Effective models of Fermion Compositeness

Composite models with higher isospin, and exotically charged particles
(doubly charged leptons L^{++} and quarks of charge $Q=5/3$ e,
heavy composite Majorana neutrinos)

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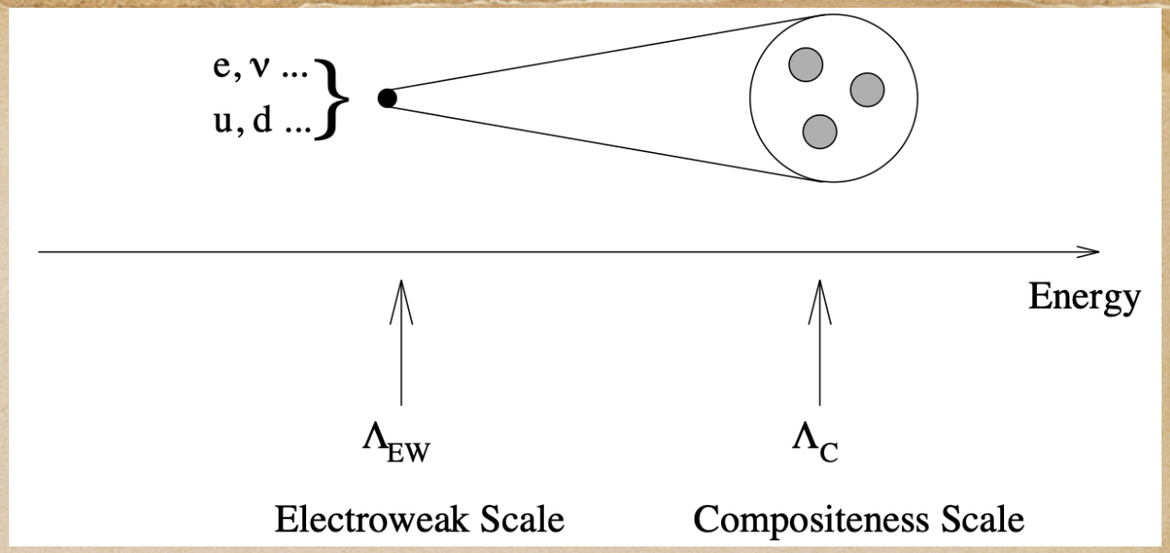
COMPOSE-IT, Perugia, January 27-28, 2020

Outline of Talk

- Brief intro to effective fermion composite models (extended iso-spin models, gauge and contact interactions, exotic states)
- Quick Recap of our group pheno-exp activities over the last 8-10 years (historical perspective)
- A few example(s):
  - Doubly Charged Leptons (where it all started!!)
  - Heavy composite Majorana neutrino (pheno + CMS analysis);
  - Phenomenology of production at LHC of heavy Q(5/3)
  - UNITARITY, (implementation method not uniquely defined)
- Conclusions/outlook

Composite Models



- The idea is that at some high energy scale Λ a further level of compositeness of the so called "elementary" particles will show up. It goes back quite some time.
- P.A.M Dirac, Sci. Am. 208,45 (1963); Terazawa et al., PRD 15, 480 (1977); Eichten, Lane, Peskin, PRL 50, 811 (1983); Cabibbo, Maiani, Srivastava, PLB 139, 459 (1984);
- Quite natural expectations in such framework are:
  - excited states (e*,q* etc..) of mass m*;
  - contact interactions which are the residual forces stemming from the new and unknown dynamic of the 'preonic' constituents

- Over the years phenomenology and experimental searches concentrated to the isospin $I_W = 0, \frac{1}{2}$ multiplets.

- Higher weak isospin multiplets ($I_W = 1, \frac{3}{2}$) contain exotic states (doubly charged leptons, and quarks of charge Q = 5/3 e) [Pancheri-Srivastava, Phys.Lett. 146B (1984) 87-94] ;

- Somehow the phenomenology of these exotic states remained mostly unexplored; All phenomenology concentrated with the doublet/scalar case.

- We have been filling the gap!

Lepton sector

I_W	Multiplet	Q	Y	Coupled to
0	E^-	-1	-2	e_R through B_μ
$\frac{1}{2}$	$\begin{pmatrix} E^0 \\ E^- \end{pmatrix}$	0 -1	-1	$\ell_L = \binom{\nu_\ell}{\ell^-}$ through W^μ and B^μ
1	$\begin{pmatrix} E^0 \\ E^- \\ E^{--} \end{pmatrix}$	0 -1 -2	-2	e_R through $\mathbf{W}_\mu$
$\frac{3}{2}$	$\begin{pmatrix} E^+ \\ E^0 \\ E^- \\ E^{--} \end{pmatrix}$	1 0 -1 -2	-1	$\ell_L = \binom{\nu_\ell}{\ell^-}$ through W^μ

Quark sector

I_W	Multiplet	Q	Y	Coupled to
0	$(i)\quad U$ $(ii)\quad D$	$2/3$ $-1/3$	$4/3$ $-2/3$	u_R through B^μ and $G^{\mu,a}$
$\frac{1}{2}$	$\begin{pmatrix} U \\ D \end{pmatrix}$	$\begin{pmatrix} 2/3 \\ -1/3 \end{pmatrix}$	$1/3$	$q_L = \begin{pmatrix} u_L \\ d_L \end{pmatrix}$ through W^μ B^μ and $G^{\mu,a}$
1	$(i)\begin{pmatrix} U^+ \\ U \\ D \end{pmatrix}$ $(ii)\begin{pmatrix} U \\ D \\ D^- \end{pmatrix}$	$\begin{pmatrix} 5/3 \\ 2/3 \\ -1/3 \end{pmatrix}$ $\begin{pmatrix} 2/3 \\ -1/3 \\ -4/3 \end{pmatrix}$	$4/3$ $-2/3$	u_R through W^μ d_R through W^μ
$\frac{3}{2}$	$\begin{pmatrix} U^+ \\ U \\ D \\ D^- \end{pmatrix}$	$5/3$ $2/3$ $-1/3$ $-4/3$	$1/3$	$q_L = \begin{pmatrix} u_L \\ d_L \end{pmatrix}$ through W^μ

Magnetic type gauge Interactions

$$\mathcal{L}_{\rm int}^{(I_W=3/2)} = \frac{g f_{3/2}}{\Lambda} \sum_{M,m,m'} C(\frac{3}{2}, M|1, m; \frac{1}{2}, m') \times$$

$$\left(\bar{\Psi}_M \sigma_{\mu\nu} q_{Lm'}\right) \partial^\nu (W^m)^\mu + h.c.$$

(dim=5 operators)

$$\mathcal{L}_{\rm int}^{(I_W=1)} = \frac{g f_1}{\Lambda} \sum_{m=0,\pm 1} \left[\left(\bar{\rm U}_m \sigma_{\mu\nu} u_R\right) + \right.$$

$$\left.\left(\bar{\rm D}_m \sigma_{\mu\nu} d_R\right)\right] \partial^\nu (W^m)^\mu + h.c.$$

⇒Exotic states couple only to SU(2) gauge field (W^μ)

⇒Implementation in CalcHEP generator

⇒Parameter Space: [Λ, m*]

Contact interactions

$$\mathcal{L}_{\mathrm{CI}} = \left(\frac{g_*^2}{2\Lambda^2}\right) j^\mu j_\mu,$$

$$j_\mu = (\eta \bar{f}_L \gamma_\mu f_L + \eta' \bar{f}_L \gamma_\mu f_L^* + \eta'' \bar{f}^*{}_L \gamma_\mu f_L^* + \mathrm{H.c.}) + (L \to R),$$

(dim=6 operators)

- Standard normalisation is: $g_*^2 = 4\pi$
- Fermion interactions are obtained as an effective field theory after the high energy modes ($\approx \Lambda$) have been integrated out
- Implementation in the CalcHEP generator

$\Rightarrow$ Parameter Space: [Λ, m*]

Recap of Recent Activities (I)
(from a New Physics Lagrangian to the constraints on the model parameters from actual LHC data)

- Phenomenology of doubly charged leptons at LHC ; [Maser thesis of S. Biondini (2011), PRD 85, 095018 (2012), S. Biondini, O.Panella, G. Pancheri, Y. N. Srivastava and L. Fanò ;
- Doubly charged heavy leptons at LHC via Contact interactions; [Master thesis of R. Leonardi, (2013), R. Leonardi, O. Panella, Livio Fanò, PRD 90, 035001 (2014)]
- Heavy composite Majorana neutrinos —from a theoretical model [EPJC, 76, 593 (2016)] to a REAL experimental analysis (CMS-PAS-16-026) [Ph. D. thesis of R. Leonardi and L. Alunni-Solstizi (XXIX ciclo, December 2016)];
- Search for a heavy composite Majorana Neutrino in the final state with two leptons and two quarks at sqrt(s) = 13 TeV, Phys. Lett. B. 775 (2017), 315-337 , CMS Collaboration, A. M. Sirunyan et al. — guest author of this CMS paper!!—]
- Production of exotic composite quarks of charge Q=5/3e at the LHC [Ph. D. thesis of R. Leonardi (Dicembre 2016), Phys. Rev. D96 (2017) 0750034];

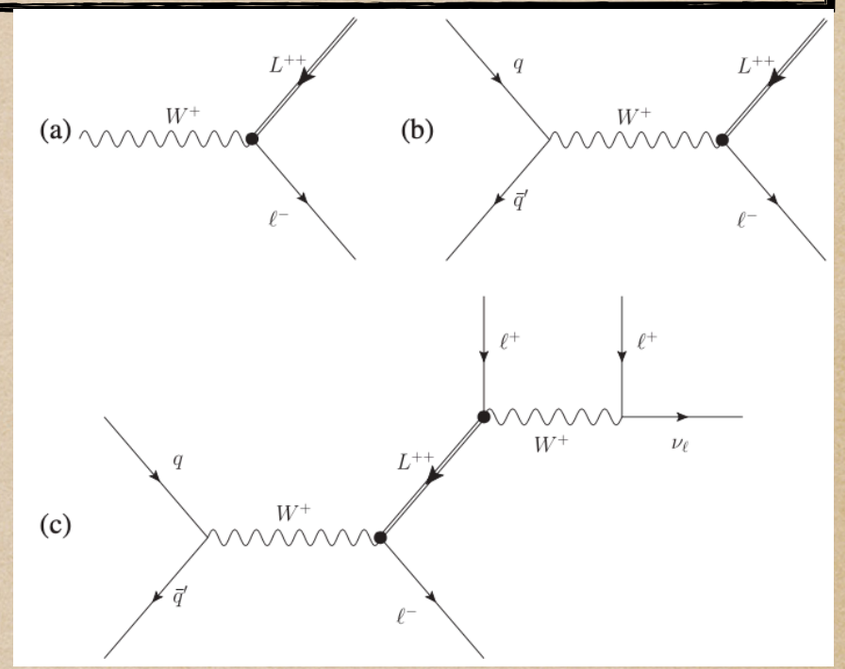
Recap of Recent Activities (II)
(from a New Physics Lagrangian to the constraints on the model parameters from actual LHC data)

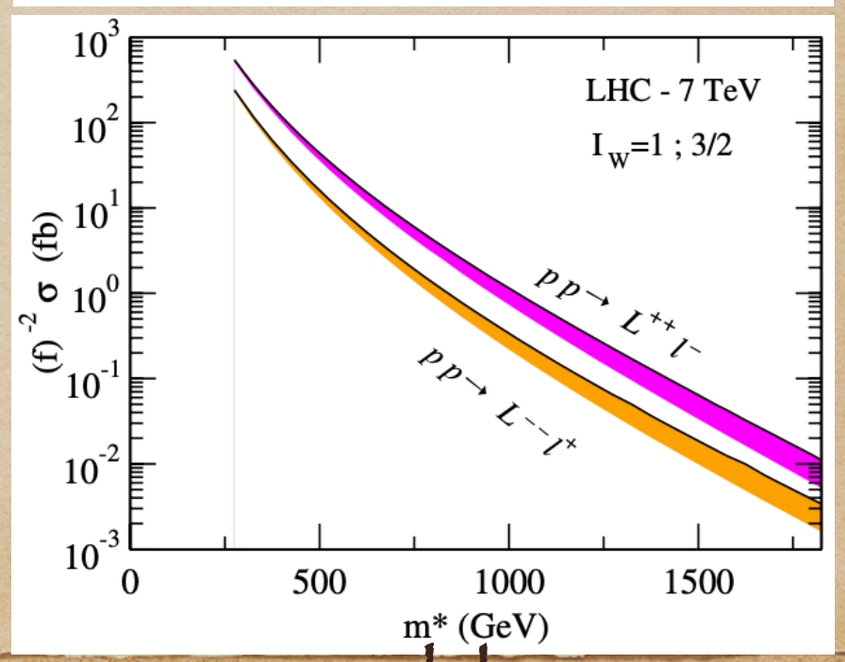
- Leptogenesis and Composite Heavy neutrinos with gauge mediated interactions ; [S. Biondini and O. Panella (2011), Eur. Phys. Journal C77 (2017), 644] See Talk by S. Biondini.
- Search for heavy composite Majorana neutrinos at the HL- and the HE-LHC, P. Azzi, C.Cecchi, L. Fanò, A Gurrola; W, Johns, R Leonardi, E. Manoni, M. Narain, O. Panella, M. Presilla, F. Romeo, S. Sagir, P. Sheldon, F. Simonetto, E usai, W. Zhang (CMS). Report from Working Group 3: BSM physics at the HL-LHC and HE-LHC, Xavier Cid Vidal et al. CERN Yellow Report Monogr. 7 (2019) 585-865]
- New Mirror model of LNV with composite Majorana neutrinos — model with two mass eigenstates implemented in CalcHEP and MadGraph [M. Presilla, R. Leonardi, and O. Panella, February 2017, Report from Working Group 3: BSM physics at the HL-LHC and HE-LHC, Xavier Cid Vidal et al. CERN Yellow Report Monogr. 7 (2019) 585-865]
- Perturbative Unitarity Bounds for effective composite models — [S. Biondini, R. Leonardi, O. Panella and M. Presilla, Phys. Lett. B795 (2019) 644-649, Erratum, arXiv: 1903.12285]. See Talk by Matteo Presilla.

