TPC considerations

tpc.nb

Initialize

Criteria for Pad Granularity

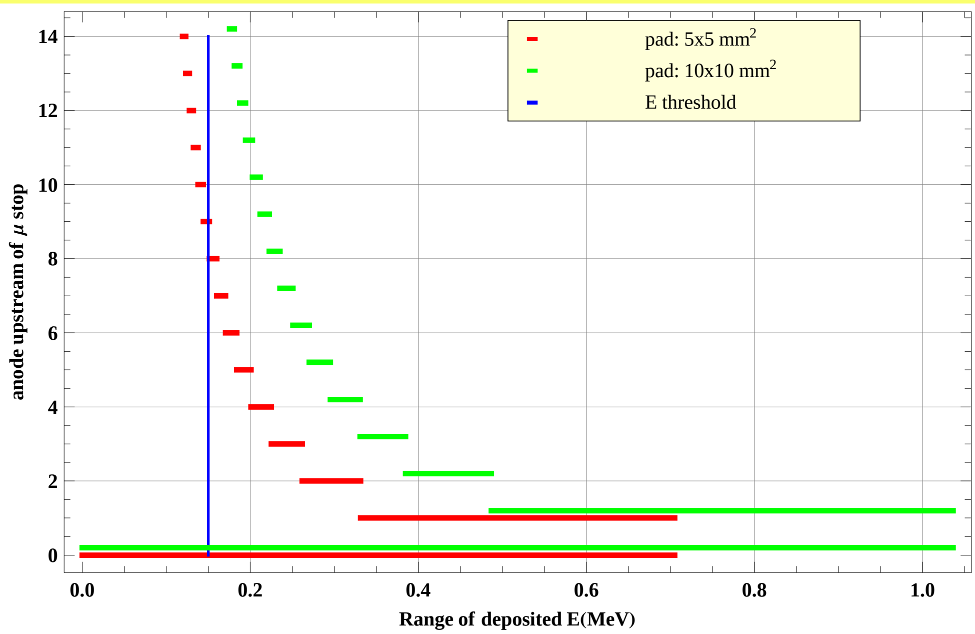
General considerations

The detection plane should be roughly 10x10 cm2. With 1cm pads we get 100 readout channels, with 5mm pads 400 readout channels. Around 100 would be a convenient number for existing FADC etc. Much higher granularity will also make the full analog readout harder.

Muon energy deposition

The muon energy deposition relative to the stopping pad is shown in the figure. A 10x10 mm^2 pad has the advantage of "seeing" all muons entering the chamber, a 5x5 mm^2 pad has higher resolution, but the muons are only seen ~35 mm upstream of the stop pad.

```
T[r_] := (r/KHmu)^(1/1.8)
KHmu = 9.3786218; (* ϕ=5% *)
delT[d_, an_, alen_] := T[d + alen an] - If[an > 0, T[d + alen (an - 1)], 0.]
del = 0.2;
alen = 5;
th = 0.006;
p1 = ParametricPlot[
  {Table[{delT[d, i, alen], i}, {i, 0, 14}], {0.15, d 14 / alen}}, {d, 0.0, alen},
  FrameLabel → {"Range of deposited E(MeV)", "anode upstream of μ stop"}, PlotStyle →
   {{RGBColor[1, 0, 0], Thickness[th]}, {RGBColor[0, 0, 1], Thickness[th 0.5]}}];
alen = 10; p2 = ParametricPlot[{Table[{delT[d, i, alen], i + del}, {i, 0, 14}]}, {d,
  0.0, alen}, FrameLabel → {"Range of deposited E(MeV)", "anode upstream of μ stop"},
 PlotStyle → {{RGBColor[0, 1, 0], Thickness[th]}}];
l = {{Graphics[{Red, Thick, Line[{{0.05, .7}, {0.4, .7}}]}], "pad: 5x5 mm² "},
  {Graphics[{Green, Thick, Line[{{0.05, .7}, {0.4, .7}}]}], "pad: 10x10 mm² "},
  {Graphics[{Blue, Thick, Line[{{0.05, .7}, {0.4, .7}}]}], "E threshold"}
 };
pp = ShowLegend[Show[p1, p2], {l, LegendPosition → {-.0, 0.4},
  LegendSize → {.7, .2}, LegendShadow → {0, 0}, LegendBackground → LightYellow}]
Export["mu.eps", p2];
```



For reference we include the table of fusion products and their range.

