Acceptance Studies for Dark Sectors

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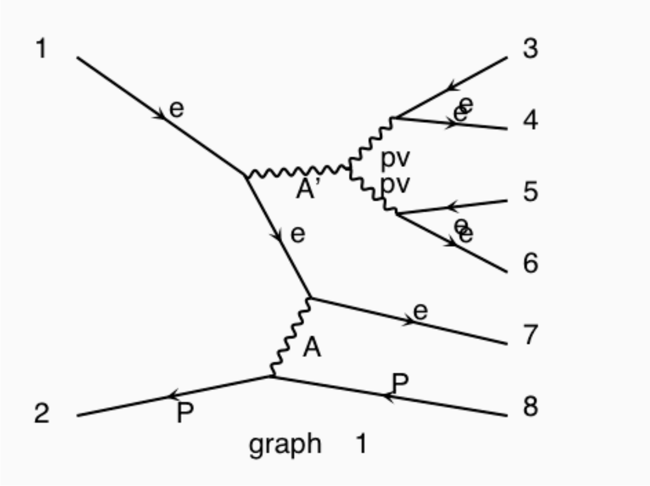
Introduction

- HPS is optimized for sensitivity to dark photons decaying into electrons
- It is important to keep in mind that dark sectors may be more complicated then the Arkani-Hamed &friends model
  - Hidden valley scenarios in general (esp if no new physics at LHC Run2)
- In this talk:
  - Assume dark photon decays into pairs of W’, which in turn decay into electron pairs. Very different kinematics, plus W’ can be long-lived.
  - Test acceptance of different detector configurations to different lifetimes / masses / etc ($M_{A'}$, $M_{W'}$, $c\tau$, E_{beam}, B grid)
  - Toy simulation:
    - Tracker layers (0 to 90 cm) in magnetic field, no field between 90 cm and ECAL
    - Propagate electrons as helixes through magnetic field
    - count “hits” on the tracks
  - Only mess with the tracker so far
    - Larger ECAL may help, but here treat it as mainly a trigger device

A′ → W′ W′ → 4e

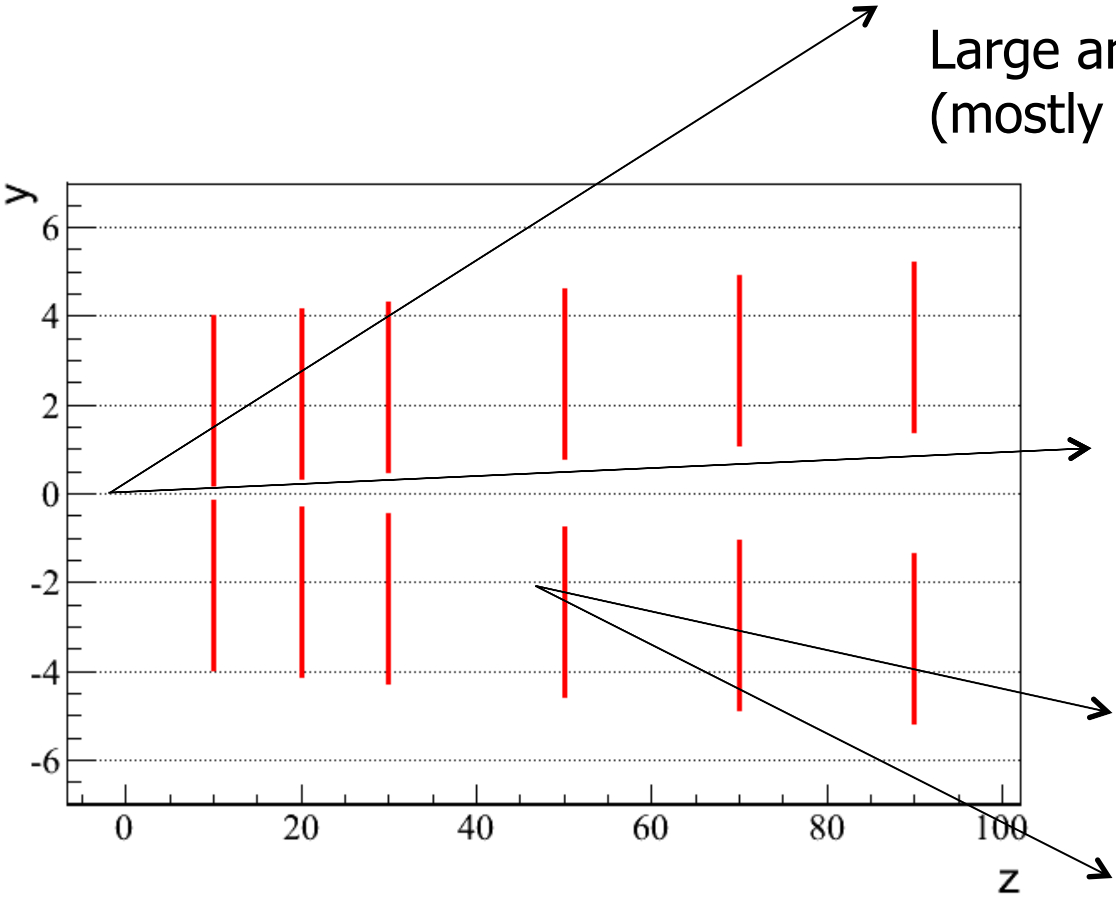
- Compared to A′ search, we have extra α^2 working in our favor since the "physics" background is now order α^4, plus 3 mass peaks instead of one



$$N \sim 10^5 \left(\frac{N_e}{1\,C}\right) \tilde{\chi} \left(\frac{T}{0.1}\right) \left(\frac{\epsilon}{10^{-4}}\right)^2 \left(\frac{100\ MeV}{m_{A'}}\right)^2$$

