BSM Physics at the LHeC and FCC-he

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http://lhec.web.cern.ch/

FCC Week 2015

23-27 mars 2015

Marriott Georgetown Hotel

US/Eastern timezone

U.S. DEPARTMENT OF ENERGY | Office of Science

http://indico.cern.ch/event/340703/overview

Outline

- **The LHeC and FCC-he** → see yesterday's session
  - LHeC CDR published in 2012
- **High PT BSM physics**
  - LQ, contact interactions, compositeness, heavy/excited fermions, anomalous couplings…
  - Supersymmetric signals:
    - RPV, BSM Higgs decays, improved precision
  - composite Higgs
  - expect many new bounds and potential discoveries from LHC

  → improve on sensitivity, better potential in some cases
- **BSM Higgs and EWSB**
  - for SM Higgs, → see M. Klein's talk earlier in this session
  - Vector Boson scattering
    - anomalous couplings?, CP properties

Most results shown are preliminary:
continuing studies to get better precision on
potential discoveries and constraints on BSM models
Detector performance simulation in progress → see P. Kostka's talk
very forward boosts at FCC-he

Introduction: BSM physics

- **LHC is/will be the main discovery machine**
  - LHeC/FCC-eh has potential for improving, or possibly discover new phenomena
    - improved $\alpha_{s,}$ pdf's (especially gluon)
      → higher precision from measurements performed at LHC
    - cleaner environment than LHC → better S/N
- **Since LHeC CDR…**
  - Strong LHC constraints on new physics up to ~ 1 TeV
    - ➔ window of discovery at LHeC remains open only for specific channels
    - ➔ FCC-eh energy offers more potential
  - Higgs has been discovered !!
    - Naturalness problem:
      quantum corrections must be fine-tuned to explain the low H mass
      → is the Higgs truly the SM Higgs boson ?
      → need to study deviations from SM
      → expect new physics at TeV scale, but expect deviations to be small
  - strong dynamics: composite Higgs, technicolor
    - Higgs as a PGB,
      rich new phenomenology: ρ-like diboson resonances, vector-like quarks
  - SUSY
    - strong bounds obtained on MSSM and possibly some simple extensions
    - need to explore extended SUSY parameter space
  - FCC options
    - higher energies: greater window in TeV region

Common Quantum numbers and interactions of e's and q's:

same electric charge, EW interaction, 1st of 3-flavor generations

→ suggest some fundamental symmetry, or common compositeness

→ leptoquarks? excited fermions?

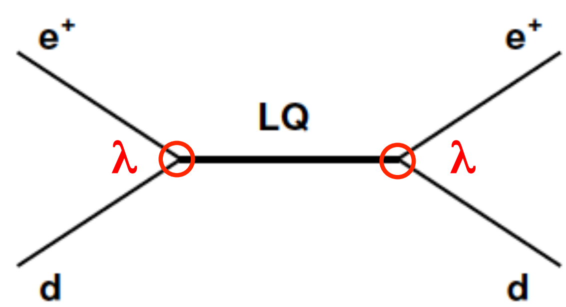
→ new heavy fermions? vector-like fermions?

Leptoquarks

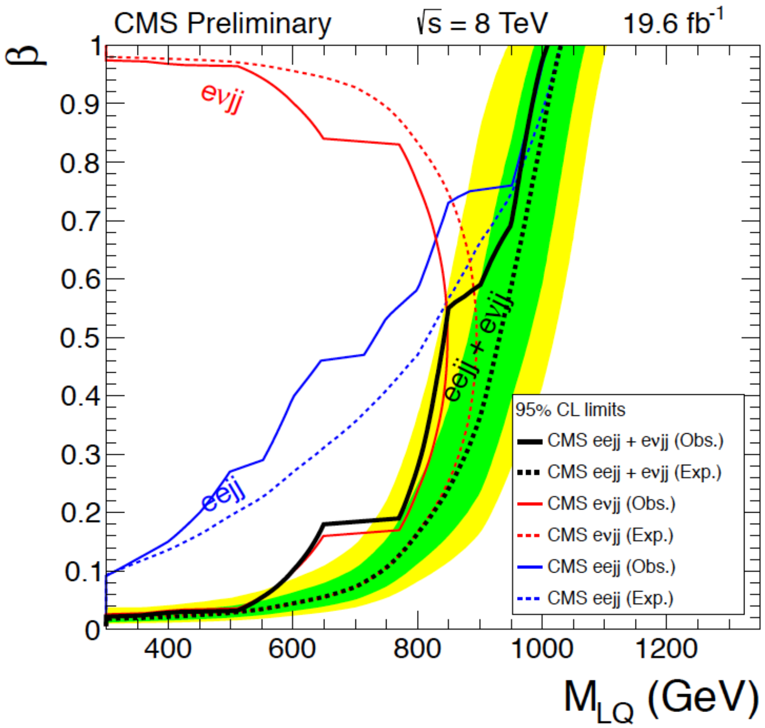
- E6 GUT, technicolor, Pati-Salam model: predict new fields, possibly having both B and L quantum numbers
- squarks decaying by R-parity violation **$P_R = (-1)^{3(B-L)+2s}$**

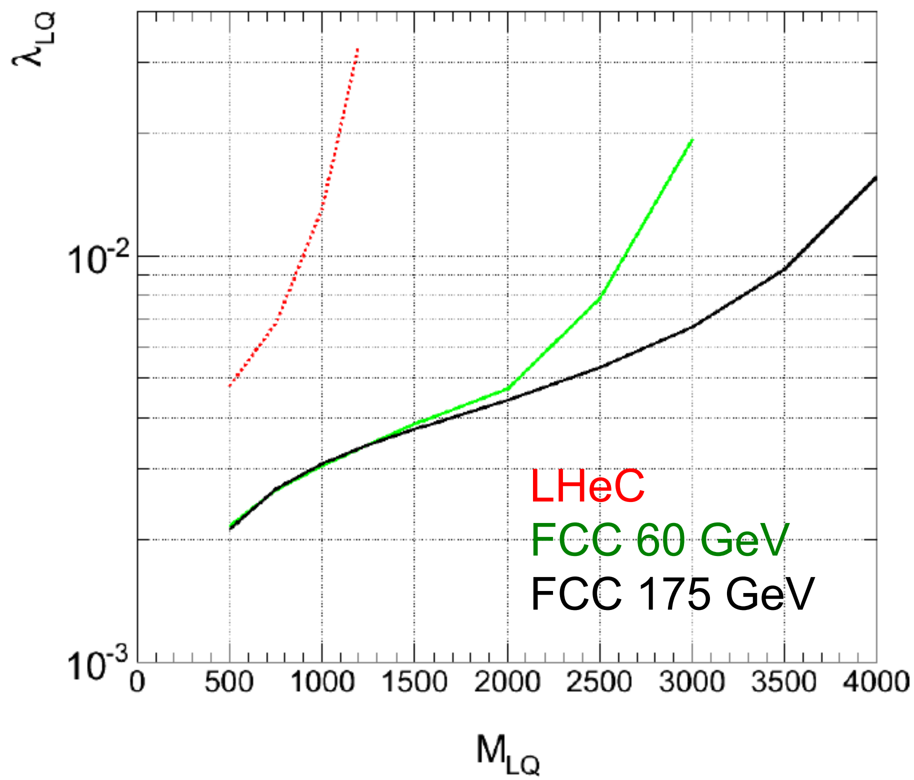
$$\mathcal{W}_{RPV} = \lambda'_{ijk} L_i Q_j \bar{D}_k \quad \Rightarrow \begin{cases} e^- + \bar{d} \to \bar{\tilde{u}} \to e^- + \bar{d} \\ e^- + u \to \tilde{d} \to e^- + u \end{cases}$$

- LQ's can be scalar or vector, Fermion number 0 or 2 ➔ Buchmüller classification
- **at the LHC:** pair production is essentially insensitive to *LQ-q-e coupling λ*
  - single production suppressed by dependence on λ
- **at LHeC**: single production, sensitive to λ



Present LHC bounds





1st generation Leptoquarks, for β =1:

ATLAS and CMS (20 fb^{-1}):

m_{LQ} <~ 1000 GeV **PAS EXO-12-041**

can expect ~ 1.5 TeV (pair production) with full luminosity at LHC14

note : sensitive to $\lambda \ll e = \sqrt{4\pi\alpha} = 0.312$

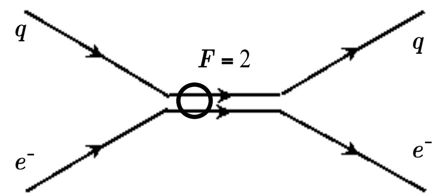
Preliminary Study in Progress

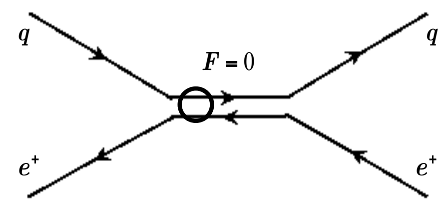
Measuring the LQ quantum numbers with LHeC

Quantum numbers and couplings:

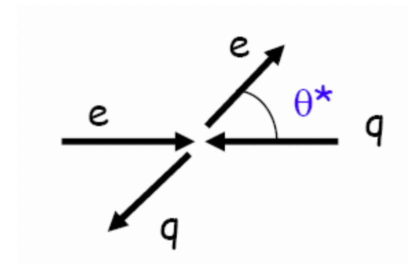
- **Fermion number:**
  - can be obtained from asymmetry in single LQ production, since q have higher x than $\bar{q}$
  - at LHC: very poor asymmetry precision achievable in single LQ production

$$A = \frac{\sigma_{e^-} - \sigma_{e^+}}{\sigma_{e^-} + \sigma_{e^+}} \begin{cases} > 0 \text{ for F=2} \\ < 0 \text{ for F=0} \end{cases}$$





- **spin**
  - at LHC, pair production of LQ-LQ leads to angular distributions which depend on the g-LQ-LQ coupling
    - ➔ may need to look for spin correlations
  - at LHeC, cos θ* distribution is sensitive to the spin
  - vector leptoquarks can have anomalous couplings



- **couple chirally (i.e. to L or R but not both) ?**
  - could be probed by measuring sensitivity of cross sections to polarization of the electron beam
- **generation mixing ?**
  - does LQ decay to 2nd generation?
- **BR to neutrino, good S/B in νj channel**

$$e_L^- u_L \rightarrow S_3 \rightarrow \nu_e d_L$$

Contact Interactions

New physics at a higher scale $\Lambda \gg \sqrt{s}$:

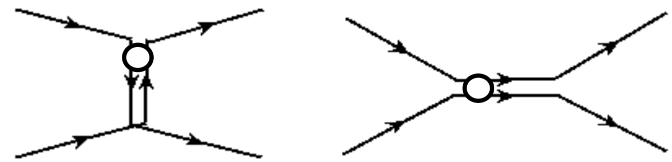
seen as an effective 4-fermion interaction

$$\mathcal{L} = \frac{4\pi}{2\Lambda^2} j_\mu^{(e)} j^{\mu(q)};$$

$$j_\mu^{(f=e,q)} = \eta_L \bar{f}_L \gamma_\mu f_L + \eta_R \bar{f}_R \gamma_\mu f_R + h.c.$$

$\Rightarrow$ all combinations of couplings $\eta_{ij} = \eta_i^{(e)} \eta_j^{(q)}; \quad q = u,d$

$$\Lambda \equiv \begin{cases} LQ, \text{ mass } \gg \sqrt{s} \\ \text{Planck scale } (M_S) \text{ of extra-dimensional models} \\ \text{compositeness scale} \\ \ldots \end{cases}$$



present LHC constraints on scale of $qqll$ contact interaction:

$\sim 15 - 26$ TeV (ATLAS)

$\rightarrow$ up to 40 TeV at 14 TeV LHC

sensitive to fermion radius 10^{-19}–10^{-20} m at LHeC (FCC)

