

# Triggering on LLP signatures

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## Theory/Pheno utopian wish list

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Searches for long-lived particles at the LHC:  
Workshop of the LHC LLP Community

CERN, Geneva

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# Theory Perspective

- LLPs can have
- ~ any lifetime
  - ~ any production mode  
(hence associated object)
  - ~ any SM charge

Some subset of the above possibilities is most theoretically motivated (see white paper skeleton) but a priori we'd like to be sensitive to any of these possibilities.

To do a search, triggers must record signal.

In current LHC main detectors, a fundamental limitation is that **no tracker information** is available at Level 1

How could triggers record LLP signals?

# Charged LLPs

Anything heavy that reaches calorimeter systems can be picked up by L1 trigger

Even so, if it's too light (below prompt hadronic/EM thresholds), identification would rely on vetoes of activity closer to IP

Charged LLPs could also decay before reaching calorimeters. **Situation similar as for neutral LLPs!**

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Charged LLPs could also decay before reaching calorimeters. **Situation similar as for neutral LLPs!**

**In these cases, need some tracker info for search!**

# Neutral LLPs

LLPs decaying into or produced alongside

- leptons
- high energy final states (above few 100 GeV)
- photons (higher E than leptons)

are a bit easier, since **PROMPT TRIGGERS** can pick them up

High-mass or LLPs  
decaying to  
leptons are easier

very difficult:  
 $m_{\text{LLP}} < 200 \text{ GeV}$   
LLP  $\rightarrow$  hadrons

# Catching LLPs with Prompt Triggers

Have to make sure prompt triggers are inclusive enough to catch LLP production and decay

Careful with rising trigger thresholds!

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Careful with rising trigger thresholds!

Canonical and extremely highly motivated theory example:

125 GeV Higgs decaying to LLPs,  
trigger inclusively on Higgs production (VBF,VH)

This is necessary, but can be inefficient.  
Can we do better?



# Dedicated LLP triggers

Already exists at L1 (ATLAS):

dedicated LLP triggers in outer detector subsystems

feasible due to “easy rejection” of prompt background by just vetoing any activity in lower-lying detector systems.

(No complicated LLP decay reconstruction required)

# Dedicated LLP triggers

So let's focus on (neutral or charged)  
LLPs decaying in the tracker!

# Triggering on LLPs decaying in tracker

Ideally:

full track and vertex reconstruction @ LI

→ DV/impact parameter based triggers @ LI

That would be perfect.

If we can't have that, what could you do?

# A Conservative Approach

L1 thresholds  $\longrightarrow$  L2/HLT

- would like full track reconstruction (CMS already does this?)
- impact parameter vs DV based triggers? (is CPU an issue here?)

Essentially want:  
any L1 threshold + displaced signal in tracker  
 $\Rightarrow$  write to tape

This can help with rising trigger thresholds

# A Conservative Approach

Theoretical favorite:

we need to gain sensitivity for  $h \rightarrow$ LLPs decaying  
in tracker by triggering on

**(VBF or lepton) inclusively**

or

**(VBF or lepton) + DV @ L2/HLT**

to lower thresholds compared to inclusive triggers

# A Conservative Approach

L1 thresholds  $\longrightarrow$  L2/HLT

- would like full track reconstruction (CMS already does this?)
- impact parameter vs DV based triggers? (is CPU an issue here?)

## How to implement?

Online track reconstruction might have to be optimized for prompt objects...

could a displaced trigger be constructed by simply vetoing “nice” prompt signals in combination with L1 threshold?

May be the way to go for template-based approaches (ATLAS FTK)

