Searches for high-mass (experimantally) non-resonant signals at CMS

Heavy Gauge Boson W', Type III Seesaw Heavy Fermions, Black Holes

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on behalf of the CMS Collaboration

Physics Institute III A
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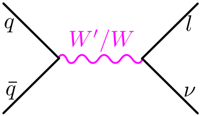
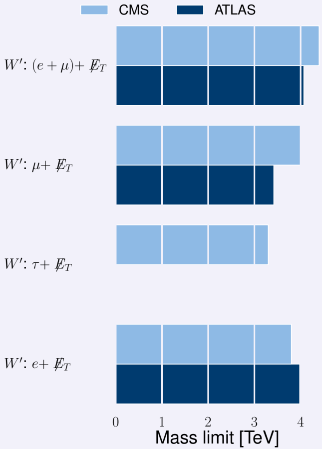
Heavy Gauge Bosons W′



Results



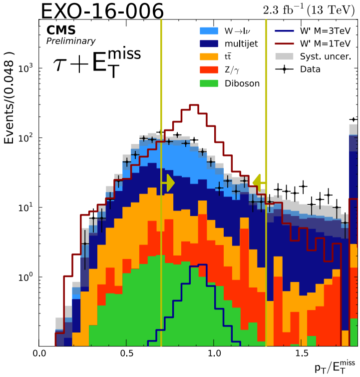
Model Assumptions:

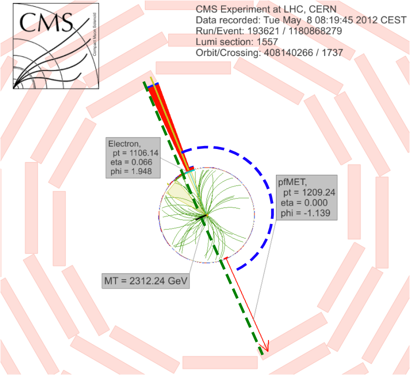
- W′ serves as classic benchmark model for new heavy gauge bosons
- Sequential Standard Model (SSM) with same coupling as SM (generic)
- Models in this talk suppress coupling to gauge bosons.

Heavy Gauge Bosons W′

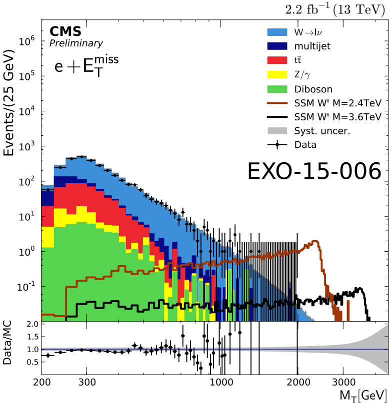
Search Strategy:

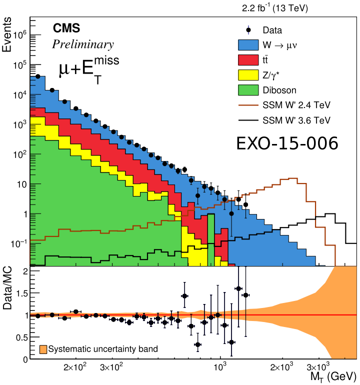
- Select events with one well reconstructed high-p_T lepton
- Consider two-body decay kinematic for heavy W′:
  - Balanced:
    - e/μ: $0.4 < p_T/\not{E}_T < 1.5$
    - τ: $0.7 < p_T/\not{E}_T < 1.3$
  - Back-to-back:
    - e/μ: $|\Delta\phi\left(p_T^l, \vec{p}_T^{miss}\right)| < 2.5$
    - τ: $|\Delta\phi\left(p_T^l, \vec{p}_T^{miss}\right)| < 2.4$