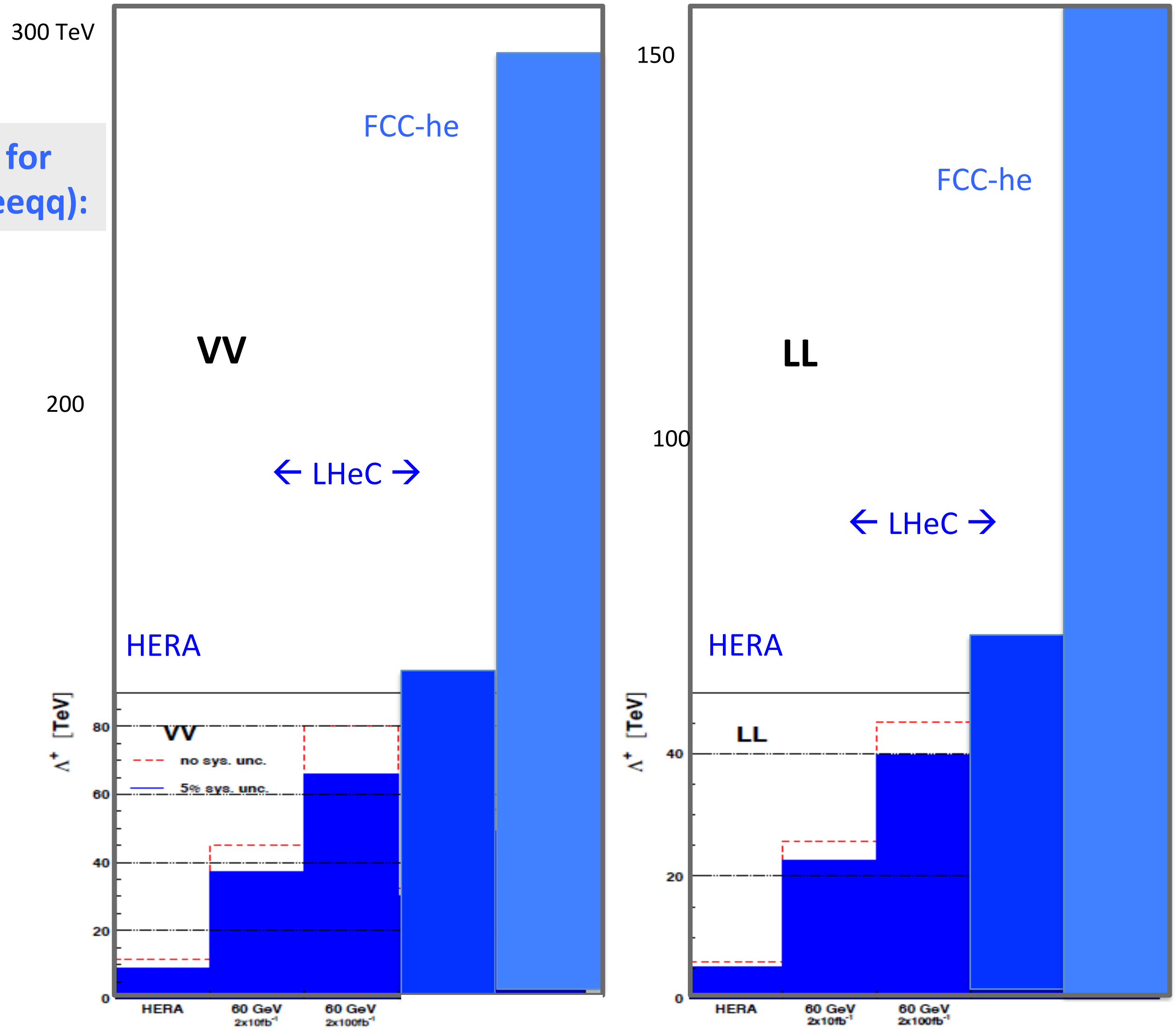
$$\frac{\hbar c}{1.3\text{ TeV}} = 1.5 \times 10^{-4}\text{ fm}$$

form factor: $f(Q^2) = 1 - \frac{1}{6}\langle r^2 \rangle Q^2$

$$\frac{d\sigma}{dQ^2} = \frac{d\sigma_{SM}}{dQ^2} f_e^2(Q^2) f_q^2(Q^2)$$

Scale of contact interaction at Future Colliders

Reach for Λ (CI eeqq):



LHeC: see CDR 2012

FCC - rough scaling only – very preliminary

Excited fermions

- Excited fermions could be produced directly if their mass is below compositeness scale

  Assume spin = ½, L, R doublets

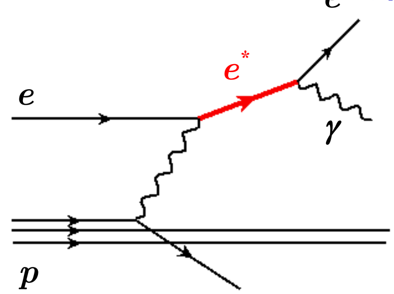
  - gauge interaction Lagrangian

$$\mathcal{L} = \frac{1}{2\Lambda} \bar{f}^{*}_{R} \sigma_{\mu\nu} \left[g f \frac{\tau_a}{2} W^{a}_{\mu\nu} + g' f' B_{\mu\nu} + g_s f_s \frac{\lambda_a}{2} G^{a}_{\mu\nu} \right] f_L$$

  - contact interaction Lagrangian

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

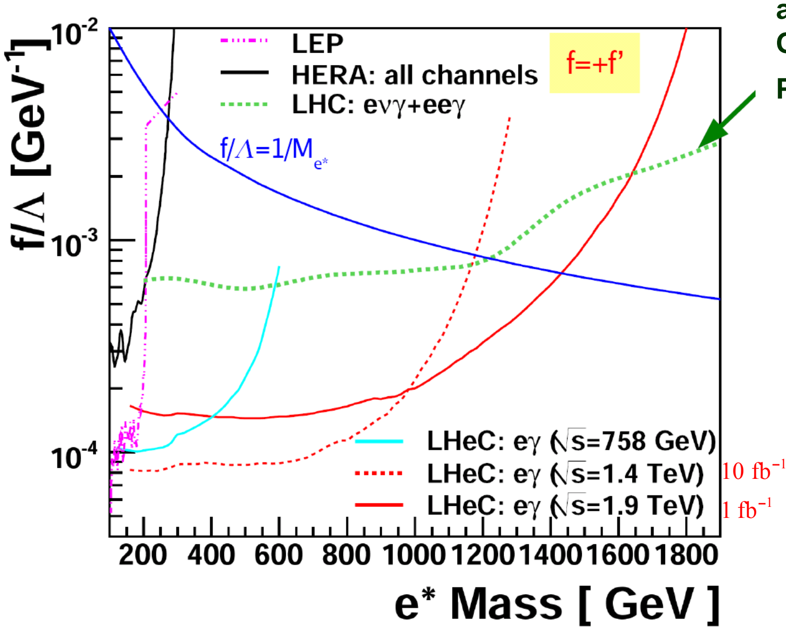
$$j_\mu = \eta_L \bar{f}_L \gamma_\mu f_L + \eta'_L \bar{f}^{*}_L \gamma_\mu f^{*}_L + \eta''_L \bar{f}^{*}_L \gamma_\mu f_L + h.c. + (L \leftrightarrow R)$$



at LHC

O.J.P. Éboli, S.M. Lietti, P. Mathews,

Phys. Rev. D 65, 075003 (2002)



T. Nguyet Trinh and E. Sauvan,

1st ECFA-CERN LHeC workshop (Divonne, 2008)

http://indico.cern.ch/conferenceDisplay.py?confId=31463

LHC could probe up to 1-2 TeV

for $f = f' = 1, \Lambda = m_{e^*}$ (or $f/\Lambda = 1/m_{e^*}$)

O. Cakir, A. Yilmaz, S. Sultansoy,
PR D70 (2004) 075011,
A. Belyaev, C. Leroy, R. Mehdiyev,
Eur Phys J C 41, s02, 1–10 (2005)

e-p colliders could extend sensitivity to f/Λ and mass reach to ≲ c.m.

Heavy fermions/ colored bosons

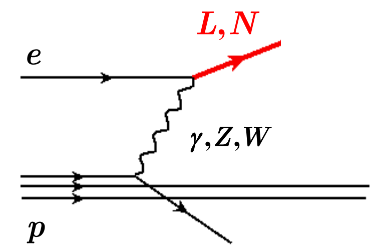
heavy leptons:

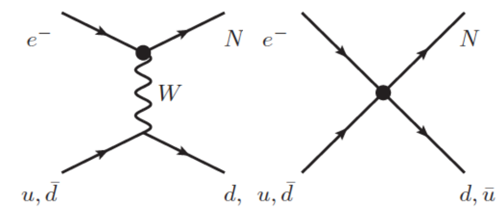
- vector-like leptons: left and right chiralities have same transformation properties
  - predicted in GUT theories (E_6) or in Composite Higgs Models
  - couplings: $eEZ, \nu EW, eEH; \quad \nu NZ, eNW, \nu NH$
- Majorana Neutrino Production in an Effective Approach

  (L. Duarte et al. 1412.1433)

  SM background from $p\gamma \to \ell^+ + 3j + \nu \quad pe^- \to e^+ + 3j + 2\nu_e$

  able to discover Majorana neutrinos up to 700 GeV (for E_e = 50 GeV)



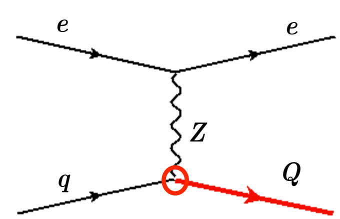


$N \to \ell^+ + \text{jets}$

vector-like quarks?

- single production of top partners, sensitive to couplings: $qQZ, qQW, qQH;$

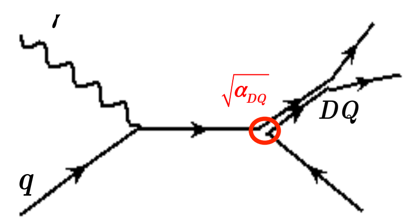
  (coupling to light quarks)



diquarks

- predicted in superstring inspired E6 and composite mode
- could carry charge 1/3, 2/3, 4/3 and be scalar or vector
- in gp production

M Şahin and O. Çakir, arXiv:0911.0496

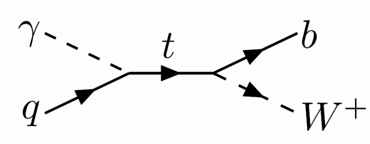


$$\mathcal{L}_{|B|=2/3} = \left(g_{1L} \bar{Q}_L^c i\tau_2 Q_L + g_{1R} \bar{u}_R^c d_R \right) DQ_1^c + \text{h.c.}$$

LHeC reach excluded
vector and scalar diquarks can be distinguished
by the angular distribution of their decays

Top quark FCNC coupling

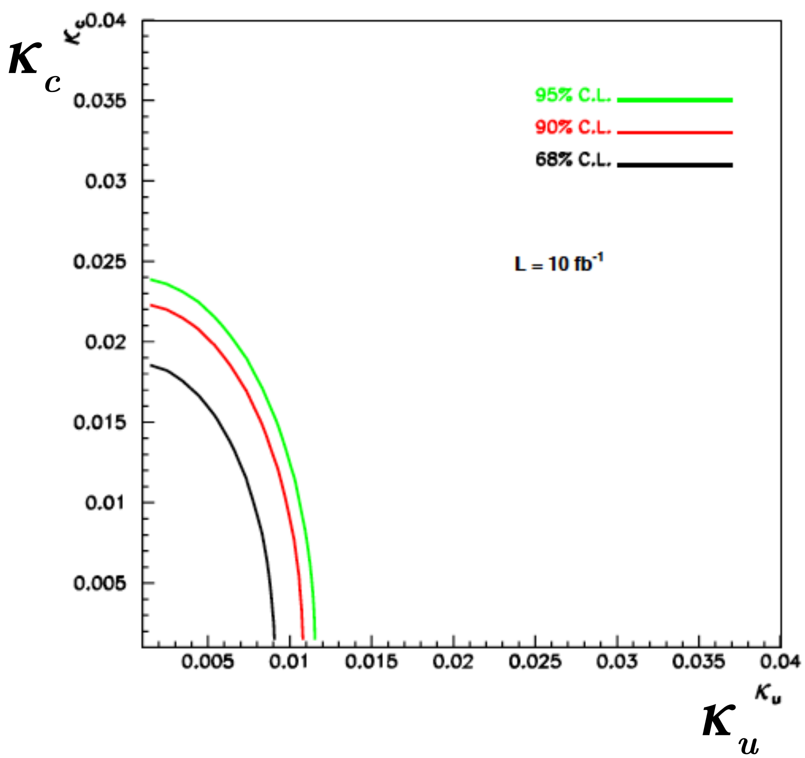
$$\mathcal{L}_{NC}^{t} = g\frac{\kappa_\gamma^t}{\Lambda}\bar{t}\,\sigma_{\mu\nu}\,t\,F^{\mu\nu} + \text{h. c.}$$