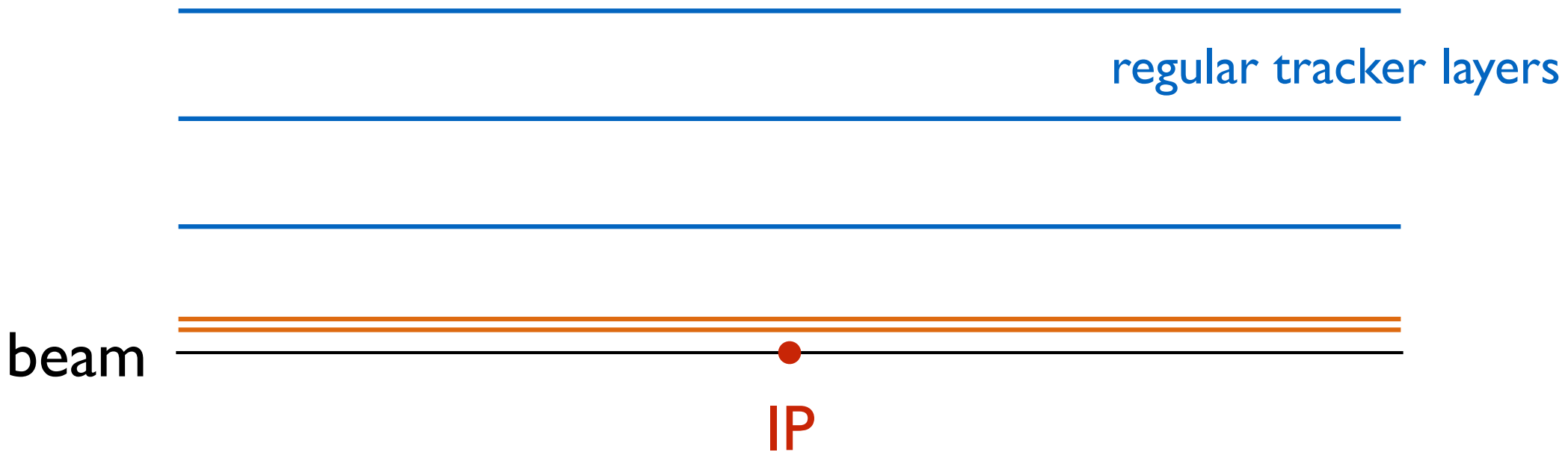
# Let's get a little crazy

(Warning: the next slides contain stupefying ignorance)

**Million-Dollar-Question: Could we implement  
Level I LLP trigger in the tracker?**

# Additional Close Tracker Layer

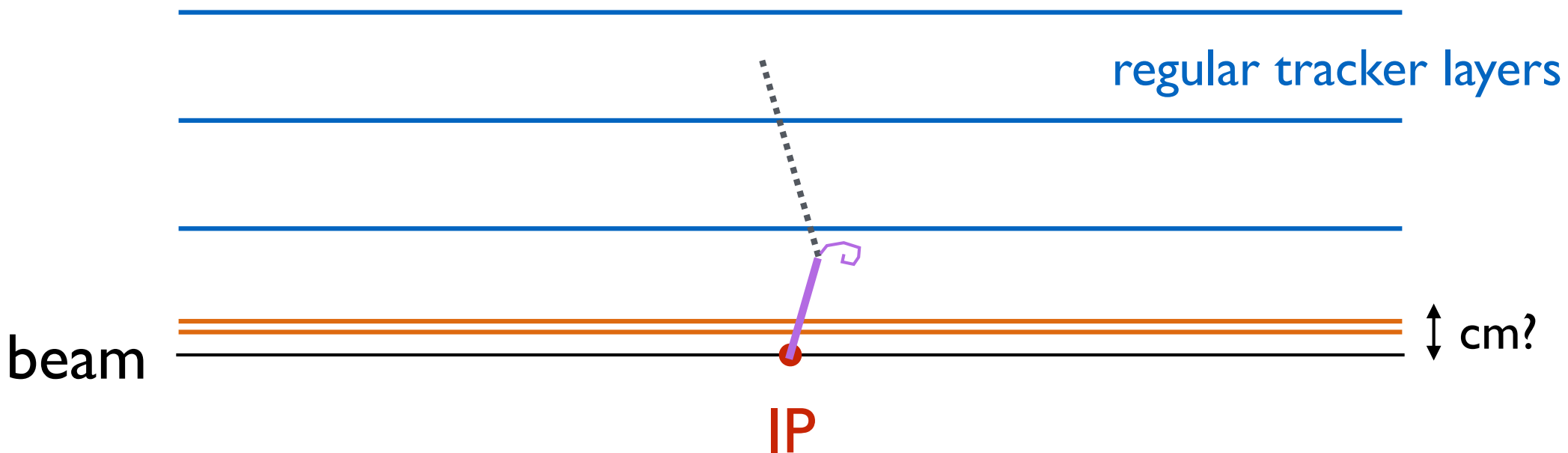
What if we had a single high-res double-layer of tracker very close to beam-pipe?





# Additional Close Tracker Layer

What if we had a single high-res double-layer of tracker very close to beam-pipe?

