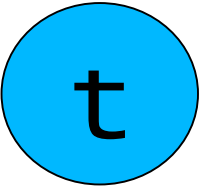
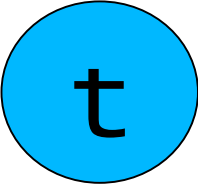
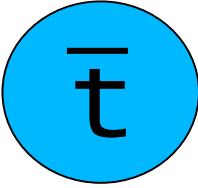


Top physics at the

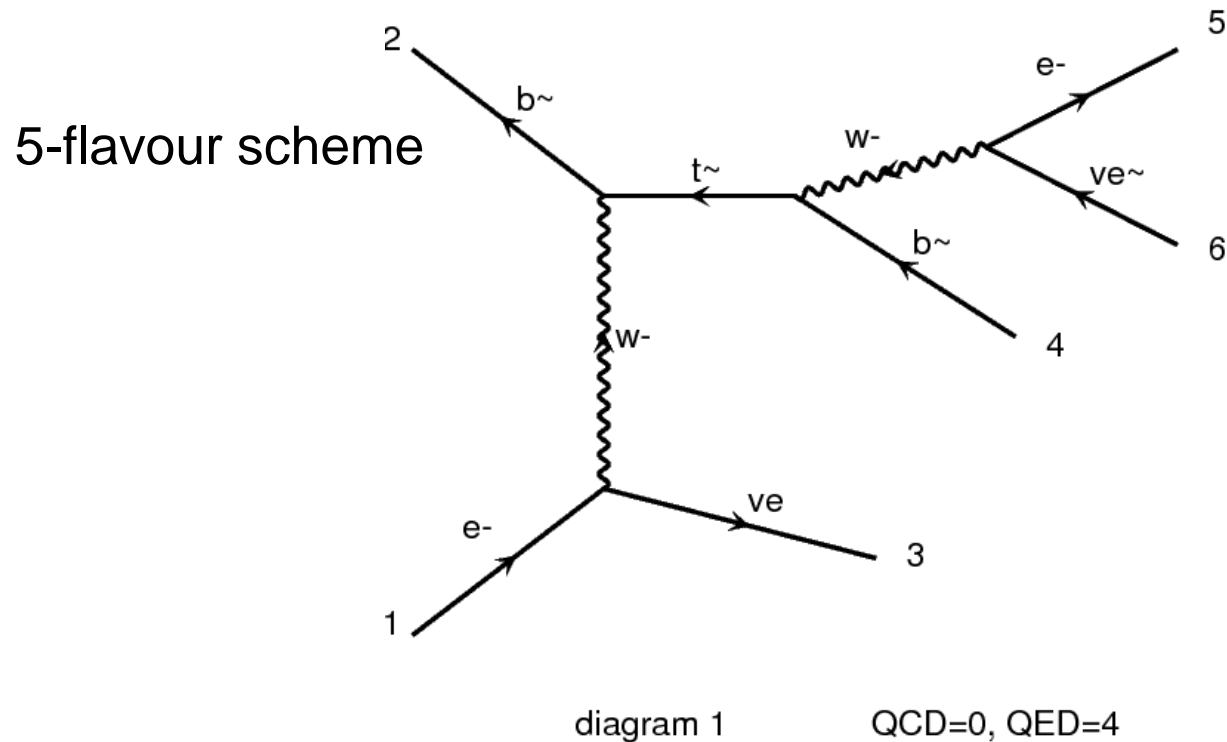


LHeC workshop 20th january 2014

Olaf Behnke (DESY)

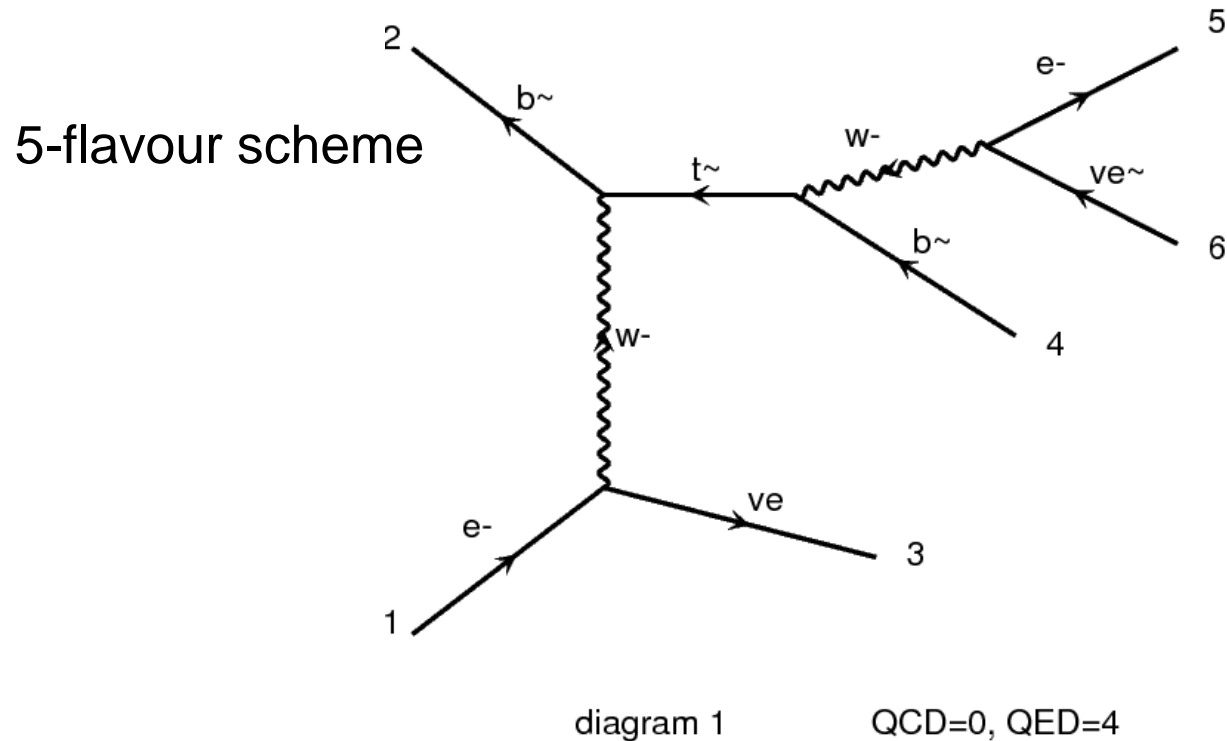
- Single top production 
- Top pair production  
- Anomalous production: FCNC,
Heavy Top partners (study by J. Ferrando)

Single Top production in charged currents



- Determine V_{tb} from cross section
- Check for *anomalous* production
- Depending on (sensitive to) effective b-quark density in proton

Single Top production in charged currents



- Determine V_{tb} from cross section
- Check for *anomalous* production
- Depending on (sensitive to) effective b-quark density in proton

Can be determined in situ from F2bb measurements at LHeC !

