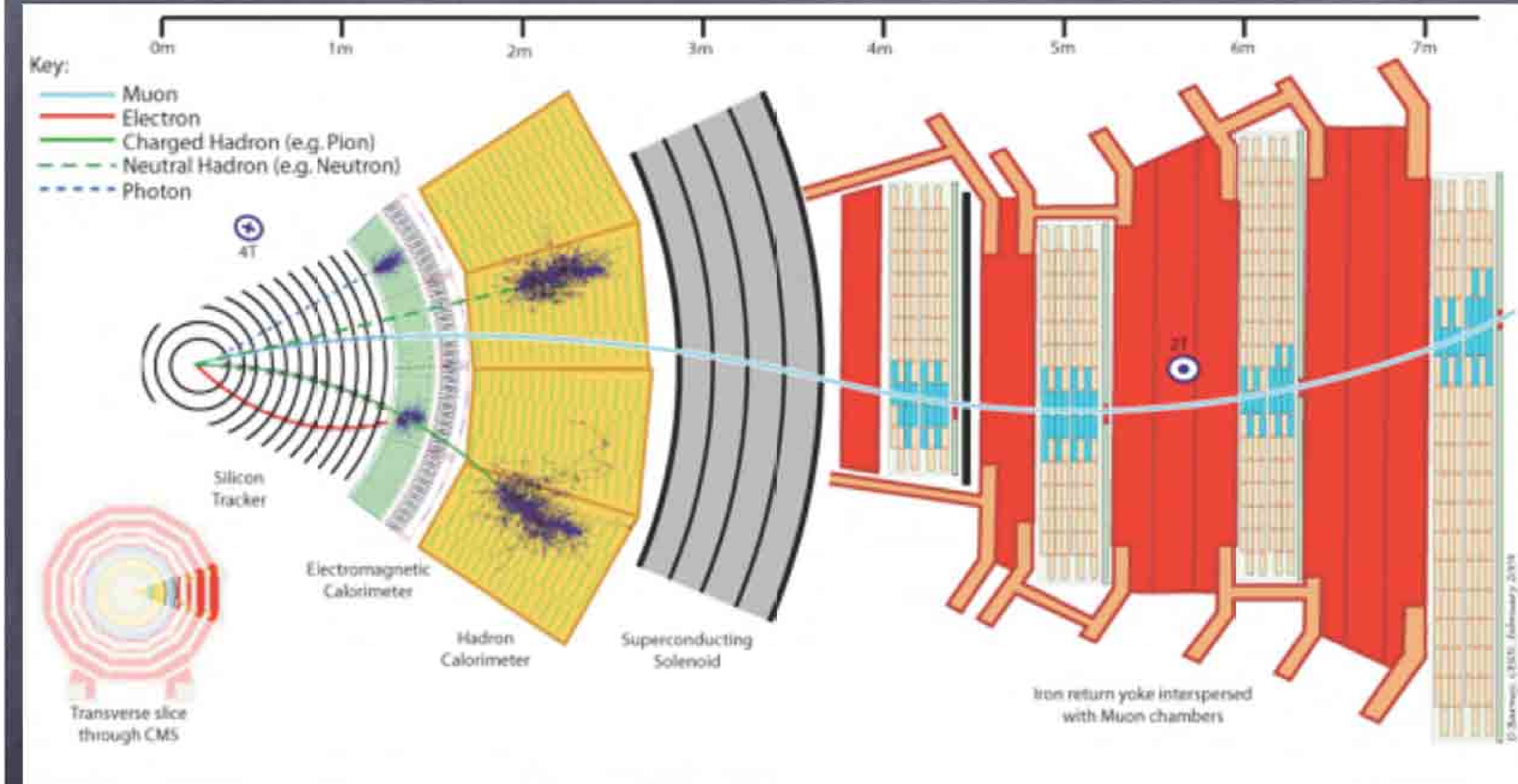
20-22/Dec/2011, ShunXin Beijing

Key Words: Light stop quark,
Neutralino-stop coannihilation, LHC and ILC search

SKLTP



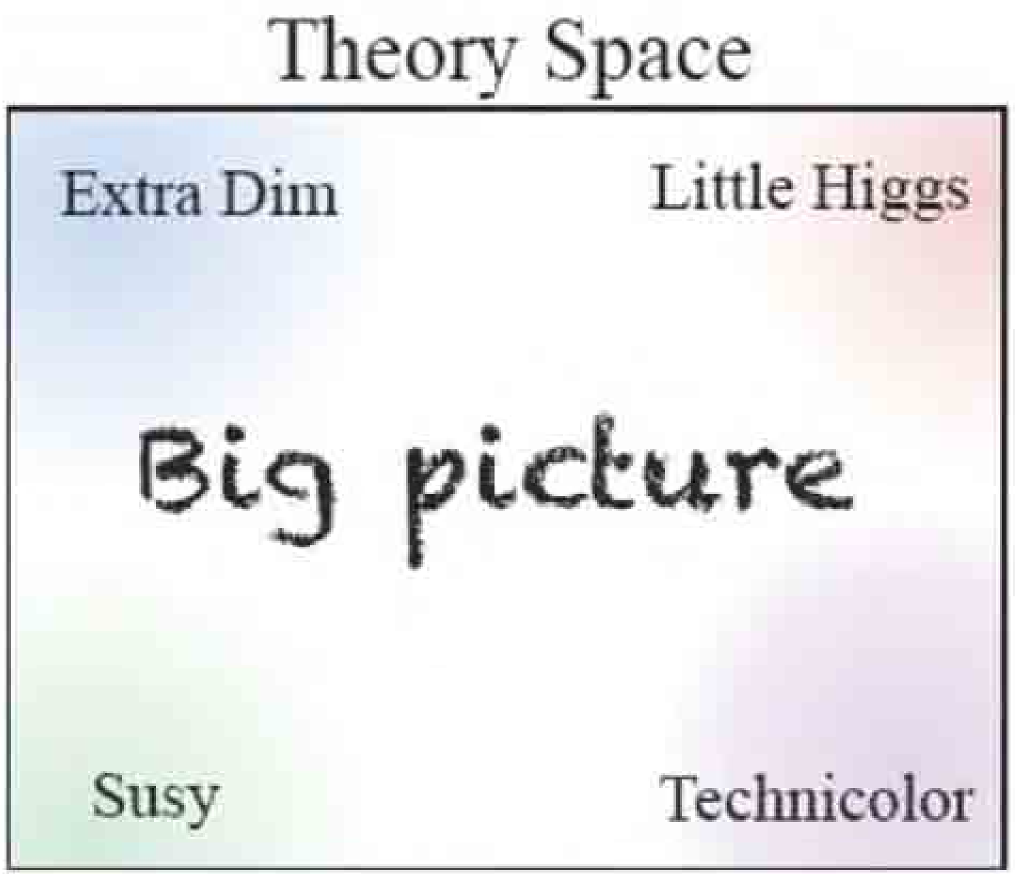
Collecting data > 5/fb

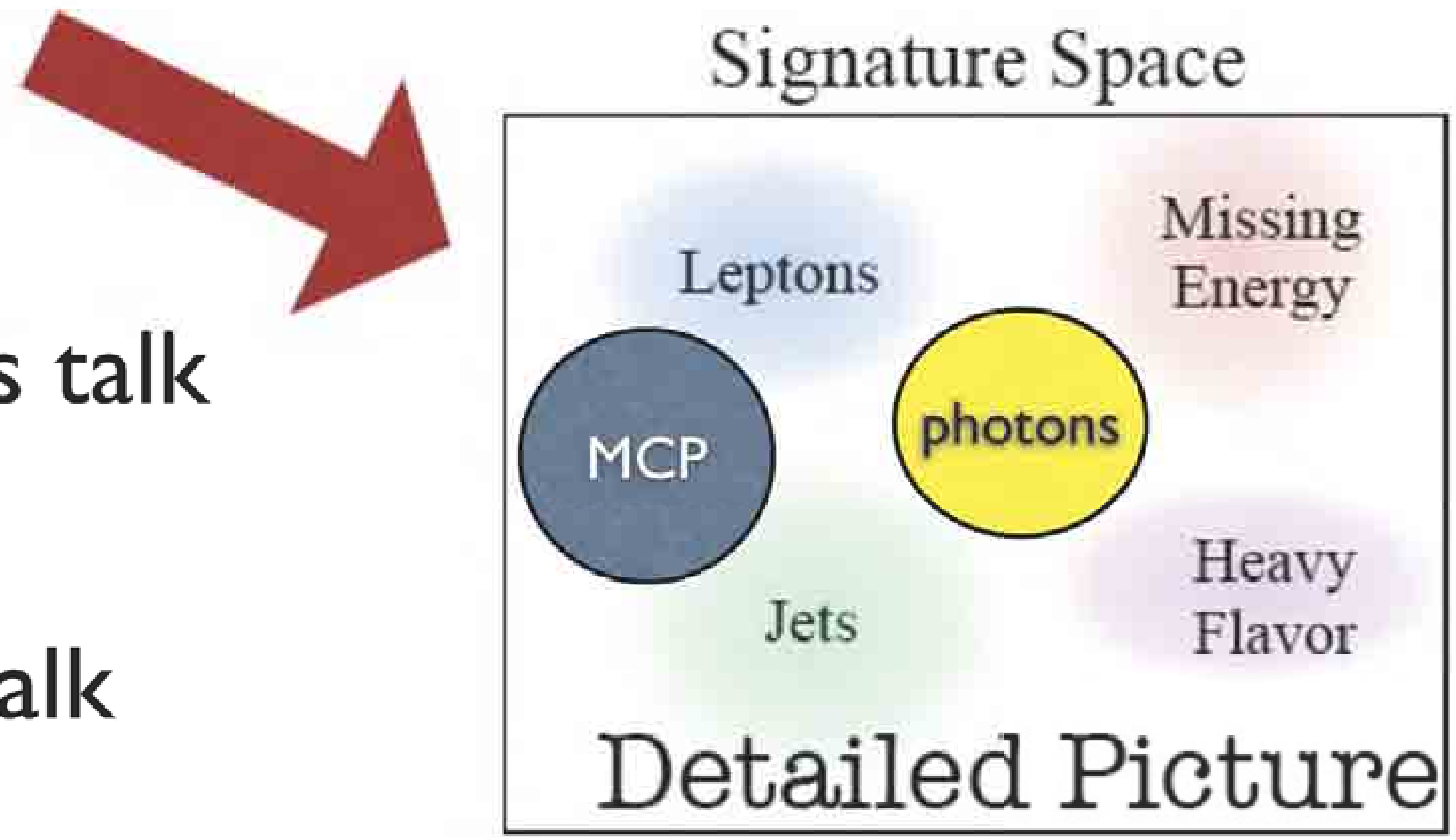


CMS Detector

SKLTP

Constructing Signature Space
from Theory Space
not easy/efficient

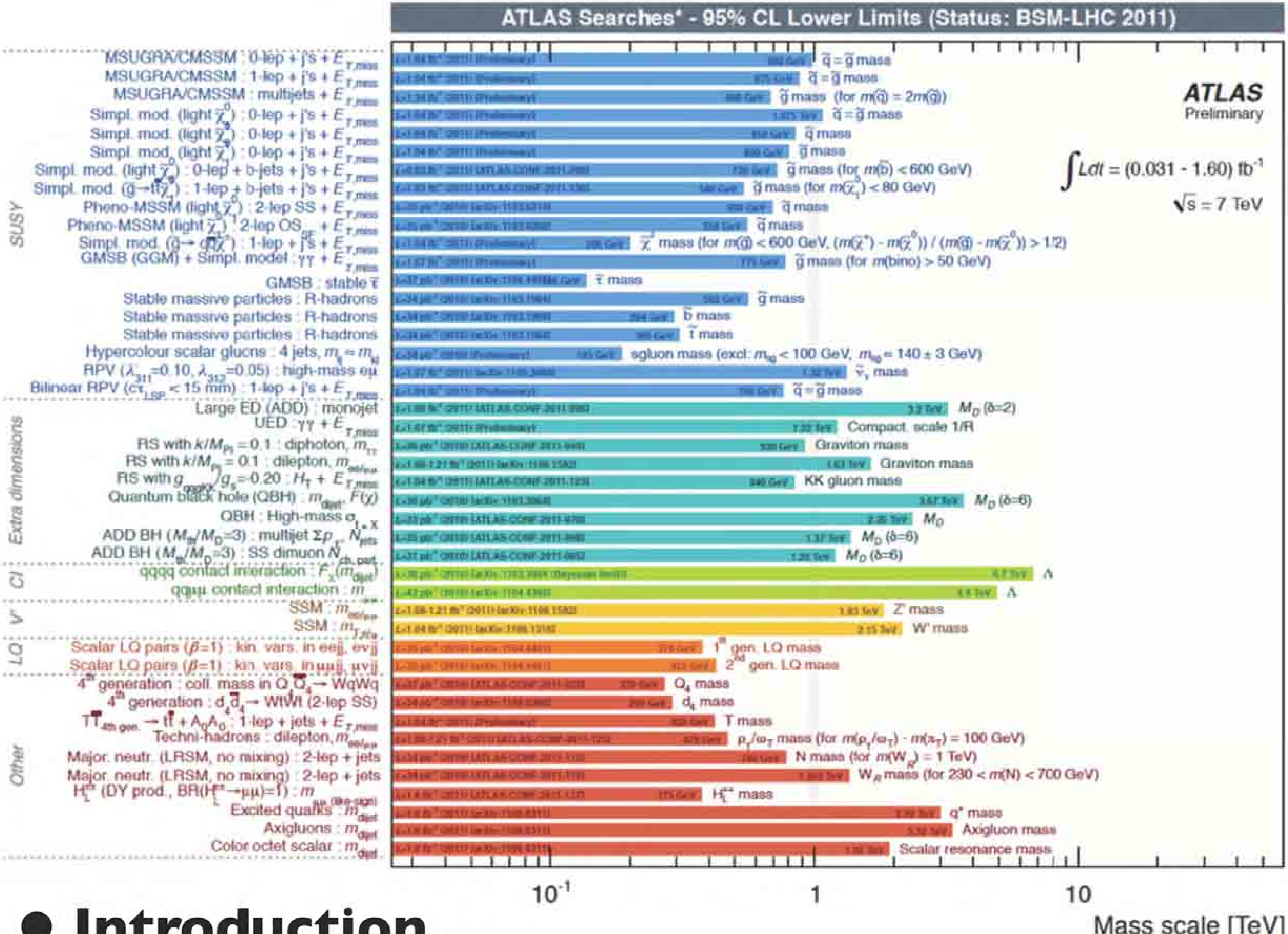




mirror See Hong-Jian's talk

4f See Yu-Feng's talk

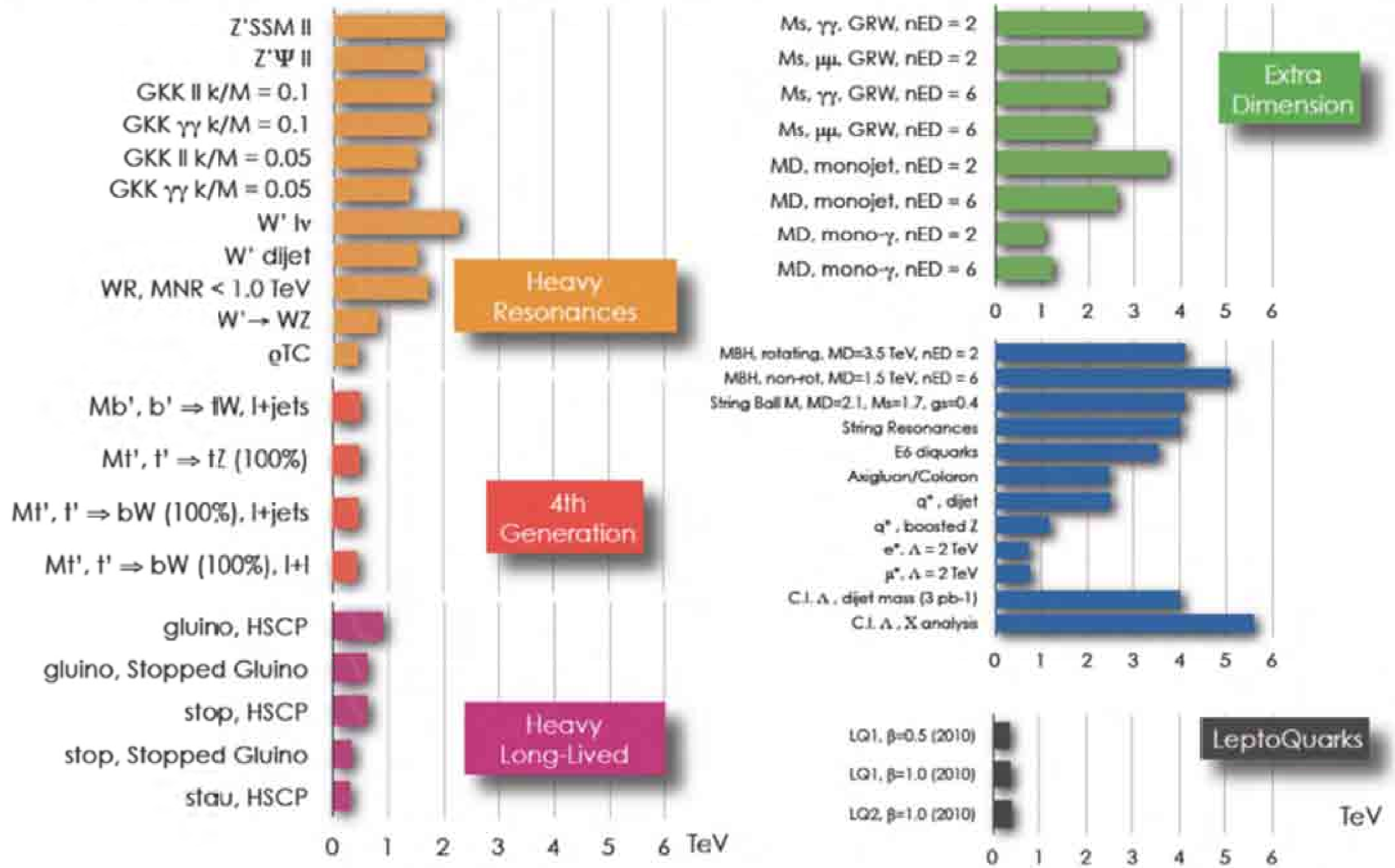
From J. Walker,'s talk@pheno-2011



● Introduction

CMS Grand Summary

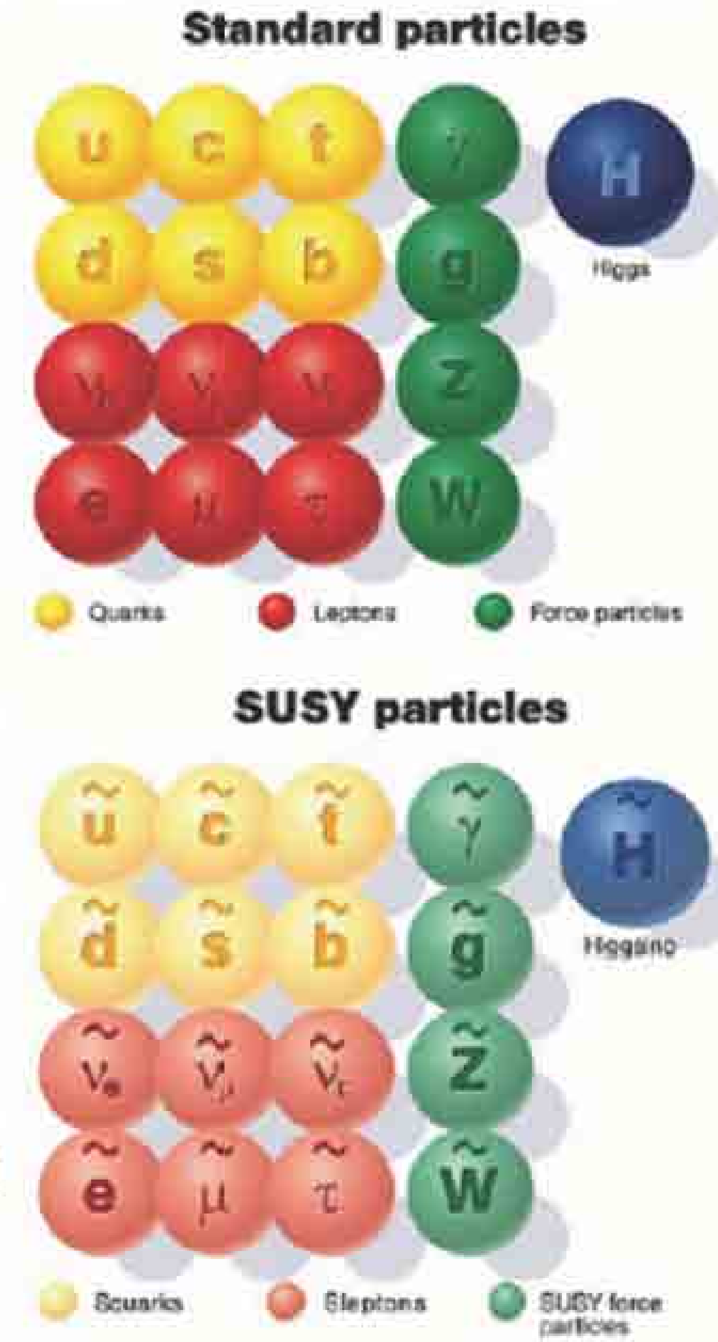
As of PIC2011
Thanks to S. Rahatlou



Wednesday, December 21, 2011

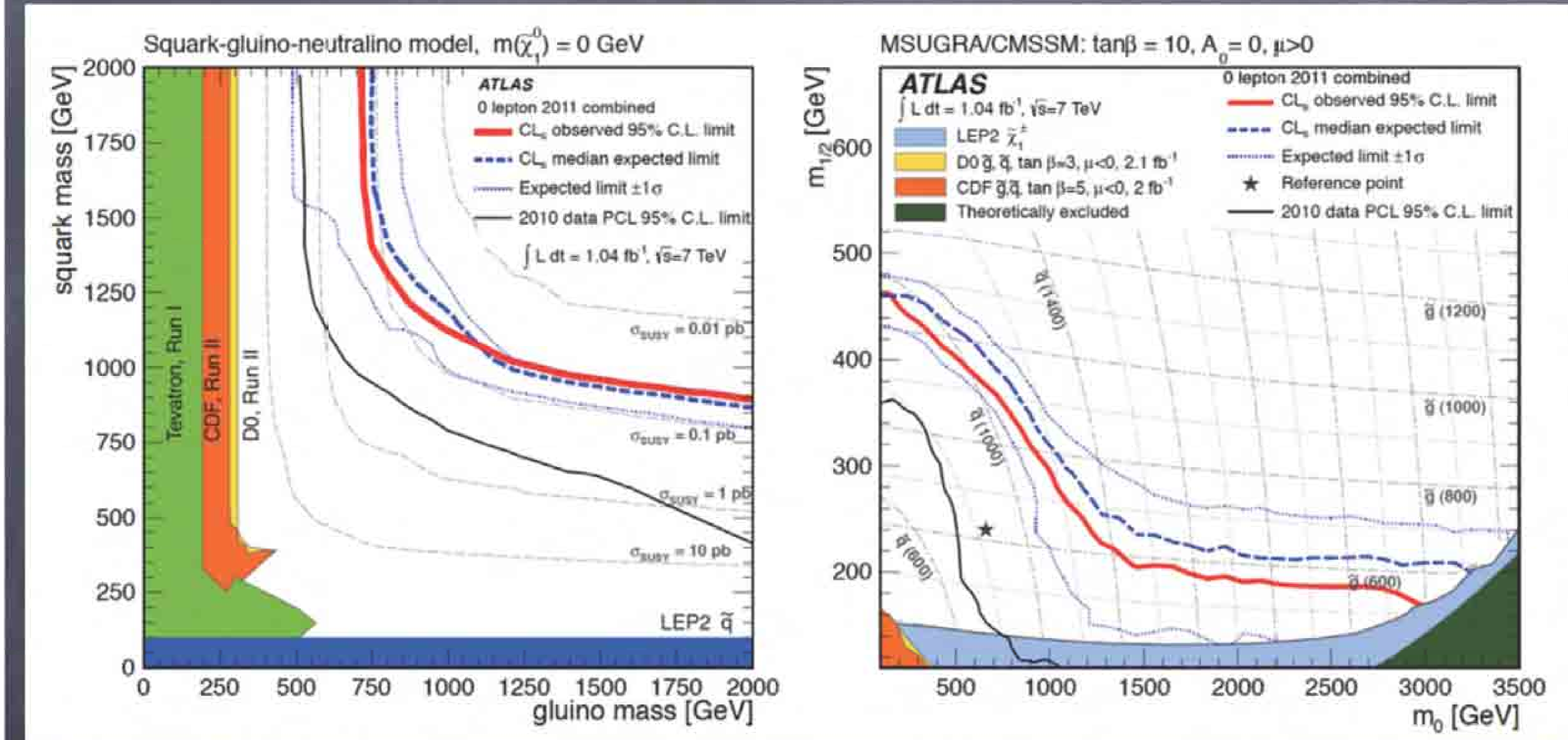
One of the most popular extensions of the SM

- SUSY postulates "superpartners" to each SM particles (same quantum numbers, but spin differs by ½) and R-parity $R = (-1)^{3(B-L)+2s}$
- if R-parity is conserved, SUSY particles are pair produced and the lightest one (LSP) is stable
- Why is SUSY popular? It answers many open questions at once:
  - allows unification of gauge couplings
  - provides a solution to the hierarchy problem: the fermion/boson contribution to the Higgs mass exactly cancel
  - if R-parity is conserved the LSP is stable and is a dark matter candidate
- but the MSSM has 124 free parameters …



See Yi Cai's and Tao Liu's talk for a more concrete and specific model construction

SKLTP



1109.6572, ATLAS

SKLTP

Outline

- 1.Introduction
- 2.Dark matter relic density constraint
- 3.Challenge in LHC search
- 4.ILC search for light stop
- 5.Discussion and conclusion

SKLTP

1. Introduction

Why a light stop quark? Naturalness

- RGE of $m_{U_3}^2$ drives the right-handed stop to be light
- The large trilinear term of stop mass matrix A_t enlarges the mass splitting of $\tilde{t}_1$ and $\tilde{t}_2$
- Neutralino-stop coannihilation can explain the dark matter relic density of our universe
- A first order of electroweak phase transition for baryogensis needs a light stop quark Carena,et.al
- Such a light stop quark is expected to be copiously produced due to its strong interaction nature

1. Introduction

How a light stop can decay?

