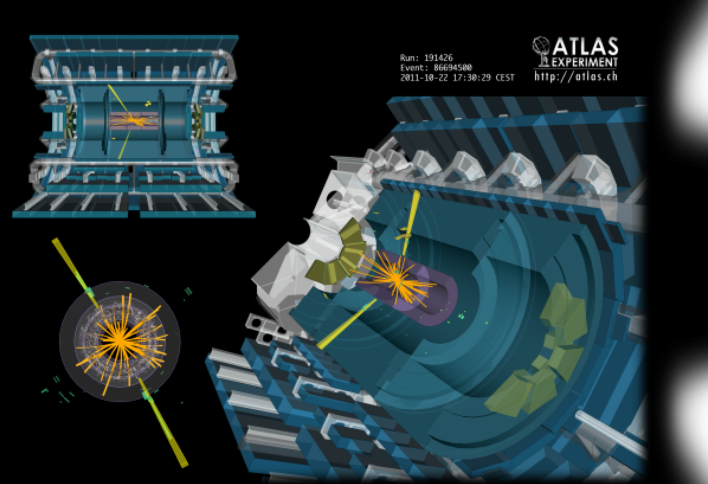
Isolated Photons at NNLO QCD accuracy

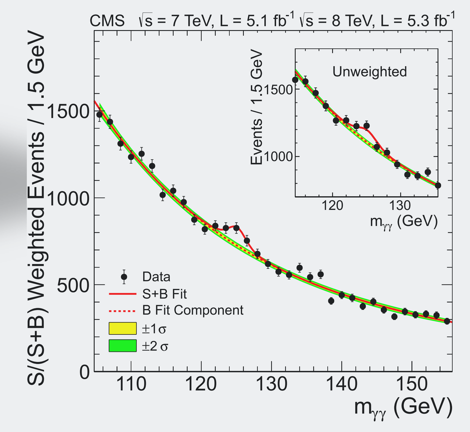
Xuan Chen, Thomas Gehrmann, Marius Höfer, Robin Schürmann

University of Zurich[UZH]

