Design Considerations for a Magnetized MRD for TITUS

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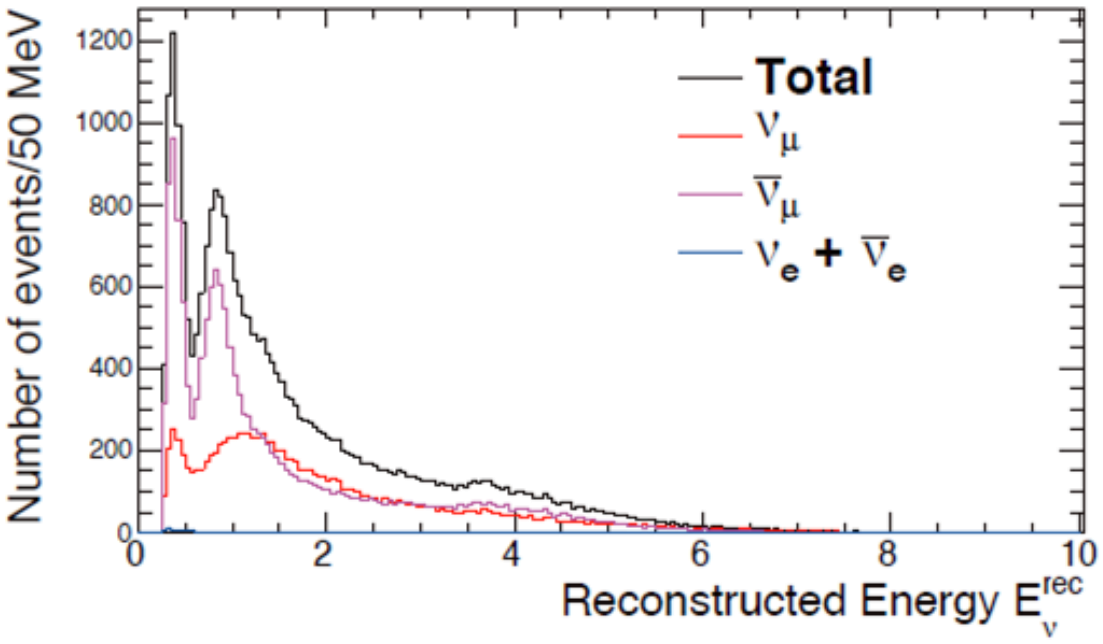
6th Open Meeting for the Hyper-Kamiokande Project

Near Detector / Flux Pre-meeting

28-31 January 2015, Kavli IPMU, University of Tokyo, Kashiwa

N.B. Lots of work here by Etam Noah and Alain Blondel

There is a significant wrong-sign component in anti-neutrino mode



Constraining this component by measuring the charge of the muons would be a great advantage

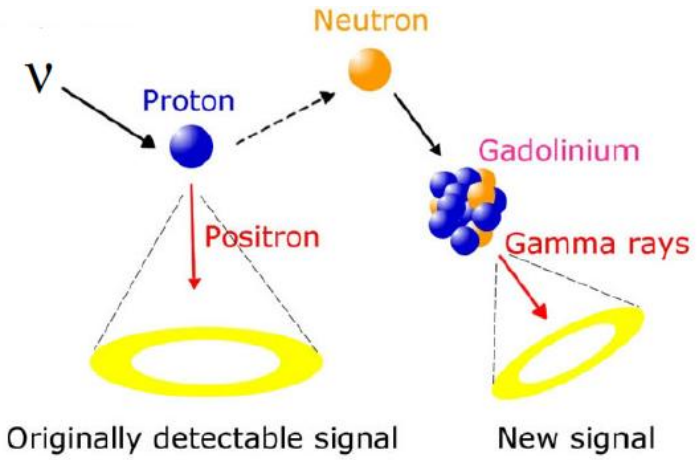
Gadolinium is exciting, but somewhat untested, and not 100% efficient

$$\upsilon\, n \rightarrow \ell\, p$$

$$\bar{\upsilon}\, p \rightarrow \ell\, n$$

detect with Gd

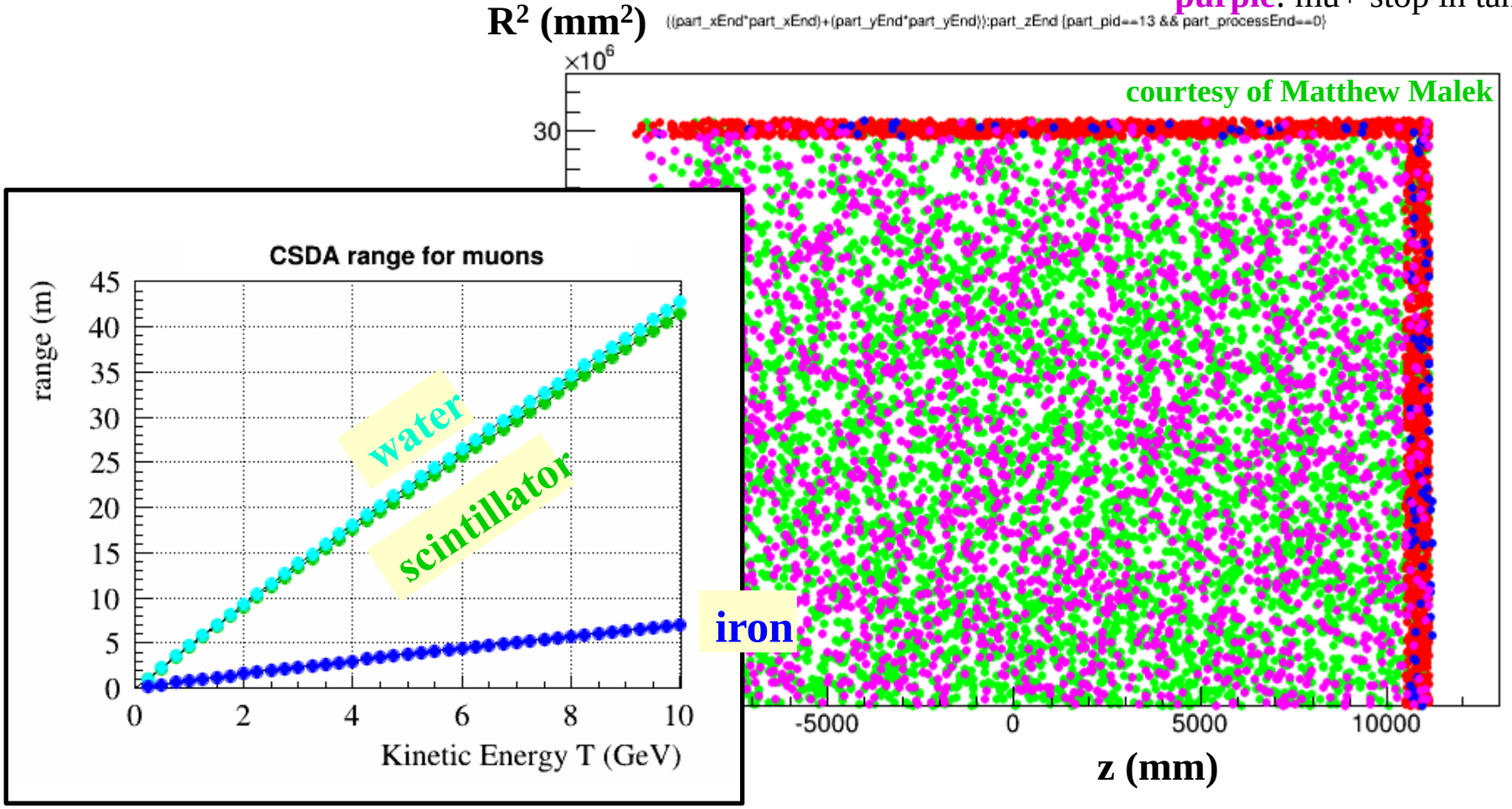
$\varepsilon_Q \approx 88\%$???



