Long-lived Particle Searches Using Precision Timing and Muon System
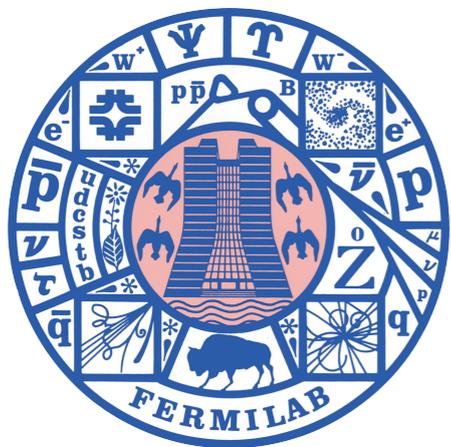
Artur Apresyan, **Cristián Peña** (Fermilab)

Zhen Liu (University of Maryland)
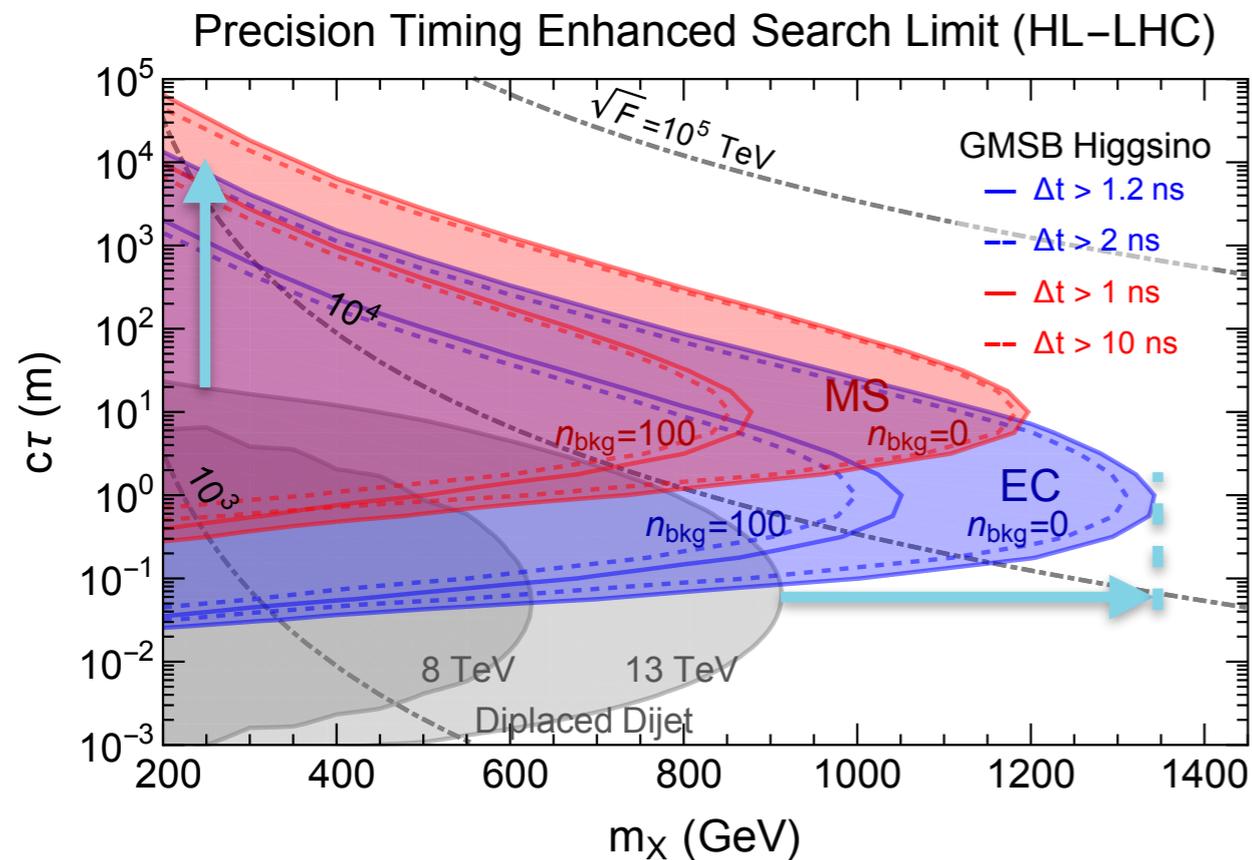
