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SFB 676 – Projekt B2

Search for Supersymmetry at CMS
(EPS Summary)

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LHC Discussion Meeting – Hamburg – 25th July '11

PHYSICS AT THE TERA SCALE
Helmholtz Alliance

Outline

- Introduction
- Exotic signatures
  - Stopped HSCP
  - Slowly moving HSCP
- "Conventional" searches
  - Jets, leptons and MET
  - Jets
- Summary

Disclaimer: Very personal selection of topics; much more excellent results have been shown by CMS speakers

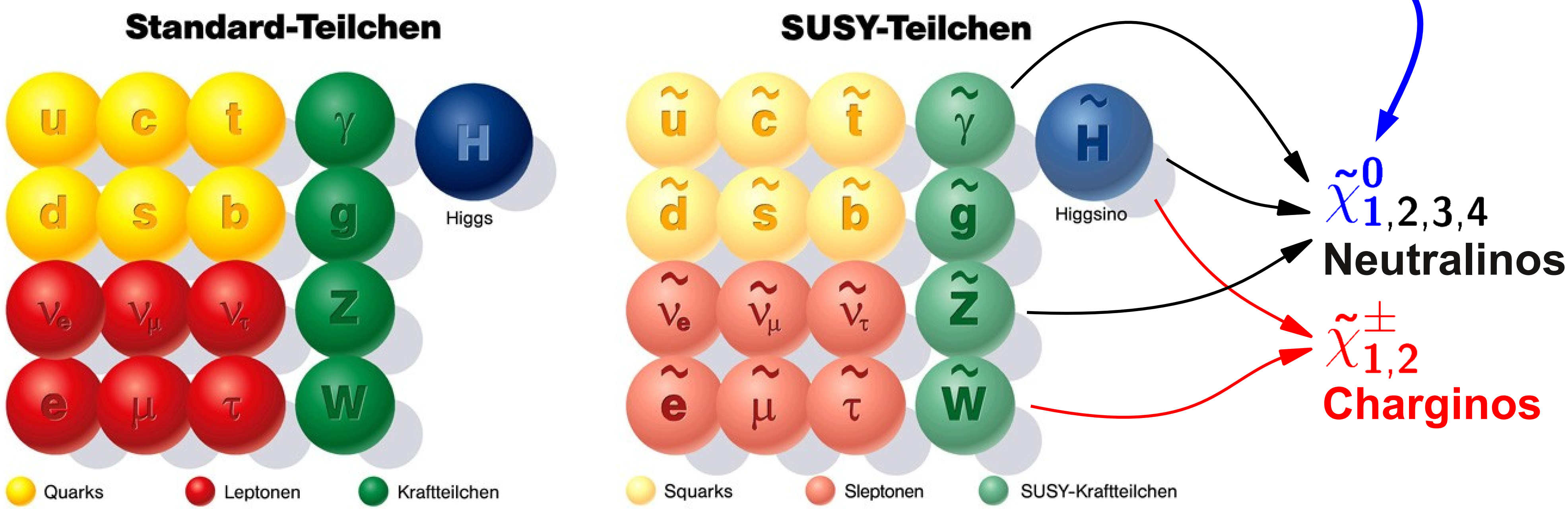
Supersymmetry

- New (last possible) symmetry between fermions and bosons
- Each SM particle gets identical SUSY partner (except for spin: ±½)
- Many attractive properties! **But: No SUSY particle discovered so far!**

  → **SUSY is broken** (typical masses ≤ ~1 TeV to keep attractive features)
- New conserved quantum number *R* parity: $R = (-1)^{3(B-L)+2S}$

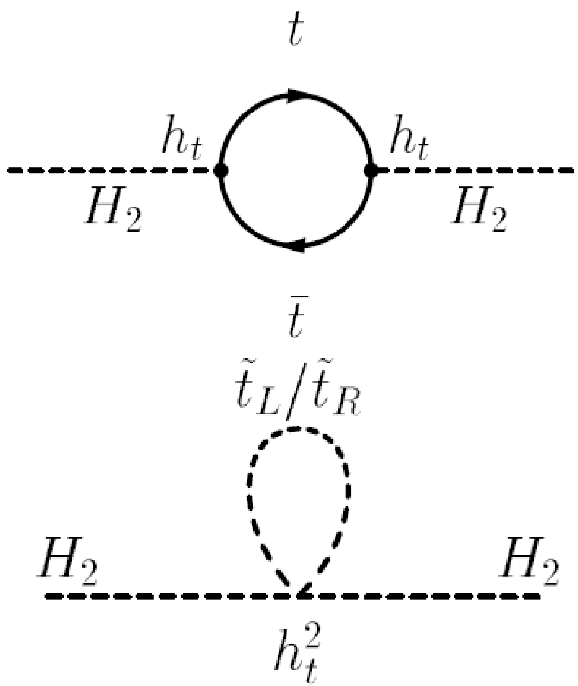
  → SUSY particles are only produced in pairs or associated

  → **Lightest SUSY particle (LSP) is stable → DM candidate**

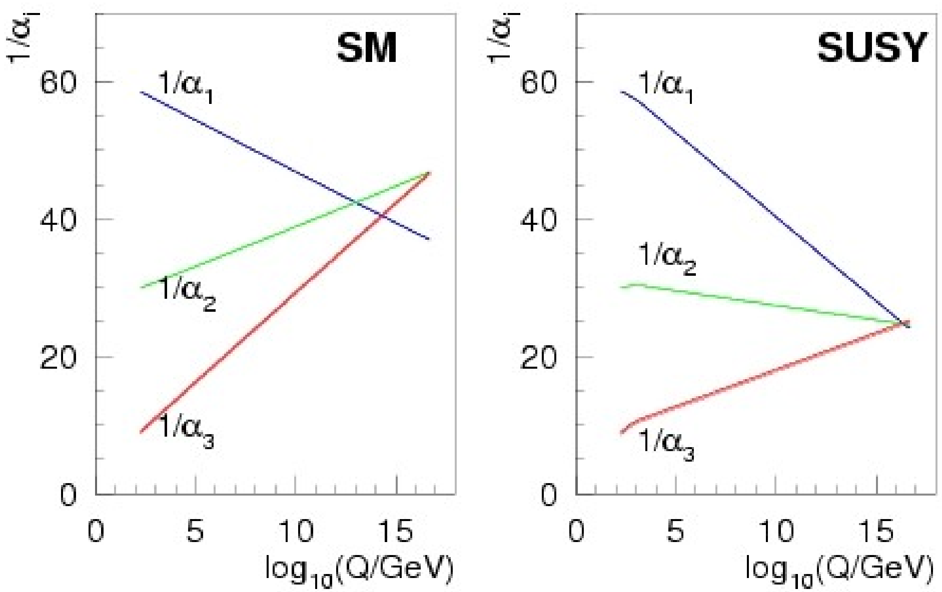


Supersymmetry

- **Fine tuning problem**
  - Radiative corrections to Higgs mass of order Λ (energy scale up to which SM is valid)
  - M_H at ~100 GeV requires accidental cancellations
  - **SUSY contributions = - SM contributions**
  - Similar arguments to explain hierarchy problem
- **Gauge unification**
  - New particle content changes running of couplings