	E (MeV)	E_{obs} (MeV)	R (mm)
^{3}He	0.82	0.6	0.18
^{3}Heμ	0.80	0.75	0.6
t	1.01		1
p	3.02		16

Energy resolution

We simply assume that fusion recoils escape a pixel, if they are within R/4 to the next wall. The relative escape fraction then is

$\frac{L^2-(L-R/4)^2)}{L^2} \sim \frac{R}{2L}$, which gives for 5 mm and 10 mm pixels

$$R = 0.18; \left\{\frac{R}{10}, \frac{R}{20}\right\}$$

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{0.018, 0.009}
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which in both cases seems small compared to the intrinsic 1-sigma energy resolution of

$$\frac{30.}{800}$$

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0.0375
```

Of course, in principle, one can always add neighbouring pixels to contain the whole signal. The noise, however, will probably add with the square root of the number of pixels used. We will investigate how the muon stop position in y can be determined by the Bragg distribution. It should be possible to determine stops in y 0.5 mm from y pixel boundaries.
MC is needed for a quantitative assessment. The low capacitance and low pick-up readout of the pad plane needs to be designed.

Impurity detection

Probably the most convincing requirement for good granularity comes from the possibility of detection of proton emission after capture. We are working on a model for this, but 5x5 certainly would be an advantage in this measurement.

Impact parameter cut

For the run 8 analysis an impact parameter cut 120 mm was used. Probably we cannot cut tigher than a 50 mm impact parameter cut. Two dimensions (z from dE/dx and y from drift) can be reconstructed at the mm level. So both choices, 5x5 or 10x10 mm^2 pixels are acceptable.

Systematics due to fusion products

At the nominal ϕ=0.05, the probability for emission of charged fusion products is several precent. Does the interference of these tracks with the muon track distort the μ-e time distribution?

The probability distribution restricted to the range tf<tm can be written as

$$f(tf, tm) = ff(tf)\, fm(tm) \tag{1}$$

tf (tm) denotes the fusion time (muon decay time). Eqn.1 indicates that the marginal probabilities are independent. (Does the restriction affect this statement?). If that is the case, they would not induce any systematic distortions. Any efficiency change because of a fusion at time tf would not change the primary decay exponential.
Eqn.1 can be derived in the following way

$$P(tf, tm) = P(tf \mid tm > tf)\, fm(tm - tf) \tag{2}$$

where P (tf | tm' > tf) can be expressed as ff(tf) P(tm'>tf), and ff(tf) is the solution of the kinetic equations setting the muon decay rate λ to 0.
So the terms together, we get P(tf,tm) = $e^{-\lambda\, tf}$ ff(tf) λ $e^{-\lambda\,(tm-tf)}$ = ff(tf) λ $e^{-\lambda\, tm}$.
Of course, these arguments are always prone to mistakes, so one could check that statement with simple MC models.

Let us consider that case where there exists a systematic correction s(t) due to a time dependent correction effect. The most obvious example is md diffusion. In that case Eqn.1 is not the full story, but is should be modified to include s(t). The s(t) is predicted from a diffusion model assuming μ-e vertex resolution, diffusion etc. In that case changing the muon stop resolution by overlap with fusion might modify the predicted s(t) to a modified s'(t). In that sense the fusion products can change the observed distribution. The model prediction of s'(t) has to correctly account for the new situation.

Conclusions

Let us define the 10x10 mm^2 pad as the baseline configuration and a mixed configuration inner 4x4 cm^2 has 5x5 mm^2(64 pixel) and outer 3 cm have 10x10 mm^2 pixel (84 pixel) as an option to study. We should also test the idea of brick wall configuration to obtain better x resolution.