Maria Spiropulu, Si Xie — (Caltech)
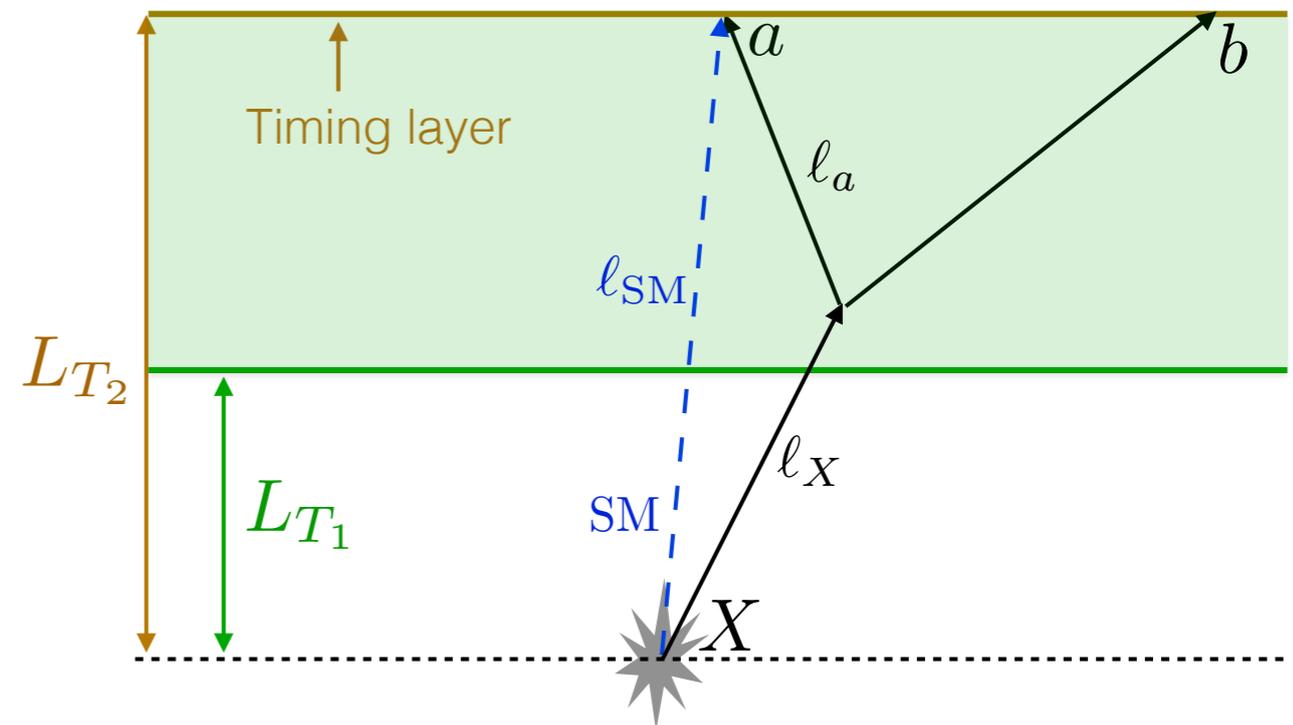
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June 2020

LLPs and Precision Timing

study by Liu, Liu, Wang, 1805.05957.