A magnetized MRD can achieve very high charge reconstruction efficiencies

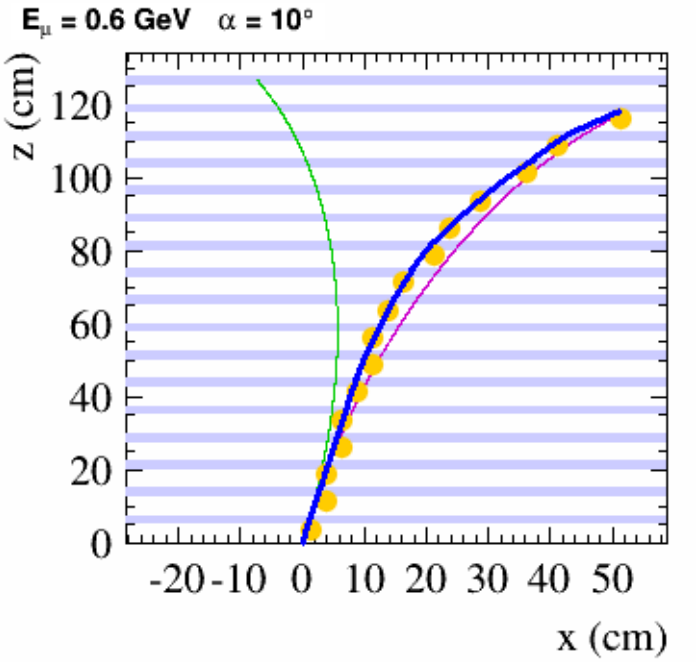
red: mu- leave tank
blue: mu+ leave tank
green: mu- stop in tank
purple: mu+ stop in tank

18% of muons escape the tank



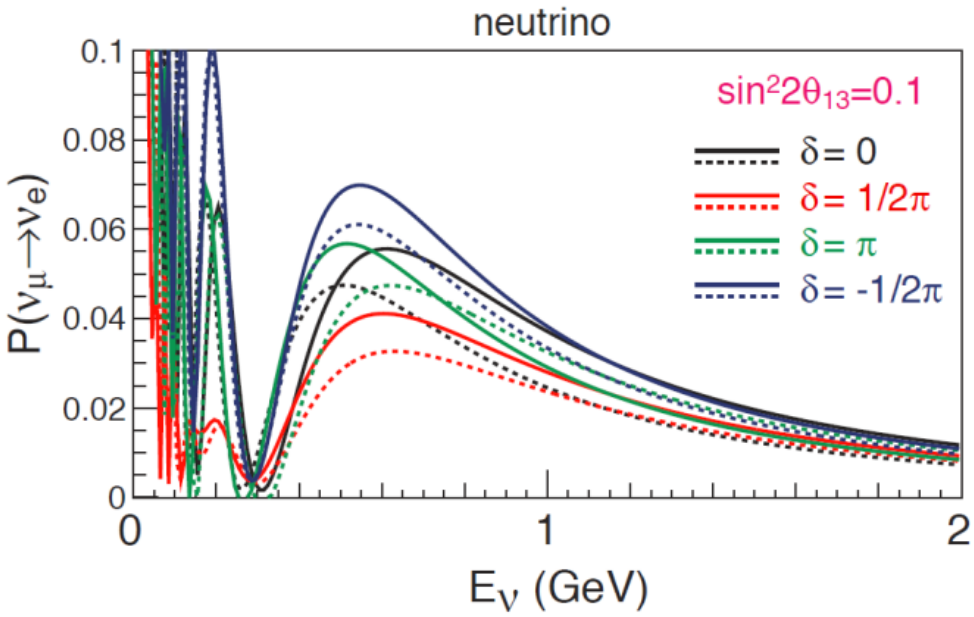
NB Many interesting muons don't escape
(The nature of a large detector, and indeed by design…)

Reconstructing the charge of long, high energy, tracks is easy



Compare χ^2 in the + and – hypotheses (well known from past experiments)

Let's optimize reconstruction in the interesting E_ν < 2 GeV region



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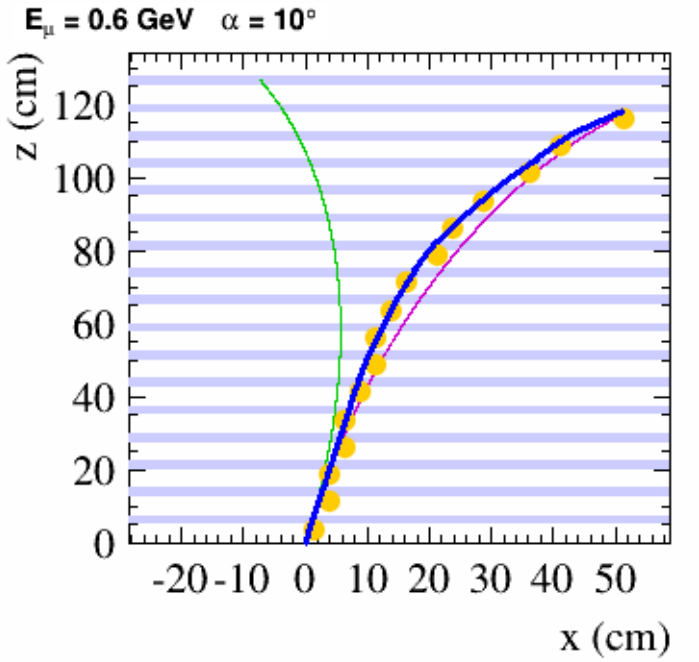