Phenomenology of excited doubly charged heavy leptons @ LHC

Phys. Rev. D (2012) 85, 095018, S. Biondini, O. Panella, G. Pancheri, Y.N. Srivastava, and L. Fano`.

- First complete study of searches @ LHC of exotic heavy composite states (L++): $pp \to L^{--}\ell^{-}$
- Magnetic typeGauge interactions;
- implementation of model (interactions) in the generator (CalcHEP);
- L^{++} interacts only via gauge interactions: (i) $L^{++} \to \ell^+\ell^+\nu_\ell$
- or (ii) $L^{++} \to \ell^+\ell^- q\bar{q}'$
- final signature : $pp \to \ell^-\ell^+\ell^+\nu_\ell$





Note: also $pp \to \ell^+\ell^- jj$ signature is possible !!

Signal and SM background

- Signal: $pp \to \ell^- L^{++} \to \ell^- \ell^+ \ell^+ \nu_\ell$

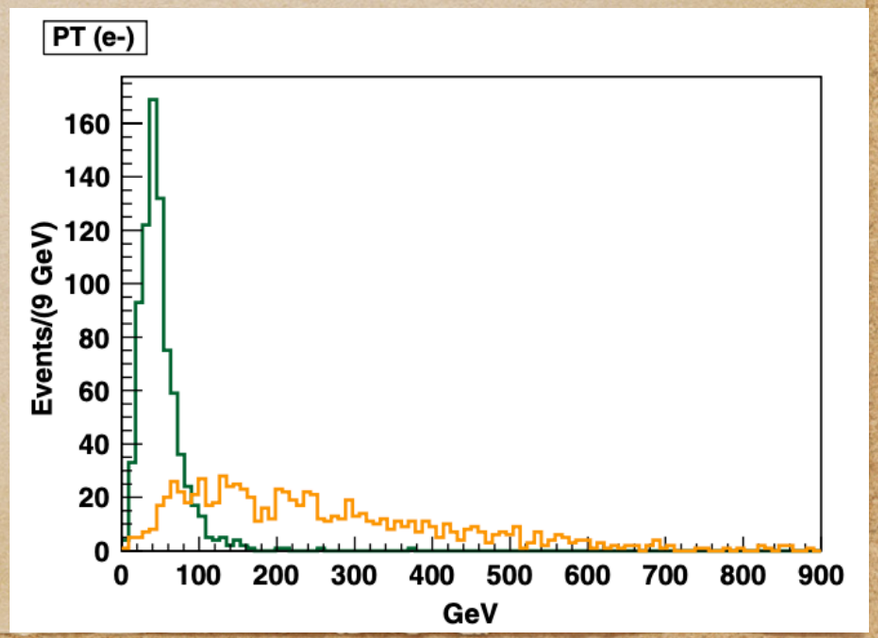
- main SM background and is *t t-bar* and *WWW* production:
  $pp \to W^+ Z \to \ell^+ \ell^- \ell^+ \nu_\ell$
- Kinematic study to optimize Statistical Significance

  - Angular, p_T, reconstructed invariant mass ($M_{\ell\,\ell}$) distributions

  - Fast simulation of detector reconstruction with DELPHES

  - Most efficient cuts:

$$\begin{cases} p_T(e^-) > 80\,\mathrm{GeV} \\ |\eta(e_1^+)| < 2 \end{cases}$$

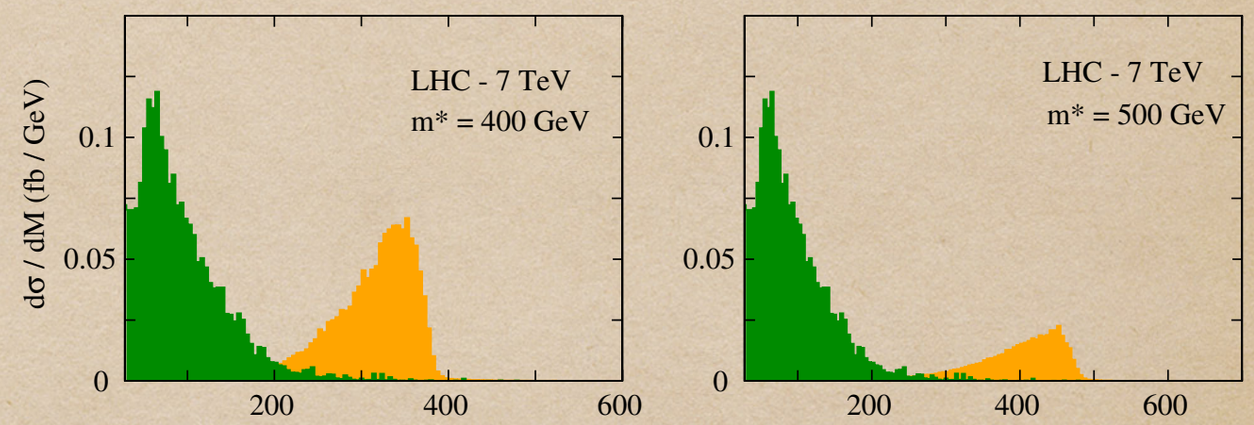


Like sign dileptons invariant mass distribution and Luminosity curves

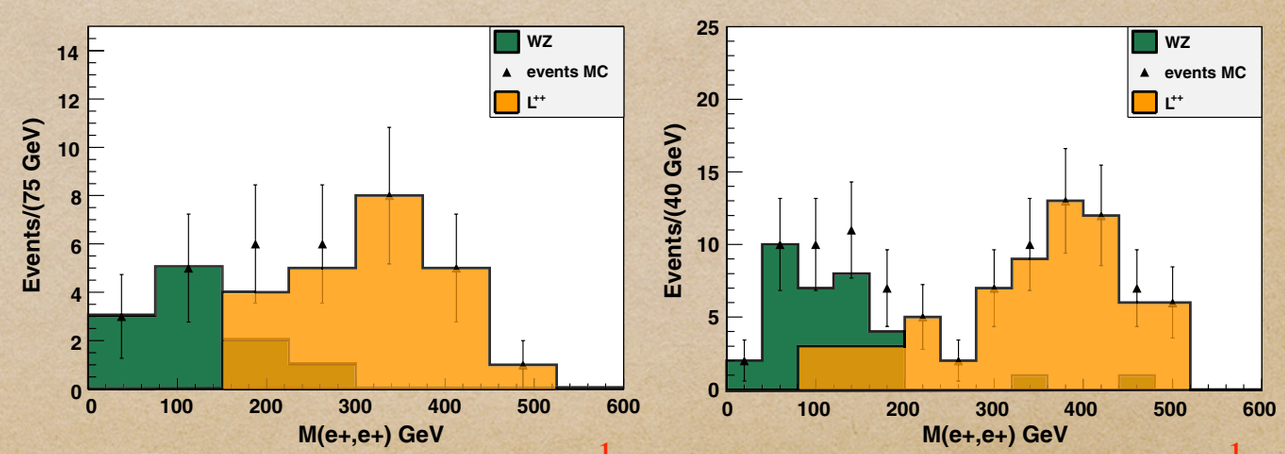
- Strong correlation of Like sign dilepton invariant mass with the mass of the excited doubly charged Lepton:

$$\left[m^2_{(\ell^+,\ell^+)}\right]_{\max} = \frac{(m^{*2} - m_W^2)(m_W^2 - m_\nu^2)}{m_W^2} \rightarrow \left[m^2_{(\ell^+,\ell^+)}\right]_{\max} = m^{*2} - m_W^2$$

@ Generator level



Reconstructed (Delphes)



$\sqrt{s} = 7\text{TeV}, L = 10\text{fb}^{-1}$ $\sqrt{s} = 7\text{TeV}, L = 30\text{fb}^{-1}$

Luminosity Curves

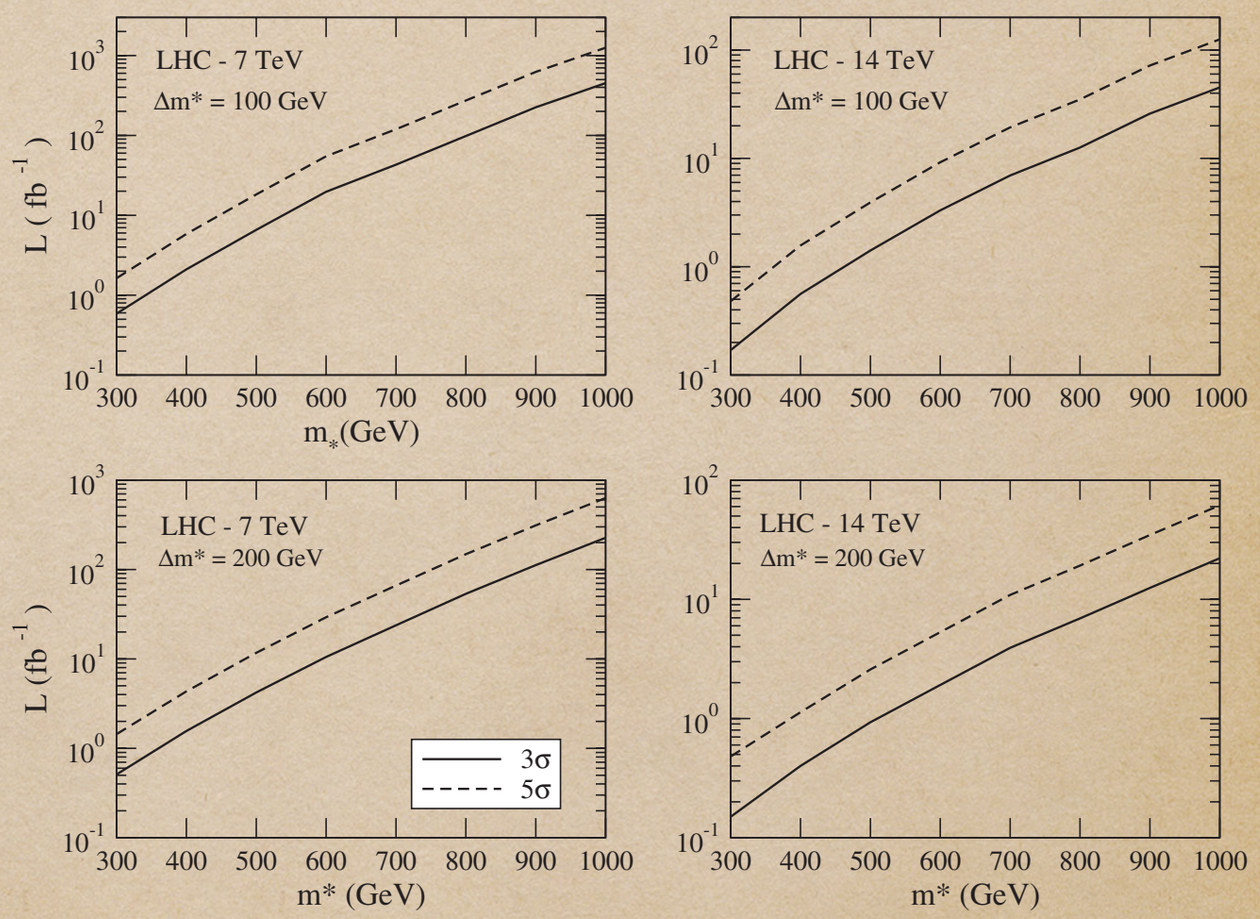
- With $N_s = \sigma_s L$ and $N_b = \sigma_b L$ the Statistical Significance s is computed: $$s = \frac{N_s}{\sqrt{N_s + N_b}}$$

$$N_s = L \int_{m^*-\Delta m^*}^{m^*} dm_{(\ell^+,\ell^+)} \frac{d\sigma_s}{dm_{(\ell^+,\ell^+)}}$$

$$N_b = L \int_{m^*-\Delta m^*}^{m^*} dm_{(\ell^+,\ell^+)} \frac{d\sigma_b}{dm_{(\ell^+,\ell^+)}}$$

