FCC PHYSICS, DETECTOR AND ACCELERATOR WORKSHOP @ ISTANBUL

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COLOR OCTET ELECTRON

e_8 @ FCC-hh, CLIC AND FCC-he

DEEP INSIDE OF MATTER

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OUTLINE

- Motivation: Why Preonic Models?
- Color Octet Electrons (e_8) in Preonic Models
- e_8 at different colliders
- e_8 at the LHC (the latest study)
- Lagrangian and Decay Width
- Production Cross Sections of e_8 @ FCC-pp, CLIC
- e_8 at FCC-pe
- Conclusion

The failures of the SM ——>

- **More than 50 fundamental particles** and **26 free parameters** in the minimal SM3 indicates that the Standard Model is manifestation of **more fundamental theory.**
- Physics met similar situation two times in the past:

Stages	1870s-1930s	1950s-1970s	1970s-2020s
Fundamental Constituent İnflation	Chemical Elements	Hadrons	Quarks, leptons
Systematic	Periodic Table	Eight-fold Way	Flavor democracy?
Confirmed Predictions	New elements	New Hadrons	Fourth family?
Clarifying Experiments	Rutherford	SLAC DIS	LHC?
Building Blocks	Proton, neutron, electron	Quarks	Preons?
Energy Scale	MeV	GeV	TeV?
İmpact on Technology	Exceptional	Indirect	Exceptional?

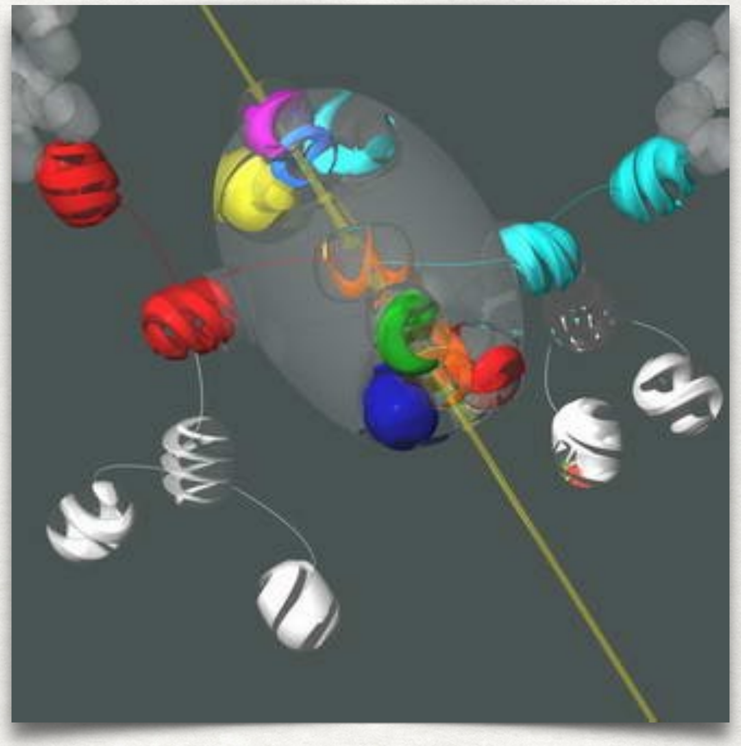
  - Periodic Table of the Elements was clarified by Rutherford's experiment
  - Hadron inflation has resulted in quark model
  - This analogy implies the preonic structure of the SM fermions

- Why are we choosing preonic models?

WHY PREONIC MODELS ?

- The composite models are particularly interesting for the continued simplification and describe nature in terms of its most fundamental building blocks.

- These fundamental constituents were called PREONS by Pati and Salam.



- Family replication and especially SM fermion mixings can be considered as indication of preonic structure of matter.

- Could provide a solution to some of the aforementioned problems with an effective model at the preonic level.

- Quark-lepton compositeness is a well-known BSM scenario and the preonic models predict;
  - Excited leptons and quarks, leptogluons, leptoquarks, diquarks, dileptons, color sextet quarks etc …

- In models with coloured preons, leptogluons have the same status as excited leptons and leptoquarks.

COLOR OCTET ELECTRON IN PREONIC MODELS

- Strongly interacting partners of the SM leptons.
- Model example;

Leptons: In the framework of fermion-scalar models, leptons would be a bound state of one fermionic preon and one scalar anti-preon,

$$l = (F\bar{S}) = 1 \oplus 8 \qquad (1)$$

then each SM lepton has one colour octet partner. In a three fermion model, the colour decomposition

$$l = (FFF) = 1 \oplus 8 \oplus 8 \oplus 10 \qquad (2)$$

predicts the existence of two colour octet and one colour decouplet partners.

Quarks: In fermion-scalar models, anti-quarks are consist of one fermionic and one scalar preons which means that each SM anti-quark has one coloured sextet partner,

$$\bar{q} = (FS) = \bar{3} \oplus 6\,. \qquad (3)$$

According to the three fermion models

$$q = (F\bar{F}F) = 3 \oplus \bar{3} \oplus \bar{6} \oplus 15 \qquad (4)$$

therefore, for each SM quark one anti-triplet, one anti-sextet and one 15-plet partners are predicted.

In this study, they choose fermion-scalar model.

A Search for sextet quarks and leptogluons at the LHC
A. Celikel, M. Kantar, S.Sultansoy, Phys.Lett. B443 (1998) 359-364

