



Contact Interaction and excited states with CompHEP

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- ◆ **Contact Interaction (CI), Compositeness search at LHC**
- ◆ **Implementation with LanHEP+compHEP**
- ◆ **probe of CI scale : di-lepton production with SM+CI**
- ◆ **Comparison with Pythia for single excited lepton production**



Introduction (I)



- ◆ Proliferation of quarks and leptons inspired possible substructure (preon) of them, which introduces new interactions. **Contact Interaction** of 4 fermions:

$$L_{contact}^{ef} = (1 + \delta_{ef})^{-1} \frac{g_c^2}{\Lambda^2} \sum_{i,j=L,R} [\eta_{ij} (\bar{f}_i \gamma_\mu f_i) (\bar{e}_j \gamma^\mu e_j)]$$

- ◆ Λ is the compositeness scale. $\eta = 0, \pm 1$, L (R) denotes the left (right) chirality of the fermionic currents.

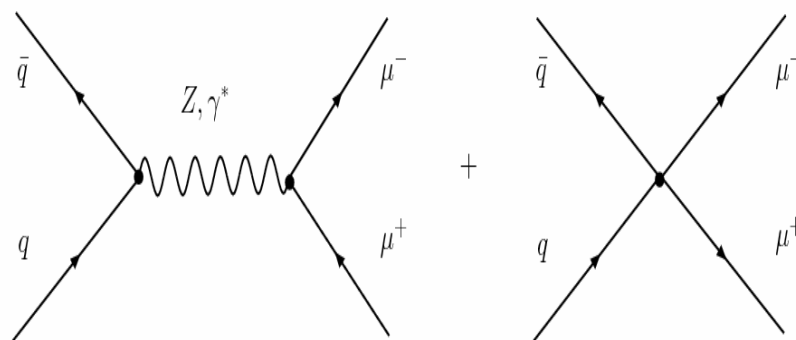
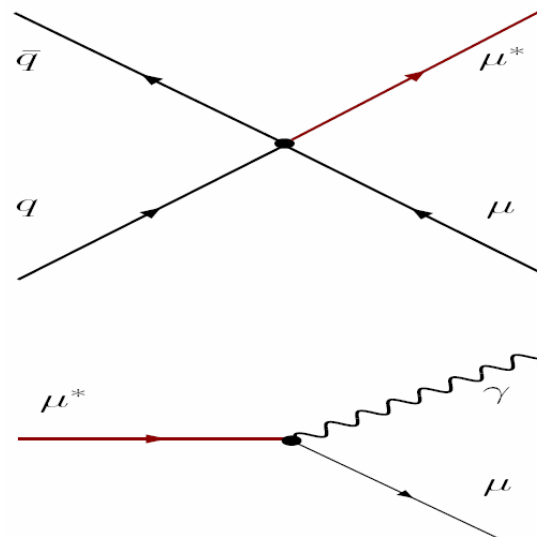
- ◆ Interaction between ordinary and **excited states**

$$L_{trans} = \frac{1}{2\Lambda} \bar{f}_R^* \sigma^{\mu\nu} (g_s f_s \frac{\lambda^a}{2} G_{\mu\nu}^a + g f \frac{\tau}{2} \cdot W_{\mu\nu} + g' f' \frac{Y}{2} B_{\mu\nu}) f_L + H.c.$$

- ◆ U.Baur, M.Spira, P.Zerwas PRD42(1990) 815
E.Eichten,K.Lane,M.Peskin PRL(1983) 811

Two most interesting search
(with lepton/photon final
states) at LHC:

- ◆ resonance search of excited lepton, in the multi-lepton or lepton-photon channels.
- ◆ examine invariant mass spectrum of di-lepton
- ◆ No published results based on full simulation at LHC so far. D0 RunII 400/pb limits 4-10 TeV of Λ for various η





Feynman Rule by IanHEP



◆ IanHEP handles the lagrangian, and derive Feynman rule

```
%Contact interaction between 4-fermions,auxiliary field X are introduced  
lterm gc/(2)*( gxl*anti(psi)*gamma*(1-g5)*X*psi +  
gxr*anti(psi)*gamma*(1+g5)*X*psi)  
%EW interaction between ordinary and excited states.  
lterm 1/(2*Lambda)*anti(psix)*(1+g5)/2*sigma  
*(g*f*taupm*ttW/2+fpr*g1*Y*tB/2)*(1-g5)/2*psi+AddHermConj
```