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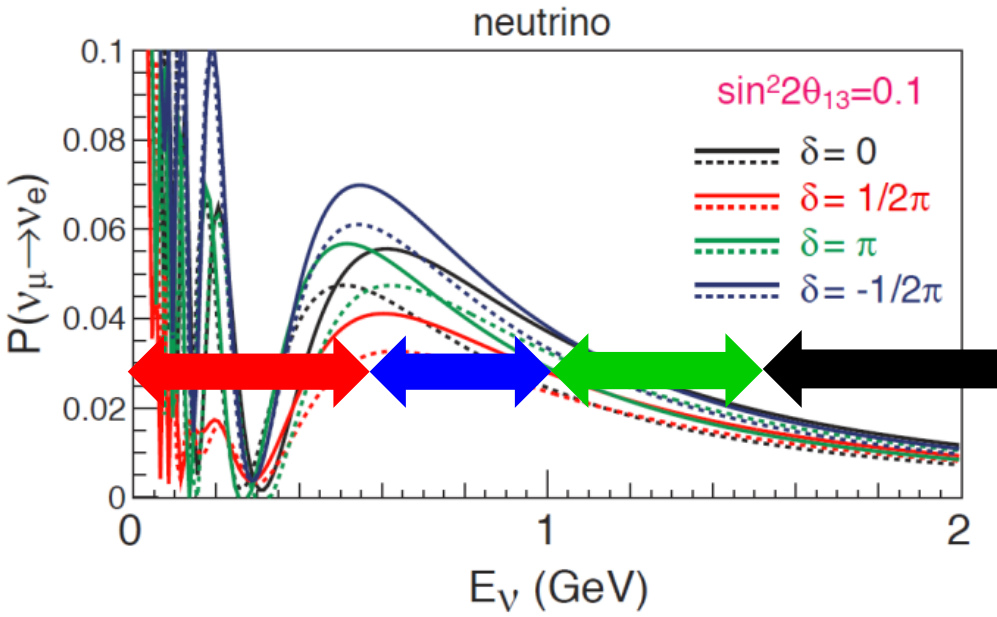
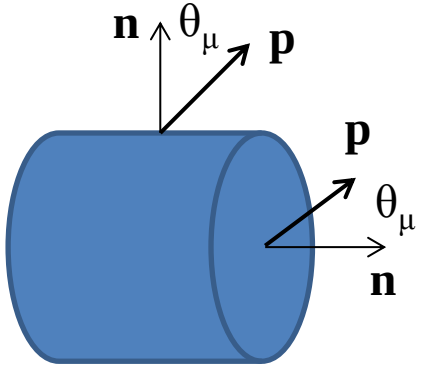
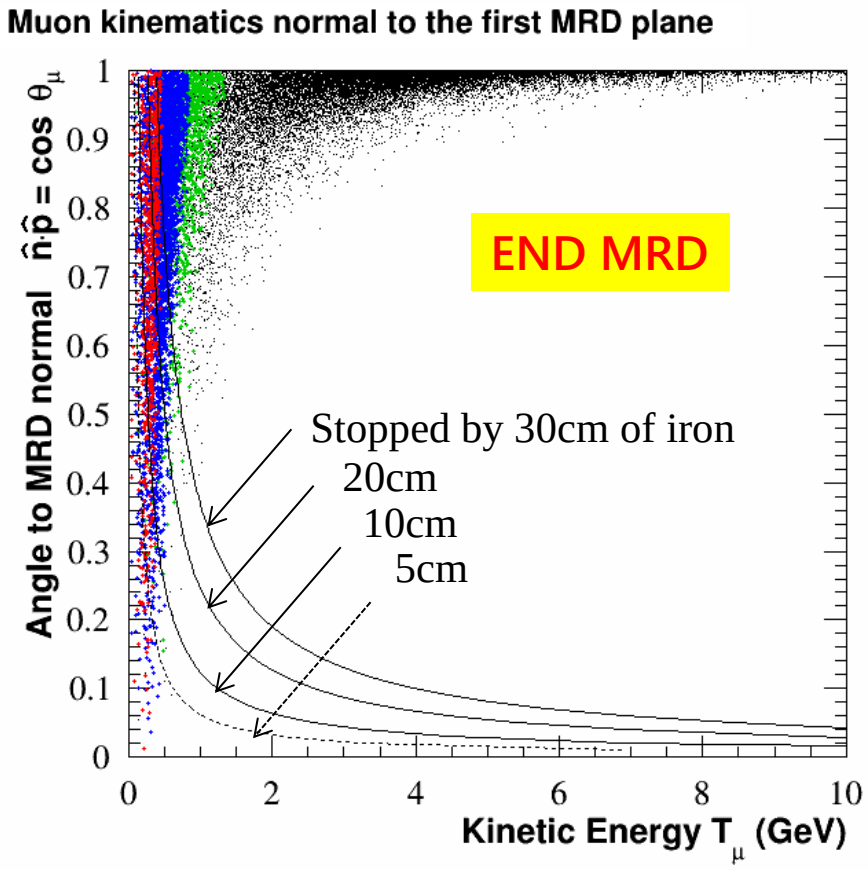
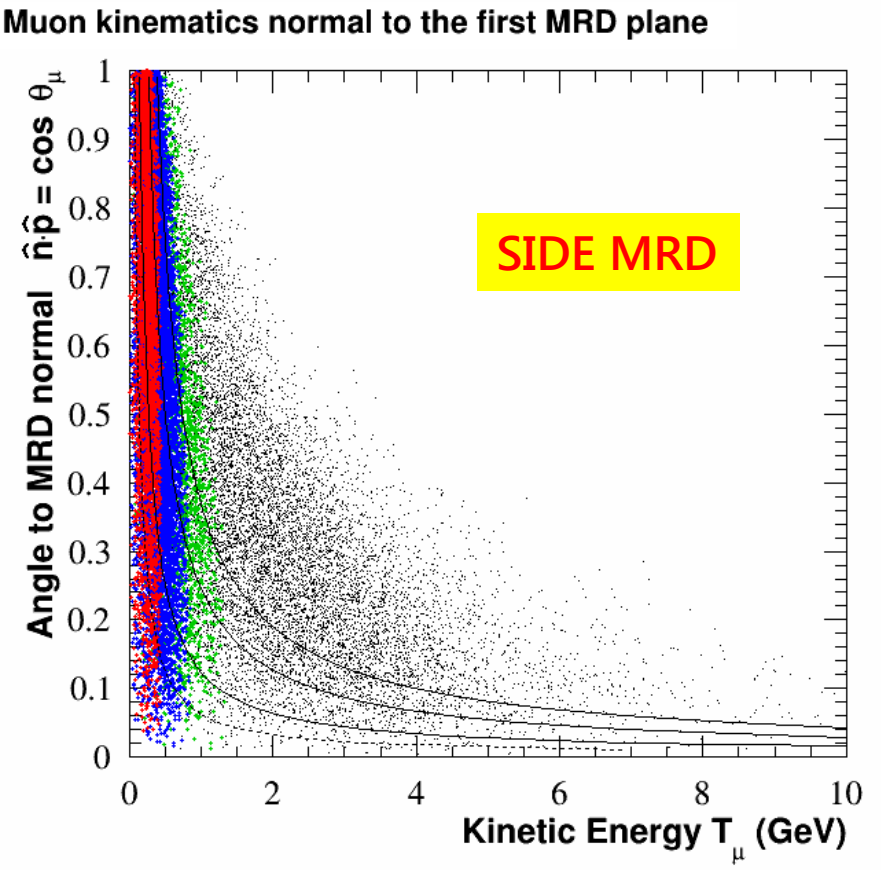