Studies with Madgraph 5

generate $e^- p \rightarrow \nu_e t\bar{t}$

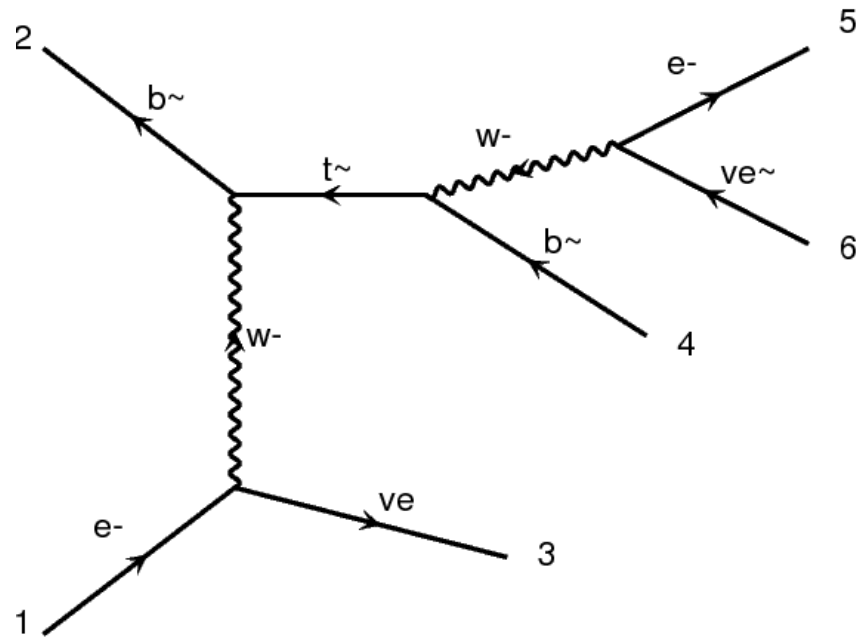


diagram 1

QCD=0, QED=4

Madgraph parameters used throughout this talk

- Collider scenario: 7 TeV p on 60 GeV electrons
- So far only on parton level
- Standard madgraph cards (e.g. CTEQ6L1)
- 5-flavour scheme

Studies with Madgraph 5

generate e- p > ve t~

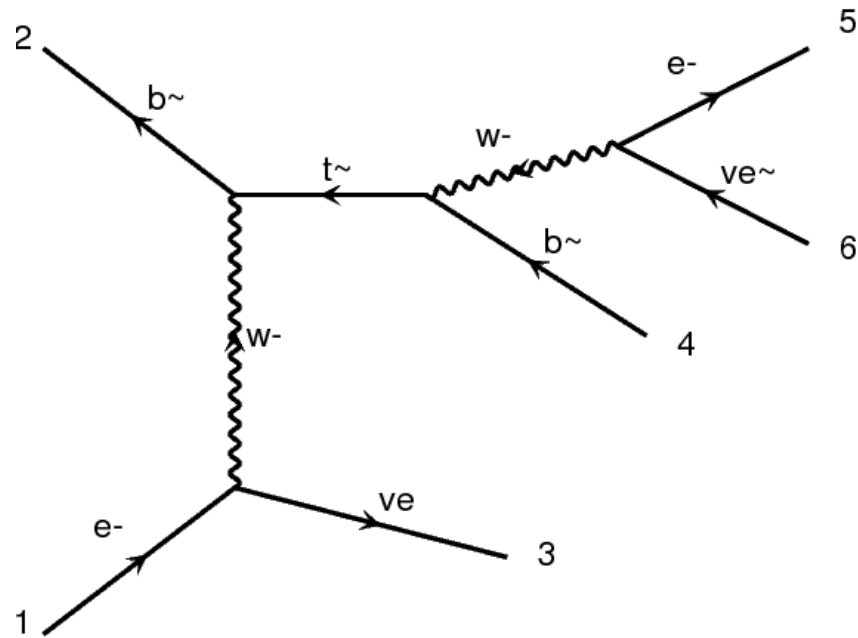
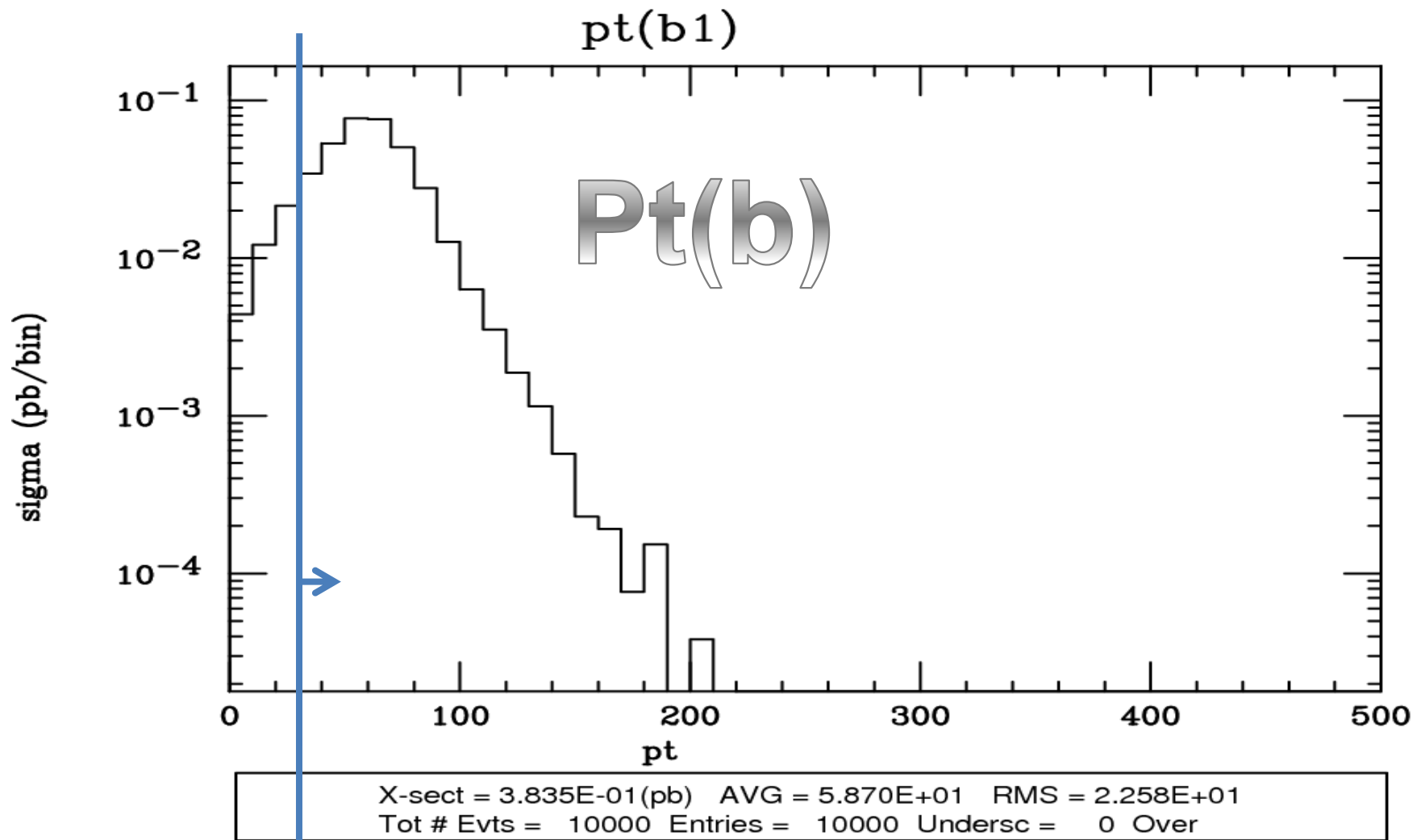