Electric charges of scalar and fermionic preons

S_1	0	1/3	1/2	2/3	1
F_1	0	1/3	1/2	2/3	1
F_2	−1	−2/3	−1/2	−1/3	0
S_2	1/3	0	−1/6	−1/3	−2/3

$$\nu_e = (F_1\bar{S}_1), \quad e = (F_2\bar{S}_1);$$

$$\bar{d} = (F_1 S_2), \quad \bar{u} = (F_2 S_2)$$

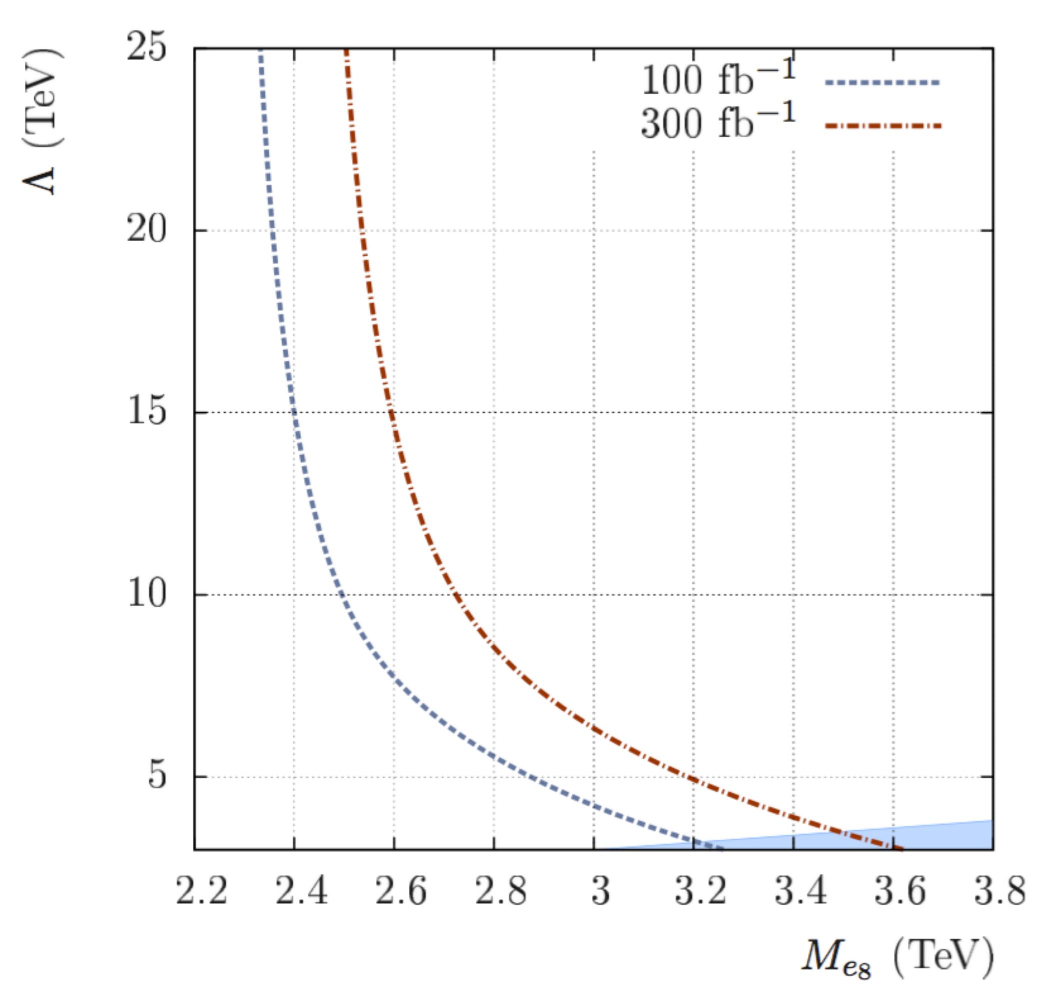
e_8 : AT DIFFERENT COLLIDERS

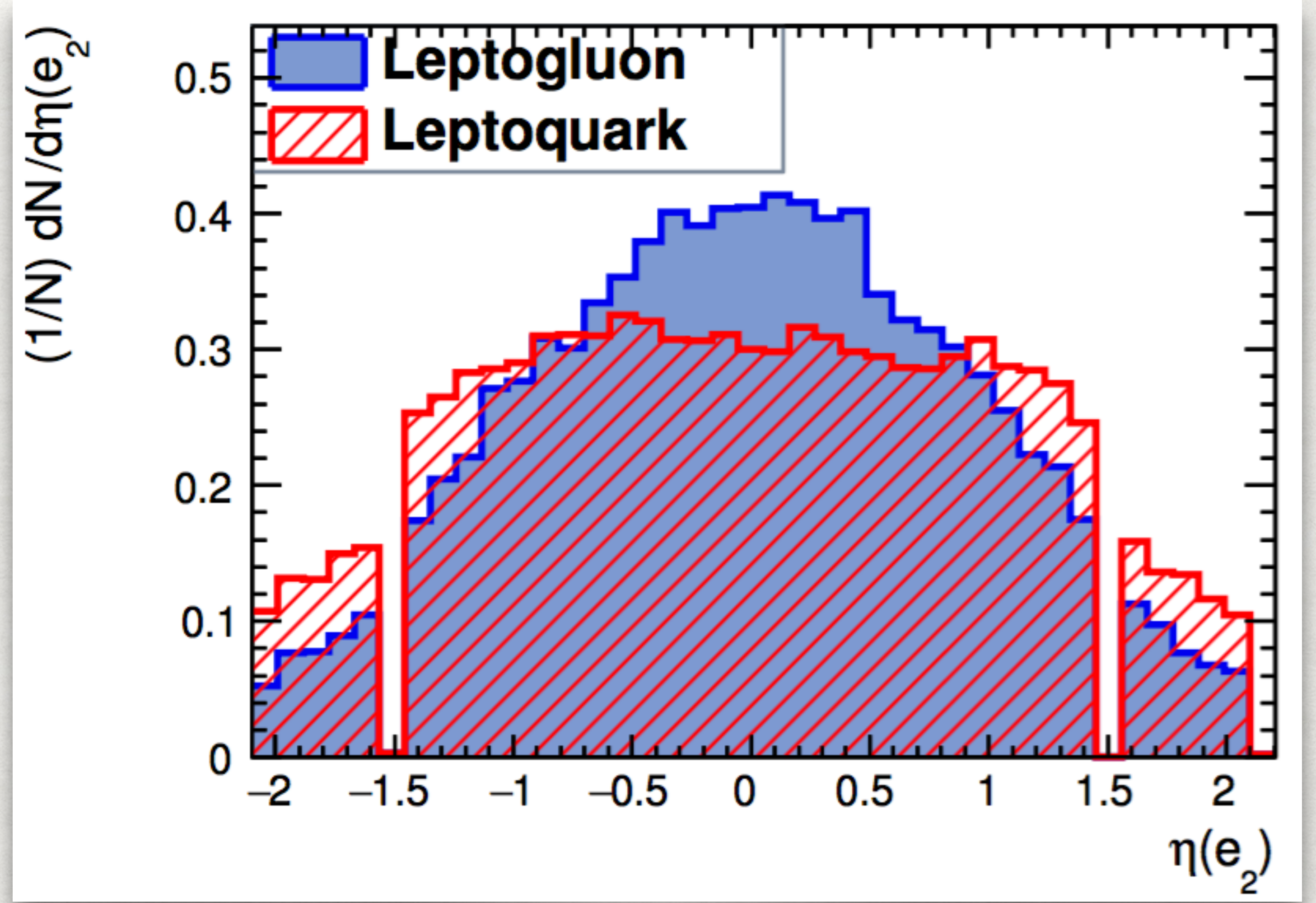
- **p-p collider**
  - Probing Color Octet Electrons at the LHC
    - Tanumoy Mandal (IMSc, Chennai), Subhadip Mitra (Orsay, LPT). Nov 2012. 9 pp. Phys.Rev. D87 (2013) 9, 095008
- **e-p collider**
  - Resonant Production of Color Octet Electron at the LHeC
    - M. Sahin (TOBB ETU, Ankara), S. Sultansoy (TOBB ETU, Ankara & Baku, Inst. Phys.), S. Turkoz (Ankara U.). Jan 2010. 13 pp. Phys.Lett. B689 (2010) 172-176
- **e^-e^+ collider**
  - Indirect search for color octet electron at next generation linear colliders
    - A.N. Akay (TOBB ETU, Ankara), H. Karadeniz (TAEK, Ankara), M. Sahin (TOBB ETU, Ankara), S. Sultansoy (TOBB ETU, Ankara & Baku, Inst. Phys.). Dec 2010. 7 pp. Europhys.Lett. 95 (2011) 31001

THE LATEST STUDY ON e_8

Probing Compositeness with the CMS eejj **&** eej **Data**

Tanumoy Mandal, Subhadip Mitra and Satyajit Seth





- They disfavour e_8 mass below 1.5 TeV from eejj data.
- The **η** distribution can be used to distinguish spin-0 LQs from spin-1/2 LGs.