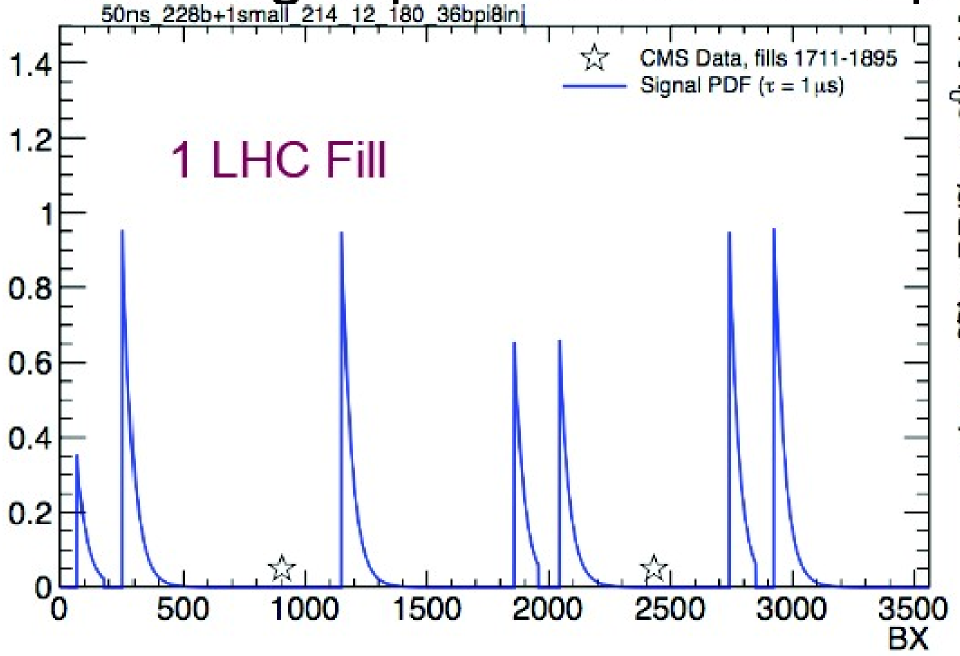


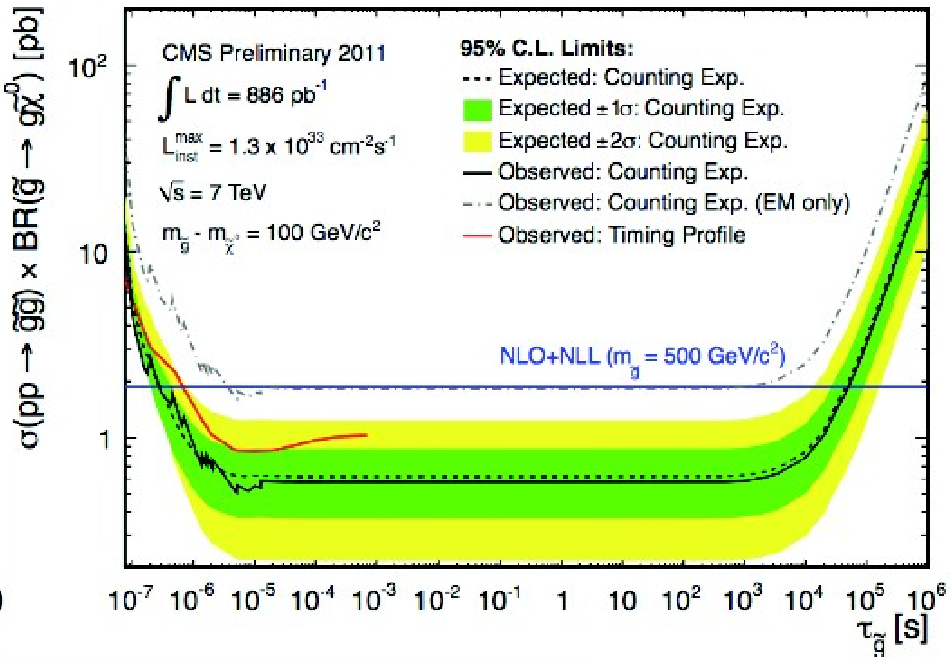
- Graviton (s = 2) ↔ $g/W/Z/\gamma$ (s = 1)
- **DM candidate**
  - In many scenarios the neutralino or the gravitino is a perfect candidate
- **"Natural" radiative EW symmery breaking**



Stopped HSCP

Counting experiment and time-profile analysis are performed





Lifetime	$L_{eff}(pb^{-1})$	Expected Bg	Observed
75 ns	4.3	0.11 ± 0.05	0
100 ns	12.5	0.35 ± 0.14	0
1 μs	139	3.3 ± 1.3	4
10 μs	352	10.1 ± 4.1	9
30 μs - 10^3 s	360	10.4 ± 4.2	10
10^4 s	268	10.4 ± 4.2	10
10^5 s	65	10.4 ± 4.2	10
10^6 s	7.5	10.4 ± 4.2	10

Counting Exp.

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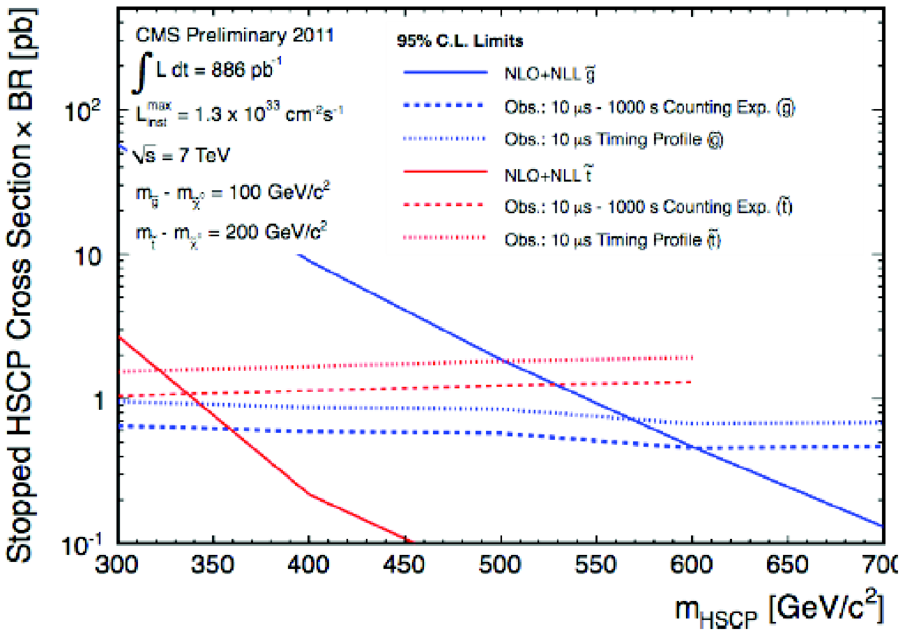
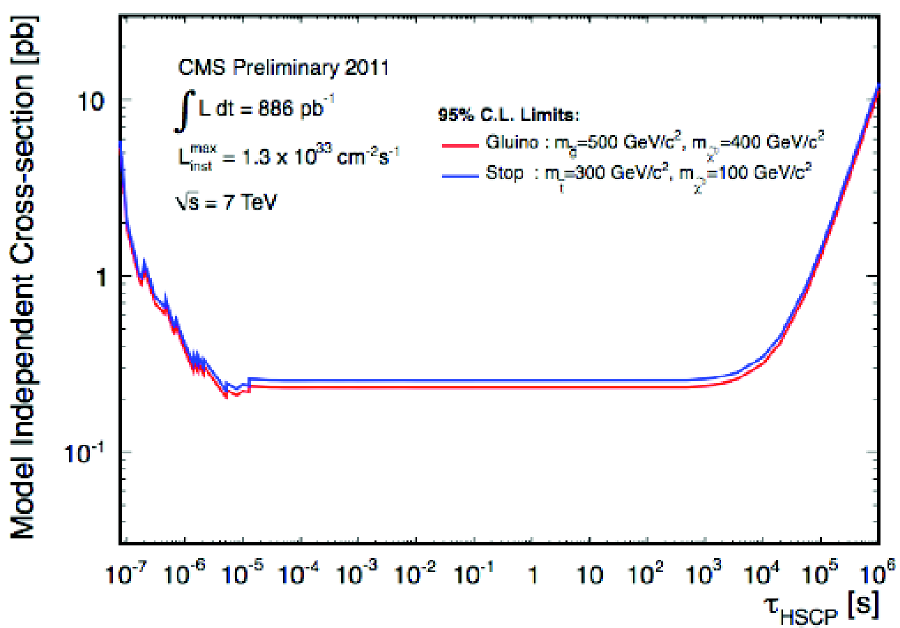
Stopped HSCP

- Gluino
  - M_{gluino} - $M_{neutralino}$ > 100 GeV, Br(gluino → g + neutralino) =100%, m_{gluino} < 601 GeV are excluded @95% C.L. for lifetimes from 10 μs to 1000 s
- Stop ← NEW Addition
  - For M_{stop} - $M_{neutralino}$ > 200 GeV, Br(stop → top + neutralino) =100%, m_{stop} < 337 GeV are excluded @95% C.L. for lifetimes from 10 μs to 1000 s
- Substantially extends our previous gluino limit (PRL 106 (2011) 011801) of 370 GeV
- 95% C.L. limits are also set for cross-section X BR X stopping efficiency to be interaction model independent