diagram 1

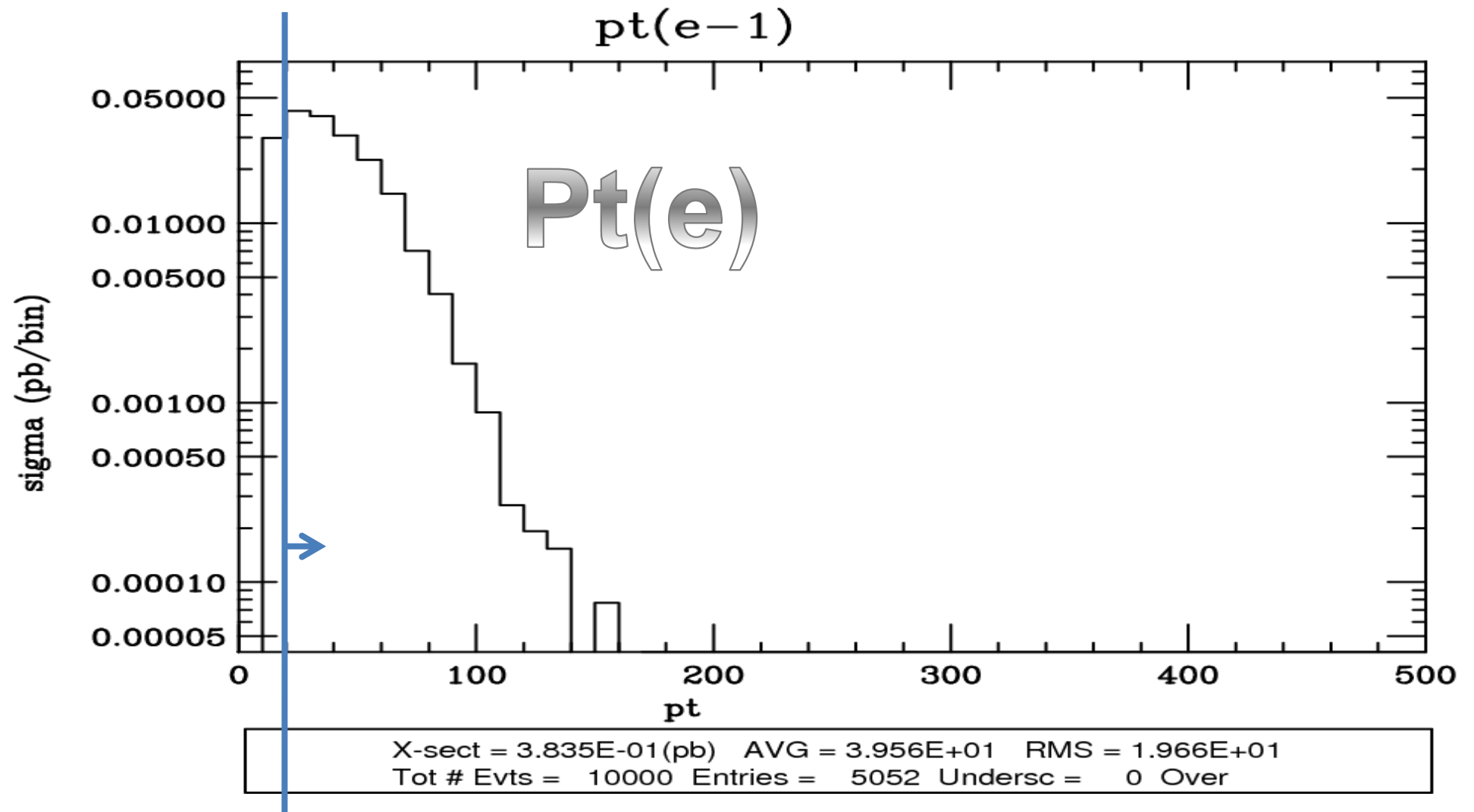
QCD=0, QED=4

Obtained total LO Cross Section: 1.8 pb

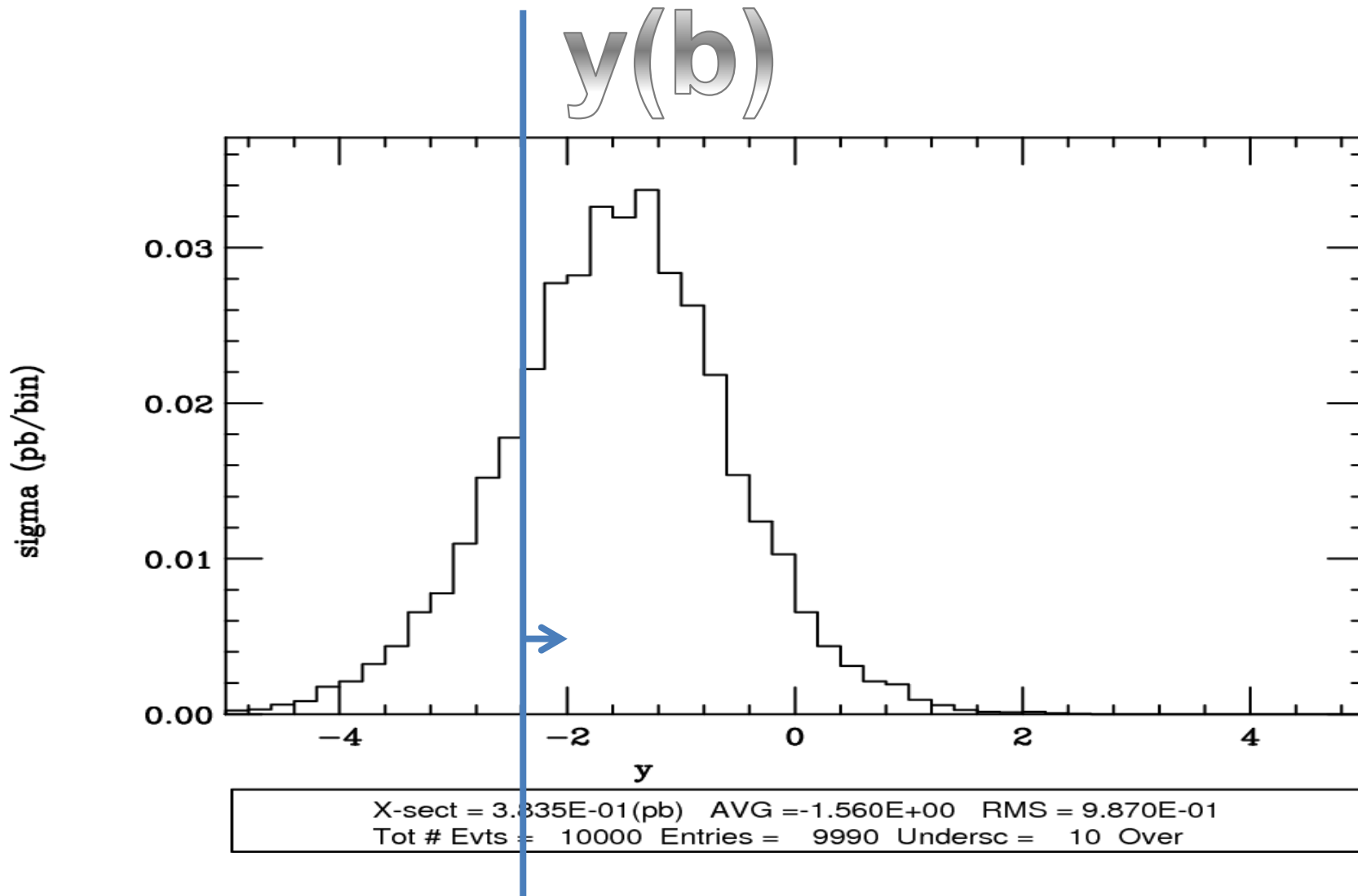
Check in the following slides the decay kinematics (is it within the LHeC detector?)