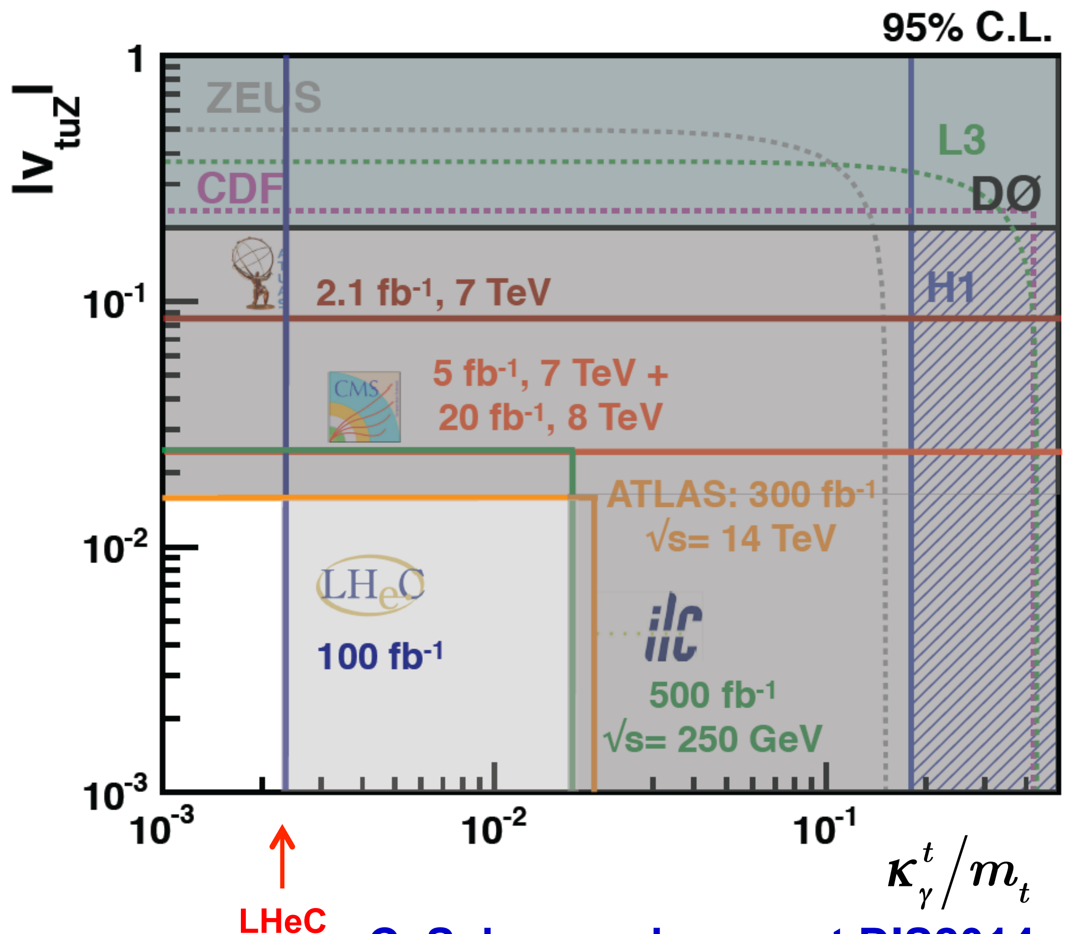


Using γp option, with simple cuts, can reach better limits on κ/Λ than LHC

note: $\kappa/\Lambda = 0.01 \Leftrightarrow BR(t \to u\gamma) \sim 2\times10^{-6}$

O. Cakir and S. Sultansoy, PL B685, 170 (2010)





C. Schwanenberger at DIS2014

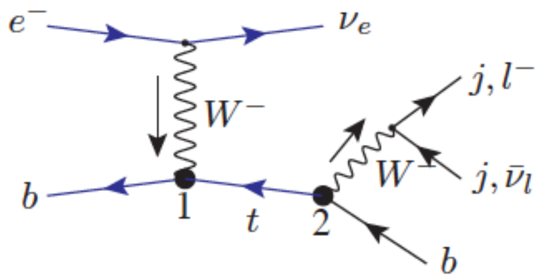
Wtb anomalous couplings

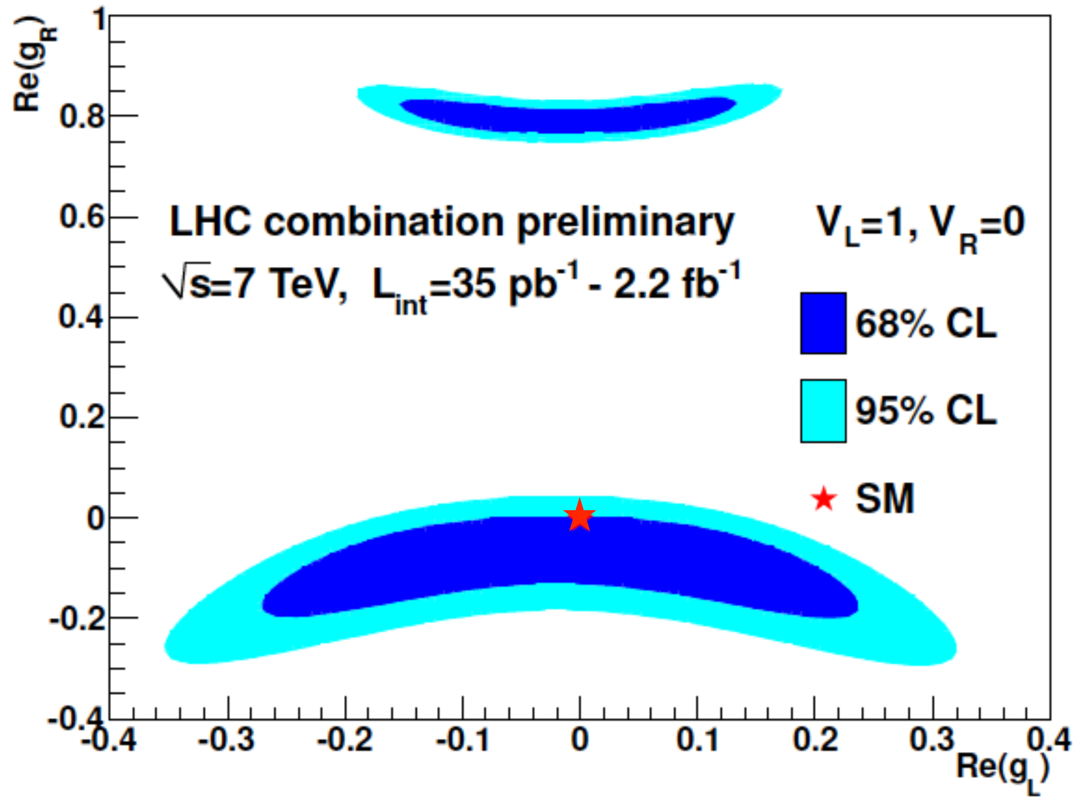
J.A. Aguilar-Saavedra, NP B812 (2009) 181

$$\mathcal{L}_{Wtb} = -\frac{g}{\sqrt{2}}\bar{b}\,\gamma^{\mu}\left(V_L P_L + V_R P_R\right) t\, W_{\mu}^{-} - \frac{ig}{\sqrt{2}}\bar{b}\,\frac{\sigma^{\mu\nu} q_{\nu}}{M_W}\left(g_L P_L + g_R P_R\right) t\, W_{\mu}^{-} + h.c.$$

RH vector

LH & RH tensor





ATLAS-CONF-2013-033/CMS PAS TOP-12-025

S. Dutta et al., arXiv:1307.1688

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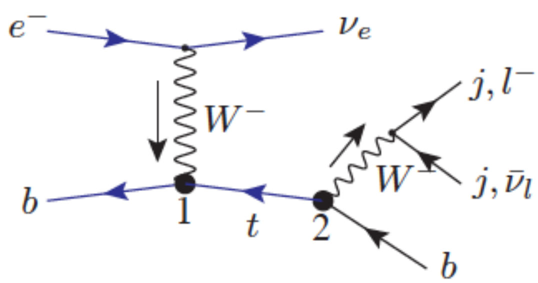
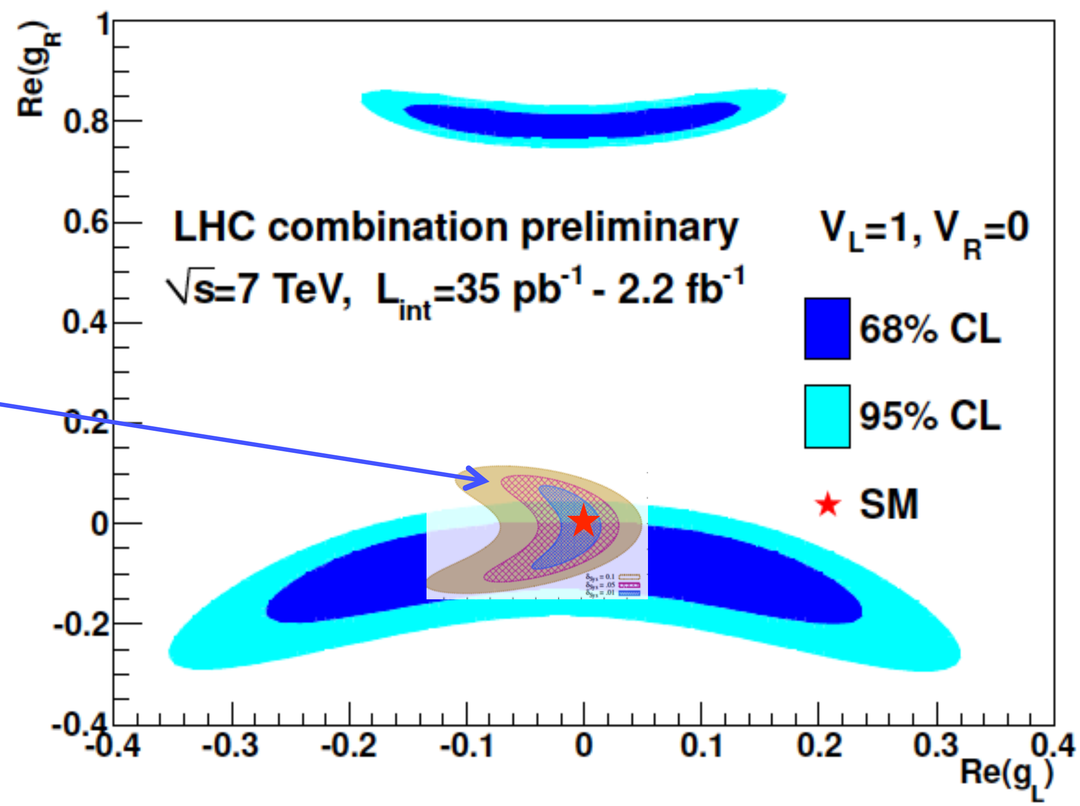


95% limit for hadronic mode, at LHeC, with varying levels of assumed systematic error (1-10%)

ATLAS-CONF-2013-033/CMS PAS TOP-12-025
S. Dutta et al., arXiv:1307.1688
C. Schwanenberger at DIS2014



see also: **I.A. Sarmento-Alvarado et al., 1412.6679**

- LHeC provides a cleaner environment than LHC
- better assessment of V_{tb} (or better sensitivity to higher dimensional operators (V_L))
- small improvement on VR, poorer sensitivity for gR
- significantly better lepton-quark contact interactions

Comparison of LHC and LHeC for tensor component

- based on asymmetry of distributions of kinematic variables
- similar sensitivity with leptonic mode

Higgs: present status

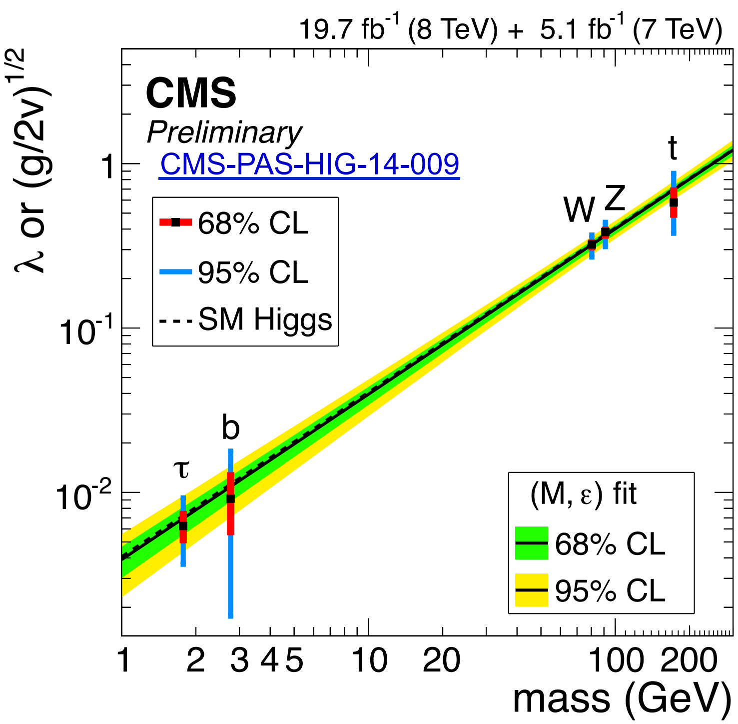
Today, the Higgs boson looks very much like the fundamental BEH scalar of the SM → expect small effects, if new physics is present