- $\tilde{t}_1 \to b\chi^+ \to b\ell + \not{E}$
- $\tilde{t}_1 \to b\ell\tilde{\nu}$
- $\tilde{t}_1 \to t\chi^0$
- $\tilde{t}_1 \to c\chi^0$
- $\tilde{t}_1 \to bff'\chi^0$
- R hadron

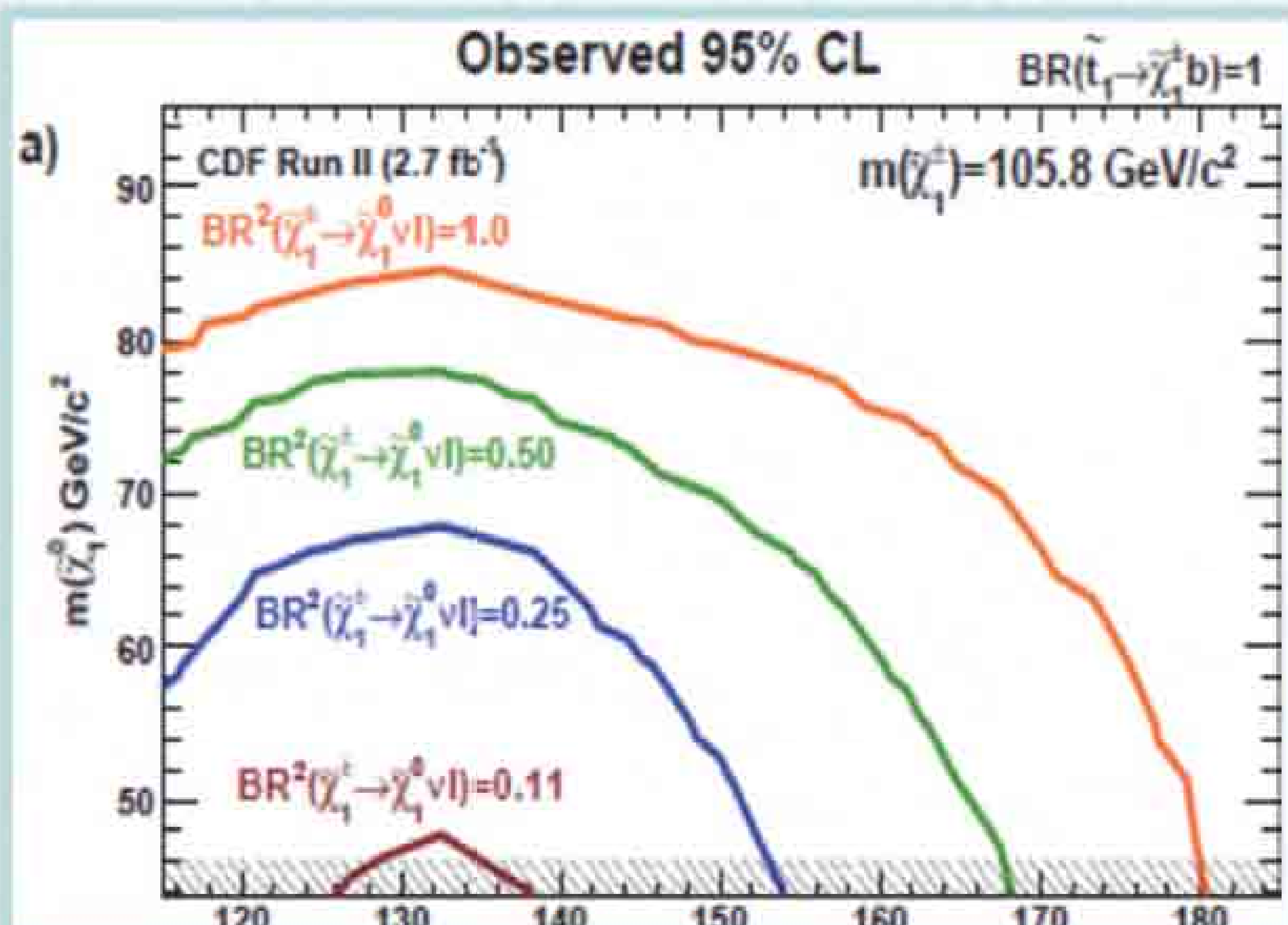
1. Introduction

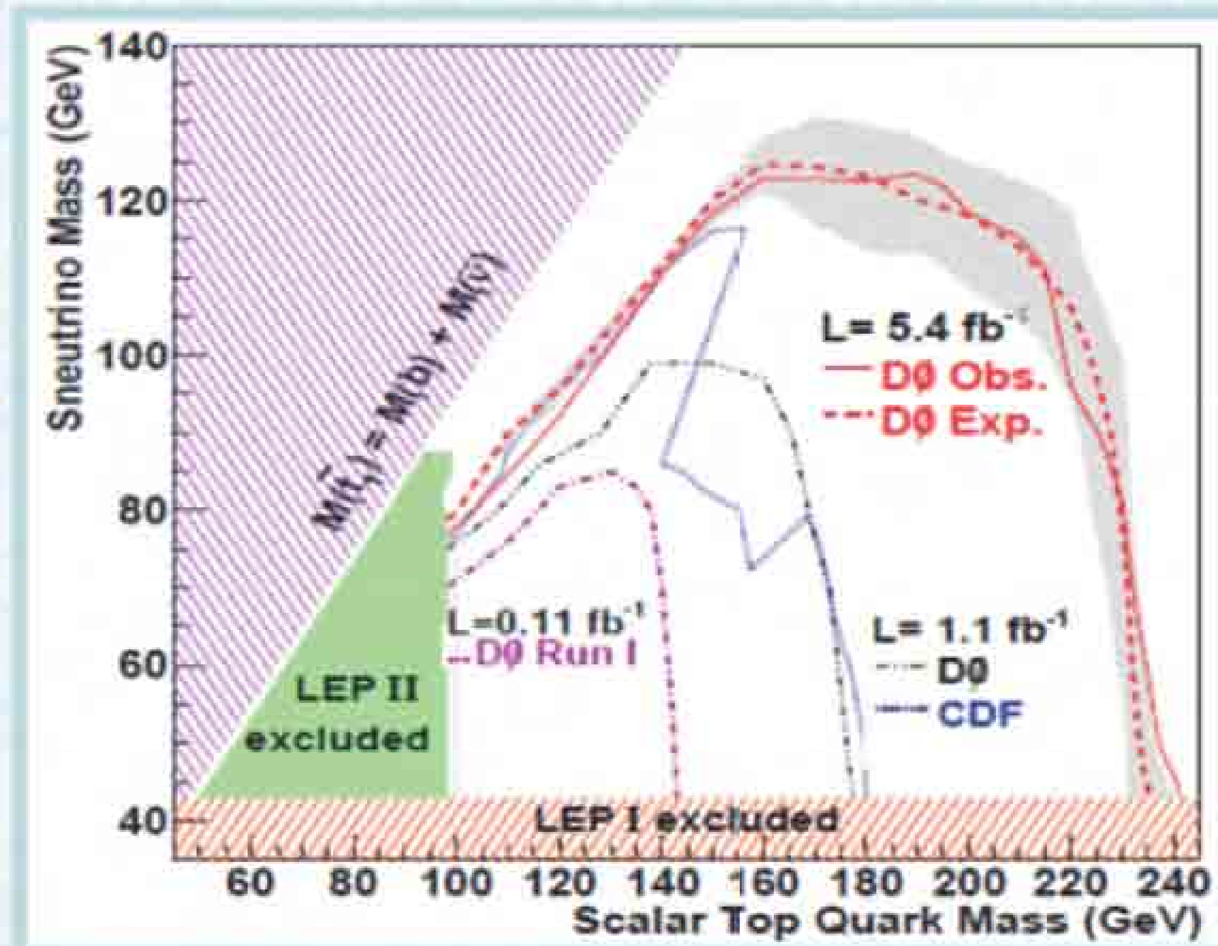
What's the bound for a light stop quark?

- **Set limits according to different decay modes**
  - $\tilde{t}_1 \to b\chi^+ \to bl\nu\chi_1^0$.

    CDF, 2.7fb^{-1}, 0912.1308
  - $\tilde{t}_1 \to bl\tilde{\nu}$, **final** $e^\pm \mu^\mp b\bar{b}\nu\bar{\nu}\chi_1^0\chi_1^0$

    D0, 5.4fb^{-1}, 1009.5950





1. Introduction

What's the bound for a light stop quark?

- $\tilde{t}_1 \to t\chi_1^0$,

  An example of general search T'->t+X

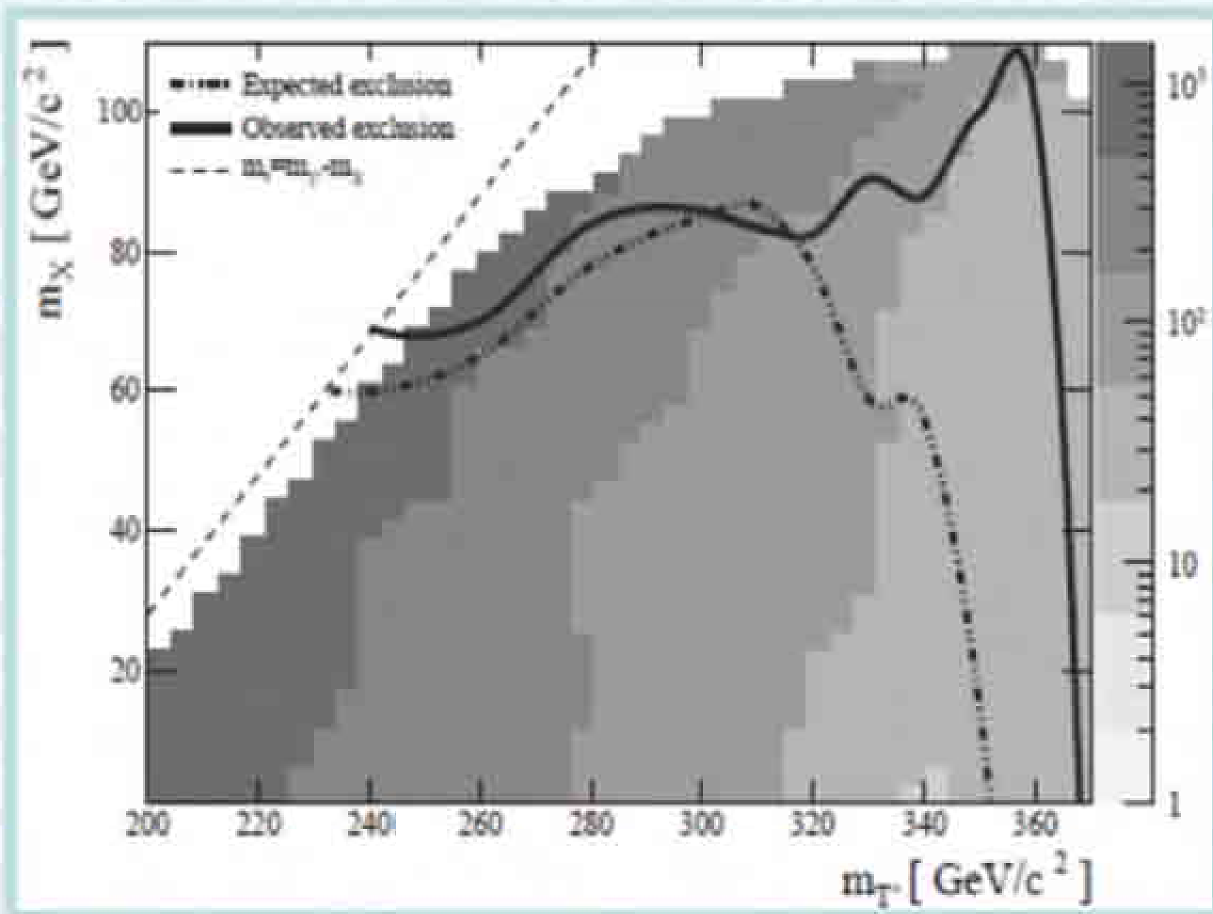
  final $t\bar{t}XX \to W^+W^-b\bar{b}XX$

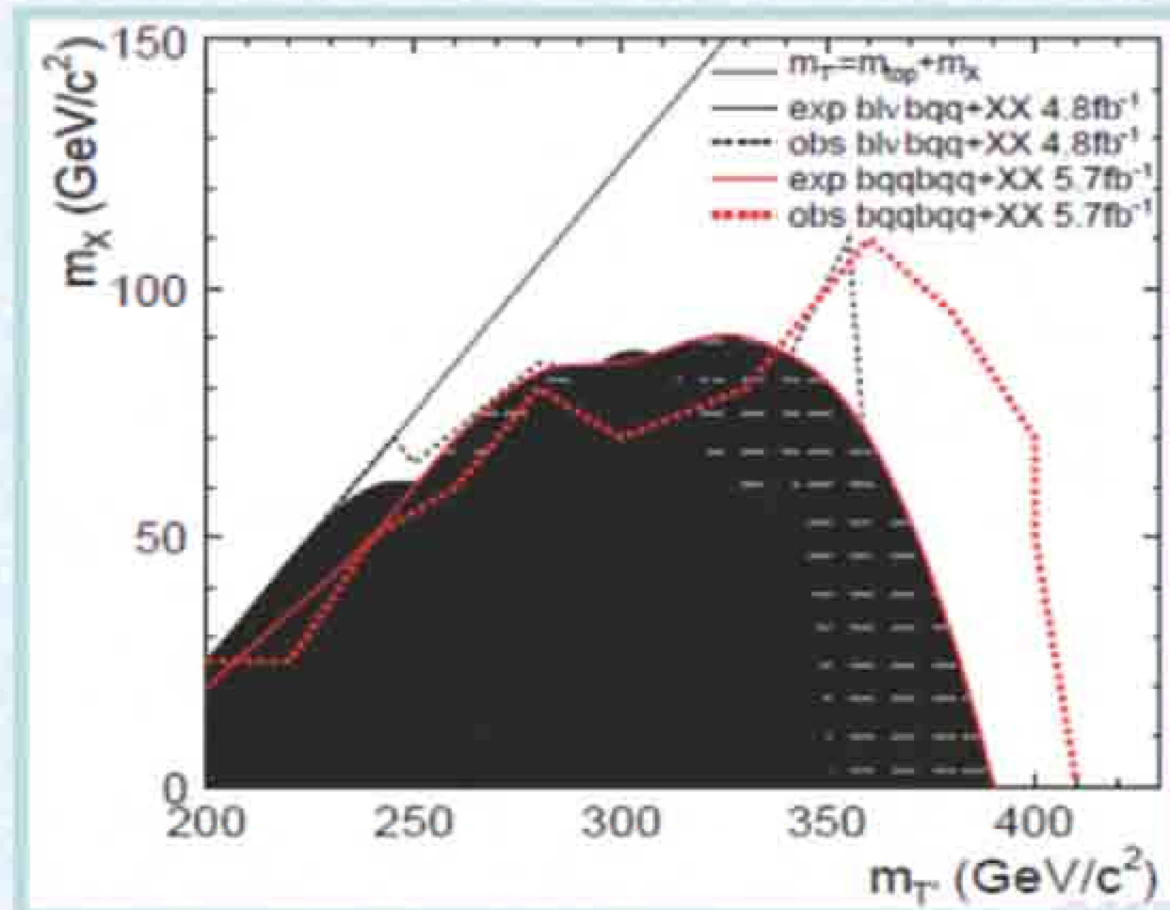
- Semi-leptonically decay

  CDF, 4.8fb^{-1}, 1103.2482

- hadronically decay

  CDF, 5.7fb^{-1}, 1107.3574





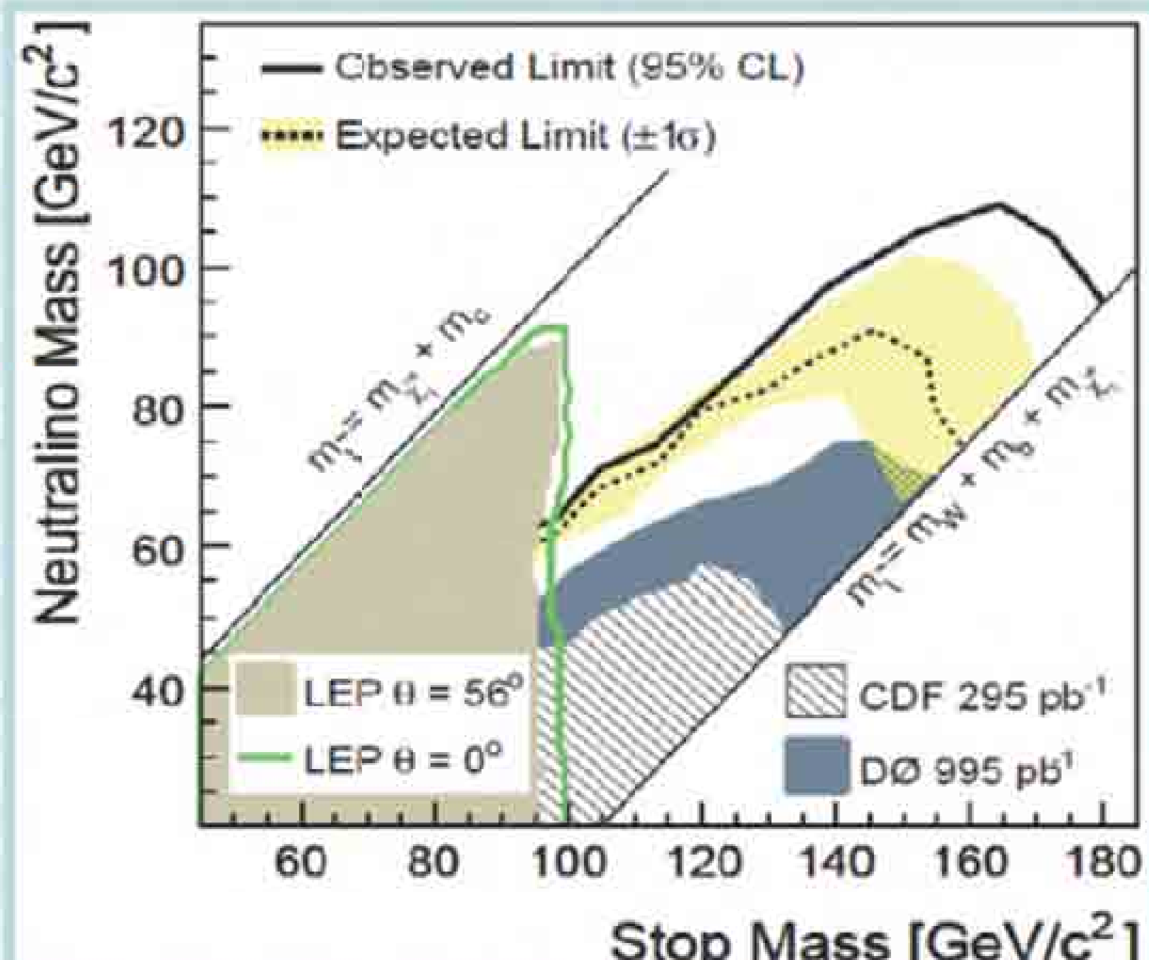
1. Introduction

What's the bound for a light stop quark?

- $\tilde{t}_1 \to c\chi_1^0$,

  FCNC decay, Suppressed by small CKM, important for small mass splitting between stop and neutralino

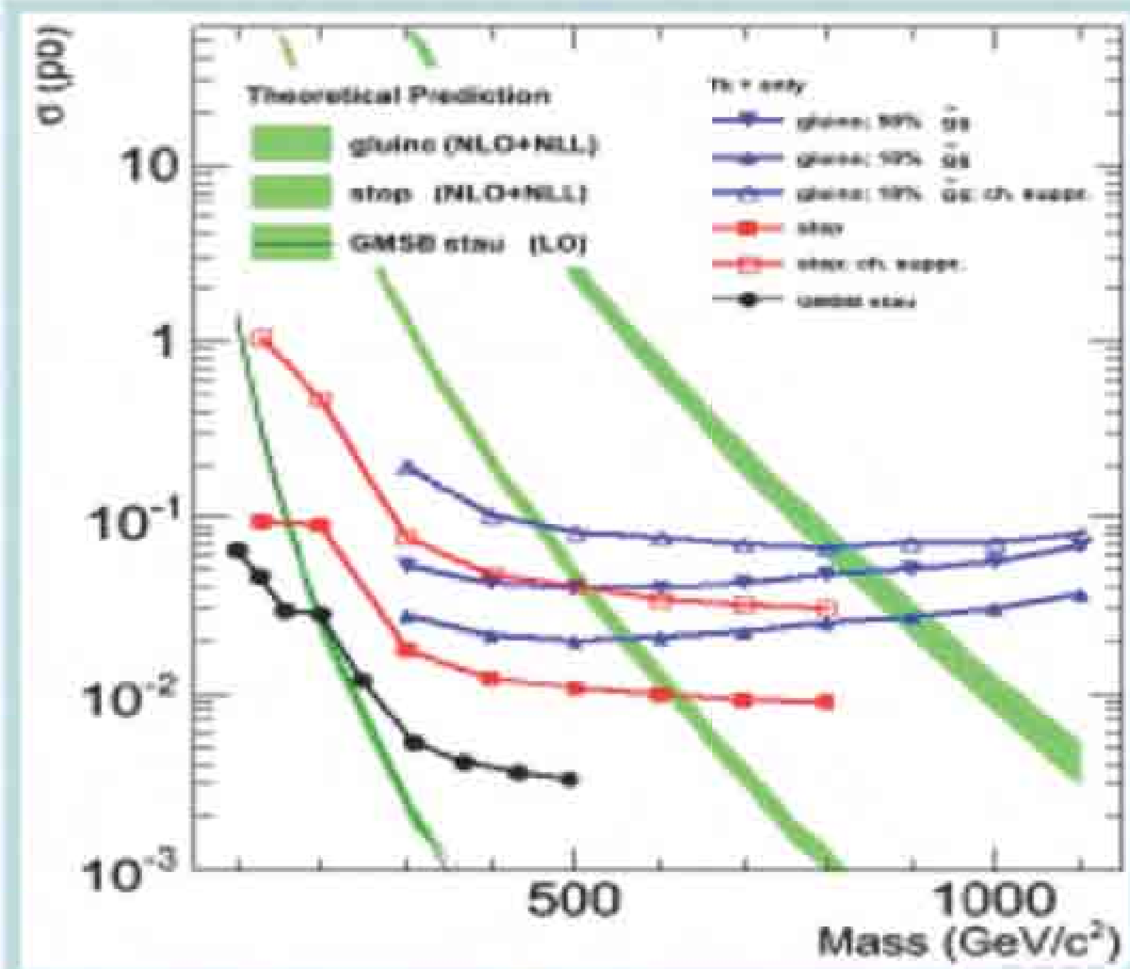
  CDF, 2.6fb^{-1}, public note



- R-hadron

  The life-time of stop is long enough. Depend on R-hadron models

  CMS, 1.1fb^{-1} , public note



1. Introduction

Why study non-universal SUSY?