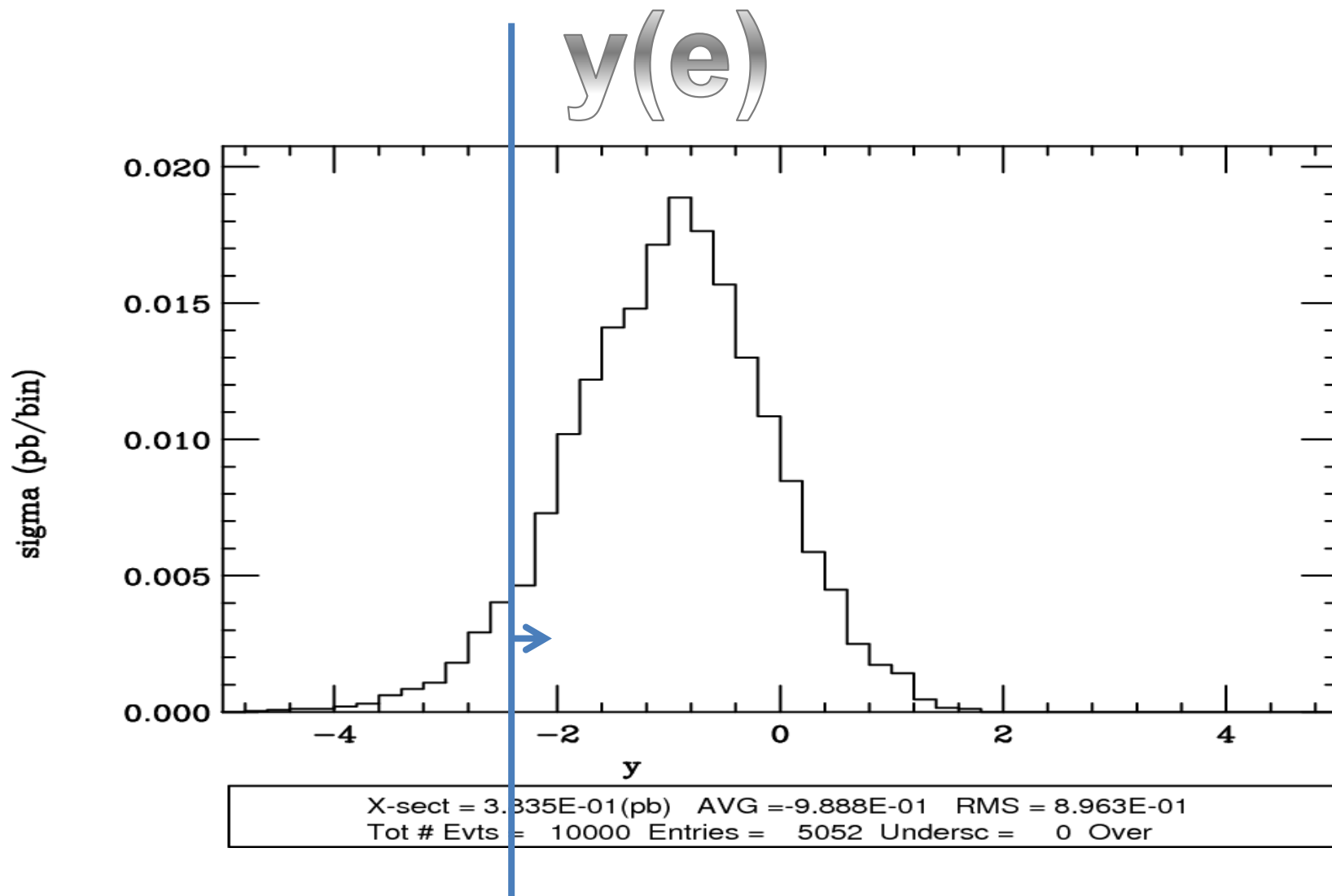
Typical LHC cut (ATLAS, CMS)



Typical LHC cut



Typical LHC cut



Typical LHC cut

Conclusion from kinematic studies on charged current Single Top production

- Majority of events is **within** the anticipated LHeC detector acceptance.

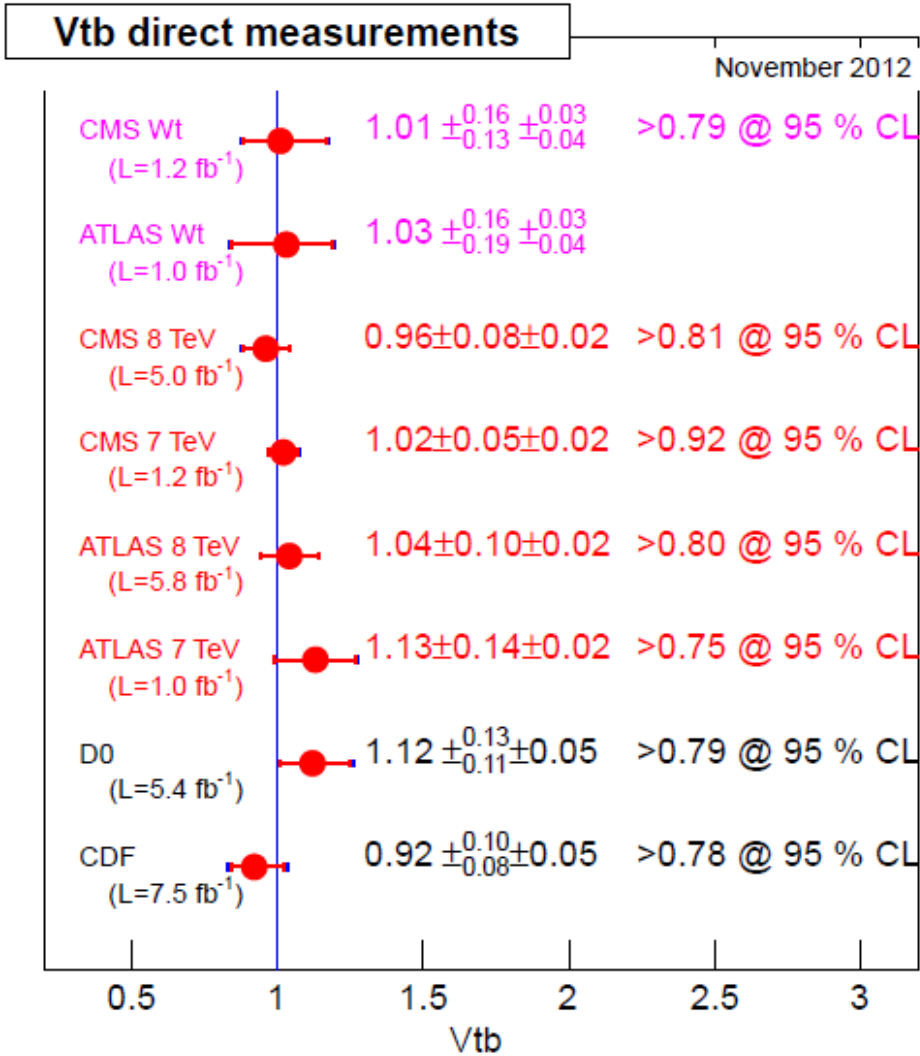
CC Single Top at LHeC compared to LHC

	s-channel	t-channel	tW-channel	tt prod.
LHC				
$\sigma @7\text{TeV (pb)}$ (NNLO Kidonakis)	4.6	64.2	15.7	163
LHeC				
$\sigma \text{ (pb)}$ (LO Madgraph)	1.8	0.0029	~0.01 in DIS	
→ Expected #events for 1000 fb ⁻¹	1.8M	2900	~10000	

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$\sigma \text{ (pb)}$ (LO Madgraph)	1.8	0.0029	~ 0.01 in DIS	
\rightarrow Expected #events for 1000 fb ⁻¹	1.8M	2900	~ 10000	
	Available for precise V_{tb} determination			