- The main issue is efficiency:
  - For 300 MeV and $\varepsilon=10^{-6}$ one gets N ~ $\left(\frac{N_e}{1\,C}\right) \tilde{\chi} \left(\frac{T}{0.1}\right)$

Sources of inefficiency

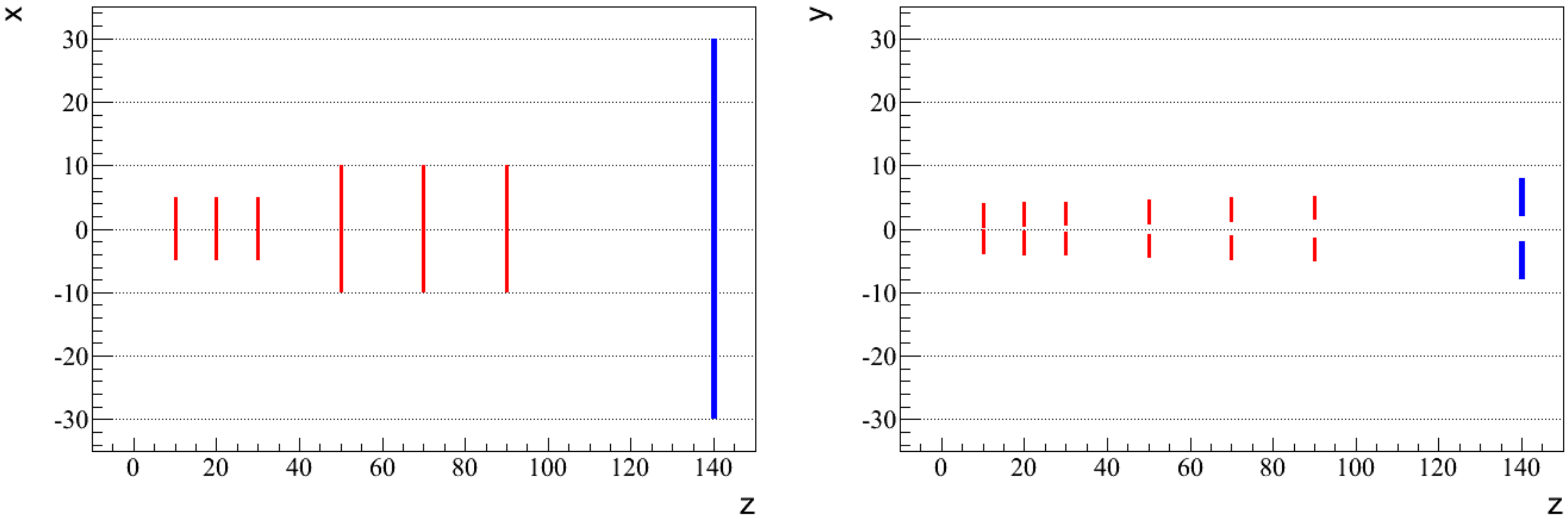


Large angle tracks are softer (mostly for large m(A')/Ebeam)

Heavily boosted tracks (mostly for small m(A')/Ebeam)