- Non-universal soft breaking terms $(m_0^{1,2}, m_0^3)$ are expected to solve flavor problems of MSSM in low energy region
- A non-universal gaugino masses is well-motivated in SUSY Gut models

1. Introduction

Why study non-universal SUSY?

$$Ref_{\alpha\beta}(\phi)F^{\alpha}_{\mu\nu}F^{\beta\mu\nu} = \frac{\eta(\Phi^s)}{M}Tr(F_{\mu\nu}\Phi^N F^{\mu\nu})$$

$$SU(5): \quad (24 \times 24)_{symm} = 1 + 24 + 75 + 200$$

$$SO(10): \quad (45 \times 45)_{symm} = 1 + 54 + 210 + 770$$

Representation	$M_3 : M_2 : M_1$ at M_{GUT}
75 of $SU(5)$	1:3:(-5)
200 of $SU(5)$	1:2:10
770 of $SO(10)$: $H \to SU(4) \times SU(2) \times SU(2)$	1:(2.5):(1.9)

SKLTP

1. Introduction

free parameters in our model

$m_0^1 = m_0^2,\ m_0^3,\ M_{1/2}^1 = M_{1/2}^2,\ M_{1/2}^3,\ A_0,\ \tan\beta,\ sign(\mu)$

- **Suspect: for SUSY parameter scan, calculate sparticle mass spectrum**
- **MicrOMEGAs: DM relic density, DM-nucleon scattering cross section, constraints from g-2 and flavor physics**
- **Prospino: stop pair production cross section including NLO contributions**
- **SDECAY: branching ratios of sparticle decay modes**
- **MadGraph: hard process** backgrounds: Alpgen
- **PYTHIA: sparticle decays , showing and hadronization**
- **PGS: simple detector simulation**

SKLTP

1. Introduction

- **Parameter scan**

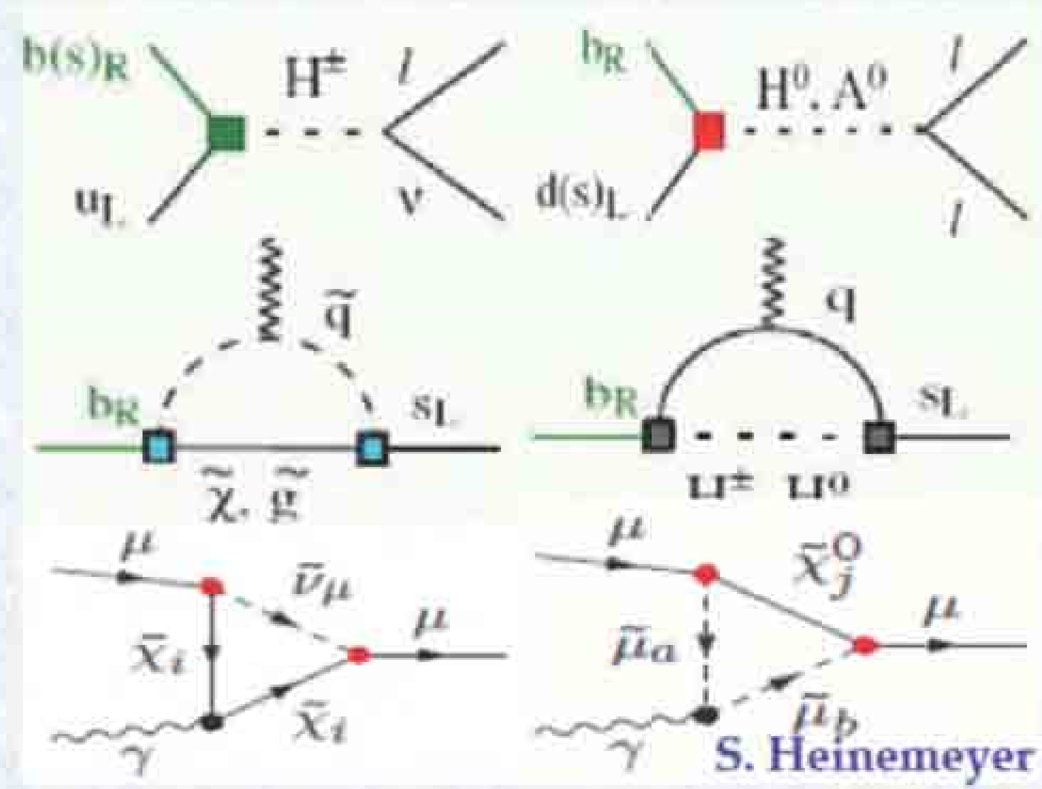
  100 GeV< $M_{1/2,3}$ < $M_{1/2}$ < 800 GeV ,

  100 GeV< $M_{0,3}$ < M_0 ,

  300 GeV< M_0< 2000 GeV ,

  -1< A_0 /m_0< 1 ,

  2< tan β <50 , sign(μ)=+1



- **Constraints from DM and high-energy experiments**

  Br(b->s γ)=(3.55 +- 0.24) X 10^{-4} , (3σ limits)

  Br(B_s->$\mu^+ \mu^-$)=(0 +- 1.4) X 10^{-8} ,

  Br(B_u->τ ν)/SM=1.28 +- 0.38,

  Ωh^2 <0.1288 , (only take 3σ upper-limit)

  -11.4X 10^{-10} < g_μ-2 < 9.4X 10^{-9} (conservative limits)

  m_{higgs}>114 GeV ,

  LEP limits for chargino (>~104GeV) and charged sfermions (>~100GeV)

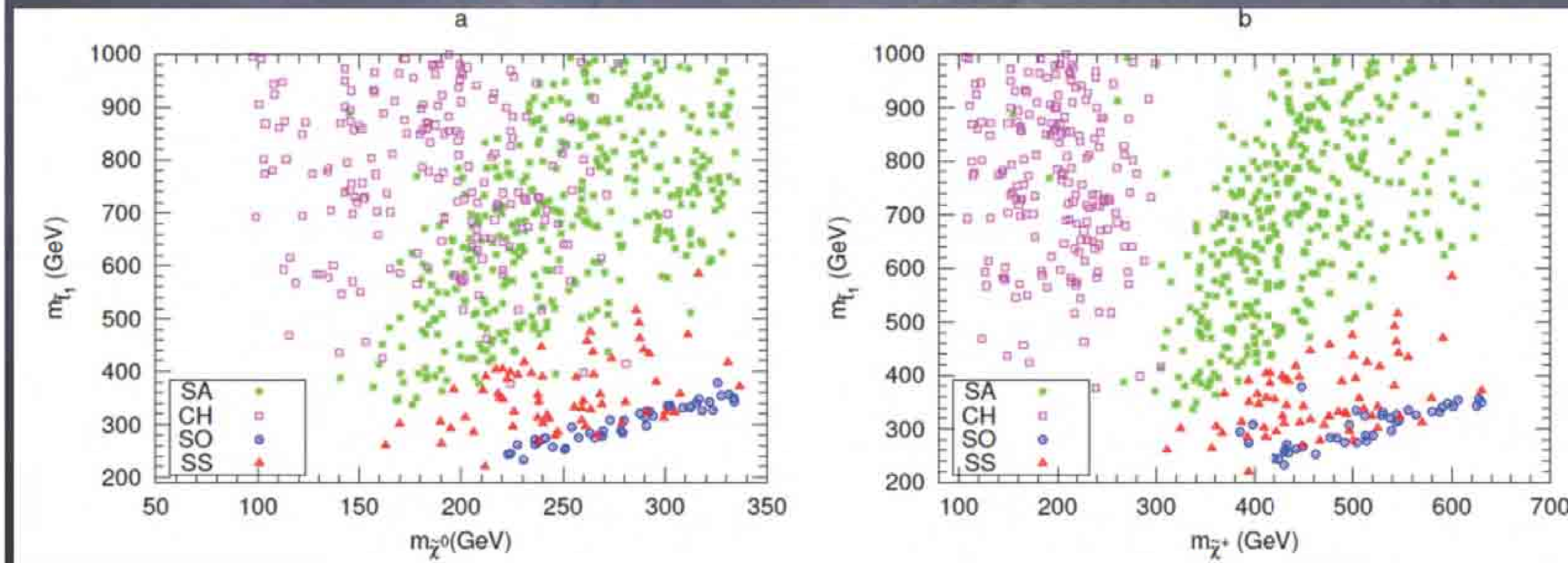
2. Dark Matter Bounds

(1) the stop pattern (SO): $m_{\chi_1^0} < m_{\tilde{t}_1} < m_{\tilde{\tau}_1}, m_{\chi_1^\pm}$;

(2) the stau/stop pattern (SS): $m_{\chi_1^0} < m_{\tilde{\tau}_1} < m_{\tilde{t}_1} < m_{\chi_1^\pm}$;

(3) the stau pattern (SA): $m_{\chi_1^0} < m_{\tilde{\tau}_1} < m_{\chi_1^\pm} < m_{\tilde{t}_1}$;

(4) the chargino pattern (CH): $m_{\chi_1^0} < m_{\chi_1^\pm} < m_{\tilde{\tau}_1}, m_{\tilde{t}_1}$.



2. Dark Matter Bounds

- **Co-annihilation effects from NLSP could reduce DM relic density**
- **Effective DM annihilation cross section contains all the contributions from LSP LSP-> SM SM, NLSP LSP-> SM SM, NLSP NLSP->SM SM , if the mass splitting is small, e.g. (m_{NLSP}-m_{LSP})/m_{LSP} <20%**

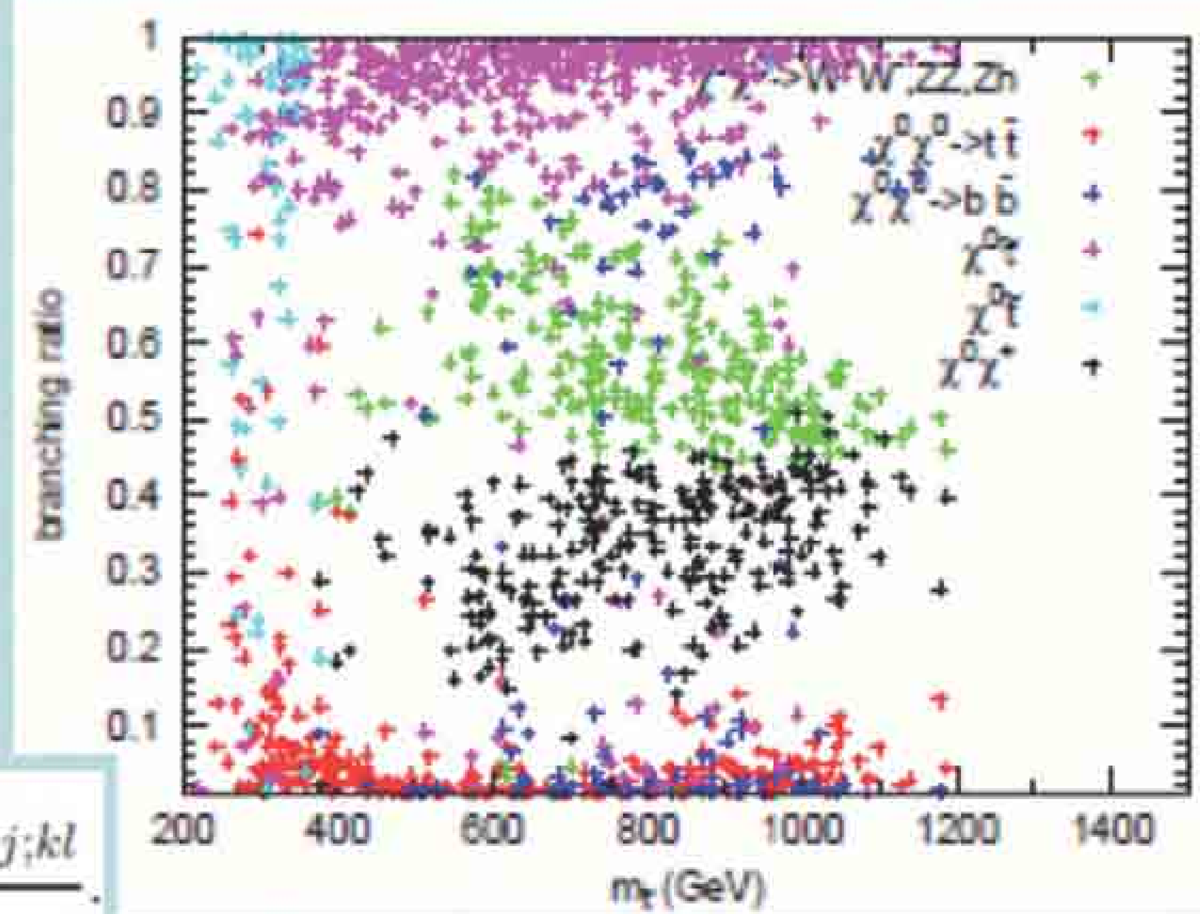
$$\sigma_{eff} = \Sigma_{ij;kl}\sigma_{ij;kl} r_i r_j$$

$$r_i = \frac{n^i_{eq}}{n_{eq}} = \frac{g_i}{g_{tot}}(1+\Delta_i)^{3/2} exp(-\Delta_i m_{\tilde{\chi}^0_1}/T)$$

$$\Delta_i = (m_i - m_{\chi^0_1})/m_{\tilde{\chi}^0_1}$$

- **The relative contribution of different annihilation channels**

$$< \sigma v >= \frac{\Sigma_{ij} g_i g_j \int ds \sqrt{s} K_1(\sqrt{s}/T) p^2_{ij} \Sigma_{kl}\sigma_{ij;kl}}{2T(\Sigma_i g_i m^2_i K_2(m_i/T))^2}.$$



SKLTP

2. Dark Matter Bounds

- Co-annihilation effects from NLSP could reduce DM relic density
- Effective DM annihilation cross section contains all the contributions from LSP LSP-> SM SM, NLSP LSP-> SM SM, NLSP NLSP->SM SM, if the mass splitting is small, e.g. (m_{NLSP}-m_{LSP})/m_{LSP} <20%

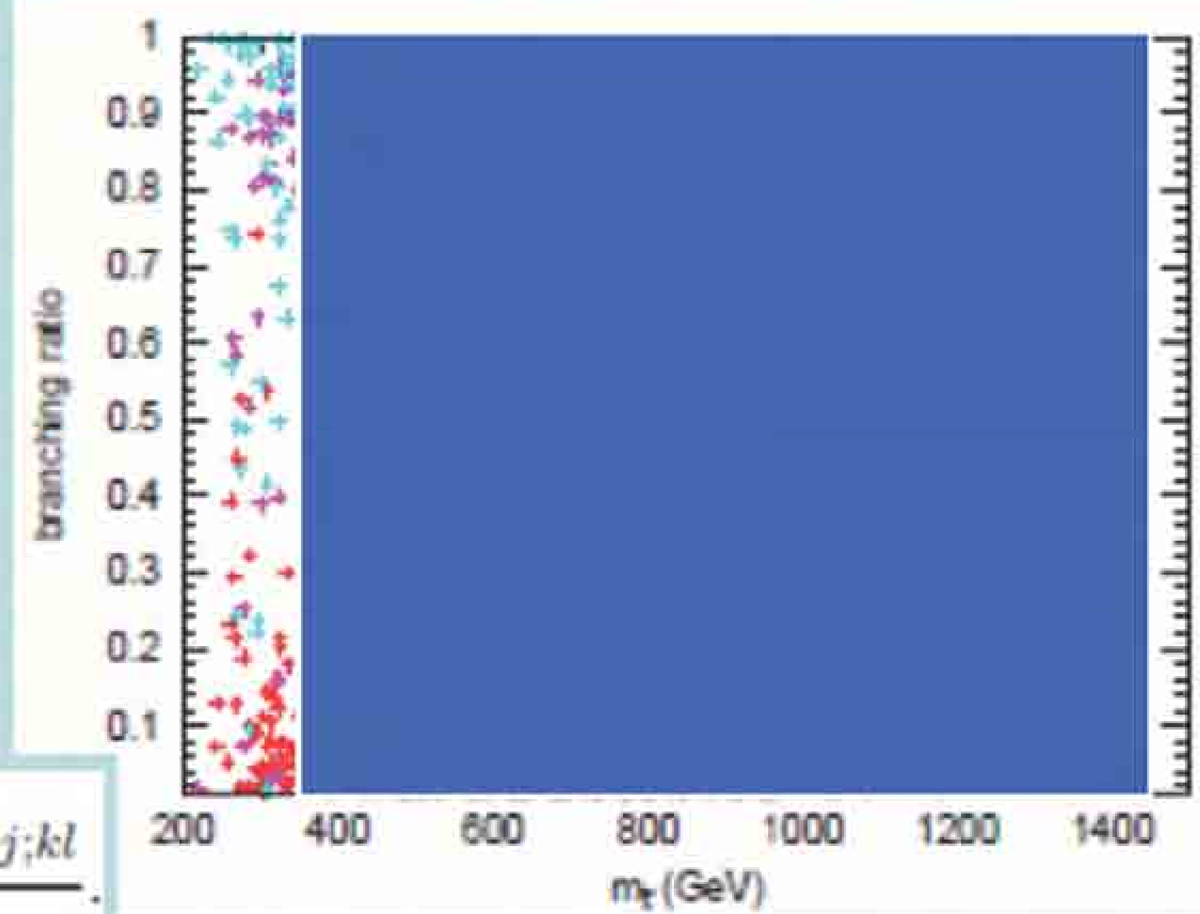
$$\sigma_{eff} = \Sigma_{ij;kl}\sigma_{ij;kl}r_i r_j$$

$$r_i = \frac{n_{eq}^i}{n_{eq}} = \frac{g_i}{g_{tot}}(1+\Delta_i)^{3/2}exp(-\Delta_i m_{\tilde{\chi}_1^0}/T)$$

$$\Delta_i = (m_i - m_{\chi_1^0})/m_{\tilde{\chi}_1^0}$$

- The relative contribution of different annihilation channels

$$< \sigma v >= \frac{\Sigma_{ij}g_i g_j \int ds\sqrt{s}K_1(\sqrt{s}/T)p_{ij}^2\Sigma_{kl}\sigma_{ij;kl}}{2T(\Sigma_i g_i m_i^2 K_2(m_i/T))^2}.$$



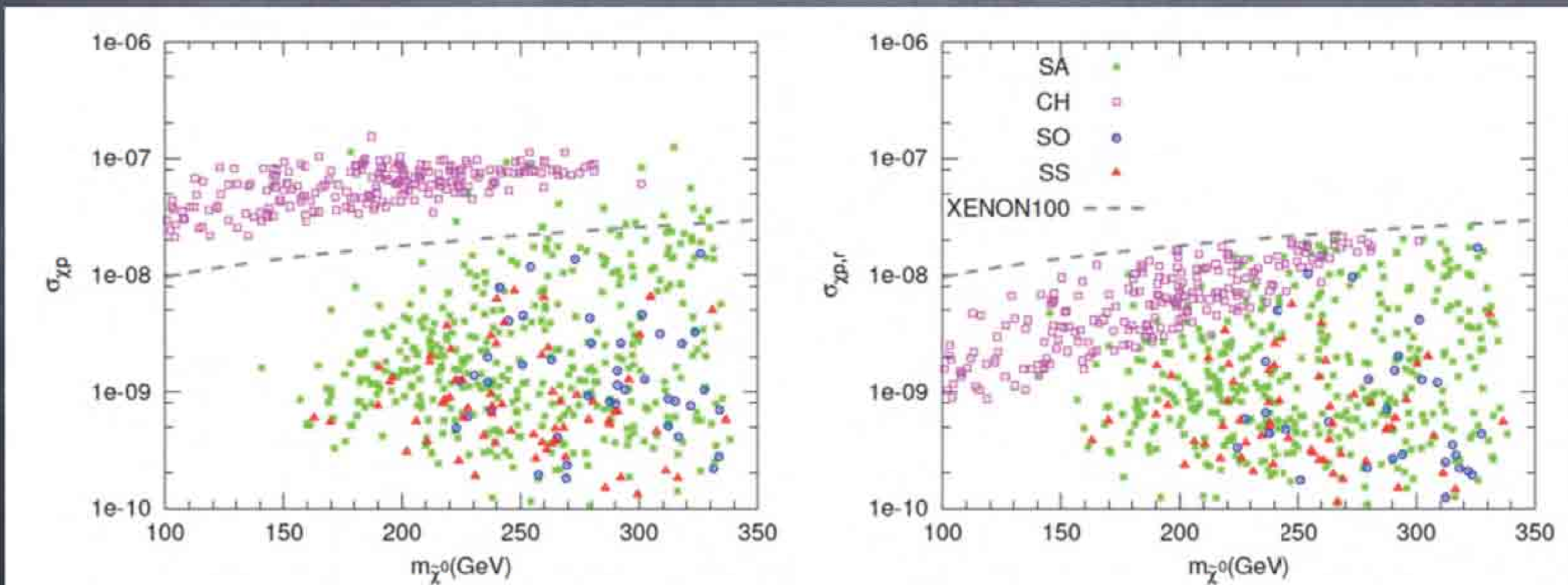
SKLTP

2. Dark Matter Bounds

- consider reduced DM-nucleon cross section, because there may exist other DM candidates in the universe…

$$\sigma_{\tilde{\chi}_1^0 p,r} = \sigma_{\tilde{\chi}_1^0 p}(\Omega_{\chi_1^0} h^2 / \Omega h^2)$$

- The DM may be produced via some non-thermal mechanism…
- Constraints from XENON100, 48X100.9 kg days 1104.2549

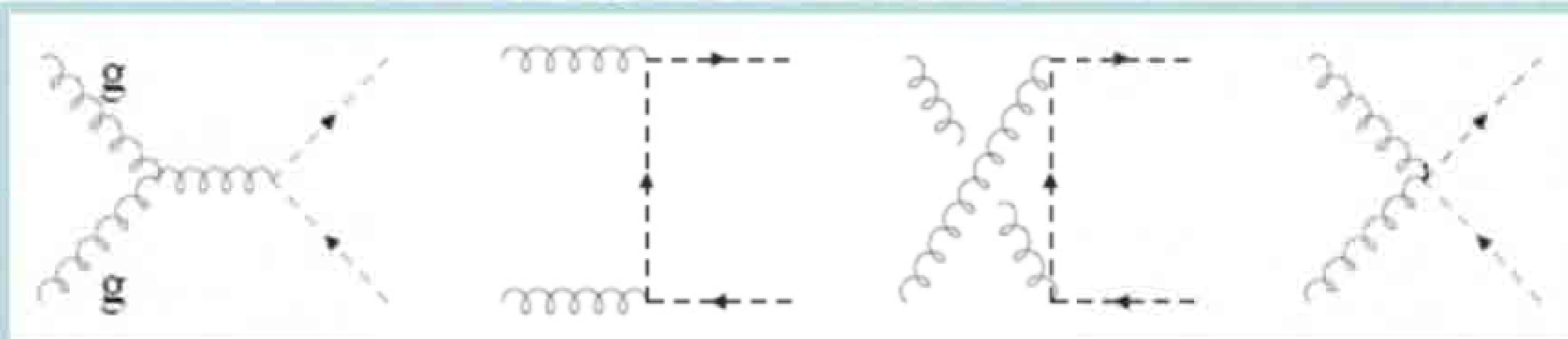


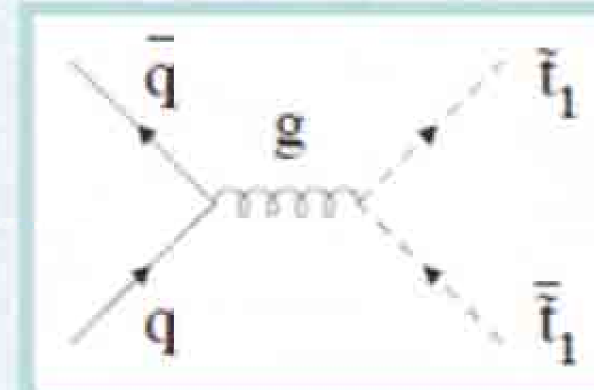
SKLTP

3. LHC Search

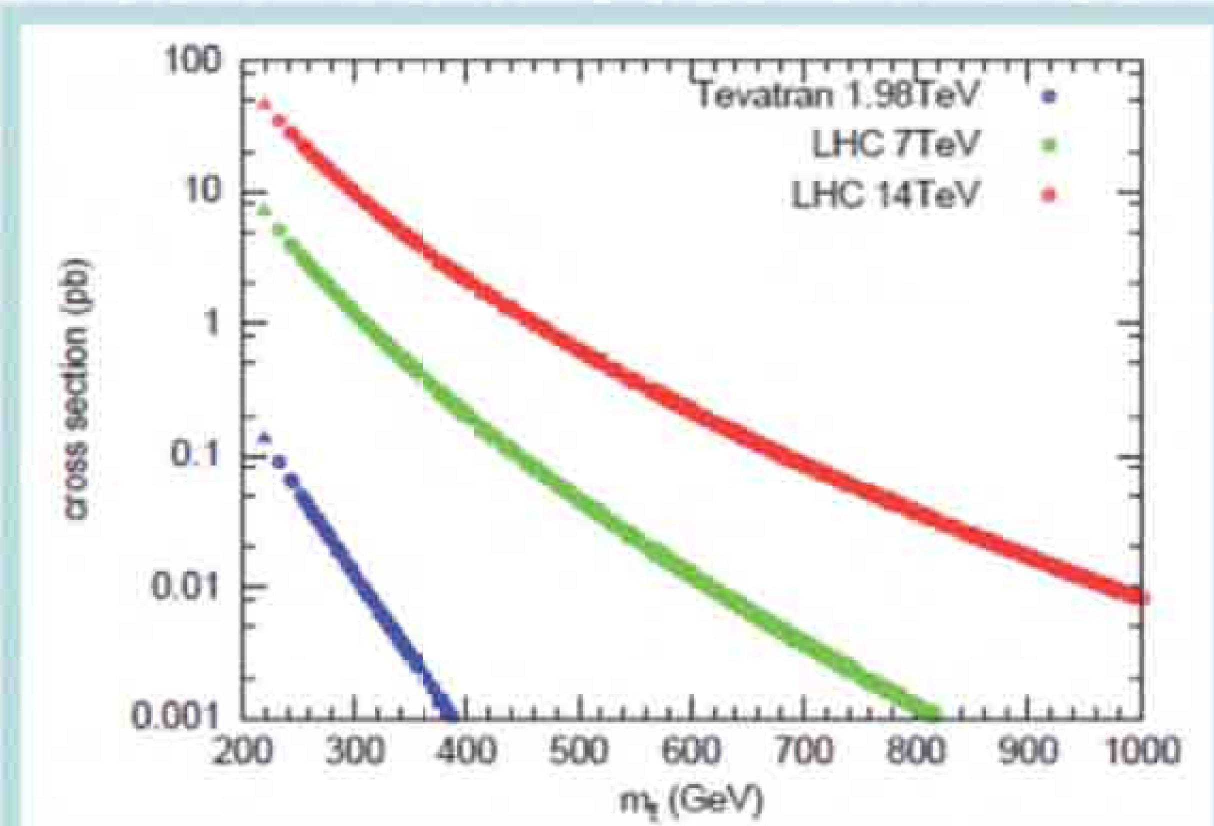
- Produced via QCD process.