CC Single Top: Status of V_{tb} at LHC

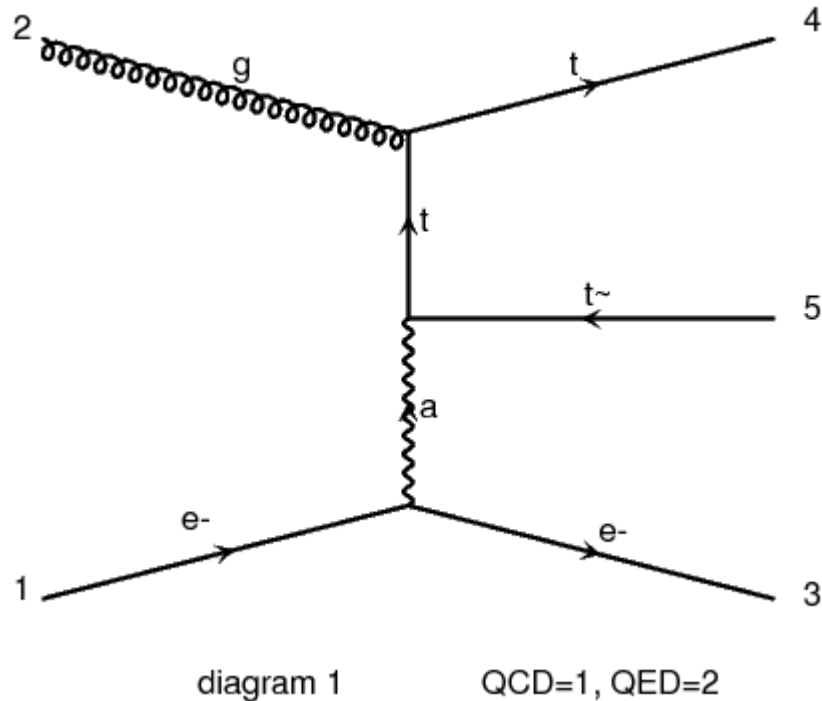


Georgio Chiarelli, arXiv:1302.1773

Using the current single top cross section measurements, one can compile (see figure 10) a list of the direct determination of $|V_{tb}|$. The situation is far from being satisfying. While the CMS 7 TeV measurement [5] has an uncertainty of $\approx 5\%$, all the other results (including the most recent one by CMS at 8 TeV) have uncertainties at the level of 10%, too large to challenge the SM. As the LHC has already large statistics, these measurements are (mostly) systematics limited. It is a challenge to tackle in order to use this process as a tool to search for new physics in the top sector.

→ Further detector level studies are needed to assess the LHeC potential for V_{tb} (Acceptance, Backgrounds from W production etc.)

Top pair production in DIS at LHeC



- Sensitive to the proton gluon density at high x

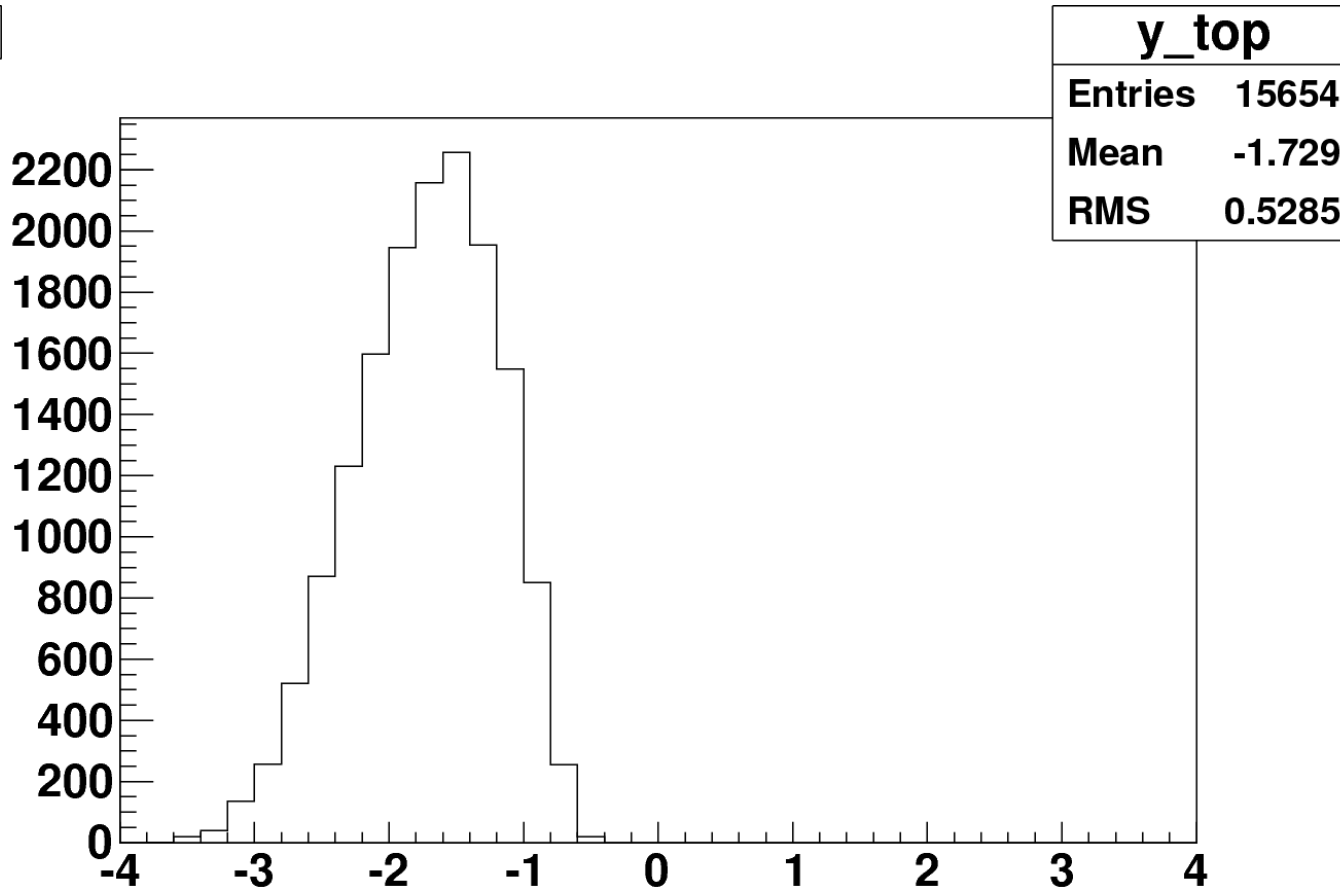
Madgraph LO Cross Section: 9.9 fb

Expect more from photoproduction (not simulated yet)