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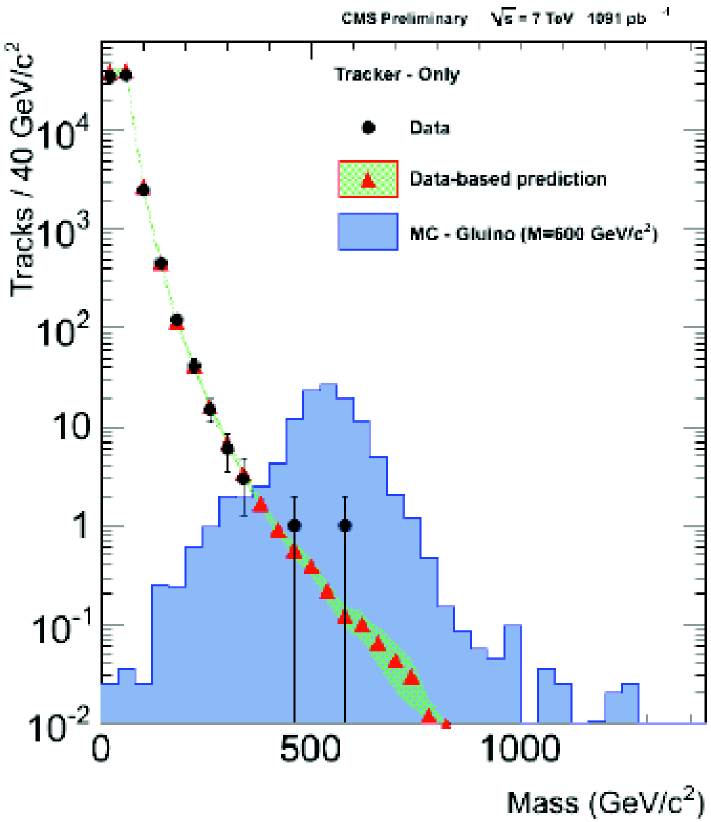
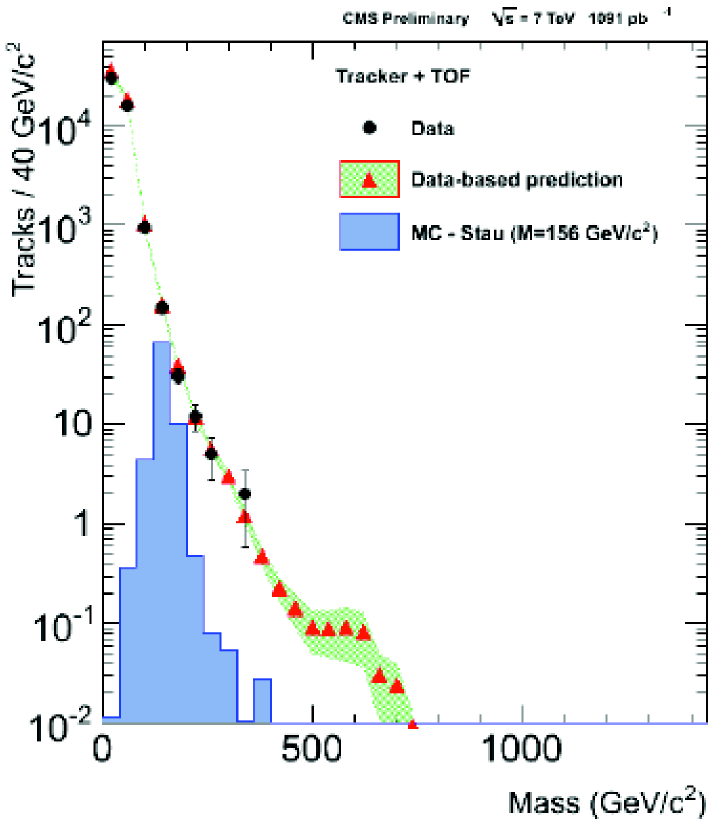
- Data-driven way to estimate background, utilizing the non-correlation between I_{as}, and β^{-1} and p_T
- Mass prediction made from pseudo-exp, using p, I_h, and β^{-1} PDF obtained from non-signal region
- Counting experiment in mass window [$M_{reco} - 2\sigma_{Mreco}$, 2 TeV] is performed with optimized I_{as}, β^{-1} and p_T selection to get the best expected limit for each model mass point considered





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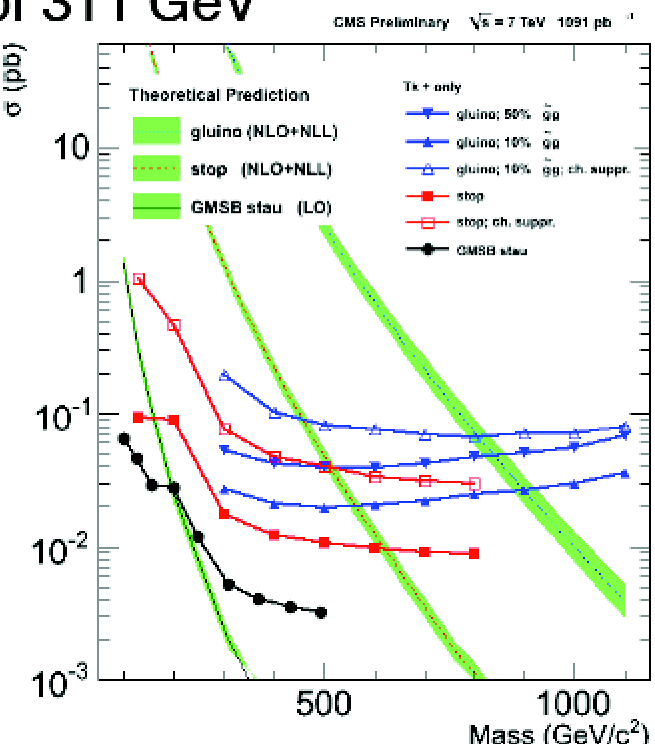
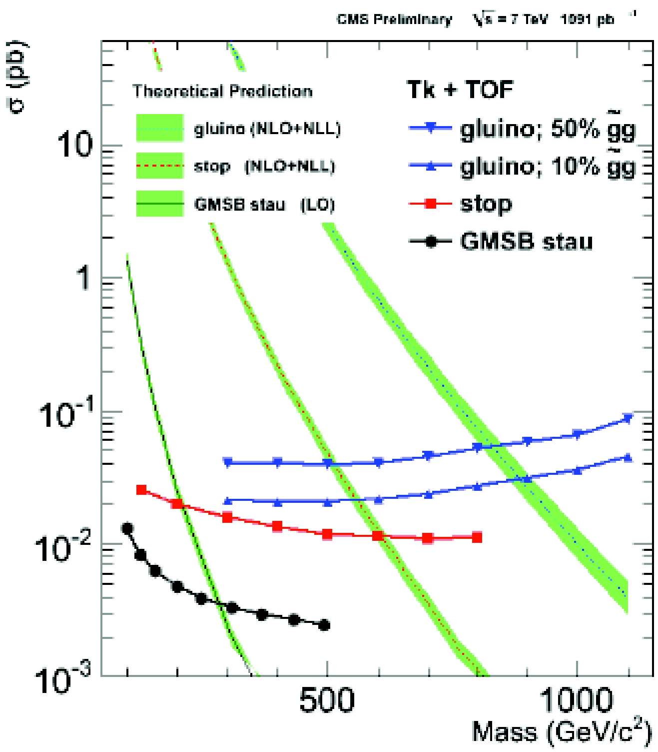
Slowly Moving HSCP

95% C.L. mass limits are set for

- Cloud model interaction scenario
  - Gluino (10% ~gg): 899 GeV, Gluino (50% ~gg): 839 GeV
  - Stop: 620 GeV GMSB Stau:293 GeV ← NEW Addition
- Charge suppression interaction scenario
  - Gluino(10% ~gg): 808 GeV, Stop: 515 GeV

Significant improvement over our previous gluino limit (JHEP 03 (2011) 024) of 311 GeV





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"Conventional" Searches

- R parity conserving SUSY models + neutralino LSP

  → Signature:
  - High energetic jets
  - Possibly, one or more high energetic leptons
  - Large amounts of MET
- The tails of some distributions are difficult to simulate
  - Lepton isolation
  - MET from detector effects

  → Do not rely on Monte Carlo simulation only, but perform data driven background estimates