Solve for L @ given statistical significance:

$$L = s^2 \left(\frac{\sigma_s + \sigma_b}{\sigma_s^2} \right)$$

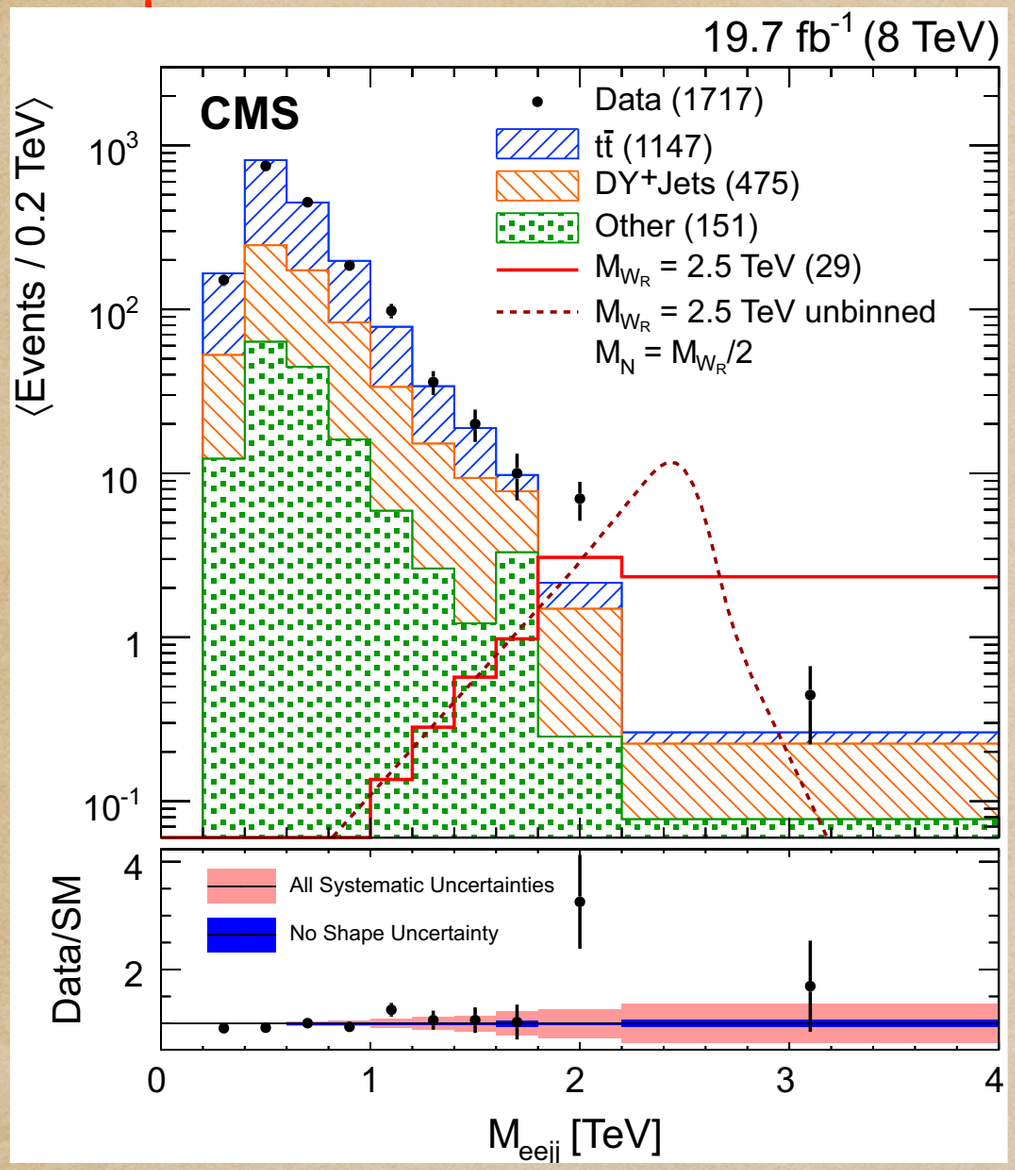


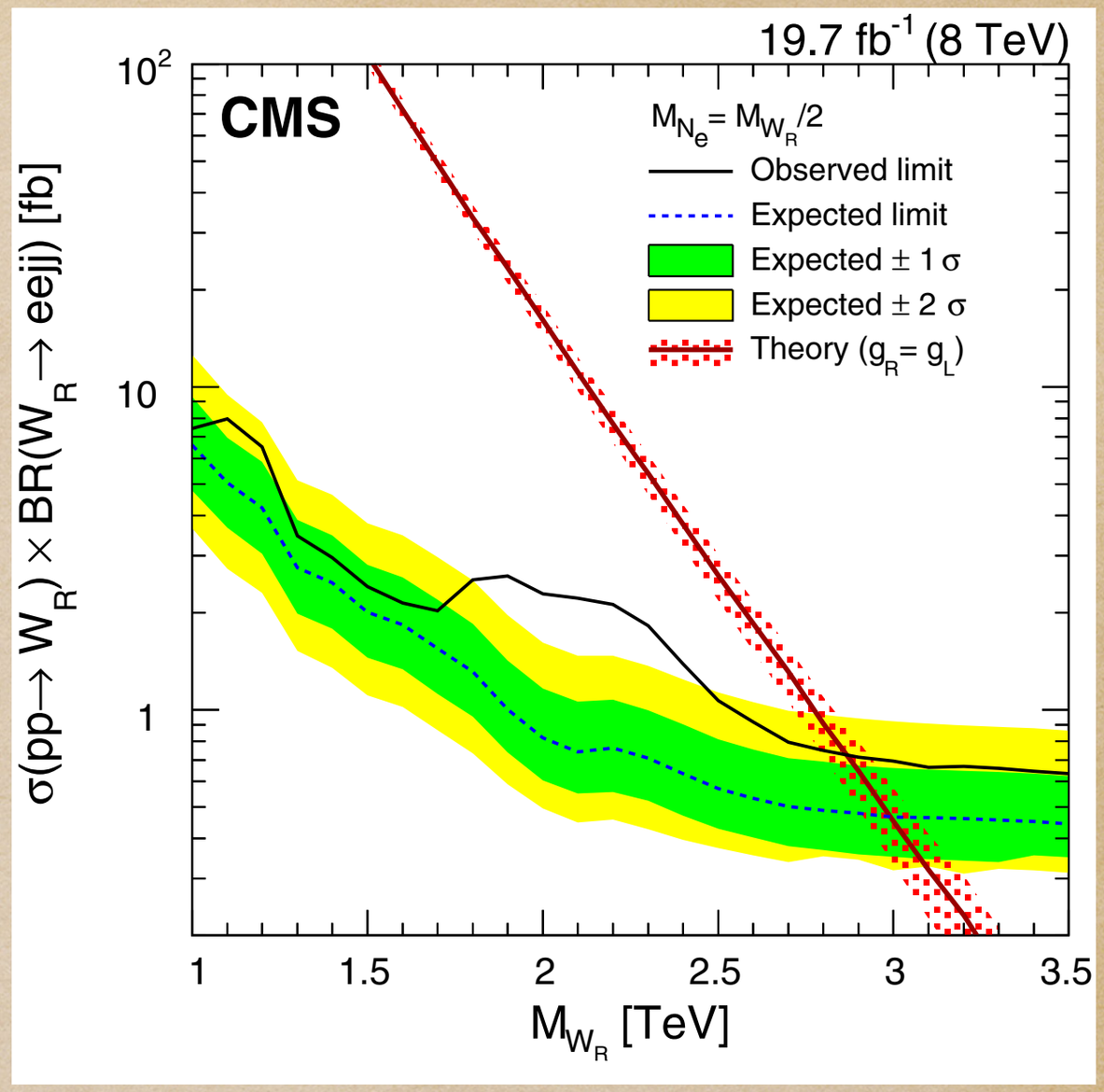
High Mass reach!!

L^{++} production @LHC conclusions and outlook

- First Pheno-Exp synergy paper [Phys. Rev. D (2012) 85, 095018]. Found quite interesting results (high mass reach);
  - First implementation of the composite magnetic type ($\sigma_{\mu\nu}$) gauge interactions (dim=5 operators) in the CalcHEP generator.
  - Left open the inclusion of contact interactions in theoretical model and full exploration of the two-dimensional parameter space (Λ,m*);
- In subsequent paper (second pheno-exp synergy paper) Contact interactions for the composite model are implemented for the first time in the CalcHEP generator [Phys. Rev. D90, 035001 (2014), R. Leonardi, O. Panella, and L. Fanò, master thesis of Roberto Leonardi]
- Production of doubly charged leptons is studied in view of larger cross sections induced by dominant contact interactions;

