Roundtable

Savannah Clawson

DESY SM group meeting

Tuesday 13th May, 2025

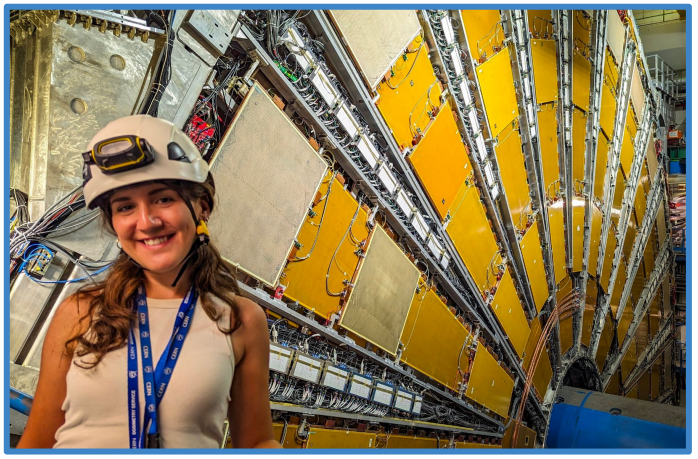
HELMHOLTZ

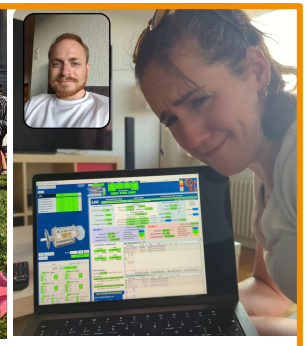
DESY.

ATLAS EXPERIMENT

What am I working on?

- **Photon-induced WW**
  - ➞ Heavily involved in observation analysis
  - ➞ Unfolded dilepton kinematic distributions in follow-up differential analysis
- **Photon-induced ττ**
  - ➞ Author of pheno study into prospects of constraining tau g-2 in LHC pp collisions
  - ➞ Analysis contact for γγ→ττ in pp analysis
  - ➞ Also involved in ATLAS heavy ion γγ→ττ analysis (mostly through supervision)
- **Forward proton CP**
  - ➞ No longer convener of AFP CP group!!
  - ➞ Involved in ALPs+AFP analysis via CP
  - ➞ Hosting upcoming ATLAS Roman Pots General Meeting at DESY
- **Soft-QCD convener**
  - ➞ Convenership started on 1st Jan 2025





Also lots of operations at CERN as AFP on-call expert

Photon-induced $t\bar{t}$

Comparison of photon-fusion MC generators

	Superchic Lucian Harland-Lang 2410.10978	**Gamma-UPC in MG5** H.-S. Shao & D. d'Enterria 2207.03012	**Standalone MG5**
Type of process	Specific physics processes hard-coded. Generation of elastic and dissociative processes via proton structure function	Generation of arbitrary AB→AXB processes Only capable of generating elastic processes	Generation of arbitrary AB→AXB processes Generation of elastic and dissociative processes
Handling of soft survival	Survival effects are included fully differentially in the final-state momenta on an event-by-event basis	Global factor applied with impact parameter dependence	None (S = 1)
Photon flux	EPA with proton form factors: Double-dipole parameterisation	EPA with proton form factors: Two options: EDFF (not recommended), ChFF (dipole param.)	Elastic: EPA with "improved" Weizsacker-Williams flux Dissociative: photon PDFs
Order in QED/EW corrections	LO	NLO for $\gamma\gamma\to\mu\mu$, $\tau\tau$ [2407.13610]	LO

CMS analysis used Gamma-UPC+MG5 as nominal signal and did a data-driven (derived in dimuon CR) scaling of the elastic prediction to account for dissociation. SuperChic v4 was used as an alternative signal sample to cross-check the elastic scaling.

Gamma-UPC+MG5 was also used to generate all photon-induced backgrounds

Photon flux modelling

Big topic of discussion in HI UPC analyses

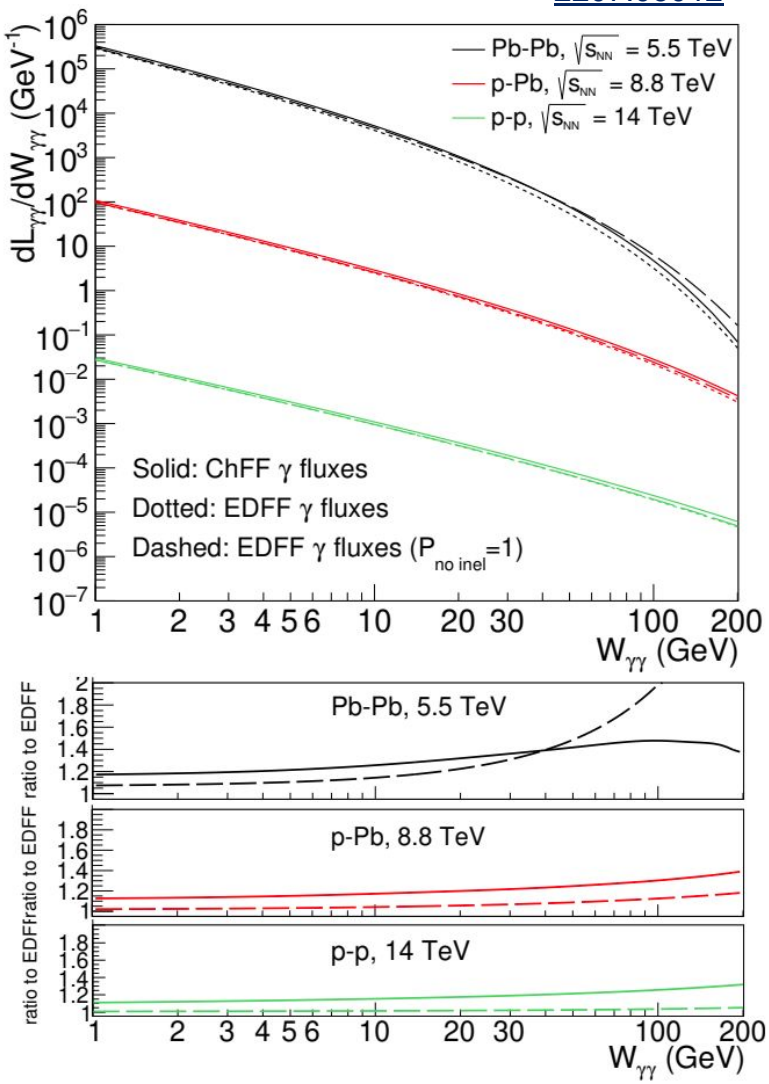
ChFF is more realistic than EDFF as it considers also the photon flux within the nuclei

If one were to naively take a **2-point systematic** of EDFF and ChFF cross sections, uncertainties from photon flux would be 12–25% for PbPb and **6–12% for pp**

EDFF flux is unphysical and not recommended. **Gamma-UPC ChFF photon flux gives results that are similar to SuperChic's flux implementation**

Ultimately, we expect that
photon flux uncertainties will have a smaller effect in proton collisions and are also convoluted with soft survival and dissociation uncertainties (directly measured in most HI analyses via neutron vetoes in ZDC)