Heavy Gauge Bosons W': e/μ channels

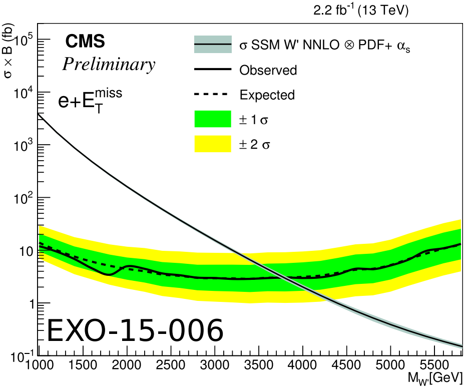


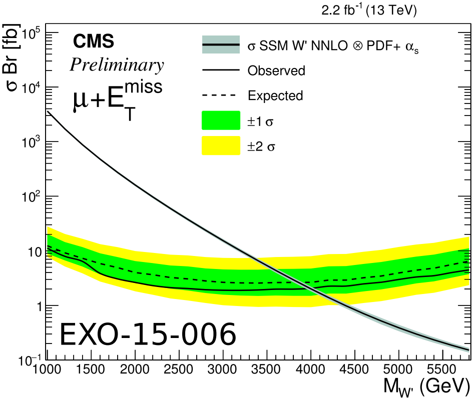


- Dominating uncertainty: PDFs ($\sim$ 9% at 2 TeV)
- Event with highest mass: $M_T = 2.0$ TeV

- Dominating uncertainty: muon p_T scale ($\sim$ 21% at 2 TeV)
- Event with highest mass: $M_T = 1.3$ TeV

Heavy Gauge Bosons W': e/μ channels





Electron Channel:

- W' mass limit: 3.8 TeV

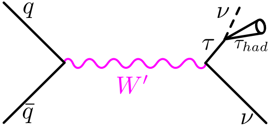
Muon Channel:

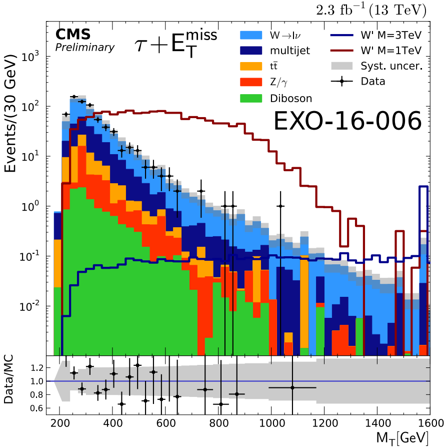
- W' mass limit: 4.0 TeV

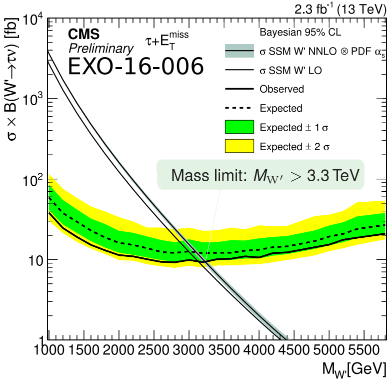
- **Combined W' mass limit**: 4.4 TeV

Heavy Gauge Bosons W': τ (had) channel

- $p_T^\tau > 80\,\text{GeV}$, $|\eta| < 2.1$
- Dominating uncertainty: tau p_T scale (20% on yield for $M_T > 1$ TeV)
- Event with highest mass: $M_T = 1.0\,\text{TeV}$

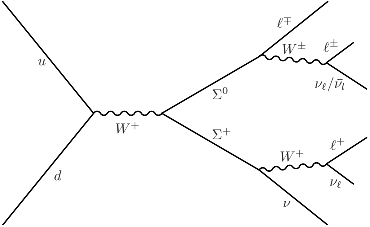






- Model unspecific limits in PAS

Type III Seesaw Heavy Fermions

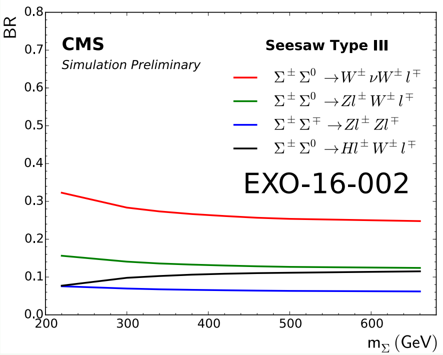


Theory

- Neutrinos are majorana particles
- Type III Seesaw mechanism explains masses with coupling to heavy SU(2) triplet:
  - Two charged dirac leptons $\Sigma^\pm$
  - One neutral majorana lepton Σ^0
- Flavor democratic mixing angles: $V = 10^{-6}$