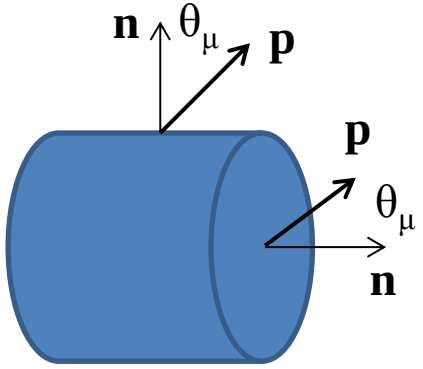


Muon kinematics of υ_μ CC events entering the MRD

0 GeV < E_υ < 0.6 GeV
0.6 GeV < E_υ < 1.0 GeV
1.0 GeV < E_υ < 1.5 GeV
E_υ > 1.5 GeV



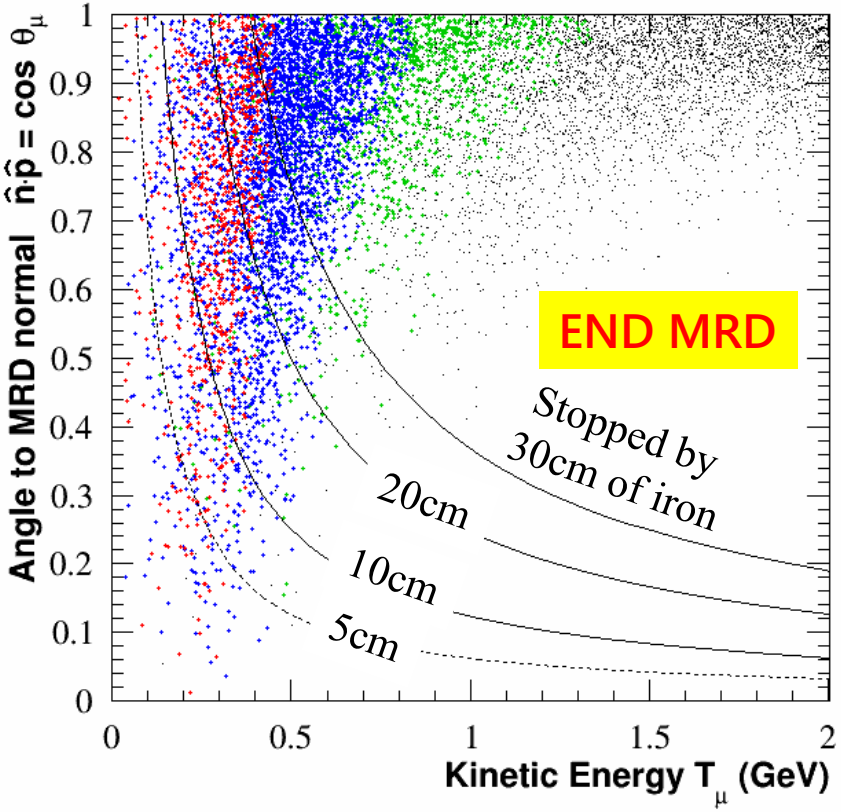




Muon kinematics of υ_μ CC events entering the MRD
ZOOM to oscillation region

0 GeV < E_υ < 0.6 GeV
0.6 GeV < E_υ < 1.0 GeV
1.0 GeV < E_υ < 1.5 GeV
E_υ > 1.5 GeV

Muon kinematics normal to the first MRD plane



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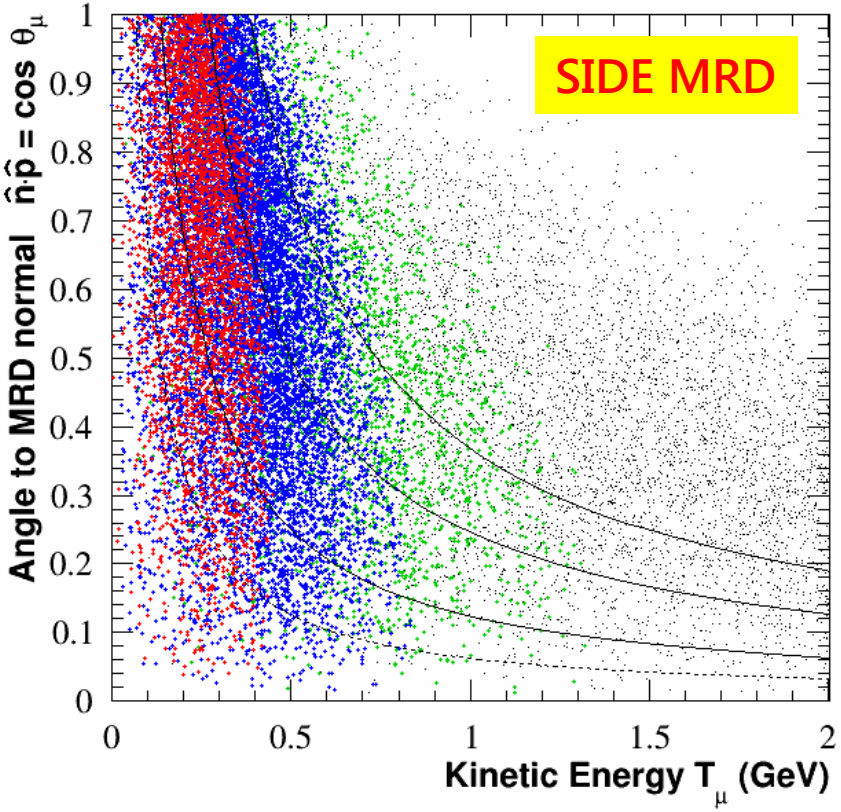
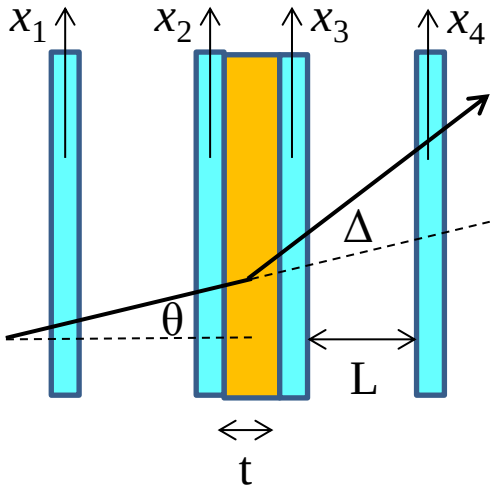
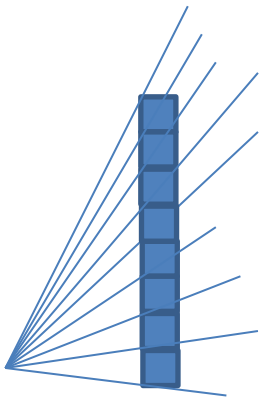