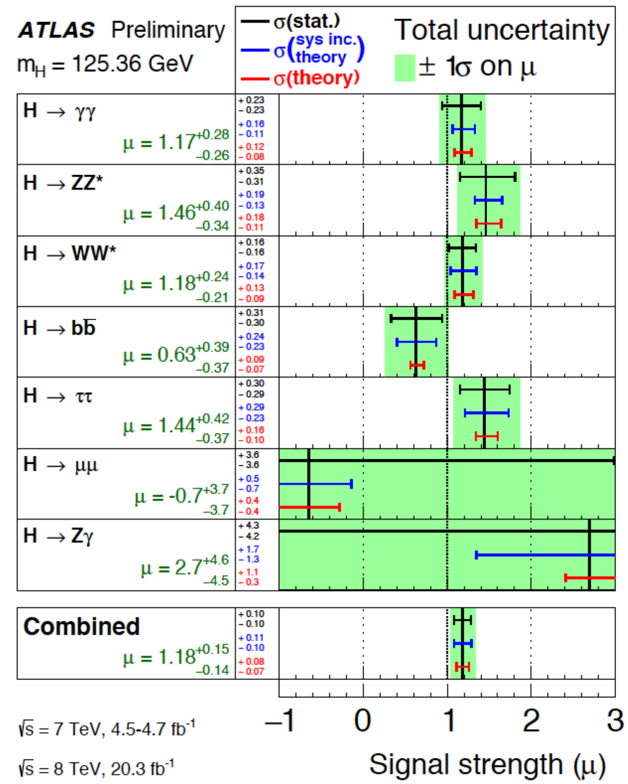
Best fit σ/σ_{SM}, averaged over different channels:

1.00±0.09(stat.)+0.08−0.07(theo.)±0.07(syst.) CMS-PAS-HIG-14-009

1.18 ± 0.10(stat) ± 0.07(expt) ± 0.08(th.) ATLAS-CONF-2015-008

Couplings consistent with SM predictions:



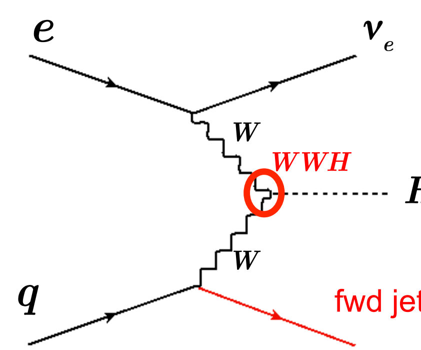


expect improved precision, using LHeC pdf's

ATLAS-COM-CONF-2015-11

CP properties of Higgs boson

LHC has shown that the discovered Higgs boson is consistent with 0+ state, but: are there small additional dimension-5 anomalous couplings to the vertex H-W-W ?



$$i\Gamma^{\mu\nu}(p_-,p_+)\varepsilon_\mu(p_-)\varepsilon^*_\nu(p_+)$$

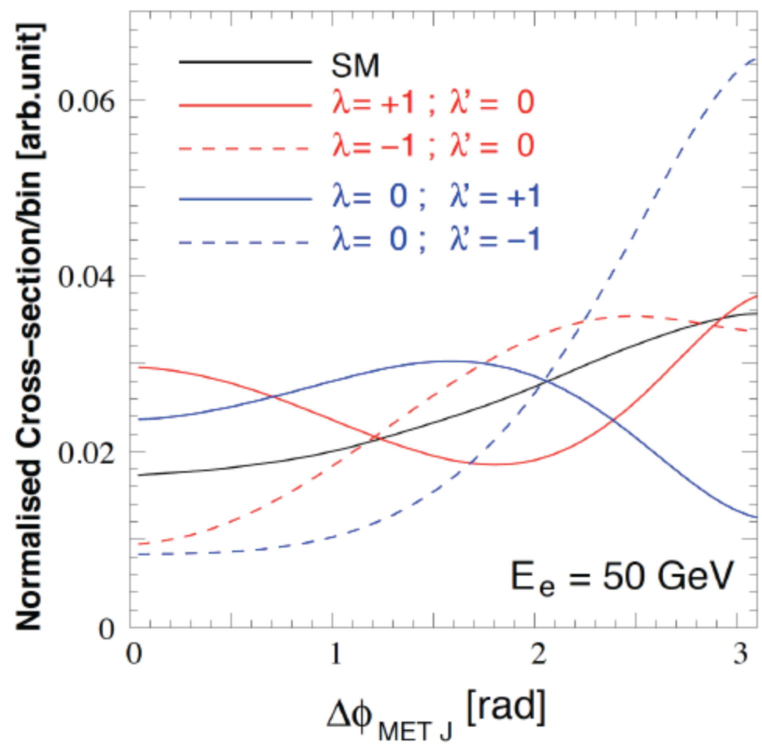
$$\Gamma^{\mu\nu} = g M_W\left(-g^{\mu\nu} + \frac{1}{M_W^2}\left[\lambda\left(p_-\cdot p_+ g^{\mu\nu} - p_-^\nu p_+^\mu\right) + i\lambda'\varepsilon^{\mu\nu\rho\sigma}p_{-\rho}p_{+\sigma}\right]\right)$$

SM CP-even CP-odd

azimuthal angle distribution between E_T^{miss} and forward jet is sensitive to CP nature

T. Plenh et al., arXiv:hep-ph/0105325

with 50 fb^{-1}, sensitivity up to $\lambda \sim 0.05$ and $\lambda' \sim 0.2$



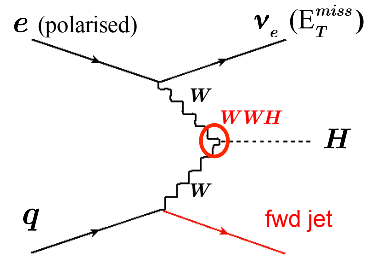
S. Biswal et al., arXiv:1203.6285 and update

BSM in Vector Boson Scattering at FCC-he

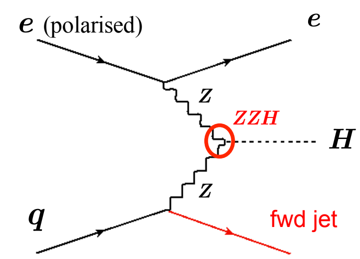
- **VB Higgs production with BSM decay**
  - explore RPV cases

$$H \rightarrow \chi_1^0 \chi_1^0 \rightarrow 3j\,3j \text{ (resonances)}$$

  - need to understand background…



Charged Current



Neutral Current

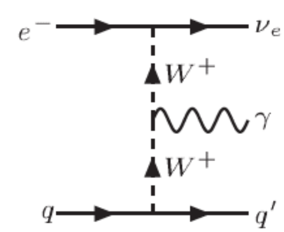
- **Vector Boson scattering at high mass:**

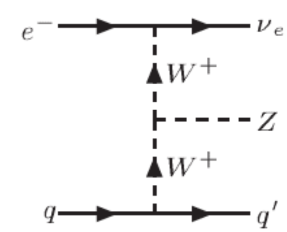
mass dependence of cross section

  - anomalous TGC, QGC couplings in VVV, VVVV ?

I.T. Cakir et al, 1406.7696:

→ *sensitivity comparable to LHC*



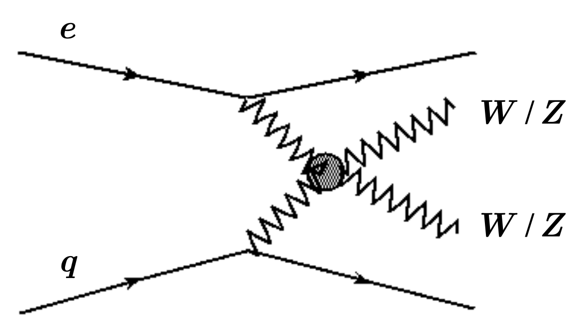


  - Is unitarity restored only by Higgs? are there new resonances (CH model) ?
    - expect below ~ 2-3 TeV

$$e^- q \rightarrow e^-(q)WZ, \quad (\nu q)WZ$$

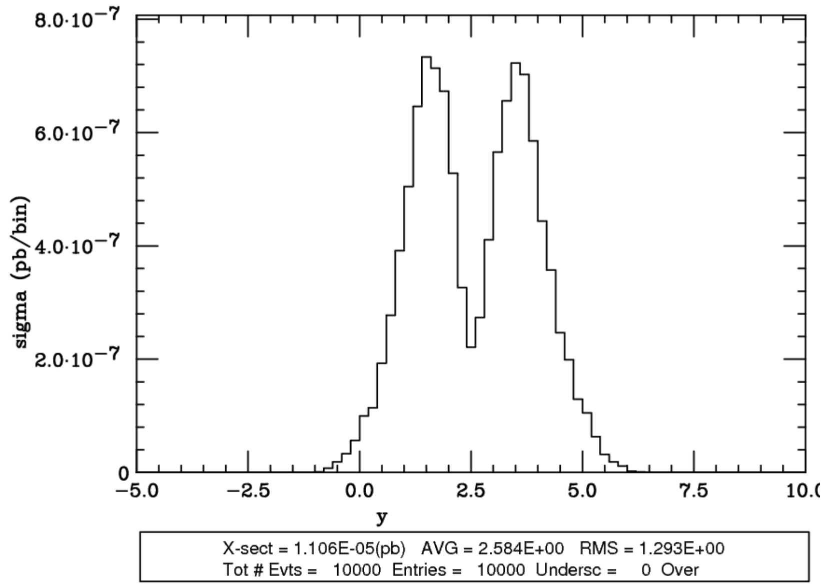
→ *look for deviations from SM predictions:*

- high background from QCD diagrams at LHC, absent at FCC-eh
- challenging at LHC if no lepton trigger is used, and because of pileup

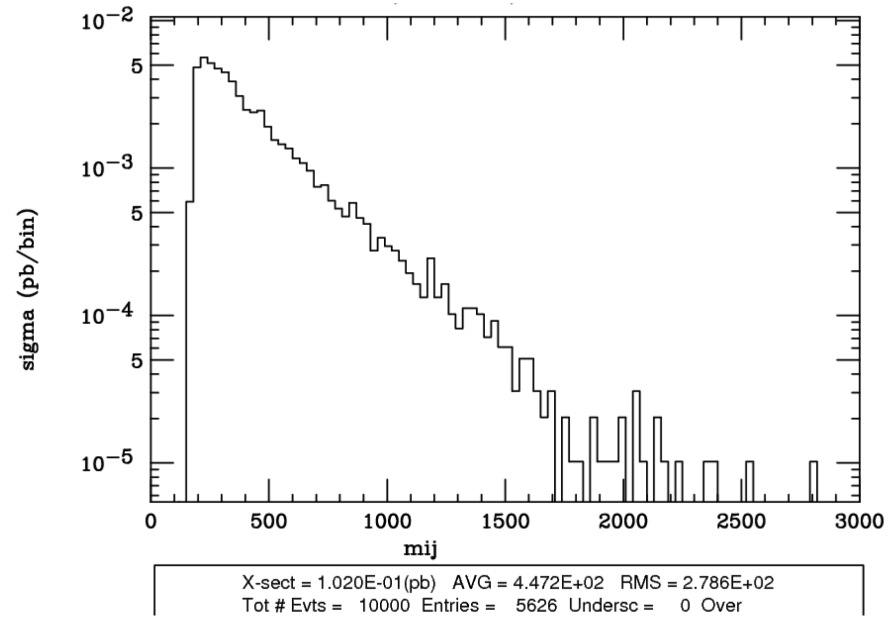


Vector Boson Scattering

y(Z), 2 TeV resonance



m(WZ), background



preliminary !!

typical cross sections for 2 TeV resonance (c_F=0, c_H=1, g_V=3, 120GeV x 50 TeV)

Heavy Vector Triplet model, D. Pappadopoulo et al., JHEP 1409 (2014) 060, 1402.4431

- highly dependent on acceptance and performance of detector)
- LHC14: S = 0.12 fb B_{QCD} = 4.2 pb B_{EW} = 300 fb
- FCC-eh S = 0.01 fb B_{EW} = 100 fb

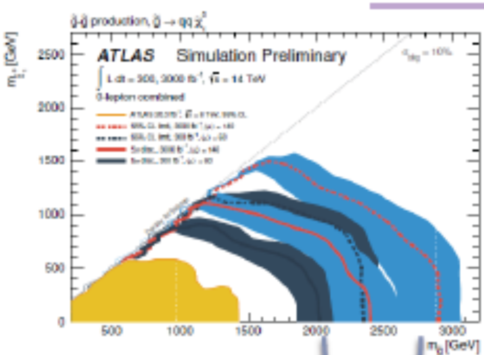
low cross section, but kinematics of signal distinct from background
need v. good detector performance

possibly use hadronic decay of W and Z (boosted, high mass object)?

