



Can you put M^3 into
SpinQuest?

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w/help from D. Hoang, C. Mantilla, B. Ramson

Where do you place M³?



Where do you place M³?



Disclaimer

This work is just an idea

The hope is to discuss the pros and cons of
this idea

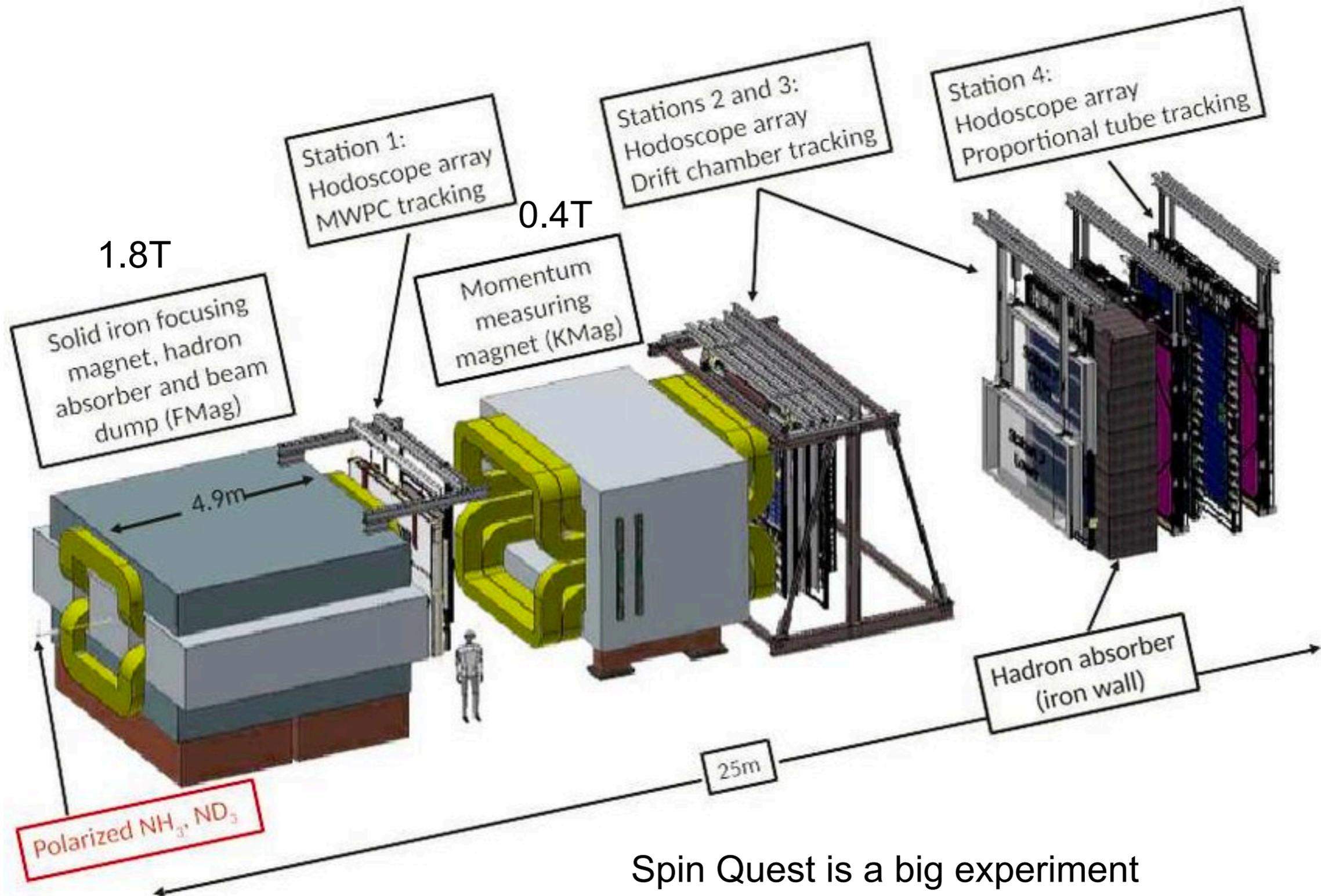
I am not yet sure this is a

good idea

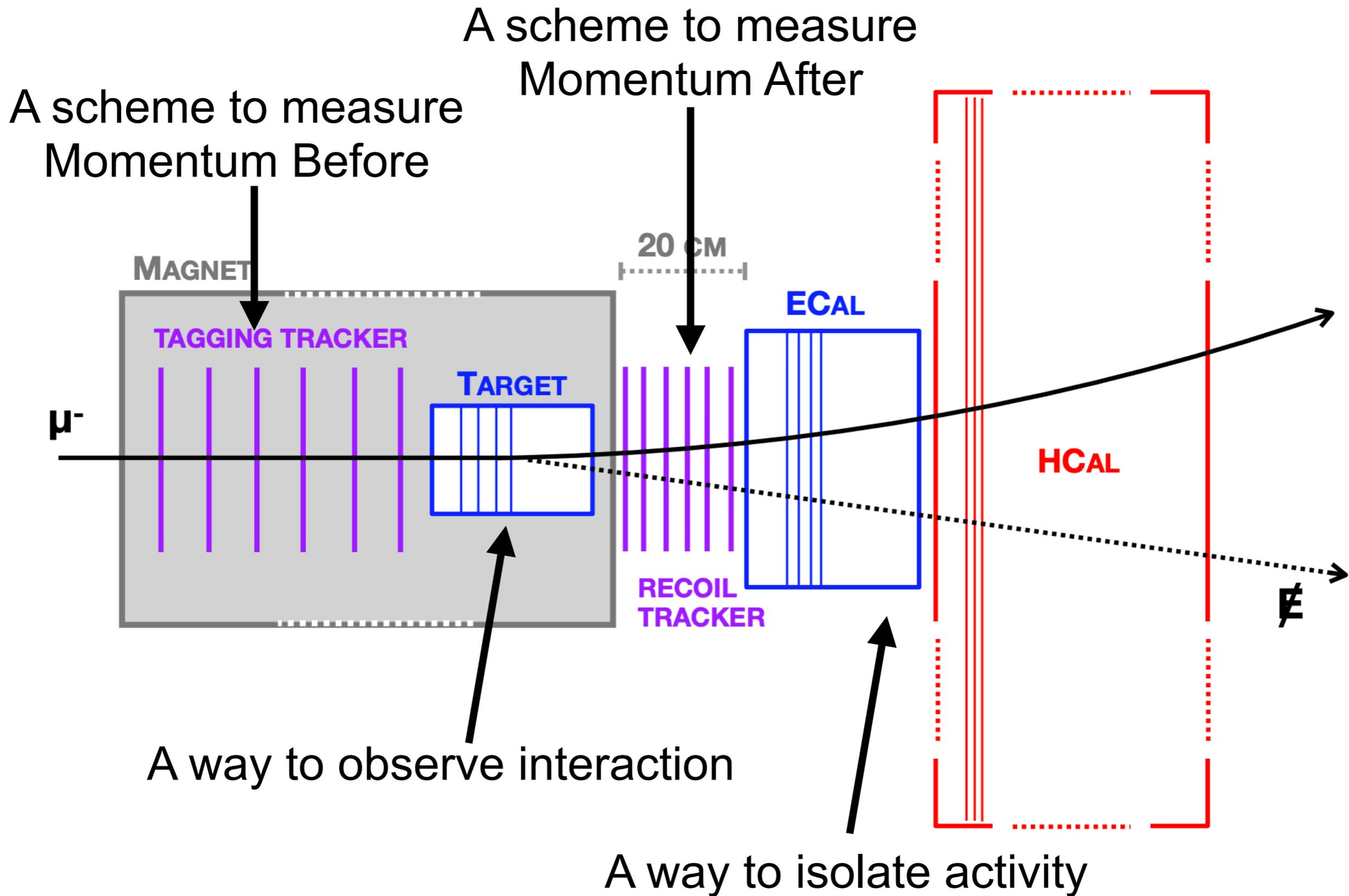
or a

bad idea

Spin Quest



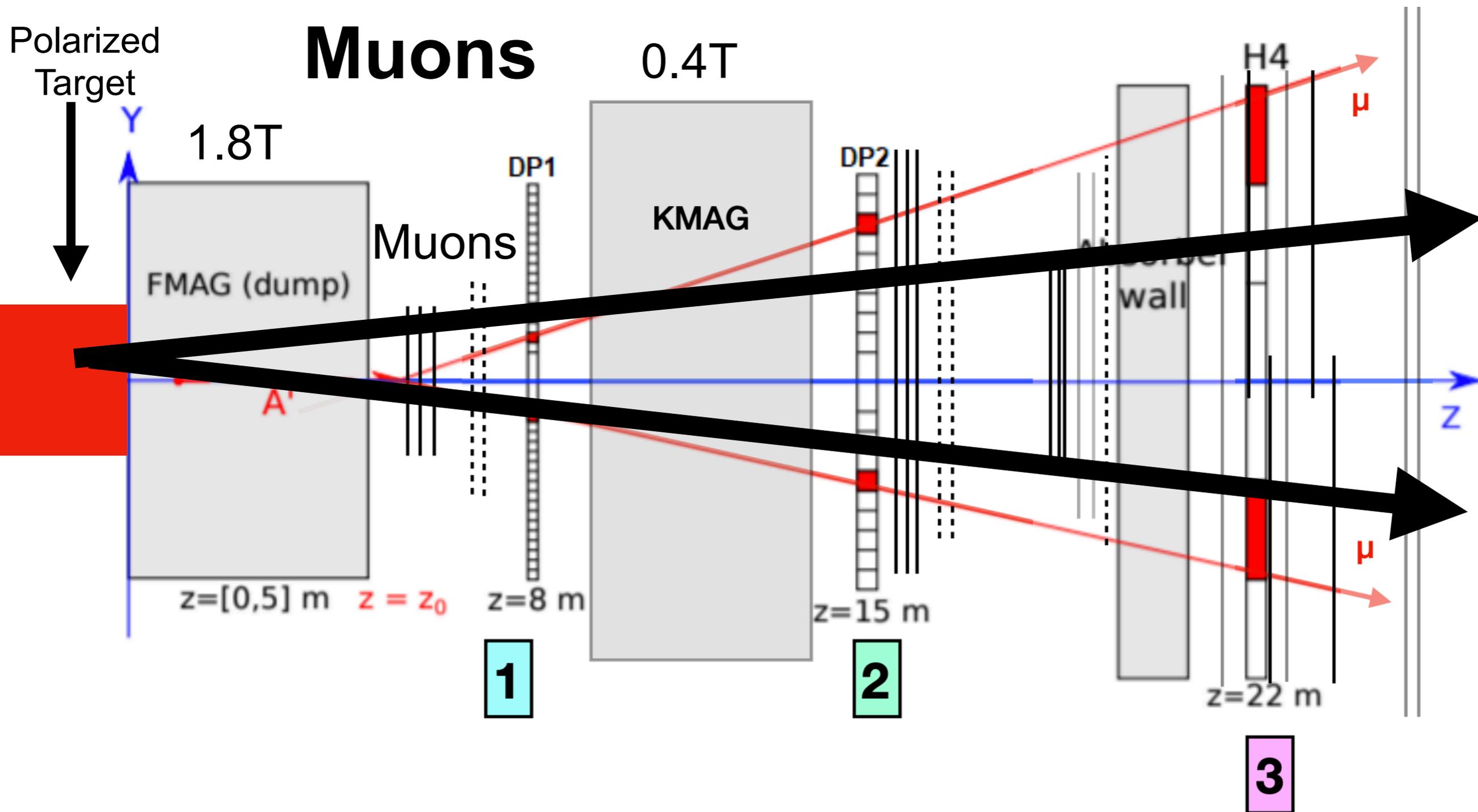
Spin Quest is a big experiment
 Its goal is to measure muons on the edge of detector



What do we need?

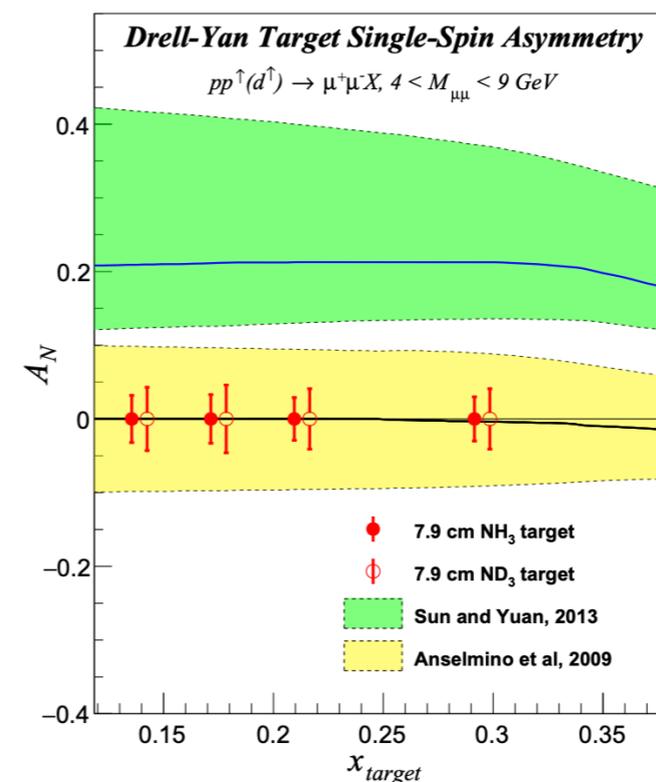
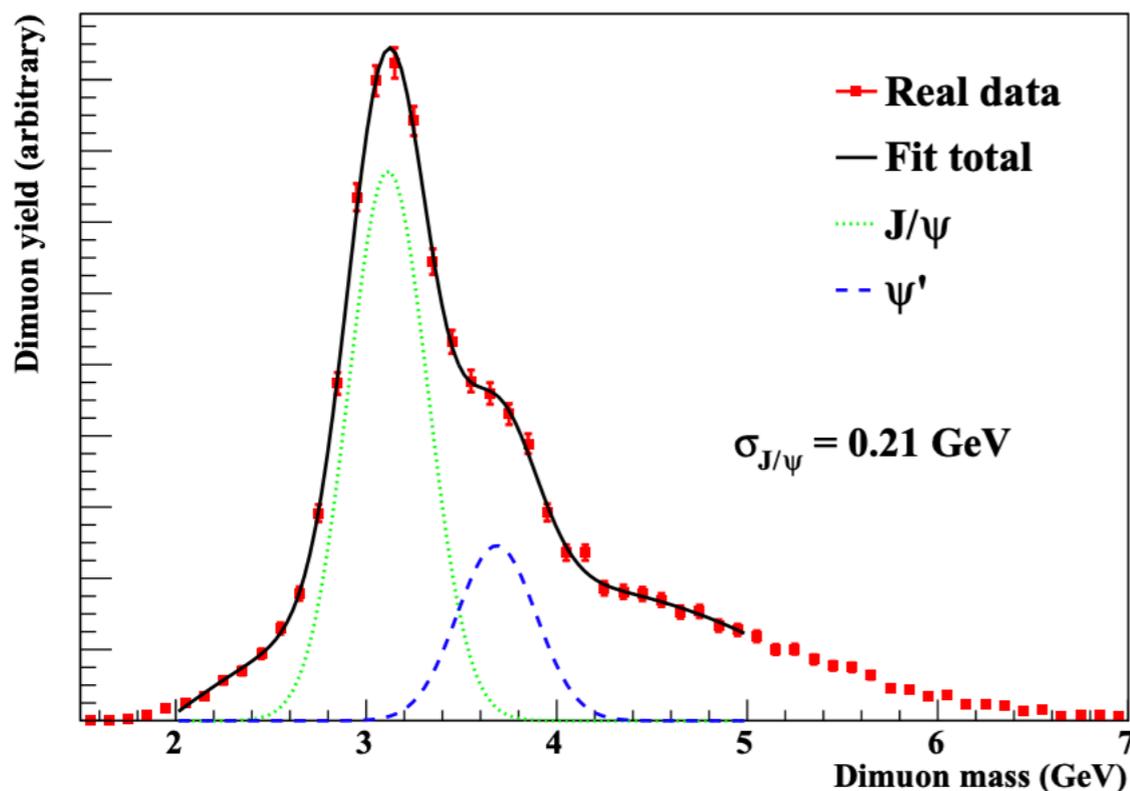
- Preserve physics for SpinQuest
- Enough Muons to do M^3
- Upgraded detector do M^3 (and improve DQ/SQ)

SpinQuest

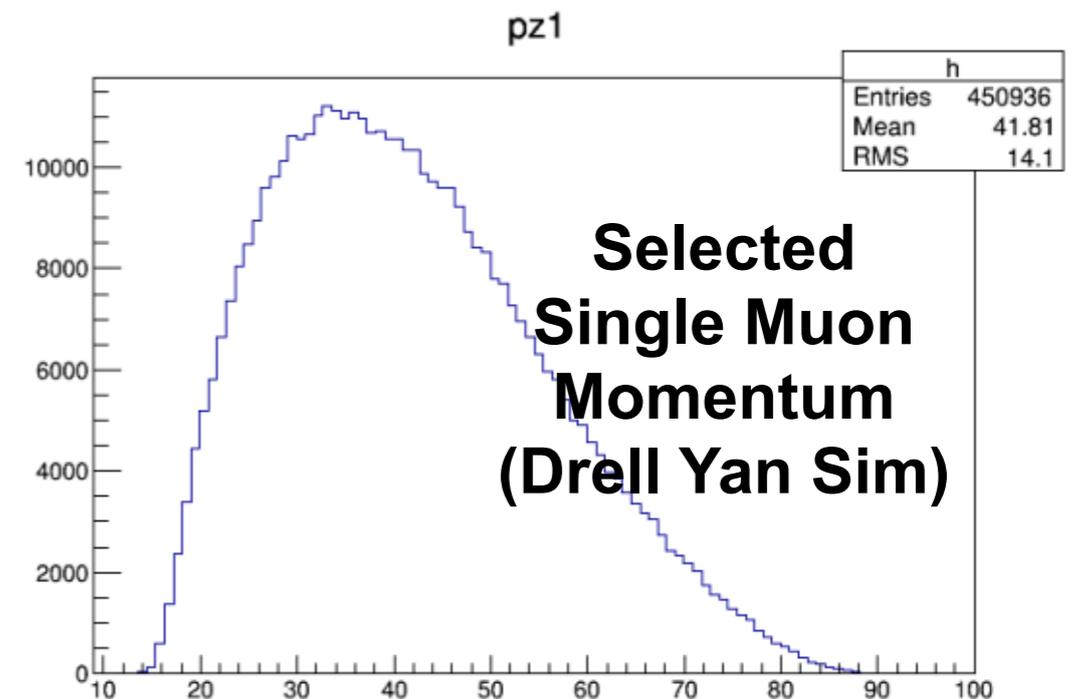
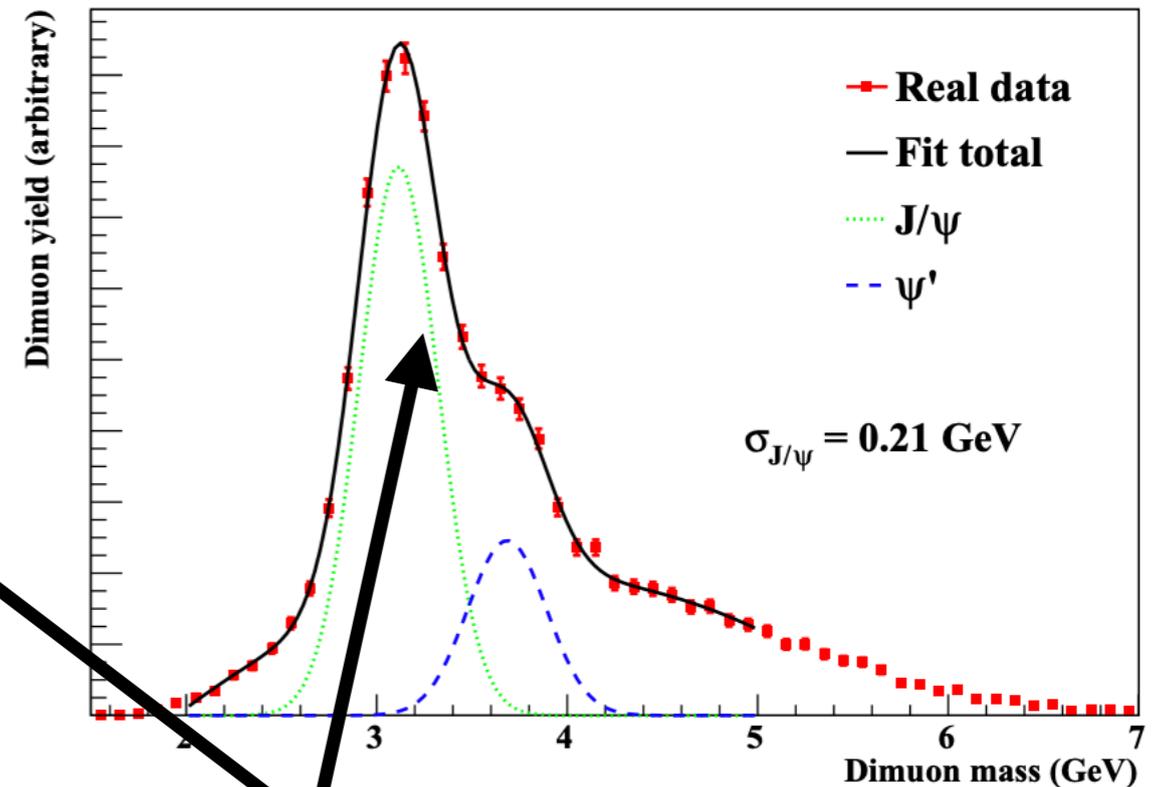
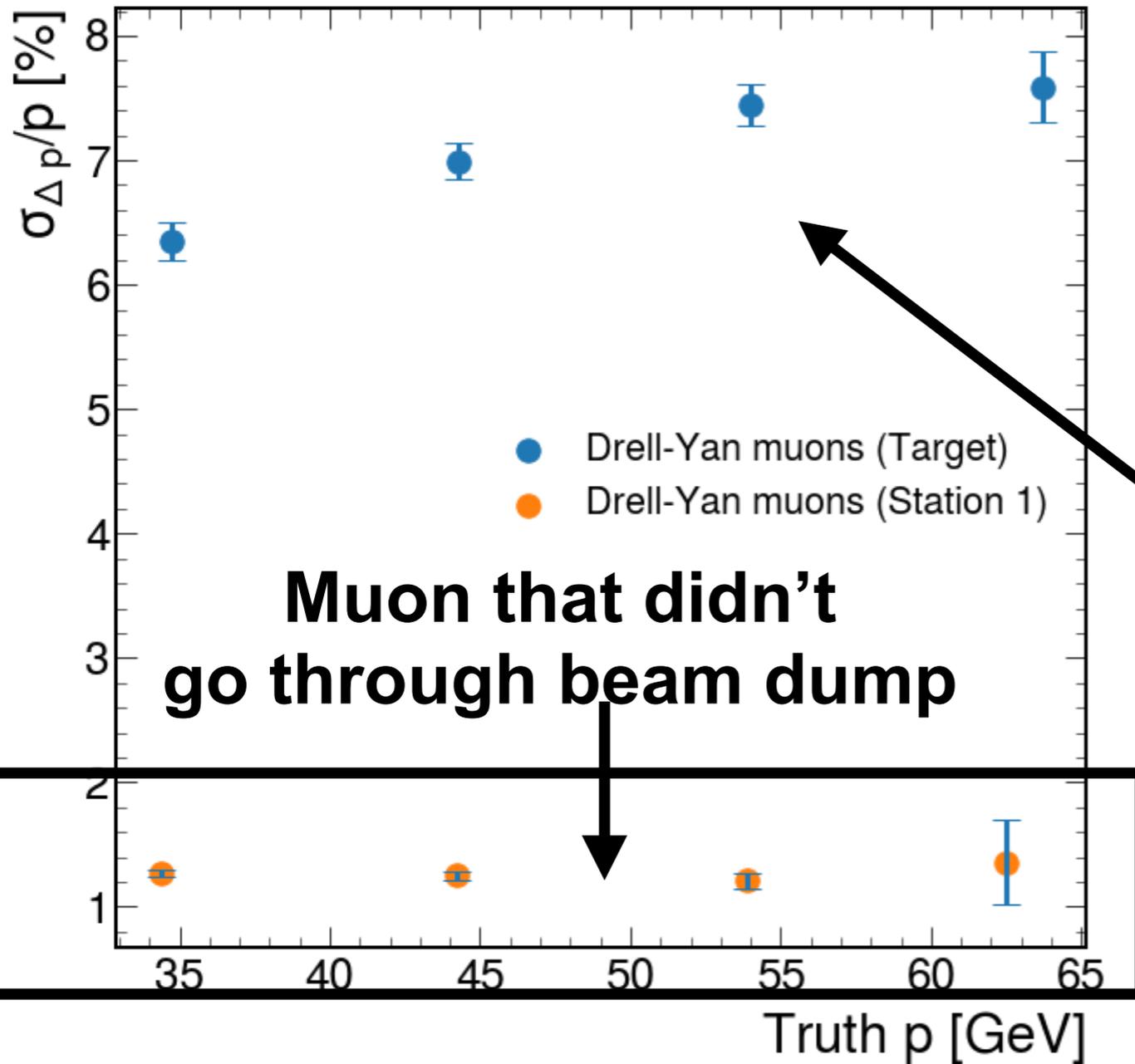