Experimental motivations from LHC searches @ Run I

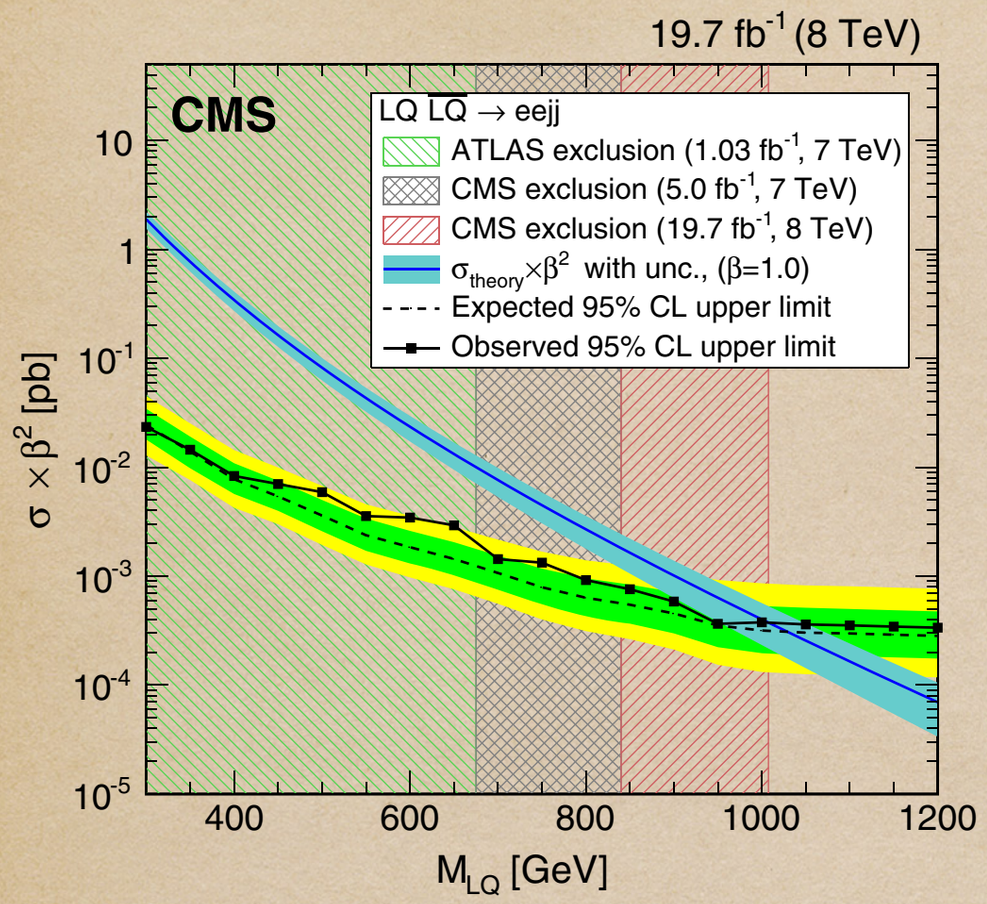


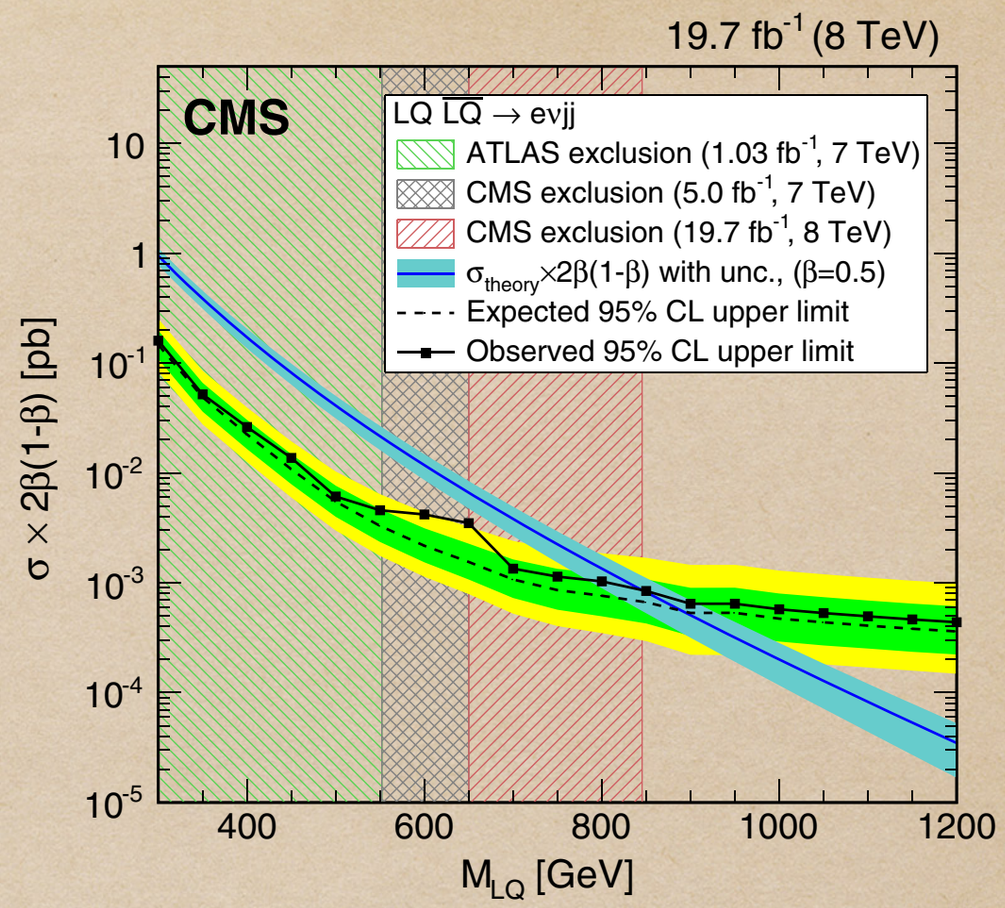


- (CMS Collab.) EPJC 74:3149 (2014) "Search for heavy neutrinos and W_R bosons ..." ($\ell\ell jj$ - final state)
- 2.8σ excess found in the interval 1.8 TeV < M_{eejj} < 2.2 TeV
- Same excess not observed in the ($\mu\mu jj$) channel!!

(back in 2016/17)

Experimental motivations from LHC searches @ Run I





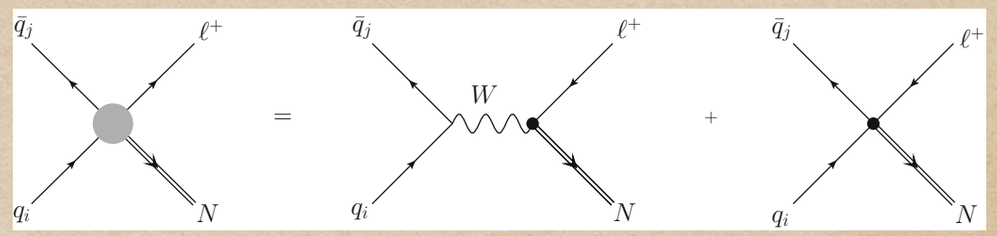
- CMS Collab. Phys. Rev. D 93 (2016) 032004, "Search for pair production of lepto-quarks ..." ($\ell\ell jj$ and $\ell\nu jj$ - final states)
- 2.3σ (2.6σ) excess found
- Same excess not observed in the (μμjj) channel!!

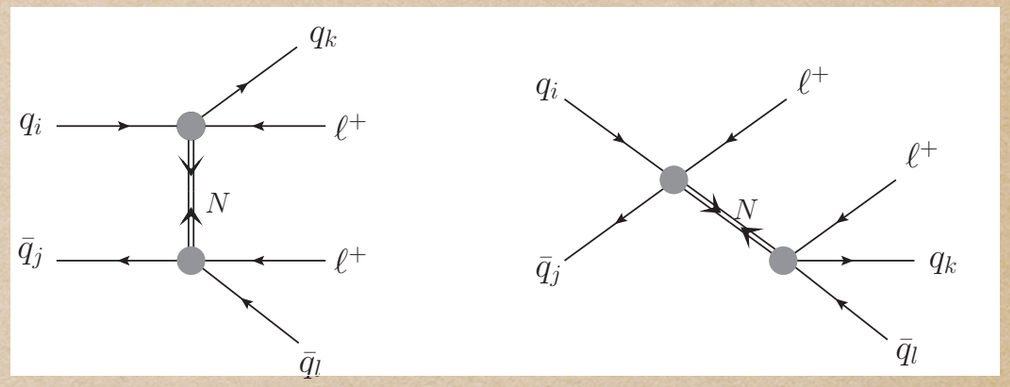
(back in 2016/17)

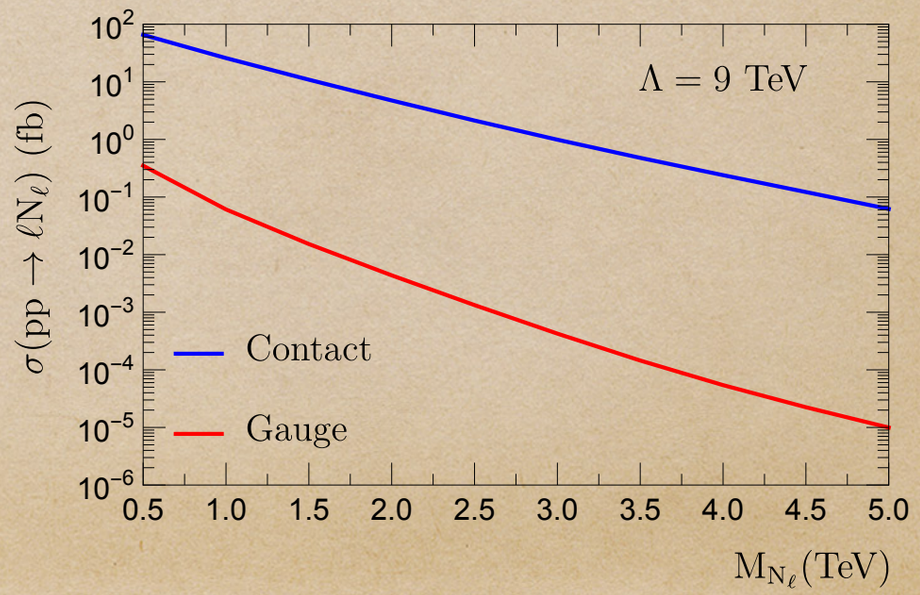
Heavy Composite Majorana Neutrino (HCMN) production @ LHC

Eur. Phys. J. C (2016) 76:593, Leonardi, Alunni, Romeo, Fanò, and Panella

- First complete study of searches @ LHC of exotic composite Majorana Neutrino; $pp \to \ell N_\ell$
- Gauge AND contact interactions;
- implementation of model (interactions) in the generator (CalcHEP);
- N_ℓ interacts via both gauge and contact interactions:
- $N_\ell \to \ell q\bar{q}', N_\ell \to \nu\bar{\nu}q\bar{q}', N_\ell \to \ell\ell\nu\nu$
- final signature : $pp \to \ell\ell jj$







Invariant mass distribution

- Signal: $pp \to \ell N \to \ell\ell jj$

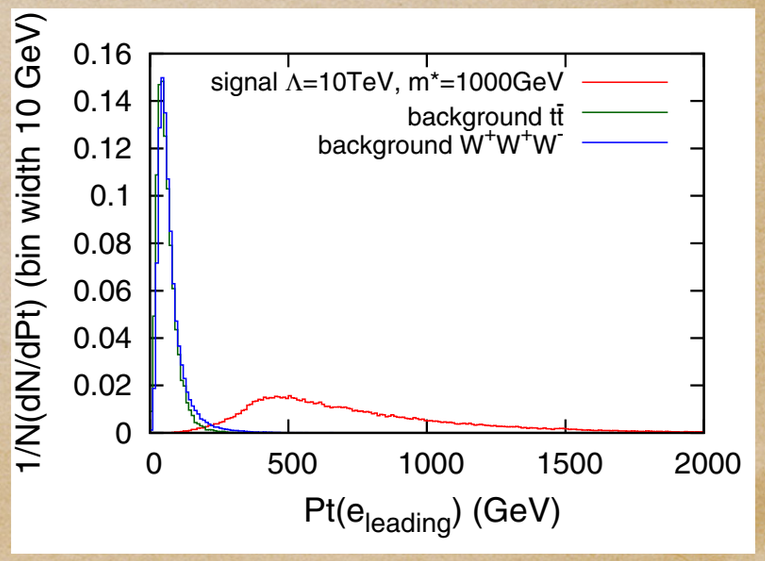
- main SM background and is *t t-bar* and *WWW* production:
  $pp \to t\bar{t} \to \ell^+\ell^+\nu\nu\, jets$ $\quad pp \to W^+W^+W^- \to \ell^+\nu\ell^+\nu\, jj$
- Kinematic study to optimize Statistical Significance

  - Angular, p_T, reconstructed invariant mass ($M_{\ell\,\ell\,j\,j}$) distributions

  - Fast simulation of detector reconstruction with DELPHES

  - Most efficient cut:

$$\begin{cases} p_T(e^+_{\text{leading}}) \geq 200\,\text{GeV}, \\ p_T(e^+_{\text{second-leading}}) \geq 100\,\text{GeV}. \end{cases}$$



Contour maps of S @ 5- and 3-σ within statistical error

- Signal events:

  $N_s = L\sigma_s\epsilon_s$

- background events:

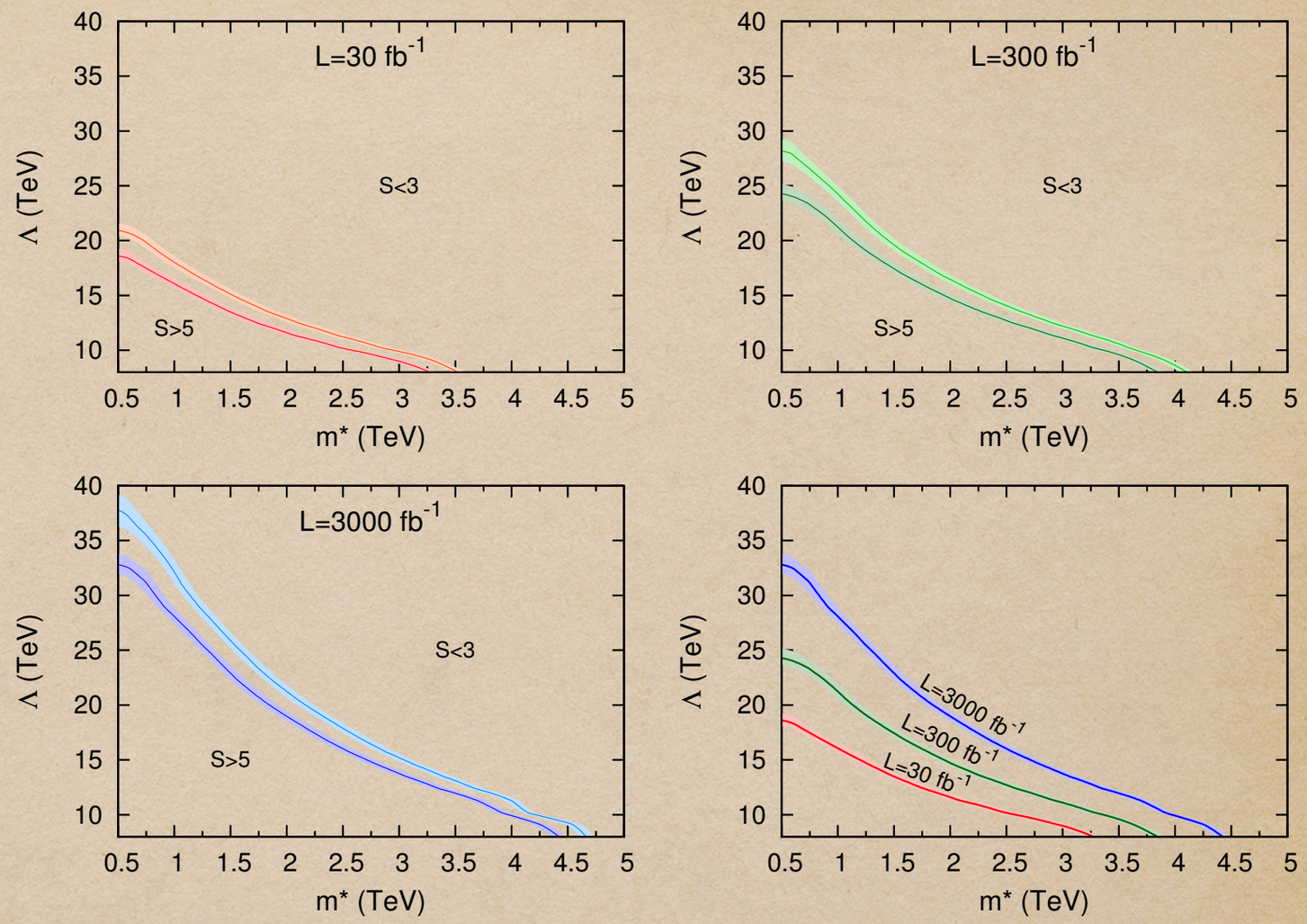
  $N_b = L\sigma_b\epsilon_b$

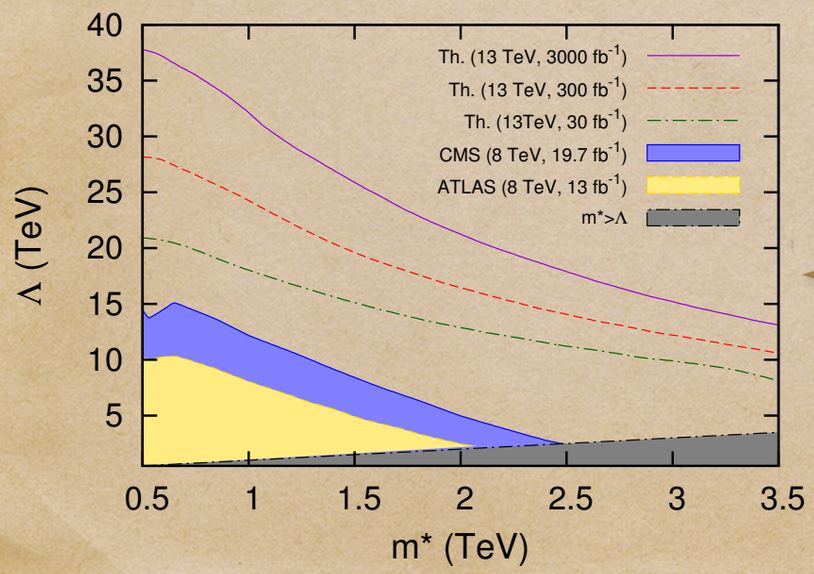
- Statistical Significance S:

  $S = \frac{N_s}{\sqrt{N_s + N_b}}$

- L = (30, 300, 3000) fb^{-1}

- $\sqrt{s}$ = 13 TeV

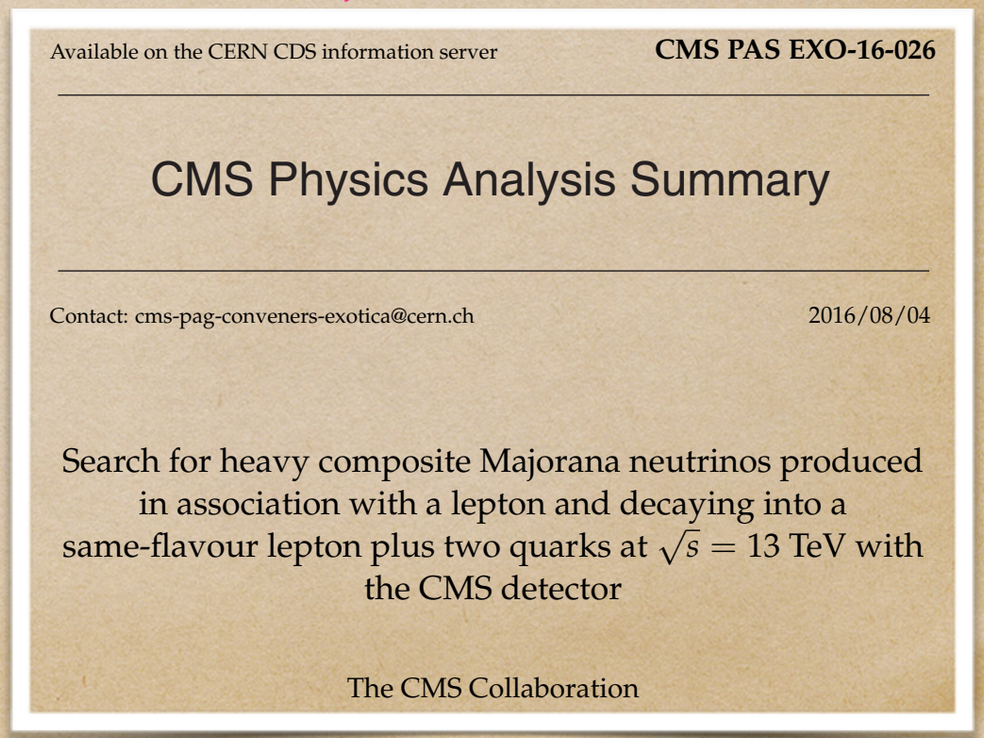




Current exclusion regions at 95% C.L. from CMS and ATLAS (Run I) vs the discovery reach expected at Run II @ 3-σ from the *eejj* signature due to a heavy composite Majorana neutrino

Experimental search of HCMN signature [CMS-PAS-16-026]

- Implementation of the Majorana neutrino with gauge and contact interactions in the CalcHEP generator
- Preparation of private signal samples with the theoretical model implemented in CalcHEP
- CMS analysis of data collected in Run II (2015) corresponding to 2.3 fb^{-1} integrated luminosity.
- Presented @ ICHEP 2016
- PhD thesis of R. Leonardi e L. Alunni



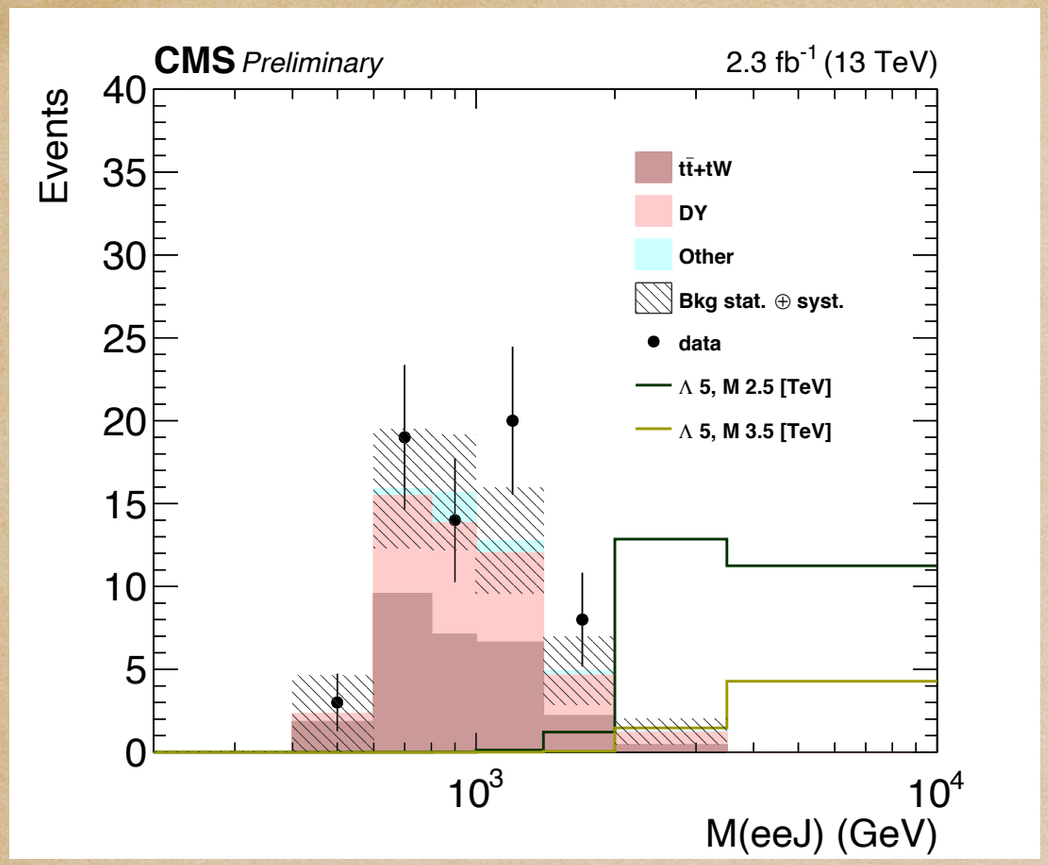
Available on the CERN CDS information server **CMS PAS EXO-16-026**