Multiple Scattering is the one unavoidable obstacle to charge reconstruction

In practice, however, track sampling resolution is just as big an effect



$$\sigma_\Delta \simeq \frac{2\sigma_x \cos^2\theta}{L}$$

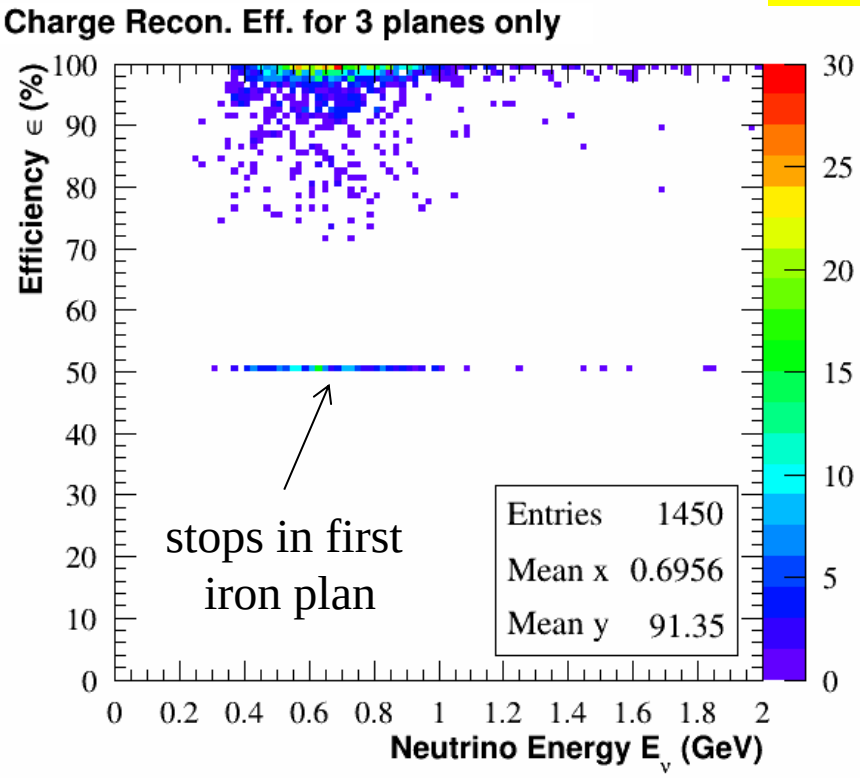


(or RPCs…?)

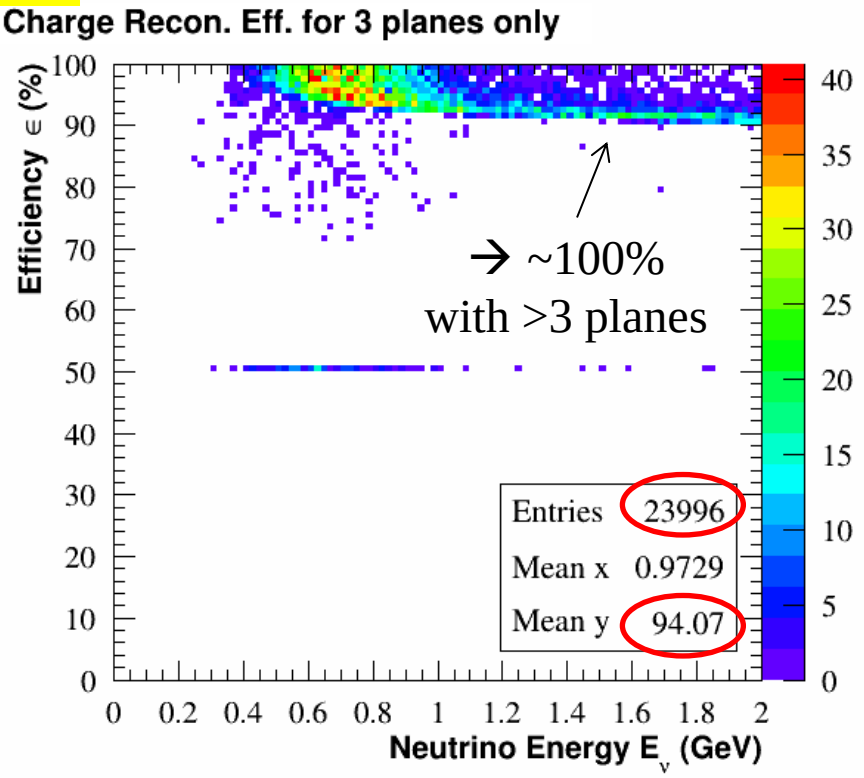
We can greatly improve the charge reconstruction of short tracks by including and optimizing a gap *L* between the initial few measurement planes

Reconstruction with just three 5cm magnetized planes (L=10cm)