What can SQ do?

- Spinqwest is designed to **measure muons from a target**
 - The momentum resolution is not perfect
 - But it is pretty good
- Strategy for SpinQuest in one line:
 - **Measure di-muon asymmetry from Drell-Yan or J/ψ**

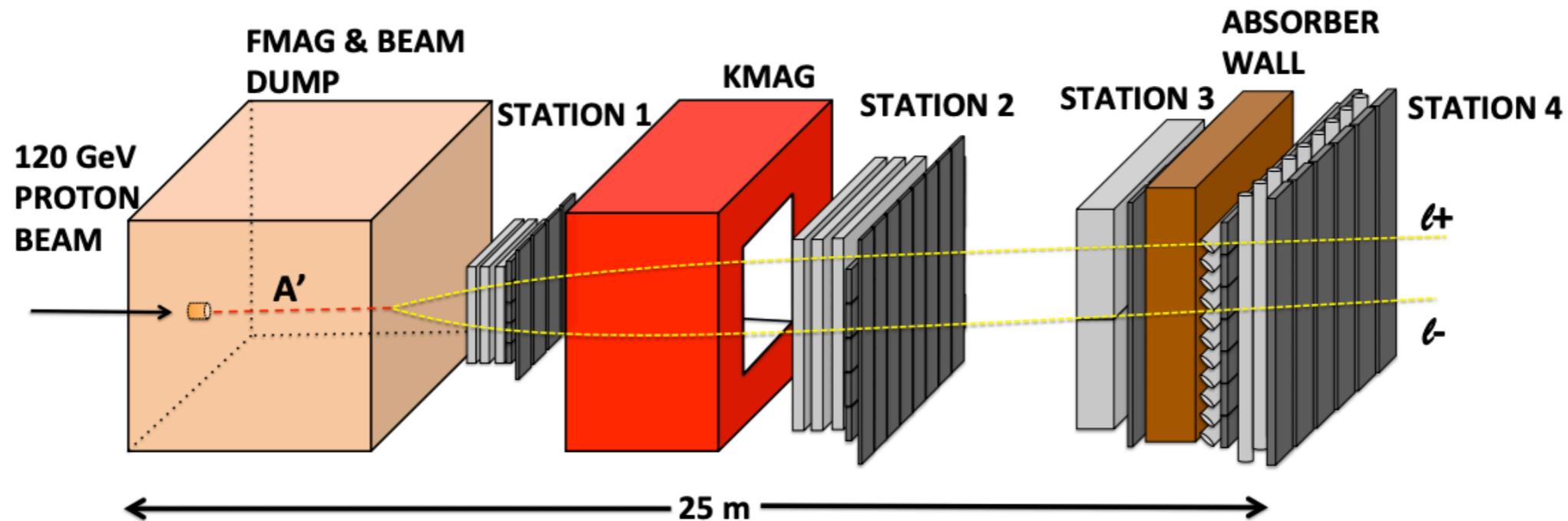


Spin Quest Resolution

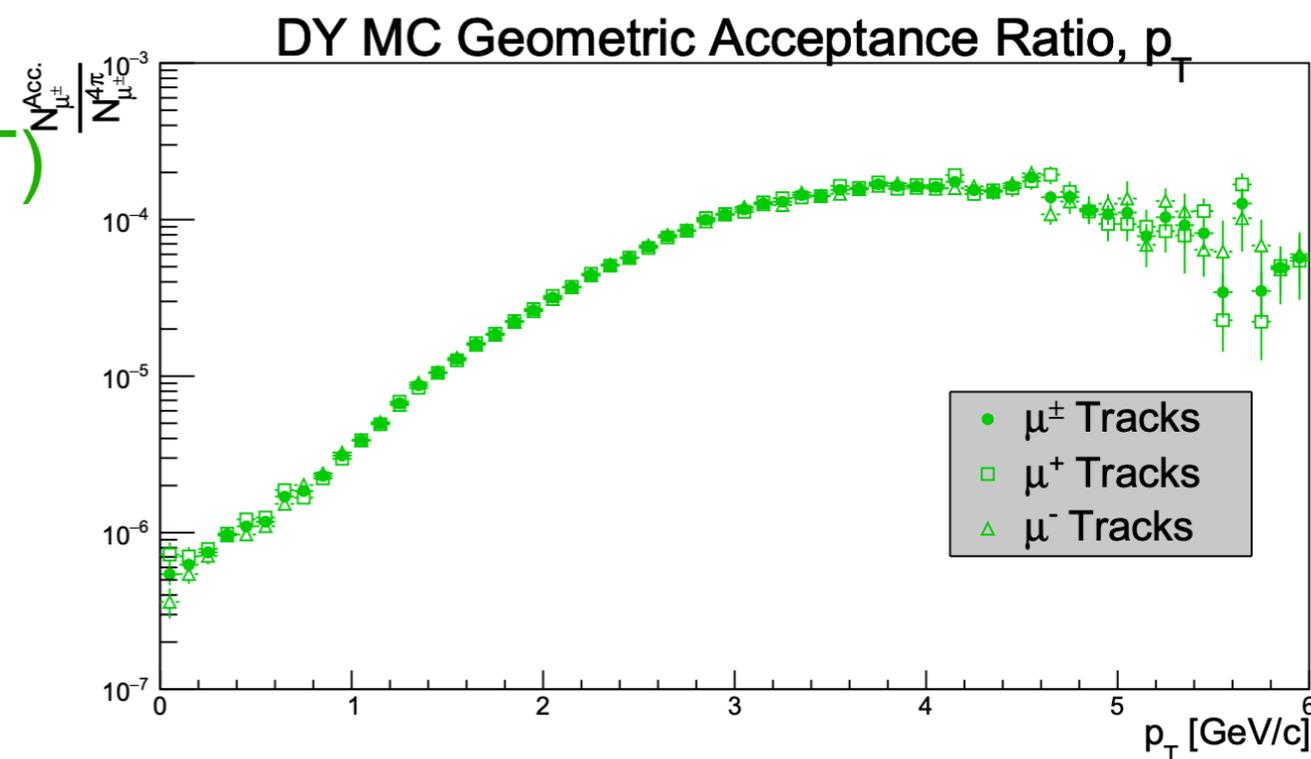


Spin Quest Targets muons
 in 9 to 60 GeV range
 But most above 30 GeV

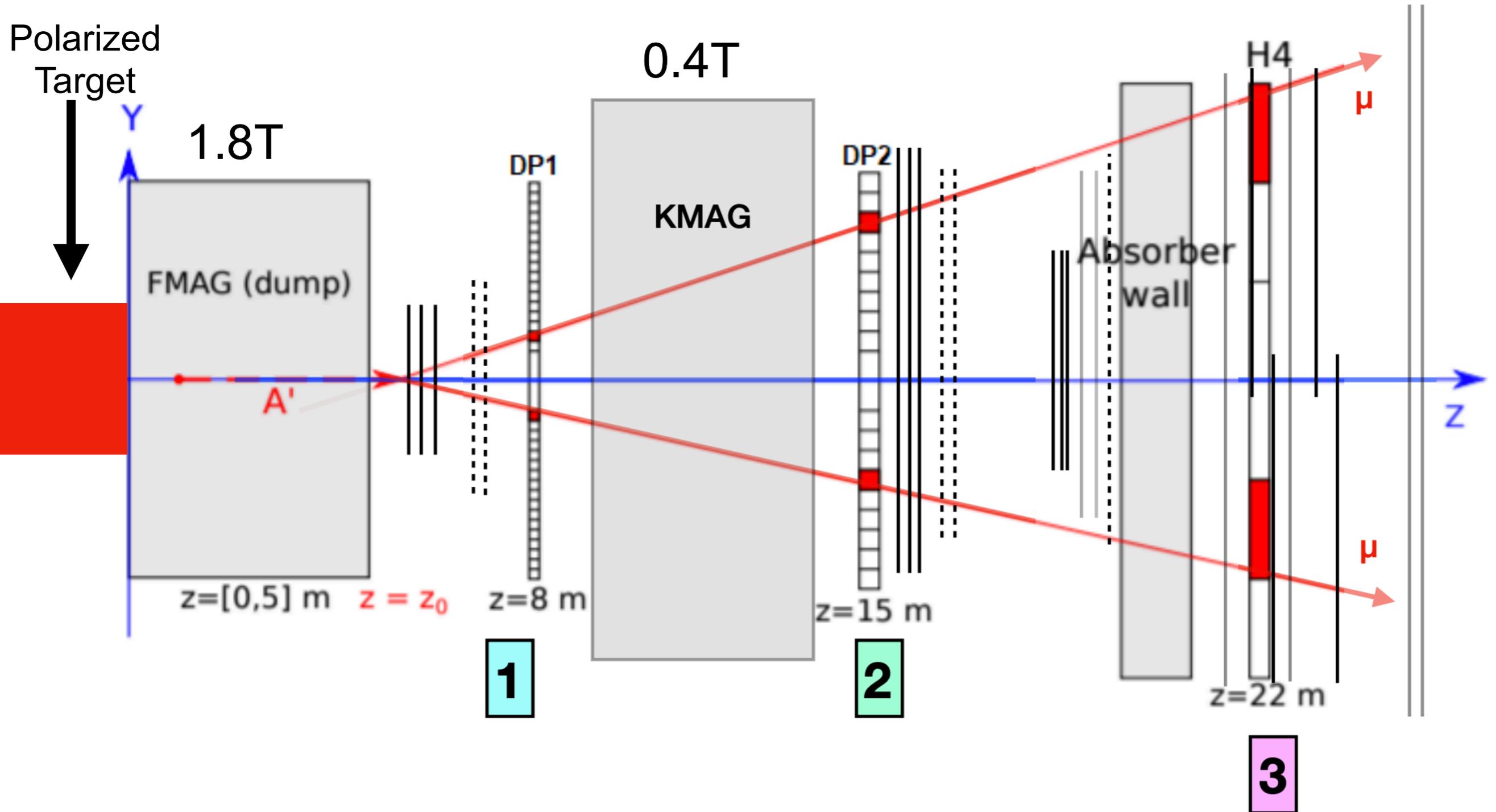
Spin Quest Event Acceptance



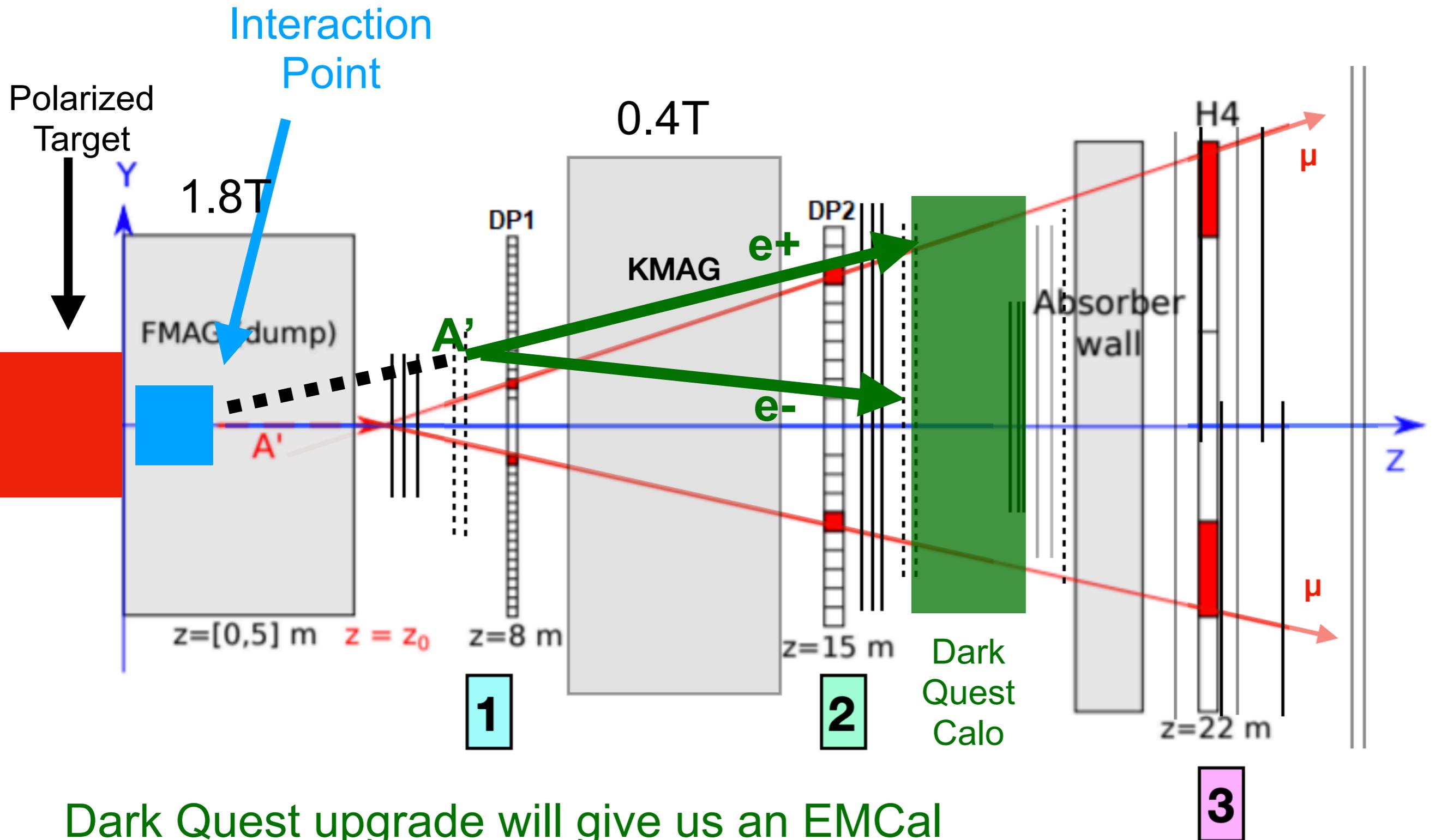
- Spin Quest aims for dimuon
 - Wide di-muons are best (high p_T)
 - Not so much in center
- Room to gain with
 - More and better instrumentation



SpinQuest to DarkQuest

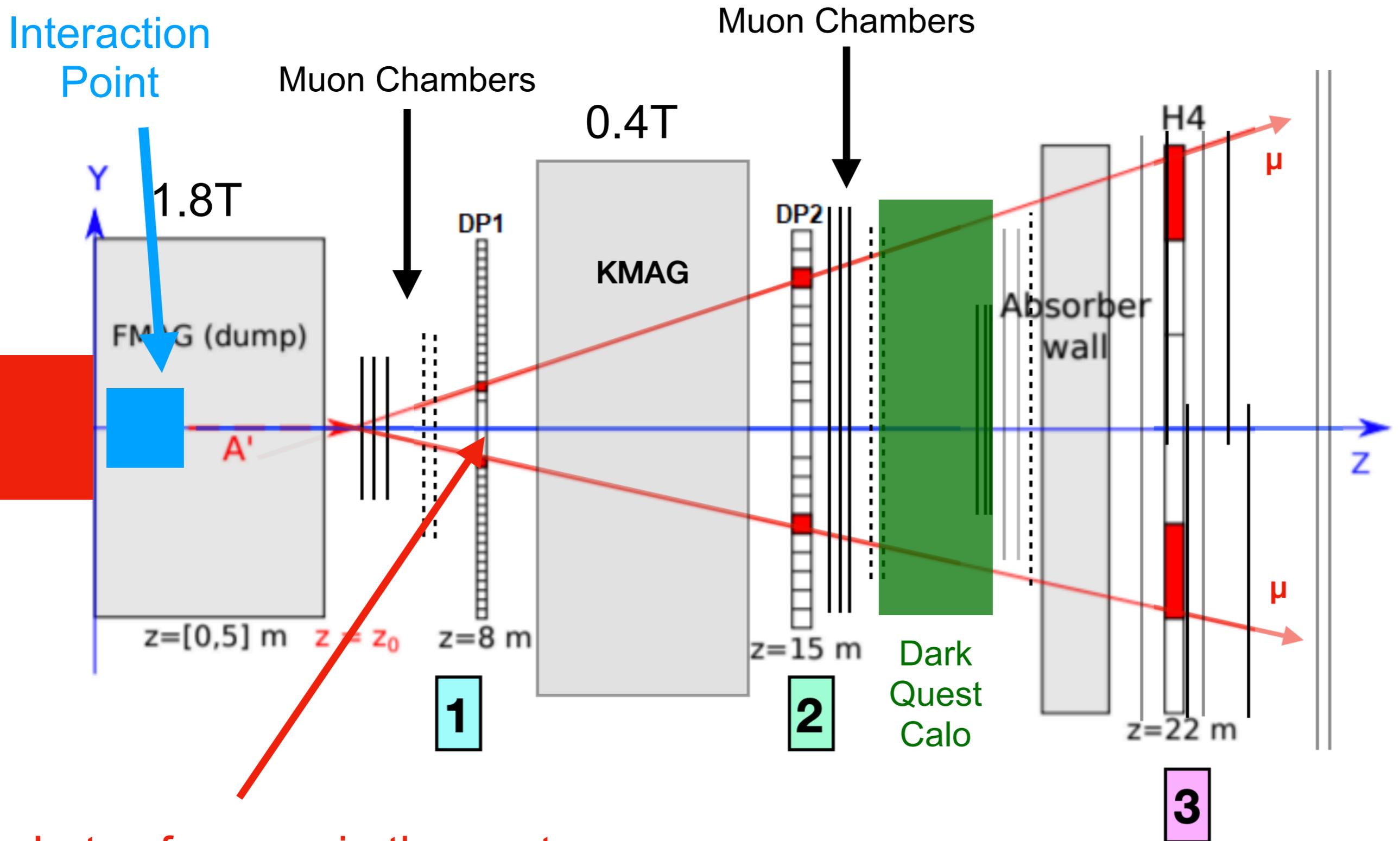


SpinQuest to DarkQuest



Dark Quest upgrade will give us an EMCal
This can enable dark photon to electrons

