

SEARCH FOR LONG-LIVED PARTICLES AT CMS

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Gearing Up for LHC 13

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DIPARTIMENTO DI FISICA



SAPIENZA
UNIVERSITÀ DI ROMA



OUTLINE

- Most exotic part of exotic program
- Search for long-lived particles relies on detector features more than other exotic searches
 - dedicated trigger
 - ▶ stopped particles
 - dedicated reconstruction algorithms
 - ▶ muon reconstruction: heavy stable charged particles
 - ▶ tracking: disappearing tracks
 - dedicated detector calibration
 - ▶ ECAL time calibration
- Many searches in Run I but no discrepancy or excess
- Only a selection of searches discussed in this talk
 - not latest nor best known
- *Identify strategies and searches with highest potential for Run2 in light of Run I **non-excesses** and some **wishful excesses***

LONG-LIVED APPROACHES

- Delayed tracks
 - classic heavy stable charged particles
- Tracks with large impact parameters
 - standalone muons in muons system
 - two or more tracks displaced from primary vertex
- Spatially displaced vertices
 - both for high and low mass particles
 - some dedicated tracking to increase efficiency for tracks displaced from primary vertex
- Displaced jets
 - relies on displaced tracks
- Delayed photons
 - measurement of time of flight with ECAL
 - photon conversions

LONG-LIVED PICTURE

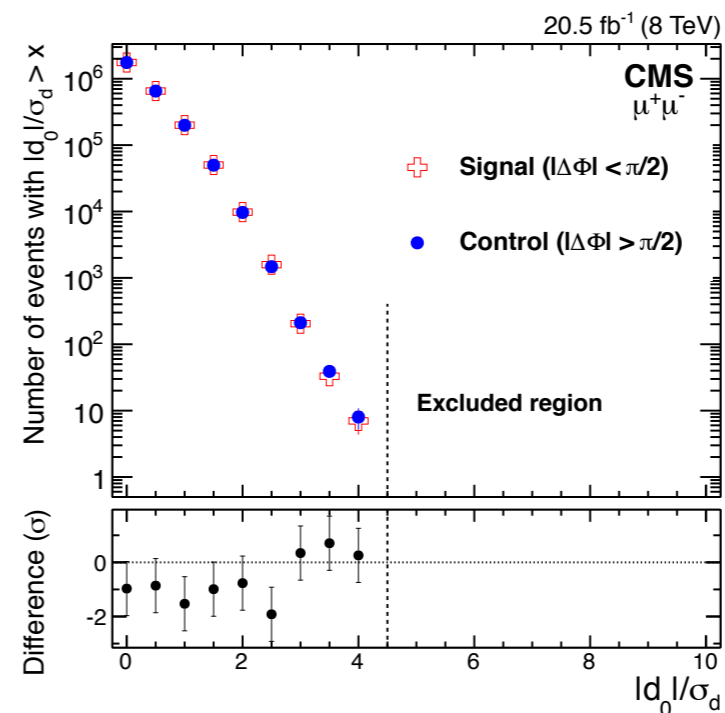
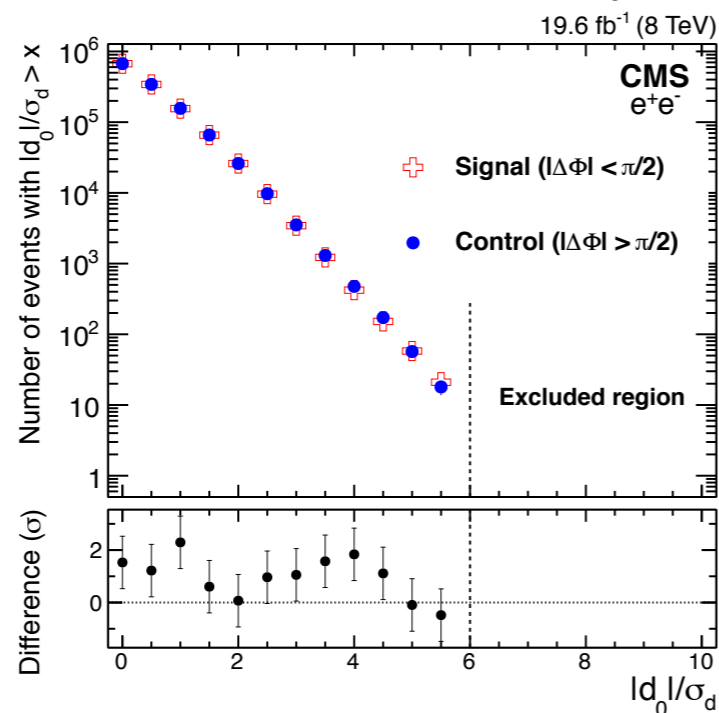
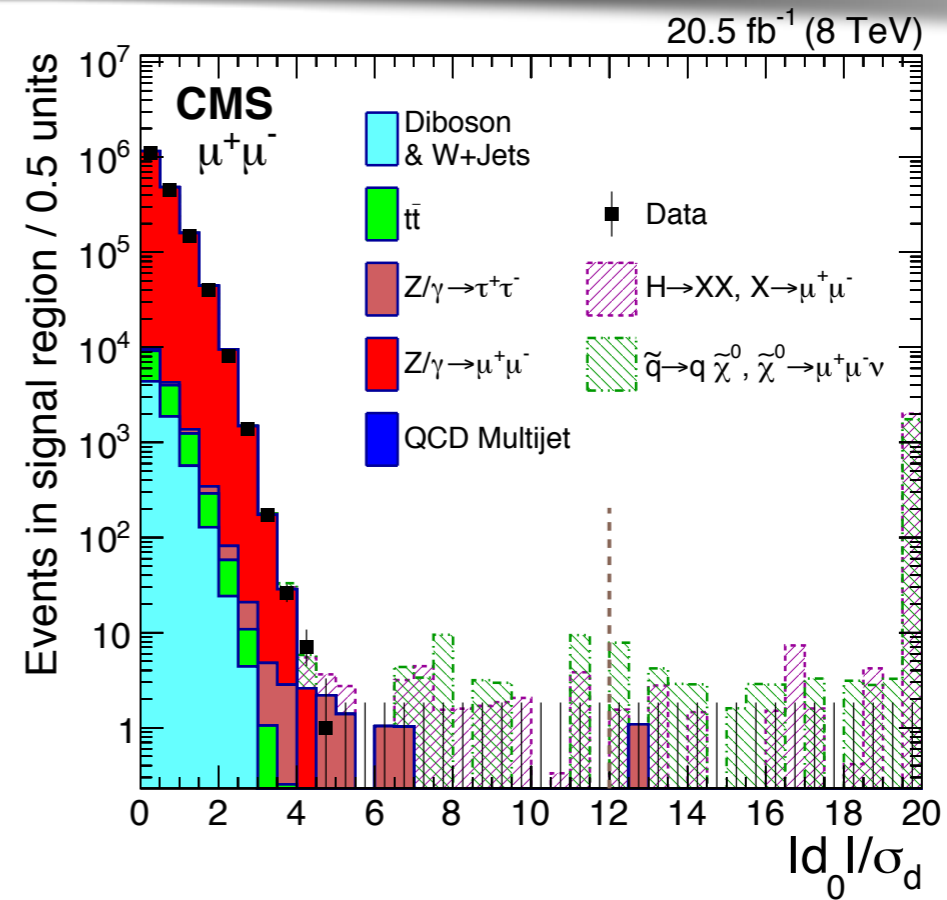
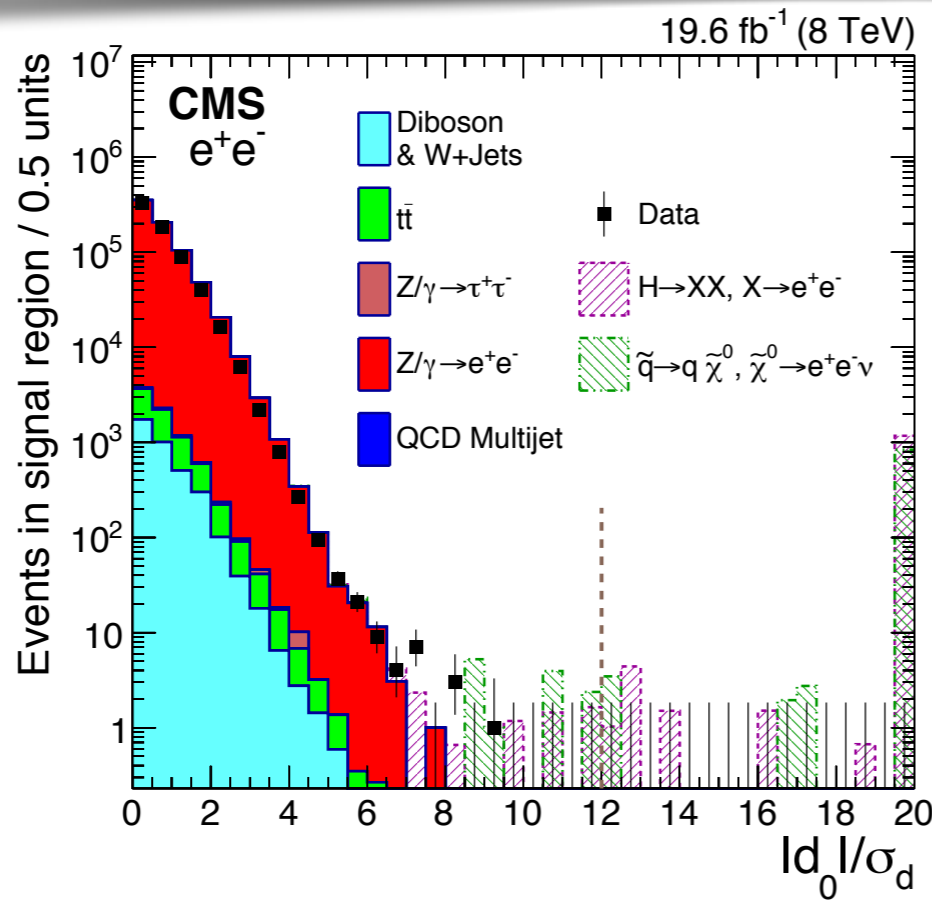
Detector Understanding (time)

- Delayed charged tracks
- Tracks with large impact parameters
- Spatially displaced vertices
- Displaced Jets
- Delayed photons

