Detector Requirements for New physics searches at the FCCee

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General Remarks

- BSM is a very broad subject
  - by spanning new physics models, one span all the possible detector requirements (timing, vertexing, energy and angular resolution, etc)
- FCCee has NP potential but the driving motivation is precision SM measurements
- One cannot motivate the detector cost just by BSM needs
- On the other hand, some "exotic" signature could be covered (possibly) at small cost
- We considered here some specific "benchmark"

New Physics from prompt particle

- Whatever model doesn't come with exotic signatures
- Typical example: SUSY ewkinos
- Not much to say on this
  - a detector capable of precision SM physics would be perfect
- Some special care with invisible particles, but that was studied already at depth

Detector design so far

(as we understood it…)

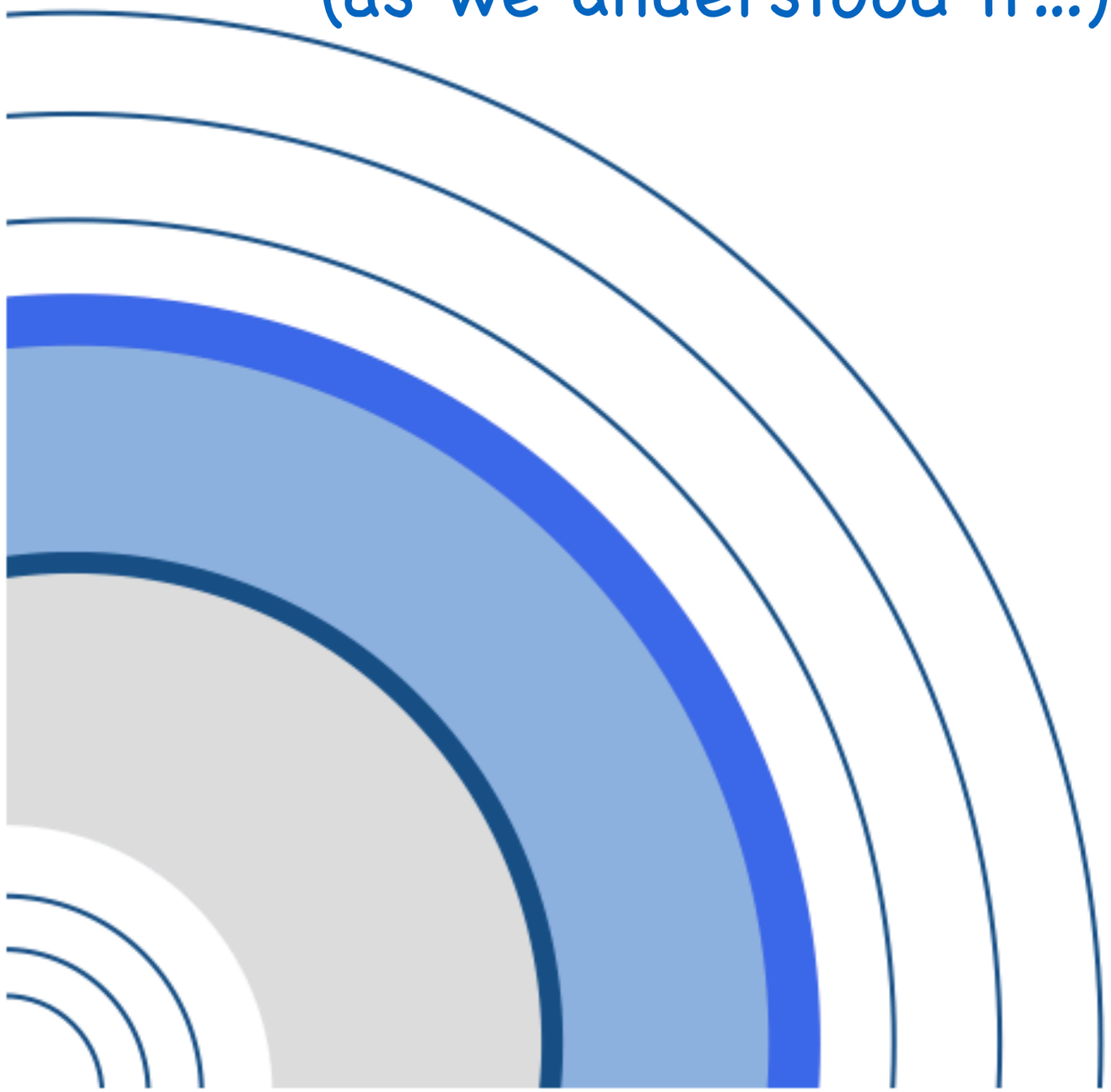
Outer tracker/
μ detector

Magnet

Dual readout calorimeter

Preshower