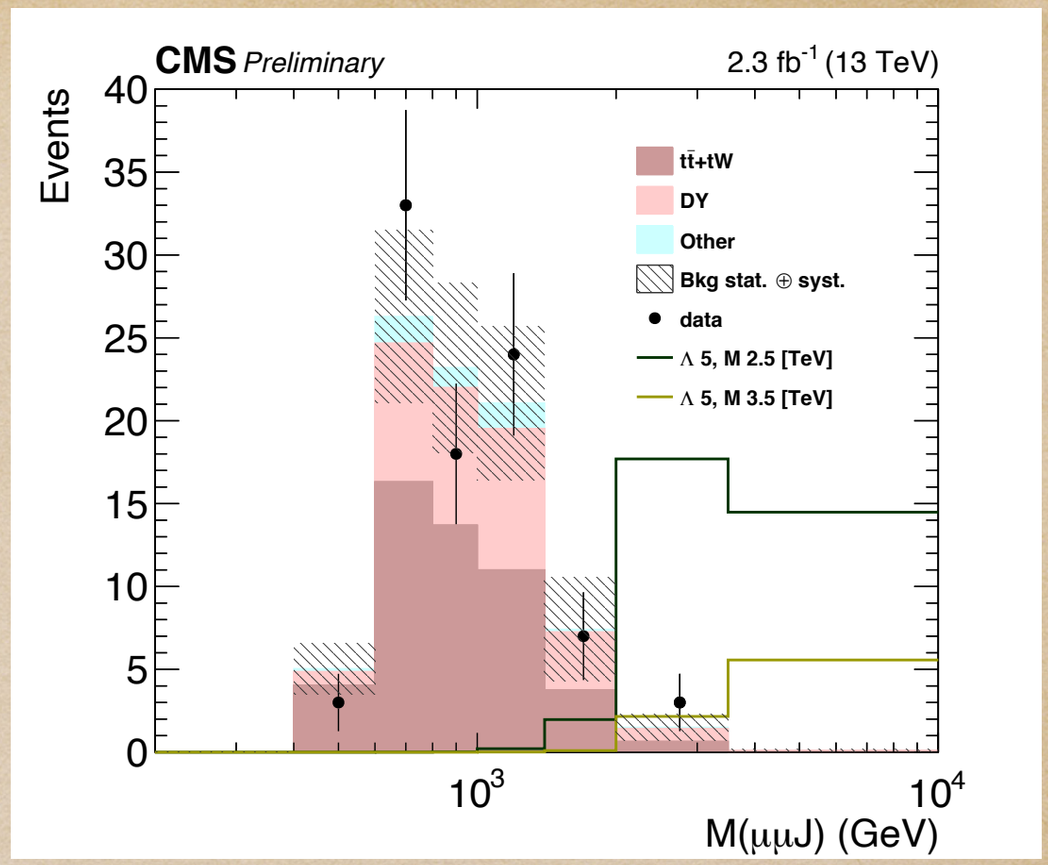
CMS Physics Analysis Summary

Contact: cms-pag-conveners-exotica@cern.ch 2016/08/04

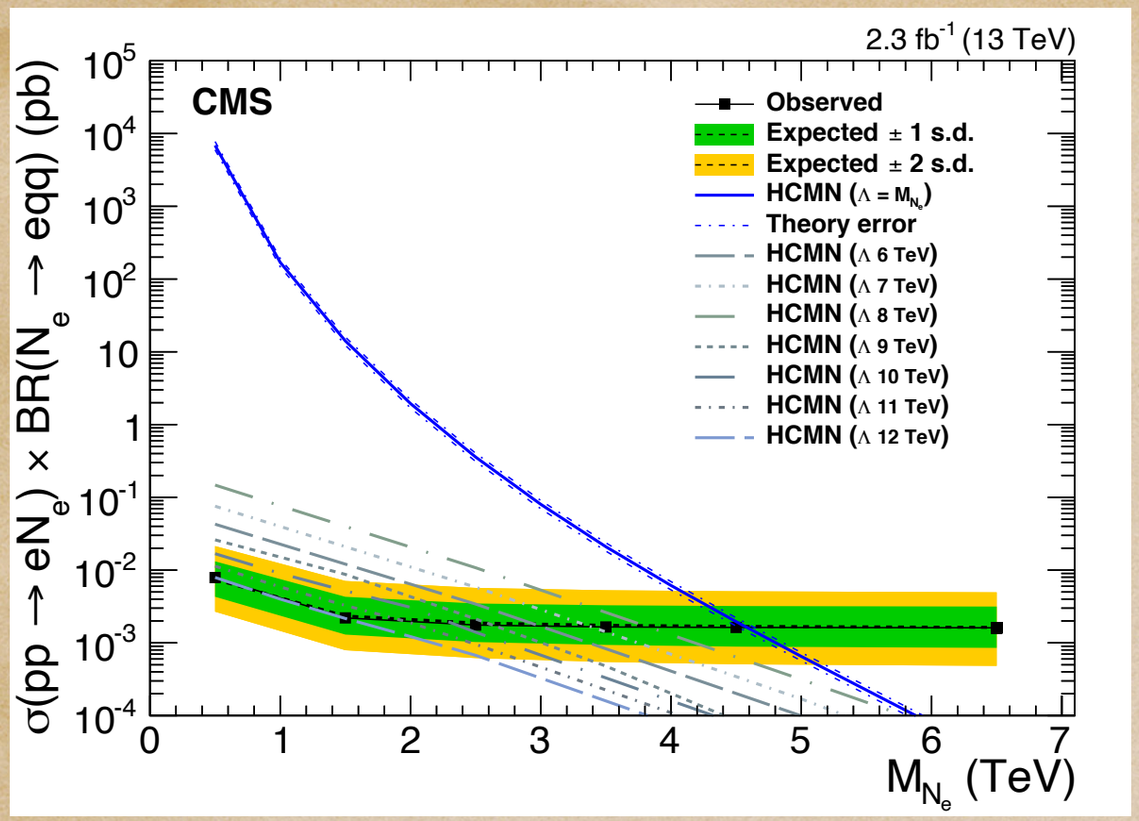
Search for heavy composite Majorana neutrinos produced in association with a lepton and decaying into a same-flavour lepton plus two quarks at $\sqrt{s} = 13$ TeV with the CMS detector

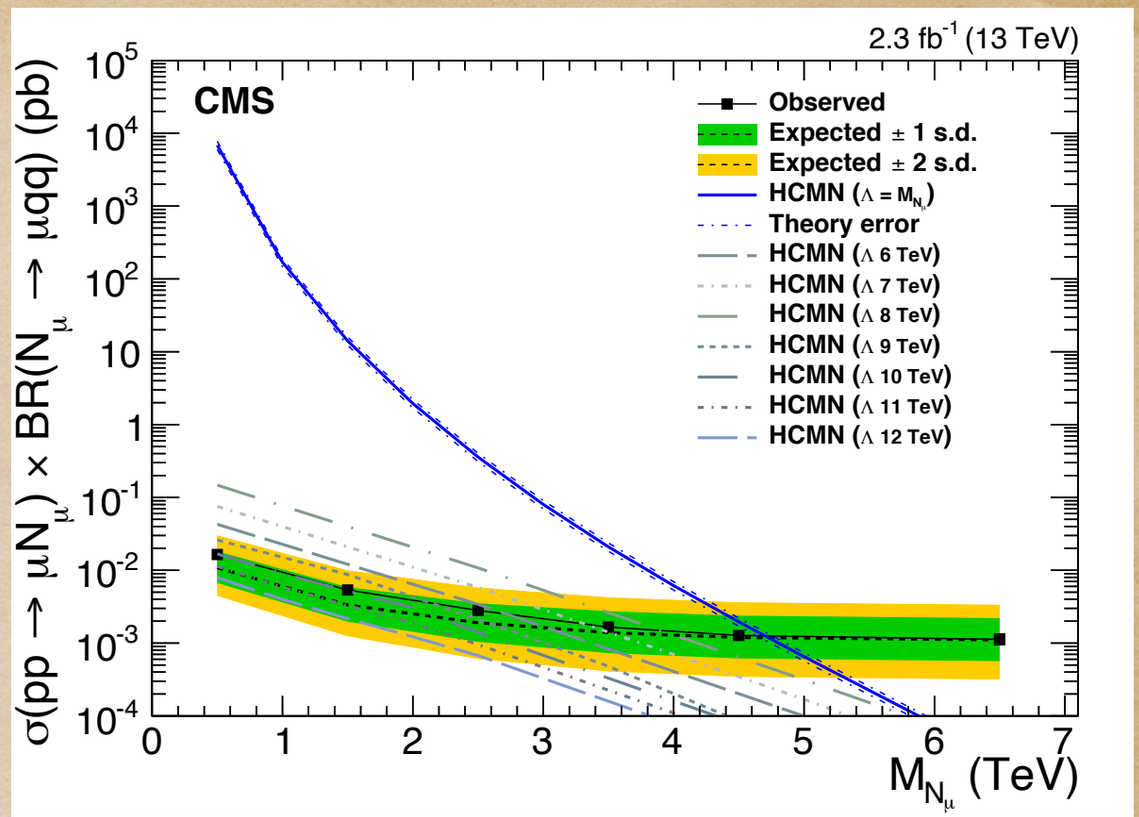
The CMS Collaboration





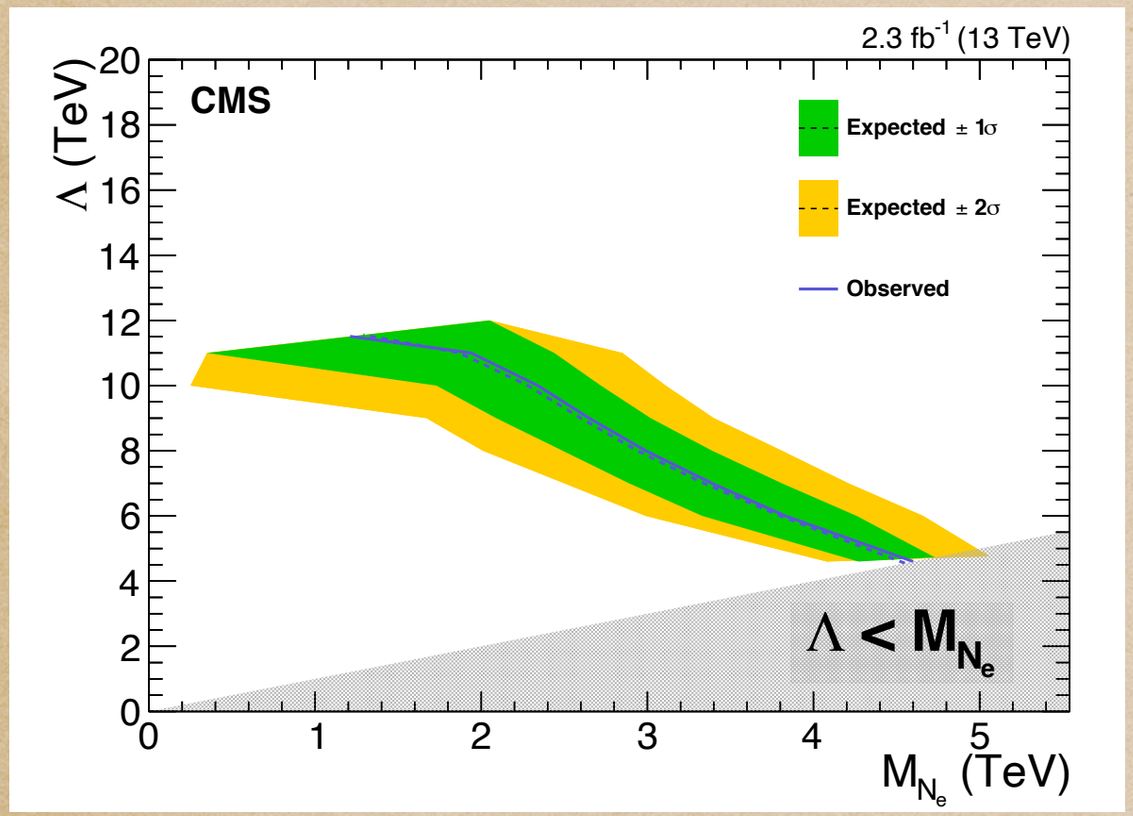
- Distribution on M_{llJ} for: data (black dots) and standard model expectations (stack plots) and signal (lines) from (eeqq and μμqq analyses) @ Λ = 5 TeV.
- No significant deviations from SM expectations are observed: → Set upper limits.

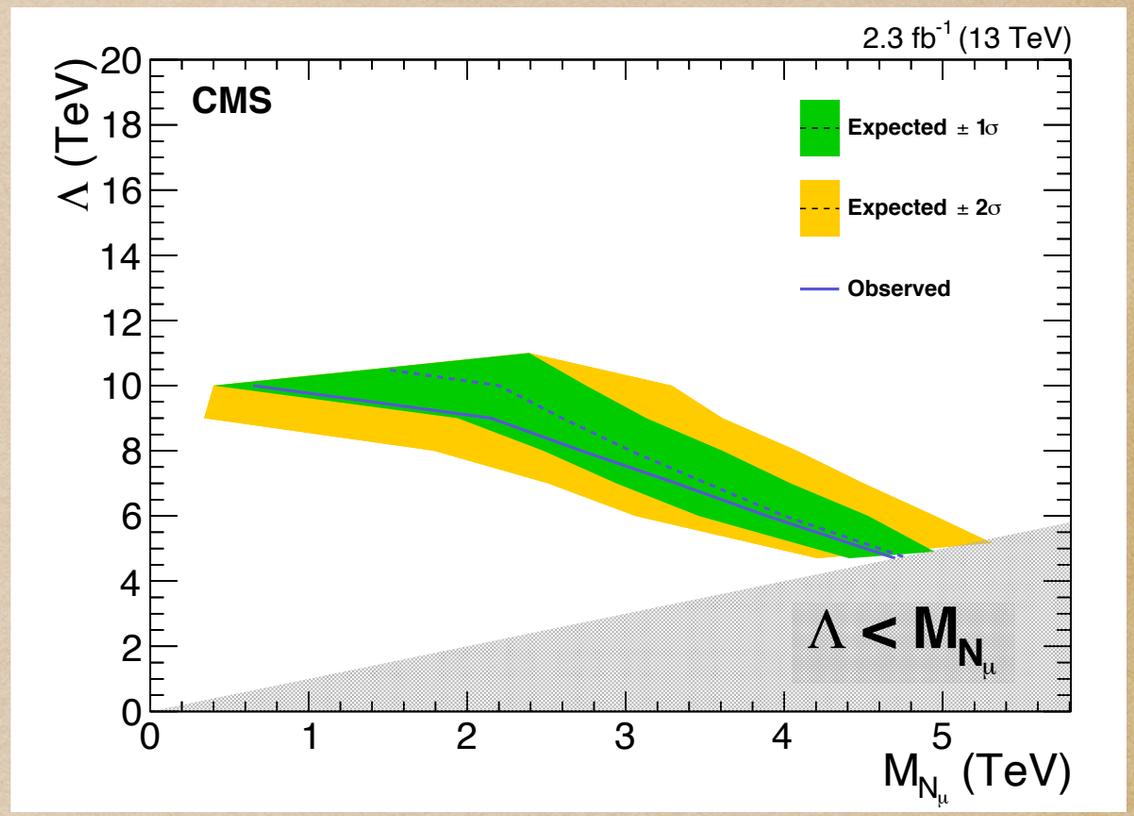




- Observed 95% C.L. upper limits on $\sigma(pp \to \ell N) \times B(N \to \ell qq)$ (black solid line) from (eeqq and μμqq analyses);
- For $\Lambda = M_N = m^*$ (blue line) limits are: $M_N > 4.60$, (4.70) TeV