2207.03012

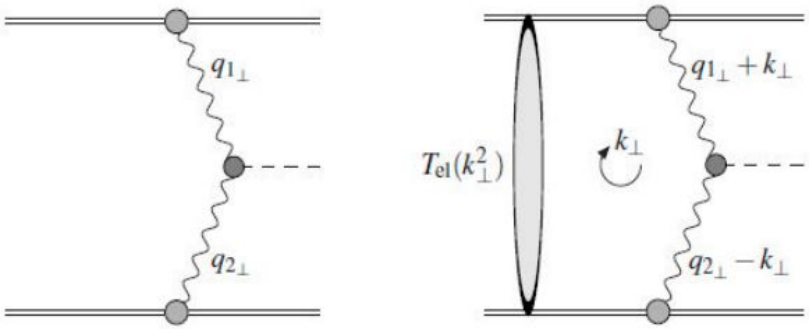


Soft survival modelling

Proton soft survival = probability that there are no additional QCD interactions between the two incoming protons

Effectively, the **probability that there is no MPI in a photon-induced event**

Typically soft-QCD, **difficult to model!**



📌 Key Conceptual Difference

- **Gamma-UPC:**
  - Computes photon fluxes in b-space.
  - Applies a survival factor $S^2(b)$ integrated over impact parameter.
  - Result: A **global factor** modifying total cross sections.
  - Assumes the **soft and hard parts factorize.**
- **SuperChic:**
  - Computes the amplitude **differentially** in transverse momenta.
  - Uses a **multi-channel eikonal model** based on **Good–Walker formalism.**
  - Keeps survival entangled with the **full kinematics** of the event.

Thanks to ChatGPT for the discussion :)

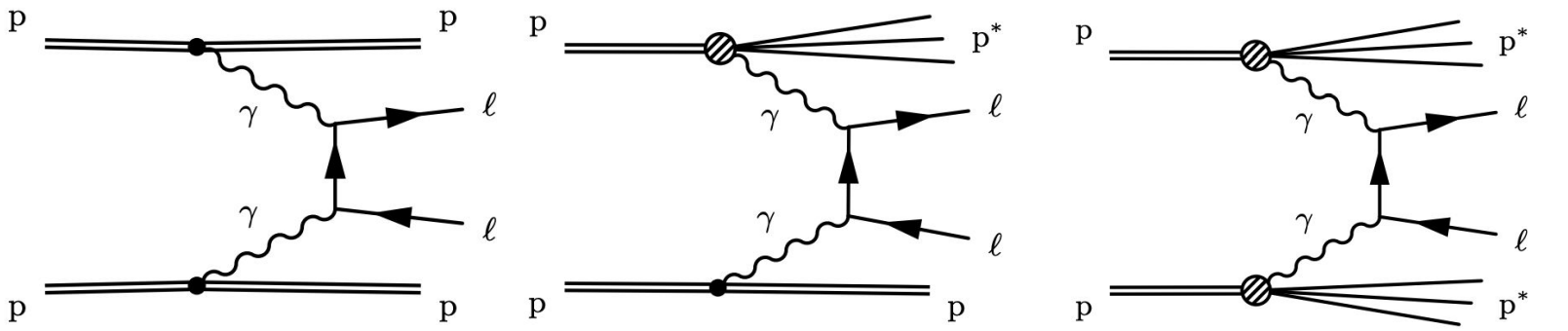
- This is where **SuperChic** really wins - its **handling of soft survival and proton dissociation is far more sophisticated** than any other generator

Generating $\gamma\gamma \to ll$ with SuperChic

Intro

- Generating all processes with **SuperChic5.1 + Pythia8.310** (Ath,23.6.29)

Elastic (EL) **Single-dissociative (SD)** **Double-dissociative (DD)**

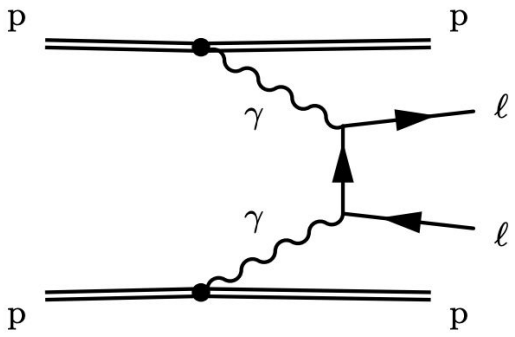


ATLAS SuperChic interface: gitlab.cern.ch/atlas/athena/-/tree/main/Generators/Superchic_i

Interfacing to parton showers

- Parton showers generally don't know how to handle photon-induced processes

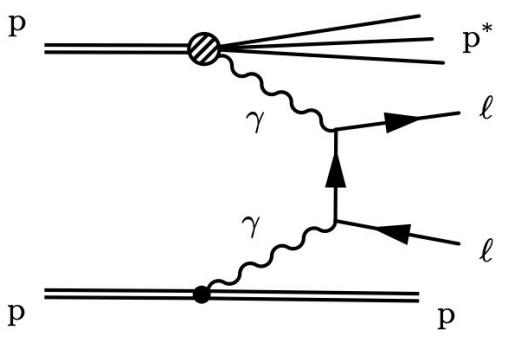
Elastic (EL)



Pythia wants to shower the protons, have to turn off multi-parton interactions and enforce a dipole shower scheme (no colour flow)

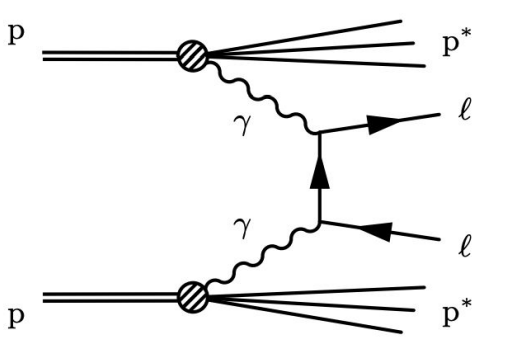
```
PartonLevel:MPI=off
SpaceShower:dipoleRecoil=on
```

Single-dissociative (SD)



This is the most difficult to get right. Pythia doesn't know how to handle one proton that doesn't shower and one that does. Lots of fiddling around with shower parameters in the config.