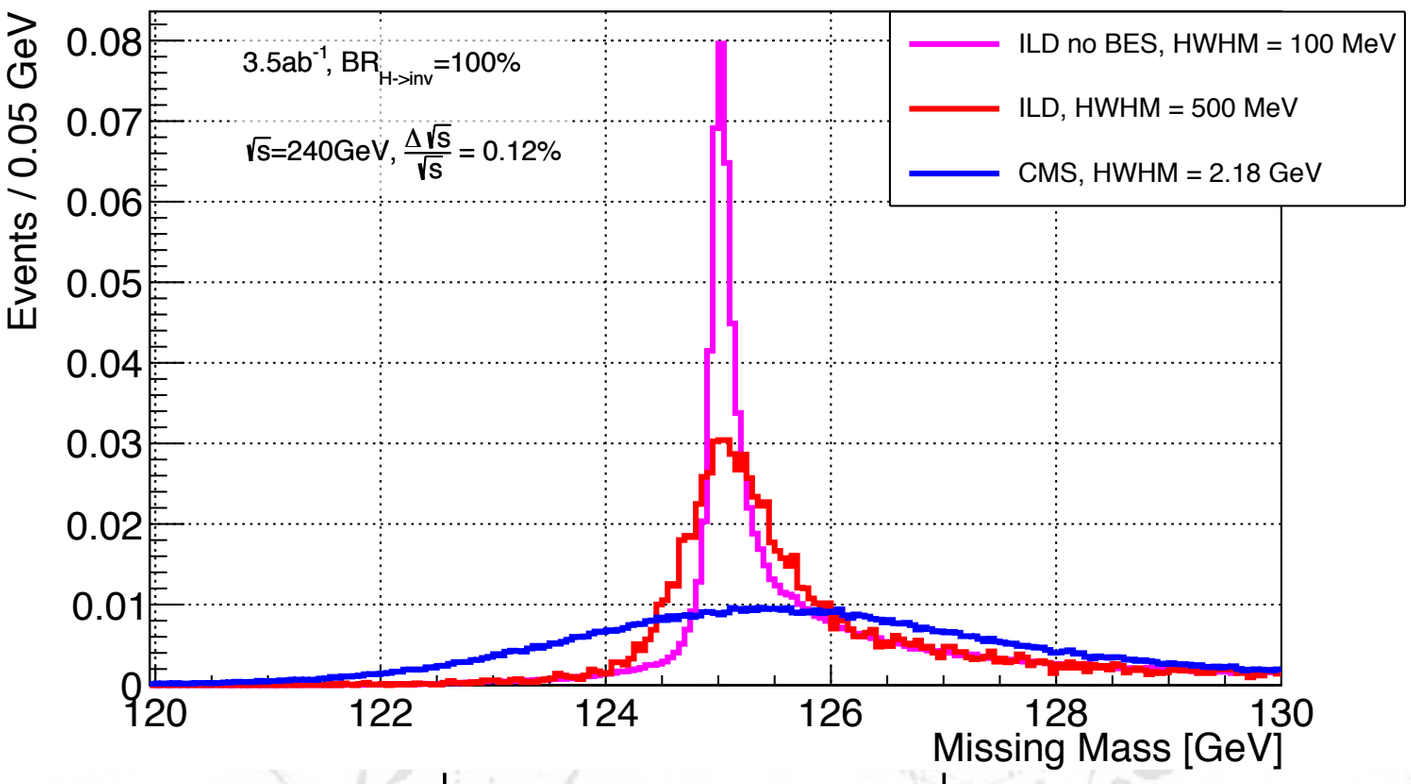
Inner
tracker



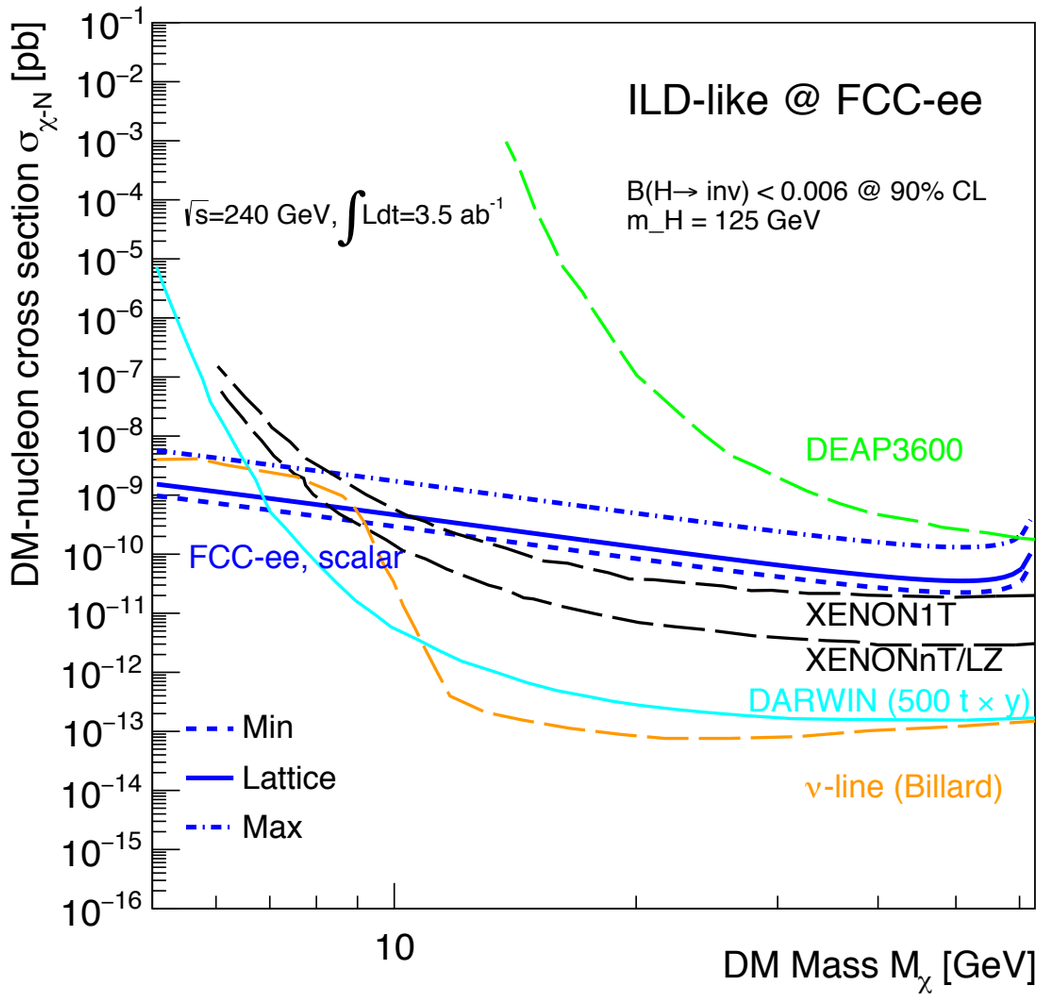
Invisible & tracker

- Detector resolution goals could be benchmarked with BSM sensitivity
- Used H-> invisible decays to study impact of tracking resolution vs energy spread

Simulated missing mass normalized distribution in HZ and Z→ l^+l^- tagged events (M_Z+/- 4 GeV)

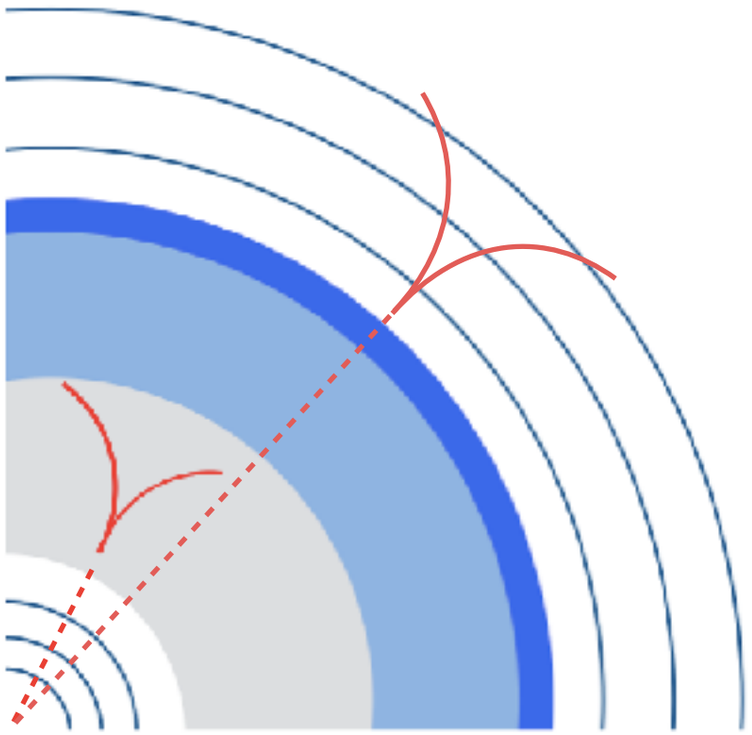


	$BR_{95\%limit}$	$BR_{5\sigma}$
CMS-like	$0.92 \pm 0.32\%$	$2.5 \pm 0.3\%$
ILD-like	$0.63 \pm 0.22\%$	$1.7 \pm 0.1\%$



