Polarized Electroweak Boson Scattering at Very High Energies

Snowmass on the Zoom-issippi: EF04 Group Meeting

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[1] on behalf of many collaborators

the Lol's big question

Question: How does the electroweak theory behave at very high energies?

Letter of Interest: EW effects in very high-energy phenomena

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to be submitted to the Theory Frontier (TF07) and Energy Frontier (EF04)

1 Introduction

Phenomena that take place at multi-TeV scales — high-energy elementary particle scattering or the annihilation/decay of ultra heavy states such as dark matter particles — can give rise to relativistic, final states that are naturally accompanied by additional radiation, that in turn leads to particle showers and final states with large particle multiplicities. In the the Standard Model, the effects of QCD and QED radiation are well understood and treated at various level of sophistication. These range from fixed-order computations at an increasing accuracy to resummed computations via parton showering algorithms and semi-analytic approaches. Even matching/merging between the two while keeping their respective accuracies is available.

In such multi-TeV scales processes typical momentum transfers Q are much larger than the electroweak (EW) scale $m \sim m_Z$, and intial- and final-state EW radiation becomes important. In particular, EW boson emission gives rise to transition rates that grow with logarithms of the type $\log Q/m$. For sufficiently large Q, these logarithms must be resummed in order to recover physically meaningful results. Despite recent progress, a fully exclusive approach that can take care of fixed-order EW corrections, resum large EW logarithms in both inital and final states, systematically account for power corrections, and is implemented in ready-to-use Monte Carlo

Snowmass 21 LoI: SNOWMASS21-TF7_TF0-EF4_EF0-026

Many *fascinating* ways to explore this, e.g., EW parton showers and PDFs

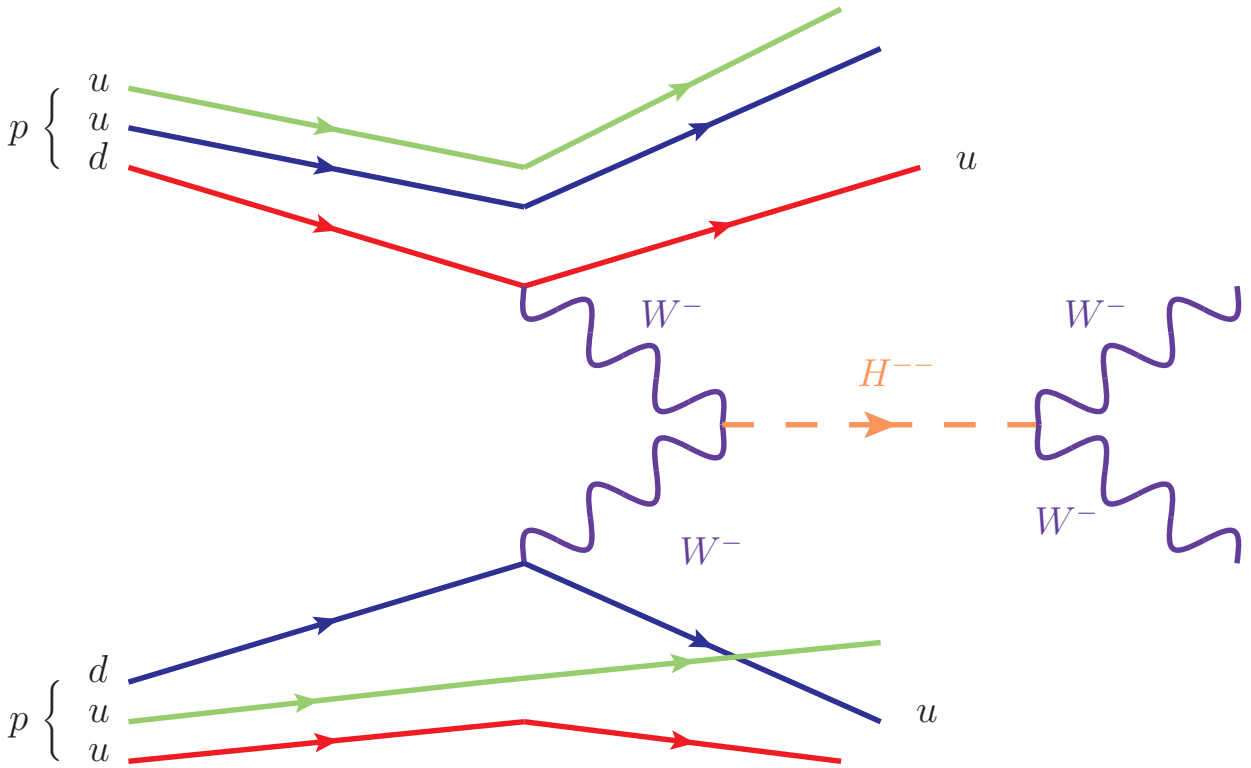
see Keping Xie's talk next!