Double-dissociative (DD)



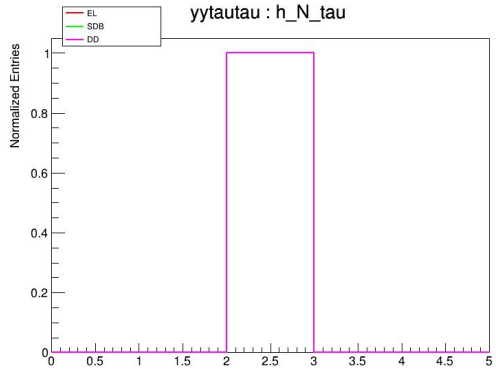
Looks more like what Pythia is used to but still need to prevent colour flow between the beam remnants with dipole shower scheme

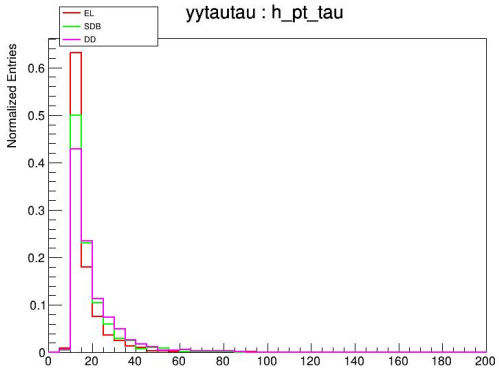
$\gamma\gamma \rightarrow \tau\tau$ validation

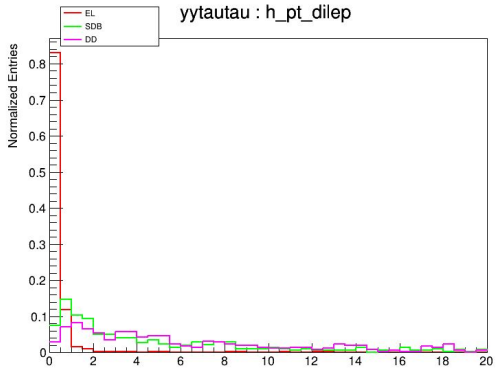
Generating 1000 events in Ath,23.6.29, SC v5.1, Py v8.310

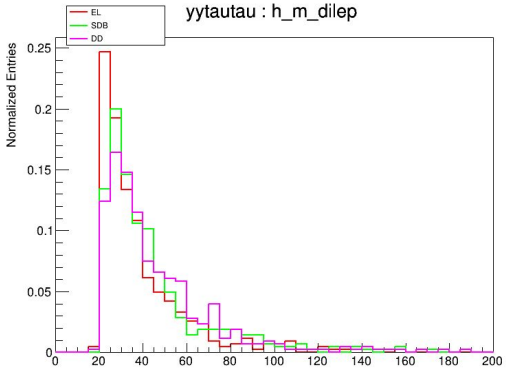
SDA job failed due to runtime

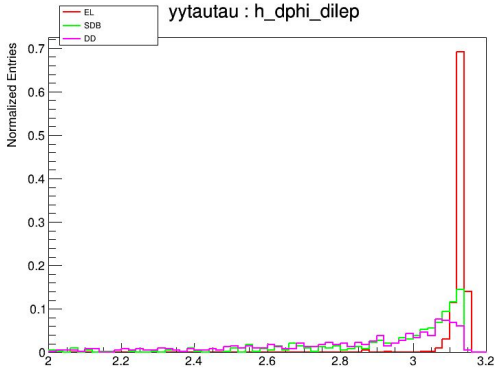
- Generally, central leptons and dilepton system looks reasonable

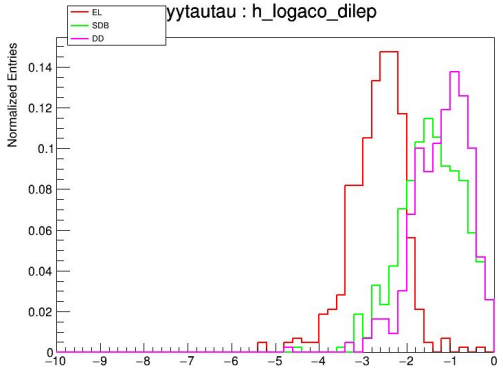






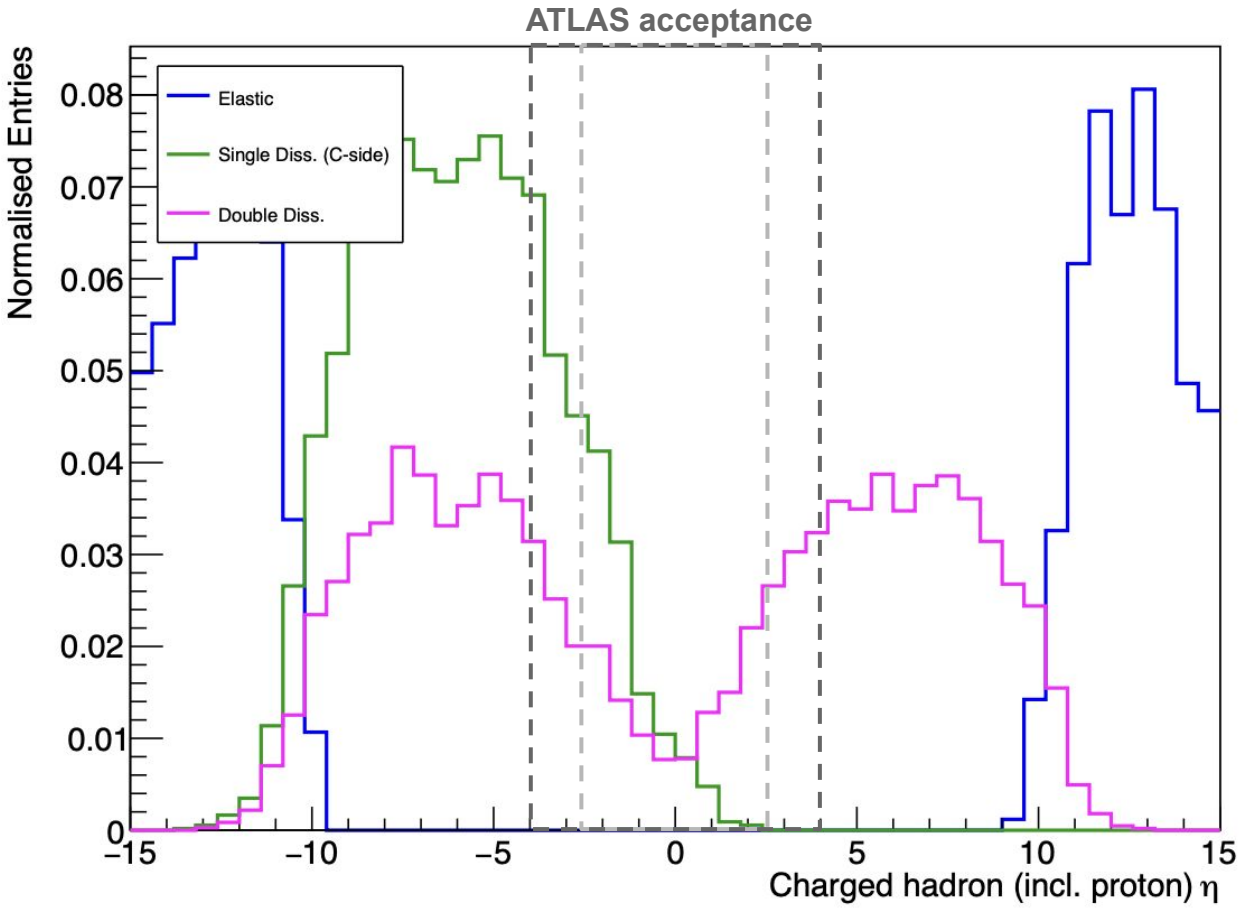






Proton dissociation problems

- However, I then started looking forward…
  - ➞ Adding truth protons and charged hadrons (not from tau) to validation:



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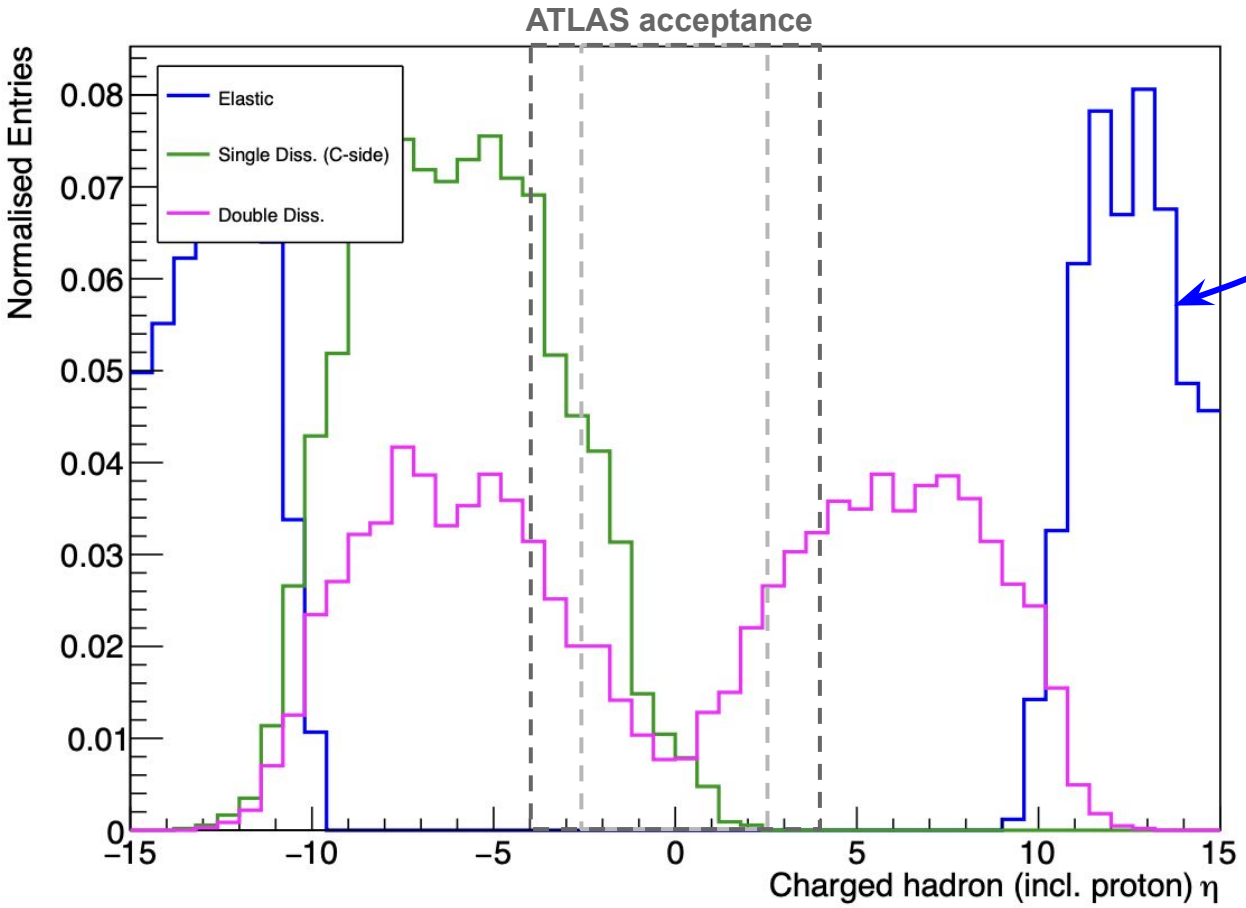
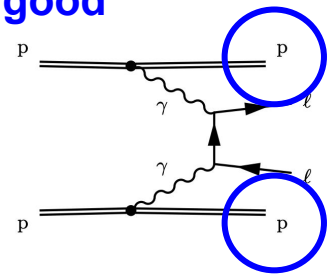


Elastic protons look good



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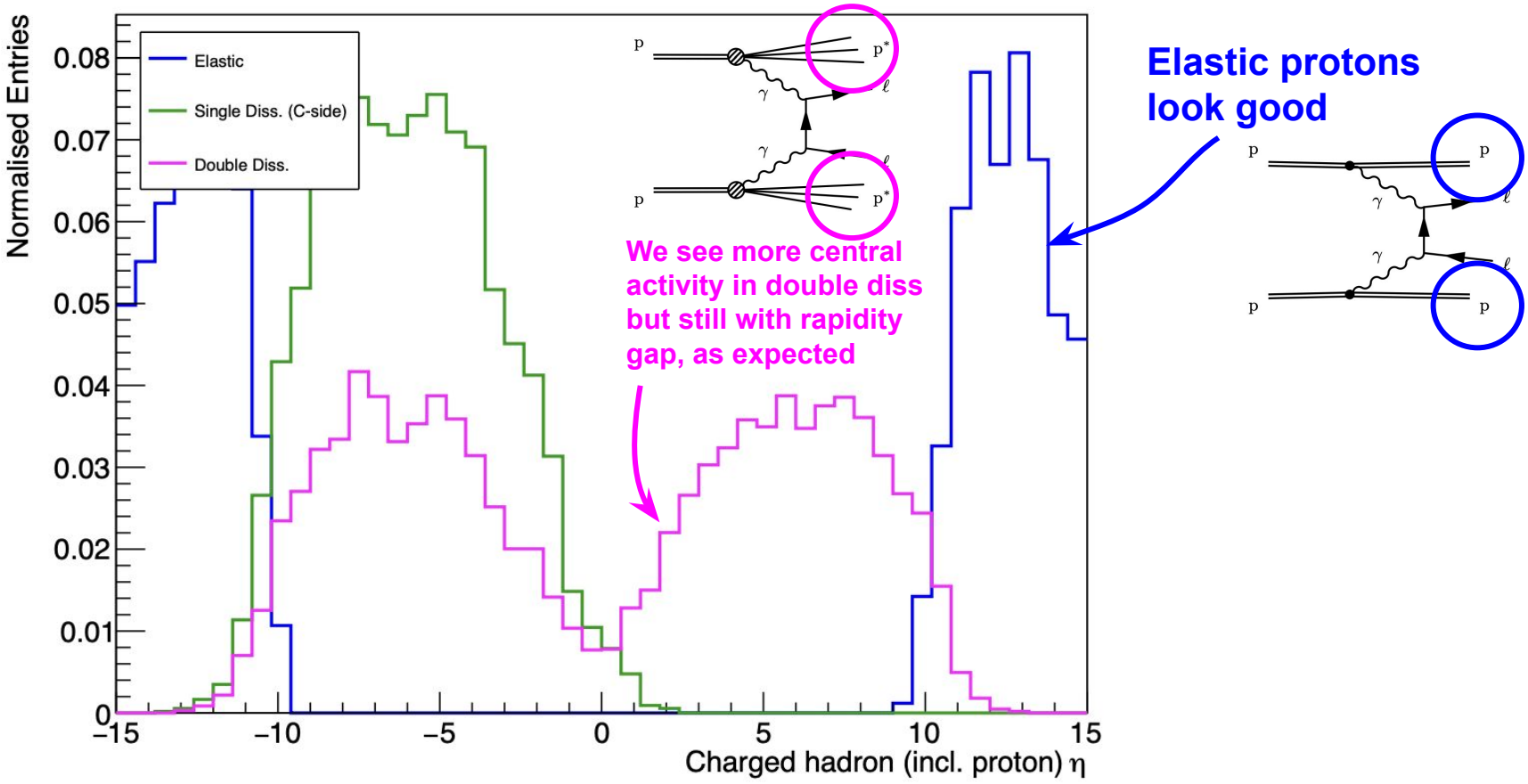

