Constraining Z’ widths from p_T measurements in Drell-Yan processes

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Beyond Standard Model (BSM) physics at the LHC:

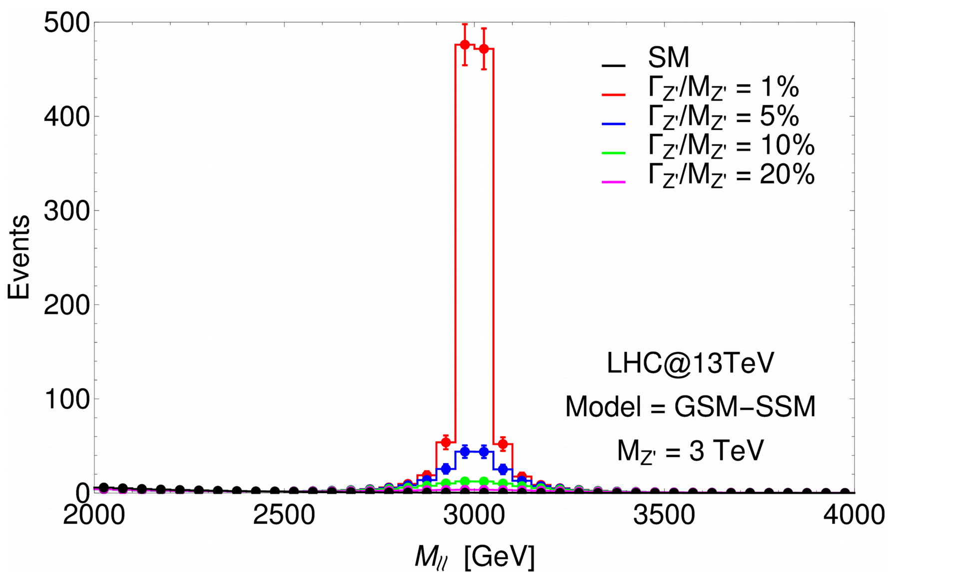
The LHC machine is the most powerful tool for high energy physics probes. Its recent upgrade at ***13 TeV*** c.o.m. energy, and the high integrated luminosity (***$\mathscr{L}$ = 300 fb^{-1}***) that will be collected by the end of the scientific program, will deliver an impressive amount of new data. The hope for the forthcoming future is that the analysis of those experimental precise measurements will reveal signals of BSM physics.

Quest for Z’-boson discovery:

Many BSM constructions feature extra massive neutral gauge bosons (***Z’***) and their discovery is an ongoing challenge in particular at the CMS and ATLAS experiments. With the most recent data available, the two collaborations agree on setting mass limits around ***4 TeV*** for narrow *Z’*-bosons. The most sensitive and precise measurements for the detection of *Z’*-bosons are generally performed looking for a peak in the distribution of high invariant mass di-lepton pair final states. Experimental fits scan the invariant mass spectrum assuming a **Breit-Wigner (BW)** line-shape for the new physics signal standing over a smooth background.

Warning:
This approach is designed to optimise the sensitivity of the analysis to narrow resonances (*Γ/M ~1%*).

As the resonance width grows, our sensitivity rapidly falls. Poor sensitivity already for *Γ/M >5%*.