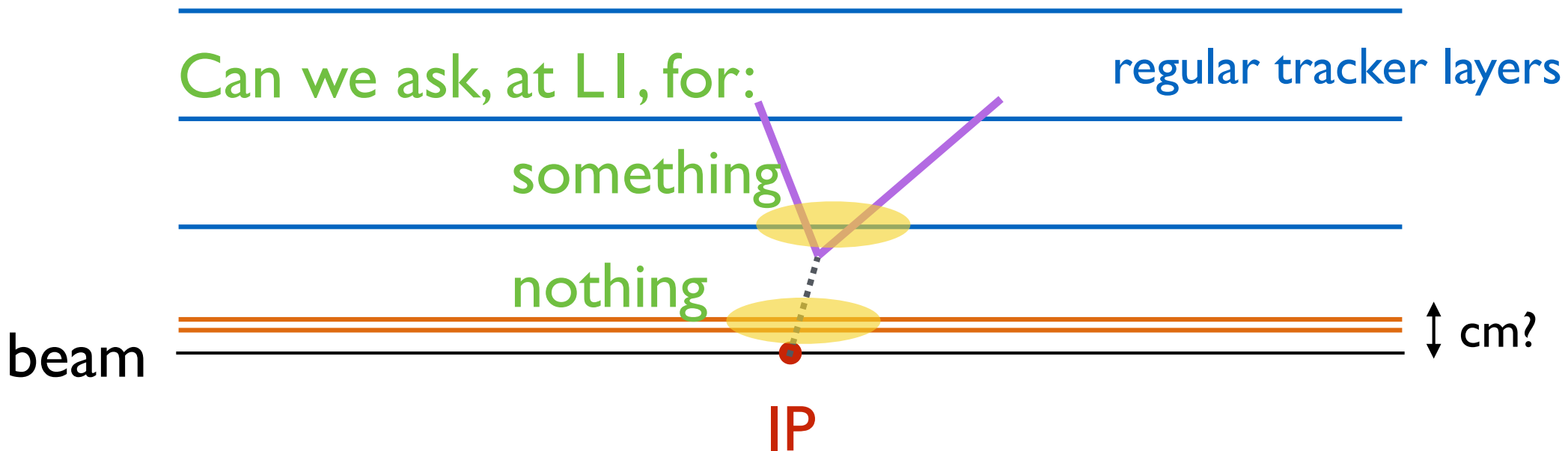


Could help with short-lived charged LLP searches (independent of trigger) by detecting “track stubs”

(talk to Rakhi Mahbubani, Pedro Schwaller, Jose Zurita)

# Additional Close Tracker Layer

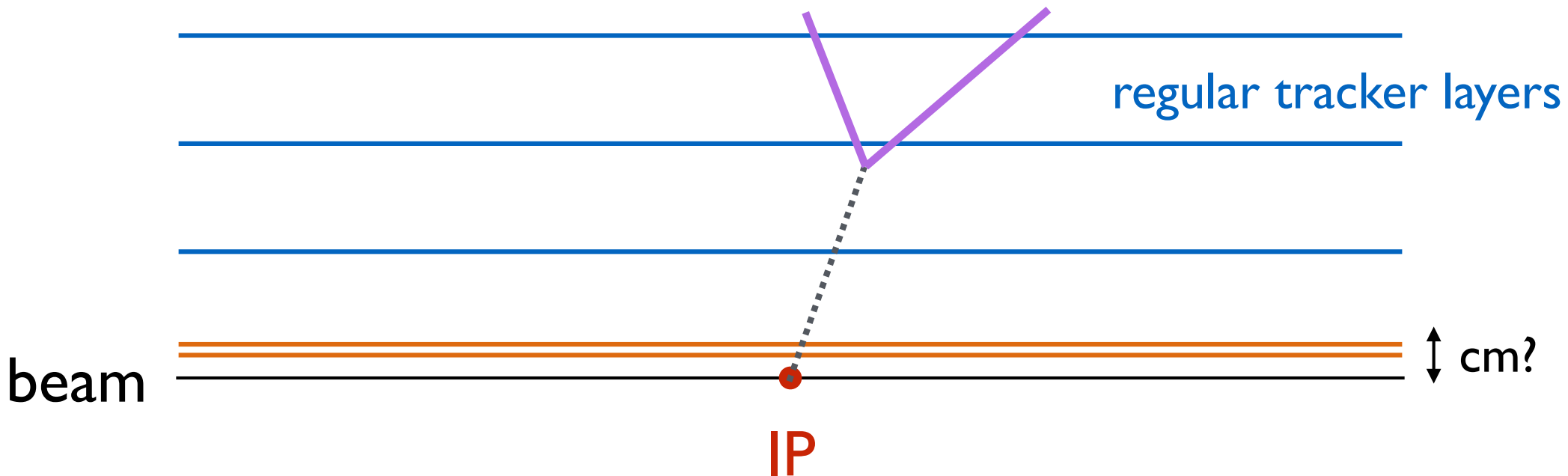
What if we had a single high-res double-layer of tracker very close to beam-pipe?



Could we use similar strategy used for outer detector LLP triggers, by **vetoing activity closer to IP?**

# Additional Close Tracker Layer

What if we had a single high-res double-layer of tracker very close to beam-pipe?



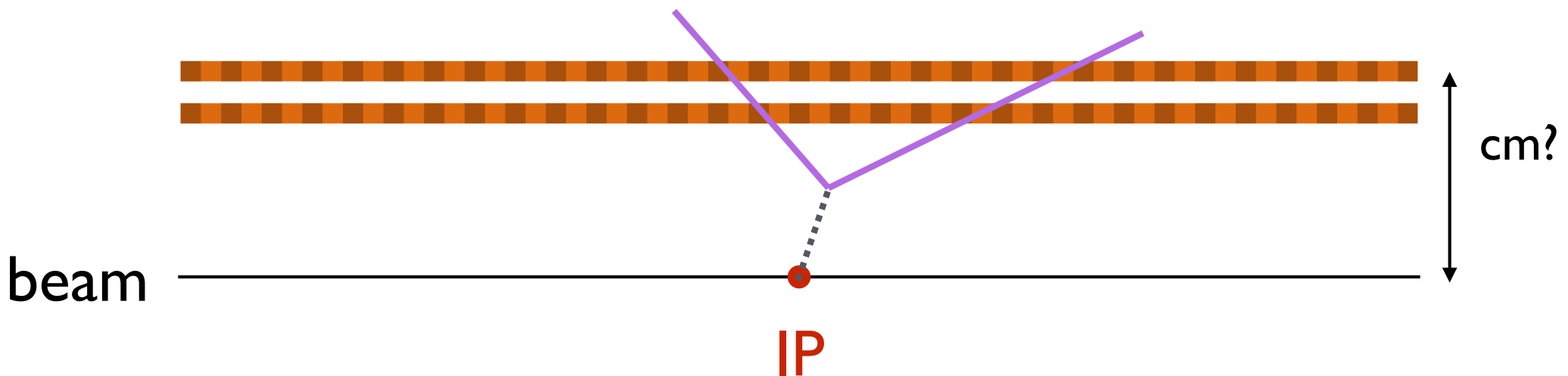
If decay length is long enough, could use existing layers?