- One focus: polarized EW boson scattering (in three parts)

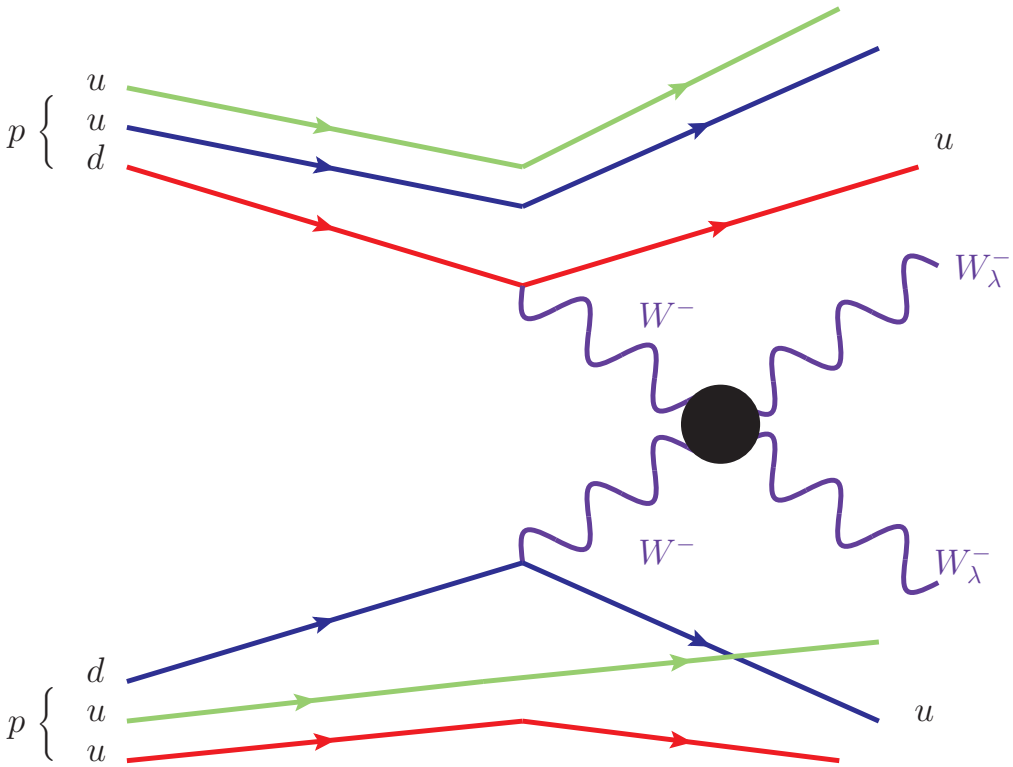
Polarized Electroweak Boson Scattering at High Energies

Why?

- Polarization measurements test $V \pm A$ (chiral) structure in (B)SM
- Polarization and VBS test gauge+unitarity structure in (B)SM
- VBS/VBF is just super cooooool!
- High-energy VBS explores EW symmetry in massless limit