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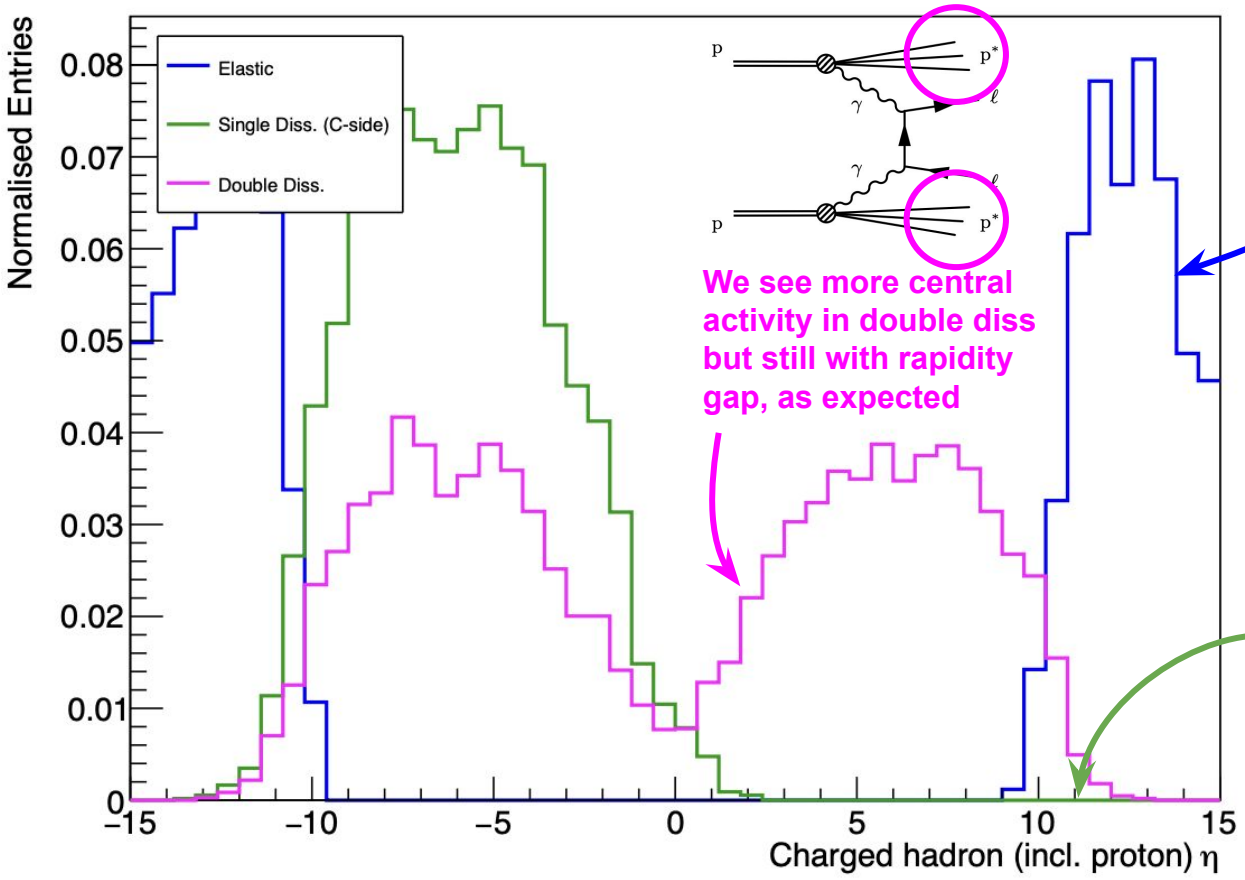
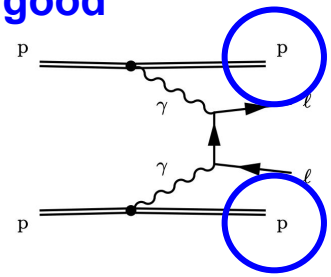
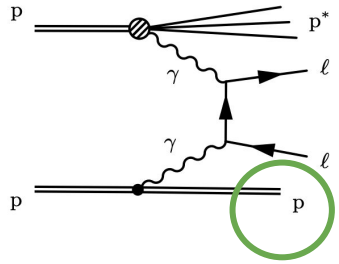


We see more central activity in double diss but still with rapidity gap, as expected