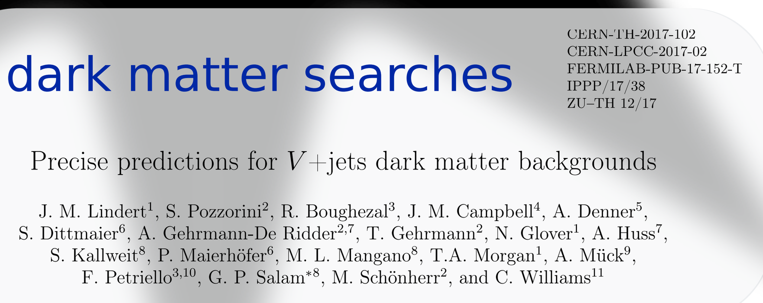
Photons at the LHC



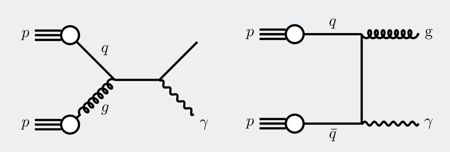
Higgs discovery channel



dark matter searches


Precise predictions for V+jets dark matter backgrounds

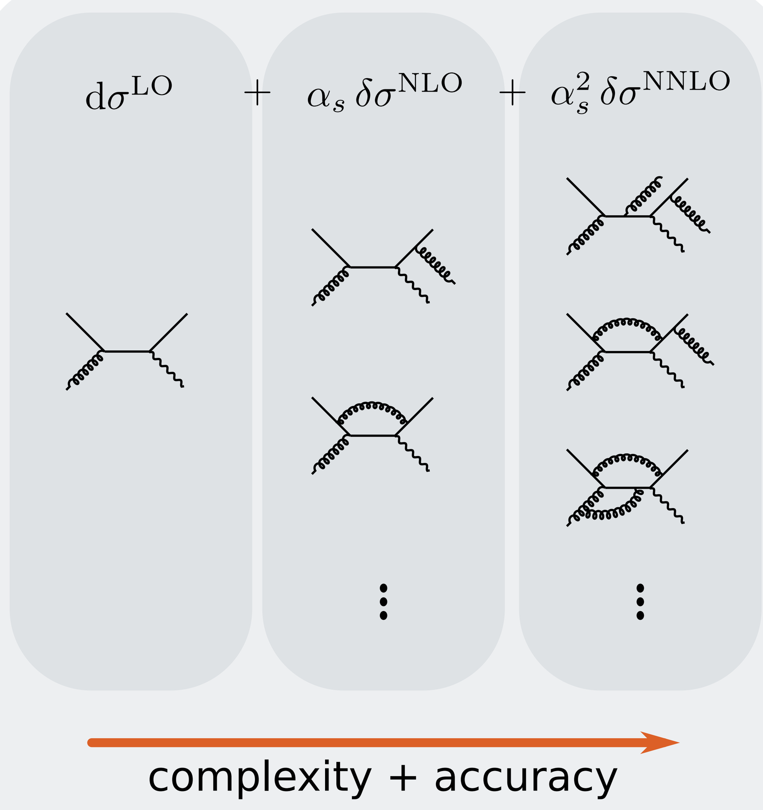
proton substructure



Fixed order calculations

Particle physics is a permanent interplay between experiment and theory. As the experimental uncertainties shrink, the accuracy of theory calculations has to increase. The calculations can be organised as a perturbative expansion in the coupling α_s. The more orders we include, the more accurate the result will be, but the calculation will also become more and more complex.

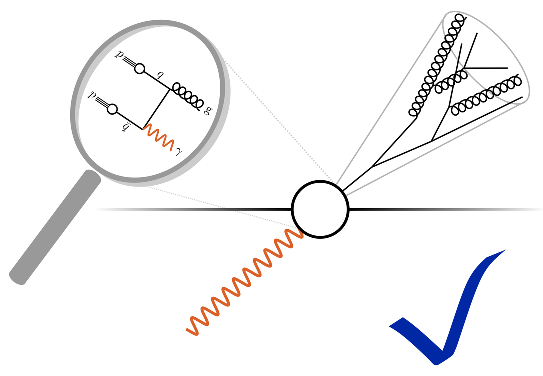
$$d\sigma^{LO} + \alpha_s\,\delta\sigma^{NLO} + \alpha_s^2\,\delta\sigma^{NNLO}$$



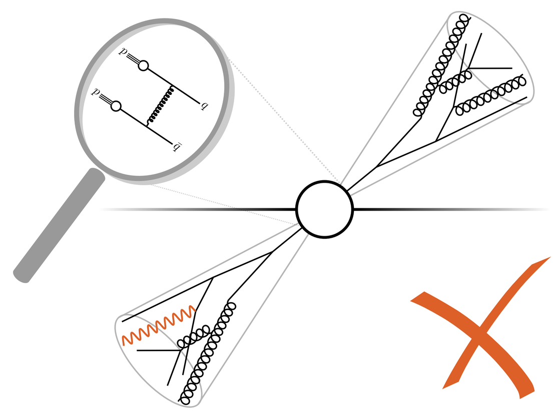
What *is* a Photon at a collider?

Hadron-collisons are complicated processes and in general many photons are produced. We have to come up with a way to distinguish the photons from the core of the interaction, the hard scattering of elementary particles, from photons of different origin:

Photons from hard process



Photons of different origin



Idea:
measure hadronic activity close to the photon

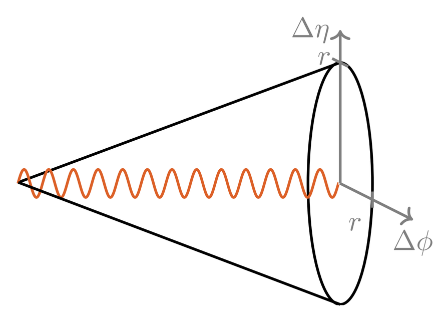
Compare transverse energies of photon candidate and surrounding hadrons. Set a upper limit:

$$E_T^{had} \le E_T^{max}(p_T^\gamma)$$

Define a distance from the photon candidate:

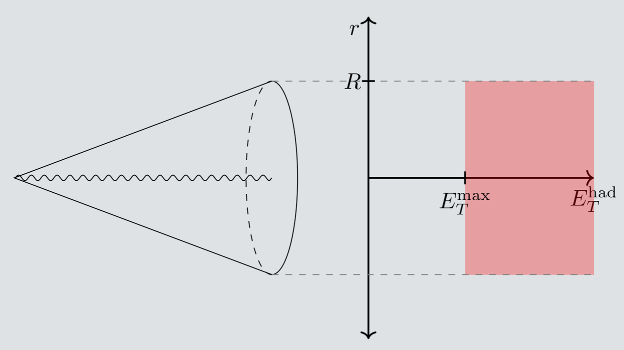
$$r = \sqrt{\Delta\eta^2 + \Delta\phi^2}$$

This describes a cone around the photon direction:



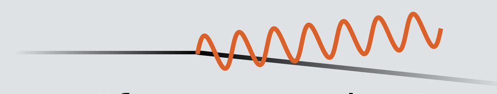
Cone based isolations

fixed cone



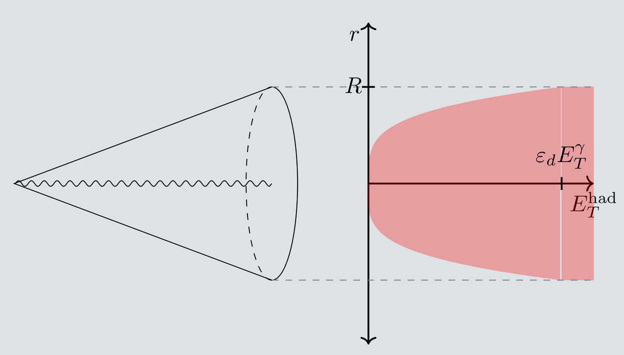
$$E_T^{had} \le E_T^{max}(p_T^\gamma) = \epsilon p_T^\gamma + E_T^{thres}$$

- conceptually simple
- applicable in experiment
- theoretically challenging:

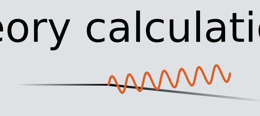


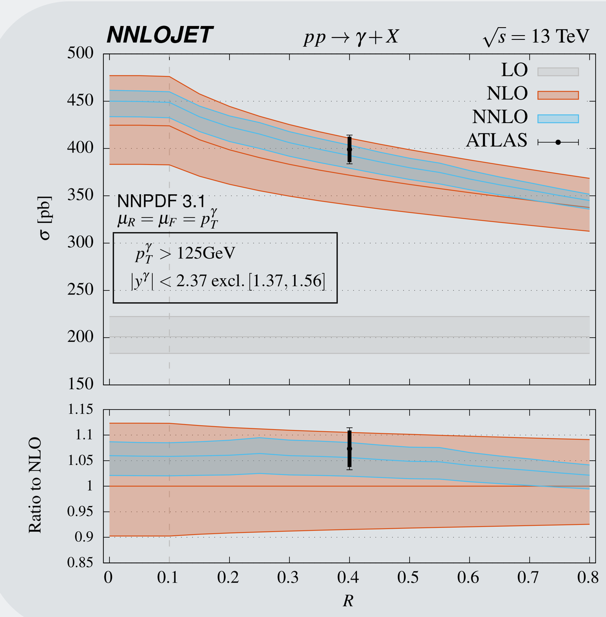
"fragmentation"