Opposite Sign Di-Leptons (Z Veto)

Two data driven methods used in this search:

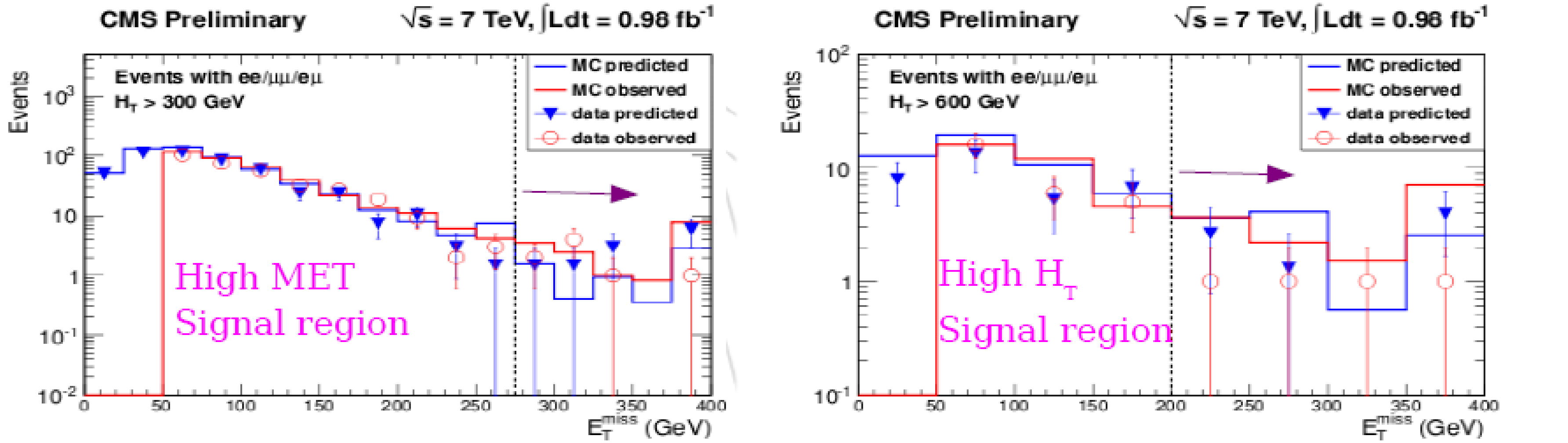
a) Lepton spectrum method ($p_T(ll)$) [V. Pavlunin, PRD 81, 035005 (2010)

This method relies on the $p_T(ll)$ distribution to get $p_T(\nu\nu)$

In SM, the neutrino and the lepton p_T are anti-correlated in an given event

- Overall spectra are similar

Corrections are needed to account for cuts on MET, polarization effects due to Ws. Both of these are well modeled in MC.



	high E_T^{miss} signal region	high H_T signal region
observed yield	8	4
MC prediction	7.3 ± 2.2	7.1 ± 2.2
ABCD′ prediction	4.0 ± 1.0 (stat) ± 0.8 (syst)	4.5 ± 1.6 (stat) ± 0.9 (syst)
$p_T(\ell\ell)$ prediction	14.3 ± 6.3 (stat) ± 5.3 (syst)	10.1 ± 4.2 (stat) ± 3.5 (syst)

The observation is consistent with the prediction

Sanjay Padhi

OS Di-Leptons (with Z)

Search for SUSY in Z + Jets + MET final state (e.g $\chi^2_0 \rightarrow Z\, \chi^1_0$)

- Two isolated leptons (e, μ): p_T > 20 GeV
- At least 3 jets with p_T > 30 and $|\eta|$ < 3.0, MET > 30 GeV
- Require same-flavor pairs in Z mass window $|m_{ll} - Z| < 20$ GeV

<u>Backgrounds:</u>

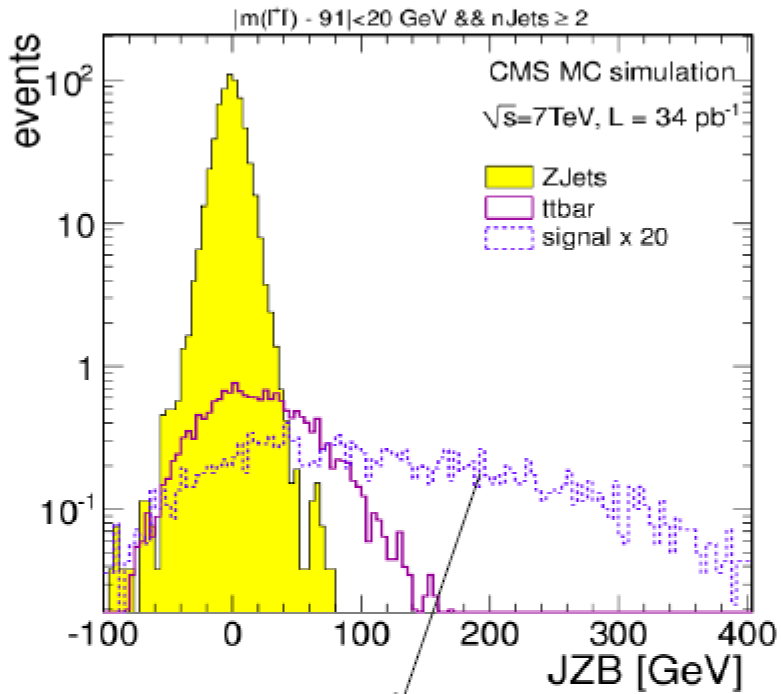
- Z + Jets + instrumental MET
- OSSF dileptons from ttbar

  (Predict using OSOF subtraction method)

Define:

$$JZB = \left|\sum_{jets} \vec{p}_T\right| - \left|\vec{p}_T^{\,Z}\right|$$

JZB < 0: Control region



Substantial tail for SUSY in JZB > 0 events

Use JZB (<0) peak events to predict

JZB (>0) peak events after the eμ subtraction

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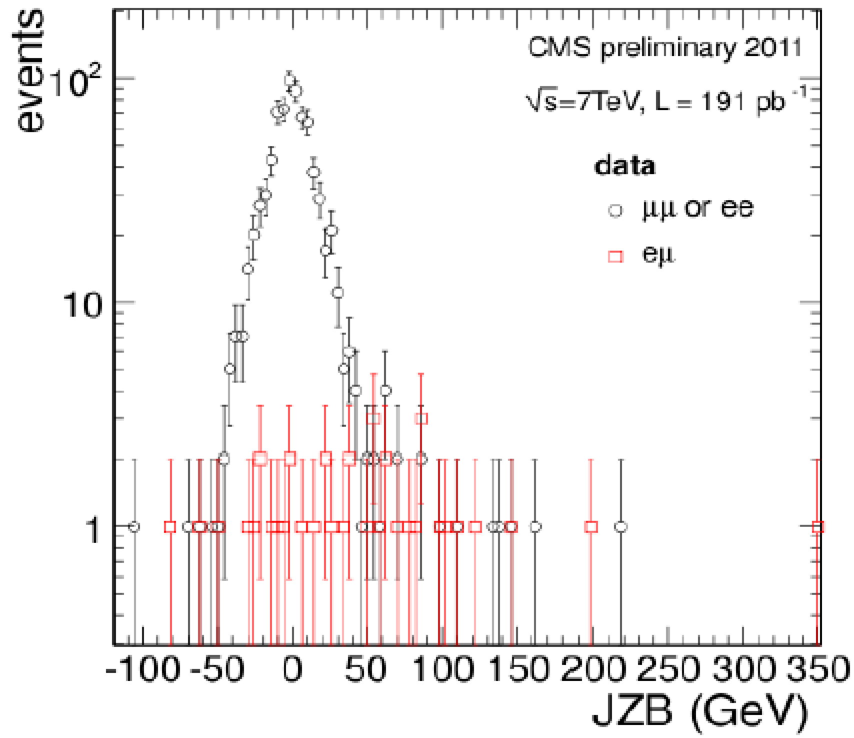
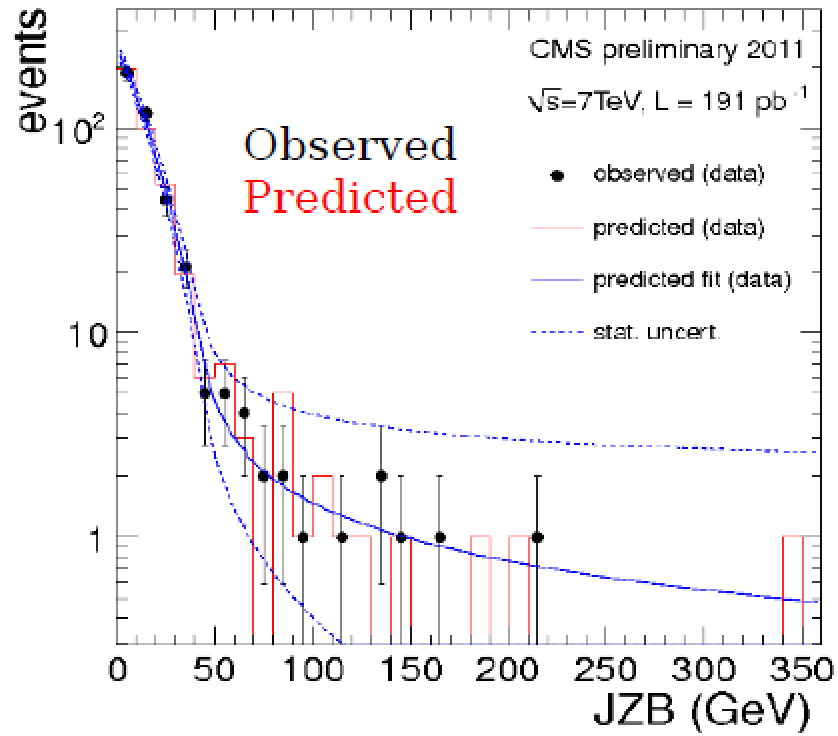
OS Di-Leptons (with *Z*)