LAGRANGIAN AND DECAY WIDTH FOR COLOR OCTET LEPTONS

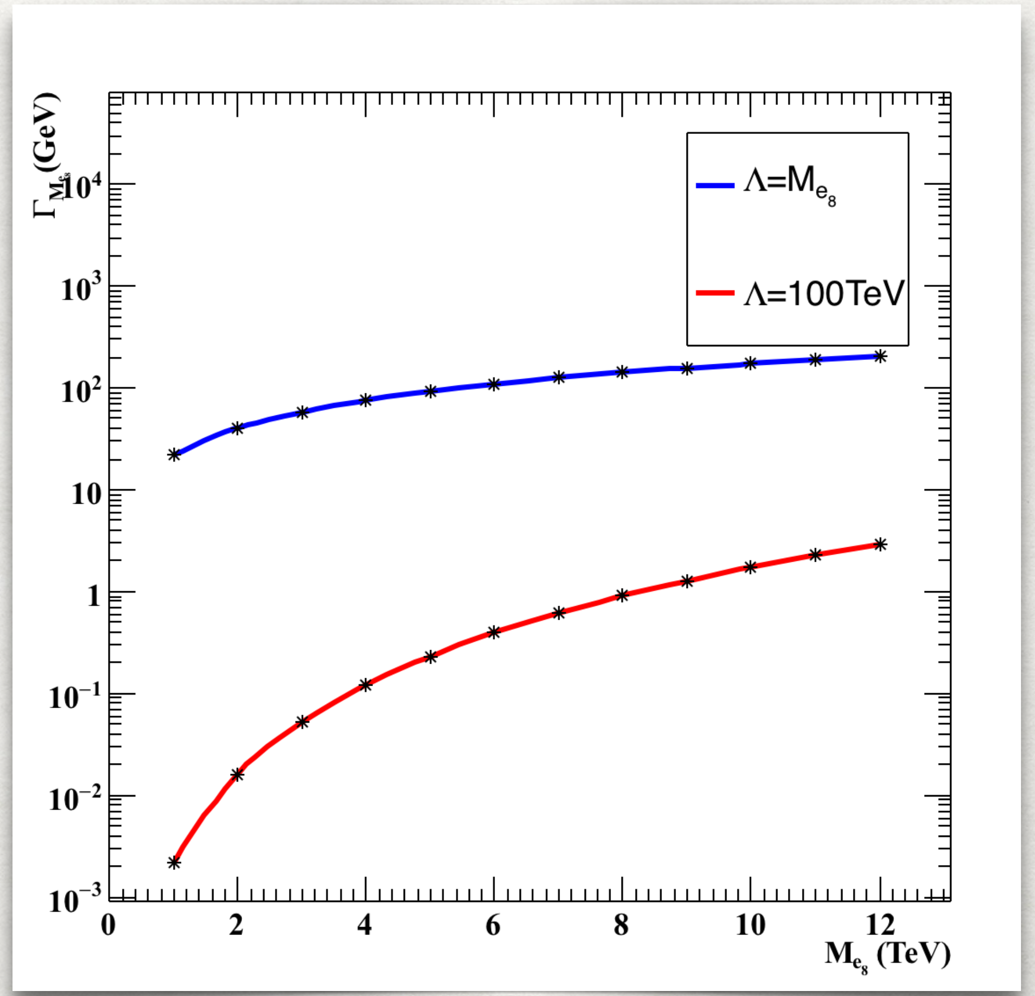
- The interaction lagrangian of color octet leptons (denoted by l_8) with their corresponding lepton (denoted by l);

$$L_{Int} = \frac{1}{2\Lambda} \sum_{l} \bar{\psi}_{l_8} g_s F^a_{\mu\nu} \sigma^{\mu\nu} (\eta_L \psi_{l,L} + \eta_R \psi_{l,R}) + h.c.$$

- η_L and η_R →chirality factors
- $\psi_{l,L}$ and $\psi_{l,R}$ denote left and right spinor components of lepton
- $F^a_{\mu\nu}$ → gluon field strength tensor
- $\sigma_{\mu\nu}$ → antisymmetric tensor
- g_s → strong coupling constant

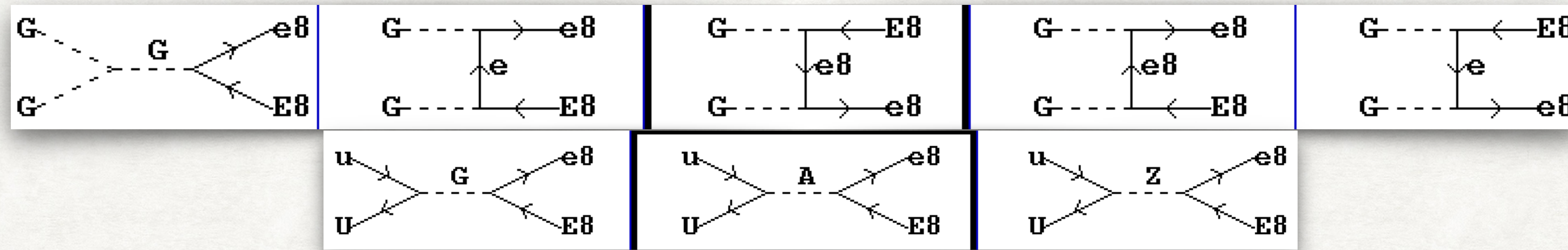
$$\Gamma_{e_8} = \frac{\alpha_s(M_{e_8}) {M_{e_8}}^3}{4\Lambda^2}$$