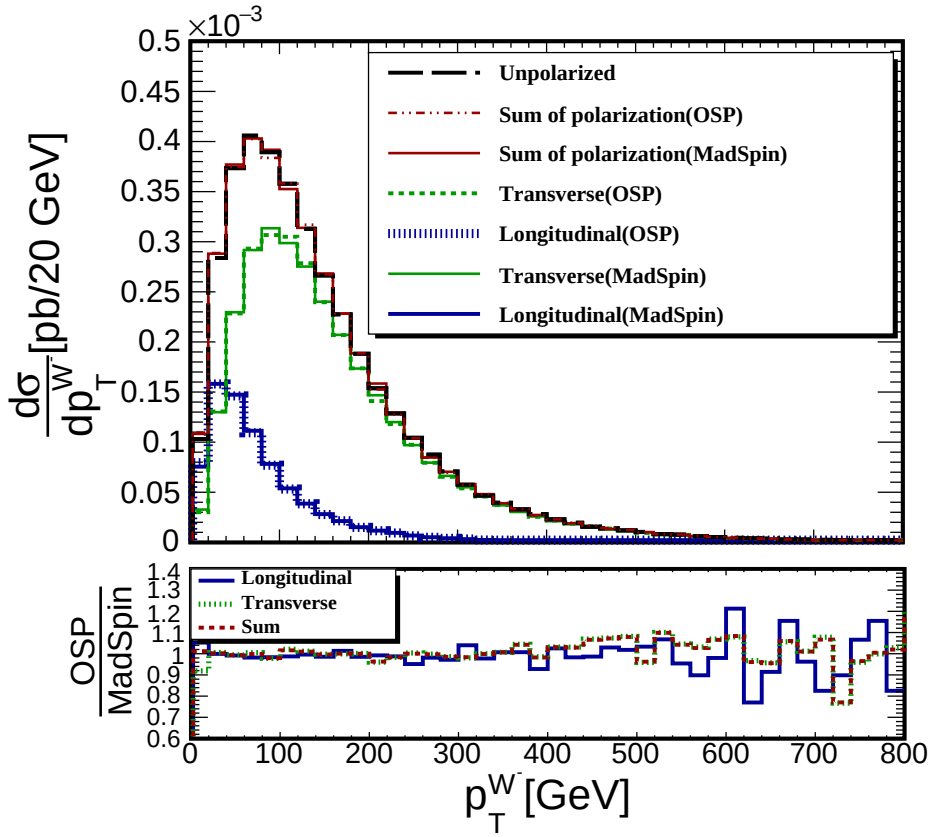


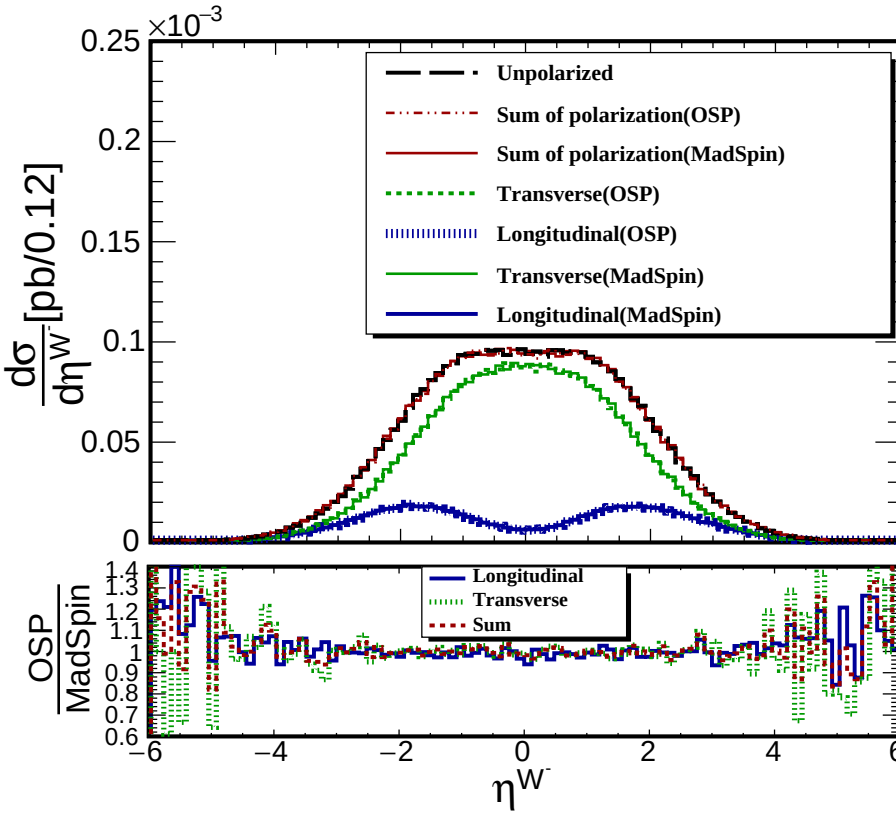
Part I: Automated predictions from polarized matrix elements (Polarized Matrix Elements from `MadGraph5`)[2]