Two regions defined: JZB > 50 GeV (reference region); JZB > 100 GeV (search region)





The background prediction has been fitted to ±σ display uncert. band

Region	Observed events	Background prediction	MC expectation
$JZB > 50\,\text{GeV}$	20	$24 \pm 6(\text{stat})\pm 1.4(\text{peak})^{+1.2}_{-2.4}(\text{sys})$	16.0 ± 1.2 (MC stat)
$JZB > 100\,\text{GeV}$	6	$8 \pm 4(\text{stat})\pm 0.1(\text{peak})^{+0.4}_{-0.8}(\text{sys})$	3.6 ± 0.4 (MC stat)

Prediction agrees well with the observation in both regions

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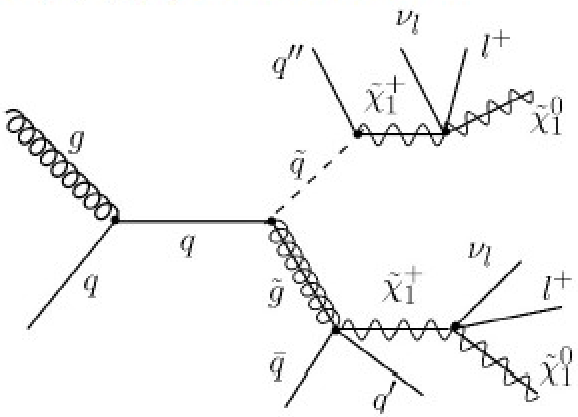
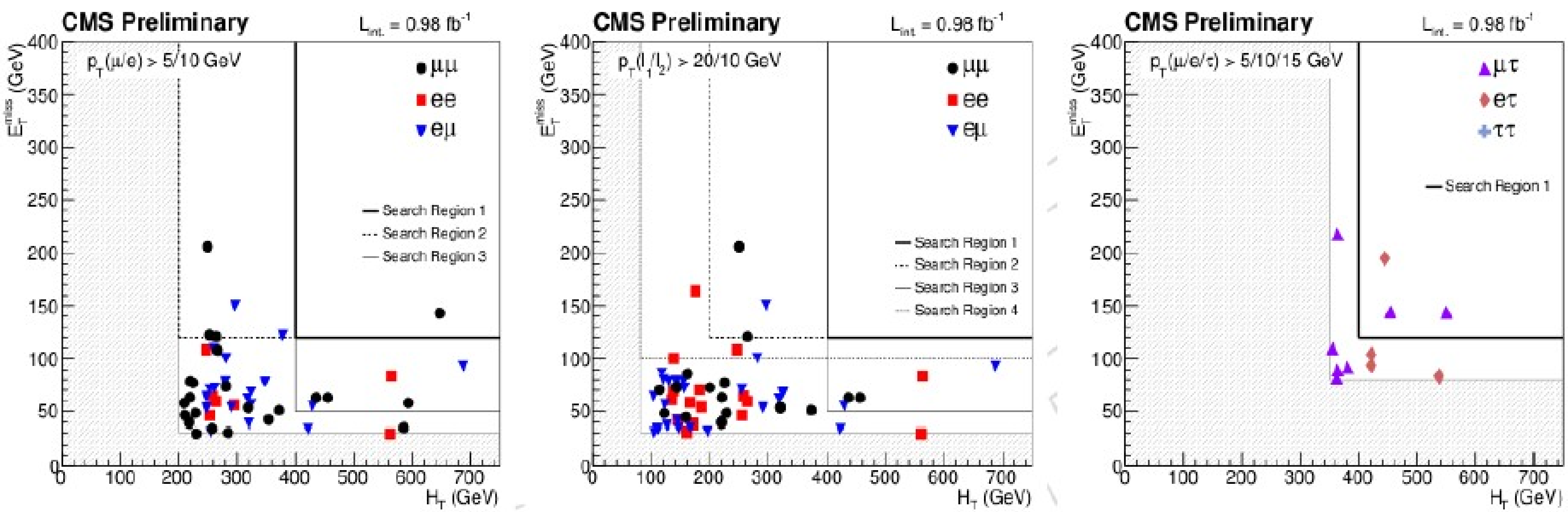
Same Sign Di-Lepton Searches

- Isolated same sign dileptons (SS) are very rare in the SM
- Several search regions with three lepton flavors (e, μ, τ) are studied
- A natural SUSY signature
- All cross channels are included in

three lepton flavors :





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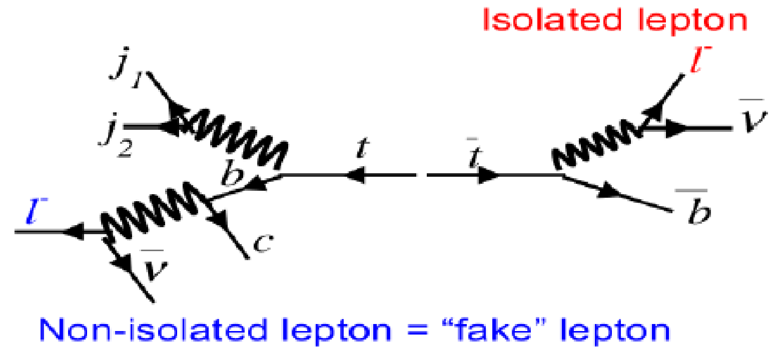
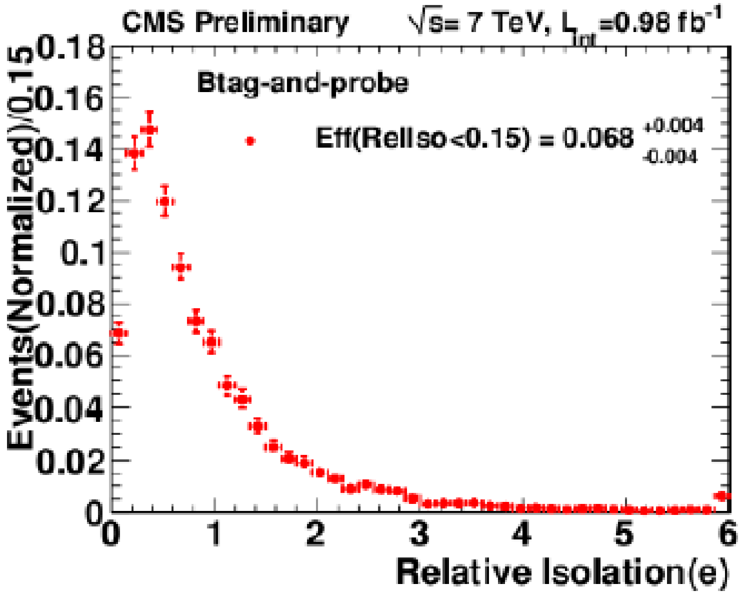
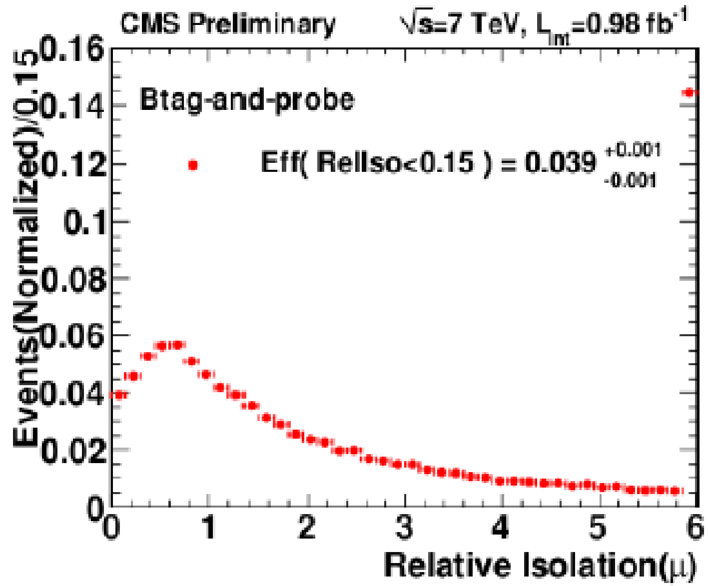
SS – Charge Misidentification