W. Beenakker et. al. 97





- Cross section depends on stop mass



- Decay modes depend on sparticle mass hierarchies
- Two body decay

  $\tilde{t}_1 \to t\chi_1^0 \qquad \tilde{t}_1 \to b\chi^+$
- Three body decay

  $\tilde{t}_1 \to bW\chi_1^0 \qquad \tilde{t}_1 \to b\nu\tilde{\tau}$
- FCNC decay

  $\tilde{t}_1 \to c\chi_1^0$
- Four body decay

  $\tilde{t}_1 \to bj'j'\chi_1^0$

SKLTP

3. LHC Search Methods

The search using M_{T2}

- M_{T2} is a generalization of transverse mass to a system with two semi-invisibly decaying particles [Lester, Summers, 1999]:

$$M_{T2}(m_\chi) = \min_{p_T^{\chi(1)} + p_T^{\chi(2)} = p_T^{miss}} \left[\max \left(m_T^{(1)}, m_T^{(2)} \right) \right]$$

- Each m_T is the transverse mass of a sparticle decaying to a visible system and LSP; for the correct value of m_χ, M_{T2} has an endpoint at the parent sparticle mass.
- Assuming zero masses and no ISR or UTM, M_{T2} assumes a simple form: $(M_{T2})^2 = 2p_T^{vis(1)} p_T^{vis(2)} (1 + cos\phi_{12}) \implies$ apparent that back-to-back visible systems have low M_{T2}
- For an n-jet system, two "pseudo-jets" are formed from reconstructed event hemispheres.

3. LHC Search Methods

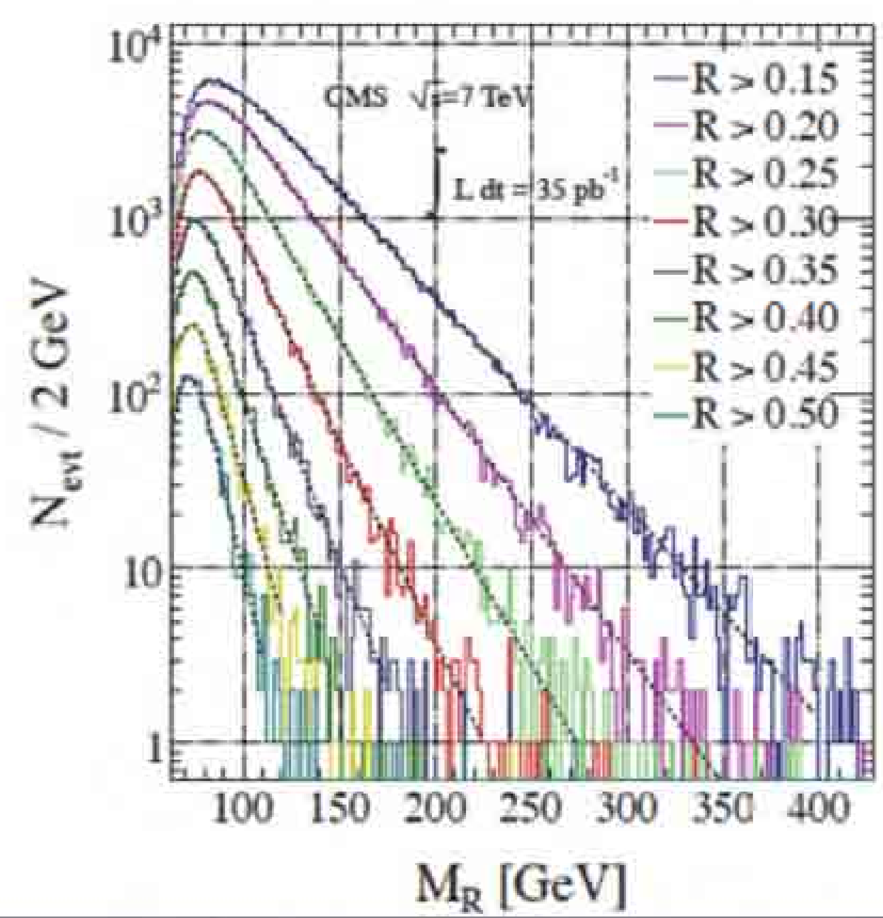
The search using Razor variables

- The "Razor" variables R, M_R were designed to discover and characterize events with heavy pair-produced particles [Rogan, arXiv:1006.2727].
- Reconstructed objects are grouped into two hemispheres with 3-momenta $\vec{p}$, $\vec{q}$ ($\vec{M}$ denotes MET).
- M_R peaks at M_Δ, whereas M_T^R has a kinematic edge at M_Δ.
- $R \equiv \frac{M_T^R}{M_R}$ provides strong rejection of QCD multi-jet events:

$$M_R = 2\sqrt{\frac{(|\vec{p}|q_z - |\vec{q}|p_z)^2}{(p_z - q_z)^2 - (|\vec{p}| - |\vec{q}|)^2}}$$

$$M_T^R = \sqrt{\frac{|\vec{M}|(|\vec{p}| + |\vec{q}|) - \vec{M}\cdot(\vec{p} + \vec{q})}{2}}$$

$$M_\Delta = \frac{m_{\tilde{q}}^2 - m_{\tilde{\chi}_1^0}^2}{2m_{\tilde{q}}}$$

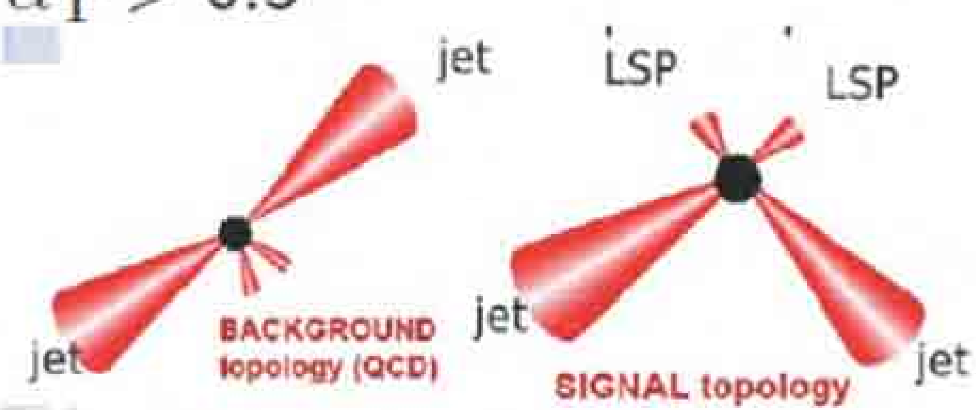


SKLTP

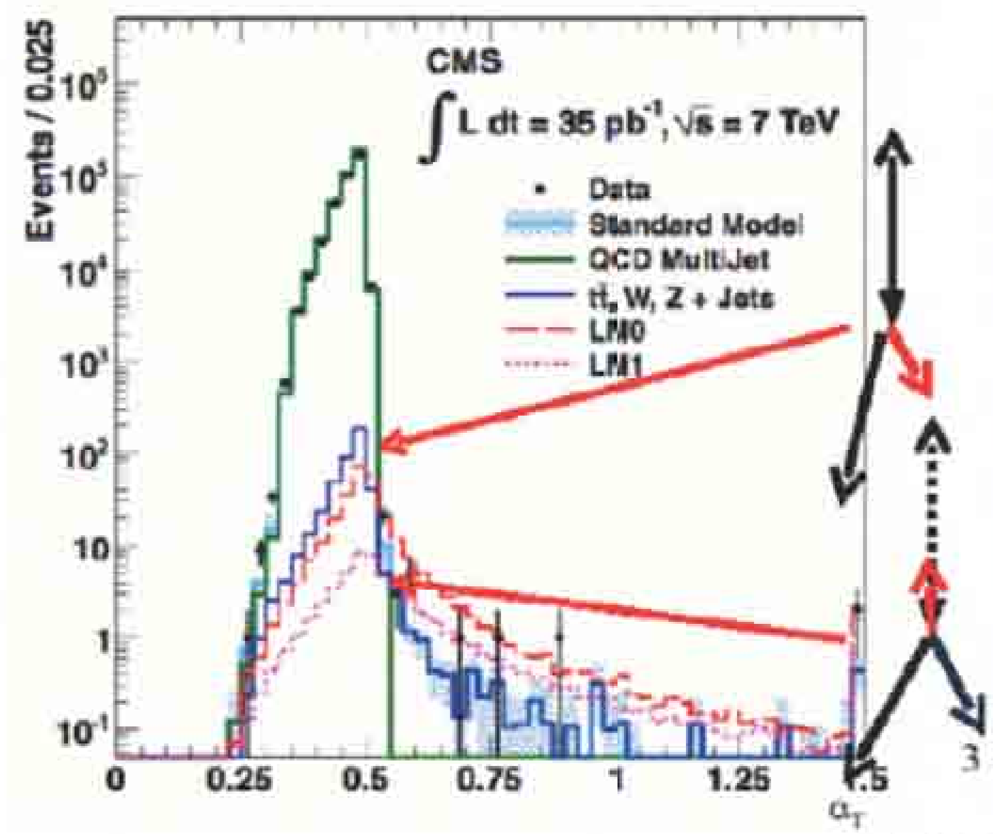
3. LHC Search Methods

The search using α_T

- Inspired by the variable α [Randall, Tucker-Smith, 2008]
- For a di-jet system, $\alpha_T \equiv \frac{E_T^{\text{jet2}}}{M_T}$.
- QCD expectation $= 0.5$
- Jet mis-measurements cause $\alpha_T < 0.5$
- Events with genuine MET can have smaller M_T, and hence $\alpha_T > 0.5$



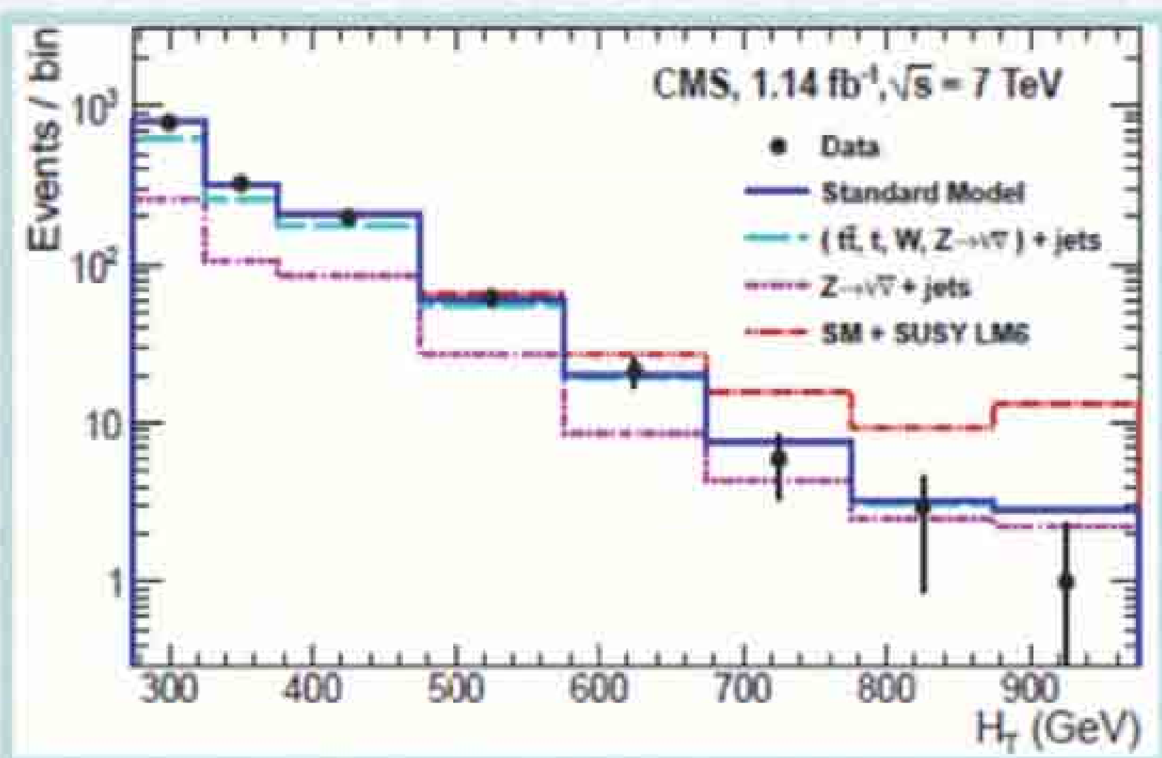
- For an n-jet system, form two "pseudo-jets" defined by balance in pseudo-jet $H_T \equiv \sum_j E_T$
- $\alpha_T \equiv \frac{1}{2}\frac{H_T - \Delta H_T}{M_T}$.

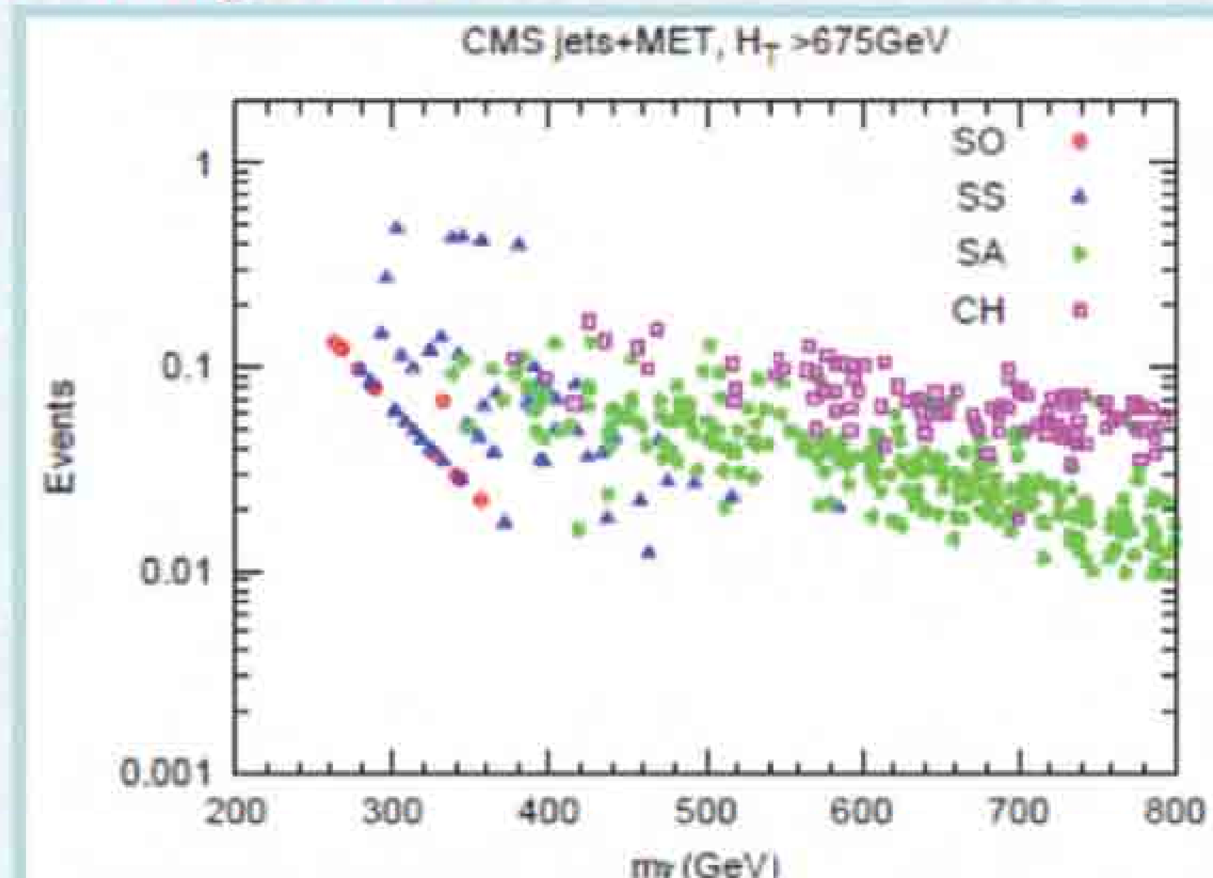


3. LHC Search

- Signal: **MET+jets**, 7TeV and $1.14 fb^{-1}$ data , 1109.2352
- Selections (conventions: $p_T(j_1) > p_T(j_2) > \ldots p_T(j_i)$)
  - Jets: $|\eta|_j < 3.0$, $p_T(j) > 50$ GeV
  - $|\eta|_{j1} < 3$, $p_T(j_1)$, $p_T(j_2) > 100$ GeV
  - $H_T > 275$ GeV
  - Reject events: leptons with $p_T > 10$ GeV , photons with $p_T > 25$ GeV
- Selections : **reduce fake MET from QCD background**
  - $\alpha_T > 0.55$
- Main background:

  W+jets, $Z(\to \nu\nu)$+jets, tt/ t





SKLTP

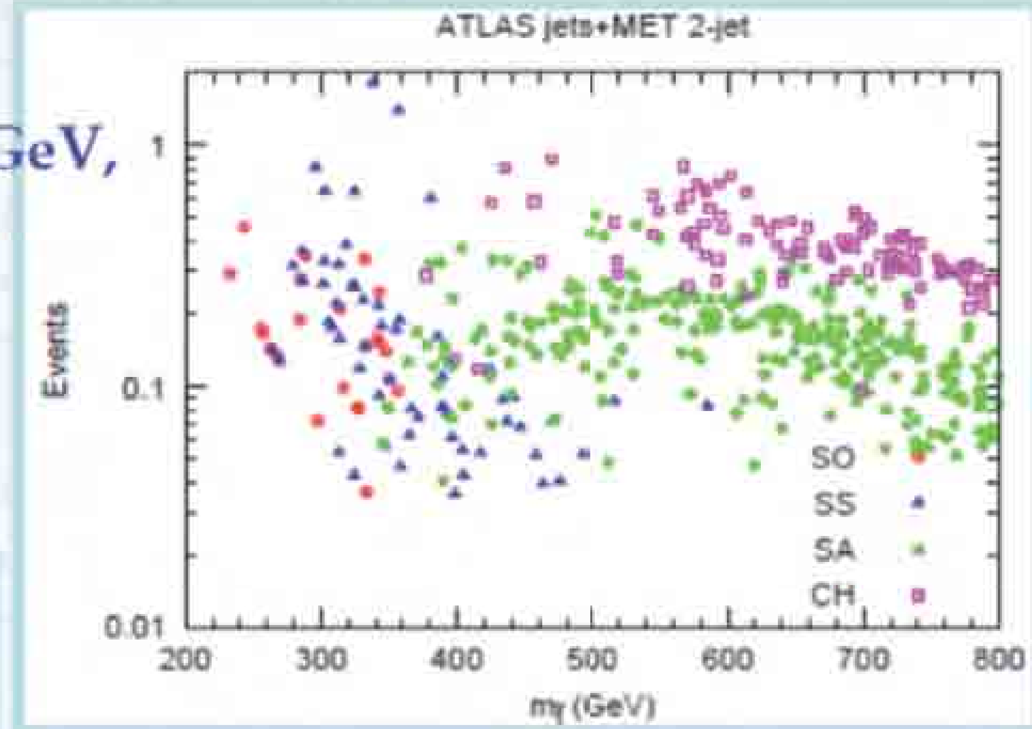
3. LHC Search

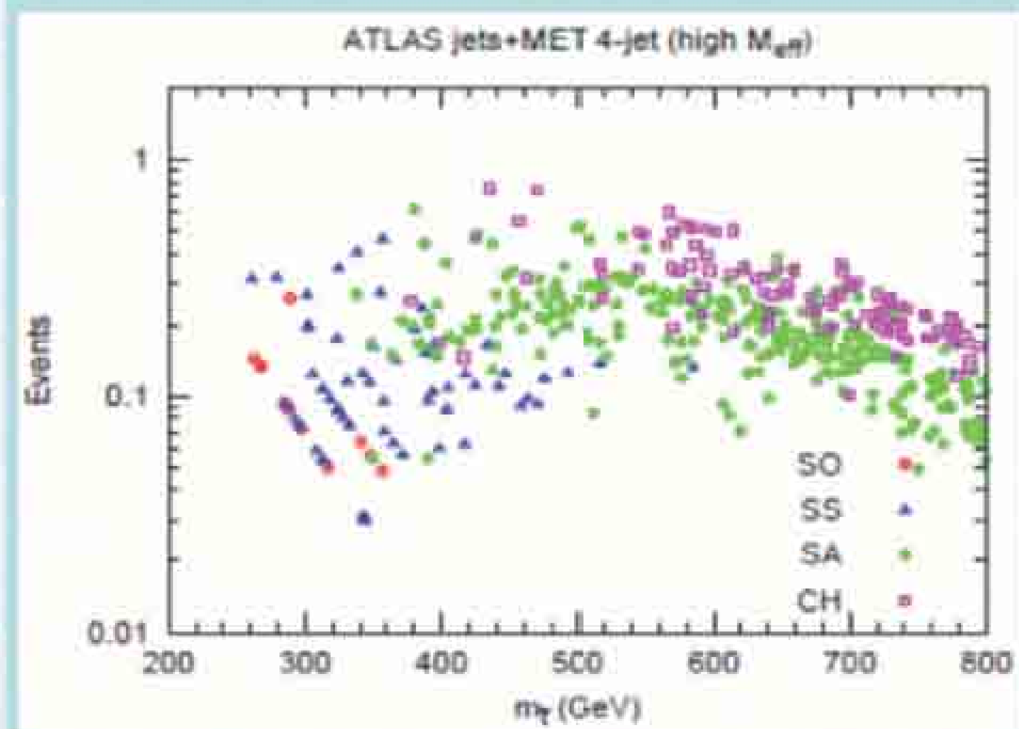
- Signal: MET+jets, 7TeV and 1.04fb^{-1} data , 1109.6572
- Selections
  - Reject events: electrons with $|\eta|_l<2.47$, $p_T(l)>10$ GeV, muons with $|\eta|_l<2.4$, $p_T(l)>10$ GeV
- Signal region:

For $\tilde{q}\tilde{q}, \tilde{q}\tilde{g}, \tilde{g}\tilde{g}$, require at least 2,3,4 jets

Signal Region	$\geq$ 2-jet	$\geq$ 3-jet	$\geq$ 4-jet	High mass
E_T^{miss}	> 130	> 130	> 130	> 130
Leading jet p_T	> 130	> 130	> 130	> 130
Second jet p_T	> 40	> 40	> 40	> 80
Third jet p_T	–	> 40	> 40	> 80
Fourth jet p_T	–	–	> 40	> 80
$\Delta\phi(\text{jet}, \vec{P}_T^{miss})_{min}$	> 0.4	> 0.4	> 0.4	> 0.4
E_T^{miss}/m_{eff}	> 0.3	> 0.25	> 0.25	> 0.2
m_{eff}	> 1000	> 1000	> 500/1000	> 1100

- 95% upper-limits: 22, 25, 429, 27 and 17 fb for different regions respectively



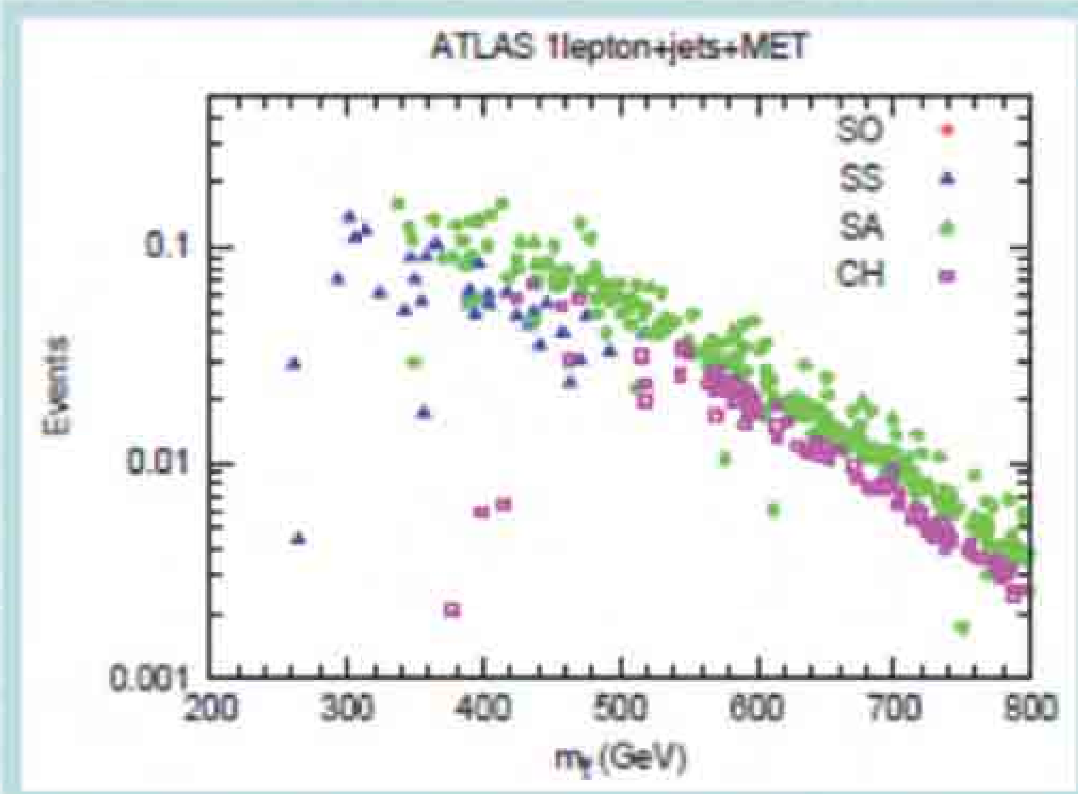


SKLTP

3. LHC Search

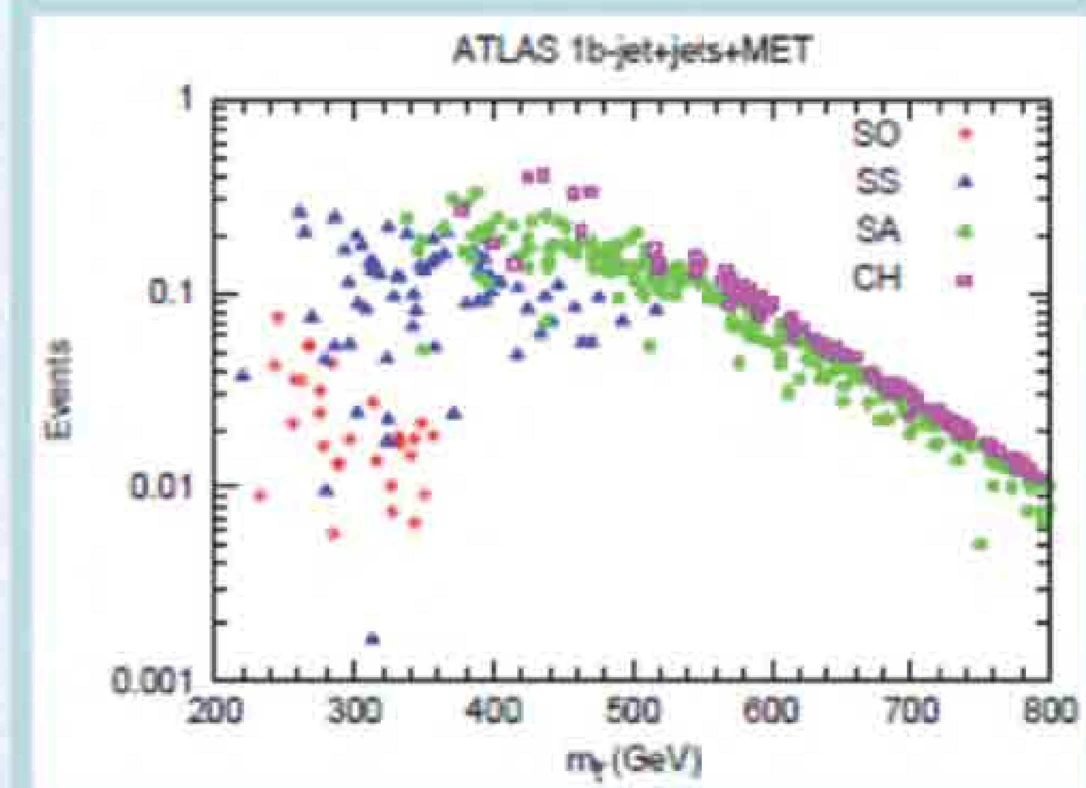
- **ATLAS: 1lepton+MET+jets, 1102.2357**

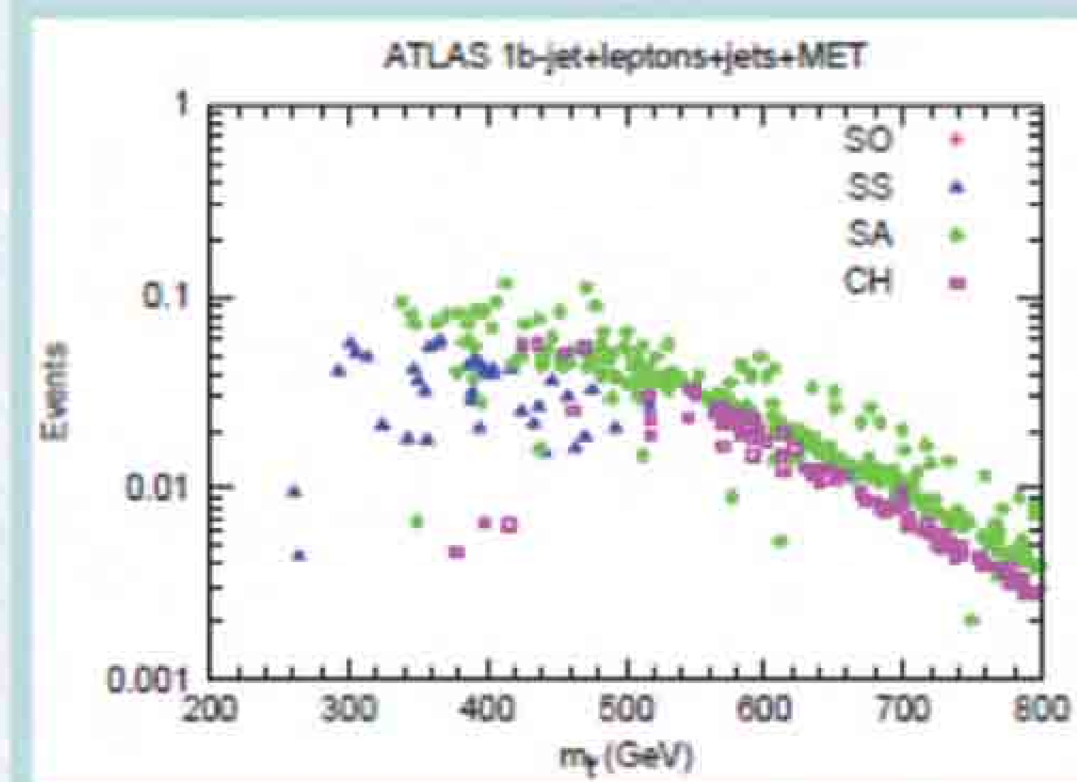
  95% CL : 2.2 (for electron) and 2.5(for muon)



- **ATLAS: 1bjet+MET+jets, 1103.4344**

  95% CL: 10.4 (for 0 lepton) and
  4.7 (for at least 1lpeton)

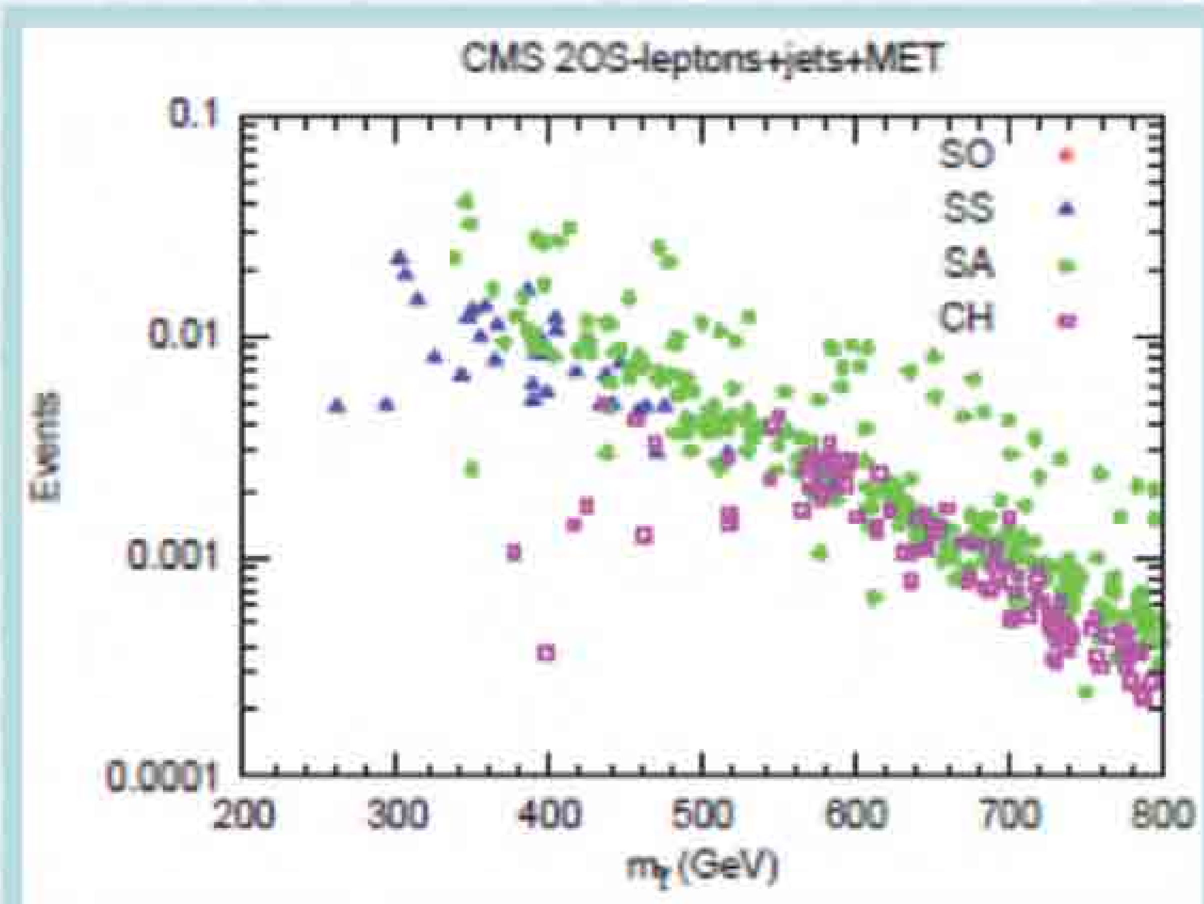


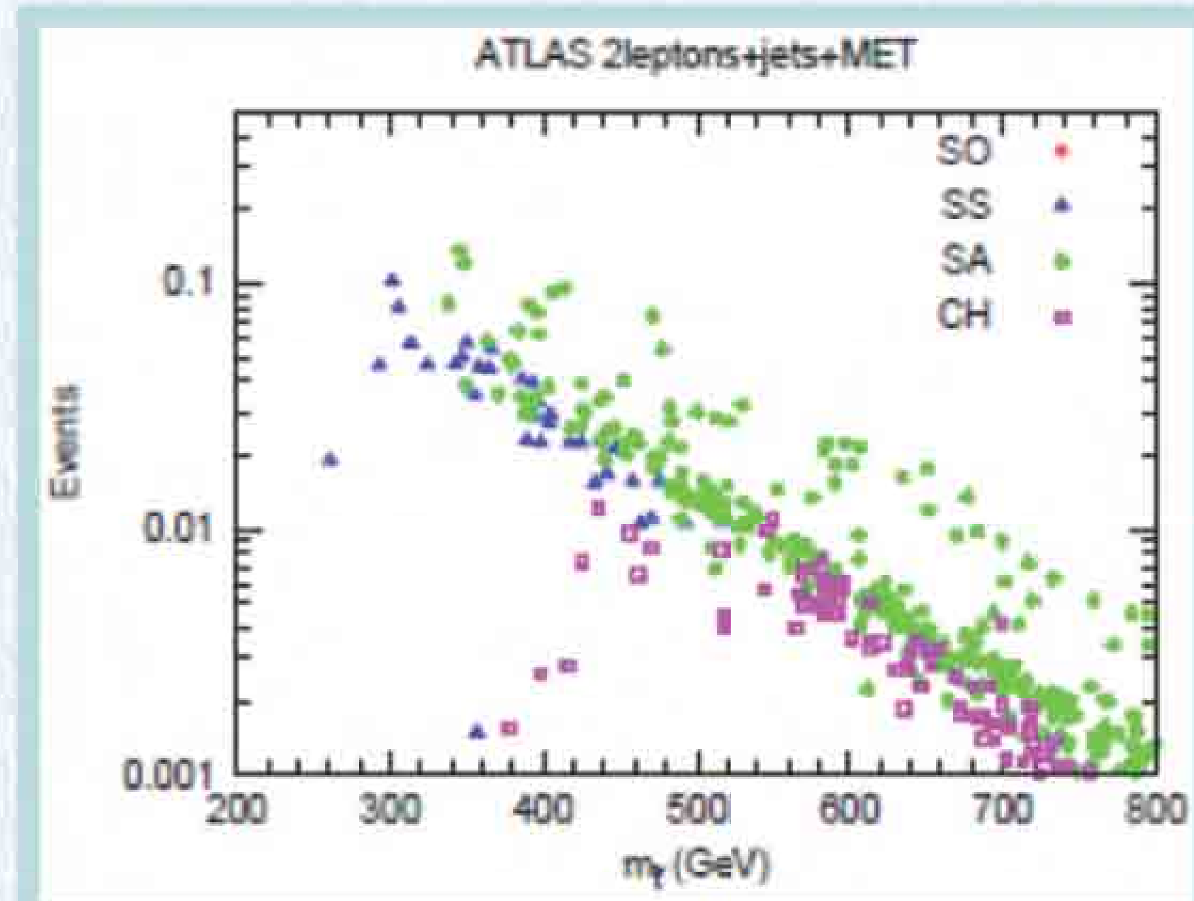


3. LHC Search

- **CMS: 2 OS leptons+MET+jets, 1102.2357**
  95% CL : 4

- **ATLAS: 2leptons+MET+jets, 1103.6214**
  95% CL : 2.45 (SS), 3.15 (ee), 7.35 (μμ), 7.7(eμ)





SKLTP

3. LHC Search

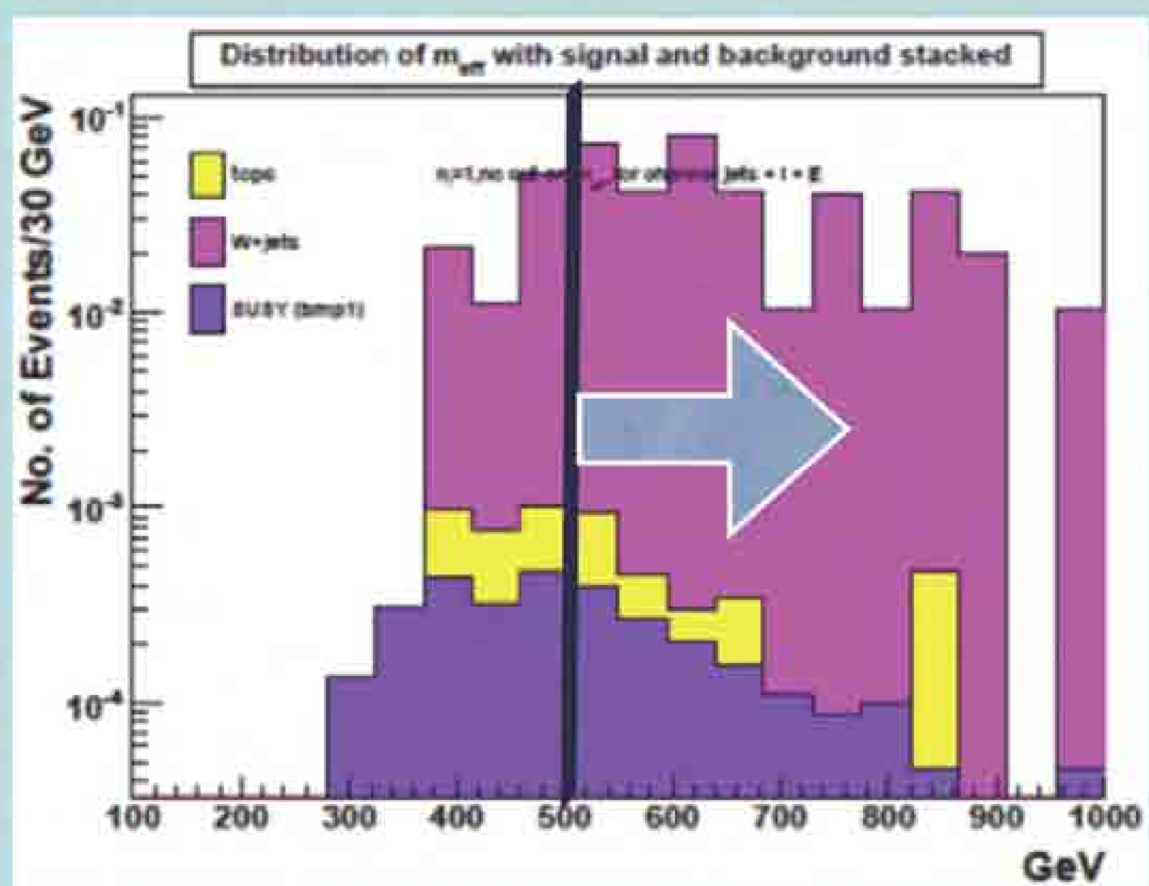
Lepton and jet multiplicities (BMP1)

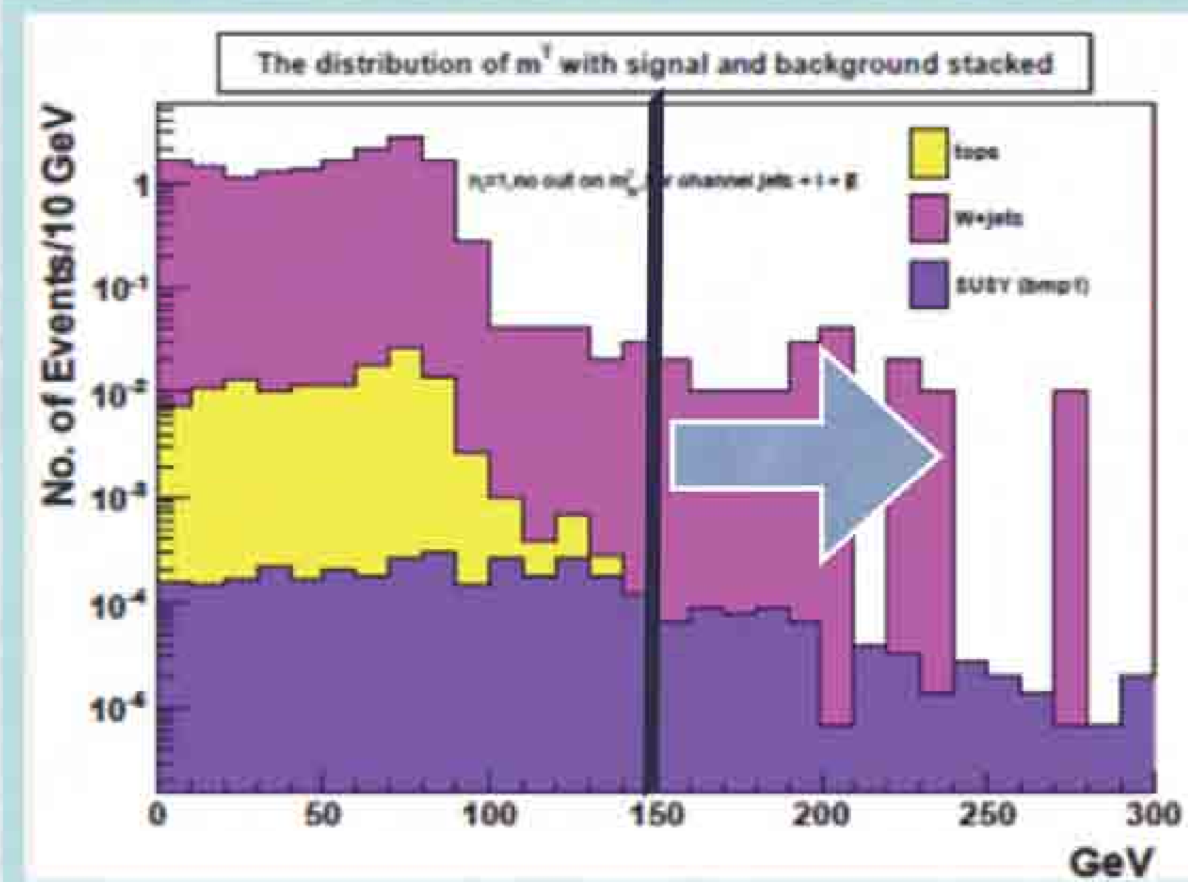
$Br(\tilde{t} \to t\chi^0) = 98.1\%$

	$2j$	$3j$	$4j$	$5j$	$\geq 6j$
$n_\ell = 0$	3%	8%	15%	16%	19%
$n_\ell = 1$	3%	7%	7%	4%	2%
$n_\ell = 2$	0.9%	0.6%	–	–	–

Benchmark points	BMP1	BMP2	BMP3	BMP4
$m_{\tilde{t}_1}$	390	243	264	338
$m_{\tilde{\tau}_1}$	207	471	199	179
$m_{\chi_1^+}$	383	424	356	337
$m_{\chi_1^0}$	206	223	190	176
σ at 7 TeV (pb)	0.23	3.74	2.33	0.55
σ at 14 TeV (pb)	2.54	28.42	18.91	5.46