END MRD



muons which stop in or before the fourth iron plane



all muons with E_υ < 2 GeV

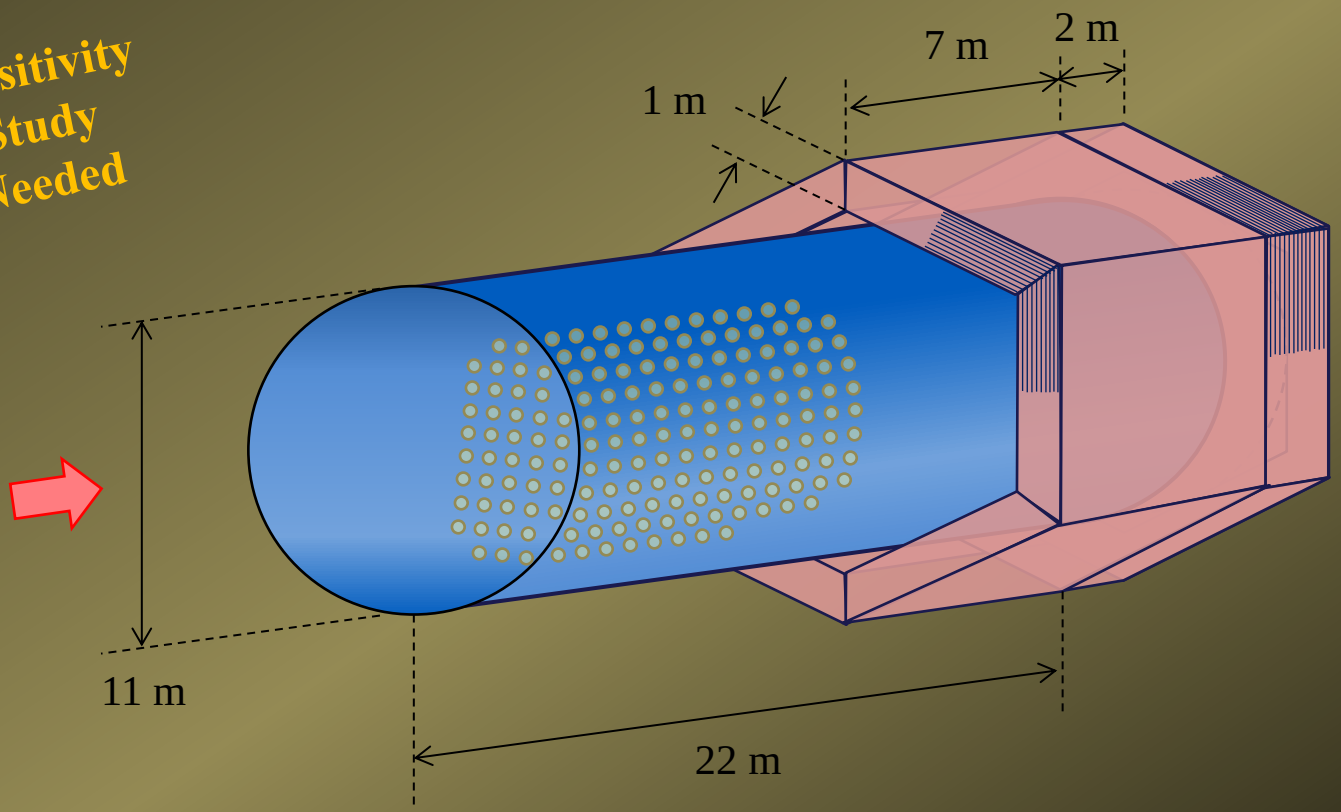
Estimated 94% charge reconstruction efficiency in the oscillation region