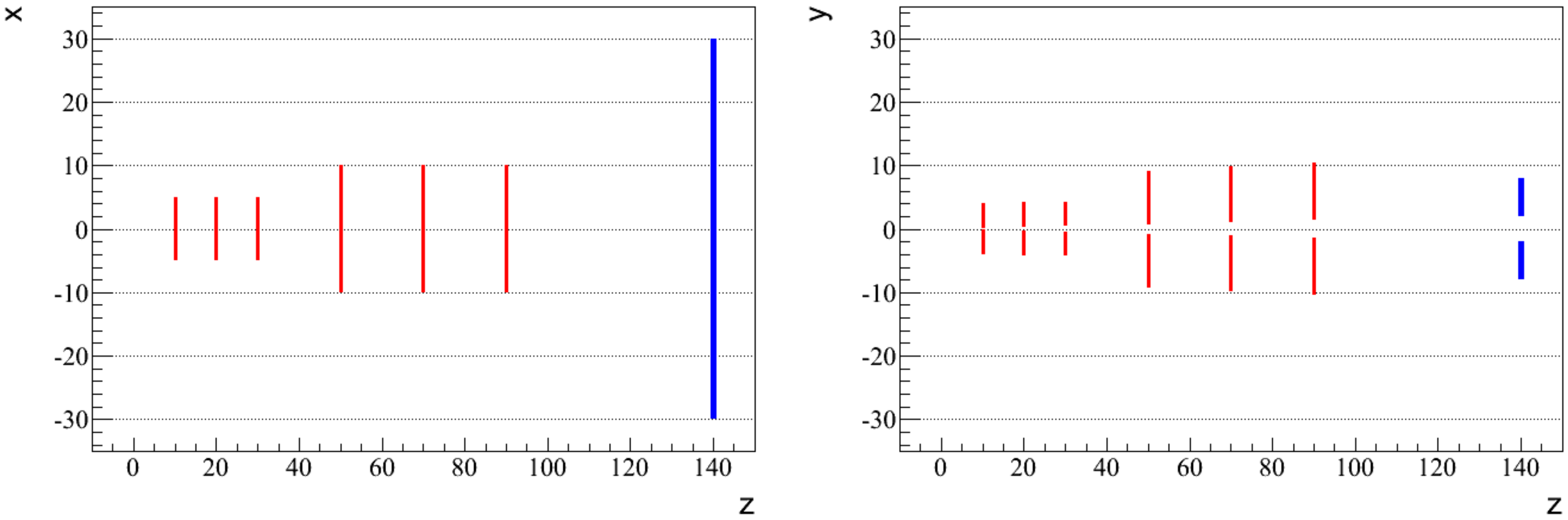
Large lifetimes

“HPS”-like geometry



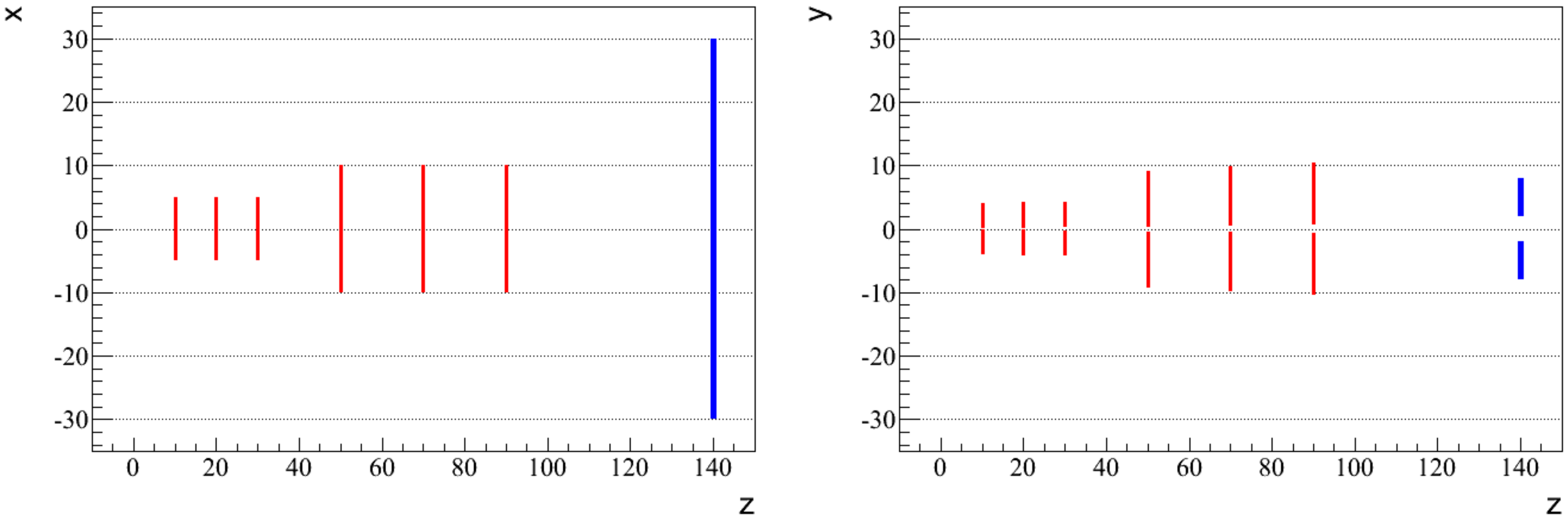
Note how the angular acceptance in vertical is much smaller then horizontal

Geometry 1



Trying to equalize the large angle acceptance
~2 times the silicon area

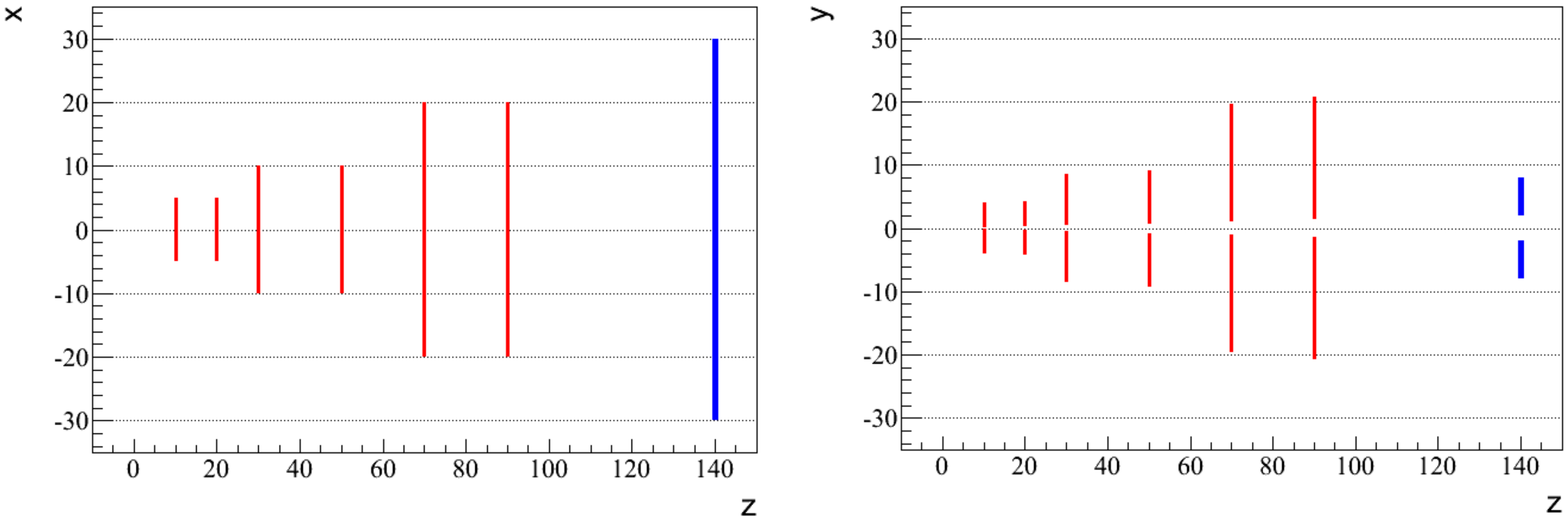
Geometry 2



Same as 1, but close the gap near the “sheet of death” by a factor of 2

- May not be feasible, but great diagnostics that tells you where you loos the particles