Precision Timing Enhanced Search Limit (HL–LHC)

$$\Delta t = \frac{\ell_X}{\beta_X} + \frac{\ell_a}{\beta_a} - \frac{\ell_{SM}}{\beta_{SM}}$$

- Timing results in large gains in $c\tau$ and mass reach

- Requires L1-trigger to fully exploit LLP potential

- ~50 ps resolution available at HL-LHC

- Next generation detectors (FCC-hh) below 5 ps? — IF input

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Experimental Considerations

- Study LLP physics reach as a function of detector timing resolution
  - Input to and from Instrumentation Frontier
  - Technology development/limitations very important
  - DAQ and L1 critical to unlock full LLP potential
    - see some trigger discussion in the next slide

- Define simplified models to allow comparison with other approaches
  - Will work with MC Task Force

- The authors have been working on these studies for several years — on phenomenology and detector development.
  - Snowmass great platform to complete these forward-looking studies

LLPs and Precision Timing
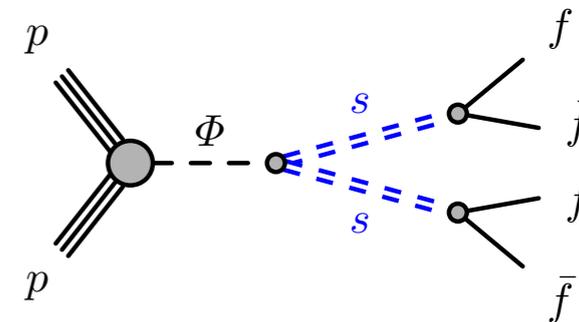
- Use **Timing** (MTD or ECAL) to tag Jets at L1
  - 30 ps for 20 GeV neutral energy deposits in ECAL
 - 30 ps for MIPS
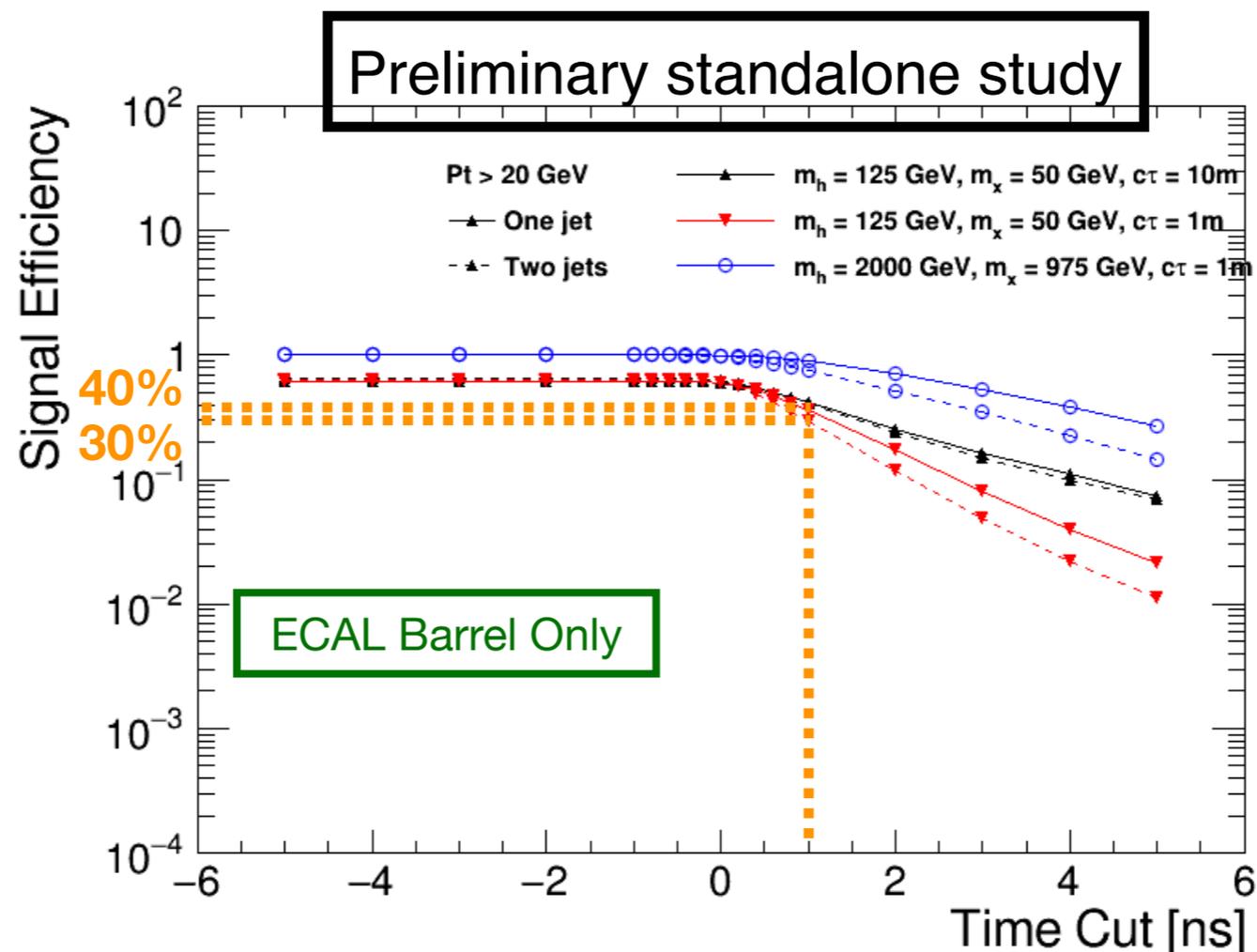
M_h = 125 GeV