Elastic protons look good

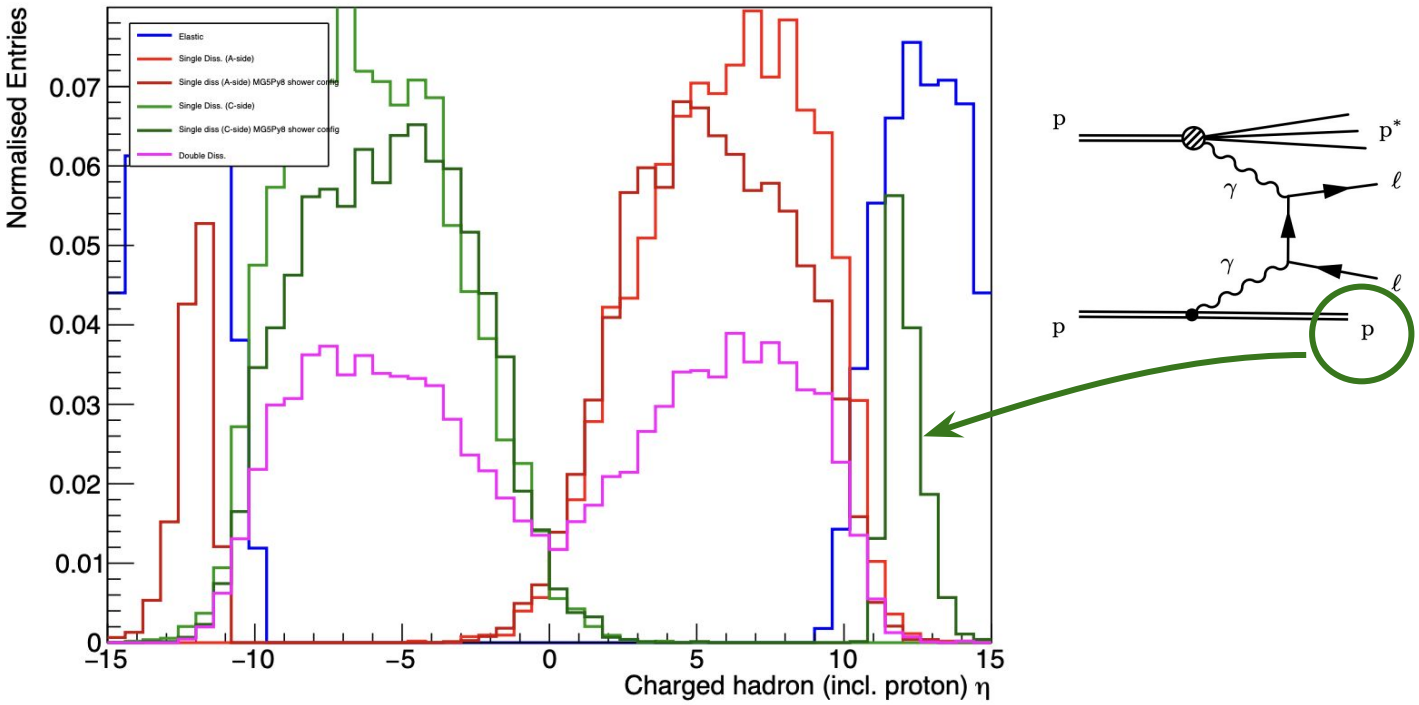


But where is our elastic proton in single diss events? :(



Testing alternative shower settings

- MGPy single-diss. shower settings look more reasonable



- Elastic and double-diss. here still using SuperChic+Pythia shower settings
  - → **Elastic proton in SD** seems to have smaller |η| with narrower width than in **purely elastic**
  - → Likely to originate from MadGraph PDF photons vs SuperChic form factor approach?

Summary

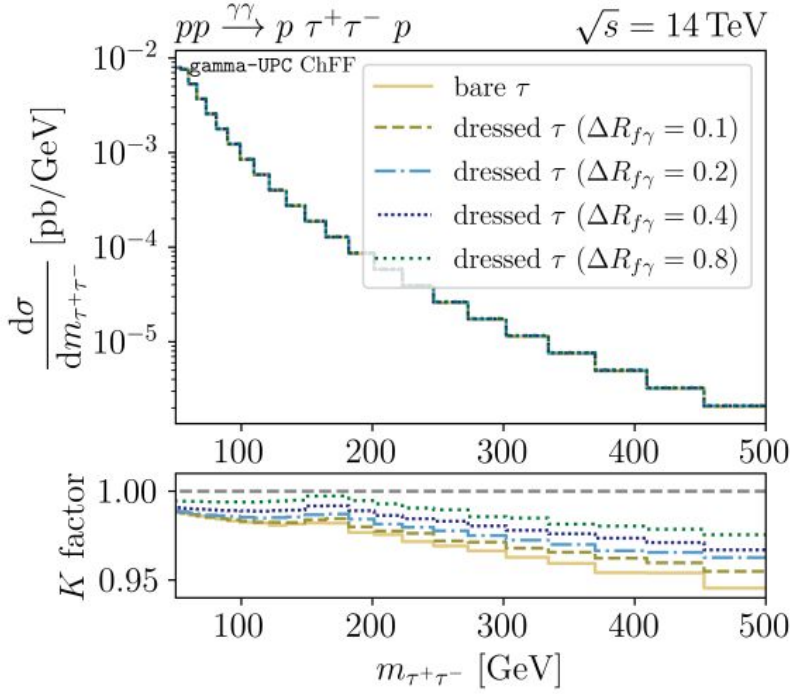
- I am set up to generate SuperChic $\gamma\gamma \to ll$ processes for all elastic and dissociative modes
  - ➞ Should be easily extendable to $\gamma\gamma \to WW$ but requires a little more config
- **TO-DO:** ATLAS SuperChic interface needs updating to properly generate the $\gamma\gamma \to \tau\tau$ process with new BSM modifications in SC v5.4
- Getting the parton shower right for photon-induced processes (especially single-dissociation) is not trivial
  - ➞ Lots of work going into finding appropriate settings
  - ➞ Theory uncertainties will likely come from variations in shower settings

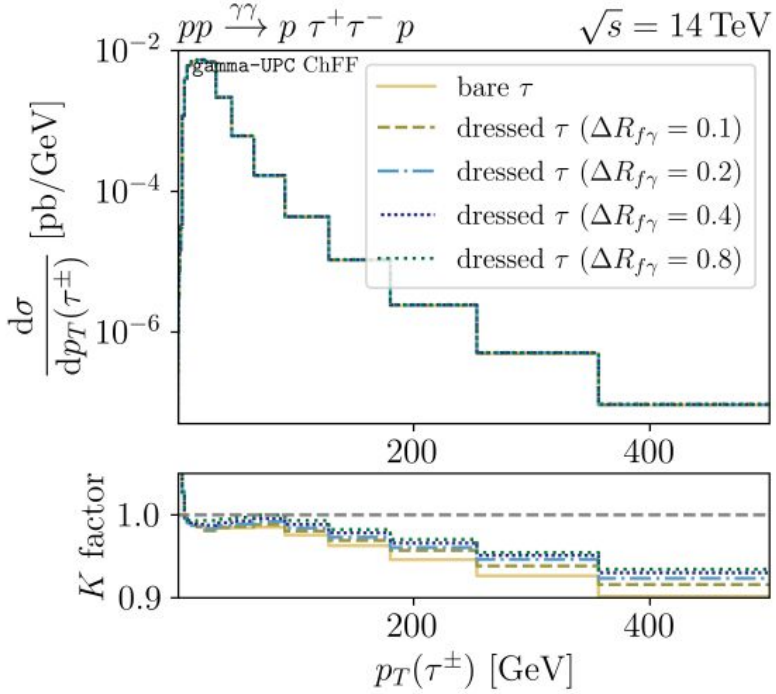
Backup

Impact of NLO vs LO EW

[2504.10104]

gamma-UPC is now capable of NLO QCD + EW corrections but can only do NLO matching to PS for QCD corrections (for processes without jets) [2504.10104]