Top pair production in DIS at LHeC

Rapidity of top

y of t

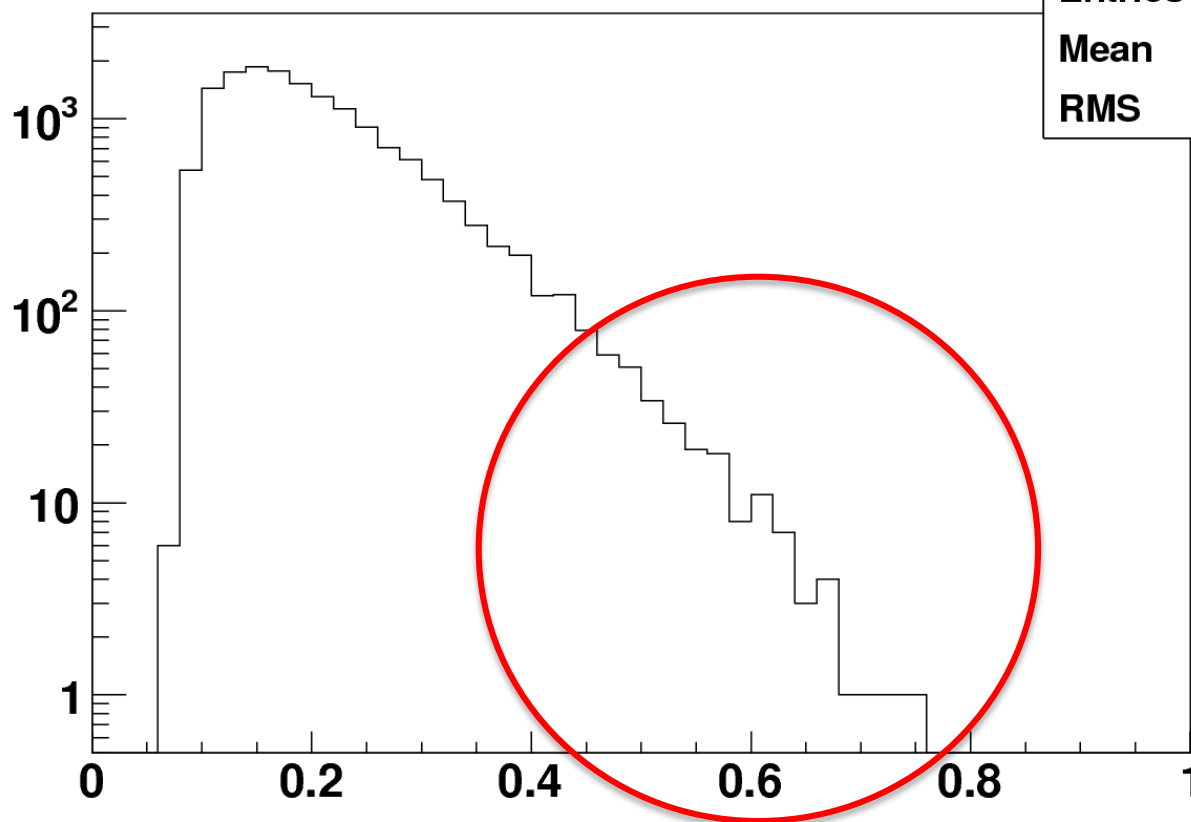


Forward to very forward production

Top pair production in DIS at LHeC

x of gluon

x of parton from proton

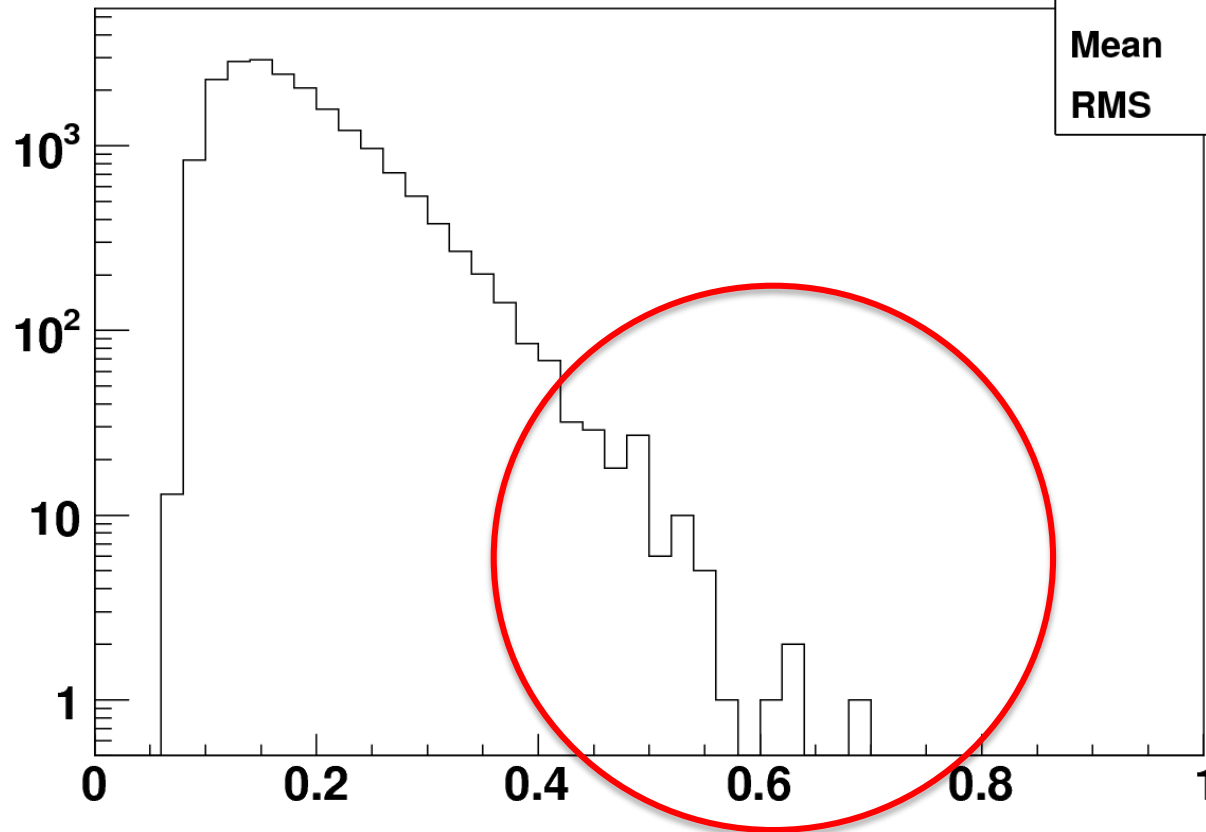


With $L=1000 \text{ fb}^{-1}$ expect some tens of events produced at high $x > 0.5$

Top pair production in DIS at LHeC

x of gluon after final state cuts

x of parton from proton



x2	
Entries	19722
Mean	0.1825
RMS	0.06813

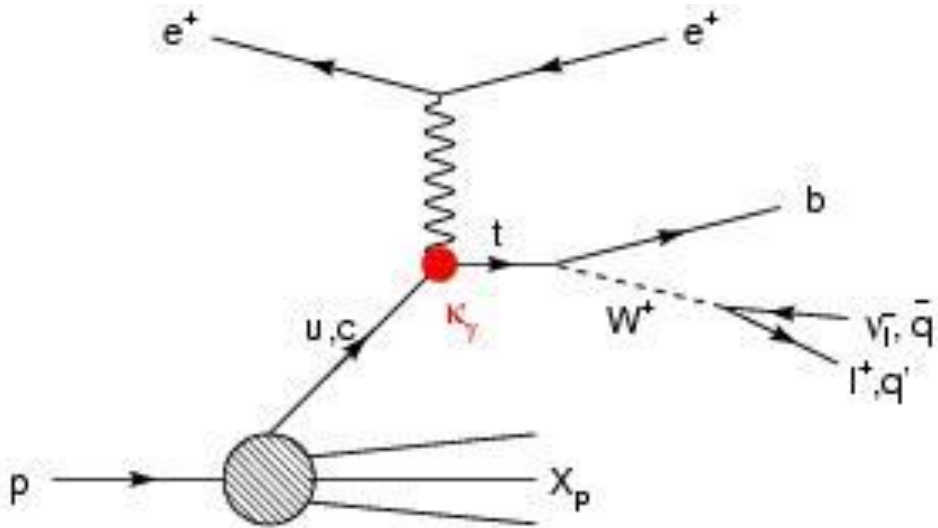
← Corresponds to higher L

t-> blν, t~-> blν
pt(b)>10 GeV,
pt(l)>10 GeV
y(b)<3.0
y(l)<3.0

Total kinematic acceptance ~50%, high x somewhat suppressed

New physics with top at LHeC

FCNC Anomalous Single Top production



- Extremely suppressed in SM
- Potential window to BSM

Study by G. Brandt (LHeC 2008 workshop, Divonne)