Models for Reinterpretation

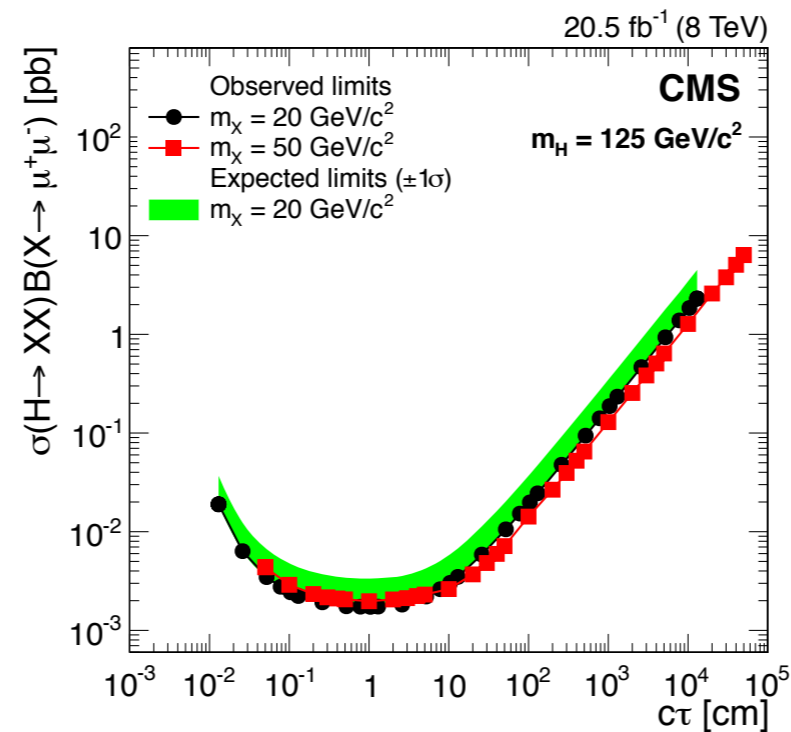
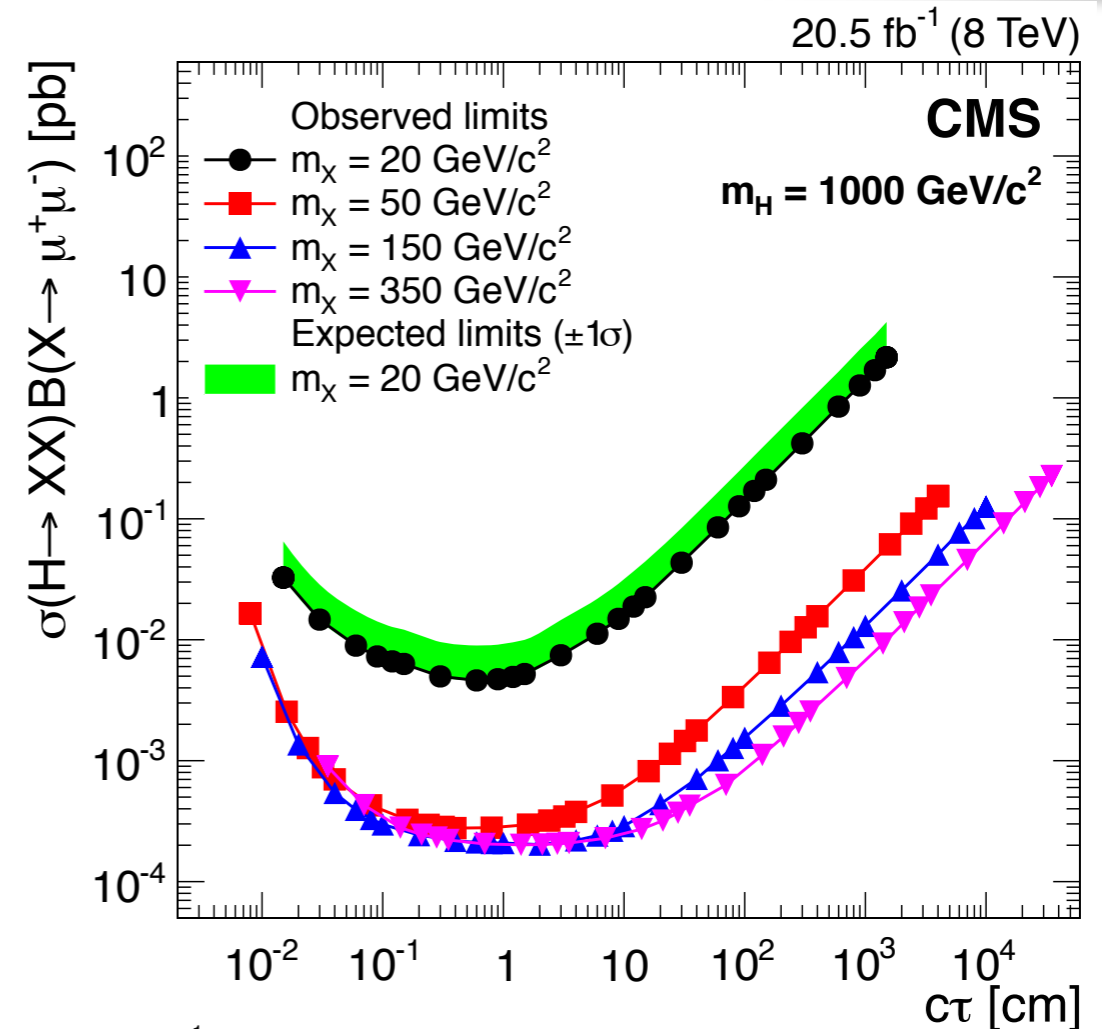
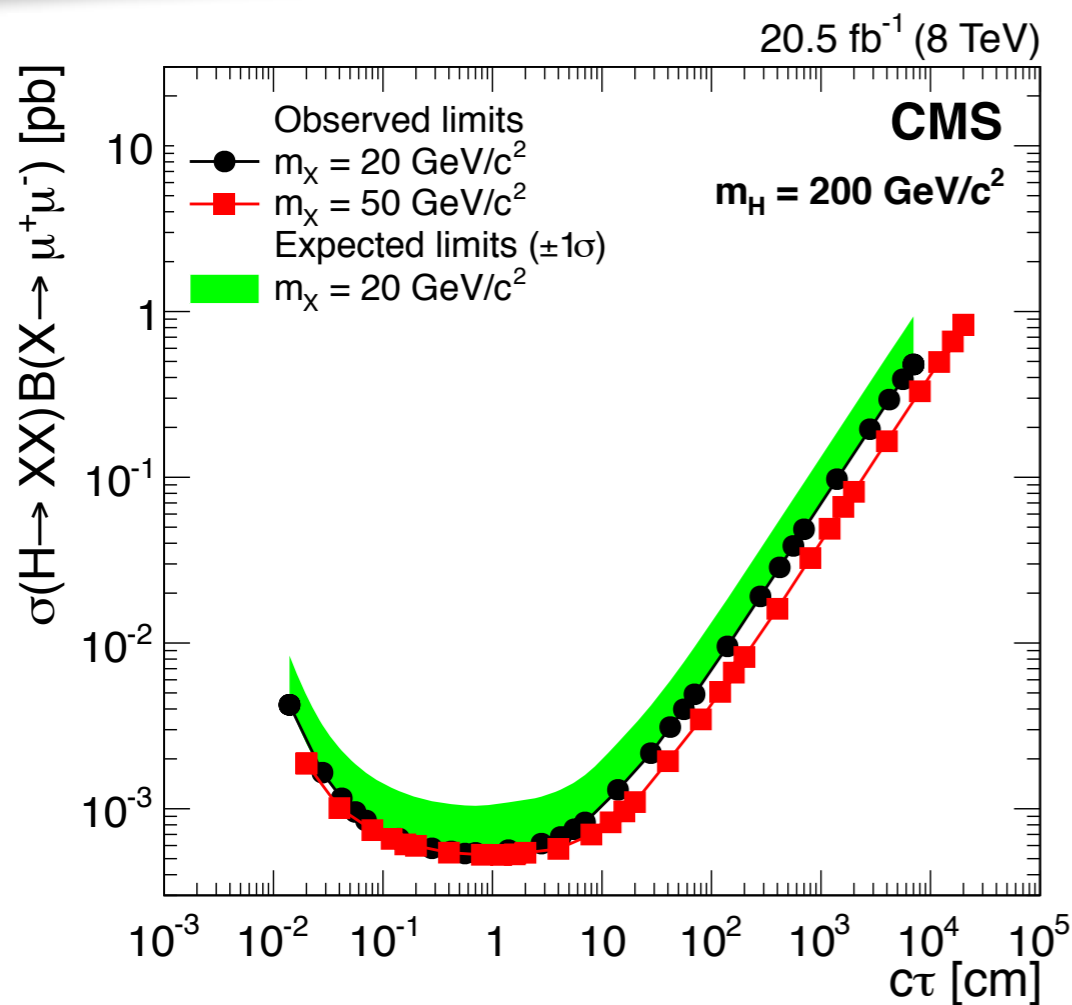
DISPLACED VERTEX