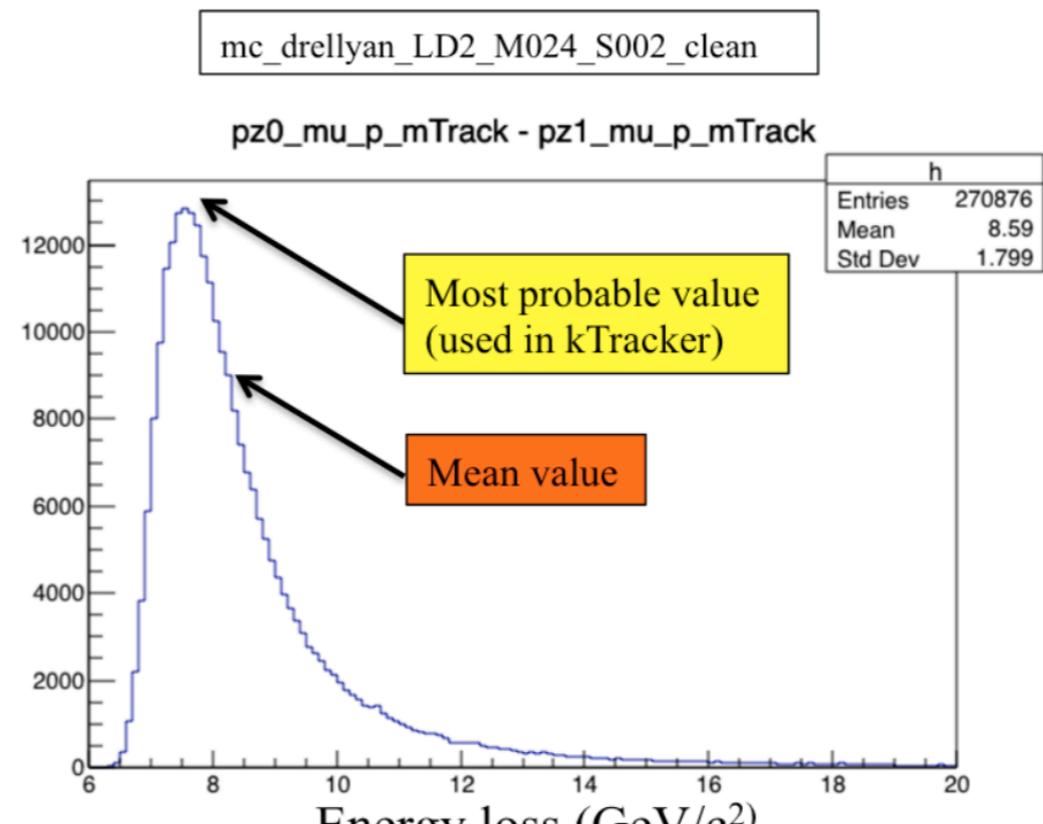
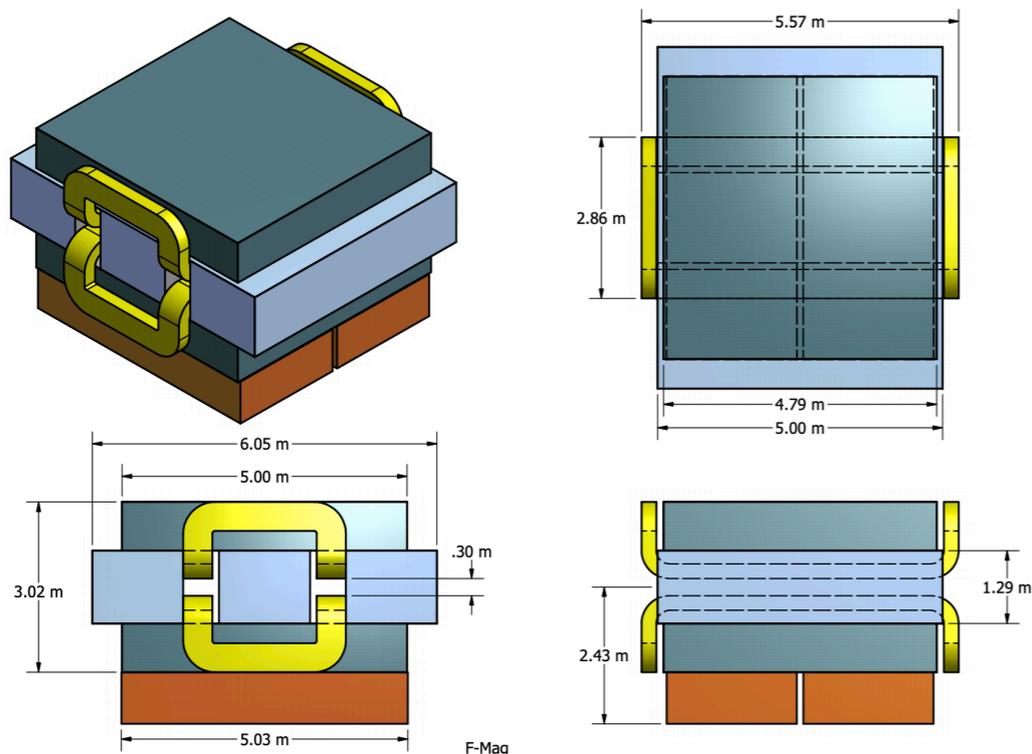
Can SpinQuest do M³



Lots of muons in the center

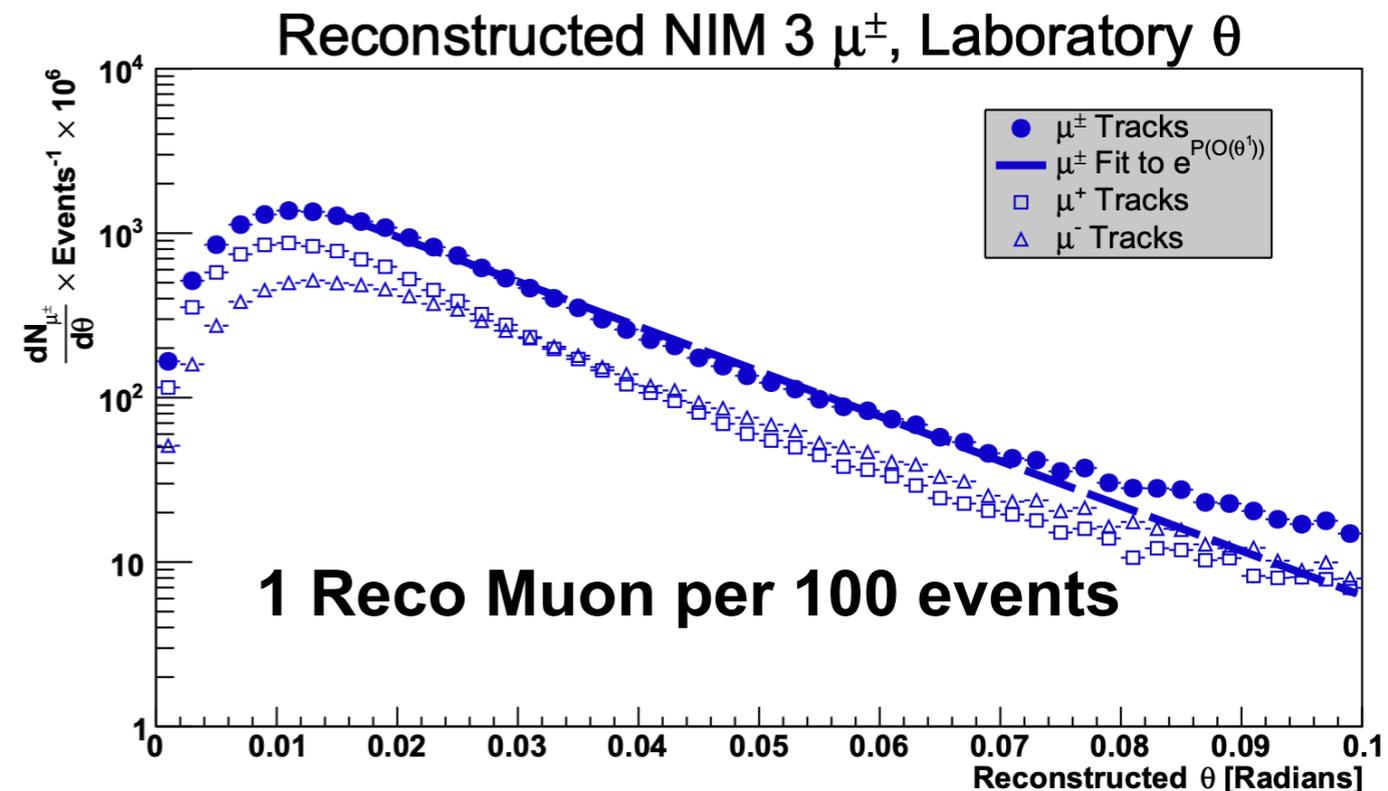
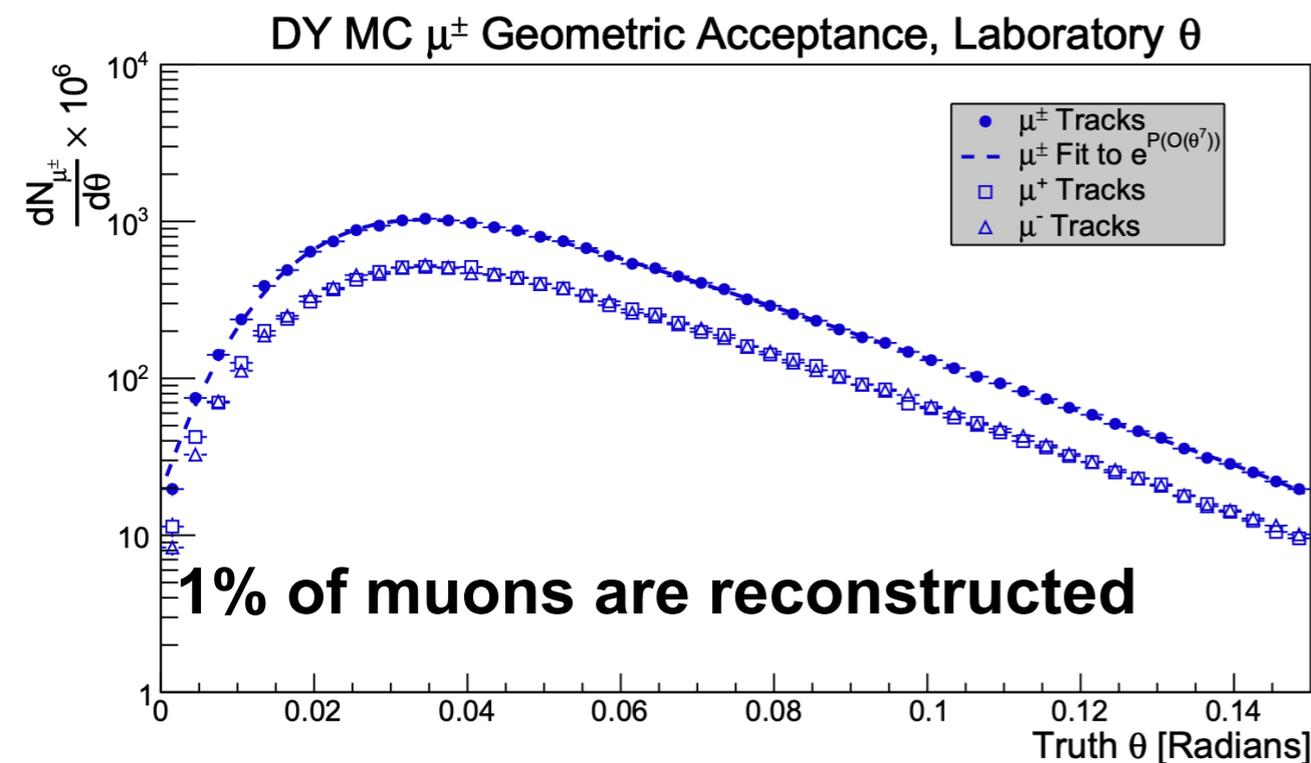
Muon Beam in SpinQuest

- Muons get bent out of the FMag
 - To survive the FMag you need 8 GeV
- Gets rid of the pions produced in the beam dump
 - Puts some energy limit on good muons (>10 GeV)
- ▶ After all this expect at least one good muon per beam



Muon Beam in SpinQuest

- The SpinQuest beam has a lot of protons on target: 10^5
 - For every proton on target
 - ▶ Roughly get a muon out of it in the beam dump
 - Question: How many muons leave the beam dump?
- Of those, how many muons do we reconstruct?



Numerology

- We need to get 10^{10} muons
- Beam is :
 - 10^5 protons at 52 MHz for 4s **every minute**

- 100 total days of running gives

▶ 3000×10^{10} events

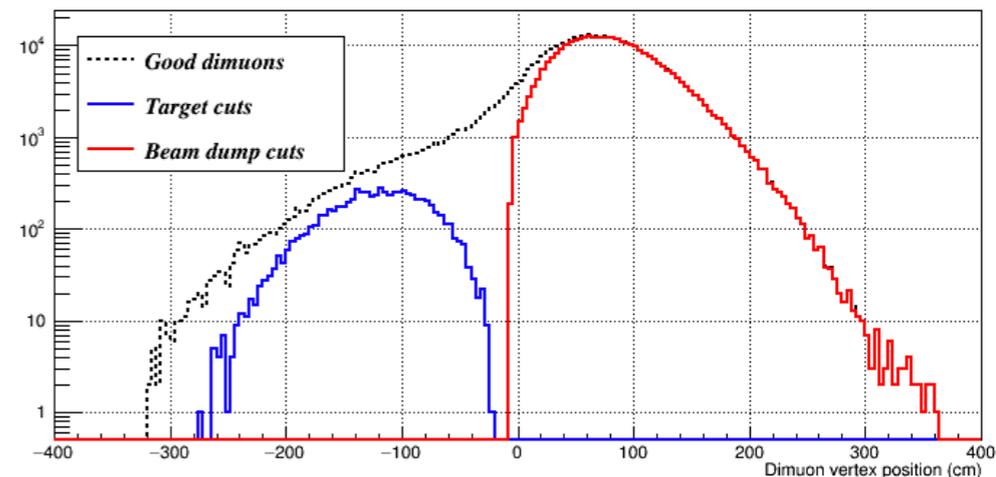
- Per event we get 10^{-2} muons per event

- Making it out of the beam dump

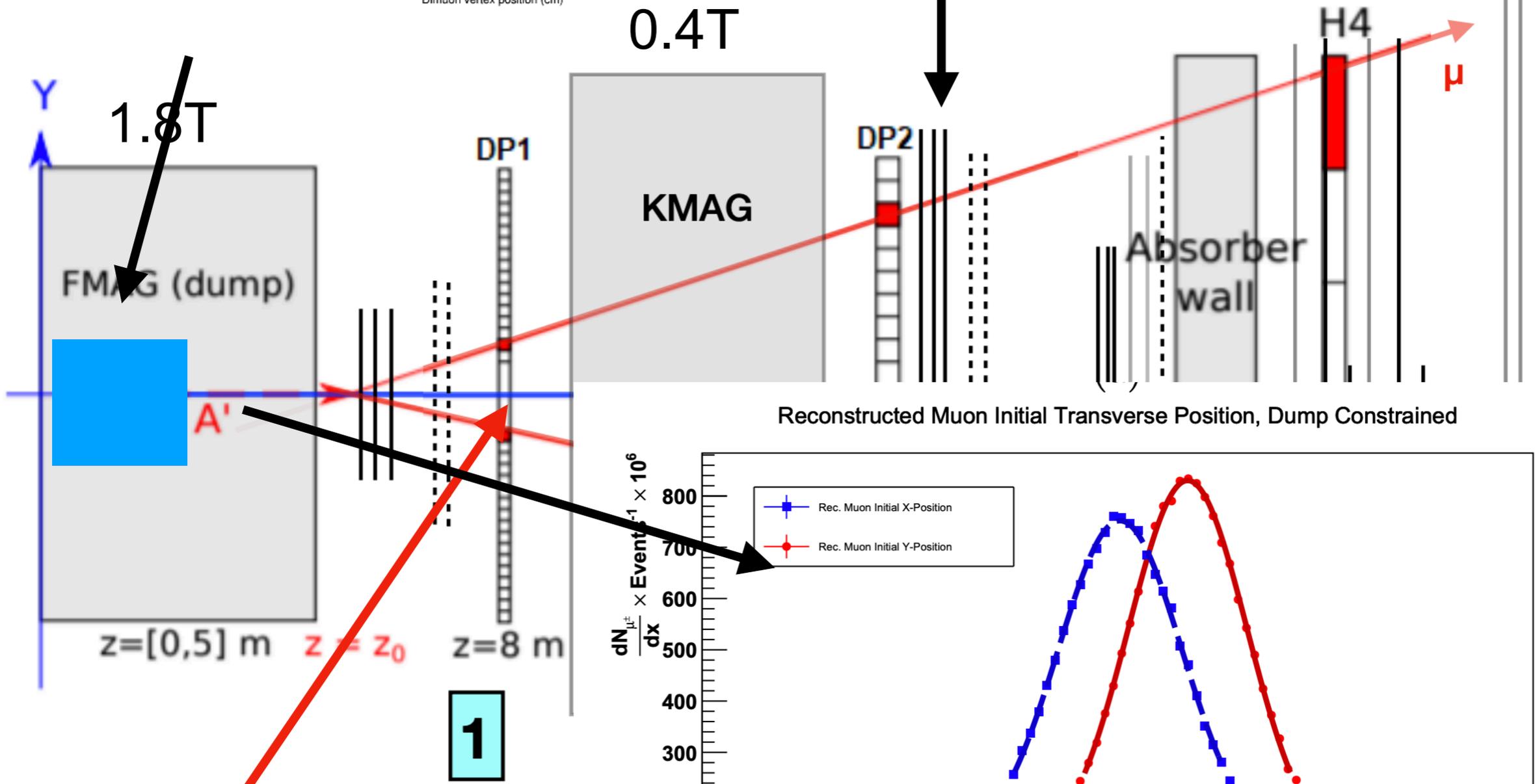
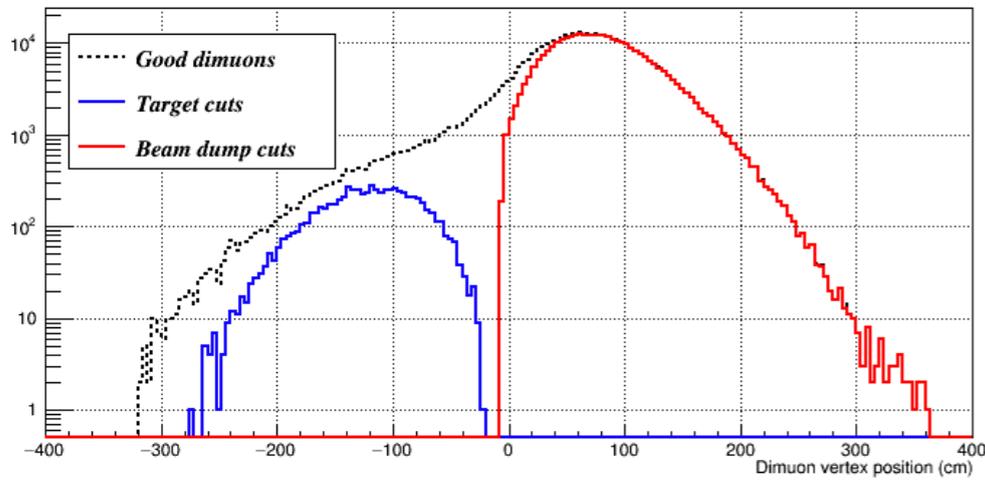
- We need a fiducial area that is 1/30th SQ