Is this solvable by “smart wiring”?

Totally unfeasible due to PU?

# Triggering on very short lifetimes?

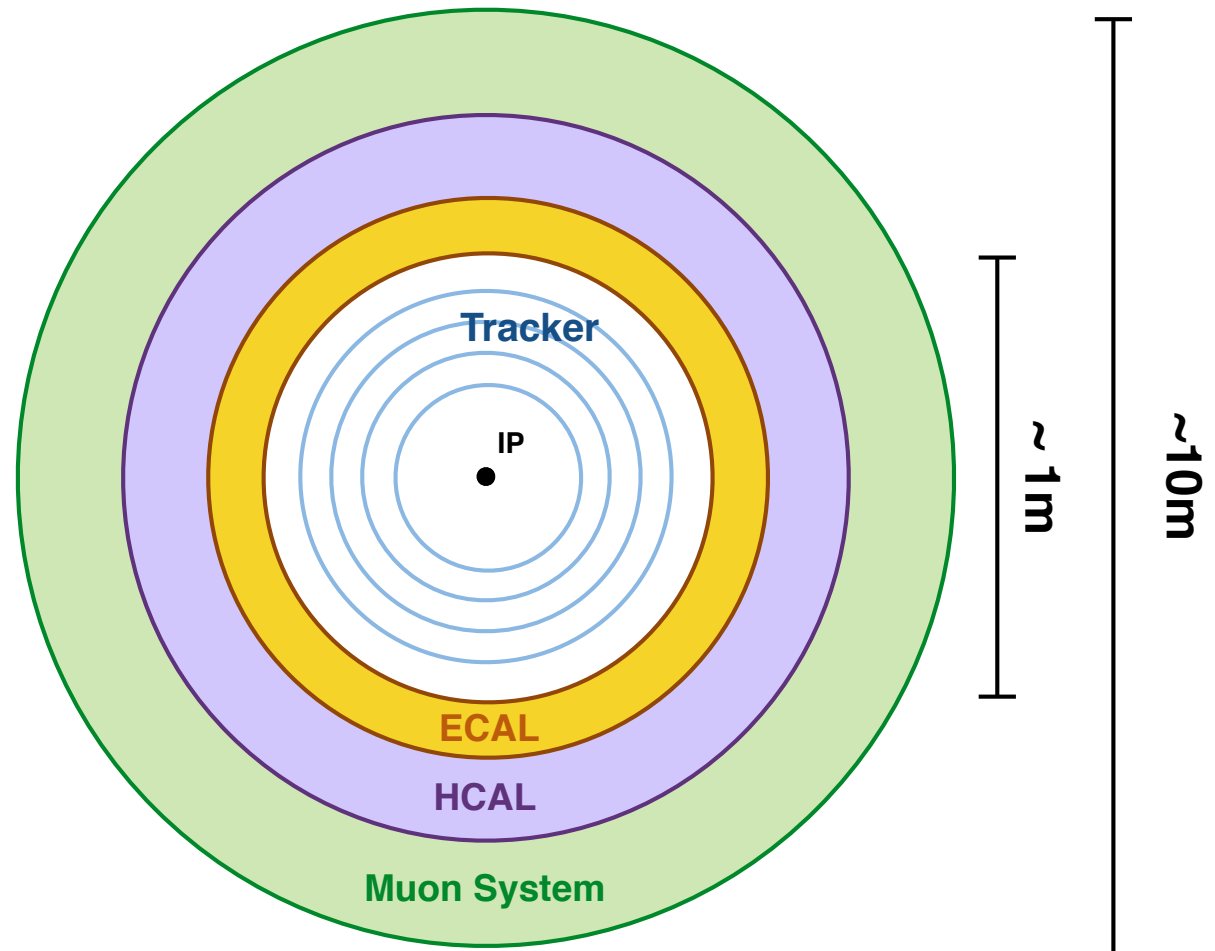
What about triggering on very short decay lengths in tracker?



Some sort of **tracklet-based DV reconstruction** in the double-layer to trigger on possible LLP decay?

