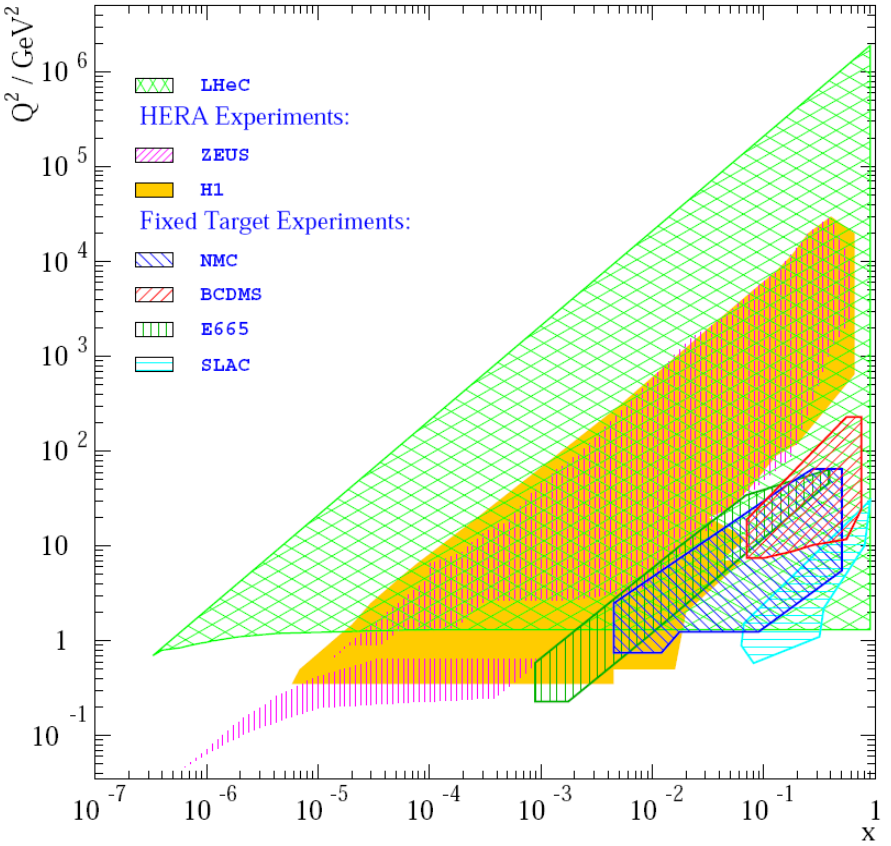
1st ECFA-CERN LHeC Workshop
Divonne-les-Bains, 1-3 September 2008

Single Production of Excited Leptons @ LHeC

T. Nguyet TRINH, Emmanuel SAUVAN
Centre de Physique des Particules de Marseille, France

Plan

- Composite Models of fermions
- Status of excited lepton searches at colliders
  - ↘ LEP, HERA, TEVATRON
  - ↘ LHC: imminent turn-on
- Sensitivity to e* in ep collisions at 1.4 TeV (electron ring) and 1.9TeV (electron linac)?
  - ➔ e* production through Gauge Mediated (GM) Interactions
    - ↘ Cross section
    - ↘ Search for e*→e γ
    - ↘ Expected limit on f/Λ
  - ➔ e* production through Contact Interaction (CI)
    - ↘ What is the importance of CI source in ep?



Excited states ...

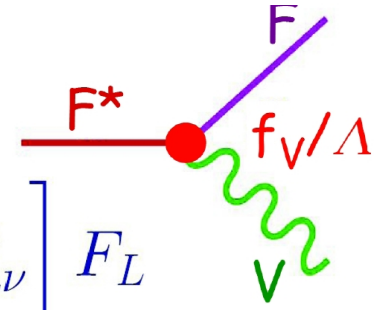
- If found, direct proof of compositeness
- Main approach: Excited fermion (f*) couple to gauge boson via Gauge Mediated Interaction (GM)

  [Hagiwara et al. ZPC 29(1985)115]

  [Boudjema et al. ZPC 57(1990)425]

  ↘ assuming f* have spin, isospin ½ and exist in weak doublets $F^*_{L,R}=(\nu^*,e^*)_{L,R}$

  ↘ only right-handed components of F* involved in the exchange

  ↘ Lagrangian described the f↔f* transitions:

$$\mathcal{L}_{GM} = \frac{1}{2\Lambda}\bar{F}^*_R\sigma^{\mu\nu}\left[gf\frac{\tau^a}{2}W^a_{\mu\nu} + g'f'\frac{Y}{2}B_{\mu\nu} + g_s f_s\frac{\lambda^a}{2}G^a_{\mu\nu}\right]F_L$$

  SU(2) U(1) SU(3)

  →Λ: composite scale and f,f',fs: electroweak and strong gauge couplings

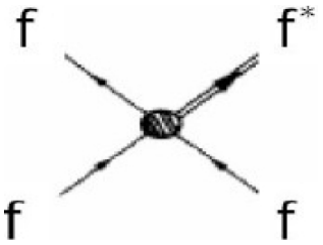
- Other approach: couplings of F* to quarks and leptons via Contact Interaction (CI)

  [Baur et al. PRD 42(1990)815]

  ↘ Lagrangian described the f↔f* transitions:

$$\mathcal{L}_{CI} = \frac{4\pi}{2\Lambda^2}j^\mu j_\mu$$

$$j_\mu = \eta_L\bar{F}_L\gamma_\mu F_L + \eta'_L\bar{F}^*{}_L\gamma_\mu F^*_L + \eta''{}_L\bar{F}^*{}_L\gamma_\mu F_L + h.c. + (L\to R)$$

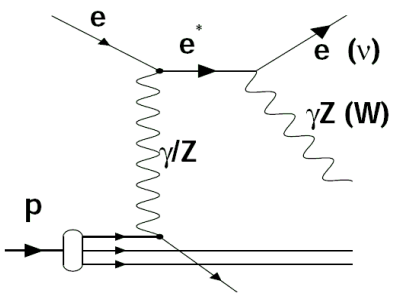
  

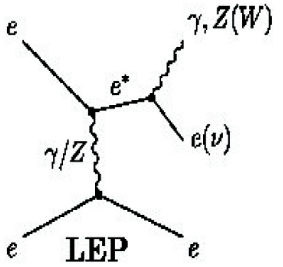
  →for convention: $\eta_L=1,\ \eta_R=0$

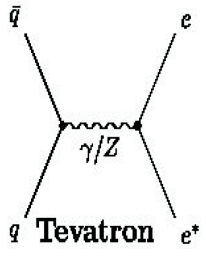
  ↘ similar phenomena, mainly differs from GM by a normalization factor