EXO-12-037

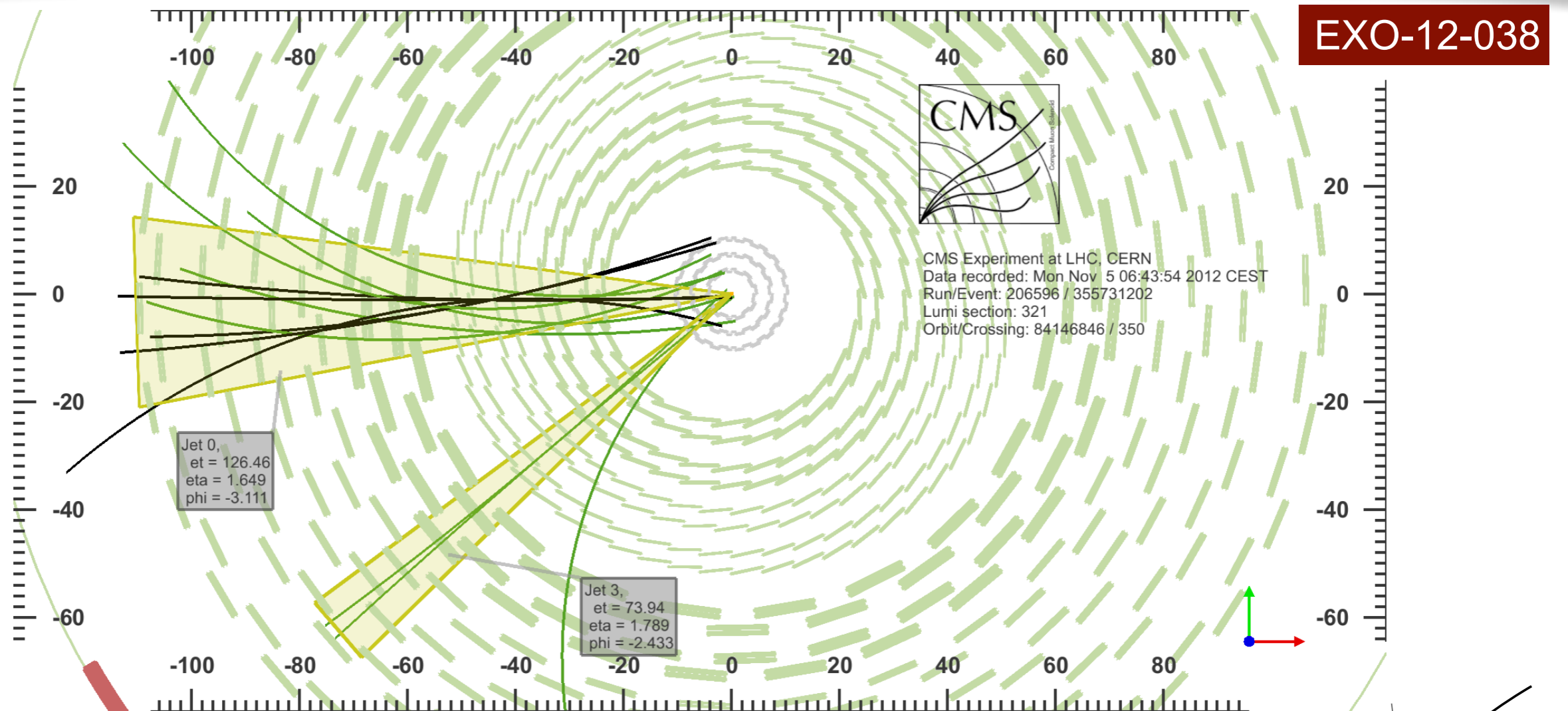


- Displaced di-lepton vertices from tracks with large impact parameter

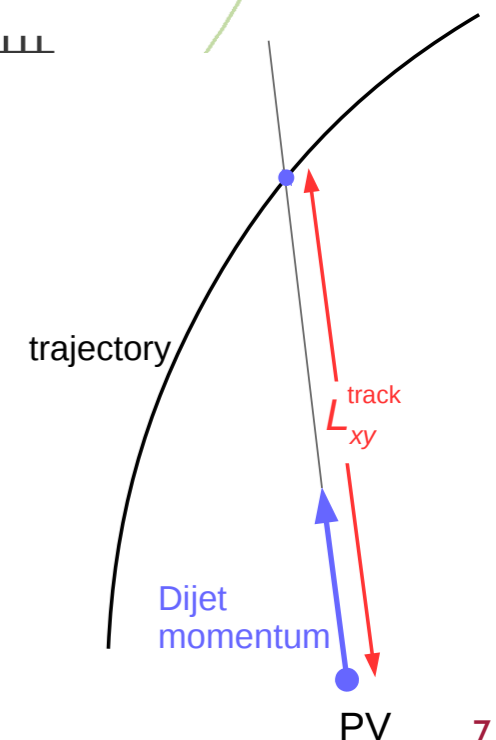
DISPLACED VERTEX INTERPRETATION



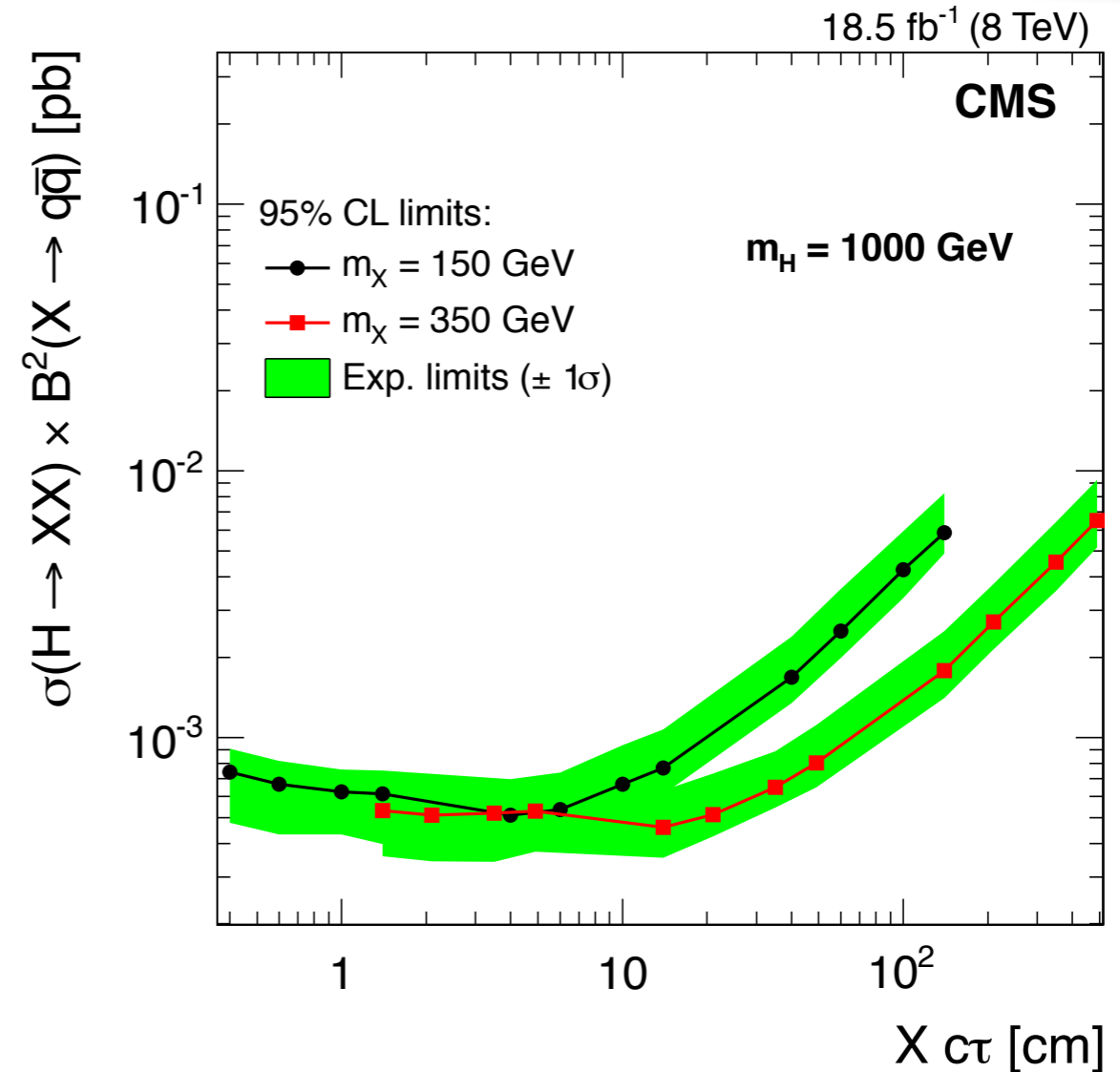
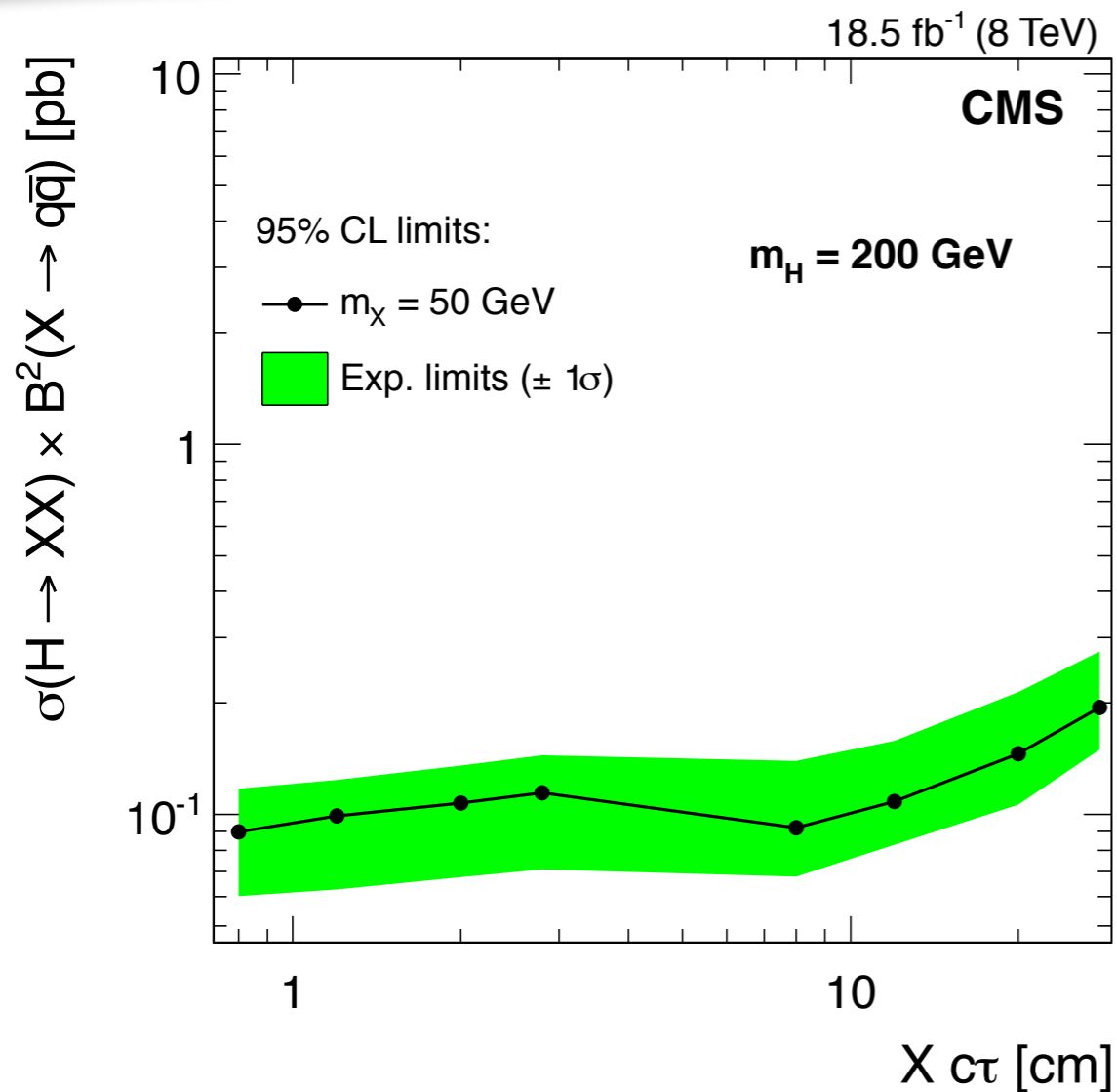
DISPLACED JETS