- Λ→ compositeness scale

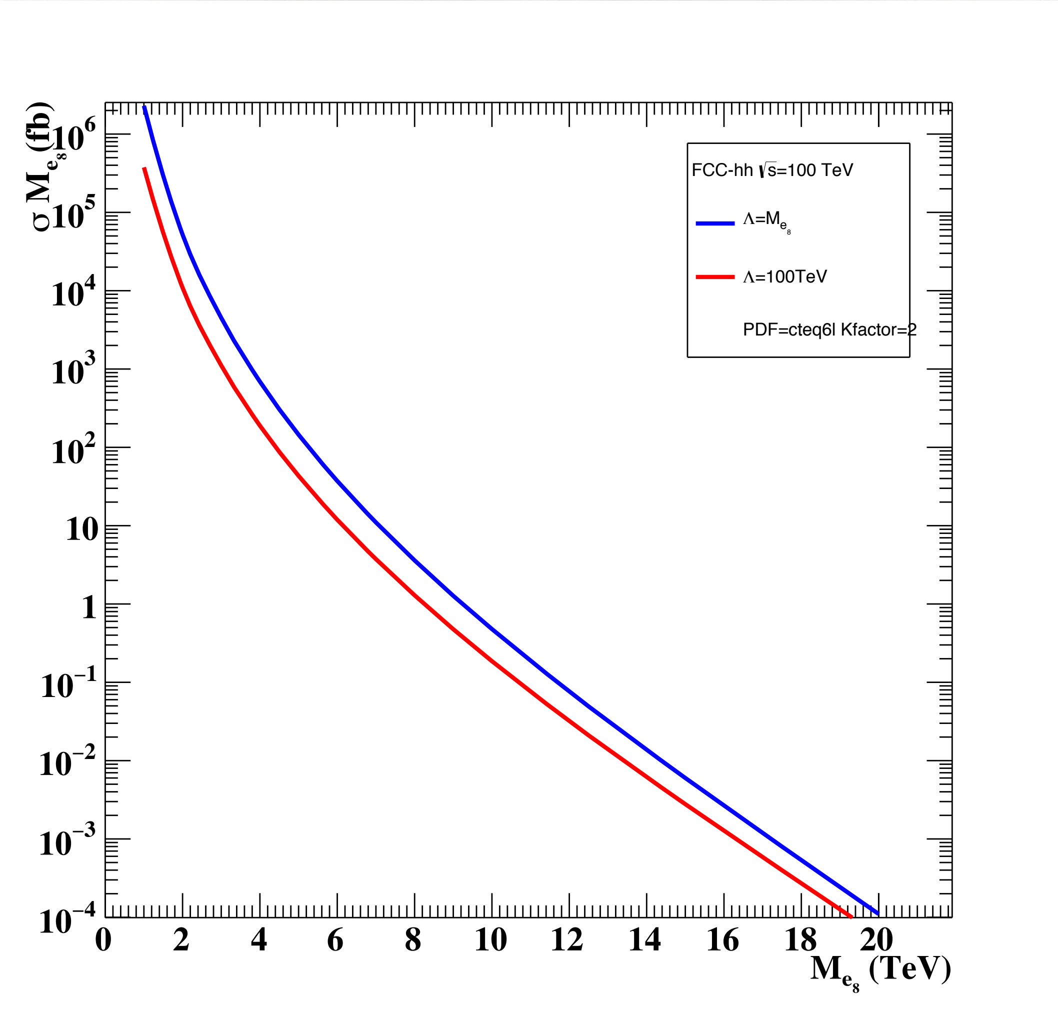


PRODUCTION CROSS SECTION OF e_8 @ FCC-hh

PAIR PRODUCTION

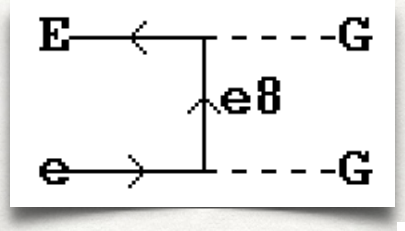


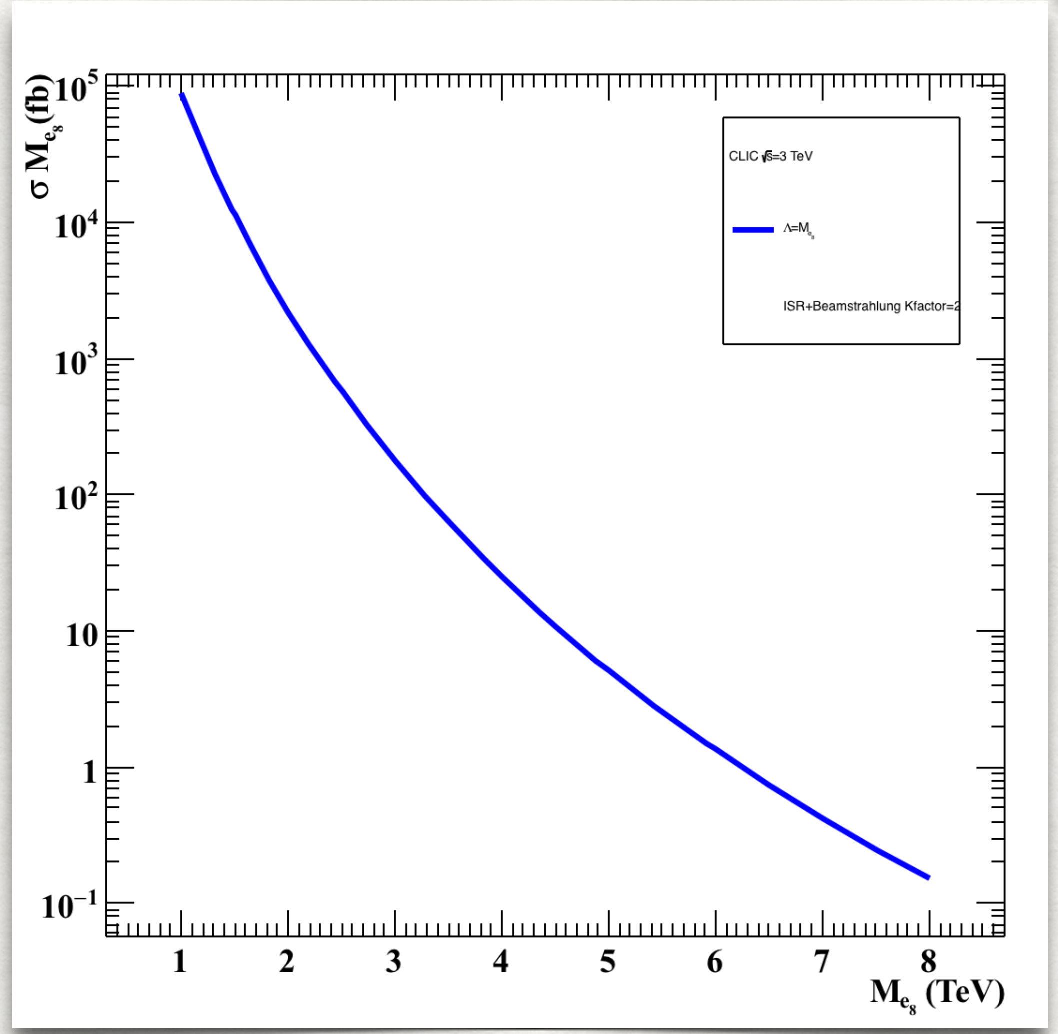
- discovery limit ≈15 TeV (300 fb^{-1})
- cross section of single production goes like $1/\Lambda^2$