▶ Assuming normal spinquest reconstruction to get muon

- More muons from more detectors makes it easier

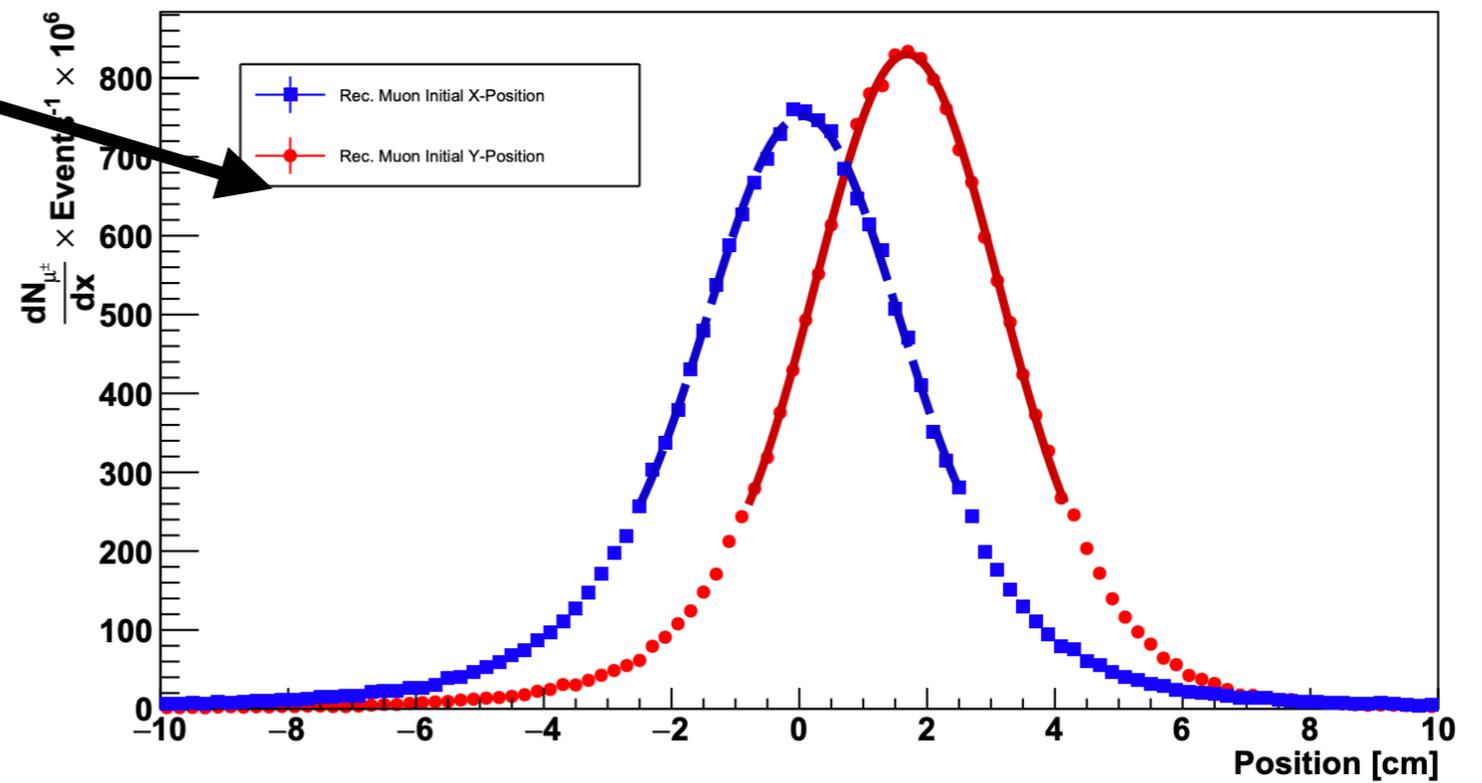


The Beam

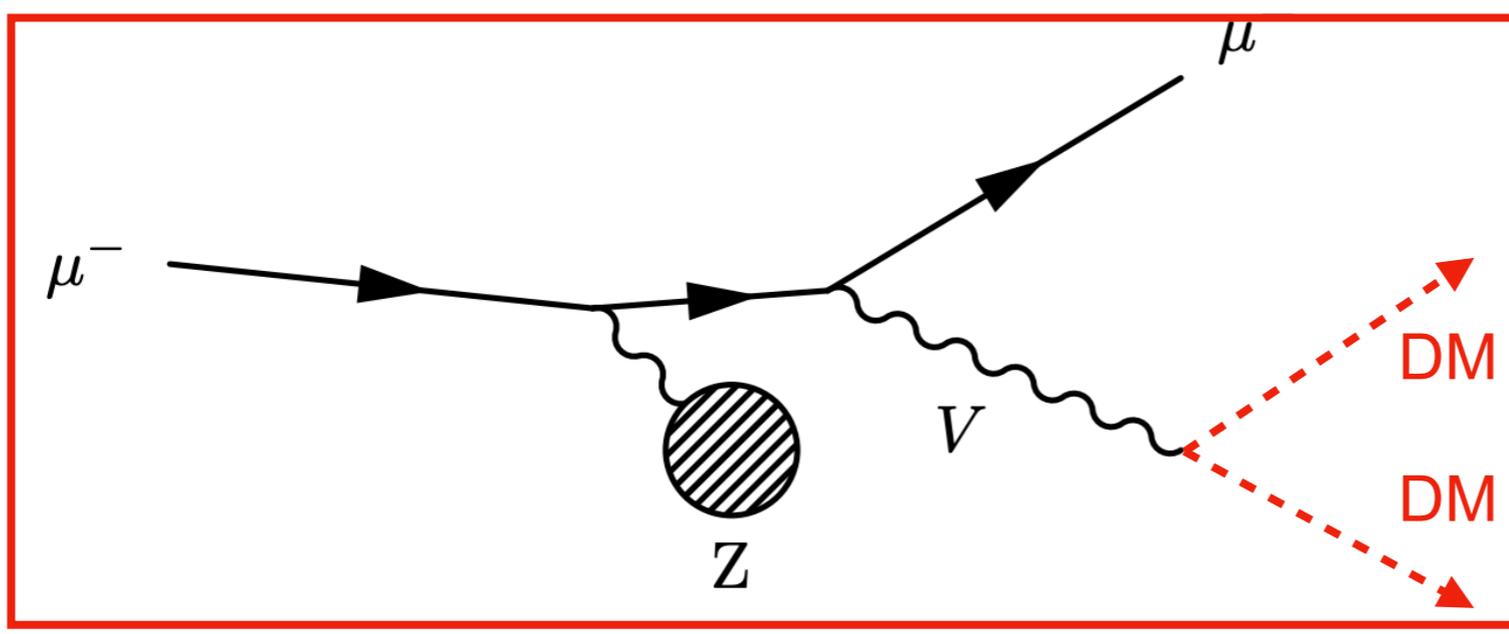


Lots of muons

Reconstructed Muon Initial Transverse Position, Dump Constrained

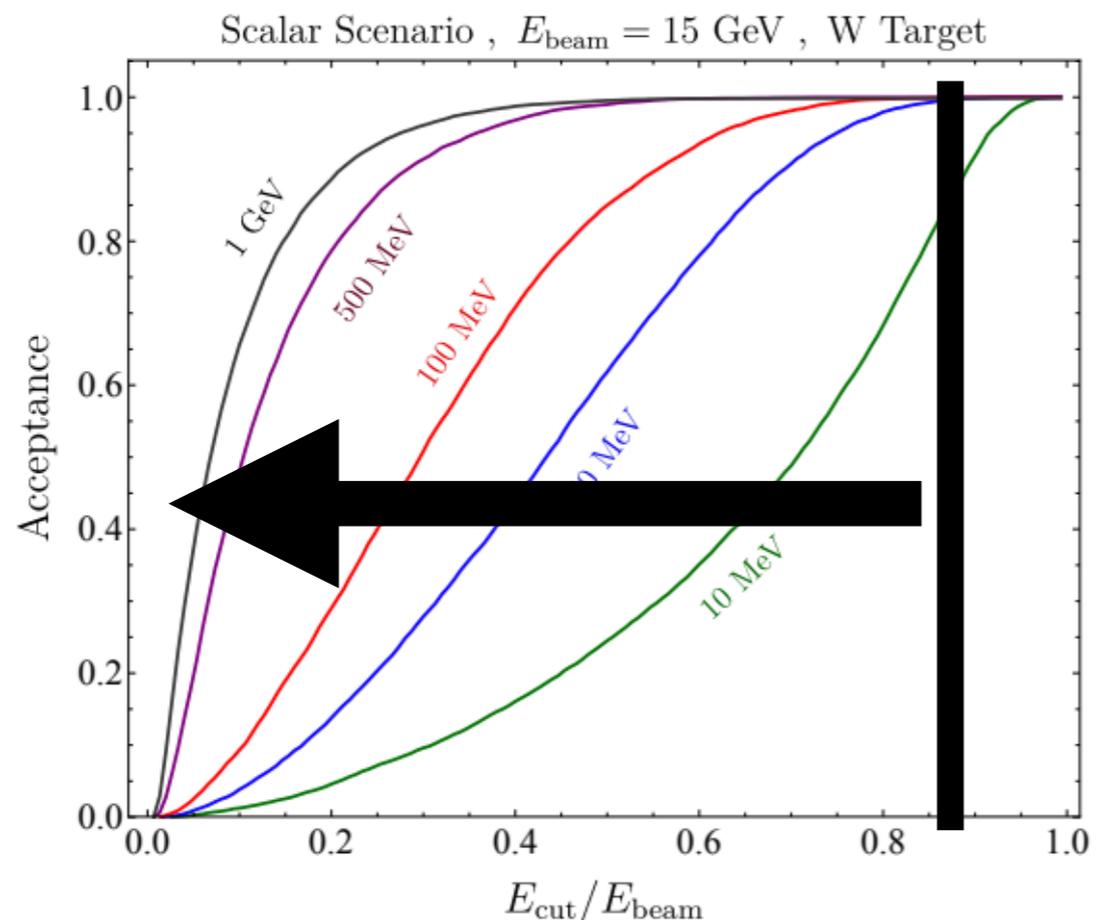


g-2 related Signatures

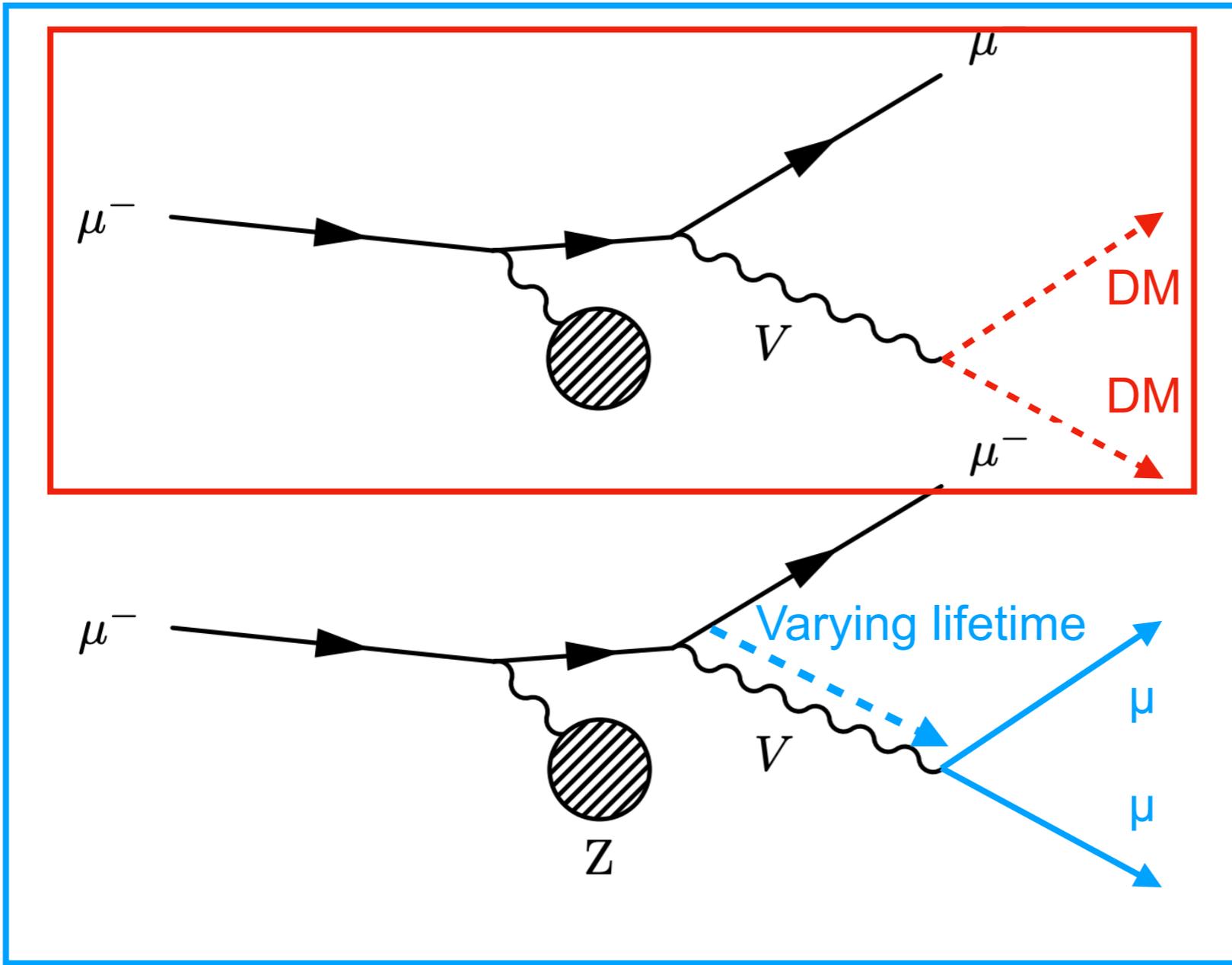


Invisible Signature
Mediator decays to DM
Look for kink

$\Delta p > 10\%$ (note current res is *in p* 1%)



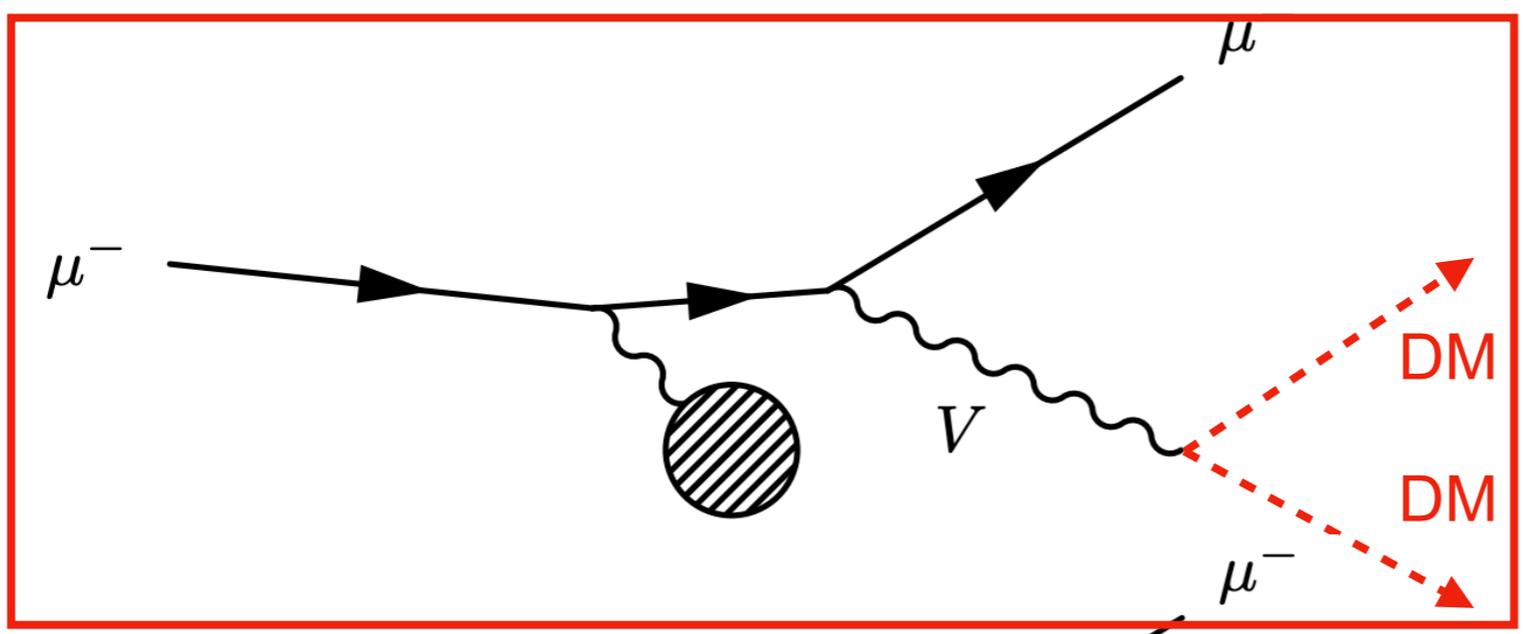
g-2 related Signatures



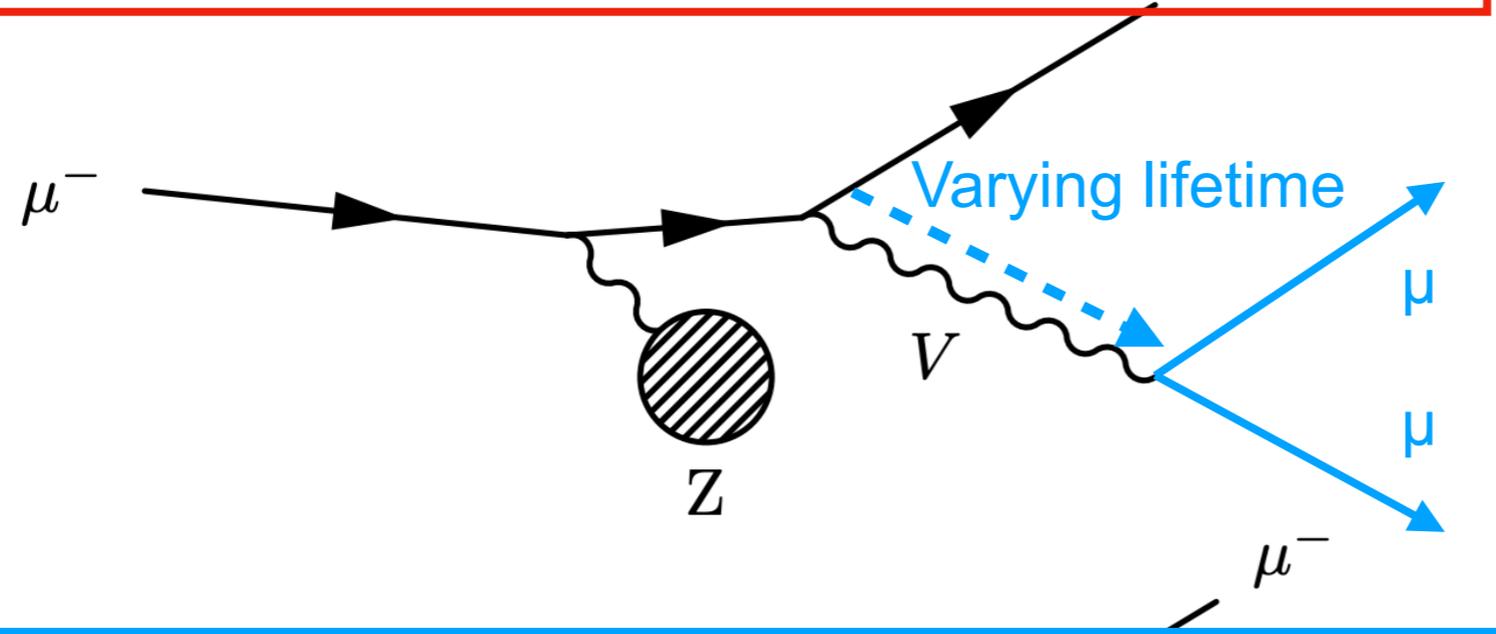
Invisible Signature
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Tri-muon events
Di-muon can be displaced

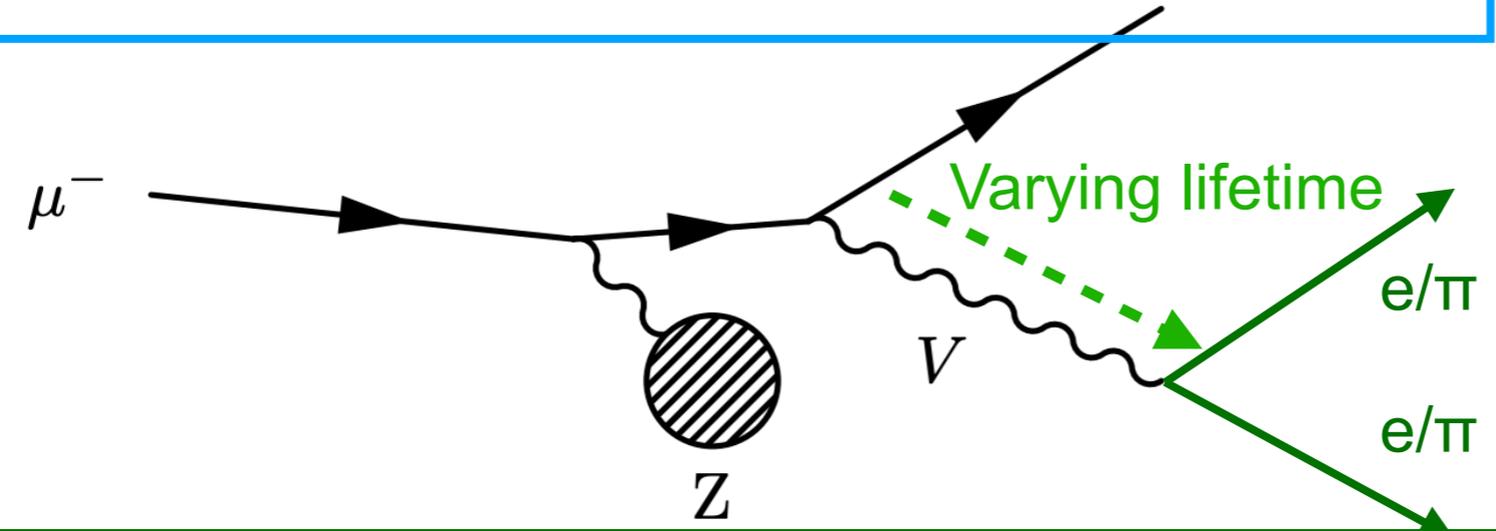
g-2 related Signatures



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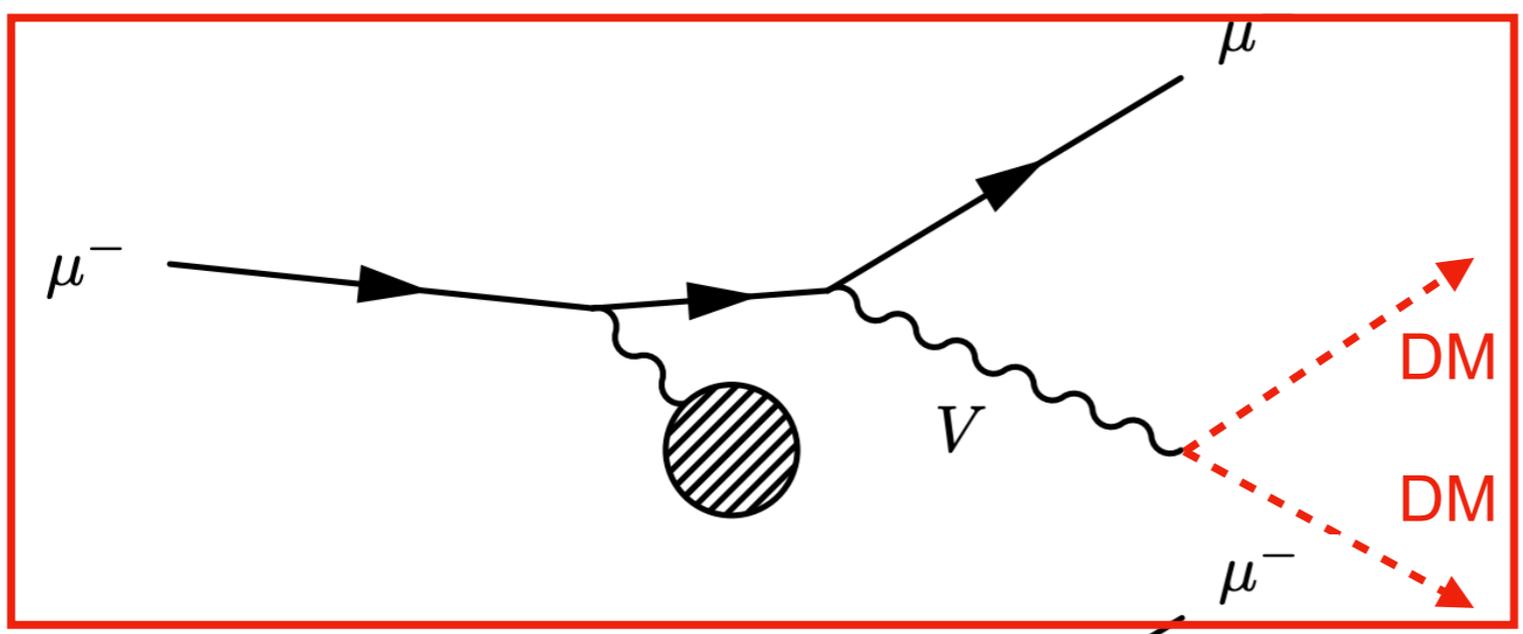