Exclusion regions of 2-dim parameter space (Λ, M_N)





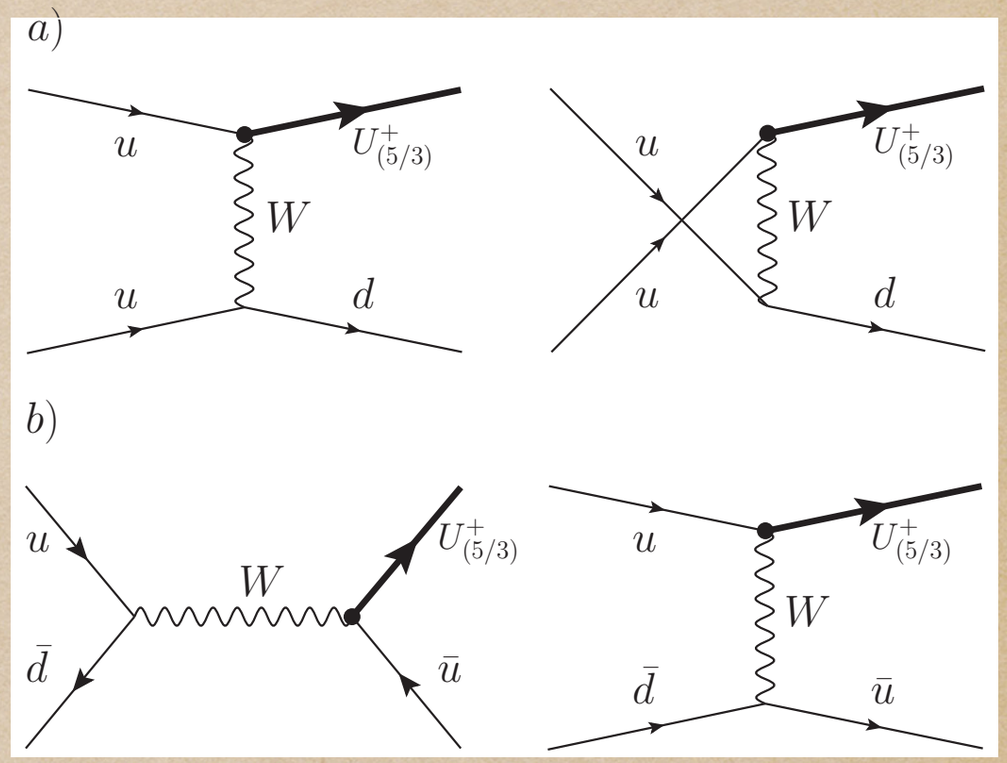
- Observed 95% C.L. Exclusion regions (below the curve) on the 2-dim parameter space (Λ,M_N), from (eeqq and μμqq analyses);

HCMN (theory+exp) conclusions and outlook

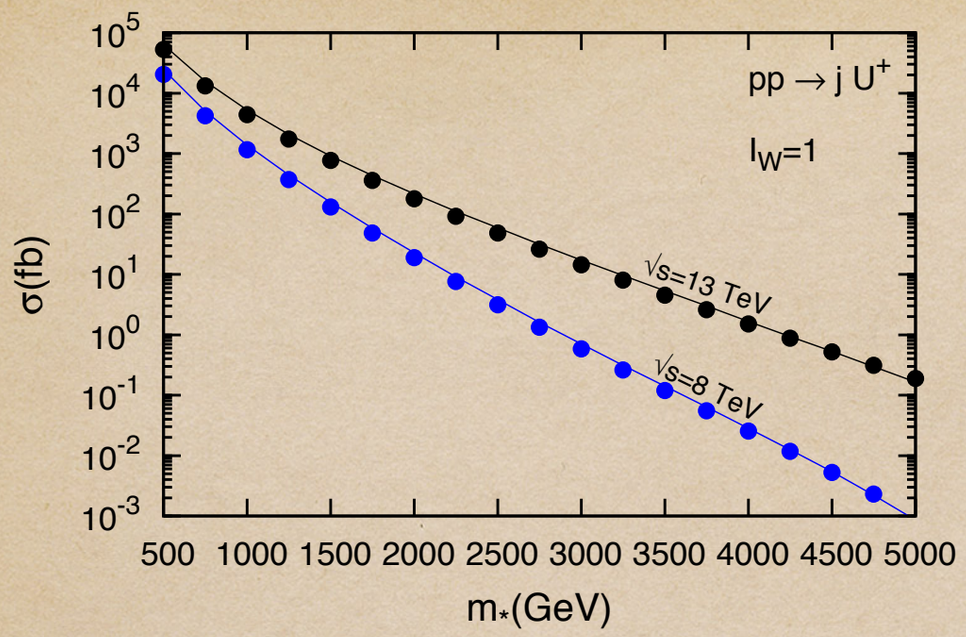
- Pheno paper [Eur. Phys. J. C (2016) 76:593] Quite interesting results (high mass reach);
  - Inclusion of contact interactions in theoretical model and full exploration of the two-dimensional parameter space (Λ,m*);
- CMS analysis (CMS-PAS EXO-16-026) (published in PLB):
  - if Λ=m*(=M_N) current limits are: $M_N > 4.60$ TeV (eeqq channel) and $M_N > 4.70$ TeV ($\mu\mu$qq channel)
- Update of the results of the current analysis with higher RUN II statistics; ("Reload" of CMS-PAS EXO-16-026, currently undergoing), See talk by Valentina Mariani.
- Extension to a Mirror type model with two Majorana mass eigenstates, (three-dim parameter space, [Λ, m_1, m_2]. Possible role of interference effects

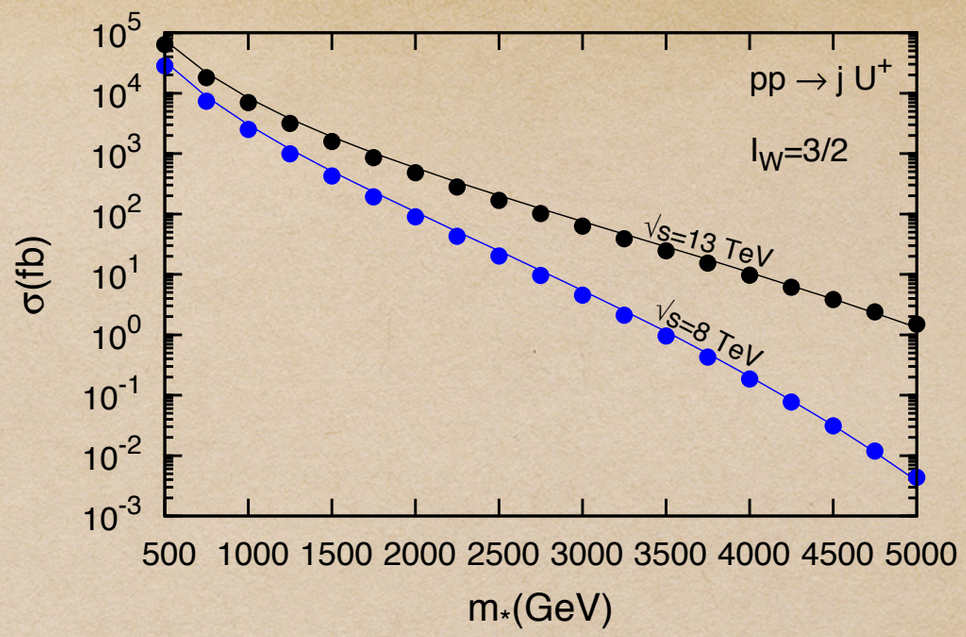
Production of $U^+_{(5/3)}$ @ LHC

- First feasibility study of searches @ LHC of exotic composite quarks;
- Consider at first only magnetic type gauge interactions;
- implementation of model (interactions) in the generator (CalcHEP);
- $U^+_{(5/3)}$ interacts only via the W gauge boson. Decay: $U^+_{(5/3)} \to Wu \to Wjet$
- Consider leptonic decay of W gauge boson: $W \to \ell\nu$
- final signature is : $pp \to \ell \not{p}_T jj$



$$U^+_{5/3} \to W j \to \ell\nu j \to \ell \not{p}_T j$$





- Model implemented in CalcHEP (• , •)
- Checked against analytic/numerical calculations (solid lines)

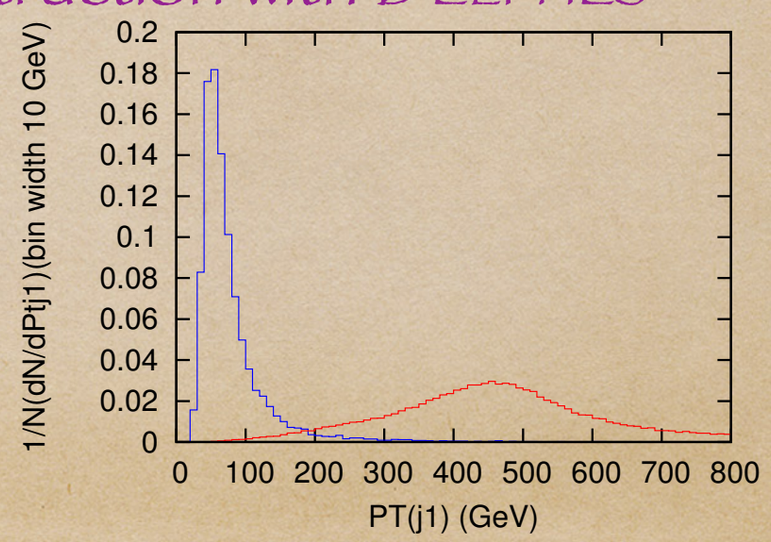
$$\sigma = \sum_{a,b} \int_{\frac{m_*^2}{s}}^{1} \int_{\tau}^{1} d\tau \, \frac{dx}{x} \, f_a(x, \hat{Q}) \, f_b(\frac{\tau}{x}, \hat{Q}) \, \hat{\sigma}(\tau s, m_*) \, .$$

- Cross sections quite interesting !!
- $\sigma \approx O(10^2)$ fb for masses $m^* \approx 2500$ GeV @ 13 TeV