dynamical cone

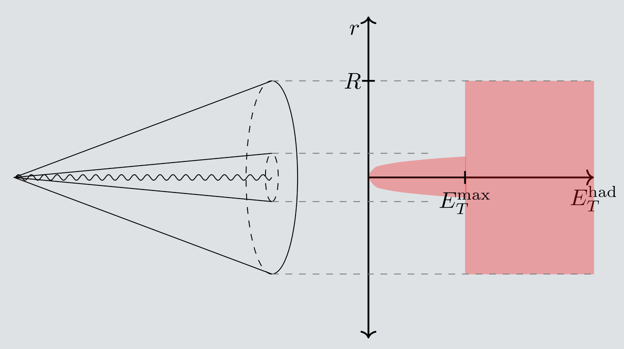


$$E_T^{had} \le E_T^{max}(p_T^\gamma, r) = \epsilon p_T^\gamma \left(\frac{1-\cos r}{1-\cos R}\right)^n \quad \forall r \le R$$

- simplifies theory calculation: takes care of 
- cannot be implemented in experiment
- parameters can be tuned



hybrid cone



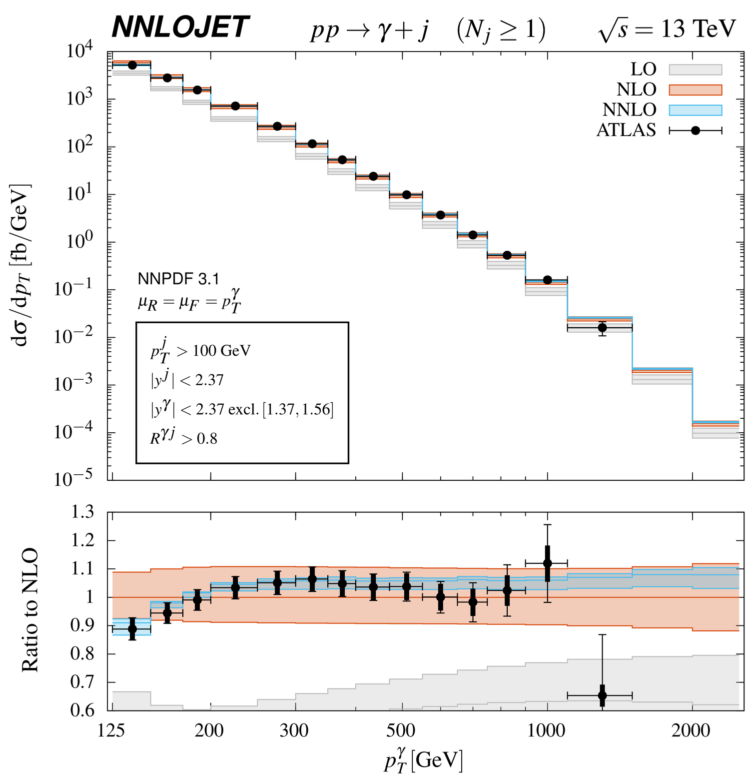
fixed + dynamical cone

- dyn. cone: takes care of 
- fix. cone: mimic experiment
- dependence on isolation parameters can be studied

Differential distributions

To understand more about the underlying dynamics we look at differential distributions. They tell us how the cross-section of the process changes as a function of certain observables, here for example the transverse energy of the photon, p_T^γ:

$$\frac{d\sigma}{dp_T^\gamma} = \frac{d\sigma^{LO}}{dp_T^\gamma} + \alpha_s \frac{\delta\sigma^{NLO}}{dp_T^\gamma} + \alpha_s^2 \frac{\delta\sigma^{NNLO}}{dp_T^\gamma}$$



Summary

- photons are important for many aspects of collider physics
- higher order calculations are needed to increase accuracy
- the definition of a photon in the collider environment is non-trivial and requires a photon-isolation prescription

- X. Chen, T. Gehrmann, N. Glover, M. Höfer, A. Huss - **Isolated photon and photon+jet production at NNLO QCD accuracy** - arXiv:1904:01044
- X. Chen, T. Gehrmann, N. Glover, M. Höfer, A. Huss - **Isolated photon and photon+jet production at NNLO QCD accuracy and the ratio $R^\gamma_{13/8}$** - Moriond Proceedings - arXiv:1905.08577