EW Sphalerons: Discussion Points

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Topological Effects in the Standard Model: Instantons, Sphalerons and Beyond at LHC
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Implications

See contribution by **David Ho**

- Critical field strength where sphaleron energy vanishes is

$$B_{\mathrm{crit}}^{(2)} = \frac{m_{\mathrm{H}}^2}{e} \approx 5.2 \times 10^4 \ \mathrm{GeV} \approx 2.7 \times 10^{20} \ \mathrm{T}$$

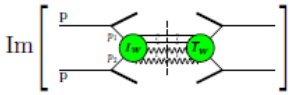
- Magnetic fields in LHC heavy-ion collisions $\sim 1 \ \mathrm{GeV}^2$ and scale linearly with energy, so $\sqrt{s} \sim 10^5 \ \mathrm{TeV}$ required.
- 10 TeV Pb-Pb collisions lower sphaleron energy by $\sim 0.1\%$.
- Unsuppressed sphaleron production due to magnetic fields not feasible in forseeable future.
- Potential cosmological/astrophysical sources:
  - Superconducting cosmic strings
  - Magnetically charged black holes
  - Inflation produced large scale magnetic fields

Contribution by
Kazuki Sakurai

- **Theoretical prediction for cross-sections is largely unknown..**

- **Optical theorem**

  [Khoze, Ringwald '91], ...



- **Semi-Classical method**

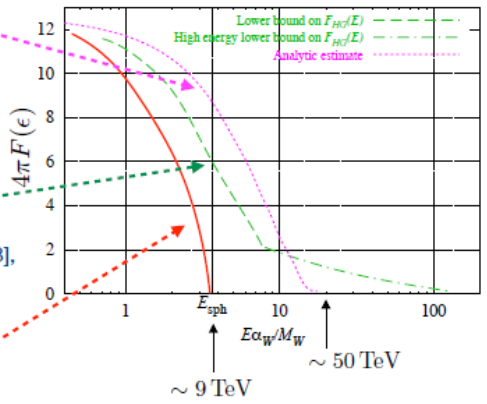
  [Bezrukov, Levkov, Rebbi, Rubakov, Tinyakov '03],

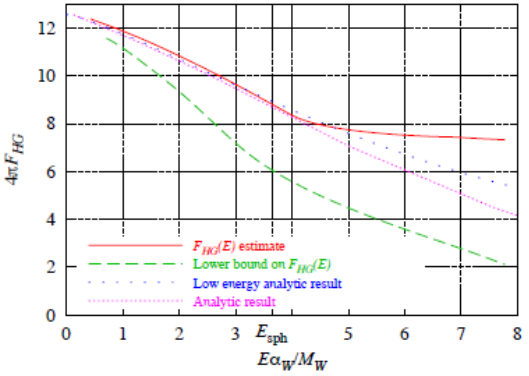
  [Rubakov, Tinyakov '92], ...

- **Treating N_{CS} as a dynamical variable**

  [Tye, Wong '15 '16]

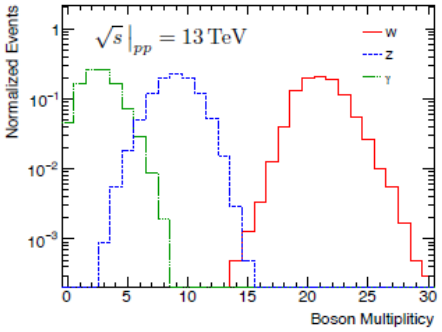
[Bezrukov, Levkov, Rebbi, Rubakov, Tinyakov '03]





- **Boson multiplicities in the final state?**

  - LO instanton PT predicts large multiplicity of EW bosons.
  - This estimate is valid only for E << 10 TeV, what do we expect for E > 10 TeV?
  - Important to understand the experimental signatures: CMS sphaleron search assumes only fermion productions.



- **Any effect from BSM physics?**
- **Where should be looked at? Colliders, Cosmic rays, ..**
- **If observed, how are we sure if it is instanton/sphaleron? Sphaleron vs BH?**

Contribution by **Gia Dvali**

1) Production of multi particle states in 2 to n collisions is exponentially suppressed at weak coupling. Unless the state saturates entropy bounds. This happens at critical collective and ' t Hooft couplings:

$$\lambda_c \equiv \alpha n = 1, \qquad \lambda_t \equiv \alpha N = 1$$

at this point n- particle state (saturon) saturates unitarity.

The cross section at optimal truncation:

$$\sigma = \bullet \; f(\lambda_t)^{\frac{1}{\alpha}}$$

$\hookrightarrow = 1$ for $\lambda_t \sim 1$

2) Saturons behave as black holes:

$$S = ER = \frac{1}{\alpha} = (Rf)^2$$

3) Beyond the saturation point a renormalizable asymptotically free theory must either hit a fixed point or generate a mass gap: Either confine or enter the Higgs phase.

4) If theory is not asymptotically free or perturbatively hits a strong coupling, it can UV-complete by classicalization.

5) In QCD confinement is correlated with the saturation of entropy bound by instanton, and by multi- gluon states. It therefore appears to be a self-defense against violation of entropy bounnd and unitarity by colored states.

Further general discussion points

1. Theory uncertainty on SM xsec
   - "Holy grail" function
2. Model dependence on BSM xsec and possible final states

   See, e.g. Cerdeño, Reimitz, Sakurai, Tamarit [1801.03492]
   - EFT treatment/Heavy particle (non-)decoupling
   - New chiral gauge U(1)' models, e.g. baryon or lepton number
   - Also related: Possible axion effect on instanton rates (P. Schwaller)
3. Higher energy colliders or other synergistic experiments?