Tri-muon events
Di-muon can be displaced

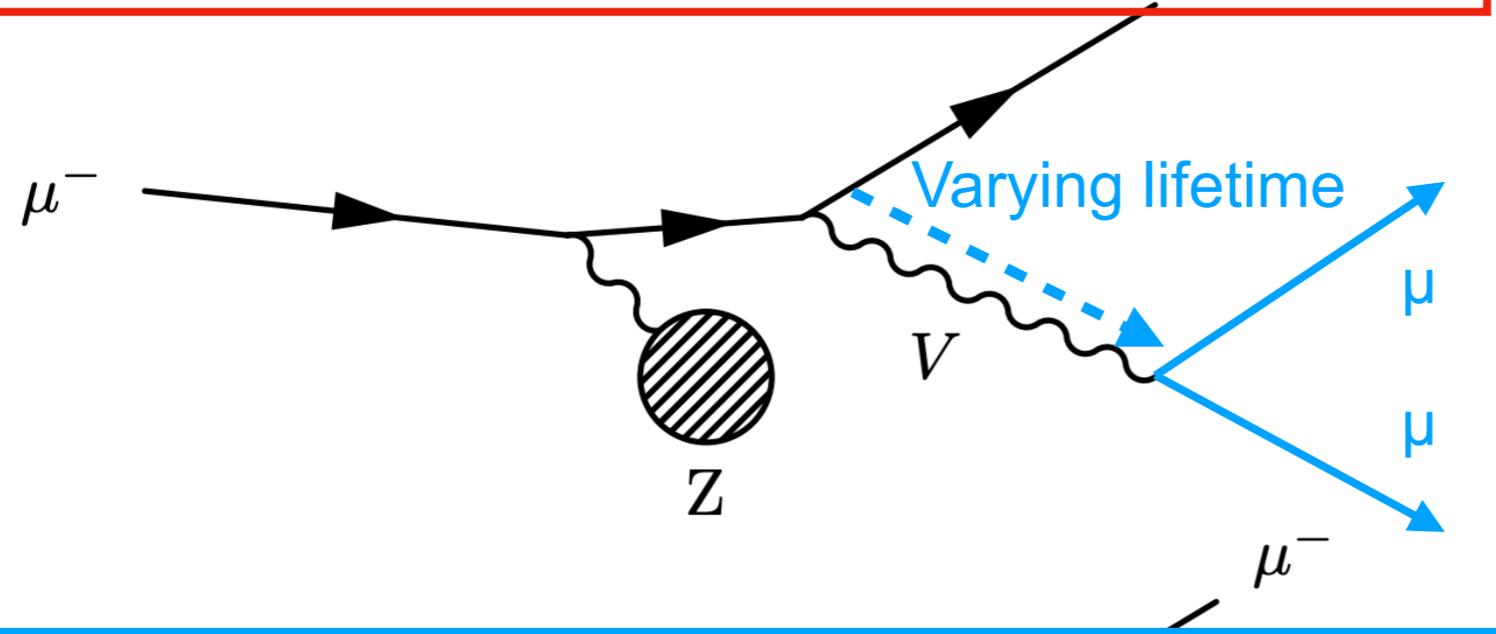


Decays to electrons
and hadrons
displaced

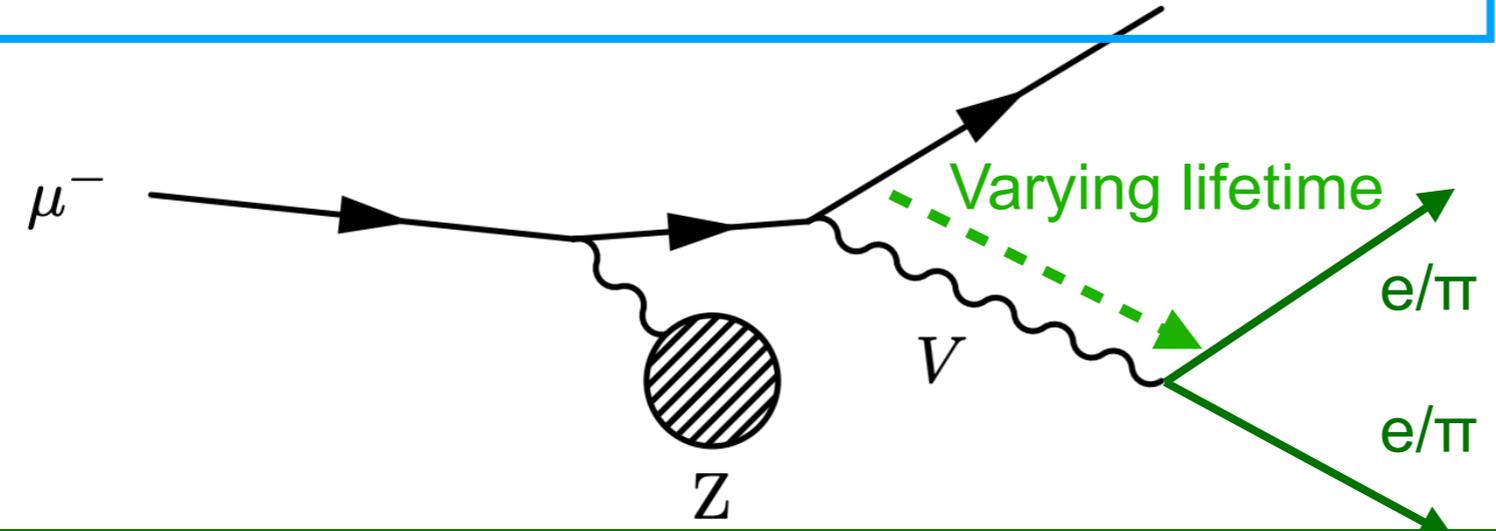
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Invisible Signature
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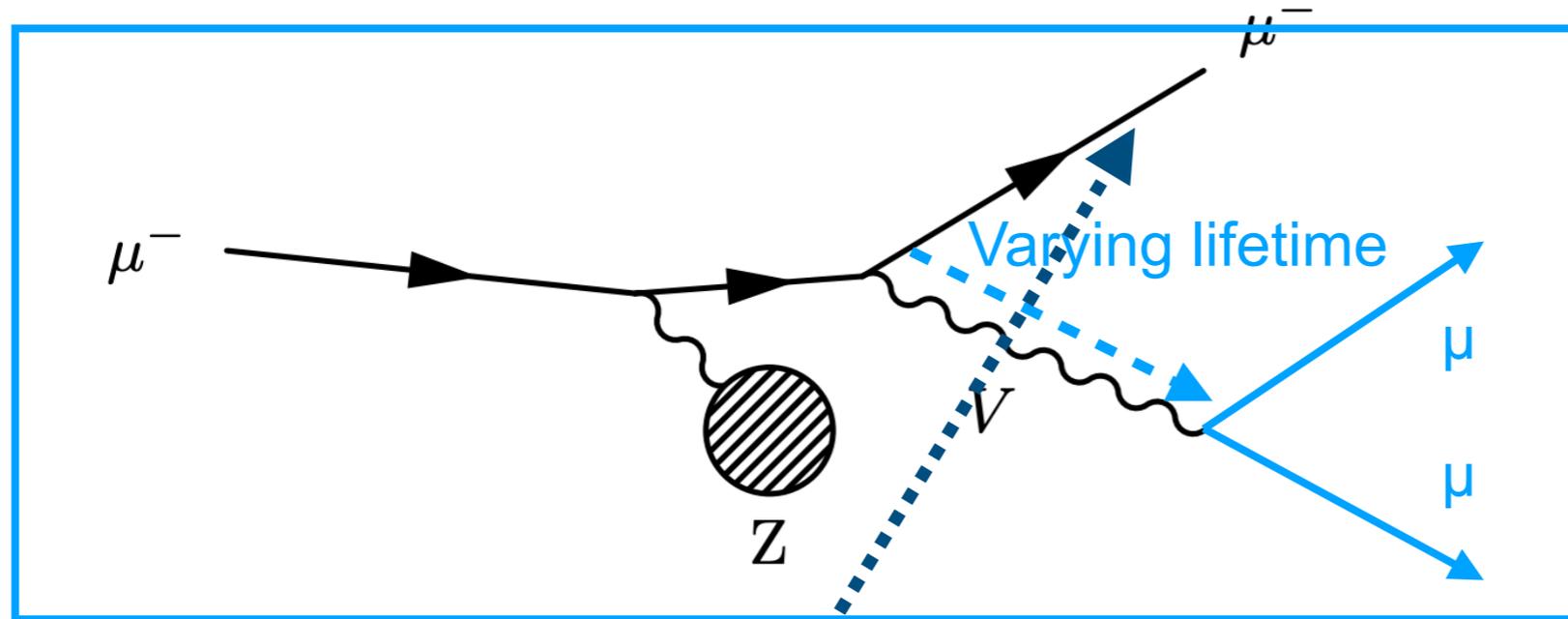
Tri-muon events
 Di-muon can be displaced



Decays to electrons and hadrons displaced

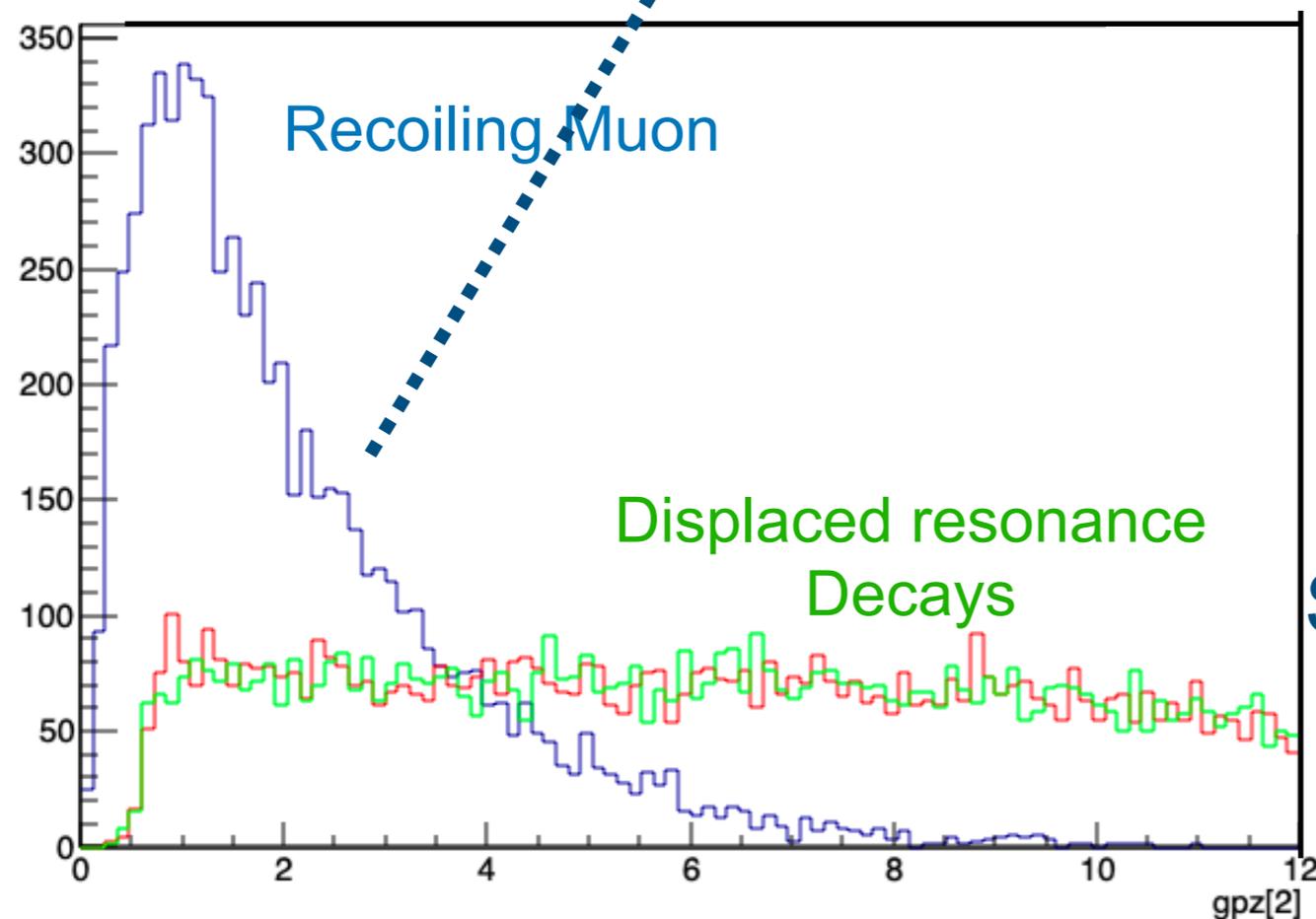
What about semi-visible?

Tri-Muon Signature



Tri-muon events
Di-muon can be
displaced

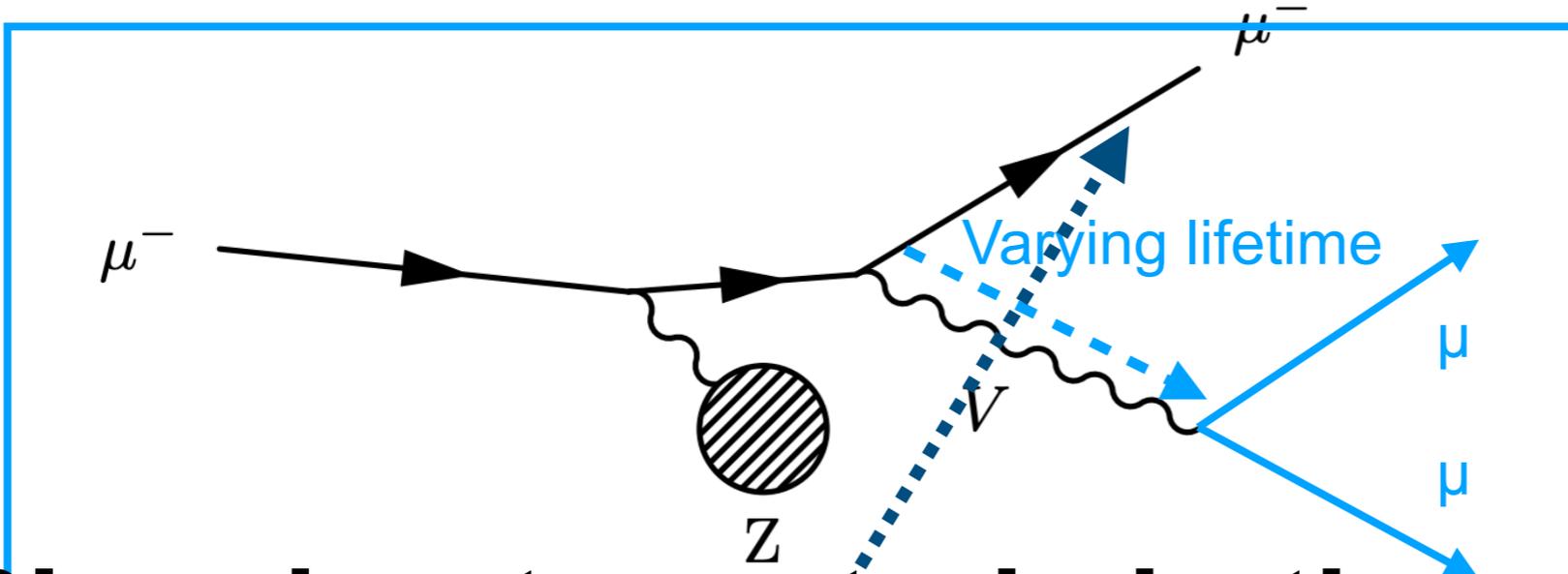
Thanks to Cristina!



We have run a Tri-muon event
in SpinQuest

Small recoiling muon will require
interaction after beam dump

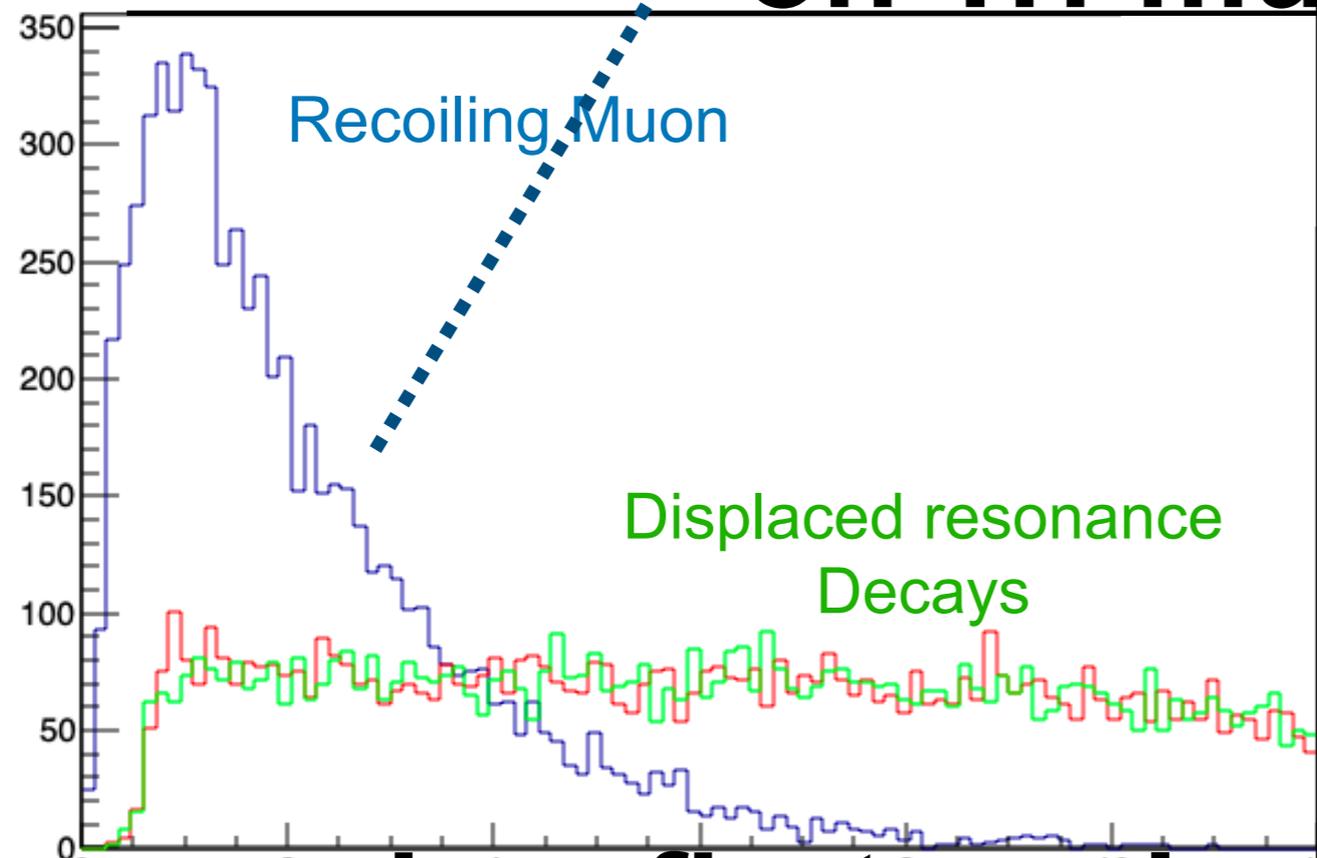
Tri-Muon Signature



Tri-muon events
 Di-muon can be displaced

Planning to a study in the next few weeks on Tri-muon

Thanks to Cristina!