Major Backgrounds:

- "~Fake" leptons from ttbar (b/c → e,μ)
- Charge Mis-reconstruction
- QCD fakes in case of tau final states







- Use tag and probe in bbbar (QCD) events to measure isolation efficiency
- Re-weight this distribution to reflect lepton p_T and Njets in ttbar expectation
- Use this isolation efficiency to determine background

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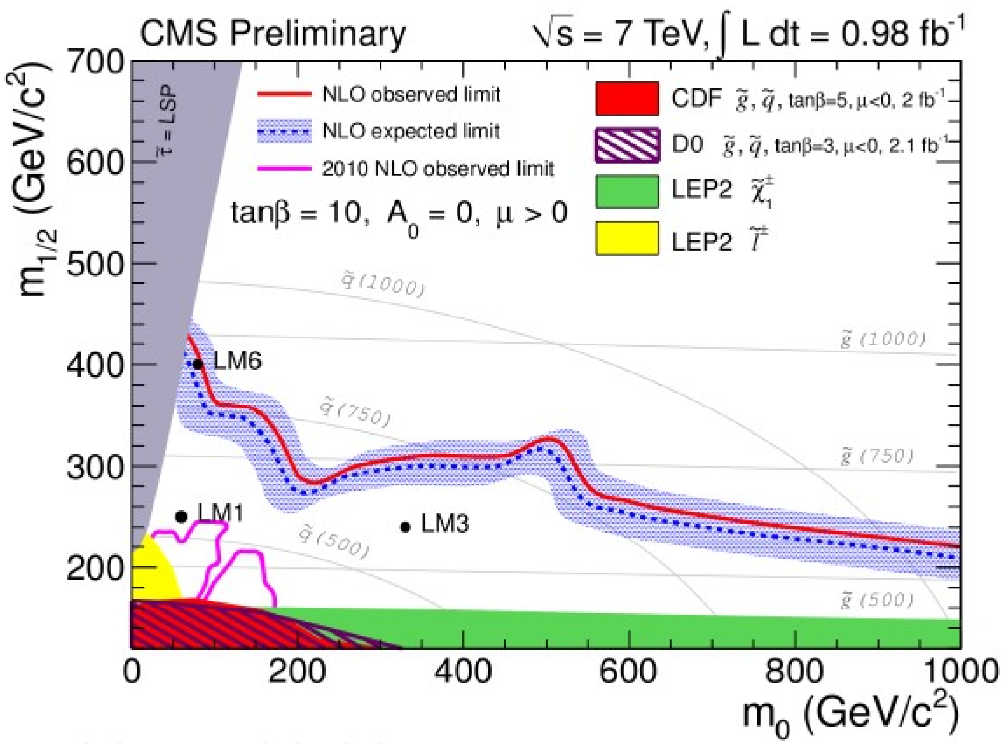
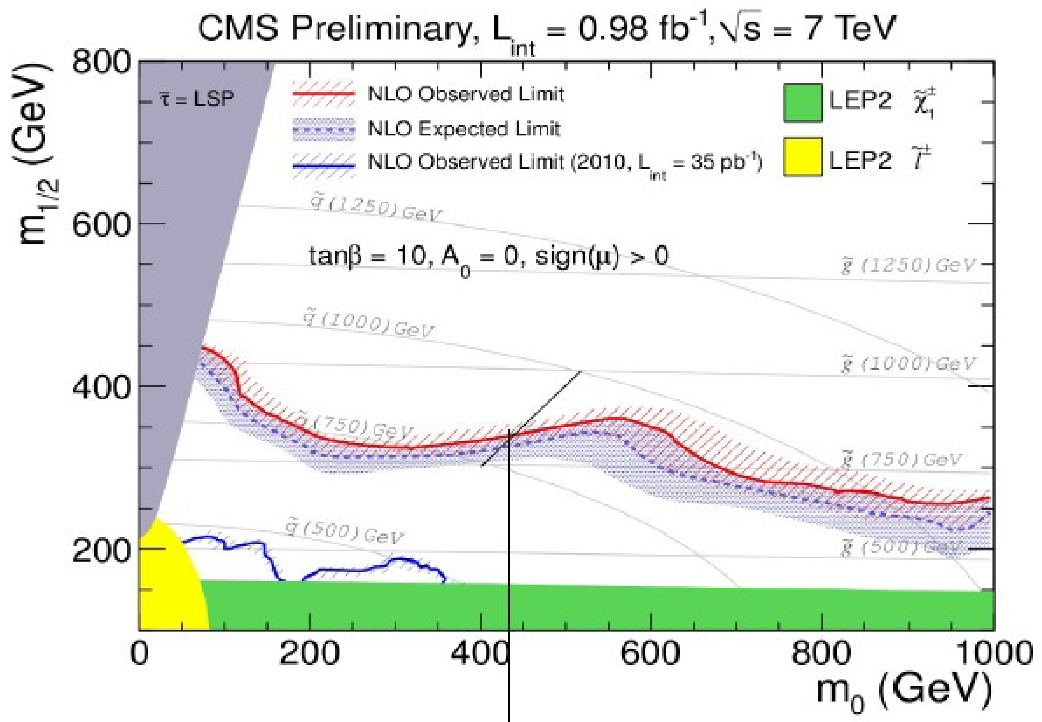
Leptonic Searches – Results 1 fb^{-1}

<u>OS dileptons study</u>



<u>SS dileptons study</u>



- CMS exclusion reach is well beyond previous Tevatron limits
- Assuming same squarks and gluino masses

CMS using 0.98 fb^{-1} excludes @ 95% CL., M_{SUSY} ~ 825 GeV

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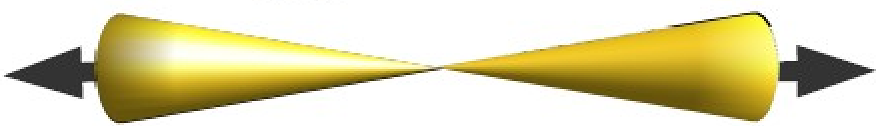
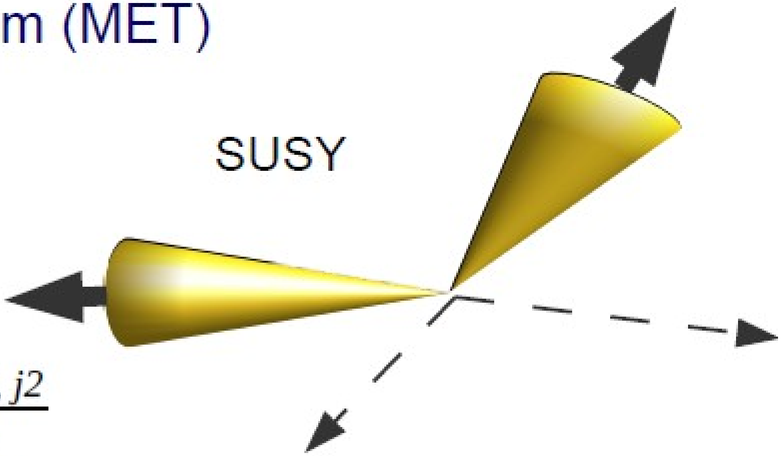
The α_T Search