[2] w/ D. Buarque Franzosi, O. Mattelaer, S. Shil [1912.01725]

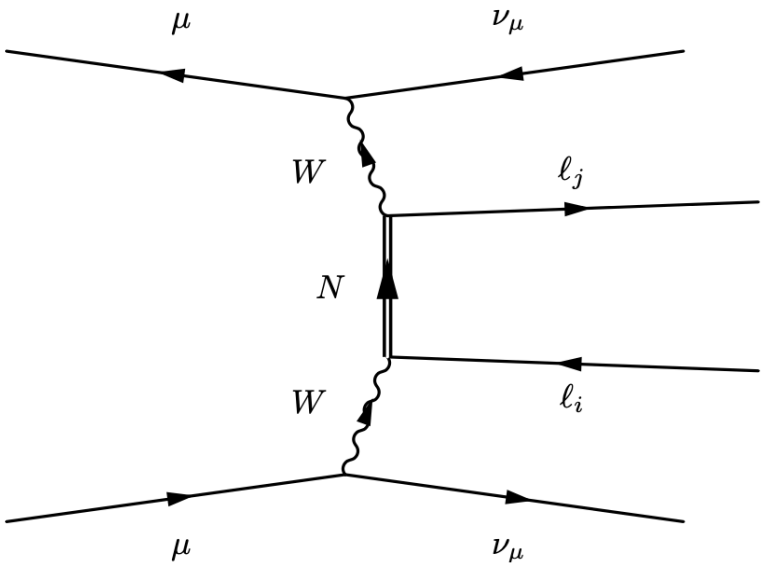
Generating helicity-polarized events at LO with the Monte Carlo event generator MadGraph5 is as easy as simulating unpolarized processes