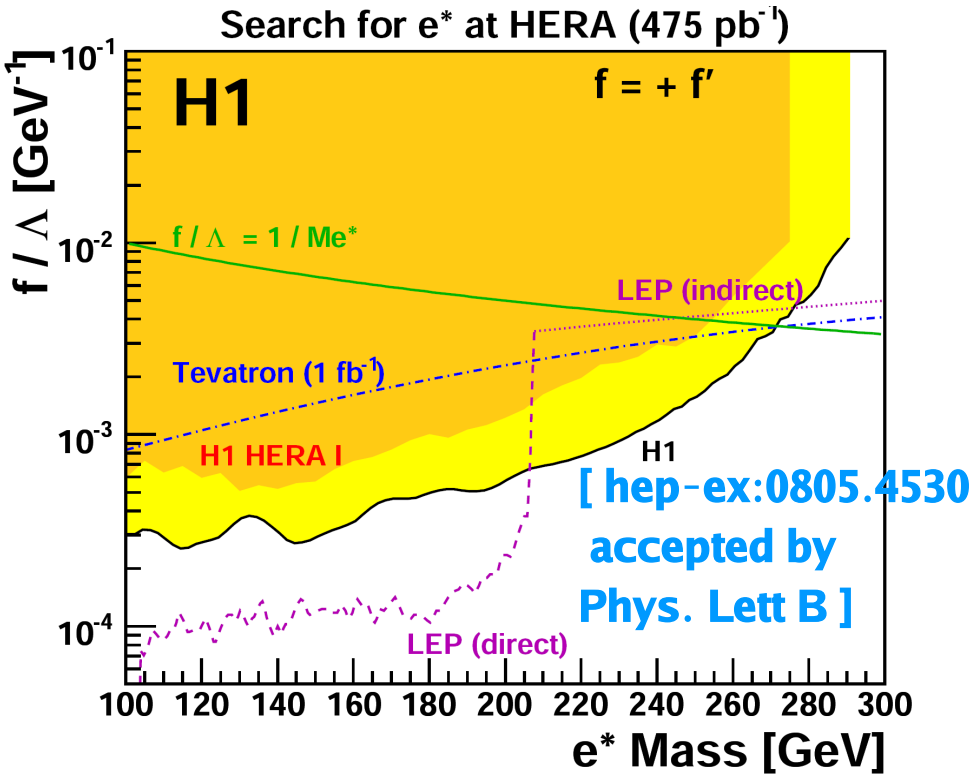
Existing limits from present colliders

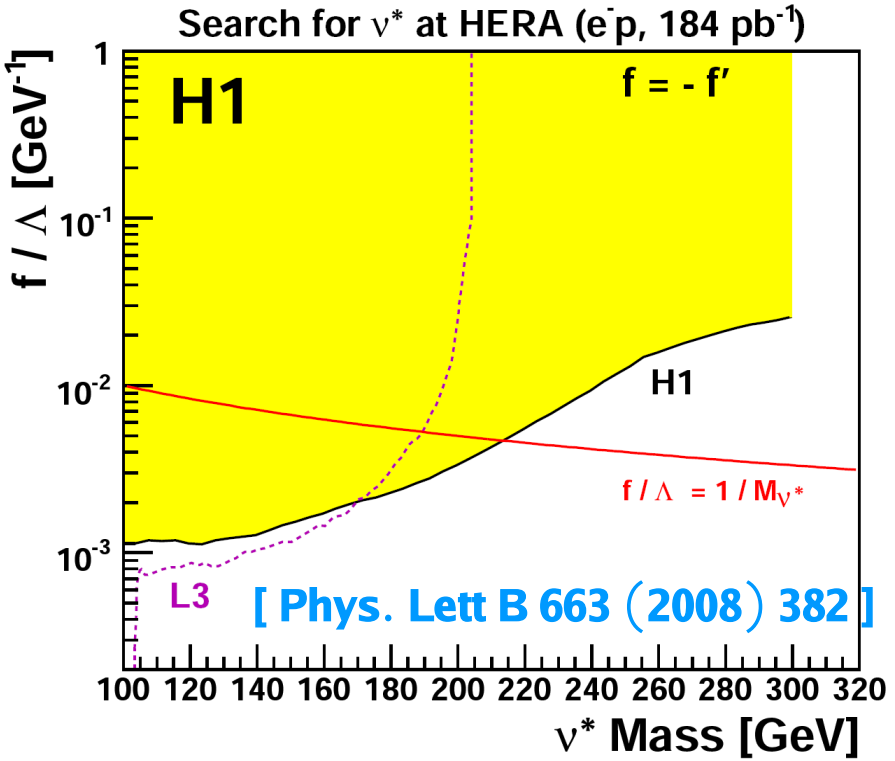
- At LEP, HERA, Tevatron colliders:







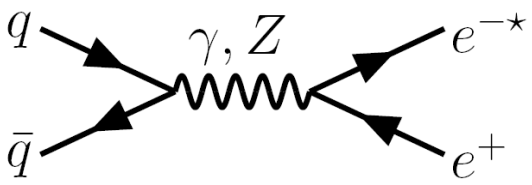


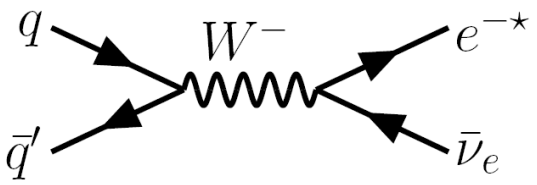


- ν* at HERA: best sensitivity to masses beyond the LEP reach
- e* at HERA: new H1 limit is more stringent than present LEP or Tevatron results in the intermediate e* mass range

Excited leptons at future LHC, ILC, LHeC colliders

- Single production of excited leptons at LHC collider (with √s=14 TeV):





[Phys. Rev D 65 (2002) 075003]

[Phys. Rev D 70 (2004) 075011]

↘ assuming f=f'=1 and M*=Λ, the LHC will be able to extend considerably the range of excited lepton masses that can be probe up to about **1-2 TeV**