◆ Output vertex in CompHEP format.

```
P1 |P2 |P3 |P4 |> Factor <|> dLagrangian/ dA(p1) dA(p2) dA(p3)  
U |u |X | |gc/2 |gxl*G(m3)*(1-G5)+gxr*G(m3)*(1+G5)  
E1 |ex |A | |EE/(8*Lambda) |f*G(m3)*G(p3)*(1+G5)-  
f*G(p3)*G(m3)*(1+G5)+fpr*G(m3)*G(p3)*(1+G5)-fpr*G(p3)*G(m3)*(1+G5)
```



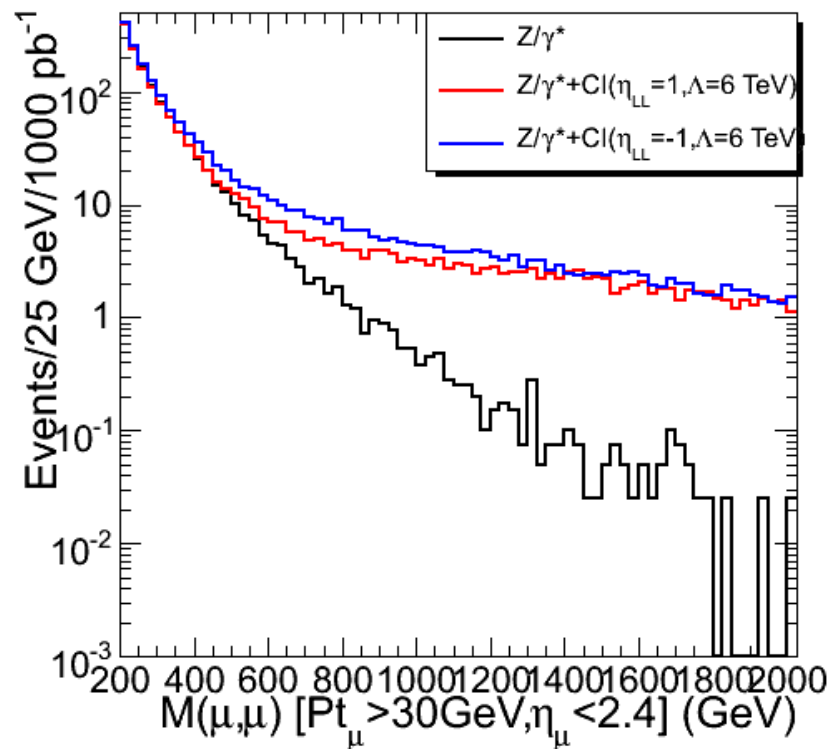
Di-lepton production with SM+CI



◆ Cross section modified by Contact Interaction:

$$\frac{d\sigma_T}{dM} = \frac{d\sigma_{sm}}{dM} + \frac{I}{\Lambda^2} + \frac{C}{\Lambda^4}$$

- ◆ Events generated with compHEP 443 and passed to pythia .Two final state muons are required to be within CMS detector($|\eta| < 2.4$)
- ◆ A powerful test of compositeness scale Λ