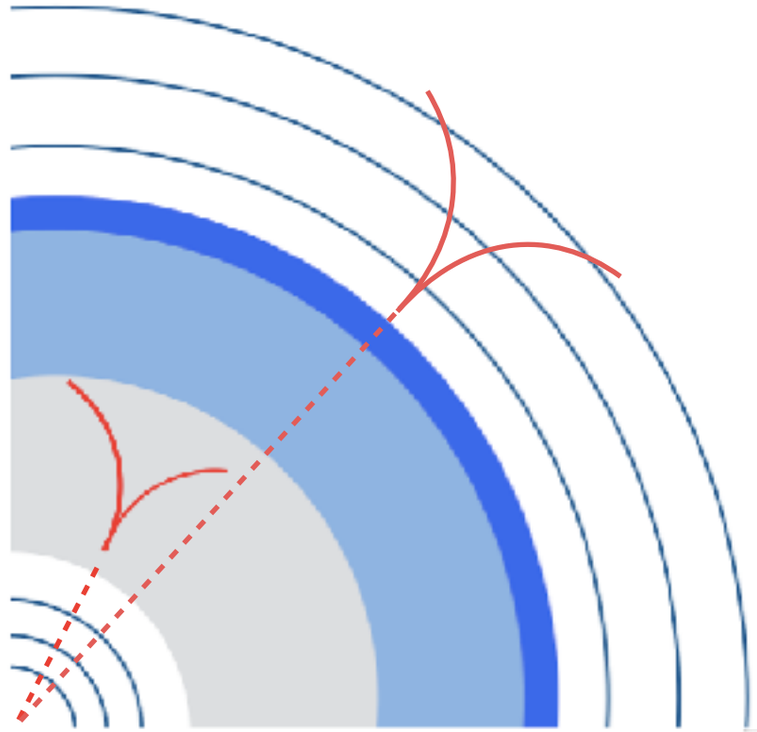
Displaced vertices

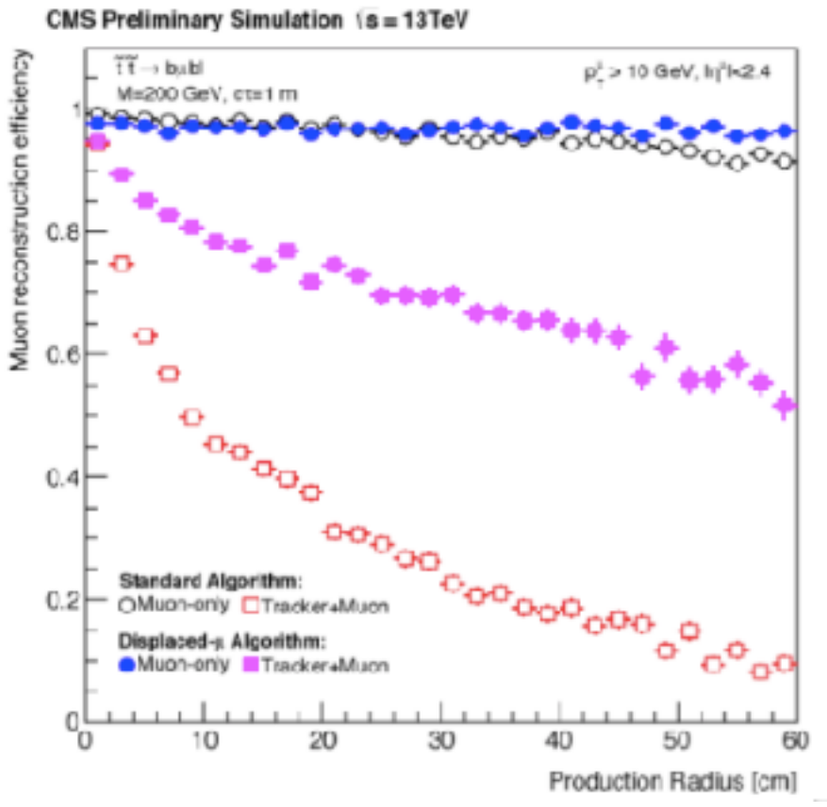
- Displaced vertices arise in many BSM scenarios with long living particles
  - Compressed SUSY
  - Right-handed neutrinos
  - Higgs decays to dark sector
- Experimentally challenging
  - keep high tracking efficiency with large displacement
- How important is the outer tracking (μ stations)?
  - Favourable S/B
  - Higher cost?
  - Lifetime distribution still peaks at small displacements



Displaced vertices

- Assessing the sensitivity requires some detector simulation
- Need displaced signatures in FASTSIM codes
  - Could assume tracking performances (e.g. from LHC experiments)
  - Neglect detector background (realistic @e^+e^- collider)
- Study physics reach vs efficiency/resolution model
- Then translate efficiency/resolution model int a detector design