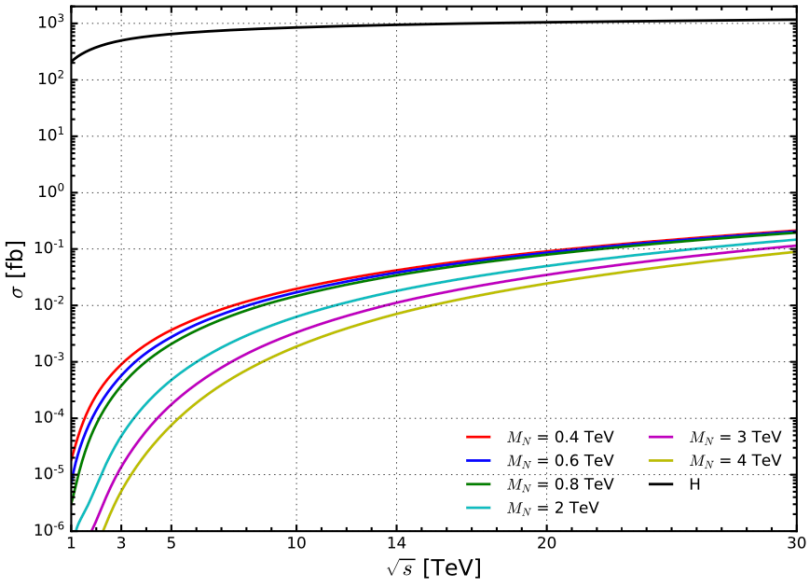




- Just be careful to set which frame the polarizations are defined

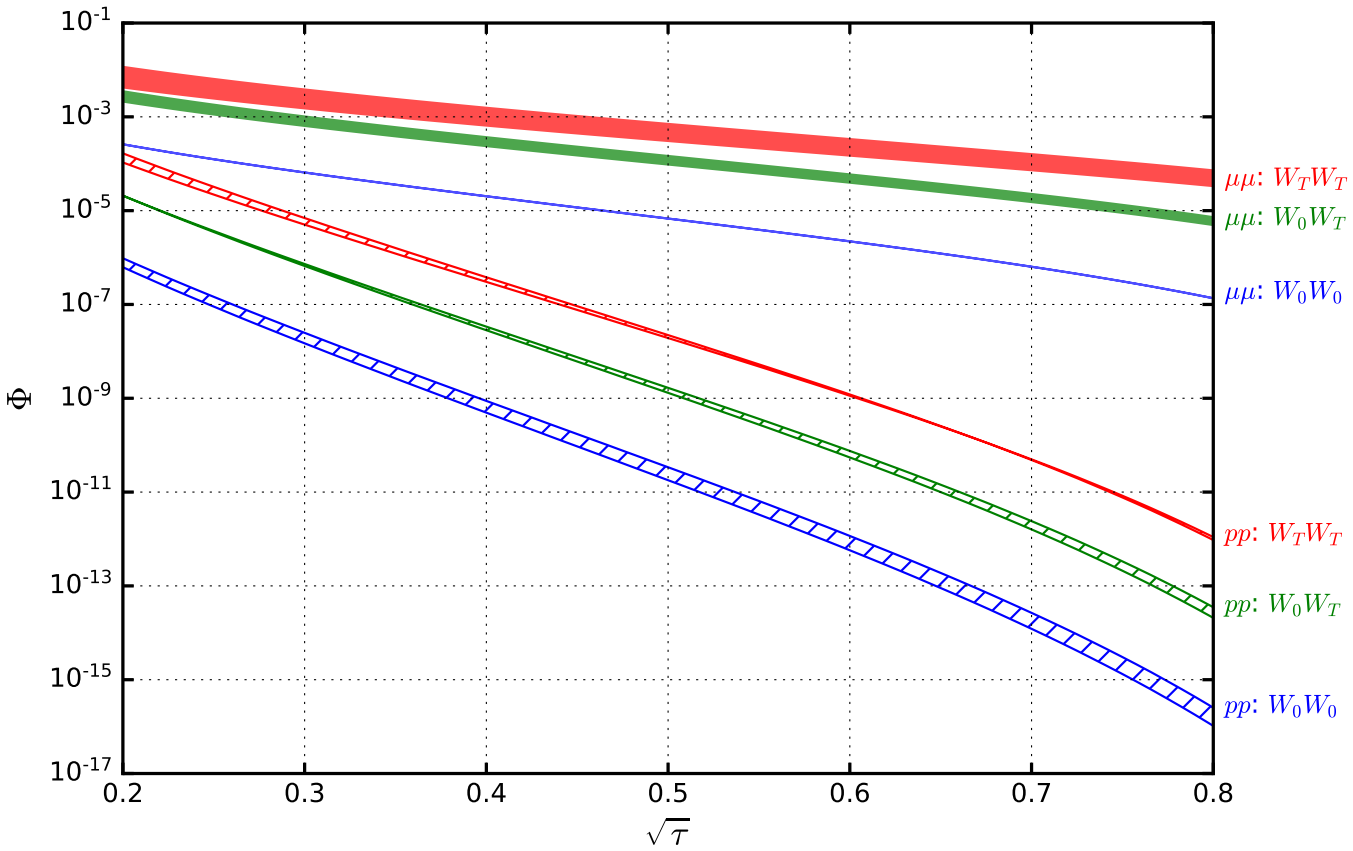
Part II: Exploring VBF with multi-TeV muon colliders[3]