- Dedicated trigger
 - 2 jets with displaced tracks selected at High Level Trigger
- Only track and vertex information used

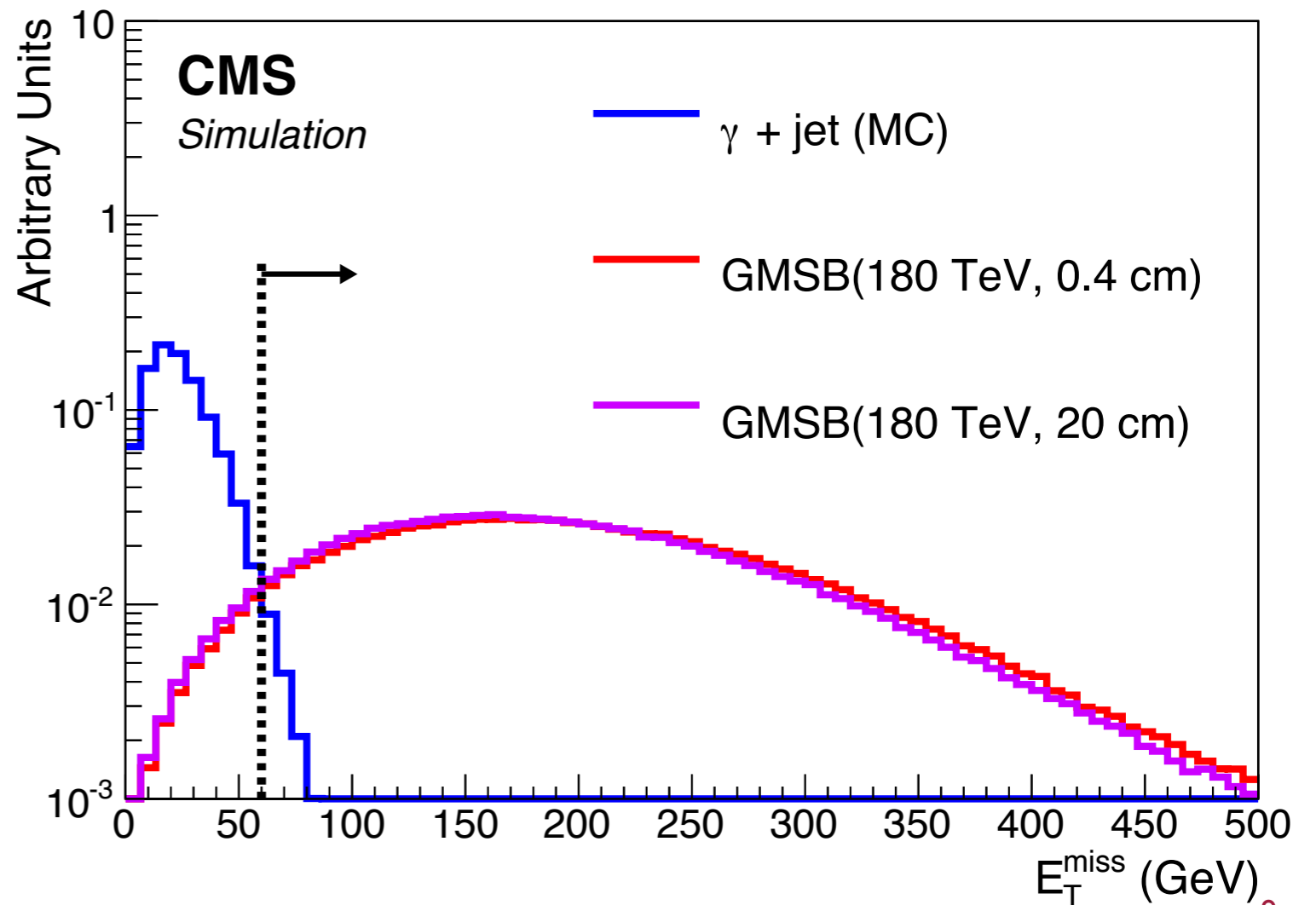
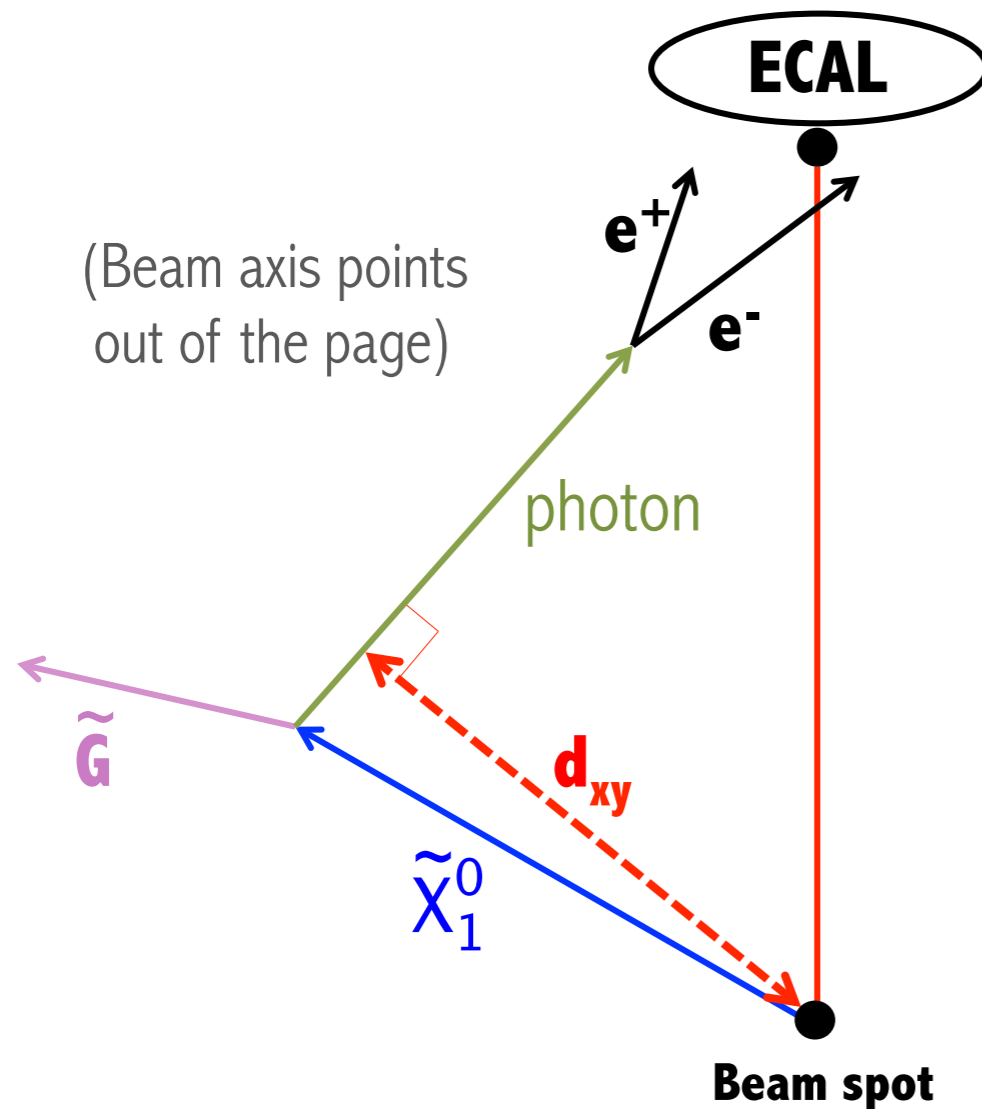
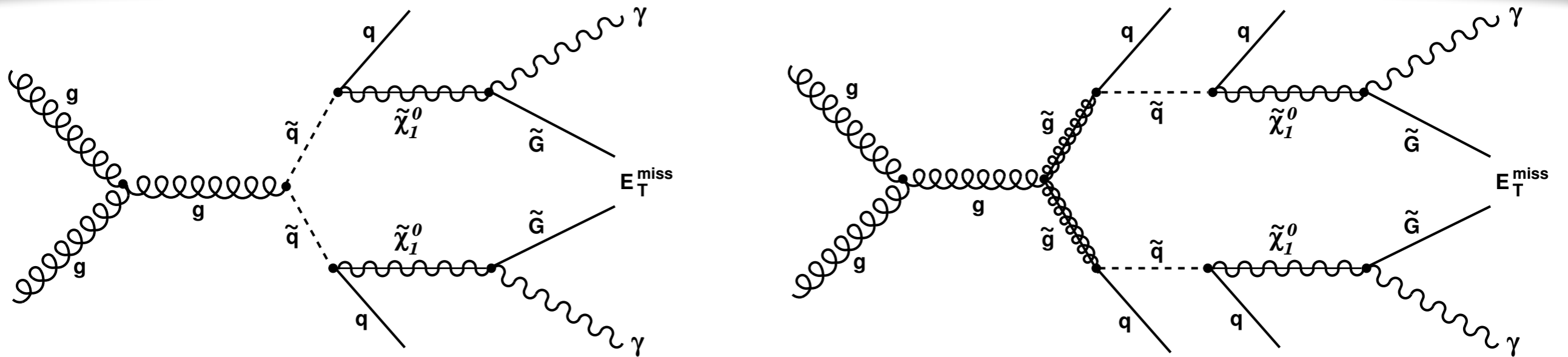