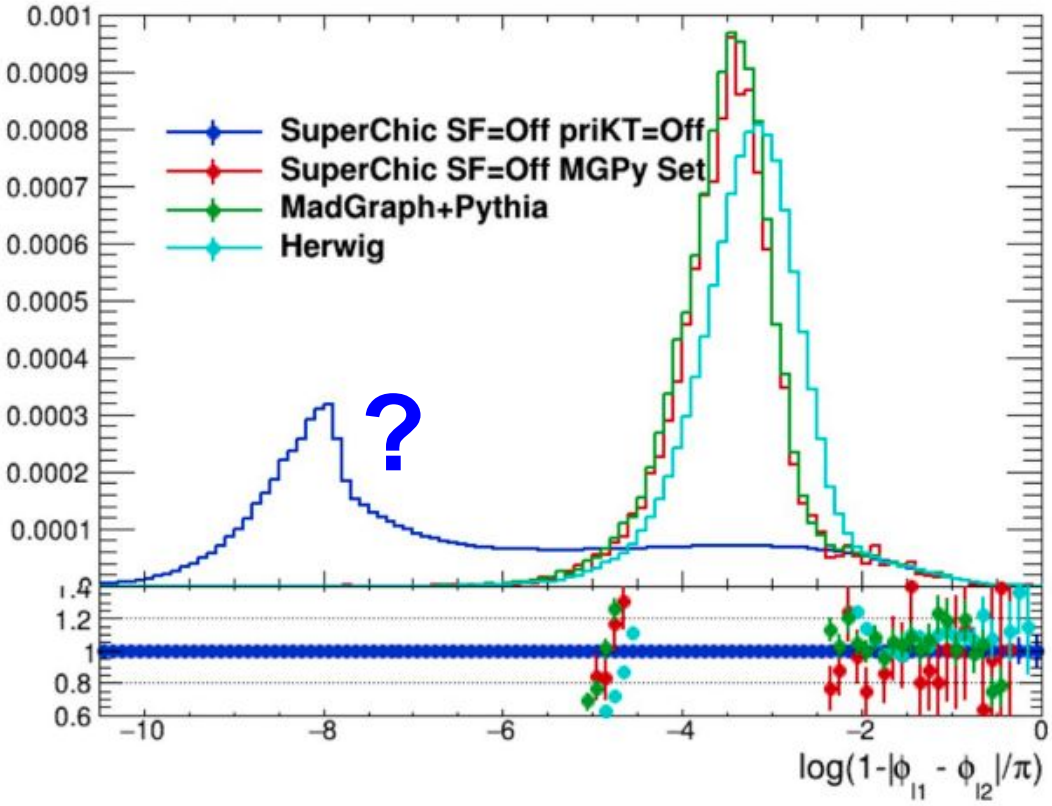


Up to 10% effect at high p_T

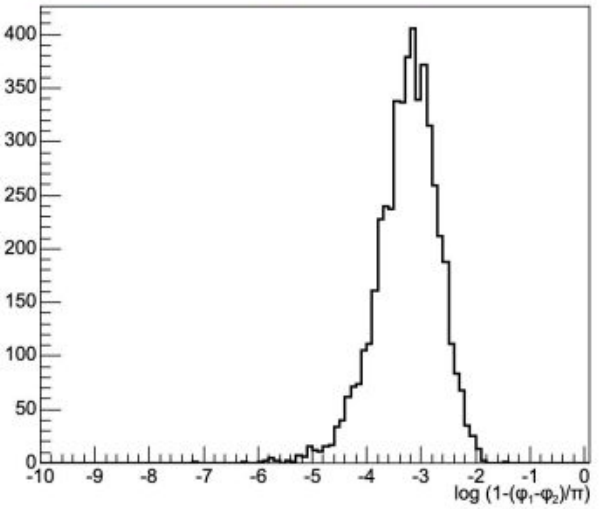
p_T-dependent k-factors could be important for a_tau fits

Pythia interface settings

- Acoplanarity difference for yy->ll elastic case
  - log(acoplanarity) (yy->ll, mll>160 GeV, p_T^l > 15 GeV)



Before PS with Pythia (output of SuperChic):



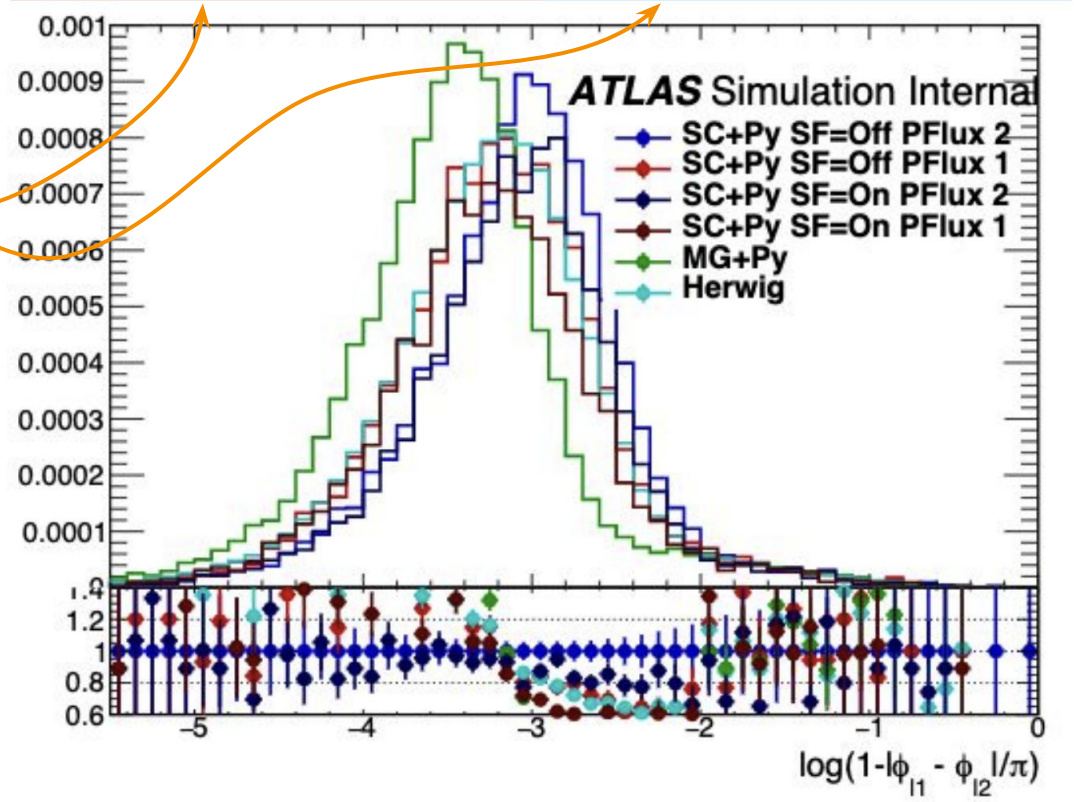
From Aleksandra's summary of yyWW signal MC request

Elastic Pythia settings for yyWW request

```
genSeq.Pythia8.Commands += [
    "PartonLevel:MPI = off",
    "SpaceShower:pTmaxMatch = 2",
    "SpaceShower:pTdampMatch = 1",
    "SpaceShower:dipoleRecoil = on",
    "LesHouches:matchInOut = off",
    "PDF:BeamA2gamma = on",
    "PDF:BeamB2gamma = on",
    "PDF:Proton2gammaSet = 1/2",
    "Photon:ProcessType = 4",
]
```