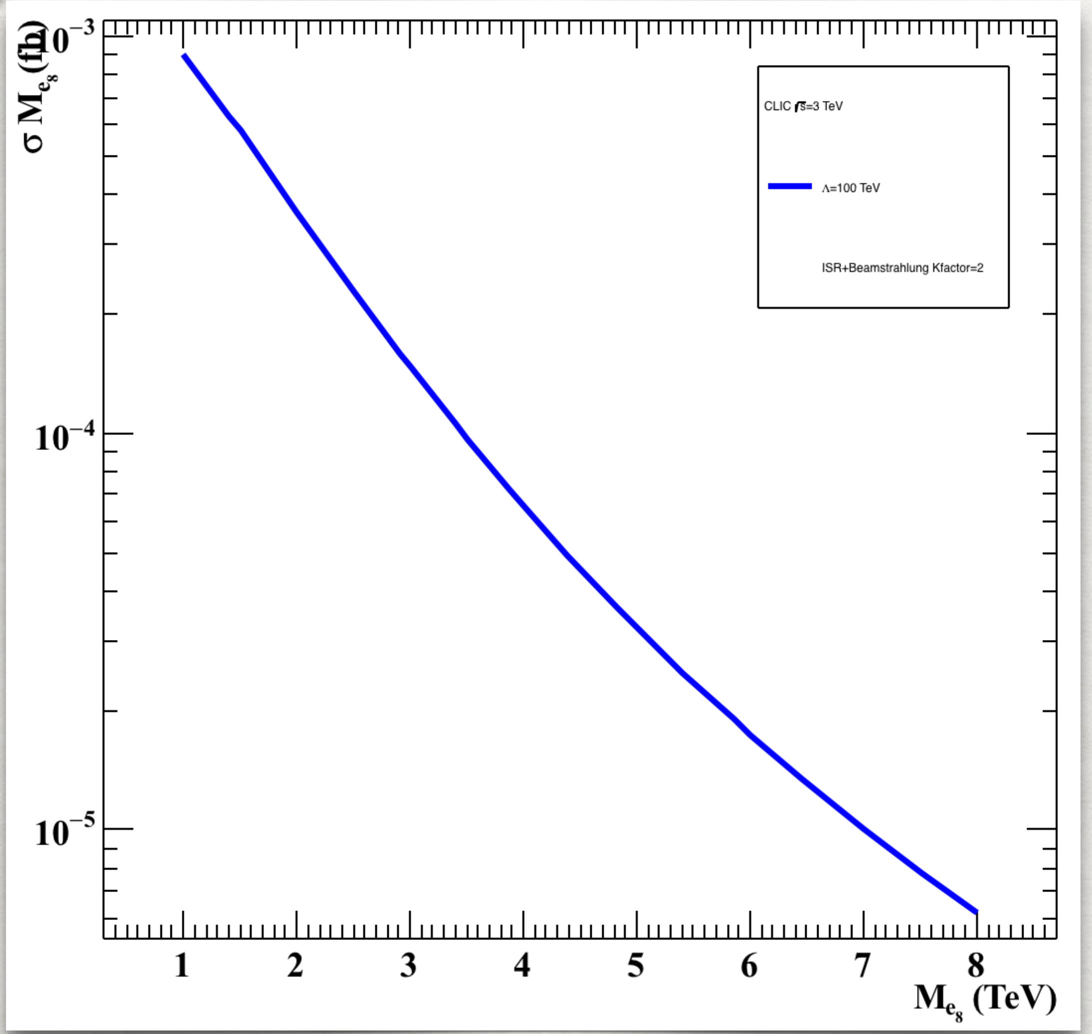


PRODUCTION OF e_8 @ CLIC

INDIRECT PRODUCTION







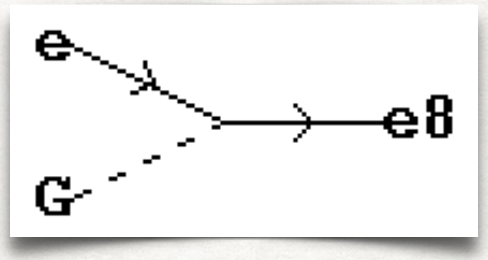
$\Lambda = Me_8$