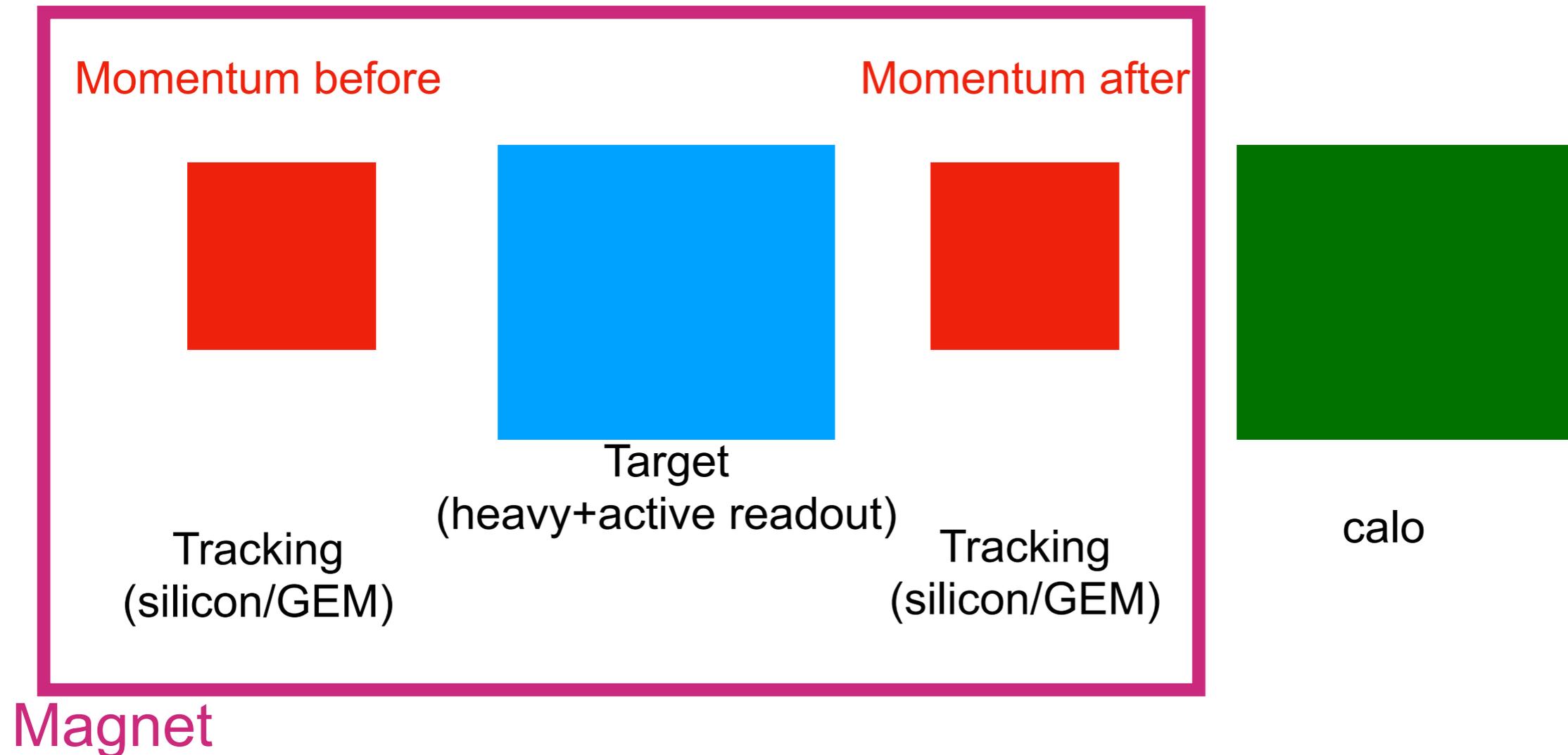


We have run a Tri-muon event in SpinQuest

Small recoiling muon will require interaction after beam dump

We can do a first analysis on SQ Data(NOW)

What is critical for M³

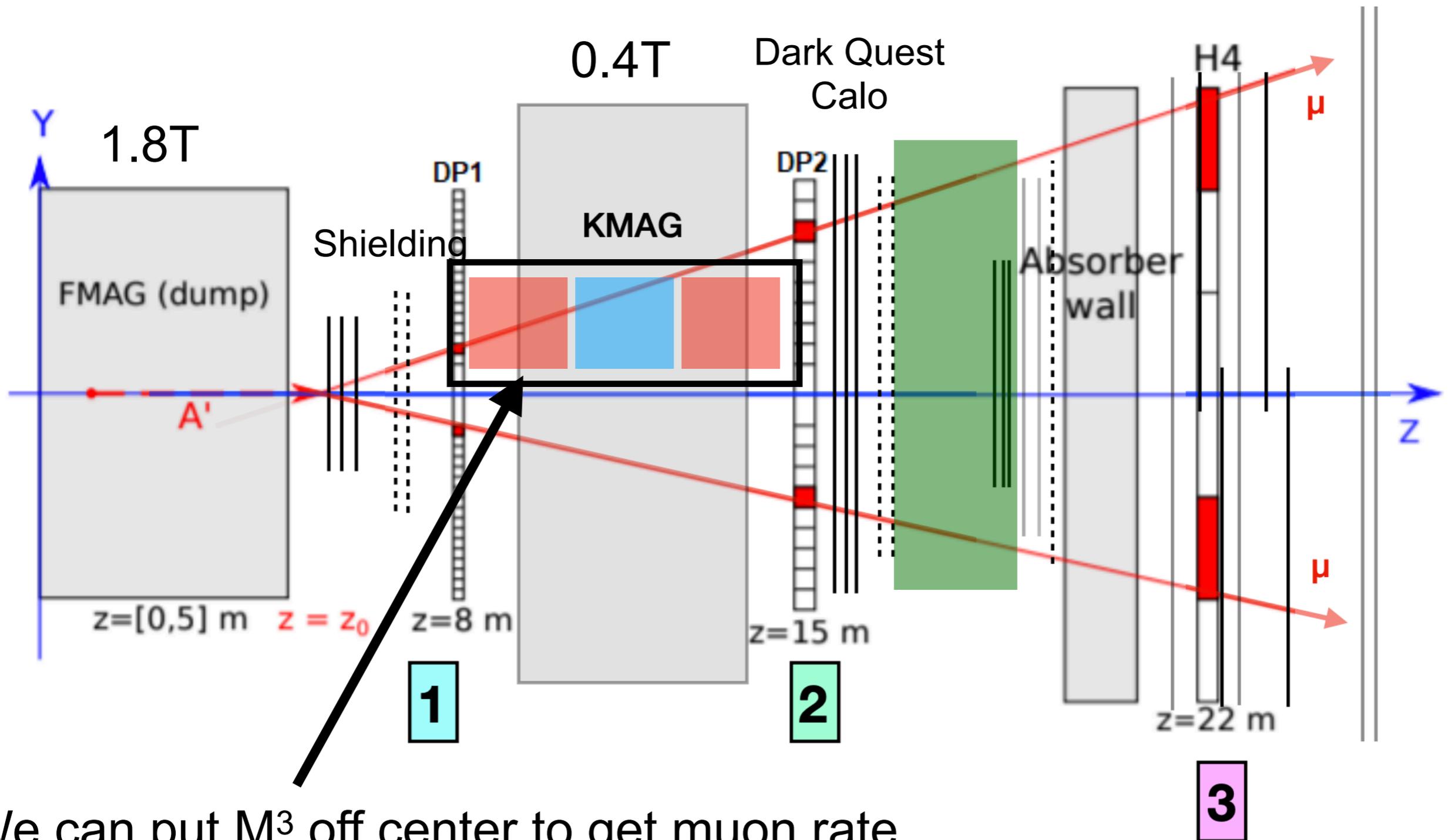


Lets use these shapes as a key

Note: M³ propose silicon and a fancy target,
we don't necessarily need that

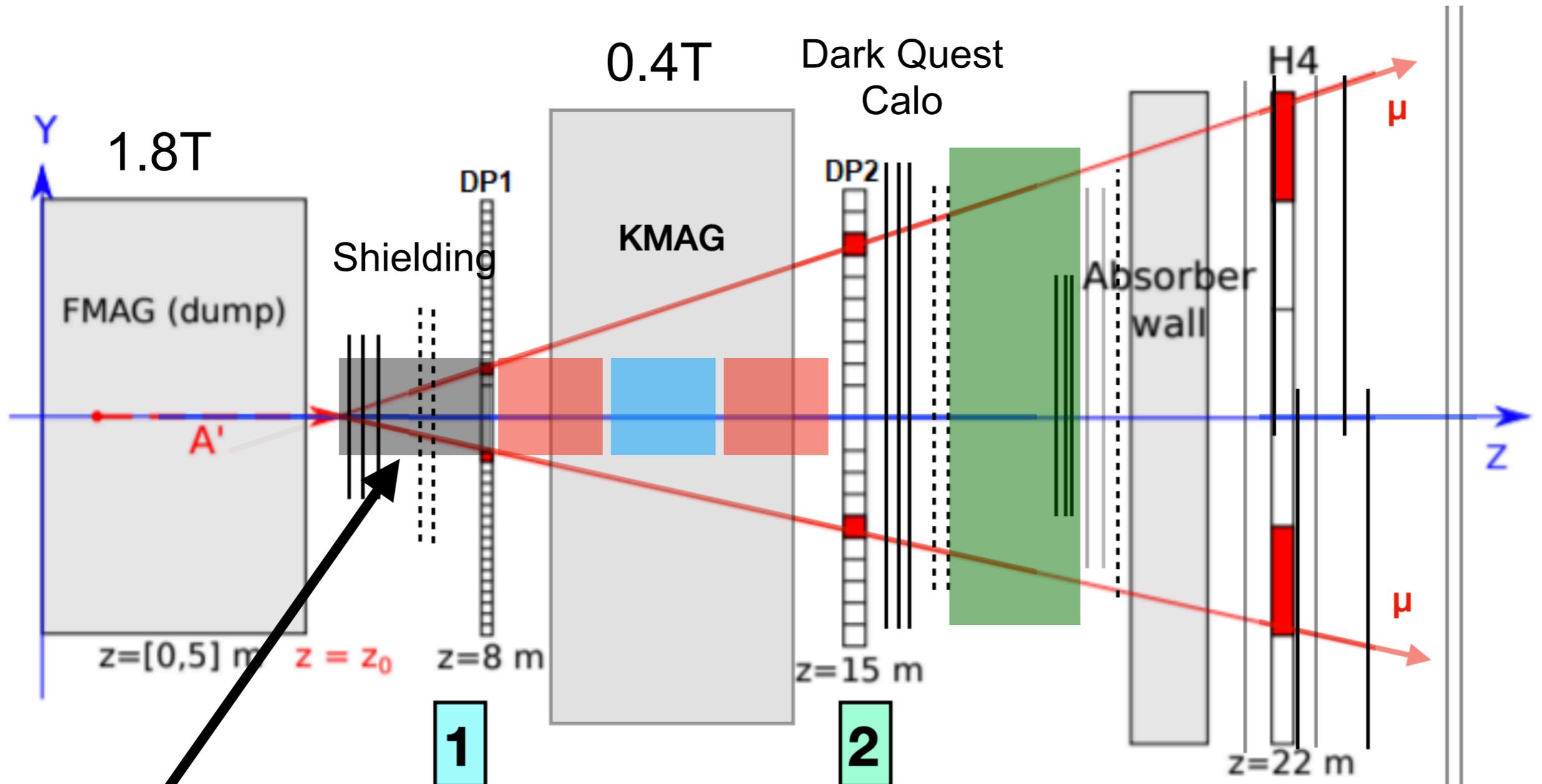
Same deal for tracking can make it larger and/or cheaper

Can SpinQuest do M³



We can put M³ off center to get muon rate

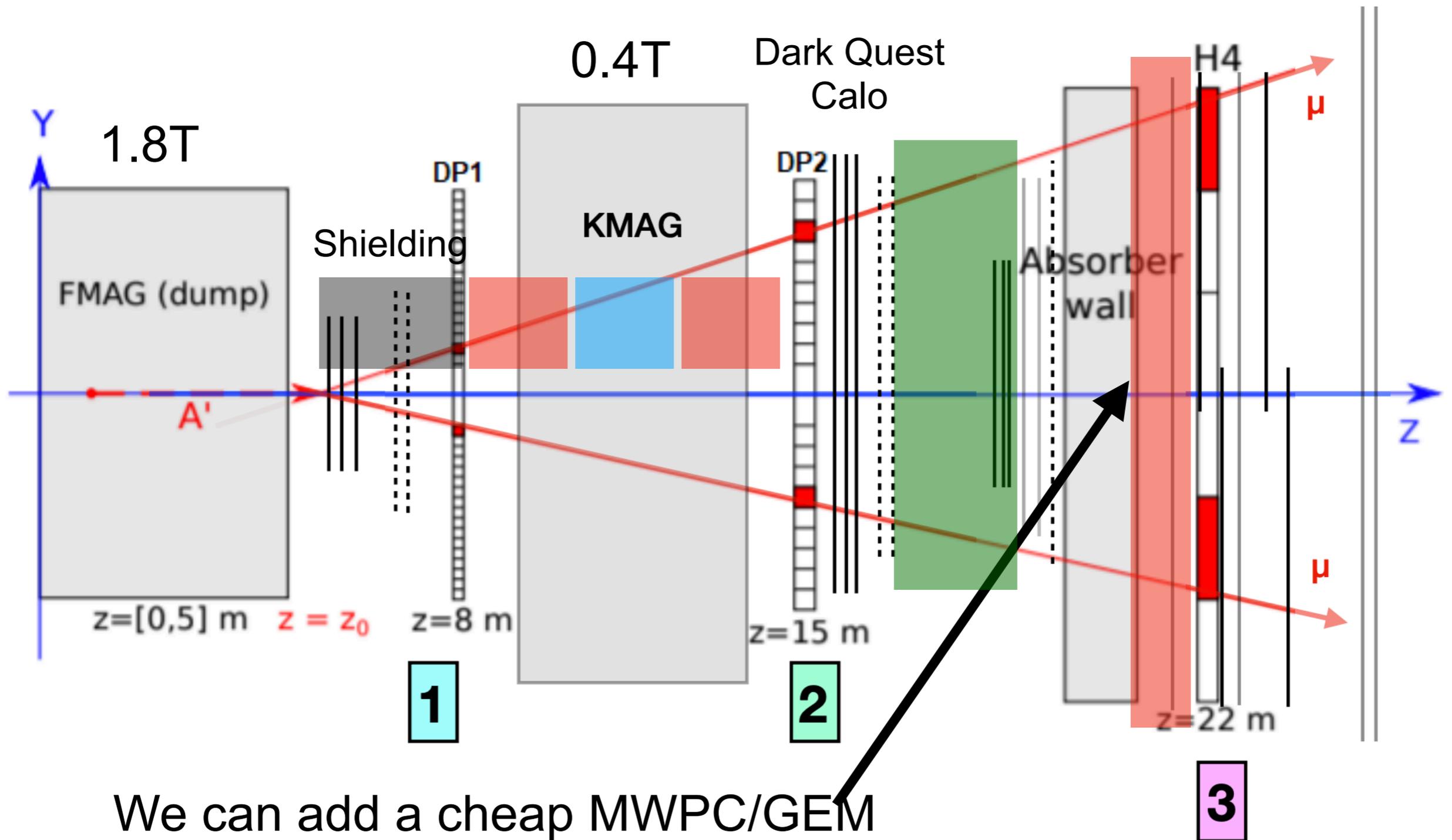
Can SpinQuest do M³



We can add shielding to reduce rate
Should add small impact on SpinQuest

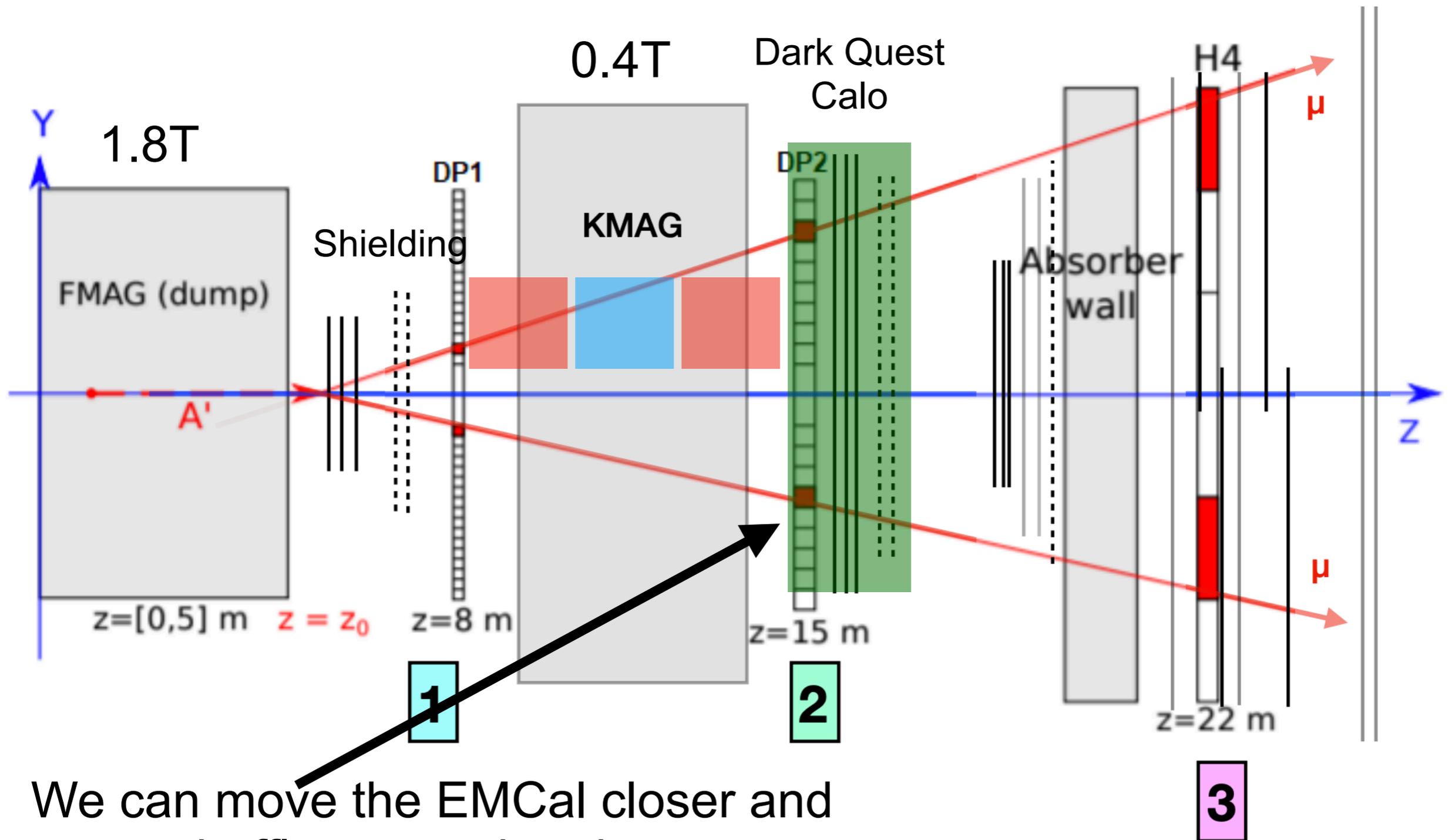
3

Can SpinQuest do M³



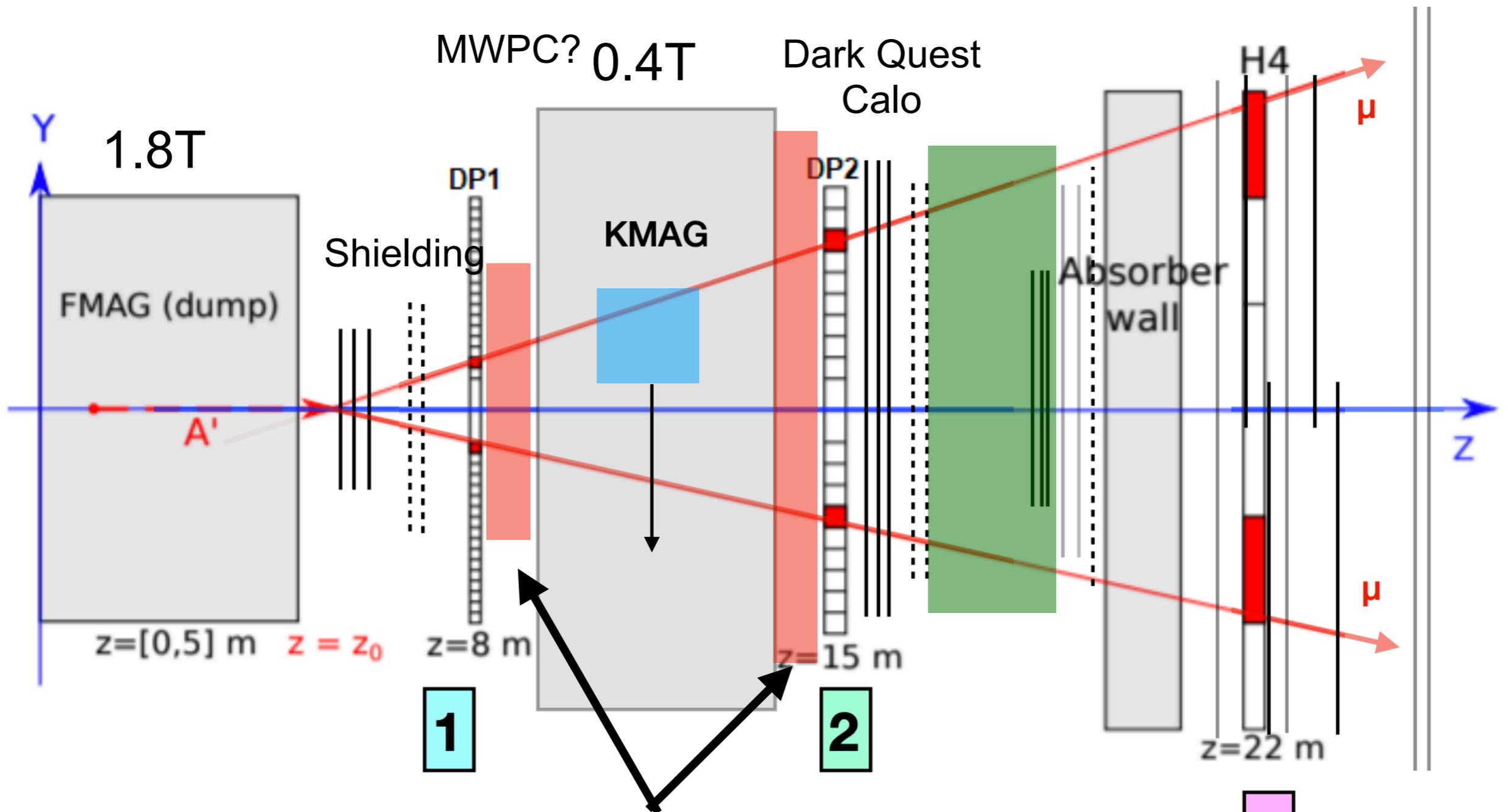
We can add a cheap MWPC/GEM
for large lever arm (improved muons for everybody)