PDF impact on searches

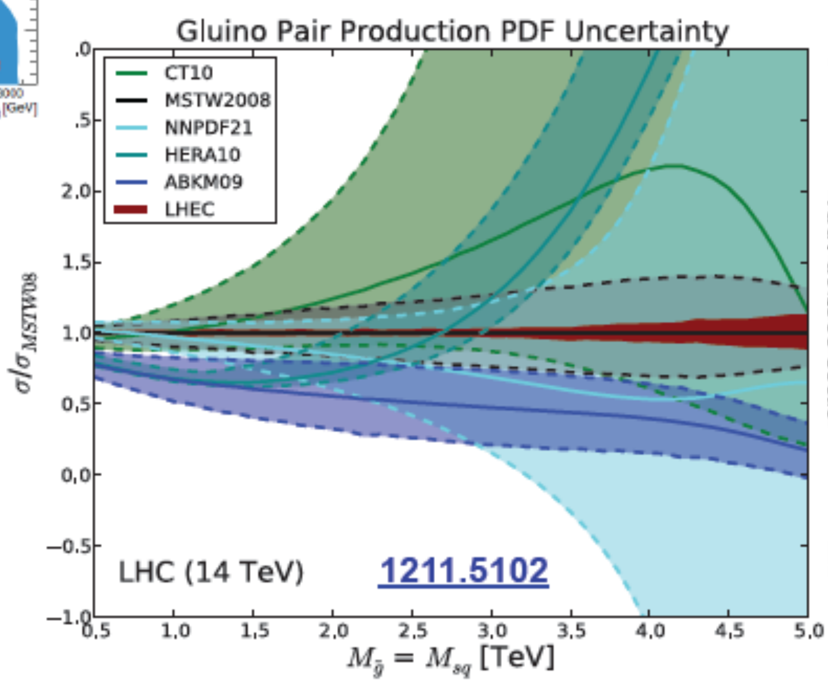
- **For SUSY:** Searches near HL-LHC kinematic boundary may ultimately be limited by knowledge of PDFs (especially gluon at x → 1)
  - Example: gluino production at HL-LHC

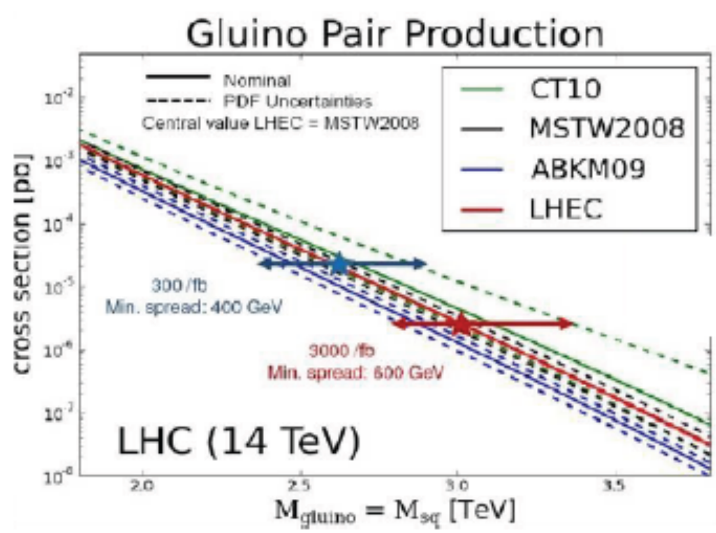
ATL-PHYS-PUB-2014-010



Effect could be up to 1 TeV

→ >100% PDF uncertainty → Dependency on discovery potential and exclusion limits at 300 and 3000 /fb for 14 TeV c.o.m.





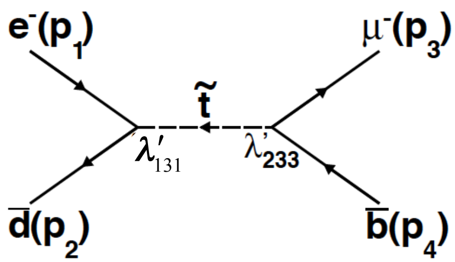
also NNPDF3.0
1410.8849

Monica D'Onofrio, ICFA 2014, Bejing 28/10/2014

SUSY – RPV $\lambda'_{ijk}\hat{L}_i\hat{Q}_j\hat{D}^C_k$

R-parity violation ➔ squark production (similar to leptoquarks, with generation mixing)

stop

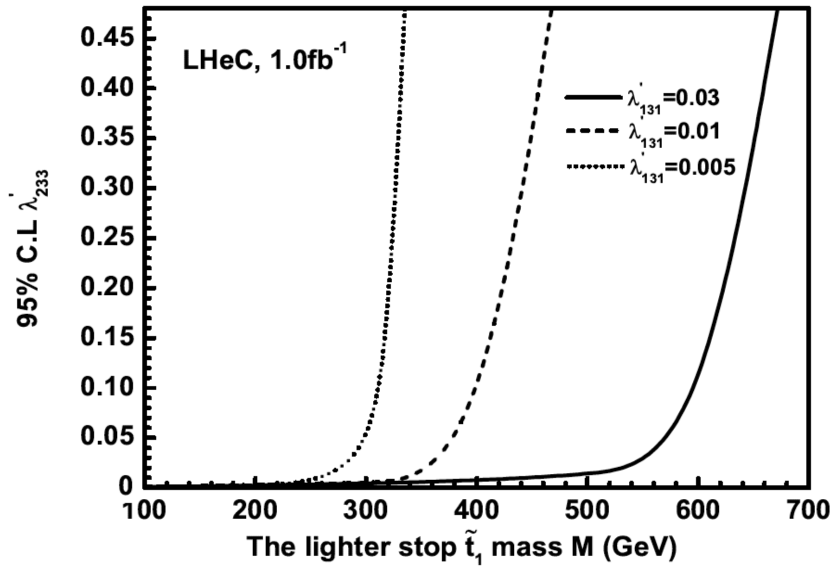


$\lambda'_{131} < 0.03 \dfrac{m_{\tilde{t}_L}}{100\ \text{GeV}}$

also strong bounds from $\beta\beta 0\nu$

Barbier hep/ph-0406039

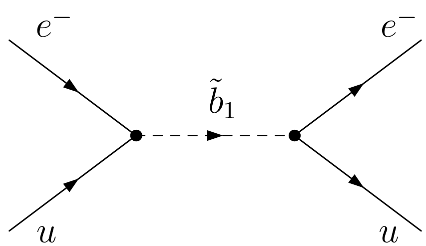
W Hong-Tang et al., [arXiv:1107.4461]



- sensitivity up to 700-800 GeV with just 1 fb^{-1}, but expect constraints from LHC.
- Very promising with high lumi, ~ 100 fb^{-1}
- requires good b-tagging efficiency

sbottom

$p_T^e > 20\ \text{GeV}, \quad p_T^{jet} > 20\ \text{GeV}, \quad |y_e| < 3.2, \quad |y_{jet}| < 4.9,$



lepton-flavor-conserving process under single coupling dominance hypothesis

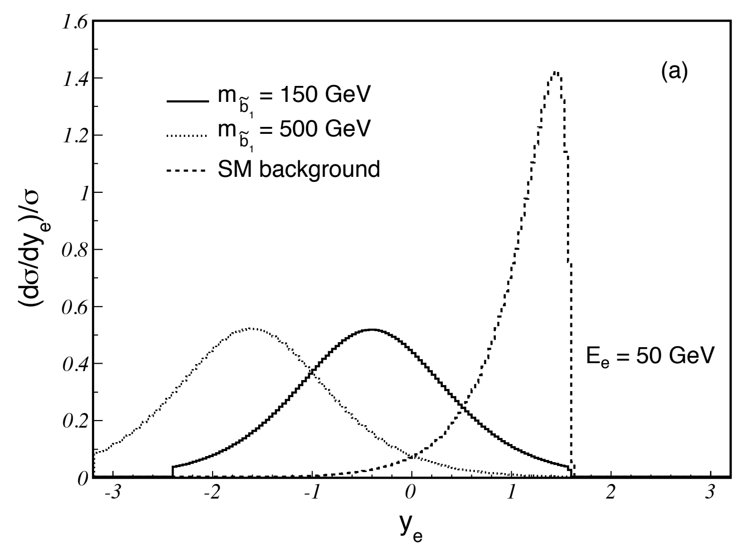
$\lambda'_{113} < 0.02 \dfrac{m_{\tilde{b}_R}}{100\ \text{GeV}}$

also strong bounds from $\beta\beta 0\nu$

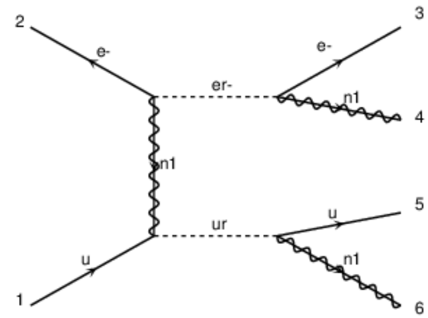
Barbier hep/ph-0406039

[arXiV: 1401.4266]

< 100 fb-1 needed for 1 TeV RPV sbottom 5s discovery



- $\tilde{q}\,\tilde{\ell}$ **production**
  - constraints from LHC
    - for large $\Delta m(\tilde{\ell} - \chi_1^0) > 100 - 150\ \mathrm{GeV}$
      → expect low p_T leptons
    - low $\Delta m(\tilde{q} - \chi_1^0)$ constrained by monojet analysis

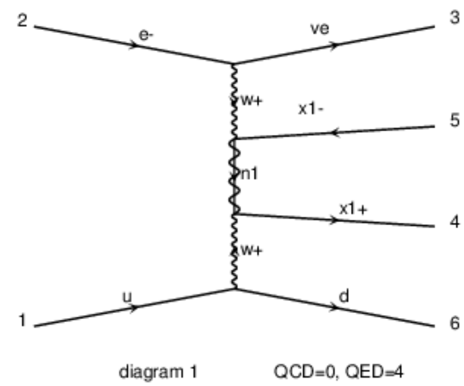


- **EWK SUSY**
  - via Vector Boson Fusion

$$ep \to \tilde{\chi}_1^{\pm}\tilde{\chi}_1^{\pm} j\, j;$$

$$\hookrightarrow \tilde{\chi}_1^{0} W^{\pm *}$$

$$\hookrightarrow j\, j \text{ (very soft)}$$



→ high background…

Conclusions

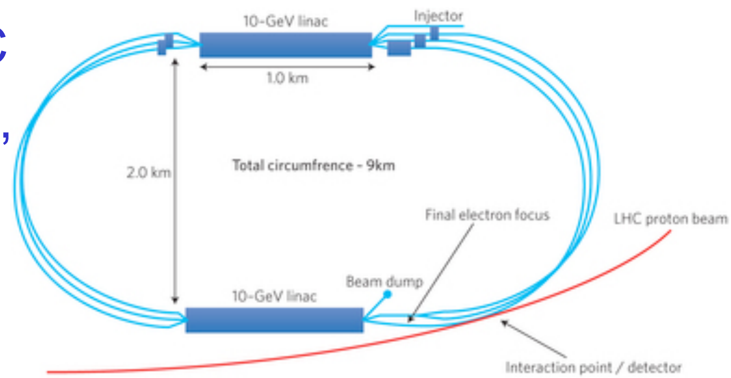
- Exotica and BSM physics
  - High mass leptoquarks at FCC-he, with sensitivity to coupling
  - lepton-quark compositeness: sensitivity still at LHeC
  - anomalous top couplings
  - …
- Higgs couplings need to be measured with high precision
  - coupling to gauge bosons *HWW, HZZ*: measure and probe anomalous couplings
- High precision measurements of proton (and nuclear) structure are the main goals of LHeC and FCC-he
  - improve dramatically precision of LHC and HL-LHC searches and measurements

higher sensitivity in all channels at FCC-he

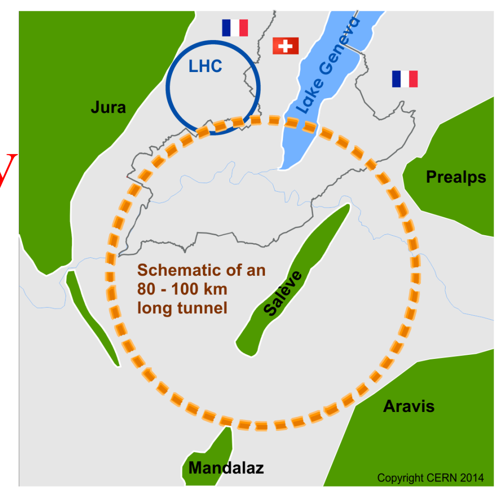
Studies ongoing: a lot remains to be done

backup

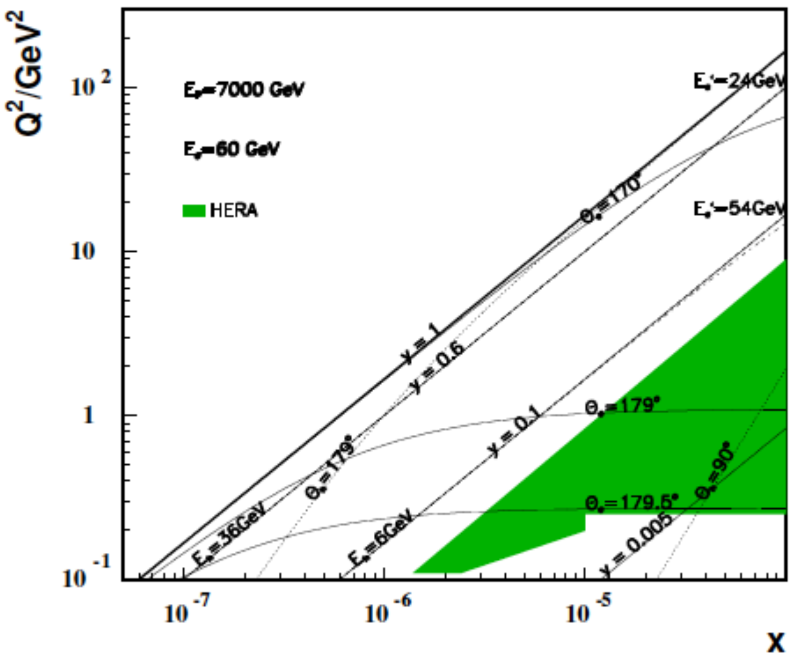
- **LHeC Baseline Design: 60 GeV x 7 TeV, √s=1.3 TeV**
  - should be synchronous with *pp* operation of LHC
  - L= $10^{33\text{-}34}$ $cm^{-2}s^{-1}$, : Q^2_{max}= 10^6 GeV^2, 10^{-6} < x< 1,
  - 10-100 fb^{-1}/yr, 0.1-1 ab-1 total
  - Linac-Ring (LR) option: *now baseline design*
    - energy recovery LINAC (ERL)
    - possible polarised e^- (up to 90%), γ beam, using Compton Back-scattering, but low luminosity for e^+
    - eventually possible Higgs factory γγ collider