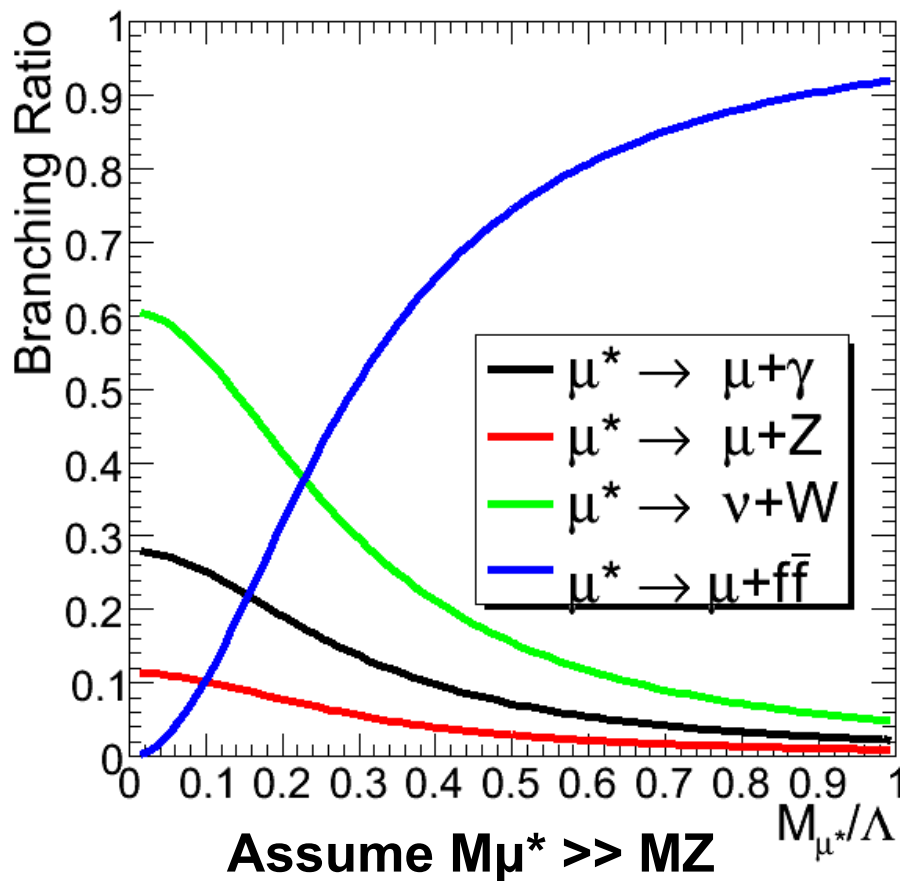


$pp \rightarrow \mu \mu^*$



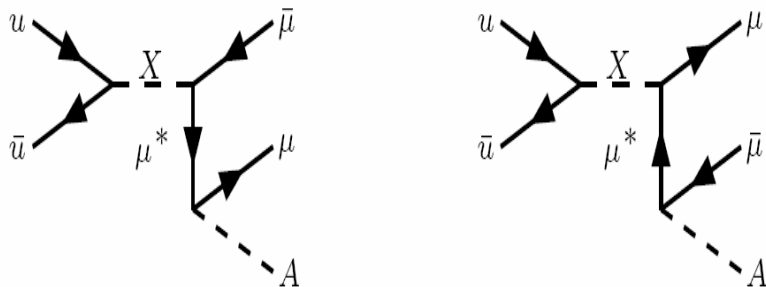
- ◆ Dominated by Contact interaction at LHC
- ◆ Leading order cross section, given $\Lambda = 6\text{TeV}$, $\eta_{LL}=1$

$\sigma(pp \rightarrow \mu\mu^*)(\text{pb})$ at $\sqrt{s} = 14\text{TeV}$, CTEQ5L, $\mu_f = M_{\mu^*}$		
$M_{\mu^*}(\text{GeV})$	CompHEP 443	Pythia 6.4
500	4.08E-01	4.07E-01
1000	1.72E-01	1.73E-01
1500	7.52E-02	7.58E-02
2000	3.36E-02	3.37E-02
2500	1.48E-02	1.49E-02
3000	6.47E-03	6.50E-03