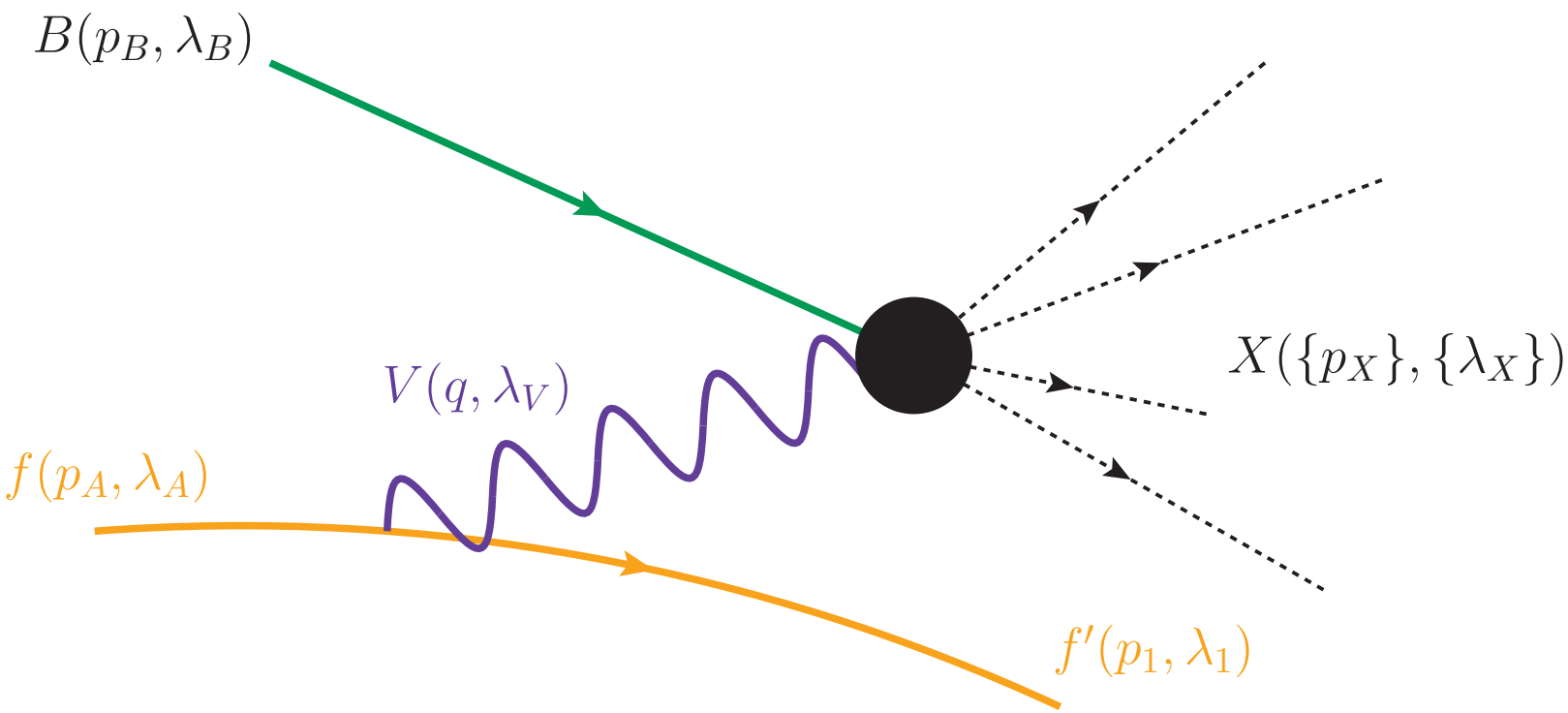


[3] w/ A. Costantini, F. De Lillo, F. Maltoni, L. Mantani, O. Mattelaer, X. Zhao [2005.10289]

LOTS of results, but notworthy that $W_\lambda W_{\lambda'}$ parton luminosities (Φ) at a $\mu^+\mu^-$ can exceed those of pp collider



Part III: Automated Predictions for the Effective Vector Boson Approximation[4]



[4] w/ A. Costantini, F. Maltoni, O. Mattelaer, et al [soon]