Geometry 3



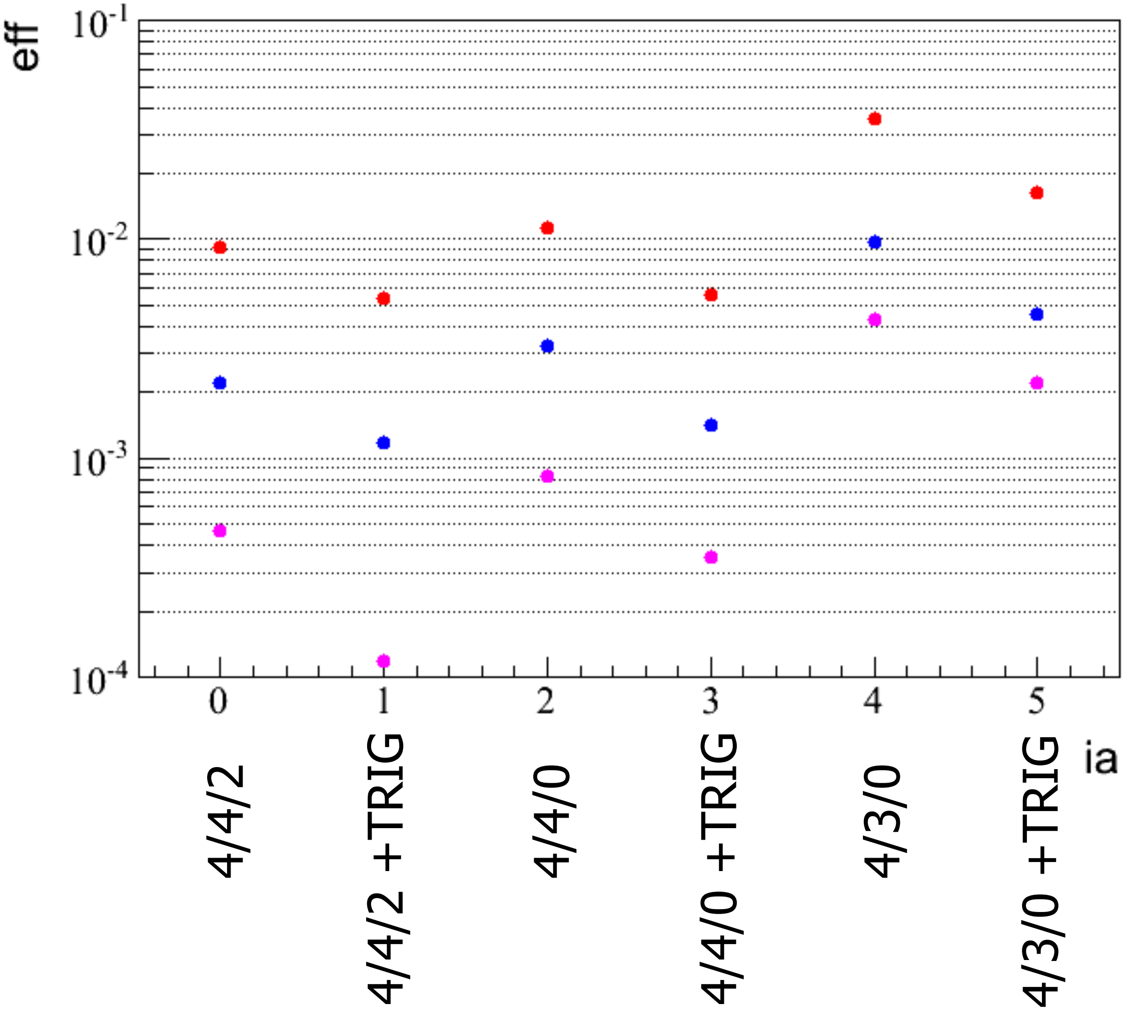
Enhance the large angle acceptance

~ 5 times the silicon area

Acceptance

- Need to cut on number of hits on the track
- Three configurations
  - 4 tracks with >=4 hits, 2 out of them with >=5
  - 4 tracks with >=4 hits
  - 4 tracks with >=3 hits, 3 out of them with >=4
- Two trigger conditions
  - no trigger ☺
  - >= 2 clusters with E/E_{beam}>0.08 and total ECAL energy > 0.3 E_{beam}