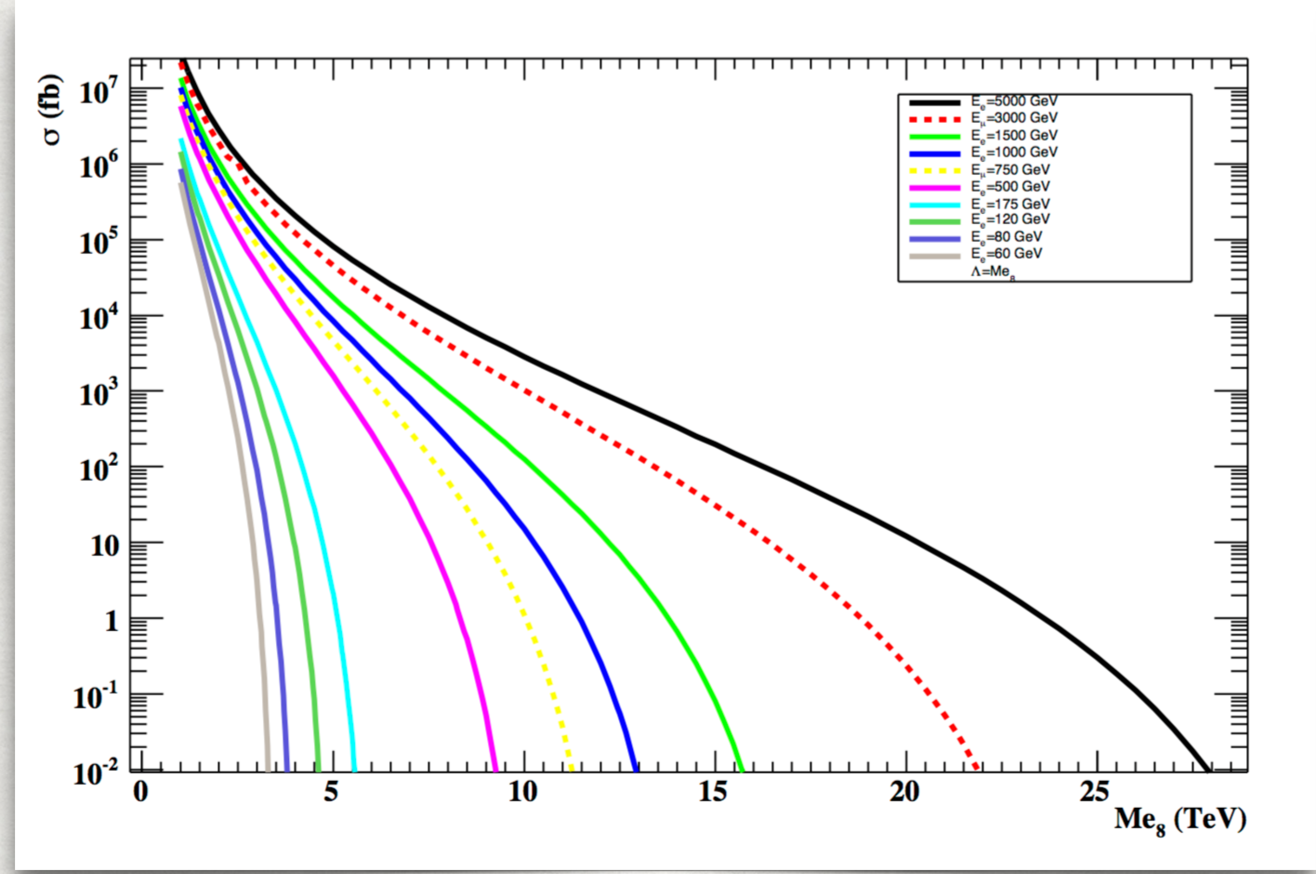
Λ=100 TeV

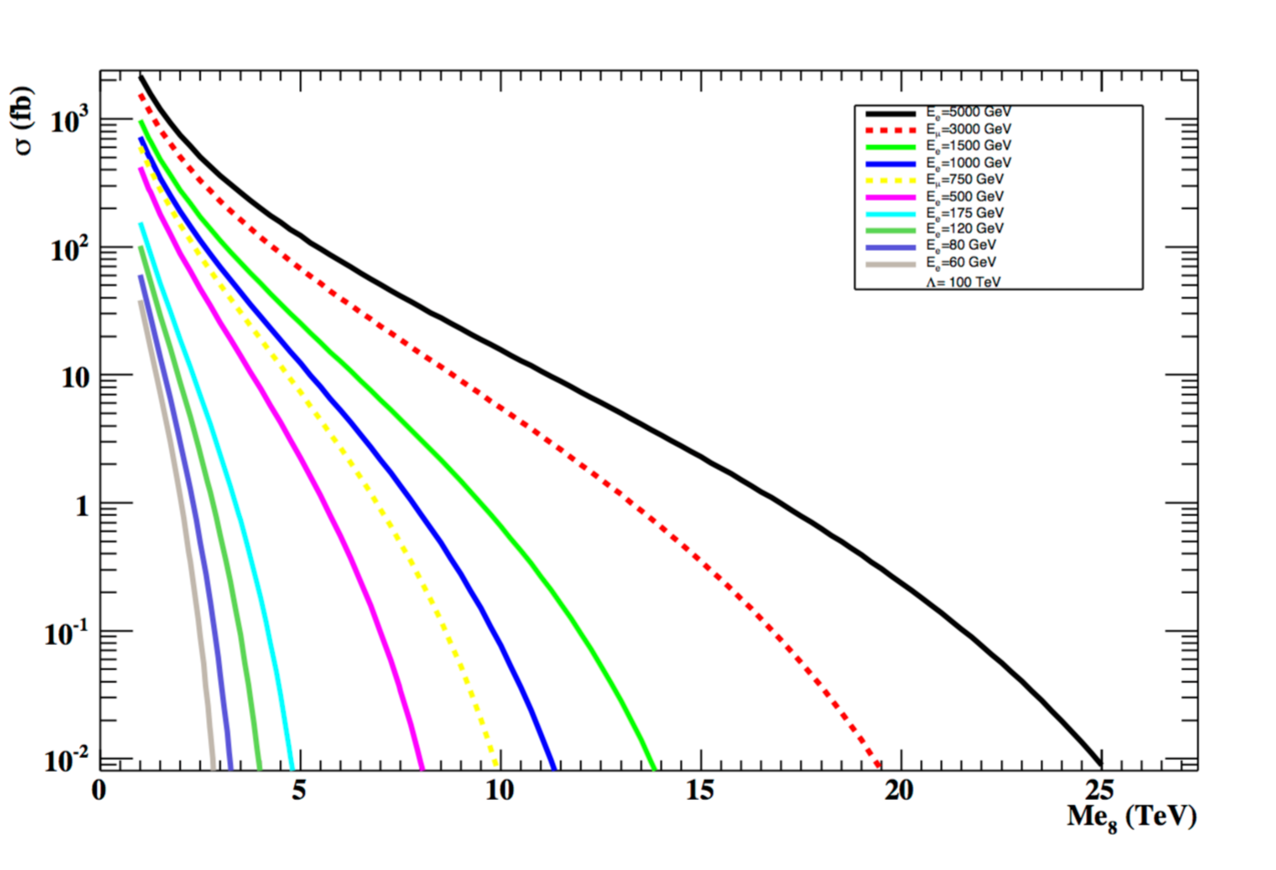
For direct production we reach me_8=sqrt{s}/2=1.5 TeV