Can SpinQuest do M3



We can move the EMCal closer and shuffle muon chambers

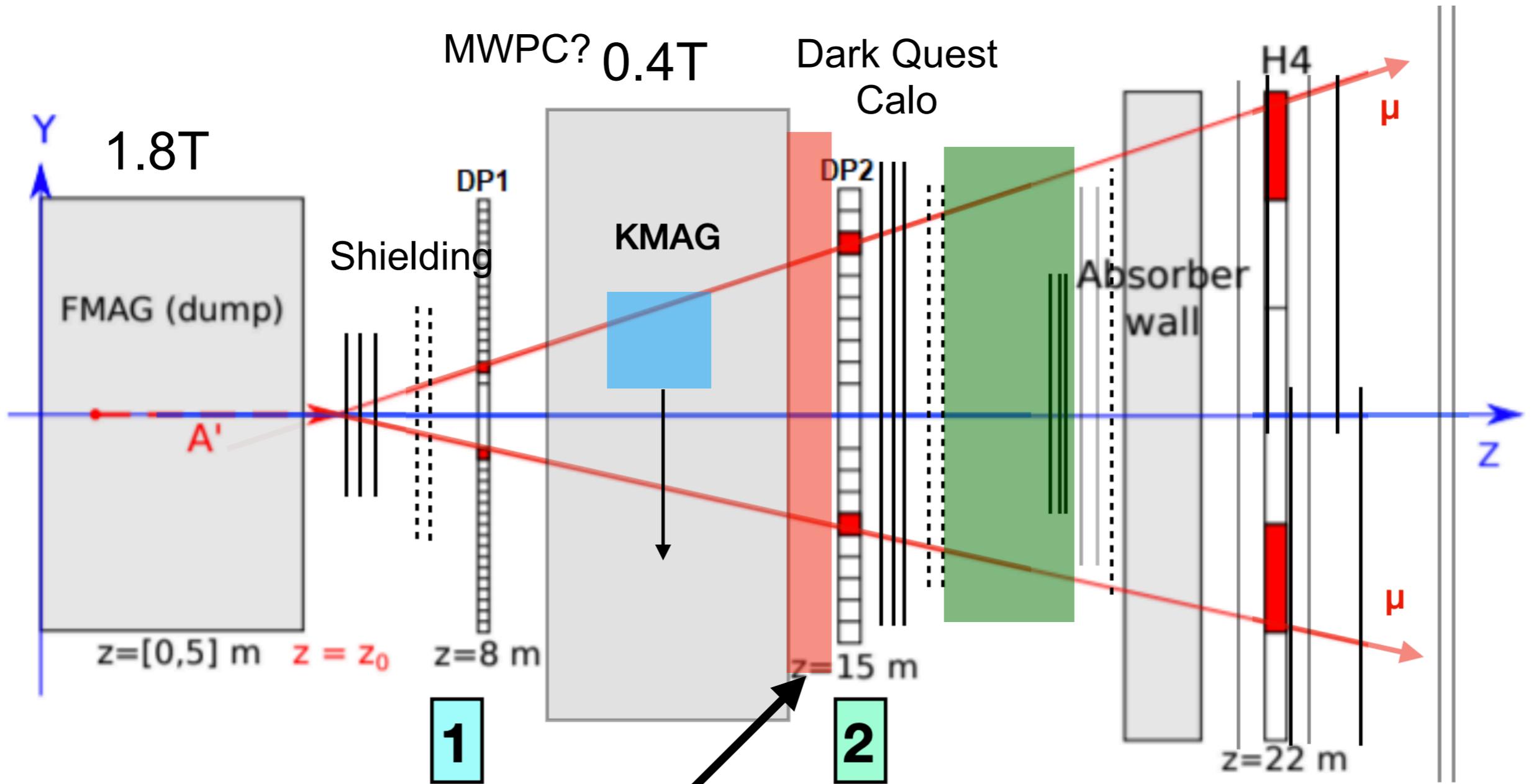
Can SpinQuest do M³



Can put wire chambers/GEM outside of magnet **3**

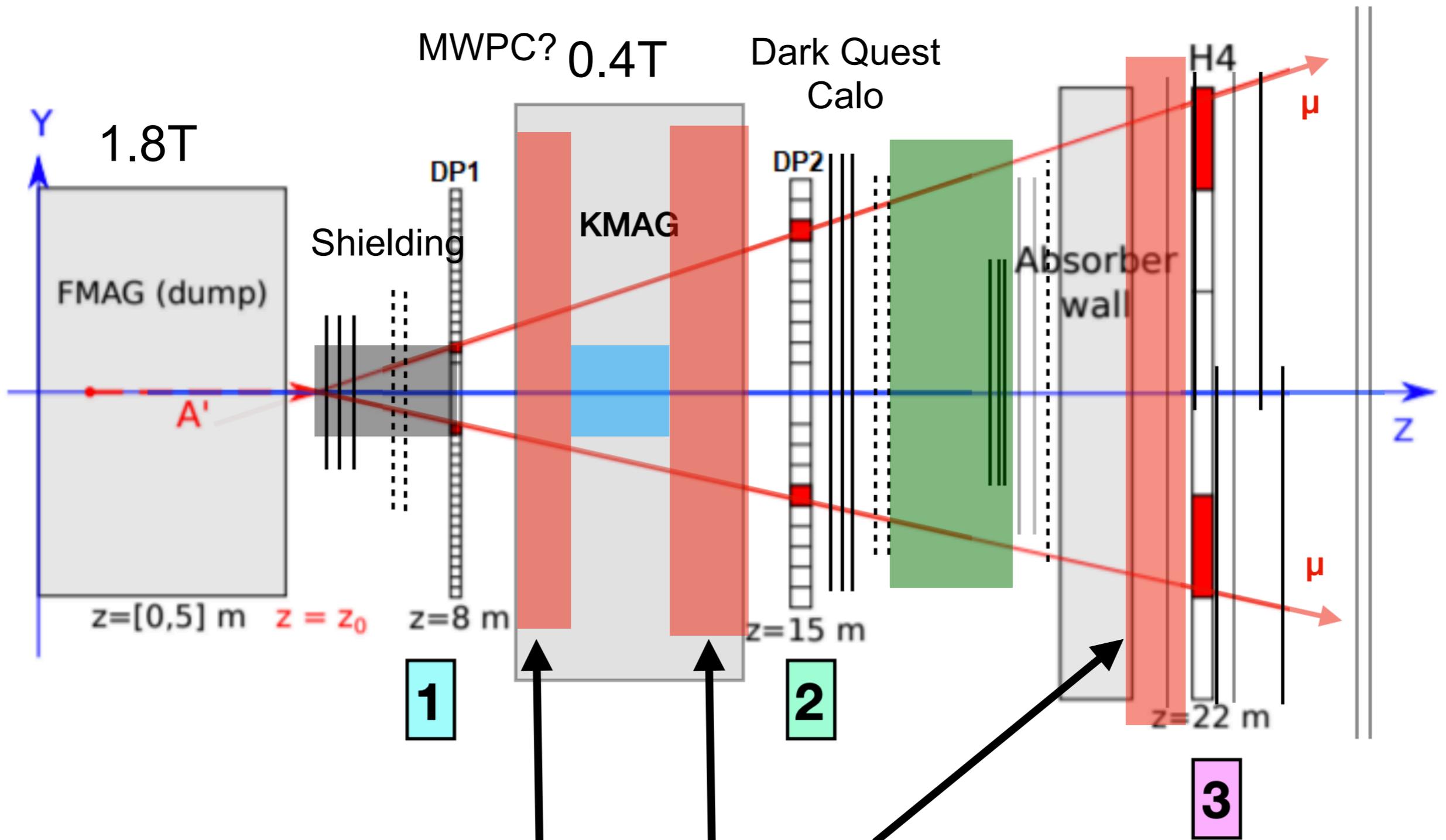
Big gain in acceptance for SpinQuest 1st Muon momentum harder

Can SpinQuest do M³



Can put wire chambers/GEM outside of magnet **3**
 Minimal approach

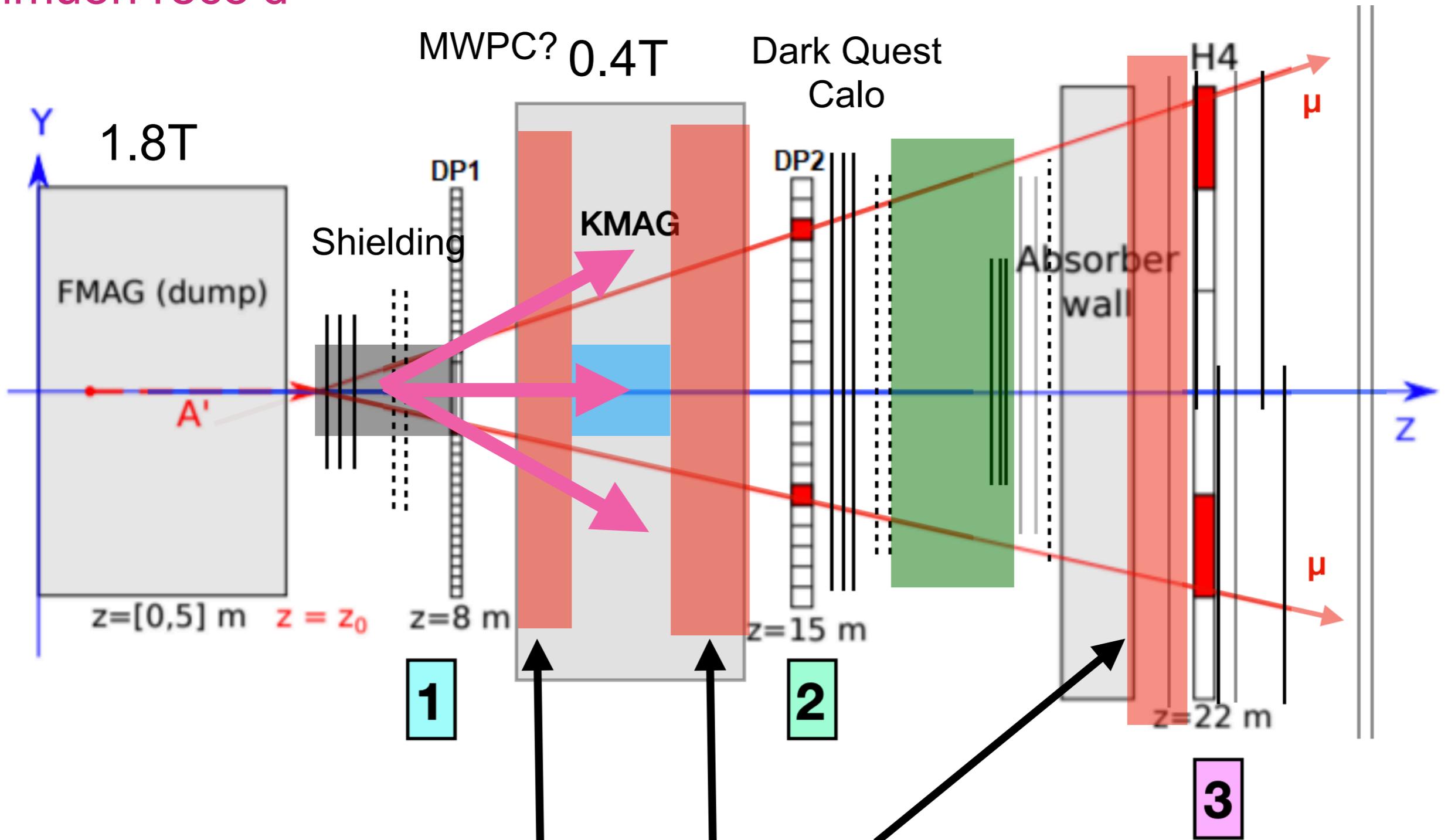
Can SpinQuest do M³



Ultimate Momentum Resolution + Acceptance gain

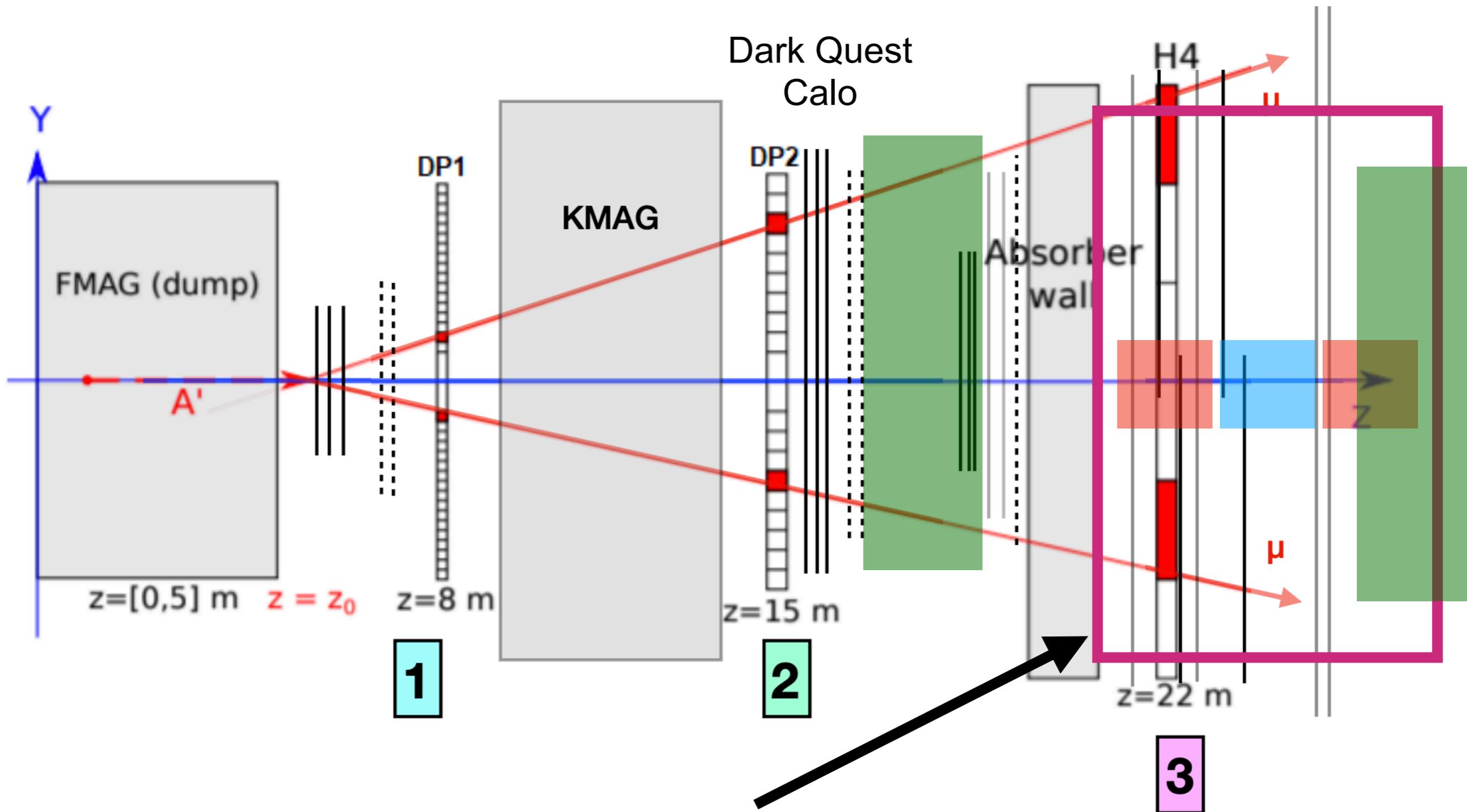
Can SpinQuest do M³

Trimuon reco'd



Ultimate Momentum Resolution + Acceptance gain

Can SpinQuest do M³



Long Quest Style upgrade (would need to check beam/should work)

M³+SQ Advantages

- Having one detector do all brings some advantages
 - Can reuse a lot of stuff
 - ▶ All of the core infrastructure is there
 - Same detector hall for everything
- Additionally brings together a bunch of measurements
 - Larger collaboration of people
 - Easier to present to funding agencies
 - New detectors upgrade SpinQuest/DarkQuest
 - ▶ Nice Spin physics program to complement Dark Matter
 - Probably other stuff we haven't thought about

What do we need?

- Preserve physics for SpinQuest
 - Yes and improve it (need to keep > 20 GeV muons)
- Enough Muons to do M^3
 - Yes, and seems like we can reconstruct them
- Upgraded detector do M^3 (and improve DQ/SQ)
 - We need a target and some more tracking
 - ▶ Don't need the fanciest thing in the world
- There is a lot of functionality we have not thought about

Summary

- By merging SpinQuest with M3 we add a lot of functionality
 - Can search for all related decays in one fell swoop
 - Existing SpinQuest framework makes instrumentation easier
 - Removes need for calorimeter/perhaps a muon chamber
- Adds lots of acceptance of tri-muon events
 - Larger scale and instrumented detectors make it easier
 - Additionally can deal with displaced decays to electrons
- **Are there other things that we can do?**
 - Improved Spinquest measurements
 - Improved displaced object decays?

Beams

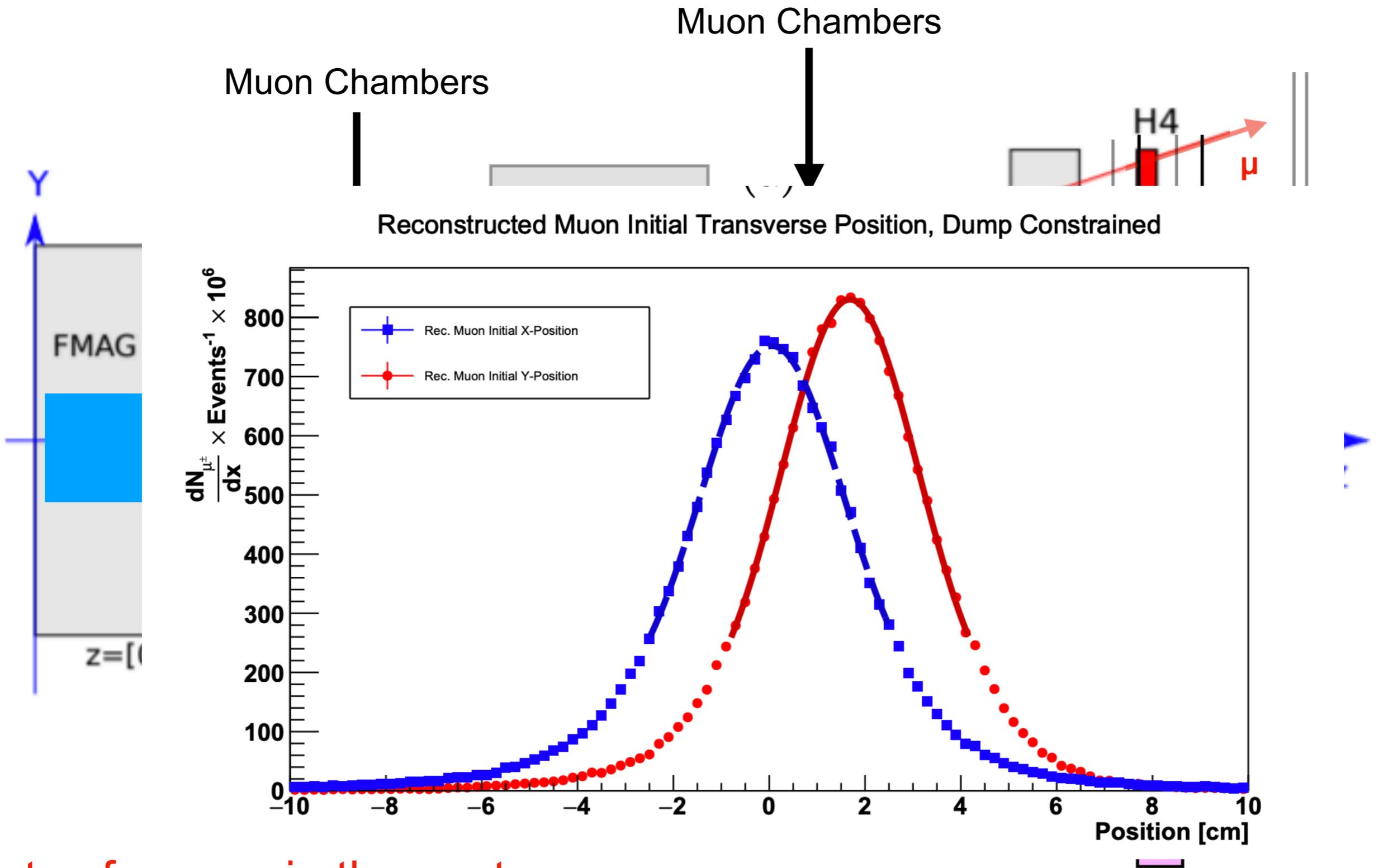
- Proposed M³ uses the same beam as SpinQuest
 - Both use the switchyard
 - 4s pulses running at 52MHz 120 GeV proton beam
- SpinQuest produces muons from beam dump

- Proposed M³ would use some other beam dump
 - I am not sure what the plan is
 - Does it exist?