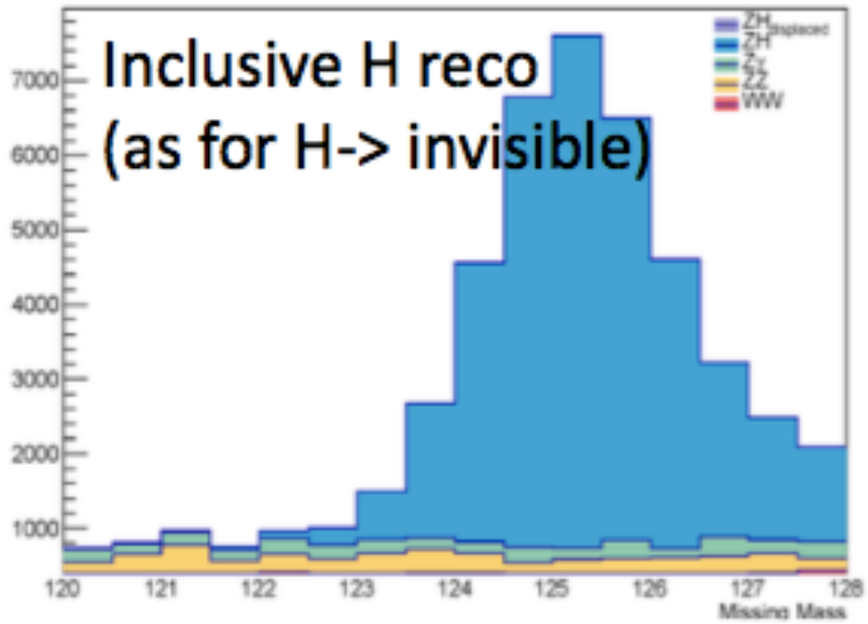


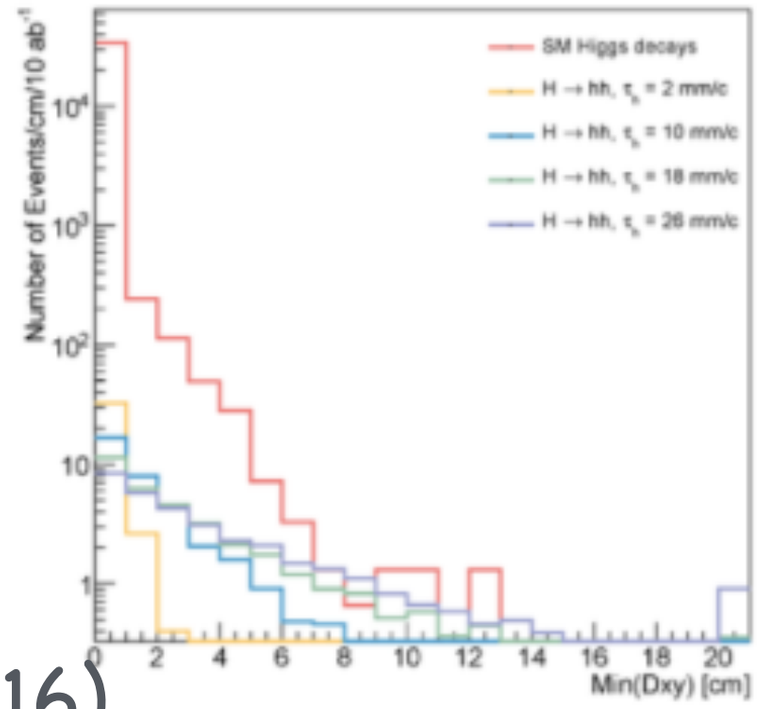


Displaced vertices

- Preliminary study with (strong) simplification
- Perfect efficiency model for displaced tracks (= prompt tracks)
- Based on Delphes CMS Phase II geometry
- No attempt to emulate detector backgrounds
- Simple analysis
- No displaced vertexing attempted
- "Robust" variable to quantify displacement
- Result in pessimistic limit (i.e., we should have better limits)

$e^+e^- \rightarrow HZ$ $H \rightarrow hh$ $Z \rightarrow ll$
$h \rightarrow bb$ (displaced)





(D. Douqa, NMS CERN Summer student 2016)

Displaced vertices

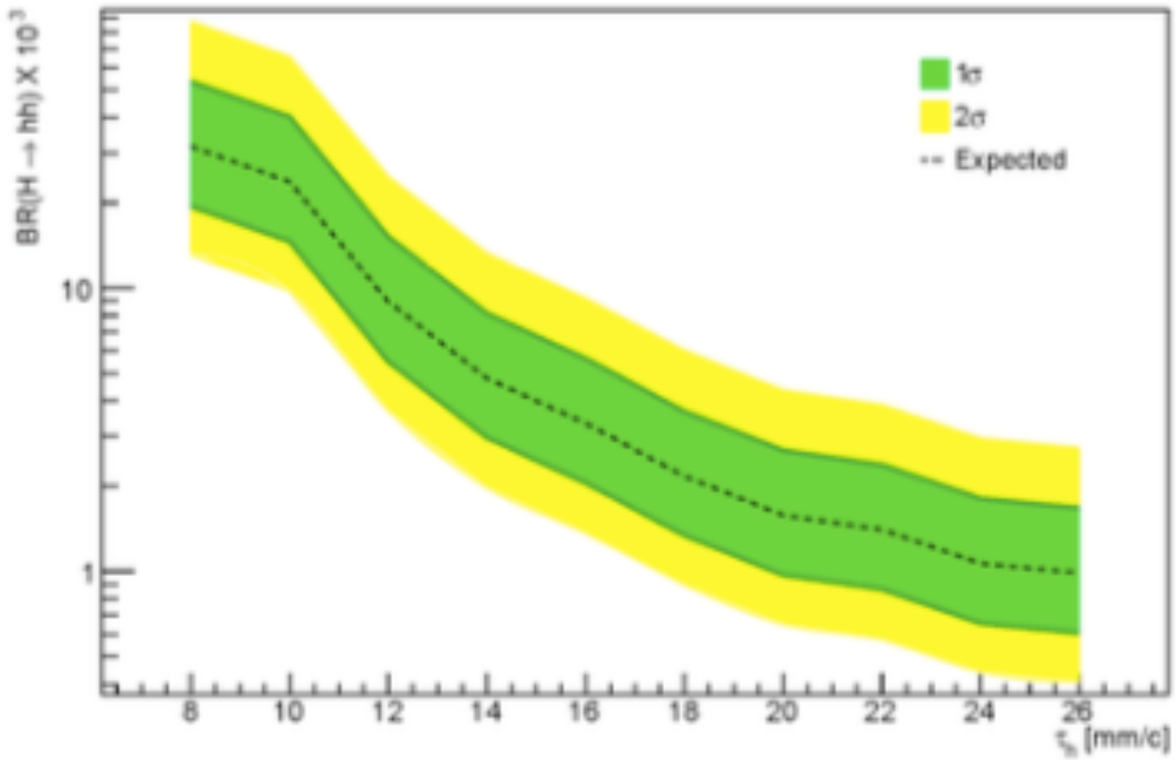
- Use robust quantity to assess sensitivity (min observed displacement for tracks in the event, probing the presence of prompt tracks)

- Not exploring at best the displacement
  - better options would be vtx displacement significance, etc
  - Need a full reconstruction framework for that (or tuned smearing functions)

- A starting point, to be improved in the future

$e^+e^- \rightarrow HZ \quad H \rightarrow hh \quad Z \rightarrow ll$

$h \rightarrow bb$ (displaced)