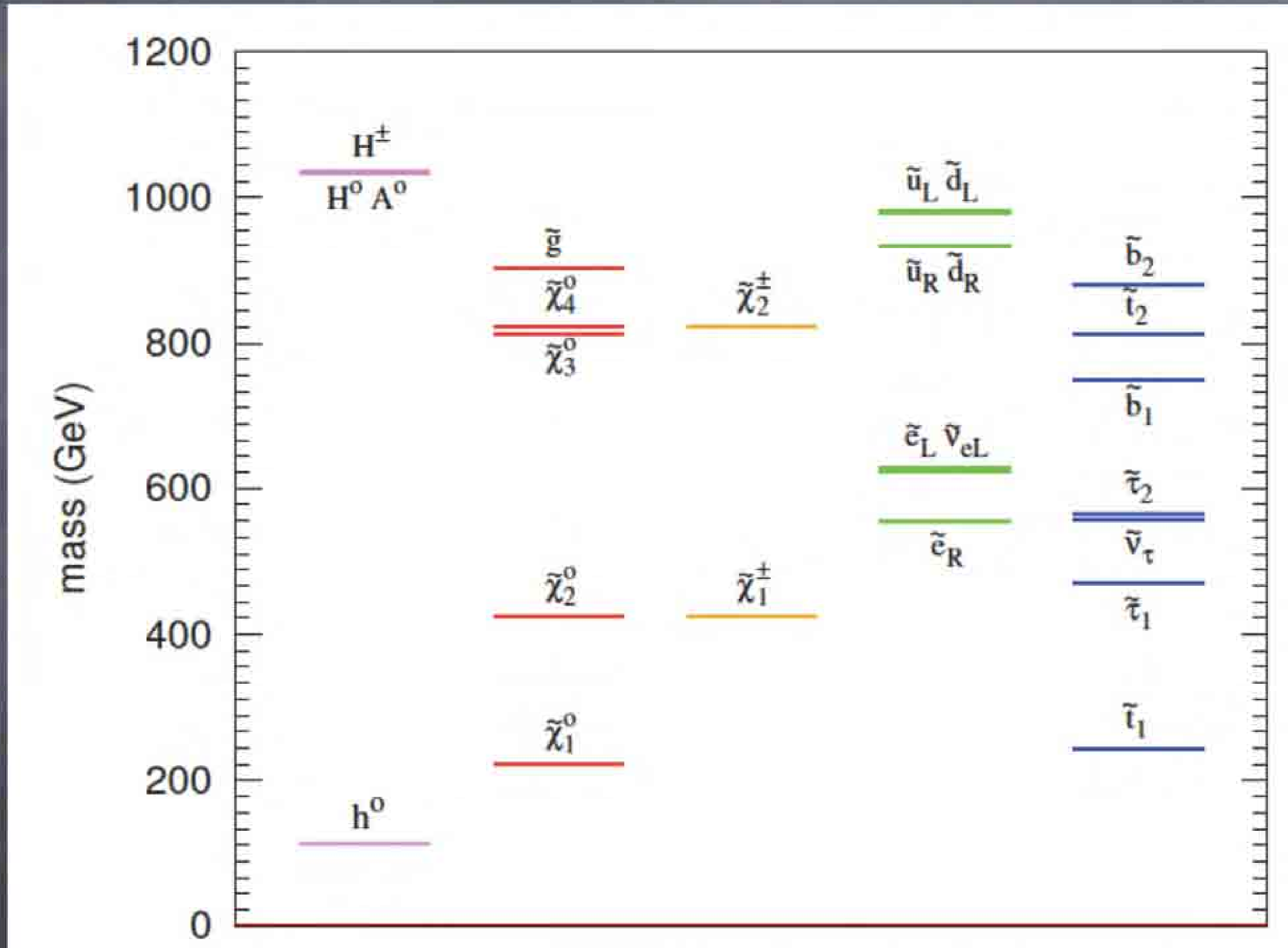
Distribution





SKLTP

3. LHC Search



Mass spectra of BMP2

SKLTP

3. LHC Search

- Lepton and jet multiplicities (BMP2)

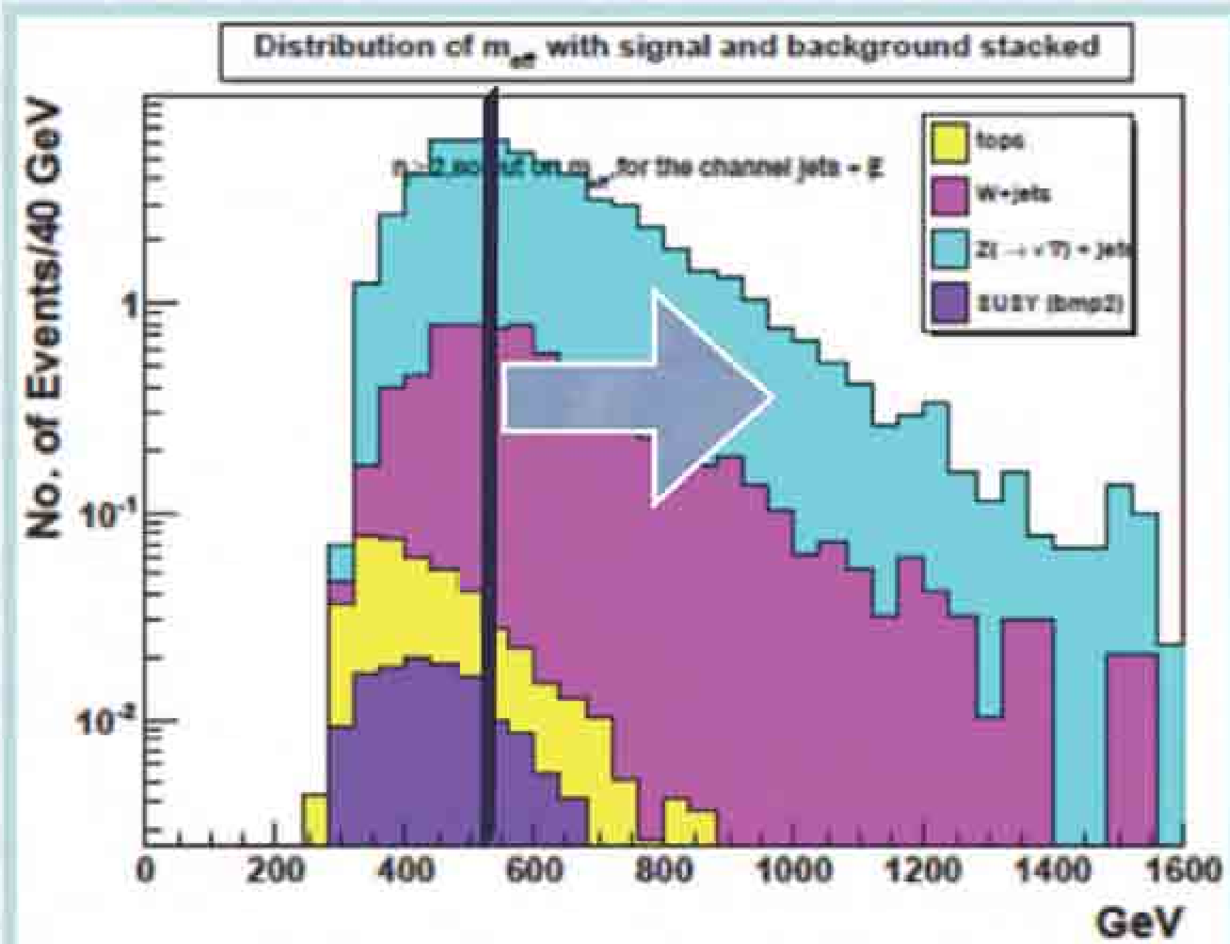
$Br(\tilde{t} \to c\chi^0) = 98.7\%$

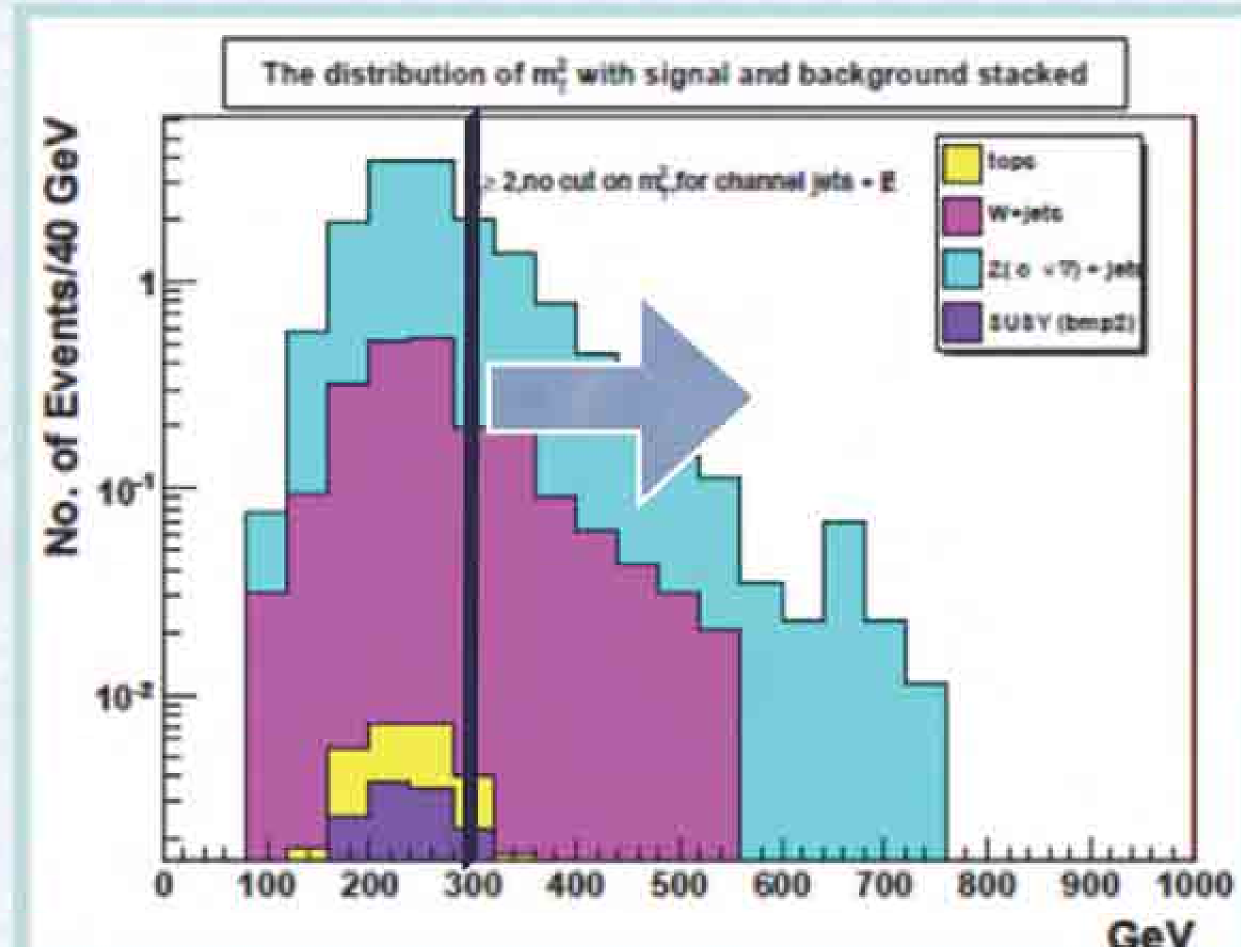
	$2j$	$3j$	$4j$	$5j$	$\geq 6j$
$n_\ell = 0$	20%	9.5%	3.0%	1%	–

- Discovery potential

	signal	background	S/B	$S/\sqrt{S+B}$	Lum. (7 TeV)
BMP1	0.04	4.0 [49]	1×10^{-2}	0.02	62.5 fb^{-1}
BMP2	0.01	24.5 [48]	4×10^{-4}	0.002	6250 fb^{-1}

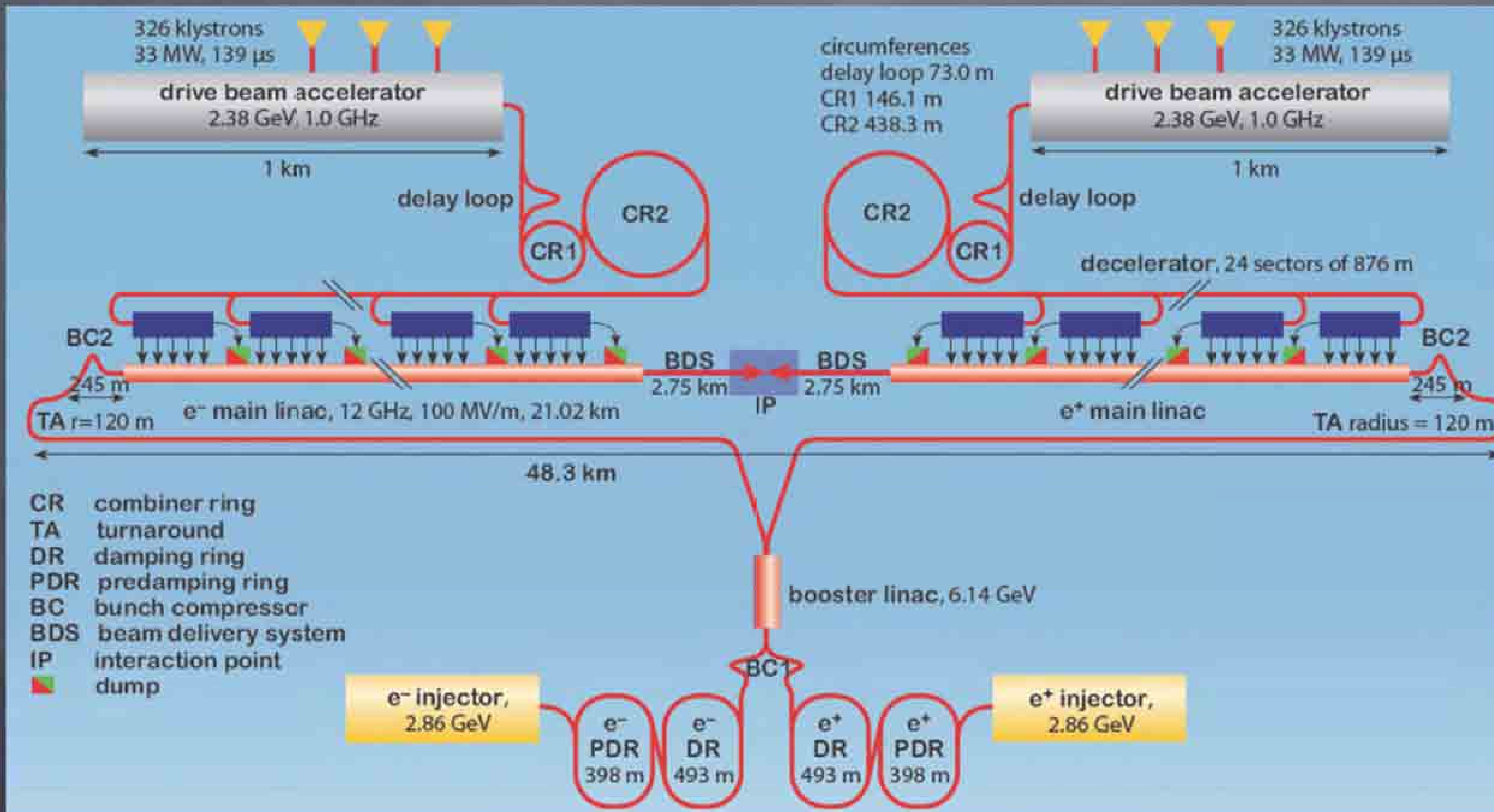
- Distribution





SKLTP

4. ILC Search

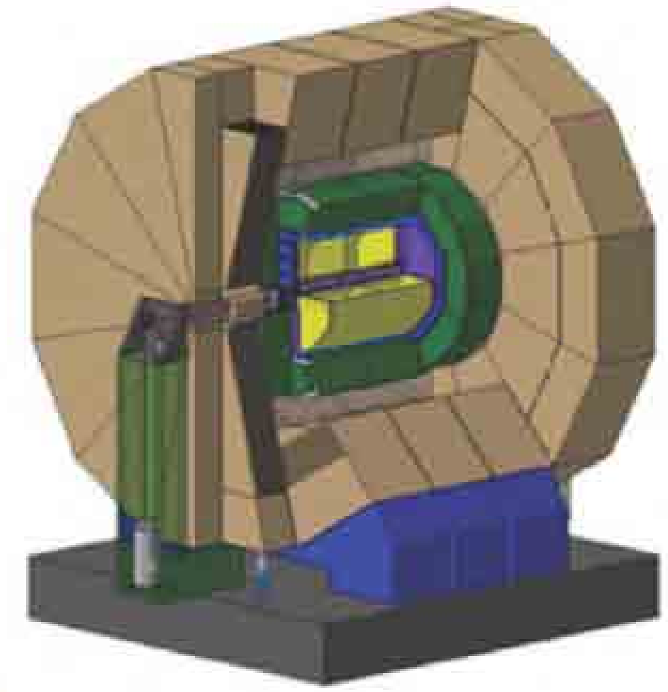


CLIC layout

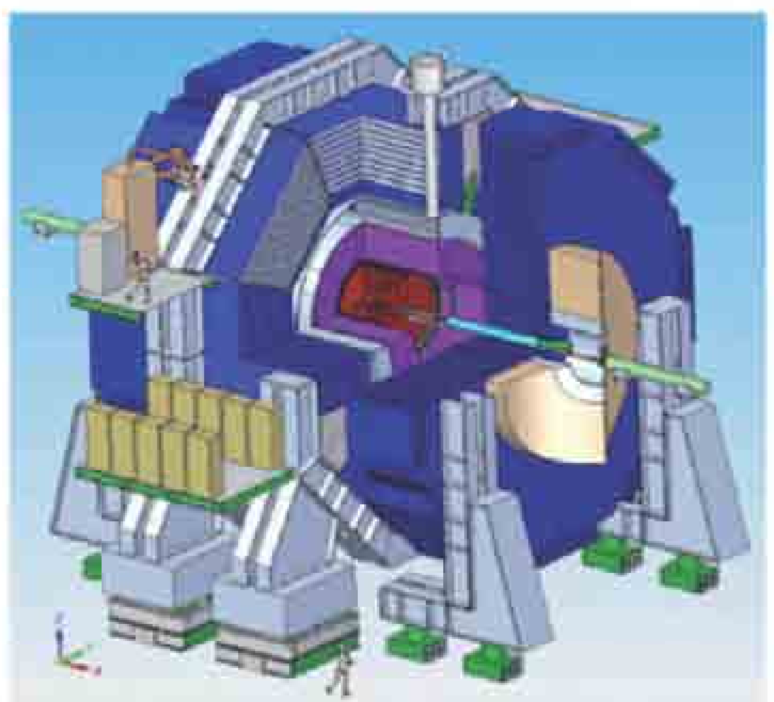
SKLTP

4. ILC Search

ILC detectors



- ILD: International Large Detector
  - "Large" - tracker radius 1.8m, silicon and TPC
  - High granularity calorimetry for particle flow analysis
  - Both in large solenoid with 3.5 T field

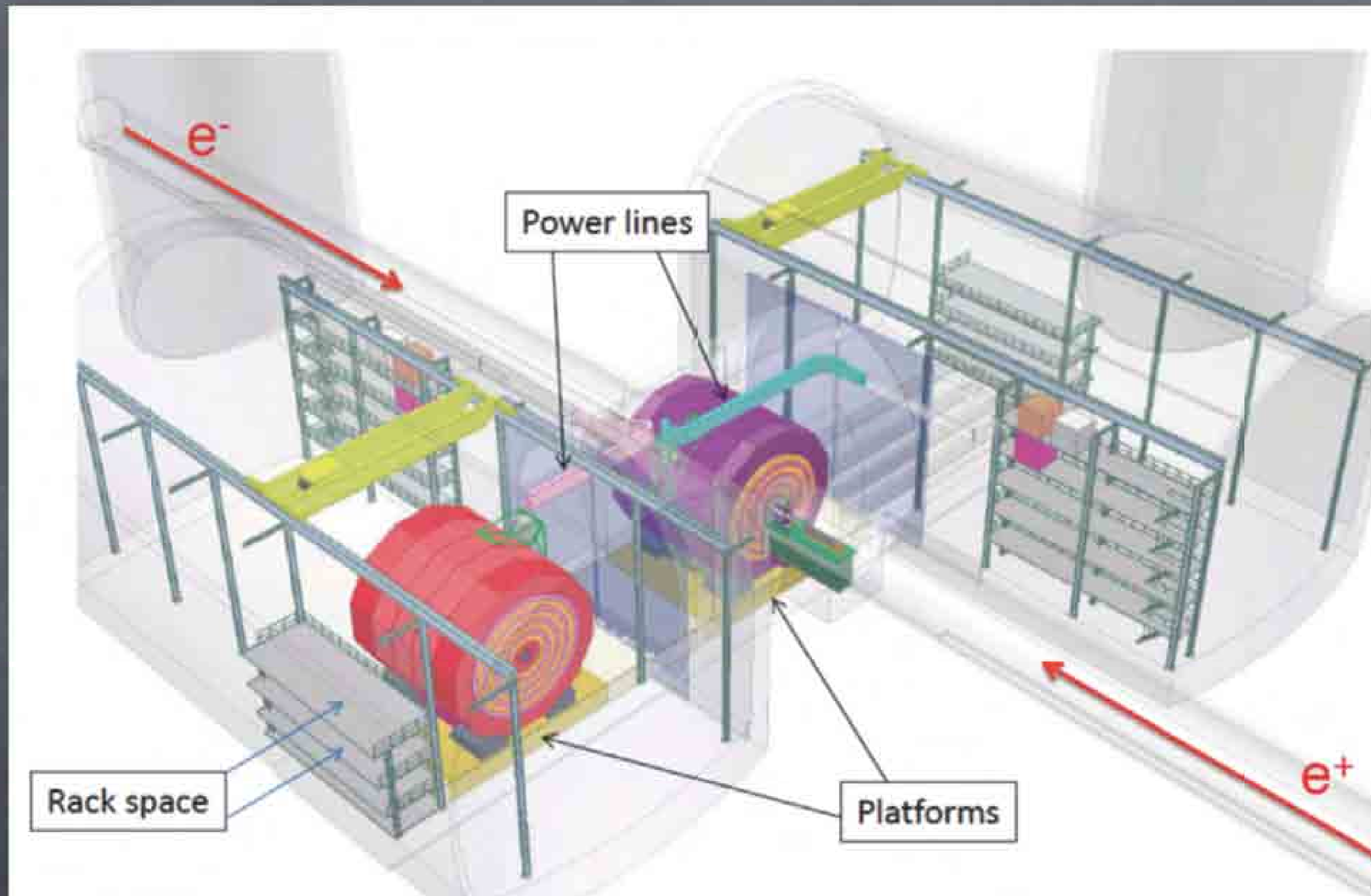


- SiD: Silicon Detector
  - Tracker radius 1.2m, all silicon
  - High granularity calorimetry for particle flow analysis
  - Both in large solenoid with 5 T field – pushing magnet technology

Two concept designs

SKLTP

4. ILC Search



Push-Pull

SKLTP

4. ILC Search

Areas requiring significantly improved precision compared to LHC detectors to achieve the physics goals of ILC/CLIC:

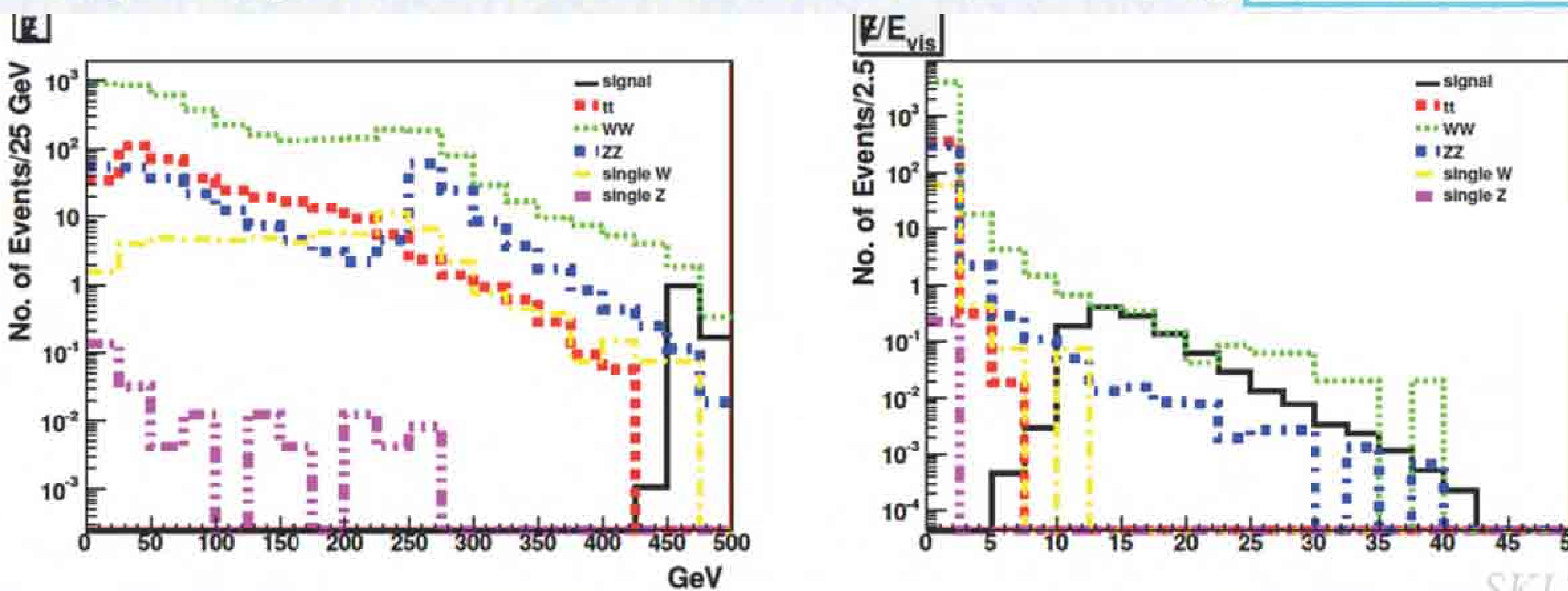
- Jet energy resolution to $\sigma(E)/E_{jet} \sim 3\%$ [LHC: ~10% at 100 GeV]
  - distinguish hadronic decays of W, Z, H, top, χ
  - high granularity calorimeters and particle flow algorithms
- Momentum resolution $\sigma(1/p_T) = 5 \times 10^{-5}$ (GeV^{-1}) [LHC: $\sigma(1/p_T) = \sim 2 \times 10^{-4}$ (GeV^{-1})]
  - Higgs recoil mass (HZ events) and SUSY decay end-points
- Impact parameter resolution $\sigma = 5 \oplus 10/(p \sin^{3/2}\theta)$ μm [LHC: $\sigma = 20 \oplus 100/(p \sin^{3/2}\theta)$ μm]
  - Identify Z and H heavy quark (b, c) decays
- Implications for tracker:
  - Minimise material in trackers to reduce multiple scattering
  - Sensor precision must be matched by stable structures and precise alignment

ILC project, EPS, Pippa Wells' talk

SKLTP

4. ILC

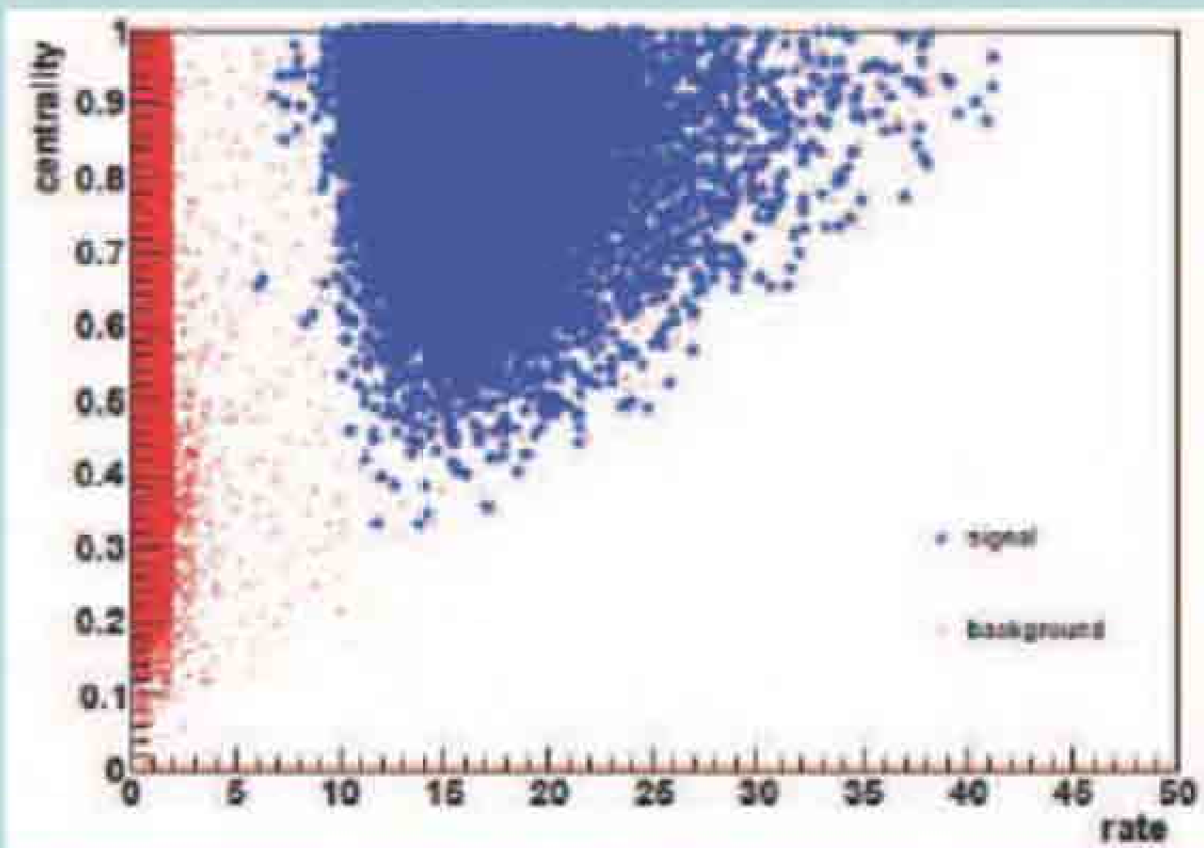
- $e^+e^- \to \tilde{t}_1\tilde{t}_1^*$, low background
  possible to scan CM energy for stop pair production
- may reconstruct missing energy, rather than transverse missing energy
- Small eletro-weak production cross section,
  low CM energy: 500/1000/3000 GeV
- May be helpful to discover SUSY "hidden" at the LHC, e.g. $Br(\tilde{t} \to c\chi^0) = 98.7\%$

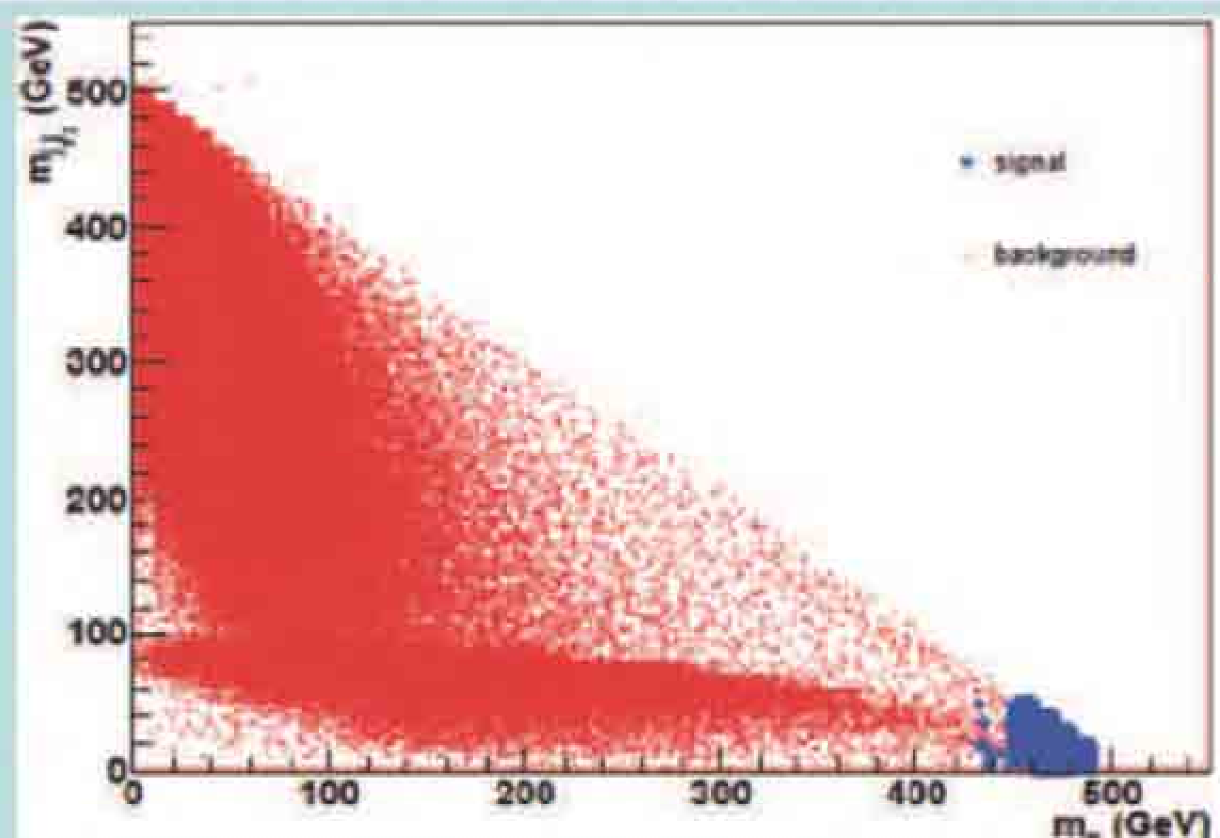


4. ILC Search

- ILC, 0.5TeV and $10fb^{-1}$ of data
  - Cut 1, ME>300 GeV and lepton veto
  - Cut 2, ME>425 GeV, rate>10, and m_{12}<60 GeV
  - $37fb^{-1}$ of data required for 5σ significance

	signal	$t\bar{t}$	WW	$\nu\bar{\nu}W$	ZZ	eeZ	S/B	$S/\sqrt{S+B}$
No. of Events after preselection	11.1	6.2	336.7	8.9	44.8	–	0.03	0.54
No. of Events after a few cuts	11.1	–	18.6	1.0	0.7	–	0.5	1.9
No. of Events after NN	9.6	–	0.9	0.7	0.4	–	4.8	2.6





SKLTP

5. Discussions and Conclucions

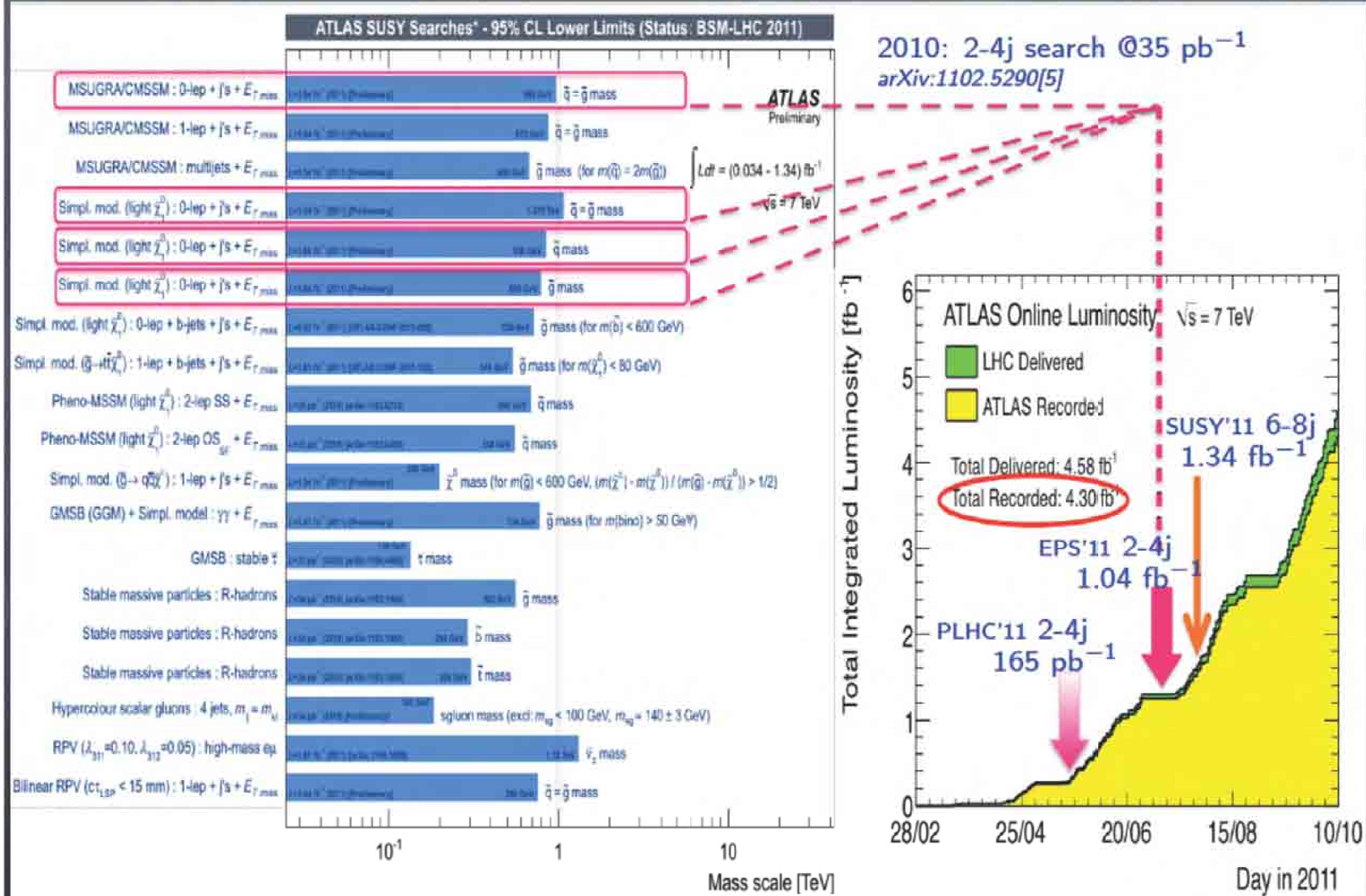
- Light stop is naturally in the SUSY, but may be difficult to be detected
- For the "Flavor-Split" scenario, SUSY may be "hidden" at the LHC for 7TeV and low luminosity
- Special search strategies are needed
- Study such scenario at the ILC
- Consider other strategies at the LHC, e.g MET+ mono jet/gamma ?

1112.4461, B.He, T.Li, Q. Shafi

Thank Your Attention

Backup Slides

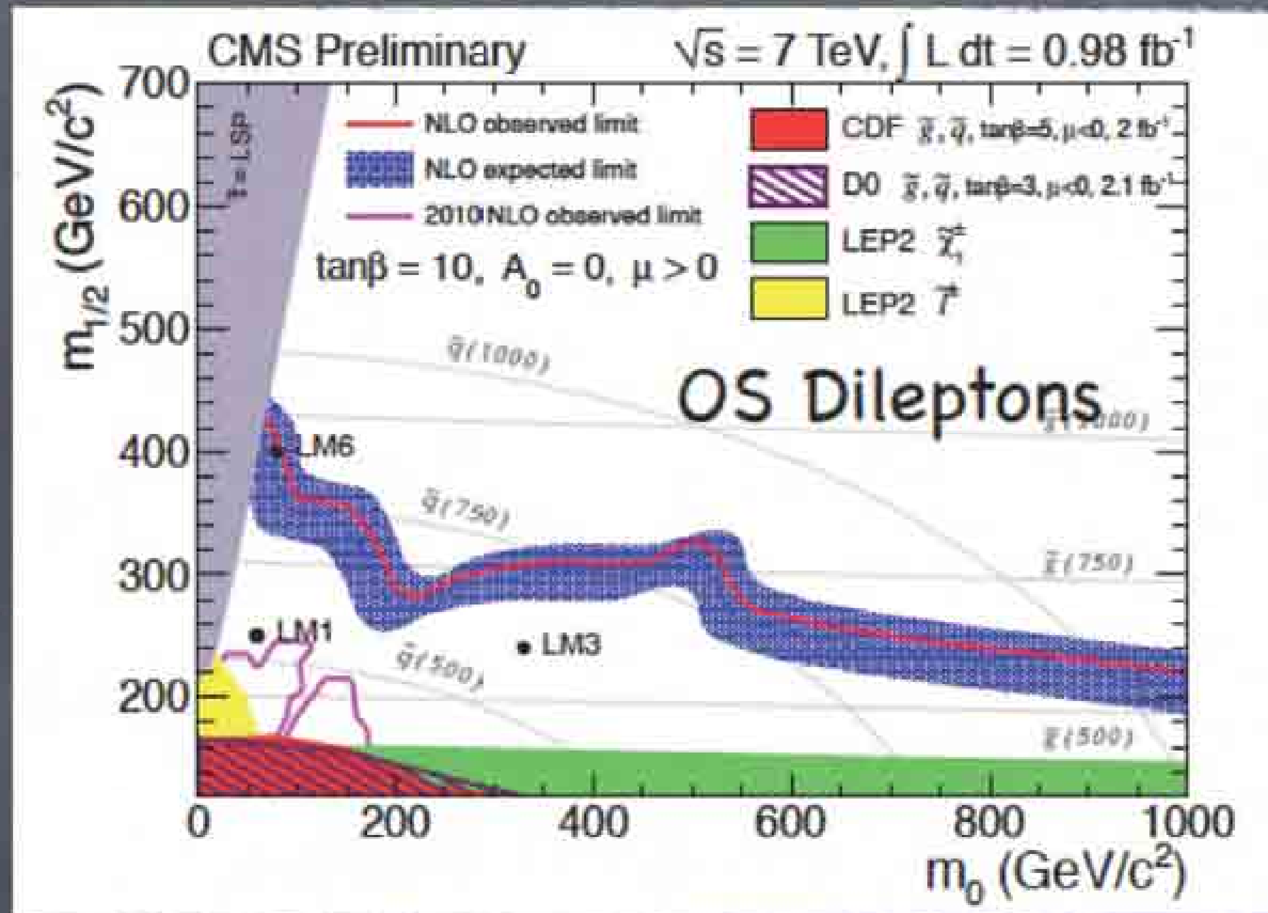
SKLTP

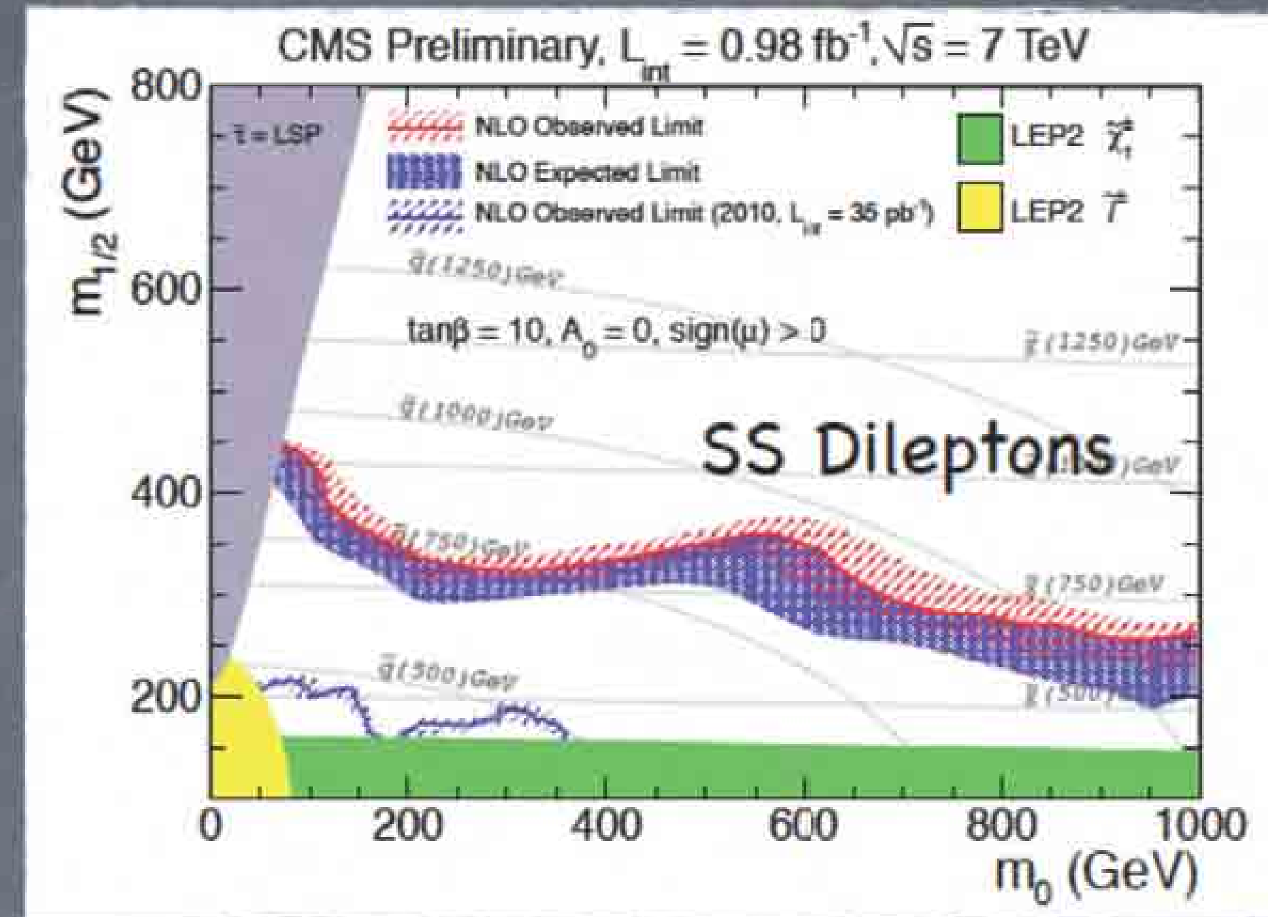

ATLAS SUSY Searches* - 95% CL Lower Limits (Status: BSM-LHC 2011)
MSUGRA/CMSSM : 0-lep + j's + $E_{T,miss}$
MSUGRA/CMSSM : 1-lep + j's + $E_{T,miss}$
MSUGRA/CMSSM : multijets + $E_{T,miss}$
Simpl. mod. (light $\tilde{\chi}_1^0$) : 0-lep + j's + $E_{T,miss}$
Simpl. mod. (light $\tilde{\chi}_1^0$) : 0-lep + j's + $E_{T,miss}$
Simpl. mod. (light $\tilde{\chi}_1^0$) : 0-lep + j's + $E_{T,miss}$
Simpl. mod. (light $\tilde{\chi}_1^0$) : 0-lep + b-jets + j's + $E_{T,miss}$
Simpl. mod. ($\tilde{g} \to t\bar{t}\tilde{\chi}_1^0$) : 1-lep + b-jets + j's + $E_{T,miss}$
Pheno-MSSM (light $\tilde{\chi}_1^0$) : 2-lep SS + $E_{T,miss}$
Pheno-MSSM (light $\tilde{\chi}_1^0$) : 2-lep OS_{SF} + $E_{T,miss}$
Simpl. mod. ($\tilde{g} \to q\bar{q}\tilde{\chi}_1^{\pm}$) : 1-lep + j's + $E_{T,miss}$
GMSB (GGM) + Simpl. model : $\gamma\gamma$ + $E_{T,miss}$
GMSB : stable $\tilde{\tau}$
Stable massive particles : R-hadrons
Stable massive particles : R-hadrons
Stable massive particles : R-hadrons
Hypercolour scalar gluons : 4 jets, $m_{ij} \approx m_{kl}$
RPV (λ'_{311}=0.10, λ_{312}=0.05) : high-mass eμ
Bilinear RPV ($c\tau_{LSP}$ < 15 mm) : 1-lep + j's + $E_{T,miss}$
$\tilde{q} = \tilde{g}$ mass
$\tilde{q} = \tilde{g}$ mass
$\tilde{g}$ mass (for $m(\tilde{q}) = 2m(\tilde{g})$)
$\tilde{q} = \tilde{g}$ mass
$\tilde{q}$ mass
$\tilde{g}$ mass
$\tilde{g}$ mass (for $m(\tilde{b})$ < 600 GeV)
$\tilde{g}$ mass (for $m(\tilde{\chi}_1^0)$ < 80 GeV)
$\tilde{q}$ mass
$\tilde{q}$ mass
$\tilde{\chi}_1^{\pm}$ mass (for $m(\tilde{g})$ < 600 GeV, $m(\tilde{\chi}_1^{\pm}) - m(\tilde{\chi}_1^0)) / (m(\tilde{g}) - m(\tilde{\chi}_1^0))$ > 1/2)
$\tilde{g}$ mass (for m(bino) > 50 GeV)
$\tilde{\tau}$ mass
$\tilde{g}$ mass
$\tilde{b}$ mass
$\tilde{t}$ mass
sgluon mass (excl: m_{sg} < 100 GeV, $m_{sg} \approx 140 \pm 3$ GeV)
$\tilde{\nu}_\tau$ mass
$\tilde{q} = \tilde{g}$ mass
ATLAS
Preliminary
$\int L dt = (0.034 - 1.34)\ fb^{-1}$
$\sqrt{s}$ = 7 TeV
10^{-1}
1
10
Mass scale [TeV]
2010: 2-4j search @35 pb^{-1}
arXiv:1102.5290[5]
ATLAS Online Luminosity
$\sqrt{s}$ = 7 TeV
LHC Delivered
ATLAS Recorded
Total Delivered: 4.58 fb^{-1}
Total Recorded: 4.30 fb^{-1}
SUSY'11 6-8j
1.34 fb^{-1}
EPS'11 2-4j
1.04 fb^{-1}
PLHC'11 2-4j
165 pb^{-1}
Total Integrated Luminosity [fb^{-1}]
0
1
2
3
4
5
6
28/02
25/04
20/06
15/08
10/10
Day in 2011