PRODUCTION CROSS SECTION OF e_8 @ FCC-pe

RESONANT PRODUCTION



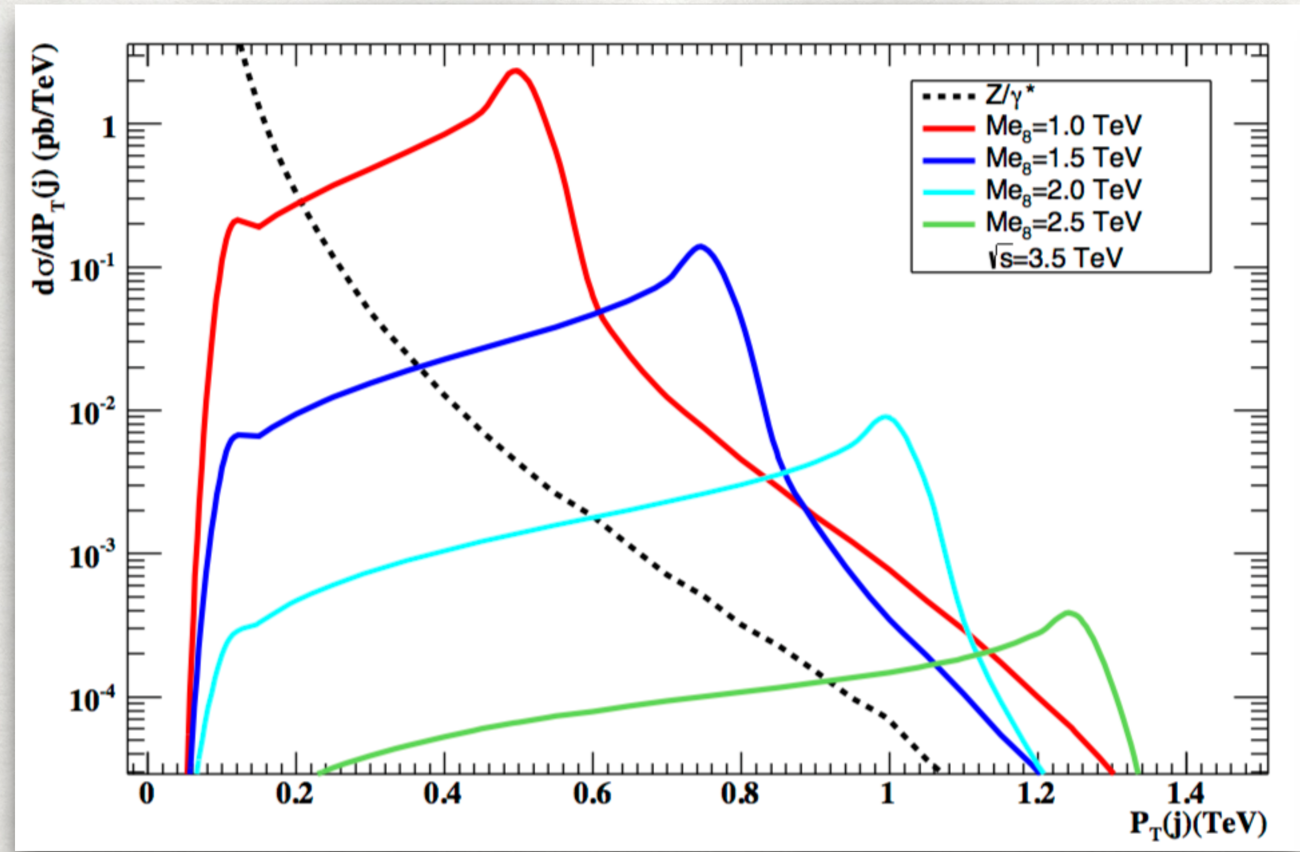


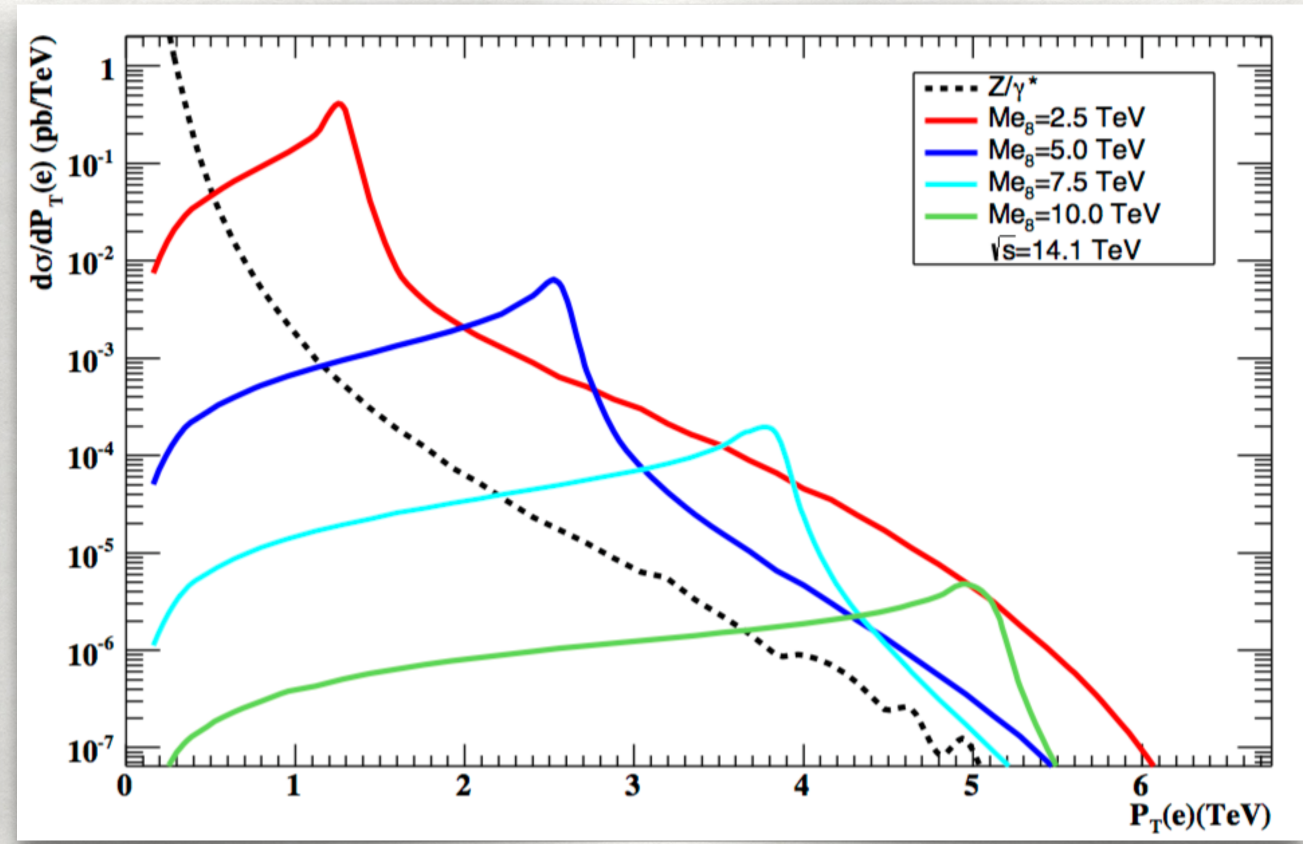


$\Lambda = Me_8$ $\quad$ $\Lambda = 100$ TeV

It seems Me_8 = 27 TeV (25 TeV) is reachable for $\Lambda = Me_8$ (Λ=100 TeV).