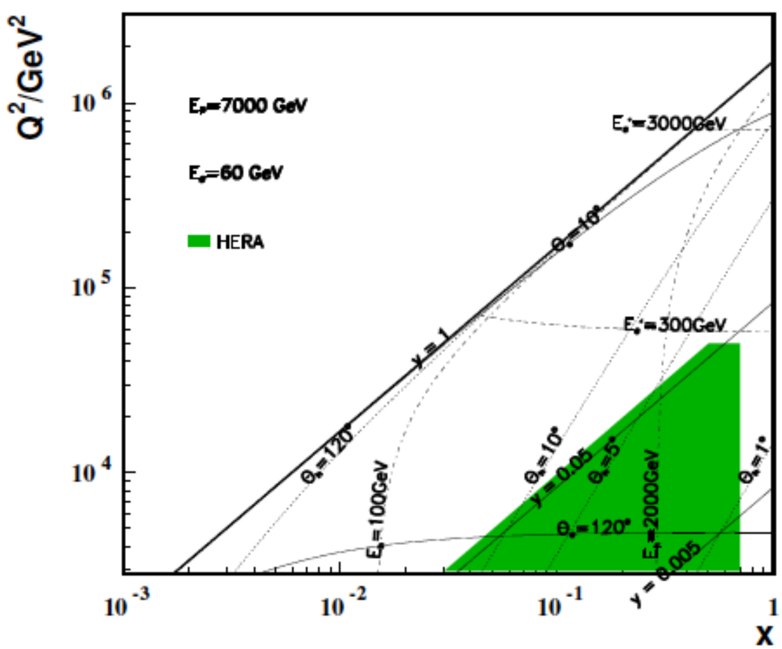
- **FCC-he**
  - 80-100 km tunnel infrastructure in Geneva area
  - **80 (pol.), 120, 175 GeV x 50 TeV → √s = 2.8, 3.5, 4.2 TeV**
  - colliding beams from *FCC-ee* and *FCC-hh* yields ***FCC-he*** luminosity of about **2×10^{34} $cm^{-2}s^{-1}$ at E_e=80 GeV** and **2×10^{33} $cm^{-2}s^{-1}$ at 175 GeV**;



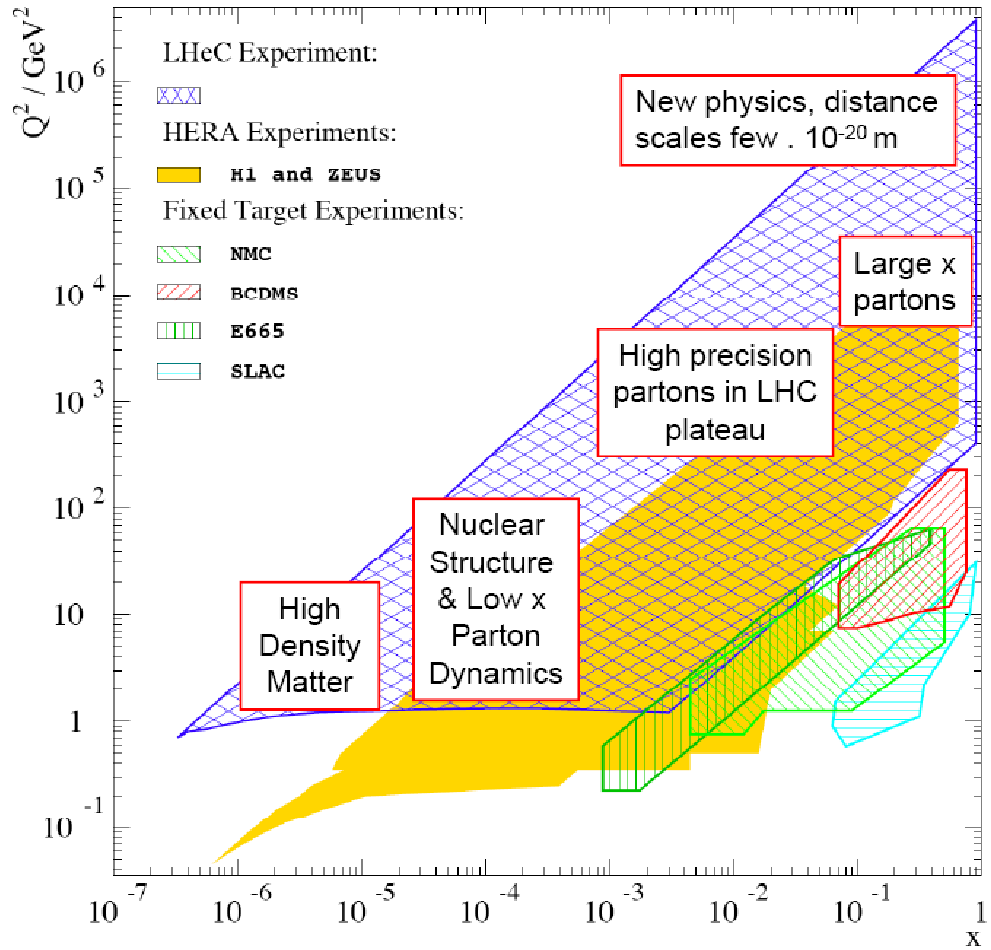
from F. Zimmermann, FCC Study Kickoff meeting, Feb 2014, Geneva



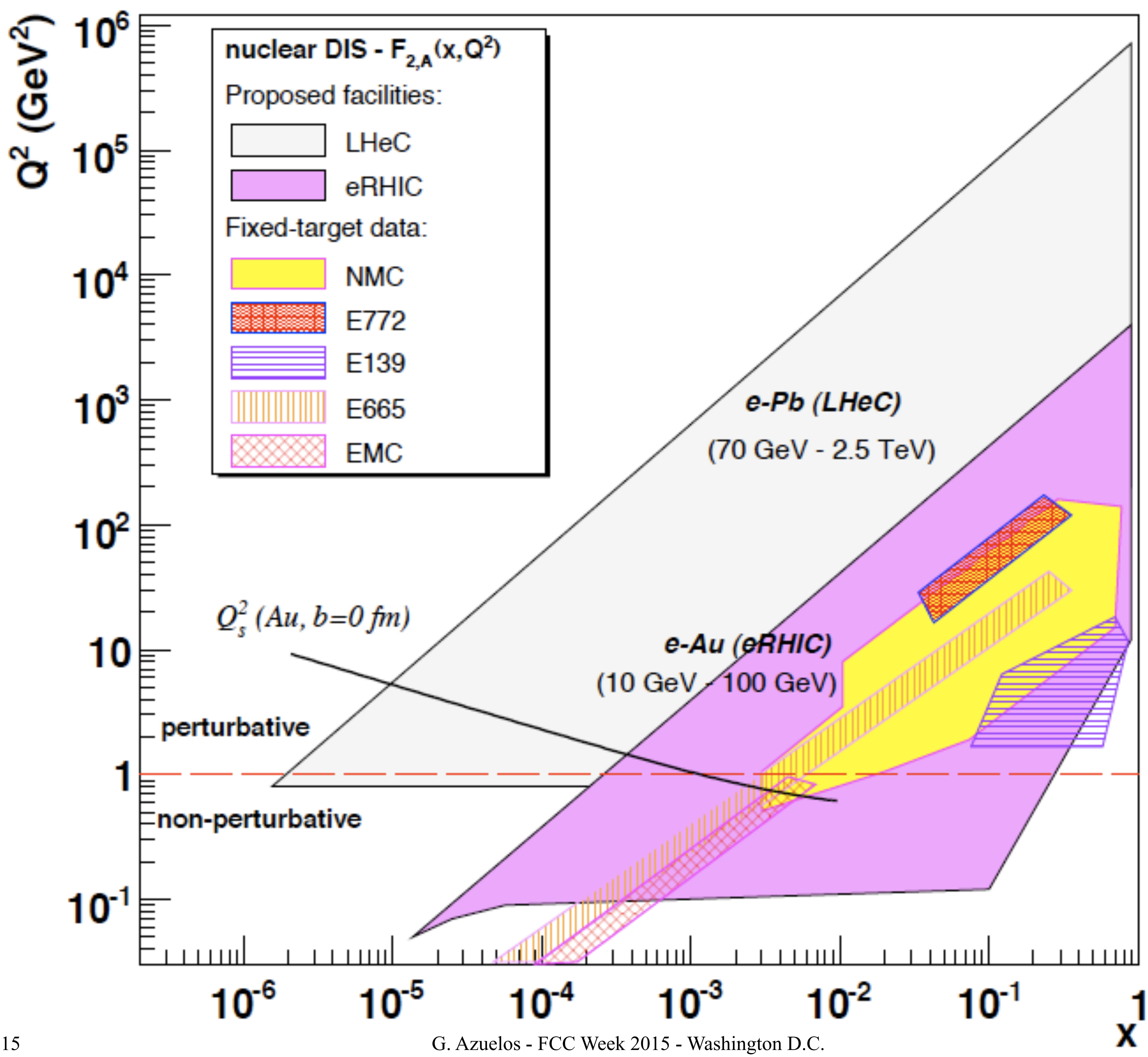
Q²/GeV²
E_p=7000 GeV
E_e=60 GeV
HERA
E_e'=24GeV
E_e'=54GeV
θ_e=170°
y = 1
y = 0.6
θ_e=179°
y = 0.1
θ_e=179.5°
θ_e=90°
E_e=36GeV
E_e=6GeV
y = 0.005
10 ²
10
1
10 -1
10 -7
10 -6
10 -5
x



Q²/GeV²
E_p=7000 GeV
E_e=60 GeV
HERA
E_e'=3000GeV
E_e'=300GeV
θ_e=10°
y = 1
θ_e=120°
E_f=100GeV
θ_e=10°
y = 0.05
θ_e=5°
θ_e=120°
E_f=2000GeV
y = 0.005
θ_e=1°
10 6
10 5
10 4
10 -3
10 -2
10 -1
1
x