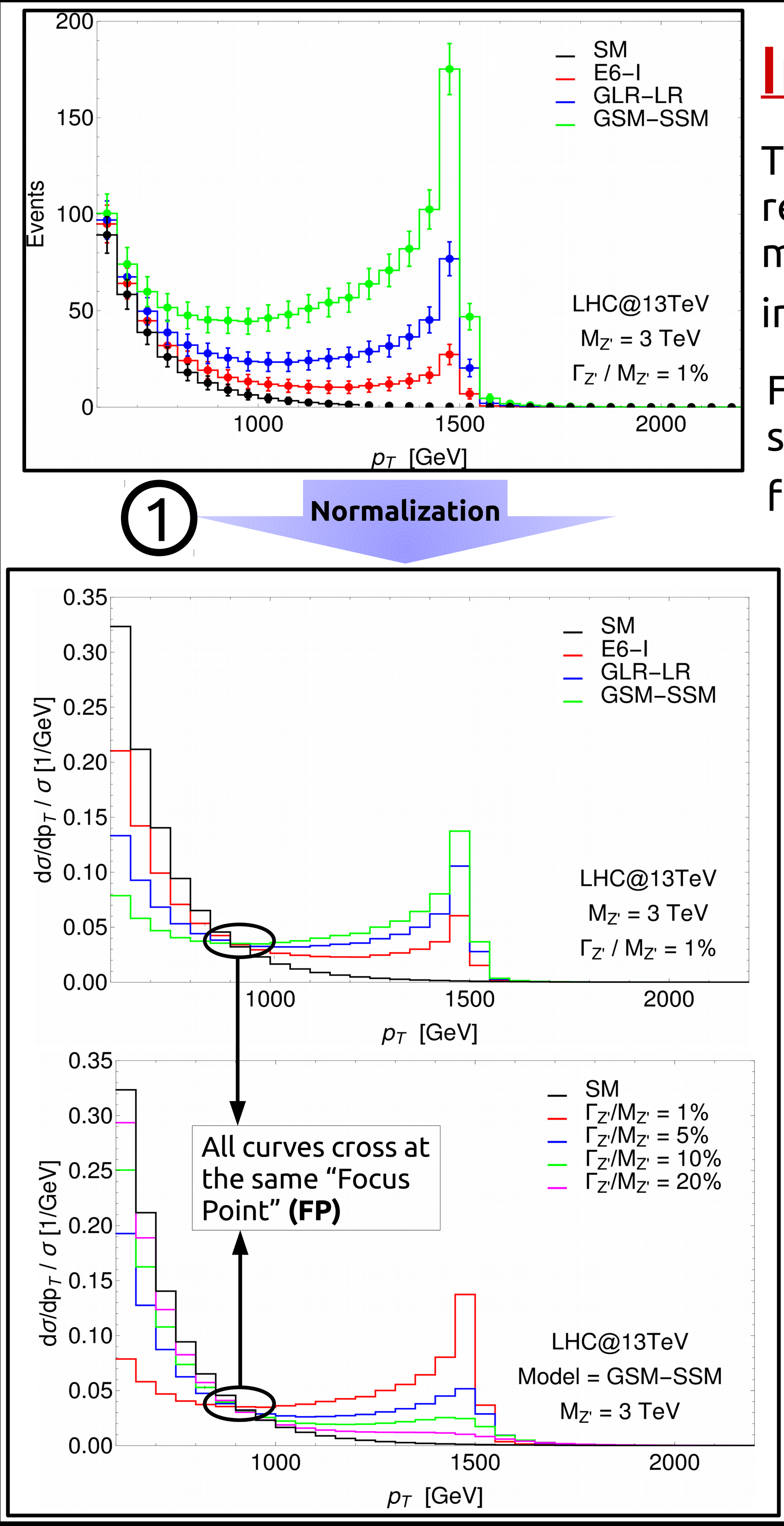


Number of events per bin in invariant mass distribution in the specific Z’-boson model for different choices of the resonance width.