M_x = 50 GeV, $c\tau$ = 1m

Final results expected
for CMS L1-TDR

- Jet pT > 20 GeV and EB time > **1ns**

- One jet trigger → signal efficiency is around **40%**
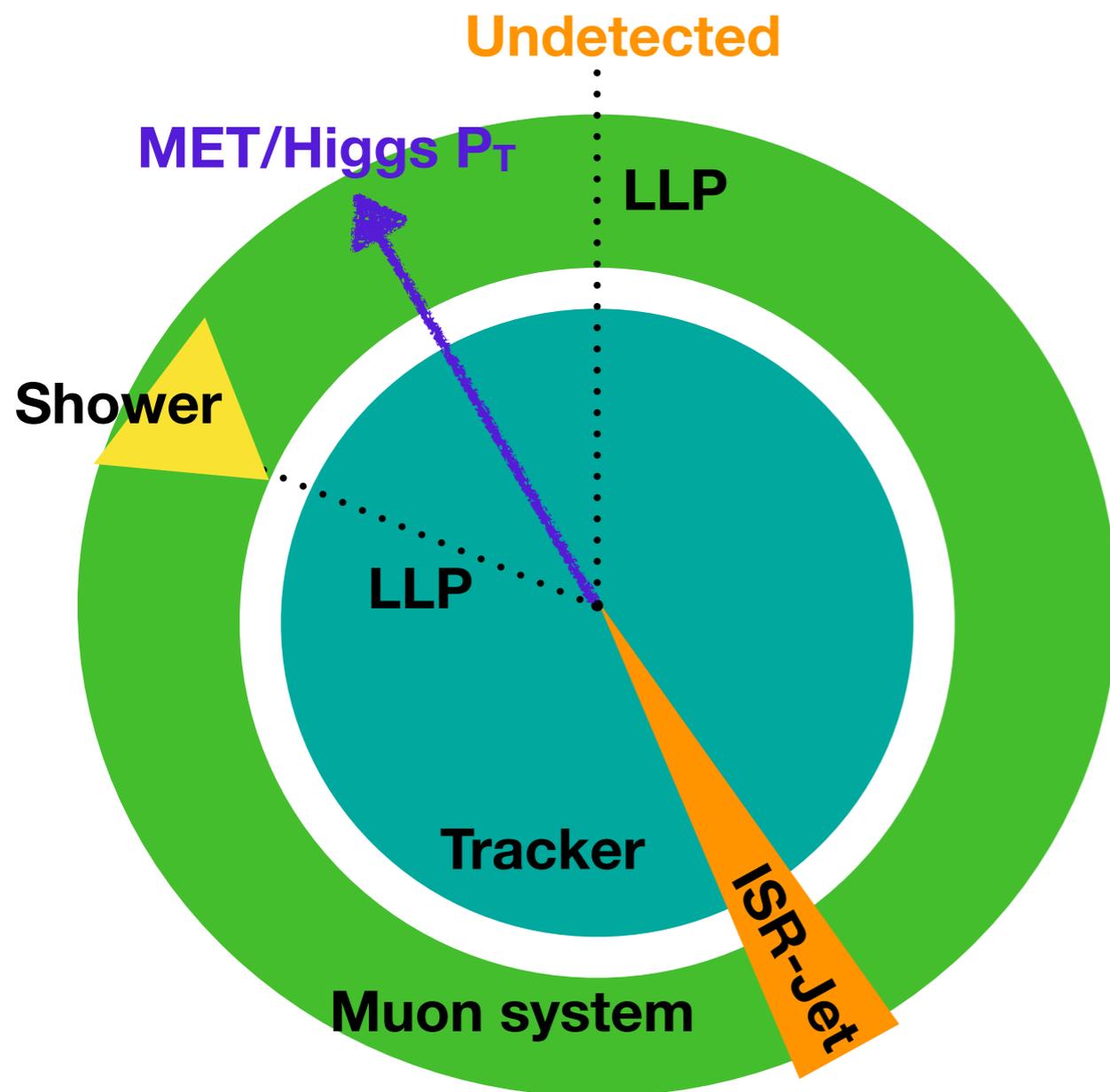
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Endcap Muon Systems: example CMS