# Modified tracker geometry?

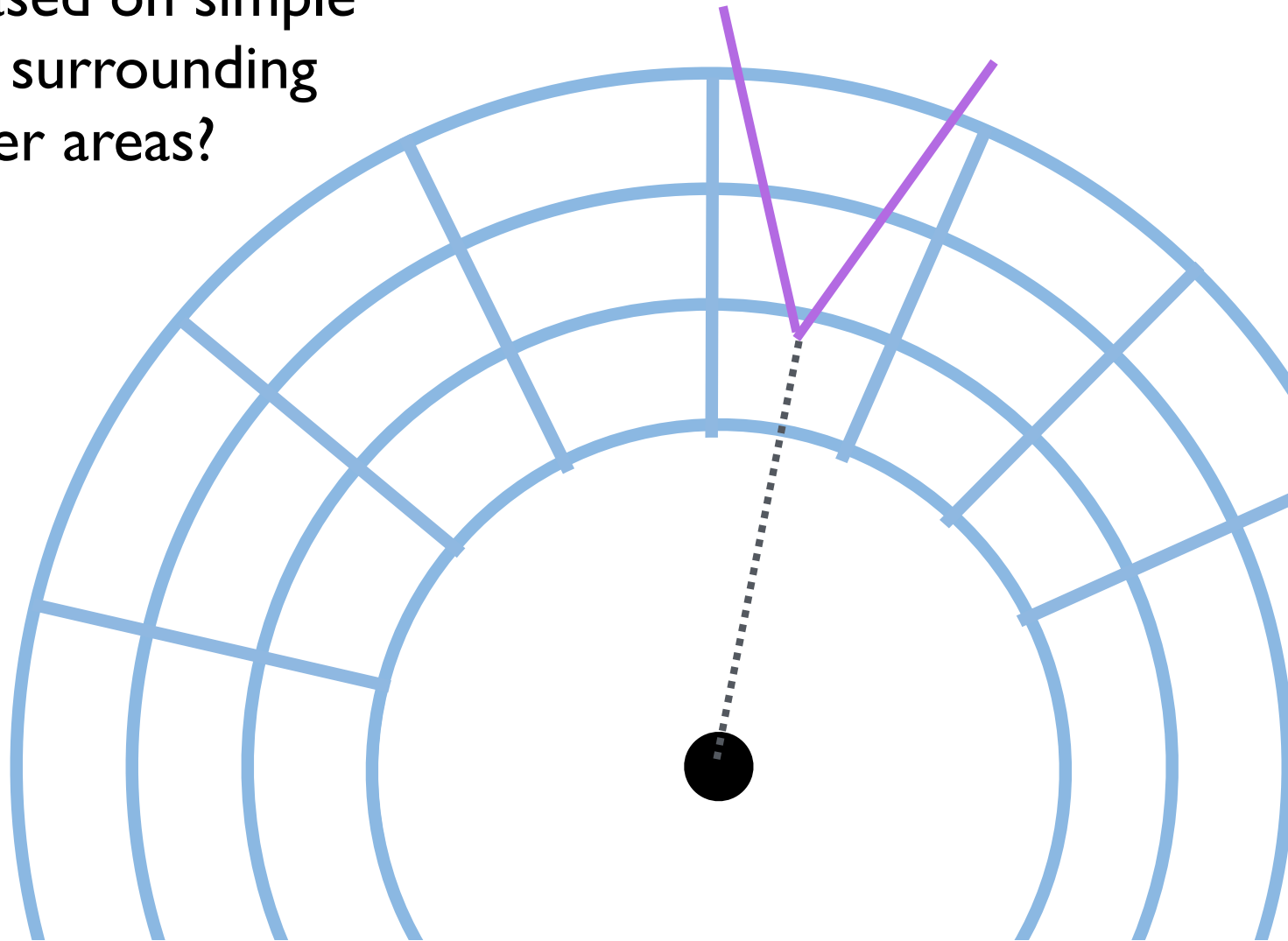
For obvious reasons, everything about the main detectors is laid out radially, assuming emanation from central IP



# Modified tracker geometry?

Could a different segmentation allow for fast hardware-based “LLP reconstruction” based on simple vetoes of activity surrounding certain tracker areas?