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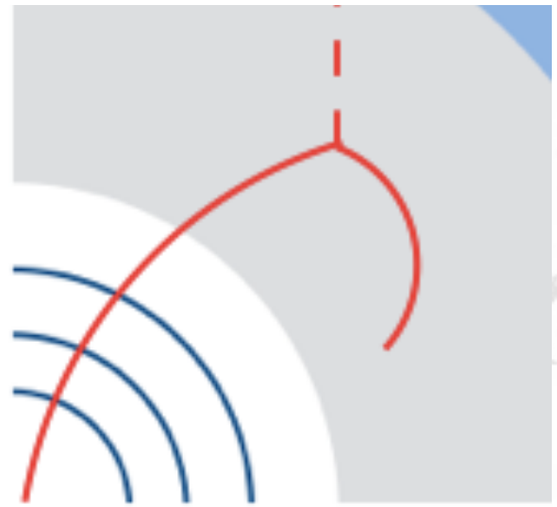
Other track-related signatures

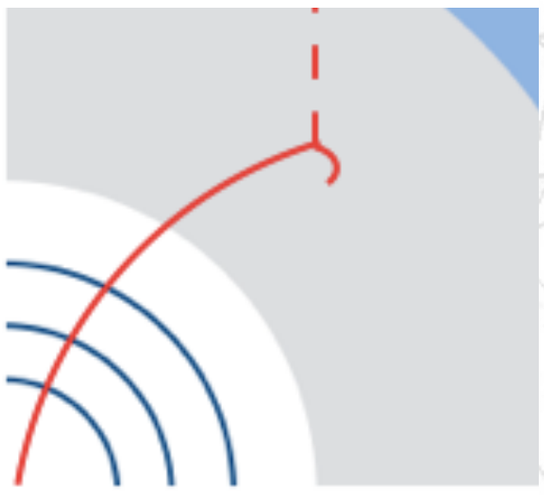
- Good tracking performances at the peripherals of the inner tracker guarantees sensitivity to other weird signatures

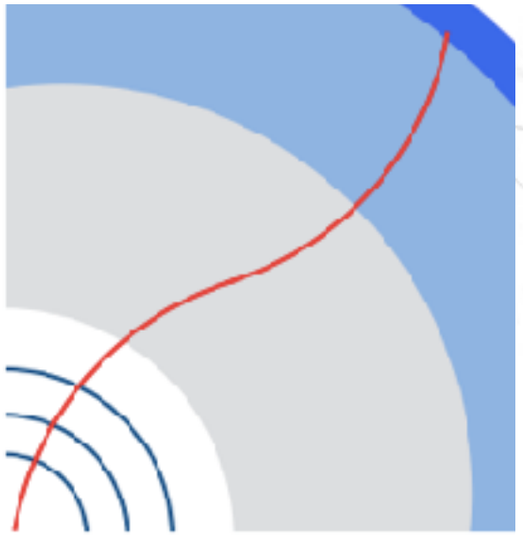
  - kinks / stopping tracks / tracks swapping sign

- To improve bkg rejection and characterize a potential signal, it would be good to have PID