Search Strategy

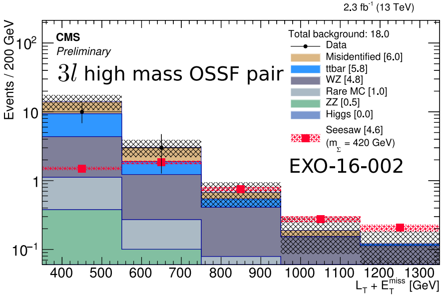
- Search for pair production of $\Sigma^\pm, \Sigma^0$
- Search in sum of lepton p_T: L_T
- Split 3 lepton final states by opposite-sign same flavor (OSSF) mass: low mass, on-Z, high mass
- New in 13 TeV: 4 lepton final states with at least one OSSF

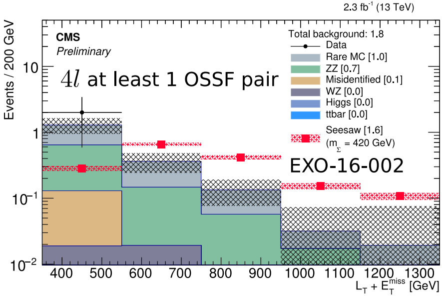


Type III Seesaw Heavy Fermions

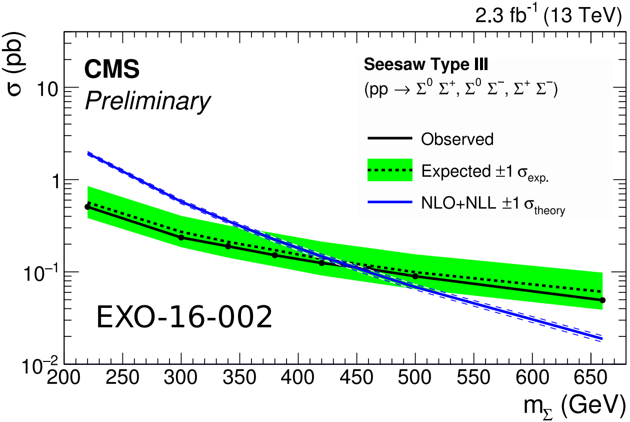
Uncertainties

- Most channels are hardly influenced by systematics due to small statistics
- Background yield uncertainties:
  - Normalization in data driven estimates: 5% – 40%
  - $\not{E}_T$ resolution: 0.6% – 6.5%
- Influence from PDF, renormalization / factorization scales on signal covered by 10% uncertainty





Type III Seesaw Heavy Fermions



Mass limit: $M_\Sigma > 440\,\text{GeV}$

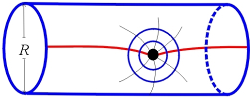
Black Holes

Theory:

- Arkani-Hamed Dvali Dimopulos (**ADD**) model
- n_{ED} additional compactified dimensions
- Fundamental Planck scale M_D lowered to TeV region
- Black hole (BH) models with ADD as base theory
- Production cross section $\approx$ area of disk with Schwarzschild radius
- BH production above threshold $\mathrm{M}_{BH}^{min} \geq \mathrm{M}_D$

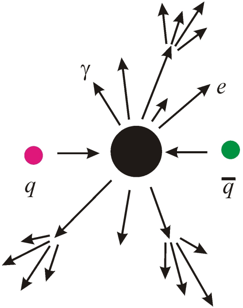
BH Decays

- **Semiclassical $\mathbf{M_{BH}^{min} \gg M_D}$:**
  BH evaporates via Hawking radiation $\rightarrow$ multi particle final states with particle type distribution according to degrees of freedom
- **Quantum Black Holes $\mathbf{M_{BH}^{min} \approx M_D}$:**
  Decay into few objects before thermalization (e.g. $e\mu$)



$$\mathrm{R}_s = \frac{1}{\sqrt{\pi}\mathrm{M}_D}\left[\frac{\mathrm{M}_{BH}}{\mathrm{M}_D}\left(\frac{8\Gamma\frac{n_{ED}+3}{2}}{n_{ED}+2}\right)\right]^{\frac{1}{n_{ED}+1}}$$

$$\sigma \approx \pi \mathrm{R}_s^2$$



Images ©Sabine Hossenfelder

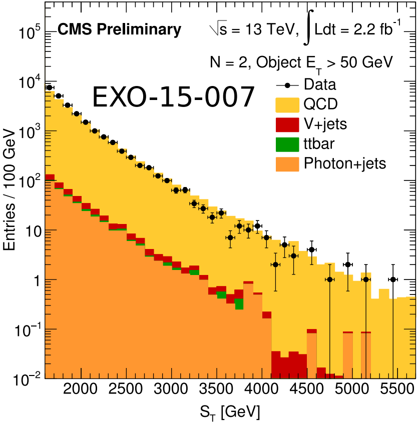
Black Holes

Analysis Strategy:

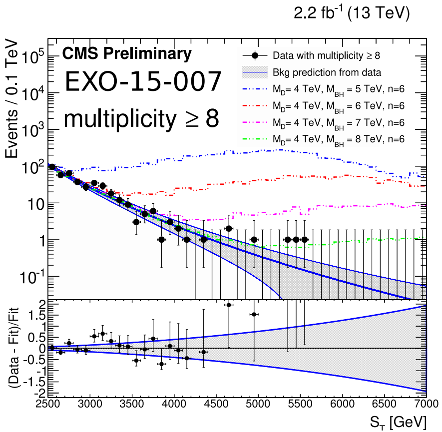
- Define final states only by particle multiplicity
- Search variable $\mathrm{S_T} = \left(\sum_{i=1}^{N} E_{\mathrm{T},i}\right) + (\not{E}_T > 50\ \mathrm{GeV})$

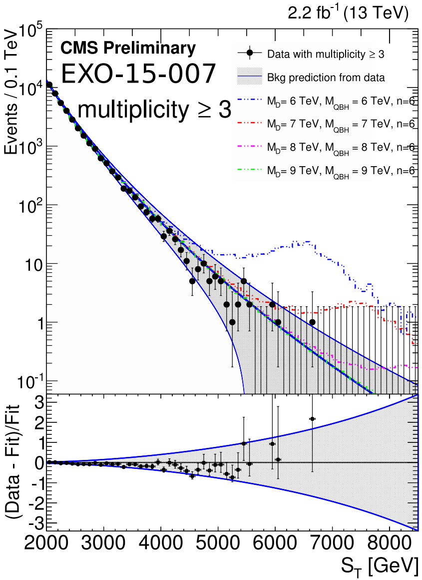
Data Driven Background Estimation:

- Empirical observation: Shape of $\mathrm{S_T}$ distribution does not depend on multiplicity for multijet events above turn-on threshold.
- Normalize multijet background to dijet spectrum at small $\mathrm{S_T}$ $\rightarrow$ negligible signal expectation



Black Holes

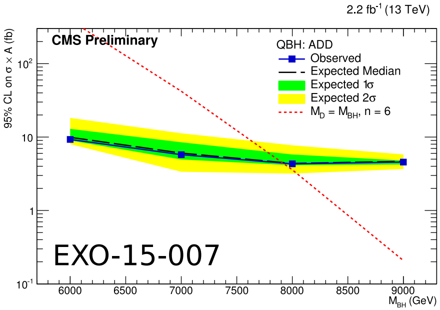


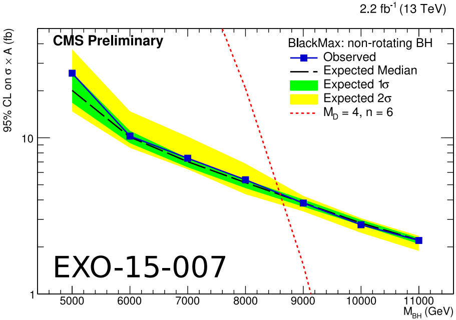


Systematic Uncertainties:

- Several uncertainties contribute with O(5%)
- Uncertainty from background fit (up to 200%) dominates in most regions