At very high scales $Q \gg M_W, M_Z$, EW bosons can be treated as partons

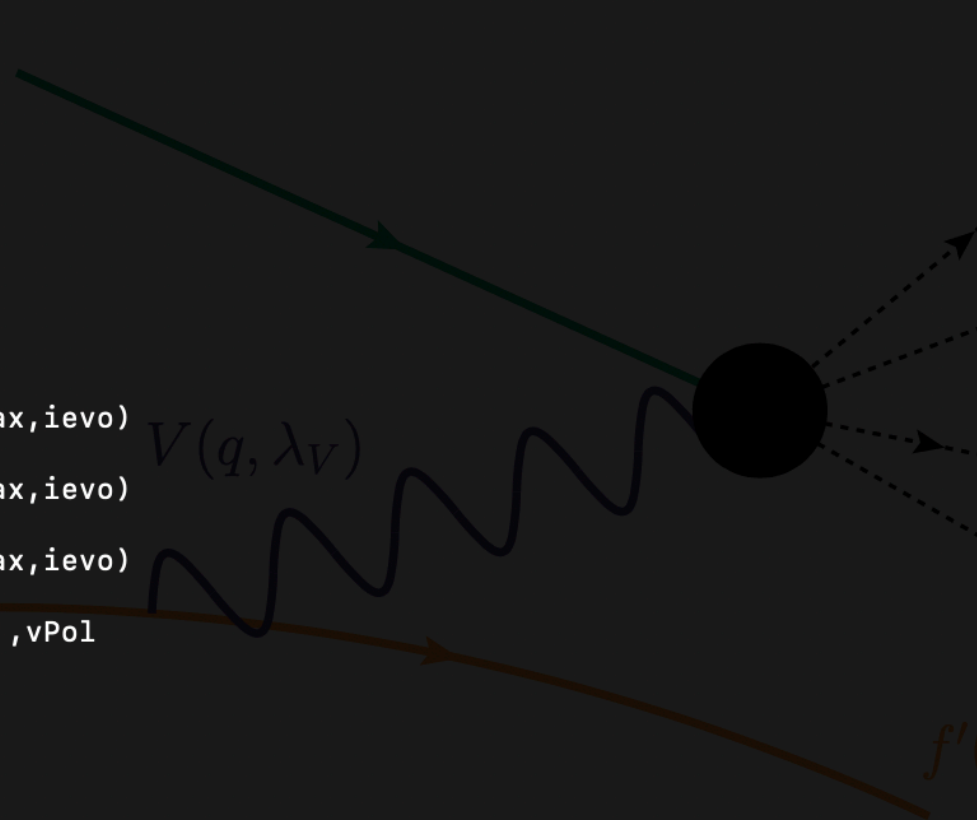
a.k.a. the Effective W Approximation [Dawson('85); Kane, et al ('84); Kunszt and Soper ('88)]

- W/Z PDFs will be available very soon in MadGraph5

```
real*8 function eva_get_pdf_by_PID_evo(vPID,fPID,vpol,fLpol,x,q2max,ievo)
implicit none
integer vPID,fPID,vpol,ievo
real*8 fLpol,x,q2max
real*8 eva_fX_to_vm,eva_fX_to_v0,eva_fX_to_vp

real*8 gg2,gL2,gR2,mv2,tmpPDF
call eva_get_mv2_by_PID(mv2,vPID)
call eva_get_gg2_by_PID(gg2,vPID)
call eva_get_gR2_by_PID(gR2,vPID,fPID)
call eva_get_gL2_by_PID(gL2,vPID,fPID)

select case (vpol)
case (-1)
   tmpPDF = eva_fX_to_vm(gg2,gL2,gR2,fLpol,mv2,x,q2max,ievo)
case (0)
   tmpPDF = eva_fX_to_v0(gg2,gL2,gR2,fLpol,mv2,x,q2max,ievo)
case (+1)
   tmpPDF = eva_fX_to_vp(gg2,gL2,gR2,fLpol,mv2,x,q2max,ievo)
case default
   write(*,*) 'vPol out of range; should not be here',vPol
   tmpPDF = 0d0
end select
eva_get_pdf_by_PID_evo = tmpPDF
return
end
```



How the EW theory behaves at very high energies is being explored!

- Exploring polarized matrix elements with `MadGraph5`

  w/ D. Buarque Franzosi, O. Mattelaer, S. Shil [1912.01725]

- Exploring EW VBF with multi-TeV muon colliders

  w/ A. Costantini, F. De Lillo, F. Maltoni, L. Mantani, O. Mattelaer, X. Zhao [2005.10289]

- Exploring the Effective W/Z Approximation with `MadGraph5`

  w/ A. Costantini, F. Maltoni, O. Mattelaer, et al [soon!]

Thank you.