  - **dE/dx in silicon & drift chamber**

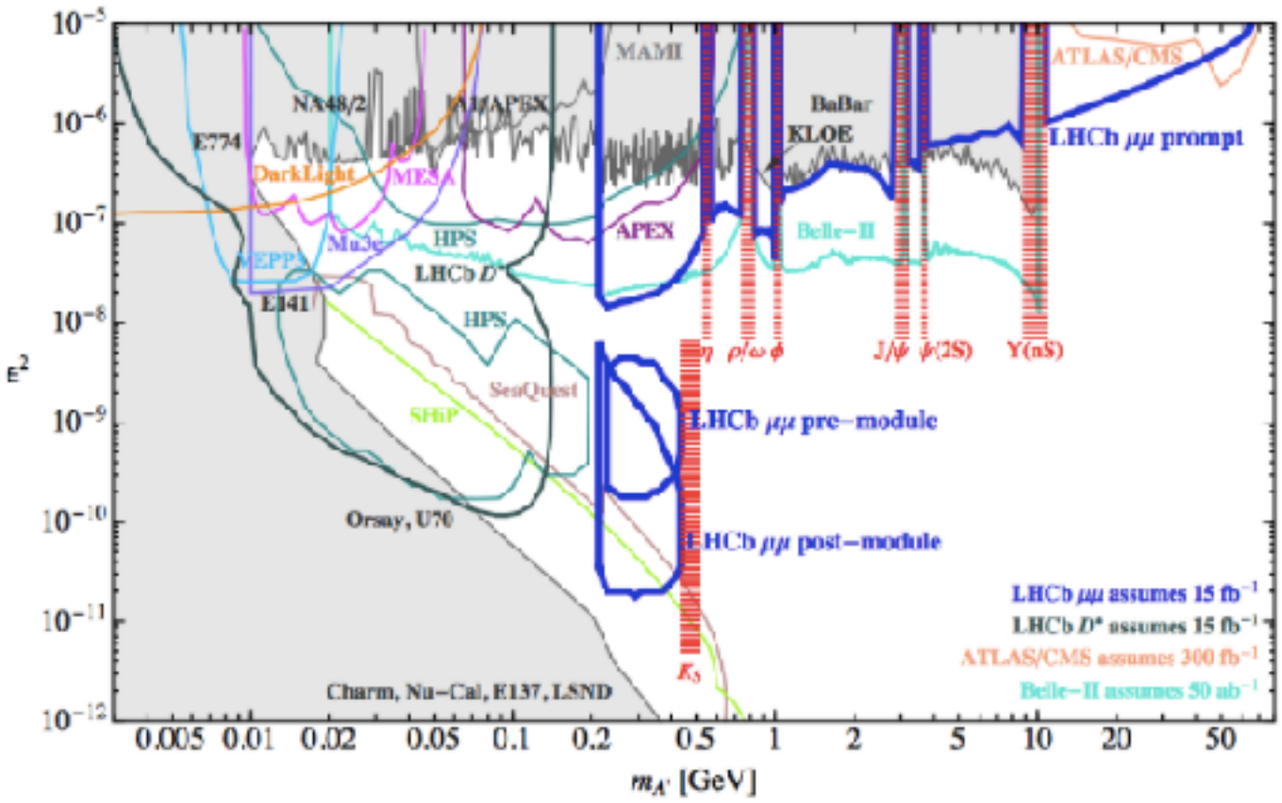




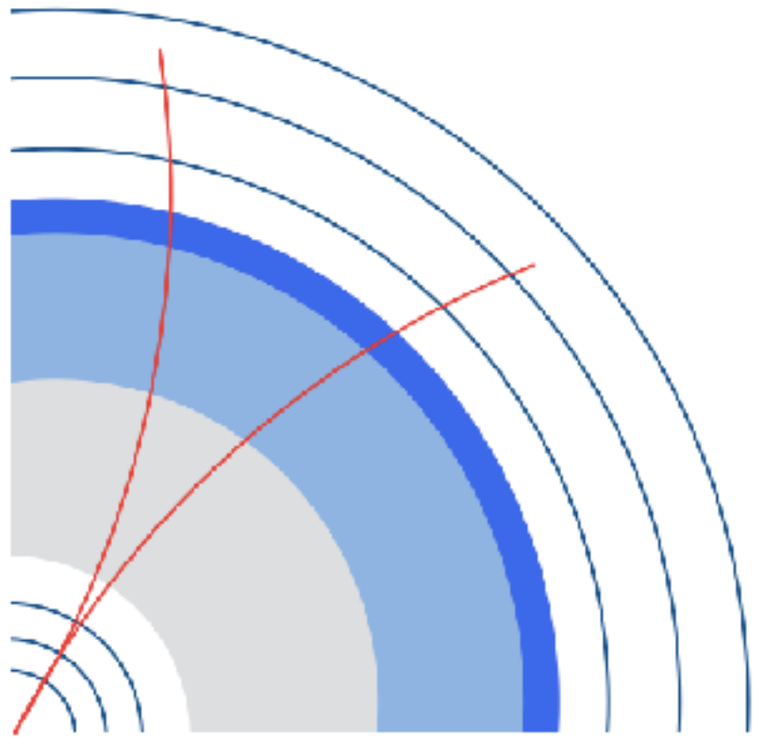


Very light resonances

- Growing interest on dark photon models
  - massive photons that decays to lepton pairs
  - mass could be anywhere
  - For small couplings, could become long living