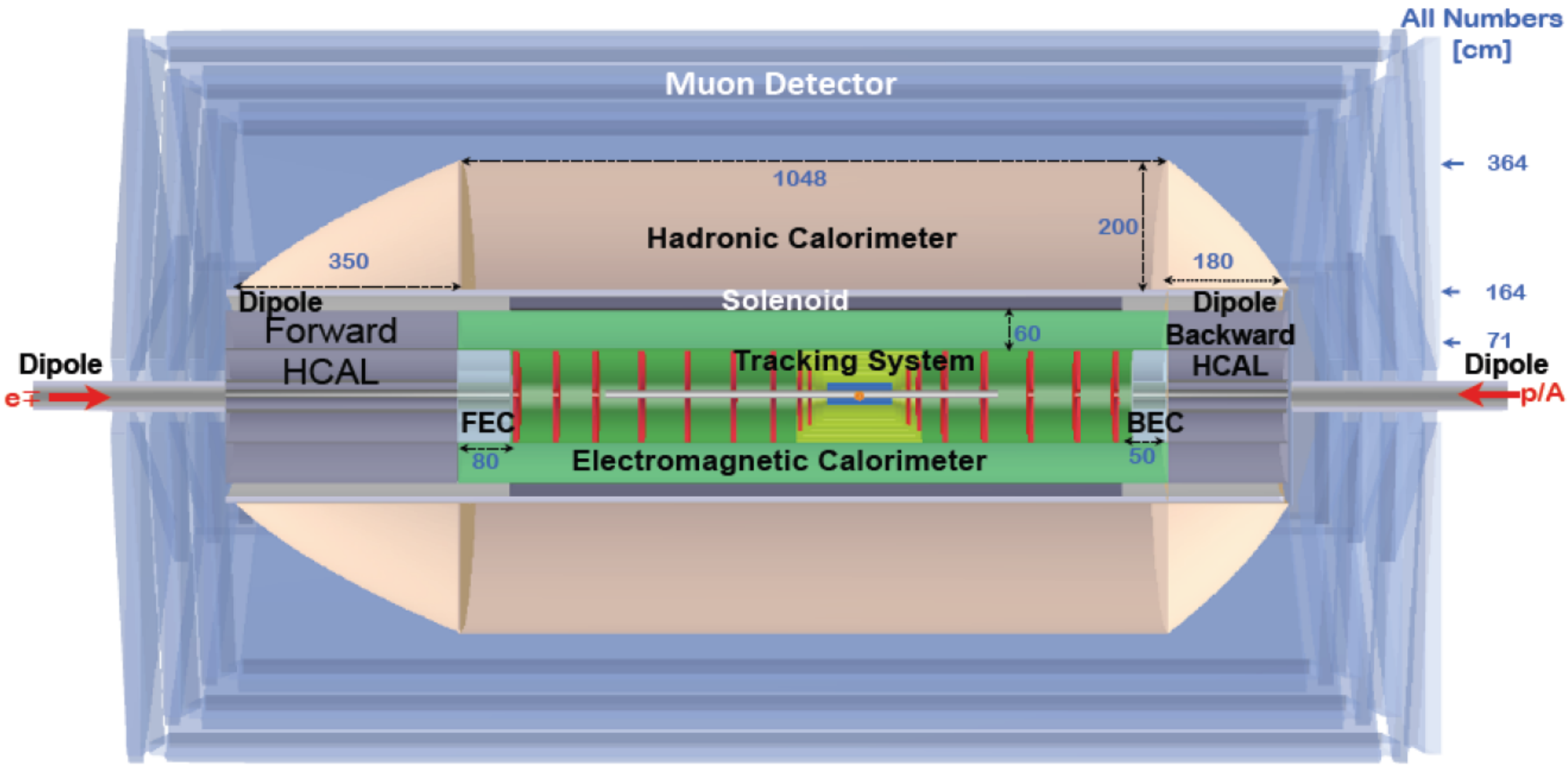


Q² / GeV²
LHeC Experiment:
HERA Experiments:
H1 and ZEUS
Fixed Target Experiments:
NMC
BCDMS
E665
SLAC
New physics, distance scales few . 10⁻²⁰ m
Large x partons
High precision partons in LHC plateau
Nuclear Structure & Low x Parton Dynamics
High Density Matter
10 6
10 5
10 4
10 3
10 2
10
1
10 -1
10 -7
10 -6
10 -5
10 -4
10 -3
10 -2
10 -1
1
x

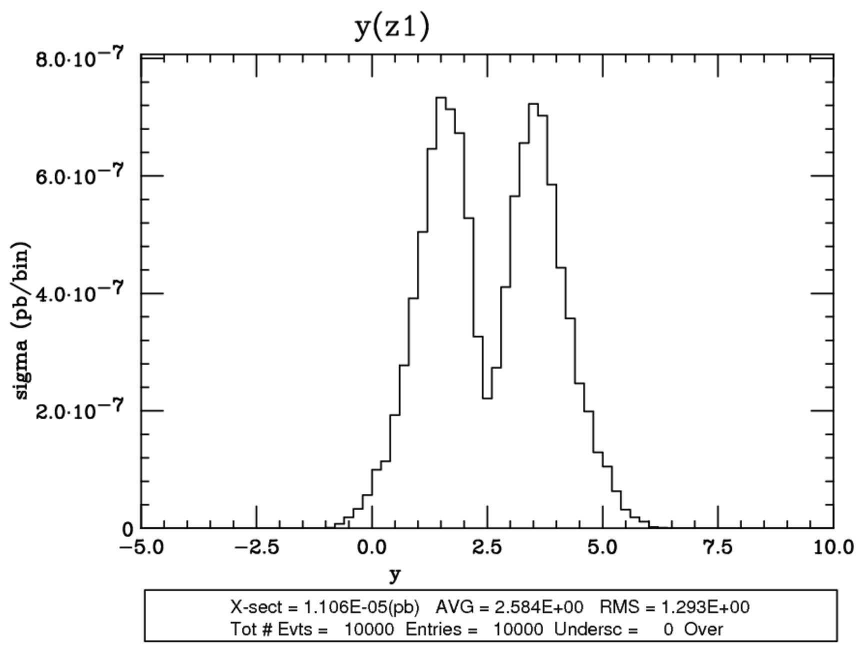

Q² (GeV²)
10⁶
10⁵
10⁴
10³
10²
10
1
10⁻¹
nuclear DIS - F2,A(x,Q²)
Proposed facilities:
LHeC
eRHIC
Fixed-target data:
NMC
E772
E139
E665
EMC
e-Pb (LHeC)
(70 GeV - 2.5 TeV)
Q²s (Au, b=0 fm)
e-Au (eRHIC)
(10 GeV - 100 GeV)
perturbative
non-perturbative
10⁻⁶
10⁻⁵
10⁻⁴
10⁻³
10⁻²
10⁻¹
1
x

FCC-he detector layout

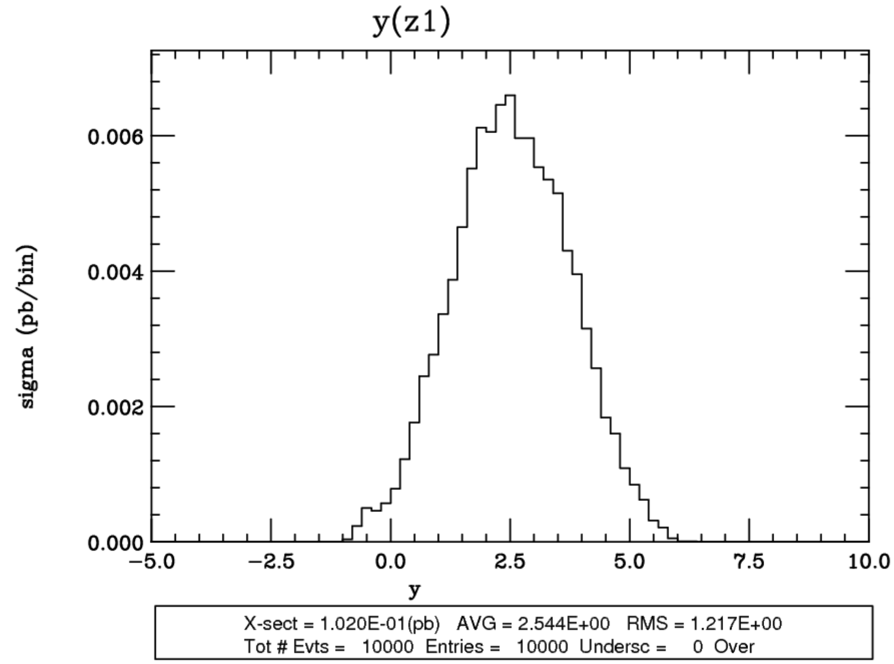
- Longer than LHeC in p direction (x 2 for calorimeters to contain showers)
- Same or slightly longer in electron direction (about 1.3 for 120 GeV)



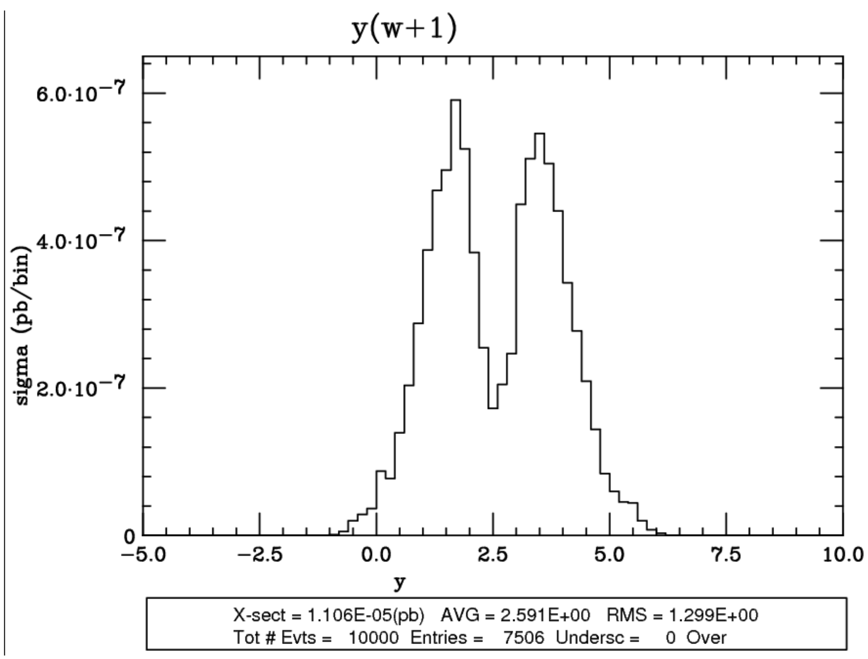
Alessandro Pollini and Peter Kostka
https://indico.cern.ch/event/282344/session/15/contribution/100/material/slides/0.pdf



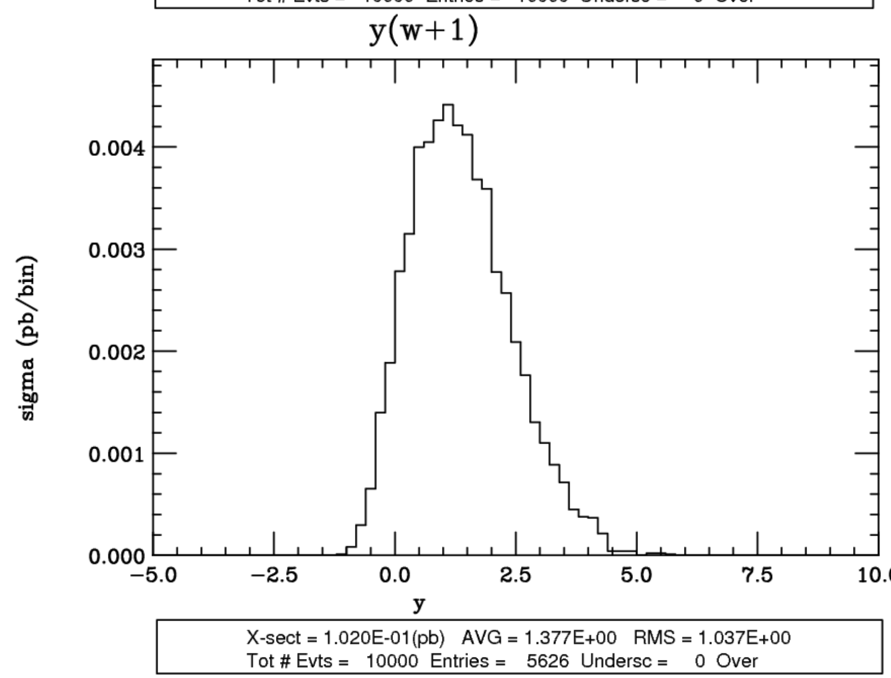
y(z1)
8.0·10^{-7}
6.0·10^{-7}
4.0·10^{-7}
2.0·10^{-7}
0
sigma (pb/bin)
−5.0 −2.5 0.0 2.5 5.0 7.5 10.0
y
X-sect = 1.106E-05(pb) AVG = 2.584E+00 RMS = 1.293E+00
Tot # Evts = 10000 Entries = 10000 Undersc = 0 Over



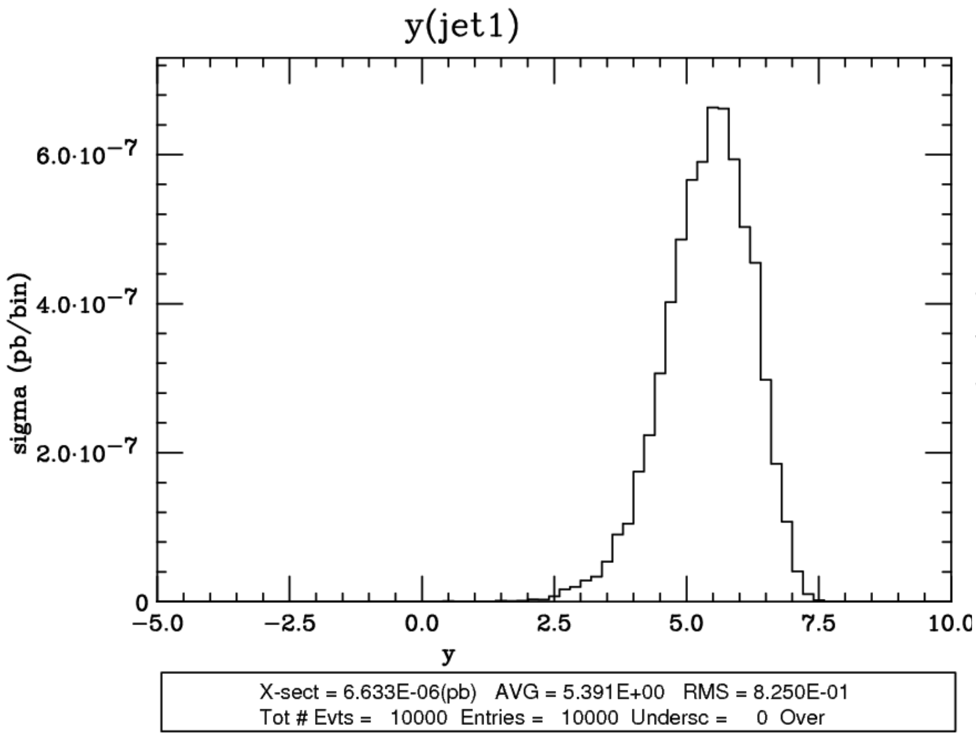
y(z1)
0.006
0.004
0.002
0.000
sigma (pb/bin)
−5.0 −2.5 0.0 2.5 5.0 7.5 10.0
y
X-sect = 1.020E-01(pb) AVG = 2.544E+00 RMS = 1.217E+00
Tot # Evts = 10000 Entries = 10000 Undersc = 0 Over