Need to demonstrate this with a detailed Monte Carlo

Option 1

A fully enclosed tank is very difficult to justify because of cost

Sensitivity Study Needed

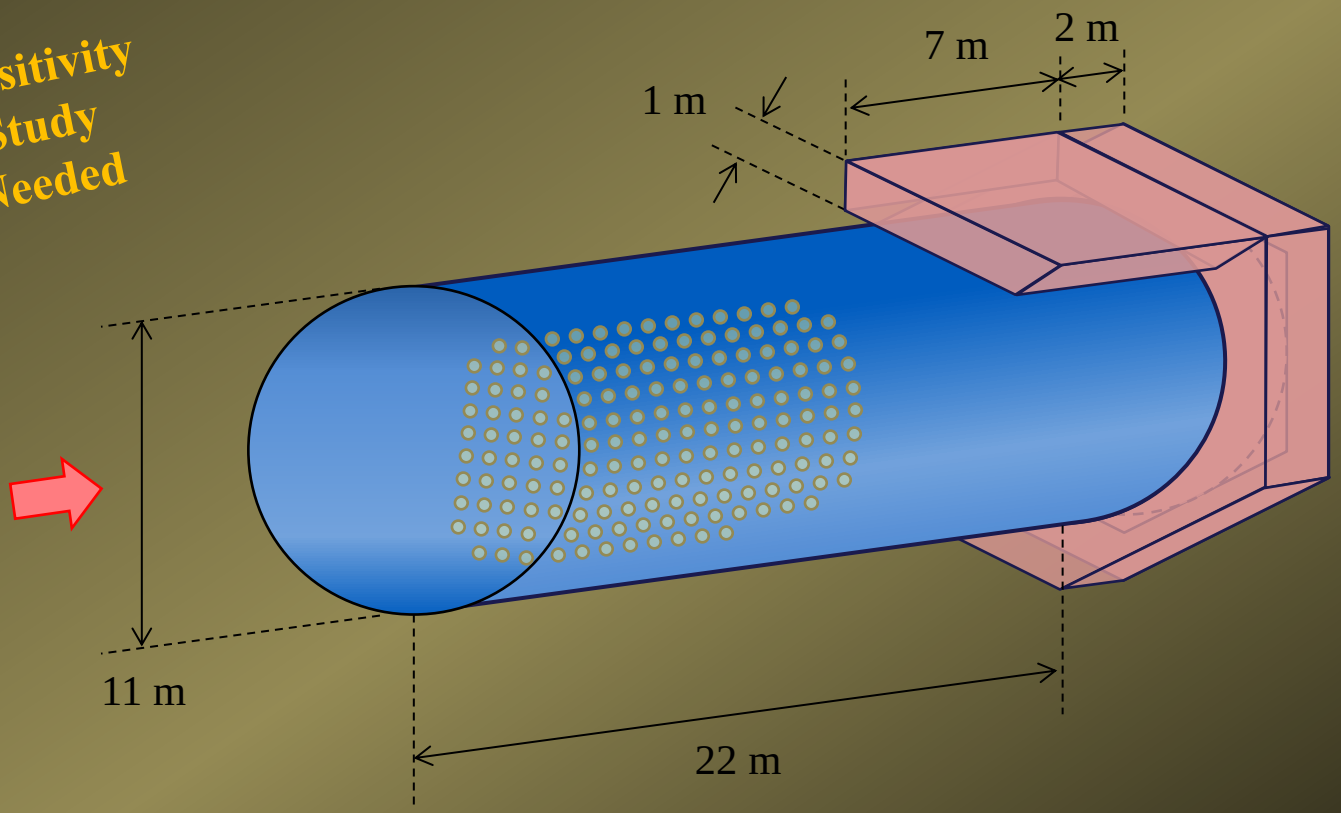


We can take advantage of the symmetry along the z-axis

Option 2

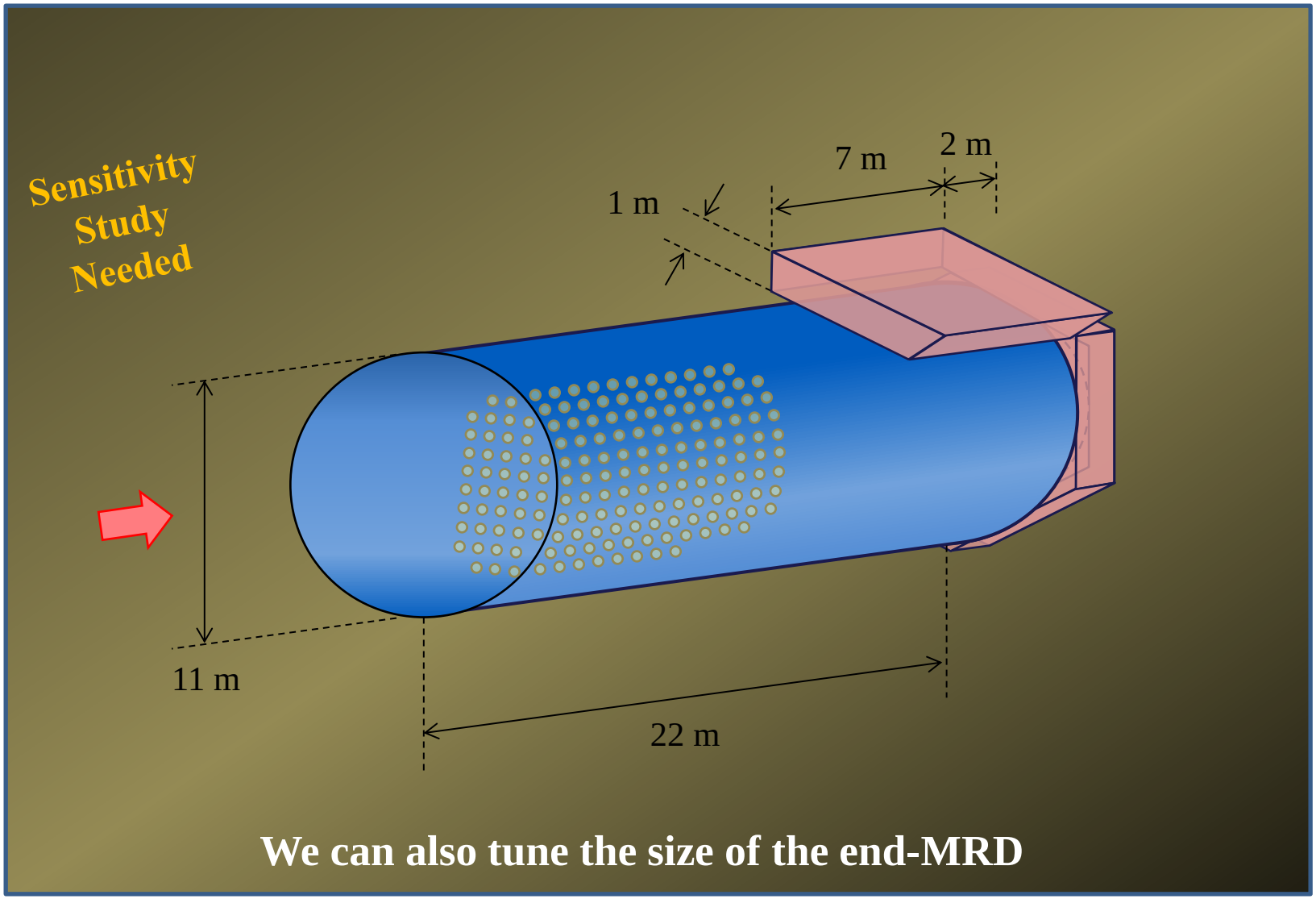
There is also approximate azimuthal symmetry

Sensitivity Study Needed

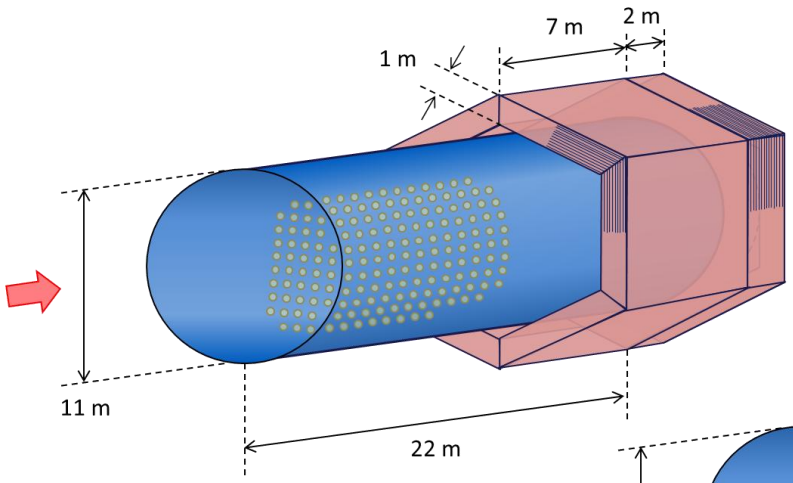


Saving, and still reduced systematics on high-angle cross sections?

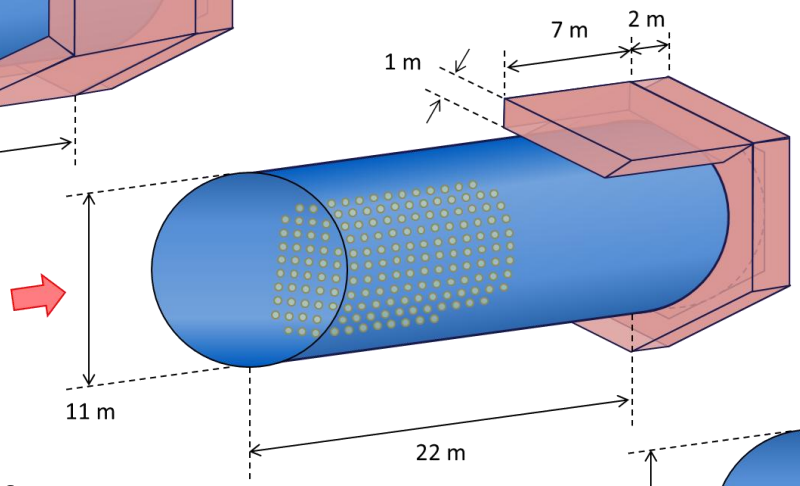
Option 3


Sensitivity Study Needed
7 m
2 m
1 m
11 m
22 m
We can also tune the size of the end-MRD