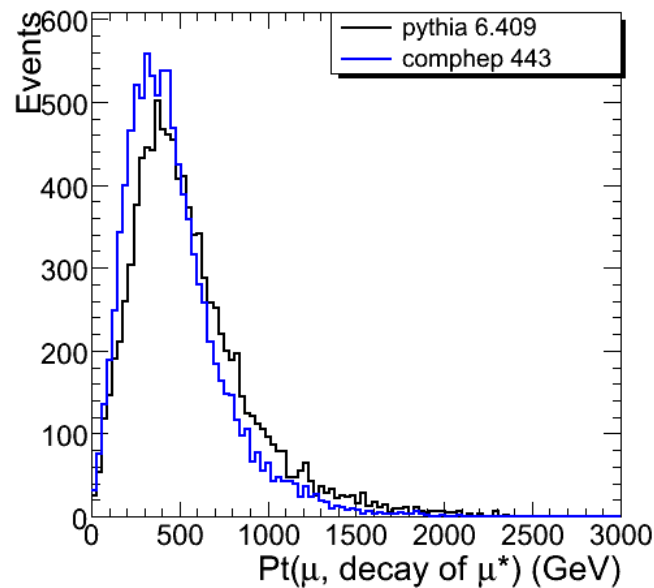
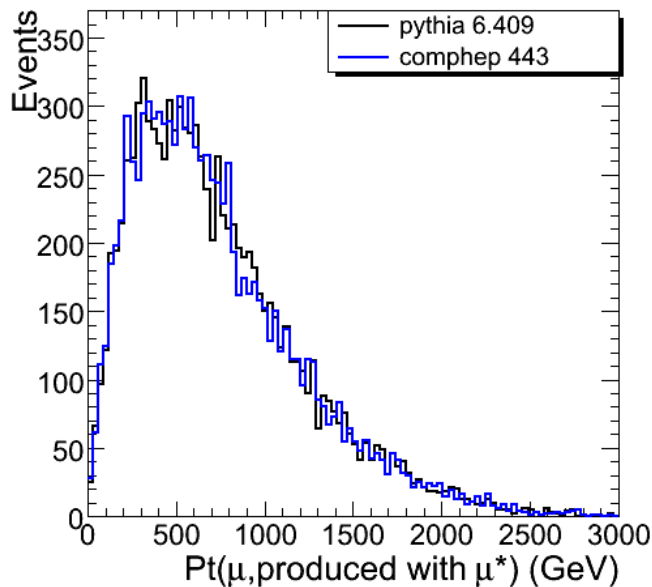
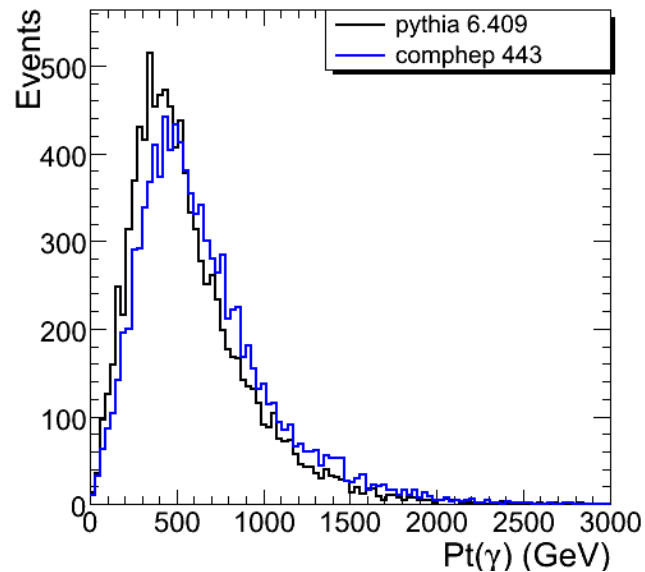