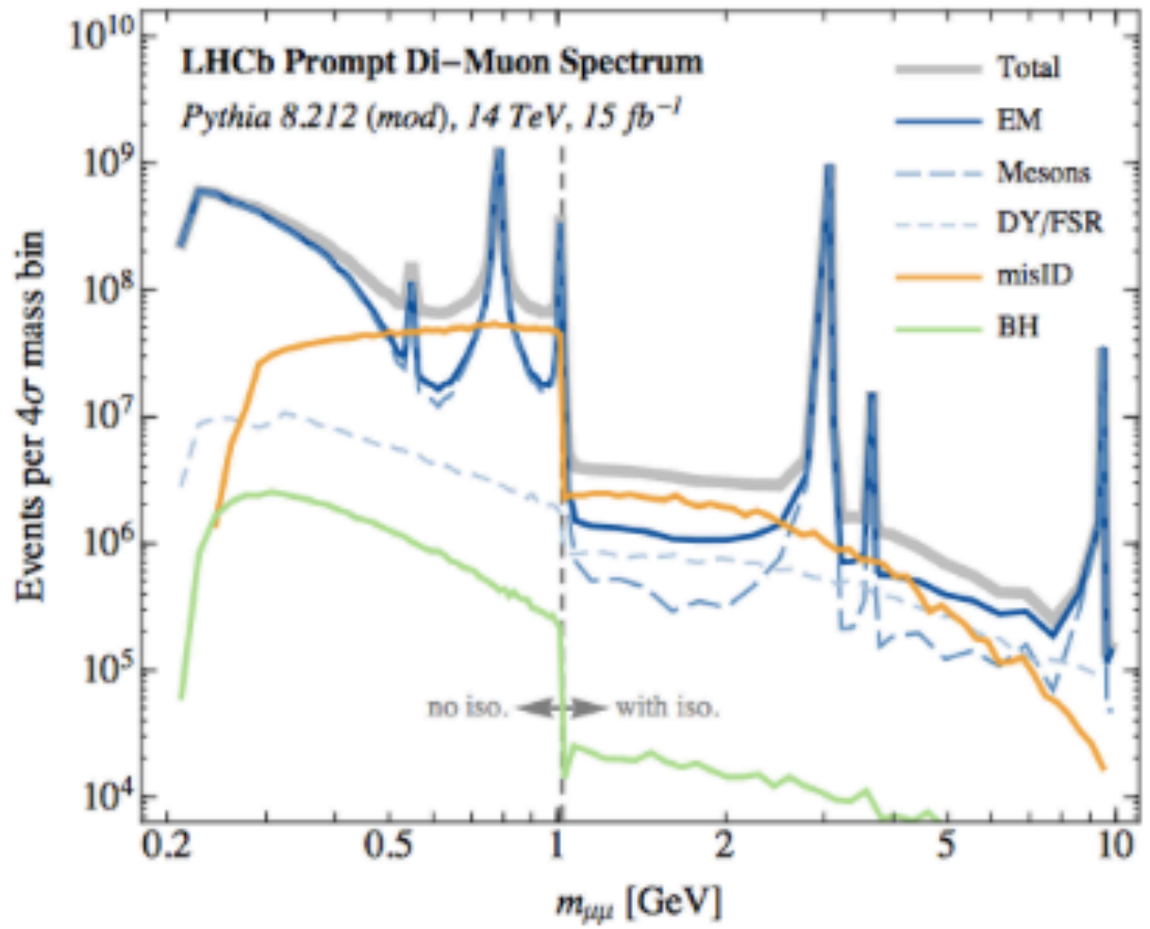


- No experimental challenge above 10 GeV
- long living -> displaced vtx (see previous slides)
- very light mass could bring resolution challenges
  - A large tracking volume in this case could help to measure angular distance (see LHCb in next slide)



Sensitivity study: LHCb example

- Feasibility study done for LHCb
- Assumed performances for LHCb tracking and mass resolution
- Exploit at best the essence of LHCb (long spectrometer)
- We could repeat this study to asses sensitivity vs detector performances



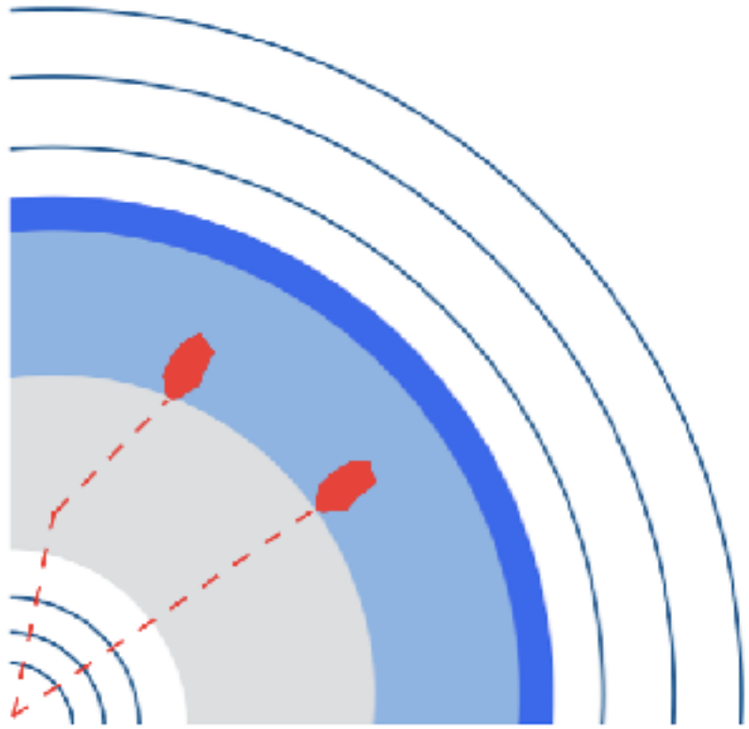
$$\sigma_\tau \approx 50\ \text{fs}\,,$$

$$\sigma_{m_{\mu\mu}} \approx \begin{cases} 4\ \text{MeV} & m_{\mu\mu} < 1\ \text{GeV} \\ 0.4\%\, m_{\mu\mu} & m_{\mu\mu} > 1\ \text{GeV} \end{cases}$$

1. **Prompt**: $\text{IP}_{\mu^\pm} < 2.5\,\sigma_{\text{IP}}$;
2. **Displaced (pre-module)**: $\ell_{\text{T}} \in [5\,\sigma_{\ell_{\text{T}}}, 6\,\text{mm}]$;
3. **Displaced (post-module)**: $\ell_{\text{T}} \in [6\,\text{mm}, 22\,\text{mm}]$.

Out-of-time neutral particles

- Ongoing R&D for fast timing detectors for HL-LHC
  - Aim to ~10 ps resolution
- Such a device, integrated in the FCCee detector, would serve as a ToF for out-of-time particles
  - displaced photons from the displaced decay of heavy neutral objects (e.g., $\chi^0_2 \rightarrow \chi^0_1 \gamma$)
  - heavy neutral stable particles



Conclusions

- A detector tuned for precision physics is excellent to look for "plain" BSM models
- A few key features could extend physics reach to exotic scenarios
  - Large tracker volume
  - Fast timing (with the calorimeter preshower used as time of flight?)
  - dE/dx for PID in the inner tracker
  - Good tracking efficiency in the external part of the inner tracker
  - A large volume for outer tracker
- Identified a few benchmark scenarios to study physics reach vs detector performances
- Will set goals for the fine-tuning of the detector design