Forward proton detectors at 420m?

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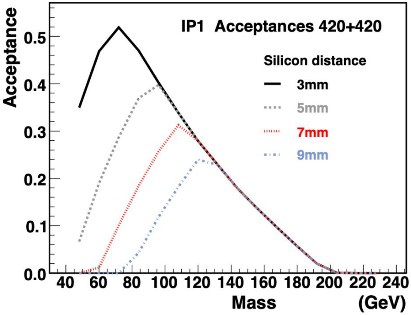
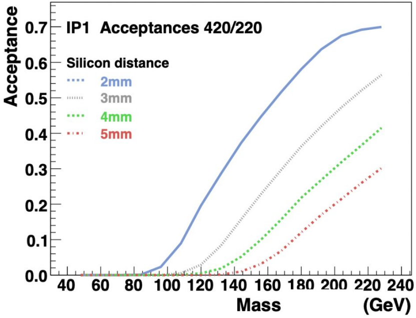
Photon-induced processes, IPPP, Durham, 3rd November 2022

Back to the future: Forward proton detectors at 420m (I)





- Proposed in 2008 for the LHC (FP420), but not funded.
- Silicon detectors for proton ξ measurement
- Fast timing detectors for proton time-of-flight measurement

Back to the future: Forward proton detectors at 420m (II)

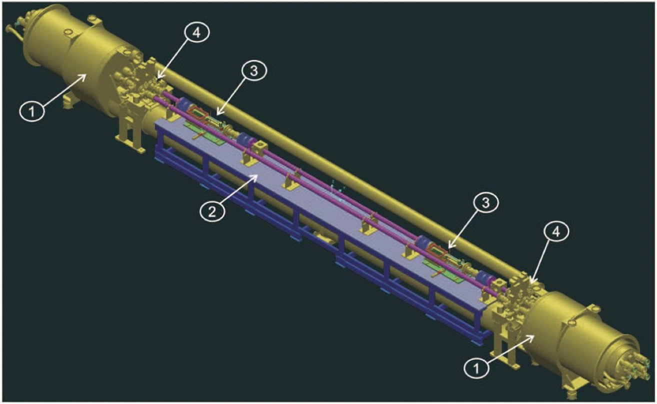
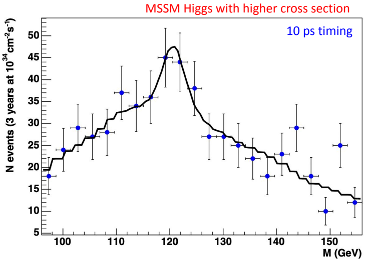
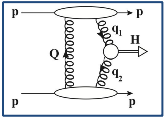


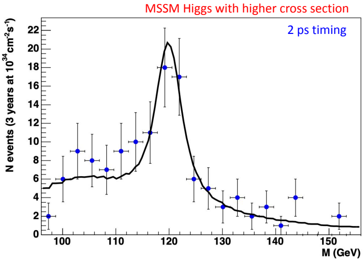
Fig. 49: Schematic view of the connection cryostat (1) and detector arm with support table (2), two detector sections (3) and vacuum pumping sections (4).

420m is in the cold region of the LHC: requires (i) new cryostat design and (ii) Hamburg Pipe instead of Roman Pots to house the detectors.

Back to the future: The (MSSM) Higgs physics case







Being 2008, the physics case was heavily based on Higgs:

- Small exclusive Higgs cross section meant H->bb decays are the viable ones (mainly).
- Trigger strategy was limiting factor (high rate difficult for low-p_T jets).
- Stringent cuts on track multiplicity, vertex-matching from time-flight, kinematic matching to reduce the combinatorial background (where protons come from different interaction(s) to the bb system)

HL-LHC: Physics analysis considerations

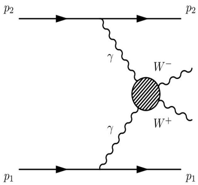
Major upgrades to experiments would make the physics analysis with 420m detectors easier at HL-LHC:

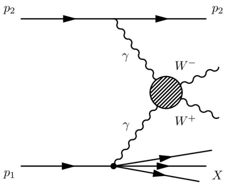
- Increased trigger latency. For LHC, L1 latency was too small (3.2μs) for proton information to arrive in time. For HL-LHC, L0 latency is longer (10μs).
- New TDAQ strategies such as Trigger Level Analysis means that high-rate processes do not have to be pre-scaled (though have less detailed information)
- The central detectors will be able to measure the time of charged particles to an accuracy of 30ps (e.g. HGTD at ATLAS). Can match the time of hard scatter to the forward proton time measurements:
  - Timing information for $|\eta| < 4.0$ for CMS
  - Timing information for $2.4 < |\eta| < 4.0$ for ATLAS

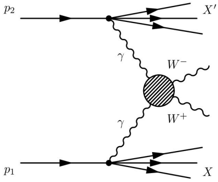
But, the combinatorial background is worse:

- grows quadratically with luminosity

Reminder of the Run-II $\gamma\gamma\rightarrow$WW programme

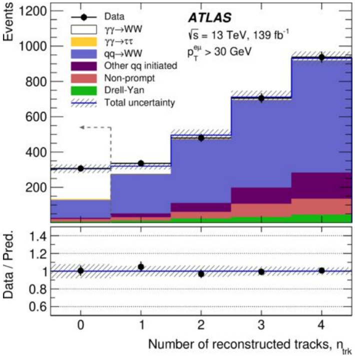






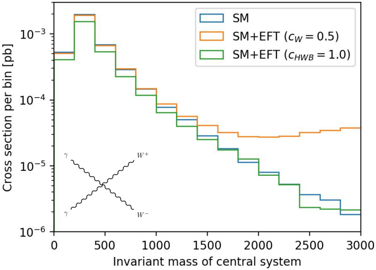
- Observation of $\gamma\gamma\rightarrow$WW (PLB 816 (2021) 136190)
- Reasonable agreement between data and theory predictions
- Next natural step: differential cross sections

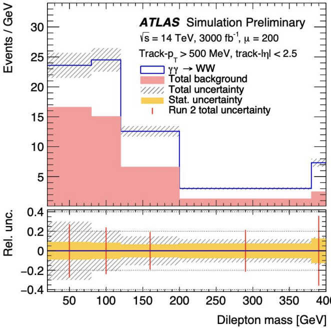
Important to establish longer-term viability of this programme at the HL-LHC.

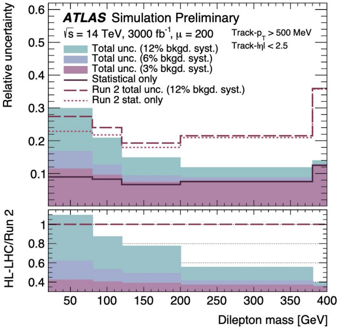


$\gamma\gamma\rightarrow$WW: HL-LHC prospects without forward protons

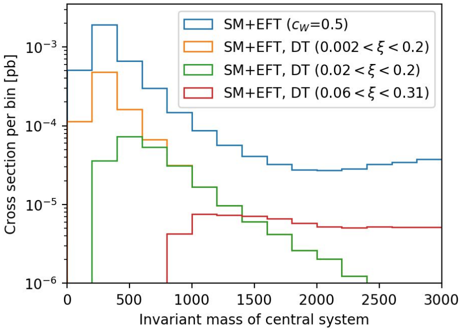
- HL-LHC sensitivity of the $\gamma\gamma\rightarrow$WW analysis was studied by ATLAS
- Do not gain the simple sqrt(L) improvement in uncertainties (analysis cuts harsher to control background).
- Modelling (and additional rejection) of background will be critical

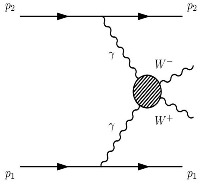






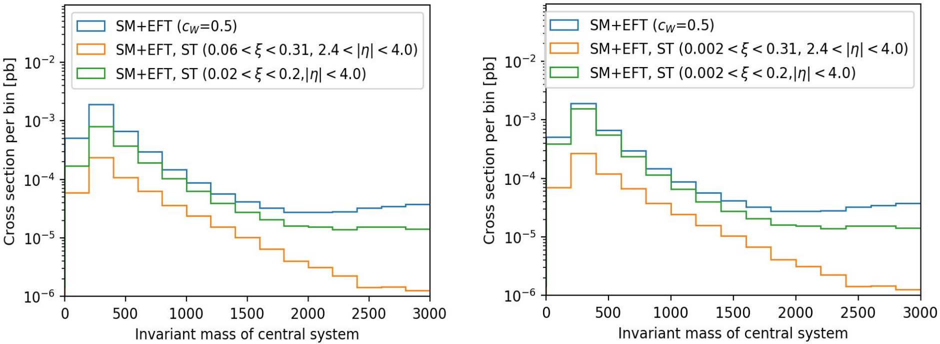
$\gamma\gamma \to$WW: usefulness of double proton tag analysis





- Elastic production is only 28% of the photon fusion cross section = immediate loss of events
- Sensitivity to new physics at high mass scales highly dependent on detector acceptance

Photon fusion: usefulness of single proton tag analysis



- Single-tagged analyses *may* be possible due to central-detector timing information
- For single-tagged analyses, the most important consideration is the central detector coverage for timing charged particles.
- Additional acceptance at low-mass with detectors at 420m.

Summary

- Photon fusion analyses that seek to tag both protons will immediately lose about ¾ of the available signal. Useful if:
  - can use proton information to very efficiently reject backgrounds (i.e. reject 95%)
  - proton information provides unique information (i.e. spin-CP?)

- The addition of central timing detectors for charged particles opens up the possibility of photon fusion analyses at HL-LHC with a single proton tag. This is largely unexplored in the literature.

- For photon-induced processes, detectors at 420m (in addition to detectors placed at 220m) would gain acceptance at lower values of missing-mass.