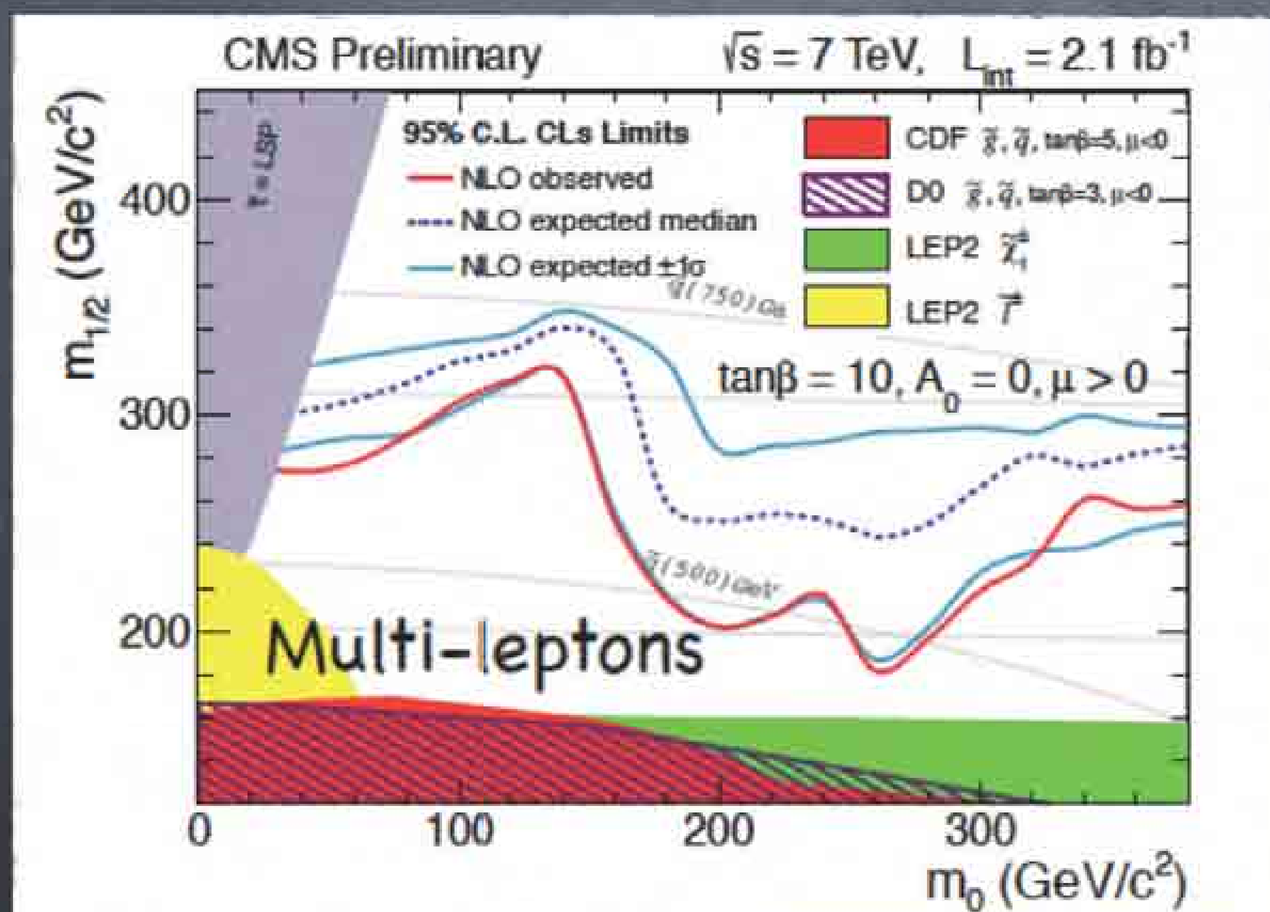
SKLTP

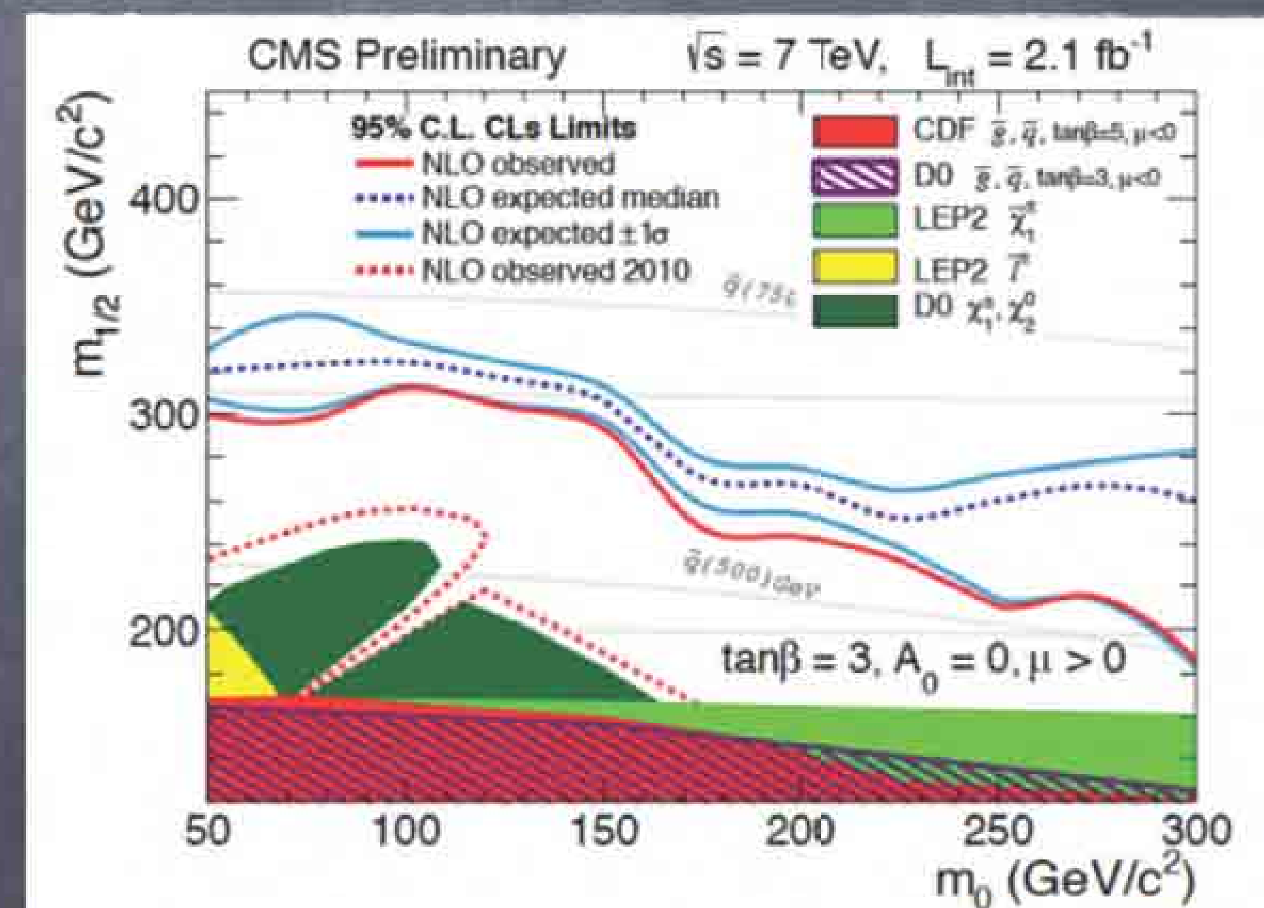
	non-Z OS dileptons			Z OS dileptons		SS dileptons			3+ leptons
lepton p_T: $\ell 1/\ell 2$	20/10			20/20		μ:5 e:10	μe: 20/10	μ:5,e:10, τ:15	μe: 8 τ: 8 or 15
lepton $\lvert\eta\rvert$: μ/e	2.4/2.5			2.4/2.5		2.4/2.4			2.1/2.1
Isolation: I_{rel}	0.15			0.15		0.15			0.15
jet: $p_T/\lvert\eta\rvert$	30/3			30/3		40/2.5			40/2.5
Njets/ΔR(jet,ℓ)	2+/0.4			2+/0.4		--/0.4			--/0.4
HT	100	300	600	--		200		350	>50 or <50
MET	50	275	200	100	200	--			>200 or <200
Z veto for OSSF	$12<M_{\ell\ell}<76$ & $M_{\ell\ell}>106$			$81<M_{\ell\ell}<101$		--			$M_{\ell\ell}>12$ & in or outside Z

CMS multilepton channels

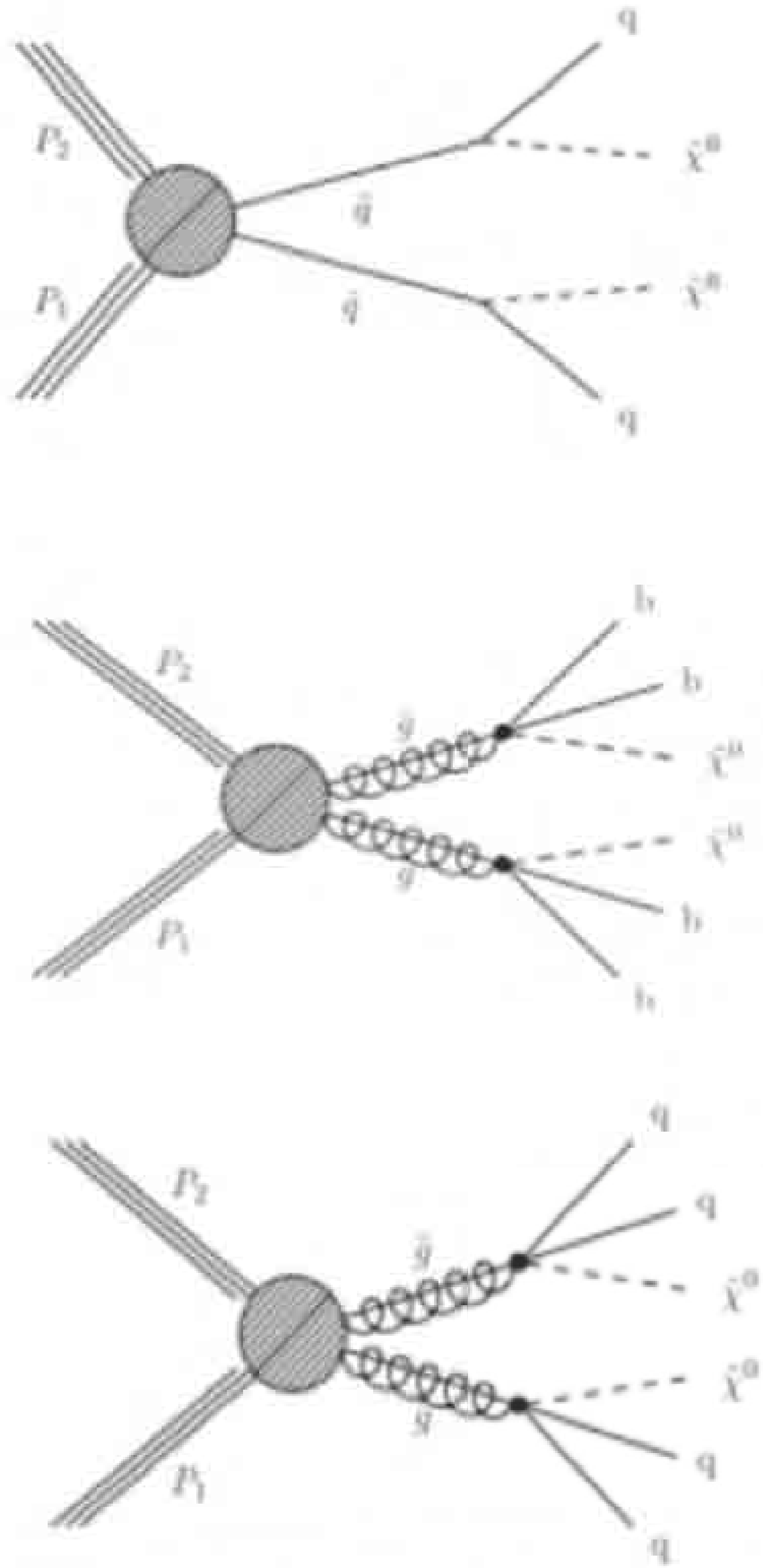

CMS Preliminary
√s = 7 TeV, ∫ L dt = 0.98 fb⁻¹
NLO observed limit
NLO expected limit
2010 NLO observed limit
CDF
D0
LEP2
LEP2
tanβ = 10, A0 = 0, μ > 0
OS Dileptons
LM6
LM1
LM3
m1/2 (GeV/c²)
m0 (GeV/c²)

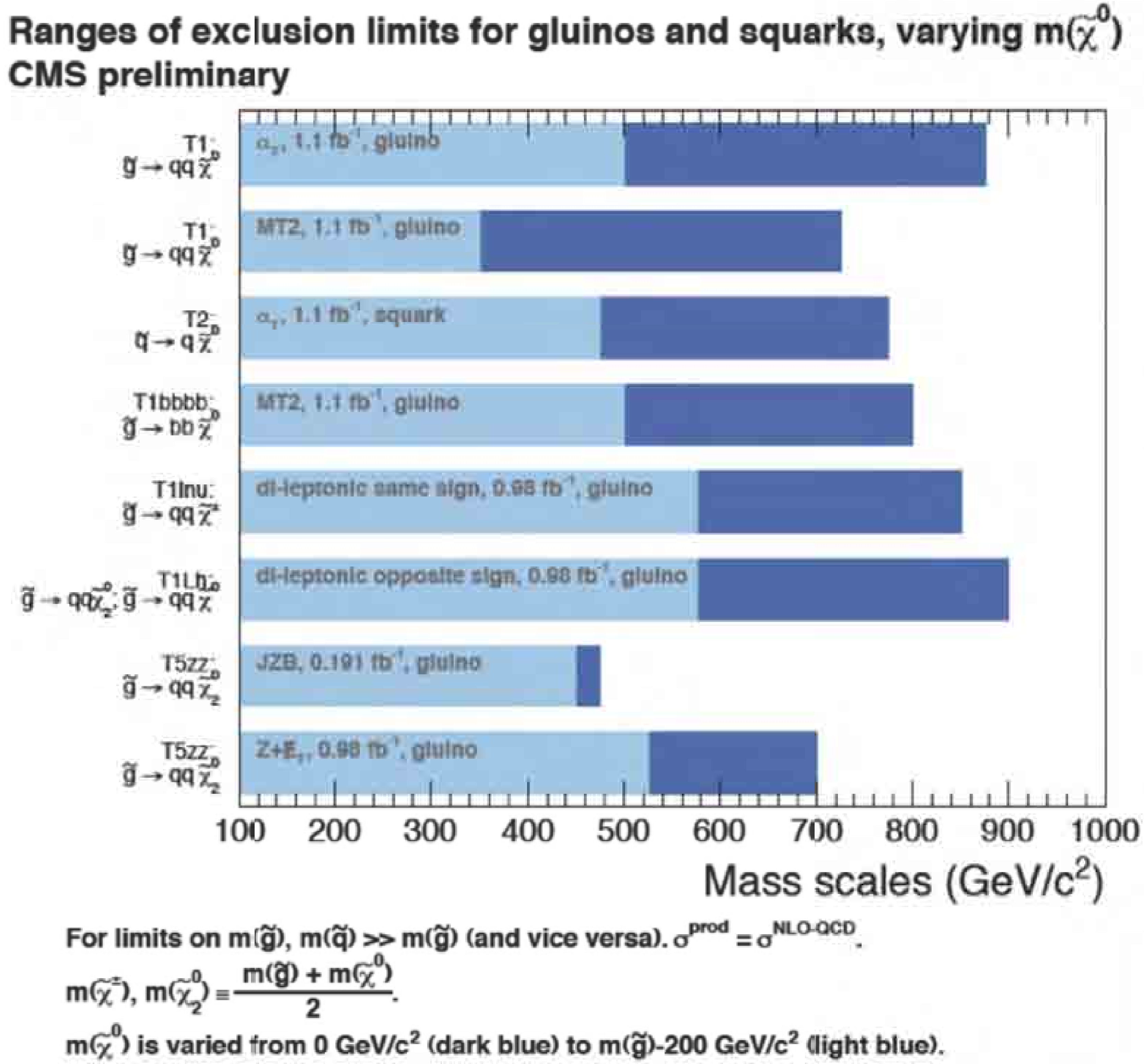

CMS Preliminary, Lint = 0.98 fb⁻¹, √s = 7 TeV
NLO Observed Limit
NLO Expected Limit
NLO Observed Limit (2010, Lint = 35 pb⁻¹)
LEP2
LEP2
tanβ = 10, A0 = 0, sign(μ) > 0
SS Dileptons
m1/2 (GeV)
m0 (GeV)


CMS Preliminary
√s = 7 TeV, Lint = 2.1 fb⁻¹
95% C.L. CLs Limits
NLO observed
NLO expected median
NLO expected ±1σ
CDF
D0
LEP2
LEP2
tanβ = 10, A0 = 0, μ > 0
Multi-leptons
m1/2 (GeV/c²)
m0 (GeV/c²)


CMS Preliminary
√s = 7 TeV, Lint = 2.1 fb⁻¹
95% C.L. CLs Limits
NLO observed
NLO expected median
NLO expected ±1σ
NLO observed 2010
CDF
D0
LEP2
LEP2
D0
tanβ = 3, A0 = 0, μ > 0
m1/2 (GeV/c²)
m0 (GeV/c²)

SKLTP





Gheorghe Lungu's talk at Berkeley SUSY Workshop

SKLTP

- The weak scale is determined by:

$$\frac{m^2_{Higgs}}{2} = -|\mu|^2 + \ldots + \delta m^2_H$$

$$\delta m^2_H \simeq -\frac{3y_t^2}{8\pi^2}\left(m^2_{Q_3} + m^2_{U_3} + |A_t|^2\right)\ln\left(\frac{M}{m_{\tilde{t}}}\right)$$

- The physical Higgs mass is

$$m_h^2 \simeq m_Z^2 \cos^2 2\beta + \frac{3}{4\pi^2}\frac{m_t^4}{v^2}\left[\log\frac{m^2_{\tilde{t}}}{m_t^2} + \frac{X_t^2}{m^2_{\tilde{t}}}\left(1 - \frac{X_t^2}{12 m^2_{\tilde{t}}}\right)\right] \quad X_t = A_t - \mu\cot\beta$$

- LEP bound $m_H > 114$ GeV requires heavy stops

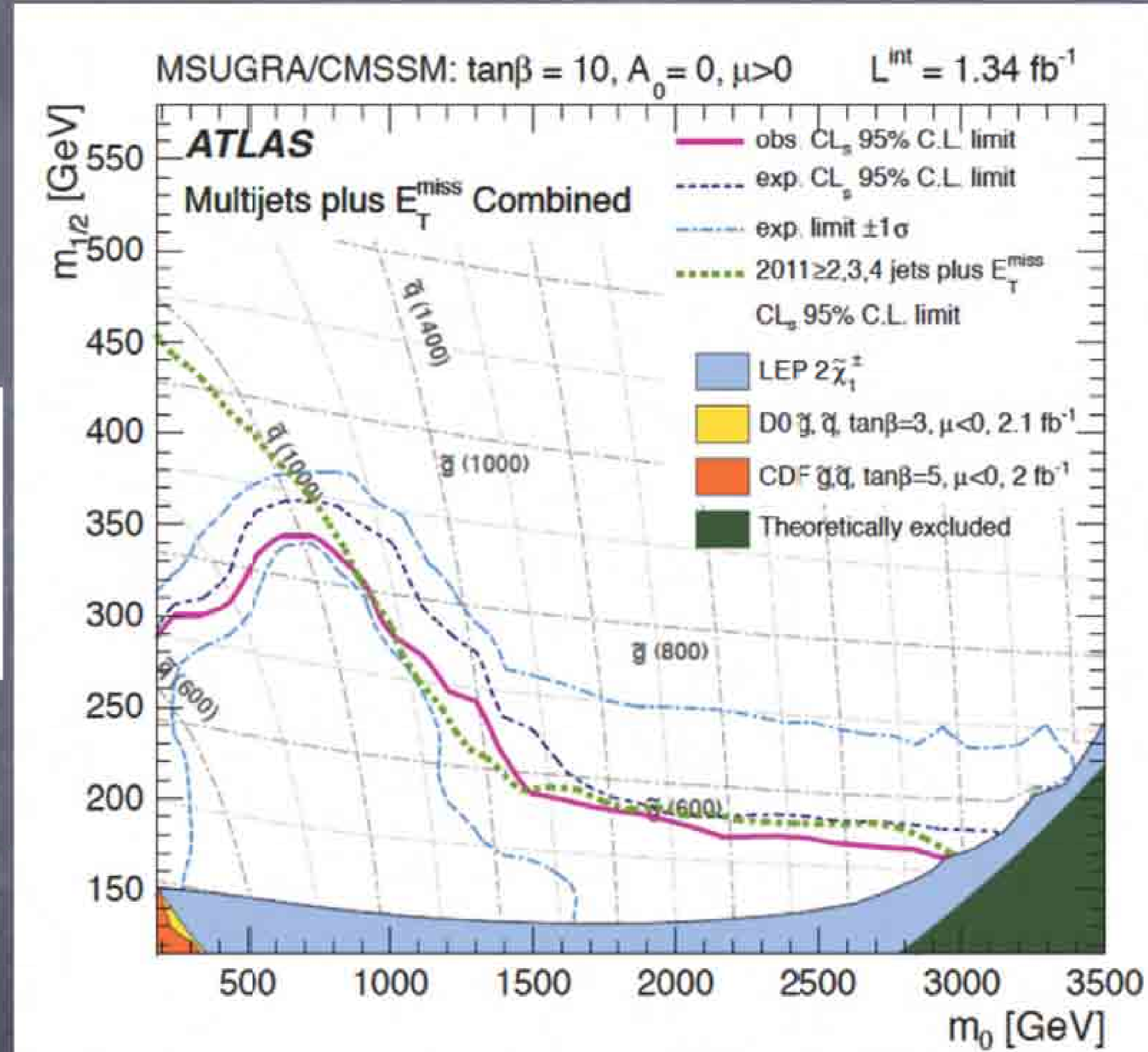
- tuning of ~ few %

Signal Region	$\geq$ 2-jet	$\geq$ 3-jet	$\geq$ 4-jet	High mass
E_T^{miss}	> 130	> 130	> 130	> 130
Leading jet p_T	> 130	> 130	> 130	> 130
Second jet p_T	> 40	> 40	> 40	> 80
Third jet p_T	–	> 40	> 40	> 80
Fourth jet p_T	–	–	> 40	> 80
$\Delta\phi(\text{jet}, \vec{P}_T^{miss})_{min}$	> 0.4	> 0.4	> 0.4	> 0.4
E_T^{miss}/m_{eff}	> 0.3	> 0.25	> 0.25	> 0.2
m_{eff}	> 1000	> 1000	> 500/1000	> 1100

1109.6572

SKLTP

Signal region	7j55	8j55	6j80	7j80
Jet p_T	> 55 GeV		> 80 GeV	
Jet $\|\eta\|$	< 2.8			
ΔR_{jj}	> 0.6 for any pair of jets			
Number of jets	≥ 7	≥ 8	≥ 6	≥ 7
$E_T^{miss} / \sqrt{H_T}$	> 3.5 GeV$^{1/2}$			



1110.2299,ATLAS bounds from multijets

SKLTP

In the MSSM

- At the one loop

$$m_h^2 \leq m_Z^2 \cos^2 2\beta + \frac{3}{4\pi^2} y_t^4 v^2 \sin^4 \beta \log\left(\frac{m_{\tilde{t}_1} m_{\tilde{t}_2}}{m_t^2}\right)$$

- The MSSM is SM like in most part of the parameter space

⇒ LEP bound: $m_h \geq 114.4\,\mathrm{GeV}$

Necessity of <u>rather heavy stops</u>!

Fine tuning!

(since the stops contribute at one loop also to m_Z)

"Susy little hierarchy problem"

SKLTP