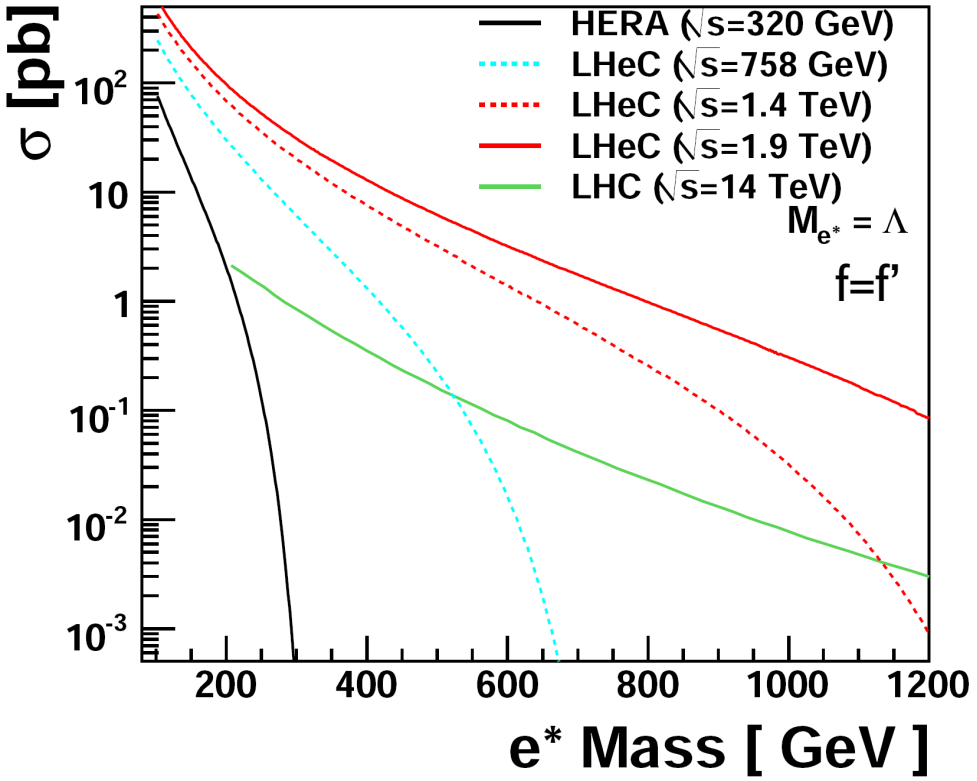
- At ILC collider (with √s ~ 500 GeV): **[Phys. Rev D 56 (1997) 2920]**

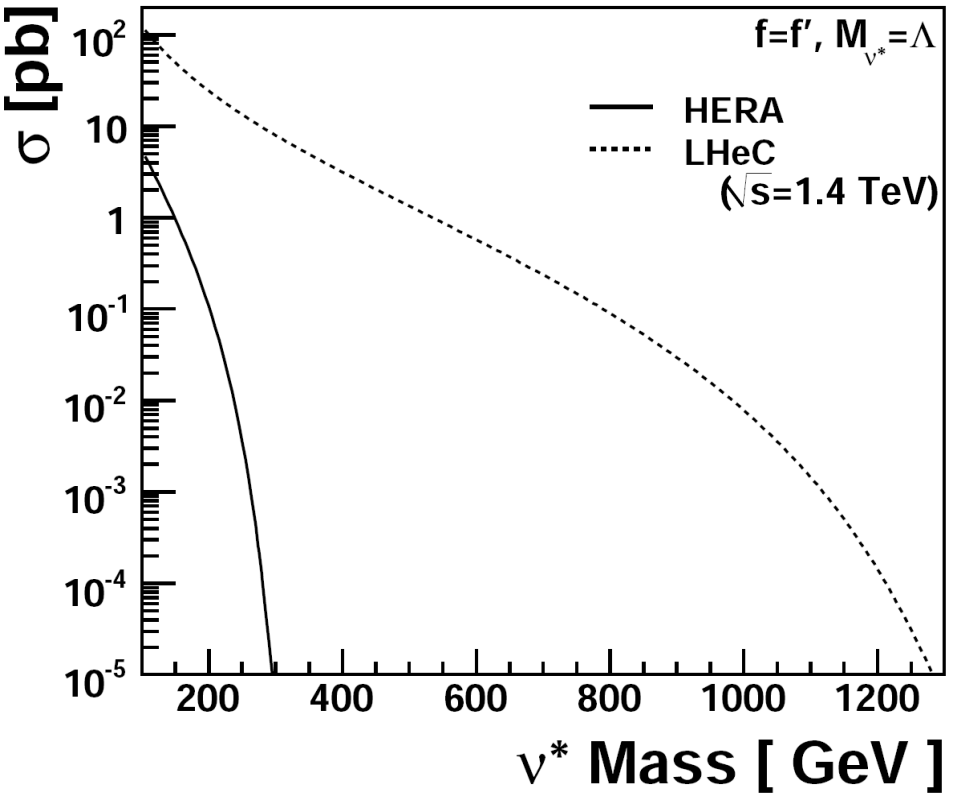
↘ assuming f=f'=1 and M*=Λ, the ILC can discover excited leptons up to the kinematical limit

- At LHeC collider (with √s ~ 1.4 TeV or 758 GeV or 1.9TeV) ?

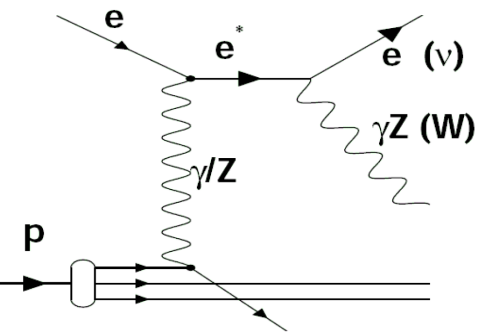
Excited leptons @LHeC

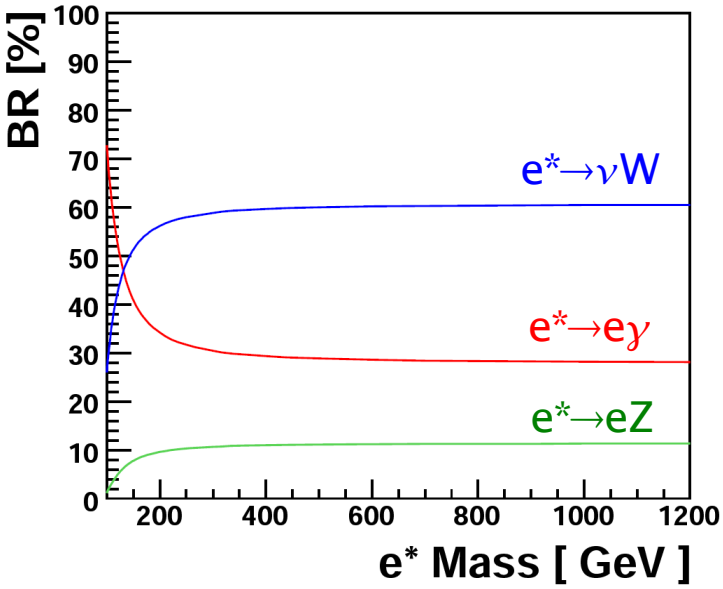
- Total cross section for l* productions through GM interaction at LHeC, assuming M*=Λ
  - ↘ comparison with HERA and LHC