DISPLACED JET INTERPRETATION

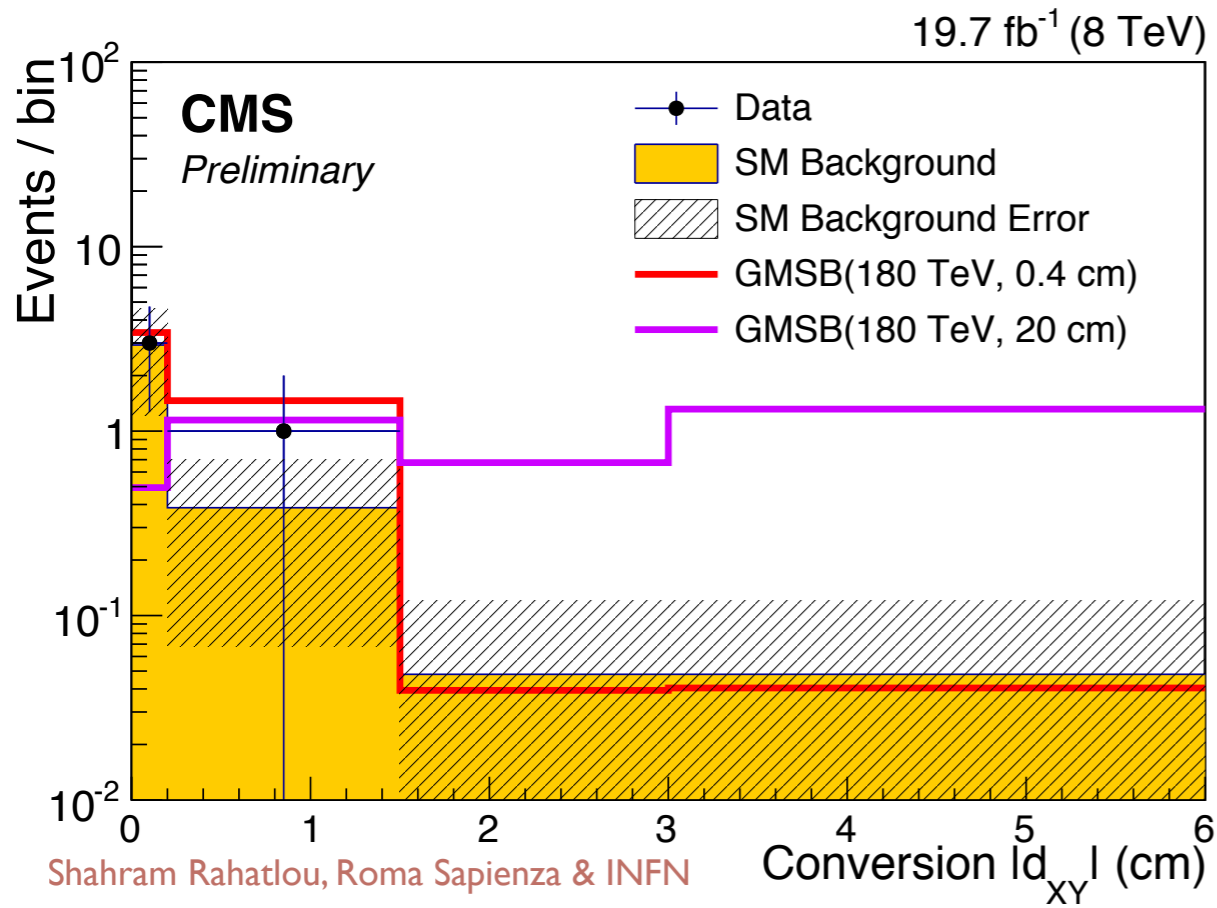
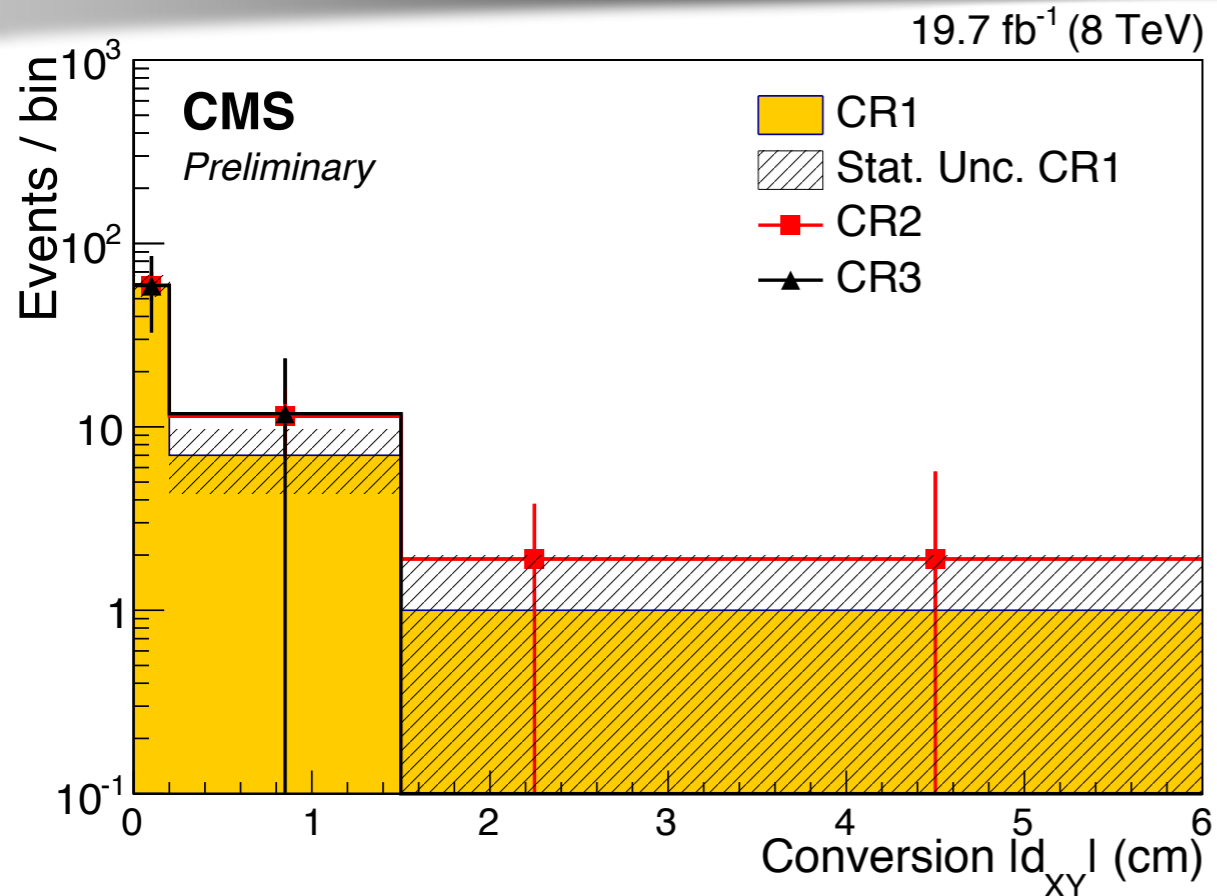


- Higgs-like interpretation remains a favorite benchmark
- Addition of ECAL time information in Run2 under study