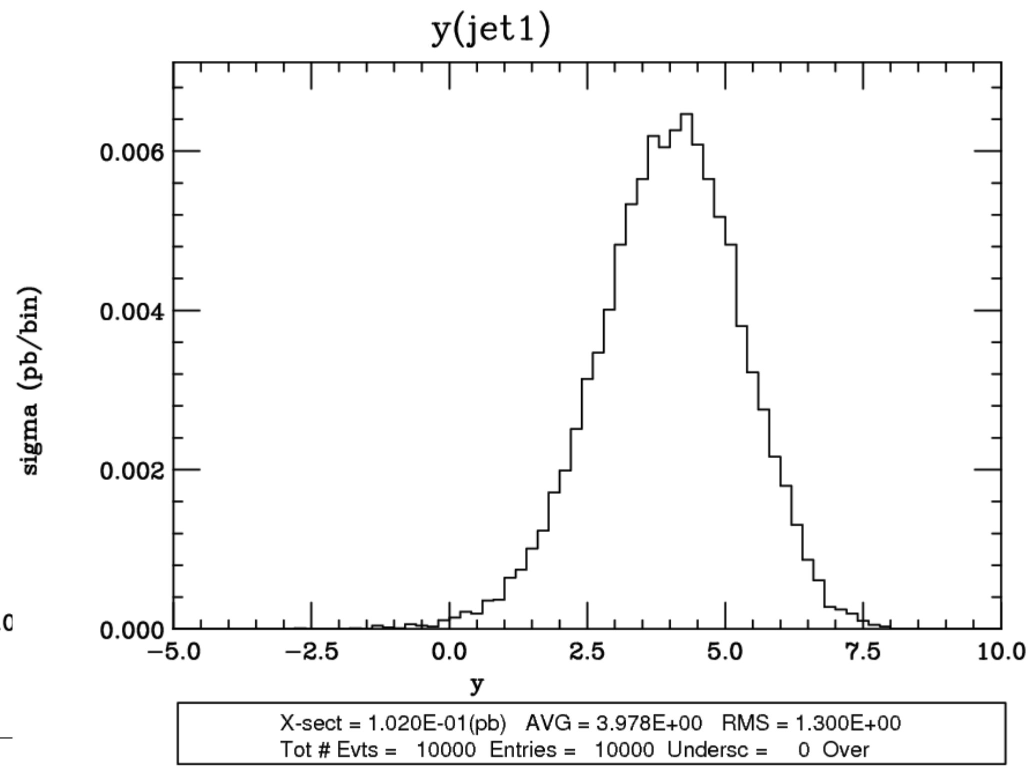
y(w+1)
6.0·10^{-7}
4.0·10^{-7}
2.0·10^{-7}
0
sigma (pb/bin)
−5.0 −2.5 0.0 2.5 5.0 7.5 10.0
y
X-sect = 1.106E-05(pb) AVG = 2.591E+00 RMS = 1.299E+00
Tot # Evts = 10000 Entries = 7506 Undersc = 0 Over



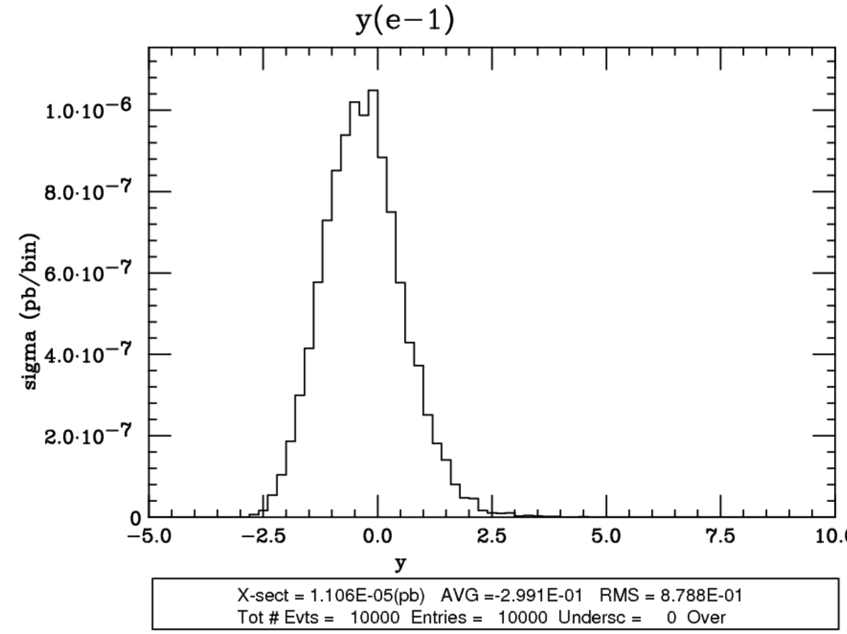
y(w+1)
0.004
0.003
0.002
0.001
0.000
sigma (pb/bin)
−5.0 −2.5 0.0 2.5 5.0 7.5 10.0
y
X-sect = 1.020E-01(pb) AVG = 1.377E+00 RMS = 1.037E+00
Tot # Evts = 10000 Entries = 5626 Undersc = 0 Over

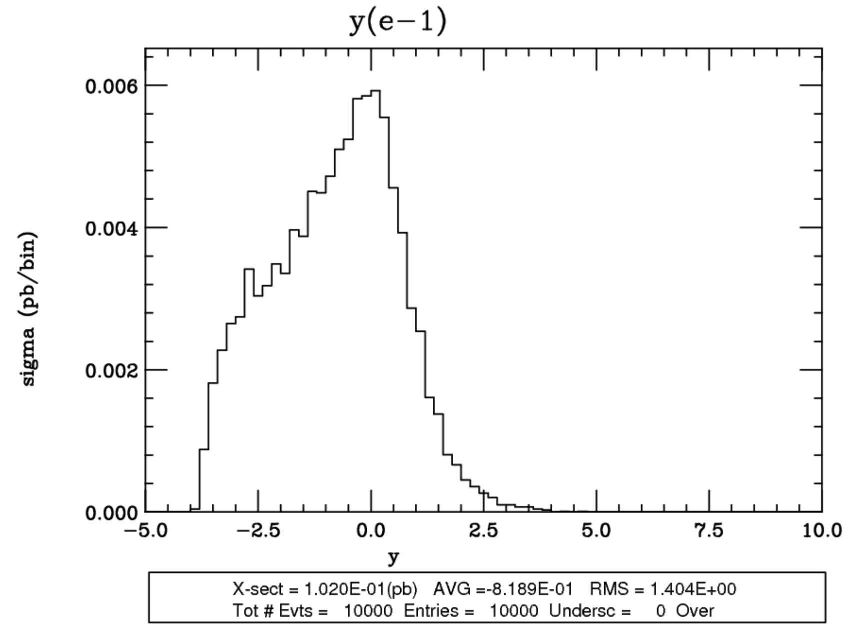


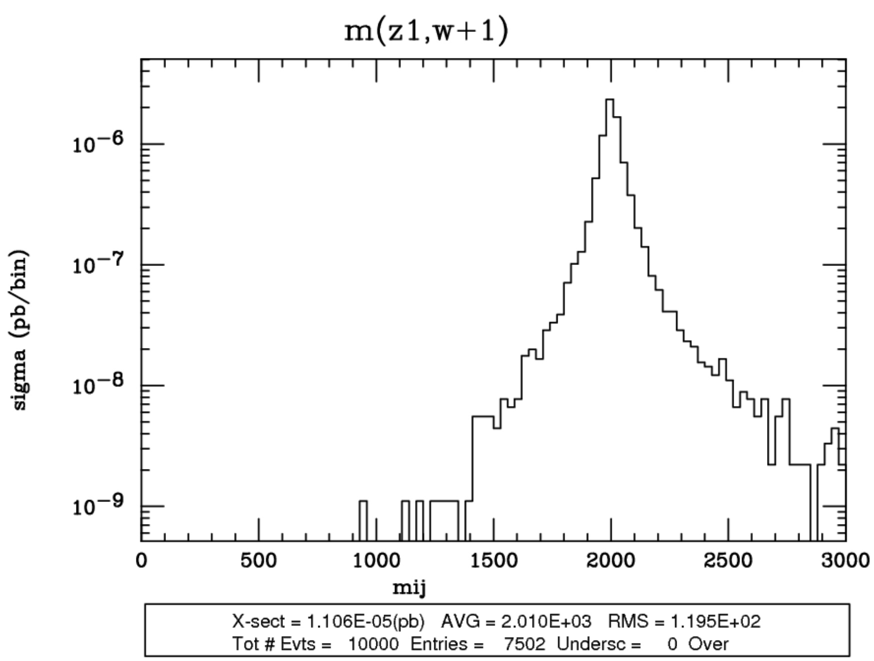
y(jet1)
sigma (pb/bin)
6.0·10⁻⁷
4.0·10⁻⁷
2.0·10⁻⁷
0
−5.0
−2.5
0.0
2.5
5.0
7.5
10.0
y
X-sect = 6.633E-06(pb) AVG = 5.391E+00 RMS = 8.250E-01
Tot # Evts = 10000 Entries = 10000 Undersc = 0 Over

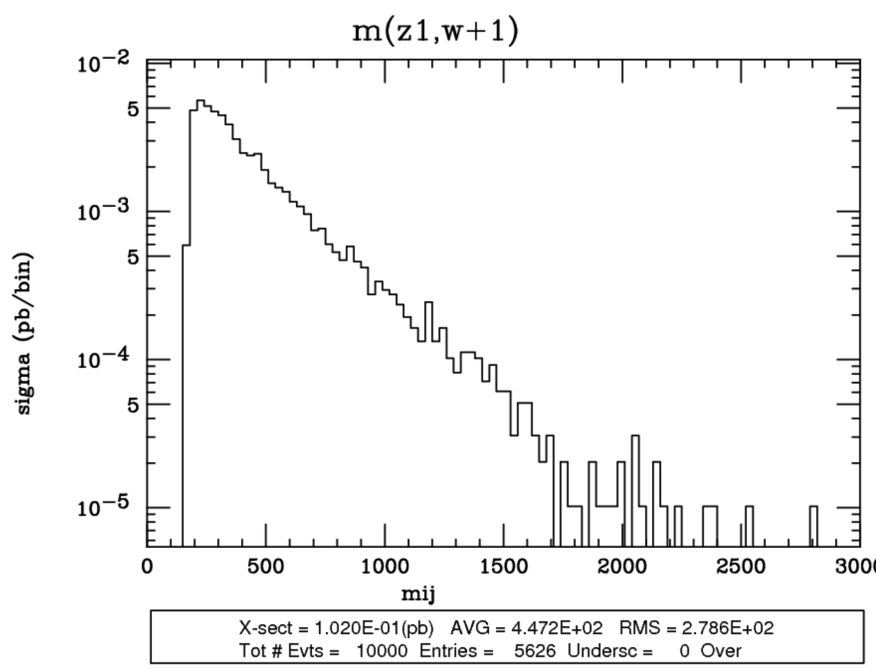


y(jet1)
sigma (pb/bin)
0.006
0.004
0.002
0.000
−5.0
−2.5
0.0
2.5
5.0
7.5
10.0
y
X-sect = 1.020E-01(pb) AVG = 3.978E+00 RMS = 1.300E+00
Tot # Evts = 10000 Entries = 10000 Undersc = 0 Over


y(e−1)
sigma (pb/bin)
y
X-sect = 1.106E-05(pb) AVG =-2.991E-01 RMS = 8.788E-01
Tot # Evts = 10000 Entries = 10000 Undersc = 0 Over


y(e−1)
sigma (pb/bin)
y
X-sect = 1.020E-01(pb) AVG =-8.189E-01 RMS = 1.404E+00
Tot # Evts = 10000 Entries = 10000 Undersc = 0 Over


m(z1,w+1)
sigma (pb/bin)
mij
X-sect = 1.106E-05(pb) AVG = 2.010E+03 RMS = 1.195E+02
Tot # Evts = 10000 Entries = 7502 Undersc = 0 Over


m(z1,w+1)
sigma (pb/bin)
mij
X-sect = 1.020E-01(pb) AVG = 4.472E+02 RMS = 2.786E+02
Tot # Evts = 10000 Entries = 5626 Undersc = 0 Over