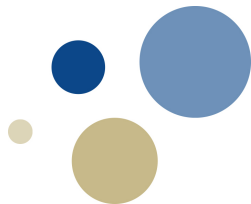




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Kunnskap for en bedre verden



Electroweak bremsstrahlung effects on Dark Matter abundance

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Overview



About me

Groundwork

Dark matter indirect search

- Neutralino
- Accompanied bremsstrahlung processes

Electroweak bremsstrahlung

- Quark pair production

Summary

About me

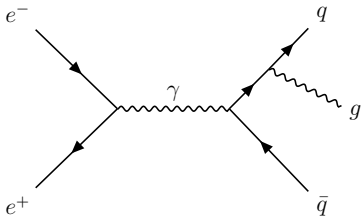
- Originally from Oslo, Norway
- Currently enrolled in a Master program in Physics
- Norwegian University of Science and Technology (NTNU) in Trondheim
- Supervisor: Prof. Michael Kachelrieß (NTNU)



Figure: Trondheim

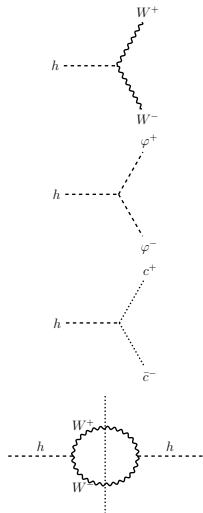
Starting Point

- QCD: Quark pair production, gluon emission
- IR divergencies
- Kinoshita-Lee-Nauenberg (KLN) theorem
- Go to the massive case ↓



Intermezzo: $h \rightarrow W^+W^-$

- Different approaches:
 - i) Unitary gauge
 - ii) Feynman-'t Hooft gauge — additional Goldstone bosons, ghosts
 - iii) Using Goldstone boson equivalence theorem (GBET) — additional Goldstone bosons
 - iv) Cutkosky cut of charged boson loop
- Pedagogical paper



Dark Matter I



- Indirect search for Dark Matter (DM)
- Popular DM candidate: Neutralino
 - Lightest SUSY particle in the MSSM
 - Majorana spin-1/2 particle
- DM annihilation (exclusively) into SM particles

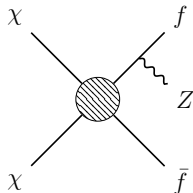
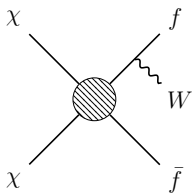
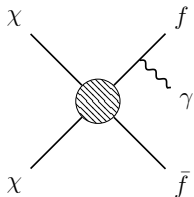
$$\chi + \chi \rightarrow f + \bar{f}, \dots \quad (1)$$

- Helicity suppression

Dark Matter II

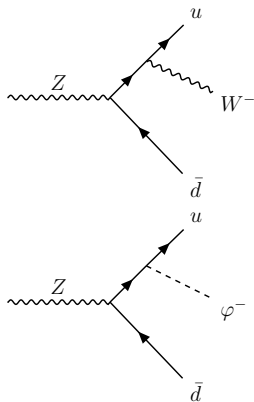


- Bremsstrahlung processes
 - Photon bremsstrahlung
 - W/Z bremsstrahlung
- Decay of W/Z leads to photon, lepton and/or hadron production



Electroweak bremsstrahlung I

- Consider s-channel fermion pair production
 - Initial and final state factorizes
- Include bremsstrahlung diagrams
- Assume $m_\chi \gg m_W, m_Z$
- Goldstone boson equivalence theorem



Electroweak bremsstrahlung II



- Large logarithms $\sim \ln^2(m_\chi^2/m_W^2)$ in total cross sections
- Compare with gluon emission
- Bremsstrahlung processes: significant annihilation channels
- Constrain DM particle properties

Summary



- Majorana Dark Matter particle (e.g. neutralino)
- Annihilation into SM particles
- Electroweak bremsstrahlung
- Large logarithms
- DM particle constraints

Bibliography



Nicole F. Bell et al. “Dark Matter Annihilation Signatures from Electroweak Bremsstrahlung”. In: *Phys. Rev. D* 84 (2011), p. 103517. DOI: 10.1103/PhysRevD.84.103517. arXiv: 1101.3357 [hep-ph].



Nicole F. Bell et al. “W/Z Bremsstrahlung as the Dominant Annihilation Channel for Dark Matter, Revisited”. In: *Phys. Lett. B* 706 (2011), pp. 6–12. DOI: 10.1016/j.physletb.2011.10.057. arXiv: 1104.3823 [hep-ph].



Gerard Jungman, Marc Kamionkowski, and Kim Griest. “Supersymmetric dark matter”. In: *Phys. Rept.* 267 (1996), pp. 195–373. DOI: 10.1016/0370-1573(95)00058-5. arXiv: hep-ph/9506380 [hep-ph].



Jorge C. Romao and Joao P. Silva. “A resource for signs and Feynman diagrams of the Standard Model”. In: *Int. J. Mod. Phys. A* 27 (2012), p. 1230025. DOI: 10.1142/S0217751X12300256. arXiv: 1209.6213 [hep-ph].