NLO QCD with Massive Quarks

An extension of the NSC subtraction scheme

Bachelor Degree in Physics

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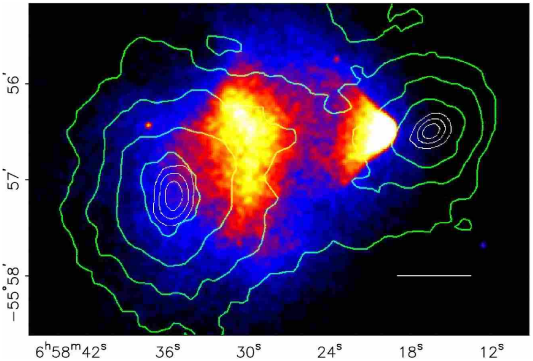
Precision estimates at the LHC

Evidence for Beyond-Standard-Model physics



Main BSM evidence

- dark matter and dark energy
- matter-antimatter asymmetry
- neutrino masses

Figure from Clowe et al. 2006.
Offset between the observed baryonic mass distribution and the gravitational potential in the Bullet Cluster (1E 0657-56).

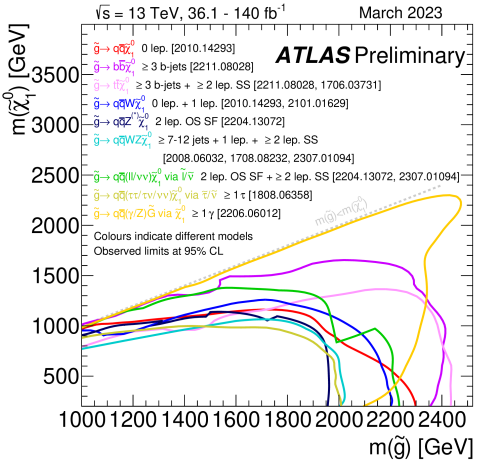
Precision estimates at the LHC

BSM constraints and shift in research paradigm

Main BSM proposals

- supersymmetric models (MSSM, ...)
- dark matter models (WIMPs, axions, ...)
- extended gauge sectors (SO(10), ...)
- SM Effective Field Theory (SMEFT)

Figure from ATLA PUB Note 2023–025. Exclusion limits in the $\tilde{g} - \tilde{\chi}_1^0$ mass plane for various models for the decay of the gluino to the lightest supersymmetric particle.



Precision estimates at the LHC

Factorization theorem and perturbative QCD

factorization theorem and perturbative expansion of $\mathrm{d}\hat{\sigma}_{a,b}$

IR-pole structure of QCD

Radiative correction to partonic processes

real and virtual corrections

IR-pole structure of QCD

Dimensional Regularization of IR singularities

soft and collinear singularities (in CDR, show in real corrections)

IR-pole structure of QCD

Subtraction schemes

subtraction scheme to regulate divergences

NSC subtraction scheme

Extraction of poles via operators

introduce the NSC SS

NSC subtraction scheme

Pole cancellation

briefly show pole cancellation in the NSC SS

NSC SS with massive quarks

Mass-regualtion of soft and collinear limits

explain why massive quarks change $I_{\mathsf{S}}(\epsilon)$ and $I_{\mathsf{V}}(\epsilon)$, but not $I_{\mathsf{C}}(\epsilon)$

NSC SS with massive quarks

Generalized soft operator

show how $I_S(\epsilon)$ changes (in particular massive angular integrals)

NSC SS with massive quarks

Generalized virtual operator

show how $I_V(\epsilon)$ changes (in particular, colour-correlated ϵ^{-2}-poles in $\mathcal{V}_{i,j}(\epsilon)$ coefficients)

NSC SS with massive quarks

Pole cancellation: generalized pole terms

highlights of pole cancellation in $I_{\mathrm{S+V}}(\epsilon)$, define $\chi_{i,j}(\epsilon)$ coefficients and explain their property

NSC SS with massive quarks

Pole cancellation: colour-correlated terms

show pole cancellation in the colour-correlated sum of $I_{\mathsf{S+V}}(\epsilon)$, leaving the same (and opposite) pole terms of $I_{\mathsf{C}}(\epsilon)$

NSC SS with massive quarks

Generalized integrated counterterms

show integrated counterterms and highlighting massive logs

Conclusions

Future developments

draw conclusions and point out possible further developments