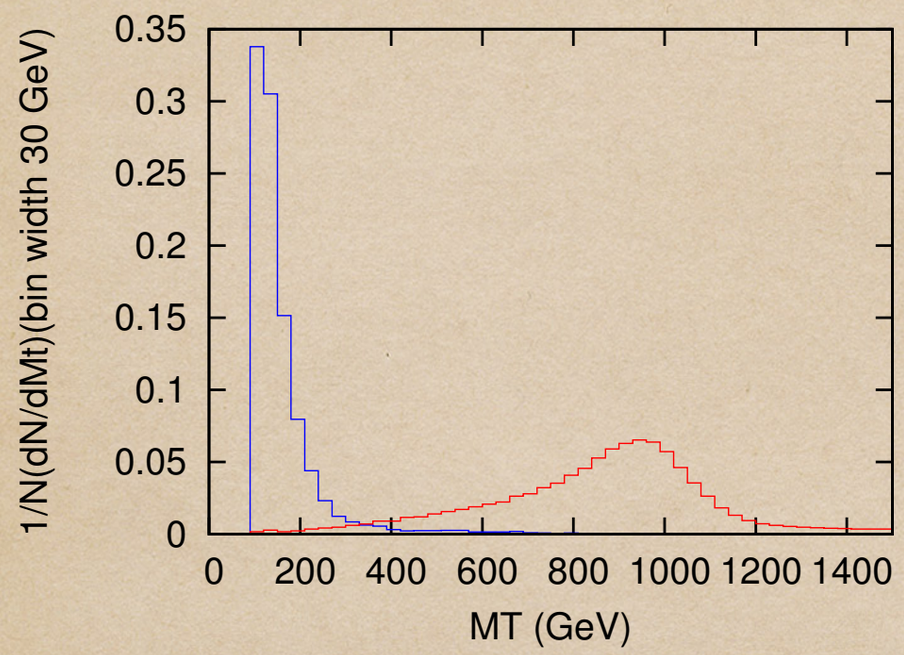
Signal and SM background

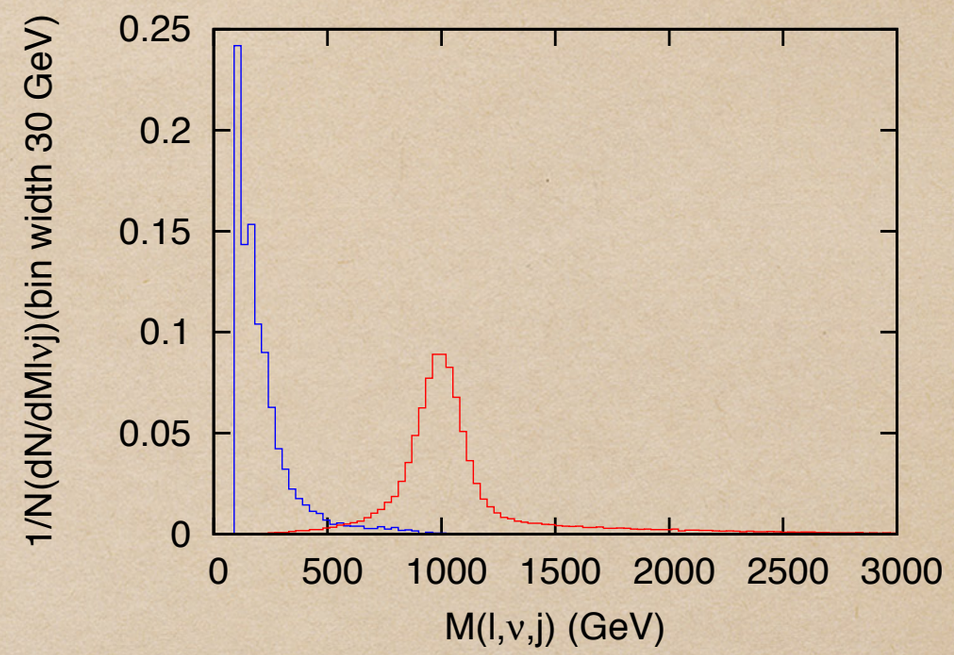
- Signal:
  $pp \to U^+ u \to \ell \not{p}_T jj$
- main SM background is Wjj production with $W \to \ell \nu$:
  $pp \to Wjj \to \ell \not{p}_T jj$
- Kinematic study to optimize Statistical Significance:
  - Angular, p_T, Transverse -mass (M_T) and reconstructed invariant mass ($M_{\ell \nu j}$) distributions
  - Fast simulation of detector reconstruction with DELPHES
  - Most efficient cut:

$$\begin{cases} p_T(j_{\text{leading}}) \geq 180\,\text{GeV}, \\ p_T(j_{\text{second-leading}}) \geq 100\,\text{GeV}. \end{cases}$$



Transverse -mass (M_T) and reconstructed invariant mass ($M_{\ell\nu j}$) distributions highly correlated with m* ($\Lambda = 10$ TeV, $m^* = 1000$GeV)





$$M_T^2 = \left(\sqrt{p_{TW}^2 + M_W^2} + p_{Tj1}\right)^2 - (\boldsymbol{p}_{TW} + \boldsymbol{p}_{Tj1})^2$$

$\Longrightarrow$ M_T distribution shows a clear peak with a relatively sharp end-point at $M_T \approx m^*$

$\Longrightarrow$ Longitudinal neutrino momentum, hence $M_{\ell\nu j}$, can be reconstructed:

$$M_W^2 = (p_\ell + p_\nu)^2$$

$$(1 - B^2)(p_L^\nu)^2 - 2A\,B\,p_T^\nu\,p_L^\nu + (p_T^\nu)^2(1 - A^2) = 0$$

$$A = \frac{M_W^2 + 2\,\boldsymbol{p}_T^\ell \cdot \boldsymbol{p}_T^\nu}{2E_\ell p_T^\nu}, \qquad B = \frac{p_L^\ell}{E_\ell}$$

$$p_L^\nu = \frac{1}{1 - B^2}\left[AB \pm \sqrt{A^2 + B^2 - 1}\right] p_\nu^T$$

Efficiencies

- Signal events:

  $N_s = L\sigma_s\epsilon_s$

- background events:

  $N_b = L\sigma_b\epsilon_b$

- Statistical Significance:

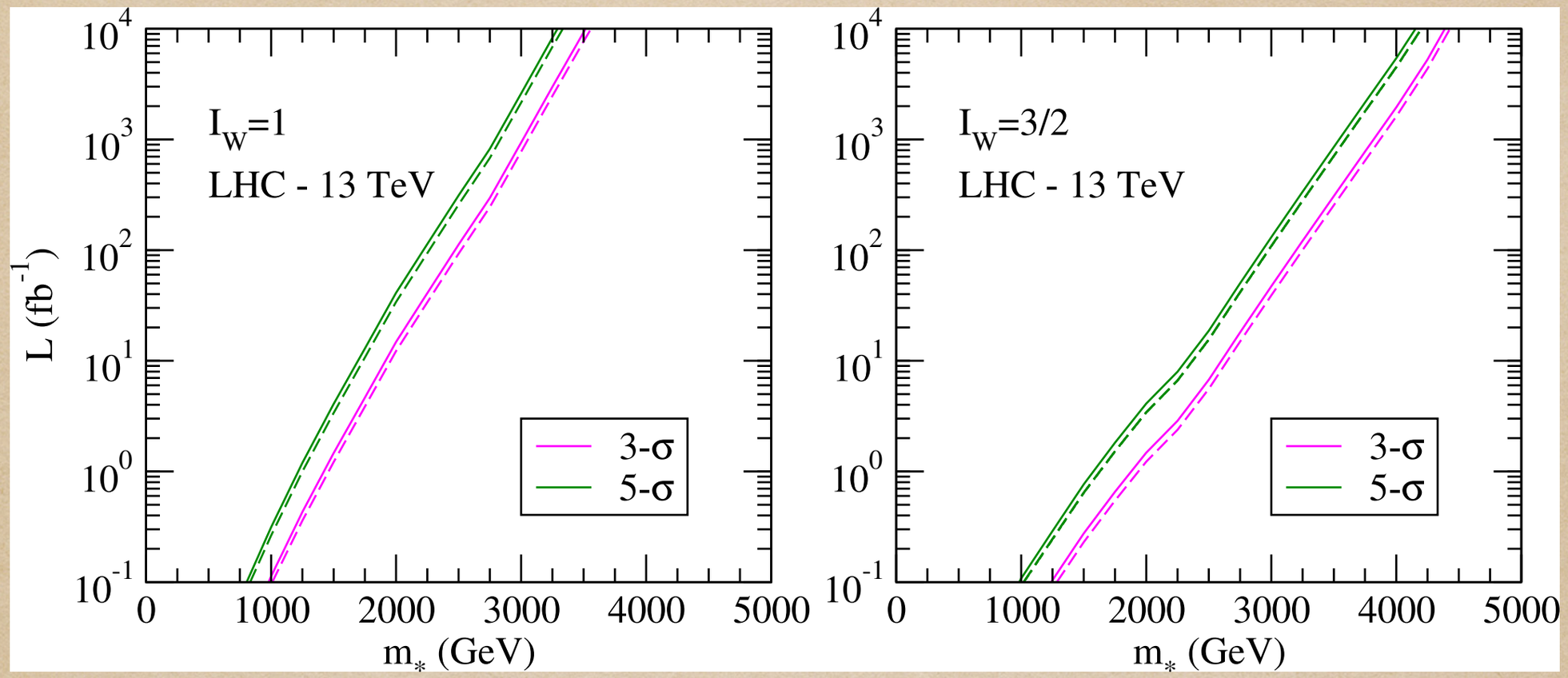
  $$S = \frac{N_s}{\sqrt{N_s + N_b}}$$

- Luminosity:

  $$L = \frac{S^2}{\sigma_s\epsilon_s}[1 + \frac{\sigma_b\epsilon_b}{\sigma_s\epsilon_s}]$$

Background			
	σ_b before cut (fb)	σ_b after cut (fb)	(ϵ_b)
	8200000	14678	0.00179
Signal $(I_W = 1)$			
m_* (GeV)	σ_s before cut (fb)	σ_s after cut (fb)	(ϵ_s)
500	7782	5416.74	0.69606
1000	1277	1064.33	0.83346
1500	344.6	298.489	0.86619
2000	107.7	95.1185	0.88318
2500	39.05	34.7037	0.8887
3000	13.5	12.0555	0.893
3500	4.281	3.84352	0.89781
4000	1.424	1.28213	0.90037
4500	0.4957	0.446665	0.90108
5000	0.1799	0.162518	0.90338
Signal $(I_W = 3/2)$			
m_* (GeV)	σ_s before cut (fb)	σ_s after cut (fb)	(ϵ_s)
500	11080	5819.11	0.52519
1000	2240	1649.89	0.73656
1500	806.3	646.065	0.80126
2000	343.2	283.964	0.8274
2500	159.9	134.147	0.83894
3000	60.25	51.8626	0.86079
3500	23.55	20.0983	0.85343
4000	9.347	7.57986	0.81094
4500	3.191	2.60797	0.81729
5000	1.043	0.845737	0.81087

Luminosity curves @ 5- and 3-σ within statistical error



- Mass reach @ 3-σ for L=(30, 300, 3000) fb^{-1}
- I_W = 1 m_* ≥ (2230,2780,3280) GeV
- I_W = 3/2 m_* ≧ (2930,3540,4140) GeV

Q(5/3) conclusions and outlook

- Quite encouraging results (high mass reach);
- More detailed studies of signature warranted:
  - Full exploration of the two-dimensional parameter space (Λ,m_*);
  - Inclusion of contact interactions;
- Start a new analysis on LHC data ? (it would be the first ever for excited quarks of charge 5/3 within composite models);
- Possible collaboration with CMS group @ Brown University (USA);

Unitarity bounds on single production of heavy Composite fermions

- "Perturbative Unitarity bounds for effective composite models" S. Biondini, R. Leonardi, O. Panella, and M. Presilla, [Phys. Lett. B795 (2019) 644-649, Phys. Lett. B799 (2019) 134990]
- NO SPOILER, → see following talk by MATTEO PRESILLA.
- However main takeaways:
  - Theoretical unitarity bound in parton Collisions $q\bar{q}' \to \ell N_\ell$ $\frac{g^4}{1152\pi^2\Lambda^2}\frac{\hat{s}^2(2\hat{s}+M^2)}{(\hat{s}-m_W^2)^2}\left(1-\frac{M^2}{\hat{s}}\right)^2 \leq 1$
  - Implementation of the bound @ pronton-proton collisions NOT UNIQUELY DEFINED;
  - Impact can be significative on experimental searches of excited composite fermions but ULTIMATELY DEPENDENT ON THE IMPLEMENTATION SCHEME
- This workshop is organized to foster discussion between theorists and experimentalists to discuss the unitarity issues in composite models, Dark Matter searches, VBS ....

Conclusions

- Fair to say that we have produced quite a good amount of work over a period of about 8 years; (≈ 12-15 joint papers (20 including proceedings)
- AMAZING SYNERGY between experimental (CMS-Perugia and recently CMS Padova) and theory groups (R. Leonardi, M. Presilla, S. Biondini and O. P.)
- Pheno-studies of exotic composite states L^{++} , Q(5/3) and Heavy Majorana Neutrinos
- Connection of model with Cosmology via Leptogenesi
- UNITARITY BOUNDS with impact in current experimental searches @LHC (THAT'S WHY WE ARE HERE !!)
- CMS PAS EXO-16-026 Analysis on Run II 2015 data set on Heavy Composite Majorana Neutrino
- COMING SOON!! New CMS analysis of the Heavy Composite Neutrino search with full Run II data set (reaload of CMS PAS EXO-16-026)
- New analysis on LHC data? (Experimental search for excited Doubly Charged Leptons L^{++} and Quarks of charge 5/3 it would be the first ever within composite models.);

Outlook

- DISCUSSION FOR A BETTER UNDERSTANDING ON HOW TO IMPLEMENT UNITARITY BOUNDS @LHC
- PREPARATION OF THE DOCUMENT: (Overleaf link) everyone is welcome to participate!!
- SCHELETON OF THE OUTCOMING DOCUMENT:
  - Intro and HISTORICAL OVERVIEW of effective fermion composite models;
  - REVIEW OF PHENOMENOLOGICAL STUDIES and EXPERIMENTAL SEARCHES;
  - Connection of composite models with Cosmology: Leptogenesi;
  - Impact of higher Multiplets and bounds from electroweak precision observables
  - UNITARITY bounds for LHC searches, implementation methods etc ...
  - UNITARITY in Dark Matter Searches
  - UNITARITY in VBS searches
  - .....