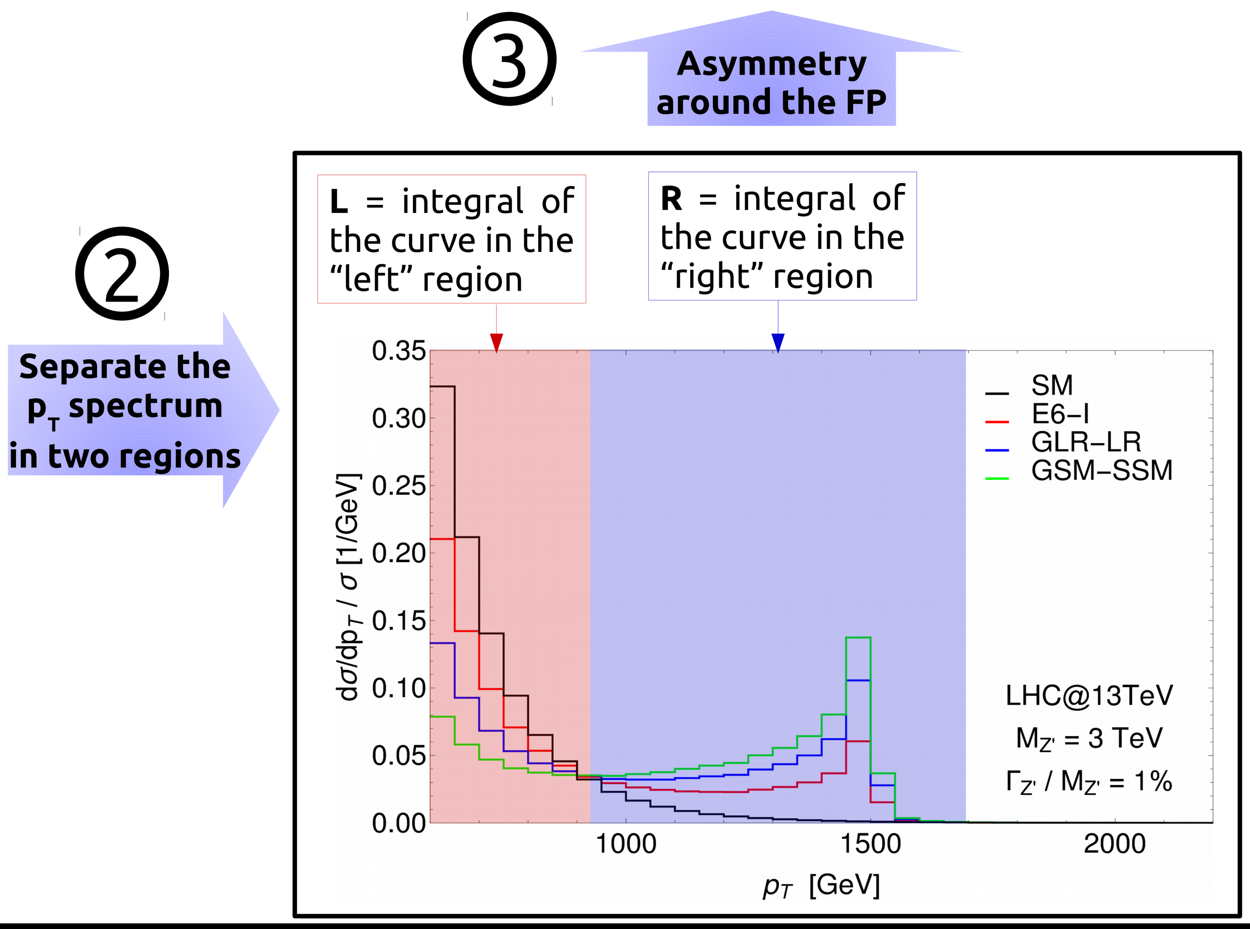
Introducing a new observable for Z’ analysis:

The free parameters in the **BW** fitting function used in the analysis are indeed the Mass and the Width of the ***Z’*** resonance. The new observable will be able to set independent constrains on the ***Z’*** width from a simple measurement in the transverse momentum (p_T) distribution of either lepton, which can be imported in the successive invariant mass distribution fit.

For a given ***Z’*** mass (either obtained from the invariant mass peak position, or assumed in a mass - width parameter space scan) we observe the p_T distribution of one of the leptons in the final state, considering only the events above a fixed $p_{T,min}$ that can be chosen at convenience to maximise the sensitivity of the observable on the new physics signal.



$$A_{FP} = \frac{L - R}{L + R}$$



(1) The distributions obtained normalising each curve, all cross through the same point, that we define as the Focus Point (**FP**).
(2) Obtain **L** and **R** integrating the normalized curves in the separated regions lying on the left and on right side of the **FP** in the p_T spectrum.
(3) The normalised difference between the **L** and **R** values defines the **Asymmetry around the Focus Point (AFP)**.

Properties & Features!