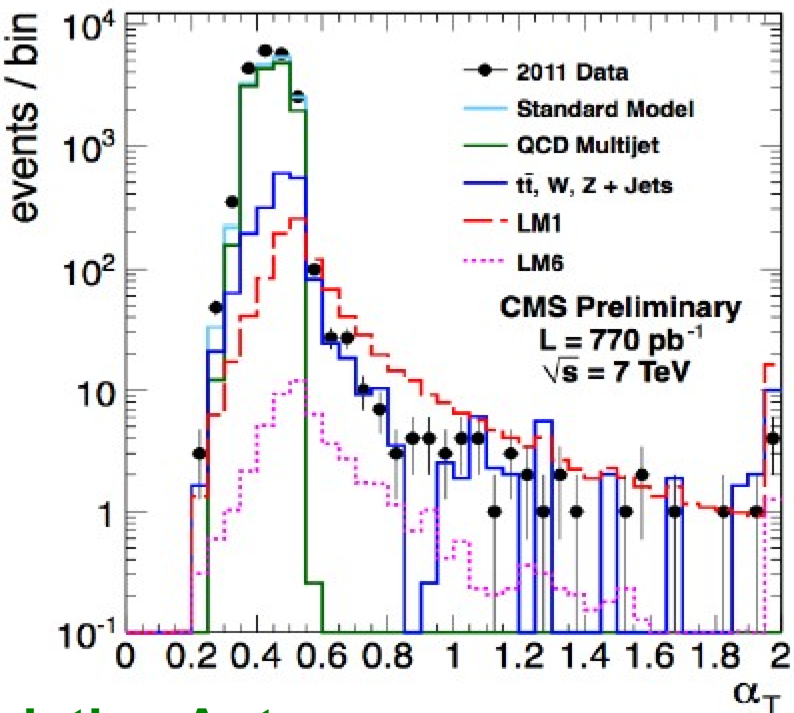
Recombine jets to two pseudo-jets, suppress QCD by α_T:

- α_T uses jet momenta and angles
- no direct use of missing transverse momentum (MET)

CMS PAS SUS-2011-003







$$\alpha_T = \frac{p_{T,j2}}{M_T}$$

$$M_T = \sqrt{2 p_{T,j1}\, p_{T,j2} (1 - \cos(\Delta\phi))}$$

$$\rightarrow \alpha_T = \sqrt{\frac{p_{T,j2} / p_{T,j1}}{2(1 - \cos\Delta\phi)}}$$

In QCD: $\alpha_T \leq 0.5$ since $p_{T,j2}$ is by definition the lower momentum jet.
Exception: A third jet is completely lost.

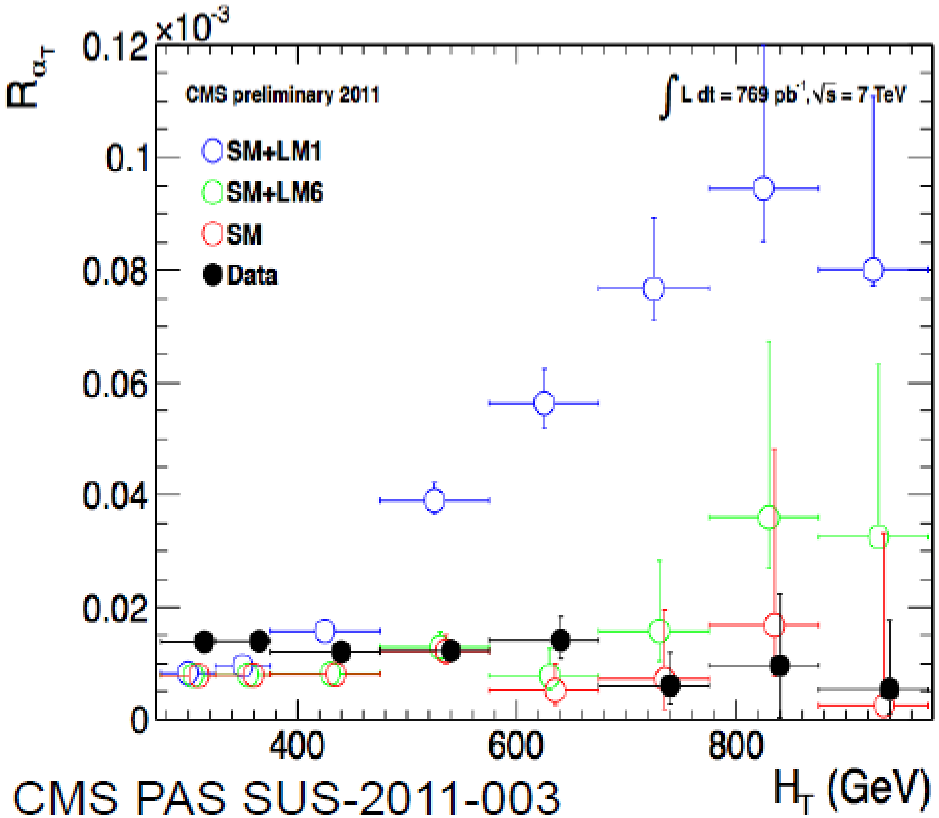
Christian Autermann

Christian Autermann

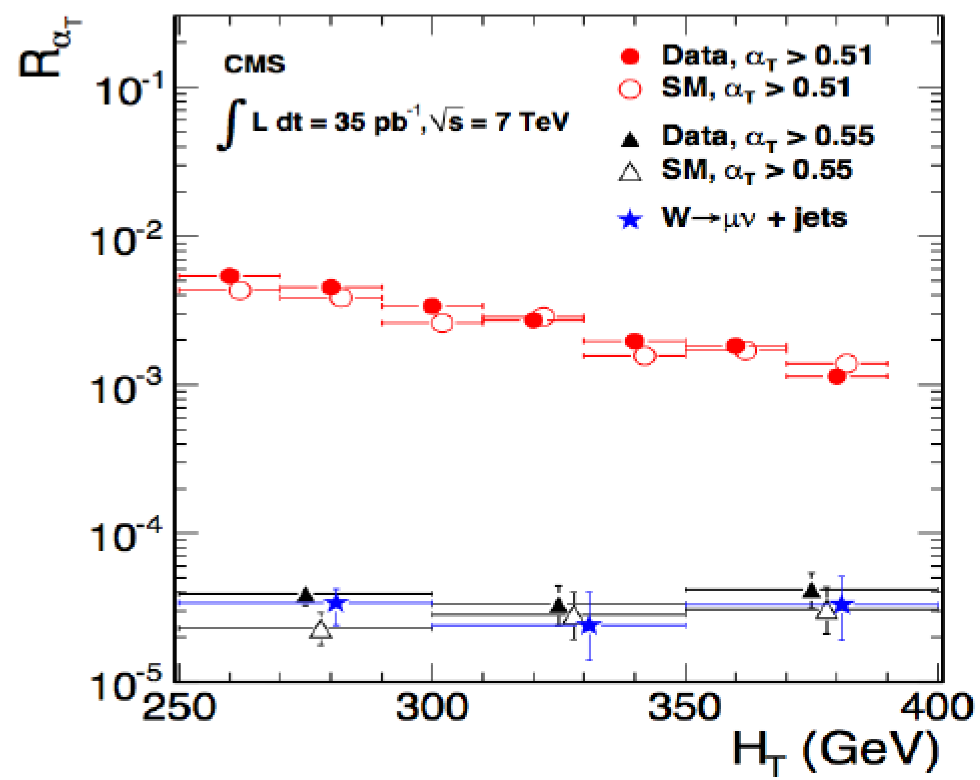
$$R_{\alpha_T} = \frac{\alpha_T > 0.55}{\alpha_T < 0.55}$$