Black Holes: Benchmark Results



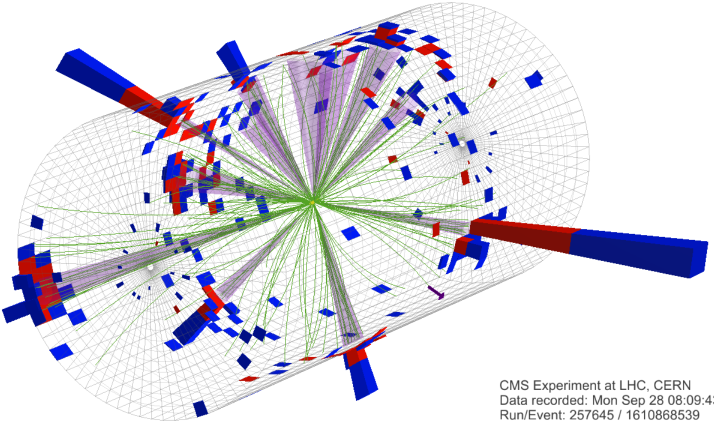


- **Semiclassical**
  (ADD n=6, $M_D = 4$ TeV) $M_{BH}^{min} < 8.7$ TeV
- **QBH**
  (ADD n=6) $M_{BH}^{min} < 8$ TeV

Model unspecific limits in PAS

Conclusion

- Searches for non-resonant signatures found no evidence for new physics
- Limits for W', ADD and Black Hole models extended with new 13 TeV data
- Expect more results and additional interpretations soon



CMS Experiment at LHC, CERN
Data recorded: Mon Sep 28 08:09:43 2015 CEST
Run/Event: 257645 / 1610868539

Backup

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W′: e/μ Object Selection

Global

- Objects reconstructed with particle-flow technique
- Vetos for calorimeter noise, beam halos, jets near dead channels

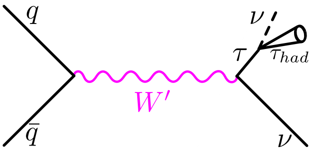
Electrons

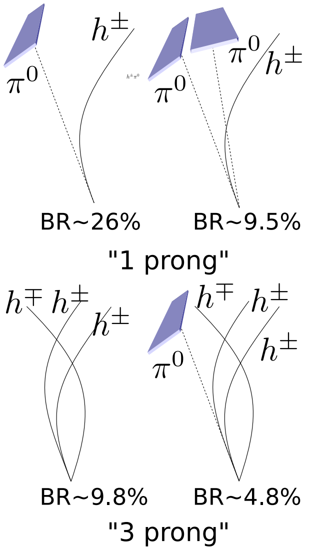
- Offline $p_T > 130$ GeV
- Isolation in tracker and calorimeters
- Ratio of Ecal & Hcal isolation
- Electronmagnetic shower shape
- One hit in innermost track layer
- Veto events with additional electrons with $E_T > 35$ GeV

Muon

- Dedicated high-p_T reconstruction
- Hits in pixel & strip tracker
- Hits in at least 2 muon system segments
- Primary vertex:
  - Transverse impact parameter $|d_{xy}| < 0.02cm$
  - Longitudinal distance $|d_z| < 0.5cm$
- isolated in tracker
- fit quality $\sigma_{p_T}/p_T < 0.3$
- Veto event with additional muons with $p_T > 25$ GeV

Heavy Gauge Bosons W′: τ channel





Tau Selection:

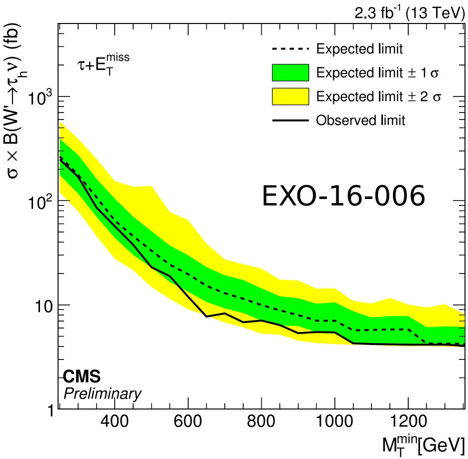
- $p_T^\tau > 50\,\text{GeV}$, $|\eta| < 2.1$
- "Hadron plus strips" algorithm based on decay modes via specific intermediate resonances
- Isolation: No additional charged hadrons / photons objects near τ candidate
- Total reconstruction efficiency 80% flat above $p_T^\tau > 500\,\text{GeV}$

Heavy Gauge Bosons W': τ channel

Model unspecific limits:

- W' limit influenced by assumptions about signal shape
- Consider only total background yield above M_T threshold
- Limit valid for W'-like models $\rightarrow$ comparable signal efficiency in acceptance

Model unspecific limit will be added for e/μ in journal publication



Black Hole Model unspecific Limit