Using anotop MC with $K_{uty} = 0.01$:

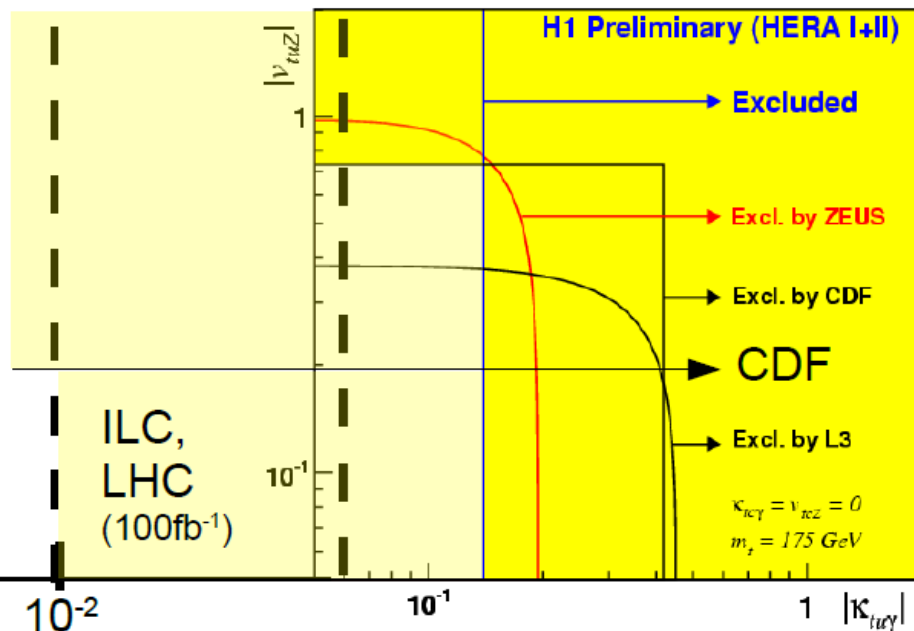
→ Expect for 7 TeV x 70 GeV

LHeC with 1000 fb⁻¹

7600 FCNC top events

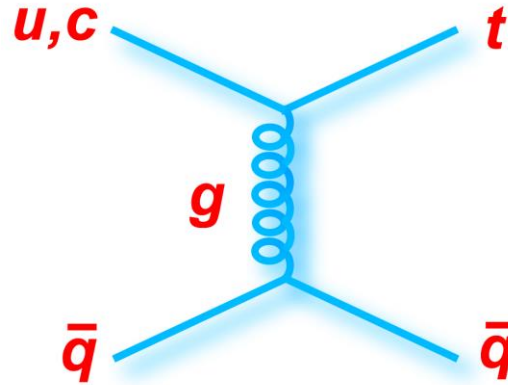
But large *backgrounds* from SM W and CC single top

Better prospects at LHeC-based γp collider mode, see LHeC CDR, p.205



FCNC single top – LHC results (2013)

- **Production studies:**



ATLAS 2.05 fb⁻¹

CERN-PH-EP-2012-032

$$K_{ugt}/\Lambda < 0.0069 \text{ TeV}^{-1}$$

$$K_{cgt}/\Lambda < 0.016 \text{ TeV}^{-1}$$

- **Mostly decay studies:** exploit $BR(t \rightarrow qZ) \sim (K_{tqZ})^2$

The best current limits just starting to probe the $< 10^{-3}$ range:

Kerim Suruliz

Top 2013 workshop:

- $BR(t \rightarrow qZ) < 0.07\%$ at 95% CL (CMS, TOP-12-037, 19.5fb⁻¹ at $\sqrt{s} = 8$ TeV)

- $BR(t \rightarrow cg) < 1.6 \cdot 10^{-4}$ (ATLAS-CONF-2013-063, $\sqrt{s} = 8$ TeV)

- $BR(t \rightarrow cH) < 3.1 \cdot 10^{-3}$ (SUS-13-002; also ATLAS-CONF-2013-063, both $\sqrt{s} = 8$ TeV)

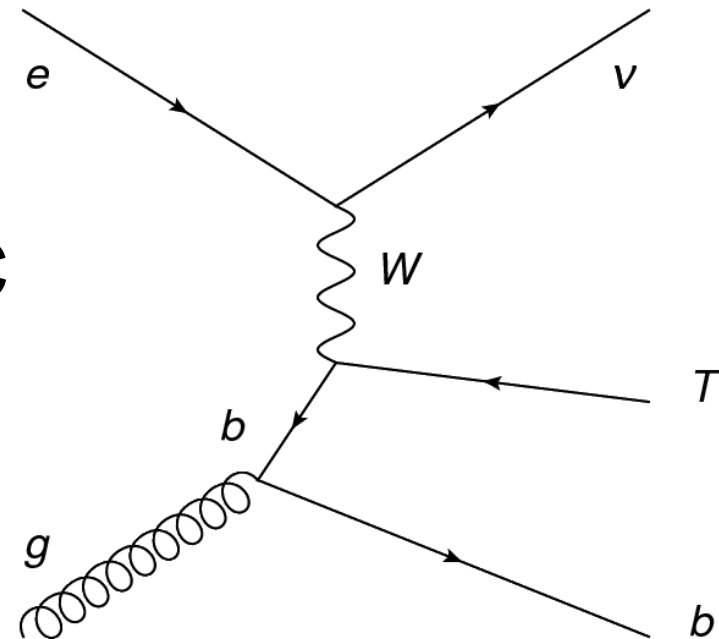
The interesting range is however below this - Randall-Sundrum, 2DHM, (RPV) SUSY and other BSM model values typically expected to be $10^{-5} - 10^{-4}$, or less.

Could LHeC with $\sim 2\text{M}$ top quarks make sensitive decay studies?
 $t \rightarrow qZ$ not enough statistics, but perhaps $t \rightarrow q\gamma$ (to be checked)

Top Partners

J. Ferrando

- Potential top-like BSM:
 - heavy vector-like quarks T arise in many BSM scenarios:
 - extra dimensions, composite Higgs ...
- T decays to Wb , tH , tZ with BR of order unity
- Lower mass limits at the LHC (pair production)
 $M(T)$ 687-782 GeV (arXiv:1311.7667)
- Single production possible at the LHeC



Top Partners : Production

- Try using generic model of Wulzer et al. (arXiv:1211.5663) in Madgraph 5
- 700-800 GeV only a handful of events
- Some freedom in coupling choice (maybe enough for a factor of 4 in cross section)

Mass (GeV)	Cross-section (fb)	BR(T->Wb)	BR(T->tZ)	BR(T->tH)
400	13.3	0.64	0.13	0.23
500	1.85	0.58	0.17	0.25
600	0.277	0.56	0.20	0.24
700	3.91e-02	0.55	0.21	0.24
800	4.7e-03	0.54	0.22	0.23

Top Partners: Signatures

- General signature:
 - Missing transverse momentum + forward b-jet
- tH, tZ and Wb for T decay
- Acceptance should be high so long as selection focusses on T decay products
- Main backgrounds:
 - Single top
 - Single top + Z (0.94 fb) or + H (4.59e-2 fb)