$pp \rightarrow \mu \mu^* (\mu \gamma)$: PT distribution

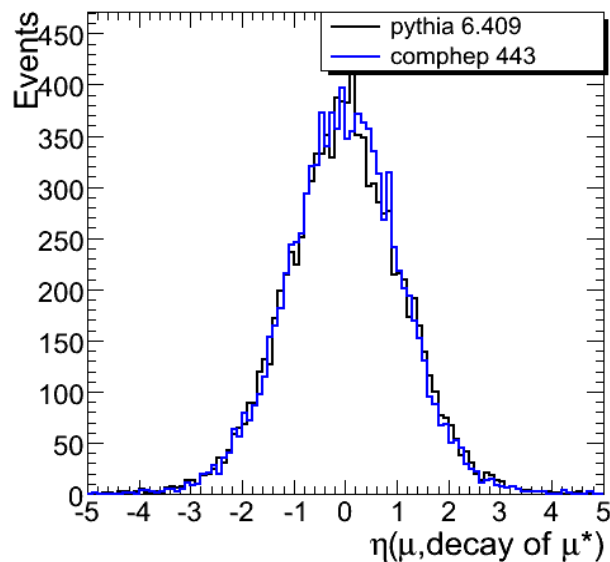
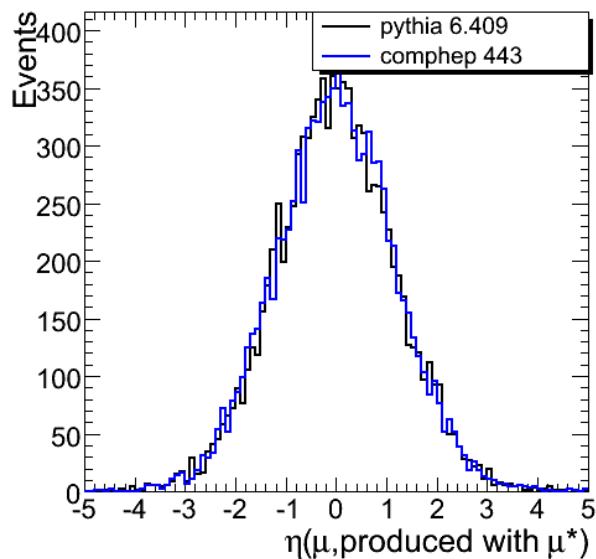
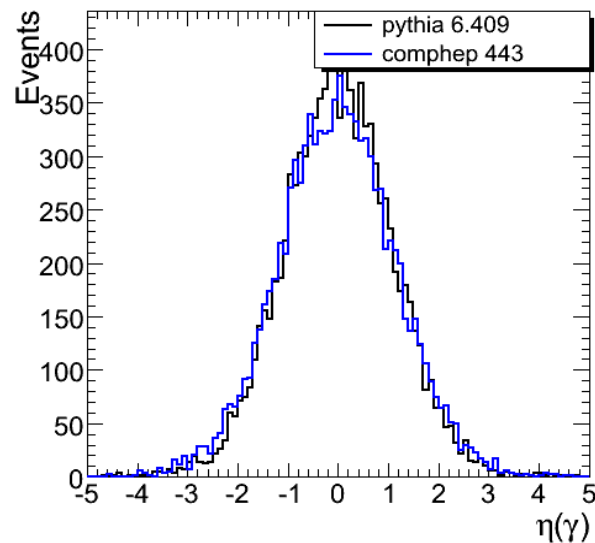
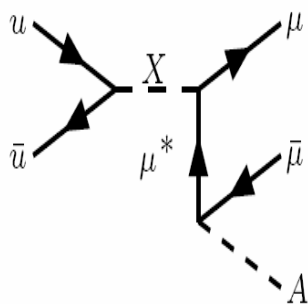
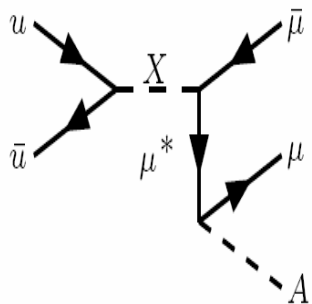


$M_{\mu^*} = 1\text{TeV}$



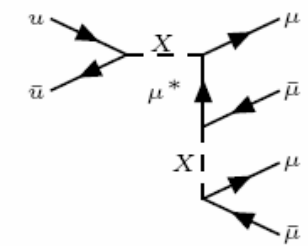
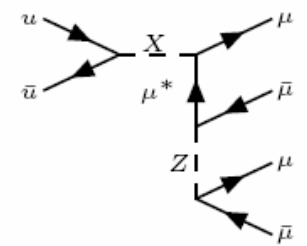
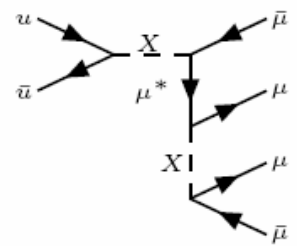
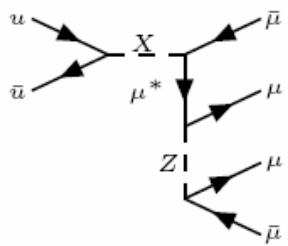