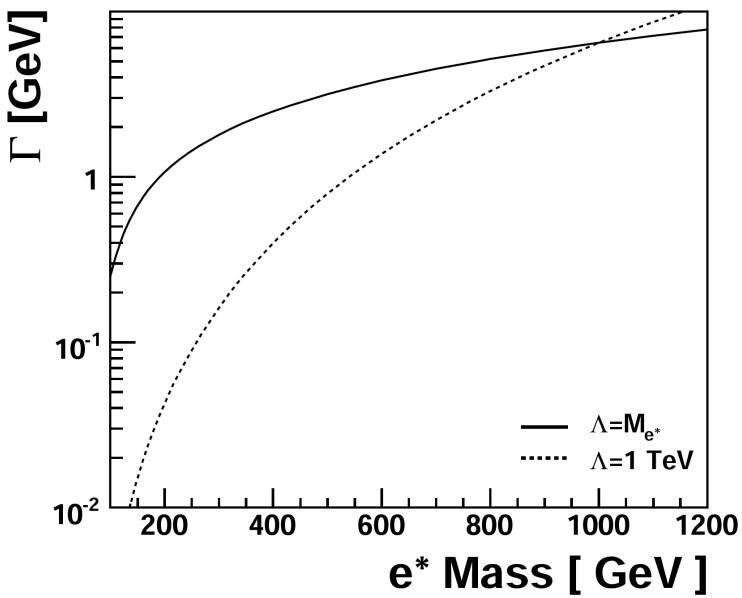




Search for e+p→e*→eγ







➔ Following results only for e*→eγ topology (BR~35%): clear signature, small background

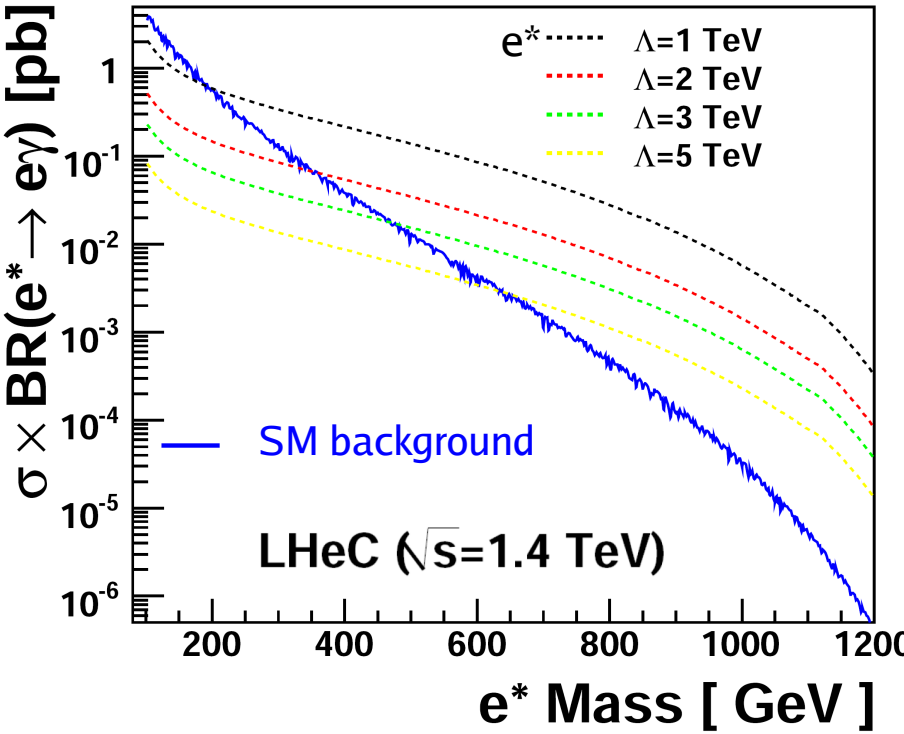
↘ Signal: using Fermion generator

↘ Considered main SM backgrounds: Neutral current and Compton events

☞ Selected events:

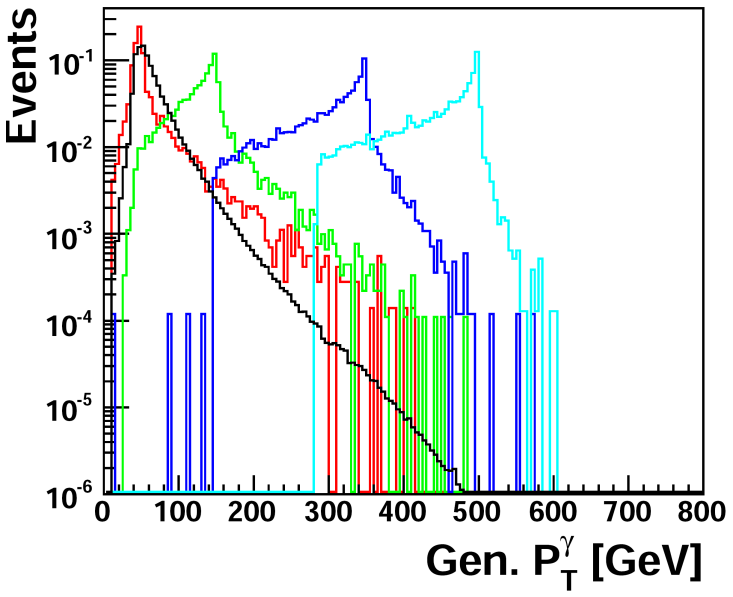
❶ 1 electron: P_T > 15 GeV, 5°<θ<145°

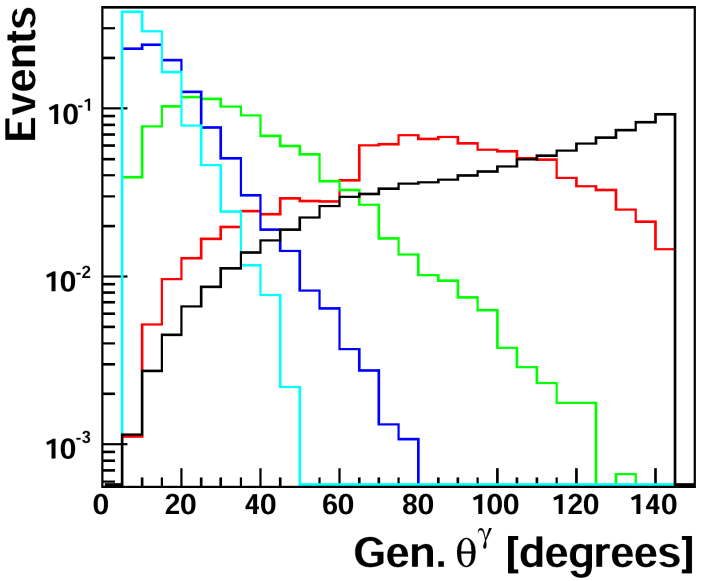
❷ 1 photon: P_T > 10 GeV, 5°<θ<145°



Search for e+p→e*→eγ

- Distributions of $P_T^{e,\gamma}$ and $\theta^{e,\gamma}$

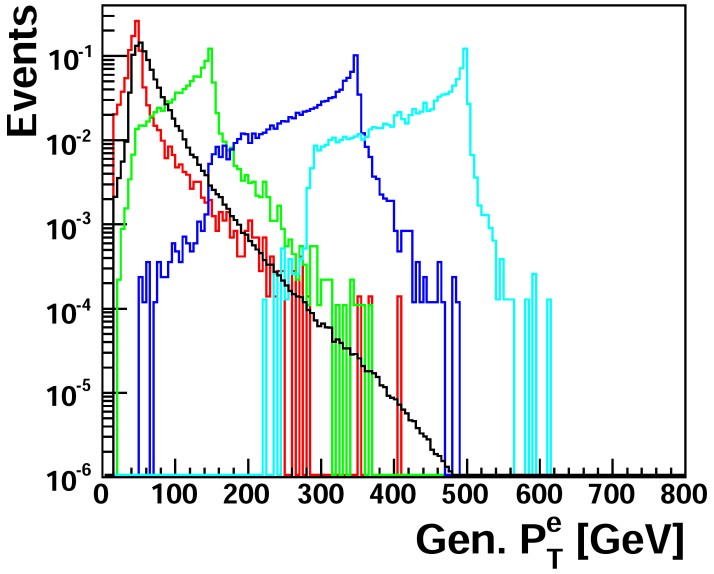


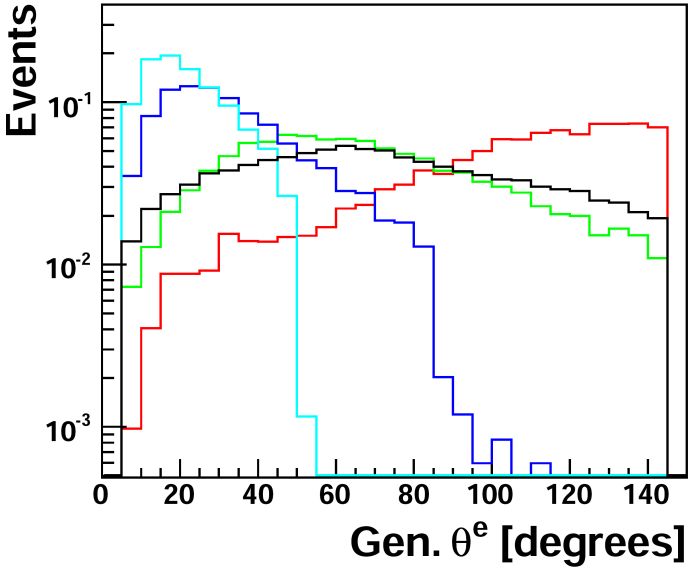


e* M=100 GeV
e* M=300 GeV
e* M=700 GeV
e* M=1 TeV
SM Background

(arbitrary signal / SM normalization)