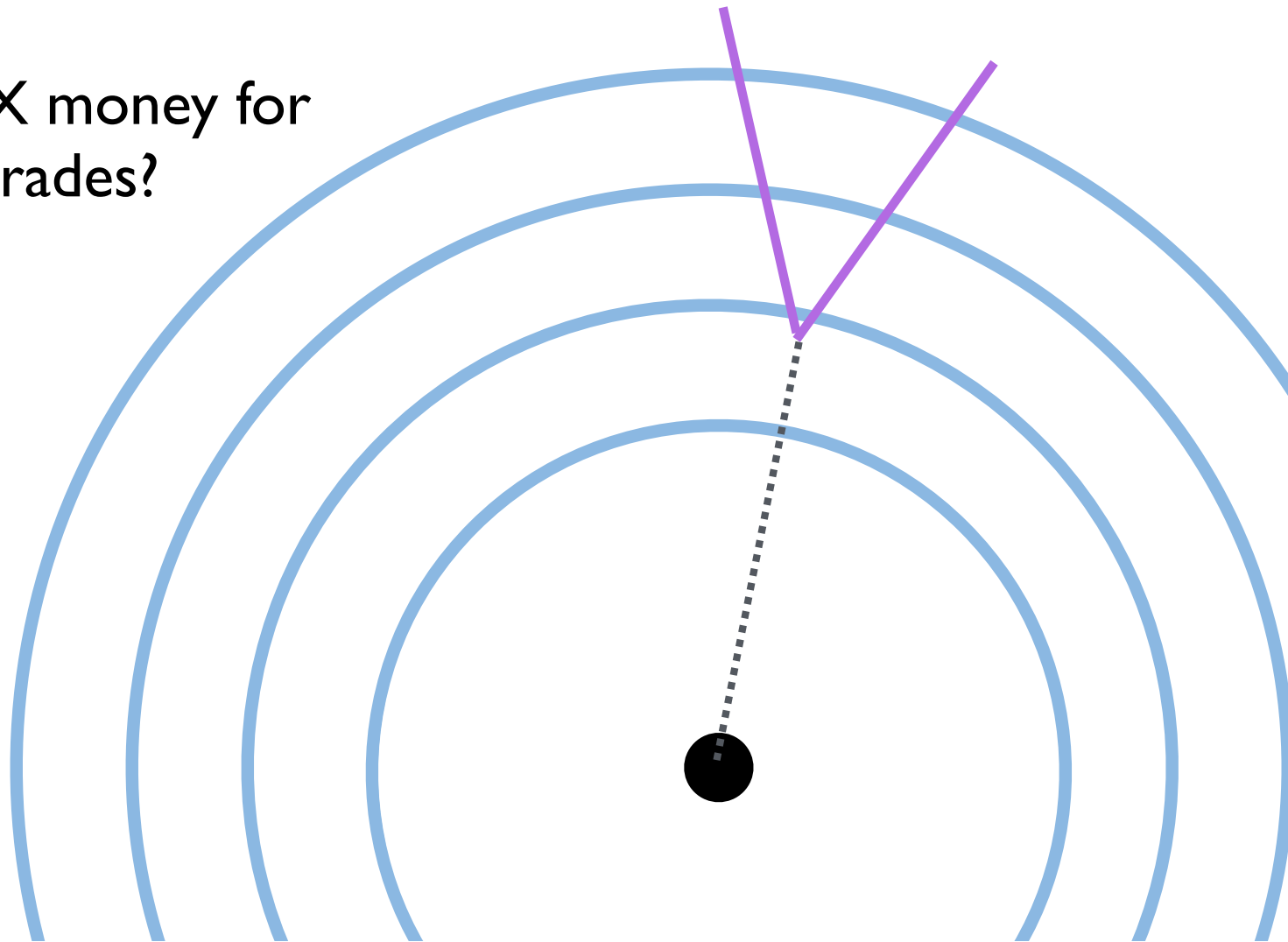
*Honeycomb  
vs  
radial?*



# LI tracking & smart wiring?

... or is there any way to use LI tracking upgrades @ HL-LHC to trigger on DVs??

What if you had \$X money for HL-LHC upgrades?