Example Acceptances: HPS-like



$M_{A'}=0.2$ GeV
$M_{W'}=0.08$ GeV
$E_{beam}=2.2$ GeV

Red: $c\tau = 0$

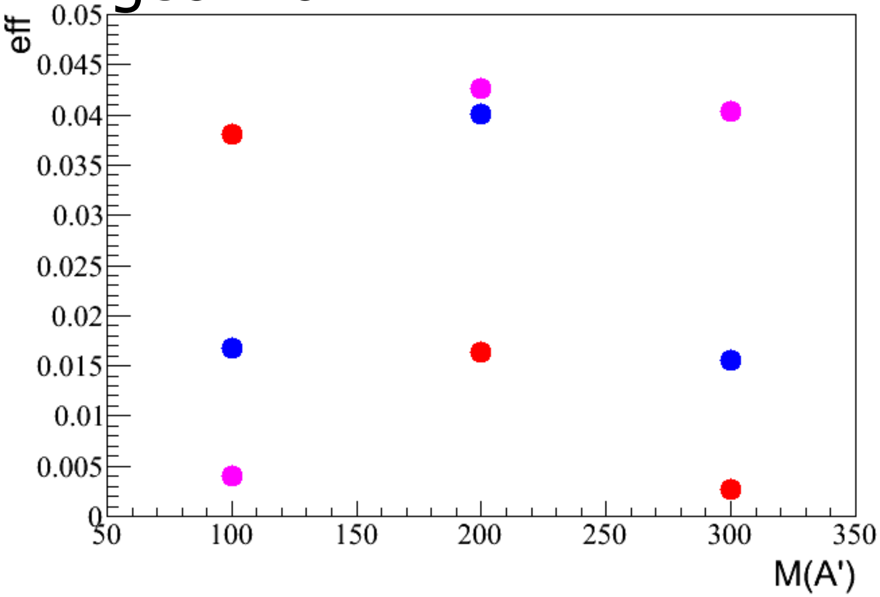
Blue: $c\tau = 2$cm

Purple: $c\tau = 4$cm

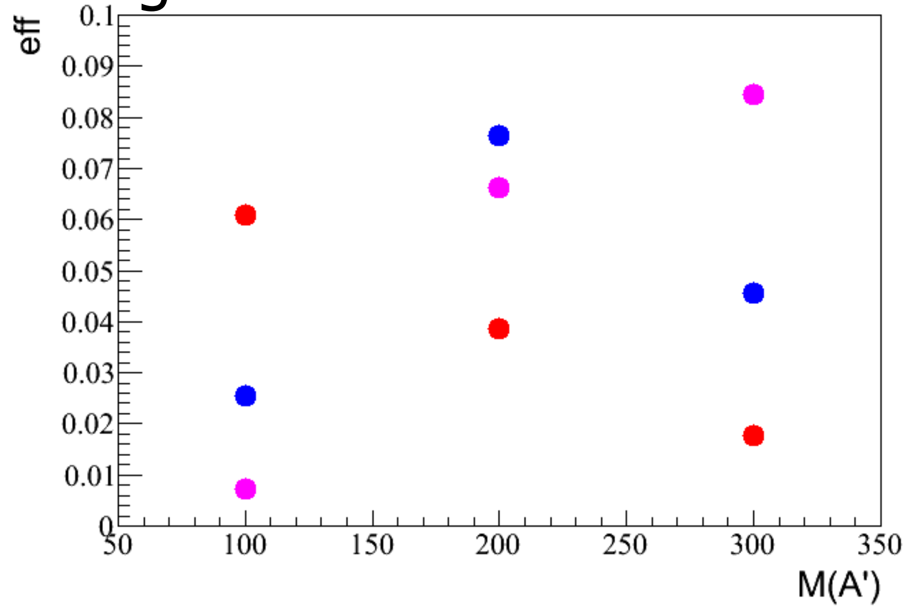
Have to accept shorter tracks for long-lived W′