$pp \rightarrow \mu \mu^* (\mu \gamma): \eta$ distribution

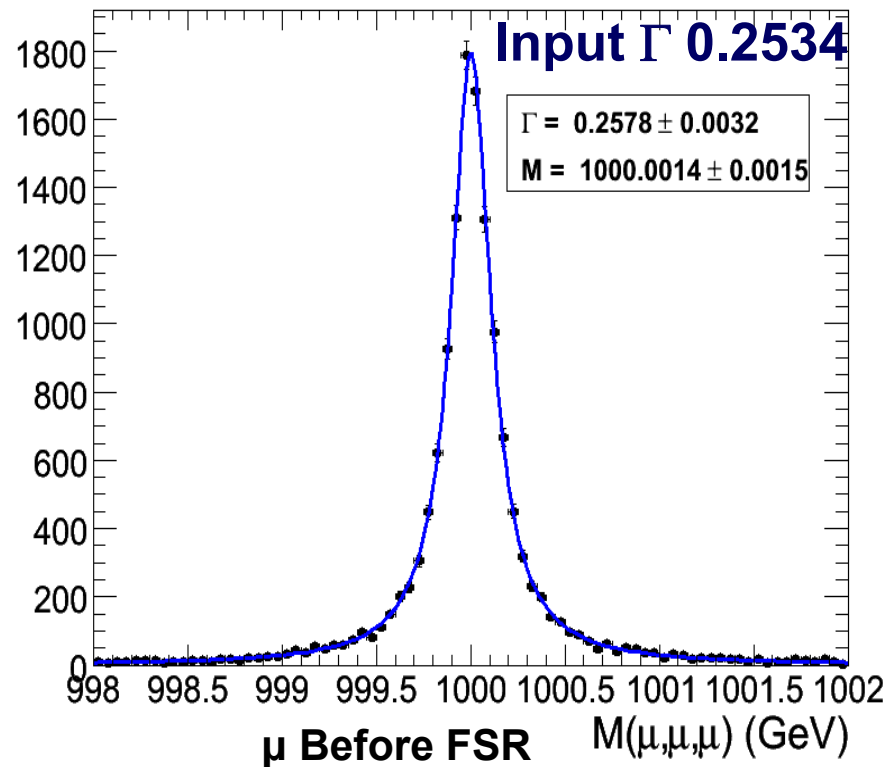
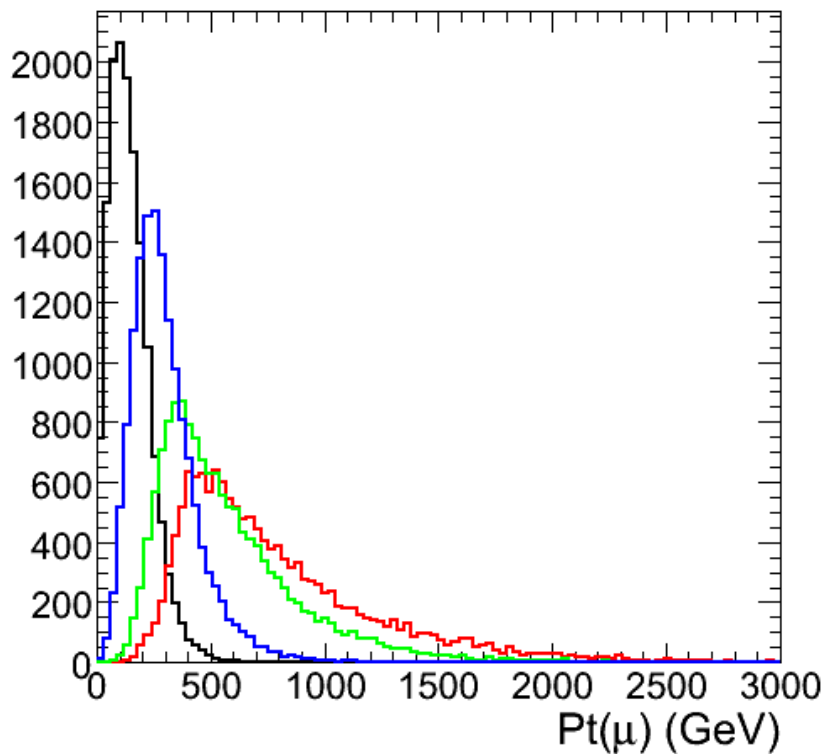




$pp \rightarrow \mu \mu^* (\mu \mu \mu)$



◆ 4 high-Pt Muons, very clean Signature.





Summary



- ◆ **At LHC, contact interaction predicts deviation from standard model in the di-lepton spectrum. It also dominates the production of excited lepton. In principle those effects can show up at low luminosity if Λ is not too large.**
- ◆ **Full lanHEP model for excited and composite states was developed to generate Feynman rules for compHEP. Some cross checks with pythia built-in matrix elements. Generation of decay of excited lepton to multi-lepton is available with compHEP (not in pythia 6.4)**
- ◆ **Analysis ongoing with full detector simulation in CMS exotica group.**
- ◆ **Thank you.**