Supplies?

- According to Nhan :
 - There exists a 5 T Mu Cool magnet
 - A bunch of silicon lying around
 - HGcal?
 - There is also an MWPC lying around
- It would be good to know what is relatively cheap or not

Can SpinQuest do M³



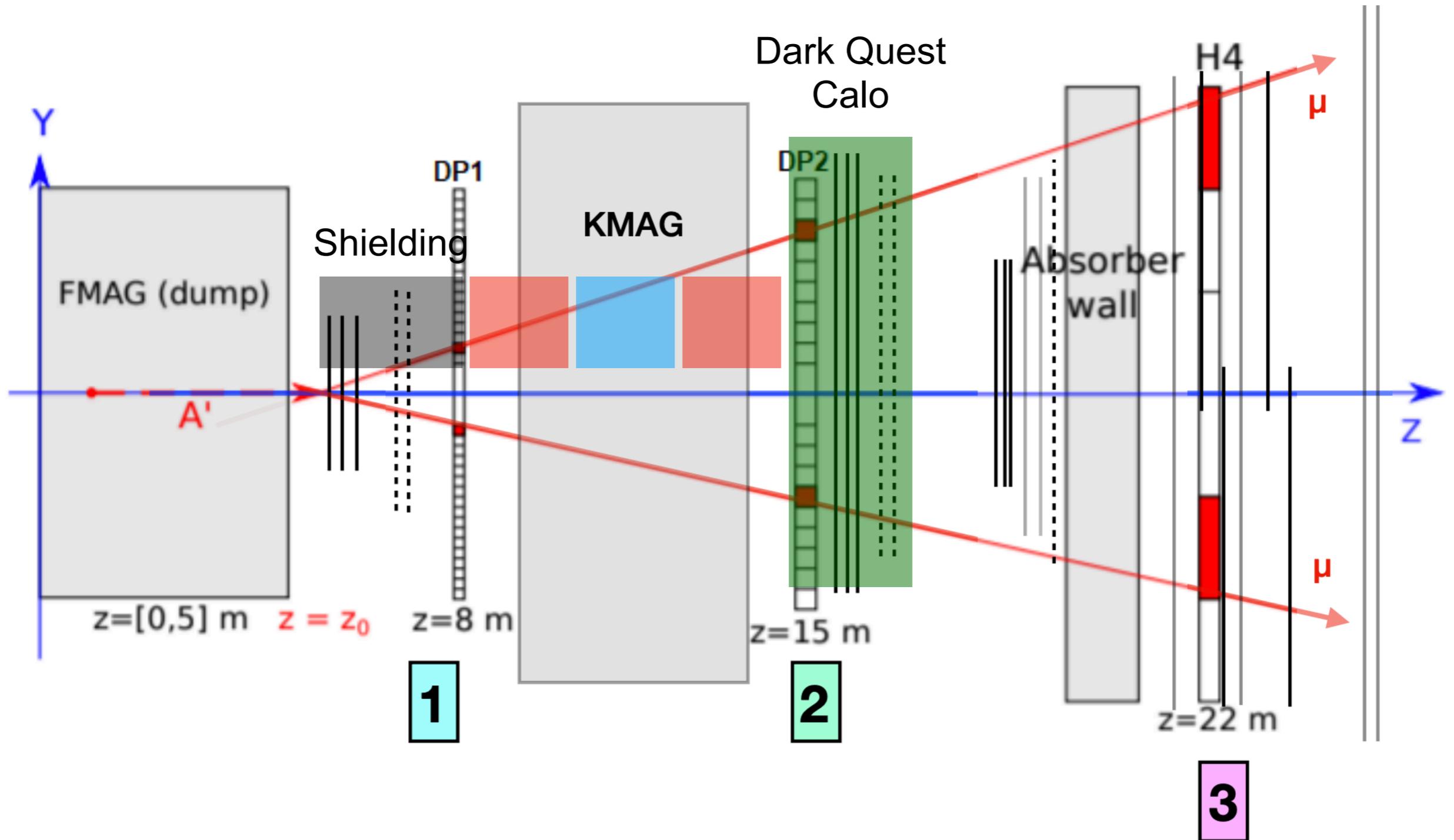
Lots of muons in the center

What is critical for M3

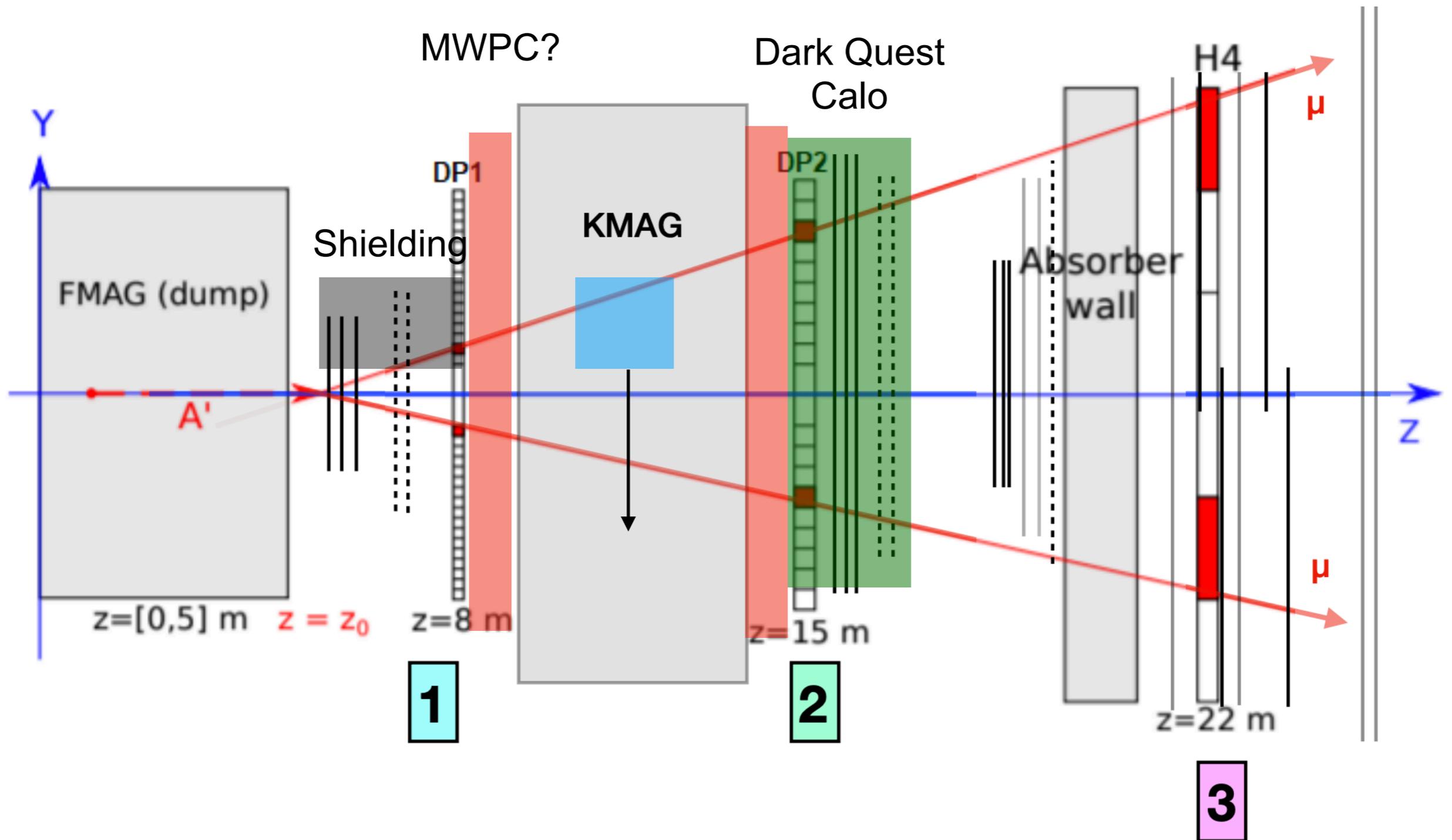


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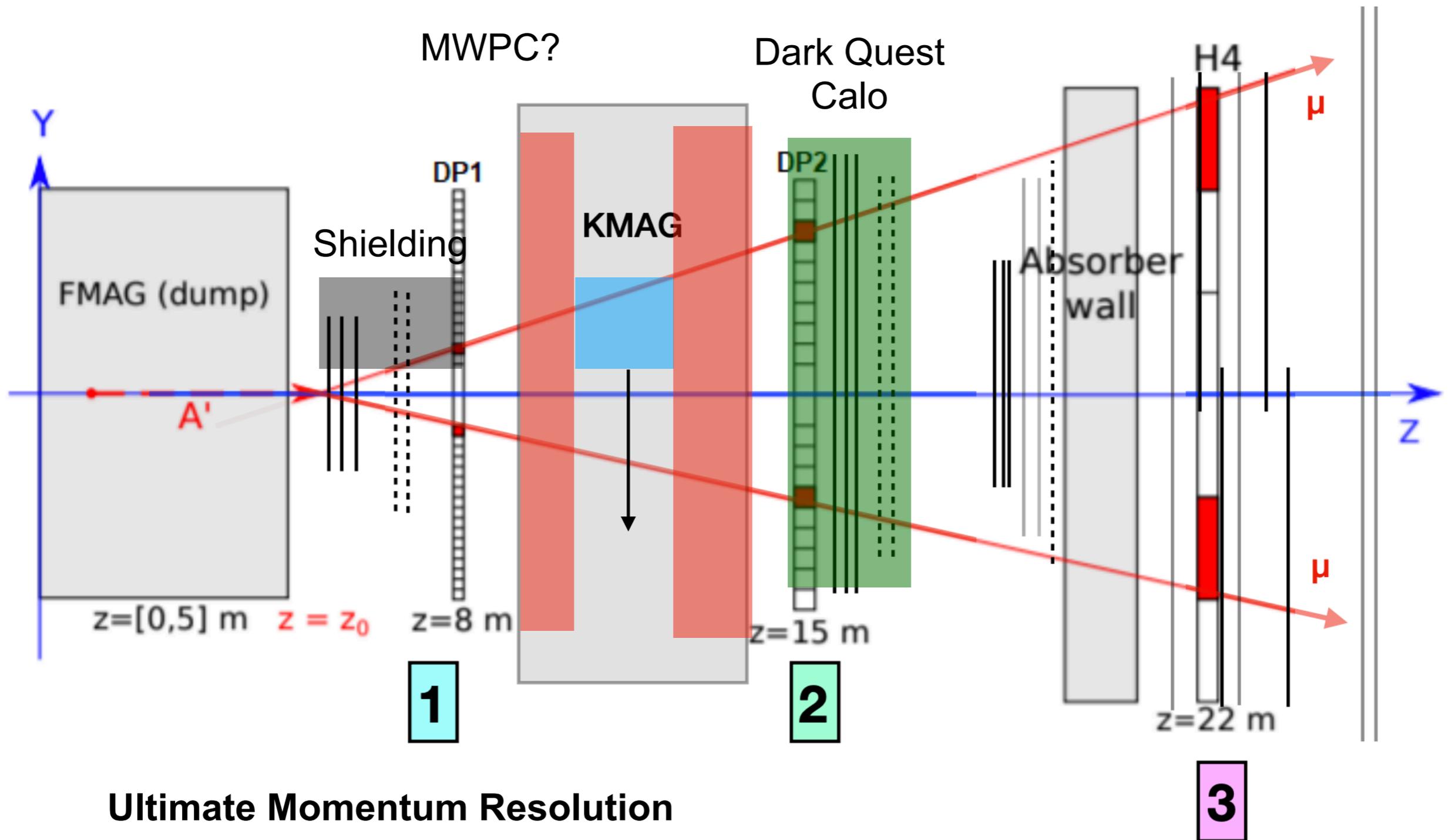
Can SpinQuest do M³



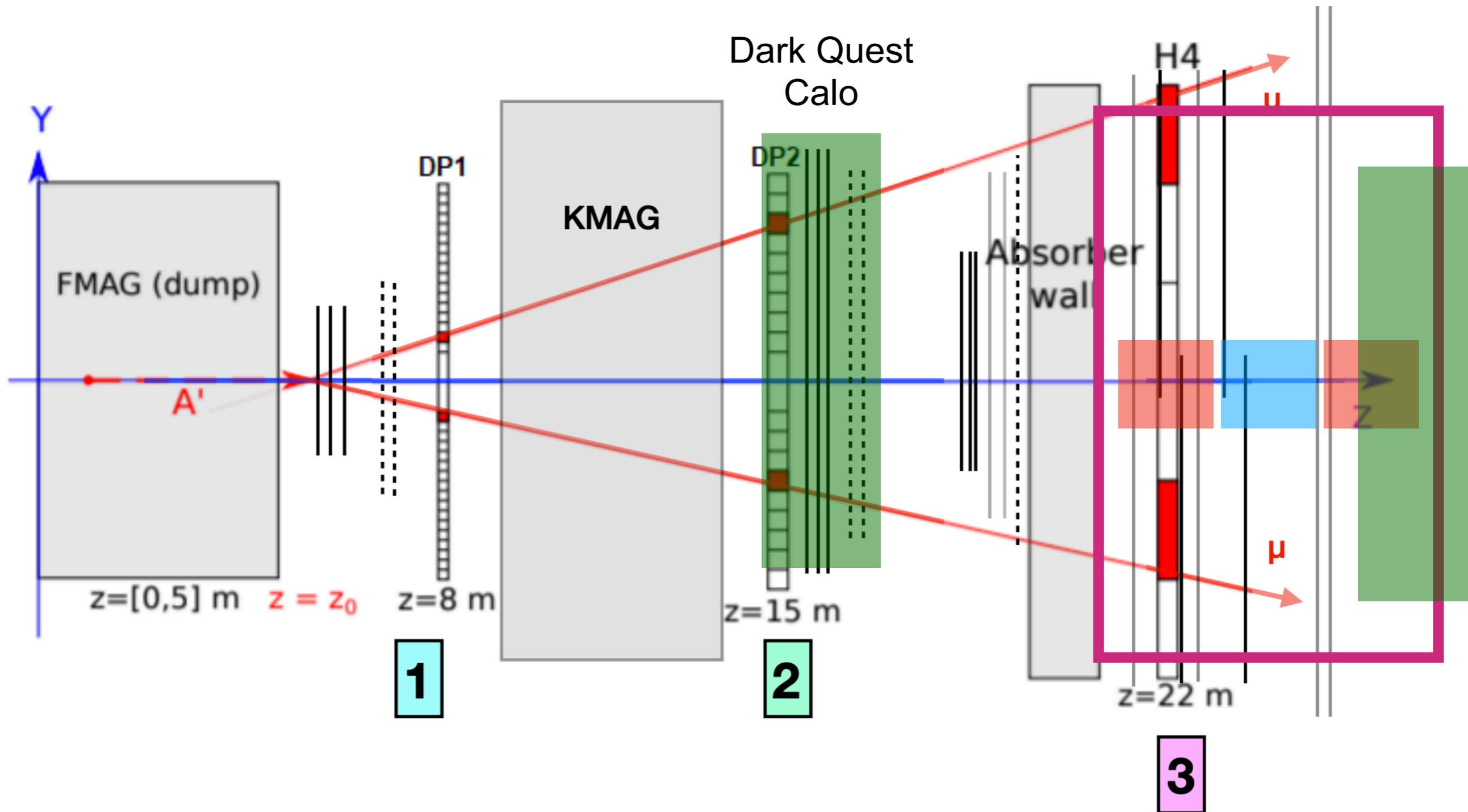
Can SpinQuest do M³



Can SpinQuest do M³



Can SpinQuest do M³

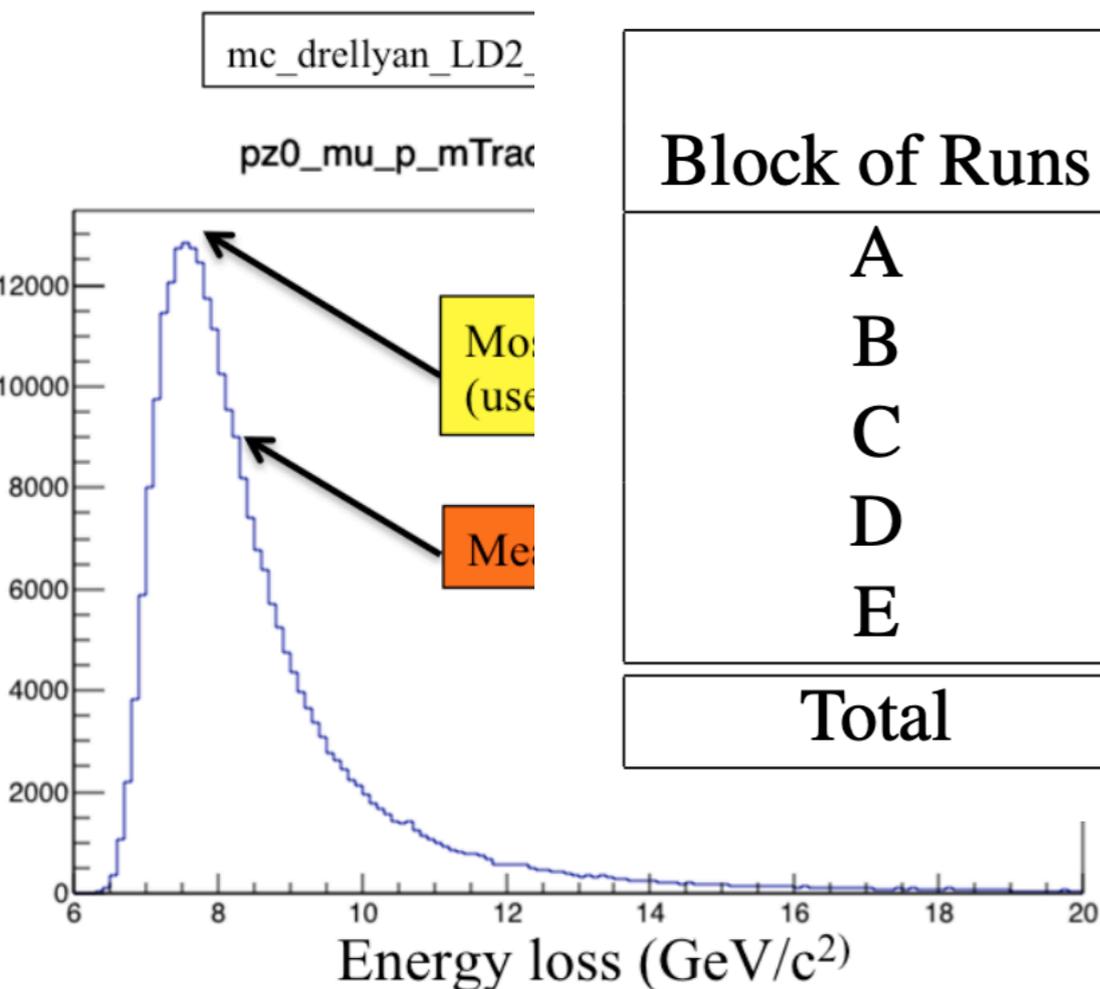


Additional Points

- Can we generate muons from upstream?
- Muons from pion decays upstream can help
- Can add stuff upstream

Muon Beam in SpinQuest

- The SpinQuest beam has a lot of protons on target: 10^5
 - For every proton on target
 - ▶ Roughly get a muon out of it



Block of Runs	Default data set		Seed data set		Increase 6 weeks 6×10^{11}	
	μ^+	μ^-	μ^+	μ^-	μ^+	μ^-
A	10653	12729	36271	35053	339%	274%
B	6274	6311	17508	19837	278%	313%
C	4928	4988	14096	15863	285%	317%
D	1896	2000	13351	13777	703%	688%
E	3168	3293	9952	10420	313%	315%
Total	26919	29321	91178	94950	239%	224%