Example Geometry vs E_{beam}

geom 0



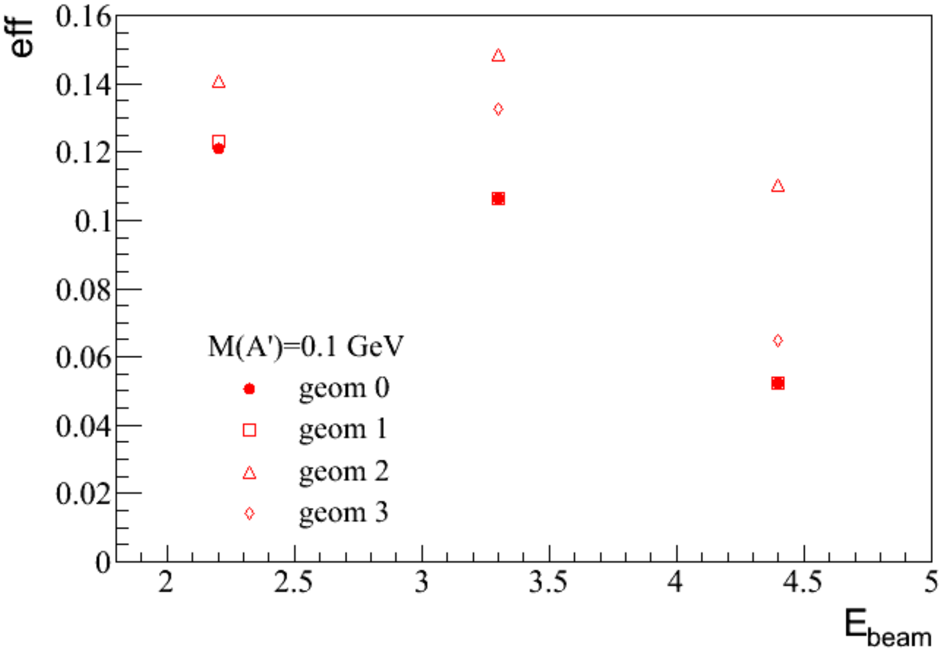
geom 3

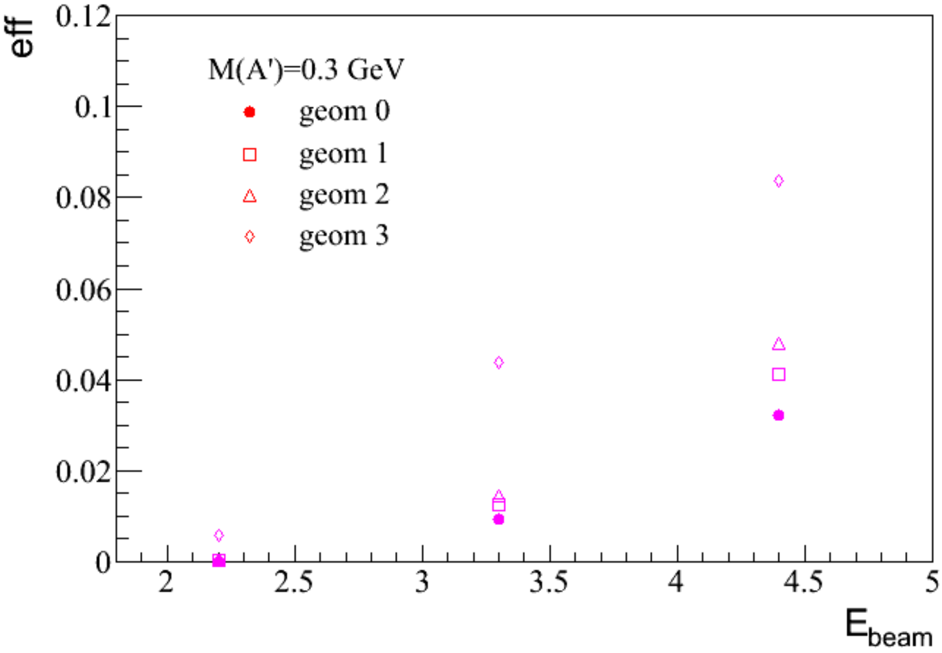


Red: 2.2 GeV, Blue: 3.3 GeV, Purple: 4.4 GeV

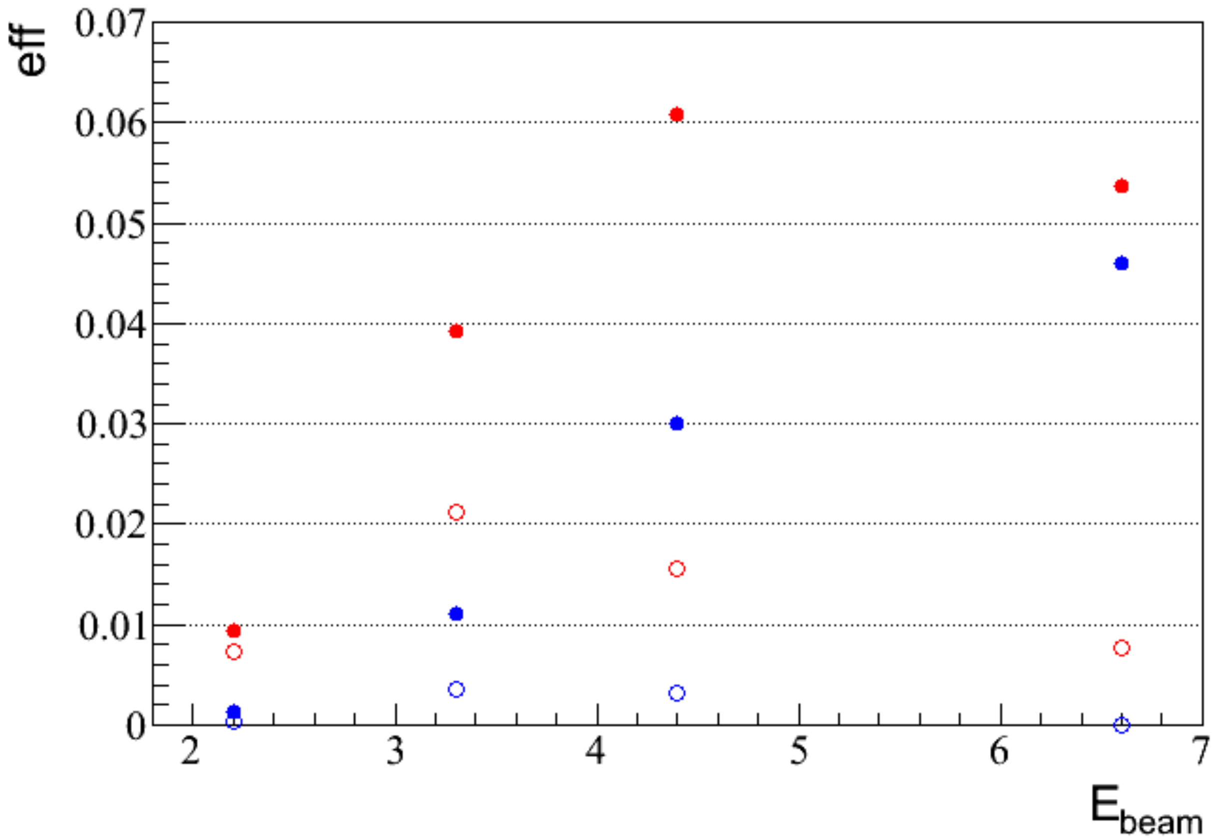
Example Geometry Impact

- For small mass it's important to go closer to the beam
- For large mass it's important to have wide angles