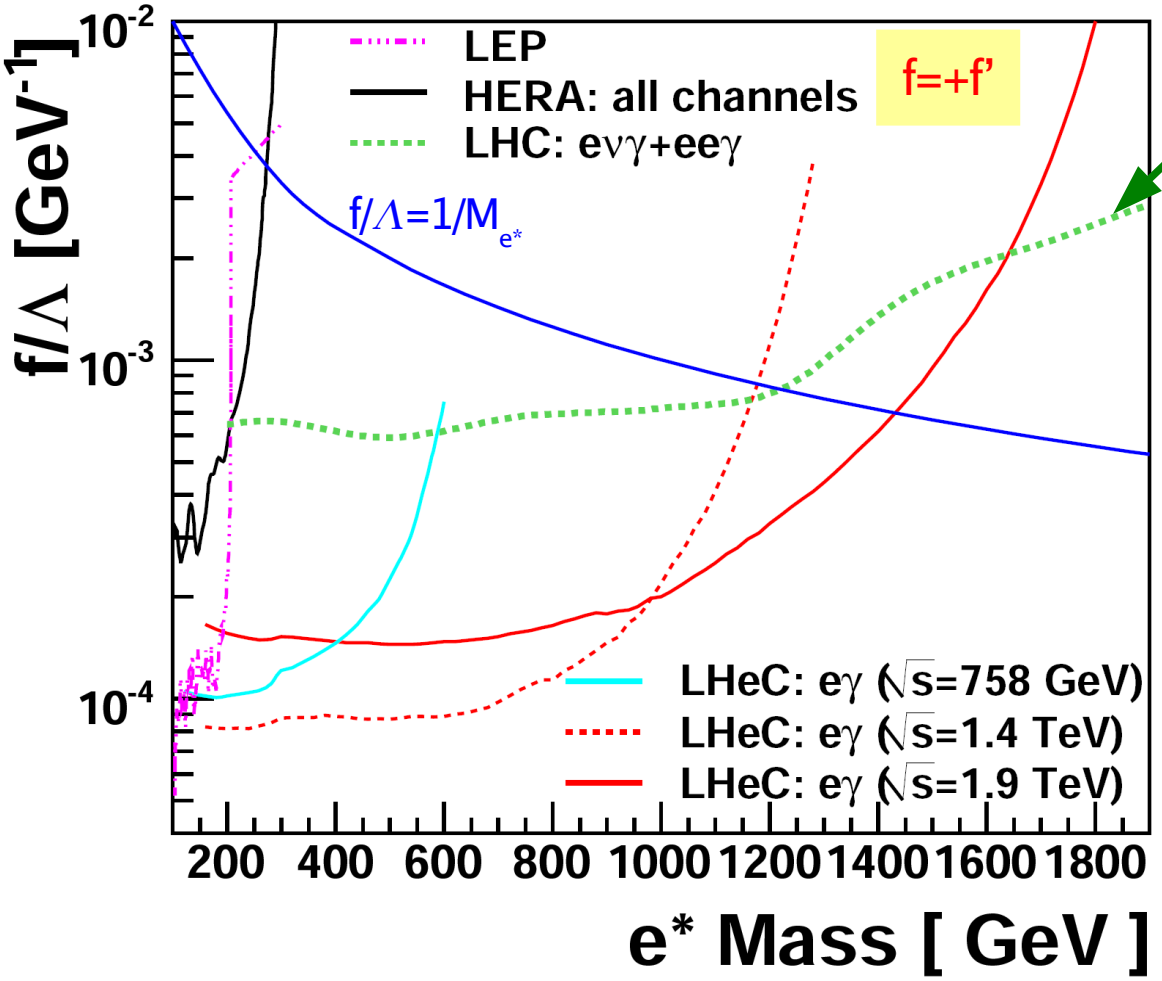
$M_{e\gamma}$ resolution = 3% M_{e^*}





Expected limit at 95% C.L

- Expected limits derived at 95% C.L using Modified Frequentist Approach



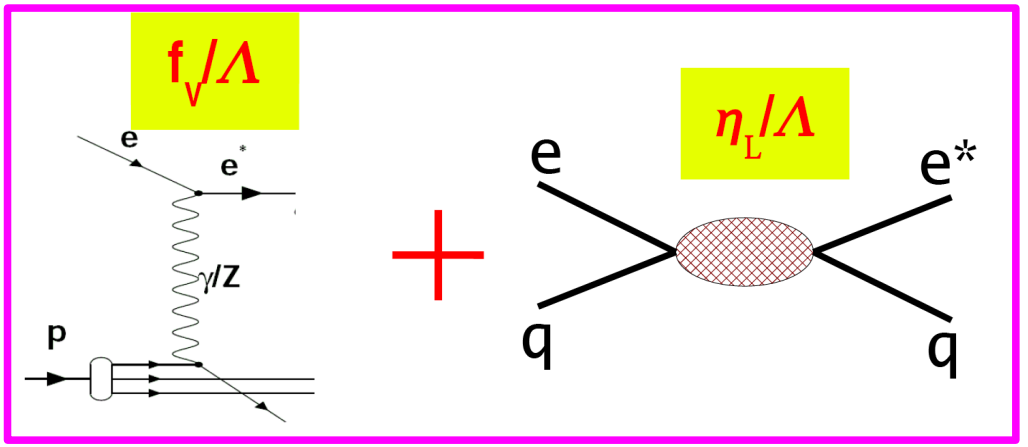
[Phys. Rev D 65 (2002) 075003]

LHeC sensitivity,
with L=10 fb^{-1} for Ee=70/20 GeV
with L=1 fb^{-1} for Ee=140 GeV

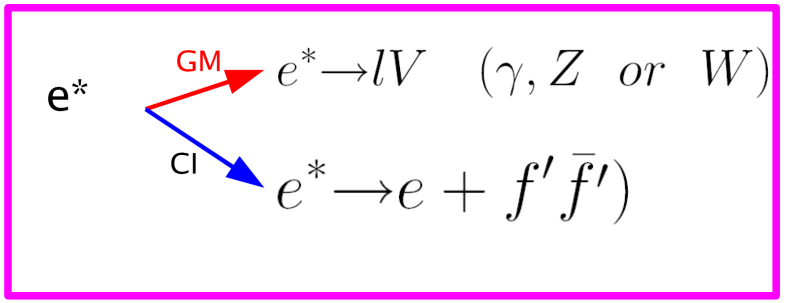
- At LHeC, if f/Λ=1/M$_{e^*}$ and f=f': M$_{e^*}$ < 1.2 (1.5) TeV are excluded, for $\sqrt{s}$=1.4 (1.9) TeV
- At LHC, if f/Λ=1/M$_{e^*}$ and f=f': M$_{e^*}$ < ~1.2 TeV are excluded
  - Expected sensitivity of LheC is more stringent than others colliders

e* @LHeC via Contact Interaction

- Motivation: consider also e* production via CI
  - For production:



  - For decay:

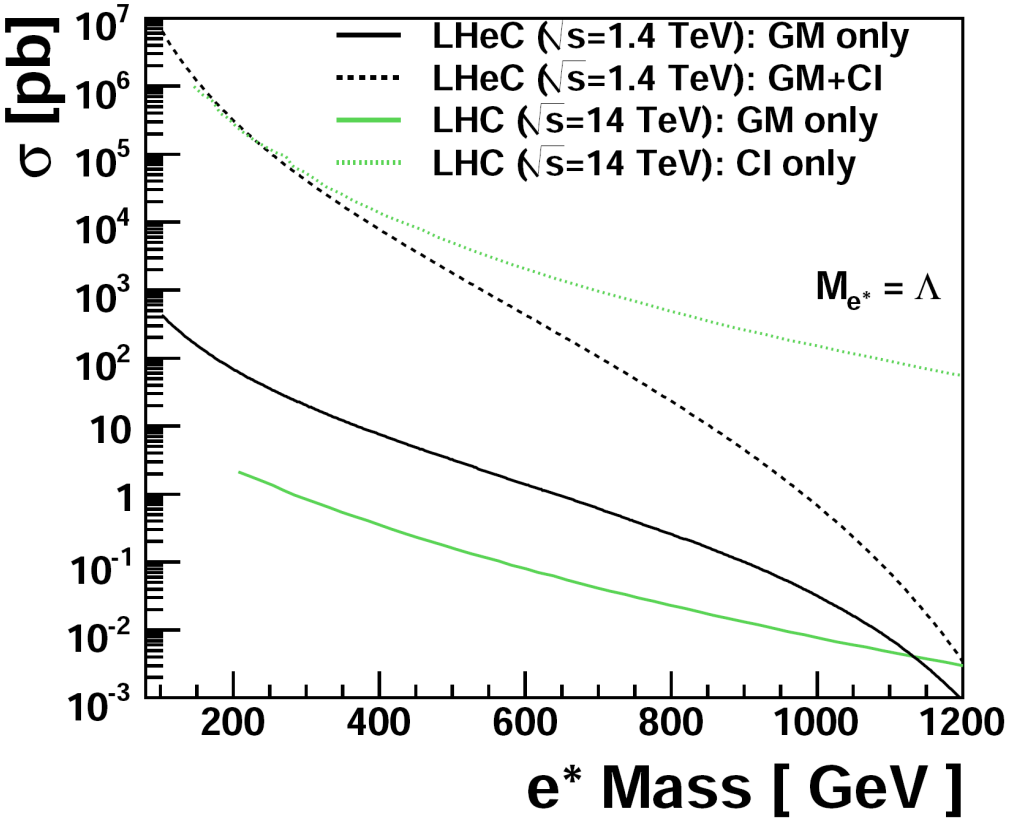


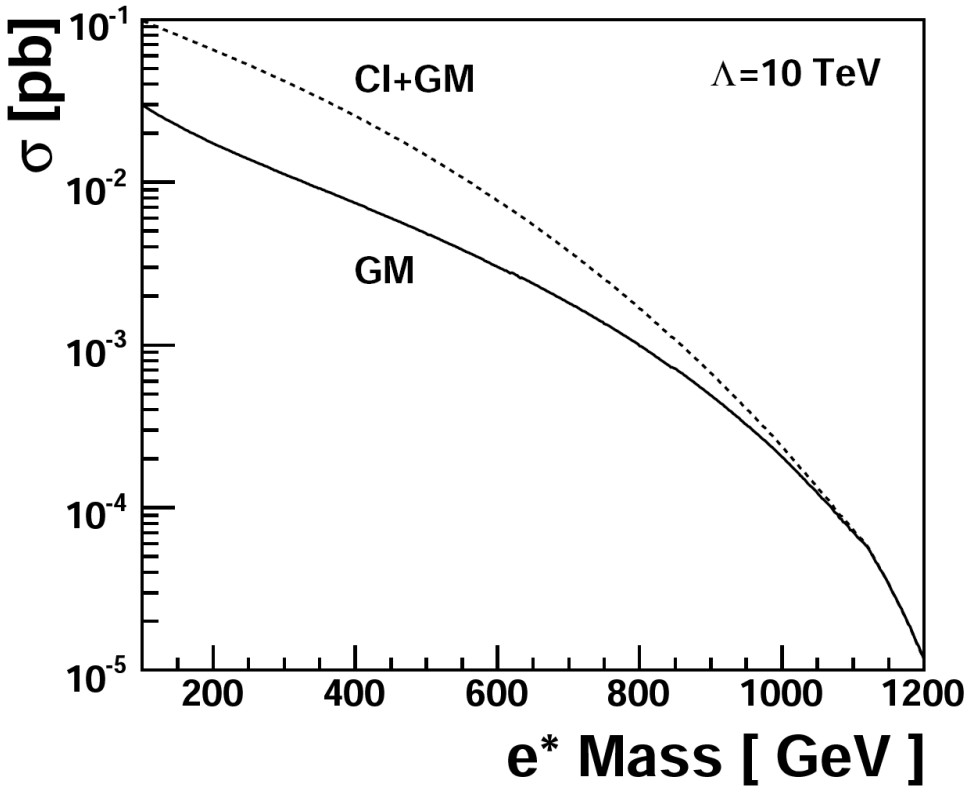
- Total cross section of e* production is now: $\sigma^{CI+GM} = \sigma^{GM} + \sigma^{CI} + \sigma^{interf}$
  - Note: for simplicity, η_R=0 and η_L=1, f=f'=1
    - cross section comparisons between GM/CI
    - branching ratio comparisons of e* via GM/CI
    - limit estimation if e* production via GM+CI

(Code for cross section calculation from M. Spira)

Excited electron @LHeC via Contact Interaction

- Total cross section for e* production through CI at LHeC

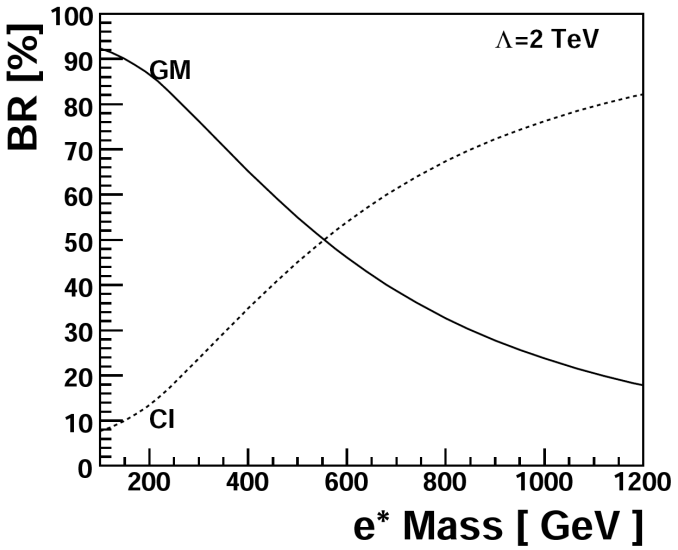


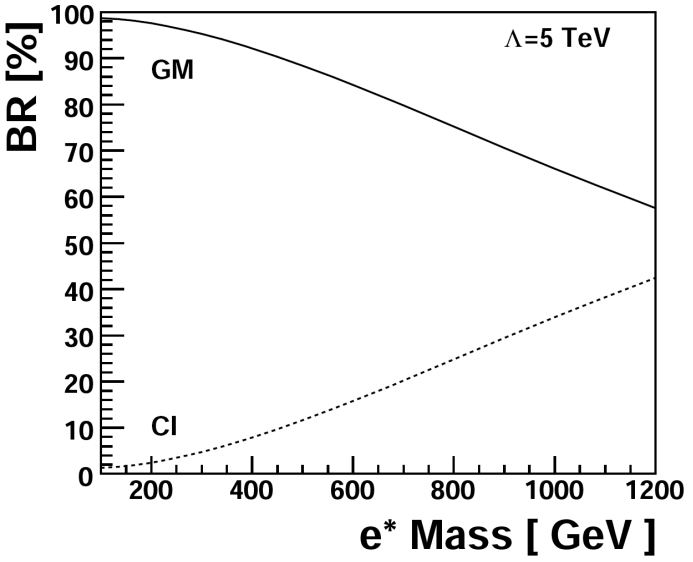


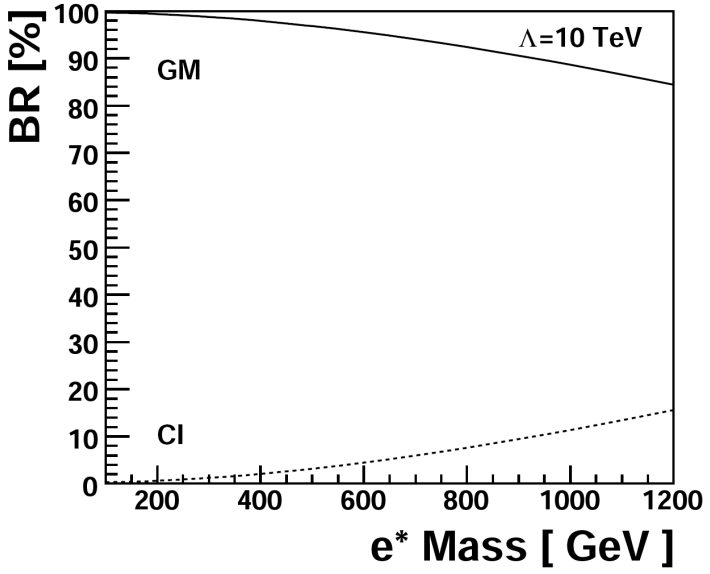
- In ep collisions (HERA, LHeC): main source of e* production is dominated by GM
- In pp collisions (Tevatron, LHC): main source of e* production is dominated by CI

Excited electron @LHeC via Contact Interaction

- The branching ratio of GM and CI decays as a function of e* mass and for some different Λ (=2, 5, 10 TeV)