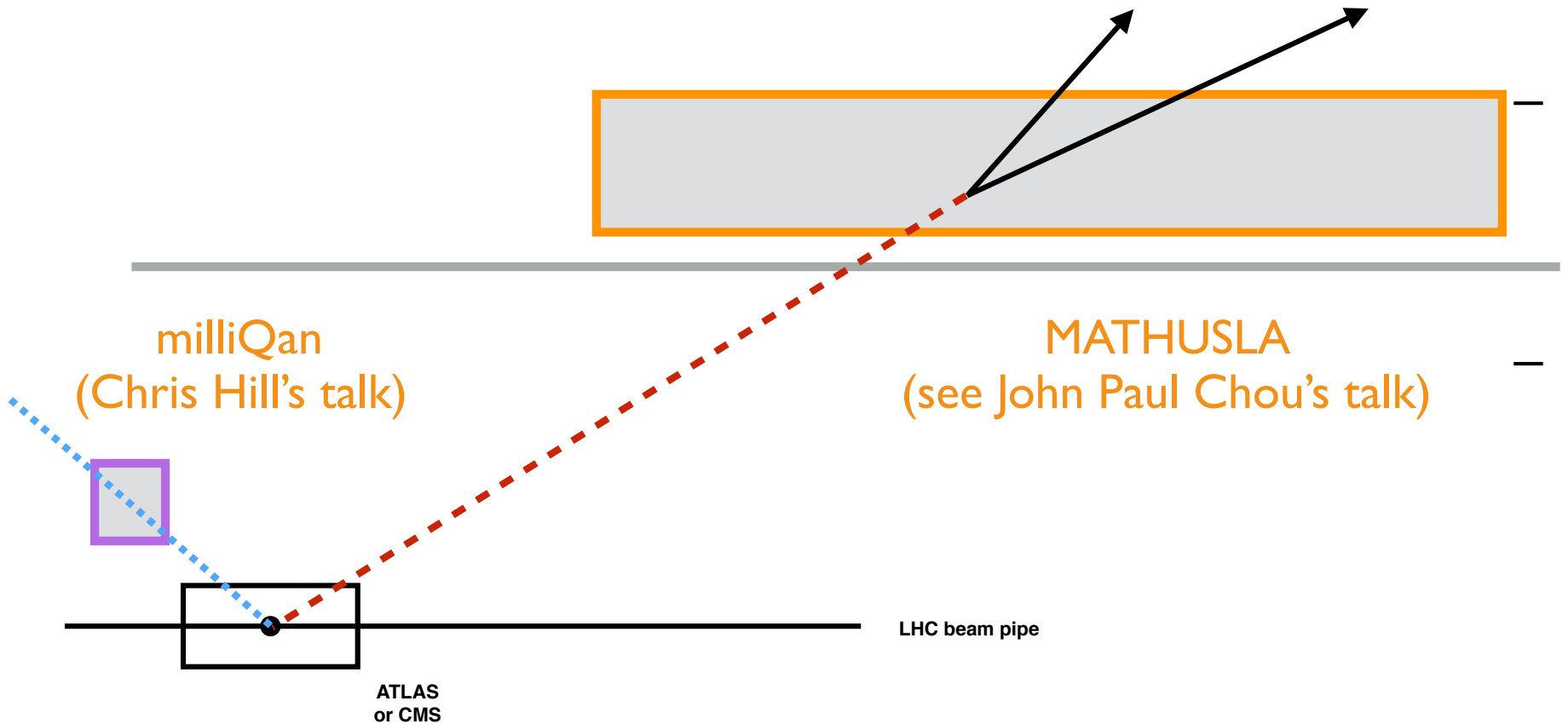


Well that was fun...

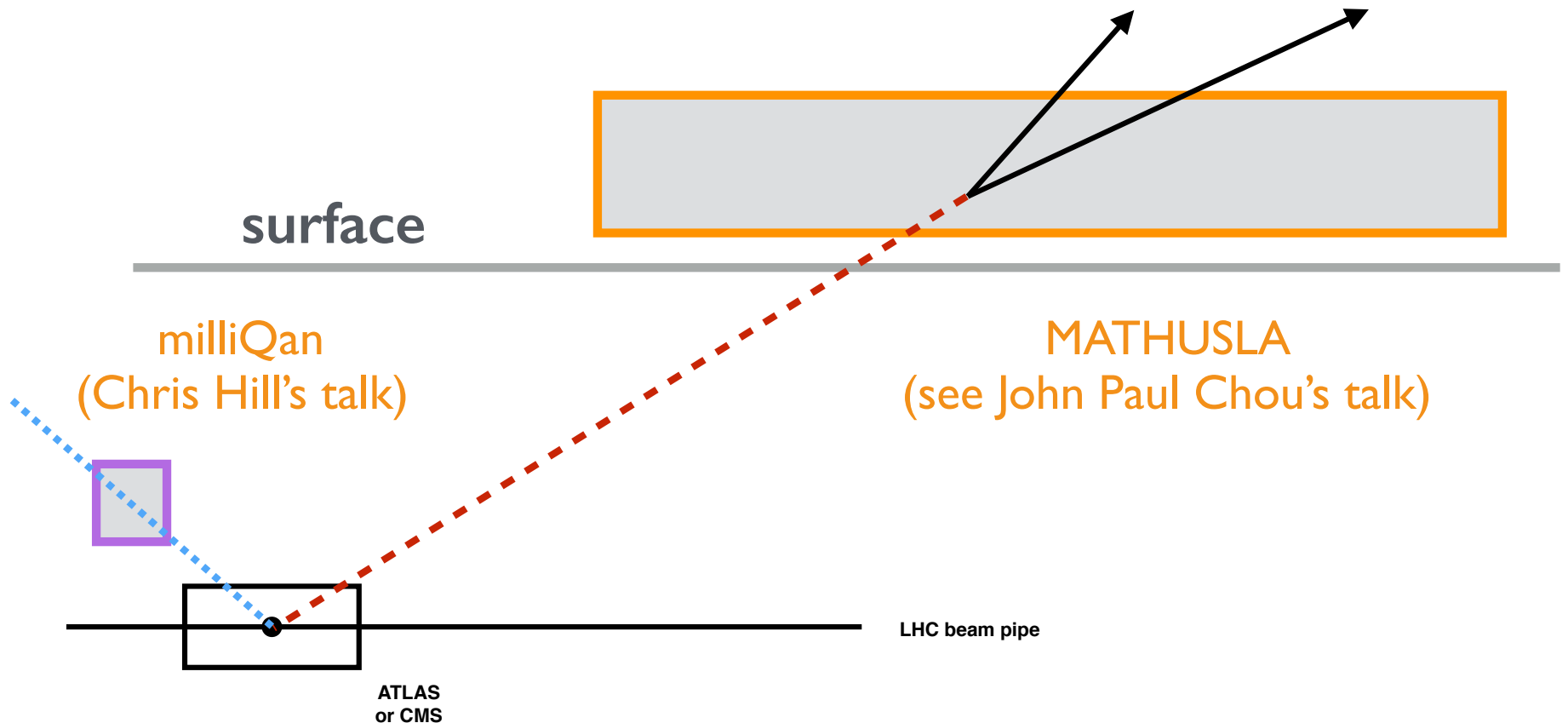
... But there are some new (and maybe not so crazy) possibilities for longer lifetimes as well!