- At fixed c.o.m. energy, the position of the **FP**, and consequently the value of the **AFP** observable, depends only on the ***Z’*** mass and on the normalisation (specifically on the $p_{T,min}$). For the LHC@13TeV we have adopted the following empirical relation: $FP = p_{T_{min}} + 10\% M_{Z'}$
- As visible in ② the appearance of a FP is common to *any BSM single **Z’** model*, and for *any choice of the **Z’** width.*

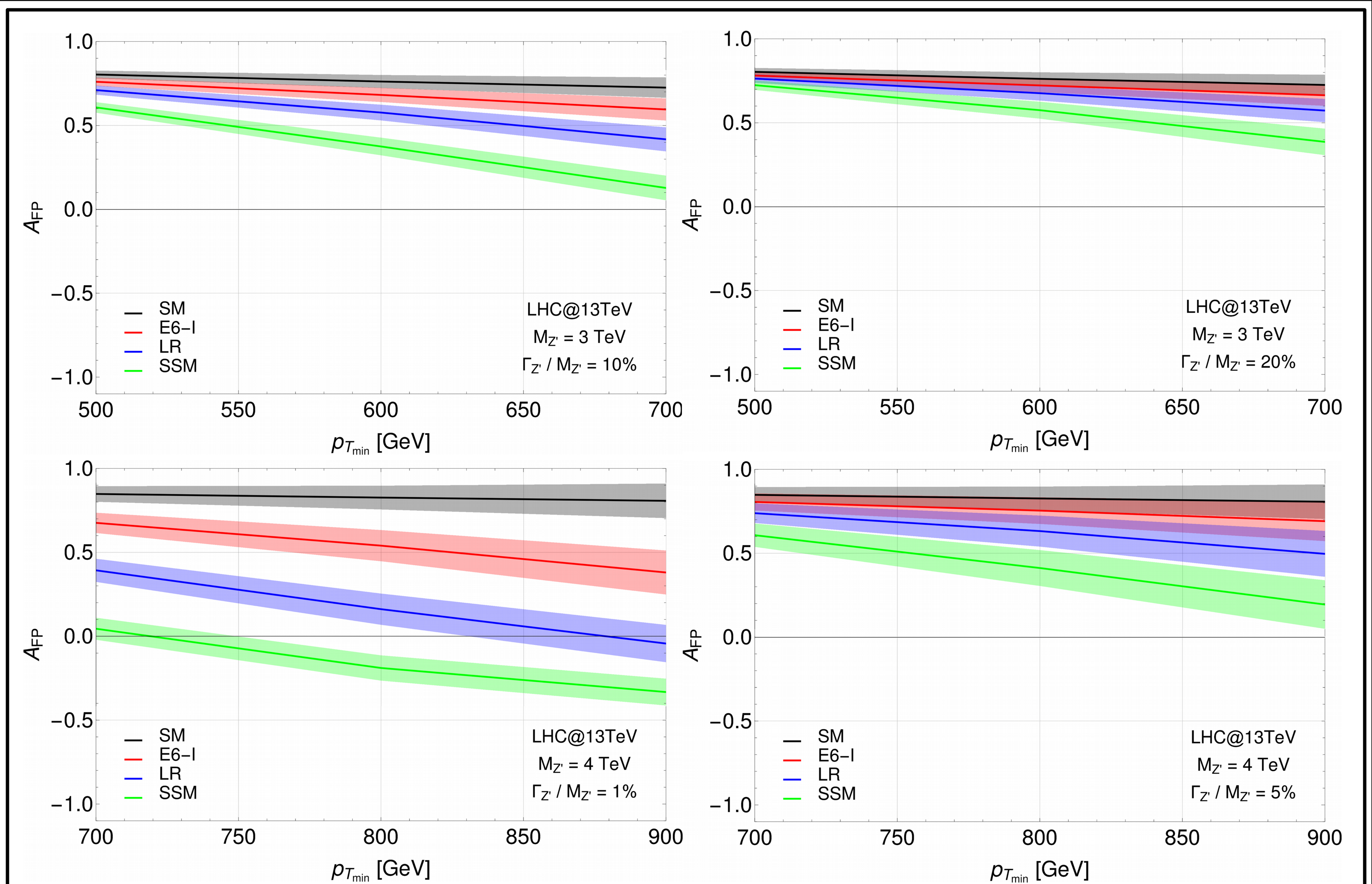
AFP measurements at the LHC:

The measured value of the **AFP** observable can be extracted from the data and compared with the **SM** or with the single-***Z’*** model Monte Carlo predictions.