- **Large shielding**: up to 27 nuclear interaction lengths of iron

- **Several layers of active material**: muon system as a sampling calorimeter

- Large shielding allows to massively **suppress background**
  - dominant remaining backgrounds: neural SM-LLP from pileup

- Highly **sensitive to LLPs with large range of masses**. Detector measures LLP energy not only mass
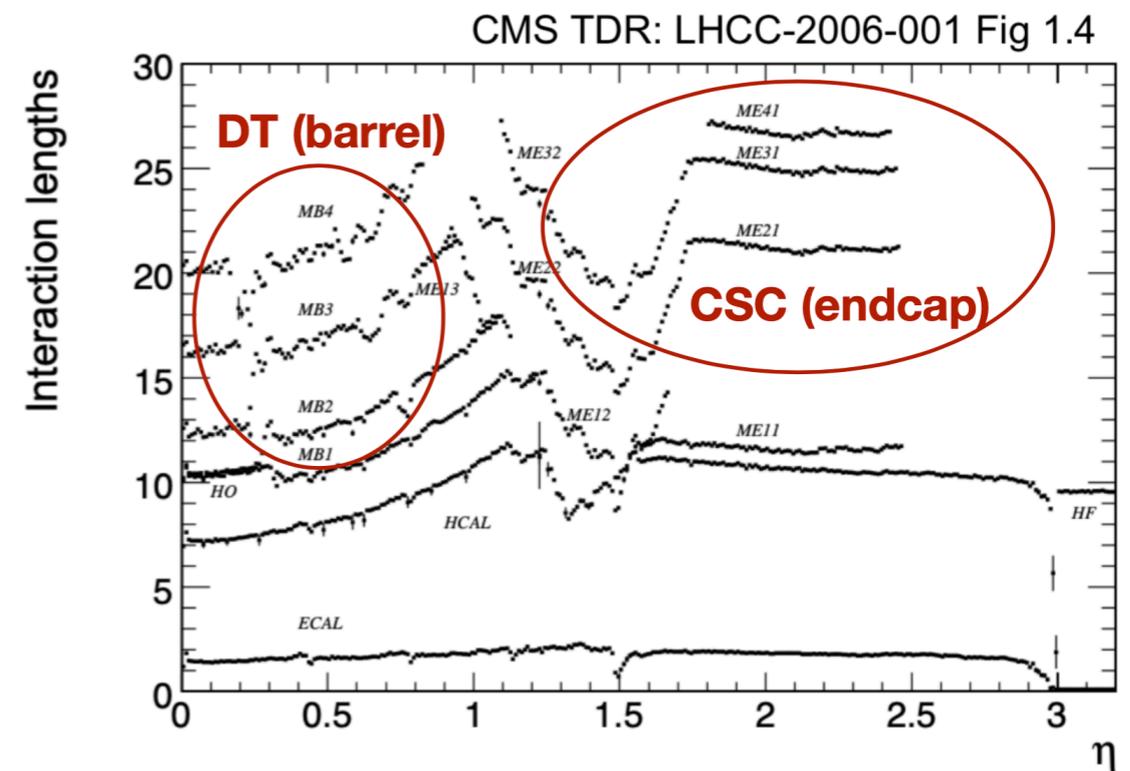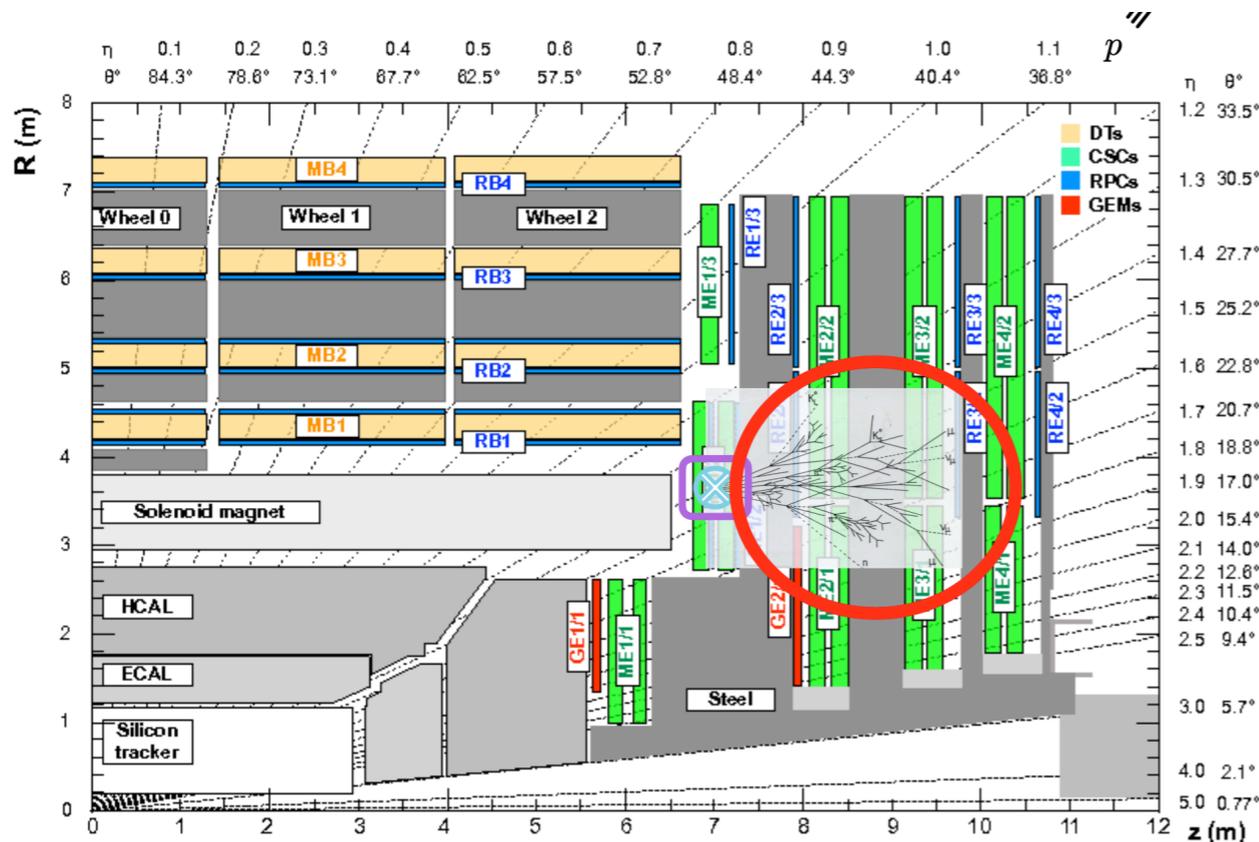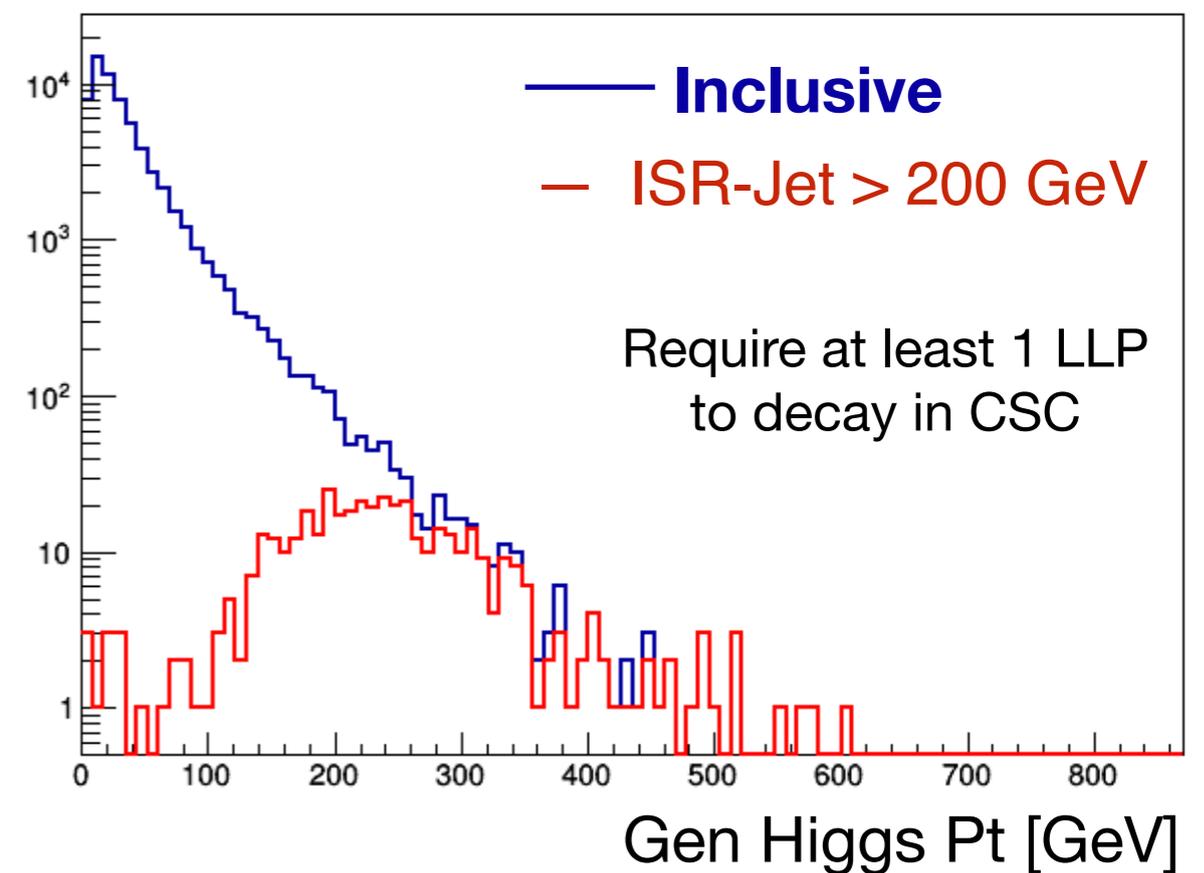
Muon System Analysis: current status

- In H→SS model. ggH allows Run2 search due to the large cross section
- Trigger on **MET (lack of dedicated trigger)** from recoil of Higgs against ISR
  - For large cτ one of the LLPs will decay outside the calorimeter

- ~1% signal events kept after MET cut
- **~4500 events in acceptance**

Require at least 1 LLP to decay in CSC

Gen Higgs Pt [GeV]

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LLP Muon Systems Study

- CMS presented a plan for a **dedicated L1 trigger for Run3**

  - S. Dildick @ 7th LHC LLP Workshop

  - Cathode Strip Chambers allow to count raw hit multiplicity → **10x gains in trigger efficiency**

- Study LLP potential of CMS Muon System for Run3 and HL-LHC to a wide range of representative models

  - Different LLP decays: quarks, gluons, hadrons, photons, leptons

  - Sensitivity to light LLP produced through Higgs, W and Z bosons

- Build upon HL-LHC sensitivity study to optimize FCC-hh Muon System design

- Looking forward to working on this group

Backup

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HL-LHC Beamspot

- Beamspot has a width in time of ~180ps