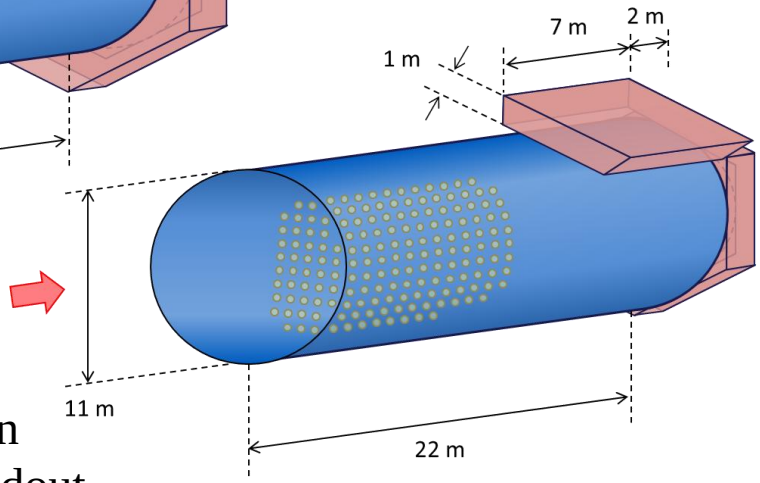
Rough, ballpark Cost Estimates



2.2 M€ for iron
8.4 M€ for readout
10.6 M€



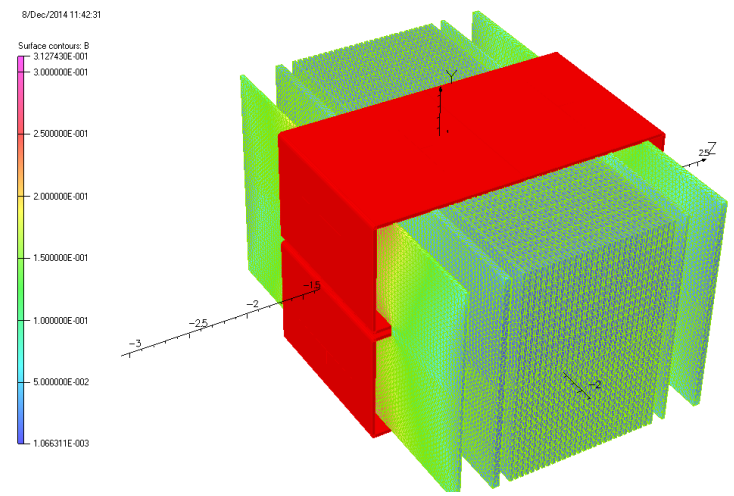
1.5 M€ for iron
2.5 M€ for readout
4.0 M€

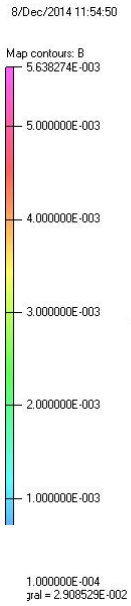


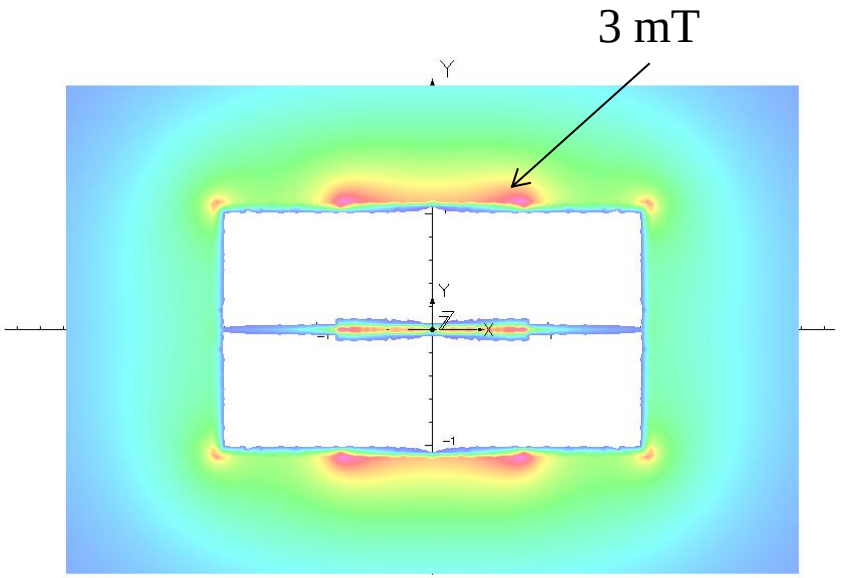
1.3 M€ for iron
2.2 M€ for readout
3.0 M€

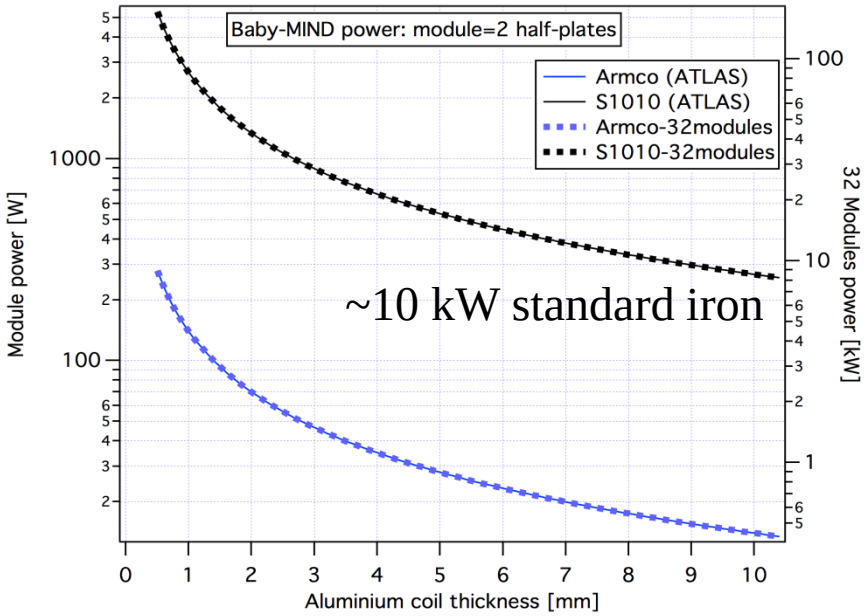
We will decide based on sensitivity studies

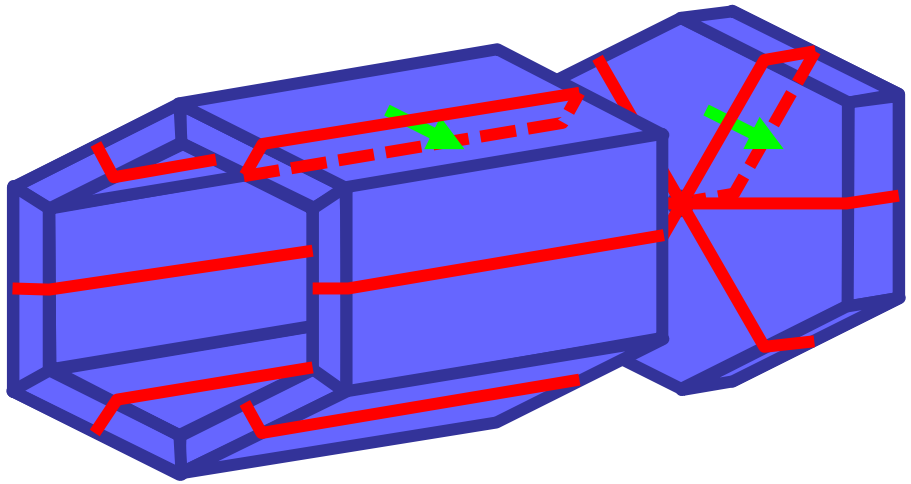
1.5 Tesla Magnetization of the MRD











Summary

- A magnetized MRD would be a great complement to Gd
- A great deal of synergy with the design for Wagasci
- The sensitivity of several options needs to be investigated