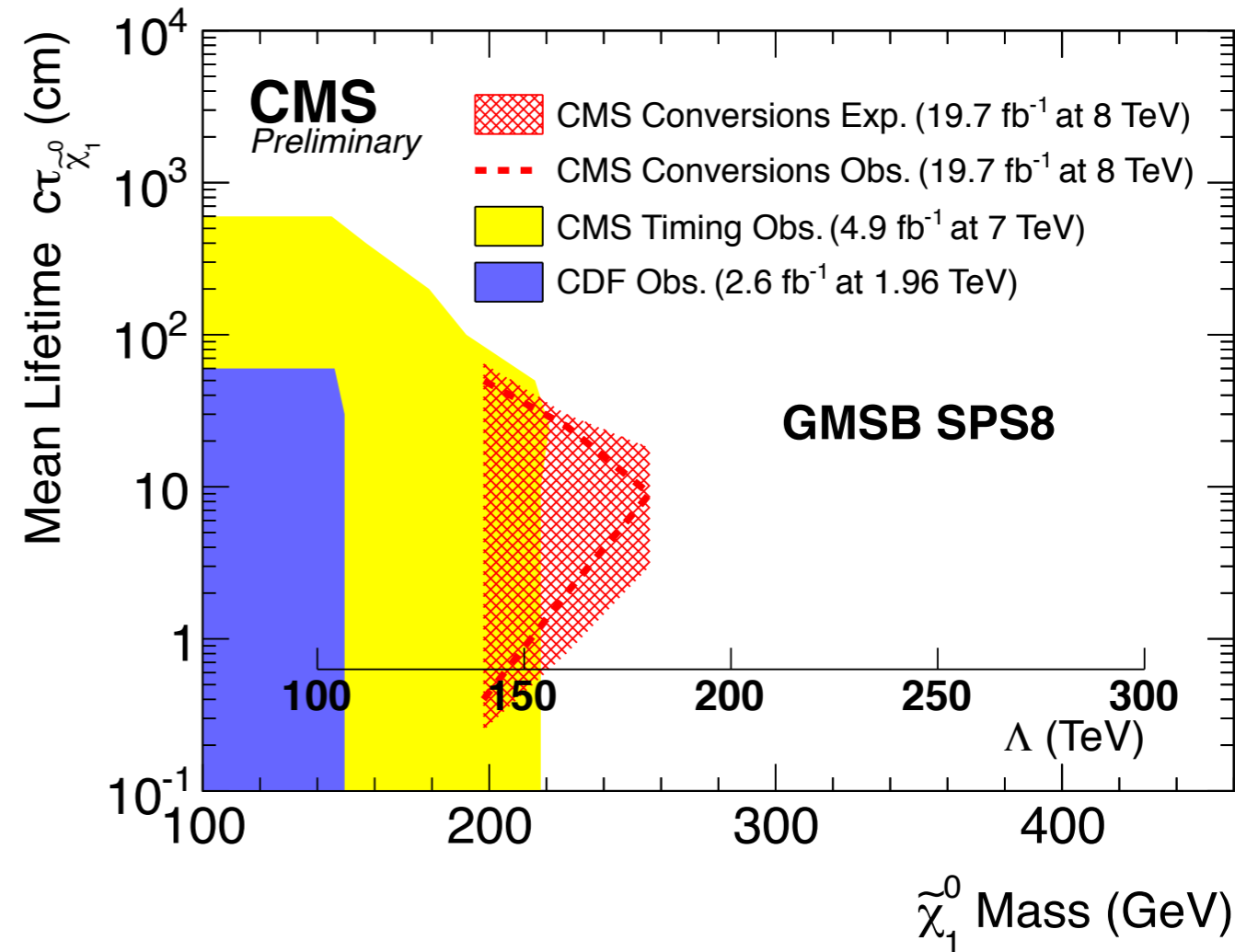
DELAYED CONVERTED PHOTONS



LONG-LIVED NEUTRALINO

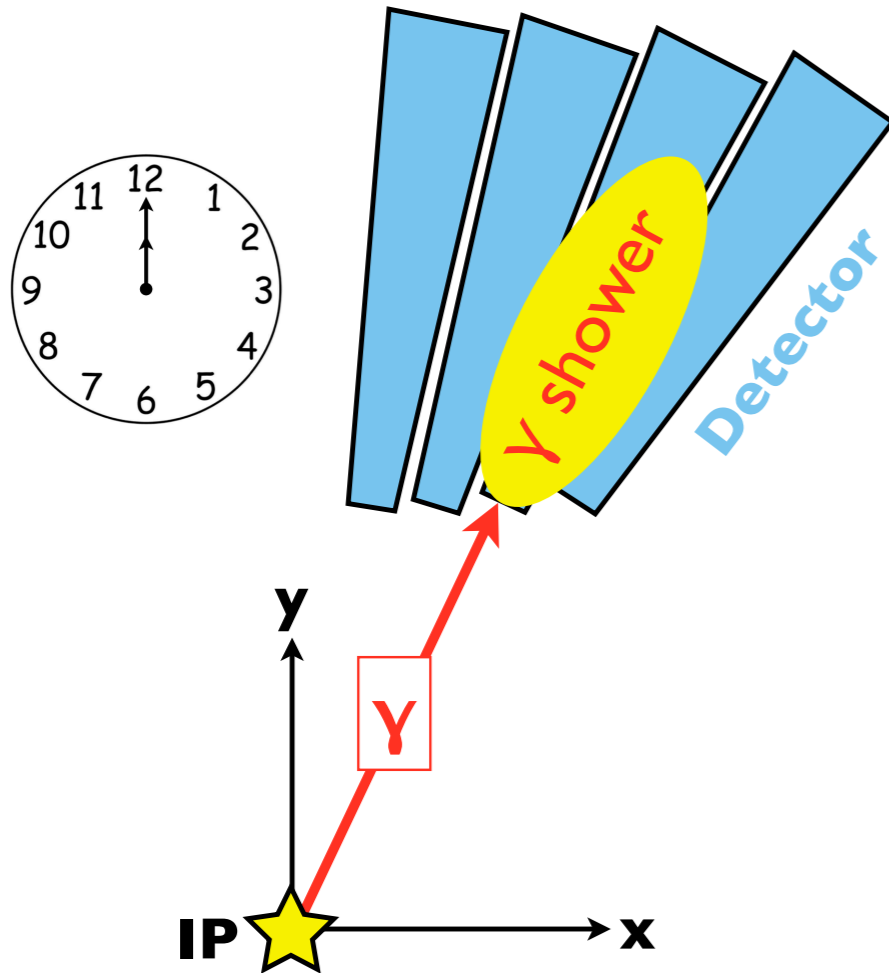


EXO-14-017



DELAYED PHOTON WITH TIMING

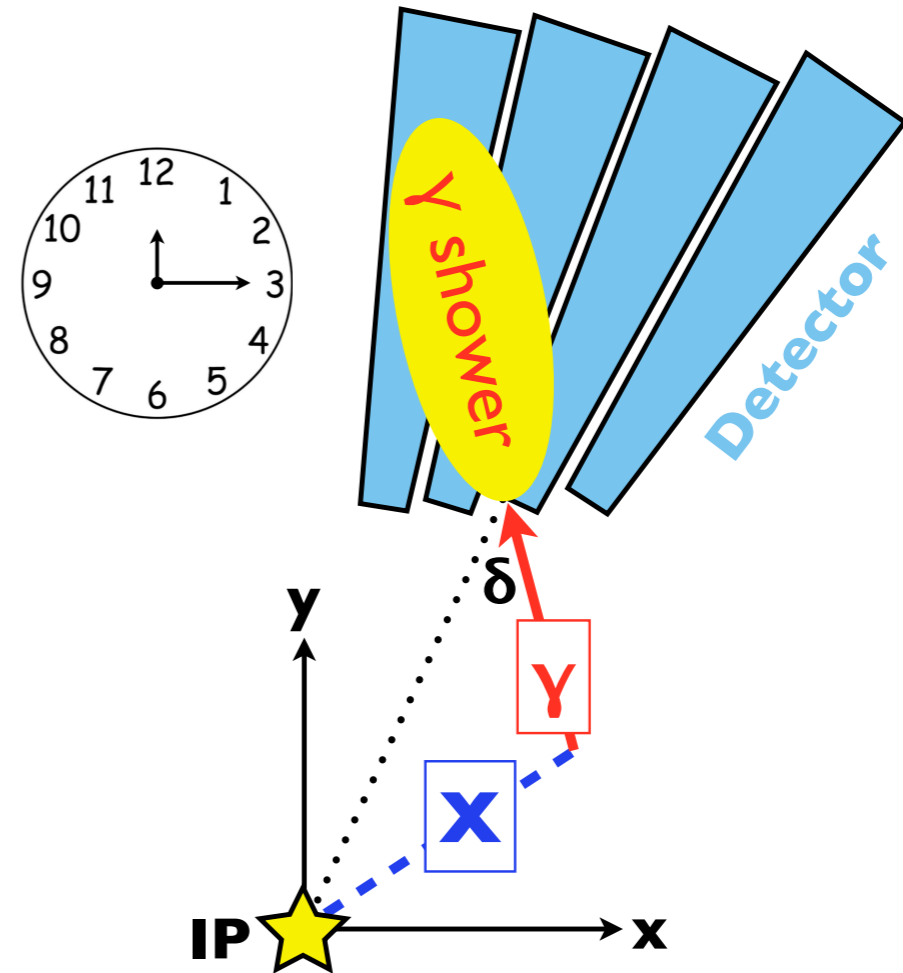
Zero lifetime



In-time photon

➔ Arrival time compatible with that of a relativistic particle from the IP