The figures show the value of the **AFP** as function of the $p_{T,min}$ the latter chosen in the range of values that maximise its sensitivity to new physics at the assumed mass scale. The shaded areas represent the statistical 1σ error band.

The **AFP** can be used for many significant purposes:

- To support the identification of broad ***Z’*** resonances when in presence of mild excesses
- To set independent constrains on the ***Z’*** resonance width (***Γ***) which can be imported in the experimental analysis to improve the quality of the data fit.
- To help disentangling the underlying **BSM** construction, as it is also sensitive to the underlying ***U(1)’*** class of models.

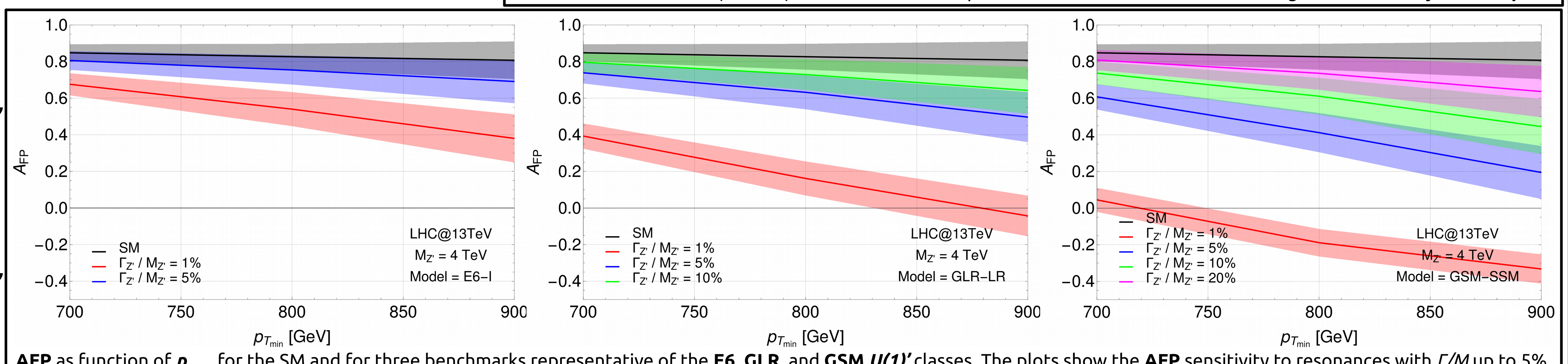


AFP as function of $p_{T,min}$ for the SM and for three benchmarks representative of the **E6**, **GLR**, and **GSM *U(1)’*** classes. The plots show the **AFP** sensitivity to resonances with *Γ/M = 10%* and *20%* and a mass of ***3 TeV*** (top), and with *Γ/M = 1%* and *5%* and a mass of ***4 TeV*** (bottom). The shaded areas represent the statistical error for an integrated luminosity ***$\mathscr{L}$ = 300 fb^{-1}***.

Exploiting the AFP potential:

The expected data for the LHC@13TeV program corresponding to an integrated luminosity of ***$\mathscr{L}$ = 300 fb^{-1}***, the **AFP** will be sensitive to *Γ/M* up to *10-20%* for ***Z’*** masses around ***3-4 TeV***, as visible in the panel on the right.

The value of the **AFP** do not vary much within each **Z’** class of models. For a ***Z’*** mass of ***4 TeV*** the **AFP** is sensitive to resonances with *Γ/M* between 5% and 20%, depending on the BSM construction.



AFP as function of $p_{T,min}$ for the SM and for three benchmarks representative of the **E6**, **GLR**, and **GSM *U(1)’*** classes. The plots show the **AFP** sensitivity to resonances with *Γ/M* up to 5%, 10% and 20% for a ***Z’*** mass of ***4 TeV***, respectively in the **E6**, **GLR** and **GSM** class of models. The shaded areas represent the statistical error for an integrated luminosity ***$\mathscr{L}$ = 300 fb^{-1}***.

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