Lifetime



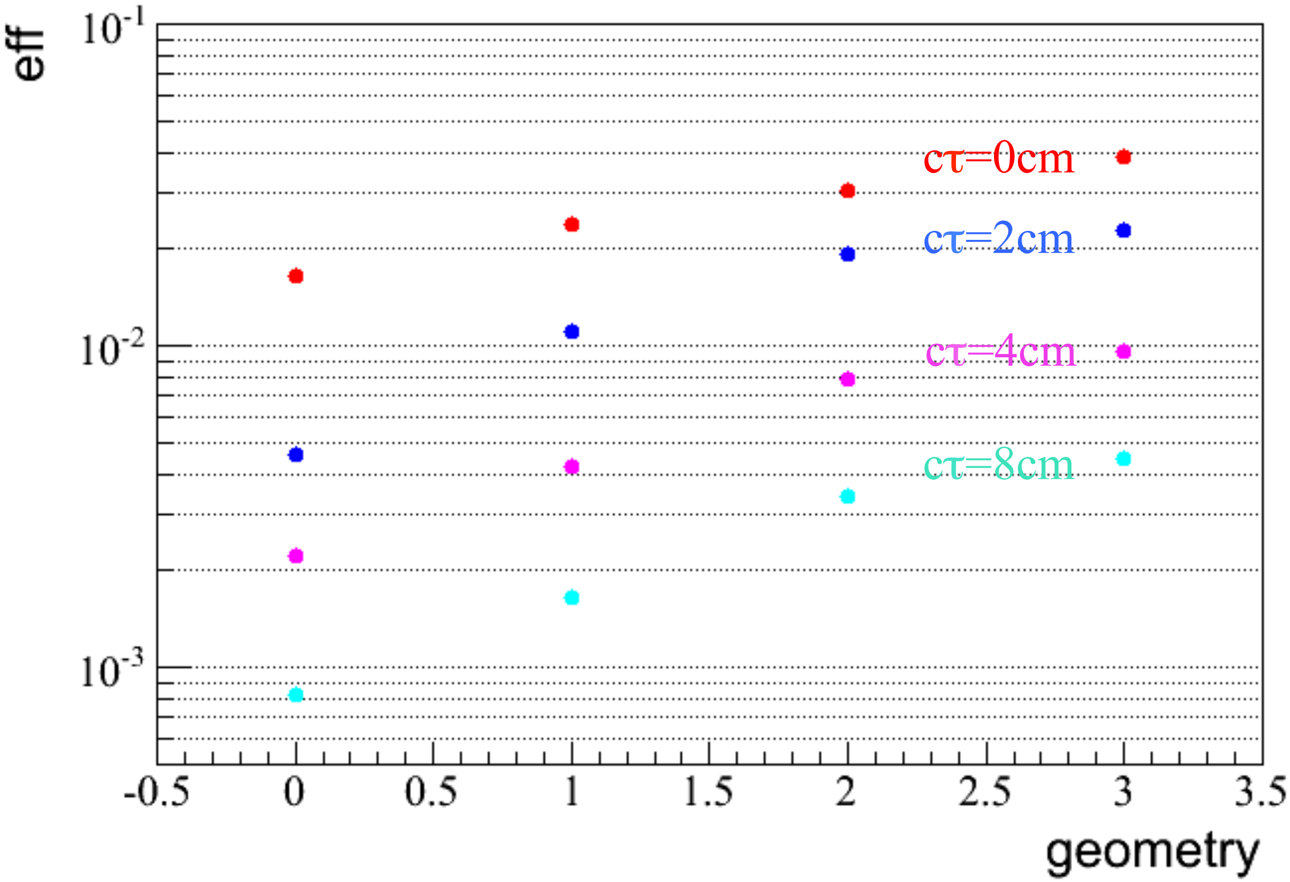
$M_{A'}$=0.3 GeV
$M_{W'}$=0.1 GeV

Red: geom 3
Blue: geom 0

Open: $c\tau$ = 2cm
Solid: prompt

- Note that the most favorable E_{beam} is different for prompt and long-lived

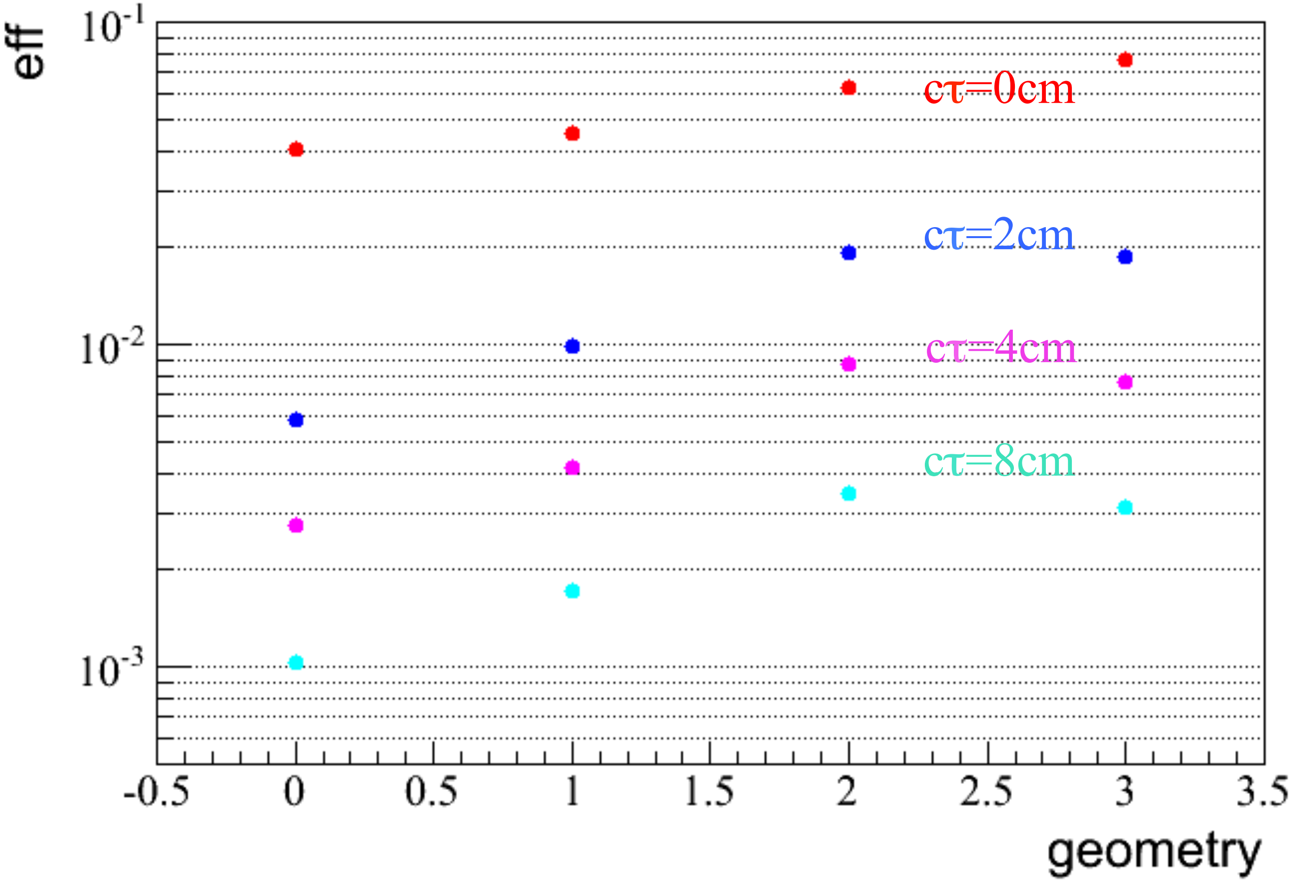
Lifetime vs. Geometry



$M_{A'}$=0.2 GeV
$M_{W'}$=0.08 GeV

E_{beam}= 2.2 GeV

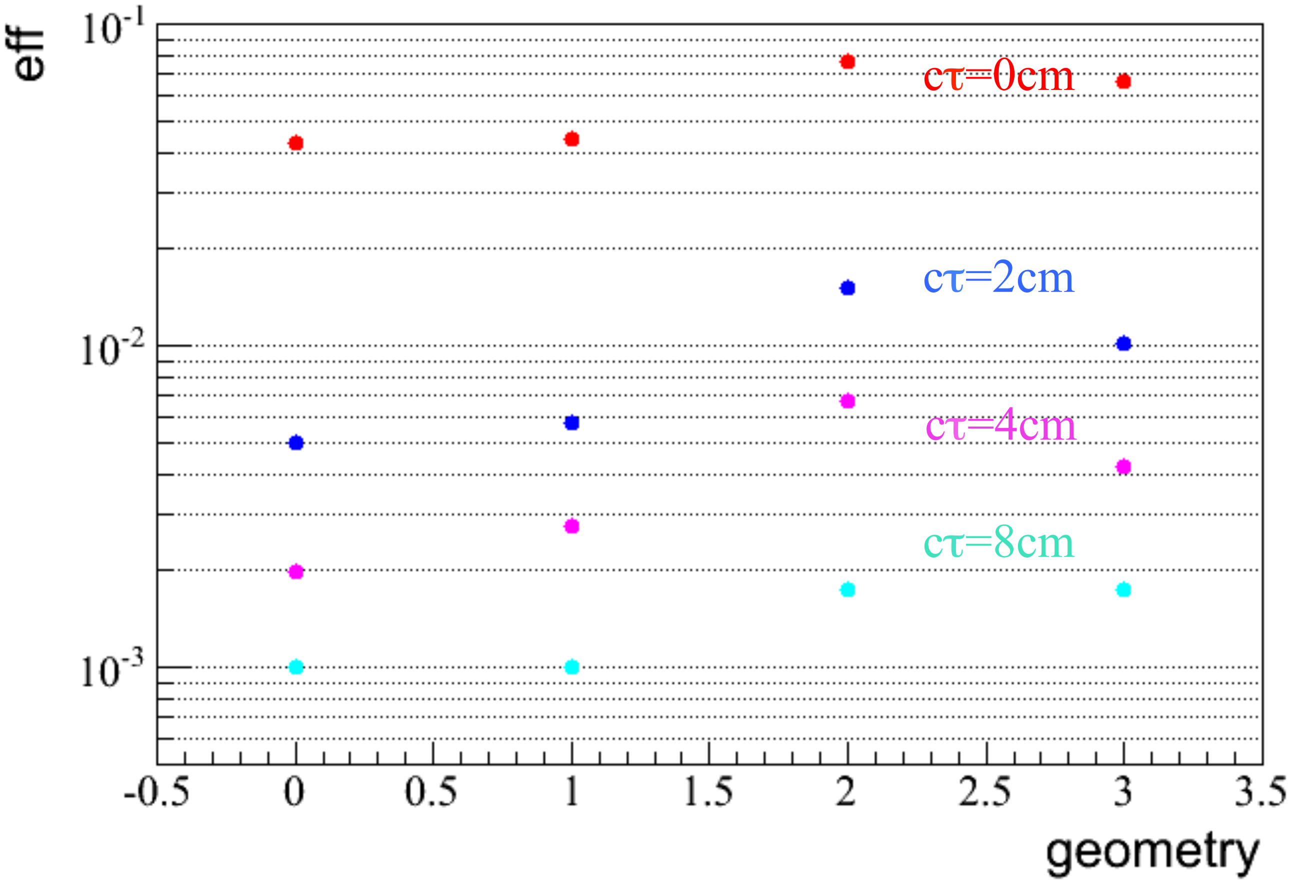
Lifetime vs. Geometry



$M_{A'}$=0.2 GeV
$M_{W'}$=0.08 GeV

E_{beam}= 3.3 GeV

Lifetime vs. Geometry



$M_{A'}$=0.2 GeV
$M_{W'}$=0.08 GeV

E_{beam}= 4.4 GeV

Larger trackers especially useful for long-lived scenarios

Not BG-free possibilities

- Fully detect one of the W′ and one track from the other
  - Estimates show extra factors of 2 in eff
- Detect just one of the W′
  - Works also when A′ → W′ + MET
  - Large background from tridents – will have to rely on the transverse kick of the W′
    - Need to have a realistic BG simulation
    - Trigger becomes a problem?
- Need to understand ultimate B-factories reach for topologies like this

Summary

- We started making steps towards fixed target study of more complex hidden sectors
- The main problem seems to be the acceptance
- Depending on the masses and lifetimes
  - Doubling tracker area results in a factor of 2-3 in efficiency
  - Going to 5x the area gives ~5 times improvement
  - (note that the HPS silicon area is very small)
- For the chosen topology, requiring trigger in ECAL cost about factor of 2 in acceptance
  - one can think about alternative ways to trigger
- Just starting up, need BG and more topologies / options to consider