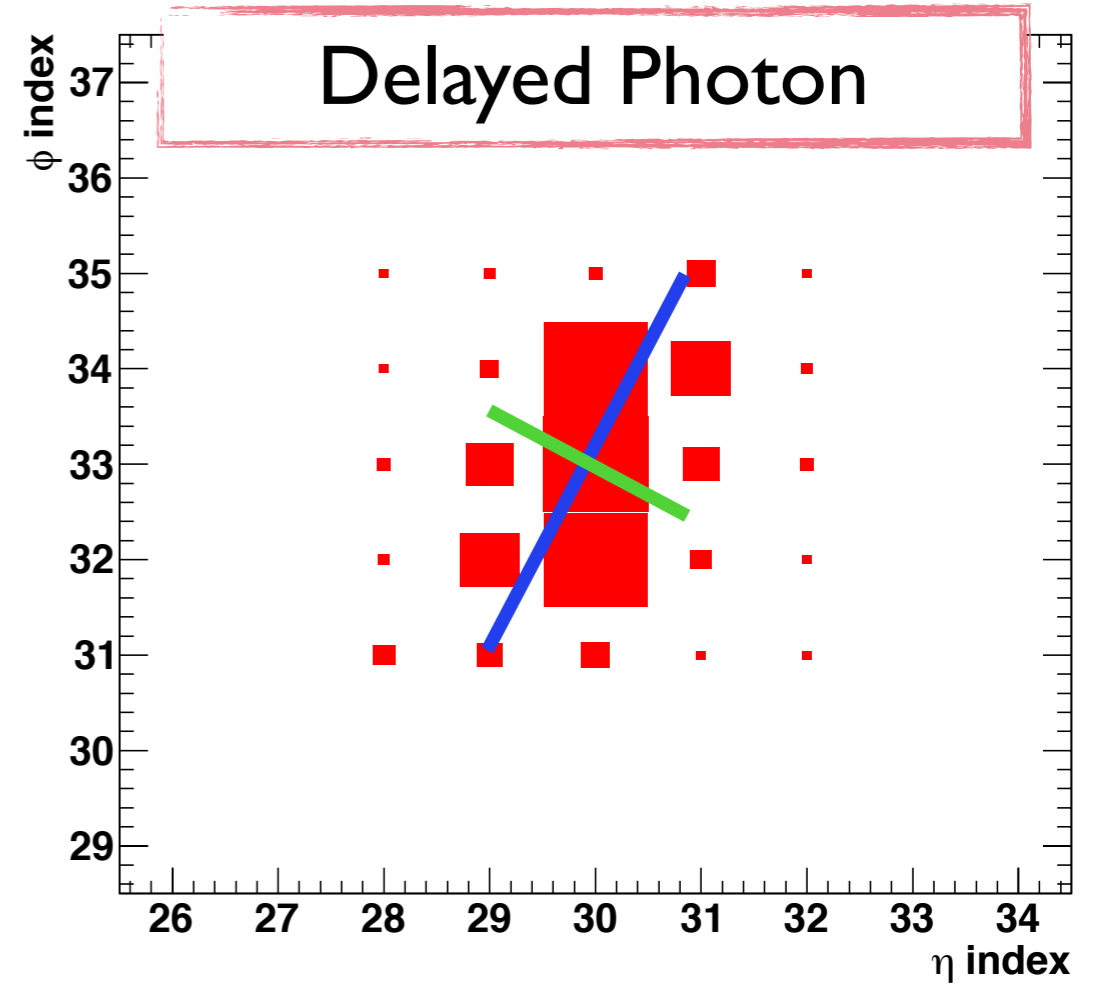
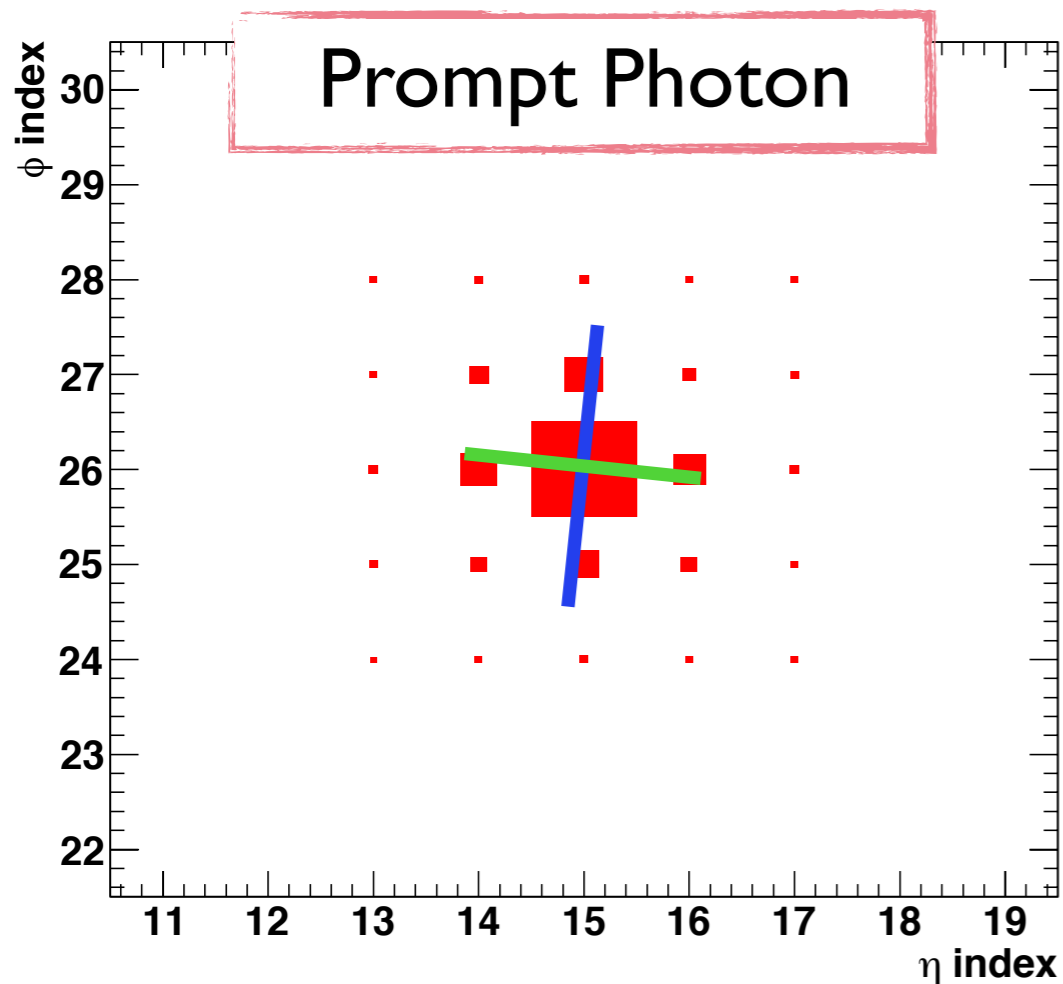
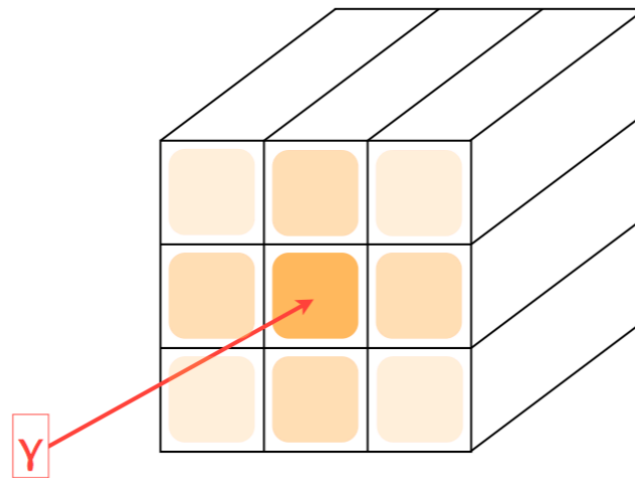
Non-zero lifetime



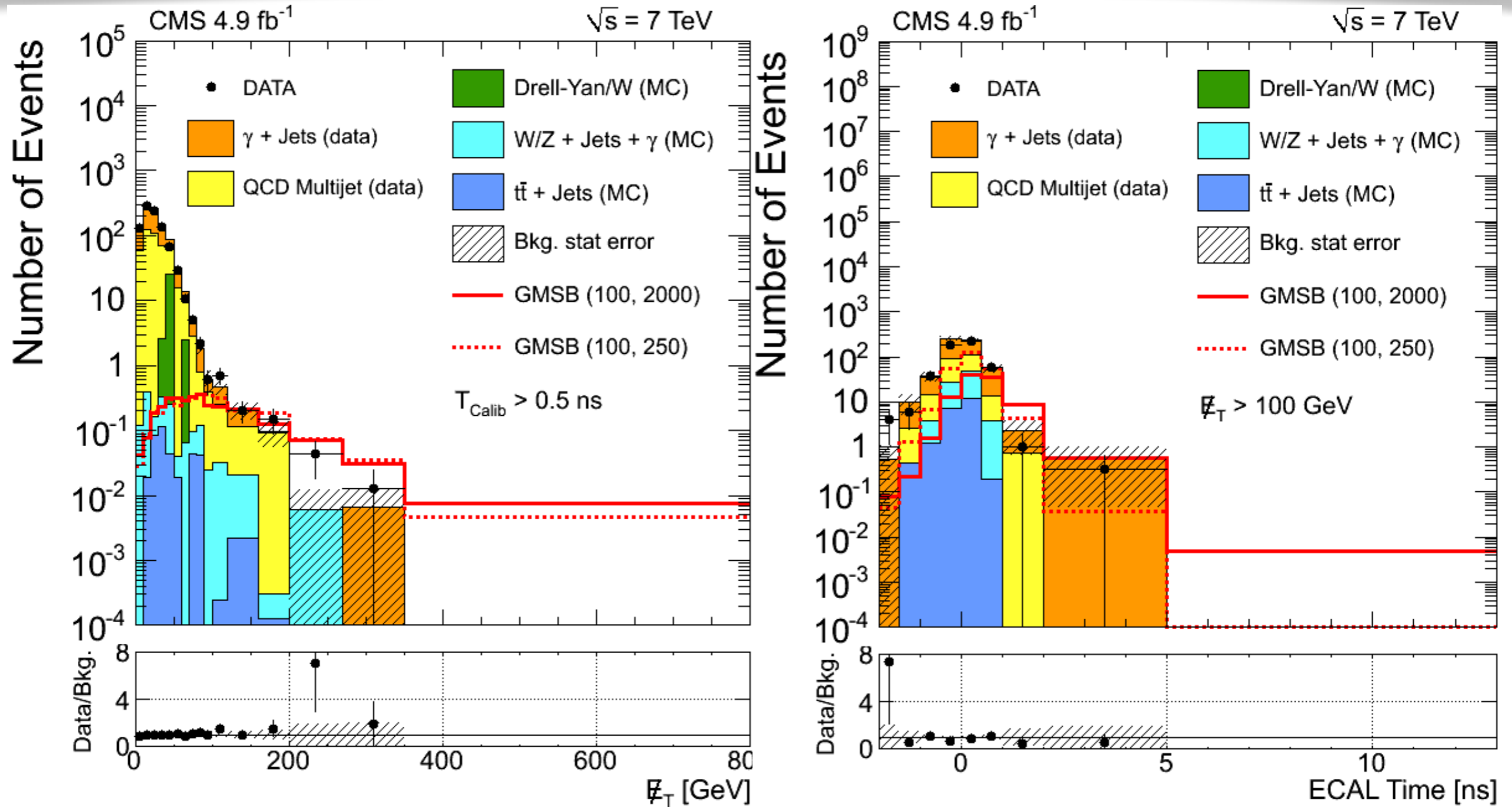
Off-time photon

➔ Arrival time sensibly increases with parent particle lifetime
➔ $\Delta T \sim O(\text{ns})$