Conclusions on top at LHeC

- Study top production for the first time at an ep collider → is a unique test of the SM
- Single Top production in charged currents: Expect precision measurement of V_{tb}
- Top Pair production in DIS and photoproduction: clean test of proton gluon density at high x (but suffers from rather low statistic)
- In general: sensitive tests of new physics through anomalous production channels/cross sections and decays
- Further studies at detector level needed (including background simulation) for detailed assessment of physics potential.
- Further physics topics not discussed here: e.g. potential for top mass measurement from reconstructed decays or from the threshold behaviour of production (e.g. in pair production in DIS)

Backup slides

Top physics at the

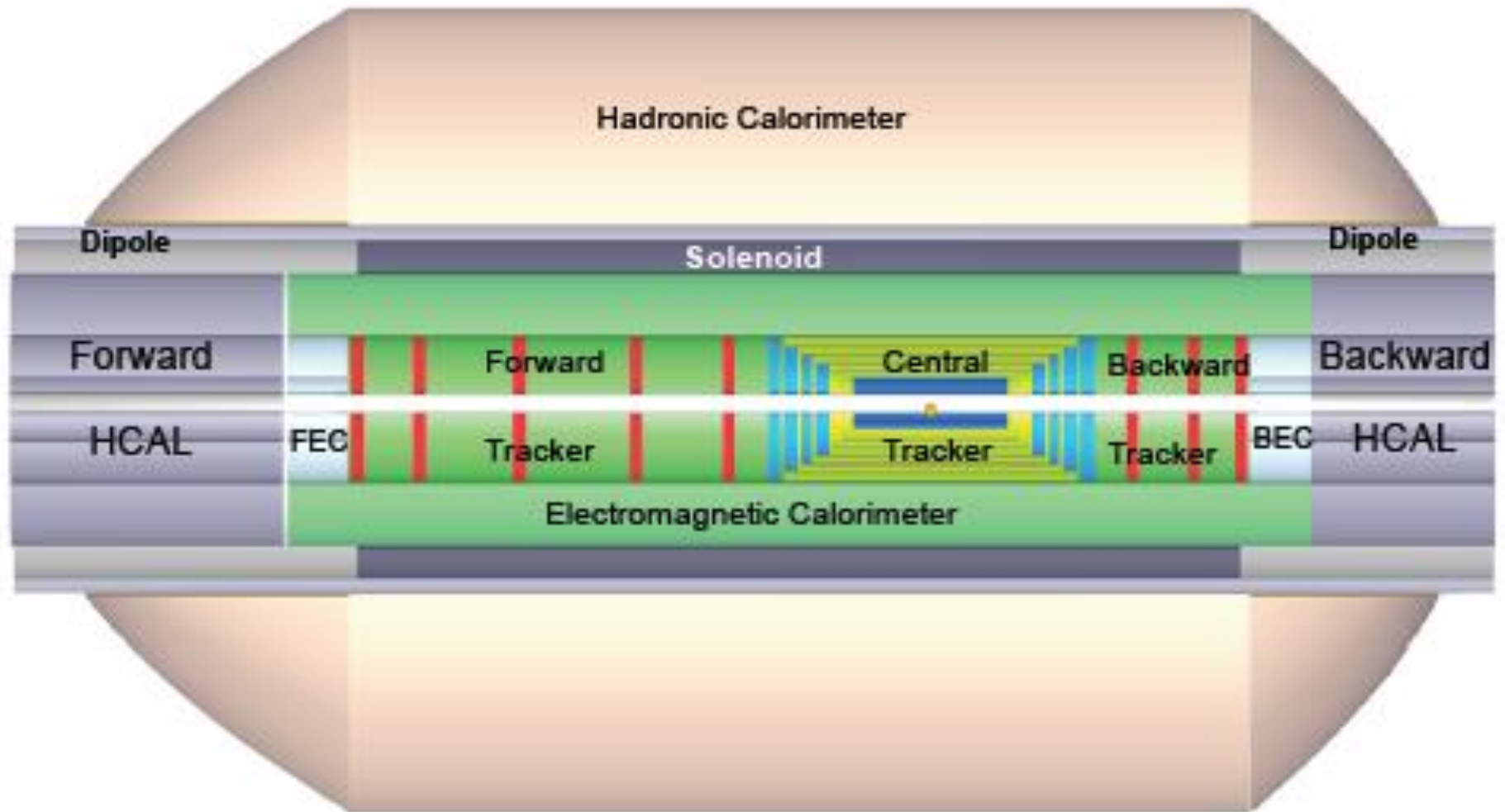


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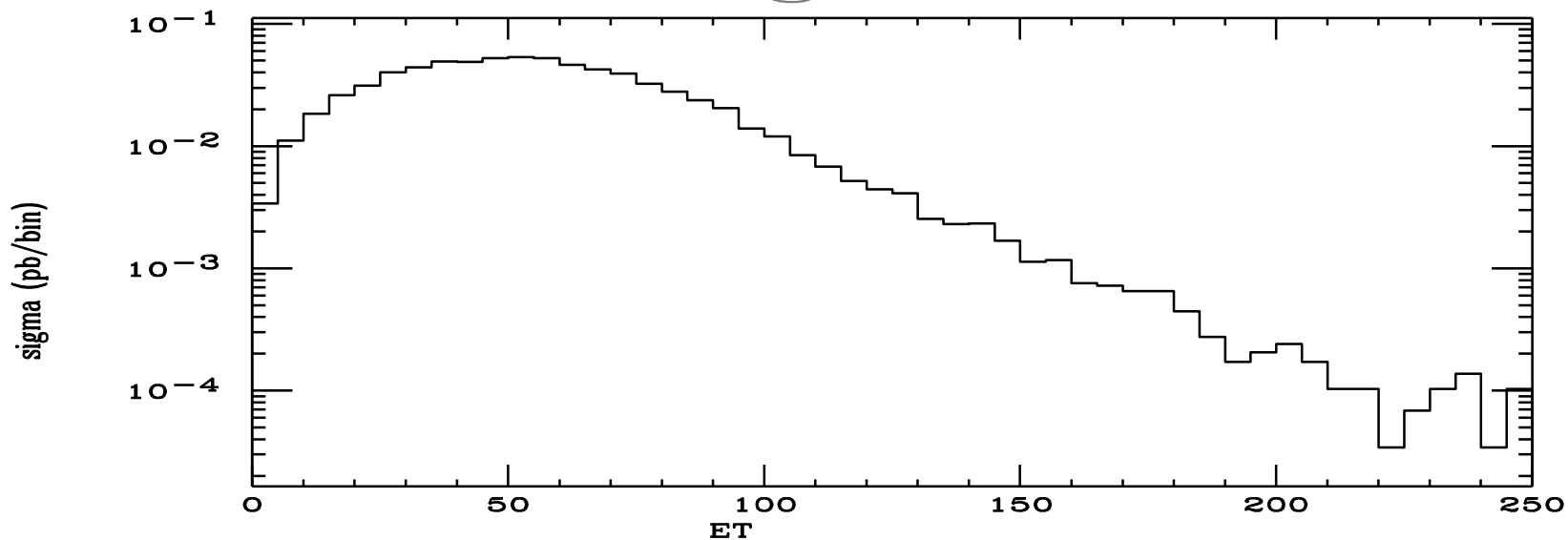
- Single top production $Wb \rightarrow t$, $\gamma b \rightarrow tW$, FCNC $\gamma u \rightarrow t$
- Top pair production $\gamma g \rightarrow t \bar{t}$

The Detector 'that should do it': Ring-Linac scenario



Outer detectors (HAC tailcatcher/muon detectors not shown)
also not shown: forward proton taggers, backward lumi monitors

Missing ET



X-sect = 7.354E-01(pb) AVG = 5.730E+01 RMS = 2.992E+01
Tot # Evts = 21406 Entries = 21402 Undersc = 0 Over