SIGNALS AND BACKGROUNDS

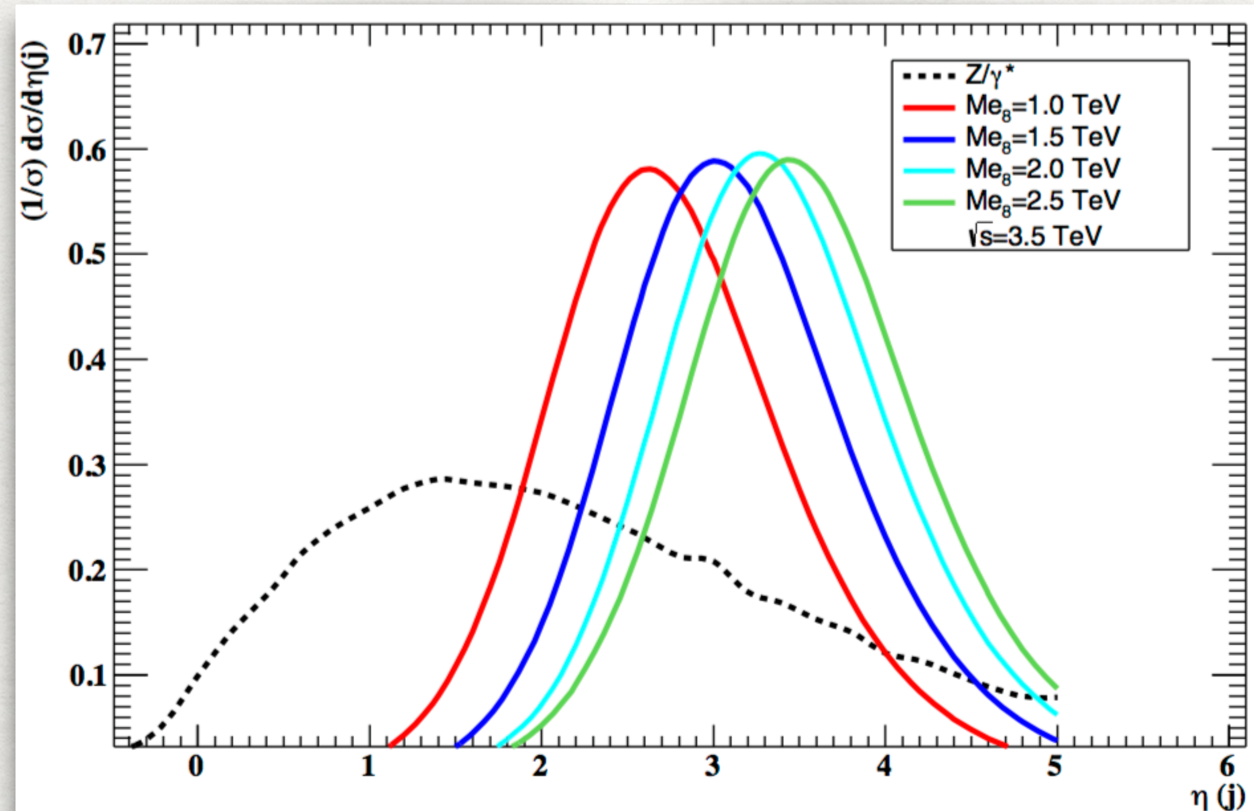




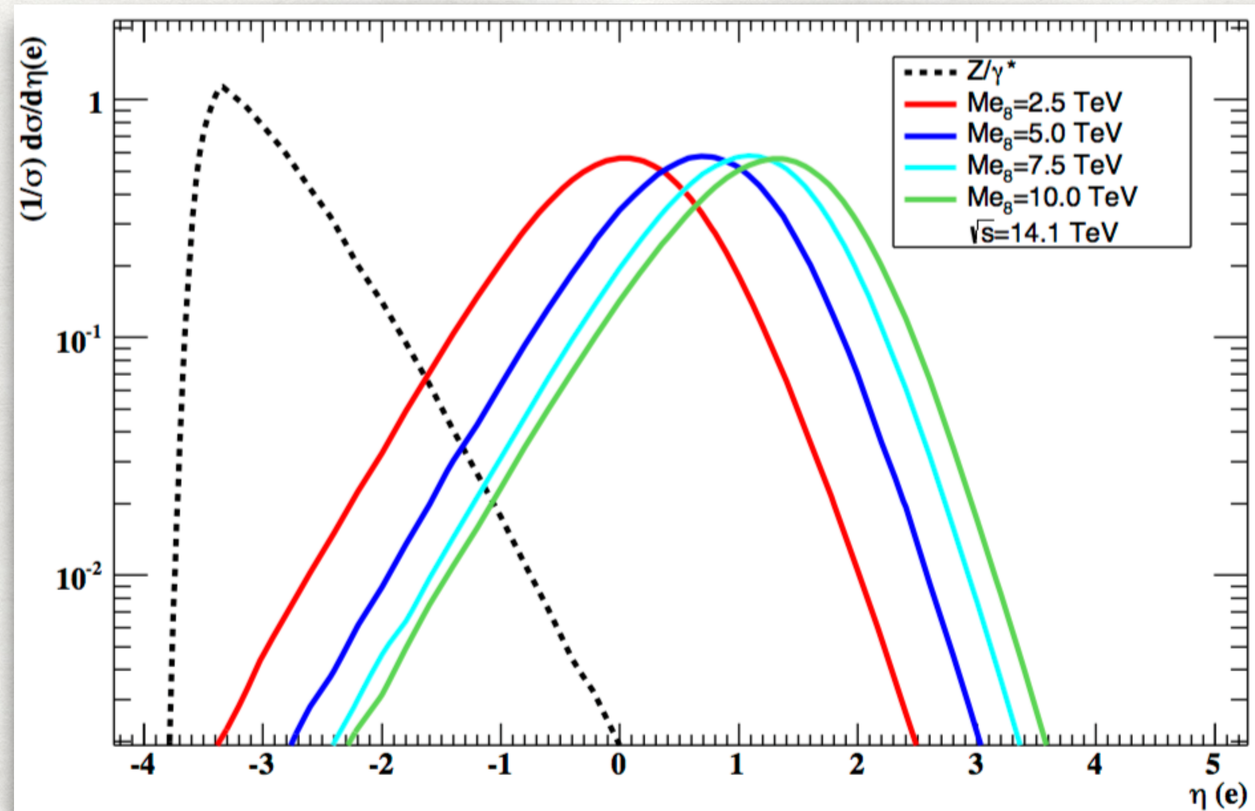
Transverse momentum distribution of **jet** for signals and backgrounds at ERL60-FCC

Transverse momentum distribution of **electron** for signals and backgrounds at OPL1000-FCC

SIGNALS AND BACKGROUNDS



Normalised pseudo-rapidity distribution of **jet** for signals and backgrounds at ERL60-FCC



Normalised pseudo-rapidity distribution of **electron** for signals and backgrounds at OPL1000-FCC

CUTS

- It is seen that pt > 400 GeV cut essentially reduces background, whereas signal is almost unaffected (especially for large m_{e_8} values).

- We use pt(e) > 400 GeV, pt(j) > 400 GeV as a discovery cut for all ep colliders, keeping in mind m_{e_8} > 1.2 TeV from the LHC $\sqrt{s}$ = 8 TeV data.

Electron Energy, GeV	60	175	500	1000
η_e	$1<\eta_e<4$	$0<\eta_e<4$	$-1<\eta_e<4$	$-1.5<\eta_e<4$
η_j	$2<\eta_j<4$	$1<\eta_j<4$	$0<\eta_j<4$	$-0.5<\eta_j<4$

Pseudo-rapidity cuts for different ep collider options

MASS LIMITS

Collider Name	Λ	L_{int}, fb^{-1}	m_{e_8}, GeV 3σ	m_{e_8}, GeV 5σ
ERL60-FCC $\sqrt{s} = 3.46$ TeV	m_{e_8}	10	2990	2900
		100	3150	3085
	100 TeV	10	1150	-
		100	1690	1485
FCC-e175 $\sqrt{s} = 5.92$ TeV	m_{e_8}	40	5110	4970
	100 TeV	40	2675	2350
OPL500-FCC $\sqrt{s} = 10.0$ TeV	m_{e_8}	10	7825	7500
		100	8450	6600
	100 TeV	10	3800	3200
		100	5070	4520
OPL1000-FCC $\sqrt{s} = 14.1$ TeV	m_{e_8}	5	10200	9640
		50	11220	10800
	100 TeV	5	5000	4100
		50	6750	6000

$\Lambda = M_{e_8}$

- m_{e_8}<2.9 TeV at ERL60-FCC
- m_{e_8}<4.9 TeV at FCC-e175
- m_{e_8}<7.5 TeV at OPL500-FCC
- **m_{e_8}<10.8 TeV** at OPL1000-FCC

Λ=100 TeV

- m_{e_8}<1.5 TeV at ERL60-FCC
- m_{e_8}<2.4 TeV at FCC-e175
- m_{e_8}<4.5 TeV at OPL500-FCC
- **m_{e_8}<6.0 TeV** at OPL1000-FCC

Λ LIMITS

ERL60-FCC	3σ		5σ	
	L=10 fb^{-1}	L=100 fb^{-1}	L=10 fb^{-1}	L=100 fb^{-1}
1000	100000	195000	85000	150000
1500	62000	105000	49000	82000
2000	32000	51000	26800	48000
2500	15000	27000	10000	20000

FCC-e175	3σ	5σ
	L=40 fb^{-1}	
1000	280000	210000
2000	135000	122200
3000	60000	47200
4000	27500	21000

OPL500-FCC	3σ		5σ	
	L=10 fb^{-1}	L=100 fb^{-1}	L=10 fb^{-1}	L=100 fb^{-1}
1000	363000	653000	277000	503000
3000	156250	283000	119000	218000
5000	57500	105500	43250	81000
7000	16750	32000	12000	24000

OPL1000-FCC	3σ		5σ	
	L=5 fb^{-1}	L=50 fb^{-1}	L=5 fb^{-1}	L=50 fb^{-1}
1000	255000	368000	191000	342000
2500	172500	295000	126000	228000
5000	67000	120000	52000	97000
7500	29000	54000	22000	41000
10000	11420	23000	7750	16750

- M_{e_8}=1.5 TeV **Λ**=300000 is reachable (OPL1000-FCC).
- M_{e_8}=1.5 TeV **Λ**=82000 is reachable (ERL60-FCC).

CONCLUSION

- If we discover e_8 (Me_8<15 TeV) at FCC-hh, then we can reach approximately 300 TeV region for compositeness scale.
- If we don't discover e_8 (Me8<15 TeV) at FCC-hh, then we can check higher mass region, namely me_8<20 TeV at FCC-he.
- μ_8 search at FCC-μp will be considered in next study.

Its my pleasure to thank Saleh Sultansoy, Bilgehan Barış Öner,
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THANK YOU FOR YOUR ATTENTION