SHAPE OF PHOTONS IN CALORIMETER



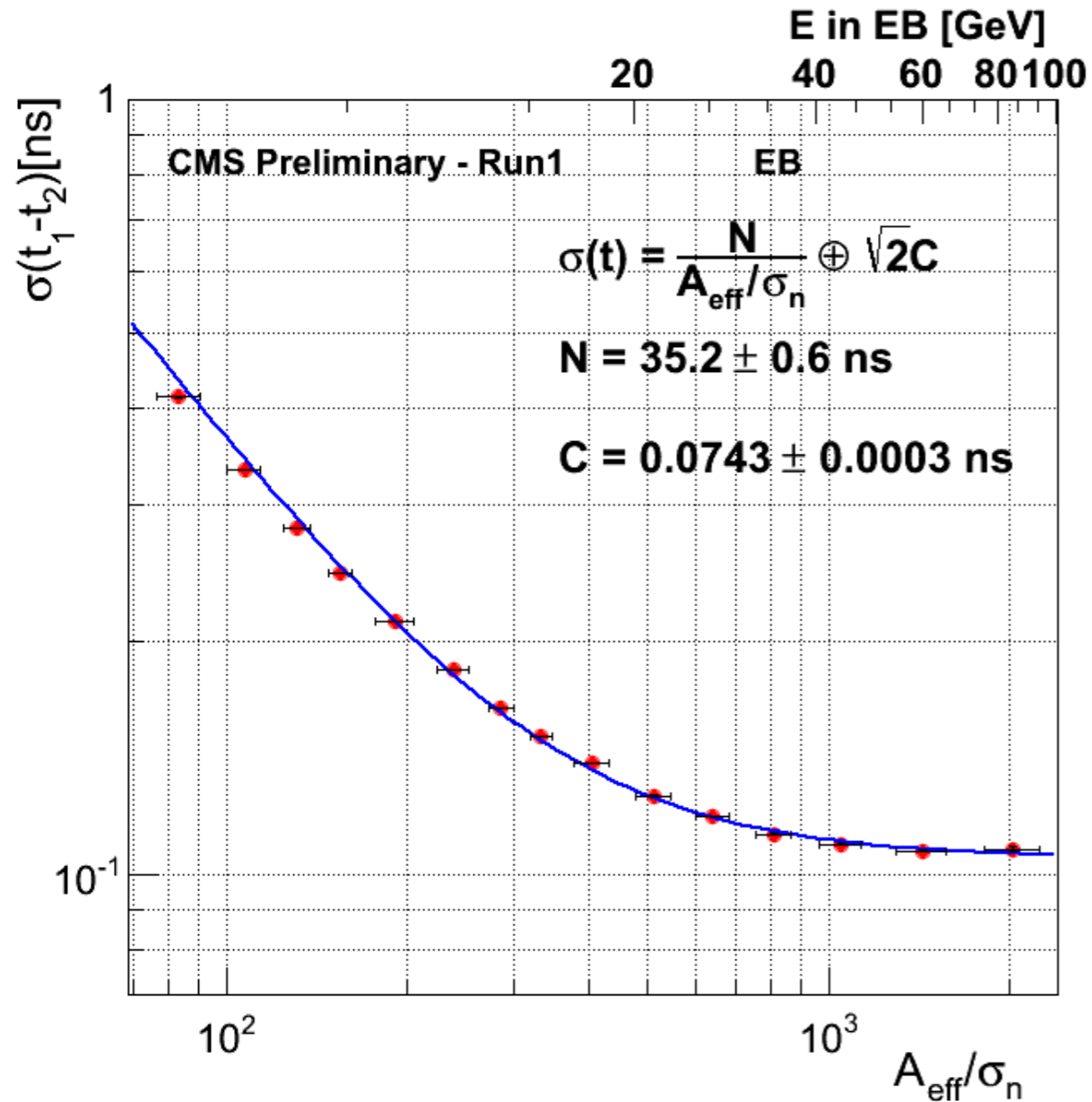
DELAYED PHOTONS IN 7 TEV DATA



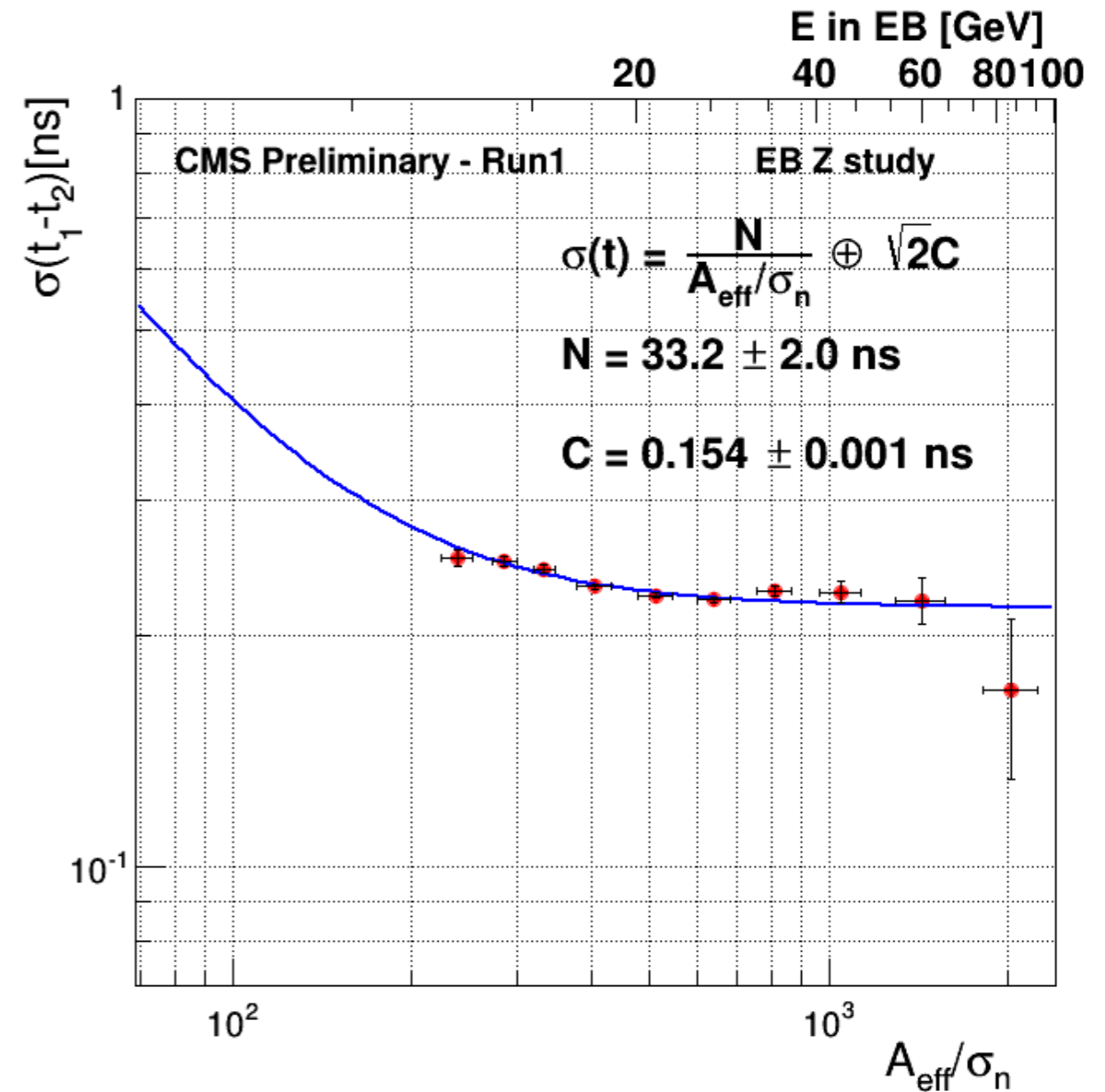
- This analysis requires detailed study and calibration of ECAL time measurement
 - No other physics client than this analysis so far

EXO-11-035

ECAL TIME RESOLUTION

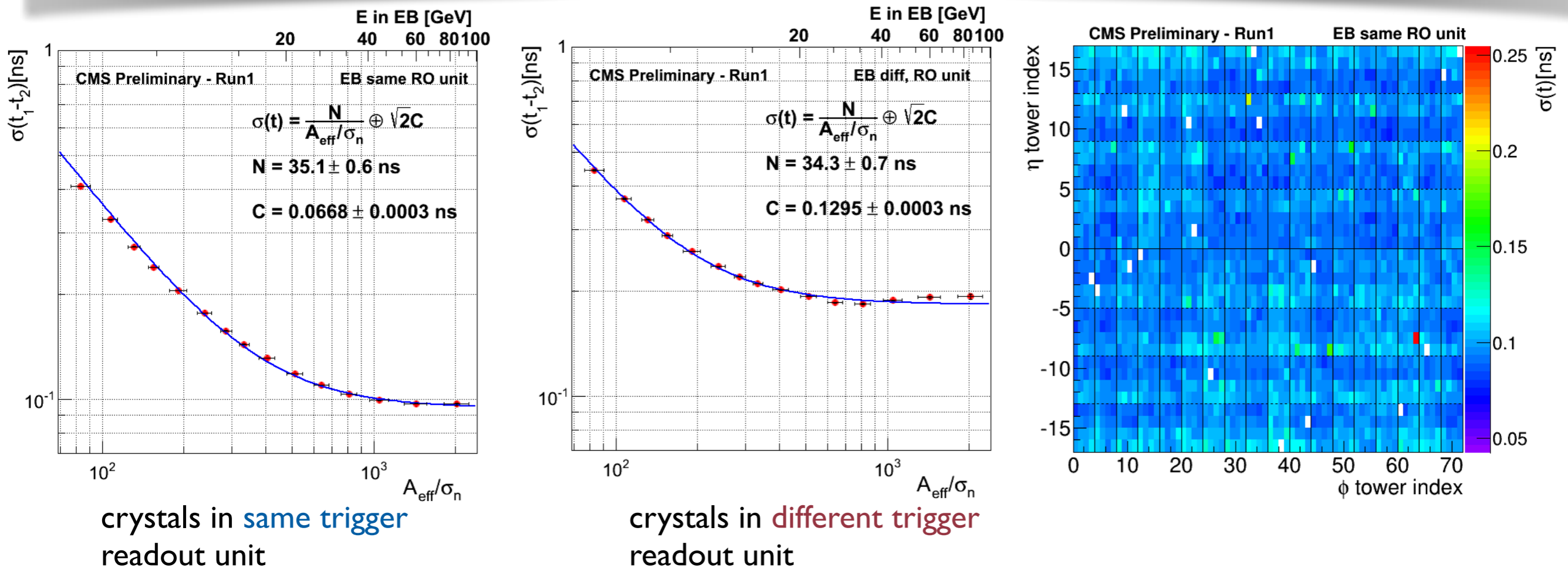


- $E_1, E_2 < 120 \text{ GeV}$
- $|E_1/E_2| < 1.2$



- $E_1, E_2 > 10 \text{ GeV}$
- $E_1, E_2 < 120 \text{ GeV}$
- $60 \text{ GeV} < m_{ee}(e_1, e_2) < 150 \text{ GeV}$

ULTIMATE ECAL RESOLUTION



crystals in **same trigger** readout unit

crystals in **different trigger** readout unit

- Limiting factors in ECAL time resolution (compared to design) identified
 - upgrade of ECAL barrel electronics part of Phase 2 program
 - distribution of clock to each crystal one of primary challenges
 - Pile-up mitigation is the best known motivation
 - *But long-lived particles will be an important physics client*
- ECAL time measurement so far has been used only in one physics analysis!

FOOD FOR THOUGHT

- Extensive SUSY program at Run I indicates any preferred or favorite corner of parameter space for long-lived particles?
- Can we do more than the two primary benchmarks?
 - Higgs-like decays to X pairs
 - ▶ 3 free parameters
 - squark decays to neutralino + X
- Which searches are worth upgrading (e.g. use of time information) rather than just adding up data
- Are photons really so lonely?

OUTLOOK

- Search for long-lived particles use simple and basic detector information
 - unlike some of *sophisticated* variables needed in many Higgs and BSM searches
- Deeper understanding of detector response typically implies longer time scale for long-lived searches
 - and longer term detector activity commitment
- Displaced vertices remain perhaps most profitable approach
 - results can be interpreted in many models, specially in terms of **some flavor of some Higgs-like particle**
 - ▶ *Higgs remains a catchy name*
- Time of flight for photons and electrons requires heavy investment in detector studies but can pay dividends
 - clean experimental signature
 - unfortunately not enough theoretical models to get people excited