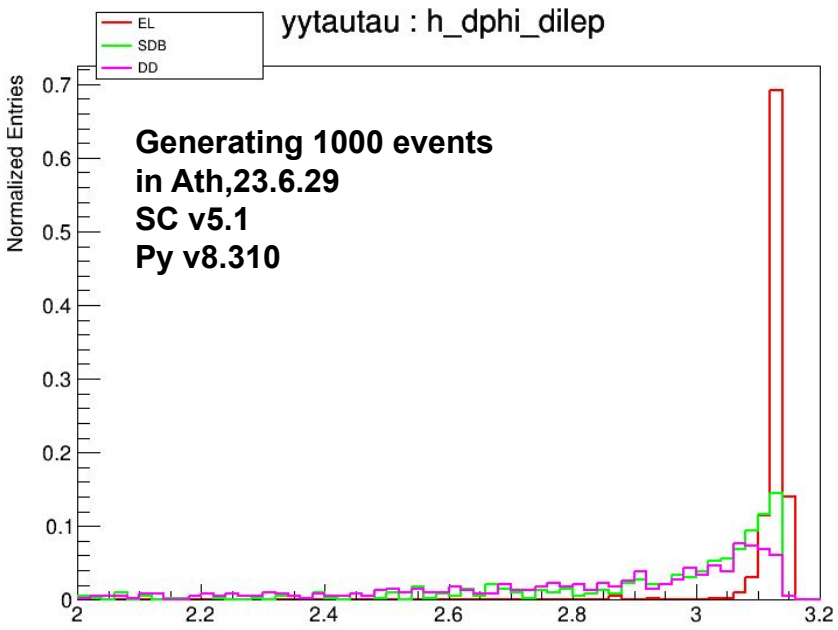
PDF:Proton2gammaSet
`option` **1** : Use virtuality integrated photon flux from Budnev et al. As the flux is integrated over *Q^2*, the virtuality is always set to zero and the scattered beam proton does not have any transverse momentum. When this option is applied the *Q^2* sampling will be turned off.

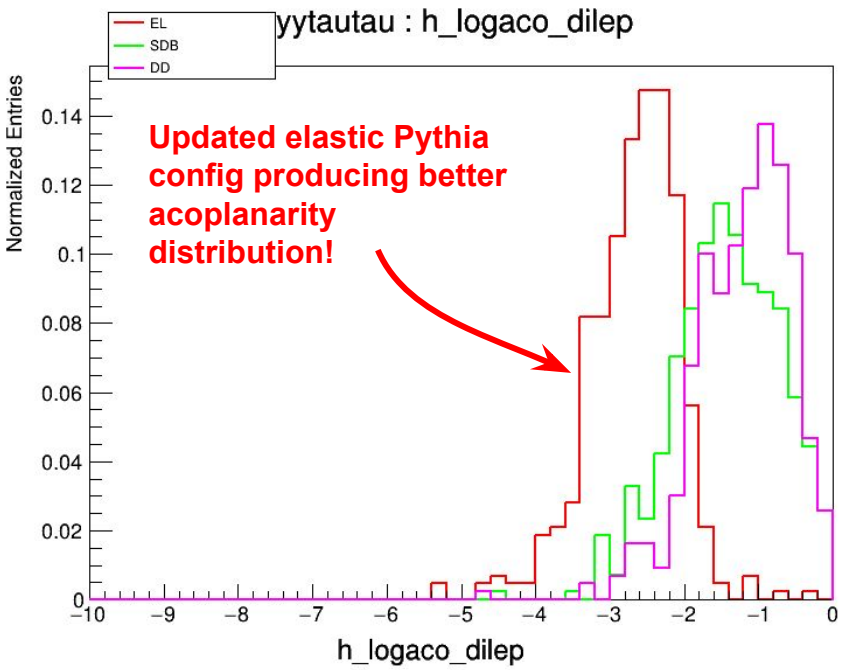
PDF:Proton2gammaSet
`option` **2** : Use a virtuality-dependent flux similar to the approximation by Drees and Zeppenfeld. Uses a dipole form factor to appropriately suppress high virtualities.

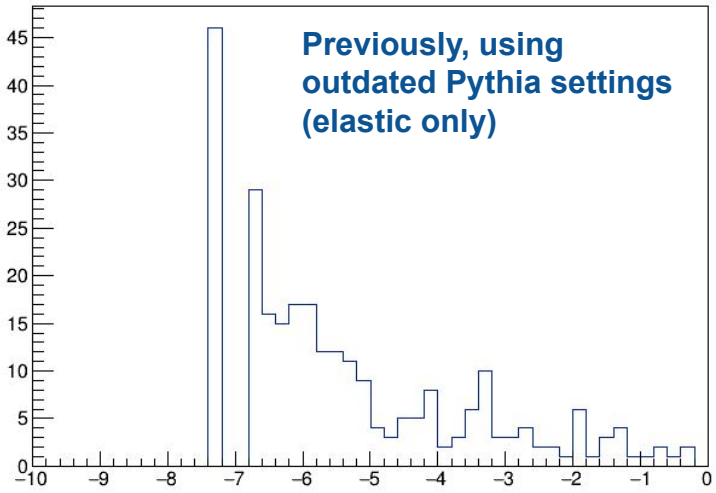


However,
"LesHouches:matchInOut = off" results in violation of momentum conservation! Pythia authors working on a more proper handling.

Validation: γγ→tautau







SDA job failed due to runtime

Validation: Pythia interface

However,
"LesHouches:matchInOut = off"
results in violation of momentum conservation! Pythia authors working on a more proper handling.

- I see the same issue when generating elastic $\gamma\gamma \to ll$ events with SC+Py8:

```
--------  PYTHIA Event Listing  (hard process)  -----------------------------------------------------------------------

   no         id  name            status     mothers   daughters     colours      p_x        p_y        p_z        e          m
    0         90  (system)           -11     0     0     0     0     0     0      0.000      0.000      0.000  13600.000  13600.000
    1       2212  (p+)               -12     0     0     3     0     0     0      0.000      0.000   6800.000   6800.000      0.938
    2       2212  (p+)               -12     0     0     4     0     0     0      0.000      0.000  -6800.000   6800.000      0.938
    3         22  (gamma)            -21     1     0     5     6     0     0      0.554      0.394      2.985      3.061      0.000
    4         22  (gamma)            -21     2     0     5     6     0     0     -0.005     -0.014     -9.258      9.258      0.000
    5         13  mu-                 23     3     4     0     0     0     0     -1.523      2.661     -8.098      8.660      0.106
    6        -13  mu+                 23     3     4     0     0     0     0      2.072     -2.281      1.825      3.583      0.106
                                 Charge sum:  0.000          Momentum sum:      0.549      0.380     -6.274     12.243     10.492
```

Explanation of sensible Pythia settings

- **PartonLevel:MPI=off** otherwise you are effectively double counting the survival factor. To have this on also does not account for specific impact parameter dependence of EL, SD and DD, giving uniformly S^2~10% and no kinematic dependence.
- **SpaceShower:dipoleRecoil=on** is specifically designed for cases where there is no colour flow between the two initiating protons
- **SpaceShower:pTmaxMatch=2** in order to fill the whole phase space with the parton shower
- **SpaceShower:pTdampMatch=1** to damp emission when it is above the scale SCALUP in the LHE, which we set to the maximum of the two photon q^2; in practice, this latter option is found to have little effect on the results.
- **BeamRemnants:primordialKT=off** as we wish to keep the initiating quark (proxy for initiating proton in pythia) completely collinear to fully match the kinematics from the structure function calculation
- **SpaceShower:QEDshowerByQ=off** (only relevant for SD production due to one elastic and one inelastic emission in the event) such that there is no back evolution from the photon, consistent with this being an elastic emission. Treating the initiating photon as on–shell in the event kinematics is an approximation to the true result, but for most purposes is a very good one.