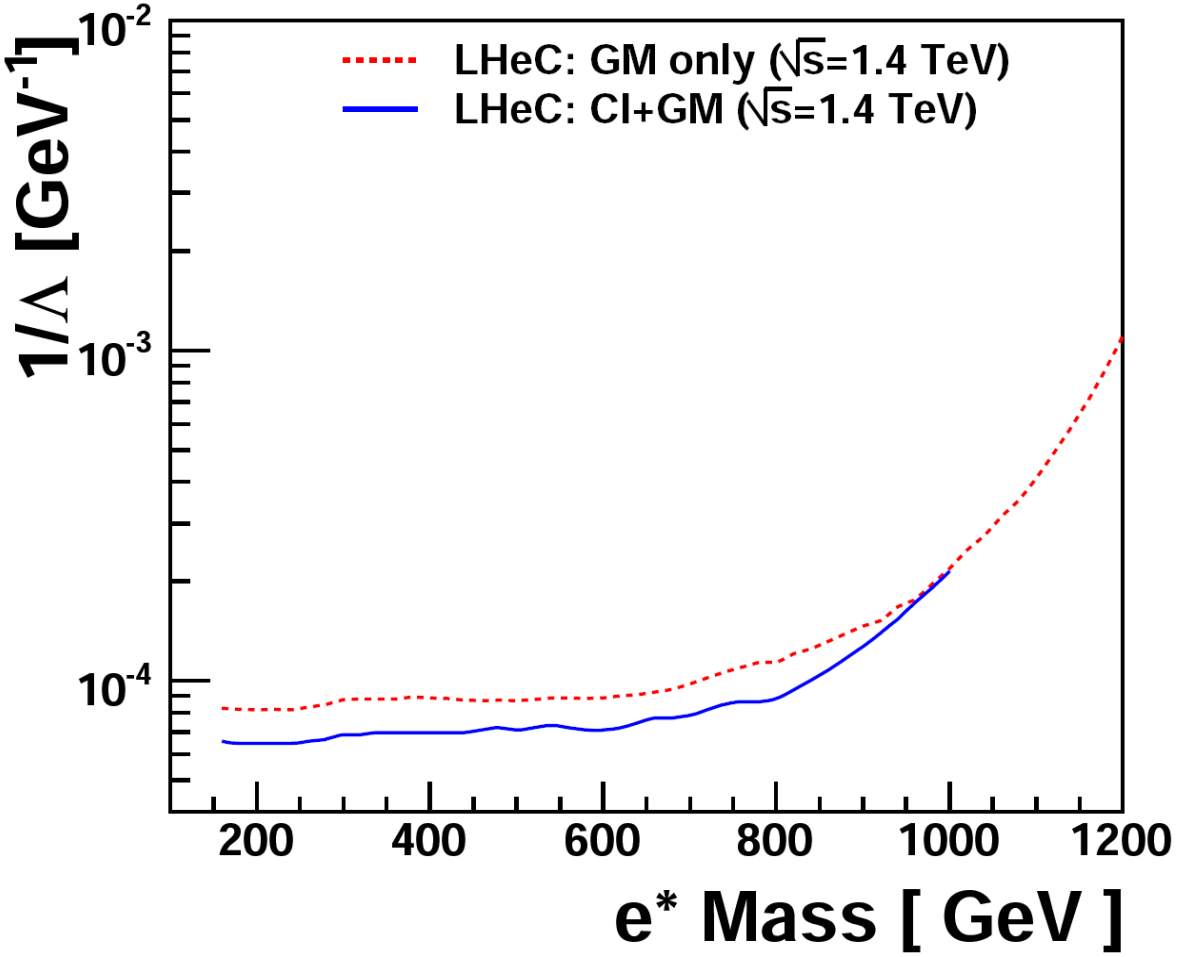




↘ For large Λ, e* decays via CI are negligible

Expected limit on $1/\Lambda$ at 95% C.L

- What do we gain by including CI production model to GM in ep?



↘ No large change of LHeC sensitivity if CI production is considered

Conclusions

- Status of single production of excited lepton at colliders have been reviewed

- Single production of excited lepton at future LHeC collider have been briefly studied

  ↘ Total e* production cross sections at LHeC have been calculated for both CI and GM production modes

  ↘ The case $e^* \to e\gamma$ is studied

  ➔ For GM model, expected limit on coupling f/Λ derived at 95% C.L, assuming f=f'=1

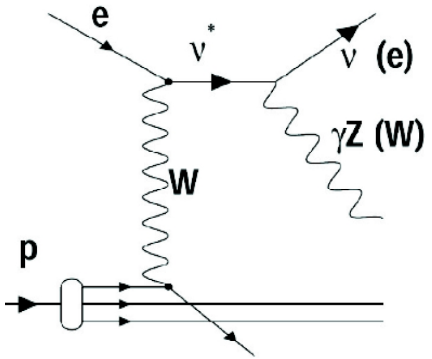
  ☛ Expected limit obtained is more stringent than others colliders

  ➔ For CI model, expected limit on $1/\Lambda$ also derived at 95% C.L, assuming η_L=1, η_R=0 and f=f'=1

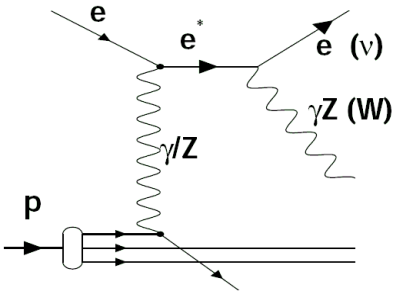
  ☛ additional CI contribution to e* production changes sensitivity by a small factor

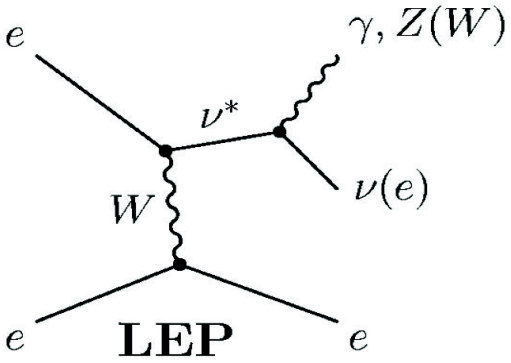
LHeC has larger sensitivity than the LHC and ILC for e* production

Status of excited leptons at "current" colliders-I

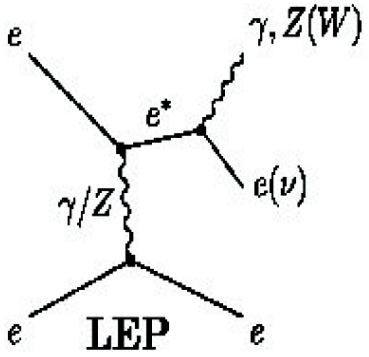


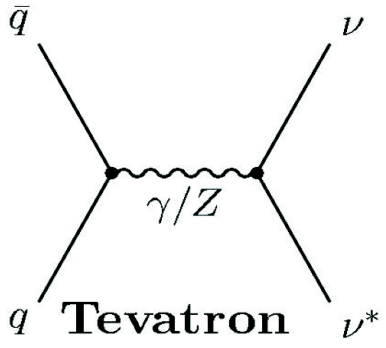
- Production of e*,ν* via t-channel W or γ/Z exchange
- Leptons de-exitation by emission of W or γ/Z
- ν* production: cross section much larger in e-p due to favourable valence u-quarks and helicity enhancement
- e* search: done for both CI and GM modes





- Similar production mechanism
- Larger cross section and smaller background
- Smaller energy in center-of-mass





- ν*search: not yet done
- e* search:
  - signature: (2e+γ) or (2e+jets)
  - just analyze for (2e+γ)
  - both CI and GM considered