EWK: real MET ↔ constant $R_{\alpha T}$

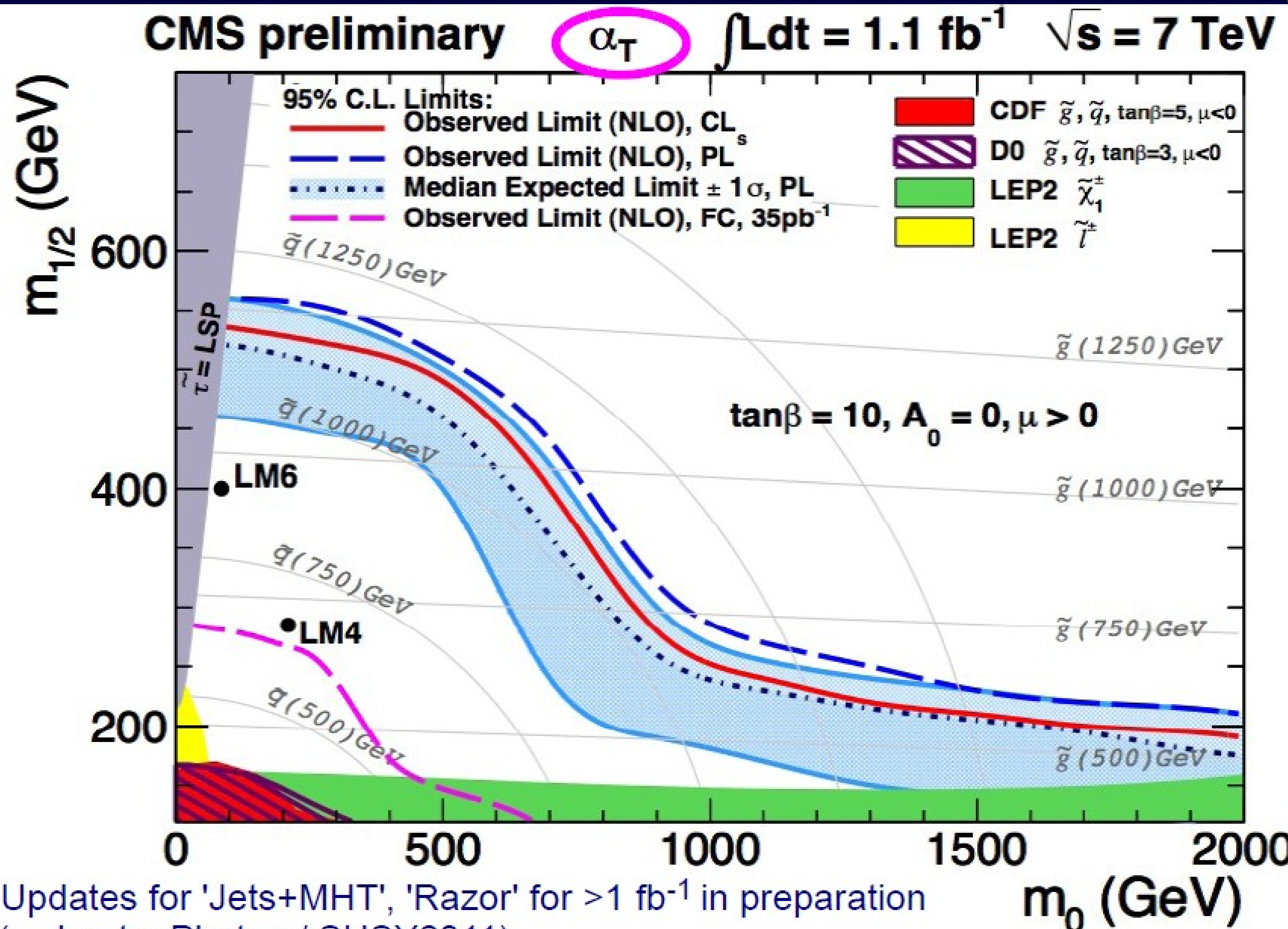
QCD: MET from jet-resolution ↔ $R_{\alpha T}$ Falling with HT since jet resolution improves with pT



CMS PAS SUS-2011-003



The α_T Search – Results with 1.1 fb^{-1}



- Updates for 'Jets+MHT', 'Razor' for >1 fb^{-1} in preparation (→ LeptonPhoton / SUSY2011)

Christian Autermann

Summary

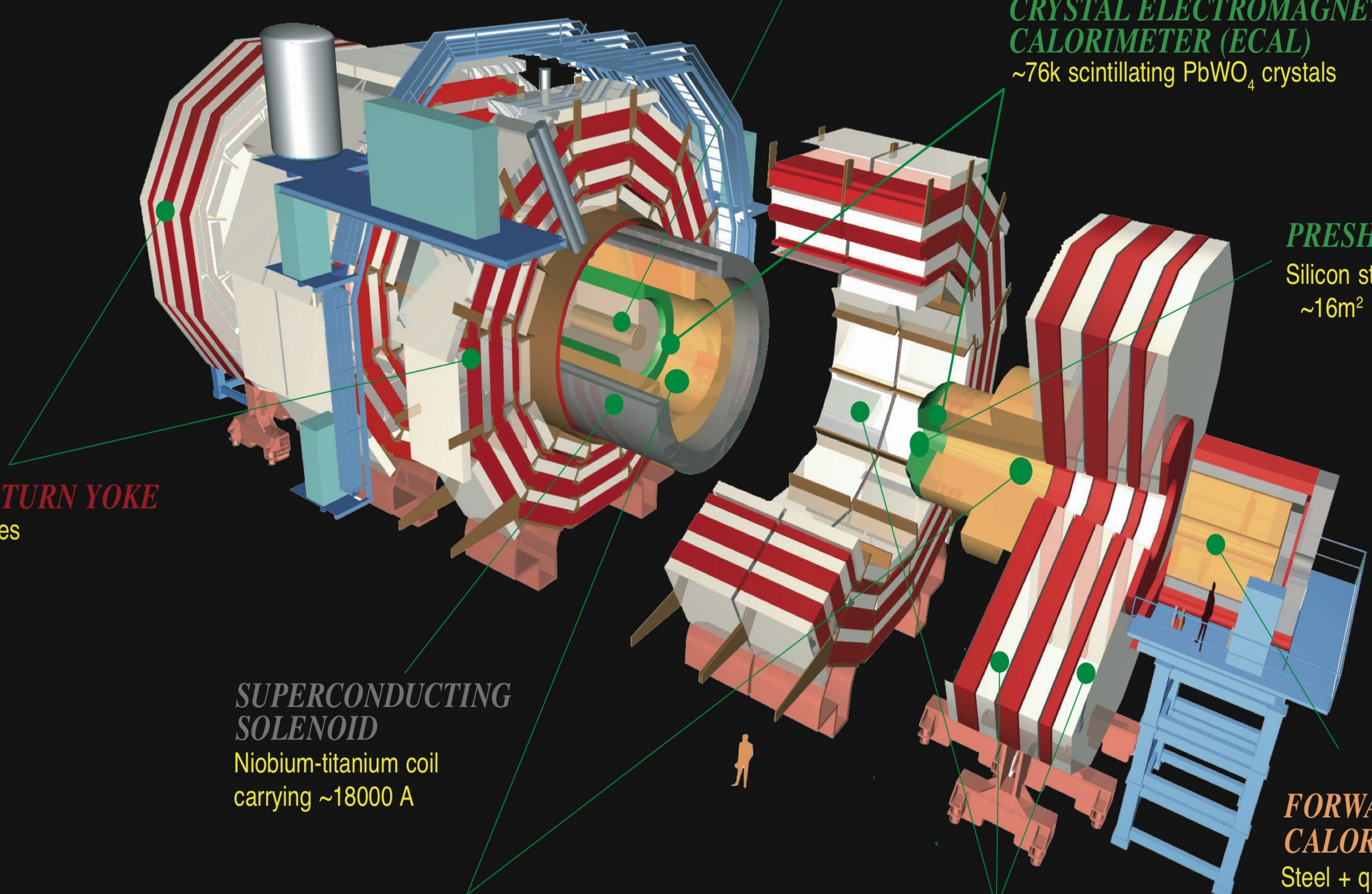
- CMS performed searches for supersymmetry in a wide range of possible signatures
- **So far, no significant deviation from the SM has been found**

  → Setting (together with ATLAS) most stringent limits on SUSY models

… more data is coming in → Stay tuned!

Backup

CMS Detector



Total weight	**: 14000 tonnes**
Overall diameter	**: 15.0 m**
Overall length	**: 28.7 m**
Magnetic field	**: 3.8 T**