# New Detectors as Triggers



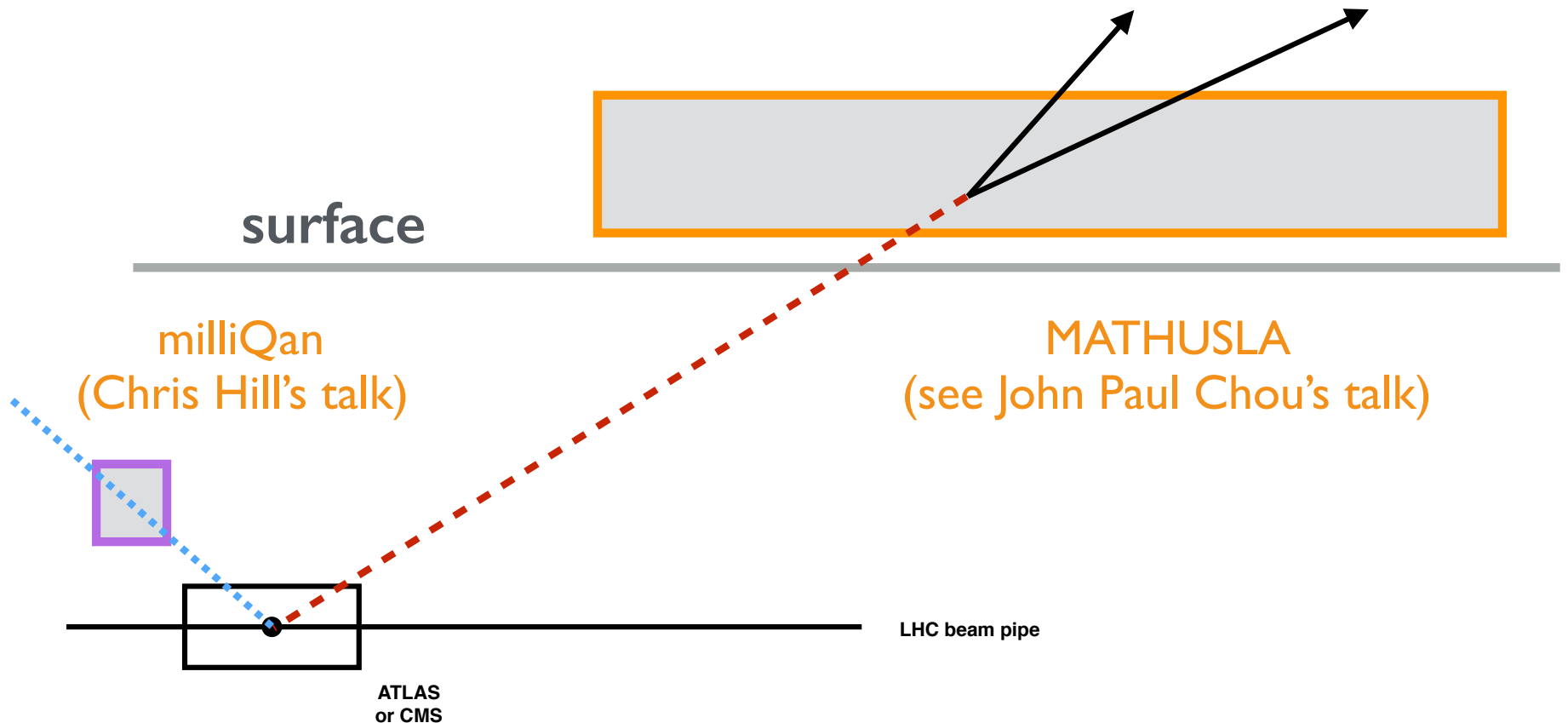
# New Detectors as Triggers



**Could these external detectors fire the LI trigger?**

Would need to lay some fibre, but might be possible...

# New Detectors as Triggers



**Could these external detectors fire the LI trigger?**

Would allow study of LLP production modes using information that would otherwise not be recorded!

# Conclusion

The **Lifetime Frontier** is the cutting edge of LHC physics!

Need to maintain maximum trigger sensitivity within boundaries of current hardware

If the “usual” prompt searches continue to yield null results, LLP searches should become a major focal point

Dedicated hardware modifications for LLP detection may then be in the cards. Think of possibilities now!